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#10-237 Development of a neutron spectrometer prototype: DONEUT project

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To accurately estimate neutron dose rates, accurate measurements of both the initial kinetic energy and the incident flux of neutrons are crucial. This presentation will discuss a project focused on developing a transportable neutron spectrometer/dose rate meter, using multiple detectors embedded within a moderator volume. This development has resulted in the creation of a novel multi-detector prototype as part of the DONEUT (DOsimetre NEUTrons) project initiated 4 years ago. This prototype has been optimized to measure neutron dose rates from 0 to 20 MeV.

The spectrometer employs a polyethylene moderator with thermal neutron detectors positioned at varying depths to reconstruct neutron energy spectra. A first prototype has been developed and tested. It is based on a 25 cm diameter polyethylene cylinder with 32 embedded detectors. These detectors use a combination of lithium fluoride and zinc sulfide (ZnS:LiF) scintillators, glued to a light guide and coupled with a wavelength-shifting fiber that channels scintillation to a SiPM matrix.

Recent efforts have focused on optimizing the spectrometer's design through simulation and tests. Simulations were performed to optimize the detector configuration and design. For this purpose, unfolding methods, MAXED and GRAVEL, were applied to different moderator volume designs and to a range of neutron energy spectra—using both moderated and unmoderated sources of Am/Be and 252Cf—simulated with the GEANT4 Monte-Carlo code. These simulations led to the development and testing of a "dome"design prototype which improved response uniformity across a wide range of vertical angles and reduced the prototype's weight. Additionally, a sixth detection depth was added to enhance the robustness of the deconvolution, particularly in the epithermal range, and the number of detectors was reduced from 32 to 24 while maintaining measurement accuracy. For both the original and the dome configurations, the dose equivalent rate (H*(10)) achieved an accuracy within 15%, even at lower dose rates around 2 μSv/h in a 10-minute measurement period.

In terms of data processing, a new Python-based implementation of the GRAVEL deconvolution algorithm has been developed based on [1]. This code replaced GRAVEL and MAXED codes and provides enhanced flexibility, efficiency, and speed for reconstructing the energy spectra of radioactive sources

This presentation will cover the simulation studies, the Python unfolding method and the corresponding results for both the spherical and "dome"designs. Results from the new prototype tests with moderated and non moderated Am/Be sources will also be presented and compared to the dose rate measured by the NNS [2].

[1] Tyler Doležal, « Unfolding the AmBe Neutron Spectra using GRAVEL and MLEM », Department of Engineering Physics, Air Force Institute of Technology (2021) https://github.com/tylerdolezal/Neutron-Unfolding

[2] Dubeau, J et al.. "A neutron spectrometer using nested moderators", Radiation Protection Dosimetry, 150 (2), 217 (2012)

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