Nuclear Solutions Institute

Applications of Novel Linear Accelerators for Use in the Detection of Special Nuclear Material & FLASH Radiotherapy

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NSSPI
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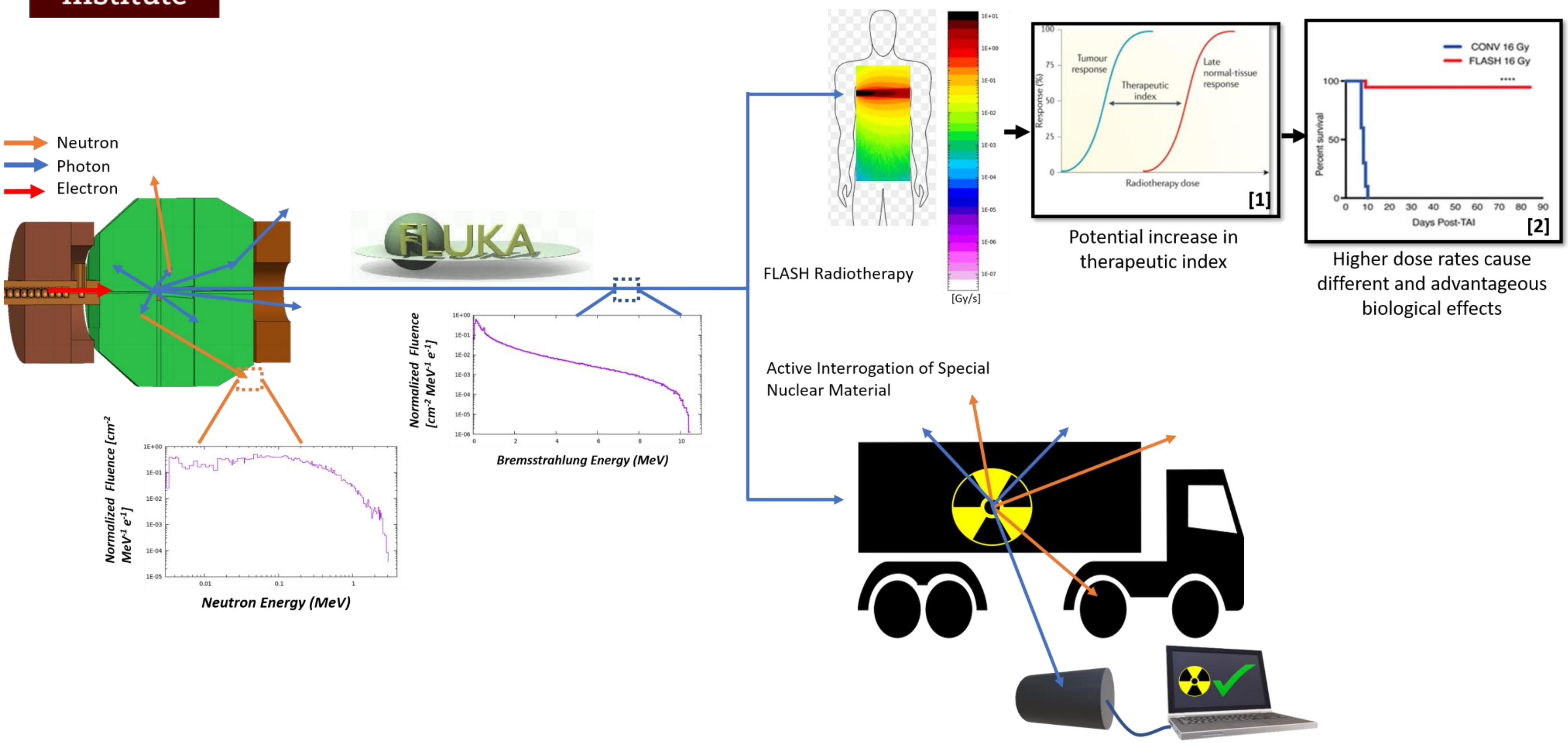

The Science

My proposed research is to design and optimize a mobile bremsstrahlung target and shielding configuration of a high-powered linear accelerator for active interrogation of trucks and cargo containers moving at high speed and at far standoff distances. A similar high-powered linear accelerator system is also being developed for the study of the biological effects of FLASH radiotherapy, which has been shown to increase the therapeutic index for the treatment of certain cancers.

The Impact

The research seeks to expand our understanding of radiation physics through this unique application in the space of nuclear threat reduction and radiation biology/health physics. Both research thrusts would incorporate components linear accelerator physics in order to optimize with regards to effective dose rate, nuclear properties of SNM/radiobiological effects, and the computational methods used in my research.

Summary

While the ends of each project are different, the process of optimization and design is similar. The optimization of the target will be performed by changing three aspects related to bremsstrahlung yield: the dimensions and material of the target and the shape of collimators. Not all of the yield parameters can be optimized to their most favorable value for the given target design. The optimization parameters are listed according to their relative importance in the overall target optimization.

1. The bremsstrahlung energy spectrum will be optimized to be high energy to ensure the transmission of photons through various potentially high area density materials.
2. The target will be optimized so that the number of bremsstrahlung produced per electron is maximized.
3. The angular distribution will be optimized such that a maximum of the bremsstrahlung will be directed toward what is being scanned.
4. Secondary electrons and back-streaming ions will be minimized in order to have a more coherent energy spectrum as well as reducing the electrons scattering back into accelerating cavities.

Secondly, collimators, the beam stop, and linear accelerator components will affect the bremsstrahlung produced and will be designed in parallel to the optimization of the bremsstrahlung target. Collimators will be designed in order to focus and shape the bremsstrahlung beam as well as provide shielding from secondary radiation. The dimensions and materials of the collimators will be optimized as a part of this research in order to produce the designed bremsstrahlung beam profile as a function of distance. The collimators will be designed in such a way that variations in collimator size can be changed in order to account for potential variations in the distance of the container being scanned. The beam stop will be designed in order to maximize the attenuation of electrons that are transmitted through the target and minimize the attenuation of bremsstrahlung. Thirdly, as a part of the design of the target, the shielding for the surrounding area will also be designed such that the dose meets regulatory standards. The device is proposed to be operating in uncontrolled areas with regards to radiation, which has an effective dose rate limit of 0.01 mSv/w. Meeting this effective dose rate limit will require integrated shielding and beam collimators, as well as a shielded cabinet. Detailed analysis of penetrations for the bremsstrahlung photons and equipment will need to be considered, and an assessment of component lifetime will also be made.

References

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2. K., Levy, S., Natarajan, J. S., Chow, B. W., Loo Jr., E. B., Rankin et al. 'FLASH irradiation enhances the therapeutic index of abdominal radiotherapy in mice' bioRxiv 2019.12.12.873414; https://doi.org/10.1101/2019.12.12.873414

Biography

Andrew Rosenstrom is a Ph.D. student in NSSPI investigating the design optimization of *bremsstrahlung* yield for compact linear accelerator targets. *Bremsstrahlung* photons will be harnessed to scan cargo containers and trucks that could potentially be transporting special nuclear material or other illicit material with the Stanford Linear Accelerator Center Radiation Physics Group in a collaboration between Texas A&M University's Radiological Engineering, Detection, and Dosimetry (RED^2) Laboratory under Dr. Dewji. The optimization of the target includes the optimization of the energy spectra for x-ray radiography, angular distribution of *bremsstrahlung* emissions, reduction of secondary electrons, shielding, target heating, accessibility of an operator using the device, and dose estimation to stowaways. Design optimization is being conducted preliminary with Monte Carlo simulations using the FLUKA code.

Additionally, Rosenstrom is working on an auxiliary project estimating the external dose persons using ICRP reference phantoms exposed to prompt and delayed radiation using source terms from the RERF Hiroshima and Nagasaki atomic bomb survivor data. Rosenstrom graduated from the Georgia Institute of Technology with a BS in Nuclear and Radiological Engineering and a minor in philosophy in May 2019. He has interned at Lawrence Berkeley National Lab in the accelerator physics and applied technology division where he helped to develop a mobile associated particle imaging system aimed at producing volumetric distributions of carbon and other isotopes 75000 cubic centimeter samples of soil. Rosenstrom specifically worked to verify the neutron emission rate through the development of a dead time independent rate estimate algorithm and characterized the LaBr and NaI detection efficiency throughout the measurement space through experimental and Monte Carlo methods. He now works with Dr. Dewji at TAMU in collaboration with the Stanford Linear Accelerator Center.