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Ultra-fast timing with diamond detectors for online ion range verification in hadrontherapy

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Hadrontherapy can be defined as radiotherapy by means of proton or light ion beams. This alternative technique enables a highly localized dose deposition and better organ-at-risk protection, compared to conventional photon radiotherapy. Therefore, the treatment quality strongly relies on the control of the effective ion range in the patient body. In this context, the French CLaRyS collaboration (Contrôle en Ligne de l'hAdronthérapie par Rayonnements Secondaires) aims to develop various online ion range verification techniques by detecting secondary particles emitted by the patient following nuclear interactions along the ion path. Prompt-Gamma Imaging (PGI) is one of these techniques. It consists in the detection of prompt-gamma photons by either a collimated- or a Compton-camera [1]. It has been shown that their emission profile is spatially correlated to the ion range. The performances of such detection systems can be improved by Time-of-Flight discrimination. A high-count-rate beam hodoscope may be necessary to measure the arrival time of ions on the patient. The MoniDiam project at LPSC is developing an ultra-fast beam tagging hodoscope, based on CVD (Chemical Vapor Deposition) diamond sensors [2]. CVD diamonds exhibit a fast time response, high resistivity and radiation hardness that make them good candidates for such a detector concept. We have characterized polycristalline (pc), single crystal (sc) and heteroepitaxially grown on Iridium (DoI) diamond samples with full planar metallization, under different irradiation conditions (α and β radioactive sources, 95 MeV/u 12C ions at GANIL, 8.5 keV photons pulsed micro beam at ESRF and 68 MeV protons at ARRONAX). During all these tests, we performed data acquisition using a 8-channel WaveCatcher digitizer, reaching a sampling speed of 3.2 GS/s. We investigated the charge collection properties of these diamond sensors and their time-, spatial- and energy-resolutions. We will present characterization results demonstrating time resolution below 100 ps, energy resolution between 7% and 10% and a good charge collection efficiency. In order to build a 2D position tagging hodoscope, we are also developing double-side stripped diamond sensors. Our first samples' performances were tested at the micro-diffraction end station (in air) of the ID21 beamline at ESRF. We will present the current mapping and time resolution we measured for these detectors.

References

[1] J Krimmer et al., Nucl. Instr. Meth. A 787, 98-101(2015) doi:10.1016/j.nima.2014.11.042

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