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Development of scatter correction for integration mode proton imaging for a small animal irradiation platform

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Introduction

A novel system 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 the object's water-equivalent thickness (WET). However, image quality is strongly affected by multiple Coulomb scattering. We present experimental results and methods for proton scatter correction.

Materials & Methods

Image contrast is achieved by recording the proton energy deposition in the detector pixels for several incoming beam energies and a signal decomposition method that retrieves the WET. A single planar 114x65mm2 CMOS sensor (49.5µm pixel pitch) behind the imaged object was used. The 65MeV beam at Centre Antoine-Lacassagne (Nice, France) was passively degraded to produce probing energies suitable for small-animal sized objects.

To assess WET accuracy, a micro-CT calibration phantom with 10 inserts of tissue-mimicking materials was imaged (see Figure 1). The phantom-to-detector distance was 0.3, 1.3 and 3.3cm. Several methods (Monte Carlo-based and analytical) for proton scatter correction were investigated, some using a CBCT image of the phantom as prior knowledge.

Results

The average relative WET error compared to ground truth was <1% for 0.3cm spacing and <2% for 1.3cm. For the worst case of 3.3cm distance, preliminary results showed that WET relative error was improved from 30% to only 3% using scatter correction. Spatial resolution was better than 0.2mm, when scatter correction is applied.

Summary

A pixelated CMOS detector and post-processing methods enable proton radiographic imaging for small-animal-sized objects with reasonable WET accuracy and excellent spatial resolution by exploiting prior knowledge.

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