EVALUATION OF GEANT4 MONTE CARLO TOOLKIT PHYSICS MODELS FOR USE IN HEAVY ION THERAPY

Andrew Chacon[1,2], Mitra Safavi-Naeini[1,2,3], Susanna Guatelli[1,4], Harley Rutherford[1,2] Akram Mohammadi[5], Munetaka Nitta[5], Fumihiko Nishikido[5], Yuma Iwao[5], Hideaki Tashima[5], Eiji Yoshida[5], Taiga Yamaya[5], Theresa Hofmann[6], Marco Pinto[6], Katia Parodi[6], Marie-Claude Gregoire[2], and Anatoly B. Rosenfeld[1,3]

[1] Centre for Medical Radiation Physics, University of Wollongong, Wollongong, NSW, Australia

[2] Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW, Australia

[3] Brain & Mind Centre, University of Sydney, Sydney, NSW, Australia

[4] Illawarra Health and Medical Research Institute, University of Wollongong, Wollongong, NSW, Australia

[5] National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba 263- 8555, Japan

[6] Department of Medical Physics, Faculty of Physics, Ludwig-Maximilians-Universitat Munchen,. Munchen, Germany

Introduction: Heavy ion therapy delivers a highly conformal therapeutic radiation dose to a treatment region while minimising damage to surrounding healthy tissues [1]. Through the imaging of the positron emitting secondary fragments the range of the primary beam can be estimated [2]. Monte Carlo simulation techniques have played a crucial role in the development and clinical application of range verification techniques in heavy ion therapy.

In this study, the 3D distribution and relative production yields of positron emitting nuclei resulting from the injection of a ^{12}C beam into a variety of homogeneous phantoms are experimentally measured through static and dynamic analysis of images obtained using a whole-body single ring OpenPET (WBSROP), an in-beam positron emission tomography scanner developed at the National Institute of Radiological Sciences (NIRS) [2]. Results are compared to Monte Carlo simulations performed using three built-in ion, hadronic, inelastic scattering physics models in two versions of Geant4.

Materials and methods: Experimental validation of the Geant4 physics models was performed by comparing the simulated and experimentally measured positron yield and estimating the yield of different positron-emitting nuclei in three homogeneous phantoms. All experiments were performed at the physics beam course at the Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan using the in-beam WBSROP PET scanner. All Monte Carlo simulations were performed using the Geant4 toolkit, version 10.2, with three Geant4 ion, hadronic, inelastic scattering physics models: Quantum Molecular Dynamics (QMD), Binary Ion Cascade (BIC) and Liege Intranuclear Cascade model (INCL++). Monoenergetic beams of ^{12}C ions with peak energies of 230 MeV/u, 290 MeV/u and 350 MeV/u were applied to three homogeneous gelatine, poly (methyl methacrylate) (PMMA) and polyethylene) phantoms. Line profiles were extracted from the reconstructed static PET images and compared to the filtered one-dimensional positron yield profiles, both normalised to the total number of positron emitters to get a percentage yield.

Results: The types and percentage yields of positron-emitting nuclei resulting from irradiation by monoenergetic ^{12}C ions in a PMMA phantoms will be presented in the conference. Analysis of the simulated and experimental results are continuing, with full results to be presented at the conference.

Conclusion: Our preliminary results demonstrate that currently no physics model provides a perfect description of the production of positron emitting nuclei resulting from target and primary ion fragmentation in all phantoms. This study provides valuable data for the Geant4 user and developer community working in the field of heavy ion therapy, and is essential to developing improved physics models which can be used to provide an accurate estimate of the delivered dose based on observed PET images.

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