Implementation of a High-Resolution PET Scanner for 3D Proton Beam Quality Assessment

This work presents the development and application of an innovative, compact, and high-resolution PET system—HadronPET, based on easyPET technology—for assessing proton beam quality in proton therapy facilities. The HadronPET has two opposite detector modules that rotate intelligently through a motor system with two degrees of freedom (fan and axial motor rotation). His design minimizes the number of components, enhancing the system's portability, a key advantage for integration into various settings, such as proton therapy centers. Additionally, the system achieves a spatial resolution of less than 1 mm, thanks to its precise scanning movements, high density of scanned lines of response, and the integration of a dedicated image reconstruction algorithm.

This work uses both Monte Carlo simulations and experimental data to evaluate the 3D distribution of β+ emitters produced by the HadronPET system during proton beam irradiation. The simulations modeled the irradiation of homogeneous and heterogeneous phantoms with a monoenergetic proton beam (ranging from 80 to 160 MeV) and generated the corresponding HadronPET images. The distribution maps of β+ emitters produced during irradiation were compared with the corresponding reconstructed PET images, showing a high degree of similarity. Based on these promising results, in situ testing of the HadronPET system was initiated. The first experimental tests were conducted at Gantry 1 of the Paul Scherrer Institute (PSI), where PET images of irradiated PMMA phantoms were acquired. The tested beam energies ranged from 138 to 195 MeV, with the cyclotron current set to the clinical level of 140 nA.

This work aimed to conduct an initial evaluation of the HadronPET system's capability to assess proton beam quality. Despite some necessary improvements, this study successfully generated PET images of the beam that align with the simulated patterns, demonstrating the potential of the HadronPET system.

Keywords: Positron Emission Tomography, easyPET, Proton Therapy, proton beam quality control.

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