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 L_{LOm}

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.

<table>
<thead>
<tr>
<th>Detector-Source-Detector Angle θ</th>
<th>10°</th>
<th>20°</th>
<th>30°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured Integrated Count Rate (counts/sec)</td>
<td>2.798</td>
<td>0.6954</td>
<td>0.3301</td>
</tr>
<tr>
<td>MCNPX-PoliMi Integrated Count Rate (counts/sec)</td>
<td>3.213</td>
<td>0.7313</td>
<td>0.3561</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>12.91%</td>
<td>4.901%</td>
<td>7.292%</td>
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Cross-Talk Counts for Various L_{LOm}
• Further analysis in MCNPX-PoliMi to investigate cross-talk counts as a function of L_{LOm}
• Post-processing script utilized to extract cross-talk counts from total observed counts in simulations
• Relative cross-talk counts defined as:

\[ \text{Cross-Talk Count} \times 100 = \text{Relative Cross-Talk Counts [%]} \]

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 L_{LOm} 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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Cross-Talk Counts for Various L_{LOm}

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- 20°: 4.901% 
- 30°: 7.292%

Figure 4. Relative cross-talk counts at various θ for L_{LOm} = 70 keVee – 350 keVee

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

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.