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## Design of a new prompt gamma detection system associated to proton pulsed beam

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in the framework of the MSCA-IF IV program and by the INFN in the framework of the program for young researcher grants. The main goal of PRAGUE was the design, simulation, realization, and characterization of a real-time depth-dose distribution detector system based on thin Silicon Carbide multilayers for conventional and flash proton beams in the energy range between 30 MeV to 150 MeV. The detector developed was designed to work at the regime of extremely high dose rate beams and it allows the retrieval of real-time depth dose distributions with a high spatial resolution thanks to the development and use of a 10  $\mu\text{m}$ , fully depleted 15x15 mm<sup>2</sup> square SiC detector. A detector prototype was already realized, simulated, and tested with 30 and 70MeV conventional proton beams. The obtained results indicate the SiC detector is a suitable detector for relative dosimetry with charged particles. It showed, in fact, a stable and reproducible response and extremely good behaviour in terms of linearity with respect to absorbed dose was found. The negligible dependence of its response against energy and dose-rate and the high radiation hardness, represent advantageous features with respect to other commercial solid-state detectors for ion beam dosimetry.

## **O 087 - Mitigation of range uncertainty for proton beam therapy using a millimeter-scale diode-based in vivo dosimeter**

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**Objective:** Proton beam range uncertainty, day-to-day anatomical variations, and target motion can potentially lead to both inaccurate targeting and increased toxicity via inadvertent dose to neighboring OARs. Key to mitigating these challenges is real-time knowledge of dose deposition within the tumor and OARs. Given both the highly non-linear dose deposition (LET) and mapping to biological effect of heavily-charged particles, real-time measurements of single-particle LET are needed.

**Methods:** Here, we present a novel 0.96x0.94x0.3 mm<sup>3</sup> single-particle sensitive, diode-based in vivo dosimeter silicon chip, capable of direct implantation within tumors and near OARs. 4,096 nearly minimum size (1  $\mu\text{m}^2$ ) diodes, signal amplifiers, and memories are all integrated into a silicon chip. The sensor directly measures protons incident on the sensor, providing relative measurements of particle LET and count with single-particle sensitivity in real-time. Only minimal electrical power ( $\sim 0.5 \mu\text{W}$ ) and digital communication are needed to operate the sensor, suitable for future wireless implementation. Dose data streamed from sensors can be used to adjust the beam settings (i.e. proton energy), enabling real-time quality assurance for accurate tumor and OAR dose deposition.

**Results and Conclusion:** The sensor is successfully verified under a clinical 67.5 MeV proton beam in a water tank setup, and the measurement data is compared with Monte-Carlo simulation (TOPAS). The proposed novel system is the first proof of principle that can be utilized to deliver real-time, spatially localized tumor and OAR dose data, to ultimately improve the treatment outcomes by addressing dose and range uncertainties in proton EBRT.

## **O 088 - Design of a new prompt gamma detection system associated to proton pulsed beam**

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The on-line monitoring of the ion path in the patient in hadrontherapy represents a challenge whose resolution will make it possible to reduce the margins around the Clinical Target Volume (CTV) and the number of irradiation fields required. This monitoring can be performed by means of the detection of secondary particles such as the prompt gamma rays (PG) generated during nuclear reactions undergone by a fraction of the incident ions [Krimmer NIM 2018: <https://doi.org/10.1016/j.nima.2017.07.063>]. The objective of this work is to study and compare two detection systems and determine their operating

regimes at low and high pulse beam intensities of the synchro-cyclotron S2C2 developed by IBA. These detection systems consist of scintillator detectors located around the patient and they have their own acquisition modalities. The new detection system envisaged to accommodate the highest beam intensities during processing is based on the measurement of the photon energy deposited during a processing spot of a few microseconds (Prompt Gamma Energy Integral). The comparison is made with an event-by-event acquisition system using the Prompt Gamma Peak Integral technique [Krimmer APL 2017: <https://doi.org/10.1063/1.4980103>] which is based on photon-by-photon detection on each of the detection channels. The feasibility study of these PGEI and PGPI techniques performed with Monte Carlo simulations (Gate version 9) will be discussed and compared to experimental results obtained with various types of gamma detectors.

## O 089 - Stopping-Power-Ratio (SPR) acquisition using counting CT information for charge particle therapies

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**Purpose:** Most of current treatment planning systems use single-energy CT (SECT) Hounsfield Units (HU) to estimate charge particle SPRs for dose computation. Several recent studies suggested that Dual Energy CT (DECT) can be employed to improve the accuracy of SPRs by extracting both electron density and effective Z number from scans. With Counting-CT (CCT) technology emerging, an opportunity to further improving the accuracy of SPR calculation was presented. In this work, we explore an approach of using CCT scan information to acquire SPR values.

**Methods and Materials:** Both CCT and DECT scans were acquired on a CIRS electron Density phantom using SOMATOM and NAEOTOM CT scanners (Siemens Healthineer Co.), respectively. Electron density and effective Z number were extracted from DECT whereas decomposed material component was extracted from CCT scan using Siemens image processing software. Effective Z number was subsequently calculated using material component data extracted from CCT data. The average SPR values of each material for both proton and carbon ions were then calculated using Hunemohr's method for both scans. Both CCT results and DECT results were compared to the gold standard calculated using CIRS provided data.

**Results and Conclusions:** The comparison results suggested that SPR values calculated using CCT scan are closely in align with gold standards. The root mean square errors of SPRs from CCT scan are even smaller than its counterpart from DECT scan. We therefore conclude CCT scan can potentially be utilized to enhance the accuracy of SPR value even further compared to DECT scans.

## O 090 - Ex-vivo proton range uncertainty verification of dose calculation on CT and CBCT-based virtual CT

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**Objective:** To estimate calculated range uncertainty in CT images and synthetic CT from CBCT of an in-house phantom.

**Method:** A single-beam PBS plan has been optimized in Raystation 11B with the aim to achieve a uniform dose distribution with constant range in water behind an in-house ex-vivo phantom. The resulting PBS plan was recalculated on two synthetic CTs (sCT) based on a CBCT acquired in a Proteus One. The sCTs were generated using the "Virtual CT" (VCT) and "Corrected CBCT" (CorrCBCT) algorithms of RayStation 12B. Using a 2D array of parallel plane ion chambers (MatriXX One, IBA Dosimetry) in a DigiPhant PT water phantom a series of planes at different depths were measured and 3D dose distribution were reconstructed by stacking planes. Depth dose profiles were extracted from TPS calculation and measurement matching coordinates of every MatriXX detector.