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Neutron induced capture and fission gamma measurements in the resolved resonance region

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Measurements are routinely performed at the Rensselaer Polytechnic Institute (RPI) Gaerttner Linear Accelerator (LINAC) Center to generate nuclear data for different neutron reactions in multiple energy ranges. These measurements use neutrons generated by a 60 MeV pulsed electron LINAC and various neutron and gamma detection systems at different flight path lengths. A new project was developed to assess the accuracy of capture gamma-rays generated from nuclear structure evaluations when used for different applications [1]. To achieve the project goal, a new simulation method was developed based on MCNP 6.2 [2] to more accurately model and transport neutron capture gamma-ray cascades. The results of this new method were compared with recent experimental neutron capture gamma-ray data generated at the RPI LINAC. Methods are also under development for actinides such as U-235 where fission and capture gammas are both emitted.

The recent neutron capture gamma-ray measurements were performed using the RPI 16-segment NaI multiplicity detector [3] and the neutron time-of flight method. This detector is located at a flight path of about 25.5m and is useful in the energy range from 0.01-3000 eV. The detected gamma-ray pulses are digitized, streamed to a computer, and saved for multidimensional post processing. The neutron capture gamma-ray spectra for different energy ranges and observed multiplicities were derived for comparison with simulations. The neutron capture gamma-ray spectra for a single resonance in a particular material can be analyzed to determine spin dependence. In the case of U-235, this information was used to simultaneously measure the capture and fission cross sections.

The Monte Carlo codes DICEBOX [5] and a modified version of MCNP 6.2 were used along with pertinent nuclear structure evaluations found in ENSDF [4], to calculate the neutron capture gamma-ray cascade spectrum and validate against the RPI LINAC experiments. A modification of the MCNP code allowed for reading gamma-ray cascade data generated by DICEBOX and subsequent transport of these gamma-rays through the RPI detector geometry. The resulting output was an event-by-event list of gamma-ray energy deposition in each of the 16 segments in the detector system. The simulation output is similar in form to the experiment results thus direct comparison was possible. It was demonstrated than when the neutron capture gamma-ray cascade is well known, such as in the case of Fe-56, the experiment and simulation are in very good agreement with respect to the individual detector spectrum as well as the coincidence spectrum (from all detectors) generated by thermal neutrons. Therefore, the simulation methodology was validated for the RPI experimental capture data. The system was used for a variety of materials including F-56, Ta-181, U-238 and U-235.

References

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