125 YEARS SIF

1897-2022

108° CONGRESSO NAZIONALE

Società Italiana di Fisica

Milano, 12-16 settembre 2022

UNIVERSITÀ DEGLI STUDI DI MILANO

INFN Istituto Nazionale di Fisica Nucleare

POLITECNICO MILANO 1863

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

A cura di B. Alzani, M. Bellacosa e G. Bianchi Bazzi
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108° CONGRESSO NAZIONALE SOCIETÀ ITALIANA DI FISICA

Milano, 12-16 settembre 2022

Dipartimento di Fisica
Università degli Studi di Milano
Via Celoria 16

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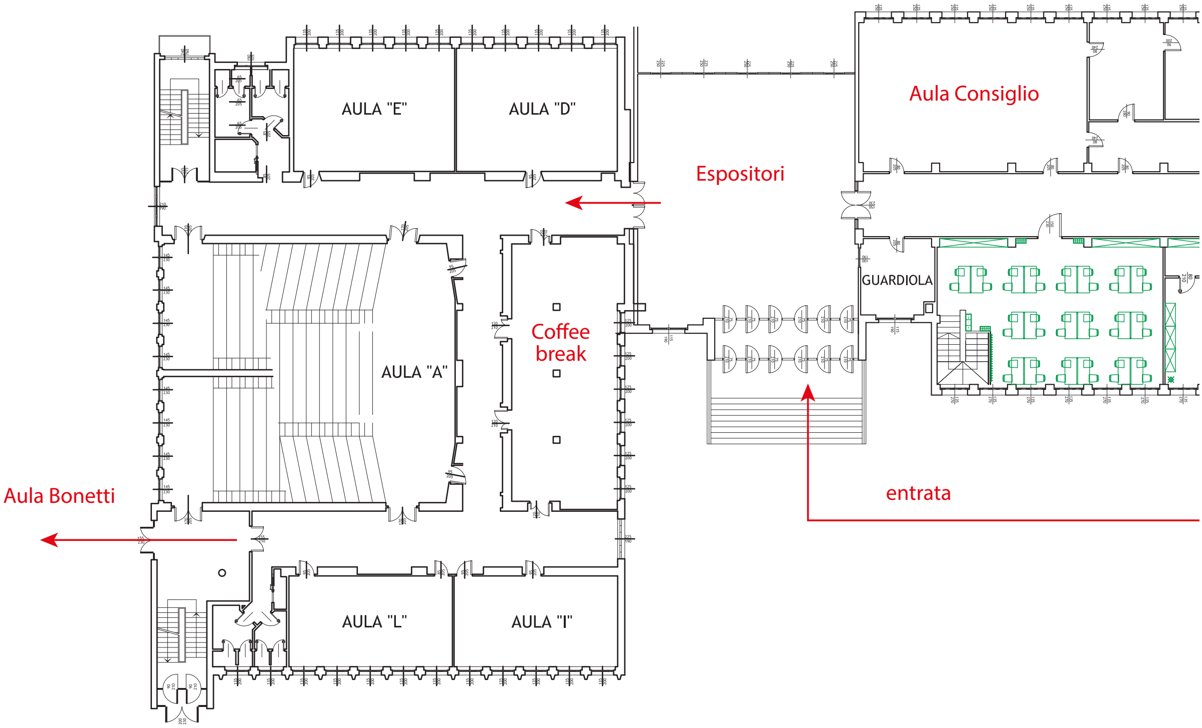

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SEZIONE 1 - AULA B “MARIA GOEPPERT-MAYER”

SEZIONE 2 - AULA D “MARIANNA CICCONE”

SEZIONE 3 – AULA T “CATERINA SCARPELLINI”

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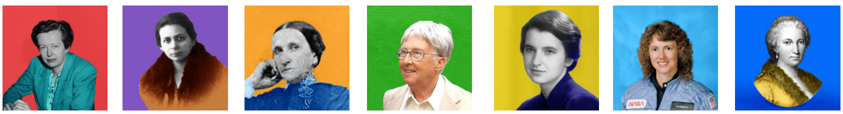
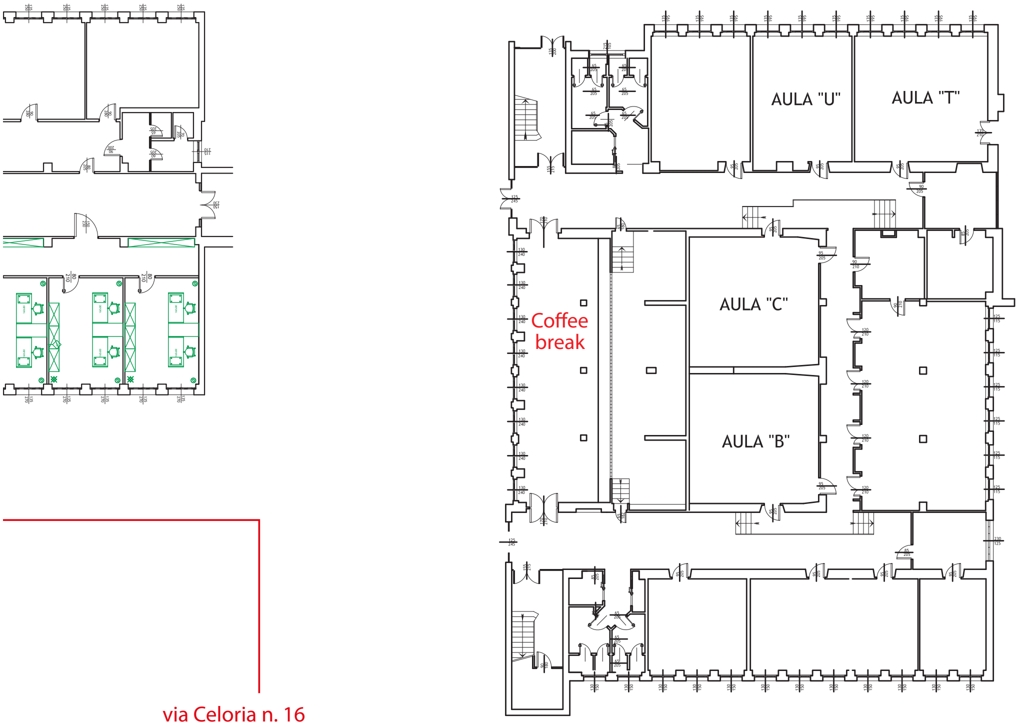


SEMINTERRATO



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SOCIETÀ ITALIANA DI FISICA

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(Milano)

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Sezione Giovani **In collaborazione con l'Associazione Italiana Studenti di Fisica (AISF) e con il Progetto Young Minds dell'EPS.**

INFORMAZIONI GENERALI

Sede del Congresso

La cerimonia di inaugurazione si terrà il 12 settembre alle ore 9.00 presso la Casa Cardinale Ildefonso Schuster, Salone Pio XII, Via Sant'Antonio 5.
I lavori si svolgeranno presso il Dipartimento di Fisica dell'Università di Milano, Via Celoria 16.

Iscrizioni

Quote di iscrizione al Congresso per i Soci (*)	
Socio Ordinario	€ 75,00
Socio Junior (under 40)	€ 60,00
Socio Invitato (neolaureato in Fisica)	€ 60,00

(*) Per i Relatori su Invito e i Chair si applica la stessa quota dei Soci Ordinari

Quote di iscrizione al Congresso per i non Soci	
Partecipante Ordinario	€ 145,00
Partecipante Junior (under 40)	€ 120,00

Le iscrizioni devono essere effettuate online entro le ore 12:00 dell'8 settembre 2022.
La quota dà diritto alla cartella congressuale contenente il volume degli Atti del Congresso con i riassunti delle relazioni e delle comunicazioni. Per partecipare ai lavori congressuali è necessario essere muniti di targhetta nominativa che attesti la registrazione al Congresso.

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 rispettivamente circa 20/25 minuti e 10/12 minuti, 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 segnalerà al Consiglio di Presidenza della SIF una o più comunicazioni per ogni Sezione giudicate migliori sulla base del contenuto e dell'esposizione. La premiazione dei relatori avrà luogo durante la cerimonia inaugurale del Congresso Nazionale SIF del 2023. Inoltre circa il 25-30% delle comunicazioni presentate saranno selezionate per la pubblicazione di un breve articolo (4 pagine) nonostante non facciano parte della rosa dei vincitori.

Elezioni delle cariche sociali della SIF per il triennio 2023-2025

L'Assemblea Elettorale è convocata mercoledì 14 settembre 2022 alle ore 9.00. Il Seggio Elettorale verrà aperto alle ore 10.00 di mercoledì 14 settembre e verrà chiuso alle ore 10.00 di venerdì 16 settembre 2022. L'assemblea di ratifica e proclamazione degli eletti è prevista alle ore 19.00 di venerdì 16 settembre.

Si ringraziano i seguenti Enti e aziende che, con il loro Patrocinio e il loro contributo finanziario e operativo, hanno reso possibile l'organizzazione del Congresso

ADALTA
A.D.S. International
CAEN
EPJ
GSSI - Gran Sasso Science Institute
Hamamatsu Italia
INFN - Istituto Nazionale di Fisica Nucleare
INGV - Istituto Nazionale di Geofisica e Vulcanologia
INRIM - Istituto Nazionale di Ricerca Metrologica
Mori Meccanica
Polaris Engineering
Prodotti Gianni
SAES GETTERS
Springer
STMicroelectronics

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Sezione 6 – **Fisica applicata, acceleratori e beni culturali**
Presidenti: Danilo Rifuggiato (INFN-LNS, Catania)
Roberto Senesi (Università di Roma Tor Vergata)

Lunedì 12 settembre, ore 14:00 .... ≫ 35
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Sezione 7 – **Didattica e storia della fisica**
Presidenti: Daniela Di Martino (Università di Milano Bicocca)
Ileana Rabuffo (Università di Salerno)

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Casa Cardinale Ildefonso Schuster - Salone Pio XII **ore 9:00 – 10:40**

CERIMONIA DI INAUGURAZIONE
INTRODUZIONE DEL PRESIDENTE
Prof. Angela Bracco

PREMIAZIONI:

Premio "Enrico Fermi"
Premio "Giuseppe Occhialini" SIF-IOP (Institute of Physics)
Premio "Friedel-Volterra" SIF-SFP (Société Française de Physique)
Premio per la Storia della Fisica
Premio per la Comunicazione Scientifica
Premio "Laura Bassi" per le Donne nella Fisica
Premio SIF-SoNS "Neutrons Matter"
Premio "Giuliano Preparata"
Premio "Sergio Panizza e Gabriele Galimberti"
Borsa "Ettore Pancini"
Premi per giovani laureati in Fisica dopo il maggio 2015 e dopo il maggio 2019
Premi per le Migliori Comunicazioni al Congresso Nazionale 2021
Soci Benemeriti della SIF

Casa Cardinale Ildefonso Schuster - Salone Pio XII **ore 10:45 – 11:40**

SEZIONE I
Fisica nucleare e subnucleare
Presiede: COBAL M. (Università di Udine)

Relazione Generale

Fisica del flavour a LHCb.

PASSALEVA G.
INFN, Sezione di Firenze

La ricca dinamica delle interazioni tra i quark e l'esistenza stessa di più famiglie ("flavours") di particelle elementari costituiscono ad oggi uno dei filoni di indagine più attivi e interessanti nella fisica delle particelle. In questo campo, LHCb è ad oggi l'esperimento più importante e produttivo al mondo. LHCb, installato a LHC, ha come missione principale la ricerca di nuova fisica tramite misure di precisione di violazione di CP e lo studio di decadimenti rari di adroni contenenti quark pesanti. LHCb è anche leader mondiale nello studio della spettroscopia adronica. LHCb ha prodotto risultati storici come la scoperta della violazione di CP nel charm, la prima evidenza del decadimento ultra-raro $B^0 \to \mu^+\mu^-$, la scoperta dei penta-quarks e molti altri. Inoltre, misure di precisione nell'ambito della fisica del charm e della violazione di CP nel settore dei mesoni B, come la misura dell'angolo γ della matrice CKM, hanno costituito test estremamente severi per il Modello Standard. Dopo i Run 1 e 2 di LHC, LHCb è stato largamente aggiornato per acquisire un volume di dati circa 5 volte più grande, che nei prossimi anni consentirà di raggiungere precisioni sempre maggiori e di esplorare nuovi aspetti della fisica del flavour.

Casa Cardinale Ildefonso Schuster - Salone Pio XII ore 11:45 – 12:40

Sezione VI

Fisica applicata, acceleratori e beni culturali

Presiedono: Rifuggiato D. (INFN-LNS, Catania)
Senesi R. (Università di Roma Tor Vergata)

Relazione Generale

Synchrotron radiation X-ray methods and non-invasive spectroscopies to preserve the beauty of colors in paintings.

Monico L.
Istituto di Scienze e Tecnologie Chimiche "Giulio Natta", SCITEC-CNR, Perugia, Italy e AXIS, NANOlab Centre of Excellence, Department of Physics, University of Antwerp, Belgium

Within heritage conservation a grand challenge is the prevention of color change in paintings due to chemical alteration of pigments. Darkening or fading, often occurring along with loss of paint stability, affect numerous artworks in museums, with serious risks for their understanding, preservation and management. In this context, the use of synchrotron radiation (SR)-based X-ray methods has seen a considerable increase over the last two decades due to their capabilities to provide spatially resolved elemental speciation and structural information at the (sub)micrometer scale length. Notably, XRD, XRF and XAS investigations have been exploited to prove that redox reactions are responsible for the chromatic alteration of several pigments and to identify the nature of related degradation compounds. Moreover, macro-scale non-invasive measurements (from the IR to the X-ray range) by portable devices, performed *in situ* directly on paintings, have also given the possibility to visualize and map areas where paint components at major risk of degradation are present or alterations are currently in development. This paper reviews the most recent application of non-destructive/non-invasive X-ray methods (employing SR and traditional sources) combined with UV-Vis and vibrational spectroscopies to study the alteration processes of pigments, with a focus on the darkening of chrome yellows used by Vincent van Gogh and the fading of cadmium yellows and cadmium reds employed by Edvard Munch and Jackson Pollock. The contribution that the described experimental findings can make to the virtual reconstruction of original colors and the prediction of their change overtime will be also discussed.

Sponsored by EPJ

Aula B - Maria Goeppert-Mayer **ore 14:00 – 19:00**

Sezione I

Fisica nucleare e subnucleare

Presiedono: Azzi P. (INFN, Sezione di Padova)
Carminati L. (Università di Milano)

LHC physics results

Relazioni su invito

▲ High-precision measurement of the *W*-boson mass with the CDF II detector.

Chiarelli G.
INFN, Sezione di Pisa

The mass of the W-boson —M_W— is one of the fundamental parameters in the standard model of elementary particles and basic interactions. Following the observation, ten years ago, of the Higgs boson, a measurement of M_W provides a stringent test of the model. We measured M_W using the CDFII detector, with a data set corresponding to $8.8\,\mathrm{fb}^{-1}$ of integrated luminosity of proton-antiproton collisions at 1.96 TeV centre-of-mass energy at the Fermilab Tevaron collider. A sample of approximately four million W-boson candidates is used to obtain $M_W = 80433.5 \pm 6.4(\mathrm{stat}) \pm 6.9(\mathrm{syst}) = 80433.5 \pm 9.4\,\mathrm{MeV}/c^2$, whose precision currently exceeds that of all previous measurements combined. This measurement is in significant tension with the standard model expectation.

▲ 10 years of the Higgs boson at the LHC.

Di Nardo R. (1), Di Marco E. (2)
(1) *Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre e INFN, Sezione di Roma Tre, Italia*
(2) *INFN, Sezione di Roma, Italia*

In July 2012, the ATLAS and CMS Collaborations at the CERN Large Hadron Collider announced the discovery of a boson with a mass of around 125 GeV, using its decays to vector bosons, with rates roughly consistent with the predictions of the Standard Model of particle physics. Ten years later, and with the 30 times larger data set, the two collaborations made extensive studies of the properties of the Higgs boson. Both experiments have observed it in fermionic and bosonic decay channels, determined its mass, established its spin-parity quantum numbers, and measured its production cross-sections in various modes. These measurements are compatible with the predictions of the Standard Model. In this contribution, we report the most up-to-date results on the properties of the Higgs boson by ATLAS and CMS based on data from proton-proton collisions at a center-of-mass energy of 13 TeV.

▲ Fisica del top e misure di Modello Standard con gli esperimenti ATLAS e CMS a LHC.

Pinamonti M. (1), Tosi S. (2)(3)
(1) *INFN, Sezione di Trieste, Gruppo Collegato di Udine*
(2) *Dipartimento di Fisica, Università di Genova*
(3) *INFN, Sezione di Genova*

Gli esperimenti all'acceleratore LHC del CERN nel corso degli anni hanno contribuito a verificare con grande precisione le previsioni del Modello Standard della fisica delle particelle.

All'inizio del Run 3, una nuova mole di risultati verrà riportata a un'energia mai raggiunta in precedenza. La presentazione illustrerà una selezione dei risultati più recenti riportati dalle collaborazioni ATLAS e CMS nei settori della fisica del Modello Standard ed in particolare del quark top.

▲ **L'upgrade di Fase2 di ATLAS: Il rivelatore ITk.**

Lapertosa A.

INFN, Sezione di Genova e Università di Genova

L'attuale tracciatore dell'esperimento ATLAS sarà sostituito da un nuovo rivelatore interamente al silicio per far fronte all'aumento di luminosità istantanea a HL-LHC (fino a 7.5 volte superiore a LHC). L'Inner Tracker (ITk) consisterà in un rivelatore a pixel interno e un rilevatore a strip esterno, in particolare 5 layer di pixel e 4 double layer di strip nella parte centrale (barrel) e una serie di ring nelle parti laterali (endcap) con estensione fino a $|\mu| = 4$. Le performance attese di tracking, ricostruzione di vertici e identificazione di oggetti sono simili o migliori dell'attuale sistema di tracciamento in un ambiente molto più complesso (fino a 200 collisioni per bunch crossing). Il layout è stato ottimizzato in termini di spessore, occupanza, bandwidth e resistenza alla radiazione, la pre-produzione dei componenti è iniziata. Il rivelatore sarà operativo per più di 10 anni, nei quali ATLAS raccoglierà fino a $4000\,\mathrm{fb}^{-1}$ di dati.

Comunicazioni

● **Study of the quantum interference between singly- and doubly-resonant top quark production in $WbWb$ phase-space with the ATLAS detector.**

Bianco G.

INFN e Università di Bologna

The top quark is the heaviest known elementary particle of the Standard Model. Thanks to its particular properties, it allows to explore unique physics domains, inaccessible otherwise. One of them is the quantum interference between singly (tW) and doubly ($t\bar{t}$) resonant top quark production in proton-proton collisions, which can lead to identical $WbWb$ final states when an additional b-quark is radiated during a singly-resonant production. Studying this process is very important for a better knowledge of the Standard Model, but also to investigate some Beyond the Standard Model processes. In this contribution, the measurement of the particle level differential cross-section of the $WbWb$ production in the dilepton channel is provided, in order to better investigate the interference-sensitive regions of these processes. The measurement is performed using the full dataset collected by the ATLAS detector from proton-proton collisions at the LHC during Run-2. The differential cross-section is measured as a function of an interference-sensitive variable called minimaxmbl.

● **Triple Parton Scattering with the CMS experiment.**

Ascioti M.E.

Dipartimento di Fisica e Geologia, Università di Perugia, Italia e INFN, Sezione di Perugia, Italia

The recent observation of three J/Ψ production from the same event from the CMS Collaboration raised large interest in the Triple Parton Scattering (TPS) component of the pp interaction. In this contribution a description of the measurement will be provided, together with the results interpretation in terms of Single, Double and Triple Parton Scattering. Also, ongoing promising studies on the possibilities of observing TPS in events containing open charm mesons (*i.e.*, $J/\Psi + J/\Psi + D^*$) will be discussed.

Measurements of Z boson production in association with heavy-flavour jets at ATLAS.

BISCEGLIE E.
Università della Calabria

Measurements of W/Z-boson production in association with jets are an important test of perturbative QCD prediction and also provide information about the parton distribution functions of the proton. In this contribution, we present the latest measurements of the production of a Z boson in association with heavy-flavour jets performed using proton-proton collision data collected by the ATLAS experiment at $\sqrt{s} = 13\,\text{TeV}$. This includes inclusive and differential cross-section measurements up to extreme phase spaces characterized by high-transverse-momentum jets. The data are compared to predictions provided by the state-of-the-art Monte Carlo event generators.

$Z \to \tau\tau$ differential cross-section and forward-backward asymmetry in pp collisions at $\sqrt{s} = 13\,\text{TeV}$ with the ATLAS detector.

PADOVANO G., MORODEI F., BAUCE M., CORRADI M., GIAGU S.
INFN, Sezione di Roma e Sapienza Università di Roma

Interest has been raised in recent years in precision measurements involving tau leptons, which allow extensive testing of the Standard Model and measurement of its fundamental parameters. In this contribution the prospects for a measurement of $Z \to \tau\tau$ multi-differential cross-section and of its forward-backward asymmetry, with the ATLAS experiment at LHC, are presented. Details on the analysis strategy are given, including background rejection, trigger acceptances, unfolding of the kinematic distributions, both in fully hadronic and semi-leptonic di-tau final states. Tau lepton identification and reconstruction techniques will also be briefly discussed, with particular focus on hadronic tau decays.

Measurement of the Higgs boson mass in the di-photon decay channel with $140\,\text{fb}^{-1}$ of pp collisions data at $\sqrt{s} = 13\,\text{TeV}$ collected by the ATLAS detector.

NASELLA L.
Dipartimento di Fisica, Università degli Studi di Milano, Italia e INFN, Sezione di Milano

In this communication the latest Higgs boson mass measurement in the di-photon channel with the ATLAS detector is presented; the analysis uses proton-proton collisions data from the Large Hadron Collider at a centre-of-mass energy of 13 TeV for a total integrated luminosity of $140\,\text{fb}^{-1}$. To measure the Higgs boson mass, the di-photon and four leptons decays are the best channels as all of the decay particles can be reconstructed by the ATLAS detector with high precision. The Higgs mass in the $\gamma\gamma$ channel is evaluated from the position of the narrow resonant peak in the di-photon invariant mass distribution over a large, monotonically decreasing, continuum background. Despite the higher branching ratio with respect to the $4l$ decay, the $\gamma\gamma$ channel exhibits larger background and systematic uncertainties from photon calibration procedures: for this reason the new measurement exploits the most updated knowledge of the detector performance and calibrations and uses an event categorisation optimized to reduce the impact of the total uncertainty.

Measurement of the the production of a W boson in association with charm quark at $\sqrt{s} = 13\,\text{TeV}$ with ATLAS detector.

MANCO G.
Dipartimento di Fisica, Università di Pavia, Italia

One of the major challenges for the proton-proton collider physics is to increase the precision of proton parton distribution functions (pdfs). Actually, most of the physics results delivered by LHC experiments are affected by their uncertainties. While the valence quark pdfs are known with relatively good precision, the uncertainty on the strange pdf is considerably larger. In this contribution, I will show an ATLAS analysis that aims to constrain the strange pdf through the study of the associated production of W boson with charm quark (tagged as a jet containing a soft muon).

Using Graph Neural Networks to improve flavour-tagging and its modeling for the measurement of WH and ZH production in the $H \to bb$ and $H \to cc$ decay channel.

Tanasini M.
Università di Genova e INFN, Sezione di Genova

Graph Neural Networks (GNNs) are machine learning algorithms particularly suitable for modeling data with complex topological correlations. In this communication, their application in the measurement of WH and ZH production in the $H \to bb$ and $H \to cc$ decay channel is presented. First, a new GNN algorithm which is being developed in ATLAS to identify jets containing b-hadrons by representing them as graphs of tracks and silicon hits is illustrated. Then, a GNN-based technique for weighting events according to the probability of the jets being b-tagged is presented.

Measurement of inclusive isolated-photon cross-section with the ATLAS detector using the Frixione isolation prescription.

Cella S., Carminati L., Turra R.
Università degli Studi di Milano

The differential cross-section for inclusive isolated-photon production in proton-proton collisions is measured at a center-of-mass energy of 13 TeV with the ATLAS detector, using an integrated luminosity of $36\,\mathrm{fb}^{-1}$. The differential cross-section is presented as a function of the photon transverse momentum in the 20–140 GeV range. The measurement is performed using two criteria for photon isolation: the standard fixed-cone approach and, for the first time, the Frixione isolation prescription, which requires the energy in a cone to vanish when its radius approaches zero. The Frixione isolation is used in theoretical calculations since it allows the rejection of the fragmentation contribution. To apply it experimentally, it is necessary to use a discrete version, based on a finite set of cones, which still provides a good suppression of fragmentation photons and allows a coherent treatment of isolation between theoretical calculations and data analysis. The measurement is compared with the NLO Jetphox calculation and the Monte Carlo predictions from Pythia and Sherpa. The predictions provide a good description of the data within the experimental and theoretical uncertainties.

First measurement of the top-quark pair production cross-section in pp collisions at centre-of-mass energy of 13.6 TeV with the ATLAS experiment at the LHC.

Pintucci L.
Università di Trieste e INFN, Gruppo Collegato di Udine

The inclusive top quark pair ($t\bar{t}$) production cross-section is measured in proton-proton collisions at a centre-of-mass energy of $\sqrt{s} = 13.6$ TeV, using the first data collected in 2022 during Run 3 by the ATLAS experiment at the LHC. The top-antitop cross-section is measured in both the dilepton and single-lepton final states of the $t\bar{t}$ system.

A sensitivity study of triboson production to dimension-6 EFT operators at the LHC.

Tarricone C.
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In the electroweak sector of the Standard Model (SM), triple and quartic gauge couplings of vector bosons emerge due to the non-Abelian nature of the corresponding symmetry group. These couplings play an important role in vector boson scattering and multi-boson production processes. Therefore, the accurate measurement of gauge couplings in triboson production in proton-proton collisions represents an excellent probe of the gauge structure of the electroweak sector of the SM. In addition, potential deviations from SM predictions may provide a hint of the existence of higher-dimension correction terms arising in the context of Effective Field Theories (EFTs). The EFTs constitute a theoretical framework that generalizes the dimension-4 SM Lagrangian with the inclusion of higher-dimension operators, most commonly dimension-6 and dimension-8 operators. In this contribution, I present a parton-level study exploring where new physics phenomena beyond the SM could occur in triboson production processes. In particular, there is presented the evaluation of the sensitivity of triboson production processes to anomalous kinematic effects deriving from the presence of dimension-6 operators.

Measurements of Higgs boson production cross-sections and couplings in the WW decay channel.

Camaiani B.

Dipartimento di Fisica e Astronomia, Università di Firenze, Italia e INFN, Sezione di Firenze, Italia

The most recent measurements of Higgs boson production cross-sections and couplings in the WW decay channel will be presented. The measurements make use of the Run 2 LHC data collected by the CMS detector in proton-proton collisions at a center-of-mass energy of 13 TeV. The presented results cover the ggH, VBF, WH and ZH Higgs boson production mechanisms and span a large variety of final states with 2, 3 and 4 charged leptons. The measurement of Higgs boson production cross-sections in the Simplified Template Cross-Sections (STXS) framework will also be presented. The higher integrated luminosity and the newly developed analysis techniques allowed an unprecedented precision of the cross-sections and couplings measurements, with a significant improvement with respect to the latest published results.

Observation of vector boson scattering W^+W^- pair production in proton-proton collisions at a center-of-mass energy of 13 TeV with the CMS detector.

Bulla A.

Dipartimento di Fisica, Università di Milano-Bicocca, Italia e INFN, Sezione di Milano-Bicocca, Italia

The observation of vector boson scattering (VBS) W^+W^- pair production, with the two W bosons decaying leptonically, has been reported by the CMS Collaboration at the CERN LHC. The data sample analyzed corresponds to an integrated luminosity of 138 fb^{-1} of proton-proton collisions at $\sqrt{s} = 13$ TeV collected by the CMS detector. Events are selected by requiring exactly two opposite-sign leptons (electrons or muons) and two jets with large pseudorapidity separation and high dijet invariant mass. Machine learning techniques are employed to deal with the irreducible background from the QCD-induced production of W bosons and the large background from the production of top quarks pair. The VBS W^+W^- signal is observed with a significance of 5.6 standard deviations (5.2 expected) with respect to the background-only hypothesis. The measured fiducial cross-section is 10.2 ± 2.0 fb, in agreement with the standard model prediction of 9.1 ± 0.6 fb.

Higgs boson anomalous couplings using the di-photon channel with CMS experiment.

De Riggi F.
Dipartimento di Fisica, Università di Roma 1, Italia e INFN, Sezione di Roma 1, Italia

Studies of *CP* violation and anomalous couplings of the Higgs boson to vector bosons are presented. The data were acquired by the CMS experiment at the LHC and correspond to an integrated luminosity of $138\,\mathrm{fb}^{-1}$ at a proton-proton collision energy of 13 TeV. The kinematic effects in the Higgs boson's two-photons decay and its production in association with two jets (Vector-Boson-Fusion, VBF) are analyzed, using a full detector simulation and matrix element techniques or, alternatively, multivariate algorithms to identify the production mechanisms and to increase sensitivity to the Higgs boson tensor structure of the interactions. A simultaneous measurement is performed for multiple Higgs boson couplings to electroweak vector bosons (HVV).

Prospects for heavy Higgs boson searches in the top-quark pair decay channel with the ATLAS experiment at the LHC and at future high-energy colliders.

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The existence of additional scalar and pseudoscalar Higgs-like bosons is predicted by several new physics models, particularly the so-called two Higgs doublet models (2HDM). In this framework, given the recent indications by the LHC experiments, one of the most appealing channels to search for the neutral heavy Higgs bosons is the top-quark pair decay channel. This study investigates the possibility of seeing such a heavy Higgs scalar/pseudoscalar boson through this decay channel at the ATLAS experiment by thoroughly analysing the Run 2 and Run 3 data and at the High-Luminosity LHC and future high-energy colliders. Monte Carlo simulations with different boson masses have been employed, varying the couplings with leptons and quarks, and analysed considering the signal-background interference effects.

Discovery prospects of top squark at the ATLAS Experiment in HL-LHC.

De Santis F.
INFN, Sezione di Lecce, Lecce, Italy e Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy

The direct production of top squark pairs is one of the processes predicted by supersymmetry at LHC. One of the channels to search for this process targets the top squark decay in final states with two opposite-charge leptons (electrons or muons), jets and missing transverse momentum, investigated in previous searches using Run2 data. This contribution is about the discovery prospects of top squark in this channel with the ATLAS experiment in the High-Luminosity accelerator phase, when LHC is expected to reach a center-of-mass energy of 14 TeV and to collect an integrated luminosity up to $3000\,\mathrm{fb}^{-1}$.

Search for BSM physics in final state with a top quark and invisible particles at CMS experiment.

Cagnotta A.
Dipartimento di Fisica, Università di Napoli, Italia e INFN, Sezione di Napoli, Italia

A signature-based study involving top quarks produced in association with invisible particles using proton-proton collisions at $\sqrt{s} = 13\,\mathrm{TeV}$ with CMS data is presented. The final state involves a single top quark decaying hadronically, and either Dark Matter (DM) particles or neutrinos, that can be indirectly detected through the missing transverse momentum of the event. Of the above two scenarios, the first one is based on a model that predicts a privileged interaction between top quarks and DM particles through a new boson ϕ, the second one on a model including a Vector-Like Quark (VLQ) T that decays to a top quark plus a Z boson. The contribution focuses on the reconstruction of top quarks through hadronic jets. The reconstruction can be performed through three different topologies, making use of jets reconstructed by anti-k_t algorithms with different radii. Machine Learning algorithms have been trained on the three different kinds of reconstructed top quarks to improve signal efficiency and background rejection. Preliminary results will be presented for different mass hypotheses of ϕ boson, in the first scenario, and of VLQ T, in the second one.

Search for the W' boson decaying to a top and a bottom quark with the CMS detector at the LHC by employing machine learning techniques.

Giordano C.
Dipartimento di Fisica, Università di Napoli, Italia e INFN, Sezione di Napoli, Italia

An analysis strategy for the search of a W' boson decaying to a top quark and a bottom quark using Machine Learning (ML) techniques is presented. The analysis is performed on Monte Carlo simulated samples of W' signal events and its main background processes, produced in proton-proton collisions at a centre-of-mass energy of 13 TeV at the Large Hadron Collider and reconstructed with the CMS detector. Leptonic decays of the top quark are considered and, in order to improve the top quark reconstruction efficiency, a ML algorithm is employed to define several categories for the top candidate according to the separation of the lepton and b-jet from the top quark decay. Projections of expected upper limits on the W' production cross-section are given for the full Run 2 statistics of $137\,\text{fb}^{-1}$. The obtained results are promising and will be the centre of future developments for the analysis to be implemented in Run 3.

A search for resonances decaying into a Higgs boson and a new particle X in the $XH \to qqbb$ final state with the ATLAS detector.

D'Avanzo A. (1), Auricchio S. (1), Cirotto F. (1), Conventi F. A. (2), Rossi E. (1)
(1) *Università Federico II di Napoli e INFN, Sezione di Napoli*
(2) *Università Pathenope di Napoli e INFN, Sezione di Napoli*

A search for resonances decaying into a Higgs boson (H) and a new particle (X) is reported, utilizing proton-proton collision data with the ATLAS detector at the CERN Large Hadron Collider. The particle X is assumed to decay to a pair of light quarks, and the fully hadronic final state is analyzed. A two-dimensional phase space of XH mass *vs.* X mass is scanned for evidence of a signal. Upper limits are set on the production cross-section of the resonance as a function of XH and X masses.

Aula D - Marianna Ciccone **ore 14:00 – 19:00**

Sezione II
Fisica della materia
Presiedono: Celebrano M. (Politenico di Milano)
Marino A. (ISASI-CNR, Napoli)

Plasmonics and nanophotonics

Relazioni su invito

▲ **Mid-infrared integrated photonics with Ge quantum wells.**
Frigerio J. (1), Barzaghi A. (1), Falcone V. (1), Calcaterra S. (1), Giani R. (1), Ballabio A. (1), Isella G. (1), Chrastina D. (1), Ortolani M. (2), Virgilio M. (3)
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In recent years, mid-infrared (MIR) integrated photonics has raised an increasing interest due to the envisioned applications in molecular sensing, environmental monitoring and security. Nowadays, MIR photonics based on the silicon-on-insulator platform, working up to $3.2\,\mu$m has already reached a high technology readiness level. Nevertheless, extending the operational wavelength toward the long-wave-infrared (LWIR) is still challenging and key functionalities such as photodetection, high-speed modulation and wavelength conversion are still not available. In this framework, Ge/SiGe quantum wells could be exploited to fill the gap. Intersubband optical transitions in the valence band of such heterostructures can be used for light detection, for high-speed modulation through the quantum confined Stark effect (QCSE), and for wavelength conversion through second-harmonic generation. Ge/SiGe QWs can be easily grown on top of SiGe buffers, making them fully compatible with the existing SiGe-on-Si material platform. In this contribution, we show an experimental demonstration of second-harmonic generation and a preliminary study for the realization of integrated modulators and photodetectors.

▲ **Protein conformational changes probed by infrared nano-spectroscopy.**
Giliberti V.
Center for Life Nano- and Neuro-Science, Istituto Italiano di Tecnologia, Rome, Italy
Atomic force microscopy-based infrared (IR) methods enable IR nano-spectroscopy and nano-imaging with a resolution far below the conventional optical diffraction limit. These approaches have emerged as a frontier for the study of complex heterogeneous materials and nanometer-sized ones, finding applications in a variety of fields including the study of 2D materials, plasmonic structures and biomolecules. Here we apply AFM-assisted IR nano-spectroscopy based on the photothermal expansion effect (AFM-IR) to the study of protein conformational changes, *i.e.*, the modifications of the native 3D protein structure that are strictly related to the role of proteins in living cells. By exploiting the field enhancement in the plasmonic nanogap that forms between a gold-coated AFM tip and an ultraflat gold surface, we were able to probe the slight functional conformational changes with an unprecedented sensitivity of less than 100 molecules. After a brief introduction on the physics underlying the AFM-IR technique, I will present our recent results obtained on i) cell membrane flakes embedding optogenetic proteins, and ii) toxic aggregates of a protein relevant for neurological diseases.

▲ **Quantum technology in lithium niobate waveguides.**

Lobino M.
Univerità di Trento

Lithium niobate is one of the most used materials for the fabrication of integrated optical devices. This is because of its large nonlinearity and electro-optic effect which enables the manufacturing of fast amplitude and phase modulators. Recently this material has been used as a platform for quantum photonics applications including the generation and manipulation of nonclassical states of light on chip. The monolithic nature of these devices means that the correct phase can be stably realized in what would otherwise be an unstable interferometer, greatly simplifying the task of implementing sophisticated photonic quantum circuits. Using this material platform, experimental results on the generation, manipulation, and detection of squeezed vacuum state on chip will be reported, which represents an essential resource for continuous variable quantum computation. Finally, frequency conversion of single photons, and integration of multiple components on chip will be discussed.

Comunicazioni

● **Dielectric properties and exciton tunability of two-dimensional WS_2 in van der Waals bilayers.**

Peci E. ([1]), Magnozzi M. ([1])([2]), Ramò L. ([1]), Ferrera M. ([1]), Convertino D. ([3])([4]), Pace S. ([3])([4]), Orlandini G. ([3]), Sharma A. ([5]), Milekhin I. ([5])([6]), Salvan G. ([5]), Coletti C. ([3])([4]), Zahn D.R.T. ([5]), Bisio F. ([7]), Canepa M. ([1])
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The opto-electronic properties of two-dimensional tungsten disulfide can be manipulated via its inclusion in tailored van der Waals (vdW) multilayer heterostacks. We present a spectroscopic ellipsometry (SE) investigation of several vdW heterostacks featuring WS_2 in monolayer configuration, $2H$ and $3R$ bilayer stacking, and WS_2/MoS_2 vertical heterostructure. Exploiting a parametric optical model, a Kramers-Kronig consistent dielectric function is extracted for each system, which allows to precisely identify the A, B and C excitons, to highlight their energy shifts (tens of meV) as a function of the different stacking configuration and to rationalize them based on different dielectric environments and interlayer interaction. The stacking-dependent energy shifts of the excitonic peaks observed through SE are also confirmed by transmittance spectroscopy. An exciton tunability up to 40 meV is thus demonstrated.

● **Superchiral surface waves for surface enhanced chiroptical spectroscopy.**

Pellegrini G. ([1]), Mogni E. ([2]), Jil-Rostra J. ([3]), Yubero F. ([3]), Simone G. ([4]), Fossati S. ([5]), Dostálek J. ([5])([6]), Martínez Vázquez R. ([7]), Osellame R. ([7]), Celebrano M. ([2]), Finazzi M. ([2]), Biagioni P. ([2])
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Chirality is ubiquitous in nature and accordingly in the modern pharmaceutical industry, where the vast majority of newly developed drugs is chiral. Chiroptical techniques employ polarized light for the molecular structure characterization and are flexible, low-cost, and time-efficient. Yet, their limited sensitivity prevents their integration for on-chip chiral analysis. We introduce the concept of superchiral surface waves at the surface of dielectric multilayers, and design a platform capable of a two orders of magnitude signal enhancement in the analysis of chiral molecules compared to standard illumination, with broadband spectral operation and arbitrarily large active area, based on the superposition of TE and TM Bloch surface waves. We experimentally fabricate and characterize such a platform. We finally demonstrate how genetically evolved multilayers can support superchiral surface waves from the ultraviolet to the near infrared regime. These findings pave the way towards the integration of chiroptical techniques with microfluidic networks, enriching the widespread lab-on-chip technology with new functionalities not available so far.

All-dielectric phonon-polariton nonlinear nanoantennas for terahertz-photonics.

Arregui Leon U. ([1]), Rocco D. ([2])([3]), Carletti L. ([2])([3]), Peccianti M. ([4]), Maci S. ([5]), Della Valle G. ([1])([6]), De Angelis C. ([2])([3])
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The Terahertz (THz) spectrum offers the potential of a plethora of applications, ranging from imaging to wireless communications and THz-photonics. The latter framework would greatly benefit from the development of optical-to-THz wavelength converters. Exploiting Difference Frequency Generation in a nonlinear all-dielectric nanoantenna, we propose a compact solution to this problem. By means of a near-infrared pump beam (at ω_1), the information signal in the optical domain (at ω_2) is converted to the THz band (at $\omega_3 = \omega_2 - \omega_1$). We numerically reveal an efficiency of up to $2 \cdot 10^{-7}\,\mathrm{W}^{-1}$ from a single AlGaAs nanopillar, 8 orders of magnitude higher than that obtained from plasmonic split-ring nanoresonators; such a high value can be ascribed to the large bulk $\chi^{(2)}$ of AlGaAs as well as to the presence of phononic resonances at the THz region. The approach is particularly suitable for launching surface waves when integrated in a THz metasurface platform, and paves the way to further engineer the nonlinear emission pattern.

Nonlinear optics with resonant nanostructures.

Zilli A. ([1]), Carletti L. ([2]), Di Francescantonio A. ([1]), Rocco D. ([2]), Locatelli A. ([2]), Wu X. ([3]), Fagiani L. ([4]), Moia F. ([5]), Vinel V. ([6]), Borne A. ([6]), Feichtner T. ([4]), Biagioni P. ([1]), Duò L. ([1]), Neshev D.N. ([7]), Hecht B. ([3]), Bollani M. ([4]), Toma A. ([5]), Leo G. ([6]), Finazzi M. ([1]), De Angelis C. ([2]), Celebrano M. ([1])
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The ability to harness nonlinear optical processes at the nanoscale would enable the integration of functionalities such as frequency conversion and generation of entangled photon pairs in compact devices. However, the intrinsically perturbative character of these processes often brings about very low efficiencies when they occur in nanometric volumes. To make up for this drawback, one can tailor and exploit the electromagnetic resonances of nanostructures to concentrate light well below the diffraction limit, thereby enhancing light-matter interaction. In our contribution, we will survey various strategies successfully deployed over the last few years by our research group with our international collaborators to boost nonlinear interactions in nanostructured systems, such as single nanoparticles and planar nanoparticle arrays called metasurfaces. We investigated several nonlinear optical processes, including harmonic generation and coherently controlled frequency mixing, with a rich phenomenology ruled by the resonant behavior. We will highlight the opportunities offered by different material platforms (dielectric *vs.* plasmonic) and the key role played by the breaking of inversion symmetry.

Breaking of the electronic-optical dynamics correspondence in ultrafast plasmonics: a universal mechanism beyond the perturbative regime.

Crotti G. ([1])([2]), Schirato A. ([1])([2]), Gonçalves Silva M. ([3]), Teles-Ferriera D. C. ([3]), Manzoni C. ([4]), Proietti Zaccaria R. ([2])([5]), Laporta P. ([1])([4]), De Paula A. M. ([3]), Cerullo G. ([1])([4]), Della Valle G. ([1])([4])([6])
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Understanding the transient optical response of plasmonic nanostructures is of crucial relevance for a variety of fields and applications, from light harvesting to nonlinear nanophotonics. Accurate predictions of the dynamics of ultrafast processes taking place at the nanoscale following excitation with electromagnetic radiation are critical to this aim. So far, a strict correspondence has been assumed between the temporal evolution of the optical signal (retrieved via interaction with a low-intensity probe pulse, in the framework of transient absorption spectroscopy) and the dynamics of the population of photoexcited hot-electrons, described in terms of their temperature. We report on a study testing this hypothesis by investigating the transient optical response of Au nanoparticles in a non-perturbative excitation regime, both theoretically and experimentally. Our results indicate that the correspondence does not hold under such a regime; moreover, the main mechanism presiding over its breaking is universal in plasmonics, being related to the nonlinear smearing of the Fermi-Dirac distribution, describing the occupation probability of the hot electrons in any metallic lattice.

Generalized plasma waves in layered systems: general properties and relevance for THz spectroscopy.

Gabriele F., Castellani C., Benfatto L., Udina M.

Department of Physics and ISC-CNR, Sapienza University of Rome, Rome, Italy

In a layered and strongly anisotropic system the hybrid modes provided by the propagation of electromagnetic waves in the matter identify two well separate energy scales connected to the large in-plane plasma frequency and to the soft out-of-plane Josephson plasmon. Due to such a large spectrum of axcitations, there is a wide interest in the detection and manipulation of plasmons, by means of different experimental protocls, in layered sustems. Indeed, the anisotropy of the superfluid response leads to two intertwined hybrid light-matter modes with mixed longitudinal and transverse character, also known as generalized plasmons. In this talk, I will discuss the relevance of such modes for ultrafast phenomena, such as pump-probe oscillations and third-harmonic generation, which have been recently observed in layered cuprates by means of non-linear terahertz sectroscopy. I will first ilustrate the case of in-plane and out-oof plane light polarization, for which our predictions of plasma waves are in excellent agreement with the experiments. Lastly, I will discuss the case of arbitrary light polaarization, for which the inclusion of longiudinal-transverse mixing effect is crucial.

The impact of bacteria exposure on the plasmonic response of silver nanostructured surfaces.

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(1) *Politecnico di Milano, Dipartimento di Fisica*

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(3) *Consiglio Nazionale delle Ricerche, Istituto per la fotonica e le nanotecnologie*

Silver, in the form of nanostructures, is widely employed as an antimicrobial agent. Despite the large body of work addressing the effects of silver on the antibacterial mechanism and on the (bio)physical chemistry pathways that drive bacterial eradication, little effort has been devoted to the investigation of nanostructured silver plasmon response upon interaction with bacteria. We investigate the bacteria-induced changes of the plasmonic response of silver nanoplates after exposure to the bacterial model *Escherichia coli* (*E. coli*). Ultrafast pump-probe measurements indicate that the dramatic changes on particle size/shape and crystallinity, likely stemming from a bacteria-induced oxidative dissolution process, translate into a clear modification of the plasmonic response. Finally, we exploit such an effect to build up photonic crystals embedding silver nanostructures, which have the potential to reveal colorimetrically the presence of bacteria. This study opens innovative avenues in the biophysics of bio-responsive materials.

Optical characterization of holographic acoustic tweezers.

Marrara S. (1)(2), Bronte Ciriza D. (1)(2), Magazzù A. (2), Caruso R. (2), Lupò G. (2), Saija R. (1)(2), Foti A. (2), Gucciardi P.G. (2), Mandanici A. (1)(2), Maragò O.M. (2), Donato M.G. (2)

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Acoustic tweezers make use of sound waves to trap solid or liquid samples. Ultrasonic transducers can be used to achieve acoustic tweezers in air, giving a trapping point at a target position. This method permits to trap and manipulate single or multiple particles for studying them even *in situ*, without altering their properties. In particular, our experimental setup consists of an 8×8 flat array of ultrasonic emitters. Trapped particles are styrofoam beads with mm radius. To study their dynamics in the acoustic trap, we use two different optical detection methods. In the first method, we illuminate the trapped particle with a laser beam, tracking down the fluctuations of its shadow on a quadrant photodiode (QPD).

With the second procedure, we track the image of our trapped particle with a CCD camera and a telescope, then we extract data on the particle position using a video tracking software. With both methods we detect the particle displacement in x, y, and z directions that is the particle dynamics in the trap. We analyze the experimental data to obtain the force constants of the acoustic trap referring to a harmonic-oscillator model.

Ultra-sensitive measurement of mechanical displacements with photonic gears.

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Dipartimento di Fisica, Università degli Studi di Napoli "Federico II", Italia

Accurately measuring mechanical displacements is essential for a vast portion of current technologies. Several optical techniques accomplish this task, allowing for non-contact sensing even below the diffraction limit. Structured light can be a resource for enhanced sensing purposes as for instance in the "photonic gears". This technique enables a boost of the sensitivity in roll angle measurements thanks to a bidirectional mapping between the polarization state and a properly tailored vectorial mode of a paraxial light beam. Similarly, ultra-sensitive measurements of a transverse displacement can be performed by mapping it into the polarization rotation of a laser beam. By exploiting this technique, dubbed "linear photonic gears", we measured, in ordinary ambient conditions, the relative shift between two objects with a resolution of 400 pm. We argue that a resolution of 50 pm should be achievable with existing state-of-the-art technologies. Our single-optical-path scheme is intrinsically stable and it could be implemented as a compact sensor, using cost effective integrated optics.

Microsphere in hollow core photonic crystal fiber as temperature probe for hydrogen combustors.

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Hydrogen combustors could provide a carbon neutral way to power our homes and reduce our environmental impact. However, when the combustors operate at high efficiency, the burner flame could arrive in regions not designed to handle high temperature, leading to expensive damage (flashback). The temperature inside the combustor must be measured to provide an early warning for this phenomenon. In this contribution, a microsphere-hollow core photonic crystal fiber temperature measurement system is explored, both theoretically and experimentally. The device is self-calibrating, and features a high spatial resolution, as the position of the microsphere probe can be controlled with micrometric precision through manipulation of the fiber-coupled laser beams. The temperature is obtained by probing the local gas viscosity through analysis of the motion of the microsphere, which is interpreted by monitoring the transmitted light. The system has pressure control provided by a vacuum pump, which allows tuneable temperature sensitivity.

Tunable electrical, optical and plasmonic properties of multifunctional metastructures based on alternative plasmonic materials.

Mancarella C. [1], Moscardi L. [2], Lamperti A. [3], Terraneo G. [4][5], Sygletou M. [6], Bricchi B.R. [1], Stasi L. [1], Tovaglieri L. [1], Bisio F. [7], Scotognella F. [2][5], Li Bassi A. [1][5]
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At present, the established potentialities of plasmonic effects in boosting light-matter interactions are at the basis for next-generation metamaterials merging multifunctionality, tunability of properties and broader spectral responses. The archetypal plasmonic materials, *i.e.*, noble metals, show limited modulation outside the visible spectrum. This justifies the spreading interest for alternatives (transparent conductive oxides, transition metal nitrides or oxynitrides) and periodically arranged multi-phase nanostructures, where the high level of control in carrier concentration is achievable directly at synthesis or with an "active" approach (*e.g.*, external bias). In this framework, we present a variety of original multilayers and nanocomposites fabricated in one-step, for instance 1-D photonic crystals or hyperbolic metamaterials, to fulfill tailorable plasmonic/photonic behaviours from VIS to IR, while controlling nanoscale morphology, structure, and electrical performances. The list of practical applications includes, but is not limited to, plasmon-functionalised transparent electrodes, biosensors, optoelectronic elements for color manipulation and thermophotovoltaic emitters.

Hetero-structured silicon, 2D materials and nanowire-based devices for quantum photonics.

Cornia S. ([1])([2])([3]), Cammarata S. ([4])([5]), Kaplan E. ([1])([6]), Demontis V. ([1])([7]), Vitali V. ([8]), Fontana A. ([1]), Lacava C. ([1])([6]), Rossella F. ([1])([2]), Salamon A. ([9]), Bellani V. ([1])([3])
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([2]) *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena and Reggio Emilia, Italy*
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([9]) *Istituto Nazionale di Fisica Nucleare, Sezione di Roma Tor Vergata, Italy*

We are developing integrated silicon photonic devices heterostructures with two-dimensional (2D) topological materials and semiconductor nanowires (NWs), for integrated quantum optics with single/few photons manipulation. Two- and one-dimensional materials are under development for topological photonics; to this respect, we fabricated and studied heterostructures with silicon and graphene, hexagonal boron nitride and III-V semiconductor. 2D materials are prepared by means of micro-mechanical cleavage and chemical vapor deposition, while high-quality NWs can be grown resorting to epitaxial techniques. Our platform envisions 2D materials and NWs placed on the silicon structures by micro manipulation transfer and drop casting techniques. The materials and devices are studied using several techniques including scanning electron microscopy, photoluminescence, elastic/inelastic light scattering and electrical transport. We use analytical and numerical methods in order to design the devices and predict and analyse the experimental results. Our combined experimental and theoretical goal is the development of new paradigms of single/few photon sources and the generation and study of novel quantum states.

Ultrafast hot electron relaxation processes in plasmonic titanium nitride films.

ROTTA LORIA S. (1), BRICCHI B.R. (2), SCHIRATO A. (1)(3), LI BASSI A. (2), DELLA VALLE G. (1), ZAVELANI-ROSSI M. (4)(5)
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(2) *Dipartimento di Energia, Laboratorio Materiali Micro e Nanostrutturati, Milano, Italy*
(3) *Istituto Italiano di Tecnologia, Genova, Italy*
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(5) *IFN-CNR, Milano, Italy*

Titanium nitride (TiN) has raised increasing attention due to its refractory nature, CMOS- and bio-compatibility and chemical stability. Moreover, its optical response presents a permittivity tunable by synthesis and a broadband plasmonic resonance, making it an interesting plasmonic material. However, a clear description of the transient optical response of TiN is still missing, mainly concerning the timescale of electron-phonon interactions following photoexcitation. Here, we present the ultrafast dynamics of TiN films ($\sim 200\,\mathrm{nm}$ thick), with tailored characteristics, produced by pulsed laser deposition (PLD). We use pump-probe spectroscopy with temporal resolution down to almost 15 fs, tunable pump and broadband probe, extending over the plasmon resonance. The experimental analysis is supported by numerical modelling based on a two-temperature model (TTM), including a dispersed contribution for the modulation of interband transitions. Electron-phonon coupling in TiN is shown to be much stronger than in gold, with relaxation taking place in about 200 fs. Our findings lead to a deeper understanding of the physics of TiN, and provide relevant insights in view of device design.

Aula T - Caterina Scarpellini **ore 14:00 – 19:00**

SEZIONE III
Astrofisica
Presiede: BRUNETTI G. (IRA, Bologna)

GW+MM/ASTRO

Relazioni su invito

▲ **Binary black holes across cosmic time.**
MAPELLI M.
INFN, Sezione di Padova e University of Padova
The results of LIGO and Virgo open a new perspective for the study of binary black holes: we now know of nearly one hundred candidate systems. Because of the new data, theoretical and numerical models of binary-black-hole formation face a serious challenge: several LIGO-Virgo black holes have mass in the upper mass gap (~ 60–120 Msun) predicted by pair-instability theory, others partially overlap with the lower mass gap (~ 2–5 Msun). On the one hand, population models of massive binary stars predict black-hole masses in the range ~ 3–50 Msun, with nearly aligned spins, but are affected by large uncertainties. On the other hand, dynamics of dense stellar clusters can trigger the formation of binary black holes with largely misaligned spins, and even fill the pair instability mass gap. In this contribution, I will present new theoretical models of the formation of massive (> 60 Msun) black holes via multiple stellar collisions and hierarchical mergers of low-mass black holes in dense star clusters. Furthermore, the redshift evolution of binary black holes is one of the key features to understand their formation, in preparation for next-generation gravitational-wave detectors.

▲ **Einstein Telescope: Status and perspectives.**
PUNTURO M.
Istituto Nazionale di Fisica Nucleare, Sezione di Perugia, Italia
Einstein Telescope (ET) is the European project for a third-generation gravitational wave observatory. ET promises to investigate the entire Universe through gravitational wave signals emitted in the coalescences of black holes or neutron stars. ET entered the ESFRI roadmap for future research infrastructures in Europe in 2021, and the ET project and Collaboration have recently been formalised. The exciting scientific goals in astrophysics, nuclear physics, fundamental physics and cosmology will be briefly introduced. The technological challenges for the realisation of the ET observatory will be described, ranging from civil engineering, to the necessary precision mechanics, to new optical and photonic solutions. Finally, the progress of the project and the realisation plan will be presented.

▲ **Searching for ultra-long period gravitational waves with the Pulsar Timing Arrays (PTAs).**
POSSENTI A.
INAF, Osservatorio Astronomico di Cagliari, Italia
A Pulsar Timing Array (PTA) exploits the remarkable rotational stability of an ensemble of rapidly spinning pulsars in order to use them as pieces of a galactic scale gravitational wave detector. In particular, a PTA provide the possibility to search for gravitational waves in the ultra-long period range, between few months to few decades, thus nicely complement other current and future gravitational waves detectors, which are sensitive at much shorter

gravitational wave periods. After about 15 years of constant progresses, recent results from various regional PTA efforts (the European EPTA, the North-American nanoGrav, the Australian PPTA and the Indian InPTA), as well as from the combined International Pulsar Timing Array (IPTA), might indicate that a detection is not far in time anymore. A report will be given about the status of the various experiments, with particular focus on the Italian/European contribution.

▲ **AGN ultra-fast outflows.**

Braito V. (1), Reeves J. (2), Severgnini P. (1), Della Ceca R. (1)
(1) *INAF, Osservatorio Astronomico di Brera, Merate (LC) , Italy*
(2) *Department of Physics, Institute for Astrophysics and Computational Sciences, The Catholic University of America, Washington, DC, USA*

Over 2 decades ago X-ray observations first revealed the presence of blue-shifted iron K absorption features in the spectra of nearby Active Galactic Nuclei. They indicate the presence of powerful ultra-fast outflows launched from the innermost regions of the accretions disk with velocities up to $0.3c$. Systematic studies then showed that these disk winds are present in $\sim 40\%$ of the nearby AGN and may be connected to the outflows that are seen on large scales in the host galaxies. Recently, tailored X-ray observational programs on the best examples of these disk winds are shedding more light on their nature and driving mechanisms. At the same time, we are increasing the sample of powerful disk winds with deep ALMA observations that will allow us to understand whether the disk winds have indeed an effect on the large-scale cold ISM. Here we shall review our recent results obtained thanks to XMM & NuSTAR observations on the prototypes of the most powerful disk winds focusing on the importance of variability studies.

Comunicazioni

● **Perspectives for multi-messenger astronomy with the next generation of gravitational-wave detectors and high-energy satellites.**

Ronchini S., Banerjee B.
Gran Sasso Science Institute e INFN, Laboratori Nazionali del Gran Sasso

The Einstein Telescope (ET) is an ambitious project for the future of multi-messenger astrophysics and the optimisation of the synergy with astronomical facilities is a cardinal point which needs to be addressed. In order to detect the counterparts of binary neutron star (BNS) mergers at high redshift, the observation of high-energy signals will play a crucial role. I will show the predictions of the high-energy emission of BNS mergers and its detectability in a theoretical framework based on a universal jet structure and able to reproduce the properties of the current sample of short GRBs. The rate of joint detection of gravitational-waves and high-energy radiation is estimated for both the prompt and afterglow emissions, with the aim of determining the best observational strategies. I will emphasise the crucial role of future wide field X-ray missions also for the detection of the fainter emission outside the jet core, which will allow us to probe the yet unexplored population of low-luminosity short GRBs in the nearby Universe, as well as to unveil the nature of the jet structure and the connections with the progenitor properties.

● **General relativistic magnetohydrodynamical simulations of accretion onto spinning black-hole binaries.**

Cattorini F. (1)(2), Giacomazzo B. (2)(3)
(1) *DiSAT, Università degli Studi dell'Insubria, Como, Italy*
(2) *INFN, Sezione di Milano-Bicocca, Milano, Italy*

([3]) *Dipartimento di Fisica G. Occhialini, Università di Milano-Bicocca, Milano, Italy*

Massive black-hole binary (MBHB) mergers are mighty gravitational wave (GW) events, which will be detected by future space-based laser interferometers such as LISA. MBHBs are a natural outcome of the hierarchical process of galaxy mergers, and their coalescence may occur in a magnetized, gas-rich environment, yielding powerful electromagnetic (EM) emissions. To explore the features of the plasma surrounding these binaries, we produce a suite of general relativistic magnetohydrodynamical (GRMHD) simulations of the late-inspiral and merger of MBHBs. Our work models for the first time the GRMHD evolution of binaries of spinning black holes, with spins either aligned or misaligned to the orbital angular momentum. Our goal is to capture the effects of spins on the mass accretion rate, the gas dynamics, and the EM energy emitted during the binary late-inspiral and merger. We identify quasiperiodic modulations in the premerger accretion rate that evolve in parallel with the GW signal. This result could provide a valuable signature of EM emission concurrent to low-frequency GW detection, offering a novel outlook for future multimessenger astronomy.

Formation and ejection of double-helix plasma structures from gravitational waves emitters.

Coppi B., Coppi P.S.

MIT, Cambridge, MA, USA e Yale University, New Haven, CT, USA

Double-helix plasma structures have been identified theoretically and shown to form in and propagate away from the time-dependent plasmas in which black-hole binaries can be imbedded. These structures are envisioned to propagate up to plasma regions where they can be disrupted. By now experimental observations of the termination of jets have revealed that they can involve double-helix magnetic topologies. Theoretically these structures are found to emerge as non-linearly coupled torsional Alfvén waves in the presence of a magnetic field in both the formation and in the terminal plasma while evolving into torsional ion sound waves when the background magnetic field vanishes. They corotate with the binary and propagate in either of the two vertical directions. The coupling involves intrinsic gravitational modes present in the circumbinary disk and inner gravitational fluctuations originating from the swept (toroidal) regions traced by one or both black holes.

Cross-correlation of the Astrophysical Stochastic Gravitational Wave Background with the Cosmic Microwave Background.

Perna G.

Dipartimento di Fisica e Astronomia "G. Galilei", Università degli Studi di Padova, Padova, Italy e INFN, Sezione di Padova, Padova, Italy

We focus in this contribution on the analysis and characterization of the anisotropic part of the Astrophysical Gravitational Wave Background (AGWB). Specifically, we analyse the cross-correlation between its anisotropies and the Cosmic Microwave Background (CMB) ones: the physics behind them is analogous and the two signals are expected to be correlated. Such cross-correlation would provide a new complementary probe for the LSS evolution, for testing general relativity at large scales, for the understanding of dark energy. Furthermore, in this contribution we focus on the possibility to measure non-Gaussianity (NG) using the cross-correlation signal. If well constrained, in fact, NG could be used to rule out some inflationary models that predict huge deviations from Gaussianity. We focus on how the introduction of NG modifies the cross-correlation spectrum between the AGWB and the CMB anisotropies. In addition to the theoretical formalism, we develop a python code to account for the merging of the sources contributing to the background. We modify the code CLASS to obtain the cross-correlation angular spectrum, with the inclusion of the astrophysical dependences and NG.

Il laboratorio SarGrav: Uno dei siti più quieti tra 2 e 10 Hz sulla faccia della Terra.

Rozza D.
Dipartimento di Scienze Chimiche, Fisiche, Matematiche e Naturali, Università di Sassari, Italia e Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italia

L'Einstein Telescope (ET) sarà l'interferometro europeo di terza generazione. In Sardegna, presso la cittadina di Lula nel nuorese, è stato identificato un sito, la miniera di Sos Enattos, che soddisfa tutti i requisiti scientifici di ET riguardo ai disturbi originati nell'ambiente circostante. Campagne sismiche hanno già rivelato il basso contributo dovuto alla sismicità della regione. Il laboratorio SarGrav, realizzato nei pressi della miniera nella prospettiva di collocazione di ET in loco, prevede di ospitare esperimenti che necessitano questo basso rumore ambientale: esperimenti sotterranei, criogenici, a bassa frequenza. Aree sperimentali sono già operative in superfice e in diverse camere sotterranee. Un esperimento di fisica fondamentale, Archimedes, è in fase di installazione, mentre il suo prototipo, un tiltmetro, ha già pubblicato degli ottimi risultati sul basso rumore. Questo sito, inoltre, ospiterà anche i prototipi per l'isolamento sismico degli specchi dell'interferometro ET proprio nella zona di interesse per lo studio delle sorgenti di onde gravitazionali osservate tra 2 e 10 Hz.

Hidden interaction in the supernova SN 2020faa.

Salmaso I.
Dipartimento di Fisica e Astronomia "G. Galilei", Università degli Studi di Padova, Italia e Istituto Nazionale di Astrofisica, Osservatorio Astronomico di Padova, Italia

During its life, a massive star can shed the outer layers of its envelope through stellar winds. The ejected material arranges around the star and enriches the circumstellar medium (CSM). In most cases, a massive star will end its life in a supernova (SN) explosion, when the nucleus of the star collapses and the envelope is violently ejected. The explosion gives rise to a tremendous display of energy and light. In fact, the interaction of the ejecta with a dense CSM provides an extra power source for the luminosity and can dominate the displayed light curve even at early phases. Interaction is usually detected in spectra thanks to the presence of narrow emission lines coming from the unshocked CSM, but there are cases in which the interaction can be hidden due to the geometry of the system. In this contribution, we present the acquired dataset and analysis of SN 2020faa, a peculiar SN in which the interaction is hidden. We determine the masses and energies involved in the explosion and propose an interpretation for the observed spectro-photometric evolution.

Light Curves Bayesian analysis to characterize Core-Collapse Supernovae.

Cosentino S.P. (1), Pumo M.L. (1)(2)(3)
(1) *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania*
(2) *INAF, Osservatorio Astrofisico di Catania*
(3) *INFN, Laboratori Nazionali del Sud, Catania*

The launch of the Legacy Survey of Space and Time (LSST) and other future dedicated surveys are going to open the possibility to perform statistical studies of Core-Collapse Supernovae (CC-SNe) and similar transients, that need sufficiently fast and accurate procedures for the characterization of these events. In this framework, we have developed Bayesian procedures, based on our new post-explosive semi-analytic model, that are able to reconstruct SN Light Curves and infer the main physical parameters describing CC-SNe progenitors at explosion. These new procedures as well as their validation will be presented.

Opening the path to hard X-/soft Gamma-ray focussing: The ASTENA-pathfinder mission.

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(5) *INAF/IASF of Palermo, Palermo, Italy*
(6) *INRiM of Torino, Torino, Italy*

Hard X-/soft Gamma-ray astronomy is a key field for transient, nuclear and multimessenger astrophysics. However, the spatial localization, imaging capabilities and sensitivity of the measurements are strongly limited for the energy range $> 70\,\mathrm{keV}$. To overcome these limitations, we have proposed a mission concept, ASTENA, submitted to ESA for its program "Voyage 2050". We will report on a pathfinder of ASTENA, that we intend to propose to ASI as an Italian mission with international participation. It will be based on one of the two instruments aboard ASTENA: a Laue lens with 20 m focal length, able to focus hard X-rays in the 50–700 keV passband. It makes use of bent crystals that diffract gamma-ray photons in transmission configuration. A 3D position-sensitive spectro-imager detector will be positioned on the lens focus. The combination of the focussing properties of the lens and of the localization properties of the detector will provide unparalleled imaging and spectroscopic capabilities, thus enabling studies of phenomena such as Gamma-ray bursts afterglows, supernova explosions, positron annihilation lines and many more.

High-resolution Optical Emission Spectroscopy characterization of hydrogen and argon laboratory magneto-plasmas of astrophysical interest.

Emma G. (1)(2), Bezmalinovich M. (3)(4), Finocchiaro G. (1)(2)(5), Mauro G.S. (2), Mazzaglia M. (2), Mishra B. (1)(2), Naselli E. (2), Pidatella A. (2), Santonocito D. (2), Torrisi G. (2), Reitano R. (1)(2), Mascali D. (2)
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(2) *INFN, Laboratori Nazionali del Sud, Catania, Italia*
(3) *Dipartimento di Fisica, Università degli Studi di Camerino, Italia*
(4) *INFN, Sezione di Perugia, Italia*
(5) *CSFNSM, Catania, Italia*

In the last decades there has been a growing interest to investigate the origin of elements heavier than iron in the Universe, produced via r-process nucleosynthesis. Detection of kilonovae, released after the merging of compact binary objects, is relevant to constrain the r-process nucleosynthesis elements yield in these astrophysical *loci*. In the framework of the PANDORA project, we are developing a new plasma trap for the emulation of kilonovae ejecta properties at a specific stage of their evolution, providing measurements of plasma opacity and new insights about heavy-elements nucleosynthesis. To verify the feasibility of this kind of measurements in terms of temperature and density (order of eV and $10^{12}\,\mathrm{cm}^{-3}$, respectively) we used the Flexible Plasma Trap, operative at INFN-LNS, as testbench for PANDORA, to characterize gaseous plasma (H_2, Ar) parameters by Optical Emission Spectroscopy. The experimental results will be presented, concerning estimates of plasma density and temperature, deduced by means of the line-ratio method, from spectra analysis in the visible range under different plasma trap configurations.

Aula U - Giuliana Cini Castagnoli **ore 15:00 – 18:15**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Marotta A.M. (Università di Milano)

Quality of the environment

Relazioni su invito

▲ **Multiscale study of subsurface heterogeneity and its effects on contaminant transport in groundwater: The challenges posed by the realization of the national radioactive waste disposal facility.**

Giudici M. (1), Comunian A. (1), Giacobbo F. (2)
(1) *Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano*
(2) *Dipartimento di Energetica, Politecnico di Milano*

The design and realization of radioactive waste disposal facilities (RWDF) requires a safety assessment, which is based also on a risk analysis related to dispersion of radioactive isotopes in the environment, after accidental leakage from the engineered barriers. Potential sites selected for the national RWDF and many of the present-day temporary repositories of low- and intermediate-level radioactive wastes, are located in areas characterized by thick alluvial deposits of fluvial and glacio-fluvial, porous sediments. Therefore, modeling of groundwater flow and solute transport in porous media is fundamental at different scales: adsorption phenomena, which occur at the pore/grain scale, are often studied with laboratory experiments and mathematical models; sediments' heterogeneity affects contaminant transport in aquifers from the near-field (the area near the point of release) to the far-field (even at large distance along the groundwater flow direction) and is studied by geological and geophysical surveys and mathematical simulations. This presentation gives a review of results from multi-disciplinary and multi-scale studies of these topics.

▲ **Role of Coherent Vortices on scalar transport and exchange processes within and above the Amazon Forest.**

Mortarini L.
ISAC-Institute of Atmospheric Sciences and Climate, CNR, Italy e Departamento de Fisica, Universidade Federal de Santa Maria, Santa Maria, RS, Brazil

Exchange processes between canopies and the Atmosphere are relevant in many environmental applications, from urban heat islands to the net ecosystem exchange in forest. Both above and within canopies the dynamics of scalars is dominated by non-local coherent vortices generated at the canopy-Atmosphere interface and themselves evolving depending on thermal stratification. In the present work, observations taken at seven levels (14 m – 325 m) during a 19-days campaign at the Amazon Tall Tower Observatory (ATTO) site were used to study the vertical evolution of the turbulent field in the roughness sublayer and in the surface layer above it in different stability conditions. An extremely stable regime, characterized by low wind speeds, the almost completely suppression of turbulence and a dominance of submeso motions, was identified. The shear length scale, responsible of the coherent vortices generation, increases with decreasing stability, presenting two asymptotes for large unstable and stable stratification and a linear behaviour close to neutral stratification. An original method based on 5-minutes autocorrelation functions was applied to the detection of coherent structure time and length scales. The characteristic timescales of vertical velocity, temperature and scalar fluxes are presented, together with their relationship to the scalar fluxes characteristic time-scales.

Comunicazioni

Tecniche avanzate di source apportionment per l'identificazione delle sorgenti di aerosol atmosferico.

CROVA F. (1), BERNARDONI V. (1), FORELLO A.C. (1)(2), VALENTINI S. (1), VALLI G. (1), VECCHI R. (1)
(1) *Dipartimento di Fisica, Università degli Studi di Milano e INFN-Milano, Milano, Italia*
(2) *Dipartimento di Fisica e Astrofisica, Università degli Studi di Firenze, Sesto Fiorentino, Italia*

L'aerosol atmosferico è un sistema altamente complesso per le diverse proprietà delle particelle che lo compongono e per la varietà delle sorgenti emissive. Per sviluppare strategie di mitigazione efficaci sugli impatti dell'aerosol atmosferico, è necessario individuare le sorgenti emissive che contribuiscono alle concentrazioni osservate e quantificare tali contributi. Per questo scopo vengono sempre più utilizzati i modelli a recettore, che si basano sull'analisi multivariata di variabili fisico-chimiche misurate nel sito "recettore". Un altro metodo efficace per lo studio delle sorgenti, in particolare dell'aerosol carbonioso, sfrutta invece misure di radiocarbonio sul particolato atmosferico tramite Accelerator Mass Spectrometry. L'integrazione di questi approcci risulta uno strumento potente per irrobustire la caratterizzazione delle sorgenti. In questa presentazione verranno illustrati gli approcci avanzati che il gruppo di Fisica dell'Ambiente dell'Università di Milano ha sviluppato per la modellistica a recettore e la nuova linea di preparazione per analisi di radiocarbonio su campioni di aerosol atmosferico (esperimento INFN-ISPIRA).

Sviluppo di un nuovo strumento a spettro luminoso continuo per analisi ottiche del particolato atmosferico.

ISOLABELLA T. (1)(2), BERNARDONI V. (3)(4), BRUNOLDI M. (1), MASSABÒ D. (1)(2), PARODI F. (2), VERNOCCHI V. (2), PRATI P. (1)(2)
(1) *Dipartimento di Fisica, Università di Genova*
(2) *INFN, Sezione di Genova*
(3) *Dipartimento di Fisica, Università degli Studi di Milano*
(4) *INFN, Sezione di Milano*

Il Black Carbon (BC) e il Brown Carbon (BrC) sono, tra le varie sostanze che formano il particolato atmosferico (PM), quelle più rilevanti per l'assorbimento luminoso e quindi per il riscaldamento globale. Il BC presenta elevato assorbimento su tutta la banda del visibile, mentre il BrC assorbe prevalentemente a lunghezze d'onda corte. Le caratteristiche di assorbimento del PM sono espresse tramite l'esponente di Angström (AAE), che quantifica la dipendenza spettrale del coefficiente di assorbimento $b_{abs} \approx \lambda^{-AAE}$. Presso il Laboratorio di Fisica Ambientale all'Università di Genova è stato sviluppato uno strumento per l'analisi dell'assorbimento ottico del PM. Lo strumento, ancora in fase di prototipo, sfrutta una sorgente di luce bianca e uno spettrometro ad alta risoluzione per misurare b_{abs} nella banda (350, 900) nm con una risoluzione di 5 nm. Tali misure sono quindi analizzate con apposito software per ricavare la proporzione di BC e BrC all'interno del campione studiato. Nel talk verranno presentati il prototipo, la procedura di riduzione e analisi dati e alcuni dei risultati preliminari.

Year-round study of the optical properties of airborne dust in Antarctica.

Potenza M.A.C. (1), Cremonesi L. (1), Delmonte B. (2), Delguasta M. (3)
(1) *Dipartimento di Fisica - Università La Statale, Milano*
(2) *Dipartimento di di Scienze dell'Ambiente e della Terra - Università di Milano Bicocca*
(3) *Istituto Nazionale di Ottica - CNR, Firenze*

OPTAIR is a multidisciplinary project to study the optical properties of airborne particles at Concordia Station, on the East Antarctic plateau, to assess the relationship among the optical properties of dust suspended in air and deposited by the snow. A permanent instrument based on the Single Particle Extinction and Scattering (SPES) method specifically designed and realized in Milan has been installed in November 2018. It continuously produces time resolved data providing several optical properties for each particle, aiming to feed the models describing radiation transfer through the Earth's atmosphere, an open issue for what concerns the effects of dust. Data show evidence of important changes of the optical properties of dust across the year, with a relevant fraction of particles accumulated during short bursts lasting a few hours. This shows the need of time resolved information about the optical properties of dust to infer the effective impact of dust on radiative transfer.

Measuring the quasi-universality properties of wavelength-scale scatterers.

Cremonesi L. (1)(2), Teruzzi L. (1), Potenza M.A.C. (1)
(1) *Dipartimento di Fisica, Università degli Studi di Milano*
(2) *DISAT, Università degli Studi di Milano-Bicocca*

Some peculiar quasi-universality properties and patterns in light scattering by particles in the intermediate size range have been the subject of several recent theoretical studies, with a particular focus on dielectric spheres. We report experimental evidence of such behaviour by measuring the forward scattered intensity by size-polydisperse water droplets suspended in air, as well as oil-in-water emulsions, and independently deducing their refractive index, hence the internal coupling parameter for each particle. Moreover, we find deviations from the quasi-universality behaviour of spheres for non-spherical objects, especially when size is close to the wavelength of light. We expect that these properties help refine sizing and characterization of particles in the critical micrometric size range spanned by aerosol particles most relevant to radiative transfer.

An improved GUI software for light obscuration sensors.

Teruzzi L. (1), Cremonesi L. (1)(2), Artoni C. (2), Ravasio C. (2), Potenza M.A.C. (1)
(1) *Dipartimento di Fisica, Università degli Studi di Milano, Italia*
(2) *Dipartimento di Scienze dell'Ambiente e della Terra, Università degli Studi di Milano Bicocca, Italia*

Light obscuration sensors are widely used for measuring the size distribution of insoluble mineral dust particles in ice core samples. They work on a flow-through basis: the sample is melted and pumped through a small cell transilluminated by a laser beam. When a microparticle intercepts the beam, a photodiode measures a decrease in the transmitted power and the optical extinction cross-section is obtained, thus the particle size retrieved. Such instruments are calibrated by means of reference spherical particles with refractive index 1.58, which leads to unavoidable systematic errors when determining the size of particles of different materials. In this contribution, we propose a reliable and consistent method to overcome this limitation by leaving the refractive index as a parameter to be set according to the sample composition. An ad hoc graphical interface has been developed to this purpose to drive an in-line instrument. We present results obtained from spheres of reference materials and compare them with an independent optical method. This method will improve the accuracy in ice core record characterization and reduce discrepancies between data obtained with different methods.

Analisi per il dimensionamento di un sistema Lidar per il monitoraggio di campi agricoli.

Pasquale G., Rutigliano N., Martellucci L., Puleio A., Rossi R., Wyss I., Gaudio P.
Università di Roma Tor Vergata, Dipartimento di Ingegneria Industriale

In agricoltura l'individuazione di anomalie dovute alla variazione di densità locale può contribuire in maniera decisiva nel prevenire incendi e nel monitorare lo stato di salute del campo. Una tecnica che offre la possibilità di riconoscere concentrazioni anomale di molecole che possono definirsi come allarme in ambiente è il Lidar. Un grande vantaggio associato a questa tecnica è quello di poter effettuare un monitoraggio in tempo reale e in maniera del tutto automatica su lunghe distanze. In questo lavoro viene mostrato il dimensionamento di un apparato Lidar e la sua valutazione nelle prestazioni in termini di sensibilità. La scelta delle varie componenti del sistema è stata effettuata sulla base di simulazioni numeriche di possibili scenari di rilascio di molecole. Inoltre, vengono proposte future implementazioni del sistema per migliorarne la capacità di classificazione dell'agente estraneo.

BONRAD: Una procedura di prevenzione per il contenimento del rischio radiologico. Rinvenimento di otto sorgenti orfane di ^{226}Ra sepolte in un'area industriale.

Ragozzino E. (3), Sapia G. (3), Mastroberardino A. (2), Procopio S. (1)
(1) *ARPACal, Laboratorio fisico Majorana E. Dipartimento di Catanzaro*
(2) *Dipartimento di Fisica Università della Calabria e Gruppo Collegato INFN di Cosenza, Rende, CS, Italia*
(3) *Dipartimento di Fisica Università della Calabria, Rende, CS, Italia*

La prevenzione del rischio radiologico presso l'ARPACAL in aree ambientali ostili con l'applicazione sistematica e continuativa della procedura Bonrad. La verifica preventiva consiste nella misura dei livelli di radioattività ambientale, attraverso misure di rateo equivalente di dose ambientale e della contaminazione superficiale, diretta o tramite campionamento e sopralluogo, prima che il personale preposto al campionamento di matrici solide e liquide sia direttamente esposto. In genere, il teatro di intervento è costituito da aree prive di conoscenze pregresse sulla radioattività ambientale e dove insiste un rischio radiologico potenziale per la popolazione e per i lavoratori dei servizi territoriali e laboratoristici che svolgono attività di campionamento. La procedura ha condotto al rinvenimento di 8 sorgenti di ^{226}Ra sepolte sotto il manto stradale, in un'area industriale. Il lavoro descrive le attività di dissepoltura delle sorgenti, la valutazione della dose per i lavoratori impegnati nelle operazioni di rinvenimento, la gestione del materiale ritrovato e l'opportunità di impiego di una procedura per il contenimento del rischio per i lavoratori e la popolazione.

Determinazione della concentrazione di attività di radon (^{222}Rn) in acqua destinata al consumo umano: Tecniche di misura a confronto.

Ragozzino E. (3), Sapia G. (3), Mastroberardino A. (2), Procopio S. (1)
(1) *ARPAcal, Laboratorio fisico Majorana E. Dipartimento di Catanzaro*
(2) *Dipartimento di Fisica, Univerisità della Calabria e Gruppo Collegato INFN di Cosenza, Rende, CS, Italia.*
(3) *Dipartimento di Fisica, Univerisità della Calabria, Rende, CS, Italia*

Nello studio vengono esaminate le tecniche di misura impiegate per la determinazione della concentrazione di attività volumetrica in campioni di acqua, presso il laboratorio Majorana dell'ARPACal, accreditato per la prova di radon in acqua. In particolare, su una sorgente di acqua con un livello medio annuo di concentrazione di attività ricadente nell'intervallo tra $(60\div80) \pm 10$ Bq/m^3 di radon, si confrontano i risultati ottenuti con metodo di prova normato che impiega un rivelatore al silicio e un metodo analitico non normato che utilizza uno scintillatore a stato solito. Entrambe le tecniche soddisfano a pieno i requisiti tecnici proposti dalle norme ISO 13164-3:2013 o UNI ISO 13164-3:2021 di riferimento e dalla normativa del decreto legislativo n. 28/2016. La norma stabilisce infatti un parametro di riferimento specificatamente per il gas radon disciolto in acqua in termini di concentrazione di attività media annuale.

Aula E - Rosalind Franklin **ore 14:00 – 19:00**

Sezione V

Biofisica e fisica medica

Presiedono: Toschi N. (Università di Roma Tor Vergata)
Arosio P. (Università di Milano)

Relazioni su invito

▲ **Deep learning per l'analisi di immagini radiologiche nella pandemia da COVID-19: Metodi, spiegabilità, validazione clinica.**

Scapicchio C. per la Collaborazione AIM
Dipartimento di Fisica, Università di Pisa, Italia e Istituto Nazionale di Fisica Nucleare, Sezione di Pisa, Italia

Durante la crisi pandemica da Covid-19, l'intelligenza artificiale è stata identificata come uno strumento utile per supportare il medico radiologo nella valutazione dei pazienti. Nell'ambito dell'esperimento AIM (Artificial Intelligence in Medicine) dell'INFN sono stati sviluppati alcuni esempi di sistemi di analisi automatica. Uno fra questi è *LungQuant*, un sistema software basato su una combinazione di tre reti neurali di tipo CNN e di tipo U-net in cascata, in grado di segmentare sia il parenchima polmonare che il volume della lesione nelle CT di pazienti affetti da polmonite da Covid-19, e di quantificare in maniera automatica la percentuale di volume polmonare compromesso. L'algoritmo è stato validato clinicamente seguendo un protocollo di analisi statistica e di confronto tra l'output del software e le valutazioni dei medici radiologi. I buoni risultati raggiunti da *LungQuant* in termini di performance (accuratezza del 90%) e di validazione clinica aprono la strada all'estrazione delle features radiomiche dalle lesioni segmentate, sulle quali costruire modelli di reti neurali per predire ad esempio il decorso favorevole o sfavorevole della malattia.

▲ **Physically inspired neural networks for data-driven inference of biological mechanism.**

Ferrante M.
Department of Biomedicine and Prevention, University of Rome Tor Vergata, Italy

Systems biology and neurophysiology have recently emerged as powerful tools for a number of key applications in biomedical sciences. Such multiphysics and multiscale models require ad hoc computational strategies and pose extremely high computational demands. Recent developments in the field of deep neural networks have demonstrated the possibility of formulating nonlinear, universal approximators to estimate solutions to highly nonlinear and complex problems with significant speed and accuracy advantages in comparison with traditional models. Physically Constrained Neural Networks (PINN) include analytical and physical constraints in the computational graphs, generating interpretable and parsimonious solutions to complex forward and inverse problems. We will present diverse applications of PINN-based, specialized deep learning architectures, like e.g. inference of hidden neuronal dynamics from real-world data and derivation of arterial input functions from image data exclusively in quantitative PET imaging. PINN-base strategies have the potential to provide high-capacity models with physical plausibility while battling the data paucity commonly observed in biomedical applications.

Comunicazioni

Machine learning classification for COVID19 patients performed on small datasets of CT scans.

Marrale M. (1)(2), La Fiura A. (1)(3), Collura G. (1)(2), D'Oca M.C. (1)(2), Lizzi F. (4)(5)(6), Brero F. (7)(8), Cabini R.F. (7)(8), Postuma I. (7)(8), Rinaldi L. (7)(8), Scapicchio C. (5)(6), Castiglioni I. (3), Cristofalo G. (9), Grassedonio E. (9), Galia G.M. (9), Scichilone N. (10), Retico A. (5)
(1) *Department of Physics and Chemistry "Emilio Segrè", University of Palermo, Palermo, Italy*
(2) *National Institute of Nuclear Physics, Catania division, Catania, Italy*
(3) *Department of Physics "Giuseppe Occhialini", University of Milano Bicocca, Milan, Italy*
(4) *Scuola Normale Superiore, Pisa, Italy*
(5) *National Institute of Nuclear Physics, Pisa division, Pisa, Italy*
(6) *Department of Physics, University of Pisa, Italy*
(7) *National Institute of Nuclear Physics, Pavia division, Pavia, Italy*
(8) *Department of Physics, University of Pavia, Pavia, Italy*
(9) *Department of Biomedicine, Neuroscience and Advanced Diagnostics, University of Palermo, Palermo, Italy*
(10) *Department of Promotion of Health, Maternal-Childhood, Internal and Specialized Medicine of Excellence "G. D'Alessandro", University of Palermo, Palermo, Italy*

In this work we evaluated the possibility of carrying out classifications of the outcome of patients with COVID19 disease through machine learning (ML) techniques working on small datasets of computed tomography (CT) images. In fact, one of the most common problems for medical artificial intelligence (AI) applications is the limited availability of annotated clinical data for model training. In the framework of the artificial intelligence in medicine (AIM) project funded by INFN, we analyzed datasets of CT scans of 79 subjects combined with clinical data containing information relating to positive outcome (no need for intensive care) or poor prognosis (admission into intensive care unit and/or death). After segmentation of ground glass opacities related to this pathology, the radiomic features were subsequently extracted from the CTs, selected through various algorithms of dimension reduction or feature selection and used for the training various classifiers. Values of the area under the ROC curve (AUC) of 0.84 were obtained with Gradient Boosting after BORUTA feature selection. Features selected are related to disease characteristics of poor prognosis patients.

Harmonization of multi-center MRI data to improve the performance of machine learning models.

Saponaro S. (1)(2), Giuliano A. (3), Bellotti R. (4)(5), Lombardi A. (4)(5), Tangaro S. (5)(6), Oliva P. (7)(8), Calderoni S. (9)(10), Retico A. (2)
(1) *University of Pisa, Pisa, Italy*
(2) *National Institute for Nuclear Physics, INFN, Pisa Division, Pisa, Italy*
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(4) *Physics Department, University of Bari "Aldo Moro", Bari, Italy*
(5) *National Institute of Nuclear Physics, INFN, Bari Division, Bari, Italy*
(6) *Department of Soil, Plant and Food Sciences, DISSPA, University of Bari "Aldo Moro", Bari, Italy*
(7) *Department of Chemistry and Pharmacy, University of Sassari, Sassari, Italy*
(8) *National Institute for Nuclear Physics, INFN, Cagliari Division, Cagliari, Italy*
(9) *Developmental Psychiatry Unit - IRCCS Stella Maris Foundation, Pisa, Italy*
(10) *Department of Clinical and Experimental Medicine, University of Pisa, Pisa, Italy*

Multi-center data collection has favored an even greater diffusion of the use of ML-based analyses in medical imaging. However, they may suffer the batch effect which, especially in case of MRI studies, should be curated to avoid confounding effects for ML classifiers. This is particularly important in the study of barely separable populations according to MRI data, such as subjects with autism spectrum disorders (ASD) compared to controls with typical development (TD). In this study, we show how the implementation of a harmonization framework on brain structural features improves the ability of case-control ML separation in the analysis of a multi-center MRI dataset. This effect is demonstrated on the ABIDE data collection. After data harmonization, the overall ASD *vs.* TD discrimination capability by a Random Forest (RF) classifier improves from a very low performance (AUC $= 0.58 \pm 0.04$) to a still low, but reasonably significant AUC $= 0.67 \pm 0.03$. The performances of the classifier have been evaluated also in the age-specific subgroups. Peculiar and consistent patterns of anatomical differences related to the ASD condition have been identified.

Spatiotemporal learning of dynamic positron emission tomography data improves diagnostic accuracy in breast cancer.

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(1) *Department of Biomedicine and Prevention, University of Rome Tor Vergata, Rome, Italy*
(2) *Department of Surgery and Cancer, Imperial College London, London, UK*
(3) *Department of Radiology, Athinoula A. Martinos Center for Biomedical Imaging, Boston, MA, USA*

Positron emission tomography (PET) tracer distribution is a dynamic process where tissue-specific biochemical properties are reflected in temporal PET dynamics. This cannot be accurately accounted for by conventional static SUV imaging. We posit that PET diagnostic accuracy can be improved exploiting the biochemical and metabolic information embedded in the shape of the tissue time activity curves obtained with a dynamic PET acquisition. We aimed to discriminate tumoral from healthy tissue in a cohort of 88 breast cancer patients who received dynamic $3'$-deoxy-$3'$-^{18}F-fluorothymidine PET scans with deep-learning filters which learn temporal patterns from 1D time sequences. Compared to the gold standard SUV method (85% accuracy), the best performance was obtained by our CONV1D model which delivered 92% accuracy. Our method is superior to conventional SUV analysis and paves the way for more sophisticated applications where deep-learned time signal intensity pattern analysis can be used for tumor segmentation or kinetic assessment without any pharmacokinetic model or invasive measurement of the arterial input function.

Classificazione caso/controllo nei disturbi dello spettro autistico con connettività funzionale cerebrale su dataset multicentrico.

Serra G. (1), Golosio B. (1)(3), Oliva P. (2)(3), Retico A. (4)
(1) *Dipartimento di Fisica, Università di Cagliari, Italia*
(2) *Dipartimento di Fisica, Università di Sassari, Italia*
(3) *INFN, Sezione di Cagliari*
(4) *INFN, Sezione di Pisa*

In questo lavoro sono state investigate le performance di classificazione dei soggetti affetti da disturbi dello spettro autistico, rispetto ad un gruppo di controllo, utilizzando tecniche di machine learning applicate alla connettività funzionale rs-fMRI, utilizzando un dataset multicentrico pubblico, ovvero un dataset composto da scansioni provenienti da più centri clinici. Sono state valutate le performance di classificazione al variare dell'atlante cerebrale utilizzato, del numero di feature considerate nell'analisi, delle misure di connettività. Sono state osservate due configurazioni migliori, ottenendo performance di classificazione aventi

un AUC di 0.74(3) e 0.76(1) rispettivamente. Sono inoltre state affrontate le problematiche legate alla dimensionalità e all'armonizzazione dei dati. Sono stati utilizzati due differenti schemi di armonizzazione: un primo schema più tradizionale, in cui tutti i soggetti di controllo sono utilizzati per stimare i parametri del modello di armonizzazione, ed un secondo schema, potenzialmente meno soggetto a bias, in cui si utilizzano solo i controlli del training set interno alla validazione incrociata per la definizione di tali parametri.

Diagnosi computerizzata basata su deep learning nell'imaging di tomosintesi digitale mammaria.

Ricciardi R. (1)(2), Mettivier G. (2)(3)
(1) *Scuola di Specializzazione Fisica Medica, Università di Napoli "Federico II", Napoli, Italia*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Napoli, Italia*
(3) *Dipartimento di Fisica "Ettore Pancini", Università di Napoli "Federico II", Napoli, Italia*

Il progetto DeepLook (finanziato dall'INFN) sta sviluppando un'architettura di deep learning per la diagnosi automatizzata della presenza di lesioni maligne in immagini di tomosintesi digitale mammaria, anche nota come mammografia 3D, basata su reti neurali convoluzionali. In collaborazione con radiologi ospedalieri, è in corso di realizzazione un ampio archivio di immagini cliniche annotate che include immagini acquisite con diverse unità cliniche, con diverse geometrie di acquisizione, su diverse centinaia di pazienti, contenenti una varietà di possibili lesioni mammarie e casi normali di assenza di lesioni. La rete neurale sviluppata è in grado di diagnosticare vari tipi di lesioni a livello delle immagini di singole fettine tissutali di tomosintesi, con una accuratezza del 94% ed una sensibilità del 93%, fornendo inoltre una localizzazione della massa sospetta ottenuta applicando algoritmi di Gradient-weighted Class Activation Mapping.

Cascata di convolutional neural network per il contornamento dei polmoni e di noduli tumorali del polmone.

Postuma I (1), Brero F. (1), Cabini R. (1)(2), Panebianco S. (3), Preda L. (4)(5)(1), Filippi A. (4)(5), Bortolotto C. (1), Lascialfari A. (1)(3)
(1) *Istituto Nazionale di Fisica Nucleare, Sezione di Pavia, Pavia, Italia*
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(3) *Dipartimento di Fisica, Università degli Studi di Pavia, Pavia, Italia*
(4) *Dipartimento di Scienze Chirurgiche, Diagnostiche e Pediatriche, Università degli Studi di Pavia, Pavia, Italia*
(5) *Fondazione IRCCS Policlinico San Matteo, Pavia, Italia*

Con la digitalizzazione dei dati di diagnostica medica si stanno gradualmente e continuamente accumulando grandi quantità di informazioni. L'elaborazione manuale di questi dati richiede esperienza e in molti casi è a lungo termine; il carattere soggettivo delle operazioni richieste è inoltre difficilmente replicabile da parte di operatori diversi, in buona parte dei casi. Tra le attività di elaborazione, la segmentazione volumetrica di immagini tomografiche richiede tempi molto lunghi. Con l'aumento della potenza di calcolo dei PC e il contemporaneo sviluppo di algoritmi di Machine Learning basati su reti neurali convoluzionali, è ora possibile automatizzare questo processo. Si osservi inoltre che, al fine di ottenere un modello ad alte prestazioni, è necessario allenare la rete neurale usando dati precedentemente classificati da esperti. In questo lavoro si mostrerà la metodologia di allenamento di una cascata di reti convoluzionali basata sul pacchetto nnUNet scritto in PyTorch, per ottenere una segmentazione automatica. Verrà inoltre dimostrato come l'allenamento dipende dai dati di input e si proporranno approcci che in futuro possano migliorare le prestazioni della rete.

Ottimizzazione di ^{19}F-MRI con tecniche di deep learning.

Provenzano M.
INFN, Sezione di Roma 1

La ^{19}F-MRI è una tecnica di imaging innovativa che sta suscitando crescente interesse in vari settori. È stato proposto di utilizzare ^{19}F-MRI per misurare la distribuzione dei carrier in terapie dei tumori quali la Boron Neutron Capture Therapy (BNCT) e la Proton Boron Fusion Therapy (PBFT), quest'ultima studiata dalla collaborazione INFN-NEPTUNE. Il ^{19}F è praticamente assente nel corpo umano, può quindi essere usato come tracciante, ma il segnale che si può ottenere è limitato dalla concentrazione. Per questo motivo la tecnica presenta limiti importanti come basso rapporto SNR, scarsa risoluzione delle immagini acquisite e tempi di acquisizione prolungati. Questo studio si propone di ottimizzare l'acquisizione MRI in funzione della tipologia di tracciante e di applicare tecniche basate su reti neurali profonde finalizzate all'incremento di SNR tramite la riduzione del rumore nello spazio delle frequenze di acquisizione. Risultati preliminari indicano che un SNR di circa 1 è ottenibile a 3 T con risoluzioni dell'ordine dei $5 \times 5 \times 5\,\mathrm{mm}^3$ (con acquisizioni da 1 h e $20'$) su fantocci contenenti 13.6 mM di FBPA, dosaggio tipico per applicazioni di BNCT, prima dell'applicazione della rete.

Correzione dell'attenuazione di immagini PET mediante Deep Learning.

<u>Valeri F.</u> (1), Cupparo I. (1)(2), Lasagni L. (1), Nerattini M. (1), Berti V. (1), Talamonti C. (1)(2)
(1) *Dipartimento di Scienze Biomediche, Sperimentali e Cliniche "Mario Serio", Università degli Studi di Firenze, Italia*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione Firenze, Italia*

L'obiettivo di questo studio è implementare una rete neurale per generare immagini PET corrette per l'attenuazione senza acquisire le immagini TC. La rete ha un'architettura UNET allenata usando la tecnica del transfer learning, caratterizzata da un Inception-Resnet v2 come encoder, pre-allenata sul dataset di ImageNet. Il dataset utilizzato include immagini PET/CT (FDG-18) cerebrali di 727 pazienti di cui 638 immagini sono state usate per il training, 34 per il validation e 55 per il test. La rete è stata allenata utilizzando i sistemi di calcolo messi a disposizione dall'INFN di Firenze. La performance è stata valutata calcolando la variazione percentuale del valore medio di specifiche VOIs nell'immagine predetta dalla rete e nella corrispondente ground truth. L'analisi nella zona centrale, quella più significativa per la diagnosi della malattia, mostra risultati dell'ordine di $\pm 3\%$, tali valori aumentano spostandosi nelle aree periferiche rimanendo attorno al 10%. È In corso la validazione da parte del medico nucleare. I risultati preliminari mostrano che la rete è capace di ricostruire l'immagine PET corretta per l'attenuazione anche senza la mappa dell'attenuazione.

Deep learning applied to medical image analysis: Epistemology and data.

Lizzi F.
Scuola Normale Superiore, Pisa, INFN, Sezione di Pisa e Dipartimento di Fisica, Università di Pisa

Deep learning (DL) is changing the way we analyze medical images. What do these changes consist of? I will introduce some interpretations according to which AI epistemology is moving towards a new paradigm called the "fourth paradigm" in which theory, hypothesis and experiment are going to be unified through the data. In this context, the famous statement "Correlation is enough" seems to be an effective way to describe this evolution. This change raises several issues related to medical image analysis that can be discussed. One of the most interesting I want to speak about is data. Data are a main part of DL development especially because DL algorithms are not explainable. Medical images data sets are scarce, underpopulated and usually do not contain acquisition and reconstruction parameters, which could be helpful to harmonize multicentric data. It is only knowing data characteristics that we can define the boundaries in which an algorithm can properly work. Mean performances on very diverse data are not reliable and correlation is not enough if data are complex and models are opaque. The research of causation is an interesting point to be discussed among physicists.

Machine-learning–based metabolic imaging: A bridge between *in vitro* models and clinical applications.

BIANCHETTI G., SERANTONI C., ABELTINO A., DE SPIRITO M., MAULUCCI G.
Dipartimento di Neuroscienze, Sezione di Biofisica, Università Cattolica del Sacro Cuore, Roma, Italia e Policlinico Universitario "A. Gemelli", IRCCS, Roma, Italia

Thanks to recent advances in the optical microscopy field, new methods for fine metabolic characterization of living systems have been developed. Moreover, the combination of molecular biology and *in vivo* imaging gives rise to metabolic functional imaging, a discipline that enables the real-time fine monitoring of molecular changes and supra-molecular properties essential to cell survival, thus allowing the enhancement of the available biological informative content. However, some limits and uncertainties mainly regarding the management of large amounts of data as well as the lack of specificity, remain. In this perspective, we have developed machine-learning–based techniques that allow assessing different metabolic cellular processes, including, among others, autophagy, and lipid turnover. Here, we propose the application of ML-based metabolic imaging to evaluate and characterize cellular metabolic reprogramming occurring in several pathological conditions, focusing on diabetes-related complications and tumors.

Aula L - Christa Mc Auliffe **ore 14:00 – 19:00**

Sezione VI

Fisica applicata, acceleratori e beni culturali

Presiede: Pastrone N. (INFN, Sezione di Torino)

Relazioni su invito

▲ **Interaction region design of future circular collider e^+e^-.**

Boscolo M.
INFN, Laboratori Nazionali di Frascati

The design of the interaction region of the positron-electron future circular collider must comply with various important constraints, imposed by high beam currents, short bunches, high beam energy, high luminosity need for polarization, and crossing scheme. The innovative IR layout of the FCC-ee is based on the crab-waist collision scheme and it will be compatible for all beam energies foreseen, from 182.5 to 45.6 GeV. It will be shown how the latest layout for the interaction region matches with requirements and physical constraints as confirmed by numerical simulations performed on critical topics such as synchrotron radiation, trapped modes, collective effects, etc. The FCC project is presently in its feasibility phase, aiming at the optimization of the FCC-ee collider and the tunnel infrastructure. This activity is partially funded also by the EC HORIZON 2020 (EU project FCC-IS, grant agreement No. 951754).

▲ **Synchrotron radiation and cultural heritage. The experience of Elettra.**

Zanini F.
Elettra-Sincrotrone Trieste, Basovizza, Trieste, Italy e Postgraduate School of Archaeology, Trieste, Italy

The use of synchrotron radiation (SR) for the analysis of cultural samples has been increasing over the past years, and experiments related to cultural heritage (CH) study have been performed at many beamlines of Elettra, the Italian SR facility. TwinMic, the Soft X-ray Microscope, integrates the advantages of complementary scanning and full-field imaging modes into a single instrument. X-Ray Fluorescence is a highly versatile beamline, optically designed for spectroscopy as well as for microscopy. The flexible design of the MCX beamline allows a wide range of diffraction experiments relevant for the CH, from phase identification to atomic structural studies. SYRMEP, the X-ray microtomography station, is a highly flexible beamline allowing analysis in both absorption and phase contrast mode. The XAFS beamline provides microscopic structural information through the analysis of a sample X-ray absorption spectrum. UV resonant Raman spectroscopy performed at IUVS beamline is a non-destructive powerful tool for obtaining a detailed compositional characterization of pigments in artworks. Infrared Microscopy techniques at SISSI beamline offer the possibility to correlate the sample morphological features with its vibrational local pattern at diffraction limited spatial resolution. The SPEM hosted at the ESCA microscopy beamline allows to combine chemically surface sensitive measurements with high spatial resolution. The XAFS beamline provides microscopic structural information through the analysis of a sample X-ray absorption spectrum. UV resonant Raman spectroscopy performed at IUVS beamline is a non-destructive powerful tool for obtaining a detailed compositional characterization of pigments in artworks. Infrared Microscopy techniques at SISSI beamline offer the possibility to correlate the sample morphological features with its vibrational local pattern at diffraction limited spatial resolution. The SPEM hosted at the ESCAmicroscopy beamline allows to combine chemically surface sensitive measurements with high spatial resolution

▲ **Optical reflectance spectroscopy of inhomogeneous materials: Application to ancient documents and textiles.**

Missori M.
Institute for Complex Systems, National Research Council, Rome, Italy e Department of Physics, Sapienza University of Rome, Italy

Reflectance spectroscopy in the ultraviolet and visible regions, also known as Fiber Optics Reflectance Spectroscopy (FORS), is used to provide qualitative analytical information, in particular for dyes and pigments. Quantitative information, on the other hand, is difficult to obtain for optically inhomogeneous materials characterized by the presence of light scattering. Documents and textiles represent striking examples of this class of materials where it is not possible to obtain a useful absorption spectrum without taking account of light scattering. In this contribution, I will briefly illustrate how to obtain quantitative absorption spectra through FORS by using an integrating sphere and analyzing the reflectance data by means of the Kubelka-Munk theory. For cellulose-based materials, quantitative chemical information on the chromophores responsible for the observed optical degradation is obtained by using time-dependent density functional theory simulations of the optical spectrum of carbonyl groups. Applications to the analysis of Leonardo Da Vinci's drawings, ancient textiles, and monitoring of conservation interventions of paper artworks will be shown.

Comunicazioni

● **Quality assessment of cherry tomato fruits originating from different Sicilian growing areas by using delayed luminescence.**

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(1) *Dipartimento di Fisica e Astronomia, Università di Catania, Italy*
(2) *Dipartimento di Agricoltura, Alimentazione e Ambiente, Università di Catania, Italy*
(3) *Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Italy*
(4) *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Italy*
(5) *Meluna Research, Wageningen, The Netherlands*

In order to develop a non-destructive analytical technique for tomato fruit quality assessment, Delayed Luminescence (DL) measurements have been performed on several lots of cherry tomatoes grown in different areas of south-eastern Sicily, with and without the PGI certification "Pomodoro di Pachino". Preliminary results, in which obtained DL yields are compared with tomato soluble solid content, will be discussed.

● **Curcumin loaded nanobubbles for food preservation: Experimental and mathematical models.**

Stura I. (1), Ficiarà E. (1), Munir Z. (1), Cavalli R. (2), Mandras N. (3), Banche G. (3), Guiot C. (1)
(1) *Dipartimento di Neuroscienze, Università degli Studi di Torino, Italia*
(2) *Dipartimento di Scienze e Tecnologie del Farmaco, Università degli Studi di Torino, Italia*
(3) *Dipartimento di Scienze della Sanità Pubblica e Pediatriche, Università degli Studi di Torino, Italia*

Due to microbial contamination, fruits keep intact turgidity, colour and texture of the freshly picked products for a limited time on market shelves, generating waste and requiring the use of pollutants. Curcumin, a natural component of *Curcuma longa*, is a potent biodegradable antibacterial agent. Moreover, it is an effective photosensitizer able to induce photodynamic activation in blue light (400–500 nm wavelength), producing Reactive Oxygen Species (ROS) which cause bacteria death. Unfortunately, curcumin is poorly soluble in water, but is effectively deliverable by nanocarriers. Chitosan-shelled nanobubbles (NBs) are safe and resistant nanocarriers which could transport and gradually release curcumin on fruits' surface. In our preliminary experiments, different NBs formulations were tested in order to improve the release process and antibacterial ability against *E. coli*, *S. aureus* and *E. faecalis*, both with and without blue light photoactivation. A mathematical model based on previous data has been formulated to optimize the processes for maintaining bacterial proliferation under a fixed threshold, simulating an industrial context and by scaling the NBs manufacturing.

Uno studio multidisciplinare di gemme vitree.

Musa M. (1), Gagetti E. (2), Riccardi M.P. (3), Marcucci G. (1), Di Martino D. (1)
(1) *Dipartimento di Fisica, Università di Milano Bicocca, Italia*
(2) *Università "La Statale" di Milano, Italia*
(3) *Università di Pavia, Italia*

Il Museo Archeologico Nazionale di Aquileia ospita una ricca collezione di gemme vitree. Nell'ambito di un progetto multidisciplinare di analisi completamente non-distruttive, è stato selezionato e analizzato un campione di più di 150 gemme vitree che avevano una comune datazione di epoca romana, ma diverse caratteristiche stilistiche e iconografiche. Una prima campagna di misure ha riguardato analisi di emissione gamma e raggi X indotti da particelle (PIGE e PIXE), per ottenere la composizione di tutti i campioni e poter così dare un inquadramento generale del materiale studiato. Successivamente, abbiamo focalizzato l'attenzione su campioni particolari, con attribuzione dubbia tra gemme naturali e vetri ad imitazione gemme, di cui presenteremo alcuni interessanti risultati.

Influence of side chain composition and polarity of the environment on the electrochemical doping mechanism in poly[3-(6-hydroxy)hexylthiophene] and dioxythiophene derivatives.

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(1) *Center for Nano Science and Technology@PoliMi, Istituto Italiano di Tecnologia, Italia*
(2) *School of Material Science and Engineering, Georgia Institute of Technology, Atlanta, GA, USA*
(3) *School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA, USA*
(4) *CNRS, Université de Bordeaux, France*
(5) *Charles Gerhardt Institute of Montpellier, France*

We address the nature of electrochemically induced charged states in conjugated polymers, their evolution as a function of electrochemical potential, and their coupling to their local environment by means of transient absorption and Raman spectroscopies synergistically performed *in situ* throughout the electrochemical doping process. We use as benchmarks an oligoether-functionalized 3,4-propylenedioxythiophene (ProDOT) copolymer and poly[3-(6-hydroxy)hexylthiophene] (P3HHT). The changes embedded in both linear and transient absorption features show that in the case of P3HHT there is an ultrafast energy transfer between the exciton and the polaron, which is absent in the case of the ProDOT copolymer. In the case of the ProDOT copolymer we also identify a precursor electronic state with charge-transfer character that precedes the polaron formation and bulk electronic conductivity, and it is instead absent in P3HHT. This contribution provides insight into the energetic landscape of a heterogeneous polymer-electrolyte system and demonstrates how such coupling depends on environmental parameters, such as polymer structure, electrolyte composition, and environmental polarity.

Membrane-targeted molecule for cell optostimulation.

Magni A. (1)(2), Paternò G. M. (1)(2), Moschetta M. (2), Zucchi A. (3), Mattiello S. (3)(1), Mattioli G. (4), Beverina L. (3), Lanzani G. (1)(2)
(1) *Dipartimento di Fisica, Politecnico di Milano, Milano, Italy*
(2) *Center for Nano Science and Technology, Istituto Italiano di Tecnologia, Milano, Italy*
(3) *Department of Materials Science, Università di Milano-Bicocca, Milano, Italy*
(4) *ISM-CNR Istituto di Struttura della Materia, Consiglio Nazionale delle Ricerche, Monterotondo, Italy*
Light-driven modulation of cellular activity with high spatial and temporal resolution is becoming of great interest. We are considering the use of light-sensitive molecules that act as photo-actuators avoiding genetic manipulation. We present the characterization of a newly synthesized conjugated molecule (BV-1) which spontaneously partitions into lipid bilayers owing to its amphiphilicity. We performed steady-state and time-resolved spectroscopic measurements revealing the presence of a charge-transfer state upon visible light irradiation and the possibility for BV-1 to undergo intersystem-crossing towards a triplet state, which can transfer energy to molecular oxygen. *In vitro* experiments shows that BV-1 has low toxicity in dark conditions, while the illumination with visible light induces membrane poration and permeabilization, which leads to a robust depolarization in HEK cells and a phototoxic effect in *E.coli* cultures. Our data suggest the occurrence of two independent light-driven mechanisms for the increase of the membrane permeabilization: i) lipid peroxidation within the cell membrane and ii) conformational reorganization of BV-1 altering the integrity of the membrane.

Copropagating schemes for dielectric laser accelerators (DLAs).

Torrisi G. (1), Mascali D. (1), Mauro G.S. (1), Usmani A. (1), Bacci A. (2), Sorbello G. (1)(3), De Angelis C. (2)(4), Locatelli A. (2)(4)
(1) *INFN, Laboratori Nazionali del Sud, Catania*
(2) *INFN, Sezione di Milano, Milano*
(3) *Università di Catania, Catania*
(4) *Università di Brescia, Brescia*
Laser acceleration of electrons with silicon dielectric structures was demonstrated with accelerating gradients of more than 200 MeV/m. However, many of the proposed configurations (free space coupled gratings, dual pillar, phase reset devices) have an intrinsically limited interaction length, because a transversely incident laser light, impinging laterally along the whole structure's length, is required. In order to obtain both high laser-induced accelerating gradients and adequate interaction length, in this paper we describe extended accelerating structures with collinear propagation of the accelerating electromagnetic field and the particles to be accelerated: both 2D and 3D photonic crystals-based structures, and slot hollow-core waveguides are analyzed and compared in terms of accelerating gradient, damage factor, efficiency, fabrication tolerances and complexity of the laser delivery system.

Il progetto SHERPA.

Annucci D.
Dipartimento di Fisica, Sapienza Università di Roma, Italia e INFN, Sezione di Roma
L'obiettivo di SHERPA è sviluppare una tecnica efficiente per estrarre un fascio di positroni da uno degli anelli del collisore DAFNE dei LNF, creando impulsi lunghi O(ms). L'approccio più comune per estrarre da un anello consiste nell'utilizzare una tecnica risonante, creando una regione instabile nello spazio delle fasi dalla quale estrarre gradualmente le particelle dal fascio circolante tramite una combinazione di setti elettrostatici e magnetici. SHERPA propone invece di utilizzare processi coerenti in cristalli piegati, un'alternativa più economica

e meno complessa. Questa tecnica non risonante, già utilizzata negli acceleratori di adroni, fornirà un'estrazione multi-giro continua ad alta efficienza. In vista dei primi test su fascio dei cristalli prodotti per SHERPA, sono state effettuate delle simulazioni in Geant4 volte a studiare le proprietà di channeling dei positroni al di sotto del GeV. In questa regione di energie, ed in particolare per i positroni, non esistono dati sperimentali, e la validazione delle simulazioni è stata ottenuta utilizzando simulazioni semi-analitiche. I primi risultati di tali simulazioni saranno oggetto della presente comunicazione.

Modeling collective effects in linacs.

Bosco F. (1)(2), Camacho O. (4), Carillo M. (1)(2)(3), Chiadroni E. (1)(3), Faillace L. (3), Fukasawa A. (4), Giribono A. (3), Giuliano L. (1)(2), Majernik N. (4), Mostacci A. (1)(2), Palumbo L. (1)(2), Rosenzweig J.B. (4), Spataro B. (3), Vaccarezza C. (3), Migliorati M. (1)(2)
(1) *La Sapienza University of Rome*
(2) *INFN, Sezione di Roma 1*
(3) *INFN, Laboratori Nazionali di Frascati*
(4) *University of California Los Angeles, USA*

Advanced experiments in the field of high-energy physics demand use of TeV-class linear colliders. The luminosity expected for such machines implies acceleration of intense electron/positron beams over the km length scale at high repetition rates. Similarly, the brilliance of particle driven radiation sources, such as FELs and Compton machines, relies on high-brightness electron beams delivered in multi-bunch mode. The operation of such types of machines exposes charged particles to a mutual parasitic interaction caused by the excitation of wakefields which takes place either within a single bunch or among different bunches. Such fields affect the phase space quality as well as the nominal beam trajectories and, thus, their effect has to be investigated carefully in order to ensure the required performance. Here we present a dedicated tracking code that accounts for both the short-range and long-range wakefield interaction in linacs. Such effects are described in terms of an efficient matrix formalism which reduces the computational times. Examples based on state-of-the-art linac facilities are shown and, in addition, techniques aimed to mitigate the wakefield effects are discussed.

On the transverse coherence of X-ray radiation from micron-sized electron beams.

Siano M., Paroli B., Potenza M.A.C.
Dipartimento di Fisica, Università degli Studi di Milano e INFN, Sezione di Milano, Milan, Italy

Light sources with finite physical size emit radiation endowed with limited transverse coherence. For light sources composed by many independent point-like emitters (also known as incoherent, or quasi-homogeneous, thermal sources), this is expressed by the well-known Van Cittert and Zernike theorem. Here we present the first systematic characterization of the transverse coherence properties of X-ray radiation emitted by micron-sized ultra-relativistic electron beams wiggling in an undulator, indicating deviations from the quasi-homogeneous model. Measurements are performed at the NCD-SWEET beamline at the ALBA Synchrotron Light Source by varying the vertical beam size below 10 micrometers. We use the Heterodyne Near Field Speckle technique to assess the full 2D transverse coherence of 12.4 keV and 16 keV X-ray radiation. We compare results with predictions relying on the Van Cittert and Zernike theorem, and with a more rigorous approach based on statistical optics. We also discuss relevance to third- and next-generation synchrotron light sources approaching the diffraction limit, where the electron beam emittance becomes comparable to, or smaller than, the radiation wavelength.

Aula C - Maria Gaetana Agnesi **ore 14:00 – 19:00**

Sezione VII

Didattica e storia della fisica

Presiedono: Di Martino D. (Università di Milano Bicocca)
Fazio C. (Università di Palermo)

Relazioni su invito

▲ **APP come APPrendere progettando e realizzando.**

Michelini M.
Dipartimento di Matematica, Informatica e Fisica dell'Università di Udine

Negli ultimi 5 anni abbiamo voluto interpretare la normativa di attuazione del PCTO come un'occasione per la messa in gioco di studenti liceali nella progettazione e realizzazione di esperimenti per le loro stesse scuole e per migliorare l'apprendimento della fisica. Ci siamo posti come datori di lavoro per lo studio di APP da utilizzare o realizzare a questo scopo ed abbiamo dato agli studenti diretta responsabilità progettuale e realizzativa. L'esperienza realizzata con numerose classi negli anni ha riguardato temi di meccanica, acustica, energia, fenomeni termici, ottica e spettroscopia ottica. Tra gli obiettivi vi era produrre esperienze utili all'educazione alla cittadinanza in campo scientifico avendo in mente gli obiettivi Horizon 2030. Ogni studente ha realizzato due compiti operando in una sequenza di fasi di impegno individuale e di gruppo. Gli insegnanti hanno saputo sostenere i ragazzi senza intervenire nel loro operato, realizzando una collaborazione con l'unità di ricerca in didattica della fisica che si è potenziata e sempre più qualificata, offrendo risultati interessanti da molti punti di vista.

▲ **PER me si va ne la fisica recente - Particle Escape Room.**

Montagna P. (1)(2), Aimè C. (1)(2), Armanetti A. (1), Aurelio D. (1)(3), Budassi E. (1)(2), Gianatti D. (1), Pirola M. (1)(2), Restelli S. (1), Santostasi D. (1)(4), Venturini S. (1)(2), Zatti L. (1)
(1) *Dipartimento di Fisica, Università di Pavia, Italia*
(2) *INFN Sezione di Pavia, Italia*
(3) *IIS "Faravelli", Stradella (PV) , Italia*
(4) *Liceo Ginnasio Statale "B. Cairoli", Vigevano, PV, Italia*

Si presenta l'escape room "PER me si va ne la fisica recente (Particle Escape Room)" ideata dal gruppo Physics4Teenagers del Dipartimento di Fisica dell'Università di Pavia in occasione del Festival della Scienza di Genova 2021 e poi riproposta nel 2022 in alcune scuole superiori a Piacenza e a Pavia. Grazie alla capacità di combinare apprendimento e divertimento, favorendo anche lo sviluppo di numerose competenze trasversali, il format dell'escape room educativa ha acquisito grande successo negli ultimi anni. L'escape room tematica sulla fisica delle particelle permette ai partecipanti di percorrere le cruciali tappe storiche che hanno condotto alla formalizzazione del Modello Standard e di accostarsi alle questioni ad oggi ancora aperte. In occasione del 700mo anniversario dantesco, si è scelta l'analogia del viaggio affidando a Democrito il ruolo di guida dall'antica Grecia fino alle conquiste della fisica recente. Il questionario di soddisfazione proposto ai partecipanti ha raccolto giudizi molto positivi. Con questo contributo si presentano in dettaglio le attività e i risultati, discutendo le proposte di miglioramenti e future installazioni.

▲ **Il percorso di formazione in fisica per insegnanti di scuola materna e primaria alla Libera Università di Bolzano: Presupposti teorici e aspetti pratici.**

Colletti L., Corni F.
Facoltà di Scienze della Formazione, Libera Università di Bolzano, Bressanone

Poiché la formazione universitaria dei futuri insegnanti di scuola elementare e materna è una realtà piuttosto recente, la questione di come la fisica debba venire loro insegnata costituisce un problema nuovo e di una certa urgenza, attualmente affrontato in modo molto diverso da ateneo ad ateneo. Alla Libera Università di Bolzano partiamo dal presupposto che per avvicinare i bambini alla comprensione della natura occorra basarsi sulle loro preesistenti competenze cognitive, come evidenziato dalla teoria della“embodied mind”. Schemi mentali come le polarità, il binomio contenuto-contenitore, l'idea di sostanza numerabile o fluida, ecc., sono metafore concettuali di uso trasversale e molto generale, radicate nell'incontro tra il corpo e la mente e capaci di favorire lo sviluppo del pensiero analogico. Viene proposto quindi un percorso didattico che guida i futuri insegnanti nell'esplorazione delle forze della natura e delle loro caratteristiche centrato su un approccio immaginativo, narrativo e metaforico, sia sul piano teorico quanto nell'allestimento di adeguate esperienze di laboratorio.

Comunicazioni

● **Fenomeni nucleari e didattica.**

Montalbano V.
Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena e INFN sezione di Pisa

La comprensione dei fenomeni nucleari dovrebbe essere uno strumento di conoscenza dei cittadini di ogni società contemporanea. La scoperta delle radiazioni ionizzanti e la loro caratterizzazione sono indissolubilmente legate alla definizione sperimentale del modello atomico nella forma attualmente accettata. Spiegare la struttura atomica ha richiesto di introdurre le interazioni che descrivono stabilità e instabilità dei nuclei atomici, rendendo la fenomenologia nucleare un punto essenziale nella fisica moderna. Ma l'intreccio tra eventi storici e scientifici del Novecento rende il tema nucleare centrale nella cultura contemporanea. Dal Progetto Manhattan alla guerra fredda, dagli esperimenti per sviluppare ordigni sempre più distruttivi all'uso pacifico dell'energia nucleare, dalla gestione dei rifiuti radioattivi agli incidenti nucleari, dall'uso diagnostico e terapeutico in medicina fino alle bombe sporche, sono molti i temi che possono essere sviluppati in percorsi didattici sia disciplinari che interdisciplinari. Alcuni esempi sperimentati in classe in attività di terza missione verranno descritte.

● **Impact of Beam Line for School on teaching activities at our school and the EXTRA experiment at DESY 2021.**

Muscarella M.F., Turbacci S.
Liceo Scientifico "A. Scacchi", Bari, Italy

Beamline for Schools (BL4S) is an annual international competition in high-energy particle physics for high school students, organized by CERN. The students are asked to propose an experiment that can be realized at a particle beam line. Experienced scientists evaluate the proposals and select two winning teams that are then invited to perform their experiments with the help of professional scientists. The winners of the 2021 edition, the team EXTRA from Italy and the team Teomitztli from Mexico were invited to perform their measurement at the DESY (Hamburg) test beam facilities. The EXTRA (Electron X-ray Transition RAdiation) experiment was aimed to study the energy spectra and the angular distribution of the transition radiation (TR) emitted by fast electrons crossing a regular radiator. From teacher's perspective the experience of mentoring a team has been extremely beneficial to our professional development. We will describe the effects that the participation in BL4S had on us, on our students and how it has impacted our approach to teaching STEM subjects.

Il caso ILVA: Esempio di un percorso interdisciplinare basato sulla metodologia IBSE.

Palazzo P. (1), Galano S. (2), Testa I. (2)
(1) *Liceo statale "G. Mazzini" di Napoli*
(2) *Dipartimento di Fisica "E. Pancini", Università degli studi di Napoli Federico II*

Tra i temi suggeriti nelle "Linee guida per l'insegnamento" dell'Educazione Civica e nell'Agenda 2030, vi è l'"educazione ambientale, sviluppo ecosostenibile e tutela del patrimonio ambientale", un argomento interconnesso all'educazione alla legalità, alla conoscenza dei valori costituzionali, ma anche ai diritti inalienabili dell'uomo e del cittadino. Affrontare tali tematiche senza banalizzarle, prevede una conoscenza non solo dei contenuti disciplinari ma anche della Natura della Scienza. Alla luce di ciò, è stato sviluppato un modulo didattico di insegnamento-apprendimento basato sulla metodologia didattica dell'IBSE incentrato sul tema dell'inquinamento e del risanamento ambientale nel caso dell'ILVA, molto sentito nelle zone di Napoli in cui è situato l'Istituto scolastico in cui in cui il modulo è stato sperimentato per la prima volta. Il modulo prevede di coinvolgere gli studenti in un dibattito finalizzato a decidere il destino dell'area in questione compiendo scelte il più possibile consapevoli e basate sui dati raccolti, scientifici o meno, e sulla ricostruzione dei fatti inerenti l'ILVA realizzata a partire dalle notizie, dai documenti dai giornali dell'epoca.

Methodological contribution to youth futures narratives analysis in STEM education.

Caramaschi M. (1), Barelli E. (1), Tasquier G. (1), Satanassi S. (1), Branchetti L. (2), Fantini P. (1), Levrini O. (1)
(1) *Department of Physics and Astronomy "A. Righi", University of Bologna, Italy*
(2) *Department of Mathematics "Federico Enriques", University of Milan, Italy*

In this era of uncertainty, future-oriented science education aims to support youth in facing future challenges. Physics education can play a central role, providing knowledge and abilities that lead to acquiring future-scaffolding skills. Our contribution is situated in FEDORA, a project that aims to create educational modules to study the impact of science on the students' future attitudes. Initial research has focused on analysing students' narratives to investigate their perception of the future. We contribute to the methodological reflection on the analysis of students' essays describing a typical day in 2040. We show how we got to operationalize the recognition of "polarization" and "complexification" attitudes toward SSI and complex themes. Discussing the limits of the current data collection tool, we introduce the design of a SenseMaker® questionnaire to collect future stories all around Europe. This tool has the dual potentiality to stimulate students to reflect on multiple factors that influence the future, seen as a complex system, and make data more intelligible and accessible to researchers and teachers. We will discuss some results and the methodological process.

Meteo Open Data @ School.

Piccione A. (1)(2), Massa A.A. (2), Marocchi D. (3), Serio M. (3)
(1) *Èquipe Formativa Territoriale per il Piemonte, Italia*
(2) *Ministero dell'Istruzione, Ufficio scolastico regionale per il Piemonte, Italia*
(3) *Dipartimento di Fisica, Università di Torino, Italia*

Nell'ambito dell'educazione alle tematiche ambientali sono state avviate in alcune scuole del secondo ciclo attività di misura di grandezze meteorologiche e del livello di inquinamento con strumentazione a basso costo. Il progetto nasce dalla collaborazione tra EFT - USR Piemonte e Dipartimento di Fisica dell'Università di Torino e si inserisce nell'ambito del Public Engagement: attraverso un'azione di dialogo e collaborazione tra ricercatori, studenti e insegnanti del territorio si riconfigurano gli spazi e i tempi dell'insegnamento e dell'apprendimento con un approccio che consente di introdurre metodologie didattiche attive e innovative. In questo contesto, si promuove il confronto tra le diverse procedure di misura, analisi e diffusione dei dati adottate dalle scuole già attive, si fornisce il supporto scientifico e didattico attraverso incontri di formazione dedicati, si stimolano la partecipazione di altre realtà scolastiche, con particolare attenzione alla progettazione in verticale su scuole di diversi ordini. Saranno presentati gli elementi più significativi del lavoro svolto e i risultati ottenuti nell'ultimo anno di progetto.

Indagine sulle conoscenze di fisica in ingresso nei Corsi di Laurea scientifici di Roma Tre.

Postiglione A., De Angelis I.
Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre, Italia e INFN, Sezione di Roma Tre, Italia

In questo intervento presenteremo l'indagine che abbiamo realizzato all'Università di Roma Tre per sondare le conoscenze di fisica in ingresso degli studenti iscritti al primo anno dei Corsi di Laurea scientifici dell'Università. Le domande sottoposte ai partecipanti prima di seguire le lezioni di Fisica 1, tratte in parte dalla letteratura in didattica della fisica, hanno riguardato la meccanica, la termologia e la gravitazione. Nell'intervento presenteremo i risultati ottenuti, ed in particolare confronteremo le risposte degli studenti e delle studentesse iscritti al primo anno di Fisica, Matematica, Ingegneria, Biologia, Geologia, Scienze per la protezione della natura e la sostenibilità ambientale.

Luce al liceo scientifico: Un percorso laboratoriale per i 5 anni.

De Angelis I.
Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre, Italia e INFN, Sezione di Roma Tre (^{ITALY})

La luce è un ottimo organizzatore concettuale utile ad affrontare la didattica di numerosi argomenti di fisica proposti abitualmente durante i cinque anni di liceo scientifico. In questo intervento illustrerò una proposta che pone il laboratorio di fisica al centro della metodologia didattica del docente usando la luce come filo conduttore per i cinque anni. Gli esperimenti inseriti in questo percorso sono stati progettati, testati e ottimizzati nell'ambito del progetto LS-OSA, e fanno parte delle oltre 120 schede di esperimenti di fisica ora raccolte anche nel libro "Fare Laboratorio. Guida alla didattica esperienziale" dedicato ai docenti di scuola secondaria superiore.

Simulazioni computazionali e competenze di futuro: Il ruolo della ricerca in didattica delle discipline STEM.

Barelli E.
Dipartimento di Fisica e Astronomia "Augusto Righi" - Alma Mater Studiorum, Università di Bologna

Da quando, con l'emergenza climatica e la pandemia, le simulazioni computazionali, già largamente usate nella ricerca scientifica, sono uscite dagli ambienti accademici per divenire parte del dibattito pubblico, si è fatta urgente una seria riflessione in ambito educativo per formare studenti, insegnanti e cittadini a comprendere la portata metodologica, epistemologica e sociale di tali strumenti. Nella comunicazione verranno presentati i principali risultati di una tesi di dottorato volta a: i) individuare le difficoltà che diversi gruppi di non-esperti incontrano con le simulazioni di sistemi complessi; ii) mettere a punto una ricostruzione concettuale interdisciplinare in prospettiva didattica delle simulazioni equation-based ed agent-based; iii) progettare, realizzare ed analizzare i risultati di moduli didattici per la formazione iniziale degli insegnanti e per studenti di scuola secondaria. Si metterà in luce come i partecipanti abbiano sviluppato non solo conoscenze tecniche legate alla comprensione dei modelli matematici e computazionali, ma anche future-scaffolding skills, ovvero competenze strutturali e dinamiche per analizzare il presente e proiettarsi nel futuro.

STEM e CS (Citizen Science) nella Scuola Progettazione e realizzazione del prototipo di una stazione di rilevamento per la raccolta e condivisione di dati sull'ambiente.

Grosso D. ([1]), Cavicchi V. ([2])
([1]) *University of Genoa, Department of Physics*
([2]) *MIUR*

L'introduzione nella scuola di strumenti open source come arduino consente di realizzare progetti articolati e di sviluppare competenze in un contesto costruttivista, interdisciplinare e collaborativo che promuove e sviluppa competenze di base e soft skill. Questo progetto consiste nella progettazione e realizzazione del prototipo di un dispositivo per la raccolta di dati ambientali geolocalizzati in grado di connettersi alla rete ed inviarli an un server remoto capace di condividerli per consentire la loro consultazione e la realizzazione di analisi statistiche. Alcuni studenti installeranno presso la loro abitazione i dispositivi realizzati e questi rileveranno parametri ambientali anche per la valutazione della presenza di inquinanti. I dati saranno analizzati dagli studenti, interpretati ed utilizzati come base per la realizzazione di analisi e modelli, coinvolgendo insegnanti di più discipline. Dati e risultati saranno presentati in un sito web mantenuto dagli studenti.

Didattica a distanza come conseguenza della pandemia da COVID-19: come la valutano gli studenti di ingegneria e cosa influenza il loro giudizio.

Bozzi M. ([1]), Mazzola R. ([1]), Testa I. ([2]), Brambilla F. ([3]), Zani M. ([1])
([1]) *Dipartimento di Fisica-Politecnico di Milano*
([2]) *Dipartimento di Fisica-Università degli Studi di Napoli*
([3]) *METID-Politecnico di Milano*

Nel marzo 2020 la crisi sanitaria dovuta alla pandemia da Covid-19 ha imposto la chiusura delle università in tutto il mondo e il passaggio dalla didattica in presenza a quella a distanza. Allo scopo di indagare gli effetti della didattica in remoto sul percorso di apprendimento degli studenti del Politecnico di Milano, nel luglio 2021 è stato loro erogato un questionario costituito da 66 domande e focalizzato su diversi costrutti. Diversamente da ricerche precedenti, questo studio, ha indagato un effettivo apprendimento online, ha coinvolto un numero grande di partecipanti, più di 3000, sia iscritti a corsi di Laurea sia a corsi di Laurea Magistrale. Inoltre, i dati raccolti sono stati analizzati mediante tecniche di statistica inferenziale. Questa ricerca ha consentito di valutare come sia cambiato il giudizio dato dagli studenti nel passaggio dalla didattica in presenza a quella a distanza e come tale cambiamento abbia influito in termini di strategie metacognitive e di autoefficacia adattiva. È stata, inoltre, indagata la dipendenza dei risultati da alcuni predittori, quali il genere, il livello accademico degli studenti e la loro esperienza in ambito universitario.

Radioattività ambientale: Percorso interdisciplinare tra matematica e fisica.

Longo F. ([1])([2]), Bologna V. ([1]), Diaz Guerra F. ([1]), Ravasi S. ([3])
([1]) *Dipartimento di Fisica, Università di Trieste*
([2]) *INFN, Sezione di Trieste*
([3]) *Liceo Scientifico Statale "G. Oberdan", Trieste*

Come può un percorso sulla radioattività ambientale aiutare a superare le difficoltà che i docenti incontrano nell'integrazione fisica/matematica? Allo scopo abbiamo ideato per due classi quinte di un Liceo Scientifico una serie di attività che integrino rappresentazioni disciplinari multiple nell'intento di introdurre l'uso di esponenziali e logaritmi nella descrizione dei fenomeni radioattivi. Nel suo sviluppo sono stati considerati come riferimento teorico la coniugazione dell'interazione fisica/matematica e una declinazione *inquiry-based* per le attività laboratoriali di tipo informatico ed esperienziale. Dovendo coniugare il percorso con le restrizioni per la situazione pandemica, è stato creato *ex-novo* un simulatore virtuale che riproducesse fedelmente il funzionamento di un analizzatore multicanale del 1981, effettivamente utilizzato poi per le misure di radioattività ambientale. Pluralità dei linguaggi utilizzati e delle modalità di approccio hanno sviluppato negli studenti interesse e partecipazione, confermata in fase conclusiva di valutazione.

Esperienze di didattica della fisica con il metodo IBSE nella Scuola Primaria.

Confalonieri I. ([1]), Onida M.C. ([1]), Di Martino D. ([2])
([1]) *Dipartimento di Scienze Umane per la Formazione, Università degli Studi di Milano Bicocca*
([2]) *Dipartimento di Fisica, Università degli Studi di Milano Bicocca*

Il percorso che verrà descritto, incentrato sulla didattica dell'astronomia, è stato proposto ai bambini di una classe V di una Scuola Primaria, per verificare se l'approccio metodologico basato sul metodo IBSE potesse aumentare nei bambini l'interesse nei confronti di discipline come la fisica e sviluppare in loro competenze scientifiche significative e durature nel tempo. La metodologia ormai nota nella letteratura sulla didattica delle scienze è basata sull'Inquiry, prevedendo dunque momenti di discussione intorno ad una situazione problema, individuazione di domande e di possibili percorsi di ricerca, formulazione di ipotesi, progettazione e realizzazioni di esperimenti e indagini, analisi dei dati, costruzione di modelli, argomentazione e confronto coi compagni. Il percorso di ricerca ha avuto una durata di circa 40 ore, focalizzandosi sulla Luna e sui principali fenomeni che la riguardano: luce e ombre, fasi lunari, eclissi e relazioni spazio-temporali tra i corpi celesti coinvolti. Verranno descritte le metodologie utilizzate, le principali attività, le modalità di documentazione, evidenziando i punti di forza e di debolezza riscontrati durante il percorso.

Aula B - Maria Goeppert-Mayer **ore 09:00 – 13:30**

Sezione I
Fisica nucleare e subnucleare
Presiedono: Chiarelli G. (INFN Sezione di Pisa)
Tosi M. (Università di Padova)

Perfomance and Detector @LHC

Relazioni su invito

▲ **LHC Run3 status and first preliminary results.**

Tosi M. (1)(2), De Sanctis U. (3)(4)
(1) *Dipartimento di Fisica e Astronomia, Università di Padova, Italia*
(2) *INFN, Sezione di Padova, Italia*
(3) *Dipartimento di Fisica, Università di Roma II, Italia*
(4) *INFN, Sezione di Roma II, Italia*

The new LHC Run3 phase started in 2022 after a three years of Long Shutdown, reaching the highest centre-of-mass energy of proton-proton collision and with the plan of maximizing the delivered luminosity to the experiments by keeping the instantaneous luminosity at $2 \times 10^{34}\,\mathrm{Hz\,cm^{-2}}$ for several hours. Both the ATLAS and CMS experiments upgraded their detectors, electronics, trigger system and software for the event reconstruction in order to cope with such an unprecedented scenario and keep (or even improve) the physics reach. The status of the ATLAS and CMS detectors and the performance of the physics objects reconstruction in Run3 will be described. In addition, the first preliminary results will be presented.

▲ **The CMS Phase2 upgrade: the MTD detector.**

Malberti M. per la CMS Collaboration
INFN, Sezione di Milano Bicocca

The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector in CMS will measure minimum ionizing particles (MIPs) with a time resolution of 30–40 ps for MIP signals at a rate of 2.5 Mhit/s per channel at the beginning of HL-LHC operation. The precision time information from this MIP Timing Detector (MTD) will reduce the effects of the high levels of pileup expected at the HL-LHC, bringing new capabilities to the CMS detector. The MTD will consist of a central part, the barrel timing layer (BTL), based on LYSO:Ce crystals coupled to silicon photomultipliers, and an endcap region, the endcap timing layer (ETL), instrumented with low-gain avalanche diodes (LGADs). In this contribution we present an overview of the MTD design, describe the latest progress towards prototyping and production, and show test beam results demonstrating the achieved target time resolution.

▲ **Studi di di-bosoni e di-Higgs a LHC.**

Lenzi P. (1), Betti A. (2)
(1) *Università degli Studi di Firenze*
(2) *Sapienza Università di Roma e INFN, Sezione di Roma1*

Sono presentati i risultati recenti degli esperimenti ATLAS e CMS nel campo dello studio di stati finali con coppie di bosoni, includendo la produzione non risonante, quella risonante tramite bosone di Higgs, la ricerca di nuove particelle e la produzione associata VH. I risultati mostrati si basano ove possibile sull'analisi dell'intero campione di dati raccolti nel Run 2 di LHC, a 13 TeV di energia nel centro di massa. Sono presentati inoltre i risultati relativi alla produzione di coppie di bosoni di Higgs, sia nel contesto della ricerca di nuove risonanze, sia nell'ambito della misura dell'autoaccoppiamento del bosone di Higgs e dell'accoppiamento quartico con due bosoni vettori $VVHH$.

Comunicazioni

Redefinition of the RAW data format in pp collisions for CMS Run 3.

Brusamolino A.
Dipartimento di Fisica, Università di Milano-Bicocca, Italia e INFN, Sezione di Milano-Bicocca, Italia

Redefining the RAW data format using semi-processed information to reduce the event size to disk. A notable example will be the Run 3 Heavy Ion runs. The tracker digits will be dropped from the RAW event and replaced with a new tracker data format. At HLT the tracker clusters are produced, the barycenter is calculated and only this value is stored in the new RAW data format instead of the list of the silicon strip amplitudes. Preliminary studies show a size reduction of 20–25% of the whole data with respect to the traditional RAW storage scheme. Dedicated studies on physics performances, in particular tracking ones, have been performed using 2018 data and $t\bar{t}$ Monte Carlo samples. Such an approach, or similar ones, could be beneficial also for very busy proton-proton events, characterised by a high pile-up level, such as the one in the HL-LHC era.

Calibration of b-tagging algorithm of Variable Radius Track-Jets using Tag and Probe method with semileptonic $t\bar{t}$ events.

Santi L.
University of Rome "La Sapienza", CERN e INFN, Roma1

Flavor tagging, namely the identification of the parton flavor (b/c/others) initiating a jet, is one of the fundamental ingredients for many analyses in ATLAS. In particular b-tagging is a combination of Machine Learning algorithms aiming to identify jets originating from the bottom quark. The performances and the efficiency of these algorithms are evaluated on Monte Carlo simulations and then applied to data. For these reasons, we need data-to-MC calibrations for these algorithms. In general, to calibrate the b-tagging algorithm on b-jets we need a pure sample enough before the application of the tagging algorithms itself, for this reason, $t\bar{t}$ samples are suitable for this task. In this presentation, the calibration of b-tagging efficiency for Track-Jets with Variable Radius is presented. These are created by applying an anti-k_t algorithm, with a variable radius, only to the tracks in the events. The calibration is performed using $t\bar{t}$ events with a single lepton in the final state using a Tag and Probe method. The results are combined with an orthogonal measurement of the b-tagging efficiency to provide the optimal coverage as a function of the b-jet transverse momentum.

Geometric deep learning algorithms for tau lepton identification in the ATLAS experiment at the LHC.

Fiacco D.
INFN, Sezione di Roma e Dipartimento di Fisica, Università di Roma La Sapienza, Italia

The tau lepton is involved in many final states of Standard Model processes in proton-proton collisions at the LHC. It also appears in many signatures of predicted new physics beyond the Standard Model. As it decays predominantly to hadrons, it is essential to have a faithful reconstruction and identification of hadronic tau lepton decays, and a strong suppression of backgrounds. In the last few years geometric deep learning techniques have become the state of the art of many different tasks. For this reason in this contribution they are presented in different and recent geometric DL models to discriminate hadronic tau decays from noise given by QCD processes. A focus is given on the different approaches of the presented algorithms and on how their peculiar aspects influence the performances.

Comparison of track properties between Data and MC at CMS using early Run-3 data.

Bruschini D.
Scuola Normale Superiore di Pisa, Italia e INFN, Sezione di Pisa, Italia

It is of great importance to check the agreement of reconstructed track properties between Data and Monte Carlo simulation using the CMS Tracker Detector. This is necessary to verify the ingredients used to produce large simulated event samples used for physics analysis, but also to benchmark promptly the reconstruction performance against simulation-based expectations. A validation tool within the CMS Data Quality Monitoring (DQM) framework was developed for that purpose, allowing to select different kinds of physics events and study in detail the track parameters. The tool complements the official DQM application and provides prompt feedback on track reconstruction performance during data taking. Comparisons have been produced using data from the early phase of the LHC Run 3, including collisions at the LHC injection energy of 900 GeV and the first 13.6 TeV beam data. A description of the tool along with its various components will be shown and some preliminary comparison of the most relevant tracking-related physics observables used for assessing the description of the CMS tracker simulation and calibrations will be presented.

CMS tracking performance in the early Run 3 data using the tag-and-probe technique.

D'Anzi B.
Dipartimento di Fisica, Università di Bari, Italia e INFN, Sezione di Bari, Italia

Accurate reconstruction of charged particle trajectories and measurement of their parameters (tracking) is one of the major challenges of the CMS experiment. A precise and efficient tracking is one of the critical components of the CMS physics program as it impacts the ability to reconstruct the physics objects needed to understand proton-proton collisions at the LHC. In this contribution, we present the tracking performance measured in data where the tag-and-probe technique was applied to $Z \longrightarrow \mu^+\mu^-$ di-muon resonances for all reconstructed muon trajectories and the subset of trajectories in which the CMS Tracker is used to seed the measurement. The performance is assessed using early LHC Run 3 data at $\sqrt{s} = 13.6$ TeV.

Misura di performance di rivelatori a tripla GEM su Test Beam.

Stamerra A., Pellecchia A., Verwilligen P.
Dipartimento di Fisica, Università degli Studi di Bari "Aldo Moro", Italia

I rivelatori a tripla GEM rientrano tra le più moderne tecnologie di rivelazione per la fisica delle alte energie. Grazie alle buone performance in termini di efficienza di rivelazione e resistenza alla radiazione, questi rivelatori sono adatti ad essere utilizzati negli esperimenti ai futuri collisionatori nel regime multi-TeV nei sistemi di rivelazione dei muoni o come layer attivi del calorimetro adronico. L'ottima risoluzione spaziale e temporale permette infatti di raggiungere alte precisioni nella ricostruzione di tracce di particelle cariche. Questo contributo mostra le misure di performance di prototipi di piccola area di rivelatori a tripla GEM ad alta risoluzione spaziale, ottenute durante l'RD51 Test Beam nel 2021. Tali rivelatori hanno uno speciale piano di lettura dei segnali, costituito da due piani di strip disposte ortogonalmente tra loro e aventi passo di circa 260 micron, per una risoluzione spaziale attesa di circa 75 micron. Quattro prototipi di questo tipo sono stati quindi utilizzati come telescopio per il tracciamento del fascio durante il Test Beam, effettuato per testare l'integrazione delle camere di GE2/1 di CMS con l'elettronica di acquisizione di CMS.

Status of the commissioning of the CMS GE1/1 station.

Calzaferri S.
Dipartimento di Fisica, Università di Pavia, Italia e INFN, Sezione di Pavia, Italia

In December 2018 the Large Hadron Collider entered the Long Shutdown 2 phase, dedicated to the upgrade and maintenance of the infrastructures. In order to maximize the collision data statistics collected by the experiments, the High-Luminosity LHC will increase the instantaneous luminosity up to a factor 5–7 with respect to the original LHC design. To cope with this, the LHC experiments must be upgraded, and in particular, the CMS experiment has begun the installation of detectors based on triple-GEM technology, which aims at keeping under control the trigger rate in the high-pseudorapidity region, sustaining a high level of radiation while maintaining their design performance and increasing the redundancy for muon track reconstruction. In this contribution the status of commissioning of GEM detectors in CMS will be illustrated, focusing in particular on the role played by HV trips in the chamber operation and on the strategies adopted to minimize their occurrence to grant smooth operation. In addition, the operation of these detectors in the presence of magnetic field ramps will be presented, illustrating phenomena observed in CMS and in a dedicated test set up in the CERN North Area.

Neural network techniques for charged particles reconstruction in ATLAS New Small Wheels.

Carnesale M.
Sapienza Università di Roma e INFN, Sezione di Roma 1

The reconstruction of charged particles inside a detector is one of the most challenging computational problems for modern particle physics experiments. In particular, the extremely high rate of particles impinging in the detectors requires the development of innovative pattern recognition methods able to be efficient in highly dense environments. Due to the high luminosity values that LHC will reach during the Run-3 and the HL-LHC phase, the number of interactions per bunch crossing will increase, consequently increasing the detector's occupancy. For the traditional tracking algorithms used in high-energy physics, a too high occupancy constitutes a limit, both in terms of performances and processing time. New strategies for particle tracking based on machine learning techniques are presented, showing results on simulated samples and their application to the new ATLAS detectors, the New Small Wheels. In particular, the development of a DNN for position reconstruction and of a RNN for pattern finding will be discussed. These algorithms have great potential thanks to their capability to identify complex correlation in data and to parallelize operations on architectures such as FPGAs.

New small wheel micromegas trigger simulation analysis.

Montereali F.
Dipartimento di Matematica e Fisica, Università Roma Tre, Italia e INFN Sezione di Roma Tre, Italia

The ATLAS New Small Wheels (NSW) utilize two innovative detector technologies: the small strip Thin Gap Chambers (sTGC) and the Micromegas (MM) for trigger and precision tracking at the high particle rates expected for the High-Luminosity LHC phase. The simulation of both sTGC and MM trigger was implemented, and performance evaluated in different configurations, serving as a crucial input for the optimization and hardware implementation of the trigger logic. This contribution will present the results from the MM trigger simulation analysis, the optimization of the angular variable reconstruction, and the definition of Region-of-Interest (RoI) and segments for the coincidences with other stations of the spectrometer. Monte Carlo samples including pile-up and cavern background simulation are also used to evaluate trigger rates with the expected background conditions.

Studies of eco-friendly gas mixture for RPC detectors at CERN LHC experiments.

VERZEROLI M. ([1]), RIGOLETTI G. ([2]), MANDELLI B. ([2]), GUIDA R. ([2])
([1]) *Dipartimento di Fisica, Università degli Studi di Pavia, Italia*
([2]) *CERN, Ginevra, Svizzera*

The resistive plate chamber (RPC) detectors at CERN LHC experiments are operated with a freon-based gas mixture, containing $C_2H_2F_4$ and SF_6, both greenhouse gases (GHG) with a very high global warming potential. The European Union defines a set of regulations aiming at reducing the GHG emissions from fluorinated gases. These regulations could bring lower availability and higher costs in the future. The aim of this contribution is to study new eco-friendly gas mixtures that are compatible with the current CERN RPC systems and that allow a good detector performance. Some alternatives to $C_2H_2F_4$ and to SF_6 were tested, such as CO_2, He, HFO1234ze and Novec 4710. First, a characterization with cosmic muons was done by evaluating the detector efficiency, currents, streamer probability, prompt charge, cluster size and time resolution. Then, the RPC performance was evaluated at CERN Gamma Irradiation Facility where a 12 TBq ^{137}Cs source and a muon beam allow to simulate the LHC experiment radiation background. The substitution of 30% R134a concentration with He or CO_2 does not imply any change in RPC performance. Moreover, the Novec 4710 is promising as a SF_6 substitute with 0.1% concentration.

Measurement of the Paschen curves for the ATLAS NSW micromegas electrodes, for pure Ar and CO_2 gases, and for gas mixtures Ar:CO_2 and Ar:CO_2:IsoC_4H10.

SCHIOPPA M., SCHUNE P., LAPORT J.-F.
Gruppo Collegato di Cosenza e UNICAL, Arcavacata di Rende

The Paschen curves give the breakdown voltage between two electrodes as a function of the distance between them. In this communication we present the Paschen curves for different pure gases and gas mixtures, when the electrodes are those of the ATLAS NSW micromegas detectors, *i.e.*, the resistive strips and a stainless-steel mesh.

Construction of a cosmic-ray telescope with small-scale CMS Drift Tubes Chambers.

PAGGI G.
Dipartimento di Fisica e Astronomia, Università di Bologna, Italia e INFN, Sezione di Bologna, Italia

A cosmic-ray telescope has been set up in INFN Bologna using two small-scale versions of the CMS detector Drift Tubes Chambers, called “miniDTs”. The miniDTs, built at INFN Legnaro with original materials from the CMS construction, are identical to CMS Drift Tubes in cell geometry, high-voltages, gas, and front-end electronics, while custom high- and low-voltage connectors and powering modules were developed. The chambers are read out with prototype triggerless electronics being developed for the Phase2 upgrade of CMS. Signals from scintillator planes coupled to PMTs are also read out as time references for muons crossing the system, enabling detailed analysis of the chamber performance in terms of efficiency and resolution. The miniDT construction and the main features of the telescope setup will be outlined, and performance results obtained from a sample of cosmic-ray data will be presented.

Predictions for the azimuthal modulations in di-J/ψ production for the fixed-target experiments at LHC.

COLPANI SERRI A. (1), LANSBERG J. P. (2), BOR J. (2)(3), PAPPALARDO L.L. (1)
(1) *Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara, Italia*
(2) *IPNO, CNRS-IN2P3, Université Paris-Saclay, France*
(3) *Van Swinderen Institute for Particle Physics and Gravity, University of Groningen, The Netherlands*

Quarkonium production processes constitute rising tools for the exploration of sub-hadronic physics. Specifically, the production of a J/ψ-pair in a fixed-target experiment at LHC is a promising process to explore the gluon transverse momentum distributions (gTMDs), which are still very poorly known. The deep study of azimuthal modulations, arising in the cross-section of such a process from the linear polarization of gluons inside unpolarized protons, including the TMD evolution in the computation, gives improved results in this field and provides a phenomenological basis for future measurements, *e.g.*, at the LHCb experiment with the SMOG2 fixed-target apparatus. The methodology of the computation is presented along with the first results for this channel at center-of-mass energy $\sim 115\,\mathrm{GeV}$.

High-energy resummation in Higgs production at NLL.

FUCILLA M.
Università della Calabria, Arcavacata di Rende

Precision physics in the Higgs sector has been one of the main challenges in the recent years. The pure fixed-order calculations entering in the *collinear factorization* framework, which have been pushed up to N3LO, are not able to describe the entire kinematic spectrum. In particular conditions, they must be necessarily supplemented by all-order *resummations*; for instance, in the so-called *Regge* kinematical region, large energy-type logarithms spoil the perturbative behavior of the series and must be resummed to all orders. This resummation, which can be done in the NLL through the *BFKL* approach, is necessary to describe the inclusive hadroproduction of a forward Higgs in the limit of small Bjorken x, and also to study inclusive forward emissions of a Higgs boson in association with a backward identified object. We first present the full NLO result for the production of a forward Higgs boson, obtained in the infinite top-mass limit. Then, the possible extension of this calculation to the case of Higgs impact factor via gluon fusion in the central-rapidity region is also discussed.

Fermion mixing from finite modular groups.

MELONI D.
Dipartimento di Matematica e Fisica, Roma Tre

The "flavor problem" represents one of the greatest challenges of particle model building since SM does not provide "*a priori*" explanation neither of the number of fermion generations nor on their mass and mixing patterns, which appear to be very different in the lepton and quark sector. Discrete non-Abelian symmetries have gathered a lot of attention as candidates for the solutions of the latter problems. In this presentation, I will revise the latest results achieved by Modular Symmetries in the description of fermion masses and mixings, showing that this recently proposed framework is particularly suitable for a unified description of leptons and quarks.

Bubble wall dynamics at the electroweak phase transition.

GUIGGIANI A. (1)(2), DE CURTIS S. (1)(2), DELLE ROSE L. (3), GIL MUYOR Á. (4)(5), PANICO G. (1)(2)
(1) *INFN, Sezione di Firenze, Italia*
(2) *Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Italia*

([3]) *Dipartimento di Fisica, Università della Calabria, Arcavacata di Rende, Italia*
([4]) *IFAE, Universitat Autònoma de Barcelona, Spain*
([5]) *BIST, Barcelona, Spain*
Bubble nucleation is a key ingredient in a cosmological first-order phase transition. The non-equilibrium bubble dynamics and the properties of the transition are controlled by the density perturbations in the hot plasma. We present, for the first time, the full solution of the linearized Boltzmann equation. Our approach, differently from the traditional one based on the fluid approximation, does not rely on any ansatz. We focus on the contributions arising from the top quark species coupled to the Higgs field during a first-order electroweak phase transition. Our results significantly differ from the ones obtained in the fluid approximation with sizeable differences for the friction acting on the bubble wall.

Study of transverse-momentum–dependent parton distribution functions.

ROSSI L., BACCHETTA A.
Dipartimento di Fisica, Università di Pavia, Pavia, Italy e INFN, Sezione di Pavia, Pavia, Italy
The dynamics and the interactions between quarks and gluons are governed by the theory of Quantum chromodynamics (QCD), which exhibits asymptotic freedom. Two examples of high-energy processes are the Semi-Inclusive Deep Inelastic Scattering (SIDIS) and the Drell-Yan process. These are very interesting because, thanks to different factorization theorems, we can write their cross-sections in a factorized way by using the Transverse-Momentum–Dependent Parton Distribution Functions (TMD-PDFs) and Fragmentation Functions (TMD-FFs). These functions are crucial in understanding the three-dimensional structure of hadrons, because they give us information about their internal structure. For example, the TMD-PDFs give us the joint probability density of finding a particle with a certain fraction x of nucleon momentum and transverse momentum k_T inside the hadron. Moreover, these functions can be written as a product of a perturbative part, which has already been calculated at different orders, times a non-perturbative part, which can be extracted from the experimental data. We will present some results obtained from the extractions we have done regarding it.

Aula D - Marianna Ciccone **ore 09:00 – 13:30**

Sezione II

Fisica della materia

Presiedono: Bottegoni F. (Politecnico di Milano)
Picozzi S. (SPIN-CNR, Chieti)

Magnetism and superconductivity

Relazioni su invito

▲ ***In silico* synthesis of new high-T_c conventional superconductors.**

Boeri L.
Dipartimento di Fisica, Sapienza Università di Roma

The discovery of near-room-temperature superconductivity in high-pressure superhydrides has revolutionized the landscape of superconducting material research, establishing *ab initio* calculations as the tool of choice for predicting superconducting properties and synthesis conditions of new superconductors. In this contribution, I will give an overview of our recent efforts to design high-T_c conventional superconductors that can operate at ambient pressure and to explore metastable phases of multinary phase diagrams and assess the kinetic stability of promising metastable phases.

Comunicazioni

● **Electric field modulation of spin transport.**

Zucchetti C. (1), Marchionni A. (1), Bollani M. (2), Grassi P. (2), Ciccacci F. (1), Finazzi M. (1), Bottegoni F. (1)
(1) *LNESS-Dipartimento di Fisica, Politecnico di Milano, Milan, Italy*
(2) *Istituto di Fotonica e Nanotecnologie del Consiglio Nazionale delle Ricerche, Milan, Italy*

The finite spin lifetime in solids is often considered a major hindrance for the development of spintronic devices. In this contribution, we show that this feature can instead be exploited to realize a scheme where spin transport is modulated at room temperature by a modest electric field. To prove this concept, we employ a nonlocal spin-injection/detection scheme that enables one to directly investigate drift-diffusive spin transport at room temperature with a device-oriented architecture. We show that a finite spin-diffusion length combined with the application of an electric field can be capitalized to manipulate spin accumulation. We find that applying an electric field $E = 24\,\mathrm{V/cm}$ along a $40\,\mu$m-long path in germanium results in about one order of magnitude modulation of the spin-polarized electrons entering the detector. Moreover, in the best-case scenario, we directly image a spin-transport length of $40\,\mu$m. Comparable values in semiconductors have been predicted and observed only at cryogenic temperatures. Hence, our work demonstrates that electric fields can be exploited for guiding spins over macroscopic distances and for realizing room temperature modulation of spin accumulation.

● **Advanced electrical characterization of spin transport in ferroelectric Rashba semiconductor GeTe.**

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The energy consumption of information and communication technology is constantly increasing and close to turn unsustainable. An engaging approach towards ultra-low power devices beyond-CMOS has been delineated by Intel in avantgarde scientific works. They underlined the potential of materials characterized by collective states of matter (such as ferromagnets and ferroelectrics) in combination with dissipation-less spin currents. We aim at investigating ferroelectric Rashba semiconductors (FERSC) like GeTe and SnTe, as they have shown an enormous potential in this context, thanks to the intrinsic link between ferroelectric polarization and spin Hall effect, which enables the non-volatile ferroelectric control of spin-to-charge conversion. Here we combine conventional e-beam lithography with the innovative thermal scanning probe lithography to demonstrate ground-breaking devices, allowing for quantification of spin-to-charge conversion efficiency and spin diffusion length. Starting from a material science perspective, this research will show how ferroelectric polarization and spin can play a role towards beyond-CMOS devices capable of non-volatile computing.

Three-dimensional nanoscale imaging of propagating spin waves via time-resolved X-ray Laminography.

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Spin waves are wave-like perturbations of the magnetization, in which the magnetic moments precess around their axis. Since their travelling is not associated to charge motion, they hold the promise to strongly reduce the power consumption, while having sub-μm wavelengths in the GHz–THz frequency range allows the miniaturization of spin wave-based devices. Their measurement with 3D resolution is a key point for the improvement of the comprehension of spin waves. Until now, however, spin waves have only been studied with 2D time-resolved techniques, and their 3D visualization still represents a major challenge. Here, we exploit the innovative Soft X-Ray Laminography method, present at the PolLux beamline of the Swiss Synchrotron Light Source that allowed to reconstruct for the first time the sequence of 3D time-resolved images of propagating spin-wave modes and to study the variation of their localization in the z-direction. This work represents an important step towards the possibility to study and control three-dimensionally the spin waves emission and propagation for the development of innovative 3D nanomagnonic devices for the next-generation computing architectures.

Peculiar magnetic properties of Fe/Ni multilayers on Fe(001)-$p(1 \times 1)$O by spin-resolved photoemission spectroscopies.

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We present a structural and spectroscopic characterization of Ni and Fe multilayers grown on bcc Fe. The substrate is treated in order to form an oxygen superstructure, namely the Fe-$p(1 \times 1)$O surface. The presence of an oxygen overlayer, capable of floating at the Ni/Fe sample surface even at room temperature, contributes to a peculiar morphological evolution and intervenes in the structural relaxation of the metastable Ni overlayer. We investigate the magnetic properties of the multilayer, at each step of the growth, by the combined use of *in situ* spin-resolved photoemission spectroscopy (SR-PES) and inverse photoemission spectroscopy (SR-IPES). A strong decrease of the spin polarization is observed as the thickness of the bcc Ni layer increases, with a clear quenching of the magnetization at 6 ML of Ni. When iron is deposited on 6 ML Ni, there is an abrupt restoration of the spin polarization, even at one monolayer coverage, as also obtained from density functional theory (DFT) calculations. In addition, we observe the disappearance of a feature related to majority electrons above the Fermi level, directly linked to the presence of the underlying buffer layer.

Tuning electronic and magnetic properties of ultrathin and bulk magnetic oxides by adsorption of organic molecules.

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The surface of a magnetic material plays an important role in defining the electronic and magnetic properties of hybrid organic-inorganic interfaces for application in spintronic devices. We present first-principles density functional theory (DFT) methods to investigate the interface formed by a C_{60} molecular layer on a Fe(001) surface covered by a two-dimensional Cr_4O_5 layer showing that the latter enhances the induced magnetic moment on the molecules by a slower decay of the spin polarization in vacuum with respect to the pristine surface. We also show that the local hybridization between the electronic states of the Cr_4O_5 layer and those of the organic molecules is able to modify the magnetic coupling of the Cr atoms: molecules turn the ferromagnetic intra-layer coupling into an antiferromagnetic one; further patterning of the substrate spin polarization can be achieved by controlling the adsorption site. We then investigate by Hubbard-corrected DFT + U calculations the surface of bulk transition metal monooxides and their electronic and magnetic properties in the near surface region, studying the interaction with adsorbed molecules with/without intrinsic magnetic character.

The origin of magnetism in a supposedly nonmagnetic osmium oxide.

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(4) *Dipartimento di Fisica e Astronomia, Università di Bologna, Italia*
(5) *Brown University, Providence, RI, USA*
(6) *European Synchrotron Radiation Source, Grenoble, France*
(7) *Faculty of Physics and Center for Computational Materials Science, University of Vienna, Austria*
(8) *Ohio State University, OH, USA*

Despite the fact that a system characterized by a $5d^1$ spin-orbit-coupled electronic configuration should be nonmagnetic and metallic, Ba_2NaOsO_6 is a Mott insulator and develops a canted antiferromagnetic long-range order. *Ab initio* quantum chemical calculations show that, even for perfectly cubic environment, the strong Os $5d$-O $2p$ hybridization (covalency) generates a finite magnetic moment; but mostly, Jahn-Teller effects reduce the local site symmetry and enhances the magnetic moment. Here we probe $Ba_2Na_{1-x}Ca_xOsO_6$ by means of resonant inelastic X-ray scattering (RIXS) at the Os L_3 edge in order to access its electronic structure directly and monitor d-d and charge-transfer excitations as fingerprints of the effective ligand field symmetry and strength. We extract quantitative information on spin-orbit coupling, crystal field (including the degree of Jahn-Teller distortions), and covalency characterizing Ba_2NaOsO_6 and its Ca doped variants, and provide insights into the origin of their unexpected transport and magnetic properties.

Even-odd effects in the Ising and XY chains.

SACCO SHAIKH D., SASSETTI M., TRAVERSO ZIANI N.
Dipartimento di Fisica, Università degli Studi di Genova
Boundary conditions were traditionally believed not to strongly influence the properties of condensed-matter systems. This belief has been proven wrong with the advent of topological insulators, where systems with gapped bulk bands are bound to have metallic states at their physical terminations. An even more striking violation of the paradigm has recently been discovered in some antiferromagnetic spin chains with competing orders. What has been shown in this context is that, depending on the parity of the number of spins, these systems can either be gapless or gapped, and that different order parameters need to be introduced. In my contribution, I first report about a first-order quantum phase transition that is present in the quantum Ising model in a transverse field for an odd number of spins only. Subsequently, I report on how, in the XY chain, the parity of the number of spins can alter the order of the quantum phase transitions of the model. Finally, I describe how, again in the XY model, a full extra critical line appears in the odd spin case only.

Spin and orbital excitations beyond the nearest-neighbor interactions: spinon pairs and dispersing dds in infinite-layer $CaCuO_2$.

MARTINELLI L. ([1]), BETTO D. ([2]), KUMMER K. ([2]), ARPAIA R. ([3]), DI CASTRO D. ([4])([5]), MORETTI SALA M. ([1]), BROOKES N.B. ([2]), DEVEREAUX T.P. ([6]), BRAICOVICH L. ([1])([2]), GHIRINGHELLI G. ([1])([7])
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([7]) *CNR-SPIN, Dipartimento di Fisica, Politecnico di Milano, Milano, Italy*
The core of cuprate high-T_c superconductors are CuO_2 planes, which show a ground state of $x^2 - y^2$ ferro-orbital symmetry and Néel antiferromagnetic order. The elementary excitations are usually well described as local (non-collective) *dd* excitations, which show no dispersion with momentum, and $\Delta S = 1$ magnons (plus multi-magnons), respectively. However, longer-range interactions cannot always be neglected. We have performed Resonant Inelastic X-ray Scattering (RIXS) measurements on the infinite-layer compound $CaCuO_2$, where the absence of apical oxygens leads to larger than usual hopping integrals t and t', superexchange J. In the orbital spectrum we find dispersive orbital excitations and the lifting of the xz/yz degeneracy, which indicates a partially delocalized nature. Moreover, the magnetic spectral region shows a clear anomaly close to $(1/2, 0)$. With an innovative combination of polarimetric and ultra-high-resolution RIXS measurements, we reveal that it is more consistent with a spinon-pairs continuum than with a multi-magnon one. We therefore find clear signatures of exotic physics beyond the canonical ferro-orbital, AF Néel ground state.

Unconventional transport of Cooper pairs in topological Josephson junctions.

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It is well known that Josephson junctions (JJs) in the presence of a perpendicular magnetic field exhibit qualitatively different interference patterns depending on the length of the junction and the current density profile. Two paradigmatic scenarios are the SQUID and the Fraunhofer patterns, corresponding to a current density sharply peaked at the edges of the junction or to a homogeneous current density profile, respectively. In these simple cases the electrons within the Cooper pair (CP) can be treated effectively as a single entity. However, it is not hard to run into physical mechanisms under which this assumption does not hold, leading to new features in the pattern. An example is the even-odd effect in SQUID patterns due to a non-local transmission of CPs, with the two electrons travelling along opposite edges. In fancier JJs, such as in the presence of inter-edge tunnelling or broadened edge states, the two electrons can propagate and explore the junction independently. We analyse the consequences of a major role acquired by the single-electron physics in the superconducting context: the relevant flux quantum doubles, introducing unexpected periodicities, and new patterns arise.

On the superconducting critical temperature in multiband disordered $LaAlO_3/SrTiO_3$ interfaces.

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(2) *Dipartimento di Fisica, Università "La Sapienza" di Roma, Rome, Italy*

$LaAlO_3/SrTiO_3$ interfaces are a nice example of a two-dimensional disordered system that can host multi-band superconductivity once the carrier density of the electron gas is suitably tuned by means of gate voltage. Here, the interplay of two-dimensionality, multi-band character and disorder can largely affect the superconducting critical temperature T_c, suppressing superconductivity and circumventing Anderson's theorem. We propose a realistic two-band disordered model based on experimentally determined parameters to study such interplay. While confirming that a repulsive inter-band coupling favors the T_c suppression, we show that disorder alone can mix the two bands, generating a more pronounced suppression of the critical temperature in the vicinity of the Lifshitz transition. Finally, this study allowed us to disentangle microscopic from mesoscopic disorder effects, since the global behavior of T_c is well captured only if the strongly inhomogeneous nature of such compounds is considered.

Traveling-wave Josephson parametric amplifiers (TWJPA): A preliminary study.

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The growing interest in quantum technologies, from fundamental physics experiments to quantum computing, demands for extreme performance and quantum-limited electronics. Superconducting microwave amplifiers, due to their dissipationless nature, exhibit outstanding performances in terms of noise (quantum limited), and gain. However, bandwidth and saturation power still show space for substantial improvement. Within the DARTWARS (The DARTWARS Project, funded by Italian Institute of Nuclear Physics (INFN) https://dartwars.unimib.it/) Collaboration microwave superconducting amplifiers based on Josephson junction arrays and on distributed kinetic inductance transmission lines have been developed. In this contribution the characterization of the performances of traveling-wave Josephson parametric amplifiers (TWJPA) measured at $T = 0.3\,\mathrm{K}$ is reported. Although in the final experimental setup these amplifiers will operate at a base temperature of about 20 mK, their characterization at 300 mK aims to evidence the main aspects of their performances. This represents a quick and relatively inexpensive way to test these superconductive devices that can be of help to improve the design and fabrication.

Surface impedance of high-critical-temperature superconductors in high magnetic fields : Applications to high-energy physics.

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(1) *Department of Physics, University of Naples "Federico II" and CNR SPIN, Italy*
(2) *CERN, Geneva, Switzerland*

Recent envisaged high-critical-temperature (HTS) superconductor's applications in high-energy physics rely on their rf properties in very high magnetic fields. As an example, coating of surfaces facing particle beams with HTS for reducing the beam coupling impedance is being considered for the next generation of hadron colliders, such as the FCC-hh at CERN, where HTS would be exposed to the high-frequency wakefields generated by the particle bunches and to the strong field (16 T) of the steering magnets. Other considered applications are rf cavities for axion detection as well as capture cavities for muon colliders. In the present contribution we will discuss the physical basis of such applications, and we will present a simple model for the calculation of the surface impedance of HTS superconductors exposed to a strong external magnetic field. We will also discuss the possible effects of nonlinearity of the pinning potential of the vortex lattice on the superconductor performances.

Alloying as a tool to chemically tune properties of ferroelectric Rashba semiconductors.

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GeTe and SnTe are key prototypes of ferroelectric Rashba semiconductors, materials in which the ferroelectric polarization direction governs Rashba spin texture, offering an unprecedent, non-volatile electric control over spin-to-charge conversion. GeTe has been widely investigated, while ferroelectric SnTe is expected to show a larger spin-to-charge conversion efficiency thanks to a giant intrinsic spin Hall conductivity in 2D. Unfortunately, the Curie temperature of SnTe below 300 K represents a limiting factor for applications. A promising route is provided by alloying the two chalcogenides in the ternary compound $Sn_xGe_{1-x}Te$, where Ge may allow for stabilization of the ferroelectric phase up to room temperature. In this contribution, we experimentally study the band structure and ferroelectric properties of SnGeTe thin films *vs.* composition and temperature, with the support of *ab initio* calculations. The tunability of both Rashba spin-orbit coupling and ferroelectricity above room temperature on a wide range of chemical compositions opens the route to the chemical engineering of the properties of ferroelectric Rashba semiconductors.

Aula T - Caterina Scarpellini **ore 09:00 – 13:30**

Sezione III
Astrofisica
Presiede: Mapelli M. (INFN, Sezione di Padova e Università di Padova)

GW+MM/Astro

Relazioni su invito

▲ **The pathway of radio astronomy to the SKA —A focus on the astrophysics of galaxy clusters and on the large-scale structure of the Universe.**

Brunetti G.
INAF, Istituto di Radioastronomia, Bologna, Italy

Radio astronomy is undergoing a major transformation. Developments in high-speed digital signal processing and broad-band optical fiber links have allowed to realize advanced radio telescopes (*e.g.*, LOFAR, MWA, ASKAP, MeerKAT), precursors and pathfinders for the future Square Kilometer Array (SKA). The unprecedented capabilities of these facilities are currently revolutionizing radio astronomy, yielding frontier science in cosmology and astrophysics. In particular, the pan-European LOFAR array is the world's largest effort to explore the radio sky at long wavelengths. It is a network of stations, distributed across Europe, that produces unprecedented data volumes and opens a new observational window of the Universe. In this contribution I will first provide a brief overview of the most important science questions and areas that are driving the scientific roadmap toward the SKA. In the second part of the contribution I will focus on the astrophysics of non-thermal phenomena in galaxy clusters and large-scale structure of the Universe, discussing the most relevant phenomenological and physical aspects and the enormous progress we are achieving through the exploitation of LOFAR data.

▲ **The Cherenkov Telescope Array Observatory: Its scientific capabilities will open new windows of exploration at very-high energies.**

Zanin R.
Cherenkov Telescope Array Observatory gGmbH

Very-high-energy (VHE) gamma-ray astroparticle physics is a relatively young field, and observations over the past decade have surprisingly revealed almost 250 VHE emitters which appear to act as cosmic particle accelerators. These sources are an important component of the Universe, influencing the evolution of stars and galaxies. At the same time, they also act as a probe of physics in the most extreme environments known —such as in supernova explosions, and around or after the merging of black holes and neutron stars. However, the existing experiments have provided exciting glimpses, but often falling short of supplying the full answer. A deeper understanding of the TeV sky requires a significant improvement in sensitivity at TeV energies, a wider energy coverage from tens of GeV to hundreds of TeV and a much better angular and energy resolution with respect to the currently running facilities. The next-generation gamma-ray observatory, the Cherenkov Telescope Array Observatory (CTAO), is the answer to this need. In this contribution I will present this upcoming observatory from its design to the construction, and its potential science exploitation. CTAO will allow the entire astronomical community to explore a new discovery space that will likely lead to paradigm-changing breakthroughs. In particular, CTAO has an unprecedented sensitivity to short (sub-minute) timescale phenomena, placing it as a key instrument in the future of multi-messenger and multi-wavelength time domain astronomy. I will pay particular attention to the survey capabilities of this upcoming facilities.

▲ **Neutrini astrofisici di alta energia.**

Bernardini E.
Università degli Studi di Padova

L'origine dei raggi cosmici è uno dei misteri della fisica e dell'astrofisica. La comprensione del rapporto tra la radiazione elettromagnetica ed i neutrini è fondamentale per identificare e comprendere le sorgenti astrofisiche dei raggi cosmici. Per progredire in tale direzione è in atto uno studio multi-messaggero sempre più articolato che coinvolge svariate infrastrutture osservative. Sorgenti astrofisiche extra-galattiche, quali ad esempio i nuclei galattici attivi, sono caratterizzate da una notevole variabilità nella loro emissione alle alte energie, rendendo necessaria la definizione di strategie di collaborazione per la raccolta di dati simultanei. I telescopi di neutrini ricoprono un ruolo fondamentale nell'astrofisica in tempo reale. I neutrini di alta energia sono messaggeri inequivocabili di meccanismi di accelerazione ed interazione dei raggi cosmici. Osservando tutto il cielo ininterrottamente, consentono di monitorare un'ampia varietà di possibili sorgenti ed allertare la comunità astrofisica dell'occorrenza di eventi eccezionali. Questo contributo illustra lo stato dell'arte dell'astrofisica neutrinica e le strategie osservative mirate a svelarne l'origina astrofisica.

Comunicazioni

● **Cristalli LYSO:Ce di grandi dimensioni per calorimetri elettromagnetici nello spazio: Qualificazione e caratterizzazione del calorimetro di HEPD-02.**

Lega A., Nozzoli F., Ricci E., Follega F.M., Gebbia G., Iuppa R.
TIFPA INFN, Povo e Università di Trento

Grazie all'elevata densità, all'elevata resa luminosa, al rapido tempo di decadimento e all'eccellente risoluzione energetica, il L(Y)SO:Ce è stato scelto per calorimetri di precisione in numerosi apparati. Esperimenti nello spazio come DAMPE attualmente in funzione e il proposto HERD fanno uso del concetto di CaloCube, utilizzando cubi di LYSO da $30 \times 30 \times 30\,\text{mm}^3$ per la misurazione di sciami elettromagnetici. Il design dello strumento chiamato High-Energy Particle Detector (HEPD-02) a bordo della missione CSES-02 comprende due strati di cristalli scintillanti di LYSO, ciascuno composto da 3 barre $150 \times 50 \times 25\,\text{mm}^3$, 7 volte più grande di qualsiasi modulo di scintillazione simile mai utilizzato nello spazio. In questo contributo descriviamo i risultati dei test in laboratorio con sorgenti radioattive e muoni cosmici, finalizzate alla misurazione dell'uniformità in risposta e in efficienza di rilevazione delle barre di cristallo in funzione del deposito di energia e della posizione di impatto. Infine, mostriamo le prestazioni attese del calorimetro LYSO di HEPD-02 che sarà lanciato a bordo del satellite CSES-02 all'inizio del 2023.

● **A data driven framework for searching long faint astronomical high-energy transients.**

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HERMES (High Energy Rapid Modular Ensemble of Satellites)-Technologic and Scientific pathfinder (HERMES pathfinder) is an in-orbit demonstration consisting of a constellation of six 3U nano-satellites hosting simple but innovative X-ray detectors for the monitoring of cosmic high-energy transients. The main objective of HERMES pathfinder is to prove that an accurate position of high-energy cosmic transients can be obtained using miniaturized hardware. We present here a new tool to estimate the background, a key step to allow sensitive searches for excesses due to cosmic transients. We employ a Neural Network (NN) to estimate the background light curves on different timescales. We employ subsequently a fast change-point and anomaly detection technique to isolate observation segments where statistically significant excesses in the observed count rate relative to the background estimate exist. We test the new software on archival data from the NASA Fermi Gamma-ray Burst Monitor (GBM). We were able to confirm events in the Fermi GBM catalog, and found events, not present in Fermi GBM database, resembling solar flares, terrestrial flashes, GRBs.

Caratterizzazione del rivelatore X-γ per il sistema di nanosatelliti HERMES.

Della Casa G. (1)(2)(3), Zampa N. (3), Cirrincione D. (1)(3), Monzani S. (1)(3), Rashevskaya I. (8), Ambrosino F. (6), Baruzzo M. (1)(3), Cauz D. (1)(3), Campana R. (4)(5), Citossi M. (1)(3), Di Ruzza B. (8), Dilillo G. (1)(2)(3), Evangelista Y. (6)(7), Fuschino F. (4)(5), Galgóczi G. (11)(12), Labanti C. (4)(5), Pauletta G. (1)(3), Ripa J. (10)(11), Tommasino F. (8)(9), Verroi E. (8), Fiore F. (2), Vacchi A. (1)(3)
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(9) *Department of Physics, University of Trento, Trento, Italy*
(10) *Department of Theoretical Physics and Astrophysics, Faculty of Science, Masaryk University, Brno, Czech Republic*
(11) *Eötvös Loránd University, Budapest, Hungary*
(12) *Hungarian Academy of Sciences, Wigner Research Centre for Physics, Budapest, Hungary*

Nell'era dell'astrofisica multimessenger, si accentua l'interesse per i Gamma Ray Bursts (GRBs), in particolare per estendere la sensibilità degli strumenti in orbita. HERMES è una costellazione di nanosatelliti che introduce un nuovo approccio all'osservazione dei GRBs. Nel processo di ottimizzare la strumentazione dell'esperimento precursore HERMES-Technologic/Scientific Pathfinder, è stato sviluppato un rivelatore compatto in grado di coprire la banda dei raggi X e gamma (3–5 keV fino a 2 MeV). Lo strumento sfrutta le caratteristiche di risoluzione energetica di una camera a deriva di silicio accoppiata con un cristallo scintillatore GAGG:Ce. È stato conseguentemente sviluppato un apparato, che permette la caratterizzazione di questo sistema, in particolare per quanto riguarda la luminescenza residua generata dal cristallo irraggiato con un fascio di protoni a 70 MeV, con irraggiamenti di diversa durata. Tale irraggiamento è stato effettuato presso il Centro di Protonterapia di Trento. Lo scopo finale è quello di analizzare il comportamento di questo sistema di rivelazione, evidenziato dai risultati dell'analisi dati presentata, in una situazione equivalente alla vita in orbita.

The Galileo for Science (G4S_2.0) project: Precise Orbit Determination for fundamental physics experiments with the Galileo satellites DORESA and MILENA.

Cinelli M., Sapio F., Di Marco A., Fiorenza E., Lefevre C., Loffredo P., Lucchesi D., Lucente M., Magnafico C., Peron R., Santoli F., Visco M.
Istituto di Astrofisica e Planetologia Spaziale-IAPS, Istituto Nazionale di Astrofisica-INAF, Tor Vergata, Roma, Italia

G4S_2.0 is a new project funded by the Italian Space Agency which aims to perform measurements in the field of Fundamental Physics with the two satellites DORESA (E18) and MILENA (E14) of the Galileo-FOC constellation. These satellites, as the others of the constellation, have onboard accurate atomic clocks, but are characterized by an orbit with high eccentricity. After a general introduction to the main objectives of the G4S_2.0 project, the preliminary activities developed at IAPS-INAF in Rome regarding the Precise Orbit Determination (POD) of the satellites will be presented. The PODs will be performed with two different codes, GEODYN II (NASA/GSFC) and BERNESE (AIUB), with the main aim of performing measurements of the relativistic precession of the orbits and a new accurate measurement of the gravitational redshift. In particular, an accurate measurement of the overall precession of the pericenter of the orbit allows to verify the validity of the inverse square law of the distance for the gravitational interaction on a characteristic scale of about 14000 km.

The Galileo for Science (G4S_2.0) project: The measurement of the gravitational redshift with the Galileo satellites DORESA and MILENA.

Di Marco A., Sapio F., Cinelli M., Fiorenza E., Lefevre C., Loffredo P., Lucchesi D., Lucente M., Magnafico C., Peron R., Santoli F., Visco M.
Istituto di Astrofisica e Planetologia Spaziale-IAPS, Istituto Nazionale di Astrofisica-INAF, Tor Vergata, Roma, Italia

G4S_2.0 is a new project funded by the Italian Space Agency which aims to perform measurements in the field of Fundamental Physics with the two satellites DORESA (E18) and MILENA (E14) of the Galileo-FOC constellation. Indeed, the orbits of these satellites are characterized by a relatively high eccentricity of about 0.16. After a general introduction to the main objectives of G4S_2.0, the preliminary activities developed at IAPS-INAF in Rome for the measurement of the gravitational redshift, based on the time bias analysis of accurate onboard atomic clocks, will be presented. This measurement will be a test for the validity of the local position invariance, one of the ingredients of Einstein's principle of equivalence.

Aula U - Giuliana Cini Castagnoli **ore 10:00 – 13:00**

SEZIONE IV
Geofisica e fisica dell'ambiente
Presiede: SABADINI R. (Università di Milano)

CLIMATE CHANGE

Relazioni su invito

▲ **Regional Meteo-climate modeling at different temporal scales: From the short to the long term.**

FERRETTI R.
CETEMPS - Department of Physics and Chemistry, University of L'Aquila

In this talk a review of the experience acquired by the Mesoscale modeling and Climate groups at the University of L'Aquila (CETEMPS) in both research on mesoscale modeling (short and long term) and in the operational weather forecast, during the last 20 year in the Mediterranean area is presented. Most of the research activities discussed in this review concern a wide spectrum of weather- and climate-related issues at different temporal and spatial scales in complex topography. A brief review of the most important findings and of their application in the operational forecast is presented together with the role of data assimilation in the high-resolution weather forecast in complex topography. The merging of modeling expertise on the different spatial and temporal scales allowed for transferring the high-resolution modeling experience to the climate application at convection resolving scale, a few results will be briefly presented. Finally, indications for planning future studies in weather and climate spheres by using WRF model are suggested.

▲ **The Mediterranean climate change in the global context**

LIONELLO P.
DiSTeBA, University of Salento

The Mediterranean is considered a hot spot because of the magnitude and characteristics of the expected regional climate change and the consequent risks for human societies, activities, terrestrial and marine ecosystems. This region has already been affected by a temperature increase larger than the global mean warming and peculiar changes of the hydrological cycles towards drier conditions. This contribution describes the results of a large set of global CMIP5 climate projections and it links regional changes to the global mean annual temperature, showing that, as it will increase, in the Mediterranean region, precipitation will decrease and annual temperature will warm more than the global average. Climate extremes will change with different intensity between the northern and the southern areas. While the increase/decrease of warm/cold temperature extremes will be large all over the region, the existing difference in intensity of precipitation and hydrological extremes (both wet and dry) will be further increased between North (where precipitation events are more intense) and South (where conditions are drier) Mediterranean areas.

▲ **Segnali di cambiamento climatico dalle serie storiche di dati osservativi italiani.**

MAUGERI M.
Università degli Studi di Milano - Dipartimento di Scienze e Politiche Ambientali

L'Italia gioca un ruolo di assoluto primo piano nella storia della meteorologia e dispone di archivi di dati meteorologici di eccezionale valore. L'esplorazione e l'analisi dei dati contenuti in questi archivi è iniziata già negli ultimi decenni del XIX secolo quando si sono avviate le attività del Regio Ufficio Centrale di Meteorologia. Un recupero più sistematico e uno studio più completo di questi dati è però stato avviato solo a partire dagli ultimi decenni del XX secolo. In questo contesto, la presentazione si propone di sintetizzare lo stato dell'arte delle ricerche relative all'evoluzione del clima italiano nel periodo coperto dalle osservazioni meteorologiche strumentali, evidenziando, da un lato, quale siano gli aspetti più critici legati alla disponibilità e alla qualità dei dai e mostrando, dall'altro, quali siano gli andamenti più significativi che sono stati evidenziati. La presentazione non si focalizzerà solo sulle variabili maggiormente studiate (temperature e precipitazioni), ma considererà anche altre variabili come la pressione, l'umidità relativa, la copertura nuvolosa, l'eliofania, la visibilità e la radiazione solare.

▲ **Heat waves and urban heat island: What we know and what can be done to mitigate their negative impacts.**

Di Sabatino S. (1), Aragao L. (1), Barbano F. (1), Brattich E. (1), Leo L. (1), Possega M. (1), Ruggieri P. (1), Santo M. (2)
(1) *Department of Physics and Astronomy, University of Bologna, Italy*
(2) *ARPAE, Bologna, Italy*

The last IPCC report has highlighted that exacerbation of heat waves (HWs) in future years will require specific attention for the consequences on urban heat islands (UHI), given that most cities and especially in the North-American continent, will experience more intense heat waves which may lead to intense UHI. Synergy between HWs and UHI is relevant to set-up strategies to mitigate risks of extreme heat, water scarcity, energy requirements, enhancement of air pollution and many other aspects. The interplay between the two phenomena is not entirely understood. Many studies report partially incoherent outcomes, assessing both the existence and the absence of a synergistic behaviour exacerbating the urban-rural temperature difference during HWs. In this talk we will review the hypotheses and theories explaining the dynamical nature of UHI and HWs together with progress made by our group in modelling and interpreting those phenomena. We will then discuss approaches to mitigate their negative effects using results of a large EU Project (OPERANDUM) devoted to explore the efficacy of nature-based solutions taken as concrete examples to improve resilience of our territories.

Comunicazioni

● **Measurement of surface respiration: An IoT approach.**

Vitali G., Magnanini E., Arru M.
University of Bologna

In a climate change context, respiration (bidirectional flows of CO_2 and water) of natural surfaces (terrestrial and water bodies) is the main process that seems able to mitigate the effects of anthropic emissions. To the scope measurement of CO_2 and water fluxes on the different types of surface is still an important issue. Neither word-wide networks of weather stations nor satellite sensors are presently giving enough information to monitor flows of CO_2 and water to and from a surface. Terrestrial ecosystems, both natural and cultivated are characterised by a great variety, due to climate, soil and vegetation layers. Water flows and CO_2 are interrelated and affected by soil microbic activity, and the interaction with plant, affecting CO_2 assimilation (photosynthesis). That is the reason why CO_2 and water flows should be measured in the same time. The presented solution is based on use of low-cost sensors for humidity and CO_2 concentration assembled in a IOT compliant device. Measurements and estimates of flows are showing how the IoT approach can be used to obtain scalable seasonal maps of surface respiration.

Comparison of feature-tracking methods for glacier-velocity evaluation in different regions of the Earth.

Traversa G. (1)(3), Scodellaro R. (2), Fugazza D. (3), Sironi L. (2), Frezzotti M. (4)
(1) *University of Siena*
(2) *University of Milano Bicocca*
(3) *University of Milano*
(4) *University of Roma Tre*

Several feature tracking methods for glacier velocimetry calculations has been proposed in the recent years for the increasing interest in these features, being the most significant signals of Climate Change. In the present work, we compare different modules of feature tracking, i.e., IMCORR, ImGRAFT and GIV. To these existing modules, we add for testing and comparing a new Machine Learning-based method, which couples rigid image registration and correlation methods in order to disentangle the real glaciers movement from the artifacts caused by the image acquisition and provide an accurate estimation of the glacier velocity and direction. The evaluation of this last model and the cross-comparison with the previous methodologies is possible by validation with field available data, in four regions of the Earth: Antarctica (David Glacier), Italy (Miage G.), Chile (Exploradores G.) and Pakistan (Baltoro G.). This field comparison allows to evaluate existing feature tracking modules in different regions of our planet, periods and satellite (Landsat-family, Sentinel-2 and ASTER imagery) sources and to provide and validate a new method from Machine Learning techniques.

A personal path through different languages of the environment.

Georgiadis T.
Istitute for the BioEconomy, CNR, Bologna

Yes, it's my time to retire, even though I don't think I will retire at all. I wish to present you a path, my personal path, which conducts me from environmental physics to landscape planning and to civil engineering. The issue is the climate, from the day I decided I was interested in surface energy balances up to now, where the study of the urban environment has become an urgent need for understanding the tools necessary to ensure the well-being of citizens. In this environment physics is dominant but a true interdisciplinary language is needed to propose understandable solutions, and also to understand the needs of others.

Design and implementation of an open hardware and open source device for the detection of geo-localized environmental data.

Grosso D. (1), Frittoli L. (2), Thian M. (2)
(1) *University of Genoa, Department of Physics*
(2) *MIUR*

Environmental monitoring allows the collection of useful information for the preservation of the natural and landscape heritage, the assessment of the anthropic impact and the modeling of variations due to climate change. The coastal areas are of particular interest for the population density and the many activities carried out and development potential. We present a compact station for the measure of environmental parameters that can also be used in a recoverable drifter, dedicated to the detection of environmental parameters along the coast; GPS data, for example, could be used for modeling currents. The station, powered by a rechargeable battery, can also be used on shore and possibly recharged by a solar panel or a small wind generator. It has a GPS unit, accelerometer, gyroscope and sensors for sampling p, T and other parameters of interest which can be saved and/or transmitted at regular intervals.

Aula E - Rosalind Franklin **ore 09:00 – 13:30**

Sezione V
Biofisica e fisica medica
Presiedono: Marrale M. (Università di Palermo)
De Martin E. (Istituto Neurologico Besta)

Relazioni su invito

▲ **Low-intensity focused-ultrasound–based therapeutic technologies for neurodegenerative and neuro-oncological diseases.**

Conti A.
Medical Physics Section, Department of Biomedicine and Prevention, University of Rome Tor Vergata

Low-intensity focused ultrasound (FUS) is an emerging non-invasive technology with the potential to treat neurodegenerative diseases as well as a broad range of other brain disorders. Its therapeutic applications range from deep brain neuromodulation to reversible blood-brain barrier permeabilization for locally enhancing the uptake of therapeutic agents. We will describe FUS-based brain therapies with a particular focus on neuro-oncology. In particular, we will show the potential of FUS technology for boosting both chemotherapy and radiotherapy of glioblastoma (GBM) tumors. We will also introduce the use of FUS-enhanced radiosensitive nanoparticles (RNPs) uptake as a novel treatment for GBMs. By delivering a new class of RNPs through FUS in rat models of GBM we demonstrate the ability of increasing therapeutic efficacy by 170% (in comparison to RNPs+RT alone) and of reducing tumoral growth down to 27% of the growth observed in control lesions. We will also demonstrate how simulation studies can efficiently support FUS application for future drugs delivery and neurostimulation applications.

▲ **The cryo-electron-microscopy resolution revolution in structural biology.**

Bolognesi M.
Department of Biosciences & CRC Invernizzi, University of Milano

Structural biology has been a major driver of progress in biological research over the past four decades. Up to 2015 such progress has been based on X-ray crystallography (thanks to synchrotron sources) and on NMR. Following two main technical developments (cryo-protection of the samples and availability of electron-counting detectors), from 2015 on single particle cryo-electron-microscopy (cryoEM) has been providing 3D structures of biological macromolecules at near-atomic resolution (often well below 3.0 Å). The cryoEM approach to the structure of biological matter meets important criteria. On the one hand, it provides 3D structures of macromolecules in (vitrified) solution. On the other hand, it requires tiny amounts (0.1 mg) of material. In addition, the approach can be fast (days), and large molecular assemblies can be reliably handled, even if not highly purified. The size of the structural data bank (EMBD) associated to such approaches is growing exponentially. Importantly, the structural organization of specific biological specimens (to be presented), such as amyloid protein fibrils, can be approached only through cryoEM.

Comunicazioni

● **The HASPIDE project: Detectors for medical physics.**

Talamonti C. (1)(2), Pallotta S. (1)(2), Grimani C. (2)(3), Calcagnile L. (4)(5), Caricato A.P. (4)(5), Cirrone G.A.P. (6), Croci T. (7)(8), Di Lorenzo R. (8)(9)(1), Fabi

M. [2][3][1], Falciglia P.P. [6][1], Frontini L. [10][11][1], Cuttone G. [6][1], Gianfelici B. [7][8][1], Ionica M. [8][1], Italiani M. [8][12][1], Kanxheri K. [7][8][1], Large M. [13][1], Liberali V. [10][11][1], Martino M. [5][1], Maruccio G. [4][5][1], Mazza G. [6][1], Menichelli M. [8][1], Milluzzo G.G. [6][1], Monteduro A.G. [4][5][1], Morozzi A. [8][1], Moscatelli F. [8][14][1], Paolucci M. [8][9][1], Passeri D. [7][8][1], Patti I.V. [6][1], Pedio M. [8][14][1], Petasecca M. [13][1], Petringa G. [6][1], Peverini F. [7][8][1], Piccolo L. [15][1], Placidi P. [7][8][1], Quarta G. [4][5][1], Rizzato S. [4][5][1], Rossi G. [8][1], Stabile A. [10][11][1], Torrisi A. [4][5][1], Wheadon R.J. [15][1], Villani M. [2][3][1], Wyrsch N. [16][1], Servoli L. [8][1]

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[7] *Università degli Studi di Perugia, Italia*
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One of the goals of the INFN HASPIDE project (Hydrogenated Amorphous Silicon DEtectors) is to explore the possibility to use a-Si:H detectors for medical physics applications. The choice of this material as sensitive layer is driven by its resistance to radiation damage which allows the sensors to operate in very harsh conditions like, *e.g.*, in FLASH therapy. Furthermore, the sensitive layer could be very thin (order of a few micrometers) and it could be deposited on a variety of substrates, including thin flexible plastic layers of Polyimide which allows to develop sensor matrices with a great variety of shapes. First tests with a 1D prototype on clinical photon beams demonstrate that the device has a linear response as a function of the dose rate and it is fast enough to detect and measure the dose delivered by every single pulse.

A smart optical and ultrasound device for the diagnostics of breast cancer.

Maffeis G. [1], Pifferi A. [1], Dalla Mora A. [1], Di Sieno L. [1], Tosi A. [2], Conca E. [2], Giudice A. [3], Ruggeri A. [3], Tisa S. [3], Flocke A. [4], Rosinski B. [5], Dinten J.-M. [6], Perriollat M. [6], Fraschini C. [7], Lavaud J. [7], Arridge S. [8], Di Sciacca G. [8], Farina A. [9], Panizza P. [10], Venturini E. [10], Gordebeke P. [11], Taroni P. [1]

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([8]) *University College London, Department of Computer Science, London, UK*
([9]) *Consiglio Nazionale delle Ricerche, Istituto di Fotonica e Nanotecnologie, Milano, Italy*
([10]) *Scientific Institute, IRCCS, Ospedale S. Raffaele, Breast Imaging Unit, Milano, Italy*
([11]) *European Institute for Biomedical Imaging Research, Wien, Austria*

SOLUS is a H2020 funded project devoted to the design, development and testing in clinics of a Smart Optical and Ultrasound device for the diagnostics of breast cancer. Smartness stems from the purpose (discrimination of benign and malignant lesions), the method (non-invasive characterization of the tissue) and the technology (multimodal and compact device). In fact, the collaboration of all partners allowed the first integration of time domain multi-wavelength diffuse optical tomography (composition) and commercial ultrasound (morphology), color doppler (vascularization) and shear wave elastography (stiffness) in a hand-held probe. The development of miniaturized optical components was essential: laser drivers generating picosecond pulses, large-area time-gated detectors and dedicated acquisition electronics. Data analysis required a custom-made approach as well for diffuse optical tomography. After the assembly, the instrument has been thoroughly characterized in laboratory on phantoms mimicking the optical and ultrasound properties of a breast. Early results of the clinical validation of the SOLUS system now ongoing on patients with breast lesions will be presented.

Validation of a perturbative approach for the analysis of data obtained from diffuse optical monitoring of neoadjuvant chemotherapy in breast cancer patients: From simulations to tissue phantom tests.

Mule N. ([1])([2]), Maffeis G. ([1]), Spinelli L. ([1]), Santangelo C. ([2]), Cubeddu R. ([1]), Pifferi A. ([1])([3]), Panizza P. ([2]), Taroni P. ([1])([3])
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([3]) *Consiglio Nazionale delle Ricerche, Istituto di Fotonica e Nanotecnologie, Milano, Italy*

A multi-wavelength optical mammograph that works under time domain diffuse optical spectroscopy, developed by our research group, is applied to monitor the breast cancer patients' response to neoadjuvant chemotherapy. So far, a simple homogeneous data model approach to estimate tissue composition averaged along compressed breast thickness proved sensitive to therapy induced changes. The application of a perturbative model, describing the lesion as a perturbation in healthy tissue, would allow a quantitative characterization during therapy. This study validates a perturbative fitting procedure through a systematic approach starting from simple to complex scenario: first on simulations, then phantoms ("stand-in" for human tissue). This kind of systematic assessment helps us to estimate the errors in the reconstructed parameters when there are uncertainties in the input, when applied to a real case scenario like that of *in vivo* studies. Hence, by varying input parameters like perturbation volume, geometry, position and signal level, one at a time, their effect and the overall model efficiency are studied. The final aim would be to analyse the *in vivo* measurements' data.

Muscle MRI in facioscapulohumeral muscular dystrophy.

Barzaghi L. ([1])([2]), Brero F. ([3]), Colelli G. ([1])([2]), Postuma I ([3]), Felisaz P.F. ([8]), Paoletti M. ([2]), Manco G. ([2]), Deligianni X. ([4])([5]), Santini F. ([4])([5]), Monforte M. ([6]), Tasca G. ([6]), Bergsland N. ([7]), Lascialfari A. ([1])([3]), Pichiecchio A. ([2])([9])
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This study aims to predict the quantitative biomarkers of Facioscapulohumeral (FSHD) dystrophy, *i.e.*, Fat Fraction (FF) and waterT2 (wT2), by the combination of quantitative MRI, radiomic texture analysis and machine learning (ML) algorithms. Twenty-four patients were scanned on a 3 T MRI scanner with Multi-Echo Gradient-Echo (MEGE) and Multi-Echo Spin-Echo (MESE). One slice was selected from distal, medial and proximal thigh compartment and then segmented in 12 regions of interest (ROIs). For each subject's ROI, 42 radiomic features were extracted from MEGE. Ground truth FF and wT2 values were calculated by Fatty Riot algorithm and EPG simulation, then we tested the performance of a set of ML models to predict FF and wT2. Roi-wise analysis shows how the mean ML algorithms accuracy (FF $\sim 85\%$, wT2 $\sim 88\%$) and the mean accuracy error (FF $\sim 0.04\%$, wT2 $\sim 0.03\%$) have no dependency on volume size and muscles shape that are both strongly altered by FSHD progression. So it should be possible to predict with good accuracy FSHD biomarkers in any disease stage, from early to late symptoms. Moreover, algorithm-wise analysis gives a mean accuracy prediction of about 85% for both FF and wT2.

Advanced methods for ^{23}Na-MRI of the brain: Preliminary results in multiple sclerosis (MS).

<u>Egidi I.</u> ([1])([2]), Di Nuzzo M. ([2]), Fratini M. ([3])([4]), Guidi M. ([2]), Maugeri L. ([3])([4]), Giove F. ([2])([3])
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Sodium quantification in the brain is a subject of increasing interest because of its fundamental role in physiology and in the progression of some neurodegenerative diseases such as MS. MS is associated with anomalies in sodium levels because of blood-brain barrier dysfunction and demyelination. ^{23}Na-MRI is mainly performed on scanners with B_0 of 7 T and above, because of the increase in SNR with B_0. Our aim is to make ^{23}Na-MRI feasible on clinical scanners ($B_0 = 3\,\mathrm{T}$), overcoming SNR limitations. Since sodium transverse relaxation is very fast, UTE (Ultra-short Echo Time) sequences are needed for the quantification of Total Sodium Concentration (TSC) that must be associated with suitable reconstruction algorithms. FLORET (Fermat Looped, ORthogonally Encoded Trajectories) is an innovative k-space trajectory suitable for UTE scanning. The sampling trajectory impacts SNR and blurring. We are currently investigating how to optimize the k-space sampling strategy to obtain TSC maps in healthy subjects. Once validated, this technique will be used to derive biomarkers to characterize disease progression in MS patients.

Nanoparticelle magnetiche per applicazioni in MRI: Effetto del coating polimerico sulle proprietà rilassometriche.

<u>Porru M.</u> ([1])([2]), Brero F. ([2]), Albino M. ([3]), Cicolari D. ([1])([2]), Orsini F. ([4]), Sangregorio C. ([3])([5]), Innocenti C. ([3])([5]), Mariani M. ([1])([2]), Arosio P. ([4]), Lascialfari A. ([1])([2])
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([5]) *ICCOM-CNR, Sesto Fiorentino, Italia*

Le nanoparticelle magnetiche (MNP) trovano applicazione in ambito diagnostico e terapeutico, ad esempio come agenti di contrasto nell'imaging a risonanza magnetica o come agenti ipertermici anti-tumorali. In entrambi i casi le caratteristiche morfo-strutturali ne influenzano l'efficienza e il coating polimerico gioca un ruolo fondamentale in termini di biocompatibilità e biodistribuzione. Abbiamo valutato la possibile influenza del tipo di coating sulle proprietà fisico-chimiche delle nanostrutture che presentano un core di MNP. Sono stati studiati due set di MNP a base di ossidi di ferro, con core di diametro pari a 8.9 nm e 4.4 nm, rivestiti con APPA e DMSA, e con PAA, TMA e DMSA, rispettivamente. I profili sperimentali NMRD, rappresentati dai dati di rilassività nucleare longitudinale e trasversale in funzione del campo magnetico applicato, sono stati interpolati tramite il modello euristico di Roch-Muller-Gillis. Per il set di NP più piccole sono stati osservati profili diversi al variare del coating polimerico. Questo risultato suggerisce che possibili interazioni tra coating e spin superficiali del core possano influenzare le proprietà fisiche fondamentali delle MNP.

● Possibile applicazione della Centroidal Voronoi Tessellation per il rilevamento di lesioni a basso contrasto in immagini TC.

<u>Lasagni L.</u> ([1]), Muggiolu A. ([1]), Cantoni E. ([1]), Valeri F. ([1]), Cupparo I. ([1]), Gnerucci A. ([1]), Taddeucci A. ([2]), Marconi A. ([1]), Gori C. ([1])([3]), Risaliti G. ([1])
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In questo lavoro sono state mutuate delle tecniche di analisi delle immagini impiegate in astrofisica per rilevare segnali a basso contrasto in immagini di Tomografia Computerizzata (TC), combinando la Centroidal Voronoi Tessellation (CVT) e tecniche di machine learning. Diverse acquisizioni TC sono state effettuate utilizzando un fantoccio contenente inserti cilindrici di diverso diametro e diverso contrasto rispetto al fondo. Le immagini del fantoccio sono state acquisite a varie dosi (vari rapporti segnale/rumore) e a vari angoli rispetto all'asse del tomografo. Il successo nella rilevazione del segnale nella singola immagine (slice) è stato sempre maggiore dell'80%. È sempre stato correttamente identificato l'asse dell'inserto. È stata quindi generata un'immagine 2D di super risoluzione proiettando lungo tale asse le singole slices della scansione, incrementando così il SNR dell'inserto nel suo insieme. La CVT risulta molto promettente per futuri utilizzi nell'identificazione di lesioni a basso contrasto in organi omogenei, come il fegato.

● Validation of an automatic pipeline for probabilistic tractography in drug-resistant epileptic patients.

<u>Cattoretti M.</u> ([1]), Berta L. ([2]), Felisi M. ([2]), Sartori I. ([3]), Torresin A. ([2]), Arosio P. ([1]), Colombo P. ([1])([2])
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Diffusion Tensor Imaging (DTI) is a special technique of Magnetic Resonance Imaging (MRI) employed for fiber-tracking (FT) studies for pre-intervention planning activities. The aim of this work is to validate the FT probabilistic workflow in drug-resistant epileptic patients explored by stereoelectroencephalography (SEEG) at ASST Niguarda hospital. The method is based on anatomical Regions-of-Interest (ROIs) definition in a common brain template co-registered on each patient's image. The pipeline was developed in Python language using probtrackx algorithm for FT available in FSL platform (`http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/`) with ROIs as input. The accuracy of our method, able to define the different tracks, was assessed comparing results with pathways previously elaborated during clinical practice, in which ROIs were drawn manually in each patient's images. Electrophysiology data, recorded from deep intracerebral electrodes during SEEG procedures, is the reference method for the clinical validation of FT preoperative planning.

Nuove terapie: Una combinazione di adroterapia e ipertermia per la cura del tumore al pancreas.

Brero F. ([1]), Albino M. ([2]), Antoccia A. ([3]), Arosio P. ([4]), Avolio M. ([1])([5]), Berardinelli F. ([3]), Bettega D. ([4]), Calzolari P. ([4]), Ciocca M. ([6]), Corti M. ([1])([5]), Facoetti A. ([6]), Gallo S. ([4]), Groppi F. ([7]), Guerrini A. ([2]), Innocenti C. ([2])([8]), Lenardi C. ([4]), Locarno S. ([4]), Manenti S. ([7]), Marchesini R. ([4]), Mariani M. ([1])([5]), Orsini F. ([4]), Pignoli E. ([9]), Sangregorio C. ([2])([8]), Veronese I. ([4]), Lascialfari A. ([1])([5])
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([6]) *Fondazione CNAO, Pavia, Italia*
([7]) *Dipartimento di Fisica e INFN-UNIMI laboratorio LASA, Segrate, Italia*
([8]) *ICCOM-CNR, Sesto Fiorentino, Italia*
([9]) *IRCCS Istituto Nazionale dei Tumori, Milano, Italia*

Per combattere il cancro la medicina ha a disposizione svariati strumenti tra cui la chirurgia, la radioterapia a raggi X, la chemioterapia, l'adroterapia, l'immunoterapia e la radioterapia metabolica. Negli ultimi anni la ricerca ha elaborato nuove strategie contro il cancro, soprattutto relative alla medicina di precisione. Metodica in forte sviluppo è quella dei nanomateriali che, raggiunto il tumore, possono a esempio rilasciare farmaci chemio/radioterapici e/o provocare un innalzamento della temperatura se sottoposti a campo magnetico alternato, con conseguenti effetti anti-tumorali. Qui presentiamo la combinazione di ipertermia mediata da nanoparticelle magnetiche e irraggiamento con ioni carbonio/protoni/fotoni, su colture cellulari di adenocarcinoma pancreatico umano. Otteniamo: i) un effetto tossico significativo della somministrazione di nanoparticelle, *i.e.*, un aumento del tasso di morte cellulare rispetto al solo irraggiamento; ii) un effetto additivo (ioni carbonio) o sinergico (protoni, fotoni) dell'irraggiamento con ipertermia, sulla sopravvivenza clonogenica. Questi risultati aprono la strada a indagini *in vivo*, al fine di traslare in clinica questa nuova terapia.

Beam monitoring for electron FLASH beams.

Medina E., Abujami M., Bersani D., Cirio R., Data E., Galeone C., Giordanengo S., Martì Villareal O., Mas Milian F., Montalvan Olivares D., Monti V., Sacchi R., Vignati A.
Physics Department, Università degli Studi di Torino, Turin, Italy e INFN, National Institute of Physics, Turin Division, Turin, Italy

A tissue-sparing effect was demonstrated in ultra-high dose-rate irradiations (FLASH effect). Within the FRIDA project, the Turin University and INFN are characterizing the performance of thin silicon sensors and readout electronics for electron beam monitoring in ultra-high dose rates. TERA08, a chip based on the recycling integrator architecture, reads the signal of inversely polarized silicon sensors. The signal of one sensor strip is divided into the 64 chip channels and the current is obtained from summing all channels counts. The charge produced in silicon by FLASH electrons was simulated and initial tests were performed on a LINAC Elekta SL18, fully dedicated to research. Varying beam energies, distance from the beam, sensor position and dose rates (conventional range), the performance of the sensor is being evaluated. The reproducibility of the system and the possibility of studying the beam profile have been confirmed. Similar tests will be repeated after the LINAC upgrade (in the coming months) to produce high dose-rate electron beams. Different sensor geometries, alternative solid-state technologies and an upgraded version of the chip will be tested on FLASH beams.

Advances in dosimetric characterization of a new waterproof silicon carbide detector.

Guarrera M. (1)(2), Petringa G. (2)(3), Amato A. (2), Catalano R. (2), Kurmanova A. (1)(2), Massara A. (2), Messina G. (2), Passarello D. (2), Tudisco S. (2), Zappalà E. (2), Cirrone G.A.P. (2)
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(3) *ELI-Beamlines, Institute of Physics (FZU), Czech Academy of Sciences, Prague, Czechia*

The physical characteristics of Silicon Carbide (SiC) based devices, such as wide bandgap, ultra-low leakage current, high electron saturation velocity, almost near tissue-equivalence, high radiation resistance, dose rate independent response and linearity with energy in a wide dynamic range, have attracted the attention of the scientific community interested in the development of new detectors for relative dosimetry. In this work a new generation of SiC device based on p-n junction technology was investigated for dosimetric applications. The detector was manufactured in the context of a collaboration between INFN, IMM-CNR and STM. The adopted detector, built by using new technological processes, presents a detection area of $1\,\mathrm{cm}^2$ and is embedded in epoxy resin to make it waterproof. The study aimed at evaluating the potential use of the SiC detector as a relative dosimeter, in accordance with the dosimetric protocols in force (IAEA TRS-398). The detector response was tested in water with X-ray, electron and proton beam. The released absolute dose was evaluated using a standard ionization chamber.

In-beam pet monitoring for adaptive proton therapy: A voxel-based morphometry approach based on FLUKA Monte Carlo simulations.

Berti A. (1)(2)(3), Kraan A. (2), Retico A. (2), Battistoni G. (4), Del Sarto D. (2)(5), Ferrero V. (6), Fiorina E. (6)(7), Laruina F. (2)(5), Mazzoni E. (2), Morrocchi M. (2)(5), Pennazio F. (6), Rosso V. (2)(5), Sportelli G. (2)(5), Vitolo V. (7), Bisogni G. (2)(5)
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(3) *Istituto di Scienza e Tecnologie dell'Informazione, Consiglio Nazionale delle Ricerche, Pisa, Italia*
(4) *Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Milano, Italia*
(5) *Dipartimento di Fisica, Universitá di Pisa, Pisa, Italia*
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(7) *Centro Nazionale di Adroterapia Oncologica, Pavia, Italia*

One of the modalities for *in vivo*, non-invasive treatment monitoring in proton therapy is in-beam PET. Yet, no straightforward method exists to translate the information from PET images into easy to interpret information for physicians. We propose a new approach for analyzing in-beam PET monitoring images to locate, quantify and visualize morphological changes occurring over the treatment course. We thus selected a patient treated with proton therapy whose sinonasal cavity emptied over the treatment course. We generated a series of artificially modified CT scans to mimic this gradual emptying. Using a dual-head PET system geometry, we performed Monte Carlo simulations of the treatment to investigate monitoring-PET signal changes. Next, we performed two-tailed voxel-wise statistical tests to locate and quantify regions with significant morphological changes. As a result, we successfully applied our method to simulated in-beam PET images, generating three-dimensional probability maps to visualize morphological changes in the CT. Their characteristic color patterns are valuable to trigger an alarm in case of morphological changes over the treatment course.

Aula L - Christa Mc Auliffe **ore 09:00 – 13:30**

SEZIONE VI
Fisica applicata, acceleratori e beni culturali
Presiede: SASSO C.P. (INRIM, Torino)

Relazioni su invito

▲ Muon colliders: A challenging opportunity.

PASTRONE N.
INFN, Sezione di Torino, Italy

Muon colliders provide a unique route to deliver high-energy collisions that enable discovery searches and precision measurements to extend our understanding of the fundamental laws of physics. All this at a single collider and on a feasible timescale, as recently reviewed in the frame of the European Roadmap for Accelerator R&D. Muons can be accelerated in rings up to very high energies, without fundamental limitation from synchrotron radiation. The recently formed International Muon Collider Collaboration at CERN targets the design of a muon collider facility with a center-of-mass energy of 10 TeV or slightly more, which seems feasible and sustainable with technologies that can be made available in the near future. Currently a 3 TeV stage is considered viable as a post HL-LHC facility. The physics potential of muon colliders has been investigated quite extensively over the past two years as a viable path toward the high-energy, high-luminosity frontier beyond the expected reach, despite the challenges to produce bright muon beams and mitigate the drawbacks arising from the short muon lifetime at rest. The status of the project, future plans and synergies will be discussed.

▲ Navigare con i raggi X all'interno dei campioni mediante la "virtual histology".

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(1) *Università Milano Bicocca, Dipartimento di Fisica, Milano*
(2) *Università della Calabria-UNICAL, Dipartimento di Fisica, Rende*
(3) *Facoltà di Medicina e Dipartimento di Fisica, LMU Munich, Germany*
(4) *Istituto di Nanotecnologia-CNR, Roma*

La "virtual histology" è una recente tecnica di imaging, realizzata mediante l'uso di raggi X, che permette di visualizzare in 3D, a risoluzioni multiple, campioni di origine biologica. Il progresso tecnologico nell'ambito della tomografia a contrasto di fase, realizzata con e senza l'uso di mezzi di contrasto, ha permesso non solo di visualizzare la struttura di tessuti in 3D in modo mini-invasivo, cioè senza sezionare i campioni, ma anche di poter navigare virtualmente all'interno degli stessi. L'elaborazione delle immagini permette poi di seguire la struttura spaziale di classi omogenee di strutture, permettendo, per la prima volta, di studiare a livello microscopico l'architettura dei tessuti o l'evoluzione spaziale di una patologia. Le grandi potenzialità mostrate finora dall'istologia virtuale stanno dando un impulso senza precedenti alla comprensione dettagliata in 3D di strutture anatomiche e contribuendo all'interpretazione degli effetti fisiopatologici *in situ* di farmaci o di terapie innovative.

Ancient metal artifacts production technologies revealed through neutron imaging and neutron diffraction.

GRAZZI F.
Consiglio Nazionale delle Ricerche, Istituto di Fisica Applicata "Nello Carrara" e Istituto Nazionale di Fisica Nucleare, Laboratorio di Tecniche nucleari per l'Ambiente e i Beni Culturali, Sesto Fiorentino, Firenze, Italy

The history of metallurgy represented for several centuries the history of the main technological features reached by civilizations. Among metal objects production, artistic artifacts and weapons represent the most interesting objects in archaeometallurgy and historical metallurgy because they were manufactured, over the ages, using the highest quality materials and the most advanced technology and skill. The compositional and microstructural characterization of these artifacts can hence allow us to learn about the technological skills reached by different civilizations. The use of non-invasive techniques allows for the study of museum objects in excellent conservation conditions, thus giving a clear view of their characteristics. Neutron imaging and neutron diffraction are, to the author's knowledge, among the best methods to quantify phase composition and microstructure, study morphology, identifying non-metallic inclusions, cracks and defects. Thanks to the use of advanced techniques such as energy selective imaging, the microstructural features and the distribution of the different phases in metal complex artifacts can be determined, so gaining important information about composition and manufacturing treatments (both thermal and mechanical). Following this path, we have performed a number of experiments using neutron imaging and neutron diffraction to reveal the characteristics of many artifacts from different civilizations, of which the production procedures are not yet fully clear. The results obtained and presented in this contribution allow us to identify unique features that can shed new light on the manufacturing methods, thus increasing the level of our knowledge about the technological skills of such civilizations.

Comunicazioni

Anode materials based on rock-salt high-entropy oxide for Li-ion storage.

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(3) *Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali, INSTM, Firenze, Italy*

In the latest years, high-entropy oxides (HEOs), a new class of single-phase solid solution materials with very promising functional properties, have attracted growing interest for their great potential in a broad range of applications. This work demonstrates that pure single-phase $Mg_{0.2}Co_{0.2}Ni_{0.2}Cu_{0.2}Zn_{0.2}O$ HEO with rock-salt structure can be prepared, under milder conditions (shorter heat treatments at lower temperatures) than the standard solid-state techniques, by electrospinning and solvothermal method. The produced HEOs, having different different particle size, particle size range, and defect density, are evaluated as active anode materials in lithium ion batteries. Their microstructure strongly affects the electrochemical behavior. The most active $Mg_{0.2}Co_{0.2}Ni_{0.2}Cu_{0.2}Zn_{0.2}O$ nanofibers exhibit outstanding electrochemical properties in terms of high reversible capacity (480 mAh/g at 20 mA/g), superior rate capability (206 mAh/g at 2 A/g), and excellent cycling stability (390 mAh/g at 0.5 A/g after 300 cycles).

Immuno-Histo-X-ray Phase Contrast Tomography.

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(4) *Institute for Advanced Biosciences, Université Grenoble Alpes, INSERM U1209, CNRS UMR 5309, Grenoble, France,*
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(6) *Calabria University-UNICAL, Physics Department, Rende, Italy*

The still unmet ability of following the fate of specific cells or molecules within the whole body would give an outstanding breakthrough in the comprehension of disease mechanisms and in the monitoring of therapeutic approaches. Our idea is to push forward the bio-nanotechnology to a level where it serves the most advanced 3D bio-medical imaging to provide a multi-scale imaging ranging from the whole organ down to the cellular level, enabling high-resolution visualization of disease-relevant cells within the whole disease-altered biological context. We present here the first proof of concept of a novel tomography procedure, Immuno-Histo-X-ray Phase Contrast Tomography (XPCT) that combines cutting-edge XPCT, which provides detailed image of the whole organ, with molecular imaging at the cellular level, identifying the relevant cells via an immunohistochemistry-based approach. We combine metal nanoparticles and a single-domain antibody that target relevant cells. Our results lay the foundation for a new generation of 3D-bio-medical X-ray imaging.

Superconductive transition-edge sensors in tomorrow physics.

GARRONE H. (1)(2), PEPE C. (1)(2), MONTICONE E. (1), RAJTERI M. (1)
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(2) *Politecnico di Torino*

Transition-edge sensors (TESs) are outstanding calorimeters based on the steep superconductive transition of a metallic film. Among photon detectors, they belong to the top-tier positions for the high-energy resolutions and the low dark count rates. They are usually applied to detect electromagnetic energy from gamma-ray to visible and submillimetre wavelengths, but their use goes further. INRiM is presently involved in the development of TESs that pertain to different fields. In fact, TES capability of revealing massless or massive particles, while measuring their energies, can be applied in the quantum technologies, metrology and telecommunications, resolving photon signals from noise and counting them, as well as in the astrophysical and particle frameworks, from neutrino mass to multi-messenger astronomy measurements. For all these reasons, TESs are constantly under development in order to fulfil the more severe experimental requirements. The latest results obtained at INRiM on TES performances and applications will be presented.

Calibration strategy and experimental qualification of the first DEPFET pixel sensors of the DSSC camera.

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([5]) *European XFEL GmbH, Schenefeld, Germany*

A novel design of the Depleted P-Channel Field Effect Transistor (DEPFET) with non-linear response is at the heart of the 1 Mpixel DSSC camera (DEPFET Sensor with Signal Compression) for ultra-fast imaging of soft X-rays at the European XFEL. The simultaneous requirement of single-photon detection down to 0.5 keV and dynamic range up to 10^4 photons/pixel/pulse is here solved by introducing a non-linear compression of the DEPFET transistor. The accurate calibration of a 1 Mpixel DEPFET sensor with signal compression is the key to reach the desired performances but also the major challenge. The aim of this work is to discuss the general calibration strategy, to present the experimental results of the first calibration campaigns on the first 128×512 DSSC ladder and to discuss the open issues. The achieved results validate the calibration strategy of the full DSSC camera and show achievement of noise levels below 20 electrons rms and an input range of deposited energy up to several MeV per pixel per pulse.

Single-crystal diamond detector measurements of deuterium-deuterium neutrons at the new NILE facility.

<u>Paoletti M.</u> ([1]), Cazzaniga C. ([2]), Rigamonti D. ([3]), Ngo K. ([2]), Perelli Cippo E. ([3]), Tardocchi M. ([3])
([1]) *Dipartimento di Fisica, Università degli Studi di Milano-Bicocca, Milano, Italia*
([2]) *ISIS Facility, UKRI-STFC, Rutherford Appleton Laboratory, Didcot, UK*
([3]) *Istituto per la Scienza e Tecnologia dei Plasmi, CNR, Milano, Italia*

A single-crystal diamond detector (SDD) has been used for the characterization of a DD compact neutron generator of the new NILE facility of the Rutherford Appleton Laboratory (UK), where two compact DD and DT sources are being installed to produce 2.5 MeV and 14 MeV neutrons for chip irradiation experiments. In recent years SDDs have been successfully used for neutron measurements in the MeV range including high-resolution spectroscopy. At NILE the SDD has been irradiated with 2.5 MeV neutrons at different angles in order to study the neutron energy as a function of the emission angle. The measured data are here compared to the expected theoretical curves to characterise the generator and determine the amount of primary and scattered neutrons. Further measurements have been conducted placing the SDD at different angles around the generator axis in order to find the best position (in terms of amount of scattered neutrons) for chip irradiation. The performances of the SDD had been previously evaluated through a benchmark experiment realized with both 2.5 MeV and 14 MeV at the PTB Metrology Institute (D) in collaboration with CNR-ISTP, Università di Milano-Bicocca and RAL.

Compact and multi-channel readout system for the long term radioactive waste monitoring.

<u>Poma G.E.</u> ([1]), Cosentino L. ([1]), Fanchini E. ([3]), Finocchiaro P. ([1]), Garosi P. ([3]), Longhitano F. ([2]), Lucchesi A. ([3]), Ninci D. ([3]), Simonetto M. ([3]), Tintori C. ([3])
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([3]) *CAEN s.p.a., Viareggio, Lucca, Italy*

We developed gamma-ray counters (SciFi) and solid-state thermal neutron detectors (SiLiF) as a solution for radioactive waste monitoring. SciFi is a low-cost Geiger counter and consists of scintillating fiber coupled to two silicon photomultipliers (SiPM): thanks to its optimized single-photon sensitivity and left-right coincidence constraint, SciFi can be employed for long-term monitoring. SiLiF detector consists of polyethylene 103 cm^3 hollow cube for neutrons

thermalization, and double-sided silicon diode placed at its center, sandwiched between two ^{6}LiF converter layers: by means of n + ^{6}Li → ^{3}H(2.73 MeV) + ^{4}He(2.05 MeV) reaction, we can count the ^{3}H and alpha contributions and reconstruct their energy spectra. In order to obtain a compact optimized data acquisition system, a 64-channel digitizer coupled with power supply, and new CAEN Front-End board with dedicated software have been employed for neutron and gamma detection, respectively. By using γ/n sources, several tests have been carried out in laboratory environments by means of activity known point-like sources and radwaste drums with undefined compositions and activity distributions. Preliminary results will be presented.

Internal losses measurement of a dual-mode photodiode at cryogenic temperature.

Pepe C. (1)(2), Rajteri M. (2), Brida G. (2)
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(2) *Istituto Nazionale di Ricerca Metrologica, Torino, Italia*

The chipSCALe project is focussed on developing a more robust linkage to the revised SI candela for optical power measurements. The target of this project is to realize the first "NMI-on-chip" for optical power measurement. Here we present primarily results on a cryogenic temperature dual-mode self-calibrating detector that combines predictable quantum efficiency photodiodes (PQED) with electrical substitution radiometry for determination of optical power. The thermal detection is used as reference in the detector to determinate directly the internal losses of the photodiode without the need of an external reference. We report on dual-mode internal loss estimation measurements with radiation of 632 nm at different power levels from 0.1 mW to 1.5 mW.

From ultrafast holography to ultrafast tomography.

Hörmann M. (1), Cerullo G. (1), Camargo F.V.A. (2), van Hulst N. (3)(4), Liebel M. (3)
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(2) *IFN-CNR, Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche, Milano, Italy*
(3) *ICFO, Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, Castelldefels, Barcelona, Spain*
(4) *ICREA - Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain*

In optical diffraction tomography (ODT) the real three-dimensional structure of even dense objects is retrieved by combining microscopic amplitude and phase images from different angles. A common scheme to perform this angle-scanning utilizes off-axis holography, in which a reference wave is interfered with the wave front induced by the object. However, the interference relies on monochromatic light sources with long coherent lengths. Here, we present a setup capable of performing ODT with femtosecond pulses and a bandwidth of over 100 nm, respectively, in an off-axis scheme. To maintain the interference the wave fronts are perfectly matched spatially and spectrally. Further, we perform test measurements on how the chirp introduced by dispersive media influences the interference quality depending on the bandwidth. The results of this study show the successful implementation and allow directly to either perform ODT with spectral information or to extend tomography to the realm of ultrafast transient processes in pump-probe experiments, which can find application in material science (*e.g.*, photoinduced charge carrier diffusion) or bio-physics (tracking gold nanoparticles in cells).

Characterization of thin layers with negative muons.

Cataldo M. (1)(2)(6), Hillier A.D. (2), Ishida K. (3), Grazzi F. (4), Porcinai S. (5), Cremonesi O. (6), Clemenza M. (6)
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(2) *ISIS Neutron and Muon Source, Didcot,UK*
(3) *RIKEN Nishina Center, Wako, Saitama,Japan*
(4) *CNR-IFAC, Sesto Fiorentino, Italy*
(5) *Opificio delle Pietre Dure, Firenze, Italy*
(6) *INFN, Sezione di Milano Bicocca, Italy*

Muonic X-ray Emission Spectroscopy (μXES) is a novel technique in the broad field of non-destructive methods for cultural heritage analysis. It relies on the interaction of a probe of negative muons with matter and the following emission of X-ray radiation. Since the muon mass is about 200 times bigger than the electron, the emitted X-rays are highly energetic and are characteristic of the emitting atom, making it possible to cover a wide part of the periodic table (from lithium to uranium). Thanks to the multi-elemental range, a negligible self-absorption effect of the X-rays and very low residual activity left in the sample after irradiation, μXES is a very powerful probe for material characterization, especially for archaeological findings. In this contribution, preliminary results of the analysis on two gilded surfaces are reported. Here, the data analysis is coupled with the results from Monte Carlo simulations for assessing the thickness of the different layers of the samples. Monte Carlo simulations, indeed, represent an invaluable tool for this particular technique since they can help in developing the data analysis, especially for thin layer characterization.

Aula C - Maria Gaetana Agnesi **ore 09:00 – 13:30**

Sezione VII
Didattica e storia della fisica
Presiedono: Michelini M. (Università di Udine)
Guerra F. (Sapienza Università di Roma)

Relazioni su invito

▲ **La fisica a teatro per una didattica spettacolare.**

Carpineti M.
Dipartimento di Fisica "Aldo Pontremoli", Università degli Studi di Milano

"Lo spettacolo della fisica", insolito connubio tra scienza e teatro, è un progetto della Statale di Milano nato per proporre un nuovo modo di comunicare la fisica, che ha rivelato presto la sua grande potenzialità didattica. I fisici attori che mostrano gli aspetti spettacolari o contro-intuitivi, le difficoltà e i conflitti della materia che amano, riescono a far emozionare e perfino a far ridere. Si tratta di una grande innovazione, perché la scienza incontrata a scuola di solito non coinvolge la sfera emotiva. Il teatro può dunque affiancare la didattica tradizionale aiutando a vincere la resistenza verso una materia spesso non amata, stimolando la curiosità e la passione con i suoi aspetti creativi e non scontati. Dal 2004 il progetto ha dato vita a 8 pièce con oltre 420 repliche, ma anche ad attività di formazione insegnanti, a percorsi didattici formali, a conferenze spettacolari in cui si vede la fisica nella vita di tutti i giorni, fino a un MOOC (massive on line open course) per l'orientamento alla scelta dell'università. L'ingrediente comune è la certezza che la fisica deve raggiungere il cuore degli studenti, punto di partenza ideale per insegnare competenze e abilità.

▲ **Riflessione in riva al mare.**

De Luca R.
Dipartimento di Fisica "E. R. Caianiello" - Università degli Studi di Salerno

Il luccichio sulle acque del mare leggermente increspato e le figure luminose osservabili dalla riva sul fondale sono due fenomeni che possono incuriosire e deliziare chiunque. Nel primo si possono osservare dei frammenti di luce che si riflettono sulle acque del mare e danzano in sincronia con le onde davanti a un osservatore. Quest'ultimo può indossare, oppure no, occhiali con lenti polarizzate, cosicché potrà notare che l'intensità luminosa dei riflessi osservati con lenti polarizzate è minore. Nel secondo fenomeno si notano linee sinuose di luce sul fondale basso vicino alla battigia. Questi disegni luminosi sono dovuti alla rifrazione della radiazione solare: a seconda dell'angolo di incidenza dei raggi di sole sull'acqua del mare, l'intensità del raggio rifratto varia, con un picco proprio in corrispondenza con i ghirigori luminosi sul fondale. Anche il secondo fenomeno può essere osservato con o senza lenti polarizzate. In questo lavoro si è voluto trovare una plausibile spiegazione a questi due fenomeni luminosi, *riflettendo* sulle equazioni di Fresnel.

▲ **Marie Curie, née Skłodowska: Come si costruisce un Premio Nobel.**

Robotti N.
Dipartimento di Fisica, Università di Genova e Centro Studi e Ricerche "Enrico Fermi", Roma

Il 10 dicembre 1911, a Marie Curie veniva assegnato il suo secondo Premio Nobel, questa volta per la Chimica, dopo quello per la Fisica del 1903, ricevuto assieme a Pierre Curie e a metà con H. Becquerel. Se andiamo ad analizzare la produzione scientifica della Curie a partire dalla morte del marito (1906) fino al 1911, non troviamo nessuna particolare scoperta degna di un secondo Premio Nobel. Le ragioni che hanno portato a questo secondo premio vanno, invece, ricercate in quanto la Curie ha costruito intorno all'elemento Radio e come è riuscita a far sopravvivere la "coppia Curie", prendendone lei il posto, sia scientificamente che istituzionalmente (la cattedra alla Sorbona), sia con grandi imprese (l'Institut du Radium), sia come immagine, sia come presenza, diventando alla fine l'icona della nuova fisica.

Comunicazioni

Termodinamica e teoria microscopica: Una proposta didattica per la scuola superiore.

Ercoli A. (1), Lubicz V. (2)
(1) *Liceo Scientifico Statale "P. Ruffini", Viterbo, Italy*
(2) *Dipartimento di Matematica e Fisica, Università Roma Tre and INFN, Sezione di Roma Tre, Roma, Italy*

L'insegnamento della Termodinamica nelle scuole superiori ha avuto in questi anni spazi e contenuti sempre più ridotti. I suoi Principi sembrano spesso riguardare solo gas perfetti e macchine termiche e si è persa la generalità con la quale la Termodinamica affronta questioni fisiche di carattere fondamentale. Il convincimento che ad una reale, approfondita e al tempo stesso più semplice comprensione delle leggi della Termodinamica si possa giungere solo a partire dalla descrizione microscopica dei sistemi fisici ci ha portato a realizzare un percorso didattico, destinato principalmente alle scuole superiori, nel quale la teoria microscopica svolge un ruolo privilegiato. La diversità dei fenomeni che la Termodinamica correla, quali i meccanismi di trasferimento di energia (Primo Principio) o la direzionalità dei fenomeni fisici (Secondo Principio) emergono in questo modo con chiara evidenza, in un approccio basato solo sui principi della meccanica classica e della teoria delle probabilità. La proposta è stata presentata e analizzata in un corso di formazione per docenti delle scuole superiori.

Cinematica cinestetica: Sperimentazioni d'aula.

Bologna V., Peressi M.
Dipartimento di Fisica, Università degli Studi di Trieste, Italia

Coivolgere gli studenti attivamente nel processo di apprendimento favorisce lo sviluppo di abilità scientifiche e di competenze di argomentazione. Tale obiettivo è proprio di un approccio che abbiamo denominato *Early Physics*. Questo approccio promuove la concettualizzazione dei fenomeni fisici attraverso la frammentazione delle conoscenze utilizzando le rappresentazioni multiple e la pluralità dei linguaggi disciplinari, declinando i contenuti in modalità *ISLE-based*. Nell'ambito delle attività sviluppate è risultato particolarmente significativo un percorso realizzato in una classe prima di un Istituto tecnico-professionale. In palestra, in giardino e in aula gli studenti sono stati protagonisti essi stessi della definizione delle grandezze che caratterizzano il moto, della ricerca di schemi che portino ad una modellizzazione concettuale e all'applicazione dei concetti acquisiti per la risoluzione di semplici situazioni problematiche senza necessariamente ricorrere alla matematizzazione. In questo modo hanno risolto "fisicamente" problemi che in un liceo verrebbero tipicamente risolti solo in modo astratto con l'utilizzo di sistemi lineari di equazioni.

So "wrong" do they all: The plum pudding case and other quantum issues.

Lovisetti L., Giliberti M.
Department of Physics, University of Milan, Italy

Usual textbooks describe Thomson's model as a plum pudding with electrons embedded within a spherically distributed positive charge, not getting that it should rather be based on a precise mathematical model. Moreover, the problem of atomic stability is solved with an electron in a Coulomb potential (hydrogen atom), not realising that this is due to the absence of the radiative term in the Hamiltonian. Again, why in the photoelectric effect only energy conservation is used, neglecting the momentum one? Why Geiger-Mardsen experiment is described as a single test, while at least three distinct tests have been made? And why Planck's black-body law is considered a conciliation between Wien's and Rayleigh-Jeans's ones, when the latter is not prior to Planck's formulation? These examples highlight how there is often a lack of critical analysis in matching prior physics knowledge in a coherent way, as well as a widespread illiteracy of the historical development of the Quantum Theory (QT). This project, implemented by the research group of Milan, thus aims to face both problems, retracing the historical formulation of the QT and creating a coherent conceptual framework of the discipline.

"L'eleganza della meccanica quantistica": Un percorso didattico per la scuola superiore.

Melli E., Lovisetti L., Giliberti M.
Dipartimento di Fisica, Università degli Studi di Milano, Italia

La Meccanica Quantistica è oggetto di attenzione della ricerca in didattica della fisica all'incirca dagli anni Novanta del secolo scorso. Ancora oggi, però, nonostante i ricercatori non esprimano più dubbi sul fatto che essa sia fondamentale per la cultura del singolo cittadino e dell'intera società, esiste un ampio dibattito riguardo agli argomenti da proporre e a come effettuarne una traduzione didattica efficace nelle scuole. Con questo scopo, è stata progettata, sperimentata e valutata una Teaching-Learning Sequence pilota sui concetti fondanti della meccanica quantistica (stato, spazio di Hilbert, sovrapposizione, osservabile, probabilità, autovalore e autovettore, ...) rivolta a studenti e docenti di scuola secondaria superiore. La sperimentazione è avvenuta in un ciclo di 10 incontri di un'ora e mezza ciascuno su Zoom (120 partecipanti), tra ottobre 2021 e gennaio 2022. L'efficacia del percorso - punti di forza e criticità - è stata valutata raccogliendo e analizzando diversi tipi di dati derivanti da un questionario di gradimento anonimo, da 9 Moduli Google (38 domande aperte, 24 esercizi totali) e da 19 interviste singole (13 a studenti e 6 a docenti).

Discovering the quantum nature of reality at school.

Borsini I., Amendola D.
Scuola di Scienze e Tecnologie, Dipartimento di Fisica, Università di Camerino

By a combination of Thermodynamics, Quantum Field Theory and Physical Optics, black body radiation mechanism was completely described in the first thirty years of the last century. Experimental observation of black body radiation is, however, difficult at school, so attention has turned to analogues systems in the study of this radiation. We have proposed a real system that follows the Bose-Einstein statistics, capable of simulating the density of electromagnetic energy, as a function of frequency and temperature, at thermal equilibrium, in a cavity. Through a didactical comparative research, we have shown that the use of such analogous systems, especially in inquiry-based teaching environments, increases the awareness of acquired knowledge and agency, compared to different teaching techniques, encouraging the embodied cognition.

Progettare percorsi inquiry-based con Arduino e smartphone.

Gabelli L. (1)(2), Lissandron G. (3), Carli M. (1), Pantano O. (1)
(1) *Dipartimento di Fisica e Astronomia Galileo Galilei, Università di Padova, Italia*
(2) *Istituto Tecnico Industriale "Francesco Severi", Padova, Italia*
(3) *Liceo Statale "Alvise Cornaro", Padova, Italia*

Presentiamo un percorso di formazione annuale per insegnanti di fisica in servizio organizzato dalla rete di scuole dell'Ambito 21 del Veneto in collaborazione con l'Università di Padova. Il corso si poneva tre obiettivi principali: introdurre l'uso delle tecnologie nel laboratorio di Fisica, favorire lo sviluppo delle competenze di indagine scientifica degli studenti e promuovere la crescita professionale dei docenti. Dopo aver affrontato il tema della progettazione di percorsi inquiry-based e della valutazione dello sviluppo delle pratiche scientifiche, è stato proposto l'utilizzo di Arduino e phyphox, tecnologie che consentono di svolgere esperimenti a basso costo e di progettare il setting sperimentale a diversi livelli adattandosi ai bisogni delle scuole. I docenti sono stati coinvolti in progettazioni di gruppo, discussioni, valutazioni tra pari e sono stati proposti approfondimenti a partire dai risultati della ricerca didattica. Nella seconda parte del percorso ai docenti è stato chiesto di sviluppare e sperimentare in classe unità didattiche con attività laboratoriali e valutare l'apprendimento delle abilità di indagine scientifica degli studenti coinvolti.

Officina di Narrazione della Scienza: L'esperienza dell'università di Bologna.

Fabbri L. (1)(2), Brunello A. (1), Brusa M. (1)(3), Focardi P. (1), Levrini O. (1), Sanna S. (1), Tasquier G. (1)

(1) *Dipartimento di Fisica e Astronomia "Augusto Righi", Università di Bologna, Bologna, Italia*
(2) *INFN Sezione di Bologna, Bologna, Italia*
(3) *INAF Sezione di Bologna, Bologna, Italia*

Il cambiamento tecnologico e sociale, unito alla difficoltà di gestire i numerosi canali di comunicazione e la complessità inerente le questioni socio-scientifiche, sta producendo disorientamento e una crescente sfiducia nella scienza. Come accaduto durante la pandemia, gli scienziati hanno dovuto assumere il ruolo di comunicatori scientifici, senza disporre spesso di una formazione adeguata circa il rapporto complesso tra comunicazione scientifica e società. In questo scenario, il Dipartimento di Fisica e Astronomia dell'Università di Bologna ha ideato un contesto formativo chiamato "Officina di Narrazione della Scienza", una scuola estiva annuale dedicata a studenti universitari, giovani ricercatori e insegnanti che vogliano acquisire conoscenze e competenze di narrazione della scienza. Nella presentazione saranno illustrati i motivi che hanno condotto alla realizzazione della scuola e alcuni risultati emersi dalla prima edizione.

Un percorso didattico innovativo sulla scala delle distanze.

Colantonio A. (1)(2), Leccia S. (2), Tortora C. (2)

(1) *Scuola di Scienze e Tecnologie, Dipartimento di Fisica, Università di Camerino, Italia*
(2) *INAF, Osservatorio Astronomico di Capodimonte, Napoli, Italia*

Il problema della determinazione della distanza degli oggetti astronomici, oltre ad essere una delle grandi sfide per gli astrofisici, è un contesto motivante ed adatto ad affrontare alcuni dei concetti chiave della Fisica, quali la gravità, le reazioni nucleari e lo spettro elettromagnetico. Partendo dalla percezione visiva, passando per la determinazione geometrica della distanza e le candele standard fino alla legge di Hubble-Lemaitre, si presenterà un percorso didattico innovativo sulla scala delle distanze basato sulla metodologia inquiry. Il percorso didattico è stato implementato con novanta studenti frequentanti il quarto ed il quinto anno della scuola secondaria di secondo grado in un contesto di attività extra-curricolari. L'efficacia del percorso didattico è stata verificata somministrando un questionario pre-post attività appositamente progettato.

Training School MERADE MEasurements of RADioactivity in the Environment.

Groppi F. [1][2], Cadeo L. [1], Confalonieri L. [1], Vincenzi M. [1], Colucci M. [1][2]
[1] *Università degli Studi di Milano, Dipartimento di Fisica*
[2] *Istituto Nazionale di Fisica Nucleare, Sezione di Milano*

Nell'ambito della collaborazione europea Cooperation for Higher Education on Radiological and Nuclear Engineering - CHERNE è stata organizzata la Scuola MERADE - MEasurements of RAdioactivity in Environment che ha visto coinvolti per una settimana 16 studenti e studentesse dei corsi di Laurea Magistrale e/o Dottorandi di Fisica ed Ingegneria provenienti da Belgio, Germania, Italia, Portogallo, Repubblica Ceca. Suddivisi in quattro gruppi eterogenei sono stati chiamati a svolgere attività sperimentali sia in laboratorio sia in campo oltre a ricevere lezioni introduttive sui temi trattati. Sono state introdotte ed applicate tecniche di tipo radiochimico come la scintillazione liquida applicata a campioni ottenuti mediante distillazione, misure di spettrometria gamma con rivelatori HPGe su campioni di terra prelevati in campo per evidenziare zone particolarmente radio-contaminate e con rivelatori NaI su vari prodotti alimentari e per la misura della concentrazione di gas radon indoor mediante l'esposizione di canestri a carbone attivi. Verrà presentata questa ricca e stimolante esperienza che ha visto un interscambio di modalità operative dei vari laboratori di provenienza.

Un setup sperimentale portatile per la spettroscopia γ.

Petroselli C. [1], Bomben L. [1][2], Carsi S. [1], Fanzini C. [1], Lezzani G. [1], Monti-Guarnieri P. [1][2], Prest M. [1][2], Ronchetti F. [1], Selmi A. [1][2], Vallazza E. [2]
[1] *Dipartimento di Scienza ed Alta Tecnologia, Università degli Studi dell'Insubria, Italia*
[2] *INFN - Sezione Milano Bicocca, Italia*

La spettroscopia γ è una delle tecniche utilizzate nell'ambito della fisica ambientale e si basa normalmente su scintillatori inorganici accoppiati a tubi fotomoltiplicatori, oppure, nei sistemi più avanzati, su rivelatori al germanio. L'elettronica di lettura in un setup standard da laboratorio consiste in un amplificatore-shaper e un analizzatore multicanale, e quindi risulta di difficile trasporto sia nelle scuole che sul campo. Questo contributo descrive lo sviluppo di un setup sperimentale portatile basato su uno scintillatore allo NaI(Tl), letto da FotoMoltiplicatori al Silicio, e su una scheda di acquisizione che permette di processare e di visualizzare il segnale tramite un software dedicato. Il limitato consumo di potenza del sistema, alimentato con una power bank, la riproducibilità del supporto del campione, stampabile in 3D, e le dimensioni ridotte, lo rendono adatto ad attività didattiche nei laboratori e sul campo per studenti dell'ultimo anno delle scuole superiori e del percorso triennale in fisica.

Verso un insegnamento efficace del cambiamento climatico: analisi dei libri di testo scolastici.

Toffaletti S., Di Mauro M., Onorato P.
Dipartimento di Fisica - Università di Trento, Povo, Trento - Italia

La ricerca sull'educazione scientifica ha evidenziato che la presenza di misconcezioni o la mancanza di preconoscenze rilevanti può impedire agli studenti di sviluppare una comprensione efficace dei concetti scientifici; uno strumento importante in questo processo sono senza dubbio i libri di testo. Con questo lavoro ci proponiamo di effettuare un'analisi della rappresentazione in essi, sia iconica che simbolica, dell'effetto serra e dei cambiamenti climatici. Ci siamo riferiti ai testi più comunemente adottati nelle scuole superiori italiane nelle classi in cui i curriculi (delineati dai documenti ministeriali) ne prevedano l'insegnamento. Per l'analisi sono stati individuati i nuclei fondanti della disciplina e le principali misconcezioni. Inoltre, è stato costruito un quadro metodologico per analizzarli, integrando quanto già disponibile nella ricerca in questo ambito con quanto necessario per indagare i differenti aspetti di nostro interesse. Abbiamo infine confrontato quanto emerso da questa analisi con studi analoghi effettuati su questo argomento una decina di anni fa, quando questa tematica era ancora poco diffusa nei curricula, ma soprattutto nella società.

Aula A **ore 14:30 – 15:25**

SEZIONE II
Fisica della materia
Presiede: BIAGIONI P. (Politenico di Milano)

Relazione Generale

Modelling of two-dimensional magnetic materials.

PICOZZI S.
CNR-SPIN, Chieti, Italy

Combined with the global thrust towards miniaturization and with the ubiquitous research in two-dimensional (2D) materials, this contribution will focus on the modelling of magnets towards the 2D limit. In particular, after a general overview on spin-orbit coupling (SOC) in ferroics, I will focus on the magnetic and ferroelectric properties of transition-metal monolayers (mostly halides) and discuss the relevant role of SOC in the magnetoelectric coupling. The recent reports of multiferroicity in NiI_2 layers, obtained via a joint theory-experiments approach down to the single-layer limit, show the potentiality of cross-coupling phenomena in van der Waals magnets.

Aula A **ore 15:30 – 16:25**

Sezione I
Fisica nucleare e subnucleare
Presiede: Cobal M. (Università di Udine)

Relazione Generale

Solar neutrinos led to actual breakthroughs on the neutrino, Sun and star physics.

Bellini G.
University of Milan e INFN, Sezione di Milano, Italy

The study of very low-energy neutrinos requires a suppression of the natural radioactivity up to ultra-traces level. This is what the BOREXINO experiment succeeded to achieve with the development of *ad hoc* technologies, allowing a threshold down to 100 keV. So, the entire solar neutrino spectrum has been detected, together with a small, but clean and robust geoneutrino signal, providing new achievements in the solar, stars and neutrino physics, as well as opening new horizons in the study of the Earth's interior. Among the results, actual breakthroughs can be counted: the identification of the nuclear reactions which produce 99% of solar energy and then the solar luminosity, with also the demonstration of the solar stability on a 10^5 years scale; the independent demonstration of the validity of the MSW neutrino oscillation solution, through the determination in a single experiment of the transition of the electron neutrino survival probability from the vacuum to the matter regime; the first experimental detection of the CNO cycle, which dominates in the massive stars; new developments in the solar physics. Borexino is still now a unique experiment with its unprecedented radiopurity level, and is a reference for the very low-energy neutrinos study.

Aula A **ore 16:30 – 18:00**

Assemblea Generale dei Soci

L'Assemblea Generale dei Soci della Società Italiana di Fisica è convocata in occasione del Congresso Nazionale SIF 2022 in prima convocazione alle ore 16.00 e in seconda convocazione alle ore 16.30 di martedì 13 settembre 2022, l'Assemblea si riunirà nell'aula A del Dipartimento di Fisica dell'Università di Milano con il seguente ordine del giorno:

1) Approvazione dell'ordine del giorno.

2) Approvazione del verbale dell'Assemblea Generale dei Soci del 14 settembre 2021.

3) Relazione del Presidente.

4) Relazioni del Collegio dei Revisori dei Conti e approvazione dei bilanci consuntivi 2021.

5) Ringraziamento a Luciano Majorani. Ratifica e nomina dei Revisori dei Conti.

6) Discussione e approvazione della Relazione del Presidente.

7) La Commissione Didattica Permanente dell SIF: stato e prospettive.
   Intervento di E. Ercolessi

8) Il Comitato Pari Opportunità della SIF.
   Intervento di S. Pirrone

9) Varie ed eventuali.

Il Presidente della SIF
Angela Bracco

Aula A **ore 18:00 – 18:55**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Marotta A.M. (Università di Milano)

Relazione Generale

Dal nucleo alla crosta: La Terra studiata attraverso la deformazione della sua superficie.

Crescentini L.
Università di Salerno

I dati di deformazione della superficie della Terra, ottenuti sia da misure *in situ* che satellitari, sono di grande utilità per lo studio dei processi geofisici e delle loro caratteristiche a diverse scale spaziali e temporali. Per esempio, dalla deformazione nella banda mareale diurna si possono ottenere informazioni sulla dinamica del nucleo e sulle caratteristiche dell'interfaccia nucleo-mantello, così come dati di deformazione sono fondamentali in studi sui domini tettonici, anche complessi, sulle proprietà reologiche della Terra, su diversi aspetti del ciclo sismico, nelle sue fasi intersismica, sismica e postsismica, e sui movimenti di magma fino alle eruzioni. Le deformazioni indotte da fenomeni meteorologici e idrologici sono interessanti sia come fenomeno in sé che per rimuoverne le interferenze su eventuali altri importanti segnali, quali possibili deformazioni pre-sismiche. Però in molte aree della Terra la deformazione non è ben conosciuta, per insufficiente sensibilità o risoluzione spazio-temporale delle misure o per la loro assenza, nonostante che ai pochissimi strumenti terrestri ad alta sensibilità attualmente esistenti si siano da tempo affiancate misure satellitari, basate fondamentalmente sul sistema satellitare globale di navigazione e sull'interferometria con radar satellitari ad apertura sintetica. Nella relazione generale si cercherà di mettere in luce almeno alcuni fra i processi fisici all'opera sulla Terra, con particolare riferimento all'Italia, che sono stati (o possono essere) studiati privilegiatamente attraverso le misure di deformazione, evidenziandone i punti di forza e di debolezza.

Aula A **ore 9:00 – 9:30**

Assemblea Elettorale

Aula Consiglio **ore 10:00**

Apertura del Seggio Elettorale

Aula A **ore 9:30 – 10:25**

Sezione III
Astrofisica
Presiede: Blasi P. (GSSI, L'Aquila)

Relazione Generale

■ **X-ray astronomy in cosmology and astrophysics: From eROSITA to the future.**

Santangelo A.
Kepler center for Astro and Particle Physics, University of Tübingen, Germany

This year marks the 60th anniversary of the birth of X-ray astronomy. Since the discovery of X-rays from, at the time mysterious, celestial source Sco X-1, the discipline's contribution to the understanding of the astrophysical Universe and of cosmology has been enormous. In the first part of my communication, I will attempt to summarise the fundamental contributions of X-ray astronomy and astrophysics to the advancement of the study of the Universe, in conjunction with the achievements of the larger field of high-energy astrophysics. I will then summarise the scientific and technological aspects of the German eROSITA mission, on board the Spectrum X-Gamma satellite. I will also discuss some of the most significant highlights of the mission. In the third part of my contribution, I will take a look at the future of X-astronomy, discussing future missions, the scientific cases driving their development, and the challenging, new frontier of X-ray interferometry.

Aula A **ore 10:25 – 11:20**

Sezione VI

Fisica applicata, acceleratori e beni culturali

Presiedono: Rifuggiato D. (INFN-LNS, Catania)
Senesi R. (Università di Roma Tor Vergata)

Relazione Generale

Laser-accelerated secondary sources for multidisciplinary applications.

Antici P.
INRS, Varennes, Québec, Canada

The advent of high-power (TW) ultra-short (fs-ps) lasers has recently opened up the field of laser-driven plasma acceleration, which includes the acceleration of electrons, protons and X-rays. The investigation of these secondary sources and its use has triggered considereable investments and is currently challenging many research laboratories worldwide, in particular for the improved characteristics of these sources such as compactness, versatility and tunability. Among the manifold applications that these sources can enable we can cite their use as injector for large-scale accelerators, in medicine, fusion, materials science and cultural heritage. In this contribution I will give a brief overview about laser-plasma sources and some of their applications.

Aula A **ore 11:20 – 12:15**

Sezione VII
Didattica e storia della fisica
Presiedono: Di Martino D. (Università di Milano Bicocca)
Rabuffo I. (Università di Salerno)

Relazione Generale

Il museo in cui ci si innamora della scienza.

Xanthoudaki M.
Museo della Scienza e della Tecnica, Milano

Da molto tempo e a livello internazionale, l'educazione alle STEM è oggetto di studi, dibattiti e riflessioni, molti dei quali sostengono la necessità di adottare approcci e risorse educativi che aiutano non soltanto a rimanere al passo con i tempi, ma, ancor più, a creare un contesto in cui i discenti possano apprendere in modo creativo costruendo attivamente sul proprio potenziale. Il Museo Nazionale Scienza e Tecnologia Leonardo da Vinci lavora nell' e per l'educazione scientifica fin dalla sua nascita partendo da una definizione di apprendimento inclusivo e dal concetto di capitale scientifico. Entrambi sono integrati in un metodo educativo che viene arricchito da una continua ricerca pedagogica e dall'uso di risorse innovative, allo scopo di favorire una relazione fra le persone e le STEM lungo tutto l'arco della vita, inclusiva, che contribuisca allo sviluppo di competenze e di conoscenze. Il contributo discuterà esempi di questo lavoro con particolare attenzione a quelli che mirano all'innovazione nell'educazione alle STEM.

Aula B - Maria Goeppert-Mayer **ore 13:30 – 18:30**

Sezione I

Fisica nucleare e subnucleare

Presiedono: LUCCHESI D. (Università di Padova)

PINAMONTI M. (INFN, Sezione di Trieste)

FUTURE COLLIDERS

Relazioni su invito

▲ **Oltre il Modello Standard ai collider futuri.**

MELE B.

INFN, Sezione di Roma, Italia

Verranno riassunte le criticità dell'attuale teoria delle interazioni fondamentali e le prospettive di scoprire come possano essere superate realizzando collisionatori di più alta energia e/o luminosità.

▲ **Beyond LHC: The future of particle physics (HL-LHC, FCC).**

AZZI P.

INFN, Sezione di Padova, CMS Collaboration-FCC Study project

The data from the LHC will continue to advance our knowledge of the fundamental properties of matter, but several crucial questions that put in question the Standard Model will remain. To extend its capabilities the LHC will undergo a major upgrade to increase its instantaneous luminosity and collect up to $3\,\mathrm{ab}^{-1}$ (HL-LHC). An overview of the physics potential of the HL-LHC will be presented focusing on its unique strengths. Moreover, in 2020 CERN has started a feasibility study for the construction of Future Circular Colliders (FCC) in the Geneva region with a circumference of about 100 km. An e^+e^- collider (FCC-ee), covering the energy range from the Z pole ($\sqrt{s} = 90\,\mathrm{GeV}$) up to the top pair production threshold ($\sqrt{s} = 365\,\mathrm{GeV}$) is the first step to collect incredible statistics of the heaviest particles of the SM. The ultimate goal would be a pp collider (FCC-hh) reaching 100 TeV in the centre of mass. The FCC integrated project offers an incredible discovery potential with a careful mixture of precision measurements sensitive to very weak coupling or very heavy objects, and very high energies where the new heavy particle could be directly produced.

Comunicazioni

● **Characterization of sensor modules for the CMS Barrel Timing Layer at HL-LHC.**

PALLUOTTO S.

Dipartimento di Fisica, Università di Milano-Bicocca, Italia e INFN, Sezione di Milano-Bicocca, Italia

The CMS detector is undergoing an extensive upgrade program to prepare for the challenging conditions of the High-Luminosity LHC starting in 2029. In particular, a new timing detector will measure minimum ionizing particles with a time resolution of 30–60 ps. The technology selected for the central part of the detector, the Barrel Timing Layer, consists of scintillating crystals of lutetium yttrium oxyorthosilicate doped with cerium (LYSO : Ce) read out with silicon photo-multipliers. A detailed characterization of several sensor modules, consisting of a sixteen-channel crystal array coupled to a pair of SiPM arrays, will be presented. The results represent the first thorough investigation of the performance of modules made with crystals and SiPMs of different geometries characterized both with radioactive sources and laser excitation in laboratory as well as with test beam.

The Upgrade of the CMS Electromagnetic Calorimeter for HL-LHC.

Borca C.
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The High-Luminosity upgrade of the LHC (HL-LHC) at CERN will provide unprecedented instantaneous and integrated luminosities of around $5 \times 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and 3000/fb, respectively. An average of 140 to 200 collisions per bunch-crossing (pileup) is expected. The upgraded ECAL will feature new readout electronics that will greatly improve the time resolution for photons and electrons with energies above 10 GeV. We present the status of the ECAL barrel upgrade, including time resolution results from beam tests conducted during 2018 and 2021 at the CERN SPS.

Characterization of pixel sensors for the CMS Tracker upgrade at HL-LHC.

Bardelli G.
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The High-Luminosity phase of the CERN Large Hadron Collider (HL-LHC) calls for an extensive upgrade of the CMS Tracker System requiring, for the Inner Tracker detector, high-radiation tolerant silicon pixel sensors to cope with fluences up to about 2E16 $n_{\mathrm{eq}}/\mathrm{cm}^2$. CMS has recently chosen thin planar and 3D pixel sensors to instrument the upgraded Inner Tracker. The results obtained with FBK planar and 3D sensors interconnected with prototype read-out chip RD53A will be shown. First modules are also being assembled with the final CMS chip prototype, also known as C-ROC (CMS Read Out Chip). Both RD53A and C-ROC compliant sensors have $25 \times 100\,\mu\mathrm{m}^2$ cell size and $150\,\mu$m of silicon active thickness. The sensors were also irradiated and then tested in different test beam facilities in order to validate them up to the fluence figures foreseen for HL-LHC. The analysis of collected data shows very high hit detection efficiencies and excellent spatial resolutions before and after irradiation.

Primary vertex reconstruction on heterogeneous architectures.

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The future development projects for the Large Hadron Collider will constantly bring nominal luminosity increase, with the ultimate goal of reaching a peak luminosity of $5 \times 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. This would result in up to 200 simultaneous proton collisions (pileup), posing significant challenges for the CMS detector reconstruction. The CMS primary vertex (PV) reconstruction is a two-step procedure consisting of vertex finding and fitting. First, the Deterministic Annealing algorithm clusters tracks coming from the same interaction vertex. Secondly, an Adaptive Vertex Fit computes the best estimate of the vertex position in three or four dimensions. For High-Luminosity LHC (HL-LHC) conditions the reconstruction of PVs is expected to be extremely time expensive (up to 6% of reconstruction time). In this contribution we present our studies on the rethinking and porting of PV reconstruction algorithms in order to be run on heterogeneous architectures that allows us to exploit parallelization techniques to significantly reduce the processing time. We will show the results obtained focussing on computing and physics performance for both Run3 and HL-LHC conditions.

Ultimi sviluppi dei sensori UFSD per l'Endcap Timing Layer di CMS.

Lanteri L.
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La mia presentazione riguarderà gli Ultra-Fast Silicon Detectors (UFSDs), una tipologia di sensori a semiconduttore che, a differenza di quelli tradizionali, presentano un sottile layer altamente drogato, detti Low-Gain Avalanche Diodes (LGADs). Questa configurazione genera un innalzamento locale del campo elettrico in grado di moltiplicare le cariche primarie rilasciate per ionizzazione al passaggio di particelle; il risultato che si ottiene è un segnale più ampio rispetto ai classici rivelatori al silicio, ma soprattutto un miglior rapporto segnale/rumore. Grazie al loro disegno i rivelatori UFSD, con uno spessore di circa 50 μm, permettono di effettuare misure di tempo con una risoluzione temporale di alcune decine di ps. Verranno presentate le caratteristiche dei sensori UFSD e le principali misure effettuate sulle ultime produzioni. In particolare, mostrerà l'evoluzione della risoluzione temporale al variare della radiazione ricevuta e "per la prima volta" mostrerà l'uniformità di produzione su sensori di grandi dimensioni, circa 4.5 cm^2, in vista dell'utilizzo di sensori UFSD per la costruzione della parte endcap del MIP Timing Detector (MTD) per la Fase 2 del rivelatore CMS.

AI models and techniques for muons identification in the ATLAS Phase-II L0 Muon Barrel trigger.

Russo G.
Università di Roma La Sapienza, INFN, Sezione di Roma1

In order to fully exploit the potential of High Luminosity LHC, the ATLAS Muon Barrel Spectrometer will undergo some structural modifications and the L0 trigger algorithm will run on FPGAs. In this contribution new AI models have been studied to identify the muon tracks, to distinguish the tracks from random noise hits and to reconstruct the physical quantities on which to perform the trigger selection. Different techniques have been adopted in order to satisfy the strict requirements given by ATLAS and compress the algorithm to successfully run on a FPGA with minimal loss in performance.

Test of ITk 3D sensor pre-production modules with ITkPixv1.1 chip.

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To cope with the increased luminosity of LHC, the ATLAS detector will be updated. ITk detector will be the new ATLAS tracking system, it will be equipped with 3D pixel sensor modules in its innermost layer (L0). The pixel sensor cell dimensions will be either $25 \times 100\,\mu\text{m}^2$ (barrel) or $50 \times 50\,\mu\text{m}^2$ (endcap). Sensor from pre-production wafers ($50 \times 50\,\mu\text{m}^2$) produced by FBK have been bump bonded to the ITkPixV1.1 chip at IZM. These are the first preproduction modules ever tested in the Pixel project, they have been assembled in Genoa on Single Chip Cards and characterized in laboratory and at test beam, before and after irradiation ($1.6\,\frac{n_{\text{eq}}}{\text{cm}^2}$).

The Inner Tracker upgrade for the CMS experiment at HL-LHC.

Luongo F.
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The high-luminosity upgrade for the LHC (HL-LHC) is expected to deliver up to 200 pp collisions at 14 TeV every 25 ns, greatly increasing the potential for physics research and new discoveries. Close to the interaction point, the density and rate of produced particles will reach values beyond 1 GHz/cm^2, with detectors experiencing unprecedented levels of radiation. For operation in these much harsher conditions, development is ongoing at CMS for a new silicon tracking detector in place of the one currently installed in the experiment. The new detector will feature a more extended coverage up to $|\eta| = 4$, a lower material budget and trigger capabilities. In the region of the detector volume closest to the beamline, where operating conditions are the most extreme, the Inner Tracker is going to employ high-granularity ($25 \times 100\,\mu\text{m}^2$) pixel technology, enabled by innovative sensors and by the CROC, the chip for their readout, specifically designed in 65 nm CMOS technology by the RD53 collaboration for use at the HL-LHC. In this contribution, the state of the project for the upgrade of the Inner Tracker at large will be discussed, with highlights from CROC-related development.

Assembly procedures and QA/QC tests of the new double-ends readout panels of the new layer of trigger chambers for the phase II upgrade of the ATLAS barrel muon spectrometer.

Falsetti G., Schioppa M.
Gruppo Collegato INFN e UNICAL, Arcavacata di Rende

With the view to high-luminosity LHC upgrade, the ATLAS experiment will add a new layer of RPC trigger chambers into the barrel muon spectrometer. These next-generation RPC chambers will use a 1 mm gap and a single type of readout strips coupled to front-end electronics capable of providing both coordinates in the detector plane. In this communication we present the procedures for assembling the readout panels and the QA/QC tests on the individual components and on the final product, and the results on the construction of the first prototypes of 2500×650 mm paper honeycomb strip panel.

Particle identification with the cluster counting technique for the IDEA drift chamber.

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IDEA is an innovative general-purpose detector concept, designed to study electron-positron collisions in a wide energy range provided by a very large circular leptonic collider. The IDEA drift chamber is designed to provide an efficient tracking, a high-precision momentum measurement and an excellent particle identification by exploiting the application of the cluster counting technique. To investigate the potential of these techniques on physics events a simulation of the ionization clusters generation is needed. We developed an algorithm which uses the energy deposit information provided by Geant4 toolkit to reproduce the clusters number and the cluster size distribution. The results obtained confirm that the cluster counting technique allows to reach a resolution 2 times better than the $\mathrm{d}E/\mathrm{d}x$ method. A beam test has been performed during November 2021 at CERN to validate the simulations results and to perform a detailed study of the cluster counting technique at a fixed $\beta\gamma$. The setup will undergo a new test in July, exploiting a muon beam momentum in the relativistic rise range. The description of the simulations and the beam tests results will be presented.

A 10^{-3} drift velocity monitoring chamber.

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The MEG II experiment searches for the lepton flavor violating decay $\mu \to e^+\gamma$. The reconstruction of the positron trajectory is performed by a drift chamber, operated with a mixture of He and i-C_4H_{10}. For a continuous monitoring of the quality of gas, we plan to install a small monitoring chamber, that allows to give a prompt response about drift velocity variations at the 10^{-3} level. The monitoring chamber will be supplied with the gas mixture coming from the inlet and the outlet of the detector to determine if any gas contamination originate inside the main chamber or in the gas supply system. The chamber is a small box with cathode walls, that determine a highly uniform electric field inside two adjacent drift cells. Along the axis separating the two drift cells, four staggered sense wires alternated with five guard wires collect the drifting electrons. The trigger is provided by two ^{90}Sr weak calibration radioactive sources placed on top of a two-thin-scintillator-tiles telescope. We will present a detailed description of the chamber layout and its simulations and the preliminary measurements.

Innovative deep neural networks resizing for FPGA implementation in future collider experiments.

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Deep Learning techniques are widely used at the LHC and have proven to be quite effective for event processing. However, the huge amount of data produced at the LHC represents a challenge, making it hard to maintain old trigger schemes and store data for offline analysis. Trigger strategies for future high-rate collider experiments invariably envisage real-time implementations of Neural Networks on FPGAs without overtaking the available resources. Herein, we propose an original method to drop unneeded input information and prune Deep Neural Networks for FPGA implementation. Our pruning strategy can select relevant input features and cut off unimportant nodes during training. The result is an overall reduction of the neural network size, with its final dimensions determined by the user. Our solution is simple to incorporate into already developed Deep Neural Network classifiers, lowering the amount of input data and network size without significant losses in performance, and allows for the individuation of the optimum network design compatible with the FPGA resources available. Promising results are presented with a road map for future advances and applications.

Development of a DAQ system for Phase 2 recommissioning of ECAL supermodules.

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The barrel region (EB) of the electromagnetic calorimeter (ECAL) of the CMS experiment is made of 61200 lead tungstate scintillating crystals. In view of the high-luminosity phase of the LHC, the ECAL electronics must be upgraded to cope with the more stringent requirements in terms of trigger latency and rate. The current crystals and APD detectors will remain, while the upgrade will affect the front end (trigger towers) and off-detector read-out electronics of EB. The new electronics will have to follow the requirements of the upgraded L1 trigger system (the increasing rate and latency) and is needed to preserve detector energy resolution despite the increased instantaneous luminosity. Moreover, an important characteristic of the new design will be the capability to provide precision timing measurements, of the order of 30 ps, for photons and electrons. The excellent time resolution will be a key ingredient to efficiently suppress contributions from pileup events, which are expected to be 200 per bunch crossing. The new very front end and front end cards which will compose new trigger towers will be shown, as well as the first test of the new data acquisition chain.

Characterization of new PMTs and fibers for the LUCID-3 prototypes.

Cremonini D.
Università e INFN, Sezione di Bologna

Luminosity is a fundamental parameter in collider physics since it is related to cross-sections and collider performances. LUCID-2, the ATLAS luminometer during Run-2, was able to guarantee a precision of 1.7% in offline measurements. Similar performances are expected also for Run-3, but the current design will not be able to satisfy the requirement for Run-4. Therefore, a new LUCID must be built. For testing purposes, different prototypes for LUCID-3 were installed and will be used during Run-3. These prototypes use new types of PMTs and new optic fibers that require extensive characterization, from HV-gain profiles to fiber opacification under irradiation, which is the subject of this contribution.

HVCMOS modules for experiments at electron-positron colliders.

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High-voltage CMOS detectors are being developed for application in High-Energy Physics. A full-reticle size monolithic pixle detector, consisting of 49000 pixels of dimension 50 μm × 150 μm, has been realized in in TSI 180 nm HVCMOS technology. In view of applications at future electron-positron colliders, multi-chip-modules are built. The module design and its characterization by electrical test and radiation sources will be illustrated. The multi-chip-modules performance shows no degradation with respect to single-chip devices and the level of integration achieved is suitable for tracking at future accelerators like CEPC or FCCee.

Misura di asimmetria di produzione angolare di quark-antiquark bottom al futuro acceleratore FCC-ee al CERN.

Toffolin L.
Università degli Studi di Trieste, Italia e INFN, Sezione di Trieste, Gruppo collegato di Udine

I fit globali sui dati ottenuti negli studi di precisione della teoria elettrodebole hanno fornito conferme della consistenza del Modello Standard e della sensibilità ad effetti *beyond-the-SM*.

Le due determinazioni più sensibili di $\sin^2\theta_{\rm eff}^{\rm lep}$, dalle misure di $A_{0,b}^{FB}$ a LEP e di A_ℓ a SLD, sono in tensione a $\sim 3\sigma$ l'una rispetto all'altra. È necessario escludere che tale discrepanza sia dovuta a fluttuazioni statistiche o ad una sottostima delle incertezze sperimentali. In questo intervento viene presentato uno studio di fattibilità sulla misura di $A_{0,b}^{FB}$ nella produzione associata di quark bottom dal decadimento del bosone Z al futuro collisore leptonico FCC-ee. Mediante una simulazione basata sul software Delphes e regolata sui parametri di FCC-ee, è possibile identificare i jet b e $\bar{b}$ a partire dalla carica delle relative tracce o considerando le cariche dei muoni soffici ottenuti dai decadimenti degli adroni B. Sono presentate nuove proiezioni per la misura di $A_{0,b}^{FB}$ usando i dati simulati a $\sqrt{s} = 91\,\mathrm{GeV}$ a FCC-ee, con una minore incertezza sistematica rispetto alle misure di precisione a LEP.

From LHC to FCC: The high-energy QCD dynamics of Higgs-plus-jet correlations.

Celiberto F.G.
European Centre for Theoretical Studies in Nuclear Physics and Related Areas, ECT, Villazzano, Trento, Italy, Fondazione Bruno Kessler, FBK, Povo, Trento, Italy e INFN-TIFPA Trento Institute of Fundamental Physics and Applications, Povo, Trento, Italy*

Recent analyses on high-energy inclusive Higgs-boson rates in proton collisions via the gluon fusion channel, matched with state-of-the-art fixed-order calculations at N^{3}LO accuracy, have shown that the impact of high-energy resummation corrections reaches 10% at the FCC nominal energies. This supports the statement that electroweak physics at 100 TeV is expected to receive relevant contributions from small-x physics. In this contribution we will present novel predictions for transverse-momentum and rapidity distributions sensitive to the inclusive emission of a Higgs boson in association with a light-flavored jet in proton collisions, calculated within the NLL accuracy of the energy-logarithmic resummation. We will highlight how high-energy signals for this process are already present and visible at current LHC energies, and they become very important at FCC ones. We come out with the message that the improvement of fixed-order calculations on Higgs-sensitive QCD distributions is a core ingredient to reach the precision level of the description of observables relevant for the Higgs physics at the FCC.

Study of Higgs boson decay to *W* bosons at Muon Collider.

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Muon collisions at multi-TeV center-of-mass energies are ideal for studying Higgs boson properties. At energies of the order of few TeV, the production rates will allow precise measurements of Higgs couplings to fermions and bosons. The $H \to WW^*$ process is of particular interest since the production mechanism is dominated by WW-fusion at these energies. This contribution aims to present the result obtained so far on the cross-section of the Higgs boson decay into W boson pair by studying the $\mu^+\mu^- \to H(WW^*)\nu\bar{\nu}$ process. The study has been performed with a detailed simulation of the detector effects on signal and physics background events and by evaluating the effects of the beam-induced background on the detector performance. The evaluations of the sensitivity on the measurement of cross-section $\sigma(H \to WW^*)$ will be discussed at a center-of-mass energy of 3 TeV.

Study of *b*- and *c*-jets identification for Higgs coupling measurement at the Muon Collider.

Da Molin G. (1), Lucchesi D. (1)(2), Sestini L. (2), Giambastiani L. (1)(2), Buonincontri L. (1)(2)

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The Muon Collider is a possible option for the next generation of high-energy collider machines. It would permit to achieve very high energy in the center of mass using leptons without occurring in significative synchrotron radiation losses as in electrons rings. Due to the muon decay, the detector has to sustain a high level of background: beam decay products and subsequent particles from secondary interactions with the machine elements can reach the interaction point, limiting the physical performance of the detector. Nevertheless, this machine offers the possibility to produce a lot of Higgs bosons events with respect to the corresponding backgrounds, allowing the precise determination of the b- and c-quark couplings. In this contribution, a study of the identification of b- and c-jets in the Muon Collider environment will be presented, obtaining an estimation on the statistical precision on the $H \to b\bar{b}$ cross-section, accounting for the presence of the beam and the physical backgrounds. A preliminary study on the use of machine learning techniques to improve the previous result and to study the $H \to c\bar{c}$ will also be reported.

Design and optimization of a MPGD-based hadronic calorimeter for a future Muon Collider.

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Dipartimento di Fisica, Università degli Studi di Bari, Italia e INFN, Sezione di Bari, Italia

A Multi-TeV Muon Collider currently represents the ideal machine to measure the Higgs properties with extremely high precision and, possibly, to investigate for new physics. Much effort is needed in order to carefully design the most suitable detector system for the Muon Collider experiment, with the aim of mitigating the intense machine background induced by the decay of beam muons (BIB). For the first time, an innovative MPGD-based hadronic calorimeter is designed specifically for the Muon Collider environment with the aim to maximize the efficiency of the Particle Flow reconstruction of charged hadrons, neutral hadrons and jets. The detector consists of a sampling calorimeter exploiting MPGDs as active layers: they offer a fast and robust technology for high-radiation environments, and a high granularity for precise spatial measurements. The decays of H and Z bosons in jets are chosen as a benchmark for this study. Full simulations including the BIB are carried out in order to measure the jet reconstruction performance with Particle Flow algorithm and to quantify the impact of the proposed design. The detector design and the results from simulation studies will be presented.

The dual Ring Imaging Cherenkov detector for the Electron-Ion Collider

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The Electron-Ion Collider (EIC) is the new particle accelerator planned in the US and designed to collide polarized electrons with polarized protons and nuclei and investigate the dynamics of quarks and gluons. For the general purpose detector at EIC, the capability to distinguish charged particles over the full momentum range is required. A prototype of dual Ring Imaging Cherenkov (dRICH), a detector which exploits the Cherenkov light produced in two different mediums, is being developed as an EIC_NET initiative to discriminate between charged particles from few GeV/c up to 50 Gev/c, and supports electron identification in the EIC hadronic endcap. Particles crossing a layer of aerogel and a volume of C_2F_6 gas with a velocity greater than the light in medium, produce Cherenkov photons which are focalized by two different spherical mirrors onto the same photon detector array. The combined information of two imaged Cherenkov rings and the particle momentum allow to infer its mass and therefore its type. Two test beams were performed at CERN in fall 2021, when a full tracking and imaging system has been commissioned. I will describe the prototype and the results obtained.

Experimental apparatus for massive characterization of SiPM detectors at cryogenic temperature.

GIAMMARIA T. (1)(2), ANDREOTTI M. (2), CALABRESE R. (1)(2), COTTA RAMUSINO A. (2), D'AMICO R. (1)(2), FIORINI M. (1)(2), GIUGLIANO C. (1)(2), GUARISE M. (1)(2), LAX I. (4), LUPPI E. (1)(2), MONTAGNA E. (3)(4), MONTANARI A. (4), POZZATO M. (4), SIDDI B.G. (1)(2), TOMASSETTI L. (1)(2)
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The silicon photomultipliers (SiPMs) are matrices of single-photon avalanche photodiodes (SPADs) that are often used to measure scintillation light in nuclear experiments due to their high sensitivity and dynamic range, combined with high mechanical robustness and low cost. These sensors require a bias above the breakdown voltage to operate, and cryogenic temperatures to reach low-dark-noise conditions. Some important parameters for the characterization of SiPMs are the previously mentioned breakdown voltage (V_{bd}), the quenching resistor (R_{q}), and the dark count rate (DCR). The experimental apparatus developed by the collaboration of the Ferrara and Bologna Universities and the Ferrara and Bologna INFN sites is capable to perform automatic characterization of 120 SiPMs in parallel, both at cryogenic and room temperature, in one measurement session. The setup can perform current-voltage characterizations, from which it extrapolates R_{q} and V_{bd} of each SiPM by fitting data in the forward and reverse region, respectively. It also governs a mechanical stage for SiPMs immersion in liquid nitrogen and has a FPGA-based countersystem dedicated to DCR measurements.

SiPM response to radiation damage and annealing treatment for the EIC dual-radiator RICH.

RUBINI N.
University of Bologna e INFN, Bologna

Silicon photomultipliers (SiPM) are one of the potential photodetector technologies for the dual-radiator Ring-Imaging Cherenkov (dRICH) detector at the Electron-Ion Collider (EIC). To have a deeper insight on this issue of their susceptibility to radiation damage a campaign of characterisation of various sensors has been undertaken within the INFN EIC_NET Initiative. The characterisation campaign focused on measuring I-V curves, to determine V_{bias} and R_{quench}, and light response to measure Dark Count Rate (DCR) and Photon detection efficiency in various conditions. These sensors have then been uniformly irradiated with a flux of 10^9 1-MeV $n_{\mathrm{eq}}/\mathrm{cm}^2$ at the Protontherapy Center in Trento in collaboration with INFN TIFPA with a 140 MeV proton beam. A campaign to test the full readout chain has also been undertaken, based on the first 32-channel prototypes of the ALCOR ASIC chip. In this contribution I will discuss the results for several SiPM sensors, both for the I-V characterisation and for the light response at different stages: brand new, irradiated and annealed. Future prospects for the use of these results for the dRICH of the detector 1 at EIC will be discussed.

Aula D - Marianna Ciccone **ore 13:30 – 18:30**

Sezione II
Fisica della materia
Presiedono: Manzoni C. (IFN-CNR, Milano)
Lobino M. (Università di Trento)

Optical spectroscopy and microscopy

Relazioni su invito

▲ Ultrafast coherent manipulation of a free-electron wave function via electron-light quantum interaction.

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The interaction between light and electrons can be exploited for generating radiation, such as in synchrotrons and FEL, or for controlling electron beams for dynamical investigation of materials, enabling new applications in light-assisted quantum devices and diagnostics at extremely small timescales. Here, we will describe a new method for coherent longitudinal and transverse manipulation of a free-electron wave function. Using appropriately shaped light fields in space and time, we will demonstrate how to modulate the energy, linear momentum, and orbital angular momentum (vorticity) of the electron wave function with sub-fs precision. The experiments have been performed in an ultrafast-TEM, where the energy-momentum exchange resulting from the electron-photon interaction was directly mapped via momentum-resolved ultrafast electron energy-loss spectroscopy. Our approach for longitudinal and transverse electron modulation at the sub-fs timescale would pave the way to achieve unprecedented insights into non-equilibrium phenomena in advanced quantum materials, playing a decisive role in the design and engineering of future quantum photonics and electronics applications.

▲ Ultrafast molecular photophysics investigated by UV spectroscopy.

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Many molecules of biological interest present strong absorption bands in the ultraviolet (UV) spectral range. Their photo-stability is determined by the primary steps after photo-excitation. Tracking these processes is technically challenging, since they evolve in ultrafast time scales (typically tens of femtoseconds). Thanks to the extreme temporal resolution of the ultrafast spectroscopy beamline that we have developed, we have been able to track for the first time the relaxation of the wave packet in RNA/DNA nucleosides after the absorption of UV light. In particular, we have observed that the excited state of uridine relaxes in about 100 fs by means of a conical intersection, while in thymidine this mechanism takes an order of magnitude longer. Our results, supported by simulations from first principles based on mixed

quantum mechanics /molecular mechanics (QM/MM), allow us to identify ring puckering as the dominant deactivation channel and rationalize the difference in decay times with larger inertia of the methyl group in thymidine with respect to hydrogen in uridine.

▲ **Controlling the properties of complex materials with light.**
Fausti D.
University of Trieste and Elettra - Sincrotrone Trieste S.c.p.a., Trieste, Italy
The rich phase diagrams of many transition metal oxides (TMOs) is the result of the intricate interplay between electrons, phonons, and magnons. This makes TMOs very susceptible to external parameters such as pressure, doping, magnetic field, and temperature which, in turn, can be used to finely tune their properties. The same susceptibility makes TMOs the ideal playground to design experiments where the interaction between tailored electromagnetic fields and matter can trigger the formation of new, sometimes exotic, physical properties. This aspect has been explored in time domain studies and has led to the demonstration that ultrashort mid-IR light pulses can "force" the formation of quantum coherent states in matter, disclosing a new regime of physics where thermodynamic limits may be bridged and quantum effects can, in principle, appear at ambient temperatures. In this contribution, I will introduce our new approaches to time domain spectroscopy going beyond mean photon number observables and review our recent results in archetypal strongly correlated cuprate superconductors which demonstrate the feasibility of a light-based control of quantum phases in real materials.

Comunicazioni

● **Unveiling interlayer exciton formation dynamics in transition metal dichalcogenide heterostructures with femtosecond optical spectroscopy.**
Dogadov O. (1), Policht V.R. (1), Villa A. (1), Li Q. (2), Selig M. (3), Mittenzwey H. (3), Ross A.M. (1), Scotognella F. (1), Zhu X.Y. (2), Knorr A. (3), Dal Conte S. (1), Cerullo G. (1)
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In type-II transition metal dichalcogenide heterostructures (TMD HS) electrons and holes reside in different monolayers with the potential for formation of interlayer excitons (IeX). These IeX states are long-lived, opening a unique platform for fundamental studies and future applications. However, to date, little is known regarding the microscopic picture of IeX formation. In this contribution, we exploit ultrafast transient transmission spectroscopy to study the processes governing the formation of IeX in a large-area $MoSe_2/WSe_2$ HS. We simultaneously track the dynamics of both intralayer exciton (IaX) and IeX transitions following resonant excitation of lowest-energy $MoSe_2$ A exciton at 1.57 eV. The signal attributed to the IeX transition shows a rise time on the picosecond timescale, which is much longer than the formation signal of WSe_2 IaX with a build-up time of about 100 fs, unambiguously demonstrating that different physical processes are responsible for the occurrence of these signals. We attribute the delayed formation of the IeX signal to the cooling of hot IeX. Our study provides a new insight into the ultrafast processes in TMD HS.

● **Tailorable tungsten oxide for near-IR photonics and transparent-conductive films.**
Chen H. (1)(2), Carlotto A. (3)(4), Armellini C. (3), Cassinelli M. (2), Caironi M. (2), Zaghloul M. (1)(2), Tagliaferri A. (1)(2), Chiasera A. (3), Pietralunga

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Tungsten oxide is a polymorph wide-bandgap semiconductor, with multiple possible stable stoichiometries at normal conditions. Physical characteristics, including electrical, optical, and dielectric properties, are versatile and can be manipulated through stoichiometric and structural tailoring. In this sense tungsten oxide can contribute its role to a broad range of advanced applications. In our study, optical-grade tungsten oxide thin films were fabricated by non-reactive RF-sputtering and their compositional ratio as well as structural phase were adjusted by annealing in air. Analyses were performed to evaluate performances of the as-prepared and the thermally treated tungsten oxide films in different physical aspects. Results showed that tungsten oxide films may exhibit good electrical conductivity in the presence of high optical transparency in the near-IR optical range. Besides, an effective enhancement of near-IR optical field is numerically found on tungsten oxide films when integrated into 1-D photonic band-gap structures. Thus, we quest possible applications of tungsten oxide films to the fields of 1-D photonics and transparent-conductive films in the near-IR range.

Attosecond charge carrier dynamics in germanium.

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The ultrafast optical response of a solid is mainly dictated by charges in the band structure. To achieve control over such properties, the photoexcitation process must be investigated with attosecond temporal resolution. We report the first observation of intra- and inter-band dynamics of charge carriers in undoped monocrystalline germanium. In this pump-probe experiment, an intense few-femtosecond infrared pulse injects charges from the valence to the conduction band. A quasi-isolated extreme-ultraviolet (XUV) attosecond pulse then induces transitions from the 3d core states, probing the valence and conduction band dynamics. Pump-induced variations in the reflectivity of the sample are measured as a function of the XUV photon energy and the pump-probe delay. Two complementary theoretical approaches allow for an *ab initio* simulation of the experiment and to disentangle the various contributions to the ultrafast optical response. The analysis of the carrier population at high symmetry points in the photoexcited bands reveals the complex light-induced charge redistribution mechanism, in terms of real and virtual carriers, because of intra-band motion and inter-band transitions.

The role of TiO_2 in the optical coatings for gravitational wave detectors.

Durante O. (1)(2), Di Giorgio C. (1)(2), Granata V. (1)(2), Neilson J. (2)(4), Fittipaldi R. (2)(3), Carapella G. (1)(2)(3), Chiadini F. (2)(5), De Simone R. (2)(5),

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Since the expected gravitational wave signals are extremely weak, reducing the predominant noise, *i.e.*, thermal noise due to the highly reflective optical coatings of the cavity mirrors, is the biggest challenge for today's detectors. The current mirrors in the operating interferometers are based on the alternation of two materials with high (TiO_2 doped Ta_2O_5) and low (SiO_2) refractive index, selected to achieve the lowest optical and mechanical losses, and hence the lowest noise. In particular, the high-index material suffers considerably from mechanical losses, which can be reduced by a nanolayering strategy in which this homogeneous layer is replaced with layered nano-composites of dielectric oxides. In this scenario, TiO_2 material represents a good candidate for its low mechanical losses and its higher crystallization temperature. We present an experimental study of the morphological and structural properties of TiO_2 in the form of thin films and in nanolayered structure with other metal oxides, in order to address the extent of the structural and morphological reliability for high-refractive index candidates in the new-generation Bragg-like reflectors.

Enhancing the optical anisotropy of ZnTPP films by increasing the heterogenous nucleation density.

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Vacuum-deposited films of tetraphenylporphyrins (TPP) have been recently investigated for their ability in protecting the electrode surfaces from corrosion. The protective action of porphyrin films is related to both the molecule-substrate and molecule-molecule interactions, determining the type of film growth and its morphology. For example, ZnTPP shows different types of molecular aggregation, depending on the deposition and post-growth procedures. Finding the best strategy to reach a well-defined target for the film morphology plays a key role for the realization of effective protective coatings for electrodes. Here, we investigate the nucleation density of crystals in thin ZnTPP films, as a function of the substrate temperature. ZnTPP molecules were sublimated by an organic molecular beam epitaxy (OMBE) system onto a graphite substrate, controlled in temperature by using a cryostat. The morphology and type of growth were characterized by atomic force microscopy (AFM) and reflectance anisotropy spectroscopy (RAS), the latter being highly sensitive to the orientation and type of aggregation of ZnTPP on the substrate, which originate the optical anisotropy of the molecular film.

Record stability for perovskite-based X-ray detectors through the use of polymeric template.

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Lead-halide hybrid perovskites are recently emerging as promising materials for high energy radiation detection thanks to the combination of high absorption coefficient, excellent transport properties, even in polycrystalline films, and their solution processability. Here we present perovskite based X-ray detectors employing a perovskite-polymer (starch) composite thin film as active layer. The use of starch as template for the perovskite growth allows a precise control of the active layer thickness and compactness, and confers to the device exceptional stability and performances. The performances of the active perovskite layer, inserted in a photodiode architecture, were studied under 40 kV X-ray radiation. Different thicknesses were used and the top sensitivity of $5.5 \pm 0.2\,\mu\mathrm{C\,Gy^{-1}\,cm^{-2}}$ was measured for 1050 nm perovskite thickness operating in passive mode (0 V). Here we report the longest aging test on perovskite X-ray detectors up to date. We stored the samples in air for 629 days tracking the performance degradation. At the end of the experiment, the detector with 20%wt of starch retained 97% of the initial sensitivity.

Studying ultrafast carrier diffusion with transient holographic microscopy.

Visentin F. ([1]), Hörmann M. ([1]), Zanetta A. ([2]), Grancini G. ([2]), van Hulst N.F. ([3])([4]), Liebel M. ([3]), Cerullo G. ([1])([5]), Camargo F.V.A. ([5])
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Transient absorption microscopy enables the observation of ultrafast excited-state dynamics with spatial resolution. Conventional implementations are technologically limited to small fields of view around a single diffraction-limited spot, offering no statistical information on the photophysics of the sample. We recently used off-axis holography to demonstrate an all-optical lock-in camera enabling widefield transient imaging at arbitrary repetition rate. Here, we propose a structured excitation pattern comprised of hundreds of diffraction-limited spots as an effective way to study diffusion of carriers in semiconductors whilst probing the sample's heterogeneity over areas more than 100 times larger than current techniques. We validate the technique studying exciton diffusion in metal-halide perovskites thin films and we show how the signal-to-noise ratio can be increased by averaging the signal of individual spots, allowing us to measure at low excitation densities to avoid many-body effects. We envision that this technique can be used to provide a much more complete picture of photophysical processes in heterogeneous samples.

Direct temporal characterization of ultrashort ultraviolet pulses generated via resonant dispersive wave emission in gas-filled capillaries.

Cappenberg F. ([1]), Pini M. ([1]), Colaizzi L. ([1]), Vismarra F. ([1]), Lucchini M. ([1])([3]), Crego A. ([3]), Brahms C. ([2]), Travers J.C. ([2]), Borrego-Varillas R. ([3]), Reduzzi M. ([1]), Nisoli M. ([1])([3])
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Few-femtosecond (1 fs $= 10^{-15}$ s) pulses in the deep and vacuum ultraviolet (DUV/VUV) spectral regions are very attractive sources for ultrafast molecular spectroscopy. However, their generation and exploitation have traditionally been very difficult, due to the lack of suitable broadband nonlinear materials and dispersion management at these wavelengths. Recently, the generation of tuneable, broadband (Fourier transform limit time duration (FTL) below 3 fs) DUV/VUV pulses with μJ-level pulse energy via Resonant Dispersive Wave emission (RDW) in hollow capillary fibers has been demonstrated. Here, we present the direct temporal characterization of DUV pulses generated via RDW. The generated μJ-level pulses, with central wavelength (CWL) ranging from 230 to 320 nm (FTL ranging from 3 to 4 fs) are temporally characterized in a home built all-in-vacuum Self-Diffraction Frequency-Resolved Optical Gating setup. The measured full-width half-maximum time duration, for a pulse with CWL of 280 nm, is 5.4 ± 1.7 fs. The source could be readily exploited for DUV ultrafast molecular spectroscopy applications with unprecedented tunability and temporal resolution.

● *Ab initio* prediction of Vibrational Circular Dichroism beyond the harmonic approximation.

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(2) *Unit of Brescia, Consiglio Nazionale delle Ricerche-I.N.O. c/o CSMT, Brescia, Italy*

Recently, vibrational circular dichroism (VCD), *i.e.*, CD in the IR, supported by Density Functional Theory calculations has gained considerable success in assigning the absolute configuration and in evaluating the conformational properties and supramolecular interactions of chiral molecules. Inclusion of the anharmonic treatment is often still overlooked, but is mandatory to investigate some spectral regions (*i.e.*, NIR). Indeed, taking into account anharmonicity up to second-order vibrational perturbation theory allows treating combination and overtone bands both considering frequencies and intensities, that is dipole and rotational strengths. Due to the presence of resonances (Fermi and Darling-Dennison ones) and large amplitude motions, calculations for large and flexible systems still remain challenging and *ad hoc* protocols are needed. From simple alcohols to natural products to chiral astrochemical molecules, in this contribution we will present some tools to sustain anharmonic calculations allowing direct comparison with the experimental spectra.

● Role of excitons in light emission properties of thermally evaporated $CH_3NH_3PbBr_3$ perovskite.

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Metal halide perovskite semiconductors have attracted great attention for their outstanding properties, enabling their application as active materials in optoelectronic devices. For perovskites, the spontaneous emission is ruled by competitive mechanisms that affect the spectral features of the optical emission, namely free-carrier recombination, excitons (EXs) and trap states. This contribution investigates the role of light-emitting species in the spontaneous and stimulated emission of thermally evaporated thin layers of $CH_3NH_3PbBr_3$ perovskite after wet air UV light trap passivation. The EXs are identified as the main actors in the spontaneous emission process. The sample morphology strongly affects their emission properties and gives rise to a spatially inhomogeneous photoluminescence (PL), both in terms of intensity and wavelength of emission, with free and localized EXs involved to a different extent depending on the local morphological features. Amplified spontaneous emission (ASE) measurements confirm the excitonic nature of emitting species. The constant PL background is attributed to the localized EXs, while the ASE signal is due to stimulated emission from the free EXs.

Structured illumination generation with an integrated optical chip.

Calisesi F. (1), Paiè P. (1), Sala F. (2), Candeo A. (1), Ceccarelli F. (2), Valentini G. (1)(2), Osellame R. (1)(2), Bragheri F. (2), Bassi A. (1)(2)
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(2) *Istituto di Fotonica e Nanotecnologie, IFN-CNR, Milan, Italy*

Structured illumination is widely and increasingly used in fluorescence microscopy for super-resolution imaging. We present an integrated optical device able to generate and spatially translate a pattern of structured light, suitable for SIM microscopy. The miniaturized chip incorporates optical waveguides and directional couplers, manufactured with femtosecond laser micromachining, used to split a single input laser into multiple coherent light sources, balanced in optical power. The relative phases of the waveguides are controlled by a set of thermal phase-shifters, placed on top of the same device so that the SIM pattern is generated by interference of coherent beams. By exploiting the temporal phase control of the waveguides, we can spatially shift the illumination pattern over the field of view of the microscope. In this way, it is possible to acquire the multiple phase images required for SIM reconstruction, without the need of further optical elements. We show the validation of the chip, demonstrating the acquisition of super-resolved images in possible configurations of use such as in a commercially available inverted microscope or in a custom-made fluidic chip.

A multimodal widefield hyperspectral microscope.

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Fluorescence and Raman spectroscopy are complementary methods for investigating the properties of materials since they address different transitions of molecules. However, due to the huge difference in the typical cross-sections of the two effects, fluorescence has been always considered a hindrance for Raman, and no combined instrument exists. In addition, typical Raman microscopes rely on point-by-point scanning and dispersive spectrometers: this results in long acquisition times (~ 5 h for 0.1 MP images), which can be reduced only by sacrificing the spatial resolution. We have developed an innovative Fourier-transform hyperspectral microscope capable of disentangling Raman and fluorescence signals only by changing the sampling approaches. The microscope is based on an ultrastable and compact common path interferometer that enables multimodal high-throughput, widefield imaging, greatly reducing the acquisition time. Our hyperspectral microscope is capable of performing sequentially high-spatial resolution ($< 1\,\mu$m) Raman mapping and spectrally resolved fluorescence imaging in ~ 30 min for 0.1 MP image. The details of the instrument and applications will be presented.

Photoinduced ultrafast quasiparticle dynamics and exciton-phonon coupling in layered semiconductors.

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In van der Waals layered materials, the dielectric screening is reduced due to two-dimensional space confinement, resulting in the enhancement of the excitonic binding energy up to hundreds of meV and of excitonic stability at room temperature. The scientific community focuses its attention on understanding and manipulating the sub-picosecond exciton dynamics driven by light absorption. Typically, the dynamic of an exciton is affected by the interaction with other system's degrees of freedom. Recently, it was proposed that exciton-phonon coupling plays a crucial role in the incoherent relaxation dynamics as well as in the coherence and diffusion of excitons. However, how exciton-phonon coupling manifests in the energy and time domain is still an open debate between theory and experiment. To find a unified picture, we investigate the time-resolved broadband reflectivity of the layered semiconductor bismuth tri-iodide due to its high binding energy and the predicted presence of exciton-phonon interaction. Our joint effort between experiment and theory enables the isolation of the spectral fingerprints for the optical detection of exciton-phonon coupling in a layered semiconductor.

Aula T - Caterina Scarpellini **ore 13:30 – 18:30**

Sezione III

Astrofisica

Presiede: Montanino D. (Università del Salento e INFN, Sezione di Lecce)

Cosmology

Relazioni su invito

▲ **The role of Euclid in cosmology (and much more) . . .**

Cimatti A.
Università di Bologna

Euclid was selected in the framework of the ESA Cosmic Vision 2015–2025 as a M-class mission and will be launched in 2023 (TBC). Euclid is a cosmological survey mission based on a 1.2 m diameter telescope. It will cover 15000 deg^2 (Wide Survey) with visible (broad-band red filter) plus near-infrared imaging (Y, J, H filters), and with near-infrared spectroscopy in the 1.25–1.85 micron spectral range. In addition, the Deep Survey will observe in imaging (optical and near-infrared) 40 deg^2 going deeper by 2 magnitudes than the Wide Survey, and additional spectroscopy will also be done at 0.92–1.35 micron for further studies on galaxy formation and evolution. Euclid will provide high-quality images and optical/near-IR photometry for more than 2 billion galaxies, as well as redshifts and spectra for tens of million galaxies out to redshift around 2 and beyond. The revolutionary power of Euclid relies on the combination of different, independent and complementary probes capable to address the key questions of cosmology (dark energy, modified gravity, relations between luminous and dark matter): weak gravitational lensing, baryonic acoustic oscillations, redshift-space distorsions, galaxy clusters, and cross-correlations with the CMB (Laureijs *et al.*, 2011). The legacy value of the Euclid dataset will be immense for a wide range of science cases. In particular, Euclid will place tight constraints on galaxy formation and evolution with unprecedented statistics. Last but not least, the Deep Survey will allow us to shed light on the first phases of galaxy and massive black-hole formation in the young Universe during the first billion years after the Big Bang. The contribution will focus on the scientific role of Euclid, the synergies with other facilities in the next decade, and the growth of the Italian community thanks to this space mission.

▲ **First stars, first galaxies and black holes.**

Schneider R.
Sapienza University of Rome

Up to now, the epoch between 400000 years and 1 billion years after the Big Bang is still largely *terra incognita*. With the formation of the first sources of radiation, stars and Black Holes (BH) this era saw what is often referred to as the transition from the dark ages to cosmic dawn. Despite the still rather scarce observational data, impressive progress has been made in understanding the physical properties of the earliest galaxies, and specifically of those possibly responsible for the reionization of the Universe. In this contribution, I will review the emerging theoretical framework for how stars, galaxies, and black holes transformed the early universe in light of the first observations of the James Webb Space Telescope (JWST) that will allow us to confront theory with observations at the edge of time.

▲ **Fondo cosmico di microonde: L'impatto delle osservazioni del Satellite Planck e le prossime sfide.**

Baccigalupi C.
SISSA, Trieste

Descriviamo l'impatto ed il progresso in atto grazie alle osservazioni del Satellite Planck in astrofisica, cosmologia, e fisica delle particelle. Ci concentriamo inoltre sulle sfide attuali e future, in relazione alla ricerca di onde gravitazionali cosmologiche nella polarizzazione del fondo, la correlazione con altri campi cosmici per energia e materia oscure, e sul ruolo centrale che la comunità scientifica italiana sta avendo in questi contesti.

▲ **Scientific expectations and first results from the James Webb Space Telescope.**

Fontana A.
INAF, Osservatorio Astronomico di Roma

The recently launched James Webb Space Telescope (JWST) is the most advanced and sensitive IR telescope ever built. With its 6.5 m cooled mirror and state-of-the-art instrumentation, it will reach limiting fluxes, spatial and spectral resolutions from 100 to 1000 better than any previous telescope. In my contribution I will review the primary features of the satellite and the planned science goal. I will also report the very first discoveries obtained with the telescope, as scientific observations are supposed to start on July 1, 2022.

Comunicazioni

● **Determinazione del parametro di non gaussianità con la tecnica multi-tracciatore.**

Barberi Squarotti M., Camera S.
Università degli Studi di Torino

Il parametro di non gaussianità primordiale f_{NL} misura la deviazione dall'assunzione teorica standard di distribuzione gaussiana delle fluttuazioni del contrasto di densità nell'universo primordiale. Si manifesta in particolare sullo spettro di potenza dei tracciatori della distribuzione di materia a grandi scale. Le future generazioni di esperimenti cosmologici permetteranno di vincolare in modo più stringente i parametri cosmologici, tra cui f_{NL}. Con la tecnica multi-tracciatore si trovano vincoli ancora più stretti: studiando la correlazione incrociata di dati provenienti da osservabili diverse si riducono gli effetti sistematici rispetto all'analisi dei singoli campioni. Nello specifico è stata combinata la simulazione di osservazioni di galassie (dati simili a quelli che saranno disponibili con Euclid e il Roman Space Telescope) con radioastronomia tipo SKA sull'HI. Si trova che la correlazione incrociata vincola f_{NL} nell'ipotesi di indipendenza dagli altri parametri cosmologici. Presentiamo infine i risultati della tecnica multi-tracciatore ottenuti da catene MCMC in cui si lasciano liberi i parametri di bias, ampiezza e indice spettrali e f_{NL}.

● **Test della ricostruzione degli spettri per l'esperimento Euclid.**

Passalacqua F., Tosi S., Risso I., Caprioli S.
Dipartimento di Fisica, Università degli Studi di Genova, Italia e INFN, Sezione di Genova

La comprensione dell'espansione accelerata dell'Universo è una delle sfide della cosmologia moderna. I diversi modelli cosmologici esistenti, in grado di spiegare l'espansione accelerata, si differenziano per variazioni di piccole entità nelle osservazioni sperimentali. Rilevare tali variazioni richiede una precisa survey astronomica in grado di coprire la maggior parte del cielo. Per questo scopo è stata disegnata la missione spaziale Euclid, la quale mapperà le strutture a larga scala su circa un terzo del cielo e su un tempo cosmico maggiore del 75% dell'età dell'Universo. Durante la survey, Euclid, estrarrà il redshift spettroscopico di circa 20 milioni di galassie con grande precisione. Il lavoro consiste nell'effettuare simulazioni ed estrarre gli spettri delle sorgenti, includendo possibili effetti sistematici. Questo lavoro permette sia di validare la simulazione, sia di studiare le performances dello strumento. In particolare, sono state effettuate simulazioni per trovare la migliore sequenza osservativa da utilizzare durante la fase di calibrazione in volo dello strumento.

Estrazione della scala delle BAO in espansione armonica per la missione Euclid.

Verdese F. (1)(2), Camera S. (3), Davini S. (2), Di Domizio S. (1)(2), Tosi S. (1)(2)
(1) *Dipartimento di Fisica, Università di Genova, Italia*
(2) *INFN, Sezione di Genova*
(3) *Dipartimento di Fisica, Università degli Studi di Torino, Italia*

Questo lavoro si svolge nel contesto della missione spaziale Euclid, il cui lancio è in programma per il 2023. Gli scopi della missione sono molteplici, da test del modello cosmologico standard a misure di fisica fondamentale. Uno strumento molto importante a tali fini sono le oscillazioni barioniche acustiche (BAO). Attualmente Euclid si propone di misurare le BAO nel regime spettroscopico, utilizzando un campione di circa 20 milioni di galassie. Un metodo alternativo, e scopo di questo progetto, è invece estrarre le BAO dal conteggio fotometrico sviluppato in espansione armonica, calcolando dunque gli spettri di potenza angolari della distribuzione. Oltre a permettere di utilizzare l'intero campione di galassie, tale approccio consente di evitare alcune imprecisioni nel passaggio allo spazio di Fourier. A tal fine è stato sviluppato un codice che genera un template di spettri armonici, calcolati utilizzando l'approssimazione di Limber, che viene poi fittato con i dati per estrarre il parametro di shift α, che misura lo scostamento tra i picchi delle BAO. Questo contributo illustrerà i risultati preliminari del lavoro.

Baryon acoustic oscillations from HI intensity mapping: The importance of cross-correlations in the monopole and quadrupole.

Rubiola A., Camera S.
Università degli Studi di Torino

A standard ruler akin in application to standard candles, Baryon Acoustic Oscillations (BAO) are a main feature of the matter power spectrum, depending on fundamental quantities cosmologists are striving to measure. The SKA Observatory (SKAO) will look for their signal in the post-reionisation universe via neutral hydrogen Intensity Mapping, a task made challenging by astrophysical foregrounds and resolution limitations. To tackle these issues, we investigate the results emerging from the multipole expansion approach as a mitigation of such limitations and we showcase the gains made from cross-correlating the HI intensity mapping with spectroscopic galaxy observations. This is to be intended as an anticipation of future synergies between the SKAO Project and Euclid- or DESI-like instruments. Adding then the information from the quadrupole term allows for a detection of the BAO feature up to 4.5–6 sigmas at the lowest redshifts, providing robust constraints on the radial Alcock-Paczynski parameter (a proxy for the Hubble parameter). On the other hand, the corresponding perpendicular parameter remains unconstrained and prior dominated due to beam effects.

Modelli di strutture cosmologiche su larga scala.

Longo E.
Dipartimento di Fisica, Università degli Studi di Genova, Italia

Un parametro di fondamentale importanza in cosmologia per la descrizione dell'evoluzione delle perturbazioni dall'universo primordiale a quello attuale è sigma8. A diversi redshift questo rappresenta l'ampiezza del power spectrum della materia ad una scala fissata di

$8h^{-1}$ Mpc. Il mio lavoro punta a creare modelli per la correlazione temporale dell'evoluzione di sigma8 nel redshift avvalendomi di dati simulati con diversi valori dei parametri cosmologici in input.

Model-independent constraints on clustering and growth of cosmic structures from intensity mapping.

SURIANO A., CAMERA S., CARUCCI I.P.
Dipartimento di Fisica, Università degli Studi di Torino, Italia

We present a model-independent measurement of clustering amplitude and growth of cosmic structures from neutral hydrogen (HI) intensity mapping. This is achieved by generalising harmonic-space power spectra for clustering to measure separately the magnitudes of the density and of the redshift-space distortion terms, which are related to the clustering amplitude, $b\sigma_8(z)$, and the growth, $f\sigma_8(z)$. We consider a state-of-the-art HI simulation in the range $z \in [0.16; 0.45]$, divided into ten redshift bins, restricting our analysis to strictly linear scales. Intensity mapping presents strong astrophysical foregrounds that contaminate the signal, so the simulation has been convoluted with a model of the foregrounds to test nine methods of HI signal recovery. In the first part of our work the approach is applied on the original simulation by measuring the quantities $b\sigma_8(z)$ and $f\sigma_8(z)$ and comparing them with the theoretical expectation In the last part we measure again clustering and growth from some of the nine cleaned maps to understand how the cleaning affects the cosmological information.

Pseudoscalar sterile neutrino self-interactions in the light of Planck, SPT and ACT data.

ATZORI CORONA M. (1)(2), MURGIA R. (3)(8), CADEDDU M. (2), ARCHIDIACONO M. (4)(5), GARIAZZO S. (6), GIUNTI C. (6), HANNESTAD S. (7)
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(2) *INFN, Sezione di Cagliari, Complesso Universitario di Monserrato, Monserrato, Italy*
(3) *LUPM-Laboratoire Univers & Particules de Montpellier, CNRS & Université de Montpellier, UMR-5299, Montpellier, France*
(4) *Università degli Studi di Milano, Milano, Italy*
(5) *INFN, Sezione di Milano, Milano, Italy*
(6) *INFN, Sezione di Torino, Torino, Italy*
(7) *Department of Physics and Astronomy, Aarhus University, Aarhus, Denmark*
(8) *Gran Sasso Science Institute, L'Aquila, Italy*

We reassess the viability of a cosmological model including a fourth additional sterile neutrino species that self-interacts through a new pseudoscalar degree of freedom. We tested the model using various combinations of cosmic microwave background data from Planck, the Atacama Cosmology Telescope (ACT) and the South Pole Telescope (SPT). We show that the scenario under study, although capable to resolve the Hubble tension without worsening the S_8 tension about the growth of cosmic structures, is severely constrained by high-multipole polarization data from both Planck and SPT. When trading Planck TE-EE data for those from ACT, we find a $\gtrsim 3\sigma$ preference for a non-zero sterile neutrino mass, $m_s = 3.6^{+1.1}_{-0.6}$ eV (68% C.L.), compatible with the range suggested by short-baseline anomalies in neutrino oscillation experiments. The preference for a non-zero sterile neutrino mass is mostly driven by ACT favouring a higher value for the primordial spectral index n_s with respect to Planck. We show that the mild tension between Planck and ACT is due to the different pattern in the TE and EE power spectra on multipoles in the range $350 \lesssim \ell \lesssim 1000$.

21 cm with millicharged dark matter.

VERMA S. (1)(2), KATZ O. (3), OUTMEZGUINE N. (4), PANCI P. (2)(5), REDIGOLO D. (6)(7)
(1) *Scuola Normale Superiore, Pisa, Italy*
(2) *INFN, Sezione di Pisa, Italy*
(3) *Tel Aviv University, Tel Aviv, Israel*
(4) *Berkeley Center for Theoretical Physics, University of California, Berkeley, USA*
(5) *Dipartimento di Fisica, Università di Pisa, Pisa, Italy*
(6) *INFN, Sezione di Firenze, Italy*
(7) *CERN, Geneva, Switzerland*

We study scenarios where a sub-percent fraction of dark matter (DM) carries a millicharge (mDM). The small energy density of the millicharge component avoids the strong constraints from CMB but can have interesting effects on the cosmological evolution at and after recombination. For large enough charges and at small relative velocities, non-relativistic effects like Sommerfeld enhancement and bound state formation significantly impact the behavior of mDM. We systematically compute the scattering rates of mDM with hydrogen and helium and the rate of mDM capture in the interstellar medium. We discuss how these processes can leave an impact in the global 21 cm spectrum.

Aula U - Giuliana Cini Castagnoli **ore 15:00 – 18:00**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Giudici M. (Università di Milano)

Applied geophysics

Relazioni su invito

▲ **The role of the weighting function in the inversion of geophysical data.**

Fedi M. (1), Milano M. (1), Varfinezhad R. (2)
(1) *Department of Earth, Environment and Resources Sciences, University of Naples Federico II, Naples, Italy*
(2) *Department of Physics of Earth, Institute of Geophysics, University of Tehran, Iran*

The DC resistivity problem, linearized under the Born approximation, has the form of a Fredholm integral equation of the 1st kind, i.e., the same form of the gravity and magnetic forward problems. We discuss the effects of the model weighting function in the inverse problem and compare the different behavior of gravity and resistivity inversions using: depth-weighting; depth-weighting and compactness; roughness matrix for both L2-norm and L1-norm nonlinear optimization. From the results obtained by synthetic and real data inversion, we may argue that gravity and inversion is sensitive to the exponent β of depth weighting, needing a higher value for compact sources and a lower one for an interface model. Compactness increases the resolution for both compact and interface sources. For DC resistivity data inversion, the number of iterations is lower for a high value of β, while the roughness matrix tends to yield a poorer resolution at large depth. Finally, the response from different arrays is appreciably coherent with the weighting function based on the depth weighting/compactness, while the roughness matrix seems less able to reproduce consistent source models.

▲ **Zone conduttive nella crosta evidenziate da indagini magnetotelluriche in Appennino Centrale e Meridionale: Possibili implicazioni sismo-tettoniche.**

Siniscalchi A. (1), Balasco M. (2), De Girolamo M. (2), Romano G. (1), Tripaldi S. (1), Ventola I. (1)
(1) *Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari "Aldo Moro"*
(2) *Istituto di Metodologie per l'Analisi Ambientale, CNR, Potenza*

Profili magnetotellurici sufficientemente estesi (decine di chilometri) e costituiti da sondaggi a larga banda (0.001-1000 s) consentono la ricostruzione della resistività elettrica a scala crostale. Questo tipo di indagini sono state effettuate negli ultimi decenni sia in Appennino Centrale che in quello Meridionale e in special modo nelle aree interessate dai più forti terremoti verificatisi in Italia nell'ultimo secolo. I modelli di resistività elettrica ottenuti in queste aree hanno evidenziato zone conduttive che si estendono in profondità. L'analisi di tali modelli alla luce di dati indipendenti, in particolar modo degli ipocentri delle sequenze sismiche più importanti, tenendo conto che la resistività elettrica è influenzata dalla presenza di fluidi, permettono di formulare ipotesi attendibili sia sull'assetto strutturale profondo delle aree appenniniche investigate sia sul ruolo dei fluidi nella generazione degli eventi sismici considerati.

▲ **Charting the road to the green energy transition: Airborne electromagnetics for raw material exploration.**

Fiandaca G. (1), Viezzoli A. (2)
(1) *The EEM Team for Hydro & eXploration, Department of Earth Sciences "Ardito Desio", University of Milano, Milano, Italy*
(2) *EMergo srl, Vicopisano, PI, Italy*

Critical raw materials (CRMs) are fundamental to the EU industrial value chains and strategic sectors, particularly with regard to the green energy transition. Currently, the domestic supply of primary CRMs is below 3% for many important commodities. To secure its raw materials autonomy, the EU is boosting the exploration and production of CRMs, also through the financing of research projects within the Horizon Europe framework. This is for instance the case of the SEMACRET, a just-funded Horizon Europe project based on "Sustainable exploration for orthomagmatic (critical) raw materials in the EU: charting the road to the green energy transition". Within SEMACRET, airborne electromagnetic (AEM) surveys will be conducted in Portugal, Czech Republic and Finland, to refine the knowledge of the ore deposits. In fact, the AEM method allows for imaging the electrical properties of the ground down to several hundreds of meters. In particular, electrical conduction and polarization properties of the ore bodies are informative of the ore composition, and can be proxies for the presence of critical raw materials. Examples of exploration AEM surveys will be shown from all around the world.

Comunicazioni

● **La fisica per l'innovazione tecnologica nell'ambito della sostenibilità.**

Grassmann H.
Università degli Studi di Udine, Dipartimento Politecnico di Ingegneria

Ad oggi, le tecnologie tradizionali per lo sfruttamento delle energie rinnovabili non sostituiscono completamente i carburanti fossili. La fisica può dare però un contributo importante per sviluppare tecnologie fondamentalmente nuove, in grado di spianare la strada a questa sostituzione. Si discutono qui tre esempi: 1) Lo Specchio Lineare, capace di fornire energia solare termica anche ad alte temperature e d'inverno in modo facile ed economico. 2) Un nuovo assorbitore sole-aria basato su un criterio di selettività spaziale, diverso dagli assorbitori tradizionali che lavorano sul principio della selettività delle lunghezza d'onda. 3) Un gassificatore per biomasse povere che usa una grande quantità di ossigeno (mentre i gassificatori tradizionali si basano sull'assunzione di una presenza limitata di ossigeno, il che ne limita fortemente le performance) ed è capace di raggiunge una densità di potenza pari a 10 MWatt/m^3, paragonabile a quella di un reattore nucleare.

● **Airborne electromagnetics for mapping groundwater resources in the Brescia province (Italy).**

Sullivan N.A.L. (1), Viezzoli A. (2), Gisolo M. (3), Fiandaca G. (1)
(1) *The EEM Team for Hydro & eXploration, Department of Earth Sciences "Ardito Desio", University of Milano, Milano, Italy*
(2) *EMergo srl, Vicopisano, PI, Italy*
(3) *A2A Ciclo Idrico, Brescia, BS, Italy*

Starting in the spring of 2021, A2A Ciclo Idrico initiated a large-scale Airborne electromagnetics (AEM) campaign for mapping the groundwater resources in the Brescia province, Italy. More than 2000 line kilometers of AEM data have been already acquired, and another 16000 are going to be measured between late 2022 and early 2023. This mapping campaign is by far the largest AEM campaign carried out in Italy, both in terms of extension and data density. Despite of the large anthropization of Brescia province, with the related problems of galvanic and capacitive couplings that disturb AEM data in the vicinity of buildings and infrastructures, excellent resistivity models have been retrieved in the flown areas, down to 300 meters of depth, thanks to careful data processing. This has allowed to map the groundwater resources with unprecedented coverage and resolution, both discovering new aquifers and highlighting their vulnerability. We believe that AEM surveying is an indispensable tool for sustainable and resilient management of groundwater resources, which cannot prescind from an in-depth knowledge of the resources themselves.

Induced polarization effects in EM data: The Loupe system case study.

DAUTI F. (1), VIEZZOLI A. (2), FIANDACA G. (1)
(1) *The EEM Team for Hydro & eXploration, Department of Earth Sciences "Ardito Desio", University of Milano, Milano, Italy*
(2) *EMergo srl, Vicopisano, PI, Italy*

It is nowadays accepted, both in industry and in academy, that Induced Polarization (IP) affects electromagnetic (EM) data, when these are collected over a medium characterized by strong IP properties. With this study we want to verify if and how IP effects are detectable also by the new ground-EM system Loupe. The Loupe system is a two-operator walkable transient EM (TEM) profiling system designed to image the electrical properties of the ground with a high lateral and vertical resolution. In order to map the IP effects, we set up a large data space and model space analysis. IP is modelled with frequency-dependent resistivity in a series of two-layer synthetic models, and thousands of forward responses varying the model's parameters are calculated. We thus compare the forward responses affected by IP with the equivalent purely-resistive ones. We find that significant IP effects are present on most models, also with moderate and low polarization properties. These effects, if not modelled, bring to incorrect estimation of conductivity-thickness parameters when a resistivity-only inversions are carried out.

Characterization of geological heterogeneity in contaminated sites: The case of a waste-filled former gravel pit.

SIGNORA A. (1), SPAGNA S. (1), SULLIVAN N.A.L. (1), BURKEY B. (1), LONARDI M. (1), DAUTI F. (1), LUCCHELLI A. (1), GISOLO M. (2), FIANDACA G. (1)
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(2) *A2A Ciclo Idrico, Brescia, Italy*

In the recent years, time-domain induced-polarization (TDIP) surveys have been successfully employed in a wide range of environmental applications. This technique allows for characterizing the electrical properties of the ground, not only in terms of electrical conductivity, but also in terms of polarization effects at the interface between rock matrix and water. This makes TDIP particularly well suited for contaminated sites, where a detailed description of geological heterogeneity is need to predict the contaminant spreading via accurate groundwater flow modeling. In this study, 9.8 kilometers of 2D TDIP profiles have been carried out in the surroundings of a former gravel pit, filled with municipal and industrial wastes after its depletion, in the Province of Brescia. TDIP data have been inverted via traditional resistivity inversion and with full-decay spectral TDIP inversion, directly in terms of subsoil hydraulic conductivity (K), using petrophysical relations that link electrical properties and hydraulic properties derived in the laboratory. Reasonable 2D K models are retrieved, and the resistivity models improve significantly when inverted along with TDIP data.

Alcuni metodi di conversione del'energia, in particolare per un'onda superficiale tra due mezzi con differenti indice di rifrazione.

Valli F.
Roma

Il problema connesso con l'approvvigionamento di nuove fonti dell'Energia per i Sistemi complessi, come quello delle società più evolute in cui oggi viviamo "anno 2022" , sta divenendo sempre più centrale e vitale. Basti guardare ai recenti conflitti in Europa, e rende urgente la ricerca di soluzioni economiche, rapide, pratiche, veloci ed affidabili. Paradossalmente lo stato attuale di protezione della proprietà intellettuale rallenta il raggiungimento dei risultati possibili. Si propongono alcune linee di ricerca e sviluppo sulla base della disponibilità di importanti fonti energetiche irregolari. Si accennano alcune soluzioni.

Aula E - Rosalind Franklin **ore 13:30 – 18:30**

Sezione V

Biofisica e fisica medica

Presiedono: Talamonti C. (Università di Firenze)

Del Vecchio A. (San Raffele, Milano)

Relazioni su invito

▲ **BriXSinO: An innovative accelerator towards energy sustainability and advanced applications with mono-chromatic X-rays and coherent high-power THz radiation.**

Serafini L. per la BriXSinO's TDR Collaboration

INFN, Sezione di Milano e LASA, Milano

BriXSinO is a demonstrator of a new acceleration mechanism – two way in the same Linac (*à la* MariX), pursuing at the same time research of beam and machine operation in E.R.L. (Energy Recovery Linac) mode, following the original Maury Tigner's configuration of opposite way, dog-bone recirculation. BriXSinO's mission is the demonstration of high peak and average brightness beam generation, acceleration and manipulation with large energy sustainability, as requested by the high-intensity frontier. Energy sustainability implies developing accelerators with large efficiency in transforming AC power into electron beam power: BriXSinO aims at achieving efficiencies larger than 20%. Besides such a primary mission, that is in the mainstream of future strategies for large-scale particle accelerators, BriXSinO will offer unique radiation beams to users of X-rays and THz at LASA, thanks to the very large expected electron beam power/brightness. The challenge is to generate, accelerate, manipulate, characterize, deliver to users and recover back beam power of about 250 kW, at the same time reaching the high phase space density requested by the Compton source and the THz FEL operation.

▲ **X-ray phase-contrast imaging: From synchrotrons to compact systems.**

Brombal L.

Istituto Nazionale di Fisica Nucleare, Sezione di Trieste

Compared to conventional attenuation-based radiography, X-ray phase-contrast imaging (XPCI) enhances the visibility of low-Z or microgranular structures within the sample, being appealing for applications on soft and/or microstructured tissues/materials. XPCI comes in a variety of techniques, most of them pioneered in synchrotrons due to the ideal imaging conditions, *i.e.*, high coherence and flux, offered by synchrotron radiation. Nowadays, while being *de facto* a standard at synchrotrons, great efforts are being devoted to the translation of XPCI to compact systems that can be fitted in a laboratory or in a hospital. This involves technological developments either towards high brilliance X-ray sources (*e.g.*, liquid anode, inverse-Compton), or towards relaxed coherence requirements obtained through structured absorbing optical elements (as in, *e.g.*, edge illumination, grating interferometry). In this contribution, the working principles of some widely used XPCI techniques and successful examples of translation to laboratory systems will be presented.

Comunicazioni

MODFUS: A new in silico model to precisely design low-intensity focused ultrasound brain therapies.

CONTI A. (1), DE ANDRADE P.C. (1), DUGGENTO A. (1), TOSCHI N. (1)(2)
(1) *Medical Physics Section, Department of Biomedicine and Prevention, University of Rome Tor Vergata, Rome, Italy*
(2) *Department of Radiology, Athinoula A. Martinos Center for Biomedical Imaging, Boston, MA, USA*

Low-intensity focused ultrasound (FUS) is a novel therapeutic technology for treating several brain pathologies. Often, FUS studies rely on numerical simulations to perform targeting and evaluate the acoustic pressure (AP) deposited in the brain. However, such simulations only consider FUS attenuation in the skull, while brain tissue is modeled as fully homogeneous. We present MODFUS, a novel *in silico* model suitable to precisely tune both the acoustic parameters and the position of several FUS probes before performing any FUS treatment. MODFUS simulates AP transmission throughout the brain in individual human head models based on CT+MRI fusion, hence considering the heterogeneously distributed acoustic properties across the brain. By using MODFUS, we demonstrate that the AP transmitted to the brain varies i) by more than 15% when considering realistic brain tissue models ii) up to 40% when the beam incidence angle changes slightly ($< 10°$) from an orthogonal configuration. These results confirm the need of a realistic tool for FUS treatment planning as well as the need for stereotaxic setups in neurological FUS applications.

Harmonization of features extraction process using the ComBat tool in a multicenter study on stage III unresectable Non-Small-Cell Lung Cancer.

CABINI R.F. (1)(2), BRERO F. (2)(3), VILLA I. (4), LANCIA A. (5), STELITANO C. (4)(6), ONETA O. (5), BALLANTE E. (7)(8), PUPPO E. (3), MARIANI M. (2)(3), ALÍ E. (5)(9), BARTOLOMEO V. (4)(5), MONTESANO M. (5), MERIZZOLI E. (5), ALUIA D. (4)(6), AGUSTONI F. (10), STELLA G.M. (4)(11), SUN R. (11), BIANCHINI L. (7), DEUTSCH E. (12), FIGINI S. (7), BORTOLOTTO C. (6), PREDA L. (4)(6), FILIPPI A.R. (4)(5), LASCIALFARI A. (2)(3)
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(7) *Department of Social and Political Science, Pavia University, Pavia, Italy*
(8) *IRCCS Mondino, Pavia, Italy*
(9) *Radiotherapy, Perugia University, Perugia, Italy*
(10) *Medical Oncology, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy*
(11) *Respiratory Diseases, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy*
(12) *Institut Gustave Roussy, Villejuif, Paris, France*

In the BlueSky study we aim to explore the influence of different image acquisition parameters on radiomic features reproducibility in a series of stage III unresectable NSCLC patients undergoing chemo-radiotherapy and immunotherapy and to elaborate methods for correction and harmonization. The primary lung tumor was identified by oncological imaging specialists on two computed tomography scans acquired before and after chemoradiation. We extracted 42 radiomic features through the LIFEx software by applying a preprocessing image standardization phase. To assess the impact of different acquisition parameters on features extraction, we used the Combat tool with nonparametric adjustment and its longitudinal version LongComBat. Using the Kruskal-Wallis test on different acquisition parameters (scanner, KVp, convolution kernel, contrast agent, exposure time), we defined 14 acquisition protocols for the harmonization process. Before harmonization, 76% of the features were significantly influenced by these protocols. After, all the ComBat harmonized features resulted in being independent of the technical parameters, while 5% of the LongComBat ones still depended on acquisition protocols.

The role of MRI radiomic features in prediction of tumor response to NAC in breast cancer.

D'Anna A. (1), Bonanno E. (2), Rita Borzì G. (2), Cavalli N. (2), Gueli A.M. (1), Pace M. (2), Pulvirenti A. (3), Marino C. (2), Stella G. (1), Zirone L. (1)
(1) *PHysics for Dating Diagnostic Dosimetry Research and Applications, PH3DRA, Laboratories, Dipartimento di Fisica e Astronomia "E. Majorana", Università di Catania, Catania, Italy*
(2) *Department of Medical Physics - Humanitas, Istituto Clinico Catanese, H-ICC, Misterbianco, Catania, Italy*
(3) *Dipartimento di Matematica e Informatica, Università di Catania, Catania, Italy*

Pre-surgery NeoAdjuvant Chemotherapy (NAC) plays a key role in patients with Locally Advanced Breast Cancer (LABC). NAC can reduce tumor size, downstage tumors, increase the patient's surgical options, reduce metastasis, and improve the efficacy of follow-up treatment options after surgery. However, the pathological Complete Response (pCR) of NAC for Breast Cancer (BC) ranges between 10 and 50% due to the heterogeneity of tumors. Radiomics, *i.e.*, the extraction of quantitative features from the image and their correlation with the outcome, can be employed to optimize BC treatments. Specifically, MRI-based radiomics may help in the identification of pCR-related biomarkers that can be used in the prediction of pCR to NAC. This would result in a reduction of the delay in effective treatment of patients with non-responding or progressive tumors, and in avoiding side effects of unnecessary treatment. Several radiomics features have already been employed for this scope, leading to the construction of predictive models. However, the scenario is still vast, because there are lots of variables concerning radiomics features, statistical analysis, and underlying biology to be considered.

Machine learning in the histological differentiation of mediastinal bulky lymphoma with radiomic ^{18}F-FDG PET/CT features.

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(5) *Department of Pathology, Careggi University Hospital, Florence, Italy*

One of the most common forms of hematologic cancers is mediastinal bulky lymphoma (MBL). It can be characterized using both morphological and functional imaging which represents one of the fundamental diagnostic tools available. A histological mediastinal lymphomas model is fundamental to offer solutions tailored to the single patient moving toward "personalized medicine", where Machine Learning (ML) can make the difference and bring a significant contribution to the whole process. This study makes use of Machine Learning algorithms on relevant features to predict the different histological types of the mediastinal bulky masses. The aim is to understand how PET radiomic features extracted from bulky masses may predict lymphoma histology and in the future support their histological diagnosis.

Selezione di feature radiomiche per la discriminazione di regioni in un fantoccio disomogeneo mediante tecniche di machine learning.

Cupparo I. (1)(2), Valeri F. (1), Calusi S. (1)(2), Taddeucci A. (3), Pallotta S. (1)(2)(4)
(1) *Dipartimento di Scienze Biomediche, Sperimentali e Cliniche "Mario Serio", Università degli Studi di Firenze, Italia*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione Firenze, Italia*
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L'obiettivo di questo lavoro è individuare, mediante tecniche di machine learning, l'insieme di feature radiomiche capaci di discriminare gli inserti contenuti in un fantoccio disomogeneo. Questi inserti, 25 in tutto, sono stati realizzati con una stampante 3D utilizzando materiali, forme e percentuali di riempimento diverse. L'analisi è stata effettuata su immagini TC acquisendo più studi con scanner diversi e variando il protocollo di acquisizione. Per ciascun inserto è stato definito un volume di interesse dal quale sono state estratte le feature radiomiche. Per la selezione di feature sono stati adottati due approcci: un algoritmo supervisionato random forest con backward feature selection ed un algoritmo non supervisionato k-means con ottimizzazione degli iper-parametri. L'algoritmo supervisionato ha permesso di trovare un sottogruppo di tre feature in grado di discriminare bene gli inserti che differiscono per pattern e percentuale di riempimento (accuratezza $> 0.94\%$), evidenziando una bassa misclassificazione solo per due tipi di pattern. L'algoritmo non supervisionato riesce a separare in clusters diversi gli inserti che differiscono per la percentuale di riempimento.

Studio della stabilità delle feature radiomiche nella classificazione del grado dei gliomi.

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La radiomica è un importante strumento nel campo dell'analisi delle immagini mediche. In questo lavoro viene analizzata l'influenza che la normalizzazione delle immagini di risonanza magnetica (MRI) e l'ottimizzazione dei parametri di estrazione delle features (bin count) hanno sulle performance degli algoritmi predittivi del grado dei gliomi. Sono stati utilizzati due dataset, disponibili su *The Cancer Imaging Archive*, contenenti MRI cerebrali multiparametriche riguardanti pazienti affetti da glioma, classificato, in base al grado, in Low e High Grade Glioma. Le immagini sono state normalizzate considerando diversi metodi e le feature, estratte dalle segmentazioni del tumore, sono state calcolate al variare del bin count. La classificazione del grado del glioma è stata fatta utilizzando una Random Forest che prende in input le feature estratte. Le performance, valutate in Cross-Validazione k-fold, sono state studiate per diversi gruppi di feature al variare della normalizzazione e del bin count. I risultati preliminari indicano che, normalizzando le immagini rispetto all'intensità del tronco encefalico, il grado del glioma si riesce a determinare con $\mathrm{AUC} = 0.92 \pm 0.04$.

Investigating the relation between 3D-dose-based radiomics features and the complexity of radiotherapy treatment plans.

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A key element in intensity-modulated radiotherapy is the multi-leaf collimator (MLC) which acts on the beam fluence to improve tumor dose conformity while sparing surrounding organs at risk (OARs). However, the use of the MLC may increase plan complexity, affecting the distribution of the delivered dose, and the overall clinical quality and deliverability of the treatment. Different strategies can be used to control treatment plan complexity, such as limiting the maximum number of deliverable monitor units (MUs) and using the Aperture Shape Controller (ASC). Thirty VMAT patients with two clinically acceptable treatment plans at "low" and "high" complexity were considered with the aim of comparing the corresponding calculated 3D dose. To this purpose, more than 150 textural and intensity-based features were extracted from the dose distributions (dosiomics) and statistically compared between the two groups using the Wilcoxon signed rank test. For both the tumor and the OARs, no statistically significant differences were observed in the computed features, suggesting that complexity does not affect the textural and intensity properties of the calculated dose distribution.

Tools to assess the complexity of radiotherapy plans.

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In radiotherapy treatments, intensity-modulated techniques like VMAT and Tomotherapy are extensively used to guarantee both target coverage and organs at risk sparing at the same time. However, the bottleneck of using modulated fields is to limit the so-called complexity of the treatments in a way that it does not impact their final clinical quality and deliverability. In this contribution, we provide an overview of the latest results obtained at our institution concerning the benchmark of planning strategies that limit the complexity of intensity-modulated treatments without affecting the clinical quality of the plans. Furthermore, we will present two newly developed software libraries (TCoMX and VCoMX) that extract a number of so-called complexity metrics from the plans, namely indicators that quantify several possible sources of complexity. A description of how these indicators are related to the different planning strategies adopted and to the corresponding dosimetric and clinical outcomes will be provided. Finally, results about their potential application to improve the radiotherapy workflow in the future will be presented.

Knowledge-based (KB) plan prediction model for prostate SBRT delivered with CyberKnife according to the RTOG0938 protocol.

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The Aim is to extend the KB approach using the RapidPlan (RP) tool to SBRT with CyberKnife (CK) in the case of prostate treatment. Seventy-two prostate clinical plans of patients treated at our institute with CK between 2017 and 2021 were exported from CK system (Accuray Precision v.3.3) to Eclipse (Varian v.13.6). All patients were treated according to the RTOG 0938 protocol, delivering 36.25 Gy in 5 fractions. Bladder, rectum and femoral heads were considered in the KB model. Fifty-two randomly chosen plans were used to validate it. An individually tailored CK template for automatic plan optimization was created. All automatic plans (KB-TP) were compared against the original clinical plans (TP) in terms of OARs/PTVs dose-volume parameters. OARs sparing for KB-TP plans were generally better than TP plans, with a slightly worsening of PTV coverage. The feasibility of building a robust KB model for SBRT application with CyberKnife was demonstrated.

Quantifying multi-institution KB plan prediction models transferability in breast cancer radiotherapy: A step forward toward benchmark.

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KB plan prediction models were used to quantify inter-institute plan transferability for right breast RT (R-WBI) delivered with tangential fields. Models were set by 10 Institutes of the MIKAPOCo group by using RapidPlan (Varian Inc.), following same criteria of contouring, model training and validation. DVH prediction bands of OARs (heart, ipsilateral lung, contralateral lung and contralateral breast) were exported on 20 additional patients from the same Institutes (two patients each). The overall inter-institute variability of DVH and D_{mean} ipsilateral lung dose prediction, was around 2% and 0.59 Gy, respectively (1SD). The transferability of models among lnstitutions was evaluated by the overlap of the geometric Principal Component of each model when applied to the test patients of the other 9 institutes. Results showed high transferability for 9/10 models; in one institute poor transferability was found (40% of failures), likely due to a different local contouring attitude. Results are encouraging showing clear potentials for efficient incorporation of inter-institute variability on KB model and/or benchmarking for large-scale automatic KB plan optimization.

Quenching of the sensitivity of dosimeters with the increase of the radiation LET.

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Radiotherapies that exploit the high linear energy transfer (LET) related to charged particles, are receiving increasing interest. Hadrontherapy currently uses protons or carbon ions and BNCT exploits the alpha particles generated by thermal neutron reactions with the B-10 isotope. Worldwide, adequate dosimetric methods are therefore in development to achieve a good quality of the treatments. A limit to the possible dose accuracy in measurements with non-gaseous detectors is determined by the fact that their sensitivity depends on the radiation LET: as the LET increases, the sensitivity of the dosimeters decreases. This means that dosimeters underestimate just the absorbed energy that has a greater biological effectiveness. Given the importance of correcting experimental results for the quenching effect, many researchers have challenged this problem, which is difficult to investigate because the radiation effects are manifold and dissimilar in the various detector materials. The problems are more complex in hadrontherapy and easier to be solved in BNCT. For both therapies, methodological proposals and experimental verifications were carried out in our laboratory.

Applicazione di un nuovo sistema di pianificazione radioterapica automatizzata per il trattamento della mammella con tecniche IMRT e VMAT.

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Un nuovo sistema per la pianificazione radioterapica automatizzata (mCycle) è stato utilizzato per generare piani di trattamento della mammella con tecniche IMRT e VMAT (40.05 Gy in 15 frazioni). Lo studio è stato effettuato su un set di 65 casi: 20 mammelle sx a respiro libero (sRL), 25 mammelle sx a respiro trattenuto (sRT) e 20 mammelle dx a respiro libero. Per entrambe le tecniche è stata sviluppata una wishlist di obiettivi e vincoli con le rispettive priorità, la quale ha guidato l'ottimizzazione multi-obiettivo. La qualità del piano è stata valutata attraverso il raggiungimento di goal clinici e mediante l'ispezione visiva di un radioterapista esperto. Tutti i piani VMAT prodotti hanno soddisfatto le richieste e sono stati giudicati clinicamente accettabili. Gli obiettivi di dose sul PTV sono stati raggiunti da tutti i piani IMRT, ma 6 su 65 non hanno soddisfatto i vincoli sul cuore e sono stati giudicati non clinicamente accettabili (5 sRL e 1 sRT). Questo studio mostra come la pianificazione automatizzata possa dare un grande contributo, ottimizzando i tempi di pianificazione e mantenendo una buona qualità del piano.

PHYSICOCHEMICAL characterization of F127 hydrogels.

Pini C. ([1]), Brambilla E. ([1]), Farronato G. ([2]), Gallo S. ([3]), Lenardi C. ([3]), Orsini F. ([3]), Tartaglia G.M. ([2]), Locarno S. ([3]), Santangelo C. ([4])
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Thermogelling amphiphilic triblock copolymers based hydrogels have been found high interest in biomedical applications, as pharmaceutical drug delivery, since they can self-assemble into micelles in aqueous environment. Among different polymers of this family, Pluronic F127 based hydrogel presents a rapid gelation point at 37 °C, high permeability, fast dissolution, low toxicity, good drug release profile and compatibility with a great variety of chemical additives. Herein, we developed several F127 formulations with different additives able to modulate some physiochemical properties, such as reversible gelation, mucoadhesive gel formation below 30 °C, physiological *p*H, modulation of drug release, biocompatibility and biodegradability. Thanks to these features, F127 formulations are an ideal candidate for the development of products exploitable for different application such as periodontal therapy and cosmetic face masks. In addition, F127 hydrogels can be prepared in culture medium opening the chance of using such gel matrices for tissue engineering and cell encapsulation.

Aula L - Christa Mc Auliffe **ore 13:30 – 18:30**

Sezione VI

Fisica applicata, acceleratori e beni culturali

Presiede: Collini M. (Università di Milano Bicocca)

Relazioni su invito

▲ The SPES Target-Ion Source unit.

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The selective production of exotic species (SPES) project aims to construct at Legnaro National Laboratories (LNL) a new facility for the production of radioactive ion beams (RIBs) according to the isotope separation on-line (ISOL) technique. In the specific case of the SPES facility, a uranium carbide Target is impinged by a 40 MeV, 200 μA proton beam produced by a cyclotron proton driver. Under these conditions, a fission rate of approximately 10^{13} fissions per second is expected in the Target. Radioactive isotopes produced in this way are then ionized, extracted at low energy and post-accelerated through the existing ALPI accelerator complex. In this context, both the Target and the Ion Source play a crucial role in the definition of the radioactive ion beams, deeply affecting intensity and purity. In this contribution the SPES Target-Ion Source unit is presented and described in detail, with a specific focus on the last developments introduced by Additive Manufacturing technologies.

▲ Rivelatori di protoni basati su radiofotoluminescenza nel fluoruro di litio per applicazioni bio-medicali.

Montereali R.M. ([1]), Nichelatti E. ([2]), Nigro V. ([1]), Piccinini M. ([1]), Picardi L. ([1]), Ronsivalle C. ([1]), Vincenti M.A. ([1])
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Negli ultimi anni è notevolmente cresciuto l'interesse per sensori di radiazione a stato solido basati sulla luminescenza di difetti elettronici in materiali isolanti, principalmente per rivelazione di tracce nucleari e dosimetria clinica in radioterapia. La tecnica dell'imaging in fluorescenza, che sfrutta la radiofotoluminescenza visibile di centri di colore stabili indotti da protoni nel fluoruro di litio (LiF), consente la ricostruzione completa delle curve di Bragg e delle distribuzioni spaziali di dose, con applicazione alla diagnostica avanzata di fasci di protoni, sia in cristalli che in film policristallini di LiF cresciuti per evaporazione termica su substrati di varia natura. Questi rivelatori combinano la buona equivalenza con il tessuto umano del LiF, essenziale per applicazioni medicali, con un ampio intervallo dinamico, elevata risoluzione spaziale, maneggiabilità e versatilità. In questo contributo vengono presentati e discussi risultati recenti ottenuti mediante irraggiamenti effettuati con protoni di energia fino a 35 MeV prodotti dall'acceleratore lineare per protonterapia TOP-IMPLART, in realizzazione presso ENEA Frascati, e le future opportunità di sviluppo.

▲ **Perfect crystals X-ray interferometry.**

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Applied Metrology and Engineering Division, Istituto Nazionale di Ricerca Metrologica-INRIM, Torino, Italia

In the new SI, primary realizations of the kilogram use the Kibble balance or a monoisotopic Si single crystal shaped like a sphere containing a number of atoms known at 1 part in 10^{-8}. The latter realization requires bringing multiple disciplines to their cutting edge. In this contribution, fundaments of X-ray interferometry will be presented, in the framework of the dynamical theory for X-ray scattering. The key points that have led to the measure of the Si lattice parameter with an unmatched accuracy of about 2 parts in 10^{-9} will be summarized. The potentiality of X-ray interferometry as an extremely sensitive method to investigate the phase contrast introduced by the matter traversed by the photons or by their scattering with unpaired crystalline lattices, as for a relative translation of one lattice portion in a split crystal interferometer, will be reviewed. This is preparatory to the study of fundamentals of quantum mechanics by crystal interferometry with thermal neutrons (whose de Broglie frequency compares with that of phonons in the matter) in the presence of gravitational and magnetic interactions.

▲ **Neutron interferometry with split-crystal technology.**

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Perfect crystal interferometers have been a powerful tool to study the foundations of quantum mechanics for almost half a century. Different geometries and sizes of monolithic neutron interferometers have been used to explore a wide range of interactions of thermal neutrons. The main limitation of these experiments is the size of the monolithic crystals. While split-crystal X-ray interferometers have been in use since the 1970s to measure the Si lattice parameter, state-of-the-art neutron interferometers are still based on monolithic crystals. A promising solution to dramatically improve the sensitivity of neutron interferometers would be an interferometer consisting of separated crystals. We report on the first successful operation of a symmetric split-crystal interferometer performed at the high-flux reactor of the ILL (Grenoble, France), where the Atominstitut (Wien, Austria) owns a permanent thermal-neutron beamline. This proof-of-principle demonstration is just as valid also for more performant skew-symmetric setups and shows that experiments requiring long and variable interferometer arms can be realistically considered.

Comunicazioni

● **Manipulation of Carrier-Envelope-Offset to suppress frequency-to-intensity noise conversion in a pulsed laser-optical cavity locked system.**

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Enhancement optical cavities locked to pulsed laser systems have a crucial role in storing extremely high optical power for a wide range of applications, spanning from high-sensitivity spectroscopy to coherent UV light and X-rays generation. Unfortunately, frequency and intensity noises threaten the stability of the radiation trapped inside the enhancement cavity, hence noise-reduction techniques are crucial for an effective implementation of laser-cavity coupled systems. At the 108th SIF Congress, we will discuss the dependence of the frequency-to-intensity noise conversion in the locking of an ultrafast laser against a high-finesse optical enhancement resonator from the Carrier Envelope Offset (CEO) frequency. By a proper combination of the cavity finesse and laser CEO frequency, it is possible to significatively optimize the signal-to-noise ratio of the laser intensity trapped into the optical resonator. The theoretical description of the problem together with the numerical simulations and experimental results will be presented with the aim of a relevant suppression of the intensity fluctuations of the trapped laser field.

Rogowski coil for hundreds-ps current pulses.

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The technological evolution has affected accelerating machines, digital communication, electromagnetic pulse generators and many other devices and Rogowski coils are used for current diagnostics. In particular, for biophysical applications Rogowski coils are obtained both for linear structures and for the diagnostics of shorter and shorter pulses, 100 ps. Many authors have studied the Rogowski coils but none have taken into account the influence of the slit applied in order to lead the unknown current. The slit forms a capacitor and an inductor both parasite, but the capacitor can be neglected. Applying the laws of electromagnetism and solving the problem by Laplace transforms, the size of the slit affects the attenuation factor. The output current increases as the slit width increase because of the total inductance decrease. Consequently, the attenuation factor decreases *vs.* the slit width. Two different devices by plane lines were built for the study of the Cry protein. The approximate attenuation factors were 9.6 and 14.5 A/V and the rise time for both devices was of 250 ps.

Two-photon absorption cross-sections of eosin and hematoxylin.

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We present a detailed investigation of the two-photon absorption cross-sections and spectra of eosin and hematoxylin to be applied in nonlinear microscopy. In our configuration the two-photon fluorescence is excited by a mode-locked Ti:Sapphire laser tunable in the wavelength range from 740 to 880 nm in a novel microscope setup exploiting a line-shaped illumination beam. Each dye is diluted at different concentrations in deionized water solution. The emission of nonlinear fluorescence is demonstrated by the quadratic dependence of the fluorescence intensity upon the excitation intensity. While the nonlinear emission of eosin increases for increasing concentration, the emission of hematoxylin decreases suggesting that concentration quenching phenomena arise. The feasibility of two-photon microscopy exploiting the two dyes is finally confirmed by carrying out imaging of biological tissues. Our results demonstrate that eosin and hematoxylin, which are usually used together for staining samples in white-light and one-photon-fluorescence microscopy, exhibit an excellent nonlinear fluorescence response. Indeed, the images of biological samples are obtained from already prepared specimens.

Plasmonic optical fiber meta-tip for cancer biomarkers detection.

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Sensors based on Lab-On-Tip (LOT) technology, where suitably designed sensitive nanostructures are integrated on the end-face of an optical fiber, are of strategic importance especially in medicine and clinical diagnostics, where miniaturization and portability are key characteristics. LOT biosensors developed in the past are mostly based on plasmonic nanostructures and exploit a label-free detection paradigm. This detection scheme, however, has some limitations when the target molecules are small or when the specific application requires very low detection limits. To overcome such limitation, we proposed in 2017 the integration of plasmonic Metasurfaces (MSs) on the tip of the optical fiber (Optical Fiber Meta-Tip, OFMT). For their extraordinary properties, MSs are able to enhance the light-matter interaction on the fiber tip, thus sensibly improving the performance of LOT biosensors. Here we present our results on OFMTs, showing past, present and future work. In particular, we report for the first time on the remarkable capabilities of plasmonic OFMTs to perform label-free detection of cancer biomarkers with improved performances with respect to state-of-the-art LOT sensors.

Dielectric optical fiber meta-tip for labeled biosensing.

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In the framework of Lab-On-Fiber sensing technology, the integration of Metasurfaces (MSs) on the tip of the optical fiber (Optical Fiber Meta-Tip, OFMT) has represented a major breakthrough. Indeed, we showed that a suitably designed plasmonic OFMT biosensor significantly outperforms standard plasmonic ones due to the advanced light wave manipulation of MSs. To further reduce the limit-of-detection, we propose optrodes for fluorescence enhancement (FE) based on dielectric OFMT. We envision a single fiber probe with a silicon MS integrated on its tip as a light coupled substrate that illuminates the sample and simultaneously collects the enhanced emission from the dye molecules labeling the biological target. We computed numerically the FE factor of a dye molecule for different silicon MSs, obtaining a maximum value of ~ 1000. We verified that the dielectric MSs could be realized via electron beam lithography and reactive ion etching on the fiber tip, thus realizing the first dielectric OFMT. This contribution provides the main guidelines for the design and development of advanced LOF devices based on the fluorescence enhancement for labeled biosensing applications.

Label-free multimodal coherent Raman and multiphoton non-linear optical microscopy for biological applications.

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Optical microscopy is an extremely powerful investigation tool for life sciences, thanks to its ability of visualizing morphological details in cells and tissues on the sub-micrometer scale. Nonlinear optical (NLO) microscopy techniques, in particular, offer additional advantages, such as inherent 3D-sectioning capability and greater penetration depth, due to the use of infrared wavelengths. In this contribution, we will present our recent results in multimodal NLO imaging applied to biological samples. Our home-built microscopes offer different contrast mechanisms: two-photon-excited fluorescence and label-free techniques such as second-harmonic generation, highlighting non-centrosymmetric structures like collagen fibers in tissue, and chemically specific coherent Raman scattering spectroscopy (including both CARS and SRS modalities) that measures the vibrational spectrum of a molecule to provide an endogenous signature that can be used for its identification. We will present applications in tumor tissue identification and the study of senescence in human tumor cells after therapy, a major cause of cancer relapse.

Stretchable electrical sensors based on CNT/polymer composites.

FAZI L. (1), ANDREANI C. (2), D'OTTAVI C. (1), LICOCCIA S. (1), MORALES P. (2), PREZIOSI E. (2), PRIORIELLO A. (1), ROMANELLI G. (2), SCACCO V. (2), SENESI R. (2)
(1) *Department of Chemical Science and Technologies and NAST Centre, University of Rome Tor Vergata, Rome, Italy*
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There is an increasing interest in the fabrication of stretchable devices exhibiting peculiar electro-mechanical properties and their use as sensors with multiple applications ranging from medical to energy-storage devices. The use of composites is widely exploited because it allows to combine in a single material the properties of the single components. By matching the conductivity and robustness of carbon nanotubes (CNT) with the viscoelastic properties of polymer films, we have developed CNT/polymer composites that represent a promising way to obtain a low-cost, conductive, and elastic films. Since each application requires specific properties, tailoring the composite material to the requirements in terms of conductivity, stretchability, and durability is fundamental. By combining morphological, mechanical, and electrical characterization, we identified the best couplings between commercial polymeric substrates (*e.g.*, polyethylene, natural rubber) and CNT to be used in specific devices (*e.g.*, stress-strain sensors, electrodes) for biomedical or engineering applications. The Regione Lazio is greatly acknowledged for funding the research through the project DIME, n A0375-2020-36646 POR FESR LAZIO 2014-2020 PROGETTI DI GRUPPI DI RICERCA 2020 – Codice POR A0375E0084. Authors gratefully acknowledge the financial support of the Consiglio Nazionale delle Ricerche – within CNR-STFC Grant Agreement [No. 2014-2020 (N 3420)] concerning collaboration in scientific research at the ISIS (UK) of STFC – and of the JRU ISIS@MACH ITALIA, Research Infrastructure hub of ISIS (UK) – MUR official registry U. 0008642.28-05-2020.

Role of structural colour in molecular mechanism of photosynthetic light harvesting in *Chondrus Crispus*.

GARCIA FLEITAS A. (1), SARDAR S. (1), D'ANDREA C. (1), MINJU M. (1), BROADIE J. (1), LANZANI G. (1)

([1]) *Politecnico di Milano, Milano, Italy*
([2]) *Instituto Italiano di Tecnologia, Center for Nano Science and Technology, Milano, Italy*
([3]) *Natural History Museum, London, UK*

Chondrus Crispus, red macroalgae, exhibits photonic structures in the isomorphic state gametophyte and is absent in the tetrasporophyte state of its lifecycle. Here, we have investigated the influence of structural coloration in the molecular mechanism of photosynthesis in the algae using time-resolved photoluminescence (TRPL) studies. We found that the lifetime of the pigments PE, PC and APC increases with an intensification in excitation intensity and the increment saturates toward the higher intensities. This observation can be attributed to the intensity-dependent photoprotection mechanism present in *Chondrus crispus*. Simulating the role of structural coloration in tetrasporophyte a similarity of the traces after intensity normalization considering the SC, confirms the role of SC in gametophyte in attenuating the photon flux reaching the photosynthetic organisms. These results show that a light management mechanism is present in the external antenna of the red algae associated with longer dynamics where SC on gametophyte tip helps in reducing the number of photons absorbed directly by the Chl and favoring the EET through the external antenna.

Proposal of a VHEE-linac research laboratory for FLASH radiotherapy in Italy.

Giuliano L. ([1]), Alesini D. ([1]), Bisogni G. ([4]), Bosco F. ([2]), Cirrone P. ([3]), Cuttone G. ([3]), Di Martino F. ([5]), De Arcangelis D. ([2]), De Gregorio A. ([2]), Ficcadenti L. ([2]), Francescone D. ([2]), Gallo A. ([1]), Migliorati M. ([2]), Mostacci A. ([1]), Palumbo L. ([1]), Patera V. ([2]), Pensavalle J. ([5]), Torrisi G. ([3]), Sarti A. ([2]), Spataro B. ([1]), Faillace L. ([1])
([1]) *INFN, Laboratori Nazionali di Frascati, Frascati Italy*
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([3]) *INFN, Laboratori Nazionali del Sud, Catania, Italy*
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([5]) *AOUP, Pisa, Italy*

The translation of the FLASH radiotherapy in the clinical practice, requires the use of high-energy accelerators able to treat deep tumours, and Very High Electron Energy irradiations could represent a valid technique. In this scenario the design of a VHEE FLASH linac that will be installed in Italy is under study. Here we will present the preliminary results for a compact C-band system aiming to reach high pulse current necessary to deliver high dose per pulse and ultra-high dose rate required for the FLASH effect. The proposed system is composed of a low energy high current injector linac followed by a modular section of high acceleration gradient structures. To obtain the maximum energy, an energy pulse compressor option is also considered. CST code has been used to define the required RF parameters of the linac. The beam dynamics simulations have been performed using T-Step, ASTRA and GPT tracking codes. The VHEE linac suitable to satisfy FLASH criteria was simulated. Preliminary results show the possibility to obtain an energy range of 60–130 MeV, with a peak current of 200 mA (200 nC per μs).

Aula C - Maria Gaetana Agnesi **ore 13:30 – 18:30**

Sezione VII
Didattica e storia della fisica
Presiede: Robotti N. (Università di Genova)

Relazioni su invito

▲ **Le Memorie inedite di Dilworth/Occhialini.**
Tucci P., Gariboldi L.
Università degli Studi di Milano, Dipartimento di Fisica
Le Memorie, un centinaio di fogli in inglese e francese, furono scritte tra il 1992 e il 1993. Esse coprono i due periodi inglesi di Occhialini (Beppo) (1907-1993): a Cambridge tra il 1931 e il 1934 e a Bristol tra il 1945 e il 1948. Alcune parti hanno a che fare con il periodo brasiliano tra il 1937 e il 1945. Le Memorie sono ricche di commenti, non solo scientifici, su importanti scienziati (Rutherford, Blackett, Powell, Heisenberg) e su persone che avevano avuto un ruolo nella lotta al nazi-fascismo (Houtermans, Rosbaud). Le affermazioni delle Memorie non sono suffragate da date o da citazioni. Dopo una notte insonne, Beppo dirà: *il n'y a aucune preuve de ce que j'ai écrit*. Il loro intento era quello di rivendicare il ruolo di Beppo sia nello studio dei raggi cosmici sia nella costruzione di una vasta rete di scienziati e di amici; ruolo che era stato poco evidenziato sia dai suoi colleghi che dagli storici. Esse costituiscono importanti testimonianze che vanno inserite nel contesto degli studi sui raggi cosmici e del periodo postbellico, caratterizzato da sospetti nei riguardi di quanti non avessero preso parte attiva dalla parte degli Alleati nelle vicende belliche.

▲ **Incontri nucleari: I fisici italiani e tedeschi durante la Seconda guerra mondiale.**
La Rana A.
Dipartimento di Informatica, Università degli Studi di Verona, INFN, Sezione Roma 1, Società Italiana degli Storici della Fisica e dell'Astronomia
Il presente contributo offre una speciale prospettiva sui rapporti tra scienziati nucleari italiani e tedeschi durante la Seconda guerra mondiale, analizzando per la prima volta due importanti occasioni di incontro organizzate a Roma dal Kaiser-Wilhelm Institut für Kunst- und Kulturgeschichte: le conferenze di Otto Hahn, nel marzo 1941, e di Max Planck, nell'aprile 1942, tenutesi a Palazzo Zuccari. A questi eventi partecipò un variegato assortimento di persone: accanto a personalità e autorità politiche naziste, ed alti esponenti della vita culturale dell'istituto, fisici italiani e tedeschi come Edoardo Amaldi, Gian Carlo Wick, Arnold Sommerfeld. Documenti e lettere finora inediti consentono di ripercorrere la storia di complesse scelte e interazioni tra gli scienziati, e di seguirne l'evoluzione nel dopoguerra, foriera del ruolo che alcuni di loro avranno nella riorganizzazione della scienza in Europa.

▲ **Ci vuole una scienza.**
Caccianiga L.
INFN, Sezione di Milano, Italia
La comunicazione della scienza sta assumendo una rilevanza sempre più importante nel mondo odierno. Oltre che comunicare i risultati scientifici, diventa importante anche comunicare i processi della scienza, come ottiene i suoi risultati, per dare all'ascoltatore tutti gli strumenti necessari a capirne il messaggio. Anche comunicare al pubblico come si comunica

la scienza, e come difendersi da una comunicazione sbagliata può essere fondamentale. Con qualche idea, tra giochi di ruolo e canzoni, affronteremo alcune esperienze di comunicazione scientifica provando a cercare qualche strumento nuovo.

▲ **Solar cells and physics to move towards a greener world.**

Vasi S. (1), Marrara S. (1)(2), Saija R. (1), Spadaro D. (2), Calogero G. (2), Wanderlingh U. (1)
(1) *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina, Italia*
(2) *CNR-IPCF, Istituto per i Processi Chimico-Fisici, Messina, Italia*

In recent years, many efforts and significant progress have been made to ensure an increasingly environmentally sustainable future in which the physics of renewable energies plays a crucial role. In this frame, photovoltaic panels provide clean energy by exploiting the power of the Sun's rays: thanks to them it is possible to produce electricity from renewable sources in a clean way. To understand the importance of these issues and raise awareness of the whole population on these issues, it becomes essential to develop $ad - hoc$ didactic experiments, even at low cost, in order to facilitate their reproduction and dissemination. To this end, we propose an experiment that allows to acquire data on physical properties that describe the performance of solar cells through the use of a Raspberry Pi. This configuration also provides the ability to quickly analyze the data collected, displaying the obtained results via smartphone. This experiment will allow students to approach basic technologies and physics in the conversion of solar energy and also to programming microprocessors to acquire and analyze data.

Comunicazioni

● **Measurement of the average life time associated with the nuclear capture of negative muons in Fe.**

Tassone G., Occhiuto L., Schioppa M.
Università della Calabria

This experiment was conducted during the Nuclear and Subnuclear Laboratory at the University of Calabria in the academic year 2021-22. Once negative muons have been reduced at the rest state in a material medium, they have a great chance of being captured by the atom forming a mu-mesic atom. Due to its high mass with respect the electron one, the muon will move around the nucleus with a radius 200 times smaller than that of the electron. If the nucleus has a high number of mass, the muon will spend part of its time inside the nucleus where it can be captured by a proton and give rise to a weak interaction with the production of a neutron and an anti neutrino of the muon . By measuring the time between the arrival of a low-energy muon and the emission of the decay electron, it is possible to extract the average nuclear capture time. A theoretical interpretation of the result obtained is also provided in this communication.

● **Misure di concentrazione di radon in acqua - spring school.**

Capua M. (1), Groppi F. (2), Pugliese M. (3), La Verde G. (3), Procopio S. (4), Capone P. (5), Lupiano V. (6), Bruzzese A. (7)
(1) *Dipartimento di Fisica dell'Università della Calabria e INFN-CS*
(2) *Dipartimento di Fisica dell'Università degli Studi di Milano e INFN-MI*
(3) *Dipartimento di Fisica "E. Pancini" dell'Università degli Studi di Napoli Federico II e INFN-NA*
(4) *ARPACAL - Dipartimento Provinciale di Catanzaro - Laboratorio Fisico "E. Majorana"*

([5]) *ARPACAL - Dipartimento Provinciale di Vibo Valentia*
([6]) *CNR - Istituto di Ricerca per la Protezione Idrogeologica, Cosenza*
([7]) *Liceo Scientifico "G. Berto", Vibo Valentia*

Nell'ambito del progetto nazionale RadioLab dell'Istituto Nazionale di Fisica Nucleare, per la prima volta, è stata organizzata una scuola di fisica sulle tecniche di misura di concentrazione di gas radon (Rn-222) in acqua sorgiva. Rivolta a studentesse e studenti delle scuole italiane partecipanti a RadioLab la scuola, di due giorni, è stata realizzata a primavera perché fosse facilmente fruibile da parte degli studenti. Le partecipanti ed i partecipati, seguendo un ben preciso protocollo proposto, hanno prelevato campioni d'acqua presso una fontana pubblica ed effettuato le misure in laboratorio con la tecnica ad elettreti. Inoltre, hanno potuto assistere a misure in campo effettuate con la tecnica emanometrica e seguire seminari di approfondimento sul tema dell'evento. La scuola di primavera ha mostrato l'importanza della fisica applicata all'ambiente e alla salute e il ruolo della ricerca di base e applicata al benessere della società. In questo contributo, verrà presentata questa ricca e stimolante esperienza che ha coinvolto persone selezionate da scuole di Sardegna, Puglia, Lombardia, Veneto, Toscana e Calabria conducendole a risultati concreti di misure sperimentali.

A didactic experiment to measure the angular correlation between the two gamma rays emitted by a ^{60}Co source.

Nicassio N. ([1]), Pirlo R. ([1]), Amato E.C. ([1]), Anelli A. ([1]), Barbieri M. ([1]), Cataldi D. ([1]), Cellamare V. ([1]), Cerasole D. ([1]), Conserva F. ([1]), De Gaetano S. ([1])([2]), Depalo D. ([1]), Digennaro A. ([1]), Fiorente E. ([1]), Gargano F. ([2]), Gatti D. ([1]), Loizzo P. ([1]), Loparco F. ([1])([2]), Mele O. ([1]), Perfetto G. ([1]), Pillera R. ([1])([2]), Schygulla E. ([1]), Troiano D. ([1])
([1]) *Dipartimento di Fisica "M. Merlin", Università e del Politecnico di Bari, 70126 Bari, Italy*
([2]) *Istituto Nazionale di Fisica Nucleare, Sezione di Bari, 70126 Bari, Italy*

A didactic experiment carried out by a group of Physics masters' students at Bari University is presented. The purpose was the study of the angular correlation between the two gamma rays of 1.17 MeV and 1.33 MeV emitted in typical ^{60}Co decays by means of two NaI(Tl) scintillators equipped with photomultiplier tubes read out by a digital oscilloscope. Several runs were performed with the Co source at different angles between the two scintillators. Additional runs were performed removing the source, to study the backgrounds from cosmic rays and from gamma rays emitted by the radioactive isotopes ^{208}Tl and ^{40}K. Our results showed that the signal rate changes with the angular separation in agreement with the theoretical expectations by Hamilton dating back to 1940 and with recent measurements documented in literature. Students learned to plan and set up an experiment, to take data and to perform basic analysis. Care was taken to understand the limits of our experimental apparatus and possible improvements.

Measurement of the cosmic rays flux by an ArduSiPM-based muon telescope in the framework of the Lab2Go project.

Casaburo F. ([1]), Agostini V. ([1]), Arcese B. ([1]), Ascani N. ([1]), Astone P. ([2]), Bocci V. ([2]), Caperna S. ([1]), Cerica A. ([1]), D'Auria C. ([1]), De Bonis G. ([2]), Deda D. ([1]), Di Mauro F. ([1]), Di Vico A. ([1]), Faccini R. ([2])([3]), Frasca L. ([1]), Galuppi G. ([1]), Giovannetti G. ([1]), Iacoangeli F. ([2]), Ludovici G. ([1]), Martone L. ([1]), Marucci B. ([1]), Mizzoni L. ([1]), Moriconi A. ([1]), Organtini G. ([2])([3]), Piacentini F. ([2])([3]), Pietrobono A. ([1]), Pongelli F. ([1]), Severa F. ([1]), Vona D. ([1])
([1]) *Liceo Scientifico "L. Pietrobono", Alatri, FR*
([2]) *Istituto Nazionale di Fisica Nucleare, INFN - Sezione Roma*

(3) *Sapienza Università di Roma - Dipartimento di Fisica*
To establish a closer contact between school and experimental sciences at exposing high school students to experimental Physics, Sapienza Università di Roma and INFN participate to the Lab2Go project in the context of PCTO and supported by PLS. A measurement of the cosmic muons flux as a function of the Zenith angle has been proposed by tutors from Sapienza and INFN Roma to students of Liceo Scientifico "L. Pietrobono" in Alatri. The measurement has been carried out by a muon telescope constituted by two ArduSiPM. The lecture perfectly fits the goal of Lab2Go allowing students to acquire additional knowledge regarding physics topic beyond the ministerial educational programs. Indeed, the measurement allowed us to introduce concepts as elementary particles, particles shower, particle detectors, time coincidence, antimatter, special relativity and conservation of energy in a particle reactions. In this report, we will present the measurement and the obtained results.

Characterization of a compact and cost-effective readout system for germanium detectors.

Carsi S. (1), Bomben L. (1)(2), Clemenza M. (2)(3), Fontana C. L. (4), Lezzani G. (1), Monti-Guarnieri P. (1)(2), Petroselli C. (1), Prest M. (1)(2), Ronchetti F. (1)(2), Selmi A. (1)(2), Vallazza E. (2)
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(3) *Dipartimento di Fisica, Università degli Studi di Milano Bicocca, Milan, Italy*
(4) *European Commission, Joint Research Centre, JRC, Geel, Belgium*
Germanium semiconductor detectors represent the gold-standard choice for gamma spectroscopy, due to their excellent energy resolution which can be obtained with a proper temperature control. The aim of this contribution is to show a novel method to process, shape and digitize the analog signals coming from a germanium detector, without using the traditional analogic modules. This method is based on the "Red Pitaya STEMlab 125-14" a board which implements in the size of a credit card a CPU, a FPGA, a port for network connections (useful for remote access and control) and two 125 MS/s 14-bit digitizer channels. This system was experimentally tested by acquiring the spectrum of thoriated (2%) welding electrodes with a germanium detector. The system performance resulted to be comparable to the one obtained with the usual optimized electronic chain. The main advantages of this new approach are the compactness, versatility, and low cost, making it ideal also for a portable and high-resolution gamma detector.

Simple tools for discovering the radioactivity around us.

Venaruzzo M. (1), Mattone C. (1), Alberi M. (2)(3), Chiarelli E. (2)(3), Garosi P. (1), Loffredo F. (4), Quarto M. (4), Raptis K. (2)(3), Strati V. (2)(3)
(1) *CAEN S.pA*
(2) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Ferrara, Italia.*
(3) *INFN Sezione di Ferrara, Italia.*
(4) *Dipartimento di Scienze biomediche avanzate, Università degli studi di Napoli Federico II, Napoli, Italia*
One of the main goals of CAEN educational tools is to inspire students and guide them towards the analysis and comprehension of different physics phenomena with a series of experiments based on state-of-the-art technologies, instruments, and methods. An example of these applications is the discovery of the environmental radioactivity. Although the radioactivity is all around us, the collective public imagination often associates a negative feeling with this natural phenomenon. To increase the familiarity with it, CAEN has designed

dedicated kits: the first one is composed of a CsI scintillator coupled to a matrix of photodetectors and of several samples and materials. Students are asked to directly calibrate the system in terms of energy and acquire gamma spectra to study the composition of different samples. The second kit is a portable detection backpack with NaI scintillator for measuring the environmental radiation outdoor in a few minutes. These activities combine theoretical background, hands-on setup operations, data analysis, and critical synthesis of the results.

Introducing the concept of energy through heat and temperature by means of infrared cameras.

Monti F., Daffara C.
Dipartimento di Informatica, Università di Verona

We projected a learning path centred on the relation of the concepts of heat and temperature with the concept of energy and proposed it to a class of prospective primary school teachers (PPTs). The intervention extends a previously developed approach based on the use of online sensors so as to highlight the concept of energy through the use of thermal cameras. We investigated through worksheets and interviews how much the proposed path, activities and methodologies can help PPTs in learning and teaching the concepts of heat, temperature and energy as related to the use of online sensors and/or of thermal cameras. We found that the comprehension of heating and cooling as processes leading to a common equilibrium state is better gained using the online sensors, indicating that these processes are better understood in terms of measuring temperature, while the comprehension of heat in terms of energy transfer is more easily grasped through visualization by means of a thermal camera. The reason of this exclusive correspondence can be brought back to the the centrality of the idea of flow and of an abstract entity that is transferred and exchanged to the concept of energy and heat.

Dire l'Indicibile: La sfida di spiegare la sovrapposizione quantistica in una mostra rivolta a tutti.

De Renzi V. (1)(2), Frabboni S. (1)(2), Genoni M. (3), Smirne A. (3), Benedetti C. (3), Bondani M. (4)(5)
(1) *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena e Reggio Emilia*
(2) *C.N.R.- Institute of nanoSciences S3*
(3) *Dipartimento di Fisica Aldo Pontremoli, Università degli Studi di Milano*
(4) *CNR - Institute for Photonics and Nanotechnologies*
(5) *Department of Science and High Technology - University of Insubria*

Le Italian Quantum Weeks sono un'iniziativa collettiva di durata triennale, promossa da scienziati, divulgatori ed educatori italiani per far conoscere il mondo dei quanti e le opportunità offerte dalla seconda rivoluzione quantistica. In questo ambito è stata allestita in diverse città italiane la mostra "Dire L'Indicibile - La sovrapposizione quantistica". Dal punto di vista didattico, Il percorso mira a spiegare in modo rigoroso, ma comprensibile anche a coloro che sono digiuni di matematica, il concetto di sovrapposizione. Seguendo la lezione di Feynman, un video ripercorre l'esperimento della doppia fenditura, realizzato utilizzando due fenditure incise con il FIB, il microscopio TEM, e un detector a singolo elettrone. Il concetto viene sviluppato attraverso analogie, quali le immagini bistabili, la sovrapposizione di colori e degli stati di polarizzazione della luce. Gli assiomi della MQ e la non commutatività sono illustrati con polarizzatori e dimostratori basati sulla sovrapposizione di forma e colore. Particolare attenzione è rivolta a chiarire i limiti e l'utilità di queste analogie, nell'ottica di evitare fraintendimenti e idee scorrette.

La Forza Nascosta: Un dialogo tra Fisica Arte e Storia.

Marcello S. (1)(2), Ceresole A. (1), De Marco N. (1), Pastrone N. (1)
(1) *I.N.F.N. Torino*
(2) *Dipartimento di Fisica, Università di Torino*

In forma di piéce teatrale, con la narrazione delle storie di alcune donne che hanno avuto un ruolo decisivo nell'avanzamento delle conoscenze e delle idee della Fisica, questo progetto ha lo scopo di portare all'attenzione di tutti, come le Donne col loro lavoro di ricerca hanno contribuito a cambiare la Storia scientifica, politica e sociale. Raccontare la complessa realtà del Novecento attraverso una pluralità di vite, di percorsi di ricerca, di visioni del mondo, valorizzando le differenze e le intersezioni, ispirerà i giovani ed in particolare le ragazze a rispettare il proprio Genio e a seguire le proprie Ispirazioni. Nello specifico, il progetto si propone di dare risalto alle Scienziate che hanno lavorato nei campi di indagine della Fisica Nucleare, delle Particelle e dell'Astrofisica, sia in ambito teorico che sperimentale con importanti ricadute tecnologiche per la società. Questo lavoro, progettato e portato avanti da un gruppo di artiste e scienziate, dimostra come l'Arte giochi un ruolo cruciale insieme alle discipline scientifiche, realizzando un autentico progetto STEAM (Science, Technology, Engeneering, Arts and Mathematics) per l'educazione e il dibattito storico-sociale.

Un'analisi delle idee degli studenti di scuola secondaria superiore su fotone, elettrone e struttura dell'atomo.

Giuliana G. (1), Marzoli I. (1), Scotti di Uccio U. (2), Testa I. (2)
(1) *Scuola di Scienza e Tecnologia, Università di Camerino*
(2) *Dipartimento di Fisica, Università di Napoli Federico II*

La letteratura in didattica ha mostrato che gli studenti hanno molte difficoltà ad apprendere la fisica quantistica (FQ). L'astrattezza, la contro-intuitività, il passaggio da una visione deterministica a una probabilistica e il pesante formalismo matematico sono all'origine delle difficoltà concettuali degli studenti. Recentemente, anche in Italia, è stata introdotta la FQ nel curriculum dei licei. Tuttavia, vi è scarsa evidenza dell'efficacia di questa riforma. Lo scopo di questo lavoro è l'analisi delle idee degli studenti sui concetti di base del curriculum, al termine degli studi secondari superiori. Le domande di ricerca specifiche che hanno guidato questo studio sono: quali sono le idee degli studenti sulle proprietà e il comportamento di atomi, elettroni e fotoni? Quali sono i profili degli studenti che possono essere identificati attraverso queste idee? Nella presentazione si discuteranno i risultati ottenuti con un campione di circa 500 studenti che hanno seguito attività curriculari e extracurriculari.

Un percorso PLS per l'introduzione dei semiconduttori.

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(1) *Dipartimento di Fisica, Università di Napoli Federico II*
(2) *Scuola di Scienza e Tecnologia, Università di Camerino*

Si presenta un percorso dal titolo "Dal gatto di Schrödinger alla conduzione elettrica nei solidi" sperimentato nell'ambito del PLS di fisica 2022. Il percorso è articolato in tre fasi: 1) i gatti di Schrödinger e la funzione d'onda: dagli orbitali atomici agli orbitali molecolari e al legame metallico; 2) un esperimento sulla fisica degli isolanti e dei metalli: la fotoconducibilità; 3) la banda di valenza e la banda di conduzione dei solidi. Il percorso ha l'obiettivo di introdurre il comportamento dei semiconduttori, il concetto di probabilità nella meccanica quantistica, evidenziare la differenza tra i diversi legami e il ruolo della meccanica quantistica per spiegare la differenza rispetto alla conduzione elettrica tra un metallo e un isolante. Durante la fase laboratoriale l'attività degli studenti è stata improntata alla scoperta del comportamento di un LED e di una fotoresistenza. In particolare, con successivi tentativi, scoprono che è possibile trasformare un isolante in un metallo. Il percorso prevede una verifica finale, i cui risultati sembrano mostrare che gli studenti hanno appreso le idee chiave del percorso.

Premi Nobel in Fisica: Anomala distribuzione statistica stagionale dei periodi di nascita.

Marazzani P.
Dipartimento di Scienze Biomediche, Università di Milano

Tra il 1901 e il 2021 sono stati assegnati 218 premi Nobel in Fisica. Suddividendoli per le più diverse varianti si è osservata una scarsità di premiati nati nei primi 30 giorni dell'inverno (21 dicembre - 19 gennaio): solo 7 a fronte di 25 nati nei primi 30 giorni dell'estate, 18 nei primi 30 giorni dell'autunno e 16 nei primi 30 giorni della primavera. Si può quindi ipotizzare l'esistenza di un nesso fra le ore di luce del periodo di nascita e le capacità logico-matematiche indispensabili per vincere un Nobel in Fisica. Non si può escludere anche un ruolo dell'indoor pollution.

Aula B - Maria Goeppert-Mayer **ore 09:00 – 13:00**

Sezione I

Fisica nucleare e subnucleare

Presiedono: Pirrone S. (INFN, Sezione di Catania)

Scomparin E. (INFN, Sezione di Torino)

Fisica nucleare

Relazioni su invito

▲ **L'isospin nella dinamica nucleare ad energie intermedie.**

De Filippo E.
INFN, Sezione di Catania

Lo studio della equazione di stato (EOS) della materia nucleare asimmetrica in funzione della densità costituisce una tematica di grande interesse perché la sua caratterizzazione proviene da diversi campi della ricerca nucleare: i) la dinamica delle collisioni tra ioni pesanti, ii) i moti collettivi nei nuclei (risonanze), iii) le proprietà statiche dei nuclei come le masse o i raggi dei nuclei ricchi in neutroni, iv) la fisica delle stelle a neutroni. In questo contributo si illustrerà come le collisioni tra ioni pesanti dalle energie di Fermi (20–100 MeV/A) alle collisioni pre-relativistiche (100–1000 MeV/A) permettano di definire osservabili sperimentali per la parametrizzazione del termine di simmetria dell'EOS in funzione della densità: dalle densità al di sotto di quella di saturazione dei nuclei ρ_0 (energie di Fermi) verso la materia nucleare compressa attorno a $2\rho_0$ alle più alte energie. Verranno descritti i nuovi progetti per la misura dei flussi collettivi di protoni e neutroni al GSI nelle reazioni Au + Au fino a 1000 MeV/A e le prospettive di aumentare la sensibiltà e precisione nella parametrizzazione dell'energia di simmetria con l'uso di fasci radioattivi.

▲ **The research activities at the INFN-Laboratori Nazionali del Sud.**

Tumino A.
INFN, Laboratori Nazionali del Sud, Catania, Italy e Facoltà di Ingegneria e Architettura, Università degli Studi di Enna "Kore", Enna, Italy

The INFN-Laboratori Nazionali del Sud (INFN-LNS) represent a well-established international research reality of INFN. The research activities of INFN-LNS are mainly devoted to the study of nuclear reactions at low and intermediate energies, relevant for fundamental nuclear physics and nuclear and particle astrophysics. Pivotal research activity is also in multidisciplinary fields such as accelerator physics, plasma physics, nuclear physics for medicine, biology and cultural heritage, environmental and radioactive waste monitoring. The INFN-LNS house two accelerators, the Tandem MP and the superconducting Cyclotron that can deliver light- and heavy-ion beams in the regions of low and medium energy. In June 2020, the accelerators have been turned off to start the upgrade of the entire infrastructure, mainly aimed at the production of high-intensity light-ion beams ($12 < A < 20$, power up to 10 kW) accelerated with the Superconducting Cyclotron. The high-intensity program, including the determination of the nuclear matrix elements (NME) of double beta decays and the study of EOS for nuclear matter with large neutron content, is expected by 2024. I will give highlights of the whole research activity with current and future programs.

▲ Studi di struttura nucleare al GSI.

BENZONI G.
INFN, Sezione di Milano

Con la rimessa in funzione del sistema di acceleratori al GSI (Darmstadt, Germania), la Collaborazione HISPEC-DESPEC ha ripreso la propria campagna sperimentale volta allo studio della struttura nucleare attravreso misure di decadimento beta. I recenti sviluppi dei sistemi di rivelazione, a partire dai rivelatori alla data acquisition, garantiscono accesso a nuove regioni nella carta dei nuclidi. In questo contributo verranno illustrati il design della campagna sperimentale e i primi risultati derivanti da esperimenti condotti negli anni 2020–2021–2022.

▲ Nuclear astrophysics: A review of the most interesting recent results.

PALMERINI S.
Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, Italia, INFN, Sezione di Perugia, Italia e INAF, Osservatorio Astronomico di Roma, Monte Porzio Catone, RM, Italia

Measuring neutron capture cross-sections on unstable nuclei and their half-lives in stellar plasma is the ultimate frontier of experimental nuclear astrophysics. However, many other pivotal results have been achieved so far. Among the most recent ones we review 4 cases. The ^{12}C + ^{12}C reaction, whose measurements by an indirect technique has been extensively debated and turned out to deeply affect the exploitability of the SN progenitors. The ^{7}Be + n reaction, involved the cosmological lithium problem, whose rate has been measured by two different approaches demonstrating the feasibility of investigating neutron capture cross-sections on unstable nuclei at astrophysical energies. The ^{13}C$(a,n)^{16}$O and ^{22}Ne$(a,n)^{25}$Mg reactions that are the neutron sources for the s-process and have been measured with high precision in order to provide constraints to both the s- and the r-process nucleosynthesis. The ^{17}O$(p,a)^{14}$N and ^{17}O$(p,g)^{18}$F reactions, whose roles in the radiative H-burning are well known, but whose nucleosynthesis yields vary significantly according with the reaction rate recommended by the different authors, defining different scenarios for the nucleosynthesis of ^{17}O and ^{18}O.

Comunicazioni

● ^{24}Mg + ^{12}C fusion reaching the no-coupling limit far below the barrier.

<u>DEL FABBRO M.</u> (1), MONTAGNOLI G. (2), STEFANINI A.M. (3), JIANG C.L. (4), HAGINO K. (5), NIOLA F. (2), BRUGNARA D. (1)(2), COLOVIC P. (6), COLUCCI G. (7), CORRADI L. (3), DEPALO R. (8), FIORETTO E. (3), GOASDUFF A. (3), PASQUALATO G. (3), SCARLASSARA F. (2), SZILNER S. (6), ZANON I. (3)
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(5) *Department of Physics, Kyoto University, Kyoto, Japan*
(6) *Ruder Boskovic Institute, Zagreb, Croatia*
(7) *Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland*
(8) *Department of Physics, University of Milan and INFN, Milan, Italy*

The low-energy fusion experiment on ^{24}Mg + ^{12}C showed that the cross-sections far below the Coulomb barrier, actually reach the no-coupling limit. The ratio of experimental cross-sections (σ_{exp}) to no-coupling calculations (σ_{noc}) *vs.* energy distance from the Coulomb barrier has been obtained and compared with ^{30}Si + ^{12}C and two heavier systems ^{48}Ca + ^{48}Ca and ^{58}Ni + ^{54}Fe. In all these cases the no-coupling calculations are based on Woods-Saxon potentials. The hindrance effect has been observed in all four systems. As expected, the sub-barrier enhancement is larger for the heavier systems, with respect to the two lighter systems. This prevents observing the behaviour of the ratio $\sigma_{exp}/\sigma_{noc}$ below a certain limit, whereas it is clearly seen that for ^{30}Si + ^{12}C and in particular for ^{24}Mg + ^{12}C the ratio decreases to one (no enhancement) at the lowest energies. The question is then whether the cross-sections follow the no-coupling calculation or if, since the ion-ion potential effectively becomes a one-body potential after the touching point, the excitation function decreases even below that limit.

Study of the ^{20}Ne(p, γ)^{21}Na reaction at LUNA.

Barbieri L.
Università degli Studi di Padova e INFN, Sezione di Padova, Padova, Italy

The synthesis of Ne, Na, Mg, and Al isotopes is connected to the NeNa-MgAl cycles of stellar burning. The entire cycle speed is controlled by the ^{20}Ne(p, γ)^{21}Na ($Q = 2431.68$ keV) reaction, which is the first and slowest reaction of the whole NeNa cycle. According to the state of the art, the associated reaction rate uncertainty thus affects the production of the cycle elements in various stellar environments. In the temperature range from 0.1 GK to 1 GK, the rate is mainly dominated by the 366 keV resonance, corresponding to the excited state of $E_X = 2797.5$ keV, and by the direct capture component. The present study focuses on the direct capture below 400 keV. At LUNA (Laboratory for Underground Nuclear Astrophysics) the ^{20}Ne(p, γ)^{21}Na reaction has been measured using the intense proton beam delivered by the LUNA 400 kV accelerator and a windowless differential-pumping gas target. Two high-purity germanium detectors allow the detection of the products of the reaction. The experimental details and preliminary results of the campaign will be shown, together with their possible impact on the ^{20}Ne(p, γ)^{21}Na reaction rate.

The SIDDHARTA-2 experiment for high-precision kaonic-atoms X-ray spectroscopy.

Sgaramella F.
Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati

The study of kaonic atoms plays a key role for the understanding of the low-energy quantum chromodynamics (QCD) in the strangeness sector, by allowing to directly access the antikaon-nucleus interaction at threshold. State-of-the-art X-ray detectors and suitable experimental technologies allow to perform kaonic-atoms X-ray spectroscopy with unprecedented precision, providing fundamental results for the nuclear, particle and astrophysics research. To this end, the SIDDHARTA-2 experiment at INFN-LNF DAFNE collider is carrying on its data taking campaign, aiming at performing high-precision X-ray spectroscopy of kaonic atoms, in particular the first measurement of kaonic-deuterium X-ray transition to the fundamental level to completely solve the isospin-dependent antikaon-nucleon scattering length. The scientific case and the SIDDHARTA-2 experiment will be presented.

SIDDHARTA-2 experiment at DAFNE accelerator: The kaonic-4 measurement.

Sirghi D. per la SIDDHARTA Collaboration
INFN, Laboratori Nazionali di Frascati

Light-kaonic-atoms spectroscopy is a unique tool for the investigation of the low-energy strangeness Quantum Chromodynamics (QCD). Precise measurements of the radiative X-ray transitions towards low-n levels of these systems provide information on the kaon-nucleus interaction at threshold which, in typical scattering experiments, would require an extrapolation towards zero energy, making them method dependent. In this context, a special role is played by the lightest kaonic atoms, namely kaonic hydrogen, deuterium, and helium. The kaonic-deuterium X-ray measurement, important experimental information missing in the low-energy antikaon-nucleon interactions filed, will be realized by the SIDDHARTA-2 experiment. The SIDDHARTINO setup, the pilot run for the SIDDHARTA-2 experiment, was installed in DAFNE in 2019 aiming to measure kaonic helium, to quantify the background in the new DAFNE configuration. During this run, the transitions to the $2p$ level of kaonic helium 4 was measured, which represents the most precise one for a gaseous target and is expected to contribute to a better understanding of the kaon-nuclei interaction at low energy.

Nuclear resonance effects in kaonic atoms.

De Paolis L. (1), Curceanu C. (1), Bazzi M. (1), Bosnar D. (2), Bragadireanu M. (3), Cargnelli M. (4), Clozza A. (1), Del Grande R. (5), Friščić I. (2), Guaraldo C. (1), Iliescu M. (1), Miliucci M. (1), Napolitano F. (1), Piscicchia K. (7), Scordo A. (1), Sgaramella F. (1), Shi H. (4), Sirghi D. (1), Sirghi F. (1), Sławomir W. (6), Skurzok M. (6), Tüchler M. (4), Zmeskal J. (4)
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The nuclear $E2$ resonance effect occurs when atomic de-excitation energy is closely matched by nuclear excitation energy. It produces an attenuation of some of the atomic x-ray lines from resonant *vs.* normal isotope targets. The investigation of the nuclear $E2$ resonance effect in kaonic ticklish atoms could provide important information about strong kaon nucleus interaction. In four kaonic molybdenum isotopes (molybdenum-94, -96, -98 and -100), the nuclear $E2$ resonance effect is expected at the same transition and could be studied in DAFNE during the SIDDHARTA-2 experiment. The aim is to exploit the negatively charged kaons emitted by the DAFNE e^+e^- collider in the horizontal direction, not collected by the SIDDHARTA-2 experiment. Four solid strip targets each enriched with one molybdenum isotope could be exposed to negatively charged kaons, using a germanium detector for x-ray transition measurements. A solid strip target of molybdenum-92, in which nuclear $E2$ resonance effect does not occur, would be used as a reference for standard yield transition. This experiment represents a unique opportunity to study kaon-nucleus strong interaction in kaonic ticklish nuclei.

Search for octupole deformation in $A \sim 225$ Po-Fr nuclei.

Polettini M. (1)(2), Benzoni G. (2), Pellumaj J. (3)(4), Valiente-Dobón J.J. (4), Zhang G. (5), Mengoni D. (5), Perez Vidal R.M. (4), Huang Z. (5), Hubbard N. (6), Albers H. (7), Bracco A. (1)(2) per la HISPEC-DESPEC Collaboration for S460 experiment
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Evidence of static octupole deformation can be found only in selected regions of the nuclear chart ($A \sim 146$ and $A \sim 222$), where orbitals differing by $\Delta j, \Delta l = 3$ approach the Fermi level for both protons and neutrons. $A \sim 225$ Rn-Th nuclei are expected to show the largest static octupole deformations, as highlighted by recent experimental measurements and by theoretical calculations. Very few direct measurements of $E3$ transitions were performed in recent years in ^{220}Rn, ^{224}Ra and ^{228}Th highlighting a typical de-excitation pattern. We performed an experiment at GSI in April 2021 within the DESPEC Collaboration experimental campaign, with the aim to search for evidence of octupole deformation in $220 < A < 230$ Po-Fr nuclei via beta decay measurements. The ions were produced in in-flight fragmentation reactions, selected and identified using the FRagment Separator (FRS) and implanted in the DEcay SPECtroscopy (DESPEC) station. The ions are let decay in a stack of DSSDs and the internal structure of the daughter nuclei is performed with ion-beta-gamma correlation and fast timing techniques. Recent results of the data analysis will be reported on.

Ultimi risultati su NArCoS: Correlatore per neutroni e particelle cariche.

Pagano E.V. (1), Cardella G. (2)(1), Castoldi A. (4), De Filippo E. (2), Geraci E. (2)(3), Gnoffo B. (2)(3)(1), Guazzoni C. (4), Lanzalone G. (1)(5), Maiolino C. (1), Martorana N.S. (1)(3), Pagano A. (2), Pirrone S. (2), Politi G. (2)(3), Risitano F. (2)(6), Rizzo F. (1)(3), Russotto P. (1), Trimarchi M. (2)(6)
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(5) *Università Kore di Enna, Enna, Italy*
(6) *Dipartimento di Scienze MIFT, Università di Messina, Messina, Italy*

Con l'avvento delle nuove facility per fasci radioattivi prevalentemente ricchi di neutroni, si pensi a SPES a LNL, FRAISE a LNS a FAIR al GSI, per fare qualche esempio, la rivelazione dei neutroni con elevata risoluzione energetica ed angolare, insieme alle particelle cariche, diventa di estrema importanza. Nel contributo saranno illustrati i risultati di recenti test volti alla costruzione di un prototipo di correlatore per neutroni e particelle cariche ad alta risoluzione energetica ed angolare, denominato NArCoS (Neutron ARray for COrrelation Studies). Tale attività di ricerca è stata recentemente selezionata tra i progetti di rilevante interesse nazionale finanziati (PRIN ANCHISE prot. n. 2020H8YFRE).

Numerical investigation of non-homogeneous ECR plasma opacities assuming an external black-body radiation, relevant for astrophysical scenario.

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Laboratory plasma may become an attractive environment for making innovative experiments in the context of multi-messenger astronomy. In this scenario, one of PANDORA project's aims consists in measuring, for the first time at $n_e \sim 10^{12}\,\text{cm}^{-3}$ and $T_e \sim 1$–$5\,\text{eV}$, plasma opacities relevant for addressing the opacity input for the kilonovae signal interpretation. We numerically estimated the electron densities and temperatures of the non-homogeneous laboratory Electron Cyclotron Resonance plasma in Non Local Thermodynamic Equilibrium conditions through a Particle-In-Cell code along 1D line of sight. By passing these and a black-body radiation as input to the population kinetics code FLYCHK, we extracted information on plasma opacity through analysis of emission spectra and level population distributions, first for Ar ions and later for heavy metals like Se, Sr, Zr, Nb. Finally, we studied the behaviour of the out-coming intensity as affected by the opacity from both radiation-perturbed and unperturbed plasma. Results presented offer benchmarks on plasma induced radiation field distortion, in support of laboratory spectral characterizations.

Space-resolved characterization of X-ray emission from an ECR magneto-plasma in the PANDORA project frame.

Finocchiaro G. (1)(2)(3), Bezmalinovich M. (4)(5), Biri S. (6), Emma G. (1)(3), Mauro G.S. (3), Mazzaglia M. (3), Mishra B. (1)(3), Naselli E. (3), Pidatella A. (3), Ràcz R. (6), Santonocito D. (3), Torrisi G. (3), Mascali D. (3)
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Theoretical predictions suggest that the behavior of β-decays can dramatically change in relation to the ionization state of in-plasma isotopes. The PANDORA project aims at measuring nuclear β-decays in stellar-like conditions in high-temperature plasmas confined in B-minimum magnetic traps, which require a continuous monitoring of plasma parameters. X-ray space-resolved emission characterization can provide relevant features of the magneto-plasma in terms of distribution of its density and temperature. We arranged a full-field X-ray pin-hole setup consisting in a $400\,\mu$m hole in a lead disk coupled with a 4MP X-ray (2–20 keV) CCD camera. For the first time the system was coupled to a Pt-Ir shutter to suppress the readout noise, thus permitting SPhC (single photon counting) acquisitions at low exposure times, fixed at 10 ms during the experiment. In the Flexible Plasma Trap (used as test bench for the PANDORA project) we arranged an X-ray diagnostic line to perform measurements by exciting a plasma of air and argon. First collected images have been processed by an original algorithm to obtain energy-resolved imaging.

Integrazione della camera del Focal Plane Detector nello spettrometro MAGNEX dell'esperimento NUMEN.

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La fase di studio e progetto per l'integrazione dell'apparato MAGNEX è nella sua fase finale con la progettazione della camera per il Focal Plane Detector (FPD). La nuova configurazione di questo spettrometro magnetico prevede anche un beam dump al quale convergono le due linee di fascio degli ioni che non hanno interagito nel bersaglio, in uscita dallo stesso apparato, affiancate ai due lati dell'FPD, rispettivamente ioni ossigeno e ioni neon. L'FPD include due rivelatori, il tracciatore e il PID (Particle Identification) wall, entrambi in un'atmosfera di isobutano e separati dalla parte in vuoto da una sottile finestra di mylar. L'elettronica di readout è posizionata al di sopra dei rivelatori, in aria, collegata con una serie di schede di interfaccia ai rivelatori stessi. Data la complessità del sistema, la movimentazione dei rivelatori è possibile solo dall'alto. L'ulteriore richiesta di gestire fasci di carbonio richiede comunque un riposizionamento del PID wall che complica l'integrazione nel suo insieme, tenendo conto anche del posizionamento della strumentazione per la gestione e diagnostica dei fasci di ioni e della strumentazione per il vuoto e l'atmosfera di isobutano.

Dipendenza della temperatura dall'isopin nelle reazioni ^{78}Kr + ^{40}Ca e ^{86}Kr + ^{48}Ca a 10 AMeV.

Gnoffo B. (1)(2), Pirrone S. (2), Politi G. (1)(2), Cardella G. (2), De Filippo E. (2), Geraci E. (1)(2), Maiolino C. (3), Martorana N.S. (1)(3), Pagano A. (2), Pagano E.V. (3), Papa M. (2), Risitano F. (2)(4), Rizzo F. (1)(3), Russotto P. (3), Trimarchi M. (2)(4)
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Verrà presentato uno studio sull'influenza dell'isospin sulle caratteristiche termometriche, nelle reazioni ^{78}Kr + ^{40}Ca e ^{86}Kr + ^{48}Ca a 10 AMeV. L'esperimento è stato realizzato ai Laboratori Nazionali del Sud dell'INFN, a Catania, utilizzando per la rivelazione dei prodotti di reazione il multirivelatore a 4π CHIMERA. L'evaporazione termica sia dal nucleo composto che dal Quasi-Proiettile è stata studiata estraendo la temperatura con due diversi metodi termometrici, vale a dire lo slope thermometer, con le particelle alfa come sonda, e il termometro basato sul doppio rapporto delle rese isotopiche. I risultati dell'analisi suggeriscono che la temperatura del sistema dipende dal rapporto N/Z. Infatti, indipendentemente dalla natura del metodo utilizzato per la sua determinazione, nel sistema ricco di neutroni rispetto a quello neutron poor, è stato osservato un valore di temperatura più basso per il Quasi-Proiettile e uno più alto per il sistema composto. Questa tendenza è confermata dal confronto con i calcoli del modello statistico GEMINI++.

Sezione d'urto della fusione tra ioni pesanti con tecniche di intelligenza artificiale.

Dell'Aquila D. (1)(2), Gnoffo B. (3), Lombardo I. (3), Porto F. (4), Russo M. (3)(4)
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(4) *Università degli Studi di Catania*
In collisioni nucleari tra ioni pesanti a basse energie, la fusione nucleare è uno dei meccanismi di reazione prevalenti. La dipendenza energetica della sezione d'urto di fusione presenta diversi andamenti a seconda della regione energetica, particolarmente complessi da descrivere con modelli universali. In letteratura, diversi modelli teorici e semi-empirici si sono occupati della descrizione sistematica dei dati sperimentali. Tuttavia, una descrizione completa di tutte le regioni energetiche con un unico modello è ad oggi particolarmente complicata. In

questa comunicazione, si discuterà una nuova analisi "data-driven" che coinvolge un gran numero di dati di fusione nucleare per sistemi fino a massa intermedia, attraverso un innovativo approccio di modellizzazione formale dei dati basato su tecniche di intelligenza artificiale. L'approccio fa uso di una ibridazione di programmazione genetica e reti neurali artificiali, in grado di derivare un modello analitico per la descrizione dei dati sperimentali e di suggerire le variabili nucleari che hanno una maggiore influenza sulla grandezza studiata.

Studio di processi rari negli isotopi naturali di Hf e Zr utilizzando cristalli scintillatori di Cs_2HfCl_6 e Cs_2ZrCl_6.

Leoncini A. ([1])([2]), Caracciolo V. ([1])([2]), Belli P. ([1])([2]), Bernabei R. ([1])([2]), Cerulli R. ([1])([2]), Merlo V. ([1])([2]), Cappella F. ([3])([4]), Incicchitti A. ([3])([4]), Laubenstein M. ([5]), Nisi S. ([5]), Nagorny S.S. ([6]), Wang P. ([7])
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Recentemente si è sviluppato un notevole interesse nello sviluppo di cristalli scintillatori della famiglia degli esacloruri metallici Cs_2MCl_6 (M = Hf o Zr) grazie alle loro eccezionali proprietà: un'elevata resa di luce (fino a 50000 fotoni/MeV), ottima linearità nella risposta energetica, eccellente risoluzione energetica ($< 3.5\%$ a 662 keV nella migliore configurazione) e un'eccellente capacità di discriminazione della forma dell'impulso (PSD) tra le particelle $\gamma(\beta)$ e α. In particolare, un esperimento, utilizzando un cristallo scintillatore Cs_2HfCl_6 (CHC), è stato condotto presso la facility STELLA ai LNGS. I risultati sui decadimenti nucleari rari negli isotopi di Hf, come il decadimento α allo stato fondamentale e ai primi stati eccitati e il doppio decadimento β di ^{174}Hf, sono qui presentati insieme alle prospettive future di queste misure. Inoltre presentiamo un primo studio su cristalli scintillatori di CZC in termini di purezza chimica e contaminanti radioattivi residui, prestazioni di scintillazione, performance della PSD e studi preliminari sui decadimenti beta singolo di ^{96}Zr e doppio beta in isotopi di ^{94,96}Zr.

Ricerca del processo di cattura elettronica in ^{176}Lu.

Ghezzer L.E. ([1]), Nozzoli F. ([2]), Bertuolo G. ([3])
([1]) *Dipartimento di Fisica, Universitá di Trento, Italia*
([2]) *INFN-TIFPA, Trento, Italia*
([3]) *Liceo Scientifico "Leonardo da Vinci", Trento, Italia*

^{176}Lu decade normalmente β^- in ^{176}Hf con una vita media di $3.7 \cdot 10^{10}$ anni. Il rapporto Lu/Hf è utile nella datazione radiometrica di strutture geologiche ed oggetti astronomici. Pertanto uno studio dettagliato dei processi di decadimento di ^{176}Lu è utile per minimizzare le incertezze di questo metodo di datazione geocronologica. Dal punto di vista teorico anche il decadimento di ^{176}Lu in ^{176}Yt mediante processo di cattura elettronica è permesso, tuttavia è soppresso da regole di selezione sul momento angolare e nessuno studio sperimentale è riuscito ad evidenziarlo. In questo contributo verrà descritto l'esperimento LuCE (lutezio cattura elettronica) che impiega un cristallo di scintillatore LYSO (lutetium-yttrium oxy-orthosilicate) in coincidenza con un rivelatore HP-Ge. Rispetto ai precedenti esperimenti, che si basavano sulla spettroscopia gamma di una sorgente passiva di Lu, la misura in coincidenza dell'energia di scintillazione del LYSO permette una migliore reiezione del fondo costituito dal decadimento β^- del ^{176}Lu.

Temperature dependence of ρ meson-nucleon coupling constant from the AdS/QCD soft-wall model.

Nasibova N.
ANAS, Institute of Physics, Baku, Azerbaijan

We investigate the dependence of the ρ meson-nucleon coupling constant on the temperature of the medium using the soft-wall model of AdS/QCD. The finite temperature profile functions for the vector and fermion fields are applied to the model having a thermal dilaton field. The interaction Lagrangian in the bulk between these fields is written as in the zero-temperature case and includes minimal- and magnetic-type interactions. The temperature dependence of the $g\rho N\ N(T)$ coupling constant and its terms are plotted. We observe that the coupling constant and its separate terms become zero at the medium temperature near the Hawking temperature of phase transition.

The FOOT experiment: A first measurement of nuclear fragmentation cross-section for hadrontherapy.

Ubaldi G., Villa M.
Dipartimento di Fisica, Università di Bologna, Italia e INFN Sezione di Bologna, Bologna, Italia

The FOOT (FragmentatiOn Of Target) experiment has been conceived with the main aim of measuring differential nuclear cross-sections of target and beam fragments in the energy range of interest for hadrontherapy and space radioprotection, which suffers the lack of experimental results. A first analysis of data taken at the GSI with a beam of ^{16}O at both $200\,\mathrm{MeV}/n$ and $400\,\mathrm{MeV}/n$ against two targets of polyethylene (C_2H_4) and carbon (C) will be presented, showing the first measurements of differential cross-sections as a function of the fragment charge ($1 \leq Z \leq 8$) and angle ($1^\circ \leq \theta \leq 10^\circ$) and total energy distribution. The analysis is performed taking full advantage of the current performances of the apparatus, with a particular focus on the charge estimation algorithm and on the optimization of the track reconstruction Kalman filter algorithm, both fundamental for the correct fragment identification and the measurements of its kinemastics. A pile-up reduction method will also be shown, specifically developed studying the data present in this analisys.

Aula D - Marianna Ciccone **ore 09:00 – 13:00**

Sezione II
Fisica della materia
Presiedono: Guerra R. (Università di Milano)
Achilli S. (Università di Milano)

Theoretical and computational physics of matter

Relazioni su invito

▲ **Computational laboratory of low-temperature plasma.**
Taccogna F., Minelli P., Bruno D., Cichocki F., Sciortino V.
CNR-ISTP
Low-Temperature Plasma (LTP) is an electrically neutral mixture of electrons, ions and neutral particles interacting with electromagnetic fields. The highly nonequilibrium nature of LTP (due to the difference in electron and neutral/ion masses) induces a high physical and chemical reactivity. Advancing theory and developing validated computational tools are critical to fully realize the extraordinary potential of LTP science and technologies. The contribution will focus on the following 3 research activities: 1) plasma thrusters for space propulsion; 2) plasma-wall interaction in thermonuclear fusion reactor; 3) negative ion source for neutral beam heating of fusion reactors.

▲ **Dynamical freezing of relaxation to thermal equilibrium.**
Iubini S. ([1]), Chirondojan L. ([2]), Politi P. ([1]), Politi A. ([3]), Oppo G.-L. ([2])
([1]) *Istituto dei Sistemi Complessi, Consiglio Nazionale delle Ricerche, Italy*
([2]) *SUPA and Department of Physics, University of Strathclyde, Glasgow, UK*
([3]) *Institute for Complex Systems and Mathematical Biology & SUPA University of Aberdeen, Aberdeen, UK*
Slow processes in statistical physics are typically ascribed to the presence of high free energy barriers which require the emergence of strong fluctuations for them to be overcome. Certain slow phenomena, however, can occur also from purely dynamical effects. An example is the slowing-down of relaxation to equipartition due to phase-space regions characterized by a nearly integrable dynamics. In this contribution we intend to discuss a peculiar dynamical mechanism leading to an extremely slow relaxation process in a spatially extended nonlinear lattice. This phenomenon occurs when discrete breathers, *i.e.*, intrinsic localized nonlinear excitations, appear in the system. We will analyze this mechanism and its implications in the Discrete Nonlinear Schroedinger Equation (DNLSE) and show that it is due to an adiabatic invariant which freezes the dynamics of high-energy breathers. We conjecture that the resulting exponentially slow relaxation is a key ingredient contributing to the non-ergodic behavior observed in the DNLSE.

▲ **Loop expansion around the Bethe solution for disordered models.**
Angelini M.C., Lucibello C., Parisi G., Ricci-Tersenghi F., Rizzo T.
Dipartimento di Fisica, Sapienza Università di Roma
Recently we have introduced a new loop expansion around the Bethe solution that could be applied to any model well defined on a Bethe lattice. This new expansion is an alternative to the standard field-theoretical renormalization group approach, which can be viewed as a loop expansion around fully connected mean-field models. We will illustrate the application of

this new method in understanding the phase transitions undergone by different disordered systems and emphasize its possible application to models where the standard expansion does not work, for example, Anderson localization or (bootstrap) percolation. We will also illustrate the progress achieved by the use of this new expansion in the characterization of avalanches in the Random Field Ising Model or the study of the transition in finite dimensions for the Spin Glass model in an external field, emphasizing the differences in the results with respect to those obtained by standard perturbative expansion.

Comunicazioni

The case for the heterogeneous structure of glasses.

Jug G.
DiSAT, Università dell'Insubria, Como, Italy e INFN, Sezione di Pavia, Pavia, Italy

Since 1932, the structure of glasses and other amorphous solids has been taken to be homogeneously disordered (with the exception of a few researchers). However, recent developments in the low-temperature physics of glasses and amorphous films have strengthened the case for the ubiquitous heterogeneous intermediate-range structure made up of jam-packed solid-like frozen-in regions and liquid-like active regions in between. Evidence for this type of heterogeneity will be presented and the advantages of the refined structural model of glasses will be advocated for. In particular, evidence will be presented for a new type of paramagnetism due to the vitreous solid state itself. The theory for the magnetic effects in glasses based on this scenario bears the promise for much interesting new physics and a theory for the melting of glasses will be proposed.

***Ab initio* studies of the electronic structure and optical properties of amino acids and cyclo-dipeptides.**

Molteni E. (1)(2)(3), Sangalli D. (1)(3)
(1) *Istituto di Struttura della Materia-CNR ISM-CNR, Division of Ultrafast Processes in Materials FLASHit, Area della Ricerca di Roma 1, Italia*
(2) *Dipartimento di Fisica, Università degli Studi di Milano, Italia*
(3) *European Theoretical Spectroscopy Facility, ETSF*

Besides their importance as monomer units of proteins, amino acids can be also used in the synthesis of nanomaterials. Cyclo-dipeptides (CDPs), *i.e.*, the smallest cyclic peptides, made of two amino acids, are interesting both due to their biological and pharmacological activities and as possible building blocks for nanodevices. We report on our *ab initio* investigations of the electronic and optical properties of some biomolecules of the above-mentioned classes, focusing on the valence electronic structure of three aromatic cyclo-dipeptides, and on the electronic properties and absorption and circular dichroism (CD) spectra of alanine. For cyclo-dipeptides, our calculations have helped interpreting measured photoemission spectra, highlighting the role of the side chain in determining the photochemical properties of the molecules. Moreover, both for alanine and for CDPs we have investigated the effects of choosing different *ab initio* schemes, such as plane wave *vs.* Gaussian basis codes, different exchange-correlation functionals, and Independent Particle *vs.* GW *vs.* TDDFT methods. For circular dichroism we have used our recent implementation of CD calculations in the Yambo code.

Novel topological states in a thin strip of Haldane model.

Traverso S.
Dipartimento di Fisica, Università degli Studi di Genova, Italia

In 1988 F.D.M. Haldane conceived the first proposal for a Chern insulator: his model —nowadays known as the Haldane model— describes spinless electrons on a honeycomb lattice, and it achieves a topological phase with non-zero Chern number by breaking time-reversal symmetry without net magnetic flux. The topological phase of the model is characterized by the presence of one-dimensional chiral edge states, with energy in the bulk gap and connecting the valence and conduction bands. Interestingly, if one considers a thin enough strip of the honeycomb lattice, then the chiral modes on the two edges will hybridize with each other, causing the opening of a gap in the edge spectrum. We found that, for a specific choice of the strip edge type, this gap can host a pair of zero energy modes, corresponding to topological states localized at the two ends of the strip. Moreover, we discovered that for a strip of appropriate width the model manifests an even richer phenomenology. Indeed, in such special configuration, the topological phase described above is only achievable after a topological phase transition, which can be induced through the introduction of an on-site staggered potential.

Noise-enhanced stability of sine-Gordon breathers.

De Santis D. (1), Guarcello C. (2), Spagnolo B. (1), Carollo A. (1), Valenti D. (1)
(1) *Dipartimento di Fisica e Chimica "Emilio Segrè", Università degli Studi di Palermo, Italia*
(2) *Dipartimento di Fisica "E.R. Caianiello", Università di Salerno, Italia*

We study the dynamics of sine-Gordon (SG) breathers in the presence of lossy and stochastic perturbations. In a solely dissipative case, a breather radiatively decays within a time interval of the order of the inverse damping coefficient. Our simulations, for which the initial condition is a stationary breather with a random phase value, indicate that a spatially uniform noisy source can make this solitonic mode last much longer than it would in the noise-free scenario. Notably, we find a nonmonotonic behavior of an average characteristic time *vs.* the noise intensity, which is a signature of the noise-enhanced stability effect. Both the frequency domain and the energy localization are examined to show the efficacy of the phenomenon. We also discuss the dependence of the results on the excitation's starting energy and their robustness against thermal fluctuations. This framework is useful for tackling the long-standing problem of the breather's detection in long Josephson junctions and its subsequent applications, *e.g.*, in information transmission and quantum computation. Lastly, SG breathers are also actively studied, *e.g.*, in cuprate superconductors, geology, and DNA systems.

First-principles calculation of transport and thermoelectric coefficients in liquid $Ge_2Sb_2Te_5$.

Baratella D., Dragoni D., Bernasconi M.
University of Milano-Bicocca

Phase change materials are exploited in key enabling technologies such as non-volatile electronic memories. In phase change memories (PCM) the two digital states are encoded in the amorphous and crystalline phases of the $Ge_2Sb_2Te_5$ (GST) alloy that features a difference in the electrical resistivity by about three orders of magnitude. The readout of the memory consists of measuring the resistance at low bias while the set/reset processes consist of the reversible transformation between the two phases induced by Joule heating. Thermoelectric effects play an important role in the programming operations due to the presence of large electric fields and thermal gradients. Numerical simulations based on finite-elements methods have been performed to reproduce the electrical characteristics of PCMs based on GST in the set/reset regimes. The electrothermal modeling of the device requires the knowledge of transport coefficients such as the Seebeck coefficient, the electrical and thermal conductivities at different temperatures. In this contribution, we calculate these transport coefficients of liquid GST at a few temperatures above melting by means of density functional molecular dynamics.

Exploring diffraction of wave-driven particles.

PUCCI G. (1)(2), OZA A.U. (3), BELLAIGUE A. (2)
(1) *Consiglio Nazionale delle Ricerche, Istituto di Nanotecnologia, CNR-Nanotec, Italy*
(2) *Institut de Physique de Rennes, CNRS and Université Rennes 1, France*
(3) *Mathematical Sciences, New Jersey Institute of Technology, USA*

Millimetric liquid droplets can bounce on the surface of a vertically vibrating bath of the same liquid. In some regimes, these droplets self-propel on the liquid surface by bouncing on the wave field created by their previous impacts. A series of experiments with these walking droplets have shown quantum-like behaviors. One of the seminal experiments suggested that single-particle diffraction and interference may be obtained when a droplet crosses a single or double aperture between submerged barriers. Later experiments with finer control of experimental parameters yielded different results, thus reopening the question of the extent of the analogy between walking droplets and quantum particles. Here we use the pilot-wave model developed by Oza *et al.* to describe walking droplets and explore the diffraction of a two-dimensional, wave-piloted particle by one-dimensional barriers. The statistical distribution of deflection angles generally exhibits multiple peaks, the number of which depends on the obstacle geometry.

Low-frequency vibrational modes of realistic model of glasses.

BONFANTI S. (1), ALVAREZ-DONADO R. (1), GUERRA R. (2), PROCACCIA I. (3), ZAPPERI S. (2), SOBKOWICZ P. (1), ALAVA M. (1)
(1) *NOMATEN CoE, National Centre for Nuclear Research, Otwock, Poland*
(2) *Center for Complexity and Biosystems, Department of Physics, University of Milan, Milan, Italy*
(3) *The Weizmann Institute of Science, Rehovot, Israel*

Understanding the vibrational features of amorphous glassy systems is the key to rationalize their peculiar low-temperature properties. Theoretical considerations pointed out for quite some time that low-frequency vibrational modes in amorphous glassy systems at low temperature are expected to present a universal density of states which depends as the fourth power of the frequency. The verification of this law in computer simulations however occurred only recently, due to the fact that the modes which are expected to exhibit this universal scaling are quasi-localized modes that in large systems hybridize strongly with low-frequency delocalized elastic (Debye) extended modes. Quasi-localized modes have been disentangled in simplified models of glasses. However, how wide this class of systems is and whether it also pertains to more realistic models of glasses remains an open question. Here we aim to establish the validity of the universal law of the density of quasi-localized modes also in richer and more realistic model glasses, such as silica and high entropy metallic glasses.

Relativistic quantum theory for modeling electron scattering in different scenarios.

TRIGGIANI F. (1), TAIOLI S. (2), SIMONUCCI S. (1)
(1) *University of Camerino, INFN, Section of Perugia*
(2) *ECT*-FBK Trento*

In this contribution we present a method for calculating relativistic electron scattering with nuclei, atoms and molecules including the temperature dependence. In particular, we focus on the mean-field approximation of the Dirac equation for many-fermion systems and its self-consistent numerical solutions, which are obtained by using either radial mesh or Gaussian basis sets. The former approach is right for spherical symmetric problems, such as atoms, while the second one is more suitable for studying non-spherical non-periodic polycentric systems, *e.g.*, molecules. We apply it to electron scattering with water molecules useful for the study of ionization processes in biological systems, which are crucial in adrontherapy, and the study of weak decays in nuclei of astrophysical and medical interest. These processes are also important for spectroscopic applications (Auger, XPS, etc.).

Hong-Ou-Mandel interference in the quantum Hall regime: The role of channel mixing.

ACCIAI M. (1), ROULLEAU P. (2), TAKTAK I. (2), GLATTLI D.C. (2), SPLETTSTOESSER J. (1)
(1) *Department of Microtechnology and Nanoscience, MC2, Chalmers University of Technology, Göteborg, Sweden*
(2) *Université Paris-Saclay, CEA, CNRS, SPEC, Gif-sur-Yvette, France*

We consider an electronic Hong-Ou-Mandel interferometer in the integer quantum Hall regime, where two electronic states are generated by applying voltage pulses to ohmic contacts and subsequently sent towards a quantum point contact acting as a beamsplitter. When the sources are synchronised, the noise measured at the output of the interferometer is expected to vanish, due to the Pauli principle that forces the incoming states to exit the interferometer in two different channels. However, a recent experiment performed in the integer quantum Hall regime at filling factor $\nu = 2$ has reported a finite noise even for synchronised sources. The aim of this work is to investigate possible mechanisms leading to such an outcome. It is known that electron-electron interactions cannot account for this effect and always lead to a full suppression of the Hong-Ou-Mandel noise. We show instead that mixing of the copropagating edge channels (arising from tunneling events between them) can account for a finite noise, in agreement with the experiment.

Unconventional supersymmetry and graphene.

CERCHIAI B.L.
Consiglio Nazionale delle Ricerche, Istituto di Matematica Applicata e Tecnologie Informatiche "Enrico Magenes", Sezione di Milano, Italia

This project applies a model of unconventional supersymmetry to study the non-trivial topological properties of the electrons in two-dimensional graphene-like materials in condensed matter. It harnesses the full power of techniques developed for field theories in high-energy physics and in general relativity, by making use of a holographic map relating a conformal field theory to a gravitational model in one dimension higher on a curved AdS spacetime.

Aula T - Caterina Scarpellini **ore 09:00 – 13:00**

SEZIONE III
Astrofisica
Presiede: FIORILLO G. (Università di Napoli Fedrico II e INFN, Sezione di Napoli)

UNDERGROUND-NEUTRINOS-ETC.

Relazioni su invito

▲ **Il neutrino, messaggero di nuova fisica.**
MONTANINO D.
Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento e INFN, Sezione di Lecce
Dalla scoperta delle oscillazioni di flavor avvenuta circa 24 anni fa la fisica del neutrino ha avuto un tumultuoso sviluppo in cui la gran parte dei parametri di oscillazione sono stati stabiliti con grande precisione sebbene alcuni tasselli fondamentali siano ancora mancanti (per esempio, le masse dei neutrini o la loro natura Dirac/Maiorana). Contestualmente, il ruolo dei neutrini in astrofisica ha avuto un grande sviluppo, sia per la misura di precisione del flusso dei neutrini solari che per la scoperta di neutrini di alta energia, la cui origine non è ancora ben chiarita, che ha aperto alla possibilità di uno astronomia multimessaggero. Infine i neutrini hanno un ruolo importantissimo in cosmologia. In questo contributo si vuole fornire una rapida rassegna della fenomenologia corrente e delle prospettive per il futuro, in particolare la misura dei parametri di oscillazione ancora incogniti e le misura delle masse assolute. Inoltre si cercherà di delineare le possibilità offerte dai neutrini per le misure di tipo astrofisico (per esempio nelle supernovae) o cosmologica (misura del fondo di neutrini primordiali).

▲ **Neutrinoless double beta decay.**
BELLINI F.
Sapienza Università di Roma e INFN, Sezione di Roma
Neutrinoless double beta decay is a hypothesised nuclear process in which two neutrons simultaneously decay into protons with no neutrino emission. The prized observation of this decay would point to the existence of a process that violates a fundamental symmetry of the Standard Model of particle physics, and would allow to establish the nature of neutrinos. Today, the lower limits on the half-life of this process exceed 10^{25}–10^{26} yrs. I will review the current status of the searches for double beta decay and the perspectives to enhance the experimental sensitivity in the next years.

Comunicazioni

● **Il rivelatore JUNO-TAO e il suo ruolo per JUNO.**
LOMBARDO C.
Università degli Studi di Catania, Dipartimento di Fisica ed Astronomia "E.Majorana" e INFN, Sezione di Catania
JUNO-TAO sarà un rivelatore sferico riempito da liquido scintillante la cui luce prodotta verrà raccolta attraverso 4000 SiPM operanti a $-50\,^{\circ}$C. Sarà posizionato a 30 m dalla centrale nucleare di Taishan per misurare lo spettro di antineutrini elettronici prodotti, e studiarne le strutture fini. Nel contributo verranno esposti le caratteristiche di JUNO-TAO, il suo ruolo per JUNO e l'impatto che avrà per la fisica del neutrino.

Misura dei parametri di fluorescenza dello scintillatore di JUNO.

Beretta M. (1), Basilico D. (1)(2), Brigatti A. (2), Caccianiga B. (2), Ferraro F. (1)(2), Landini C. (2), Lombardi P. (2), Re A. (1)(2)
(1) *Dipartimento di Fisica, Università degli Studi di Milano, Italia*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Milano, Italia*

Il progetto SHELDON (Separation of cHErenkov Light for Directionality Of Neutrino) ha lo scopo di eseguire misure accurate sulle proprietà dello scintillatore dell'esperimento JUNO (Jiangem Underground Neutrino Observatory), i cui obiettivi sono la determinazione dell'ordi namento di massa dei neutrini tramite la rivelazione di anti-neutrini da reattore, la spettroscopia dei neutrini solari e la rivelazione dei neutrini da supernova. Il rivelatore principale di JUNO è costituito da 20 kton di scintillatore organico liquido, che rendono questo esperimento il più grande nel suo genere. Conoscere con estrema accuratezza le proprietà ottiche e temporali dello scintillatore di JUNO risulta essere di cruciale importanza per determinare al meglio la risposta in energia e la risoluzione del rivelatore. Verrà presentato il setup sperimentale di SHELDON, situato presso l'Università degli Studi di Milano, e le tecniche utilizzate che hanno permesso di ottenere le migliori misure ad oggi dei parametri che descrivono l'emissione di luce nello scintillatore di JUNO.

L'esperimento ReD per la verifica della sensibilità direzionale di una TPC ad Ar in doppia fase.

Pino N., Albergo S.F.
Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Catania, Italia e Dipartimento di Fisica e Astronomia "E. Majorana", Università degli Studi di Catania, Italia

Uno degli scopi dell'esperimento Recoil Directionality (ReD), all'interno della Collaborazione DarkSide, è quello di dimostrare il possibile effetto direzionale dei segnali indotti da collisione elastica WIMP-nucleone in una TPC ad Argon Liquido (LAr) in doppia fase tramite lo studio dell'effetto della ricombinazione colonnare. Nella campagna di misure presso i Laboratori Nazionali del Sud (LNS), Catania, la TPC di ReD ($125\,\mathrm{cm}^3$) è stata irradiata con un fascio di neutroni quasi-monocromatico prodotto tramite la reazione p(^{7}Li, ^{7}Be)n, indotta ad energia tale da produrre un rinculo dell'Ar di energia circa $70\,\mathrm{keV}_{nr}$. A seguito dello scattering elastico in LAr, i neutroni sono intercettati da uno spettrometro di scintillatori liquidi installato a valle del sistema per studiare la direzione della traccia di rinculo del nucleo di Ar rispetto al campo elettrico applicato alla TPC. I dati raccolti sono stati utilizzati anche per derivare un'analisi con algoritmi di Machine Learning ed estrarre possibili correlazioni utili a studiare l'andamento del fenomeno della ricombinazione, al momento non descritto da una teoria definitiva.

Neutrino event reconstruction with the liquid-argon target of SAND in the DUNE Near Detector.

Vicenzi M.
Dipartimento di Fisica, Università di Genova, Italia e INFN, Sezione di Genova, Italia

SAND (System for on-Axis Neutrino Detection) will be the on-axis beam monitor in the Near Detector of the DUNE experiment, aiming at controlling the flux and systematics uncertainties for the oscillation analysis. It consists of a solenoidal magnet, an electromagnetic calorimeter, an inner tracker system and a 1-ton liquid-argon target named GRAIN (GRanular Argon for Interaction of Neutrinos). GRAIN will allow to collect samples of ν-Ar interactions, exploiting the reconstruction power of the downstream systems and its own calorimetric light readout to precisely infer the incoming neutrino energy. In addition, innovative optical imaging systems based on coded apertures or UV lenses are envisioned to boost GRAIN capabilities by using scintillation light to spatially reconstruct the tracks and provide topological information of the events. In this contribution, the design of GRAIN and its optical readout are described, as well as the expected reconstruction performance of neutrino events in liquid argon within SAND.

Studio della sensibilità dell'esperimento JUNO all'ordinamento di massa dei neutrini.

Percalli E.
Università degli Studi di Milano

JUNO è un esperimento attualmente in costruzione in Cina che misurerà, dal 2024, gli spettri degli antineutrini prodotti da due reattori nucleari, situati ad una distanza di circa 52 km dal rivelatore. Attualmente sono noti i valori assoluti delle differenze di massa tra i neutrini, ma non il segno dello splitting $\delta m^2_{31,32}$. JUNO si prefigge di stabilire l'ordinamento di massa corretto e di misurare con precisione sub-percentuale i valori dei parametri di massa e oscillazione dei neutrini: $\Delta m^2_{31,32}$, Δm^2_{21} e θ_{12}. Il rivelatore avrà una massa attiva di 20 kt di scintillatore liquido ultrapuro, circondato da oltre 43000 fotomoltiplicatori, tramite cui verranno rivelati gli antineutrini che interagiscono tramite reazione beta inversa. Sarà fondamentale per JUNO raggiungere una risoluzione energetica migliore del 3% al MeV, essendo questa strettamente legata alla sensibilità di JUNO alla differenza tra i due ordinamenti. In questo contributo sarà mostrata la sensibilità di JUNO al NMO in funzione di parametri sperimentali interessanti, quali la risoluzione energetica, e tenendo in considerazione eventuali sistematiche.

Misura delle proprietà ottiche dello scintillatore JUNO.

Reina G.
Università degli Studi di Milano

JUNO è un esperimento di fisica del neutrino in fase di costruzione in Cina, il quale inizierà la presa dati nel 2024. Gli obiettivi principali di JUNO sono la determinazione della gerarchia di massa e la misura di precisione dei parametri di oscillazione $\Delta m^2_{31,32}$, Δm^2_{21} e θ_{12}. Il rivelatore è costituito da 20 kton di scintillatore liquido organico, la cui caratterizzazione è cruciale per la buona riuscita dell'esperimento. Il progetto SHELDON, apparato basato sulla tecnica di conteggio di singolo fotone, permette di studiare le proprietà temporali dell'emissione di luce e di misurare il contributo della luce emessa per effetto Cherenkov. Inoltre, con un rifrattometro funzionante nello spettro ultravioletto è possibile misurare accuratamente l'indice di rifrazione alle lunghezze d'onda per le quali l'emissione di luce Cherenkov è importante. Questo studio consiste nella misura dei parametri di scintillazione, del contributo Cherenkov, dei tempi di fluorescenza e dell'indice di rifrazione. Verrà mostrato, quindi, l'impatto di questi parametri sulle capacità di ricostruzione degli eventi in JUNO, tramite metodi di simulazione Monte Carlo.

Studi di sensibilità dell'esperimento JUNO ai flussi di neutrini solari.

Malabarba M.
Dipartimento di Fisica, Università degli Studi di Milano, Italia

Nel recente passato sono stati misurati i flussi dei neutrini solari della catena pp e del ciclo CNO. Rimane ancora aperta, tuttavia, la questione della metallicità solare, definita come la frazione di metalli presenti nella nostra stella. Per distinguere tra gli scenari di alta metallicità e di bassa metallicità è necessario migliorare la precisione delle misure dei flussi dei neutrini dovuti al ciclo CNO e di alcune componenti dei neutrini della catena pp. In questo contesto si propone JUNO (Jiangmen Underground Neutrino Observatory), rivelatore a scintillatore liquido ultrapuro in costruzione in Cina. Lo scopo primario di JUNO è la determinazione dell'ordinamento di massa dei neutrini; ma allo stesso tempo è il candidato ideale per la spettroscopia di precisione di neutrini solari. Ciò sarà reso possibile grazie alla massa attiva di 20 kton di scintillatore, all'eccellente radiopurezza dello scintillatore, alla presenza di oltre 43000 fototubi e alla risoluzione energetica senza precedenti pari al 3% all'energia di 1 MeV. In questo contributo verrà mostrata la sensibilità di JUNO ai flussi di neutrini solari in funzione di diversi parametri sperimentali di interesse.

Short-Baseline neutrino oscillation searches with the ICARUS detector.

Campani A. per la ICARUS Collaboration
Università degli Studi di Genova e INFN, Sezione di Genova

The ICARUS Collaboration employed the 760-ton T600 detector in a successful three-year physics run at the underground LNGS laboratories, performing a sensitive search for LSND-like anomalous νe appearance in the CNGS beam. After a significant overhaul at CERN, the T600 detector was installed at Fermilab and in 2020 the cryogenic commissioning began. ICARUS has then started operations and is presently in its commissioning phase, collecting the first neutrino events from the Booster Neutrino Beam and the NuMI off-axis. The main goal of the first year of ICARUS data taking will be the definitive verification of the recent claim by NEUTRINO-4 short baseline reactor experiment. After the first year of operations, ICARUS will search for evidence of a sterile neutrino jointly with the SBND near detector. The ICARUS exposure to the NuMI beam will also give the possibility for other physics studies such as light dark matter searches and neutrino-argon cross-section measurements. The proposed contribution will address ICARUS achievements, its status and plans for the new run at Fermilab and the ongoing developments of the analysis tools needed to fulfill its physics program.

Study on the performance of the new High Angle Time Projection Chamber prototype for T2K ND280 Upgrade.

Feltre M. per la T2K Collaboration
INFN, Sezione di Padova e University of Siena

The T2K Collaboration is developing new gas-based Time Projection Chamber (TPC) detectors to be exploited in the upgrade of "near" neutrino detector ND280 located in the J-PARC laboratory (Tokai, Japan). HA-TPCs are based on a gaseous active volume contained in a Field Cage, with a central cathode splitting the chamber into two halves, that are devoted to the detection of charged particles at large angle with respect to the neutrino beam. In 2021, a prototype has been built for the validation of the manufacturing process, in order to test the performances and to start the production of five full scale Field Cages. This contribution focuses on the study of the prototype performances, in particular by looking at 1) Electric Field uniformity with a laser source and 2) data collected in a test beam at CERN (2021). An external tracking system consisting of 8 planes of silicon strips will be compared with data from the TPC to investigate possible biases in the position reconstruction. Furthermore, preliminary tests with the full scale Field Cage are currently being performed.

The DUNE photon detection system.

Massari C. per il DUNE PDS Consortium
Dipartimento di Fisica, Università Milano-Bicocca, Italia e INFN, Sezione di Milano-Bicocca, Milano, Italia

DUNE is the US flagship project in neutrino physics and is currently under construction at Fermilab and South Dakota. The DUNE far detector is based on the liquid-argon TPC technology proposed by C. Rubbia in 1977. Liquid argon is also a high-yield scintillator, which produces about 25000 128 nm photons per MeV. In this contribution, I will present the DUNE photon detection system (PDS) to shift, trap, and record the scintillator light, and provide the interaction time of neutrinos in DUNE together with a calorimetric energy measurement (light-charge anticorrelation). I discuss the performance of the system measured in the DUNE laboratories of Milano-Bicocca using both cosmic rays and alpha sources with custom cryogenic SiPMs. Special emphasis will be given to cryo-reliability of the semiconductor detectors and the light trapping system (coated dichroic filters coupled with WLS bars) in liquid nitrogen and liquid argon. The tests demonstrated the long-term reliability of the setup and initiated the assembly of the PDS in the ProtoDUNE-SP detector at CERN. The status of the construction and perspectives for the Run II of ProtoDUNE-SP in 2022 will also be reviewed.

Aula U - Giuliana Cini Castagnoli **ore 10:00 – 13:00**

Sezione IV

Geofisica e fisica dell'ambiente

Presiede: Crescentini L. (Università di Salerno)

Earth observation and application

Relazioni su invito

▲ **Advances in the Research Component of the European Earth Observation System.**

Silvestrin P.

ESA ESTEC, Noordwijk, The Netherlands

The European Space Agency develops a comprehensive satellite system to observe the Earth. Its research component includes missions in orbit, e.g. Aeolus to derive wind and aerosol atmospheric profiles from ultraviolet Doppler lidar measurements, and missions close to launch, e.g. Biomass to measure forest biomass from long-wavelength synthetic-aperture radar (SAR) data. After outlining them, upcoming research missions, such as Harmony and the Mass change And Geosciences International Constellation (MAGIC), will be described. Harmony uses two small satellites for bistatic SAR measurements to derive 3D Doppler and radar backscatter and observe – in a first phase – 3D land surface deformations, ocean surface motion, surface winds, directional surface wave spectra, and more. In a second phase, single-pass SAR interferometry provides surface elevation of glaciers, permafrost, icebergs and volcanoes. MAGIC measures the varying gravity field to enable new applications, e.g. groundwater storage monitoring. MAGIC derives the geoid, to 1 mm accuracy at 3 (10) day intervals and 500 (150) km spatial resolution, from inter-satellite distances, measured with laser interferometers, and from ultra-sensitive accelerometers data, enhanced in future using cold atom matter-wave interferometry.

▲ **GNSS applications for Earth Science.**

Palano M.

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania

In the last two decades, the rapid growth in continuous Global Navigation Satellite Systems (GNSS) networks allowed the acquisition of continuous and spatially extensive datasets over large regions of Earth, significantly increasing the range of geoscience applications. In addition, the promising results obtained by the scientific community and the free availability of data, which permitted drastic cost reductions, have drawn increasing interest from the administrative managing office for the mapping and monitoring of ground deformation issues. The GNSS technique provides a set of 3D geodetic observations at a limited number of points on the ground surface and its continuous technological development is currently offering a wide range of new applications for solid and fluid Earth investigations. This contribute aims to provide a general overview of some geoscience applications of GNSS technique, commonly used to study the surface deformation related to co- and post-seismic deformation, subsurface movements of magma beneath active volcanoes, soil deformation (natural/anthropic uplift/subsidence), monitoring of landslide, monitoring of industrial settlements, ice sheets motion, etc.

▲ Sensitivity of quantum satellite gravimetry to geophysical signals - from Tibetan lakes to isostasy in the Iranian Plateau.

BRAITENBERG C., PASTORUTTI A., PIVETTA T.
Dipartimento di Matematica e Geoscienze, University of Trieste

The quantum technology (QT) gravimeter has a flatter spectral measurement band compared to electrostatic accelerometers, which leads to a lower noise level in the measured gravity potential. The MOCAST+ project simulated the payload of a QT gravity gradiometer and clock in a multi-satellite architecture. We investigate the added value of the QT mission in terms of detecting earth gravity signals, covering static and time-variable sources. We address climate induced variations in lake levels and glaciers melting, mass movements hidden to surface observations. Regarding density structure, we consider which improvements on the knowledge of seismic faults or crustal structure can be expected from future QT gravity missions. The knowledge of the density column of the lithosphere is the parameter needed for defining the present isostatic equilibrium of the crust, and the physical reasons for vertical uplift or gravitative pull. The objective of this work is to discuss the geophysical signals and their spectral energies in terms of spherical harmonic expansion in comparison to the noise spectral curves of the QT satellite mission.

▲ La stima del geoide e le correnti geostrofiche nel Mediterraneo.

BARZAGHI R.
DICA, Politecnico di Milano

Il geoide è una particolare superficie equipotenziale del campo della gravità terrestre. La stima del geoide è usualmente ottenuta come soluzione di un problema al contorno per funzioni armoniche a partire da dati di gravità noti sul geoide o sulla superficie terrestre. Inoltre, su mare, mediante osservazioni radar altimetriche da satellite è stimabile la cosiddetta Sea Surface Height che differisce dal geoide per la Dynamic Ocean Topography (DOT). Dunque, a partire dalla stima gravimetrica del geoide e utilizzando dati radar altimetrici è possibile ottenere la DOT che, a sua volta, è strettamente collegata alla circolazione oceanica. Il progetto internazionale GEOMED2 ha avuto come scopo proprio quello di stimare la DOT e le correnti nel Mediterraneo. A tal fine, si sono raccolti e validati tutti i dati di gravità ivi disponibili, si sono applicate e confrontate diverse metodologie per la stima del geoide e si sono utilizzati i più recenti dati radar altimetrici presenti nell'area mediterranea. In questa relazione si presentano i risultati così ottenuti e si discutono gli aspetti geofisici e oceanografici connessi ai risultati stessi.

Comunicazioni

● The MOCAST+ proposal for a quantum space gravimetry mission.

MIGLIACCIO F. (1), REGUZZONI M. (1), ROSSI L. (1), KOÇ Ö. (1), BATSUKH K. (1), BRAITENBERG C. (2), PASTORUTTI A. (2), PIVETTA T. (2), ROSI G. (3), TINO G.M. (4), SORRENTINO F. (5), MOTTINI S. (6), VITTI A. (7), BENCIOLINI B. (7)
(1) *Department of Civil and Environmental Engineering, Politecnico di Milano, Italy*
(2) *Department of Mathematics and Geosciences, University of Trieste, Italy*
(3) *The National Institute for Nuclear Physics, Florence and AtomSensors srl, Italy*
(4) *Department of Physics and Astronomy and LENS, University of Florence, Italy*
(5) *The National Institute for Nuclear Physics, Genova, Italy*
(6) *Thales Alenia Space Italia, Torino, Italy*
(7) *Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy*

MOCAST+ (MOnitoring mass variations by Cold Atom Sensors and Time measures) is a study funded by the Italian Space Agency (ASI) and carried out by several Italian research groups, proposing a novel concept for a gravimetry mission based on quantum technology. Quantum technologies and quantum sensing promise to offer higher sensitivity, drift-free measurements, and higher absolute accuracy than "classical" sensors, both for terrestrial and space missions, giving access to more precise long-term measurements of the gravity field. In MOCAST+ the proposed payload is a Cold Atom Interferometer based on strontium atoms and acting as a gravity gradiometer, plus an optical frequency measurement using an ultra-stable laser, providing time measurements. We studied the level of accuracy which can be expected from the mission and the level of accuracy needed to detect and monitor phenomena identified in the Scientific Challenges of the ESA Living Planet Program, in particular Cryosphere, Ocean and Solid Earth. We will present the proposed payload, mission profile and preliminary platform design, and the results of end-to-end simulations and assessment of the impact on geophysical applications.

Integration of numerical modelling and gravity data to disclose the dynamics of the Gulf of Aden.

Bollino A. ([1]), Regorda A. ([1]), Sabadini R. ([1]), Barzaghi R. ([2]), Marotta A.M. ([1])
([1]) *University of Milan, Department of Earth Science, Milano, Italy*
([2]) *Politecnico di Milano, Department of Civil and Environmental Engineering, Milano, Italy*

Gulf of Aden is a young oceanic basin that offers an excellent opportunity to understand breakup processes during extension. Regional stress field or thermal upwelling of the asthenosphere, inherited zones of weakness and the rheological structure of the lithosphere are the factors contributing to the initiation of rifting and deformation of lithosphere. We use a 2D thermo-mechanical model to simulate the formation of oceanic crust and serpentinite due to the hydration of upwelling mantle peridotite. A strongly integration between modeling and gravitational data provided valuable constraints to our analysis. Our preliminary results show that: a) four main tectonic phases develop during rifting, each one characterized by particular distributions of velocity gradients and strain rates inside divergent crustal blocks, which allow us to determine when breakup occurs; b) the timing of mantle serpentinization is not affected by the initial thermal configuration of the system but is related to crustal thickness; c) the timing of mantle partial melting strongly depends on the thermal conditions in both lithospheric plates; d) evolution of the model with crustal and lithospheric thickness of 40 and 150 km, respectively, well fit with the geodynamic reconstruction of the Gulf of Aden, considering the timing of break-up that occurs 20 Myr after the onset of the extension for 0.05% percentage of mantle hydration (in agreement with magma-poor rift margins). Finally, the results obtained so far support the hypothesis that the Gulf of Aden developed as a slow passive rift in thin lithosphere with thick crust and that the variations in features along the passive margins could be related to lateral variations in the amount of H_2O in the mantle, which determines the different times of mantle melting.

The Next Generation Gravity Mission (NGGM): A breakthrough in our understanding of Solid Earth dynamics.

Sabadini R.
Università degli Studi di Milano

Space gravity missions play a key role in our understanding of planet dynamics. SLR allowed us to constrain the rheology of the mantle and the ice loss in Antarctica and Greenland at low harmonics and GRACE, at harmonic l=60 for the time dependent gravity field, confirmed and improved these SLR discoveries. For the static field GOCE constrains the dynamics of subduction and rifting, disclosing in-depth density anomalies and the coupling between the plates, for the knowledge of the genesis of large earthquakes. In this regard, GRACE demonstrated the feasibility of gravity data to obtain the fault characteristics of large earthquakes, Mw=8.5 - 9 by adding, compared to the classical seismology, the benefit of uniform data coverage. Based on these results and on just accomplished findings from new studies, a breakthrough is expected from NGGM, an ESA/NASA double-pair gravity mission at l=250 spatial resolution for the time dependent gravity field, to detect the slow gravity changes due to active tectonics and the co-, post- and inter-seismic phases of earthquakes as low as Mw=7 - 7.5.

Evaluation of CO and HCN emissions from Indonesia during 2015 wildfires season using satellite observation.

Bruno A.G. (1)(2), Wilson C. (3)(4), Harrison J.J. (1)(2), Moore D.P. (1)(2), Chipperfield M.P. (3)(4)
(1) *University of Leicester, School of Physics and Astronomy, Leicester, UK*
(2) *National Centre for Earth Observation, NCEO, University of Leicester, Leicester, UK*
(3) *University of Leeds, School of Earth and Environment, Leeds, UK*
(4) *National Centre for Earth Observation, NCEO, University of Leeds, Leeds, UK*

Indonesia is seasonally affected by intense fire events, often driven by El Niño events. These events release substantial amounts of carbon stored in the soil as peat into the atmosphere, affecting the air quality and the atmospheric composition of the region and on a global scale. During the 2015 El Niño event, a strong enhancement of Indonesian peat fires was observed from space by the Infrared Atmospheric Sounding Interferometer (IASI) instrument monitoring atmospheric carbon monoxide (CO) and hydrogen cyanide (HCN) concentration. These satellite observations are used to estimate CO and HCN fire emissions using the INVICAT inverse modelling framework. The derived emissions in Indonesia are found to be substantially different from the Global Fire Emissions Database (GFEDv4.1s) emission inventory, highlighting uncertainties in its estimates. IASI-based fire emissions capture observed variations more accurately, thus atmospheric composition satellite observations have a high potential to constrain the actual emission inventories whose estimates are based only on fire information such as fire counts, fire radiative power and burned area.

Inter-calibration and statistical validation of topside ionosphere plasma density observations made by CSES-01 mission.

De Michelis P., Pignalberi A., Pezzopane M., Giannattasio F., Coco I., Tozzi R., Consolini G.
Istituto Nazionale di Geofisica e Vulcanologia

In situ probing of the topside ionosphere plasma through Langmuir Probes (LPs) on-board low Earth orbit (LEO) satellites is of outstanding importance to get information both on the electron density (Ne) on a global scale and in regions difficult to probe with ground-based instrumentations. Moreover, data collected by LEO satellites in the topside ionosphere are the raw material on which ionospheric empirical models like the International Reference Ionosphere (IRI) rely to describe the spatial and temporal variations exhibited by Ne in the topside ionosphere. LP *in situ* Ne measurements collected by CSES-01 mission offer the opportunity of improving the current knowledge and modeling capabilities of the topside ionospheric plasma. Data recorded in the years 2019-2021 are first compared with corresponding data recorded by instruments on-board the ESA Swarm B satellite and with values modeled by IRI. In a second stage, CSES-01 Ne data are calibrated through corrected Swarm B Ne LP data. Finally, the goodness of the calibration procedure is validated through a statistical comparison with Ne observations from Incoherent Scatter Radars located at Jicamarca, Arecibo, and Millstone Hill.

i-ϕ-male: A novel hybrid machine learning phasor-based approach to retrieve a full-set of solar-induced fluorescence metrics and biophysical parameters.

Scodellaro R. (1), Cesana I. (2), D'Alfonso L. (1), Bouzin M. (1), Collini M. (1), Miglietta F. (3), Celesti M. (4), Schuettemeyer D. (5), Colombo R. (2), Chirico G. (1), Cogliati S. (2), Sironi L. (1)
(1) *Laboratory of Advanced Bio-spectroscopy, Physics Department "G.Occhialini", University of Milano-Bicocca*
(2) *Remote Sensing of Environmental Dynamics Lab., DISAT, University of Milano-Bicocca*
(3) *Institute of Biometeorology, National Research Council, CNR-IBIMET, Firenze*
(4) *HE Space for ESA, ESTEC, Noordwijk, The Netherlands*
(5) *ESA-ESTEC, Noordwijk, The Netherlands*

Solar-induced Fluorescence (F) is a pivotal parameter to monitor vegetation health as it provides crucial information on photosynthetic processes. Actually, only the atmospheric O_2-bands of high-resolution apparent reflectance spectra (R_{app}) are exploited to retrieve F. We propose a new method, i-ϕ-male, based on the phasor approach coupled to supervised machine learning (S-ML) techniques. The 650-800nm R_{app} spectra are Discrete Fourier transformed on consecutive spectral windows, where the S-ML algorithm, trained with a radiative transfer (RT) model, estimates: F, Leaf Area Index, Chlorophyll Content, Absorbed Photosynthetic Active Radiation, F Quantum Yield and F at photosystem level. We validated i-ϕ-male on RT simulations (error $< 3\%$) and provided analysis of field measurements acquired for increasing spectrometer-canopy distances, up to 100m (where O_2 bands are affected by atmospheric oxygen absorption). The simultaneous retrieval of biophysical variables and F from spectra acquired at multiple distances from the canopy paves the way to new important perspectives related to the real time monitoring of vegetation stress level on high scales.

Aula E - Rosalind Franklin **ore 09:00 – 13:00**

Sezione V

Biofisica e fisica medica

Presiedono: Ronda L. (Università di Parma)
Ricci C. (Università di Milano)

Relazioni su invito

▲ **Bacterial efflux systems, the first survival kit.**

Ruggerone P., Gervasoni S., Malloci G., Vargiu A.V., Bosin A.
Department of Physics, University of Cagliari, Cittadella Universitaria, Monserrato, Cagliari, Italy

Antibiotic resistance is a major threat to public health, especially in the form of multidrug resistance. Gram-negative pathogens, such as *Pseudomonas aeruginosa*, are of particular concern. One of the first survival kit of Gram-negative bacteria is the active export of drugs out of the cell, mainly mediated by resistance-nodulation-division (RND) efflux pumps. They are complex molecular machines able to efficiently shuttle chemically different compounds out of the cell. A strategy to avoid their action should be based on a knowledge at molecular level of the functioning of the RND efflux systems. Computational methods are well suited to provide key insights thereon. In particular, our results outline molecular-level information that could help the rational design of new inhibitors and new antibiotics less susceptible to the efflux mechanism.

Comunicazioni

● **Computer aided iron quantification in digital images of liver biopsies.**

Panzeri D. (1), Scodellaro R. (1), Lancellotti C. (2), Chirico G. (1), Di Tommaso L. (2)(3), Sironi L. (1)
(1) *Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca, Milan, Italy*
(2) *Unit of Pathology, Humanitas Clinical and Research Hospital - IRCCS, Rozzano, Milan, Italy*
(3) *Department of Biomedical Science, Humanitas University, Pieve Emanuele, Milan, Italy*

Liver biopsies are an invaluable tool for the prognosis and diagnosis of iron overload disorders. Perls Stain (PS) is exploited to visualize iron accumulation in blue, quantified in our study in 10 whole-slide images (WSI) of liver biopsies. We developed a pipeline able to objectively estimate: percentage liver biopsy covered by PS, mean intensity of PS stain, density and dimension of PS granules, and PS heterogeneity. To reproduce the procedure followed by pathologists we performed our analysis at different zoom scales, while simultaneously applying image-wide color correction. We developed two methods: optical density color thresholding and a custom spectral phasor approach, both characterized by $< 5\%$ error when compared to pathologist's semi-quantitative evaluation. Furthermore, to improve intra-section evaluation, we generated heatmap overlays to highlight statistically significant tissue patches. Our pipeline paves the way toward a rapid and objective method for the evaluation of hepatic iron accumulation. Moreover, it can also be tuned and applied to different staining protocols (*e.g.*, PicroSirius Red for the quantification of liver fibrosis).

A deep learning-based method to spectrally separate overlapping fluorophores based on their fluorescence lifetime.

Cuneo L. (1)(2), Castello M. (2)(4), Piazza S. (3)(4), Nepita I. (2), Cainero I. (2), Tortarolo G. (3), Lanzanò L. (2)(5), Bianchini P. (2), Vicidomini G. (3)(4), Diaspro A. (1)(2)(4)
(1) *DIFILAB Department of Physics, University of Genoa, Genoa, Italy*
(2) *Nanoscopy&NIC@IIT, Istituto Italiano di Tecnologia, Genoa, Italy*
(3) *Molecular Microscopy and Spectroscopy, Istituto Italiano di Tecnologia, Genoa, Italy*
(4) *Genoa Instruments Srl, Genoa, Italy*
(5) *Department of Physics and Astronomy "Ettore Majorana", University of Catania, Catania, Italy*

To investigate biological samples via fluorescence microscopy, fluorophores should be carefully chosen in order to avoid spectral overlap. This poses constraints on the number and type of fluorophores that can be used at the same time on the sample. The fluorescence lifetime is a useful feature to demultiplex the fluorescence signal of spectrally overlapping fluorophores. So far, several methods have been proposed to separate fluorophores based on temporal or spectral fingerprints, including phasor approach and SPLIT. However, these methods usually rely solely on linear separation. During the last decade, the development of machine learning approaches offers great possibilities in terms of data analysis and processing speed. In this contribution, we exploited the deep learning benefits to separate two spectrally overlapping fluorophores using their fluorescence lifetime. Taking into account also the non-linear contributions, our solution offers improved performance with respect to the state-of-the-art approaches. The training was implemented on synthetic images of cells stained with two spectrally overlapped fluorophores, while the test was performed on both synthetic and real images.

Nonivasive monitoring of equine muscle hemodynamics by time domain near infrared spectroscopy.

Frabasile L. (1), Lacerenza M. (1)(2), Buttafava M. (2), Contini D. (1), Straticò P. (4), Petrizzi L. (4), Dalla Costa E. (5), Minero M. (5), Rabbogliatti V. (5), Zani D. (5), Torricelli A. (1)(3)
(1) *Politecnico di Milano, Dipartimento di Fisica, Milano, Italy*
(2) *PIONIRS s.r.l., Milano, Italy*
(3) *Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche, Milano, Italy*
(4) *Facoltà di Medicina Veterinaria, Università degli Studi di Teramo, Teramo, Italy*
(5) *Department of Veterinary Medicine and Animal Sciences, DIVAS, Università degli Studi di Milano, Italy*

Non-invasive and real-time hemodynamic monitoring of equine muscle is crucial to avoid the occurrence of myopathies related to prolonged muscle compression, as it often occurs during long surgical or diagnostic procedures. In this pilot study, we explored the possibility of detecting equine muscle optical proprieties by means of Time Domain Near-Infrared Spectroscopy. A custom-made portable TD-NIRS tissue oximeter, based on pulsed diode lasers, single photon detection and timing electronics. The device was used to retrieve tissue hemodynamics on muscles of living horses, during static measurements before and after induction of anesthesia for surgical and diagnostic procedures. The potential advantage in usage of this technique lies in the fact that it allows to monitor the absolute hemodynamic parameters in real time, during prolonged measurements on hardly accessible investigation sites. A custom optical probe was developed, to avoid motion artifacts and to be robust enough to withstand the weight of the horse. The use of TD-NIRS oximetry technology seems a clinically feasible means to assess tissue oxygenation in most of adult horses, despite the presence of hair and dark skin.

Development of a super-resolution optical microscope enabling fluorescence and label-free approaches.

Nepita I. (1), Bianchini P. (1)(2), Callegari F. (1)(3), Castello M. (1)(2), Cuneo L. (1)(3), Sheppard C.J.R (1)(4), Diaspro A. (1)(2)(3)
(1) *Nanoscopy&NIC@IIT, Istituto Italiano di Tecnologia, Genoa, Italy*
(2) *Genoa Instruments Srl, Genoa, Italy*
(3) *DIFILAB, Department of Physics, University of Genoa, Genoa, Italy*
(4) *Molecular Horizons, School of Chemistry and Molecular Biosciences, University of Wollongong, Australia*

Coupling microscopy and spectroscopy with the idea of extracting all the information carried by the collected photons may have a deep impact in biological research. We are developing a Multimodal Optical MIcroscopy Image Correlation Sensing approach, MOMIX(tm). It enables super-resolution lifetime imaging and label-free Mueller matrix polarization control and analysis. The setup is based on a laser scanning confocal microscope, which implements polarization resolved and two-photon excitation fluorescence (2PEF) imaging modalities. The first method exploits a photoelastic modulator (PEM) to modulate the polarization of the light at a resonant frequency of 50 kHz. A lock-in detection scheme allows to analyse intensities differences due to alterations of the polarization state in tens of microseconds. One- and two-photon excited fluorescence can also be collected by MOMIX. In particular, fluorescence lifetime can be imaged at high spatial resolution taking advantage of the image scanning detection scheme. Real-time synchronization of electro-optical devices (scanners, PEM, detectors), pixel-by-pixel signal acquisition, and processing will be presented.

Automatic wavefront engeneering for intravital two-photon imaging.

Pagani E. (1)(2), Haham N. (2), Lubart A. (2), Blinder P. (2)
(1) *Dipartimento di Fisica, Università degli Studi di Milano-Bicocca, Italia*
(2) *Neurobiology department, Tel Aviv Univeristy, Israel*

Two-photon microscopy is invaluable for *in vivo* imaging, although its performance is hindered by aberrations induced by thick biological samples. Adaptive optics (AO) introduces a compensatory distortion of the laser wavefront to minimize aberrations and improve image quality. To improve the accessibility of indirect AO, we developed an automatic wavefront correction tool based on genetic algorithm that allows simple control of the compensation process. We showed that, without AO, more laser power is required to obtain the same intensity signal in mice brain samples. This suggests that our tool may reduce the use of high laser power which increases photodamage. Then we exploited our AO solution while performing single penetrating vessel occlusions. The significant improvement of the signal intensity collected from the sample allowed us to better evaluate microglia surveillance.

Investigating heterochromatin distribution in laminopathies model cell line.

Cainero I. (1), Usai C. (1)(2), Baldini F. (1), Bianchini P. (1), Lanzanò L. (1)(3), Diaspro A. (1)(2)
(1) *Istituto Italiano di Tecnologia, Genoa, Italy*
(2) *DIFILAB, Università degli Studi di Genova, Genoa, Italy*
(3) *Dipartimento di Fisica e Astronomia "Ettore Majorana", Università degli Studi di Catania, Catania, Italy*

Chromatin architecture and genome regulation are crucial in maintaining cell physiology. However, even a single variation in the genomic code can induce alterations leading to different pathologies. In particular, we focus on a model for laminopathies disease, Hutchinson-Gilford Progeria Syndrome, HGPS, in which the patient ages rapidly from the first two years of life. HGPS is induced by a single mutation of lamin A gene resulting in inappropriate processing of its related protein. The lamin A is one of the nuclear lamina components, and it has the following roles: chromatin scaffold and somehow regulates cellular processes (transcription, replication, repair). Therefore, its mutation can cause massive damage to the cells. Our work is focused on exploiting super-resolution microscopy to investigate heterochromatin organization in HGPS. More in detail, we aim to investigate how lamin A mutation affects the peripheral organization of chromatin, thus we perform multicolor colocalization analysis of heterochromatin and lamina-associated proteins. Our single-cell approach could lead to a deeper understanding of the starting events associated with Hutchinson-Gilford Progeria Syndrome.

Narrow-bandwidth LEDs arrays as versatile, medium-power UV-C sources.

Di Lazzaro P., Bollanti S., Flora F., Gallerano G.P., Mezi L., Murra D.
ENEA Research Centre of Frascati, Italy

Light Emitting Diodes (LEDs) are a new class of UV-C (200–280 nm) radiation source, which attracted the attention of specialists. UV-C LEDs can be organized in multi-element arrays, resulting in medium-power devices. They transform about 2% of the electrical power into radiation. This requires rapid dissipation of excess heat. At the ENEA Centre in Frascati, we assembled arrays of LEDs emitting radiation peaked at 277 nm, with 11 nm FWHM bandwidth and 120° full angle of emission. We have developed software that calculates the spatial distribution and average radiation value of UV-C intensity *vs.* distance from the LED array with a given number of LEDs and their and relative distance. The results are in excellent agreement with the experimental data. Despite the aspect ratio ≈ 3 of the array, the UV-C spot has an almost circular shape at any distance larger than the short side of the array. After a description of our LEDs arrays, we present the results of two irradiation applications: 1) enhancement of hormesis (innate defence mechanisms of plants against pathogens) in fruits and vegetables exposed to pathogens, and 2) low-dose inactivation of SARS-Cov-2 *in vitro*.

Optical microscopy approach to investigate changes in chromatin organization during adipocyte differentiation and hypertrophy.

Zeaiter L. (1)(2), Baldini F. (2), Cuneo L. (2)(3), Diab F. (1), Bianchini P. (2), Portincasa P. (4), Vergani L. (1), Diaspro A. (2)(3)
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(2) *Nanoscopy, Istituto Italiano Tecnologia, Genoa, Italy*
(3) *DIFILAB Department of Physics, University of Genoa, Genoa, Italy*
(4) *Clinica Medica "A. Murri", Department of Biomedical Sciences & Human Oncology, University of Bari Medical School, Bari, Italy*

The adipose tissue is the physiological energy and fat store acting also in endocrine regulation of metabolic homeostasis. Adipocyte hypertrophy occurring in obesity refers to an increase in adipocyte size due to lipid droplets enlargement. Our aim is to investigate the nuclear architecture and epigenetics during adipocyte differentiation and hypertrophy using an *in vitro* model of 3T3-L1 preadipocytes firstly differentiated into mature adipocytes, then cultured with fatty acids to induce hypertrophy. On mature and hypertrophic adipocytes, we assessed lipid accumulation as a marker of hypertrophy. Through confocal and super-resolution STED microscopy we assessed the remodelling of nuclear architecture. By immunoassay we quantified the average changes in the DNA methylation (5-mc). Confocal and STED analyses show appreciable differences in the nuclear architecture DNA methylation average between mature and hypertrophic adipocytes. Taken together, these preliminary results indicate a remodelling of both epigenome and nuclear organization during adipocyte differentiation and hypertrophy thus paving the way toward new strategies to treat/prevent obesity and its metabolic complication.

The interaction between hypericin and supported lipid bilayers mimicking coronavirus envelopes.

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Biological membranes are one of the most important self-assembled structures in nature. They provide many functional and protective features for cells and have a fundamental role in enveloped virus infectivity. The targeting of the viral envelope is an emerging strategy in the development of broad-spectrum antivirals, also based on photosensitizers (PS). PS are molecules that trigger the production of singlet oxygen upon photo-excitation. Singlet oxygen is a strong oxidant capable of damaging biomolecules, such as phospholipids. For a few decades, PS have been employed in a therapy called Photodynamic Therapy (PDT) mostly against cancer cells, but also against bacteria and viruses. We focused on hypericin (Hyp), a photosensitizer that was found to inactivate enveloped viruses, including SARS-CoV-2, not only upon photo-excitation, but also in dark conditions. To study the effects of hypericin on a viral envelope we used supported lipid bilayers, an excellent model system for membranes, with a lipid mixture to mimic the viral envelope. By performing AFM microscopy and AFM-STED correlative nanoscopy (Hyp is fluorescent), we reported a noticeable effect of Hyp at various concentrations.

Non-invasive brain cortex hemodynamic monitoring: A step towards motor disorder assessment via TD fNIRS.

Lacerenza M. (1)(2), Frabasile L. (1), Buttafava M. (2), Spinelli L. (3), Torricelli A. (1)(3), Contini D. (1)
(1) *Politecnico di Milano, Dipartimento di Fisica, Milano, Italy*
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(3) *Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche, Milano, Italy*

The state-of-the-art in the diagnosis of motor disabilities includes the detection of anomalies while observing the patient performing specific movements. This method is affected by the subjectivity of perception conditioned by the operator's experience. A more rigorous approach involves the monitoring of cerebral response to motor stimuli by functional Magnetic Resonance Imaging. However, this solution forces the subject to maintain a static condition, therefore limiting the range of responses. Time-domain functional near-infrared spectroscopy (TD fNIRS) exploits the diffusion of picosecond laser pulses in cerebral tissue to allow for quantitative and non-invasive acquisition of brain functional activity. Given the latest hardware development pioneered by our research group, it is now possible to exploit compact and wearable TD fNIRS devices allowing for real-time brain monitoring of unconstrained moving subjects. To assess the potential of the TD fNIRS technique in the field of motor disorder, we studied motor cortex hemodynamic response functions on 16 healthy subjects performing standard physiotherapy protocols including goal-oriented and non-goal-oriented motor tasks.

Study of *p*H-dependent structural properties of transfection lipids layers for RNA delivery.

Grava M. (1), Mohd I. (2), Pusterla J. (1), Schwierz N. (2)(3), Schneck E. (1)
(1) *Institute for Condensed Matter Physics, Department of Physics, Technische Universität Darmstadt, Darmstadt, Germany*
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(3) *Institute of Physics, University of Augsburg, Germany*

The most effective messenger RNA (mRNA) delivery systems are cationic lipid-based nanoparticles. This technology holds much promise for a broader use in biomedical applications, especially for patient-specific cancer treatments and vaccines. However, the transfection efficiency depends on the physicochemical properties of the lipid molecules, specifically on their charge and its dependence on *p*H. In order to determine their *p*H-dependent structural properties, *p*H-induced changes in internal molecular organization, and the protonation degree of monolayers of positively chargeable transfection lipid mixtures, we combine synchrotron-based X-ray scattering and X-ray fluorescence with atomistic molecular-dynamics simulations. The experimental techniques allow to discover the peculiarities on the lipids-RNA interactions by studying lipid surface charge and electron density profiles, while complementary molecular-dynamics simulations help to investigate the conformations of the lipid species, the area per molecule and the distribution of counterions.

Aula Bonetti **ore 09:00 – 13:00**

Sezione V

Biofisica e fisica medica

Presiedono: Veronese I. (Università di Milano)
Brero F. (Università di Pavia)

Relazioni su invito

▲ Monte Carlo dosimetric investigation of a brain tumor model irradiation using laser-driven very high energy electron beams.

Del Sarto D. (1)(2)(3), Labate L. (1)(4), Di Martino F. (3), Koester P. (1), Palla D. (1), Panetta D. (5), Gizzi L.A. (1)(4)
(1) *Laboratorio di Irraggiamento Laser Intensi (ILIL) , Istituto Nazionale di Ottica, CNR, Pisa, Italy*
(2) *Scuola di Specializzazione di Fisica Medica, University of Pisa, Italy*
(3) *Azienza Ospedaliero-Universitaria Pisana, Pisa, Italy*
(4) *Istituto Nazionale di Fisica Nucleare, Sezione di Pisa, Italy*
(5) *Istituto di Fisiologia Clinica, CNR, Pisa, Italy*

Electron beams with energy up to ~ 10 MeV are commonly used in radiotherapy for treatments of superficial tumors or IORT. Laser-Plasma Acceleration (LPA) of Very High Energy Electrons (VHEE), with energy 100–250 MeV, opens perspectives for compact, hospital compliant accelerators for new treatments of deep seated tumors. Moreover, LPA offers a promising method to produce VHEE beams with the ultra-high dose rate needed to exploit the recently discovered "FLASH effect". We present the results of a Monte Carlo study aimed at assessing the dosimetric features of a typical LPA VHEE beam, such as the one available at the ILIL laboratory of CNR-INO in Pisa, and studying the beam scanning irradiation of a deep seated tumor. Simulations show that, via an appropriately designed collimator, a 5 mm size pencil beam can be obtained, with good symmetry and flatness and a therapeutic range of about 8 cm. The dose deposition in a tumor placed within a CT reconstructed human head indicates good target conformation and coverage with minimal lateral spread. A discussion of the tissue sparing due to the FLASH effect, included in the study via a parametric approach, will also be given.

▲ Effect of phenylalanine derivatives on dosimetric and mechanical properties of innovative PVA hydrogel matrices for external radiation therapy.

Locarno S. (1), Arosio P. (1), Gallo S. (1), Mattei I. (2), Orsini F. (1), Pignoli E. (3), Veronese I. (1), Lenardi C. (1)
(1) *Dipartimento di Fisica, Università degli Studi di Milano, Italy*
(2) *National Institute of Nuclear Physics, INFN, Section of Milan, Italy*
(3) *Fondazione IRCCS "Istituto Nazionale dei Tumori", Milano, Italy*

Fricke gel (FG) were improved by the addition of self-assembled phenylalanine derivatives which favor the formation of fibrous structure network that fills the porosity of the Polyvinyl alcohol (PVA) matrix and, consequently, increases the hardness and the elastic properties of the gel. This advancement would make it possible to produce anthropomorphic phantoms with an elasticity comparable to various soft tissues of the human body, allowing the dosimetric verification of sophisticated radiotherapy treatments also for organs subjected to natural movement (*i.e.*, breathing). The self-assembly ability of peptides inside the gel is

evaluated and a complete characterization of the new matrix is provided. Moreover, mechanical tests have shown that the addition of the peptide led, with respect to the common FG, to higher stiffness, toughness and stretchability of the hydrogels and that the matrix can be appropriately tailored by regulating the amount of the added peptide. The basis for a possible dosimetric characterization in a pre-clinical scenario will be laid.

Comunicazioni

Dosimetric impact of real-time motion and daily anatomical changes during ultra-hypofractionated prostate cancer radiotherapy.

Di Franco F.
Léon Bérard Cancer Center, Université de Lyon, Lyon, France e CREATIS, INSA, Université de Lyon, CNRS UMR5220, Inserm U1044, Lyon, France

During ultra-hypofractionated prostate cancer radiotherapy treatments, prostate motion and daily anatomical variations degrade the delivered dose to the clinical target volume (CTV) and to the organs at risk. Hence, patients would benefit from real-time prostate tracking and from a strict protocol for bladder and rectal filling. Our purpose was to study the synchronization of prostate's displacements with the beam's geometry and to evaluate the dosimetric impact of real-time motion and daily anatomical changes. A trans-perineal ultrasound probe was used to track prostate translations for 15 patients treated by volumetric-modulated arc therapy. The prescription dose was 36.25 Gy to 100% of the CTV-prostate in 5 fractions. The daily dose distribution was calculated generating synthetic CTs for dose accumulation. Afterwards, original RT-plans were first divided into sub-arcs following the plan's control points and then calculated in the treatment planning system. Finally, the voxel shifting method was used to synchronize prostate's displacements with beam's geometry. The shifted dose maps were then summed and the dosimetric parameters were evaluated in the presence of motion.

Implementazione dell'algoritmo ACUROS-XB per il calcolo della dose in Radioterapia.

Perna M., Didonna V., Cristofaro C., Bernardi R.M.
Istituto Tumori Giovanni Paolo II - IRCCS Bari

Nel nostro centro il calcolo della dose in radioterapia veniva fatta attraverso l'algoritmo di Varian. Nel 2019 abbiamo acquistato l'algoritmo ACUROS-XB. In questo contributo ci concentreremo nel cercare di confrontare i risultati dei due algoritmi in modo da verificare se effettivamente il nuovo algoritmo riesce a modellizzare meglio la dosimetria delle interfacce tessuto-aria.

Studio Monte Carlo del range monitoring inter-frazione 3D in un trattamento di protonterapia con il rivelatore PAPRICA.

Ciancia V.
Dipartimento di Fisica, Università degli Studi di Milano, Italia

In un trattamento di adroterapia il rilascio di dose al paziente avviene in diverse frazioni. Una Computed Tomography del paziente viene acquisita per la pianificazione. Durante il trattamento potrebbero avvenire delle variazioni morfologiche nella regione irraggiata, per cui è necessario un monitoraggio inter-frazione per decidere se acquisire una CT di controllo. A questo scopo, si può sfruttare la rivelazione dei fotoni prompt prodotti dalle reazioni nucleari del fascio con i nuclei target. Il progetto PAPRICA propone una nuova tecnica di imaging dei fotoni prompt sfruttando la produzione di coppie nel rivelatore. In questo contributo si riporterà lo studio delle performance di PAPRICA per il monitoraggio inter-frazione 3D in un trattamento di protonterapia di un paziente affetto da ACC trattato al

CNAO durante il trial clinico di INSIDE. Il trattamento di protonterapia è simulato con il codice Monte Carlo FLUKA ed inviato su due diverse CT del paziente, acquisite ad inizio e a metà trattamento. Il confronto tra le mappe di emissione dei fotoni ricostruite, tramite un codice di analisi data-like, determina l'applicabilità di PAPRICA in ambito clinico.

A new double dose measurement method for TLD-100H.

Sallah A., D'Anna A., Galvagno R., Gueli A.M., Matamoros A., Stella G.
Physics for Dating Diagnostic Dosimetry Research and Applications, PH3DRA, Laboratories, Dipartimento di Fisica e Astronomia "E. Majorana", Università di Catania, Catania, Italy

The aim of this work was to investigate optically and thermally stimulated luminescence (OSL and TL) properties of lithium fluoride (LiF) doped with magnesium (Mg), copper (Cu) and phosphorous (P) (LiF:Mg, Cu, P), commercially known as TLD-100H. Greater accuracy and precision of dosimetric measurements can be achieved through a method that allows, for each irradiation, two independent dose measurements. Pre-and post-annealing conditions, their effects on the OSL and TL curves, the ideal temperature during OSL readout, and fading properties were investigated. Optimal parameters were obtained and used for calibration curves determination. For irradiation and readout was employed a Risø TL/OSL DA 15 system equipped with a calibrated ^{90}Sr/^{90}Y beta source, blue LEDs ($470\,\text{nm} \pm 30\,\text{nm}$) for optically stimulation, a thermocouple for thermal stimulation, and a bialkali EMI 9235QB PMT for light detection. Calibration curves showed two different trends for TL and OSL values *vs.* absorbed dose in the range from 0 and 4 Gy, *i.e.*, a polynomial trend for TL and linear one for OSL. This result confirms the independent response for the two stimulation methods.

Radiological and dosimetric characterization of 3D printing materials.

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The aim of this work was to study dosimetric and CT number responses for some Fused Filament Fabrication 3D printing materials, *i.e.*, PoLylActide (PLA) and Acrylonitrile Butadiene Styrene (ABS). The certified phantom CIRS was used as reference. It is composed of several cylindrical inserts of tissue-equivalent materials: dense bone, trabecular, liver, lung (exhale and inhale), adipose, muscle and breast. Using the 3D CAD Inventor and 3D slicing IdeaMaker software, and a RAISE 3D pro2 plus 3D printer, cylindrical samples were designed and printed setting different infill densities to reproduce the CIRS soft tissues. To reproduce CIRS hard tissues, printed hollow cylinders were filled with different mixtures of water and plaster. For each printed sample: Hounsfield Unit (HU) was measured in CT using large and small FOV; charge and dose values (6–10 MV photon beams, 100 MU, TrueBeam LinAc) were measured through a Farmer ionization chamber positioned on 5 slabs of RW3 and under two slabs of RW3 (SSD = 100 cm), printed phantom was placed on the RW3 at field centre. 3D printing conditions and mixtures of water and plaster for reproducing CIRS tissue-equivalent materials were obtained.

Stima personalizzata della dose di radiazione mediante scansione ottica corporea in esami di tomografia computerizzata a raggi X.

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Abbiamo sviluppato una metodologia per la stima personalizzata di dose in un esame di tomografia computerizzata a raggi X (CT). La tecnica richiede una scansione ottica del paziente, al fine di ottenerne le dimensioni corporee. È stato realizzato un codice Monte Carlo con toolkit Geant4 (ver. 10.6) validato sperimentalmente su scanner clinico (del quale sono stati riprodotti spettro e profilo del fascio), nel quale l'anatomia umana è rappresentata da un fantoccio voxellizzato. I fantocci utilizzati sono stati forniti dal National Cancer Institute (NCI, USA), con riferimento a protocolli per la testa. La simulazione produce mappe 3D di dose assorbita agli organi interni. I fantocci NCI standardizzati relativi a maschio e donna adulti sono stati adattati all'interno della silhouette ricavata dalla scansione ottica del soggetto. Le differenze relative di dose agli organi della testa con fantoccio di riferimento e con fantoccio personalizzato sono dell'ordine di ±15% nei due casi esaminati. Si prospetta l'utilizzo di tale tecnica per ottenere una stima personalizzata della dose di radiazione al paziente prima dell'esame, per i vari distretti anatomici.

Development and characterization of a 144-channel proton counter for particle therapy applications.

Data E. (1)(2), Abujami M. (1)(2), Giordanengo S. (1), Garbolino S. (1), Hammad Ali O. (3), Mas Milian F. (1)(2)(4), Medina E. (1)(2), Mignone M. (1), Montalvan Olivares D.M. (1)(2), Centis Vignali M. (3), Vignati A. (1)(2), Martì Villareal O.A. (1)(2), Wheadon R. (1), Cirio R. (1)(2), Monaco V. (1)(2), Sacchi R. (1)(2)
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(4) *Universidade Estadual de Santa Cruz, Ilheus, Brazil*

A prototype of an innovative beam monitor for particle therapy was developed by University and INFN of Torino, in order to count single protons up to a fluence rate of 10^8 p/(cm^{2}s) in the clinical energy range (60–230 MeV). The designed detector is based on silicon sensors which show a better sensitivity and speed with respect to the state-of-the-art gas ionization chambers. The sensitive area is $2.6 \times 2.6\,\text{cm}^2$, enough to cover the whole area of fix pencil beams, characterized by a FWHM of about 1 cm at the isocenter. The sensor is a 50 μm thick Low Gain Avalanche Diode segmented in 146 strips with 180 μm pitch. The readout frontend is based on 6 custom 24-channel ASICs, named ABACUS, able to discriminate proton signals in a wide charge range (3–150 fC) with a maximum dead time of about 10 ns. ABACUS digital outputs are sent to 3 Kintex7 FPGA boards for the counting operations. A LabVIEW program reads counters on the FPGAs, displays the counting rate and saves data for the offline analysis. The results of the proton counter characterization, performed both in laboratory and with proton beams, will be presented.

Alanine/EPR dosimetry for ultra-high dose rate beams used for FLASH radiotherapy.

D'Oca M.C. (1)(2), Castronovo E.R.A. (1), Collura G. (1)(2), Gasparini A. (3)(4), Vanreusel V. (3)(4)(5), Verellen D. (3)(4), Felici G. (6), Mariani G. (6), Galante F. (6), Pacitti M. (6), Romano F. (2), Marrale M. (1)(2)
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In the last years a large interest has gronw towards radiation therapy treatments with dose rates much larger with respect to the conventional ones since experiments support the evidence of a considerable normal tissue sparing effect. This work aims at investigating the response of alanine pellets exposed to UHDR electron beams. The electron beams used with energies of 7 and 9 MeV, accelerated by a SIT-Sordina ElectronFlash Linac, at conventional and UHDR regimes were used. High average dose rates (up to several hundreds of Gy/s) were adopted for the experimental campaign, characterized by instantaneous dose rate even more than two orders of magnitudes larger. Pulse structure of the used accelerator is characterized by a pulse duration in the range 1–4 μs and a frequency up to hundreds of Hz. In order to investigate a possible dependence of alanine response on the dose rate for these UHDR beams, the depth dose profile accomplished by stacking alanine pellets along the electron beam direction was analysed. Monte Carlo simulations were performed and compared with experimental results. The results will be presented and discussed in detail.

Experimental validation of an EPID dosimetry model for pre-treatment QA.

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Modern Radiation Therapy treatment plans complexity requires accurate pre-treatment Quality Assurance (QA). Electronic portal imaging devices (EPIDs), embedded on recent LINACs, are employed for dosimetry due to their excellent spatial resolution, dose linearity and large detector area. Their adoption in clinical practice provides reliable, accurate and fast QA. We describe the validation of an EPID dosimetry model on the commercial software SunNuclear EpidDose. Firstly, we tested the model by irradiating the EPID detector with 9 appropriately MLC shaped static fields, mainly to check leaves transmission. Then, 12 selected dynamic VMAT plans were compared in terms of γ index (3%, 3 mm) with TPS calculations. Both static and VMAT plans were verified through MapCheck and ArcCheck diode arrays and ionization chamber (IC) at significant plan positions. The difference between the γ analysis of the EPID and diode arrays against TPS dose maps allows for a cross-check of the model, while IC measurements give absolute dose comparison. The average γ passing rate was 97.8% for EPID, 99.7% for ArcCheck and 96.6% for MapCheck, while the mean dose difference was -0.6%.

Valutazione dell'esposizione del cristallino degli operatori di Radiologia Interventistica mediante dosimetria personale.

POGGIALI C. ([1]), BRUZZI M. ([1]), GIOMI S. ([1]), BETTI M. ([3]), FEDELI L. ([3]), MAZZONI L.N. ([3]), QUATTROCCHI M. ([4]), ROSSI F. ([2]), TADDEUCCI A. ([2]), BELLI G. ([2]), GASPERI C. ([5]), PAOLUCCI M. ([6]), D'URSO D. ([7]), BOSCHINI A. ([7]), CICCARONE A. ([8]), CAMPANELLA F. ([9]), BUSONI S. ([2])
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La riduzione del limite di dose al cristallino da 150 a 20 mSv l'anno per l'esposizione professionale costituisce un problema per gli operatori sanitari più esposti nel rispettare tale limite e nell'assegnazione dei DPI. Questo studio si colloca all'interno di un progetto di ricerca finanziato dall'INAIL che ha come scopo la valutazione della dose al cristallino per i primi operatori coinvolti nelle procedure endovascolari e di cardiologia e neuroradiologia interventistica. La valutazione della dose è svolta per singola procedura mediante l'assegnazione di un dosimetro TLD al primo operatore, posto vicino all'occhio più esposto. I dosimetri sono forniti e gestiti dal servizio di dosimetria di Careggi accreditato ISO-17025. I risultati ad oggi ottenuti sono i seguenti (in μSv/(Gycm^2)): per le embolizzazioni di MAV e aneurismi rispettivamente 0.30 e 0.28, per coronarografie e angioplastiche 0.54, per l'installazione di PM 2.3 e per le riparazioni endovascolari EVAR e FEVAR 0.38 e 4.5. La valutazione è stata effettuata nelle condizioni di lavoro dell'equipe chirurgica: tutte le procedure sono svolte con l'impiego della paratia eccetto le installazioni di PM e le FEVAR.

Strategies to reduce radiation exposure for operators in percutaneous structural cardiac interventions.

Savio L. ([1]), Loria A. ([2]), Ingallina G. ([3]), Lenardi C. ([1]), Agricola E. ([3]), del Vecchio A. ([2])
([1]) *Dipartimento di Fisica Università degli Studi di Milano, Italia*
([2]) *Medical Physics Department, San Raffaele Scientific Institute, Italia*
([3]) *Cardiovascular Imaging Unit, San Raffaele Scientific Institute, Italia*

In recent years the number of percutaneous structural heart interventions (SHI) has increased. Significant radiation exposure for patients and operators occurs in SHI. SHI have always been performed in catheterization laboratory (CL) under fluoroscopy and only recently with the support given by transesophageal echocardiography guidance (TEG). Recently, Italian legislation reduced the eye lens equivalent dose limit by about seven times.The TEG is done by the interventional imager (IM), a new figure in the CL staff. The IM, due to both the proximity to X-ray source and absence of dedicate protections, is subjected to high-radiation exposures. Aim of this work is to find strategies in terms of educational recommendations and dedicated equipment to reduce IM exposure. First, SHI parameters were retrospectively analyzed to find the most frequently adopted for each kind of procedure. Then, simulation study was performed with an anthropomorphic phantom in the CL to identify protective c-arm projections and locations for the IM. IM eye lens real time dosimetry, before and after adoption of protective projections and locations, was performed during clinical SHI to compare the radiation doses.

Study of aminosalicilic acid derivatives as innovative Fe^{3+} chelating agents in Fricke gel dosimetry.

Predella L. ([1]), Brambilla E. ([2]), Gallo S. ([1]), Lenardi C. ([1]), Pignoli E. ([3]), Veronese I. ([1]), Locarno S. ([1]), Santangelo C. ([4])
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([4]) *Fondazione UNIMI, Milano*

This work concerns the optimization of the Polyvinyl alcohol (PVA) hydrogel matrix used in the Fricke gel (FG) dosimetry with the aim to reduce the spatial and temporal instability of the dosimeter induced by the Fe^{3+} ions diffusion and, consequently, to reduce the distance between such promising system and its application in clinical scenario. The research aims to propose new Fe^{3+} ligands with a simple chemical structure that allows the covalent functionalization of the PVA matrix with few steps and with high yield, in order to block the ions diffusion. Among other, 4-aminosalicilic acid (4-ASA) and 5-aminosalicilic acid (5-asa) derivatives are selected as chelating agents since they are able to form iron complexes which show a broad light absorbance band at 517 and 548 nm, respectively, whose intensity is linearly proportional to the adsorbed dose. A complete characterization of the new matrix is provided in terms of strength of formulation, in particular physical-chemical properties, dosimetric properties and stability over the time. Preliminary results have shown that 4-ASA is effectively a promising compound for improving FG dosimetry.

Aula L - Christa Mc Auliffe **ore 09:00 – 13:00**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiede: Manzolaro M. (INFN-LNL)

Relazioni su invito

▲ Ion sources physics, technology and related applications and developments.

Mascali D. per i LNS and LNL Ion Sources groups
Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud

Electron Cyclotron Resonance based ion sources produce extremely intense (tens of mA) beams of light ions (p,d, He), and relevant currents of heavier elements (C, O, N, and up to Xe, Pb, U). R&D activities are fundamental for supporting hadron accelerators developments towards new ion species, including exotic beam productions, as well as higher energies and beam intensities. More recently, a revival of interest about these machines in fundamental research has come from the PANDORA project, that will be the first setup attempting nuclear decays measurements in stellar-like conditions. INFN has been playing an international leading role in ECR plasma research, both for ion sources and for fundamental studies, proposing innovative technological solutions and exploring plasma properties with unprecedented precision by a variety of diagnostics methods (interferopolarimeters, X-ray imaging, etc.). The gained experience has permitted to open other interdisciplinary links with, *e.g.*, thermonuclear fusion: electromagnetic plasma heating systems and the diagnostics methods are providing valuable synergies with the DTT (Divertor Tokamak Test) project.

▲ Beyond X-ray tomography for the diagnosis of wooden works and finds: Multiparametric and multimodal 2D and 3D approaches by nuclear magnetic resonance.

Capuani S.
CNR-ISC c/o Physics Department, Sapienza Università di Roma, Rome

Non-destructive and non-invasive approaches are fundamental for cultural heritage investigations. X-ray Computed Tomography (CT) and Nuclear Magnetic Resonance (NMR) are the most important imaging techniques in the medical diagnostics field. We have translated the technology used in medical diagnostics to the diagnostics of cultural heritage, by adapting and developing it thanks to funding from DTC of Lazio Region. We will introduce the different NMR instrumentation, used in the laboratory, *in situ*, and in clinical diagnostics showing different applications for the study of wooden works and waterlogged archaeological wood. 2D images and 3D reconstructions of Neolithic tools (from the collection of the Museo Delle Civiltà in Rome) were obtained with a clinical NMR scanner and NMR images were obtained at high magnetic field with a linear resolution of around 20 microns for the recognition of wood essences. We will demonstrate a new NMR protocol to be used with portable *in situ* NMR instrumentation for monitoring the conservation status of submerged archaeological wood. NMR results and information obtained on different wood samples were compared to those obtained using CT.

▲ Super-resolution thermography as a tool for investigating the conservation state of cultural heritage artifacts.

Collini M. (1), Bouzin M. (1), Marini M. (1), Sironi L. (1), D'Alfonso L. (1), Colombo R. (2), Di Martino D. (1), Gorini G. (1), Chirico G. (1)
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The non-destructive characterization with 40 μm resolution on mesoscopic scale is a demanding need in the field of cultural heritage conservation. We present here a novel methodology to obtain space-resolved maps of the product of the thermal conductivity times the sample thickness that can be applied to solid opaque samples (oxidized metals, pigments on different substrates, wood, clay, etc.). By localizing the temperature increments sparsely induced on the sample by a focalized laser beam, the thermal conductivity of the material can be obtained once the thickness and the absorbed power are known. This method has been applied to an XVIII century organ pipe fragment. The tin foil shows evidence of oxidation processes (tin-pest). Our analysis, developed on finite elements simulations covering a wide range of conductivity values (0.1–100 W/mK), shows the possibility of correlating regions of different conductivity and thickness of the sample to its conservation state on mm^2 areas with a sub-diffraction 40 μm resolution. Our approach expands the capability of state-of-the-art infrared imaging in capturing the heterogeneity and functional state of the imaged materials.

Comunicazioni

● Large bandwidth opamp-based preamplifier and shaping filter for smart rad-hard fast detection systems.

Castoldi A., Guazzoni C., Naggi A.
Politecnico di Milano, DEIB e INFN, Sezione di Milano

Different application fields require the development of fast preamplifiers and shaping filters to be coupled with dedicated radiation detectors. In view of fast prototyping and targeting a medium number of readout channels, we present the feasibility study, design and qualification of a large-bandwidth, opamp-based, preamplifier and shaping filter suited to equip a smart rad-hard detection system intended for the diagnostics and tagging of Radioactive Ion Beams (RIBs) at high intensity (106 pps or higher) The contribution illustrates the conception and design of the fast readout system and presents the detailed analysis and qualification of its performance in view of the design of a network of smart sensors, equipped with optimized frontend electronics, DAQ with Data Real-Time Management capabilities and a dedicated software layer implementing Artificial Intelligence and machine learning techniques as a tool to improve the production, transport and use of RIBs. Different prototypes have been produced and their performance experimentally compared in terms of noise, bandwidth, resolution, … both as a standalone circuit and coupled with a sample detector prototype.

● Focus-ISM: A universal tool to enhance optical sectioning in super-resolution microscopy.

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Image Scanning Microscopy (ISM) is the evolution of Confocal Laser Scanning Microscopy (CLSM), enabling both super-resolution and excellent Signal-to-Noise Ratio (SNR). In ISM, an excitation beam scans the sample, and a detector array collects the fluorescence light, generating a micro-image for each scan point. However, although maximizing the SNR, the lack of a conventional pinhole degrades optical sectioning. Here, we present a new approach that fully exploits the information provided by the detector array, enabling optical sectioning in ISM without sacrificing the SNR. In detail, each element of the detector array generates a shifted CLSM image. First, we register the images with our adaptive pixel reassignment (APR) algorithm. The modified micro-images depend uniquely on the axial position of the fluorophores. Then, we fit each micro-image to a simple two-component model, enabling the removal of the out-of-focus background. The final image contains only the signal stemming from the focal plane. Notably, the same procedure is well suited to any laser scanning technique, such as STED or multi-photon microscopy, opening new paths for super-resolution imaging of thick samples.

Microbubble resonators as scattering-free thermometric micro-spectrometers.

Frigenti G., Cavigli L., Ratto F., Centi S., Farnesi D., Pelli S., Soria S., Nunzi Conti G.

Istituto di Fisica Applicata "Nello Carrara", Consiglio Nazionale delle Ricerche, Italia

We report on a proof-of-concept experiment where the absorption spectrum of a nanoparticles (GoldNano Rods, GNRs) suspension is reconstructed through the temperature shifts that the optical absorption induces in a MicroBubble Resonator (MBR). In the presented configuration, the nanoparticles suspension is placed inside of the MBR through a microfluidic circuit, producing maximal thermal contact between the two parts and an extremely compact system ($\approx 40\,\mathrm{nL}$). High temperature sensitivity ($\approx 10\,\mathrm{mK}$) is achieved by monitoring the position of the narrow optical resonances of the MBR while using a low optical power to excite the GNRs ($\approx 20\,\mu\mathrm{W}$). Since the detection of the absorption is thermometric, the measurement process is intrinsically scattering-free and we experimentally verified this point by reconstructing the GNRs spectrum in a clear host (water) as well as in an opaque host (water and milk). The scattering-free element is promising for the identification of absorbers in highly opaque materials (*e.g.*, nanoparticles/molecules in a biological sample), since in these cases the scattering spectrum could hide the absorption spectrum.

Thermal cross-sections of organic materials for neutron capture therapy.

Romanelli G., Andreani C., Preziosi E., Senesi R.

NAST Centre and Physics Department, University of Rome Tor Vergata, Rome, Italy

Neutron capture therapy allows cancer treatment based on body irradiation by neutrons and their capture by a specific isotope within a carrier targeting the tumour. Epithermal neutrons ensure high penetration power in the body, yet the absorption is favoured at low neutron energies. The required moderation, ensured by the scattering from hydrogen within the body, depends on the physical/chemical properties of organic molecules therein. We present a phenomenological approach, based on neutron transmission experiments and *ab initio* phonon calculations, to model the total scattering cross-section of organic molecules based on the Average Functional Group Approximation. Results are discussed in the case of proteins, human tissue, and polymers often used as phantom materials in Monte Carlo simulations for hadron therapy applications. Authors gratefully acknowledge the financial support of the Consiglio Nazionale delle Ricerche – within CNR-STFC Grant Agreement [2014-2020 (N 3420)] concerning collaboration in scientific research at the ISIS (UK) of STFC – and of the JRU ISIS@MACH ITALIA, Research Infrastructure hub of ISIS (UK) – MUR official registry U. 0008642.28-05-2020.

Wide-field broadband CARS microscopy for biological applications.

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Coherent anti-Stokes Raman scattering is an extremely powerful non-linear optical (NLO) microscopy technique for label-free vibrational imaging allowing for a detailed study of biological samples in their native state. To overcome the long acquisition times associated with raster sample scanning required in NLO microscopy, which impair real-time investigation of biological dynamics, we introduce here wide-field signal generation over a large field of view, covering tens of micrometers. To this aim, we employ an innovative approach based on the use of an amplified femtosecond ytterbium laser source delivering high-energy ($\approx \mu$J) pulses in the near infrared. This enables the generation of stable broadband Stokes pulses to measure the entire fingerprint region of the molecular vibrational spectrum, the richest in chemical information. Our results pave the way for future translational applications and clinical diagnostics with video-rate imaging capabilities.

Dual-comb laser as a versatile light source for multimodal optical microscopy.

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Advances in ultrafast laser technology have enabled new applications in many research fields: in optical microscopy, they led to the emergence of multiphoton and nonlinear imaging. Dual-comb lasers (DCLs) can be used to incorporate multiple imaging techniques in a single setup, without increasing the complexity of the multimodal microscope. For instance, pump-probe and polarization-resolved imaging can be enabled by directly exploiting the emission of a DCL, without the need for external active devices. Here, we use a newly developed single-cavity dual-comb laser to demonstrate proof-of-principle polarization-resolved measurements. We detect the signals resulting from the heterodyne mixing of the two combs. These interferograms encode the information about the polarimetric properties of samples at kHz rate. These new results, which complement earlier work with similar single-cavity dual-comb lasers demonstrating pump-probe sampling, pave the way to a new platform for multimodal microscopy.

Codice per la simulazione delle prestazioni reali di un impianto fotovoltaico domestico.

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Le prestazioni reali di un impianto FV domestico sito in Ferrara, sono simulate mediante un codice di calcolo basato sull'applicazione di quattro modelli associati ai seguenti mecca-

nismi di "perdita energetica" di un modulo FV: i) incidenza non perpendicolare della radiazione solare; ii) effetti spettrali; iii) effetti di basso irraggiamento; iv) effetti di temperatura. L'applicazione della sequenza ordinata dei quattro modelli trasforma l'efficienza nominale dei singoli moduli (STC) in quella prevista in condizioni operative reali (RRC). I dati meteo-radiometrici per il sito di Ferrara, relativi al 2021, sono ricavati dalla banca dati DEXT3R di Arpae Emilia-Romagna. La scomposizione della radiazione globale su piano orizzontale è effettuata applicando diversi modelli (Liu-Jordan, Erbs, Reindl). L'energia erogata stimata è infine confrontata con quella estratta monitorando in tempo reale l'impianto FV.

The VASCOVID: A portable and non-invasive platform for the stratification of COVID-19 patients in ICU.

Amendola C. (1), Buttafava M. (2), Carteano T. (3), Cortese L. (4), Demarteau L. (5), Durduran T. (4)(6), Frabasile L. (1), Sanoja Garciad D. (3)(1), Guadagno C. (7), Houtbeckers T. (5), Karadeniz U. (4), Lacerenza M. (2), Mesquida J. (8), Parsa S. (9), Konugolu Venkata Sekar S. (7), Tomanik J. (5), Torricelli A. (1), Tosi A. (10), Weigel U. (9), Wagenaar T. (5), Yaqubc A. (4), Zanoletti M. (4), Contini D. (1)

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(8) *Critical Care Department, Parc Taulì Hospital Universitari, Institut D'Investigaciò i Innovaciò Parc Taulì I3PT, Sabadell, Spain*
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COVID-19 pandemic dramatically challenged intensive care unit (ICU) departments all over the world. 5% of COVID-19 patients suffer from acute respiratory failure, often requiring treatments in the ICU. The European project VASCOVID aims to develop a real-time monitoring platform for the stratification and management of severe COVID-19 patients. It exploits non-invasive optical techniques, time-domain near-infrared spectroscopy and diffuse correlation spectroscopy to assess patients' endothelial health by measuring tissue oxygenation and perfusion during vascular occlusion tests (VOT). Indeed, endothelial function has been proved to be a suitable biomarker for the progression of COVID-19. We studied different VOT protocols on 19 healthy subjects to optimize the measurement settings, aiming at more reliable data. The thenar eminence's haemodynamic response to repeated VOTs has been recorded, placing the cuff in three different locations. A key finding was that the location of the cuff alters the results, and blood flow oscillations appear when end-point organs were measured, suggesting different muscles (*i.e.*, forearm) could provide better biomarker for COVID-19 stratification.

Detection of minor phenolic compounds in extra-virgin olive oils using vibrational spectroscopies.

Romanelli G. (1), Andreani C. (1), Baglioni P. (2), Licoccia S. (3), Marques M.P.M. (4), Moretti G. (2), Parker S.F. (5), Preziosi E. (1), Senesi R. (1)

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Extra Virgin Olive Oil (EVOO) is a fundamental ingredient of the Mediterranean diet. Its recognised antioxidant and health-beneficial properties are strictly related to the structure and dynamics of the phenolic components therein, and largely determined by intermolecular hydrogen-bonding interactions. We present an experimental characterization of a series of Italian EVOO samples using Inelastic Neutron Scattering and Raman spectroscopy. Comparisons with data from isolated components of EVOO are used to establish the optimal regions of the vibrational energy spectra where to study the structure-activity relationship related to the minor phenolic compounds. These regions are discussed together with experimental strategies for future investigations on minor components within complex materials. Authors gratefully acknowledge the financial support of the Consiglio Nazionale delle Ricerche – within CNR-STFC Grant Agreement [No. 2014-2020 (N 3420)] concerning collaboration in scientific research at the ISIS (UK) of STFC – and of the JRU ISIS@MACH ITALIA, Research Infrastructure hub of ISIS (UK) – MUR official registry U. 0008642.28-05-2020.

Aula I **ore 10:00 – 12:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali

SIMPOSIO DI OPTOMETRIA

Presiedono: Barbieri M. (Università di Roma Tre)
Sassella A. (Università di Milano Bicocca)

Comunicazioni

Does blue-violet filtering affect contrast sensitivity?

Tavazzi S. [1][2], Borghesi A. [1][2], Braga C. [1], Cozza F. [1], Duse A. [1][2], Miglio F. [1], Nigrotti G. [1], Ponzini E. [1][2], Zeri F. [1][2][3]
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[3] *College of Health and Life Sciences, Aston University, Birmingham, UK*

The effects of blue-violet filtering (BVF) lenses on visual performances and more specifically on contrast sensitivity (CS) are still debated in the literature. BVF can affect positively the CS by reducing intraocular scattering, but also cause a reduction in light intensity, which contributes to the formation of the retinal image. The influence of BVF on CS is attributed to a balance among these effects. In this contribution, two different studies carried out with both blue-violet filtering ophthalmic and contact lenses are presented. Results showed a significant negative correlation between change in CS with BVF lenses with respect to clear lenses and the baseline CS with clear lenses. In the choice of a BVF, practitioners should consider that BVF is expected to produce a CS worsening in subjects showing a relatively high initial CS. On the contrary, subjects showing a relatively low initial CS are expected to show a CS improvement.

Analisi vettoriale dell'astigmatismo: Confronto tra refrazione oggettiva aberrometrica e refrazione soggettiva.

Pitarresi Giannone C., Musolino D., Serio M.
Dipartimento di Fisica, Università degli Studi di Torino, Italia

Lo studio delle aberrazioni oculari permette di esaminare in modo approfondito l'ottica del sistema oculare. L'aberrometro risulta infatti oggi uno degli strumenti più accurati nel fornire i risultati di refrazione, in quanto misura, oltre alle aberrazioni di defocus e di astigmatismo, anche le aberrazioni di alto ordine che non vengono identificate con altre tecniche. Tuttavia, secondo diversi studi, una prescrizione d'occhiale basata solamente su una misurazione oggettiva non garantisce le migliori prestazioni visive in termini di comfort e di acuitv̀isiva. Questo studio si propone di effettuare un'analisi di paragone tra la refrazione oggettiva aberrometrica e la refrazione soggettiva. Mediante l'analisi delle differenze tra i due metodi di misurazione, svolta trasformando le convenzionali componenti refrattive di sfera, cilindro e asse nelle componenti vettoriali M, J0 e J45, è stato determinato che esiste una differenza statisticamente significativa tra i due metodi di misurazione. La refrazione oggettiva può quindi essere considerata un utile strumento clinico oggettivo e un valido starting point per la refrazione soggettiva, che resta il "gold standard" della refrazione.

Ocular involvement occurs frequently at all stages of amyotrophic lateral sclerosis: Preliminary experience in a large Italian cohort.

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(2) *Nemo Lab S.r.l., Milan, Italy*
(3) *Materials Science Department & COMiB Research Center, University of Milano Bicocca, Milan, Italy*
(4) *Department of Neurology and Laboratory of Neuroscience, Istituto Auxologico Italiano IRCCS, Milan, Italy*
(5) *Department of Pathophysiology and Transplantation, University of Milan, Milan, Italy*
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The study aimed to obtain optometric findings of amyotrophic lateral sclerosis (ALS) patients in different stages of the disease, and to determine the relation between ocular data and ALS-related features. The optometric protocol included tests of the ocular motility, error refraction, binocular alignment, and an ocular symptoms questionnaire. The functional measures included the Amyotrophic Lateral Sclerosis Functional Rating Scale-revised (ALSFRS-r) and Milano-Torino staging (Mi-ToS); the cognitive impairment was assessed using the Edinburgh Cognitive and Behavioural ALS Screen (ECAS). Two hundred consecutive ALS patients were recruited. Nearly 70% of patients reported at least one ocular symptom. The severely symptomatic group was characterized by significantly lower ALSFRS-r scores, and higher MiToS. Abnormal near point of convergence values were significantly related to lower ALSFRS-r total and bulbar-subscale scores. Patients with more accurate saccades and pursuits exhibited significantly higher ECAS scores. In conclusion, this study emphasizes the importance of optometric evaluations in multidisciplinary assessments to address ocular impairment early in the disease process.

Viewing distance and character size in the use of smartphone in presbyopic and non-presbyopic individuals.

Grasso P.A., Gurioli M., Boccardo L.
Department of Physics and Astronomy, School of Optics and Optometry, University of Florence

The use of handheld devices has seen a tremendous growth in recent years to the point that users spend four hours a day looking at their smartphone. It is then become increasingly relevant to identify visual habits in using smartphones across the lifespan. In the present observational study, we measured viewing distance and character size in a group of non-presbyopic (NP; $n = 157$) and presbyopic (P; $n = 60$) while participants read a simple text message. We found that NP individuals use shorter viewing distance (33.4 cm) as compared to P (39.6 cm) which results in a statistically significant higher accommodative demand (NP: 3.16 D; P: 2.6 D). Also, the average character size differed between NP (1.6 mm) and P (1.83 mm) but did not the corresponding angular size (NP: 0.53 LogMar; P: 0.5 LogMar). Our data reveal that NP and P individuals have different visual habits when using a digital device. While NP reach the desired reading acuity by reducing viewing distance, P increase character size. The increased accommodative demand in the NP group may potentially induce a larger lag of accommodation and greater fatigue which should be considered when determining the best near correction.

Differences in contrast sensitivity measurement with letters and gratings.

Rolandi R. (1), Borghesi A. (1)(2), Daini R. (3), Duse A. (1)(2), Martelli M. (4), Ponzini E. (1)(2), Tavazzi S. (1)(2), Zeri F. (1)(2)(5)
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(5) *College of Health and Life Sciences, Aston University, Birmingham, UK*

Purpose: To evaluate the difference in measuring contrast sensitivity (CS) with gratings and letters. Methods: A randomized crossover study has been carried out on a sample of 43 healthy subjects (15 females, 23.1 ± 2.1 years). CS function was measured by the Vision Chart LCD (CSO, Firenze) with two stimuli: sinusoidal gradings (Gabor patch) and letters (Sloan) both at five angular sizes ($1.3, 1.0, 0.7, 0.4$ and 0.22 logMAR). At every stimulus size, CS has been measured monocularly with the best subjective correction by the Bayesian adaptive psychometric method "QUEST". Results: In both eyes, at all stimuli sizes tested, CS for the two different types of stimuli resulted significantly different ($p < 0.001$), with a ratio between CS for gratings and letters ranging between 1.2 and 1.4. Conclusions: The study showed as it is possible measuring the CS function also by letters as well as the more traditional gratings. However, the two stimuli are not equivalent leading to different threshold evaluation in clinical setting.

Optometria di genere: Dalla geometria retinica alla percezione tridimensionale.

Colandrea C., Bussa M.P., Serio M., Marenco S., Maffioletti S.
Department of Physics, University of Torino, Italy

La ricerca scientifica in optometria mira ad aumentare la capacità di previsione dell'effetto ottico indotto dall'apposizione di lenti, permettendo di comprendere come concetti geometrici e fenomeni fisici si traducano in risposte percettive. È possibile, ad esempio, indagare il modo in cui la prospettiva differenziale influisce sulla percezione tridimensionale; infatti l'errore di parallasse oculare che si verifica poiché gli occhi sono separati orizzontalmente da una certa distanza (DAV) permette di apprezzare l'intervallo di profondità tra due punti oggetto e di trasferire questo intervallo sulla retina. In uno studio condotto all'Università di Torino le DAV rilevate su un gruppo di studenti sono state comparate con i valori di stereo acuità degli stessi, con lo scopo di evidenziare se soggetti di sesso femminile, le cui DAV sono di misura inferiore rispetto a quelle degli uomini, abbiano effettivamente meno senso di profondità. Verranno illustrati il protocollo delle misure e i risultati ottenuti. La prospettiva di ricerca è la parametrizzazione dei test optometrici, per tenere conto delle differenze dovute al genere e individuare con maggior precisione le eventuali anomalie.

Dalla psicofisica del colore alla prevenzione.

Santacatterina S.
Associazione Laureati Ottica e Optometria

Quando si parla di colore si deve far subito riferimento all'occhio umano e alle sue caratteristiche. Ogni radiazione elettromagnetica, è contraddistinta da una sua lunghezza d'onda; le radiazioni comprese tra 380 e 760 nm compongono lo spettro visibile. Newton fu tra i primi a creare un modello di classificazione del colore, poi evoluto fino ai più moderni sistemi CIE (Commission Internationale de l'éclairage) basati sulla teoria tricromatica, detta di Young-Helmholtz elaborata teoricamente da Thomas Young (medico) e in seguito confermata sperimentalmente da Hermann von Helmholtz (fisico). Su questi principi si basano i test per l'analisi della visione dei colori facendo riferimento agli assi di confusione specifici delle discromatopsie congenite riportati matematicamente su diagrammi CIE. I numerosi test che sono stati formulati per esaminare il senso cromatico possono essere raggruppati in tre grandi categorie: di screening, diagnostici e occupazionali. L'importanza nell'eseguire questi test nella pratica clinica optometrica, non è solo nell'identificazione di una possibile alterazione cromatica di origine genetica, ma risiede soprattutto nella prevenzione.

Le lenti filtranti e la percezione dei colori.

NATALI L., BALDANZI E., FARINI A.
Istituto Nazionale di Ottica, CNR-INO, Firenze

La percezione dei colori rappresenta la capacità del nostro sistema visivo di poter distinguere le differenti lunghezze d'onda dello spettro visibile. I test in uso corrente spesso non riescono a rilevare piccole variazioni nella visione dei colori rosso/verde (RG) e giallo/blu (YB). In questo lavoro di tesi è stato utilizzato il CAD test, che permette di effettuare un'indagine approfondita e dettagliata, valutando le soglie di discriminazione dei colori RG e YB e classificando eventuali deficienze coinvolte. Per la prima volta, servendosi di questo test, è stata valutata la variazione della discriminazione dei colori tramite una lente blueblock e una lente arancione. La lente blueblock non risulta influenzare in maniera statisticamente significativa la percezione cromatica, mentre la lente arancione provoca un'evidente alterazione dei colori. I risultati sono stati dimostrati sia confrontando le lenti filtranti con una lente non filtrante sia attraverso un'analisi statistica. Essendo uno studio preliminare si pensa ad un approfondimento legato a questo aspetto, coinvolgendo più osservatori, ottenendo una maggior validità dei risultati trovati e ulteriori conoscenze.

Teleoptometria: Stato dell'arte e prospettive future.

BOCCARDO L., GRASSO P.A., GURIOLI M.
Dipartimento di Fisica e Astronomia, Università di Firenze

La teleoptometria si occupa della qualità visiva e permette di fornire assistenza optometrica anche quando operatore e paziente non si possono incontrare di persona. Permette di monitorare le abitudini visive, raccogliere informazioni, fornire rassicurazioni, consigli e trattamenti a distanza su questioni non urgenti e di individuare le persone che invece hanno effettiva necessità di un esame di persona per questioni più gravi. Essa comprende lo sviluppo di tecniche che sfruttano la tecnologia digitale, come ad esempio il monitoraggio tramite app o dispositivi indossabili, le valutazioni attraverso videoconsultazioni, oppure l'utilizzo di questionari psicometrici online validati. Analizzando la letteratura scientifica, si osserva un primo interesse nei confronti della teleoptometria intorno all'anno 2000, ma si evidenzia una crescita di interesse soprattutto negli ultimi anni. Poiché la teleoptometria è un settore con notevoli opportunità di sviluppo, che vanno al di là della recente situazione di emergenza, può essere opportuno andare a studiare le sue modalità di applicazione e trovare soluzioni per migliorare e risolvere le varie limitazioni esistenti.

Capturing correlations in vision parameters by artificial neural networks.

ERCULEI A., CIMINI V., BARBIERI M., ROTONDI A.
Dipartimento di Scienze, Università degli Studi Roma Tre

In the analysis of vision, functions are often assessed as independent abilities, despite the fact that correlations are actually present. A more comprehensive view may assist practitioners in evaluating critically the outcomes of their measurements, as well as in highlighting possible anomalies. Due to the natural variability of physiological data, these correlations are not expected to be sharp, and a model guiding our intuition can often be hard to find. Machine learning (ML) techniques offer these days the possibility of inspecting large sets of data, and of extracting relevant information in a model-independent way. We report on the application of a prominent ML paradigm, artificial neural networks to successfully recover the correlation present between visual acuity (VA) and refractive errors with a simple algorithm. The optimisation of our network demonstrates that this operation can be performed with reduced complexity, despite the small size of our data sample. With the inception of these techniques beyond this well-known case, a path can be opened up in which more general correlations can be unveiled.

Accuratezza e precisione di un frontifocometro basato sul sistema di Hartmann.

SPAZIANI N., FARINI A., PEZZATI L.
CNR-INO, Istituto Nazionale di Ottica, Firenze

Un frontifocometro è uno strumento oftalmico che ha la funzione di misurare il potere delle lenti oftalmiche e viene utilizzato da optometristi e ottici nella pratica di tutti i giorni. Lo scopo del lavoro di tesi è valutare l'accuratezza e la precisione del frontifocometro Solos, disponibile come prototipo avanzato al momento della redazione. A tale scopo si confrontano le misure effettuate dal Solos con quelle effettuate dagli strumenti CL-300 e VX-40, anch'essi di recente realizzazione, basati su un sistema detto test di Hartmann. Per prima cosa si verifica che il Solos rispetti le condizioni imposte dalla normativa ISO 8598-1, utilizzando un set di lenti ISO il cui potere è noto con elevata accuratezza. Si valutano poi l'accuratezza e la precisione del Solos su una serie di lenti monofocali e progressive e alcuni occhiali monofocali. L'accuratezza strumentale viene stimata tramite diagrammi di correlazione e Bland-Altman. Per la precisione si evidenziano le deviazioni standard risultanti dalle misure. Al termine del lavoro, si afferma che il Solos risponde alle richieste della normativa e dimostra un'accuratezza e una precisione superiori a quelle necessarie nella pratica.

Aula C - Maria Gaetana Agnesi **ore 09:00 – 13:00**

Sezione VII
Didattica e storia della fisica
Presiede: Tucci P. (Università di Milano)

Relazioni su invito

▲ **Il LabEx ai tempi del COVID.**
D'Alfonso L., Colombo A., Varisco L., Rossini R., Bulla A.C.M., Piarulli M.
Dipartimento di Fisica "G. Occhialini", Università degli Studi di Milano-Bicocca
LabEx è un Laboratorio di Fisica Sperimentale messo a punto nell'ambito del Piano Lauree Scientifiche e realizzato presso il Dipartimento di Fisica "G. Occhialini" dell'Università di Milano-Bicocca a partire dall'anno 2005. Scopo del laboratorio è quello di avvicinare gli studenti delle scuole secondarie al metodo scientifico e permettere loro di compiere esperimenti interattivi, per stimolarli a porsi nuove domande sia sull'esperimento in questione, che sul mondo circostante. A partire da marzo 2020 anche LabEx ha dovuto reinventarsi per affrontare la difficile sfida di rimanere attrattivo e interattivo nonostante la necessitàdi effettuare tutte le attività didattiche da remoto. Nella prima fase del lockdown ai partecipanti collegati da casa venivano mostrati i filmati degli esperimenti, sostituiti poi dai tutor in presenza che, muniti di telecamera orientabile, mostravano l'esperimento in diretta. L'utilizzo delle sessioni interattive con assegnazione casuale di piccoli compiti da svolgere in autonomia ha permesso ai tutor sia di seguire i gruppi più in difficoltà, sia di intavolare interessanti discussioni di approfondimento con i gruppi interessati ad un approccio critico.

▲ **Usque tandem?**
Giliberti M.
Dipartimento di Fisica, Università degli Studi di Milano, Italia
"Una spiegazione scientifica è una storia su come alcune entità immaginate, ma considerate reali, possano agire insieme per produrre il fenomeno da spiegare" diceva John Ogborn, cui faceva eco il fisico dei fondamenti Günther Ludwig "I fatti sono come un iceberg, per la maggior parte sommersi sotto la superficie dell'esperienza immediata. La parte sommersa di questi fatti deve essere ipotizzata, parleremo a tale proposito di realtà immaginate o di 'favole' ". Ne consegue una visione della scienza come narrazione; per questo è fondamentale comunicare per capire. Tale comunicazione può avvenire attraverso modalità differenti delle quali oggi ci sono esperienze sempre più documentate. I linguaggi sono molti, non sempre equivalenti, ma complementari e veicolati in modalità diverse: dal teatro al gioco di ruolo, dal racconto attraverso le storie ai giochi educativi, da video sempre più preganti alla realtà aumentata e a differenti esperienze museali e multimodali. Siamo sospesi nel linguaggio diceva Bohr; è possibile che linguaggi differenti aiutino ad affrontare "differenti" tematiche. Fino a quando utilizzeremo la solita lingua per i nuovi concetti?

▲ **Le fisiche italiane.**
Rossi P. (1), Di Ciaccio A. (2), Masullo M.R. (3), Pirrone S. (4), Rinaldi M. (5), Soria S. (6)
(1) *Università di Pisa*
(2) *Università di Roma Tor Vergata*
(3) *INFN Sezione di Napoli*

([4]) *INFN Sezione di Catania*
([5]) *Università di Trento*
([6]) *IFAC CNR*
Sono state raccolte le biografie scientifiche, sotto forma di brevi schede, delle donne che hanno svolto attività scientifica nel mondo universitario e in quello della ricerca fino a tutto il XX secolo. La raccolta è ancora in corso di completamento per il periodo successivo alla II guerra mondiale, ma può dirsi esaustiva per tutto il periodo precedente. La raccolta al momento comprende più di un centinaio di studiose per il periodo prebellico e oltre duecento nominativi per la seconda metà del Novecento. Una breve introduzione apre la raccolta proponendo un'analisi di lungo periodo della presenza femminile nella fisica italiana e alcune considerazioni sulle tendenze più recenti.

Comunicazioni

La scoperta di alcuni scritti di fisici italiani in una rivista diretta nel 1948 dal Prof. Giovanni Polvani.
Bagni E.
Dipartimento di Economia e Management, Università di Pisa
Nell'immediato secondo dopoguerra, il Prof. Giovanni Polvani diresse una rivista di Scienze Matematiche, Fisiche e Naturali, pubblicata nel 1948 solo per pochi numeri e poi cessata, nella quale sono stati scoperti alcuni scritti di fisici italiani tra i quali, oltre allo stesso Polvani, i coniugi Giuseppe Cocconi e Vanna Tongiorgi, Nello Carrara, Luigi Puccianti, Bruno Ferretti, Augusto Occhialini e Giorgio Valle. Gli articoli rinvenuti trattano argomenti diversificati, spaziando dai raggi cosmici al radar, dalla disintegrazione di un nucleo alla conduzione elettrica nei gas, fino al regolo musicale a scala logaritmica.

Archivio Giuliano Preparata.
Srivastava Y.
Physics Department, Northeastern University Boston MASS USA and Dipartimento di Fisica e Geologia, Università di Perugia
L'Associazione Giuliano Preparata presenta per la prima volta l'inventario analitico informatizzato dell'Archivio Preparata (1942-2000), consultabile sul sito `www.giulianopreparata.com`, con un link alla pagina web della Società Italiana di Fisica. Nell'archivio, che ripercorre la storia della Fisica dagli anni '60 al 2000, sono conservati appunti, corrispondenza, trasparenze, fotografie, documenti a stampa, ordinati cronologicamente all'interno di circa 2000 fascicoli dallo stesso autore, che ne ha anche descritto il contenuto con un titolo sintetico. L'inventario, che descrive analiticamente il contenuto di ciascun fascicolo, è arricchito da accurati indici di persone, Istituti di ricerca, convegni nazionali e internazionali ed è consultabile con un efficace motore di ricerca.

L'eredità di Galilei: Percorsi di Astronomia per insegnare Fisica.
Leonardi A.M. ([1]), Carli M. ([1]), Talas S. ([2]), Pantano O. ([1])
([1]) *Dipartimento di Fisica e Astronomia, Università di Padova, Padova, Italia*
([2]) *Museo di Storia della Fisica "Giovanni Poleni", Università di Padova, Padova, Italia*
Dall'ultima riforma scolastica, l'insegnamento dell'Astronomia non è più presente all'interno dell'istruzione secondaria superiore italiana. Tuttavia, il profilo dello studente al termine di questo ciclo richiede la conoscenza dei concetti fondamentali di Astronomia. Il contesto per insegnare questi contenuti dovrebbe essere la Fisica, i cui temi sono intrecciati con l'Astronomia. Al fine di indagare la possibilità di introdurre concetti di Fisica attraverso l'Astronomia, abbiamo strutturato ATENA (Asiago TEachers Network on Astrophysics),

un corso di formazione per docenti in servizio di Fisica di scuola superiore. L'inizio è previsto per il prossimo anno scolastico attraverso una comunità di apprendimento, sul modello della precedente esperienza del progetto COLLABORA. Per introdurre ATENA, abbiamo organizzato due workshops a carattere laboratoriale e museale. In questo intervento presenteremo i risultati di queste attività, costruite secondo il paradigma Object-Based Learning, che hanno coinvolto la costruzione di due strumenti astronomici e la visita a due musei. L'obiettivo è esplorare come questo approccio possa favorire l'apprendimento integrato di Astronomia e Fisica.

Paradossi fisici, matematici e logici.

Torre M.
Liceo "G. Peano" di Tortona, AL

Un paradosso è un'affermazione o un esperimento mentale che porta a un ragionamento circolare e contraddittorio oppure a una situazione logicamente impossibile. Generalmente si tende a usare la parola "paradosso" anche per includere i "paradossi percepiti", ovvero quelli per cui esiste una via d'uscita perché magari il paradosso nasconde un trucco che deliberatamente porta il lettore fuori strada e una volta scoperto il trucco, la contraddizione sparisce. Il contributo presenta un percorso sui paradossi scientifici (matematici e fisici) e logici, rivolto a studenti di due classi 5° Liceo Scientifico. Non c'è bisogno di conoscenze scientifiche per apprezzare i paradossi, ma sono convinto che il loro impiego in ambito didattico sia importante per lo sviluppo di competenze e abilità trasversali sia in ambito disciplinare che educativo (per formare futuri cittadini consapevoli).

Crossing boundaries between disciplines: Analysis of an interdisciplinary course about spacetime between physics, mathematics, and philosophy.

Miani L. (1), Maranzano M. (1), Cattabriga A. (2), Moruzzi S. (3), Levrini O. (1)
(1) *Dipartimento di Fisica "A. Righi", Università di Bologna, Italia*
(2) *Dipartimento di Matematica, Università di Bologna, Italia*
(3) *Dipartimento di Filosofia e Comunicazione, Università di Bologna, Italia*

Interdisciplinarity is considered a key approach to face the challenges of our society. Literature shows that teachers and students struggle with the siloed division of knowledge in disciplines. We present an analysis of an interdisciplinary teaching course for master's degree students based on the theme of "paradoxes in space-time". The course was part of the MINOR VAST (Viaggio Attraverso Spazio e Tempo) offered by the University of Bologna that straddled the disciplines of physics, mathematics, and philosophy, and it was attended by students from scientific and humanistic disciplines. Key points of the course were co-teaching, co-planning of lessons, and group activities. The course was analysed using two frameworks: "Boundary crossing and boundary object" from Akkerman & Bakker to focus on interdisciplinary processes and the reconceptualized "Family Resemblance Approach" applied to the Nature of Science from Erduran & Dagher to focus on the peculiarities of disciplines. A questionnaire and a subsequent focus group allowed us to collect data on how students perceived the course and to extrapolate guidelines for developing intrinsically interdisciplinary teaching modules.

Cosmologia: Scienza, Arte e Filosofia un dialogo fruttuoso.

Streit-Bianchi M. (1), Catapano P. (2), Galbiati C. (3), Magnani E. (4)
(1) *ARSCIENCIA*
(2) *CERN*

(3) *Princeton University e GSSI*
(4) *https://www.enricomagnani-art.com/*
Molte delle ricerche avanzate in Cosmologia all'interfaccia tra la fisica delle particelle, l'astrofisica e l'interferometria rappresentano una sfida e anche un'opportunità unica. Alcune delle ricerche in atto, che vi saranno brevemente presentate, usano mezzi e tecnologie diverse e complementari per dare risposta alle molte questioni ancora oggi irrisolte e che sono di interesse comune. Comprendere l'origine e la natura della materia e dell'energia oscura, chiarire l'asimmetria barionica che potrebbe fornire informazioni importanti alla comprensione dell'universo primordiale, comprendere se l'espansione accelerata dell'Universo continuerà e quale sia il destino dell'Universo sono alcune delle molte questioni a cui si cerca di dare risposta. Molte di esse portano a porsi domande di tipo filosofico e suscitano interesse in ambito artistico. Spingere i confini della conoscenza umana verso l'ignoto mediante l'intuizione accumunano Scienza, Filosofia e Arte. Un dialogo che ci sembra necessario e mette in evidenza quanto Scienza, Filosofia e Arte siano espressione di una necessità che dalla notte dei tempi ci spinge a cercare di comprendere il mondo e l'universo in cui viviamo.

● **Hypothetical six-dimensional topology.**
Bonacci E.
Physics Unit, Athens Institute for Education and Research, ATINER, Greece
Although the hypothesis of a six-dimensional spacetime with SO(3,3) symmetry has been investigated by several scholars for over four decades, the related topological analysis still seems inadequate. We propose the Inherently Spinning Spacetime (ISST) as proper background for any 6D geometrodynamics based on the three-dimensional time. The ISST is an axiomatization of the General Relativity manifold where each event is characterized by its own spin angular velocity as additional property. If each point of the continuum is a structureless rotating sphere of null radius, the orientation of its spinning axis is defined by two parameters interpreted as timelike extra-dimensions.

● **A new look at the Antikythera Mechanism.**
Amabile A.
Dipartimento di Fisica "E. Pancini", Università degli Studi di Napoli Federico II
In this talk I'll sketch the outlines of an alternative historical framework for the interpretation of the Antikythera Mechanism (AM). My aim is to twofold: 1) to reassess the role of construction of spheres in the development, reception, and transmission of Greek mathematical astronomy. 2) To reconstruct the astronomical theory embedded in the AM, following the constraints imposed by the specific purposes of sphairopoiia and by the methods of Hellenistic mathematics, as exemplified by the extant works of Euclid, Archimedes, and Apollonius. My conjecture is that the AM embedded a dynamical and relational theory of astronomical motions, with the Sun-Earth system working as a reference-motion for all the others. My general claim is that sphairopoiia shaped as much as geometry the theoretical structure of Greek mathematical astronomy, the ground on which the edifice of classical mechanics was built. In a wider philosophical perspective, a thorough study of sphairopoiia will provide key insights into the nature of Greek astronomy, with far-reaching consequences for the long-term history of western science.

● **Sulla fisica cibernetica di Eduardo R. Caianiello.**
Giannetto E.
Università degli Studi di Bergamo
Recentemente, il paradigma scientifico trasversale dell'informazione si è affermato definitivamente: ne è emersa una nuova concezione informazionale della Natura, dell'Universo come un

computer potenzialmente infinito. Mancano però ancora una fisica e una cosmologia elaborate matematicamente in termini di informazione. A questo obiettivo, si è legata negli ultimi anni la ricerca di Eduardo R. Caianiello (1921-1993), fisico e cibernetico napoletano, che, nel 1980, formulò la teoria quantistica in uno spazio delle fasi relativistico a 8 dimensioni XA (x, ct; p, p4 = E/c) non-Euclideo, curvo, che non ha che formalmente la forma di una geometria ma è una dinamica scritta in forma geometrica. Gli operatori dell'algebra di Heisenberg sono espressi (anche la posizione e il tempo) in una quantizzazione in termini di derivate covarianti e le relazioni di commutazione quantistica sono interpretate come componenti del tensore di curvatura. La curvatura geometrica esprime così l'indeterminazione quantistica in termini di entropia informazionale (si tratta di una geometria dell'informazione complessa: il ds2 coincide con la cross-entropy). L'algebra è quella degli ottonioni.

Auditorium Pascoli, PoliMi **ore 09:00 – 13:00**

Sezione Giovani
Presiedono: De Domenico F. (AISF)
Ostinato M. (Progetto Young Minds, EPS)

Relazioni su invito

▲ **L'energia da fissione e da fusione. Quali prospettive per la transizione ecologica?**
Romanelli F.
Università di Roma Tor Vergata
La lotta al cambiamento climatico e la necessità di differenziare l'approvvigionamento energetico a seguito dell'invasione dell'Ucraina richiedono soluzioni che siano sostenibili sul lungo periodo. L'energia da fissione e da fusione possono giocare un ruolo essenziale per garantire la transizione energetica. In questa presentazione si discuterà quali sono i vantaggi di queste tecnologie, che tipo di contributo possono dare alla transizione ecologica, quali sono le principali sfide che devono essere affrontate per renderle pienamente fruibili e come possono integrarsi con altre fonti energetiche come solare ed eolico. In particolare, l'energia da fusione ha in principio numerosi vantaggi: combustibile inesauribile e diffuso, sicurezza intrinseca, limitato problema con le scorie. Il contributo farà il punto di dove siamo con le ricerche e quando realisticamente potremo avere elettricità da fusione.

▲ **Soft-X-ray spectroscopy of ultrafast dynamics in materials for solar energy applications.**
Faccialà D.
Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche, Milano
Metal halide perovskites have intriguing properties, such as high absorption, tunable bandgaps, and long charge carrier lifetimes. In particular, perovskite solar cells (PSCs) recently received attention due to their high conversion efficiencies of up to 25.5%. However, the success of PSCs has been hindered by their rapid degradation, the presence of lead, a toxic constituent, and the presence of moving defects affecting the dynamics of carriers. Understanding these dynamics on their natural time-scale is then an essential prerequisite for establishing reliable technology based on perovskites. In this respect, I will show how ultrafast soft-X ray spectroscopy enables the investigation of the processes involving interactions between electrons, phonons, and photons with an unprecedented temporal resolution, down to the attosecond time scale (10^{-18} s). Moreover, since photon absorption occurs locally at the atomic cores, it has the further advantage of being site-selective and oxidation- and spin-state specific. Due to the high temporal resolution and high sensitivity to the chemical composition, this technique promises to stimulate potential new solutions for future photovoltaics.

▲ **Eventi estremi in un clima che cambia.**
Pasquero C.
Università di Milano Bicocca

Aula A **ore 14:00 – 14:55**

Sezione V
Biofisica e fisica medica
Presiede: Lenardi C. (Università di Milano)

Relazione Generale

Physics against cancer. Unleashing the potential of protons in the fight against cancer.

Lomax T.
Centre for Proton Therapy, Paul Scherrer Institut, Switzerland

Proton therapy (RT) is an increasingly important weapon against cancer. By controlling proton energy, and thus proton range, the dose can be concentrated in tumour more effectively than with conventional radiotherapy with photons. As such, proton therapy is rapidly spreading around the world. However, much can still be done to improve the accessibility, precision, and therefore clinical effectiveness, of proton therapy. In this contribution, three areas where developments will, or are making significant advances will be discussed: Imaging, treatment planning and delivery. On-line imaging developments will both help to reduce delivery uncertainties as well as allow for dynamic, potentially real-time adaptions of patient treatments, whereas developments in treatment planning will further exploit the inherent flexibility of protons for radiotherapy, by improving both treatment accuracy and efficiency. Finally, advances in delivery technology will reduce facility size and costs, as well as reduce treatment times to move towards more cost efficient, but also patient friendly treatments.

Aula B - Maria Goeppert-Mayer **ore 15:00 – 18:30**

Sezione I
Fisica nucleare e subnucleare
Presiedono: Leoni S. (Università di Milano)
Rizzo F. (INFN, Sezione di Catania)

Fisica nucleare

Relazioni su invito

▲ **Experiments with AGATA.**
Gottardo A.
INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy
AGATA is an innovative γ-ray tracking array, built by a collaborations of thirteen European countries. It represents the state of the art for γ-ray spectroscopy in Europe. The detector is composed of hyper-pure Ge segmented crystals, and it allows one to determine the photon interaction positions inside the detector with a five mm precision. The single photon scattering path inside the crystal can then be reconstructed. These features enable unprecedented energy resolution as well as a large detection efficiency. AGATA started its first physics measurements at Laboratori Nazionali di Legnaro (LNL) in 2009, and then moved to GSI, Germany and to GANIL, France. AGATA has then moved again to LNL for a new physics campaign stating in 2022 and lasting several years. In this contribution, I will briefly summarize the past physics results from AGATA and then concentrate on the γ-ray spectroscopy campaign at LNL, describing the different phases foreseen as well as the ancillary detectors employed to select the reaction channel of interest. Selected nuclear structure physics cases will be presented.

▲ **Spettroscopia esotica a BESIII: Prima osservazione della risonanza isoscalare η_1(1855) e ultimi risultati sugli stati XYZ.**
De Mori F. per la BESIII Collaboration
Università degli Studi di Torino e INFN sez. di Torino
L'esperimento BESIII installato presso il collisionatore BEPCII ad IHEP (Pechino, Cina), ha permesso di accumulare il più grande campione di dati al mondo da collisioni e^+e^- in un range di energia nel centro di massa tra 2.0 e 4.9 GeV, ed è uno dei protagonisti nello studio degli stati stati esotici sia nel settore dei mesoni leggeri, sia nell'ambito degli stati charmonium-like. In questa comunicazione verrà presentata una recente analisi in onde parziali del decadimento $J/\psi \to \gamma\eta\eta'$ e la prima osservazione di uno stato isoscalare, chiamato $\eta_1(1855)$, con numeri quantici $J^{PC} = 1^{-+}$ con una significatività statistica maggiore di 19σ. Verranno inoltre presentati i più significativi risultati recenti della Collaborazione BESIII riguardanti gli stati XYZ.

Comunicazioni

● **Deuterium burning measurement at LUNA and its astrophysical and nuclear implications.**
Cavanna F.
Istituto Nazionale di Fisica Nucleare, Sezione di Torino
Light elements were produced in the first few minutes of the Universe through a sequence of nuclear reactions known as Big Bang Nucleosynthesis (BBN). Among the light elements produced during BBN, deuterium is an excellent indicator of cosmological parameters because

its abundance is highly sensitive to the primordial baryon density. Although astronomical observations of primordial deuterium abundance have reached percent accuracy, theoretical predictions based on BBN were hampered by large uncertainties on the cross-section of the deuterium burning $\mathrm{D}(p,g)^3\mathrm{He}$ reaction, before the LUNA measurement. I will report the recent LUNA results on the $\mathrm{D}(p,g)^3\mathrm{He}$ reaction recently published in *Nature*. In addition, new results on the measurement of the angular distribution with an innovative technique will also be shown. To further improve the theoretical predictions on the primordial deuterium abundance, it is now important to perform a new and precise measurement of the $\mathrm{D}(d,n)^3\mathrm{He}$ and $\mathrm{D}(d,p)^3\mathrm{H}$ reactions. Future prospects to solve this issue will also be presented.

The low-energy fusion in the system $^{12}\mathrm{C} + {}^{26}\mathrm{Mg}$.

Cobo Zarzuelo A. (1), Del Fabbro M. (1)(2), Montagnoli G. (1), Stefanini A. (3), Stramaccioni D. (1), Brugnara D. (1), Colucci G. (4), Cintora de la Cruz A. (1), Diklić J. (5)(1), Galtarossa F. (3), Ortega G. (1), Palombini L. (1), Pellumaj J. (2)(3), Pilotto E. (1), Zago L. (1)(3), Zanon I. (3)
(1) *Dipartimento di Fisica e Astronomia, Università di Padova e INFN, Sezione di Padova*
(2) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Italy*
(3) *INFN, Laboratori Nazionali di Legnaro*
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The fusion excitation function for $^{12}\mathrm{C} + {}^{24}\mathrm{Mg}$ was recently measured down to few microbarns and it has been evidenced that the hindrance effect starts at a relative high sub-barrier cross-section (about 1 mb). This may be due to the α-like structure of $^{24}\mathrm{Mg}$ or to its prolate deformation. The investigation of hindrance in $^{12}\mathrm{C} + {}^{26}\mathrm{Mg}$ may establish the underlying physics because $^{26}\mathrm{Mg}$ is also deformed but does not have an α-like structure. Furthermore, the available data on $^{12}\mathrm{C} + {}^{24}\mathrm{Mg}$ far below the barrier are well reproduced by calculations in the one-dimensional barrier penetration model. This interesting feature should be checked in the nearby case $^{12}\mathrm{C} + {}^{26}\mathrm{Mg}$. For these reasons, an experiment aimed at measuring the deep sub-barrier fusion in the latter system was carried out at the Laboratori Nazionali di Legnaro, using $^{26}\mathrm{Mg}$ beams from the XTU Tandem accelerator and detecting the fusion evaporation residues with a E-ΔE-ToF detector telescope following an electrostatic beam deflector. The results obtained will be presented in this contribution.

Risultati recenti sul nuovo fragment separator FRAISE in costruzione presso i Laboratori Nazionali del Sud dell'INFN.

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Presso i Laboratori Nazionali del Sud dell'INFN è in corso un progetto di upgrade del ciclotrone superconduttore che mira a produrre fasci stabili ad alta intensità. Per sfruttare pienamente tale potenzialità, si è progettato un nuovo apparato, denominato FRAISE (FRAgment In-flight SEparator), che consentiràdi produrre RIBs (Radioactive Ion Beams), sfruttando il metodo di frammentazione in volo del proiettile, con intensità da 10^2 pps a 10^7 pps. L'elevata intensitàraggiungibile con FRAISE richiede l'uso di adeguati sistemi di diagnostica e tagging. Tali sistemi saranno basati sull'utilizzo di rivelatori a nuova tecnologia SiC. Nel presente contributo verranno presentati lo stato dell'apparato FRAISE, dei sistemi di diagnostica e tagging, e i possibili fasci disponibili grazie all'utilizzo dell'apparato.

Testing the Pauli Exclusion Principle with the VIP-2 Experiment and beyond.

Napolitano F.
Laboratori Nazionali di Frascati

The Pauli Exclusion Principle (PEP) is one of the main cornerstones of the Quantum Theory at the basis of many phenomena, from the stability of the matter to neutron stars and from white dwarfs to superconductivity. Violation of the PEP, albeit small, could be motivated by physics beyond the Standard Model which entail extra space dimensions, violation of the Lorentz invariance, non-commutative space-time. These scenarios can be experimentally constrained with stat-of-the-art X-ray spectroscopy, searching for forbidden transition in atomic systems. The VIP-2 Experiment at Laboratori Nazionali del Gran Sasso targets PEP violation signal by introducing a strong direct current in a copper target, measuring X-ray through a silicon drift detector. The analysis of the experimental VIP-2 data is presented. A brief outlook of the future VIP-3 experiment is also shown.

Criticità nella determinazione sperimentale degli effetti di schermo elettronico in reazioni nucleari di interesse astrofisico.

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In esperimenti a bersaglio fisso a energie di collisione di interesse astrofisico ($\lesssim 50\,\mathrm{keV}$), la dinamica delle reazioni nucleari tra particelle cariche è influenzata dagli elettroni legati al proiettile e al bersaglio. La variazione indotta sulla sezione d'urto dipende dalle proprietà dell'ambiente. Alcune misure con bersagli atomici, molecolari e isolanti (non-metallici), suggeriscono delle deviazioni significativamente più alte delle attese teoriche relative al caso di uno schermo dovuto solo ad elettroni atomici. Questo lavoro mira a studiare in modo più approfondito il grado di compatibilità dei dati sperimentali con la teoria atomica standard. In questa comunicazione si presenta uno studio fenomenologico della reazione $^6\mathrm{Li} + \mathrm{p} \rightarrow {}^3\mathrm{He} + \alpha$. Si confrontano diversi approcci per la stima degli effetti di schermo dai dati, discutendo per ognuno di essi le criticità che possono essere introdotte nell'analisi. Ulteriormente, si mostra l'importanza nel risultato dello stato di carica del proiettile prima della collisione.

The nuclear structure of ^{46}Ar: A study of the direct proton-transfer $^{46}\mathrm{Ar}(^3\mathrm{He}, d)^{47}\mathrm{K}$ reaction.

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Direct reactions represent a unique mechanism to investigate the nuclear-structure properties and the nature of single-particle states of nuclei along shell closures. In this contribution, the ^{46}Ar(^{3}He, d)^{47}K proton-transfer reaction is proposed to shed light on the properties of the ground state of the radioactive neutron-rich ^{46}Ar isotope. The measurement, performed at the SPIRAL 1 facility in GANIL, France with a post-accelerated radioactive 9 MeV/u ^{46}Ar beam impinging on a high-density cryogenic ^{3}He target, aimed at quantifying the transfer cross-section to the $3/2^{+}$ level relative to the $1/2^{+}$ ground state in ^{47}K. The experimental evidence indicates a substantially suppressed $L = 2$ transfer to the first excited state of ^{47}K, at odds with shell-model calculations that predict the $s^{1/2}$ and $d^{3/2}$ orbitals as almost degenerate and not entirely occupied. The results will be also discussed in the framework of *ab initio* and mean-field calculations. In these theoretical results, the low occupancy of the $s^{1/2}$ orbital, in agreement with the high relative spectroscopic factor measured, implies a central depletion of the proton wave function. This contribution presents the first experimental evidence of this phenomenon in ^{46}Ar.

γ decay from the near-neutron-threshold 2^{+} state in ^{14}C: A probe of collectivization phenomena in light nuclei.

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Light nuclei, with mass $A < 20$, are among the best probes of most advanced nuclear theory models. Of particular interest are near-threshold states, *i.e.*, narrow resonances lying in proximity of particle-emission thresholds. According to theory, the existence of near-threshold states is a universal phenomenon, and their structure should provide relevant information on the microscopic mechanism leading to the onset of clusterization phenomena in molecular-like nuclei, *e.g.*, C, O, Ne . . . . So far, the decay properties of near-threshold states in neutron-rich systems have been poorly explored, and almost uniquely via particle spectroscopy. The γ-decay branch is in fact at the level of 10^{-3}–10^{-5} of the dominant particle-decay mode, *i.e.*, below the detection capabilities of conventional γ-ray spectrometers. In this contribution we will present preliminary results from a first experiment performed at Argonne (USA) with the GRETINA tracking array, aiming at the investigation of the γ decay of the second 2^{+} in ^{14}C, located at 8318 keV, *i.e.*, 142 keV above the neutron-decay threshold. Comparison with model predictions will be also discussed.

Persistence of the weak-coupling limit around ^{132}Sn: The case of the 1p-2h ^{131}Sb nucleus.

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In this contribution, the lifetime of the first $11/2^+$ state in the $1p$-$2h$, ^{131}Sb nucleus around doubly magic ^{132}Sn was measured by fast-timing techniques, yielding $\tau = 5(3)$ ps. This finding, at the limit of sensitivity of the experimental method, enabled to asses the transition probability to the $7/2^+$ ground state, providing $B(E2) = 1.5(9)$ W.u., similar to the value reported for the first 2^+ state of ^{130}Sn. The experiment was carried out at Insititut Laue-Langevin (ILL) by using neutron-induced fissions of ^{235}U and the LOHENGRIN spectrometer, with a detection setup at the focal plane composed by an ionization chamber, two HPGe detectors and four $LaBr_3$(Ce) fast scintillators. The experimental results were compared to realistic large-scale shell-model calculations, with a ^{100}Sn core and a two-body effective interaction derived from the CD-Bonn *NN* potential. This suggests the validity of the weak-coupling limit description in this nucleus and implications on the emergence of collectivity around ^{132}Sn will be discussed.

Lifetime measurements in $A \simeq 96$ isotopes via the fast-timing technique.

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Shape coexistence is a fundamental phenomenon found in atomic nuclei. It consists in some states displaying different intrinsic deformations while having relatively similar excitation energies. Neutron-rich nuclei belonging to the $A \simeq 100$ region of the nuclear chart are known to show a large degree of deformation. Due to the interplay between these spherical and deformed configurations, shape coexistence is expected in nuclei lying at the border between the two regions. Nuclei belonging to the low-Z edge of the $A \simeq 100$ deformed region of the nuclear chart were produced in the thermal-neutron–induced fission of a ^{233}U target. Lifetime measurements of excited states in ^{96}Rb, $^{93\text{-}96}$Y and $^{94\text{-}95}$Sr were measured using the fast-timing technique with $LaBr_3 : Ce$ γ-ray detectors, which is able to provide precise measurements down to the picosecond regime. From these measurements, $B(E2)$ and Q_0 values were extracted to provide information on nuclear deformation in this region. In this contribution, preliminary results of the fast-timing analysis on several excited states in the mentioned nuclei will be discussed, together with some still tentative insight of their physical interpretation.

Studio di strutture a cluster in nuclei neutron-rich leggeri tramite rivelatori FARCOS.

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Lo studio di strutture a cluster rappresenta uno strumento efficace per sondare le proprietà dell'interazione nucleare forte. In questo ambito, ai Laboratori Nazionali del Sud dell'INFN (Catania) è stato realizzato l'esperimento CLIR in cui, tramite reazioni di break-up coulombiano, si vogliono studiare gli stati a cluster in nuclei neutron-rich leggeri. Un fascio di ioni radioattivi, ad energie intermedie, prodotto dalla facility FRIBs, contenente diverse specie di isotopi tra cui ^{16,17}C, ^{12,13,14,15}B, ^{10,11,12}Be, ^{7,8,9}Li e ^{6}He, è stato fatto reagire con un target di polietilene (C_2H_4). Le diverse componenti isotopiche del fascio cocktail sono state identificate tramite un sistema di tagging e i prodotti di reazione sono stati analizzati tramite il multirivelatore CHIMERA, accoppiato a quattro telescopi FARCOS. In questo ambito saranno mostrate le calibrazioni effettuate per il sistema di tagging ed i telescopi FARCOS. Saranno inoltre mostrati risultati preliminari dell'analisi spettroscopica del ^{16}C.

FARCOS nella misura CHIFAR: Calibrazione energetica ed identificazione.

Zagami C. ([1])([2]), Pagano E.V. ([1]), Russotto P. ([1]), De Filippo E. ([3]), Acosta L. ([4])([5]), Cap T. ([6]), Cardella G. ([3]), Favela F. ([7]), Fichera F. ([3]), Geraci E. ([2])([3]), Gnoffo B. ([2])([3]), Guazzoni C. ([4])([8]), Lanzalone G. ([1])([9]), Maiolino C. ([1]), Martorana N.S. ([1])([2]), Matulewicz T. ([10]), Pagano A. ([3]), Papa M. ([3]), Piasecki K. ([10]), Pirrone S. ([3]), Piscopo M. ([1]), Planeta R. ([11]), Politi G. ([2])([3]), Risitano F. ([3])([12]), Rizzo F. ([1])([2]), Saccà G. ([3]), Sicari V. ([4])([8]), Siwek-Wilczynska K. ([10]), Skwira-Chalot I. ([10]), Trimarchi M. ([3])([12])
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Il correlatore FARCOS (Femtoscope ARray for COrrelation and Spectroscopy), progettato con il contributo di INFN-LNS, INFN-Sezione di Catania e INFN-Sezione di Milano, è stato accoppiato al multi-rivelatore 4π CHIMERA per lo studio della produzione di IMFs nelle reazioni ^{124}Xe + ^{64}Ni e ^{124}Xe + ^{64}Zn ad energia di fascio 20 AMeV nell'esperimento CHIFAR. Uno studio condotto sui rivelatori Double Sided Silicon Strip Detectors (DSSSDs), che costituiscono i primi due stadi di rivelazione del telescopio, ha permesso di stimarne la risoluzione energetica totale ($\sim$ 1.1%–2.2%) e le sue componenti intrinseca e relativa alla catena elettronica, la quale ultima è quella predominante. Il contributo mostrerà anche l'identificazione delle particelle, effettuata mediante la tecnica ΔE-E, che permette una buona identificazione isotopica per frammenti con numero atomico sino a $Z \approx 10$.

ASIC-based techniques for high-density channel γ spectroscopy.

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The rise of Application Specific Integrated Circuits (ASIC) technology allowed the realization of compact low-power-consumption devices, with a large number of acquisition channels for nuclear physics experimental setups. The CAEN 5202 FERS-5200 board is an all-in-one front end optimized to work with signals coming from SiPMs. The acquisition lines are 64 in total and are provided by two 32 channels Citiroc-1A chips. This kind of chip generally is not used for spectroscopy measurement since it has small peaking time. Through this contribution, we demonstrate that according to the SiPM dimension, it is still possible to acquire gamma spectra from crystals like cerium-doped lutetium yttrium orthosilicate (LYSO(Ce)), caesium iodine (CsI), and bismuth germanate (BGO), obtaining energy resolutions comparable with literature and with an alternative system. Measurements with other radioactive sources are in progress to test the A5202 capabilities to work with faster scintillators like lanthanum bromide ($LaBr_3$) and cerium bromide ($CeBr_3$). This system could be suitable for experiments requiring many acquisition channels with SiPM and scintillation detectors.

● Studio dello stato di chamonio $h_c(1^1P_1)$ mediante il decadimento $\psi(2S) \to \pi^0 h_c$ a BESIII.

Scodeggio M.
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Ancora oggi gli stati $c\bar{c}$ possono ancora essere degli ottimi test delle nostre previsioni QCD, in quanto il charmonio si trova nella regione di transizione tra QCD perturbativa e non perturbativa. Nonostante la necessità di conferme sperimentali, la statistica limitata, dovuta ai processi di produzione di tutti gli stati non vettoriali, è uno dei maggiori ostacoli. Le proprietà e molti canali di decadimento di alcuni stati di charmonio (come $h_c(1P)$ o $\eta_c(2S)$) sono ancora lontani dall'essere conosciuti. Dal 2009, BESIII sta studiando la regione del charmonium per fare luce su queste questioni ancora aperte. Grazie ai suoi campioni di J/ψ e $\psi(2S)$, BESIII può superare i limiti statistici. In questa comunicazione, il recente studio di BESIII dello stato di singoletto in onda P del charmonio $h_c(1^1P_1)$ viene presentato. Usando 448 milioni di eventi di $\psi(2S)$, la Collaborazione BESIII ha studiato massa ed ampiezza della risonanza e misurato il rapporto di ramificazione dei decadimenti coinvolti.

● AEgIS phase 2: Upgrades and first data.

Volponi M. per la AEgIS Collaboration
CERN - European Organization for Nuclear Research, Università di Trento e INFN, Sezione di Trento
AEgIS (Antimatter Experiment: Gravity, Interferometry, Spectroscopy) is an experiment at the Antiproton Decelerator (AD) facility at CERN whose goal is to study the asymmetry between matter and antimatter and, in particular, the effect of the Earth's gravitational potential on anti-hydrogen. During the run in 2018, anti-hydrogen formation was achieved, leading to considerable gain of knowledge on the processes involved. In the meantime, a new decelerator, ELENA, has been introduced, changing the beam received. Therefore, in the last two years, during CERN Long Shutdown 2, multiple upgrades to the experiment have been carried out, spanning from new degraders, a new Hbar formation trap scheme, an entirely new control system, a more efficient positron accumulation line, two new lasers and a laser hut, and more efficient sensors. This work is necessary towards the goal of creating the first pulsed beam of neutral antimatter, which will enable us to perform inertial studies on antimatter with high degrees of precision. In this contribution I will present the different

upgrades, the validation of the new approach with beam, and the further developments foreseen in the future.

The ENUBET monitored neutrino beam.

Lutsenko E. per la ENUBET Collaboration
INFN, Sezione di Milano-Bicocca, Italia e Università degli Studi di Milano-Bicocca, Italia
The main source of systematic uncertainty on neutrino cross- section measurements at the GeV scale is represented by the poor knowledge of the initial flux. The ENUBET project has been funded by the ERC in 2016 with the goal of cutting down this uncertainty to 1% through the monitoring of charged leptons produced in association with neutrinos, by properly instrumenting the meson decay region of a conventional narrow-band neutrino beam. Large angle muons and positrons from kaons are measured by a sampling calorimeter on the decay tunnel walls (tagger), while muon stations after the hadron dump can be used to monitor the neutrino component from pion decays, thus providing a full control on both the muon and electron neutrino fluxes. Furthermore, the narrow momentum width ($< 10\%$) of the beam provides a precise measurement ($O(10\%)$) of the neutrino energy on an event-by-event basis, thanks to its correlation with the radial position of the interaction at the neutrino detector. This contribution will report the final design of the horn-less beamline together with the assessment of the systematic budget on the neutrino flux. The construction of the tagger demonstrator will be also discussed.

Determination of the Zemach radius of the proton by exciting the spin-flip in muonic atoms: The FAMU experiment.

Rossini R. per la Italian FAMU Collaboration
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The measure of the charge radius of the proton showed a disagreement between electronic and muonic hydrogen atoms: the so-called "proton radius puzzle". The FAMU experiment at the Rutherford Appleton Laboratory (UK) is designed to measure the Zemach radius of the proton in muonic hydrogen (μH), to check this disagreement. A beam of negative muons produced by the ISIS synchrotron is directed to a gaseous hydrogen-oxygen target. A custom-made laser, designed to have a wavelength around $6.8\,\mu$m, is injected into the cryogenic chamber filled with the gas mixture, to stimulate resonant spin-flip in μH atoms. These atoms promptly de-excite, acquiring $\sim 120\,$meV of kinetic energy. As a consequence, the probability of the muon transfer to an oxygen atom is increased and the process is followed by X-ray emission around $100\,$keV. The resonant wavelength, corresponding to the hyperfine splitting of μH, is obtained by measuring the X-ray emission at different wavelengths. Through QED calculations, the Zemach radius is then determined with a precision better than 1%. A confirmation in the difference between the radii would point to physics beyond the Standard Model.

Aula D - Marianna Ciccone **ore 15:00 – 18:30**

Sezione II
Fisica della materia
Presiedono: Petti D. (Politecnico di Milano)
Vanacore G.M. (INFN, Sezione di Milano Bicocca)

Nanofabrication and characterization

Comunicazioni

Calorimetry through dielectric measurements: A powerful investigation technique for condensed matter.

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Froehlich entropy (FE) is the entropy variation of a material under an applied electric field. Under suitable hypotheses, this quantity can be calculated from the real part of the permittivity as a function of temperature. A straightforward physical interpretation correlates FE to the state-of-order of the considered physical system, when the analysis of FE gives several information about the evolution in temperature of the explored compound, especially of its phase transition features. Here we present a comprehensive review of the physical systems (dipolar liquids and nematicons, organic molecular crystals, metallic nanoparticles, inorganic disordered ferroelectrics, etc.) where this method has been used with the aim of evaluating their state-of-order on temperature. The variety of compounds where this approach was applied indicates that the estimation of the FE is a reliable tool to accomplish studies on the state-of-order of different classes of materials. Therefore, FE estimation can be considered a fruitful and trustworthy investigation technique, which can be used as an alternative to standard experimental approaches.

Growth process and post-growth evolution of tetraphenylporphyrin thin films.

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The control of the growth of organic semiconductor thin films is one of the most intriguing challenges within the framework of organic electronics, in view of improving thin-film properties and device performances, and many efforts have been devoted to the understanding and modelling of film evolution and growth mechanisms. Here, the growth of Nickel-tetraphenylporphyrin (NiTPP) thin films deposited by organic molecular beam epitaxy on two substrates, an organic crystal and graphite (KAP and HOPG), is studied by monitoring their morphology *ex situ* by Atomic Force Microscopy (AFM). On KAP, post-growth evolution is observed, leading to the formation of peculiar triangular-shaped NiTPP nanoaggregates, possibly originating from organic epitaxy with the substrate; however, by tuning the growth parameters, one single stable phase can be selected, driven by the intermolecular interactions among NiTPP molecules. On HOPG, post growth evolution is detected by AFM as well, and the analysis of images of NiTPP films with different thickness by height-height correlation function leads to model the growth as a complex process in which surface diffusion and step-edge barriers are involved.

Dynamical imaging of MEMS devices at sub-micrometer scale using time-resolved scanning electron microscopy.

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Present MEMS characterization rests mostly on separated time and space information. In this contribution, we present MEMS morphological imaging by time-resolved scanning electron microscopy, with simultaneous sub-micrometric and sub-microsecond resolution. MEMS devices are actuated close to their resonant frequencies and imaged by a pulsed electron beam probe, generated by beam blanker slicing. The time delay between the periodic actuation voltage and the electron pulse landing is kept constant during the acquisition of secondary electron images. MEMS stroboscopic motion movies are obtained by the sequential acquisition of images over an equispaced mesh of delay times. The technique provides unprecedented local in plane point-by-point trajectory information, potentially allowing the time-resolved characterization of oscillatory modes, local strain and stress, structural deformations and defects, and nonlinear effects. We will further focus on the present limits of the technique, mostly related to the e-beam induced charging. We will discuss strategies to mitigate these instrumental artifacts, improving space and time resolution performances towards the nanometer and ultrafast time scale.

Low-energy-filtered secondary-electron emission microspectroscopy using a cylindrical mirror analyzer.

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The local work function, surface potential, charging/discharging behavior, and elemental/chemical properties are among the information conveyed by the energy spectra of secondary electrons (SE) emitted by electron impact from materials. In this contribution, we present SE emission spectroscopy (SEES) from different material surfaces. The samples are locally excited by a microscope electron beam, and the spectra are collected using a cylindrical mirror analyzer (CMA). The line shape profile and the onset of the spectra are studied as a function of the sample orientation, primary-beam energy, and sample bias. The CMA transmission, showing a low-energy cutoff at about 15 eV, is efficiently adapted to investigate the SE range (0 to 50 eV) by applying proper bias voltages in a tilted primary-beam incidence geometry. We also discuss the spectral shape evolution as a function of sample bias in terms of SE emission physics and instrumental artifacts. In perspective, SEES can pave the way for nanoscale hyperspectral and time-resolved electron microscopy investigation of surface phenomena like catalysis, phase transitions, and collective dynamics (*e.g.*, plasmons and phonons).

Facile co-precipitated synthesis, structural, optical, and magnetic characteristics for $Cd_{x-1}Fe_xO$ nanoparticles.

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The structural, optical, and thermal properties of undoped and Fe-doped CdO powder nanostructures prepared by the Co-precipitate calcinations method have been investigated. X-ray diffraction (XRD) results revealed that pure and Fe-doped CdO has polycrystalline with a face-centered cubic (FCC) structure. The crystallite size for undoped and $1, 5, 10, 15, 20, 30\%$ of Fe-doped CdO samples were 44.25, 46.08, 65.66, 56.56, 50.1, 44.58, and 60.06 nm, respectively. The optical band gap of the samples was determined from the diffused reflectance spectra, and E_g values for undoped and $1, 5, 10, 15, 20, 30\%$ of Fe-doped CdO samples were found to be 1.978, 2.044, 2.024, 1.96, 1.92, 1.859, 1.88 eV, respectively. The thermal stability of pure and Fe-doped CdO was measured by a thermogravimetric analyzer (TGA) in the temperature range from room temperature to 1000 at 15 deg/min. The magnetic properties were investigated by VSM and ESR analysis which proves the promising magnetic performance employed for future applications.

Scintillation performances of $CsPbBr_3$ thin films deposited by laser ablation under alpha-particles irradiations.

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Perovskites are widely investigated as a new generation of materials thanks to their potentialities in different fields. In particular, the photophysical properties of cesium lead bromide ($CsPbBr_3$) perovskite have stimulated extensive efforts to properly understand and optimize its performances. Its use as indirect radiation detector is attracting due to its photophysical properties and high stopping power. The film performances are also strictly dependent on the deposition technique. Here we report on the properties of $CsPbBr_3$ films deposited by Pulsed Laser Deposition (PLD) technique to be used as scintillator material. $CsPbBr_3$ were deposited using a KrF excimer laser ($\lambda = 248$ nm, $\tau = 20$ ns) at a fluence of 1 J/cm^2, of a mechanochemically synthesized target prepared by mixing 1:1 molar ratio of $PbBr_2$ and CsBr powders. The as-deposited films were annealed in air using two different protocols, since annealing treatments are proved to enhance photoluminescence and affect the evolution of the films. The crystalline, morphological and emission properties are reported together with the scintillation properties under alpha-particles irradiations emitted by an Am-241 source.

Monitoraggio di scariche su HVPTF attraverso spettroscopia di raggi X.

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Università degli Studi Milano-Bicocca e Istituto per la Scienza e Tecnologia dei Plasmi-CNR

La tenuta di alti voltaggi (HV) nel vuoto è un importante filone di ricerca nel contesto dei Neutral Beam Injector (NBI), che sono il principale metodo di riscaldamento di plasmi da fusione. Lo sviluppo di prototipi di NBI per ITER (per esempio MITICA) richiede strutture in grado di produrre HV fino ad un megavolt, ed a tal fine è di fondamentale importanza l'impedire la formazione di scariche. Lo High Voltage Padova Test Facility (HVPTF) è una macchina realizzata per testare differenti condizioni di vuoto e diversi elettrodi per studiarne la tenuta sotto alti HV (fino a 800 kV). In particolare, i processi fisici delle scariche sono osservati attraverso una serie di scintillatori (LaBr, LYSO e GEM) che rilevano i raggi X prodotti attraverso bremsstrahlung da cariche accelerate dall'HV e frenate sugli elettrodi. Questo contributo dettaglia come la spettroscopia X offra una migliore risoluzione temporale nello studio delle scariche rispetto ai valori I/V ed evidenzia delle prospettive nell'identificare le condizioni che portano alle scariche più intense, con il fine di implementare correzioni online per impedirne l'occorrenza.

Time-resolved core level photoemission reveals transient lattice distortions in 2H-MoTe$_2$ crystals.

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In this contribution, we present the time-resolved X-ray photoemission study of a semiconductive 2H-MoTe$_2$ crystal performed at the ANCHOR-SUNDYN endstation of the Elettra Synchrotron (Trieste). Upon photoexcitation, we observe a long-lived core level shift to lower binding energies that is due to the formation of surface photovoltage fields. Interestingly, in the sub-nanosecond range the photoemission peaks shift to the opposite direction, suggesting the presence of a distinct physical process at shorter timescales. With the support of DFT calculations, we modeled the deformation of the MoTe$_2$ lattice in the out-of-plane direction, which is along the pathway for the 2H-1T$'$ phase transition. Our data indicate an intermediate lattice excitation state with a measured lifetime of ~ 600 ps, in which the displacement of Mo and Te atoms causes the core photoelectrons to shift to higher binding energies. These results show that high-resolution time-resolved photoemission, combined with suitable theoretical simulations, is a valuable tool for studying not only the electronic and chemical modifications of photoexcited systems, but also lattice distortions and phase transitions.

Fabrication and characterization of master for nano-imprint lithography trough solid state dewetting.

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Solid-state dewetting (SSD) is a natural shape instability occurring in thin solid films when heated at high temperature: it transforms a flat layer in isolated islands in a timeframe independent of the sample size. Being a spontaneous phenomenon driving changes of morphologies, it offers interesting technological perspectives. The aim of this work is to use SSD as an alternative way to a standard lithographic approach, or in combination with it, to produce over arbitrary scales random or order patterns to be used as master for soft

nanoimprint lithography (NIL). Controlling the dewetting instability using amorphous Ge, we report the nanofabrication of patterns of Ge islands. To control their final shape and distribution, different Ge thicknesses and annealing temperatures have been tested employing a short time-consuming process. Then, the obtained patterns have been transferred in the Si substrate to obtain a scalable master for NIL. The combination of the two techniques, considering their capability to pattern large surface area at low cost, represents a promising alternative to texturize, for example, the back-mirror of ultra-thin solar cells.

Femtosecond laser micromachining of integrated devices for XUV generation.

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Politecnico di Milano e CNR-IFN

Extreme ultraviolet radiation (XUV, 10–124 eV) is at the core of the most advanced technologies for the in-depth study of matter, but the need for huge and expensive facilities to generate such high-energies photons limits its availability to few laboratories around the world. We propose a new kind of approach, based on integrated photonic, to generate and manipulate XUV radiation in a few-centimeter platform, consisting of a network of empty channels embedded in a glass sample. To realize this platform, we push beyond the limits of an extremely versatile micromachining technique called Femtosecond Laser Irradiation followed by Chemical Etching, which allows the realization of a 3D hollow core structure inside transparent materials. We demonstrated that these structures can host the interaction between a noble gas and a femtosecond laser beam, triggering high-order harmonic generation which ends up in the delivery of ultrashort XUV pulses, with a conversion efficiency of up to 10^{-5} in the 40–50 eV spectral region. This result represents the basis for the future development of a miniaturized and a highly efficient XUV source.

***Ab initio* insights into the initial steps of the Oxygen Reduction Reaction on CoTPyP metal-organic framework.**

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Metalorganic molecules self-assembled on surfaces form a template to host regular arrays of metal atom caged inside the molecules. Each single metal atom act as a catalyst, whose selectivity and efficiency towards specific chemical reactions can be tuned changing either the atomic species or molecular residues, or else the substrate. We focus here on a monolayer of Cobalt TetraPyridyl Porphyrins (CoTPyP) grown on a graphene/Ir(111) substrate, showing that it is able to stabilize hydroperoxyl molecule (OOH), that is widely accepted to be a fundamental reaction intermediate in Oxygen Reduction Reactions (ORR) but has an elusive behavior and is difficult to be detected. Experiments and *ab initio* density-functional theory modeling suggest the formation of a OOH-water cluster on top of the molecules at room temperature in $O_2 + H_2O$ atmosphere. The detailed analysis of the electronic properties provides a clear picture of the bonding nature and the role of CoTPyP and water in the OOH stabilization process, showing that a surprising combination of charge transfer, dipole and H-bonds and water solvation determines the hydroperoxyl-water complex stability.

Wave propagation in a stratified fluid —From mesoscopic to macroscopic length scales.

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A stratified fluid can be generated in different ways, either starting from the initial condition of a homogeneous binary mixture stressed by a temperature gradient or the one where a solid is made to dissolve in a fluid at the starting time. Both these cases can generate density profiles evolving with time and are thus subject to non-equilibrium (NE) conditions. We have performed experiments where we investigated the evolution of NE concentration fluctuations at different wavelengths and we have observed propagating modes occurring at the mesoscale. We have also performed experiments by introducing a macroscopic object able to levitate in a density gradient, a configuration where propagating waves are also observed, but at the macroscopic scale. Both phenomena are well described by the Brunt-Väisälä oscillations that take place in stratified fluids, such as the atmosphere and stars.

Mechanical energy harvesting from electrostrictive polymeric nanocomposites.

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Harvesting systems capable of transforming mechanical vibration into electrical energy have attracted considerable interest with particular focus on electroactive polymers. We are developing harvester systems compatible to a shoe sole structure and capable of recovering energy from human gait, then sustaining the energy consumption of a sensor platform to monitor biophysical parameters. In this contribution, a composite material consisting of a polyurethane matrix filled with a high-k ceramic nanofiller ($CaCu_3Ti_4O_{12}$) is fabricated by doctor blade coating. Single strips, with sputtered electrodes, are electrically connected in parallel increasing electrical capacitance. The required bias voltage is provided by two alternative solutions, a rechargeable battery or a custom electret made by corona charging. When a 50 V bias was supplied by the battery, we obtained energy density output of about $5\,\mu J/cm^3$. Utilizing the electret, we measured an energy density output a factor 3 to 10 higher. The energy, initially stored in a supercapacitor, will then be managed in an optimized way to power sensing components integrated in the shoe sole.

Measuring thermal diffusivity with Scanning Ultrafast Electron Micro-Diffraction.

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Ultrafast Electron Diffraction provides direct experimental access to the fundamental timescales of atomic motion. In this technique, a femtosecond laser pulse excites a sample, and an equally short electron pulse probes the structural response. When the sample is excited far from equilibrium, the complex relaxation process can involve multiple timescales and competing energy-transport mechanisms. We describe a method for probing sample response both picoseconds, microseconds and milliseconds after femtosecond excitation, providing a more complete picture of the structural dynamics. By scanning a micron-sized diffraction probe across the sample surface, this method is able to map out thermal transport in both space and time. We present results of an experiment performed on a Moiré heterobilayer ($MoSe_2/WSe_2$) that points to the role played by interlayer excitons in heat diffusion.

Aula T - Caterina Scarpellini **ore 15:00 – 18:30**

SEZIONE III
Astrofisica
Presiede: BELLINI F. (Sapienza Università di Roma e INFN, Sezione di Roma)

UNDERGROUND-NEUTRINOS-ETC.

Relazioni su invito

▲ **Dark matter direct detection.**
FIORILLO G.
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The direct detection (DD) of dark matter has been the Holy Grail of particle physics for decades. Yet no experiment could confirm the existence of WIMPs, the strongest dark matter candidate since the 1980s. The null result of both DD and LHC searches has produced a paradigm shift in the community that is now expanding the hunt to cover 90 orders of magnitude in mass. Current and next generation of detectors will push the sensitivity for WIMPs down to the neutrino floor. At the same time many groups are gearing up for implementing new experimental techniques, should these global efforts fail to find evidence of dark matter interactions. This contribution will provide a review of the most sensitive experiments and some perspective on the new technologies.

Comunicazioni

● **Calibrazione di XENON1T con sorgente di ^{37}Ar diffusa nel rivelatore.**
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Il progetto XENON, situato presso i Laboratori Nazionali del Gran Sasso dell'INFN, si pone come obiettivo la rivelazione diretta di particelle di materia oscura, attraverso la loro interazione con atomi di xeno all'interno di una Camera a Proiezione Temporale a doppia fase. Al termine dell'acquisizione dei dati scientifici dell'esperimento XENON1T nel 2018, è stata effettuata una calibrazione nella regione a bassa energia mediante l'utilizzo di una sorgente di ^{37}Ar diffusa all'interno del rivelatore. L'isotopo ^{37}Ar decade per cattura elettronica, con un tempo di dimezzamento di 35 giorni, emettendo fotoni ed elettroni che producono segnali monoenergetici a 2.82 keV (shell K) e 0.27 keV (shell L). Vengono riportati i risultati finali della calibrazione che confermano che il comportamento del rivelatore è ben descritto anche nella regione a bassa energia vicino alla soglia di rivelazione. Viene anche mostrato che, grazie alla capacità di rimuovere efficacemente l'argon tramite distillazione criogenica, è possibile effettuare tale calibrazione regolarmente nei rivelatori multi-tonnellata di ultima generazione, come XENONnT.

● **New results of GERDA on the search for bosonic Super-WIMPs.**
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The GERmanium Detector Array (GERDA) experiment at the Laboratori Nazionali del Gran Sasso has searched for the ^{76}Ge neutrinoless double-beta decay. Using an array of

enriched high-purity germanium diodes, GERDA combined an excellent energy resolution to an ultra-low background level. This helped to explore other rare phenomena as the interactions of bosonic superweakly interacting massive particles (super-WIMPs). GERDA has searched for these keV-scale dark matter candidates via their absorption by an electron of a germanium atom. In this study, we considered an additional process, *i.e.*, the Compton-like scattering, which is dominant for masses above $150\,\mathrm{keV}/c^2$. A binned Bayesian analysis was applied for masses in $[60; 2m_e]\,\mathrm{keV}/c^2$ to either detect or set a 90% C.I. upper limit on the type of interactions that can induce a Gaussian peak in the energy spectrum. By including the dark Compton scattering, which has not been used in any other super-WIMP search experiment, and using a larger dataset of 119.8 kg yr of total exposure, previous GERDA upper limits for pseudoscalar and vector super-WIMP couplings to electrons were improved.

Status of the XENONnT dark matter experiment.

Di Gangi P.
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XENONnT is a dark matter direct detection experiment located at the INFN, Laboratori Nazionali del Gran Sasso. The core detector is a dual-phase time projection chamber (TPC) filled with 5.9 t of liquid xenon and instrumented with a total of 494 photomultiplier tubes (PMTs). The TPC is installed in the center of a stainless-steel tank filled with 700 t of water instrumented with 84 PMTs and operated as an active water Cherenkov Muon Veto (MV). A novel sub-detector, the Neutron Veto (NV), is contained within the MV and surrounds the TPC in order to suppress the neutron background. The highly reflective NV volume is optically separated from the Muon Veto and instrumented with 120 high-QE low-radioactivity PMTs. The water will be eventually doped with gadolinium to maximize the neutron detection efficiency. In 2020 XENONnT replaced the successful XENON1T experiment, which was the world's most sensitive detector for direct dark matter searches. After a few months of commissioning, since mid-2021 XENONnT started its science data acquisition. In this contribution we will review the most relevant achievements of XENON1T, and describe the concept, the performances and the scientific program.

Performances and first results of the Neutron Veto of XENONnT.

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The Neutron Veto of the XENONnT experiment is a Gd-loaded water Cherenkov detector designed to detect the radiogenic neutrons coming from the detector materials, in order to reduce one of the main nuclear recoil background components in the XENONnT time projection chamber. The Neutron Veto (NV) is instrumented with 120 (8″ Hamamatsu R5912) photomultiplier tubes, featuring high-QE and low radioactivity, installed in a high light collection volume delimited by ePTFE reflector panels all around the cryostat. The XENONnT experiment is currently taking Science Data, with the NV operating in demi-water; in this contribution, I will overview the NV working principle and its initial performances in terms of PMT main parameters and in terms of neutron tagging efficiency, as resulting from the calibration and first months of data-taking.

Status of the Gd-water purification plant of the XENONnT Neutron Veto system.

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One of the novel subsystems of the XENONnT experiment is the Neutron Veto, designed to reduce the neutron background by tagging them in a suited water Cerenkov detector. One of the key ingredients is the doping of water with gadolinium, the element with the highest neutron capture cross-section, in the form of 0.5% Gd-sulphate. In this contribution we will present the current status of the Gd-water purification plant, designed to maintain good optical properties of the solution, and the results of the "Reflectivity Monitor", which allows to check the performances of the detector, before and after the addition of Gd, in terms of transparency of the water and reflectivity of the walls.

Stato e prospettive di DAMA/LIBRA fase2 migliorata.

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L'apparato sperimentale DAMA/LIBRA fase2 (circa 250 kg di NaI(Tl) altamente radiopuro) opera presso il Laboratorio Nazionale del Gran Sasso dell'INFN. In questa comunicazione saranno presentati i risultati recenti e le loro implicazioni. Inoltre sarà discussa la configurazione potenziata dell'apparato attualmente in misura con lo scopo di studiare eventi ad energie al di sotto della soglia software di 1 keV. Sarà data enfasi anche all'impatto che tale miglioramento può avere nello studio di modelli teorici di candidati di materia oscura, di possibili effetti al secondo ordine rispetto alla modulazione annuale e di vari scenari astrofisici.

Directional dark matter searches with CYGNO experiment.

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The CYGNO experiment aims to exploit the optical readout approach of multiple Gas Electron Multipliers (GEM) structures in large volume TPCs for the study of rare events as interaction of low-mass (few GeV) Dark Matter (DM) or solar neutrinos. The TPC volume is filled with an He:CF_4 gas mixture at atmospheric pressure. The photons produced in the multiplication process are read out by sCMOS sensors, which guarantees a high read granularity, a high sensitivity and a low noise level. The drift time of ionization is measured by PMTs in order to obtain the coordinate perpendicular to the camera plane. The combined use of high-granularity sCMOS cameras and fast light sensors allows the reconstruction of the 3D direction of the tracks, offering good energy resolution and very high sensitivity in the few keV energy range. A detector sensitive to the incoming particle direction, in case of DM discovery, will be important in order to study its properties. The CYGNO experiment goal is to build and to operate a 1 m^3 demonstrator underground at the Gran Sasso National Laboratories (LNGS) aiming at a larger scale apparatus (30 m^3–100 m^3) at a later stage.

Ricerca di materia oscura con l'esperimento COSINUS.

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COSINUS (Cryogenic Observatory for SIgnals seen in Next-generation Underground Searches) è un esperimento attualmente in costruzione presso i Laboratori Nazionali del Gran Sasso che utilizza lo ioduro di sodio (NaI) come calorimetro criogenico scintillante per la ricerca di materia oscura. La scelta di tale materiale come assorbitore consente a COSINUS di fornire un test "model-independent" dei risultati di DAMA/LIBRA. Operare lo ioduro di sodio come calorimetro criogenico scintillante ha il duplice vantaggio di ottenere una bassa soglia per i rinculi nucleari ($\sim 1\,\mathrm{keV}$) e di identificare il segnale evento per evento sfruttando la differente resa di luce di rinculi nucleari (segnale) ed eventi beta/gamma (fondo). Al fine di poter raggiungere le performance richieste è necessario eseguire un approfondita caratterizzazione ed ottimizzazione dei sensori di temperatura e del setup sperimentale. In questo contributo, presentiamo una breve descrizione dell'esperimento, dell'attività di sviluppo del rivelatore e della costruzione.

● *In situ* $^{77(m)}$Ge production rates for different neutron moderator configurations in the LEGEND-1000 experiment.

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(3) *Gran Sasso Science Institute, L'Aquila, Italy*
(4) *INFN, Laboratori Nazionali del Gran Sasso, Assergi, L'Aquila, Italy*
(5) *Department of Physical and Chemical Sciences University of L'Aquila, L'Aquila, Italy*

LEGEND experiment is placed at LNGS in Italy, aiming to suffer less from cosmic radiations. Even so, the *in situ* production of long-lived isotopes by cosmic muon interactions can generate a non-negligible background. The LEGEND experiment, which searches for $0\upsilon\beta\beta$, foresees the construction of LEGEND-1000, a ton-scale detector, and recent studies have shown that the underground production of $^{77(m)}$Ge through the rapid capture of neutrons at ^{76}Ge may be one of the primary sources of cosmogenic background. Aiming to attenuate these background events and facilitate the work of the tagging and discrimination algorithms, the use of neutron moderators has been investigated. The idea is that the hydrogen-containing neutron moderators behave by slowing down the neutrons produced in the liquid argon, thus increasing the likelihood of them being captured by the argon instead of the germanium detectors, decreasing the $^{77(m)}$Ge production rate. Using Monte Carlo simulations, four different moderator designs were implemented, and several parameters were evaluated to optimize the moderator screening effect while the background index remained unaffected.

● Josephson-qubit oscillations resonantly activated by axions.

Grimaudo R., Guarcello C., Filatrella G., Spagnolo B., Valenti D.
Università degli Studi di Palermo

In the last years Josephson junctions (JJs) have been supposed to interact with axions, the hypothetical elementary particles candidate as a possible component of cold dark matter. Unexplained experimental effects on Josephson systems can be well justified on the basis of the axion-JJ theory. This hypothesis, thus, has paved the way for the possibility of thinking of JJs as possible axion detectors. Further, the interaction of axion-induced photons with Josephson qubit in a cavity has been recently proposed. In this contribution, an effective quantum description of the axion as a two-level dynamic system is proposed. The direct coupling (not mediated by photons in a cavity) with a Josephson qubit is studied through an effective spin-spin Hamiltonian model. When the axion and the Josephson frequencies match, the axion-Josephson qubit interaction can be responsible for a resonance effect. Thus, experimentally detectable oscillations induced in the Josephson qubit by the axion are clearly derived. This phenomenon, causing a periodic magnetization reversal in the junction, can be exploited for the axion detection in the quantum limit of low noise intensity.

Calibrazione di rinculi di bassa energia in argon liquido con l'esperimento ReD.

Cesarano R.
Sapienza Università di Roma

La Time Projection Chamber dell'esperimento ReD viene usata in un setup ideato per supplire ad una mancanza di dati sperimentali su rinculi nucleari in argon liquido a bassa energia, nel range tra 1 keV e 10 keV. Un'accurata misurazione dello yield di carica in questo range di energia è essenziale nella ricerca di particelle di materia oscura di massa inferiore a 10 GeV mediante TPC ad argon liquido, come l'esperimento DarkSide-50 che detiene correntemente il limite sperimentale più stringente per la sezione d'urto di dark matter nel range $1.8 < M_{DM} < 3.5\,\text{GeV}$. Il setup utilizza un fascio collimato di neutroni di fissione da una sorgente taggata di ^{252}Cf, uno shield per schermare la radiazione della sorgente, la TPC di ReD e un doppio array di scintillatori plastici da 1 pollice, ciascuno composto da 9 elementi. Verranno mostrati i primi risultati sulla caratterizzazione del setup sperimentale utilizzando sorgenti radioattive.

Aula U - Giuliana Cini Castagnoli **ore 15:15 – 17:30**

Sezione IV
Geofisica e fisica dell'ambiente
Presiede: Braitenberg C. (Università di Trieste)

physical volcanology

Relazioni su invito

▲ Monitoring Volcanic Hazards through Multi-Source Satellite Imagery.

Ganci G.
Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo

Volcanic eruptions produce a wide-range of hazardous phenomena spanning from lava flows, pyroclastic flow to volcanic ash emissions, with impact ranging from local to continental. Satellite monitoring of active volcanoes is an ever-growing technological solution for volcanic hazard assessment, offering low cost, high temporal resolution and high spatial coverage measurements. A comprehensive space-based strategy for quantitative volcano hazard monitoring that integrates the most recent satellite imagery products with physic-based models of eruptive processes is presented here. Time-averaged discharge rates (TADRs) obtained from multispectral satellite data (e.g. MODIS, SEVIRI) are complemented and fine-tuned with the time-varying evolution of lava flow emplacement derived from higher spatial resolution satellite data (e.g. Landsat8/9, Sentinel2), as well as the flow thickness variations, retrieved from satellite stereo pairs (e.g. Pléiades, Skysat). All these space-derived parameters are used as input and validation tags for the numerical modelling of lava flow scenarios. The strategy was successfully applied to different volcanoes worldwide such as Fogo, Nabro, Etna, Cumbre Vieja.

▲ C'è interazione tra Campi Flegrei e Vesuvio? Una possibile risposta dall'interferometria SAR.

Amoruso A. (1), Crescentini L. (1), Acocella V. (2)
(1) *Università degli Studi di Salerno*
(2) *Università degli Studi di Roma Tre*

Vulcani vicini possono mutuamente influenzarsi, ma tali influenze sono difficili da identificare e, ancor di più, da provare sia su scale temporali brevi sia lunghe. Vesuvio e Campi Flegrei sono fra i vulcani a più alto rischio nel mondo e sarebbe molto importante e utile, anche per stime di pericolosità, accertare o escludere una loro interazione. Già in passato, studi petrologici sui prodotti delle eruzioni avevano indicato la possibile esistenza di un unico "reservoir" magmatico, che alimenterebbe entrambi i vulcani. Su scale temporali più brevi e in tempi più recenti, possono essere di grande aiuto dati di deformazione del suolo da interferometria SAR, viste le caratteristiche di copertura spaziale e di risoluzione delle misure. Vari anni fa, ricercatori di IREA/CNR avevano prodotto e messo a disposizione serie temporali di deformazione nella regione di interesse, utilizzando immagini dalle missioni ERS-ENVISAT. In questa relazione saranno mostrati i risultati da noi recentemente ottenuti dall'analisi di tali serie temporali, con tecniche che spaziano dalla scomposizione in "Empirical Orthogonal Functions" all'inversione per sorgenti di deformazione espansive o in contrazione.

Comunicazioni

Spectral analysis in time and space of lava flows erupted by Etna (Italy), Cumbre Vieja (Spain) and Geldingadalir (Iceland) volcanoes.

Amato E. (1)(2), Corradino C. (1), Torrisi F. (1)(3), Del Negro C. (1)
(1) *Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania*
(2) *Department of Mathematics and Computer Science, University of Palermo*
(3) *Department of Electrical, Electronic and Computer Engineering, University of Catania*

Satellite optical sensors allow to measure the lava spectral radiance in time and space in terms of both emitted and reflected radiation. Since the latter contribution is prevalent when lava flow is cooled, under this condition its spectral signature, i.e., radiation reflected as a function of wavelengths, can be retrieved. Lava spectral signature depends on several factors, e.g., lava composition and age, revegetation and temperature of fusion and crystallization. Thus, a deeper knowledge about lava properties can be inferred by investigating its measured spectral signature. Here, we compare the spectral response of lava in time and space inspecting visible to infrared satellite images. Firstly, we analyze the temporal changes from 2016 to 2021 in the spectral response of a lava flow emplaced on Mt. Etna in 2002. Secondly, we compare the spectral responses of chemically different lava flows, from different volcanoes. We use the ESA Sentinel-2 MSI TOA reflectance images to address these tasks. Our results allow to give an insight into physical-chemical properties of the investigated lavas using the spectral response obtained with high spatial resolution satellite data.

Forecasting of thermal behavior of lava fountains with the synergic use of multi-sensor satellite data.

Torrisi F. (1)(2), Amato E. (1)(3), Corradino C. (1), Del Negro C. (1)
(1) *Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo - Sezione di Catania*
(2) *Department of Electrical, Electronic and Computer Engineering, University of Catania*
(3) *Department of Mathematics and Computer Science, University of Palermo*

Infrared radiometers on-board of geostationary and polar satellites orbiting around the Earth are increasingly used to measure radiance from high-temperature volcanic features, whose released energetic content is quantified by the volcanic radiative power (VRP). Geostationary satellite sensors offer high temporal resolution capabilities with which it is possible to characterize the fast-changing dynamics of short and rapid eruptive phenomena, like lava fountains. Under this perspective, they allow to get accurate temporal information of the monitored volcanic phenomena, such as the exponential decay factor of a lava fountain cooling curve. On contrast, polar satellite sensors offer mid-high spatial resolution with which it is possible to spatially characterize eruptive phenomena and to retrieve accurate spatial information such as the areal extent of the volcanic thermal anomaly. In this work, we forecast the thermal behaviour of the long sequence of lava fountains occurred at Mt. Etna on 2021 by combining the temporal features provided by geostationary satellite sensors and the spatial features provided by polar satellite sensors, in order to get more accurate VRP estimates.

Multi-parametric and multi-layer study of 2021-2022 Hunga Tonga eruptions.

D'Arcangelo S. (1)(2), Bonforte A. (3), De Santis A. (1), Maugeri R. (1), Perrone L. (1), Soldani M. (1), Brogi F. (4), Calcara M. (1), Campuzano S.A. (5), Cianchini G. (1), Del Corpo A. (6), Di Mauro D. (1), Ippolito A. (1), Lepidi S. (6), Marchetti D. (7), Montagna C. (4), Nardi A. (1), Orlando M. (1), Piscini A. (1), Regi M. (6), Sabbagh D. (1)
(1) *Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italia*
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([3]) *Istituto Nazionale di Geofisica e Vulcanologia, Catania, Italia*
([4]) *Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italia*
([5]) *Instituto de Geociencias IGEO, CSIC-UCM, Madrid, Spagna*
([6]) *Istituto Nazionale di Geofisica e Vulcanologia, L'Aquila, Italia*
([7]) *College of Instrumentation and Electrical Engineering, Jilin University, Changchun, China*

A unique series of eruptions in history took place at Hunga Tonga-Hunga Ha'apai volcano starting on 20 December 2021, with the main explosion on 15 January 2022. Propagation of pressure waves from this last event produced global effects, causing relevant anomalies in atmosphere and ionosphere. We focused our attention on both pre- and post-eruptive effects observed in the lithosphere, with a seismological analysis; in the atmosphere, affected by the release of trace gases; and in the ionosphere, through the analyses of magnetic field and electron density from Swarm and CSES-01 satellites, ionospheric electron density from ionosonde data, and Total Electron Content from GNSS ground stations. Our comprehensive study confirms the coupling among the different geolayers and gives us a better understanding of this complex phenomenon.

Aula E - Rosalind Franklin **ore 15:00 – 18:30**

Sezione V
Biofisica e fisica medica
Presiedono: Ruggerone P. (Università di Cagliari)
Bianchini P. (IIT, Genova)

Relazioni su invito

▲ ***Staphylococcus aureus* IsdB hemophore interaction with human hemoglobin: Structural and functional insights.**

Ronda L. (1)(2), De Bei O. (3), Marchetti M. (1), Levantino M. (4), Gianquinto E. (5), Spyrakis F. (5), Campanini B. (3), Bettati S. (1)(2)
(1) *Department of Medicine and Surgery, University of Parma, Parma, Italy*
(2) *Institute of Biophysics, National Research Council, Pisa, Italy*
(3) *Department of Food and Drug Science, University of Parma, Parma, Italy*
(4) *ESRF, Grenoble, France*
(5) *Department of Drug Science and Technology, University of Turin, Turin, Italy*

Iron is a necessary nutrient for bacteria and *Staphylococcus aureus* acquires hemic iron from humans by forming a complex with hemoglobin (Hb) through its hemophore IsdB. Static Small (SAXS) and Wide (WAXS) Angle X-ray Scattering measurements were performed to characterize the IsdB interaction with both metHb, the dominant form *in vivo*, and oxyHb, which is insensitive to heme removal and was exploited as a tool to investigate an intermediate state along the extraction process. Static SAXS/WAXS patterns allowed us to confirm complex stoichiometry and to characterize the Hb dimerization and monomerization induced by IsdB. A novel setup featured with a stopped-flow apparatus online with WAXS beamline at the European Synchrotron Radiation Facility was successfully applied to follow the structural changes induced by rapid mixing of IsdB with metHb. Coupled with time-resolved fluorescence and absorption spectroscopy, data allowed to a) define a sequential model describing the observed kinetics and determine its microscopic constants and b) explore how the function of this receptor is dependent on dynamic interactions that guarantee the fast and efficient heme transfer to the bacterium.

▲ **Improvement in correlation microscopy: Nikon microscope integration with CrestOptics spinning disk and super resolution module.**

Zorloni A. (1), Oggioni M. (1), Bacchi F. (2)
(1) *Nikon Europe B.V.*
(2) *CrestOptics*

Correlative microscopy has recently become an important tool in biophysics to obtain live imaging of subcellular dynamics structures, like organelles, vesicles, cytoskeleton filaments, with high spatial and temporal resolution and low photon burden. To answer these requirements, CrestOptics combined a Spinning Disk confocal system (V3) with a Structured Illumination microscopy one (DeepSIM). V3 features micro-lenses–based homogeneous illumination, high temporal resolution (up to 500 fps) with FOV25 and dual cameras setup to get simultaneous multi-color acquisitions (400–750 nm) at high confocal throughput and speed, with minimum photobleaching. With such technology, fast dynamic events are consistently tracked in real-time and in large tissue sections. DeepSIM doubles the confocal spatial resolution (100 nm lateral) to resolve fine subcellular details and specifically designed masks of micro lenses and pinholes generate 2D-lattice illumination patterns to scan the sample at

depth penetration comparable with confocal, with temporal resolution higher than 10 fps. These aspects altogether foster the seamless integration of the two imaging modalities and their meaningful data correlation.

▲ **Deciphering protein cooperative interaction in pathological diseases.**

Ricci C. (1), De Luigi A. (2), Colombo L. (2), Salmona M. (2), Fragneto G. (3), Schubert U. (4), Del Favero E. (1), Cantù L. (1)
(1) *Biometra Department University of Milan, Italy*
(2) *Istituto di Ricerche Farmacologiche "Mario Negri", Milan, Italy*
(3) *Institut Laue-Langevin, Grenoble Cedex, France*
(4) *Department of Clinical and Molecular Virology, Friedrich-Alexander Universitat Erlangen-Nurnberg, Germany*

It is known that, in neurodegenerative diseases, a protein can modify its conformation and thus change its pathway of interaction, reaching self-aggregation or aggregation with other molecules. The different extents of conformational changes and the types of molecular assemblies also reflect in their toxicity and could correlate with physiopathology, and in the end, with the disorder. Thus the knowledge of the biochemical and biophysical features of the proteins involved, in particular the study of the structure they acquire in presence of different partners, can give insight on the onset of the pathologies. I will present our recent results on the tau protein, involved in different neurodegenerative diseases. We used the full-length, wild-type tau, and punctual mutated isoforms comparing their course from intrinsically disordered monomers in solution to early-stage recruitment in complexes and then fibrils. We showed that diversity in the kinetics of recruitment and aggregate structure occurs from the beginning and all over their aggregative pathway. Also a change of the protein propensity of the interaction with other molecules or with the cellular membrane can act as an adjuvant in the spreading of the pathology, as we saw for p6 protein, involved in HIV-1 replication cycle.

Comunicazioni

● **Biophysics at the nanoscale using the intelligent multimodal optical microscope.**

Diaspro A.
Nanoscopy, CHT, Istituto Italiano di Tecnologia, Italy, Department of Physics, DIFILAB, University of Genoa, Italy e Institute of Biophysics, CNR, Genova, Italy

Advanced optical microscopes have been implemented in the last decades, shining a new light on the cellular and molecular biology questions. Multimodal optical microscopy is a growing attitude boosted by artificial intelligence that makes the microscope intelligent. In the era of super-resolved fluorescence microscopy, fluorescence plays a significant role, including its photochemical parameters, from brightness to lifetime, and non-linear approaches, like those associated with multi-photon excitation, also able to exploit intrinsic fluorescence and SHG/THG. In this framework, polarisation methods, like Mueller matrix microscopy, expand contrast mechanisms available for imaging toward label-free. The intelligent microscope is AI-guided through a computational core based on independent component analysis (ICA) un-supervised machine learning towards supervised deep learning. The ambitious target is to create a robust virtual environment "to see" what we could not perceive before. An interesting case study is related to understanding the role of chromatin remodelling in physiological/pathological processes.

Un approccio fotodinamico contro SARS-CoV2.

Abbruzzetti S. (1), Delcanale P. (1), Mussini A. (1), Viappiani C. (1), Abbruzzetti S. (1), Uriati E. (1)(2), Mariangeli M. (1)(2), Moreno A. (3), Lelli D. (3), Cavanna L. (4), Bianchini P. (2), Diaspro A. (2)(5)
(1) *Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università degli Studi di Parma, Parma, Italy*
(2) *Nanoscopy @ Istituto Italiano di Tecnologia, Genova, Italy*
(3) *Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, Brescia, Italy*
(4) *Dipartimento di Oncologia-Ematologia, Azienda USL di Piacenza, Piacenza, Italy*
(5) *DIFILAB, Dipartimento di Fisica, Università di Genova, Genova, Italy*
Sebbene sia noto un certo numero di malattie umane associato a infezioni virali, sono poche le terapie antivirali approvate, spesso con uno spettro ristretto di azione. Questo limita la loro efficacia e versatilità e ripropone il problema di trovare farmaci ad ampio spettro in grado di fornire una risposta adeguata. SARS-CoV2 offre un esempio importante di questa questione, in quanto appartiene a una consistente categoria di agenti patogeni virali che sono accomunati dalla presenza di una membrana che avvolge il virus, e la necessità di fondere tale membrana virale con quella cellulare dell'ospite. Questi rappresentano il bersaglio di strategie antivirali ad ampio spettro, tra cui quelle emergenti, che utilizzano composti fotosensibilizzanti. In questo ambito abbiamo studiato l'azione di un fotosensibilizzatore naturale l'ipericina, valutandone sperimentalmente l'interazione con particelle di SARS-CoV2 e la sua efficacia antivirale. L'approccio fotodinamico appare decisamente promettente nel fornire costrutti in grado di inattivare un'ampia categoria di agenti patogeni, ma anche di "specializzare" tali costrutti per un'azione mirata verso virus specifici, come SARS-CoV2.

Cryo-EM undiscloses structural and mechanistic details on iron hijacking by *Staphylococcus aureus*: An insight into the interaction of IsdB hemophore with human hemoglobin.

Marchetti M. (1), De Bei O. (2), Ronda L. (1)(2)(3), Gianquinto E. (4), Lazzarato L. (4), Chirgadze D.Y. (5), Hardwick S.W. (5), Cooper L.R. (5), Cozzi M. (1), Faggiano S. (3)(6), Spyrakis F. (4), Luisi B.F. (5), Campanini B. (2)(6), Bettati S. (1)(2)(3)
(1) *Department of Medicine and Surgery, University of Parma, Italy*
(2) *Interdepartmental Center Biopharmanet-TEC, University of Parma, Italy*
(3) *Institute of Biophysics, National Research Council, Pisa, Italy*
(4) *Department of Drug Science and Technology, University of Torino, Italy*
(5) *Department of Biochemistry, University of Cambridge, Cambridge, UK*
(6) *Department of Food and Drug, University of Parma, Italy*
Iron is an essential nutrient for almost all organisms and in the human body is primarily bound to the heme cofactor of hemoglobin (Hb), myoglobin and other heme-binding proteins. During infection, *Staphylococcus aureus* exploits Hb heme pool as favored iron source, capturing and internalizing it by cell wall hemophores. The first step is performed by IsdB, which intercepts free Hb and extracts heme. IsdB, a proven virulence factor, is an attractive putative target for antimicrobials development but its mechanism of action needs to be further detailed. To this aim, we used cryo-EM single-particle analysis to study IsdB:Hb complex formation and heme extraction. The key complexes before and after heme extraction were solved at 2.9 and 5.8 ångström resolution using carboxyHb, resistant to heme removal, and oxidized Hb, the physiologic IsdB substrate. IsdB first binds to Hb beta-chains, enhancing Hb dimerization to favor a second IsdB molecule binding to alpha-chains before extraction. These results greatly improve our current knowledge of IsdB structural and functional dynamics, thus promoting future studies on new potential antimicrobials aimed at impairing *S. aureus* iron acquisition.

Temperature dependence iteration of the optical properties of porcine tissue.

Bossi A., Bianchi L., Saccomandi P., Pifferi A.
Politecnico di Milano

The study of the optical properties of a biological sample can be of great interest for the minimally invasive thermal treatment of tumors. We exploited a unique workstation for time-domain broadband diffuse optical spectroscopy to disentangle the absorption and scattering coefficient of a turbid sample based on the photon time of flight. We present a study on the evolution in time of the absorption and scattering coefficient during thermal treatment of a biological muscle sample using a thermal bath. We measured a slower rate of change in the scattering coefficient compared to the absorption coefficient. Different processes govern the two coefficients. The scattering coefficient is related to the tissue microstructure. It increases with cell membrane destruction and protein denaturation caused by heat. The absorption coefficient is related to the chemical composition such as water content and the reaction of the hemoglobin into deoxyhemoglobin. This study is relevant since it can help in deciphering the tissue transformation during thermal treatment, and open to photonics technologies assisting the surgeon in grading the treatment during minimally invasive interventions.

Mechanical cell behaviour alteration triggered by inorganic NPs and cancer thermal therapy using gold core/shell NPs.

De Matteis V., Cascione M., Rinaldi R.
Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, Lecce

Metal oxide NPs are largely used in medicine applications due to their unique physicochemical properties. However, there are many worries regard their toxicity especially from a mechanical viewpoint. Cell mechanics is a critical factor of cell health regulating physiological phenomena. The cell elasticity perturbation in two cancer cell lines (namely intestinal and alveolar) exposed to SiO_2NPs and TiO_2NPs were reported. Cell Young's modulus measurements showed different values in the two cell lines demonstrating the strong correlation between the elasticity alterations and NPs toxicity. Then, the cell mechanics analysis following NP exposure, could represent a new protocol to evaluate the safety of NPs predicting any complications triggered by NPs. Finally, since the inorganic NPs group includes also noble metals, a green protocol was developed to obtain AuNPs with a polyphenols shell, which do not induce macrophages activation. At 43 °C (the temperature used to treat cancer cells by thermotherapy), the polyphenol-shelled AuNPs behave as heat synergized tools in the thermal treatment of two types of cancer cell, breast and neuroblastoma due to the high Au thermal conductivity.

Diatom biosilica in plasmonics: Applications in biosensing and biomedicine.

De Luca A.C. (1), Managò S. (1), Mangini M. (1), De Tommasi E. (2), Zito G. (2), De Stefano L. (2), Tramontano C. (2), Chianese G. (2), Rea I. (2)
(1) *Institute of Endocrinology and Experimental Oncology "G. Salvatore", IEOS, Second Unit, National Research Council, Napoli, Italia*
(2) *Institute of Applied Sciences and Intelligent Systems ISASI, Naples Unit, National Research Council Napoli, Italia*

Diatom microalgae are characterized by nano-structured silica shells, whose optical properties can be exploited in biophotonics and biomedical applications. Metallization of diatom biosilica, both in the shape of intact frustules or diatomite particles (DNPs), can trigger plasmonic effects that in turn can find application in highly sensitive SERS (surface-enhanced Raman scattering) detection platforms, allowing to obtain effective nanosensors at low cost and on a large scale. In this contribution, diatom-based plasmonic devices are developed for SERS imaging of cell membrane components with several exciting prospects including sub-diffraction resolution and single molecule sensitivity which would aid studies of trans-membrane transport dynamics. A hybrid nanoplatform of DNPs decorated by gold nanoparticles and capped by a layer of gelatin was developed for monitoring the drug release in colorectal cancer cells at a femtogram scale by SERS. The combination of the drug-loading capacity of DNPs with the strong Raman enhancement enabled combining therapeutic purposes with label-free intracellular drug monitoring.

Gold nanorods plasmonic chirality allows detection and characterization of alpha-synuclein fibrils generated *in vitro* and *in vivo*.

Longhi G. ([1]), Boujelbene R. ([1]), Abbate S. ([1])([2]), Sandre M. ([3]), Bubacco L. ([3]), Longhena F. ([1]), Pizzi M. ([1]), Bellucci A. ([1])
([1]) *Department of Molecular and Translational Medicine, University of Brescia, Brescia, Italy.*
([2]) *INO-CNR, Brescia Unit, Brescia, Italy*
([3]) *Department of Biology, University of Padova, Padova, Italy*

Alpha-synuclein (αSyn) aggregates are found in Lewy bodies, key neuropathological hallmarks of Parkinson's disease (PD). Recently, it was shown that gold nanorods assume helical arrangements in the presence of human full length (fl) αSyn fibrils, generating optical activity at the plasmon wavelengths. In this way, nanomolar concentrations of both fl and C-terminally truncated (1–120) αSyn fibrils are detected through plasmonic circular dichroism (CD). We worked on fibrils generated *in vitro* from human recombinant fl and (1–120) αSyn and on fibril-enriched protein extracts produced from 1) neuroblastoma cells treated with αSyn monomers either fl or (1–120) αSyn protofibrils; 2) the striatum of mice that received the unilateral injection of adeno associated viral vectors overexpressing human fl αSyn; 3) *post-mortem* brains of PD patients at two different stages of PD. In all cases, characteristic bisignate CD signals were recorded, exhibiting wavelength shift from fl to (1–120) αSyn fibrils. Also, sign reversal of the CD couplet was observed from *in vivo* to *in vitro* fibrils, supporting that chiroptical spectroscopies are sensitive to fibril handedness and different morphologies.

Improving the efficiency of virtual screening by filtering ligands conformations through a new shape-matching algorithm.

Basciu B. ([1]), Venanzi N.A.E. ([2]), Manganelli B. ([3]), Malloci G. ([1]), Dikicioglu D. ([2]), Ruggerone P. ([1]), Bosin A. ([1]), Vargiu A.V. ([1])
([1]) *Department of Physics, University of Cagliari, Cittadella Universitaria, Monserrato, CA, Italy*
([2]) *Department of Biochemical Engineering, University College London, London, UK*
([3]) *London, UK*

Modern drug design relies crucially on the accurate knowledge of the structures formed by a putative drug with its receptor(s). Computational methods such as molecular docking, which aims to reproduce drug-receptor complexes in silico, have become established tools in this context. Unfortunately, the accuracy of docking is severely constrained by conformational changes taking place upon binding, which are rarely considered by standard methods. Recently, we proposed "EDES", a new computational protocol able to generate bound-like conformations of several protein targets. Accurate description of ligand flexibility is equally crucial, particularly in a virtual screening (VS) context where structures of thousands of ligands are generated without considering any structural adaptation functional to binding. To address this issue, we developed a strategy to select, from a set of ligand structures, only those that snugly fit into the binding site of a receptor. We tested the method on the DUD-e dataset, widely employed to benchmark VS pipelines. Coupled with EDES, our method predicted the true complex structure of all the systems tested while saving a large fraction of computational time.

Calcium binding and induced folding of osteocalcin as a function of its carboxylation degree investigated by biophysical approaches.

Natalello A., Ami D., Bovio F., Santambrogio C., Grandori R., Cipolla L.
Department of Biotechnology and Biosciences, University of Milano-Bicocca, Milan, Italy

Osteocalcin (OC) is a 49-amino-acids protein that plays several biological roles, from regulation of bone mineralization to biomarker of bone turnover and metabolic hormone. *In vivo*, OC undergoes vitamin-K-dependent γ-carboxylation of three glutamyl residues. In this contribution, the behaviour of the eight differently carboxylated OC forms has been investigated through biochemical and complementary biophysical approaches: circular dichroism and Fourier transform infrared spectroscopies, native mass spectrometry and isothermal titration calorimetry. In particular, we found that the carboxylation degree affects the affinity for Ca^{2+} ions, the secondary structure of the free OC variants and the calcium-induced conformational transition of the proteins. Interestingly, the complementary information obtained by these biophysical approaches clearly disclosed that the three γ-carboxyglutamic acids of OC are not equivalent for calcium affinity and protein conformational features. Our data could provide a structural explanation of the very different biological roles of this multifunctional protein. This work has been supported by Fondazione Cariplo, grant No. 2018-0458.

Aula L - Christa Mc Auliffe **ore 15:00 – 18:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiede: Capuani S. (ISC-CNR, Roma)

Relazioni su invito

▲ **The EuPRAXIA project: A plasma-based accelerator user facility for the next decade.**
Ferrario M.
INFN, Laboratori Nazionali di Frascati
The EuPRAXIA project, European Plasma Research Accelerator with eXcellence In Applications, is expected to provide by the end of 2028 the first European Research Infrastructure dedicated to demonstrating usability of plasma accelerators delivering high-brightness beams up to 1–5 GeV for users. Recently the European Strategy Forum on Research Infrastructures (ESFRI) has assessed the maturity of the EuPRAXIA project during the last review of new research infrastructures for Europe, leading to the inclusion of EuPRAXIA in the ESFRI Roadmap 2021. Among the possible EuPRAXIA applications the realization of a short-wavelength Free Electron Laser (FEL) able to provide radiation in the "water window" of the e.m. spectrum for bio-physical investigations is one of its main goals. The production of high-quality electron beam as the one required to drive an FEL is expected to be also a fundamental milestone towards the realization of a plasma driven future Linear Collider (LC). In this talk we report about the recent progress in the context of the EuPRAXIA collaboration with particular emphasis to the recent breakthrough results obtained at the EuPRAXIA test facility SPARC_LAB at INFN-LNF.

▲ **First results with Hydrogenated Amorphous Silicon devices to detect ionizing radiation fluxes.**
Servoli L. (1), Calcagnile L. (2), Caricato A. P. (2), Cirrone G.A.P. (3), Croci T. (4), Di Lorenzo R. (1), Fabi M. (5), Falciglia P.P. (3), Frontini L. (6), Cuttone G. (3), Gianfelici B. (7), Grimani C. (5), Ionica M. (1), Italiani M. (1), Kanxheri K. (7), Large M. (8), Liberali V. (6), Martino M. (2), Maruccio G. (2), Mazza G. (9), Menichelli M. (1), Milluzzo G.G. (3), Monteduro A.G. (3), Morozzi A. (4), Moscatelli F. (10), Pallotta S. (11), Paolucci M. (1), Passeri D. (4), Patti I.V. (3), Pedio M. (1), Petasecca M. (8), Petringa G. (3), Peverini F. (7), Piccolo L. (9), Placidi P. (4), Quarta G. (2), Rizzato S. (2), Rossi G. (1), Stabile A. (6), Talamonti C. (11), Torrisi A. (2), Wheadon R.J. (9), Villani M. (5), Wyrsch N. (12)
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(5) *INFN, Sezione di Firenze e DISPEA, Università di Urbino "Carlo Bo"*
(6) *INFN, Sezione di Milano e Dipartimento di Fisica, Università degli Studi di Milano*
(7) *INFN, Sezione di Perugia e Dipartimento di Fisica e Geologia, Università degli Studi di Perugia*
(8) *Centre for Medical Radiation Physics, University of Wollongong, Australia*
(9) *INFN, Sezione di Torino*

([10]) *INFN, Sezione di Perugia e CNR-IOM*
([11]) *INFN, Sezione di Firenze e Dipartimento di Scienze Biomediche, Sperimentali e Cliniche "Mario Serio", Università di Firenze, e Medical Physics Unit, AOU Careggi*
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The INFN HASPIDE project (Hydrogenated Amorphous Silicon —a-Si:H— DEtectors) aims to develop a-Si:H sensors to be employed in three use cases: 1) monitoring of ionizing radiation beams, of both particles and photons; 2) detection of Solar Energetic Particles in the spatial environment; 3) neutron detection after deposition of a thin layer of ^{10}B over the a-Si:H structures. a-Si:H devices have already been used to monitor proton therapeutic beams at CNAO. The material showing intrinsic radiation resistance can be deposited in thin layers over many different substrates, including plastic ones like Kapton or Mylar. The radiation hardness will ensure the sensor operation also in very harsh environments. On the other hand the possibility to realise detector in matrix configurations deposited on flexible thin substrate could provide innovating monitoring system at the accelerators-in-the-air exit window giving real-time information about beam size and flux. The first results with prototypes exposed to X-ray beams show a linear response in current as a function of the dose rate, with a relative uncertainty of about 1–2% with two types of devices: p-i-n diodes and charge selective contacts.

▲ **New methodologies in the stable isotope analysis for cultural heritage.**

Lubritto C., Tafury M.A., Soncin S., Farese M., Formichella G., Panella S., Bernardini S., Cocozza C., Di Cicco M., Altieri S., Mantile N.
iCONa Lab, isotope Carbon Nitrogen Oxygen analysis, and Marea Centre, Mediterranean bioarcheology Research Advances, of the University of Campania - DiSTABiF e University of Rome La Sapienza

In the last decades there has been a growing interest about archaeometric researches upon osteoarcheological remains as a source of information to investigate past lifestyles. In particular stable isotope analysis carried out on human archaeological tissues or bone, with the aim of investigating different aspects of human lifeways (*e.g.*, subsistence practices) is nowadays a common procedure in bioarchaeological research. Indeed stable isotope analysis of collagen, the organic component of the bone, allows us to gather a wealth of information ranging from paleo-diet, climate changes, social status, exploitation of local resources, migrations, weaning age, breeding and farming practices of ancient populations. In the present paper we present some recent methodologies introduced in these field such as: i) incremental dentine isotopic methodologies; ii) Bayesian modelling tool; iii) carbon and nitrogen isotope analysis of amino acids (compound-specific isotope analysis of amino acids CSIA-AA). These approaches were tested on sample coming from different sites (Pompeii, Ostia, Herculaneum) to investigate the life of ancient community in some of the central economic hubs of the Roman Empire.

Comunicazioni

● **Monte Carlo study of 3D image reconstruction of boron dose distribution in BNCT with CZT-based Compton camera.**

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The Boron Neutron Capture Therapy (BNCT) is a innovative radiotherapy with high selectivity capability over cancer tissue based on $^{10}\mathrm{B}(\mathrm{n},\alpha)^{7}\mathrm{Li}$ reaction. One of the main issues of BNCT effectiveness is to have a qualified *in vivo* imaging dosimetry method. In this context it becomes important to be able to reconstruct the spatial distribution of the dose in the area of interest and the related isodose curves with imaging technique methods such as emission computed tomography. It has been proposed to reconstruct *in vivo* imaging of the spatial distribution of the dose from $^{10}\mathrm{B}$ by "Compton Camera techniques", taking advantage of the 478 keV photon emitted. In this contest is has been proposed a 3D cadmium-zinc-telluride (CZT) based drift strip detector, able to perform room temperature measurements of photon energy, timing and 3D positioning up to the MeV region. In this contribution we have performed Monte Carlo simulations and image reconstruction with iterative methods and morphological filtering to study the real-time imaging therapeutic dose monitoring capabilities of 3D CZT parallel planar field sensors using different gamma source configurations.

Space charge analysis for photoinjector emittance compensation.

Carillo M. ([1])([4]), Behtouei M. ([3]), Bosco F. ([1])([4]), Chiadroni E. ([1])([3]), Camacho O. ([2]), Faillace L. ([1])([3]), Ficcadenti L. ([4]), Fukasaway A. ([2]), Giuliano L. ([1])([4]), Migliorati M. ([1])([4]), Mostacci A. ([1])([4]), Spataro B. ([3]), Rosenzweig J.B. ([1])([2]), Palumbo L. ([1])([4])
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([3]) *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionale di Frascati*
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Beam dynamics studies are performed in the context of a C-band hybrid photo-injector project developed by a collaboration between UCLA/Sapienza/INFN-LNF/RadiaBeam. From the analysis of the beam-slice evolution, a more accurate compensation of the beam emittance is obtained. Emittance oscillations are studied by means of the slice analysis, which allows correlation of the position of the emittance minima with the slope of the slices in the transverse phase space. Furthermore, the significant reduction in the normalized emittance observed by varying the transverse shape of the beam while assuming a longitudinal Gaussian distribution has been analytically justified. Indeed, a new method for deriving the expression of space charge forces has shown that the emittance growth is due to nonlinear space-charge fields that occur immediately after the beam emission from the cathode, giving insight into the optimum laser profile needed for minimizing the emittance.

Preliminary results on a new Thomson Parabola Spectrometer design for laser-driven ion accelerators.

Kurmanova A. ([1])([2]), Cirrone G.A.P. ([1])([1]), Petringa G. ([1])([3])
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Advances in laser technology have paved the way for extensive use of laser based particle accelerators for several scientific and technological applications, including compact systems for radiation therapy. The latter has attracted much attention due to its smaller size, lower costs, and radiation safety requirements, compared to conventional particle accelerators. However, diagnostic solutions for the characterization of laser-plasma beams are as limited as essential, owing to the complex mix of energies and emittance of particles present. The

Thomson Parabola Spectrometer (TPS) is a promising tool, capable of analyzing various aspects of high-energy ion beams from laser-based accelerators. We present here the first results on the design and realization of a custom TPS developed at INFN-LNS suited to the requirements of a laser-driven beam. The design is performed in the MC simulation toolkit TOPAS which allows modification of TPS parameters according to experimental configurations, as well as properties of the source.

A boron-coated GEM detector for thermal neutron transmission: Design and first results.

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Experiments at modern neutron spallation sources require an ever increasing number of detectors with advanced features such as high spatial resolution and high detection efficiency. The most common neutron detector is based on ^{3}He, but the well-known ^{3}He shortage makes this kind of detectors not a valuable option. A suitable alternative are gas-based detectors like GEM-based ones. The detector presented in this contribution is characterised with the presence of the innovative boron-coated GEM foils (BGEM), a standard GEM foil coated on both sides with a boron layer. The presence of many BGEM foils, at least 6 or more, will allow to reach an expected detection efficiency in the order of 20%. This contribution presents the design of the detector, the numerical simulation of a multi-layer boron-coated GEM (MBGEM) detector and the preliminary tests of a prototype at L.E.N.A reactor. The MBGEM detector prototype has been built up in two configurations, with either 3 (3MBGEM) or 6 (6MBGEM) foils in order to study the rise of the detection efficiency with the number of layers. Data analysis shows that the detection efficiency rises from 7% for the 3MBGEM detector to 11% for the 6MBGEM.

Development of a new device for thermal neutrons detection by using a sandwich of two high-purity ^{10}B enriched layers.

Provenzano C. (1)(2), Caricato A.P. (2)(3), Marra M. (2)(3), Finocchiaro P. (4), Amaducci S. (4), Calcagnile L. (2)(5), Martino M. (2)(3), Quarta G. (2)(5)
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We report on the development of a new device for the detection of thermal neutrons by using a sandwich of two ^{10}B-enriched conversion thin films, grown by PLD, coupled with two silicon detectors. As for the conversion materials, ^{10}B is one of the most valid choices, thanks to its high neutron capture cross-section and relatively high Q value. In previous works we have already shown the possibility to grow by PLD high quality, large area ^{10}B thin films which coupled with Si detectors showed good performances for thermal neutron detection. In the frame of the INFN BoLAS_NEXT our research efforts have been focused in the development of a new set-up aimed at improving detection efficiency, sensitivity and discrimination against gamma background, produced by neutron capture reaction. This new detection geometry involves the combined use of two conversion layers (1.5 μm thick) and two solid state silicon detectors, with the main goal of enhancing the detection efficiency compared to the single-layer geometry. We present the obtained results with improved efficiency, when our detector is exposed to a neutron flux. Comparison of experimental data with Geant4 simulations is also provided.

Investigazione di reperti dell'età del bronzo con XRF, microscopia ottica e metodi Monte Carlo.

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I moderni sviluppi di tecniche non distruttive per lo studio quantitativo e qualitativo di antichi manufatti offrono oggi nuove opportunità di ricerca per la metallurgia antica. Specialmente in presenza di manufatti di particolare valore storico/archeologico, analisi non distruttive sono infatti le uniche tecniche di investigazione utilizzabili. In questo contributo, si presenteranno dei recentissimi risultati di un'indagine di fluorescenza a raggi X in dispersione di energia su reperti in lega aurea e in bronzo, risalenti all'età del bronzo e probabilmente di origine Egea, appartenuti all'insediamento protostorico di Roca (Melendugno, Lecce). Per l'indagine di diversi preziosi ornamenti in lega aurea, l'analisi XRF è stata affiancata da un'investigazione di microscopia ottica, che permette di risalire con maggiore accuratezza alle tecniche di lavorazione usate per la produzione degli artefatti. Per i reperti in bronzo, si discuterà l'opportunità di usare metodi avanzati Monte Carlo per l'interpretazione quantitativa degli spettri in fluorescenza, al fine di preservare completamente gli oggetti anche in presenza di strati superficiali di ossidazione del materiale.

Multi-technique device for *in situ* analyses based on a single X-ray source.

Sottili L. (1)(2), Re A. (1)(2), Guidorzi L. (2)(1), Magalini M. (1)(2), Marabotto M. (1)(2)(3), Vigorelli L. (1)(2)(3), Castelli L. (4), Czelusniak C. (4), Giuntini L. (4)(5), Massi M. (4), Mazzinghi A. (4)(5), Ruberto C. (4)(5), Taccetti F. (4), Torres R. (6), Arneodo F. (6), Lo Giudice A. (1)(2)
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In the last decades the role of non-invasive non-destructive X-ray–based analysis techniques has become more and more important in the field of heritage science due to the successful results obtained for diagnostic and preservation of works of art. INFN-CHNet, the network of the Italian National Institute for Nuclear Physics (INFN) devoted to Cultural Heritage, has been created for developing instruments and methods in this field. Among the others, a new bench-top multi-technique device, based on the INFN-CHNet MA-XRF scanner, has been developed. The available techniques of this instrument are X-ray fluorescence (XRF), X-ray–induced luminescence (XRL), and radiography (RX). XRF is a leader technique for composition analysis. The potentiality of XRL in cultural heritage field was recently tested to study the provenance of lapis-lazuli. The usefulness of RX technique is well established, for instance to study the conditions of panel paintings and wooden statues. Results will be presented.

An easy method to obtain thin piezoelectric composite based on polyvinylidene fluoride.

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Polyvinylidene fluoride (PVDF) is a polymer existing in several phases, characterized by a different atomic configuration of the polymer chains. In its β phase it arranges in an all-trans configuration with dipolar symmetry, exhibiting piezoelectric effects. During the production of thin PVDF films by spin coating, the polymer chains are not aligned with each other, and the dipoles are not oriented. To achieve the desired piezoelectric behavior, it is necessary to optimize the chain alignment and dipole orientation processes. The aim of this paper is to provide an easy process to maximize the percentage of the β phase in the polymer realization. Moreover, an experimental methodology to achieve a high electro-mechanical coupling efficiency in the polymer piezoelectric material will be presented. The efficiency of such methods will be assessed through FTIR and Raman spectroscopies and the mechanical properties of the film will be evaluated with dynamic mechanical tests. Moreover, to exploit its application as an electrode, a completely organic piezoelectric composite made of PVDF and carbon nanotubes will be presented. Authors gratefully acknowledge the financial support of the Consiglio Nazionale delle Ricerche – within CNR-STFC Grant Agreement [No. 2014-2020 (N 3420)] concerning collaboration in scientific research at the ISIS (UK) of STFC – and of the JRU ISIS@MACH ITALIA, Research Infrastructure hub of ISIS (UK) – MUR official registry U. 0008642.28-05-2020.

Aula I **ore 15:00 – 17:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali

SIMPOSIO DI OPTOMETRIA

Presiedono: Bussa M.P. (Università di Torino)
Gurioli M. (Università di Firenze)

Comunicazioni

Brain correlates of adaptation to multifocal contact lenses.

Zeri F. (1)(2)(3), Berchicci M. (4)(5), Bianco V. (4)(6), Borghesi A. (1)(2), Di Russo F. (4)(7), Di Vizio A. (8), Lucia S. (4), Naroo S. (3), Pitzalis S. (4)(7), Ponzini E. (1)(2), Tavazzi S. (1)(2)
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One billion and 300 million people worldwide are currently affected by presbyopia. One common option to correct presbyopia is providing simultaneous images with multifocal contact lenses (MCLs). However, patient satisfaction with MCLs is not uniform and not fully predictable. Understanding the neuroadaptation mechanisms behind MCLs use would have important clinical implications. In this study the cortical activity in visual and non-visual areas just after neophyte presbyopes were corrected with MCLs, was studied measuring visual evoked potentials with a high-density electrode array. Multifocal presbyopia corrections produced a loss of feedforward activity in the primary visual cortex (C1 and N1 amplitude reduction) that was compensated by extra feedback activity from other areas (enhanced amplitude of the P1 and the P2 components). This compensation seems to be engaged only in extrastriate areas, but in both early and late visual processing.

Comparison of visual performance of dual focus contact lenses for myopia control *vs.* single vision contact lenses.

Villani V., Pietroni D., Offi F., Petrini D.
Dipartimento di Scienze, Università degli Studi Roma Tre, Roma

Myopia is a globally widespread ametropia; this has led to the development of approaches for slowing myopic progression, including the use of specific dual focus (DF) contact lenses (CL) for myopia control. In this study the visual performance of a dual focus lac (MiSightTM) and a single vision (SV) CL (Bausch & Lomb Ultra) were compared. For this, 25 subjects (15 ± 3), myopic (Sp from -0.50 D to -6.00 D) with max astigmatism of 1.00 CD were recruited. A preliminary visit to verify the inclusion criteria of the study was performed. During this visit, monocular and binocular visual acuity (VA) with spectacles were recorded and corneal topoaberrometry (Keratron Onda) was performed. Subsequently, for each subject, monocular and binocular Low Contrast Visual Acuity (LCVA) and High Contrast Visual Acuity (HCVA), were assessed, with the DFCL and with the SVCL; visual quality was objectively evaluated by performing Total Ocular Aberrometry. The results obtained will be presented to evaluate the effect of dual focus CL on vision.

Visual performance with an extended depth of focus contact lens for myopia control and corneal topography in assessing lens centration.

Rizzo G. (1)(2), Borghesi A. (1)(2), Di Vizio A. (3), Ponzini E. (1)(2), Tavazzi S. (1)(2), Zeri F. (1)(2)(4)
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Increasing in myopia prevalence worldwide led to develop control strategies to slow down myopia progression. One option is represented by extended depth of focus (EDOF) contact lens (CL) to control retinal defocus. Decentration in EDOF CLs can decrease the quality of vision. This study was carried out to evaluate accuracy and repeatability of the centration assessment of EDOF CLs using corneal topography, and to compare the visual performance of EDOF with a control single vision CL. For each EDOF CL, a topography over the CL and a slit lamp (SL) digital picture were taken. For the SL images, a software was used to assess the position of the lens; for the topography acquisitions, the position was detected using a qualitative procedure, by two observers and repeated after 15 days. Visual acuity (VA), with both lenses, was evaluated at high and low contrast. After the analysis, the accuracy of the topographic assessment with respect to SL assessment resulted good. Intra- and inter-observer reliability of the measurement were good, but the clinical experience of the observer affected the repeatability of the method. VA with EDOF CLs was significantly lower compared to single vision CL.

The effects of smoking on the tear film and on soft contact lenses.

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Smoking is frequently associated with systemic and ocular diseases. Considering the fundamental role in eye health of the precorneal tear fluid, its analysis could offer unique contributions to gather information on the ocular status. Smoking has a negative effect on tear film stability and quality by affecting different components, which can be assessed only by multiple tests. In addition, smoking is a risk factor for microbial keratitis and corneal infiltrates in contact lens (CL) wearers. In this contribution, we analyzed the interaction between nicotine and CL materials. CLs from FDA groups I, II, IV, and V were incubated in a nicotine solution for 24 h and then in a saline solution for the next 24 h. We monitored the amount of absorbed and released nicotine per CL by ultraviolet spectrophotometry, normalizing to the mass of the hydrated CL. Group IV and V CLs displayed the highest and lowest nicotine absorption, respectively. The results suggest that CL affinity for nicotine could be ascribed to the interaction between the positive charge of nicotine pyrrolidine nitrogen and the negative charges of the CLs.

Analisi tribometrica della superficie di Lenti a Contatto.

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La ricerca scientifica sulle Lenti a Contatto (LAC) continua ad essere sollecitata al fine di minimizzare il discomfort, riducendone così il drop out. In questa prospettiva, la conoscenza della proprietà tribologiche di superficie delle LAC assume un ruolo fondamentale. Il gruppo di ricerca CeRCA dell'Università del Salento ha messo a punto un protocollo di analisi, basato sull'uso del Nanotribometro NTR3 (Anton Paar), per la determinazione del coefficiente di attrito dinamico delle LAC, in risposta ad una pressione applicata pari a quella esercitata dalla palpebra durante un ammiccamento e sull'uso di AFM per la determinazione della morfologia superficiale. Il protocollo di misura ottimizzato prevede un ambiente di misura liquido, non solo soluzione fisiologica ma anche soluzioni per la manutenzione. I risultati delle analisi realizzate su diverse LAC morbide e giornaliere commerciali appaiono in accordo con i valori forniti dalle aziende produttrici, confermando la bontà del protocollo di misura messo a punto che si intenderà usare per la caratterizzazione sia di nuovi polimeri biocompatibili sia dell'impatto di nuovi sostituti lacrimali sulla risposta tribometrica delle LAC.

Lactoferrin as a biomarker of ocular diseases and contact lens discomfort.

Ponzini E. ([1])([2]), Borghesi A. ([1])([2]), Grandori R. ([3]), Santambrogio C. ([3]), Scotti L. ([4]), Tavazzi S. ([1])([2]), Zambon A. ([1]), Zeri F. ([1])([2])
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Lactoferrin (Lf) is frequently described as a diagnostic marker for different ocular diseases, such as dry eye (DE), Sjögren syndrome, and diabetic retinopathy. We therefore performed a meta-analysis on the average Lf concentration in healthy subjects and those affected by ocular diseases. The results suggest that Lf level is a good candidate as DE syndrome diagnostic biomarker, even though there is still a need for further development of standardized protocols of tear collection, processing and storage. To investigate Lf as a biomarker for contact lens (CL) discomfort, we developed a diagnostic method based on terbium fluorescence to detect Lf directly into human tears. Lf concentration was found to be unchanged after a period of CL wear and after a period of CL suspension. Instead, the results reveal a significant change in Lf affinity for terbium upon CL wear. An alteration of the protein conformational state or of its substrate-binding site leads to protein inactivation and triggers an inflammatory response. Indeed, high levels of protein denaturation have been found to be correlated with adverse effects, such as papillary conjunctivitis and CL discomfort.

Photochromic contact lenses: Optical analysis and visual effects of their transition dynamics.

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Department of Physics and Astronomy "G. Galilei", University of Padova

Since their introduction, the evolution of contact lenses has been mainly routed by criteria of wearing comfort, increased oxygen permeability, and correction of refractive errors, while less attention has been paid to the improvement of visual functions. More recently, a new type of contact lens has been designed and marketed containing photochromic additives that enable the filtering in the visible range depending on the intensity and spectrum of the environmental light. In this contribution, we have characterized the dynamics over time of commercial photochromic contact lenses in order to quantify their filtering effect in the visible as a function of the input wavelength and estimate the transition time necessary for their activation and deactivation. In addition, we have compared the influence of photochromic contact lenses *vs.* standard non-photochromic control lenses on visual functions during specific indoor and outdoor activities. The present research encompasses an optical characterization of the constituent photosensitive material and an investigation of the expected visual benefits provided by the use of this new type of optical devices.

Haidinger's brushes: Perceiving the polarization of light via an entoptic phenomenon.

Ruffato G., Mottes J., Ortolan D.
Department of Physics and Astronomy "G. Galilei", University of Padova

Entoptic phenomena are visual artifacts arising from the interaction of light with the specific physical structure of the eye. While they are too subtle to actually enable additional visual abilities, their perception can provide indirect information on the physiological conditions of the visual system. Among the most famous ones, Haidinger's brushes consist in the appearance of a yellowish bow tie perceived in the presence of linearly polarized white light and arise from the particular spatial distribution of dichroic carotenoid molecules forming a sort of embedded radial polarizer in the macula. We have developed a compact versatile optical setup for the psychophysical analysis of the perceptual threshold of such entoptic effect. The tests on a group of 113 healthy individuals under conditions of maximum contrast (blue light) reveal the human capability to perceive an average polarization degree around 16%. The same analyses in white light suggest a polarization sensitivity around 55%. The developed prototype outlines a new platform to train the user in the perception of polarization and can help infer the condition of macular pigments allowing for early diagnosis of diseases.

Measurement of tear volume using Strip Meniscometry: Two procedures compared.

Giusti S., Lorè F., Lupelli L.
Dipartimento di Scienze, Università degli Studi Roma Tre

Introduction: Strip Meniscometry (SM) is an available tear test, designed to touch the strip into the lower marginal tear meniscus, which allows a rapid assessment of tear volume *in vivo*. Purpose: To compare the results obtained using the same examination procedure with and without the aid of the slit lamp (SL). Materials and methods: A stopwatch, a thermo-hygrometer, a series of strip-shaped tools composed of a fluid-absorbing material (Vita Tests - Italy) and a SL 990/3 (CSO - Italy) slit lamp, represent the instruments used to carry out the study. Over the course of a month (January 2022) thirty volunteers (23–67 years old) took part in the project. Each subject was subjected to a total of six SM measurements with five minutes interval, three acquired with the aid of SL, three without. Results: Through the construction of the Bland-Altman graph it was possible to note that almost all the experimental points are within the agreed/permitted limits and many of these are evenly distributed around the average. Furthermore, the confidence interval contains zero, a reason that leads us to believe that the two methods can be considered concordant and interchangeable.

Single-tear proteomics for noninvasive biomarker discovery and precision medicine.

Ponzini E. (1)(2), Ami D. (3), Borghesi A. (1)(2), De Palma A. (4), Di Silvestre D. (4), Duse A. (1)(2), Grandori R. (3), Mauri P. (4), Natalello A. (3), Pezzoli F. (1), Santambrogio C. (3), Tavazzi S. (1)(2), Zeri F. (1)(2)
(1) *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, Italia*
(2) *Optics and Optometry research center, COMiB, Università degli Studi di Milano-Bicocca, Italia*
(3) *Dipartimento di Biotecnologie e Bioscienze, Università degli Studi di Milano-Bicocca, Italia*
(4) *Istituto di Tecnologie Biomediche, Consiglio Nazionale delle Ricerche, Italia*

In the last decades, the lacrimal fluid has gained increasing interest as a potential source of biomarkers, thanks to its accessibility, moderate complexity, and responsiveness to physiopathological conditions. Despite the still limited number of studies, tear investigation, in particular single-tear analysis, could offer unique contributions to the identification of non-invasive and easily accessible biomarkers, and to the development of feasible approach to precision medicine. High-performance liquid chromatography-mass spectrometry (LC-MS) has led to promising approaches to tear proteomics, despite the intrinsic limitations in sample amounts that can be collected. By ultrahigh-resolution, shotgun proteomics, we developed and effective analytical pipeline for single-tear analysis and we analyzed the tear fluid of 23 healthy volunteers, achieving high-confidence identification of 890 proteins. This study demonstrates the feasibility of single-tear quantitative proteomics, highlighting the unique contributions that this unconventional body fluid can offer to personalized approaches in biomedicine.

Tear-based vibrational spectroscopy for noninvasive biomarker discovery in amyotrophic lateral sclerosis.

Duse A. (1)(2), Ambrosio F. (3), Ami D. (3), Borghesi A. (1)(2), Cozza F. (2)(4), Grandori R. (3), Lunetta C. (5), Natalello A. (3), Pezzoli F. (1), Ponzini E. (1)(2), Tavazzi S. (1)(2), Zeri F. (1)(2)
(1) *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, Italia*
(2) *Optics and Optometry research center, COMiB, Università degli Studi di Milano-Bicocca, Italia*
(3) *Dipartimento di Biotecnologie e Bioscienze, Università degli Studi di Milano-Bicocca, Italia*
(4) *Centro Clinico NeMO Milano, Italia*
(5) *Istituto Maugeri IRCCS Milano, Italia*

Biofluid analysis by vibrational spectroscopies is gaining interest due to its potential to revolutionize diagnostics and precision medicine. However, the lack of robust biomarkers combined with the unaccomplished identification of convenient biofluids has drastically hampered optical advancements in clinical diagnosis and monitoring of neurodegenerative disorders. Our findings show that vibrational spectroscopy is a new potential amyotrophic lateral sclerosis (ALS) diagnostic approach and indicate that tears are a reliable and non-invasive source of ALS biomarkers. Our proposed approach has been validated using Fourier transform infrared (FTIR) and Raman microspectroscopies. In conjunction with multivariate analysis, this vibrational approach made it possible to discriminate between tears from ALS patients and healthy controls (HCs) with high specificity (97% and 100% for FTIR and Raman spectroscopy, respectively) and sensitivity (88% and 100% for FTIR and Raman spectroscopy, respectively). Additionally, this work allowed us to disclose ALS spectroscopic markers related to protein and lipid alterations, as well as to a reduction of the phenylalanine level, in comparison with HCs.

Valutazione della densitometria corneale da immagini tomografiche in occhi normali e con cheratocono.

Frisani M., Bussa M.P., Carpi F., Gazzera P., Greco M.
CdL Ottica e Optometria, Dipartimento di Fisica, Università di Torino, Italia

La perdita di trasparenza del tessuto corneale è un elemento fondamentale da monitorare nella pratica oftalmica. Essa può essere sintomatica di molte condizioni: alterazioni della fisiologia, esiti di infezioni, degenerazioni del tessuto e distrofie corneali come il cheratocono. Il cheratocono è un'ectasia corneale caratterizzata da un progressivo assottigliamento e dalla deformazione. Per questa patologia, l'insorgenza nei due occhi non è simultanea (bilateralità asimmetrica). Sono state analizzate 180 immagini del segmento anteriore di 60 occhi normali e 50 immagini di occhi appartenenti a 22 soggetti con cheratocono evidente solo in un occhio. Per ciascuna tomografia, acquisita con il tomografo Sirius (CSO Italia) dotato di Scheimpflug camera, sono stati segmentati i due principali strati, stroma ed epitelio, entro i 3 mm di diametro centrali ed è stato stimato un valore densitometrico con un'analisi eseguita, lungo il meridiano orizzontale, nell'ambiente di calcolo MATLAB. Le segmentazioni sono state classificate e i valori densitometrici sono stati confrontati con gli studi riportati in letteratura usando tomografie Pentacam®.

Aula C - Maria Gaetana Agnesi **ore 15:00 – 18:30**

SEZIONE VII
Didattica e storia della fisica
Presiede: LA RANA A. (Università di Verona)

Relazioni su invito

▲ Cristalli e vetri... in medio stat virtus: Quasicristalli.

BINDI L.
Dipartimento di Scienze della Terra, Università degli Studi di Firenze

Il mondo ben ordinato dei materiali solidi è stato costretto a rivedere le sue regole quando circa quaranta anni fa è stato scoperto un nuovo "tipo" di materiale, i quasicristalli. Questi materiali, a differenza dei cristalli ordinari, mostrano una disposizione atomica che è quasi-periodica. Ciò significa che in essi due o più gruppi atomici si ripetono a intervalli diversi e che il rapporto fra tali periodi di traslazione è irrazionale cioè non esprimibile come frazione; in altre parole, presentano una sorta di dissonanza nello spazio. Poiché sono quasiperiodici, i quasicristalli possono avere delle simmetrie di rotazione vietate nei cristalli ordinari, inclusa la simmetria pentagonale in un piano o una simmetria icosaedrica in tre dimensioni. Ma possono esistere in natura? La scoperta del primo quasicristallo naturale, della sua formazione agli albori del sistema solare e della spedizione scientifica nelle remote terre siberiane alla ricerca di nuovi campioni, verrà presentata raccontando tutti gli eventi che si sono succeduti durante questa incredibile avventura scientifica.

▲ Post-war reconstruction in Milan: The three accelerators.

GARIBOLDI L.
Dipartimento di Fisica "Aldo Pontremoli", Università degli Studi di Milano, Italia

While Giovanni Gentile jr and Giovanni Polvani showed some interest in planning an accelerator for the Institute of Physics of Milan University already before the post-war reconstruction (actually a new construction) — *e.g.* with the suggestion to Giorgio Salvini to study a feasibility project of a betatron — the actual possibility of building a machine in Milan only materialized in the post-war period. The Institute of Physics and two research institutions very closely connected to it such as CISE and INFN managed to equip themselves with accelerators for theoretical and applicative research in nuclear physics: the CISE Cockcroft-Walton and the INFN linear accelerator in the 1950s, and the cyclotron of the Institute of Physics in the 1960s. The aim of this report is to describe the historical-scientific context that saw the creation of these new research tools in close connection with the developing interests of the Lombard industrial environment.

▲ Un percorso semplificato per introdurre la trasformata di Fourier tramite smartphone e altri dispositivi con sensori.

TUFINO E., OSS S., GRATTON L.
Dipartimento di Fisica, Università di Trento, Via Sommarive 14, 38123 Trento, Italia

Negli ultimi anni si è diffuso l'uso degli smartphone o di Arduino e altri dispositivi dotati di sensori (come iOLab), introducendo così, in modo semplice e poco costoso, tecniche digitali per l'acquisizione dei dati in laboratori introduttivi di fisica. Tali dispositivi consentono di calcolare e di visualizzare graficamente la trasformata di Fourier dei segnali acquisiti tramite i sensori. In questa comunicazione presentiamo un percorso didattico, adatto per gli ultimi anni del liceo o per un corso introduttivo di fisica, in cui, dopo aver introdotto gli aspetti più importanti della trasformata di Fourier in ambito digitale ed esplicitato tramite esempi il teorema di Nyquist e il fenomeno dell'aliasing, si applica la trasformata in esperimenti di meccanica, acustica ed elettromagnetismo con l'utilizzo di vari sensori. Si mostrerà anche l'uso della trasformata di Fourier in un esperimento in cui si impiega un sensore di luce per misurare l'intensità luminosa dello schema di interferenza prodotto da un interferometro di Michelson-Morley.

Comunicazioni

Giorgio Salvini (1920-2015): L'uomo e lo scienziato.

Pancheri G. (1), Bonolis L. (2)
(1) *INFN Laboratori Nazionali di Frascati*
(2) *Max Planck Institute for the History of Science, Berlin, Germany*

Si ricorda Giorgio Salvini nel 102mo anniversario della nascita, illustrando i tanti e diversi contributi da lui dati alla scienza italiana e internazionale. Salvini è stato primo direttore e artefice dei Laboratori Nazionali dei Frascati dell'INFN. Con la costruzione dell'elettrosincrotrone da 1100 MeV nel 1959, e l'approvazione della costruzione di AdA, il primo anello di accumulazione al mondo per elettroni e positroni nel 1960, Salvini ha garantito l'ingresso dell'Italia nel mondo della grande fisica delle particelle elementari, presente in prima persona alle scoperte degli anni '70 con ADONE, guidando la partecipazione italiana alle scoperte del bosone intermedio al CERN, e preparando le nuove generazioni alla scoperta del bosone di Higgs. Professore di Fisica Generale presso l'Università di Roma ha ispirato generazioni di studenti, alcuni dei quali iscritti a Fisica a seguito delle Lezioni di Fisica da lui trasmesse dalla Rai-TV nel 1959. Salvini fu anche Presidente dell'INFN, poi dell'Accademia dei Lincei e Ministro nel governo Ciampi.

Direzioni: Un secolo di storia dell'Istituto di Fisica di Catania attraverso l'opera dei suoi direttori.

Geraci E. (1)(2), Lombardo I. (2), Pellegriti M.G. (2), Di Gregorio P. (3), Grimaldi M.G. (1)
(1) *Dipartimento di Fisica ed Astronomia, Università di Catania, Catania, Italia*
(2) *Istituto Nazionale Fisica Nucleare - Sezione di Catania, Catania, Italia*
(3) *Dipartimento di Scienze Politiche e Sociali, Università di Catania, Catania, Italia*

Il contributo presenta la genesi e la realizzazione del volume, di prossima pubblicazione sui Quaderni di Storia della Fisica, riguardante i direttori dell'Istituto di Fisica dell'Università di Catania dal 1870 al 1970. Le figure dei direttori descritte nel volume si sviluppano durante un secolo di progressiva crescita dei dipartimenti scientifici, e includono scienziati che hanno visto Catania come una parentesi della propria carriera accademica (quali Bartoli, Cocconi, Carrelli), scienziati che hanno profuso un costante impegno nei confronti dell'Istituto Etneo (vedi Grimaldi, Bellia, Ricamo), teso a consolidarne e garantirne la crescita, e altri (vedi Quercia) che hanno supportato l'Istituto alternando gli impegni sull'Isola con quelli per gli enti di ricerca nazionali a Roma. Il contributo si propone di offrire un momento di analisi e studio della nascita e dello sviluppo di un istituto, tramite le diverse azioni realizzate dalle figure guida del dipartimento, descrivendo un paradigma comune alle università italiane a cavallo dei due secoli.

Beyond disciplinary frontiers: The value of the history of science in teaching.

Fortino M.
Liceo Classico Statale "Bernardino Telesio" - Cosenza

"The legitimate, safe, fruitful method, capable of preparing a mind to accept a physical hypothesis is the historical one", argued the French theoretical physicist Pierre Duhem (1861-

1916), in La théorie physique: son objet et sa structure (1906). Starting from this position of thought, with this contribution we want to broaden our gaze to try to briefly outline an "overall conception" of the history of science, in the light of its possible declinations and its epistemological implications, beyond the disciplinary frontiers , to foster a true education of the mind or, better, to understand, according to the French style, the formative value of a philosophical history of science in teaching.

Futuri insegnanti di Fisica e Matematica a confronto con le discipline e l'interdisciplinarità: Il caso del moto parabolico.

Branchetti L. (1), Satanassi S. (2), Fantini P. (2), Levrini O. (2)
(1) *Università Statale di Milano*
(2) *Università di Bologna*

Nell'ambito del progetto Erasmus+ IDENTITIES, un team di ricercatrici nelle didattiche disciplinari (matematica e fisica, in particolare) sta elaborando un modello di formazione iniziale per insegnanti incentrato sull'interdisciplinarità. Al centro di questo nuovo approccio ci sono la problematizzazione dell'interdisciplinarità, vista spesso come l'attraversamento di confini rigidi tra domini del sapere, e la presa di consapevolezza da parte dei futuri insegnanti di cò che caratterizza le discipline stesse. Combinando il quadro teorico di Akkerman e Bakker (2011) relativo alle dinamiche di confine, e il Family Resemblance Approach di Erduran e Dagher (2014), verranno presentati alcuni risultati di ricerca relativi a sperimentazioni (Bologna, Parma e Milano) sul tema del moto parabolico che hanno visto coinvolti studenti universitari di Matematica e Fisica. In particolare si mostrerà come al cuore del processo di appropriazione del tema ci possano essere due dinamiche profondamente diverse, quelle dello scambio o dell'accettazione della trasformazione del proprio punto di vista. Verrà inoltre discusso il ruolo di scaffolding delle lenti teoriche condivise con gli studenti.

Il LES come modello d'intervento: Un percorso tra ricerca e didattica della fisica.

Artiano G. (1)(2), Balzano E. (2)(3), Piccialli P. (3)
(1) *Dipartimento di Matematica e Fisica, Università della Campania "Luigi Vanvitelli", Caserta*
(2) *Dipartimento di Scienze Formative, Psicologiche e della Comunicazione, Università Suor Orsola Benincasa, Napoli*
(3) *Dipartimento di Fisica, Università degli Studi di Napoli Federico II*

In che modo le attività scientifiche nei contesti informali possono contribuire al miglioramento dell'insegnamento e dell'apprendimento della fisica a scuola e nell'università? Questa è una delle tante domande su cui riflettiamo da tempo. Crediamo che le attività svolte in ambienti informali possano dare un contributo sostanziale non solo all'educazione scientifica su larga scala per sviluppare senso critico nei cittadini ma anche consolidare l'insegnamento nei contesti formali se scuola e università sanno cogliere e valorizzare il loro senso. Il contributo del nostro gruppo di ricerca si caratterizza per il riconoscimento della funzione che l'educazione scientifica, matematica e tecnologica può svolgere nella formazione culturale generale delle persone, sviluppando modelli di intervento "risonanti" con la comunità educante. Ci sembra che, dopo anni di impegno diretto, i risultati finora raggiunti siano giudicati molto promettenti da tutti i soggetti coinvolti, e iniziamo a intravedere come l'approccio sviluppato dalla comunità del Laboratorio per L'Educazione alla Scienza (LES) sia efficace e in grado di rispondere in modo adeguato alle richieste dei territori in cui operiamo.

Implementation of Ambitious Science Teaching framework in a physics master course: A case study.

DE ZUANI CASSINA F., LEVRINI O.
Dipartimento di Fisica e Astronomia, Università di Bologna, Italia

Making the classroom a safe place where students feel free to self-express is challenging, especially in STEM education. Ambitious Science Teaching is a framework designed by the University of Washington which aims to improve classroom participation and deep understanding of science ideas. It has been introduced to 29 graduate physics students of the master's course "Laboratory of Physics Education" at the University of Bologna, within a six-lecture module held by one of the framework's designers, prof. David Stroupe. Students could experience the framework from a teacher perspective, as most of them are attending the curriculum of physics education to become teachers, but also from a student perspective since they were required, as a task of the course, to design explanatory models of metronomes phase-locking phenomenon, on which nobody had previous knowledge. Results from a preliminary analysis show that this dual perspective allowed students to engage in a deeper way with science practices such as expressing and revising ideas or asking for evidence, also during the construction of their explanatory model, given that the setting was felt enough safe.

Globalizing Physics: One Hundred Years of the International Union of Pure and Applied Physics.

LALLI R.
Politecnico di Torino

The talk presents major results of the project "One Hundred Years of IUPAP: A History" with a focus on role of Italian physicists and institutions in various phases the Union's history. It will show that after the IUPAP had been rather inactive in the interwar period, the post-WWII period saw the emergence of various committees devoted to specific sectors of physics. After discussing the major features of this transformation, the talk chronicles main developments of the IUPAP in the following decades and discusses how the scientific activities of the IUPAP were deeply conditioned by the changing political contexts.

Il ruolo della storia nella formazione in Fisica. Motivazioni e prospettive future: una discussione introduttiva.

MONTI F.
Dipartimento di Informatica - Università di Verona

Tra le sfide più importanti che l'evoluzione della nostra società, dominata dallo sviluppo dell'intelligenza artificiale, dalla tecnologia dei big data e dai social network, pone alla formazione dei giovani, due sono a mio avviso particolarmente rilevanti per la loro natura trasversale rispetto a qualsiasi tema specifico: quella di stimolare una capacità di pensiero libero e indipendente e quella di coltivare la fiducia nella possibilità di costruire un futuro sempre migliore. Dopo i recenti accadimenti legati alla pandemia, queste necessità stanno diventando sempre più cogenti, e si accompagnano al tema, di rinnovata attualità, della "natura della scienza". In questo contesto vorrei condividere alcune riflessioni, che traggono spunto anche dalla mia esperienza di ricerca, didattica e istituzionale a livello universitario, sulle molteplici ragioni per una crescente importanza del ruolo della Storia, della Storia delle Scienze e della Storia della Fisica in particolare, nella formazione delle nuove generazioni, a partire proprio dal livello universitario, e sulle possibili prospettive future di una formazione scientifica che comprenda questa dimensione in modo esplicito e stabile.

Aula 501 - Città Studi - Via Valvassori Peroni **ore 14:30**

Sezione VII
Didattica e storia della fisica

SESSIONE SPECIALE COORDINATA SISN-SIF

Presiede: Bruni F. (Università di Roma Tre)

Comunicazioni

The training on Neutron Techniques School.

Magli R.
Dipartimento di Scienze Biomediche Chirurgiche e Odontoiatriche, Università degli Studi di Milano

SISN organizes a three-year program of Specialized Summer Schools called Training on Neutron Techniques (TNT), open to Graduate and PhD students and to Post-Docs working in scientific disciplines as Biology, Chemistry, Earth Sciences, Material Sciences, Physics, Sciences for Cultural Heritage Conservation, and similar. The physical bases of neutron sources and of neutron scattering techniques for the study of condensed matter are presented and discussed, with examples and applications in various scientific fields. Specific attention is paid to recent developments and to those in progress and expected for the current decade. The scientific potentialities of the experimental methods are discussed for instruments accessible both at reactor-based facilities and at spallation sources, also in view of the European ESS project (the future European Neutron Scattering facility). The 2022 edition focuses on Diffraction and Structural Imaging, while the topic of 2023 will be Inelastic Scattering and in 2024 Small Angle Scattering and Reflectometry will be dealt with.

Training on Neutron Techniques (TNT): Neutron Diffraction and Structural Imaging.

Magli R. (1), Ceretti M. (2), Formisano F. (3), Grazzi F. (4), Pietropaolo A. (5)
(1) *Dipartimento di Scienze Biomediche Chirurgiche e Odontoiatriche, Università degli Studi di Milano*
(2) *ICGM, CNRS Montpellier*
(3) *CNR-IOM, Grenoble*
(4) *CNR-IFAC, Sesto Fiorentino, INFN-CHNet*
(5) *ENEA, Frascati*

The first edition of the TNT Summer Schools, focused on Neutron Diffraction and Structural Imaging, took place from 11 to 19 June 2022 in S. Giovanni (BZ). The School has been attended by 25 students coming from Asian and European laboratories. The physical basis of the neutron sources (both reactors and spallation sources) and of the instrumentation needed for structural studies have been introduced and discussed. Then neutron diffraction with crystals, powder and disordered systems has been discussed with examples and tutorials ranging from single crystal applications to magnetic scattering, to materials science, to cultural heritage conservation, etc. The second part of the school has been devoted to Structural Imaging. After introductory lectures on the theory of neutron imaging and on the related instrumentation, several applicative seminars and tutorials have presented and discussed imaging techniques, as energy selective, phase contrast, polarized imaging, grating interferometry, neutron resonance imaging.

Le Advanced Summer Schools della SISN Edizione 2018.

del Rosso L. (1), De Francesco A. (2), Guarini E. (3)
(1) *CNR-IFAC, Sesto Fiorentino, Italia*
(2) *CNR-IOM c/o Institut Laue Langevin, Grenoble, France*
(3) *Dipartimento di Fisica e Astronomia, Università di Firenze, Sesto Fiorentino, Italia*

La scuola del 2018, più specialistica rispetto alla tradizionale offerta didattica della SISN, è stata la prima a carattere internazionale e ad essere dedicata non solo a dottorandi e postdoc ma anche a ricercatori, esperti di scattering di neutroni, interessati ad approfondire le conoscenze sui metodi statistici e computazionali utili nell'analisi e interpretazione dei dati. La gestione dei dati, le procedure di correzione, i principali programmi, i modelli di fit più generali e le tecniche di simulazione sono stati trattati per le diverse tecniche (ND, QENS, INS, SANS) allo scopo di affrontare le tipiche difficoltà che si presentano dopo una misura. La scuola si proponeva di trattare i tanti aspetti relativi ad un'accurata analisi e i modi per verificare l'affidabilità dei risultati, sia tramite il confronto con simulazioni, sia attraverso controlli statistici basati sull'inferenza Bayesiana. Docenti e studenti, a volte volutamente scambiati nei loro ruoli - dando vita a un Simposio più che ad una scuola tradizionale - provenivano da Europa, Asia, Stati Uniti, Sud America. Dai questionari è emerso un grande apprezzamento per il tipo di formazione e per l'organizzazione generale.

Neutroni e Muoni per il magnetismo: Edizione del 2019 dell'Advanced Summer School SISN.

Chicco S. (1), Guidi T. (2)(3), Caciuffo R. (1)(4)(5), Moneta E. (5)
(1) *Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università di Parma, Italia*
(2) *ISIS Neutron and Muon Source, Rutherford Appleton Laboratory, Harwell Oxford, United Kingdom*
(3) *Scuola di Scienze e Tecnologie, Sezione di Fisica, Universti'a di Camerino, Italia*
(4) *Istituto Nazionale di Fisica Nucleare, Genova, Italia*
(5) *Joint Research Centre, Karlsruhe, Germany*

L'edizione 2019 dell'Advanced Summer School SISN è stata dedicata alle applicazioni di neutroni e muoni allo studio del magnetismo. La Scuola, organizzata dalla SISN in collaborazione con il Joint Research Centre (JRC) della Commissione Europea, si è svolta dal 2 al 6 Settembre 2019 presso il centro di ricerca del JRC situato ad Ispra (Varese), sulla riva lombarda del Lago Maggiore. La Scuola ha ricevuto 42 domande di partecipazione e sulla base delle motivazioni espresse nelle lettere di candidature, sono stati ammessi 21 studenti, provenienti da 10 diverse nazioni. La Scuola si è articolata in una serie di lezioni sulle principali tecniche d'interesse per lo studio dei fenomeni e dei materiali magnetici, seguite da esercitazioni pratiche sull'uso di programmi di calcolo per la visualizzazione dei dati e per la loro interpretazione. Tre lezioni, dettate da docenti di assoluto prestigio scientifico, quali Claudia Felser, Stuart Parkin and Vincent Cros, sono state dedicate ad argomenti non direttamente collegati alle tecniche sperimentali oggetto della scuola, ma molto innovativi e di elevato interesse scientifico.

Le Giornate Didattiche SISN: Dal 2004 al 2022 la fucina dei giovani neutronisti italiani.

Spinozzi F. (1), Noferini D. (2), Zanatta M. (3)
(1) *Università Politecnica delle Marche, Dipartimento di Scienze della Vita e dell'Ambiente*
(2) *European Spallation Source ERIC, Lund, Svezia*
(3) *Università di Trento, Dipartimento di Fisica*

La formazione dei giovani ricercatori è una delle principali finalità della Società Italiana di Spettroscopia Neutronica (SISN). A tale scopo, dal 2004 la SISN organizza le Giornate

Didattiche (GD), una scuola introduttiva allo scattering di neutroni con forte connotazione interdisciplinare. Le GD sono infatti pensate per studenti, dottorandi e giovani ricercatori provenienti da diverse aree: Fisica, Chimica, Biologia, Geologia, Scienza dei Materiali, Conservazione dei Beni Culturali… Nella prima parte delle GD vengono introdotti i fondamenti dello scattering di neutroni e delle varie tecniche; nella seconda gli studenti applicano quanto appreso conducendo veri esperimenti, dal 2007 presso l¡92¿Institut Laue-Langevin (Francia). Post pandemia, le GD riprendono nel 2022 con una seconda sessione basata su esperimenti virtuali (causa temporaneo shutdown di molte sorgenti europee) svolti da gruppi di studenti con supervisione di un tutor. Come nel caso reale, gli studenti approfondiranno un caso scientifico, valuteranno i parametri strumentali, analizzeranno dataset reali e presenteranno i risultati con un seminario. Nel corso degli anni, le GD hanno formato centinaia di giovani ricercatori, molti dei quali hanno proseguito la loro avventura nella neutronica. Oltre alla storia delle GD, i direttori presenteranno dati sulla loro efficacia per la formazione.

L'esperienza sul campo delle GD: Gli esperimenti virtuali 2022. Dinamica di protoni in elettroliti solidi per celle a combustibile di nuova generazione.

NOFERINI D., E GLI STUDENTI DELLE GD2022
European Spallation Source ERIC, Lund, Svezia

Gli zirconati di bario drogati sono al centro di grande attenzione per le possibili applicazioni come elettroliti solidi in celle a combustibile di nuova generazione. Sebbene la presenza del dopante sia necessaria per la conduzione dei protoni, non è ancora stato del tutto delucidato il legame fra le modifiche alla struttura locale dovute al dopante e la dinamica dei protoni. Anche i dettagli del meccanismo della conduzione dei protoni sono ancora dibattuti. Lo scattering inelastico di neutroni permette di investigare con grande efficacia la dinamica dei protoni in questi materiali, grazie all'elevata cross section di scattering incoerente dell'idrogeno. Durante l'esercitazione gli studenti possono confrontarsi con dati acquisiti con uno spettrometro di neutroni su campioni di zirconato di bario drogati. In particolare possono seguire la trasformazione dei dati da intensità misurata a fattore di struttura dinamico e la susseguente analisi volta ad identificare le caratteristiche della dinamica dei protoni.

Transizione di fase di un doppio strato lipidico studiata tramite riflettometria neutronica.

GERELLI Y. E GLI STUDENTI DELLE GD2022
Università Politecnica delle Marche, Dipartimento di Scienze della Vita e dell'Ambiente

Il doppio strato lipidico è un paradigma per studi biologici e tecnologici, ad esempio per l'indagine delle interazioni e dei processi molecolari coinvolti nella funzione cellulare, nelle malattie e per lo sviluppo di biosensori. Inoltre, è uno dei prototipi di sistemi naturali autoassemblanti. Grazie a questa capacità, la struttura di doppi strati lipidici è in grado di variare spontaneamente in risposta a stimoli esterni, cambi di composizione e interazioni con molecole ospiti. La riflettometria neutronica è una tecnica non invasiva capace di fornire una descrizione su scala nanometrica della struttura di doppi strati lipidici depositati su superfici planari. In questo esperimento è stata applicata per caratterizzare la variazione di struttura di doppi strati lipidici in funzione della temperatura. In particolare, la tecnica ha permesso di identificare variazioni di densità all'interno del doppio strato lipidico, *i.e.* in una regione inaccessibile da altre tecniche di microscopia.

Interazioni tra membrane lipidiche e proteine studiate tramite diffusione a piccolo angolo dei neutroni (SANS).

RONDELLI V. E GLI STUDENTI DELLE GD2022
Università degli studi di Milano "La statale", Dipartimento di Biotecnologie Mediche e Medicina Traslazionale

Il design di un esperimento di scattering di neutroni a basso angolo (SANS) richiede di valutare accuratamente diversi aspetti. Una volta inquadrato il problema scientifico è fondamentale la conoscenza del campione e questo richiede, ove possibile, lo svolgimento di misure di caratterizzazione preliminari. Anche la scelta della facility dove richiedere tempo macchina e lo strumento specifico sono molto importanti e sono strettamente legati al problema scientifico, al tipo di campione da studiare e alla quantità di campione disponibile. Talvolta può essere d'aiuto effettuare misure preliminari su strumenti meno performanti per poter poi richiedere accesso alle facilities più richieste con strumenti più performanti. Una volta raccolti i dati, l'analisi di questi per ottenere informazioni strutturali richiede lo sviluppo di modelli teorici per la loro interpretazione o, come spesso accade, può essere effettuata a mezzo di programmi di analisi già sviluppati a questo proposito. Durante l'esercitazione questi aspetti verranno declinati rispetto ad un caso scientifico di interazione membrana lipidica-proteina.

Dopo le giornate didattiche SISN: L'esperienza di due alumni. Analisi dell'effetto della composizione lipidica sull'attività della fosfolipasi tipo A in sistemi di membrane modello.

Corucci G.
Institut Laue-Langevin, Grenoble, France

Le fosfolipasi-A (PLA) appartengono al gruppo degli enzimi idrolitici (EC-3), e catalizzano l'idrolisi dei glicerofosfolipidi (GFL) in acidi grassi e liso-fosfolipidi (LFP). Le PLA possiedono una grande varietà di funzioni nelle cellule viventi, che spaziano dal rimodellamento delle membrane cellulari, fino al rilascio di molecole segnale (come l'acido arachidonico). Alcune di queste PLA sono di rilevanza medica perchè risultano coinvolte in malattie neuro-degenerative ed autoimmuni. Per questo motivo risulta importante la comprensione del meccanismo di azione, come primo passo verso la cura di queste patologie PLAcorrelate. Ad oggi, i fattori che regolano la specificità enzima/substrato non sono del tutto compresi. Questo progetto tenta di elucidare la complessa interazione PLA/substrato, cercando di comprendere quali siano i fattori che spingono l'enzima a preferire un substrato rispetto ad un altro, delucidando il meccanismo di azione con il quale agiscono. Studi precedenti dimostrano che la reazione mediata dalle fosfolipasi avviene in due step: efflusso del GFL dalla membrana, dove il GFL lascia la membrana plasmatica per entrare nel sito attivo dell'enzima; e l'accomodazione, che indica il grado di assestamento del GFL nella tasca catalica. In questo progetto analizziamo in dettaglio questa teoria mediante l'utilizzo di scattering di neutroni e tecniche biofisiche complementari come QCM-D, ellissometria e spettrometria di massa.

Studio del confinamento dell'acqua in nanotubi di imogoliti.

D'Angelo A. (1)(2), Paineau E. (1), Launois P. (1), Rols S. (2)
(1) *Laboratoire de Physique des Solides, CNRS-Université Paris Saclay, Orsay, France*
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I nanotubi di imogoliti (INT) con stechiometria $(OH)_3Al_2O_3Si(OH)$ sono particolari materiali argillosi formati da fogli di gibbsite arrotolata con all'interno unità isolanti SiO_3. Gli INT possono essere sintetizzati con processi di chimica soft e gli atomi di silicio (SI-INTs) possono essere sostituiti da atomi di germanio (Ge-INTs). In entrambi i casi, il diametro interno di questi nanotubi idrofilici è realmente nanometrico, 1.5 nm per i Si-INTs e 3 nm per i Ge-INTs. Per questo motivo, le proprietà di superficie prevalgono e gli INTs sono ottimi sistemi modello per studiare il ruolo delle interfacce sul comportamento dell'acqua. Risultati recenti sui Ge-INTs hanno mostrato che i wetting-layer si stabilizzano a 300 K con una simmetria locale triangolare. Questo studio si concentra sulle Si-INTs e sul processo di assorbimento e diffusione dell'acqua nelle loro cavità interne. I risultati presentati sono stati ottenuti da esperimenti di scattering quasielastico, inelastico e spin-echo, combinati con simulazioni di dinamica molecolare (MD) ottenute con una parametrizzazione esistente per il potenziale di interazione acqua-imoglolite. Gli spettri QENS e la densità degli stati simulate dell'acqua assorbita in Si-INT saranno comparati con i Ge-INT e con i dati sperimentali ottenuti all'Institut Laue Langevin, sugli spettrometri IN6-SHARP, PANTHER e WASP.

Aula B - Maria Goeppert-Mayer **ore 09:00 – 13:30**

Sezione I
Fisica nucleare e subnucleare
Presiedono: Cifarelli L. (Università di Bologna)
Nania R. (INFN, Sezione di Bologna)

b-physics and ion-ion collisions

Relazioni su invito

▲ **Un tracciatore a pixel 3D a trincea con 10 ps di risoluzione temporale per l'upgrade di Fase 2 di LHCb.**

Cardini A.
INFN, Sezione di Cagliari

I futuri esperimenti ai collider necessiteranno di nuovi rivelatori ad altissima risoluzione temporale per poter ricostruire gli eventi acquisiti in condizioni di alta luminosità istantanea. In particolare, quando LHCb opererà a $1.5 \cdot 10^{34}$/cm/s, 2000 tracce provenienti da 40 collisioni avvenute in ogni bunch crossing dovranno essere ricostruite nel rivelatore di vertice (VELO). Per garantire l'efficienza di questa ricostruzione sarà necessario che gli hit nel VELO siano misurati temporalmente con una accuratezza di circa 50 ps. Per ottenere questo, una delle tecnologie più promettenti attualmente in fase di studio è quella dei sensori a pixel 3D "a trincea", sviluppati dalla collaborazione INFN chiamata TimeSPOT. Questi pixel di $55\,\mu\text{m} \times 55\,\mu\text{m}$ di area sono costruiti su un silicio di spessore $150\,\mu$m e consistono in una giunzione planare lunga $40\,\mu$m posizionata tra due giunzioni continue. Questa geometria garantisce delle distanze di deriva dei portatori di carica di circa $20\,\mu$m e tempi totali di raccolta della carica inferiori ai 300 ps. Due lotti di sensori 3D "a trincea" sono stati prodotti da FBK nel 2019 e nel 2021. I più recenti test su fascio sono stati svolti nel 2021 e 2022 a SPS/H8 durante i quali strutture di test, consistenti in singoli pixel o decine di pixel disposti in linea, sono stati letti con un'elettronica a basso rumore basata su un doppio stadio di amplificatore a transimpedenza, e i segnali sono stati acquisiti con un oscilloscopio digitale ad alte prestazioni. Il tempo di arrivo delle particelle è stato misurato con un'accuratezza di circa 7 ps utilizzando due MCP-PMT posizionati sul fascio. Le forme d'onda dei segnali dei sensori 3D sono analizzate con algoritmi software per misurare le ampiezze, i tempi di arrivo e le efficienze dei rivelatori. I risultati preliminari indicano delle efficienze di rivelazione vicine al 100% con inclinazioni dei sensori di almeno 10 gradi, e risoluzioni temporali di 10 ps. I test attualmente in corso a SPS/H8 stanno indicando analoghe prestazioni anche per sensori irraggiati fino a $2.5 \cdot 10^{16}$ 1-MeV neutron equivalent. Altri risultati saranno presentati. I rivelatori a pixel 3D "a trincea" sono una promettente tecnologia per i futuri rivelatori di vertice negli esperimenti operanti ad altissime luminosità istantanee.

▲ **The ALICE experiment: Recent highlights and future perspectives.**

Masera M. per la ALICE Collaboration
Dipartimento di Fisica dell'Università di Torino e INFN, Sezione di Torino

ALICE is the experiment originally designed to study the physics of heavy-ion collisions at the LHC. In its first decade of activity, ALICE turned out to be an excellent experiment to study strongly interacting matter formed not only in nucleus-nucleus collisions, but also in proton-nucleus and proton-proton collisions. In this overview, a selection of recent results obtained by the ALICE Collaboration will be presented, together with the expectations for the next LHC runs after the major upgrade carried out since the end of the LHC Run 2 in 2018.

Comunicazioni

Picosecond timing resolution with 3D trench silicon sensors.

Borgato F. (1)(2), Cardini A. (1), Cossu G. (1), Garau M. (1), Lai A. (1), Lampis A. (1), Loi A. (1), Mulargia R. (1), Obertino M. (1), Simi G. (1), Vecchi S. (1)
(1) *Università degli Studi di Padova*
(2) *INFN, Sezione di Padova*

In the high-luminosity LHC phase the collider will operate at 1.5×10^{34}/cm/s and strict requirements will be posed on subdetectors capabilities. Concerning the LHCb Upgrade2 VELO, to guarantee a good detector performance the additional information of the hit time stamping with an accuracy of at least 50 ps is needed. A very promising option today to achieve this level of timing precision is the 3D trench silicon pixel, developed by the INFN TimeSPOT Collaboration. This kind of sensor would allow to build a 4D tracker, capable of excellent resolution in both space and time measurements. The latest beam test with the 3D trench sensors has been performed at SPS/H8 in 2021. By means of low-noise custom electronics boards featuring a two-stage transimpedance amplifier it was possible to test silicon pixels and strips made with the 3D trench technology. To extrapolate the sensor time resolution, the crossing time of a particle was estimated using two MCP-PMTs as time tag, with an accuracy of approximately 7 ps. Preliminary results show that the standard deviation of the core of the pixels time distribution is about 10 ps and the tilted sensor has shown an efficiency close to 100%.

Violazione di CP dipendente dal tempo nei decadimenti dei mesoni B a Belle II.

Di Cicco A. per la Belle II Collaboration
INFN, Laboratori Nazionali di Frascati

L'esperimento Belle II, in operazione presso il collisionatore asimmetrico e^+e^- SuperKEKB al laboratorio KEK in Giappone, ha accumulato una luminosit'a integrata di circa 350 fb^{-1}. Gli studi di violazione di CP dipendente dal tempo nei decadimenti dei mesoni B sono un potente strumento per misurare con precisione i parametri fondamentali del Modello Standard e per ricercare Nuova Fisica. In questo contributo verrano presentati i principali risultati ottenuti da Belle II con il campione di dati finora raccolto.

Decadimenti del mesone B con energia mancante all'esperimento Belle II.

Gaudino G.
Scuola Superiore Meridionale, Napoli, Italia e INFN, Sezione di Napoli, Italia

Belle II, esperimento alla super B factory SuperKEKB, è stato ideato per misure di precisione e ricerca di nuova fisica nel settore del sapore. L'acceleratore di elettroni e positroni è stato progettato per avere una luminosità istantanea massima di 6.5×10^{35} cm^{-2} s^{-1} e la raccolta di dati ha come obiettivo un campione finale di 50 ab^{-1}. Eventi del tipo $e^+e^- \to \Upsilon(4S) \to B\bar{B}$, prodotti a SuperKEKB, permettono di studiare decadimenti rari del mesone B con energia mancante nello stato finale attraverso l'applicazione di diverse tecniche sperimentali. Tali processi possono ricevere contributi non previsti dal modello Standard. In questo contributo si discuteranno in particolare stato e prospettive di due modi di decadimento con energia mancante: $B \to \tau\nu$ e $B \to K(^*)\nu\nu$.

Performance studies of an all-layer monolithic pixel vertex detector for the Belle II upgrade.

Massaccesi L.
Dipartimento di Fisica, Università di Pisa, Italia e INFN, Sezione di Pisa, Italia

The Belle II experiment at the SuperKEKB e^+e^- collider has started developing an upgrade program for the time frame of 2026–2027 to improve the detector performance and robustness against beam-induced backgrounds. To replace the current pixel-and-strips VerteX Detector (VXD), the VTX concept has been developed: an all-pixel detector based on Depleted Monolithic Active Pixel Systems (DMAPS) organized in five, or possibly more, barrel layers. To optimize the VTX design, and to compare it to the current VXD, a full-simulation framework has been developed and integrated with the standard Geant4-based Belle II simulation, allowing to directly compare different layouts. This communication will present the VTX detector concept, the simulation framework, and the results obtained from the simulation of benchmark physics channels that include D mesons from B decays. A significant improvement (in terms of reconstruction efficiency, as well as impact parameter and vertex resolution) will be shown, with respect to the current VXD. Also, it will be shown how this simulation work forms the basis for further optimization of the VTX design.

● **Search for the B meson decays with $X(3872)$ at the CMS experiment.**

Basile C.
Dipartimento di Fisica, Università di Roma I, Italia e INFN, Sezione di Roma 1, Italia

A study of the exotic multiquark candidate resonance $X(3872)$ is presented. The $X(3872)$ production in the decay of neutral mesons is investigated using a sample of proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$ with the CMS detector at the CERN LHC. Such measurement, combined with analogue studies of the $X(3872)$ production in charged B meson decays, is fundamental to shed light on the puzzling nature of the $X(3872)$ particle and in the understanding of the QCD theory.

● **Misura della vita media effettiva del mesone B_s^0 nel decadimento in due muoni con l'esperimento ATLAS ad LHC.**

Raffaeli F.
Università degli Studi di Roma Tor Vergata

Il decadimento dei mesoni B^0 e B_s^0 in due muoni è fortemente soppresso nel Modello Standard poiché mediato da processi di tipo FCNC. Per questo motivo il BR di questi due decadimenti e la vita media effettiva del decadimento del B_s^0 in due muoni sono grandezze particolarmente sensibili a scenari di nuova fisica. In questa presentazione verranno illustrati e discussi i risultati della misura della vita media del mesone B_s^0 nel decadimento raro in due muoni.

● **Medusa, a multithread 4-body decay fitting and simulation software.**

Ricci A.M. ([1]), Alves Junior A.A. ([2]), Brundu D. ([1]), Contu A. ([1]), Dordei F. ([1]), Muzzetto P. ([1])
([1]) *INFN, Sezione di Cagliari*
([2]) *Institut für Astroteilchenphysik at Karlsruher Institut für Technologie, IAP/KIT*

High Energy Physics (HEP) experiments keep collecting increasingly larger datasets, which often require correspondingly complex data analysis. For instance, the PDFs used for modeling phenomena can have hundreds of free parameters. Consequently, the optimization of such models involves a significant computational effort, which usually can run for days, before reaching a result. Medusa is a C++ application designed to perform physics data analysis of generic 4-body decays deploying massively parallel platforms (multicore CPUs and GPUs) on Linux systems. It relies on Hydra, a header-only library that provides a high-level and user-friendly interface for common algorithms used in HEP, abstracting away the complexities associated with the implementation of code for different massively parallel architectures. Medusa has been tested through the measurements of the CP-violating phase in decays. By deploying such technologies as CUDA, TBB and OpenMP, Medusa accelerates the optimization of the full model, running over 500000 events, by factors 74 (multicore CPU) and 370 (GPU) in comparison with a non-parallelized program.

Study of the full Probability Density Function for strange hadron production in pp collisions with ALICE.

Pucillo S. per la ALICE Collaboration
Università degli Studi di Torino, Italia e INFN, Sezione di Torino

Measurements of strange hadron production in pp and p-Pb collisions have been used as a reference for the study of quark-gluon plasma formation in heavy-ion collisions. Recently, further studies by the ALICE Collaboration unveiled unexpected features in the yield ratio of strange hadrons to pions. These observations have been obtained by a statistical analysis of the number of strange particles in a given set of inelastic pp events; in this sense, formation rates account for the average of the Probability Density Function (PDF) underlying the production mechanism. More insightful information on the production of strange particles and, in general, on hadronization would come from the knowledge of the full PDF. In this work, a new event-by-event technique for extracting the full PDF for single and multi-strange hadron production will be illustrated. The analysis technique involves topological selection of the particle decay chain, signal extraction with invariant mass weights and an unfolding procedure which profits from realistic Monte Carlo simulations. First estimates on the statistical accuracy achievable by analyzing LHC Run 2 data will be discussed.

Measuring μB at the LHC with ALICE via antiparticle-over-particle ratios.

Ciacco M. per la ALICE Collaboration
Politecnico di Torino e INFN, Sezione di Torino

The baryon chemical potential μB is a fundamental parameter for the statistical mechanical description of particle production in heavy-ion collisions: its value is connected to the asymmetry between the produced matter and antimatter. The first μB measurement in high-energy Pb-Pb collisions at the LHC was published in 2018 in *Nature*, and it was found that $\mu B = 0.7 \pm 3.8\,\mathrm{MeV}$. In the Statistical Hadronisation Model, antimatter-over-matter ratios R are connected to μB as $R\alpha \exp[-2(B + S/3)\mu B/T - 2I_3\mu I_3/T]$ where B, S and I_3 are the baryon number, strangeness and third isospin component of the considered particle species, respectively. In this contribution, an improved μB measurement based on the study of such ratios for protons, ^{3}He and hypertriton (Λ^3H) using the data collected by ALICE in Run 2 of the LHC, is presented. The isospin chemical potential is also determined via the π^-/π^+ ratio. The study of the pion, proton and helium ratios is based on standard analyses, while the selection of Λ^3H candidates, which are reconstructed via the two-body charged-π mesonic decay of the hypertriton, is performed using Boosted Decision Trees. The obtained μB represents the most precise measurement.

Charm-tagged jets and correlation measurements with ALICE.

Palasciano A. per la ALICE Collaboration
Università degli Studi di Bari

The ALICE Collaboration performed precise measurements of the production of a wide spectrum of charmed mesons and baryons. Complementary aspects of the charm quark production can be investigated by measuring charm-tagged jets and correlations providing, respectively, a closer access to the parton kinematics than single-particle measurements and a characterization of the charm-jet in terms of shape and composition. Measurements of the fragmentation function of jets containing fully reconstructed D^0 or Λ_c^+ baryons in pp collisions will be discussed. The first observation of the dead-cone effect impacting on the charm parton showers will be also presented via the measurements of D^0-tagged jets in pp collisions. The new measurement of the nuclear modification factor R_{AA} of D^0-jets in 0-10% Pb–Pb collisions will also be presented to address the effects of the energy loss mechanisms in the QGP. The description of the charm quark fragmentation will be then completed by discussing the measurements of azimuthal correlations between D mesons and charged particles in pp collisions, useful for validating Monte Carlo models, and in p–Pb collisions, seizing the impact of cold nuclear matter effects.

A new phenomenological model for heavy-ion fusion cross sections.

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We describe a novel universal phenomenological formula that is able to reproduce, with a few parameters, experimental data of fusion excitation functions obtained in heavy-ion collisions, in a broad domain of masses and asymmetries and with unprecedented accuracy. Within the approach adopted in this paper, we observe the occurrence of a saturation behaviour for the critical angular momentum as a function of the compound excitation energy; for medium-light systems, the extracted limiting angular momenta are in reasonable agreement both with experimental values and theoretical predictions based on the liquid drop model. A detailed comparison of our predictions with experimental data suggests the occurrence of possible nuclear structure effects in the fusion of systems with nearly zero fusion Q-values.

The new readout system for the Alice Zero Degree Calorimeters in LHC Run 3.

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(1) *INFN, Sezione di Torino*
(2) *Università del Piemonte Orientale, Alessandria*
(3) *Politecnico di Torino*

The Alice Zero Degree Calorimeters (ZDC) provide information on centrality, time of the collision, vertex position, event plane and luminosity in heavy-ion operation. The operating conditions for the ZDC in LHC Run 3 will be very challenging in heavy-ion collisions, due to the presence of a physical background from electromagnetic dissociation processes with a resulting event rate that could reach 5 M event/s. The new readout system, that was re-designed in order to operate in continuous mode without dead time, is based on a commercial 12-bit digitizer with a sampling rate of about 1 GSps, assembled on an FPGA Mezzanine Card. The signals produced by the 26 ZDC channels are digitized and the samples are processed through an FPGA where an auto trigger algorithm is implemented, allowing the online selection of the interesting physical events and data reduction directly at the front end level. Information as timing, baseline average estimation and luminosity measurements are also extracted. The architecture of the new readout system, the operation of the digitizer, the auto trigger strategy, the firmware organization and performance during the commissioning are presented.

Measurement of heavy-flavor production in the high-mass dimuon spectrum in pp collisions at $\sqrt{s} = 13\,\text{TeV}$ with ALICE.

PENNISI M.
Università di Torino e INFN, Sezione di Torino

Studies of the production of heavy-quarks in pp collisions, besides serving as a reference for heavy-ion collisions, represent a powerful tool for testing various aspects of QCD. An analysis technique little explored until now at the LHC energies is the analysis of the high-mass region of the dilepton invariant mass spectrum ($m_{\ell\ell} > m_{J/\Psi}$), significantly populated by the semileptonic decays of hadron pairs containing charm and beauty quarks. Analyses

based on Monte Carlo simulations are crucial to reproduce the invariant mass and p_T spectra of muon pairs measured at forward rapidity with the ALICE muon spectrometer, as well as to disentangle the contributions from heavy-flavour decays, separately for charm and beauty, and light-flavour hadrons, the latter representing the main background source of this analysis. In this contribution, the results of PYTHIA8 simulations for the contributions coming from charm, beauty, and light-flavours hadrons, will be reported and compared to the p_T and mass spectra measured by ALICE in pp collisions at $\sqrt{s} = 13\,\text{TeV}$, based on an integrated luminosity of about $\sim 25\,\text{pb}^{-1}$.

Probing the hadronic phase of large hadronizing system through the study of the $\Lambda(1520)$ resonance with ALICE at the LHC.

Agrawal N. per la ALICE Collaboration

INFN, Sezione di Bologna, Italy e Department of Physics, University of Bologna, Bologna, Italy

The measurement of hadronic resonance production in heavy-ion collisions at the LHC has led to the observation of a prolonged hadronic phase after hadronisation. Due to their short lifetimes, resonances experience the competing effects of regeneration and rescattering of the decay products in the hadronic medium. Studying how the experimentally measured yields are affected by these processes can extend the current understanding of the properties of the hadronic phase and the mechanisms that determine the shape of particle transverse momentum spectra. In this contribution, new preliminary results on the production of the $\Lambda(1520)$ resonance measured in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ with the ALICE detector at the LHC are presented. These results on $\Lambda(1520)$ ($\tau = 12.6\,\text{fm}/c$) are compared with those from a set of hadronic resonances with a lifetime span of 1 to $46\,\text{fm}/c$ such as $\rho(770)^0$, $K^*(892)^0$, $\Sigma(1385)^{\pm}$, $\Xi(1530)^0$ and $\Phi(1020)$ measured by the ALICE experiment. The shape of particle transverse momentum (p_T), mean p_T and particle ratios are compared with those from the Blast-Wave, MUSIC with a SMASH afterburner and statistical hadronisation model predictions.

Measurement of the elliptic flow of muons in pp collisions at $\sqrt{s} = 13\,\text{TeV}$ with the ALICE experiment.

Boi S. per la ALICE Collaboration

Dipartimento di Fisica, Università degli Studi di Cagliari, Italia e INFN, Sezione di Cagliari, Italia

Heavy flavour hadrons are produced in hard-scattering processes in hadron collisions before the QGP formation. The interactions of HF hadrons with the plasma lead to an azimuthal deformation of the momentum distribution, which can be studied with a Fourier expansion. The elliptic flow v_2 is the second term of the expansion and indicates an azimuthal elliptic deformation of the plasma. Its value reflects both the initial state asymmetry and the QGP hydrodynamic characteristics. Indications of non-zero v_2 in pp collisions have been reported from different experiments. In the ALICE experiment, the inclusive muon elliptic flow can be measured from the two-particle azimuthal correlation between muon tracks, detected in the forward rapidity region, and the SPD tracklets. A significant contribution of the semimuonic decays at intermediate and high p_T is expected to be due to HF particles. In this contribution, the analysis strategy for the measurement of the inclusive muon v_2 at forward rapidity using ALICE RUN2 pp collisions data at $\sqrt{s} = 13\,\text{TeV}$ will be shown. The analysis was performed as a function of p_T, using the two-particle correlation method.

Timing performance of thin Low-Gain Avalanche Detectors (LGADs).

Strazzi S.
Dipartimento di Fisica, Università di Bologna, Italia

The work here presented concerns the characterization and performance study of the first very thin Low-Gain Avalanche Detectors (LGADs) prototypes produced by the Fondazione Bruno Kessler (FBK). Due to its excellent timing performance, this technology is already being considered for many detector upgrades. However, the future-generation experiments, like ALICE 3 in LHC Run 5, have further increased the interest in the R&D of high-resolution timing detectors, aiming to achieve a resolution of the order of 20 ps. A thinner LGAD design could allow to reach this value. Here, LGADs with a thickness of 25 μm and 35 μm have been considered. After a full characterization through laboratory measurements followed by preliminary studies using an infrared laser, these sensors were tested for the first time in a beam test setup at PS, CERN. Several measurements on this new generation of LGADs will be shown in the contribution, including many extracted characteristics, such as drift electric field, noise and charge distributions. Finally, the results of a comprehensive analysis on the timing performance will be reported as a function of the gain (voltage) and sensor characteristics.

Performance of Analog Pixel Test Structure of monolithic sensors with Operational Amplifier output buffer for ALICE ITS3 upgrade.

Ferrero C.
Dipartimento di ingegneria elettrica, elettronica e delle comunicazioni, Politecnico di Torino, Italia, Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italia e Dipartimento di Fisica, Università degli Studi di Torino, Italia

A new vertex detector composed of curved ultra-thin monolithic silicon sensors arranged in cylindrical layers is planned to be installed during the LHC LS3 to replace the innermost three layers of the ALICE Inner Tracking System at CERN. This contribution explores the first tests on the Analog Pixel Test Structure with an Operational Amplifier output buffer (APTS OPAMP). The sensor matrix is a 4×4 pixels test structure with analogue output channels and the aim of this technology is to provide an excellent timing performance by exploiting a high-speed operational amplifier buffer. Laboratory tests conducted through the in pixel pulsing circuit had allowed to find the best working point through a detailed study of the circuital parameters and they will be exposed together with the characterization with a ^{55}Fe source, demonstrating promising performances in terms of timing and charge collection efficiency. Finally, the results of the beam tests that took place at the Super Proton Synchrotron (SPS) at CERN, which operates at up to 450 GeV, on the Analog Pixel Test Structure of monolithic sensors with OPAMP buffer will be presented.

A coalescence afterburner for antinuclei production in hadronic collisions with Monte Carlo generators.

<u>Bellini F.</u>, Tripathy S., Jacazio N., Malfattore G., Rath R., Agrawal N.
Università di Bologna e INFN, Sezione di Bologna

The advent of the LHC as antimatter factory has enabled an unprecedented effort to measure the production of light (anti)nuclei from pp to heavy-ion collisions, providing input for a detailed study of nucleosynthesis in high-energy interactions. The production of these bound states, however, is not modelled in commonly employed event generators. To fill this gap, we developed a coalescence afterburner to be used within Monte Carlo generator inputs to model the production of light (anti)nuclei in hadronic interactions on an event-by-event basis. In this contribution, the PYTHIA8 event generator is preliminarily tuned to describe (anti)proton yields as measured at the LHC. The PYTHIA8 input is fed to a Wigner function-based coalescence afterburner that forms a nucleus when two or more nucleons are close in phase space, depending on the momentum distribution of the nucleons, the nucleus wave function, and the size of the nucleon emitting source. The results are discussed in comparison to ALICE data and in perspective, for applications of the model to the estimate of the flux of cosmic antinuclei for indirect dark matter searches with space-based experiments like AMS and GAPS.

Minimum-bias and the underlying event measurements with ALICE at the LHC.

Tripathy S. per la ALICE Collaboration
INFN, Sezione di Bologna, Bologna, Italy

To understand the similarities between small and large collision systems, one can study minimum-bias and underlying-event (UE) observables in pp, p-Pb and Pb-Pb collisions. In this contribution, we present the results obtained using UE techniques, allowing the measurement of the particle density in different topological regions with respect to the leading trigger particle. The charged-particle multiplicity in the transverse region is used as a multiplicity estimator to study particle production mechanisms. The UE studies are used to search for jet-like modification. In addition, results on very forward energy, measured by the ALICE zero-degree calorimeters, and differential studies of particle production will be presented for pp and p-Pb collisions. In the second part of the contribution, we will introduce the upgraded Run 3 ALICE configuration and the new Monolithic Active Pixel Sensors-based Inner Tracking System, which allows full tracking and vertexing for $|\eta| < 2.5$. The performance of the new detector and the tracking/matching algorithms will be presented for the $\sqrt{s} = 900\,\mathrm{GeV}$ pp pilot-beam data taken in autumn 2021.

Identification and prospects for light (anti)nuclei measurements with the upgraded ALICE detector at the LHC Run 3.

Malfattore G.
Dipartimento di Fisica ed Astronomia, Università di Bologna, Italy e INFN, Sezione di Bologna, Italy

The ALICE detector at the CERN LHC is particularly suited to study light (anti)nuclei such as (anti)deuterons, (anti)tritons and (anti)^{3}He produced in high-energy hadronic collisions. Their production mechanism is investigated by comparing experimental data with phenomenological models such as the SHM and coalescence. The coalescence mechanism also has several applications in cosmic-ray antinuclei studies and indirect dark-matter searches. The ALICE apparatus underwent a series of major upgrades during the LHC long shutdown 2 to take advantage of the luminosity increase. We will present particle identification performance for light (anti)nuclei studies and prospects for precision measurement of $A = 3$ and $A = 4$ nuclei and antinuclei in proton-proton and heavy-ion collisions that will be enabled by the unprecedented integrated luminosities expected in Run 3.

Study of MAPS silicon detector prototypes for ALICE ITS3 upgrade.

Ricci R.
Dipartimento di Fisica e INFN, Università di Salerno, Italia

The ALICE experiment at CERN has planned an upgrade of the Inner Tracking System (ITS), named ITS3, for the LHC Long Shutdown 3, in 2025. The cornerstone of the upgrade is a new CMOS pixel sensor built in 65 nm technology and in bent-cylindrical configuration, replacing the inner layers of the existing detector. The ITS3 will reach unprecedented tracking and vertexing performance, thanks to the improved spatial resolution and the much-reduced material budget. Results of data collected at beam tests using both bent ALPIDE chips and APTS Source Follower, a flat analog pixel sensor prototype, will be reported. The performance in terms of their total efficiency and spatial resolution in different experimental configurations will be discussed.

Aula D - Marianna Ciccone **ore 09:00 – 13:30**

Sezione II
Fisica della materia
Presiedono: Picone A. (Politecnico di Milano)
Trioni M.I. (SCITEC-CNR, Milano)

Surfaces and low dimensional materials

Relazioni su invito

▲ **Unexpected screening of field-effect in graphene-MoS_2 van der Waals heterojunctions.**

Roddaro S.
Università di Pisa, Pisa, Italy e NEST, CNR-Istituto Nanoscienze and Scuola Normale Superiore, Pisa, Italy

Van der Waals heterostructures play a key role in devices built out of two-dimensional materials, but their response to field effect can be rather non-trivial, due to their low density of states. Unfortunately, a direct investigation of these effects is often complex, since the layers forming the heterojunction typically cannot be probed independently. In my contribution, I will illustrate back-gated MoS_2 field-effect transistor (FET) architectures integrating multiple graphene contacts, where each contact can act as an additional FET. This allows an independent probing and correlation of the conducting properties of bare MoS_2 and of the graphene contact regions. Experiments reveal how a MoS_2 overlayer can significantly suppress the n-side field-effect in graphene, even in a configuration where it would not be expected to do so. I will show —thanks to *ab initio* calculations— that this effect can be understood as caused by deep traps associated with sulfur vacancies, which counterintuitively impact the field effect. Perspectives for the investigation of generic heterojunctions are discussed.

▲ **Reshaping 2D semiconducting layers for large-scale photon harvesting and nanoelectronics.**

Giordano M.C., Buatier de Mongeot F.
Dipartimento di Fisica, Università di Genova, Genova, Italy

Two-dimensional (2D) Transition Metal Dichalcogenide semiconductors (TMDs) have attracted diffuse interest due to their exceptional optoelectronic properties. However, the inherent low photon absorption of the atomic layers demands novel light coupling schemes. Additionally, there is an urgent request to scale up the lateral size of the 2D layers, limited in micrometric flakes, and to engineer their shape at the nanoscale. Here the nanoscale reshaping of 2D TMDs layers is shown over large-scale demonstrating superior photon harvesting properties, and opening new perspectives in nanoelectronics. In a first activity we show a flat-optics scheme based on large-area few-layers MoS_2 forming periodic nanogratings. These 2D nanopatterned layers support Rayleigh anomalies that promote strong in-plane light confinement and photon absorption enhancement, with impact in photo-conversion. As a step forward, arbitrarily defined few-layer MoS_2 nanopaths has been achieved thanks to a new additive nanofabrication, based on the thermal-Scanning Probe Lithography, showing the potential of these nanocircuits as building blocks for nanoelectronics and nanophotonics.

▲ **"And yet they move": A journey at the nanoscale.**

Baletto F.
University of Milan, Physics Department, Milano

Do not think it is a stretch to adapt the famous Galileo's quote to atoms at the nanoscale! When we squeeze our view to the atomistic scale, atoms, small clusters, and nanoparticles are very dynamic. So much that we should treat nanomaterials as 4D objects. Indeed, their chemophysical properties depend on their shape, size, and chemical ordering. As a consequence, they rely on morphological changes too. In the case of metallic nanoparticles, typical time scales are as short as hundreds of ns. In this contribution, we will review human history alongside the development of new materials. We will also look at the future and the opportunities, needs, and current challenges the community working in nanomaterials face. Examples in nanocatalysis will be presented in more detail.

▲ **Nonequilibrium transport properties of an asymmetric tunnel Josephson junction.**

Guarcello C. (1)(2), Braggio A. (3), Giazotto F. (3), Citro R. (1)(2)(4)
(1) *Dipartimento di Fisica "E.R. Caianiello", Università di Salerno, Fisciano, Salerno, Italy*
(2) *INFN, Sezione di Napoli, Gruppo Collegato di Salerno, Complesso Universitario di Napoli, Italy*
(3) *NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa, Italy*
(4) *CNR-SPIN c/o Università degli Studi di Salerno, Fisciano, Salerno, Italy*

We delve into the electric transport properties of a Josephson junction (JJ) formed by diverse superconductors residing at different temperatures. We demonstrate the peculiar behavior of Josephson and quasiparticles currents as a function of both temperatures and superconducting gaps, shedding light on the role played by the alignment of singularities in the DOS and anomalous components, which can be triggered in different ways, *e.g.*, temperature, biasing, or exchange fields. We first discuss the unusual behavior of the critical current, which shows abrupt variations and may even counterintuitively increase by enhancing the temperature of one electrode, instead of monotonically reducing as naively expected. Then, we present the bipolar thermoelectric effect on the quasiparticle current generated by the spontaneous breaking of the particle-hole symmetry, due to the thermal gradient across the JJ as the supercurrent is suppressed. Finally, we present the feasibility of controlling the response of a thermally biased JJ by a more convenient "magnetic knob", *i.e.*, via an alternative setup taking advantage of magnetic fluxes through superconducting loops enclosing the JJ electrodes.

Comunicazioni

● **Manganese oxides and zinc manganite thin films produced by pulsed laser deposition as cathodes for future Zn-ion batteries.**

Macrelli A. (1), Casari C.S. (1), Russo V. (1), Bozzini B. (2), Bussetti G. (3), Li Bassi A. (1)
(1) *Micro- and Nanostructured Materials Lab, NanoLab, Department of Energy, Politecnico di Milano, Milano, Italy*
(2) *Battery Materials Engineering Laboratory, BMEL, Department of Energy, Politecnico di Milano, Milano, Italy*
(3) *Solid-Liquid Interface Nanomicroscopy and Spectroscopy Lab, SoLINano-Σ Lab, Department of Physics, Politecnico di Milano, Milano, Italy*

In this contribution, we report on the synthesis by Pulsed Laser Deposition (PLD) of manganese oxides (MnO_x) and zinc manganite ($Zn_xMn_{3-x}O_4$) nanostructured thin films as candidates for cathodes in rechargeable aqueous zinc-ion batteries (AZIBs), which represent a safe and cost-effective alternative to lithium-ion batteries but still suffer from many limitations. PLD is a versatile technique for the synthesis of nanostructured thin films of several materials and with a wide range of properties. The control of deposition parameters like the pressure of background gas and the laser fluence enables one to tailor the morphology, stoichiometry, crystallinity, and phase of the film, which results in tunable optical, electrical, and electrochemical properties. All the films are produced at room temperature and in a wide range of gas pressures using a Nd:YAG laser with 532 nm pulses. Film crystallinity and phase are further modified by post-deposition thermal treatments. Extensive characterization is carried out to link the synthesis conditions to the material structure and properties. Finally, thin films are used as model systems to investigate the electrochemical mechanism.

Photogravitactic MXene-derived microrobots for nanoplastics capture and detection.

Urso M., Ussia M., Pumera M.

Central European Institute of Technology, CEITEC, Brno University of Technology, Czech Republic

Nanoplastics pollution represents an increasing concern due to the easier diffusion and higher hazard associated with their small sizes, justifying the pressing demand for effective strategies to quantify and remove nanoplastics in wastewater. This contribution presents the on-the-fly capture of nanoplastics in the 3D space by multifunctional MXene-derived oxide microrobots and their further detection. A thermal annealing process converts titanium carbide MXene into photocatalytic multi-layered titanium dioxide, followed by metal layer deposition and magnetic nanoparticles decoration. The MXene-derived microrobots show negative photogravitaxis, resulting in a powerful fuel-free motion with six degrees of freedom under light irradiation. Owing to the unique combination of self-propulsion and programmable Zeta potential, the microrobots quickly attract and trap nanoplastics on their surface. Utilized as self-motile preconcentration platforms, they enable nanoplastics electrochemical detection using low-cost and portable electrodes. This proof-of-concept study paves the way toward the on-site screening of nanoplastics in wastewater and its successive remediation.

Graphene-semiconductor Schottky diodes for new-generation field-effect transistors.

Anzi L., Tagliabue A, Sordan R.

Dipartimento di Fisica, Politecnico di Milano, Italia

Graphene forms a Schottky junction (SJ) with many conventional semiconductors because its semimetal nature. The graphene-semiconductor SJ have been used to fabricate solar cells and photodetectors. However, they can also be used to modulate the conductivity of the channel of a graphene-semiconductor field-effect transistor (FET). This contribution will discuss the characterization of the SJ between graphene and the following three n-type semiconductors: Ge, Si, and GaAs. We will also demonstrate that the graphene-GaAs SJ can be used as a gate of a FET. This FET exploits the possibility of adjusting the graphene work function by an additional control gate stack fabricated on top of the graphene gate. A change of the graphene work function results in the modulation of the graphene-GaAs Schottky barrier height (SBH) and, therefore, the threshold voltage (V_{th}) of the FET. We used the modulation of the SBH to realize FETs that can be converted from the depletion mode FETs (with a negative V_{th}), into the enhancement mode FETs (with a positive V_{th}). This allowed the fabrication of digital logic gates with a positive switching threshold, which is needed for realizing integrated circuits.

Aspects on the synthesis of infinite-layer nickelate thin films and related transport properties.

PREZIOSI D., KRIEGER G., VERSINI G., VIART N.
Université de Strasbourg, CNRS, IPCMS UMR 7504, Strasbourg, France

In the last three decades, motivated by a theoretical prediction, several efforts were devoted at achieving an orbital engineering in nickelate heterostructures. The goal was to mimic the electronic structure and conduction properties of cuprates. Finally, these efforts led to the realization of superconducting $Nd_{0.8}Sr_{0.2}NiO_2$ infinite-layer thin films below 15 K with a Ni-3d$^{9-\delta}$ configuration and reduced dimensionality. The main step to achieve this result is an oxygen de-intercalation of the pristine perovskite $Nd_{1-x}Sr_xNiO_3$ phase via a topotactic reduction by using a CaH_2 powder as a reagent. Existing challenges regarding the synthesis of Sr-doped nickelate thin films, combined with the pivotal handling of the topotactic reduction, make it hard to establish a reproducible route towards superconducting infinite-layer nickelates. This explains why, so far, the zero-resistance state could be reproduced by only few groups. Here, we will report on our synthesis approach to stabilize the infinite-layer phase together with anisotropic magnetotransport measurements, and briefly discuss a novel approach to obtain the infinite-layer phase.

Two-dimensional lateral IV-ene heterostructures for innovative topological devices.

DEBERNARDI A. (1), DOUMA D.H. (2)
(1) *CNR-IMM, Unit of Agrate Brianza, Agrate Brianza, MB, Italy*
(2) *Groupe de Simulations Numériques en Magnétisme et Catalyse, Faculté des Sciences et Techniques, Université Marien Ngouabi, Brazzaville, Congo*

Silicene, germanene and stanene, three honeycomb two-dimensional (2D) lattices constituted by Si, Ge, and Sn, respectively, are predicted to be topological insulators and to present an electronic bandgap in correspondence to Dirac's cone. Recently, the lateral growth of pseudomorphic germanene/stanene junctions has been experimentally achieved triggering further interest on these materials. Within the framework of the density functional theory, by plane wave pseudopotential techniques we computed the band offset of lateral heterostructures composed of silicene/germanene and germanene/stanene nanoribbons, thus forming 2D layers. We simulated the structural properties and the microscopic mechanisms responsible of the dependence of the band-offset on the orientation of the heterojunction. We enlightened the electronic properties governing the band alignment of H functionalized heterojunctions to design 2D heterostructures with tunable band-offset to be used as building block in forthcoming electronic devices based on 2D materials. The study of quantum confinement and topological effects complete the work.

Unusual hexagonal NaCl structures at lead halide perovskite surfaces: New insights from first-principles calculations.

PECORARO A. (1), MUNOZ-GARCIA A.B. (1), MADDALENA P. (1), DELLI VENERI P. (2), PAVONE M. (3)
(1) *Dipartimento di Fisica, Università degli Studi di Napoli "Federico II"*
(2) *Centro Ricerche ENEA di Portici*
(3) *Dipartimento di Scienze Chimiche, Università degli Studi di Napoli "Federico II"*

Sodium chloride NaCl is a ionic compound that is used in heterogeneous junctions for tuning the electronic properties of the interface. In photovoltaics, NaCl is often used in perovskite solar cells as interlayer between the photoactive material and the charge transport layers. Despite its simplicity, unexpected complex NaCl interfacial structures can be found at high pressure or low dimensions. The most stable surface facet of cubic NaCl is the (100), nevertheless recent experiments found different surface termination depending on the chemical nature and the structure of the substrate, for example a hexagonal surface of NaCl has been found on the diamond (110) surface. In this framework, this contribution explores the interface between NaCl and the prototypical lead halide perovskite (MAPI) with first-principles calculations at the DFT level of theory. Our results show different possible NaCl surface reconstructions depending on the MAPI terminations and the nature of the interactions at play. Effects on MAPI electronic structure (work function, band edge potentials) are also discussed. These findings will help the design of new and better performing perovskite solar cells.

Long-lived photogenerated carriers in 2D TMDs nanosheets made by liquid-phase exfoliation (LPE).

Morabito F.
Politecnico di Milano e Istituto Italiano di Tecnologia, IIT

Two-dimensional (2D) transition metal dichalcogenides (TMDs) such as MoS_2 and WS_2 are excellent candidates for next-generation energy storage and optoelectronics due to their strong light-matter interaction. The preparation of monolayer TMDs by mechanical exfoliation is a labour-intensive process and the yield is low. An alternative top-down approach, which may be more suitable for industry, is the liquid phase exfoliation technique (LPE) which can produce an extremely high yield with reasonable quality. In this study, we investigate LPE MoS_2 samples using time-resolved optical spectroscopy. The transient response of these materials is dictated by the formation and recombination of bound states, *e.g.*, excitons, trions, and biexcitons. Using a specially designed pump-probe setup, we measured the lifetime of these photoexcited states from the femtosecond (10^{-15} s) to microsecond range (10^{-6} s). Pumping at 3.5 eV, we observe spectral features which exhibit dynamics up to ~ 100 ns. Understanding the origin of complex physical processes in this temporal range is crucial for applications which rely on long-lived states.

***In situ* and in real time electrochemical-stm analysis of sulphate adsorption on vicinal Cu(111) electrode surfaces.**

Filoni C. (1), Bussetti G. (1), Duò L. (1), Ciccacci F. (1), Wandelt K. (2)
(1) *Department of Physics, Politecnico di Milano, Italy*
(2) *Institute of Physical and Theoretical Chemistry, Bonn University, Germany*

Copper has been termed the “metal of the 21st century”. The electrochemical production of integrated copper circuitry has revolutionized information technology. The decreasing dimension of the circuitry wires and vias calls for a detailed understanding of the electrochemical behaviour of copper on the nanometer, even atomic, scale. This turns the gaze on the influence of atomic scale surface defects in the electrochemical deposition and etching processes. In this contribution we present *in situ* electrochemical scanning tunnelling microscopy results on the reconstruction of well-defined vicinal Cu(111) electrodes of progressively reduced terrace width (*e.g.*, Cu(21 21 16) and Cu(221)) in dilute sulfuric acid solution (H_2SO_4). In contact with H_2SO_4 the flat reference Cu(111) electrode is known to reconstruct in a stable Moiré superstructure. At the potential for which bare Cu(221) is expected, the surface appears directly covered by some regular stripes, forming three ensembles of the Cu(221) terraces (1.2 nm; 2.1 nm and 3.3 nm). All three widths are significantly larger than the bare Cu(221) terrace (0.74 nm) but fully consistent with multiples of the size of a Moiré unit.

Analysis of the formation of *sp*-carbon chains by pulsed laser ablation in liquid through *in situ* UV resonance Raman spectroscopy.

Marabotti P. (1), Peggiani S. (1), Rossi B. (2), Gessini A. (2), Li Bassi A. (1), Russo V. (1), Casari C.S. (1)

([1]) *Dipartimento di Energia, Politecnico di Milano, Italia*
([2]) *Elettra Sincrotrone Trieste SCpA, Italia*

Polyynes are 1D systems consisting of linear chains made of *sp*-hybridized carbon atoms. Their outstanding predicted properties attracted the interest of material scientists over the last decades. Vibrational spectroscopy emerged as a fundamental tool to investigate these properties. Indeed, polyynes are characterized by a Raman-active collective vibration which is strongly influenced by chain structural and electronic properties. Pulsed laser ablation in liquid (PLAL) turned up as the most efficient and versatile physical method to synthesize polyynes. However, the formation of polyynes during PLAL is still unclear. Thus, we investigated the synthesis of polyyne by PLAL through synchrotron-based *in situ* UV resonance Raman spectroscopy. Thanks to the resonance condition and the tunability of the synchrotron radiation, we could track the entire evolution of the formation of polyynes with an improved time resolution. We found that the synthesis yield is higher in solvents with a high C/H ratio and low polarity, increases with the laser energy and we discovered a threshold fluence when ablating at 1064 nm. We evaluated the production of single shots and the diffusion mechanisms.

● High-throughput search, characterization and engineering of novel 2D and 1D materials.

Campi D. ([1]), Mounet N. ([1]), Gibertini M. ([1]), Pizzi G. ([1]), Marzari N. ([1])
([1]) *Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*
([2]) *Università di Milano-Bicocca, Milano, Italy*
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Low-dimensional materials have emerged as promising candidates for next-generation applications in the fields of electronics, optoelectronics and energy storage. In a previous study we performed an extensive high-throughput screening of experimentally known inorganic materials, identifying more than 1800 compounds exfoliable into novel two-dimensional monolayers. Thanks to the inclusion of new structures obtained from an additional experimental database, new versions of the original sources and a refined screening procedure, we have added 1200 candidates to our portfolio. We also completed a broad characterization of their properties, focusing on relevant descriptors for field-effect applications, superconductivity and photocatalysis. More recently we start exploring how the properties of these materials can be engineered by controlled layering, strain and functionalizations. Finally, using a similar screening procedure we identified more than 800 1D or quasi-1D wires that could be isolated from their vdW-bonded parents.

● Moiré-regulated distribution of Co adatoms and nanoclusters on epitaxial graphene.

Del Puppo S., Stavrić S., Chesnyak V., Panighel M., Comelli G., Africh C., Peressi M.
University of Trieste

Graphene(G) grown on Ni(100) is periodically corrugated due to the lattice mismatch with the substrate, resulting in an alternate arrangement of strongly and weakly interacting G regions. In striped Moiré patterns, larger concentration of Co adatoms and nanoclusters on G's ridges as compared to valleys is experimentally observed. We performed density functional theory calculations and predicted that Co prefer to bind to ridge much stronger than on valley. Similar results are obtained for small Co clusters. The analysis of charge redistribution upon Co adsorption on G/Ni(100) shows that an electron rearrangement takes place, originating a repulsive Co-Ni interaction mediated by G and modulated by its corrugation: the farther the Co from Ni is, the weaker the repulsion is and the higher the binding energy on G is. Moreover, the repulsive nature of this interaction increases the adsorbate mobility, allowing Co atoms to drift more easily from the valley to the ridge than in any other direction, as suggested by the calculated diffusion barriers. These findings are in line with experimental scanning tunneling microscopy images that show small Co clusters sitting exclusively on the ridges.

Aula T - Caterina Scarpellini **ore 09:00 – 13:30**

Sezione III
Astrofisica
Presiede: Bucciantini N. (INAF, Osservatorio astrofisica di Arcetri, Università di Firenze e INFN)

Cosmic rays

Relazioni su invito

▲ **Rivelazione diretta di raggi cosmici.**
Adriani O.
Università di Firenze e INFN, Sezione di Firenze
In questa relazione verranno presentati e discussi i più recenti risultati sperimentali relativi alla rivelazione diretta di raggi cosmici, ottenuti utilizzando principalmente rivelatori in orbita attorno alla Terra. Saranno in particolare illustrati i risultati relativi agli spettri di protoni, elettroni e nuclei leggeri, nonché le misure dei flussi di antiparticelle (antiprotoni e positroni). Verranno anche presentate le più recenti misure dei rapporti tra nuclei secondari e nuclei primari, particolarmente importanti per lo studio dei meccanismi di propagazione dei raggi cosmici nella nostra galassia.

▲ **I raggi cosmici di altissima energia e le loro sorgenti: Recenti risultati e interpretazioni.**
Boncioli D.
Università degli Studi dell'Aquila e INFN, Laboratori Nazionali del Gran Sasso, Assergi, L'Aquila
I raggi cosmici di altissima energia possono trasportare informazioni sui processi che li hanno generati in sorgenti astrofisiche e sui dettagli della propagazione nello spazio extra-galattico. Come possiamo dunque sfruttare le osservazioni degli attuali esperimenti per approfondire le nostre conoscenze sulle possibili sorgenti dei raggi cosmici? In questo contributo, i recenti risultati sperimentali e le loro interpretazioni in termini di scenari astrofisici verranno illustrati. La connessione dei raggi cosmici con altri messaggeri astrofisici, presumibilmente prodotti a seguito delle interazioni dei raggi cosmici nelle sorgenti o durante la propagazione nello spazio extra-galattico, verrà discussa come possibile strada per incrementare la comprensione della natura e del funzionamento dei siti di accelerazione dei raggi cosmici.

▲ **Ammassi stellari ed emissione di alta energia.**
Morlino G.
INAF, Osservatorio Astrofisico di Arcetri, High Energy Astrophysics Division
A distanza di un secolo dalla scoperta dei raggi cosmici, la loro origine continua ad essere tema di acceso dibattito. In particolare non è ancora chiaro quali siano le sorgenti galattiche capaci di accelerare protoni fino all'energia del PeV equivalente a 10^{15} eV. I candidati da sempre favoriti, cioè i resti di supernovae, non sembrano in grado di raggiungere tali energie: mancano sia le evidenze osservative che una solida giustificazione teorica. Per tale motivo la ricerca di sorgenti alternative assume una rilevanza sempre maggiore. In questo contributo discuterò la possiblità che i raggi cosmici all'energia del PeV siano accelerati dai venti collettivi prodotti dalle giovani stelle in ammassi stellari. Discuterò un modello che prevede l'accelerazione delle particelle allo shock terminale di tali venti e la successiva emissione di

radiazione gamma risultante dalla collisione delle particelle accelerate con il gas che circonda gli ammassi stellari. Discuterò inoltre la possibilità di osservare l'emissione gamma con i telescopi Cherenkov presenti e futuri.

Comunicazioni

Measurement of daily proton flux temporal evolution with AMS-02 on the ISS.

FALDI F. PER LA AMS-02 COLLABORATION
Università degli Studi di Perugia, Dipartimento di Fisica e Geologia e INFN, Sezione di Perugia

The Alpha Magnetic Spectrometer (AMS-02) is a high-energy particle detector designed to precisely study the properties of cosmic rays from GV to TV rigidities in space. The experiment is currently operating in the International Space Station (ISS) since its installation in May 19, 2011 and has continuously collected cosmic rays since then. Here we present the precision measurement of the monthly and daily proton fluxes by AMS-02 on the ISS using data collected from May 20, 2011 to October 29, 2019, in the rigidity interval from 1 to 100 GV. We observed that the proton fluxes exhibit distinct variations and periodicities emerging at the various scales of time and rigidity. These results are of particular interest for the study of transient solar events, such as flares, coronal mass ejections, and their influence on the transport of cosmic rays in interplanetary space.

The cosmic antiproton puzzle.

D'ANGELO F., MASI N., OLIVA A.
INFN, Sezione di Bologna e Università degli Studi di Bologna-Alma Mater Studiorium, Dipartimento di Fisica

As there are no known astrophysical sources of cosmic ray (CR) antiprotons, they represent a good channel for indirect dark matter search. The secondary antiproton background is produced in collisions between primary CRs and the interstellar medium (spallation). In the last decade, thanks to high-precision measurements by AMS-02 and PAMELA, a possible tension between the observed antiproton flux and different predictive models has been highlighted, between 1 and 500 GeV in the antiproton kinetic energy. The large uncertainties which afflict antiproton flux predictions do not allow us to confirm the presence of an exotic signal, deserving further investigations. In the 10–100 GeV range, the dominant uncertainties are the production cross-section ones: the pp, p-He and He-p channels are responsible for almost all the cosmic antiprotons. Different models (Monte Carlo approaches, parametrisations, etc.) are used to predict the antiproton production cross-section but they are in tension among themselves. For this purpose, the COMPASS++/AMBER experiment will help us to resolve this tension with incoming p-He collisions data.

Il modulo LEM per la missione spaziale NUSES.

NICOLAIDIS R., NOZZOLI F.
Dipartimento di Fisica, Università degli Studi di Trento, Italia e INFN, Trento Institute of Fundamental Physics and Applications, Italia

La missione spaziale NUSES ospiterà due strumenti, Terzina e Zirè, allo scopo di esplorare nuove tecnologie per la fisica del neutrino e per lo studio di fenomeni di interazione tra litosfera e magnetosfera, rispettivamente. In particolare elettroni sub-MeV intrappolati nelle fasce di Van Allen, rappresentano un canale importante per rivelare fenomeni transienti della litosfera. La misura contemporanea dell'energia cinetica, della direzione e della massa di particelle di bassa energia richiede normalmente lo sviluppo di spettrometri voluminosi e complessi. Sarà presentato il rivelatore compatto (LEM, Low Energy Module) che mediante due strati di silicio di diverso spessore è in grado di misurare la massa e l'energia cinetica delle particelle di bassa energia utilizzando la tecnica ΔE-E. La presenza di uno strato esterno, costituito da scintillatore plastico e da una maschera di alluminio opportunamente forati, permette al LEM di selezionare la direzione di incidenza delle particelle. Il volume ridotto del LEM, $10 \times 10 \times 5\,\text{cm}^3$, consente di ospitare tale detector come sotto-rivelatore del telescopio Zirè previsto nella missione spaziale NUSES.

Arrival directions of UHECRs after the end of phase 1 of the Pierre Auger Observatory.

Mariani F.M. per la Pierre Auger Collaboration
Dipartimento di Fisica, Università degli Studi di Milano, Milano, Italia e INFN, Sezione di Milano, Milano, Italia

The Pierre Auger Observatory is the largest and most important hybrid detector designed to investigate the origin and the nature of Ultra High Energy Cosmic Rays. The observatory has been in operation continuously since 2004, and has achieved a total detection exposure of approximately $122 \times 10^3\,\text{km}^2\,\text{sr}\,\text{yr}$. During the currently more than 18 years of research, the Auger Observatory has collected a huge amount of high-quality data which gave us knowledge about the origin of the most energetic particles ever observed in the universe. This contribution will present the main and most recent results of the arrival direction studies obtained with the Auger phase 1 dataset, *i.e.*, the one before the installation of the upgrade Auger Prime, currently in completion. These include the searches for possible sources from small to large scale: studies of dipolar and multipolar anisotropies, search for excesses of the order of the scale of tens of degrees at the highest energies, and search for excesses of the order of the angular resolution (approximately 1 degree) to look for neutral particles.

LIMADOU monolithic pixel sensors for the study of earthquakes from Space.

Savino U. (1)(2), Perciballi S. (1)(2), Ferrero C. (2), Coli S. (2), Dumitrache F. (2), Benotto F. (2), Beolè S. (1)(2)
(1) *Dipartimento di Fisica, Università degli Studi di Torino, Italia*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italia*

CSES (China Seismo-Electromagnetic Satellite)-LIMADOU is a scientific program of Space missions that aims to deepen the comprehension of the time correlation between the main earthquake shocks and an increase in the electron flux in the inner Van Allen belt. For this purpose, the LIMADOU Collaboration is realizing the first space tracker consisting of monolithic silicon pixel sensors based on the ALPIDE (ALice PIxel DEtector) technology, developed for the ALICE (A Large Ion Collider Experiment) ITS upgrade at CERN. In this contribution, the assembly procedures together with the qualification tests, which allow to select the best modules for the tracker construction, will be presented. Furthermore, the sensor performance as a function of temperature will be discussed.

The NUSES fiber tracker.

Panzarini G. per la NUSES Collaboration
INFN, Sezione di Bari e Dipartimento interateneo di Fisica dell'Università di Bari e del Politecnico di Bari

We have built a tracker prototype for the ZIRÈ detector to be installed onboard the NUSES satellite. The tracker consists of multiple planes of scintillating fibers readout with Silicon Photomultipliers (SIPMs). The fibers in each plane are oriented perpendicularly to those in the adjacent plane, in order to allow 3D track reconstruction. Scintillating fibers allow a reduced material budget while providing a good spatial resolution and a fast response. This design is therefore suitable to track low-energy cosmic rays down to a few MeV. The prototype has been tested with particle beams, cosmic rays and radioactive sources. The tracker design will be presented and some preliminary results obtained with the prototype will be discussed.

The NUSES mission.

Lorusso L. per la NUSES Collaboration
INFN, Sezione di Bari e Dipartimento interateneo di Fisica dell'Università di Bari e del Politecnico di Bari

NUSES is a pathfinder project for innovative satellite-borne particle detectors dedicated to the study of cosmic radiation, astrophysical neutrinos, Sun-Earth environment, space weather and magnetosphere ionosphere lithosphere coupling. The satellite will host two payloads, named ZIRÈ and TERZINA. The ZIRÈ instrument will measure the fluxes of low-energy cosmic-ray protons, light nuclei, electrons, positrons and gamma rays with energies up to a few hundreds of MeV. TERZINA will test innovative techniques for the detection of astrophysical neutrino signals, looking at the Cherenkov light produced by the extensive air showers generated in the atmosphere. The scientific objectives and features of the NUSES project will be presented.

Aula U - Giuliana Cini Castagnoli **ore 10:00 – 12:00**

Sezione IV

Geofisica e fisica dell'ambiente

Presiede: Marotta A.M. (Università di Milano)

Tectonophysics and seismology

Relazioni su invito

▲ Earthquake forecasting in Italy.

Gasperini P. (1)(2), Biondini E. (1), Gulia L. (1), Lolli B. (2), Vannucci G. (2)
(1) *Dipartimento di Fisica e Astronomia, Università di Bologna*
(2) *Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna*

Even if the deterministic prediction of earthquakes is presently not feasible and perhaps it will never be, several methods of probabilistic operational forecasting have been proposed in the last decades. Many of such methods take advantage of the well-known property of earthquakes to cluster in space and time. In order to verify the method, a testable hypothesis must be formulated based on a retrospective analysis but the real verification can only be made prospectively, based on data that will occur only after the final definition of the hypothesis. Any successive modification of the forecasting hypothesis will require a restart of the prospective test. The formulation and the testing require an earthquake catalog as most complete and homogenous as possible, particularly regarding the magnitude of events. This can be obtained by a careful calibration of available magnitude data.

▲ Moment tensor solutions from waveform inversion of digital and analog data: Physical exploration of seismogenic stress fields and geodynamic processes on different scales.

Orecchio B.
Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università degli studi di Messina

Moment tensor solutions are important constraints useful to depict the kinematics and to model the dynamics of seismically active areas. In this context moderate-to-major earthquakes, mainly related to regional-scale processes, may be crucial to characterize regional geodynamics and seismic hazard, while lower magnitude earthquakes may contribute to better detail seismic processes and related stress fields on a local scale. Then, capability of estimating high-quality MT solutions through waveform inversion is a crucial issue: on one side the goal is that of lowering the threshold magnitude for stable and reliable MT solutions of recent events, on the other relevant earthquakes occurred from the early age of seismometry to the advent of the digital era need to be analyzed by adapting modern techniques to lower-quality analog data. This effort permit to investigate not fully resolved events of the past by enhancing the invaluable capital of data collected in early instrumental periods. Results presented here, obtained in several applications of different methods, may help understanding how reconstruction of seismic and geodynamic processes at regional and local scale can be improved.

▲ The challenging seismotectonic characterization of multi-depth compressional domains in areas with low-deformation rates and blind thrusting.

de Nardis R.
DiSPuTer, Department of Psychological, Health and Territorial Sciences, University "G. d'Annunzio" Chieti-Pescara, Chieti, Italy e CRUST - Centro inteRUniversitario per l'analisi SismoTettonica tridimensionale, Italy

Defining the geometry and kinematics of potentially seismogenic structures in compressional domains is not straightforward, especially in areas with low-deformation rates and blind onshore or offshore thrusting. Furthermore, the coastal and offshore zones do not allow proper seismic and geodetic monitoring systems leading to inaccurate locations of seismic events, unconstrained GPS velocities, and consequently a poor knowledge of the active tectonics. I will show key cases of 3D fault modeling and seismotectonic characterization, along the Outer Thrust System (OTS) of Italy, defined by integrating geological and seismological data with variable quality. Starting from recent findings of multi-depth compressional domains in eastern Central Italy, built with high-resolution seismic locations, I will discuss the possible extension of the deformation style of compressional domain in Northern Italy and Sicily by using spatio-temporal seismicity cluster and kinematics analysis. Finally, I will present new seismic tomography results, along a segment of OTS located in the Abruzzi-Molise region, highlighting an unknown thick-skinned deformation style.

Comunicazioni

● Analisi multi-parametrica del terremoto di M7.2 avvenuto il 15 giugno 2019 nelle isole Kermadec (Nuova Zelanda).

<u>Orlando M.</u> (1), De Santis A. (1), Perrone L. (1), Calcara M. (1), Campuzano S.A. (2), Cianchini G. (1), D'Arcangelo S. (1)(3), Di Mauro D. (1), Marchetti D. (4), Nardi A. (1), Piscini A. (1), Sabbagh D. (1), Soldani M. (1)
(1) *Istituto Nazionale di Geofisica e Vulcanologia,Rome, Italy*
(2) *Instituto de Geociencias IGEO, CSIC-UCM, Madrid, Spain*
(3) *Universidad Complutense de Madrid, UCM, Madrid, Spain*
(4) *College of Instrumentation and Electrical Engineering, Jilin University, Changchun, China*

Il movimento di una faglia inversa lungo il margine di subduzione Tonga-Kermadec ha provocato un importante evento sismico il 15 giugno 2019 nelle isole Kermadec (Nuova Zelanda) di magnitudo 7.2. Questo lavoro mostra un approccio multi-parametrico volto a studiare i processi legati alla nucleazione di un evento sismico e in particolare alla sua fase preparatoria, attraverso analisi di diverse tipologie di dati registrati nella litosfera, nell'atmosfera, fino ad arrivare alla ionosfera. Nel dettaglio verranno mostrati i risultati ottenuti dalle analisi di dati sismici forniti dai cataloghi, di dati atmosferici ottenuti a partire dagli archivi climatologici ed infine di dati ionosferici sia da terra attraverso il TEC sia dallo spazio, attraverso lo studio della densità elettronica, del campo elettrico e del campo magnetico registrati dai satelliti Swarm (ESA) e CSES (CNSA - ASI). Questa analisi multi-parametrica dimostra un accoppiamento tra litosfera-atmosfera-ionosfera (LAIC) in occasione di forti eventi sismici.

● Correlation between Western Pacific earthquakes and NOAA electron bursts and their transfer entropy.

<u>Fidani C.</u> (1)(2), De Santis A. (1), Perrone L. (1)
(1) *Istituto Nazionale di Geofisica e Vulcanologia*
(2) *Central Italy Electromagnetic Network*

The NOAA-15 satellite high-energy particle database has been analyzed for nearly two decades together with shallow M6+ earthquakes (hypocentral depth < 200 km) in Westerm

Pacific. Electron burst events resulted at 1.5-3.5 hours before the earthquake events. This result was robust since it was obtained with an appropriate statistical significance. A conditional probability formulation of earthquake occurrence following satellite measurements was realized for binary events. This was expressed through the Phi correlation coefficient, i.e. the so called Matthews correlation, which is the Pearson's correlation between binary events. Finally, the transfer entropy has been calculated analytically, starting from the conditional probability distributions. It revealed a consistent transfer of information from the set of electron bursts to those of earthquakes, corresponding to the correlation peak, together with a new and less pronounced exchange of information, about two and a half days later. The significance of these results is discussed with respect to the possible cause-effect relationship between the two sets of events.

Aula E - Rosalind Franklin **ore 09:00 – 13:00**

Sezione V
Biofisica e fisica medica

Presiedono: Chiesa C. (Istituto Nazionale dei Tumori, Milano)
Zito M. (Policlinico di Milano)

Relazioni su invito

▲ **Magnetic nanostructures for therapy and diagnostics in biomedicine.**
Mariani M.
Università degli Studi di Pavia, INFN e INSTM, Pavia
Starting from the new millennium the interest for the study of superparamagnetic nanoparticles (NPs) has progressively increased with the ability in manipulating matter at the nanoscale. This has paved the way to the creation of a plethora of novel systems characterized by extremely appealing properties exploitable in a wide number of clinical theranostic applications: the most prominent are Magnetic Resonance Imaging (MRI) and Magnetic Fluid Hyperthermia (MFH). Superparamagnetic nanoparticles are nanometric objects composed by a magnetic core (usually based on magnetite or maghemite) covered with an organic coating. In this framework, we investigated the NPs properties for their application as contrast agents for MRI (diagnostics) and heating agents for MFH (therapy). In particular we focused on their magnetic, relaxometric and hyperthermic properties, in order to improve their efficiency. We verified these features as a function of the kind and size of magnetic core ion, of the shape of the NPs and of the kind of coating.

Comunicazioni

● **Cross-section of the production of theranostic-relevant terbium isotopes by deuterons beam irradiation of dysprosium targets.**
Colucci M. (1)(2), Carminati S. (1)(2), Manenti S. (1)(2), Haddad F. (3), Groppi F. (1)(2)
(1) *Department of Physics, University of Milan, Milano, Italy*
(2) *INFN, Section of Milano, Milano, Italy*
(3) *GIP ARRONAX, Saint-Herblain, Nantes, France*
Recently, lot of interest has arisen in studying the production of four terbium radioisotopes that could be employed for therapy and diagnostic in nuclear medicine. ^{149}Tb can be used for both alpha targeted radiotherapy and PET imaging due to its double decay modality, ^{152}Tb and ^{155}Tb have suitable characteristics for SPECT and PET imaging techniques respectively, while ^{161}Tb, whose decay comes with an intense Auger electrons emission, may found medical application in the Auger Targeted Radiation Therapy. Several production routes have been proposed. We investigated the possibility to produce high specific activity terbium radioisotopes via the $^{\mathrm{nat}}\mathrm{Dy}(d,x)^{1xx}\mathrm{Tb}$ reactions, by determining the cross-section and the thin target yield in an energy range between 15 and 32 MeV for the incident deuterons beam. Targets have been irradiated with the ARRONAX cyclotron (Saint-Herblain, Nantes, France) using the stacked foil technique. The determination of the produced activity using high-resolution gamma-ray spectrometry was performed at LASA laboratory (Segrate, Milano). In this contribution we present the preliminary results of this work and the future perspectives.

An analytical method for the calculation of Voxel S-Values for ^{177}Lu

Pistone D. (1)(2), Auditore L. (1)(2), Italiano A. (2)(3), Amato E. (1)(2)
(1) *BIOMORF Department, University of Messina, Messina, Italy*
(2) *INFN, Section of Catania, Catania, Italy*
(3) *MIFT Department, University of Messina, Messina, Italy*

Voxel S-Values (VSVs) are commonly employed to perform 3D internal dosimetry for non-uniform activity distributions of radionuclides, but are generally calculated and made available for a limited number of voxel sizes. In this study we present an analytical method developed to easily calculate VSVs in any cubic voxel dimension of practical utility in the case of ^{177}Lu, a β-emitter widely used in radionuclide therapies. For this purpose, we evaluated via GAMOS GEANT4-based Monte Carlo simulations the ^{177}Lu VSVs in homogeneous soft-tissue geometries made of $15 \times 15 \times 15$ cubic voxels of sides d within the range (2 mm, 6 mm), in steps of 0.5 mm. For each d, the VSVs as a function of the normalized radius $R_n = R/d$ (R being the distance from the center of the source voxel) were fitted with an appropriately built function. The trends of the fit parameters as a function of d were consequently deduced, and through them it was finally made it possible to calculate the VSVs for any d within the mentioned range, by simply exploiting a dedicated electronic spreadsheet.

Standardization of I-131 using portable $4\pi\beta(LS)$-γ coincidence detection system in OPBG hospital.

Abubaker F. (1)(2), Capogni M. (3), Capone M. (3), Cannata V. (4), Donatiello S. (4), Tortorici F. (1)(2), Sutera C. (1)(2), Pepe F. (5), Corbo M. (5), De Felice P. (3), Bellini V. (1)
(1) *University of Catania, Department of Physics, Italy*
(2) *Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Italy*
(3) *ENEA, Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti, INMRI, C.R Casaccia, Rome, Italy*
(4) *Ospedale Pediatrico Bambino Gesù (OPBG) hospital in Vatican City, Italy*
(5) *Costruzioni Apparecchiature Elettroniche Nucleari, CAEN, Viareggio, Italy*

This project concerned the development at ENEA-INMRI of new *in situ* $4\pi\beta(LS)$-γ coincidence detection system (4PBLSG) for activity measurement of the short half-life radionuclides used in nuclear medicine. For the first time the portable 4PBLSG detector is used directly at the OPBG hospital in Vatican City, Italy, to measure the activity of I-131 and to calibrate the OPBG ionization chamber used for routine applications. The hardware of the new portable 4PBLSG detector was developed at ENEA-INMRI, in collaboration with Catania University and INFN, by implementing a gamma channel on the existing TDCR portable detector available at ENEA. A data analysis software was updated at CAEN in order to analyze the data recorded in list-mode by the new detector equipped with the CAEN desktop digitizer DT5720. The activity measurements for short half-life radionuclides used in nuclear medicine can be then computed. Two primary activity measurement —TDCR and $4\pi\beta(LS)$-γ coincidence— methods were then used to determine the activity of I-131 in the OPBG hospital. The TDCR parameter is measured for I-131 standard solution using both CAEN and ENEA data analysis software.

The impact of Internal Bremsstrahlung on the Dose Point Kernel: The case of ^{90}Y.

Auditore L. (1)(2), Italiano A. (2)(3), Pistone D. (1)(2), Amato E. (1)(2)
(1) *BIOMORF Department, University of Messina, Messina, Italy*
(2) *INFN, Section of Catania, Catania, Italy*
(3) *MIFT Department, University of Messina, Messina, Italy*

Internal Bremsstrahlung (IB) is a process accompanying beta decay and consisting in the emission of photons with continuous energy up to the end-point of the beta spectrum. It is usually neglected when Dose Point Kernels (DPKs) are estimated for beta emitting radioisotopes. In this study, the DPK for ^{90}Y was re-calculated including IB in Monte Carlo (MC) simulations, so that the contribution of IB to DPK was assessed. GAMOS MC simulations were carried out scoring the energy deposited in concentric spherical shells, made of water, having radii ranging from 0.01 mm to 30 mm. Results show that the contribution of IB photons to DPK is negligible for distances within the beta-particle range, where the contribution of beta particles is dominant; for larger distances, IB photon contribution becomes higher than 20% thus confirming the relevant role of Internal Bremsstrahlung emission when estimating DPK at distances larger than beta-particle range. Consequently, the inclusion of IB photons as an additional source term in MC simulations is advisable for ^{90}Y DPK estimation.

Radiobiological model for β-emitter radiopharmaceutical therapy in dynamic cell cultures in the framework of the ISOLPHARM project.

Arzenton A. (1)(2), Andrighetto A. (1), Lunardon M. (3)(4), Mariotti E. (2)(5), Morselli L. (1)(6)
(1) *INFN, Laboratori Nazionali di Legnaro, Legnaro, Padova, Italia*
(2) *Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena, Siena, Italia*
(3) *Dipartimento di Fisica e Astronomia, Università di Padova, Padova, Italia*
(4) *INFN, Sezione di Padova, Padova, Italia*
(5) *INFN, Sezione di Pisa, Pisa, Italia*
(6) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Ferrara, Italia*

In medical physics and radiobiology, the most common method to probe the efficacy of radiation therapy approaches *in vitro* is the cell survival trial. Recently, the traditional procedure for external beams has been extended by some groups to targeted radionuclides. In parallel, the bioengineering state of the art allows for the use of 3D tissue-mimicking scaffolds to obtain realistic cell cultures in dynamic conditions. The aim of this study is to implement a mathematical model for the assessment of β-emitting radiopharmaceuticals, considering their molecular kinetics *in vitro* and how it affects the radiation delivery to cells. The molecular transitions will be assumed to fulfill the definition of Markov processes, while the cell survival will depend on the DNA damage, in competition with a logistic growth. The solutions of the resulting differential system will be evaluated and compared to numerical examples, *in silico* simulations and literature data. This work belongs to the framework of the ISOLPHARM project, headed by INFN-LNL, which has the aim of developing innovative radiopharmaceuticals exploiting the Isotope Separation On-Line (ISOL) at the SPES facility.

Production and characterization of ^{111}Ag radioisotope for medical use in a TRIGA Mark II Nuclear Reactor.

Morselli L. (1)(2), Lunardon M. (3)(7), Stevanato L. (3), Andrighetto A. (2), Corradetti S. (2), Donzella A. (4), Zenoni A. (4), Asti M. (5), Bortolussi S. (6), Zangrando L. (7), Salvini A. (8), Gandini A. (8), Ferrari M. (9)
(1) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Italia*
(2) *INFN, Laboratori Nazionali di Legnaro*
(3) *Dipartimento di Fisica e Astronomia, Universitàdi Padova, Italia*
(4) *Dipartimento di Ingegneria Meccanica ed Industriale, Università di Brescia, Italia*
(5) *Dipartimento di Fisica, Università di Pavia, Italia*
(6) *AUSL Reggio Emilia, Italia*

([7]) *INFN, Sezione di Padova*
([8]) *Laboratorio Energia Nucleare Applicata, Pavia, Italia*
([9]) *CERN, Svizzera*

RadioPharmaceutical Therapy (RPT) comes forth as a promising technique to treat a wide range of tumors while ensuring low collateral damage to nearby healthy tissues. Recently ^{111}Ag was proposed as a promising core of a therapeutic radiopharmaceutical for the treatment of large tumors given its penetrating β-emission. Moreover, it also emits two γ-rays (342 keV $I_\gamma = 6.7\%$ and 245 keV $I_\gamma = 1.24\%$), suitable for SPECT imaging, making the therapy follow-up feasible. Finally, its half-life of 7.5 days allows for all the mandatory radiochemical procedures that lead from the radioisotopes to the actual radiopharmaceutical. In this contribution, the production of ^{111}Ag via neutron activation inside a nuclear reactor was modeled using two different Monte Carlo codes (MCNPX and PHITS) and compared with experimental measurements. The whole process was simulated starting from an MCNPX-based reactor model. Irradiation experiments were carried out using both natural and enriched palladium samples, irradiated inside the central thimble of a Triga Mark II Research Reactor. A natural palladium sample was measured also after the chemical separation procedure.

First steps to study if low-energy neutron irradiation boosted by Aβ-selective neutron capture agents can be a performing AD treatment.

Pascali V. ([1])([2]), Altieri S. ([1])([2]), Alberti D. ([3]), Bitonto V. ([3]), Micocci S. ([3]), Geninatti-Crich S. ([3]), Deagostino A. ([4]), Azzi E. ([4]), Renzi P. ([4]), Protti N. ([1])([2])
([1]) *Department of Physics, University of Pavia, Italy*
([2]) *National Institute of Nuclear Physics, INFN, Pavia Unit, Italy*
([3]) *Department of Biotechnology and Health Sciences, University of Torino, Italy*
([4]) *Department of Chemistry, University of Torino, Italy*

NECTAR (Neutron Capture Enhanced Treatment of neurotoxic Amyloid aggRegates) project aims to study the effectiveness of neutron capture reactions in the degradation of β-amyloid (Aβ) protein aggregates involved in Alzheimer's disease (AD). AD is a neurodegenerative disorder characterized by the accumulation of β-amyloid protein in the brain which compromises the nervous system. It is therefore necessary to search a performing AD treatment. NECTAR's idea is to study the effectiveness of neutron capture reactions on B-10 and Gd-157 in damaging protein aggregates. This is made possible thanks to the action of the charged secondaries produced, whose range matches well with the protein structures size, and the gamma, which cause a neuroinflammatory response of the glia cells promoting further clearance. The contribution will present the preliminary results achieved. In particular, the first *in vitro* experiments carried out at the nuclear reactor of the University of Pavia and the first Monte Carlo simulations conducted at microdosimetric scale. In view of the NECTAR developments which concerns mouse irradiation treatment plans, the new mouse phantom will be presented.

Towards a Timepix4 compact gamma camera for coded aperture nuclear medicine imaging with depth resolution.

Cerbone L.A. ([1])([2]), Cimmino L. ([1])([2]), Mettivier G. ([1])([2]), Sarno A. ([1])([2]), Biesuz N. ([3])([4]), Fiorini M. ([3])([4]), Russo P. ([1])([2])
([1]) *Dipartimento di Fisica "Ettore Pancini", Università di Napoli "Federico II", Napoli, Italia*
([2]) *Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Napoli, Italia*
([3]) *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Ferrara, Italia*
([4]) *Istituto Nazionale di Fisica Nucleare, Sezione di Ferrara, Ferrara, Italia*

The Timepix4 $24.7 \times 30.0\,\mathrm{mm}^2$ hybrid pixel detector readout ASIC ($55\,\mu$m pitch) is under test by the Medipix4 Collaboration. A dedicated readout system is under development at University and INFN Ferrara. We have designed a compact gamma camera based on a 1 mm thick CdTe semiconductor pixel detector for nuclear medicine tasks, *e.g.*, sentinel lymph node imaging with Tc-99*m* radiotracer and I-123 thyroid imaging. The detector will be coupled to a coded aperture collimator (modified uniformly redundant array, rank 31, antisymmetric, with 0.25 mm diameter round holes made of 3D printed 1 mm thick tungsten). The detector assembly works in minification for a variable field of view. Geant4 Monte Carlo simulations showed that for a Tc-99*m* source, at 50 mm source-collimator distance, where the field is $123.5 \times 150.0\,\mathrm{mm}^2$, the collimator sensitivity is 370 times that of a single hole in the mask and the spatial resolution is < 2 mm FWHM. Real-time coded aperture image reconstruction is performed via autocorrelation deconvolution. First tests with a silicon pixel detector bump-bonded to a Timepix4 chip show time-over-threshold and time-of-arrival capabilities with Sr-90, Am-241 and Fe-55 sources.

Dose-Response analysis for a patient cohort treated with ^{90}Y-TARE according to a personalized dosimetric workflow: Preliminary results.

Milano A. (1), Capotosti A. (1), Breschi L. (1), Meffe G. (1), Cremonesi M. (1), Gallo S. (1), Veronese I. (1), Indovina L. (1), De Spirito M. (1)
(1) *Policlinico Universitario "A. Gemelli", IRCCS, Roma*
(2) *European Institute of Oncology, IEO, IRCCS*
(3) *Università degli Studi di Milano*
(4) *Università Cattolica del Sacro Cuore, Milano*

The aim of the work is to investigate the role of both dosimetric and clinical parameters as classifiers or predictors of response to the ^{90}Y radioembolization treatment and to present possible response cut-off. Dosimetric data were extracted from personalized absorbed dose maps obtained with convolution of Voxel S-values kernel with the patient actual ^{90}Y activity distribution, derived from PET images. Beside common parameters as Mean Absorbed Dose to the Tumor (MADt) and to the Healthy Liver, other variables were also selected from Dose Volume Histograms, such as D30,t, D95,t and V120,t, along with clinical data. D95 $\geq$ 103.50 Gy and MADt $\geq$ 228.75 Gy were found to be optimal cut-off values for complete response, while D30 $\geq$ 180.30 Gy and MADt $\geq$ 117.30 Gy were selected as cut-off values for at least partial response and predicted a better survival. CT-based contouring resulted to be a more accurate delineation approach than the PET-based one: MADt,PET showed neither correlation nor predictive power with response or survival. Finally, the results also indirectly demonstrate the reliability of the dosimetric workflow developed in this Institute, based on a patient specific approach.

Aula L - Christa Mc Auliffe **ore 09:00 – 13:30**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiede: Ballan M. (INFN-LNL)

Relazioni su invito

▲ **Magneti superconduttori per acceleratori del futuro.**
Farinon S.
INFN, Sezione di Genova
I gruppi di superconduttività dell'INFN sono impegnati da più di trent'anni nella progettazione e costruzione di magneti superconduttori per acceleratori. A titolo di esempio, l'INFN ha seguito la realizzazione del primo dipolo di LHC e ha progettato e costruito il primo dipolo pulsato curvo per il SIS300 di FAIR (GSI). Le sfide più recenti ci hanno portato a fornire importanti contributi all'upgrade ad alta luminosità di LHC, ovvero la progettazione e costruzione dei dipoli di separazione/ricombinazione e dei correttori di ordine superiore, che verranno installati nell'acceleratore durante il prossimo long shutdown previsto a partire dal 2026. In vista della richiesta di magneti ad alto campo proveniente dagli sviluppi degli acceleratori di prossima generazione, come il Future Circular Collider (FCC-hh), siamo inoltre impegnati nella realizzazione di un dipolo superconduttore in Nb_3Sn come parte del programma CERN High Field Magnets. Altre attività sono iniziate quest'anno, come la progettazione e costruzione di un dimostratore di un gantry per adroterapia oncologica, o sono in fase di proposta, come alcuni sviluppi di magneti superconduttori relativi al Muon Collider.

▲ **Advances in low-working-temperature gas sensors.**
Baratto C.
CNR-INO, PRISM Lab, Brescia, Italy
Gas sensors are more and more requested nowadays for several applications like industrial pollution, food safety, human's health. Measuring the variation in conductance or capacity of a sensing material is the cheapest way to realize a device. Metal oxide semiconductors-based gas sensors have been extensively explored due to their high sensing response, cost-effectiveness, long-term stability, and simple fabrication. Recent trends deal with the use of nanostructured and low-dimensional materials to boost the sensing capabilities. Gas sensing is achieved at high temperature, but reduction in power consumption is essential for long-term usage; moreover, room temperature operation is needed for explosive environment or if the sensor is in contact with the food. In this contribution we will focus on gas sensors based on nanowires, by investigating the effect of light activation for low-temperature operation. We will also review our latest achievements in developing paper sensors for food spoilage, where the sensing material is made of cellulose.

Comunicazioni

● **Silicon photonics directional coupler design for non-deterministic C-NOT quantum gate implementation.**
<u>Frontini L.</u> (1)(2), Armani F. (2), Dao T. H. (9)(10), De Matteis F. (9)(10), Di Giuseppe G. (6)(7), Gunnella R. (6)(7), Iadanza S. (3)(4), Liberali V. (1)(2), Natali R. (6)(7),

Palini L. (1), Pergentili P. (6)(7), Salamon A. (10), Shojaii J. (5), Stabile A. (1)(2), Vitali D. (6)(7)(8)
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(3) *Munster Technological University, Cork, Ireland*
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(5) *Swinburne University of Technology, Melbourne, Australia*
(6) *Dipartimento di Fisica, Università di Camerino, Italia*
(7) *INFN, Sezione di Perugia, Italia*
(8) *CNR-Istituto Nazionale di Ottica, Firenze, Italia*
(9) *Università di Roma Tor Vergata, Italia*
(10) *INFN, Sezione di Roma Tor Vergata, Italia*
Silicon photonics opens the way for an easy integration of complex optical systems in the telecom C-band with integrated electronic circuits and for quantum computation purposes. This contribution will focus on the simulation results of a Photonic Circuit (PC) presently under fabrication within INFN QUANTEP project. Our PC contains several configurations of an integrated Directional Coupler realized with rectangular silicon waveguide (height 220 nm, width 450 nm). We will discuss the results of the simulations, focusing on how the transmission and reflection factors of the DC depend on waveguide's gap, coupling lengths and curvature. This first batch PC, realized for lithographic tuning purposes, represents an intermediate step towards the fabrication of a universal two-qubit Controlled-NOT (C-NOT) gate which is the simplest universal quantum gate. The simulation results, evaluated in a classical light framework with the Lumerical FDTD software, will be compared against the experimental results from the prototype chip. Attention will be paid to the simulation of edge coupling for light insertion and extraction with optical fibers connecting the PC to sources and detectors.

Studio di un equivalente elettrico di un living sensor.

Rapisarda S. (1), Gueli A.M. (2), Trigona C. (3)
(1) *Dipartimento di Scienze Umanistiche DISUM, Università degli Studi di Catania*
(2) *Dipartimento di Fisica e Astronomia DFA "Ettore Majorana", Università degli Studi di Catania*
(3) *Dipartimento di Ingegneria Elettrica Elettronica e Informatica DIEEI, Università degli Studi di Catania*
L'obiettivo principale riguarda l'implementazione e la modellizzazione di un circuito elettrico equivalente di un living sensor ed in particolare di una *Sansevieria Cylindrica*, pianta con capacità di sensing e buona immunità ad interferenze ed influenze. Ciò ha determinato la volontà di caratterizzare le sue proprietà elettriche per la misura di parametri ambientali per varie applicazioni con particolare enfasi alla conservazione preventiva di beni culturali. È stato effettuato uno studio su una pianta composta da più steli nei quali sono stati realizzati contatti elettrici per effettuare tre campagne di misure. La prima campagna riguarda due diversi contatti di un unico stelo, la seconda considera il cross-coupling tra due steli differenti e la terza riguarda il collegamento tra uno stelo ed il terreno. Ogni campagna ha riguardato misure della resistenza e della capacità dell'equivalente circuitale nel range 100 Hz–100 kHz. I risultati hanno consentito di sviluppare e caratterizzare il circuito equivalente elettrico nelle diverse configurazioni prima descritte al fine di associare un modello analitico per la descrizione del sistema.

Detection of low VOCs concentration through IR spectroscopy.

Mancini T. (1), Paolozzi M.P. (2), D'Arco A. (1)(3), Macis S. (1)(3), Marcelli A. (3), Radica F. (4), Tranfo G. (5), Lupi S. (1)(6), Della Ventura G. (2)(7)

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([6]) *INFN-Rome1*
([7]) *INGV Istituto Nazionale di Geofisica e Vulcanologia*
The term Volatile Organic Compounds (VOCs) refers to a group of toxic organic chemical species able to evaporate at room temperature thanks to their high vapor pressure. Being VOCs recognized to be dangerous for human health, they need to be monitored in real time, in particular in working sites. In this contribution, we will discuss a novel monitoring system based on Infrared (IR)spectroscopy able to measure very low concentrations of various VOCs down to sub-ppm level and to discriminate among different chemical species. We will present the experimental setup and the procedure to measure VOCs concentration from their IR absorbances. Here, the calibration for four VOCs (styrene, acetone, ethanol and isopropanol) is carried out, demonstrating that the technique offers the possibility to discriminate low concentrations and obtain very accurate quantitative information. Mixtures of acetone/styrene are also studied obtaining excellent results in the extrapolation of their individual concentration (in ppm) just starting from their whole IR spectrum. This work is a very promising starting point for designing a portable device for the detection of gaseous pollutants at very high sensitivity.

X-ray microtomography for the characterization of optical fibers.

Crocco M.C. ([1])([3]), Ferraro M. ([1])([2]), Crocco M.C. ([1])([3]), Mangini F. ([2]), Jonard M. ([4]), Sangiovanni F. ([1]), Zitelli M. ([2]), Filosa R. ([1])([3]), Beltrano J.J. ([1])([3]), De Luca A. ([3]), Barberi R.C. ([1])([3]), Agostino R.G. ([1])([3]), Couderc V. ([4]), Wabnitz S. ([2])([5]), Formoso V. ([1])([3])
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The full characterization of glass optical fibers consists of determining the value of the refractive index within their entire volume. In this framework, optical techniques present some limitations, *e.g.*, these require the absence of plastic coating. The latter, in fact, absorbs the optical radiation, thus preventing light from reaching the glass fiber, hindering its post-coating characterization. In order to overcome these limits, we propose to exploit the X-ray absorption properties of glass, thus demonstrating a new tool for the measurement of the 3D spatial profile of the refractive index of standard optical fibers. In particular, by means of absorption contrast X-ray microtomography, we characterize both microstructured (*e.g.*, photonics crystal fibers) and standard optical fibers, whose core/cladding refractive index difference is provided by doping either the core or the cladding. In order to confirm the validity of our approach, the results obtained are compared with complementary characterization techniques, based on electron spectroscopy and multiphoton microscopy.

Infrared spectroscopy characterization of MERS-CoV, SARS-CoV and SARS-CoV-2 spike proteins for sensoristic platform.

D'Arco A. ([1]), Di Fabrizio M. ([2]), Mancini T. ([3]), Mosetti R. ([4]), Della Ventura G. ([5]), Marcelli A. ([6]), Petrarca M. ([7]), Lupi S. ([3])

([1]) *La Sapienza University e INFN, Laboratori Nazionali di Frascati*
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([3]) *La Sapienza University, Department of Physics e INFN, Sezione di Roma 1*
([4]) *La Sapienza University, Department of Physics*
([5]) *University Roma Tre e INFN, National Laboratories of Frascati*
([6]) *INFN, National Laboratories of Frascati*
([7]) *La Sapienza University, SBAI Department e INFN, Sezione di Roma 1*

Motivated by the request to monitor the airborne pathogens, like viruses, using ultrasensitive vibrational spectroscopy, we propose a comparative infrared spectroscopic study of viral glycoprotein spikes (S) of MERS-CoV, SARS-CoV and SARS-CoV-2, for the first time, at least to our knowledge. The aim is the investigation of a part of the pathogen, in this case the structural S proteins and their complex secondary structure that match the protein functionality, observing the amide I band (1590–1730 cm^{-1}) in serological ambient and their potential differences. We experimentally observed that the three viruses have S proteins with different secondary conformations. SARS-CoV-2 has a secondary conformation characterized by the formation of intermolecular β-sheet structures, linked to the ability to anchoring virus-human receptors. Moreover, we also proved that the conformation of SARS-CoV-2 strongly change by passing from an alkaline to mild acid environment. Instead, the results pave the way to use vibrational spectroscopy as an alternative monitoring approach, overcoming the limitations of conventional bio-chemical ones.

Improvement of stability and response to nitrogen dioxide of graphene on SiC sensors after functionalization with nickel phthalocyanine.

Freddi S. ([1]), Casotto A. ([1]), Zanotti M. ([1]), Drera G. ([1]), Pagliara S. ([1]), Schio L. ([2]), Verdini A. ([2]), Floreano L. ([2]), Sangaletti L. ([1])
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2D materials show unique physical and chemical properties which can be exploited in several applications, including gas sensors. Among 2D materials, graphene has attracted particular interest, and it has started to be used as a sensing element to detect concentration of gases released in the environment. Nevertheless, pristine graphene does not show remarkable performances as gas sensor, and functionalization is often required to improve its sensing capability. Nickel phthalocyanine powder has been sublimated in UHV with a custom-made thermal evaporator and deposited on a monolayer graphene on silicon carbide substrate. After characterization through Raman, XPS and AFM measurements, the functionalized sample and a pristine graphene layer have been settled on a properly designed platform, able to monitor the sensor response simultaneously, allowing us to directly compare the performances of the sensors under the same working condition. Exposures to ammonia and nitrogen dioxide have been carried out, disclosing an improvement of the sensor response after functionalization, as well as a higher stability of the functionalized layer in the case of nitrogen dioxide exposures.

Spectroscopic and molecular-dynamics analyses to characterize CNT/polymer composites.

Prioriello A. ([1]), Andreani C. ([2]), Fazi L. ([1]), Licoccia S. ([1]), Morales P. ([2]), Preziosi E. ([2]), Romanelli G. ([2]), Scacco V. ([2]), Senesi R. ([2])
([1]) *Department of Chemical Science and Technologies and NAST Centre, University of Rome Tor Vergata, Rome, Italy*

([2]) *Department of Physics and NAST Centre, University of Rome Tor Vergata, Rome, Italy*
Carbon nanotubes (CNT) incorporation in polymeric composite materials allows the realization of planar and stretchable conductors, which can find application in electronics, sensors and medicine. A stable CNT grafting on polymer through adhesion can be achieved with a thermal cycle close to the melting temperatures of the host polymer matrices, without the use of reagents or chemical catalysts. Nevertheless, this process requires a deeper investigation because the grafting mechanisms affects the properties of the composite. In this work, information about the composite material conformation at the polymer-CNT interface has been obtained via Confocal Raman Microscopy but to better investigate the interaction between CNT and polymeric chains an additional molecular-dynamics study has been carried out. These analyses provide a twofold insight on different scales of the interaction mechanism existing between nanotubes and polymeric chains and they allow to estimate how much nanotubes penetrate the substrate, affecting the composite's properties. Authors gratefully acknowledge the financial support of the Consiglio Nazionale delle Ricerche – within CNR-STFC Grant Agreement [No. 2014-2020 (N 3420)] concerning collaboration in scientific research at the ISIS (UK) of STFC – and of the JRU ISIS@MACH ITALIA, Research Infrastructure hub of ISIS (UK) – MUR official registry U. 0008642.28-05-2020.

Il progetto "FRATERNISE": Facility ad elevata accuRAtezza Temporale pEr espeRimeNti di fISica fondamEntale.

Cantoni E. ([1]), Cerretto G. ([1]), Gnesi I. ([2]), Sellone M. ([1])
([1]) *Divisione di Metrologia Quantistica e Nanotecnologie, Istituto Nazionale di Ricerca Metrologica, Torino, Italia*
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Obiettivo del progetto è realizzare una facility dedicata alla caratterizzazione metrologica e taratura di apparati di timing per la Fisica Fondamentale, nonché di ricevitori GNSS utilizzati per il confronto remoto di orologi atomici e scale di tempo. In particolare, negli esperimenti di Fisica Fondamentale, il tempo riveste un ruolo cruciale, consentendo di definire la marcatura temporale degli eventi, di risalire alla loro simultaneità, aprendo alla possibilità di effettuare importanti deduzioni circa le caratteristiche dei fenomeni osservati. Sempre più spesso, infatti, diviene necessario correlare tra loro eventi di esperimenti che si sviluppano su grandi distanze o eventi misurati da esperimenti diversi, dislocati in luoghi lontani, indaganti fenomeni simili. Il progetto vuole fornire un contributo nell'ottimizzazione dei sistemi di timing per questo tipo di esperimenti, valutando anche la possibilità di sincronizzare gli eventi direttamente con la scala di tempo atomica nazionale italiana UTC(IT). La facility sarà anche dotata di una unità "viaggiante", progettata per consentire la taratura di apparati quando non fisicamente trasportabili.

Innovative method for quench localization in superconducting high-order magnets.

Mariotto S.
Dipartimento di Fisica, Università degli Studi di Milano, Milano, Italia e Istituto Nazionale di Fisica Nucleare, Laboratorio di Acceleratori e Superconduttività Applicata, Milano, Italia
The quench event is the transition into the normal resistive state of superconducting magnets. Since this critical event can damage the magnet and limit its performance, huge efforts in the scientific community are spent to localize its development and study the causes. Conventional methods for quench detection, such as voltage taps, are embedded in the magnet, representing a potential risk of short circuits during the coil operation. Less invasive methods, such as quench antennas, have many advantages but can be applied to few magnet designs. During my PhD research, I developed an innovative idea based on the analysis of the

magnetic field perturbation induced by the superconducting hysteresis magnetization. Using standard field measurement technologies, I demonstrated that the residual superconducting magnetization of the high-order corrector magnets for the CERN High-Luminosity LHC upgrade, allows the quench position reconstruction with a 100% efficiency and high accuracy. This method allowed us to find different quench developments, not measured by standard techniques. The excellent results encouraged the implementation of this analysis for future superconducting magnets.

Non-destructive diagnostic study of architectural terracotta sculptures.

Crocco M.C. (2)(3), López-Prat M. (1), Agostino R.G. (2)(3), Bandyopadhyay S.R. (4), Carrascosa B. (1), Crocco M.C. (2)(3), De Luca R. (5), Filosa R. (2)(3), Formoso V. (2)(3), Lancelotti C. (6), Noori N.A. (7), Pecci A. (8), Simón-Cortés J. (1), Miriello D. (5)
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(3) *Physics Department, Università della Calabria, Rende, CS, Italy*
(4) *Department of Ancient Indian History and Culture, University of Calcutta, Calcutta, India*
(5) *Dipartimento di Biologia, Ecologia e Scienze della Terra, Università della Calabria, Arcavacata di Rende, CS, Italy*
(6) *CaSEs Research Group, Universitat Pompeu Fabra, Barcelona, Spain*
(7) *Archaeology Institute of Afghanistan, Kabul, Afghanistan*
(8) *ERAAUB Research Group, Universitat de Barcelona, Barcelona, Spain*

A fragment of a terracruda sculpture from the Buddhist archaeological site of Tepe Narenj (Kabul, Afghanistan, 5th–9th century AD) was studied using X-ray micro-CT. This site represents one of the most important Afghan archaeological complexes due to the presence of large statues located in what remains of a Buddhist monastery. Being a non-invasive diagnostic technique, X-ray micro-CT allows the 3D virtual reconstruction of the sculptures, without altering their conservation conditions. Moreover, the analysis of the micro-CT images by means of segmentation techniques makes it possible to isolate the various components of these archeological findings, such as sand with different granulometry, clay and traces of organic material. The results obtained permits to shed light on the technique used in ancient times for the manufacturing of these sculptures, thus rediscovering the original manufacturing "recipe" which had been lost over time. Our results will find application to the conservation and the restorations of ancient findings. Moreover, it is worth mentioning that, starting from the results of our study, artisans are currently building new artifacts using the original technique.

Aula C - Maria Gaetana Agnesi **ore 09:00 – 13:30**

Sezione VII
Didattica e storia della fisica

Presiedono: Carpineti M. (Università di Milano)
Caccianiga L. (INFN, Sezione di Milano)

Relazioni su invito

▲ **Quanta didattica coi quanti.**
Ercolessi E.
Dipartimento di Fisica e Astronomia, Università di Bologna
"Today, our ability to use previously untapped quantum effects in customised systems and materials is paving the way for a second revolution. With quantum theory now fully established, we are required to look at the world in a fundamentally new way: objects can be in different states at the same time (superposition) and can be deeply connected without any direct physical interaction (entanglement)." (Dall'introduzione del Quantum Manifesto, 2016.) Il cambiamento di prospettiva imposto dagli sviluppi nell'ambito delle nuove scienze e tecnologie quantistiche e il loro impatto —anche economico e sociale— impongono una riflessione sulle finalità, gli obiettivi e le metodologie di insegnamento della fisica quantistica. Dobbiamo/possiamo esportare la seconda rivoluzione quantistica all'ambito didattico? Quali possono essere i pilastri fondamentali su cui impostare l'elaborazione e la sperimentazione di nuovi percorsi?

▲ **Riedizione di un testo universitario: Un'esperienza da curatori.**
Iotti R.C., Barbero G.
Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, Italia
Nella storia di ogni buon libro di testo, le riedizioni sono testimonianza e al tempo stesso impulso di vitalità. I due volumi di "Fisica" di P. Mazzoldi, M. Nigro e C. Voci, pubblicati per la prima volta nel 1991, sono stati subito accolti con grande apprezzamento a livello nazionale. Dopo una seconda edizione e numerose ristampe, gli autori hanno iniziato un'opera di revisione e aggiornamento, senza poterla purtroppo portare a termine. È toccato a noi, su invito della casa editrice, completare il lavoro sul secondo volume. Nel farlo, abbiamo cercato di mantenere il più possibile l'identità e l'impianto originali dell'opera e, simultaneamente, di migliorarne la fruibilità attuale. A conclusione di ogni capitolo sono stati inseriti un riepilogo dei concetti e dei risultati principali in esso contenuti e un elenco di quesiti utili a verificare la comprensione e a stimolare la riflessione su quanto appreso. Numerosi restano sia gli esempi, risolti in dettaglio, che i problemi, proposti alla fine dei capitoli. Particolare cura è stata dedicata alla rimozione dei refusi. Le figure sono in quadricromia. Alcuni contenuti opzionali e aggiuntivi sono consultabili in formato digitale.

▲ **ArduSiPM: Una guida "quasi" completa allo studio dei raggi cosmici.**
Rozza D.
Dipartimento di Scienze Chimiche, Fisiche, Matematiche e Naturali, Università di Sassari, Italia e INFN Laboratori Nazionali del Sud, Catania, Italia
Lo studio dei raggi cosmici è un tema molto interessante per poter avvicinare gli studenti delle scuole, in particolare quelli delle scuole secondarie superiori, alla fisica moderna e ai suoi quesiti ancora senza risposta. Diversi rivelatori di queste particelle sono ormai alla portata

di tutti e l'ArduSiPM risulta essere il più piccolo e versatile. In questo intervento verranno proposte diverse esperienze laboratoriali (dai primi esperimenti sui raggi cosmici alla muografia) accompagnate da trattazioni trasversali che interessano diverse discipline scolastiche (dalla statistica alla biologia passando attraverso le scienze della Terra e l'elettronica).

Comunicazioni

Cosmos-lovers symphonic guide to galaxy.

Iovenitti S., Jais R., Beretta D.
INAF - Osservatorio Astronomico di Brera

Everybody knows that there are several topics in common between the fundamentals of astronomy and classical music, but how deeply can we search for intimate connections? Are they useful to improve our understanding of physics? Do they provide useful hints for people interested both in music and research? We present in this contribution a new possible approach to the valuable binomial of music and astronomy. Diversely from the past, we propose to search for analogies not in acoustic or melody features, but rather in the formal arrangement of the component itself. We applied this recipe to the case of topics related to the structure of the Universe, in analogy to symphonies by Rebel, Rameau, and Ligeti. The connections between music and physics are discussed by the relator and the orchestra director. Afterward, the opera was played by the Symphonic Orchestra of Milan. Images, animations, and videos were projected in the concert hall both during explanations and the performance, in a very immersive experience for the public. This initiative came after "Beethoven and Black holes" and the concert "Dark Matter, a symphonic mystery" realized with INFN-Laboratori Nazionali del Gran Sasso.

Advanced and compact solutions for nuclear and particle Physics experiments.

Mattone C. ([1]), de Asmundis R. ([4]), Garosi P. ([1]), Loffredo F. ([2]), Quarto M. ([2]), Romano A. ([3])
([1]) *CAEN S.pA*
([2]) *Dipartimento di Scienze biomediche avanzate, Università degli studi di Napoli Federico II, Napoli, Italia*
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([4]) *INFN Sezione Napoli, Italia*

The CAEN Educational kits are Silicon Photo-Multipliers (SiPM) based and consist in a series of experiments with different difficulty level, covering from the fundamentals of Statistics to Nuclear Physics, Particles Detection, and Nuclear Imaging. Many applications are exploited in the Kits, starting from experiments about gamma and beta spectroscopy, cosmic rays to applications like to build a prototype of PET (positron emission tomography), detect and measure radioactivity on the field. All the necessary tools are included in the kit: detectors, detection system based on SiPMs or PMTs, power supply and amplification module, and the digitizer to read out the signal. The user can acquire the energy spectra, calibrate it in terms of emitted energy, study the composition of different samples, etc. Finally, the new software platform called Hera makes available most of the experiences, giving the possibility to acquire the spectra and analyze them. Step-by-step instructions are given to guide even non-expert personnel towards the final measurement and combine theoretical background, hands-on setup operations, data analysis, and critical synthesis of the results for a complete training.

Measurement of the cosmic radiation flux in water as a function of detector depth.

Liguori D., Fantini A., Fiammingo G., Petronio C., Schioppa M., Tone F.
Gruppo Collegato INFN di Cosenza e IIS Patrizi di Cariati

High school students and teachers perform Domenico Pacini's experiment in a modern key on the origin of the natural ionizing radiation that surrounds us. With the collaboration of INFN researchers and the University, the schools prepared for about 2 months for this event, collecting a large amount of data in the air and analyzing them. Then they went to a lake where they performed the measurements at different depth in water.

Mocku for change: An experimental study on the use of "mockumentary" language for Climate Change education.

D'Orto E., Levrini O., Tasquier G.
Dipartimento di Fisica, Alma Mater Università di Bologna, Italia

In the "society of acceleration and uncertainty" (Rosa, 2013), the young are struggling to interpret our complex and fast-changing world. The entity and the velocity of changes are so enormous that we need new narratives or languages to conceptualise them. Among those changes "Climate Change" is placed in a particular difficult position. As the writer A. Ghosh said: "The current climate crisis is also a crisis of culture, and thus of the imagination". In fact, in today's literature and cinema a strong dichotomy exists between fictional and non-fictional works, but none of those extremities seems suitable to picture an "adequate representation" of climate change issues, particularly those that are related to future. The main goal of my study, conducted within FEDORA EU project, was to understand to what extent the hybrid film form called "mockumentary" (a language that adopts the aesthetics of factual production to give an illusion of truth to invented stories) could inspire and help students in overcoming the mentioned dichotomy, working as a tool to foster the development of argumentative and imaginative skills needed to picture "fictional yet realistic" climate change scenarios.

Un Questionario Two-Tier sui fenomeni astronomici di base.

Galano S., Testa I.
Dipartimento di Fisica "E. Pancini", Università degli studi di Napoli Federico II

Nell'ambito dell'attività di ricerca in didattica dell'astronomia, in cui il nostro gruppo è attivo da anni, è stato sviluppato uno strumento di misura TT-Astro utile a valutare le conoscenze degli studenti sui fenomeni astronomici di base (stagioni, eclissi e fasi lunari) e il loro interesse nei confronti dell'Astronomia. Lo strumento sviluppato ha la struttura Two-Tier, con 15 quesiti a risposta multipla, cinque per ciascun fenomenico astronomico, composti da due tier. Nel primo viene posta agli studenti una domanda sulla conoscenza delle cause, delle caratteristiche o delle proprietà dei fenomeni astronomici proposti, mentre nel secondo è chiesta la motivazione della risposta fornita al primo tier. Il TT-Astro inoltre comprende 13 quesiti utili a valutare l'attitudine e l'interesse verso l'Astronomia e l'utilità percepita della stessa. In questo intervento saranno presentati i risultati emersi dall'analisi della prima sottomissione del questionario ad un campione di circa 200 studenti degli Istituti Secondari di Secondo grado della provincia di Napoli.

Nano-spazio: Un programma per istituti superiori e ITS su "tecnologie per lo spazio".

Citossi M., Fiore F.
INAF - Osservatorio Astronomico di Trieste

Il percorso didattico che presentiamo ripercorre l'esperienza di un progetto realizzato nell'ambito dei PCTO. Nella prima fase verranno fornite agli studenti le basi teoriche per comprendere il complesso procedimento del passaggio dall'idea alla realizzazione pratica di un progetto complesso come un esperimento spaziale. Successivamente verranno realizzati dei laboratori interattivi in cui si applicheranno le idee studiate nei primi moduli. Per i test verrà utilizzato l'ArduSiPM, un rivelatore di particelle didattico basato su una scheda sviluppata da V. Bocci (INFN Roma). Grazie alla grande versatilità di questo rivelatore ed alla possibilità di sostituire il cristallo scintillatore sarà possibile studiare anche le radiazioni gamma, utilizzando un cristallo GAGG, già montato nei rivelatori dei nano-satelliti di HERMES-SP. Gli studenti, saranno coinvolti dalla progettazione alla realizzazione della sonda, nello studio dei principi teorici della fisica e delle tecnologie aerospaziali, nonché nella fase del lancio del pallone aerostatico e nella successiva raccolta ed analisi dei dati.

L'astronomia come mezzo per trattare la fisica: Un case study da Roma Tre.

Di Blasi M.
Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre, Italia

L'astronomia rappresenta uno strumento prezioso per avvicinare i giovani alle discipline scientifiche ed in particolare alla fisica. Essa, infatti, attira e incuriosisce i ragazzi, e permette di trattare numerosi argomenti di fisica: dal concetto di campo e di forza alle leggi della dinamica, dalle leggi di Keplero all'ottica, dalla fisica nucleare alla relatività. In questo intervento presenteremo un percorso di fisica sviluppato proprio mediante la trattazione di argomenti di astronomia e astrofisica e rivolto a studenti del secondo biennio della scuola superiore. Il percorso, della durata di 20 ore, si è svolto in presenza presso le due scuole coinvolte nel progetto ed è stato molto apprezzato dai partecipanti.

Intelligenza Artificiale e Fisica in classe.

Marino T. (1)(2), Piccione A. (3)(4), Massa A.A. (4)
(1) *Sezione AIF Settimo Torinese, Italia*
(2) *WSW World Space Week, Italia*
(3) *Équipe Formativa Territoriale per il Piemonte, Italia*
(4) *Ufficio Scolastico Regionale per il Piemonte, Italia*

L'intelligenza artificiale (AI) e i sistemi di apprendimento automatici sono sempre più presenti in ogni aspetto della vita; per questa ragione occorre avviare processi educativi e formativi che possano permettere agli studenti di divenire utilizzatori consapevoli e non solo dei fruitori di tale tecnologia, come indicato anche nel recente DigComp 2.2. Verranno presentati alcuni percorsi formativi tenuti dall'Équipe Formativa Territoriale (EFT) del Piemonte e alcune attività che ne sono derivate, in particolare attraverso l'uso di piattaforme gratuite per l'addestramento di sistemi di riconoscimento immagini, voce e movimento e per l'elaborazione e l'utilizzo dei Big Data. Sulla base di queste esperienze saranno discusse alcune proposte per introdurre lo studio di sistemi fisici utilizzando tecniche di AI.

Studio della periodicità di sistemi binari ad eclisse: Un contributo degli studenti del Piano Lauree Scientifiche alla ricerca scientifica in Astrofisica.

D'Elia M., Licchelli D., Strafella F., De Giorgi M.L., Orofino V.
Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, Lecce

L'Astronomia è una scienza in cui anche studenti ed appassionati possono contribuire alla ricerca scientifica. Nell'ambito dello studio di stelle variabili, la disponibilità di dataset provenienti da survey robotiche e da missioni spaziali (es. TESS) hanno esteso il campo delle possibili indagini. In quest'ottica, l'argomento scelto nell'edizione 2021-22 del Piano Lauree Scientifiche Fisica - percorso Astrofisica, è stato l'analisi periodale di sistemi binari interagenti. Gli studenti hanno determinato il Time of Minimum di sistemi ad eclisse e costruito il relativo diagramma O-C includendo tutti i dati storici presenti in letteratura.

Hanno così potuto evidenziare, per ogni sistema, i fenomeni fisici sottostanti, dal trasferimento di materia attraverso i punti lagrangiani alla presenza di un terzo corpo orbitante. I risultati ottenuti sono stati inseriti in un apposito database internazionale gestito dalla Variable Star and Exoplanet Section of Czech Astronomical Society. La semplicità concettuale del metodo ne ha fatto apprezzare la sua valenza didattica e permesso agli studenti la produzione di nuovi dati, utili perfino nei programmi di ricerca scientifica specialistici.

Un approccio autentico per corsi introduttivi di laboratorio.

Alemani M.
Physics and Astronomy Department, University of Potsdam, Germany

I corsi di laboratorio (CdL) sono una parte essenziale del curriculum di fisica. Essi offrono infatti agli studenti la possibilità di imparare tecniche di misura e analisi dati e capire come funzionano i processi della fisica sperimentale. Tradizionalmente, nei CdL introduttivi, gli studenti utilizzano apparati sperimentali e tecniche di analisi dati pre-ottimizzati dagli insegnanti e seguono una serie di istruzioni dettagliate per riprodurre risultati noti della letteratura. Questo tipo di CdL sono stati recentemente oggetto di critiche. Vari studi didattici hanno infatti messo in discussione la loro efficacia per imparare concetti di fisica, acquistare competenze scientifiche e comprendere la natura della fisica sperimentale. Di conseguenza, sono stati proposti nuovi approcci didattici per i CdL. In questa comunicazione presenterò il processo di trasformazione dei CdL introduttivi avvenuto all'università di Potsdam in Germania. In questa trasformazione abbiamo utilizzato i risultati della ricerca e creato attività autentiche in cui gli studenti esercitano il design e l'ottimizzazione di un apparato sperimentale, la creazione di modelli per interpretare gli esperimenti e il lavoro di gruppo. Alla fine della comunicazione presenterò i metodi usati per valutare l'efficacia di questa trasformazione e i risultati ottenuti.

Performance of the new eco-friendly gas mixtures for the MRPC muon telescopes of the EEE Project.

Panetta M.P. per la EEE Collaboration
INFN, Sezione di Lecce, Lecce, Italy

The Extreme Energy Events Project is a large network of 60 telescopes, devoted to study the muon component in the Extensive Air Showers. The EEE telescopes are distributed over Italy, mainly located in high-school buildings where teachers and students are involved in an educational and scientific program. Each telescope consists of three Multi-gap Resistive Plate Chambers which operate in avalanche mode by using so far, a gas mixture containing $C_2H_2F_4$ and SF_6 . These are fluorinated gases with a high Global Warming Potential, and first studies for new suistanable gas mixtures were performed already in 2018. At present, in compliance to the regulation of European Union and in line with its educational goals, the EEE Collaboration decided to completely phase out these greenhouse gases, starting a R&D campaign to test eco-friendly mixtures. Taking into account the binary gas system and the bias voltage provided by the MRPC power supply, the most promising mixtures have proved to be HFO-based with CO_2 and He. Some EEE telescopes have been taking data for months with the new mixtures to test both performance and stability. The most recent results of the campaign will be presented.

Aula Consiglio **ore 10:00**

Chiusura del Seggio Elettorale

Aula A **ore 14:30 – 15:25**

Sezione II
Fisica della materia
Presiede: Biagioni P. (Politecnico di Milano)

Relazione Generale

Generation and use of highly entangled photons from semiconductor quantum dots.

Rastelli A.
Institute of Semiconductor and Solid State Physics, Johannes Kepler University-JKU, Linz, Austria

Entanglement is one of the most peculiar phenomena in quantum science and a key resource for quantum technologies. More than two decades after the initial proposal, semiconductor quantum dots (QDs) are now beginning to outperform other sources for the generation of entangled photon pairs. Among different material systems, QDs in the (Al)GaAs platform have demonstrated the highest degree of polarization entanglement to date together with other appealing features for quantum science and technology. In this contribution, we will discuss the properties of GaAs QDs obtained by the droplet etching method and present recent results relevant to their application in quantum communication, *i.e.*, entanglement-based quantum key distribution, quantum teleportation and entanglement swapping.

Aula B - Maria Goeppert-Mayer **ore 15:30 – 19:00**

Sezione I
Fisica nucleare e subnucleare

Presiedono: Cardini A. (INFN, Sezione di Cagliari)
Masera M. (Università di Torino)

Dark Matter, MuonE

Relazioni su invito

▲ **Ricerche dirette e indirette di materia oscura.**
Rescigno M.
INFN, Sezione di Roma 1
Lo sviluppo delle tecniche sperimentali e in particolare la scalabilità dei rivelatori a gas nobili liquefatti ha consentito di stabilire limiti assai stringenti alle sezioni d'urto tra ipotetiche particelle di materia oscura e la materia ordinaria con esperimenti condotti in condizioni di background estremamente ridotto. Alla vigilia di una nuova generazione di esperimenti che hanno recentemente cominciato ad operare o che sono in via di costruzione e raggiungeranno il cosiddetto neutrino floor, verrà illustrato il panorama sperimentale e le sue prospettive nel quadro più generale delle ricerche in diversi range di massa delle particelle di materia oscura e dell'utilizzo di molteplici tecniche sperimentali.

▲ **Ricerche di materia oscura nell'esperimento PADME.**
Spadaro T.
INFN, Laboratori Nazionali di Frascati
Le ricerche di materia oscura sono oggigiorno una parte integrante del programma scientifico di molti esperimenti di fisica delle particelle agli acceleratori. Questo nuovo approccio alla ricerca di segnali di particelle non barioniche, che rappresentano la componente più abbondante dell'universo, non ha ancora prodotto alcuna evidenza, ma ha contribuito a fissare limiti più stringenti alle caratteristiche della materia oscura. L'esperimento PADME (Positron Annihilation into Dark Matter Experiment), in corso presso i Laboratori Nazionali di Frascati dell'INFN, si inserisce in questo contesto. Studiando lo spettro di annichilazioni di positroni con gli elettroni di un bersaglio fisso, indaga la possibilità che esistano particelle debolmente accoppiate con la materia ordinaria che possano spiegare le osservazioni cosmologiche: "fotone oscuro" (A'), ALPs (Axion-Like Particles), dark Higgs, bosoni protofobici (*i.e.*, X17). PADME raggiungerà una sensibilità $\sim 10^{-6}$ nella misura di ε^2, il coefficiente accoppiamento cinematico tra fotone ordinario e fotone scuro (per masse $mA' < 23.7\,\mathrm{MeV}$) e potrebbe chiarire, con una misura dedicata, l'esistenza della ipotetica particella X17 rivelata dal gruppo ungherese di Debrecen. Al fine di dimostrare le capacità del rivelatore PADME, la sezione d'urto del processo $e^+e^- \to \gamma\gamma$ è stata misurata con precisione a $\sqrt{s} = 21\,\mathrm{MeV}$ utilizzando un set di dati raccolto nel 2020. Il risultato di questo studio è in accordo con le previsioni del Modello Standard Next-to-Leading-Order e fissa dei limiti all'esistenza di particelle nascoste che decadono in coppie di fotoni.

▲ Status and plans of the MUonE experiment.

Spedicato E. per la MUonE Collaboration
Dipartimento di Fisica, Università di Bologna, Italia

The MUonE experiment aims to measure with extremely high precision the leading-order hadronic contribution to the muon anomalous magnetic moment, related to the vacuum polarization (LO-HVP), which represents the largest uncertainty in the theoretical prediction of a_μ. A first run has been conducted in 2021 to test the fundamental components of the detector, silicon sensors and related electronics, and the collected data are under analysis. The detector assembly and the tests will be carried on during 2022. In 2023 a Test Run is foreseen to validate the proposed methods and technologies, which will lead to the final proposal of the experiment. The current status of MUonE will be presented, including the available results of the analysis of the beam test data. These tests are fundamental to evaluate the capability of the apparatus to reach the needed accuracy of 10 ppm on the shape of the μ-e elastic scattering cross-section.

Comunicazioni

● Ricerca di X17 con fasci di positroni ad LNF.

Long E.
Sapienza Università di Roma

La recente conferma nei nuclei di ^{4}He della cosiddetta "Anomalia del ^{8}Be" ha rinnovato l'attenzione a modelli di settori oscuri con mediatori molto leggeri. In particolare l'interpretazione particellare dell'anomalia prevede l'esistenza di una nuova particella di massa 17 MeV accoppiata ad elettroni e positroni: "X17". L'esperimento PADME ai Laboratori Nazionali di Frascati è in grado di produrre X17 in interazioni di positroni su bersaglio fisso. Durante il RUN II nel 2020 PADME ha raccolto dati ad un'energia nel centro di massa di ~ 20 MeV. Un passo fondamentale verso il RUN III, in cui PADME sposterà la propria energia alla risonanza di X17 (ECM = 17 MeV), è lo studio della sensitività di PADME ai decadimenti visibile di particelle oscure nei dati 2020 oggetto di questa comunicazione.

● Il detector di PADME alla ricerca del fotone oscuro.

Capirossi V.
Politecnico di Torino e INFN, Sezione di Torino

L'elusività della materia oscura ha stimolato ricerche innovative e a largo spettro, che coprono un ampio intervallo di energie con rivelatori ad alta sensibilità In questo scenario, il Positron Annihilation into Dark Matter Experiment (PADME) sta acquisendo dati presso i Laboratori Nazionali di Frascati dell'INFN. PADME sta cercando il segnale di un ipotetico fotone oscuro studiando lo spettro di massa mancante degli stati finali di singolo fotone risultanti da eventi di annichilazione positronica sugli elettroni di un bersaglio fisso. L'approccio di PADME permette di cercare qualsiasi nuova particella prodotta in una collisione e^+e^- attraverso un fotone virtuale off-shell, ad esempio Dark Higgs e ALPs. Dopo la messa in opera del rivelatore e l'ottimizzazione della linea di fascio, la Collaborazione PADME ha raccolto nel 2020 circa 5×1012 positroni sul bersaglio, a 430 MeV. I dati sono ora studiati per ottimizzare gli strumenti di analisi. Il contributo presenterà una panoramica delle performance del rivelatore e delle procedure di calibrazione.

● Dark sector searches in final states with prompt neutral particles with the ATLAS detector.

Pompa Pacchi E.
Sapienza Università di Roma, ATLAS experiment e INFN, Sezione di Roma

The possibility that Dark Matter constitutes a new sector of particles with a new interaction is investigated by the ATLAS experiment at LHC. Searches often look for single dark photon

(DP) jets reconstructed from exotic decays of the Higgs boson into dark particles, which shower into a pair of DPs that decay back into pairs of collimated leptons or light hadrons. I will report recent results on final states with at least two reconstructed DP jets, which allow to probe wider areas of the free model parameter space under the hypothesis that the DP decays promptly into SM particles.

Ricerca di mediatori della materia oscura nel decadimento raro $K^+ \to \mu^+ \nu X$, $X \to \gamma\gamma$ con il rivelatore NA62 al CERN.

Panichi I.
Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Italia e INFN, Sezione di Firenze, Italia

Un mediatore della materia oscura (X) leggero, scalare e neutro rispetto alle interazioni del Modello Standard, che si accoppi preferenzialmente con i muoni, potrebbe spiegare, tramite Nuova Fisica al di sotto della scala elettrodebole, la discrepanza fra il valore sperimentale e la previsione teorica del momento magnetico anomalo del muone, $(g-2)_\mu$. Un mediatore di questo tipo potrebbe essere prodotto nei processi rari che conservano il sapore leptonico. In particolare, i decadimenti rari dei mesoni K rappresentano il luogo ideale per indagare le forze muoniche. L'esperimento NA62 al SPS del CERN, che ha come obiettivo principale la misura del BR del decadimento ultra raro $K^+ \to \pi^+ \nu\bar{\nu}$ con una precisione del 10%, sta producendo un numero di K^+ mai ottenuto prima e potrebbe avere una sensibilità senza precedenti alla produzione del decadimento $K^+ \to \mu^+ \nu X$, con $m_X < m_K - m_\mu$. Presenterò uno studio preliminare su un sottocampione di dati (2017B) della sensitività di NA62 al processo $K^+ \to \mu^+ \nu X,\ X \to \gamma\gamma$, assumendo che il decadimento in due fotoni sia quello principale se $m_X < 2m_\mu$.

L'esperimento SND@LHC.

Centanni D. per la SND@LHC Collaboration
Università Parthenope di Napoli e INFN, Sezione di Napoli

Lo Scattering and Neutrino Detector at the Large Hadron Collider (SND@LHC) è un nuovo esperimento, approvato dal Research Board del CERN in marzo 2021, in presa dati da aprile 2022, progettato per effettuare misure con neutrini di alta energia prodotti ad LHC in una regione in pseudo-rapidità completamente inesplorata compresa tra 7.2 e 8.4 durante il RUN 3. L'esperimento è posizionato 480 m a valle del punto di interazione di ATLAS, nel tunnel TI18. Il rivelatore è composto da un sistema ibrido basato su un bersaglio compatto ad emulsioni nucleari e tungsteno associato a piani di tracciatori elettronici a fibre scintillanti, seguiti da un sistema di tracciamento di muoni a valle. Il design dell'esperimento offre un calorimetro elettromagnetico fornito dalla combinazione di bersaglio ad emulsioni e rivelatori traccianti e un calorimetro adronico costituito dal sistema di identificazione di muoni. La sinergia tra bersaglio ad emulsioni e tracciatori elettronici fornisce a SND@LHC la capacità di distinguere i tre sapori di neutrino, permettendo così di sondare la fisica associata alla produzione di sapori pesanti.

The SAND detector at the DUNE near site.

Poppi F.
INFN, Sezione di Bologna

DUNE is a next-generation experiment for long baseline neutrino physics. The near detector (ND) complex aims at constraining the systematic uncertainties to ensure high-precision measurements of neutrino oscillation parameters and CP violation. The SAND apparatus is one of the three components of the ND, permanently located on-axis to monitor the neutrino beam stability and measure its flux. SAND exploits a 0.6 T superconducting magnet coupled with an electromagnetic calorimeter made of a mixture of lead and scintillating fibers. The inner magnetized volume is provided with a novel LAr detector and a low-density Straw Tube Tracker (STT). In this contribution the major components of SAND and their role in the measurements of (anti)neutrinos interactions are presented.

The analysis strategy of the MUonE experiment.

PILATO R.N. PER LA MUONE COLLABORATION
Dipartimento di Fisica, Università di Pisa e INFN, Sezione di Pisa

The precision on the muon g-2 theoretical prediction is currently limited by the leading-order hadronic contribution a_μ^{HLO}, which is traditionally determined through a dispersive approach. The latest evaluation leads to a 4.2σ discrepancy between theory and the experimental value. A recent calculation of a_μ^{HLO} based on lattice QCD is in tension with the dispersive one, and weakens the discrepancy with the experiment to 1.5σ. An independent crosscheck is thus required to solve this tension and consolidate the theoretical prediction. The MUonE experiment proposes a novel approach to determine a_μ^{HLO}. It is based on the extraction of the running of the electromagnetic coupling constant in the space-like region from a very precise measurement of the μ-e elastic scattering differential cross-section. The measurement will be performed at CERN's North Area by scattering a 160 GeV muon beam on the atomic electrons of a low-Z target. A Test Run on a reduced detector is planned to validate this proposal. The analysis strategy will be discussed in this contribution, focusing on the assessment of the main systematic uncertainties in the Test Run.

Calorimetry for MUonE.

CESARE S.
Università degli Studi di Padova

The MUonE Collaboration aims at a very precise measurement of the muon-electron elastic scattering cross-section, to extract the leading hadronic contribution, due to vacuum polarization, which enters in the calculation of the muon anomalous magnetic moment. The experiment will consist of a cascade of 40 tracking stations, each composed of a low-Z target and few silicon trackers, and an electromagnetic calorimeter. The role of the calorimeter and the status of the R&D will be illustrated, with emphasis on the challenges implied in the measurement of the electron energy in the MUonE setup.

Single π^0 production in μe scattering at MUonE.

DEL PIO C.L. (1)(2), BUDASSI E. (1)(2), CARLONI CALAME C.M. (2), PICCININI F. (2)
(1) *Dipartimento di Fisica, Università degli Studi di Pavia, Italia*
(2) *INFN, Sezione di Pavia, Italia*

The MUonE experiment at CERN aims at determining the leading-order hadronic vacuum polarisation (HLO) contribution to the muon anomalous magnetic moment, $a_\mu = (g-2)_\mu/2$. At the moment, the Standard Model theoretical prediction of a_μ presents a tension of 4.2σ with the experimental results. Such a discrepancy can point to possible New Physics (NP) signals. The MuonE experiment will provide an independent determination of the HLO contribution, one of the dominant terms to the theoretical uncertainty on a_μ, via the study of elastic muon-electron scattering at small momentum transfer, with a precision of the order of 10 ppm. In this contribution, the analysis of a potential source of reducible background at MUonE, coming from the π^0 production in μ-e scattering, is presented, motivated by the fact that the π^0 production is dynamically enhanced in the region of small electron and muon scattering angles, which is particularly interesting for MUonE. Moreover, the effects of this same process as a background to possible NP searches at MUonE are analysed, such as the production of a light new gauge boson Z' or of a dark photon A'.

The Strong2020 and Radio MonteCarLow activities.

DRIUTTI A. PER STRONG2020 E RADIO MONTECARLOW WORKING GROUPS
University of Pisa e INFN Pisa

In the past 15 years, the Radio MontCarLow WG ("Radiative Corrections and Monte Carlo Generators for Low Energies" Working Group) supported the development of radiative corrections and Monte Carlo generators for low-energy e^+e^- data and tau-lepton decays. This group has been facilitating communication between theorists and experimentalists, which leads to the report *Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data* by Actis *et al.* that has more than 300 citations. Parts of the Radio MonteCarLow WG program were recently included in the European hadron physics community group application, Strong2020, with the goal of producing an annotated database for low-energy hadronic cross-sections in e^+e^- collisions. These efforts have also been revived by the measurement of the muon anomalous magnetic moment at Fermilab that differs by 4.2σ from the Standard Model prediction when combined with the previous result from the Brookhaven experiment. We will report on these Radio MonteCarLow and Strong2020 activities.

Development of an advanced modular setup for the on beam characterization of oriented crystals.

MONTI-GUARNIERI P. (1)(2), BANDIERA L. (3), BOMBEN L. (1)(2), CARSI S. (1), DE SALVADOR D. (4)(5), DIOCIAIUTI E. (6), GUIDI V. (3)(7), HAURYLAVETS V. (8), KORJIK M. (8), LOBKO A. (8), MARTELLOTTI S. (6), MASCAGNA V. (9)(10), MAZZOLARI A. (3), MOULSON M. (6), PAESANI D. (6), PREST M. (1)(2), ROMAGNONI M. (3), RONCHETTI F. (1)(2), SARRA I. (6), SELMI A. (1)(2), SGARBOSSA F. (4)(5), SOLDANI M. (3)(7), SYTOV A. (3), TIKHOMIROV V. (8), VALLAZZA E. (2)

(1) *Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria, Como, Italia*
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(3) *Istituto Nazionale di Fisica Nucleare, Sezione di Ferrara, Italia*
(4) *Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Italia*
(5) *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, Italia*
(6) *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Italia*
(7) *Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara, Italia*
(8) *Institute for Nuclear Problems, Belarusian State University, Belarus*
(9) *Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Brescia, Italia*
(10) *Istituto Nazionale di Fisica Nucleare, Sezione di Pavia, Italia*

Recently, the particle physics community has put an increasing effort in developing radiation detectors and equipment based on oriented crystals. A key feature that distinguishes an oriented crystal from the ordinary matter is the reduction of the radiation length (X_0) seen by electrons, positrons and photons crossing the lattice along one of its symmetry axes. This effect has been experimentally observed only in the last few years and with samples limited in number, composition and length. In order to define a standardized procedure for the characterization of the oriented crystals, the INSULAB research group has developed an advanced modular setup, which allws to study the features of any crystal sample with both electron and photon beams. This contribution will describe the key elements of this setup (*i.e.*, silicon strip trackers, plastic scintillators, SiPMs coupled to the crystal under test and an electromagnetic spectrometer) and will focus on their performances, which have been evaluated during several beam tests, performed at the CERN and DESY extracted beam lines.

The Active Photon Converter of the STORM Collaboration.

Bomben L. [1][2], Bandiera L. [3], Carsi S. [1], Lezzani G. [1], Mangiacavalli S. [1], Mascagna V. [4][5], Prest M. [1][2], Romagnoni M. [3], Ronchetti F. [1], Soldani M. [3][6], Vallazza E. [2]
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([2]) *INFN, Sezione di Milano Bicocca*
([3]) *INFN, Sezione di Ferrara*
([4]) *Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Brescia*
([5]) *INFN, Sezione di Pavia*
([6]) *Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara*

The unique properties of oriented crystals can be exploited in order to —among other things— enhance the radiation produced by a high-energy electron/positron or photon crossing the crystal lattice, effectively decreasing the radiation length of the material. The STORM Collaboration intends to study this effect in different crystals, using 5–120 GeV/c electron beams. In this contribution we shall present the simulation, development and commissioning of the Active Photon Converter (APC), a detector developed by the INSULAB group and employed in the STORM beamtests. The APC will allow to estimate the average number of photons produced by a particle crossing an oriented crystal. It consists of two plastic scintillator tiles (the first acting as a veto for charged particles), readout by photomultiplier tubes and a thin (0.2 X_0) copper radiator positioned between the tiles.

Aula D - Marianna Ciccone **ore 15:30 – 19:00**

Sezione II

Fisica della materia

Presiedono: Genoni M.G. (Università di Milano)
Osellame R. (IFN-CNR, Milano)

Quantum theory and communication

Relazioni su invito

▲ Exotic effects in non-Hermitian quantum optics.

Carollo A. (1), Roccati F. (1), Lorenzo S. (1), Calajò G. (2), Palma G.M (1)(3), Ciccarello F. (1)(3)
(1) *Università degli Studi di Palermo, Dipartimento di Fisica e Chimica*
(2) *ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology*
(3) *NEST, Istituto Nanoscienze-CNR*

Non-Hermitian photonic reservoirs provide a testbed for intriguing phenomena which cannot be observed in an Hermitian environment. We investigate exotic effects due to the interaction of atoms with such reservoirs. We study the effective interactions between atoms mediated by the photonic modes of a lossy photonic lattice. We show in a paradigmatic case study that when these losses are suitably structured, exotic emission properties can be observed. Photons can mediate dissipative, fully non-reciprocal, interactions between the emitters with range critically dependent on the loss rate. When this loss rate corresponds to specific points in the spectrum of the reservoir, called "exceptional points", the effective couplings are exactly nearest-neighbour, implementing a dissipative, fully non-reciprocal effective interaction between atoms, which is called Hatano-Nelson model. Counterintuitively, this occurs irrespectively of the lattice boundary conditions. Thus, photons can mediate an effective emitters' Hamiltonian which is translationally invariant despite the fact that the field is not. We interpret these effects in terms of metastable atom-photon dressed states, which can be exactly localised.

▲ Quantum-classical dynamical distance for walks on graphs: Quantumness and decoherence.

Benedetti C., Gualtieri V., Bressanini G., Paris M.G.A.
University of Milan, Physics Department

Quantum walks (QWs), the quantum counterpart of classical random walks, are a powerful tool for many applications, from the modelling of quantum transport to universal quantum computation and quantum algorithms. We introduce a fidelity-based measure to quantify the differences in the dynamics of classical and quantum continuous-time walks over a graph. We provide graph-independent analytic expressions of this quantum-classical dynamical distance in the case of unitary quantum dynamics. We show that at short times it is proportional to the coherence of the walker, *i.e.*, a genuine quantum feature, whereas at long times it depends only on the size of the graph. We then address different models of decoherence in QWs and employ the quantum-classical dynamical distance as a figure of merit to assess whether, and to which extent, decoherence classicalizes the CTQW, *i.e.*, turns it into the analogue classical process. We show that while dephasing in the position basis asymptotically destroys the quantumness of the walker, making it equivalent to a classical random walk, decoherence in the energy basis does not fully classicalize the walker and partially preserves its quantum features.

▲ **Quantum turbulence in a fluid of light.**

Ballarini D., Panico R., La Notte A., De Giorgi M., Sanvitto D.
CNR-NANOTEC

Turbulent phenomena are among the most striking effects that both classical and quantum fluids can exhibit. While classical turbulence is ubiquitous in nature, the observation of quantum turbulence requires the precise manipulation of quantum fluids such as superfluid helium or atomic Bose-Einstein condensates. Here we discuss our recent experimental results showing the turbulent dynamics of a two-dimensional quantum fluid of exciton-polaritons, hybrid light-matter quasiparticles that arise from the strong light-matter coupling in semiconductor microcavities. By measuring the kinetic energy spectrum and the onset of vortex clustering, we demonstrate the tendency of the vortex-gas towards highly excited configurations despite the dissipative nature of the system. In particular, we discuss the inverse energy cascade and its first direct measurement in a two-dimensional quantum fluid. We highlight the advantages of optical systems in the analysis of turbulent flows and the differences with respect to Bose-Einstein condensates of ultracold atoms. These results lay the basis for the investigations of quantum turbulence in two-dimensional fluids of light.

▲ **Frequency and spatial multimode beams generation and applications.**

Parisi M. ([1]), Marino A. ([2]), Mosca S. ([1])
([1]) *CNR-Istituto Nazionale di Ottica*
([2]) *CNR-Istituto di Scienze Applicate e Sistemi Intelligenti*

A multimode beam can have a single spatial mode and multiple frequency components, or be monochromatic and have multiple spatial modes. Recent studies have analysed analogies between frequency multimode laser source with equally spaced frequency lines, such as optical frequency comb and spatial multimode beams carrying orbital angular momentum. Optical frequency combs, originally conceived for absolute and precise measurement of optical frequencies, nowadays have kicked off a growing number of applications including frequency division multiplexing in optical communications. On the other side, orbital angular momentum is a degree of freedom, encoded in the spatial transverse profile of the optical beam and it can in principle take unlimited values. This unique peculiarity has attracted much interest in the quantum information and communication fields, opening the possibility to transfer a wealth of information between different nodes of a network. Here we present different techniques to generate both optical frequency combs and orbital angular momentum beams, their analogies and their main applications.

Comunicazioni

● **Entanglement measure from a minimum distance principle.**

Franzosi R., Bel-Hadj-Aissa G., Vesperini A.
DSFTA, University of Siena, Siena, Italy

Entanglement and quantum correlation are precious resources for quantum technologies implementation based on quantum information science, as, for instance, quantum communication, quantum computing, quantum sensing, and quantum complex systems. Nevertheless, a directly computable measure for the entanglement of multipartite mixed-states is still lacking. In this contribution, we derive from a minimum distance principle an explicit measure able to quantify the degree of quantum correlation for pure or mixed multipartite states. Also, we derive a directly measure of entanglement for the case of a general mixed state. Thus, our measures allow one to distinguish between quantum correlation detached from entanglement and the one induced by entanglement. Since all the relevant quantities in our approach, descend from the geometry structure of the projective Hilbert space, the proposed method is of general application. Finally, we apply the derived measures to some examples of multipartite mixed states.

Delta-T noise for fractional quantum Hall states at different filling factor.

Rebora G.
Dipartimento di Fisica, Università degli Studi di Genova

The current fluctuations due to a temperature bias, *i.e.*, the delta-T noise, allow to access properties of strongly interacting systems which cannot be addressed by the usual voltage-induced noise. In this contribution, I present our study of the excess delta-T noise between two different fractional quantum Hall edge states, with filling factors (ν_L, ν_R), coupled through a quantum point contact and connected to two reservoirs with different temperatures. We have solved exactly the problem for all couplings and for any set of temperatures in the specific case of an hybrid junction $(1/3, 1)$. Moreover, we derive a universal analytical expression at the first order in the temperature mismatch, which connects the excess delta-T noise to the equilibrium one for all generic pairs (ν_L, ν_R) belonging to the Laughlin sequence. We expect that this linear term can be accessible in nowadays experimental set-ups. We describe the two opposite coupling regimes focusing on the strong one which correspond to a non-trivial situation. This analysis on delta-T noise allows to better understand the transport properties of strongly interacting systems.

Enhancing coherent energy transfer between quantum batteries via a mediator.

Crescente A.
Dipartimento di Fisica, Università di Genova, Genova, Italy e SPIN-CNR, Genova, Italy

We consider energy transfer processes between two quantum batteries (QBs), *i.e.*, two-level systems (TLSs). As a prototypical scenario we present a direct energy transfer between the first and second QB and we compare its performances with two mediated cases. The first one is when the energy from the first QB is transferred by a third TLS to the other QB, the second scenario is when the energy transfer is mediated by a cavity with a single photonic mode. We propose the analysis of the energy transfer process in resonance and off-resonance. The latter being really important for future experimental implementation, since it is really difficult to create TLSs with identical energy separation. As a result we observe that both in and off resonance we obtain better performances, concerning both the amount of energy and the time exploited to achieve the energy transfer, when we consider the cavity-mediated scenario.

Fast charging of Dicke quantum batteries.

Ferraro D.
Università degli Studi di Genova

Quantum information theorems state that it is possible to exploit collective quantum resources to greatly enhance the charging power of quantum batteries, miniaturized devices able to fastly store energy outperforming their classical counterparts. In this direction, we investigate a model of a quantum battery that can be engineered in solid-state and molecular platforms for quantum electrodynamics. It consists of N two-level systems coupled to a single photonic mode in a cavity. We contrast this collective model ("Dicke quantum battery"), to the one in which each two-level system is coupled to its own separate cavity mode ("Rabi quantum battery"). We demonstrate the emergence of a quantum advantage in the charging power of collective QBs, which is further enhanced by properly engineering a more exotic two-photon matter-radiation coupling. The first experimental evidence of this phenomenology has been reported very recently in a system where fluorescent organic molecules play the role of two-level systems embedded in a microcavity.

IBM quantum platforms: A quantum battery perspective.

Gemme G. [1], Grossi M. [2], Ferraro D. [1][3], Vallecorsa S. [2], Sassetti M. [1][3]
[1] *Dipartimento di Fisica, Università di Genova, Genova*
[2] *CERN, Geneva, Switzerland*
[3] *CNR-SPIN, Genova*

We characterize for the first time the performances of IBM quantum chips as quantum batteries, specifically addressing the single-qubit Armonk processor. By exploiting the Pulse access enabled to some of the IBM quantum processors via the Qiskit package, we investigate advantages and limitations of different profiles for classical drives used to charge these miniaturized batteries, establishing the optimal compromise between charging time and stored energy. Moreover, we consider the role played by various possible initial conditions on the functioning of the quantum batteries. As main result of our analysis, we observe that unavoidable errors occurring in the initialization phase of the qubit, which can be detrimental for quantum computing applications, only marginally affects energy transfer and storage. This can lead counterintuitively to improvements of the performances. This is a strong indication of the fact that IBM quantum devices are already in the proper range of parameters to be considered as good and stable quantum batteries, comparable to state-of-the-art devices recently discussed in the literature.

Criticality induced compatibility in multiparameter metrology.

Di Fresco G., Spagnolo B., Valenti D., Carollo A.
Dipartimento di Fisica e Chimica "E. Segrè", Università degli Studi di Palermo, Italia

Many-body systems near a quantum phase transition (QPT) exhibit several properties which makes them appealing for metrological purposes. Indeed, it is now well established that the divergences of the quantum Fisher information (QFI) observed near a QPT can be used to increase the precision in the estimation of a parameter. Meanwhile, when it comes to the simultaneous estimation of multiple parameters, the benefits of criticality are much harder to analyze due to possible incompatibilities arising from the Heisenberg uncertainty. This involves the use of quite convoluted quantities, as the Holevo-Cramer-Rao bound, which are generally difficult to evaluate. Here we study the quantumness (R), a scalar index, which provides an asymptotic bound on the compatibility of a metrological scheme. The advantage of this approach is that R can be easily evaluated once the QFI and the mean Uhmlann curvature are known. Moreover, a scaling analysis of R reveals that many-body criticalities generally improve the compatibility in a multi-parameter framework. We also evaluate R in different representative systems, such as Ising chain and XY chain, in which we find this positive criticality effects.

Aula T - Caterina Scarpellini **ore 15:30 – 19:00**

Sezione III
Astrofisica
Presiede: Boncioli D. (Università Aquila e INFN)

Cosmic rays

Relazioni su invito

▲ **Astronomia gamma da terra con l'esperimento LHAASO.**
Di Sciascio G.
INFN, Sezione di Roma Tor Vergata
L'identificazione delle sorgenti di raggi cosmici è uno dei maggiori problemi aperti nell'astrofisica delle alte energie. L'osservazione di particelle neutre come fotoni e neutrini è il modo migliore per identificarle perché non vengono deflesse dai campi magnetici e quindi permettono di fare astronomia. Mentre i neutrini osservati sono ancora pochi e la loro natura astrofisica ancora dibattuta, moltissime sono le sorgenti di fotoni identificate sia nella nostra Galassia che in altre. Lo scorso anno l'esperimento LHAASO, situato in Cina sull'altopiano tibetano, ha osservato per la prima volta emissione di fotoni con energia anche superiore a 10^{15} eV (il PeV) aprendo così alle osservazioni l'ultima finestra dello spettro elettromagnetico. L'osservazione di queste sorgenti (i cosiddetti PeVatroni) è di grande importanza perché strettamente correlata all'identificazione delle sorgenti di raggi cosmici. In questa comunicazione verranno descritte le caratteristiche dell'esperimento LHAASO, riassunte le più recenti osservazioni e discusse le prospettive dell'astronomia gamma di altissima energia.

▲ **Pulsar wind nebulae.**
Bucciantini N.
INAF, Osservatorio Astrofisico di Arcetri, Firenze, Italy, Dipartimento di Fisica e Astronomia, Università di Firenze, Sesto Fiorentino, Italy e INFN, Sezione di Firenze, Sesto Fiorentino, Italy
Pulsar wind nebulae are the prototypical relativistic accelerators, and one of the foremost laboratory where the study of relativistic plasma physics, and non-thermal emission can be performed. The Crab Nebula, for example had been at the heart of many astrophysical discoveries, and its study has been the driver for much of our present understanding of particle acceleration. I will review here the current status of our knowledge of these systems, and how it has progressed in the past decade thanks to a combination of high-resolution observations and state-of-the-art numerical techniques, and how its has impacted the broader astrophysical community. I will then discuss the still many unknowns that remain, and the prospects for future advancements.

▲ **TeV-halos and related physics.**
López-Coto R.
IAA-CSIC, Granada, Spain e INFN, Sezione di Padova, Italy
The origin and propagation of cosmic rays (CRs) is one of the most important questions in astroparticle physics nowadays. CRs generated by known sources also serve as background to those putatively generated by more exotic phenomena. Apart from the known electrons of primary origin and positrons of secondary one, pulsars and sources powered by them are one of the main candidates to contribute to the total amount of CR electrons and positrons. TeV

halos are sources powered by a central pulsar whose electrons and positrons have escaped from the shock region dominated by the pulsar wind and are freely propagating into the interstellar medium. They have been postulated only a couple of years ago and up to date there are only two confirmed sources. In this contribution, I will give a review of the current understanding of TeV halos, the observational status and their contribution to the CR sea in the Galaxy.

Comunicazioni

Investigating past activity of the Fermi Bubbles using cosmic-ray signatures in paleodetectors.

Veutro A., Caccianiga L., Galelli C.
Università degli Studi di Milano

The Fermi Bubbles, two large lobes of plasma extruding from the Galactic Center, are theorized to be remnants of a past AGN-like activity of the Milky Way some Myr ago. AGNs are promising candidate sources of cosmic rays, so it is possible that the flux of these particles in the past was significantly higher. This flux could have left traces in natural mineral formations in the Earth's crust. In fact, interactions with secondary cosmic rays can leave visible tracks that can be preserved up to the Gyr timescale. These so-called "Paleo-Detectors" have been proposed also for other astroparticle physics applications, such as atmospheric neutrino flux evolution and supernova neutrino detection. The age of the Fermi Bubbles is serendipitously coincident to the Mediterranean draining event known as the "Messinian salinity crisis" which produced evaporites, mostly halites. These minerals were at first exposed to the cosmic-ray flux and then covered during the sudden reflooding of the Mediterranean basin 5.3 Myr ago; the cosmic-ray flux information remained then frozen due to the shielding of the body of water, possibly allowing us to extract them and compare them to the present day flux.

A model for the structure of the gamma-ray bubbles in Milky Way galaxy.

Cardinali A. (1), Coppi B. (2)
(1) *Istituto Sistemi Complessi Consiglio Nazionale delle Ricerche, Politecnico di Torino, Italy*
(2) *Massachusetts Institute of Technology, Cambridge, MA, USA*

A plasma outflow coming from the center of our Galaxy is assumed to reach a "plowed" nearly stationary magnetic field at characteristic galactic distances. Then a lower hybrid mode is envisioned to be excited by the non-thermal features of the nuclei outflow distribution (beam). This mode can then transfer energy, parallel to the magnetic field to high-velocity electrons which can be held responsible for the observed high-energy radiation emission at large distances from the center of the galaxy defining the edge of each bubble.

The upgrade of the Pierre Auger Observatory —AugerPrime.

Anastasi G.A.
Osservatorio Astrofisico di Torino, INAF, Pino Torinese, Torino, Italia e INFN, Sezione di Torino, Torino, Italia

Over the last 15 years the Pierre Auger Observatory has accumulated the world's largest exposure to ultrahigh-energy cosmic rays (UHECRs) and the analysis of this dataset led to major advances in our understanding about the nature of UHECRs. The new perspectives opened by the current results call for an upgrade of the Observatory (dubbed AugerPrime), whose main aim is the collection of new information about the primary mass of UHECRs, mandatory to interpret all the observations in a unified picture. The upgrade program includes: the installation of a plastic scintillator detector on top of each water-Cherenkov detector (WCD) of the surface array; an extension of the dynamic range of measurementthrough an additional small photomultiplier tubein each WCD; an array of underground scintillator detectors to measure the muonic component of extensive air showers; the deployment of a radio antenna atop each WCD; new electronics to process the signals from all the detectors. An overview of the upgrade is provided, together with the expected performances and the improved physics sensitivity.

Controllo della stabilità operativa dei nuovi rivelatori a scintillazione per l'Osservatorio Pierre Auger.

CONTE M. PER LA PIERRE AUGER COLLABORATION
Instituto Nazionale di Fisica Nucleare, Sezione di Lecce, Italia

Una parte rilevante di AugerPrime, l'upgrade dell'Osservatorio Pierre Auger, consiste nell'installazione di nuovi rivelatori basati su scintillatori plastici collocati sopra i rivelatori di superficie Cherenkov già esistenti. Con il dislocamento sul campo di questi moduli, avviato nel 2019, si è reso necessario elaborare dei meccanismi di controllo per valutarne la stabilità operativa e testare il comportamento della nuova elettronica delle stazioni prevista dall'upgrade. In particolare, trattandosi di rivelatori a scintillazione collocati nella pampa Argentina e operanti ininterrottamente giorno e notte, è importante determinare e garantire la tenuta di luce della struttura meccanica che li racchiude e monitorarla nel tempo. Verrà illustrata una metodologia innovativa di controllo della tenuta di luce dei rivelatori operanti nell'Osservatorio basata direttamente sui dati raccolti dagli stessi e che permette il controllo automatico per tutta la vita dell'Osservatorio.

Aula E - Rosalind Franklin **ore 15:30 – 19:00**

Sezione V
Biofisica e fisica medica

Presiedono: Abruzzetti S. (Università di Parma)
d'Alfonso L. (Università di Milano Bicocca)

Relazioni su invito

▲ Soft perfusion bioreactor to engineer skeletal muscle 3D volumetric constructs onto a porous scaffold.

Piazzoni M., Locarno S., Gerges I., Iberite F., Guarnera D., Ricotti L., Lenardi C.
Università degli Studi di Milano

3D skeletal muscle cell cultures are a promising tool to recapitulate *in vitro* the physiological conditions found in the native biological tissue. However, it is still a challenge to deliver oxygen in avascular cell constructs thicker than 450 μm. In this study we manage to develop an all-soft perfusion bioreactor to engineer skeletal muscle tissue constructs at the macroscale onto a porous scaffold. The device is composed of a macroporous polyurethane scaffold matching the muscle stiffness, that is first wrapped in a compliant silicon chamber, and then sealed at the edges with two hollow tendon-like structures. After device assembly, the scaffold surface was conjugated with fibronectin proteins to allow myoblasts' adhesion onto its surface. Dynamic cell cultures performed using a peristaltic pump attested the ability of the device to enable 3D skeletal muscle cell cultures with a volume of 1 cm^3. We strongly believe that the proposed device can recreate a native tissue environment while administering cells with multiple external stimuli, thus holding the potential of boosting skeletal muscle tissue engineering at its limits.

▲ Comparison of the thermal gradient and radiofrequency on the spread of Covid-19 and proliferation of zebrafish.

Nassisi V. (1)(2)(3), Calcagnile M. (3), Tredici M.S. (3), Velardi L. (1)(4), Mazzei A. (3), Paladini F. (1)(2), Del Vecchio G. (3), Barca A. (3), Alifano P. (3), Verri T. (3)
(1) *Department of Mathematics and Physics, University of Salento, Lecce, Italy*
(2) *INFN section of Lecce, Italy*
(3) *Department of Biological and Environmental Sciences and Technologies, University of Salento, Lecce, Italy*
(4) *CNR, IMM Lecce, Italy*

We present and discuss how specific weather factors are responsible for COVID-19 transmission. The heavy spread of the COVID-19 pandemic worries humanity. We analysed the incidence of COVID-19 as a function of latitude and in particular on the temperature differences 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 2021. The pandemic peaks as a function of latitude are around $-25\,(^\circ)$ and $+50\,(^\circ)$ which are disjoint from only temperature. Similar results are also confirmed in 2022. But today the heart is invaded by radiofrequency. So different electromagnetic generators were made to stress zebrafish (*Danio rerio*) embryos. The stress was operated by static, low frequency magnetic and radio frequencies fields. Embryos were exposed to static, very low frequency, low frequency, very high frequency and ultra-high frequency field irradiations. Untreated embryos were used as control and their survival was 60%. Survival of zebrafish larvae at 5 days after exposure to magnetic fields and radiofrequencies reached up to 80% when static, 0.2 Hz magnetic field, or 100 MHz electromagnetic field are used. This result is an excellent result that allows us to improve the development and spread of species.

Comunicazioni

Non-destructive fruit internal quality control by TD-NIRS: From contact to non-contact measurements.

Levoni P. (1), Vanoli M. (2), Torricelli A. (1)(3), Spinelli L. (3)
(1) *Physics Department, Politecnico di Milano, Milano, Italy*
(2) *Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, CREA, Centro di Ricerca Ingegneria e Trasformazioni agroalimentari, CREA-IT, Milano, Italy*
(3) *Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche, Milano, Italy*

Nowadays, fruit internal quality control is mostly based on destructive, sampling techniques, leading to product waste and bad quality of marketed products.In this study, we exploit a time domain near-infrared spectroscopy (TD-NIRS) device providing non-destructive, non-sampling fruit internal quality control, evaluating its suitability for the industry. Firstly, we assessed the degree of ripeness of a set of 1380 pears at harvest, by measuring absorption and reduced scattering coefficients of all pears in reflectance geometry at 671 nm. Then, pears were divided into 23 comparable batches addressed to different storage conditions (atmosphere, chemical treatment, time), and evaluated again by TD-NIRS after storage.Secondly, we performed simulations for the design of a non-contact system suitable for the industry. Exploiting a homogeneous sphere model, we simulated different values of absorption and reduced scattering coefficient, injection-detection angle and sphere radius. The resulting detection signal results sufficient to perform TD-NIRS measurements, *i.e.*, a non-contact device can be developed.

Muscle cells and tissue photostimulation.

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(2) *Physics Department, Politecnico di Milano, Italy*
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(4) *Department of Chemistry, Materials and Engineering Chemistry "Giulio Natta", Politecnico di Milano, Italy*

Nowadays living cells stimulation is an emerging and hot topic. In particular, contactless and wireless methods are extremely appealing due to a reduced alteration of the analyzed biological systems. Light is an ideal tool to satisfy these requirements and achieve high spatio-temporal resolution. Conjugated molecules and macromolecules, characterized by chemical synthesis' easiness and relatively low toxicity, have proven their efficacy at the interface with living cells when used as phototransducers. Excitable cells are interesting candidates to test the material-based photostimulation. Indeed, muscle cells are a fascinating target due to their contraction ability and electrical properties. Photostimulation can be even more appealing in muscular tissue pacing where the highly organized structure must be preserved for an efficient contraction. In this work, we used an azobenzene compound to control muscular cells and tissue. We characterized the cells-phototransducers interaction evaluating cell's electrophysiology, calcium wave and contraction activity. Finally, the proposed photostimulation was used on *in vitro* micro-physiological system.

Biologically inspired artificial neural network for higher performance and robustness.

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(1) *Department of Biomedicine and Prevention, University of Rome Tor Vergata, Rome, Italy*
(2) *Department of Radiology, Athinoula A. Martinos Center for Biomedical Imaging, Boston, MA, USA*

While biological neural networks exhibit much richer organization as compared to, *e.g.*, multilayer perceptrons (MLPs – made of chain of bicliques, never observed in biological organisms), this higher and more efficient representational capability is not exploited in common network design strategies. In order to exploit the topological features selected by the evolutionary pressure, we propose the Elegant Neural Network (ENN), a feedforward neural network which shares its underlying undirected graph, at the microscopic scale, with the connectome of the *C. elegans* nematode. Our aim is twofold: to contribute to the advancement of neural architecture search and to provide connectionists with a valuable simulation tool. We train both an ENN and a MLP, under the same number of neurons and parameters, to perform discrimination tasks with multidimensional input, and test the robustness of each network to node removal; ENNs either match or surpass the equivalent MLPs in terms of accuracy. Results indicate a complex interplay between topology, performance and robustness, and point towards novel, bio-inspired strategies in generating optimal neural architectures.

Elucidating efflux inhibition and avoidance in *Pseudomonas aeruginosa* through molecular-dynamics simulations.

GERVASONI S., MARGIOTTA E., BOSIN A., VARGIU A.V., MALLOCI G., RUGGERONE P.
University of Cagliari

Antibiotic resistance is a major threat to public health. Gram-negative pathogens, such as *Pseudomonas aeruginosa*, are of particular concern. One of the prevalent bacterial defence mechanisms is the active export of drugs out of the cell, mainly mediated by resistance-nodulation-division (RND) efflux pumps. The major RND efflux pump of *P. aeruginosa* is MexAB-OprM, in which the inner membrane transporter MexB is responsible for recognition and binding of compounds. Due to the difficulty of producing co-crystals, computational methods are crucial to gaining insights into the interactions between compounds and MexB. We exploited multi-copy molecular-dynamics simulations to investigate the binding of peptidomimetics compounds to MexB. Based on microbiology studies, this series was shown to include efflux substrates, inhibitors, and avoiders. The detailed analysis of protein-ligand interactions (both direct and water-mediated) revealed characteristic patterns for each class of compounds, highlighting significant differences. Our results outline molecular-level information that could help the rational design of new inhibitors and new antibiotics less susceptible to the efflux mechanism.

Proteins —A celebration of consilience.

ŠKRBIĆ T. (1)(2), BANAVAR J.R. (1), MARITAN A. (2), GIACOMETTI A. (3), HOANG T.X. (4)
(1) *Department of Physics, University of Oregon, Eugene, OR, USA*
(2) *Dipartimento di Fisica e Astronomia, Università di Padova, Italia*
(3) *Dipartimento di Scienze Molecolari e Nanosistemi, Università Ca' Foscari Venezia, Italia*
(4) *Institute of Physics, Vietnam Academy of Science and Technology, Hanoi, Vietnam*

Proteins are the common constituents of all living cells. They are molecular machines that interact with each other as well as with other cell products and carry out a dizzying array of functions with distinction. These interactions follow from their native state structures and therefore understanding sequence-structure relationships is of fundamental importance.

What is quite remarkable about proteins is that their understanding necessarily straddles several disciplines. The importance of geometry in defining protein native state structure, the constraints placed on protein behavior by mathematics and physics, the need for proteins to obey the laws of quantum chemistry, and the rich role of evolution and biology all come together in defining protein science. Here we present an interdisciplinary framework that aims to marry ideas from Plato and Darwin and demonstrates an astonishing consilience between disciplines in describing proteins. We discuss the consequences of this framework on protein behavior.

Enhancing recurrent neural networks with biologically inspired synaptic plasticity.

Duggento A. (1), Toschi N. (1)(2)
(1) *Department of Biomedicine and Prevention, University of Roma Tor Vergata, Italy*
(2) *A.A. Martinos Center for Biomedical Imaging, Harvard Medical School/MGH, MA, USA*
Synaptic plasticity in brain cells is the fundamental mechanism that modulates synaptic strengths and lets us form memories, recall experience, and learn new tasks without forgetting previous ones. Hebbian/anti-Hebbian plasticity theory postulates that the efficacy of synaptic connections between two neurons increases/decreases with pre- and postsynaptic synchronicity. We investigate Hebbian plasticity in Echo State Networks (ESN), a class of artificial recurrent neural networks which consists of an input layer, a hidden layer (or reservoir) and an output layer. ESN are especially suited to predict and classify temporal data while minimizing overtraining. We study how different biologically inspired plasticity rules can be applied to the connections (synapses) between reservoir neurons and demonstrate that including plasticity can improve classification performance. Further, akin to its biological counterpart, we show that synaptic plasticity helps in retaining high performances during sequential learning, where learning new tasks does not necessarily lead to catastrophic forgetting of previously learned tasks.

Virtual H&E staining and automatic segmentation of liver biopsies by means of a convolutional neural network coupled to a phasor-based algorithm.

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(1) *Laboratory of Advanced Bio-spectroscopy, Physics Department "G.Occhialini", University of Milano-Bicocca, Milano, Italy*
(2) *Division of Vascular Oncology and Metastasis, German Cancer Research Center Heidelberg, DKFZ-ZMBH Alliance, Heidelberg, Germany*
(3) *European Center of Angioscience, ECAS, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany*
Nowadays, pathologists provide their diagnosis by analysing stained biopsies and qualitatively evaluating the morphology and distribution of relevant biological structures. However, staining procedures are time-consuming, specimen-destructive and expensive. In an effort to manage some of these drawbacks, here, we propose a convolutional neural network (CNN) able to Haematoxylin & Eosin (H&E) virtually stain entire murine hepatocarcinoma biopsies. The CNN, trained with 13000 patches ($50 \times 50\,\mu\text{m}^2$), was validated on 4000 regions by pixel-wise comparing the image colour content between the virtual and the real staining procedures (RRMSE $< 5\%$). Then, phasor-based algorithms analysing colour and texture contents were applied to the virtually stained images to detect tumorous tissue and to segment relevant biological structures (accuracy $> 90\%$ compared to the expert manual analysis). These results demonstrate the pipeline effectiveness to virtually stain and to segment entire biopsies. This Digital Pathology tool paves the way toward faster and quantitative diagnosis, reducing the costs sustained by the National Health System.

3D printed dopamine microfluidic sensor based on thermally induced graphitic electrodes on diamond.

Britel A. (1)(2), Amine N. (1), Tomagra G. (3), Carabelli V. (3), Olivero P. (1)(2), Picollo F. (1)(2)
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(2) *National Institute of Nuclear Physics, Section of Torino, Torino, Italy*
(3) *Department of Drug Science and Technology, University of Torino, Torino, Italy*

Dopamine (DA) is a neurotransmitter that regulates diverse physiological operations in the brain, whereas malfunctions of the dopaminergic system are associated with many diseases. Therefore, detecting the concentration of DA *in vitro* from neuroendocrine cell is relevant for drug screening investigations or early diagnosis of sickness. In this contribution, we intend to merge the electrochemical properties of the thermally induced graphite on artificial diamond and the capabilities of a stereolithography 3D printer to produce a droplet-based microfluidic biosensor capable of detecting DA in physiological solutions. The solution under analysis is confined into micro-drop directly created into the microfluidic sensor taking advantage of its immiscibility into the oil stream which works as carrier. Each micro-drop can be considered as a single micro Petri dish and can be individually analysed by the diamond biosensor. The detection process takes advantage of the proportionality between the DA concentration and the generated amperometric current intensity. Our approach relies on developing a versatile method, assuring a time-effective and simple fabrication method with reasonable sensitivity.

Probing the nanomechanical properties of lipid membranes: The effect of trodusquemine.

Relini A. (1), Odino D. (1), Leonardini B. (1), Errico S. (2), Ferrando R. (1), Chiti F. (2), Canale C. (1)
(1) *Dipartimento di Fisica, Università di Genova*
(2) *Dipartimento di Scienze Biomediche Sperimentali e Cliniche, Università di Firenze*

We have used atomic force spectroscopy to study the effects of trodusquemine, a promising drug candidate against neurodegenerative disorders, on the mechanical properties of supported lipid bilayers (SLBs) mimicking neuronal membranes. These biomimetic SLBs exhibit a phase separation between a disordered, fluid phase and an ordered, condensed phase. Through an accurate analysis, taking into account the thickness of the bilayer and correcting for the influence of the rigid substrate, we were able to determine the intrinsic values of the bilayer Young's modulus in the different phases as a function of trodusquemine concentration. We found that both the bilayer's Young's modulus, which represents the stiffness of the lipid layer, and the force required to penetrate the membrane, or breakthrough force, increase in the presence of trodusquemine. This increase in mechanical strength could contribute to an increased resistance of the membranes to the toxic action of misfolded protein oligomers.

Aula L - Christa Mc Auliffe **ore 15:30 – 19:00**

Sezione VI
Fisica applicata, acceleratori e beni culturali
Presiede: Farinon S. (INFN, Sezione di Genova)

Relazioni su invito

▲ **Research activities on the production of innovative radionuclides of medical interest at INFN-LNL: The ISOLPHARM and LARAMED projects.**

Ballan M. ([1]), Pupillo G. ([1]), Andrighetto A. ([1]), Esposito J. ([1]), Corradetti S. ([1]), Vettorato E. ([1])([2]), Mou L. ([1])([3]), Cisternino S. ([1]), Manzolaro M. ([1]), Martini P. ([3])([4]), Morselli L. ([1])([3]), Khwairakpam O.S. ([1])([5]), Arzenton A. ([1])([5]), Tosato M. ([1])([2]), De Dominicis L. ([1])([2]), Scarpa D. ([1]), Sciacca G. ([1]), Lunardon M. ([2])([6]), Boschi A. ([3]), Donzella A. ([7]), Asti M. ([8]), Mariotti E. ([5])
([1]) *INFN, Laboratori Nazionali di Legnaro, Legnaro, Padova, Italy*
([2]) *University of Padova, Padova, Italy*
([3]) *University of Ferrara, Ferrara, Italy*
([4]) *INFN, Sezione di Ferrara, Ferrara, Italy*
([5]) *University of Siena, Siena, Italy*
([6]) *INFN, Sezione di Padova, Padova, Italy*
([7]) *University of Brescia, Brescia, Italy*
([8]) *AUSL Reggio Emilia, Reggio Emilia, Italy*

The production of innovative and alternative radionuclides of medical interest is fundamental for the research advancement in the field of radiopharmaceuticals, important tools for the modern nuclear medicine diagnostics and therapy routines. In such framework, at INFN-LNL, thanks to the recent installation of the 70 MeV proton cyclotron of the SPES (Selective Production of Exotic Species) facility, two complementary accelerator-based projects, ISOLPHARM (ISOL technique for radioPHARMaceuticals) and LARAMED (LAboratory of RAdionuclides for MEDicine), were outlined. The first one will explore the new opportunities and innovative radionuclides such as ^{111}Ag provided by the SPES ISOL (Isotope Separation On-Line) facility, where the combination of the electromagnetic mass separation, typical of the ISOL technique and an eventual chemical separation process can ensure high specific activity. LARAMED will be focused on the direct-activation method exploring the proton-based production of ^{99m}Tc, ^{67}Cu, $^{52/51}$Mn, ^{47}Sc and recently Tb-isotopes. The current research activities up to the preclinical tests for both projects will be presented in detail.

▲ **BriXSinO: Brilliant source of X-rays based on Sustainable and innOvative accelerators.**

Petrillo V. per il BriXSinO Group
Università di Milano

We present the design study of the innovative accelerator BriXSinO. BriXSinO is able to generate high repetition rate (multi-MHz-class) high-brightness electron beams by using a Super Conducting Linac, operating in Continuous Wave mode, equipped with an arc bringing the electrons back to the Linac. The electron beam travels therefore twice through the Super Conducting Linac, permitting to work either in energy recovering regime for sustainable operations or in the two-pass two-way mode, doubling the final energy. In addition to allowing the exploration of these fundamental and promising Beam Dynamical processes, BriXSinO drives two synchronized radiation sources: a Free-Electron Laser Oscillator producing terahertz waves and an Inverse Compton Scattering based on a laser in Fabry-Pérot cavity, delivering X-rays.

▲ **Non-destructive techniques for cultural heritage characterization based on muonic atom spectroscopy.**

CARPINELLI M., CLEMENZA M.
Università di Milano Bicocca, Dipartimento di Fisica "G. Occhialini" e INFN

Patterns associated to the place of origin of archaeological finds raw materials, as well as manufacturing processes and ancient trading routes, are possible by means of elemental analysis. At RIKEN-RAL several experiments have been made to optimize Muonic Atom X-rays spectroscopy as an innovative non-invasive and non-destructive technique for elemental analysis of ancient metal artefacts. Artefacts have been exposed to the double pulsed muon beam at PORT4 of RIKEN-RAL facility, using germanium crystals to detect Muonic Atom X-rays and a muon beam monitor made by Scintillating fibers read by SiPM.

Comunicazioni

● **Trap states ruling photoconductive gain in tissue-equivalent, printed organic X-ray detectors.**

FRATELLI I. (1)(2), BASIRICÒ L. (1)(2), CIAVATTI A. (1)(2), ANTHONY J. (3), KYMISSIS I. (4), FRABONI B. (1)(2)
(1) *Department of Physics and Astronomy, University of Bologna, Bologna, Italy*
(2) *National Institute of Nuclear Physics, INFN, Section of Bologna, Bologna, Italy*
(3) *University of Kentucky, Center for Applied Energy Research, Lexington, KY, USA*
(4) *Department of Electrical Engineering, Columbia University, New York, NY, USA*

In the last decades organic semiconductors demonstrated to be excellent candidates for the development of a new class of X-ray detectors able to fulfill emerging requirements such as the mechanical flexibility, the possibility to cover large areas. Moreover, their chemical composition makes them human tissue equivalent in terms of radiation absorption. On the one hand, this is a highly desirable property for the development of dosimeters to be employed in medical field but, it offers poor absorption limiting the detection efficiency. To tackle this issue, one of the most effective strategies is based on the enhancement of their detection mechanism based on a photoconductive gain (PG). In this study we employed organic field effect transistors where organic semiconductors have been deposited by Pneumatic Nozzle Printing to reach a full control on the crystallization of thin films. The investigation of the PG mechanism has been conducted by a new technique called Photocurrent Spectroscopy Optical Quenching. By these measurements we employed both the X-rays and visible light to study and identify the electrical traps in organic semiconductors which activate the PG effect under ionizing radiation.

● **Development of GEM-based beam monitor operated in N_2 for ESS-Freia.**

ALIMAGNO H. (1), PERELLI CIPPO E. (2), MURARO A. (2), CANCELLI S. (1), CROCI G. (1)
(1) *Università degli Studi di Milano-Bicocca, Milano, Italia*
(2) *Istituto per la Scienza e la Tecnologia dei Plasmi, CNR, Milano, Italia*

The work is related to the design and development of a gas-based beam monitor for cold neutrons for ESS. The innovative element of this monitor lies in the use of a gas mixture (Ar-N_2) both as a conversion agent and as an ionizable gas, exploiting in particular a nuclear reaction in nitrogen for neutron conversion. For applications in ESS, the monitor has to be small in size with low impact on the beam, *i.e.*, no more than 2% of the neutron beam can be removed by the monitor. Simulations are carried on with the Geant4 software to discriminate which material has less impact on the beam and to evaluate the dimensions of each layer to optimize the interaction efficiency between gas and neutrons. Experimental results are shown in this work about the characterization of the monitor prototype with the use of X radiation at the ISTP institute and at Milano-Bicocca University to study its physical and electronical functionality. Preliminary results with thermal and cold neutrons were also obtained using the neutron source at LENA.

Effect of Single Event Effects on long-lasting and high altitude radiation detection experiments: The Gamma-Flash case.

Preziosi E. (1), Andreani C. (1), Campana R. (2), Gorini G. (3), Picozza P. (1), Romanelli G. (1), Tardocchi M. (4), Senesi R. (1)
(1) *Department of Physics and NAST Centre, University of Rome Tor Vergata, Rome, Italy*
(2) *INAF-OAS, National Institute for Astrophysics, Bologna, Italy*
(3) *Dipartimento di Fisica "G. Occhialini", Università di Milano-Bicocca, Milan, Italy*
(4) *Institute for Plasma Science and Technology, National Research Council, Milan, Italy*

In microelectronics, Single Event Effects (SEEs) occur when particles composing the natural cosmic-rays background (*i.e.*, gamma-photons, neutrons and charged particles) strike specific electronic components (*e.g.*, memories or integrated circuits) causing errors in the systems. The electronics composing the power supply and readout systems of radiation detectors are subjected to SEEs and their performance and reliability can be hampered by this threat. This problem is particularly relevant for long-lasting and high-altitude measurements. One of the purpose of the Gamma-Flash project is the development of a new neutron detection apparatus for the study of high-energy particles production following thunderstorm activity. The apparatus is located and operates on top of Mt. Cimone (2165 m a.s.l., Sestola, Italy). In this work, the influence of SEEs on the performance of the Gamma-Flash neutron detectors is reported, following results from experiments carried out at the ChipIR beamline at ISIS Neutron and Muon Source (UK). The experiments allowed to estimate the influence of the neutron irradiation on the performance of the detectors and the reliability of measurements carried out. Authors gratefully acknowledge the financial support of the Consiglio Nazionale delle Ricerche – within CNR-STFC Grant Agreement [No. 2014-2020 (N 3420)] concerning collaboration in scientific research at the ISIS (UK) of STFC – and of the JRU ISIS@MACH ITALIA, Research Infrastructure hub of ISIS (UK) – MUR official registry U. 0008642.28-05-2020.

The MUTOMCA project: Addressing nuclear safeguard aspects with muography.

Lorenzon A.
Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Padova, Italy e Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Padova, Italy

Ever since nuclear power plants have been used for the electricity production, nuclear waste, mainly spent fuel from nuclear reactors, have been accumulating worldwide. The typical handling of this highly radioactive material includes encapsulating it in strongly shielded casks, stored in dedicated interim facilities. As a safeguard measure the inspection of these containers is often required: in particular, in the unlikely event that all the existing containment and surveillance methods fail, a safe non-destructive re-verification method for casks is highly desirable. In this context, imaging techniques based on cosmic-ray muons can be applied to characterize the nuclear material inside these containers. In order to assess the capability of the muography techniques to detect the diversion of fuel assemblies, the MUTOMCA project, which is the result of an international collaboration among INFN (Italy), the Jülich Research Center (Germany), BGZ Company for Interim Storage (Germany) and European Commission DG ENERGY, aims to build a two-module muon tracker and perform a field test at a storage facility in Germany. The status of the project and preliminary results will be presented.

Additive manufacturing of copper and copper alloys for accelerating systems.

Candela V. (1)(2), Bonesso M. (1)(3), Favero G. (1)(4), Candela S. (1), Dima R. (1), Pepato A. (1), Rebesan P. (1)(5)
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(2) *Centro Ricerche Fusione, University of Padova, Padova, Italy*
(3) *Department of Industrial Engineering, University of Padova, Padova, Italy*
(4) *Department of Management Engineering, University of Padova, Vicenza, Italy*
(5) *Department of Mechanical Engineering, Politecnico di Milano, Milano, Italy*

In accelerating systems components, complex shapes are typically needed to satisfy the design requirements and to achieve the best in-operation performance from both the material and the pieces. Additive Manufacturing (AM) is a growing area of interest and represents a promising solution, able to replace conventional technologies and manufacturing processes, especially for materials that show very interesting properties for some specific applications, such as pure copper and copper alloys. Even though, many drawbacks are still limiting the applicability of AM. Some very complex prototypes, like acceleration grids for negative ions and SRF Nb-coated copper cavities, which are characterized by several critical design aspects, have been successfully printed and preliminary tests have been carried out. In this work, material properties of copper and copper alloys, manufactured by means of different AM machines, are summarized: density, thermal conductivity and mechanical properties. In addition, a focus on AM technology is done to show the printability of such components, and post-manufacturing processes are studied in order to achieve the best design targets.

Laser powder bed fusion of refractory metals: A new way to produce components and devices for nuclear physics.

Rebesan P. (1)(2), Candela S. (1), Ballan M. (3), Bonesso M. (1)(4), Candela V. (1)(5), Corradetti S. (3), Dima R. (1), Favero G. (1)(6), Manzolaro M. (3), Pepato A. (1)
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(3) *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, Legnaro, Italia*
(4) *Department of Industrial Engineering, University of Padova, Padova, Italia*
(5) *Centro Ricerche Fusione, University of Padova, Padova, Italia*
(6) *Department of Management and Engineering, University of Padova, Vicenza, Italia*

Refractory metals are of great interest for many applications. For instance, they are used in aerospace and biomedical sectors and for nuclear physics purposes, especially nuclear fusion and particle acceleration devices. High melting points, high wear resistance, and good mechanical strength at high temperatures are some of the characterizing properties of such metals. The production of components made of refractory metals via conventional manufacturing routes and the high cost of raw material do not allow an easy management of these materials. Additive Manufacturing (AM) overcomes many issues found in the traditional production processes. Also, it allows producing objects with complex shapes, minimizing wastage. This study investigates the Laser Powder Bed Fusion (LPBF) of refractory metals. The influence of process parameters on the quality of AM parts is extensively assessed. Mechanical, thermal, and electrical tests are carried out to estimate the AM material properties. The characterization process aims at producing pure Mo and Ta ion source parts, appositely redesigned for assembly and for performance improvement, whereas pure Nb is characterized to produce SFR cavities.

An improved AISHa ion source for new clinical protocols, nuclear-physics and material experiments.

LEONARDI O. (1), CELONA L. (1), CASTRO G. (1), NERI L. (1), CHINES F. (1), PASSERELLO S. (1), GAMMINO S. (1), FALBO L. (2), MONFERRATO R. (2), SIRONI S. (2), VIGONI A. (2), RUSSO F. (2), COSTANZO G. (2), MAUGERI C. (2), VERCESI V. (3)(1), LANZA A. (3), KOURKOUMELI A. (3), VERCELLATI F. (3), SCAGLIOTTI C. (3)
(1) *INFN, Laboratori Nazionali del Sud, Catania, Italy*
(2) *CNAO, Pavia, Italy*
(3) *INFN, Sezione di Pavia, Pavia, Italy*

Hadron therapy is a well-known clinical practice to treat an increasing number of oncological pathologies, in particular inoperable or radioresistant cancers, when it is essential to minimize the dose absorbed by healthy tissue as in paediatrics or brain tumours. Due to its unique peculiarities, the ECR Ion Sources able to produce multiply charged ion beams with low ripple, high stability and reproducibility, are the most suitable choice for medical applications, but also to nuclear-physics and material experiments. In the framework of the INSpIRIT projects, in collaboration with the Centro Nazionale di Adroterapia Oncologica (CNAO), an improved Advanced Ion Source for Hadrontherapy (AISHa) is being assembled in Pavia in order to increase the CNAO potential in the field of experimental and industrial research, particle physics and with the long-term goal of introducing new ionic species into clinical practice such as helium, oxygen, argon and later also iron and lithium useful for bio-spatial research. The key peculiarity and the experimental results of the Aisha ion source will be presented together with an overview of INSpIRIT project.

Design of high-gradient C-band linacs for VHEE-FLASH radiotherapy.

FAILLACE L. (1), ALESINI D. (1), BISOGNI G. (4), BOSCO F. (2), CARILLO M. (2), CIRRONE P. (3), CUTTONE G. (3), DE ARCANGELIS D. (2), DE GREGORIO A. (2), DI MARTINO F. (5), FICCADENTI L. (2), FRANCESCONE D. (2), FRANCIOSINI G. (2), GALLO A. (1), MIGLIORATI M. (2), MOSTACCI A. (1), PALUMBO L. (1), PATERA V. (2), PENSAVALLE J. (4), TORRISI G. (3), SARTI A. (2), SPATARO B. (1), VANNOZZI A. (1), GIULIANO L. (2)
(1) *INFN, Laboratori Nazionali di Frascati, Frascati Italy*
(2) *Sapienza University of Rome, Italy e INFN, Sezione di Roma*
(3) *INFN, Laboratori Nazionali del Sud, Catania, Italy*
(4) *University of Pisa e INFN, Sezione di Pisa, Italy*
(5) *AOUP, Pisa, Italy*

The use of Very High Electron Energy (VHEE) electron beams could represent a valid technique for the treatment of deep tumors in the scenario of the FLASH effect. For the translation to clinical practice, the electron energy should be varied in the range 60–130 MeV. The needed electron peak current is the order of 200 mA, that is 200 nC per 1 μs pulse. The irradiation system also requires compactness for the installation inside a hospital or treatment facility. In order to satisfy both requirements, *i.e.*, high energy and compact system, we propose a radio-frequency (RF) linear accelerator-based electron-beam source working in C-band at 5.712 GHz. In particular, we present the RF design and beam dynamics of optimized high-gradient C-band linear accelerating structures for the transport of high beam current beams for FLASH applications.

Aula C - Maria Gaetana Agnesi **ore 15:30 – 19:00**

Sezione VII
Didattica e storia della fisica

Presiedono: Ercolessi E. (Università di Bologna)
Immè J. (Università di Catania)

Relazioni su invito

▲ **INFN Kids: Giocare e imparare con la scienza.**
Fedi M.
INFN Sezione di Firenze, Sesto Fiorentino, FI, Italia
Le nuove tecnologie digitali sempre più parte della nostra vita quotidiana contribuiscono a stimolare un'intensa discussione a proposito di quali possano essere i metodi migliori, ora, per raccontare al pubblico la fisica, e la scienza in generale. Del resto, la divulgazione non è un'azione fine a se stessa oppure un puro esercizio, ma anzi raccontare e fare esperienza della scienza concorrono alla costruzione di una società più aperta e inclusiva e stanno quindi diventando sempre di più parte del "lavoro" di ricercatrici e ricercatori. È in questo contesto che nasce INFN Kids, con l'obiettivo di incuriosire e appassionare alla fisica bambini e ragazzi in età da scuola primaria e secondaria di primo grado. Fra le idee fondamentali alla base di INFN Kids sono: adattamento delle attività a seconda dell'età dei bambini o dei ragazzi ai quali ci stiamo rivolgendo; racconto ed esperienze pratiche dirette, non necessariamente mediate dagli insegnanti; uso del gioco come mezzo per abbattere l'apparente distanza che si può venire a creare fra pubblico e addetti ai lavori. Nella presentazione parlerò proprio di come queste idee si applicano nelle nostre attività divulgative.

▲ **Italian Quantum Weeks: Un progetto di divulgazione della meccanica quantistica.**
Bondani M.
CNR - Istituto di Fotonica e Nanotecnologie, Como, Italia
Con l'avvento delle tecnologie quantistiche, le caratteristiche peculiari della Meccanica Quantistica sono diventate strumento di progettazione di nuovi dispositivi e applicazioni tra cui computer quantistici, protocolli di comunicazione sicuri, simulazioni di sistemi complessi e nuovi sensori ultra-precisi. Il progetto triennale Italian Quantum Weeks propone a studenti e grande pubblico attività dedicate all'esplorazione dei fondamenti e delle applicazioni della Meccanica Quantistica: una mostra didattico-divulgativa, giochi educativi, attività e laboratori interattivi, conferenze e visite guidate ai laboratori di ricerca. L'obiettivo è offrire ai partecipanti un'esperienza interattiva del peculiare comportamento del mondo quantistico e delle sue potenzialità applicative. Più di 130 ricercatori di 40 organizzazioni in 17 città italiane hanno lavorato per elaborare contenuti e strategie comunicative, perché il messaggio fornito fosse scientificamente preciso ed efficace, e per valutare l'efficacia della comunicazione. Maria Bondani, coordinatrice nazionale del progetto, presenta a nome di tutti i partecipanti elencati nella pagina web `https://www.quantumweeks.it/chi-siamo/`.

▲ **The ECFA Early-Career Researchers (ECR) panel.**
Benato G. ([1]), Brizioli F. ([2]), Diociaiuti E. ([3]), Mancini G. ([3]), Zaccolo V. ([4])
([1]) *INFN-LNGS*
([2]) *INFN-Perugia*

([3]) *LNF INFN*
([4]) *University and INFN Trieste*
The ECFA ECR (Early-Career Researchers) panel is a group of 74 delegates from 30 European Countries and main Accelerator Laboratories. It was formed with the goal of collecting ideas from the research community and providing inputs to the ECFA Panel. The goal of the ECFA ECR Panel is to discuss the aspects that contribute in a broad sense to the future of the research field of particle physics and to the aspects that involve diversity and inclusion of physics programs, sustainability and the career path for young researchers. In its advisory role, the ECR panel provides an annual report to the Plenary ECFA meetings. In this context a survey has been carried out by the Italian representatives within the Italian community of non-permanent INFN employees and associates, from undergraduate students to tenure track researchers. The survey was composed of 28 questions regarding the research activity, the career perspectives, responsibilities, diversity, working conditions and recognition. More than 300 answers were collected within 10 days, confirming the high interest within the community: the results will be shown and discussed in this contribution.

Comunicazioni

Identità disciplinari ed interdisciplinarità per la formazione iniziale degli insegnanti: Approccio e risultati del progetto IDENTITIES.

Levrini O. ([1]), Barelli E. ([1]), Branchetti L. ([2]), Satanassi S. ([1])
([1]) *Dipartimento di Fisica e Astronomia "Augusto Righi" - Alma Mater Studiorum, Università di Bologna*
([2]) *Dipartimento di Matematica "Federigo Enriquez" - Università degli Studi di Milano*
In una società in cui la conoscenza in molti ambiti del sapere è sempre più interdisciplinare, gli insegnanti continuano ad essere formati, a livello universitario, in percorsi disciplinari. Per rispondere a questo disallineamento, il progetto Erasmus+ IDENTITIES ha elaborato un modello di formazione iniziale per insegnanti incentrato sull'interdisciplinaritš tra fisica, matematica ed informatica. Combinando il quadro teorico di Akkerman e Bakker sulla metafora del confine, e il Family Resemblance Approach per la Natura della Scienza di Erduran e Dagher, IDENTITES ha prodotto linee guida per la progettazione di moduli didattici che, da una parte, valorizzano le singole identità disciplinari e, dall'altra, ne analizzano le relazioni nella zona di confine. Il modello è stato applicato nella progettazione di moduli su temi curriculari (moto parabolico e crittografia) e su temi STEM (epidemie, cambiamenti climatici, nanotecnologie, tecnologie quantistiche e simulazioni). Nella comunicazione si presenterà la struttura dei moduli e si discuteranno i principali risultati ottenuti nelle sperimentazioni in contesti nazionali ed europei, tra cui le due scuole estive del progetto.

Meteorology in an Italian province in the mid-nineteenth century: The case of the Urbino Observatory.

Mantovani R.
Università di Urbino "Carlo Bo", Dipartimento di Scienze Pure e Applicate, Gabinetto di Fisica: Museo urbinate della Scienza e della Tecnica.
Today's old Physics Cabinet of the University of Urbino preserves some valuable and significant historical meteorological instruments, all in good condition. These are various pieces such as thermometers, barometers, hygrometers, electrometers and single and multiple lightning rod tips. Their history is linked to the foundation in Urbino of a Meteorological Observatory that began its activities in May 1850. This talk will provide a description of some of these surviving instruments and an analysis of the activities and meteorological studies developed by the scientist and member of the Scolopian order Alessandro Serpieri (1823-1885),

whose principal merit was to have proposed, among the first in Italy, the use of the telegraph at the service of Meteorology. In the context of the History of Synoptic Meteorology and the use of the telegraph to weather forecasting, this communication will try to reconstruct the history of this Meteorological Observatory, which, even today, after 173 years, is functioning and in total operational activity.

Italian Quantum Weeks @Trieste: Scientific dissemination about the second quantum revolution in a local context.

Paparelle I. (1), Mishina O. (1)(2), Trombettoni A. (3)
(1) *Consiglio Nazionale delle Ricerche, Istituto Nazionale di Ottica, Trieste, Italia*
(2) *Scuola Internazionale Superiore di Studi Avanzati, Trieste, Italia*
(3) *Dipartimento di Fisica, Università di Trieste, Italia*

The technologies that rely on the first quantum revolution are omnipresent: to disclose the potential of the second quantum revolution to the public and attract new talents, dissemination is fundamental. To help quantum research appear less out of reach, it is useful to create local dissemination events that exploit features of the hosting city and highlight the local research. On the national series of events Italian Quantum Weeks, seventeen cities organized workshops, conferences, exhibitions, etc. In Trieste the initiatives were held mainly in historical and literary cafes in the city center and involved local researchers and professors. A whole day was dedicated to students: the "Giovani quantistici", young local researchers in quantum sciences and technologies, shared their experience with short presentations. During six conferences for the general public, researchers of the same quantum field dialogued among themselves and with the public, at the beloved "aperitivo" hour in the cafes. Finally, we organized Quantum Game Café nights. We report on the positive outcome and feedback of these events, while sharing the improvements and suggestions for the future.

Circuiti logici e circuiti ottici: Un percorso di costruzione della computazione quantistica per studenti di scuola secondaria di secondo grado.

Sutrini C. (1), Zuccarini G. (1), Malgieri M. (1), Ceruti M. (2), Pancani G. (3), Macchiavello C. (4)
(1) *Dipartimento di Fisica, Università di Pavia, Italia*
(2) *Liceo scientifico e delle scienze applicate "A. Volta", Castel San Giovanni, PC, Italia*
(3) *Liceo scientifico "A. Gramsci", Firenze, Italia*
(4) *Dipartimento di Fisica, Università di Pavia, Italia*

La possibilità di costruire dispositivi sperimentali a partire dalla rappresentazione circuitale di algoritmi e protocolli di computazione e informazione quantistici è insita nella formulazione matematica alla base degli stessi e ne rappresenta uno dei tratti caratteristici. L'impostazione diagrammatica, infatti, si manifesta sia in alcuni approcci recenti legati ai fondamenti della meccanica quantistica che in ambiti strettamente applicativi. Tale possibilità diventa estremamente rilevante se inserita in un contesto didattico in cui l'aspetto logico formale voglia essere supportato da realizzazioni fisiche ideali. Presentiamo i materiali costruiti a questo scopo e i primi esiti di due sperimentazioni condotte da insegnanti del liceo Volta di Castel san Giovanni (PC) e del liceo Gramsci di Firenze. L'approccio seguito mira a costruire una proficua dialettica tra rappresentazioni diagrammatiche e setup sperimentali ideali con dispositivi ottici, coinvolgendo gli studenti mediante strategie didattiche di tipo inquiry con l'obiettivo di favorire la comprensione e la costruzione del linguaggio formale e della logica dei protocolli quantistici.

Quantum mechanics at high school: An inquiry-based-like activity on wave-particle duality for distance learning environments.

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The interest in studying quantum mechanics is increasing in our society and topics related to quantum physics are now part of high schools' programs. This leads researchers to implement suitable actions to meet social needs of knowledge of quantum physics. A possibility can be to focus on one of the main conceptual issues of quantum mechanics, that is the wave-particle duality and develop suitable learning strategies to highlight the manifestation of the dual nature of matter and light. We present an inquiry-based-like laboratory on wave-particle duality for high school students (17-19 years old) implemented with the RIALE online platform, developed by CRS4. The activity has been done in the period December 2021 - May 2022 at the Physics Department of the University of Cagliari and more than 100 hundred students from different high schools in Sardinia have been involved. We will show the design of the activity and the experiments performed. We will give some details about the platform we used during the online laboratory and its potential use as an online educational tool in high schools. A brief discussion about the assessments and motivational issues will be done.

Elementarizzazione degli algoritimi quantistici: Chiarificazione della struttura interna ed esiti di apprendimento preliminari.

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Descriviamo una proposta di elementarizzazione per la fase di *information processing* degli algoritmi quantistici e riportiamo i risultati di un'indagine preliminare sulla sua utilità didattica condotta su studenti volontari della scuola secondaria. Sulla base dell'analisi di algoritmi affrontabili a tale livello, suggeriamo di decomporre la manipolazione dell'informazione in: 1) attivazione del parallelismo per mezzo di porte Hadamard; 2) trasferimento dell'intera informazione codificata nell'oracolo ai registri target sotto forma di un segno positivo o negativo associato a ciascun vettore di base; 3) attivazione dell'interferenza per mezzo di una rete di porte logiche allo scopo produrre lo stato desiderato. Per quanto il test abbia coinvolto un piccolo campione di studenti in didattica a distanza nel rispetto delle misure restrittive adottate durante l'emergenza pandemica, questo lavoro di chiarificazione ha promosso la costruzione di una corretta comprensione concettuale della struttura degli algoritmi sia in termini informazionali che – almeno in parte – in termini fisici.

Didattica del quantum computing nel metaverso.

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I primi prototipi di computer quantistici hanno suscitato interesse nella computazione quantistica e nei principi base della meccanica quantistica. In questo contesto si inserisce il progetto di educazione sulle basi fisiche del quantum computing basato sulla descrizione sperimentale con metodi virtuali dell'implementazione fisica dei primi 5 principi di Di Vincenzo. Il processo di computazione è implementato come trasformazioni di qubits codificati nella polarizzazione di fotoni ottici. Dette trasformazioni sono implementate come quantum gates realizzati come oggetti virtuali 3D usando Blender. Nel dettaglio sono realizzati i modelli di: Laser Ar+, PBS, HWP/QWP, BBO, APD, SMF, Elettronica di controllo. Con i modelli 3D è stato realizzato un laboratorio virtuale o più propriamente uno spazio nel Metaverso dove è possibile familiarizzare con i processi base del quantum computing: produzione di fotoni annunciati, trasformazione di un qubit, misura di un qubit, produzione di fotoni entangled, trasformazione di due qubits, misura di due qubits. La realizzazione di modelli fisici da usare nel metaverso potrebbe colmare il vuoto didattico dovuto alla assenza di laboratori di quantum optics.

Peer education: Un'esperienza formativa?

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Negli attuali suggerimenti di percorsi formativi nati dall'esperienza costruttivista si parla spesso di "peer education" per indicare la proposta educativa in base alla quale alcuni membri di un gruppo vengono formati per svolgere un ruolo di educatore e tutor per il gruppo di coetanei o di studenti leggermente più giovani. Il percorso che vogliamo presentare ha preso l'avvio dall'esame di uno dei nodi concettuali evidenziati dalla ricerca didattica, i principi della dinamica, e dall'idea di presentare il contenuto agli studenti di I liceo scientifico attraverso la riflessione e l'azione di studenti del quarto anno, che hanno in questo modo vissuto un'esperienza di PCTO. L'attività di formazione ha previsto una prima fase di riflessione ed approfondimento da parte degli studenti più grandi, durante la quale hanno affrontato la loro personale comprensione delle leggi del moto. Successivamente hanno ideato e realizzato un percorso didattico, con questionari, lezioni, esperienze di laboratorio, etc. che hanno proposto alla classe prima. L'attività formativa ha giovato innanzitutto agli studenti tutori, sia come approfondimento disciplinare che come scoperta dell'azione didattica.

Aula A **ore 19:00**

Assemblea di ratifica e proclamazione degli eletti

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PROGRAMMA SOCIALE

Tutti gli eventi sono gratuiti, con prenotazione nominale obbligatoria a questa pagina: `https://2022.congresso.sif.it/info/eventi`

Lunedì 12 settembre

Ore 18:15	Aperitivo di benvenuto con visita libera dell'orto botanico Orto Botanico Città Studi - Università degli Studi di Milano Via C. Golgi 18

Mercoledì 14 settembre

Ore 19:00	Cena a buffet Museo Nazionale Scienza e Tecnologia Leonardo da Vinci Spazio Polene, Padiglione Aeronavale Via S. Vittore 21 Possibilità di visita del Museo

Giovedì 15 settembre

Ore 19:15	Concerto di Brahms (Clarinetto, violoncello e pianoforte) A seguire cena a buffet Aula Magna dell'Università degli Studi di Milano Via Festa del Perdono 3

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