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In-vivo Range Measurement of Therapeutic Protons from Prompt Gamma Emission

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Proton beam therapy is emerging as a major radiation therapy modality for cancer patients due to the improved dose distribution of protons, which allows for increased dose to the tumor while sparing surrounding healthy tissues. This work addresses the problem of range uncertainty through the development of a detector, which will measure proton range in each patient during beam delivery with millimeter accuracy, effectively eliminating proton range uncertainty. During proton interactions with atoms in tissues, gamma rays, including prompt photons from nuclear reactions and delayed photons from the decay of unstable products, are emitted. The rate of secondary radiation used in the measurement is low, making accurate measurement challenging. We have used the MCNPX simulation package to model a detector consisting of 35 Cesium Iodide crystals with dimensions of 9x9.9x0.4 cm and a lead based collimator grid with 0.4cm thick plates. A Gaussian proton pencil beam impinged on a cylindrical water phantom with a diameter of 10 cm. The distance between the cylinder axis and the collimator surface was approximately 20 cm. We simulated the response of the detector to several mono-energetic pencil beams delivering protons in the energy range 80MeV - 160MeV. A sigmoid curve fit to the spatial distribution of the simulated gamma emission data was used in order to locate an edge in gamma emission pattern that is correlated with the position of the Bragg peak. These simulations of a prompt gamma detector for in-vivo range measurement for therapeutic proton beam scanning suggest that range measurement for individual pencil beams (spots) may be feasible. Further work will address the optimization of the detector geometry and placement, as well as advanced detector design.

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