Offline Pulse Shape Discrimination Algorithms for Neutron Spectrum Unfolding

Marek Flaska and Sara A. Pozzi

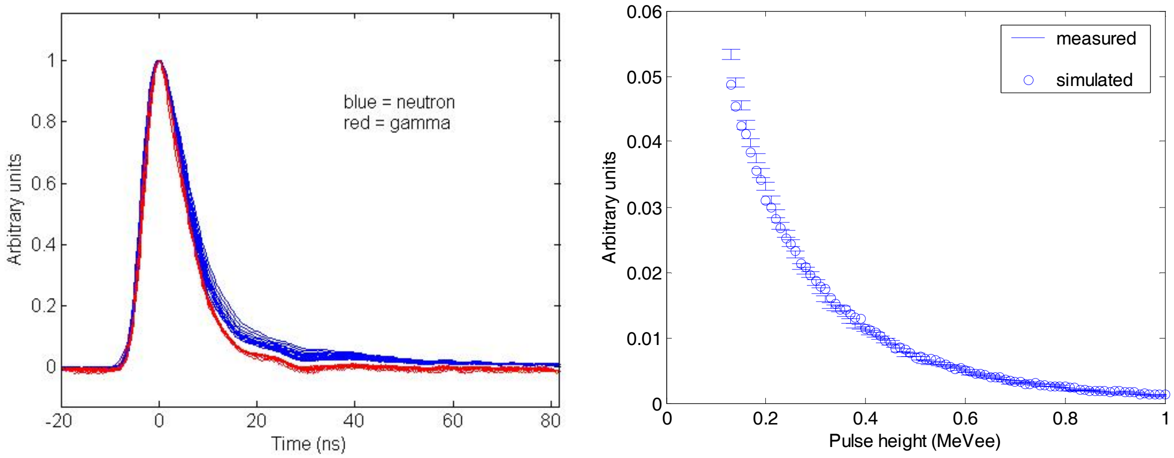
Oak Ridge National Laboratory
P.O. Box 2008, Oak Ridge, Tennessee 37831-6010
Email: flaskam@ornl.gov, pozzisa@ornl.gov

Accurate knowledge of neutron energy spectra is of great interest in many research applications, such as homeland security and nonproliferation of nuclear materials. Neutron and gamma ray pulse shape discrimination (PSD) using liquid scintillators is a widely adopted technique in these fields [1]. For this reason, organic liquid scintillators are frequently used in current measurement systems and are expected to be a main component of future portable measurement systems. Generally, the decision time of currently adopted PSD techniques lies in microsecond range. However, in order to perform measurements at high count rates, a much shorter decision time needs to be achieved [2]. This improvement can increase the sensitivity of the assays performed on nuclear materials with the main objective to detect and to determine the mass and composition of these materials [3].

A robust and efficient pulse shape discrimination technique is essential to determine the neutron pulse height distribution. Once this distribution has been measured with the liquid scintillator, neutron unfolding techniques can be applied. However, since even a small variation in the measured distribution leads to a large variation in the unfolded neutron spectrum, it is crucial to identify neutrons with a very high accuracy and to separate them from gamma rays, which are typically present in the background. In this paper, we present the results of the analysis of a large number of neutron and gamma ray pulses with a liquid scintillator BC-501 using a Tektronix digital oscilloscope TDS-5104. A PSD technique based on pulse integration is developed, optimized, and applied to discriminate neutrons from gamma rays.

Preliminary experiments were performed using neutrons and gamma rays emitted by a Cf-252 source. This source was placed at a distance of 100 cm from the detector. About 4200 pulses were captured at a time with a resolution of 0.2 ns. The pulses were then binned according to their total area into 14 groups, so that each group comprised approximately 500 to 1000 pulses. The average waveforms shown in Fig. 1a were obtained by averaging the pulses that belong to each of the groups, and normalizing them to the maximum value. A small difference in the tail of the waveforms can be seen in Fig. 1a. This difference will be used in the PSD algorithms to distinguish neutrons from gamma rays.

In the full paper, we will describe the PSD analysis algorithms and their optimization. The results of experimental pulse height distributions will be shown both for Cf-252 neutrons measured using the time-of-flight method, and for neutrons identified using the proposed PSD method. We expect these distributions to be very similar, and reasons of disagreement, if any, will be identified and discussed. For the illustration, the measured and simulated pulse height distributions (PHD) for Cf-252 are shown in Fig. 1b. The



simulated PHD was obtained by using the MCNP-POLIMI Monte Carlo code [4], which is a very suitable tool for the simulations of correlation measurements. In the comparison in Fig. 1b, a very good agreement was achieved.

Fig. 1 a) Measured neutron and gamma ray pulses from liquid scintillator (left)
b) Measured and simulated pulse height distribution from the Cf-252 neutron source (right)

References

1. G. Ranucci, P. Goretti, P. Lombardi, "Pulse Shape Discrimination of Liquid Scintillators," *Nucl. Instr. Meth. A*, **412**, 374-386 (1998).
2. J.T. Mihalczo, J.A. Mullens, J.K. Mattingly, T.E. Valentine, "Physical Description of Nuclear Materials Identification System (NMIS) Signatures," *Nucl. Instr. Meth. A*, **450**, 531 (2000).
3. J.A. Mullens, J.D. Edwards, S.A. Pozzi, "Analysis of Scintillator Pulse-Height for Nuclear Material Identification," Institute of Nuclear Materials Management, 45th Annual Meeting, Orlando, FL, July 18-22 (2004).
4. S.A. Pozzi, E. Padovani, M. Marseguerra, "MCNP-PoliMi: a Monte Carlo code for correlation measurements," *Nucl. Instr. Meth. In Phys. Res. A*, **513/3**, 550-558 (2003).