FLORIDA ATLANTIC UNIVERSITY
CHARLES E. SCHMIDT COLLEGE OF SCIENCE

Department of Physics

Professional Science Master in Medical Physics

Thesis Defense

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A Monte Carlo study of the neutron ambient dose equivalent from a proton pencil beam medical therapy unit

ABSTRACT

Proton therapy, an effective cancer treatment, has unintended consequences for personnel due to secondary neutron production. This study aims to investigate neutron attenuation in shielding materials like concrete, using Monte Carlo (MC) simulations to optimize shielding requirements. MC simulations address experimental limitations such as detector sensitivity, energy range response, and spatial resolution by modeling radiation transport and neutron interactions with shielding materials. The TOPAS-MC code was implemented to simulate secondary neutrons generated by a 226.5 MeV proton beam on a tissue-equivalent target enclosed in a spherical concrete shell. Energy deposition and particle fluence were scored at various points, and total dose equivalent values were calculated using conversion coefficients from the ICRU Report No. 95.

Two methods, classical single-exponential and double exponential formulas, were compared for estimating neutron dose equivalent outside the shield and accounting for non-equilibrium neutron spectra in concrete. The results revealed non-equilibrium neutron spectra for lower shielding thicknesses, with energy spectrum varying with depth and attenuation behavior deviating from mono-exponential behavior due to proton energy and shielding material composition. The double exponential formula better captures non-equilibrium neutron spectra, resulting in a more accurate estimation of neutron dose equivalent and reducing statistical uncertainty from 13% to 8%. It also more accurately describes complex neutron attenuation behavior in concrete, as demonstrated by a reduced standard deviation compared to the single-parameter formula (8.7% vs. 14.4%).

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All Are Cordially Invited