Accurate Identification of Neutron Sources Using the Liquid Scintillator BC-501A

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INTRODUCTION

Correct identification of radioactive sources is required in many fields of research and industry, and it has many applications in areas such as nonproliferation, control and accountability of radioactive materials, and nuclear safeguards. In all these areas, it is essential to correctly identify typical neutron sources, such as californium-252 (Cf-252) or americium-beryllium (Am-Be). Therefore, it is very important to develop robust new methods for efficient identification of neutron sources. An offline digital neutron-gamma-ray pulse shape discrimination (PSD) method using a liquid scintillation detector with subsequent unfolding of the original neutron source energy spectrum is a very promising method. The advantage of using the digital technique comes from the recent rapid development of waveform digitizers that allowed the increase of measurement count rates and maximized the amount of information obtained from a detector. This approach also increases the sensitivity of assays performed on various nuclear materials.

The neutron source spectrum represents a unique “signature” and can be used for source identification. It should be noted that successful neutron spectrum unfolding relies on the accurate measurement of the neutron pulse height distribution. This accuracy is required because even a small variation in the measured distribution leads to a large variation in the unfolded neutron spectrum. This requires very accurate PSD method to be applied.

COLLECTION OF DATA AND APPLICATION OF THE PSD TECHNIQUE

We used a fast waveform digitizer, 1-GHz, 8-bit digital oscilloscope Tektronix TDS-5104 with a maximum sampling rate of 5GS/s, to record many thousands of pulses from the anode of the liquid scintillator BC-501A. The detector is 7.7-cm thick with a diameter of 15.2 cm. For subsequent offline analysis, an optimized PSD method based on the standard analog charge integration technique was used. The PSD method was optimized by using correctly attributed neutron and gamma-ray pulses from a Cf-252 and a Cs-137 source, respectively. A time of flight method was used to attribute Cf-252 neutrons. In the investigation of “unknown” neutron sources, the following sources were tested: Cf-252, Am-Be, and americium-lithium (Am-Li). Each of these frequently used sources has a different neutron energy spectrum, which makes it a good choice for our investigation.

We investigated the effect of lead (Pb) and polyethylene (PE) shields placed between the source and the detector. In fact, materials commonly present around sources can significantly influence the measured pulse height distribution, depending on the material properties and the size of the shielding. Therefore, this aspect must be also investigated.

RESULTS

Figure 1 shows the result for the measurement of the Am-Be source with 1-in. Pb shield placed between the source and the detector. A very good separation of the neutron and gamma-ray pulses is shown. The ratio of tail and total pulse integrals has been carefully chosen to correctly separate neutrons from gamma rays.

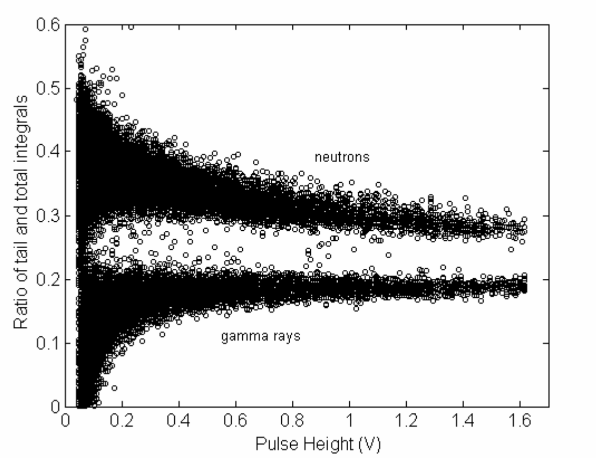

Fig. 1. Am-Be source placed 30 cm from the liquid scintillator BC-501A with a shield of 1 in. of Pb. The separation point lies in the valley between the peaks (around 0.26).

Figure 2 shows the measured pulse height distributions for the Cf-252 and the Am-Be source in several source-shielding-detector configurations. It is apparent that the distributions are not significantly changed with the presence of the shields. The sources can be clearly distinguished from each other, which makes it very easy to identify typical neutron source distributions (fission spectrum of Cf-252 vs. double-peak spectrum of Am-Be). Unfolding can be applied when information on the initial neutron spectrum is needed.

In the full paper, we will discuss results obtained using the sequential least-square unfolding method [1]. In addition, we will present simulated pulse height distributions obtained using the MCNP-PoliMi code [2] to verify the accuracy of the measurements and the applied PSD method. Finally, results using shields of different thickness will be shown to assess the sensitivity of the method.

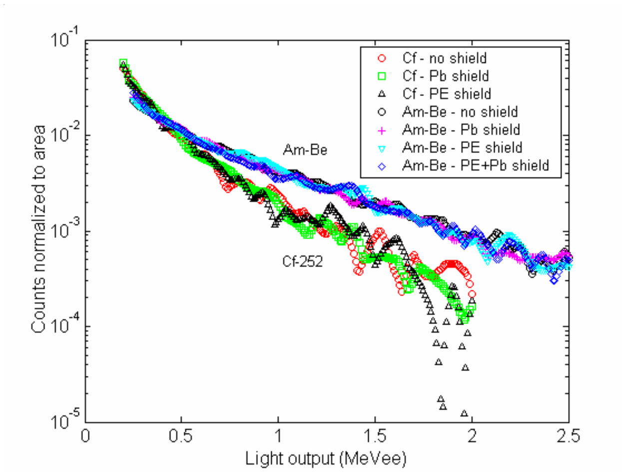

Fig. 2. Pulse height distributions for the Cf-252 and the Am-Be source placed at a distance of 30 cm from the BC-501A. Each shielding block has a thickness of 1 in. The errors are not shown to allow reader to distinguish different configurations.

REFERENCES

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2. S.A. Pozzi, E. Padovani, M. Marseguerra, "MCNP-PoliMi: A Monte Carlo Code for Correlation Measurements," *Nucl. Instr. Meth. A*, **513**, pp. 550–558 (2003).