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DEVELOPMENT OF INTEGRATION MODE PROTON IMAGING WITH A SINGLE CMOS DETECTOR FOR A SMALL ANIMAL IRRADIATION PLATFORM

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A novel irradiation platform for pre-clinical proton therapy studies foresees proton imaging for accurate set-up and treatment planning. In integration mode, imaging at modern synchrocyclotron-based proton therapy centres with high instantaneous particle flux is possible. Commercially available detectors, such as large-area CMOS sensors, allow the determination of the object's water-equivalent thickness (WET). We present experimental results from two proton therapy facilities, supported by extensive Monte Carlo (MC) simulations, demonstrating the feasibility of this imaging modality for pre-clinical studies.
Image contrast is achieved by recording the proton energy deposition in the detector pixels for several incoming beam energies and applying a signal decomposition method that retrieves the WET. A single planar 114x65mm^2 CMOS sensor (49.5µm pixel pitch) behind the imaged object was used. In experimental campaigns at two isochronous cyclotron-based facilities, probing energies suitable for small-animal sized objects were produced once with the built-in energy layer switching ability and the other time using a custom degrader wheel.
To assess WET accuracy, a micro-CT calibration phantom with 10 inserts of tissue-mimicking materials was imaged. The phantom-to-detector distance was 0.3, 1.3 and 3.3cm.
The average relative WET error compared to the ground truth was <1% for 0.3cm spacing and the spatial resolution was 0.2mm. For 1.3cm spacing the results were <2% relative WET error and 0.4mm spatial resolution. For 3.3 cm proton scattering had considerable impact and WET relative error increased to 30%. Imaging time with the built-in energy switching was 95s, of which 82s are attributed to the limitations of the too slow (~4s) energy switching time (considerably reduced in new versions).
A pixelated CMOS detector and post-processing methods can enable fast proton radiographic imaging for small-animal-sized objects with high WET accuracy and spatial resolution.

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(2) Meyer et al: PMB62(2017), 1096-1112