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Feasibility study for small-animal proton radiography using passive energy variation and a single planar detector

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Introduction

Image-guidance is of great importance to improve the precision of small-animal proton irradiation experiments. We present a method for position verification and direct measurement of the two-dimensional water-equivalent thickness (WET) distribution of small-animal sized objects, based on passive energy variation and a single planar pixel detector (similar to [1]).

Materials & Methods

An extensive simulation study to examine the feasibility and to explore different beam characteristics and setup geometries was performed using the FLUKA Monte-Carlo (MC) code. Fan-beams and mini-beams at 51 proton energies ranging from 45 to 70MeV were scanned over a 20x20x20mm³ water phantom with four different material inserts (3x3x20mm³ each). Energy deposition was scored in a model of a commercially available, pixelated CMOS detector (1024x512 pixels, 48µm pixel pitch, 2µm sensitive thickness), which was placed at varying distances downstream of the phantom. For each detector pixel, signal versus proton energy was recorded and converted to WET by a linear signal decomposition [2] using a MC-based lookup-table matrix.

Results

Due to multiple Coulomb scattering in the phantom and surrounding air, the image quality decreases with increasing phantom-detector-distance. A compromise between acceptable spatial resolution (<0.5mm) and practicability (geometrical constraints, acquisition time) in a future experimental setup was found using fan-beams and a phantom-detector-distance of 1.5cm. With these settings, differences between reconstructed and true WET were below 2% for the entire phantom, aside from pixels close to material interfaces (fig.1).

Summary

According to MC simulation results, our proposed method for small-animal proton radiography is suitable for fairly accurate WET-determination at a good spatial resolution. Based on these promising results, we are aiming to further improve radiographic performance and then extent this method towards tomographic imaging.

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Appendix

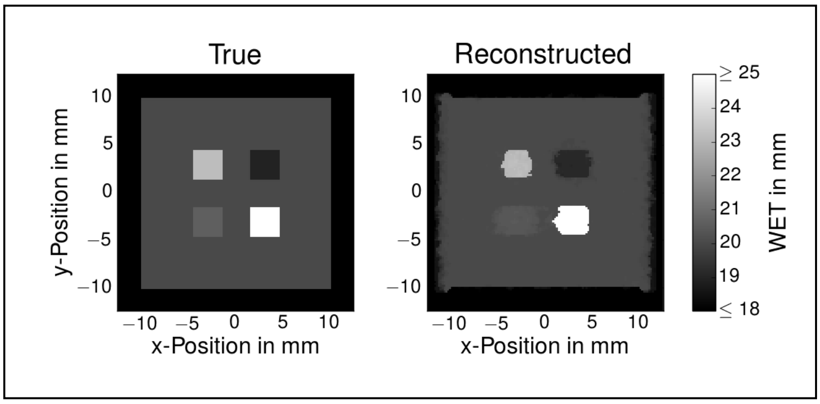

Fig.1: True/Reconstructed WET-distribution.

Literature

[1] Telsemeyer et al: PMB57(2012), 7957-7971
[2] Meyer et al: PMB62(2017), 1096-1112