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Innovative Positron Emission Tomography for a Beam Range Monitoring in Proton Radiotherapy

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Improving the precision and conformity of proton treatment delivery by application of proton beam range monitoring remains to be one of the greatest challenges of the proton radiation therapy[1]. One of the most commonly investigated approaches is to measure proton beam range by means of detection of annihilation gammas produced in patient during irradiation. A new, modular, easy-configurable plastic scintillator based J-PET technology[2,3] is being developed at the Jagiellonian University, Poland offering the possibility to address the proton beam range monitoring by means of positon emission tomography (PET) imaging[4].

We developed a workflow to perform Monte Carlo simulations (GATE)[5] of proton therapy treatment of patients including β+ activity production, coincidence events detection and PET image reconstruction (CASToR)[6] just after the irradiation. Six different J-PET based scanner setup configurations (single-layer, multi-layer, cylindrical, dual-head) were designed and investigated. We compared efficiency, number of registered coincidences (true and scattered) and reconstructed activity images distribution for different geometrical setup configurations. The expected activity reconstructed using J-PET scanner was compared to the actual β+ activity distribution produced in the patient.

Our results show that all investigated J-PET setup configurations are feasible to acquire and reconstruct the β+ activity produced during patient irradiation with a proton beam. The efficiency of the configurations ranges from 0.06% (single layer dual-head) to 0.52% (triple layer barrel). The reconstructed PET images were compared to ground truth production activity distribution revealing good agreement, which will be further improved by optimization of the reconstruction and image post-processing protocols. Experimental validation of the simulations will be performed on phantoms and in the clinical-like conditions in order to fully evaluate the J-PET detector capabilities.

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[5] Grevillot, L., et al. "GATE-RTion: a GATE/Geant4 release for clinical applications in scanned ion beam therapy." Medical Physics 47.8 (2020): 3675-3681.
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