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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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Purpose: Proton imaging allows direct assessment of the relative (to water) stopping power (RSP) of protons in tissue, needed for accurate treatment planning in proton therapy. At modern synchrocyclotron-based proton therapy centers, the instantaneous particle flux exceeds the rate capabilities of state-of-the-art single particle tracking detection systems. An alternative for such facilities is integration mode imaging using a single planar CMOS sensor behind the object of interest. By varying the proton beam energy and recording the accumulated energy deposition in the pixels for each energy step individually, the water-equivalent thickness (WET) of the object can be determined. We present experimental results, supported by extensive Monte Carlo (MC) simulation studies, demonstrating the feasibility of this imaging modality for preclinical studies.

Materials and Methods: The experiment was performed at the 65 MeV Medicyc beamline of Centre Antoine-Lacassagne, used to treat ocular cancers. A commercially available 114 x 65 mm^2 CMOS sensor with 49.5 µm pixel size was used to image a micro-CT calibration phantom composed of a solid water base (10 mm thickness, 30 mm diameter) with 10 inserts (16 mm length, 3.5 mm diameter) of tissue-mimicking materials. With a custom degrader, the different, small animal compatible probing energies were provided. Measurements were taken for phantom-detector distances of 0.3, 1.3 and 3.3 cm. FLUKA MC simulations, including models of the calibration phantom and the CMOS sensor, supported the development of the algorithm for retrieval of the WET of the traversed material. The obtained WET was compared to the RSP multiplied by the geometrical insert length (l_{Ins}) deduced from water column measurements [1] deemed as ground truth.

Results: The difference between WET retrieved from the proton radiographies and ground truth is on average lower than 1% for the lowest distance and lower than 2% for the 1.3 cm distance. For 3.3 cm proton scattering had considerable impact and WET relative error increased to 30%. Optimization to overcome this issue is ongoing and the achievable accuracy will be presented. Spatial resolution varies from 0.2 mm to 0.9 mm depending on the phantom-detector distance.

Conclusions: A planar pixelated CMOS detector allows proton radiographic imaging for small animals with reasonable WET accuracy and spatial resolution. The compact set-up consisting only of a single integration-mode detector behind the object is of special interest for synchrocyclotron proton beam facilities.

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[1] Hudobivni et al, Medical Physics, doi:10.1118/1.4939106

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