Up-grade on prostheses materials and devices SPR evaluation by proton computed tomography

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Abstract

This study presents an up-date on pCT methodology applied to complex metal prostheses, to evaluate their mean SPR values and to reconstruct their metal structures within a millimeter scale. Comparison of artifacts on same implant devices xCT and pCT images will be presented and discussed.

*Speaker

Data-driven Forward Projector for Optimization of the Proton Stopping Power Calibration in Treatment Planning Based on Sparse Proton Radiographies

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Abstract

Introduction: Optimization of the Hounsfield Unit (HU) to Relative (to water) Stopping Power calibration (RSP) in treatment planning based on sparse integration-mode proton radiographies (pRads) is inherently limited by approximations in the forward projection operator. We propose a data-driven model for accurate and fast prediction of the dose distribution within an integration-mode pRad detector. By deriving integrated depth-dose profiles from these predictions, the conventional, approximative forward-projector in the optimization workflow can be replaced.
Methods: A modified version of the DoTa architecture is trained on Monte Carlo simulated data, where the 3D detector dose distribution is predicted from an RSP-calibrated patient CT for a fixed pencil beam energy. By choosing this transformer architecture, the sequential nature of proton transmission through matter is represented inherently (see Figure 1). The model is trained on _˜73k pencil beams from six patients and validated on _˜24k pencil beams from 2 patients, using the optimizer AdamW and a Cosine Annealing learning rate schedule with warmup phase and warm restarts. To enforce dependency of the predicted detector dose on a patient-specific RSP curve, each CT is included in the training set multiple times with different, randomly modified underlying RSP calibrations.

Results: Preliminary evaluation of the network performance on the validation data set shows promising results. Further training and hyperparameter optimization are ongoing, full testing on an independent dataset will be performed upon completing model training.

Conclusions: The transformer model is a promising candidate for learned, approximation-free forward projection. Next steps will be embedding the learned forward projector in the RSP optimization workflow.
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*Speaker

Relative Proton Stopping Power measurements by proton Computed Tomography Apparatus

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Abstract

Purpose: The experimental procedure followed to measure the 3D map of the proton stopping power relative to water (SPR) of a tissue-substitute phantom (CIRS 062-M) using a proton Computed Tomography (pCT) apparatus is described. The final aim of this measurement is to build a look-up-table (xCT Hounsfield Units vs. SPR) based on the CIRS phantom inserts to be used for dose calculation within a commercial treatment planning system (TPS).
Methods: The pCT apparatus (1) is made of a silicon microstrip tracker followed by a YAG:Ce scintillating crystals calorimeter. The system has been installed in the room of the 'Trento Proton Therapy Center' of APSS (Azienda Provinciale per i Servizi Sanitari – Trento, Italy). After an instrumental calibration of the apparatus (2), the CIRS phantom has been mounted on the rotating platform of the pCT system and a dataset of proton triggers equally distributed in 400 angles (corresponding to a total dose of about 14 mGy) has been taken. The tomographic image has been reconstructed using a filtered backprojection proton CT reconstruction along most likely paths (3).

Results: The SPR of the 9 tissue equivalent inserts were scored from the pCT image. Independent SPR measurements of the inserts were carried out also with a multi-layer ionization chamber and the results of the two experimental approaches were compared. A measurement performed on a water phantom is used to validate the tuning of the experimental system. The SPR vs HU curve determined with the above-mentioned method will be used in clinical TPS to calibrate patient CT images aiming at reducing the impact of range uncertainties on plan quality.

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*Speaker

Sandwich time-of-flight proton CT image reconstruction using the Adam optimizer with automatic differentiation

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Abstract

Proton computed tomography (pCT) is an imaging modality which provides several benefits including the accurate estimation of the relative stopping power (RSP) distribution for proton therapy treatment planning. Conventional proton CT scanners measure the energy loss of each proton individually, along with their positions and directions before and after the object, to estimate the integral of the RSP along each proton's most likely path (MLP). However, keeping reasonable acquisition times and moderate manufacturing costs with this design is challenging. As a potential solution, a novel design was recently proposed where the RSP distribution is inferred from the time-of-flight (TOF) of protons between two detectors sandwiching the object, without needing a residual energy tracker. However, a major difficulty stems from this new design: to each measured TOF corresponds infinitely many possible water-equivalent path lengths (i.e., RSP integrals) because the velocity of the proton depends on the order of the materials encountered along the MLP. Consequently, no reconstruction algorithm is currently available for this set-up. We propose a reconstruction procedure that uses an iterative optimization scheme to reconstruct the sought RSP distribution. First, a forward model was implemented, which computes the TOF of a proton from its measured positions and directions using an estimate of the RSP distribution. Then, this estimate is evaluated using a loss function that calculates a distance between the TOFs obtained from the forward model and those directly measured by the scanner. Finally, the gradient of the cost function is calculated using the automatic differentiation engine provided by PyTorch, *autograd*, and a new estimate of the RSP distribution is calculated using the Adam optimizer. This iterative method was assessed on simulated TOF data generated using GATE version 10. Although computationally demanding, the method yielded satisfactory reconstructions of the RSP distribution, without relying on energy measurements.

*Speaker

Treatment planning adaptation in ion beam therapy using sparse in-room ion radiographies

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Abstract

This work is part of a broader project exploring the use of sparse ion radiographies for adaptive radiation therapy, addressing both calibration and registration problems, with the goal of advancing the clinical translation of ion imaging. Specifically, it proposes a physics-informed neural network for adaptive ion beam therapy using in-room ion radiographies combined with a prior planning image.

In this work, the Learned Primal-Dual (LPD) network (1), originally developed for reconstruction, is extended and adapted to address the 2D-3D registration problem (2). To enhance feature extraction, each image-domain block of the LPD network is combined with a U-Net module (LPD+U-Net) (Figure 1). A dataset consisting of ten anthropomorphic head phantoms is adopted. The ion radiographies are obtained by forward-projecting the original phantoms, representing the in-room scenario. To generate the treatment planning scenario, controlled anatomical changes are introduced by deforming the phantoms using Gaussian derivative-based transformations, simulating effects such as tissue shrinkage and dilation. The Gaussian parameters (anisotropic standard deviations, amplitude and location) are randomly sampled within clinically realistic ranges. Each phantom is transformed three times, each according to five different transformations. In a preliminary test, a seven-slice slabs per transformation are selected, resulting in 150 volumes used for training, validation, and testing of the network.

The results demonstrate that the original LPD can effectively estimate transformations. The performance of the LPD+U-Net is currently limited by global inaccuracies, which affect also untouched regions (Figure 2). Ongoing work is focused on incorporating dedicated data consistency layers to mitigate these issues.

The lower performance of the LPD+U-Net compared to the original LPD is likely due to the higher complexity of the architecture, which makes training more difficult, requires more data, and involves careful hyperparameter tuning. After this study under idealized conditions, the network is planned to be tailored to realistic ion radiographies.

*Speaker

Primary and secondary radiation detection for range verification through Prompt Gamma Timing technique

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Abstract

A detector system was developed to measure the Time of Flight (ToF) between primary ions and secondary Prompt Gamma (PG) emissions, aiming at range verification in carbon ion therapy using the Prompt Gamma Timing (PGT) method.
Signals from single carbon ions were detected using an n-on-p silicon strip sensor with an active thickness of 60 μm and a total area of 17.6 mm^2, read out by a custom-designed board. PG photons were detected using a 1.5-inch cylindrical LaBr(Ce) scintillation crystal coupled to a 5×5 silicon photomultiplier (SiPM) array, with a total active area of 2.4×2.4 cm^2.

Two different data acquisition (DAQ) systems were evaluated for signal readout and timing measurements: one based on a CAEN DT5742 digitizer, and the other employing a CAEN PicoTDC Time-to-Digital Converter. In both setups, the PG signal was used to trigger the acquisition of primary ion signals, thereby enhancing detection efficiency. To correct for time walk effects in the TDC measurements, the Time-Over-Threshold (ToT) method was applied.

PGT distributions were measured using the PG detector positioned at 50$\circ$ with respect to the beam axis. The measurements were performed by irradiating a homogeneous PMMA phantom with 398 MeV/u carbon ions and compared to those obtained from a second setup featuring a 4-cm air gap within the phantom. The presence of the air gap led to a noticeable reduction in prompt gamma production, with a corresponding drop observed around 14.5 ns in the PGT distribution.
The experimental setup and preliminary measurements were performed at the National Center for Oncological Hadrontherapy (CNAO). Results from preliminary PGT measurements at clinical beam rates are promising, demonstrating the system's sensitivity to range variations caused by changes in material density along the beam path. Further investigations are underway to quantitatively assess the differences in PGT distributions.

*Speaker

vpgTLE: Track-length estimator for MC simulations of the prompt-gamma emission sources in proton therapy

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Abstract

Proton therapy allows for highly localized dose deposition, making it a powerful cancer treatment technique. However, since protons stop within the patient's body, direct in-vivo monitoring of the beam range remains challenging. A promising solution is prompt gamma (PG) imaging, as PG and dose distributions are closely related. Developing and optimizing PG detectors requires accurate Monte Carlo simulations. Yet, PG emission often originates from rare processes such as nuclear fragmentation, leading to very long computation times. Variance reduction techniques (VRT) are therefore essential to achieve realistic and efficient simulations. In this context, the voxelized prompt gamma track length estimator (vpgTLE), a VRT method, was recently ported to the python-based GATE 10 framework, and refined with the aims of updating its implementation and extending its scope to account for prompt gammas induced by both incident protons and secondary neutrons. Since neutrons diffuse over large volumes and contribute to PG production through inelastic interactions, distinguishing PG from protons and PG from neutrons is crucial for improving detector design and obtaining a clearer signature of the proton beam. To achieve this, we constructed databases of PG yield constants from both proton- and neutron-induced reactions using a dedicated Geant4 script. Energy and time-of-flight emission spectra were then computed voxel by voxel within a voxelized geometry. Validation has already been performed for proton-induced PG, demonstrating consistent agreement with reference data (Fig. 1–2). Validation for neutron-induced PG is still ongoing, particularly in realistic CT-based patient geometries. Furthermore, extending the method to heavier ions such as carbon represents a promising perspective to broaden the applicability of PG imaging in hadron therapy.

*Speaker

First imaging results with a mixed helium-carbon beam for image-guided particle therapy

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Abstract

To fully exploit the potential of carbon ion radiation therapy, real-time online treatment monitoring is essential. The PROMISE project explores the use of mixed beams to achieve this goal. By combining carbon and helium ions, which have nearly the same charge-to-mass ratio, they can be accelerated together efficiently. At the same velocity, the lighter helium ions have triple the range of carbon ions. While carbon is used for therapy, helium can traverse the patient and serve as an effective imaging tool, providing information about the beam range and patient anatomy.

In May 2025, we conducted extensive imaging and range probing experiments with a mixed beam at the GSI Helmholtzzentrum für Schwerionenforschung, where the first mixed beam was produced in 2023. Our experimental setup included ionization chambers, multi-wire proportional chambers and radiosensitive films. For helium imaging, we used a scintillation detector developed at University College London which uses three cameras to capture lateral, top, and distal views of the beam. We scanned various geometrical phantoms to demonstrate the imaging capabilities of the scintillator detector system.

This presentation will discuss the first results of our experiments, highlighting the feasibility and advantages of using mixed beams for online monitoring in carbon ion therapy. The findings promise to enhance the precision and safety of this advanced cancer treatment modality.

*Speaker

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Imaging dose estimation in ion CT for the image quality comparison of proton CT and helium CT

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Abstract

Helium ion computed tomography (HeCT) has recently gained interest as a potential alternative to proton computed tomography (pCT) in particle therapy imaging, offering the promise of improved spatial resolution and potentially reduced imaging dose (1). In this study, we present the methodology required for a comparative evaluation of imaging dose and image quality in pCT and HeCT images acquired using a prototype scanner.
We begin with an overview of ion CT dose estimation methods, focusing on two key approaches: a front-tracker-trigger-based method and an energy-detector-trigger-based method. The front-tracker-trigger approach uses primary particle information recorded upstream of the phantom to construct a standardised phase space file, which serves as input for Monte Carlo-based dose simulations. This method has been successfully implemented and validated in pCT scanners, demonstrating satisfactory agreement.

In parallel, we evaluate an energy-detector-trigger-based approach, which estimates imaging dose through an attenuation correction model based on the energy loss of ions traversing known materials and geometry. Drawing on our prior preliminary experience with this method, initial validation in pCT scanner confirms its consistency with experimental data.
Using these two tools, we plan to propose a unified framework to compare HeCT and pCT images under identical experimental conditions, including the same scanner geometry and phantom configurations. Leveraging the established relationship between imaging dose and image variance (2), our comparison aims to quantitatively evaluate the spatial resolution, imaging dose and relative stopping power (RSP) accuracy for both modalities, thereby characterising their respective performance. This work could establish a foundation for the systematic evaluation of HeCT and pCT scanners, supporting informed decisions on modality selection in clinical ion imaging applications.

*Speaker

Proton imaging using the IEM-PCT system

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Abstract

Proton computed tomography (pCT) offers a direct measurement of the proton relative stopping power (RSP), reducing range uncertainties that limit current proton therapy treatment planning based on X-ray CT (1, 2). To investigate this potential, we have designed and built a compact pCT system at IEM. The setup combines high-energy-resolution tracking detectors with a residual-energy detector, to determine the individual proton trajectories and their energy losses (3, 4).
Three experimental campaigns were carried out during 2021 and 2022 at the Cyclotron Centre Bronowice, in Krakow, Poland, using proton beams with energies ranging from 80 to 220 MeV, enabling the study of the system performance under different imaging conditions. Data were acquired for various sample configurations, providing the basis for the first tomographic reconstructions using this system.

In this contribution, we will present our preliminary results of the tomographic reconstructions using filtered back-projection (FBP) algorithm. In addition, the first reconstructions performed using the dedicated PCT reconstruction toolkit (5) will be shown. Ongoing work is directed toward further optimization of the reconstruction chain and quantitative evaluation of RSP determination.

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*Speaker

Results update of the INSIDE clinical trial for head-and-neck cancer: in-vivo treatment verification by means of in-beam PET

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Abstract

Background: In-vivo treatment verification devices are highly desired in particle therapy to fully exploit the potential of charged particle dose deposition. Integrating these systems into clinical workflows will enable patient-tailored optimisation by validating tumour dose coverage and healthy tissue sparing.
The INSIDE collaboration is conducting a trial at CNAO (ClinicalTrials.gov NCT03662373), monitoring head-and-neck and brain cancer patients with in-beam PET and a charged secondary particle tracker during proton and carbon ion treatments. This study focuses on the in-beam PET.

Materials and Methods: The trial began in 2019 with 20 patients to assess measurement reproducibility and sensitivity to morphological changes. In 2024, a second phase started with 20 additional patients to evaluate clinical applicability using updated treatment plans. The INSIDE system (fig. 1) includes an in-beam PET scanner and a secondary charged particle tracker (Dose Profiler). The PET consists of 20 modules with LFS crystals coupled to SiPM matrices and read out via TOFPET1-based electronics. In-beam PET reconstructs the β activity distribution generated during irradiation, related to particle range.

*Speaker

Results: In the first phase, system performance was optimised, achieving 4 mm sensitivity for proton treatments. Inter-fractional changes were detected in some patients using two image analysis techniques: the beam's-eye-view method and gamma index. Performance depends on treatment geometry and beam dose contribution. For carbon ions, results were less satisfactory, strategies to compensate for low statistics require validation on a larger cohort. Preliminary results from the second phase are more challenging to quantify. Modern plans use more fields with fewer particles, making image reconstruction more complex and noisier. Advanced techniques will be needed to integrate data from all fields.
Conclusions: Clinical in-vivo results from the second phase of the INSIDE trial will be presented, focusing on detecting inter-fractional morphological changes during proton and carbon ion treatments.

Single Plane Positioning Tracking Proton and Helium Pencil Beam Radiographs: Phantom Study

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Abstract

Purpose:
To evaluate the feasibility and performance of single-plane position tracking for proton and helium pencil beam radiography using a prototype of particle imaging system, with the goal of providing a cost-effective solution for proton radiography and enabling helium radiography in mixed carbon-helium beams.

Methods:

The study used the low-intensity extraction mode of the Heidelberg Ion Beam Therapy (HIT) synchrotron to generate proton and helium beams for imaging. A customized Proton-VDA scanner served as the particle detector. Various phantoms were employed, including 3D printed spatial resolution phantoms, motion phantoms to evaluate motion tracking, and

*Speaker

cylindrical PMMA phantoms with tissue equivalent inserts to evaluate water equivalent thickness (WET) accuracy. Anthropomorphic abdominal and lung phantoms were also used to simulate realistic clinical conditions. Imaging parameters such as spatial resolution, frame rate and WET accuracy were quantified.

Results:

Single-event radiography protocols were established. Spatial resolution reached 1 lp/mm for helium and 0.5 lp/mm for proton beams in single-plane configurations for the simple line phantoms. Motion phantom imaging was achieved at a frame rate of 2 fps over a field size of 10 cm $\times$ 10 cm. WET reconstruction accuracy was measured to be less than 2 mm for protons and 3 mm for helium ions over eight tissue-equivalent slices. Results from anthropomorphic phantoms demonstrated the potential of the method for application to complex geometries.

Conclusion:
This phantom study confirms the feasibility of single plane position tracking for proton and helium pencil beam radiographs. The system demonstrated acceptable spatial resolution and WET reconstruction accuracy. Future efforts will focus on improving image quality for complex geometries, reducing noise for helium imaging, and developing real-time radiographic reconstruction capabilities during beam pauses.

Non clinical research and mixed beam developments at CNAO

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Abstract

CNAO is one of the four centres in Europe, and six worldwide, offering treatment of tumours with both protons and carbon ions.
Since its start in September 2011 more than 5500 patients have been treated. Besides clinical activity, CNAO has also research as institutional purpose. In this framework a room dedicated to experimental activities is available also to external researchers to perform activities related to radiation biophysics, radiobiology, space research, SEE and SEU electronics tests, medical physics, range verification, detector development etc.

The CNAO synchrotron provides energies up to 400 MeV/u for carbon ions and up to 227 MeV for protons (Bragg peak depth of 27 and 32 cm in water respectively).

An additional ion source is under commissioning and additional ions will be made available in the next years. The beam distribution in the CNAO experimental room is based on the same active scanning system in use in the treatment rooms. According to the needs of the experiment to be performed the experimental beamline can be arranged in four different configurations depending on the space required downstream the target or the dimensions of the scanning field. Furthermore, access to a biological laboratory with all the necessary equipment can be provided.
One of the developments ongoing at CNAO is the study of the use of mixed beams for the verification of patient anatomy and position repeatability (range verification). Having a very

*Speaker

similar mass to charge ratio, carbon and helium ions can be accelerated at the same time in a synchrotron. For the same velocity, helium has a range three times larger than carbon and can be used for range verification during treatments. In May 2025 we had the chance to participate to the mixed beam experiments at GSI and to test our detector. Preliminary results of that campaign are reported.

PCT, an Insight Toolkit (ITK) module for proton computed tomography

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Abstract

PCT, an Insight Toolkit (ITK) module for proton computed tomography
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Since our seminal work on filtered backprojection (FBP) proton computed tomography (pCT) reconstruction using most likely paths (MLP) (1), we have shared our software implementation with several other groups who have successfully used it to reconstruct their own (simulated and real) list-mode pCT data. The software has been enriched with several developments over the years, e.g., different types of pCT imaging (energy-loss, attenuation, scattering and time-of-flight pCT) and several MLP alternatives. This code is publicly accessible since 2021 on GitHub (https://github.com/RTKConsortium/PCT). As the reconstruction toolkit (RTK, https://www.openrtk.org), the repository recently underwent a complete refactoring to become a remote module of the Insight toolkit (https://www.itk.org) and to remove all dependencies but NumPy, ITK and RTK. This process enabled the compilation of Python packages wrapping the C++ code which can be easily installed on all major operating systems. The Python packages provide command line tools for each step of pCT reconstruction, mainly conversion to water equivalent path lengths, pre-filtering of nuclear events, binning of projection images and FBP reconstruction. Continuous integration implemented with GitHub actions prevents any regression after the inclusion of new developments. The documentation uses Sphinx and is distributed by Read the Docs at https://proton-ct.readthedocs.io/. It provides basic examples to simulate data with GATE

*Speaker

v10 (https://github.com/OpenGATE/openGate) and pre-process the simulated root data using uproot. The software architecture and its main functionalities will be presented at the ion imaging workshop.

(1) Rit, S., Dedes, G., Freud, N., Sarrut, D. and Létang, J. (2013), 'Filtered backprojection proton CT reconstruction along most likely paths', Med Phys 40(3), 031103.

Development of a fast calorimeter for proton Computed Radiography

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Abstract

Purpose: This work is performed in the framework of the INFN pRad project. One of the main tasks of this project is to develop an apparatus able to record high quality proton radiographies in times of the order of 1 s and a dose levels of the order of 10 uGy. The main goal is to demonstrate the feasability of such a system for range verification and patient positioning in clinical hadron therapy.
Methods: The apparatus will be based on the INFN pCT system developed by the INFN Firenze group, composed of a silicon microstrip tracker followed by a segmented YAG:Ce scintillating crystals calorimeter. In order to achieve the required acquisition rate of the order of 1 MHz, a new calorimeter is being developed based on a plastic scintillator material, which has a light decay time constant much smaller than the YAG (few ns compared to 70 ns) and a faster read-out which makes uses of photomultiplying tubes (PMT) instead of Si photodiodes. In order to validate this setup, a first prototype composed of a 4x4 matrix of 30x30x400 cm3 scintillating bars has been assembled and characterized with proton beams up to 228 MeV in the experimental room of the 'Proton Therapy Center' of 'Azienda Provinciale per i Servizi Sanitari' – Trento, Italy. Moreover, in order to detect a possible influence of magnetic field variations on the PMT response, a set of measurements has also been taken in the treatment room using different magnets configurations.
Results: The results of the calibration curves obtained with the 4x4 prototype will be presented and discussed. The response of the scintillating bars coupled with PMTs show excellent results in terms of energy resolution (well below 1%) and negligible sensitivity to magnetic field variations.

*Speaker

Research Activities in Trento: from basic radiobiology to advanced treatment planning

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Abstract

The talk will provide an overview of the research activities in the fields of radiation biophysics and medical physics currently ongoing in Trento. This is based on the collaboration of three institutions, namely the INFN TIFPA, the University of Trento and the local healthcare provider (APSS). The presentation will start introducing the Trento Proton Beam Line, a research facility open to external users where it is possible to perform experimental activity with a clinical proton beam. Selected research topics will then be presented, in order to provide a snapshot of the present research program in Trento.

*Speaker

In vivo treatment verification in head and neck tumors using secondary fragments in 12C ion therapy

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Abstract

In Carbon Ion Radiotherapy treatments (CIRT) safety margins are adopted due to possible inter-fraction morphological variations to ensure a high tumor control probability (TCP) for a given patient anatomy, at the expense of possible over-dosage of healthy tissues. For such reasons, there is a clinical need for daily dose verification and daily optimized plans, relying on in-vivo treatment monitoring devices. The implementation of adaptive plans could help in minimizing the safety margins used in robust optimization, tailoring them to the anatomical variations of the patient. In this contribution we present the results obtained when monitoring CIRT patients at CNAO.
The Dose Profiler is a device designed to function as an online treatment verification system. It operates by reconstructing 3D emission maps of charged secondary particles. We developed a method to detect morphological variations by comparing reconstructed maps from different treatment fractions using a gamma test. This approach helps to identify subtle morphological changes that could significantly affect the absorbed dose distribution. The proposed method is under test at the CNAO by the INSIDE collaboration in the context of a clinical trial (ClinicalTrials.gov Identifier: NCT03662373).

The analysis of first 10 patients clearly indicates that an early detection of morphological changes occurring in the tissues crossed by the beam in its entrance path is possible using the secondary charged fragments detection as experimental observable. The sensitivity of the method will be re-assessed on additional ten patients with the help of a refined trial procedure (additional CT scan for benchmarking will be done)

*Speaker

The second part of the trial in which the last 10 patients will be monitored with the Dose Profiler has started in December 2024. The in-vivo performance of the technique analysing the last data-set will be presented and the results discussed in the context of CIRT treatment verification.

Plastic-scintillator based proton radiography relying on time of flight measurement: the tofprad project

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Abstract

Proton radiography is an imaging technique which relies on the measurement of the energy loss in an object. While x-rays imaging is sensitive on material attenuation coefficients, proton based imaging provides direct information on stopping power of crossed materials. This would significantly help in reducing range uncertainties in protontherapy due to Hounnsfield Units – stopping power conversion operated at planning stage. Moreover, a proton-radiography device integrated in the treatment room could be exploited to spot potential morphological variation between different treatment sessions, allowing to replan the treatment when needed. The TOFpRad project aims to assess the viability of a proton radiography system based on the TOF measurment of the trasmitted protons exploiting plastic scintillators read-out by Silicon Photomultipliers. Such technology would allow for developing low-cost systems, while ensuring an excellent time resolution as well as a larger rate capability with respect to inorganic scintillators typically used in the calorimetric approach. The Tofprad system will consist in two tracking units made of plastic scintillating fibers which will provide proton position at entrance end at exit of the target, while ToF system will be composed by two layers of plastic scintillators thought to operate with a distance of ˜ 2m. A test has been performed with a preliminar version of the detector at CNAO with 70-230 MeV protons in 2024, showing the capability of the system to detect an air gap of the order of a few millimetres located at different depths in a water equivalent phantom. Details about the TOFpRad project, the FLUKA Monte Carlo simulation studies and the results of the data taking will be presented.

*Speaker

New time-of-flight ion computed tomography system based on LGADs

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Abstract

Low Gain Avalanche Diodes (LGADs) are advanced silicon-based detectors capable of simultaneously measuring the interaction position and time of individual particles, achieving exceptional temporal (< 50ps) and spatial ($< 100\mu$m) resolution. With these unparalleled 4D-tracking capabilities, LGADs have become a key technology for tackling the challenges associated with high track densities in high-luminosity environments, not only in high-energy physics but also in medical physics applications.
In this contribution, we focus on the use of LGADs in ion computed tomography (iCT), an imaging technique that enables direct measurement of the relative stopping power (RSP) distribution within the patient. In conventional iCT setups, the RSP is typically derived by estimating the particle's path and corresponding energy loss using a combination of a tracking system and a separate residual energy or range detector. LGADs, however, offer the unique advantage of enabling both tracking and energy loss measurements with a single detector technology. The latter can be achieved through time-of-flight (TOF) measurements, either downstream of the patient (TOF-iCT) or across the patient using detectors placed before and after the target (Sandwich TOF-iCT).
To investigate the potential of LGADs for TOF-iCT, we developed a new TOF-iCT demonstrator system at GSI. The setup consists of 12 single-sided LGAD strip detectors, developed in collaboration with Fondazione Bruno Kessler, TU Wien, and the High Energy Physics Institute of Vienna. Using this system, we successfully performed water-equivalent thickness (WET) measurements on various CIRS tissue-equivalent slabs. In addition, we acquired helium radiographies of a plastic mouse phantom provided by TU Hamburg and of a sacrificed mouse at MedAustron.

The experimental results, along with an evaluation of the performance of the new TOF-iCT system, will be presented and discussed.

*Speaker