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Measuring spill microstructure of medical synchrotron on primary and secondary ion radiation fields using Timepix3 detectors

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Radiation therapy with ions has been used for cancer treatments showing high dose conformity while sparing surrounding organs at risk and healthy tissue. For such treatments, synchrotrons are used to produce pencil-like ion beams, which are magnetically deflected laterally and modulated in range to cover the entire cancer volume [1]. As the beam extraction is in terms of spills at a fixed beam energy, spill quality is of high importance [2]. Moreover, this is also highly important in the field of ultrahigh dose-rate radiotherapy well-known as FLASH. However, there is a lack of detectors giving information about the spill structure either for radiobiology studies with ions or treatment radiation fields [3]. This contribution aims at the measurement of the spill microstructure of a medical synchrotron in ion radiation fields.

In this contribution, Timepix3 detectors with a silicon sensitive area of 2 cm2 and 300 μm thickness were used, exploiting their nanosecond time resolution. Irradiations were carried out at the Heidelberg Ion Beam Therapy Center in Germany. Three ion types (protons, helium and carbon ions) were used as primary ion radiation field (see fig. 1a). Measurements of the spill microstructure were also performed behind a patient-like head model in order to not interfere the primary radiation field. To generate a secondary ion radiation field, a carbon-ion treatment field was designed to irradiate the head model, producing secondary charged fragments which were detected by the Timepix3 detectors (see fig. 1b).

For the primary radiation field, individual spills of each ion type and energy were analyzed by applying the fast Fourier transformation to calculate the acceleration frequency (see fig. 2a). From it, the periods of the spill microstructure were obtained (see fig. 2b). These results are in agreement to those obtained by Magalhaes Martins et al, [4]. For the secondary radiation field, each spill of the treatment plan was analyzed (see fig. 2c). The corresponding frequency and period of each spill were then obtained. From the obtained periods, beam energies were measured and compared to the nominal ones (see fig. 2d).

We have shown the capabilities of Timepix3 detectors for measuring the spill microstructure and also the primary beam energy even in clinic-like treatment situations. This procedure is of great interest to be used in radiobiology research and as complementary spill quality assurance during cancer treatment irradiations.

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