Neutron Cross-Talk Characterization of Liquid Organic Scintillators for Cross-Correlation Measurements

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Abstract

Scatter-based organic scintillators have been introduced as a promising alternative to thermal neutron capture detectors (i.e. He-3). However, these scintillators are prone to neutron cross-talk events, which occur when a single neutron scatters and deposits energy above acquisition threshold in two or more separate detectors, adversely increasing correlated counts. The experimental setup designed to isolate cross-talk neutrons from a Cf-252 spontaneous fission source was modeled in MCNPX-PoliMi and show agreement within 15% for all cases. The relative contribution of cross-talk counts on the total observed counts were characterized by three parameters: detector-detector distance, detector-source-detector angle, and light output threshold. Results show that cross-talk counts increase for decreasing values of detector-detector distance and detector-source-detector angle. Furthermore, simulations show that cross-talk counts decrease with increasing light output threshold. Characterization of neutron cross-talk can be implemented in optimizing nuclear nonproliferation and safeguards measurement systems that utilize arrays of scintillators.

Goals and Objectives

- Measure cross-talk neutrons from a Cf-252 spontaneous fission source at various positions
- Validate MCNPX-PoliMi simulations
- Quantify the relative contribution of cross-talk counts as a function of detector-detector distance (d_{dd}), detector-source-detector angle (Θ), and light output threshold LO_{th}

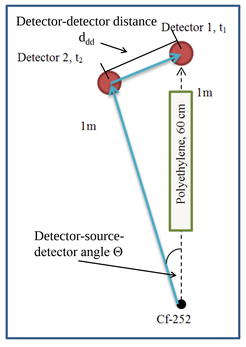

Figure 1. A schematic diagram showing the path of a cross-talk neutron

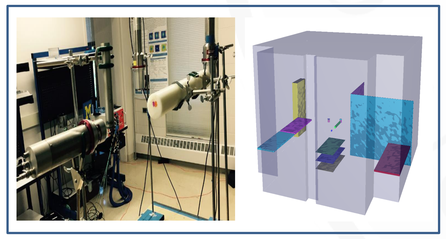

Figure 2. Image of the experimental setup and the detailed MCNPX-PoliMi model.

Methods

- Cf-252 spontaneous fission source was measured with two 7.62cm x 7.62cm cylindrical liquid organic scintillators set to acquire coincident detections
- Polyethylene shadow bar was placed to isolate cross-talk events while mitigating true correlated counts

Results

Validate MCNPX-PoliMi Simulations with Measured Data

- MCNPX-PoliMi simulations were validated by comparing the time distribution of correlated neutron counts and the integrated count rate and show good agreement

Table 1. Comparison of integrated count rates.

Detector-Source-Detector Angle Θ	10°	20°	30°
Measured Integrated Count Rate [counts/sec]	2.798	0.6954	0.3301
MCNPX-PoliMi Integrated Count Rate [counts/sec]	3.213	0.7313	0.3561
Percent Difference	12.91 %	4.901 %	7.292 %

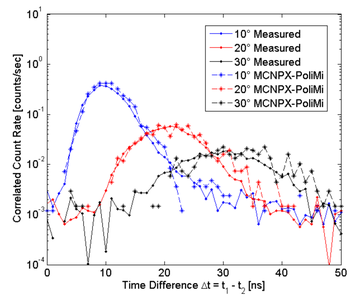

Figure 3. Time distribution of correlated neutron counts, processed with LO_{th} = 70 keVee

Cross-Talk Counts for Various d_{dd} and Θ

- Integrated time distributions as a function of detector-detector distance (d_{dd}) exhibited at various detector-source-detector angle (Θ)

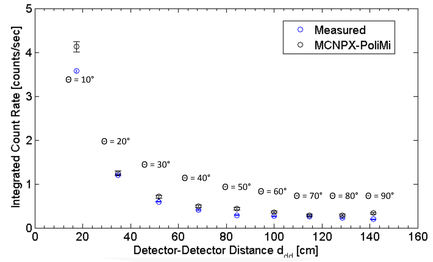

Figure 4. Integrated count rates as a function of d_{dd} and Θ, processed with LO_{th} = 70 keVee

Cross-Talk Counts for Various LO_{th}

- Further analysis in MCNPX-PoliMi to investigate cross-talk counts as a function of LO_{th}
- Post-processing script utilized to extract cross-talk counts from total observed counts in simulations
- Relative cross-talk counts defined as:

$$\frac{Cross\text{-}Talk\ Counts}{Total\ Observed\ Counts} x\ 100 = Relative\ Cross\text{-}Talk\ Counts\ [\%]$$

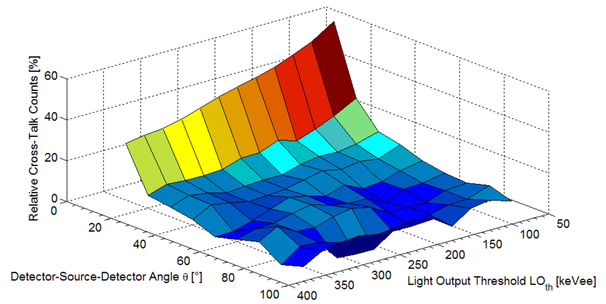

Figure 4. Relative cross-talk counts at various Θ for LO_{th} = 70 keVee – 350 keVee

Conclusion

- Cross-talk neutrons from a Cf-252 spontaneous fission source were measured and agree well with MCNPX-PoliMi simulations
- Both simulation and measurement results show that cross-talk counts are on the order of true coincidences at low d_{dd} and Θ
- The relative magnitude of cross-talk counts on the total observed counts increases as LO_{th} decreases

Future Work

- Future work will investigate methods to isolate cross-talk neutrons from true correlated neutron counts in the laboratory setting

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