lambda accounts for both the physical decay of the radionuclides and a contribution that simulates the biological wash-out. The WIDMApp prototype proved to be effective: the results were comparable with the ones from the commercial dosimeter.
The correct functioning of the phantom was proved: the development of a dynamic system that simulates both the physical and biological wash-out of an organ is possible. This phantom could be used to test different nuclear medicine devices in realistic conditions.

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Nuovi ambiti - multidisciplinare

Abstract CO.38.223

A multi-disciplinary in silico strategy to address the radiobiological effects in non-conventional irradiation conditions

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The advanced radiotherapeutic strategies aim at reducing toxicity relying on non-conventional administration of therapeutic doses. In particular, the FLASH effect, consists in a relative sparing of non-cancerous tissues obtained by administering irradiation at very high dose rates in short pulses, while a similar effect has been observed using shaped in spatial combs (minibeam effect). In spite of the increasingly accumulating data, the mechanistic determinants of these effects are not completely clarified.
In silico studies are particularly challenging, because the radiobiological cascade of events started by irradiation spans 12–15 orders of magnitude in the size/time domains, from the local ionization, to creation and diffusion of radicals damaging DNA, and finally to the cell signaling biochemistry determining its different possible fates. At each different stage, computer modelling requires different techniques which must be matched.
Here we report the general workflow of the modelling strategy we developed under the Tuscany Health Ecosystem Spoke-1 PNRR, and within the MIRO-INFN project. The different stages include the use of Monte-Carlo reaction diffusion, atomistic reactive and coarse grained molecular dynamics, development and optimization of low resolution and stochastic empirical models. We exploited a continuous exchange of data between experiment and simulations, used to both validate models, and to support measurement interpretation. AI algorithms are integrated, both in the simulation data analysis and in the models optimization. We illustrate in more detail, a low resolution model of chromatin aimed at unravelling the clustering of damage on DNA, observed in super-resolution fluorescence microscopy images, which displays some differences between conventional and unconventional irradiation modalities
By combining different modelling approaches and experimental data in a coherent view we aim at giving global picture of the sub-cell molecular determinants of the sparing effects in non conventional irradiation modality.
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Nuovi ambiti - multidisciplinare

Abstract SAI.01.228

Artificial intelligence in BNCT: a dosimetric assessment of treatment planning using human- or AI-segmented medical images

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Artificial Intelligence (AI) has emerged as a powerful tool for addressing challenges in the field of medical physics, offering significant advancements in image analysis, segmentation, and treatment optimization. In particular, cutting-edge Deep Learning (DL) models have shown exceptional accuracy and reliability of image segmentation tasks, enhancing treatment precision. Within the INFN-CSN5 Young Researchers Grant project “AI_MIGHT” and the PNC-PNRR ANTHEM project, we applied DL to Boron Neutron Capture Therapy (BNCT), an emerging radiotherapy modality that leverages boron-containing drugs and neutron irradiation for targeted tumor treatment. BNCT has the potential to respond to radioresistant tumors and AI can offer a tool for better personalization. Our study investigates the application of DL for the segmentation of computed tomography images of patients affected by Glioblastoma Multiforme sourced from The Cancer Imaging Archive. We selected a suitable dataset and employed the nnUNet architecture, a state-of-the-art DL model, for automated segmentation of medical images. The dataset was split into training and testing subsets, and the nnUNet model was trained and evaluated accordingly. The performance of the trained algorithm was analyzed by assessing the quality of segmentations on the testing set. To further evaluate the clinical applicability of the DL-generated segmentations, we simulated BNCT treatment plans for a subset of test cases using the IT-STARTS Treatment Planning System developed by the INFN research group in Pavia. Plans were designed for optimal tumor dose distribution while keeping typical dose constraints for healthy brain, adopting a conservative approach. Dosimetric comparisons were performed between manual contouring, considered as the “ground truth”, and automatically generated segmentations.
The trained nnUNet model successfully segmented CT images, producing results comparable to manual segmentation.
The results demonstrate the potential of DL-based segmentation for BNCT treatment planning, highlighting the opportunity to explore automatic tools to generate faster treatment processes, boost research and enhance precision.

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Nuovi ambiti - multidisciplinare

Abstract CO.36.230

A minimalistic model of the ultra high dose rate effect of ionizing radiation: insights in the flash effect

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In phenomenological stochastic models of the biological cellular effect of ionizing radiation, e.g. the multiple target multiple hit model (MTMH), one uses the concept of threshold – the effect happens if at least M critical cellular targets are hit by at least N ionizing particles each, the effect doesn’t take place otherwise. A notable sigmoidal shape of the biological

effect versus absorbed dose curve originates from the spatial inhomogeneity of the cellular regions hit by the radiation - some regions are hit many times and contribute to the possible cellular effect, the others aren't. The active radicals and ions created by the ionizing particles and eventually (directly or indirectly) causing the biological damage also have spatially inhomogeneous concentration, – mesoscopic spatial fluctuations around the average value. The fluctuations of the radical concentration dissipate due to the diffusion and the recombination processes in competition with creation of new radicals due to the dose deposition at a given dose rate, and this kinetics affects the eventual biological effect.

We present a simple theory of the diffusive relaxation of the mesoscopic, non-thermodynamic fluctuations of radical concentration and its application within a MTMH-type model to the FLASH effect. We will also discuss the matching points of the model with atomistic simulations.

The conclusions of the model are in qualitative agreement with the recent review [1] collecting the available in vivo experimental results of the FLASH sparing effect for normal tissue complications probability, pooling different tissues, and animals.

In particular, the model succeeds in predicting the onset and increase of the FLASH effect at higher doses and also the threshold dose below which the FLASH sparing is not observed.

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Reference

[1] Böhlen TT et al. Int J Radiat Oncol Biol Phys 2022;114(5):1032–44.

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Nuovi ambiti - multidisciplinare

Abstract CO.41.236

Deep learning for malignant breast lesion segmentation in 3T DCE-MRI using V-NET

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In the realm of medical imaging, since the progressive introduction of sophisticated analyses such as radiomics to characterize tumours, increasing attention has been given to lesion segmentation.

Traditional manual approaches are not only highly dependent on the operator but also time-consuming.

Both of these challenges might be mitigated through automated approaches. This work aims to propose a fully automated deep learning segmentation model based on the V-Net architecture for malignant breast lesions in DCE-MRI data.

DCE-MRI scans from a 3T scanner were collected from a cohort of 131 women with breast cancer between 2016 and 2021, prior to neoadjuvant chemotherapy. The second subtracted post-contrast images were used for training, paired with binary masks manually produced by radiologists.

A first V-Net was trained to segment the full breast area, then the search area was restricted to the breast only. An overlap-and-tile approach was employed, training a second V-Net using multiple 3D patches to preserve fine-grained details. The pipeline involves the initial segmentation of the breast, followed by lesion detection and segmentation on individual patches, and a final fusion of outputs from all patches to produce the result. Fine-tuning of parameters, such as the percentage of background patches used in training and the binarisation threshold, was necessary to achieve the best model performance.

Automated segmentation was compared with the manual ground truth using the Dice score.

Using the full information, including all lesion and background patches and an intermediate binarisation threshold of 0.5, a median Dice score of 0.77 (IQR 0.66–0.83) was achieved for training and 0.71 (IQR 0.51–0.82) on the test set.

Satisfactory results were achieved, both in reducing segmentation times by at least a factor of five and in obtaining reliable segmentation. However, in some cases, human supervision might still be necessary to check for false positives.

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Nuovi ambiti - multidisciplinare

Abstract CO.38.254

Graphite calorimetry for flash radiotherapy with ultra-high dose rate proton and electron beams

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Small portable calorimeters are recently becoming valuable alternative approaches for reference dosimetry in FLASH radiotherapy. A portable secondary standard graphite calorimeter (GCal) was realized at the National Physics Laboratory (NPL, UK) consisting of a central 2 mm thick, 16 mm diameter graphite core, was experimentally tested by the INFN Catania group with both ultra-high dose rate (UHDR) electron and proton beams.

Specifically, the 228MeV UHDR proton beam accelerated at the Trento Proton Therapy Center was used to determine the dose to water with the GCal varying the beam current (average dose rate from 10 Gy/s to 250 Gy/s). The 9 MeV UHDR pulsed (4us) electron beam accelerated by the Electron FLASH linac at the Centro Pisano for Flash Radiotherapy in Pisa was also used to extend the study of the GCal response to extreme instantaneous dose rate conditions (up to 2 MGy/s). The last characterization was performed in the framework of the AIFM working group dedicated to the dosimetry for FLASH and SFRT modalities, during the