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Design and implementation of the Hybrid Detector for Microdosimetry (HDM): Challenges in readout architecture and experimental results

Thursday 5 October 2023 09:00 (20 minutes)

This talk presents the Hybrid Detector for Microdosimetry (HDM), capable of providing a superior characterization of the radiation fiend. This is of critical importance in radiation therapy, where a better description of the radiation field can lead to a better treatment plan and, therefore, a better treatment outcome.
HDM is composed of a commercial gas microdosimeter, TEPC, and a tracker made of 4 silicon LGADs layers. This presentation will cover the challenges in implementing the HDM readout architecture, including synchronization and triggering, and will show first measurements obtained with clinical protons.

Summary (500 words)

Over the past 30 years, clinical results have shown that ion therapy may be a superior treatment option for several types of cancer, including recurrent cancers, compared to conventional radiation. Despite these promising results, there are still several treatment uncertainties related to biological and physical processes that prevent the full exploitation of particle therapy.
Among the physical characterizations, it is paramount to measure the quality of the irradiating field in order to link the biological effect to its physical description. In this way, uncertainties in treatment can be reduced and outcomes optimized. One tool for studying the radiation field that has become increasingly important in the last decade is microdosimetry. The latter provides a description of radiation at the micrometer level typical of cell dimensions, where energy deposition exhibits stochastic behavior.
In microdosimetry, the fundamental quantity is the lineal energy y, defined as the energy deposition in the detector divided by the Mean Chord Length (MCL): an approximation used to estimate the track length traveled by radiation in the detector, valid in an isotropic, uniform radiation field. A more accurate description of the radiation field can be obtained by replacing the mean chord with the actual track traveled by radiation in the detector.
Following this rational, we designed the Hybrid Detector for Microdosimetry (HDM), composed of a commercial gas microdosimeter Tissue Equivalent Proportional Counter (TEPC) followed by 4 silicon detector layers of Low Gain Avalanche Detectors (LGADs) strips, capable of measuring the actual track length.
Although HDM has been validated and optimized with Monte Carlo simulations, the readout implementation of this detector is still a technological challenge.
As a two-stage detector, the information obtained is interdependent. The energy deposited in the TEPC is correlated with the corresponding particle track observed by LGADs.
Specifically, the signal generated by the TEPC, after being amplified by three different amplification lines, is digitized by three FPGA-controlled ADCs. Since the FPGAs are based on the Zynq architecture, the approximately 100 Mbps data stream is sent to the processor via Direct Memory Access (DMA) and then to a PC via TPC-IP protocol, where it is stored. The signal from the LGADs is managed by dedicated ASICs capable of setting the thresholds and producing a digital signal when the strips are activated. Four layers are required to spatially identify two points along the particle track, for a total of 284 channels. Again, FPGAs are used to manage the readout, one for each layer.
In this talk, I will give a detailed description of the HDM readout architecture and discuss the main challenges,

namely synchronization and triggering, and how we are addressing them. In addition, I will show the first experimental data obtained with clinical protons at the Trento Proton Therapy Facility, where layers of HDM were characterized over different experimental conditions.

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