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Quantitative proton radiography for a small-animal irradiation platform based on a miniaturized Timepix detector

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Precision of pre-clinical proton irradiation can be enhanced using proton radiographic and tomographic imaging prior to treatment. We present a novel setup and experimental results for small-animal proton radiography based on a single miniaturized Timepix detector.

Experiments were performed at the experimental beamline of a clinical proton therapy facility with 75MeV protons. The 2cm2 large silicon hybrid pixel detector (55µm pixel pitch) was placed 1cm behind a commercial small calibration phantom with 10 tissue-equivalent inserts. Since phantom dimensions exceeded the sensor area, the phantom was laterally moved by motorized translation stages for imaging the entire object. Due to the frame-based read-out of the detector, beam intensity was reduced to a few 1000 protons per second, assuring detection of individual hits. Energy deposition in the 300µm thin sensor chip was recorded and events were spatially binned (100µm width) and filtered to eliminate bad events. The mean deposited energy per bin was converted to water-equivalent thickness (WET) of the traversed material using FLUKA Monte-Carlo simulations along with an experimentally validated conversion curve.

Comparing the retrieved WET with ground truth values based on dual-energy CT measurements of larger tissue-equivalent samples showed an agreement better than 3% for all insert materials. Increasing the distance from 1 to 5cm resulted in more blurring and subsequently larger deviations due to multiple Coulomb scattering. Yet, results were still satisfying at 3cm distance. The acquisition time per radiography was 15-20 minutes. According to subsidiary Monte-Carlo simulations, the imaging dose was below 5mGy.

We tested a setup for quantitative proton imaging in a pre-clinical scenario based on a miniaturized Timepix detector. The relatively long acquisition time can and will be reduced with the latest detector model allowing event-based read-out and therefore much higher particle rates.

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