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Particle Neutron Gamma-X Detection (PNGXD) based localization for ion beam radiotherapy

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Abstract

Particle neutron gamma-x detection (PNGXD) is a novel imaging concept proposed for tumor localization during proton therapy. The premise is to use secondary neutron interactions with a gadolinium contrast agent (GDCA) to produce photons within the 40–200 keV energy region that can be used for spectroscopic detection [1]. Previous work has investigated the experimental measurement of photons resulting from gadolinium neutron capture (GdNC) using a passive double scattering proton therapy treatment unit [2]. This research expands on these results by investigating the application of PNGXD for other ions (protons, helium ions and carbon ions). To investigate these additional ions, Monte Carlo (MC) simulations were performed using a 15-25 cm spread out-Bragg peak (SOBP) centered on a 2 cm3, 3 mg/g Gd infused tumor. It was determined that 3.9×1011, 7.4×1011 and 3.0×1011 neutron captures per Gy of dose (captures/Gy) occur for protons, helium ions, and carbon ions, respectively. As a result of this study, helium ions would produce nearly two times more GdNC than protons for the same administered dose. When normalizing to an estimate of RBE weighted dose (Gray Equivalent: GyE) this ratio reduces to 1.4. A total of 3.9×106 Gd photons of energies 43, 79.5 and 181.9 keV would be produced per GyE of administered dose from helium particles. This research indicates that the secondary neutron production from helium ions would be more beneficial than protons for the application of PNGXD or gadolinium dose enhancement from neutron capture.

[1] Gräfe JL. Proton Neutron Gamma-X Detection (PNGXD): An introduction to contrast agent detection during proton therapy via prompt gamma neutron activation. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms. 2017; 407:20-4.

[2] Van Delinder KW, Crawford D, Zhang T, Khan R, Gräfe JL. Investigating neutron activated contrast agent imaging for tumor localization in proton therapy: a feasibility study for proton neutron gamma-x detection (PNGXD). Physics in Medicine & Biology. 2020 Jan 24;65(3): 035005.

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