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CMOS Integration Mode Proton Imaging for a Small Animal Irradiator

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Introduction

A novel irradiation platform for pre-clinical proton therapy studies foresees proton imaging for set-up and accurate treatment planning. In integration mode, imaging at modern synchrocyclotron-based proton therapy centers with high instantaneous particle flux is possible. Commercially available detectors, such as large-area CMOS sensors allow the determination of a small-animal sized object's water-equivalent thickness (WET) by variation of the incoming proton beam energy (here called probing energy). Previous work has shown the feasibility of this imaging modality for preclinical studies. We present results from experimental campaigns at two proton therapy centers with a new detector, providing stable data acquisition at up to 25 frames per second, including proton radiography at a clinical synchrocyclotron.

Materials&Methods

Image contrast is achieved by recording the proton energy deposition in the detector pixels for several probing energies and applying a signal decomposition method to retrieve the WET. The 12×14 cm^2 CMOS sensor Lassena (Nordson, Ohio, USA) with 50µm pixel pitch was placed behind the imaged object to acquire up to 2000 frames with 60ms integration time in each frame. Experiments were conducted at the isochronous cyclotron at the Danish Centre for Particle Therapy (DCPT, Aarhus, Denmark) and the synchrocyclotron of the Centre Antroine-Lacassagne (CAL, Nice, France) with automated energy switching to generate the probing energies suitable for small-animal sized objects. Additionally, experiments were performed at the ocular treatment site of the CAL, where the 65MeV beam was passively degraded to the probing energies. Imaging time for one radiography ranged between 45s (DCPT) and 15 minutes in the manual beam-on/beam-off mode used at CAL.
To assess WET accuracy, a micro-CT calibration phantom (SmART scientific solutions, Maastricht, The Netherlands) with 10 inserts of tissue-mimicking materials was imaged. To evaluate spatial resolution, a PMMA step phantom with 1mm step size, and a phantom with holes (diameter from 0.2mm to 0.9mm) were imaged. The phantom-to-detector distance was varied from 0 to 3 cm for the micro-CT phantom and 0 to 1cm for the spatial resolution phantoms to evaluate the influence of proton scattering on the image quality.

Results

Preliminary evaluation indicates an average relative WET error of 1% for 0cm and 1cm air gap, and a spatial resolution of 0.3mm and 0.5mm, respectively. For larger air gaps, proton scattering considerably impacts WET determination and spatial resolution, leading to 15% and 25% relative WET error and 0.9mm and 1.1mm spatial resolution for 2cm and 3cm air gap, respectively. Final results in terms of WET accuracy and spatial resolution will be presented.

Conclusion

Proton radiographies of several phantoms were recorded with promising WET accuracy and spatial resolution using a compact setup including the new Lassena detector

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