Offline Pulse-Shape Discrimination Algorithms for Neutron Spectrum Unfolding

Nuclear Science Symposium
October 31, 2006, San Diego, California

Marek Flaska and Sara Pozzi
flaskam@ornl.gov; pozzisa@ornl.gov
Presentation Outline

- Motivation
- Project Objective
- Optimization of Offline Pulse-Shape Discrimination (PSD) Method
- Application of PSD to Measured Data
- Results and Conclusions
- Future Work
Motivation

Accurate identification of the origin of neutron radiation is of great interest in many areas, such as nuclear nonproliferation, international safeguards, nuclear material control and accountability, national security, and counterterrorism.

For safeguards applications, a fast and robust method for identification of neutron sources is essential.

The possibility of performing an accurate unfolding of neutron spectra increases the sensitivity of assays performed on various nuclear materials.
Project Objective and Planning

- Identification of typical neutron sources by discrimination of neutrons from gamma rays that originate from the same source.

- Accurate discrimination method is essential for any unfolding technique to obtain the incident neutron source spectrum and will allow identification of neutron sources in a fast and robust way.

1. Measurement of pulses from a radioactive source using a liquid organic scintillator
2. Offline pulse discrimination for correct separation of neutrons from gamma rays
3. Creation of neutron pulse-height distribution from discriminated data
4. Unfolding of pulse-height distribution into neutron energy spectrum
5. Neutron source identification based on the neutron spectrum obtained
Offline PSD Method

- Fast waveform digitizer, oscilloscope TDS-5104 is used with liquid scintillator BC-501A to capture pulses with high resolution (5 GS/s).

- The PSD method is based on pulse integration over time during offline postprocessing of measured neutron and gamma pulses with Matlab® scripts.

**PSD discrimination ratio** \( R_C \):

\[
R_C = \frac{A_2}{A_1}
\]

- \( R < R_C \) – gamma pulse
- \( R > R_C \) – neutron pulse
Optimization of PSD Method

- Neutron pulses from Cf-252 using time-of-flight method.
- Gamma pulses from Cs-137.
Experimental Setups

**Neutron sources:**
- Cf-252 (~60e3 n/s)
- Am-Be (~10e5 n/s)

**Shielding:**
- 1-inch Pb block
- 1-inch PE block

**Source Distance:**
- 50 cm

**Data structure:**
- 200 ns/pulse
- ~4500 pulses/acquisition
Neutron Field from Cf-252 Source

- MCNPX simulation; vertical plane is shown.
- Isotropic source Cf-252 placed 50 cm from BC-501A.
- Attenuation in the detector is observed.
Application of MCNP-PoliMi code

- The MCNP-PoliMi was used to compare simulated pulse-height distributions with those obtained from the measured data, by using the optimized PSD method.

Main MCNP-PoliMi Features:
- Detailed information on the interactions of neutrons and gamma rays inside user-defined cells (typically detectors) are printed to a collision output file, and afterward analyzed with a postprocessing code.

- Neutron interactions and secondary gamma rays are correctly linked (unlike the standard MCNP code).

- Neutron and gamma fission multiplicity distributions are implemented.
Pulse-Height Distributions – Cf-252

- Very good agreement between the measurement and PoliMi.
- Pb shielding results in more neutron pulses per acquisition, which improves statistics of neutron data.
- Detection threshold of 0.094 MeVee.
Pulse-Height Distributions – Am-Be

• Isotropic source in MCNP-PoliMi.
• Distributions are shifted to higher energies, compared to Cf-252.
• The presence of Pb improves the quality of measured data, especially at low energies.
PHDs – Various Shields
Conclusions

• The offline PSD method has been developed and optimized, which is fast and accurate.

• A combination of oscilloscope TDS-5104 and detector BC-501A allows for fast acquisition of neutron and gamma pulses. Matlab® is used for subsequent analysis of the pulses. This experimental/postprocessing system, once complemented with unfolding system, is promising for neutron source identification.

• MCNP-PoliMi results are in very good agreement with measured data.
Continuing Work

- Shielding material can change measured pulse height spectra significantly. These changes make unfolding of neutron spectra very difficult. Therefore, additional investigation is needed.

- There are several unfolding techniques (sequential least-square method, neural network, inverse method), which could be applied to measured data. The first two techniques are being tested to choose the best unfolding method.

- Optimization of unfolding procedures is being performed to further improve the unfolding process.
Acknowledgments

This work was supported by the Oak Ridge National Laboratory and U.S. Department of Energy, National Nuclear Security Administration, Office of Nonproliferation Research Engineering (NA-22).

The authors thank Paul Hausladen (ORNL) for fruitful discussions on PSD methods.
PHDs – Cf-252 (continued)

- Measurement data are more 'noisy' because of lower number of neutron pulses per acquisition, as a consequence of the presence of PE shield.
PHDs – Am-Be (continued)

- Combination of PE and Pb gives more low-energy counts.