Contribution ID: **162** Type: **Oral**

Readout development of a LGAD-based Hybrid Detector for Microdosimetry (HDM)

Thursday, 3 March 2022 11:30 (20 minutes)

Clinical outcomes collected over the past three decades have suggested that ion therapy has the potential to be a treatment modality superior to conventional radiation for several types of cancer, including recurrences, as well as for other diseases. Although the results have been encouraging, numerous treatment uncertainties remain a major obstacle to the full exploitation of particle radiotherapy.

To overcome therapy uncertainties optimizing treatment outcome, the best possible radiation quality description is of paramount importance linking radiation physical dose to biological effects.

Microdosimetry was developed as a tool to improve the description of radiation quality. By recording the energy deposition at the micrometric scale (the typical size of a cell nucleus), this approach takes into account the non-deterministic nature of atomic and nuclear processes, and creates a direct link between the dose deposited by radiation and the biological effect induced. Microdosimeters measure the spectrum of lineal energy y, defined as the energy deposition in the detector divided by most probable track length travelled by radiation. The latter is provided by the so-called "Mean Chord Length"(MCL) approximation, and it is related to the detector geometry.

To improve the characterization of the radiation field quality, we define a new quantity replacing the MCL with the actual particle track length inside the microdosimeter. In order to measure this new quantity, we propose a two-stage detector consisting of a commercial Tissue Equivalent Proportional Counter (TEPC) and 4 layers of Low Gain Avalanche Detectors (LGADs) strips. The TEPC detector records the energy deposition in a region equivalent to 2 um of tissue, while the LGADs are very suitable for particle tracking, because of the thickness thinnable down to tens of micrometers and fast response to ionizing radiation.

The concept of HDM has been investigated and validated with Monte Carlo simulations. Currently, a dedicated readout is under development. This two stages detector will require two different systems to join complementary information for each event: energy deposition in the TEPC and respective track length recorded by LGADs tracker. This challenge is being addressed by implementing SoC (System on Chip) technology, relying on Field Programmable Gated Arrays (FPGAs) based on the Zynq architecture. TEPC readout consists of three different signal amplification legs and is carried out thanks to 3 ADCs mounted on a FPGA board. LGADs activated strip signal is processed thanks to dedicated chips, and finally, the activated strip is stored relying again on FPGA-based solutions.

In this work, we will provide a detailed description of HDM geometry and the SoC solutions that we are implementing for the readout.

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Session Classification: LGAD

Track Classification: LGAD