Masters Thesis Information Showcase
Spring Semester-2026
Year 2026

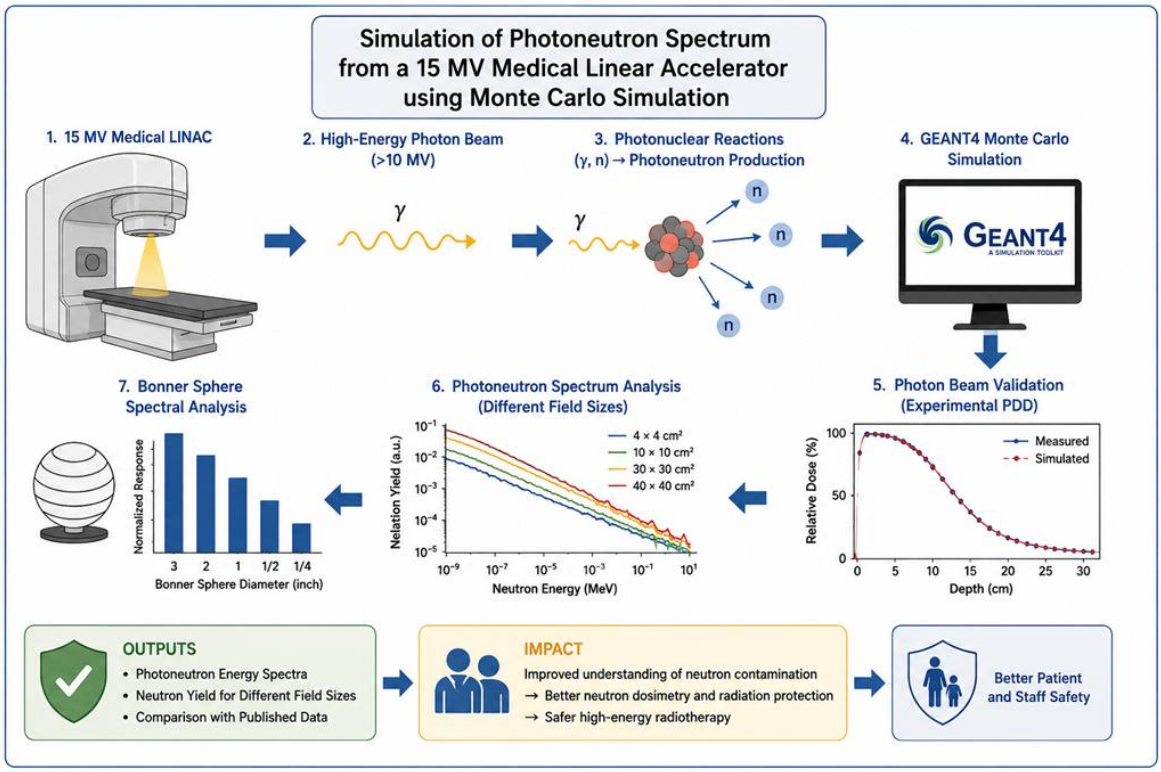
Department: Physics
Programme: Masters of Science
Specialization: Medical Physics

1	**Title of the Thesis** Simulation of Photoneutron Spectrum from a 15 MV Medical Linear Accelerator Using Monte Carlo Simulation
2	**Abstract** (min 300 to 500 words) High-energy medical linear accelerators (LINACs) are widely used in external beam radiotherapy for the treatment of deep-seated tumors because of their improved penetration and favorable depth-dose characteristics. However, photon beams with energies above approximately 10 MV can induce photonuclear reactions in high-atomic-number materials within the LINAC treatment head, resulting in the production of secondary photoneutrons. These neutrons contribute to unintended radiation exposure and may increase long-term radiation risks for patients, particularly pediatric patients and long-term cancer survivors. Accurate characterization of photoneutron energy spectra is therefore important for radiation protection, neutron dosimetry, and the safe clinical use of high-energy radiotherapy beams. This study investigated the photoneutron energy spectra generated by a 15 MV medical linear accelerator using the GEANT4 Monte Carlo simulation toolkit. Experimental measurements of percentage depth dose (PDD) and beam profiles were performed for a Varian Clinac 2100C medical linear accelerator using an MP3 Standard 3D water phantom for different field sizes. The measured photon-beam characteristics were used to assess beam quality and provide reference data for Monte Carlo validation. The simulation model incorporated a phase-space photon source, collimator jaw geometry, a tantalum target for photoneutron production, the NeutronHP physics package, and Bonner sphere configurations for neutron spectral analysis. Photon-beam validation was performed by comparing simulated and experimentally measured PDD distributions. Photoneutron spectra were subsequently evaluated for field sizes of 4 × 4, 10 × 10, 30 × 30, and 40 × 40 cm². The results demonstrated the production of continuous photoneutron energy spectra and variations in neutron yield with field size and Bonner sphere diameter. The simulated spectral characteristics showed reasonable agreement with previously published studies, supporting the capability of the developed GEANT4 model to investigate secondary neutron production from high-energy photon beams. The study demonstrates the usefulness of Monte Carlo simulation for investigating photoneutron contamination in high-energy radiotherapy environments. The findings provide computational data that can support neutron dosimetry, radiation protection assessment, treatment-room shielding studies, and future experimental validation of photoneutron spectra. Further improvements involving increased simulation histories, high-performance computing, detailed LINAC head geometries, advanced neutron

	spectrometry, and dose-equivalent calculations are recommended to improve the clinical applicability of the developed model.
3	**Impact on SDG#3: "Good Health and Well-being"** (min 500 words) (Please mention the impact of the relevant attained SDG) This research directly contributes to Sustainable Development Goal 3 (SDG 3): Good Health and Well-being by supporting efforts to improve the safety, effectiveness, and quality of cancer treatment using high-energy radiotherapy. Cancer is a major global health challenge, and radiotherapy is an essential treatment modality used for a significant proportion of cancer patients. Medical linear accelerators provide high-energy photon beams that enable effective treatment of deep-seated tumors while reducing radiation exposure to superficial tissues. However, the use of photon energies above approximately 10 MV can result in the production of secondary photoneutrons through photonuclear interactions with high-atomic-number materials present within the treatment head of the linear accelerator. Although photoneutrons are not part of the prescribed therapeutic radiation dose, they can contribute to additional radiation exposure to patients and the surrounding treatment environment. Neutrons have relatively high biological effectiveness and can produce complex biological damage. Therefore, accurate characterization of photoneutron energy spectra and neutron contamination is important for evaluating radiation risks, improving radiation protection practices, and ensuring the safe clinical application of high-energy radiotherapy beams. The present research supports SDG 3 by using the GEANT4 Monte Carlo simulation toolkit to investigate photoneutron spectra generated by a 15 MV medical linear accelerator. Monte Carlo simulation provides a powerful computational approach for modeling the production, transport, and interaction of secondary radiation in complex radiotherapy environments. The developed simulation model enables the evaluation of photoneutron energy distributions under different irradiation conditions and provides useful information that would be difficult to obtain using conventional experimental measurements alone. An important contribution of this research is the validation of the photon-beam simulation using experimentally measured percentage depth dose distributions. Experimental measurements obtained from a medical linear accelerator and water phantom were compared with simulated results to evaluate the performance of the computational model. Establishing agreement between simulation and measurement improves confidence in the developed methodology and provides a foundation for further investigations of secondary neutron radiation. The study also evaluates photoneutron energy spectra for different treatment field sizes and Bonner sphere configurations. Understanding how neutron production and energy distributions vary with irradiation conditions can support the development of improved neutron dosimetry techniques, radiation protection strategies, and shielding designs for high-energy radiotherapy facilities. Such information may contribute to reducing unnecessary radiation exposure to patients, radiotherapy personnel, and the public. The research is particularly relevant to improving radiation oncology practices in countries where access to advanced neutron spectrometry equipment and extensive experimental facilities may be limited. Computational modeling provides a cost-effective research approach for investigating radiation safety issues and developing scientific expertise in

	medical physics. The use of open and advanced Monte Carlo simulation tools can support research capacity building, postgraduate education, and the development of locally relevant radiation protection studies. Furthermore, the outcomes of this research can contribute to the long-term improvement of cancer treatment quality and patient safety. Better understanding of secondary neutron contamination can assist medical physicists and radiation protection professionals in evaluating high-energy treatment techniques, optimizing shielding requirements, and developing appropriate monitoring strategies. Therefore, this research contributes to SDG 3 by advancing scientific knowledge related to radiotherapy safety, supporting the assessment of unintended radiation exposure, promoting the application of computational methods in medical physics, and providing a foundation for future research aimed at reducing radiation-related risks associated with high-energy cancer treatments. The study ultimately supports the broader objective of delivering safer, more effective, and scientifically optimized healthcare services for cancer patients.
4	**Scholar Name** (along with contact details) Labiqua Shayyan MP-255004 labiquashayyan20@gmail.com
5	**Supervisor & Co-supervisor Name** (along with contact details) Supervisor: Mr. Fayzan Ahmed Department of Physics NED University of Engineering & Technology Karachi, Pakistan Co-Supervisor: Mr. Siraj Muneer Medical Physicist Aga Khan University Hospital Karachi, Pakistan

6



Graphical Abstract