Motivation and Introduction

- Neutron spectrometry without time-of-flight can be extremely useful in safeguards and nonproliferation applications, e.g., neutron imaging for material accountability and verification (Fig. 1), to discriminate between fissile material and other neutron emitting sources.
- Organic scintillators are intrinsically able to reconstruct the incident neutron spectrum, by unfolding the measured pulse-height distribution with the known response of the scintillator to monoenergetic neutrons.
- The use of organic scintillators is well established for the measurement of neutron spectra above several hundred keV.
- Pulse-height spectrum results from energy deposited both by proton recoils, produced by neutron interactions with H-1 nuclei in the scintillator, and electron recoils, generated by gamma-rays via Compton scattering.
- Improved algorithms are needed and have been developed both to maximize gamma-neutron discrimination capability and increase fidelity of neutron spectrometry and thus decrease the neutron energy detection threshold.

Pulse shape discrimination

GAMMA-NEUTRON DISCRIMINATION

Charge Integration (CI) of the pulse in the time domain

Principal component analysis (PCA) of the pulse in the frequency domain

Neutron spectra unfolding

UNFOLDING

More efficient data representation:
- 2 or 3 dimensions sufficient (out of more than 100)
- Powerful to classify millions of pulses

Two methods tested and compared using experimental data [2]

Distance [cm]

<table>
<thead>
<tr>
<th>Distance</th>
<th>2.5</th>
<th>7.5</th>
<th>15</th>
<th>20</th>
<th>50</th>
<th>90</th>
<th>130</th>
<th>175</th>
</tr>
</thead>
<tbody>
<tr>
<td>EJ-309</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cf-252</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Experimental setup

- Cf-252 @ 10 cm from the detector face, total count rate ~ 900 cps
- Cs-137 moved from 2.5 cm to 175 cm SDD

Fig. 2 Neutron count rate classified using the CI and PCA methods.

Fig. 3 Posterior probability of each pulse to result from a neutron detection.

Unfolded neutron energy spectrum from Cf-252 detected by SPIRAL [1] (top) and the proposed MCMC method (bottom).

References


This work was funded in-part by the Consortium for Verification Technology under the Department of Energy National Nuclear Security Administration award number DE-NA0002534.

Conclusions and Future Work

- Principal component analysis does not require parameter optimization to perform the classification.
- Domain transformation mitigates the effect of temporal delays.
- Novel unfolding algorithm to be used for neutron energy reconstruction using a single liquid scintillator (ill-conditioned response matrix).
- Trend of the reconstructed neutron spectrum compares well with analytic spectrum function uncertainty compensation needed. Incorporate the pulse shape discrimination to the unfolding algorithm to improve fidelity at low energies.