

Physics for Health:

New perspectives in medical applications and radiation safety



8th - 12th May 2026, Erice

COURSE DIRECTORS:

**Maurizio MARRALE,
Francesco D'ERRICO,
Cristina LENARDI**

INTERNATIONAL SCHOOL ON NONEQUILIBRIUM PHENOMENA

Directors of the School: Alessandra
LANZARA, G. Massimo PALMA,
Bernardo SPAGNOLO

BOOK OF ABSTRACTS AND CONFERENCE PROGRAMME

Welcome

School Directors and Organizing Committee

Patronages and Sponsors

Conference Programme

Abstracts: Lectures

Poster Presentations

List of Presentations

“LET effects on the ESR/alanine signal: a spectral decomposition approach”

^{1,2*}de Farias Soares, A., ^{1,2,3}D’Oca, M.C., ^{1,2,4}Romeo, M., ^{1,2}Cottone, G., ¹Corvaia, E., ^{1,4}Maggio, E., ¹Valenti, D., ⁵Ciocca, M., ⁶Mantovani, L., ⁶Di Liberto, R., ⁵Mirandola, A., ⁵Rossi, E., & ^{1,2}Marrale, M.

¹Department of Physics and Chemistry “Emilio Segré”, University of Palermo, Palermo, Italy.

²National Institute for Nuclear Physics (INFN), Italy.

³Advanced Technologies Network Centre, University of Palermo, Italy.

⁴Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, University of Palermo, Palermo, Italy.

⁵National Centre for Oncological Hadrontherapy (CNAO), Italy.

⁶IRCCS Policlinico San Matteo Foundation, Italy.

Alanine dosimeters based on electron spin resonance (ESR) are widely used in medical dosimetry due to their reliability. Upon ionising radiation exposure, three main radicals are produced in the material (R1, R2 and R3). These radicals refer to the deamination of a protonated radical anion, the hydrogen subtraction from the central carbon, and an oxidation product, respectively [1]. Although the ESR/alanine signal response is linear over a wide range of doses for photons (i.e., low linear energy transfer (LET) radiation), for higher LET radiations, quenching effects and changes in the spectrum are observed. The latter, usually studied by means of the x/y ratio [2].

This study, therefore, aimed to investigate the influence of LET on the radiation-induced radicals in alanine using spectrum decomposition. For that, alanine pellets were irradiated with photons (6 MV X-rays) at the San Matteo Policlinico, and with proton and carbon ion beams at CNAO (both in Pavia, Italy). The latter two in a spread-out Bragg peak (SOBP) condition. Dose-averaged LET spanned from 0.5 up to 100 keV/μm, and doses between 8 and 40 Gy. The 3-component simulated spectrum was obtained using the EasySpin MATLAB [3], with the *pepper* function, including hyperfine interactions. Experimental ESR spectra were acquired with a 580 Bruker spectrometer (Germany) operating in the X-band at different microwave powers. Experimental spectra were fitted with those simulated using the least-squares method. The weight of each component and (in-)homogeneous broadenings were considered. The goodness of the fitting was evaluated by percentage root-mean-square-deviation (%RMSD).

Results demonstrated that under low-microwave-power (< 3 mW) and low-LET (~0.5 keV/μm) conditions, R1 and R2 are the main contributors to the signal, whilst R3 becomes the predominant at high-LET and high-microwave-power conditions. Radicals’ microwave saturation behaviour and inhomogeneous broadening analyses suggested that radiation quality affects both the relative amounts of each radical and the environmental lattice surrounding it.

References

- [1] M.Z. Heydari, E. Malinen, E.O. Hole, E. Sagstuen, “Alanine Radicals. 2. The Composite Polycrystalline Alanine EPR Spectrum Studied by ENDOR, Thermal Annealing, and Spectrum Simulations,” J. Phys. Chem. A, vol. 106, pp. 8971–8977, 2002.
- [2] M. Romeo, A. de Farias Soares, M.C. D’Oca, M. Ciocca, L. Mantovani, R. Di Liberto, A. Mirandola, E. Rossi, L.M.C. Gomez, M. Marrale, “Comparison of the alanine response to clinical proton and carbon ion beams,” Int. J. Radiat. Biol., pp. 1–12. 2025.
- [3] S. Stoll, A. Schweiger, “EasySpin, a comprehensive software package for spectral simulation and analysis in EPR,” J. Magn. Reson., vol. 178, pp. 42–55, 2006.