



Società Italiana di Fisica

# 111° CONGRESSO NAZIONALE

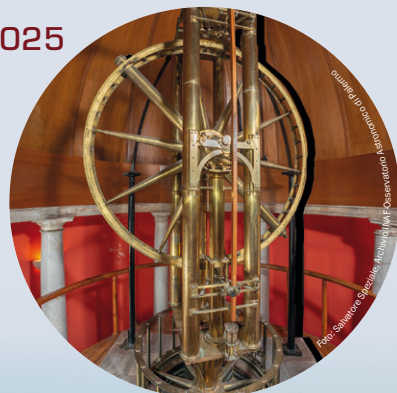
Palermo, 22-26 settembre 2025



Università  
degli Studi  
di Palermo



INTERNATIONAL YEAR OF  
Quantum Science  
and Technology



Polo Didattico del Campus dell'Università di Palermo



**A cura di Barbara Alzani, Marco Bellacosa e Giovanna Bianchi Bazzi**  
**Redazione dei testi a cura di Barbara Ancarani e Marco Bellacosa**  
**Progetto grafico a cura di Simona Oleandri**

**Società Italiana di Fisica**

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# 111° CONGRESSO NAZIONALE

## Società Italiana di Fisica



Palermo, 22-26 settembre 2025



Polo Didattico del Campus dell'Università di Palermo



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*Ornella Pantano* (Università di Padova)
- SEZIONE GIOVANI **In collaborazione con l'Associazione Italiana Studenti di Fisica (AISF)  
e con EPS Young Minds.**

**SIMPOSI**

**La Fisica e l'Industria**

**Optometria**

**Il Fisico nelle professioni di oggi**



## INFORMAZIONI GENERALI

### Sede del Congresso

I lavori del Congresso si svolgeranno presso il Polo Didattico del Campus dell'Università di Palermo in Viale delle Scienze presso l'Edificio 19 e l'Edificio 7.

L'inaugurazione si terrà lunedì 22 settembre a partire dalle ore 9.00 presso l'Aula Magna "Giovanni Battista Filippo Basile", Edificio 7.

La segreteria sarà aperta presso l'Aula Seminari C, Section C, Edificio 19, dal 22 al 26 settembre per tutta la durata dei lavori.

### Iscrizioni

Quote per i Soci in regola per l'anno 2025 (*)	
Socio Ordinario	€ 110,00
Socio under 40	€ 95,00
Socio Invitato (neolaureato in Fisica)	€ 95,00

**(\*) Per i Relatori su Invito e i Chair si applica la stessa quota dei Soci in regola con il versamento della quota sociale 2025**

Quote di iscrizione al Congresso per i non Soci	
Partecipante Ordinario	€ 180,00
Partecipante under 40	€ 155,00

Le iscrizioni devono essere effettuate online entro le ore 10:00 del 15 settembre 2025.

Per partecipare ai lavori congressuali è necessario essere muniti di targhetta nominativa che attesti l'avvenuta iscrizione.

### Relazioni Generali, Relazioni su Invito e Comunicazioni

Nel programma sono segnalate dai seguenti simboli:

- Relazioni Generali
- ▲ Relazioni su Invito
- Comunicazioni

Per la presentazione orale delle relazioni su invito e delle comunicazioni gli autori avranno a disposizione 20 minuti + 5 di discussione (relazioni su invito) e 10 minuti + 2 di discussione (comunicazioni), compatibilmente con il programma della Sessione. L'autore, il cui nome figura sottolineato, sarà il presentatore della comunicazione. Almeno uno degli autori, possibilmente il presentatore, deve essere Socio della Società Italiana di Fisica.

### Migliori comunicazioni

Un'apposita commissione segnerà al Consiglio di Presidenza della SIF un certo numero di comunicazioni (il 20% circa) per ogni sezione giudicate migliori sulla base del contenuto e/o dell'esposizione. Per i presentatori che vinceranno sono previsti premi e/o la pubblicazione degli articoli in un fascicolo speciale de Il Nuovo Cimento, garantendo una pubblicazione on-line in "open access". La premiazione dei relatori avrà luogo durante la cerimonia inaugurale del Congresso Nazionale SIF del 2026.

Esclusivamente gli iscritti al Congresso avranno la possibilità di partecipare alla selezione.

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ORNELLA PANTANO (Università di Padova)

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Aula Magna G.B.F. Basile, Edificio 7

ore 9:00 – 10:30

CERIMONIA DI INAUGURAZIONE  
INTRODUZIONE DEL PRESIDENTE

Prof. Angela Bracco

PREMIAZIONI:

Premio “Enrico Fermi”

Premio “Giuseppe Occhialini” SIF-IOP

Premio per la Storia o la Didattica della Fisica

Premio per la Comunicazione Scientifica

Premi “Laura Bassi” per le Donne nella Fisica *early career & mid-to-full career*

Premio SIF-SoNS “Neutrons Matter”

Premio congiunto SAIIt-SIF “Giovanni Bignami”

Premio per la Fisica Teorica “Giuliano Preparata”

Premio per la Fisica della Materia “Paolo Mazzoldi”

Borsa per la Fisica Nucleare e Subnucleare “Ettore Pancini”

Premi per nuovi talenti in Fisica dopo il maggio 2018 e dopo il maggio 2022

Premi per le Migliori Comunicazioni al Congresso Nazionale 2024

Soci Benemeriti della SIF

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Aula Magna G.B.F. Basile, Edificio 7

ore 10:30 – 11:10

Sezione VII

**Didattica e storia della fisica**

Presiedono: GARGANO M. (INAF, Napoli)

PANTANO O. (Università di Padova)

Relazione Generale

■ **The two births of quantum mechanics.**

KRAGH H.

*Niels Bohr Institutet, Copenhagen, Denmark*

In a sense, quantum mechanics was born twice. The origin of the quantum revolution is undoubtedly to be found in Werner Heisenberg's enigmatic yet ground-breaking *Umdeutung* paper from September 1925 soon to become matrix mechanics. But quantum mechanics, as we know it today, was as much rooted in Erwin Schrödinger's alternative wave theory from March 1926 which, to a large extent, was independent of Heisenberg's. In both cases, the new theory had its origin in unsolved problems of the earlier theory of atoms and quanta. The two formulations had to address the same experimental anomalies and methodological problems of a theoretical nature. Apart from summarizing the two birth processes and the relations between them, I will consider the quantum revolution from the more general perspective of so-called scientific revolutions. Was it a revolution in the strong sense suggested by Thomas Kuhn in 1962? How does it compare with other revolutionary changes in the history of science? Another and related question is when the revolution ended, that is, when quantum mechanics obtained status as a generally accepted paradigm of microphysics. The chronological framework of the contribution will be largely limited to the years 1924–1926.

*Sponsored by EPJH*



Aula Magna G.B.F. Basile, Edificio 7

ore 11:10 – 11:50

SEZIONE II

**Fisica della materia**

Presiede: PATERNOSTRO M. (Università di Palermo)

Relazione Generale

■ **2025 —International year of quantum science and technology.**

FAZIO R.

*International Centre for Theoretical Physics, ICTP, Trieste, Italy e Dipartimento di Fisica, Università di Napoli “Federico II”, Napoli, Italy*

We are celebrating in 2025 the international year of quantum science and technology one hundred years after the publication of the work of Heisenberg that lead to the formulation of modern quantum theory. This year celebrates not only the pioneering scientists whose insights into quantum mechanics laid the foundation for these advances, but it also recognizes a century of global collaborative efforts in harnessing quantum phenomena for societal benefit. Furthermore, as quantum technologies transition from theoretical constructs to practical applications, we stand at the threshold of a new technological era. I will briefly describe the history, plans and activity of the international year and discuss some examples of quantum technological applications.

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Aula Magna G.B.F. Basile, Edificio 7

ore 11:50 – 12:30

SEZIONE V

**Biofisica e fisica medica**

Presiede: GIOVE F. (CREF, Roma)

Relazione Generale

■ **AI-assisted optical imaging of large-area brain activity.**

PAVONE F.

*Università degli Studi di Firenze*

In this contribution, I will present examples of how AI will play a crucial role in reconstructing functional connectivity in brain activity, alongside cytoarchitectonics and structural connectomics. Optical imaging modalities will be discussed, with a particular focus on the role of AI in feature extraction for image analysis and the development of a human-unassisted microscope.

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Aula Magna G.B.F. Basile, Edificio 7

ore 14:00 – 19:00

## SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: OPPEDISANO C. (INFN, Sezione di Torino)

Relazioni su invito

**▲ Highlights of precision measurements at the ATLAS and CMS experiments at the LHC.**

PINAMONTI M.

*INFN, Sezione di Trieste, Gruppo Collegato di Udine*

The ATLAS and CMS experiments at CERN carry out a broad Physics programme that includes a wealth of precision measurements to test the Standard Model with increasing accuracy. This presentation focuses on recent results from the two experiments, based on data collected during the LHC Run 2 and Run 3. A selection of highlights is presented, ranging from electroweak and top quark measurements to Higgs boson property studies and differential cross-section determinations. These analyses, exploiting state-of-the-art theoretical predictions and advanced experimental techniques, provide stringent constraints on the Standard Model and offer potential sensitivity to physics beyond it through indirect effects.

**▲ BESIII: verso il 2030 con il CGEM-IT.**

AMOROSO A. BES3 COLLABORATION

*Dipartimento di Fisica, Università di Torino e INFN Sezione di Torino*

L'esperimento BESIII ha un ricco programma di fisica che lo ha reso protagonista della fisica adronica fin dalla sua partenza nel 2009. A seguito dell'approvazione dell'estensione della presa dati fino almeno al 2030, lo spettrometro e l'acceleratore sono stati sottoposti ad un upgrade per affrontare le sfide del futuro. Il CGEM-IT, progetto nato in seno alla parte italiana della collaborazione BESIII, è il nuovo tracciatore interno dell'esperimento, installato nell'autunno 2024 e ora messo in opera con i primi dati con fascio. La relazione presenterà lo stato dell'esperimento, con alcuni risultati significativi, e poi si concentrerà sul programma di upgrade, con particolare riferimento al CGEM-IT e alle prospettive future sulle sfide che attendono la collaborazione.

**▲ Risultati recenti dell'esperimento Belle II.**

TONELLI D. THE BELLE II COLLABORATION

*INFN, Sezione di Trieste*

Dal 2019, l'esperimento di fisica delle particelle Belle II studia i prodotti delle collisioni tra elettroni da 7 GeV e positroni da 4 GeV generate dall'acceleratore SuperKEKB a KEK, in Giappone. Le collisioni, all'energia di soglia del mesone  $\Upsilon(4S)$ , avvengono alle più alte intensità mai raggiunte, e sono ricostruite con un rivelatore dedicato, offrendo campioni abbondanti e puri di quark bottom e charm, e di leptoni  $\tau$ . Questi permettono risultati d'avanguardia che abbracciano i test indiretti del Modello Standard attraverso le interazioni deboli dei quarks, le ricerche dirette di materia oscura, le misure dei parametri fondamentali del Modello Standard, e la caratterizzazione delle interazioni forti in regime non perturbativo. La relazione presenta una selezione di rilevanti risultati recenti che coprono un'ampia porzione del programma scientifico di Belle II. Attenzione particolare è data alle ricerche di violazione del numero leptonico ed agli aggiornamenti degli eccessi anomali osservati in decadimenti  $b \rightarrow c\tau$  rispetto a  $b \rightarrow c\mu/e$ , noti come  $R(D^{(*)})$ , e nei decadimenti  $b \rightarrow s\nu\bar{\nu}$ .

▲ **LHCb physics highlights.**

LUPATO A.

*Università degli studi di Bergamo e INFN, Sezione di Padova*

The LHCb experiment at the Large Hadron Collider continues to deliver high-precision measurements in key areas such as heavy-flavour physics, CP violation, and tests of the Standard Model. Recent results include the observation of CP violation in baryon decays, updated determinations of CKM matrix parameters, studies of lepton flavour universality, observations of rare decays, and the characterization of new exotic hadronic states. LHCb has also expanded its research program to include heavy-ion and fixed-target collision studies. The start of Run 3, supported by a fully software-based trigger system and upgraded subdetectors, enables an ambitious program of measurements with enhanced sensitivity to phenomena beyond the Standard Model, reinforcing LHCb's leading role in the search for new physics.

Comunicazioni

● **Precision measurements of the top quark mass using  $t\bar{t}$ +jet events and  $t\bar{t}$  events with Soft Muon Tagging.**

PRADES IBANEZ A., VANADIA M., CERRITO L., DE SANCTIS U., PAGANI L., GIULI F., TRUNCALI D.

*INFN, Sezione di Roma Tor Vergata*

The top quark is the most massive elementary particle in the Standard Model, making it a crucial component in our understanding of fundamental physics and its potential extensions. This talk will present recent results from the ATLAS collaboration using the LHC Run 2 dataset, including a differential cross-section measurement for  $t\bar{t}$ +jet events, unfolded to particle level and used to extract the top mass from the shape of a sensitive observable, and a top mass measurement in events with semi-leptonic decays of b-hadrons in  $t\bar{t}$  events. These two channels are sensitive to different systematic uncertainties and thus provide complementary measurements of the top mass. Future prospects for improving these measurements, also exploiting machine learning techniques, will be discussed.

● **Ricerca del fotone oscuro da decadimento del bosone di Higgs con i dati raccolti da ATLAS nel Run 3.**

MAINERI G.

*Università degli Studi di Milano e INFN, Sezione di Milano*

Verrà presentata una ricerca del fotone oscuro prodotto dal decadimento del bosone di Higgs usando i dati raccolti dall'esperimento ATLAS durante il Run 3 di LHC. Il canale di ricerca è il decadimento dell'Higgs in un fotone e un fotone oscuro, la cui segnatura è il momento trasverso mancante. L'analisi si propone di indagare il canale di produzione della fusione di gluoni, finora inesplorato; a questo scopo, è stato sviluppato un algoritmo di trigger composito, basato sulle variabili del momento trasverso mancante, della massa trasversa e del momento trasverso del fotone. La Regione di Segnale (SR) è ottimizzata per aumentare la sensibilità dell'analisi e ridurre il fondo sperimentale, a cui contribuiscono diversi processi previsti dal Modello Standard e processi in cui un elettrone o un jet è ricostruito erroneamente come un fotone. Verranno descritte le diverse tecniche data-driven utilizzate per la stima dei processi di fondo e le relative Regioni di Controllo (CRs). Un fit simultaneo nella SR e nelle CRs permette di estrarre un limite superiore atteso sulla Branching Ratio del decadimento  $H \rightarrow \gamma\gamma$ .

● **Characterization of large area SiC detectors with a 3D microbeam.**

LA FAUCI L., CARBONE D., SPATAFORA A., BRISCHETTO G.

*Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania*

Silicon carbide (SiC) detectors are a state-of-the-art solution for particle detection, combining high radiation hardness and good energy resolution. In the context of the NUMEN project, large area SiC detectors (about  $2 \text{ cm}^2$ ) were chosen as  $\Delta E$  stages in telescopes for the MAGNEX magnetic spectrometer at INFN-LNS. The single-pad detectors ( $15.4 \times 15.4 \text{ mm}^2$ ,  $110 \text{ }\mu\text{m}$  thick:  $100 \text{ }\mu\text{m}$  epitaxy and  $10 \text{ }\mu\text{m}$  substrate) feature a  $400 \text{ }\mu\text{m}$  edge structure. Homogeneity in depletion voltage and substrate thickness is essential across the 720 telescopes that will be part of the MAGNEX PID system. IV and CV tests defined the full depletion voltage (FDV) and doping profile of the tested sensors. In order to study the charge collection efficiency (CCE), IBIC tests were performed at the Ruder Bošković Institute in Zagreb using a proton microbeam with  $2 \text{ }\mu\text{m}$  spot size and  $10 \text{ }\mu\text{m}$  scan steps. In this contribution results from 3D CCE profiling via scans at different proton energies will be presented. Also energy loss measurements through a 6 MeV proton beam to validate the energy loss tables in SiC material and measurements of the depletion depths with back-side irradiation at different angles will be discussed.

● **Risultati dell'esperimento CROSSTEST ai LNL: probabilità di crosstalk per NArCoS.**

GNOFFO B. <sup>(3)(4)</sup>, PAGANO E.V. <sup>(1)</sup>, BARBON A. <sup>(3)(4)</sup>, BOIANO C. <sup>(2)</sup>, CARDELLA G. <sup>(3)</sup>, CASTOLDI A. <sup>(2)(5)</sup>, DE FILIPPO E. <sup>(3)</sup>, GERACI E. <sup>(3)(4)</sup>, GUAZZONI C. <sup>(2)(5)</sup>, LANZALONE G. <sup>(1)(6)</sup>, MAIOLINO C. <sup>(1)</sup>, MARCHI T. <sup>(7)</sup>, MARTORANA N.S. <sup>(3)</sup>, NOTO F. <sup>(1)</sup>, PIRRONE S. <sup>(3)</sup>, POLITI G. <sup>(3)(4)</sup>, QUATTROCCHI L. <sup>(3)(8)</sup>, RISITANO F. <sup>(3)(8)</sup>, RIZZO F. <sup>(1)(4)(9)</sup>, RUSSOTTO P. <sup>(1)</sup>, SACCÀ G. <sup>(3)</sup>, SANTAGATI G. <sup>(1)</sup>, TRIMARCHI M. <sup>(1)(3)(8)</sup>, ZAGAMI C. <sup>(1)(4)(9)</sup>

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<sup>(4)</sup> Dipartimento di Fisica e Astronomia, Università di Catania

<sup>(5)</sup> Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano

<sup>(6)</sup> Università Kore, Enna,

<sup>(7)</sup> INFN, Laboratori Nazionali di Legnaro

<sup>(8)</sup> Dipartimento di Scienze MIFT, Università di Messina

<sup>(9)</sup> Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania

Rivelare neutroni e particelle cariche leggere con alta risoluzione angolare ed energetica acquisisce una importanza strategica per i futuri studi di dinamica e struttura nucleare che saranno condotti con i fasci radioattivi prodotti nelle nuove facilities come FRAISE ai LNS, SPES ai LNL, FAIR al GSI, FRIB all'MSU per fare qualche esempio. La costruzione di un prototipo di correlatore, per neutroni e particelle cariche NArCoS (Neutron Array for Correlation Studies) è un obiettivo dell'esperimento CHIRONE (CNS3) e ha tratto nuova linfa dal progetto PRIN ANCHISE (2020H8YFRE), che tra i suoi scopi si propone di utilizzare un materiale scintillatore di nuova generazione (EJ276) accoppiato a fotosensori compatti (SiPM) come elemento base di rivelazione. Nel presente contributo verrà presentata l'analisi dell'esperimento CROSSTEST, eseguito presso la facility CN dei LNL-INFN volto alla misura della probabilità di crosstalk tra le celle elementari del prototipo del nuovo correlatore NArCoS.

● **Baryon Form Factors Studies at BESIII.**

ROSINI F.

*Università di Perugia e INFN, Sezione di Perugia*

The BESIII Collaboration has provided precise measurements of the baryon form factors, a leading tool in unraveling the baryon's internal properties, which are described by Quantum Chromodynamics (QCD) interactions. The high-statistics dataset allows for precise measurements of the time-like nucleon form factors in the processes  $e^+e^- \rightarrow p\bar{p}$  and  $e^+e^- \rightarrow n\bar{n}$  over a wide range of  $q^2$ . The oscillating behavior of the proton and neutron effective form factors has been updated and extended to near-threshold measurements using the initial state radiation (ISR) technique. New results on the hyperon form factors, including those for the  $\Lambda$ ,  $\Lambda_c$ ,  $\Sigma$ ,  $\Omega$ , and  $\Delta$  baryons, are also discussed. In particular, new results for the  $\Lambda$  and  $\Sigma$  baryons provide a better understanding of the hyperon's internal structure, enabling comparisons with nucleon cases. The complete time-like measurement of these light baryons, coupled with a phenomenological analysis based on dispersion relations, yields valuable insights into the physical properties of baryons. This includes the physical phase of the form factor's ratio and the charge radius of the neutral  $\Lambda$  baryon.

● **Precision analysis of b-fragmentation properties using soft muon tagging and machine learning.**

PAGANI L., DE SANCTIS U., PRADES A., VANADIA M.

*Università di Roma Tor Vergata*

Soft Muon Tagging (SMT) is a robust technique for identifying heavy-flavor jets by detecting muons from  $b/c \rightarrow \mu + X$  decays within hadronic jets. By leveraging Machine Learning, the performance of SMT can be further improved, enhancing its efficiency and rejection power. The SMT technique has been already used in several measurements, and in this talk, I will present its application to study the properties of the b-quark fragmentation process in  $t\bar{t}$  events with the ATLAS detector at the LHC.

● **Recenti aggiornamenti sullo stato del charmonio  $h_c(1^1P_1)$  presso l'esperimento BESIII.**

DI FIORE E. PER LA COLLABORAZIONE BESIII ITALIA

*Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara e INFN, Sezione di Ferrara*

Sebbene lo spettro del charmonio sia stato ampiamente studiato, molte delle sue proprietà restano ancora poco note. L'esperimento BESIII, situato presso il collisore BEPCII, ha raccolto un campione di  $(27.12 \pm 0.14) \times 10^8$  eventi  $\psi(3686)$ , permettendo di indagare i decadimenti del mesone  $h_c(1^1P_1)$ , uno stato in onda-P di singoletto di particolare interesse per testare le previsioni della QCD nella regione di transizione tra il regime perturbativo e non perturbativo. Sono stati osservati diversi canali di decadimento verso stati adronici leggeri con significatività superiori a  $5\sigma$ :  $h_c \rightarrow \gamma\pi^+\pi^-$ ,  $\gamma\pi^+\pi^-\eta$ ,  $\gamma 2(\pi^+\pi^-)$  e  $\gamma p\bar{p}$ . È stata riportata la prima evidenza sperimentale del decadimento  $h_c \rightarrow \gamma f_2(1270)$  verso uno stato tensoriale. BESIII ha anche osservato per la prima volta  $h_c \rightarrow 3(\pi^+\pi^-)\pi^0$  e fornito evidenza per altri canali multipionici. Questi risultati offrono nuovi vincoli sperimentali per i modelli QCD nella regione non perturbativa e aprono la strada a futuri studi sulla spettroscopia del charmonio, evidenziando il ruolo centrale di BESIII in questo ambito.

● **An accurate and empirical determination of the mass of the electron from properties of the W boson vector: an attempt to a theory of the electron mass.**

VINCIGUERRA V.

*STMicronics, Catania*



An accurate and empirical relationship between the electron mass and the mass of the W boson vector, is proposed. The electron mass, calculated in this way, differs from the experimental value by 25 ppm; the error arises from the uncertainty of the W boson mass. By calculating the expectation value of the Wilson loop (rectangle  $R \times T$ ) for a U(1) gauge field, it becomes necessary to compare the Bohr energy of a suitably chosen particle-antiparticle pair with the time scale determined by the electron mass, possibly corrected for the value of the electron's gyromagnetic ratio. It is demonstrated that by appropriately choosing an off-shell  $W+W^-$  pair, a Bohr energy can be determined that agrees with the mass value of the electron-positron pair. From these considerations, a dependence on the square of the fine-structure constant  $\alpha$ , the mass of the W boson, and the cosine of an angle compatible with the Weinberg angle is deduced. Once appropriately validated, the theory allows for the deduction of the electron's coupling constant with the Higgs field and reduces the number of free parameters in the Standard Model.

● **Higgs boson measurements in the precision era with the CMS experiment.**

QUINTO S., LENZI P., VILIANI L., CALANDRI A., LIZZO M.

*Università di Firenze e INFN, Sezione di Firenze*

Already at the end of LHC run 2 several Higgs boson cross section measurements were systematically limited. Unless strategies are devised to limit the systematics impact, the benefit of additional data is severely diminished. In this contribution we present strategies to limit the impact of systematics using in the context of  $H \rightarrow WW$  measurements at CMS. We employ advanced machine learning techniques with the joint objective of discriminating signal and reducing systematics impact. With these strategies we will ensure effective optimization of the analysis for Run 3.

● **Study of photon-photon interactions in heavy ion collisions with the CMS detector at LHC.**

LAGANA C.

*Sapienza Università di Roma e INFN, Sezione di Roma*

In this talk, I will present the study of photon-photon interactions in ultra peripheral lead-lead (Pb-Pb) collisions, as observed with the CMS detector. Due to the purely electromagnetic nature of these interactions, the cross section is significantly enhanced by nearly a factor of 10 compared to proton-proton (p-p) collisions. The two-photon final state is well understood within the Standard Model and serves as a valuable probe for the potential production of new, exotic particles. Similarly, the final state involving two quarks results in two hadronic jets and an otherwise nearly empty detector. This distinctive signature offers a unique opportunity to both search for new resonances and to study the performance of flavor-tagging algorithms in an exceptionally clean experimental environment.

● **Tracking performance of the ARCADIA fully depleted MAPS.**

ZINGARETTI A. <sup>(1)(2)</sup>, AZZI P. <sup>(2)</sup>, BACCHETTA N. <sup>(2)(3)</sup>, BONINI C. <sup>(1)(2)</sup>, CHIAPPARA D. <sup>(1)(2)</sup>, CIARLANTINI S. <sup>(1)(2)</sup>, GIUBILATO P. <sup>(1)(2)</sup>, MATTIAZZO S. <sup>(1)(2)</sup>, PANTOUVAKIS C. <sup>(1)(2)</sup>, RIGNANESE M. <sup>(1)(2)</sup>, ROLO M. <sup>(4)</sup>, WYSS J. <sup>(2)(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Padova*

<sup>(2)</sup> *INFN, Sezione di Padova*

<sup>(3)</sup> *Fermi National Accelerator Laboratory, Illinois, USA*

<sup>(4)</sup> *INFN, Sezione di Torino*

<sup>(5)</sup> *Università degli Studi di Cassino e del Lazio Meridionale*

The need for advanced tracking sensors for application at future collider experiments, such as FCC (Future Circular Collider), is pushing the particle physics community to challenge

the current silicon detector limits. The INFN ARCADIA collaboration developed a Fully Depleted Monolithic Pixel Sensor in LFoundry 110 nm technology node. This sensor has a custom backside process that grants uniform electric field distribution. Several technology demonstrators were built with different thicknesses, making them suitable both for charged particles and X-rays. The sensor array is made of  $512 \times 512$  pixels, with a pitch of  $25 \mu\text{m}$ , for a total area of  $1.3 \times 1.3 \text{ cm}^2$ . The pixel output is digital and the readout is event-driven. The chip can handle rates up to  $100 \text{ MHz/cm}^2$  and is optimized for very low power consumption ( $10\text{-}30 \text{ mW/cm}^2$ ). The characterization of ARCADIA was carried out with table-top setup (radioactive sources and x-ray machine) and at test beam with Minimum Ionizing Particles, with a custom-made three layers telescope. Some results on sensor performance and tracking resolution are given in this contribution.

● **A new inner tracking system for ALICE: status report of the ITS3 project.**

STURNIOLO A. ON BEHALF OF ALICE COLLABORATION

*Università di Messina e INFN, Sezione di Catania*

During the Long Shutdown 3 (LS3, scheduled 2026-2030) a new Inner Tracking System (ITS) will be installed in ALICE for the future Run 4 data taking. The upgraded ITS will be the third version of the tracker, named ITS3, and will use innovative, large-scale stitched sensors, produced with a 65 nm technology and bent to a truly half-cylindrical shape. Sensor bending, as well as the replacement of the present water cooling with air cooling, will reduce the need for mechanical support: the material budget is expected to drop to an average of just  $0.09\% X_0$  per layer. The upgraded ITS will also be closer to the interaction point with a minimum radial distance of 19 mm, and is required to withstand up to  $10^{13} \text{ 1 MeV } n_{eq} \text{ cm}^{-2}$  NIEL and 10 kGy TID radiation loads. In this contribution an overview of the ALICE ITS3 upgrade will be presented: among the latest developments, the ongoing characterisation of stitched test devices has shown how a  $> 99\%$  detection efficiency and  $< 6 \mu\text{m}$  spatial resolution can be achieved, while the prototypes for the final ITS3 sensors, the MOSAIX, have been designed and are awaiting submission.

● **Calibrazione dell'algoritmo di flavour tagging GN2X per il canale  $Z \rightarrow \ell\ell$  in ATLAS.**

FILIPPIG M. <sup>(1)</sup>, COBAL M. <sup>(2)</sup>, PANIZZO G. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Matematiche, Informatiche e Fisiche, Università degli Studi di Udine*

<sup>(2)</sup> *Dipartimento Politecnico di Ingegneria e Architettura, Università degli Studi di Udine*

L'identificazione di bosoni di Higgs e Z che decadono in coppie di quark bottom ad alto impulso trasverso è di cruciale importanza per il programma di fisica dell'esperimento ATLAS. GN2X è l'algoritmo utilizzato dall'esperimento per identificare getti a largo raggio ( $R=1.0$ ) che contengono coppie di adroni pesanti. La calibrazione di questo algoritmo avviene tramite una misura nei dati del rapporto di efficienze di identificazione dei getti prima e dopo l'utilizzo del tagger GN2X. Questa presentazione illustra la metodologia utilizzata per misurare l'efficienza di pre-tagging, utilizzando il picco del bosone Z in eventi  $Z \rightarrow \ell\ell$  (dove  $\ell = e, \mu$ ). La minor presenza dei fondi di questo canale di decadimento permette di ottenere un'efficienza prima dell'utilizzo del tagger, scalando poi il risultato al canale del segnale  $Z \rightarrow b\bar{b}$ . Verranno presentati i risultati sui dati collezionati durante il Run 2 (2015-2018) e Run 3 (2022-2024) di LHC dall'esperimento ATLAS.

● **La costruzione del nuovo rivelatore di vertice di ATLAS a HL-LHC.**

MARTINA F. ON BEHALF OF THE ATLAS ITK PIXEL COLLABORATION

*Istituto Nazionale di Fisica Nucleare, Sezione di Lecce*

La scoperta del bosone di Higgs nel 2012 al CERN di Ginevra da parte degli esperimenti ATLAS e CMS ha aggiunto l'ultimo tassello necessario alla conferma della teoria delle interazioni fondamentali (premio Nobel a P. Higgs e F. Englert che ne predissero l'esistenza). Un significativo potenziamento degli esperimenti è in programma per la presa dati che inizierà nel 2030 e che mira ad accumulare un campione di dati 10 volte più abbondante di quello raccolto fino ad allora, ampliando notevolmente le capacità di scoperta di nuovi fenomeni. In particolare, il sistema di tracciamento e ricostruzione dei vertici di interazione delle particelle, posto in prossimità della zona di interazione protone-protone sarà completamente rinnovato da un nuovo tracciatore (ITk). Diversi gruppi di ricerca italiani di ATLAS hanno la responsabilità di costruire una intera parte di esso e più precisamente uno dei due End Cap a Pixel Ibridi di Silicio. Esso permetterà di estendere la regione di tracciamento in avanti ed aumentare la capacità di studio dell'interazione tra due bosoni di Higgs, principale motivazione di Fisica di HL-LHC.

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Aula 11, Section C, Edificio 19

ore 14:00 – 19:00

SEZIONE II

**Fisica della materia**

Presiede: CASPANI L. (Università dell'Insubria)

Relazioni su invito

▲ **Experimental quantum analog-to-digital converter with integrated photonics.**

CIMINI V. <sup>(1)</sup>, CARUCCIO E. <sup>(1)</sup>, RONCALLO S. <sup>(2)</sup>, ALBIERO R. <sup>(3)</sup>, PENTANGELO C. <sup>(3)</sup>,  
CECCARELLI F. <sup>(3)</sup>, CORRIELLI G. <sup>(3)</sup>, OSELLAME R. <sup>(3)</sup>, SPAGNOLO N. <sup>(1)</sup>, MACCONE  
L. <sup>(2)</sup>, MACCHIAVELLO C. <sup>(2)</sup>, SCIARRINO F. <sup>(1)</sup>

<sup>(1)</sup> *Sapienza Università di Roma*

<sup>(2)</sup> *Università di Pavia*

<sup>(3)</sup> *Istituto di Fotonica e Nanotecnologie, IFN-CNR, Milano*

Quantum metrology, conventionally, focuses on providing evidence of enhanced sensitivity for the estimation of continuous-valued parameters, surpassing classical limits by exploiting quantum probes. However, many practical applications require digital information processing to enable real-time feedback and ensure integration with classical and quantum computing architectures. This necessitates a shift in paradigm towards the study of digital quantities, where parameters are directly encoded into discrete bit values. In this contribution, we present the first Quantum Analog-to-Digital Converter (QADC) for a phase estimation protocol together with its experimental realization. By exploiting the quantum phase estimation algorithm, we obtain the estimate of the parameter of interest using a sequence of probes states with increasing dimensionality i.e. single-photon states, two-photon entangled states, and four-photon Greenberger-Horne-Zeilinger (GHZ) states. To quantify the advantage coming from the use of quantum probes, we examine the retrieved mutual information, allowing us to directly quantify the informational gain achieved through quantum probes in a discrete estimation setting.

▲ **Sculpting quantum light.**

BELLINI M.

*CNR - Istituto Nazionale di Ottica, Sesto Fiorentino, LENS e Dipartimento di Fisica e Astronomia, Università di Firenze*

Gaining full control over the quantum state and the mode structure of nonclassical light represents one of the most significant challenges in the development of next-generation quantum technologies. These advancements are crucial for enabling robust quantum communication, scalable quantum computing, and highly sensitive quantum metrology. In this talk, I will present recent experimental progress in this direction, focusing on the controlled generation and photon-by-photon manipulation of ultrashort quantum light pulses. Our approach combines ultrafast optics with quantum state engineering techniques, allowing for precise sculpting of nonclassical light wavepackets with arbitrary spectrotemporal shapes by mode-selective quantum operations.

▲ **Up-Conversion Photon-Number-Resolving Detector.**

ALLEVI A., CASSINA S., POZZOLI A., LAMPERTI M.

*Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Como*

The number of applications of infrared light has significantly increased in the field of quantum communication due to the possibility of exploiting the available fiber-optic infrastructure

working around  $1.5\ \mu\text{m}$ . Although the potential of using photon-number-resolving (PNR) detectors in the field of quantum communication has recently been demonstrated both theoretically and experimentally, detection solutions operating in the infrared range are still lacking. Reversely, in the visible spectral range, we have recently demonstrated the suitability of Silicon photomultipliers (SiPM) for quantum optics and quantum information measurements. Such detectors are compact, robust, and low cost, thus being excellent candidates for quantum communication receivers. Here we show the implementation of a PNR detector, based on SiPM and nonlinear interactions, for fiber-compliant telecommunication around  $1.5\ \mu\text{m}$  with coherent-state encoding. Unlike other solutions, the main advantages of the detector are its room-temperature operation and high PNR capability. These aspects open new perspectives in exploiting the mesoscopic intensity regime for quantum applications.

▲ **Intermodal quantum key distribution over 18 km of free-space propagation with adaptive optics for fiber injection.**

VEDOVATO F.

*Università di Padova*

We report the realization of a free-space testbed for intermodal Quantum Key Distribution (QKD) over an 18 km link between Monte Grande and the city center of Padova. The goal is to demonstrate the integration of commercial fiber-based QKD systems into free-space links using adaptive optics (AO) for efficient single-mode fiber (SMF) coupling. A remotely operated transmitter installed on a weather tower at Monte Grande sends beacon and quantum signals toward Padova, using a commercial QKD device at 1565.50 nm implementing the one-decoy BB84 protocol. The optical receiver, located at the Department of Information Engineering and based on a 41 cm telescope, includes an AO bench to compensate for turbulence. After SMF injection, the QKD signal is routed to a separate building hosting a commercial QKD Receiver connected to either SPAD or SNSPD detectors. This architecture reflects scenarios envisioned in future ESA missions such as Eagle-1 and SAGA. Coupling performance was benchmarked against a theoretical injection model, showing excellent agreement with real data. The QKD experiment, including synchronization and key distillation, was successfully completed.

Comunicazioni

● **Quantum key distribution with an integrated photonic receiver.**

GUARDA G. <sup>(1)(2)</sup>, RIBEZZO D. <sup>(2)(3)</sup>, OCCHIPINTI T. <sup>(4)</sup>, ZAVATTA A. <sup>(2)(4)</sup>, BACCO D. <sup>(3)(4)</sup>

<sup>(1)</sup> *European Laboratory for Non-Linear Spectroscopy, Sesto Fiorentino*

<sup>(2)</sup> *CNR, Istituto Nazionale di Ottica, Firenze*

<sup>(3)</sup> *Dipartimento di Fisica e Astronomia, Università di Firenze*

<sup>(4)</sup> *QTI Srl, Firenze*

Photonic integrated circuits (PICs) are key to advancing quantum technologies for secure communications, offering inherent stability, low losses, and compactness compared to standard fiber-based and free-space systems. Our research demonstrates the effectiveness of PICs in enhancing quantum communication by implementing a three-state BB84 protocol with a decoy-state method. We employ an integrated receiver and superconducting nanowire single-photon detectors (SNSPDs) to achieve significant technological progress. Notably, we extract a secret key over a record-breaking 45 dB channel attenuation, marking a milestone in maximum covered distance. Additionally, we observe a 220% increase in the secret key rate (SKR) compared to our prototype fiber-based receiver at 10 dB channel attenuation. These results underscore the potential of integrated photonics to push the boundaries of quantum communication.

● **Tailoring photonic correlations with structured light.**

SCHIANO C. <sup>(1)</sup>, SEPHTON B. <sup>(1)</sup>, AIELLO R. <sup>(1)</sup>, GRAFFITTI F. <sup>(2)</sup>, LAL N. <sup>(1)</sup>, CHIURI A. <sup>(3)</sup>, SANTORO S. <sup>(3)</sup>, AMATO L.S. <sup>(4)</sup>, MARRUCCI L. <sup>(1)(5)</sup>, DE LISIO C. <sup>(1)</sup>, D'AMBROSIO V. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(2)</sup> *Institute of Photonics and Quantum Sciences, School of Engineering and Physical Sciences*

<sup>(3)</sup> *Enea, Centro Ricerche Frascati*

<sup>(4)</sup> *ASI, Centro di Geodesia Spaziale Giuseppe Colombo*

<sup>(5)</sup> *CNR-ISASI, Institute of Applied Science and Intelligent Systems*

Quantum interference and structured light are key resources for a wide range of quantum technologies, including imaging, communication, and computation. While quantum interference typically requires identical photons, it can also be induced by performing projective measurements that erase distinguishing information - a process known as a quantum eraser. By combining this effect with the versatility of structured light, we design and experimentally demonstrate a simple and robust scheme that tailors quantum interference to shape photonic spatial correlations. The resulting correlation patterns are not visible in conventional intensity measurements and reveal genuinely non-classical spatial structures. Our technique is based on a compact and stable scheme which can be scaled up to multi-photon regimes, providing a promising platform for high-dimensional quantum communication and imaging protocols.

● **Programmable quantum photonic circuit in free space.**

AMMENDOLA M.G. <sup>(1)(2)</sup>, DEGHAN N. <sup>(3)(4)</sup>, SCARFE L. <sup>(3)</sup>, D'ERRICO A. <sup>(3)(4)</sup>, MARRUCCI L. <sup>(1)(5)</sup>, DI COLANDREA F. <sup>(1)(3)</sup>, KARIMI E. <sup>(3)(4)(6)</sup>, CARDANO F. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

<sup>(2)</sup> *Scuola Superiore Meridionale, Napoli*

<sup>(3)</sup> *Nexus for Quantum Technologies, University of Ottawa, Canada*

<sup>(4)</sup> *National Research Council of Canada, Ottawa, Canada*

<sup>(5)</sup> *CNR-ISASI, Institute of Applied Science and Intelligent Systems, Pozzuoli*

<sup>(6)</sup> *Institute of Quantum Studies, Chapman University, Orange, CA, USA*

Photonic circuits, engineered to couple optical modes according to a specific map, serve as processors for classical and quantum light. Here, we present a fast on-demand photonic circuit implementing large-scale unitary maps in free space. The proposed architecture encodes information in structured photonic modes, having circular polarization and quantized transverse momentum, processed using three Spatial Light Modulators. We demonstrate the scalability and programmability of the platform by simulating different quantum walks across one-dimensional and two-dimensional lattices, realizing up to 30 steps with 7000 coupled modes. By simulating time-dependent dynamics, such as those featuring temporal disorder, we observe the transition from ballistic to diffusive spreading in quantum walks. We also perform bulk measurements of geometrical and topological properties of chiral-symmetric processes. Finally, by extracting coincidence measurements performed with a time-stamping camera, we validate the possibility of using the platform in quantum optics experiments reconstructing far-field distributions of heralded single photons.

● **Programmable non-Hermitian photonic quantum walks via dichroic metasurfaces.**

SAVARESE P. <sup>(1)</sup>, BANSAL S. <sup>(1)</sup>, AMMENDOLA M.G. <sup>(1)(2)(1)</sup>, BARBOZA R. <sup>(3)</sup>, SALVATORE M. <sup>(1)</sup>, OSCURATO S.L. <sup>(1)</sup>, PICCIRILLO B. <sup>(1)</sup>, DI COLANDREA F. <sup>(1)</sup>, MARRUCCI L. <sup>(1)(4)</sup>, CARDANO F. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

<sup>(2)</sup> *Scuola Superiore Meridionale, Napoli*

<sup>(3)</sup> *Dipartimento di Scienze e Ingegneria della Materia, dell'Ambiente ed Urbanistica, Università Politecnica delle Marche, Ancona*

<sup>(4)</sup> *CNR-ISASI, Institute of Applied Science and Intelligent Systems, Pozzuoli*

In recent years, non-Hermitian (n-H) photonics collected significant attention as a rising field in optics due to the emergence of numerous physical concepts and novel effects. Here, we propose an innovative approach for simulating n-H dynamics by realizing a non-unitary photonic quantum walk based on a light beam propagating in free space and manipulated via step operators acting jointly on its polarization and transverse momentum. We use the latter degrees of freedom to encode the coin and walker systems respectively. To induce spin-rotation, we utilize a uniform liquid-crystal (LC) plate and an LC dichroic polarization grating to obtain a spin-dependent non-unitary translation operation on the walker. Through the combination of LCs and absorbing dyes, we can manipulate both polarization and light amplitude, effectively recreating a dissipative system. This development yields a compact and versatile platform that significantly expands the scope of photonic simulations in studying quantum dynamics. It introduces a new dimension for manipulating topological states, enabling the observation of phenomena such as those related to n-H topological phases.

#### ● **Integration of optical metamaterials with optical fiber technology.**

PRINCIPE M. <sup>(1)</sup>, VAIANO P. <sup>(1)</sup>, BERRUTI G. <sup>(1)</sup>, MICCO A. <sup>(1)</sup>, CONSALES M. <sup>(1)</sup>, CUSANO A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria, Università del Sannio, Benevento*

<sup>(2)</sup> *Centro Regionale Information Communication Technology, CeRICT srl, Benevento*

Optical fibers are of great technological importance due to their unique features such as strong light confinement, and efficient light transportation over large distances, representing a key element in a multitude of applications in modern optics, including communications, optical trapping, nonlinear light generation, sensing, and imaging. The integration of optical metamaterials on the end facet can enormously expand the functionalities of optical fibers, by endowing a simple optical fiber with extraordinary capabilities of light manipulation. Functional optical fibers can replace traditional bulky optical components, with the great advantage of reducing the size of the devices, thus facilitating the integration with on-chip photonics and with microfluidic circuits for biomedical applications. Here we show our progress in the integration of metamaterials with optical fibers. We present the realization of in fiber beam splitters and focusing lenses. We show also some preliminary results about the integration of hyperbolic metamaterials on a properly angled tip of a multi-mode fiber. Last, we show the integration of metasurfaces with multi-core fibers for multi-analyte sensors.

#### ● **Homodyne-like with gaussian discrete modulation.**

CASSINA S., LAMPERTI M., ALLEVI A.

*Dipartimento di scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Como*

Our group is currently working on a continuous variable detection scheme based on photon-number-resolving detectors performing as a quantum communication channel based on coherent states. We have already published a first proof of principle demonstrating its feasibility and comparing its performance with the one of a standard homodyne detector in terms of error probability and mutual information in the case of binary state discrimination. In this contribution we want to push the results further by coding the transmitted information into four different phases, evaluating the improvements in terms of error probability and mutual information.

● **Learning quantum states of continuous variable systems.**

MELE F.A. <sup>(1)</sup>, MELE A.A. <sup>(1)</sup>, BITTEL L. <sup>(2)</sup>, EISERT J. <sup>(2)</sup>, GIOVANNETTI V. <sup>(1)</sup>, LAMI L. <sup>(1)</sup>, LEONE L. <sup>(1)</sup>, OLIVIERO S.F.E. <sup>(1)</sup>

<sup>(1)</sup> *Scuola Normale Superiore di Pisa*

<sup>(2)</sup> *Freie Universität Berlin*

We are pleased to submit our paper ‘Learning quantum states of CV systems’ (arXiv:2405.01431).

We determine the ultimate achievable performance of quantum state tomography of continuous-variable (CV) systems, such as bosonic and quantum optical systems, revealing fundamental limitations that all certification procedures of photonic quantum devices must obey. Although CV tomography has been a well-established concept since the 1990s and is routinely performed in quantum optics laboratories, our work provides the first and at the same time exhaustive investigation of its optimal performance, while also introducing innovative, experimentally feasible methods to perform tomography of physically relevant classes of states. We would structure our talk as follows: We begin with a self-contained introduction to quantum state tomography and CV systems, ensuring that our results are accessible to a broad physics audience. We then show that tomography of non-Gaussian states is extremely inefficient. On a more positive note, we prove that tomography of Gaussian states is efficient. Finally, we explore how the complexity of tomography grows with increasing non-Gaussianity.

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Aula Capità, Edificio 7

ore 14:00 – 19:00

SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: FAFONE V. (Università di Roma Tor Vergata e INFN)

Relazioni su invito

▲ **Overview and recent results of the Alpha Magnetic Spectrometer on the International Space Station.**

OLIVA A.

*INFN, Sezione di Bologna*

The Alpha Magnetic Spectrometer (AMS-02) is a high-precision, large-acceptance magnetic spectrometer that has been continuously operating aboard the International Space Station (ISS) since its installation in May 2011. AMS-02 precisely measures the fluxes of all cosmic ray components, from the most abundant matter particles to rare antimatter ones, over a wide energy range extending from sub-GeV to multi-TeV scales. AMS-02 observations have revealed unexpected spectral features across multiple cosmic ray species, challenging the current understanding of cosmic ray origin, acceleration, and propagation. These measurements have also been used to investigate fundamental questions in particle physics, searching for possible signatures of dark matter annihilation in the Galaxy. An overview of the latest results, their scientific implications, and the ongoing and future efforts will be presented.

▲ **16 years of gamma-ray observations by the Fermi Large Area Telescope.**

PESCE ROLLINS M. ON BEHALF OF THE FERMI LAT COLLABORATION

*INFN, Sezione di Pisa*

Launched in June 2008, the Fermi Large Area Telescope (LAT) is a gamma-ray space observatory designed to monitor the entire sky from 20 MeV to up to greater than 300 GeV. The science goals of the LAT span from the Earth and solar system to our local galaxy and beyond to the most distant corners of the universe. Thanks to its continuous coverage, the LAT has revealed how surprisingly dynamic and variable the gamma-ray sky truly is. In this talk I will present some of the most significant discoveries made by the Fermi-LAT over the past 16 years in orbit.

▲ **Misure di polarizzazione della radiazione cosmica di fondo.**

SIGNORELLI G.

*Università di Pisa e INFN, Sezione di Pisa*

La radiazione cosmica di fondo (CMB) è una delle principali fonti di informazione sull'universo primordiale. In particolare, la misura della sua polarizzazione permette di investigare fenomeni fondamentali come l'inflazione cosmica, la generazione delle perturbazioni primordiali e la presenza di onde gravitazionali a bassa frequenza. In questo contributo verranno presentati i recenti progressi nella misura della polarizzazione della CMB, con un'attenzione particolare ai segnali di tipo B, considerati una potenziale firma di onde gravitazionali primordiali. Saranno inoltre discussi gli obiettivi scientifici e gli aspetti tecnologici della missione spaziale LiteBIRD, promossa dall'Agenzia Spaziale Giapponese (JAXA) con una forte partecipazione internazionale, il cui scopo principale è ottenere una mappa di alta precisione della polarizzazione della CMB su tutto il cielo. Saranno infine illustrati gli sviluppi strumentali in corso e le sfide principali nella realizzazione dei rivelatori dedicati a questa missione.

▲ **Phase I results of the the Pierre Auger Observatory and future perspectives.**  
VALORE L.

*INFN, Sezione di Napoli e Università di Napoli "Federico II"*

The Pierre Auger Observatory is the World's largest facility dedicated to the detection of ultra-high-energy cosmic rays. It utilizes a hybrid detection system that combines a Surface Detector of 1660 water-Cherenkov stations spread over 3000 km<sup>2</sup> with 27 fluorescence telescopes located at four sites, which monitor the atmosphere above the array during nights with good atmospheric conditions and low Moon fraction. In its Phase I, the Pierre Auger Observatory has published numerous breakthrough results on the nature of the most energetic particles in the Universe, thanks to its unprecedented precision and statistics. Major achievements obtained so far include the energy spectrum and its features, the observables linked to the UHECR mass composition and the distribution of arrival directions of the most energetic events. With AugerPrime, the Pierre Auger Observatory enters Phase II, enabling enhanced sensitivity to the mass composition of ultra-high-energy cosmic rays through the extended data set collected with the upgraded detectors. This work presents a summary of the most important findings and outlines the scientific prospects with AugerPrime.

● **Overview of the JEM-EUSO Program.**

CARUSO R. ON BEHALF OF THE JEM-EUSO COLLABORATION

*Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

Since 2010, the international JEM-EUSO (Joint Exploratory Missions for Extreme Universe Space Observatory) Collaboration has been developing an ambitious program with the support of International and National Space Agencies and research funding institutions, to enable ultra-high-energy cosmic ray and high-energy neutrino observations from space. Its main objective is to develop a large mission looking down on the Earth atmosphere from space, both towards nadir and/or towards the limb, to detect the Extensive Air Showers initiated by such particles. This strategy will complement the observations made with ground-based observatories, by allowing a significant increase in the exposure and achieving near-uniform full sky coverage. Over time, the JEM-EUSO collaboration successfully developed five intermediate missions: one ground based (EUSO-TA), three balloon-borne (EUSO-Balloon, EUSO-SPB1, EUSO-SPB2) and two space-based (MINI-EUSO, TUS). Important studies for a full-scale mission have also been carried out, namely K-EUSO, and the stereo double telescope Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) for the next decades. The technical and scientific achievements of this rich and manifold program will be reported. The near-future developments of the JEM-EUSO program (continuation of the MINI-EUSO and the new balloon-borne mission PBR) will be also presented.

Comunicazioni

● **Performance of the high energy particle detector on board the second China seismo-electromagnetic satellite.**

PERCIBALLI S. ON BEHALF OF THE CSES-LIMADOU COLLABORATION

*Università di Torino*

The second China Seismo-Electromagnetic Satellite (CSES-02) is a space mission with the aim of investigating the near-Earth electromagnetic environment, gaining further understanding of the lithosphere-atmosphere-ionosphere-magnetosphere coupling. This space mission will be launched in June 2025 and will join the first of future network of satellites, CSES-01, increasing the sky coverage and adding further sensitivity to the results obtained by the previous mission. Between the payloads onboard CSES-02, there is the High Energy Particle Detector, which is optimized for measuring fluxes of electrons and protons in the

3-100 MeV and 30-200 MeV energy range respectively. HEPD-02 is composed of two layers of plastic scintillators used as trigger, a range detector of twelve plastic scintillators and two planes of LYSO bars. Moreover HEPD-02 has a precise tracking system based on Monolithic Active Pixel Sensors which is the first of such instruments relying on this technology for space applications. This contribution will give a general overview of the detector and will focus on the in-orbit performance during the commissioning phase.

● **Extending cosmic antimatter searches with HEPD-02: a MAPS-based detector onboard CSES-02.**

PUC CETTI N. <sup>(1)</sup>(<sup>2</sup>), FOLLEGA F.M. <sup>(1)</sup>(<sup>2</sup>), IUPPA R. <sup>(1)</sup>(<sup>2</sup>), NOZZOLI F. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Trento*

<sup>(2)</sup> *TIFPA, Trento Institute for Fundamental Physics and Applications*

The High Energy Particle Detector (HEPD-02), aboard the upcoming China Seismo-Electromagnetic Satellite (CSES-02), is a novel instrument designed to detect protons (30-200 MeV), electrons (3-100 MeV), and light nuclei for cosmic ray, geophysical and space weather studies. Beyond its main goals, HEPD-02 offers a unique opportunity to explore low-energy antimatter in space, notably antideuterons and antiprotons, messengers in indirect dark matter searches. HEPD-02 is the first space-based payload using a tracker built with Monolithic Active Pixel Sensors (MAPS), featuring a single-hit resolution of 5  $\mu\text{m}$ . This unprecedented granularity enables potential detection of low-energy antideuteron annihilations in the 10-30 MeV/n range, a region unexplored by experiments such as BESS-Polar II and AMS-02. We present the detector's sensitivity to antideuterons and the future analysis strategy, combining pixel-level tracking and calorimetry to suppress backgrounds from protons, deuterons, and heavier nuclei. Investigating this energy region would add complementary information to the current experimental scenario, also helping validate several theoretical models concerning new physics.

● **An advanced pulse-avalanche stochastic model of long gamma-ray burst light curves.**

MACCARY R. <sup>(1)</sup>(<sup>2</sup>), MAISTRELLO M. <sup>(1)</sup>(<sup>2</sup>), GUIDORZI C. <sup>(1)</sup>(<sup>2</sup>)(<sup>3</sup>), BAZZANINI L. <sup>(1)</sup>(<sup>2</sup>), FERRO L. <sup>(1)</sup>(<sup>2</sup>)

<sup>(1)</sup> *Università degli studi di Ferrara*

<sup>(2)</sup> *INAF, Osservatorio di Astrofisica e Scienza dello Spazio di Bologna*

<sup>(3)</sup> *INFN, Sezione di Ferrara*

A unified explanation of the variety of long gamma-ray burst (GRB) light curves (LCs) is essential for identifying the dissipation mechanism and possibly the nature of their central engines. A stochastic pulse avalanche model was previously proposed and tested by comparing average temporal properties of simulated and real LCs. We recently revived this model and optimised it via genetic algorithm (GA), and now present an advanced version that constrains the single pulse peak flux distribution and evaluate its performance on Fermi/GBM data. With new parameters and an added comparison metric (the signal-to-noise distribution), we test the new model on 3 datasets: CGRO/BATSE, Swift/BAT, and Fermi/GBM. The updated sets of parameters further reduces the loss compared to both the original model and our earlier optimisation. Parameter differences across the datasets are linked to the instrument energy passbands, effective areas, and, ultimately GRB populations. Our findings strengthen the case for a stochastic, avalanche-like dissipation mechanism behind long GRB prompt emission, and position the model as a robust tool for simulating GRB LCs for future missions.

● **EPSI: R&D of a space-based synchrotron radiation detector for charge sign discrimination in cosmic rays.**

DE GIORGI G. <sup>(1)(2)</sup>, BERTI E. <sup>(2)</sup>, CAMAIANI A. <sup>(1)(2)</sup>, VOLPATO C. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università di Firenze*

<sup>(2)</sup> *INFN, Sezione di Firenze*

The direct measurement of the positron component in cosmic rays provides crucial insights on their acceleration/propagation mechanisms and represents a powerful tool for indirect dark matter searches. Space instruments performing charge sign discrimination using magnetic spectrometers are, however, not suited to extend current measurements at higher energies. Therefore, it is important to develop alternative techniques that could be integrated with future experiments based on large size calorimeters. Investigating one of such techniques is the main goal of the Electron Positron Space Instrument (EPSI) project, an R&D that has been approved and financed in Italy as a PRIN (Research projects of relevant national interest). The guiding principle of the project is the simultaneous detection of an electron/positron with a calorimeter and of the synchrotron radiation it emits as it travels through the geomagnetic field with an x-ray detector, which would allow the discrimination between the two leptons at the event level. The main challenges are to develop a space-compliant x-ray detector with a large active area, high x-ray detection efficiency and low energy threshold.

● **Measurement of cosmic-ray helium flux in extended acceptance with CALET on ISS.**

MATTIAZZI M.

*Dipartimento di Fisica e Astronomia, Università di Padova e INFN, Sezione di Padova*

High-precision measurements of nuclei from direct cosmic-ray experiments provide deeper insights into the mechanisms of cosmic-ray acceleration and propagation in the Galaxy. Recently, space-based calorimetric instruments, CALET as well as DAMPE, have revealed a new spectral feature: a softening in the flux at tens of TeV, that is not explained by conventional cosmic-ray models. However, substantial uncertainties remain in the multi-TeV energy range, primarily due to limited data statistics. In this contribution, we present an analysis aimed at measuring the cosmic-ray helium flux with improved statistical precision, using CALET data in extended acceptance. The event selection strategy, based on Boosted Decision Trees (BDT), is described and preliminary results are compared with both the standard analysis and flux measurements from other experiments.

● **Observation of the May 2024 Forbush decrease by the network of MRPC telescopes of the Extreme Energy Events Project.**

RIPOLI C. ON BEHALF OF THE EEE COLLABORATION

*Università di Salerno e INFN, Sezione di Napoli Gruppo Collegato di Salerno*

The exceptional Forbush event observed in May 2024 due to a series of intense solar flares accompanied by coronal mass ejections was detected by the MRPC muon telescopes of the Extreme Energy Events (EEE) Project as well as by the three EEE scintillator telescopes installed at Ny-Alesund, in the Svalbard archipelago, at a high latitude (79° N). The EEE MRPC gas detectors operate with a new eco-friendly gas mixture based on HFO and He, marking the first large-scale application of this kind. This contribution reports the latest results concerning the observation of this event, which highlight the capability of the stations of the EEE array to measure the muon rate variations of muon associated with the event, demonstrating both high sensitivity and excellent uniformity in response across the network.

● **Calibration of the HEPD-02 detector on board the CSES-02 satellite.**

AMOROSO S.

*INFN, Sezione di Roma Tor Vergata*

The CSES/Limadou mission, a joint Italian-Chinese collaboration started in 2013, involves the launch of several satellites over the coming years. Following the launch of CSES-01 (China Seismo-Electromagnetic Satellite 01) in 2018, the next satellite, CSES-02, is scheduled for the summer of 2025. Among its 11 payloads is the HEPD-02 (High-Energy Particle Detector 02), designed to measure charged particles -protons (30-200 MeV), electrons (3-100 MeV) and light nuclei- with very good energy and angular resolution. The trigger logic enables precise measurements in high-radiation areas such as the South Atlantic Anomaly (SAA) and also to record gamma-ray bursts (GRBs). Current efforts focus on calibrating the instrument, including equalizing the calorimeter by developing an energy renormalization algorithm for reconstructed energy based on the position of incident particles. This equalization is enabled by the precise track propagation allowed by HEPD-02's innovative pixel tracking system, which is being used for the first time in a space mission. This work presents a detailed description of the ongoing calibration approach, using data both from beam tests and cosmic muon acquisitions.

● **Search for  $\gamma$ -ray emission from microblazars with FERMI-LAT.**

CONTI F.

*Dipartimento di Fisica, Università degli Studi di Palermo*

The results of the search for gamma-ray emission from three candidate microblazars (4U 1543-47, MAXI J1836-194, V4641 Sgr) are presented, using the Fermi-LAT Pass 8 dataset. This search is influenced by the recent detection of TeV radiation by High-Altitude Water Cherenkov Observatory (HAWC) of the microquasar V4641 Sgr. A search for gamma-ray emission from these sources was conducted using flare events and 16 years of Fermi-LAT dataset. For all of the aforementioned sources, both standard unbinned and binned analyses have been performed. These analyses have revealed no significant gamma-ray excess above the background noise at the location of each source.

● **Radiation damage assessment of SiPMs for the Ziré Experiment on board the NUSES space mission.**

FONTANELLA G. ON BEHALF OF THE NUSES COLLABORATION

*Gran Sasso Science Institute, L'Aquila*

NUSES is an innovative space mission proposed and coordinated by the Gran Sasso Science Institute, in collaboration with INFN, various academic institutions and Thales Alenia Space Italia. The mission hosts two main scientific payloads: Ziré and Terzina. Ziré is designed to measure the energy spectra of low-energy cosmic and gamma rays, monitor the Sun-Earth environment, study space weather phenomena and investigate Magnetosphere-Ionosphere-Lithosphere couplings. A dedicated Low Energy Module (LEM) will extend the sensitive energy range down to the MeV scale for charged particles. Terzina is an explorer that aims to detect atmospheric Cherenkov light from orbit, for the study of ultra-high energy cosmic rays (UHECR) and neutrino astronomy. To achieve their scientific objectives, both payloads use silicon photomultipliers (SiPM) supplied by Hamamatsu for Ziré and by the Bruno Kessler Foundation (FBK) for Terzina. In this paper, we report simulations of the radiation environment, performance and radiation tolerance, regarding the Total Ionising Dose (TID) of three SiPM devices developed by FBK, which differ in size and technological design.

● **Tracing ultra-high-energy cosmic-ray trajectories through galactic magnetic fields: insights from the Pierre Auger Observatory.**

BIANCIOOTTO M.

*Dipartimento di Fisica, Università degli Studi di Torino e INFN, Sezione di Torino*

Unveiling the sources of ultra-high-energy cosmic rays remains one of the main challenges of high-energy astrophysics. Measurements of anisotropies in their arrival directions are key to identifying their sources, yet deflections by intergalactic and Galactic magnetic fields obscure direct associations. In this work, we reconstruct the sky regions of origin of the highest-energy events detected by the Pierre Auger Observatory by tracing their trajectories through Galactic magnetic fields using the most up-to-date models and fully accounting for uncertainties in energy and direction. By incorporating constraints on the maximum propagation distances, we also allow for a three-dimensional localization of the potential source regions. Our findings provide new constraints on the origin of the most energetic cosmic-ray particles and offer fresh insights into the influence of Galactic magnetic fields in shaping the observed ultra-high-energy cosmic-ray sky.

● **DAQ and electronics development and characterisation for the multiPMT prototype for the SWGO experiment.**

SANSONE F.

*Dipartimento di Fisica, Università degli Studi di Napoli Federico II e INFN, Sezione Napoli*

The Southern Wide Field Gamma-ray Observatory (SWGO) is a next-generation ground array using the Water Cherenkov technique for the detection of gamma rays, to be deployed at 4,770 m a.s.l. in Chile's Atacama Astronomical Park. Covering energies from hundreds of GeV to PeV, SWGO will complement northern observatories (HAWC, LHAASO), offering Southern sky gamma-ray coverage which includes the galactic center. The SWGO Naples group has proposed a multiPMT module of seven 3 PMTs as photodetector whose intrinsic advantage is directionality, to improve event reconstruction and gamma/hadron discrimination. Building on Hyper-Kamiokande expertise, we have designed a modular electronics chain for power, signal conditioning and data transfer, alongside a DAQ system for synchronized acquisition. A prototype at CBPF in Rio de Janeiro is undergoing environmental monitoring since December 2024 and has recorded self-triggered events. Integration with a muon tracker will refine event selection. Coincidence analyses have revealed PMT signal asymmetries, likely due to partial Cherenkov-cone coverage. Two further prototypes are foreseen to be installed at the Pathfinder array at the SWGO site.

● **Development of a multiPMT detector for the SWGO experiment: Simulation and performance study on muon tagging with machine learning techniques.**

GRIECO V.M.

*Scuola Superiore Meridionale, Napoli e INFN, Sezione di Napoli*

Imaging Air Cherenkov Telescopes and Ground Based Arrays are the major contributors to Gamma Ray astronomy at ground level. The Southern Wide-Field Gamma-ray Observatory (SWGO) will be a water Cherenkov Array located in the Atacama Desert in Chile that will monitor the VHE and UHE sky. The Naples group has proposed a multi-photomultiplier (multiPMT) detector for SWGO, based on KM3NeT and HyperKamiokande designs, consisting of seven 3-inch outward-facing PMTs. A multiPMT photosensor offers intrinsic sensitivity to the directionality of incoming particles Cherenkov light cone, large dynamical range and increased time resolution. My work demonstrates the advantages of the multiPMT over the single-PMT alternative. I developed a detailed simulation of the multiPMT and studied ways to improve Cherenkov light collection and upgrade the original design of the prototype. I also investigated the muon tagging capabilities of multiPMTs in water Cherenkov tanks

using various machine learning models and explored the potential of using the multiPMT's directional sensitivity for neutrino detection in the context of Multimessenger Astronomy.

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Aula Seminari B, Section B, Edificio 19

ore 14:00 – 19:00

SEZIONE IV

**Geofisica e fisica dell'atmosfera**

Presiede: PAONITA A. (INGV, Palermo)

Relazioni su invito

▲ **Earthquake physics in a volcanic caldera: Imaging, fracture dynamics, and risk implications at Campi Flegrei.**

ZOLLO A.

*Department of Physics E. Pancini, University of Naples Federico II*

The ongoing unrest at Campi Flegrei caldera (southern Italy) presents complex challenges in terms of hazard assessment and risk mitigation. Over the past decade, and particularly during the recent 2019–2024 crisis, we have investigated the evolution of seismicity and ground deformation using a multidisciplinary approach. High-precision earthquake locations reveal a fine-scale, elliptical fault network within the caldera, capable of hosting events up to magnitude 5.1. High-resolution 3D seismic tomography identifies a shallow gas-rich reservoir beneath the area of maximum uplift, structurally controlled by a deformed caprock. Rupture dynamics from moderate earthquakes show sub-shear rupture velocities and a clear inverse relationship between stress drop and propagation speed, pointing to dominant off-fault damage processes that may limit rupture extent. Finally, probabilistic seismic hazard analyses —integrated with engineering design thresholds— support targeted risk reduction strategies, particularly for reinforced concrete structures. These findings offer critical updates for both scientific understanding and civil protection planning.

▲ **Modeling volcanic tephra fallout in the HPC era: An application case to the long-term hazard assessment from Neapolitan volcanoes.**

MASSARO S.

*Istituto Nazionale di Geofisica e Vulcanologia di Bologna*

Volcanic eruptions are multiphase and multiscale processes that can release large quantities of tephra into the atmosphere that deposit up to very distal areas, posing hazards to people, infrastructure and aviation. Robust models are essential for both real-time hazard forecasting and long-term risk assessment. With the increasing of computational power, tephra transport models developed for high-performance computing (HPC) environment have become pivotal in this field, allowing volcanologists to simulate larger domains at high resolution. Here, I summarize a new methodology for long-term probabilistic tephra fallout hazard assessment in South Italy, associated to the 3 active Neapolitan volcanoes. Using the FALL3D (v8.0), we ran over 10000 simulations using the ECMWF ERA5 dataset over the past 30 years. Simulated tephra deposits were processed through a Bayesian workflow to calculate the mean annual frequency at which ground tephra load exceeds critical thresholds within a 50-year exposure time. Results include hazard maps disaggregated by source and eruption size, offering a multi-volcano hazard perspective. This represents the first tephra fallout hazard assessment worldwide adopting a fully probabilistic, simulation-based approach comparable to those used for earthquakes and tsunamis, paving the way for a homogenized multi-hazard quantification of natural events.



▲ **Interpretative models of the dynamics of Campi Flegrei.**

MACEDONIO G., CHIODINI G., CALIRO S., GIUDICEPIETRO F.

*Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy*

Campi Flegrei are a volcanic caldera located in the Neapolitan area. Over the past 15000 years, more than 60 eruptions occurred in the area, most of them explosive in nature. The most recent eruption, of small magnitude, took place in 1538 and was preceded by a ground uplift of over twenty meters, six of which occurred in the year preceding the eruption. In addition to volcanic eruptions, Campi Flegrei also show ground uplift and subsidence that do not necessarily culminate in an eruption. Since 1968, the ground in the Phlegraean area has experienced three uplift crises, the most recent of which began in 2005. This event has shown a ground uplift of 1.4 meters, accompanied by an increase in seismicity and in the emission of gas from the ground and fumaroles. These phenomena are generally interpreted as being caused by an increase in the flow of deep magmatic fluids ( $\approx 6-8$  km) which, rising upward, heat the shallow hydrothermal system ( $\approx 3$  km), causing an increase in the system's temperature and pressure. This contribution will describe models of the system's behavior that are consistent with the geophysical measurements carried out.

Comunicazioni

● **Ground deformation of Campi Flegrei and Vesuvio since 1993 using SAR data.**

AMORUSO A., CRESCENTINI L., SALICONE G.

*Dipartimento di Fisica, Università di Salerno, Italia*

Since the 1950s, Campi Flegrei have experienced periodic unrest. The episode of unrest between 1982 and 1984 was followed by a long period of subsidence and the Campi Flegrei have been experiencing renewed unrest since 2005. Vesuvio has been considered active but dormant since 1944. The eruptive histories of Campi Flegrei and Vesuvio are distinct, and the products of their past eruptions have different characteristics, but it is possible that a common 8–10 km deep magmatic layer exists. Recent studies using ERS/ENVISAT (1993–2010) and SNT1 (2015–present) SAR data have also indicated the activity of a deformation source at a depth of about 8 km, a deep depressurisation beneath Vesuvio in the early 2000s, and a probable deep interaction between the two volcanoes during the transition from subsidence to uplift of Campi Flegrei. The period 2010–2015 is therefore of particular interest. ESA project PP0094512 allowed the generation of 2010–2015 deformation time series from RST2 images over the entire volcanic area and the objective was achieved by implementing a specific procedure. The results obtained by combining ERS/ENVISAT, RST2 and SNT1 data are presented in detail.

Relazioni su invito

▲ **Moment tensor inversion and waveform clustering constrain seismic sources associated with the unrest of Campi Flegrei volcanic system, Italy.**

SACCOROTTI G. <sup>(1)</sup>, RAPAGNANI G. <sup>(1)(2)</sup>, CESCO S. <sup>(3)</sup>, PETERSEN G. <sup>(3)</sup>, BIANCO F. <sup>(4)</sup>, GRIGOLI F. <sup>(1)(2)</sup>

<sup>(1)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*

<sup>(2)</sup> *Dipartimento di Scienze della Terra, Università di Pisa, Italy*

<sup>(3)</sup> *GFZ, Helmholtz Centre for Geosciences, Germany*

<sup>(4)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Italy*

Campi Flegrei (CF) is a volcanic system located in a densely populated area West of Naples, southern Italy. With a long history of eruptions, CF is the largest active caldera system

in Europe. The most prominent feature of CF activity is ground deformation (so-called “bradyseism”), which consists of rapid uplift usually accompanied by seismicity, followed by slow subsidence aseismic phases. The most recent awakening episode started almost 20 years ago, climaxing by early 2025 with more than 2000 events/month, and largest magnitude  $M_d = 4.6$ . We investigate this seismicity using the catalogue provided by the INGV, Osservatorio Vesuviano, for the 2014–early 2025 time interval. For a selected subset of  $\sim 100$  events with  $M_d > 2.5$ , we perform time-domain, full-waveform Moment Tensor (MT) inversion using data recorded by up to 20 stations within 50 km epicentral range. The inversion is conducted using a probabilistic approach, adopting different velocity models and frequency bands for stations located at distinct distance intervals. We obtain full, deviatoric and double-couple MT solutions for more than 80 events. From waveform similarity we identify 7 earthquake clusters, each characterized by similar locations and focal mechanisms. Most mechanisms indicate normal faulting; offshore events have locations and fault plane orientations which resemble the geometry of the caldera rim, while those in the most active Solfatara region mostly strike WSW-ENE. These results reveal with unprecedented detail the geometry and kinematics of the active fault structures in the Campi Flegrei region, and their relationships with volcano-tectonic lineaments.

#### ▲ Towards the core: Unveiling magma processes and geothermal potential at Krafla.

PAPALE P., GARG D.

*Istituto Nazionale di Geofisica e Vulcanologia, Pisa*

The Krafla Magma Testbed (KMT) is an international geoscience initiative aiming to establish the world’s first magma observatory at the Krafla volcanic system in Iceland, where magma resides at an accessible depth of  $\sim 2$  km. KMT presents an unprecedented opportunity to directly investigate magma dynamics, crustal interactions, and the processes that initiate volcanic eruptions. By enabling *in situ* observations and long-term monitoring near an active magma body, the project addresses fundamental scientific challenges in understanding the architecture and evolution of volcanic systems. It also promises to advance eruption forecasting capabilities and inform hazard mitigation strategies. Concurrently, KMT supports the development of super-hot geothermal technologies by exploring the extraction of energy from supercritical fluids at extreme temperatures and pressures. The integration of volcanology, geophysics, and geothermal engineering at KMT represents a transformative step toward both scientific discovery and sustainable energy innovation.

#### ▲ Monitoring volcanic plumes using remote sensing: State of the art and future strategies.

SCOLLO S. <sup>(1)</sup>, MEREU L. <sup>(2)</sup>, ROMEO F. <sup>(1)</sup><sup>(3)</sup>

<sup>(1)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etno*

<sup>(2)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna*

<sup>(3)</sup> *Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome*

During explosive eruptions, large amounts of volcanic particles are ejected upward from the vent by the pressure of expanding gases, forming tall eruption columns. As the plume ascends into the surrounding less dense atmosphere, it eventually reaches an altitude where its density equals that of the cooler ambient air. This level is known as the neutral buoyancy region and is typically marked by a spreading of the eruption column, known as the umbrella region. In this region, volcanic particles, ranging in size from microns to several centimetres, can be transported and deposited up to hundreds of kilometres from their source, making the volcanic ash dispersion one of the most widespread volcanic hazards. Moreover, given

that over 500 million people live near active volcanoes, explosive eruptions pose a significant threat not only to local populations and infrastructure but also to human health and global air traffic. For this reason, accurate monitoring of volcanic plumes during explosive activity is essential. In this work, we review the most commonly used remote sensing systems for monitoring volcanic clouds. Many of these systems focus on estimating key Eruption Source Parameters (ESPs), such as column height, mass eruption rate, and total grain size distribution. Near real-time measurements of these parameters are crucial for modelling plume dispersion and implementing preventive measures. While satellite-based remote sensing remains the most widely used method due to its global coverage and accessibility, visible and thermal cameras are increasingly important tools for estimating ESPs such as column height. Additionally, instruments such as lidar and radar networks offer high spatial and temporal resolution, making them highly effective for volcano monitoring. We highlight how multidisciplinary approaches, such as those employed at well-monitored volcanoes like Etna, can provide reliable data during volcanic crises, overcoming the limitations of satellite-only systems and improving the accuracy of the ESPs estimates. Finally, we discuss current gaps in monitoring capabilities and suggest directions for future developments.

#### ▲ Integrating ground-based and satellite sensors for detection of tephra fallout coverage.

MEREU L. <sup>(1)</sup>, ROMEO F. <sup>(2)(3)</sup>, PRESTIFILIPPO M. <sup>(3)</sup>, SCOLLO S. <sup>(3)</sup>

<sup>(1)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy*

<sup>(2)</sup> *Department of Information Engineering, Electronics and Telecommunications, Sapienza, University of Rome, Rome, Italy*

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When a volcano erupts explosively, large amounts of tephra, *i.e.*, volcanic particles of varying size and shape, are ejected into the atmosphere. Depending on the eruption style, particle characteristics and prevailing meteorological conditions, tephra fallout can affect areas located tens of kilometers from the eruptive vent, posing a significant hazard to populations living on or near the volcano's flanks. Consequently, during a volcanic crisis, it is essential to identify the areas affected by the tephra deposition. To this end, many volcanic observatories employ volcanic ash dispersal models to simulate predefined eruptive scenarios using Eruption Source Parameters (ESPs), such as total erupted mass, mass eruption rate, total grain size distribution and column height, typically derived from analyses of past eruptions. However, actual eruptive events often differ from these scenarios. In this study, we explore the potential of combining ground-based and satellite-based sensors to identify areas affected by the tephra fallout. Specifically, we utilize an X-band weather radar (XWR) and the SE-VIRI imager sensor onboard the Meteosat Second Generation (MSG) geostationary satellite. As a case study, we focus on Mt. Etna (Italy), given its frequent explosive activity in recent years and the availability of advanced monitoring systems. We propose a new method for detecting tephra-covered areas by integrating data from radar and satellite sources. The identified regions are imported into the Quantum Geographic Information System (QGIS) to analyze the spatial intersection of areas detected by both sensors. The results are validated using deposit data from the literature and compared with tephra fallout maps generated by a volcanic ash dispersal model, which incorporates ESP derived from both sensors. This analysis aims to evaluate whether a single sensor provides sufficient accuracy for tephra fallout mapping or whether the integration of multiple sensor types significantly enhances assessment reliability.

▲ **A digital twin for volcanic unrest detection at Mount Etna: Integrating FEM simulations and AI.**

GARG D., PAPAIE P., BRUNI R., CANNAVÒ F., ALLEGRA M., PAOLO D.E.

*Istituto Nazionale di Geofisica e Vulcanologia*

With growing computational power and data availability, the EU is advancing toward creating a digital replica of the Earth through initiatives like Destination Earth (DestinE) to model and predict natural phenomena. This effort includes the development of several Digital Twins (DTs), each simulating specific Earth system components. DTGEO is a EU-funded project focused on geophysical extremes, aiming to build 12 DT components for events such as tsunamis, earthquakes, volcanoes, and anthropogenic seismicity. These DTs leverage HPC and cloud infrastructures like FENIX RI and EuroHPC to run large-scale simulations and manage real-time data. Within this framework, we are developing a DT to detect volcanic unrest driven by dike intrusions at Mount Etna. Such intrusions generate pressure anomalies and surface deformation signals captured by monitoring networks. Our DT combines 3D simulations of elastostatic rock deformation for over 10 million dike scenarios, computed with the multi-physics FEM code GALES, and AI models to identify signs of unrest from multiparametric monitoring data and infer the probability distribution of the underlying dynamic pressure sources.

Comunicazioni

● **Monitoring volcanic unrest at Mount Etna (Italy) using satellite land surface temperature time series from satellite data.**

PISCINI A., FIDANI C.

*Istituto Nazionale di Geofisica e Vulcanologia*

Mount Etna's volcanic activity was monitored from 2020 to 2024 using NASA-JPL's ECOSTRESS land surface temperature data (~ 70 m resolution). Two pixels were analyzed—one near the vent and one stable background—using the SAD algorithm to detect thermal anomalies, with wavelet analysis for validation. The study assessed the method's sensitivity to different volcanic events, including eruptions of various VEI, lava fountains, and ash emissions. During three eruptive phases from 2022–2024, the method identified anomalies preceding the May 2023 South-East crater eruption (VEI 1, ash dispersion) and the April 7, 2024 Bocca Nuova ash emission (VEI 2). However, no anomalies were found during the first phase (November 2022–February 2023), despite lava flow and VEI 1 explosive activity. Satellite-based infrared sensing presents a valuable tool for better understanding volcanic precursors and strengthening disaster preparedness. This technique is applicable not only to Mount Etna but also to other active volcanoes globally.

● **First observations from geophysical, hydromorphological and biochemical monitoring of Maccalube di Aragona mud volcano (Sicily, Italy) in the framework of INGV-PROMUD project.**

CUSANO P.<sup>(1)</sup>, MADONIA P.<sup>(2)</sup>, PETROSINO S.<sup>(1)</sup>, BELLUCCI Sessa E.<sup>(1)</sup>, COSTANZA A.<sup>(3)</sup>, DE TOMMASI N.<sup>(4)</sup>, FALANGA M.<sup>(5)</sup>, FERTITTA G.<sup>(3)</sup>, MANCINI S.<sup>(5)</sup>, GUCCIARDO D.<sup>(6)</sup>

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<sup>(6)</sup> Legambiente Sicilia, Gestione RNI, Maccalube di Aragona, Italy

PROMUD INGV project aims to monitor mud volcano (MV) activity and to delineate the dynamical evolution. Our strategy is based on the interplay of multidisciplinary disciplines

such as geophysics, biogeochemistry and geomorphology. Here we focus on the observations so far gathered at Maccalube di Aragona: seismicity shows a main frequency content  $< 5$  Hz, the absence of local amplifications, a possible periodic behaviour of amplitude; meteorological data and temperature, water content and electric conductivity of soil, number and position of active vents, and apparent soil moisture content indicate a strong control of the hydrological cycle on the number and distribution of vents, and on the rheological properties of the emitted fluids; metabolomic analyses of hydroalcoholic extracts of aerial parts of *Suaeda vera* suggest a local biochemical adaptation; the environmental  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  emissions from soil revealed a high concentration only in correspondence with the active vents; very homogeneous concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{137}\text{Cs}$  radionuclides were measured in the dried plants suggesting a possible link between that radionuclide and the plant's activity.

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Aula 9, Section C, Edificio 19

ore 14:00 – 19:00

SEZIONE V

**Biofisica e fisica medica**

Presiede: SANCATALDO G. (Università di Palermo)

Relazioni su invito

▲ **Thermoacoustic characterization of particle beams.**

VALLICELLI E.A., DE MATTEIS M.

*Dipartimento di Fisica, Università di Milano-Bicocca, Italia e Istituto Nazionale di Fisica Nucleare, Sezione di Milano-Bicocca, Italia*

Thermoacoustic imaging of particle beams is an emerging technique in hadron therapy that allows the reconstruction of 2/3D dose deposition by sensing the pressure signal (10–300 kHz ultrasound) generated by the fast deposition of energy in the target medium (patient or water phantom). The most interesting application concerns the real-time monitoring of hadron therapy treatments, where it promises sub-mm accuracies and sub-ms latencies, competitive compared to classic nuclear imaging techniques (*e.g.*, PET). Moreover, it is particularly suitable for high dose rate therapies such as FLASH due to the high dynamic range and linearity of piezoelectric sensors, rendering this technique immune to detector saturation and dead time effects. The main challenge in this area concerns the ability to acquire and process the weak signals (tens of mPa) of hadron therapy treatments, in bandwidths of few tens kHz where flicker noise is predominant. This requires strong improvements in detector technology, namely dedicated multichannel wide-bandwidth piezoelectric sensors, integrated circuits front-ends and denoising/imaging algorithms to precisely map the dose deposition in space for each beam pulse.

▲ **Boron Neutron Capture Therapy research from radiobiology to neutron beam design: A truly interdisciplinary voyage.**

BORTOLUSSI S. <sup>(1)(2)</sup>, POSTUMA I. <sup>(2)</sup>, FATEMI S. <sup>(2)</sup>, RAMOS R. <sup>(2)</sup>, DEMICHELIS M.P. <sup>(1)(2)</sup>, GARINI G. <sup>(2)</sup>, PEZZI C. <sup>(1)(2)</sup>, MARCACCIO B. <sup>(1)(2)(3)</sup>, BAGNALE L. <sup>(4)(5)</sup>, ANSELMITAMBURINI U. <sup>(2)(6)</sup>, AIROLDI L. <sup>(2)</sup>, SOMMI P. <sup>(2)(7)</sup>, CANSOLINO L. <sup>(2)(8)</sup>, FERRARI C. <sup>(2)(8)</sup>, DELGROSSO E. <sup>(9)</sup>, RIVA F. <sup>(2)(10)</sup>, RICCI S. <sup>(2)(10)</sup>, PORTU A. <sup>(3)(11)(12)</sup>, GONZALEZ S. <sup>(3)(11)(12)</sup>, VERCESI V. <sup>(2)</sup>

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<sup>(8)</sup> *Department of Clinical Surgical, Diagnostic and Pediatric Sciences, University of Pavia, Italy*

<sup>(9)</sup> *Department of Civil Engineer and Architecture, University of Pavia, Italy*

<sup>(10)</sup> *Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Italy*

<sup>(11)</sup> *National Atomic Energy Commission, CNEA, Argentina*

<sup>(12)</sup> *National Scientific and Technical Research Institute, CONICET, Argentina*

Boron Neutron Capture Therapy (BNCT) is a targeted radiotherapy that exploits the nuclear reaction  $^{10}\text{B}(n, \alpha)^7\text{Li}$ . Following selective boron accumulation in the tumor via a specific agent, subsequent neutron irradiation induces the emission of high-LET, short-range charged particles within the cancerous cells. While the concept of using a nuclear reaction for selective dose deposition is straightforward, its efficacy depends on a complex interplay of factors, including boron distribution, boron absolute concentration in tumour and normal tissues, and the spectral characteristics of the neutron beam. Accurate dose prescription and clinical outcome prediction necessitates the understanding and modeling of the relationship between absorbed dose and biological effect. The production of radiobiological data is needed to translate the BNCT dose into photon-equivalent units based on the observed results in models. Moreover, it is necessary to design a neutron beam to reach the tumour with high flux and good uniformity. This contribution will show BNCT research in the frame of PNC-PNRR ANTHEM and GIOCONDA projects, highlighting how the results of physics, chemistry and biological experiments are crucial to deliver safe and effective treatment to patients.

#### ▲ **Terapia FLASH: sfide verso la transizione clinica.**

MATTEI I.

*National Institute of Nuclear Physics, INFN, Roma I Section, Rome, Italy e Department of Basic and Applied Sciences for Engineering, University of Rome "La Sapienza", Rome, Italy*

La terapia FLASH è una promettente innovazione nella radioterapia, basata sulla somministrazione della dose terapeutica con dei rate che superino i 40 Gy/s (0.01 Gy/s in modalità convenzionale). In questa modalità si osserva una riduzione della tossicità ai tessuti sani, denominata "effetto FLASH", misurata ad oggi con fasci generati da elettroni, protoni e fotoni. Tra questi, i Very High Energy Electrons (VHEE, 70–130 MeV) si rivelano particolarmente promettenti per il trattamento di tumori profondi avendo un'ottima compatibilità con l'erogazione in regime FLASH. In questo contesto si colloca il progetto SAFEST della Sapienza Università di Roma, volto allo sviluppo di un acceleratore compatto per VHEE utilizzabile in ambito clinico che verrà installato nel 2026. Per studiare le potenzialità di tale apparato è stato realizzato un sistema di pianificazione specifico per VHEE-FLASH e sono stati studiati tre casi clinici relativi a pazienti con tumore al pancreas con alte prescrizioni di dose per frazione (stereotassia ablative). I risultati preliminari mostrano elevata conformità al bersaglio e ridotta dose agli organi a rischio, suggerendo un promettente potenziale clinico.

Comunicazioni

#### ● **Calcoli di radioprotezione per l'attivazione di un paziente dopo Boron Neutron Capture Therapy.**

GARINI G. <sup>(1)(2)</sup>, MAGNI C. <sup>(3)</sup>, POSTUMA I. <sup>(2)</sup>, FATEMI S. <sup>(2)</sup>, RAMOS R. <sup>(2)</sup>, MARCACCIO B. <sup>(1)(2)</sup>, PEZZI C. <sup>(1)(2)</sup>, BAGNALE L. <sup>(4)</sup>, SANDRI S. <sup>(5)</sup>, DE MATTEIS G. <sup>(5)</sup>, PAOLISSO G. <sup>(6)</sup>, VERCESI V. <sup>(2)</sup>, BORTOLUSSI S. <sup>(1)(2)</sup>

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Un nuovo centro di ricerca e di applicazione clinica di Boron Neutron Capture Therapy con fascio neutronico prodotto da acceleratore (AB-BNCT) verrà costruito a Caserta nell'ambito del progetto PNC-PNRR ANTHEM. La sorgente neutronica impiegata è ottenuta tramite un acceleratore quadrupolo a radiofrequenza da 5 MeV e 30 mA, accoppiato con un bersaglio di berillio e un Beam Shaping Assembly (BSA). Al fine di garantire la sicurezza per la popolazione, è necessario determinare dopo quanto tempo il paziente trattato possa essere dimesso. Poiché nella normativa italiana non sono presenti indicazioni dirette per i trattamenti con BNCT, è stato necessario introdurre un nuovo criterio per valutare il tempo di degenza per il paziente dal punto di vista della radioprotezione. Il criterio proposto è basato sul limite di 600 MBq di I-131 stabilito per la medicina nucleare. Attraverso l'utilizzo del codice Monte Carlo PHITS accoppiato a DCHAIN e il fantoccio ICRP 145, È stata valutata la dose ambientale H\* prodotta dallo iodio e paragonata con quella proveniente dall'attivazione del paziente in BNCT a diverse distanze dal paziente e variando il tempo dalla fine dell'irraggiamento.

#### ● First results on silicon sensors for UHDR proton beam monitoring.

DE ASTIS S.

*Università degli Studi di Torino, Dipartimento di Fisica, Torino, Italy e National Institute of Nuclear Physics, INFN, Sezione di Torino, Torino, Italy*

FLASH radiotherapy, characterized by ultra-high dose rates (UHDR), introduces significant challenges in beam monitoring. For this purpose, thin segmented silicon sensors have emerged as promising candidates. Previous studies by INFN and the University of Torino have already demonstrated the effectiveness of such sensors in monitoring electron FLASH beams. Further developing this approach, strip and multi-pad silicon sensors with active thicknesses between 15 and 45  $\mu\text{m}$  were tested, for the first time, on proton beams at both the Trento Proton Therapy Center and the HollandPTC facilities. Sensor signals were acquired using the multichannel TERA09 ASIC, with custom current divider boards employed to reduce the input current and prevent saturation under UHDR conditions, ensuring accurate operation throughout the measurements. Results demonstrated a linear response at dose rates up to 1.4 kGy/s, confirming the reliability of silicon sensors and the associated electronics under UHDR conditions. Additionally, their proven ability to resolve the beam profile highlights their potential for real-time beam monitoring in FLASH radiotherapy.

#### ● Low-energy electron FLASH radiotherapy as a novel approach to treat uveal melanoma.

SCAPICCHIO C. (<sup>2</sup>), CELENTANO M. (<sup>1</sup>)(<sup>2</sup>)(<sup>3</sup>), FUENTES T. (<sup>4</sup>), PENSAVALLE J. H. (<sup>3</sup>)(<sup>5</sup>), GIULIANO A. (<sup>6</sup>), RETICO A. (<sup>2</sup>), MASTURZO L. (<sup>3</sup>), CAVALIERI A. (<sup>1</sup>)(<sup>3</sup>)(<sup>7</sup>), PAIAR F. (<sup>3</sup>)(<sup>4</sup>), DI MARTINO F. (<sup>3</sup>)(<sup>6</sup>)

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Uveal melanoma is an aggressive tumor, common among adults. It is generally treated using brachytherapy, charged particle therapy or stereotactic radiotherapy (SRT) in order to preserve the eye. This study aims to verify the possibility of using low-energy electron FLASH radiotherapy in order to spare normal tissues surrounding the tumor. To this purpose, a Monte Carlo simulation of the existing ElectronFlash (EF) LINAC, situated in Santa Chiara Hospital (Pisa), has been developed. It can deliver 7–9 MeV electron beams in both FLASH ( $> 40$  Gy/s) and conventional (2 Gy/min) regimes. EGSnrc Monte Carlo algorithm was used for the simulation and the code was validated using flashDiamond detector and gafchromic films EBT-XD. The analysis was performed on selected clinical cases and showed that energies  $< 10$  MeV are insufficient to cover deep targets ( $> 2$  cm). To overcome this limitation, virtual energy spectra were generated (up to 30 MeV) to achieve better target coverage (95% cross profiles + 90% axial uniformity), comparable to the conventional SRT technique. We thank: Fondazione Pisa for funding CPFR (grant “prog. n. 134/2021”); PNRR -M4C2-I1.5-ECS00000017-Tuscany Health Ecosystem (THE).

● **From segmentation to positioning: How an AI-based TPS can optimize BNCT for glioblastoma multiforme treatment.**

PEZZI C. <sup>(1)(2)</sup>, MOROSATO F. <sup>(1)</sup>, MARCACCIO B. <sup>(1)(2)(3)</sup>, BAGNALE L. <sup>(4)(5)</sup>, BORTOLUSSI S. <sup>(1)(2)</sup>, RAMOS R.L. <sup>(2)</sup>, VERCESI V. <sup>(2)</sup>, POSTUMA I. <sup>(2)</sup>, FATEMI S. <sup>(2)</sup>

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Artificial Intelligence (AI) is increasingly integrated into medical physics, offering powerful tools for automatic image segmentation and enhancing treatment planning. In Boron Neutron Capture Therapy (BNCT), an innovative and promising radiotherapy that selectively targets tumors using boron-containing drugs and neutron irradiation, particularly suitable for the most resistant ones, AI can support precise treatment. This work presents a novel Treatment Planning System (TPS) applied for BNCT in Glioblastoma Multiforme (GBM) patients, integrating the application of Convolutional Neural Networks for Deep Learning-based CT segmentation. A key innovation is the implementation of an automated and analytical approach to patient positioning, a crucial issue in BNCT, based on dosimetric analysis within the GTV and OAR, enabling accurate, reproducible setups and direct comparison between AI-generated and manual contours. The goal is to maximize dose delivered in the tumor while sparing healthy tissues, simplifying the planning process and ensuring consistent, reproducible results. The proposed AI-supported TPS represents a step forward to more automated, optimized BNCT treatment planning.

● **Photon isoeffective microdosimetric dose model for Glioblastoma Multiforme in Boron Neutron Capture Therapy.**

MARCACCIO B. <sup>(1)(2)(3)</sup>, PORTU A. M. <sup>(3)(4)(5)</sup>, SANTA CRUZ G. A. <sup>(3)(5)</sup>, PEZZI C. <sup>(1)(2)</sup>, POSTUMA I. <sup>(2)</sup>, FATEMI S. <sup>(2)</sup>, BORTOLUSSI S. <sup>(1)(2)</sup>, GONZÁLEZ S. J. <sup>(3)(4)(5)</sup>

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Boron Neutron Capture Therapy consists in the administration of a boron drug, selectively targeting the tumor, and the subsequent irradiation with low-energy neutrons. Neutrons

captured in boron-10 produce charged particles with a range comparable with cellular diameters, able to cause lethal damage to the cell where the reaction occurs. While typically dosimetry assumes uniform boron distribution, experimental studies show that boron concentration varies significantly in different tissues and also within individual cells, affecting the spatial distribution of ionization events, and ultimately the biological impact of BNCT. This work extends the photon isoeffective dose model for Glioblastoma Multiforme (GBM) with the stochastic aspects of energy deposition at the cellular level and considering the nucleus-cytoplasm boron concentration ratio as a stochastic variable. Boron concentration microdistribution in the two subcellular compartments was measured for the first time in a GBM cell line. The new model is shown in the treatment planning of a clinical case. Progression-free survival is used as a figure of merit to evaluate the impact of considering the non-uniformity of boron.

● **Experimental validation of the scattering libraries for thermal neutron transport within moderators for BNCT.**

ROMANELLI G. <sup>(1)(2)</sup>, MINNITI T. <sup>(1)</sup>, FATEMI S. <sup>(3)</sup>, BORTOLUSSI S. <sup>(4)</sup>, AIROLDI L. <sup>(3)</sup>, KRZYSTYNIAK M. <sup>(2)</sup>, POSTUMA I. <sup>(3)</sup>, RAMOS R. <sup>(3)</sup>, VERCESI V. <sup>(3)</sup>, SENESI R. <sup>(1)</sup>

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Thermal Neutron Scattering Libraries (TNSL) are used in radiation transport codes for a number medical and radiation-protection applications. TNSLs are significantly affected by the structure and dynamics of a given material at the atomic scale, as well as by temperature and material processing. Here we present a self-consistent experimental approach for the determination of TNSL of materials used in the Beam Shape Assembly (BSA) of a clinical BNCT facility within the PNC-PNRR-ANTHEM project. In particular, we present results on sintered  $\text{AlF}_3\text{-MgF}_2$  compounds for epithermal-neutron moderation within the BSA. Experimental measurements were performed at the VESUVIO beamline at the ISIS Facility (UK), at several temperatures of interest. Experiments were performed concurrently combining neutron transmission, neutron diffraction, neutron resonance capture analysis and deep inelastic neutron scattering. Based on the experimental results, we present the modelling of the measured TNSLs considering the crystallographic information at the atomic scale, the effect on sintering at the nanometre scale, and the impact of fluorine zero-point nuclear energy at different temperatures.

● **Internal dosimetry for paediatric patients through GATE Monte Carlo simulations using the UF/NCI phantoms.**

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Internal Dosimetry (ID) plays a key role in nuclear medicine, and its standard-model-based approach is the MIRD S-factors formalism. While various databases of Specific Absorbed

Fractions (SAFs) for adult computational phantoms exist, data for pediatric phantoms are scarce. This work presents a Monte Carlo dosimetric study in which GATE simulations were implemented to compute SAFs on the UF/NCI pediatric voxelized phantoms. Emissions of monoenergetic photons and electrons (5 keV–10 MeV) were simulated from source organs of interest (*e.g.*, thyroid, brain, liver), and absorbed doses were scored in a larger set of target organs, enabling to evaluate the SAFs for couples of organs of interest. Simulations were performed on the Marconi 100 HPC cluster, exploiting parallelization to ensure uncertainties below 5% for photon SAFs and < 1% for electron auto-SAFs (*i.e.*, source = target). SAFs observed dependencies on particle energy, organ sizes, distance, and phantom age will be presented. These results contribute to the creation of dosimetric reference data for pediatric ID and will be a basis for future extensions including more organ pairs.

● **Feasibility study of a wearable multi-detector system for personalized internal dosimetry: The WIDMApp project.**

D'ANGELI C. <sup>(1)</sup>, ANTONINI M. <sup>(1)(3)(6)</sup>, CACCIA B. <sup>(1)(3)</sup>, CAMPANA L. <sup>(7)</sup>, CARRUEZZO M. <sup>(1)(2)(3)</sup>, CASSANO B. <sup>(5)</sup>, CENSI F. <sup>(4)</sup>, COLLAMATI F. <sup>(3)</sup>, DANTE V. <sup>(1)</sup>, DE SIMONI M. <sup>(1)(3)</sup>, FACCINI R. <sup>(3)(6)</sup>, IACCARINO G. <sup>(5)</sup>, MANCINI-TERRACCIANO C. <sup>(3)(6)</sup>, MARAFINI M. <sup>(3)(8)</sup>, MATTEI E. <sup>(4)</sup>, MIRABELLI R. <sup>(2)(3)</sup>, MORGANTI S. <sup>(3)</sup>, NICOLANTI F. <sup>(3)(6)</sup>, ORSI I. <sup>(1)</sup>, POZZI S. <sup>(1)(3)</sup>, SORIANI A. <sup>(5)</sup>, SOLFAROLI-CAMILLOCCI E. <sup>(1)(3)</sup>  
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In nuclear medicine therapy, personalized internal radiation dosimetry (IRD) increases local tumor control and reduces overall toxicity. Traditionally, IRD relies on standardized numerical models or, at best, on time sequences of 4–6 SPECT scans to estimate radiopharmaceutical biokinetics during Molecular RadioTherapy (MRT). The Wearable Individual Dose Monitoring Apparatus (WIDMApp) proposes a new approach for continuous and personalized monitoring of absorbed dose in patients undergoing MRT. The system includes: a wearable, non-invasive multi-detector system to monitor *in vivo* photon emissions; a Monte Carlo simulation based on a single SPECT/CT scan of the patient to estimate activity distribution, simulates particle interactions in the body and calculates the radiation detection probability for each sensor; an unfolding algorithm integrates detector data and simulation results to reconstruct the actual absorbed dose at organ level. A proof of principle of the proposed multi-channel detection system prototype was realized using an IEC/NEMA body phantom with a dynamic system that allows dilution and emptying of radionuclide-filled spheres to simulate biokinetics organ clearance.

● **The reSPECT and TRONDHEIM projects for the usage of high-Z doped plastic scintillators in SPECT imaging and radiometabolic dosimetry.**

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<sup>(11)</sup> Department of Industrial, Electronic and Mechanical Engineering, Roma Tre University, Rome, Italy

In fighting cancer, upgrading detection techniques represents an important objective to improve treatment monitoring quality. Currently, the widely used clinical SPECT systems rely on NaI(Tl) crystals that, however, are limited by long scintillation decay times, reducing their count-rate capabilities. In the reSPECT project innovative organic scintillators doped with high-Z impurities have been developed to provide for an increased count-rate performance given by fast scintillation signals without decreasing the photoelectric effect related to detection efficiency. Our custom-made samples have shown encouraging results in terms of transparency and dopant homogeneity. Light yield and timing characteristics were found to be comparable with commercial standards. Therefore, these prototypes can be a candidate for the realization of a lightweight portable dosimeter. The aim of the TRONDHEIM project is to monitor the radiometabolic washout curve in metastatic castration-resistant prostate cancer patients treated with Lu177-PSMA-617. This approach would enable patient-specific metabolism tracking, to optimize dosage to enhance therapeutic efficacy while reducing exposure to healthy tissues.

### ● First dosimetric characterization of kHz repetition rate laser-driven high-energy electron beams.

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Laser Wakefield Acceleration (LWFA) is the most compact technique for generating Very High Energy Electron (VHEE) beams, making it a promising candidate for future radiotherapy devices, as it can accelerate electrons to hundreds of MeV in just a few millimeters of gas.

Until recently, laser-plasma accelerators lacked the necessary dose rates to enable pre-clinical studies with sufficient statistics. The recent demonstration of kHz electron beams up to 50 MeV at the ALFA beamline of the ELI Beamlines facility represents a key milestone in the field. Beyond technological advancements, a thorough understanding of beam dosimetry is essential to enable the clinical application of LWFA-VHEE. Here, we present the first dosimetric characterization of ALFA kHz electron beam using 3D water-equivalent GafChromic-based detectors (custom-designed detectors based on PMMA slabs and GafChromic films). Measured PDDs at various axial positions are reported and compared with detailed Geant4 simulations.

● **Study of radiobiological effects of cell irradiation experiments and simulations for the construction of an accelerator-based BNCT facility.**

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Boron Neutron Capture Therapy (BNCT) is an advanced form of radiation therapy, binary and highly selective. Patients are first administered with a boron10 ( $x^{10}\text{B}$ ) carrier that is attached to tumour cells with higher concentration than to normal cells. The tumour is then irradiated with low-energy neutrons with specific spectral characteristics, causing neutron capture in boron with the production of high-LET, short-range charged particles releasing significant energy (2.31 MeV) over a short range (5–9  $\mu\text{m}$ , roughly the size of a single cell) able to kill the tumor. The focus of this work is to use Geant4-DNA, an extension of the Geant4 Monte Carlo simulation toolkit, to model and investigate DNA-level radiobiological damage induced by BNCT-relevant radiation. BNCT produces a radiation mixed field, with components that vary in LET and biological impact. To disentangle these effects, simulations were performed using each component (neutrons, alphas, lithium ions, and protons) as isolated primary sources. The validation procedure includes cell irradiation experiments at the TRIGA reactor of PAVIA and the CIRCE laboratory in Caserta within the framework of the PNC-PNRR ANTHEM project.

● **Explainable radiomics for prostate cancer diagnosis.**

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Prostate cancer diagnosis can be challenging. Artificial intelligence (AI) and radiomic models are emerging as valuable tools for identifying malignant cells. However, the black-box nature of these models hinders their clinical use. Explainable AI (XAI) is gaining traction to clarify how machine learning models make decisions, enhancing interpretability for users. This study presents preliminary results from explainable radiomics models trained on a dataset from ARNAS Ospedali Civico Di Cristina, consisting of PET-CT DICOM images of patients with suspected prostate cancer who underwent standard PET/CT examinations. Our analysis focuses on the retrospective reconstruction of tumor diagnosis. AI models for radiomic feature extraction were implemented using the PyRadiomics toolbox. An explainability study was conducted to understand the decision-making processes of the AI framework. Results indicate that our model can predict disease diagnosis while identifying influential features. The radiomics model shows promise in detecting cancerous cells, with added explainability enhancing its potential for clinical implementation.

● **Development of SiPM-based detectors for the FLASH particle and radiation therapy.**

MYSTRIDIS G. <sup>(1)(2)</sup>, ACERBI F. <sup>(1)</sup>, DI RUZZA B. <sup>(2)</sup>

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Radiotherapy (RT) using X-rays is the primary treatment for tumors. However, a significant challenge with RT is that delivering a lethal dose to cancerous cells often results in damage to surrounding healthy tissue, leading to both short- and long-term side effects. One promising alternative is FLASH radiotherapy and particle therapy (FLASH RT/PT). It is performed by delivering radiation at ultra-high dose rates (UHDR), specifically exceeding 40 Gy/s. The advantage of FLASH over Conventional RT (CONV) is due to the “FLASH effect”; improved normal tissue sparing while still maintaining tumor control. Precise dosimetry and real-time beam monitoring are essential for its clinical application, but are difficult to obtain due to the current detectors experiencing saturation issues. We present our development of a novel dosimeter designed for UHDR particle therapy, utilizing advanced silicon photomultiplier (SiPM) detectors coupled with scintillating fibers (SciFi) to provide enhanced time and spatial resolution compared to existing commercial systems. Our dosimeter is set to be tested with a proton UHDR beam ranging from 70 MeV (for CONV RT) to 228 MeV (for FLASH RT).

● **Valutazione del rischio radiologico per il biota non umano in uno scenario di riutilizzo di residui NORM: un approccio multi-tier con ERICA Tool.**

IMPARATO C. <sup>(1)</sup>, AMBROSINO F. <sup>(2)</sup>, POJE SOVILJ M. <sup>(3)</sup>, PUGLIESE M. <sup>(2)</sup>, SABBARESE C. <sup>(1)</sup>, LA VERDE G. <sup>(2)</sup>

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La tutela degli ecosistemi è tra le priorità delineate dall’Unione Europea nel Green Deal con lo scopo di indicare le linee guida per una transizione sostenibile dell’economia. Anche per la radioprotezione, dunque, è crescente la necessità di introdurre strumenti e metodologie standardizzati, che possano guidare la caratterizzazione di nuovi scenari espositivi che includano il biota non umano. Il presente studio ha come obiettivo la valutazione dell’impatto radiologico sull’ecosistema marino in uno scenario reale in cui residui industriali contenenti Naturally Occurring Radioactive Material (NORM) vengono riutilizzati nell’edilizia urbana. Per fare ciò è stato utilizzato il software ERICA Tool, articolato su tre livelli progressivi di

approfondimento. Ad una prima fase di identificazione e accertamento del potenziale rischio radiologico (Tier 1) è seguita una dettagliata caratterizzazione dello scenario, con la selezione degli specifici organismi del biota coinvolti e l'utilizzo dei più recenti coefficienti di dose (Tier 2). Infine, si è svolta una valutazione probabilistica che ha consentito l'individuazione dei parametri più influenti nel determinare l'esposizione (Tier 3).

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Aula 10, Section C, Edificio 19

ore 14:00 – 19:00

SEZIONE V

**Biofisica e fisica medica**

Presiede: ABBENE L. (Università di Palermo)

*Le relazioni su invito si terranno nell'Aula 9, i lavori si sposteranno nell'Aula 10 per le seguenti comunicazioni.*

Comunicazioni

● **Dosimetric evaluation of Left Anterior Descending Artery (LAD) exposure in VMAT-Based Left Breast Cancer (LSBC) treatment planning. A new protocol implementation of RTOG1005 normal tissues constraints.**

PETRUCCI C. <sup>(1)</sup>, CAPOCCIA A. <sup>(1)</sup>, VITTORINI F. <sup>(3)</sup>, BARTOLUCCI F. <sup>(3)</sup>, MIHOCI I. <sup>(2)</sup>, FRANZESE P. <sup>(2)</sup>, VARRASSI E. <sup>(2)</sup>, SEBASTIANI R. <sup>(2)</sup>, FERELLA L. <sup>(2)</sup>, VALLA P. <sup>(1)</sup>, RUGGIERI V. <sup>(2)</sup>, DI STASO M. <sup>(2)</sup>, GRAVINA G.L. <sup>(1)(2)</sup>, GIMENEZ DE LORENZO R. <sup>(3)</sup>

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Radiotherapy for LSBC presents challenges due to potential irradiation of the heart and LAD, increasing the risk of cardiac events. This study evaluates the integration of RTOG1005 normal tissue constraints with LAD-specific dosimetric parameters in VMAT-based treatment planning. A cohort of 203 LSBC patients treated from 2023 onward with VMAT was analyzed. The prescribed dose was 40 Gy to the whole breast with a simultaneous 48 Gy boost. All plans ensured  $\geq 95\%$  of the Planning Target Volume (PTV) received  $\geq 95\%$  of the dose. RTOG1005 dose constraints for organs at risk, including the heart, were respected. Additional LAD-specific constraints —mean, maximum, D2, D5, D10, D25— were introduced. The results confirmed effective PTV coverage and reduced dose to cardiac structures. A weak correlation was observed between LAD and heart dose, suggesting that LAD-specific optimization enhances cardiac protection. Incorporating LAD-specific limitations within the RTOG1005 framework is crucial to reduce the risk of major adverse cardiac events. This approach improves radiotherapy safety for LSBC patients and supports further refinement of cardiac-sparing strategies.

● **An overview on Monte Carlo applications for Boron Neutron Capture Therapy with focus on radiobiology experiments and patient dosimetry.**

PISTONE D. <sup>(1)(2)</sup>, SICA R. <sup>(3)</sup>, BAGNALE L. <sup>(1)(2)</sup>, FORMICOLA E. <sup>(1)(2)</sup>, BUOMPANE R. <sup>(1)(2)</sup>, PORZIO G. <sup>(1)(2)</sup>, GIALANELLA L. <sup>(1)(2)</sup>, MANTI L. <sup>(1)(2)(4)</sup>

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Boron Neutron Capture Therapy (BNCT) is a radiotherapy technique based on administering a  $^{10}\text{B}$ -labelled pharmaceutical with preferential uptake in tumors and on subsequent irradiation with neutrons. The triggered  $^{10}\text{B}(n, \alpha)^7\text{Li}$  reaction produces high-LET short-ranged



particles enabling localized therapeutic effect. Given the complex radiation field produced by the interactions of neutrons with biological tissues, Monte Carlo (MC) simulations have a central role in the research and development of BNCT procedures and facilities, including the one planned in Caserta for the University “Luigi Vanvitelli” within the ANTHEM project. An overview on MC applications devoted to BNCT will be presented, with focus on two major research lines investigated by our research group: a) radiobiology and b) patient dosimetry. Simulations for dosimetry of cellular samples irradiated with particles of BNCT interest, supporting experimental radiobiology experiments at the CIRCE Tandem facility, will be described. A new dosimetric workflow for patient dosimetry based on anthropomorphic voxelized computational phantoms will be also presented, detailing the synergistic links between a) and b) in BNCT.

● **Optimisation of a SiC detection 2-dimensional matrix system for UHDR beams for FLASH therapy.**

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The application of ultra-high dose rate (UHDR) beams, with rates surpassing 40 Gy/s, has attracted attention because of the FLASH effect. However, conventional detectors exhibit limitations, including saturation and non-linearity when exposed to UHDR conditions. A promising solution comes from SiC (silicon carbide) detectors, which have been developed also by the STLab start-up in partnership with the Catania Division of the National Institute for Nuclear Physics and University of Palermo. The DALI project aims to characterize a radiation detection system based on a first and never realized prototype of SiC detectors arranged in a two-dimensional matrix, optimized for QA in FLASH radiotherapy. The detectors’ response was evaluated under the FLASH-RT regime through Monte Carlo simulations and computational analyses. The achievements accomplished include simulating dose distribution, optimizing the arrangement of detectors to improve dose reconstruction through mathematical methods and reducing associated costs. This work was partially funded by the European Union - Next Generation EU through Projects Mission 4 Component 2 Inv. 1.5 CUP B83C22003930001.

● **Toward the use of silicon-carbide-based detector for protontherapy microdosimetry.**

PETRINGA G. <sup>(1)</sup>, VERONA C. <sup>(2)(3)</sup>, CATALANO R. <sup>(1)</sup>, GUARRERA M. <sup>(1)</sup>, KURMANOVA A. <sup>(1)</sup>, BRIGHEL L. <sup>(4)</sup>, SCIUTO A. <sup>(1)</sup>, TUDISCO S. <sup>(1)</sup>, CIRRONE G.A.P. <sup>(1)</sup>

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This study investigates the application of a silicon carbide (SiC)-based microdosimeter for use in proton therapy, leveraging the material’s high radiation hardness, low leakage current, and stable charge collection efficiency. A custom-designed SiC p-n junction diode with a 10  $\mu\text{m}$  epitaxial layer was fabricated and electrically characterized. Microdosimetric spectra were acquired under proton irradiation at energies of 30, 70 and 150 MeV at different

depths in water. The performance of the SiC detector was evaluated against established microdosimeters including a silicon-based MicroPlus probe and a single-crystal diamond device. Monte Carlo simulations were employed to assess the water-equivalent thickness of the SiC detector and to validate the measured spectra. Key microdosimetric quantities, such as frequency-mean and dose-mean lineal energy, were extracted to estimate the linear energy transfer (LET) and the relative biological effectiveness. The measured spectra revealed depth-dependent trends in agreement with expected LET variations and the microdosimetric parameters derived from SiC data were consistent with both reference detectors and simulations.

● **Microdosimetric spectra evaluation for proton minibeam radiotherapy through Monte Carlo Geant4 simulations.**

CORVAIA E. <sup>(1)(2)</sup>, DI MARTINO F. <sup>(3)(4)(5)</sup>, GUATELLI S. <sup>(6)</sup>, VALENTI G. <sup>(1)</sup>, COTTONE G. <sup>(1)(2)</sup>, ROMEO M. <sup>(1)(2)</sup>, MONTAGNO CAPPUCCINELLO A. <sup>(1)</sup>, STOCHINO P. <sup>(1)</sup>, GALATI V.M. <sup>(1)</sup>, MARRALE M. <sup>(1)(2)</sup>, MILLUZZO G. <sup>(2)</sup>, ROMANO F. <sup>(2)</sup>

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*In vivo/vitro* experiments carried out using the proton minibeam radiotherapy technique show a potential advantage in sparing healthy tissue over conventional radiotherapy. Within the INFN MIRO (MInibeam RadiOtherapy) project, we investigated the beam-quality variation along the beam pattern to assess correlations between the physical dosimetric parameters characterizing the beam and the radiobiological outcome. The Geant4 advanced example exp-microdosimetry was used to run Monte Carlo simulations of dose distributions in a water phantom with various collimator designs. A silicon microdosimeter inside the phantom records energy deposition within the detector's active layer to study the variation in the peak and valley regions. This first study reveals distinct variations in the frequency-mean lineal energy across different positions within the beam profile, suggesting new radiobiological effects to investigate. The resulting estimates serve as a foundation for calculating the relative biological effectiveness used in radiobiological models. This work was partially funded by the European Union - Next Generation EU through Projects Mission 4 Component 2 Inv. 1.5 CUP B83C22003930001.

● **A GPU accelerated Monte Carlo tool for investigations on preclinical minibeam radiation therapy.**

LUONGO N. <sup>(1)(2)</sup>, CRIMALDI U. <sup>(1)(2)</sup>, CERBONE L.A. <sup>(2)(3)</sup>, CLEMENTE S. <sup>(4)</sup>, FIORINO C. <sup>(5)</sup>, JIA X. <sup>(6)</sup>, LAI Y. <sup>(6)</sup>, METTIVIER G. <sup>(2)(7)</sup>, OLIVIERO C. <sup>(4)</sup>, PACELLI R. <sup>(1)(4)</sup>, RUSSO P. <sup>(2)(7)</sup>, SPINELLI A. <sup>(8)</sup>

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Minibeam Radiation Therapy (MBRT) is a radiotherapy technique based on the spatial modulation of the dose using a series of narrow beamlets and it is under investigation in several centers for preclinical research. A Monte Carlo GPU-based platform based on version 11.6 CUDA code for the dose evaluation in MBRT was realized and validated through a comparison with TOPAS code. We evaluated the dose maps and the Peak to Valley Dose Ratio (PVDR) of the transverse dose profile as a function of depth in the phantom. The dose distribution in a  $2 \times 2$  cm<sup>2</sup> water cube was measured with or without the presence of a multi-slit collimator. Finally, a mouse phantom was used to study the dosimetry in the tumor and the surrounding healthy tissues. The two codes are comparable in terms of dose value and PVDR, with a maximum discrepancy of 1% in the case of a beam with  $10^{11}$  primary photons with a time reduction of  $10^2$ .

#### ● **Commissioning of the carbon ion pencil beam algorithm in RayStation 2024A.**

GIUFFRÈ J. <sup>(1)</sup>, SCHAFASAND M. <sup>(3)</sup><sup>(4)</sup>, ROISL P. <sup>(3)</sup>, ROMEO M. <sup>(1)</sup><sup>(2)</sup>, MARRALE M. <sup>(1)</sup><sup>(2)</sup>, STOCK M. <sup>(3)</sup><sup>(4)</sup>, CARLINO A. <sup>(3)</sup>

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This study presents the commissioning of the carbon ion pencil beam (cPB) dose calculation algorithm v7.0 in RayStation 2024A at MedAustron. Improvements over the previous version (v3.0) include the RaShi-Airgap model, Trichrome model, and nuclear interaction correction for enhanced dose accuracy. Commissioning covered 1D/2D calibration, spot profiles, and 3D dose delivery for various geometries and clinical plans. RBE-weighted dose was assessed using LEM-I and MKM models. Absolute dose at R80% showed good agreement across energies, with minor range underestimation (0.1 mm). Spot FWHM differences were within  $\pm 0.2$  mm. Global dose differences ( $\langle \Delta_G \rangle$ ) stayed within  $\pm 2\%$  for targets and  $\pm 3\%$  for clinical plans, with improved results for beams using RaShi. RBE comparisons between versions showed differences  $< 0.5$  Gy for head and neck and  $< 1.0$  Gy for other sites. The updated algorithm improves accuracy and was successfully implemented, enhancing treatment planning in particle therapy. This work was partially funded by the European Union - Next Generation EU through Projects Mission 4 Component 2 Inv. 1.5 CUP B83C22003930001.

#### ● **Investigation of the temporal structure of conventional and UHDRE beams using a-Si:H detector, on behalf of Haspide and Pandora Collaboration.**

PONZECCHI M. <sup>(1)</sup><sup>(2)</sup>, KANXHERI K. <sup>(3)</sup><sup>(4)</sup>, ROSSI M.V. <sup>(1)</sup>, GAZZERA E. <sup>(1)</sup>, CAPUTO D. <sup>(5)</sup><sup>(6)</sup>, DE CESARE G. <sup>(5)</sup><sup>(6)</sup>, SERVOLI L. <sup>(4)</sup>, TALAMONTI C. <sup>(1)</sup><sup>(2)</sup>

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<sup>(6)</sup> *Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italia*

For real-time monitoring in FLASH radiotherapy, this research investigates the application of an innovative nip diode matrix, based on hydrogenated amorphous silicon (a-Si:H), for the temporal characterization of Ultra-High-Dose-Rate Electron (UHDRE) beams. The detector,

with a 0.4  $\mu\text{m}$  thick a-Si:H layer, was connected to a TetrAMM picoammeter working at 100 kHz. Acquisitions were conducted with 8 MeV conventional (CONV) electron and 10 MeV UHDRE beams. Measurements were performed at the isocenter (CONV-UHDRE) and 53 cm from the source (UHDRE), at the maximum depth, setting a  $10 \times 10 \text{ cm}^2$  field and varying the PRF. The device resolved distinct electron pulses, while maintaining stable signal characteristics in both CONV and UHDRE modes. At the isocenter, the dose per pulse was 0.5 mGy (CONV) and 0.63 Gy (UHDRE), increasing to 2.22 Gy (UHDRE) closer to the source. For example, the average pulse charges acquired with one pixel were 1.17 pC (CONV) and 2.163 nC (UHDRE), with amplitudes of 15.4 nA and 31.23  $\mu\text{A}$ . At 53 cm from the source, UHDRE pulses registered 3.33 nC and 47.4  $\mu\text{A}$ . The flexible a-Si:H detector exhibited strong potential for fast, real-time dosimetry in FLASH radiotherapy.

● **Development of a novel prototype and electronics for 2D dosimetric measurements with silicon carbide detectors for FLASH radiotherapy.**

MONTAGNO CAPPUCCINELLO A. <sup>(1)</sup>, CORVAIA E. <sup>(1)(2)</sup>, VALENTI G. <sup>(1)</sup>, COTTONE G. <sup>(1)(2)</sup>, D'OCA M.C. <sup>(1)(2)</sup>, ROMEO M. <sup>(1)(2)</sup>, MANTINEO P. <sup>(1)</sup>, MOSCATO S. <sup>(3)</sup>, CAMARDA M. <sup>(3)</sup>, MILLUZZO G. <sup>(2)</sup>, ROMANO F. <sup>(2)</sup>, MARRALE M. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica "Emilio Segrè", Università degli Studi di Palermo, Palermo, Italia*

<sup>(2)</sup> *Istituto Nazionale di Fisica Nucleare, INFN, Sezione di Catania, Catania, Italia*

<sup>(3)</sup> *STLab srl, Catania, Italy*

The use of ultra-high dose rate (UHDR) beams ( $> 40 \text{ Gy/s}$ ) triggering the FLASH effect is gaining interest for its potential to expand the therapeutic window. However, commercial dosimeters often fail under these conditions due to saturation. The DALÌ (Development of Advanced Dosimetric Techniques for UHDR Beams) project, led by the University of Palermo in collaboration with INFN Catania Division and STLab, aims to design an innovative detection system based on a 2D matrix of silicon carbide (SiC) sensors optimized for QA in FLASH radiotherapy. The 64-channel prototype features custom electronics with high-speed ADC and a Raspberry Pi 4 for data acquisition. Dedicated software enables fast one-shot acquisitions, while a user-friendly interface supports real-time use and background correction. Simulations guided design choices and dose reconstruction via interpolation. The system is scalable beyond 500 channels, offering a cost-effective solution for next-generation dosimetry and reducing radiation protection issues typical of UHDR irradiations. This work is partially funded by the European Union Next Generation EU through Projects Mission 4 Component 2 Inv. 1.5 CUP B83C22003930001.

● **Study of tumor invasiveness by super resolution fluorescence microscopy in cells irradiated with FLASH and conventional radiotherapy.**

MILANESI A. <sup>(1)(2)(3)</sup>, CELLA ZANACCHI F. <sup>(1)(2)(4)</sup>, CAPACCIOLI S. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> *Department of Physics "Enrico Fermi", University of Pisa, Italy*

<sup>(2)</sup> *Center for Instrument Sharing of the University of Pisa, CISUP, Italy*

<sup>(3)</sup> *Pisa Multidisciplinary Center for Research and Clinical Implementation of Flash Radiotherapy, CPFR, University of Pisa, Italy*

<sup>(4)</sup> *Italian Institute of Technology, Nanoscopy and NIC@IIT, Italy*

The effects of FLASH Radiotherapy (FLASH RT) on tumor invasiveness remain poorly understood, particularly at the molecular level of cell adhesion. In this study, murine and rabbit-derived tumor cell lines were irradiated using FLASH RT ( $\geq 40 \text{ Gy/s}$ ) and Conventional Radiotherapy (CONV RT) ( $\sim 2 \text{ Gy/min}$ ). Cells were fixed and labeled with fluorophore-conjugated antibodies targeting N-Cadherin and Integrin  $\alpha_v\beta_3$ , then imaged using STORM super resolution fluorescence microscopy. Structural changes in the distribution,

clustering, and density of these adhesion proteins were quantitatively analyzed. FLASH RT induced distinct alterations in adhesion protein organization compared to CONV RT, suggesting differences in how tumor cells regulate cell-ECM interactions after exposure. These findings highlight the importance of investigating dose rate-dependent changes in cell adhesion and high-resolution visualization of adhesion molecule remodeling, to better understand how FLASH RT may influence tumor invasiveness.

● **A new diagnostic system based on SiC technology for UHDR proton beam range detection.**

GUARRERA M. <sup>(1)</sup>, PETRINGA G. <sup>(1)</sup>, AMATO A. <sup>(1)</sup>, BARBAGIOVANNI A. <sup>(2)</sup>, CATALANO R. <sup>(1)</sup>, CUTTONE G. <sup>(1)</sup>, KURMANOVA A. <sup>(1)</sup>, TUDISCO S. <sup>(1)</sup>, CIRRONE G.A.P. <sup>(1)</sup>

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Radiotherapy (RT) treatments at ultra-high doses (UHDR, > 40 Gy/s) can reduce the toxicity induced on healthy tissues while achieving therapeutic goals (in terms of tumor control probability, TCP) that are comparable to those typically attained in conventional dose rate (CONV) treatments, according to a large number of *in vitro* and *in vivo* studies conducted over the past ten years. Ultra-fast treatments would significantly enhance patient comfort, reduce treatment duration, expand the capacity to treat more patients in clinics, and concurrently decrease the toxicity of the treatment by widening the therapeutic window. However, implementing reliable and accurate dosimetric procedures and developing new absolute and relative dosimetric detectors that can operate properly under these novel and extreme irradiation conditions are necessary for integrating FLASH-RT into clinical practice. In this work, a device based on silicon carbide (SiC) technology was tested for the first time with UHDR (from 20 Gy/s to 230 Gy/s) 62 MeV proton beams. The SiC device was tested in terms of dose linearity as the dose rate varied. The detector sensitivity was also evaluated.

● **TPM-FC come strumento predittivo personalizzato nella radioterapia oncologica: analisi biofisica label-free a singola cellula.**

DE VITA C. <sup>(1)</sup>, D'ALELIO V. <sup>(2)</sup>, DURANTE M. <sup>(1)(3)</sup>, FERRARO P. <sup>(4)</sup>, GIORDANO G. <sup>(4)</sup>, GIUGLIANO G. <sup>(4)(5)</sup>, MICCIO L. <sup>(4)</sup>, MOTTAREALE R. <sup>(1)</sup>, PIRONE D. <sup>(4)</sup>, PUGLIESE M. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica "Ettore Pancini", Università degli Studi di Napoli "Federico II"*

<sup>(2)</sup> *IRCCS Istituto Nazionale Tumori Fondazione "G. Pascale" di Napoli*

<sup>(3)</sup> *GSI Helmholtzzentrum für Schwerionenforschung, Biophysics Department, Darmstadt, Germany*

<sup>(4)</sup> *CNR-ISASI, Istituto di Scienze Applicate e Sistemi Intelligenti "E. Caianiello", Pozzuoli, NA*

<sup>(5)</sup> *Dipartimento di Matematica e Fisica, Università della Campania Luigi Vanvitelli, Caserta*

L'analisi delle proprietà biofisiche e morfologiche delle cellule sta diventando uno strumento chiave e sempre più utilizzato per distinguere i tumori, valutarne la progressione e prevederne la risposta a trattamenti mirati, inclusi farmaci e radioterapia. La Tomographic Phase Microscopy (TPM) rappresenta una tecnica avanzata di imaging olografico che permette di estrapolare specifiche caratteristiche biofisiche tridimensionali a livello di singola cellula. Questa tecnica label-free, combinata con la citometria a flusso (Tomographic Phase Microscopy in Flow Citometry, TPM-FC), permette di ottenere una capacità di analisi cellulare (high-throughput) in assenza di marcatori fluorescenti, consentendo una caratterizzazione morfologica e biofisica delle linee cellulari. Il lavoro all'interno del progetto FIGHT-TUMOR si propone di investigare l'utilizzo della TPM-FC come saggio predittivo personalizzato nella radioterapia oncologica. Dalla ricostruzione dei tomogrammi dalle immagini

acquisite tramite TPM-FC per singola cellula verranno identificati i parametri biofisici e confrontati con i dati ottenuti *in vitro* tramite saggio clonogenico.

● **Red bone marrow dosimetry in  $^{177}\text{Lu}$  therapy of metastatic prostate cancer: A Monte Carlo study.**

AUDITORE L. <sup>(1)(2)</sup>, JACCARD R. <sup>(3)</sup>, FLUCKIGER L. <sup>(3)</sup>, AMATO E. <sup>(1)(2)(4)</sup>, MEDICI S. <sup>(3)</sup>, GNESIN S. <sup>(3)</sup>

<sup>(1)</sup> *Department of Biomedical and Dental Sciences and of Morphofunctional Imaging, BIOMORF, University of Messina, Italy*

<sup>(2)</sup> *INFN, National Institute for Nuclear Physics, Section of Catania, Italy*

<sup>(3)</sup> *Institute of radiation physics, Lausanne university hospital and University of Lausanne, Lausanne, Switzerland*

<sup>(4)</sup> *Health Physics Unit, University Hospital "Gaetano Martino", Messina, Italy*

[ $^{177}\text{Lu}$ ]Lu-PSMA radioligand therapy is currently applied in metastatic castration-resistant prostate cancer (mCRPC) patients. Dosimetry studies highlighted that salivary glands, kidneys, and bone marrow are organs at risk, potentially limiting the number of therapy cycles. The aim of this study was to assess the absorbed dose (AD) to the red bone marrow (RBM) in patients with different tumour burdens for an optimal therapy planning. ICRP110 adult male computational phantom was implemented in GAMOS for Monte Carlo simulation, low to high burden disease configurations were considered. Without lesions, assuming 0.39 h, 1.84 h, 1.75 h, 20.0 h and 27.5 h as the time-integrated activity coefficients (TIACs) for salivary glands, liver, kidneys, cortical regions and rest-of-body, respectively, the ADs to RBM due to these source regions are 0.03 mGy/GBq, 0.27 mGy/GBq, 0.30 mGy/GBq, 9.29 mGy/GBq and 2.79 mGy/GBq, being the contribution from cortical regions the highest. In a severe burden scenario, *i.e.*, 10 lesions distributed on humeri, sternum, femora head, thoracic and lumbar spine, the AD due to lesions is relevant. AD to RBM as a function of the lesion' distribution will be also discussed.

● **Commissioning of a pre-clinical image-guided radiotherapy system.**

CATALANO R. <sup>(1)</sup>, RAFFAELE L. <sup>(1)</sup>, RUSSO G. <sup>(1)(2)</sup>, ALBERGHINA C. <sup>(1)(2)</sup>, CAMMARATA F.P. <sup>(1)(2)</sup>, CIRRONE G.A.P. <sup>(1)</sup>, CUTTONE G. <sup>(1)</sup>, PETRINGA G. <sup>(1)</sup>, SALEEM S. <sup>(3)</sup>

<sup>(1)</sup> *INFN - Laboratori Nazionali del Sud, Catania*

<sup>(2)</sup> *CNR - Istituto di Bioimmagini e Sistemi Biologici Complessi, Cefalù*

<sup>(3)</sup> *Università degli Studi di Catania, Dipartimento di Fisica e Astronomia*

The development of new radiotherapy approaches, including the creation of radiosensitizing agents for tumor areas and radioprotective agents for organs at risk (OAR), requires the execution of preclinical radiotherapy studies, typically conducted on mice. At the same time, it is essential to ensure an accurate dosimetric study that enables the generation of robust and reproducible results. Therefore, it is necessary to establish a precise characterization of the radiation beam, which is also generated by an X-ray tube, and to carry out an accurate dosimetric evaluation, specifically tailored for the small fields typically required for these studies. Our study presents the commissioning of the Varex-based (mod. HPX-320-11) small-field biological irradiator, developed for irradiation *in vivo* of mice for preclinical radiotherapy and *in vitro* for cell lines. The system delivers a 320 kVp X-ray beam with half-value layer of 1.3 mm of Cu and square field sizes ranging from  $8 \times 8$  to  $40 \times 40 \text{ mm}^2$  at a source-to-surface distance of 50 cm. The output dose rate measured at isocenter for the largest field was 1.02 Gy/min. Dosimetric characterization included measurements of relative output factors (ROF), percent depth-dose (PDD), and beam profiles using PTW microDiamond detectors and EBT4 radiochromic films. Measurements were conducted in both a large water phantom ( $30 \times 30 \times 30 \text{ cm}^3$ ) and a smaller phantom ( $6 \times 6 \times 6 \text{ cm}^3$ ) to

simulate clinical and small animal scattering conditions, respectively. Results demonstrated excellent beam symmetry and flatness, resulted to be better than 1%, sharp penumbra that do not exceed 1.5 mm, and ROF strongly decreasing with smaller field sizes. Phantom size significantly affected backscatter, impacting ROF and PDD values. The microDiamond and EBT4 measurements showed good agreement within 2%, confirming their suitability for accurate small-field dosimetry. The irradiator's performance supports precise and reliable radiotherapy studies in vitro and for small animals.

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Aula 7, Section B, Edificio 19

ore 14:00 – 19:00

Sezione VI

**Fisica applicata, acceleratori e beni culturali**

Presiedono: GAMMINO S. (INFN, Laboratori Nazionali del Sud)

BONIZZONI L. (Università di Milano)

Relazioni su invito

▲ **30 anni di accelerazione a plasma, il futuro prossimo venturo.**

ROSSI A.R.

*Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Italia*

Sebbene l'accelerazione di fasci di elettroni tramite plasma fu per la prima volta teorizzata da Tashima e Dawson nel 1979, divenne una tecnica effettivamente percorribile solo dopo l'invenzione della Chirped Pulse Amplification da parte di Mourou e Strickland nel 1985. Il raggiungimento di laser dotati di potenza sufficiente per permettere un'effettiva operatività di questo tipo di accelerazione ha richiesto circa 10 anni di perfezionamenti. Negli anni si sono succeduti diversi esperimenti proof-of-principle che hanno costantemente innalzato il record di energia raggiunta. A partire dagli anni '10 si è cominciato a perseguire il miglioramento della qualità dei fasci prodotto raggiungendo risultati rilevanti nel pilotare sorgenti di radiazione avanzate. In tempi più recenti il focus si è spostato sull'innalzamento del repetition rate. In questo contributo ripercorreremo la storia dell'accelerazione al plasma mettendo in luce i contributi più rilevanti, i risultati raggiunti e le sfide in corso per far diventare di uso diffuso questa tecnica di accelerazione avanzata.

▲ **HTS magnets for energy sustainability of research infrastructures and society.**

SORTI S. <sup>(1)</sup>(<sup>2</sup>), BALCONI L. <sup>(1)</sup>(<sup>2</sup>), DE MATTEIS E. <sup>(2)</sup>, MARIOTTO S. <sup>(1)</sup>(<sup>2</sup>), ROSSI L. <sup>(1)</sup>(<sup>2</sup>), SANTINI C. <sup>(2)</sup>, STATERA M. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Milano, Italia*

<sup>(2)</sup> *Sezione di Milano, Laboratorio LASA, INFN, Italia*

Research infrastructures for high-energy physics, nuclear fusion, cancer therapy, and MRI, increasingly rely on applied superconductivity and advanced cryogenics. For their long-term viability and societal support, however, these facilities must balance performance with economic sustainability. The most common technical superconductor, Nb-Ti, is practical for high-field applications (up to 12 T) only if cooled to a few kelvins, thus requiring liquid helium (LHe). However, LHe is scarce and increasingly costly, and the related Carnot efficiency is extremely poor. In this context, 2G high-temperature superconductors (HTS) offer the most promising solution. They outperform Nb-Ti even above 20 K, with a fivefold rise of cooling efficiency, while HTS solenoids can reach 40 T at lower temperatures. However, HTS pose significant challenges. Their fabrication is complex, yielding robust tapes but vulnerable, for instance, to delamination. Still, the growing demand for HTS in nuclear fusion, power transmission, and ultra-high-field applications has significantly driven their development, paving the way for the next generation of research infrastructures, and for wider societal applications.



## Comunicazioni

● **SABINA: l'infrastruttura per utenti con radiazione THz prodotta da fascio di elettroni.**

BALOSSINO I. <sup>(1)</sup>, ANANIA M. <sup>(1)</sup>, CAPONERO M.A. <sup>(2)</sup>, DE BERNARDIS G. <sup>(1)</sup>, DEL FRANCO M. <sup>(1)</sup>, DI PIRRO G. <sup>(1)</sup>, DI RADDIO G. <sup>(1)</sup>, DI PASQUALE E. <sup>(1)</sup>, FERRARIO M. <sup>(1)</sup>, GHIGO A. <sup>(1)</sup>, GIANNESI L. <sup>(1)</sup>, LIEDL A. <sup>(1)</sup>, LUPI S. <sup>(3)</sup>, MACIS S. <sup>(3)</sup>, MOSESSO L. <sup>(3)</sup>, NGUYEN F. <sup>(2)</sup>, PETRALIA A. <sup>(2)</sup>, POLIMADEI A. <sup>(2)</sup>, STELLA A. <sup>(1)</sup>, SELCE A. <sup>(1)</sup>, VANNOZZI A. <sup>(1)</sup>, SABBATINI L. <sup>(1)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali di Frascati

<sup>(2)</sup> ENEA, Frascati

<sup>(3)</sup> Università degli Studi di Roma La Sapienza

SABINA è un progetto di potenziamento dell'infrastruttura di ricerca SPARC-LAB presso i Laboratori Nazionali di Frascati. I primi obiettivi hanno riguardato il consolidamento dei sistemi tecnologici e il miglioramento delle prestazioni dell'acceleratore, per garantirne un'elevata stabilità di fascio. Raggiunta una buona affidabilità operativa, l'infrastruttura può essere messa a disposizione anche ad utenti esterni, provenienti dal mondo scientifico e industriale. Questo contributo si focalizza sulla nuova linea per utenti dedicata alla radiazione THz generata da un laser a elettroni liberi. Verrà descritta la linea di fascio, composta da tre ondulatori in grado di produrre impulsi controllabili in durata, energia e soprattutto polarizzazione. Saranno inoltre illustrate le possibili applicazioni della radiazione THz, evidenziando le potenzialità di collaborazione con diversi istituti di ricerca e i molteplici ambiti tecnologici coinvolti. Infine, si discuterà del ruolo della linea THz come attività propedeutica a progetti futuri come EuPRAXIA, dedicato all'accelerazione di particelle basata su tecnologie avanzate al plasma e laser.

● **Stability and volatility in financial markets: an unconventional liaison.**

VALENTI D. <sup>(1)</sup>, FAZIO G. <sup>(2)(3)</sup>, SPAGNOLO B. <sup>(1)</sup>

<sup>(1)</sup> Dipartimento di Fisica e Chimica, Università degli Studi di Palermo

<sup>(2)</sup> Business School, Newcastle University, Newcastle, UK

<sup>(3)</sup> SEAS, Università degli Studi di Palermo

Financial practitioners usually look at greater volatility, i.e. price fluctuations, as a source of greater market instability. However, large negative and positive price variations, i.e. crashes and rallies, respectively, follow often long periods characterized by small fluctuations of prices and returns. Here the behaviour of a financial market is investigated by using a mean first hitting time (MFHT), suitably defined, as an indicator of the price stability. More in detail, the daily returns of 1071 stocks traded in the New York Stock Exchange are analyzed, observing that the MFHT is characterized by a nonmonotonic behavior, with a maximum, as a function of the volatility. This phenomenon is known as noise enhanced stability. Interpreting the MFHT as a stability proxy allows to conclude that an optimal volatility value exists, for which the system is far from critical events, namely downturns or upturns. In addition, a nonlinear Heston model is used to reproduce the nonmonotonic behaviour of the MFHT. These results offer a new perspective, indicating that, contrary to conventional wisdom, higher market instability is related not only to high, but also to low volatilities.

● **Layered Na<sub>0.8</sub>(Ti<sub>0.2</sub>Mn<sub>0.2</sub>Fe<sub>0.2</sub>Co<sub>0.2</sub>Ni<sub>0.2</sub>)O<sub>2</sub> high-entropy oxides as highly stable cathodes for Na-ion electrochemical storage.**

SANTANGELO S. <sup>(1)(2)</sup>, TRIOLO C. <sup>(1)(2)</sup>, BEERE H.K. <sup>(1)</sup>, MUSOLINO M.G. <sup>(1)(2)</sup>, CODURI M. <sup>(3)</sup>, CALLEGARI D. <sup>(3)</sup>, MAISURADZE M. <sup>(2)(4)</sup>, NASSIRI A. <sup>(4)</sup>, GIORGETTI M. <sup>(2)(4)</sup>

<sup>(1)</sup> *Mediterranean University, Department of Civil, Energy, Environmental and Materials Engineering, Italia*

<sup>(2)</sup> *National Ref. Center for Electrochemical Energy Storage, Interuniversity Consortium for the Science and Technology of Materials, Firenze, Italia*

<sup>(3)</sup> *Pavia University, Department of Chemistry, Pavia, Italy*

<sup>(4)</sup> *Bologna University, Department of Industrial Chemistry Toso Montanari, Bologna, Italia*

Sodium-ion batteries (SIBs) have gained significant attention as a cost-effective and sustainable alternative to lithium-ion batteries (LIBs). However, their commercialization is hindered by several challenges, including the development of high-performance cathode materials. The project PRIN “OPHELIA” (PRIN 20227YZZ9E, funded by the European Union through Next-Generation EU via PNRR - Mission 4 - C2 component - Investment 1.1) mainly aims at developing, studying and optimizing sodium-layered high-entropy oxides, as advanced cathode materials for Na-ion electrochemical storage. Initial studies conducted within this project have demonstrated that materials consisting of larger and better-crystallized grains outperform those with similar composition and different microstructure both in terms of rate capability and long-term stability. This contribution is focused on layered  $\text{Na}_{0.8}(\text{Ti}_{0.2}\text{Mn}_{0.2}\text{Fe}_{0.2}\text{Co}_{0.2}\text{Ni}_{0.2})\text{O}_2$  cathode materials produced by a simple and scalable technique. The material prepared by the sol-gel method under optimized conditions is able to deliver 105 mAh/g and retain approximately 90% capacity over 200 cycles at a rate of 1C (150 mA/g).

● **The Italian ocean sound monitoring sub-system for the Italian integrated environmental research infrastructures system (ITINERIS) project.**

SANFILIPPO S., BONANNO D., DIEGO-TORTOSA D., DI MAURO L. S., IDRISSE A., RICCIBENE G., VIOLA S.

*INFN, Laboratori Nazionali del Sud, Catania*

The aim of the Italian Integrated Environmental Research Infrastructures System (ITINERIS) project, funded under the NextGen-EU PNRR programme, is to establish the Italian Hub of Research Infrastructures within the environmental scientific domain. ITINERIS will create a flexible system to collect and store, for the first time in a national integrated system, ocean data and metadata and make them available for the entire scientific community. LNS coordinates the design and operation of a novel deep-sea Junction Box (JB) to be installed at the infrastructure of Portopalo di Capo Passero, Italy, at a depth of about 3450 m. The JB hosts a broadband hydrophone whose data will be continuously streamed to shore and analyzed in real time. Two JB of the same class of the ITINERIS JB have been in operation since October 2024 and their hydrophones' data are continuously recorded. LNS is also leading the implementation of the Ocean Sound sub-system, part of the Italian Ocean Data Portal developed under the ITINERIS project. In this contribution, an overview of the project is discussed and an analysis on biological sound searches and ambient noise monitoring will be also presented.

● **Filter Efficiency Evaluation for 18F Air Emission in [18F]-FDG Production.**

BARBAGIOVANNI PISEIA A. <sup>(1)(3)</sup>, RUSSO G. <sup>(1)(2)</sup>, GALLITTO G. <sup>(4)</sup>, SCOPELLITI F. <sup>(5)</sup>, RAPISARDA G.G. <sup>(2)(4)</sup>, IPPOLITO M. <sup>(1)(5)</sup>

<sup>(1)</sup> *CNR, Institute of BioImaging and Complex Biological Systems, Cefalù*

<sup>(2)</sup> *INFN, Laboratori Nazionali del Sud, Catania*

<sup>(3)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

<sup>(4)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(5)</sup> *Nuclear Medicine Department, AOE Cannizzaro, Catania*

The objective of this study was to evaluate the efficiency of filtration systems in reducing radioactive emissions during the production of PET radiopharmaceuticals. The assessment was conducted at the Cannizzaro Hospital radiochemistry facility, focusing on compliance with ICRP 103 and EURATOM Directive 2013/59, which limits public exposure to 10  $\mu\text{Sv}/\text{year}$ . The study examined the absorption efficiency of activated carbon filters alone and a combination of activated carbon and absolute filters, using both new and worn filters (six months of use). The evaluation involved a calibration procedure using large-area multi-wire proportional meters (LB 6377, Berthold) and a nebulized  $[^{18}\text{F}]\text{-FDG}$  solution to determine airborne activity concentrations ( $\text{kBq}/\text{m}^3$ ). The results showed that the combination of absolute and activated carbon filters maintained a consistent efficiency of about 98%, while activated carbon filters alone exhibited a significant drop in efficiency from 24% (new) to 13% (worn). These findings emphasize the importance of regular filter maintenance and the limitations of activated carbon alone in controlling radioactive emissions.

● **Infrared spectroscopy and Machine Learning approach for post-consumer recycled plastics.**

MOSETTI R. <sup>(1)(2)</sup>, MANCINI T. <sup>(2)</sup>, BERTELÀ F. <sup>(2)</sup>, MACIS S. <sup>(2)</sup>, D'ARCO A. <sup>(2)</sup>, LUPI S. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento SBAI, Sapienza Università di Roma*

<sup>(2)</sup> *Dipartimento di Fisica, Sapienza Università di Roma*

Nowadays, plastic pollution is one of the main environmental issues. In the last few decades, the production and use of plastic have caused an exponential increase in pollution worldwide. One of the key actions we can take to address this critical situation is the implementation of recycling technologies for post-consumer plastic waste. A promising strategy to produce high-quality resins from plastic waste is the real-time monitoring of organic compounds generated during the recycling process or due to previous use. An innovative approach is the combined use of infrared (IR) spectroscopy and machine learning (ML) algorithms. Here, we study various recycled plastics through Attenuated Total Reflectance Infrared (ATR-IR) spectroscopy and establish quantifiable metrics through machine learning algorithms for classification of four plastics classes of interest. Recycling technologies offer a promising solution, but the presence of organic contaminants in recycled resins often hinders their reuse and limits their quality standards. Thus, we implement a selectively identifier for organic chemical compounds present on the surface of these materials, taking advantages of ML technologies.

Relazioni su invito

▲ **Physics for archaeometry: A multitechnique approach with X-rays and particle beams to study ancient materials.**

RE A.

*Dipartimento di Fisica, Università di Torino e INFN, Sezione di Torino*

X-ray and particle beams lie at the core of a wide range of physical techniques routinely employed for the characterisation of materials. These methods are increasingly applied to study materials of historical, artistic, and archaeological relevance, providing valuable insights and contributing to our understanding of Cultural Heritage. The development of new methodologies and experimental approaches based on these techniques is essential to further strengthening the role of physics within archaeometry. Such advancements promote integration with a broad spectrum of disciplines, fostering a multi-, inter-, and trans-disciplinary research framework. This contribution will illustrate selected case studies involving the University of Torino and the INFN, section of Torino. In these examples, X-ray, proton, neutron,

and electron beams have been successfully utilised within a multi-technique strategy, always guided by research questions posed by historians, archaeologists, conservators, and restorers. These questions have often required, and stimulated, the development of new, previously unavailable, tools and methodologies.

### ▲ The future of electron storage rings.

DI MITRI S.

*Elettra Sincrotrone Trieste e Dipartimento di Fisica, Università di Trieste*

The race to full transverse coherence of soft to hard x-rays as only produced by electron storage ring light sources has been launched. I will report on the recent success of diffraction-limited storage ring light sources, next-coming facilities, residual challenges and potential solutions to fully meet the light sources user community's wish list. The strict connection between experimental needs, particle beam physics and technology advancement, is shown to elevate modern storage ring light sources to broad scientific and technology drivers.

Comunicazioni

### ● Spot the light: synchrotron radiation X-ray luminescence analysis of $\text{CdS}_{1-x}\text{Se}_x$ pigments.

ORSILLI J. <sup>(1)(2)</sup>, CAGLIO S. <sup>(1)</sup>, D'ACAPITO F. <sup>(2)</sup>, GALLI A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Scienza dei Materiali, Università di Milano Bicocca*

<sup>(2)</sup> *CNR, Istituto Officina dei Materiali, Trieste*

Materials can be studied by exploiting their luminescence emission in response to a particular exposure. X-ray luminescence (XRL) has proved to be useful for mineral characterization, being successfully exploited for provenance studies of jade and lapis lazuli stones. Indeed, different minerals present different luminescence properties relative to their crystal chemistry, internal structure or the presence of trace elements. However, this technique is rarely applied due to the low intensity of the luminescence signal and to the limited choice of suitable samples.  $\text{CdS}_{1-x}\text{Se}_x$  pigments seem to belong to the possible materials that can be studied with XRL, as they show an intense luminescence when irradiated with X-rays. We decided, hence, to apply this technique to a family of seven pigments, spanning from lemon yellow to deep red, which was well-characterized with other spectroscopic methods to study their XRL emission spectrum. With this new study, we aim to increase the pool of samples that can be analyzed with XRL, expanding its applications in the cultural heritage field.

### ● Challenges in ceramic authentication: the threat of artificial irradiation.

PANZERI L., MARTINI M., MASPERO F., RONCHI F., GALLI A.

*Dipartimento di Scienza dei Materiali, Università degli Studi di Milano Bicocca*

The authentication of ceramics is crucial to determine their origin, age and authenticity. It is essential not only for collectors and museums but also to ensure transparency in the art market and to protect cultural heritage from forgeries and counterfeits. Authentication relies on a combination of scientific analysis, stylistic examination, and provenance research. From a scientific perspective, techniques such as Thermoluminescence (TL) or Optically Stimulated Luminescence (OSL) are widely used. Recently, a sophisticated method of scientific forgery has been developed: forgers use ionizing radiation, often X-rays, to irradiate a recently manufactured object to simulate its aging. This makes the object appear ancient when analysed by TL and OSL, which measure the absorbed radiation dose. In this study, we develop protocols able to identify counterfeit and fraudulently irradiated objects based on the different penetration depth of radiation into ceramics (and generally into solid materials). Alpha particles, in fact, have a low penetration power (about 25  $\mu\text{m}$ ), while beta particles penetrate for a few millimeters and X-rays and gamma rays up to several centimeters.

● **Valorizzazione e conservazione delle opere d'arte tramite sorgenti luminose a spettro controllato.**

ALAIMO P. <sup>(1)</sup>, SCACCIANOCE G. <sup>(1)</sup>, MOSCA M. <sup>(1)</sup>, SAIANO F. <sup>(2)</sup>, CABIBBO M. <sup>(3)</sup>, MACALUSO R. <sup>(1)</sup>, CRUPI I. <sup>(1)</sup>, PERSANO ADORNO D. <sup>(4)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria, Università degli Studi di Palermo*

<sup>(2)</sup> *Dipartimento di Scienze Agrarie, Alimentari e Forestali, Università degli Studi di Palermo*

<sup>(3)</sup> *Dipartimento di Ingegneria Industriale e Scienze Matematiche, Università Politecnica delle Marche*

<sup>(4)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

La corretta illuminazione rappresenta un fattore chiave nella conservazione e valorizzazione delle opere d'arte, influenzando sia la fruizione visiva sia l'integrità dei materiali. In questo contesto, nuove opportunità vengono offerte dall'uso di sorgenti luminose a LED con spettro variabile, ottenuto tramite l'integrazione di carbon dots (CDs). I CDs, nanostrutture di carbonio caratterizzate da elevata efficienza luminosa e flessibilità spettrale, consentono di modulare l'emissione luminosa riducendo i rischi di degrado fotoindotto. Nel seguito verrà descritto lo sviluppo di sistemi di illuminazione per ambienti museali indoor, con spettro adattabile in funzione delle specifiche cromatiche e materiche delle opere esposte. Tale approccio permette di ottimizzare l'esperienza visiva nel rispetto delle esigenze conservative. L'integrazione tra nanotecnologie e ottica applicata apre nuove prospettive nella gestione museale per soluzioni sostenibili, personalizzabili e orientate alla tutela del patrimonio culturale.

● **A laboratory-based phase contrast X-ray imaging system for Cultural Heritage and medical applications.**

TROCINO D. <sup>(1)</sup>, ARFELLI F. <sup>(2)</sup>, BOANO R. <sup>(3)</sup>, BRAVIN A. <sup>(4)</sup><sup>(5)</sup>, BROMBAL L. <sup>(2)</sup>, BRUN F. <sup>(6)</sup>, CERELLO P. <sup>(1)</sup>, DI FRANCIA E. <sup>(1)</sup><sup>(7)</sup>, DI MARTINO D. <sup>(4)</sup>, DONATO S. <sup>(8)</sup>, FIORINA E. <sup>(1)</sup>, GARAGIOLA C. <sup>(1)</sup><sup>(7)</sup>, GIUSTETTO R. <sup>(9)</sup>, GUIDORZI L. <sup>(1)</sup><sup>(7)</sup>, LO GIUDICE A. <sup>(1)</sup><sup>(7)</sup>, LONGO R. <sup>(2)</sup>, MAGALINI M. <sup>(1)</sup>, MARABOTTO M. <sup>(1)</sup>, MARCUCCI G. <sup>(4)</sup>, MENK R.-H. <sup>(10)</sup>, MOSCO N. <sup>(1)</sup>, POZZI F. <sup>(11)</sup>, RAMELLO L. <sup>(1)</sup><sup>(12)</sup>, RE A. <sup>(1)</sup><sup>(7)</sup>, RICCHIARDI G. <sup>(13)</sup>, RICCI C. <sup>(11)</sup>, RIGON L. <sup>(2)</sup>, RIZZO G. <sup>(6)</sup>, VIGORELLI L. <sup>(4)</sup>

<sup>(1)</sup> *INFN, Sezione di Torino*

<sup>(2)</sup> *Dipartimento di Fisica, Università degli Studi di Trieste e INFN, Sezione Trieste*

<sup>(3)</sup> *Dipartimento di Scienze della Vita e Biologia dei Sistemi, Università degli Studi di Torino*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Milano Bicocca e INFN, Sezione di Milano Bicocca*

<sup>(5)</sup> *Dipartimento di Fisica, Università della Calabria*

<sup>(6)</sup> *Dipartimento di Ingegneria e Architettura, Università degli Studi di Trieste e INFN, Sezione di Trieste*

<sup>(7)</sup> *Dipartimento di Fisica, Università degli Studi di Torino*

<sup>(8)</sup> *Dipartimento di Matematica e Informatica, Università della Calabria e INFN, Laboratori Nazionali di Frascati*

<sup>(9)</sup> *Dipartimento di Scienze della Terra, Università degli Studi di Torino*

<sup>(10)</sup> *Elettra-Sincrotrone Trieste SCpA e INFN, Sezione di Trieste*

<sup>(11)</sup> *Centro per la Conservazione e il Restauro dei Beni Culturali La Venaria Reale*

<sup>(12)</sup> *Dipartimento per lo Sviluppo Sostenibile e la Transizione Ecologica, Università del Piemonte Orientale*

<sup>(13)</sup> *Dipartimento di Chimica, Università degli Studi di Torino*

Phase-Contrast (PC) X-ray imaging is a high-resolution, non-invasive technique for detecting micro-structural features in weakly absorbing materials, using a partially coherent X-ray beam to produce differential-phase and dark-field images alongside the traditional absorption-contrast image. Among PC methods, Grating Interferometry (GI) enables the

development of compact laboratory apparatuses, with great potential in medical and Cultural Heritage (CH) applications. The PITCH and Vi\_Hi projects (funded by MUR under the PRIN2022 program and by INFN-CSN5, respectively) aim at designing, building, and commissioning a laboratory-based PC-GI imaging setup using a liquid-anode X-ray source, both for radiographic and tomographic analyses. Different data acquisition methods and algorithms for signal extraction and tomographic reconstruction will be explored. The goal of PITCH is the high-precision analysis of various materials (wood, parchment, textiles, etc.) and the characterization of samples relevant to CH preservation projects. Vi\_Hi aims at optimizing the setup to perform 3D imaging of biological tissue samples (Virtual Histology) with a resolution better than 10  $\mu\text{m}$ .

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Aula 8, Section B, Edificio 19

ore 14:00 – 19:00

SEZIONE VII

**Didattica e storia della fisica**

Presiede: CHINNICI I. (INAF, Osservatorio Astronomico di Palermo)

Relazioni su invito

▲ **Gli anni di Emilio Segrè a Palermo (1935-1938).**

ZINGALES R.

*Gruppo Nazionale di Fondamenti e Storia della Chimica, Palermo*

Segrè giunse a Palermo alla fine del '35, vincitore della Cattedra di Fisica sperimentale, e vi rimase fino al giugno del '38, quando, già a Berkeley per motivi di studio, a seguito della promulgazione delle leggi razziali, si stabilì negli Stati Uniti. A Palermo, cercò di costituire un centro di ricerche in Fisica nucleare, come quello di Fermi a Roma, richiamando, come assistenti incaricati, due laureati della Normale, Cacciapuoti e Mandò, e ottenendo la Cattedra di Fisica teorica, assegnata poi a Wick. Vista la limitata disponibilità di fondi, cercò nelle piastrine bersaglio del ciclotrone di Berkeley le sorgenti radioattive necessarie alle proprie ricerche. A Palermo, con l'aiuto del chimico Perrier, estrasse da queste l'isotopo  $^{32}\text{P}$ , che Artom utilizzò per innovative ricerche fisiologiche, dando vita a un gruppo di ricerca multidisciplinare di grande prospettiva, poi dissolto dalla politica antisemita del Governo. All'inizio del '37, insieme a Perrier, dimostrò che una piastrina radioattiva di molibdeno conteneva piccolissime quantità dell'elemento a numero atomico 43, mai prima isolato con certezza. Per l'Italia, era la prima scoperta di un elemento chimico, poi chiamato Tecneto (in greco, artificiale), che spostò la ricerca di nuovi elementi dall'analisi chimica dei minerali, alla sintesi, con processi fisici, di quelli non esistenti in Natura.

▲ **La collezione storica degli strumenti di fisica dell'Università di Palermo: aspetti didattici.**

AGLIOLO GALLITTO A.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

Nel 2011 l'Università di Palermo ha istituito il Sistema Museale di Ateneo (SiMuA) per la tutela e la valorizzazione del patrimonio culturale. Il SiMuA coordina 6 musei (Orto Botanico, 1789; Museo di Geologia G. G. Gemmellaro, 1861; Museo di Zoologia P. Doderlein, 1863; Museo della Specola ospitato nell'Osservatorio Astronomico, 1790; Museo di Radiologia, 1995; Museo Storico dei Motori e dei Meccanismi, 2011), 5 siti di interesse storico e 14 collezioni. La Collezione Storica degli Strumenti di Fisica è esposta presso il Dipartimento di Fisica e Chimica Emilio Segrè nell'edificio storico di via Archirafi 36. Gli strumenti più antichi risalgono all'inizio del XIX secolo, con Domenico Scinà (1764-1837) titolare della cattedra di Fisica Sperimentale e direttore del Gabinetto di Fisica della Regia Università degli Studi (1806). La Collezione oggi raccoglie più di 500 strumenti che testimoniano la ricerca scientifica condotta a Palermo a partire dal XIX secolo. Nella relazione, dopo un'introduzione storica, saranno descritti alcuni strumenti della Collezione, con particolare attenzione alle attività laboratoriali condotte con le scuole del territorio.

▲ **L'ultima impresa scientifica di Orso Mario Corbino: la nascita dell'Istituto Nazionale di Elettroacustica a via Panisperna.**

FOCACCIA M.

*Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma*

Che cosa successe a via Panisperna, dopo l'estate del 1936, quando il Regio Istituto di Fisica traslocò presso la nuova cittadella universitaria? Il destino della palazzina fu, ancora, legato

alla brillante attività di Orso Mario Corbino, vero e proprio manager della ricerca scientifica del suo tempo, il quale, consapevole di aver collaborato a una stagione eccezionale per la scienza italiana e fiducioso degli sviluppi futuri della fisica nucleare, decise di dedicarsi ad un altro campo di ricerche a cui da tempo era legato: l'elettroacustica. Con Decreto del 10 luglio 1936 del Presidente Guglielmo Marconi, veniva costituito l'Istituto Nazionale di Elettroacustica del CNR, con sede proprio in via Panisperna. La presente relazione intende ripercorrere la fondazione e la storia di questo Istituto, che rappresenta l'ultima impresa scientifica del poliedrico scienziato siciliano, a partire dallo stretto sodalizio scientifico e istituzionale esistente tra Corbino e Marconi, che decretò il successo dell'operazione, facendo altresì luce su un periodo meno noto della storia di via Panisperna.

### ▲ At the beginnings of physics teaching.

TALAS S.

*Museo Giovanni Poleni, Università di Padova*

From the early 18th century, a totally new kind of lecture-demosntrations started spreading throughout Europe. These lectures no longer dealt with the whole natural philosophy, but mainly focused on the fields that constitute what we today call physics. Based on experiments, they started to be called experimental philosophy or experimental physics lectures. After examining the main features of the new lecture-demonstrations, the present paper will discuss their audiences and focus on the challenges the first professors of experimental philosophy had to face. The paper will then examine the impact of 18th-century experimental philosophy courses, showing how they shaped physics teaching and marked the birth of physics in a modern sense. We will also see how the new lectures stimulated the birth of science popularization and contributed to make a new generation of physicists emerge from the early 19th century.

## Comunicazioni

### ● Forgotten makers of progress: Rediscovering J.G. Hofmann's legacy in the dialogue between science and technology.

LOVISETTI L.

*Dipartimento di Fisica, Università degli Studi di Milano*

In 2024, at the Deutsches Museum, I had the opportunity to study an instrument crafted by the "mysterious" J.G. Hofmann, an optical instrument maker active in 19th-century Paris. That work sparked research that led me to reconstruct Hofmann's life and activity. Though now largely forgotten, Hofmann was internationally celebrated in his time and his instruments can be found in several of the world's most prestigious collections. Indeed, his devices were appreciated by renowned scholars and employed in major scientific expeditions, such as the Italian mission to Sicily for the 1870 solar eclipse and that to Muddapur, led by Tacchini, to observe the 1874 Venus transit. This presentation seeks to illuminate how stories like Hofmann's underscore the essential interplay between science and technology, where scientific instruments extend human perception, while new discoveries drive the invention of more refined tools. This mutual reinforcement drives innovation forward, in a virtuous cycle. Reflecting on Hofmann's role thus sheds light on the ongoing dialogue between science and technology-a dynamic partnership that pushes the boundaries of knowledge and shapes human understanding.



● **La scienza elettrica di Giovanni Poleni. Produzione di conoscenze e diffusione di pratiche sperimentali nell'Italia del Settecento.**

VOLTOLINA L.

*Università di Padova*

A metà del XVIII secolo, la moda dell'elettricismo si diffuse in tutta Italia. Essenziale fu il contributo dei cosiddetti sassoni, dimostratori itineranti stranieri che, verosimilmente, introdussero le prime macchine elettriche a rotazione nel territorio cisalpino. Però, il ruolo dei ricercatori italiani nella diffusione di conoscenze e pratiche elettriche, e l'originalità delle loro indagini, rimangono argomenti scarsamente analizzati in letteratura. Questo contributo esplora la figura di Giovanni Poleni, professore del primo corso di Filosofia Sperimentale dell'Università di Padova, e il suo interesse per l'elettricità nel periodo 1742-1748. Attraverso la sua corrispondenza con alcuni costruttori di strumenti scientifici lombardi, precursori dei baromàta ottocenteschi, come G. Castelnuevo e P. Casati, e con due dimostratori elettrici stranieri (C. X. Wabst e F. Bossaert), verrà analizzata la complessa rete di scambi intellettuali che ha caratterizzato l'indagine scientifica nell'Italia illuminista, fornendo altresì nuovi indizi circa la paternità del primo trattato italiano interamente dedicato all'elettricità, il *Dell'Elettricismo* (1746).

● **Il Museo della Specola di Bologna si rinnova!**

ROSSI E.

*Università di Bologna*

In occasione della prossima riapertura del Museo della Specola dell'Università di Bologna, questa comunicazione presenta il nuovo allestimento dedicato in parte a Guido Horn d'Arturo (1879-1967), direttore dell'Osservatorio dal 1921 e titolare della cattedra di Astronomia dal 1925. Figura poliedrica, Horn affiancò all'astrofisica un forte interesse per la progettazione di strumenti, l'ottica fotografica e gli effetti fisiologici dell'osservazione. In due spedizioni per eclissi solari (Oltregiuba 1926, Peloponneso 1936), studiò la goccia nera – un ponte scuro tra pianeta e Sole dovuto ad astigmatismo oculare – e le ombre volanti – bande di luce e ombra causate da un'atmosfera non uniforme – interpretandone con lungimiranza le cause fisiche. Il nuovo percorso espositivo valorizza questi studi, il progetto pionieristico del primo telescopio con specchio segmentato (precursore dei moderni multi mirror telescopes) e l'attività di divulgatore di Horn (fondatore di *Coelum*), con materiali inediti e nuove tecnologie museali, impiegate per la valorizzazione dell'eccezionale patrimonio storico-scientifico custodito nella Torre della Specola.

● **Il Cerchio di Ramsden: storia di un capolavoro della tecnica.**

MIRABELLO F., CAROTENUTO M.R., AGLIOLO GALLITTO A., CHINNICI I.

*Università di Palermo e INAF, Osservatorio Astronomico di Palermo*

Il più importante strumento storico del Museo della Specola presso l'Osservatorio Astronomico di Palermo è il cerchio astronomico altazimutale realizzato dal costruttore londinese Jesse Ramsden (1735-1800). Con questo telescopio, padre Giuseppe Piazzi (1746-1826) scoprì nel 1801 il primo asteroide del sistema solare, Cerere Ferdinanda, ed effettuò le osservazioni astronomiche per le due edizioni del suo catalogo stellare (pubblicate nel 1803 e nel 1814). Piazzi considerava il cerchio di Ramsden un capolavoro della tecnica. Nel presente contributo verranno esposti dettagli meccanici inediti relativi alla tecnica costruttiva, soluzioni che ancora oggi, a distanza di secoli, rivelano la genialità di Ramsden. Considerando le conoscenze tecniche dell'epoca, la realizzazione del telescopio fu un'impresa complessa, che lo stesso Ramsden definì titanica. Attraverso l'analisi dei dettagli costruttivi visibili sullo strumento e la loro rilettura alla luce delle attuali conoscenze, è stato possibile ricostruire con buona approssimazione il ciclo di lavorazione seguito per creare uno strumento unico nel suo genere che ha permesso di dare contributi importanti allo sviluppo dell'astronomia.

● **La Terza Roma di Quintino Sella: la questione dei musei scientifici.**

VERDUCI D.

*Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma e Università di Bologna*

Il tentativo di dare vita a un Museo della Scienza a Roma risale al momento stesso della proclamazione della città a capitale del Regno d'Italia. Già Quintino Sella ne parlava all'interno di un progetto ben più ampio, quello della Terza Roma, una Roma della scienza moderna, dopo quella dei Cesari e quella dei papi. La discussione del disegno di legge per il concorso dello Stato nelle opere edilizie e di ampliamento della capitale permise a Sella, che ne era relatore, di diffondersi a lungo sulle infrastrutture scientifiche e culturali assolutamente necessarie per rispondere ai doveri dell'Italia di fronte al mondo contemporaneo: in particolare, Sella aveva proposto di erigere un Palazzo delle Scienze come sede dell'Accademia e dei relativi musei, che ne dovevano essere parte integrante. Grazie al supporto di alcuni documenti d'archivio, il presente contributo mira a ricostruire le varie tappe dell'interessante ed intricata vicenda dei musei scientifici, per i quali Sella si profuse a lungo, dapprima nella zona di via Panisperna, dove desiderava edificare un quartiere scientifico, e poi a Palazzo Corsini, che finì con l'ospitare solo l'Accademia dei Lincei, senza musei annessi.

● **Comunicare la ricerca: il caso della rivista Universi.**

SANDRI M.

*INAF*

Universi è un periodico di divulgazione scientifica dell'Istituto Nazionale di Astrofisica (INAF), pubblicato dal 2023 con cadenza semestrale. La rivista presenta attività, risultati e prospettive scientifiche dell'ente, configurandosi come un vero e proprio house organ. Distribuito gratuitamente in formato cartaceo, Universi mira a informare il pubblico sulle iniziative dell'INAF, facilitare la circolazione delle informazioni con Ministeri, istituti scientifici e culturali, e raggiungere chiunque sia interessato alla scienza e all'astronomia. A oggi sono usciti cinque numeri. Oltre alla versione cartacea – alla quale è possibile abbonarsi gratuitamente – è disponibile anche un'edizione online. Il contributo illustrerà la struttura editoriale della rivista, i criteri di scelta dei contenuti, le figure professionali coinvolte, l'andamento degli abbonamenti e la diffusione su scala nazionale.

● **La comunicazione del Museo Enrico Fermi tra sfide e opportunità.**

LO PIANO A.

*Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma*

Il Museo Enrico Fermi affronta la comunicazione della scienza con una strategia sinergica alle linee di ricerca dell'ente. Le peculiarità del Museo è la sua ubicazione di non facile accesso, la sua valenza storica e simbolica, e la sua natura di museo scientifico e storico che presentano sfide uniche. Tuttavia, queste stesse caratteristiche si trasformano in opportunità per una narrazione coinvolgente. L'obiettivo primario di questa strategia è la diffusione di una cultura scientifica inclusiva, rivolta a un pubblico eterogeneo. Il modello comunicativo adottato si inserisce attivamente nel dibattito contemporaneo sul ruolo del museo, traendo ispirazione dalle più recenti ricerche e proposte del settore.

● **Lucrezio padre della scienza moderna.**

ZANGARI DEL BALZO G.

*Sapienza Università di Roma*

La lettura scientifica del *De rerum natura* sconvolge: Lucrezio non fu solo il grande poeta latino che ci è stato tramandato dalla scuola, ma l'autentico sorprendente padre della scienza moderna. Siamo dunque, così, al cospetto di un testo scientifico eccezionale, scritto

duemila anni fa, che fa del *De rerum natura* il primo grande capolavoro della storia della scienza. Le intuizioni scientifiche lucreziane precorrono di duemila anni le scoperte della scienza odierna, dal Big Bang ai fotoni, alla caduta dei gravi di Galileo, all'origine delle specie, al DNA, ai frattali, all'entropia. Nel corso dei secoli in effetti la figura di Lucrezio scienziato non emerge perché il *De rerum natura* fu considerato patrimonio esclusivo degli studi umanistici e filologici. Ancor oggi questa interpretazione riduttiva porta a ritenere Lucrezio sbrigativamente un atomista tout court -perché discepolo di Epicuro- e a vistosi errori di interpretazione, mentre le geniali intuizioni di Lucrezio non riguardano né la teoria atomica, né la legge di Lavoisier o la tavola di Mendeleev, ma le particelle elementari della fisica moderna. D'altronde la disamina scientifica spetta a chi di scienza si è nutrito.

● **Gli echi della scienza: i padiglioni di fisica della mostra d'oltremare di Napoli tra memoria e futuro.**

AMODEO G., ALLOCCA L., COCIFOGLIA F., DE LUISE V., ESPOSITO A.M., IODICE G., LA RANA G., STAZIO I., STORNAIOLO C.

*Associazione All'Ombra del Cervo di Rodi APS, Napoli*

I Padiglioni di Fisica della Mostra d'Oltremare di Napoli hanno visto, alla fine degli anni '50, la nascita delle prime scuole napoletane di fisica, che hanno contribuito negli anni alla formazione di generazioni di scienziati. Per decenni hanno ospitato attività didattiche e di ricerca teorica e sperimentale svolte da istituzioni scientifiche, in particolare l'Università di Napoli Federico II e l'INFN, rappresentando un raro esempio di architettura della conoscenza e un simbolo della modernità scientifica. Oggi, sebbene in stato di abbandono dal 2000, questi luoghi continuano a trasmettere gli echi di un passato ricco di fermenti culturali e scientifici. L'Associazione All'Ombra del Cervo di Rodi APS sta promuovendo un progetto di rigenerazione che prevede la nascita di un Centro di Eccellenza per la ricerca, l'innovazione tecnologica e la formazione continua. Il contributo intende offrire una riflessione sul valore della memoria scientifica e sul potenziale di questi spazi per diventare nuovamente luoghi di ricerca, dialogo e alta divulgazione.

● **Philipp Frank physicist and logical empiricist on the general theory of knowledge and the importance of the philosophy in science teaching.**

FORTINO M.

*Cosenza*

In this communication I would like to turn my attention to Philipp Frank (1884-1966), a Viennese theoretical physicist, successor to Einstein at the University of Prague from 1912 to 1938 and representative of the logical empiricism of the Vienna Circle. I wish to emphasise his critical conception of physics as a chapter of human knowledge. Thus his *Modern Science and its Philosophy* (1949), and others essays, revealed the need to integrate science, philosophy and the history of science into teaching practice and in the physics student's curriculum. I advocate the need for the the closest possible rapprochement between philosophy and science, to build a bridge between science and philosophy that has grown up on the soil of science. This idea can be considered since the first philosophical articles of Frank. In these, the great speculative value of Henri Poincaré's conventionalism and Ernst Mach's ideas was recognised, in antithesis with traditional philosophy, or rather with the metaphysical prejudices of school philosophy.

● **L'ultima scoperta del Cav. Melloni.**

DEL MONTE R., AUTERI A.

*Centro Musei delle Scienze Naturali e Fisiche, Università di Napoli Federico II*

Il fisico italiano Macedonio Melloni (1798-1854), noto soprattutto per il suo lavoro sul calore radiante, dedicò gli ultimi anni della sua vita al campo dell'elettricità e del magnetismo.

Nell'ambito delle sue ricerche, poco prima di morire progettò e costruì un innovativo elettrometro a induzione di particolare importanza storica e scientifica. Un esemplare dello strumento, conservato presso il Museo di Fisica dell'Università di Napoli Federico II, reca sul quadrante la scritta *Ultima scoperta del Cav. Melloni*. Melloni era fermamente convinto che, con l'aiuto di questo elettroscopio, fosse possibile dimostrare, con un "coup de baguette", come il principio fondamentale dell'elettrostatica dovesse essere messo in discussione e ridefinito. In questo lavoro, collocheremo questo strumento nel contesto dei contributi scientifici di Melloni e nel panorama più ampio degli studi contemporanei sull'induzione elettrostatica. Discuteremo inoltre il significato di questo strumento, esaminando le sue origini e la sua eredità scientifica, e porremo a confronto i tre esemplari tutt'ora esistenti.

● **The Belli's Multiplier and its relevance in the development of electrical induction machines.**

TRAVERSINI R.

*Milano*

The evolution of physical ideas, in the theoretical and applied domains, are often marked by the development of specific procedures and devices implementing them. One relevant case of those devices is the so-called Belli's Multiplier, an electrical machine, based on electrostatic induction. Giuseppe Belli, a Physics teacher of the Liceo Parini, Milan in the years 1821 - 1840, invented it in 1831. During a survey of the historical collection of didactical instruments hosted by this Liceo, a prototype of this device was found, most probably the first built by Belli leveraging the mechanical workshop of the other Liceo in Milan, Liceo Sant'Alessandro (now Liceo Beccaria). Examining in detail the design of this particular device, it appears that it can be considered a turning point in the development of electrical induction machines, from charge amplifiers to high voltage generators. The investigation of this development process provides not only a view of the history of the electrical theory in the nineteenth century but also the backbone of a relevant didactical experience, where students can be involved, understanding the origin of fundamental concepts in electricity.

● **La scoperta della dispensa intitolata Complementi di Fisica a cura degli studenti Oddino Nardini, Gilberto Bernardini, Giovanni Gentile Jr. Anno Scolastico 1924-25.**

BAGNI E.

*Dipartimento di Economia e Management, Università di Pisa*

Da una ricerca dell'autore è emersa una dispensa universitaria di Complementi di Fisica relativa all'anno accademico 1924-25 a cura di Oddino Nardini, Gilberto Bernardini e Giovanni Gentile Jr., tre studenti della Regia Università di Pisa e allievi del Collegio Regia Scuola Normale Superiore Universitaria di Pisa.

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Aula Magna G.B.F. Basile, Edificio 7

ore 09:00 – 13:30

## SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: DE GRUTTOLA D. (Università di Salerno)

Relazioni su invito

**▲ The ALICE experiment: studying strongly interacting matter at the LHC.**

OPPEDISANO C. ALICE COLLABORATION

*INFN, Sezione di Torino*

The ALICE experiment at the CERN LHC was specifically designed to study the collisions of ultra-relativistic heavy ions and to characterize the Quark-Gluon Plasma (QGP), the deconfined state of quark and gluons, formed in such collisions. However, the study of smaller collision systems, proton-proton and proton-nucleus, unexpectedly revealed features that were predicted to occur only in presence of a deconfined medium. This opened the field to different possible interpretations, spanning from the interaction of overlapping strings in the partonic medium to the creation of QGP droplets even in small systems. ALICE measurements also provide insights into the hadronization mechanisms, the formation of light nuclei and build a connection to astrophysics. The detector upgrade, completed for Run 3, allowed to run in triggerless mode and to collect data volumes orders of magnitude larger than in previous runs. This leap in statistics unlocked a new era of high-precision, differential measurements across a broad spectrum of observables. Results in different collisions systems to assess the fundamental nature of strongly interacting matter under extreme conditions will be presented.

**▲ Status of the FOOT experiment and first results.**

TOPPI M. ON BEHALF OF FOOT COLLABORATION

*Sapienza Università di Roma e INFN, Sezione di Roma*

The study of nuclear fragmentation plays a central role in many important applications: from Particle Therapy up to radiation protection for space missions. The fragmentation dose released to a patient during a Particle therapy treatment and to an astronaut protected by a shielding have to be known with high accuracy. The FOOT physics program foresees a comprehensive set of measurements employing ion beams (mainly  $^4\text{He}$ ,  $^{12}\text{C}$  and  $^{16}\text{O}$ ) and targets similar to the composition of human tissues from one side and spacecraft shielding materials on the other. The goal of the experiment is to measure double differential cross-sections as a function of scattering angle and fragment energy within the 100-800 MeV/u range, achieving a precision level exceeding 5%. This presentation will provide an overview of the experiment's current status, recent results obtained with a  $^{16}\text{O}$  beam of 200-400 MeV/u interacting with C and  $\text{C}_2\text{H}_4$  targets, including the first  $^{16}\text{O} + \text{H}$  fragmentation cross section, preliminary results obtained with a  $^{12}\text{C}$  beam with the full FOOT setup and details on the upcoming experimental campaigns.

**▲ AMBER physics program: present status and future perspective.**

BREZZAN A. AMBER COLLABORATION

*Università di Trieste e INFN, Sezione di Trieste*

AMBER has started taking data in 2023 and 2024, addressing the measurement of antiproton productions on H2 and deuterium targets. In the next years the measurement of the proton

charge radius while the future Drell-Yan program will, in its first stage, give new insight in the pion PDFs, study nuclear effects and the charmonium production mechanism. We will review this program and give some perspective for measurements that can be performed further in the future.

▲ **Selected highlights of the search of new phenomena at ATLAS and CMS experiments at the LHC.**

TRAMONTANO R. CMS AND ATLAS COLLABORATIONS

*Physik Institut, Universität Zurich, Switzerland*

The ATLAS and CMS experiments at CERN have a very wide-ranging physics program. This presentation focuses on the search for exotic physics beyond the standard model of particle physics. Highlights of the recent results up to summer 2025 and based on data collected during the LHC Run2 and Run3 are presented. A limited subset of the physics analyses being performed at ATLAS and CMS is discussed here, focusing on unprecedented investigations, unexplored final states and innovative analysis techniques aimed at enhancing the discovery potential.

Comunicazioni

● **Search for rare radiative decays of the Higgs boson with the CMS experiment.**  
FERRANDO E.

*Dipartimento di Fisica, Università di Torino e INFN, Sezione di Torino*

With the full Run2 data set of the LHC at  $\sqrt{s} = 13$  TeV it is possible to search for ultra-rare, radiative decays of the Higgs boson. These include  $H \rightarrow \text{quarkonium} + \gamma$  decays and  $H \rightarrow \gamma + \phi/\rho/K^{*0}$ , which can probe the Yukawa couplings to the light ( $u, d, s$ ) quarks and the presence of BSM effects that can enhance these processes. The combination of multiple Higgs-boson production modes is used to optimize sensitivity in such rare channels.

● **Algoritmi di machine learning per identificazione di oggetti pesanti a CMS.**

SALERNO F. <sup>(1)</sup>, IORIO A.O.M. <sup>(1)</sup>(<sup>2</sup>)

<sup>(1)</sup> *INFN, Sezione di Napoli*

<sup>(2)</sup> *Università degli studi di Napoli Federico II*

Le ricerche di nuova fisica in regime ad alto impulso sono una parte essenziale del programma di fisica a LHC, in quanto puntano a rivelare la presenza di nuove risonanze pesanti predette da molte teorie oltre il Modello Standard (MS). All'interno della collaborazione CMS sono stati sviluppati numerosi algoritmi di identificazione ("tagging") di jet adronici originati da particelle del MS, come quark top, bosoni di Higgs o bosoni vettori prodotti nei processi di nuova fisica. I moderni algoritmi di Machine Learning (ML) sono molto efficienti nello sfruttare le caratteristiche di tali jet sia per discriminare tra differenti ipotesi di particelle pesanti che per rigettare jet provenienti da processi di fondo. Queste tecniche di tagging sono state ampiamente utilizzate in ricerche di nuova fisica per migliorare la ricostruzione del segnale e la selezione del fondo. Questo contributo punta a mostrare lo stato dell'arte di tali algoritmi, descrivendo le loro prestazioni in analisi effettuate su dati raccolti nel Run-II and Run-III di LHC con energie nel centro di massa rispettivamente di 13 e 13.6 TeV.

● **Tuning of new hadronisation models in PYTHIA 8.3: Rope Hadronisation and Closepacking.**

BERNARDINIS L., ZACCOLO V.

*Università di Trieste e INFN, Sezione di Trieste*

Hadronisation due to its non-perturbative nature is described with phenomenological assumptions. Various models are implemented in the Monte Carlo event generator PYTHIA

8.3 and the tuning of two hadronisation models, Rope Hadronisation and Closepacking, will be presented in this contribution. Both models assume that increased string tension enhances strange hadron production in high-density string environments, employing different mechanisms. The Rope Hadronisation model is tuned for the first time with ALICE strangeness data. The new tune reproduces strange mesons and baryons as a function of multiplicity with 5-10% precision. The  $\Lambda/K_S^0$  and  $\Lambda/\pi$  ratios is now compatible with ALICE data, although the  $p/\pi$  ratio remains inconsistent. Secondly, the first tuning of Closepacking reproduces nearly all particle ratios as a function of multiplicity within one standard deviation, with improved agreement for the  $p/\pi$  ratio compared to the Ropes model, although some deviations persist. These results demonstrate the ongoing challenges of modelling both strange and non-strange light-flavour hadrons, highlighting limitations in hadronisation models.

● **The calibration of the microstrip silicon detector in the FOOT experiment.**

MAZZOLANI S. FOR THE FOOT COLLABORATION

*Scuola di Studi Avanzati, Università degli Studi di Camerino e INFN, Sezione di Perugia*

The FOOT (FragmentatiON Of Target) experiment has a relevant role in both medical physics, to increase knowledge on Hadrontherapy, and aerospace engineering, for Radiation Protection in Space. It aims to measure double differential cross-sections in nuclear fragmentation processes as a function of the emission angle and kinetic energy of the fragments, with a precision better than 5%. The Microstrip Silicon Detector (MSD) is one of the components of the magnetic spectrometer used to measure the fragments momentum. It also measures the  $dE/dx$  of each fragment, contributing to its Z determination. The MSD consists of three planes, with two sensors (X-Y views) each. For each sensor (100 cm<sup>2</sup> active area and 150  $\mu$ m thickness) 640 strips with 150  $\mu$ m pitch are readout. Several data taking campaigns have been carried out: in 2021 at GSI, Darmstadt, in 2022 at HIT, Heidelberg and in 2023 and 2024 at CNAO, Pavia. The study on calibration runs will be presented, obtaining pedestal and single strip noise for each microstrip in each data taking campaign. Also a preliminary study on the detector signal clustering will be shown, in order to evaluate the MSD reconstruction efficiency.

● **A target of solid hydrogen for the SAND detector in DUNE.**

ROSELLI C., BATTISTI F.

*Dipartimento di Fisica, Università di Bologna e INFN, Sezione di Bologna*

The Deep Underground Neutrino Experiment (DUNE) is a next-generation experiment designed to achieve unprecedented precision in the study of neutrino flavour oscillations. To reduce systematic uncertainties related to neutrino flux and interaction cross-sections, DUNE will employ a near detector (ND) complex. The System for On Axis Neutrino Detection (SAND), one of the three ND components, is permanently located on-axis to monitor beam stability. SAND features a 0.6 T superconducting magnet and an electromagnetic calorimeter made of lead-scintillating fibres. Its inner volume hosts a novel liquid argon (LAr) detector and a low-density tracker. A key role of SAND is to constrain uncertainties in neutrino interactions, which are significantly affected by nuclear effects. A sample free from such effects can be obtained in SAND via statistical subtraction, using tunable slabs of CH<sub>2</sub> and carbon (C) to construct an effective solid hydrogen target. The effectiveness of this technique and its impact on systematic control in DUNE will be discussed.

● **Measurements of the production cross-section for a Z boson in association with b-jets with ATLAS experiment at LHC.**

SANTORO G. <sup>(1)(3)</sup>, MEONI E. <sup>(1)(3)</sup>, SFORZA F. <sup>(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università della Calabria*



<sup>(2)</sup> *Dipartimento di Fisica, Università di Genova*

<sup>(3)</sup> *INFN, Sezione di Genova*

Measurements of Z boson production in association with b-jets (Z+b-jets) in proton-proton collisions at the LHC contribute to the understanding of perturbative QCD and of the proton structure. Furthermore, such measurements are valuable inputs for the improvement of Monte Carlo simulations used to estimate the Z+b-jets background in Higgs boson measurements and in searches for New Physics. In 2024 the ATLAS collaboration published a measurement of the inclusive and differential cross-sections of Z+b-jets using a large dataset ( $140 \text{ fb}^{-1}$ ) of proton-proton collisions at the center-of-mass energy of 13 TeV. In this talk, new measurements of differential cross-sections for the Z+2 b-jets process are presented as a function of observables not shown in the previous publication. Differential cross-sections are also presented in the boosted region at high transverse momenta where the 2 b-jets are reconstructed as a single large-radius jet. The measurements are compared with the predictions of the state-of-the-art Monte Carlo simulations.

● **Accessing full-rate level-1 trigger data with the CMS level-1 data scouting system at CERN LHC.**

CRISTOFORETTI D.

*Università di Torino*

trigger systems are essential for selecting interesting physics events in high-rate experiments. The CMS experiment at CERN LHC performs selection based on a coarse reconstruction of the event produced by the Level-1 Trigger (L1T), discarding more than 99% of all events in the process. With the upcoming CMS Phase-2 upgrade, the L1T will deliver data with reconstruction quality approaching that of offline analyses, offering new opportunities for physics analysis. The Level-1 Data Scouting (L1DS) project is designed to collect L1T data at the full 40 MHz bunch-crossing rate, independently of trigger decisions. This allows CMS to collect a broad and inclusive dataset, well-suited for studies of rare processes, low-mass resonances, long-lived particles, and to monitor detector performance.

● **Anti-nuclei leggeri in collisioni pp a LHC: produzione per coalescenza e interazione di anti-nucleoni.**

CIAVARELLI N., ERCOLESI F.

*Dipartimento di Fisica, Università di Bologna e INFN, Sezione di Bologna*

Lo studio dei meccanismi di produzione dei nuclei leggeri ai collisionatori ha acquisito crescente rilevanza negli ultimi anni, sia per la fisica adronica sia per le sue implicazioni nella ricerca indiretta di materia oscura, in particolare nei canali con produzione associata di antimateria. Grazie all'elevata statistica accumulata dall'esperimento ALICE a LHC, sarà possibile ottenere misure di precisione delle abbondanze di anti-nuclei di deuterio e elio, nonché determinare con accuratezza le relative sezioni d'urto. Questi dati permetteranno inoltre di caratterizzare l'interazione nucleone-nucleo attraverso analisi di correlazione. In questo lavoro presentiamo le predizioni di un modello di coalescenza, implementato con un afterburner per l'interazione nucleone-nucleone e accoppiato agli stati finali simulati con PYTHIA in collisioni pp a  $\sqrt{s} = 13.6 \text{ TeV}$ . I risultati sono confrontati con i dati sperimentali raccolti da ALICE durante il Run 2 di LHC, discutendo le implicazioni per gli studi con dati di Run 3 e oltre.

● **Quarkonium evolution in the quark-gluon plasma via an open quantum systems approach coupled to a full relativistic transport model.**

COCI G. <sup>(1)(2)</sup>, PLUMARI S. <sup>(1)(2)</sup>, GRECO V. <sup>(1)(2)</sup>, FALCI G. <sup>(1)(3)(4)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(2)</sup> *INFN, Laboratori Nazionali del Sud, Catania*



<sup>(3)</sup> *INFN, Sezione di Catania*

<sup>(4)</sup> *CNR-IMM, Istituto per Microelettronica e Microsistemi, Catania*

Recent progresses in quantum computation and related technologies have conducted to new theoretical developments, which have found applications in various research fields, including high-energy physics. In this work, we present an open quantum systems approach to study the suppression of quarkonium, a bound state formed by a heavy quark (charm or beauty) with its antiquark. This has been considered for many decades a key probe to understand the main features of the Quark-Gluon Plasma (QGP) produced in heavy-ion collisions. We describe the dynamics of quarkonia in the QGP by means of the Lindblad quantum master equation, which we couple to a full relativistic transport model based on the Boltzmann equation for a realistic evolution of the QGP environment. Within this unified framework, we study the impact of different medium properties, such as viscosity and temperature dependence of the diffusion coefficient, on the dissociation and regeneration of quarkonia. In this respect, we aim to identify the main physical quantities which enhance the quantum decoherence of the maximum entangled states, a novel perspective to gain insights into the properties of strong interacting matter.

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Aula 11, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE II

**Fisica della materia**

Presiede: CIMINI V. (Sapienza Università di Roma)

Relazioni su invito

▲ **Amplification and squeezing generation in a flux tunable Josephson Traveling Wave Parametric Amplifier.**

ESPOSITO M.

*CNR-SPIN, Complesso di Monte S. Angelo, Napoli*

Josephson traveling-wave parametric amplifiers (J-TWPAs) are superconducting Josephson-junction-based nonlinear transmission lines enabling parametric amplification and broadband squeezing generation. I will present our last experimental results on near quantum-limited amplification and squeezing generation in a flux tunable J-TWPA based on SNAIL (superconducting nonlinear asymmetric element) unit cells with inverted flux polarity. Such a device was first introduced in the literature as a four-wave-mixing (4WM) amplifier, and squeezer. Subsequent investigations have shown that flux tunability can be used to activate residual three-wave-mixing (3WM) non-linearity, enabling second harmonic generation and amplification with a dynamical phase matching mechanism. I will present experimental results aiming at exploiting flux-tunability to investigate the effect of residual 3WM on both amplification and generation of squeezing. The outcomes of our investigation could help in defining new operational configurations for generating multi-mode squeezing in TWPAs, possibly extending the range of applications in the framework of microwave photonics.

▲ **Enhancing second harmonic generation with quantum light form parametric down conversion beyond the photon pairs regime.**

CASPANI L. <sup>(1)(2)</sup>, DICKINSON T. <sup>(1)(2)</sup>, AFXENTI I. <sup>(3)</sup>, ASTRAUSKAITE G. <sup>(4)</sup>, HIRSCH L. <sup>(3)</sup>, NERENBERG S. <sup>(4)</sup>, JEDRKIEWICZ O. <sup>(2)(5)</sup>, FACCIO D. <sup>(4)</sup>, MÜLLENBROICH C. <sup>(4)</sup>, GATTI A. <sup>(5)</sup>, CLERICI M. <sup>(2)(3)</sup>

<sup>(1)</sup> *Institute of Photonics, Department of Physics, University of Strathclyde, Glasgow, UK*

<sup>(2)</sup> *Como Lake Institute of Photonics, Dipartimento di Scienza e Alta Tecnologia, Università dell'Insubria, Como*

<sup>(3)</sup> *James Watt School of Engineering, University of Glasgow, UK*

<sup>(4)</sup> *School of Physics and Astronomy, University of Glasgow, UK*

<sup>(5)</sup> *CNR - Istituto di Fotonica e Nanotecnologie, Milano*

Stimulating two-photon processes such as second harmonic generation (SHG) and two-photon absorption (TPA) with entangled photons generated by parametric down-conversion (PDC) is expected to result in higher efficiencies compared to classical illumination. This has been demonstrated for both SHG and TPA in experiments conducted at low photon fluxes, where the PDC modes are, on average, populated by less than one photon, and for spatially single-mode PDC radiation. This resulted in very low SHG/TPA signals, with limited practical applications. We experimentally investigate SHG driven by broadband PDC radiation, characterized by a high number of spatial and temporal modes ( $> 104$ ), and compared its efficiency with that of SHG driven by classical radiation. We observed a quantum enhancement for driving intensities up to  $\sim 10$  photons/mode, almost 10 times larger than the bound for quantum advantage considered so far. For the classical benchmark, we employed a standard laser pulse rather than a quantum state spoiled by losses as often done

in previous experiments. Our results shed light onto the ongoing debate on the physics of quantum enhancement in two-photon processes and demonstrate that it can be achieved at intensities larger than previously thought, paving the way for practical applications.

### ▲ **Harnessing rotation: from wave amplification to quantum entanglement.**

BRAIDOTTI M.C.

*University of Glasgow, UK*

Rotation – an everyday yet deeply fundamental form of non-inertial motion – continues to reveal surprising effects across physics, from classical wave dynamics to the quantum realm. In this talk, I will begin with recent experimental evidence showing wave amplification caused by a spinning cylinder, shedding new light on the long-predicted Zel'dovich effect. This effect, originally describing enhanced scattering from rotating absorbers, shares deep connections with Penrose superradiance and illustrates how rotational energy can fuel wave amplification under specific conditions. I will then move to the quantum domain, where only a few experiments have explored how rotational motion impacts quantum entanglement. Using a new framework based on Sagnac interferometry and advanced quantum tools, I show that rotation can reveal, reshape, and even generate entanglement between initially uncorrelated particles. Unlike traditional scattering-based approaches, which often demand extreme conditions, this method offers a more accessible path to probing foundational quantum phenomena.

Comunicazioni

### ● **Efficiente parametric down-conversion fuori accordo di fase in guide d'onda solitoniche.**

FAZIO E. <sup>(1)</sup>, BILE A. <sup>(1)</sup>, NABIZADA A. <sup>(1)</sup>, BELARDINI A. <sup>(1)</sup>, SCALORA M. <sup>(2)</sup>, CHAUVET M. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Scienze di Base e Applicate per l'Ingegneria, Sapienza Università di Roma*

<sup>(2)</sup> *FCDD-AMT-MGR, DEVCOM AvMC, Charles M. Bowden Research Center, Redstone Arsenal, AL, USA*

<sup>(3)</sup> *FEMTO-ST insNtute, Université Franche-Comté, France*

Riportiamo per la prima volta un processo di Parametric Down-Conversion ottico in una guida d'onda solitonica in un film sottile di niobato di litio su isolante (LNOI). Un treno di impulsi ultracorti nel violetto è stato focalizzato nel film. Al campione è stato applicato un gradiente termico per generare un campo elettrico di bias piroelettrico. Il treno di impulsi, fruttando la non linearità fotorifrattiva, si è autoconfinato in un fascio solitonico che ha indotto una guida d'onda per altre frequenze. All'interno di questa guida è stato inviato anche un seme infrarosso in continua. La coincidenza spazio-temporale del pump violetto e dell'idler IR ha permesso di amplificare l'idler e contemporaneamente generare un signal complementare. Abbiamo misurato efficienze di conversione molto maggiori di quelle teoriche per una conversione fuori phase-matching: questo è dovuto al phase-locking tra gli impulsi di pump, signal e idler che, grazie alle elevate non linearità, viaggiano alla stessa velocità di fase. Il processo qui osservato ha una grandissima importanza per la generazione di stati ottici quantistici di tipo entanglement.

### ● **Artificial fractal platforms for imaging and sensing.**

LO FARO M.J. <sup>(1)</sup>, LEONARDI A.A. <sup>(2)</sup>, GALLETTA M. <sup>(3)</sup>, FAZIO B. <sup>(3)</sup>, PRIOLO F. <sup>(1)</sup>, IRRERA A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica ed Astronomia, Università di Catania*

<sup>(2)</sup> *Dipartimento di Scienze Chimiche, Biologiche, Farmaceutiche e Ambientali, Università*

*degli Studi di Messina*

<sup>(3)</sup> CNR-IMM, Messina

Disordered optical media with strong light scattering are emerging as powerful imaging, sensing, and energy harvesting platforms. Silicon nanowires (Si NWs), compatible with microelectronics, are especially promising. We demonstrate a 2D fractal array of light-emitting Si NWs fabricated via metal-assisted chemical etching, a scalable, cost-effective method enabling tunable nanowire morphology. Their room-temperature photoluminescence and fractal geometry offer exciting prospects for silicon-compatible near-infrared photonic devices and biosensing of proteins and genomes. We investigate random networks of Si NWs and silver dendrites. We combine structural disorder with unique optical functionality through real-space microscopy and Fourier imaging, assessing out-of-plane coherent Raman beam- ing. Diffusion and localization lengths are extracted from imaging profiles. Additionally, silver dendrites form self-similar 3D fractals with broad optical resonances, enabling high-sensitivity SERS. We detect lysozyme under hydration with a 10 enhancement, demonstrating strong biosensing potential of engineered fractal disorder for advanced light manipulation, gases and biomolecules detection.

● **Ultra-sensitive angular displacement measurements with structured light.**

THOMAS R., SEPHTON B., DE LISIO C., D'AMBROSIO V.

*Dipartimento di Fisica, Università degli studi di Napoli Federico II*

Angle is a fundamental physical quantity in high-precision metrology and angle sensors play an important role in a wide range of scientific and industrial domains for applications such as alignment, machine-tool calibration and surface profile measurements. The non-contact nature of optical methods for measuring angles makes them particularly beneficial for applications involving delicate or deformable components. In this work, we propose a compact method for ultra-sensitive angular displacement measurements with structured light. We measured tilt displacements with a sensitivity of  $157.3 \mu\text{W/mrad}$  by mapping angular displacements into the polarization rotation of a laser beam. Our approach significantly reduces the complexity usually involved in high precision angular measurements while simultaneously achieving high sensitivity. This technique is characterized by its stability, compactness, and ease of implementation, relying on cost-effective optical elements. Our results may have a strong impact on research and industry with significant potential in advanced metrological systems.

● **Wavelength-tunable lasing in quantum dot superparticles.**

REALE M., CASTRONOVO P., CANNAS M., MARINO E., SCIORTINO A., MESSINA F.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

Semiconductor quantum dots (QDs) stand out for their remarkable optical properties, including size-tunable absorption/emission, near-unity quantum yields, and synthetic versatility. Recently, QDs have been employed as building blocks for mesoscale assemblies called superparticles (SPs), unlocking novel optoelectronic functionalities. Here, we assemble CdSe/CdS core/shell QDs via a source-sink emulsion process to obtain red-fluorescent SPs ( $11 \mu\text{m}$ ) acting as spherical microcavities that support laser emission through sharp whispering-gallery mode resonances. We investigate individual-SP lasing using steady-state and time-resolved spectroscopy under tunable laser excitation. Notably, varying the pump wavelength induces reversible shifts in lasing modes, attributed to selective excitation of QD cores or shells. Simulations link this tunability to the wavelength-dependent light penetration depth, which modulates coupling with specific cavity modes. Despite their isotropic emission, directional lasing is achieved by coupling a single SP to an optical fiber. These results position QD-based SPs as compact, versatile and tunable microlasers for next-generation portable photonic devices.

● **From few to many emitters cavity QED: Energy levels and emission spectra from weak to deep-strong coupling**

ZAPPALÀ A. <sup>(1)</sup>, MERCURIO A. <sup>(2)(3)</sup>, LAMBERTO D. <sup>(1)</sup>, NAPOLI S. <sup>(1)</sup>, DI STEFANO O. <sup>(1)</sup>, SAVASTA S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina*

<sup>(2)</sup> *Laboratory of Theoretical Physics of Nanosystems, Institute of Physics, Ecole Polytechnique Fédérale de Lausanne, Switzerland*

<sup>(3)</sup> *Center for Quantum Science and Engineering, EPFL, Lausanne, Switzerland*

We provide a systematic study of the emission properties under incoherent excitation of systems composed by  $N$  two-level non-interacting quantum emitters coupled to a single cavity mode. We adopt a general theoretical framework for open cavity QED systems which is valid for any light-matter interaction regime and ensures gauge invariance for truncated Hilbert spaces. We have investigated the emission spectra under incoherent excitation of the two-level atoms, considering coupling strengths ranging from the weak coupling to the ultrastrong and deep-strong coupling regimes. We also studied the impact on the spectra of considering a collective reservoir, individual reservoirs, or their coexistence for the ensemble of emitters. These results also clarify how the system evolves towards a system of two single-mode interacting bosonic fields with the increasing of the number  $N$  of emitters.

● **Circuit quantum electrodynamics with two-dimensional materials-based devices.**

VARRICA V., PALADINO E., FALCI G.A., PELLEGRINO F.M.D.

*Dipartimento di Fisica e Astronomia, Università di Catania e INFN, Sezione di Catania*

Hybrid superconductor-semiconductor systems have emerged as promising platforms for quantum information processing since they have opened the possibility of realising noise-protected qubits. In particular, devices composed of graphene combined with superconductors, such as the so-called graphene Josephson junction, embedded in nanocircuits, have demonstrated significant potential applications in quantum technologies due to their tunability and the peculiar low-energy characteristics of 2D materials. In this work, we study the inductive interaction between a superconducting loop with an embedded short ballistic graphene Josephson junction and a quantum LC resonator. Specifically, within a mean-field approach, we analyse how the properties of the global system ground state are affected by the light-matter coupling strength and the graphene chemical potential. We show that the current-phase relation of the equilibrium supercurrent exhibits signatures relatable to a spontaneous time reversal symmetry breaking. Furthermore, we derive the hybridized light-matter excitations spectrum by calculating the retarded linear response function of the quantum LC resonator flux.

● **Renormalization and low-energy effective models in cavity and circuit QED.**

LAMBERTO D. <sup>(1)</sup>, MERCURIO A. <sup>(2)(3)</sup>, DI STEFANO O. <sup>(1)</sup>, SAVONA V. <sup>(2)(3)</sup>, SAVASTA S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina*

<sup>(2)</sup> *Laboratory of Theoretical Physics of Nanosystems, Institute of Physics, Ecole Polytechnique Fédérale de Lausanne, Switzerland*

<sup>(3)</sup> *Center for Quantum Science and Engineering, EPFL, Lausanne, Switzerland*

The quantum Rabi model (QRM) is a cornerstone in the study of light-matter interactions within cavity and circuit quantum electrodynamics (QED). It effectively captures the dynamics of a two-level system coupled to a single-mode resonator, serving as a foundation

for understanding quantum optical phenomena in a great variety of systems. However, this model may produce inaccurate results for large coupling strengths, even in systems with high anharmonicity. Moreover, issues of gauge invariance further undermine its reliability. In this work, we introduce a renormalized QRM that incorporates the effective influence of higher atomic energy levels, providing a significantly more accurate representation of the system while still maintaining a two-level description. To demonstrate the versatility of this approach, we present two different examples: an atom in a double-well potential and a superconducting artificial atom (fluxonium qubit). This procedure opens new possibilities for precisely engineering and understanding cavity and circuit QED systems, which are highly sought-after, especially for quantum information processing.

● **Dissipation and non-thermal states in cryogenic cavities.**

CHIRIACÒ G.

*Università di Catania*

We study the properties of photons in a cryogenic cavity, made by cryo-cooled mirrors surrounded by a room temperature environment. We model such a system as a multimode cavity coupled to two thermal reservoirs at different temperatures. Using a Lindblad master equation approach, we derive the photon distribution and the statistical properties of the cavity modes, finding an overall non-thermal state described by a mode-dependent effective temperature. We also calculate the dissipation rates arising from the interaction of the cavity field with the external environment and the mirrors, relating such rates to measurable macroscopic quantities. These results provide a simple theory to calculate the dissipative properties and the effective temperature of a cavity coupled to different thermal reservoirs, offering potential pathways for engineering dissipations and photon statistics in cavity settings.

● **Nanoscale imaging and strain mapping of semiconductor devices via Raman and tip-enhanced Raman spectroscopy.**

PROIETTI A. <sup>(1)</sup>, BUCCINI L. <sup>(1)</sup>, PASSERI D. <sup>(1)(2)</sup>, ROSSI M. <sup>(1)(2)</sup>

<sup>(1)</sup> *Department of Basic and Applied Engineering Sciences, Sapienza Università di Roma*

<sup>(2)</sup> *Research Center for Nanotechnology Applied to Engineering, Sapienza Università di Roma*

Raman and tip-enhanced Raman spectroscopy (TERS) enable nanoscale characterization of advanced semiconductors, including two-dimensional (2D) structures, heterojunction interfaces, and defects. While conventional Raman is diffraction-limited to hundreds of nanometers, TERS achieves  $\sim 10$  nm spatial resolution with enhanced sensitivity. In 2D materials, TERS mapping reveals localized phonon and strain variations at edges and grain boundaries that are indiscernible by far-field Raman. At semiconductor heterojunctions, TERS resolves compositional gradients across interfaces spanning only tens of nanometers]. It can also detect defect-induced vibrational modes (e.g., from single-atom vacancies) that are otherwise masked in bulk Raman signals. Collectively, these capabilities provide unprecedented insight into local electronic and optical phenomena paving the way for nanoscale defect and interface analysis in future nanoelectronic devices like Gate All Around (GAA) structures.

● **Criticalities and counter-intuitive dynamics in a two-qubit quantum Rabi model.**

GRIMAUDO R.

*Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

The quantum Rabi model with two interacting qubits is studied. Using an exact approach, the model's integrability is demonstrated, and exact solutions are found in specific cases.

The analysis also reveals level crossings and a quantum phase transition, the latter requiring a newly defined thermodynamic limit tailored to the two-qubit system. Finally, the study highlights unexpected and intriguing effects arising from the collective dynamics driven by the qubit-qubit interaction: the two qubits can exhibit a weak-coupling dynamics also when they strongly interact with the field mode.

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Aula 12, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE II

**Fisica della materia**

Presiede: SCIORTINO A. (Università di Palermo)

Relazioni su invito

▲ **Mott materials: a journey from non-thermal switching to ultrafast coherent control.**

GIANNETTI C.

*Università Cattolica del Sacro Cuore*

Achieving the full understanding and control of the insulator-to-metal transition in Mott materials is key for the next generation of electronics devices, with applications ranging from ultrafast transistors, volatile and non-volatile memories and artificial neurons for neuromorphic computing. We will review the state-of-the-art knowledge of the Mott transition, with specific focus on the paradigmatic Mott insulator V<sub>2</sub>O<sub>3</sub>. We will emphasize the current attempts in controlling the Mott switching dynamics via the application of external voltage and electromagnetic pulses and we will discuss how the recent advances in time- and space-resolved techniques are boosting the comprehension of the firing process and the role of topological defects of the order parameter. The nature of the voltage/light-induced Mott switching is inherently different from what is attainable by the slower variation of thermodynamic parameters, thus offering promising routes to achieving the reversible and ultrafast coherent control of conductivity in Mott nanodevices.

▲ **Photoconductivity and stability of 2D perovskites: Exploring lead and tin-based materials for future optoelectronic and neuromorphic applications.**

DURANTE O. <sup>(1)</sup>, DEMONTIS V. <sup>(2)</sup>, DE STEFANO S. <sup>(1)</sup>, MARONGIU D. <sup>(2)</sup>, MAZZOTTI A. <sup>(1)</sup>, SABA M. <sup>(2)</sup>, MURA A. <sup>(2)</sup>, BONGIOVANNI G. <sup>(2)</sup>, CRACIUN M. <sup>(3)</sup>, RUSSO S. <sup>(3)</sup>, DI BARTOLOMEO A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Salerno, Fisciano*

<sup>(2)</sup> *Dipartimento di Fisica, Università di Cagliari, Monserrato*

<sup>(3)</sup> *Centre for Graphene Science, College of Engineering, Mathematics and Physical Sciences, University of Exeter, UK*

Two-dimensional (2D) perovskite semiconductors are emerging materials for next-generation optoelectronic devices due to their tunable properties and environmental adaptability. This study examines two materials: (PEA)<sub>2</sub>PbI<sub>4</sub> and (PEA)<sub>2</sub>SnI<sub>4</sub>, both offering promising features for diverse applications. For (PEA)<sub>2</sub>PbI<sub>4</sub>, synthesized using a space-confined growth technique, the device exhibits excellent photoresponse under broadband white light, with ultra-low dark current (10<sup>-14</sup> A), and high specific detectivity (10<sup>9</sup> Jones). The temperature and wavelength dependence of the photocurrent suggests exciton dissociation as a key mechanism, alongside strong stability under air and light exposure. In contrast, (PEA)<sub>2</sub>SnI<sub>4</sub> devices show strong visible light absorption and favorable charge transport, with a sublinear power dependence, indicating trap-assisted photoconductivity. Temperature-dependent measurements reveal a transition from trap-limited conduction to phonon- and ion-migration-limited conduction. These findings highlight the potential of 2D perovskites for advanced optoelectronic and neuromorphic systems.



## Comunicazioni

● **Investigating the high-pressure vibrational and optoelectronic response of 2D diammonium-based hybrid perovskites by optical spectroscopy.**

ARMIERI C. <sup>(1)</sup>, ROMANO C. <sup>(2)</sup>, D'ALÒ B. <sup>(1)</sup>, STELLINO E. <sup>(2)</sup>, POSTORINO P. <sup>(1)</sup>

<sup>(1)</sup> *Department of Basic and Applied Sciences for Engineering, Sapienza Università di Roma*

<sup>(2)</sup> *Dipartimento di Fisica, Sapienza Università di Roma*

We conducted a high-pressure study on a 2D hybrid organic-inorganic perovskites with stoichiometry  $(1,4 - \text{XDA})\text{PbBr}_4$ . Raman spectra reveal three transitions associated with octahedral rearrangement, while infrared spectra of the molecular modes show a single transition, suggesting decoupling in the responses of organic and inorganic layers. Photoluminescence measurements, at ambient pressure, show a peak from free exciton recombination (FE), and a broad band from self-trapped exciton (STE) recombination. On increasing pressure, the FE initially intensifies but then diminishes, vanishing above 1.5 GPa, with its energy redshifting by 5 nm. This behavior reflects competition between enhanced in-plane carrier confinement due to octahedral distortion and reduced quantum confinement due to increasing overlap between the wavefunctions of adjacent inorganic planes. Meanwhile, the STE redshifts from 0 to 3 GPa, stabilizing at higher pressure, with intensity gradually fading. Our findings confirm pressure as a powerful tool to tune lattice and optoelectronic properties in 2D hybrid perovskites, with great potential for material design.

● **Effect of Silicon and Oxygen pre-implantation on thermal oxidation of 4H-SiC.**

SANGREGORIO E. <sup>(1)</sup>, MAZZAMUTO F. <sup>(2)</sup>, SOHL C. <sup>(2)</sup>, KIM L. <sup>(2)</sup>, BONGIORNO C. <sup>(1)</sup>, LA VIA F. <sup>(1)</sup>

<sup>(1)</sup> *CNR - Institute for Microelectronics and Microsystems, Catania*

<sup>(2)</sup> *Axcelis Technologies Inc., Beverly, MA, USA*

Thermal oxidation of 4H-SiC is a crucial step in the fabrication of devices for high-power and high-temperature applications, but it is often hindered by slow oxide growth and defect formation at the  $\text{SiO}_2/\text{SiC}$  interface, which degrade device performance. This study explores the impact of high-dose silicon and oxygen ion implantation on the oxidation behavior of 4H-SiC. Implanted samples were thermally oxidized at 1100 °C for one hour in dry oxygen ambient and compared to a non-implanted reference. Both implanted samples exhibited enhanced oxidation rates and thicker oxide layers, with distinct growth kinetics depending on the implanted species. The silicon-implanted sample showed increased surface roughness and residual crystal damage, indicating incomplete oxidation of the damaged region. Conversely, the oxygen-implanted sample displayed a smoother surface and no visible crystal defects, suggesting more complete oxidation. These findings demonstrate the significant role of implantation species in modifying oxidation dynamics and surface morphology, offering useful insights for optimizing thermal oxidation processes in SiC-based power device technologies.

● **A time-resolved investigation of the optical behaviour of MOF UiO-66.**

TORTORICI C., FICARRA G., CANNAS M., SCIORTINO A., BUSCARINO G.

*Dipartimento di Fisica e Chimica, Università di Palermo*

Metal-organic frameworks (MOFs) are an emerging class of porous crystalline materials with highly customizable structures. Luminescent MOFs are key nanomaterials in photonics due to their tunable optical properties and photostability. The Zr-based UiO-66 is known for its structural robustness, though its optical behaviour remains underexplored. Our research focuses on understanding the mechanisms behind its luminescence, particularly under thermal and environmental variations. The optical properties of UiO-66 in powdered form were studied using steady-state and nanosecond time-resolved photoluminescence (PL) spectroscopy.

PL spectra revealed a double-peak emission with lifetimes of 1.5 ns and 5 ns. In contrast, UiO-66 in aqueous solution exhibited a single peak (lifetime of 5 ns), demonstrating sensitivity to the environment. Temperature-dependent studies showed reduced emission intensity and increased lifetimes with rising temperature. Based on these findings, we developed a model illustrating the photophysical processes in UiO-66, involving excitation transfer from the light absorbing linker to the Zr metal node.

● **Study of the phase-change behavior of antimony.**

MAZZARELLO R.

*Dipartimento di Fisica, Sapienza Università di Roma*

Phase-change materials (PCMs) are employed in non-volatile memories and optoelectronic devices and are very promising materials for neuromorphic computing applications. Typical PCMs consist of Ge-Sb-Te alloys. Recently, we showed that elemental antimony can function as a PCM when properly nanoconfined. Its compositional simplicity offers several advantages over conventional PCMs for ultrascaled devices. Here I present our recent computational work on antimony, which has elucidated its switching behavior - including the nucleation rate and the kinetics of the liquid - and the reflectivity contrast between the amorphous and crystalline state.

● **Decoding step-edge effects: Ion adsorption and molecular ordering on Cu(111) in acidic environments.**

BUSSETTI G. <sup>(1)</sup>, YIVLIALIN R. <sup>(1)</sup>, FILONI C. <sup>(1)</sup>, BROEKMANN P. <sup>(2)</sup>, WILMS M. <sup>(3)</sup>, DUÒ L. <sup>(1)</sup>, CICCACCI F. <sup>(1)</sup>, WANDELT K. <sup>(4)(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Politecnico di Milano*

<sup>(2)</sup> *Department of Chemistry, Biochemistry and Pharmaceutical Sciences, University Bern, Switzerland*

<sup>(3)</sup> *Leibniz-Institut für Polymerforschung, Dresden, Germany*

<sup>(4)</sup> *Institute of Physical and Theoretical Chemistry, Bonn University, Germany*

<sup>(5)</sup> *Institute of Experimental Physics, University of Wrocław, Poland*

Copper is a key material for many technologies, especially those involving operations in liquid environments. Although ion adsorption on Cu surfaces has been extensively studied, the role of surface defects in guiding molecular self-assembly remains less explored. In this work, we investigate how step-edge confinement on vicinal Cu(111) surfaces influences electrochemically induced molecular ordering. Upon immersion in dilute H<sub>2</sub>SO<sub>4</sub> and application of an appropriate potential, porphyrin molecules typically form ordered superstructures on Cu(111). However, the reduced terrace width on the vicinal surfaces introduces spatial constraints that could hinder this ordering. Surprisingly, our results show that molecular self-assembly still occurs and is accompanied by a potential-driven restructuring of the copper terraces. This dynamic rearrangement restores the conditions for molecular ordering, while the initial step confinement crucially affects the orientation of the superstructure and copper atom diffusion. These findings offer new insights into the interplay between substrate restructuring and molecular adsorption under electrochemical control.

● **ARPES/Spin-ARPES investigations of the topological superconductor candidate PbTaS<sub>2</sub> and spin-valley locking in ML – WSe<sub>2</sub>.**

PETACCIA L. <sup>(1)</sup>, DI SANTO G. <sup>(1)</sup>, ZHAO W. <sup>(1)(2)</sup>, GAO J. <sup>(3)</sup>, LIANG X. <sup>(3)</sup>, SONG C. <sup>(4)</sup>, LU W. <sup>(3)</sup>, LUO X. <sup>(3)</sup>, SUN Y. <sup>(3)</sup>, FUJI J. <sup>(5)</sup>, VOBORNIK I. <sup>(5)</sup>, HUANG Y. <sup>(6)</sup>, WU S. <sup>(6)</sup>, OKUDA T. <sup>(7)</sup>, MIYAMOTO K. <sup>(7)</sup>, LIU G. <sup>(6)</sup>

<sup>(1)</sup> *Elettra Sincrotrone Trieste*

<sup>(2)</sup> *ISM-CNR Trieste*

<sup>(3)</sup> *Institute of Solid State Physics, Chinese Academy of Sciences Hefei, PR China*

<sup>(4)</sup> *Beijing Orient Institute of Measurement and Test, PR China*

<sup>(5)</sup> *IOM-CNR Trieste*

<sup>(6)</sup> *Institute of Physics, Chinese Academy of Sciences Beijing, PR China*

<sup>(7)</sup> *Hiroshima Synchrotron Radiation Center, Japan*

Angle resolved photoemission spectroscopy (ARPES)/Spin-ARPES is a powerful tool for investigating the spin degenerate/resolved electronic structure of materials with exotic properties and phenomenological effects with interesting applications in quantum computing, spintronics and valleytronics. Two case studies are presented: the topological superconductor candidate PbTaS<sub>2</sub>, and the monolayer (ML) of the transition metal dichalcogenide WSe<sub>2</sub>. The existence of topological nodal line states and Drum-head like surface states in the centrosymmetric type-II superconductor PbTaS<sub>2</sub> has been verified by ARPES and DFT calculations opening the route toward a comprehensive study of Majorana modes which can be used to realize topological quantum computing because of their topological protection. ARPES and Spin-ARPES have been used to study mechanically exfoliated ML – WSe<sub>2</sub> samples, targeting their spin character and showing high valley-dependent spin polarization at the K/K' points, pointing to interesting spin-related phenomena and potential applications of this kind of material in the fields of spintronics and valleytronics.

### ● Monolayer di fosforo di boro su superfici metalliche: screening di substrati promettenti mediante principi primi.

ZUCCOLIN W., PERESSI M.

*Dipartimento di Fisica, Università degli Studi di Trieste*

Il monolayer di BP (hBP) è un semiconduttore predetto teoricamente, che presenta un reticolo esagonale e proprietà interessanti per applicazioni fotovoltaiche ed è il più stabile tra gli allotropi proposti. In questo studio vengono indagate, attraverso simulazioni *ab-initio*, le proprietà di stato fondamentale dell'hBP su superfici FCC (111) di vari metalli di transizione, puntando ad individuare un substrato appropriato per la sua sintesi. Essendo i reticoli cristallini non commensurabili, l'hBP genera un effetto di Moiré, descritto utilizzando una cella di simulazione minimale con una tolleranza del 3% circa per deformazioni tensive o compressive dell'overlayer. L'energia di adesione, la distanza di separazione, il buckling e il trasferimento di carica tra substrato e overlayer indicano che il substrato meno interagente sia l'Ag. Dimostriamo che il disallineamento dell'hBP rispetto alla superficie di Ag non influisce sull'interazione. Completiamo l'indagine valutando la dinamica della crescita di ribbon di hBP sulla superficie di Ag(111), calcolando le barriere di attaccamento degli atomi costituenti in diversi siti di terminazione.

### ● Broadband infrared study of the semiconductor-to-metal transition in SnSe<sub>2</sub>.

STELLINO E. <sup>(1)</sup>, CAPITANI F. <sup>(2)</sup>, D'ALÒ B. <sup>(3)</sup>, POSTORINO P. <sup>(3)</sup>

<sup>(1)</sup> *Department of Basic and Applied Sciences for Engineering, Sapienza Università di Roma*

<sup>(2)</sup> *Synchrotron SOLEIL, France*

<sup>(3)</sup> *Dipartimento di Fisica, Sapienza Università di Roma*

SnSe<sub>2</sub> is an earth-abundant n-type semiconductor with an indirect band gap in the near-infrared range. In our work, we study the pressure-induced metallic transition in SnSe<sub>2</sub> by broadband, synchrotron-based infrared spectroscopy. Reflectivity measurements show the insurgence of a Drude band above 15 GPa, whose spectral weight increases with pressure. The estimates of the DC optical conductivity extracted from the Drude fit indicate that the conducting character of SnSe<sub>2</sub> remains poor even well above the metallization threshold (up to 26 GPa). Transmission measurements enable us to track the pressure evolution of the band gap, which is found to reduce with pressure until closing in correspondence with the

onset of the Drude contribution. Above 18 GPa, a distinct feature emerges around 2000 cm in the transmittance spectrum, suggesting the opening of a new channel for electronic transitions.

● **Deposition and characterization of nanolayered coatings for gravitational wave detectors.**

GRANATA V. <sup>(1)(2)</sup>, AVALLONE G. <sup>(2)(3)</sup>, CANEPA M. <sup>(4)</sup>, CAPACCIOLI S. <sup>(5)</sup>, CARAPPELLA G. <sup>(2)(3)</sup>, CHIADINI F. <sup>(2)(6)</sup>, DE SIMONE R. <sup>(2)(6)</sup>, FITTIPALDI R. <sup>(2)(7)</sup>, FIUMARA V. <sup>(8)</sup>, MAGNOZZI M. <sup>(4)</sup>, MERENI L. <sup>(9)</sup>, PIERRO V. <sup>(2)(10)</sup>, PINTO I.M. <sup>(2)</sup>, SILENZI L. <sup>(11)</sup>, TRAPANANTI A. <sup>(11)</sup>, TRAVASSO F. <sup>(11)</sup>, VECCHIONE A. <sup>(7)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria Industriale, Elettronica e Meccanica, Università di Roma 3*

<sup>(2)</sup> *INFN, Sezione di Napoli Gruppo Collegato di Salerno*

<sup>(3)</sup> *Dipartimento di Fisica, Università di Salerno*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Genova*

<sup>(5)</sup> *Dipartimento di Fisica, Università di Pisa*

<sup>(6)</sup> *Dipartimento di Ingegneria Industriale Università di Salerno*

<sup>(7)</sup> *Istituto SPIN-CNR*

<sup>(8)</sup> *Dipartimento di Ingegneria, Università della Basilicata*

<sup>(9)</sup> *Laboratoire des Matériaux Avancés, France*

<sup>(10)</sup> *Dipartimento di Ingegneria, Università del Sannio, Benevento*

<sup>(11)</sup> *School of Science and Technology - Physics Division, Università di Camerino*

Reducing thermal noise in the optical cavity mirrors is a key step to extend the observational range of interferometric detectors of gravitational waves. Thermal noise in the highly reflective test-mass coatings is the dominant term. Different R&D lines are under way aimed at exploring different coating designs and different coating materials. Our Group proposed and developed the idea of using nanolayered films (in particular based on SiO<sub>2</sub> and TiO<sub>2</sub>) in place of the homogeneous (amorphous) metal oxide layers currently in use. Compared to these latter, the nanofilms withstand higher annealing temperatures without crystallizing, and feature lower mechanical losses at the cryogenic operating temperatures of 3rd generation detectors. In this contribution we summarize the results of extensive work made in Collaboration with other Virgo Coating R&D Groups, aimed at improving the deposition process and characterizing the relevant structural, morphological, optical and viscoelastic properties of the nanofilms deposited using ion-assisted e-beam facility in our Lab, using state-of-the-art facilities (X-Ray Reflectivity, Raman Spectroscopy, Spectroscopic Ellipsometry, and GeNS).

● **Produzione e indagine elettrochimica di membrane polimeriche dopate con MoS<sub>2</sub>**

VASI S. <sup>(1)(2)</sup>, WANDERLINGH U. <sup>(1)(2)</sup>, GIOFRÈ S.V. <sup>(3)</sup>, CECCIO G. <sup>(4)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli Studi di Messina*

<sup>(2)</sup> *OPENFIS S.R.L., Messina*

<sup>(3)</sup> *Dipartimento di Scienze Chimiche, Biologiche, Farmaceutiche ed Ambientali, Università degli Studi di Messina*

<sup>(4)</sup> *Nuclear Physics Institute of CAS, Department of Neutron and Ion Methods, Řež, Czech Republic*

Le membrane nucleari, prodotte mediante la tecnica di ion track etching, sono ampiamente utilizzate per la produzione di elementi attivi e passivi in elettrochimica e nei sistemi di filtrazione. Geometrie particolari, ottenute con diverse procedure di etching, producono interessanti comportamenti elettrochimici, ad esempio la rettificazione e la selettività ionica

in presenza di particolari elettroliti. La combinazione di questi sistemi con dicalcogenuri di metalli di transizione bidimensionali può ampliare il campo di applicazione. In questo lavoro, viene prima presentata una nuova strategia per la produzione di  $\text{MoS}_2$  a bassa dimensionalità mediante tecnica di esfoliazione in fase liquida assistita da microonde e successivamente i risultati ottenuti nell'utilizzo di tali dicalcogenuri come parte di eterogiunzioni con membrane in elettroliti liquidi mediante studi di voltammetria ciclica, spettroscopia di impedenza elettrica e analisi del potenziale transmembrana.

● **Driving ions in reverse: spectroscopic insights into bias-induced migration in perovskite solar cells.**

BARBAROSSA S. <sup>(1)</sup>, FERRUGGIA BONURA S. <sup>(1)</sup>, TORMENA N. <sup>(2)</sup>, TRIVELLIN N. <sup>(2)</sup>, BUFFOLO M. <sup>(2)</sup>, MENEGHINI M. <sup>(2)</sup>, MATTEOCCI F. <sup>(3)(4)</sup>, DI CARLO A. <sup>(3)(5)</sup>, CANNAS M. <sup>(1)</sup>, AGNELLO S. <sup>(1)</sup>

<sup>(1)</sup> *Università di Palermo*

<sup>(2)</sup> *Università di Padova*

<sup>(3)</sup> *Università di Roma Tor Vergata*

<sup>(4)</sup> *Center for Hybrid and Organic Solar Energy*

<sup>(5)</sup> *CNR-ISM*

Within the renewable energy technologies, solar cells have been subjected steadily to a growing market demand. Such demand drives efforts to improve the energy conversion efficiencies at accessible costs. Lead Halide Perovskites are among the most promising materials to meet this goal due to their strong light absorption, tunable bandgaps and low cost. However, key challenges remain in material degradation and long-term device performance. Our research aims to investigate ion-vacancy migration processes on  $\text{FAPbBr}_3$ , generated by a reverse bias in solar cells. The latter will be carried out by Raman spectroscopy, so to evaluate structural differences due to the ionic movements. In addition, steady-state and time-resolved photoluminescence will be employed to explore the electronic dynamics during these structural transitions. This contribution has been developed in the framework of the project Network 4 Energy Sustainable Transition - NEST, code PE0000021, CUP B73C22001280006, Spoke 1, funded under the National Recovery and Resilience Plan (NRRP), Mission 4, by the European Union - NextGenerationEU.

● **Thermal modulation of optical and electronic features of 2D Molybdenum Disulfide on  $\text{SiO}_2/\text{Si}$ .**

SANGIORGI E. <sup>(1)</sup>, MADONIA A. <sup>(1)</sup>, MIGLIORE F. <sup>(1)</sup>, PANASCI S. E. <sup>(2)</sup>, SCHILIRÒ E. <sup>(2)</sup>, GIANNAZZO F. <sup>(2)</sup>, ESPOSITO F. <sup>(3)(4)</sup>, SERAVALLI L. <sup>(3)(1)</sup>, BUSCARINO G. <sup>(1)(5)</sup>, CANNAS M. <sup>(1)(1)</sup>, AGNELLO S. <sup>(1)(2)(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

<sup>(2)</sup> *CNR, Istituto per la Microelettronica e Microsistemi CNR-IMM, Catania*

<sup>(3)</sup> *CNR, Institute of Materials for Electronics and Magnetism IMEM-CNR, Parma*

<sup>(4)</sup> *Department of Chemical Science, Life, and Environmental Sustainability, Università di Parma*

<sup>(5)</sup> *ATEN Center, Università di Palermo*

Two-dimensional materials like molybdenum disulfide ( $\text{MoS}_2$ ) are promising for future electronic and optoelectronic devices. Single-layer  $\text{MoS}_2$  (1L -  $\text{MoS}_2$ ), with its 1.8 eV bandgap and strong fluorescence, is a key candidate, but achieving uniform large-scale synthesis remains difficult. Properties such as strain and doping are strongly influenced by both the growth method and the substrate. This study compares 1L -  $\text{MoS}_2$  grown by chemical vapor deposition on  $\text{SiO}_2/\text{Si}$  with samples from gold-assisted exfoliation, applying thermal treatments in  $\text{O}_2$  and Ar to tune physical properties. Raman and photoluminescence analyses show that Ar mainly reduces strain, while  $\text{O}_2$  also decreases n-type doping and enhances

fluorescence up to sevenfold. No significant morphological damage occurs below 225°C. These results suggest a reproducible post-synthesis strategy to optimize MoS for device applications, regardless of the growth method.

● **Giant Berry-phase-driven X-ray beam translations in strain-engineered semiconductor crystals.**

FELICI M. <sup>(1)</sup>, PETTINARI G. <sup>(2)</sup>, FRATINI M. <sup>(3)</sup><sup>(4)</sup>, BARBA L. <sup>(5)</sup>, BIRINDELLI S. <sup>(1)</sup>, CAMPI G. <sup>(6)</sup>, RUBINI S. <sup>(7)</sup>, SCHÜLLI T. <sup>(8)</sup>, CAPIZZI M. <sup>(1)</sup>, POLIMENI A <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Sapienza Università di Roma*

<sup>(2)</sup> *CNR, Institute for Photonics and Nanotechnologies, Roma*

<sup>(3)</sup> *CNR-Nanotec, Roma*

<sup>(4)</sup> *Santa Lucia Foundation, Roma*

<sup>(5)</sup> *CNR, Institute of Crystallography, Basovizza*

<sup>(6)</sup> *CNR, Institute of Crystallography, Monterotondo*

<sup>(7)</sup> *CNR, Istituto Officina dei Materiali, Basovizza*

<sup>(8)</sup> *ESRF - The European Synchrotron, Grenoble, France*

The manipulation of light through its interactions with artificially structured media is a key tenet of photonics. Extending this concept to the X-ray realm—thus enabling control of X-ray light with the precision seen in the visible/IR range—has been hindered by the challenge of realizing photonic structures with the required sub-nm resolution. A promising approach to this challenge leverages the Berry-phase effect, where X-ray beams undergo large translations in a deformed crystal due to the presence of Berry curvatures in both real and reciprocal space. Here, the controlled crystal distortions required to rein in this effect are obtained by pairing the lattice expansion observed upon H irradiation of GaAsN with spatially selective hydrogenation. The observed  $\sim 100\text{ }\mu\text{m}$  beam translations are a macroscopic manifestation of the Berry curvatures associated with the sub-nm, H-induced distortions introduced in the lattice. The comparison with a dedicated theoretical model traces the individual translation branches observed in X-ray transmission back to specific deformation features, establishing a predictive framework for the control of X-ray propagation in the fabricated structures.

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Aula Capità, Edificio 7

ore 09:00 – 13:30

## SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: REALE F. (Università di Palermo)

Relazioni su invito

**▲ A thousand star-forming regions at 1000au resolution. The early formation of clusters with the ALMAGAL survey.**

MOLINARI S.F. FOR THE ALMAGAL CONSORTIUM

*INAF-IAPS, Roma*

Most stars form in clusters within dense “clumps”, parsec-size condensations of gas and dust of thousands solar masses and more. The understanding of how these clumps fragment into smaller “cores” where single stars form, however, is still elusive. What are the physical agents responsible for this fragmentation ? How do the protostellar seeds build up their mass? I will illustrate the early results from the ALMAGAL Large Project for more than 1000 dense Galactic clumps in terms of fragmentation statistics and cores mass distribution as a function of environment, physical properties of the hosting clump and evolution. Early analysis favours very dynamical fragmentation and accretion scenarios as opposed to monolithic collapse solutions. Fragmentation due to instability appears to be constantly at work in the dense clumps, with a distribution of core masses that changes with time until reaching Salpeter-like IMF distribution toward later stages of evolution.

**▲ The EWOCS view of supermassive stellar clusters.**

GUARCELLO M.G. FOR THE EWOCS TEAM

*INAF, Osservatorio Astronomico di Palermo*

Star formation in our Galaxy typically occurs in environments less massive than  $10^4$  solar masses. However, a few more extreme star forming environments on the Milky Way exist, where hundreds of thousands to millions of stars form in dense regions. Often called “supermassive stars clusters”, they are rare in our Galaxy today, while they are common in galaxies experiencing epochs of starburst. The international project EWOCS (Extendend Westerlund 1 and 2 Open Clusters Survey) is targetting the two closest superstar clusters in the Milky Way with a multi-wavelength survey which is based on an extensive set of data from radio to X-rays, with the main objective of studying the formation and early evolution of stars over the whole mass spectrum in a starburst environment. In this talk, I will discuss the objectives of the project, the published results and the future developments.

**▲ Astrochemical study of early embedded disks: the iSEEDS project.**

BIANCHI E.

*INAF, Osservatorio Astrofisico di Arcetri*

Understanding when and how planets begin to form is a central challenge in modern astrophysics. Despite significant advances, many aspects of the star and planet formation process remain elusive. In particular, the difficulty of measuring the mass and chemical composition of young protostellar disks has hindered meaningful comparisons with the observed diversity of exoplanet populations. Recent evidence suggests that planet formation begins earlier than previously thought, in disks younger than 0.5 million years, still embedded in their natal envelopes. In this context, I will present the iSEEDs project, which introduces a novel



interdisciplinary approach combining astrochemistry, data mining, and machine learning to unveil the physical and chemical structure of a large sample of young embedded disks, the birthplaces of planets. iSEEDs aims to quantify the mass available for planet formation, determine the chemical composition eventually inherited by forming planets, and trace the growth of dust into planetesimals in the disk midplane. Ultimately, iSEEDS will constrain the initial mass and chemical budget at the onset of planet formation.

▲ **Galactic archaeology: Decoding the fossil record of Milky Way formation and evolution.**

CASSISI S.

*INAF, Osservatorio Astronomico d'Abruzzo*

One of most important issue in Astrophysics is the achievement of a robust understanding of the processes that contributed to the building up of the Milky Way. This is obviously important not only "on a local scale" in order to recover the history of formation and evolution of our Galaxy, but also, in general, for understanding the formation process of spiral galaxies. In the last decade, the advent of high precision photometric, spectroscopic and seismic surveys as well as the possibility to estimate, thanks to the ESA Gaia mission, accurate distance for a huge number of field stars is actually opening a new era for this kind of investigations. We will review the common scenarios for the formation of the Milky Way, and present some recent results about the early phases of the Milky Way formation and evolution.

▲ **Star clusters as cosmic ray factories.**

MORLINO G.

*INAF, Osservatorio Astrofisico di Arcetri*

In the past decade or so, several star clusters in the Milky Way have been associated to high energy sources emitting in gamma-rays as revealed by Fermi-LAT (in the GeV band) and Imaging Atmospheric Cherenkov Telescopes (in the TeV band). This evidence suggest that star clusters may be efficient cosmic rays accelerators. In particular, the LHAASO experiment has detected photons at energies beyond  $10^{15}$  eV from the Cygnus cocoon, an extended gamma-ray source surrounding the powerful Cygnus OB2 cluster. This suggest that stellar clusters could be even classified as PeVatrons. However, at the moment it is still unclear which physical process could be responsible for the particle acceleration. Three scenarios have been proposed in the literature, one invoking the acceleration at the stellar wind termination shock, one at the shock of supernova remnant exploded inside the cluster core and, finally, acceleration due to strong magnetic turbulence generated inside the wind-blown bubble surrounding the star cluster. I will illustrate pros and cons of those scenarios, highlighting the role that star clusters may have in the gamma and neutrino astronomy.

▲ **On the origin of the very-high energy gamma-ray diffuse flux: the role of galactic cocoons.**

AMBROSONE A.

*Gran Sasso Science Institute e INFN, Laboratori Nazionali del Gran Sasso*

A diffuse gamma-ray flux has been measured in our galaxy, from GeV up to PeV energies, by respectively the Fermi-LAT and LHAASO collaborations. While these observations demonstrate the presence of cosmic-rays (CRs) sources across our galaxy, there is compelling evidence that the gamma-ray flux exceeds the predictions based on the local CR flux alone. In this talk, I scrutinize the role of galactic cocoons, namely large regions where CRs can accumulate grammage before being injected into the galactic disk. In fact, recent secondary-over-primary CR ratio measurements by DAMPE and CALET hint a flattening above TV



rigidities pointing towards source grammage accumulated by CRs. I show that assuming a source grammage of  $\sim 0.4 \text{ gr/cm}^2$ , compatible with the grammage accumulated by CRs in the downstream regions of Supernova Remnant shocks, and fitted against high-energy B/C measurements, the corresponding gamma-ray emission must substantially contribute to the diffuse gamma-ray flux providing a natural explanation of the gamma-ray hardening observed in the inner Galaxy and the LHAASO observations. I discuss also the role of galactic high-energy neutrinos flux to scrutinize this scenario.

### ▲ Probing neutrino physics with cosmological probes.

PUGLISI G.

*Università di Catania*

Relativistic neutrinos significantly contributed to the radiation-dominated era's energy density and primordial light element synthesis. Indeed the Hot Big Bang paradigm predicts  $10^{87}$  neutrinos per flavor in the observable universe, being the second most abundant particle after CMB photons. Furthermore, the relic neutrinos impacted the cosmic large scale structure formation as they constitute  $\sim 0.5\%$  of total matter density, assuming the lower limit on mass of 70 meV obtained from oscillation experiments. We focus on reviewing the neutrino cosmology, with a specific focus on how precisely the forthcoming data from cosmic microwave background observations or from the surveys of large-scale structure can provide an upper bound on the sum of neutrino masses of order  $\sim 100 \text{ meV}$ , opening up new perspectives on neutrino hierarchies and neutrino masses well into the sub-eV range.

Comunicazioni

### ● COSMIC: Photometric Catalogs of Observed Stars in the Magellanic Clouds.

FRANCO A. <sup>(1)(2)(3)</sup>, NUCITA A.A. <sup>(1)(2)(3)</sup>, DE PAOLIS F. <sup>(1)(2)(3)</sup>, STRAFELLA F. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> INFN, Sezione di Lecce

<sup>(2)</sup> INAF, Sezione di Lecce

<sup>(3)</sup> Dipartimento di Matematica e Fisica, Università del Salento, Lecce

We present two deep and comprehensive stellar photometric catalogs, COSMIC-L and COSMIC-S, based on observations obtained with the Dark Energy Camera (DECam) at the Blanco Telescope (Cerro Tololo Inter-American Observatory, Chile). Thanks to its wide field of view and high sensitivity, DECam is particularly well-suited for crowded stellar fields such as those in the Magellanic Clouds. Our dataset includes images acquired between February 2018 and January 2020, covering large regions of both the Magellanic Clouds. We performed point-spread function (PSF) photometry using the SExtractor and PSFEx tools, producing calibrated magnitudes in the SDSS gri filters. The resulting catalogs reach a mean photometric uncertainty of 0.04 mag, are complete down to magnitude 22, and extend to a limiting magnitude of 25. COSMIC-L contains over 57 million sources in the Large Magellanic Cloud, while COSMIC-S includes more than 10 million stars in the Small Magellanic Cloud. To validate the quality of the data, we analyzed color-magnitude and color-color diagrams, which confirm the depth and precision of the photometry across the surveyed fields.

### ● Light infrastructure facility for exochemistry: an innovative tool for experimental simulations of Planetary Atmospheres Systems (LIFE+).

MANGIONE A., CIARAVELLA A. <sup>(1)</sup>, JIMENEZ-ESCOBAR A. <sup>(1)</sup>, CECCHI-PESTELLINI C.

INAF, Osservatorio Astronomico di Palermo

The growing number of available data concerning the atmospheres of exoplanets makes this topic increasingly in-depth, and reinforces the need to experimentally simulate these systems, also considering the still persistent complexity of detections. The LIFE+ laboratory

at INAF-OAPa includes an analysis chamber designed to host atmospheres composed of different species, kept at controlled pressure and temperature conditions. A DC power source delivers High Voltage to a specifically designed system of electrodes, to simulate electric phenomena in the atmosphere. A variety of electric phenomena are also simulated by using a plasma generator, connected to a microwave generator, working both in continuous and pulsed mode. The chamber is equipped with an X-Rays and UV sources to simulate the host star. The composition of the atmospheres is monitored by a high resolution FT-IR spectrometer, with a gas cell module that extends the optical path up to 5m through multiple reflections, and by a Quadrupole Mass Spectrometer allowing the detection of ions, neutrals and radicals mass spectra, and energy distributions.

● **Unraveling cosmic chemistry: the role of organic compounds in astrobiology and prebiotic chemistry.**

JIMENEZ A. <sup>(1)</sup>, CIARAVELLA A. <sup>(1)</sup>, CECCHI-PESTELLINI C. <sup>(1)</sup>, MANGIONE A. <sup>(1)</sup>, PI-AZZESE F. <sup>(2)</sup>, PISCOPO V. <sup>(2)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

Organic compounds are crucial in understanding the chemical complexity of the interstellar medium. Many of these molecules can't be solely attributed to gas-phase reactions, so reactions on cosmic dust grains are significant. Molecules formed on these grains become integral to comets and small celestial bodies in our solar system. The delivery of these compounds to a primitive Earth may have influenced the emergence of life, making them astrobiologically significant. Understanding their formation and transformation provides insights into prebiotic chemistry, bridging the gap between cosmic phenomena and the origin of life on Earth. Laboratory studies at INAF (OAPa) use the LIFE system, an ultra-high vacuum setup with advanced spectroscopic techniques, to analyse products from photochemical and thermal reactions in interstellar and circumstellar ice analogues. This research focuses on the viability of Strecker synthesis under icy conditions, particularly examining the role of acetonitrile (CH<sub>3</sub>CN). This pathway leads to the formation of amino acids, which are fundamental to life. By elucidating these processes, we gain a deeper understanding of organic compound formation in space and the chemical pathways that may have contributed to the dawn of life on Earth. These findings are essential for advancing astrobiology and prebiotic chemistry.

● **CHEX-MATE cosmology with galaxy cluster sizes: Constraining H<sub>0</sub> with X-ray and relativistic SZ data.**

MAZZOTTA P., DE LUCA F., BOURDIN H.

*Università degli Studi di Roma Tor Vergata*

Independent constraints on the Hubble constant from local distance ladders and early Universe CMB data can be derived from cluster sizes by combining X-ray and millimetre observations of the intracluster medium. Using XMM-Newton and Planck data, we present the inference on H<sub>0</sub> by studying systematic mismatches,  $\eta_T$ , between X-ray and millimetre temperature (or pressure) estimates:  $T_{X-ray} = \eta_T P_{SZ}/n_{e,X-ray}$ . However, cosmology is only one of the factors influencing  $\eta_T$ . Several astrophysical and observational systematics contribute to this discrepancy, including assumptions regarding the cluster structure, such as spherical symmetry, clumpiness, as well as the chemical composition of the ICM, or the neglect of relativistic effects in the SZ signal. To systematically account for all these effects, we employ a Bayesian approach, comparing observational data with numerical simulations from The Three Hundred project. This framework is applied to the CHEX-MATE sample, consisting of 116 clusters of Planck-selected systems. Additionally, we evaluate the impact

of relativistic corrections to the SZ signal on thermodynamic profiles and their effect on the inferred value of  $H_0$

● **A time-resolved, systematic approach to gamma-ray burst physics.**

HOLZMANN AIRASCA A. <sup>(1)(2)</sup>, BISSALDI E. <sup>(1)(3)</sup>, DI VENERE L. <sup>(1)</sup>, LONGO F. <sup>(4)</sup>

<sup>(1)</sup> INFN, Sezione di Bari

<sup>(2)</sup> Università degli Studi di Trento

<sup>(3)</sup> Politecnico di Bari

<sup>(4)</sup> Università degli Studi di Trieste e INFN, Sezione di Trieste

The Fermi mission is a space-based observatory designed to study the gamma-ray sky. It consists of two main instruments: the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM), covering a broad energy range from  $\sim 10$  keV to  $> 300$  GeV. Among its core scientific goals is the detection and characterization of Gamma-ray Bursts (GRBs), although the mechanisms driving their prompt emission and the precise location of the emission sites remain open questions. A joint spectral analysis of GRBs simultaneously detected by both LAT and GBM enables the characterization of their prompt emission over several decades in energy, allowing for a detailed investigation of spectral evolution. In this work, we perform the first systematic, time-resolved spectral study of the complete sample of GRBs jointly observed by both Fermi instruments. We present preliminary results from the joint fits and quantitatively assess the impact of high-energy emission on the inferred spectral parameters by comparison with GBM-only analyses. Leveraging Fermi's broadband capabilities, this study provides new insights into GRB physics.

● **Gamma-ray flares from blazars: Fermi-LAT monitoring and multi-wavelength follow-up.**

CASABURO F. <sup>(1)(2)(3)</sup>, CIPRINI S. <sup>(3)(4)</sup>

<sup>(1)</sup> INAF, Osservatorio Astronomico di Roma

<sup>(2)</sup> Dipartimento di Fisica, Sapienza Università di Roma

<sup>(3)</sup> INFN, Sezione di Roma Tor Vergata

<sup>(4)</sup> Space Science Data Center, Agenzia Spaziale Italiana

As part of the Fermi-LAT collaboration, the Flare Advocate service activity is a science operation service addressed to all-sky monitoring. The main goals of this activity are the review of possibly interesting events detected during the regular monitoring of the gamma-ray sky, identifying temporal trends and possible new sources, variability patterns, flaring states and transient phenomena, mainly from AGNs, but including also other types of sources. ATels have been issued reporting both potential newly-detected objects and significant flaring events from both known and unknown sources. A selection of these cases will be presented, with a focus on gamma-ray flares and their association with multi-wavelength counterparts. Particular attention will be given to the case of SBS 1343+537, which exhibited enhanced gamma-ray activity and was followed up by a X-ray, optical and radio observing coordinated multi-frequency campaign in 2024.

● **Analisi sistematica temporalmente risolta di lampi di raggi gamma rivelati da Fermi-GBM.**

DEPALO D. <sup>(1)(2)</sup>, BISSALDI E. <sup>(1)(2)</sup>, HOLZMANN AIRASCA A. <sup>(1)(2)</sup>, BALA S. <sup>(3)</sup>, GOLDSTEIN A. <sup>(3)</sup>, DE BARRA C. <sup>(4)</sup>

<sup>(1)</sup> Dipartimento Interateneo di Fisica dell'Università e del Politecnico di Bari

<sup>(2)</sup> INFN, Sezione di Bari

<sup>(3)</sup> Science and Technology Institute, Universities Space Research Association, Huntsville, AL, USA

<sup>(4)</sup> *School of Physics, Centre for Space Research, Science Center North, University College Dublin, Ireland*

Il telescopio per raggi gamma Fermi, operativo dal 2008, è in grado di rivelare raggi gamma con energie tra 8 keV e 300 GeV, permettendo lo studio di vari tipi di sorgenti galattiche ed extragalattiche. In particolare, il Gamma-Ray Burst Monitor è il rivelatore di gamma-ray bursts più prolifico di sempre, con circa 4000 eventi osservati finora. Il lavoro che presentiamo è un'analisi sistematica temporalmente risolta di un sottogruppo di GRB brillanti rivelati da GBM nei primi anni della missione. Le curve di luce sono suddivise in intervalli temporali usando il metodo dei Blocchi Bayesiani, mentre l'analisi spettrale viene fatta utilizzando i nuovi Gamma-Ray Data Tools, un toolkit in Python. A ogni intervallo sono applicati diversi modelli, e attraverso opportuni criteri statistici viene selezionato il migliore tra essi. In questo contributo illustreremo le varie fasi di analisi e alcuni risultati preliminari, che includono le distribuzioni dei parametri dei migliori modelli. L'obiettivo finale è implementare questa pipeline automatizzata per un'analisi sistematica di tutti i GRB rivelati da GBM nel corso della missione.

### ● Probing the limits of spectroscopy in the low-surface brightness Universe with LEWIS.

BUTTITTA C., IODICE E.

*INAF, Osservatorio Astronomico di Capodimonte, Napoli*

In the standard cosmological framework of  $\Lambda$ CDM, low-surface brightness (LSB) galaxies are the Universe's building blocks. Ultra-diffuse galaxies (UDGs) play a crucial role. This class of extreme galaxies have a central surface brightness fainter than  $\mu_0 \geq 24$  arcsec<sup>2</sup> and an effective radius larger than  $R_e \geq 1.5$  kpc, thus can be considered as the extreme LSB tail of the size-luminosity distribution of the dwarf galaxies population. Due to their extremely faint and diffuse nature, collecting deep spectroscopic data is challenging and time-consuming, and only a few dozen UDGs have been studied with spectroscopy. In this context, the LEWIS project (Looking into the faintEst With MUSE, P.I. Enrica Iodice) promises to revolutionise the scientific panorama of the UDGs, doubling the number of spectroscopically studied UDGs to date. It aims to study the structural properties of a nearly complete sample of UDGs in the Hydra I cluster of galaxies. In this contribution, I would like to present the recent groundbreaking results we achieved with LEWIS, highlighting the challenges we faced in extracting structural properties of these extremely faint objects.

### ● Can AI understand our Universe?

WANG Y. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, SAHAKYAN N. <sup>(1)</sup><sup>(2)</sup><sup>(4)</sup>

<sup>(1)</sup> *ICRA, Dipartimento di Fisica, Sapienza Università di Roma*

<sup>(2)</sup> *ICRANet, Pescara*

<sup>(3)</sup> *INAF, Osservatorio Astronomico d'Abruzzo, Teramo*

<sup>(4)</sup> *ICRANet-Armenia, Yerevan, Armenia*

We examine whether large language models (LLMs), as the current stage of artificial intelligence (AI), can process scientific data and yield valid physical interpretations. In this study, we fine-tune a generative pre-trained GPT model using astronomical data. We show that a single model can interpret multiple types of astronomical observations, including classification of astrophysical sources, differentiation between gamma-ray burst (GRB) types, redshift estimation of quasars, and inference of black hole (BH) parameters. We consider this a successful test, demonstrating the AI's capability in scientific research. This approach shifts from isolated domain expertise to an integrated framework, enabling more coherent and connected insights into the physical universe. It marks the beginning of a new phase in scientific investigation.

Aula Seminari B, Section B, Edificio 19

ore 09:00 – 13:30

## SEZIONE IV

## Geofisica e fisica dell'atmosfera

Presiede: MASSARO S. (INGV)

Relazioni su invito

**▲ Passive acoustic investigations at the shallow hydrothermal field of Panarea Island (southern Italy): Inverse modelling for estimating fluid emissions.**SEMPREBELLO A., LAZZARO G., CARUSO C., SCIRÈ SCAPPUZZO S., MORICI S., GATTUSO A., CRISCILLO M., TORRE A., LONGO M.*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo*

Submarine hydrothermal systems are characterized by extreme environmental conditions (*e.g.*, low pH, high  $T$  and  $P$ ); therefore, continuous monitoring activities based on direct measurements and conventional methods are challenging. In this framework, passive hydroacoustics represents an effective alternative for monitoring, as the typical source mechanisms radiate sound pressure following different acoustic modes directly related to fluid release dynamics. In this study, we investigate different phenomenologies of fluid emission, related to thermal water and free gases, at the shallow hydrothermal field located  $\sim 2$  miles off the Panarea coast (Aeolian Islands, southern Italy) by coupling passive acoustic techniques and physical modelling. This integrated approach allowed us to depict the spectral acoustic features associated to different mechanisms of ascending fluids. Furthermore, the flow emission rates from a single vent, through the application of customised algorithms of inverse modelling, are also estimated. Results agree with direct measurements, confirming that passive hydroacoustics is a powerful tool for research and monitoring activities in such extreme environments.

**▲ From seafloor mapping to geochemical characterisation: A multidisciplinary exploration of the Panarea hydrothermal field (southern Italy).**TORRE A. <sup>(1)</sup>, CRISCILLO M. <sup>(1)</sup>, SEMPREBELLO A. <sup>(1)</sup>, GATTUSO A. <sup>(1)</sup>, CARUSO C. <sup>(2)</sup>, LAZZARO G. <sup>(2)</sup>, LONGO M. <sup>(2)</sup>, MESCHIS M. <sup>(2)</sup>, SCIRÈ SCAPPUZZO S. <sup>(2)</sup>, ITALIANO F. <sup>(3)</sup><sup>(1)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, INGV, Sezione di Palermo, Sede Operativa di Milazzo, Milazzo, Italy*<sup>(2)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, INGV, Sezione di Palermo, Palermo, Italy*<sup>(3)</sup> *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, OGS, Trieste, Italy*

Panarea, the smallest island of the Aeolian archipelago (SE of the Tyrrhenian Sea), hosts the largest hydrothermal system of the entire Mediterranean Sea. In this study, we combine new high-resolution morpho-bathymetric mapping with a detailed geochemical characterisation performed in the near offshore of the island, to investigate more deeply the natural processes driving the intense submarine hydrothermal activity featuring the area. Multi-beam morpho-bathymetric survey reveals undocumented seafloor features, including craters, pockmarks, chimney-shaped formations, and fault scarps. Geochemical investigations in the water column, already performed and planned for the near future above the newly discovered area, allow us to estimate dissolved gas outputs and concentrations, and to characterise the physico-chemical properties potentially affecting local seawater acidification. Through this integrated approach, a more comprehensive understanding of the effective aerial extension, dynamics and environmental impact of the Panarea hydrothermal system will be provided.

Furthermore, the outcomes will help to better define the energy budget feeding the hydrothermal reservoir, with broader tectono-volcanic implications within the central Aeolian Arc.

#### Comunicazioni

##### ● Volcanic carbon dioxide retrieved by hyperspectral satellite data.

SPINETTI C., ROMANIELLO V., PISCINI A.

*Istituto Nazionale di Geofisica e Vulcanologia*

Measuring carbon dioxide sources and sinks from space represents an advance in the knowledge of carbon cycle. Active volcanoes are the main natural source of carbon dioxide in atmosphere. A large and fast view of volcanic plumes as detection and measurements of volatiles is possible by using hyperspectral remote sensing. In the present study the algorithm to calculate CO<sub>2</sub> columnar abundance in tropospheric volcanic plume is applied to PRISMA hyperspectral data. The algorithm is based on CIBR “Continuum Interpolated Band Ratio” technique initially developed to calculate water vapor columnar abundance. PRISMA satellite data have been processed over Mt. Etna and Campi Flegrei (Italy) and Lusi volcano (Indonesia). The atmosphere has been simulated using a radiative transfer model in the spectral range 1.9–2.1 microns. CAMS data have been analyzed over the volcanic areas to individuate the atmospheric background. The results are spatial distributions of CO<sub>2</sub> columnar abundance of the volcanic plumes. The obtained results have been compared to the CO<sub>2</sub> flux rate deduced by the SO<sub>2</sub>/CO<sub>2</sub> ratio measured at ground in the available sites.

##### ● Analysis of volcanic CO<sub>2</sub> emissions using next-generation satellite hyperspectral data.

SAPIA E. <sup>(1)</sup>, CURCIO L. <sup>(1)</sup>, AIUPPA A. <sup>(1)</sup>, BUONGIORNO M. F. <sup>(2)</sup>, ROMANIELLO V. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Scienze della Terra e del Mare, DiSTeM, Università di Palermo, Italy*

<sup>(2)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy*

The present work explores advanced methods to detect and estimate volcanic carbon dioxide (CO<sub>2</sub>) emissions from degassing plumes and fumarole fields using hyperspectral data acquired by satellite and airborne sensors. Considering well-established algorithms such as Continuum Interpolated Band Ratio (CIBR), Matched Filter (MF) and Imaging Mapping Differential Optical Absorption Spectroscopy (IMAP-DOAS), the study introduces innovative approaches to leverage the high spectral resolution of satellite sensors like the ASI satellite mission PRecursore IperSpettrale della Missione Applicativa (PRISMA) launched in 2019, and operating in the Visible and Near-InfraRed (VNIR) and Short-Wave InfraRed (SWIR) spectral ranges. Quantification of the CO<sub>2</sub> columnar content relies on the analysis of CO<sub>2</sub> absorption features in the range 1950–2150 nm. Specifically, the PRISMA channels used for the CIBR method are at 1984.6 nm, 2061.0 nm and 2143.3 nm. The goal is to produce high-resolution maps of CO<sub>2</sub> concentration and flux, improving current accuracy standards, to support the volcanic monitoring and to investigate degassing processes and their climatic implications.

#### Relazioni su invito

##### ▲ Recycling atmospheric volatiles in the Earth’s interior: What do mantle minerals tell us?

ITALIANO L. <sup>(1)</sup>, ALDANMAZ E. <sup>(2)</sup>, ARIENZO I. <sup>(3)</sup>, CARACAUSI A. <sup>(4)</sup>, CORREALE A. <sup>(4)</sup>, PAONITA A. <sup>(4)</sup>, PAPPALARDO L. <sup>(3)</sup>, ROTOLO S.G. <sup>(1)(4)</sup>, STAGNO V. <sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Scienze della Terra e del Mare, Università di Palermo, Palermo, Italy*

<sup>(2)</sup> *Kocaeli University, Turkey*

<sup>(3)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Palermo, Italy*

<sup>(4)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Naples, Italy*

<sup>(5)</sup> *Dipartimento di Scienze della Terra, Sapienza Università di Roma, Roma, Italy*

Mantle products retain evidence of the Earth's history and the mantle's pristine composition, as well as signatures of geodynamic processes occurring at depth, such as subduction that contributed to the mantle heterogeneity. These processes influence mantle composition over time by introducing fluids of crustal and atmospheric origin, facilitating the recycling of volatiles between the mantle and atmosphere. Mantle-derived materials play a critical role in transferring mantle volatiles to the crust and ultimately to the atmosphere. This process significantly influences the origin and evolution of the Earth's atmosphere. Since heterogeneity in the chemical composition of the pristine mantle has been observed in mantle xenoliths from continental areas, further investigation of unstudied continental regions is crucial to improve the understanding of the variability in mantle composition, its origins and evolution. This study focuses on mantle xenoliths from continental regions of NW Turkey, and concerns the systematics of noble gas isotopes (He, Ne, Ar), major and trace elements, and radiogenic isotopes of 10 mantle xenoliths, as well as an investigation of the internal structure of minerals (by micro-CT), which plays a key role in the interpretation of the origin of volatiles trapped in Earth's mantle minerals.

#### Comunicazioni

##### ● Investigating the interplay between volcanic activity and climate change.

AMATO E. <sup>(1)</sup>, ZAGO V. <sup>(1)</sup>, CARIELLO S. <sup>(1)(2)</sup>, CORRADINO C. <sup>(1)</sup>, DI BELLA G. S. <sup>(1)</sup>, LA SPINA A. <sup>(1)</sup>, MALAGUTI A. B. <sup>(1)</sup>, TORRISI F. <sup>(1)</sup>, DEL NEGRO C. <sup>(1)</sup>

<sup>(1)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania, Osservatorio Etneo, Catania, Italy*

<sup>(2)</sup> *Dipartimento di Ingegneria Elettrica Elettronica e Informatica, Università degli Studi di Catania, Italy*

The climate system is highly complex and influenced by multiple forcing mechanisms, with significant social and economic consequences. Among natural forcings, explosive volcanic eruptions play a key role, injecting gases and particles into the atmosphere and potentially altering climate conditions. However, assessing the impact of individual eruptions remains challenging due to uncertainties in eruption parameters and limited knowledge of the initial climate state. These analyses require vast datasets and advanced modeling tools, often beyond the capacity of traditional methods. Emerging technologies —such as Artificial Intelligence (AI) and Quantum Computing (QC)— offer new opportunities to improve the study of volcano-climate interactions. These approaches enhance the accuracy and speed of simulations, optimize computation, and reduce uncertainties, enabling the identification of critical patterns and feedbacks. This contribution explores how frontier methodologies can support the modeling of climate variability and volcanic influences, with the goal of improving predictive capabilities and offering deeper insights into the processes that link major eruptions to climate anomalies.

##### ● Non-linear fluid models of atmospheric disturbances generated by strong seismic events.

LEPRETI F. <sup>(1)</sup>, CARBONE F. <sup>(2)</sup>, GENCARELLI C. <sup>(3)</sup>, PRIMAVERA L. <sup>(1)</sup>, CIARDULLO G. <sup>(1)</sup>, MALARA F. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università della Calabria, Italia*

<sup>(2)</sup> *Istituto sull'Inquinamento Atmosferico, Consiglio Nazionale delle Ricerche, CNR, Italia*



*(<sup>3</sup>) Istituto di Geologia Ambientale e Geoingegneria, Consiglio Nazionale delle Ricerche, CNR, Italia*

Strong seismic events are able to generate atmospheric waves which can propagate in the atmosphere up to the ionosphere and magnetosphere, producing fluctuations of the ionospheric plasma density, as well as variations of the resonance frequency of magnetospheric field lines. The interest in these physical phenomena has significantly increased during the last years, especially thanks to the rapid progresses in the observations of co-seismic signals in the atmosphere, ionosphere, and magnetosphere. In this contribution, we present a study of the generation and propagation in the atmosphere of perturbations due to strong seismic events. To this aim, non-linear fluid models are used, in which an earthquake is described through a suitable time profile which includes the main features of real seismic signals. The excitation and vertical propagation of non-vanishing modes is investigated for different values of the model control parameters. This study was carried out within the “Space It Up” project funded by the Italian Space Agency, ASI, and the Ministry of University and Research, MUR, under contract No. 2024-5-E.0 - CUP No. I53D24000060005.

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Aula 9, Section C, Edificio 19

ore 09:00 – 13:30

## SEZIONE V

## Biofisica e fisica medica

Presiede: BORTOLUSSI S. (Università di Pavia e INFN)

Relazioni su invito

▲ **Digital wound diagnostics: AI tools for clinical evaluation of chronic ulcers.**CURTI N. <sup>(1)(2)</sup>, DALL'OLIO L. <sup>(3)</sup>, ZENGARINI C. <sup>(4)(5)</sup>, MERLI Y. <sup>(4)(5)</sup>, CASTELLANI G. <sup>(5)(6)</sup>, REMONDINI D. <sup>(1)(2)</sup><sup>(1)</sup> *Department of Physics and Astronomy, University of Bologna, Bologna, Italy*<sup>(2)</sup> *INFN, Sezione di Bologna, Bologna, Italy*<sup>(3)</sup> *IRCCS Institute of Neurological Sciences of Bologna, Data Science and Bioinformatics Laboratory, Bologna, Italy*<sup>(4)</sup> *Dermatology Unit, IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy*<sup>(5)</sup> *Department of Medical and Surgical Sciences, University of Bologna, Italy*<sup>(6)</sup> *IRCCS Azienda Ospedaliero Universitaria di Bologna, Bologna, Italy*

The treatment of ulcers is often complex, particularly in the case of chronic wounds, which require specialized care, incur greater time and financial costs, and place a significant burden on healthcare systems. Clinical wound assessment involves evaluating multiple features of the ulcer site to guide prognosis and therapeutic decisions. Key parameters include wound margins, base, exudate amount, peri-wound skin condition, color, shape, and size. Due to the high inter- and intra-operator variability in assessing these characteristics, we developed a novel AI-based approach for the automated analysis of digital images of chronic wounds. Our objective is to build a mobile application for image acquisition, management, and classification, enabling rapid and consistent evaluation of clinically relevant wound parameters. We compiled a dataset of over 9000 smartphone-acquired images from more than 1000 patients, each annotated with clinical scores. AI models were trained for image recognition, segmentation, and characterization, forming the basis of a clinical decision support system for wound care management.

▲ **Walking through data: Interpretable machine learning for neurological gait disorders.**

OLIVA P.

*Dipartimento di Fisica "E. Fermi", Università di Pisa e Istituto Nazionale di Fisica Nucleare, Sezione di Pisa*

Artificial Intelligence (AI) is playing an increasingly prominent role in the quantitative analysis of medical data. In particular, eXplainable AI (XAI) techniques enhance the transparency of these models, improving their reliability and interpretability. Gait analysis —an established method for assessing motor function— produces rich spatiotemporal and kinematic data essential for diagnosing and treating gait impairments, especially those related to neurological conditions. This contribution shows how AI methods, empowered by XAI, can identify key gait features linked to neurological disorders. These insights support not only diagnosis but also the ongoing monitoring and personalization of rehabilitation strategies. The work is part of the TELE-NEURART project, funded by the Ministry of Health, which aims to develop a pediatric network for telemonitoring and telerehabilitation in neurodevelopmental disorders and disabilities.

▲ **From probe to pattern: Analyzing molecular interactions through fluorescence.**

SANCATALDO G., ANSELMO S., DE LUCA G., FERRARA V., VETRI V.

*Dipartimento di Fisica e Chimica, Emilio Segrè, Università di Palermo*

Fluorescent probes have become indispensable tools for visualizing and quantifying molecular interactions across a wide range of scientific disciplines. By translating nanoscale events into measurable optical signals, these probes allow researchers to explore dynamic processes in real time and *in situ*. This contribution will provide an overview of how fluorescent labels, coupled with spectroscopic and imaging techniques, can reveal patterns of molecular behavior, from interactions to structural changes. Particular focus will be given to fluorescence lifetime imaging microscopy (FLIM), a powerful technique that adds temporal resolution to spatially resolved fluorescence data, enabling the detection of subtle variations in the local environment, such as polarity, pH, and proximity interactions. By bridging molecular specificity with high-resolution imaging, fluorescence-based methods offer a unique window into the complexity of molecular systems, paving the way for interdisciplinary insights and innovations.

▲ **Cryo-EM structure of *Homarus americanus*  $\alpha$ -crustacyanin reveals the astaxanthin molecular tuning in marine invertebrate colouration.**

CIANCI M. <sup>(1)</sup><sup>(10)</sup>, CEDRI M.C. <sup>(1)</sup>, BANSIA H. <sup>(2)</sup>, AMICI A. <sup>(3)</sup>, COLLET T. <sup>(1)</sup>, MORETTI P. <sup>(4)</sup>, ORTORE M.G. <sup>(4)</sup>, MCCARTHY A. <sup>(5)</sup>, MUELLER-DIECKMANN C. <sup>(6)</sup>, LINGAS R. <sup>(7)</sup>, DURBEEJ B. <sup>(7)</sup>, RAFFAELLI N. <sup>(1)</sup>, WANG T. <sup>(2)</sup>, DES GEORGES A. <sup>(2)</sup><sup>(8)</sup><sup>(9)</sup>

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The study of lipid bioactive compounds and their interactions with proteins is crucial, especially in color mechanisms in biology. Carotenoproteins are key in vibrant colors via interactions between carotenoids and proteins. In *Homarus americanus* (American lobster), the blue color results from the binding of astaxanthin (AXT) with  $\alpha$ -crustacyanin ( $\alpha$ -CR).  $\alpha$ -CR consists of  $\beta$ -crustacyanin heterodimers, where AXT binds 1:1 with protein subunits. Free AXT is red-orange ( $\lambda_{\text{max}} = 472$  nm), but shifts to purple-blue (591 nm) and dark-blue (632 nm) with  $\beta$ - and  $\alpha$ -CR, respectively. While  $\beta$ -CR has been well studied,  $\alpha$ -CR's spectral shift remained elusive. We report a 2.75 Å cryo-EM structure of  $\alpha$ -CR, supported by SAXS and X-ray diffraction. It reveals H1, H2, and a third HPR-family protein linking  $\beta$ -CR heterodimers and asymmetrically interacting with two AXT molecules, causing the shift to 631 nm. This finding clarifies lobster coloration and enables design of AXT-based scaffolds for nanotech applications.

## Comunicazioni

● **Optimization of prostate cancer diagnosis using deep learning techniques to reduce false positives in PET with 18F-PSMA and 68Ga-PSMA (preliminary studies).**

MARCHESE V.A. <sup>(1)</sup>, COMIS A. <sup>(2)</sup>, ROMEO M. <sup>(3)(4)(5)</sup>, RUNFOLA C. <sup>(5)(6)</sup>, MAGGIO E. <sup>(5)(6)</sup>, MARRALE M. <sup>(4)(5)</sup>, PULVIRENTI A. <sup>(1)</sup>

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<sup>(2)</sup> *Mediterranean Oncology Institute, IOM, REM Radiotherapy, Viagrande, CT, Italy*

<sup>(3)</sup> *Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, University of Palermo, Palermo, Italy*

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Prostate cancer is a leading cause of male mortality. The introduction of radiopharmaceuticals like 68Ga-PSMA and F18-PSMA has significantly improved metastasis detection. However, F18-PSMA shows a 22% higher false positive rate than 68Ga-PSMA, highlighting the need for advanced tools to improve diagnostic accuracy. In this context, deep learning offers promising support in distinguishing true metastases from false positives. We tested nnUNet, a self-contouring deep learning model, to distinguish true metastases from false positives in F18-PSMA PET/CT scans. A dataset of 27 PET-CT scans (4 for testing) was used. nnUNet was chosen for its adaptability to various segmentation tasks, thanks to its automated normalization and preprocessing pipeline. Training focused on auto-segmentation of metastatic lesions to reduce operator-dependent variability. Despite the limited dataset, nnUNet showed promising accuracy in segmenting lesions and reducing false positives. These findings suggest strong potential for AI in improving F18-PSMA PET imaging and support further validation on larger datasets.

● **THAIS Project – Thero AI System: A comprehensive non-anthropomorphic AI.**

ZANGARI DEL BALZO G.

*Sapienza University of Rome*

As predicted by the American visionary scientist John McCarthy in 1956, Artificial Intelligence is directed, in all its forms and developments (generative and predictive AI), to simulate human intelligence, imitating its creativity to make an important contribution to all human activities, in terms of time and productivity. This distinctly anthropomorphic design can also represent its limit because AI learns and develops its processes flowing almost every human activity, sometimes grasping prejudices, which can possibly amplify existing distortions, prejudices or inequalities (“algorithmic bias”). More worrying, however, is what results from an analysis of many algorithms: too often they do not understand nature and the environment, if not from a human utilitarian point of view. Here, too, it is an anthropomorphic drift because it reflects human alienation from nature and the environment. For this reason, the THAIS project intends to propose a non-anthropomorphic mathematical workspace more suitable for understanding nature and the environment —regardless of their utilitarian value— to face new global challenges, from pandemics to climate change.

● **In vivo detection of dosimetric deviations in conventional radiotherapy using a deep learning framework.**

LANZILLOTTA R. <sup>(1)(2)</sup>, MOZZI C. <sup>(4)</sup>, UWITONZE E. <sup>(2)</sup>, AVANZO M. <sup>(3)</sup>, LIZZI F. <sup>(2)</sup>, MARINI L. <sup>(1)(2)</sup>, PALLOTTA S. <sup>(4)(5)</sup>, PIRRONE G. <sup>(3)</sup>, RETICO A. <sup>(2)</sup>, TALAMONTI C. <sup>(4)(5)</sup>, KRAAN A.C. <sup>(2)</sup>

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<sup>(2)</sup> INFN, Sezione di Pisa

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<sup>(4)</sup> Università di Firenze

<sup>(5)</sup> INFN, Sezione di Firenze

In the context of radiotherapy we developed a deep learning model to convert acquired EPID images into portal dose images, trained on a large dataset paired with Monaco TPS-calculated doses. This work assesses its applicability in an *in vivo* alert framework. We evaluate the model's sensitivity to controlled variations in Monitor Unit, patient positioning, and thickness. EPID images were acquired using anthropomorphic, modular heterogeneous phantoms, and solid water. A custom adipose-equivalent materials 3D-printed female torso phantom, with two interchangeable breast shapes, will be used for the final alert system evaluation. Dose difference, normalized dose difference, and gamma passing rate (GPR) were used as evaluation metrics. The system showed high sensitivity: for instance, for a  $5 \times 5 \text{ cm}^2$  field with the modular phantom, increasing the delivered MU from 100 to 104 led to a GPR drop from  $(99.94 \pm 0.04)\%$  to  $(75.95 \pm 0.61)\%$ ; similarly, for a  $2 \times 2 \text{ cm}^2$  field, adding +2 cm of solid water caused the GPR to decrease from  $(98.51 \pm 0.38)\%$  to  $(77.28 \pm 1.32)\%$ . Results were compared using different DTA and DD criteria.

● **Tackling the problem of diffusion in Fricke gels dosimeters through a physics-informed neural network algorithm.**

ROMEO M. <sup>(1)(2)(3)</sup>, COTTONE G. <sup>(1)(3)</sup>, D'OCA M.C. <sup>(1)(3)(6)</sup>, LOCARNO S. <sup>(4)(5)</sup>, MILLUZZO G. <sup>(3)</sup>, ROMANO F. <sup>(3)</sup>, GAGLIARDO C. <sup>(7)(8)</sup>, DI MARTINO F. <sup>(9)(10)(11)</sup>, D'ERRICO F. <sup>(11)(12)(13)</sup>, LENARDI C. <sup>(4)(5)</sup>, MARRALE M. <sup>(1)(3)(6)</sup>

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The use of radiation in medical applications demands accurate dose measurements, particularly with the advent of high-dose rates and mini-beam fields. In this context, Fricke gels (FGs) are gaining interest for their tissue-equivalent properties. FGs rely on  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$  oxidation upon radiation exposure, that can be quantified by MRI or optical absorption (OA)

spectroscopy, enabling access to 3D dose distributions (DD). Ion diffusion brings to blurring effects in the recorded DD, limiting FG's clinical utility. The process is governed by the diffusion equation and reconstructing the backward time DD leads to a challenging inverse problem. A promising solution is given by the physics-informed neural networks (PINNs), which integrate physical laws with machine learning to solve partial differential equations. In this study, we trained PINNs to predict pre-diffusion DD in 1D, 2D, and 3D FG models, exploiting diffused data up to 100 hours post-irradiation. Predictions were compared with OA data from irradiated PVA-GTA gel and simulated data. Predictions MSE ( $10^{-6}$ – $10^{-4}$  OD2) and gamma analysis (90–100% passing rate at 3%/2 mm) indicate the PINNs potential in overcoming FG limitations.

### ● **Classificazione automatica di organoidi intestinali tramite deep learning.**

CASCIO D.

*Università degli Studi di Palermo*

Gli organoidi epiteliali intestinali rappresentano un modello fondamentale per lo studio delle cellule staminali e del cancro coloretale, ma la loro classificazione manuale è lenta e soggettiva. In questo studio è stato sviluppato un modello di classificazione automatica basato sul deep learning, utilizzando YOLOv10m (You Only Look Once), una rete neurale convoluzionale per l'object detection in immagini. Il modello è stato addestrato su un dataset pubblico contenente 840 immagini di microscopia annotate (23066 oggetti), con l'obiettivo di identificare quattro categorie: cisti, organoidi precoci, organoidi tardivi e sferoidi. Il training, eseguito per 150 epoche, ha raggiunto le prestazioni ottimali all'epoca 80, con una mean Average Precision (mAP) pari a 0.85. Le migliori performance si sono osservate nella classificazione delle cisti (mAP 0.87). Il sistema misura anche le dimensioni degli organoidi con accuratezza comparabile a quella degli esperti, ma in modo molto più rapido. Questo approccio basato su deep learning apre la strada a un'analisi scalabile e ad alta efficienza nel campo della biologia degli organoidi. Lo studio rientra nel progetto PNRR PE00000019-HEAL ITALIA.

### ● **Leveraging explainable deep learning for mammographic breast cancer diagnosis.**

NOVIELLI P. <sup>(1)</sup><sup>(3)</sup>, ROMANO D. <sup>(1)</sup><sup>(3)</sup>, MAGARELLI M. <sup>(1)</sup>, DI BITONTO P. <sup>(1)</sup><sup>(3)</sup>, DIACONO D. <sup>(3)</sup>, BELLOTTI R. <sup>(2)</sup><sup>(3)</sup>, TANGARO S. <sup>(1)</sup><sup>(3)</sup>

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<sup>(3)</sup> *Istituto Nazionale di Fisica Nucleare, Sezione di Bari*

Breast cancer remains one of the leading causes of cancer-related mortality among women worldwide, and early, accurate diagnosis is key to improving patient outcomes. We explore the integration of deep learning with explainable AI (XAI) techniques for automated classification of mammographic lesions using the publicly available CBIS-DDSM dataset. Convolutional Neural Networks (CNNs) are trained to discriminate between malignant and benign findings, while Grad-CAM generates class-specific saliency maps highlighting regions most responsible for each prediction. This approach aims to enhance diagnostic accuracy and model transparency, offering visual explanations that support trust and clinical usability. We further investigate how lesion type and breast tissue density influence classification performance and interpretability of model outputs, suggesting pathways for individualized AI-based screening tools. This study is part of the EUCAIM project: Cancer Image Europe provides a secure platform for sharing annotated cancer images, enabling robust benchmarking of AI tools and fostering collaboration among researchers, clinicians, and innovators.

● **Analyzing human locomotion: Deep learning approaches to gait biomechanics.**

G. TIDDIA G. <sup>(1)</sup>, MAINAS F. <sup>(1)(2)</sup>, RETICO A. <sup>(3)</sup>, OLIVA P. <sup>(3)(4)</sup>

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Gait analysis is the systematic study of human walking (gait), typically used to assess and treat individuals with conditions affecting their ability to walk, such as neurological diseases, injuries, or stroke. It involves measuring body movements, body mechanics, and muscle activity during walking. Traditionally, a set of physical quantities is extracted from spatiotemporal and kinematic data and used to characterize the gait, but this approach leverages only a small fraction of the information acquired from the gait analysis exam. An alternative is to apply deep-learning models that extract data-driven features directly from the full spatiotemporal dataset. This contribution presents a model based on transformers for the analysis of gait biomechanical data from healthy and injured patients, aiming to distinguish between gait patterns of different conditions. The performance of this method is compared with traditional quantitative approaches for extracting gait parameters, followed by a classification using tree-based machine learning classifiers in order to investigate how deep-learning models can enhance gait analysis in the quest for developing data-driven tools in healthcare.

● **Computed Tomography with iodine contrast: A Monte Carlo simulation study for the estimation of dose increments in organ of interest.**

AMATO E. <sup>(1)(2)(3)</sup>, DE LUCA M. <sup>(4)</sup>, AUDITORE L. <sup>(1)(2)</sup>

<sup>(1)</sup> *Department of Biomedical and Dental Sciences and of Morphofunctional Imaging, BIOMORF, University of Messina, Italy*

<sup>(2)</sup> *INFN, National Institute for Nuclear Physics, Section of Catania, Italy*

<sup>(3)</sup> *Health Physics Unit, University Hospital "Gaetano Martino", Messina, Italy*

<sup>(4)</sup> *Department of Physics and Astronomy "Galileo Galilei", University of Padova, Italy*

Iodinated contrast media in Computed Tomography (CT) improves tissue differentiation but increases radiation dose to tissue and organs. This study investigates by Monte Carlo (MC) simulations the increase of the organ absorbed doses as a function of iodine concentration and provides a predictive model of general use. The ICRP-110 Adult Male phantom was implemented in GAMOS and nine iodine concentrations ranging from 0.05 to 5 mg/ml were considered. CT irradiation was simulated by sampling the photon source with energy distribution of a typical 120 kVp X-ray tube spectrum. Absorbed dose was scored in thyroid, spleen, kidneys, pancreas and liver. For the highest iodine concentration, 5 mg/ml, thyroid, spleen and left kidney exhibit up to 43.00, 42.40 and 42.40% dose increments while lower increments were observed for right kidney, pancreas and liver, up to 35.66, 33.00 and 31.90%, respectively. A regression model was applied to data to provide a logarithmic function to be used for dose increment calculations for a whatever iodine concentration ranging from 0.05 to 5 mg/ml. This study provides an accurate estimation of organ dose increase when contrast-enhanced CT are carried out.

● **FLIM analysis reveals lipid-driven membrane dysfunction in Alzheimer's disease models.**

BONACCORSO E. <sup>(1)</sup>, ANSELMO S. <sup>(2)</sup>, CONTI NIBALI V. <sup>(1)</sup>, VETRI V. <sup>(2)</sup>, D'ANGELO G. <sup>(1)</sup>

<sup>(1)</sup> *Department of Mathematics, Computer Science, Physics and Earth Science, University of Messina*

(<sup>2</sup>) *Department of Physics and Chemistry Emilio Segrè, University of Palermo*

Alzheimer's Disease (AD) is increasingly recognised as a disorder with a significant lipidomic component, where changes in neuronal membrane lipid composition contribute to disease progression. In this study, we employed Fluorescence Lifetime Imaging Microscopy (FLIM) to investigate two synthetic model neuronal membranes, mimicking healthy and AD-like neuronal states. Our results demonstrate that the pathological composition leads to a significant alteration in lipid phase behaviour, indicative of disrupted lateral organization. These changes may impair the membrane's biophysical properties, essential for proper signalling, trafficking and protein function. To evaluate the functional implications of this altered lipid landscape, we examined the interaction of both membrane models with lysozyme, a peripheral membrane protein. Differences in binding suggest that pathological lipid reorganization may compromise protein-membrane interactions, potentially affecting signalling and contributing to AD-related dysfunctions. These findings underscore the importance of lipid homeostasis in membrane integrity and suggest membrane remodelling as a potential target in AD intervention strategies.

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Aula 10, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE V

**Biofisica e fisica medica**

Presiede: OLIVA P. (Università di Pisa e INFN, Sezione di Pisa)

*Le relazioni su invito si terranno nell'Aula 9, i lavori si sposteranno nell'Aula 10 per le seguenti comunicazioni.*

Comunicazioni

● **Maximally informative low-resolution representations of proteins discriminate key structural elements across conformational states and transition pathways.**

MENICHETTI R., GUADAGNIN PATTARO A., POTESTIO R.

*Physics Department, University of Trento, Italy e Trento Institute for Fundamental Physics and Applications, INFN TIFPA, Italy*

The main challenge of an in silico investigation of biological systems is nowadays shifting from data generation to the development of techniques enabling their rational interpretation. To distill meaningful insight, complex simulation datasets are often projected onto a subset of the system's degrees of freedom; if inappropriately chosen, such projections may compromise signal-to-noise discrimination. The mapping entropy optimization workflow (MEOW) addresses this issue by identifying the reduced representations of a system that preserve the maximum amount of statistical information on the original, high-resolution reference. Applied to protein simulations, MEOW was found to single out, in an unsupervised manner, regions of functional relevance, such as catalytic or binding sites. As the functional importance of a region may vary dynamically (*e.g.*, along a conformational change), it is possible to combine MEOW and transition path theory in a unified pipeline. Applied to the chignolin miniprotein, this approach reveals stage-specific relevant sites along the folding transition, illustrating its potential for broader application to more complex biomolecular systems.

● **Deciphering the role of water in liquid-liquid phase separation.**

ANSELMO S., SANCATALDO G., VETRI V.

*Dipartimento di Fisica e Chimica "Emilio Segrè", Università di Palermo*

Liquid-liquid phase separation (LLPS) is a fundamental physicochemical process with wide-ranging applications. It occurs when a homogeneous liquid solution demixes into two distinct liquid phases with different compositions, driven by thermodynamic factors such as temperature, solute concentration, and intermolecular interactions. A key but often overlooked aspect of this process is the role of water which may regulate protein phase behaviour through its hydrogen-bonding network by modulating hydration entropy and enthalpy. In the context of the project SAMOTHRACE, LLPS of b-lactoglobulin-Polyethylene Glycol (PEG) aqueous solutions at neutral pH were studied in different conditions revealing that, in the analysed samples, the solution behaviour is mainly regulated by excluded volume effects. Protein-PEG concentration ratio was found to regulate solution partitioning in two liquid coexisting phases. The combination of spectroscopy and microscopy was exploited to focus on the role of water by means of dye ACDAN. The experimental approach enabled the detection of subtle microenvironmental changes associated with water structuring, shedding light on its role in protein phase separation.



● **Hydration water softens propagating collective modes in proteins.**

CONTI NIBALI V. <sup>(1)</sup>, SACCHETTI F. <sup>(2)</sup>, LIBERA V. <sup>(2)</sup>, ORECCHINI A. <sup>(2)</sup>, PETRILLO C. <sup>(2)</sup>, D'ANGELO G. <sup>(1)</sup>, PACIARONI A. <sup>(2)</sup>

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<sup>(2)</sup> *Department of Physics and Geology, Perugia University, Perugia, Italy*

Within the wide range of protein motions, from femtoseconds to seconds, “collective dynamics” refers to coordinated motions on the sub-picosecond timescale. These motions impact processes such as ligand binding, allosteric signaling, and vibrational energy redistribution. Water actively participates in these processes due to its strong dynamic coupling with the biomolecule. Yet, a comprehensive molecular understanding remains lacking. Here, we investigate how hydration affects the collective dynamics of the maltose binding protein. By combining Brillouin INS and IXS experiments, we identify hydration-dependent phonon-like dynamics characterized by multiple acoustic-like and optic-like modes, a scenario remarkably different from previous research. These findings are supported by Raman and specific heat measurements, and molecular-dynamics simulations. Our results demonstrate an unprecedented softening of the phonon-like modes with increased water content, highlighting the role of hydration in modulating collective dynamics. These insights have significant implications for understanding protein function and design.

● **Quantitative live imaging of chromatin remodeling at DNA damage sites using DNA counterstains.**

PATERNÒ G. <sup>(1)</sup>, LONGO E. <sup>(1)</sup>, SCALISI S. <sup>(1)</sup>, SCOLLO F. <sup>(1)</sup>, FARETTA M. <sup>(2)</sup>, PELICCI S. <sup>(2)</sup>, DELLINO G.I. <sup>(2)(3)</sup>, PELICCI P.G. <sup>(2)(3)</sup>, DIASPRO A. <sup>(4)(5)</sup>, LANZANÒ L. <sup>(1)(4)</sup>

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DNA damage drives genomic instability, but the role of chromatin in its response remains unclear. Here, we extend QUANDO (QUAntitative ANALysis of DNA cOunterstains) to live-cell imaging. This approach combines DNA counterstains with Image Cross-Correlation Spectroscopy and DNA intensity profiling to monitor DNA damage localization and chromatin remodeling. Applying this to HeLa cells, we found that laser-induced DNA damage preferentially localizes in high DNA density regions, followed by rapid chromatin relaxation within seconds, as reflected by a decrease in Hoechst signal. Inhibition of PARP with talazoparib significantly disrupts this response, underscoring its role in chromatin remodeling at damage sites. Notably, Hoechst-only imaging yields similar results, streamlining single-channel experiments. Incorporating Imaging Scanning Microscopy further enhances spatial resolution, enabling refined characterization of chromatin changes at the nanoscale. Future developments will focus on applying this strategy to additional models and 3D spheroids, offering novel insights into chromatin dynamics under physiologically conditions. Funded by AIRC-MFAG2018 ID.21931

● **Two-color Minflux of aggregated insulin fibrils as a model of pathological amyloids.**

CANEPA P. <sup>(1)</sup>, BARBIERI M. <sup>(1)</sup>, SALERNO M. <sup>(1)</sup>, BIANCHINI P. <sup>(2)</sup>, DIASPRO A. <sup>(1)(2)</sup>, CANALE C. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics, University of Genova, Genova, Italy*

<sup>(2)</sup> *Istituto Italiano di Tecnologia, Genova, Italy*

Amyloid fibrils are insoluble aggregates formed by misfolded proteins, which have specific structure and play a role in neurodegenerative diseases such as Alzheimer's and Parkinson's. Minflux is a recently introduced fluorescence-based imaging technique that pushes the limits of super-resolution microscopy down to the single molecule level. Using the capabilities of Minflux one can potentially address the molecular organization, heterogeneity, and eventually the stoichiometry in complex assemblies like amyloid fibrils. Specific protein regions (e.g., the amine or the carboxyl terminus) can in principle be labeled and their pattern identified. Limitations currently apply to the pairs of fluorophores that can be detected in two-color mode. We have started with amine-linking fluorophores Flux640-680 and addressed optimization of dye-to-protein ratio and blinking buffer concentration of cysteamine. Preliminary results will be presented about the labeling density obtained, the two fluorophores' efficiencies and their co-localization. The latter could allow for detection of structural polymorphs with different packing or strain. Comparison of early *vs.* late fibrils will also allow to study their growth properties.

● **Exploring the free energy landscape of amyloid-beta peptides: A molecular dynamics study.**

CICCOLO A. <sup>(1)</sup>, CADENELLI I. <sup>(2)</sup>, TAGLIABUE A. <sup>(2)</sup>, ROSSI G. <sup>(2)</sup>, CONTI NIBALI V. <sup>(1)</sup>, BOCHICCHIO D. <sup>(2)</sup>

<sup>(1)</sup> *Department of Mathematics, Computer Science, Physics and Earth Science, University of Messina, Messina, Italy*

<sup>(2)</sup> *Department of Physics - University of Genova, Genova, Italy*

The Amyloid-beta ( $A\beta$ ) peptide is an Intrinsically Disordered Protein (IDP) whose aggregation process at the neuronal membrane is considered a central event in the onset of Alzheimer's disease (AD).  $A\beta$  is a 39–42 amino acid long peptide, and the ratio of its alloforms  $A\beta_{40}$ -to- $A\beta_{42}$  is believed to play a role in AD development. Due to its nature, the exploration of the conformational space remains challenging. To explore the complex free energy landscape of the  $A\beta_{40}$  and  $A\beta_{42}$  monomers and their changes due to different environments, we have conducted Well-Tempered Metadynamics simulations. In particular, we studied  $A\beta$  structural transitions in different solvents: water, hexafluoroisopropanol (HFIP), and dimethyl sulfoxide (DMSO); the latter two represent useful models for investigating how the properties of the environment influence the tendency of  $A\beta$  to sample specific secondary structures. Our results show that in water, both  $A\beta_{40}$  and  $A\beta_{42}$  mainly sample disordered conformations with a non-negligible  $\beta$ -sheet content. Conversely, HFIP promotes  $\alpha$ -helix formation, while DMSO, primarily acting as a hydrogen bond acceptor, favors protein unfolding, particularly of  $\beta$ -sheet structures.

● **Recent developments in measurement and modelling of thermal neutron cross-sections of hydrated amino acids.**

CASTELLANI M. <sup>(1)</sup>, SIMONI M. <sup>(1)</sup>, NOTARI S. <sup>(1)</sup>, GAMBARDELLA G. <sup>(1)</sup>, KRZYSTYNIAK M. <sup>(2)</sup>, MINICOZZI V. <sup>(1)</sup>, STELLATO F. <sup>(1)</sup>, BOCEDI A. <sup>(1)</sup>, SENESI R. <sup>(1)</sup><sup>(3)</sup>, ROMANELLI G. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Roma Tor Vergata, Rome, Italy*

<sup>(2)</sup> *ISIS Neutron and Muon Source, Rutherford Appleton Laboratory, Chilton, UK*

<sup>(3)</sup> *CNR-ISM, Rome, Italy*

An accurate computation of thermal neutron scattering cross-sections often involves complex simulations, which are necessary to account for the contribution of molecular motions. Recently, an approximation has been proposed to estimate thermal neutron cross-section of

hydrogen-based materials. This approximation, known as the average functional group approximation (AFGA), consists of rationalizing a complex hydrogen-rich molecule as the sum of the contributions to cross-section of its functional groups. This method is of great impact for multiple applications in the field of radioprotection. However, the model does not consider the interaction between the molecule and hydration water. To quantify the contribution of hydration water, we present the neutron measurements of total cross section, momentum distribution, and vibrational spectra of three hydrated amino acids: arginine, glycine and tryptophan, hydrated both with H<sub>2</sub>O and D<sub>2</sub>O. The comparison of the two models for hydrated and dehydrated molecules provides a better understanding of the contribution to the cross-section of hydrated systems.

● **Predicting radiobiological enhancement: Monte Carlo modeling of gold nanorods and radiopharmaceuticals.**

BIANCHI L. <sup>(1)(2)</sup>, ATTILI A. <sup>(2)</sup>, VENDITTI I. <sup>(2)(3)</sup>, DINI V. <sup>(6)(7)</sup>, BATTOCCHIO C. <sup>(3)</sup>, TORTORA L. <sup>(2)(3)</sup>, RUOCCO A. <sup>(2)(3)</sup>, SCOTOGNELLA T. <sup>(4)(5)</sup>, CALCAGNI M.L. <sup>(4)(5)</sup>, FABBRI A. <sup>(2)</sup>

<sup>(1)</sup> Dipartimento di Matematica e Fisica, Università Roma Tre, Italia

<sup>(2)</sup> Istituto Nazionale di Fisica Nucleare, Sezione di Roma Tre, Italia

<sup>(3)</sup> Dipartimento di Scienze, Università Roma Tre, Italia

<sup>(4)</sup> Unità di Medicina Nucleare, Fondazione Policlinico Universitario A. Gemelli IRCCS, Italia

<sup>(5)</sup> Istituto di Medicina Nucleare, Dipartimento di Scienze Radiologiche ed Ematologiche, Università Cattolica del Sacro Cuore, Italia

<sup>(6)</sup> Centro Nazionale per le Tecnologie Innovative in Sanità Pubblica, Istituto Superiore di Sanità, Italia

<sup>(7)</sup> Istituto Nazionale di Fisica Nucleare, Sezione di Roma 1, Italia

The SEGNAR (Synergic Effects of Gold Nanorods And Radiopharmaceuticals) project aims to develop an innovative theranostic system combining gold nanorods (AuNRs) with <sup>99m</sup>Tc-based radiopharmaceuticals. One of the key objectives is to model the AuNR system in a cellular environment to predict radiobiological enhancement following irradiation and highlight possible synergistic effects between AuNRs and <sup>99m</sup>Tc-sestaMIBI. The study employs Monte Carlo simulations within Geant4 and Geant4-DNA to model the interaction of primary radiation with tissues and AuNR systems. The integration of the chemical stage within the MKM model is underway to estimate biological effects and define radiobiological parameters for the T98G cell line. Future work will focus on quantifying lesion yields and cell survival probabilities, comparing theoretical predictions with *in vitro* experiments results. The SEGNAR project contributes to the development of optimized AuNR-radiopharmaceutical conjugates for targeted theranostic applications, offering a promising avenue for improving cancer treatment strategies.

Aula 7, Section B, Edificio 19

ore 09:00 – 13:30

SEZIONE VI

**Fisica applicata, acceleratori e beni culturali**

Presiede: GALLI A. (Università di Milano Bicocca)

Relazioni su invito

▲ **Ancient obsidian artifacts: Scientific investigations into the interplay of provenance and dating.**

BONIZZONI L.

*Dipartimento di Fisica, Università degli Studi di Milano, Italia*

Obsidian is a volcanic glass formed when lava cools rapidly, preventing crystal formation. Its sharpness made it valuable for toolmaking since the Paleolithic era and a key trade item during the Neolithic, especially around the Mediterranean. For this reason, obsidian remains of great interest in archaeological research, especially for tracking prehistoric trade networks. Chemical characterization methods, such as X-Ray Fluorescence or Synchrotron based X-ray Fluorescence, allow us to classify the provenance of obsidian artifacts accurately when referring to different sources, mostly if used in combination with statistical methods. If discrimination among sub-sources, *i.e.*, various lava flows within the same volcano, is required, dating methods are more suitable. Fission-track dating can thus be used to estimate the age of obsidian and correlate it with volcanic events, becoming at all effects a provenance study. The synergy between chemical characterization and dating techniques opens new possibilities for interpreting prehistoric trade routes and understanding the behavior of ancient communities, especially in complex volcanic regions like the Aeolian Islands.

▲ **Multimodal imaging for wooden panel painting analysis: “Consegna della regola francescana” by Colantonio, a case of study.**

PATURZO M. <sup>(1)</sup>, SALTARELLI C. <sup>(1)</sup>, DI MEO A. <sup>(1)</sup>, RIPPA M. <sup>(1)</sup>, PAGLIARULO V. <sup>(1)</sup>, CACACE T. <sup>(2)</sup>

<sup>(1)</sup> *Institute of Applied Sciences and Intelligent Systems “E. Caianiello” of CNR, Pozzuoli, NA, Italy*

<sup>(2)</sup> *Institute of Cultural Heritage Sciences of CNR, Naples, Italy*

The development of advanced diagnostics tools for investigating artworks and monitoring their health state in a non-destructive way is a key point for their preservation and restoration. Non-invasive diagnostic approaches enable the identification of damage often hidden to restorers' naked eyes, thereby facilitating the planning of appropriate restoration interventions. Here, the combined use of three full-field imaging techniques —shearography, thermography and 3D scanning— has been employed as complementary tool for the diagnostics of a panel painting. As a case study, the artwork “Consegna della regola francescana” created by the Neapolitan painter Colantonio, around 1445, was analyzed. The integrated application of the mentioned optical imaging techniques allows a comprehensive evaluation of the state of conservation of the work, revealing inserts, nails, and detachments. This synergistic approach also enhanced the interpretation of the results from each individual technique, offering a more complete understanding that would be unattainable with any single method alone.

## Comunicazioni

● **Metodi innovativi nella ricostruzione dei regimi alimentari del passato.**

LUBRITTO C., GIACOMETTI V., MANTILE N., ALTIERI S., DI CICCIO M.R.

*Università della Campania L. Vanvitelli, Caserta*

La ricostruzione delle pratiche alimentari antiche è fondamentale per interpretare le dinamiche socio-economiche e le condizioni sanitarie delle popolazioni del passato. La Bulk Stable Isotope Analysis (BSIA), basata sulla misurazione dei rapporti isotopici di  $\delta^{13}\text{C}$  e  $\delta^{15}\text{N}$  nel collagene osseo, costituisce una tecnica di riferimento per l'analisi della paleodiet. Tuttavia, la risoluzione interpretativa della BSIA è limitata dalla sovrapposizione tra le firme isotopiche di diverse fonti proteiche e dall'integrazione di segnali dietetici su scala di lungo periodo. Inoltre, fattori fisiologici e metabolici possono introdurre ulteriori variazioni, complicando l'interpretazione dei dati. Invece la Compound Specific Isotope Analysis (CSIAA) rappresenta un approccio estremamente innovativo nell'ambito delle metodologie isotopiche. Attraverso l'analisi mirata degli amminoacidi o dei lipidi, essa consente di studiare le fonti proteiche a livello molecolare e di discriminare con precisione le componenti dietetiche, migliorando significativamente l'accuratezza dei modelli isotopici, superando i principali limiti interpretativi della BSIA in ambito bioarcheologico.

● **TL and OSL cross-dating for a complex historical building site: the case of Terme della Rotonda.**CASTELLINO P.B. <sup>(1)</sup>, GALVAGNO R. <sup>(1)</sup>, GUELI A.M. <sup>(1)</sup>, LIUZZO M. <sup>(2)</sup>, MARGANI G. <sup>(3)</sup>, TARDO C. <sup>(3)</sup>, STELLA G. <sup>(1)</sup><sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*<sup>(2)</sup> *Dipartimento di Ingegneria Civile e Ambientale, Università di Enna Kore*<sup>(3)</sup> *Dipartimento di Ingegneria Civile e Ambientale, Università di Catania*

One of the objectives of the SAMOTHRACE project SiciliAn MicronanOTech Research and Innovation Center (PNRR, M4C2 Investment 1.5), Spoke 1 University of Catania, WP6 Cultural Heritage, Task 1 is to improve absolute dating techniques using thermally (TL) and optically (OSL) stimulated luminescence on bricks affected by partial bleaching. The study focused on samples from the Terme della Rotonda (Catania, Italy), a site with complex chronological and functional phases. An initial experiment on pure quartz assessed the impact of the typical temperatures reached by the structures (around 150 °C) on the equivalent dose using both TL and OSL. Then, samples from both hot (thermally bleached) and cold environments were analyzed. Quartz grains ( $\sim 200 \mu\text{m}$ ) were extracted and equivalent dose was obtained using added dose (TL) and SAR (OSL) protocols with a Riso TL/OSL DA-15 system. The annual dose was estimated through in situ gamma spectrometry, alpha counting, and ICP-MS analysis. The integration of analytical results with architectural and historical data enabled dating of construction and final use phases.

● **Osl dating of sediments from Rose Cottage and Holley Rock Shelter (South Africa).**BULGARINI S. <sup>(1)</sup>, BADER G. <sup>(2)</sup>, CALIÒ L.M. <sup>(1)</sup>, GUELI A.M. <sup>(3)</sup>, POLITI G. <sup>(3)</sup>, SCHMID V.C. <sup>(4)</sup>, STELLA G. <sup>(2)</sup>, TRIBOLO C. <sup>(5)</sup>, WILL M. <sup>(6)</sup><sup>(1)</sup> *Dipartimento di Scienze Umanistiche, Università di Catania*<sup>(2)</sup> *Department of Early Prehistory and Quaternary Ecology, Universität Tübingen, Germany and Paleo-Research Institute, University of Johannesburg, South Africa*<sup>(3)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*<sup>(4)</sup> *Osterreichische Akademie der Wissenschaften, Deutsches Archäologisches Institut, Kommission für Archäologie Außereuropäischer Kulturen, Austria*

<sup>(5)</sup> *Université Bordeaux Montaigne, Laboratoire Archéosciences, France*

<sup>(6)</sup> *Universität Tübingen, Altere Urgeschichte und Quartärökologie, Germany*

This study presents the results of optically stimulated luminescence (OSL) dating conducted on five sediment samples from two prehistoric archaeological sites in South Africa: Rose Cottage Cave (Free State) and Holley Rock Shelter (Kwazulu Natal). They are both rock shelter sites, but a bit different from each other: Rose Cottage has a key, continuous and longstratigraphic sequence (over 4.5 m), from MSA to LSA, covering the last 100 millenia. 77 dates are available from previous geochronological studies, but some discrepancies or chronological gaps needed to be solved. Three sediments samples have been taken from the base of the sequence for optical dating. Holley Rock Shelter has a relatively short sequence (< 1 m) displaying late MSA and LSA artifacts. Radiocarbon analyses have been conducted, and five sediment samples, two of which are presented here, have been taken for OSL dating. Both feldspar and quartz grains have been analyzed, with a single grain approach. They show good consistency with each other and with the other chronological data and contribute to enhance our understanding of the occupational histories of both sites.

● **I templi dorici come espressione di principi di fisica geometrica avanzata del progetto architettonico greco nel contesto culturale ed ambientale dell'antica Grecia.**

BARONE F., CASAZZA M.

*Dipartimento di Medicina, Chirurgia e Odontoiatria Scuola Medica Salernitana, Università degli Studi di Salerno*

L'adozione di una visione multidisciplinare integrata e sinergica del patrimonio culturale, sintesi delle dimensioni materiali e immateriali di un bene (UNESCO 2023), permette di superare visioni ultra-specialistiche parziali, che non consentono di comprenderne l'identità immateriale. In questo contesto, la metrologia vibroacustica, finalizzata alla formulazione di ipotesi funzionali alla comprensione del bene storico ed alla validazione quantitativa di ipotesi interpretative, sta assumendo un nuovo ruolo, pienamente congruente con l'approccio archeologico e documentale. L'innovativa interpretazione vibroacustica basata sulla fisica geometrica dei templi dorici greci del VI-IV secolo a.C. è un rilevante esempio di sintesi modellistica di dimensioni materiali ed immateriali in cui i templi sono visti come manifestazioni di principi progettuali avanzati di integrazione del progetto architettonico con le condizioni ambientali locali, parte del patrimonio culturale immateriale greco. I risultati mostrano che gli elementi strutturali dei templi agiscono come attenuatori acustici, dimostrando metrologicamente la motivazione delle loro deviazioni dal classico orientamento Est-Ovest.

Relazioni su invito

▲ **Light and art: Measuring color to understand and preserve cultural heritage.**

GUELI A.M.

*Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Catania, Italia*

Color measurement is essential for the documentation, analysis, and conservation of cultural heritage. This contribution introduces the physical principles of colorimetry, with a focus on determining the spectral reflectance factor and calculating color coordinates (CIE XYZ, CIELAB). The main measurement techniques —both contact and non-contact— as well as the instrumentation involved, including spectrophotometers and spectroradiometers, will be presented through examples from painted surfaces and polychrome materials. Particular emphasis will be placed on the measurement procedure and the influence of experimental parameters, such as the light source, luminance scale adjustment, and the optical properties of

the samples (*e.g.*, roughness, transparency, and geometry). The potential and limitations of colorimetry for pigment identification will also be discussed, along with recent advancements from the PNRR Samothrace project, which highlights the latest developments in non-invasive diagnostic techniques. The importance of standardizing protocols to ensure data reliability and repeatability will be underscored, enabling meaningful comparisons across time and contexts.

#### Comunicazioni

##### ● **Archeometria del patrimonio culturale immateriale: la caratterizzazione vibroacustica dell'accordatura delle campane.**

CASAZZA M., BARONE F.

*Dipartimento di Medicina, Chirurgia e Odontoiatria Scuola Medica Salernitana, Università degli Studi di Salerno*

Coerentemente con l'evoluzione del concetto di patrimonio culturale e paesaggistico, che include le sue molteplici componenti immateriali, è possibile implementare l'uso di metodi sperimentali e modelli fisici attraverso la hard metrology, permettendo, unitamente a dati storici ed archeologici, di sviluppare modelli multidimensionali e multi-disciplinari, utili ad interpretare non solo le evidenze materiali, ma anche quelle immateriali del patrimonio culturale e paesaggistico. Un esempio di tale approccio è costituito dall'applicazione di misurazioni e modelli vibro-acustici. In tale ambito, proponiamo un metodo di analisi delle misure, che, unitamente alla conoscenza dell'evoluzione storica della teoria musicale, permette di formulare delle ipotesi preliminari sull'epoca di costruzione del patrimonio campanario, in relazione all'accordatura di tali strumenti. Essendo, poi, sia il suono delle campane sia la conoscenza delle tecniche costruttive parti del patrimonio culturale immateriale, mostriamo quali implicazioni possa avere l'approccio innovativo proposto sia per la caratterizzazione archeometrica sia per l'interpretazione storico-archeologica.

##### ● **Tecniche ottiche di diagnostica per i beni culturali.**

PAGLIARULO V., SALTARELLI C., PATURZO M.

*CNR, Istituto di Scienze Applicate e Sistemi Intelligenti, Pozzuoli*

La diagnostica delle opere d'arte è un argomento di grande interesse, ma anche un'attività molto delicata. Lo sviluppo di strumenti efficaci basati su tecnologie ottiche avanzate per l'indagine e il monitoraggio dello stato di salute dei beni culturali è essenziale per garantirne la conservazione e il restauro. In questo lavoro, l'uso della shearografia e della scansione 3D a luce strutturata, come metodi complementari per la diagnostica di manufatti storico-artistici, è stato impiegato su diverse tipologie di oggetti. Entrambe le tecniche sono a campo pieno, senza contatto, non invasive e possono fornire informazioni sullo stato di conservazione e sulla qualità del restauro delle opere d'arte. I risultati mostrano che le tecniche diagnostiche impiegate, tra cui l'interferometria speckle e la scansione 3D, rappresentano un potente strumento per la valutazione dello stato di salute pre-restauro e adatto all'analisi in situ di opere d'arte realizzate con materiali diversi. Verranno illustrati esempi di analisi su diverse applicazioni.

##### ● **Insights into hyperspectral data and machine learning for the study of pigment materials.**

CAGLIO S.<sup>(1)</sup>, SEVESO A.<sup>(2)</sup>, GALLI A.<sup>(1)</sup>

<sup>(1)</sup> *Department of Material Science, Università di Milano Bicocca*

<sup>(2)</sup> *Department of Statistics and Quantitative Methods, Università di Milano Bicocca*

This study focuses on the automated identification of pigments in artworks using hyperspectral imaging and machine learning techniques. Hypercubes provides a detailed reflectance



spectrum for each pixel of the image, offering a unique spectral signature that enables accurate material recognition. Traditional hyperspectral data classification methods, while effective, can be computationally intensive. They rely on spectral similarity metrics, such as Spectral Angle Mapper, to identify materials by comparing their spectral signatures to known references. The research investigates novel alternatives, aiming to classify both pure and mixed pigments from lab samples and real paintings. Methods include deep learning classifiers and autoencoders, which are employed to extract meaningful features from spectral data while preserving the essential characteristics. Results indicate that machine learning techniques can offer a fast and reliable alternative to conventional methods, with strong generalisation across instruments and spectral resolutions. This contribution lays the foundation for more robust and scalable workflows for pigment identification in cultural heritage diagnostics.

● **Characterization of water fractions in ceramics for accurate RHX dating.**

MASPERO F., MARTINI M., UCCHEDDU G., PANZERI L., GALLI A.

*Dipartimento di Scienza dei Materiali, Università degli Studi di Milano Bicocca*

The results of the study on the molecular and ionic fractions of water in the ceramic matrix of materials dated using rehydroxylation (RHX) are presented. Following the experimental guidelines of previous studies., IR spectroscopy was applied to analyse the water fractions within the ceramic matrix. Specifically, samples successfully dated by RHX and samples with overestimated ages were analysed via FT-IR. The spectra were acquired after thermal treatments at increasing temperatures, up to 500 °C. The samples datable with RHX show a water release that stabilises between 200 °C and 300 °C, indicating a negligible component of interstitial water. In contrast, the overestimated samples exhibit continuous mass loss, suggesting a quantity of interstitial water comparable to the rehydroxylated fraction. The study of this difference, highlighted in the intensity graphs of the OH group peaks (3250  $\text{cm}^{-1}$  and 3450  $\text{cm}^{-1}$ ), appears to be a promising strategy to identify samples suitable for RHX dating.

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Aula 8, Section B, Edificio 19

ore 09:00 – 13:30

SEZIONE VII

**Didattica e storia della fisica**

Presiede: FAZIO C. (Università di Palermo)

Relazioni su invito

▲ **Le sfide dell'educazione alla sostenibilità: il punto di visita dell'insegnamento della Fisica.**

ONORATO P., SALMOIRAGHI A., OSS S.

*Laboratorio di Comunicazione delle Scienze Fisiche, Dipartimento di Fisica, Università degli Studi di Trento*

L'educazione scientifica ha un ruolo cruciale nel realizzare l'Agenda 2030 per lo sviluppo sostenibile, in particolare promuovendo l'alfabetizzazione scientifica come conoscenza che includa la capacità di comprendere come funziona la scienza e la sua interazione con la società ed eventualmente per poter prendere decisioni più informate riguardo alle questioni socio-scientifiche. L'educazione alla sostenibilità deve partire dal superamento della falsa concezione che essa sia una questione puramente ambientale. Partire dalla natura multidimensionale della sostenibilità richiede un approccio attento alla trans-disciplinarietà che comprenda non solo gli aspetti scientifici ma anche le dimensioni economiche e sociali. Insegnare la fisica in questo contesto più ampio, ci pone dinanzi alla sfida di educare alla cittadinanza e migliorare il rapporto tra scienza (scienziati), istituzioni e società civile, senza rinunciare ad affrontare i temi tipici della disciplina e a raggiungere gli obiettivi in termini di competenza e conoscenza della fisica. Saranno presentati alcuni esempi di attività che cercano di guardare alla sostenibilità dai diversi punti di vista delle varie discipline.

▲ **Sviluppare l'agency nella didattica della fisica: una prospettiva multidimensionale fra scienza, filosofia ed economia.**

TASQUIER G.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

La crisi climatica richiede di ripensare la didattica della fisica come spazio per sviluppare l'agency. Concetti chiave della fisica, come le retroazioni nei sistemi o l'incertezza nei modelli predittivi, offrono occasioni preziose per formare soggetti capaci di abitare la complessità della sostenibilità. Questo contributo propone una cornice teorica multidimensionale che integra scienza, filosofia ed economia e articola l'agency in tre dimensioni interrelate: Epistemic-driven, Ethical-reflective, Systemic-pragmatic. Verranno discussi modelli teorici, principi progettuali ed esempi di pratiche didattiche finalizzati a problematizzare la dicotomia sapere-azione e sostenere lo sviluppo di competenze critiche, riflessive e strategiche per affrontare scenari sempre più incerti e interconnessi.

▲ **L'inclusione sociale e il genere e il suo ruolo nei processi di apprendimento nell'ambito del PLS di Fisica.**

GALANO S.

*Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

Il Piano nazionale Lauree Scientifiche (PLS) di Fisica ha tra le sue finalità quelle di: i) mettere in atto azioni di orientamento con attenzione alla promozione dell'equilibrio di

genere nelle immatricolazioni; ii) prevenire il fenomeno dell'abbandono universitario supportando studenti e studentesse nel passaggio tra il primo e il secondo anno. All'interno della rete nazionale degli Atenei del PLS-Fisica, si è costituito il gruppo di lavoro "Gruppo 1 - l'inclusione sociale e il genere e il suo ruolo nei processi di apprendimento", che include i coordinatori delle sedi PLS-Fisica particolarmente interessati ad iniziative mirate a promuovere l'inclusione sociale e la parità di genere nei corsi di laurea in Fisica. Nell'intervento verranno presentati i principali progetti attivati dal Gruppo 1 nelle diverse sedi locali e a livello nazionale, tra cui un progetto di ricerca finalizzato ad investigare il ruolo del genere nei processi decisionali che possono concorrere al fenomeno del drop-out universitario nei corsi di laurea in Fisica.

### ▲ **Comprensione culturale della fisica: un'avventura PNLS.**

GILIBERTI M., LOVISETTI L.

*Dipartimento di Fisica, Università degli Studi di Milano*

L'importanza degli aspetti culturali della fisica nella formazione sta emergendo sempre più fortemente - tanto che uno dei gruppi tematici del GIREP, ha come tema proprio la comprensione culturale della fisica. Tuttavia, una ricerca condotta dal gruppo di Milano ha messo in luce come negli studenti di laurea magistrale e nei dottorandi in fisica la consapevolezza degli aspetti culturali della fisica sia pressoché del tutto assente e, quando presente, tali aspetti vengano confusi con la divulgazione. Il PNLS si è dotato di un gruppo di lavoro sugli aspetti culturali della fisica che ha svolto attività e promosso ricerche per esplorare come indagare teoricamente e promuovere una didattica che si interroghi sul significato di cultura scientifica è in particolare in fisica. Esso ha evidenziato che considerare gli aspetti culturali non significa solamente guardare i legami con la storia e la società, le ricadute tecnologiche e il pensiero filosofico, ma, soprattutto, vuol dire aprire a possibilità di pensiero basate sulla disciplina fisica e di interpretazione del mondo autenticamente critiche e personali, e di aiuto all'apprendimento della disciplina.

### ▲ **Le nuove indicazioni nazionali per la scuola, la riforma dell'accesso a Medicina, le lauree abilitanti: quali nuove opportunità per la Fisica?**

MONTI F.

*Dipartimento di Informatica, Università di Verona*

Proporrò una analisi volta a evidenziare alcune linee di sviluppo delle nuove indicazioni nazionali per la scuola, della riforma dell'accesso a Medicina, e della (probabile) attivazione delle lauree abilitanti in Fisica, investigando le possibili nuove opportunità che esse offrono per una maggiore valorizzazione del ruolo della fisica nella formazione delle giovani generazioni.

## Comunicazioni

### ● **Embracing complexity and uncertainties to deal with climate change challenges: an interdisciplinary module for preservice teacher education.**

MIANI L. <sup>(1)</sup>, BITSAKI C. <sup>(2)</sup>, METAXAS G. <sup>(2)</sup>, STAVROU D. <sup>(2)</sup>, LEVRINI O. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Bologna*

<sup>(2)</sup> *Department of Primary Education, University of Crete, Greece*

Climate change is one of humanity's greatest threats. In science education, its interdisciplinary and complex nature brings conceptual, epistemological, relational, and institutional challenges. To address these, we designed an interdisciplinary module to support preservice teachers in embracing complexity and managing uncertainty. Developed as part of the IDENTITIES project, the module integrates complexity and uncertainty: as conceptual content, to build a sustainability mindset; as epistemological activators to reflect on the nature

of science; and as boundary objects to enable dialogue across disciplines. Results from an international summer school show that working in an interdisciplinary setting helps future teachers uncover disciplinary assumptions that limit their ability to engage with complexity. At the same time, the trust in Newtonian classical linearity and determinism still represents a huge obstacle to developing sustainability competences. Criticalities that emerged from the implementation are our piece of evidence that contributes to arguing to what extent climate change represents a deep epistemological challenge.

● **Integrating physics education into an interdisciplinary framework to address the challenges of the ecological transition.**

CASALONE S., LEVRINI O.

*Università di Bologna*

This presentation outlines the project and the initial stages of research aimed at investigating how physics education can be integrated into an interdisciplinary framework to help high school students address the social challenges of the ecological transition. This research focuses on the social tensions triggered by renewable energy policies in Sardinia as a case study. While the region's renewable energy capacity has a strategic role in Italy's decarbonization efforts, many locals consider wind farm projects to be speculative ventures that threaten the island's landscapes and cultural heritage. A preliminary ethnographic investigation will describe these social tensions, examining their economic, political and symbolic underpinnings. Based on these findings, we will develop computational models of the conflict as educational tools to represent both its technological-scientific aspects and its socio-cultural dynamics. Finally, we will test these educational tools in schools within the communities involved in the study. If proven effective in representing the conflict, they may help students develop future-oriented agency competences.

● **Warning: dalla fisica a un progetto interdisciplinare, per riflettere sulle sfide delle società moderne.**

LEONE S., CERVELLI F., MAZZONI E.

*INFN, Sezione di Pisa*

Il progetto Warning è giunto quest'anno alla sua quinta edizione. Warning! nasce nel 2020 con lo scopo di sviluppare percorsi formativi interdisciplinari, rivolti principalmente a studenti e studentesse del triennio delle scuole superiori, sui temi dei grandi pericoli planetari e la fragilità ambientale. Visto il successo dell'iniziativa, negli anni successivi Warning si è rinnovato, proponendo diversi temi di riflessione: dagli scenari che si apriranno in un futuro prossimo a seguito delle innovazioni tecnologiche, all'insorgere di nuove questioni etiche; dall'affermarsi nel mercato del lavoro di nuove professioni, ad una analisi delle moderne teorie della complessità; dal rapporto dell'umanità con la natura, alle domande che l'uomo si pone sull'origine dell'Universo e la nascita della vita. Ogni ciclo era composto da quattro-cinque dibattiti in cui esperti da diverse discipline hanno trattato il tema in questione. Con l'approccio interdisciplinare si è sottolineata la centralità del metodo scientifico nell'affrontare problemi complessi. La fisica è stato il filo conduttore che ha accompagnato i partecipanti in questo viaggio attraverso molti settori di scienza.

● **Assessing interdisciplinary and future-oriented skills: the FEDORAS contribution.**

BRANCHETTI L., LEVRINI O., SATANASSI S.

*Università di Bologna*

The contribution will present FEDORAS, the Teacher Academy for a Future-oriented STEAM Education for a Sustainable World. FEDORAS mobilises five European Open Schooling

Networks to re-imagine secondary teacher education. Rooted in the EU-funded FEDORA, IDENTITIES, and SEAS projects, the Academy will develop and implement a comprehensive assessment approach to value changes in the school system along the three pillars of FEDORAS: interdisciplinarity, future-thinking, and new languages. This contribution zooms in on the Academy's interdisciplinary pillar and on how the research team approaches assessment across the three layers on which interdisciplinarity can be valued at school: Epistemic cognitive processes aimed to bridge disciplinary concepts to tackle complex problems; Relational dynamics aimed to foster dialogues among teachers of different disciplines and with external actors; Institutional changes, aimed to re-define norms, practices, and habits to turn schools into drivers of social innovation. Particular attention will be devoted to innovation in teacher education to promote suitable assessment practices.

● **La Citizen Science per avvicinare insegnanti e studenti alla ricerca scientifica: il caso della Citizen Science School Roma Technopole.**

POSTIGLIONE A. <sup>(1)</sup>, MAZZITELLI G. <sup>(1)</sup>, RICCI R. <sup>(1)</sup>, CERRATO S. <sup>(2)</sup>, BERTELLI S. <sup>(1)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali di Frascati

<sup>(2)</sup> European Citizen Science Association, Berlin, Germany

Nell'ambito delle attività di didattica informale e non-formale che possono avvicinare studenti e studentesse alla scienza e alla ricerca scientifica, la Citizen Science può rappresentare un esempio avvincente ed efficace. Essa, infatti, coinvolgendo i non-esperti nell'investigazione scientifica e nella raccolta dati a vari livelli, favorisce l'apprendimento sul campo del metodo scientifico, e stabilisce una connessione reale con il mondo della ricerca attraverso progetti concreti. Per questo, ai Laboratori Nazionali di Frascati dell'INFN abbiamo realizzato, in collaborazione con la European Citizen Science Association (ECSA), European Citizen Science Academy e Citizen Science Italia, una Citizen Science School rivolta a studenti delle scuole superiori, insegnanti, studenti universitari e ricercatori e incentrata sulle macroaree di ricerca del progetto Rome Technopole. In particolare, durante la scuola, il gruppo di lavoro su Fisica, energia e sostenibilità ha permesso di esplorare come la termodinamica, e la fisica in generale, siano fondamentali per creare una discussione informata e fertile sulla sostenibilità e sulla transizione energetica.

● **Questioning harmful hopes and supporting systemic thinking through a scenario-making board game.**

DE ZUANI CASSINA F., MIANI L., LEVRINI O.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

Education is a key tool for addressing the environmental crisis. Science educators can be crucial in helping to adopt a systemic approach to sustainability, working on competences such as critical thinking, problem framing, and future visioning. We present a course and a game, FyouTURES, designed to engage students with complexity, uncertainty, and decision-making in climate issues, to develop sustainability as a mindset. Students participated in scenario-making activities and simulated a decision-making process using an actual future climate simulator. Results from our study show that, even when driven by positive goals, students activated potentially harmful reasoning mechanisms deeply tied to the values of late modernity, such as efficiency, control, or optimisation. By doing so, their hope of finding a solution, based on linear and simplistic ways of reasoning, becomes harmful, as their outcomes reinforced social and economic inequalities. These scenario-building activities helped students recognise the limitations of non-systemic thinking and the need for an integrated approach to sustainability, focusing on the need to question potentially harmful sustainability approaches.

● **Fisica e gamification con Minecraft Education Edition: una sfida ai cambiamenti climatici.**

MARRARA S. <sup>(1)(2)(3)</sup>, ZAPPALÀ A. <sup>(2)</sup>, ANASTASI A. <sup>(2)</sup>, SEGRETO A. <sup>(2)</sup>, VASI S. <sup>(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Chimiche, Biologiche, Farmaceutiche ed Ambientali, Università degli Studi di Messina*

<sup>(2)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli Studi di Messina*

<sup>(3)</sup> *OPENFIS S.R.L., Messina*

La gamification e il Game-Based Learning (GBL) sono approcci innovativi utilizzati per coinvolgere i giocatori ed i più giovani in esperienze significative ed educative nell'ambito STEM e del cambiamento climatico. In questo contesto, utilizziamo Minecraft Education Edition come strumento per insegnare concetti relativi al cambiamento climatico, alla fisica ed all'energia pulita, giocando e prevenendo un aumento critico della temperatura globale. Il mondo di gioco, una rappresentazione semplificata della Terra, include diversi tipi di impianti di produzione di energia che vengono utilizzati per sostenere il consumo attuale previsto all'inizio del gioco. Inizialmente, le fonti di energia non rinnovabili prevalgono, rischiando il collasso planetario se non vengono modificate. L'obiettivo è raggiungere la neutralità climatica entro un limite di tempo, modificando le fonti energetiche, passando a quelle pulite e riducendo al minimo l'impatto sulla funzionalità del sistema.

● **Poweri Noi! Watt should we do? Un gioco da tavolo di squadra sulla transizione energetica e il cambiamento climatico.**

VERDI S. <sup>(1)</sup>, ZATTI L. <sup>(1)(2)</sup>, MONTAGNA P. <sup>(1)(2)</sup>, AIMÈ C. <sup>(3)(4)</sup>, ARMANETTI A. <sup>(5)</sup>, AURELIO D. <sup>(6)</sup>, BRAGHERI J. <sup>(1)</sup>, BUDASSI E. <sup>(1)(2)</sup>, FRANZETTI A. <sup>(1)</sup>, GHILARDI M. <sup>(1)</sup>, MARAGNANO D. <sup>(1)</sup>, RESTELLI S. <sup>(1)</sup>, SANTOSTASI D. <sup>(7)</sup>, TRUPIA D. <sup>(8)</sup>, VENTURINI S. <sup>(9)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Pavia*

<sup>(2)</sup> *INFN, Sezione di Pavia*

<sup>(3)</sup> *Dipartimento di Fisica, Università di Pisa*

<sup>(4)</sup> *INFN, Sezione di Pisa*

<sup>(5)</sup> *IMT Scuola Alti Studi, Lucca*

<sup>(6)</sup> *Dipartimento di Informatica, Università di Milano*

<sup>(7)</sup> *Liceo Scientifico Statale N. Copernico, Pavia*

<sup>(8)</sup> *ITAS C. Gallini, Voghera*

<sup>(9)</sup> *RSE-SpA Milano*

Per sensibilizzare i giovani riguardo l'impatto delle attività umane sul cambiamento climatico, è stato ideato un gioco da tavolo educativo per studenti delle scuole superiori. Sfruttando la gamification, il gioco mira a stimolare comportamenti sostenibili attraverso meccanismi ludici. I partecipanti, vestendo i panni di ministri dell'energia, devono prendere decisioni strategiche per migliorare la condizione economica e sociale della propria nazione. Un elemento chiave è la costruzione di centrali elettriche, caratterizzate da valori realistici di energia e inquinamento prodotto tratti da fonti scientifiche. Seppur presentato come gioco competitivo, lo scopo ultimo è affrontare il cambiamento climatico insieme agli avversari. Al termine dell'attività, si tiene un momento di confronto sui contenuti appresi. Il gioco è stato sperimentato al festival BergamoScienza (con circa 90 studenti), e in diverse scuole della provincia di Pavia e zone limitrofe (con circa 100 studenti), ottenendo riscontri molto positivi. Durante l'attività è prevista anche la sottomissione di un test per valutare l'efficacia didattica.

● **Il ruolo culturale della fisica nell'educazione.**

MONTALBANO V.

*Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena e INFN, Sezione di Pisa e AIF, Sezione di Siena*

L'insegnamento della fisica è previsto in ogni percorso di scuola secondaria, così come in tutti i corsi di laurea scientifici e tecnologici. La scienza moderna nasce dallo studio di fenomeni fisici e il suo metodo si è ampiamente diffuso in tutte le discipline scientifiche e tecnologiche. Poca attenzione viene però data nell'insegnamento agli aspetti culturali che possono essere rilevanti sia per comprendere le dinamiche della società contemporanea che per la formazione dei futuri cittadini. Quali aspetti possono essere sviluppati in un percorso interdisciplinare? Quali elementi di storia della scienza sono significativi nell'educazione civica? Lo scienziato vive e lavora nella società, ne è influenzato nel definire la sua etica professionale, le sue scelte possono permettere balzi in avanti della conoscenza, limitare le possibili applicazioni, provocare cambiamenti duraturi nelle economie degli stati così come nella vita dei singoli. Quali elementi inserire nell'educazione e quali metodologie suggerire agli insegnanti?

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Aula Multimediale C, Section C, Edificio 19

ore 09:00 – 13:30

### Simposio La fisica e l'industria

Presiede: VIVALDI F. (CAEN)

Relazioni su invito

#### ▲ Dai raggi cosmici all'agricoltura di precisione: la fisica al servizio dell'industria sostenibile.

STEVANATO L.

*Finapp, Montegrotto Terme*

L'incontro tra fisica fondamentale e applicazioni industriali ha aperto nuove frontiere in settori impensabili fino a pochi anni fa. Un esempio concreto è l'impiego della tecnologia Cosmic Ray Neutron Sensing (CRNS), nata da studi di fisica nucleare e oggi integrata in sistemi di monitoraggio ambientale per misurare l'umidità del suolo e la neve in tempo reale. Questa innovazione consente di migliorare l'efficienza dell'agricoltura, ridurre gli sprechi idrici, ma anche valutare l'impatto del cambiamento climatico e migliorare i sistemi di pre-allerta per disastri naturali quali frane, incendi e alluvioni. L'intervento racconterà come una competenza maturata in ambito accademico – lo sviluppo di un rivelatore di neutroni innovativo – sia stata applicata alla detection dei neutroni ambientali prodotti dai raggi cosmici e sensibili alla presenza d'acqua nell'ambiente, diventando così il cuore di una soluzione industriale concreta, sostenibile e già diffusa in molti Paesi. Finapp, spin-off dell'Università di Padova, rappresenta un viaggio tra ricerca, impresa e impatto reale e offre un nuovo strumento nuovo per affrontare sfide globali come il cambiamento climatico, la tutela della risorsa idrica e la sicurezza alimentare.

#### ▲ Quando la Fisica spicca il volo: la Flying DEMon s.r.l.

GIORDANO F. <sup>(1)</sup>, SERINI D. <sup>(2)</sup>, DI VENERE L. <sup>(2)</sup>, LOPORCHIO S. <sup>(1)</sup>, ALTOMARE C. <sup>(3)</sup>, MASTROSERIO A. <sup>(4)</sup>

<sup>(1)</sup> *Università degli Studi di Bari*

<sup>(2)</sup> *INFN, Sezione di Bari*

<sup>(3)</sup> *IMT s.r.l.*

<sup>(4)</sup> *Università degli Studi di Foggia*

Flying DEMon s.r.l. è una startup innovativa nata nel 2023 dall'esperienza di un gruppo di fisici sperimentali del Dipartimento Interateneo di Fisica dell'Università e del Politecnico di Bari e dell'Istituto Nazionale di Fisica Nucleare (INFN). L'azienda sviluppa soluzioni avanzate per l'analisi delle radiazioni ionizzanti (raggi X, gamma e particelle cariche), combinando strumentazione portatile di ultima generazione con software di elaborazione dati dedicati. Flying DEMon è specializzata in misure spettroscopiche rapide di radionuclidi, anche tramite l'impiego di droni, offrendo servizi per il monitoraggio ambientale, la caratterizzazione radiometrica di siti e applicazioni in ambito industriale e agricolo. Uno dei principali ambiti di innovazione è l'analisi della radioattività naturale del suolo per supportare la certificazione e valorizzazione dei terroir vitivinicoli, contribuendo a correlare la componente radiometrica alle caratteristiche qualitative dei vigneti. Flying DEMon opera come partner tecnologico per enti di ricerca, aziende agricole e istituzioni pubbliche, con l'obiettivo di trasferire competenze scientifiche in soluzioni operative ad alto impatto.

▲ **GEOexplorer: tecnologie, indagini e modelli per l'ambiente.**

MANTOVANI F. <sup>(1)</sup>, ALBÉRI M. <sup>(1)(2)</sup>, BARBAGLI A. <sup>(3)</sup>, COLONNA T. <sup>(3)</sup>, ELEK N.I. <sup>(1)(2)</sup>, GALLORINI F. <sup>(1)(3)</sup>, GUASTALDI E. <sup>(3)</sup>, HASNAIN G. <sup>(1)(2)</sup>, LOPANE N. <sup>(3)</sup>, PETRONE D. <sup>(1)(3)</sup>, PIERINI S. <sup>(3)</sup>, RAPTIS K.G.C. <sup>(1)(2)</sup>, STRATI V. <sup>(1)(2)</sup>

<sup>(1)</sup> *Department of Physics and Earth Sciences, University of Ferrara, Ferrara, Italy*

<sup>(2)</sup> *INFN, Ferrara Section, Ferrara, Italy*

<sup>(3)</sup> *GeoExplorer Impresa Sociale s.r.l., Arezzo, Italy*

GEOexplorer è una società nata nel 2014 come spin-off accademico del Centro per le Geotecnologie dell'Università di Siena. Costituita da un gruppo interdisciplinare di fisici, geologi, ingegneri e archeologi, GEOexplorer opera come impresa sociale, scelta che riflette l'impegno nel reinvestire interamente gli utili nello sviluppo dell'attività e nel potenziamento continuo del know-how aziendale. L'investimento in tecnologie proprietarie, software e algoritmi ha consentito alla società di occupare nicchie di mercato ad alta competitività e di collaborare con grandi realtà industriali attive su scala globale. Ad oggi ha realizzato oltre 300 progetti in 14 Paesi, contribuendo a numerosi programmi europei e operando in contesti complessi per grandi clienti industriali. La società integra attività di geofisica, idrogeologia, geomatica e monitoraggio ambientale.

▲ **ISOCORE SRL spin-off accademico dell'Università degli Studi della Campania "Luigi Vanvitelli": stato dell'arte e prospettive dopo il primo anno di attività nel campo delle analisi avanzate attraverso metodologie isotopiche ad elevata sensibilità.**

MARZAIOLI F., TERRASI F., D'ONOFRIO A., GIALANELLA L., PORZIO G., BUOMPANE R., ROCA V., PASSARIELLO I.

*Dipartimento di Matematica e Fisica, Università degli Studi della Campania "Luigi Vanvitelli", ISOCORE SRL, San Nicola La Strada, CE*

ISOCORE (ISOTopes and ChronOlogy SeRvicEs) SRL è una giovane spin-off accademica dell'Università degli Studi della Campania "Luigi Vanvitelli" (UCLV), nata dalla volontà di 8 ricercatori operanti da diversi decenni nel campo delle metodologie isotopiche applicate e di provenienza dall'area fisica sperimentale del Dipartimento di Matematica e Fisica. L'idea progettuale è stata finanziata da UCLV tramite un bando competitivo per la creazione di spin-off accademiche "Premio di attività di ricerca con impatto industriale 2022" promosso dall'Ufficio Trasferimento Tecnologico. Ad un anno dalla nascita ISOCORE SRL ha depositato un brevetto su scala nazionale, ha assunto una unità di personale e presentato il primo bilancio societario in attivo. In questo contributo verranno descritte le principali attività societarie con particolare enfasi alle prospettive di sviluppo.

▲ **MuonX —Imaging with muons.**

SARACINO G.

*Università di Napoli Federico II, INFN, Sezione di Napoli e MuonX*

At the dawn of the 20th century, the discovery of X-rays revolutionized the way we observe the human body and transformed medical diagnostics. For the first time, it became possible to examine the interior of the human body non-invasively, opening up a new frontier in medical imaging. This breakthrough not only advanced healthcare but also found applications beyond medicine, including industry and security screening. However, X-rays have inherent limitations. Their ability to penetrate matter is confined to only a few tens of centimetres, restricting their use for examining larger or denser objects. In nature, other forms of radiation possess properties that can overcome some of these limitations. Among these are muons —elementary particles that exhibit an extraordinary capacity to traverse matter, making them valuable tools for probing the internal structure of large, opaque objects. This



capability has given rise to a technique known as muon radiography, or muography. This method utilizes muons of cosmic origin to create detailed images of structures that are otherwise inaccessible using traditional radiation-based imaging techniques. Muography has been successfully employed in various fields, such as detecting hidden voids within the Egyptian pyramids, studying volcanoes, and exploring subsurface geological formations. Recognizing the potential of muography, MuonX was founded in 2022 through a collaboration between a spin-off of the University Federico II of Naples, Tecno In S.p.A. and the consortium Stress. MuonX is an innovative start-up that harnesses cutting-edge knowledge and technologies developed over decades of research in particle physics, specializes in muon radiography. This technology opens new possibilities for exploring the Earth's interior, large infrastructures, archaeological sites and more, offering insights that were previously unattainable with conventional methods or realise them in an economically competitive manner.

### ▲ Superconducting Nanowire Single-Photon Detectors (SNSPDs) as enabling technology for quantum applications.

SALVONI D. <sup>(1)(2)</sup>, ZHANG C. <sup>(1)(2)(3)</sup>, IENCO R.M. <sup>(2)</sup>, BRUSCINO C. <sup>(3)</sup>, ERCOLANO P. <sup>(3)</sup>, BUKHARI J. <sup>(3)(4)</sup>, PELUSO M. <sup>(3)</sup>, AURIEMMA F. <sup>(4)</sup>, EJRNAES M. <sup>(4)</sup>, PARLATO L. <sup>(3)</sup>, YOU L. <sup>(5)</sup>, PEPE G.P. <sup>(3)</sup>

<sup>(1)</sup> *Photon Technology Italy SRL, Naples, Italy*

<sup>(2)</sup> *Qunatech SRL, Naples, Italy*

<sup>(3)</sup> *Università degli Studi di Napoli Federico II, Naples, Italy*

<sup>(4)</sup> *CNR, Institute for SuPerconductors, INnovative materials, and devices, Pozzuoli, NA, Italy*

<sup>(5)</sup> *Shanghai Institute of Microsystem and Information Technology, Shanghai, PRC*

The advent of Superconducting Nanowire Single-Photon Detectors (SNSPDs) represents a transformative advancement in the field of quantum technologies. Indeed, as quantum systems evolve from proof-of-principle experiments to practical applications, the demand for high-performance single-photon detection becomes increasingly critical. SNSPDs have emerged as the leading detector technology in this domain, owing to their unique combination of high detection efficiency, low dark count rates, excellent timing resolution, and compatibility with a broad range of wavelengths, particularly in the telecom bands. In this work some applications of SNSPDs to quantum technologies are presented, with a focus on the achieved results, challenges and perspectives.

### ▲ Quantum Secure Communications.

ZAVATTA A.

*QTI s.r.l. e CNR-INO*

QTI s.r.l. (Quantum Telecommunications Italy) is an Italian Quantum Security company, providing industrial-grade systems and products for quantum networks. The company, based in Florence, was founded in October 2020 by a group of entrepreneurs, scientists, and researchers from the National Institute of Optics of the National Research Council (CNR-INO). QTI researchers and engineers develop and manufacture complex telecommunications network architectures based on QKD, with the vision of promoting the use of quantum technologies in industry, government, and defense to ensure the highest level of security for digital communications. In 2021, part of QTI was acquired by Telsy S.p.A., the cybersecurity and cryptography competence center of the TIM Group. The partnership between QTI and Telsy enables seamless integration of QTI's QKD system with Telsy's encryption systems. The positioning of this partnership within the TIM Group framework also provides a privileged opportunity for implementing QTI-Telsy solutions within the telecommunications networks. From its foundation, QTI has contributed with its experts to major tests, experiments, and

implemented national QKD networks in Italy and EU countries, serving multiple end-users. Among other achievements, it participated in the field testing of a three-state quantum key distribution scheme in the metropolitan area of Florence, as part of the Italian Quantum Backbone. QTI experts supported the first public demonstration of intergovernmental quantum communication between three nodes (Trieste, Ljubljana, and Rijeka) during the G20 Digital Ministers' Meeting. QTI is also a provider of QKD systems for the development of the Italian quantum communication network and for other EU Member States under the EuroQCI project.

▲ **Random Power, una piattaforma di generazione di bit di stato casuale basata su “Quantum Tunneling”.**

CACCIA M.

*Università dell'Insubria*

La casualità è quasi percepita con un senso di inquietudine o fastidio, come un elemento che riduce il controllo sulle nostre vite. Però, quando si tratta di proteggere la nostra vita digitale, e mantenerne il controllo, la casualità è essenziale. Infatti ogni protocollo di autenticazione, crittografia e protezione della privacy richiede chiavi e le chiavi sono generate a partire da numeri casuali. Random Power, nata da un atto di “serendipity” investigando le proprietà del rumore in sensori al silicio con sensibilità al singolo fotone, ha sviluppato una piattaforma di generatori di bit di stato casuale basata sull'analisi di serie temporali di impulsi auto-amplificati che originano da fenomeni di quantum tunneling. Il principio è implementato in una serie di dispositivi, tra i quali con chip sviluppato nel contesto di un progetto europeo approvato nell'ambito del programma ATTRACT, condotto in HORIZON 2020. Nel contributo, si ripercorrerà la storia di questa idea diventata una start-up, si presenteranno i risultati principali e lo stato della tecnologia, così come i prossimi passi.

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Aula Magna G.B.F. Basile, Edificio 7

ore 14:30 – 15:10

Sezione VI

**Fisica applicata, acceleratori e beni culturali**

Presiedono: MANTEGNA R. (Università di Palermo)

SERAFINI L. (INFN Sezione di Milano)

Relazione Generale

■ **Deciphering the unrolled Herculaneum papyri: Advances in imaging for revealing ancient texts.**

MILIANI C.

*CNR, Institute of Heritage Science*

Modern knowledge of ancient Greek philosophical schools largely derives from *Arrangement of Philosophers*, a substantial treatise by Philodemus of Gadara (110–30 BCE), considered the earliest surviving history of philosophy from antiquity. This work includes texts from the Epicurean Garden, one of the major Hellenistic philosophical schools, preserved almost exclusively in the carbonised Herculaneum papyri. These scrolls were unearthed between 1752 and 1754 during excavations commissioned by King Charles VII of Bourbon at the so-called Villa of the Papyri. This paper presents the results of non-invasive scientific analyses conducted on numerous unrolled papyri within the ERC-funded project GreekSchools, a multidisciplinary initiative aimed at reading and producing a new edition of Philodemus' essay. The scrolls were unrolled starting in 1753 by Abbot Antonio Piaggio using a custom mechanical device. Within this framework, techniques such as MA-XRF, multi- and hyperspectral imaging, pulsed thermography, high-definition digital infrared microscopy, and Reflectance Transformation Imaging (RTI) were applied. These advanced imaging methods, integrated with philological research through an open-source editorial platform, have significantly enhanced the legibility of many papyri. The results provide new insights into the physical characteristics of the scrolls, including layout, ink composition, and textual layering.

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Aula Magna G.B.F. Basile, Edificio 7

ore 15:10 – 16:10

### TAVOLA ROTONDA

#### Le prospettive e gli sviluppi delle imprese di interesse per i fisici

Interventi di:

Stefano Cattaneo, Cutlite Penta

Francesca Ferrazza, ENI

Angelo Geraci, Politecnico di Milano

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Aula Magna G.B.F. Basile, Edificio 7

ore 16:10 – 17:30

### Assemblea Generale dei Soci

L'Assemblea Generale dei Soci della Società Italiana di Fisica è convocata in occasione del Congresso Nazionale SIF 2025 in prima convocazione alle ore 15.40 e in seconda convocazione alle ore 16.10 di martedì 23 settembre 2025, l'Assemblea si riunirà nell'Aula Magna G.B.F. Basile, Edificio 7, Polo Didattico del Campus dell'Università di Palermo in Viale delle Scienze, con il seguente ordine del giorno:

- 1) Approvazione dell'ordine del giorno.
- 2) Nomina del Segretario Verbalizzante.
- 3) Relazione del Presidente.
- 4) La Commissione Didattica Permanente della SIF.  
*Intervento di Francesca Monti.*
- 5) Relazioni del Collegio dei Revisori dei Conti e approvazione dei bilanci consuntivi 2024.
- 6) Ratifica e nomina dei Revisori dei Conti.
- 7) Discussione e approvazione della Relazione del Presidente.
- 8) Varie ed eventuali.

Il Presidente della SIF  
ANGELA BRACCO

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Aula Magna G.B.F. Basile, Edificio 7

ore 17:30 – 18:10

Sezione III

**Astrofisica e fisica astroparticellare**

Presiedono: BETTINI A. (Università di Padova)

MICELA G. (INAF, Osservatorio Astronomico di Palermo)

Relazione Generale

■ **Km3NeT: la rivelazione di un neutrino da “record”.**

CUTTONE G. PER LA KM3NET COLLABORATION

*INFN, Laboratori Nazionali del Sud*

KM3NeT è una infrastruttura di ricerca europea dedicata allo studio dell’universo attraverso la rivelazione di neutrini di altissima energia ed allo studio delle proprietà del neutrino. Il telescopio sottomarino, denominato ARCA, è ottimizzato per lo studio di neutrino cosmici ed è attualmente in fase avanzata di realizzazione a 3500 metri di profondità, 100 km al largo di Portopalo di Capo Passero, in Sicilia, nel cuore del Mar Mediterraneo. Recentemente, la Collaborazione KM3NeT ha osservato un evento di eccezionale energia, associato a un neutrino cosmico. È stato rilevato un muone con energia stimata nell’ordine del petaelettronvolt (PeV). Considerata la sua direzione quasi orizzontale e l’energia estrema, è molto probabile che sia stato generato dall’interazione di un neutrino ancora più energetico nelle vicinanze del rivelatore sottomarino. L’energia dell’evento supera quella di qualsiasi neutrino osservato finora, suggerendo l’origine in un acceleratore cosmico ancora ignoto, oppure la prima evidenza di un neutrino cosmogenico, prodotto dall’interazione tra raggi cosmici ultra-energetici e fotoni del fondo cosmico a microonde presenti nell’universo primordiale e diffusi ovunque nello spazio. Questa osservazione rappresenta un potenziale punto di svolta nello studio dei fenomeni astrofisici più estremi e conferma il ruolo centrale di KM3NeT nell’ambito dell’astrofisica multimessaggera e della fisica delle alte energie.

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Aula Magna G.B.F. Basile, Edificio 7

ore 9:00 – 9:30

Assemblea Elettorale

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Aula Seminari C, Section C, Edificio 19

ore 10:00

Apertura Seggio Elettorale

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Aula Magna G.B.F. Basile, Edificio 7

ore 9:30 – 10:00

In occasione dell'International Year of Quantum Science and Technology (IYQ)

Presiede: BRACCO A. (Università di Milano)

Relazione Generale

■ **Hinc itur ad astra: l'Osservatorio Astronomico di Palermo e il suo plurisecolare contributo alla ricerca astronomica.**

CHINNICI I.

*INAF - Osservatorio Astronomico di Palermo*

Da oltre duecento anni l'Osservatorio Astronomico di Palermo si trova in prima fila nella ricerca astronomica, con contributi di grande rilevanza scientifica che ne hanno costellato il passato e ne illuminano il presente. Fin dalla sua fondazione, nel 1790, l'Osservatorio si distinse per l'eccellente qualità della sua strumentazione, costituita da strumenti all'avanguardia quali il Cerchio di Ramsden, fortemente voluto dal primo direttore Giuseppe Piazzi. Questo gli consentì nel 1801 la scoperta del primo asteroide, Cerere (oggi classificato come pianeta nano) e la redazione di un accurato catalogo stellare la cui prima edizione venne pubblicata nel 1803 e la seconda, riveduta ed ampliata, nel 1814. Oltre a vari altri contributi, quali osservazioni di eclissi e transiti planetari, scoperte di ammassi stellari e comete da parte di vari astronomi in forza a questa istituzione scientifica, nella seconda metà dell'Ottocento, va certamente ricordato il contributo pionieristico dell'Osservatorio di Palermo nello sviluppo dell'astrofisica, e in particolare della fisica solare. Grazie anche all'acquisizione di un ottimo telescopio Merz, che Pietro Tacchini fu tra i primi ad utilizzare per osservazioni spettroscopiche del sole, l'Osservatorio palermitano divenne uno dei centri più attivi in questo settore, contribuendo alla fondazione della Società degli Spettroscopisti Italiani e alla redazione delle sue Memorie, oggi considerate la prima rivista di astrofisica mai realizzata. Negli anni Settanta, dopo un periodo di declino, l'Osservatorio fu rilanciato da Giuseppe Salvatore Vaiana, pioniere nel campo dell'astrofisica spaziale nei raggi X, che inserì l'Osservatorio in una rete di collaborazioni internazionali e volle la realizzazione del laboratorio XACT, che numerosi contributi ha dato alla strumentazione delle principali missioni X spaziali. Ancora oggi, l'Osservatorio si muove su linee di ricerca all'avanguardia quali formazione stellare, esopianeti, resti di supernova, ecc. mantenendo alta la sua tradizione scientifica.

Aula Magna G.B.F. Basile, Edificio 7

ore 10:00 – 13:30

## SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: PIRRONE S. (INFN, Sezione di Catania)

Relazioni su invito

**▲ Investigation of the symmetry energy in the high-density regime: the ASY-EOS II experiment at GSI.**

RUSSOTTO P. ON BEHALF OF R3B AND CHIRONE COLLABORATIONS

*INFN, Laboratori Nazionali del Sud, Catania*

The R3B collaboration has recently measured the Au+Au collisions at beam energies of 280, 400, 600 and 1000 AMeV in the S122 experiment at GSI (Darmstadt, Germany). The experiment has been carried out by coupling the new KRAB detector, developed at IFJ in Krakow (Poland), 8 rings of the CHIMERA multi-detector (Catania, Italy) and the detectors Los, TofD and NeuLAND of the R3B collaboration. The experiment aims to measure the excitation function of the neutron-to-proton elliptic flow ratio to constrain the symmetry energy of the nuclear matter equation of state (EOS) at densities above the saturation one ( $\rho_0$ ). The experiment and preliminary results will be presented.

**▲ Exploring the Terra incognita and the super heavy nuclei stability island of the nuclides' chart: the approach of the FORTE experiment.**

VARDACI E.

*Dipartimento di Fisica, Università degli Studi di Napoli "Federico II" e INFN, Sezione di Napoli*

The Terra Incognita (TI) and the Island of Stability of the Super Heavy Nuclei (SHN) are regions of the Segre's chart where nuclides properties are unknown, though are very important for several reasons. For instance, the r-process, claimed to be the origin of the nucleosynthesis of the elements heavier than iron, fully crosses the TI. Multinucleon transfer (MNT) at Coulomb barrier constitutes the most promising mechanism capable of producing nuclei in the TI. MNT is a substantially unknown process due to its complexity as a many-body process and to the lack of comprehensive data set. The SHN Island of stability was predicted in 1966 at  $Z = 114$  and  $N = 184$ . There are experimental indications that such an island of neutron-rich nuclei does exist. However, the production of such nuclei, at the center of the island, is impossible with stable beams, and even the production via fusion of the nuclei in the surrounding area is dramatically limited by the competition of fusion with quasi-fission. The presentation will focus on the approach of the FORTE experiment, namely, a strategy to study MNT and retrieve indirect information on the occurrence and location of the island of SHN.

**▲ Plasmi magnetizzati per lo studio di decadimenti  $\beta$  di interesse astrofisico: il progetto PANDORA.**

MASCALI D. PANDORA COLLABORATION

*INFN, Laboratori Nazionali del Sud, Catania e Dipartimento di Fisica e Astronomia, Università di Catania e Centro Siciliano di Fisica Nucleare e Struttura della Materia*

Lo studio delle abbondanze chimiche nel cosmo si basa sui processi di nucleosintesi s- e r-, dove la cattura di neutroni (lenta o rapida) e i successivi decadimenti  $\beta$  determinano la

formazione degli elementi pesanti. I modelli astrofisici dipendono criticamente dalle sezioni d'urto neutroniche e dai tassi di decadimento  $\beta$ , che in plasmi altamente ionizzati possono variare anche di ordini di grandezza rispetto alle condizioni terrestri. Il progetto PANDORA dell'INFN, unico a livello internazionale, mira a misurare questi decadimenti in plasmi stellari emulati in laboratorio. La facility, in costruzione ai LNS, utilizza una trappola magnetica superconduttiva per confinare plasmi generati da microonde (densità  $\sim 10^{13} \text{ cm}^{-3}$ , temperature fino a 30 keV). Un array di 14 rivelatori HpGe misurerà i raggi emessi durante i decadimenti, correlati alle proprietà termodinamiche del plasma con un innovativo sistema multi-diagnostico. Tra i casi-studio principali:  $^{94}\text{Nb}$ ,  $^{134}\text{Cs}$  e  $^{176}\text{Lu}$  (decadimenti  $\beta$ ), Se e Zr per l'ulteriore opportunità offerta da PANDORA, ossia analizzare l'opacità ottica degli ejecta prodotti nella fusione di stelle di neutroni (kilonove). L'operatività è prevista dal 2026.

## Comunicazioni

### ● Novel CZT Detectors for kaonic atoms spectroscopy.

ARTIBANI F. <sup>(1)</sup>, CURCEANU C. <sup>(2)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali di Frascati

<sup>(2)</sup> Università di Roma Tre

Kaonic atoms spectroscopy provides essential observables for investigating low-energy strong interactions in systems with strangeness. I shall present an overview of the SIDDHARTA-2 collaboration's efforts in this field, with a particular focus on the development and first use of a novel Cadmium-Zinc-Telluride (CZT) detector system for studying intermediate-mass kaonic atoms. This innovative detection system, applied for the first time in fundamental physics research at a collider, extends the accessible energy range of kaonic atoms spectroscopy to the hundreds of keV. During the first data-taking campaign at the DAΦNE collider in Italy, the collaboration successfully measured kaonic fluorine and kaonic aluminium transitions, highlighting the detector's potential for advancing kaonic atom studies. These results pave the way for further applications at DAΦNE and J-PARC in Japan. Ultimately, these developments aim to refine our understanding of kaon-multinucleon low-energy strong interactions by enabling high-precision measurements of intermediate-mass kaonic atoms.

### ● High-precision kaonic atom measurements with SIDDHARTA-2 at the DAΦNE.

CLOZZA F., CURCEANU C.

*Università degli Studi di Roma Tor Vergata e INFN, Laboratori Nazionali di Frascati*

Low-energy QCD, the theory within the Standard Model that describes the strong interaction, still lacks fundamental experimental input to advance its understanding. Among these contributions, kaonic atom X-ray spectroscopy stands out as a unique gateway for probing the interaction between antikaons and nucleons at threshold energy. This research has significant implications for particle and nuclear physics, as well as astrophysics, particularly in understanding neutron stars and their equation of state. By combining the exceptional quality of the low-energy kaon beam provided by the DAΦNE collider at INFN-LNF (Italy) with cutting-edge experimental techniques, such as fast and highly precise X-ray spectroscopy detectors like Silicon Drift Detectors, the SIDDHARTA-2 collaboration has performed groundbreaking measurements of a series of kaonic atom X-ray transitions, including the first-ever measurement of kaonic deuterium. I will introduce the SIDDHARTA-2 scientific case, the experiment, and the results obtained in measuring various kaonic atoms, such as helium-4 and neon, along with a preliminary outcome on kaonic deuterium.



● **Studio della struttura dei nuclei leggeri in collisioni  $^{12}\text{C} + ^{12}\text{C}$ .**

DE ROSA A. PER LA COLLABORAZIONE NUCL-EX

*Università degli studi di Napoli Federico II e INFN, Sezione di Napoli*

Questa comunicazione discute un recente studio delle collisioni  $^{12}\text{C} + ^{12}\text{C}$  all'energia incidente di 8.75 MeV per nucleone attraverso i multi-rivelatori INDRA e FAZIA a GANIL. Tali collisioni sono un mezzo particolarmente efficace per investigare la struttura di numerosi nuclei leggeri nelle vicinanze del carbonio. Ad esempio, eventi di scattering inelastico o doppio inelastico possono essere usati per sondare la struttura del carbonio-12, mentre reazioni in cui uno o più nucleone sono trasferiti dal proiettile al bersaglio permettono di accedere agli stati fondamentali o ai primi stati eccitati di nuclei quali: carbonio-13, carbonio-11, azoto-13, boro-11, ecc. Le caratteristiche peculiari di INDRA e FAZIA consentono di identificare una grande varietà di particelle e ioni, caratterizzando in maniera completa o quasi completa gli eventi di collisione. Alcuni risultati preliminari saranno discussi nella comunicazione.

● **Equilibratura dell'isospin in collisioni nucleari indotte da Zn-70 alle energie di Fermi.**

NADDEO G.

*Università di Napoli Federico II*

L'investigazione dei fenomeni di trasporto di isospin in collisioni tra ioni pesanti è un potente strumento per sondare in laboratorio le proprietà dell'Equazione di Stato (EoS) della materia nucleare, in condizioni spesso lontane dalla saturazione. Le informazioni che ne derivano sono rilevanti anche per la descrizione delle proprietà microscopiche di complicati oggetti astrofisici come le stelle di neutroni. In questa comunicazione sarà discusso un esperimento che ha come scopo la misura del tasso di equilibratura dell'isospin in collisioni indotte da un fascio di Zn-70 a 35 MeV/nucleone. Un complesso sistema di rivelazione, costituito dall'accoppiamento dei multi-rivelatori INDRA e FAZIA a GANIL, è usato per selezionare eventi ternari in cui il cosiddetto quasi-proiettile si rompe in due frammenti. Il tasso di equilibratura dell'isospin si può dedurre dalla variazione della composizione isotopica di tali frammenti in funzione del tempo di rottura del quasi-proiettile.

● **Studio di collisioni centrali per il sistema  $^{58}\text{Ni} + ^{40}\text{Ca}$  a 35 AMeV e l'equazione di stato della materia nucleare.**

GAMBERA E. <sup>(1)(2)</sup>, COLONNA M. <sup>(3)</sup>, GERACI E. <sup>(1)(2)(5)</sup>, CARDELLA G. <sup>(2)</sup>, DE FILIPPO E. <sup>(2)</sup>, GNOFFO B. <sup>(1)(2)</sup>, MAIOLINO C. <sup>(3)</sup>, MARTORANA N.S. <sup>(2)</sup>, PAGANO E.V. <sup>(3)</sup>, PIRRONE S. <sup>(2)</sup>, POLITI G. <sup>(1)(2)</sup>, RIZZO F. <sup>(1)(3)(5)</sup>, RUSSOTTO P. <sup>(3)</sup>, TRIMARCHI M. <sup>(2)(4)</sup>

<sup>(1)</sup> Dipartimento di Fisica e Astronomia, Università degli Studi di Catania

<sup>(2)</sup> INFN, Sezione di Catania

<sup>(3)</sup> INFN, Laboratori Nazionali del Sud, Catania

<sup>(4)</sup> MIFT, Università degli Studi di Messina

<sup>(5)</sup> Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania

Lo studio della multi-frammentazione riveste un'importanza cruciale per la comprensione della materia nucleare a densità inferiori rispetto alla densità di saturazione. A tale scopo, la reazione nucleare  $^{58}\text{Ni} + ^{40}\text{Ca}$  a un'energia incidente di 35 AMeV, è stata analizzata nell'ambito dell'esperimento THERMO, condotto presso l'INFN-LNS. L'esperimento ha impiegato il ciclotrone superconduttore e il multi-rivelatore CHIMERA (4 $\pi$ ). Grazie alle peculiari caratteristiche del rivelatore CHIMERA, è stato possibile analizzare in dettaglio le proprietà dei frammenti emessi in collisioni centrali. Le osservabili sperimentali sono state confrontate con le previsioni teoriche fornite da un approccio dinamico basato sul modello Boltzmann-Langevin-One-Body (BLOB). Un'analisi particolarmente significativa ha riguardato la descrizione, nel modello, del termine di asimmetria (asy-stiffness) contenuto

nell'equazione di stato della materia nucleare, al fine di evidenziare le osservabili sperimentali più sensibili a questo ingrediente; tra esse la distribuzione di molteplicità dei frammenti di massa intermedia (IMF) ha evidenziato una notevole sensibilità.

● **Decadimento beta del  $^{113\text{m}}\text{Cd}$ .**

LEONCINI A. <sup>(1)(2)</sup>, BELLI P. <sup>(1)(2)</sup>, BERNABEI R. <sup>(1)(2)</sup>, CAPPELLA F. <sup>(3)(4)</sup>, CARACCIOLO V. <sup>(1)(2)</sup>, CERULLI R. <sup>(1)(2)(1)</sup>, DANEVICH F.A. <sup>(2)(5)(1)</sup>, FERELLA F. <sup>(6)(1)</sup>, INCICCHITTI A. <sup>(3)(4)(1)</sup>, KASPEROVYCH D.V. <sup>(5)</sup>, KLAVDIENKO V.R. <sup>(5)</sup>, KOBYCHEV V.V. <sup>(5)</sup>, LAUBENSTEIN M. <sup>(6)</sup>, NISI S. <sup>(6)</sup>, PODA D.V. <sup>(7)</sup>, POLISCHUK O.G. <sup>(5)</sup>, RAMALHO M. <sup>(8)(9)</sup>, SUHONEN J. <sup>(8)(10)</sup>, TRETYAK V.I. <sup>(5)(6)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Roma Tor Vergata*

<sup>(2)</sup> *INFN, Sezione di Roma Tor Vergata*

<sup>(3)</sup> *INFN, Sezione Roma*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Roma La Sapienza*

<sup>(5)</sup> *Institute for Nuclear Research of NASU, Kyiv, Ukraine*

<sup>(6)</sup> *INFN, Laboratori Nazionali del Gran Sasso, Assergi*

<sup>(7)</sup> *Université Paris-Saclay, CNRS/IN2P3, IJCLab, Orsay, France*

<sup>(8)</sup> *Department of Physics, University of Jyväskylä, Finland*

<sup>(9)</sup> *School of Physics, Engineering and Technology, University of York, UK*

<sup>(10)</sup> *International Centre for Advanced Training and Research in Physics, Bucharest-Magurele, Romania*

Il decadimento  $\beta$  primo-proibito non unico del  $^{113\text{m}}\text{Cd}$  è stato studiato presso i LNGS, utilizzando un cristallo scintillatore di  $^{106}\text{CdWO}_4$  arricchito in  $^{106}\text{Cd}$  e contaminato da  $^{113\text{m}}\text{Cd}$  a un livello di  $\sim (14 - 28)$  Bq. Analizzando lo spettro  $\beta$  in condizioni di basso fondo, considerando i dati raccolti nel 2009, 2015 e 2023, è stato determinato un tempo di dimezzamento  $T_{1/2}$  del decadimento  $\beta$  del  $^{113\text{m}}\text{Cd}$  pari a 13.58(22) anni. Per la prima volta è stata studiata sperimentalmente la forma spettrale del decadimento  $\beta$  di  $^{113\text{m}}\text{Cd}$  e confrontata con calcoli teorici basati sul modello a shell, includendo gli effetti del guscio elettronico. Tramite spettrometria  $\gamma$  a bassissimo fondo con rivelatori HPGe, sono stati affinati il branching ratio del decadimento isomerico, pari a 0,0792(21)%, e l'energia  $\gamma$  della transizione verso lo stato fondamentale di  $^{113\text{m}}\text{Cd}$ , risultata di 263,36(4) keV. Infine, è stato stabilito per la prima volta un limite sul  $T_{1/2}$  per il decadimento  $\beta$  di  $^{113\text{m}}\text{Cd}$  verso lo stato metastabile a 391,699 keV di  $^{113}\text{In}$ :  $T_{1/2} \geq 8.6 \times 10^6$  anni.

● **Tracking the evolution of nuclear structure in neon isotopes toward the N = 20 Island of Inversion.**

GENNA D. <sup>(1)</sup>, BOTTONI S. <sup>(1)</sup>, BENZONI G. <sup>(1)</sup>, WIMMER K. <sup>(2)</sup>, AGUILERA P. <sup>(3)</sup>, DRENT F. <sup>(2)</sup>, RECCHIA F. <sup>(3)</sup>, ANDREETTA G. <sup>(3)</sup>, ANGELINI F. <sup>(3)</sup>, BALOGH M. <sup>(4)</sup>, BARDAK J. <sup>(2)(5)</sup>, BENITO J. <sup>(3)</sup>, BLES B. <sup>(2)(5)</sup>, BRACCO A. <sup>(1)</sup>, BRUGNARA D. <sup>(4)</sup>, CAROLLO S. <sup>(3)</sup>, CHEN Z. <sup>(2)</sup>, CORRADI L. <sup>(4)</sup>, CORBARI G. <sup>(1)</sup>, CRESPI F. C. L. <sup>(1)</sup>, DEL FABBRO M. <sup>(3)</sup>, ERTOPRAK A. <sup>(4)</sup>, ESCUDEIRO R. <sup>(3)</sup>, FERRERA GONZALEZ C. <sup>(6)</sup>, FIORETTO E. <sup>(4)</sup>, GALTAROSSA F. <sup>(3)</sup>, GIAZ A. <sup>(1)</sup>, GOASDUFF A. <sup>(4)</sup>, GONGORA SERVIN B. <sup>(4)</sup>, GOTTARDO A. <sup>(4)</sup>, GOZZELINO A. <sup>(4)</sup>, JOVANCEVIC N. <sup>(5)</sup>, JUNGCLAUS A. <sup>(6)</sup>, KRÖLL T. <sup>(7)</sup>, KOSIR G. <sup>(8)</sup>, LASKAR M. S. R. <sup>(1)</sup>, LEONI S. <sup>(1)</sup>, LUCIANI M. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Milano e INFN, Sezione di Milano*

<sup>(2)</sup> *GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany*

<sup>(3)</sup> *Dipartimento di Fisica, Università degli Studi di Padova e INFN, Sezione di Padova*

<sup>(4)</sup> *INFN, Laboratori Nazionali di Legnaro*

<sup>(5)</sup> *Faculty of Sciences, University of Novi Sad, Serbia*

<sup>(6)</sup> *Instituto de Estructura de la Materia, CSIC, Madrid, Spain*

<sup>(7)</sup> *Department of Physics, Technische Universität Darmstadt, Germany*

<sup>(8)</sup> *Jožef Stefan Institute, Ljubljana, Slovenia*

<sup>(9)</sup> *Dipartimento di Fisica, Università degli Studi di Firenze e INFN, Sezione di Firenze*

<sup>(10)</sup> *Département de Physique, Université Libre de Bruxelles, Belgium*

<sup>(11)</sup> *Department of Physics, Stockholm University, Sweden*

We present recent results obtained in the  $^{22}\text{Ne} + ^{238}\text{U}$  and  $^{26}\text{Mg} + ^{238}\text{U}$  multi-nucleon transfer experiments performed at Legnaro National Laboratories with the AGATA-PRISMA setup, aiming at exploring the transition of light nuclei into the  $N = 20$  Island of Inversion. This study is primarily focused on the evolution of negative parity states from the fp shell, locating excited intruder configurations, and tracking the development of quadrupole and octupole collectivity in Ne and Mg isotopes. The AGATA  $\gamma$  array, coupled with the PRISMA magnetic spectrometer, allowed us to detect ion- $\gamma$  coincidences and to achieve sub-picosecond lifetimes of excited states via the DSAM technique. Preliminary findings on the  $\gamma$  decay and lifetimes of neutron-rich  $^{23-26}\text{Ne}$  isotopes will be discussed along with state-of-the-art calculations, including very recent ab-initio predictions.

### ● Positronium cooling in AEgIS and PsICO.

CHEHAIMI A. <sup>(1)(2)</sup>, CARAVITA R. <sup>(2)</sup>, RIENÄCKER B. <sup>(3)</sup>, MARIAZZI S. <sup>(1)(2)</sup>, BRUSA R. S. <sup>(1)(2)</sup> ON BEHALF OF THE AEGIS/AD-6 COLLABORATION

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Trento*

<sup>(2)</sup> *TIFPA/INFN Trento*

<sup>(3)</sup> *Department of Physics, University of Liverpool, UK*

The AEgIS (Antimatter Experiment: gravity, Interferometry, Spectroscopy) experiment at CERN and the PsICO (Positronium Inertial and Correlation Observations) experiment at the Antimatter Laboratory of the University of Trento, have a common history of research on low energy antimatter. AEgIS aims at the production of an antihydrogen beam via charge exchange reaction between antiprotons and Positronium (Ps) in Rydberg states, accessed via a two-step excitation scheme passing from the  $n=3$  manifold. Here, the beam will be employed to test the weak equivalence principle on baryonic antimatter. PsICO has the aim to study the entanglement of the 3 gammas emitted by the annihilation of well-defined triplet spin states of Ps, and to measure gravity effects on this hybrid matter-antimatter leptonic system using the long lived metastable  $2^3S$ -Ps. Ps production and laser manipulation are the core of both experiments. In particular, recently demonstrated Ps laser cooling plays an important role. Here, we report on the latest laser cooling tests performed on an already cryogenic Ps cloud, and we present its planned application on both AEgIS and PsICO experiments.

### ● Investigations on $\eta'$ photoproduction off quasi-free neutron at Graal.

RIGGIO A.

*Dipartimento MIFT, Università di Messina e INFN, Sezione di Catania*

An investigation on  $\eta'$  photoproduction on quasi-free neutron (Deuterium target) is presented, by showing a preliminary estimation of Beam Asimmetry  $\Sigma$  as a function of polar angle in the center-of-mass system near the threshold by analyzing the experimental data of the GRAAL experiment. The  $\eta'$  photoproduction channel is useful because it acts as an isospin filter, allowing the selection of only one-half isospin resonances. The preliminary  $\Sigma$  measurements for the  $\eta'$  photoproduction off neutron was performed in the energy interval of the interacting  $\gamma$  photon [1447-1475] MeV for five bins in the  $\Theta$ . The present estimations have been compared with the data on the proton channel, published by the GRAAL experiment, and they are consistent.

● **Novel insights into strange quark hadronization through measurements of (multi-)strange hadron production in small collision systems using the ALICE experiment.**

PUCILLO S.

*Università di Salerno*

Among the key results from LHC Run 1 and Run 2 is the observation of enhanced (multi-)strange to non-strange hadron production in small collision systems, increasing with multiplicity and reaching values similar to peripheral Pb–Pb collisions. To further investigate the production mechanisms, a novel event-by-event counting method is used to extract full multiplicity distributions of strange particles ( $P(nS)$ ), extending the study beyond average yields and probing the connection between charged-particle and strangeness production. In this contribution, the first ALICE results on the multiplicity distributions of  $K_S^0$ ,  $\Lambda$ ,  $\Xi$ , and  $\Omega$  particles in pp collisions at  $\sqrt{s} = 5.02$  TeV are presented. Additionally, particle yield ratios with exact strangeness balance ( $\Delta S = 0$ ), as well as cases exhibiting strangeness enhancement ( $\Delta S > 0$ ), are studied as a function of charged-particle multiplicity. The results are compared to state-of-the-art phenomenological models implemented in widely used Monte Carlo event generators, providing increased sensitivity to the underlying mechanisms of strangeness production.

● **Probing short-range correlations in heavy-ion double charge exchange reactions.**

GAROFALO C. <sup>(1)</sup>(<sup>2</sup>), CAPPUZZELLO F. <sup>(1)</sup>(<sup>2</sup>), CAVALLARO M. <sup>(2)</sup>, LENSKE H. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia “Ettore Majorana”, Università di Catania, Catania, Italy*

<sup>(2)</sup> *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy*

<sup>(3)</sup> *Institut für Theoretische Physik, Justus-Liebig-Universität Giessen, Giessen, Germany*

Heavy-ion Double Charge Exchange (DCE) reactions, characterized by high momentum transfer, provide a powerful tool to investigate short-range nuclear correlations beyond the mean-field in Nuclear Matrix Elements (NMEs). This is of great interest for probing the nuclear counterpart of the neutrinoless double-beta ( $0\nu\beta\beta$ ) decay. In this respect, the NUMEN project aims to constrain NME calculations by studying a broad range of heavy-ion-induced DCE reactions. One of the three mechanisms through which DCE reaction can proceed is the Majorana Double Charge Exchange (MDCE) mechanism. This involves meson exchange and is driven by an effective rank-2 isotensor interaction arising from off-shell pion-nucleon DCE scattering. Microscopic calculations of MDCE NMEs have been performed, where pion potentials act as the strong interaction counterparts to the  $0\nu\beta\beta$  neutrino potentials. The multipole structure of pion potentials and NMEs will be discussed and first preliminary results for the theoretical cross-section angular distributions will be presented and compared with experimental data.

Aula 11, Section C, Edificio 19

ore 10:00 – 13:30

## SEZIONE II

**Fisica della materia**

Presiede: TROMBETTONI A. (Università di Trieste)

Relazioni su invito

▲ **Ultrafast imaging of ytterbium atom arrays.**SCAZZA F. <sup>(1)(2)</sup>, MUZI FALCONI A. <sup>(1)</sup>, PANZA R. <sup>(1)(2)</sup>, SBERNARDORI S. <sup>(1)(2)</sup>, ABDEL KARIM O. <sup>(2)</sup>, FORTI R. <sup>(1)</sup>, MARINELLI M. <sup>(1)</sup><sup>(1)</sup> *Dipartimento di Fisica, Università di Trieste*<sup>(2)</sup> *CNR-INO, Trieste*

Detecting and manipulating individual atoms with high fidelity is essential for quantum simulation, metrology and, with even more stringent requirements, for quantum computing applications. I will present results of a novel ytterbium atom array experimental platform developed in Trieste. I will focus on the ultrafast single-atom imaging of individual tweezer-trapped atoms obtained by addressing the broad 1S0-1P1 transition, reaching near-unity single-atom detection fidelity and survival probability with few-microseconds illumination time. Beyond single-atom detection, we extend this ultrafast imaging scheme to the detection of multiple atoms in free space with single-particle resolution. By preparing and releasing multiply filled traps, we demonstrate single-atom-resolved detection without parity projection, both for short and long time-of-flights. This capability will enable new explorations of correlated many-body dynamics in tweezer-trapped atomic ensembles.

▲ **Quantum simulation of the Hall effect in strongly interacting fermions.**

FALLANI L.

*Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze*

I will present the results of recent experiments performed with ultracold atoms in optical lattices, in the presence of strong atom-atom interactions and coherent laser driving between different internal states, which implements the action of an external magnetic field on effectively charged particles. With this platform we have performed a quantum simulation of the Hall effect, with full control on the microscopic dynamics of the carriers, which enabled us to measure a strong dependence of the Hall response upon changing atom-atom interactions and the emergence of an universal regime in the strongly interacting limit. I will then discuss recent developments with the measurement of Hall voltages and Hall resistances, which provide a direct connection between quantum simulations and measured electric quantities in solid-state systems.

▲ **Scaling law for nonlinear light focusing via wavefront shaping in second-order disordered photonic media.**SAVO R. <sup>(1)</sup>, RAJU M. <sup>(1)</sup>, COCCETTI F. <sup>(1)</sup>, MORANDI A. <sup>(2)</sup>, GRANGE R. <sup>(2)</sup>, CONTI C. <sup>(1)(3)</sup><sup>(1)</sup> *Centro Ricerche Enrico Fermi, CREF, Rome, Italy*<sup>(2)</sup> *ETH Zurich, Department of Physics, Institute for Quantum Electronics, Optical Nanomaterial Group, Zurich, Switzerland*<sup>(3)</sup> *Department of Physics, University Sapienza, Rome, Italy*

Optical wavefront shaping has revolutionized the field of complex photonics enabling active control of light propagation in complex scattering media. In feedback-based focusing of light

through optical disorder, the linear universal law governing the scaling of the maximum focusing enhancement *vs.* the number of controlled input channels has been a fundamental benchmark for experiments and theory. Here we consider second-order  $\chi^2$  disordered photonic media, specifically disordered polycrystalline assemblies of lithium niobate nanocubes, which combine strong scattering with nonlinear light generation. We provide first-time evidence of a linear scaling law for the enhancement of the second harmonic generation (SHG) obtained through adaptive focusing of the SHG in transmission configuration. We argue that the observed behavior demonstrates effective control over multiply scattered trajectories of nonlinear light and evidence that diagonal elements of the scattering tensor of the nonlinear disordered medium dominate over off-diagonal cross-terms in the focusing optimization process. These results provide insight for using feedback-based nonlinear focusing in optical computing architectures such as Ising machines, neural networks and free-space circuit.

Comunicazioni

● **Stripes in binary mixtures of lattice gases.**

COSTA G., PRESTIPINO S.

*Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli Studi di Messina*

When two molecular species are mixed together, a variety of self-assembled phases can emerge, depending on the nature of like and unlike interactions. Among them, stripes hold a prominent role in materials science, since they are useful for the design of functional materials, with applications in optoelectronics, sensing, and biomedicine. In a purely classical setting, an open question concerns the specific features that particle interactions should have to promote stripe order at low temperature. Here we address this challenge for a binary mixture of lattice gases, for which we compute the full phase diagram for a wide spectrum of cases with Wang-Landau sampling, in both planar and spherical geometry. Somewhat surprisingly, stripes emerge from largely different off-core interactions, featuring all sorts of combinations between repulsive like interactions and a predominantly attractive unlike interaction. In addition to stripe patterns we also observe crystal-like structures, as well as cluster crystals and networks.

● **The mystery and illusions of the inverse of the fine constant number:  $1/\alpha \approx 137$ .**

REGGIANI L. <sup>(1)</sup>, INTINI F. <sup>(2)</sup>, VARANI L. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Matematica e Fisica, Università del Salento, Lecce*

<sup>(2)</sup> *Dipartimento di Ingegneria, Università di Modena e Reggio Emilia, Modena*

<sup>(3)</sup> *Universite de Montpellier, Institut d'Electronique et des Systèmes, France*

To reveal the mystery, we consider a black-body cavity of cubic shape, with  $L = 3.3$  cm the side length, containing a photon gas at thermodynamic equilibrium with a thermal energy equal to that of the line energy emitted by the fine structure of an H atom,  $\epsilon = 4.51 \times 10^{-5}$  eV. Then, following Sommerfeld 1916 relation and Planck's law, we affirm that the following relations hold  $\frac{1}{\alpha} = \frac{2h\epsilon_0 c}{e^2} = \delta \bar{N}^2 = \gamma \bar{N} = \frac{1}{3} (2\pi \frac{L}{\lambda})^3 = 137.0560$  with  $e$  the unit charge,  $h$  the Planck constant,  $\epsilon_0$  the vacuum permittivity,  $c$  the light speed in vacuum,  $\delta \bar{N}^2$  the variance of the photon number,  $\bar{N} = 100.1408$  the photon average number,  $\lambda = 2.786978$  cm the wavelength of the fine-structure emission light,  $\gamma = 1.368433$  the Fano factor. In conclusion, with an accuracy of 7 digits, the transcendent number  $1/\alpha = 137.0560$  is found to be a statistical property of the considered photon gas as dictated by the Planck's distribution law. Main consequences of the above statements will be detailed during the talk.

● **Observation of perfect absorption in hyperfine levels of molecular spins with hermitian subspaces.**

NAPOLI S. <sup>(1)</sup>, BONIZZONI C. <sup>(2)(3)</sup>, LAMBERTO D. <sup>(1)</sup>, GÜNZLER S. <sup>(4)</sup>, RIEGER D. <sup>(4)</sup>, SANTANNI F. <sup>(5)</sup>, GHIRRI A. <sup>(3)</sup>, WERNSDORFER W. <sup>(4)</sup>, SAVASTA S. <sup>(1)</sup>, AFFRONTI M. <sup>(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli Studi di Messina*

<sup>(2)</sup> *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena e Reggio Emilia, Modena*

<sup>(3)</sup> *Istituto Nanoscienze, CNR, Modena*

<sup>(4)</sup> *Physikalisches Institut, Karlsruhe Institute of Technology, Karlsruhe, Germany*

<sup>(5)</sup> *Dipartimento di Chimica, Università degli Studi di Firenze*

Ideal effective parity-time (PT) symmetry can be achieved in passive open systems by balancing feeding and absorption. Such PT-symmetric systems host Hermitian subspaces enabling *perfect absorption* (PA), where all incoming energy is absorbed. Here, we consider a passive open quantum system of molecular spin centers coupled to a planar microwave resonator, operating at milliKelvin temperatures and few-photon power. We experimentally show that Hermitian subspaces and thus PA can be realized even without PT symmetry, by tuning the spin detuning to control the photon-spin content of a polariton mode. This restores the necessary balance between feeding and loss rates. We show that Hermitian subspaces shape the coherent spectra of cavity QED systems and broaden the platform to explore non-Hermitian effects. Finally, we discuss how Hermitian subspaces may be exploited for efficient switches and modulators with large modulation depths across broad spectral ranges.

● **Isotope shift spectroscopy in mercury vapors.**

GRAVINA S., DI BERNARDO S., CASTRILLO A., MORETTI L., GIANFRANI L.

*Dipartimento di Matematica e Fisica, Università degli Studi della Campania, Caserta*

Isotope shift spectroscopy in heavy atoms provides a direct method to investigate new physics beyond the Standard Model by combining precise measurements of transition frequencies of different isotopes in the so-called King plots and looking for a possible King-plot nonlinearity. We recently performed accurate determinations of the absolute frequency of the  $6s^2\ ^1S_0 \rightarrow 6s6p\ ^3P_1$  intercombination transition for  $^{200}\text{Hg}$  and  $^{202}\text{Hg}$  at 253.7 nm, achieving relative uncertainties of  $6.8 \times 10^{-12}$  and  $1.3 \times 10^{-11}$ , respectively, employing comb-locked, wavelength-modulated, Lamb-dip spectroscopy in a miniature vapor cell at  $\approx 298$  K. These results lead to a determination of the  $^{200}\text{Hg} - ^{202}\text{Hg}$  isotope shift with enhanced precision and accuracy compared to previous works. Here, we present new spectroscopic measurements of the same transition in bosonic mercury isotopes at 270 K, aimed at further improving the isotope shift accuracy for this spectral line. We also report the results of a double-resonance experiment in an open three-level ladder scheme, potentially enabling new isotope shift data for transitions between excited levels.

● **Evaluating the impact of turbulent tokamak edge plasma on ion cyclotron wave propagation and absorption: a stochastic 1D model in a DTT plasma scenario.**

FRANCALANZA V. <sup>(1)(2)</sup>, CARDINALI A. <sup>(2)(3)(4)</sup>, SALVIA C. <sup>(5)</sup>, MAURO G. S. <sup>(2)</sup>, MISHRA B. <sup>(2)</sup>, PIDATELLA A. <sup>(2)</sup>, TORRISI G. <sup>(2)</sup>, MASCALI D. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

<sup>(2)</sup> *INFN, Laboratori Nazionali del Sud, Catania*

<sup>(3)</sup> *CNR, Istituto Sistemi Complessi, Politecnico di Torino*



<sup>(4)</sup> *IAPS, Istituto Nazionale di Astrofisica, Roma*

<sup>(5)</sup> *Centro Ricerche Fusione, Università degli studi di Padova*

Ion Cyclotron Resonance Heating (ICRH) is a powerful method for plasma heating and current drive in tokamaks. In earlier studies, we developed a 1D semi-analytical and numerical model to describe the propagation and absorption of an Ion Cyclotron wave in a DTT (Divertor Tokamak Test) plasma scenario, benchmarking it against full-wave codes such as TORIC. Building on this foundation, the present work introduces stochastic density fluctuations in the tokamak edge region. Such fluctuations, commonly observed in experiments, can significantly affect antenna-plasma coupling by modifying wave reflection and power absorption profiles. Here, the 1D wave equation is modified to include random perturbations of the plasma density, characterized by given correlation lengths and amplitudes. A Monte Carlo procedure generates multiple fluctuation realizations, and for each, the wave equation is solved numerically to obtain reflection coefficients and power deposition profiles. These results pave the way for more accurate predictions of ICRH performance in future devices with steep density gradients and turbulence.

● **Solving inverse problems in plasma physics and nuclear fusion using multi-diagnostic physics-informed deep learning approach.**

ROSSI R. <sup>(1)</sup>, RUTIGLIANO N. <sup>(1)</sup>, GELFUSA M. <sup>(1)</sup>, MURARI A. <sup>(2)</sup><sup>(3)</sup>, PELUSO E. <sup>(1)</sup><sup>(4)</sup>, WYSS I. <sup>(1)</sup>, GAUDIO P. <sup>(1)</sup>

<sup>(1)</sup> *Università degli Studi di Roma Tor Vergata*

<sup>(2)</sup> *Consorzio RFX, Padova*

<sup>(3)</sup> *CNR, Istituto per la Scienza e la Tecnologia dei Plasmi, Padova*

<sup>(4)</sup> *ENEA, Nuclear Department, Frascati*

Developing advanced methodologies for plasma analysis is crucial for advancing toward fusion energy. While a variety of diagnostics are employed in experimental nuclear fusion reactors, the complexity of the phenomena often limits the ability to extract coherent and accurate information. Nonlinearities and secondary effects are frequently approximated to ensure the functioning of computational models and inversion algorithms. Furthermore, diagnostics are often treated as independent sources of information, restricting the synergy achievable in a multi-diagnostic framework. A novel approach that uses deep learning techniques constrained by fundamental plasma physics equations to solve inverse problems using data from multiple diagnostics is presented. The model is based on Physics-Informed Neural Networks, which provide a robust and consistent framework for integrating data-driven models with physical laws. This enables accurate and coherent reconstructions of key plasma quantities by fully exploiting the synergy between diagnostics. We demonstrate our methodology through the reconstruction of magnetic equilibrium, validated on both synthetic data and experimental measurements.



Aula 12, Section C, Edificio 19

ore 10:00 – 13:30

SEZIONE II

**Fisica della materia**

Presiede: LO FRANCO R. (Università di Palermo)

*Le relazioni su invito si terranno nell'Aula 11, i lavori si sposteranno nell'Aula 12 per le seguenti comunicazioni.*

Comunicazioni

● **Attention-based noisy states state reconstruction with incomplete information.**

MACARONE-PALMIERI A., ZAMBRANO L., AMATO F., COMPARATO G., LO FRANCO R.

*Dipartimento di Ingegneria, Università degli Studi di Palermo*

Quantum state tomography is a fundamental tool for quantum technologies. Access to the full state enables the reconstruction of the quantum state of a system, which is crucial for advancing quantum computing, communication, and sensing, where the accurate preparation, manipulation, and verification underpin performance and reliability. However, two limitations hamper it: exponential scaling and noise. Compressed sensing techniques and convex optimisation offer a solution to the first setback, reconstructing a quantum state with fewer samples than the Shannon-Nyquist theorem requires, but are affected by the distortions caused by noise. To fight this setback, deep learning steps in as a nonlinear booster. Based on previous works, we dive into the potential offered by deep learning in either boosting compressed sensing, and its ability to mitigate the detrimental effects of noise when no prior physical knowledge of the channel is provided to the whole algorithm.

● **Tunability and characterization of the Markov to non-Markov cross-over in qubit-impurity systems.**

CHIATTO G., FALCI G., PALADINO E., CHIRIACÒ G.

*Università di Catania*

In quantum open system, memory effects associated to non-Markovianity may lead to revival of coherence and entanglement that can be exploited as resources for quantum computation. In this work, we study a phenomenological model system of a qubit coupled to an incoherent impurity which has been shown to exhibit a cross-over from a Markovian to a non-Markovian regime of dynamics, depending on the tunability of the parameters characterizing the system. We investigate this behaviour by quantifying the non-Markovianity and by studying the frequency spectrum of the qubit coherence. We study the behaviour of the dynamics in several regimes by using two non-Markovianity measures: the Breuer-Laine-Piilo and the Luo-Fu-Song. We show that the cross-over is tuned by the qubit-impurity interaction strength and by the temperature of the impurity. In addition, our work aims at introducing a more comfortable observable based on the Fourier transform of the coherence of the qubit than the non-Markovianity measures to quantify the non-Markovianity of the system.

● **Selective decoupling in multi-level quantum systems by the SU(2) sign anomaly.**

ANFUSO G., PICCITTO G., PALADINO E., FALCI G.A.

*Università di Catania*

We investigate dynamical decoupling operated by  $2\pi$ -pulses in a two-level subspaces of a multilevel system showing that it may leads to selective decoupling. This provides a flexible

strategy for decoupling transitions in a quantum network, when control to directly address them is not available which can be use to control internode interaction or actively suppress decoherence.

● **Channel capacity of small modular quantum networks in the ultrastrongly coupled regime.**

CORDOVANA S.A. <sup>(1)</sup>, GIANNELLI L. <sup>(1)(2)</sup>, MACRÌ N. <sup>(1)</sup>, BENENTI G. <sup>(3)(4)</sup>, PALADINO E. <sup>(1)(2)(5)</sup>, FALCI G.A. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(2)</sup> *INFN, Sezione di Catania*

<sup>(3)</sup> *Center for Nonlinear and Complex Systems, Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Como*

<sup>(4)</sup> *INFN, Sezione di Milano.*

<sup>(5)</sup> *CNR-IMM, Catania*

We investigate state-transfer in modular quantum computer architectures exploiting the ultrastrong coupling regime of interaction between quantum processing units and ICs. We show that protocols based on adiabatic coherent transport may achieve near-ideal single-letter quantum capacity and robustness against parametric fluctuations suppressing leakage induced by the dynamical Casimir effect.

● **Unveiling and veiling an entangled light-matter quantum state from the vacuum.**

STASSI R., CIRIO M., FUNO K., PUEBLA J., LAMBERT N., NORI F.

*Università di Messina*

The ground state of an atom interacting with the electromagnetic field in the ultrastrong coupling regime is composed of virtual photons entangled with the atom. We propose a method to promote to real the entire photonic state, while preserving the entanglement with the atom. The process can be reversed, and the entangled state can be restored in the vacuum. Our scheme considers a four-level atom, where two specific levels exhibit ultrastrong coupling to a cavity mode. The process is obtained by making use of either an ideal ultrafast pulse or a more realistic multi-tone  $\pi$ -pulse that drives only the atom. An experimental realization of this proposal will not only enable the investigation of the exotic phenomena of emission of particles from the vacuum, but will also prove that quantum states can be extracted from the vacuum. Moreover, it will allow to inspect the ground state in the ultrastrong coupling regime, and to generate on-demand entangled states for quantum information processing.

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Aula Capità, Edificio 7

ore 10:00 – 13:30

SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: LANZA A.F. (INAF, Osservatorio Astrofisico di Catania)

Relazioni su invito

▲ **The hunt for the compact object in SN1987A.**

GRECO E.

*INAF, Osservatorio Astronomico di Palermo*

Supernova 1987A is the most-recent naked-eye SN, representing a unique source to study the transition of a massive star from its late stage of evolution through its explosion to the development of its remnant. After more than 30 years of elusive detection, in the last few years new pieces of evidence across the electromagnetic spectrum have suggested the existence of a neutron star in the heart of SN1987A. In this talk, I will go through the results obtained in the radio, infrared and X-rays bands through the ALMA, JWST and NuSTAR telescopes and I will show what is the most likely nature of this compact object.

▲ **A RECAP of Reionization: probing the sources and timeline of cosmic Reionization.**

NAPOLITANO L., PENTERICCI L.

*INAF, Osservatorio Astronomico di Roma e Università di Roma Sapienza*

Cosmic Reionization marks a crucial phase in the early history of the Universe, when the intergalactic medium transitioned from mostly neutral to nearly fully ionized due to radiation from the first luminous cosmic sources. Although observations have established that Reionization did occur, current constraints - such as the Thomson optical depth to the cosmic microwave background and the transmitted rest-frame ultraviolet flux in quasar spectra - offer only a limited view, probing either the global timescale or the final stages of the process. A deeper understanding of the onset, timeline, and topology of Reionization is essential to identifying which sources shaped its evolution. I will present the strategy behind the REionization Complementary Approach Project (RECAP), a newly funded synergy grant that will provide unprecedented insights into this transformative cosmic period. RECAP brings together four international teams in a unique collaboration that combines theoretical modeling and multi-wavelength observations, including data from the James Webb Space Telescope, the Very Large Telescope, and the Atacama Large Millimeter Array Observatory.

▲ **Hunting strong gravitational lenses with Euclid.**

MENEGHETTI M.

*INAF-OAS*

I will introduce the ESA Euclid space mission, whose primary objective is to investigate the nature of dark energy and dark matter by charting the large-scale structure of the Universe. I will then present the first results from our efforts to identify strong gravitational lenses in the early Euclid data. These initial searches have already led to the discovery of over 500 galaxy-scale lenses and more than 80 cluster-scale lenses, demonstrating the mission's remarkable potential in this field. I will discuss the scientific applications of these strong lenses, including their role in constraining dark matter distributions, studying high-redshift galaxies, and testing models of structure formation. Finally, I will outline the strategies we are developing to optimize lens searches in upcoming data releases, with the goal of building the largest and most complete sample of strong lenses ever assembled.

● **Overabundance of chromium reveal extreme nucleosynthetic nonditions in Cassiopeia 'As Northeastern Jet.**

SAPIENZA V. <sup>(1)</sup>, MICELI M. <sup>(1)(2)</sup>, ONO M. <sup>(3)(4)</sup>, YOSHIDA T. <sup>(5)</sup>, NAGATAKI S. <sup>(4)</sup>, GRECO E. <sup>(1)</sup>, ORLANDO S. <sup>(1)</sup>, BOCCHINO F. <sup>(1)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(3)</sup> *Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan*

<sup>(4)</sup> *Astrophysical Big Bang Laboratory, RIKEN, Japan*

<sup>(5)</sup> *Yukawa Institute for Theoretical Physics, Kyoto University, Japan*

Core-collapse supernovae (CCSNe) drive nucleosynthesis under extreme thermodynamic conditions, yet the mechanisms transporting heavy elements from deep stellar interiors remain poorly understood. We present spatially resolved X-ray spectroscopy of Cassiopeia A's northeastern jet using archival Chandra/ACIS observations. Our analysis reveals localized chromium (Cr) enrichment, with Cr/Fe mass ratios reaching up to about 0.2 in one region, significantly exceeding values found in all previous studies. Comparisons with nucleosynthetic models indicates that this region originates from an Incomplete Silicon burning layer of the exploding star. These findings highlight the jet's role in ejecting material from the deepest explosive burning layers, challenging current explosion models.

● **Predicting the next galactic supernova: a long-term monitoring campaign on galactic red supergiants.**

LAURIANO M. <sup>(1)(2)</sup>, BOCCHINO F. <sup>(2)</sup>, MICELI M. <sup>(1)(2)</sup>, ORLANDO S. <sup>(2)</sup>, PETRUK O. <sup>(2)</sup>, PASTORELLO A. <sup>(3)</sup>, LIMONGI M. <sup>(4)</sup>, CHIEFFI A. <sup>(4)</sup>, PINCIROLI VAGO N. <sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli studi di Palermo*

<sup>(2)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(3)</sup> *INAF, Osservatorio Astronomico di Padova*

<sup>(4)</sup> *INAF, Osservatorio Astronomico di Roma*

<sup>(5)</sup> *Politecnico di Milano*

In the Milky Way a supernova explosion is statistically expected approximately every 50 years, although the last observed was the Kepler's Supernova in 1604. To address this observational gap, we started a long-term monitoring photometric campaign with short-cadence observations, targeting the Scutum-Crux galactic region, which hosts a significant number of Red Supergiants, prime candidates for supernova events. Our primary goal is to characterize stellar variability in visible and infrared bands, thereby identifying potential pre-supernova outbursts or any other anomalies possibly related to a late evolutionary stage, otherwise too faint to be detected in current extragalactic surveys. In this contribution, we present the catalogue of targets included in our monitoring program, some preliminary results based on multi-band light curves, and the next steps of the project, including the application of machine learning techniques to systematically analyze and classify the observed variability.

● **Synthesis of nonthermal emission from 3-D MHD simulations of supernova remnants.**

MARRETTA A. <sup>(1)(2)</sup>, MICELI M. <sup>(1)(2)</sup>, TUTONE A. <sup>(3)</sup>, USTAMUJIC S. <sup>(2)</sup>, REALE F. <sup>(1)(2)</sup>, ORLANDO S. <sup>(2)</sup>, ARGIROFFI A. <sup>(1)(2)</sup>, PAGANO P. <sup>(1)(2)</sup>, BARBERA M. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università degli Studi di Palermo*

<sup>(2)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(3)</sup> *INAF-IASF, Palermo*

We present a project aimed at developing an advanced diagnostic tool for the analysis of non-thermal emission stemming from supernova remnants and astrophysical plasmas. Through

post-processing of state-of-the-art 3-D MHD simulations of supernova remnants, the tool synthesizes the non-thermal multi-wavelength emission (from the radio band to gamma-rays) to get an accurate comparison with actual observations. We present here our preliminary results, showing the module for the synthesis of hadronic gamma-ray emission. The module incorporates the time-dependent acceleration of protons at the shock front, their escape during the evolution of the remnant, and the inelastic collisions with ambient protons in the post-shock material. We provide an application of the diagnostic tool to the Galactic supernova remnant IC443, by showing that it is possible to self-consistently reproduce its gamma-ray emission and obtain important insight on the efficiency of the proton acceleration process, and on the cosmic-ray energy and spectral shape.

● **Galactic archaeology in the era of large surveys.**

GRISONI V.

*Istituto Nazionale di Astrofisica*

In this talk, I will present detailed chemical evolution models of the Milky Way thick and thin discs in the light of the most recent data from Galactic surveys and missions. Currently, we are in a golden era for this field of research thanks to the advent of large spectroscopic Galactic surveys and projects, such as Gaia-ESO, APOGEE, GALAH, LAMOST, AMBRE, which are enhanced by the advent of ESA Gaia mission. In this way, detailed stellar abundances of stars Milky Way can be obtained. Moreover, asteroseismic missions such as Kepler, TESS and K2, can allow us to obtain also precise stellar ages for stars in the Milky Way. Then, by means of detailed Galactic chemical evolution models, it is possible to predict the chemical abundances expected in the stars of each Galactic component: halo, thick disc, thin disc and bulge. In particular, I will focus on the chemical bimodality between the Galactic thick and thin discs. I will start by discussing the dichotomy in the  $[\alpha/\text{Fe}]$  vs.  $[\text{Fe}/\text{H}]$  diagram where we can clearly see two distinct sequences corresponding to the thick and thin discs, and then I will discuss the bimodality in other abundance patterns, from lithium up to europium.

● **A new perspective on galactic evolution: Studing the outskirts of the Abell S1063 galaxy cluster.**

PECORARO L., MERCURIO A.

*Università di Salerno*

Galaxy clusters are ideal laboratories for studying galaxy formation and evolution, offering a full range of galaxies and regions with varying densities, from dense centers to less dense outskirts. Although environmental effects on galactic properties are evident, the mechanisms underlying quenching and structural transformations remain debated. To explore galaxy evolution scenarios at intermediate redshifts, deep and extensive photometric data ideally combined with spectroscopic ones are essential. In this presentation, we present a study of the cluster Abell S1063 at  $z = 0.346$ , using a combination of optical data from VST-GAME and near-infrared data from the VISTA Surveys to investigate galaxy evolution in different environments, extending beyond  $5r_{200}$ . The creation of a multiband catalog, which will be released for the first time over such a large field of view, has enabled us to derive photometric redshifts useful for identifying cluster members and for computing the density field, which in turn has allowed us to compare galaxy properties across different environments within the cluster.

● **Caratterizzazione del regime di accrescimento di blazar.**

VALENTE G. <sup>(1)</sup>, DELUCCHI G. <sup>(1)</sup>, SBARRATO T. <sup>(2)</sup>, TOSI S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Genova*

<sup>(2)</sup> *INAF, Osservatorio di Brera, Merate*

In questo contributo presenterò alcuni risultati preliminari di uno studio dedicato alla caratterizzazione del regime di accrescimento di blazar con tecniche di spettroscopia ottica. I blazar sono una particolare categoria di nuclei galattici attivi con un getto relativistico di particelle che investe direttamente l'osservatore, a piccoli angoli: le caratteristiche osservative del fenomeno sono pertanto determinate dall'emissione del getto, che sovrasta l'emissione della galassia ospite. La distribuzione di energia spettrale dei blazar si estende dalle frequenze del radio fino ad energie molto elevate, nei raggi X duri e nei gamma. In alcuni blazar lo spettro presenta diverse righe di emissione, alcune molto larghe, mentre in altri le righe sono sopresse se non del tutto assenti. Nel mio lavoro, tramite l'utilizzo del software QSFit, vengono analizzati gli spettri di un campione di sorgenti incluse nel catalogo ZBLlac al fine di caratterizzarne le righe larghe di emissione per comprendere meglio i tassi e le modalità di accrescimento di materia attorno al buco nero supermassiccio centrale.

### ● Black holes all over the Universe.

RUFFINI R.

*ICRANet, Pescara e ICRA, Università di Roma Sapienza*

Based on the Kerr solution and the mass energy formula of Christodoulou, Ruffini and Wheeler published in 1971 the article Introducing the Black Hole, where the energy extraction processes is occurring in the ergosphere. Generalization followed by Christodoulou-Ruffini and by Hawking. Relativistic astrophysics started by the discoveries of Sco X-1, of the Quasars and the GRBs. The first BH in our Galaxy, Cygnus X-1 was announced by Ruffini in 1972. Beppo-SAX identified the cosmological nature of GRBs. The GRBs BDHN model observe daily in the entire Universe the formation of BHs of up to  $10M_{\odot}$  originating by baryonic accretion of SN ejecta into the binary companion NS. The scrutiny of our Galactic Center by the ESO VLT GRAVITY developed by R. Genzel et al. evidenced a core of  $4 \times 10^6 M_{\odot}$ , describable by fermionic degenerate Dark Matter as the seed for the formation of BHs in the range  $10^6 - 10^{10} M_{\odot}$  composed of DM leading to: 1) SMBHs; 2) AGNs, evolving into QGN (red-dots); and 3) in Quasars. EHT determines Cygnus X-1 as a binary of a  $23M_{\odot}$  BH and the star HDE 226868 of  $34M_{\odot}$ : a new channel of formation of BHs, evolving to binary BHs.

### ● Clustering of FLUX and EW maps across energy bands in supernovae using deep learning methodologies.

CALDERARO S. <sup>(1)</sup>, PARISI G. <sup>(1)</sup>, SAPIENZA V. <sup>(2)</sup>, LO BOSCO G. <sup>(3)</sup>, MICELI M. <sup>(1)</sup>, MANTEGNA R.N. <sup>(1)</sup>, MICCICHÈ S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(3)</sup> *Dipartimento di Matematica e Informatica, Università degli Studi di Palermo*

Analyzing spectral and spatial information across energy bands in supernova remnants is key to understanding their physical and chemical evolution. We propose a deep learning methodology to cluster FLUX and Equivalent Width (EW) maps across energy bands. Our approach involves three phases: (1) synthetic image generation, (2) embedding computation, and (3) hierarchical clustering. Due to limited real data, we used Variational Autoencoders (VAEs) to generate synthetic FLUX and EW maps, training a model for each energy band. Embeddings were then computed using a Siamese Neural Network with a ResNet18 backbone, trained to group maps with similar spectral features in latent space. This compact representation accelerates clustering while preserving essential information. Hierarchical clustering using cosine distance on embeddings yielded results consistent with classical image-linearization methods and statistically validated clustering. We further validated robustness using synthetic maps from magnetohydrodynamic simulations, confirming

the approach's reliability. Our method combines generative and metric learning models to cluster spectral maps effectively, even in low-data regimes.

● **New physics from GRBs: black hole mass and magnetar magnetic field.**

RUFFINI R. <sup>(1)</sup>(<sup>2</sup>)(<sup>3</sup>), WANG Y. <sup>(1)</sup>(<sup>2</sup>)(<sup>4</sup>), MIRTORABI M. T. <sup>(1)</sup>(<sup>2</sup>)(<sup>5</sup>)

<sup>(1)</sup> *ICRANet, Pescara*

<sup>(2)</sup> *ICRA, Dipartimento di Fisica, Sapienza Università di Roma*

<sup>(3)</sup> *INAF, Roma*

<sup>(4)</sup> *INAF, Osservatorio Astronomico d'Abruzzo, Teramo*

<sup>(5)</sup> *Department of Fundamental Physics, Alzahra University, Tehran, Iran*

The Binary-driven Hypernova (BdHN) model analysis of GRBs 160625B, 220101A, and 221009A reveals three key aspects predicted by the model. 1) Newborn Neutron Star Transition: The model predicts that the newborn neutron star (vNS) evolves from a triaxial Jacobi ellipsoid to an axially symmetric Maclaurin spheroid. This transition is likely driven by gravitational wave emission. 2) Strong Field Generation: The evolution of the Carbon-Oxygen (CO) core, spun up by the companion star, amplifies its magnetic field. Subsequent fission of the CO core produces a magnetar with a magnetic field exceeding  $10^{16}$  G. 3) Black Hole Mass and Spin Inference: Using the theoretical irreducible mass formula and high-energy GRB observations, we determine, for the first time, the black hole mass to be in the range  $2.38\text{--}2.54 M_{\odot}$  and the spin parameter between 0.32 and 0.70.

● **AGN growth from black hole formed by X-Fermion dark matter.**

WANG Y. <sup>(1)</sup>(<sup>2</sup>)(<sup>3</sup>), RUFFINI R. <sup>(1)</sup>(<sup>2</sup>)(<sup>4</sup>)

<sup>(1)</sup> *ICRA, Dipartimento di Fisica, Sapienza Università di Roma*

<sup>(2)</sup> *ICRANet, Pescara*

<sup>(3)</sup> *INAF, Osservatorio Astronomico d'Abruzzo, Teramo*

<sup>(4)</sup> *INAF, Roma*

The existence of luminous quasars within the first billion years challenges models of black hole growth. By proposing that luminous AGNs are determined by the interplay between Bondi accretion and the Eddington limit, our fittings, constrained by Bayesian MCMC analysis of observed high-redshift quasars (e.g., J0313-1806 and J0100+2802), indicate that reaching the observed masses and luminosity requires initial seeds of  $> 10^6 M_{\odot}$  at  $z = 30$ . This finding is consistent with black hole seeds formed within the earliest dark matter halos composed of hypothetical  $\sim 300$  keV X-fermions. We also demonstrate how initial conditions of the seed mass and the density of the environment can channel black hole growth towards either massive AGN or less luminous little red dots (LRDs).

● **Periodic modulation of the gamma-ray flux emitted by the blazar PG 1553+113 confirmed: Clues on the SMBH relativistic jet mystery.**

CIPRINI S. <sup>(1)</sup>(<sup>2</sup>), CUTINI S. <sup>(3)</sup>, LARSSON S. <sup>(4)</sup>(<sup>5</sup>), CRISTARELLA ORESTANO P. <sup>(3)</sup>(<sup>6</sup>)

<sup>(1)</sup> *INFN, Sezione di Roma Tor Vergata*

<sup>(2)</sup> *Space Science Data Center, Agenzia Spaziale Italiana, Roma*

<sup>(3)</sup> *INFN, Sezione di Perugia*

<sup>(4)</sup> *Department of Physics, KTH Royal Institute of Technology, Stockholm, Sweden*

<sup>(5)</sup> *The Oskar Klein Centre for Cosmoparticle Physics, Stockholm, Sweden*

<sup>(6)</sup> *Dipartimento di Fisica, Università degli Studi di Perugia*

Jets from supermassive black holes (SMBHs) behave in mysterious ways. Results of  $> 15$  years of Fermi Large Area Telescope (LAT) gamma-ray monitor of the high-energy BL Lac object PG 1553+113 are presented, in comparison with optical, radio-band and X-ray multifrequency observations. A long-lived, 2.1-year gamma-ray/optical modulation is

confirmed and significant at a 4 sigma level against stochastic red noise. This work doubles the total time range w.r.t. our previous discovery paper of 2015. Independent determinations of oscillation period and phase based on data published in the earlier work and the new data are in agreement (chance probability  $< 0.01$ ). Such oscillation modulates the rapid, flaring, irregular variability. Our discovery, now allows prospects for investigating pulsational accretion flow in a, sub-parsec, binary SMBH system, or accretion flow instabilities and plasma kinks, or disk and jet precession, rotation or nutation also in case of a single central SMBH. Perturbations by massive stars (compact objects) in polar orbit around a single SMBH is another model. PG 1553+113 is emerging as a test bench to understand relativistic outflows and jets from SMBHs.

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Aula 9, Section C, Edificio 19

ore 10:00 – 13:30

## SEZIONE V

**Biofisica e fisica medica**

Presiede: VILASI S. (CNR, Istituto di Biofisica, Palermo)

Relazioni su invito

**▲ Towards synchrotron-quality computed tomography in the laboratory.**DI TRAPANI V., THIBAUT P.*University of Trieste, Elettra Sincrotrone Trieste e INFN, Sezione di Trieste*

X-ray micro Computed Tomography ( $\mu$ -CT) is a nondestructive imaging technique that finds application in several fields. In the biological context, where  $\mu$ -CT is applied to histological analysis and advanced morphological studies, the diagnostic power of images is limited by the low contrast exhibited by soft tissues. Phase-contrast imaging, typically available at synchrotron sources, overcomes this limitation. However, access to synchrotrons is highly competitive, preventing the widespread use of the technique. We recently established the OptImaTo laboratory (Trieste, Italy), a novel imaging facility designed to bridge the gap between conventional laboratory- and synchrotron-based  $\mu$ -CT. OptImaTo integrates advanced technologies, including a highly brilliant liquid metaljet X-ray source and cutting-edge imaging detectors. Combined with the development of advanced imaging techniques and acquisition protocols, this setup uniquely enables high-quality laboratory-based phase-contrast images. Here, we present the first images obtained at the OptImaTo lab, demonstrating image quality comparable to synchrotron data, thereby offering a solution for widely accessible phase-contrast imaging.

**▲ From static snapshots to redox kinetics: Unveiling copper's role in amyloid-beta dynamics via X-ray absorption spectroscopy.**STELLATO F. <sup>(1)</sup>, BEAN R. <sup>(2)</sup>, DE SANTIS E. <sup>(1)</sup>, FALCONE E. <sup>(3)</sup>, FALLER P. <sup>(4)</sup>, MINICOZZI V. <sup>(1)</sup>, VINJAMURI B. <sup>(4)</sup><sup>(1)</sup> *University of Rome Tor Vergata and INFN, Roma, Italy*<sup>(2)</sup> *European X-Ray Free-Electron Laser, Schenefeld, Germany*<sup>(3)</sup> *Laboratoire de Chimie de Coordination, LCC, CNRS, Toulouse, France*<sup>(4)</sup> *Institut de Chimie, Universite de Strasbourg, Strasbourg, France*

The accumulation of misfolded amyloid- $\beta$  peptides in oligomeric and fibrillar forms is a hallmark of Alzheimer's disease. Metal ions, in particular Cu, Zn, and Fe, can influence the misfolding and aggregation processes and act as sources of oxidative stress. Here, we present the application of a combined X-ray Absorption Spectroscopy (XAS) and molecular-dynamics approach to probe the local coordination environment and oxidation states of metal ions bound to A $\beta$ . Synchrotron XAS experimental results on Cu(I), Cu(II), and Zn(II) ions in complex with different fragments of the A $\beta$  peptide are reported. The effect of interaction with the X-ray beam on metal oxidation states and on the peptide structure is analyzed, considering the presence of different metal ions and varying temperature and irradiation conditions. Finally, the potential of performing combined XAS and fiber diffraction measurements at Free Electron Laser (FEL) sources is discussed, with the aim of gaining insight into the dynamics of metal-A $\beta$  complexes and elucidating interactions between metal ions and A $\beta$  fibrillar aggregates.

▲ **Advanced imaging techniques for biomedical applications.**

FRATINI M. <sup>(1)(2)</sup>, NICCOLINI B. <sup>(2)</sup>, CAMPI G. <sup>(3)</sup>, BARDELLI F. <sup>(1)</sup>, GIANONCELLI A. <sup>(4)</sup>, BUKREEVA I. <sup>(1)</sup>, PALERMO F. <sup>(1)</sup>, MASSIMI L. <sup>(1)</sup>, CEDOLA A. <sup>(1)</sup>, BRUN F. <sup>(5)</sup>, NICAISE C. <sup>(6)</sup>, SIERRA LOPEZ A. <sup>(7)</sup>

<sup>(1)</sup> *Cnr-Nanotec, Rome Italy*

<sup>(2)</sup> *Santa Lucia Foundation, Rome Italy*

<sup>(3)</sup> *CNRI-IC, Rome Italy*

<sup>(4)</sup> *Elettra Synchrotron, Trieste Italy*

<sup>(5)</sup> *Department of Engineering and Architecture, University of Trieste, Trieste, Italy*

<sup>(6)</sup> *URPhyM-NARILIS, Université de Namur, Namur, Belgium*

<sup>(7)</sup> *A.I. Virtanen Institute for Molecular Sciences, University of Eastern Finland, Kuopio, Finland*

To comprehensively analyse CNS abnormalities, our study uses a multimodal imaging approach that integrates X-ray phase contrast tomography with MRI, X-ray microdiffraction, fluorescence imaging and histology. This combination provides a multi-scale assessment of tissue damage and neurovascular remodelling. This integrative framework allows seamless correlation of structural, functional and molecular insights, providing a unique perspective on neurovascular pathophysiology. A novel adaptive algorithm co-registers XPCT and MRI data sets, enhancing the visualisation of neurovascular structures. This multimodal approach refines MRI contrast mechanisms and improves diagnostic accuracy. Through advanced imaging techniques, we are providing deep insights into CNS pathologies, facilitating biomarker identification and advancing biomedical research in neurodegeneration and spinal cord injury.

▲ **AI-empowered label-free optical microscopy at the molecular scale using linear, multiphoton and single molecule fluorescence as source for training.**

DIASPRO A. <sup>(1)(2)</sup>, INCARDONA N. <sup>(1)</sup>, BIANCHINI P. <sup>(1)</sup>, TOUIJER L. <sup>(1)</sup>, ONETO M. <sup>(1)</sup>, SCOTTO M. <sup>(1)</sup>, SALERNO M. <sup>(1)(2)</sup>, ANGELI E. <sup>(2)</sup>, ZBEEB H. <sup>(1)</sup>

<sup>(1)</sup> *Nanoscopy, Istituto Italiano di Tecnologia, Genoa, Italy*

<sup>(2)</sup> *SeeLife, Department of Physics, University of Genoa, Genoa, Italy*

Label-free optical microscopy allows us to observe and analyze biological cells in a natural, undisturbed state. The challenge for label-free imaging regards the ability to extract information to form molecular images. Label-free methods, such as phase-contrast or polarised Mueller matrix microscopy, preserve samples' natural state and vitality with the drawback of lacking molecular specificity, which is an obstacle in isolating specific biomolecules or molecular pathways. On the other hand, fluorescence microscopy provides high specificity and sensitivity for visualizing targeted molecules at the nanoscale. AI enhances this capability by analyzing both label-free and fluorescence images of the same sample, bridging the gap between aspecific and molecular imaging. Using generative models with a single UNet, the AI learns to predict fluorescence images from label-free data. The goal is to create a robust virtual environment to reveal previously unseen relationships, particularly regarding chromatin organization in oncological and neurodegenerative diseases.

Comunicazioni

● **Radiological techniques for astronauts' bone health assessment during long-duration spaceflight: The DXA4A project.**

CERBONE L.A.

*Scuola superiore Meridionale, Napoli, Dipartimento di Fisica "Ettore Pancini", Università di Napoli Federico II, Napoli e Istituto Nazionale di Fisica Nucleare, Sezione di Napoli,*

*Napoli*

Bone loss in astronauts during spaceflight is among the main concerns for human exploration in space. Dual Energy X-ray Absorptiometry (DXA) scans demonstrated a loss of about 0.8% per month in the bone mineral content of lower limbs, assessed before and after the flight. *DXA4A* is a project for the design of a compact DXA apparatus dedicated to astronauts, using a photon-counting CdTe pixel detector with a Timepix4 readout and a microfocus X-ray tube, to assess periodically the areal bone mineral density (aBMD) of the tibia during the missions. The extremely low radiation dose ( $< 0.001$  mSv), the compact design —material budget  $< 20$  kg, volume of  $15\text{ cm} \times 30\text{ cm} \times 40\text{ cm}$ — and the availability of a dedicated software providing readings of aBMD, allow the device to be used independently by astronauts with no need for medical guidance from Earth. We present here the design of the prototype DXA scanner and its performance evaluation via Monte Carlo simulations, providing a complete digital twin of the device.

● **Development of a microfluidic platform coupled with SAXS for *in situ* investigation of protein coagulation.**

ROQUE-DIAZ Y. <sup>(1)</sup>, MARMIROLI B. <sup>(2)(3)</sup>, SARTORI B. <sup>(2)(3)</sup>, AMENITSCH H. <sup>(2)(3)</sup>, ORTORE M.G. <sup>(1)</sup>

<sup>(1)</sup> *Department of Life and Environmental Sciences, Polytechnic University of Marche, Ancona, Italy*

<sup>(2)</sup> *Inorganic Chemistry, Graz University of Technology, Austria*

<sup>(3)</sup> *Elettra-Sincrotrone Trieste S.C.p.A., Italy*

One of the major challenges in studying biological systems is replicating physiological conditions as closely as possible. Microfluidic devices offer a promising solution by mimicking cellular microenvironments. Coupling these systems with structural characterization techniques such as synchrotron-based Small-Angle X-ray Scattering (SAXS) enables real-time monitoring of biomolecular processes, offering detailed insights into protein aggregation mechanisms. We have developed a SAXS-compatible microfluidic set-up to study a system that mimics protein coagulation under flow. The microfabrication of the device was performed in collaboration with the Deep Lithography Beamline scientists at Elettra Synchrotron, using X-ray lithography to ensure both structural integrity and X-ray transparency. SAXS measurements were conducted at the SAXS beamline of the same facility. Our preliminary results demonstrate the feasibility of the set-up and represent an important step toward studying protein aggregation in controlled flow conditions, with the long-term goal of contributing to the development of new therapeutic approaches.

● **Enhancing medical imaging datasets via conditional generative modeling of lung CTs.**

GIACOMETTI T. <sup>(1)(2)</sup>, CURTI N. <sup>(1)(2)</sup>, REMONDINI D. <sup>(1)(2)</sup>, CASTELLANI G. <sup>(3)(4)</sup>

<sup>(1)</sup> *Department of Physics and Astronomy, Alma Mater Studiorum, University of Bologna, Bologna, Italy*

<sup>(2)</sup> *INFN, Istituto Nazionale di Fisica Nucleare, Bologna, Italy*

<sup>(3)</sup> *Department of Medical and Surgical Sciences, Alma Mater Studiorum, University of Bologna, Bologna, Italy*

<sup>(4)</sup> *IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy*

Access to large-scale, annotated medical imaging datasets is often constrained by privacy and ethical restrictions, and the high cost of data acquisition and labeling, limiting the development of robust AI models. We propose a novel AI-driven pipeline for generating synthetic 3D lung CT scans that are both anatomically realistic and pathologically meaningful, aiming to augment clinical datasets while addressing data sharing constraints. Our

method builds on Conditional Flow Matching, where the generative process is trained via mini-batch optimal transport. The training has been performed on different public datasets. The number of model parameters is on the order of  $10^8$ . The generated lung scans demonstrate high structural and pathological fidelity, with state-of-the-art segmenters correctly identifying pulmonary lobes in the synthetic volumes. The implemented validation pipeline is based on statistical metrics such as privacy, statistical utility, variability and fidelity. The clinical utility will be assessed by experienced clinicians. This approach offers an efficient solution for medical image synthesis, reducing reliance on large, annotated datasets in future AI application.

● **Dose and image quality in dedicated breast CT systems with the VIT-BREAST in silico platform.**

COTENA C.

*Dipartimento di Fisica "Ettore Pancini", Università di Napoli Federico II, Italia e Istituto Nazionale di Fisica Nucleare, INFN, Sezione di Napoli, Italia*

Clinical trials are the standard approach for assessing the diagnostic performance of new X-ray imaging techniques. However, their high cost, long duration, and extensive resource requirements have prompted the development of Virtual Imaging Trials (VITs), in silico reproduction of diagnostic exams using computational models. In the field of breast imaging, our group is developing VCT-BREAST, a GPU-accelerated Monte Carlo simulation platform. The platform allows to set the scanner, phantom and detector characteristics. The simulation platform produces a dose map in the phantom and records the deposited energy and the number of photons reaching the detector plane. The detector features (energy efficiency, spatial resolution and noise) are reproduced offline and included by post-processing projection images obtained from the MC simulation. As part of the VITA project, funded by INFN (Italy), this work presents a virtual clinical evaluation of three different dedicated breast CT systems. The study focuses on a comparative analysis of image quality and glandular dose, aiming to highlight the differences in our cohort of virtual anthropomorphic voxelized breast phantoms.

● **Collimator design for X-ray preclinical minibeam radiation therapy.**

CRIMALDI U. <sup>(1)(2)</sup>, LUONGO N <sup>(1)(2)</sup>, CERBONE L.A. <sup>(2)(3)</sup>, CLEMENTE S. <sup>(1)</sup>, OLIVIERO C. <sup>(1)</sup>, PACELI R. <sup>(1)(4)</sup>, SPINELLI A. <sup>(6)</sup>, METTIVIER G. <sup>(2)(5)</sup>, RUSSO P. <sup>(2)(5)</sup>

<sup>(1)</sup> Azienda Ospedaliera Universitaria Policlinico Federico II, Naples, Italy

<sup>(2)</sup> Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Naples, Italy

<sup>(3)</sup> Scuola Superiore Meridionale, Naples, Italy

<sup>(4)</sup> Dipartimento di Scienze Biomediche Avanzate, Università di Napoli Federico II, Naples, Italy

<sup>(5)</sup> Dipartimento di Fisica, Università Federico II, Naples, Italy

<sup>(6)</sup> Centro di Imaging Sperimentale, Istituto Scientifico San Raffaele, Milan, Italy

Spatial dose fractionation has been shown to enhance healthy tissue tolerance to radiation, a key limitation of radiotherapy. xMBRT uses collimators to obtain submillimetric beams with a peak/valley dose pattern yet lacks standardized design guidelines. As part of a PNR-Sanità proof-of-concept project (San Raffaele Hospital, Milan; Policlinic & University Federico II, Naples) we optimized collimator geometry for application to a for a 225 kV X-ray irradiator (XRAD225-Cx, Precision X-ray). We used TOPAS/Geant4 Monte Carlo code to model the irradiation setup and scored 3D dose distribution in a water phantom. We tested multiple collimator configurations: patterns, apertures, thicknesses and materials. We irradiated computational mouse models, deriving dose volume histograms. For each collimator, we measured peak-valley dose ratio (PVDR) and valley dose at 1 cm depth.

Parallel collimators exhibited peak dose degradation due to beam divergence. The highest PVDR and lowest valley dose were achieved with the smallest aperture collimators, though at the cost of transmission. MC simulations help optimize collimator geometry for xMBRT, aiding future design improvements.

● **Studio mediante spettroscopia XANES delle dinamiche biochimiche di conversione di ossianioni tossici di selenio in nanoparticelle di selenio elementale da parte di ceppi batterici.**

MONTI F. <sup>(1)</sup>, LAMPIS S. <sup>(2)</sup>, PIACENZA E. <sup>(3)</sup>, PRESENTATO A. <sup>(3)</sup>, ROCCA F. <sup>(4)</sup>

<sup>(1)</sup> *Dipartimento di Informatica, Università di Verona*

<sup>(2)</sup> *Dipartimento di Biotecnologie, Università di Verona*

<sup>(3)</sup> *Dipartimento di Scienze e Tecnologie Biologiche Chimiche e Farmaceutiche, Università di Palermo*

<sup>(4)</sup> *Istituto di Fotonica e Nanotecnologie del CNR, Povo, TN*

È noto che alcuni ceppi batterici sono in grado, nel corso della loro crescita cellulare, di ridurre ossianioni tossici di metalloidi, come il selenio, presenti e assorbiti dal terreno di coltura, in nanoparticelle della forma elementale non tossica rivestite di materiale organico. I complessi meccanismi biochimici alla base di questo processo non sono stati ancora pienamente chiariti. Un significativo contributo in questa direzione viene dal nostro studio, effettuato su due ceppi di batteri gram-negativi, *Stenotrophomonas maltophilia* SeITE02 and *Ochrobactrum* sp. MPV1, che ha consentito di identificare la presenza di due intermedi di reazione fin dalle prime fasi della crescita cellulare (fra 1 ora e 6 ore), monitorando, mediante spettroscopia XANES, l'evoluzione temporale degli stati di ossidazione del selenio nelle cellule durante la loro crescita (da 0 a 48 ore), e valutando il contributo delle specie di selenio biologicamente rilevanti mediante fitting per combinazione lineare (LCF) di spettri XANES acquisiti su composti di riferimento. Le misure sono state effettuate al Sincrotrone Europeo di Grenoble.

Aula 7, Section B, Edificio 19

ore 10:00 – 13:30

SEZIONE VI

**Fisica applicata, acceleratori e beni culturali**

Presiede: CIRRONE G.A.P. (INFN, Laboratori Nazionali del Sud, Catania)

Relazioni su invito

▲ **Cultural-Heritage studies with inverse-Compton-scattering X-ray sources.**

AGOSTINO R.G.

*STAR Research Infrastructure, Università della Calabria*

Compact inverse-Compton-scattering (ICS) sources emit quasi-monochromatic X-rays from a few keV to low MeV with polarised picosecond pulses and tunable bandwidth. STAR supplies  $\approx 10^{11}$  ph s<sup>-1</sup> at 20–350 keV from a micrometric, low-divergence spot, yielding pseudo-coherent beams for absorption- or phase-contrast imaging. They penetrate centimetre-thick high-*Z* artefacts, give micrometre resolution and element-selective contrast at doses safe for conservation. Preliminary case studies:  $\mu$ -CT recovered legends on sulphide-crusts Roman coins and, with XRF, dated them; multi-energy CT of Afghan terracotta statues exposed plant-fibre cores; micrometric CT of Brettian/Lucanian silver-imitating pottery mapped tin veneers and interfaces; combined  $\mu$ -CT/XRF/Raman on a Hellenistic gold earring revealed joins and repairs. Across bronze, clay, composite metals and jewels, ICS micro-CT preserves objects while supplying 3D data on composition and condition. Energy tunability maximises contrast-to-dose, and pseudo-coherence enables phase retrieval of low-*Z* details. ICS sources offer a versatile laboratory bridge between benchtop scanners and synchrotron lines for Cultural-Heritage work.

Comunicazioni

● **From spectral acquisition to predictive modelling: a smart framework for Cultural Heritage pigments identification.**

FERRARA I., GALLO S., GUELI A.M., INCARDONA A., POLITI G., STELLA G.

*Dipartimento di Fisica e Astronomia, Università di Catania*

As part of the SAMOTHRACE project SiciliAn MicronanOTech Research and Innovation Center (PNRR, M4C2 Investment 1.5), Spoke 1 University of Catania, WP6 Cultural Heritage, Task 1, an intelligent system was developed for the automated identification of historical pigments from spectral data, supporting material analysis in archaeology and conservation. The workflow includes data acquisition, automated processing, predictive model building, and validation. The study focuses on 100 historical pigments (KREMER), analyzed using Raman spectroscopy, spectrophotometry, and X-ray fluorescence. Python scripts enabled automatic extraction of features such as colorimetric parameters and characteristic peaks. These were combined into structured files and encoded as binary barcodes, representing each pigment's digital fingerprint. A soft-distance algorithm compared barcodes, while spectral profiles were matched via curve similarity. Both approaches identified the top five closest matches, with visual comparisons and confidence scores. The system was tested across instruments and pigment samples, confirming robustness and transferability.

● **Calibration of Bragg edge neutron transmission analysis for the analysis of archaeological bronzes.**

MARABOTTO M. <sup>(1)</sup>, RE A. <sup>(1)(2)</sup>, DEMATTEIS M. <sup>(1)(2)</sup>, GUIDORZI L. <sup>(1)(2)</sup>, LO GIUDICE A. <sup>(1)(2)</sup>, GRAZZI F. <sup>(3)</sup>, SCHERILLO A. <sup>(4)</sup>, RAMADHAN R. <sup>(4)</sup>, MARCUCCI G. <sup>(4)(5)</sup>, DI MARTINO D. <sup>(5)</sup>

<sup>(1)</sup> INFN, Sezione di Torino

<sup>(2)</sup> Dipartimento di Fisica, Università degli Studi di Torino

<sup>(3)</sup> CNR, Istituto di Fisica Applicata Nello Carrara e INFN, Sezione di Firenze

<sup>(4)</sup> STFC ISIS Neutron and Muon Source, UK

<sup>(5)</sup> Dipartimento di Fisica, Università degli Studi di Milano Bicocca e INFN, Sezione di Milano Bicocca

Bragg Edge Neutron Transmission analysis (BENT) can reveal elemental and phase composition, microstructure, texture and other properties of crystalline solids non-invasively. It is based on the coherent elastic interaction between an incident neutron beam and the crystalline structure of the sample. This technique can therefore provide interesting information on metals without altering them, which makes it ideal in archaeometallurgy studies. The contribution presented here illustrates the application of BENT for the characterisation of samples realised within the INFN CHNet.BRONZE project. The aim of this project is to develop and calibrate, in a quantitative way, non-invasive techniques based on neutron absorption and scattering for the analysis of historical and archaeological bronze and copper alloys artefacts. Here, the characterisation of purposely prepared reference samples is illustrated. The results obtained from the BENT analysis allow to study the concentration of the elements in the alloy and derive information on the metal casting method. These results will help to answer questions of historical and cultural interest on archaeological bronzes.

● **Comparative luminescence dating of mortar components: TL on carbonate vs. OSL on quartz.**

GALVAGNO R. <sup>(1)</sup>, LAHAYE C. <sup>(2)</sup>, LIUZZO M. <sup>(3)</sup>, MARGANI G. <sup>(4)</sup>, REITANO R. <sup>(1)</sup>, STELLA G. <sup>(1)</sup>, TARDO C. <sup>(4)</sup>, URBANOVÁ P. <sup>(2)</sup>, GUELI A.M. <sup>(1)</sup>

<sup>(1)</sup> Dipartimento di Fisica e Astronomia, Università di Catania

<sup>(2)</sup> Archéosciences-Bordeaux, CNRS-Université Bordeaux Montaigne, Pessac, France

<sup>(3)</sup> Dipartimento di Ingegneria e Architettura, Università degli Studi di Enna Kore

<sup>(4)</sup> Dipartimento di Ingegneria Civile e Architettura, Università degli Studi di Catania

This study presents preliminary results from luminescence dating of mortars from the Terme della Rotonda (Catania), aiming to assess the reliability of cross dating by comparing Single Grain Optically Stimulated Luminescence (SG-OSL) on quartz and Thermoluminescence (TL) on the coarse grain carbonate fraction. SG-OSL was applied to quartz grains (200-250  $\mu\text{m}$ ) extracted from mortars, using a Riso TL/OSL DA-20 reader with a Hoya U-340 filter and 532 nm laser stimulation at 125 °C. Equivalent Doses (ED) were determined via the SAR protocol and analysed using statistical models to evaluate bleaching. In parallel, TL measurements were performed on the carbonate fraction, exploiting the signal formed during mortar carbonation. These were conducted by a Riso TL-DA-15 reader with a BG-39 filter, identifying a calcite-related emission between 300 and 400 °C. Preliminary results allowed optimization of parameters such as heating rate and preheat temperature. This approach enables a dual chronological check and helps reconstruct both construction and latest use of the thermal bath.



Relazioni su invito

▲ **Beam manipulation with crystals.**

BANDIERA L.

*Istituto Nazionale di Fisica Nucleare, INFN, Sezione di Ferrara*

Crystals can channel particle beams along major crystallographic directions. In a bent crystal, channeled particles follow the curvature, enabling compact and efficient beam steering. This technique is promising for high-energy hadron beam collimation at CERN's LHC, improving cleaning efficiency and reducing impedance for the HI-LUMI upgrade. Bent crystals have been tested for slow extraction at the SPS and are explored for multi-TeV fixed-target experiments at the LHC. Crystal-assisted extraction is also under study at FNAL for intense muon beams, and for electron and positron beams at current facilities (*e.g.*, DESY, DAFNE) and future accelerators. Channeling enhances electromagnetic radiation compared to Bremsstrahlung, enabling Crystalline Undulators to generate hard X-rays and gamma rays at sub-ångström wavelengths, beyond conventional undulators. Intense radiation in crystals is also studied to boost positron production for future lepton colliders like FCC-ee, ILC, and CLIC. This contribution reviews recent advances and future prospects of crystal-based technologies in accelerators.

Comunicazioni

● **Surface studies on candidate materials for the future electron Ion collider.**

ANGELUCCI M. <sup>(1)</sup>, SPALLINO L. <sup>(1)</sup>, CIMINO R. <sup>(1)</sup>, HETZEL C. <sup>(2)</sup>, VERDU ANDRES S. <sup>(2)</sup>, WEISS D. <sup>(2)</sup>

<sup>(1)</sup> *INFN, Laboratori Nazionali di Frascati*

<sup>(2)</sup> *Brookhaven National Laboratory, Upton, NY, USA*

The Electron Ion Collider (EIC) is a next-generation particle accelerator to be built in the US, aimed at colliding electrons with protons and nuclei to probe their internal structure. Its ambitious goals push the limits of current accelerator technology and require detailed studies to qualify the internal surfaces of the hadron ring vacuum chamber. Collective effects like electron cloud, impedance, and dynamic vacuum instabilities are strongly influenced by surface properties, which depend on operating temperature and electron/ion bombardment. Therefore, studying the surface characteristics of all proposed materials is essential to select the most suitable options and treatments. These properties are interconnected parts of a complex system that must be addressed as a whole to ensure stable and efficient operation. At the Material Surface Science Laboratory of LNF-INFN, we focus on surface qualification of coatings such as amorphous carbon (a-C) and NEG, which are of interest for vacuum chambers. This research also supports future colliders like FCC-ee and FCC-hh, reinforcing LNF's role in this field.

● **Pulsed current diagnostic by Rogowski coil at limit.**

NASSISI V. <sup>(1)(2)(3)</sup>, ACCODO G. <sup>(1)(2)</sup>, BUCCOLIERI G. <sup>(1)(2)</sup>, MONTEDURO L. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Matematica e Fisica, Università del Salento, Lecce*

<sup>(2)</sup> *INFN, Sezione di Lecce*

<sup>(3)</sup> *Department of Biological and Environmental Sciences and Technologies, Università del Salento, Lecce*

The use of Rogowski coils is very important in field of the evolutions of the accelerating machines, digital communications, electromagnetic pulse generators and many other devices. Currently, it is applied to diagnose shorter and shorter pulses, and for this reason the Rogowski coil must be considered as a transmission line and the Laplace transform allows to



get the different solutions. Experimentally, fast Rogowski coil responses are obtained with a low coil ring number ( $n \sim 20$ ), and as a consequence a low attenuation factor is obtained. The latest evolution we realised Rogowski coils able to perform precise measurements of sub-nanosecond rise time pulses of about 100 ps ( $\sim 200$  ps input pulse,  $\sim 300$  ps output pulse, V. Nassisi, Measurement 197, 111254 (2022)). But the most faithful solutions are obtained by introducing the resistance of the wire and the capacitance between the rings of the coil as well as that between the coil and the ground. Measurements performed with a low number of the coil have got a response like the input one, 100 ps. This result points out that the Rogowski risetime is  $< 100$  ps. The input pulse was realized by a fast switch (Reed relay h12)

### ● Vacuum Facility at LNF-INFN.

SPALLINO L., LIEDL A., ALESINI D., ANGELUCCI M., BINI S., CHIMENTI P., CIMINO R., DE BERNARDIS G., DE BIASE S., DI RADDIO G., DI RADDIO R., LOLLO V., PIETROPAOLI M., SCIARRA V., VIVIANI G., ZOTTOLA M.,  
INFN, Laboratori Nazionali di Frascati

In this work, we present the facilities available at the vacuum laboratory of LNF-INFN. This laboratory was established as a infrastructure for the design, testing and installation of vacuum components for accelerators at LNF, including historical projects such as Adone, DAΦNE, and Sparc, as well as current initiatives like TEX, EuPRAXIA, EIC, FCC, ET and others. The laboratory is equipped with systems for different activities and includes: a room dedicated to cleaning and preparation of UHV components with large ultrasonic tanks, test benches for large and heavy components, a vacuum furnace (base pressure of  $10^{-6}$  mbar) for brazing components at temperatures up to  $1200^\circ$ , a heat treatment furnace (up to  $450^\circ$ ) for large components, a dedicated outgassing characterization system for high and low outgassing materials, surface characterizations at cryogenic temperature, in their atomic composition, SEY, etc. are also available through collaboration with MaSSLab. Each system will be presented with its technical specifications, along with brief case studies demonstrating its applications.

### ● A modular and scalable dual-readout fiber-sampling prototype built with capillary tubes.

BURDYKO A. <sup>(1)</sup><sup>(2)</sup>, SANTORO R. <sup>(1)</sup><sup>(2)</sup>, CACCIA M. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> Dipartimento di Scienza ed Alta Tecnologia, Università degli Studi dell'Insubria, Como

<sup>(2)</sup> INFN, Sezione di Milano

Future high-energy lepton collider experiments (i.e., FCC and CEPC) will focus on precise measurements of the properties of the Higgs boson. Excellent calorimetric performance will be crucial for identifying significant processes by measuring the invariant masses of final-state objects. In recent years, the dual-readout method, which exploits complementary information from scintillation and Cherenkov channels, has emerged as a candidate to fulfill the requirements of these experiments. The dual-readout community has been working on the development of highly granular prototypes with scalable solutions compatible with  $4\pi$  geometry. Studies based on simulations and test beam results have investigated various detector geometries using dual-readout fiber sampling, and capillary tubes have proven to be an easy assembly technique with excellent geometrical accuracy at a moderate cost. In this contribution, the design of the hadronic shower-sized prototype (HiDRa), currently under construction, will be described. An overview will be provided of the construction technique, the innovative solutions identified to constrain all services on the back of the absorber, and the quality control of the modules produced.

Aula 8, Section B, Edificio 19

ore 10:00 – 13:30

SEZIONE VII

**Didattica e storia della fisica**

Presiede: ONORATO P. (Università di Trento)

Relazioni su invito

▲ **Il PLS Fisica 2021-23.**

FAZIO C.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

Fin dalla sua prima edizione, il PLS Fisica ha favorito la collaborazione tra Scuola e Università, valorizzando il ruolo attivo di studenti e docenti nella costruzione del sapere scientifico. Le attività hanno coinvolto migliaia di studenti e insegnanti, favorendo un apprendimento della fisica basato su metodi di indagine e scoperta scientifica. Anche nelle edizioni successive sono state promosse attività di formazione in servizio per insegnanti, scuole e laboratori estivi, PCTO e incontri con ricercatori, rafforzando la didattica laboratoriale come strumento di innovazione. Nella sua attuale edizione, il PLS Fisica continua a essere punto di riferimento nella promozione della didattica della Fisica, contribuendo alla scelta consapevole del percorso universitario. In questa relazione, descriverà le attività previste dalle Azioni del PLS Fisica e quanto finora svolto anche nell'ambito dei suoi cinque Gruppi di Lavoro, che si concentrano sullo studio dell'inclusione sociale e del ruolo del genere nei processi di apprendimento, la crescita professionale degli insegnanti, l'innovazione in didattica della Fisica, l'orientamento e l'autovalutazione e gli aspetti culturali della fisica.

▲ **ADELANTE: una comunità di pratica per co-progettare la fisica con strumenti digitali.**

ORGANTINI G. <sup>(1)</sup>, BOZZO G. <sup>(2)</sup>, CARLI M. <sup>(3)</sup>, GABELLI L. <sup>(3)</sup>, PANTANO O. <sup>(3)</sup>, SAPIA P. <sup>(2)</sup>, SURACE G. <sup>(1)</sup>, TUFINO E. <sup>(3)</sup>

<sup>(1)</sup> *Sapienza Università di Roma*

<sup>(2)</sup> *Università della Calabria*

<sup>(3)</sup> *Università degli Studi di Padova*

Il progetto ADELANTE, finanziato con un PRIN e coordinato da Sapienza Università di Roma in collaborazione con le Università della Calabria e di Padova, promuove un approccio innovativo all'insegnamento della fisica nella scuola secondaria attraverso attività laboratoriali con smartphone e microprocessori Arduino. In collaborazione con docenti esperti, sono state sviluppate attività didattiche basate sulla ricerca, affrontando le principali difficoltà di apprendimento. Le sequenze progettate sono state sperimentate da un secondo gruppo di insegnanti, coinvolti in un percorso formativo con incontri periodici e strumenti digitali per il monitoraggio quotidiano. Gli insegnanti hanno fornito osservazioni strutturate, esiti di verifica e suggerimenti, utili alla valutazione dell'efficacia didattica e dello sviluppo professionale. Il progetto ha anche favorito la nascita di una rete nazionale di docenti, con l'obiettivo di rendere il modello sostenibile, scalabile e in continua evoluzione.

▲ **Azione formazione insegnanti nel PLS-Fisica: un coordinamento con diverse linee condivise.**

MICHELINI M. <sup>(6)</sup>, BOLOGNA V. <sup>(1)</sup>, CHIOFALO M. <sup>(2)</sup>, DE ANGELIS I. <sup>(3)</sup>, MARIOTTI E. <sup>(4)</sup>, MARZOLI I. <sup>(5)</sup>

<sup>(1)</sup> *Centro di Formazione Insegnanti e Dipartimento di Fisica, Università degli Studi di Trieste*

<sup>(2)</sup> *Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa*

<sup>(3)</sup> *Università degli Studi di Roma Tre*

<sup>(4)</sup> *Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena e INFN, Sezione di Pisa*

<sup>(5)</sup> *Scuola di Scienze e Tecnologie, Università di Camerino*

<sup>(6)</sup> *Dipartimento di Matematica Informatica e Fisica, Università di Udine*

La natura progettuale nell'ambito della didattica disciplinare ed il coordinamento nazionale anche per le singole Azioni previste nel PLS-Fisica ne costruiscono il valore per la scuola e l'università. In merito all'Azione di Formazione degli insegnanti il Gruppo di Lavoro (GdL-FI del PLS-Fisica) ha proseguito il fertile coordinamento documentato nei volumi 63 del *Giornale di Fisica* (1,2) con un impegno di 33 colleghi su tre piani: 1) il confronto di strategie e metodi per la formazione degli insegnanti in servizio portato a livello internazionale (3,4); 2) realizzazione del Master IDIFO2426 gratuito per tutti i 45 insegnanti iscritti con l'impegno di 14 università italiane per 33 moduli da scegliere per percorsi formativi brevi (3cfu), di Perfezionamento (30cfu) e di Master biennale (60cfu) (5); 3) Seminari tematici di scambio delle competenze per una mutua fertilizzazione dei contributi nelle diverse sedi; 4) un approccio di ricerca (INQUIRY) per l'abilitazione degli insegnanti secondari nelle classi di concorso che comprendono la fisica a cui partecipano 27 colleghi di 11 sedi. Come in una Tavola Rotonda, un collega presenterà le attività di ogni linea di impegno del coordinamento.

### ▲ **Comunità di pratica e leadership educativa: esperienze nella formazione degli insegnanti di fisica all'Università di Padova.**

CARLI M.

*Dipartimento di Fisica e Astronomia, Università degli Studi di Padova*

Il modello della comunità di pratica si è affermato come riferimento per la formazione insegnanti. A Padova, i progetti CoLLabora, ATENA e Let's Interplay! hanno mostrato l'efficacia di questo approccio per favorire uno sviluppo professionale personalizzato e significativo degli insegnanti di fisica. Da tali esperienze è emersa una domanda di ricerca sul ruolo degli insegnanti "esperti", capaci di accompagnare i colleghi e sviluppare al contempo la propria professionalità attraverso la leadership educativa. Questo contributo presenta due progetti che hanno studiato questa figura. Il progetto Mentoring Growth (2024) ha indagato il ruolo e l'esperienza dei tutor di tirocinio indiretto nei nuovi percorsi 60 CFU, con le classi di concorso di area fisico-matematica come caso di studio. Sono state inoltre sviluppate linee guida e strumenti di autovalutazione per tirocinanti e tutor. Nel progetto ADELANTE (2023-25), 15 teacher leaders hanno co-progettato con i ricercatori sequenze didattiche poi sperimentate da colleghi. Lo studio delle loro traiettorie di sviluppo professionale contribuisce a definire un modello sostenibile di comunità di pratica per la formazione insegnanti.

### Comunicazioni

#### ● **La fisica dell'orologio: integrare Arduino in un percorso ISLE-based.**

LONGO F. <sup>(1)</sup><sup>(2)</sup>, BOLOGNA V. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, MARINI F. <sup>(1)</sup>, MILOTTI E. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Trieste*

<sup>(2)</sup> *INFN, Sezione di Trieste*

<sup>(3)</sup> *Centro di Formazione Insegnanti, Università degli Studi di Trieste*

Per coniugare l'esigenza di rinnovare i percorsi didattici del museo dell'orologeria pesarina (UD) e la possibilità di innovare l'apprendimento del concetto di tempo in fisica, ritenuto già noto e pertanto non pienamente esplorato nella didattica, abbiamo ideato alcune attività esplorative basate sull'investigazione autentica. Abbiamo realizzato il materiale didattico

basandoci sull'Investigative Science Learning Environment (ISLE). In questo ambiente di apprendimento, viene valorizzata la centralità dello studente che in modo autonomo, e rispettando la pratica scientifica, osserva, formula ipotesi, sperimenta e interpreta i dati raccolti, sviluppando competenze scientifiche di ragionamento, pensiero critico e capacità di giudizio. La misura del tempo consente di esplorare, utilizzando sistemi basati su Arduino realizzati ad hoc, sia la percezione soggettiva che la misura reale ed oggettiva del tempo, tramite l'introduzione di concetti fondamentali come periodo e frequenza, e attraverso l'analisi del funzionamento dell'orologio. Prima di realizzarle nelle stanze del museo, le attività sono state sperimentate nelle classi di un istituto tecnico. Si riportano qui gli esiti.

● **Dietro le quinte di una sperimentazione didattica.**

SARTOGO F. <sup>(1)</sup>, AMATI V. <sup>(2)</sup>, SIDORETTI S. <sup>(3)</sup>

<sup>(1)</sup> *Liceo Scientifico Statale Augusto Righi, Roma*

<sup>(2)</sup> *Liceo Ginnasio Torquato Tasso, Roma*

<sup>(3)</sup> *Liceo Statale Terenzio Mamiani, Roma*

Adelante (Adopting Digitally Enhanced Laboratories in a Network of TEachers) è una collaborazione tra Sapienza Università di Roma, Università degli Studi di Padova e Università della Calabria che si pone l'obiettivo di sviluppare TLS (Teaching-Learning Sequences) che risolvano le difficoltà di apprendimento nell'insegnamento della fisica nelle scuole superiori, mediante attività laboratoriali con strumentazione digitale. Le TLS sono concepite e sviluppate in collaborazione con insegnanti esperti (teacher leaders). Un secondo gruppo di insegnanti ha il compito di sperimentare le TLS, discutendone periodicamente con ricercatori e teacher leaders le ricadute didattiche, proponendo integrazioni ed eventuali modifiche. Questi momenti di confronto e discussione sui passaggi più delicati del lavoro in aula forniscono agli insegnanti coinvolti un contesto prezioso lo sviluppo professionale, unico nel panorama dell'offerta formativa per gli insegnanti in servizio. La comunicazione illustrerà come si svolge la sperimentazione, con particolare riferimento ai benefici che ne derivano per gli insegnanti ed i conseguenti effetti positivi sull'apprendimento degli studenti.

● **A TLS for teaching magnetic field in secondary school.**

ADDIUCCI L. <sup>(1)</sup>, BARONE P. <sup>(2)</sup>, GABELLI L. <sup>(3)</sup>, TRIFOLELLI C. <sup>(4)</sup>

<sup>(1)</sup> *Università Sapienza, Roma*

<sup>(2)</sup> *Liceo Scientifico Statale Enrico Medi, Battipaglia*

<sup>(3)</sup> *Università degli Studi di Padova*

<sup>(4)</sup> *Liceo Scientifico Statale Paolo Ruffini, Viterbo*

The contribution is part of the national research/action project ADELANTE (Adopting Digitally-Enhanced Laboratories in a Network of Teachers), aimed at innovating physics teaching through digital technologies. We present one of the TLSs developed within the project, designed for upper secondary school students and focused on magnetic field concepts. The TLS follows the ISLE model (Investigative Science Learning Environment) and combines laboratory activities, the use of smartphone magnetometers via the Phyphox app, and collaborative reflection. Students plan experiments, collect and analyze data, and derive Biot-Savart's law. The discovery-based approach, along with discussion of common student difficulties, supports deep understanding and the development of scientific modeling skills. Preliminary results from the ongoing implementation in Italian schools will be presented at the conference.

● **Progetto ADELANTE, sperimentazione di una TLS sulle onde presso Istituto Tecnico.**

MARACCI F. <sup>(1)</sup>, CARLI M. <sup>(2)</sup><sup>(1)</sup>, GABELLI L. <sup>(2)</sup>, TUFINO E. <sup>(2)</sup>, ERCOLI A. <sup>(3)</sup>, VARAGNOLO A. <sup>(4)</sup><sup>(1)</sup>

<sup>(1)</sup> ITI F. Severi, Padova

<sup>(2)</sup> Dipartimento di Fisica e Astronomia, Università di Padova

<sup>(3)</sup> Liceo Scientifico P. Ruffini, Viterbo

<sup>(4)</sup> Istituto G. Bruno R. Franchetti, Venezia-Mestre

Nel progetto PRIN 2022 ADELANTE sono state co-progettate sequenze didattiche laboratoriali che integrassero l'uso di tecnologie digitali per lo sviluppo di pratiche e abilità scientifiche. Un gruppo di lavoro si è concentrato sui fenomeni ondulatori, sviluppando una sequenza introduttiva sulle onde meccaniche e una seconda sequenza su interferenza, onde stazionarie e battimenti, anche attraverso esperimenti con Arduino e phyphox. Le attività, inizialmente pensate per studenti di classe quarta di liceo scientifico (7+11h di attività didattica), sono state poi rimodulate nei contenuti e nei tempi per proporre il percorso agli studenti di una classe seconda di un istituto tecnico, all'interno della disciplina Scienze Integrate-Fisica. Questo contributo descrive la progettazione della sequenza, il suo adattamento al nuovo contesto, e l'implementazione con una classe di 26 alunni nella primavera 2025. Le pratiche scientifiche su cui ci si è focalizzati riguardano l'interpretazione dei risultati di un esperimento utilizzando concetti e leggi fisiche note, l'individuazione, anche dai grafici, di relazioni fra grandezze, e l'argomentazione sulla base delle evidenze sperimentali.

### ● Investigazioni autentiche ISLE-based per il curriculum di Fisica della secondaria di primo grado.

BOLOGNA V. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, LEBAN S.P. <sup>(1)</sup><sup>(4)</sup>, LONGO F. <sup>(2)</sup><sup>(3)</sup>, MENOTTI F. <sup>(5)</sup><sup>(6)</sup>, PERESSI M. <sup>(2)</sup>, ROSSI M. <sup>(7)</sup>, SORZIO P. <sup>(8)</sup>, VENTURA A.P. <sup>(7)</sup>, ZAPPA L. <sup>(9)</sup>

<sup>(1)</sup> Centro di Formazione Insegnanti, Università degli Studi di Trieste

<sup>(2)</sup> Dipartimento di Fisica, Università degli Studi di Trieste

<sup>(3)</sup> INFN, Sezione di Trieste

<sup>(4)</sup> ISIS Paolino D'Aquileia, Cividale, UD

<sup>(5)</sup> Istituto Comprensivo di Cividale

<sup>(6)</sup> Centro di Formazione Insegnanti, Università degli Studi di Udine

<sup>(7)</sup> Liceo Caterina Percoto, Udine

<sup>(8)</sup> Dipartimento di Studi Umanistici, Università degli Studi di Trieste

<sup>(9)</sup> Istituto Comprensivo F.U. della Torre - L. Verni, Gradisca, GO

L'insegnamento della Fisica nella scuola secondaria di primo grado è spesso affidato all'iniziativa individuale dei docenti, nonostante le Indicazioni Nazionali (2012 e in bozza per il 2025) sottolineino l'importanza di un solido impianto concettuale precoce. Per supportare i docenti, abbiamo realizzato percorsi formativi nell'ambito di vari progetti nazionali (Piano Lauree Scientifiche e AggiornaMenti dell'INFN) e locali (FisicaMENTE, Physics for All, PHYStoGO!2025), integrando attività di tutoring, di coaching e sviluppando materiali basati sull'approccio ISLE (Investigative Science Learning Environment). I materiali, organizzati in guide didattiche per cinque temi chiave (materia, cinematica, dinamica, energia, ottica), sono stati sperimentati attraverso una triangolazione metodologica: (1) 50 docenti coinvolti in una sperimentazione volontaria, monitorati con questionari pre/post; (2) 150 ore di test in classe condotti da formatori esperti; (3) workshop tematici in contesti di formazione. Si presentano qui i risultati qualitativi e quantitativi di questa sperimentazione, che mostrano tendenzialmente un impatto positivo sia sullo sviluppo professionale degli insegnanti.

### ● Approcci basati sulla ricerca nello sviluppo professionale degli insegnanti.

DE ANGELIS A., MICHELINI M.,

*DMIF, Università di Udine*

Gli insegnanti in servizio hanno maturato una buona competenza di gestione dell'insegnamento basato sui libri di testo disponibili. L'impegno e la buona volontà ne ha fatto spesso validi

professionisti. La mancanza di formazione e risorse basate sulla ricerca fa gravare su di loro il peso di un'innovazione didattica necessaria e difficile. Parimenti problematico è organizzare un qualificante sviluppo professionale per loro. Impostazioni basate sulla ricerca ci hanno permesso di sperimentare modalità differenziate che integrano aspetti metaculturali, quesiti PCK, progettualità e consulenza seminariale. Si effettueranno esempi di esperienze condotte sia con insegnanti di scuola primaria che con insegnanti di scuola secondaria nell'ambito del PLS e del Master IDIFO.

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Aula 10, Section C, Edificio 19

ore 10:00 – 13:30

### Simposio di Optometria

Presiede: FIORETTO D. (Università di Perugia)

#### Comunicazioni

#### ● Caratterizzazione del cristallino tramite scattering Brillouin.

CIVIERO G. <sup>(1)(2)</sup>, BUSSA M.P. <sup>(1)</sup>, NAROO S. <sup>(2)</sup>

<sup>(1)</sup> *Università degli Studi di Torino, Torino, Italia*

<sup>(2)</sup> *Aston University, Birmingham, UK*

Questo studio ha valutato la ripetibilità del dispositivo BOSS (Brillouin Optical Scanning System) per la misurazione *in vivo* delle caratteristiche biomeccaniche del cristallino umano, sfruttando la misurazione dello scattering di Brillouin. È stata analizzata la dipendenza dei parametri misurati da età, spessore del cristallino (CLT), errore refrattivo e posizione della scansione. I parametri estratti includevano il modulo elastico di Brillouin (BLens), le lunghezze dei plateau superiore e inferiore, le pendenze anteriore e posteriore e la distanza dal centro pupillare. Il CLT è stato misurato con OCT, e l'errore refrattivo con autorefrattometro a campo aperto. La ripetibilità del BLens è risultata molto elevata, mentre quella degli altri parametri è stata inferiore. Sono emerse significative correlazioni tra variabili biometriche e parametri misurati. Il BOSS mostra un'eccellente ripetibilità nella misura del modulo elastico, evidenziando il suo potenziale per studi longitudinali e clinici, e rappresenta attualmente l'unico strumento disponibile per misurare il modulo elastico del cristallino *in vivo*.

#### ● On the perception of structured light with the naked eye.

RUFFATO G. <sup>(1)</sup>, ORTOLAN D. <sup>(1)</sup>, BATTAGLINI L. <sup>(2)</sup>

<sup>(1)</sup> *Department of Physics and Astronomy "G. Galilei", University of Padova, Italy*

<sup>(2)</sup> *Department of General Psychology, University of Padova, Italy*

Structured light involves controlling the spatial distribution of intensity, phase, and polarization of a beam. In particular, the non-separable combination of opposite states of polarization and orbital angular momentum originates unique spatially variant configurations, the so-called vector beams, providing the key for advanced applications in optics and photonics. While generating vector beams requires simultaneous manipulation of polarization and phase, their detection typically involves filtering methods to unveil their complex polarization patterns. Our study leverages the macula's built-in radial polarizer to filter and detect these complex light states, resulting in high-order Haidinger's brushes correlated to their phase structure. Furthermore, by judiciously structuring light intensity, we can confine this entoptic phenomenon to specific macular regions, providing an effective method to map macular pigment density. We present preliminary tests proving how humans can perceive the phase structure of a light beam directly through polarization analysis, opening new possibilities for non-invasive visual assessment and light structure analysis using the human visual system itself.

● **Evaluating Haidinger's brushes perception in individuals with macular diseases and other visual impairments.**

ORTOLAN D. <sup>(1)</sup>, ZAMBON S. <sup>(2)</sup>, RUFFATO G. <sup>(1)</sup>, MONTAGNOLI G. <sup>(1)</sup>, BATTAGLINI L. <sup>(2)</sup>

<sup>(1)</sup> *Department of Physics and Astronomy "G. Galilei", University of Padova, Italy*

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Haidinger's brushes are an entoptic phenomenon where a yellowish bow-tie shape is perceived when linearly polarized white light enters the eye. This pattern results from the unique spatial distribution of dichroic carotenoid molecules in the macula, effectively creating a built-in radial polarizer for blue light inside the eye. In recent years, we conducted multiple tests on healthy individuals to determine the normal thresholds of critical parameters influencing the pattern perception, such as the polarization degree and the rotational speed. We designed and built a specific setup combining two light sources, one polarized using a linear polarizer rotating at controlled speeds to avoid neural adaptation. We have recently extended our research to include individuals with macular diseases, pigment synthesis anomalies, and visual impairments. This study aims to evaluate the perception of Haidinger's brushes in people with anomalous visual conditions, potentially offering new insights into visual function in these disorders. Preliminary results confirm that Haidinger's brush perception could potentially serve as a quick, non-invasive, and cost-effective screening method.

● **On the use of colour illusions for fast and accessible screening of red-green colour vision anomalies.**

GALÌ M. <sup>(1)(2)</sup>, GURIOLI M. <sup>(1)</sup>, ARRIGHI R. <sup>(2)</sup>, FARINI A. <sup>(1)(3)</sup>, GRASSO P.A. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics and Astronomy, University of Florence*

<sup>(2)</sup> *Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence*

<sup>(3)</sup> *National Research Council, National Institute of Optics, Florence*

The identification of colour vision anomalies traditionally relies on standardised tests requiring specialised equipment and controlled conditions, which can limit accessibility for large-scale screening. In this study, we explored a novel method leveraging illusory colour perception to differentiate between protan (red-weak) and deutan (green-weak) deficiencies. We developed a psychophysical colour matching task where participants judged the chromaticity of a grey stimulus appearing coloured due to chromatic induction. This perceptual shift allowed assessment of colour discrimination without conventional tests. Participants' responses were analysed by hue angle in HSV colour space, yielding a continuous, quantifiable measure. The study included individuals with diagnosed protanomaly or deuteranomaly and a control group with typical trichromatic vision. Our findings showed that the illusory colour-based task reliably distinguished between protan and deutan participants based on their hue selections. This approach presents a promising, accessible alternative for detecting and classifying red-green colour vision deficiencies in both clinical and broader screening contexts.

● **From the eye to the brain: Tear fluid as a mirror of neurodegeneration.**

PONZINI E. <sup>(1)(2)</sup>, DUSE A. <sup>(1)(2)</sup>, ROLANDI R. <sup>(1)(2)</sup>, AMI D. <sup>(3)</sup>, CAZZANIGA F. <sup>(4)</sup>, BUFANO G. <sup>(4)</sup>, GRANDORI R. <sup>(3)</sup>, DEVIGILI G. <sup>(5)</sup>, MODA F. <sup>(4)(6)</sup>, NATALELLO A. <sup>(3)</sup>, PEZZOLI F. <sup>(1)</sup>, TAVAZZI S. <sup>(1)(2)</sup>

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<sup>(3)</sup> *Dipartimento di Biotecnologie e Bioscienze, Università degli Studi di Milano-Bicocca, Italia*



(<sup>4</sup>) *Unit of Laboratory Medicine - Laboratory of Clinical Pathology, IRCCS Istituto Neurologico Carlo Besta, Italia*

(<sup>5</sup>) *Movement Disorders Unit, IRCCS Istituto Neurologico Carlo Besta, Italia*

(<sup>6</sup>) *Dipartimento di Biotecnologie Mediche e Medicina Traslazionale, Università degli Studi di Milano, Italia*

Tear fluid, traditionally explored in ocular surface research, is emerging as a valuable source of systemic biomarkers, offering a non-invasive, easily accessible medium for diagnostic innovation. In this work, we present a Raman spectroscopy-based protocol tailored for the molecular profiling of human tear fluid, aimed at supporting early diagnosis of neurodegenerative diseases. Our previously published study focused on patients with Amyotrophic Lateral Sclerosis (ALS), analyzing 5  $\mu$ L tear samples dried on BaF<sub>2</sub> substrates. As a recent advancement, we extended this protocol to patients with Parkinson's Disease (PD), allowing a direct comparison of spectral fingerprints between ALS and PD. The results reveal condition-specific biochemical patterns, underlining the potential of tear fluid analysis in differential diagnosis. This approach integrates ocular science with systemic diagnostics, demonstrating how optometric research can contribute to broader medical challenges through tear-based molecular phenotyping.

#### ● **Analisi comparativa di tre strumenti ottici per la diagnostica oculare: MS-39, Sirius+ e Aladdin.**

GIORGETTI A., GRASSO P., TOMMASI F., CALOSSA A., DELLA GATTA A., DE MARTINO B., TESI V., GURIOLI M.

*Università di Firenze*

Il presente progetto si propone di condurre un'analisi comparativa strumentale tra tre dispositivi ottici utilizzati nella diagnostica oculare: l'OCT MS-39, il topografo corneale Sirius+, e il biometro Aladdin. L'obiettivo principale è valutare l'affidabilità, la ripetibilità e la coerenza dei dati biometrici e topografici forniti dai tre strumenti, con particolare attenzione al segmento anteriore oculare, alla misurazione della cornea e alla biometria assiale. Il progetto prevede l'arruolamento di un campione sperimentale composto da 350 soggetti, sottoposti a misurazioni con ciascuno dei tre strumenti. I dati raccolti saranno analizzati per identificare similarità, divergenze e limiti applicativi, sia in ambito optometrico che clinico. Le variabili oggetto di studio includono spessore corneale, raggio di curvatura, profondità della camera anteriore, lunghezza assiale e indici diagnostici specifici. I risultati attesi contribuiranno a definire criteri oggettivi per la scelta dello strumento più idoneo in base al contesto clinico e a promuovere l'uso integrato delle tecnologie ottiche per una diagnostica visiva più coerente, precisa ed efficace.

#### ● **From clarity to cloudiness: Investigating liquid-liquid phase separation in cataractogenesis.**

AFFATIGATO L., MILITELLO V., SANCATALDO G.

*Department of Physics and Chemistry "Emilio Segrè", University of Palermo*

Vision is one of our most vital senses, essential for daily activities. Unfortunately, it can decline due to aging, genetic predispositions, or environmental factors. One of the most prevalent vision disorders is cataract, characterized by the clouding of the eye's lens, often resulting in impaired vision and potential blindness. This condition is linked to the aggregation of Crystallins, specialized proteins that maintain the lens's transparency and refractive function. With aging or under environmental stress, these proteins can undergo biophysical processes that lead to supramolecular aggregation. During this process, Crystallins move from a soluble state to dense, protein-rich aggregates, contributing to the lens's opacification, a key feature of cataract formation. Gaining insight into the mechanisms behind

Crystallin aggregation may shed light on the underlying causes of cataract development and pave the way for novel treatments, including the development of biocompatible materials that mimic the distinctive properties of the natural lens. We investigated the biophysical mechanisms driving protein aggregation with a particular focus on analyzing the ability of Crystallins to undergo liquid-liquid phase separation (LLPS). The final goal is to integrate these preliminary results with *ex vivo* models to provide a comprehensive understanding of how phase separation contributes to lens opacity, ultimately offering new avenues for cataract prevention and treatment.

● **Fixation disparity as an indicator of binocular condition in subjects with and without cataracts.**

MANI E., BUSSA M.P., COLANDREA C., MIRANTI F., SERIO M.

*Physics Department, University of Turin, Turin, Italy*

Nowadays, an increasing number of patients have undergone cataract surgery. According to studies, preexisting binocular vision abnormalities are the main risk factor for predicting postoperative binocular abnormalities. The literature shows that the lack of normative data and testing procedures on binocular vision for the presbyopic population is a significant gap in the literature and clinic. The preoperative evaluation of these patients should include a comprehensive binocular and accommodative assessment; this would identify risk factors that could affect the success of surgery and reduce postoperative symptoms. However, the major limitation in binocular verification in the surgery-related clinic is time. According to this, it might be useful to verify the condition of fixation disparity with a single rapid test that would provide an indication of the subject's binocular vision. Indeed, clinical experience shows that conditions in which the patient has significant fixation disparity cause ocular fatigue and ocular strain, and according to the scientific literature, fixation disparity is a better predictor of ocular strain than phoria. The size of measured fixation disparity varies

● **Ametropia e lunghezza assiale: un nuovo modello di analisi che evidenzia la presenza della compensazione nell'ametropia e i suoi limiti.**

TESI V., GIORGETTI A., GRASSO P.A., CALOSSÌ A., CAVALIERI S., TOMMASI F.

*Dipartimento di Fisica e Astronomia, Università di Firenze*

Il legame fra ametropia e lunghezza assiale dell'occhio rappresenta un risultato ampiamente condiviso nella ricerca optometrica. In questo contributo analizzeremo il dettaglio di questo legame introducendo una nuova forma funzionale non lineare che evidenzia la presenza di un meccanismo di compensazione del sistema visivo umano. Il modello è confrontato con un vasto campione non polarizzato di giovani cinesi, presentando una robusta analisi statistica. Inoltre, grazie allo studio su un campione locale, fatto presso il Dipartimento di Fisica di Firenze, tale analisi viene estesa a un campione rappresentativo casuale di adulti (più di 700 occhi analizzati). L'analisi evidenzia la tendenza alla compensazione della lunghezza assiale nel limitare la condizione di ametropia e la regione in cui tale compensazione è efficace.

Aula 10, Section C, Edificio 19

ore 14:30 – 18:30

### Simposio di Optometria

Presiede: CIVIERO G., (Università degli Studi di Torino e Aston University)

#### Comunicazioni

● **On the correlations between ocular biometry, refractive errors, and ocular aberrations: An integrated study.**

MONTAGNOLI G., AGOSTINI A., BERTON E., FERTONANI N., RUFFATO G., FORMENTI M., COLOMBO R.

*Department of Physics and Astronomy “G. Galilei”, University of Padova, Italy*

While the interplay between the geometry of the ocular elements and their optical behaviour is at the basis of vision, many aspects regarding their complex relations remain elusive. This study aims to investigate the potential correlations between ocular biometry and optical aberrations in the human eye. A cohort of individuals underwent comprehensive ocular examinations using state-of-the-art biometric and aberrometric technologies. Key biometric parameters, including axial length, anterior chamber depth, and corneal curvature, were measured alongside both low-order and higher-order aberrations. The research aimed to identify significant relationships between these biometric measurements and various aberrations, and the results are thoroughly discussed and contextualized within the existing literature.

● **Assessing ocular refraction: A comparative study of subjective technique and objective devices.**

PISTRITTO A. <sup>(1)</sup>, BORGHESI A. <sup>(1)(2)</sup>, DUSE A. <sup>(1)(2)</sup>, OBAID A. <sup>(1)(2)</sup>, PONZINI E. <sup>(1)(2)</sup>, RIZZO G.C. <sup>(1)(2)</sup>, TAVAZZI S. <sup>(1)(2)</sup>, ZERI F. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> *Department of Materials Science, University of Milano-Bicocca, Milan, Italy*

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<sup>(3)</sup> *Ophthalmic Research Group. School of Life and Health Sciences, Aston University, Birmingham, UK*

Several methods are available to assess ocular refraction, often yielding different results. When new devices are introduced, it is essential to compare them with established gold standards to ensure accuracy. This prospective semi-randomized crossover study evaluated the agreement of ocular refraction measurements across four methods. A standard subjective refraction was compared with objective techniques using three devices: open-field and closed-field aberrometers, and an open-field autorefractor. Fifty-one participants were enrolled, including 23 presbyopes ( $54.7 \pm 8.5$  years) and 27 young adults ( $24.3 \pm 3.7$  years). Objective measurements were taken monocularly and binocularly—except with the closed-field device—in randomized order at 5-minute intervals, followed by subjective refraction. Refraction values were used to compute power vectors and assess agreement across techniques, age groups, and binocularity. Significant differences in spherical equivalent refraction emerged between objective and subjective methods, highlighting variability among techniques and underscoring the importance of method selection in clinical practice.

● **Valutazione di una tavola di lettura a due livelli di contrasto.**

FARINI A. <sup>(1)(2)</sup>, CHRISTODOULOU I. <sup>(2)</sup>, GRASSO P.A. <sup>(2)</sup>, GURIOLI M. <sup>(2)</sup>

<sup>(1)</sup> *CNR, Istituto Nazionale di Ottica, Firenze, Italia*

<sup>(2)</sup> *Dipartimento di Fisica, Università degli Studi di Firenze, Italia*

La sensibilità al contrasto è fondamentale per valutare la visione umana, ma spesso trascurata per la scarsità di strumenti semplici. È stata quindi sviluppata una tavola per visione da vicino che consente la valutazione a due livelli di contrasto: massimo e al 25% secondo Weber. Si è proceduto innanzitutto alla calibrazione del processo di stampa per garantire l'accuratezza dei valori di contrasto. La tavola è stata testata su 60 soggetti, corretti per vicino e suddivisi in tre fasce d'età. Le performance con frasi ad alto contrasto sono risultate simili tra i gruppi, mentre con contrasto ridotto si è osservato un marcato peggioramento nei soggetti più anziani. I risultati evidenziano l'importanza di includere stimoli a basso contrasto nella valutazione visiva, in quanto rappresentativi della vita quotidiana.

● **Font adattivi e ottotipi intelligenti.**

VENTURA M., ZERI F., TAVAZZI S.

*Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, Italia e Optics and Optometry research center, COMiB, Università degli Studi di Milano-Bicocca, Italia*

L'evoluzione dei display digitali ha portato alla diffusione di ottotipi su display LCD supportati da tecnologie di ottimizzazione dell'immagine come il sub-pixel rendering, tecnologie che si sono concentrate più sulla resa estetica che sull'adattamento morfologico del carattere alla condizione visiva del soggetto. In questa comunicazione si discute la compatibilità tra algoritmi di rendering e normative ISO per gli ottotipi digitali, con la prospettiva di sviluppare un sistema intelligente per l'esecuzione automatica di test optometrici attraverso un approccio adattivo. Il lavoro si basa su "Adaptifont", un meccanismo discusso in letteratura che utilizza un sistema generativo di font e ottimizzazione Bayesiana per massimizzare la velocità di lettura. In analogia, si intende costruire un modello adattivo orientato all'optometria, in grado di variare in tempo reale le caratteristiche morfologiche del carattere in funzione delle risposte visive dell'utente con un approccio retroattivo. Il lavoro si colloca all'intersezione tra ottica fisiologica, percezione visiva computazionale e apprendimento automatico, con potenziali applicazioni cliniche e di screening.

● **Validazione di una web app per la misurazione della distanza interpupillare (PD).**

FOSSETTI L., BOCCARDO L.

*Corso di Laurea in Ottica e Optometria, Università di Firenze e Istituto di Ricerca e Studi in Ottica e Optometria, Vinci, FI*

Lo studio ha esaminato una web app che sfrutta una webcam, accessibile da PC o dispositivi mobili, abbinata a una carta di credito (o simile carta con dimensioni standard) per misurare la distanza interpupillare (PD) dell'utilizzatore. L'applicazione è stata testata su 39 partecipanti, utilizzando due smartphone e un laptop. Il processo di validazione ha utilizzato come riferimento le misure ottenute con un righello e con un interpupillometro basato sul riflesso corneale. Per 30 partecipanti è stata presa una singola misura, mentre per i restanti 9 sono state ottenute cinque misure al fine di valutare la ripetibilità di tutti gli strumenti presi in esame. La PD media è risultata 61.54 mm (range 56.7–68.1). La ripetibilità è risultata buona, con deviazione standard media di 0.38 mm (contro 0.26 dell'interpupillometro e 0.52 del righello). La validazione è stata eseguita comparando le misure ottenute dalla web app con quelle degli strumenti di riferimento, attraverso grafici di Bland-Altman. I limiti di concordanza suggeriscono che le misure ottenute con la web app siano più consistenti con quelle ottenute con il righello ( $\pm 1.5$  mm), piuttosto che con l'interpupillometro ( $\pm 2.5$  mm).

● **Test per discriminare la visione globale e locale utilizzando un eye tracker e immagini ambigue.**

DELLA GATTA A. <sup>(1)</sup>, FARINI A. <sup>(1)</sup>(<sup>2</sup>), GRASSO P.A. <sup>(1)</sup>, GURIOLI M. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Firenze, Italia*

<sup>(2)</sup> *CNR, Istituto Nazionale di Ottica, Firenze, Italia*

È stato sviluppato un test, supportato da eye tracking, per valutare la predisposizione a una visione globale o locale mediante l'osservazione di immagini ambigue. Tali immagini possono essere interpretate in base ai dettagli fini (frequenze spaziali alte) o alla forma generale (frequenze basse) fornendo percezioni diverse. L'eye tracker ha permesso di registrare i tempi di percezione della figura globale e la distribuzione spaziale dello sguardo nelle due modalità percettive. I risultati sono stati confrontati con due test noti: il test di Navon, in cui figure globali (per esempio una lettera A) sono composte da elementi locali (per esempio lettere V), e il test del cilindro, dove un pattern di punti bianchi e neri genera l'illusione di un cilindro rotante il cui verso percepito dipende dal focus visivo. Il confronto tra i tre test permette una più precisa caratterizzazione dello stile percettivo individuale.

● **Confronto fra refrazione soggettiva eseguita in campo aperto e con unità di refrazione compatta.**

FAZIO M. G. <sup>(1)</sup>, BOCCARDO L. <sup>(1)</sup>(<sup>2</sup>), FOSSETTI L. <sup>(1)</sup>(<sup>2</sup>)

<sup>(1)</sup> *Corso di Laurea in Ottica e Optometria, Università di Firenze*

<sup>(2)</sup> *Istituto di Ricerca e Studi in Ottica e Optometria, Vinci, FI*

Lo studio confronta tre metodi di refrazione: oggettiva con autorefrattometro Essilor AKR800, soggettiva con unità di refrazione compatta Vision-S700 e con forottero digitale Vision-R800, abbinato a ottotipo CS Pola 600. L'acuità visiva (AV) è stata verificata con tavola ETDRS. Hanno partecipato 27 soggetti tra 19 e 68 anni. L'equivalente sferico variava tra  $-12.75$  e  $+8.00$  D, con astigmatismo fino a  $-3.75$  D. I grafici Bland-Altman dell'equivalente sferico hanno mostrato un intervallo di concordanza di  $\pm 1.25$  D (bias  $-0.19$  D) tra AKR800 e Vision-R800;  $\pm 1.75$  D (bias  $-0.23$  D) tra AKR800 e Vision-S700; e  $\pm 0.75$  D (bias  $-0.03$  D) tra le due refrazioni soggettive. Risultati simili sono emersi per l'astigmatismo. L'AV binoculare era  $-0.12$  (SD  $\pm 0.09$ ) LogMAR con CS Pola600,  $-0.08$  (SD  $\pm 0.07$ ) con Vision-S700 e  $-0.10$  (SD  $\pm 0.09$ ) con ETDRS. L'ampio intervallo di concordanza indica affidabilità limitata della refrazione oggettiva rispetto alla soggettiva. Non sono state riscontrate differenze significative tra le due refrazioni soggettive e la misura dell'AV con i tre ottotipi. I risultati confermano che la refrazione e l'AV misurate con unità compatta sono comparabili a quelle in spazio aperto.

● **L'efficacia del visual training nel miglioramento delle abilità visive e delle performance cognitive nei soggetti con dislessia.**

BINAGGIA E., FAZIO G., MILITELLO V.

*Department of Physics and Chemistry "Emilio Segrè", University of Palermo*

È stato studiato il ruolo dell'optometria e del visual training come strumenti complementari nella gestione della dislessia evolutiva, un disturbo specifico dell'apprendimento che colpisce la capacità di lettura e scrittura in soggetti con intelligenza nella norma. Il lavoro si fonda sul principio della neuroplasticità e prende in esame come un training visivo mirato possa potenziare abilità visuo-percettive, oculo-motorie e cognitive, spesso compromesse nei soggetti dislessici. La parte teorica introduce il lettore allo sviluppo del sistema visivo, ai modelli neurobiologici e cognitivi della dislessia (tra cui il modello a due vie e la teoria del deficit magnocellulare), e al ruolo dell'optometrista nella valutazione e nel trattamento dei disturbi visuo-motori. Viene inoltre illustrato il protocollo di visual training, composto da esercizi mirati al miglioramento della coordinazione oculare, della fissazione, della convergenza e della flessibilità accomodativa. La sezione sperimentale presenta il caso clinico di

un bambino di 10 anni con diagnosi di dislessia e problemi visivi associati. Il soggetto ha seguito un percorso personalizzato di visual training con incontri settimanali e l'uso di specifici esercizi (tra cui la palla di Marsden, la lettura con flipper accomodativo binoculare e l'arretamento binoculare), supportato da una lieve prescrizione ottica. Dopo alcuni mesi di trattamento, si sono riscontrati miglioramenti significativi: la lettura è diventata più fluente, con riduzione degli errori (da 2.9 a 1.7 per riga), migliorata comprensione del testo e una maggiore stabilità oculare. Anche i docenti hanno confermato un netto miglioramento del rendimento scolastico e della motivazione. In conclusione, la tesi dimostra che il visual training può rappresentare un valido complemento agli interventi logopedici ed educativi, favorendo il potenziamento delle abilità visive e cognitive nei soggetti dislessici. Pur non trattandosi di una cura definitiva, il training ha mostrato di migliorare l'efficienza visiva e l'autonomia nella lettura, confermando l'importanza di un approccio multidisciplinare e personalizzato che coinvolga optometristi, logopedisti, insegnanti e famiglie per un intervento precoce ed efficace.

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Presiede: MONTAGNOLI G. (Università di Padova)

#### Comunicazioni

##### ● **Non-invasive mechano-chemical profiling of Delefilcon A contact lenses by Brillouin-Raman microspectroscopy.**

FIORETTO D. <sup>(1)</sup>, CARDINALI M.A. <sup>(2)</sup>, LOREÈ S. <sup>(1)</sup>, PONZINI E. <sup>(3)</sup><sup>(4)</sup>, TAVAZZI S. <sup>(3)</sup><sup>(4)</sup>

<sup>(1)</sup> *Department of Physics and Geology, University of Perugia, Perugia, Italy*

<sup>(2)</sup> *Department of Chemistry, Biology and Biotechnology, University of Perugia, Perugia, Italy*

<sup>(3)</sup> *Department of Materials Science, University of Milano-Bicocca, Milan, Italy*

<sup>(4)</sup> *COMiB Research Centre in Optics and Optometry, University of Milano-Bicocca, Milan, Italy*

Water gradient contact lenses, such as Delefilcon A, offer a promising approach to enhanced comfort and wettability through their distinct structure: a 33% water content silicone hydrogel core with an approximately 6  $\mu\text{m}$  thick, 80% water content silicone-free hydrogel surface. While this soft, high-water content layer improves the wearing experience, it also raises concerns about the material's durability under physiological stresses. In this work, we propose and demonstrate the application of Brillouin-Raman microspectroscopy, a non-invasive and label-free spectroscopic method, for characterizing the chemical and viscoelastic properties of these innovative lenses. Initial measurements on hydrated Delefilcon A lenses are presented as a proof of concept.

##### ● **Refractive index of the surface layer of soft contact lenses.**

TAVAZZI S. <sup>(1)</sup><sup>(2)</sup>, PONZINI E. <sup>(1)</sup><sup>(2)</sup>, CARDINALI M.A. <sup>(3)</sup>, FIORETTO D. <sup>(3)</sup>, RIZZO G.C. <sup>(1)</sup><sup>(2)</sup>, ZERI F. <sup>(1)</sup><sup>(2)</sup>, BORGHESI A. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, Italia*

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One of the key factors affecting the performance of soft contact lenses (CLs) is their ability to maintain adequate hydration and moisture during wear. In particular, the lens surface plays

a crucial role, and various types of surface-modified or coated CLs have been specifically designed to enhance comfort and biocompatibility. One method used to characterize the surface of CLs involves measuring the refractive index in its hydrated state. In this study, refractive index measurements were carried out on different types of CLs at 36 °C using an Atago RX-5000 Alpha refractometer. The relationship between the equilibrium water content and the measured refractive index is presented, along with the comparison between the results obtained on unworn and worn CLs.

● **Factors affecting the attitude to continue using Precision1® contact lenses (CLs) in neophyte wearers: Preliminary findings from the ATP Study.**

RIZZO G.C. <sup>(1)(2)</sup>, BORGHESI A. <sup>(1)(2)</sup>, PONZINI E. <sup>(1)(2)</sup>, TAVAZZI S. <sup>(1)(2)</sup>, ZERI F. <sup>(1)(2)(3)</sup>

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<sup>(2)</sup> *Research Centre in Optics and Optometry, COMiB, University of Milano-Bicocca, Milan, Italy*

<sup>(3)</sup> *Ophthalmic Research Group. School of Life and Health Sciences, Aston University, Birmingham, UK*

To evaluate the propensity to continue using Precision1® CLs in neophyte wearers after a brief period, a prospective, single-masked clinical trial was conducted on 77 ametropes (mean age  $25.4 \pm 5.4$  years, 34 males). Participants were fitted with Precision1® daily disposable SH CLs (Alcon, USA) and instructed to wear them for 14 days. At follow-up, comfort, vision quality, overall satisfaction, and the intention and reasons to continue wearing CLs were evaluated. Comfort ratings were  $8.5 \pm 1.5$  at insertion and  $8.0 \pm 1.7$  at the end of the day ( $p < 0.001$ ). Vision quality and overall satisfaction scored  $8.6 \pm 1.6$  and  $8.6 \pm 1.4$ , respectively. The attitude of continued use was  $7.6 \pm 2.1$ ; significantly correlated to the comfort at insertion ( $p < 0.001$ ), the end of day comfort ( $p < 0.001$ ), the quality of vision ( $p < 0.001$ ), and the overall satisfaction ( $p = 0.01$ ). Key motivations to continue to wear CL were convenience ( $7.4 \pm 2.4$ ), vision ( $7.0 \pm 2.9$ ), and sport ( $7.0 \pm 3.7$ ). Overall, participants reported a positive experience and a strong inclination to keep wearing CLs. Research funded by Alcon: IIT90203571.

● **Adaptive optics applications in optometry.**

DUSE A. <sup>(1)(2)</sup>, ORTOLAN D. <sup>(3)</sup>, PONZINI E. <sup>(1)(2)(4)</sup>, TAVAZZI S. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, Italia*

<sup>(2)</sup> *Optics and Optometry research center, COMiB, Università degli Studi di Milano-Bicocca, Italia*

<sup>(3)</sup> *Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova, Italia*

<sup>(4)</sup> *Dipartimento di Biotecnologie e Bioscienze, Università degli Studi di Milano-Bicocca, Italia*

In recent decades, Adaptive Optics (AO) has improved retinal imaging by correcting ocular aberrations, enabling deeper insights into ocular anatomy, physiology and pathology. This work highlights AO-based techniques peculiarities for studying different structures, for instance retinal cone mosaic and its relationship with visual acuity, axial length or refractive error, as well as pointing out the diagnostic role in various diseases. Furthermore, optometric applications focus on AO potential in binocular setups, improving not just visual acuity but also contrast sensitivity and stereopsis assessment as it addresses the natural coupling of accommodation and convergence: light source, pupil size, and eye movements are considered influencing factors for measure outcomes. Finally, considerations will be made about the future of the techniques in enhancing clinical assessments and understanding the complex link between retinal structures and function or neural adaptation.



● **Caratteristiche ottiche di IOL e evidenze cliniche post-operatorie: ricerca di un indicatore preoperatorio.**

TOMMASI F. <sup>(1)</sup>, GIORGETTI A. <sup>(1)</sup>, MONNETTI C. <sup>(1)</sup>, ROMUALDI G. <sup>(2)</sup>, MENCUCCI R. <sup>(2)</sup>, CALOSSA A. <sup>(1)</sup>, CAVALIERI S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Firenze*

<sup>(2)</sup> *Dipartimento di Neuroscienze, Psicologia, Area del Farmaco e Salute del Bambino, NEUROFARBA, Università di Firenze*

La caratterizzazione ottica di lenti intraoculari riveste un'importanza fondamentale per comprenderne le prestazioni visive attese prima dell'impianto. L'impiego di un banco ottico consente di analizzare in modo preciso e riproducibile il comportamento ottico di queste lenti, valutandone la qualità dell'immagine fornita per diverse distanze di visione. Tale approccio è particolarmente rilevante in un contesto clinico in cui la personalizzazione della correzione visiva è sempre più richiesta, specialmente nei pazienti con aspettative funzionali elevate e secondo varie condizioni di visione. In letteratura, sono stati sviluppati metodi che correlano direttamente i parametri ottici ottenuti in laboratorio —come la funzione di trasferimento di modulazione media o la distribuzione di energia nel piano immagine— con l'acuità visiva post-operatoria a varie distanze. Questi strumenti predittivi ambiscono ad offrire una base solida per l'ottimizzazione della scelta della IOL in fase preoperatoria, contribuendo alla effettuazione della scelta più adatta per il paziente. In questo contributo si ripercorrono tali metodologie e problemi connessi e le prospettive future.

● **Sviluppi e applicazioni pratiche della stampa 3D tramite produzione additiva in Contattologia.**

RAPISARDA A.I., MILITELLO V.

*Dipartimento di Fisica e Chimica Emilio Segrè, Università di Palermo, Palermo, Italy*

Questo lavoro è incentrato su alcuni esempi di applicazione della stampa 3D in Contattologia: i) un nuovo approccio per simulare il processo di applicazione di lenti a contatto rigide gas permeabili (RGP) utilizzando la tecnologia di stampa 3D, utilizzando un modello 3D del segmento anteriore emisferico o parabolico utilizzando il software 3D Builder o Tinkercad e simulando un'applicazione di lenti a contatto RGP; ii) la stampa 3D su alcuni materiali, basata sulla fotopolimerizzazione in vasca per produrre lenti a contatto multimateriale, offrendo una correzione ottica multibanda ottimizzata, che può essere preziosa per affrontare condizioni oculari come il daltonismo; iii) uno studio attuale che dimostra la fabbricazione di lenti a contatto smart personalizzate utilizzando la produzione additiva. Lo studio comprende la modellazione tridimensionale (3D) di lenti a contatto con l'assistenza di uno strumento di progettazione assistita da computer basato sulla dimensione standard delle lenti a contatto commerciali, seguita dalla selezione dei materiali idonei e dalla stampa 3D delle lenti a contatto.

● **Lenti intraoculari toriche: caratterizzazione ottica e simulazione visione post-impianto.**

DE MARTINO B. <sup>(1)</sup>, GIORGETTI A. <sup>(1)</sup>, SANTUCCI E. <sup>(1)</sup>, SAVINI G. <sup>(2)</sup>, CALOSSA A. <sup>(1)</sup>, CAVALIERI S. <sup>(1)</sup>, TOMMASI F. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Firenze*

<sup>(2)</sup> *IRCCS Fondazione G.B. Bietti per lo Studio e la Ricerca in Oftalmologia-Onlus, Rome, Italy*

La caratterizzazione ottica delle lenti intraoculari (IOL) mediante banco ottico rappresenta una fase cruciale per la valutazione delle loro performance prima dell'impianto. La valutazione preclinica di tali dispositivi ottici risulta quindi essenziale per verificarne l'efficacia e l'adeguatezza in funzione delle specifiche esigenze refrattive del paziente. Tra le diverse tipologie di IOL, le lenti toriche rivestono un ruolo particolarmente rilevante: oltre



a ripristinare la trasparenza del cristallino compromesso dalla cataratta, sono progettate per correggere anche l'astigmatismo corneale, offrendo così un miglioramento complessivo della qualità visiva. In questo contributo viene presentata la caratterizzazione su banco ottico di IOL toriche e simulazione della visione post-impianto.

● **Spectroscopic characterization of ophthalmic lenses.**

BRIZZI G. <sup>(1)</sup>, TRIBUNA M. <sup>(1)</sup>, SANCATALDO G. <sup>(2)</sup>, MILITELLO V. <sup>(2)</sup>

<sup>(1)</sup> *Brizzi srl, Palermo, Italy*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica "Emilio Segrè", Università di Palermo, Palermo, Italy*

This work presents a general spectroscopic investigation of the optical properties of commercially available ophthalmic lenses. Using UV-Vis spectrometry, we analyzed the light transmission characteristics of different types of lenses commonly used for vision correction. The study focused on measuring the absorption and transmission spectra across a broad wavelength range, from ultraviolet to visible light. The aim was to evaluate how various lenses interact with light and to identify differences related to material composition, coatings, and design features. Particular attention was given to the filtering properties in specific regions of the spectrum, such as UV and blue light. The results highlight variations in optical behavior among different lens types, providing a useful reference for further optical assessments and potential applications in lens development. This study contributes to a better understanding of the optical performance of ophthalmic lenses and supports informed choices in both clinical and consumer contexts.

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Aula Magna G.B.F. Basile, Edificio 7

ore 14:30 – 15:10

SEZIONE IV  
**Geofisica e fisica dell'atmosfera**  
Presiede: QUARENI F. (INGV)

Relazione Generale

■ **Black swans and grey rhinos: The art of defending from tsunami risk.**

AMATO A.

*Tsunami Alert Center-INGV e ICG/NEAMTWS, UNESCO*

Twenty years ago one of the largest tsunami events ever recorded on Earth hit the Indian Ocean. Although tsunami warning had been operating in the Pacific Ocean for almost half a century, no warning was given to the local populations of Asian and African countries, resulting in 250000 fatalities and huge destruction. In the following years, the Intergovernmental Oceanographic Commission of UNESCO coordinated efforts for a global Tsunami Warning System (TWS) based on real-time earthquake monitoring. A decade later this goal was achieved, with the establishment of four Intergovernmental Coordination Groups (ICG), among which the NEAMTWS (North East Atlantic and the Mediterranean TWS). In the meantime, other huge tsunamis had occurred, like the ones in Chile (2010) and Japan (2011), and some minor but still damaging events, showing the effectiveness of the approach but also some limitations. In the last ten years, all the four ICGs greatly improved their ability to manage the tsunami risk, contributing to save lives. However, they had to face important challenges, among which the risk amplified by increased coastal population, the occurrence of volcanic tsunamis, limitations of the observing systems and forecasting techniques, low preparedness of authorities and people at risk. In this contribution I will summarize the most relevant challenges and the future trends in tsunami monitoring and risk reduction strategies.

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Aula Magna G.B.F. Basile, Edificio 7

ore 15:10 – 15:50

SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: BEOLÈ S. (Università di Torino)

Relazione Generale

■ **50 anni di plasma di quark e gluoni: passato, presente e futuro.**

ANTINORI F.

*INFN, Sezione di Padova*

Quest'anno ricorrono i 50 anni dalla pubblicazione degli articoli di N. Cabibbo e G. Parisi [PLB 59 (1975) 67] e di J.C. Collins e M.J. Perry [PRL 34 (1975) 1353] che predissero l'esistenza, ad alta temperatura e densità, di una nuova fase della materia in cui la carica di colore della QCD sarebbe stata deconfinata: il plasma di quark e gluoni (QGP). Per l'occasione cercherò di ripercorrere le tappe principali che hanno portato alla conferma di quelle predizioni e allo sviluppo di un nuovo campo: lo studio sperimentale della QCD ad alta temperatura. Richiamerò quindi brevemente alcuni aspetti chiave dello stato attuale del campo, e discuterò le sue prospettive di sviluppo per i prossimi anni.

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Aula Magna G.B.F. Basile, Edificio 7

ore 15:50 – 18:30

SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: BRESSAN A. (Università di Trieste e INFN)

Relazioni su invito

▲ **L'aggiornamento di ATLAS per la fase di HL-LHC.**

CARRATTA G.

*INFN, Sezione di Bologna e Dipartimento di Fisica e Astronomia Università di Bologna*

Nel contesto della fase HL-LHC, il Large Hadron Collider sarà aggiornato per raggiungere una luminosità istantanea fino a  $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  e raccogliere oltre  $3 \text{ ab}^{-1}$  di dati a  $\sqrt{s} = 13.6(14) \text{ TeV}$ . Con questa luminosità, l'esperimento ATLAS potrà effettuare misure di precisione in regioni inesplorate del Modello Standard, in particolare nel settore di Higgs. Per operare in condizioni sperimentali complesse, con radiazioni 10 volte superiori e fino a 200 interazioni per bunch-crossing, il rivelatore sarà profondamente aggiornato. L'upgrade prevede un nuovo tracciatore completamente in silicio con copertura estesa in rapidità, e un sistema TDAQ riprogettato per gestire una lettura continua a 40 MHz. Inoltre, l'High Granularity Timing Detector migliorerà l'associazione traccia-vertice nella regione in avanti. Sarà cruciale una misura precisa della luminosità con incertezze sistematiche sotto 11%. In questo contributo verranno presentate le motivazioni e lo stato dell'upgrade, inclusi i risultati ottenuti con prototipi e produzione.

▲ **Status of the upgrade of the CMS experiment for the High Luminosity LHC.**

CALZAFERRI S.

*Università degli Studi di Pavia e INFN, Sezione di Pavia*

The CMS experiment is preparing a major upgrade of its subdetectors during the Long Shutdown 3 phase (2026-2030) of the LHC accelerator. This effort aims to meet the luminosity delivered by the LHC during the following data-taking period, up to  $5 - 7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ . The CMS Tracker will be replaced with a new detector featuring track trigger capabilities at L1 and coverage down to  $|\eta| = 3.5$ . The calorimeter system will be also improved with new electronics in the ECAL barrel and the installation of a new High Granularity Calorimeter in the endcaps. In addition, the innovative MIP Timing Detector will be installed to profit of the timing information for the pile-up mitigation. Finally, also the muon system detectors will be improved in the electronics of the Drift Tubes (DT), Cathode Strip Chambers (CSC) and Resistive Plate Chambers (RPC). The muon system upgrade includes also the installation of new RPCs with a higher time resolution (iRPC) and new stations of Gas Electron Multiplier detectors (GEM), which will contribute to extend the coverage of the muon spectrometer up to  $4|\eta| = 2.8$ . The status of these upgrades and the latest available results will be presented.

▲ **Towards the ultimate precision in flavour physics with the LHCb experiment.**

CONTU A.

*INNFN, Sezione di Cagliari*

LHCb has been pushing the limits of flavour physics at the LHC since the last decade. World leading results in the HEP field go from the first observation of CP violation in the charm sector to precision measurements of CKM parameters, from the study of rare

decay modes to discovery of tens of new states in heavy hadron spectroscopy, including tetraquarks and pentaquarks. Primary pp interactions at the LHCb interaction point occur at reduced luminosity with respect to the general purpose LHC experiments, adding up so far to a total sample of about  $20 \text{ fb}^{-1}$ . Almost half of the integrated luminosity was collected in the ongoing Run 3, with the upgraded detector that can operate at a higher instantaneous luminosity with respect to Run 1 and 2. The improvements in the detector and data processing technology now allow for a full reconstruction of all pp interaction events. Based on the success and accumulated experience, the LHCb collaboration is now working at pushing the capabilities of the detector even further, in order to make it cope with an even higher event rate, up towards a final target of a  $300 \text{ fb}^{-1}$  integrated luminosity. This target can be reached by adding prepar

### Comunicazioni

#### ● Upgrade del calorimetro adronico di ATLAS per la fase ad alta luminosità di LHC.

LEONE S. PER IL GRUPPO ATLAS-TILECAL

*INFN, Sezione di Pisa*

TileCal è il calorimetro adronico centrale dell'esperimento ATLAS. Un programma di upgrade di TileCal è in corso, in vista della fase ad alta luminosità di LHC, prevista iniziare nel 2029, che fornirà cinque volte la luminosità istantanea nominale dell'LHC. TileCal richiederà una nuova elettronica di lettura per soddisfare i requisiti di un trigger da 1 MHz, sopportare maggiori livelli di radiazione e per garantire buone prestazioni in condizioni di elevato numero di interazioni per bunch-crossing. Il 10% dei fotomoltiplicatori, quelli che leggono le celle più esposte a radiazione, verrà sostituito. Il sistema di supporto meccanico dell'elettronica sarà più modulare di quello presente, per facilitare gli interventi durante la manutenzione. Un modulo del calorimetro equipaggiato con la nuova elettronica ma reso compatibile con il sistema di lettura esistente è stato installato in ATLAS nell'agosto 2019 per poter effettuare test nelle reali condizioni di funzionamento dell'esperimento, e sta prendendo dati dall'inizio del Run3. In questa presentazione verranno discussi lo stato del progetto di upgrade di TileCal e i risultati delle campagne di test su fascio.

#### ● Upgrade dell'elettronica di front-end del calorimetro ad argon liquido dell'esperimento ATLAS per la fase ad alta luminosità di LHC

CARBONE A. <sup>(1)</sup>, TARTARELLI F. <sup>(1)</sup>, LAZZARONI M. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *INFN, Sezione di Milano*

<sup>(2)</sup> *Dipartimento di Fisica, Università degli Studi di Milano*

L'elettronica di lettura del calorimetro ad argon liquido di ATLAS verrà aggiornata per la fase ad alta luminosità di LHC (HL-LHC). L'upgrade si rende necessario a causa dell'aumento di luminosità che porterà ad un incremento del pile-up e del danneggiamento da radiazione del rivelatore. Si è reso necessario lo sviluppo di preamplificatori e shaper custom con basso rumore, un nuovo chip ADC con due guadagni e nuove schede di calibrazione con eccellente linearità. Sono state inoltre progettate nuove schede ATCA di elaborazione del segnale con link ad alta velocità che ricevono i dati del rivelatore ed eseguono la ricostruzione di energia e tempo. Saranno anche presentate le nuove soluzioni rad-hard adottate per l'architettura di alimentazione di queste schede.

#### ● Verso HL-LHC: un Framework per l'analisi e il monitoraggio della produzione dei moduli a Pixel per ATLAS ITk.

FORTI N.

*Università di Bologna*

La fase High-Luminosity del Large Hadron Collider (HL-LHC), prevista per il 2030, aumenterà la luminosità fino a 10 volte rispetto a quanto previsto dal progetto originale, causando un incremento del pile-up e del danno da radiazione del rivelatore. Per questo motivo, la collaborazione ATLAS ha avviato la realizzazione di un nuovo tracciatore, detto Inner Tracker (ITk), composto da pixel e strip in silicio, che sostituirà l'attuale Inner Detector. Il rivelatore a Pixel è costituito da circa diecimila moduli, da assemblare e testare in una ventina di istituti. I risultati dei test verranno salvati in un apposito database. Verrà presentato lo sviluppo di un framework per la gestione e l'analisi dei dati dei moduli. Il framework è composto da un backend e un frontend che lavorano per estrarre, elaborare e visualizzare i dati in modo efficiente. Il backend automatizza il recupero e la validazione delle informazioni dei moduli dal database. Il frontend offre strumenti per il controllo qualità, confronti tra siti di produzione e monitoraggio delle prestazioni. Questo sistema garantisce l'accesso condiviso, aggiornato e coerente ai dati da parte di tutti i membri della collaborazione.

● **Performance evaluation of the ATLAS experiment dataflow subsystem in the high luminosity LHC operation.**

SCAGLIONI R.

*Dipartimento di Fisica, Università di Pavia*

LHC will be entering its High Luminosity Phase in 2030 aiming to increase the data taken by an order of magnitude. The ATLAS experiment plans to upgrade its Trigger and Data Acquisition (TDAQ) system to reach a target data rate of 1 MHz with a throughput of approximately 5 TB/s. One of the main components of this upgrade is the Dataflow TDAQ subsystem, which is responsible for moving data across the different TDAQ components, relying on a custom network messaging library. The baseline of the upgrade is to keep using it to support the new workload, but this requires extensive testing to ensure stability and performance in the much more demanding working conditions and to explore possible improvements. This presentation will show the evaluation of the library performance in different usage configurations to assess its capability to scale at the required rate and bandwidth. During this study, a new implementation was proposed improving some of the key aspects. The effects of these changes will be discussed, focusing on the impact they have in the Dataflow applications and their contribution to reach the performance requirements.

● **Ricerca di Dark Jets da portale Higgs all'esperimento ATLAS.**

COSSUTTI G. <sup>(1)(2)</sup>, COBAL M. <sup>(1)(3)</sup>, FILIPIG M. <sup>(1)(4)</sup>, PANIZZO G. <sup>(1)(3)</sup>, PINAMONTI M. <sup>(1)</sup>, RICCI B. <sup>(1)(4)</sup>

<sup>(1)</sup> INFN Sezione di Trieste, Gruppo Collegato di Udine

<sup>(2)</sup> Dipartimento di Fisica, Università degli Studi di Trieste

<sup>(3)</sup> Dipartimento Politecnico di Ingegneria e Architettura, Università degli Studi di Udine

<sup>(4)</sup> Dipartimento di Scienze Matematiche, Informatiche e Fisiche, Università degli Studi di Udine

Una delle teorie che forniscono un modello per la Materia Oscura prevede l'esistenza di un Dark Sector, composto da Dark Quark e Dark Gluons che interagiscono fra loro attraverso una Dark QCD di simmetria SU(N) simile alla QCD del Modello Standard. Una o più particelle, dette portali, si accoppiano a entrambi i settori Dark e Standard. Ai collider i Dark Quark possono venire prodotti attraverso portali in collisioni adroniche o leptoniche, e quindi iniziare uno sciame partonico e adronizzare in particelle di Materia Oscura, che formano getti detti Dark Jets. In base alla vita media delle particelle costituenti i Dark Jets e alla loro probabilità di decadere in particelle visibili del settore Standard, si identificano gli stati finali con Semi-Visible ed Emerging Jets. Finora a LHC si sono cercati Dark Jets

originati da portali di tipo scalare o bosone  $Z/\gamma$ . Si presenta qui uno studio preliminare di fattibilità volto alla ricerca di Dark Jets attraverso un bosone di Higgs come portale con una simulazione veloce dell'esperimento ATLAS.

● **Characterization of stitched prototypes chip for the ALICE ITS3 upgrade.**

RIGNANESE M.

*Università degli Studi di Padova*

During the Long Shutdown 3 of the LHC, the ALICE experiment will upgrade its Inner Tracking System (ITS2) by replacing the three innermost layers with ITS3, a new detector using ultralight, stitched Monolithic Active Pixel Sensors (MAPS) in 65 nm CMOS technology. These layers, bent to a cylindrical shape and placed closer to the beam pipe, will reduce the material budget and enhance tracking precision, especially for low-momentum particles. The first stitched sensor prototype, the MOnolithic Stitched Sensor (MOSS), has an active area of  $259 \times 14 \text{ mm}^2$  and is made by stitching ten Repeated Sensor Units (RSUs) and two end-caps. Each RSU contains two Half Units, top and bottom, with pixel pitches of 22.5  $\mu\text{m}$  and 18  $\mu\text{m}$  respectively. Extensive lab and testbeam characterizations have validated the chip functionality. This work presents results from test beam measurements at CERN PS, where small stitched prototypes (both irradiated and not-irradiated) have been tested. All devices (also irradiated ones), show values of detection efficiency  $> 99\%$  and fake hit rate  $< 10^{-6}$  hits/pixel/event, that are compatible with what required for ITS3, ensuring a good operational margin.

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SEZIONE II

**Fisica della materia**

Presiede: PALMA G.M. (Università di Palermo)

Relazioni su invito

▲ **Mechanical quantum states of motion of a levitated particle beyond ground-state.**

CIAMPINI M.A.

*Quantum Optics, Quantum Nanophysics and Quantum Information, University of Vienna, Austria*

Recently, vacuum optical traps gained attention for force sensing, thermodynamics, and quantum physics. However, their potential in spatiotemporal control and nonlinear optomechanics remains underexplored. Building on our success in ground state cooling of a levitated nanoparticle, we present two approaches combining optimal feedback, parametric modulation, and nonlinear potentials. First, we demonstrate mechanical squeezing below zero-point fluctuations at room temperature without an optical cavity, surpassing the 3 dB limit via feedback cooling while maintaining stability. This enables creation of delocalized, non-Gaussian quantum states, advancing understanding of the quantum-classical boundary. Second, we propose a scheme to prepare and detect non-Gaussian states through light pulses creating cubic and inverted potentials. Operating at short time and length scales reduces decoherence, allowing interference with nanoparticles over  $10^8$  amu delocalized by several nanometers under  $10^{-10}$  mbar at room temperature. This offers new experimental pathways and prospects for future quantum manipulation and fundamental studies.

▲ **Networks with many structural scales: from scale-free to scale-invariant.**

VILLEGAS P. <sup>(1)</sup>, POGGIALINI A. <sup>(1)</sup>, MUÑOZ M.A. <sup>(1)</sup>, GABRIELLI A. <sup>(1)</sup>

<sup>(1)</sup> *CREF - Centro Ricerche Enrico Fermi, Roma*

<sup>(2)</sup> *Instituto Carlos I de Física Teórica y Computacional, Universidad de Granada, Spain*

Scale invariance and spontaneous order are central to understanding the dynamics and structure of complex systems, from critical phenomena to chaotic behavior. We introduce a rigorous framework for identifying scale-invariant networks, characterized by a constant entropy-loss rate under renormalization-group coarse-graining. This approach distinguishes scale-invariant from scale-free networks and uncovers unique structural properties. In particular, we define a structural equivalent to 'universality classes' that allows for the classification of non-trivial structural fixed points. Furthermore, by embedding networks with non-integer dimensions into reduced reciprocal spaces, we reveal chaotic-like attractors and hidden network patterns. This bridges the gap between microscopic disorder and macroscopic structural regularities. Applications to natural and artificial systems, including the human connectome, demonstrate how scale invariance shapes fundamental properties across domains, providing novel tools to explore order within disordered systems in physics, biology, and technology.

▲ **Superconducting detectors for single photon based applications including quantum communication and searching for Dark Matter.**

PEPE G.P. <sup>(1)</sup>, PARLATO L. <sup>(1)(2)</sup>, BRUSCINO C. <sup>(1)</sup>, ERCOLANO P. <sup>(1)</sup>, PELUSO M. <sup>(1)</sup>, ZHANG C.J. <sup>(1)</sup>, ATTANASIO C. <sup>(3)</sup>, COLANGELO F. <sup>(3)</sup>, CIRILLO C. <sup>(4)</sup>, SALVONI D. <sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(2)</sup> *CNR-SPIN, Napoli*



<sup>(3)</sup> *Dipartimento di Fisica, Università di Salerno, Fisciano*

<sup>(4)</sup> *CNR-SPIN, Fisciano*

<sup>(5)</sup> *Photon Technology Italy srl, Napoli and Qunatech s.r.l., Napoli*

Superconducting Single-Photon Detectors have become important technologies in applications ranging from quantum information science both computing and communications to sensing and space communications. From 2001 significant developments in Superconducting Nanostrips Single Photon SNSPDs technology produced detectors characterized by  $> 95\%$  detection efficiency DE, picosecond time resolution, milli-Hertz Dark Count Rates DCR and nanosecond recovery time. High-performance commercial SNSPDs in customized cryostats are now available both for quantum and interdisciplinary technologies for operation up to 1550 nm wavelengths where they outperform semiconducting materials. However, many challenges are still open to optimize the performances of these devices for specific applications such as the large area coverage. Micro-sized configurations (Superconducting Microstrip Single Photon Detectors (SMSPDs) demonstrated to be quite interesting for detecting low-energy photons, as in free space communications, and dark matter detection. Our activities on S(N/M)SPDs for measurements at wavelengths 1550 nm and up to 4500 nm will be presented and discussed.

#### Comunicazioni

##### ● Optimization of static potentials for levitated nanoparticles.

CASULLERAS S. <sup>(1)</sup><sup>(2)</sup>, GROCHOWSKI P.T. <sup>(1)</sup><sup>(2)</sup>, ROMERO-ISART O. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup><sup>(4)</sup>

<sup>(1)</sup> *Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Innsbruck, Austria*

<sup>(2)</sup> *Institute for Theoretical Physics, University of Innsbruck, Austria*

<sup>(3)</sup> *ICFO-Institut de Ciències Fotoniques, Castelldefels, Barcelona, Spain*

<sup>(4)</sup> *ICREA, Barcelona, Spain*

Levitated nanoparticles offer a highly controllable and well-isolated platform for investigating fundamental quantum phenomena at macroscopic scales. We present an optimization method for identifying static potentials that generate strongly delocalized and non-Gaussian quantum states in such systems. Our approach explicitly incorporates position-dependent noise arising from fluctuations in the trapping potential. To address the computational challenges of simulating these multiscale dynamics, we introduce two key figures of merit coherence length and coherent cubicity which serve as efficient indicators of quantum delocalization and non-Gaussianity, respectively. As a proof of principle, we apply our method to a family of quartic potentials, demonstrating that the optimal configuration depends sensitively on both the strength and nature of the noise.

##### ● Coherent macroscopic mechanical states generation by post- selective photo-counting.

BORDIN M. <sup>(1)</sup><sup>(2)</sup>, CHISHOLM D. <sup>(2)</sup>, PATERNOSTRO M. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Queen's University Belfast*

<sup>(2)</sup> *Università di Palermo*

Optomechanical systems hold the promise of enabling quantum control over mechanical oscillators with macroscopic masses (pico- to nanograms). The generation of macroscopic nonclassical states is of great interest for various applications, such as testing gravity-induced entanglement or probing the macroscopic limits of quantum theory. Here, we explore the possibility of achieving this in a realistic optomechanical setup, where the mechanical state is nonlinearly conditioned via optical post-selection upon measurement with a Geiger counter. We examine the efficacy of the protocol in both pulsed and continuously driven schemes, discussing the relevant sources of decoherence for each. In both cases, we analyze the conditional

negativity of the mechanical Wigner function and the success probability of the scheme. We thus show that, under realistic experimental conditions, it is possible to engineer nonclassical macroscopic quantum states.

● **Characterization of a membrane with an on-chip loss shield for quantum transducers.**

MARZIONI F. <sup>(1)(2)(3)</sup>, NATALI R. <sup>(1)(2)</sup>, BONALDI M. <sup>(4)(5)</sup>, BORRIELLI A. <sup>(4)(5)</sup>, SERRA E. <sup>(5)(6)</sup>, MORANA B. <sup>(6)</sup>, MARIN F. <sup>(7)(8)(9)</sup>, MARINO F. <sup>(7)(8)</sup>, MALOSSÌ N. <sup>(1)(2)</sup>, VITALI D. <sup>(1)(2)(7)</sup>, DI GIUSEPPE G. <sup>(1)(2)</sup>, PIERGENTILI P. <sup>(1)(2)</sup>

<sup>(1)</sup> *Physics Division, School of Science and Technology, Università di Camerino*

<sup>(2)</sup> *INFN, Sezione di Perugia*

<sup>(3)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(4)</sup> *Institute of Materials for Electronics and Magnetism, Nanoscience-Trento-FBK Division, Povo,*

<sup>(5)</sup> *INFN, TIFPA, Povo*

<sup>(6)</sup> *Microelectronics Department, EEMCS Faculty, Delft University of Technology, The Netherlands*

<sup>(7)</sup> *CNR-INO, Firenze*

<sup>(8)</sup> *INFN, Sezione di Firenze*

<sup>(9)</sup> *Dipartimento di Fisica e Astronomia, Università di Firenze, Sesto Fiorentino*

The transduction of quantum signals at different energy scales plays a crucial role in Quantum Technologies. Since optical spectrum is well-suited for long-distance communication, while lower frequencies of the electromagnetic field prove advantageous for precise local quantum operations employing superconducting and other solid-state processors, achieving coherent conversion between optical and microwave/radiofrequency (Mw/RF) photons is one of the primary tasks of the realization of a quantum transducer. In this contribution we present a complete characterization of a nanomechanical oscillator, which might be used for the realization of an electro-opto-mechanical device that can be implemented for the sympathetic cooling of the LC circuit, and as building block of an RF/Mw optical transducer. The key element of the device is a mechanical resonator based on a metal coated (TiN) Si<sub>3</sub>N<sub>4</sub> membrane. The oscillator has been characterized from room temperature down to 18 mK. A quality factor over  $6 \times 10^7$  is measured below 100 mK by means of stroboscopic technique, which is necessary for avoiding any heating effect due to the probe beam.

Aula 12, Section C, Edificio 19

ore 15:50 – 18:30

SEZIONE II

**Fisica della materia**

Presiede: CHISHOLM D.A. (Università di Palermo)

*Le relazioni su invito si terranno nell'Aula 11, i lavori si sposteranno nell'Aula 12 per le seguenti comunicazioni.*

Comunicazioni

● **Searching for signal of quantum collapse and quantum gravity in the cosmic silence of the Gran Sasso underground laboratories.**

PISCICCHIA K.

*Centro Ricerche Enrico Fermi e INFN, Laboratori Nazionali di Frascati*

The VIP experiment is pursuing experimental studies of Quantum Mechanics (QM) foundations, investigating models of dynamical wave function collapse and performing high sensitivity tests of the Pauli Exclusion Principle (PEP) for electrons. Unification of QM and General Relativity is probably the main ambition of modern physics. Motivated by the awareness that space-time fluctuations would induce decoherence in quantum systems, the idea to gravitize the QM aroused growing interest in the last decades, especially for the privileged role that gravity may play to solve the measurement conundrum. We will report on the strong experimental constraints on the gravity-related collapse models, obtained by searching for an unavoidable side-effect of the collapse mechanism known as “spontaneous radiation emission”. It was recently shown that violation of the PEP may be induced by Quantum Gravity (QG). X-ray surveys, searching for atomic transitions prohibited by the PEP, represent stunning candidates to test QG models, at unexpectedly high energy scales. The extreme sensitivity bounds obtained by VIP will be presented.

● **Probing quantum collapse with rotational dynamics**

ARIO ALTAMURA D.G.

*Dipartimento di Fisica, Università degli studi di Trieste*

Spontaneous wavefunction collapse models, such as the Continuous Spontaneous Localization (CSL) model, provide a promising approach to address the quantum measurement problem by introducing stochastic, nonlinear modifications to the Schroedinger equation. We present new experimental constraints on the CSL model derived from recent high-precision measurements of optomechanical systems rotational motion. Using data from both the LISA Pathfinder mission and a state-of-the-art table-top short-distance gravity experiment, we show that rotational noise can place competitive, and in some regimes stronger, bounds on CSL parameters compared to translational tests. Our analysis highlights the conditions under which rotational degrees of freedom offer enhanced sensitivity to collapse-induced noise. Additionally, we design an optimized geometry of the test mass to amplify the CSL effect and access previously unexplored regions of the parameter space. These findings underscore the potential of rotational tests as a powerful tool for future dedicated experimental investigations of collapse models.

● **Hybrid classical-quantum newtonian gravity with stable vacuum.**

PICCIONE N., BASSI A.

*Dipartimento di Fisica, Università degli Studi di Trieste e INFN, Sezione di Trieste*

We investigate the Gravitational Poissonian Spontaneous Localization (GPSL) model, a hybrid classical-quantum model in which classical Newtonian gravity emerges from stochastic collapses of the mass density operator, and consistently couples to quantum matter. Unlike models based on continuous measurement schemes, GPSL ensures vacuum stability; this, together with its applicability to identical particles and fields, makes it a promising candidate for a relativistic generalization. We derive the master equation governing the dynamics, analyze the model's general properties, and compare its predictions with those of the Tilloy-Di si models. Notably, GPSL predicts a short-range gravitational back-reaction and permits decoherence rates below the Di si-Penrose bound, thereby evading the Principle of Least Decoherence. We provide explicit examples, including the dynamics of a single particle and a rigid sphere, to illustrate the distinctive phenomenology of the model. Finally, we discuss the experimental testability of GPSL, highlighting both interferometric and non-interferometric strategies to constrain its parameters and distinguish it from competing models.

● **Time-periodic driving of the photon Bose-Einstein condensate.**

ERGLIS A. <sup>(1)(2)</sup>, SAZHIN A. <sup>(3)</sup>, VEWINGER F. <sup>(3)</sup>, WEITZ M. <sup>(3)</sup>, BUHMANN S.Y. <sup>(4)</sup>, SCHMITT J. <sup>(3)(5)</sup>

<sup>(1)</sup> *Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(3)</sup> *Institut für Angewandte Physik, Universität Bonn, Germany*

<sup>(4)</sup> *Centre for Interdisciplinary Nanostructure Science and Technology CINSaT, University of Kassel, Germany*

<sup>(5)</sup> *Kirchhoff-Institut für Physik, Universität Heidelberg, Germany*

We investigate the density response of a photon Bose-Einstein condensate coupled to a reservoir of dye molecules under periodic driving. By directly pumping the molecules, we measure the condensate oscillation amplitude across various driving frequencies and obtain the spectral condensate response. Moreover, we capture the phase delay of the condensate, allowing for the extraction of imaginary and real response functions. We observe the condensate transition from overdamped to underdamped oscillation regime for increasing average photon number. Our method opens new possibilities for probing the structure and intrinsic properties of complex driven-dissipative systems.

Aula Capità, Edificio 7

ore 15:50 – 18:30

SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: BRAGGIO C. (INFN, Sezione di Padova e Università di Padova)

Relazioni su invito

▲ **10 years of gravitational waves.**

FAFONE V.

*Università di Roma Tor Vergata e INFN, Sezione di Roma Tor Vergata*

Gravitational waves, predicted by Einstein over a century ago, went undetected until 2015, when the LIGO-Virgo collaboration recorded the first signal: a space-time perturbation on the order of  $10^{-21}$ , generated by the merger of two black holes. This observation provided direct confirmation of the predictions of general relativity and marked the beginning of a new era in the investigation of the universe. Since then, the LIGO and Virgo interferometers have completed three observing runs, while a fourth is currently underway and expected to conclude in October 2025. To date, more than 90 events have been confirmed, originating from the coalescence of binary systems composed of black holes and neutron stars. Among these is the first (and so far only) observation of the merger of two neutron stars accompanied by the detection of an electromagnetic counterpart. This presentation will highlight the key results achieved in the ten years since the first detection, the planned developments for the forthcoming observing run, and the longer-term prospects.

▲ **Towards exploring the gravitational wave Universe from space: implementing LISA.**

DOLESI R.

*Dipartimento di Fisica, Università di Trento e TIFPA/INFN*

Towards exploring the gravitational wave Universe from space: implementing LISA The detection of gravitational waves has opened a new window on the Universe, with extraordinary prospects for investigating the nature of gravity, black holes, binary systems, and the formation and evolution of cosmic structures since the early stages of the Universe. With the aim of expanding the frontier of gravitational wave observation to sources emitting at low frequencies, between 0.1 mHz and 1 Hz, detectable only from the gravitationally silent deep space with long-baseline interferometers, the LISA project is rapidly progressing towards the implementation of the first space-based gravitational wave observatory, scheduled for launch in 2035. This contribution will provide an overview of the LISA measurement concept, the progress of the LISA instrumental challenges, and the status of the mission.

▲ **The Einstein Telescope, the next generation detector for gravitational-wave observation.**

D'URSO D.

*Università degli Studi di Sassari e INFN, Sezione di Cagliari*

The detection of Gravitational Waves (GWs) has opened a new window onto the Universe. The combined observation of GWs and electromagnetic signals from astrophysical phenomena in 2017 marked the beginning of Multi-Messenger Astronomy. While the LIGO-Virgo-KAGRA Collaborations continue to detect GWs, a new generation of GW observatories is being developed and will take over in the coming decades, enabling the exploration of nearly

the entire Universe. The Einstein Telescope (ET) is Europe's next-generation project for GW detection. With an order-of-magnitude improvement in sensitivity, ET will probe the depths of the Universe with the potential to drive groundbreaking advancements in astrophysics, cosmology and fundamental physics. This presentation will provide an overview of the scientific objectives, the current status of the detector design, the technological challenges and the expected impact on the progress of Gravitational Wave Astronomy.

Comunicazioni

● **From cWB to PycWB: Modernizing gravitational wave analysis for the high-performance computing era.**

DI PIERO D. FOR THE PYCWB DEVELOPMENT TEAM

*Dipartimento di Fisica, Università degli Studi di Trieste e INFN, Sezione di Trieste*

Coherent WaveBurst (cWB) is a data analysis pipeline for the detection and coherent reconstruction of transient gravitational wave signals, used to identify events, with an unmodelled search, by combining data from a network of detectors. The University of Trieste is currently involved in a project funded by the PNRR High-Performance Computing program, aimed at developing and applying algorithms for the analysis of such signals within High-Performance Computing environments. Within this context, the development of PycWB, a new Python implementation of the cWB algorithm, is underway. The project aims to leverage High-Performance Computing infrastructures to make the analysis more scalable, flexible, and efficient, addressing the increasing volume of data produced by gravitational wave observatories. PycWB is designed to integrate seamlessly with modern data analysis tools, supporting code extensibility and scientific collaboration. This study will present the details of the project and future perspectives for advanced gravitational wave signal analysis.

● **Search for continuous-gravitational-waves from 45 known pulsars in LIGO-Virgo-KAGRA O4a-data.**

D'ONOFRIO L.

*INFN, Sezione di Roma*

Known pulsars are interesting targets for the search of continuous gravitational waves (CWs). In this talk, I present the latest results on behalf of the LIGO-Virgo-KAGRA (LVK) Collaboration describing the targeted search for CWs from 45 known pulsars using data from the first part of the fourth LVK observing run (O4a). Three independent analysis methods were applied, considering both single-harmonic and dual-harmonic emission models. No CW signals were detected, and upper limits were set on the signal amplitude and neutron star ellipticity. For 29 pulsars, the upper limit on the amplitude is below the theoretical spin-down limit, with the lowest constraint of  $6.4 \times 10^{-27}$  for J0537-6910. The tightest ellipticity constraint,  $8.8 \times 10^{-9}$ , is obtained for J0437-4715. Additionally, a narrowband search for 16 pulsars found no significant signals, as did the search for non-standard polarizations predicted by Brans-Dicke theory. These results improve our constraints on neutron star properties and gravitational wave emission mechanisms.

● **Mitigation of some unusual noise sources for cryogenic mirrors in gravitational wave detectors.**

SPALLINO L., ANGELUCCI M., CIMINO R.

*INFN, Laboratori Nazionali di Frascati*

In the future generation of gravitational wave detectors (GWDs), the use of cryogenic mirrors is a great technological challenge and may present potentially noise sources limiting the desired sensitivity. As shown in KAGRA, frost formation on cold optics is a known severe

issue for cryogenic GWDs. Also, as observed in LIGO, mirror charging may severely affect sensitivity, and the mitigation method based on a high N<sub>2</sub> gas flux, could not be used at cryogenic temperature since a thick N<sub>2</sub> layer will condense on mirrors affecting detection. As observed in Virgo, one contribution to optics charging arises from low energy electrons coming from ion pumps and finally impinging on the test masses. We are developing a method that will reduce electron emission without affecting pumping speed by using ad hoc designed electrostatic screens. Moreover, we have proposed and start validating the use of low energy electron irradiation ( $\ll 1$  keV) as an active mitigation solution both for charging and frost formation. Here we present the R&D activity carried out at LNF-INFN to develop active and passive mitigation strategies, compliant with cryogenics, both for charging and frost formation.

● **Search for high-frequency gravitational waves with acoustic resonators.**

MARIANI L. <sup>(1)</sup>, ALBANI G. <sup>(1)(2)</sup>, BORGHESI M. <sup>(1)(2)</sup>, CANONICA L. <sup>(1)(2)(1)</sup>, CAROBENE R. <sup>(1)(2)</sup>, DE GUIO F. <sup>(1)(2)</sup>, FAVERZANI M. <sup>(1)(2)</sup>, FERRI E. <sup>(1)(2)</sup>, GHEZZI A. <sup>(1)(2)</sup>, GEROSA R. <sup>(1)(2)</sup>, GIACHERO A. <sup>(1)(2)</sup>, GOTTI C. <sup>(1)(2)</sup>, NUCCIOTTI A. <sup>(1)(2)</sup>, PESSINA G. <sup>(2)</sup>, ROZZA D. <sup>(1)(2)</sup>, TABARELLI DE FATIS T. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università degli Studi di Milano Bicocca*

<sup>(2)</sup> *INFN, Sezione di Milano-Bicocca*

Nella loro forma più semplice, i risonatori BAW (Bulk Acoustic Wave) consistono in un cristallo piezoelettrico posto tra due elettrodi in grado di trasdurre le vibrazioni del reticolo in segnali elettrici. Il loro utilizzo per la costruzione di un'antenna a massa risonante per onde gravitazionali di alta frequenza è stato proposto ed implementato di recente (Goryachev e Tobar, 2014). Un'antenna simile è in fase di progettazione presso l'università di Milano Bicocca, con l'obiettivo di campionare uno spettro di frequenze tra 100 kHz e 10 Mhz. Potenziali segnali in questa ragione includono candidati Dark Matter ed emissione da post-merger di binarie di stelle di neutroni. Un array di risonatori di spessore variabile, geometria ottimizzata e collocato a temperature criogeniche permetterà il raggiungimento di ottimi fattori di merito ( $\sim 10^7$ ) e bassissimo rumore termico (strain power spectral density di  $\sim \frac{10^{-21}}{\sqrt{\text{Hz}}}$ ). L'operazione multi-sito di due o più antenne in coincidenza temporale potrebbe confermare la natura extra-terrestre di potenziali eventi, aprendo la strada ad una prima rivelazione di onde gravitazionali di alta frequenza.

● **CAOS: an international laboratory for prototyping test mass suspensions.**

BALDICCHI N.

*Dipartimento di Fisica, Università degli Studi di Perugia e INFN, Sezione di Perugia*

The CAOS (Center for Applications of Gravitational Waves and Seismology) laboratory is currently under construction in Perugia and is expected to become operational in the coming years. It will serve as an international facility where two 15-meter-tall test mass suspensions will be built to form a Fabry-Perot cavity. The laboratory will support studies on various noise sources (i.e. seismic, thermal, Newtonian, and quantum noise) relevant to current and third-generation gravitational wave detectors, including Virgo and Einstein Telescope. This presentation aims to provide an overview of the current status of CAOS and the preliminary studies conducted for the realization of the project.

● **Einstein-Podolsky-Rosen frequency dependent squeezing: development of a table-top experiment for broadband sensitivity enhancement in next-generation gravitational wave detectors.**

LUNGHINI L. <sup>(1)(2)</sup>, DE MARCO F. <sup>(3)(4)</sup>, DI PACE S. <sup>(3)(4)</sup>, AHN H. <sup>(5)</sup>, ALI W. <sup>(6)(7)</sup>, BAWAJ M. <sup>(8)(9)</sup>, GARAVENTA B. <sup>(7)</sup>, KIM C. H. <sup>(10)</sup>, LAUDENZI P. <sup>(3)(4)</sup>, LEE S. <sup>(11)</sup>,

NATICCHIONI L. <sup>(4)</sup>, PARK B. J. <sup>(10)</sup>, SVIZZERETTO A. <sup>(8)(9)</sup>, DE LAURENTIS M. <sup>(1)(2)</sup>,  
LEE S. <sup>(10)</sup>, SEQUINO V. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università di Napoli Federico II*

<sup>(2)</sup> *INFN, Sezione di Napoli*

<sup>(3)</sup> *La Sapienza Università di Roma*

<sup>(4)</sup> *INFN, Sezione di Roma*

<sup>(5)</sup> *Kyung Hee University, Suwon, Republic of Korea*

<sup>(6)</sup> *Università di Genova*

<sup>(7)</sup> *INFN, Sezione di Genova*

<sup>(8)</sup> *Università di Perugia*

<sup>(9)</sup> *INFN, Sezione di Perugia*

<sup>(10)</sup> *Korean Astronomy and Science Institute, Daejeon, Republic of Korea*

<sup>(11)</sup> *Yonsei University, Seoul, Republic of Korea*

Next-generation gravitational wave(GW) detectors like Einstein Telescope and Cosmic Explorer will be Quantum Noise (QN) limited across their detection band. Frequency dependent squeezing realized via km-scale filter cavities, is the standard strategy to overcome the standard quantum limit, but add significant complexity and cost [Phys. Rev. D 90, 062006]. We propose an alternative scheme based on Einstein-Podolsky-Rosen (EPR) entangled squeezed states to achieve broadband QN reduction without filter cavities, offering a more compact and feasible solution. We report on the implementation of a table-top experiment with aim to demonstrate EPR condition squeezing at the audio frequencies in a suspended small scale interferometer limited by quantum radiation pressure noise. The set up features high-finesse arm cavities, reflective mode-matching telescopes, and automated acquisition systems. This R&D project, hosted at EGO-Virgo site, aims to breach the gap between MHz-range EPR demonstrations and the requirements of large-scale GW observatories, supporting EPR squeezing as a viable quantum technology for future detectors.

### ● Deflative Big Bang without gravitation.

LORENZI L.

*Mondovì, CN*

After retracing the Expansion Center Universe (ECU) (Lorenzi: 1989-2024), a further analysis on the peculiarities of BIG BANG is here represented according to the Expansion Center Model (ECM) (ECM papers I-II: Lorenzi 1999ab). It results that the BIG BANG event giving rise to the new Hubble law  $R_{BB} = H_{BB}R_{BB}$  can find a simple explanation in the rotating nucleus of radius  $R$ . Besides the speculation of Gamow (1946), today we can count on at least  $3 + 1$  pieces of observational evidence of cosmic rotation (cf. Section VIII of ECM paper XXX o ECU35 (Lorenzi 2019) and REU paper III o ECU45 (Lorenzi 2024d)). It also follows the rotation with angular momentum conserved of Lemaitre's primeval nucleus, whose global centripetal and additive attraction would only be nuclear due to the exclusion of the gravitational interaction, since gravity has never been tested experimentally on molecular-atomic-nuclear-subnuclear scale. The deflative BIG BANG without GRAVITATION would consist both of the disintegration (BIG CRUSH) of the primeval nucleus and in the origin of a radial velocity from the primitive angular velocity which becomes the new Hubble parameter  $H_{BB}$ .



Aula Seminari B, Section B, Edificio 19

ore 15:50 – 18:30

SEZIONE IV

**Geofisica e fisica dell'atmosfera**

Presiede: SCOLLO S. (INGV)

Relazioni su invito

▲ **La misura da satellite delle variazioni del campo gravitazionale terrestre e le sue applicazioni.**

BARZAGHI R.

*DICA, Politecnico di Milano, Milano*

La misura da satellite del campo gravitazionale terrestre è iniziata nel 1957 con il lancio del satellite Sputnik-1. Da quel momento in poi molte altre missioni hanno permesso di studiare con sempre maggiore precisione il campo gravitazionale terrestre, in particolare le missioni CHAMP, GRACE e GOCE lanciate tra il 2000 e il 2009. Tra queste, la missione GRACE (Gravity Recovery and Climate Experiment) ha consentito di stimare variazioni mensili del campo gravitazionale terrestre con risoluzione spaziale di circa due gradi. Questa missione è stata seguita da quella denominata GRACE FOLLOW-ON, ancora in corso, ed è in progetto per il 2028 il lancio di altri satelliti che la compendieranno. Altrettanto importanti sono poi le missioni radaraltimetriche, iniziate nel 1978 con il satellite SEASAT, che hanno permesso di ricavare mappe dettagliate delle maggiori correnti geostrofiche degli oceani. In questo contributo, dopo una breve panoramica sulle caratteristiche delle missioni GRACE/GRACE FOLLOW-ON e altimetriche, si discuteranno le principali ricadute di queste missioni nello studio delle variazioni di massa che avvengono nel sistema Terra a diverse scale spaziali e temporali.

▲ **Segnatura gravitazionale della tettonica.**

MAROTTA A.M.

*Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Milano, Italia*

Ogni processo fisico che si verifica nei differenti comparti della Terra comporta una ridistribuzione della massa e quindi una variazione del campo di gravità. I processi tettonici, che interessano la Terra Solida, producono movimenti di massa molto lenti e le anomalie gravitazionali associate sono generalmente considerate statiche. Verranno discussi i risultati di uno studio integrato fra dati di gravità e modellistica numerica della evoluzione geodinamica del sistema crosta-mantello in corrispondenza di margini convergenti e divergenti. Questo studio esamina come la tettonica a placche possa influenzare la distribuzione della densità della Terra e come il lento spostamento delle placche possa generare anomalie nel campo gravitazionale sufficientemente elevate da essere rilevate da future missioni spaziali. Si mostrerà come il sostanziale miglioramento dell'accuratezza spazio-temporale che ci si aspetta venga fornito dalla missione spaziale gravimetrica di nuova generazione NNGM-MAGIC programmata da ESA in concerto con la NASA potrebbe consentire di compiere un decisivo passo avanti nella nostra conoscenza della dinamica dei processi fisici presi in esame.

▲ **Fundamental grounds of Earthquake Early Warning: A deep look into the rupture process.**

COLOMBELLI S., LONGOBARDI V., ZOLLO A.

*Department of Physics E. Pancini, University of Naples Federico II*

When an earthquake happens, seismic waves develop at depth and propagate across Earth. In seconds, waves reach the surface, producing devastating effects on population, buildings

and infrastructures. Earthquake Early Warning Systems use source information inferred from the real-time recorded signals to alert distant sites before the arrival of the strongest ground shaking. Rapid characterization of the earthquake source process is crucial for the prompt activation of emergency procedures. However, the mechanism of nucleation, radiation and arrest of seismic fractures is still poorly understood and with that, the fundamental issue of seismology is still unsolved: “How do earthquakes begin and what controls their final size?”. We will present the open issues on the physical grounds of Earthquake Early Warning, passing through the fascinating world of seismic ruptures. We will discuss theories, models, parameters and observations that can shed light on the mechanism of generation and propagation of seismic ruptures and we will discuss their implications for Earthquake Early Warning.

#### ▲ Earthquake forecast using particle accelerators.

ROSSETTI CONTI M. <sup>(1)</sup>, SERAFINI L. <sup>(1)</sup>, MUTTONI G. <sup>(2)</sup>, BACCI A. <sup>(1)</sup>, BROGGI F. <sup>(1)</sup>, MAROTTA A.M. <sup>(2)</sup>, PETRILLO V. <sup>(1)(3)</sup>, PUPPIN E. <sup>(4)</sup>, ROSSI A.R. <sup>(1)</sup>, SAMSAM S. <sup>(1)</sup>, ZUCALI M. <sup>(2)</sup>

<sup>(1)</sup> *Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Milan, Italy*

<sup>(2)</sup> *Università degli Studi di Milano, Dipartimento di Scienze della Terra “Ardito Desio”, DISTAD, Milan, Italy*

<sup>(3)</sup> *Università degli Studi di Milano, Dipartimento di Fisica, Milan, Italy*

<sup>(4)</sup> *Politecnico di Milano, Dipartimento di Fisica, Milan, Italy*

We present a new study on the properties of high-energy muon beams propagating in crystalline rocks. Based on a theoretical model and a numerical simulation code developed *ad hoc*, we show that a measurable correlation may exist between the muon beam envelope behaviour, its RMS momenta, and the tectonic pressure acting in seismogenic fault areas. We infer that this mechanism may lead to a new technique for earthquake forecast: we name the technique described in this contribution ERMES, an acronym for Earthquake Reconnaissance via Muon beam Evolution in Silicon dioxide. The name also echoes Hermes, the messenger of the gods in Greek mythology, symbolically evoking the role of high-energy muons as swift carriers of information through the Earth’s crust, potentially capable of anticipating large seismic events.

#### ▲ Fluids, faults and seismicity in Italy: A multidisciplinary approach in the frame of the Near Fault Observatories.

RANDAZZO P. <sup>(1)</sup>, BARBERIO M.D. <sup>(2)</sup>, BUTTITTA D. <sup>(1)</sup>, CAMARDA M. <sup>(1)</sup>, CAPASSO G. <sup>(1)</sup>, FRANCOFONTE V. <sup>(1)</sup>, GATTUSO A. <sup>(1)</sup>, MASTROLIA A. <sup>(1)</sup>, MESCHIS M. <sup>(1)</sup>, MESSINA G. <sup>(1)</sup>, PATERNOSTER M. <sup>(1)</sup>, PECORAINO G. <sup>(1)</sup>, PISCIOTTA A.F. <sup>(1)</sup>, RIOLO G.M. <sup>(1)</sup>, TRAINA D. <sup>(1)</sup>, CARACAUSI A. <sup>(1)</sup>

<sup>(1)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy*

<sup>(2)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma, Roma, Italy*

Complex, multi-scale chemical and physical processes govern rock deformation, faulting, and seismicity. Recent studies highlighted that a comprehensive understanding of these mechanisms demands a multidisciplinary approach, integrating geochemical and geophysical multi-parametric datasets. In this regard, the Alto Tiberina Near Fault Observatory (TABOO-NFO) in the northern Apennines (Italy) is an infrastructure created to monitor active deformation along the Alto Tiberina Fault (ATF) through a multidisciplinary sensor network. TABOO-NFO is one of the EPOS Near Fault Observatories, operating in high seismic hazard regions across Europe. It is a model of integrated monitoring infrastructure that is growing up with the use of innovative technologies and the involvement of a large scientific community. In parallel it grew up the IRPINIA-NFO in the central southern Italy. However,

beyond ATF and IRPINIA NFOs, decades of study and monitoring activities in the seismic areas of the Apennines and Alps (*e.g.*, Pollino and Friuli-Slovenia, respectively) allowed to identify some regions that exhibit characteristics suitable for NFO designation, where it has been recognized the role of fluids in the seismicity at regional scale. Previous studies indicate that seismicity in these regions is strongly influenced by over-pressurized fluids trapped in crustal layers and significant CO<sub>2</sub> emissions at the surface with fluid dynamics that play a crucial role in earthquake nucleation by increasing pore pressure within fault zones. On the base of these results, the PON GRINT project (“Geoscience Research INfracstructure of Italy”) aimed at strengthening research infrastructures in southern Italy, selecting some areas suitable to install multidisciplinary instrumentations. In particular, new generations of geochemical instrumentations are equipped with sensors to monitor the physical-chemical parameters of groundwater (springs and boreholes), the CO<sub>2</sub> flux from soils (close to the CO<sub>2</sub>-rich gas emissions) and meteorological parameters, at high-frequency data acquisition. We present the first dataset from this new infrastructure, where high-frequency geophysical and geochemical records, combined with periodic direct sampling, are crucial for developing comprehensive models linking fluid emissions, seismicity, and faulting.

#### Comunicazioni

##### ● Deep learning model for identifying seismic-induced ionospheric electric field perturbations.

BABU M., CRISTOFORETTI M., IUPPA R.

*University of Trento, Trento, Italy e Bruno Kessler Foundation, Trento, Italy*

The ionosphere, influenced by both internal and external geophysical drivers, exhibits complex spatiotemporal dynamics. This study investigates the potential for detecting seismic precursors through machine learning applied to VLF electromagnetic data collected by the DEMETER satellite (altitude  $\sim 700$  km). Focusing on the period from 2005 to 2010, which includes approximately 8000 earthquakes ( $M \geq 5.0$ ), we employed a grid-based framework ( $20^\circ \times 20^\circ$ ) and analyzed 11 low-frequency electric field bands below 3 kHz. Statistical features (Q1, Q2, Q3) were extracted from the power spectrum to construct time series datasets. A Long Short-Term Memory (LSTM) Autoencoder was trained to identify anomalies in day-time orbital observations. Two analytical approaches —aggregate and feature-specific— revealed seismic anomaly ratios exceeding random baselines by over 5% and 10%, respectively. The model demonstrated strong performance in detecting ionospheric anomalies correlated with seismic activity, with specific frequency bands showing heightened relevance. These results underscore the utility of deep learning in studying ionosphere-lithosphere interactions and seismic precursors.

##### ● Meaning and use of statistical correlations between moderate seismic activity in Central Italy and atmospheric electric observations made by CIEN.

FIDANI C.

*Central Italy Electromagnetic Network, CIEN e Istituto Nazionale di Geofisica e Vulcanologia*

The Central Italy Electromagnetic Network (CIEN at <https://cfidani.wixsite.com/cien>) was created in 2006 for electromagnetic monitoring in the ELF band (4 Hz–1 kHz) of Central Italy. They are constituted by horizontal electrodes 10 m above the ground, from which induced electric potentials were recorded continuously. Characteristic oscillations of the electric field in the ELF band were recorded intensely during all the main seismic swarms in 2009, 2012, and 2016/2017. A correlation was calculated between moderate seismic events around some stations and electric oscillation events over several years. A peak was computed at  $-6$  days, which overcame the  $p$ -value level of 1%, indicating that electric oscillations

were observed mainly 6 days before earthquake occurrence. The earthquake probability around the station, given the observation of an electric field oscillation, can be evaluated. Then, several statistical classifiers are used to test the monitoring system's performance. An estimate of the cumulative probability of a moderate earthquake in a week is given.

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Aula 9, Section C, Edificio 19

ore 15:50 – 18:30

SEZIONE V

**Biofisica e fisica medica**

Presiede: CIRRONE G.A.P. (INFN, Laboratori Nazionali del Sud, Catania)

Relazioni su invito

**▲ Biophysical insights into the pathogenicity of rare genetic disease-associated proteins.**

VILASI S. <sup>(1)</sup>, LONGO L. <sup>(1)(2)</sup>, RANDAZZO L. <sup>(1)</sup>, BOLLATI M. <sup>(3)</sup>, CARROTTA R. <sup>(1)</sup>, COSTA M.A. <sup>(1)</sup>, DE ROSA M. <sup>(3)</sup>, MANGIONE M.R. <sup>(1)</sup>, MARTORANA V. <sup>(1)</sup>, CULLETTA G. <sup>(2)</sup>, TUTONE M. <sup>(2)</sup>, MARI E. <sup>(4)</sup>, ORTORE M.G. <sup>(4)</sup>, GARCIA-FRANCO P.M. <sup>(5)(6)</sup>, VELAZQUEZ-CAMPOY A. <sup>(5)(7)(8)(9)</sup>, PASSANTINO R. <sup>(1)</sup>

<sup>(1)</sup> *Institute of Biophysics, National Research Council, Palermo, Italy*

<sup>(2)</sup> *Department STEBICEF, University of Palermo, Palermo, Italy*

<sup>(3)</sup> *Institute of Biophysics, National Research Council, Milano, Italy*

<sup>(4)</sup> *Department of Life and Environmental Sciences, Polytechnic University of Marche, Ancona, Italy*

<sup>(5)</sup> *Institute of Biocomputation and Physics of Complex Systems, BIFI, Universidad de Zaragoza, Zaragoza, Spain*

<sup>(6)</sup> *Certest Biotec S.L., San Mateo de Gallego, Zaragoza, Spain*

<sup>(7)</sup> *Institute for Health Research Aragon, IIS Aragon, Zaragoza, Spain*

<sup>(8)</sup> *Networking Biomedical Research Centre in Liver and Digestive Diseases, CIBERehd, Madrid, Spain*

<sup>(9)</sup> *Department of Biochemistry and Molecular and Cell Biology, University of Zaragoza, Zaragoza, Spain*

Rare genetic diseases often originate from gene mutations that alter the conformational landscape governing protein folding, stability, and interactions. Here, we examined the impact of pathogenic mutations on the energetics of the MMACHC protein —whose dysfunction causes homocystinuria and methylmalonic aciduria (cblC type)— by integrating differential scanning calorimetry and isothermal titration calorimetry. These techniques allowed us to dissect how single-point mutations alter the population of intermediate conformational states during thermal unfolding and modulate ligand-binding thermodynamics. Calorimetric data were complemented with structural insights from circular dichroism, light scattering, synchrotron small-angle X-ray scattering, and molecular-dynamics simulations. By comparing wild-type and mutant proteins, we unveil new links between conformational energetics, structural features, and pathogenicity, providing a basis for the rational design of pharmacological chaperones or stabilizers.

**▲ The impact of structural and topological features on the evolution of DNA double-strand breaks: A coarse-grained molecular-dynamics study.**

POTESTIO R. <sup>(1)</sup>, MICHELONI M. <sup>(1)</sup>, PETROLI L. <sup>(1)</sup>, TUBIANA L. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics, University of Trento, Trento, Italy*

<sup>(2)</sup> *INFN-TIFPA, Trento Institute for Fundamental Physics and Applications, Trento, Italy*

Deoxyribonucleic acid (DNA) is constantly threatened by a variety of toxic agents from both endogenous processes and exogenous vectors, such as ionizing radiation, which can lead to a variety of deleterious DNA lesions and modifications. Among such lesions, one of the

most critical is double-strand break (DSBs), *i.e.*, the localised break of the DNA backbone on both strands. The cascade of events initiating with the interaction between radiation and the cellular medium, and leading to the modification or disruption of the DNA, spans a broad range of length and time scales. To gain insight into this intrinsically multiscale process, computer simulations can represent a valuable instrument. In this contribution, I will illustrate the results of a coarse-grained molecular-dynamics study of the interplay between the structural/mechanical properties of linear and circular double-stranded DNA filaments, and how they affect the evolution of the molecule in the presence of double-strand breaks. I will discuss the DNA rupturing as an activated process modulated by the molecule's structure and topology, and quantify the relation between breaking kinetics and quantitative measures of the topological state.

▲ **Allosteric activation in proteins explored via multiscale dynamics: Lessons from the phosphatase SHP2.**

CALLIGARI P.

*Department of Chemical Sciences, Tor Vergata University of Rome*

Characterizing allosteric mechanisms in multi-domain proteins with slow interconversion rates (on the order of seconds) remains a significant challenge for traditional computational methods. Here I will present lessons we learnt from studying the tyrosine phosphatase SHP2, a key regulator of cellular signaling, whose activating mutations are associated with developmental disorders and multiple cancer types. SHP2 comprises two SH2 domains (N-SH2 and C-SH2), followed by a catalytic PTP domain. The SH2 domains recognize and bind phosphotyrosine-containing sequences of SHP2 partners. In its inactive state, SHP2 adopts a closed conformation, with the N-SH2 domain occluding the catalytic site of the PTP domain. Activation involves SH2 domain engagement with phosphorylated partners, which induces structural rearrangements. However, the precise contribution of the SH2 domains to binding affinity and partner recruitment remains poorly understood. We will show how enhanced sampling techniques and coarse-grained molecular-dynamics simulations can reveal activation pathways and elucidate topological constraints arising from the binding of bis-phosphorylated peptides to both SH2 domains.

▲ **Radiation Damage Assay on Microtubules of MDA-MB-231 cells.**

CROCI S. <sup>(1)(2)</sup>, MANGHI M. <sup>(1)(2)</sup>, COLANGELO M.T. <sup>(1)</sup>, CELENTANO M. <sup>(3)</sup>, LEO L. <sup>(1)</sup>, VIGNATI A. <sup>(4)(5)</sup>

<sup>(1)</sup> *Dipartimento di Medicina e Chirurgia, Università di Parma*

<sup>(2)</sup> *INFN-TIFPA, Trento*

<sup>(3)</sup> *CPFR-Centro Pisano Flash Radiotherapy, Pisa*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Torino*

<sup>(5)</sup> *INFN, Sezione di Torino*

The Radiation Damage Assay on Microtubules (RADAMES) is a method that we are setting to detect radiation-induced damage to microtubules (MTs), providing better sensitivity for doses above 4 Gy than the traditional methods based on the detection of  $\gamma$ -foci on DNA. MTs are cytoskeletal structures also involved in DNA repair transport and are suitable damage targets due to their size and cellular distribution. The study presents results on MDA-MB-231 cells irradiated with protons in conventional mode at TPLB (Trento Proton Therapy Center), and with electrons in both conventional and at UHDR modes at CPFR (Centro Pisano Flash Radiotherapy) and at the Physics Department of the University of Turin, with doses up to 18 Gy. Cells were immunostained for  $\alpha$ -tubulin and analysed using confocal microscopy and STORM super-resolution microscopy. Confocal microscopy measurements showed a dose-dependent reduction in signal intensity of labelled MTs and the

dose (0–18 Gy) in the regions of interest, while super-resolution STORM microscopy provided information at the nanometre level showing a fragmentation of the MTs reconstruction, sign of nanometric structural alteration in response to radiation. RADAMES is the first test to visualize and quantify dose-dependent structural damage on nanometric structures, the microtubules, in the range of 0–18 Gy. Optimization for different types of radiation and adaptation to synthetic MTs for dosimetry will be pursued.

### Comunicazioni

#### ● Micropipette-based single-cell isolation from live spheroids.

STELLATO M. <sup>(1)</sup>, PAL V. <sup>(2)</sup>, DIOSDI A. <sup>(2)(3)</sup>, HARMATI M. <sup>(2)</sup>, REMONDINI D. <sup>(1)</sup>, NORMANNO N. <sup>(4)</sup>, CASTELLANI G. <sup>(5)(6)</sup>, PICCININI F. <sup>(4)(5)</sup>, HORVATH P. <sup>(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia Augusto Righi, Università Bologna*

<sup>(2)</sup> *Synthetic and System Biology Unit, HUN-REN Biological Research Centre, Szeged, Hungary*

<sup>(3)</sup> *Single-Cell Technologies Ltd, Szeged, Hungary*

<sup>(4)</sup> *IRCCS Istituto Romagnolo per lo Studio dei Tumori Dino Amadori, Meldola, FC*

<sup>(5)</sup> *Department of Medical and Surgical Sciences, Università di Bologna*

<sup>(6)</sup> *IRCCS Azienda Ospedaliero-Universitaria di Bologna S. Orsola, Bologna*

Single-cell isolation from 3D spheroids has gained traction as a technique able to give useful insight into cell behaviour inside tumours. Conventional methods like enzymatic digestion and mechanical dissociation require sample destruction. We propose a new technology to perform *in vitro* single-cell isolation from spheroids using a micromanipulator integrated with automatic cell selection and isolation. This technique allows to extract living single cells from the aggregate while keeping both the cell and the spheroid alive. Currently, we can select and isolate single cells of interest from the outer region of spheroids embedded into hydrogel. This technology represents an initial step toward isolating single cells while maintaining the viability of both the spheroid and the extracted cell, leading to reliable and repeatable studies and paves the way for the single-cell-based downstream analyses of selectively isolated target cells from 3D cultures. Two are the main future steps. First, isolating cells from the inner layers of the spheroids to have better insights into their behavior as a tumor model. Secondly, completely automating the process to make it fast and reproducible.

#### ● Infrared spectroscopy for biochemical characterization of lipid components in human cells.

LEPORE M., PORTACCIO M.

*Dipartimento di Medicina Sperimentale, Università della Campania Luigi Vanvitelli, Napoli*

Lipids play essential roles in various cellular functions and are involved in the biochemical processes that underlie many diseases. As a result, there is a significant interest in investigating the biochemical characteristics of lipids. In this study, we employed Attenuated Total Reflection (ATR) geometry to acquire spectra from the primary lipid components in human cells, which include phosphatidylcholine, phosphatidylethanolamine, phosphatylserine, phosphatidylinositol, C18 ceramide, sphingosine-1-phosphate, ceramide-1-phosphate, sphingomyelin, and cholesterol. The analysis of these spectra revealed contributions from the different functional groups present in the examined samples. We assigned spectral features in accordance with existing literature. Special attention was given to identifying and discussing both the commonalities and differences in the spectra, particularly between phospholipid and sphingolipid components. Additionally, a ratiometric approach enabled the quantitative analysis of the spectra for phosphatidylinositol and sphingomyelin.

● **Unconventional detection methods for polyphenols detection: LOVE at first sight.**

BATTISTI A. <sup>(1)</sup>, TORI G. <sup>(1)</sup>, MALIK N. <sup>(1)</sup>, PUNTONI G. <sup>(1)</sup>, GAGLIARDI M. <sup>(1)</sup>, CECCHINI M. <sup>(1)</sup>, BIANCHI A. <sup>(2)</sup>, TAGLIERI I. <sup>(2)</sup>, VENTURI F. <sup>(2)</sup>, SANMARTIN C. <sup>(2)</sup>

<sup>(1)</sup> *NEST, Nanoscience Institute CNR e Scuola Normale Superiore, Pisa*

<sup>(2)</sup> *Department of Agriculture, Food and Environment, Università di Pisa*

Olive fruits are rich in some specific polyphenols belonging to the classes of flavones, phenolic acids, phenolic alcohols, lignans and secoiridoids, such as hydroxytyrosol, tyrosol, caffeic acid, oleocanthal, oleacein, oleuropein, verbascoside, and some of their derivatives. Given the relationship between the polyphenols content and fruit growth, their overall concentration can serve as a marker for the ripeness degree and for the expected quality of their final products. The PRIN project LOVE explores unconventional detection methods of polyphenols based on QCM-D, which could enhance quality assessments in the olive value chain, considered part of the Italian excellence in food production and often verified with the Made in Italy certification. In parallel, the behavior of polyphenols solutions in the phasor plot was also explored by FLIM to unveil possible trends that may be used to discriminate between different phenolic compositions. The implications of these results also extend to better resource management and sustainability. Project PRIN 2022 - Cod. 2022M4WB3M (LS9) LOVE Lab-on-chip for sustainable Olive Value chains - CUP B53D23017860006.

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Aula 7, Section B, Edificio 19

ore 15:50 – 18:30

SEZIONE VI

**Fisica applicata, acceleratori e beni culturali**  
 Presiede: AGOSTINO R.G. (Università della Calabria)

Relazioni su invito

▲ **Beyond the visible: Terahertz spectral impact on heritage and airborne environment monitoring.**

PETRARCA M., MOFFA C., FRANCESCONI D., CURCIO A., FELICI A.C., BELLAVEGLIA M., PIERSANTI L., MIGLIORATI M.

*Department of Basic and Applied Sciences for Engineering SBAI, Sapienza University of Rome e INFN, Sezione di Roma1*

THz reveals characteristic absorption modes of organic dyes and pigments. Its low non-ionizing photon energy (approximately 4.2 meV at 1 THz) prevents artwork damage during multi-layer stratigraphic analysis. THz spectroscopy is thus a valuable analytical technique for conservation science. We present a THz spectral-reflection approach for chemical mapping of pictorial materials. Results demonstrate simultaneous identification of pigments in different layers and reconstruction of concealed text within superimposed layers at varying depths, achieving enhanced contrast compared to conventional time-domain analysis. Furthermore, many pollutant compounds exhibit spectral fingerprints at THz frequencies. We introduce a novel proof-of-concept airborne THz continuous-wave (CW) laser spectrometer integrated with a high-stability unmanned aerial system (UAS, drone) for real-time, remote air quality monitoring. This innovative UAS-THz-CW combination enables flexible, high-resolution *in situ* spectroscopic measurements for detecting airborne pollutants, such as volatile organic compounds (VOCs) within gaseous mixtures, which is a significant advancement in environmental monitoring.

▲ **Connettività cerebrale tramite magnetoencefalografia.**

GRANATA C. <sup>(1)</sup>, BONAVOLONTÀ C. <sup>(1)</sup>, VETTOLIERE A. <sup>(1)</sup>, AMBROSANO M. <sup>(2)</sup>, TROISI LOPEZ E. <sup>(3)</sup>, POLVERINO A. <sup>(4)</sup>, MININO R. <sup>(3)</sup>, BASELICI F. <sup>(5)</sup>, SORRENTINO P. <sup>(1)</sup><sup>(6)</sup><sup>(7)</sup>, SORRENTINO G. <sup>(1)</sup><sup>(2)</sup><sup>(4)</sup>

<sup>(1)</sup> *Institute of Applied Sciences and Intelligent Systems, National Research Council, Pozzuoli, NA, Italy*

<sup>(2)</sup> *Department of Economics, Law, Cybersecurity and Sports Sciences, DiSEGIM, University of Naples "Parthenope", Nola, NA, Italy*

<sup>(3)</sup> *Department of Education and Sport Sciences, Pegaso Telematic University, Naples, Italy*

<sup>(4)</sup> *ICS Maugeri Hermitage Napoli, Naples, Italy*

<sup>(5)</sup> *Department of Engineering, University of Napoli "Parthenope", Napoli, Italy*

<sup>(6)</sup> *Institut de Neurosciences des Systèmes, Aix-Marseille Université, Marseille, France*

<sup>(7)</sup> *Department of Biomedical Sciences, University of Sassari, Sassari, Italy*

La magnetoencefalografia (MEG) è una tecnica completamente non invasiva per lo studio dell'attività cerebrale. Essa si basa sulla misura del debole campo magnetico generato dalle correnti elettrofisiologiche associate all'attività neuronale utilizzando sensori quantistici estremamente sensibili come gli SQUIDS (Dispositivi Superconduttori ad Interferenza Quantistica). Nell'ultimo decennio, un notevole interesse nel mondo della ricerca e della clinica è stato stimolato dallo studio della connettività cerebrale funzionale tramite la MEG. Grazie

all'alta risoluzione temporale (millisecondo), la MEG permette di studiare la dinamica della connettività, riuscendo a predire la performance di un individuo, per esempio a seguito di un compito di attenzione o motorio, e risente degli effetti dell'invecchiamento e di patologie in cui si verificano disconnessioni, come la sindrome di Alzheimer e il morbo di Parkinson. In questo contributo, dopo aver introdotto i principi di funzionamento della MEG, vengono mostrati alcuni recenti risultati relativi allo studio della connettività tramite la MEG e le loro implicazioni sia da un punto di vista clinico che delle neuroscienze di base.

▲ **Studying ancient Egyptian copper-alloy objects via X-ray diffraction and machine learning.**

FESTA G. <sup>(1)</sup>, CALIRI C. <sup>(2)</sup>, BOTTICELLI M. <sup>(2)</sup><sup>(3)</sup>, FATUZZO C.G. <sup>(2)</sup><sup>(3)</sup>, FERRARIS E. <sup>(4)</sup>, AUENMÜLLER J. <sup>(4)</sup>, PAVONE D.P. <sup>(2)</sup>, PRIVITERA G. <sup>(2)</sup><sup>(3)</sup>, SCATIGNO C. <sup>(1)</sup>, MILIANI C. <sup>(2)</sup>, ROMANO F.P. <sup>(2)</sup>

<sup>(1)</sup> CREF, Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi"

<sup>(2)</sup> CNR, Consiglio Nazionale delle Ricerche, Istituto di Scienze del Patrimonio Culturale, Catania, Italy

<sup>(3)</sup> INFN, Laboratori Nazionali del Sud, Catania, Italy

<sup>(4)</sup> Fondazione Museo delle Antichità Egizie di Torino, Torino, Italy

Metals played a key role in many ancient cultures. Here, a collection of 12 Egyptian bronze vessels and stands belonging to the set of grave goods of Kha and Merit, preserved at the Museo Egizio in Turin and dating back to the mid-18th Dynasty of the New Kingdom (ca. 1425–1352 BC), is studied to extract information regarding the metalworking methods. These objects have a high archaeological and culture-historical significance because they are daily use vessels, stem from the same burial context and have been preserved in the same conditions and are, as the whole assemblage, considered a unicum. Non-destructive and non-invasive X-ray powder diffraction coupled with machine learning is applied to carry out a comparative analysis of the artefacts. Four primary groups were identified based on microscopic structure and metalworking methods, ranging from highly homogeneous structures indicative of annealing to heterogeneous ones typical of cold working. These findings are integrated with macroscopic analysis by object shape, revealing a close correlation between manufacturing techniques, design, and intended function.

Comunicazioni

● **A rigorous study on the longitudinal beam coupling impedance of a cylindrical lossy pipe in normal and anomalous regimes.**

CURCIO A., MIGLIORATI M., MOSTACCI A., PALUMBO L.

Sapienza Università di Roma

One of the primary issues in designing particle accelerators is the effect of energy losses and collective instabilities caused by the conductivity of the vacuum chamber. Due to its relevance, many authors have long focused on studying the coupling impedance of lossy pipes with various geometries and metals. Most studies were developed for relativistic beams and room-temperature conductivity. In recent years, there has been increasing interest in the high-frequency impedance behavior of ultra-short bunches, as in the case of FELs, and in the anomalous conductivity at cryogenic temperatures of the vacuum chambers. In the present contribution, we treat the problem starting from the Boltzmann transport equation to derive the electric conductivity of a cylindrical pipe in which the primary fields are associated with a charge moving on-axis at any velocity. The expression of conductivity depends on the properties of the material, the cylindrical symmetry, and the velocity of the charge. The electromagnetic interaction between the charge and the pipe has been studied in normal

and anomalous conducting regimes, deriving general analytical results for the surface and coupling impedance.

● **Simulations of losses from top-up injection and fast instabilities in the FCC-ee.**

NIGRELLI G. <sup>(1)(2)(3)</sup>, BOSCOLO M. <sup>(2)</sup>, BROGGI G. <sup>(1)(2)(3)</sup>, BRUCE R. <sup>(3)</sup>, BUFFAT X. <sup>(3)</sup>, REDAELLI S. <sup>(3)</sup>, SKOUFARIS K. <sup>(3)</sup>

<sup>(1)</sup> *Sapienza Università di Roma*

<sup>(2)</sup> *INFN, Laboratori Nazionali di Frascati*

<sup>(3)</sup> *CERN, Geneva, Switzerland*

The electron-positron Future Circular Collider (FCC-ee) is a proposed high-energy lepton collider that aims to reach unprecedented luminosity and precision in the measurement of fundamental particles. To fully exploit this potential, it is crucial to keep machine-induced detector backgrounds under control to ensure safe operation and optimal detector performance. Due to the high stored beam energy and complex operational requirements (e.g. the top-up injection scheme), controlling these backgrounds to the physics experiments becomes more challenging. We present background studies from two critical sources: top-up injection and fast beam instabilities. The top-up injection generates unavoidable losses at every cycle, originating from both the injected and circulating beams. Recent studies on collective effects have also shown that high impedance in the FCC-ee can lead to fast rise-time instabilities, where the beam amplitude grows exponentially, leading to beam loss within a few turns. Although a feedback system is being developed to mitigate this instability, failure scenarios of this feedback system need to be explored.

● **MOF-biocomposite films as next-gen optical virus biosensing.**

MANCINI T. <sup>(1)</sup>, BONGIORNO A. <sup>(2)</sup>, D'ARCO A. <sup>(1)</sup>, FALCARO P. <sup>(3)</sup>, CARRARO F. <sup>(3)</sup>, LUPI S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Sapienza Università di Roma*

<sup>(2)</sup> *Dipartimento di Chimica, Sapienza Università di Roma*

<sup>(3)</sup> *Institute of Physical and Theoretical Chemistry, Graz University of Technology, Austria*

Metal-Organic Frameworks (MOFs) are porous materials, made of inorganic metal nodes connected by organic linkers and characterized by a widely tuneable chemical versatility and stability. Through a green, biocompatible and sustainable procedure, MOFs can encapsulate biomacromolecule (biocomposites). These properties make them highly attractive for a variety of applications, from gas storage and water purification to biomedicine, drug delivery and biosensing. In this work, enzyme@MOF biocomposites film are designed to constitute a biofunctionalization strategy for the optical biosensing of viruses. The biosensor development strategy is illustrated, the film synthesis procedure is shown and optimized, and the crystalline, morphological and chemical characterization of enzyme@MOFs films is provided through XRD, FTIR and nano-IR spectroscopy. The retainment of encapsulated enzyme activity is successfully verified, since it is an essential feature to constitute a working and effective sensor. Activity essay and fluorescence microscopy test are performed, and preliminary results are reported, showing the promising, effective potential of MOFs biocomposites-based biosensing strategy.

● **Fe<sup>3+</sup> ions diffusion evaluation for hydrogel-based fricke gel dosimeters.**

LOCARNO S. <sup>(1)(2)</sup>, PASSERI D. <sup>(1)</sup>, GALLO S. <sup>(3)</sup>, PIGNOLI E. <sup>(4)</sup>, LENARDI C. <sup>(1)(2)</sup>, VERONESE I. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Milano*

<sup>(2)</sup> *INFN, Sezione di Milano*

(<sup>3</sup>) *Dipartimento di Fisica, Università di Catania*

(<sup>4</sup>) *IRCCS Foundation Istituto Nazionale dei Tumori, Milano*

Precision and effectiveness in radiation treatment delivery imply dose conformation to tumor and healthy tissues preservation, for which ionization beam spatial mapping is needed. Fricke gel dosimeters could be useful for extensive measurements of dose distribution inside tissue equivalent phantoms, though the main drawback is the diffusive behaviour of  $\text{Fe}^{3+}$  ions after irradiation. Several studies focused on the development of the hydrogel-based matrix to fix the spatio-temporal dosimetric information, since they mimic both mechanical and radiobiological features of organic tissues. In this research we studied the effect of molecular weight of polyvinyl alcohol (PVA)-based hydrogel cross-linked with glutaraldehyde on the  $\text{Fe}^{3+}$  ions diffusion. Three different chelating agents were tested and for all, we found a correlation between matrix stiffness and  $\text{Fe}^{3+}$  diffusion reduction: the samples with the highest PVA molecular weight showed the lowest flexibility and a decrease in Fe ions mobility. These results highlight the role in diffusion attenuation induced by stronger bonds between chelating agents and the hydrogel matrix.

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Aula 8, Section B, Edificio 19

ore 15:50 – 18:30

SEZIONE VII

**Didattica e storia della fisica**

Presiede: ROSSI P. (Università di Pisa)

Relazioni su invito

▲ **G.D. Cassini and the problem of the figure of the Earth.**

CIOTTI L.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

In this talk I will discuss G.D. Cassini's contributions to two important astronomical problems, the debate about the figure of the Earth and the shape of planetary orbits. After reviewing Cassini's impact and ideas in these areas, I will discuss how Newtonian mechanics finally solved the problems. I will also show how some aspects of these old debates found their way into the current scientific literature.

▲ **Contro ogni superstizione: l'avventura scientifica di Montanari tra Bologna e Padova.**

ZANINI V.

*INAF, Osservatorio Astronomico di Padova*

Geminiano Montanari (1633-1687) è stato uno dei principali esponenti del metodo sperimentale galileiano nell'Italia del XVII secolo. Scienziato poliedrico e razionalista convinto, Montanari apportò diversi contributi nei più svariati campi dello scibile umano: astronomia, meteorologia, fisica, medicina, idraulica ed economia. Formatosi sotto la guida di Paolo del Buono (1625-1659), nel 1664 divenne docente dell'ateneo bolognese, dove collaborò proficuamente con Gian Domenico Cassini (1625-1712), col quale rimase in rapporto scientifico anche dopo il trasferimento di quest'ultimo a Parigi. Nel 1678 assunse la cattedra di Astronomia e meteore a Padova, dove intensificò la sua battaglia contro le superstizioni astrologiche, fedele al metodo scientifico basato sull'osservazione e sull'evidenza empirica, inaugurato da Galileo.

Comunicazioni

● **Pioneers of communication: The Bell Telephone in Milan (1877-1878).**

MANTOVANI R.

*Dipartimento di Scienze Pure e Applicate, Gabinetto di Fisica: Museo urbinato della Scienza e della Tecnica, Università di Urbino*

Milan was among the first Italian cities to test the effectiveness of the newly invented telephone by Alexander Graham Bell. This talk examines the earliest Milanese experiments, conducted between November 1877 and January 1878, highlighting the roles of key figures such as engineer Marco Maroni, Giuseppe Colombo, Carlo Pianta, and the Gerosa brothers. Maroni carried out public demonstrations at Palazzo Litta using a self-built device. The trials, documented by Colombo and Pianta, confirmed the clear transmission of sounds and speech, even over long distances simulated by a Siemens and Halske rheostat. Simultaneously, Edoardo and Emilio Gerosa, having obtained a licence to manufacture Bell telephones, conducted experiments at Palazzo Marino, establishing vocal links between various municipal locations. The success of their demonstrations attracted the interest of military authorities, prompting further trials. These pioneering experiments marked the inception of Italian telephony, spurring research in other cities and fostering a wide-ranging debate among Italian scientists.

● **Guglielmo Marconi - Esperimento della Collina.**

PIPI F.

*Università di Bologna e Fondazione Guglielmo Marconi*

Nel 1895, Guglielmo Marconi porta a termine un esperimento, ormai leggendario, di radiotelegrafia nella residenza paterna di Villa Griffone: l'esperimento della collina dei Celes-tini. Si ritenne sufficientemente soddisfatto dai risultati ottenuti da convincersi, l'anno suc-cessivo, a trasferirsi a Londra per brevettare la sua invenzione. Lo studio presentato analizza in modo storico e fisico questo esperimento con l'obiettivo di individuarne gli elementi chiave. Una delle limitazioni nel perseguire questo scopo è la mancanza di fonti storiche coeve, da cui nasce l'esigenza di trovarne di alternative. Questo bisogno è soddisfatto dai documenti relativi al brevetto: una bozza manoscritta, forse la fonte più vicina all'esperimento; una ver-sione provvisoria; e infine il brevetto definitivo. L'analisi mette in luce due aspetti collegati e centrali riguardo al successo dell'esperimento: la modalità di lavoro empirica di Marconi, che lo porta a sfidare l'ambiente esterno e a trovare una configurazione efficace degli apparati e l'uso di un'antenna con collegamento a terra, che aumenta enormemente la distanza di propagazione delle onde elettromagnetiche.

● **L'esperimento transatlantico di Guglielmo Marconi e il suo impatto nella ricerca scientifica.**

BUCCILLI B.

*Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma*

Durante l'anno appena passato sono stati celebrati i 150 anni dalla nascita di Guglielmo Marconi, questo affascinante personaggio rappresenta tuttora la fusione di scienza e impren-ditoria, capace di bilanciare aspetti tecnici con aspetti di fisica all'avanguardia. Nel presente lavoro si cercherà di contestualizzare questa figura cercando di analizzare un tema da sempre dibattuto: può la pura esperienza suggestionare un avanzamento scientifico? Il caso paradig-matico analizzato per rispondere a questa domanda è quello dell'esperimento che Marconi denominerà: the Big Thing, l'impresa della vita che gli permise nel 1901 di inviare un se-gnale in grado di superare l'Oceano Atlantico e che sarà la base per la scoperta di uno strato dell'atmosfera riflettente: la ionosfera.

● **La dipendenza del tempo dal campo elettromagnetico nell'interpretazione delle trasformazioni di Lorentz.**

GIANNETTO E.

*Università di Bergamo*

Nel 1912, utilizzando il calcolo vettoriale assoluto senza coordinate introdotto qualche anno prima insieme a Cesare Burali-Forti, Roberto Marcolongo diede una formulazione intrinseca, vettoriale senza coordinate, delle trasformazioni di Lorentz-Poincaré. Le trasformazioni di Lorentz-Poincaré-Marcolongo non sono più interpretabili solo come trasformazioni passive tra differenti sistemi inerziali, ma sono suscettibili anche di una interpretazione quali trasfor-mazioni attive indicanti mutamenti dinamici dei sistemi fisici. Tali trasformazioni compor-tano anche una differente interpretazione del tempo, che non è più ridotto a mera coordinata dipendente dal sistema di riferimento, ma assume un nuovo significato dinamico relativistico, legata al campo magnetico, come nella prospettiva di Larmor, Poincaré ed Eddington.

● **Una nuova fonte su Bruno Rossi e la fisica dei raggi cosmici negli anni '30.**

CAMPAGNONI L.

*Dipartimento di Fisica e Astronomia, Università degli Studi di Padova*

Recentemente è stata rinvenuta una gran quantità di lettere, fotografie, oggetti personali e documenti presso la casa di Venezia in cui il fisico Bruno Benedetto Rossi (1905-1993)

nacque e visse fino al 1938, quando abbandonò definitivamente l'Italia a causa delle leggi razziali fasciste. L'autore ha iniziato a organizzarne e analizzarne il contenuto durante il lavoro di tesi magistrale, e sta ora continuando l'opera grazie a un dottorato in fisica presso l'Università degli Studi di Padova dedicato alla storia della fisica. Il contenuto dell'archivio riguarda in particolare gli anni 1930, e contiene inedite e dettagliate informazioni circa esperimenti, missioni scientifiche, contatti con fisici dell'epoca e con istituzioni nazionali ed estere. La presente comunicazione intende fornire un quadro d'insieme delle nuove scoperte e informazioni che questo ritrovamento sta fornendo e che ha il potenziale di fornire nei prossimi anni. Ci si soffermerà in particolare sulla parte di archivio già analizzata a fondo e che ha rivelato nuovi aspetti relativi alla missione scientifica che Rossi fece nella colonia di Eritrea nel 1933.

● **From the expanding Earth to the nature of light.**

SCALERA G.

*INGV, Roma*

The need from the Expanding Earth for a hydrodynamic mechanism for Newtonian and Coulomb fields (the central torrent of Bernoulli) allows to identify the branch point from which came the abandoning of Galilean transformations. It is the lack of coupling of the EM field to the underlying material causing field – the central torrent which induces hydrodynamical forces and accelerations – that gives rise to inaccuracies in the formulation of EM equations, which are incorrect for Galilean covariance. A further flaw in the formulation of electromagnetism is the erroneous identification of the flow velocity of the field (variable as  $1/r^2$ ) with the speed of light  $c$ , with which Heaviside (1888, 1889) demonstrated that the fields of charges in motion contract in the direction of motion. From these errors, due to incomplete development of many sectors of hydrodynamics, and from historic, scientific, philosophical contingencies, came Fitz Gerald's contractions and relativistic theories. Additional problems affect EM: the most serious is the illegitimate use of Gauss's Law to forbid the longitudinal nature of EM waves, the only possible nature because the hydrodynamic nature of the fields.

● **Congettura di Maxwell e sistemi viventi.**

MASTROMATTEO U.

*A.R.G.A.L., Associazione per la Ricerca della Genesi delle Anomalie Lenr, Bareggio, MI*

Il tentativo di Leo Szilard nel 1929 con un congegno in grado di simulare l'azione del demone della congettura di Maxwell, quell'essere intelligente in grado di separare due gas mescolati in due contenitori separati da una saracinesca manovrabile, confermò l'impossibilità di abbassare l'entropia del sistema per il principio di Landauer per cui lo scambio di informazione con l'esterno sullo stato del sistema andava a sovracompensare la diminuzione di entropia prodotta dal demone all'interno. Ciò sta ad indicare che senza informazione sul da farsi il demone non sarebbe in grado di agire e conferma la relazione fondamentale tra entropia e informazione. Ma, se il demone avesse le informazioni per operare senza doverle comunicare all'esterno, la diminuzione di entropia per i gas più ambiente sarebbe effettiva. Ciò è quanto si osserva durante la crescita di organismi viventi per i quali l'informazione per ordinare la materia è presente al loro interno. Esempio tipico la crescita spontanea che da un chicco di grano conduce a numerose copie dello stesso ordinando la materia inorganica estratta dal suolo dall'acqua e dall'aria, con un bilancio entropico complessivo negativo.

Aula Magna G.B.F. Basile, Edificio 7

ore 09:00 – 13:30

SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: MARSELLA G. (Università di Palermo e INFN, Sezione di Catania)

Relazioni su invito

▲ **On AsFiN (Astrofisica Nucleare) recent results.**

PALMERINI S. ON BEHALF THE ASFIN COLLABORATION

*Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, INFN, Sezione di Perugia e INAF, Osservatorio Astronomico di Roma*

The AsFiN collaboration has been dedicated, for nearly three decades, to the development of innovative techniques for nuclear astrophysics, including indirect methods (the Trojan Horse Method, THM, and the Asymptotic Normalization Coefficient, ANC), as well as the use of gamma-ray beams and high-power lasers to induce nuclear reactions under conditions as close as possible to those found in astrophysical environments. Originally conceived to study reactions between charged particles at energies typical of primordial and stellar nucleosynthesis (while avoiding the yield suppression caused by the Coulomb barrier and electron screening) the Trojan Horse Method has recently proven to be a highly effective tool for investigating reactions involving neutrons and unstable isotopes at Radioactive Ion Beam facilities. In this presentation, we will outline the most recent results and discuss future perspectives of the AsFiN Collaboration in exploring processes that play a fundamental role in both quiescent and explosive astrophysical scenarios, from stellar formation to their cataclysmic death.

▲ **Recent results in nuclear spectroscopy from the GAMMA collaboration.**

GOTTARDO A. <sup>(1)</sup>, BENZONI G. <sup>(2)</sup>

<sup>(1)</sup> *INFN, Laboratori Nazionali di Legnaro*

<sup>(2)</sup> *INFN, Sezione di Milano*

The GAMMA collaboration studies nuclear structure and reaction dynamics by means of  $\gamma$ -ray and particle spectroscopy techniques. The main research activity is centered around the physics campaign at Laboratori Nazionali di Legnaro (LNL) using the state-of-the-art  $\gamma$ -ray tracking array AGATA. This array of segmented Ge crystals, built by a large European collaboration, has been coupled to the magnetic spectrometer PRISMA as well as to other complementary detectors for heavy-ion and light particle measurement at LNL. The physics campaign has encompassed a large variety of physics cases, ranging from the sub-barrier Coulomb excitation of stable nuclei to the lifetime measurement of excited states in exotic nuclei. Studies of  $\gamma$ -ray emission from near-barrier nucleon-pair transfer and sub-barrier fusion were also performed. The collaboration further explores the structure of exotic nuclei performing experiments in the main international laboratories in EU, USA, Canada and Japan, with the aim of combining different observables to obtain a comprehensive picture of the nuclear many-body system. A panorama of the activities will be presented, with selected physics cases.

▲ **The Jefferson Lab scientific program and future perspectives.**

BONDÌ M.

*INFN, Sezione di Catania*

This talk presents an overview of Jefferson Lab's (JLab) recent highlights and future perspectives, with a particular focus on areas where the Italian collaboration plays a significant



role. Following the successful completion of the 12 GeV upgrade of the CEBAF accelerator, a broad scientific program has been developed to explore the quark and gluon structure of hadrons and to unravel the mechanisms of confinement in Quantum Chromodynamics. Beyond the hadron physics program, JLab hosts several innovative experiments targeting the dark sector, such as APEX, HPS, and BDX. Looking ahead, the laboratory is actively exploring upgrade options that could significantly extend its scientific capabilities. These include a potential increase of the CEBAF beam energy to 22 GeV and the use of positron beams, which would enable new precision measurements. Furthermore, the possibility of exploiting secondary beams - such as muons and neutrinos - is under investigation, opening promising new directions to further broaden the laboratory's scientific program. In my talk, I will present key results from the four experimental halls, with particular emphasis on Halls B and A, where Italian groups have made substantial contributions to detector development, data analysis, and physics interpretation.

### Comunicazioni

#### ● Study of the $^{14}\text{N} + \text{d}$ interaction by using the indirect Trojan Horse Method.

SERGI M.L. ON BEHALF OF THE ASFIN COLLABORATION

*Dipartimento di Fisica e Astronomia, Università degli Studi di Catania e INFN, Laboratori Nazionali del Sud, Catania*

In the last years the indirect Trojan Horse method (THM) has proven to be a useful tool for determining both charged particle and neutron-induced reaction cross sections occurring in various astrophysical environments. In particular, the results of the application of the THM to the  $^{14}\text{N} + \text{d}$  interaction will be shown for the study of two reactions,  $^{14}\text{N}(\text{n}, \text{p})^{14}\text{C}$  and  $^{11}\text{C}(\alpha, \text{p})^{14}\text{N}$ . The former is a strong neutron poison for nucleosynthesis involving the  $^{13}\text{C}(\alpha, \text{n})^{16}\text{O}$  neutron source and it is also involved in the  $^{19}\text{F}$  nucleosynthesis, that represents a useful tracer of the physical conditions in stellar interiors and it is observed with high abundance in AGB atmospheres. The  $^{11}\text{C}(\alpha, \text{p})^{14}\text{N}$  reaction is one of the most sensitive reactions to affect the abundance of  $^{11}\text{B}$  through the destruction of  $^{11}\text{C}$  and the abundance ratio of  $^7\text{Li}/^{11}\text{B}$  from supernovae could be sensitive to the neutrino mass hierarchy. The cross sections of the  $^{11}\text{C}(\alpha, \text{p})^{14}\text{N}$  reaction was evaluated by applying the principle of detailed balance to the  $^{14}\text{N}(\text{p}, \alpha)^{11}\text{C}$  cross section obtained through the THM.

#### ● $\gamma$ decay of IAS in $^{71}\text{Ge}$ : A new pathway to Gallium anomaly.

STRAMACCIONI D.

*Dipartimento di Fisica e Astronomia, Università degli Studi di Padova e INFN, Laboratori Nazionali di Legnaro*

Inverse beta decay (IBD) has long been a key process in neutrino physics. A recent study showed that the poorly known Nuclear Matrix Element (NME) relevant to IBD can be extracted from the  $\gamma$  decay width of the Isobaric Analog State (IAS) in  $^{71}\text{Ge}$ , provided the IAS is efficiently populated. The  $^{72}\text{Ge}(\text{p}, \text{d})^{71}\text{Ge}$  reaction, favored by isospin coupling, is a promising tool to achieve this. To test its suitability, we performed an experiment combining deuteron measurement with a Silicon Annular detector and  $\gamma$  spectroscopy with the AGATA array. In this talk, I will present preliminary results on the reaction cross section and IAS decay branches, which represent a key step toward a high-precision measurement of the IAS  $\gamma$  decay width.

#### ● Prima misura indiretta della sezione d'urto di $^{26}\text{Al}(\text{n}, \text{p})^{26}\text{Mg}$ e di $^{26}\text{Al}(\text{n}, \alpha)^{23}\text{Na}$ nel contesto dell'astronomia multimessaggera.

ANDREIS F. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, LA COGNATA M. <sup>(1)</sup>, MAZZOCCO M. <sup>(3)</sup><sup>(4)</sup>, TOGNI A. <sup>(3)</sup>, CACIOLLI A. <sup>(3)</sup><sup>(4)</sup>, MENGONI D. <sup>(3)</sup><sup>(4)</sup>, ACOSTA SANCHEZ L. <sup>(10)</sup><sup>(11)</sup>, ALCORTA M. <sup>(15)</sup>, CHARON

GARCIA L.E. <sup>(15)</sup>, COSTA M. <sup>(1)</sup>, DI PIETRO A. <sup>(1)</sup>, FERNANDEZ GARCIA J.P. <sup>(1)(12)</sup>, FIGUERA P. <sup>(1)</sup>, GULINO M. <sup>(1)(6)</sup>, LA COMMARA M. <sup>(9)</sup>, LAMIA L. <sup>(1)(2)(5)</sup>, LATTUADA D. <sup>(1)(6)</sup>, LENNARZ A. <sup>(15)</sup>, MILIN M. <sup>(16)</sup>, PALADA L. <sup>(14)</sup>, PALMERINI S. <sup>(7)(8)</sup>, PIGLI-  
APOCO S. <sup>(4)</sup>, PIZZONE R. <sup>(1)(5)</sup>, RAPISARDA G. <sup>(1)(5)</sup>, SANCHEZ ROJO J. <sup>(15)</sup>, SFERRAZZA  
M. <sup>(1)(13)</sup>, SOIC N. <sup>(14)</sup>, SZEGEDI N. <sup>(1)</sup>, TEIHELHOEFER A. <sup>(15)</sup>, TUMINO A. <sup>(1)(6)</sup>, UPAD-  
HYAYLA S. <sup>(15)</sup>, WAGNER L. <sup>(15)</sup>, WILLIAMS M. <sup>(15)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali del Sud, Catania

<sup>(2)</sup> Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania

<sup>(3)</sup> Dipartimento di Fisica, Università degli Studi di Padova

<sup>(4)</sup> INFN, Sezione di Padova

<sup>(5)</sup> Dipartimento di Fisica, Università degli Studi di Catania

<sup>(6)</sup> Università di Enna Kore

<sup>(7)</sup> Dipartimento di Fisica, Università di Perugia

<sup>(8)</sup> INFN, Sezione di Perugia

<sup>(9)</sup> Dipartimento di Fisica, Università di Napoli

<sup>(10)</sup> Instituto de Estructura de la Materia, CSIC, Madrid, Spain

<sup>(11)</sup> National Autonomous University of Mexico, Mexico D.F., Mexico

<sup>(12)</sup> Universidad de Sevilla, Spain

<sup>(13)</sup> Université Libre de Bruxelles, Belgium

<sup>(14)</sup> RBI, Zagreb, Croatia

<sup>(15)</sup> TRIUMF, Vancouver, Canada

<sup>(16)</sup> University of Zagreb, Croatia

L'esperimento mira a migliorare la comprensione dei processi di nucleosintesi tramite lo studio dell'isotopo radioattivo  $^{26}\text{Al}$ . Questo nucleo, primo emettitore di raggi gamma osservato nella galassia, è cruciale per comprendere l'evoluzione di stelle massive. Si misurano indirettamente le sezioni d'urto dei canali di distruzione neutronica  $^{26}\text{Al}(n, \alpha)$  e  $^{26}\text{Al}(n, p)$ , fondamentali nel determinare l'abbondanza di  $^{26}\text{Al}$ , utilizzando il Metodo del Cavallo di Troia (THM). Tale metodo permette di superare le difficoltà sperimentali relative alle misure di sezioni d'urto ad energie di interesse astrofisico, utilizzando i meccanismi di reazione di break-up quasi libero. I dati, relativi all'esperimento  $^2\text{H} + ^{26}\text{Al}$  realizzato presso il TRIUMF (Vancouver, Canada), utilizzano un fascio radioattivo di  $^{26}\text{Al}$  a 3,5 MeV/u e telescopi al silicio per rivelare i prodotti di reazione, consentendo di esplorare l'intervallo energetico rilevante negli ambienti stellari (0-1 MeV). Verrà presentato lo stato attuale dell'analisi dati dell'esperimento, includendo l'analisi di alcuni processi impiegati come controllo cinematico e dinamico della correttezza delle calibrazioni energetiche e angolari dei rivelatori.

### ● Applicazioni del correlatore FARCOS nell'esperimento CHIFAR: tecnica della pixelazione, identificazione dei IMFs e studio del ruolo dell'isospin negli effetti di emissione dinamica.

ZAGAMI C. <sup>(1)(2)(3)</sup>, PAGANO E. V. <sup>(2)</sup>, RUSSOTTO P. <sup>(2)</sup>, DE FILIPPO E. <sup>(4)</sup>, ACOSTA L. <sup>(5)(6)</sup>, CAP T. <sup>(7)</sup>, CARDELLA G. <sup>(4)</sup>, FICHERA F. <sup>(4)</sup>, GERACI E. <sup>(1)(3)(4)</sup>, GNOFFO B. <sup>(1)(4)</sup>, GUAZZONI C. <sup>(8)(9)</sup>, LANZALONE G. <sup>(2)(10)</sup>, MAIOLINO C. <sup>(2)</sup>, MARTORANA N. S. <sup>(4)</sup>, MATULEWICZ T. <sup>(11)</sup>, PAGANO A. <sup>(4)</sup>, PAPA M. <sup>(4)</sup>, PIASECKI K. <sup>(11)</sup>, PIR-  
RONE S. <sup>(4)</sup>, PISCOPO M. <sup>(2)</sup>, PLANETA R. <sup>(12)</sup>, POLITI G. <sup>(1)(4)</sup>, RISITANO F. <sup>(4)(13)</sup>,  
RIZZO F. <sup>(1)(2)(3)</sup>, SACCÁ G. <sup>(4)</sup>, SIWEK-WILCZYNSKA K. <sup>(11)</sup>, SKWIRA-CHALOT I. <sup>(11)</sup>,  
TRIMARCHI M. <sup>(4)(13)</sup>

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- <sup>(5)</sup> *Instituto de Fisica. Universidad Nacional Autonoma de Mexico, Mexico*
- <sup>(6)</sup> *Instituto de Estructura de la Materia, CSIC, Spain*
- <sup>(7)</sup> *National Centre for Nuclear Research, Poland*
- <sup>(8)</sup> *Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano*
- <sup>(9)</sup> *INFN, Sezione di Milano*
- <sup>(10)</sup> *Facoltà di Ingegneria e Architettura, Università Kore, Enna*
- <sup>(11)</sup> *Faculty of Physics, University of Warsaw, Poland*
- <sup>(12)</sup> *M. Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland*
- <sup>(13)</sup> *Dipartimento di Scienze MIFT, Università di Messina*

Nell'esperimento CHIFAR, presso INFN-LNS, il multi-rivelatore CHIMERA e 10 telescopi del correlatore FARCOS (Femtoscope ARray for CORrelations and Spectroscopy) sono stati accoppiati per realizzare il setup sperimentale. FARCOS è un triplo telescopio con 2 DSSSDs (Double Sided Silicon Strip Detectors da 300-1500  $\mu\text{m}$ ) e 4 scintillatori di CsI (6 cm), che garantisce elevata risoluzione energetica e angolare. Le particelle sono state identificate con la tecnica  $\Delta E$ -E mentre la loro posizione nel sistema del laboratorio è stata individuata tramite la tecnica della pixelazione. Finita la prima fase, è cominciato lo studio dei risultati provenienti dal merging dei dati di CHIMERA e FARCOS: l'analisi preliminare evidenzia il ruolo dell'isospin delle reazioni studiate nell'emissione dinamica. In particolare, si mostreranno risultati preliminari circa la probabilità di emissione dei Frammenti di Massa Intermedia (IMFs) e del contributo di isospin dei nuclei collidenti,  $^{124}\text{Sn}$ ,  $^{112}\text{Sn}$  e  $^{124}\text{Xe}$ , ad energia di 20 AMeV, su target di  $^{64}\text{Ni}$ ,  $^{58}\text{Ni}$  e  $^{64}\text{Zn}$ , che in CHIFAR mirano a caratterizzare l'Equazione di Stato della materia nucleare.

● **Investigating decay of the excited  $^{12}\text{C}$  levels by using CHIMERA multidetector via the  $^4\text{He} + ^{12}\text{C}$  reaction.**

CAVALLARO R. <sup>(1)(2)</sup>, MARTORANA N. S. <sup>(2)</sup>, CARDELLA G. <sup>(2)</sup>, GERACI E. <sup>(1)(2)(3)</sup>, BARBON A. <sup>(1)(2)</sup>, CASTOLDI A. <sup>(4)</sup>, DE FILIPPO E. <sup>(2)</sup>, GNOFFO B. <sup>(1)(2)</sup>, GUAZZONI C. <sup>(4)</sup>, MAIOLINO C. <sup>(5)</sup>, PAGANO E. V. <sup>(5)</sup>, PAPA M. <sup>(2)</sup>, PIRRONE S. <sup>(2)</sup>, POLITI G. <sup>(1)(2)</sup>, RISITANO F. <sup>(2)(6)</sup>, RIZZO F. <sup>(1)(3)(5)</sup>, RUSSOTTO P. <sup>(5)</sup>, TRIMARCHI M. <sup>(2)(6)</sup>, ZAGAMI C. <sup>(1)(3)(5)</sup>

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- <sup>(3)</sup> *CSFNSM, Catania*
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- <sup>(6)</sup> *Dipartimento MIFT, Università di Messina*

This contribution shows the preliminary results of an analysis aimed at investigating the  $\gamma$ -ray decay of the excited levels in  $^{12}\text{C}$ . This investigation is relevant because determining the decay width of the  $^{12}\text{C}$  excited states is useful to get more information about nucleosynthesis in astrophysical environments. In fact, the level at 7.65 MeV (Hoyle state) plays a crucial role in the  $^{12}\text{C}$  production during the helium-burning phase, while the 9.64 MeV level is involved in explosive environments. Data have been obtained from the reaction  $\alpha + ^{12}\text{C}$  performed at 64 MeV at INFN-LNS. The CHIMERA multidetector at INFN-LNS has been employed, due to its capability of detecting both  $\gamma$  rays and charged particles. Preliminary results concerning the calibration of the CHIMERA Si and CsI(Tl) detectors will be presented as well as with the identification of charged particles and  $\gamma$ -rays. In addition, first results based on the Q-value spectra will be discussed.

● **Laboratory magnetoplasmas as stellar-like environment for  ${}^7\text{Be}$   $\beta$ -decay investigations within the PANDORA project.**

NASELLI E. <sup>(1)</sup>, MISHRA B. <sup>(1)</sup>, PIDATELLA A. <sup>(1)</sup>, GALATÀ A. <sup>(2)</sup>, MAURO G.S. <sup>(1)</sup>, SANTONOCITO D. <sup>(1)</sup>, TORRISI G. <sup>(1)</sup>, MASCALE D. <sup>(1)</sup>

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<sup>(2)</sup> INFN, Laboratori Nazionali di Legnaro

Laboratory plasmas represent an intriguing environment for nuclear astrophysics studies. Theory predicts that the ionisation state of isotopes in-plasma can significantly alter their lifetimes, due to nuclear and atomic mechanisms such as bound-state  $\beta$ -decay. We focus on the case of  ${}^7\text{Be}$  electron capture (EC) decay to  ${}^7\text{Li}$ , as it has garnered great attention for the Cosmological Lithium Problem and solar neutrino physics. We explored the feasibility of measuring this decay within the new INFN PANDORA facility. We assessed the impact of atomic ionisation/excitation of  ${}^7\text{Be}$  isotopes in a He plasma by numerical modeling, providing the modified in-plasma EC decay rate. Because the decay of  ${}^7\text{Be}$  provides  $\gamma$ -rays from the  ${}^7\text{Li}^*$  excited state, used as tag, a space-dependent map of the  $\gamma$ -detection efficiency of the PANDORA HPGe detector array was determined by GEANT4 simulations. We present results of the measurement sensitivity by running a virtual experiment, indicating that measurements can achieve a  $3\sigma$  statistical significance in few hours, also considering the trade-off with the Be activity and the uncertainty in its decay constant to be reached.

● **Prestazioni del calorimetro elettromagnetico di CMS in un nuovo regime di energia: eventi dielettronici a bassa massa in Run 3.**

DE SANTIS E.

*Sapienza, Università di Roma e INFN, Sezione di Roma*

Il calorimetro elettromagnetico (ECAL) del rivelatore CMS è progettato per garantire un'eccellente risoluzione in energia e una risposta stabile nel tempo, qualità fondamentali per la ricostruzione precisa di elettroni in un ampio intervallo di energia. Con l'inizio del Run 3 al LHC, nuovi dataset con soglie di trigger abbassate-come quelli acquisiti tramite strategie di data parking-offrono l'opportunità di esplorare eventi contenenti coppie dielettroniche con basse energie trasverse. Questa tesi analizza le prestazioni dell'ECAL nella ricostruzione dello spettro di massa dielettronico in questa nuova regione cinematica, con particolare attenzione alla calibrazione dell'energia, alla qualità della selezione degli elettroni e alla gestione del rumore e del pileup. Il lavoro contribuisce alla validazione e ottimizzazione degli strumenti di analisi in condizioni sperimentali complesse, valorizzando il potenziale dell'ECAL in scenari finora poco esplorati.

● **Precision test of CPT symmetry via ground state hyperfine spectroscopy in antihydrogen at ALPHA.**

DEL VINCIO A. ON BEHALF OF ALPHA COLLABORATION

*Università di Brescia e Università di Trento*

CPT symmetry is a fundamental principle of Standard Model. Antihydrogen is ideal for testing CPT invariance by comparing its properties with those, well known, of hydrogen. ALPHA experiment at CERN focuses on producing, confining, and studying antihydrogen. Antihydrogen is synthesized by merging positrons and antiprotons in a Penning Malmberg trap, with magnetic confinement achieved using a superconducting solenoid and octupole magnets. We report on the techniques used to measure the hyperfine level of the antihydrogen 1S state at ALPHA. The measurement is conducted in a non-zero magnetic field, where the energy state degeneracy is fully resolved by the T used for confinement. Of the four hyperfine spectral lines, which differ according to the relative spin orientations of the positron and antiproton, only two correspond to trappable states. The hyperfine levels are measured by

inducing positron spin-flip transitions from trappable to untrappable states using microwave radiation directed into the trap. Detection of antihydrogen annihilation is performed using a Silicon Vertex Detector (SVD). Results obtained during the 2023 and 2024 data-taking will be presented.

● **Proton capture of  $^{17}\text{O}$  in stars.**

RAPAGNANI D. <sup>(1)(2)</sup>, STRANIERO O. <sup>(3)(4)</sup>, IMBRIANI G. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università degli studi di Napoli Federico II*

<sup>(2)</sup> *INFN, Sezione di Napoli*

<sup>(3)</sup> *INAF, Osservatorio Astronomico d'Abruzzo*

<sup>(4)</sup> *INFN, Sezione di Roma*

When stars approach the red giant branch, a deep convective envelope develops and the products of the CNO cycle appear at the stellar surface. In particular, the  $^{17}\text{O}$  is enhanced in RGB and AGB stars. Then, spectroscopic analyses of O isotopic ratios of these stars provide a powerful tool to investigate the efficiency of deep mixing processes, such as those powered by convective overshoot, rotation, thermohaline instability, gravity wave and magnetic field. However, this method requires a precise knowledge of the reaction rates that determine the  $^{17}\text{O}$  abundance in a H-burning shell, among which the  $^{17}\text{O}(\text{p}, \gamma)^{18}\text{F}$  and the  $^{17}\text{O}(\text{p}, \alpha)^{14}\text{N}$  reactions are the more relevant. Since the last release of rates compilations (see the JINA reaclib database) a number of experiments have updated the reaction rates, incorporating new low-energy cross section measurements. To provide up-to-date input to the astrophysics community, we performed simultaneous multi-channel and Monte Carlo R-matrix analyses of the two reactions including all newly available data, resulting in realistic uncertainty ranges for the rates.

● **Produzione e caratterizzazione di target per lo studio della reazione  $^{24}\text{Mg}(\text{p}, \gamma)^{25}\text{Al}$ .**

MONTELLA S. <sup>(1)</sup>, CAMPOSTRINI M. <sup>(2)</sup>, DI LEVA A. <sup>(1)</sup>, IMBRIANI G. <sup>(1)</sup>, RIGATO V. <sup>(2)</sup>

<sup>(1)</sup> *Università di Napoli Federico II*

<sup>(2)</sup> *INFN, Sezione di Padova*

Nella misura di processi nucleari a energie significativamente minori della barriera Coulombiana, un aspetto estremamente rilevante da tenere presente è il contributo al segnale misurato dovuto a reazioni indotte dagli ioni proiettile su altri nuclei presenti all'interno del materiale (beam induced background). Specifici isotopi di ioni leggeri quali  $^6\text{Li}$ ,  $^{10}\text{B}$ ,  $^{11}\text{B}$ ,  $^{19}\text{F}$ , eventualmente presenti nel bersaglio anche al livello di 10-9 mol/mol (ppb), possono produrre un segnale che può diventare competitivo se non superiore a quello di interesse. È pertanto necessario utilizzare bersagli, specificamente ottimizzati, che già a partire dal processo di produzione possano minimizzare il contenuto di contaminanti, sia nel film sottile che costituisce il bersaglio, sia nei substrati che vengono utilizzati come supporto per la deposizione, tipicamente tantalio. In questo contesto si producono bersagli di magnesio in varie forme chimiche tramite evaporazione e magnetron reactive sputtering, depositandoli su tantalio e carbonio. La determinazione delle caratteristiche e delle impurezze, sia dei bersagli che dei substrati, verrà fatta con tecniche di Ion Beam Analysis (NRA, PIGE, RBS).

● **Understanding the direct capture of  $^{24}\text{Mg}(\text{p}, \text{g})^{25}\text{Al}$ .**

SATURNO G., IMBRIANI G., RAPAGNANI D.

*Università degli Studi di Napoli Federico II*

$^{24}\text{Mg}(\text{p}, \text{g})^{25}\text{Al}$  is the main driver of the so-called MgAl cycle, which influences the nucleosynthesis in AGB stars. Even if its resonances have been studied with an adequate precision, direct capture mechanisms are presently not well constrained by experimental data. This

leads to a large uncertainty in the evaluation of stellar reactions rates. New experimental data are necessary, as well as a new comprehensive analysis of the literature data through e.g. a Monte Carlo multi-channel and multi-level R-Matrix approach. With this contribution we will present the new low energy (250-400 keV) measurement campaign which is presently performed by the LUNA collaboration at the Laboratori Nazionali del Gran Sasso of Istituto Nazionale di Fisica Nucleare.

● **Boosting the physics performances of the ENUBET monitored neutrino beam with a redesign of the hadron beamline.**

ZAPPACOSTA L.

*Università di Padova*

The ENUBET project has designed the first monitored neutrino beam, in which the measurement of charged leptons from meson decays in a suitably instrumented decay tunnel allows for a control at 1% on the resulting neutrino flux. It was demonstrated that a facility based on such a beam could perform a cross section measurement in the energy range of DUNE and Hyper-K with an overall 1% uncertainty (stat.+syst.), by employing  $5 \times 10^{20}$  400 GeV protons on target (pot) and a moderate mass neutrino detector ( $\sim 500$  ton). A new beamline, developed in the framework of Physics Beyond Colliders for an implementation at CERN, proved to be a factor 3.5 less expensive in terms of pot. The new beamline, originally simulated with the BDSIM software, has been ported as part of my work in the GEANT4 framework, allowing for higher flexibility in the analysis of the systematic uncertainty on the neutrino flux. I will present results on the optimization of the shieldings to suppress the fraction of neutrinos produced out of the instrumented decay tunnel, in particular in the target region, and the evaluation of the performance of the beamline for the operation in time-tagged mode.

● **ARCADIA - Depleted Monolithic Active Pixel Sensor (D-MAPS) technology for next-generation space experiments.**

SCHLEDEWITZ D.

*Dipartimento di Fisica, Università di Trento, INFN, Sezione di Trento e Fondazione Bruno Kessler, Trento*

Future particle physics and astrophysics experiments require tracking detectors with significantly improved tracking performance beyond current capabilities, driving a transition towards modern pixel detectors. Monolithic Active Pixel Sensors (MAPS) offer advantages, such as low material budget, simplified assembly, and potentially lower production costs. The Advanced Readout CMOS Architecture with Depleted Integrated Sensor Arrays (ARCADIA) project focuses on the development of Depleted MAPS (D-MAPS), specifically designed to improve the radiation hardness and readout capabilities for the demanding space environment. ARCADIA employs a continuous, triggerless readout architecture for high-speed data acquisition with low power consumption, requiring sophisticated offline event reconstruction. The reconstruction strategy involves two steps: first, grouping hits based on temporal proximity, followed by spatial clustering of these groups using a DBSCAN-based algorithm to identify particle events. This contribution details the clustering strategy and discusses its performance, including results from analyses using various radiation sources with the ARCADIA-MD3 detector prototype.

● **The CE $\nu$ NS frontier: Precision probes of the Standard Model and beyond.**

ATZORI CORONA M.

*INFN, Sezione di Roma Tor Vergata*

Neutrinos are among the most elusive and fascinating particles in the Standard Model (SM). One of the most striking phenomena involving neutrinos is Coherent Elastic Neutrino-

Nucleus Scattering ( $\text{CE}\nu\text{NS}$ ), a process in which the neutrino interacts coherently with the entire nucleus, significantly enhancing the interaction cross-section. Predicted by Freedman in 1973 and first observed in 2017,  $\text{CE}\nu\text{NS}$  is a purely weak neutral current process, with a cross-section that scales with the square of the neutron number of the target nucleus. In recent years,  $\text{CE}\nu\text{NS}$  has emerged as a sensitive probe for a wide range of physics scenarios, motivating global efforts to detect the tiny nuclear recoils it produces. In this contribution, I will review the current landscape of  $\text{CE}\nu\text{NS}$  searches, highlighting their implications for both Standard Model tests and searches for new physics. I will delve into the phenomenology of the process, describing its main theoretical features. Finally, I will present the NUCLEUS experiment, which employs cryogenic calorimeters capable of detecting nuclear recoils down to 20 eV —nearly two orders of magnitude below the thresholds of current-generation detectors.

● **Studio dello scattering coerente neutrino-nucleo con l'esperimento NuCLeus.**  
GIAMMEI M.

*INFN, Sezione di Roma Tor Vergata*

Lo scattering elastico coerente neutrino-nucleo ( $\text{CE}\nu\text{NS}$ ) fu predetto nel Modello Standard (SM) già nel 1973 ma osservato per la prima volta solo nel 2017: il motivo di ciò risiede nella bassa energia di rinculo del nucleo coinvolto, il che rende necessario l'impiego di rivelatori con soglia energetica dell'ordine di 100 eV. Lo scopo dell'esperimento NUCLEUS è proprio quello di misurare la sezione d'urto del  $\text{CE}\nu\text{NS}$  al livello del 5–10% di precisione. Il bersaglio di NUCLEUS è composto da matrici  $3 \times 3$  di cristalli di  $\text{CaWO}_4$  e  $\text{Al}_2\text{O}_3$ , per una massa totale di circa 10 g; i cristalli operano ad una temperatura di circa 10 mK, sono equipaggiati da Transition Edge Sensors fatti di tungsteno (W-TES) e sono circondati da un sistema complesso di schermature attive e passive, criogeniche e non. NUCLEUS è attualmente in fase di commissioning all'Università Tecnica di Monaco e verrà installato nella centrale nucleare di Chooz alla fine del 2025. In futuro è prevista la realizzazione di un nuovo rivelatore di circa 1 kg che potrà raggiungere una precisione stimata sulla sezione d'urto di circa l'1%.



Aula 11, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE II

**Fisica della materia**

Presiede: CICCARELLO F. (Università di Palermo)

Relazioni su invito

▲ **Dynamical blockade of a reservoir for optimal performances of a quantum battery.**

FERRARO D., CAVALIERE F., GEMME G., BENENTI G., SASSETTI M.

*Dipartimento di Fisica, Università di Genova*

The development of fast and efficient quantum batteries is crucial for the prospects of quantum technologies. In the present paper we demonstrate that both requirements are accomplished in the paradigmatic model of a harmonic oscillator strongly coupled to a highly non-Markovian thermal reservoir. We show that at short times, a dynamical blockade of the reservoir prevents the leakage of energy towards its degrees of freedom, promoting a significant accumulation of energy in the battery with high efficiency. The possibility of implementing these conditions in LC quantum circuits opens up new avenues for solid-state quantum batteries.

▲ **Multipartite spin entanglement from many-electron systems.**

TROIANI F. <sup>(1)</sup>, SECCHI A. <sup>(1)</sup>, ANGELI C. <sup>(2)</sup>, PITTALIS S. <sup>(1)</sup>

<sup>(1)</sup> *Centro S3, CNR-Istituto di Nanoscienze, Modena*

<sup>(2)</sup> *Dipartimento di Scienze Chimiche, Farmaceutiche ed Agrarie, Università di Ferrara*

Estimation of entanglement in atomistic systems requires a combination of advanced ab initio calculations and rigorous quantum-informational theoretical analyses. This combination is a challenging task that has not been tackled so far to investigate genuine multipartite entanglement (GME) in materials. Here we show that, contrary to conventional wisdom, a high degree of GME between spins can be extracted from closed shell fermionic states - even in the non-interacting limit. In fact, the extracted GME can be maximized via spin-independent orbital transformations, derived from the quantum Fourier transform. We further demonstrate the possibility of extracting, through localized orbitals, close-to-maximal GME from atomistic molecular states.

▲ **Supersolidity of polariton condensates in photonic crystal waveguides.**

GERACE D.

*Dipartimento di Fisica, Università di Pavia*

Supersolidity is a counter-intuitive and very fascinating phase of matter, predicted more than 50 years ago and realized only in recent years in various configurations by using condensates of cold atomic clouds: a very coherent quantum system that simultaneously behaves as a superfluid, i.e., having the characteristic property of flowing without viscosity or friction, and as a system possessing characteristics that are typical of crystalline solids, such as the periodic arrangement in space. In this seminar, a recent realization of this very exotic phase in a nanostructured semiconductor platform will be described, showing how supersolidity can arise as an emerging property in suitably engineered nanostructures supporting exciton-polaritons arising from the strong light-matter coupling between quantum well excitons and low-loss photonic eigenmodes in periodically patterned planar waveguides, i.e., photonic crystal polaritons. The subtle analogies and differences between such an emerging supersolid phase and its atomic counterpart will be discussed.



## Comunicazioni

● **Harnessing partial flat bands in graphene for long-ranged state transfer.**

DI BENEDETTO E. <sup>(1)</sup>, SUN X. <sup>(1)(2)</sup>, PINTO M. A. <sup>(1)</sup>, LEONFORTE L. <sup>(1)</sup>, CICCARELLO F. <sup>(1)(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *School of Physics and Telecommunication Engineering, Zhoukou Normal University, Zhoukou, China*

<sup>(3)</sup> *NEST, Istituto Nanoscienze-CNR, Pisa*

Flat bands (FBs) are dispersionless energy bands arising due to topology or destructive interference. Surprisingly, a FB can be formed by the set of surface modes of a topological semimetal under appropriate boundary conditions e.g., graphene with zigzag or bearded edge. When this happens, FB eigenstates are found only for a subset of quasi-momenta in the Brillouin Zone, hence forming a partial FB. In this talk, I discuss the coupling of qubits to the edge of zigzag graphene. We show that, around the Dirac cone, the few-qubits dynamics is captured by an effective open cavity-QED model whose dissipative contribution goes to zero at the Dirac point, allowing long-ranged coherent state transfer at that point. This showcases a new mechanism for state transfer due to topological edge states which, unlike standard instances, lack dispersion. Finally, I discuss the case of the gapped system in which dispersive coherent mediated interactions can be achieved with a power-law scaling.

● **Spin orbit coupling effects in a graphene Josephson junction.**

BONASERA F., FALCI G.A., PALADINO E., PELLEGRINO F.M.D.

*Dipartimento di Fisica e Astronomia, Università di Catania e INFN, Sezione di Catania*

We study a graphene Josephson junction where the inner graphene layer is subjected to a strong Spin-Orbit Coupling (SOC) by proximity effect. This could be achieved, for example, by growing the graphene layer on top of a transition metal dichalcogenide. The SOC terms heavily modify the band structure of the inner graphene layer, inducing different topological phases with associated helical or quasi-helical edge modes. We focus on the ballistic and short junction limits and study the effects of the SOC interaction on the supercurrent. For the bulk contribution, we follow an analytical approach based on the continuum model. We find combinations of SOC that significantly suppress the supercurrent by opening a gap in the graphene band structure. Other combinations, instead, enhance it, acting as an effective spin-valley resolved chemical potential. We also find that a strong Rashba spin-orbit coupling leads to a junction with a highly voltage tunable harmonic content. Finally, we study the edge contribution using a tight-binding procedure. We find it to be very robust on all graphene terminations, even showing some disorder-induced transport on previously insulating armchair edge.

● **Ultrafast holographic imaging of light-induced demagnetization in a ferromagnet.**

BASERGA A. <sup>(1)</sup>, VISENTIN F. <sup>(1)(2)</sup>, BENETTIN D. <sup>(1)</sup>, GANDINI G. <sup>(1)</sup>, RINALDI C. <sup>(1)</sup>, CARPENE E. <sup>(2)</sup>, CERULLO G. <sup>(1)(2)</sup>, DAL CONTE S. <sup>(1)</sup>, CAMARGO F.V.A. <sup>(2)(1)</sup>

<sup>(1)</sup> *Politecnico di Milano*

<sup>(2)</sup> *INFN-CNR, Milano*

Ultrashort laser pulses provide a powerful means to probe out-of-equilibrium magnetism. While pump-probe techniques track femtosecond magnetization dynamics, spatially resolved studies remain scarce. We developed a self-referencing ultrafast holographic microscope capable of imaging light-induced demagnetization in Pt/CoFeB/MgO with 100-fs and sub- $\mu\text{m}$  resolution, revealing spatially dependent magnetization dynamics. Our widefield transient

absorption microscope employs holographic multiplexing to measure the probe beam's polarization ellipse. When an intense light pulse excites a magnetized metal, hot electrons transfer energy to phonons, rapidly reducing magnetization. Our technique captures these ultrafast spatial perturbations with exceptional resolution, yielding transient absorption, transient optical rotatory dispersion rotation and transient circular dichroism in a single measurement. We observe a central positive signal, corresponding to demagnetization, surrounded by a larger negative halo, likely due to the closing of magnetic field lines. Demagnetization dynamics depend on distance from the center, revealing heat dissipation and offering insights into spin diffusion.

### ● Phaseonium engine thermodynamics.

AMATO F. <sup>(1)</sup>, ADESSO G. <sup>(2)</sup>, PALMA G.M. <sup>(3)(4)</sup>, LORENZO S. <sup>(3)</sup>, LO FRANCO R. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria, Università degli Studi di Palermo,*

<sup>(2)</sup> *School of Mathematical Sciences and Centre for the Mathematical and Theoretical Physics of Quantum Non-Equilibrium Systems, University of Nottingham, UK*

<sup>(3)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(4)</sup> *NEST, Istituto Nanoscienze-CNR, Pisa*

We present a realistic implementation of a quantum engine powered by a phaseonium gas of coherently prepared three-level atoms where quantum coherence acts as a thermodynamic resource. Using a collision model framework, we derive the exact thermalization dynamics of a cavity field interacting with phaseonium and construct a full engine cycle based on two non-thermal reservoirs, each characterized by coherence-induced effective temperatures. This configuration enhances the efficiency of a simple optomechanical engine operating beyond standard thermal paradigms. We further address scalability by coupling a second cavity in cascade configuration, where the same phaseonium gas drives both cycles. Other than scaling the engine, this second cavity may be used as a non-invasive quantum probe of the first. Our results demonstrate the operational viability of coherence-driven quantum engines and their potential for future thermodynamic applications.

### ● Charging free fermion quantum batteries.

GRAZI R. <sup>(1)(2)</sup>, CAVALIERE F. <sup>(1)(2)</sup>, SASSETTI M. <sup>(1)(2)</sup>, FERRARO D. <sup>(1)(2)</sup>, TRAVERSO ZIANI N. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Genova*

<sup>(2)</sup> *CNR-SPIN, Genova*

We derive an analytical expression for the energy stored via a double sudden quench in quantum systems whose Hamiltonians reduce to  $2 \times 2$  free fermion problems and whose initial state is thermal. Our results apply to two-band electronic systems and quantum spin chains solvable via Jordan-Wigner transformation. We specifically study the quantum Ising chain, the quantum XY chain, the cluster Ising model, and the long-range SSH model. We find: (i) The stored energy strongly depends on the quantum phase diagram of the charging Hamiltonian even at finite temperature, with non-analyticities at quantum phase transitions in the thermodynamic limit; (ii) In the Ising chain, increasing the temperature reduces the stored energy's dependence on Hamiltonian parameters; (iii) Charging the Ising or the XY chain prepared in the ground state of their classical points leads to an amount of stored energy that, within a large parameter range, does not depend on the charging parameters; (iv) Despite exhibiting quantum phase transitions, the cluster Ising and long-range SSH models do not show super-extensive scaling of the charging power.

● **Daemonic ergotropy in continuously monitored dicke quantum batteries.**

CENEDESE G. <sup>(1)(2)</sup>, BENENTI G. <sup>(1)(2)</sup>, FERRARO D. <sup>(3)</sup>, GENONI M. <sup>(4)</sup>

<sup>(1)</sup> *Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Como*

<sup>(2)</sup> *INFN, Sezione di Milano*

<sup>(3)</sup> *Dipartimento di Fisica, Università di Genova*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Milano*

Dicke quantum batteries represent a paradigmatic model for quantum energy storage. Previous studies have shown that, even in the presence of dissipation and under strong coupling conditions, these systems can exhibit superextensive power scaling in the thermodynamic limit. However, for finite-size systems, the extractable energy, quantified by the ergotropy, vanishes due to the approach to a passive steady state. In this work, we show that by continuously monitoring the photon output from the cavity - using quantum trajectory methods within the framework of open quantum systems - it is possible to restore a superextensive scaling of the ergotropic power even in finite systems, specifically in terms of the so-called daemonic ergotropy. This result highlights the potential of continuous measurement protocols as a practical route toward experimentally realizable quantum batteries.

● **Cyclic solid-state quantum battery: Thermodynamic characterization and quantum hardware simulation.**

GEMME G. <sup>(3)(4)</sup>, RAZZOLI L. <sup>(1)(2)</sup>, KHOMCHENKO I. <sup>(1)(2)(5)</sup>, SASSETTI M. <sup>(3)(4)</sup>, OERDANE H. <sup>(5)</sup>, FERRARO D. <sup>(3)(4)</sup>, BENENTI G. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università degli Studi dell'Insubria, Como*

<sup>(2)</sup> *INFN, Sezione di Milano*

<sup>(3)</sup> *Università di Genova*

<sup>(4)</sup> *CNR-SPIN, Genova*

<sup>(5)</sup> *Skolkovo Institute of Science and Technology, Moscow, Russia*

We introduce a cyclic quantum battery model, based on an interacting bipartite system, weakly coupled to a thermal bath. The working cycle of the battery consists of four strokes: system thermalization, disconnection of subsystems, ergotropy extraction, and reconnection. The thermal bath acts as a charger in the thermalization stroke, while ergotropy extraction is possible because the ensuing thermal state is no longer passive after the disconnection stroke. Focusing on the case of two interacting qubits, we show that phase coherence, in the presence of non-trivial correlations between the qubits, can be exploited to reach working regimes with efficiency higher than 50% while providing finite ergotropy. Our protocol is illustrated through a simple and feasible circuit model of a cyclic superconducting quantum battery. Furthermore, we simulate the considered cycle on superconducting IBM quantum machines. The good agreement between the theoretical and simulated results strongly suggests that our scheme for cyclic quantum batteries can be successfully realized in superconducting quantum hardware

● **Relativistic quantum thermometry through a moving sensor.**

EBRAHIMI ASLMAMAGHANI S. <sup>(1)</sup>, RANGANI JAHROMI H. <sup>(2)</sup>, LO FRANCO R. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria, Università degli Studi di Palermo*

<sup>(2)</sup> *Physics Department, Faculty of Sciences, Jahrom University, Iran*

We present results on estimating the temperature of a static thermal bath, modeled as a massless scalar field in a thermal state, with a moving two-level quantum probe. The research analyzes different types of probe field interaction, specifically time derived (TD) and Unruh-DeWitt (UDW) couplings, under various physical scenarios. It is shown that the Lamb shift does not contribute to the accuracy of temperature estimation. The velocity of the probe along with the initial quantum state, the control of environmental parameters, and the design

of the experiment are studied for their impact on thermometric precision. An experimental scheme is designed to potentially demonstrate the feasibility of these predictions. The study also uses a fast-moving thermal probe to show the superiority of joint parameter estimation over individual estimation in multi-parameter contexts.

● **Non-positive energy quasidistributions in coherent collision models.**

PEZZUTTO M., DE CHIARA G., GHERARDINI S.

*CNR, Istituto Nazionale di Ottica*

We determine the Kirkwood-Dirac quasiprobability (KDQ) distribution associated to the stochastic instances of internal energy variations for the quantum system and environment particles in coherent Markovian collision models. In the case the interactions between the quantum system and the particles do not conserve energy, the KDQ of the non-energy-preserving stochastic work is also derived. These KDQ distributions can account for non-commutativity, and return the unperturbed average values and variances for a generic interaction-time, and generic local initial states of the quantum system and environment particles. Using this non-equilibrium-physics approach, we certify the conditions under which the collision process of the model exhibits quantum traits, and we quantify the rate of energy exchanged by the quantum system by looking at the variance of the KDQ energy distributions. Finally, we propose an experimental test of our results on a superconducting quantum circuit implementing a qubit system, with microwave photons representing the environment particles.

● **Exploring dynamical quantum phase transitions and work extraction in open quantum systems.**

DI BELLO G. <sup>(1)</sup>, CATAUDELLA V. <sup>(2)</sup><sup>(3)</sup>, DE CANDIA A. <sup>(2)</sup><sup>(3)</sup>, DE FILIPPIS G. <sup>(2)</sup><sup>(3)</sup>, FARINA D. <sup>(1)</sup>, FORMICOLA F. <sup>(1)</sup>, JANSEN D. <sup>(4)</sup>, PAVAN F. <sup>(1)</sup>, PERRONI C. A. <sup>(2)</sup><sup>(3)</sup>, PONTICELLI A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(2)</sup> *SPIN-CNR e Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(3)</sup> *INFN, Sezione di Napoli*

<sup>(4)</sup> *ICFO-Institut de Ciències Fotoniques, The Barcelona Institute of Science and Technology, Castelldefels, Spain*

We study the dynamical and thermodynamic properties of an open two-qubit Rabi model using tensor-network methods. At equilibrium, we apply the density matrix renormalization group algorithm; out of equilibrium, the time-dependent variational principle algorithm. The system, represented as a matrix product state, undergoes dynamical quantum phase transitions following a quench in the qubits-oscillator coupling. We identify two types of transitions, signaled by kinks in the Loschmidt echo rate function and linked to a Berezinskii-Kosterlitz-Thouless (BKT) thermodynamic transition. These are further evidenced by magnetization bimodality and changes in qubits entanglement. We then investigate local ergotropy, the maximum extractable work via local cyclic unitary operations, and its fluctuations across the BKT equilibrium transition. A realistic, tunable protocol for charging, storage, and extraction is proposed, optimized via Bayesian tools. Strong bath coupling nearly doubles the ergotropy after charging and dynamically tracks the BKT transition. Finally, we extend the approach to disordered XXZ chains, where local ergotropy dynamics serves as a probe of localization transitions.

Aula 12, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE II

**Fisica della materia**

Presiede: NAPOLI A. (Università di Palermo)

Relazioni su invito

▲ **Classical simulation of bosonic-encoded quantum computations.**

FERRARO A. <sup>(4)</sup>, CALCLUTH C. <sup>(1)</sup>, HAHN O. <sup>(2)</sup>, BERMEJO-VEGA J. <sup>(3)</sup>, FERRINI G. <sup>(1)</sup>

<sup>(1)</sup> *Department of Microtechnology and Nanoscience, Chalmers University of Technology, Göteborg, Sweden*

<sup>(2)</sup> *Department of Basic Science, University of Tokyo, Japan*

<sup>(3)</sup> *Departamento de Electromagnetismo y Física de la Materia, Universidad de Granada, Spain*

<sup>(4)</sup> *Dipartimento di Fisica, Università degli Studi di Milano*

Classical simulation algorithms are crucial for benchmarking quantum computing platforms, even if not efficient in general. We focus on continuous-variable architectures based on bosonic codes, particularly the Gottesman-Kitaev-Preskill (GKP) code, which shows strong experimental potential for error correction. However, due to the highly non-Gaussian nature and large Wigner negativity of GKP states, existing simulation methods are extremely ineffective. We introduce a new classical simulation framework leveraging the Zak-Gross Wigner function, which allows efficient simulation of circuits initialized with ideal stabilizer GKP states. We then extend the method to finitely squeezed, realistic GKP states. The runtime depends on the negativity of the Zak-Gross function, which decreases with increasing squeezing – contrary to known methods. Our results demonstrate that even some large-scale circuits can be simulated with modest overhead in the high-squeezing regime, making our algorithm a promising tool for validating bosonic platforms aimed at fault-tolerant quantum computation.

▲ **On the ultimate limits of entanglement testing and the generalised quantum Stein's lemma.**

LAMI L.

*Scuola Normale Superiore, Pisa*

I will introduce the fundamental task of entanglement testing, which consists in discriminating a given entangled state from the set of all separable (i.e. un-entangled) states. The ultimate limits of this task, as measured by the largest type-1 and type-2 error exponents that are achievable with arbitrary measurements, can be calculated with the help of two key results in entanglement theory, the generalised Sanov theorem and the generalised quantum Stein's lemma. I will survey the history of these statements presenting their connections with the theory of entanglement manipulation and the notion of asymptotic reversibility. Funded by the European Union under the European Research Council (ERC Grant Agreement No. 101165230).

▲ **Extracting the complete CHSH parameter from each entangled photon pair.**

DEGIOVANNI I.P. <sup>(1)(2)</sup>, VIRZÌ S. <sup>(1)</sup>, REBUFELLO E. <sup>(1)</sup>, ATZORI F. <sup>(1)(3)</sup>, AVELLA A. <sup>(1)</sup>, PIACENTINI F. <sup>(1)</sup>, VILLA F. <sup>(4)</sup>, GRAMEGNA M. <sup>(1)</sup>, COHEN E. <sup>(5)</sup>, GENOVESE M. <sup>(1)(2)</sup>

<sup>(1)</sup> *INRIM, Torino*

<sup>(2)</sup> *INFN, Sezione di Torino*

<sup>(3)</sup> *Politecnico di Torino*

<sup>(4)</sup> *Politecnico di Milano*

<sup>(5)</sup> *Bar Ilan University, Ramat Gan, Israel*

Since their formulation, Bell inequalities have been one of the pillars of quantum foundations and quantum information. A long path, awarded by the 2022 Nobel prize, has gone along since their introduction, finally reaching conclusive Bell inequality violations in 2015. However, none of the experiments run so far was able to extract information on the entire Bell inequality from every entangled pair measured, because of the wavefunction collapse. Here we illustrate an actual paradigm shift in this perspective, since we experimentally demonstrate the possibility of extracting information on the full Bell parameter (specifically the CHSH one) from each entangled pair measured and, at the same time, still conserving most of the pair entanglement after the measurement exploiting weak interaction.

### ▲ Quantum-optimal frequency estimation of stochastic AC fields

LUPO C. <sup>(1)(2)</sup>, DEY A. <sup>(3)(4)</sup>, MOURADIAN S. <sup>(5)</sup>, HUANG Z. <sup>(3)(4)(6)</sup>

<sup>(1)</sup> *Dipartimento Interateneo di Fisica, Politecnico e Università di Bari*

<sup>(2)</sup> *INFN, Sezione di Bari*

<sup>(3)</sup> *School of Mathematical and Physical Sciences, Macquarie University, Australia*

<sup>(4)</sup> *ARC Centre of Excellence for Engineered Quantum Systems, Macquarie University, Australia*

<sup>(5)</sup> *Department of Electrical and Computer Engineering, University of Washington, USA*

<sup>(6)</sup> *Centre for Quantum Software and Information, Faculty of Engineering and Information Technology, University of Technology Sydney, Australia*

The resolution in the measurement of a time-dependent field is classically limited by the bandwidth. It is known that quantum estimation, supported by quantum control, may overcome this bound, yet the full potential of quantum metrology and the role played by entanglement have remained elusive so far. Here we frame the problem of frequency measurement as the estimation of a correlated dephasing quantum channel. We determine the ultimate quantum limit in AC magnetic sensing. We find exact upper bounds for the frequency of stochastic fields. In particular, given two close signals with frequency separation  $f$ , we find that the quantum Fisher information for the separation estimation is approximately  $1/f$ , i.e. inversely proportional to the separation. The bounds are achieved by probing the field with superpositions of Dicke states. GHZ states are suboptimal but improve precision over unentangled states, achieving Heisenberg scaling in the low-bandwidth limit. This work establishes a robust framework for stochastic AC signal sensing that can be extended to arbitrary time-dependent and stochastic fields.

## Comunicazioni

### ● Unveiling the role of magic and scrambling in quantum extreme learning.

LO MONACO G., VETRANO M., INNOCENTI L., LORENZO S., PALMA G.M.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

Efficient estimation of expectation values is crucial for many quantum algorithms. Shadow tomography enables reconstruction of expectation values for low-rank observables via randomized measurements but suffers from noise-induced bias, often requiring error correction. Quantum Extreme Learning Machine (QELM) provides a noise-resilient alternative: the target state interacts with a fixed, uncalibrated quantum reservoir, which is measured in the computational basis. A weight matrix, trained on known states, maps measure outcomes to observable estimates. This talk investigates how many-body dynamics –specifically information scrambling and magic– affect QELM performance. Estimation error decreases

with increased scrambling and remains low beyond the scrambling time. To analyze the role of non-classicality, we model the reservoir interaction as a quantum circuit and show that magic is a necessary resource. This rules out Clifford-only circuits and classical simulation of training. Finally, I derive a lower bound on the T-gate count required for observable estimation, from which bounds on circuit depth directly follows.

### ● Routing for aggregated quantum networks.

LO PIPARO N., MUNRO W.J., NEMOTO K.

*Okinawa Institute of Science and Technology, Japan*

Quantum networks allow remote users to utilize various quantum technologies that surpass the performance of current classical systems. However, delay effects may require storing quantum packets in quantum memories, where relaxation reduces fidelity and causes information loss. To counter this, quantum error correction codes encodes the state into a higher-dimensional system, but this demands high-capacity channels. Quantum aggregation solves this by distributing the encoded state across multiple low-capacity paths, using all available channels. The quantum state is then recombined and decoded at the receiver's node. Assigning these initial channels is key to meeting user needs. We model an aggregated quantum network where two distant nodes, connected by paths of varying length, exchange quantum information. To optimize channel assignment, we design a routing protocol that allocates resources based on user requests. A practical example shows how loss and memory decoherence impact the transmitted state's fidelity.

### ● Dynamics of quantum resources under noisy spatial deformation of identical particles.

FERRARA A. <sup>(1)</sup>, NOSRATI F. <sup>(1)</sup>(<sup>2</sup>), SMIRNE A. <sup>(3)</sup>(<sup>4</sup>), PILO J. <sup>(5)</sup>, LO FRANCO R. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria, Università degli Studi di Palermo*

<sup>(2)</sup> *IMDEA Networks Institute, Madrid, Spain*

<sup>(3)</sup> *Dipartimento di Fisica, Università degli Studi di Milano*

<sup>(4)</sup> *INFNF, Sezione di Milano*

<sup>(5)</sup> *Department of Physics and Astronomy, University of Turku, Finland*

We investigate the dynamics of quantum resources in a system of identical particles under noisy spatial deformation within the sLOCC framework. We consider two initially uncorrelated, spatially separated particles with distinct spatial and spin degrees of freedom, evolving in a double-well potential. Spatial overlap is modeled via a tunneling or beamsplitting Hamiltonian, whose interplay with the action of local dephasing baths is analyzed. We present an analytical microscopical derivation of a Lindblad master equation, taking into account the system-environment evolution. We explore how noise affects known indistinguishability-based scenarios, such as Hong-Ou-Mandel interference, entanglement generation and distillation. We compare dephasing effects at different stages of the spatial deformation (before, during, after), showing that simultaneous deformation and noise can produce rich, nontrivial dynamics, including shifts in bunching behavior and noise-induced quantum correlations. These findings emphasize the critical role of noise timing for robust quantum information processing with controlled identical particles.

### ● Learning topologies of complex quantum networks via external probes.

CHISHOLM D.A., CAMPBELL C.J., MACKINNON M., PATERNOSTRO M.

*Università degli Studi di Palermo*

The characterisation of quantum networks is fundamental to understanding how energy and information propagates through complex systems, with applications in control, communication, error mitigation and energy transfer. In this work, we explore the use of external



probes to infer the network topology in the context of continuous-time quantum walks, where a single excitation traverses the network with a pattern strongly influenced by its topology. The probes act as decay channels for the excitation, and can be interpreted as performing an indirect measurement on the network dynamics. By making use of a Genetic Optimisation algorithm, we demonstrate that the data collected by the probes can be used to successfully reconstruct the topology of any quantum network with high success rates, where performance is limited only by computational resources for large network sizes. Moreover, we show that increasing the number of probes significantly simplifies the reconstruction task, revealing a tradeoff between the number of probes and the required computational power.

● **Entanglement percolation in random state quantum networks.**

ROMANCINO A. <sup>(1)</sup>, PALMA M. G. <sup>(1)(2)</sup>, SANPERA A. <sup>(3)(4)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *NEST, Istituto Nanoscienze-CNR, Pisa*

<sup>(3)</sup> *Grup d'Informaciion Quantica, Departament de Fisica, Universitat Autònoma de Barcelona, Bellaterra, Spain*

<sup>(4)</sup> *ICREA, Barcelona, Spain*

Quantum information (QI) shows that entanglement is a crucial resource for applications that go beyond classical capabilities. However, entanglement distribution remains a challenging experimental endeavor. Classical entanglement percolation (CEP) exploits the features of a quantum network of partially entangled states and, using LOCC only, it's able to create a maximally entangled state between two arbitrary nodes. The protocol can be perfectly mapped to classical percolation theory and simulated efficiently. Still, CEP has been shown to be, in general, suboptimal, and an improvement called quantum entanglement percolation (QEP) has been developed by first preparing the network using local quantum operation. We have generalized the problem by relaxing the original assumption that the initial states are fixed. By using random states and results from extreme value theory we have found out that only the average initial entanglement is important for entanglement distribution purposes and, in general, the QEP protocol can be worse than the CEP protocol in this more realistic scenario. We will explore this as an example of the beautiful interplay between QI and network theory.

● **Proprietà di entanglement di Graph-States.**

FRANZOSI R., DE SIMONE L., VESPERINI A.

*Dipartimento di Scienze Fisiche della Terra e dell'Ambiente, Università di Siena e INFN, Sezione di Perugia*

Si presenta un'esplorazione delle proprietà di entanglement e connettività dei grafi negli stati a grafo (Graph States, GSs). L'entanglement tra qubit negli stati a pseudografo (Pseudo Graph States, PGSs) viene quantificato utilizzando la Distanza di Entanglement (Entanglement Distance, ED), una misura recentemente introdotta dell'entanglement bipartito.

● **Superactivation of backflow of information in a classical Markov environment.**

NICHELE G., BENATTI F.

*Dipartimento di Fisica, Università degli Studi di Trieste e INFN, Sezione di Trieste*

I will discuss the superactivation of backflow of information (SBFI), namely the phenomenon whereby the tensor product of a non-Markovian dynamics with itself exhibits backflow of information (BFI) from the environment to the system, even though the individual dynamics do not. This effect, which has no classical counterpart, is investigated through the discrete-time non-Markovian dynamics of two open qubits, each collisionally coupled to an environment described by a classical Markov chain. In this context, I will show that SBFI



can be attributed to a decrease in qubit-qubit-environment correlations and an increase in intra-environment correlations. The purely quantum nature of the effect is further discussed, as it does not generally require entangled states throughout the evolution.

● **Study of Shortcuts to Adiabaticity on QAOA.**

VIZZUSO M., PASSARELLI G., CANTELE G., LUCIGNANO P.

*Università degli Studi di Napoli Federico II*

The Quantum Approximate Optimization Algorithm (QAOA) is a promising hybrid quantum-classical algorithm that can solve combinatorial optimization problems. The quantum part of the algorithm involves using parametric unitary operations on a quantum computer to prepare a trial solution state. The parametric QAOA angles are variationally optimized minimizing a cost function using classical methods. We study a generalized QAOA ansatz that includes corrections to the Trotter expansion at the first and second order based on the Baker-Campbell-Hausdorff (BCH) expansion, that we call QAOA-2CD. In our work, we have better performances of QAOA-2CD with respect to QAOA. In a regime in which QAOA is close to Quantum Annealing (QA), these new unitaries correspond to the countediabatic potential of Shortcuts to Adiabaticity. The latter assists the adiabatic evolution limiting excited state hoppings of the ground state and making the evolution time-independent. In our work, we reveal an expected connection between a property valid for QAOA-2CD and QA. A system with a huge minimal gap  $\Delta_{eg}$  can be treated easily not only in QA but also in QAOA and QAOA-2CD.

Aula Capitò, Edificio 7

ore 09:00 – 13:30

SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: FIORE F. (INAF, Osservatorio Astronomico di Trieste)

Relazioni su invito

▲ **Solaris: a permanent radio observatory in Antarctica for solar physics and space weather applications.**

PELLIZZONI A.

*INAF, Osservatorio Astronomico di Cagliari*

Solaris is a scientific and technological project aimed at the development of a smart Solar monitoring system at high radio frequencies based on single-dish imaging techniques. It combines the implementation of dedicated and interchangeable high-frequency receivers on existing small single-dish radio telescope systems available in our laboratories and in Antarctica, adapted for solar observations. Solaris can perform continuous solar imaging observations nearly 20h per day during Antarctic summer with optimal sky opacity, and it will be the only solar facility offering continuous monitoring at 100 GHz. In perspective our system could be implemented also in the north hemisphere to offer unprecedented monitoring of the solar chromosphere for the whole year, and Space Weather services as part of national and international networks. In the frame of the first Solaris campaign in Antarctica recently concluded, early solar imaging observations were successfully performed, obtaining more than 100 images at 95 GHz, including the identification and continuous monitoring of peculiar solar active regions producing strong flares and associated geomagnetic storms on Earth.

▲ **When will we get better space weather forecasts? Tomorrow.**

PAGANO P.

*Università degli Studi di Palermo e INAF, Osservatorio Astronomico di Palermo*

Space Weather is the term used to describe the set of solar phenomena that influence human activities in space and on Earth. The solar activity that manifests itself through flares, coronal mass ejections and ionising radiation continuously disrupts the space around the Earth and, by interacting with the Earth's magnetic field, can also cause interference in radio communication, disruption of electricity and navigation systems, and damage to orbiting satellites and spacecraft. Therefore, making space weather forecasts has become critically important. In this talk, I will discuss the most recent significant events to illustrate what are the tangible consequences of space weather and will present some of the state of art models used to deploy forecasts and what are their expected most promising outlooks for the future.

▲ **Stellar physics with the space mission PLATO.**

LANZA A.F.

*INAF, Osservatorio Astrofisico di Catania*

PLATO is an M-class mission of the European Space Agency dedicated to discover planets around bright late-type stars for a full characterization of their physical parameters, especially radius, mass, and age. To this purpose, accurate measurements of stellar mass, radius, chemical composition, and age are crucial. I shall briefly review the methods to achieve those stellar measurements for the benefit of planetary science. From a more general point

of view, I shall also briefly discuss how PLATO can help us to improve our understanding of the evolution of stars and planetary systems and to reach a better characterization of the interactions between stars and their planets from the point of view of stellar physics.

### ▲ **Esopianeti: un'era di scoperte e nuove frontiere.**

CARLEO I.

INAF

Negli ultimi decenni, la ricerca sugli esopianeti ha compiuto progressi straordinari grazie a una varietà di tecniche osservative. Il metodo del transito e la velocità radiale hanno permesso di costruire ampi cataloghi di pianeti, mentre l'imaging diretto ha reso possibile lo studio di giovani giganti gassosi. Il microlensing gravitazionale ha rivelato pianeti freddi e di piccola massa, ampliando la nostra comprensione della distribuzione planetaria. La spettroscopia atmosferica, tramite transito ed emissione termica, sta aprendo nuove prospettive sulla composizione chimica e sulle proprietà fisiche delle atmosfere esoplanetarie. Con oltre 5.500 esopianeti confermati, la ricerca si avvale già di missioni come JWST, e vedrà in futuro il contributo di PLATO, Ariel, Roman e telescopi di nuova generazione come ELT, che permetteranno una caratterizzazione sempre più dettagliata delle proprietà fisiche e chimiche dei pianeti extrasolari. Questo intervento discuterà gli ultimi risultati e le sfide aperte nella scoperta di esopianeti.

Comunicazioni

### ● **Exploring short-term stellar activity in dM stars: a volume-limited perspective.**

GALLETTA G. <sup>(1)(2)</sup>, COLOMBO S. <sup>(3)</sup>, PRISINZANO L. <sup>(3)</sup>, MICELA G. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

<sup>(2)</sup> *Blue Skies Space Italia S.R.L., Milano*

<sup>(3)</sup> *INAF, Osservatorio Astronomico di Palermo, Palermo, Italia*

The objective of this work is to characterize the flaring properties of an unbiased, volume-limited sample of M-type stars using TESS. We selected 173 stars within 10 pc from Gaia DR3 and analyzed their light curves with an iterative Gaussian process to remove stellar activity, identifying 17,229 flares. For each event, we derived amplitude, duration (2-8000 s), and total energy (down to  $\sim 10^{30}$  erg). The cumulative energy distribution was modeled with one-slope and two-slope fits, yielding average slopes of  $-0.79 \pm 0.64$  and  $-1.23 \pm 1.32$ . We introduced the Flare Energy Index (GF-0.1) to characterize flare frequency, revealing two populations: fainter stars exhibit fewer high-energy flares, while brighter stars have more frequent low-energy flares. Two highly active stars, G 227-22 and G 258-33, were analyzed over a long time baseline to explore their flare properties.

### ● **The 'Global Architecture of Planetary Systems project.**

BENATTI S. FOR THE GAPS TEAM

INAF, Osservatorio Astronomico di Palermo

The GAPS (Global Architecture of Planetary Systems) project brings together most researchers working in Italy in the field of exoplanets. Established in 2012, GAPS seized the opportunity offered by the HARPS-N spectrograph at the Telescopio Nazionale Galileo (TNG) to study the architectures of planetary systems around stars with different properties. Over time, the project evolved thanks to the expertise gained, the upgrades at TNG, and advances in exoplanetary science worldwide, like understanding the diversity of planetary systems. GAPS now mainly operates through three long-term programs: the characterization of exoplanet atmospheres, the mass measurement of planets in the super-Earth/mini-Neptune

transition region, and the search for planetary companions to Gaia discoveries. Throughout, GAPS has maintained strong scientific coordination. In this contribution, I will present the project's scientific goals and some of its most impactful results, which have helped establish the Italian exoplanet community as a leading force at international level.

● **Modeling the interplanetary environment and the propagation of solar disturbances.**

BIONDO R. <sup>(1)</sup>, BEMPORAD A. <sup>(1)</sup>, PAGANO P. <sup>(2,3)</sup><sup>(1)</sup>, REALE F. <sup>(2,3)</sup><sup>(1)</sup>, FRASSATI F. <sup>(1)</sup>, PRETE G. <sup>(4)</sup>, MANCUSO S. <sup>(1)</sup>, NISTICÒ G. <sup>(4)</sup>, PERRI S. <sup>(4)</sup>, SUSINO R. <sup>(1)</sup>, ZIMBARDO G. <sup>(4)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astrofisico di Torino*

<sup>(2)</sup> *Università di Palermo*

<sup>(3)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(4)</sup> *Università della Calabria*

Understanding the propagation of solar disturbances such as solar energetic particles (SEPs) and coronal mass ejections (CMEs) requires an accurate reconstruction of the background solar wind and its small-scale structures, which play a crucial role in shaping the evolution, arrival time, and geoeffectiveness of these events. We have taken an original multi-step approach to this task called "Reverse In situ and MHD Approach" (RIMAP), which is able to preserve the fine-scale structure of the solar wind better than other existing models. We have used this background to model in detail the propagation of CMEs. We have pinpointed the possibility to measure the chemical composition of the plasma as originally ejected from the Sun. We have reproduced magnetic switchbacks with pulses in sheared magnetic field. Furthermore, we are reproducing in an unprecedented detail the observed CME on September 5, 2022, with the specific aim to constrain the shock fronts ahead of the cloud and to shed more light on the important issue of the propagation of SEPs. Our results highlight the potential of RIMAP-based modeling for advancing both heliospheric science and operational space weather forecasting.

● **Ariel-IT end-to-end exercise from the astrophysical scene to planetary spectra: simulations and retrieval.**

BOCCHIERI A. <sup>(1)</sup><sup>(2)</sup>, LORENZANI A. <sup>(2)</sup>, PETRALIA A. <sup>(3)</sup>, MICELA G. <sup>(3)</sup>, ARIEL-IT COMMUNITY <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, La Sapienza Università di Roma*

<sup>(2)</sup> *INAF, Osservatorio Astrofisico di Arcetri*

<sup>(3)</sup> *INAF, Osservatorio Astrofisico di Palermo*

The Ariel mission will conduct the first spectroscopic survey of hundreds of exoplanet atmospheres in visible/infrared wavelengths. Currently in Phase C, a Dry-Run exercise is ongoing to assess early preparedness and highlight key areas for further work for the 2029 launch. The Ariel-IT community has established an end-to-end simulation procedure, from target selection to simulated transit observations and retrieval. The current focus is on a sample of hot Jupiters and planets orbiting active stars, with key activities including determination of stellar and planetary properties, planetary formation and evolution models, star-planet interaction, atmospheric evolution, and spectral synthesis. These simulations are input into ExoSim2, alongside Ariel payload specs and PAOS-generated PSFs. ExoSim2 produces time-domain photometric/spectroscopic simulated data, including stellar activity and spacecraft line-of-sight jitter. Preliminary WASP-69b results demonstrate compliance with scientific requirements on post-processing noise and the ability to distinguish between input atmospheric compositions. Current limitations and next steps to complete the sample analysis will be discussed.

● **XUV emission of stars with planets in the era of JWST and Ariel.**

PILLITTERI I. <sup>(1)</sup>, MAGGIO A. <sup>(1)</sup>, SANZ-FORCADA J. <sup>(2)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(2)</sup> *Centro de Astrobiología, CSIC-INTA, Madrid, Spain*

High energy emission in X-rays and UV bands (altogether XUV) is a key feature that characterizes the evolution of the stars and their planets since the formation stage. XUV irradiation is responsible for the heating, photoevaporation, and photochemistry of protostellar disks and planetary atmospheres. The shape of XUV spectra depends on the thermal structure of the optically-thin plasma in the stellar upper chromosphere and corona, whose determination requires high resolution spectroscopy in UV and X-ray bands. However, this is feasible only for nearby XUV-bright stars. We present a novel methodology to determine the so-called plasma Emission Measure Distribution (EMD) vs. temperature, based on the parameterization of a set of well-determined EMDs of nearby stars as a function of their surface X-ray flux. This calibration allows to determine an EMD with a minimal knowledge of the X-ray emission of a given star, and to synthesize its XUV spectrum, especially the Extreme UV part that cannot be observed due to gas absorption. This approach eventually provides a fundamental ingredient for modeling the structure and long-term evolution of planetary atmospheres

● **The impact of stellar activity on exoplanet detection and characterization: from observational challenges to the SpotCCF tool.**

DI MAIO C., BENATTI S., MICELA G., PETRALIA A.

*INAF, Osservatorio Astronomico di Palermo*

Since the discovery of the first exoplanet, major efforts have focused on detecting and characterizing planetary systems. Advances in instruments and analysis techniques have enabled the discovery of smaller, Earth-like exoplanets, including rocky planets in habitable zones. Precise measurements of mass and radius, along with host star characterization, are key to understanding planetary formation and crucial for atmospheric studies, particularly with JWST observations and the upcoming Ariel mission. The two main detection techniques are the transit method, measuring dips in stellar brightness, and Doppler spectroscopy, tracking radial velocity (RV) variations. However, stellar magnetic activity, such as starspots and plagues, introduces temperature inhomogeneities that distort transit lightcurves and spectral lines, biasing both transit depth and RV measurements. I will present the impact of stellar activity on exoplanet observations and introduce SpotCCF, a tool that models the Cross-Correlation Function in the presence of spots, improving RV extraction for active, fast-rotating stars and enabling recovery of spot properties, thus enhancing our exoplanet detection capabilities.

● **PAStar: stellar activity through surface inhomogeneities modelling.**

PETRALIA A., DI MAIO C., BENATTI S., MICELA G.

*INAF, Osservatorio Astronomico di Palermo*

The characterization of exoplanets requires a good description of the host star. Stellar activity acts as a source of noise which can alter planet radii as derived from the transit depth or atmospheric characterization. Here, we propose a model to describe photospheric activity in the form of spots and faculae which could be applied to both photometric and spectroscopic time series. The occulted flux by a transiting planet is saved to allow further studies of the transmission spectrum. The adopted stellar atmosphere is a combination of three components, the quiet photosphere, spots and faculae. Each component is characterized by a stellar atmosphere at a given temperature. The model takes into account the effects of star inclination, doppler shifts due to stellar rotation as well as for limb darkening, independent

for each component. The model has been validated against optical solar data. The Sun is a unique laboratory to test stellar models because of the possibility to relate unambiguously flux variations to surface inhomogeneities configuration. Finally, I present a database of synthetic stellar spectra and its applicability to define the activity of an observed star.

● **Exoplanetary atmospheres retrieval via quantum extreme learning machine.**

VETRANO M., ZINGALES T., PALMA G.M., LORENZO S.

*Università degli Studi di Palermo*

The study of exoplanetary atmospheres traditionally relies on forward models to analytically compute the spectrum of an exoplanet by fine-tuning numerous chemical and physical parameters. However, the high-dimensionality of parameter space often results in a significant computational overhead. In this work, we introduce a novel approach to atmospheric retrieval leveraging on quantum extreme learning machines (QELMs). QELMs are quantum machine learning techniques that employ quantum systems as a black box for processing input data. In this work, we propose a framework for extracting exoplanetary atmospheric features using QELMs, employing an intrinsically fault-tolerant strategy suitable for near-term quantum devices, and we demonstrate such fault tolerance with a direct implementation on IBM Fez. The QELM architecture we present shows the potential of quantum computing in the analysis of astrophysical datasets and may, in the near-term future, unlock new computational tools to implement fast, efficient, and more accurate models in the study of exoplanetary atmospheres.

● **Single line analysis: a powerful tool to probe exoplanetary atmospheres.**

D'ARPA M.C.

*INAF, Osservatorio Astronomico di Palermo*

Transmission spectroscopy is the primary technique to study atomic and molecular species in exoplanetary atmospheres. During transit, starlight filters through the atmosphere, imprinting spectral features that reveal its composition. While cross-correlation with templates effectively detects weak signals by combining many lines, single-line analysis offers insights into vertical distribution, wind patterns, and rotation. I present results from a framework developed for single-line analysis, applied to hot planets like warm-Saturns and hot-Jupiters. For KELT-9 b, using HARPS-N data, we identified 70 lines from seven species, including the first detections of H $\epsilon$ , H $\zeta$ , Cr II, and Sc II. NLTE models confirmed these detections and highlighted blended regions. The same method applied to TOI-5398 b revealed H $\alpha$  and He I triplet lines, consistent with predictions from the ATES evaporation model. Finally, for TOI-1518 b, we combined HARPS-N and GIANO-B data, detecting H $\alpha$ , NaD $_2$ , and multiple species through cross-correlation, along with a preliminary detection of average Fe II and Ti II lines.

● **True masses through Hipparcos and Gaia astrometry.**

PICCININI G.

*INAF, Osservatorio Astronomico di Palermo*

Thanks to the high precision of Gaia observations, numerous stellar companions have been investigated over the past decade, particularly through astrometric techniques. Long-period companions have been detected and characterized through long-term radial velocity surveys. In this work, we re-analyze a small sample of targets using a combined approach that integrates radial velocity data with astrometry. By merging Hipparcos and Gaia astrometry, specifically using the proper motion anomaly method, with radial velocity measurements, we are able to tightly constrain orbital inclinations and accurately determine the true masses of long-period companions. Additionally, we compare our results with the sensitivity curve, a

tool that identifies the range of companion masses capable of inducing astrometric signals as a function of orbital separation and stellar mass. This comparison serves as a validation of our results and as to gain new information about the planetary system. Our revised analysis reveals that some targets previously classified as brown dwarfs or low-mass stars have, in fact, a planetary nature.

● **Hunting triple planetary systems in high-magnification microlensing events with Roman.**

SAGGESE V. <sup>(1)(2)</sup>, BACHELET E. <sup>(3)</sup>, CALCHI NOVATI S. <sup>(3)</sup>, BOZZA V. <sup>(4)</sup>, COVONE G. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(2)</sup> *INFN, Sezione di Napoli* <sup>(3)</sup> *IPAC, California Institute of Technology, Pasadena, CA, USA* <sup>(4)</sup> *Dipartimento di Fisica, Università di Salerno, Fisciano*

Gravitational microlensing is a powerful method for exoplanet detection, offering a significant advantage due to its independence from bias toward planets near or beyond the snow line. Despite its potential, the number of multi-planetary systems identified using this technique remains relatively small. This raises questions about the effectiveness of next-generation observatories in detecting these systems. To explore this, we utilized VBMicrolensing, a numerical tool designed to model magnification in complex lensing configurations, including systems with multiple lenses, such as triple-lens configurations and beyond. Using VBMicrolensing, we ran simulations to assess the ability of Roman to detect triple-lens planetary systems. These simulations were carried out by reproducing the experimental light-curve data of Roman. Our results indicate that Roman has the potential to detect such systems in approximately 60% of high-magnification events, those in which the source trajectory passes near the central caustic. This result highlights the exceptional sensitivity of Roman in detecting complex lensing events and its potential to provide invaluable data on multi-planetary systems.

● **Spot modelling through multi-band photometry: the analysis of V1298 Tau.**

BIAGINI A. <sup>(1)(2)</sup>, PETRALIA A. <sup>(1)</sup>, DI MAIO C. <sup>(1)</sup>, BETTI L. <sup>(3)(4)</sup>, PACE E. <sup>(3)(4)</sup>, MICELA G. <sup>(1)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(3)</sup> *Dipartimento di Fisica ed Astronomia, Università degli Studi di Firenze, Sesto Fiorentino*

<sup>(4)</sup> *Osservatorio Polifunzionale del Chianti, Barberino Val d'Elsa*

Stellar activity is comprised of various phenomena, mainly spots and faculae. It is one of the main sources of noise in exoplanets observations because it affects both spectroscopic and photometric observations. In studying young active planetary systems, we need to model the activity of the host stars to remove astrophysical noise from our observational data. We model the contribution of stellar spots in photometric observations. Through the use of multi-band photometry, we aim to extract the geometric properties of the spots and constrain their temperatures. We analysed multi-band photometric observations acquired with the 80 cm Marcon telescope of the Osservatorio Polifunzionale del Chianti of V1298 Tau, assuming the photometric modulation observed in different bands is attributed to cold spots. We constrained the effective temperature of the active regions present on the surface of V1298 Tau, resulting from a combination of spots and faculae. Furthermore, we tested our hypothesis on solar data, verifying that we successfully measured the size of the dominant active region and its averaged effective temperature.

● **The Euclid galactic bulge survey: past and future of microlensing planets in one shot.**

SALMERI L. <sup>(1)</sup>, BOZZA V. <sup>(1)(2)</sup>, ROTA P. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Salerno*

<sup>(2)</sup> *INFN, Sezione di Napoli*

Microlensing surveys such as KMTNet, OGLE, and MOA have produced extensive datasets of events, many of which overlap with the observational fields of Euclid and future Roman surveys. In this study, we perform a statistical analysis to derive the distributions of lens proper motions relative to the sources, based on existing data and Galactic models. The Euclid survey provides a crucial astrometric baseline for Roman, enabling prompt mass measurements and extending the temporal window for lens resolution. We estimate the number of microlensing events where lens detection is feasible, focusing on published planetary events. Moreover, the overlap of nearly 10,000 past microlensing events within Euclid's fields offers a unique opportunity for a statistical study of lenses in the Galactic bulge, allowing the validation of microlensing planets and precise mass estimates. Our findings highlight the potential of future space-based observatories to advance our understanding of microlensing phenomena and their astrophysical relevance.

● **Introducing NOCTIS, a coordinated network of small telescopes.**

BENATTI S. <sup>(1)</sup>, TOSI S. <sup>(1)</sup>, SAVAGLIO S. <sup>(1)</sup>, RAINER M. FOR THE NOCTIS TEAM

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(2)</sup> *Università degli Studi di Genova*

<sup>(3)</sup> *Università della Calabria*

<sup>(4)</sup> *INAF, Osservatorio Astronomico di Brera, Merate*

The project NOCTIS aims at building and coordinating a network of already existing small telescopes covering the whole Italian territory. These regional and/or private observatories may be used to perform simultaneous observations or to overcome the drawback of local bad weather allowing delocalised observations. NOCTIS will provide both scientific photometric data (either stand-alone or complementary to other observational programs) and educational outreach programs. At the moment, the network consists of six observatories in different regions (Sicily, Calabria, Campania, Tuscany, and Liguria), but it is open to any additional interested parties. One of the scientific cases already covered by some of the sites is the monitoring of exoplanetary transits.



Aula Seminari B, Section B, Edificio 19

ore 09:00 – 13:30

SEZIONE IV

**Geofisica e fisica dell'atmosfera**

Presiede: ITALIANO L. (Università di Palermo)

Comunicazioni

● **Rete magnetica italiana e mappe del campo geomagnetico dell'Italia all'epoca 2025.0.**

DI MAURO D., DOMINICI G., MELONI A., LEPIDI S., SOLDANI M.

*Istituto Nazionale di Geofisica e Vulcanologia, Italia*

Per modellare il Campo Magnetico Terrestre (CMT) su grande scala, si utilizzano dati da osservatori magnetici, satelliti, campagne oceanografiche e misure al suolo in aree di interesse (rilievi magnetici). Le variazioni lente del CMT, osservate tramite campagne ripetute a intervalli regolari in siti selezionati e rioccupati nel tempo, permettono di caratterizzare il comportamento magnetico del nucleo esterno terrestre e, su scala regionale, la componente crostale generata sopra il mantello. In questo lavoro presentiamo i risultati del rilievo della Rete Magnetica Italiana, riferito all'epoca 2025.0, eseguito tra la fine del 2024 e l'inizio del 2025. I dati acquisiti dalla configurazione attuale, composta da circa 40 punti di misura integrati con 4 osservatori geomagnetici e 2 stazioni variometriche sul territorio nazionale, elaborati tramite procedure di riduzione temporale e normalizzazione spaziale, hanno permesso di produrre mappe dei principali elementi del campo magnetico (D – declinazione; H – componente orizzontale; Z – verticale; e F – intensità totale) e delle loro variazioni temporali.

● **The INGV interdepartmental project “TROPOMAG”: Possible effects of geomagnetic storms on the troposphere.**

MADONIA P. FOR THE INGV TROPOMAG TEAM

*Istituto Nazionale di Geofisica e Vulcanologia, Italy*

TROPOMAG is a project aimed to investigate the connection between Space Weather, Meteorological Weather and Climate, for verifying results from preliminary studies highlighting possible increases in rainfall, and atmospheric pressure anomalies, during the occurrence of geomagnetic storms. The confirmation of a possible relationship between tropospheric disturbances and changes in the Earth's magnetic field could contribute to a better quantification of natural sources of atmospheric variability. The observational network has been established in Italian active volcanic areas, considered that volcanoes generate thermal anomalies, and input in the atmosphere solid and gaseous particles, which create a vertical corridor connecting different atmospheric levels. The dynamics of these fluxes and of the Earth's electromagnetic field can influence the water vapor content of the atmospheric column, due to the electrically charged nature of many of these particles (polar molecules or ions) and to the electrostatic field generated by the volcanic particulates. This process creates an electromagnetic bridge between the low, neutral troposphere and the high, electrically charged ionosphere.

● **A novel technique for particle bursts analysis within the cses-01 mission.**

CALZÀ L. <sup>(1)</sup>, BATTISTON R. <sup>(1)</sup><sup>(2)</sup>, FOLLEGA M.F. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Trento*

<sup>(2)</sup> *Trento Institute of Fundamental Physics and Applications*

The CSES-01 (China Seismo-Electromagnetic Satellite) was launched on February 2 2018 in a Low-Earth (~ 500 km) Sun-synchronous orbit. Predecessor to CSES-02 launching in June

2025 to provide a complete observation of the planet, the goal is to monitor electromagnetic fields and plasma variations induced by natural and anthropogenic sources; and to study possible correlations with seismic events. Among the instrumentation, detectors measuring MeV particles such as the Italian HEPD (High Energetic Particle Detector), and hundreds of keV and hundreds of MeV particles such as HEPP (High Energetic Particle Package), are present. The latter is subdivided in three payloads, dedicated to low (HEPP-L) and high (HEPP-H) energies, and keV X-rays (HEPP-X). Unlike structures such as the Van Allen Belts and the South Atlantic Anomaly, fast ( $\sim 1$  second) and sporadic fluctuations appear: an analysis shows an increment ( $\geq 1$  order of magnitude) with respect to nearby regions, of measured electrons, and coincidences inside HEPP-L. Via polynomial fitting techniques, a catalogue of anomalies can be built to verify their correlation with different events (lightning strikes, earthquakes, GRB, etc).

● **Astronomical calibration (2.59 Ma) of the Gauss/Matuyama magnetic polarity reversal in the Gelasian (Lower Pleistocene) reference section of Monte San Nicola Gela (Sicily).**

CARUSO A. <sup>(1)</sup>, FLORINDO F. <sup>(2)</sup>, MILITELLO G. <sup>(1)</sup><sup>(3)</sup>, DI CHIARA A. <sup>(2)</sup>, COSENTINO C. <sup>(1)</sup>, ADDANTE M. <sup>(3)</sup>, GIRONE A. <sup>(3)</sup>, MAIORANO P. <sup>(3)</sup>, MARINO M. <sup>(3)</sup>, SCOPELLITI G. <sup>(4)</sup>, ROBERTS A. <sup>(5)</sup>

<sup>(1)</sup> *Università degli Studi di Palermo, STEBICEF*

<sup>(2)</sup> *Istituto Nazionale di Geofisica e Vulcanologia, Roma*

<sup>(3)</sup> *Università degli Studi di Bari Aldo Moro, Dipartimento di Scienze della Terra e Geoambientali*

<sup>(4)</sup> *Università degli Studi di Palermo, DISTEM*

<sup>(5)</sup> *Research School of Earth Sciences, The Australian National University, Canberra, Australia*

A high-resolution integrated climate framework has been reconstructed from the Gelasian GSSP section outcropping at Monte San Nicola (southern Sicily). This succession is the reference section for the beginning of the Quaternary System and the Pleistocene series. Our multiproxy record is based on stable oxygen isotopes, measured in planktonic foraminifera, alkenones and calcareous plankton assemblages in the interval between  $\sim 2.7$  and 2.5 Ma, which includes the Gelasian GSSP between MIS G4 and the beginning of MIS 99. The base of the Quaternary (Pleistocene/Gelasian) is almost coincident with the Gauss/Matuyama magnetic reversal that has been astronomically calibrated at 2.59 Ma. The results also allowed us to: i) highlight the changes in surface water dynamics related to the African monsoon activity and the North Atlantic climate variability; ii) strengthen the evidence that the first significant southward migration of the mid-latitude subarctic front occurred during MIS 104; iii) highlight millennial-scale glaciations, related to North Atlantic ice debris transport events within MIS 104 and MIS 100.

● **Leveraging data of stable isotopes in CO<sub>2</sub> to decode atmospheric dynamics: A new CO<sub>2</sub> monitoring network in the Mediterranean region.**

DI MARTINO R.M.R., GURRIERI S., LIOTTA M.

*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo*

This study presents the rationale behind establishing a research infrastructure for monitoring the latitudinal variation of CO<sub>2</sub> and its relationship with atmospheric circulation within the Mediterranean area. The primary goal is evaluating the impact of the European Green Deal on reducing anthropogenic CO<sub>2</sub> emissions from cities. The contribution will include data collected in Palermo over a one-year period of monitoring. The proposed monitoring network comprises 12 stations designed to gather and disseminate data, enabling the examination of

atmospheric CO<sub>2</sub> variations along a North-South transect from the Alpine region to Lampedusa. Each station is equipped with an isotope analyser to measure the concentration and both carbon and oxygen isotopes in atmospheric CO<sub>2</sub>. Extensive research underscores the significance of monitoring stable isotopes to distinguish emission sources and sinks, as well as to trace the CO<sub>2</sub> biogeochemistry. The system's data collection facilitates the identification of diverse CO<sub>2</sub> sources with high accuracy. Additionally, the network's spatial resolution and low latency ensure the data suitability for integration into atmospheric dynamics modelling.

● **Water vapour as key driver in determination of planetary temperatures.**

CAMPOSEO S. <sup>(1)(2)</sup>, OROFINO V. <sup>(3)</sup>, DI VENERE L. <sup>(2)</sup>

<sup>(1)</sup> *Università di Padova*

<sup>(2)</sup> *INFN, Sezione di Bari*

<sup>(3)</sup> *INFN, Sezione di Lecce*

In this contribution, we present a simple model for thermal characterization of rocky planets, based on the strong greenhouse effect driven by water vapour and carbon dioxide gases. This model is based on known data regarding Mars, Earth and Venus. Aim of this work is to make a quantitative comparison between the two gases, which could be useful for both planetary and climate sciences. Dominance of water vapour greenhouse over the carbon dioxide one is a known fact. Confirming this, we find that water vapour is almost six times stronger than carbon dioxide (as greenhouse gas) if the same concentration is considered.

● **Caratterizzazione di un prototipo di spettrometro basato su cavità integratrici.**

DE ANGELIS R. <sup>(1)</sup>, AGUGLIARO A. <sup>(1)</sup>, ALBERGO S. <sup>(1)(2)(3)</sup>, DI BARI I. <sup>(4)</sup>, PERSIANI R. <sup>(2)</sup>, SCIMONE V. <sup>(3)</sup>, SCIUTO A. <sup>(3)(4)</sup>, TRICOMI A. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania, Italia*

<sup>(2)</sup> *INFN, Sezione di Catania, Italia*

<sup>(3)</sup> *CSFNSM-Centro Siciliano di Fisica Nucleare e di Struttura della Materia, Catania, Italia*

<sup>(4)</sup> *CNR-IMM, Catania, Italia*

Si presentano i risultati preliminari ottenuti con uno spettrometro a doppia linea sviluppato nell'ambito del progetto Samothrace. Due porta-campioni sferici in materiale altamente riflettente (di raggio 2 cm e realizzati in PTFE) sono impiegati per ospitare l'analita ed il riferimento. L'elevata riflettanza della cavità garantisce un lungo cammino ottico dei fotoni all'interno del porta-campione, favorendo l'assorbimento di luce da parte dell'analita (anche per basse concentrazioni). Le due sfere identiche (contenenti rispettivamente analita e acqua ultra-pura, come riferimento) sono collegate a due SiPM per la misura del segnale di luce trasmesso. Una sorgente pulsata allo xenon, collegata ad un monocromatore, è accoppiata alle due sfere tramite fibre ottiche operando nella regione spettrale tra 240 nm e 500 nm. Il prototipo è stato testato utilizzando una soluzione acquosa di riboflavina a diverse concentrazioni, e le prestazioni sono state comparate con quelle di uno spettrofotometro commerciale. La tecnica impiegata si presta ad applicazioni in fisica ambientale, per la rivelazione di inquinanti e il monitoraggio della qualità delle acque.

● **A comparison of water balance methods for agro-forested areas.**

VITALI G.

*Università di Bologna*

Several approaches are used to estimate surface fluxes in agro-forested areas. However, most satellite-based methods are hindered by cloud cover, vegetation canopy, and soil conditions, making them less reliable for accurate estimation and management purposes. Many of these

areas are affected by phenomena such as floods and erosion, or require careful monitoring of water resource use, particularly for irrigation. In this study, empirical methods and machine learning (ML) tools are compared with other approaches, with a focus on distributed modelling of the soil-plant-atmosphere system.

● **Un nuovo gassificatore per biomasse di scarto.**

BOTSULA D., COBAL M., GRASSMANN H., SHARMA P.R.

*DPiA, Università degli Studi di Udine*

In Italia ogni anno si raccolgono più di 109 kg di biomasse di scarto. Una delle vie più promettenti per valorizzare a fini energetici tali biomasse, inclusi gli scarti agricoli, è la gassificazione. Il principale prodotto della gassificazione è il syngas, una miscela gassosa ricca di idrogeno e monossido di carbonio, utilizzabile per la produzione di energia tramite motori, turbine e celle a combustibile, o per la sintesi di composti chimici. I gassificatori normalmente lavorano con una quantità ridotta di ossigeno e producono tanto catrame, che finisce con il danneggiare gli impianti. A Udine abbiamo sviluppato un gassificatore di nuova concezione che lavora in un regime di alto flusso d'aria, riducendo questo problema. Il gas prodotto può poi venire utilizzato come una volta il "gas di città" (con la differenza che il gas prodotto da biomasse è CO<sub>2</sub> neutrale). Vengono presentati nuovi risultati e misure effettuate su diverse biomasse. Future applicazioni potrebbero includere la produzione di benzina sintetica o la fornitura di idrogeno. Il nuovo gassificatore è inserito nel progetto "Future Energy Park" dell'Ateneo di Udine.

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Aula 9, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE V

**Biofisica e fisica medica**

Presiede: FRATINI M. (CNR-Nanotec e Santa Lucia Foundation, Roma)

Relazioni su invito

▲ **Functional MRI approaches to quantitatively map brain oxygen metabolism.**

CHIARELLI A.M.

*Department of Neuroscience, Imaging and Clinical Sciences, DNISC, Institute for Advanced Biomedical Technologies, ITAB, University G. D'Annunzio of Chieti-Pescara, Chieti, Italy*  
The human brain relies on aerobic respiration to function. Lacking oxygen storage, the cerebral metabolic rate of oxygen consumption (CMRO<sub>2</sub>) follows the conservation of mass principle, making CMRO<sub>2</sub> equal to the product of oxygen supply (derived from cerebral blood flow, CBF, and arterial oxygen concentration) and oxygen extraction fraction (OEF). MRI offers non-invasive methods for quantifying CMRO<sub>2</sub> with techniques probing CBF, such as arterial spin labeling (ASL). Imaging OEF is more challenging, requiring estimation of deoxyhemoglobin in venous blood via its paramagnetic features. Microvascular mapping of deoxyhemoglobin faces two main issues: it requires knowledge of cerebral blood volume and is influenced by alternative susceptibility sources. Functional MRI methods, typically used to study OEF modulations induced by neurovascular coupling and infer brain activity, can also estimate baseline OEF when combining different fMRI weightings. These methods probe deoxyhemoglobin oscillations, dampening sensitivity to alternative susceptibility sources. This contribution will describe calibrated fMRI, with a focus on new emerging techniques and comparison with alternative MRI technologies.

▲ **Studi preclinici sul metabolismo cerebrale e l'Alzheimer: dai fattori di rischio ai modelli transgenici.**

CANESE R.

*MRI Unit, Core Facilities, Istituto Superiore di Sanità, Roma*

I meccanismi biologici che consentono al sistema nervoso di controllare le funzioni dell'organismo sono ad oggi non completamente chiariti e la loro comprensione rappresenta una delle maggiori sfide nel campo delle neuroscienze. Le demenze, tra queste l'Alzheimer, sono oggi una delle patologie più invalidanti in Italia e nel mondo, con l'incidenza in continua crescita. La spettroscopia di risonanza magnetica (MRS) *in vivo*, in grado di rilevare alterazioni metaboliche in specifiche regioni cerebrali a tempi precoci dall'insorgenza di sintomi patologici è uno strumento fondamentale per studiare i processi biologici che causano le demenze. Dopo una breve introduzione alla MRS quantitativa saranno presentati gli studi MRS su modelli animali sottoposti a diversi fattori di rischio per le demenze e su un modello di topo transgenico che sviluppa Alzheimer.

Comunicazioni

● **Modeling cerebral blood flow response to local brain activation.**

RABBITO R. <sup>(1)</sup>, FICIARÀ E. <sup>(2)</sup>, STURA I. <sup>(1)</sup>, ROATTA R. <sup>(1)</sup>, GUIOT C. <sup>(1)</sup>

<sup>(1)</sup> *Department of Neurosciences, University of Turin, Italy*

<sup>(2)</sup> *School of Pharmacy, University of Camerino, Italy*

Neurovascular coupling describes how local neuronal activation induces increased blood flow to meet higher metabolic demands. Recent studies suggest that this response originates

from vasodilatory signals at the level of arterioles and capillaries, propagating upstream to large cerebral arteries. To quantify this phenomenon we employed a hemodynamic model of cerebral circulation based on the extended Windkessel approach, which models vessels as electrical circuits of resistances and capacitances. The model accounts for six vascular territories (bilateral MCA, ACA, PCA) and includes global autoregulation and CO<sub>2</sub> reactivity. To simulate local neurovascular activation, we altered resistance and compliance in the distal compartments and assessed the resulting flow changes in the main arteries. Simulations were compared with Transcranial Doppler data from healthy subjects during functional tasks and from patients with carotid occlusion before and after surgery. The model, despite its simplicity, provides a physiologically realistic representation of microvascular contributions to CBF modulation, supporting the interpretation of cerebral hemodynamics in both normal and pathological states.

● **Microstructural characterization of white matter hyperintensities in the Alzheimer's disease spectrum.**

D'ANDREA E. <sup>(1)</sup><sup>(2)</sup>, MANCINI M. <sup>(1)</sup><sup>(2)</sup>, BONAROTA S. <sup>(2)</sup>, CARUSO G. <sup>(2)</sup>, SERRA L. <sup>(2)</sup><sup>(3)</sup>, GIOVE F. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Centro Ricerche "Enrico Fermi", Rome, Italy*

<sup>(2)</sup> *Neuroimaging Laboratory, Fondazione "Santa Lucia", Rome, Italy*

<sup>(3)</sup> *Department of Human Sciences, Guglielmo Marconi University, Rome, Italy*

White matter hyperintensities (WMH) are areas with abnormal contrast visible in MRI scans of the brain, often associated with cognitive decline and vascular degeneration. Spatial classification of lesions, based on their distance from the ventricles, correlates with cognitive status but relies on arbitrary thresholds. As the mechanisms giving rise to this hyperintense contrast have a microstructural origin, quantitative MRI may help elucidate the histopathological nature of WMH in relation to clinical status. We segmented and analyzed WMH in patients with Alzheimer's disease, mild cognitive impairment, subjective cognitive decline, and healthy controls who underwent structural and multi-shell diffusion MRI. We extracted six microstructural measures (fractional anisotropy, mean diffusivity, and radial diffusivity from DTI; neurite density, orientation dispersion, and free water from NODDI) and used PCA to identify the related main sources of variance. Using unsupervised clustering, we identified distinct WMH clusters based on microstructural properties, and compared them to spatial criteria. Preliminary results suggest that specific clusters could reflect distinct phenomena.

● **Modelling cerebral physiology: Predicting metabolic and vascular responses to activation and hypercapnia.**

GIULIETTI G. <sup>(1)</sup>, GUIDI M. <sup>(2)</sup>, GIOVE F. <sup>(1)</sup><sup>(3)</sup>, DI NUZZO M. <sup>(4)</sup>

<sup>(1)</sup> *Neuroimaging Laboratory, Fondazione Santa Lucia IRCCS, Rome, Italy*

<sup>(2)</sup> *INFN, Laboratori Nazionali del Sud, Catania, Italy*

<sup>(3)</sup> *Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Rome, Italy*

<sup>(4)</sup> *Netabolics SRL, Rome, Italy*

Hypercapnia, an artificially induced increase of carbon dioxide levels in the blood, is widely employed in functional MRI (fMRI) studies to assess cerebrovascular reactivity and calibrate BOLD signals. However, its potential effects on brain metabolism remain a subject of debate. We present a computational model that integrates neurovascular and neurometabolic coupling, comprising ten compartments and seventy differential equations to simulate brain metabolism and cerebral blood flow regulation. Validated against experimental data across various levels of neuronal activity, the model reliably predicts cerebral responses to both neuronal activation and hypercapnic challenges. Our results confirm that mild hypercapnia

significantly increases cerebral blood flow (CBF) and volume (CBV), while exerting minimal effects on oxygen metabolism (CMRO<sub>2</sub>). This supports its use in fMRI calibration and offers a more robust foundation for interpreting BOLD signals. The model offers a versatile platform for investigating both physiological and pathological brain states, paving the way for the development of more accurate imaging biomarkers and therapeutic strategies in neurodegenerative diseases.

### ● Cerebrovascular reactivity mapping with BOLD, VASO and ASL.

SINGH T. <sup>(1)(2)</sup>, GIULIETTI G. <sup>(1)(3)</sup>, GUIDI M. <sup>(1)(2)</sup>, BONAROTA S. <sup>(3)</sup>, CARUSO G. <sup>(3)</sup>, SERRA L. <sup>(3)</sup>, GIOVE F. <sup>(1)(3)</sup>

<sup>(1)</sup> Museo Storico della Fisica e Centro Studi e Ricerche “Enrico Fermi”, Rome, Italy

<sup>(2)</sup> Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy

<sup>(3)</sup> Neuroimaging Laboratory, Fondazione Santa Lucia IRCCS, Rome, Italy

Cerebrovascular reactivity (CVR) is a measure of the ability of cerebral blood vessels to respond to vasoactive stimuli and it is increasingly being studied as a biomarker of neurodegenerative diseases, such as Alzheimer’s disease (AD). This study, conducted at the Fondazione Santa Lucia (Rome), utilized a Siemens MAGNETOM 3T Prisma scanner. A total of 43 participants: 24 healthy controls ( $63.1 \pm 9.5$  y) and 19 patients ( $71 \pm 4.7$  y) underwent the MRI session which included a vascular space occupancy (VASO) and an arterial spin labeling (ASL) functional sequence. This study involves respiratory manipulation to assess vascular reactivity to hypercapnia and consists of alternating every 2 min medical air and gas mixture (5% CO<sub>2</sub>, 21% O<sub>2</sub>, 74% N<sub>2</sub>) through a face mask. The functional time series were processed in order to generate CVR maps for each contrast. A trend towards reduced CVR from healthy controls to patients was observed, with significant differences for BOLD-CVR (gray matter [ $p = 0.0022$ ], white matter [ $p = 0.0023$ ]) and for VASO-CVR (gray matter [ $p = 0.0130$ ], white matter [ $p = 0.0315$ ]). The results are in agreement with the literature, offering a further contribution to the understanding of vascular mechanisms.

### ● Development of quantitative magnetic resonance imaging methods of the spinal cord.

ERCOLANO C. <sup>(1)(2)</sup>, FRATINI M. <sup>(2)(3)</sup>, COLAMARINO E. <sup>(4)</sup>, BIGIONI A. <sup>(2)</sup>, MATTIA D. <sup>(2)</sup>, GIOVE F. <sup>(2)(5)</sup>

<sup>(1)</sup> Università degli Studi Roma Tre, Roma, Italy

<sup>(2)</sup> Fondazione Santa Lucia IRCCS, Roma, Italy

<sup>(3)</sup> Istituto di Nanotecnologia-CNR c/o Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy

<sup>(4)</sup> Dipartimento di Ingegneria Informatica, Automatica e Gestionale “Antonio Ruberti”, Sapienza Università di Roma, Roma, Italy

<sup>(5)</sup> Museo Storico della Fisica e Centro Studi e Ricerche “Enrico Fermi”, Roma, Italy

Spinal Cord Injury (SCI) causes temporary or permanent impairment and is classified as traumatic or non-traumatic, often with limited recovery. Quantitative MRI (qMRI) provides reproducible maps reflecting tissue microstructure, assessing myelin and axonal density<sup>3</sup>. We developed a spinal cord imaging and analysis protocol, based on the spine generic protocol, and applied it to healthy controls (HC) and 14 patients with both SCI types. Macrostructural analysis showed significant spinal cord cross-sectional area (CSA) reduction in SCI patients: 4% decrease in T1-weighted ( $p < 0.01$ ) and 8% in T2-weighted images ( $p < 0.001$ ). A vertebral level  $\times$  group interaction ( $p = 0.023$ ) in T2w suggests level-dependent atrophy. Microstructural analysis using Magnetization Transfer Ratio (MTR) revealed reduced MTR values in white matter of patients compared to HC ( $p = 0.016$ ), especially in traumatic SCI. In the lateral corticospinal tract, traumatic patients had greater MTR loss ( $p < 0.05$ ), indicating more severe motor pathway damage. These findings confirm SCI-related atrophy



and demyelination and support qMRI biomarkers as valuable tools for assessing structural damage, prognosis, and therapy monitoring.

● **Integrating morphological network-based features to radiomics: An application to MRI for deep endometriosis.**

PELUSO S. <sup>(1)(2)</sup>, LUCIDI V. <sup>(3)</sup>, DI GIOVANNI M.C. <sup>(3)</sup>, BERTOLDO L. <sup>(1)</sup>, DE GOBBI V. <sup>(1)</sup>, AGUZZI A. <sup>(1)</sup>, BIONDI R. <sup>(4)</sup>, SERACCHIOLI R. <sup>(1)</sup>, MOSCONI C. <sup>(3)</sup>, RAIMONDO D. <sup>(1)</sup>, CASTELLANI G. <sup>(1)(2)</sup>, CURTI N. <sup>(5)(6)</sup>

<sup>(1)</sup> *Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy*

<sup>(2)</sup> *IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy*

<sup>(3)</sup> *Department of Radiology, IRCCS Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy*

<sup>(4)</sup> *IRCCS Istituto delle Scienze Neurologiche di Bologna, Data Science and Bioinformatics Laboratory, Bologna, Italy*

<sup>(5)</sup> *Department of Physics and Astronomy, University of Bologna, Bologna, Italy*

<sup>(6)</sup> *INFN, Sezione di Bologna, Italy*

This study introduces a novel radiomic framework for the MRI-based assessment of deep infiltrating endometriosis (DIE), addressing the current lack of standardization and high operator dependency in lesion interpretation. Furthermore, we introduced a novel approach for the characterization of complex 3D shape morphology (graphomic) capable of enriching the radiomic approach and able to quantify relevant features in this context. Radiomic (intensity and texture) and graphomic features were extracted from 89 segmented lesions on 61 T2-weighted MRI scans and linked to histological classification (active *vs.* fibrotic) and pain symptoms. Graphomic features, capturing 3D lesion complexity, achieved 69.9% balanced accuracy in lesion type classification and 88% in predicting chronic pelvic pain. Radiomic features from original images performed best in predicting dysmenorrhea (80.3%) and dyschezia (78.4%), highlighting their complementary role. This multi-parametric, machine-learning-based approach enables objective, reproducible lesion characterization and pain symptoms profiling, supporting non-invasive biomarkers for precision diagnosis and personalized therapeutic planning in DIE.

● **Studio simulativo di un dispositivo indossabile basato su f-NIRS per la diagnosi precoce del carcinoma mammario.**

BONOMO F. <sup>(1)</sup>, GIACONIA G.C. <sup>(2)</sup>, CHIARELLO G. <sup>(2)</sup>, BAIAMONTE G. <sup>(2)</sup>, PERSANO ADORNO D. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica E. Segrè, Università di Palermo, Italia*

<sup>(2)</sup> *Dipartimento di Ingegneria, Università di Palermo, Italia*

La diagnosi precoce del carcinoma mammario rappresenta un obiettivo prioritario per migliorare la prognosi e limitare l'aggressività delle terapie. In questo contributo si presentano i risultati preliminari di uno studio simulativo finalizzato allo sviluppo di un dispositivo indossabile non invasivo basato sulla spettroscopia funzionale nel vicino infrarosso (f-NIRS), tecnica che misura le concentrazioni di ossiemoglobina (HbO) e deossiemoglobina (HbR) tramite l'assorbimento differenziale della luce (650–900 nm). La f-NIRS non usa radiazioni ionizzanti, è portatile e adatta anche a tessuto mammario denso. Il sistema utilizza una matrice di sorgenti LED (735 e 850 nm) e fotorelevatori ottici (SiPM) disposti sulla superficie. I segnali rilevati variando la posizione dell'emettitore riflettono le variazioni di assorbimento e scattering lungo diversi cammini fotonici, evidenziando anomalie nell'attività vascolare e metabolica del tessuto. Usando il metodo FEM per la risoluzione della RTE (Radiative Transfer Equation), si ricavano mappe 3D del coefficiente di assorbimento per localizzare e stimare le dimensioni della massa tumorale.



● **Ultra-short-term analysis of cardiovascular interactions at rest and during stress using stochastic interaction.**

RAIMONDI A. <sup>(1)</sup>, SAPUTO R. <sup>(1)</sup>, JAVORKA M. <sup>(2)</sup>, BUSACCA A. <sup>(1)</sup>, FAES L. <sup>(1)</sup>, PERNICE R. <sup>(1)</sup>

<sup>(1)</sup> *Department of Engineering, University of Palermo, Palermo, Italy*

<sup>(2)</sup> *Department of Physiology, Jessenius Faculty of Medicine in Martin, Comenius University in Bratislava, Martin, Slovakia*

Recently, a growing interest has been paid to the study of the complex regulatory mechanisms of the human organism, such as cardiovascular coupling usually assessed through bivariate analysis of the interactions between beat-to-beat variability of heart period and systolic arterial pressure (SAP). The increasing use of low-cost wearable devices has also showed the need for evaluating the reliability of Ultra-Short-Term (UST) variability analysis, with reduced storage requirements compared to traditional 300-beat-long short-term (ST) recordings. This study investigates the reliability of stochastic interaction of cardiovascular dynamics computed from UST time series if compared to ST recordings. The analyses have been carried out on electrocardiographic R-R intervals and SAP time series acquired on 127 healthy young volunteers (75 females; age:  $18.6 \pm 3.3$  years), all normotensive and with normal body mass index, at rest and during postural and mental stress. Results evidence that although shortening the time series reduces the correlation with ST data, the stochastic interaction computed from UST series of down to 180 samples can still reliably discriminate rest from stress condition.

● **Development of an explainable AI model for early classification of MCI and Alzheimer's disease using T1 MRI scans.**

MAGGIO E. <sup>(1)</sup>, RUNFOLA C. <sup>(1)</sup>, ROMEO M. <sup>(1)(2)(3)</sup>, COTTONE G. <sup>(1)(2)</sup>, GAGLIARDO C. <sup>(4)(5)</sup>, MARRALE M. <sup>(1)(2)</sup>

<sup>(1)</sup> *Department of Physics and Chemistry Emilio Segrè, University of Palermo, Palermo, Italy*

<sup>(2)</sup> *National Institute for Nuclear Physics, INFN, Catania Division, Catania, Italy*

<sup>(3)</sup> *Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, University of Palermo, Palermo, Italy*

<sup>(4)</sup> *Department of Biomedicine, Neurosciences and Advanced Diagnostics, University of Palermo, Palermo, Italy*

<sup>(5)</sup> *University Hospital Paolo Giaccone of Palermo, Palermo, Italy*

This research project focuses on the development of an explainable artificial intelligence (XAI) model for the classification of patients with Mild Cognitive Impairment (MCI) and Alzheimer's Disease (AD). The goal is to combine the accuracy of convolutional neural networks (CNN) with the transparency and interpretability that are crucial in clinical settings. The data used come from the ADNI (Alzheimer Disease Neuroimaging Initiative) database, with a particular focus on T1 MRI MPRAGE scans, extracted using the FastSurfer tool. A CNN was trained on these images for disease classification, while an explainability technique based on Grad-CAM was integrated to highlight the brain areas relevant to classification, enhancing model interpretability. The project is funded by the AD-RICAMI program, Spoke 2, PNRR, within the RAISE program, aiming to provide a diagnostic tool that is not only accurate but also understandable and usable by healthcare professionals. Initial results show promising clinical applications for the early diagnosis of neurodegenerative diseases.

● **Implementation of an AI-based motion correction pipeline in brain MR spectroscopy.**

ROSSI C. <sup>(1)(2)</sup>, LONARDO A. <sup>(1)</sup>, CIARDIELLO A. <sup>(3)</sup>, GIAGU S. <sup>(1)(2)</sup>, MAIURO A. <sup>(2)(4)</sup>, CAPUANI S. <sup>(3)</sup>, GIOVE F. <sup>(4)</sup>, ARGIENTO B. <sup>(1)</sup>, ROSSI E. <sup>(1)</sup>

<sup>(1)</sup> *National Institute for Nuclear Physics Rome Division, Rome RM, Italy*

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<sup>(3)</sup> *NMR Laboratory and Medical Physics, CNR Institute for Complex Systems, ISC, UOS Roma Sapienza, Physics Department, Sapienza University, Rome, Italy*

<sup>(4)</sup> *NeuroImaging Laboratory, Santa Lucia Foundation, Rome, Italy*

The REal-time motion CorrEctioN in magneTic REsonance (RECENTRE) project proposes an innovative motion correction technique for MR spectroscopy of the human brain based on real-time deep learning techniques. More in detail, a LSTM Neural Network (NN) is integrated within the workflow of the Siemens syngo MR MAGNETOM system, where the Siemens Image Calculation Environment (ICE) operates image reconstruction exploiting roto-translation correction parameters predicted by the the LSTM NN model implemented on the Siemens Framework for Image Reconstruction Environment (FIRE). In this context, the FIRE containerized Python server receives ISMRMRD raw data coming from an Emitter Functor within the ICE sequence to feed a running Pytorch process in which the pre-trained NN is instantiated. The output parameters are then sent back to the ICE pipeline via an Injector Functor and used by the reconstruction sequence to perform the motion correction. This setup has been validated and tested on a simulated environment; in the project target setup, the FIRE server will be deployed onto the Siemens MARS computer leveraging the on-board GPU cards to enhance the performance of the NN inference task.

#### ● **Super-phantoms for lung research: A hierarchical platform.**

RATTO F. <sup>(1)</sup>, CAVIGLI L. <sup>(1)</sup>, VANORE I. <sup>(2)</sup>, INSERO G. <sup>(2)</sup>, BOSSI A. <sup>(3)</sup>, DI SIENO L. <sup>(3)</sup>, DALLA MORA A. <sup>(3)</sup>, MARRAZZO L. <sup>(2)</sup>, ROMANO G. <sup>(2)</sup>, FUSI F. <sup>(2)</sup>, PALLOTTA S. <sup>(2)</sup>

<sup>(1)</sup> *Istituto di Fisica Applicata Nello Carrara, Consiglio Nazionale delle Ricerche*

<sup>(2)</sup> *Dipartimento di Scienza Biomediche Sperimentali e Cliniche, Università degli Studi di Firenze*

<sup>(3)</sup> *Dipartimento di Fisica, Politecnico di Milano*

Tissue-mimicking super-phantoms offer alternatives to animal models for biophysics research, crucial for assessing multimodal protocols (*e.g.*, diffuse optics, rad-MRI). Addressing lung anatomy, we propose a hierarchical platform replicating lung structure and multiphysical/dynamic properties. Our concept provides a gas-porous architecture within PDMS composite walls (ECM analog) embedding  $\mu\text{m}$ -hydrogel inclusions (cell mimics), enabling biochemical/contrast agent integration. Manufacturing employs a hierarchical pipeline from microemulsion and sponge fabrication to soft lithography, using PDMS, agarose, and paraffin as sacrificial porogen. The material exhibits relevant compressibility and promising contrast for diffuse optics, MRI, and CT under dynamic conditions. Challenges include shelf stability and integration in anatomical robots (*e.g.*, ADAM, Univ. Florence), specifically dehydration due to PDMS permeability and additive manufacturability for physiopathological shapes. This versatile platform aims to inspire advanced phantoms, accelerating the translation of medical tools for critical organs like the lungs.

#### ● **Evaluation of individual exposure to RF electromagnetic fields.**

AMIN M. <sup>(1)</sup>, CAPUTO E. <sup>(2)</sup>, PEDROLI C. <sup>(2)</sup>, GIRANI M. <sup>(3)</sup>, VIGNATI A. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Torino, Italia*

<sup>(2)</sup> *ARPA Piemonte, Dipartimento Rischi Fisici e Tecnologici, Struttura Semplice Radiazioni Non Ionizzanti, Ivrea e Torino, Italia*

<sup>(3)</sup> *Dipartimento di Fisica, Università di Torino, Italia*

Non-ionizing electromagnetic fields (EMFs), emitted by sources such as mobile phones, Wi-Fi routers, and power lines, have raised health concerns. While exposure at rural-urban,

indoor-outdoor, and household levels has been studied, individual-level exposure remains poorly understood. This study presents a field-based methodology to evaluate personal RF-EMF exposure in daily life. Using the ExpoM-RF 4 exposimeter, participants from the University of Turin were monitored across everyday environments, including home, workplace, university, gyms, parks, riversides, hills, and while walking, driving, or using public transport (bus, train, metro). The device recorded exposure across a wide RF spectrum (50 MHz to 6 GHz), covering FM radio, mobile networks (2G–5G), Wi-Fi, and broadcasting services. Participants also maintained 24-hour activity diaries detailing phone use, commuting, internet calls, Wi-Fi work, and rest periods. These were synchronized with exposure data and processed using Python. The protocol provides a scalable framework for characterizing personal RF-EMF exposure.

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SEZIONE VI

**Fisica applicata, acceleratori e beni culturali**

Presiede: MASCALI D. (INFN, Laboratori Nazionali del Sud, Catania)

Relazioni su invito

▲ **Intense highly charged ion beams production at INFN-LNS.**

LEONARDI O., CASTRO G., COSTANZO G., RUSSO F., SILIATO D., CELONA L., RIFUGGIATO D., GAMMINO S.

*INFN, Laboratori Nazionali del Sud, Catania, Italy*

Electron Cyclotron Resonance Ion Sources (ECRIS) are reliable devices capable of providing ion beams to particle accelerators, with adjustable charge states and intensity according to experimental requirements. At INFN-LNS, current efforts are focused on the upgrading of the Superconducting Cyclotron, with the goal of increasing the beam power up to 10 kW for ions with mass number  $A \leq 40$  and energies between 15 and 70 AMeV. Until now, the primary beams have been provided by two ECR ion sources developed in the 1990s: SERSE, a source with superconducting magnets, that in recent years has been temporarily out of operation due to issues with its liquid helium cryostat, and CAESAR, a room temperature source able to produce up to now the beams adapted to the Cyclotron needs, though insufficient for the above-mentioned challenges. While requiring the funding for a modern 3rd-generation ECR ion source, the Advanced Ion Source for Hadrontherapy (AISHa) is serving as a test bench for the development of the intense beams requested for nuclear physics, to be also used for applications in medical physics and materials science.

▲ **A compact C-band electron linac for FLASH radiotherapy.**

GIULIANO L. <sup>(1)(2)</sup>, CHIADRONI E. <sup>(1)(2)</sup>, COPPOLA M. <sup>(1)(2)</sup>, CURCIO A. <sup>(1)(2)</sup>, DE GREGORIO A. <sup>(1)(2)</sup>, DI CARLO C. <sup>(1)(2)</sup>, FARINA S. <sup>(1)(2)</sup>, FRANCOSINI G. <sup>(1)(2)</sup>, MAGI M. <sup>(1)(2)</sup>, MOSTACCI A. <sup>(1)(2)</sup>, MIGLIORATI M. <sup>(1)(2)</sup>, PATERA V. <sup>(1)(2)</sup>, REMETTI R. <sup>(1)(2)</sup>, SARTI A. <sup>(1)(2)</sup>, PALUMBO L. <sup>(1)(2)</sup>, FICCADENTI L. <sup>(2)</sup>, LALLI E. <sup>(2)</sup>, ALESINI D. <sup>(3)</sup>, CARDELLI F. <sup>(3)</sup>, DI RADDIO R. <sup>(3)</sup>, FAILLACE L. <sup>(3)</sup>, FRANZINI G. <sup>(3)</sup>, GALLO A. <sup>(3)</sup>, PIESANTI L. <sup>(3)</sup>, PIOLI S. <sup>(3)</sup>, SPATARO B. <sup>(3)</sup>, VANNOZZI A. <sup>(3)</sup>, CUTTONE G. <sup>(4)</sup>, MAURO G.S. <sup>(4)</sup>, SORBELLO G. <sup>(4)</sup>, TORRISI G. <sup>(4)</sup>

<sup>(1)</sup> *Sapienza University of Rome*

<sup>(2)</sup> *INFN, Sezione di Roma, Rome*

<sup>(3)</sup> *INFN, Laboratori Nazionali di Frascati*

<sup>(4)</sup> *INFN, Laboratori Nazionali del Sud*

FLASH therapy is emerging as a revolutionary approach in cancer treatment. It can cure tumors while dramatically reducing collateral damage to healthy tissues, thus enhancing the therapeutic index. Very High-Energy Electrons (VHEE) in the 50–150 MeV range are required to unlock the full potential, especially for deep-seated tumors. In this context, within the SAFEST project, Sapienza University, in collaboration with INFN, is developing a compact C-band linear accelerator demonstrator, delivering 24 MeV (loaded) beam energy with a 100 mA peak current. This contribution delves into the complete development pathway of this accelerator, from electromagnetic design and beam dynamics, offering a comprehensive roadmap to realizing a high-performance FLASH-ready linac in a university environment.

## Comunicazioni

● **Power and beam dynamics optimization of a compact LINAC for FLASH radiotherapy with prospects for VHEE.**

FARINA S., CURCIO A., GALLO A., VANNOZZI A., SARTI A., MOSTACCI A., DE GREGORIO A., SPATARO B., FRANCESCONI D., ALESINI D., CHIADRONI E., CARDELLI F., FRANCIOSINI G., CUTTONE G., SORBELLO G., MAURO G., FRANZINI G., TORRISI G., FICCADENTI L., PIERSANTI L., GIULIANO L., FAILLACE L., PALUMBO L., MAGI M., CARILLO M., COPPOLA M., MIGLIORATI M., DI RADDÒ R., PATERA V.

*Dipartimento SBAL, Sapienza Università di Roma*

FLASH radiotherapy is an emerging technique that delivers ultra-high dose rates, effectively targeting tumor cells while minimizing damage to healthy tissue. Thanks to their compact size and cost-efficiency, electron linear accelerators (linacs) are promising candidates for clinical implementation. However, treating deep-seated tumors requires Very High Energy Electrons (VHEE), with energies exceeding 100 MeV. Developing a compact and cost-effective VHEE linac capable of delivering FLASH doses is therefore a critical step toward making FLASH therapy viable for deep tumors and broader clinical use. At La Sapienza University, research is underway on a compact 24 MeV C-Band prototype as part of the SAFEST project, which aims to design a 100 MeV C-Band FLASH electron accelerator. Achieving high beam current while minimizing RF power demands introduces significant challenges in beam dynamics. This contribution presents the strategies developed to address these challenges, along with results demonstrating the preservation of key FLASH beam characteristics throughout the acceleration process.

● **Risposta di un sensore a silicio amorfo idrogenato esposto a un fascio di elettroni erogato in modalità FLASH.**

CITTADINI F. PER LA HASPIDE COLLABORATION

*Università degli Studi di Padova e INFN, Sezione di Perugia*

In ambito di terapia oncologica con fasci esterni, sta emergendo la modalità FLASH di erogazione di radiazione ionizzante, in particolare di fasci di elettroni. Le caratteristiche di tali fasci sono una dose per impulso molto elevata (20-60 Gy), con l'impulso della durata di qualche microsecondo. L'esperimento HASPIDE dell'INFN si basa sullo sviluppo di sensori innovativi a stato solido realizzati in silicio amorfo idrogenato (a-Si:H), in cui uno strato di a-Si:H estremamente sottile ( $\approx \mu\text{m}$ ) è compreso tra due elettrodi e agisce come volume sensibile per la rivelazione di radiazione ionizzante. Il tutto è depositato su kapton per ottenere dispositivi flessibili e con capacità di misura in trasmissione. Questo lavoro si basa sul test effettuato utilizzando un sensore spesso  $2.5 \mu\text{m}$  e di area  $5 \times 5 \text{ mm}^2$ , sottoposto a un fascio FLASH di elettroni a 10 MeV, frequenza 6 Hz e dimensioni campo pari a  $10 \times 10 \text{ cm}$ . In particolare, il sensore è stato irraggiato con un dose per pulse nominale variabile tra 2.2 e 20 Gy ed è stato studiato il comportamento in funzione della tensione di polarizzazione del sensore. I risultati preliminari di questa campagna di misure sono molto incoraggianti.

● **The growing adventure of CdZnTe detectors in room temperature X-ray and gamma ray detection.**

ABBENE L.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

In the last two decades, we have witnessed the development of new-generation X-ray and gamma ray detection systems based on room temperature semiconductor detectors (RTSDs), allowing direct radiation detection and superb room temperature performance. Among RTSDs, cadmium zinc telluride (CdZnTe or CZT) represented the leading detector material: the combination of high atomic number ( $Z_{max} = 52$ ) and wide bandgap (1.6 eV),

together with the continuous progress in crystal growth and device technology, gives high detection efficiency within a few millimetres and excellent room-temperature energy resolution. In this work, we will present the room temperature performance of new CdZnTe-based detection systems, recently developed by our group. Several detector prototypes will be presented, designed for applications in nuclear medicine, food inspections and high-precision X-ray measurements in accelerator environments.

● **New generation of Germanium drift detectors for hard X-ray spectroscopy and ultra-low noise applications.**

MASON A. <sup>(1)(2)</sup>, CASTOLDI A. <sup>(1)(2)</sup>, GHISSETTI M. <sup>(1)(2)</sup>, GUAZZONI C. <sup>(1)(2)</sup>, SCARBELLO A. <sup>(1)(2)</sup>, KRINGS T. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano*

<sup>(2)</sup> *INFN, Sezione di Milano*

<sup>(3)</sup> *Institut für Kernphysik, Forschungszentrum Jülich, Germany*

Hard X-ray experiments at modern X-ray synchrotron facilities require novel detector developments, beyond thicker silicon, to satisfy demanding challenges in terms of energy resolution and photon flux. We started a R&D program towards the design and exploitation of Ge drift topologies in a new fully planar technology able to bring the benefits of ultra-low capacitance peculiar of the sideward depletion principle into high resolution hard X-ray spectroscopy and imaging. This paves the way to detectors operating over a broader energy range, e.g. from soft to hard X and gamma-rays, tailored to the experiment thanks to the flexibility of the planar process. Ultra-low noise capability would also be relevant for rare event detection (like dark matter) where a low energy threshold is critical. This contribution presents the results of the experimental qualification of the first prototype of Germanium Drift Detector built in planar technology. Mapping the detector response clearly showed the expected relationship drift time vs. drift distance, witnessing the achievement of sideward depletion. To our knowledge, it is the first evidence of a Germanium drift detector in planar technology.

● **Interleaving 20-bit 160 Msps ADC architecture for direct sampling in X-ray spectroscopy.**

ABBA A. <sup>(1)</sup>, CAPONIO F. <sup>(1)</sup>, CARLOTTI E. <sup>(1)</sup>, PEDRETTI B. <sup>(2)</sup>, CARSI S. <sup>(1)</sup>, AROSIO V. <sup>(1)</sup>, LAZARI M. <sup>(1)</sup>, CARMINATI M. <sup>(2)</sup>, FIORINI C. <sup>(2)</sup>, VENTURINI Y. <sup>(3)</sup>

<sup>(1)</sup> *Nuclear Instruments SRL, Lambrugo, CO, Italy*

<sup>(2)</sup> *Politecnico di Milano, DEIB, Milano, Italy*

<sup>(3)</sup> *CAEN S.P.A., Viareggio, Italy*

We present a novel digital signal processing technique for X-ray detectors, particularly silicon drift detectors (SDDs), optimized for high-count rate applications without compromising energy resolution. Traditional approaches employing transistor reset preamplifiers encounter significant limitations due to the dominant voltage ramp at the preamplifier output, which can obscure low-amplitude signals of interest. To overcome this, we adopted a high-resolution 20-bit SAR ADC capable of directly sampling the preamplifier output, offering a dynamic range exceeding 1:1000000 and enabling effective signal acquisition despite the ramp. To achieve high throughput, we implemented a system architecture based on four interleaved ADCs, providing an aggregate sampling rate of 160 Msps. Signal readout and control are handled by a Zynq System-on-Chip (SoC), which also manages phase alignment, gain calibration, digital filtering via a trapezoidal algorithm, and PC interfacing. Initial experimental validation was carried out using the multipixel SDD ARDESIA detector developed at Politecnico di Milano. Despite the prototypal status, our system demonstrated superior resolution compared to conventional analog reshaping techniques. Specifically, we achieved a full width at half-maximum (FWHM) resolution of 128 eV at 2  $\mu$ s peaking time, and 140 eV at an event rate of 1 Mcps using a faster shaping configuration.

Relazioni su invito

▲ **AI and machine learning techniques for LNL accelerators.**

ONG Y.K., BELLAN L., MONTIS M., COMUNIAN M., BORTOLATO D., GIACCHINI M., GRESPAN F., PISENT A., FAGOTTI E., ZEBELE D., YI JIAN Q., MARCATO D., GALATÀ A., GALLO S.C., CARLETTO O., MANZOLARO M., SCARPA D., MONETTI A., MARCHI T.

*INFN-LNL, La Sapienza Università di Roma*

The integration of Artificial Intelligence (AI) and Machine Learning (ML) into particle accelerator systems has emerged as a powerful approach to managing complex operations and improving performance. At Legnaro National Laboratories (LNL), both offline and on-line AI/ML-driven initiatives have been implemented to enhance beam dynamics, reduce setup times, and increase overall accelerator efficiency. Offline developments include surrogate modelling of complex beamlines like ANTHEM and TAP-SPES and virtual diagnostics through supervised neural networks. These tools significantly boost beam optimization by leveraging AI/ML techniques such as Bayesian Optimization (BO), Genetic Algorithms (GA), and Reinforcement Learning (RL). On the other hand, real-time online optimization strategies using Bayesian algorithms and Particle Swarm Optimization (PSO) have shown impactful results. A key achievement was realized in the PIAVE-ALPI superconductive accelerator, where the application of BO improved beam transmission to 85%, a substantial increase from the usual operating average of 35%. These advances highlight the growing role and future potential of AI/ML in accelerator science.

▲ **Label-free, ultra-thin optical neural interfaces with deep brain regions.**

PISANO F.

*Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova e Padova Neuroscience Center, Università di Padova*

The growing impact of brain diseases in an ageing population is a significant health challenge that raises the demand for a deeper understanding of physiological and pathological neural mechanisms. In the past two decades, the synergistic development of optical methods and genetically expressed, light-sensitive molecular probes has enabled remarkable advances in fundamental and pre-clinical neuroscience research. Nonetheless, the existing tools and methods are still shortsighted with respect to multifaceted neural dynamics and a clear path towards clinical translation is still elusive. To address this challenge, this contribution will discuss the opportunities offered by a broader outlook on the physical phenomenologies involved light-brain interactions, with particular focus on endoscopic spectroscopy approaches based on ultra-thin optical fiber probes reaching arbitrarily deep brain regions.

▲ **Revealing hidden instabilities: Digital holographic speckle pattern interferometry in wall painting conservation.**

ROCCO A., CHABAN A., DI SARNO V., FONTANA R., STRIOVA J.

*CNR, Istituto Nazionale di Ottica*

Advanced restoration of wall paintings increasingly relies on non-invasive diagnostic tools to assess structural integrity and inform conservation strategies. This study explores the applications of Digital Holographic Speckle Pattern Interferometry (DHSPI), an optical, full-field, and contactless technique combining holographic and electronic speckle pattern interferometry. DHSPI detects sub-micrometric surface displacements induced by controlled thermal excitation (IR), allowing the identification of hidden structural anomalies such as detachments, voids, and crack patterns. The method generates interferometric fringe maps that reveal the mechanical response of the surface, enabling quantitative analysis of deformation fields and contributing to the assessment of potential degradation risks. Designed for *in*



*situ* applications, the system is fully portable and optimized for use at significant heights and on scaffolding. Over recent years, it has been successfully employed in diagnostic campaigns on historical wall paintings in Italy, as part of broader multi-instrument analysis and conservation projects.

## Comunicazioni

### ● Neural network-based segmentation of dentate nuclei from 3T b0 brain images: a semi-supervised approach.

RUNFOLA C. <sup>(1)</sup>, MAGGIO E. <sup>(1)</sup>, ROMEO M. <sup>(1)</sup><sup>(3)</sup><sup>(4)</sup>, COTTONE G. <sup>(1)</sup>, GAGLIARDO C. <sup>(2)</sup>, MARRALE M. <sup>(1)</sup><sup>(3)</sup><sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Palermo*

<sup>(2)</sup> *Department PROMISE, Università di Palermo*

<sup>(3)</sup> *INFN, Sezione di Catania*

<sup>(4)</sup> *Dipartimento di Scienze e Tecnologie Biologiche, Chimiche e Farmaceutiche, Università di Palermo*

<sup>(5)</sup> *Advanced Technologies Network Center, Università di Palermo*

The dentate nuclei (DN) of the cerebellum are essential for communication with the brain and are part of the Dentate Rubro-Talamic (DRT) Tract, involved in movement disorders such as Essential Tremor (ET). Accurate DN segmentation is crucial for clinical and research applications. Traditional methods like manual delineation or atlas-based approaches are time-consuming and variable. Some use uncommon MRI sequences, like susceptibility-weighted imaging. In young adults, B0 images at 3T offer a more accessible option. In this study, we implemented a semi-supervised method to segment DN on 3T b0 DWI images, which are widely available. A fully Convolutional Neural Network was developed using T1 and b0 images. HCP dataset images were used to generate binary masks for training. Performance was compared to a model based on nnUNet. Preliminary results showed a Dice Score (DS) of  $0.85 \pm 0.05$  for our model vs.  $0.83 \pm 0.08$  for nnUNet, indicating high accuracy. Our method is promising for planning neurosurgical treatment of essential tremor.

### ● Label-free sensing of soluble biomolecules using pixelated SEIRA and site-specific vibrational probes.

ESPOSITO E., DI MEO V., SANITÀ G., OLIVER A., SANDOMENICO A., MOCCIA M., RENDINA I., CRESCITELLI A., GALDI V., MENOTTI R.,

*CNR, Institute of Applied Sciences and Intelligent Systems, Napoli*

Spectrochemical analysis of trace elements in complex matrices is critical but often hindered by background noise and the challenge of detecting analytes at ultralow concentrations. Surface-Enhanced Infrared Absorption (SEIRA) spectroscopy addresses these limitations by enabling label-free detection of soluble, unmodified analytes via interactions with bioreceptors site-specifically labeled with small infrared-active probes. We present a mid-infrared spectroscopy platform combining a pixelated SEIRA substrate with a distinct azide-based vibrational tag, which offers a sharp signal near  $2100 \text{ cm}^{-1}$ , in the cell- and protein-silent region, while preserving protein structure and function. As a model, we use a trastuzumab-derived Fab' fragment, chemically modified with azidoacetic acid, and its target Her2 antigen. This system allows us to monitor Fab' immobilization and detect analyte levels as low as 83 attomoles within a  $100 \text{ }\mu\text{m}^2$  sensing area. This approach enables highly sensitive molecular detection and offers strong potential for applications in diagnostics, biosensing, and biochemical analysis.



Aula 8, Section B, Edificio 19

ore 09:00 – 13:30

SEZIONE VII

**Didattica e storia della fisica**

Presiede: BONDANI M. (Università dell'Insubria)

Relazioni su invito

▲ **1925-1926: la nascita della meccanica quantistica.**

ROSSI P.

*Dipartimento di Fisica, Università di Pisa*

Gli aspetti fondamentali della meccanica quantistica furono completamente delineati nell'arco dell'anno che va dall'articolo di Heisenberg (luglio 1925) che sta alla base della meccanica delle matrici al lavoro di Born sull'interpretazione probabilistica della funzione d'onda (giugno 1926) passando per i contributi di Born, Heisenberg e Jordan e per la formulazione di Schroedinger della meccanica ondulatoria. Si ricostruiscono brevemente i principali passaggi dello sviluppo della teoria, segnalando anche i lavori più significativi di altri autori non sempre ricordati nell'usuale narrazione.

▲ **Un secolo in chiaroscuro: i 100 anni della Meccanica Quantistica, i suoi successi e le sue criticità, con un case study: Franco Selleri e la sua critica filosofica e sociopolitica.**

ROMANO L.

*Arpa Puglia*

In questo 2025, Anno Internazionale della Scienza e della Tecnologia Quantistica, il presente contributo introduce le diverse interpretazioni dei fenomeni quantistici che si sono succedute a partire dal 1900, unitamente al lungo dibattito che ha fatto seguito al 1925, annus mirabilis in cui è stata introdotta la Meccanica Quantistica. Una teoria potente, dai numerosi successi e dalle molteplici applicazioni tecnologiche presenti nella nostra vita ma con diversi aspetti poco chiari dal punto di vista filosofico. Si è anche analizzato un case study, esponendo l'approccio critico del fisico italiano Franco Selleri (1936-2013), incentrato su motivazioni filosofiche e sociopolitiche.

▲ **From light quanta to entanglement: Einstein's struggles with the Lord's subtleties.**

DI MAURO M. <sup>(1)</sup>, NADDEO A. <sup>(2)</sup>

<sup>(1)</sup> *INFN, Sezione di Roma*

<sup>(2)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

Despite having his name inextricably tied with the theories of relativity, Albert Einstein arguably devoted much more mental energy to the other scientific revolution of the early XX century, quantum physics. After giving many groundbreaking and far-sighted contributions to old quantum theory, Einstein notoriously fiercely opposed the interpretations of the new quantum mechanics that emerged particularly from the Göttingen and Copenhagen schools. In this contribution, a selection of this wealth of work will be reviewed, discussing how several fundamental concepts of quantum theory, such as quantization of light, wave-particle duality and probability, emerged from Einstein's work before 1925. His deep conceptual and philosophical reflections on the new quantum mechanics, which in fact have their roots in that early work, and which much later triggered a tumultuous development - which future

historians may even recognise as a second quantum revolution - will be addressed as well. Some hints and suggestions which may turn out to be useful for the teaching of quantum theory will be included.

▲ **La seconda rivoluzione quantistica: future thinking e svolte culturali.**

LEVRINI O., SATANASSI S.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

La seconda rivoluzione quantistica, basata sull'utilizzo tecnologico delle proprietà genuinamente quantistiche di singoli sistemi, sfida la logica binaria e deterministica dell'epoca Moderna. La sua forza trasformativa risiede non solo nella potenza delle sue applicazioni tecnologiche, ma anche nella diffusione culturale e educativa di una nuova epistemologia. Si argomenterà come, per discuterne le implicazioni in contesti didattici, sia importante integrarne la riflessione con pratiche di future thinking, superando narrazioni polarizzate e problematizzando la relazione tra esseri umani-natura-cultura. Solo così la trasformazione in atto può diventare un'occasione per immaginare e abitare futuri più consapevoli, sostenibili e condivisi.

Comunicazioni

● **Le Accademie Nazionali e i Premi per la Fisica: 1900-1945.**

LEONE M. <sup>(1)(4)</sup>, ROBOTTI N. <sup>(2)(4)</sup>, GUERRA F. <sup>(3)(4)</sup>

<sup>(1)</sup> *Università di Torino*

<sup>(2)</sup> *Università di Genova*

<sup>(3)</sup> *Sapienza Università di Roma*

<sup>(4)</sup> *Centro Ricerche Enrico Fermi, Roma*

Con l'obiettivo di esplorare l'ingresso in Italia della meccanica quantistica, di cui quest'anno ricorre il centenario, si è condotta un'analisi sistematica dei premi e delle medaglie assegnate dalle principali accademie scientifiche nazionali nei primi decenni del Novecento. In questo contributo ci si soffermerà in particolare sul prestigioso Premio Reale per la Fisica e sul premio della Fondazione Alfonso Sella, entrambi conferiti dalla Reale Accademia dei Lincei ed entrambi legati alla figura del grande scienziato, economista e politico Quintino Sella. Oggetto di particolare attenzione sarà anche la prestigiosa Medaglia Matteucci della Società Italiana delle Scienze detta dei XL, conferita all'autore della Memoria o scoperta di fisica la più importante, nazionale o estero, fatta negli ultimi tempi. Attraverso l'analisi delle relazioni e dei fascicoli delle commissioni incaricate di giudicare i vincitori dei premi emergerà l'attenzione prestata per la fisica moderna, dalla meccanica quantistica, alla fisica nucleare, alla fisica dei raggi cosmici, e si aggiungerà un ulteriore tassello alla ricostruzione di un periodo fondamentale della storia della fisica nel nostro paese.

● **History of contextuality in quantum foundations and beyond: Interdisciplinary applications.**

SHARIQ HUSAIN S., PATRA S.

*Jindal School of Government and Public Policy, Center for Complexity Economics Applied Spirituality and Public Policy, Jindal Global University, India*

Contextuality, and its mathematical correspondence with the concept non-locality, in quantum mechanics, is a dense and contested domain. However, general measures of contextuality is not only insightful for quantum foundations, but also for emerging interdisciplinary literature of quantum-cognition, which is a mathematical-philosophical interface (without physical reductionism) between quantum formalism and cognitive science in general, and certain processes like decision making or different types of perceptions. Hence its critical to revisit the

history and philosophy of contextuality in quantum foundations, and applications beyond itself given the growing foundational and application works. Here we begin with Neils Bohr's original framework of contextuality-complementarity (though his contextuality ideas have not been rigorously mathematized, till only recently, using indirect measurement theory) with its philosophical underpinnings (relating to Kantian wholes), then through Bell and Specker, to recent ideas of invertible maps between Bell contextuality and Bell non-locality. constructing a general contextuality theory for relating to seemingly disconnected domains of knowledge.

● **Misconcezioni e criticità nel ragionamento sui principi di relatività ed equivalenza nella meccanica classica: un'indagine tramite questionario a scelta multipla.**

ZAMBONI A. <sup>(1)</sup>, MARZARI A. <sup>(1)</sup>, SALMOIRAGHI A. <sup>(1)</sup>, MALGIERI M. <sup>(2)</sup>, ONORATO P. <sup>(1)</sup>, OSS S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Trento*

<sup>(2)</sup> *Dipartimento di Fisica, Università di Pavia*

Un obiettivo centrale della ricerca in didattica della fisica è l'identificazione e l'analisi delle difficoltà concettuali incontrate dagli studenti nell'apprendimento. Questo studio esplora la comprensione di alcuni concetti fondamentali della relatività classica, nello specifico il Sistema di Riferimento, il Principio di Relatività e il Principio di Equivalenza, da parte di studenti universitari. A questo scopo è stato progettato e somministrato un questionario a scelta multipla composto da 21 domande, rivolto a un campione di circa 260 studenti e studentesse frequentanti il corso di laurea in fisica. L'indagine è stata svolta utilizzando varie tecniche statistiche – tra cui l'analisi classica dei test, l'analisi dei cluster e il modello di Rasch – da un lato per valutare l'affidabilità dello strumento e la sua efficacia nel rilevare eventuali misconcezioni, dall'altro per mettere in luce difficoltà ricorrenti nell'elaborazione di vari concetti, offrendo indicazioni utili per il miglioramento delle strategie didattiche nell'insegnamento della meccanica classica.

● **L'entanglement e la seconda rivoluzione quantistica.**

SATANASSI S., LEVRINI O.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

Il 2025 è stato proclamato dalle Nazioni Unite Anno internazionale delle scienze e delle tecnologie quantistiche, decisione che sottolinea il ruolo sempre più centrale di questo ambito per lo sviluppo scientifico, tecnologico e sociale del presente e futuro. Il gruppo di ricerca in didattica della fisica dell'Università di Bologna è attivo da anni su questi temi, promuovendo l'alfabetizzazione quantistica attraverso la progettazione di percorsi formativi rivolti sia a studenti della scuola secondaria di secondo grado, sia a docenti, in formazione iniziale e in servizio. In occasione di questa ricorrenza, è stato progettato un percorso rivolto a studenti di scuola secondaria, finalizzato a introdurre la fisica quantistica e a valorizzarne la portata culturale e rivoluzionaria. La comunicazione si concentrerà, in particolare, sulle attività sviluppate per introdurre l'entanglement, il secondo mistero alla base della seconda rivoluzione quantistica. Ispirandosi al lavoro di Gisin, sono state progettate esperienze didattiche volte a caratterizzare e valorizzare l'entanglement come trigger of change, capace di promuovere il passaggio dal pensiero classico al pensiero quantistico.

● **Visualizzazione propedeutica a concetti matematici della meccanica quantistica.**

DANELUZZO M., CLAUDIO F., GILIBERTI M., LOVISETTI L.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

Nella ricostruzione didattica della meccanica quantistica sviluppata dal Gruppo di ricerca in Didattica della Fisica dell'Università degli Studi di Milano, il significato di autovettori e autovalori riveste un ruolo rilevante. Com'è risaputo, lo sviluppo di strumenti grafici può supportare la comprensione dei concetti matematici. Per questo, a partire da alcuni lavori precedenti, sono state sviluppate due applicazioni, realizzate in Python, che sfruttano librerie matematiche (NumPy, SciPy) e grafiche per GUI (PyQt5), per lo studio grafico di autovettori e autovalori in  $R^2$ , in  $C^2$  e in  $C^3$ . La prima applicazione consente la rotazione interattiva di un vettore, e il suo confronto visivo con il risultato dell'azione di un operatore lineare (matrice  $2 \times 2$ ). L'estensione al caso complesso realizza una visualizzazione in 3D, a istogramma, e permette—cosa non banale—la determinazione di autovettori e autovalori complessi con metodo grafico. Entrambe le applicazioni saranno testate in prossime sperimentazioni con insegnanti e studenti di Scuola Secondaria di Secondo Grado

● **Un approccio alternativo alle distribuzioni quantistiche.**

D'ANNA M.

*Liceo di Locarno, Svizzera*

Questo intervento propone un percorso che consente di ricavare le distribuzioni quantistiche utilizzando un approccio adatto già a partire dai corsi di approfondimento delle scuole superiori o dai primi anni universitari. A questo scopo (a) viene introdotta la nozione di sito, inteso come generico posto che può accogliere particelle; (b) siti di un medesimo tipo ma che presentano numeri di occupazione diversi vengono considerati come appartenenti a sostanze elementari distinte; (c) il cambiamento del numero di occupazione viene considerato come una reazione tra sostanze elementari; (d) imponendo che, all'equilibrio, la forza motrice per tutte le possibili reazioni sia nulla, sono determinate le probabilità relative che un dato sito sia occupato esattamente da  $n$  particelle. Infine, facendo l'ipotesi che un sito possa essere occupato al massimo da una sola particella, oppure da un numero qualsiasi di particelle, si ottengono rispettivamente le distribuzioni di Fermi-Dirac e di Bose-Einstein. Il confronto con la distribuzione classica di Boltzmann e alcuni accenni ad applicazioni significative per l'insegnamento concluderanno questo intervento.

● **Italian high school students perception of quantum technologies.**

TARTAGLIA D. <sup>(1)</sup><sup>(2)</sup>, TONINELLI C. <sup>(1)</sup>

<sup>(1)</sup> *Istituto Nazionale di Ottica CNR-INO*

<sup>(2)</sup> *Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

Second quantum revolution technologies are becoming part of the daily life of EU citizens. To ease the transition and to inform them of the incoming revolution, outreach and educational initiatives are needed. However, little is known about the relationship European citizens have with quantum physics and its applications. The research here presented aims at filling this gap using a survey administered to Italian high school students. The survey was administered to participants during outreach events organized by CNR-INO and partners from November 2023 to October 2024 in Italy. This survey focus on the possible relationship between the respondents and the implementation of quantum technology in industrial settings as well as their opinions on the topic. The results of the statistical analysis of the answers to the questionnaires are presented and commented. The focus sample for the moment is limited to high school students who answered the survey prior to taking part in the events. As a future investigation these results could be compared with those from different cohorts of the non-student public.

● **The Italian summer students program at Fermilab and other US laboratories.**

DONATI S., MAMBELLI M., BARZI E., BELLETTINI G.

*Università di Pisa e INFN, Sezione di Pisa*

Since 1983 the Italian groups collaborating with Fermilab (US) have been running a 2-month summer training program for Master students in Physics and Engineering. Many students have extended their collaboration with Fermilab with their Master Thesis and PhD. The program has involved more than 600 Italian students from more than 20 Italian universities. Each intern is supervised by a Fermilab Mentor responsible for the training program. Training programs spanned from Tevatron, CMS, Muon (g-2), Mu2e and SBN and DUNE design and data analysis, development of particle detectors and accelerators, and software tools for tera-data handling and quantum computing. In 2015 the University of Pisa included the program within its own educational programs. Summer Students are enrolled at the University of Pisa for the duration of the internship. After positive evaluation by a University of Pisa Examining Board, interns are acknowledged 6 ECTS credits for their Diploma Supplement. In the years 2020 and 2021 the program was canceled due to the sanitary emergency but in 2022 it was restarted. Since 2022, more than 60 students were trained for nine weeks at Fermilab.

● **CAEN Educational: un ponte tra didattica e ricerca scientifica.**

MATTONE C. <sup>(1)</sup>, GAROSI P. <sup>(1)</sup>, BARBA P. <sup>(1)</sup>, CORTOPASSI A. <sup>(1)</sup>, MANTOVANI F. <sup>(2)</sup><sup>(3)</sup>,  
ALBERI M. <sup>(2)</sup><sup>(3)</sup>, CHIARELLI E. <sup>(2)</sup><sup>(3)</sup>

<sup>(1)</sup> CAEN S.p.A.

<sup>(2)</sup> Dipartimento di Fisica e Scienze della Terra, Università di Ferrara

<sup>(3)</sup> INFN, Sezione di Ferrara

Il progetto CAEN Educational nasce con l'obiettivo di trasferire nei laboratori didattici l'esperienza maturata da CAEN in oltre quarant'anni di collaborazione con la comunità della Fisica Nucleare e delle Alte Energie. Il cuore del progetto è rappresentato da kit sperimentali progettati per introdurre studenti e docenti allo studio di fenomeni fisici complessi attraverso esperienze pratiche. L'offerta si rivolge a un pubblico ampio: dalle scuole secondarie ai corsi universitari, fino alla formazione avanzata per dottorandi e tecnici. I contenuti spaziano dalla statistica alla rivelazione di particelle, dalla radiazione naturale all'imaging nucleare. Elemento distintivo della proposta formativa di CAEN è l'organizzazione di corsi, seminari e scuole tematiche. Ogni anno si svolgono eventi presso la sede aziendale, aperti a laureandi e dottorandi, che uniscono teoria e pratica in un ambiente altamente specializzato. Queste iniziative si realizzano anche grazie a importanti collaborazioni con università ed enti di ricerca. CAEN rafforza così il proprio ruolo nella diffusione della cultura scientifica e nella formazione delle future generazioni di scienziati e professionisti.

Aula Multimediale C, Section C, Edificio 19

ore 09:00 – 13:30

## Sezione Giovani

Relazioni su invito

### ▲ My quantum journey.

VENEGAS-GOMEZ A.

*QURECA*

It is common to hear that once you study physics, you end up either doing research or going to industry. In a career path, there is no either or; your professional experience is built day by day by your choices and the skills you develop. I studied aerospace engineering and ended up working in industry, for the number one European multinational aerospace and defence corporation. At that time, my career development was settled, and I would have become one of the leading managers. However, I asked myself the questions: what do I want to do? What makes me happy? In this contribution I will take you through my professional journey, how I built QURECA, and how we support the quantum ecosystem globally.

### ▲ Unique career paths in quantum: Embracing the journey.

MESSARITAKI A.

*IOP Publishing*

Your career journey after you graduate will be unique : it is a personalized path, shaped by your academic backgrounds, skills, personal interests and market demands. As a recent graduate or an early-career physicist, you have a myriad of career options open to you, as your expertise are in high demand across a variety of sectors from healthcare to data science and beyond. If you have expertise in quantum science, you are uniquely positioned to make your mark on industry. According to the State of Quantum 2024 report, 33 countries around the world have government initiatives or national strategies in quantum technology. So there is also a substantial and growing need to build a quantum workforce with the necessary physics knowledge and quantum proficiency. But there is generally significant growth of physics-based roles in other sectors such as green energy, engineering and data science, too. Physics skills have always been valued by many industries even those not directly related to physical sciences, such as finance. The physics know-how is considered an advantage, as is the ability to creatively solve complex problems. But most jobs require more than just scientific expertise—they generally ask for additional transferable skills that will enable candidates to successfully apply their scientific knowledge within the workplace. I have experienced that first hand by pursuing a career in scientific publishing. I will share my own career journey with you as well as the non-conventional career journeys of some highly successful physicists and offer insights on the demands for physics expertise in the current job market.

### ▲ QTris: Playing the theory to grasp its logic. An operational formalism to explore the structure of quantum mechanics.

NAZZARO M.

*Università degli Studi di Napoli “Federico II”*

QTris is the quantum version of the classic tic-tac-toe game: a board game designed as a playable formalism of quantum mechanics, grounded in quantum information theory. The

entire game dynamics are isomorphic to those of a system composed of 9 qubits: each square of the  $3 \times 3$  grid corresponds to a qubit (an elementary subsystem); the available actions (represented by playing cards) operate on one or two qubits at a time. The gameplay mirrors the operational structure of a quantum experiment, articulated in its three fundamental phases: preparation, operations, and measurements. Each card encodes an operation that the player can strategically apply to a quantum state, modifying the arrangement of the tiles on the grid to steer the outcome of the game to their advantage. Without relying on metaphors, the game promotes direct and strategic engagement with the core concepts of the theory, offering a form of science communication grounded in authentic accessibility.

▲ **Common (Quantum) People: learning, living and building the Quantum Future.**

FOTI C.

*Algorithmiq*

Quantum mechanics doesn't just reshape our scientific understanding –it redefines how we think. By challenging our most intuitive notions of reality, it opens space for radically new ideas, technologies, and perspectives. But if we want to build a future shaped by quantum technologies –transforming fields from medicine and materials science to AI and beyond– we need more than algorithms and lab results. We need people: curious, creative, and equipped with the language of quantum thought. In this talk, I share reflections from my journey through research, education, and science communication –from my PhD years to my work at Algorithmiq and the development of QPlayLearn. I explore how embracing intuition, navigating uncertainty, and colouring outside disciplinary lines can foster inclusive, interdisciplinary innovation –and help shape a more accessible quantum future.

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Aula 10, Section C, Edificio 19

ore 09:00 – 13:30

### Simposio Il Fisico nelle professioni di oggi

Presiede: RIZZO L. (LABRIS, Castro, LE e Ordine dei Fisici e dei Chimici di Lecce e Brindisi)

Relazioni su invito

#### ▲ Il lungo percorso della Professione Fisico: dalla Legge 4/2013 sulle professioni non ordinistiche all'attuale Federazione Nazionale dei Fisici e dei Chimici.

PIRANEO S.

*UO di Fisica Sanitaria ASP di Agrigento*

In Italia gli ordini professionali, come li conosciamo oggi, sono nati nel 1944 con il Decreto Legislativo n. 382, con lo scopo di vigilare sul comportamento dei propri iscritti e verificare l'osservanza degli obblighi deontologici, nell'interesse degli stessi iscritti. La professione del fisico non era regolamentata da alcun ordine professionale, fino a poco tempo fa sono esistite solo associazioni professionali e scientifiche. Nel 2013, la legge n. 4 ha previsto la possibilità per il singolo professionista, iscritto o meno a un'associazione, di ottenere da un organismo accreditato dall'Ente Unico Nazionale di Accreditamento, la certificazione di conformità a una "norma tecnica" relativa all'esercizio della professione. La certificazione rilasciata non costituiva comunque requisito necessario per l'esercizio dell'attività professionale. Solo nel 2018 con la Legge n. 3 (Legge Lorenzin), di riordino delle professioni sanitarie e tecniche, viene istituito l'ordine unico dei fisici e dei chimici, prevedendo dei requisiti per l'iscrizione e l'esercizio della professione, prima non codificati.

#### ▲ Il ruolo del fisico nella ricerca e innovazione tecnologica per la sicurezza: competenze, metodologie e applicazioni.

FALCONI S.

*Ministero dell'Interno, Dipartimento della Pubblica Sicurezza, Polizia di Stato, Roma, Italia*

Il fisico riveste un ruolo strategico nella ricerca e innovazione tecnologica per la sicurezza, grazie alla sua formazione nell'analisi quantitativa, nella modellizzazione di sistemi complessi e nella sperimentazione avanzata. Contribuisce allo sviluppo di tecnologie emergenti chiave come la sensoristica avanzata, i materiali funzionali, la crittografia quantistica, e le reti di comunicazione sicure. È inoltre centrale nell'analisi predittiva e nella simulazione di scenari critici, applicando modelli fisico-matematici e algoritmi di machine learning per il riconoscimento di anomalie e la gestione di grandi dati. In ambito applicativo, opera in contesti multidisciplinari per la sicurezza civile, militare e ambientale, partecipando alla progettazione di sistemi resilienti e alla valutazione del rischio tecnologico. Il fisico agisce infine da ponte tra ricerca di base e soluzioni operative, contribuendo a risposte efficaci, scalabili e scientificamente fondate alle sfide della sicurezza contemporanea. Programmi europei come Horizon Europe, in particolare nel Cluster "Civil Security for Society", valorizzano il contributo del fisico promuovendo progetti di ricerca integrata, trasferimento tecnologico e cooperazione internazionale, ponendo la figura del fisico al centro dell'innovazione per la protezione delle infrastrutture critiche e la gestione dei rischi complessi.



▲ **Verifica di compatibilità di vernici con tecnica EDS.**

PETRAGLIA A., MARZAIOLI F., RUBINO M.

*Dipartimento di Matematica e Fisica, Lab. Circe, Università degli Studi della Campania "Luigi Vanvitelli", Caserta*

In questo contributo descriviamo un'applicazione della Spettrometria X a Dispersione di Energia (Energy Dispersive X-ray Spectrometry – EDS), collegata ad un Microscopio a Scansione Elettronica (Scanning Electron Microscope – SEM) per la verifica di compatibilità tra vernici automobilistiche in un caso studio reale. Il caso esemplifica l'efficacia della tecnica nell'identificazione e confronto di materiali in ambito forense e industriale. È stato analizzato un lamierino prelevato da un'auto urtata, recante una strisciata, poi confrontato con due campioni di vernice possibili sospetti. Una prima analisi ha permesso di distinguere la composizione chimica della strisciatura da quella della vernice originale del veicolo. Nella susseguente indagine, i due campioni di vernice testati hanno mostrato spettri sostanzialmente diversi da quelli rilevati sulla strisciatura. Si è quindi potuto ragionevolmente concludere l'incompatibilità tra le vernici e le tracce rilevate sull'auto.

▲ **Elementi di geofisica forense: il caso di via Civita Giuliana a Pompei.**

LEUCCI G.

*Istituto di Scienze del Patrimonio Culturale, ISPC, Consiglio Nazionale delle Ricerche, CNR*

Le scienze forensi sono definite come l'applicazione dei principi e dei metodi scientifici alle tradizionali investigazioni di carattere giudiziario sia esso civile che penale. Lo sviluppo delle scienze forensi procede di pari passo con l'affinamento dell'investigazione scientifica e lo sviluppo culturale. Sebbene lo sviluppo tecnologico negli ultimi anni ha consentito un notevole passo avanti per le investigazioni, la modalità di utilizzo e il pensiero scientifico rivolti all'applicazione della scienza all'attività investigativa sono molto più antiche. Con il termine di "Geofisica Forense" si intende l'insieme delle metodologie della Geofisica Applicata rivolta alla risoluzione di alcune problematiche legate alle investigazioni sia in ambito civile sia in ambito penale. I contributi della geofisica per le scienze forensi sono infatti molteplici e vanno dalla semplice indagine legata ad esempio alla individuazione della presenza o meno delle barre in acciaio nel calcestruzzo armato (cause civili) alla ricerca ben più complicata di sepolture e occultamento di resti umani (cause penali). Si pensi ad esempio anche agli studi sui siti legati a discariche abusive (dove è necessario rivolgere particolare attenzione al grado di un eventuale inquinamento della falda acquifera), alla soluzione di casi inerenti alla presenza di acqua come causa di dissesto nei centri urbani (è importante conoscere le principali vie di scorrimento dell'acqua nel sottosuolo, valutare il contenuto volumetrico d'acqua dei suoli che, assieme alla stima di altri fattori, contribuiscono, ai fenomeni di crollo). Vengono presentate le principali metodologie di indagine legate alla geofisica forense con un caso di studio legato alle indagini geofisiche svolte in via Civita Giuliana a Pompei per evidenziare la presenza o meno di scavi clandestini.

▲ **La fisica applicata alle scienze forensi: il caso degli incidenti stradali con esito grave.**

RIZZO L.

*LABRIS, Laboratorio Ricostruzione Incidenti Stradali Ambiente e Lavoro, Castro, LE e Ordine dei Fisici e dei Chimici di Lecce e Brindisi*

La fisica applicata alle scienze forensi risponde, allo stato attuale, alla cogente necessità emergente nel mondo delle indagini civili o penali, di offrire strumenti adeguati e innovativi, oltreché metodiche di indagine rigorosa, per la risoluzione di casi giudiziari. In tale contesto il fisico può applicare a piene mani strumenti e metodi che rispondono alle esigenze della Giustizia, come nel caso della ricostruzione di eventi incidentali, e in particolare

degli incidenti stradali con esito grave o mortale. Passando dal rilievo sul campo, all'analisi fotogrammetrica dei mezzi, all'applicazione dei Principi di Conservazione della Quantità di Moto e dell'Energia e della verifica *ex post* dell'indagine ricostruttiva mediante l'applicazione di *software* di simulazione basati su tecniche multiphysics, è possibile ricostruire un incidente stradale con esito grave giungendo all'individuazione degli elementi di concausalità che hanno determinato l'evento fisico "incidente".

▲ **Gli aspetti organizzativi quali cause radice degli eventi incidentali di natura colposa.**

CATALDO I.

*LABRIS, Laboratorio Ricostruzione Incidenti Stradali Ambiente e Lavoro, Castro, LE*

Molti degli incidenti di natura colposa sono stati nel tempo attribuiti all'errore *umano*, nell'accezione in cui il termine umano identifica l'operatore che esegue un'azione in grado di compromettere l'esecuzione di una attività, causando un danno per imprudenza, imperizia o negligenza. Un evento incidentale potrebbe però accadere anche in conseguenza di altri fattori, che nell'immediato potrebbero apparire slegati rispetto all'evento stesso, ma essere ugualmente in grado di contribuire ad aumentare anche sensibilmente la probabilità di rischio. Tra questi figurano le criticità e le carenze di tipo "organizzativo", ovvero aspetti non sempre facili da individuare, ma talvolta determinanti nell'insieme complessivo delle cause di eventi incidentali colposi, fino anche a concludere che il solo avvicinare le persone per evitare l'errore umano, senza però averle risolte, potrebbe non essere sufficiente, quando non del tutto inutile. L'obiettivo dichiarato di questo intervento è quello di i) aiutare chi si occupa di *risk assessment* a individuare anche le criticità e le carenze di tipo "organizzativo", tra quelle che in qualche misura sono state, o che potrebbero contribuire a essere, causa di eventi incidentali colposi; ii) mostrare quanto il fisico, con la sua forma mentis naturalmente portata verso il *problem solving*, la formulazione di ipotesi e l'osservazione critica e attenta degli elementi del contesto in rappresentazione, può affrontare con professionalità anche questo ambito. Per meglio fissare le idee sul contributo degli aspetti organizzativi, saranno commentati un paio di casi di studio relativi a eventi incidentali colposi realmente accaduti e tristemente noti per la loro gravità, facendo osservare, a giudizio dell'autore, quanto il sistema organizzativo abbia potuto contribuire nel determinarli.

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Aula Magna G.B.F. Basile, Edificio 7

ore 14:30 – 15:10

SEZIONE II

**Fisica della materia**

Presiede: PATERNOSTRO M. (Università di Palermo)

Relazione Generale

■ **Materiali quantistici modificati da cavità.**

CIUTI C.

*Université Paris Cité, Laboratoire Matériaux et Phénomènes Quantiques, MPQ, CNRS-UMR7162, France*

L'interazione tra sistemi di materia condensata e campi elettromagnetici quantizzati ha aperto nuove prospettive per il controllo dei materiali quantistici. In particolare, l'inserimento di sistemi elettronici all'interno di cavità elettromagnetiche ha mostrato come le fluttuazioni del vuoto e i modi quantizzati del campo possano modificare in modo sostanziale sia lo stato fondamentale sia gli stati eccitati dei materiali, anche in assenza di illuminazione esterna. In questo intervento presenterò una panoramica degli sviluppi teorici ed esperimenti recenti in questo campo emergente. Illustrerò come il campo del vuoto di una cavità possa rimodellare i gap elettronici, influenzare le proprietà topologiche, modificare le proprietà di trasporto elettronico e incidere su fasi quantistiche fortemente correlate, come l'effetto Hall frazionario.

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Aula Magna G.B.F. Basile, Edificio 7

ore 15:10 – 18:30

SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: PALMERINI S. (Università di Perugia e INAF, Osservatorio Astronomico di Roma)

Relazioni su invito

▲ **Il progetto ePIC al futuro Electron-Ion Collider (EIC).**

ELIA D.

*INFN, Sezione di Bari*

La sperimentazione al futuro Electron-Ion Collider (EIC) presso i laboratori di BNL in USA avrà inizio entro la prima metà del prossimo decennio. EIC rappresenta l'unica nuova macchina prevista su questa scala di tempi in grado di accelerare in un ampio intervallo di energie nel centro di massa (da 30 a 140 GeV) e con alta luminosità (fino a  $\sim 10^{34}$  cm $^{-2}$ s $^{-1}$ ) fasci polarizzati di elettroni, protoni e ioni. Nel 2022 si è costituita ufficialmente la collaborazione ePIC (electron-Proton/Ion Collider), finalizzata alla sperimentazione ad EIC con l'omonimo apparato. Il progetto, incentrato su un rivelatore sfidante nelle principali tecnologie di tracciamento, calorimetria e identificazione di particelle, punta a realizzare misure di scattering profondamente inelastico per la comprensione di aspetti fondamentali e tuttora oscuri dell'interazione forte nel Modello Standard. La presentazione offrirà una panoramica dello stato attuale del progetto EIC nonché dei lavori in corso per la definizione e la successiva costruzione del rivelatore ePIC e dei suoi obiettivi di fisica, con particolare enfasi al ruolo della comunità italiana attualmente coinvolta.

▲ **The IDEA detector concept for the FCC-ee.**

PEZZOTTI L.

*INFN, Sezione di Bologna*

The IDEA detector concept, designed for the FCC-ee, is optimized for its unique physics program and operating conditions. It features an ultra-light tracking system with a high-precision vertex detector inside a large drift chamber, wrapped by silicon layers. The calorimetry includes a high-resolution dual-readout crystal electromagnetic calorimeter and a dual-readout fiber hadronic calorimeter. A high-temperature superconducting solenoid provides the magnetic field, and muon detection is achieved through three layers of chambers embedded in the flux return yoke. This integrated design aims to deliver excellent momentum resolution, efficient particle identification, and precise energy measurements to fully exploit the FCC-ee's physics potential.

▲ **The NA60+/DiCE experiment at the CERN SPS.**

SCOMPARIN E. NA60+/DiCE COLLABORATION

*INFN, Sezione di Torino*

The CERN-SPS energy range ( $\sqrt{s_{NN}} \sim 6 - 17$  GeV) is ideal, in the frame of Quark-Gluon Plasma studies, for the investigation of the region of the phase diagram corresponding to finite baryochemical potential ( $\mu_B$ ). We recently proposed a new experiment, NA60+/DiCE, that aims at studying, in Pb-Pb collisions, the energy dependence of the production of thermal dimuons, to obtain a caloric curve of the QCD phase diagram that may be sensitive to the order of the phase transition. In addition, the measurement of a  $\rho - a_1$  mixing

will provide insights into the restoration of the chiral symmetry of QCD. Studies of open charm and charmonium production will address the measurement of transport properties of the QGP and of the onset of the deconfinement transition. Reference measurements with proton-nucleus collisions are an essential part of this program. The experimental set-up couples a vertex telescope based on MAPS detectors to a muon spectrometer with MWPC detectors. Two existing CERN dipole magnets, MEP48 and MNP33, will be used for the vertex and muon spectrometers, respectively. The start of the data taking is foreseen by 2029/2030.

## Comunicazioni

### ● Top quark mass measurement at FCC-ee.

CARRAMUSA G.

*Università di Trieste e INFN, Gruppo Collegato di Udine*

The top quark, the heaviest known elementary particle, plays a key role in the physics of the Standard Model. A precise measurement of its mass will be one of the goals of the Future Circular Collider (FCC), a next-generation collider currently under design and planning by CERN. This contribution presents a simulation study based on Monte Carlo methods for  $e^+e^-$  collisions in the region of  $t\bar{t}$  pair production, with the aim of achieving an improved sensitivity to the top quark mass with respect to existing measurements.

### ● Characterization of depleted monolithic CMOS active pixel sensors for the upgrade of the Belle II Vertex Detector.

BENFRATELLO G.F. FOR THE BELLE II VTX COLLABORATION

*Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa*

The Belle II experiment currently records data at the SuperKEKB  $e^+e^-$  collider, which plans to push luminosity up to  $6 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ . To cope with the increased hit rate and provide minute tracking precision, a new pixelated vertex detector (VTX) is under development, based on the most recent CMOS pixel detection technologies. The radiation environment requires a tolerance to an equivalent 1 MeV neutron fluence of  $5 \times 10^{14} \text{ 1 MeV n}_{\text{eq}}/\text{cm}^2$  and to 1 MGy. In addition, the minimal material budget limits the cooling power and requires operation of the sensor at room temperature. VTX will be equipped with a new depleted monolithic active pixel sensor, OBELIX, designed in the Tower Jazz 180 nm technology, whose pixel matrix is derived from the TJ-Monopix2 sensor. The characterization of the forerunner TJ-Monopix2 sensor after irradiation is crucial for the development of the new OBELIX chip sensor. In this contribution, I will present results from the latest test campaign of the TJ-Monopix2, conducted combining laboratory measurements with beam tests using a 4.2 GeV electron beam at DESY, focusing on sensor performance across a range of temperature and irradiation fluences.

### ● The dRICH detector at the future ePIC experiment.

OCCHIUTO L. ON BEHALF OF THE EPIC-DRICH COLLABORATION

*Univeristà della Calabria e INFN, Sezione di Cosenza*

The ePIC detector is designed as a general-purpose detector to enable the entire physics program of the future Electron-Ion Collider (EIC) at BNL, USA. A key feature will be particle identification (PID). A PID system covering a wide pseudorapidity range  $[-3.3, 3.5]$  is critical for accurately separating electrons from hadrons such as pions, kaons, and protons. PID in the forward region will be provided by a dual Radiator Ring Imaging Cerenkov (dRICH) detector. Photons will be focused by spherical mirrors and detected by silicon photomultiplier sensors placed on six spherical tiles. This presentation aims to provide a concise overview

of the dRICH. The latest studies of the achievable pion-kaon separation efficiency will be shown, exploring its dependence on particle momentum and selected pseudorapidity intervals. Furthermore, GEANT4-based simulation studies will be presented, with a particular emphasis on one of the two radiators integrated in the dRICH, the aerogel, which enables a detailed investigation of particle behavior at the low-momentum regime. The detector's performance, based on chosen geometries, will also be discussed.

● **LHCspin: a polarized fixed-target experiment at the LHC.**

PICCOLI A. <sup>(1)(2)</sup>, LENISA P. <sup>(1)(2)</sup>, PAPPALARDO L. L. <sup>(1)(2)</sup>, CIULLO G. <sup>(1)(2)</sup>, DI NEZZA P. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara*

<sup>(2)</sup> *INFN, Sezione di Ferrara*

<sup>(3)</sup> *INFN, Laboratori Nazionali di Frascati*

Understanding the complex structure of nucleons in terms of quarks and gluons represents one of the most pivotal and contemporary challenges in particle physics. A significant advancement has been made through measurements accessing their multi-dimensional structure, crucial for gaining new insight into the strong interaction in the non-perturbative regime of QCD, as well as for opening new physics frontiers. The LHCspin project aims to precisely investigate the 3D structure of the proton and to perform spin physics studies via high-energy polarized fixed-target collisions, exploiting new probes and exploring new processes in a unique kinematic regime. The LHCspin apparatus requires the installation of a polarized gas target in front of the LHCb spectrometer, bringing spin physics to the LHC for the first time. This builds on the recent installation of SMOG2, an unpolarized gas target that made LHCb the first experiment capable of acquiring data simultaneously in the collider mode at  $\sqrt{s_{NN}} = 14$  TeV and in the beam-target mode at  $\sqrt{s_{NN}} = 100$  GeV. The current status of the LHCspin project is presented along with its scientific potential and experimental setup.

● **The ePIC-dRICH readout system: The RDO card and first irradiation tests.**

GEMINIANI S. ON BEHALF OF THE ePIC-dRICH COLLABORATION

*Dipartimento di Fisica e Astronomia, Università di Bologna e INFN, Sezione di Bologna*

The dual-radiator RICH detector is part of the PID system of the ePIC experiment at the future Electron-Ion Collider. The dRICH is located in the ePIC hadron endcap within a  $\sim 1$  T magnetic field and it ensures hadron identification from 3 up to 50 GeV/c thanks to two Cherenkov radiators. More than 300 thousand  $3 \times \text{mm}^2$  SiPMs are used as photosensors and each of them constitutes a single readout channel. The readout is organized in 1248 Photon Detection Units (PDU), each integrating a FPGA-based readout card (RDO) that controls 4 ALCOR ASICs connected to 256 SiPM pixels. This compact module is designed to fit the dRICH geometry, ensuring reliable performance in a moderately hostile radiation environment that causes sensor damages and potential electronic component failures. The dRICH readout chain will be shown, focusing on the PDU-RDO card connected to the ePIC DAQ system through a 10 Gb/s link. Results from proton irradiation campaigns for key components of the RDO card will be discussed, considering radiation cumulative and single event effects. Finally, the mitigation techniques selected for each electronic component will be highlighted.

● **Innovative approaches to methane capture: from CERN's greenhouse gas reduction strategies to sustainable livestock emissions management.**

TAMIGIO A. <sup>(2)</sup>, ANGIULLI F.A. <sup>(1)(2)</sup>, AIMÈ C. <sup>(1)(2)</sup>, ARENA M.C. <sup>(3)(4)</sup>, BIAGINI D. <sup>(5)(6)</sup>, BRAGHERI A. <sup>(2)</sup>, BRUNOLDI M. <sup>(1)(2)</sup>, CALZAFERRI S. <sup>(1)(2)</sup>, DINUCCIO E. <sup>(5)(6)</sup>,

DONDI D. <sup>(3)</sup><sup>(4)</sup>, FINCO L. <sup>(6)</sup>, GUIDA R. <sup>(4)</sup>, KUMAR KAMESWARAN N. <sup>(1)</sup>, MANDELLI B. <sup>(4)</sup>, MONTAGNA P. <sup>(1)</sup><sup>(2)</sup>, RICCARDI C. <sup>(1)</sup><sup>(2)</sup>, SALVINI P. <sup>(2)</sup>, VAI I. <sup>(1)</sup><sup>(2)</sup>, VADIVEL D. <sup>(3)</sup>, VERNA R. <sup>(6)</sup>, VITULO P. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Pavia*

<sup>(2)</sup> *INFN, Sezione di Pavia*

<sup>(3)</sup> *Dipartimento di Chimica, Università di Pavia*

<sup>(4)</sup> *CERN, Geneva, Switzerland*

<sup>(5)</sup> *Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università di Torino*

<sup>(6)</sup> *INFN, Sezione di Torino*

In recent years at CERN, different strategies have been adopted to prevent the release of greenhouse gases (GHG) into the atmosphere, such as the development of gas recirculation and recuperation systems. The CH<sub>4</sub> Livestock Emission (CH<sub>4</sub>rLiE) project aims at developing a prototype for methane emissions capture in a barn environment. Since a single cow can release 110 kg of methane annually, emissions from livestock farms are significant. CH<sub>4</sub>rLiE, suggests utilizing a recovery system derived from CMS Cathode Strip Chambers CF<sub>4</sub> recovery systems to address the methane that has already been produced and dispersed in the atmosphere. Therefore, the study of gas adsorption by porous materials and the creation of a methane capture prototype system that will be installed in an actual barn are the main objectives of the project. An initial phase of gas diffusion simulations and a campaign of gas concentration measurements in various barn areas are supporting this study. In this contribution I will present the update on the results obtained with the COMSOL simulation software regarding the diffusion of methane in the barn.

### ● Characterization and simulation of SiC-Based Detectors for dosimetry and beam tagging within the SAMOTHRACE ecosystem.

BARBON A. <sup>(1)</sup><sup>(2)</sup>, MARTORANA N.S. <sup>(1)</sup>, D'AGATA G. <sup>(1)</sup><sup>(2)</sup>, CARDELLA G. <sup>(1)</sup>, GERACI E. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, ACOSTA L. <sup>(4)</sup><sup>(5)</sup>, ALTANA C. <sup>(6)</sup>, CASTOLDI A. <sup>(7)</sup>, DE FILIPPO E. <sup>(1)</sup>, DE LUCA S. <sup>(6)</sup>, FIGUERA P. <sup>(6)</sup>, GNOFFO B. <sup>(1)</sup><sup>(2)</sup>, GUAZZONI C. <sup>(7)</sup>, MAIOLINO C. <sup>(6)</sup>, PAGANO E.V. <sup>(6)</sup>, PIRRONE S. <sup>(1)</sup>, POLITI G. <sup>(1)</sup><sup>(2)</sup>, QUATTROCCHI L. <sup>(1)</sup><sup>(8)</sup>, RISITANO F. <sup>(1)</sup><sup>(8)</sup>, RIZZO F. <sup>(2)</sup><sup>(3)</sup><sup>(6)</sup>, RUSSOTTO P. <sup>(6)</sup>, SAPIENZA G. <sup>(6)</sup>, TRIMARCHI M. <sup>(1)</sup><sup>(7)</sup>, TUDISCO S. <sup>(6)</sup>, ZAGAMI C. <sup>(2)</sup><sup>(3)</sup><sup>(6)</sup>

<sup>(1)</sup> *INFN, Sezione di Catania*

<sup>(2)</sup> *Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

<sup>(3)</sup> *CSFNSM, Catania*

<sup>(4)</sup> *Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico*

<sup>(5)</sup> *Instituto de Estructura de la Materia, CSIC, Spain*

<sup>(6)</sup> *INFN, Laboratori Nazionali del Sud, Catania*

<sup>(7)</sup> *DEIB Politecnico Milano e INFN, Sezione di Milano*

<sup>(8)</sup> *Dipartimento MIFT, Università di Messina*

Silicon Carbide (SiC) has recently attracted significant attention for radiation particle detection, thanks to its remarkable properties over traditional silicon detectors. SiC offers high radiation resistance, thermal stability, excellent thermal conductivity, a wide bandgap, and a higher breakdown electric field. Additionally, it provides good time and energy resolution key point for beam tagging. In medical physics, X-rays and ion beams are standard in cancer treatment. More recently, radioactive ion beams (RIBs) like Carbon-11 have emerged as promising tools due to their dual role in hadron therapy and medical imaging. Within the SAMOTHRACE project, SiC detectors are being evaluated for use as dosimeters, micro-dosimeters, and beam tagging for RIBs such as Carbon-11. This study presents the characterization and the simulation of two SiC devices: one with 1 cm surface and 10 m thickness tested as a dosimeter using a radioactive source, and another with the same surface area but

100 m thick. Comparative analysis with other detectors, including silicon and diamond, is also discussed.

● **Quality control of LYSO:Ce crystals for the CMS barrel MIP timing detector.**  
TRABUCCO G.

*Sapienza Università di Roma e INFN, Sezione di Roma*

In the next years, the Large Hadron Collider will enter its High-Luminosity phase. Many CMS subsystems will be upgraded to maintain the current physics performance, despite the higher levels of pileup and radiation. To further mitigate the pileup, a MIP Timing Detector (MTD) for charged particles will be constructed, with a target time resolution of 30-60ps, to distinguish the primary vertices of tracks using timing information. The MTD is divided into two regions, the Barrel and the Endcap Timing Layers (BTL/ETL). The active elements of BTL are arrays of lutetium-yttrium-oxorthosilicate (LYSO) scintillating bars doped with cerium (LYSO:Ce), each readout by two silicon photo-multipliers arrays. The quality of BTL LYSO crystals in the production phase has been controlled in the past years in a dedicated laboratory in INFN Rome. This has been done, both for a sample of arrays and single crystals, by monitoring dimensional properties, light output, time resolution, optical cross talk and decay time, by means of a Na-22 radioactive source. The quality assurance phase for BTL is concluded. In this presentation a summary of the activity and a presentation of the results will be given.

● **Studio del danno da radiazioni da protoni nei Silicon Photomultiplier del rivelatore dual RICH in ePIC.**

VALENTI M. PER LA COLLABORAZIONE EPIC-DRICH

*Dipartimento di Fisica e Astronomia, Università degli studi di Catania e INFN, Sezione di Catania*

L'Electron-Ion Collider (EIC) è un futuro acceleratore di particelle progettato per esplorare l'interazione forte mediante collisioni tra fasci polarizzati di elettroni e ioni o protoni. La Collaborazione ePIC si sta occupando dello sviluppo dell'omonimo esperimento e dei vari sistemi di rivelatori, tra cui il dRICH (dual-radiator RICH) che sarà impiegato per la Particle Identification su un intervallo di impulsi che va da alcune centinaia di MeV/c fino a 50 GeV/c nella regione forward e utilizzerà SiPM per rivelare i fotoni Cherenkov. In questa comunicazione si presenteranno i risultati di uno studio sul danno da radiazione in tre modelli di SiPM Hamamatsu, irradiati con protoni al TIFPA di Trento fino a una fluensa di  $e9 \text{ MeV.n}_{eq}$ . Sono stati misurati la tensione di breakdown e il dark count rate, prima e dopo cicli di annealing di 150 ore a 175 °C. I risultati ottenuti saranno discussi in vista della qualificazione dei sensori per l'esperimento.

● **Misura della diffusione di Ar nella miscela TFE:SF6:iso-C4H10 per i volumi di gas degli RPC di ATLAS fase 2.**

PERRONE M.F.

*Università della Calabria e INFN, Sezione di Cosenza*

Per far funzionare efficientemente e a lungo un rivelatore gassoso di grande superficie è necessario rinnovare costantemente il gas di cui è riempito. L'inserimento del gas fresco e il recupero di quello usato devono avvenire in modo che tutto il volume sia interessato da questa sostituzione, senza lasciare isole di gas non rinnovato che porterebbero ad un malfunzionamento locale del rivelatore. Tuttavia, è inevitabile che nel volume della gap esistano zone sfavorite in cui il ricambio di gas, dovuto soltanto al flusso di gas fresco iniettato nella gap, è minimo o almeno molto inferiore al valor medio della gap. In queste zone la diffusione diventa perciò il meccanismo dominante per garantire il ricambio. Presentiamo



qui un metodo per misurare i coefficienti di diffusione di vari gas nel volume di un RPC a gap sottile di ATLAS fase 2 di formato  $10\text{ cm} \times 280\text{ cm}$ .

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Aula 11, Section C, Edificio 19

ore 15:10 – 18:30

SEZIONE II

**Fisica della materia**

Presiede: LORENZO S. (Università di Palermo)

Relazioni su invito

▲ **Photonic quantum convolutional neural networks with adaptive state injection.**

POLACCHI B. <sup>(1)</sup>, MONBROUSSOU L. <sup>(2)</sup><sup>(3)</sup>, YACoub V. <sup>(2)</sup>, CARUCCIO E. <sup>(1)</sup>, RODARI G. <sup>(1)</sup>, HOCH F. <sup>(1)</sup>, CARVACHO G. <sup>(1)</sup>, SPAGNOLO N. <sup>(1)</sup>, GIORDANI T. <sup>(1)</sup>, BOSSI M. <sup>(4)</sup><sup>(5)</sup>, RAJAN A. <sup>(4)</sup><sup>(5)</sup>, DI GIANO N. <sup>(4)</sup><sup>(5)</sup>, ALBIERO R. <sup>(5)</sup>, CECCARELLI F. <sup>(5)</sup>, OSELLAME R. <sup>(5)</sup>, KASHEFI E. <sup>(2)</sup><sup>(6)</sup>, SCIARRINO F. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Sapienza Università di Roma*

<sup>(2)</sup> *Laboratoire d'Informatique de Paris 6, Sorbonne Université, France*

<sup>(3)</sup> *CEMIS, Direction Technique, Naval Group, France*

<sup>(4)</sup> *Dipartimento di Fisica, Politecnico di Milano*

<sup>(5)</sup> *CNR, Istituto di Fotonica e Nanotecnologie*

<sup>(6)</sup> *School of Informatics, University of Edinburgh, UK*

Linear optical systems have been widely explored for applications in quantum computing and quantum machine learning. Recently, photonic quantum machine learning approaches have incorporated adaptive features, such as dynamic circuit reconfiguration, to improve expressivity, algorithm performance, and scalability. Furthermore, the particle-number-preserving feature of such platforms has been recently shown to offer advantages in terms of computational efficiency and parameter economy of quantum convolutional neural networks, compared to other models. We design and experimentally realize a photonic quantum convolutional neural network based on particle-number-preserving circuits enhanced with adaptive state injection, an emerging strategy aimed at improving the controllability of linear optical architectures, enabled via post-selection processing. We test it on a binary image classification task through a photonic setup based on a semiconductor quantum dot single-photon source and programmable integrated photonic interferometers with 8 and 12 modes. Our findings support applications of Boson Sampling equipped with adaptive techniques, compatible with near-term quantum devices.

▲ **Neural quantum simulation of quantum dynamics: recent advances and limitations.**

VICENTINI F.

*Ecole Polytechnique, Paris, France*

Neural-network encodings of quantum states have been shown in recent years to be powerful tools to tackle the quantum many body problem. While several outstanding results have been shown, especially when tackling spin systems such as the J1-J2 model, simulating variational dynamics is proving to be much challenging. In this presentation, I will discuss recent advances in simulating dynamics by using a multitude of approaches, ranging from repeated state compression approaches (pt-VMC), discussing global optimisation ones that yield the full solution with a single optimisation problem, and finishing with the variational representation of full Krylov-like subspaces. Then, I will discuss our recent understanding of what is limiting those simulations, how this is related to the limits of Tensor Network methods, and what are the advantages of those neural-network based approaches.

▲ **On the tight relations between shadow tomography and quantum extreme learning machines.**

INNOCENTI L.

*Dipartimento di Fisica e Chimica Emilio Segré, Università di Palermo*

Shadow tomography and quantum extreme learning machines (QELMs) have recently been shown to be highly interesting approaches to estimate features from input states. On the surface, these might seem completely distinct methods: shadow tomography offers a way to estimate many properties of an unknown state using a surprisingly small number of measurements, while quantum extreme learning machines (QELMs) adaptively learn to predict desired outcomes from training data without requiring prior calibration of the measurement apparatus. I will discuss how these seemingly different approaches are actually very naturally tightly related. More specifically, training a QELM can be seen as the data-processing step of shadow tomography, and furthermore the estimation strategy of shadow estimation precisely mirrors the readout layer of a QELM. This explains why QELMs self-calibrate on imperfect hardware, shares the same sample efficiency as shadow protocols under suitable measurement conditions, and suggests hybrid strategies that combine the best of both worlds.

Comunicazioni

● **Experimental quantum state estimation via quantum extreme learning machine.**

ZIA D., INNOCENTI L., MINATI G., LORENZO S., SUPRANO A., DI BARTOLO R., SPAGNOLO N., POLINO E., GIORDANI T., CIMINI V., PALMA G.M., FERRARO A., SCIARRINO F., PATERNOSTRO M.

*Università di Roma La Sapienza*

Addressing the pivotal task of accurately estimating properties of quantum states in quantum information science, our focus lies on harnessing Quantum Extreme Learning Machines (QELMs) to recover properties of photonic quantum states encoded in the polarization degree of freedom, utilizing orbital angular momentum (OAM) as an ancillary degree of freedom. We investigated both the single-photon and two-photon regimes, respectively studying the reconstruction of their polarization state and the witnessing of their entanglement. Our QELM-based strategy offers a remarkably flexible, resource-efficient, and resilient approach to quantum state estimation. Our experimental implementation, leveraging the controlled quantum walk dynamics in a photonic platform that intertwines the polarization and OAM degrees of freedom of a photon, showcases excellent performance in property reconstruction without the need for the accurate and careful characterization of the platform. Indeed, working on the measured probabilities, our approach is agnostic to the underlying dynamics. Therefore, it automatically accounts for noise and imperfections and self-calibrates to the specific experimental setting.

● **Noise classification in three-level quantum networks by machine learning.**

MUKHERJEE S. <sup>(1)</sup>, PENNA D. <sup>(2)</sup>, CIRINNÀ F. <sup>(2)</sup>, PATERNOSTRO M. <sup>(3)(4)</sup>, PALADINO E. <sup>(1)(5)(6)</sup>, FALCI G. <sup>(1)(5)(6)</sup>, GIANNELLI L. <sup>(1)(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(2)</sup> *Leonardo S.p.A., Cyber and Security Solutions, Catania*

<sup>(3)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(4)</sup> *Centre for Theoretical Atomic, Molecular, and Optical Physics, School of Mathematics and Physics, Queens University, Belfast, UK*

<sup>(5)</sup> INFN, Sezione di Catania

<sup>(6)</sup> CNR-IMM, UoS Università, Catania

We investigate machine learning-based classification of noise affecting a three-level system, aiming to detect spatial or multilevel correlations and their interplay with Markovianity. We control a three-level system by inducing coherent population transfer with different pulse amplitude combinations and train a feedforward neural network to classify classical dephasing noise. We demonstrate that supervised learning can distinguish between three non-Markovian noise types quasi-static correlated, anti-correlated, and uncorrelated and Markovian noise with over 99% accuracy. However, within the Markovian class, correlated and anti-correlated noise cannot be discriminated by our method. We show that it is possible to apply the same approach to a system of two ultrastrongly coupled qubits, and to successfully classify Markovian noise correlations as well. Our method is robust against statistical measurement errors and remains effective even with limited sample sizes, making it highly suitable for experimental implementation. These results pave the way for classifying spatial noise correlations in quantum architectures.

● **Machine learning-aided optimal control of a qubit under non-markovian dynamics.**

CANTONE R. <sup>(1)</sup>, MUKHERJEE S. <sup>(1)</sup>, GIANNELLI L. <sup>(1)(2)</sup>, PALADINO E. <sup>(1)(2)(3)</sup>, FALCI G. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> Dipartimento di Fisica e Astronomia, Università di Catania

<sup>(2)</sup> INFN, Sezione di Catania

<sup>(3)</sup> CNR-IMM, Catania

We apply a graybox machine learning framework to model and control a qubit undergoing Markovian and non-Markovian dynamics from environmental noise. The approach combines physics-informed equations with a lightweight transformer neural network trained on tomographically complete simulated data. It learns an effective operator that predicts observables accurately, even with strong memory effects. We study Random Telegraph Noise and Ornstein-Uhlenbeck noise, both inducing pure dephasing, across a range of coupling strengths. RTN is considered in a regime with a switching rate high enough for the noise to fluctuate dynamically during the system's evolution. At weak coupling, the model achieves prediction errors below 1% and maintains good accuracy in more challenging regimes. The trained emulator supports gradient-based quantum optimal control, achieving gate fidelities above 90%, and exceeding 99% in certain regimes. We also assess limitations by benchmarking against known protocols, such as the Uhrig Dynamical Decoupling sequence. As quantum technologies near practical deployment, data-efficient models, grounded in physics are increasingly valuable for scalable, noise-aware control.

● **Memory-augmented hybrid quantum reservoir computing for complex systems.**

SETTINO J. <sup>(1)</sup>, SALATINO L. <sup>(1)</sup>, MARIANI L. <sup>(2)</sup>, PLASTINA F. <sup>(1)</sup>, GIORDANO A. <sup>(2)</sup>, MASTROIANNI C. <sup>(2)</sup>, D'AMORE F. <sup>(2)</sup>, GENCARELLI C.N. <sup>(3)</sup>, PRIMAVERA L. <sup>(1)</sup>, CARBONE F. <sup>(3)</sup>

<sup>(1)</sup> Università della Calabria

<sup>(2)</sup> CNR-ICAR

<sup>(3)</sup> CNR-IIA

Reservoir computing (RC) is an effective method for predicting chaotic systems by using a high-dimensional dynamic reservoir with fixed internal weights, while keeping the learning phase linear, which simplifies training and reduces computational complexity compared to fully trained recurrent neural networks (RNNs). Quantum reservoir computing (QRC)

utilizes the exponential growth of Hilbert spaces in quantum systems, allowing for greater information processing, memory capacity, and computational power. We present a hybrid quantum-classical approach that implements memory through classical post-processing of quantum measurements, thus avoiding the need for multiple coherent input injections. This approach has been applied to predict the dynamics of chaotic systems, such as the Lorenz system and the projection of the Navier-Stokes equations onto a finite set of coupled normal modes. We observe a clear relationship between the neuromorphic network's performance and the underlying dynamics of the analyzed time series.

● **Detection of noise correlations in two qubit system by Machine Learning.**

FASONE D. <sup>(1)(2)</sup>, MUKHERJEE S. <sup>(1)</sup>, PENNA D. <sup>(1)</sup>, CIRINNÀ F. <sup>(3)</sup>, PATERNOSTRO M. <sup>(4)</sup>, PALADINO E. <sup>(1)(5)(6)</sup>, GIANNELLI L. <sup>(1)(5)</sup>, FALCI G. <sup>(1)(5)(6)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(2)</sup> *Università degli Studi di Napoli Federico II*

<sup>(3)</sup> *Leonardo S.p.A., Cyber and Security Solutions, Catania*

<sup>(4)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(5)</sup> *INFN, Sezione di Catania*

<sup>(6)</sup> *CNR-IMM, UoS Università, Catania*

We propose a method to detect spatial noise correlations affecting two qubits. Our detector consists in two ultra-strongly coupled qubits driven by a two-tone field. The dynamics is reduced to an effective three-level system in a ladder configuration. We analyze the parameters regime for which it is possible to effectively apply the STIRAP protocol transfers population from the ground state of the two-qubits to the doubly excited state. By analyzing the efficiency under different pulse conditions, we show it is possible to classify the correlations of noise affecting the two qubits. This, in turn, provides insight into the Markovian or non-Markovian nature of the environmental noise.

Aula 12, Section C, Edificio 19

ore 15:10 – 18:30

SEZIONE II

**Fisica della materia**

Presiede: CAROLLO A. (Università di Palermo)

Relazioni su invito

▲ **Optical nonlinearities of exciton-polaritons in 2D semiconductors.**

BALLARINI D., SANVITTO D., DE GIORGI M., POLIMENO L., TODISCO F., FIERAMOSCA A.  
*CNR-NANOTEC*

Exciton-polaritons are hybrid light-matter quasiparticles that arise from the strong coupling between excitonic resonances and confined optical modes in microcavities. While foundational studies have primarily focused on GaAs-based heterostructures, the emergence of two-dimensional semiconductors such as transition metal dichalcogenide (TMD) monolayers and layered perovskites has opened new avenues for exploring polariton physics in novel material and photonic regimes. This presentation focuses on the simultaneous enhancement of light-matter coupling and polariton nonlinearities by engineering both the electromagnetic environment and the excitonic properties of the active materials. Coupling efficiency and interaction strength are further improved through unconventional cavity designs that leverage phenomena such as surface optical modes and bound states in the continuum, as well as through material innovations like suspended monolayers and single-crystal layered perovskites. The results establish 2D polaritons as promising platforms for fundamental investigations, as well as for the development of integrated photonic technologies for classical and quantum information processing.

▲ **Topological photon-mediated interactions with giant atoms.**

CICCARELLO F.

*Università di Palermo*

A set of (artificial) atoms coupled off-resonantly to an engineered photonic bath generally undergo a unitary dynamics described by an effective decoherence-free atomic Hamiltonian. If the bath is provided with non-trivial topology, this can be inherited by the atomic Hamiltonian. Here, we consider “giant atoms”, i.e. artificial atoms coupled non-locally to the field, which can be today implemented e.g. in circuit-QED setups. We derive general, model-independent, conditions in order for the atomic Hamiltonian to be endowed with non-trivial topology. This can occur even when the photonic bath has trivial topology. Some paradigmatic instances in 1D and 2D lattices are discussed.

▲ **Engineering polariton superconductivity in twisted 2D materials.**

POLINI M.

*Università degli Studi di Pisa*

Twisted 2D materials such as twisted bilayer graphene (TBG) and twisted WSe<sub>2</sub> tend to host (unconventional) superconducting states only deep in the flat-band regime near the magic angle. By using TBG in the framework of the Eliashberg theory of superconductivity, in this talk I will discuss how dark polaritonic cavities can be used to engineer polariton-mediated superconductivity in TBG away from the magic-angle regime.

## Comunicazioni

● **Strong coupling between a single-photon and a two-photon state.**

SAVASTA S. <sup>(8)</sup>, WANG S.P. <sup>(1)(2)(3)</sup>, MERCURIO A. <sup>(4)</sup>, RIDOLFO A. <sup>(5)</sup>, WANG Y. <sup>(1)</sup>, CHEN M. <sup>(1)</sup>, LIU Y. <sup>(1)</sup>, SUN H. <sup>(1)</sup>, LI T. <sup>(1)(6)</sup>, NORI F. <sup>(7)</sup>, YOU J.Q. <sup>(3)</sup>

<sup>(1)</sup> *Beijing Academy of Quantum Information Sciences, China*

<sup>(2)</sup> *Quantum Physics and Quantum Information Division, Beijing Computational Science Research Center, China*

<sup>(3)</sup> *3Zhejiang Key Laboratory of Micro-Nano Quantum Chips and Quantum Control, School of Physics and State Key Laboratory for Extreme Photonics and Instrumentation, Zhejiang University, Hangzhou, China*

<sup>(4)</sup> *Institute of Physics, EPFL, Lausanne, Switzerland*

<sup>(5)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(6)</sup> *School of Integrated Circuits, and Frontier Science Center for Quantum Information, Tsinghua University, Beijing, China*

<sup>(7)</sup> *Quantum Computing Center and Cluster for Pioneering Research, RIKEN, Wako-shi, Saitama, Japan*

<sup>(8)</sup> *Dipartimento MIFT, Università di Messina*

The realization of strong nonlinear coupling between single photons has been a long-standing goal in quantum optics and quantum information science. Here, we report an experimental observation of the strong coupling between a single-photon and a two-photon Fock state in an ultrastrongly-coupled circuit-QED system. This strong nonlinear interaction is realized by introducing a detuned flux qubit working as an effective coupler between two modes of a superconducting coplanar waveguide resonator. The ultrastrong light-matter interaction breaks the excitation number conservation, and an external flux bias breaks the parity conservation. The combined effect of the two enables the strong one-two-photon coupling. Quantum Rabi-like avoided crossing is resolved when tuning the two-photon resonance frequency of the first mode across the single-photon resonance frequency of the second mode. Within this new photonic regime, we observe thresholdless second harmonic generation for a mean photon number below one. These results represent a key step towards a new regime of quantum nonlinear optics, where individual photons can deterministically and coherently interact with each other.

● **Quantum optics with giant atoms in a structured photonic bath.**

LEONFORTE L. <sup>(1)</sup>, SUN X. <sup>(1)(2)</sup>, VALENTI D. <sup>(3)(1)</sup>, SPAGNOLO B. <sup>(3)(1)</sup>, ILLUMINATI F. <sup>(4)(5)(6)(1)</sup>, CAROLLO A. <sup>(1)(1)</sup>, CICCARELLO F. <sup>(1)(7)(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *School of Physics and Telecommunication Engineering, Zhoukou Normal University, China*

<sup>(3)</sup> *Dipartimento di Fisica e Chimica, Group of Interdisciplinary Theoretical Physics, Università di Palermo*

<sup>(4)</sup> *INFN, Sezione di Napoli, Gruppo collegato di Salerno*

<sup>(5)</sup> *Dipartimento di Ingegneria Industriale, Università degli Studi di Salerno, Fisciano*

<sup>(6)</sup> *Institute of Nanotechnology, CNR NANOTEC, Lecce*

<sup>(7)</sup> *NEST, Istituto Nanoscienze-CNR, Pisa*

Giant atoms are an emerging paradigm of quantum optics, which can exhibit unprecedented effects thanks to their multiple, non-local coupling to a photonic waveguide/ lattice. Here, their behavior is for the first time settled within a general theory based on the Green's function. This encompasses, within a comprehensive framework, effects such as decoherence-free Hamiltonians (DFHs) in a waveguide and emergence of atom-photon bound states (BSs)

in structured lattices. As a major application, we provide for the first time a general criterion to predict/engineer DFHs of giant atoms, which can be applied both in and out of the photonic continuum and regardless of the structure or dimensionality of the photonic bath. This is used to show novel DFHs in 2D baths such as a square lattice, photonic graphene and an extended photonic Lieb lattice.

● **Non-Markovian dynamics of a qubit due to accelerated light in a lattice.**

SFERRAZZA G.L. <sup>(1)</sup>, PINTO M. A. <sup>(1)</sup>, DE BERNARDIS D. <sup>(2)(3)</sup>, CICCARELLO F. <sup>(1)(4)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *National Institute of Optics, CNR-INO, Sesto Fiorentino*

<sup>(3)</sup> *European Laboratory for Non-Linear Spectroscopy, LENS, Sesto Fiorentino*

<sup>(4)</sup> *NEST, Istituto Nanoscienze-CNR, Pisa*

We investigate the emission of a qubit weakly coupled to a one-band coupled-cavity array where, due to an engineered gradient in the cavity frequencies, photons are effectively accelerated by a synthetic force  $F$ . For strong  $F$ , a reversible emission described by an effective Jaynes-Cummings model occurs, causing a chiral time-periodic excitation of an extensive region of the array, either to the right or to left of the qubit depending on its frequency. For weak values of  $F$  instead, a complex non-Markovian decay with revivals shows up. This is reminiscent of dynamics induced by mirrors in standard waveguides, despite the absence of actual mirrors, and can be attributed to the finite width of the energy band which confine the motion of the emitted photon. In a suitable regime, the decay is well described by a delay differential equation formally analogous to the one governing the decay of an atom in a multi-mode cavity where the cavity length and time taken by a photon to travel between the two mirrors are now embodied by the amplitude and period of Bloch oscillations, respectively.

● **Revealing environment-induced topological phase transitions.**

PAVAN F., PERRONI C.A., DE FILIPPIS G., DI BELLO G., DE CANDIA A., CATAUDELLA V.  
*Università di Napoli Federico II*

We study nonperturbative effects of environmental coupling in the Su-Schrieffer-Heeger (SSH) chain, where local oscillator baths interact with intra- or intercell hopping. Contrary to common assumptions, such coupling can induce topological phase transitions when suitably engineered. In order to go beyond the weak-coupling Lindblad regime, we use world-line Quantum Monte Carlo (QMC) and Matrix Product States (MPS) to map the model's phase diagram. We identify the polarization probability distribution as a marker of topological transitions under open boundaries. For periodic boundaries, we complement this with a qualitative analysis using cluster perturbation theory, which yields accurate dressed Green's functions and reveals bulk observables sensible to topological phase. Moreover this approach provides an effective non-Hermitian fermionic description. Finally, we simulate the system's dynamics under various filling conditions using the Matrix Product Operator (MPO) formalism, revealing distinct signatures of topological transitions induced by fermion-boson coupling.

● **Amplitude, phase, and topological fluctuations shaping the complex phase diagram of two-dimensional superconductors.**

MIDEI G. <sup>(1)(2)</sup>, FURUTANI K. <sup>(3)(4)</sup>, PERALI A. <sup>(5)</sup>, SALASNICH L. <sup>(6)(7)(8)</sup>

<sup>(1)</sup> *School of Science and Technology, Physics Division, Università di Camerino*

<sup>(2)</sup> *INFN, Sezione di Perugia*

<sup>(3)</sup> *Department of Applied Physics, Nagoya University, Japan*

<sup>(4)</sup> *Institute for Advanced Research, Nagoya University, Japan*



<sup>(5)</sup> *School of Pharmacy, Physics Unit, Università di Camerino*

<sup>(6)</sup> *Dipartimento di Fisica e Astronomia, Università di Padova e QTech Center, Padova*

<sup>(7)</sup> *INFN, Sezione di Padova*

<sup>(8)</sup> *CNR, Istituto Nazionale di Ottica, Sesto Fiorentino*

We study the amplitude and phase fluctuations of the Ginzburg-Landau quasiorder parameter for superconductors in two spatial dimensions. Starting from the mean-field critical temperature, we calculate the beyond-mean-field critical temperature by including thermal fluctuations of the quasiorder parameter within the Gaussian level. Moreover, from our beyond-mean-field results, we derive the Berezinskii-Kosterlitz-Thouless critical temperature, which takes into account topological vortex-antivortex excitations in the phase fluctuations as well as the amplitude fluctuations, to obtain the shifts of transition temperatures. We elucidate how the Gaussian thermal fluctuations and phase fluctuations associated with vortex excitations affect thermodynamic properties by determining the H-T phase diagram for a type-II superconductor and computing the critical behaviors of the heat capacity, which are experimentally accessible, allowing the characterization of the cascade of different kinds of fluctuations in 2D superconductors.

### ● Emission dynamics in a photonic lattice with quadratic atom-photon interaction.

IPPOLITO G. <sup>(1)</sup>, DI BENEDETTO E. <sup>(1)</sup>, RABL P. <sup>(2)</sup><sup>(3)</sup><sup>(4)</sup>, CICCARELLO F. <sup>(1)</sup><sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *Technical University of Munich, TUM School of Natural Sciences, Garching, Germany*

<sup>(3)</sup> *Walther Meissner Institut, Bayerische Akademie der Wissenschaften, Garching, Germany*

<sup>(4)</sup> *Munich Center for Quantum Science and Technology, Munich, Germany*

<sup>(5)</sup> *NEST, Istituto Nanoscienze-CNR, Pisa*

In recent years, atom-photon interactions in engineered photonic lattices, such as coupled-cavity arrays, have attracted growing interest also due to their potential applications for quantum technologies. So far, a standard Jaynes-Cummings-like (JCL) interaction was considered. Here, we investigate for the first time the emission of a two-level atom under quadratic atom-photon interaction such that the emitter's decay to the ground state produces two photons instead of a single one. We analytically study the emission dynamics in the weak-coupling regime in the case of a 1D homogeneous coupled cavity array (CCA). We show that the system behaves like an atom emitting into a 2D CCA via the standard JCL interaction. Remarkably, by introducing attractive photon-photon interactions via local Kerr terms, we unveil a regime where the atom effectively behaves as if it were coupled to a 1D CCA through the standard JCL interaction, but the fact the emitted photon is replaced by a pair of bound photons.

## SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: SALAMANNA G. (Università di Roma Tre)

Relazioni su invito

▲ **Status of the DarkSide-20k experiment.**

BONIVENTO W.M. FOR THE DARKSIDE-20K COLLABORATION

*INFN, Sezione di Cagliari*

DarkSide-20k is an experiment aimed at the direct detection of Weakly Interacting Massive Particle dark matter. Currently under construction at the Laboratori Nazionali del Gran Sasso (LNGS) of the INFN in Italy, the experiment is based on a 50-tonne dual-phase Liquid Argon TPC filled with underground, low-radioactivity argon. This TPC is surrounded by two active veto systems, all housed within a proto-DUNE-like membrane cryostat. Although certain components, such as the membrane cryostat, have already been produced and installed, the construction of the experiment still faces several technical challenges. These include the assembly and testing of 20 m<sup>2</sup> of cryogenic SiPMs into readout modules, the construction of a fully acrylic-based TPC, and the development of industrial-scale facilities for the extraction, purification, and testing of underground argon. To validate the chosen technical approaches, a few prototypes are currently undergoing testing at both LNGS and the University and INFN of Naples. The experiment is anticipated to achieve world-class sensitivity in the search for both high- and low-mass WIMP dark matter and the detection of supernova neutrinos.

▲ **The XENONnT experiment: detector performance, results, and future prospects.**

SELVI M. ON BEHALF OF THE XENON COLLABORATION

*INFN, Sezione di Bologna*

The XENONnT experiment, located deep underground at the INFN Laboratori Nazionali del Gran Sasso, is designed to search for dark matter particles with unprecedentedly low background levels. Its core is a dual-phase xenon time projection chamber with a 5.9-ton active target, shielded and complemented by water Cherenkov muon and neutron veto detectors. Since the beginning of operations at the end of 2020, XENONnT has achieved an exposure of approximately 3.1 tonne-years by August 2023. This initial dataset demonstrated the lowest electronic recoil background ever recorded in a dark matter detector, clarified the excess previously observed by XENON1T, and placed stringent constraints on various new physics scenarios, including improved limits on WIMP interactions. Since then, XENONnT has completed an additional science run with greater exposure, enhanced radon mitigation, and an upgraded gadolinium-doped neutron veto, further improving sensitivity. In this contribution, we report on the performance of the detector, the results achieved, and the future prospects of the experiment.

▲ **QUAX.**BRAGGIO C. <sup>(1)(2)</sup>, CARUGNO G. <sup>(1)</sup>, DI VORA R. <sup>(3)</sup>, MAIELLO D. <sup>(1)(2)</sup>, ORTOLAN A. <sup>(3)</sup>, RUOSO G. <sup>(3)</sup>, SARDO INFIRRI G. <sup>(1)(2)</sup><sup>(1)</sup> *INFN, Sezione di Padova*<sup>(2)</sup> *Dipartimento di Fisica e Astronomia, Università di Padova*<sup>(3)</sup> *INFN, Laboratori Nazionali di Legnaro*

QUAX is an axion haloscope, which looks for the resonant conversion of dark matter axions to microwave photons in a strong magnetic field. It is designed to probe higher mass

axions compared to existing haloscopes, within an unexplored range that poses a number of technological challenges. In its latest runs, the apparatus installed at LNL has reached almost KSVZ sensitivity in a relatively broad range of masses around 42 microeV, proving its readiness to evolve into an observatory. This talk will describe the recent progress we have made in this experimental search based on a dielectrically-boosted, tunable cavity resonator readout by a travelling-wave parametric amplifier, and parallel experimental efforts to improve the sensitivity of the detector by the use of transmon-based microwave photon counters.

## Comunicazioni

### ● L'esperimento ReD+ per la caratterizzazione di rinculi nucleari in argon alla scala del sub-keV.

PINO N. PER IL WORKING GROUP DI ReD+

*INFN, Laboratori Nazionali del Sud, Catania*

Camere a Proiezione Temporale ad argon in doppia fase (LAr TPC) sono utilizzate per la ricerca diretta di particelle di materia oscura (masse  $\sim 100$  GeV) debolmente interagente (WIMP). Le future LAr TPC mirano ad avere una sensibilità tale da estendere la ricerca a WIMP con masse dell'ordine del GeV. Queste darebbero in LAr Rinculi Nucleari (NR) di pochi keV, scala di energia alla quale la risposta dell'argon non è ben nota. L'esperimento Recoil Directionality (ReD) della collaborazione DarkSide-20k ha da poco studiato la risposta per NR fino a 2 keV, con un approccio di cinematica a due corpi, irraggiando una LAr TPC con neutroni prodotti da una sorgente di  $^{252}\text{Cf}$ . Oggetto di questo contributo è il progetto PRIN ReD+. Una LAr TPC appositamente progettata verrà calibrata presso i Laboratori Nazionali del Sud dell'INFN sia con neutroni da  $^{252}\text{Cf}$  che neutroni prodotti da un generatore deuterio-deuterio. L'obiettivo è studiare NR ad energie minori di quelle osservate con ReD, fino alla scala del sub-keV. ReD+ (2022JCYC9E) è supportato dal Min. Univ. e Ricerca tramite PNRR, M4-C2-Inv. 1.1 e finanziato dall'Unione Europea-NextGeneration EU (CUP I53D23000690006).

### ● Esperimento CUPID e segnatura di assioni.

PETRILLO L.

*Dipartimento di Fisica, Università la Sapienza di Roma e INFN, Sezione di Roma*

CUPID (CUORE Upgrade with Particle IDentification) è un esperimento di nuova generazione per la ricerca del decadimento doppio beta senza neutrini ( $0\nu\beta\beta$ ), un processo chiave per indagare la natura di Majorana del neutrino e testare violazioni del numero leptonico. Il rivelatore, basato su bolometri scintillanti, è in grado di effettuare una lettura simultanea del segnale di calore e della luce di scintillazione. CUPID combina un'eccellente risoluzione energetica, alta radiopurezza e una grande massa attiva, rendendolo uno degli esperimenti più sensibili per la fisica oltre il Modello Standard. In questo contesto, presento un'analisi condotta sui dati dell'esperimento precursore CUPID-0, mirata alla ricerca di assioni, particelle ipotetiche candidate a costituire la materia oscura. L'analisi si focalizza sull'interazione degli assioni nei cristalli scintillanti, basata su processi quali l'effetto assio-elettico e la produzione di coppie indotta da assioni, con l'obiettivo di porre nuovi vincoli sperimentali sulle costanti di accoppiamento. Questi risultati contribuiranno a restringere lo spazio dei parametri dei modelli teorici e a guidare future ricerche sperimentali.

### ● Searching for axion dark matter with radio telescopes.

VISINELLI L.

*Dipartimento di Fisica, Università degli Studi di Salerno e INFN, Sezione di Napoli, Gruppo Collegato di Salerno*

The QCD axion, originally proposed to resolve the strong CP problem, is also a compelling dark matter (DM) candidate. In strong magnetic fields, such as those surrounding neutron stars, axions can convert into photons, potentially generating detectable radio signals. This axion-photon coupling offers a unique avenue for experimental searches in a well-defined mass range. In this seminar, I will present an observational study using the Green Bank Telescope (GBT) to search for transient radio signals from axion-photon conversion. Focusing on the core of Andromeda, we employ the VErsatile GBT Astronomical Spectrometer (VEGAS) and the X-band receiver (8-10 GHz) to probe axions with masses between 33 and 42  $\mu\text{eV}$ , achieving a mass resolution of  $4 \times 10^{-10}$  eV. We describe our observational strategy and analysis techniques, which reach an instrumental sensitivity of 2 mJy per spectral channel. While no candidate signals exceeding the  $5\sigma$  threshold were detected, I will discuss future improvements, including expanding the search to additional frequency bands and refining theoretical models, to strengthen constraints on axion DM scenarios. Based on 2407.13060, 2011.05378, 2011.05377.

● **Proto0: a versatile two-phase argon TPC prototype for DarkSide-20k.**

FLORES L., FIORILLO G., MATTEUCCI G.

*Dipartimento di Fisica, Università di Napoli Federico II*

DarkSide-20k (DS20k) is a dark matter direct detection experiment that aims to hunt for WIMPs using a two-phase argon time projection chamber (TPC). Within the DS20k programme, a small prototype named DarkSide-Proto0 (Proto0) was recently operated to investigate and optimize the production of the ionization signal (S2) in two-phase argon TPCs and validating many of the novel technologies featured in the DS20k detector on a smaller scale. The TPC of Proto0 is designed to accommodate two PDUs, the  $20 \times 20 \text{ cm}^2$  SiPM-based photon counters developed for DS20k. The main feature of the Proto0 detector is its flexible TPC design, with independently moving components during operation. This enables an optimization study of S2 formation in relation to geometrical factors and electrical properties. The results obtained from Proto0's scientific program will help fine-tune the DS20k TPC design and contribute to a broader understanding of the engineering behind future two-phase experiments. The data taking campaign was carried out at the cryogenic laboratory at Unina/INFN Naples and data analysis is ongoing.

● **Study of muon-induced neutrons in XENONnT.**

BELIGOTTI V. ON BEHALF OF THE XENON COLLABORATION

*Università di Bologna e INFN, Sezione di Bologna*

XENONnT, the latest detector of the XENON project, situated at the INFN Laboratori Nazionali del Gran Sasso, aims to detect WIMP through Nuclear Recoils in a dual-phase LXe TPC. It employs two dedicated veto systems to suppress backgrounds: the Muon Veto (MV), for identifying muon signals, and the Neutron Veto (NV), which detects neutrons, primarily of radiogenic origin. Cosmic muons and their induced neutrons remain one of the main sources of natural background, even for underground experiments. We present here an overview of the background produced by cosmic muons that reach the experiment and the impact of their induced particles in the TPC. Particular focus is given to the production of muon-induced neutrons, whose interactions in the LXe target can mimic WIMP-like signals, if not properly identified.

● **X-fermion as the dark matter of the Universe**

VERESHCHAGIN G., RUFFINI R.

*ICRANet, Pescara*

Decades of observations of the Galactic center led to the determination of the mass of Sgr A\* in  $4.3 \times 10^6 M_\odot$  and firm limits on its angular momentum. The most straightforward

interpretation of these observations is a Schwarzschild black hole. We consider an alternative, which is a self-gravitating system of dark matter fermions (X-fermions) having a quantum degenerate core and extended to non-degenerate isothermal halo. Upon accreting baryonic matter the core may collapse providing seeds to supermassive black holes. We address the implications of X-fermions with mass  $m_X \sim 300$  keV endowed with a large and negative chemical potential on structure formation. The Jeans mass of X-fermions peaks at  $10^{10} M_\odot$  at  $z \sim 10^9$ , setting the scale of galactic structures. The degenerate cores forming as early as  $z \sim 14$  are consistent with observations of the Little Red Dots at  $4 < z < 12$  harboring supermassive black holes in the range  $10^6 - 10^9 M_\odot$ . Assuming that Sgr A\* is not yet a BH the upper limit on the X-fermion mass of  $m_X < 381$  keV are established, relevant for ongoing JWST observations and the planning of accelerators in CERN.

● **The SABRE north project at Gran Sasso Laboratory.**

KHATTAK S.G., ANANNA C., CATALDI G., MICCOLI A., DE GIORGI M.L., DI CARLO M., DI GIACINTO A.D., IANNI A., D'INCECCO M., NISI S., PIETROFACCIA L., VIGNOLI C., BOLOGNINO I., D'ANGELO D., MARTINENGHI E., TOSO V., CAPODIFERRO M., CHIODI G., DIEMOZ M., D'IMPERIO G., IANNONE M., MARIANI A., PETTINACCI V., RAHATLOU S., TOMEI C., ZUHRA S.

*Università del Salento e INFN, Sezione di Lecce*

The SABRE-North experiment aims to deploy an array of ultra-low-background NaI(Tl) crystals to model-independently search for annual modulation signature of dark matter. The SABRE detector will be installed underground at LNGS and consists of an array of 9 ultra-high radiopurity NaI(Tl) detectors (5 kg mass each) in a Cu and PE shielding. The anticipated background rate in the 1,6 keV ROI is of around 0.5 dru, similar to that of the DAMA/LIBRA experiment. To achieve low intrinsic background, SABRE purifies the NaI crystals through the Zone Refining process. This latter can reduce the radioactive impurities concentration by factor 10. The Z.R. technique involves locally melting a moving zone of the ingot which causes impurities to segregate toward the ends of the crystal. My talk focuses on a mathematical model based on mass transfer equations that numerically simulates the Z.R. process. The model accounts for parameters such as the crystal's geometry, dimensions, and the type of impurity. It can be calibrated against ICP-MS measurements to determine the segregation coefficients and to optimize the number of passes required during production.

● **Stationary rotating and axially symmetric dust systems as peculiar General Relativistic objects.**

RUGGIERO M.L.

*Università degli Studi di Torino e INFN, Laboratori Nazionali di Legnaro*

We examine an exact solution of Einstein's equations that describes a self-gravitating dust system with axial symmetry and stationary rotation. We demonstrate that such a configuration does not have a counterpart in Newtonian gravity. In the low-energy limit, the existence of this solution is governed by a Grad-Shafranov equation in vacuum, which can be interpreted as a Laplace equation for the toroidal component of the gravitomagnetic potential. Notably, in this system, relativistic rotational effects are comparable in magnitude to their Newtonian counterparts. Based on this, we suggest that the solution likely contains singularities, and we explore the implications of employing such a model as a simplified representation of galactic dynamics.

Aula Seminari B, Section B, Edificio 19

ore 15:10 – 18:30

SEZIONE IV  
**Geofisica e fisica dell'atmosfera**  
Presiede: MADONIA P. (INGV)

Relazioni su invito

▲ **The UN decade of ocean science for sustainable development: The coastal resilience challenge.**

PINARDI N.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

Oceans play a vital role in the climate system, with their interactions with coastlines presenting both opportunities and critical hazards. Rising sea levels, marine heatwaves, storms, pollution, and erosion highlight the urgent need for better coastal system understanding and risk management. As part of GOOS, CoastPredict integrates real-time data with predictive models to enhance short-term risk response and long-term mitigation. Expanding digital twins to include nature-based solutions is key to advancing coastal protection beyond traditional infrastructure. A core aspect of CoastPredict's approach is leveraging cloud-based computing and fostering public-private collaboration to ensure accessible, integrated data systems. This contribution will present the GlobalCoast experiment and the cutting-edge solutions proposed for implementation.

▲ **La previsione meteorologica operativa in Italia a supporto dell'utenza multi-settoriale del Paese. L'opportunità offerta dall'Agenzia ItaliaMeteo.**

CACCIAMANI C.

*Agenzia ItaliaMeteo*

L'informazione meteo-climatica è fondamentale per numerosi settori della società. Oltre alla protezione civile (che la utilizza per valutare rischi da eventi estremi come alluvioni o tempeste), è essenziale anche per l'ottimizzazione della produzione e distribuzione dell'energia, per la pianificazione delle semine e la difesa delle colture, per la prevenzione di crisi idriche e per una organizzazione efficiente e sicura dei trasporti, con importante ricaduta nel settore del turismo. L'evoluzione tecnologica (satelliti, radar, modelli previsionali) ha migliorato la precisione delle previsioni, rendendole uno strumento fondamentale per chi prende decisioni pubbliche o private in situazioni potenzialmente critiche. In Italia, l'offerta di servizi meteo-climatici è ancora limitata, disomogenea e poco coordinata. A differenza di molti altri Paesi, l'Italia ha avuto per lungo tempo solo un servizio meteorologico civile legato all'ambito militare e dell'aviazione. Ciò ha portato alla nascita di diversi servizi regionali, soprattutto al Nord, creando però frammentazione, mancanza di standard comuni e, di conseguenza, inefficienze. Per superare queste criticità, è nata l'Agenzia ItaliaMeteo (istituita con la legge 205/2017) con l'obiettivo di coordinare e valorizzare l'intero sistema meteorologico nazionale, unificando risorse, competenze e tecnologie. I suoi compiti principali includono la centralizzazione e distribuzione dei dati meteo tramite il portale MeteoHub, la gestione del sistema di modellazione ICON per le previsioni, la promozione della formazione e della standardizzazione della comunicazione meteorologica. La sede centrale dell'Agenzia è a Bologna, al momento presso la sede della Regione Emilia-Romagna, ma presto si trasferirà al DAMA Tecnopolo di Bologna, che da tempo ospita anche il Data Centre del Centro Meteorologico Europeo per le previsioni a Medio Termine (ECMWF). Nell'ambiente stimolante del Tecnopolo, che offre il massimo della innovazione tecnologica in materia di calcolo e gestione

di big data, l'Agenzia potrà sempre più elaborare e distribuire prodotti e servizi climatici, occuparsi di formazione, partecipare a progetti e programmi europei e internazionali in materia di meteorologia e climatologia e promuovere la collaborazione coi soggetti privati che a loro volta contribuiscono a diffondere servizi meteo e climatici ai vari settori produttivi del paese.

#### Comunicazioni

##### ● **Measurement of radioactivity on the sea near the Apulian coasts.**

LARocca F. <sup>(1)</sup>, MAGALETTI L. <sup>(1)(2)</sup>, PATICCHIO V. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Bari Aldo Moro, Italia*

<sup>(2)</sup> *INFN, Sezione di Bari, Italia*

<sup>(3)</sup> *Politecnico di Bari, Italia*

This work presents the results of gamma-ray spectroscopic analysis of seawater samples collected along the Apulian coast between June and September 2024, with measurements concentrated primarily in the provinces of Brindisi and Taranto. High-Purity Germanium (HPGe) detectors were employed to perform high-resolution measurements aimed at identifying both natural and anthropogenic radionuclides. As expected, potassium-40 was consistently detected in all samples; in selected locations, traces of other natural radionuclides such as isotopes of lead, thallium, and bismuth were also observed. A comparative analysis with 2025 data, currently being acquired from the same and additional sites, will provide insights into spatial and temporal variability. The campaign is expected to expand along the coasts of all Apulian provinces, laying the groundwork for a standardized and continuous environmental monitoring program.

##### ● **Characterization of dynamical properties and indicators of regime change in intermittent chaotic systems.**

BARONE A. <sup>(1)</sup>, SAVARY T. <sup>(2)</sup>, DEMAEYER J. <sup>(2)</sup>, VANNITSEM S. <sup>(2)</sup>, CARRASSI A. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics and Astronomy, University of Bologna, Bologna, Italy*

<sup>(2)</sup> *Royal Meteorological Institute of Belgium, Brussels, Belgium*

Intermittency, once seen as the alternation between regular and irregular states, now includes systems that switch among multiple regimes. This behavior spans fields such as geophysics, plasma physics, neuroscience, and economics. Traditional studies have focused on global indicators—for example, the average frequency of regime changes or their response to external forcing. However, these indicators miss the local spatio-temporal characteristics of the dynamics. We propose a combined global and local analysis of intermittency across five systems of varying complexity and three types of intermittency. Using tools such as Lyapunov exponents and Covariant Lyapunov Vectors (CLVs), we characterize both global dynamics and local transitions. Notably, we find a robust correlation between CLV alignment and transitions, consistent across all cases. These findings improve our understanding of intermittency mechanisms and may enhance prediction of regime changes in turbulent geophysical flows, rainfall, and atmospheric convection. They also support the development of early warning systems and training of neural networks in a low-dimensional latent space for automatic prediction.

##### ● **Modeling natural complex systems: The interplay of nonlinearity and noise.**

VALENTI D. <sup>(1)</sup>, GRIMAUDO R. <sup>(2)</sup>, LAZZARI P. <sup>(3)</sup>, SOLIDORO C. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica “Emilio Segrè”, Università degli Studi di Palermo, Palermo, Italy*

<sup>(2)</sup> *Department of Physics and Astronomy “E. Majorana”, University of Catania, Catania,*



*Italy*

<sup>(3)</sup> *National Institute of Oceanography and Applied Geophysics-OGS, Trieste, Italy*

A marine ecosystem, described by the 0-dimensional stochastic version of the well-known biogeochemical flux model, is investigated. More specifically, experimental data of the solar irradiance, collected on the sea surface, are used in a system of partial differential equations to model the stochastic dynamics of bacterial and planktonic populations. The coefficient of variation (a proxy of the variance) of the biomass shows a nonmonotonic behaviour as a function of the noise intensity, suggesting a noise-induced transition of the ecosystem to an out-of-equilibrium steady state. This result indicates that, to correctly and exhaustively grasp experimental features of natural systems, the mathematical description can neglect neither nonlinearity nor environmental random perturbations, whose interplay is the key ingredient to explain the dynamics of real natural complex systems such as marine ecosystems.

● **Climatic oscillations between 5.2 and 4.8 million years (Lower Pliocene, Zanclean) in the Capo Bianco succession (Eraclea Minoa, Sicily).**

CARUSO A. <sup>(1)</sup>, GUCCIONE P. <sup>(1)</sup><sup>(2)</sup>, COSENTINO C. <sup>(1)</sup>, SCOPELLITI G. <sup>(3)</sup>, HERBERT T. <sup>(4)</sup>

<sup>(1)</sup> *Università degli Studi di Palermo, STEBICEF*

<sup>(2)</sup> *Università degli Studi di Bari Aldo Moro, Dipartimento di Scienze della Terra e Geoambientali*

<sup>(3)</sup> *Università degli Studi di Palermo, DISTEM*

<sup>(4)</sup> *Brown University, Department of Earth, Environmental, and Planetary Sciences, Providence, RI, USA*

The Zanclean is an interval of the Earth characterized by high concentrations of CO<sub>2</sub>, comparable to current measurements in the atmosphere with values up to 500 ppm. Paleoclimatic data and average temperature of the Earth indicate during the early Zanclean values higher than about 3–4 °C than the current one. A high-resolution study, conducted on a succession outcropping at Capo Bianco (Eraclea Minoa, Sicily), highlighted how the temperatures of the surface waters of the central Mediterranean oscillated between 23 and 27 °C. These oscillations influenced the productivity of calcareous plankton and the productivity of biogenic carbonate. The spectral analysis highlighted that these parameters were controlled by the precession of the equinoxes with a periodicity of 21 ky.

● **The role of aerosol types in mediating the impact of galactic cosmic rays on climate variability over the past two decades.**

KARIMIAN SARAKHS F. <sup>(1)</sup>, MADONNA F. <sup>(1)</sup><sup>(2)</sup>, DE PASQUALE S. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics, University of Salerno, Italy*

<sup>(2)</sup> *National Research Council of Italy-Institute of Methodologies for Environmental Analysis, CNR-IMAA*

Galactic Cosmic Rays (GCRs), high-energy particles from supernovas, may influence the Earth's climate by ionizing atmospheric aerosols, accelerating cloud condensation nuclei (CCN) formation, and altering cloud cover. However, the magnitude of this natural forcing remains a subject of debate. This study uses multivariate linear regression to model monthly anomalies in near-surface air temperatures based on GCR flux and other solar/climate variables: sunspot number, geomagnetic indices, greenhouse gas concentrations (CO<sub>2</sub>, CH<sub>4</sub>), cloud effective radius (CER), cloud liquid water, radiation, and aerosol optical depth (AOD) across different latitudes. Data from the past 20 years, sourced from satellite, surface instruments, and neutron monitoring stations in Hermanus (South Africa, low-latitude), Newark (USA, mid-latitude), and Oulu (Finland, high latitude), were analyzed. CER and AOD emerged as the most significant predictors across all stations. Including GCR flux improved model performance, raising adjusted  $R^2$  values from 0.22 to 0.31 (Oulu), 0.37 to



0.52 (Newark), and 0.69 to 0.78 (Hermanus). ECMWF reanalysis suggests sea salt aerosols (5–20  $\mu\text{m}$ ) dominate, possibly aiding GCR-driven CCN.

● **Exploring the concept of climatology for application in preventive conservation.**

FRASCA F. <sup>(1)</sup>, BERTOLIN C. <sup>(2)</sup>, SIANI A.M. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics, Sapienza University of Rome, Rome, Italy*

<sup>(2)</sup> *Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology, Trondheim, Norway*

The rising importance of microclimate studies in preventive conservation has resulted in increased availability of long-term data series. Despite the potential of acclimatisation, there is still little consensus on calculation procedures and how to overcome inherent limitations, such as minimal time series length and persistence of risky conditions. Inspired by the WMO Climatological Standard Normal, this contribution aims to provide a data-driven procedure to establish the indoor climatological standard normal. This enables investigating the acclimatisation of hygroscopic materials, helping to limit mechanical deterioration. The procedure explores approaches with increasing complexity to compute allowable fluctuations based on multi-year microclimate observations collected in various indoor conservation spaces. A novel aspect of the proposed humidity data analysis is its focus on the frequency of values beyond allowable fluctuations and their persistence. In conclusion, detailed knowledge of the minimal microclimate history of a material is pivotal for understanding its current conservation state and addressing present and future challenges posed by climate-driven extreme events.

● **Space weather in Italy: An outline of the state-of-the-art and some perspectives about future developments.**

PIANA M. <sup>(1)</sup>, VILLANTE U. <sup>(2)</sup>, CASOLINO M. <sup>(3)</sup>, DEL MORO D. <sup>(4)</sup>, LAURENZA M. <sup>(5)</sup>, LEPIDI S. <sup>(6)</sup>, PIERSANTI M. <sup>(2)</sup>, TOZZI R. <sup>(6)</sup>

<sup>(1)</sup> *MIDA, Dipartimento di Matematica, Università di Genova*

<sup>(2)</sup> *Dipartimento di Scienze Fisiche e Chimiche, Università dell'Aquila*

<sup>(3)</sup> *Istituto Nazionale di Fisica Nucleare, Sezione Roma "Tor Vergata"*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Roma "Tor Vergata"*

<sup>(5)</sup> *IAPS, Istituto Nazionale di Astrofisica*

<sup>(6)</sup> *Istituto Nazionale di Geofisica e Vulcanologia*

Space weather aims at understanding and predicting the manifestations of the active Sun and their impact on the interplanetary and planetary environments. Studying the conditions on the Sun, in the solar wind, and in the magnetosphere, ionosphere, and thermosphere, space weather develops computational and data analysis models that can forecast and nowcast the influence of such conditions on both space-borne and ground-based technological assets. Also in view of the 2026 edition of the European Space Weather Week, for the first time hosted by Italy, this contribution will describe the state of the art of Italian research in space weather and outline its next most promising developments.

● **Measurement of the cosmic rays rate at different altitudes in the range 220-1880 masl from Cosenza to botte donato refuge in Sila Grande.**

SCHIOPPA M. <sup>(1)</sup>, PASSARELLI D. <sup>(2)</sup>, PETRONIO C. <sup>(3)</sup>

<sup>(1)</sup> *Università della Calabria and INFN*

<sup>(2)</sup> *Catanzaro high school*

<sup>(3)</sup> *IIS A. Volta - Reggio Calabria*

The aim of this work is to introduce modern equipment and technologies, employed in particle physics, to high school students, to improve physics teaching and learning. The

chosen natural phenomena to investigate with the students was the ionizing particle present in the air all around us. This research activates abilities that we often do not know we possess, improves our understanding of one or more phenomena and above all instills curiosity and provides the key to understanding the natural phenomena observed, and ultimately helps to communicate their discoveries and thoughts to others. A group of about 40 students, from three different institutes, was trained for a whole day by competent and authoritative university researchers in this field of physics. Then, the measurement campaign was carried out during an excursion in Sila Grande in May 2024. The activity concludes with the analysis of the acquired data, the discussion of the results and the drafting of the final note. The results of the satisfaction tests of the activity carried out by the students and the final evaluation of what the students acquired in terms of notions and language skills are presented in this report.

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Aula 9, Section C, Edificio 19

ore 15:10 – 18:30

## SEZIONE V

## Biofisica e fisica medica

Presiede: MARRALE M. (Università di Palermo e INFN, Sezione di Catania)

Relazioni su invito

▲ **Biological applications at the AQUA beamline of the EuPRAXIA@SPARC LAB Free Electron Laser.**

DE SANTIS E. <sup>(1)</sup>, ANDRÈ T. <sup>(2)</sup>, BEAN R. <sup>(3)</sup>, FERRARIO M. <sup>(4)</sup>, MARCELLI A. <sup>(4)</sup><sup>(5)</sup>, MINICOZZI V. <sup>(1)</sup>, PRINCIPI E. <sup>(6)</sup>, TIMNEANU N. <sup>(2)</sup>, CALEMAN C. <sup>(2)</sup><sup>(7)</sup>, STELLATO F. <sup>(1)</sup>

<sup>(1)</sup> *Department of Physics, University of Rome Tor Vergata and INFN, Italy*

<sup>(2)</sup> *Department of Physics and Astronomy, Uppsala University, Sweden*

<sup>(3)</sup> *European XFEL GmbH, Germany*

<sup>(4)</sup> *INFN-LNF, Italy*

<sup>(5)</sup> *RICMASS & ISM-CNR, Italy*

<sup>(6)</sup> *Elettra-Sincrotrone Trieste, Italy*

<sup>(7)</sup> *Center for Free-Electron Laser Science, DESY, Germany*

Free Electron Lasers produce intense, coherent, femtosecond X-ray pulses with exceptional brightness, coherence, and tunability, enabling time-resolved studies of electronic, structural, and chemical dynamics across physics, chemistry, and biology. The EuPRAXIA project is a pan-European initiative to build the first dedicated plasma-based accelerator user facility. As part of this effort, EuPRAXIA@SPARC LAB in Frascati will deliver soft X-ray FEL pulses to a diverse international user community. The AQUA endstation, a key component of this facility, will support experiments in atomic and molecular physics, chemistry, and life sciences. Operating in the “water window” AQUA provides high contrast between carbon-rich biomolecules and their aqueous environment, allowing visualization of proteins, viruses, and cellular fragments under near-physiological conditions. This contribution explores AQUA’s potential to drive advances in biology, focusing on simulations of combined coherent diffractive imaging and Coulomb explosion imaging applications. These examples highlight how AQUA will open new frontiers in structural biology, biophysics, and biochemical reaction dynamics.

▲ **Laser fabricated microlenses for in vivo imaging.**

CHIRICO G.

*Dipartimento di Fisica G. Occhialini, Università di Milano-Bicocca, Milano*

Non-linear excitation optical microscopy is not enough to reach through skin imaging. The electric field is in fact spread in both space and time, only a small fraction of the injected energy reaches the target object and the spot size increases with the penetration depth. Physical correction of the scattering arising from tissue can be done by means of holographic approaches. However, the small size of the isoplanatic patches in tissues is a strong practical limitation. I will discuss how the use of microfabricated biocompatible and implantable lenses can overcome some of the issues. Microlenses were implanted in two animal models, chicken embryo and mice and observed for long-lasting experiments. By employing them under two- or three-photon excitation, we could obtain a label-free characterization of the type of cells recruited to the implant site. These results, part of a EU project (IN2SIGHT, GA:964481), are promising in the direction of label-free digital pathology on small animals.

▲ **Laser-plasma radiation production for life science applications: status and perspective with the upcoming I-LUCE facility at INFN-LNS**

CIRRONE G.A.P., ABUBAKER F., ALTANA C., AMATO A., ARJMAND S., BANDIERAMONTE D., BONANNO D., CARUSO A., CATALANO R., CUTTONE G., FAROKHI F., GUARRERA M., FATTORI S., HASSAN A., KURMANOVA A., MACALUSO N., MANNA C., MESSINA G.E., MIRAGLIA A., MUSUMECI M.S., OLIVA D., PAPPALARDO A.D., PETRINGA G., SUAREZ J., TUDISCO S., RIZZO D., SCIUTO A., VINCIGUERRA F.

*Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy*

The potential for developing compact, high-brightness particle and radiation sources have given a strong impetus to the development of the underpinning laser technology, including increasing the efficiency and repetition rate of the lasers. A result of this technological development can be seen in the new generation of ultrafast high-power laser systems working at a high repetition rate which are in development around the world. A new high-power laser facility called "I-LUCE" (INFN Laser induced radiation production) will be realized at LNS-INFN (Laboratori Nazionali del Sud - Istituto Nazionale di Fisica Nucleare) in 2026. The laser systems are currently being developed, and the facility is expected to be fully operational by 2028. The facility realization is funded by three projects financed by the PNRR (Piano Nazionale ripresa resilienza) Italian program: EuAPS (EuPRAXIA Advanced Photon Sources), Samothrace (SiciliAn MicronanOTech. Research And Innovation) and Anthem (AdvaNced Technologies for HumancentrEd Medicine). The Ti:Sapphire laser will have two outputs: the first one will be a 45 TW/10Hz beam while the main beam line will be a 320TW/2.5Hz laser I-LUCE will serve two distinct experimental areas known as E1 and E2. E1 will offer a globally unique combination of laser-generated plasmas with accelerated heavy ion beams, generated by a Superconducting Cyclotron and a Tandem (already installed at LNS), thereby providing opportunities for intriguing experiments in the fields of plasma physics, nuclear physics, and atomic physics. For moderate laser beam intensities (up to 45 TW), the experimental room E1 will be dedicated to conducting experimental runs focused on nuclear fusion and studying stopping power in plasma. Conversely, the E2 experimental room will be dedicated to both proton and electron acceleration. A specialized beamline designed to select, transport, and focus proton beams with energies between 5-60 MeV will be installed and optimized for radiobiological experiments. A station dedicated to electron acceleration in the laser wakefield acceleration (LWFA) regime will also be installed. This station will be equipped with a gas-jet system, online diagnostics, and a selection system capable of isolating electrons with energies ranging from 100 MeV to several GeV. A corresponding beamline for selecting electron beams will also be implemented. Furthermore, stand-alone experiments involving intense laser beams will be conducted to explore various studies, including X-ray laser generation and neutron production. This presentation will provide an overview of the current status and future prospects of the I-LUCE facility.

Comunicazioni

● **Inorganic nanocarriers for cancer therapy.**

LEPORATTI S.

*CNR Nanotec, Istituto di Nanotecnologia, Lecce*

Inorganic materials, such as nanoclays and silica nanoparticles, have tuneable properties and are ideal candidates for several biomedical applications, such as cancer therapy. This contribution wants to report recent developments of inorganic nanoparticles. Furthermore, novel strategies of administration routes by using different types of inorganic nanoparticles are also overviewed.

● **Covid-19 and thermal gradient.**

NASSISI V. <sup>(1)(2)</sup>, ALIFANO P. <sup>(3)</sup>

<sup>(1)</sup> *Department of Mathematics and Physics, University of Salento, Lecce, Italy*

<sup>(2)</sup> *Department of Biological and Environmental Sciences and Technologies, University of Salento, Lecce, Italy*

<sup>(3)</sup> *Laboratory of Microbiology, Department of Experimental Medicine, University of Salento, Lecce, Italy*

The heavy spread of the Covid-19 pandemic worries humanity. Currently, the Covid-19 pandemic is extinguished, but following its evolution is very important. We discuss how specific weather factors have influenced the virus transmission. We analysed the incidence of Covid-19 as a function of latitude and in particular on the temperature speed during the morning up, and in the afternoon down, and other factors that justify the spread of the pandemic in the world and in Italy. The studies on the spread of Covid-19 were conducted in January 2025. The pandemic peaks as a function of latitude are around  $-25$  (°) and  $+50$  (°) which are independent of only temperature. In-depth studies were conducted for the Italian regions from 2019 to 2025 finding out that the slope of total cases is always positive.

● **Spectroscopic profiling of SH-SY5Y cell differentiation: An FTIR microspectroscopy approach to identify key biomolecular changes.**

NATALELLO A. <sup>(1)</sup>, AMI D. <sup>(1)</sup>, BOVIO F. <sup>(1)</sup>, FORCELLA M. <sup>(1)</sup>, BRIOSCHI M. <sup>(1)</sup>, MEREGHETTI P. <sup>(2)</sup>, FUSI P. <sup>(1)(3)</sup>

<sup>(1)</sup> *Department of Biotechnology and Biosciences, University of Milano-Bicocca, Milano, Italy*

<sup>(2)</sup> *Bioinformatics Consultant, Arquata Scrivia, AL, Italy*

<sup>(3)</sup> *MISTRAL, Interuniversity Research Centre "Integrated Models of Study for Health Protection and Prevention in Living and Working Environments", University of Brescia, Milano-Bicocca and Verona, Italy*

SH-SY5Y cells are a widely used *in vitro* model for studying neurotoxic effects and neurological conditions. Understanding the molecular mechanisms of their differentiation is crucial for advancing related research. This study employs Fourier Transform Infrared (FTIR) microspectroscopy to characterize intact SH-SY5Y cells during all-trans retinoic acid (ATRA)-induced differentiation. FTIR microspectroscopy effectively distinguished between undifferentiated and differentiated cells by identifying characteristic marker bands in the infrared spectra. FTIR microspectroscopy, coupled with multivariate analysis of spectral data, revealed significant changes in global protein phosphorylation, glycogen content, and lipid physicochemical modifications during differentiation. These spectroscopic results were correlated with specific molecular events through complementary biochemical, metabolic, lipidomics, and proteomics analyses. The study highlights FTIR (micro-)spectroscopy as a powerful *in situ* approach for detecting and monitoring key marker factors orchestrating SH-SY5Y cell-fate determination during ATRA-induced differentiation.

● **Evaluation of the response of the ESR-alanine signal to different LET irradiations.**

SOARES A.F. <sup>(1)(2)</sup>, D'OCA M.C. <sup>(1)(2)(3)</sup>, ROMEO M. <sup>(1)(2)(4)</sup>, CIOCCA M. <sup>(5)</sup>, MANTOVANI L. <sup>(6)</sup>, DI LIBERTO R. <sup>(6)</sup>, MIRANDOLA A. <sup>(5)</sup>, ROSSI E. <sup>(5)</sup>, COLOMBO GOMEZ L. M. <sup>(6)</sup>, MARRALE M. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> *Department of Physics and Chemistry "Emilio Segrè", University of Palermo, Palermo, Italy*

<sup>(2)</sup> *National Institute for Nuclear Physics, INFN, Catania Division, Catania, Italy*

<sup>(3)</sup> *Advanced Technologies Network Centre, University of Palermo, Palermo, Italy*

<sup>(4)</sup> *Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, University of Palermo, Palermo, Italy*

<sup>(5)</sup> *Medical Physics Unit, Clinical Department, Fondazione CNAO, National Center for Oncological Hadrontherapy, Pavia, Italy*

<sup>(6)</sup> *IRCCS Policlinico San Matteo Foundation, Medical Physics Department, Pavia, Italy*

The use of charged particles in tumour treatment, known as hadrotherapy, provides similar dose coverage to photon therapy while better sparing healthy tissues due to the finite range of particles, which is advantageous for complex-shaped tumours. However, charged particles have a higher linear energy transfer (LET) than photons, potentially causing saturation and/or recombination in certain radiation detectors, such as alanine dosimeters. This study investigates the quenching effects of charged particle irradiation on the electron spin resonance (ESR) signal of alanine and explores its spectrum shape as a LET discrimination factor. Alanine dosimeters were irradiated at San Matteo Hospital and Fondazione CNAO in Pavia, Italy, using proton and carbon ion beams. The ESR signal was measured and the ratio of satellite to central lines was analysed. Preliminary results showed variations in this ratio under different LET and microwave power conditions. This work was partially funded by the European Union - Next Generation EU through Projects SAMOTHRACEs (MUR, PNRR-M4C2, ECS\_00000022) and Mission 4 Component 2 Inv. 1.5 CUP B83C22003930001.

● **Quantitative analysis of DNA damage and repair by advanced microscopy.**

SCALISI S. <sup>(1)</sup>, PATERNÒ G. <sup>(1)</sup>, LONGO E. <sup>(1)</sup>, SCOLLO F. <sup>(1)</sup>, LANZANÒ L. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Catania, Italia*

<sup>(2)</sup> *Nanoscopy, CHT Erzelli, Istituto Italiano di Tecnologia, Genova, Italia*

Understanding DNA damage and repair is key to improving cancer therapies and limiting side effects. We present an integrated imaging-based approach to investigate DNA damage and repair mechanisms in relation to DNA replication. Our method combines confocal and super-resolution microscopy with custom algorithms for single-cell quantitative analysis. By fluorescently labeling DNA damage and replication foci, we assess their number, size, and intensity across the cell cycle, using pixel-based analysis of replication foci. We also apply an image cross-correlation spectroscopy algorithm to quantify colocalization between damage and replication, revealing phase-specific interactions. This strategy is applied to U937-PR9 cells, a leukemia model where DNA damage is induced by oncogene expression or by the radiomimetic Neocarzinostatin (NCS), and to glioblastoma cells treated with NCS or X-rays. By targeting PARP1, we examine how impaired repair affects DNA damage accumulation. This approach provides insights into early tumorigenic processes and treatment response (funded by AIRC-MFAG 21931 and PNC0000003 project ANTHEM).

● **From *in vitro* validation to prototype development of a 222 nm far-UVC light barrier for airborne pathogen suppression.**

INSERO G. <sup>(1)</sup>, BENIGNI G. <sup>(1)</sup>, ROMANO G. <sup>(1)</sup>, FUSI F. <sup>(1)</sup>, BACCANI I. <sup>(2)</sup>, POLLINI S. <sup>(2)</sup>, PIAZZA C. <sup>(3)</sup>, PISTELLO M. <sup>(3)</sup>, TOCI G. <sup>(4)</sup>, ROSSI F. <sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Biomediche, Sperimentali e Cliniche "Mario Serio", Università degli Studi di Firenze, Italia*

<sup>(2)</sup> *Dipartimento di Medicina Sperimentale e Clinica, Università degli Studi di Firenze, Firenze, Italia*

<sup>(3)</sup> *Centro Retrovirus, Dipartimento di Ricerca Traslazionale e delle nuove tecnologie in Medicina e Chirurgia, Università di Pisa, Pisa, Italia*

<sup>(4)</sup> *Istituto Nazionale di Ottica, Consiglio Nazionale delle Ricerche, INO-CNR, Firenze, Italia*

(<sup>5</sup>) *Istituto di Fisica Applicata “Nello Carrara”, IFAC-CNR, Consiglio Nazionale delle Ricerche, Firenze, Italia*

The COVID-19 pandemic and the rise of antimicrobial resistance have highlighted the need for innovative technologies to prevent the spread of airborne infections, typically transmitted via droplets. This study is organized into 3 phases, where *in vitro* and *in vivo* experiments demonstrate the efficacy of a novel 222 nm UVC light barrier acting as an invisible shield against airborne pathogens, with potential use in human-occupied spaces due to its reduced mutagenic risk. Over 30 clinically relevant bacterial and viral strains, including antibiotic-resistant isolates, were irradiated in liquid (Step 1) and aerosol (Step 2) phases. *In vivo* validation (Step 3) was conducted using a dual-cage mouse model, in which airflow between infected and healthy mice passed through the UVC barrier. *In vitro* tests showed > 3-log CFU reduction at 10–30 mJ/cm<sup>2</sup> for most bacteria, while viruses, including SARS-CoV-2 and A/H1N1, required lower light dose. *In vivo*, the barrier effectively prevents infection transmission to healthy mice. Accurate modelling of the light source was used in optical simulations to design a prototype of 10 cm thick UVC light curtain, suitable for real applications.

### ● Temperature and cosolute regulate the liquid-liquid phase separation in BSA solution.

MERINO B.M., FUOCO E., BARTUCCI R., GUZZI R.

*Department of Physics, Molecular Biophysics Laboratory, University of Calabria, Rende, CS, Italy*

Biomolecular condensates form *in vivo* under physiological conditions in the crowded cellular environment and are favoured in macromolecules containing large portion of disordered regions. The liquid-liquid phase separation (LLPS) of protein solutions, in which macromolecule-rich regions are separated from the aqueous solution, can also be observed *in vitro* under specific experimental conditions of temperature, pH, components concentration. We present the dynamical formation of LLPS of bovine serum albumin (BSA) induced by PEG-5000 and temperature. The LLPS of BSA and droplet formation were characterized by temperature-dependent turbidity, optical microscopy and infrared spectroscopy. The results show that the lower the PEG concentration, the lower the LLPS transition temperature of BSA solution. At PEG concentration of 10% (*m/v*) the average diameter of BSA droplets is about 8  $\mu\text{m}$  at 10 °C, decreases to about 2  $\mu\text{m}$  at 20 °C and at higher temperature a homogeneous phase is observed. The real time formation of the BSA droplets is also followed by ATR-FTIR kinetic experiments evidencing no variation of protein secondary structure in the condensates compared to the homogeneous phase.

Aula 7, Section B, Edificio 19

ore 15:10 – 18:30

SEZIONE VI

**Fisica applicata, acceleratori e beni culturali**

Presiede: TUDISCO S. (INFN, Laboratori Nazionali del Sud, Catania)

Relazioni su invito

▲ **Il potenziamento del Ciclotrone Superconduttore a INFN-LNS: fasi conclusive in vista del commissioning.**

RUSSO A.D., RIFUGGIATO D.

*INFN, Laboratori Nazionali del Sud*

Il potenziamento del Ciclotrone Superconduttore dei Laboratori Nazionali del Sud rappresenta un traguardo fondamentale al fine di aumentare l'intensità dei fasci di ioni leggeri come richiesto dalla comunità scientifica, in particolare dai proponenti dell'esperimento NUMEN e degli esperimenti con fasci radioattivi prodotti per frammentazione. Dopo la fase di avvio delle procedure di acquisto e di assiduo controllo delle forniture delle nuove parti della macchina, l'imminente arrivo del nuovo magnete superconduttivo comporta l'avvio delle fasi conclusive del progetto. La presente relazione discute gli interventi tecnici necessari all'incremento dell'intensità di fascio estratto, con particolare attenzione ai test condotti in fabbrica intesi a valutare le prestazioni del nuovo magnete superconduttivo e alle attività collaterali fondamentali per il riavvio e la messa in servizio del Ciclotrone Superconduttore.

▲ **The high-brightness frontier of electron beams.**

GIRIBONO A.

*Laboratori Nazionali di Frascati, INFN, Frascati, RM, Italy*

Exploring the frontier of high-brightness electron beams is essential for developing next-generation light sources and enabling advanced applications in physics, materials science, and medicine. Brightness, tied to beam emittance and peak current, is a fundamental figure of merit for beam quality. Pushing brightness to its limits demands meticulous tuning and comprehensive insight into complex beam physics processes. Innovative technologies, such as cutting-edge high-repetition-rate photoinjectors, plasma-based acceleration, and novel beam compression techniques, are propelling significant advancements in the realm of high-brightness electron beams. This contribution will explore these technologies and outline the vision for future user facilities based on high-brightness beams, such as advanced and compact light sources, which promise to unlock new frontiers in ultrafast and high-resolution science.

Comunicazioni

● **Modellazione numerica e caratterizzazione sperimentale di un risuonatore a microonde di forma innovativa per sorgenti ioniche di tipo ECR.**

BIANCONI D. <sup>(1)</sup>, MAURO G.S. <sup>(1)</sup>, TORRISI G. <sup>(1)</sup>, LEONARDI O. <sup>(1)</sup>, GALATÀ A. <sup>(2)</sup>, GALLO C.S. <sup>(2)</sup>, PIDATELLA A. <sup>(1)</sup>, MISHRA B. <sup>(1)</sup>, RUSSO F. <sup>(1)</sup>, CHYHYRYNETS E. <sup>(2)</sup>, PIRA C. <sup>(2)</sup>, GALLO A. <sup>(3)</sup>, DIMA R. <sup>(3)</sup>, CESTER D. <sup>(3)</sup>, SALVÒ L. <sup>(3)</sup>, REBESAN P. <sup>(3)</sup>, PEPATO A. <sup>(3)</sup>, MASCALI D. <sup>(1)</sup>

<sup>(1)</sup> *INFN, Laboratori Nazionali del Sud, Catania*

<sup>(2)</sup> *INFN, Laboratori Nazionali di Legnaro*

<sup>(3)</sup> *INFN, Sezione di Padova*

Tra i metodi per migliorare le prestazioni di sorgenti ioniche Electron Cyclotron Resonance (ECR), la riprogettazione della camera di plasma e del sistema di iniezione di microonde



riveste un ruolo fondamentale. Il design innovativo, denominato IRIS (Innovative Resonator Ion Source), ricalca la distribuzione elettronica esapolare dettata dalla configurazione magnetica di confinamento a B-minimo. Il nuovo sistema di iniezione consta di una guida d'onda con aperture diffrattive integrata nelle pareti della camera. Il comportamento elettromagnetico è stato simulato usando CST Studio Suite, con l'obiettivo di aumentare la potenza assorbita dal plasma massimizzando il campo elettrico lungo l'asse. Il design del sistema di raffreddamento è stato effettuato utilizzando COMSOL Multiphysics. Il prototipo è stato fabbricato con tecnologia Additive Manufacturing (AM), processo Laser Powder Bed Fusion (LPBF), e rifinito tramite Plasma Electrolytic Polishing (PEP). La caratterizzazione sperimentale mostra una corrispondenza coerente con le simulazioni in termini di parametri di scattering e misura di campo elettrico tramite bead-pull, validando il design proposto.

● **Kinetic and fluid analysis of electromagnetic instabilities induced in electron cyclotron resonance plasmas confined in compact magnetic traps.**

PIDATELLA A. <sup>(1)</sup>, CARDINALI A. <sup>(1)(2)(3)</sup>, FINOCCHIARO G. <sup>(1)(4)</sup>, FRANCALANZA V. <sup>(1)(4)</sup>, MAURO G.S. <sup>(1)</sup>, MISHRA B. <sup>(1)</sup>, NASELLI E. <sup>(1)</sup>, PERI B. <sup>(1)(5)</sup>, TORRISI G. <sup>(1)</sup>, MASCAI D. <sup>(1)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali del Sud, Catania

<sup>(2)</sup> CNR, Istituto Sistemi Complessi, Politecnico di Torino,

<sup>(3)</sup> INAF, IAPS, Roma

<sup>(4)</sup> Dipartimento di Fisica e Astronomia, Università degli Studi di Catania

<sup>(5)</sup> Università degli Studi di Roma La Sapienza

In electron cyclotron resonance (ECR) generated plasmas confined in magnetic traps, electromagnetic (EM) instabilities can develop owing to i) electron temperature anisotropy, ii) accelerated ion beam, iii) fast electron, leading to measured cyclotron EM emission. Some of these phenomena resemble what is observed as electron cyclotron MASER emission in astrophysical magneto plasmas. If from one side they interfere with ECR Ion Sources stability and performance, on the other one it is scientifically relevant to predict and control them in laboratory to scale-up the outcomes to astrophysical scenarios. To predict the frequency and the mode of the unstable EM emission, we present a mathematical model based on the kinetic and fluid theory to study the instability growth/damping rate as function of the plasma parameters, i.e., the temperature anisotropy, the magnetic field profile, and the velocity of electron beams. The kinetic approach relies on the solution of some integrals (in the velocity space) of the gradient of electron distribution function. Preliminary results compared to experimental measurements of fast time-dependent RF emissions in ECR trap will be presented.

● **TOF-based ion spectroscopy for p-B11 fusion diagnostics in laser-plasma experiments.**

MACALUSO N. <sup>(1)</sup>, CIRRONE G.A.P. <sup>(1)</sup>, ABUBAKER F. <sup>(1)</sup>, ALTANA C. <sup>(1)</sup>, ARJMAND S. <sup>(1)</sup>, CATALANO R. <sup>(1)</sup>, CONSOLI F. <sup>(1)</sup>, CUTTONE G. <sup>(1)</sup>, GUARDO L. <sup>(1)</sup>, GUARRERA M. <sup>(1)</sup>, HASSAN A. <sup>(1)</sup>, MESSINA G. <sup>(1)</sup>, MIRABELLA S. <sup>(1)</sup>, RASO A.M. <sup>(1)</sup>, PAPPALARDO A.D. <sup>(1)</sup>, PETRINGA G. <sup>(1)</sup>, SCANDURRA A. <sup>(1)</sup>, SCISCIO M. <sup>(1)</sup>, TUDISCO S. <sup>(1)</sup>, VERONA C. <sup>(1)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali del Sud, Catania

<sup>(2)</sup> Dipartimento di Fisica e Astronomia, Università degli studi di Catania

<sup>(3)</sup> Università di Roma Tor Vergata

Time-of-flight (TOF) diagnostics with diamond or silicon detectors are key in high-intensity laser-matter interaction experiments aimed at investigating fusion reactions such as proton-boron-11 (p-B11). The use of multiple TOF detectors at different observation angles allows

reconstruction of the energy spectra and angular distributions of emitted ions. These diagnostics enable the identification and analysis of fusion reaction products, even in the presence of strong background signals. By introducing aluminum absorbers (stoppers), it is possible to suppress heavy ion components and enhance the detectability of lighter fusion products, such as alpha particles. Thanks to their excellent time resolution and radiation hardness, diamond and silicon detectors provide reliable measurements under extreme conditions, supporting the optimization of experimental parameters relevant to inertial confinement fusion and aneutronic reaction studies.

● **SORGENTINA-RF project: Fusion neutrons for radioisotopes and beyond.**  
PIETROPAOLO A.

*ENEA, Nuclear Department, Nuclear Technologies Laboratory*

The SORGENTINA-RF project is presented in terms of general structure and description of the main tasks and activities to be carried out. It is devoted to the design and development of a medium power 14 MeV fusion neutron source relying on a rotating target and a deuterium/tritium ion accelerator. The main focus of the neutron facility is the production of radiopharmaceutical precursors, in particular  $^{99}\text{Mo}$  as precursor of  $^{99\text{m}}\text{Tc}$ , a radio-tracer used in single-photon emission computed tomography. The nuclear reaction involved in the production of  $^{99}\text{Mo}$  is the inelastic reaction  $^{100}\text{Mo}(n, 2n)^{99}\text{Mo}$ . The facility will assess the chain that starts with the irradiation of the natural molybdenum (where  $^{100}\text{Mo}$  has an isotopic abundance of about 10%) up to the production of the so-called mother solution, a liquid solution named sodium molybdate. The facility will also make available fast and thermal neutrons beams for studies on innovative medical radioisotopes as well as materials. This contribution will be devoted to the presentation of the project and the discussion of experimental tests on the rotating target prototype and ion accelerator.

● **Ritenzione di radioisotopi nelle reazioni di Szilard-Chalmers: nuove osservazioni sperimentali.**

LOMBARDO I. <sup>(1)</sup>, REDIGOLO L. <sup>(1)</sup>, MASSARA A. <sup>(2)</sup>, DELL'AQUILA D. <sup>(3)</sup>

<sup>(1)</sup> *Università di Catania e INFN, Sezione di Catania*

<sup>(2)</sup> *INFN, Laboratori Nazionali del Sud, Catania*

<sup>(3)</sup> *Università di Napoli Federico II e INFN, Sezione di Napoli*

Le reazioni di Szilard-Chalmers rappresentano un mezzo raffinato ed elegante per la separazione, ad altissimo arricchimento, di un radioisotopo formato per cattura neutronica su un prestabilito bersaglio di natura organica o inorganica. A distanza di 90 anni dalla scoperta e molteplici esperimenti, restano però ancora oscuri alcuni meccanismi chimico-fisici di tale classe di reazioni, legati alla meccanica dell'atomo caldo, che portano all'aumento dei fenomeni di ritenzione dei radioisotopi nel materiale irraggiato. In questa comunicazione verranno descritti i risultati di un esperimento di radiochimica di tale natura, condotto ai LNS di Catania su un bersaglio liquido di iodoetano, che mostrano una curiosa dipendenza dalla diluizione del campione con etanolo. Viene inoltre suggerita una possibile origine molecolare del fenomeno osservato.

● **Fluorescent nuclear track detectors based on photoluminescent colour centres in lithium fluoride for low-energy proton track imaging.**

VINCENTI M.A. <sup>(1)</sup>, PICCININI M. <sup>(1)</sup>, NICHELATTI E. <sup>(2)</sup>, NIGRO V. <sup>(1)</sup>, MONTEREALI R.M. <sup>(1)</sup>, AMPOLLINI A. <sup>(1)</sup>, NENZI P. <sup>(1)</sup>, RONSIVALLE C. <sup>(1)</sup>

<sup>(1)</sup> *ENEA Nuclear Department, C.R. Frascati, Roma*

<sup>(2)</sup> *ENEA Nuclear Department, C.R. Casaccia, Roma*

Fluorescent Nuclear Track Detectors based on lithium fluoride (LiF) crystals and films enable single-proton track detection by acquiring the visible photoluminescence emitted by

radiation-induced  $F_2$  and  $F_3^+$  colour centres, using an optical microscope at high magnification under blue light illumination. They are characterized by high intrinsic spatial resolution, large field of view, wide dynamic range, insensitivity to ambient light, reusability and do not require post-processing. LiF detectors were irradiated with proton beams produced by the TOP-IMPLART linear accelerator at energies below 5 MeV. The proton beam fluence was estimated by counting the fluorescent proton tracks in the acquired images of LiF crystals, exposed perpendicular to the proton beam. LiF films, grown by thermal evaporation on Si(100) substrates, were irradiated placing the film substrate parallel to the impinging proton beam direction of energy  $\sim 1$  MeV. They allowed imaging entire single-proton tracks, reconstructing the luminescent Bragg curve and estimating the beam energy spectrum. This approach is promising to detect very low current levels as required for the CRYPTOMARS Project in progress.

● **Exploring cancer incidence through environmental, social, and economic factors using complex networks and machine learning.**

LO SASSO A. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, BELLANTUONO L. <sup>(2)</sup><sup>(4)</sup>, OMODEI E. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento Interateneo di Fisica, Università degli Studi di Bari Aldo Moro, Bari, Italy*

<sup>(2)</sup> *Istituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy*

<sup>(3)</sup> *Department of Network and Data Science, Central European University, Vienna, Austria*

<sup>(4)</sup> *Dipartimento di Biomedicina Traslazionale e Neuroscienze, DiBraIN, Università degli Studi di Bari Aldo Moro, Bari, Italy*

This study explores how social, economic, and environmental factors relate to cancer incidence using SDG indicators and WHO 2022 data. A weighted complex network was built from SDG indicators, with statistically significant links filtered using the disparity filter. Community detection via modularity optimization identified representative indicators, which were then used in an XGBoost regression model predicting cancer incidence with 60% variance explained. SHAP analysis revealed that factors such as biodiversity strategies (SDG 9), and water resource indicators (SDG 6) significantly influence cancer rates. These results highlight non-obvious links between sustainability and health, suggesting the value of predictive network science in addressing global health challenges.

● **10B microdistribution studies and concentration measurements for BNCT research applications.**

DEMICHELI M.P. <sup>(1)</sup><sup>(2)</sup>, BORTOLUSSI S. <sup>(1)</sup><sup>(2)</sup>, POSTUMA I. <sup>(2)</sup>, MARCACCIO B. <sup>(1)</sup><sup>(2)</sup><sup>(3)</sup>, ANSELMi TAMBURINI U. <sup>(2)</sup><sup>(4)</sup>, AIROLDI L. <sup>(2)</sup>, SOMMI P. <sup>(2)</sup><sup>(5)</sup>, PORTU A. <sup>(3)</sup><sup>(6)</sup><sup>(7)</sup>, GADAN M. <sup>(6)</sup><sup>(8)</sup>, VERCESI V. <sup>(2)</sup>

<sup>(1)</sup> *Department of Physics, University of Pavia, Italy*

<sup>(2)</sup> *National Institute of Nuclear Physics INFN, Unit of Pavia, Italy*

<sup>(3)</sup> *National University of San Martín UNSAM, Argentina*

<sup>(4)</sup> *Department of Chemistry, University of Pavia, Italy*

<sup>(5)</sup> *Department of Molecular Medicine, University of Pavia, Italy*

<sup>(6)</sup> *National Atomic Energy Commission CNEA, Argentina*

<sup>(7)</sup> *National Scientific and Technical Research Institute CONICET, Argentina*

<sup>(8)</sup> *University of Cavaloro, Ciudad Autónoma de Buenos Aires, Argentina*

Boron Neutron Capture Therapy (BNCT) is a targeted radiotherapy that exploits the nuclear reaction  $^{10}\text{B}(n,\alpha)^7\text{Li}$ . In order to improve the knowledge of the physiological behaviour of  $^{10}\text{B}$  in BNCT, it is necessary not only to determine average  $^{10}\text{B}$  concentration, but also to study its microdistribution in tumor and surrounding tissue. Understanding the localization of  $^{10}\text{B}$  within tissues-and even at the cellular level-is essential to assess the likelihood of therapeutic success and to interpret the radiobiological effects observed after treatment. Only

a limited number of techniques allow for accurate studies of boron microdistribution, among which neutron track autoradiography (NTD) stands out as a particularly valuable option due to its high spatial resolution and relatively low cost. This talk will show BNCT research in the framework of GIOCONDA and in the context of the bilateral cooperation program CONICET-CUIA, with the aim of obtaining radiobiological data and  $^{10}\text{B}$  microdistribution studies applied to borated molecules (BPA) and novel  $^{10}\text{B}$ -containing formulations (borated nanoparticles).

● **Characterisation of Laser Powder Bed Fusion metal samples using Bragg Edge Neutron Transmission analysis.**

DEMATTEIS M. <sup>(1)(2)</sup>, VIGORELLI L. <sup>(3)(4)</sup>, COSTA M. <sup>(1)(2)</sup>, GRAZZI F. <sup>(5)(6)</sup>, ORLANDI D. <sup>(7)</sup>, CORTIS D. <sup>(7)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Torino, Italia*

<sup>(2)</sup> *Istituto Nazionale Fisica Nucleare, sezione di Torino, Italia*

<sup>(3)</sup> *Dipartimento di Fisica “Giuseppe Occhialini”, Università degli Studi di Milano-Bicocca, Italia*

<sup>(4)</sup> *Istituto Nazionale Fisica Nucleare, sezione di Milano-Bicocca, Italia*

<sup>(5)</sup> *Consiglio Nazionale delle Ricerche, Istituto di Fisica Applicata “Nello Carrara”, Italia*

<sup>(6)</sup> *Istituto Nazionale Fisica Nucleare, sezione di Firenze, Italia*

<sup>(7)</sup> *Laboratori Nazionali del Gran Sasso, L’Aquila, Italia*

Bragg Edge Neutron Transmission analysis (BENT) is a non-destructive technique for the investigation of some properties of crystalline solids. Irradiating a sample with a neutron beam the transmission spectrum can be studied. By interacting with the crystalline lattice of the materials, neutrons will give coherent elastic scattering until the Bragg condition is verified: there is a maximum wavelength above which the Bragg scattering is no longer possible; this wavelength corresponds to an edge in the transmission spectrum. The presented work illustrates the application of BENT as a diagnostic technique for the characterisation of samples realised by Additive Manufacturing, in particular with the Laser Powder Bed Fusion (LPBF) printing method. BENT is used to detect eventual microstructural defects that can affect the overall functionality of the workpiece, providing detailed quantitative information about the manufacturing process. Three different samples are considered: 316L stainless steel, 16MnCr5 steel and pure copper. BENT analysis is able to provide information on texture, microstructure, strain or defects present in the samples.

Aula 8, Section B, Edificio 19

ore 15:10 – 18:30

SEZIONE VII

**Didattica e storia della fisica**

Presiede: LEONE M. (Università di Torino)

Relazioni su invito

▲ **Educating to quantum physics with art-science languages.**

CHIOFALO M.

*Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa*

Theoretical understanding and experimental control over quantum matter is driving a scientific revolution expected to reshape our lives, economy and job market. Yet, public is exposed to shallow or hyped information and schools rarely teach modern physics early enough. Even university students should be better prepared for the quantum workforce with conceptual, practical, interdisciplinary education. Common to all is the unique teaching/learning quantum physics educational challenge of mastering creativity, experimental, and math literacy to rigorously connect reality and our interpretation of it. In this contribution, I will first elaborate on our more recent physics education research collaborative efforts within EU-funded projects. After discussing the Culturo-Scientific Storytelling theoretical framework, I will focus on quantum games, conceptual digital labs, and art-science interactive tools to engage diverse learners. I will present cases where the abstraction of art languages works to express essential quantum physics concepts, useful in outreach to compensate for limited mathematical literacy and in higher-instruction degrees to inform intuition before entering technicalities.

▲ **Qubits, games, and paradoxes: New approaches to teaching Quantum Physics.**

BONDANI M.

*CNR, Institute for photonics and nanotechnology*

The second quantum revolution enables new strategies for teaching quantum physics through innovative, accessible approaches at multiple educational levels: teachers, students and general public. Moving beyond traditional methods, we employ hands-on labs, visual simulations, interactive exhibits, and games to introduce key quantum concepts. The central strategy is the two-state formalism, a simplified yet powerful framework that presents core ideas like superposition, entanglement, measurement, and Bell's inequality violations with minimal mathematics. Remarkably, a Bell inequality violation has been demonstrated experimentally in a secondary school optics laboratory in Genova within a students' PCTO and a teachers' training course. Tools such as QTris, a board game mapping quantum axioms, and Quantum Cards, supporting activities like BB84 and the CHSH game, engage students through experimentation and play. These efforts are developed in collaboration with national initiatives like PLS, IQWs and NQSTI, and international programs including the Quantum Flagship's QTEdu and World Quantum Day (WQD), fostering a coordinated, global approach to quantum education.

▲ **Quantum Quest.**

MONTANGERO S.

*Quantum Computing and Simulation Center,, Dipartimento di Fisica e Astronomia, Università di Padova*

Presentiamo il gioco Quantum Quest, sviluppato dal Dipartimento di Fisica e Astronomia dell'Università di Padova in collaborazione con Carlo Camarotto e Nestore Mangone. Il gioco

si propone di introdurre il pubblico ai concetti e alle attuali sfide della seconda rivoluzione quantistica: dai quattro pilastri delle tecnologie quantistiche (calcolo, simulazione, sensoristica e comunicazioni) alla necessità di creare e scalare le risorse quantistiche utili per poter supportare le nuove tecnologie: entanglement e numero di qubits.

▲ **QTris: a board game to teach Quantum Mechanics.**

AMABILE A., HAMMA A.

*Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

QTris is a board game designed to familiarize with the laws and conceptual structure of Quantum Mechanics (QM) within the framework of Quantum Information Theory. In this communication we will describe the game, how it encodes the key features of the theory and how it can be used as a pedagogical platform to teach the elements of QM at high-school level. In particular, I will highlight QTris' utility in clarifying core concepts such as state superposition, mixed states and entanglement. In addition, we will provide some actual examples of QTris' use drawn from experimentations carried out in different settings throughout last years.

▲ **RadioLab: un progetto dell'INFN tra scienza e scuola.**

PUGLIESE M.

*Dipartimento di Fisica, Università di Napoli Federico II e INFN, Sezione di Napoli*

Il progetto RadioLab, finanziato dall'INFN, mira ad avvicinare le nuove generazioni e la popolazione a ciò che attiene le radiazioni ionizzanti e alle sue ricadute sulla salute dell'uomo. In esso comunicazione scientifica, didattica e ricerca scientifica si integrano mettendo in atto azioni di orientamento formativo mediante un processo che ricalca le fasi attraverso cui evolve un lavoro di ricerca. La consapevolezza della presenza di una radioattività ambientale di origine naturale fa in modo che gli studenti, i loro docenti e le loro famiglie prendano confidenza con queste tematiche. La loro partecipazione al progetto permette anche di condurre attività di monitoring di radon indoor e di radionuclidi nell'ambiente. L'ampiezza del tema affrontato in RadioLab educa inoltre gli studenti ad un approccio che è per sua stessa natura multidisciplinare, abituandoli a riconoscere e integrare contenuti affini appartenenti a diversi ambiti disciplinari (Fisica, Chimica, Biologia, Informatica, Inglese, Educazione Civica ...).

Comunicazioni

● **Didattica innovativa della Meccanica Quantistica nella Scuola Secondaria: prima realizzazione sperimentale del Test di Bell in un Liceo Italiano.**

LOSERO E. <sup>(1)</sup>, CARLINI A. <sup>(2)</sup>, OÑATE OROZCO M. <sup>(3)</sup>, BONDANI M. <sup>(4)</sup>

<sup>(1)</sup> *Quantum Metrology and Nano Technologies Division, INRiM, Torino*

<sup>(2)</sup> *Liceo Classico Scientifico e Sportivo Statale M.L. King, Genova*

<sup>(3)</sup> *Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria*

<sup>(4)</sup> *CNR, Istituto di Fotonica e Nanotecnologie*

Il paradosso EPR e le disuguaglianze di Bell mettono in discussione le nozioni classiche di realtà e località, e rappresentano pertanto caratteristiche fondamentali della meccanica quantistica, sia scientifiche che epistemologiche. Presentiamo un percorso didattico innovativo nato dalla collaborazione tra ricercatori e docenti e realizzato presso il Liceo Classico Scientifico e Sportivo Statale M.L. King di Genova. Superando l'approccio storico all'insegnamento della Meccanica Quantistica, il progetto ha coinvolto una dozzina di studenti e docenti, in due corsi in cui i principi quantistici sono stati introdotti attraverso concetti accessibili a studenti del triennio, come la polarizzazione della luce, l'algebra vettoriale

ed i numeri complessi. Il percorso ha incluso una consistente parte sperimentale realizzata in un laboratorio scolastico installato con fondi PNRR. L'attività è culminata nella prima realizzazione scolastica in Italia dell'esperimento che è valso ad Aspect, Clauser e Zeilinger il Nobel per la Fisica 2022, ovvero la violazione delle disuguaglianze di Bell, risultato ottenuto dagli studenti nell'aprile 2025.

● **QUANTO, un gioco per avvicinare alla meccanica quantistica.**

MENOTTI C.

*Pitaevskii BEC Center, CNR-INO BEC e Dipartimento di Fisica, Università di Trento*

QUANTO è un gioco di carte ideato per far conoscere alcuni aspetti fondamentali della meccanica quantistica. Il meccanismo di gioco consiste nell'abbinare e scartare carte che rappresentano stati quantistici di due qubit. L'abbinamento avviene tramite opportune operazioni sugli stati, passaggio che richiede concentrazione e stimola abilità logiche. Partendo dal comportamento dei due qubit in varie situazioni, con QUANTO si scopre cosa sono gli stati e i gate quantistici, il principio di sovrapposizione, la misura e l'entanglement, e se ne verificano le implicazioni più profonde. Il gioco è reso accessibile e avvincente da una strategia a breve termine, arricchita da elementi di interazione tra giocatori e da una grafica chiara e accattivante. Grazie alla possibilità di calibrare facilmente il livello di gioco in base all'età e alle competenze dei partecipanti, QUANTO è in grado di svelare gradualmente i fenomeni più sorprendenti della fisica quantistica e di proporre sfide di complessità crescente. In questo contributo, verrà discusso come il gioco può essere inserito in moduli formativi adattabili alle richieste didattiche delle scuole superiori di primo e secondo grado.

● **Rilevare l'invisibile: un percorso didattico interattivo sulla fisica delle particelle per la scuola superiore.**

BIANCHI L. <sup>(1)(2)</sup>, DI BLASI M. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Matematica e Fisica, Università Roma Tre*

<sup>(2)</sup> *INFN, Sezione Roma Tre*

L'insegnamento della fisica tramite esperienze pratiche è cruciale per stimolare l'interesse degli studenti e migliorare la comprensione dei concetti teorici. Presentiamo Fisica delle Particelle: rilevare l'Invisibile, un percorso didattico originale che integra teoria e pratica per avvicinare gli studenti delle scuole superiori alle discipline scientifiche, con la radioattività come filo conduttore. Il progetto, svolto presso il Dipartimento di Matematica e Fisica dell'Università Roma Tre (durata 18 ore), ha guidato attivamente gli studenti nella concezione di un esperimento, nella sua realizzazione hardware e software, e nell'analisi dei dati. Attraverso discussioni ed esperienze laboratoriali, gli studenti sono stati protagonisti del processo di indagine scientifica. La valutazione, basata su questionari finali, ha evidenziato un elevato livello di gradimento e apprezzamento per l'approccio pratico e interattivo offerto dal percorso.

● **Il progetto STAGE dell'INFN.**

ZATTI L. <sup>(1)(2)</sup>, VERDI S. <sup>(1)</sup>, AIMÈ C. <sup>(3)(4)</sup>, BUDASSI E. <sup>(1)(2)</sup>, COCCATO S. <sup>(5)</sup>, PEGORARO L. <sup>(6)</sup>, GOZZELINO A. <sup>(6)</sup>, GARZIA I. <sup>(7)(8)</sup>, ANDREOTTI M. <sup>(8)</sup>, MONTAGNA P. <sup>(1)(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Pavia*

<sup>(2)</sup> *INFN, Sezione di Pavia*

<sup>(3)</sup> *Dipartimento di Fisica, Università di Pisa*

<sup>(4)</sup> *INFN, Sezione di Pisa*

<sup>(5)</sup> *Dipartimento di Fisica e Astronomia, Università di Padova*

<sup>(6)</sup> *INFN, Laboratori Nazionali di Legnaro*



(<sup>7</sup>) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara*

(<sup>8</sup>) *INFN, Sezione di Ferrara*

Si presenta il nuovo progetto STAGE proposto dall'INFN ponendo in sinergia sotto un'unica sigla tre esperienze simili esistenti da anni presso i Laboratori Nazionali di Legnaro e le Università/INFN di Pavia e Ferrara. È uno stage residenziale di 5-10 giorni proposto a giugno 2025 contemporaneamente nelle tre sedi, a un totale di 130 studenti di 4a di ogni indirizzo di scuole secondarie di secondo grado provenienti da tutta Italia e particolarmente appassionati di fisica. L'obiettivo è far vivere agli studenti un'esperienza di full immersion nel mondo della ricerca scientifica, favorendo così un loro orientamento universitario verso corsi STEM. Le attività laboratoriali (hands on Physics) sono preponderanti e svolte a gruppi, con presentazione dei risultati in un workshop finale. Ai laboratori si affiancano seminari su temi di fisica moderna e di frontiera e visite didattiche a centri di ricerca particolarmente significativi delle tre sedi. Il tutto in un ambiente stimolante e informale, nel quale i ragazzi vivono a stretto contatto con ricercatori, tecnologi, tecnici, dottorandi e studenti. La presentazione include i risultati dei questionari di gradimento.

● **GATE/GEANT4 simulations as a didactic tool for teaching medical radiation physics topics.**

PISTONE D.

*Dipartimento di Matematica e Fisica, Università degli Studi della Campania Luigi Vanvitelli, Caserta e INFN, Sezione di Napoli*

GATE (GEANT4 Application for Tomographic Emission) is a free and open-source, medical physics-oriented interface to GEANT4, a versatile and widely used Monte Carlo simulation toolkit for modeling radiation-matter interactions. GEANT4 is employed in various areas of research in physics, including nuclear and particle physics. GATE provides a user-friendly layer for simulating tomographic imaging, external and internal radiotherapies, human dosimetry, and other medical applications involving radiation sources. This work presents how GATE can be effectively used as a didactic tool, focusing on experiences from the 2024/25 academic year. At a basic level, introducing only essential features such as particle tracks visualization, its use in early-year health-related degree courses and outreach activities for final-year high school students will be illustrated. At an intermediate level, the experience from a Master's course in Physics focused on medical applications, in which students developed their own simulations, will be summarized. Finally, some examples of advanced didactic use that evolved into Master's thesis research projects will be outlined.

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Aula 10, Section C, Edificio 19

ore 15:10 – 18:30

### Simposio Il Fisico nelle professioni di oggi

Presiede: RIZZO L. (LABRIS, Castro, LE e Ordine dei Fisici e dei Chimici di Lecce e Brindisi)

Relazioni su invito

#### ▲ Innovazione tra scienza, tecnologia, mercato e società.

GIORDANI S.

*TTP Lab, Vicenza*

I risultati della ricerca scientifica e tecnologica sono e sono stati il motore dello sviluppo con la loro capacità di generare crescita e valore nelle imprese, nell'economia, nella società. La trasformazione dei risultati della ricerca in un percorso di impatto efficace per la creazione di valore —che, al di là e oltre ad essere un valore monetario, è soprattutto un valore economico dove si inseriscono valori di crescita e benessere sociale e di stimolo per altra ricerca, altri risultati— richiede un approccio sistematico alla definizione delle strategie e delle traiettorie di sfruttamento. Ci sono almeno tre aspetti particolarmente rilevanti che fanno anche riferimento a specifiche skill: l'indagine di traiettorie scientifico-tecnologiche nel contesto socio-economico, l'individuazione di ricadute applicative, l'applicazione del *troubleshooting*. Alcuni esempi tratti dalla pratica professionale offriranno scenari diversi in cui il fisico professionista si confronta e si muove tra tecnologie diverse e a diversi livelli di sviluppo, e si confronta con materiali, fenomeni fisici, configurazioni di prodotto, esigenze, evoluzioni e vincoli non solo tecnici, ma anche di "mercato".

#### ▲ Acustica, disciplina multisettoriale e approccio applicativo.

MISSINEO F.

*Studio Spin Up Associati, Borgarello, PV*

L'acustica, disciplina che interessa molti ambiti di studio teorico-sperimentale, assume aspetti applicativi in diversi settori, peraltro contraddistinti dalla contaminazione di differenti discipline, tali da impegnare il professionista acustico alla complementarità delle competenze finalizzate all'ottimizzazione dei risultati. Ambiti di interesse sono riferibili ad esempio al settore ambientale (misure, analisi e valutazione d'impatto acustico, di clima acustico o anche nella definizione delle zone acustiche del territorio); al settore edilizio (misure, analisi e valutazione dei requisiti acustici passivi degli edifici in funzione della destinazione d'uso); al settore della sicurezza sul lavoro (misure, analisi e valutazione di rumore-vibrazioni a tutela della salute dei lavoratori di ogni settore produttivo); al settore civilistico/penale (misure e analisi di supporto al G.I. in ambito di valutazione della normale tollerabilità al rumore o anche dell'eventuale danno biologico); etc. Di tali ambiti di interesse multisettoriale si descrive l'approccio teorico-applicativo illustrando casi tipologici di interesse peculiare.

#### ▲ Applicazioni delle metodologie isotopiche alle scienze forensi presso il Laboratorio CIRCE.

MARZAIOLI F. <sup>(1)(2)</sup>, PASSARIELLO I. <sup>(1)</sup>, PORZIO G. <sup>(1)(2)</sup>, TERRASI F. <sup>(1)(2)</sup>, D'ONOFRIO A. <sup>(1)(2)</sup>, PETRAGLIA A. <sup>(2)</sup>

<sup>(1)</sup> ISOCORE SRL, Spin off Accademico dell'Università degli Studi della Campania Luigi Vanvitelli, San Nicola La Strada, CE

(<sup>2</sup>) *POLAR-CIRCE, Dipartimento di Matematica e Fisica, Università degli Studi della Campania Luigi Vanvitelli, Caserta*

Le metodologie isotopiche rappresentano un settore di ricerca all'avanguardia in differenti settori di studio permettendo di ottenere informazioni sulla storia di un campione andando ad "interrogare" la materia a livello nucleare. A questo livello di analisi sono necessarie elevate sensibilità di rivelazione, precisione e accuratezza. In questo ambito, la spettrometria di massa per rapporti isotopici sia convenzionale che con acceleratore rappresenta la tecnica di elezione al fine di garantire queste elevate caratteristiche analitiche. Il Laboratorio CIRCE (Centre for Isotopic Research on Cultural and Environmental heritage), parte del centro PoLaR del Dipartimento di Matematica e Fisica, è da decenni un centro di riferimento per la spettrometria di massa per rapporti isotopici. Nel presente contributo verranno discussi i principali casi forensi a cui il CIRCE, in collaborazione con la polizia scientifica e altri enti, ha contribuito ad indagare e verranno discusse le principali prospettive di sviluppo in questo ambito di applicazione.

▲ **Pericolosità Laser: ciò che già sappiamo o che dovremmo sapere.**

FAZIO E. (<sup>1</sup>), BILE A. (<sup>1</sup>), ANDREO F. (<sup>2</sup>), GAVELLI G. (<sup>3</sup>)

(<sup>1</sup>) *Dipartimento di Scienze di Base e Applicate per l'Ingegneria, Sapienza Università di Roma*

(<sup>2</sup>) *Brescia*

(<sup>3</sup>) *Lugo di Romagna, RA*

La pericolosità dei laser rappresenta un aspetto cruciale per garantire un utilizzo sicuro di questa tecnologia in molteplici settori, dall'industria alla medicina, dall'intrattenimento alla ricerca. Sebbene siano state sviluppate normative e linee guida per la protezione degli operatori e del pubblico, è fondamentale comprendere appieno tutti gli aspetti delle pericolosità e, di conseguenza, di un uso sicuro delle sorgenti laser, oltre le nostre possibili sensazioni e preconcezioni, per identificare le aree in cui la conoscenza può essere ancora migliorata. La pericolosità dei laser dipende da vari fattori che troppo spesso sono sottovalutati a causa di una troppa confidenza che noi reputiamo che si possa avere dall'esperienza: invece il pericolo si nasconde proprio dietro l'angolo, dietro le nostre sicurezze, le nostre credenze e superficialità. È quindi essenziale promuovere la cultura della conoscenza, che è la migliore e responsabile sicurezza. Solo attraverso una maggiore consapevolezza e formazione possiamo prevenire incidenti e garantire un uso etico e sicuro dei laser in ogni ambito.

Aula Seminari C, Section C, Edificio 19

ore 10:00

Chiusura Seggio Elettorale

Aula Magna G.B.F. Basile, Edificio 7

ore 09:00 – 13:30

## SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: LUCCHESI D. (Università di Padova e INFN)

Relazioni su invito

**▲ Results and perspectives of the SNDLHC experiment at CERN.**

DI CRESCENZO A.

*Università di Napoli Federico II e INFN, Sezione di Napoli*

SND@LHC is a compact experiment operating in the forward region ( $7.2 < \eta < 8.4$ ), designed to detect neutrinos produced at the LHC a region previously unexplored. Installed 480 m downstream of IP1, it uses a hybrid system with tungsten targets, emulsion and electronic trackers, followed by a calorimeter and a muon system, enabling flavour identification and studies of forward heavy-flavour production. Since 2022, SNDLHC has been collecting data and has reported the first observation of neutrino interactions at a collider, with evidence of muon neutrino events and neutrinos without muons in the final state. We report results of the 2024 data analysis and outline the upgrade program for HL-LHC, which includes increased target mass, tracking based on silicon detectors, and enhanced muon identification, aiming to extend flavour sensitivity and improve cross-section measurements in the TeV range.

**▲ Misura delle oscillazioni dei neutrini con gli esperimenti long- baseline di nuova generazione.**

TOSI N. PER LE COLLABORAZIONI DUNE E HYPERKAMIOKANDE

*INFN, Sezione di Bologna*

Il fenomeno dell'oscillazione dei neutrini, benché ampiamente confermato, è ancora caratterizzato da incertezze su parametri fondamentali quali l'ordinamento delle masse, la fase della violazione di CP e l'angolo di mixing  $\theta_{23}$ . La necessità di misurare questi parametri ha portato alla progettazione di due nuovi esperimenti long-baseline: HyperKamiokande e DUNE (Deep Underground Neutrino Experiment), entrambi in costruzione. HyperKamiokande è la terza generazione della famiglia di esperimenti water-Cherenkov a Kamioka in Giappone; utilizzerà un fascio prodotto a J-PARC con un acceleratore da 1.3 MW; il rivelatore, distante 295 km, avrà una massa fiduciale di 187 kton. Il far detector di DUNE utilizzerà fino a quattro moduli Time Projection Chamber ad argon liquido, ciascuno con una massa fiduciale di 10 kton. Il fascio di neutrini sarà prodotto a Fermilab, a 1300 km di distanza, con una potenza di 1.2 MW. Entrambi gli esperimenti saranno dotati di rivelatori “near” per la misura dei fasci non oscillati, che consentiranno la riduzione delle incertezze sistematiche. Sia DUNE che HyperKamiokande condurranno anche un vasto programma di fisica non legato alle oscillazioni.

▲ **Recenti osservazioni sui fenomeni di alfa-clustering nei nuclei leggeri.**

DELL'AQUILA D.

*Università degli Studi di Napoli "Federico II" e INFN, Sezione di Napoli*

I fenomeni di clusterizzazione occorrono in svariati sistemi fisici, biologici o sociali. Nel dominio dei nuclei atomici, essi giocano un ruolo fondamentale, specialmente nella descrizione della struttura dei nuclei leggeri, dove aggregati di due protoni e due neutroni possono ricoprire il ruolo di mattoni fondamentali delle strutture clusterizzate. Un rilevante esempio è costituito da un particolare stato eccitato del nucleo di carbonio-12 detto "stato di Hoyle", in onore dell'astronomo britannico Fred Hoyle che per primo ne teorizzò l'esistenza. Lo stato di Hoyle, proprio in virtù della sua singolare natura a cluster di tre particelle alfa, facilita il bruciamento dell'elio nelle stelle giganti rosse, rendendo possibile la produzione del carbonio, il principale costituente della materia organica. Lo stato di Hoyle è stato recentemente oggetto di un rinnovato interesse teorico e sperimentale, a motivo delle sue proprietà uniche e del suo ruolo chiave nella nucleosintesi degli elementi. Questa comunicazione descrive alcuni recenti sviluppi nel campo del clustering nei nuclei leggeri, con particolare enfasi sull'affascinante caso dello stato di Hoyle nel carbonio-12.

▲ **PADME Run III results on the X17 search.**

MANCINI M.

*INFN, Laboratori Nazionali di Frascati e Università di Roma Tor Vergata*

The PADME experiment (Positron Annihilation into Dark Matter Experiment), conducted at the INFN Frascati National Laboratories, has been engaged in the search for the hypothetical X17 particle since autumn 2022. The experimental observable consists of the products of collisions between the positron beam from the DAΦNE LINAC and the electrons of a fixed diamond target. In particular, PADME searches for the new particle through a possible increase in the cross-section, with respect to Standard Model predictions, in the production of  $e^+e^-$  pairs and photons. The results presented are based on the analysis of data collected during the Run III of the experiment, in which the beam energy was varied in the range 265-300 MeV, corresponding to  $\sqrt{s}$  values between 16.4 and 17.5 MeV. This interval fully covers the center-of-mass region indicated by the ATOMKI collaboration as relevant for the observation of the X17 particle. The obtained exclusion limit was calculated using a statistical analysis based on the CLs method, a modified frequentist approach based on the comparison of likelihood fits between the background-only and the signal-plus-background hypotheses.

Comunicazioni

● **Performance del Photon Detection System di ProtoDUNE-HD.**

BALBONI A. PER LA COLLABORAZIONE DUNE

*Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara e INFN, Sezione di Ferrara*

ProtoDUNE-HD è una camera a proiezione temporale ad argon liquido (LArTPC), che sfrutta la tecnologia horizontal drift (HD) per la raccolta della carica. Esso è stato costruito e ha operato presso la Neutrino Platform area del CERN durante il 2024. Si tratta del prototipo del secondo modulo del far detector (FD) del Deep Underground Neutrino Experiment (DUNE), un esperimento di nuova generazione per lo studio della fisica di neutrini in costruzione negli USA. Il corretto funzionamento di ProtoDUNE-HD dimostrerà l'efficacia della tecnologia pensata per il FD-HD. In particolare, il Photon Detection System (PDS) sarà fondamentale per il programma di fisica di DUNE. L'interazione di un neutrino nella LArTPC è ricostruita osservando le tracce delle particelle cariche secondarie che producono

luce di scintillazione e cariche libere a seguito della ionizzazione dell'argon. Il tempo di riferimento dell'evento è dato dall'istante in cui viene rivelata la luce di scintillazione, per mezzo di moduli X-ARAPUCA, ovvero trappole di luce dotate di SiPM. In questo contributo verrà presentato il design del PDS di ProtoDUNE-HD, insieme ai risultati preliminari legati al suo funzionamento.

### ● **Caratterizzazione dei moduli del PDS di DUNE.**

MEAZZA L.

*Università di Milano Bicocca e INFN, Sezione di Milano Bicocca*

Il Far Detector (FD) di DUNE utilizza la tecnologia delle Time Projection Chamber ad Argon Liquido (LArTPC): particelle cariche che attraversano il rivelatore ionizzano l'argon liquido e la carica di ionizzazione raccolta permette di ottenere una ricostruzione 3D delle tracce. L'informazione temporale, e quindi il posizionamento della traccia nel volume attivo, è data dalla luce di scintillazione emessa in seguito alla ricombinazione di parte della carica di ionizzazione. L'argon liquido è infatti un eccellente scintillatore nonostante la difficoltà nella raccolta e nella rivelazione della luce emessa, data dalla lunghezza d'onda nel VUV (128 nm). Il Photon Detection System (PDS) è il rivelatore di luce del FD di DUNE, basato sul sistema di intrappolamento chiamato XArapuca. L'XArapuca permette di realizzare detector con ampie superfici di raccolta sfruttando materiali WLS e superfici riflettenti per intrappolare e trasportare i fotoni verso fotosensori SiPM posizionati lungo i bordi del modulo. In questo contributo vengono descritte le implementazioni dell'XArapuca nei primi due moduli del FD e le misure effettuate nei laboratori della collaborazione DUNE per la caratterizzazione dei singoli moduli.

### ● **Muon: who ordered that?**

KARUZA M.

*INFN Sezione di Trieste e Università di Rijeka, Croazia*

Starting from the famous sentence by Isaac B. Rabi, referred to the newly discovered muon particle – “who ordered that?” –, I will go through the history of the heavy brother of the electron with a particular emphasis on the Muon g-2, including the last measurement of the Fermilab experiment recently released, and on the searches for Charged Lepton Flavor Violation and Electric Dipole Moment. I will then describe the future of the research in this field describing the possibilities that a muon accelerator can open to future searches in High Energy Physics. Finally, I will briefly touch on muons in other fields: muography, muon spin spectroscopy, muon-catalyzed fusion.

### ● **Status of the MUonE experiment.**

PUNZI L. ON BEHALF OF THE MUONE COLLABORATION

*Scuola Normale Superiore di Pisa e INFN, Sezione di Pisa*

The MUonE experiment at CERN aims to determine the leading-order hadronic contribution to the muon anomalous magnetic moment ( $a_\mu^{HLO}$ ) with an innovative approach, by means of elastic scattering of 160 GeV muons on atomic electrons in a low-Z target. The M2 beam line at CERN provides the intensity needed to reach the experiment's statistical goal of 0.3% precision on  $a_\mu^{HLO}$  in a few years of data taking. A first run with a minimal prototype setup was carried out in 2023. A pilot run is being prepared for 2025, with a reduced setup of the full detector components. We will present the status of the experiment, some preliminary results and future plans.

● **Particle tracking in the DUNE-SAND detector: An extended Kalman filter approach.**

LUPI G. <sup>(1)(2)</sup>, PIA V. <sup>(2)</sup>, POZZATO M. <sup>(2)</sup>, TENTI M. <sup>(2)</sup>

<sup>(1)</sup> *Università di Bologna*

<sup>(2)</sup> *INFN, Sezione Bologna*

The DUNE long-baseline neutrino experiment includes precise measurement of neutrino oscillation parameters, such as the CP-violating phase and neutrino mass ordering. DUNE features a Far Detector of four 17 kt LArTPCs at the Sanford Underground Research Facility (SURF), 1300 km from Fermilab, where the neutrino beam originates. A Near Detector (ND) complex will characterize the unoscillated beam. The SAND apparatus, part of the ND, enables beam monitoring, flux measurements, and neutrino interaction studies. It consists of a superconducting magnet, electromagnetic calorimeter, Liquid Argon active target, and low-density tracker system. We present a track reconstruction algorithm for SAND based on the Extended Kalman Filter, well suited for non-linear systems such as charged particles in magnetic fields. Validated through Monte Carlo simulations, the algorithm reconstructs helical trajectories over a broad momentum range and includes energy loss and multiple scattering. A full reconstruction pipeline including digitization and a tracklet-finder adaptable to different geometries has been developed. Latest results from GEANT4 simulations of muon-neutrino CC events will be presented.

● **Reconstruction of neutrino interactions in the Liquid Argon detector of the SAND apparatus.**

SANTONI G.

*Dipartimento di Fisica e Astronomia, Università di Bologna e INFN, Sezione di Bologna*

The Deep Underground Neutrino Experiment (DUNE), a long-baseline neutrino oscillation experiment under construction in the United States, will enable precise determination of oscillation parameters, including the neutrino mass ordering and the CP-violating phase. DUNE will consist of a Near Detector complex at Fermilab and a Far Detector in South Dakota, about 1300 km away. A key component of the Near Detector complex is SAND (System for on-Axis Neutrino Detection), designed to constrain systematic uncertainties in neutrino interactions. SAND comprises a 0.6 T superconducting magnet, an electromagnetic calorimeter, a target-tracking system, and GRAIN, a 1-ton Liquid Argon active target. GRAIN is designed to image neutrino interactions using LAr scintillation light detected by an optical readout system based on coded-aperture cameras and lenses. This contribution presents the performance of a track-finding algorithm developed for the reconstruction of charged-current quasi-elastic muon-neutrino interactions in the GRAIN volume, assuming that only coded aperture cameras are implemented. The reconstruction techniques and the results obtained from simulation studies are discussed.

● **Upgrade of the muon identification system at the SND@LHC experiment.**

MOZZINA L. <sup>(1)(2)</sup>, GUIDUCCI L. <sup>(1)(2)</sup>, PAGGI G. <sup>(1)(2)</sup>, DALLAVALLE G.M. <sup>(2)</sup>, BATTILANA C. <sup>(1)(2)</sup>, CINDOLO F. <sup>(2)</sup>, CRUPANO A. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Bologna*

<sup>(2)</sup> *INFN, Sezione di Bologna*

The Scattering and Neutrino Detector (SND@LHC) experiment at CERN can discriminate all neutrino flavors in a previously unexplored pseudo-rapidity region. The signal events are interactions of neutrinos with energies between 100 GeV and 1 TeV, produced in the very forward direction from LHC  $pp$  collisions in the ATLAS interaction point. The main background for the selection of  $\nu_\mu$  interactions is given by neutral hadrons produced by muon deep inelastic scattering in the material around the detector. To improve muon identification, in

March 2025 two Mini Drift Tubes (MiniDT) modules, miniature versions of CMS Drift Tubes, were added to the SND@LHC muon identification system. MiniDT modules provide high resolution x-y position and direction measurements for a more precise track reconstruction, enabling accurate muon flux measurements and a better discrimination between background and muon neutrino interactions in the SND@LHC target. The contribution presents the integration of MiniDTs in the SND@LHC detector, DAQ and control systems, together with the developments of the offline software and results on track reconstruction with  $pp$  collision data.

● **A monitored neutrino beam at the European Spallation Source.**

SCANU A. ON BEHALF OF THE ESSNUB+ COLLABORATION

*Dipartimento di Fisica, Università di Milano Bicocca e INFN, Sezione di Milano Bicocca*

Monitored neutrino beams are a new class of beams designed for high-precision neutrino cross-section measurements. This technology has been successfully developed by the ENUBET Collaboration for implementation at CERN and is also being considered at the European Spallation Source (ESS) to investigate cross sections in the sub-GeV energy range. In this talk, I will present the proposal for a monitored neutrino beam at the ESS (MNB@ESS), developed within the ESSNUB+ design study. I will focus on the simulation of the beamline and instrumentation using FLUKA and GEANT4. In particular, I will demonstrate that the ESS LINAC can be used in its current configuration without interfering with the standard ESS neutron program. I will also show that the MNB@ESS beamline can achieve percent-level precision in cross-section measurements using conventional beamline components and a moderate-mass detector. Finally, I will discuss key aspects related to radiation hardness and the design of the beam diagnostics system.

● **UNIFORMITY response study of dual-readout prototypes.**

TACCHINI L.D.

*Dipartimento di Fisica, Università di Pavia e INFN, Sezione di Pavia*

Precision measurements at future lepton colliders require excellent energy resolution, especially in multi-jet events, to successfully separate Z, W, and Higgs decays. The dual-readout method, which uses both scintillation and Cherenkov light, has proven to be a promising solution. This technique provides two independent energy measurements of the hadronic shower, allowing event-by-event compensation for the electromagnetic fraction fluctuations. A prototype of a dual readout calorimeter, based on stainless-steel capillary tubes, is under construction. It is readout with SiPM in the core region, surrounded by PMTs in the peripheral zone. The prototype will address the scalability and feasibility of the proposed technique in view of proposing it for future experiments. In order to better understand the preliminary results obtained on a partial prototype, made of half of the modules foreseen for the final calorimeter, systematic studies on the uniformity response of the PMTs and on the optical coupling between fibres and these photodetectors have been performed. In the presentation obtained results will be shown.

● **Searches for physics beyond the standard model at the short-baseline near detector.**

FRICANO G. FOR THE SBND COLLABORATION

*Università di Palermo e Fermilab*

The Short-Baseline Near Detector (SBND) is a 112-ton liquid argon time projection chamber 110 m away from the Booster Neutrino Beam (BNB) target at Fermilab (Illinois, USA). In addition to its role as a near detector enabling precision searches for short-baseline neutrino oscillations, the proximity of SBND to the BNB target makes the experiment ideal for many

beyond the Standard Model (BSM) searches of new particles produced in the beam. The nanosecond-timing resolution of the scintillation light detectors further boosts the experiment capabilities. In this talk, we present the status and expected sensitivity to new BSM particles produced in the decay of mesons and in proton-target interactions.

● **Vector boson scattering results from CMS.**

BUITRAGO CEBALLOS D.

*Università di Perugia e INFN, Sezione di Perugia*

The study of vector boson scattering (VBS) is a fundamental tool that allows the exploration of the mechanisms of spontaneous electroweak symmetry breaking. It also allows the search for hints of new physics beyond the Standard Model (BSM). In particular, the production of two W bosons of the same charge (SSWW) in proton-proton collisions at the LHC, offers a clean channel that is sensitive to possible deviations, since the model without the Higgs mechanism would lead to a violation of unitarity in this type of processes at high energies. An overview of the analysis conducted by the CMS Collaboration will be presented in this talk, with a discussion of the results. A special focus will be put on polarization investigations, and especially on the longitudinal component of the boson polarization, since the precise observation of this component represents a direct test of the symmetry breaking dynamics and could reveal physics effects beyond the Standard Model (BSM). In addition, some future prospect, specifically focused on the fully hadronic final state and boosted topology will be discussed, as particularly promising from Run3 and beyond.

● **Study of the impact of a new ATLAS  $\tau$ -identification algorithm on the search for Higgs boson pair production in the  $HH \rightarrow b\bar{b}\tau\tau$  final state.**

CAPRIO L.

*Dipartimento di Fisica, Sapienza Università di Roma e INFN, Sezione di Roma*

The presentation focuses on the impact of integrating the new GNTau algorithm based on graph neural networks on the search for Higgs boson pair production in the  $HH \rightarrow b\bar{b}\tau\tau$  final state within the ATLAS experiment, using Run-3 samples. Di-Higgs searches are a main goal of the High-Luminosity LHC, but are limited by statistical sensitivity. Any improvement in signal efficiency is therefore crucial. In this final state, hadronically decaying tau leptons must be distinguished from QCD jets. Enhancing this discrimination is crucial not only for increasing signal yield, but also for reducing systematic uncertainties from jet-to-tau misidentification. This study evaluates how different strategies for integrating GNTau into the analysis affect the overall sensitivity of the  $HH \rightarrow b\bar{b}\tau\tau$  search on Run-3 data. Rather than simply adopting the default working point of the previous algorithm, multiple re-optimization scenarios are explored to leverage GNTau's improved discrimination power. Increasing true-tau efficiency while maintaining comparable jet rejection can lead to gains in signal sensitivity, showing the potential of advanced tau ID techniques.

● **Muon momentum reconstruction in Icarus-T600 LArTPC via multiple scattering.**

GULIZIA C. <sup>(1)(2)(3)</sup>, VARANINI F. <sup>(2)(3)</sup>, CHERUBINI S. <sup>(1)(2)(3)</sup>, GUGLIELMI A. <sup>(2)(3)</sup>, CHIELLO G. <sup>(2)(3)</sup>

<sup>(1)</sup> *Università di Catania*

<sup>(2)</sup> *INFN, Sezione di Catania*

<sup>(3)</sup> *Fermilab*

The discovery of neutrino oscillations, implying massive neutrinos contrary to the Standard Model (SM), poses a major challenge to the SM and points to new physics. Hints of eV-scale sterile neutrinos have emerged from anomalies in accelerator (LSND, MiniBooNE), Gallium



(GALLEX, SAGE), and reactor (Neutrino-4) experiments. The ICARUS T600 detector, a large Liquid Argon Time Projection Chamber (LArTPC), serves as the far detector in the Short Baseline Neutrino (SBN) program at Fermilab. Its goal is to probe sterile neutrino scenarios via  $\nu_\mu$  disappearance and  $\nu_e$  appearance along the Booster Neutrino Beam (BNB). For particles escaping the active volume, ICARUS uses Multiple Coulomb Scattering (MCS) to estimate momenta, a method effective in the 0-3 GeV range typical of BNB neutrinos. A delta-ray rejection algorithm is being developed to improve the performance of MCS-based momentum reconstruction.

● **Sviluppo e implementazione di rivelatori di luce criogenici per CUPID.**

MOLINARI I.

*Dipartimento di Fisica, Università di Milano Bicocca*

CUPID (CUORE Upgrade with Particle Identification) è un esperimento di nuova generazione per la ricerca del decadimento doppio beta senza emissione di neutrini ( $0\nu\beta\beta$ ). L'osservazione di questo processo implicherebbe la violazione della conservazione del numero leptonico provando l'esistenza di fisica oltre il Modello Standard. L'esperimento utilizzerà cristalli di  $\text{Li}_2\text{MoO}_4$  arricchiti in  $^{100}\text{Mo}$  come rivelatori bolometrici scintillanti. Per permettere la discriminazione tra diversi tipi di particella, i cristalli saranno accoppiati a rivelatori di luce criogenici per misurare i segnali di scintillazione. Presenterò un prototipo innovativo di rivelatore di luce: un wafer di silicio equipaggiato con elettrodi di Indium Tin Oxide (ITO), per sfruttare l'effetto Neganov-Trofimov-Luke e amplificare il segnale termico. La caratteristica principale dell'ITO è la trasparenza alla luce di scintillazione, che permette di realizzare elettrodi molto grandi, garantendo buona amplificazione senza inficiare l'efficienza di raccolta dei fotoni.

● **Muon momentum reconstruction in ICARUS-T600 LArTPC via Multiple Scattering.**

CHIELLO G.

*Università di Pisa*

The SBN program at Fermilab investigates the possible existence of eV-scale sterile neutrinos. This work focuses on reconstructing muon momentum in  $\nu$ -Ar interactions within the ICARUS-T600 LArTPC detector using Multiple Coulomb Scattering (MCS), the only viable method for non-contained muons. Two algorithms are evaluated: the "Gran Sasso" algorithm (2D, Collection view) and the "MicroBooNE" algorithm (3D angles), applied to 2391 simulated and 2255 real stopping muon tracks (0.4-1 GeV/c). Performance is assessed via bias and resolution, using range-based momentum as a reference. Two enhanced versions of the "Gran Sasso" algorithm are also developed: one combining all three wire plane views, and one using 3D angles. Results show that the "MicroBooNE" algorithm performs slightly better, with resolution down to 14% in simulation and 16% in real data. These improvements significantly boost  $\nu\mu$  CC statistics, enhancing sensitivity to  $\nu\mu$  disappearance and 3+1 oscillation signals.

Aula 11, Section C, Edificio 19

ore 09:00 – 13:30

SEZIONE II

**Fisica della materia**

Presiede: ROCCATI F. (Università di Palermo)

Comunicazioni

● **Fokker-Planck approach for magnetic fluctuations in 2D anti-ferromagnetic semiconductors.**

MARTELLO E. <sup>(1)</sup>, PALADINO E. <sup>(1)(2)(3)</sup>, FALCI G.A. <sup>(1)(2)(3)</sup>, PELLEGRINO F.M.D. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(2)</sup> *INFN, Sezione di Catania*

<sup>(3)</sup> *CNR-IMM, UoS Università*

In the transition metal-phosphorus-trisulfide (MPS3), low-frequency noise is observed experimentally and attributed to magnetic fluctuations near the transition temperature. In this work, within a phenomenological model, we examine the role of spin fluctuations in electronic transport close below the Néel temperature. Using the Fokker-Planck formalism, we analyse how magnetization dynamics contribute to the low-frequency noise spectrum. Our results suggest that thermal magnetic fluctuations can explain deviations from conventional generation-recombination (GR) noise models and provide new insights into the transport properties of low-dimensional anti-ferromagnetic materials.

Relazioni su invito

▲ **Hydrodynamics and the eigenstate thermalization hypothesis.**

MAZZA L. <sup>(1)</sup>, CAPIZZI L. <sup>(1)</sup>, WANG J. <sup>(2)</sup>, WU X. <sup>(3)</sup>, POLETTI D. <sup>(3)</sup>

<sup>(1)</sup> *Université Paris-Saclay, CNRS, LPTMS, Orsay, France*

<sup>(2)</sup> *Department of Mathematics, Computer Science and Physics, University of Osnabrück, Germany*

<sup>(3)</sup> *Science, Mathematics and Technology Cluster, Singapore University of Technology and Design, Singapore*

The eigenstate thermalization hypothesis (ETH) describes the properties of diagonal and off-diagonal matrix elements of local operators in the eigenenergy basis. In this talk, I discuss a relation between (i) the singular behavior of the off-diagonal part of ETH at small energy differences and (ii) the smooth profile of the diagonal part of ETH as a function of the energy density. This connection is established from the decay of the autocorrelation functions of local operators, which is constrained by the presence of local conserved quantities whose evolution is described by hydrodynamics. Our predictions are corroborated through numerical simulations of two distinct nonintegrable spin-1 Ising models, exhibiting diffusive and superdiffusive transport behaviors.

▲ **Temporal entanglement, dynamical quantum phase transitions and the complexity of simulating the out of equilibrium dynamics.**

TAGLIACOZZO L.

*Institute of Fundamental Physics, IFF-CSIC, Madrid*

The out of equilibrium dynamics can be encoded in the contraction of a spatio-temporal tensor network. Its complexity is thus dictated by the complexity of contracting the network.

For specific strategies, this is determined by the scaling of temporal entanglement. I will review its definition, how it can be measured in experiments and that its scaling form strongly depends on the analytic structure of the evolution operator when continued to the complex time plane. I will conclude by presenting a tensor network algorithm exploiting the temporal entanglement structure, that allows to predict the evolution of local observables for arbitrary times with polynomial resources.

### ▲ Universal properties and phase diagrams of long-range systems.

TROMBETTONI A.

*Università di Trieste e INFN, Sezione di Trieste*

Several recent experiments in atomic, molecular and optical systems motivated a huge interest in the study of quantum long-range spin systems, following a long-standing interest in classical interacting long-range systems. The goal of the talk is to present a general description of the critical behavior and phases of long-range systems. In the first part I will first discuss and review results on classical long-range systems. By introducing a convenient ansatz for the effective action, one can determine the phase diagram for the N-component quantum rotor model with long-range interactions, with N=1 corresponding to the Ising model. The phase diagram shows a non-trivial dependence on the power-law exponent of the spatial decay of the couplings.

Comunicazioni

### ● Predicting fermionic densities using a Projected Quantum Kernel method.

PERCIAVALLE F. <sup>(1)</sup>(<sup>2</sup>), PLASTINA F. <sup>(1)</sup>(<sup>2</sup>), PISARRA M. <sup>(1)</sup>(<sup>2</sup>), LO GULLO N. <sup>(1)</sup>(<sup>2</sup>)

<sup>(1)</sup> *Dipartimento di Fisica, Università della Calabria, Arcavacata di Rende*

<sup>(2)</sup> *INFN, Gruppo Collegato di Cosenza*

We use a support vector regressor based on a projected quantum kernel method to predict the density structure of 1D fermionic systems of interest in quantum chemistry and quantum matter. The kernel is built on with the observables of a quantum reservoir implementable with interacting Rydberg atoms. Training and test data of the fermionic system are generated using a Density Functional Theory approach. We test the performance of the method for several Hamiltonian parameters, finding a general common behavior of the error as a function of measurement time. At sufficiently large measurement times, we find that the method outperforms the classical linear kernel method and can be competitive with the radial basis function method.

### ● Coherent heat exchange in a prethermalizing open quantum system.

ARTINI S. <sup>(1)</sup>, LORENZO S. <sup>(1)</sup>, PATERNOSTRO M. <sup>(1)</sup>(<sup>2</sup>)

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *Centre for Quantum Materials and Technologies, School of Mathematics and Physics, Queen's University Belfast, UK*

We investigate a simple model exhibiting a non-Markovian prethermal phase a metastable state that emerges before full thermalization through the framework of quantum stochastic thermodynamics. In particular, we explore the impact of initial energy coherences on heat exchange with the bath and their contributions to entropy production, as quantified by a heat exchange fluctuation theorem. This relation is derived using the End-Point Measurement (EPM) scheme, a protocol that accounts for initial quantum coherences in energy statistics at the cost of introducing additional classical uncertainty in the initial state. We compare these results with those obtained from the widely used Two-Point Measurement (TPM) scheme, which, due to projective measurements at both the initial and final times, fails to

capture such quantum effects. Finally, leveraging a non-equilibrium Landauer's principle alongside the EPM scheme, we infer constraints on the dimensionality of the bath coupled to the system.

● **Local ergotropy dynamically witnesses many-body localized phases.**

FORMICOLA F. <sup>(1)</sup>, DI BELLO G. <sup>(1)</sup>, DE FILIPPIS G. <sup>(2)</sup><sup>(3)</sup>, CATAUDELLA V. <sup>(2)</sup><sup>(3)</sup>, FARINA D. <sup>(1)</sup>, PERRONI C.A. <sup>(2)</sup><sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(2)</sup> *SPIN-CNR and Dipartimento di Fisica, Università di Napoli Federico II*

<sup>(3)</sup> *INFN, Sezione di Napoli*

Anderson localization (AL) and Many-Body localization (MBL) are dynamical phenomena in which the quantum system fails to dynamically achieve the thermodynamical equilibrium. In addition to entanglement entropy, previous works show the possibility of distinguishing the phases via thermodynamic quantities that relied on global observables. This process needs an energy price to switch-off the interactions between the subsystem and the rest, which acts as an environment. The aim of the research is to demonstrate that local ergotropy, the maximum extractable work via local unitary operations on a small subsystem, is also a dynamical signature for localization phenomena without turning off any Hamiltonian coupling. In particular, the one-dimensional disordered XXZ Heisenberg model is analysed via extended numerical simulations. Taking two spins as subsystem, local ergotropy time behaviour is showed to clearly vary distinguishing MBL and ergodic phases. A fundamental consequences of our results is that an experimenter can have access to a quantum thermodynamical marker for dynamical phenomena without the need of local observables, but only via local measures of extracted work.

● **Dissipative quantum North-East-Center model: steady-state phase diagram and nonergodic dynamics.**

BRIGHI P. <sup>(1)</sup>, BIELLA A. <sup>(2)</sup><sup>(3)</sup>

<sup>(1)</sup> *Faculty of Physics, University of Vienna, Austria*

<sup>(2)</sup> *Pitaevskii BEC Center, CNR-INO e Dipartimento di Fisica, Università di Trento*

<sup>(3)</sup> *INFN-TIFPA, Trento Institute for Fundamental Physics and Applications, Trento*

Open quantum many-body systems host non-equilibrium phases of matter with no counterpart at equilibrium. In this work, we study the quantum dynamics of the dissipative North-East-Center model: a two-dimensional spin lattice subject to kinetically constrained chiral dissipation. In isolated systems, kinetically constrained models have unique nonergodic properties with characteristic dynamical features. Here, we combine kinetic constraints and dissipation, considering models where chirality is induced by local incoherent spin flips conditioned by an asymmetric majority-vote rule. In addition to the dissipative terms, we introduce quantum fluctuations. We determine the steady-state phase diagram within a cluster mean-field approach and we find the emergence of a bistable ferromagnetic phase, with two distinct steady states with opposite magnetization. Finally, we study the real-time reabsorption dynamics of bubbles of the minority phase in large lattices showing evidence of nonergodic behavior in the bistable phase.

● **Superradiant quantum phase transition in open systems: system-baths interaction at the critical point.**

ORLANDO G., SAVASTA S., LAMBERTO D.

*Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina*

The occurrence of a second-order quantum phase transition in the Dicke model is a well-established feature. On the contrary, a comprehensive understanding of the corresponding

open system, particularly in the proximity of the critical point, remains elusive. When approaching the critical point, the system inevitably enters first the system-bath ultrastrong coupling regime and finally the deep strong coupling regime, causing the failure of usual approximations adopted to describe open quantum systems. We study the interaction of the Dicke model with bosonic bath fields in the absence of additional approximations, which usually relies on the weakness of the system-bath coupling. We find that the critical point is not affected by interactions with environments displaying metastable minima. Moreover, such interactions cannot affect the system ground-state condensates in the superradiant phase, whereas the bath fields are infected by the system and acquire macroscopic occupations. The obtained reflection spectra display lineshapes which become increasingly asymmetric, both in the normal and superradiant phases, when approaching the critical point.

● **From no-click to lindblad: Measurement-induced phase transitions with imperfect detectors.**

DI FRESCO G. <sup>(1)</sup>, PAVIGLIANITI A. <sup>(1)</sup>, SILVA A. <sup>(1)</sup>, SPAGNOLO B. <sup>(2)</sup>, VALENTI D. <sup>(2)</sup>, CAROLLO A. <sup>(2)</sup>

<sup>(1)</sup> *International School for Advanced Studies, Trieste*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica, Group of Interdisciplinary Theoretical Physics, Università degli Studi di Palermo*

Out-of-equilibrium closed systems undergo very interesting physical phenomena such as thermalization, transport, and entanglement properties. Recently, a lot of attention has been given to these systems in situations where unitary dynamics are alternated with measurements. This is particularly due to measurement-induced phase transitions (MIPT), where the interplay between measurement and unitary dynamics gives rise to different non-equilibrium phases characterized by distinct entanglement structures. In this work, we investigate whether signatures of MIPT persist under partial post-selection, i.e., averaging over a subset of trajectories as opposed to the full ensemble. Conceptually, this corresponds to retaining only partial information about the measurement outcome. Here, we introduce a Liouvillian model that interpolates between the full post-selected scenario, i.e., the so-called no-click limit, and the Lindbladian model. We examine the steady state of a continuously monitored fermionic Kitaev chain, characterizing its correlation and entanglement properties across the whole phase diagram.

● **Interplay of entanglement and stabilizer entropy in spin models.**

VISCARDI M. <sup>(1)(2)</sup>, DALMONTE M. <sup>(3)</sup>, HAMMA A. <sup>(1)(2)(4)</sup>, TIRRITO E. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

<sup>(2)</sup> *INFN, Sezione di Napoli*

<sup>(3)</sup> *The Abdus Salam International Center for Theoretical Physics, Trieste*

<sup>(4)</sup> *Scuola Superiore Meridionale, Napoli*

Quantum complexity hinges on two fundamental resources: entanglement and nonstabilizer-ness. Understanding their interplay is, therefore, crucial for uncovering the fundamental origins of quantum complexity. Recent works have proposed entanglement spectral quantities, such as the antiflatness of the entanglement spectrum and the capacity of entanglement, as effective complexity measures, establishing direct connections between entanglement and stabilizer Rényi entropies. In this study, we employ these measures to explore quantum complexity across a broad set of spin models, showing these quantities to consistently differentiate between distinct phases of matter. Specifically, we provide a detailed analysis of spin chains including the XXZ model, the transverse-field XY model, its extension with Dzyaloshinskii-Moriya interactions, as well as the Cluster Ising and Cluster XY models. Our findings reveal that entanglement spectral quantities and stabilizer entropies serve as

intertwined, robust indicators of quantum phase transitions, highlighting their significance in characterizing quantum complexity in many-body systems.

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Aula 12, Section C, Edificio 19

ore 09:00 – 13:30

## SEZIONE II

**Fisica della materia**

Presiede: AGNELLO S. (Università di Palermo)

*Le relazioni su invito si terranno nell'Aula 11, i lavori si sposteranno nell'Aula 12 per le seguenti comunicazioni.*

## Comunicazioni

● **Quantum noise spectroscopy in hybrid superconducting artificial atoms.**VERGA A.M. <sup>(1)</sup>, PALADINO E. <sup>(1)(2)</sup>, G.A. FALCI <sup>(1)(2)</sup><sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*<sup>(2)</sup> *INFN, Sezione di Catania*

Quantum noise spectroscopy is an effective technique for characterizing noise sources that affect superconducting qubits. In this work, we apply various dynamical control protocols to a multilevel artificial atom based on a ferromagnetic Josephson junction, known as the ferrotrasmon. In particular, we employ the spin-locking protocol using AC-driven pulses to probe magnetic noise and quasiparticle-induced noise. To this end, the multilevel system is reduced to few level multiplets and we apply phenomenological and microscopic approaches, including the Time-Convolutionless (TCL) method and microscopic master equation. These analyses are made possible by the ferrotrasmon's tunability, enabled by its ferromagnetic Josephson junction core.

● **Andreev non-Hermitian Hamiltonian for open Josephson junctions from Green's functions.**CAPECELATRO R. <sup>(1)(3)</sup>, MARCIANI M. <sup>(1)</sup>, CAMPAGNANO G. <sup>(2)</sup>, LUCIGNANO P. <sup>(1)</sup><sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Napoli Federico II*<sup>(2)</sup> *CNR-SPIN, Napoli*<sup>(3)</sup> *Dipartimento di Fisica, Università di Salerno, Fisciano*

We investigate the transport properties of open Josephson junctions (JJs) through a minimal effective non-Hermitian (NH) approach derived from the Green's function (GF) formalism. We consider a JJ with a quantum dot barrier coupled to a normal metal reservoir. The coupling introduces an imaginary self-energy term in the JJ Hamiltonian which can be naturally accounted for in the NH formalism. While most approaches to similar problems work with the full junction Hamiltonian we propose a scheme to derive an effective NH Hamiltonian for the Andreev bound states (ABS) only, that we compute from the singular part of the dot GF. To establish the range of applicability of this NH model we benchmark our results for both the dot density of states and the supercurrent against exact GF predictions in different transport regimes. As a rule of thumb, the Andreev NH description is accurate when the spectral overlap between the ABS and the near-gap continuum states is negligible, i.e. when the ABS energies lie sufficiently far from the superconducting gap relative to their linewidth. This method highlights the effective physics of the JJ and offers a scalable framework to study large-size devices.

● **Structure analysis and electric performances evaluation of Cu:Sb<sub>2</sub>Se<sub>3</sub> solar cells.**

FERRUGGIA BONURA S. <sup>(1)</sup>, BARBAROSSA S. <sup>(1)</sup>, BRONZONI M. <sup>(2)</sup>, SPAGGIARI G. <sup>(2)</sup>, PATTINI F. <sup>(2)</sup>, BARRANTES J. J. N. <sup>(3)</sup>, BUFFOLO M. <sup>(3)</sup><sup>(5)</sup>, DE SANTI C. <sup>(3)</sup>, TRIVELLIN N. <sup>(3)</sup><sup>(4)</sup>, MENEGHINI M. <sup>(3)</sup><sup>(5)</sup>, CANNAS M. <sup>(1)</sup>, AGNELLO S. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

<sup>(2)</sup> *CNR, Istituto dei Materiali per l'Elettronica ed il Magnetismo, Parma*

<sup>(3)</sup> *Dipartimento di Ingegneria Informatica, Università di Padova*

<sup>(4)</sup> *Dipartimento di Ingegneria Industriale, Università di Padova*

<sup>(5)</sup> *Dipartimento di Fisica e Astronomia, Università di Padova*

Antimony selenide (Sb<sub>2</sub>Se<sub>3</sub>)-based solar cells are emerging as efficient and sustainable photovoltaic devices, with a theoretical conversion efficiency of 32.2%. In this work, Cu-doped Sb<sub>2</sub>Se<sub>3</sub> thin films were deposited on Fluorine-doped Tin Oxide (FTO) substrates using Pulsed Electron Deposition (PED), starting from Sb<sub>2</sub>Se<sub>3</sub> targets with 5 at% Cu. Alongside complete solar cells, single layers of each component were deposited on dedicated substrates for individual analysis. Electrical performance was evaluated through current-voltage (IV) and external quantum efficiency (EQE) measurements under dark and illuminated conditions. To investigate defects and recombination dynamics, steady-state and time-resolved photoluminescence spectroscopy was conducted across multiple excitation wavelengths. Key results on device performance and optoelectronic properties will be presented. This work has been developed in the framework of the project Network 4 Energy Sustainable Transition - NEST, code PE0000021, CUP B73C22001280006, Spoke 1, funded under the National Recovery and Resilience Plan (NRRP), Mission 4, by the European Union - NextGenerationEU.

● **Polarons in Er<sub>2</sub>Ru<sub>2</sub>O<sub>7</sub>: an obstacle to metallic altermagnets.**

RETICCIOLI M. <sup>(1)</sup>, RADAELLI P. <sup>(2)</sup>, STROPPA A. <sup>(1)</sup>

<sup>(1)</sup> *CNR-SPIN L'Aquila*

<sup>(2)</sup> *University of Oxford, UK*

Altermagnets, a novel class of magnetic materials, bridge the gap between conventional antiferromagnets and ferromagnets by hosting spin-split electronic structures without net magnetization. These materials hold promise for spintronic applications due to their unique symmetry-driven properties. In this work, we explore altermagnetism in the oxide semiconductor Er<sub>2</sub>Ru<sub>2</sub>O<sub>7</sub>, which exhibits a rare double altermagnetic ordering arising from the Er and Ru magnetic sublattices. Using density functional theory, we investigate the impact of doping on the magnetic properties. Our findings show that while the Er sublattice demonstrates remarkable robustness against p-doping, the Ru sublattice undergoes significant changes. Notably, excess electrons and hole lead to formation of polarons, which hinder any doping-induced transition towards metallic phases. These results highlight the intrinsic difficulty in achieving metallic altermagnets crucial for spintronic applications due to the formation of polaronic states that localize charge carriers and suppress metallicity.

● **Pressure induced multigap superconductivity in HgS.**

TRESCA C. <sup>(1)</sup>, FORCELLA P.M. <sup>(1)</sup>, SANNA A. <sup>(3)</sup><sup>(4)</sup>, PROFETA G. <sup>(1)</sup><sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Fisiche e Chimiche, Università degli Studi dell'Aquila*

<sup>(2)</sup> *CNR-SPIN c/o Dipartimento di Scienze Fisiche e Chimiche, Università degli Studi dell'Aquila*

<sup>(3)</sup> *Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany*

<sup>(4)</sup> *Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany*

Mercury chalcogenides are a class of materials that exhibit diverse structural phases under pressure, leading to a range of exotic physical properties, including topological phases and



chiral phonons. In particular, the phase diagram of mercury sulfide (HgS) remains difficult to characterize, with significant uncertainty surrounding the transition pressure between phases. Building on recent experimental findings, we present a comprehensive theoretical investigation of the pressure-induced phase transition in HgS and the emergence of superconductivity as the crystal transitions from the cinnabar phase (space group P3221) to the rock salt phase (space group Fm-3m). Using Density Functional Theory (DFT), we analyze the electronic and dynamical properties across the pressure-dependent phase diagram, revealing critical features that promote superconductivity. Our study aims to refine the understanding of phase transitions in HgS, offering new insights into its electronic behavior and the conditions under which superconductivity arises.

### ● Fractons from covariant higher-rank 3D gauge theories.

SACCO SHAIKH D. <sup>(2)</sup><sup>(4)</sup>, BERTOLINI E. <sup>(1)</sup>, BLASI A. <sup>(2)</sup>, CARREGA M. <sup>(3)</sup>, MAGGIORE N. <sup>(2)</sup><sup>(4)</sup>

<sup>(1)</sup> *School of Theoretical Physics, Dublin Institute for Advanced Studies, Ireland*

<sup>(2)</sup> *INFN, Sezione di Genova*

<sup>(3)</sup> *CNR-SPIN*

<sup>(4)</sup> *Dipartimento di Fisica, Università di Genova*

Fracton phases of matter constitute an interesting point of contact between condensed matter and high-energy physics. In our works we adopt a pure field theoretical approach to investigate 3D actions involving a rank-2 symmetric tensor gauge field  $a_{\mu\nu}(x)$  invariant under the covariant fracton symmetry. Firstly, we studied the most general 3D action of  $a_{\mu\nu}(x)$  with mass dimension one and the theory appears as a traceless non-topological higher-rank generalisation of the ordinary Chern-Simons model. Once matter is introduced, a fractonic behavior naturally emerges and the model shows a Hall-like dipole current together with a vectorial flux-attachment relation for dipoles. Subsequently, we studied the 3D field theory of two tensor gauge fields with mass dimension one:  $a_{\mu\nu}(x)$ , transforming under the covariant fracton symmetry, and  $B_{\mu\nu}(x)$ , with no symmetry on its indices. The corresponding invariant action is a non-topological higher-rank BF-like model and, once matter is introduced, a subdimensional behavior emerges, with both fractons and lineons. Moreover our theory can be mapped to the low-energy effective field theory of the Rank-2 Toric Code.

### ● Effects on 4H-SiC photoluminescence of high-pressure post-deposition annealing in oxygen or helium

LAURELLA G. <sup>(1)</sup>, MIGLIORE F. <sup>(1)</sup>, CANNAS M. <sup>(1)</sup>, GELARDI F. M. <sup>(1)</sup>, COCCORESE C. <sup>(2)</sup>, BOSCAGLIA M. <sup>(2)</sup>, PIRNACI M. D. <sup>(2)</sup>, AGNELLO S. <sup>(1)</sup><sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *STMicroelectronics Catania*

<sup>(3)</sup> *AtenCenter, Università degli Studi di Palermo*

4H-SiC is a promising semiconductor for power devices, with superior properties over Si, though defects and passivation still limit full performance. We investigate the effects of high-pressure (800 PSI) thermal annealing on 4H-SiC in oxygen and helium atmospheres at 400 °C and different durations by monitoring exciton recombination lifetime. Three wafer types were studied: a bare epitaxial layer (A), an oxide-covered sample (B), and a NO post-deposition annealed sample (C). Photoluminescence decay measurements reveal that oxygen annealing decreases lifetime in sample A, increases it in sample B, and has little to no effect on sample C. Comparison between Oxygen- and Helium-treated samples reveals only thermal effects for the latter, highlighting the role of oxygen in defect passivation, particularly at the oxide/SiC interface. These results suggest that Oxygen post-deposition annealing is a promising alternative to NO processes, capable of improving interface quality

without introducing foreign atoms. This approach may enhance device performance while maintaining material stability. We would like to thank STMicroelectronics (Catania) for funding this Ph.D. research project.

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Aula Capitò, Edificio 7

ore 09:00 – 13:30

## SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: SELVI M. (INFN, Sezione di Bologna)

Relazioni su invito

▲ **Status of the LEGEND experiment.**

SALAMANNA G. ON BEHALF OF THE LEGEND COLLABORATION

*Università di Roma Tre e INFN, Sezione di Roma Tre*

If neutrinos were Majorana type, they could undergo neutrino-less double-beta decay ( $0\nu\beta\beta$ ). This would have substantial repercussions on cosmology. So far the best statistical sensitivity on the half-life for the ( $0\nu\beta\beta$ ) process is around  $10^{26}$  yr, from experiments employing germanium both as a source and as detector. This sensitivity is attained by combining the current analysis of data from the LEGEND-200, GERDA and MAJORANA Demonstrator experiments. In this contribution I will give an update on the “LEGEND” project: using a two-stage approach with about 200 kg first and then 1000 kg of germanium diodes enriched in the active isotope,  $^{76}\text{Ge}$ , LEGEND aims to attain a half-life sensitivity around  $10^{28}$  yr, thus probing the inverted-ordering of the neutrino masses. I will review the general concept and design of LEGEND-200 and describe the detector and its current results, from the first data taking periods in 2023 and 2024 at the Laboratori Nazionali del Gran Sasso in Italy. I will also illustrate how the backgrounds affect the sensitivity and in which way they are characterized and suppressed. Finally, I will provide an expected timeline for LEGEND-1000 and the related R&D activities.

▲ **CUPID, the CUORE upgrade with particle identification.**

BELLINI F.

*Sapienza, Università di Roma e INFN, Sezione di Roma*

Neutrinoless double-beta decay ( $0\nu\beta\beta$ ) addresses key open questions in particle physics, such as lepton number conservation and whether neutrinos are Majorana particles. Recent efforts aim to improve sensitivity to this process, aiming for half-life sensitivities beyond  $10^{27}$  years. Low-temperature calorimetry is among the most promising techniques and will play a key role in CUPID (CUORE Upgrade with Particle IDentification), a next-generation experiment search for  $0\nu\beta\beta$  decay of  $^{100}\text{Mo}$  using  $\text{Li}_2\text{MoO}_4$  scintillating bolometers. CUPID builds on experience from CUORE, the first ton-scale bolometric detector, operating at Laboratori Nazionali del Gran Sasso, and will use its cryogenic infrastructure. It will feature 1,596 enriched  $\text{Li}_2\text{MoO}_4$  crystals and 1,710 light detectors, allowing simultaneous heat and light readout for particle identification and strong alpha background rejection. This contribution presents the current status and perspectives of CUPID.

Comunicazioni

● **Probing non-standard neutrino properties with low-energy scattering experiments.**

ATZORI CORONA M., CADEDU M., DORDEI F., GIUNTI C., CARGIOLI N.

*INFN, Sezione di Roma Tor Vergata*

The study of non-standard neutrino properties represents one of the most promising avenues to unveil deeper insights into the nature of neutrinos and possible connections to new physics

beyond the Standard Model (SM). For instance, massive neutrinos are expected to acquire a magnetic moment, whose value can be significantly enhanced in various extensions of the SM. Furthermore, neutrinos could carry a small electric charge, a so-called millicharge, that would modify their interaction rates with ordinary matter. Low-energy neutrino interactions, in particular elastic scattering with electrons and nuclei, offer a powerful probe to test and constrain these exotic properties. In this talk, I will present world-leading constraints on the neutrino magnetic moment and millicharge obtained by analyzing data from the LUX-ZEPLIN (LZ) direct dark matter experiment. Moreover, I will explore the complementarity with coherent elastic neutrino-nucleus scattering (CE $\nu$ NS) data, showing that they provide the strongest direct bound on the electron neutrino millicharge.

● **First operation of superconducting quantum bits as particle detectors.**

BONOMO C.

*Dipartimento di Fisica, Sapienza Università di Roma e INFN, Sezione di Roma*

Quantum bits based on superconducting circuits are the frontier of information processing. In recent years, however, it has been shown that they are susceptible to interactions with cosmic rays and ambient radioactivity. But what if we turned this weakness into a strength? Being operational at cryogenic temperatures, they would be perfect for detecting small signals produced by low-energy particles. We explored this idea by testing a chip containing eight qubits under two very different environmental conditions: the deep underground INFN Gran Sasso Laboratory (LNGS, Italy) and the surface-level Fermilab (FNAL, USA). At LNGS, the chip is placed inside a cryostat in the Ieti facility, shielded from ambient radioactivity by lead and screened from cosmic rays by the Gran Sasso rock burden. On the other hand, at FNAL the chip is not screened at all. In this contribution, I will present the detection scheme and the analysis algorithms we developed to operate a qubit as a particle detector. I will demonstrate how these novel techniques enable us to clearly distinguish the differing radioactive environments of LNGS and Fermilab.

● **Misure di contaminazione radioattiva in cristalli di calorimetri criogenici.**

TROMBETTA L.

*Dipartimento di Fisica, Università di Milano Bicocca e INFN, Sezione Milano Bicocca*

CUPID (CUORE Upgrade with Particle IDentification) è un esperimento progettato per la ricerca del decadimento doppio beta senza emissione di neutrini ( $0\nu\beta\beta$ ) del  $^{100}\text{Mo}$ , attraverso l'utilizzo di calorimetri criogenici scintillanti di  $\text{Li}_2\text{MoO}_4$ . Attualmente in fase di progettazione, l'esperimento verrà installato presso i Laboratori Nazionali del Gran Sasso. Qualora osservato, questo processo dimostrerebbe che il neutrino è una particella di Majorana. La segnatura sperimentale consiste in un picco monocromatico al Q-valore della transizione, con tempi di dimezzamento superiori a  $10^{27}$  anni. Per massimizzare la sensibilità sperimentale è essenziale avere bassi livelli di fondo radioattivo nella regione di interesse e un'ottima risoluzione energetica. Quindi è fondamentale assicurarsi elevata radiopurezza di tutti i materiali che costituiscono il rivelatore, e al contempo prestazioni calorimetriche ottimali. A tale scopo sono previsti dei CCVR (Crystal Validation Runs). Nell'intervento presenterà i risultati dell'analisi di uno dei run.

● **Ridurre il fondo per vedere l'invisibile: il muon veto di Cupid tra sfide e risultati.**

GALLI G.

*Dipartimento di Fisica, Università degli Studi di Milano Bicocca e INFN, Sezione di Milano-Bicocca*

CUPID è un esperimento all'avanguardia nella ricerca del decadimento doppio beta senza neutrini, fondamentale per dimostrare la natura di Majorana del neutrino. Evoluzione del

progetto CUORE, CUPID utilizza rivelatori bolometrici avanzati e punta sulla drastica riduzione del fondo tramite un sistema di identificazione particellare (particle ID). Questo sistema consente di discriminare ed eliminare segnali nella ROI dovuti a particelle esterne, come neutroni, particelle alfa e muoni cosmici. Sebbene CUORE sfrutti già la schermatura naturale fornita dai 3600 metri equivalenti di roccia per proteggersi dai muoni, CUPID punta a uno shielding migliore basato su un sistema di rivelatori che circondi completamente il calorimetro. La mia comunicazione si concentrerà sui risultati ottenuti finora riguardo alla schermatura da muoni. Illustrerò qual è lo stato dell'arte di questa tecnologia, quali sono gli studi attualmente attivi riguardo alla sua implementazione in CUPID e quali sono gli sviluppi futuri in quella che è sfida cruciale: ridurre i fondi per riuscire a osservare un decadimento rarissimo, capace di cambiare per sempre ciò che sappiamo sui neutrini.

● **High-energy neutrino flux from SN 2024ggi: constraints from semi-analytic modeling of its post-explosive electromagnetic emission.**

BUCCHERI M. <sup>(1)</sup>, COSENTINO S.P. <sup>(1)(2)</sup>, PUMO M.L. <sup>(1)(2)</sup>

<sup>(1)</sup> Dipartimento di Fisica e Astronomia, Università degli Studi di Catania

<sup>(2)</sup> INAF, Osservatorio Astrofisico di Catania

Core-collapse supernovae (SNe) are potential sources of high-energy neutrinos (HE- $\nu$ ), especially when strong interaction between the SN ejecta and a dense circumstellar medium (CSM) occurs. SN 2024ggi, a Type II SN in the nearby galaxy NGC 3621 ( $\sim 7$  Mpc), is one of the closest SNe of the decade and shows clear evidence of CSM interaction, making it a promising target for multimessenger studies. In this work, we present a semi-analytical model of the post-explosive spectrophotometric evolution of SN 2024ggi, linking its electromagnetic emission to the physical conditions of the progenitor system and its surrounding environment. This framework allows us to infer key parameters governing the particle acceleration and to estimate the associated HE- $\nu$  flux. In this communication, we present these parameters and also discuss the detectability of such emission by current neutrino telescopes, including KM3NeT, comparing it with that of other nearby interacting SNe.

● **Ricerca di neutrini sterili con CUPID-0.**

PIETRAROTA S.

Università degli Studi di Roma La Sapienza e INFN, Sezione di Roma

CUPID (CUORE Upgrade with Particle IDentification) è un esperimento di nuova generazione finalizzato alla ricerca del doppio decadimento beta senza emissione di neutrini ( $0\nu\beta\beta$ ), un processo ipotetico che dimostrerebbe la natura di Majorana del neutrino e la violazione del numero leptonico. Il dimostratore CUPID-0, basato su cristalli arricchiti in  $\text{Zn}^{82}\text{Se}$ , ha validato con successo la tecnica di rivelazione simultanea di segnali termici e di luce di scintillazione, ottenendo una significativa riduzione del fondo radioattivo nella regione d'interesse per il  $0\nu\beta\beta$ . Oltre al canale principale di ricerca, CUPID-0 si presta anche all'esplorazione di fenomeni oltre il Modello Standard, tra cui l'eventuale esistenza di neutrini sterili, i quali interagirebbero unicamente per via gravitazionale. In questo studio si indagano i doppi decadimenti beta con emissione di neutrini, cercando deformazioni nel continuo dello spettro energetico compatibili con la presenza di uno stato sterile ( $\nu N\beta\beta$ ). Vengono quindi presentati i metodi di analisi sviluppati ed i limiti sperimentali posti sul mescolamento tra neutrini attivi e sterili.

● **Gravity test.**

ZENUCCHINI C.

Dipartimento Fisica, Università di Milano

The tensor gravity is symmetric and its trace is related to the local mass density according to the Poisson equation. In free space the trace vanishes if the potential is Newtonian, mass density

distribution around did no influence this result. But if the potential is nonNewtonian the trace doesn't vanish also in the free space. In the seventies Wagone, Fujii and O'Hanion argued that a sort-range force additional to gravity was expected. With this assumption the mass of the Earth or other cosmic bodies would be  $4/3$  of the currently accepted values. If demonstrable experimentally, this is relevant on theoretical ground. For the homogeneous spherical Earth model the trace of the tensor gravity is  $769E$  on the surface. Measuring the trace at different points on Earth, we can test if the Laplacian doesn't vanish with significant statistics. Unlike gravity method, in 2018, Donini use the neutrinos and the Earth is scanned with two ways: neutrino oscillation and neutrino flux attenuation. The preliminary data obtained from ICE CUBE show Earth neutrino mass is lightly larger than Earth gravity mass. Quite different the values of the Earth Core mass  $4/3$  greater than the value estimated by PREM with Newton  $g$ .

● **Outgassing e scariche dell'elettronica in condizioni di vuoto nel sistema di fotorivelatori multi-PMT per l'esperimento Hyper-Kamiokande.**

PONTICELLI E.

*Dipartimento di Fisica, Università degli Studi di Napoli Federico II e INFN, Sezione di Napoli*

Hyper-Kamiokande (Hyper-K) è il rivelatore Cherenkov ad acqua di nuova generazione sviluppato in Giappone, con dimensioni superiori a Super-Kamiokande e miglioramenti significativi in termini di fotosensori e beamline. Utilizzerà due tipi di rivelatori: PMT da 20" e moduli multi-PMT (mPMT), costituiti da 19 PMT da 3" disposti in orientazioni differenti all'interno di un vessel. I rivelatori saranno immersi in acqua degassificata, che tende a acquisire aria dai vessel attraverso le membrane permeabili, modificando le condizioni di pressione e densità del gas all'interno. Questo fenomeno, noto come outgassing, è stato analizzato considerando possibili canali di permeabilità e rappresenta un rischio per l'elettronica ad alta tensione, che potrebbe subire scariche elettriche in condizioni di vuoto. Sono stati effettuati test in camera a vuoto per identificare la pressione limite a cui possono insorgere scariche. La scheda HV è stata testata in varie condizioni, rilevando fenomeni di scarica legati all'effetto punta su pin dei PMT e sulla resistenza di misura e individuando distanze critiche dei limiti di scarica attraverso lo studio dei modelli teorici delle curve di Paschen.

● **From CUORE to CUPID: pioneering next-generation bolometric detection.**

PERACCHI D.

*Dipartimento di Fisica, Università di Milano Bicocca*

Building on the experience of CUORE, the CUORE Upgrade with Particle Identification (CUPID) experiment proposes the use of lithium molybdate (LMO) crystals as scintillating bolometers to search for neutrinoless double beta decay ( $0\nu\beta\beta$ ) in  $^{100}\text{Mo}$ . The dual readout-scintillation light and thermal signal enables effective particle identification, as different particles yield distinct scintillation responses. The fast light signal improves pile-up rejection, the main expected background. The Vertical Slice Test Tower (VSTT) is a prototype designed to test and optimize CUPID's detector technologies. It hosts LMO crystals read out via NTD thermistors, with light signals detected by silicon-based light detectors using Neganov-Trofimov-Luke (NTL) amplification. Its geometry replicates a single CUPID tower and includes improved holders to reduce noise. Now in commissioning, the VSTT will be installed in the Hall A cryostat at LNGS, where I am working on cryostat preparation and thermistor tests. It is essential for validating mechanical, thermal, and readout performance, and will guide the final CUPID design by assessing pile-up rejection, background reduction, and stability.

### ● JUNO detector: status and physics goals.

BELLANTONIO B.

*Dipartimento di Fisica, Università degli Studi di Milano*

One of the most important open problems regarding neutrino physics is the determination of the neutrino mass ordering (NMO). This is the main goal of JUNO (Jiangmen Underground Neutrino Observatory), a multipurpose experiment located in China, which is going to study the NMO through spectroscopy of reactor antineutrinos. The main source of antineutrinos are two nuclear power plants located 53 km away from JUNO. The central detector is composed of a 35 m diameter spherical vessel containing 20 kt of ultrapure liquid scintillator and it will detect electronic antineutrinos using the inverse beta decay reaction. Other goals of JUNO are the study of solar neutrinos, supernova neutrinos, geoneutrinos and atmospheric neutrinos. The project was first proposed in 2008 and the civil construction began in 2015. Once the construction was completed, in December 2024 the commissioning phase started. This is a two-stage process, first the inner detector is filled with pure water, then the water is gradually replaced with the liquid scintillator. The topic of this talk is an introduction to the structure of the detector, its main physics goals and an update on the commissioning status of JUNO.

### ● JUNO sensitivity to neutrino oscillation physics.

CASLINI A.

*Dipartimento di Fisica, Università degli Studi di Milano e INFN, Sezione di Milano*

The determination of the neutrino mass ordering, that is the relative ordering of the neutrino mass eigenstates, is one of the most compelling open questions in particle physics. The Jiangmen Underground Neutrino Observatory (JUNO) is an underground neutrino experiment located in Jiangmen, in southern China. Its core consists of a large organic liquid scintillator mass (20 kton), contained within an acrylic sphere of 35.4 m of diameter and surrounded by 43.212 PMTs. The experimental design also includes a water Cherenkov detector and a top tracker for muon veto. JUNO will primarily detect reactor antineutrinos from two nuclear power plants at a distance of 53 Km, by means of the inverse beta decay (IBD) reaction. Thanks to its large target mass (which will allow to collect data with high statistics) and its unprecedented energy resolution (3% at 1 MeV), JUNO aims, over six years, to determine the neutrino mass ordering with a significance of  $3\sigma$  and to measure three neutrino mixing parameters ( $\sin^2 \theta_{12}$ ,  $\Delta m_{21}^2$  and  $|\Delta m_{31}^2|$ ) out of six with a precision better than 0.5%.

### ● Primi risultati di LEGEND-200: alla ricerca del doppio decadimento beta senza neutrini.

FERIOZZI R.

*Gran Sasso Science Institute, L'Aquila*

Il decadimento beta senza neutrini ( $0\nu\beta\beta$ ) è un processo raro che può avvenire solo se i neutrini sono particelle di Majorana. La sua osservazione implicherebbe la violazione del numero leptonico e rappresenterebbe una prova di Fisica oltre il Modello Standard. L'esperimento LEGEND, che utilizza rivelatori di germanio arricchiti in  $^{76}\text{Ge}$ , è progettato per cercare questo decadimento. La fase iniziale, LEGEND-200, è attiva dal 2023 ai LNGS con 142 kg di rivelatori e punta a un'esposizione di 1 ton anno e un background di  $2 \cdot 10^{-4}$  conteggi/(keV kg anno), per raggiungere una sensibilità di scoperta ( $3\sigma$ ) sul tempo di dimezzamento di  $10^{27}$  anni. La fase successiva, LEGEND-1000, prevede 1000 kg di rivelatori, con un background atteso di  $10^{-5}$  conteggi/(keV kg anno) e un'esposizione di 10 ton anno, consentendo di raggiungere una sensibilità di scoperta di oltre  $10^{28}$  anni, coprendo l'intera regione di gerarchia

di massa inversa. In questo contributo verrà introdotto l'esperimento LEGEND-200, le routine di analisi utilizzate nell'identificazione del segnale e nella soppressione del fondo, con focus nella regione di interesse  $Q_{\beta\beta}$ .

● **Caratterizzazione delle coincidenze casuali nei moduli multi-PMT per Hyper-Kamiokande presso l'esperimento WCTE@CERN.**

ROMANO P.F.

*Dipartimento di Fisica, Università di Napoli Federico II e INFN, Sezione di Napoli*

Hyper-Kamiokande (Hyper-K) è un rivelatore Cherenkov ad acqua di nuova generazione, attualmente in costruzione in Giappone, progettato per esplorare con precisione fenomeni come le oscillazioni di neutrino e la violazione della simmetria CP nel settore leptonic. Il rivelatore impiegherà gli innovativi moduli multi-PMT, ciascuno composto da 19 PMT da 3" alloggiati all'interno di un vessel a tenuta. I moduli mPMT che saranno utilizzati in Hyper-K sono stati installati nel rivelatore dell'esperimento WCTE@CERN per studiarne le prestazioni. L'analisi dei dati acquisiti ha permesso lo studio delle coincidenze casuali tra i segnali registrati da diversi PMT dello stesso modulo in un intervallo temporale. Le coincidenze casuali, pur prive di correlazione fisica tra i segnali, possono mimare eventi reali e rappresentano una delle principali fonti di fondo per i rivelatori a elevata granularità temporale. L'analisi delle coincidenze ha permesso di evidenziare la capacità di discriminazione del rumore di fondo e permetterà una cruciale ottimizzazione degli algoritmi di ricostruzione.

● **Simulation of the front end electronics chain of the LEGEND-200 experiment.**

GAUDIO R.

*Università degli Studi di Padova e INFN, Sezione di Padova*

Neutrinoless double beta decay ( $0\nu\beta\beta$ ) is a lepton-number-violating process. If observed, it would constitute evidence of physics beyond the Standard Model and demonstrate that neutrinos are Majorana particles. The LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay) experiment searches for  $0\nu\beta\beta$  using high purity germanium detectors enriched in  $^{76}\text{Ge}$ . To identify  $0\nu\beta\beta$  signals in a background-dominated energy spectrum, Pulse Shape Discrimination (PSD) techniques are employed. PSD distinguishes events based on the shape of the waveforms produced by the Front End electronics. A novel Python-based simulation of the LEGEND-200 charge sensitive amplifier is presented, incorporating realistic electronic components and cryogenic operating temperatures. The simulation includes a temperature dependent model for silicon JFETs that incorporates the temperature dependence of several semiconductor properties. The simulation addresses a missing component in the LEGEND Pulse Shape Simulation framework, enabling realistic waveform generation. Validated on experimental data, the simulation shows good agreement.

● **The no-hair theorems at work in M87\*.**

IORIO L.

*Ministero dell'Istruzione e del Merito, MIM*

Recently, a perturbative calculation to the first post-Newtonian order has shown that the analytically worked out Lense-Thirring precession of the orbital angular momentum of a test particle following a circular path around a massive spinning primary is able to explain the measured features of the jet precession of the supermassive black hole at the centre of the giant elliptical galaxy M87. It is shown that also the hole's mass quadrupole moment  $Q_2$ , as given by the no-hair theorems, has a dynamical effect which cannot be neglected, as, instead, done so far in the literature. New allowed regions for the hole's dimensionless spin parameter  $a^*$  and the effective radius  $r_0$  of the accretion disk, assumed tightly coupled with the jet, are obtained by including both the Lense-Thirring and the quadrupole effects



in the dynamics of the effective test particle modeling the accretion disk. One obtains that, by numerically integrating the resulting averaged equations for the rates of change of the angles  $\eta$  and  $\phi$  characterizing the orientation of the orbital angular momentum with  $a^* = +0.98$  and  $r_0 = 14.1$  gravitational radii, it is possible to reproduce, both quantitatively and qualitatively, the time series for them recently measured with the Very Long Baseline Interferometry technique. Instead, the resulting time series produced with  $a^* = -0.95$  and  $r_0 = 16$  gravitational radii turn out to be out of phase with respect to the observationally determined ones, while maintaining the same amplitudes

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SEZIONE V

**Biofisica e fisica medica**

Presiede: CHIARELLO A.M. (Università di Napoli Federico II)

Relazioni su invito

▲ **Unraveling variability in BBB opening with FUS and bubbles: Toward standardized and controlled protocols.**

CONTI A.

*Department of Biomedicine and Prevention, University of Rome Tor Vergata*

Focused ultrasound (FUS) combined with microbubbles (MBs) is a promising technique to transiently and non-invasively open the blood-brain barrier (BBB), enabling targeted delivery of therapeutics to the brain. This method is gaining traction in both preclinical and clinical settings for treating neurological diseases. However, despite its potential, experimental outcomes show high variability, and the reasons for this remain unclear in the current literature. In this contribution, we will introduce FUS for drug delivery and examine the acoustic parameters that influence bubble cavitation and BBB permeabilization. We will also discuss strategies to improve the safety of FUS-mediated BBB opening by using advanced real-time monitoring of acoustic emissions during treatment. Finally, we will highlight the role of sophisticated treatment planning tools in enhancing targeting accuracy and reproducibility, with the goal of optimizing both clinical and preclinical applications.

▲ **Deep learning models for targeting in neurosurgical treatments with transcranial MR-guided Focused Ultrasound Surgery (tcMRgFUS).**

MARRALE M. <sup>(1)(2)</sup>, ROMEO M. <sup>(1)(2)(3)</sup>, GAGLIARDO C. <sup>(4)(5)</sup>, COTTONE G. <sup>(1)(2)</sup>, COLLURA G. <sup>(1)(5)</sup>, RUNFOLA C. <sup>(1)</sup>, MAGGIO E. <sup>(1)</sup>, BRUNO E. <sup>(4)(5)</sup>, D'OCA M. C. <sup>(1)(2)</sup>, MIDIRI M. <sup>(4)</sup>, LIZZI F. <sup>(6)</sup>, POSTUMA I. <sup>(7)</sup>, LASCIALFARI A. <sup>(7)(8)</sup>, RETICO A. <sup>(6)</sup>

<sup>(1)</sup> *Department of Physics and Chemistry Emilio Segrè, University of Palermo, Palermo, Italy*

<sup>(2)</sup> *National Institute for Nuclear Physics, Catania Division, Catania, Italy*

<sup>(3)</sup> *Department of Biological Chemical and Pharmaceutical Sciences and Technologies, University of Palermo, Palermo, Italy*

<sup>(4)</sup> *Department of Biomedicine Neurosciences and Advanced Diagnostics, University of Palermo, Palermo, Italy*

<sup>(5)</sup> *Neuroradiology Unit University-Hospital Paolo Giaccone of Palermo, Palermo, Italy*

<sup>(6)</sup> *National Institute for Nuclear Physics, Pisa Division, Pisa, Italy*

<sup>(7)</sup> *National Institute for Nuclear Physics, Pavia Division, Pavia, Italy*

<sup>(8)</sup> *Department of Physics, University of Pavia, Pavia, Italy*

In recent years, *in vivo* tractography has become essential in neuroscience, including non-invasive brain connectivity studies and presurgical planning. There is growing interest in diffusion tractography for target identification in functional neurological disorders, enabling a more tailored approach. This technique is widely used for established neurosurgical treatments like Deep Brain Stimulation (DBS) and is powerful also for newer methods such as transcranial Magnetic-Resonance-guided Focused Ultrasound Surgery (tcMRgFUS). Tractography provides more accurate, patient-specific information compared to stereotactic atlases, but it is not very user-friendly and requires hours for MRI data processing. This study

presents the development of a deep learning framework for rapid target predictions using probabilistic tractography. It utilizes a Convolutional Neural Network (CNN) to predict the location of the Ventral Intermediate Nucleus of the thalamus (VIM). Trained on Human Connectome Project datasets, the CNN demonstrated strong predictive capability for the VIM region using only T1w images, achieving results in fractions of a second per subject, allowing real-time use during treatment.

## Comunicazioni

● **Physico-chemical characterization of Baicalin (BA)/sulfobutylether- $\beta$ -cyclodextrin (SBE- $\beta$ -CD) inclusion complex by  $\mu$ -Raman, FTIR-ATR and XRD techniques.**

PALADINI G. <sup>(1)</sup>, CARIDI F. <sup>(1)</sup>, MAJOLINO D. <sup>(1)</sup>, VENTURA C. A. <sup>(2)</sup>, DE GAETANO F. <sup>(2)</sup>, STANCANELLI R. <sup>(2)</sup>, TOMMASINI S. <sup>(2)</sup>, MOTTESE A. F. <sup>(3)</sup>, FAGGIO G. <sup>(3)</sup>, VENUTI V. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli Studi di Messina, Messina, Italy*

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Over the last years, many efforts have been devoted to the design of high-performance drug delivery systems capable to transport suitable dosage of the drug with high spatial and temporal accuracy. In this context, we report here a detailed experimental  $\mu$ -Raman, FTIR-ATR and XRD investigation of Baicalin (BA)/sulfobutylether- $\beta$ -cyclodextrins (SBE- $\beta$ -CD) inclusion complexes. The molecular interactions existing between BA and SBE- $\beta$ -CD driving the complexation process were investigated by monitoring the spectral changes upon the activation of new "host-guest" interactions. Moreover, molecular docking simulations were used to further explore the inclusion complex geometries and their energetically favourable orientations. This work falls in the framework of the PRIN 2022 project "Future challenges in management of recurrent/resistant Infection: development of antimicrobial Nanoparticulate systems and physical-chemical investigation of their Interactions with biofilm-associated infection" (FINI), CUP: J53D23008880006, PNRR - Mission 4, Component 2, Investment 1.1 - PRIN 2022 Call for Proposals - Directorial Decree No. 104 of 02-02-2022, funded by the European Union - Next Generation EU.

● **Label-free molecular profiling of tear fluid by Raman spectroscopy for neurodegenerative disease differentiation.**

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Tear fluid is an accessible, non-invasive biofluid with strong potential for revealing molecular biomarkers of neurodegenerative diseases. In our previous study, we developed a Raman spectroscopy-based protocol to analyze tear samples from patients with Amyotrophic Lateral Sclerosis (ALS) and healthy controls. Tears (5  $\mu$ L) were deposited on BaF<sub>2</sub> substrates and air-dried under controlled conditions. Raman mapping was performed using a 532 nm laser (6 mW, 1  $\mu$ m spot size) across the 150–1800  $\text{cm}^{-1}$  spectral range. Distinct spectral features—including peaks at 1005, 1450, 1575, and 1670  $\text{cm}^{-1}$ —were significantly enhanced in ALS samples, with the 1450  $\text{cm}^{-1}$  C-H deformation band showing up to 80% higher intensity than controls. Building on these findings, we recently extended the protocol to include tear fluid from patients with Parkinson's Disease (PD). Comparative spectral analysis revealed distinct molecular patterns between ALS and PD groups. This tear-focused, label-free approach highlights the potential of Raman spectroscopy for early, non-invasive differential diagnosis in neurodegenerative disorders.

● **Hop agricultural waste products as latent stocks of material for well-being and food safety.**

ORTORE M.G. <sup>(1)</sup>, MARI E. <sup>(1)</sup>, VILASI S. <sup>(2)</sup>, MANGIONE M.R. <sup>(2)</sup>, LONGO L. <sup>(2)</sup>, GALEAZZI R. <sup>(1)</sup>, MOBBILI G. <sup>(1)</sup>, MINNELLI C. <sup>(1)</sup>, ESPOSITO E. <sup>(3)</sup>, FONTANA R. <sup>(3)</sup>, LETO L. <sup>(4)</sup>, CHIANCONE B. <sup>(4)</sup>, GUARRASI V. <sup>(2)</sup>, MARCONI P.C.R. <sup>(3)</sup>

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Extracts from hop, *Humulus lupulus* L., exhibit antimicrobial activity, as well as amyloid aggregation inhibition properties. Hop is a climbing perennial plant that dies back and grows up from the ground each year. Every year there is a lot of waste after the harvest, since the cones that encase the essential oils and resins used to flavour our beers represent less than 5% of the biomass. Nowadays we need a paradigm shift from viewing agricultural waste as disposal problem to recognizing its inherent value as a secondary raw material. Our contribution to this shift has been to evaluate the constituents that can be recovered, from different genotypes and harvest years, and to repurpose them. By a combination of biophysical techniques, we tested extracts from hop biomass waste as inhibitors of proteins involved in amyloidosis, with very promising results, and encapsulated them in drug delivery systems, able to show significant antibacterial activities, altering bacterial membrane permeability, and promoting biofilm removal. Our experiments demonstrate that hop agricultural waste can be used against phytopathogens, and for amyloidosis prevention.

● **Spectral information dynamics: A new framework to assess multi-order interactions in network neuroscience and physiology.**

SPARACINO L., ANTONACCI Y., BARÀ C., PERNICE R., FAES L.

*Department of Engineering, University of Palermo*

Advances in signal processing and information theory are boosting the development of new approaches for the data-driven modelling of complex network systems. In the fields of Network Physiology (NP) and Neuroscience (NN), where the signals of interest are rich of oscillatory content, the spectral representation of network systems is essential to ascribe interactions to specific oscillations with physiological meaning. We introduce a coherent framework integrating several information dynamics approaches to quantify node-specific, pairwise and

high-order interactions in network systems. A hierarchical organization of interactions of different order is established using measures of information rate to quantify the dynamics of individual nodes, the links between pairs of nodes, and the redundant/synergistic hyperlinks in groups of nodes. All measures are formulated in the time domain and then expanded to the spectral domain to obtain frequency-specific information in the context of Gaussian data represented by linear parametric models. The framework is illustrated using simulation examples and then applied to representative multivariate time series in the context of NP and NN.

● **Atomic force micro-rheology and Brillouin-Raman micro-spectroscopy as new tools for the investigation of ADLD pathology.**

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The nucleus architecture and mechanics are governed by nuclear lamina. Gene duplication and overexpression of lamin B1 have been identified in families affected by autosomal dominant leukodystrophy (ADLD), with increased nuclear stiffness observed in correlation with this overexpression. The primary method for characterizing cell mechanics is nanoindentation by atomic force microscopy (AFM). However, determining nuclear elasticity through indentation approaches is a challenging task, as the nucleus is an internal organelle not directly accessible to the AFM probe. To overcome this, we applied a poroelastic model combined with stress-relaxation technique to calculate the poroelastic diffusion coefficient ( $D_p$ ) in living cells. This investigation revealed a significant difference in poroelastic behavior between ADLD and healthy cells, which was more pronounced than changes in stiffness alone. Moreover, the modifications in nuclear mechanics are characterized by Brillouin-Raman micro-spectroscopy, a contact-free elastography method achieving sub-cellular spatial resolution. The proposed correlative approach sets a new standard for studying pathological nuclear conditions.

● **Physical determinants of nanoparticle-mediated lipid membrane fusion.**

LEONARDINI B. <sup>(1)(3)</sup>, BOCHICCHIO D. <sup>(1)</sup>, VOLPE P. <sup>(1)</sup>, STELLACCI F. <sup>(2)</sup>, DANTE S. <sup>(3)</sup>, CANEPA E. <sup>(4)</sup>, ROSSI G. <sup>(1)</sup>, RELINI A. <sup>(1)</sup>

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Membrane-embedded amphiphilic gold nanoparticles (AuNPs) have recently been studied as artificial fusogens *in vitro*, but the physical factors driving AuNP-mediated fusion remain largely unclear. Here, we investigate the combined roles of nanoparticle core size (2–5 nm) and membrane curvature in modulating the fusion process. We employed AuNPs with identical surface chemistry but varying core diameters, interacting with biomimetic zwitterionic

vesicles of different membrane curvature. Fluorescence spectroscopy assays, quartz crystal microbalance with dissipation monitoring, and molecular dynamics simulations reveal that small AuNPs promote vesicle fusion regardless of membrane curvature. In contrast, larger AuNPs do not exhibit fusogenic properties with low-curvature membranes and can induce fusion only in the presence of highly curved membranes. The steric hindrance of larger nanoparticles prevents the transition from the stalk state to the hemifused state—an effect only partially mitigated by increased membrane curvature. These results highlight the importance of understanding these physical determinants to fully exploiting the potential of novel synthetic fusion strategies.

● **Nano insights and cellular forces: Revealing cytoskeletal dynamics in mechanically driven diseases.**

PARENTI V. <sup>(1)</sup><sup>(3)</sup>, ZANACCHI F.C. <sup>(1)</sup><sup>(2)</sup><sup>(4)</sup>, MAGRASSI R. <sup>(3)</sup><sup>(5)</sup>, RISSO T. <sup>(2)</sup>, VITI F. <sup>(3)</sup><sup>(5)</sup>, DIASPRO A. <sup>(1)</sup><sup>(3)</sup>

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Understanding molecular organization and cellular mechanical properties at the nanoscale is crucial for studying mechanosensitive diseases and cancer progression. Super-Resolution Microscopy (SRM) offers great tools for examining these mechanisms at high spatial resolution. In this work, we employ Single Molecule Localization Microscopy (SMLM) and MINFLUX (Minimal photon fluxes) microscopy with resolutions down to below 10 nm to examine cytoskeletal structure and mechanosensing. Traditional SMLM and MINFLUX are used to examine the nanoscale structure of the cytoskeletal network in various cell models, with a focus on mechanosensitive contexts in which cytoskeletal dynamics and cell mechanics are highly coupled. We also determine the potential of integrating SRM with Traction Force Microscopy (TFM), an assay which quantifies displacement fields in the extracellular matrix (ECM) *in vitro*. These techniques have the potential to be applied in key research areas, from actin-related mechanical diseases to cancer, with relevance to the understanding of the mechanical behavior and migratory potential of tumor cells during metastasis.

● **Minflux tracking of model nanoparticles in 2D and 3D environments simulating the cell cytoplasm.**

ANGELI E. <sup>(1)</sup>, LUCA A. <sup>(1)</sup>, SALERNO M. <sup>(1)</sup>, CIVITA S. <sup>(2)</sup><sup>(3)</sup>, SIMEONE M. <sup>(2)</sup><sup>(4)</sup>, MARIANGELI M. <sup>(2)</sup>, BIANCHINI P. <sup>(2)</sup>, DIASPRO A. <sup>(1)</sup><sup>(2)</sup>

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The study of diffusion processes in biological environments may greatly benefit from super-resolution microscopy techniques, enabling unprecedented spatial and temporal resolution. Minflux technique, in particular, has demonstrated single-molecule-level localization precision, which allows for tracking proteins in the cellular cytoplasm—a typical case of a crowded environment due to the presence of a large number of macromolecules and organelles. We present preliminary measurements of diffusion coefficients for fluorescent nanoparticles of different sizes in fluids of various viscosities. The nanoparticle trajectories acquired by using a Minflux apparatus are analyzed by Python and MATLAB code. Then, we address

model systems where the diffusion of fluorescently labeled particles is confined by tethering polymers or nanoconstraining structures mimicking nano-objects' behaviour in biological systems.

● **Spectral and dynamic analysis of LLPS in synthetic membrane-less compartments via FCS and Spectral Phasor approaches.**

SCOLLO F. <sup>(1)</sup>, LONGO E. <sup>(1)</sup>, DE LUCA G. <sup>(2)</sup>, SCALISI S. <sup>(1)</sup>, PATERNÒ G. <sup>(1)</sup>, VETRI V. <sup>(2)</sup>, LANZANÒ L. <sup>(1)</sup>

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<sup>(2)</sup> *Dipartimento di Fisica e Chimica "Emilio Segrè", Università degli Studi di Palermo, Palermo, Italia*

Recent studies have identified Liquid-Liquid Phase Separation (LLPS) as a central mechanism for organizing membrane-less compartments, such as nucleoli, within cells. However, the principles governing biomolecular self-assembly *in vivo* remain poorly understood, highlighting the need for tuneable synthetic systems that minimize cellular complexity. We engineer cell-inspired, controllable compartments that mimic membrane-less organelles and allow systematic investigation of how confinement and crowding affect protein condensation and reaction dynamics. We combine Fluorescence Correlation Spectroscopy (FCS) and Spectral Phasor analysis of ACDAN, an environment-sensitive dye, to monitor protein assembly, diffusion, and nanoscale interactions in real time. We also plan to employ Image Scanning Microscopy (ISM) and Stimulated Emission Depletion (STED) for structural insights. This work advances understanding of LLPS structure function relationships, dynamics, and links to disease, bridging simplified models and cellular complexity with broad implications for biomedicine and nanotechnology. Funded by PRIN 2022 PNRR - Project: LLIPS P20228CCLL.

● **IsdH hemophore from *Staphylococcus aureus* contains a disordered region putatively involved in iron acquisition.**

MARCHETTI M. <sup>(1)</sup>, DE BEI O. <sup>(1)</sup>, BUOLI COMANI V. <sup>(2)</sup>, RONDA L. <sup>(1)</sup><sup>(3)</sup>, CAMPANINI B. <sup>(2)</sup>, FAGGIANO S. <sup>(2)</sup><sup>(3)</sup>, PARIS G. <sup>(4)</sup>, LUISI B. F. <sup>(4)</sup>, BETTATI S. <sup>(1)</sup><sup>(3)</sup>

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*Staphylococcus aureus* fulfills its need for iron, essential for bacterial survival and pathogenicity, by exploiting heme as preferred source. The dedicated Iron-regulated surface determinant (Isd) system has evolved to extract heme from host hemoglobin (Hb). The first two proteins employed in Hb binding are the surface-exposed receptors IsdB and IsdH. While the former is a proven virulence factor, studies on the biological role of the latter are still ongoing and a likely function is heme extraction from the haptoglobin-hemoglobin (Hp-Hb) complex. IsdH structure consists of three NEAT (Near iron transporter) domains connected by two linker regions, one forming a well-defined helical bundle, while the one bridging NEAT1 and NEAT2 appears to be intrinsically disordered. Using single-particle cryo-EM we investigated IsdH structure in complex with Hb and Hp and we found that the disordered region does not appear in our density maps, suggesting that it remains flexible and unresolved even in the Hb:Hp complex. Further analysis about the function and dynamics of this disordered region could help to shed light on specific strategies employed by *S. aureus* to evade host immune defenses.



● **Unveiling the complex self-organization of cancer circular DNA with polymer physics.**

CONTE M.

*Dipartimento di Fisica, Università di Napoli "Federico II" e INFN*

Extrachromosomal DNAs (ecDNAs) are DNA rings found in the nucleus of a broad range of human cancer cells. They can form clusters that have been associated to oncogene overexpression, as they carry genes and corresponding regulatory elements. Their mode of action, though, to organize and stimulate oncogene activation remains mostly unclear. Here, we use polymer physics models to understand the mechanisms whereby ecDNAs self-assemble and establish promiscuous contacts. As a case study we focus on a MYC-harboring ecDNA discovered in COLO320-DM colorectal cancer cells, which has been shown to form clusters tethered by the bromodomain and extraterminal domain (BET) protein BRD4, resulting in a strong overexpression of the MYC oncogene. We find that BRD4 induces phase separation of ecDNA aggregates, resulting in the self-assembly of clusters whose predicted 3D structure is validated against experimental HiChIP data. This phase separation establishes contact domains enriched with regulatory interactions, with a high affinity cluster around the MYC oncogene. Our model further reveals that JQ1, a BET inhibitor, disrupts ecDNA phase separation, abolishing contact domains and regulatory interactions, thereby reducing MYC transcription in COLO320-DM cells. Overall, our results clarify the physical mechanisms whereby ecDNA clusters boost selective oncogene activation, their pathogenic implications, and the potential role of BET inhibitors as anti-cancer drugs targeting BRD4-mediated oncogene-regulator interactions.

● **Discriminating SK-N-BE2 neuroblastoma cell variants using gold-nanoparticles-based imaging.**

PAKRAVANAN K. <sup>(1)</sup>, SALERNO M. <sup>(1)</sup>, ZBEEB H. <sup>(3)</sup>, ANGELI E. <sup>(1)</sup>, VERGANI L. <sup>(3)</sup>, DIASPRO A. <sup>(1)</sup><sup>(2)</sup>

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Neuroblastoma, the most common extracranial solid tumor in children, displays a broad spectrum of differentiation states, often complicating therapeutic strategies. In this study we explore the use of gold nanoparticles (AuNPs) as a tool to distinguish behavioral differences between two subtypes of the SK-N-BE2 neuroblastoma cell line: the parental Mock and the S1.1 variant. Nanoparticle internalization and associated morphological responses were evaluated using confocal microscopy at predetermined exposure time points. This imaging-based approach complements conventional molecular methods and confirms the importance of nanoparticle-cell interaction studies in developing targeted diagnostic or therapeutic strategies for neuroblastoma.



Aula 7, Section B, Edificio 19

ore 09:00 – 13:30

Sezione VI

**Fisica applicata, acceleratori e beni culturali**

Presiedono: MARINO A. (ISASI-CNR, Napoli)

MANTEGNA R. (Università di Palermo)

Relazioni su invito

▲ **Robust and sensitive mid-IR QEPAS sensors: From laboratory innovation to field-ready applications.**

SPAGNOLO V. <sup>(1)(2)</sup>, ZIFARELLI A. <sup>(1)</sup>, MENDUNI G. <sup>(1)</sup>, ELEFANTE A. <sup>(1)</sup>, GIGLIO M. <sup>(1)</sup>, SAMPAOLO A. <sup>(1)(2)</sup>, PATIMISCO P. <sup>(1)(2)</sup>, WU H. <sup>(2)</sup>, LEI D. <sup>(2)</sup>

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Recent advancements in quartz-enhanced photoacoustic spectroscopy (QEPAS) have fostered the development of compact, fiber-coupled, and highly sensitive gas sensors tailored for real-world applications. Innovations include the integration of interband and quantum cascade lasers with indium fluoride fibers and custom acoustic modules, enabling selective multi-gas detection down to ppb levels. The adoption of dual-laser fiber combiners, multi laser sources and overtone excitation of tuning forks enhances system versatility, stability, and detection sensitivity, even in challenging environments such as hydrogen-rich matrices. Applications span from detection of VOCs like BTEX for air quality monitoring, to ammonia in hydrogen for fuel purity analysis, and natural gas composition assessments. These systems could eliminate free-space optics, offering robust plug-and-play operation. Such advancements mark a significant leap towards miniaturized, scalable, and field-deployable spectroscopic platforms, supporting critical needs in environmental, energy, and industrial sectors.

Comunicazioni

● **Modelling of mercury concentration in human body under chronic exposure conditions.**

DENARO G. <sup>(1)(2)</sup>, COSENZA B. <sup>(3)</sup>, CURCIO L. <sup>(1)</sup>, VALENTI D. <sup>(4)</sup>, AVELLONE G. <sup>(2)(5)</sup>

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<sup>(5)</sup> *Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, Università di Palermo*

The dynamics of mercury concentrations in the human body is investigated by using a modified biologically based dynamic (MBBD) model, which considers the inputs via ingestion of both organic and inorganic mercury. The MBBD model reproduces the methylmercury and inorganic mercury concentrations in biological matrices and in main organs of European populations residing close to chlor-alkali plants. The calibration procedure of MBBD model

parameters is based on the experimental datasets published in previous works. The model is validated by using the total mercury concentrations measured in biological matrices collected in the adult population residing in the Augusta Bay. The model results show that the total mercury concentrations in blood and hair of populations residing in Italy and Spain are higher than the risk level 1 fixed by Human Biomonitoring Commission and World Health Organization. The high methylmercury concentrations in major organs of Italian and Spanish populations obtained numerically are enough to cause adverse effects for human health. The MBBD model could become a useful tool for studying and preventing diseases associated with chronic mercury exposure conditions.

● **Atmospheric simulation chamber study on the air pollution mitigation potential of urban vegetation.**

MAZZEI F. <sup>(1)(2)</sup>, BOSIO M. <sup>(3)</sup>, BRUNOLDI M. <sup>(1)(2)</sup>, MASSABÒ D. <sup>(1)(2)</sup>, PARODI F. <sup>(2)</sup>, VERNOCCHI V. <sup>(2)</sup>, PRATI P. <sup>(1)(2)</sup>, ROCCOTIELLO E. <sup>(3)</sup>

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<sup>(3)</sup> *Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova*

Initiatives to mitigate urban air pollution have concentrated on decreasing particulate matter (PM) and nitrogen dioxide (NO<sub>2</sub>) emissions, with plants contributing to pollutant absorption via surface deposition and stomatal uptake. This study seeks to quantify, for the first time, plant-pollutant interactions using an atmospheric simulation chamber (ChAMBRé: Chamber for Aerosol Modelling and Bioaerosol Research), isolating the impacts of specific pollutants to further understanding of each plant species' air purification capabilities. Three species were selected for this purpose based on literature and field data: *N. oleander*, *T. baccata*, and *M. communis*. Plants markedly affected NO<sub>2</sub> levels in ChAMBRé, contingent upon relative humidity (RH): NO<sub>2</sub> elimination predominantly transpired during daylight hours and, to a lesser degree, at night. The species exhibited a distinct capacity to capture the PM in ChAMBRé. These novel findings elucidate the plant's reaction to airborne pollutants and, for the first time, disclose both the individual effects and interactions of these critical pollutants in port operations. This data will inform focused greening projects in urban environments.

● **Application of X-ray fluorescence spectrometry for trace elements detection in Sicilian pistachio seeds and agricultural soils.**

PANEBIANCO S. <sup>(1)</sup>, BARONE G. <sup>(2)</sup>, CAGGIANI M.C. <sup>(2)</sup>, CIRVILLERI G. <sup>(1)</sup>, FINOCCHIARO C. <sup>(2)</sup>, LANZAFAME G. <sup>(2)</sup>, MAZZOLENI P. <sup>(2)</sup>, MUSUMARRA A. <sup>(3)(4)</sup>, PELLEGRITI M.G. <sup>(4)</sup>

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X-ray Fluorescence (XRF) spectroscopy is increasingly applied in the agri-food sector for fast and non-destructive elemental analysis, supporting quality control, authenticity verification and traceability of food products. Thus, we propose an in-situ protocol to accurately assess the quality of Sicilian pistachio according with its origin. This study is part of the project PRIN 2022 PNRR P20223P48S focused on the application of non-destructive physical techniques to assess the quality and safety of Sicilian traditional agri-food products. XRF measurements were performed on pistachio seeds by using a portable XRF spectrometer. The samples were collected from the Bronte and Raffadali districts, in Catania and Agrigento provinces, known respectively for the Pistacchio Verde di Bronte PDO and Pistacchio di Raffadali PDO production, as well as from Messina province. At the same time,

elemental analyses were also performed on the agricultural soils where the pistachio samples were harvested. Preliminary results, including comparisons between XRF spectra, elemental yields detected in pistachio samples and elemental composition of the corresponding soils, will be discussed.

● **Development of a custom-designed device for controlled force application on plants in physiological conditions for the study of cytosolic calcium signal transmission.**

PASSERI D. <sup>(1)</sup>, ORLANDO MARCHESANO B.M. <sup>(2)</sup>, ASCHERO L. <sup>(1)</sup>, GUSLINI D. <sup>(1)</sup>, LENARDI C. <sup>(1)</sup>, COSTA A. <sup>(2)</sup>, RESENTINI F. <sup>(2)</sup>, ORSINI F. <sup>(1)</sup>

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Signal transmission is a fundamental mechanism by which living organisms adapt to environmental changes. In plants, one of the earliest responses to mechanical stress is a rapid increase in cytosolic calcium concentration. This calcium signaling plays a key role in triggering downstream stress responses and can be monitored using fluorescence-based imaging techniques. However, our understanding remains largely qualitative due to the lack of reliable tools for applying quantified mechanical forces. To address this need, we developed a custom-designed system capable of delivering measurable mechanical stimuli to plant leaves. The device combines a calibrated spring with a micrometer head allowing controlled application of forces to the leaf via a cylindrical cap integral with the micrometer rod. A slide placed on top of the specimen secures it in position and allows for integration with fluorescence microscopy systems. The device was calibrated with force measurements from a few to hundreds of newtons. Validation was performed on leaves of tobacco and Arabidopsis adult plants by applying different forces and imaging local and systemic cytosolic calcium response.

● **Preliminary THz-TDS analysis of canvas samples and pigment mixtures for cultural heritage diagnostics.**

DI SARNO V. <sup>(1)</sup>, MADDALONI P. <sup>(1)</sup>, VANNINI E. <sup>(1)(2)</sup>, DAL FOVO A. <sup>(1)</sup>, FONTANA R. <sup>(1)</sup>, ROCCO A. <sup>(1)</sup>, CATAPANO I. <sup>(3)</sup>

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<sup>(2)</sup> *Università di Firenze*

<sup>(3)</sup> *CNR, Istituto per il Rilevamento Elettromagnetico dell'Ambiente*

This work presents preliminary analyses using terahertz time-domain spectroscopy and imaging on canvas samples and other cultural heritage materials. The experimental setup, operating in transmission mode with sub-millimetric resolution, enables point-by-point analysis of the absorption coefficient across frequencies. Using asynchronous optical sampling (ASOPS), hyperspectral absorption maps were obtained, revealing internal features such as graphite sketches hidden beneath acrylic paint. Three canvas samples painted with different pigments and isolated graphite were tested. Results show clear contrast between graphite and non-graphite areas in specific spectral bands, independent of the overlying pigment composition. Mixed-pigment tablets were also analysed to assess the technique's ability to resolve individual components. The method showed consistent and reliable performance. Ongoing work includes controlled-environment measurements to enhance signal quality and repeatability, highlighting the potential of this non-invasive approach for cultural heritage diagnostics.

● **Non-invasive analysis of Egyptian wooden funerary stelae by MA-XRF and MA-XRD: an interdisciplinary study on materials and technology.**

FALCONE F. <sup>(1)(2)</sup>, KLADOURI N.K. <sup>(4)(5)</sup>, BOTTICELLI M. <sup>(1)(2)</sup>, TSAMPA K. <sup>(4)</sup>, RAVAN

E.L. <sup>(1)(3)</sup>, SANTAGATI G. <sup>(1)(2)</sup>, GRIGORAKI A. <sup>(5)</sup>, LAZARIS P. <sup>(5)</sup>, PANAGAKOS I. <sup>(5)</sup>, TSAKRI K. <sup>(5)</sup>, ROMANO F.P. <sup>(1)(2)</sup>, MILIANI C. <sup>(1)</sup>, KARYDAS A.G. <sup>(4)</sup>, CALIRI C. <sup>(1)(2)</sup>

<sup>(1)</sup> CNR, Istituto di Scienze del Patrimonio Culturale

<sup>(2)</sup> INFN Laboratori Nazionali del Sud, Catania

<sup>(3)</sup> Dipartimento di Scienze dell'Antichità, Sapienza Università di Roma

<sup>(4)</sup> Institute of Nuclear and Particle Physics, NCSR Demokritos, Greece

<sup>(5)</sup> Hellenic National Archaeological Museum, Greece

Non-invasive imaging techniques such as MA-XRF and MA-XRD are advanced tools for the in-situ analysis of polychrome surfaces, enabling chemical and mineralogical characterization without sampling. This work presents the results of a study conducted on seven Egyptian wooden funerary stelae dated to the 25th Dynasty (712-664 BC), currently preserved at the Hellenic National Archaeological Museum of Athens. The analyses were carried out using scanning systems developed by the XRAYLab of ISPC-CNR (Catania, Italy), in collaboration with the Institute of Nuclear and Particle Physics, NCSR Demokritos (Athens, Greece). MA-XRF imaging provided high-resolution elemental maps, revealing the use of arsenic- and iron-based pigments, along with recurring calcium-sulfur associations in the ground layers. The integration with MA-XRD analysis allowed the identification of crystalline phases such as minium (Pb<sub>3</sub>O<sub>4</sub>) and hematite (Fe<sub>2</sub>O<sub>3</sub>), as well as traces of lead and tin in copper-based blue pigments, suggesting the recycling of leaded bronze scraps in the production of Egyptian blue. This integrated approach offers valuable insights into ancient manufacturing practices while fully preserving the integrity of the artifacts.

#### ● Micro-Raman Analysis of pigments on Majolicas of Gerace.

BARBA CASTAGNARO I. <sup>(1)</sup>, CASTRIOTA M. <sup>(1)(2)</sup>

<sup>(1)</sup> Department of Physics, University of Calabria, Rende, CS

<sup>(2)</sup> CNR-Nanotec c/o Department of Physics, University of Calabria, Rende, CS

Micro-Raman spectroscopy was applied to characterize the pigments in historical maiolica samples dating from the 16th to the 18th centuries, originating from Gerace and Venice, with one vase of uncertain origin (probably Gerace or Caltagirone). This non-invasive analytical technique, renowned for its high spectral and molecular resolution, enabled the precise, reliable, and non-destructive identification of white, yellow, orange, red, blue, and green pigments commonly used in ceramics of the investigated period. The analysis provided a detailed definition of the typical color palette, delivering valuable data on specific pigment formulations and variants present on the ceramic surfaces. These spectral data confirm the value of micro-Raman spectroscopy as an indispensable tool for the non-destructive and in-depth diagnostics of historical ceramic materials. The obtained results offer a solid scientific basis to deepen the understanding of traditional production processes and guide targeted conservation and restoration strategies essential for the protection, enhancement, and safeguarding of cultural heritage.

Relazioni su invito

#### ▲ Beam dynamics calculations of stable and radioactive ion beam lines.

MASCALI G.R., BELLAN L., CARLETTO O., COMUNIAN M., FRANCESCON P., GALLO C.S., GIRALDO F., KALVAS T., MARTINI D., GALATÀ A.

INFN, Laboratori Nazionali di Legnaro

At INFN, Legnaro National Laboratories, highly charged heavy ion beams —both stable and radioactive— will be produced by two ECR-based devices: an existing source LEGIS (LEGnaro ecrIS) and a so-called Charge Breeder (SPES-CB), part of the ADIGE injector of the SPES project. Beam quality directly affects the acceleration process, impacting transmission

efficiency. For radioactive beams, their intrinsically low intensity presents an additional key challenge to deal with at SPES. This contribution presents numerical beam dynamics studies performed on the LEGIS and SPES-CB extraction systems and related LEBTs. On the one hand, results from a case study on a  $^{208}\text{Pb}^{31+}$  beam extracted from LEGIS shed light on the reasons for the transmission losses and the difficult set-up of the fixed-beta beamline for ions with different mass-to-charge ratios. On the other hand, the characterization of the beam extracted from the SPES-CB allowed the evaluation of the optimal transport optics as a function of the beam parameters and the mass-to-charge ratio, essential in view of the commissioning of the ADIGE injector expected in autumn 2025.

## Comunicazioni

### ● Wafer buckling as a spontaneous symmetry breaking.

VINCIGUERRA V., LANDI A., MALGIOGLIO G.L.

*STMicronics, Catania*

A correlation between the phenomenon of wafer buckling and that of spontaneous symmetry breaking (SSB) has been established. By developing an analytical approximation of the elastic energy of a wafer coated with a thin layer, it is shown as the elastic potential energy, interpreted as a quantity contributing to the thermodynamic free energy, can be investigated within the framework of the Landau theory of the second order phase transitions. The elastic energy of a buckled wafer is a complex function of the stress and the curvatures in the two perpendicular directions. In this work, it is shown as a translation of the coordinate system of the curvatures allows to gain a potential which has a Mexican hat shape. This is a distinctive trait of the phenomenon of spontaneous symmetry breaking (SSB). Moreover, it is shown as the values of the coordinates at the minimum of the SSB potential agrees with those provided by the theory. Buckling is hence a phenomenon that can also be interpreted as a spontaneous symmetry breaking where the rotational symmetry of a disc shaped wafer is broken. It occurs because of a lowering of the wafer energy in the SSB broken symmetry configuration.

### ● Guiding hadron beams with crystals: observation and simulation of channeling effects at hadron-therapy regimes.

CERVATO B. <sup>(1)</sup>, ANDREAZZA A. <sup>(1)</sup>, D'AURIA S. <sup>(1)</sup>, GARATTINI M. <sup>(2)</sup>, LARI T. <sup>(1)</sup>, MEREGHETTI A. <sup>(3)</sup>, PULLIA M. <sup>(3)</sup>, ROSSI R. <sup>(4)</sup>, VALENTE P. <sup>(2)</sup>, VARIOLA A. <sup>(2)</sup>, ZANZOTTERA R. <sup>(1)</sup>, SCANDALE W. <sup>(4)</sup>

<sup>(1)</sup> *Università degli Studi di Milano e INFN, Sezione di Milano*

<sup>(2)</sup> *INFN, Sezione di Roma*

<sup>(3)</sup> *CNAO, Centro Nazionale di Adroterapia Oncologica*

<sup>(4)</sup> *Imperial College, London, UK*

Channeling in oriented crystals is a promising beam manipulation technique for medical physics applications, particularly in hadron therapy, at energies of 300-400 MeV/u. The interaction of relativistic charged particles with the periodic potential of a crystal lattice enables coherent guidance along crystallographic planes, reducing angular dispersion and improving beam collimation. In this context, channeling can be exploited to enhance spatial precision in dose delivery and to develop compact, passive beam deflection devices. Simulations that use Geant4 models are employed to analyse the behaviour of channeled beams in various crystal orientations and experimental setups. Experimental data collected at the National Centre for Oncological Hadrontherapy (CNAO) in Pavia (Italy) will be presented. Results indicate the presence of channeling at this regime, paving the way for novel high-precision beam shaping technologies for treating deep-seated tumours.

● **AI tools development for X-ray plasma diagnostics imaging and spectroscopy in the PANDORA project frame.**

PERI B. <sup>(1)(2)</sup>, NASELLI E. <sup>(1)</sup>, FINOCCHIARO G. <sup>(1)</sup>, MISHRA B. <sup>(1)</sup>, PIDATELLA A. <sup>(1)</sup>, MASCALI D. <sup>(1)</sup>

<sup>(1)</sup> INFN, Laboratori Nazionali del Sud, Catania

<sup>(2)</sup> Sapienza Università di Roma

PANDORA is a multidisciplinary project for the investigation of  $\beta$  decays in stellar-like laboratory plasmas, for fundamental studies in astrophysics and in a wide range of applications. An algorithm for X-ray imaging in SPC was developed, enabling powerful space-resolved spectroscopy in the soft X-ray domain. I'll present the results of further development and optimization of the algorithm by implementing an AI-based machine learning model encoded in MATLAB. Starting with different datasets acquired under varying plasma conditions in two magnetic plasma traps, each event was characterized in terms of its geometrical and intensity-related parameters. Through the AI tool based on the K-means clustering algorithm, clusters of events exhibiting similar features were identified, highlighting parameters that allow discrimination between real and spurious events. Then, a labelled dataset for training a neural network was created, capable of discriminating and minimizing spurious pile-up events. This approach aims to maximize the signal-to-noise ratio and provide unprecedented accuracy in characterizing soft X-ray fluorescence and bremsstrahlung emissions from such plasmas.

● **Analytical modeling of a proton recoil telescope for neutron spectrometry and fusion diagnostics.**

CORDELLA F.

ENEA C.R. Frascati

Understanding the response function of proton recoil telescopes is fundamental to accurate neutron spectrometry, particularly in fusion diagnostics. This work presents a general analytical model, following the approach of Weise (1968), to compute the response function and detection efficiency of proton recoil telescopes for a wide range of geometrical configurations, including extended, off-axis, and non-symmetric neutron sources. The results of Gotoh (1973) are recovered as a limiting case with axial symmetry, thin radiators, and parallel beams. This confirms the derivation's correctness and broader applicability. The results are then extended using asymptotic approximations for short and long source-detector distances, enabling simple enough formulas to be visualized. It accounts for proton energy loss and assumes flat, uniform surfaces. The analytical expressions are validated against Monte Carlo simulations and provide a practical advantage in experimental design, enabling fast system optimization without extensive computations.

● **Tritium production by using fusion-fission hybrid reactors (FFHR).**

PANZA F. <sup>(1)(2)</sup>, BUSTREO C. <sup>(3)</sup>, CIOTTI M. <sup>(1)</sup>, CLAPS G. <sup>(4)(5)</sup>, CORDELLA F. <sup>(4)(5)</sup>, DE LEO V. <sup>(4)(5)</sup>, ORSITTO F. P. <sup>(1)</sup>, PACELLA D. <sup>(4)(5)</sup>, PALUMBO G. <sup>(3)(6)</sup>, PIOVAN R. <sup>(3)</sup>, RIPANI M. <sup>(2)</sup>

<sup>(1)</sup> ENEA, Dipartimento Nucleare, Divisione PLAS, Frascati

<sup>(2)</sup> INFN, Sezione di Genova

<sup>(3)</sup> Consorzio RFX, Padova

<sup>(4)</sup> ENEA, Dipartimento Nucleare, Divisione PLAS, Laboratorio FIPI, Frascati

<sup>(5)</sup> INFN, Laboratori Nazionali di Frascati

<sup>(6)</sup> Università degli Studi di Padova, Dipartimento di Fisica

FFHRs are composed on a coupling between a fusion neutron source driving a subcritical fission core. These systems could be flexible and can be customized for many purposes

like tritium production and its monitoring. Tritium is currently produced using CANDU reactors, but the actual tritium amount will be not sufficient when the future fusion reactors will be operating. Even if the fusion devices will be equipped with a dedicated tritium blanket, the tritium production amount may not sufficient and so, a complementary approach based on FFHR seems to be a good proposal. A FFHR with a breeding area surrounded by a moderator slowing down the fission neutrons until the thermal region, where the tritium production cross-section (from Li6) is higher has been studied. A simulation strategy based on neutrons evaluations, using codes covering many aspects has been performed. Some configurations have been investigated with the aim of maximizing the tritium production with a high TBR value. This new and parallel approach based on dedicated FFHR could guarantee a high net tritium production for providing the fuel necessary for the future fusion plants allowing also a simpler blanket structure.

● **Space and time-resolved X-ray spectroscopy measurements on magnetically confined plasma.**

GIORGIO FINOCCHIARO G. <sup>(1)(2)</sup>, BIRI S. <sup>(3)</sup>, MAURO G. <sup>(2)</sup>, MISHRA B. <sup>(2)</sup>, NASELLI E. <sup>(2)</sup>, PERI B. <sup>(2)(4)</sup>, PIDATELLA A. <sup>(2)</sup>, RÁCZ R. <sup>(3)</sup>, SANTONOCITO D. <sup>(2)</sup>, TORRISI G. <sup>(2)</sup>, MASCALI D. <sup>(2)</sup>

<sup>(1)</sup> *Università degli Studi di Catania*

<sup>(2)</sup> *INFN, Laboratori Nazionali del Sud, Catania*

<sup>(3)</sup> *Atomki, Debrecen, Hungary*

<sup>(4)</sup> *Università La Sapienza, Roma*

In the context of electron cyclotron resonance (ECR) magnetically confined plasma, within the PANDORA INFN project, preliminary results are shown from a recent experimental campaign performed at the ATOMKI ECR plasma facility, to investigate the dynamics of a B-minimum plasma in a compact magnetic plasma trap by X-ray space- and time-resolved spectroscopy measurements. Several complementary measurements of a wide and interdisciplinary interest have been performed to investigate on continuous and pulsed plasma regimes, by an energy-space-time resolved diagnostic tool, consisting of an X-ray pinhole camera (sensitive in  $\sim 30$  keV energy range) with a Pt-Ir X-ray shutter allowing exposure times of few ms. Time-integrated measurements have been carried out via the X-ray fluorescence filtered imaging technique to spatially investigate for the first time the plasma confinement structure as influenced by the debated gas mixing effect (combining Ne, Kr, Ar, Xe). Time-resolved plasma imaging has been performed to study plasma transients, such as ignition and after-glow plasma decay, observing for the first time the evolution of such phenomena on ms time windows.

● **4H-SiC epitaxial defect and related failure: a case study of triangular defect.**

BOTTAI C., ADAMO S., CARBONE B., ALESSANDRINO M.S., RUSSO A.

*STMicronics, Catania*

Silicon carbide (SiC) is a promising material for power electronic device due to its excellent physical properties, such as wide band gap, higher electron mobility, and higher critical breakdown electric field. Despite its great potentials, the producing of high-quality SiC epilayers with low density of defects is complex and remains a great challenge. Extended defect can affect the performance and reliability of semiconductor devices. Early life failure rate (ELFR) tests on SiC devices are crucial for understanding and improving product reliability. These accelerated tests help identify and remove defective devices, provide feedback for process improvements and define testing and screening strategies to meet customer requirements. In this study, we present a case involving a failed device with a triangular defect located at the edge of the active area in 4H-SiC MOSFET. We examine the applied stress

condition able to activate the defect and the resulting current leakage. Furthermore, we discuss about the physical principles underlying the techniques used to localize defect on die area. This case study highlights how the presence of the triangular defects at the edge of the device are able influence the reliability of the device, extending the focus beyond defects within the active area. This insight has been shared with the quality team responsible for wafer inspection, leading to improve in inspection practices to analyze the entire die rather than just the active area.

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Aula 8, Section B, Edificio 19

ore 09:00 – 13:30

SEZIONE VII

**Didattica e storia della fisica**

Presiede: PIRRONE S. (INFN, Sezione di Catania)

**Sessione a cura del Comitato Pari Opportunità della SIF**

*“Educazione Inclusiva: Affrontare le Disuguaglianze di Genere nella Didattica”*

Relazioni su invito

▲ **The gender of science: A scientific analytically-based project to enhance secondary school students' awareness of gender stereotypes in STEM.**

LICCARDO A., GARGANO A., PASTENA A.

*Università di Napoli e INFN, Sezione di Napoli e University of Warwick*

This paper presents a pedagogical intervention targeted at secondary school students developed by two researchers in physics. The project seeks to narrow the gender gap in STEM fields by fostering students' critical awareness of gender stereotypes and roles, helping them to recognize the influence that gender has on their educational choices and professional aspirations. Unlike other orientation programs, here STEM subjects are not the explicit content, rather the working methodology. Our intervention adopts a project-based learning approach introduced by a board game designed to engage students in the topic. Students are guided in carrying out an autonomous investigation of gender discrepancies within their family, school, and peer contexts through a scientific approach, by administering surveys, gathering and analyzing data, and using gender indicators. The final objective is developing a Gender Report of the school. After presenting the project, we document the project experience in nine schools of the Naples (Italy) area through a qualitative analysis of students' Reports, focusing on the gender dynamics they have identified, as well as the facilitators' observations.

▲ **Strumenti e iniziative per la promozione delle STEM: l'esperienza del centro Milly Villa women's studies.**

CIUCHI F.

*Comitato scientifico centro Milly Villa women's studies, Università della Calabria e CNR*

Le donne nelle discipline STEM E STEAM sono in minoranza. Nell'ambito del centro ci occupiamo di variare la percezione di queste discipline presso le studentesse. Tra i progetti per ora intrapresi ci sono la realizzazione di un gioco di carte rappresentanti donne del passato ed attuali, poco conosciute ma fondamentali nelle STEAM e un PCTO dedicato, per ora, alle studentesse delle scuole superiori. In quest'ultimo le ragazze passano una mattinata a fianco delle ricercatrici.

▲ **Indagare l'Autoefficacia Scientifica nella scuola primaria: riflessioni sulle differenze di genere.**

GIARRATANO G.

*Dipartimento di Psicologia, Pedagogia, dell'Esercizio Fisico e della Formazione, Università degli Studi di Palermo.*

Nonostante i progressi degli ultimi decenni, il gender gap in ambito scientifico è ancora evidente. Le ricerche mostrano che nelle ragazze l'interesse per la scienza inizia a diminuire

intorno agli 11 anni e, col tempo, cala anche il senso di autoefficacia scientifica (SSE). Questo studio descrive il processo di validazione di un questionario con scala Likert, volto a misurare la SSE negli alunni della scuola primaria, tra gli 8 e i 12 anni, nel contesto italiano. Il questionario, realizzato sulla base della letteratura, è stato somministrato a 320 alunni di diverse aree della Sicilia e sono state condotte analisi secondo il modello di Rasch e un'analisi fattoriale esplorativa. Successivamente, lo strumento è stato impiegato in una sperimentazione sull'energia con 70 alunni di quinta primaria. Ha permesso di comprendere come, e in che misura, la metodologia IBSE adottata nel percorso didattico abbia favorito lo sviluppo di SSE negli studenti, in particolare nelle studentesse. La ricerca evidenzia l'importanza di intervenire precocemente per promuovere attività che stimolino l'interesse e la crescita della SSE in una fascia d'età cruciale per lo sviluppo futuro.

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#### Relazioni su invito

##### ▲ Il Nuovo Cimento e la Meccanica Quantistica: 1900-1954.

ROBOTTI N., GARIBOLDI L., GUERRA F., LEONE M., PISCICCHIA K., ROSSI P.

*Università di Genova, Centro Ricerche Enrico Fermi*

In occasione del Centenario della nascita della Meccanica Quantistica, si è ricostruito il contributo dei fisici italiani al processo di sviluppo di questa teoria, attraverso l'analisi dei contenuti della rivista della SIF, *Il Nuovo Cimento*. In particolare si è proceduto a una selezione degli articoli più significativi pubblicati tra il 1900, scoperta di Planck, e il 1954, centenario della Rivista. Di questi articoli (circa un centinaio), è stata fatta una scheda di presentazione in cui, oltre che dare informazioni sull'autore, se ne contestualizzano i contenuti nel panorama della fisica del momento. Da questa analisi è emerso che le attività svolte dai fisici italiani furono notevoli, ad esempio, la scoperta dell'effetto Stark-Lo Surdo, la statistica di Fermi-Dirac, la teoria del decadimento beta, l'esperimento di Pancini-Piccioni-Conversi, l'universalità delle interazioni deboli. Di queste attività, troviamo traccia su *Il Nuovo Cimento* che ne è stato lo specchio fedele. Obiettivo finale è quello di mettere gli articoli selezionati, con la loro scheda, a disposizione del pubblico sul sito della SIF.

#### Comunicazioni

##### ● Emozioni epistemiche nella ricerca in didattica della fisica: uno stato dell'arte.

RICCIONI F., LEVRINI O.

*Dipartimento di Fisica e Astronomia, Università di Bologna*

Le emozioni epistemiche emergono come fattori determinanti nei processi di costruzione della conoscenza in fisica. Visto il loro potenziale trasformativo, anche nei contesti di apprendimento e insegnamento, esse sono oggetto di indagine nella ricerca in didattica della fisica. In questo contributo si propone uno stato dell'arte che faccia emergere le prospettive teoriche, metodologiche e applicative di quello che sembra a tutti gli effetti un filone di ricerca in fase di formalizzazione.

##### ● Studio di metodi e tecnologie didattiche per la fisica applicati ad uno studente neurodiverso.

ZITO E., FAZIO C.

*Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

La didattica della fisica oggi deve tenere conto del continuo cambiamento e sviluppo dell'Intelligenza Artificiale che, sempre di più, entra nella quotidianità di studenti e lavoratori. Modelli di Linguaggio a grandi Dimensioni (LLM) sono sempre più in grado di

ottenere la comprensione e la generazione di linguaggio di ambito generale, questo grazie alla loro capacità di adoperare grandi quantità di dati per apprendere miliardi di parametri grazie al deep learning. Programmi come chatGPT, se utilizzati con consapevolezza, sono strumenti che possono ottimizzare e facilitare l'apprendimento. Tramite metodologie di apprendimento come lo Using Explicit e l'Inquiry, verranno illustrati in questo lavoro i pro e i contro dell'uso dell'IA in una serie di esperimenti di elettromagnetismo svolti da uno studente neurodiverso, nello specifico autistico ad alto funzionamento, frequentante un corso di laurea triennale in fisica. Inoltre, verranno anche considerati e esposti i pro e i contro delle metodologie di apprendimento utilizzati dal docente/ricercatore sullo studente neurodiverso con e senza la partecipazione di un gruppo di studenti.

● **AI e Feedback: interazione tra agenti umani e artificiali e questionari standard di valutazione in fisica.**

ROMITA M. <sup>(1)</sup>, FIorentino M. G. <sup>(2)</sup>, MONTONE A. <sup>(2)</sup>

<sup>(1)</sup> *IISS G. Cesare, Bari*

<sup>(2)</sup> *Dipartimento di For.Psi.Com., Università degli Studi di Bari*

Il contributo analizza come l'IA può supportare l'attività del docente nel fornire feedback a gruppi numerosi di studenti generando percorsi interattivi e trasformativi in una logica ecosistemica. Si parte dai primi risultati della ricerca del progetto Prin Ai&F, il quale analizza come il feedback automatizzato, reso possibile da strumenti tecnologici avanzati rappresenti una frontiera emergente circa le sfide legate alla personalizzazione e alla scalabilità della valutazione. Il supporto dell'IA favorisce lo sviluppo professionale dei docenti attraverso percorsi di formazione mirati a integrare il feedback automatizzato nel processo valutativo. Il contributo presenta alcuni risultati preliminari relativi alla sperimentazione nelle grandi aule del corso di Scienze della Formazione Primaria nel corso di Didattica della Fisica. L'analisi si basa sulla somministrazione di alcuni questionari classici provenienti dalla letteratura (p.e. FCI), i quali valutano gli apprendimenti in fisica e la loro ibridazione con modelli preconcepi degli allievi. Si analizza addestramento dell'IA per ottimizzare l'efficacia didattica e di interazione dei feedback tra IA e studenti e IA e docenti.

● **Astro-Tamagotchi: an innovative ICT-based approach to interactive astrophysics education.**

LEONARDI L. <sup>(1)</sup>, BADIA C. <sup>(1)</sup>, DARICELLO L. <sup>(1)</sup>, FULCO M.T. <sup>(1)</sup>, GALLETI S. <sup>(1)</sup>, MALASPINA M. <sup>(1)</sup>, MIGNONE C. <sup>(1)</sup>, MOLINARI D. <sup>(2)</sup>, PAOLETTI D. <sup>(1)</sup>, SANDRI M. <sup>(1)</sup>

<sup>(1)</sup> *INAF*

<sup>(2)</sup> *CINECA*

Astro-Tamagotchi is an innovative educational initiative that leverages information and communication technologies (ICT) to enhance the learning of astrophysics. Drawing inspiration from the popular Tamagotchi concept, the project enables participants to adopt a virtual star and track its entire life cycle, from formation to its final evolutionary stages. Users interact with the system via a Telegram chatbot, employing intuitive commands to care for the star and influence its development, ensuring its correct evolution. This activity integrates key educational elements, including coding, robotics, and augmented reality (AR), to offer an engaging platform that makes complex scientific concepts more accessible. Developed by Play Coding at the National Institute for Astrophysics, Astro-Tamagotchi was introduced at the 2024 Festival of Science in Genoa, engaging 1,964 participants. During the forthcoming congress, findings will be presented regarding the educational effectiveness of the activity and user satisfaction, underscoring the potential of ICT technologies to enhance science education by making it more interactive and engaging.

● **Improving teaching through research experience.**

CHIARELLI G. <sup>(1)</sup>, CAVALLARO M. <sup>(4)</sup>, GOZZELINO A. <sup>(3)</sup>, MANNARELLI M. <sup>(5)</sup>, MIOZZI S. <sup>(2)</sup>, MOU L. <sup>(3)</sup>, NAPOLANO V. <sup>(6)</sup>, PAGLIAROLI G. <sup>(5)</sup>, PEGORARO L. <sup>(3)</sup>, RAPISARDA G. <sup>(4)</sup>, VELCANI E. <sup>(6)</sup>

<sup>(1)</sup> INFN, Sezione di Pisa

<sup>(2)</sup> INFN, Sezione di Roma Tor Vergata

<sup>(3)</sup> INFN, Laboratori Nazionali di Legnaro

<sup>(4)</sup> INFN, Laboratori Nazionali del Sud

<sup>(5)</sup> INFN, Laboratori Nazionali del Gran Sasso

<sup>(6)</sup> European Gravitational Observatory

We present PID (Programma INFN per Docenti), a residential professional development course aimed at high school teachers. Each course lasts from Monday to Friday for a total of 40 hours and includes both lectures and four hands-on laboratories, where all participants (divided into groups) rotate. The lectures focus on the research conducted at the host facility, as do the laboratory activities. Latter are derived from daily work and are structured so that the participating teachers, in collaboration with researchers, perform the required measurements. The basic idea is that teachers will transform what they have learned into educational activities using their creativity and skills. By leveraging the complementary research conducted at the involved facilities, participants gain comprehensive knowledge of the Institute's research in Italy, strengthen (or acquire) laboratory measurement skills, and build direct relationships with researchers. Furthermore, the residential format facilitates networking among participants for exchanging knowledge, experiences, and opportunities.

● **Sperimentazione di metodologie didattiche applicate all'insegnamento della fisica.**

MAGLIARDITI G., SAIJA R.

*Gruppo AIF Politiche attive di formazione e aggiornamento, Sezione di Messina e PLS Fisica e Dipartimento MIFT, Università di Messina*

In questa presentazione si intende esporre un metodo per testare l'efficacia di un processo formativo. L'idea è stata quella di proporre lo stesso argomento a due classi parallele dello stesso Istituto che presentavano, quindi, caratteristiche simili. In una di queste classi la tematica è stata trattata con processi tradizionali ovvero sono state svolte lezioni frontali, nell'altra, invece, lo stesso argomento è stato affrontato applicando metodiche ispirate alla metodologia della lezione partecipata. In entrambe le classi è stato proposto lo stesso test di ingresso; test che è stato riproposto ancora una volta ai due gruppi al termine del processo. Il confronto fra i risultati dei test in uscita con quelli di ingresso ha consentito di comparare le due differenti metodiche di insegnamento.

● **Un tubo di Newton per tutti, come rendere indipendente un esperimento dallo sperimentatore.**

LEOTTA L., WANDERLINGH U., VASI S., TESFAYE N.B.

*Dipartimento MIFT dell'Università degli studi di Messina*

Un tubo di Newton è un classico esperimento della fisica che permette di visualizzare come tutti i gravi cadano con una medesima accelerazione in assenza di attrito. Il tubo di Newton, che è stato realizzato, ha come scopo di rendere accessibile a chiunque l'esperimento, rendendo innessario l'intervento dello sperimentatore per eseguire lo stesso. Lo strumento, automatizzato con un microcontrollore, funziona in tre fasi: vengono sollevati degli oggetti contenti parti ferrose tramite una piattaforma sollevata da un gradiente di pressione all'interno del tubo; viene attivato tramite una fotocellula un magnete che permette di fissare gli oggetti all'estremo superiore del tubo; viene fatto un basso vuoto e al raggiungimento della pressione

desiderata è disattivato il magnete cosicché avvenga la magia della fisica. Lo strumento proposto è, inoltre, facilmente replicabile e con un costo estremamente contenuto permettendo di realizzare un interessante exhibit da utilizzare negli eventi divulgativi nelle scuole e nelle università.

● **Elaborazione di un percorso di apprendimento sulle onde elettromagnetiche.**

CATENA D., MICHELINI M.

*Università di Udine*

È stato elaborato un percorso di apprendimento sulle onde elettromagnetiche indirizzato a studenti dell'ultimo anno di licei scientifici. Il percorso affronta i principali aspetti concettuali che hanno caratterizzato lo sviluppo epistemico della teoria classica del campo elettromagnetico, in relazione alle relative difficoltà di apprendimento identificate in letteratura. Il quadro teorico adottato consiste in una rivisitazione del Model of Educational Reconstruction. Dopo aver sperimentato una prima versione della proposta didattica con un campione di 66 studenti – di un liceo di Trieste – i risultati di apprendimento ottenuti sono stati misurati tramite un test in-out, consistente in 6 quesiti a risposta aperta. Ogni quesito era relativo ad un obiettivo di apprendimento specifico, e l'analisi è stata effettuata categorizzando i profili di risposta. Sulla base dei risultati ottenuti, sono stati modificati alcuni aspetti del percorso di apprendimento – soprattutto in relazione all'identificazione delle sorgenti delle onde elettromagnetiche e alle loro rappresentazioni – in vista di una seconda implementazione attualmente in corso, i cui risultati saranno illustrati al congresso.

● **Dal pendolo alle biforcazioni: esperimenti e modellizzazione.**

D'ANNA M.

*Liceo di Locarno, Svizzera*

In questo intervento viene studiato il comportamento di un pendolo composto, accoppiato ad una molla. Il pendolo è costituito da un disco munito di un carico eccentrico, ed è costruito in modo che, variando la massa di quest'ultimo, è possibile passare da situazioni in cui il sistema possiede una sola posizione di equilibrio a situazioni in cui ve ne sono due. La posizione angolare viene registrata attraverso un sistema di acquisizione dati on-line, mentre con l'utilizzo della modellizzazione dinamica è possibile ottenere un confronto quantitativo tra le misure sperimentali e le previsioni teoriche per l'evoluzione temporale della posizione angolare. Lo studio viene completato considerando gli aspetti energetici, in particolare con l'elaborazione del paesaggio energetico che illustra graficamente l'insorgere delle biforcazioni.

● **I progetti educativi europei: un approccio innovativo all'insegnamento della fisica.**

PERSANO ADORNO D. <sup>(1)</sup>, PIZZOLATO N. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Palermo*

<sup>(2)</sup> *ICS Maredolce, Palermo*

I programmi europei offrono un contesto privilegiato per innovare le pratiche didattiche nell'ambito dell'insegnamento della Fisica. Attraverso metodologie attive, attività collaborative internazionali e percorsi di mobilità, tali progetti promuovono lo sviluppo di competenze trasversali fondamentali, stimolando nei discenti curiosità scientifica, creatività e pensiero critico. Laboratori interdisciplinari, attività ludico-didattiche e pratiche di ricerca applicata costituiscono strumenti efficaci per avvicinare i giovani alla Fisica in modo coinvolgente e concreto, rafforzando la motivazione all'apprendimento. Nel corso della presentazione verranno analizzati esempi di buone pratiche tratte da recenti iniziative Erasmus+, con particolare attenzione all'impatto osservato sull'apprendimento e sulla motivazione degli studenti e dei docenti. Verrà altresì discusso il potenziale di tali esperienze nel sostenere la formazione

continua degli insegnanti di Fisica, nonché le modalità attraverso cui esse possono essere integrate nei curricula nazionali, al fine di formare cittadini scientificamente alfabetizzati e capaci di esercitare un pensiero critico consapevole.

● **Studiare la diffusione molecolare con un diavoleto di Cartesio.**

CARPINETI M. <sup>(1)</sup>, VILLA S. <sup>(1)</sup>, VOLPARI C. <sup>(2)</sup>, CROCCOLO F. <sup>(3)</sup>, VAILATI A. <sup>(1)</sup>

<sup>(1)</sup> 1) *Dipartimento di Fisica, Università degli Studi di Milano*

<sup>(2)</sup> 2) *Liceo Artistico Statale di Brera, Milano*

<sup>(3)</sup> 3) *Université de Pau et des Pays de l'Adour, Anglet, France*

Proponiamo un esperimento coinvolgente realizzabile con oggetti di uso comune che permette di introdurre con diversi livelli di approfondimento, concetti di base su alcuni temi fondamentali della fisica come l'idrostatica, le oscillazioni armoniche e la diffusione molecolare. L'esperimento, adatto sia a studenti universitari sia di scuola superiore è una variante del classico esperimento del diavoleto di Cartesio nel quale il corpo, invece di trovarsi in un liquido di densità uniforme, è inizialmente in equilibrio all'interfaccia tra due liquidi miscibili con densità diverse. Applicando al contenitore sigillato un impulso di pressione, che provoca un corrispondente incremento della densità del diavoleto, si genera una forza di richiamo elastica che mette il diavoleto in oscillazione con una frequenza che dipende dal gradiente di densità. Così è possibile monitorare l'evoluzione del gradiente di densità nel tempo ed eseguire un confronto quantitativo tra i dati sperimentali e quelli teorici ottenuti dalla soluzione numerica dell'equazione di diffusione.

● **The importance of hands-on laboratories in the Virtual Era: a case of study at La Sapienza's DICMALAB.**

BONACCI E.

*Physics Section of the Natural Sciences Unit, ATINER, Athens, Greece*

In the Era of Virtual Laboratories, the traditional Science Laboratory could seem an old-fashioned practice. This is an erroneous belief because the results provided by digital simulations are necessarily partial and, sometimes, misleading. Let us consider, e.g., two alternative mixers for a stirred tank reactor used to crystallize citric acid: a three-blade marine impeller and a Rushton turbine. Any simulation program shows that the marine impeller performs better than the Rushton turbine. This outcome is correct but incomplete and could lead to the wrong perception of a choice between an optimal agitator and a good one. A full comprehension of the situation requires hands-on experience fixing the flaws in computational fluid dynamics and testing the efficacy of each mixer in the crystallization process. It happened in the DICMALAB of La Sapienza University of Rome where the Department of Chemical Engineering Materials Environment established the hazard of Rushton turbine in terms of system stability, power consumption, and noise pollution. Such a mixer was therefore ruled out as dangerous, not just as a low-efficient agitator, a decision hardly predictable via software only.

Aula Magna G.B.F. Basile, Edificio 7

ore 14:30 – 15:10

Sezione VI

**Fisica applicata, acceleratori e beni culturali**

Presiedono: MANTEGNA R. (Università di Palermo)

SERAFINI L. (INFN, Sezione di Milano)

Relazione Generale

■ **30 years of Free Electron Lasers, the way ahead.**

MAZZA T.

*European X-Ray Free Electron Laser Facility, Schenefeld, Germany*

X-ray Free Electron lasers (XFELs) are light sources with brilliance exceeding third-generation synchrotrons by several orders of magnitude, delivering pulses made of many X-ray photons and with very short durations. Pulse durations reaching the (sub-)femtosecond regime, implemented in pump-probe setups either exploiting multipulse delivery schemes or synchronized external sources, give access to the natural time scale of nuclear down to electronic motion. This opens the way to time-resolved experiments from the recording of molecular movies which capture nuclear dynamics, to measurements in which electronic dynamics can be observed, or even electronic control can be exerted. The exceptionally high X-ray pulse energies which can be delivered by FELs, on the other hand, pushed already in early stages the quest for observing strong field effects at nm-sized wavelengths. In a similar manner as decades ago sub-ps pulses gave access to strong field phenomenology in the optical regime, it is anticipated that non-perturbative interaction of X-rays with matter requires the delivery of sub-fs X-ray pulses. In my contribution I will give an overview of the development of Free Electron Laser devices from their infancy in the 1990s until the current state of the art, with specific focus on the recent achievements in the generation, characterization and implementation of attosecond Ångström pulses.

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Aula Magna G.B.F. Basile, Edificio 7

ore 15:10 – 15:50

SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: BEOLÈ S. (Università di Torino)

Relazione Generale

■ **LUNA: Experimental challenges in Underground Nuclear Astrophysics Laboratory.**

FORMICOLA A.

*INFN, Sezione di Roma*

Accurate knowledge of thermonuclear reaction rates is important in understanding the generation of energy, the luminosity of neutrinos, and the synthesis of elements in stars. The LUNA Collaboration has shown that, by going underground and by using the typical techniques of low background physics, it is possible to measure nuclear cross-sections down to the energy of the nucleosynthesis inside stars. Capitalising on the success of the last three decades, the LUNA Collaboration also secured funds for a new 3.5 MV accelerator to allow for the study of He, C, and advanced stellar burning stages, the new accelerator opens up unprecedented opportunities for further studies underground. I will present a summary of the main recent achievements highlighting some of the open questions that remain.

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Aula Magna G.B.F. Basile, Edificio 7

ore 15:50 – 18:50

SEZIONE I

**Fisica nucleare e subnucleare**

Presiede: PASTRONE N. (INFN, Sezione di Torino)

Relazioni su invito

▲ **The Feasibility Study of FCC.**

CIARMA A., BOSCOLO M. ON BEHALF OF THE RD\_FCC COLLABORATION

*INFN, Laboratori Nazionali di Frascati*

The Feasibility Study of the Future Circular Collider has been recently completed and published on time for the 2025 European Particle Physics Strategy Update. The integrated Future Circular Collider (FCC) programme consists of FCC-ee followed by an energy-frontier hadron collider (FCC-hh). This talk will review the accelerator design for FCC-ee with the R&D for key technologies, highlighting the Italian contribution to the project, and a mention to the FCC-hh status.

▲ **Collider a muoni: tecnologia di frontiera per esplorare la nuova fisica.**

LUCCHESI D.

*Università di Padova e INFN, Sezione di Padova*

Le collisioni di fasci di mu a energie di diversi TeV nel centro di massa rappresentano una opportunità sia per esplorare nuova fisica in un regime energetico mai raggiunto prima, sia per effettuare misure di precisione senza precedenti dei processi previsti dal modello standard. L'alta energia di queste collisioni, raggiungibile grazie al fatto che i muoni sono particelle elementari più pensanti degli elettroni, permette di accedere a osservabili fisiche sensibili a nuovi fenomeni come per esempio accoppiamenti non previsti dal modello standard e allo studio del potenziale del campo di Higgs con una sensibilità senza precedenti. Tuttavia, la realizzazione di una macchina a muoni comporta sfide tecnologiche considerevoli. La produzione di fasci di muoni ad alta intensità e alta energia richiede lo sviluppo di nuove soluzioni per la generazione, il raffreddamento e l'accelerazione dei muoni, tenendo conto della loro breve vita media a riposo. Inoltre, la gestione del fondo generato dal decadimento dei muoni lungo la macchina impone requisiti stringenti sulla progettazione dell'interfaccia macchina-rivelatore e sull'ottimizzazione dei rivelatori stessi.

▲ **Grandi infrastrutture di ricerca in Cina.**

GRECO M.

*Università di Torino e INFN, Sezione di Torino*

Le grandi infrastrutture di ricerca in Cina sono finalizzate principalmente alla ricerca di base o fondamentale, costruite e messe a disposizione di una più ampia comunità di ricercatori, e caratterizzate da una politica di accesso basata sulla libera competizione tra proposte/sperimentazioni che vengono classificate sostanzialmente considerando solo la loro rilevanza scientifica a livello internazionale. L'accesso si declina in grandi collaborazioni internazionali (come avviene di solito quando si tratta di fisica delle alte energie o di fisica dei neutrini), o su base individuale o di piccoli gruppi di ricerca (come per le strutture di supercalcolo o nel caso di centri di ricerca per sorgenti pulsate di neutroni o con luce di sincrotrone). Oltre a illustrare le caratteristiche delle principali infrastrutture di ricerca cinesi in operazione in cui è coinvolto un numero significativo di collaboratori italiani (come BEPCII e JUNO), si presenteranno quelle future come CEPC e si indicherà quale interesse possa avere la comunità scientifica europea nel sostenere tali iniziative.

● **Antideuteron production from beauty-hadron decay: A path for collider searches.**

RAZZA M., JACAZIO N., BELLINI F.

*Università di Bologna e INFN, Sezione di Bologna*

The nature of Dark Matter remains unknown. In the particle hypothesis, the detection of antinuclei by space-borne experiments near Earth has been identified as a potential smoking gun for dark matter signals. Due to the highly suppressed astrophysical background for kinetic energies below 1 GeV/c, antinuclei represent an attractive search channel. Recently, new potential channels for antinuclei production via beauty-hadron decays were proposed, which could contribute to the Dark Matter signal. These decays have never been observed and require experimental validation. The LHC offers the ideal environment to search for such processes and determine their branching ratios; however to drive the research in this field, reliable estimates are needed. In this contribution, we present a prediction of the  $\bar{\Lambda}_b \rightarrow \bar{d} + X$  and  $B^- \rightarrow \bar{d} + X$  branching ratios. PYTHIA is used to simulate the production of these particles and their respective decays. A state-of-the-art coalescence model is applied to the resulting antinucleons to produce antideuterons. Then, we also discuss the feasibility of measuring these new channels at the LHC.

● **Development of a MPGD-based hadron calorimeter for future colliders.**

ALI M. <sup>(1)</sup>, GENEROSO L. <sup>(2)</sup>, ZAZA A. <sup>(2)</sup>, COLALEO A. <sup>(2)</sup>, STAMERRA A. <sup>(2)</sup>, PELLECCIA A. <sup>(2)</sup>, ZAVAZIEVA D. <sup>(3)</sup>, SIMONE F.M. <sup>(2)</sup>, SEKHNIADZE G. <sup>(4)</sup>, MOLERI L. <sup>(3)</sup>, LONGO L. <sup>(2)</sup>, ALVIGGI M. <sup>(3)</sup>, BIANCO M. <sup>(5)</sup>, BIGLIETTI M. <sup>(6)</sup>, DELLA PIETRA M. <sup>(4)</sup>, MAGGI M. <sup>(2)</sup>, BUONSANTE M. <sup>(2)</sup>, CAMERLINGO M.T. <sup>(2)</sup>, BORYSOVA M. <sup>(3)</sup>, IODICE M. <sup>(6)</sup>, IENGO P. <sup>(4)</sup>, VERWILLIGEN P. <sup>(2)</sup>, DI NARDO R. <sup>(6)</sup>, RADOGNA R. <sup>(2)</sup>, VENDITTI R. <sup>(2)</sup>, SCHARENBERG L. <sup>(5)</sup>, OLIVERI E. <sup>(5)</sup>, FLÖTHNER K. <sup>(5)</sup>

<sup>(1)</sup> *Università di Padova e INFN, Sezione di Bari*

<sup>(2)</sup> *Università di Bari e INFN, Sezione di Bari*

<sup>(3)</sup> *Weizmann Institute of Science, Israel*

<sup>(4)</sup> *University Federico II e INFN, Sezione di Napoli*

<sup>(5)</sup> *CERN, Geneva, Switzerland*

<sup>(6)</sup> *INFN, Sezione di Roma Tre*

Next-generation colliders such as FCC-ee and the Muon Collider demand calorimeters with outstanding spatial, timing, and energy resolution to meet the requirements of 5D calorimetry. This enables particle-flow (PF) techniques for superior jet energy resolution and sub-percent accuracy in Higgs' quark coupling measurements. We propose a novel hadron calorimeter (HCAL) based on resistive Micro Pattern Gaseous Detectors (MPGDs), including Micromegas and  $\mu$ -RWELL. These detectors feature high granularity ( $\text{cm}^2$ -scale), radiation hardness, and rate capability up to 10 MHz/ $\text{cm}^2$ -well-suited for the Muon Collider's challenging background. Their excellent spatial resolution, uniform response, and operational stability make them ideal for PF calorimetry. We present recent developments including GEANT4 simulations, Pandora PF reconstruction, and results from test beams with an 8-layer MPGD-HCAL prototype exposed to pion beams up to 10 GeV.

● **Spatial resolution performance of ATLAS NSW Micromegas detectors exploiting timing information.**

CHMIEL K.

*Università Roma Tre e INFN, Sezione di Roma Tre*

The ATLAS experiment at the Large Hadron Collider underwent significant upgrades during Long Shutdown 2, notably the installation of the New Small Wheel (NSW) system in

the Muon Spectrometer's forward region. The NSW enhances muon triggering and tracking capabilities, which are crucial for handling the high-rate environment of LHC Run 3 and beyond. This system utilizes two novel detector technologies: small-strip Thin Gap Chambers and resistive Micromegas. This presentation focuses on the spatial resolution performance of the resistive Micromegas detectors. A detailed study of Micromegas timing alignment procedures was carried out to achieve the best possible spatial resolution, quantifying how optimized timing directly impacts and improves the achievable spatial resolution. The improvements achieved in understanding and optimizing the timing characteristics of the Micromegas detectors within the challenging LHC Run 3 conditions will be highlighted, demonstrating their operational stability and readiness for ongoing data-taking and future physics analyses.

● **Characterization of IBIS RUN 1 back-side illuminated SiPM prototypes for imaging application in future experiments.**

ROVATI E. <sup>(1)(2)</sup>, PREGHENELLA R. <sup>(2)</sup>, MONTANARI A. <sup>(2)</sup>, TOSI N. <sup>(2)</sup>, RIGNANESE L.P. <sup>(2)</sup>, MONTAGNA E. <sup>(2)</sup>, NANIA R. <sup>(2)</sup>, GOLA A. <sup>(3)</sup>, PATERNOSTER G. <sup>(3)</sup>, FICORELLA A. <sup>(3)</sup>, KACHRU P. <sup>(3)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università degli Studi di Bologna, Bologna, Italia*

<sup>(2)</sup> *INFN Sezione di Bologna*

<sup>(3)</sup> *Fondazione Bruno Kessler, FBK, Trento*

The IBIS Project (Innovative Backside Illuminated Silicon Photomultipliers) in collaboration with FBK (Fondazione Bruno Kessler) is developing a novel type of SiPMs-Back-Side Illuminated (BSI) SiPMs-that introduces a clear separation between the charge collection and multiplication regions, which enables the possibility of introducing a charge-focusing mechanism. This approach allows for an enhanced fill factor ( $\sim 100\%$ ) even for small cells, improved VUV sensitivity via optimized surface treatments, increased radiation hardness due to a reduced high-field region, and easier integration with Readout Chips (ROC) via bump bonding, as all contacts are on one side. This technology is particularly relevant for experiments utilizing the Cherenkov technique, such as ALICE 3, LHCb, and ePIC, as well as cryogenic neutrino experiments like DUNE. We report on the studies aiming at the first IBIS RUN 1 prototype sensors, fabricated by FBK with SPAD pitches from 15 to 35  $\mu\text{m}$ . To assess their main characteristics, we conducted a comprehensive set of tests, including measurements in dark conditions, in a climatic chamber, and at cryogenic temperatures (77 K).

● **Simulation of solid-state particle detectors with arbitrary geometries using physics-informed neural networks.**

ROSA A. <sup>(1)</sup>, ANDERLINI L. <sup>(1)</sup>, BOMBINI A. <sup>(1)</sup>, BUTI C. <sup>(1)(2)</sup>, PASSALEVA G. <sup>(1)</sup>

<sup>(1)</sup> *INFN, Sezione di Firenze*

<sup>(2)</sup> *Dipartimento di Fisica, Università di Firenze*

The timing performance of 3D diamond detectors, obtained via laser graphitization of the electrodes, has long been constrained by the high resistance of the graphite electrodes. However, recent advances in fabrication technology have reduced this limitation, making electrode resistance comparable to geometrical contributions. At the same time, engineering resistive elements in silicon devices can lead to a drastic increase of spatial resolution. In this talk, we present a novel simulation framework based on Physics-Informed Neural Networks and the Ramo-Shockley theorem to model 3D solid-state detectors to accurately capture the detector response. Our method is validated against a beam test at CERN of 3D diamond sensors. Replacing the most computationally expensive parts of the simulation with ML models trained on Partial Differential Equations (PDEs) and experimental data, we drastically reduce computation time while enabling large-scale design investigation. This enables faster, scalable

exploration of detector designs, integrating CAD and NVIDIA Modulus tools, and allowing efficient optimization of next-generation timing detectors through direct solution of the underlying PDEs.

● **Large-scale validation of assembled PCBs and SiPMs for dual-readout fibre-sampling prototype.**

CALÌ V.I. <sup>(1)</sup>, PERSIANI R. <sup>(1)</sup>, BURDYKO A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Astronomia, Università di Catania*

<sup>(2)</sup> *INFN, Sezione di Catania*

<sup>(3)</sup> *Università dell'Insubria*

<sup>(4)</sup> *INFN, Sezione di Milano*

Physics programs for future accelerators (FCC, CEPC) demand high-precision measurement of the four-momenta of jets produced in collisions, making the performance of calorimeters crucial. Dual-readout calorimetry, sampling the scintillation and the Cherenkov signals with different e/h ratios, promises to meet this requirement by correcting event-by-event EM fraction fluctuations in hadronic showers. The HiDRa collaboration aims to identify a suitable, scalable and cost-effective solution for realizing a dual-readout calorimeter for the future IDEA detector. A longitudinally unsegmented, highly granular, fibre-sampling dual-readout calorimeter demonstrator large enough to contain hadronic showers is now under construction. Its central core will house 10 mini-modules instrumented with SiPMs, each fibre precisely aligned to the photosensor by custom-shaped boards. This design drives the need for mass qualification of approximately 10k SiPMs. In this presentation, we will give an overview of the full qualification and the performance measured on every device before and after their assembly.

● **Test results of a medium-scale drift chamber prototype for the SAND inner tracker.**

CHIAPPONI F.

*Università di Bologna e INFN, Sezione di Bologna*

The SAND apparatus, part of the DUNE Near Detector complex, consists of a superconducting magnet, an electromagnetic calorimeter, an active liquid argon target, and a low-mass tracker equipped with interchangeable nuclear targets. SAND is designed to monitor the stability of the neutrino beam, enable precision neutrino cross-section measurements, and perform searches for physics Beyond the Standard Model. One of the technologies currently under investigation for the inner tracker is based on Drift Chambers (DCH). Small- and medium-scale prototypes are being developed and tested. This contribution presents the results of tests performed on a medium-scale DCH prototype. The prototype was exposed to cosmic rays and to muons from the CERN SPS beam line, with readout provided by the TIGER ASIC. These tests aim to validate the tracker geometry and to characterise its time and spatial resolutions.

● **The TetraBall neutron spectrometer.**

DURISI E. <sup>(1)</sup><sup>(2)</sup>, COSTA M. <sup>(1)</sup><sup>(2)</sup>, IANTORNO D. <sup>(2)</sup>, MAFUCCI E. <sup>(2)</sup>, MARCHISIO-CAPRIOGLIO M. <sup>(1)</sup><sup>(2)</sup><sup>(1)</sup>, MONTI V. <sup>(1)</sup><sup>(2)</sup>, BEDOGNI R. <sup>(3)</sup>, CABALLERO PACHECO M.A. <sup>(3)</sup>, CASTRO CAMPOY A.I. <sup>(3)</sup>, PIETROPAOLO A. <sup>(3)</sup>, RUSSO L. <sup>(3)</sup>

<sup>(1)</sup> *Università di Torino*

<sup>(2)</sup> *INFN, Sezione di Torino*

<sup>(3)</sup> *INFN, Laboratori Nazionali di Frascati*

This contribution presents a novel single-moderator neutron spectrometer, named “Tetra-Ball”, developed at INFN and optimized for characterizing the neutron field in the CMS

experimental cavern. The TetraBall condenses the functionality of several Bonner Spheres in a single moderator and it is equipped with 42 SiC radiation-hard detectors organized in a tetrahedral geometry designed to be insensitive to incident gammas and charged particles. Thanks to lead inserts, it can respond up to GeV energies. It works in single exposure mode, suitable for real-time monitoring. It is designed to be used as neutron monitor during the High-Luminosity LHC data taking. First results with real data collected at CMS will be presented.

● **Studio delle performance dei rivelatori RPC per ATLAS fase 2 con raggi cosmici.**

ARCURI M.

*Università della Calabria e INFN, Sezione di Cosenza*

Con l'upgrade di fase 2 di LHC lo spettrometro per muoni di ATLAS si doterà di un'ulteriore strato di camere di trigger nel barrel per migliorare l'accettanza e l'efficienza di trigger. I rivelatori sono RPC sottili (gap da 1 mm, HPL da 1,5 mm) con double edge readout. La costruzione dei rivelatori è iniziata nel novembre 2023 e si completerà nei primi mesi del 2026. Nel laboratorio Alte Energie di Cosenza del dipartimento di Fisica dell'Università della Calabria è stato allestito un setup sperimentale per lo studio delle performance mediante raggi cosmici dei suddetti rivelatori. I risultati preliminari di questi studi saranno riportati in questa presentazione.

● **Neutron induced reactions for BBN: an indirect approach.**

PIZZONE R.G. ON BEHALF OF ASFIN COLLABORATION

*Dipartimento di Fisica e Astronomia Ettore Majorana, Università di Catania e INFN, Laboratori Nazionali del Sud, Catania*

Nuclear reactions induced by neutrons play a key role in several astrophysical scenario like primordial nucleosynthesis, s and r process and so on. From an experimental point of view, their reaction cross sections and reaction rates at astrophysically relevant temperatures are usually a hard task to be measured directly. Nevertheless big efforts in the last decades have led to a better understanding of their role in the different nucleosynthetic networks. In this work we will review the possibility of application of the Trojan Horse Method to extract the cross section at astrophysical energies for neutron induced reactions, examining validity tests as well as different applications. Moreover a detailed study of the  ${}^3\text{He}(n, p){}^3\text{H}$  reaction off the  ${}^2\text{H}({}^3\text{He}, pt)\text{H}$  three-body process will be discussed. The experiment was performed using the  ${}^3\text{He}$  beam, delivered at a total kinetic energy of 9 MeV by the University of Notre Dame. Data extracted from the present measurement are compared with other published sets available in literature. The reaction rate will be calculated and the astrophysical applications will also be discussed.

Aula 11, Section C, Edificio 19

ore 15:50 – 18:50

SEZIONE II

**Fisica della materia**

Presiede: VALENTI D. (Università di Palermo)

Relazioni su invito

▲ **Enhancement of stability of metastable states in the presence of Levy noise.**

GUARCELLO C. <sup>(1)(2)</sup>, DUBKOV A.A. <sup>(3)</sup>, SPAGNOLO B. <sup>(4)</sup>

<sup>(1)</sup> *Dipartimento di Fisica Università degli Studi di Salerno, Fisciano*

<sup>(2)</sup> *INFN, Sezione di Napoli, Gruppo Collegato di Salerno*

<sup>(3)</sup> *Radiophysics Department, Lobachevsky State University, Nizhny Novgorod, Russia*

<sup>(4)</sup> *Dipartimento di Fisica e Chimica, Group of Interdisciplinary Theoretical Physics, Università degli Studi di Palermo*

We study the barrier-crossing dynamics of superdiffusive particles subjected to symmetric Levy flights. Starting from the fractional Fokker-Planck equation, we derive a general integro-differential equation for the mean residence time (MRT) of a particle within a finite interval, for arbitrary Levy index  $\alpha$  and smooth potential profiles with a sink. For a Cauchy noise ( $\alpha = 1$ ) and a cubic metastable potential, we obtain a closed-form expression for the MRT in quadratures, as a function of noise intensity, initial position, and potential parameters. We perform extensive numerical simulations by integrating the corresponding Langevin equation changing the noise intensities, confirming the excellent agreement with analytical results. We observe a nonmonotonic behavior of the MRT, indicating the enhancement of metastable state stability at low noise intensities, due to the competition between trapping and long jumps induced by Levy noise. Our results provide useful analytical tools to describe anomalous transport and metastable dynamics in complex systems, especially those characterized by non-Gaussian noise and non-exponential relaxation.

▲ **Many-body quantum optics in a Bose-Hubbard waveguide.**

ROCCATI F.

*Università di Palermo*

Waveguide QED with interacting photons provides a platform to explore many-body quantum optics. However, how photonic correlations modify emitter dynamics remains an open question. We study collective decay and coherent interactions in a system of quantum emitters coupled to a one-dimensional Bose-Hubbard waveguide—an array of coupled photonic modes with repulsive photon-photon interactions—which hosts superfluid and Mott insulating phases. We find that photon-photon interactions alone can trigger a superradiant burst, independent of emitter spacing and frequency. Off-resonant with quasiparticle bands, the emitters exhibit two distinct regimes of dipole-dipole interactions: delocalized superfluid quasiparticles induce distance-insensitive couplings, while Mott-insulator excitations yield waveguide-QED-like interactions mediated by doublons and holons. Our work bridges many-body physics and waveguide QED, revealing how photonic many-body states shape emitter dynamics.

▲ **Electromagnetic mode management in transparent DMD electrodes for high angular color stability in white OLEDs.**

TRIOLO C. <sup>(1)</sup>, LORUSSO A. <sup>(2)(3)</sup>, MASI S. <sup>(4)</sup>, MARIANO F. <sup>(3)</sup>, DELLA TORRE A. <sup>(5)</sup>, ACCORSI G. <sup>(3)</sup>, ARIMA V. <sup>(3)</sup>, DE LEO S. <sup>(6)</sup>, RINALDI R. <sup>(2)(5)</sup>, PATANÈ S. <sup>(7)(1)</sup>, MAZZEO M. <sup>(2)(3)</sup>

<sup>(1)</sup> *Dipartimento di Ingegneria Civile, dell'Energia, dell'Ambiente e dei Materiali, Università Mediterranea, Reggio Calabria*

<sup>(2)</sup> *Department of Mathematics and Physics Ennio De Giorgi, Università del Salento, Lecce*

<sup>(3)</sup> *CNR NANOTEC Institute of Nanotechnology, Lecce*

<sup>(4)</sup> *Institute of Advanced Materials, Universidad Jaume I, Spain*

<sup>(5)</sup> *CNR IMM-Institute for Microelectronics and Microsystems, Lecce*

<sup>(6)</sup> *Department of Applied Mathematics, Campinas State University, Sao Paulo, Brazil*

<sup>(7)</sup> *Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, Università di Messina*

The integration of photonic structures into optoelectronic devices is a broad and evolving field of research. Recently, great interest has been directed to dielectric/metal/dielectric (DMD) structures, which has been shown to be suitable for replacing ITO electrodes. In this work, DMD structures (consisting of WO<sub>3</sub>/Ag/WO<sub>3</sub> layers) were produced via UHV thermal evaporation and used to build a Transparent White Organic Light-Emitting Diode (TWOLED). The optical response in the visible range was studied with Variable Angle Spectroscopic Ellipsometry (VASE), varying the thicknesses of the dielectric layers. VASE data allowed understanding the relation between the transparency degree of the DMD structures and the polarization state of the output light. The electroluminescence spectrum of the p-i-n TWOLED device, which integrates an optimized DMD structure, was investigated. An analysis of the optical modes that contribute to the power dissipation in TWOLED reveals a very large angular stability of the EL signal from TWOLED, with negligible colour coordinates variation in an escaping light visual cone of 120°, thus paving the way for a new generation of transparent white lighting sources.

▲ **Genuine multipartite entanglement of mechanical oscillators.**

FADEL M.

*ETH Zurich, Switzerland*

We present recent progress in preparing and detecting entanglement and Einstein-Podolsky-Rosen (EPR) correlations in macroscopic systems composed of mechanical oscillators with microgram-scale effective mass. In our setup, two spatially separated mechanical oscillators are coupled via a piezoelectric material to a superconducting qubit. This qubit enables precise control over the oscillators' bosonic vibration modes, which is essential for preparing and measuring nonclassical states of motion. Utilizing parametric processes and quantum optimal control techniques, we demonstrate the feasibility of generating a variety of bipartite and multipartite mechanical entangled states.

Comunicazioni

● **Hybrid superconductor-semiconductor platform with extremely weak electron-phonon coupling for sub-Kelvin caloritronic devices.**

DE SIMONI G., BATTISTI S., PAGHI A., BRAGGIO A., SORBA L., GIAZZOTTO F.

*CNR-NEST, Istituto Nanoscienze e Scuola Normale Superiore, Pisa*

Caloritronic devices aim to heat or cool electrons out of equilibrium above or below of the phonon thermal bath. However, their performances are usually limited by the strength of the electron-phonon coupling which anchors the electronic temperature to that of the



phonons. Here, we present a hybrid superconducting-semiconducting platform, which exploits a superconducting-proximitized Si-doped InAs superficial layer hosted by a InAlAs/GaAs heterostructure, as an ideal support to implement coherent caloritronic devices operating at sub-kelvin temperatures. Our devices exhibit electron-phonon coupling strength up to two orders of magnitude lower than that of state-of-the-art all metallic caloritronic devices. Such a reduced electron-phonon energy exchange enables efficient control of electronic temperature with minimal power input, paving the way for advanced caloritronic components, including single-photon detectors, bolometers, thermometers, and superconducting heat-based logic.

● **Non-linear anomalous Edelstein response at altermagnetic interfaces.**

TRAMA M. <sup>(1)(2)</sup>, GAIRDONI I. <sup>(1)</sup>, GUARCELLO C. <sup>(1)(3)</sup>, FACIO J. I. <sup>(4)</sup>, MAIELLARO A. <sup>(5)</sup>, ROMEO F. <sup>(1)(3)(5)</sup>, CITRO R. <sup>(1)(5)</sup>, VAN DEN BRINK J. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli studi di Salerno*

<sup>(2)</sup> *IFW Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, Germany*

<sup>(3)</sup> *INFN, Sezione Collegata di Salerno*

<sup>(4)</sup> *Centro Atomico Bariloche, Argentina*

<sup>(5)</sup> *CNR-SPIN, Gruppo associato di Salerno*

In altermagnets, time-reversal symmetry breaking spin-polarizes electronic states, while total magnetization remains zero. In addition, at altermagnetic surfaces Rashba-spin orbit coupling is activated due to broken inversion symmetry, introducing a competing spin-momentum locking interaction. Here we show that their interplay leads to the formation of complex, chiral spin textures that offer novel, non-linear spin-to-charge conversion properties. Whereas altermagnetic order suppresses the canonical linear in-plane Rashba-Edelstein response, we establish the presence of an anomalous transversal Edelstein effect for planar applied electric and magnetic field, or alternatively, an in-plane magnetization. Additionally, we predict a purely electric-field-driven non-linear out-of-plane magnetization. We compute the anomalous response within a general altermagnet d-wave model, with parameters extracted from the ab-initio electronic structure of an altermagnetic bilayer. Our results establish altermagnetic surfaces as a promising platform for unconventional spintronic functionalities.

● **Edelstein effect in isotropic and anisotropic Rashba models.**

GAIRDONI I. <sup>(2)</sup>, TRAMA M. <sup>(2)(4)</sup>, MAIELLARO A. <sup>(2)(3)</sup>, GUARCELLO C. <sup>(1)(2)</sup>, ROMEO F. <sup>(1)(2)</sup>, CITRO R. <sup>(1)(2)(3)</sup>

<sup>(1)</sup> *INFN, Sezione di Napoli, Gruppo Collegato di Salerno*

<sup>(2)</sup> *Dipartimento di Fisica, Università di Salerno, Fisciano*

<sup>(3)</sup> *CNR-SPIN, Salerno*

<sup>(4)</sup> *Institute for Theoretical Solid State Physics, IFW Dresden, Germany*

We investigate spin-to-charge conversion via the Edelstein effect in a 2D Rashba electron gas using the semiclassical Boltzmann approach. We analyze the magnetization arising from the direct Edelstein effect, taking into account an anisotropic Rashba model. We study how this effect depends on the effective masses and Rashba spin-orbit coupling parameters, extracting analytical expressions for the high electronic density regime. Indeed, it is possible to manipulate the anisotropy introduced into the system through these parameters to achieve a boost in the Edelstein response compared to the isotropic Rashba model. We also discuss the theoretical framework to study the inverse Edelstein effect and calculate self-consistently the electric current induced by the proximity of the system to a ferromagnet. These results provide insights into the role of Rashba spin-orbit coupling and anisotropic effects in spin-charge conversion phenomena.



● **Theory of charge-to-spin conversion under quantum confinement.**

MAIELLARO A. <sup>(1)</sup>, ROMEO F. <sup>(2)(3)</sup>, TRAMA M. <sup>(2)</sup>, GAIARDONI I. <sup>(2)</sup>, SETTINO J. C. <sup>(4)</sup>, GUARCELLO C. <sup>(2)(3)</sup>, CITRO R. <sup>(2)(3)</sup>

<sup>(1)</sup> CNR-SPIN, Salerno

<sup>(2)</sup> Dipartimento di Fisica, Università di Salerno, Fisciano

<sup>(3)</sup> INFN, Sezione di Napoli, Gruppo Collegato di Salerno

<sup>(4)</sup> Dipartimento di Fisica, Università della Calabria, Arcavacata di Rende

We develop a spin dependent scattering matrix approach to describe spin and charge transport in a multiterminal system in the presence of Rashba spin-orbit interaction. Our framework generalizes the Buttiker formalism by providing explicit expressions for the real space spin and charge current densities. It simultaneously captures the effects of quantum confinement, the orbital response to external magnetic fields, and the intrinsic (geometric) properties of the electronic bands, offering a comprehensive description of the spin-to-charge conversion mechanisms at play in a Hall bar in agreement to experiments.

● **Tuning the electronic properties and spin textures in buckled two-dimensional compounds.**

BARRECA V. <sup>(1)</sup>, NINNO D. <sup>(1)</sup>, STROPPA A. <sup>(1)</sup>, CANTELE G. <sup>(1)</sup>

<sup>(1)</sup> Dipartimento di Fisica, Università degli Studi di Napoli Federico II

<sup>(2)</sup> CNR-SPIN, L'Aquila

<sup>(3)</sup> CNR-SPIN, Napoli

In the last decades, there has been a notable increase in the interest in two-dimensional materials, due to their high tunability. The research was initially focused on the graphene, then it moved to other materials. Among them, there are some compounds of the MX type, where M and X belong to either III-V groups of the periodic table, or the IV group, that show a low-buckled honeycomb lattice structure. Our work consists in the study from first principles of some materials belonging to this family, in particular GaAs, GaP and GeSn. Some bilayers and quadrilayers made of these compounds have been studied in different stacking geometries, in order to see how the variation of such degree of freedom allows to tune their properties. Then, we identified the most stable systems and analyzed their structural and electronic properties, with a specific focus on the similarities and the differences between the III-V compounds and the GeSn. In the last part of the analysis we performed also calculations of the spin-textures for some selected systems, to discuss how and to which extent spin-orbit and Rashba effects show up in this kind of compounds.

● **Counterflows and reduced angular momentum in dipolar supersolids.**

TRABUCCO S. <sup>(1)</sup>, POLI E. <sup>(1)</sup>, MANNARELLI M. <sup>(1)</sup>, FERLAINO F. <sup>(1)</sup>

<sup>(1)</sup> Gran Sasso Science Institute, L'Aquila

<sup>(2)</sup> INFN, Laboratori Nazionali del Gran Sasso, L'Aquila

Supersolidity is a peculiar phase of matter in which both superfluid and crystalline properties coexist. Due to its double nature, a rotating supersolid system exhibits both a linear response (typical of a rigid body) and a discrete response, arising from vortex nucleation (a hallmark of superfluidity). Here, we investigate the rotational response of a rotating supersolid made of ultracold dipolar atoms and we employ a novel approach based on a suitable decomposition of the velocity field, disentangling the linear response from the vortex field. Remarkably, the linear response generates a counterpropagating current that effectively reduces the total angular momentum. This result explains why in a supersolid the angular momentum carried by the vortex is a fraction of  $\hbar$ . These findings provide new insights into the rotational properties of systems with multiple simultaneously broken symmetries, including supersolid-like phases of nuclear matter in the neutron star's interior.

Aula 12, Section C, Edificio 19

ore 15:50 – 18:50

SEZIONE II

**Fisica della materia**

Presiede: MESSINA F. (Università di Palermo)

*Le relazioni su invito si terranno nell'Aula 11, i lavori si sposteranno nell'Aula 12 per le seguenti comunicazioni.*

Comunicazioni

● **Analisi elettrica, termica e termomeccanica dei meccanismi di invecchiamento di un MOSFET di potenza al carburo di silicio.**

D'AMBROSIO M. <sup>(1)</sup>, TRIPODI C. <sup>(1)</sup>, GARESCÌ F. <sup>(2)</sup>, CALABRETTA M. <sup>(3)</sup>, PATANÈ S. <sup>(1)</sup>  
<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina*

<sup>(2)</sup> *Dipartimento di Ingegneria, Università di Messina*

<sup>(3)</sup> *STMicroelectronics, Catania*

Negli ultimi anni, l'impiego di transistor basati su semiconduttori a wide-bandgap si è rivelato cruciale per l'intera transizione ecologica, trovando applicazione sia nella produzione di energia pulita sia nella mobilità sostenibile. In questo contesto, i MOSFET di potenza al carburo di silicio (SiC) si distinguono come dispositivi altamente promettenti, grazie alla loro capacità di gestire elevate tensioni e correnti. Quando il gate viene polarizzato, gli impulsi di corrente che scorrono nel dispositivo generano calore per effetto Joule, causando temporaneamente deformazioni termomeccaniche. Questo fenomeno è già stato identificato come una delle cause di invecchiamento per questa classe di dispositivi, ma la catena di eventi che porta al fallimento necessita di ulteriori studi. In questo lavoro, un power MOSFET commerciale e decapsulato è stato invecchiato in maniera controllata, monitorando il comportamento elettrico, termico e meccanico ad ogni step di invecchiamento. La correlazione tra l'evoluzione del comportamento elettrico e meccanico fornisce un metodo più affidabile per la stima del tempo di vita rimanente.

● **Spalled freestanding oxides micro-membranes: method, results and perspectives.**

SAMBRI A. <sup>(1)</sup>, SCUDERI M. <sup>(2)</sup>, DI GENNARO E. <sup>(1)(3)</sup>, GUARINO A. <sup>(4)</sup>, STORNAIUOLO D. <sup>(1)(3)</sup>, VECCHIONE A. <sup>(4)</sup>, GRANATA C. <sup>(5)</sup>, SAND JESPERSEN T. <sup>(6)</sup>, MILETTO GRANOZIO F. <sup>(1)</sup>

<sup>(1)</sup> *CNR-SPIN, Napoli*

<sup>(2)</sup> *IMM-CNR, Catania*

<sup>(3)</sup> *Università di Napoli Federico II*

<sup>(4)</sup> *CNR-SPIN, Fisciano*

<sup>(5)</sup> *ISASI, Pozzuoli*

<sup>(6)</sup> *Department of Energy Conversion and Storage, Technical University of Denmark*

Freestanding oxide membranes are emerging as a new frontier in functional materials, thanks to their exceptional flexibility and structural tunability far beyond that of bulk and conventional epitaxial films. The discovery of the water-soluble  $\text{Sr}_3\text{Al}_2\text{O}_5$  sacrificial layer, a simpler alternative to HF-removable oxides, marked a breakthrough in their fabrication. Here, we present an alternative method that avoids sacrificial layers, based on strain engineering in

PLD-grown samples, developed at CNR- SPIN Naples. This spalling technique enables the fabrication of freestanding epitaxial bi-layer membranes with lateral sizes from tens down to a few microns. We investigate the role of PLD parameters in the membrane formation and demonstrate its application to SrTiO<sub>3</sub>-based bi- and tri-layer membranes and oxide films on ruthenate substrates. We also show their integration with Si platforms via van der Waals stacking, reporting electrical characterization of LaAlO<sub>3</sub>/SrTiO<sub>3</sub> membranes on SiO<sub>2</sub>/Si. These results point to promising advances in oxide-based electronics.

● **Study of the optical properties of micro- and nanoplastics coupled with metal nanoparticles using the T-Matrix method and neural networks.**

REZAEI S. <sup>(1)</sup>, GUCCIARDI P.G. <sup>(1)</sup>, MARAGÒ O.M. <sup>(1)</sup>, SALJA R. <sup>(1)(2)</sup>, IATÀ M.A. <sup>(1)</sup>  
<sup>(1)</sup> *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina*

<sup>(2)</sup> *CNR-IPCF, Istituto per i Processi Chimico-Fisici, Messina*

In recent decades, metal nanoparticles have attracted growing interest for their unique properties and broad applications. Meanwhile, micro- and nanoplastics(MNP) have become a growing concern within the scientific community because of their widespread environmental distribution and potential risks to human health and ecosystems. Identifying micro- and nanoplastics, particularly at smaller scales, remains a significant challenge, highlighting the need for accurate detection methods. Optical and Raman tweezers have recently emerged as powerful tools for trapping and analyzing these particles without contamination. There is growing interest in developing sensitive SERS structures, which enhance particle detection and characterization by leveraging electromagnetic hot spots. Efficient computational methods for simulating the enhanced optical response of MNPs in the presence of metal nanoparticles are valuable for designing SERS substrates and improving detection techniques. We study the optical properties of nanoclusters made of plastic particles with metal nanoparticles, using T-matrix method and neural networks. This combined method also improves computational efficiency.

● **Optical properties in 1L – MoS<sub>2</sub> and enhancements through thermal treatments.**

MADONIA A. <sup>(1)</sup>, SANGIORGI E. <sup>(1)</sup>, MIGLIORE F. <sup>(1)</sup>, LAURELLA G. <sup>(1)</sup>, PANASCI S. E. <sup>(2)</sup>, SCHILIRÒ E. <sup>(2)</sup>, GIANNAZZO F. <sup>(2)</sup>, ESPOSITO F. <sup>(3)(4)</sup>, SERAVALLI L. <sup>(3)</sup>, PÍŠ I. <sup>(5)</sup>, BONDINO F. <sup>(5)</sup>, BUSCARINO G. <sup>(1)(6)</sup>, CANNAS M. <sup>(1)</sup>, AGNELLO S. <sup>(1)(2)(6)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

<sup>(2)</sup> *CNR, Istituto per la Microelettronica e Microsistemi*

<sup>(3)</sup> *CNR, Istituto dei Materiali per l'Elettronica ed il Magnetismo*

<sup>(4)</sup> *Department of Chemical Science, Life, and Environmental Sustainability, Università di Parma*

<sup>(5)</sup> *CNR, Istituto Officina dei Materiali*

<sup>(6)</sup> *ATEN Center, Università di Palermo*

Transition metal dichalcogenides as monolayer molybdenum disulphide (1L – MoS<sub>2</sub>) are highly appealing due to their unique properties. 1L – MoS<sub>2</sub> exhibits excellent charge-carrier mobility and light-absorption capabilities. When excited by visible light, it emits through exciton recombination, leading to intense photoemission around 1.8 eV. External factors, including production route and interactions with the external environment, significantly influence these optical characteristics. However, these factors can be manipulated to enhance photoluminescence. This study demonstrates that thermal treatments under controlled atmospheres predictably modify 1L – MoS<sub>2</sub>'s electronic and structural properties while tuning its emission. The enhanced optical properties suggest that post-synthetic procedures can

address limitations in production routes. Our findings aim to deepen the understanding of 1L – MoS<sub>2</sub>'s properties and explore ways to control its optical capabilities, enabling tailored heterostructure devices through versatile post-synthetic treatments.

● **Exploring the electrical and optoelectronic properties of BP/MoS<sub>2</sub> heterojunctions under different pressure conditions.**

MAZZOTTI A. <sup>(1)</sup>, DURANTE O. <sup>(1)</sup>, MARTUCCIello N. <sup>(2)</sup>, KHARSAH O. <sup>(3)</sup>, SLEZIONA S. <sup>(3)</sup>, SCHLEBERGER M. <sup>(3)</sup>, DI BARTOLOMEO A. <sup>(1)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università di Salerno, Fisciano*

<sup>(2)</sup> *CNR-SPIN, Salerno*

<sup>(3)</sup> *Fakultät für Physik and CENIDE, Universität Duisburg-Essen, Germany*

Two-dimensional (2D) materials hold great promise for next-generation nanoelectronic applications thanks to their distinctive physical, chemical, and mechanical characteristics. Their ability to form van der Waals heterostructures without requiring lattice matching makes them particularly advantageous in a wide range of physical systems. Through the combination of different 2D materials, one can engineer electronic and optoelectronic devices with enhanced or entirely new functionalities. Among the most promising combinations, black phosphorus (BP) and molybdenum disulfide (MoS<sub>2</sub>) stand out due to their excellent electronic behavior and tunability via gate voltage. Notably, BP offers high carrier mobility and strong photoresponse. In this study, we investigate charge transport in a vertically stacked BP/MoS<sub>2</sub> heterostructure built on a SiO<sub>2</sub>/Si substrate and operated in a back-gate configuration. Special attention is given to the influence of pressure, ranging from atmospheric conditions to 10<sup>-4</sup> mbar. Our results demonstrate that lower pressures yield improved electrical performance.

● **Magnetic phase transitions and mixed spin in double perovskite.**

KHAIREDDINE S. <sup>(1)</sup>, ASSAD R. <sup>(2)</sup>, EL FALAKI M. <sup>(2)</sup>, AHL LAMARA R. <sup>(3)</sup>, BTISSAM DRISSI L. <sup>(1)</sup>

<sup>(1)</sup> *LPHE-MS, Faculty of Science, Mohammed V University in Rabat, Morocco*

<sup>(2)</sup> *CPM, Centre of Physics and Mathematics, Faculty of Science, Mohammed V University in Rabat, Morocco*

<sup>(3)</sup> *National Center for Scientific and Technical Research CNRST, Morocco*

The magnetic properties of the double perovskite oxide Sr<sub>2</sub>FeMoO<sub>6</sub> are analyzed using a mixed-spin Ising model with spins 1 2, 5 2 in the presence of a random crystal field and exchange interactions J on a three-dimensional (3D) cubic lattice. The study employs both the Mean-Field Approximation (MFA) based on the Bogoliubov inequality for Gibbs free energy and Monte Carlo (MC) simulations using the Metropolis algorithm to provide a comprehensive analysis of the system's phase transitions and magnetization behavior, with focusing on the role of Fe and Mo sublattices. We establish the ground-state phase diagram, identifying multiple stable magnetic configurations and first-order transitions at low temperatures. Indicate compensation temperature T<sub>comp</sub>. This work provides deeper insight into the thermodynamic, physics statistic and magnetic properties of Sr<sub>2</sub>FeMoO<sub>6</sub>, with implications for future applications in spintronics and magnetic storage technologies.

● **Hybrid perovskite materials: New results obtained using pump-probe and photoluminescence techniques.**

MAZZOLA M.

*Politecnico di Milano*

In the recent years, the class of hybrid perovskite materials has gained an enormous interest. Mixed halogen hybrid perovskites hold great promise because of their excellent optoelectronic

properties and because they can be used to produce low-cost and high-performance solar panels, LEDs and sensors. The technological limit that, to date, holds back the use of these materials outside of research laboratories is their tendency to segregate into small domains rich in only one ionic species at a time and this leads to a dramatic degradation of their performance. Furthermore, these segregation mechanisms are yet to be understood and there is much debate in the scientific community. My team and I are in a privileged position because we have the possibility to use different ultrafast spectroscopy techniques at different repetition rates to investigate the phenomenon of photoinduced segregation on different time scales. I will show some new, interesting results obtained using pump-probe and photoluminescence techniques and I will comment on the effect that some parameters such as fluence and repetition rate of external illumination sources have on the degradation mechanisms.

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Aula Capità, Edificio 7

ore 15:50 – 18:50

SEZIONE III

**Astrofisica e fisica astroparticellare**

Presiede: GUARCELLO M.G. (INAF, Osservatorio Astronomico di Palermo)

Relazioni su invito

▲ **Mapping the Universe with the Square Kilometre Array.**

PRANDONI I.

*INAF, Istituto di Radioastronomia*

The Square Kilometer Array (SKA) is an integral part of the next-generation observatories that will survey the Universe across the electromagnetic spectrum, and beyond, revolutionizing our view of Fundamental Physics, Astrophysics and Cosmology. In the present talk I will describe the SKA Observatory, its timeline and main scientific scopes, focussing on ongoing construction and commissioning activities. The involvement of the Italian community will be also highlighted.

▲ **CTAO status updates.**

PERON G. FOR THE CTAO XOLLABORATION

*INAF, Osservatorio Astrofisico di Arcetri*

Gamma-ray astronomy has been featuring a significant technological boost in recent years that allowed the community to explore the extreme emitters of the Universe. This concerns the study of Galactic sources like pulsars, supernova remnants, microquasars and star clusters, but also extra-Galactic sources, mainly coincident with active Galactic nuclei and gamma-ray bursts. The next-generation of ground-based Cherenkov telescopes and especially the Cherenkov Telescope Array Observatory (CTAO) are expected to push the understanding of gamma-ray sources even further. The CTAO with its two sites, located in the Northern and in the Southern hemisphere, a wide energy band spanning almost 4 decades, will improve the sensitivity of the currently operating instruments by at least one order of magnitude and will be able to better identify the source positions thanks to its unprecedented angular resolution. I will present the Observatory and the status of its development, providing an overview of the scientific cases that the CTAO will be able to address.

▲ **Space science and space economy.**

FIORE F. <sup>(1)</sup>, ELVIS M. <sup>(2)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Trieste*

<sup>(2)</sup> *Harvard-Smithsonian Center for Astrophysics*

Will it be possible in the future to realize large, complex space missions dedicated to basic science like HST, Chandra and JWST? Today's space scenario is completely different from that of the time when these missions were made. Space-related investments have grown exponentially in recent years, with monetary investment exceeding half a trillion dollars in 2024. This boom is greatly aided by the rise of the new space economy driven by private fundings, which for the first time last year surpassed public investments in space. The establishment of a market logic in space activities results in more competition, cost and time reduction. Can space science take advantage of these benefits? We argue that this goal would be made possible building on one side on the experience gained in the past years under the NASA Explorer program and in the broad area of cubesat projects, and on the other side taking

advantage of the three pillars beyond the innovation of the new space economy: 1) technology innovation; 2) business innovation, through vertical integration and scale production, and 3) cultural innovation, through risk openness and iterative development.

#### Comunicazioni

##### ● Investigating Cherenkov Telescope Array Observatory capability to detect gamma-ray emission from simulated neutrino sources identified by KM3NeT.

CICCIARI G.M. <sup>(1)</sup> <sup>(2)</sup>, G. FERRARA <sup>(3)</sup>, MALLAMACI M. <sup>(1)</sup><sup>(2)</sup>, MARSELLA G. <sup>(1)</sup><sup>(2)</sup>, ROSALES DE LEON A. <sup>(4)</sup>, SERGIJENKO O. <sup>(5)</sup><sup>(6)</sup>

<sup>(1)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(2)</sup> *INFN, Sezione di Catania*

<sup>(3)</sup> *Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

<sup>(4)</sup> *Astronomical Observatory, Taras Shevchenko National University of Kyiv, Ukraine*

<sup>(5)</sup> *Main Astronomical Observatory of the National Academy of Sciences of Ukraine, Kyiv, Ukraine*

<sup>(6)</sup> *AGH University of Krakow, Poland*

Gamma-ray observations are crucial to understanding neutrino production in extreme cosmic environments. The Cherenkov Telescope Array Observatory (CTAO), the first open-access ground-based gamma-ray observatory, is under construction in both hemispheres: CTAO-North (La Palma, Spain) and CTAO-South (Atacama Desert, Chile). Covering 20 GeV to 300 TeV, CTAO will offer unprecedented sensitivity to transient multi-messenger sources. We use the Python code FIRESONG to simulate a population of neutrino-emitting sources, including steady and flaring blazars, accounting for parameters like source density and neutrino luminosity. We assess CTAO's potential to detect gamma-ray counterparts to these neutrino sources, which could also be observed by KM3NeT. The KM3NeT collaboration is deploying the ARCA telescope in the Mediterranean Sea to improve sensitivity to high-energy neutrinos from the Southern Sky. Our results indicate that CTAO and KM3NeT together will significantly enhance the identification of multi-messenger sources, with CTAO-South's Large Telescopes (LSTs) providing a major boost for southern-sky observations.

##### ● Modal analysis of Ni-P coated cryogenic mirrors for the Ariel mission.

CARDINALE V.D. <sup>(1)</sup>, D'ANCA F. <sup>(1)</sup>, COLLURA A. <sup>(1)</sup>, SAITTA C. <sup>(1)</sup>, GULIZZI A. <sup>(1)</sup>, GUERRIERO E. <sup>(1)</sup>, MICELA G. <sup>(1)</sup>, PACE E. <sup>(2)</sup>, PRETI G. <sup>(2)</sup>, SCIPPA A. <sup>(2)</sup>, LILLI R. <sup>(2)</sup>, PICCHI P. <sup>(3)</sup>, TOZZI A. <sup>(3)</sup>, CHIOETTO P. <sup>(4)</sup>, ZUPPELLA P. <sup>(4)</sup>, PASCALE E. <sup>(5)</sup>, BOCCHIERI A. <sup>(5)</sup>, TINETTI G. <sup>(6)</sup>, CALDWELL A. <sup>(7)</sup>, ECCLESTON P. <sup>(7)</sup>, BRIENZA D. <sup>(8)</sup>, TOMMASI E. <sup>(8)</sup>, OLIVIERI A. <sup>(8)</sup>, MALAGUTI G. <sup>(9)</sup>

<sup>(1)</sup> *INAF, Osservatorio Astronomico di Palermo*

<sup>(2)</sup> *Univiversità degli Studi di Firenze*

<sup>(3)</sup> *INAF, Osservatorio Astrofisico di Arcetri*

<sup>(4)</sup> *CNR, Istituto di Fotonica e Nanotecnologie*

<sup>(5)</sup> *Sapienza Università di Roma*

<sup>(6)</sup> *University College, London, UK*

<sup>(7)</sup> *STFC Rutherford Appleton Laboratories, UK*

<sup>(8)</sup> *Agenzia Spaziale Italiana*

<sup>(9)</sup> *INAF, Osservatorio di Astrofisica e Scienza dello Spazio*

The Atmospheric Remote-sensing Infrared Exoplanets Large-survey (ARIEL) is a European Space Agency mission within the Cosmic Vision 2015-2025 program. It aims to study exoplanet atmospheres through spectroscopy, improving our understanding of planetary system formation. The mission, lasting 3.5 years, will use a 1-meter telescope with two spectrometer channels (1.957.8 m) and four photometric channels in the visible to near-infrared range.

This study focuses on the thermo-mechanical characterization of Nickel-Phosphorus (NiP) coating on aluminum alloy (Al6061-T651), conducted at METALab (INAF-Palermo). It supports NiP coating development for ARIEL's mirrors, examining its effects on natural frequencies, mode shapes, and damping. Key objectives include evaluating coating thickness, thermal variations, validating finite element models (FEM), and detecting anisotropic effects. Understanding dynamic changes in coated mirrors is crucial for optimizing lightweight mirror systems. These findings enhance ARIEL's ability to provide precise spectroscopic data, supporting astrophysical research on exoplanetary atmospheres.

● **Doppia funzionalità per la beamline XACT a Palermo: calibrazione e criogenia per la tecnologia spaziale.**

GUERRIERO E. <sup>(1)</sup>, D'ANCA F. <sup>(1)</sup>, COLLURA A. <sup>(1)</sup>, MICELA G. <sup>(1)</sup>, SCIPPA A. <sup>(2)</sup>, FERNANDEZ SOLER A.J. <sup>(3)</sup>, PEREZ ALVAREZ J. <sup>(3)</sup>, PACE E. <sup>(4)</sup><sup>(5)</sup>, PRETI G. <sup>(4)</sup>, PICCHI P. <sup>(5)</sup>, TOZZI A. <sup>(5)</sup>, FILIZZOLO M. <sup>(6)</sup>, VARISCO S. <sup>(1)</sup>, SAITTA C. <sup>(1)</sup>, GULIZZI A. <sup>(1)</sup>, TODARO M. <sup>(1)</sup>, SCIORTINO L. <sup>(1)</sup>, CARDINALE V.D. <sup>(1)</sup>, LO CICERO U. <sup>(1)</sup>, BARBERA M. <sup>(1)</sup><sup>(7)</sup>, DI CICCÀ G. <sup>(1)</sup>, CANDIA R. <sup>(1)</sup>, CHIOETTO P. <sup>(5)</sup><sup>(8)</sup>, PASCALE E. <sup>(9)</sup>, LILLI R. <sup>(2)</sup>, GOTTINI D. <sup>(2)</sup>, BRUCALASSI A. <sup>(5)</sup>, ZUPPELLA P. <sup>(5)</sup><sup>(8)</sup>, MORGANTE G. <sup>(10)</sup>, BOCCHIERI A. <sup>(9)</sup>, OLIVIERI A. <sup>(11)</sup>, BRIENZA D. <sup>(11)</sup>, TOMMASI E. <sup>(11)</sup>

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La beamline XACT (X-ray Astronomy Calibration and Testing) dell'INAF di Palermo, progettata in origine per la calibrazione e il test di ottiche e rivelatori per l'astronomia X, è in fase di trasformazione strategica. Entro luglio 2025, la Telescope Chamber sarà riconfigurata in una Cryo-Facility per ospitare specchi fino a un metro, operando in vuoto spinto, a temperature di circa 90 K. La configurazione della facility permetterà di mantenere la funzionalità XACT originaria e acquisendo così una doppia vocazione, unica nel panorama nazionale. L'infrastruttura sarà dotata di: interferometro 4D, sistema criogenico ad elio a circuito chiuso e supporti meccanici custom per garantire stabilità e un efficiente accoppiamento termico. Il primo banco di prova della facility sarà il Primary Mirror Structural Model con proprietà ottiche (SM-M1) della missione Ariel, uno specchio interamente in alluminio, operante nel VIS/IR. Questa evoluzione si inserisce nella visione di rendere Palermo un polo di riferimento per la sperimentazione e la qualifica di tecnologie spaziali. Durante la presentazione verranno illustrati i primi risultati ottenuti dai test sullo SM M1 di Ariel.

● **Optical absorbing performance of Aluminum-coated carbon nanotube pellicles for the NASA MUSE space mission.**

ALAIMO E. <sup>(1)</sup><sup>(2)</sup>, TODARO M. <sup>(2)</sup>, SCIORTINO L. <sup>(2)</sup>, LO CICERO U. <sup>(2)</sup>, D'ANCA F. <sup>(2)</sup>, FIORENTINO F. <sup>(1)</sup><sup>(2)</sup>, TÖRMÄ P.T. <sup>(3)</sup>, MIKLADAL B. <sup>(4)</sup>, HAQ B. <sup>(4)</sup>, BARBERA M. <sup>(1)</sup><sup>(2)</sup>

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Exploring the mechanisms of coronal heating and the evolution of flares remains an enduring challenge in solar astrophysics. EUV spectroscopy observatories, such as the NASA MUSE (Multi-slit Solar Explorer) mission, are currently being developed to provide the experimental background needed for the future modeling of solar corona dynamics. As part of MUSE, we are developing novel carbon nanotube (CNT)-based optical blocking filters coated with metal to shield the highly sensitive detectors from the solar optical load. CNT pellicles, being sturdy and EUV-transparent, are a very promising candidate for the substrate of choice for the metal coatings. We are investigating different types of CNT pellicles coated with aluminum to assess their optical blocking performance. We report results of UV, Vis, and NIR spectroscopy, performed at the Astronomical Observatory of Palermo (INAF-OAPA) XACT facility, and compare the experimental visible transmittance of such filters with the very demanding out of band attenuation (10-6) requirements required by MUSE. This study will improve the filters' technology readiness level for the MUSE mission and for other future EUV solar physics experiments

### ● Zirconium-coated Carbon nanotube pellicles for high-energy optical filter applications.

FIorentino F. <sup>(1)(2)</sup>, LO CICERO U. <sup>(2)</sup>, ALAIMO E. <sup>(1)(2)</sup>, SCIORTINO L. <sup>(2)</sup>, TODARO M. <sup>(2)</sup>, D'ANCA F. <sup>(2)</sup>, VARISCO S. <sup>(2)</sup>, CANDIA R. <sup>(2)</sup>, DI CICCÀ G. <sup>(2)</sup>, TORMA P. <sup>(3)</sup>, LIPSANEN H. <sup>(4)</sup>, MIKLADAL B. <sup>(5)</sup>, HAQ B. <sup>(5)</sup>, BARBERA M. <sup>(1)(2)</sup>

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In recent years a few space missions, such as NASA's MUSE and ISAS/JAXA and NAOJ's Solar-C, are being developed with the aim to observe the Sun in the extreme ultraviolet (EUV) energy range. Such missions generally employ detectors sensitive to a broad range of energies, so it's necessary for them to employ optical blocking filters to reject radiation out of their scope. Such filters are generally metal-coated as metals are excellent rejecters of low energy radiation; thus, metal coating is a crucial step for high-energy optical filters. Recently, a promising filter technology has been investigated based on carbon nanotube (CNT) thin pellicles due to their transparency in the EUV. Metal coating of such pellicles is challenging, due to the intrinsic porosity given by its mesh structure. In this work we present the results of zirconium coating of CNT thin films; zirconium is an ideal choice for EUV applications since it exhibits a transmission window between 70 and 120 eV. The coating has been performed using different physical vapor deposition techniques such as e-Beam evaporation and Sputtering, and a morphological analysis has been conducted using Scanning Electron Microscopy.

### ● Cosmology and multi-messenger astrophysics with next-generation GRB space missions.

AMATI L. ON BEHALF OF THE THESEUS CONSORTIUM

*INAF, Osservatorio di Astrofisica e Scienza dello Spazio, Bologna*

The huge luminosity, the redshift distribution extending at least up to  $z \sim 10$  and the association with the explosive death of very massive stars make long Gamma-Ray Bursts (GRBs) extremely powerful probes for investigating the early Universe, providing a unique channel for directly detecting the first population of stars, unveiling the bulk of low-mass/luminosity primordial galaxies, investigating the sources and evolution of cosmic reionization. At the same

time, as demonstrated by the joint detection of the GW170817 event and GRB170817A, GRBs are a key electromagnetic counterpart of gravitational waves produced by the merging of NS - NS and NS - BH star binary systems. GRB space mission projects for the next decade, the most advanced one being THESEUS (Transient High-Energy Sky and Early Universe Surveyor), under study by ESA as candidate M7 for a launch in 2037, aim at fully exploiting these great potentialities of the GRB phenomenon, providing also an ideal synergy with the very large astronomical facilities of the future (e.g., ELT, CTA, SKA) and third generation GW observatories like the Einstein Telescope (ET) and COsmic Explorer (CE).

● **Deep learning and generative AI in astrophysical research.**

SAHAKYAN N. <sup>(1)</sup>, RUFFINI R. <sup>(1)</sup>, WANG YU. <sup>(1)</sup>

<sup>(1)</sup> ICRANet, Pescara

<sup>(2)</sup> ICRANet-Armenia, Yerevan, Armenia

<sup>(3)</sup> ICRANet.ai

Artificial intelligence (AI) is revolutionizing astrophysical research, enabling the efficient analysis of large and complex datasets and the discovery of hidden patterns. AI applications have become central to tasks such as the classification of astrophysical sources, the modeling of spectral energy distributions, and the interpretation of multiwavelength and multimessenger observations. Furthermore, the emergence of generative AI methods offers new possibilities for data augmentation and predictive modeling, further expanding the scope of discovery. In this presentation, we demonstrate how convolutional neural networks (CNNs), trained on both leptonic and lepto-hadronic scenarios, can model the broadband emission of blazars and provide deeper insights into jet physics. Additionally, we present astroLLM, a novel AI-powered multi-agent research assistant designed to facilitate multiwavelength and multimessenger studies in astrophysics. These developments illustrate how AI not only enhances modeling and data analysis but also opens new windows for the comprehensive study of different astrophysical phenomena.

● **Prototype Schwarzschild-Couder Telescope: status and upgrade.**

TRIPODO G. ON BEHALF OF THE CTA-SCT WORKING GROUP

*Dipartimento di Fisica e Chimica, Università degli studi di Palermo*

The Schwarzschild-Couder Telescope (SCT) is a proposed medium-sized telescope for the Cherenkov Telescope Array Observatory. It features a dual-mirror design with 9.7 m and 5.4 m optics, which correct for spherical and comatic aberrations. The optical system achieves an 8-degree field of view while reducing the focal plane plate scale, enabling the use of a very compact camera approximately 80 cm in size-based on Silicon PhotoMultipliers (SiPMs). Custom TARGET (TeV Array Readout with GSa/s Sampling and Event Trigger) front-end electronics are used for sampling the signals at gigasample-per-second rates. A prototype telescope pSCT has been installed at the Lawrence Whipple Observatory in Arizona, USA. A major upgrade of the focal plane is ongoing, aiming to fully equip the camera with 11,328 SiPMs. During this phase, numerous components must be produced and tested. The astroparticle physics group at the University of Palermo is contributing to the development of these new devices. In this contribution, an overview of the pSCT will be presented, with a focus on the camera and the testing efforts that will lead the telescope to its final configuration.

● **A novel semi-analytical approach to model ejecta-CSM shock interaction in H-rich transients: the case of AT2019abn.**

BENEDET M. <sup>(1)</sup>, COSENTINO S.P. <sup>(2)</sup><sup>(3)</sup>, VALERIN G. <sup>(4)</sup>, REGUITTI A. <sup>(4)</sup>, PASTORELLO A. <sup>(4)</sup>, PUMO M.L. <sup>(2)</sup><sup>(3)</sup>

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<sup>(2)</sup> *Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

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Intermediate-Luminosity Red Transients (ILRTs) represent a rare class of H-rich stellar explosions with peak luminosities between classical novae and core-collapse supernovae (SNe). Despite growing observational efforts, the physical origin of these events remains debated, with electron-capture SNe from 8-10  $M_{\odot}$  progenitors being a leading scenario. A major challenge in interpreting ILRTs lies in the presence of a dense, extended circumstellar medium (CSM), which strongly shapes the light curves through ejecta-CSM interaction. In this contribution, we present a novel semi-analytical model developed to describe the radiative output from the interaction between SN ejecta and a structured H-rich CSM. Our approach enables exploration of a wide parameter space and derivation of constraints on both explosion properties and CSM configuration, directly from photometric data. We apply this model to the well-monitored ILRT AT2019abn as a case study, and discuss the resulting constraints on its progenitor system and pre-explosion mass-loss history.

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Aula 9, Section C, Edificio 19

ore 15:50 – 18:50

SEZIONE V

**Biofisica e fisica medica**

Presiede: CONTI A. (Università di Roma Tor Vergata)

Relazioni su invito

▲ **Phase transitions in the nucleus of cells.**

NICODEMI M.

*University of Naples Federico II e Max Delbrück Center, Berlin, Germany*

The sequencing of the human genome has yielded a comprehensive catalogue of its constituent genes. However, the fundamental mechanisms governing genome operation remain incompletely elucidated. The differential expression of genes across distinct tissue types, or the processes underlying the activation of long-dormant oncogenes, constitute key unresolved questions. Recent evidence indicates that gene regulation is mediated by the establishment of physical contacts between genes and distal regulatory regions along the DNA molecule. Thus, the three-dimensional architecture of the genome within the nuclear space is a critical determinant of gene expression patterns, thereby determining cell fates. This shows that the functional characterisation of DNA requires not only the determination of its linear sequence but also the reconstruction of its complex three-dimensional structure within the cell nucleus. This contribution will review selected recent findings from my research group, integrating polymer physics, computational modelling, and molecular biology experimentation, which discovered that chromosome structure and function are governed by phase transitions. These findings ground the comprehension of the very functioning of the genome on the physics of complex systems, and open the way to the development of new diagnostic tools and therapeutic strategies for genetic diseases, such as congenital disorders and cancer.

▲ **Physical principles of genome re-structuring in healthy and pathogenic genomes.**

CHIARIELLO A.M.

*Department of Physics “Ettore Pancini”, University of Naples “Federico II” e INFN, Sezione di Napoli*

Within the cell nucleus of eukaryotic organisms, chromosomes are organized in a complex, non-random three-dimensional (3D) spatial structure, which is intimately linked to vital functional purposes. Indeed, a correct folding allows an efficient communication between genes and their distal regulatory elements while, if altered, it can cause severe diseases. Here I will discuss how polymer physics, combined with molecular-dynamics simulations and machine-learning-based inference, represent a powerful tool to quantitatively investigate the complexity of 3D organization of real genomes, as highlighted by recent microscopy and biochemical experiments. Simple physical processes, widely studied in statistical mechanics, such as phase separation of molecular aggregates and polymer phase transitions, allow us to make sense of experimental observations including the tissue-specific DNA structure and the variability of chromatin at the single cell level. Also, alteration of these physical processes can be linked to pathogenic contexts and can be used to study, *e.g.*, aberrant looping or the effect of viral infections from SARS-CoV-2 or avian Influenza A H5N1 virus.

▲ **Large-scale genome structure-to-function relationship studied via polymer physics models.**

BARBIERI M.

*University Medical Center Göttingen, Germany*

Far from being randomly distributed in our cell's nuclei, DNA regulatory regions need to be spatio-temporally coordinated in order to perform the correct genetic program. Such a complex orchestration is mediated via the interaction with a multitude of proteins. In fact, large-scale DNA structural rearrangements are determined by a multitude of protein species binding the relevant coding and non-coding regions of the genome, protein-protein dynamical interactions prompting the formation of macromolecular condensates and ATP-driven active processes. Understanding the nature of these aspects as much as how they influence each other is key to dissecting the regulatory role of genome-protein structures. I tackle this challenge by the integration of genomic perturbative wet-lab experiments with predictions via polymer physics models and in-silico simulations of all the above aspects. Thanks to this approach I could show that the organization of the genome is regulated by a network of collaborative and competitive interactions of the molecular actors populating the nuclear environment.

Comunicazioni

● **Effects of PFOA acid on *V. campbellii* BB120 vibriions and mutants.**

NASSISI V. <sup>(1)(2)</sup>, CALCAGNILE M. <sup>(2)(3)</sup>, GIULIANO A. <sup>(2)(3)</sup>, PALADINIA F. <sup>(1)</sup>, TREDICI S.M. <sup>(2)</sup>, ALIFANO P. <sup>(3)</sup>

<sup>(1)</sup> *Laboratory LEAS, Department of Mathematics and Physics, University of Salento, Lecce, Italy*

<sup>(2)</sup> *Laboratory of Microbiology, Department of Biological and Environmental Sciences and Technologies, University of Salento, Lecce, Italy*

<sup>(3)</sup> *Department Laboratory of Microbiology, Department of Experimental Medicine, University of Salento, Lecce, Italy*

Currently, the extensive use of PFOA, perfluorooctanoic acid, used as a non-stick for cookware and for many different clothes represents a problem plaguing humanity. The PFOA effects can be anticipated by studying the bioluminescent vibriions during their growth on normal medium and on PFOA doping medium. To gain more insight about the mechanisms involved in stimulation of bioluminescence by PFOA at early growth time points, *V. campbellii* BB120 samples (wild) and three derivative mutants were used: KM387, JMH603, and JAF633, unable to synthesize, the autoinducers AI-2, CAI-1, and HAI-1, respectively. To monitor bioluminescence, *V. campbellii* BB120 was spotted on PFOA-containing or control LA agar plates. The use of bioluminescent vibriions lies in the fact that the emitted light is indicative of the microbial physiology of the species. Two very sensitive photomultipliers (PMT 1P28) capable of recording light were used. The sensitivity range is 185–700 nm. Measurements of medium wettability were also performed. A data acquisition system was used to record the output signals every 30 min. The first observations showed that the kinetics of light emission were affected by the PFOA presence.

● **Epigenome remodeling and acetylated chromatin distribution during ncNDM29-induced retro-transformation of neuroblastoma cells.**

ZBEEB H. <sup>(1)(2)</sup>, ZEAITER L. <sup>(1)(2)</sup>, TOULIER L. <sup>(1)</sup>, PAGANO A. <sup>(3)</sup>, BIANCHINI P. <sup>(1)</sup>, DIASPRO A. <sup>(1)(4)</sup>, VERGANI L. <sup>(2)</sup>

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<sup>(2)</sup> *Department of Earth, Environment and Life Sciences, DISTAV, University of Genova,*

Genova, Italy

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<sup>(4)</sup> Department of Physics, DIFILAB, University of Genova, Genova, Italy

Neuroblastoma (NB) is an aggressive childhood tumor that originates from neural crest-derived sympathetic cells. Neuroblastoma Differentiation Marker 29 (NDM29) is a non-coding RNA transcribed by RNA polymerase III, known to promote neuronal differentiation and reduce malignancy in NB cells. In this study, SKNBE2 cells were genetically modified via transfection with a vector carrying the NDM29 gene, resulting in the overexpression of NDM29 in S1.1 cells, which exhibit a shift from a malignant to a more differentiated, neuron-like phenotype. Mock cells, transfected with an empty vector, served as control. We hypothesize that this differentiation involves chromatin remodeling, driven by specific histone modifications. Using molecular biology techniques (ELISA Assay, western blot, and microarrays) and fluorescence imaging (NSPARC), we analyzed histone modifications, mainly focusing on H3K27ac, in both S1.1 and mock cells. Histone H3K9 distribution data were investigated using IsoConcentraChromJ approach. This study aims to uncover the role of epigenetic changes in differentiation and malignancy suppression in neuroblastoma.

● **Enhancing bioFET performance for clinical microRNA-155 detection using a PEG-based approach under high ionic strength.**

LAVECCHIA DI TOCCO F. <sup>(1)(2)</sup>, BIZZARRI A.R. <sup>(1)</sup>

<sup>(1)</sup> Biophysics and Nanoscience Centre, DEB, Università della Tuscia, Viterbo, Italy

<sup>(2)</sup> Department of Biomedical Sciences and Technologies, Università Roma Tre, Rome, Italy

MicroRNAs are short non-coding RNAs whose deregulation is linked to various disorders, making them valuable biomarkers. Field Effect Transistor-based biosensors (bioFETs) represent a promising method for microRNA detection. These devices use biological probes immobilized on a gate electrode, where probe-target interactions alter the gate potential. BioFET effectiveness is limited by Debye screening at high ionic strengths required for hybridization. To address this, we evaluated polyethylene glycol (PEG) to destabilize the interfering layer, enabling microRNA detection at high ionic strengths. We selected oncogenic miR-155 as target and its complementary strand as probe. Preliminary tests using different techniques on gold electrodes showed optimal kinetics. The gold electrode was integrated in a home-made FET. Co-immobilizing antimiR probes with PEG improved device sensitivity without altering kinetics. The results enable bioFET development for microRNA for clinical purpose, overcoming Debye screening without amplification.

● **Modeling genome architecture with polymer physics and machine learning in health and disease.**

ESPOSITO A.

Dipartimento di Fisica, Università di Napoli Federico II e INFN, Sezione di Napoli

The spatial organization of the genome plays a crucial role in gene regulation and cellular function. Recent high-throughput experimental techniques (*e.g.*, Hi-C) have unveiled a complex, non-random three-dimensional (3D) folding of chromosomes, raising fundamental questions about how such structures emerge and influence biological activity. Modeling frameworks are emerging as promising tools capable of rationalizing such complexity from first principles. In this contribution, I will show that polymer physics and statistical mechanics provide a natural language to describe chromosome organization, allowing us to interpret data and make testable predictions. In particular, models based on micro-phase separation and coil-globule transitions capture essential features of genome folding across scales. When combined with machine learning strategies, these models enable the inference of effective DNA-binding profiles that explain observed 3D contacts with high accuracy. This integrated approach reveals a combinatorial architectural code linking the linear organization of

the genome to 3D structural features, which we validated genome-wide and across different cell types. The framework is also predictive: it explains how structural variants affect chromatin architecture and allows in silico modeling of the consequences of disease-associated mutations. Overall, these findings show that genome architecture arises from basic physical principles shaped by biological context and provide a foundation for predicting the effects of genetic variation and disease-associated mutations.

● **Physical principles of phase-separation action on DNA folding associated to pathogenic gene activation.**

FONTANA A.

*Università degli Studi di Napoli "Federico II" e INFN, Sezione di Napoli*

Phase separation of proteins resulting from genetic mutations has been shown to trigger aberrant chromatin looping, contributing to disease development, including cancer. However, the physical mechanisms regulating these processes remain unclear. In this study, we employ polymer physics models of chromatin to investigate the relationship between protein self-aggregation and chromatin structure. We show that a simple model, including only protein-protein and protein-chromatin interactions, effectively explains the aberrant looping around certain oncogenes in cells expressing the NUP98-HOXA9 chimeric protein, commonly found in leukemia. Finally, leveraging on our numerical simulations, we compare our findings with experimental data and show that phase-separation properties of chimeric proteins can be harnessed to prevent aberrant gene-regulator contacts.

● **Studies of nuclear fragmentation with the FOOT and DAMON experiments.**

BOCCIA V. <sup>(1)(2)</sup>, LAURIA A. <sup>(1)(2)</sup>, ALEXANDROV A. <sup>(2)</sup>, DE LELLIS G. <sup>(1)(2)</sup>, GALATI G. <sup>(3)</sup>, MONTESI M.C. <sup>(1)(2)</sup>, D'AMBROSIO N. <sup>(4)</sup>, ASADA T. <sup>(5)</sup>, TIOUKOV V. <sup>(2)</sup>

<sup>(1)</sup> *Università di Napoli "Federico II"*

<sup>(2)</sup> *INFN, sezione di Napoli*

<sup>(3)</sup> *Università di Bari "Aldo Moro"*

<sup>(4)</sup> *Laboratori Nazionali del Gran Sasso, INFN*

<sup>(5)</sup> *Toho University, Narashino, Tokyo*

This work presents recent progress in studying hadron beam fragmentation in particle therapy, where nuclear interactions from protons and heavy ions lead to significant biological damage. The FOOT (FragmentatiON Of Target) experiment is performing the first measurements of nuclear fragmentation cross-sections of 200 MeV/n and 400 MeV/n <sup>16</sup>O and <sup>12</sup>C beams on C, C<sub>2</sub>H<sub>4</sub> and H, providing key data for improving RBE and Monte Carlo models. The experiment's physics program includes both projectile fragmentation and target fragmentation in inverse kinematics. Target fragmentation processes are also under study in direct kinematics with a new generation of fine grained nuclear emulsions known as Nano Imaging Trackers (NIT) within the DAMON (Direct meAsureMent of target fragmentatiON) project. Recently, R&D efforts were carried out at the Gran Sasso National Laboratories and at the universities of Toho and Nagoya in Japan to improve the sensitivity of NIT to protons at clinical energies. This contribution will include the latest results from the nuclear emulsion spectrometer of the FOOT experiment, as well as an overview of the first direct studies of target fragmentation with NIT.



SEZIONE VI

**Fisica applicata, acceleratori e beni culturali**

Presiede: SERAFINI L. (INFN, Sezione di Milano)

Relazioni su invito

▲ **Beam manipulation with plasmas.**

POMPILI R.

INFN

Plasmas are able to sustain huge electromagnetic fields and have been exploited to demonstrate the acceleration of GeV beams in few centimeters and focusing magnetic gradients of kT/m. In this contribution I will review some of the advancements that have been recently achieved and the perspectives for future user-oriented applications.

▲ **Ni-based microflowes for H production via water splitting.**

MIRABELLA S., URSO M., BRUNO L.

*Dipartimento di Fisica e Astronomia, Università di Catania, Italia e CNR-IMM*

The quest for sustainable and efficient electrocatalysts for hydrogen production via water splitting has driven extensive research toward the development of novel and more performing Ni-based nanostructures. We present a comprehensive investigation into the oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) applications of Ni-based microflowes prepared by chemical bath deposition. The optimization of alkaline OER was performed by the identification of the ideal crystal structure between  $\text{Ni}(\text{OH})_2$  and NiO and the optimum transition metal dopant, achieving a lowest overpotential of 297 mV at  $10 \text{ mA cm}^{-2}$  and a high intrinsic activity. Regarding alkaline HER, NiO microflowes with ultralow amounts of chemically synthesized Pt nanoparticles demonstrated a remarkably low overpotential of 66 mV at a current density of  $10 \text{ mA cm}^{-2}$ . The superior number of active sites and the enhanced electrocatalytic activity open avenues for developing cost-effective and highly efficient electrocatalysts for water splitting technologies.

Comunicazioni

● **Una stazione di test per linee superconduttive e grandi magneti.**

SAGGESE A. <sup>(1)(2)</sup>, CHIUCHIOLO A. <sup>(2)</sup>, D'AGOSTINO D. <sup>(2)</sup>, DE PASQUALE S. <sup>(1)(2)</sup>, SEVERINO C. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Fisica, Università degli Studi di Salerno*

<sup>(2)</sup> *INFN, Sezione di Napoli, Gruppo Collegato di Salerno*

La richiesta di tecnologie green per la trasmissione di energia elettrica sostenibile, ha stimolato la superconduttività di potenza connessa alla disponibilità di infrastrutture in campo criogenico. In questo ambito il programma IRIS ha permesso alla collaborazione tra cinque Università (Genova, Milano Statale, Federico II, Salento e Salerno), INFN e CNR di realizzare una nuova facility di test nel campo della superconduttività di potenza. La struttura sarà in grado di testare linee superconduttive alla temperatura di 20 K da 40 kA /25 kV CC. La sede di questa infrastruttura è il campus dell' Università di Salerno, dove è già presente una parte della facility, impegnata nei test dei moduli per il SIS100 nell'ambito di una collaborazione precedente tra INFN, GSI-FAIR e Università di Salerno. Il nuovo edificio,



ospiterà la strumentazione per i test delle linee di trasmissione di energia sostenibile. La facility, dunque, lavorerà nell'ambito delle applicazioni più promettenti della superconduttività, ovvero la sostenibilità energetica e le tecnologie alla base dello sviluppo di moderni apparati di ricerca come gli acceleratori di particelle.

● **Model of quality factor for (111) 3C-SiC double-clamped beams.**

GAROFALO A. <sup>(1)</sup>, MUOIO A. <sup>(2)</sup>, LA VIA F. <sup>(2)</sup>

<sup>(1)</sup> *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano Bicocca*

<sup>(2)</sup> *CNR-IMM, Catania*

Silicon carbide (SiC) is an interesting semiconductor for MEMS (Micro Electro-Mechanical System) devices. The high-value Young's modulus of silicon carbide facilitates high frequencies and Quality (Q) factors in resonant devices built with double-clamped beams. The aim of the work is to achieve the determination and modeling of the Q-Factor for samples of micromachined 3C-SiC film on (111) Silicon substrates. The study demonstrates that the experimental datasets created by Romero et al., integrated with the thicker samples reported in our work, fit the theoretical model. Furthermore, the influence of the crystallographic defects present at the 3C-SiC/Si interface on the Q-factor can be observed both in the analytical model of Romero and in the numerical model present in COMSOL. Increasing the 3C-SiC film thickness resulted in the quality factor reaching  $6.3 \times 10^5$  in correspondence with 1  $\mu\text{m}$  thickness of the 3C-SiC layer. This is quite a high value, 3C-SiC layers with thickness greater than 600 nm are needed to achieve an ideal performance from double-clamped beams.

● **Characterization of the electric field in silicon carbide detectors by Optical Beam Induced Current**

DE LUCA S. <sup>(1)</sup>, DE LUCA S. <sup>(1)</sup>, MANCUSO A. S. <sup>(1)(2)</sup>, MUOIO A. <sup>(1)</sup>, SANGREGORIO E. <sup>(1)</sup>, LA VIA F. <sup>(1)</sup>

<sup>(1)</sup> *CNR-IMM, Catania*

<sup>(2)</sup> *Università degli Studi di Catania*

Silicon carbide (SiC) is a wide bandgap semiconductor material with exceptional properties for a variety of applications, particularly for high-voltage devices. SiC has proven to outperform traditional silicon (Si) based power electronic devices. In this work the OBIC (Optical Beam Induced Current) technique will be applied to examine the electric field distribution inside the structure of SiC bipolar diodes with different epitaxial layer thickness. To create electron-hole pairs inside the semiconductor, a 325 nm UV laser beam is used. The focused laser beam was moved on the surface of the device with steps of 2 microns. We have tested bipolar diodes with both 10 microns epilayer thickness and 100 epilayer thickness. The OBIC is measured by Keithley 2450 SMU (Source Measurement Unit) and is then mapped in 2-directions (X and Y) or just along one line in a chosen direction. The intensity of the photo-generated current is linked to the intensity of the average electric field and therefore to the reverse voltage applied to the detector under test. We obtained several OBICs by re-scanning the same location at different reverse voltages (up to 200 V) applied to the same SiC diode.

● **Analysis of the response of SiC power MOSFET devices with different thicknesses under atmospheric-like and monoenergetic neutron irradiation, supported by FLUKA simulations.**

PIETROSANTI V. <sup>(1)</sup>, MINNITI T. <sup>(2)</sup>, PINTACUDA F. <sup>(3)</sup>, PRINCIPATO F. <sup>(4)</sup>, CAZZANIGA C. <sup>(5)</sup>, FROST C. <sup>(5)</sup>

<sup>(1)</sup> *Dipartimento di Scienze e Tecnologie Chimiche, Università degli Studi di Roma Tor Vergata*

<sup>(2)</sup> *Dipartimento di Fisica e Centro NAST, Università degli Studi di Roma Tor Vergata*

<sup>(3)</sup> *STMicronics, Catania*

<sup>(4)</sup> *Dipartimento di Fisica e Chimica, Università di Palermo*

<sup>(5)</sup> *ISIS Facility, STFC, Rutherford Appleton Laboratory, Harwell, UK*

Silicon carbide (SiC) is a promising material for power devices in avionics and space applications due to its high breakdown field and thermal conductivity. SiC power MOSFETs may experience destructive failure when exposed to neutrons in the terrestrial environment, such as single event burnouts (SEBs), which affect devices biased at high voltages. The mitigation of SEBs is essential to ensure the electronics reliability. In this study, devices operate at low voltages to act as neutron detectors to avoid SEB, enabling correlation of signal amplitude with deposited neutron energy, which is simulated using FLUKA. Neutron irradiation is performed at the ISIS Neutron and Muon Source (UK) using ChipIr (1-800 MeV) and NILE (14 MeV) beamlines. Devices with active layer thicknesses of 9.5, 14, and 20  $\mu\text{m}$  are tested under identical conditions. Results show that the device response mainly depends on thickness at a constant breakdown voltage ratio. SEBs are not primarily caused by reactions on SiC, as secondary particles deposit insufficient energy. The dominant contribution is likely from high-LET particles. Further studies with monoenergetic neutrons at varied energies are planned.

● **Advancements of micro-SORS for the non-invasive study of cultural heritage samples.**

LUX A. <sup>(1)(2)(3)</sup>, BOTTEON A. <sup>(1)</sup>, MONICO L. <sup>(4)</sup>, MOSCA S. <sup>(3)</sup>, MATOUSEK P. <sup>(3)</sup>, CONTI C. <sup>(1)</sup>

<sup>(1)</sup> *CNR, Institute of Heritage Science, Milano*

<sup>(2)</sup> *Sapienza Università di Roma, Faculty of Literature, Department of Classics*

<sup>(3)</sup> *Central Laser Facility, Research Complex at Harwell, STFC Rutherford Appleton Laboratory, Harwell Oxford, UK*

<sup>(4)</sup> *CNR, Institute of Chemical Sciences and Technologies Giulio Natta, Perugia*

Thanks to its high versatility and chemical specificity, Spatially Offset Raman Spectroscopy (SORS) has proved effective for the non-invasive analysis of the subsurface of materials both in-situ and in laboratory environments, demonstrating its capability of retrieving signal from the inner parts of the analyte. Moreover, micro-SORS is particularly suited when dealing with micrometre scale issues, as it often happens in cultural heritage materials: for example, the technique can be useful to study painted layer sequences, the stratigraphic distribution of degradation products or to discover hidden text below layers of paper. In this presentation, we will show the potential of micro-SORS and data analysis routines when dealing with cultural heritage samples, including pigment degradation processes in paintings. This research exploits micro-SORS mapping of artificially aged paint mock-ups consisting of multiple layers (aged and unaged) of different chemical composition; the maps are reconstructed using a Python routine allowing the immediate visualization of the distribution of degradation products on and below the surface, to evaluate its extent. Additionally, we will present the coupling of other advanced detection technologies with micro-SORS, allowing non-invasive investigations while simultaneously rejecting ambient light interference.

● **Atmospheric neutron effects in Power Transistors and MONeutron application.**

PINTACUDA F. <sup>(1)</sup>, PRINCIPATO F. <sup>(2)</sup>, MINNITI T. <sup>(3)</sup>, ANDREANI C. <sup>(3)(4)</sup>

<sup>(1)</sup> *STMicronics, Palermo*

<sup>(2)</sup> *Dipartimento di Fisica e Chimica, Università degli Studi di Palermo*

<sup>(3)</sup> *Dipartimento di Fisica e NAST Centre, Università di Roma Tor Vergata*

<sup>(4)</sup> *CNR, Institute for Polymers Composites and Biomaterials, Pozzuoli*

The cosmic ray interaction with the atmosphere creates cascades of interactions and reactions products, including neutrons with energies from meV to GeV. These neutrons can collide with the nucleus of an atom in a semiconductor device and cause its destructive failure. This susceptibility of power devices to neutrons, impact the reliability of power systems for automotive and avionics applications, such as such as electric vehicles, rail transport and DC/DC or DC/AC converters. Nowadays, semiconductor manufactures estimate the neutron failure rate of power transistors by accelerated neutron tests by using dedicated facilities where are available neutron beams with atmospheric-like energy spectrum. The results of accelerated neutron tests of STMicroelectronics power transistors (MOSFET) performed at the ChipIr faciity - ISIS Neutron and Muon Source (UK) are shown. In addition, we will show an application where SiC power MOSFETs are positioned next to the MONeutron facility - a new class of neutron Monitor of ISIS@MACH ITALIA research Infrastructure, operating in the Campus of University of Rome Tor Vergata, working as a neutron detector. In this experiment we are employing at least 50 power MOSFETs, which is roughly the amount used in the applications, such as three phase DC/DC or DC/AC converters. The MONeutron with power SiC MOSFET transistors is counting neutron strikes inside the MOSFETs and evaluates the charge deposited in the device. We can estimate the energy of the neutron comparing it with the similar results obtained in ChipIr facility. These results will provide important information about the actual neutron impact in life condition for a typical power application.

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Aula 8, Section B, Edificio 19

ore 15:50 – 18:50

SEZIONE VII

**Didattica e storia della fisica**

Presiede: MONTI F. (Università di Verona)

Relazioni su invito

▲ **SHINE: integrare il pensiero sistemico nell'educazione scientifica a scuola.**

CORNI F.

*Libera Università di Bolzano*

Il progetto Erasmus+ SHINE (mainstreaming Systems tHinking In Natural sciences and Environmental education) si propone di fornire risorse innovative per integrare il pensiero sistemico (system thinking) nell'insegnamento della fisica e delle scienze a livello di scuola primaria e secondaria con particolare attenzione ai temi del cambiamento climatico. Dopo la prima fase di analisi delle best practice europee, il progetto si è concentrato sullo sviluppo di materiali per la formazione insegnanti volti a fornire conoscenze sul pensiero sistemico e offrire approcci didattici innovativi per l'applicazione in classe. Si sono quindi svolti corsi di formazione insegnanti nei paesi partner (Germania, Estonia, Italia e Portogallo). I partner si concentreranno ora sullo sviluppo di un toolkit didattico digitale, che includerà un gioco educativo cooperativo, moduli didattici per studenti (8-16 anni) e strumenti di valutazione. In questo contributo, dopo un'introduzione a SHINE e allo stato dell'arte dello sviluppo dei suoi materiali, verranno presentati i risultati della sperimentazione in Italia nel corso di fisica della laurea magistrale in scienze della formazione primaria.

▲ **STEAM - le Arti nelle STEM: un semplice mezzo o qualcosa di più?**

TUVERI M.

*Dipartimento di Fisica, Università degli Studi di Cagliari e INFN, Sezione di Cagliari*

Le Arti nelle STEM sono solo un ornamento divulgativo e comunicativo o rappresentano una chiave per ripensare l'educazione scientifica? Le ricerche in didattica della fisica suggeriscono che linguaggi narrativi, poetici e teatrali possano fare molto più che "abbellire" l'insegnamento: essi aprono spazi di senso, favoriscono l'accesso ai concetti, potenziano l'apprendimento attivo e lo sviluppo del pensiero fisico. Esperienze condotte nella scuola primaria e secondaria mostrano che l'integrazione tra scienza e linguaggi artistici stimola la curiosità, la creatività e l'inclusione, specialmente nell'affrontare temi complessi della fisica contemporanea come, ad esempio, la cosmologia e le onde gravitazionali. In questa relazione, si discute il ruolo degli approcci STEAM (Science, Technology, Engineering, Art, Mathematics) nell'apprendimento e insegnamento della fisica nella scuola. Ci si soffermerà sul ruolo del linguaggio nello sviluppo dei modelli mentali per la comprensione e la costruzione della descrizione dei fenomeni fisici. Verranno infine illustrate le implicazioni degli approcci interdisciplinari per la didattica con esempi pratici tratti dalla ricerca.

▲ **Apprendimento non-formale in ambito STEM per la Scuola Primaria: STEM@UniCal**

BOZZO G., FELICETTI F., MASIELLO D., SAPIA P.

*Dipartimento di Matematica e Informatica, Università della Calabria e Agorà LAB, Laboratorio per la diffusione della cultura scientifica e tecnica per la cittadinanza del XXI secolo*

L'integrazione di attività di apprendimento non formale nei percorsi curricolari STEM rappresenta una leva motivazionale per studenti e studentesse, favorendo la comprensione del

ruolo della scienza nella società e lo sviluppo di una cittadinanza scientifica consapevole. In Calabria, si avverte un forte bisogno di iniziative educative non formali che arricchiscano la didattica STEM, sia nelle scuole primarie che nelle scuole secondarie di primo grado. Nell'ultimo anno accademico, il laboratorio Agorà LAB dell'Università della Calabria ha lanciato STEM@UniCal, come naturale evoluzione della mostra scientifica Scienza per Gioco (proposta dal 2018 fino al 2024), con l'obiettivo di offrire esperienze laboratoriali immersive a discenti di scuola primaria e secondaria di primo grado. Il progetto promuove l'apprendimento delle STEM attraverso attività pratiche e metodologie didattiche innovative, coinvolgendo circa 5000 bambini e 400 docenti. Nel contesto del Congresso SIF 2025, verrà presentato il progetto, analizzando i percorsi proposti, i modelli didattici e l'impatto sul territorio, evidenziando la sinergia tra università e scuole per una cultura scientifica accessibile e inclusiva.

## Comunicazioni

### ● **Didattica della Fisica per futuri insegnanti della Scuola Primaria: un intervento di ricerca innovativo per promuovere le soft skills.**

LUPO I. <sup>(1)</sup>, SECHI C. <sup>(2)</sup>, FAZIO C. <sup>(1)</sup>

<sup>(1)</sup> *Università degli Studi di Palermo*

<sup>(2)</sup> *Università degli Studi di Cagliari*

In linea con l'Agenda 2030, il presente studio valorizza l'integrazione delle competenze chiave per l'apprendimento permanente personal, social and learning to learn skills all'interno di un corso universitario di didattica della Fisica. Recenti ricerche evidenziano il ruolo della psicologia positiva come approccio efficace per la promozione delle soft skills, soprattutto in relazione a variabili cruciali per l'apprendimento nelle discipline STEM, quali motivazione accademica, mentalità di crescita e percezione di autoefficacia (Damrongpanit, 2019). Il contributo presenta un intervento didattico innovativo, realizzato all'interno dell'insegnamento di Fisica per la Scuola Primaria e dell'Infanzia nel corso di laurea in Scienze della Formazione Primaria. L'obiettivo è valutare l'impatto dell'intervento a favore di alcune soft degli studenti, attraverso la somministrazione di scale validate prima e dopo l'intervento. I risultati, ottenuti mediante analisi statistiche quantitative, saranno discussi in relazione all'efficacia dell'intervento e alle implicazioni per la formazione in didattica della Fisica dei futuri insegnanti.

### ● **Barattoli in gara: la fisica del rotolamento per una didattica esperienziale.**

ALBANI G., DI MARTINO D.

*Università di Milano Bicocca*

Il corso di Fisica e Didattica della Fisica con Laboratorio del Corso di Laurea Magistrale a ciclo unico in Scienze della Formazione Primaria dell'Università Milano-Bicocca coinvolge circa 500 studenti, spesso poco motivati verso le discipline scientifiche e in particolare verso la fisica, percepita come difficile, astratta e distante dalla quotidianità. Oltre a fornire contenuti disciplinari, il corso mira a risvegliare curiosità e interesse per i fenomeni naturali attraverso attività pratiche ed esperienziali. In questo contributo documentiamo un'esercitazione dedicata al tema del Movimento, durante la quale gli studenti, utilizzando materiali di uso comune, realizzano un set-up per una gara di rotolamento tra diversi barattoli e ne analizzano i risultati. Partendo dalla formulazione di ipotesi, alla raccolta e analisi dei dati, i gruppi sono guidati in un percorso di ricerca dal quale emergono da un lato misconceptions e dall'altro processi di apprendimento. Discuteremo infine come questa attività favorisca l'acquisizione di competenze scientifiche e metodologiche.

● **Una nuova visione per spiegare la formazione dei miraggi.**

FRUTON P. <sup>(1)</sup>, OCCHILUPO C. <sup>(1)</sup>, VOLPARI C. <sup>(2)</sup>, VAILATI A. <sup>(1)</sup>, CARPINETI M. <sup>(1)</sup>

<sup>(1)</sup> *Università degli studi di Milano*

<sup>(2)</sup> *Liceo artistico di Brera, Milano*

Sia nella scuola che nell'università, con le classiche lezioni frontali, gli studenti incontrano difficoltà nella comprensione del percorso della luce e del suo legame con la formazione delle immagini, in particolare con il fenomeno dei miraggi. Abbiamo dunque sviluppato un progetto basato su metodologie didattiche inquiry-based che è stato sperimentato con successo in un liceo in due edizioni. Gli studenti sono gli attori protagonisti della sperimentazione e, formulando ipotesi, comprendono passo dopo passo il percorso della luce attraverso un mezzo omogeneo, due mezzi diversi e infine un mezzo stratificato. Gli studenti possono dunque comprendere la formazione dei miraggi che si verifica quando la luce attraversa un mezzo stratificato, grazie alla possibilità osservare la luce da diverse prospettive. La tradizionale visione laterale proposta sui libri scolastici può essere confrontata nello stesso esperimento con il punto di vista soggettivo di chi riceve frontalmente la luce. Questo permette di associare il percorso curvo della luce con lo spostamento e la deformazione degli oggetti visti attraverso il mezzo disomogeneo e fa finalmente vedere sperimentalmente un miraggio.

● **L'impiego dei libri di divulgazione scientifica per bambini nella didattica della fisica: un'esperienza collaborativa tra università e territorio.**

LAURORA A.

*Dipartimento per l'Innovazione Umanistica Scientifica e Sociale, Università della Basilicata*

Il presente contributo analizza l'integrazione di libri di divulgazione scientifica per bambini nella didattica della fisica, evidenziando le sfide relative alla valutazione del contenuto scientifico e della validità didattica, nonché alla motivazione alla lettura. Si presenta un'esperienza collaborativa tra il corso di Didattica e storia della fisica del Corso di Laurea in Scienze della Formazione Primaria dell'Università della Basilicata e una libreria indipendente di Matera. L'attività si è focalizzata sull'analisi di criteri di selezione di libri per l'infanzia e sul coinvolgimento degli studenti del Corso in un gruppo di lettura per bambini. Si discutono le riflessioni emerse in merito al potenziale della divulgazione scientifica nei libri come strumento per l'apprendimento delle scienze.

● **The Physical Clown.**

ONATE OROZCO M., ACCATTATO M., BONDANI M.

*Università degli studi dell'Insubria, Como e Associazione Culturale Scuola di Arti Circensi e Teatrali, Milano*

The Physical Clown is an ongoing PhD research project that explores the use of clownerie to communicate scientific concepts. At its core is a theatrical lesson-show on the physics of metals, created under the scientific guidance of physicist Maria Bondani and directed by Maurizio Accattato, clown and director of the Milano Clown Festival. The result is an innovative performance that blends rigorous scientific content with the universal language of physical comedy, pantomime, juggling, Commedia dell'Arte, and live music. The main character the Physical Clown leads the audience through a journey of discovery, using experimental demonstrations and artistic storytelling to foster empathy and curiosity. The show has been successfully performed in high schools and at public science events, reaching audiences of different ages and educational backgrounds. Its effectiveness has been assessed with both quantitative and qualitative feedback. The next phase of the project proposes a 12-hour PCTO module combining formal physics lessons with expressive arts laboratories. Students will ultimately co-create and perform their own science lesson-show, based on their interests and aptitudes.

● **Enlighting Co-visions. Contaminazioni tra arte, scienza e design.**

BALDANZI. E. <sup>(1)(2)</sup>, MARINO A. <sup>(3)</sup>, GIUSTI C. <sup>(4)</sup>, LANGELLA C. <sup>(5)</sup>, AMATO C. <sup>(6)</sup>, NICHILÒ G. <sup>(5)</sup>, BATTAGLIA S. <sup>(7)</sup>, FARINI A. <sup>(1)(2)</sup>, GURIOLI M. <sup>(1)(2)</sup>

<sup>(1)</sup> *Università degli Studi di Firenze*

<sup>(2)</sup> *CNR, Istituto Nazionale di Ottica*

<sup>(3)</sup> *CNR, Istituto di Scienze Applicate e Sistemi Intelligenti*

<sup>(4)</sup> *Science Exhibition designer, Città della Scienza, Napoli*

<sup>(5)</sup> *Dipartimento di Architettura, Università degli Studi di Napoli Federico II*

<sup>(6)</sup> *Dipartimento di Salute Mentale e Fisica e Medicina Preventiva, Università degli Studi della Campania Luigi Vanvitelli, Caserta*

<sup>(7)</sup> *Museo Galileo, Firenze*

Co-Visions è il progetto che esplora il dialogo tra arte, design e scienza come linguaggio contemporaneo per comunicare la ricerca. La mostra è ispirata alla fisica della luce e percezione, traducendo concetti scientifici in esperienze visive accessibili. Seguendo una tradizione in cui diverse discipline si influenzano a vicenda, il progetto dimostra come le innovazioni scientifiche richiedano nella società odierna nuovi codici di espressione. I giovani designer del Corso di Laurea Magistrale Internazionale in Designer per l'Ambiente Costruito (DBE), del Dipartimento di Architettura dell'Università Federico II, hanno avuto l'opportunità di collaborare con ricercatori e professionisti di diversi ambiti del sapere come la fisica e l'arte per sviluppare progetti nel campo del design di prodotto, del design digitale e dell'exhibit design che indagano le connessioni tra queste discipline. Le attività si sono svolte da aprile a giugno 2024 presso la Città della Scienza di Napoli e il Dipartimento di Architettura dell'Università Federico II, per confluire in una mostra presentata in anteprima in occasione di Futuro Remoto a Napoli e presso il CREF a Roma.

● **Beyond the frame: dynamics in videos between sports, science and space.**

COSTA V. <sup>(1)</sup>, COSENTINO S.P. <sup>(2)(3)(4)</sup>, NOVARA V. <sup>(1)</sup>, ARENA C. <sup>(3)(4)</sup>, CINARDI G. <sup>(5)</sup>, PUMO M.L. <sup>(2)(3)</sup>

<sup>(1)</sup> *Istituto di Istruzione Superiore Gulli e Pennisi, Acireale, Liceo Scientifico Aci Bonaccorsi*

<sup>(2)</sup> *Dipartimento di Fisica e Astronomia, Università degli Studi di Catania*

<sup>(3)</sup> *INAF, Osservatorio Astrofisico di Catania*

<sup>(4)</sup> *Gruppo Astrofili Catanesi Guido Ruggieri, Catania*

<sup>(5)</sup> *Dipartimento di Agricoltura, Alimentazione e Ambiente, Università degli Studi di Catania*

Beyond the Frame, is an interdisciplinary educational initiative designed to cultivate scientific culture among high school students. The project combines experimental and theoretical approaches, bridging real-world observation with mathematical modelling and digital tools. Using the open-source software Tracker, students extract kinematic data from diverse video sequences featuring moving subjects, making the dynamics principles tangible and engaging. The learning path begins with classical physics experiments, progresses to analysing video sequences to extrapolate quantities such as speed, height, and energy dissipation, and applies this to sports game situations. Finally, after familiarising themselves with the software, the students can track artificial satellite motion using videos recorded by amateur astronomers. The final phase extends beyond physics, integrating discussions on the civic and ethical dimensions of space as a strategic resource. This includes environmental consequences of light pollution, but also its importance in many aspects of today's life. This presentation outlines the project plan and results obtained by students.

*Venerdì 26 settembre - Sezione VII*

**Aula Magna G.B.F. Basile, Edificio 7**

**ore 18:50**

Assemblea di ratifica e proclamazione degli eletti

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