Evaluation of Accidental Coincidences in Active Interrogation of Special Nuclear Material

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INTRODUCTION

The detection and identification of concealed nuclear material is of increasing concern to the United States and the world. Specifically, passive detection of enriched uranium is extremely difficult because of its low spontaneous fission rate. As a result, systems relying on active interrogation are gaining more attention from the research community. The focus of the work here is active photon interrogation in conjunction with coincidence counting. Scintillation detectors will be used due to their sensitivity to both high-energy neutrons and gamma-rays; they are also durable and reliable. Multiple detectors will be used to enable coincidence counting of the particle emissions following irradiation; here particles are recorded from the detectors with reference to the time-delay between their arrivals.

Such a system has the potential to provide a reliable indication of the presence of fissionable material. However, one caveat of systems based on pulsed gamma-ray sources is the presence of accidental coincidences in the detectors. The occurrence of many photonuclear events simultaneously generates photons and neutrons at essentially the same time. The arrival of these particles simultaneously at the detectors causes a coincident detection event. These accidental coincidences contain no useful information about the interrogated material and should therefore be minimized. It is the goal of this work to evaluate this effect in order to obtain realistic estimates of measurement results.

SIMULATION METHODS

In order to compute the time-analysis quantities necessary to simulate coincidence detection systems, a Monte Carlo code system named MCNP-PoliMi has been recently developed [1]. In order to treat photonuclear events, a source file is generated using a modified version of MCNPX by simulating the interrogation of fissionable material and recording relevant information on all photonuclear events. The information recorded to file includes the location of the event, the number of neutrons and gamma-rays emitted, as well as the energy and direction of the emitted particles. This source is read by MCNP-PoliMi, and the particles are transported through the system and into the detectors. A detector-specific, post processing script is used to analyze the results from MCNP-PoliMi; this script models the detector response and computes statistical quantities of interest, including time correlations and multiplicity distributions [2].

The evaluation of accidental coincidences can be performed on the basis of the target detector time-of-flight signatures. The target detector time-of-flight gives the neutron and gamma-ray probability of detection in each detector as a function of the time lag (i) between the photonuclear event at the target and the detection event at the detector. Figure 1 shows a sample time-of-flight distribution scaled to a varying number of source photons.

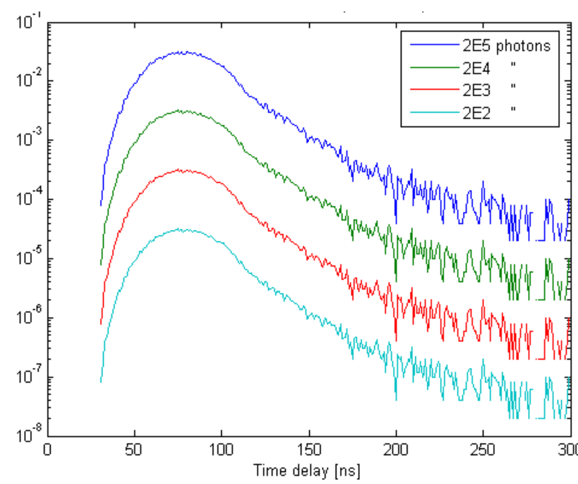

Fig. 1. Time-of-flight distribution from the target for varying numbers of source particles.

The detection probability at time delay i in one of the detectors is always much smaller than unity, which means that there two possibilities: either one count is obtained with probability equal to the average number of counts, p_i, or no count is obtained, with probability $1-p_i$. Because either zero or one counts are sampled at the detectors, the probability of accidental pairs (APP) can be defined as the product of the two probabilities as follows

$$APP(k) = \sum_i p_i \cdot p_{i+k} \tag{1}$$

where p_i is the detection probability at time lag i and p_{i+k} is the detection probability at time lag i plus time delay k.

RESULTS

An interrogation system consisting of 15-MeV bremsstrahlung photons incident on a depleted uranium target between two 50-cm by 50-cm plastic scintillation detectors was modeled using the MCNP-PoliMi code system. The number of accidental coincidences occurring in this system was computed using Eq. (1) and compared with the real coincidences for varying the number of photons per simulated accelerator pulse. Figure 2 shows this comparison.

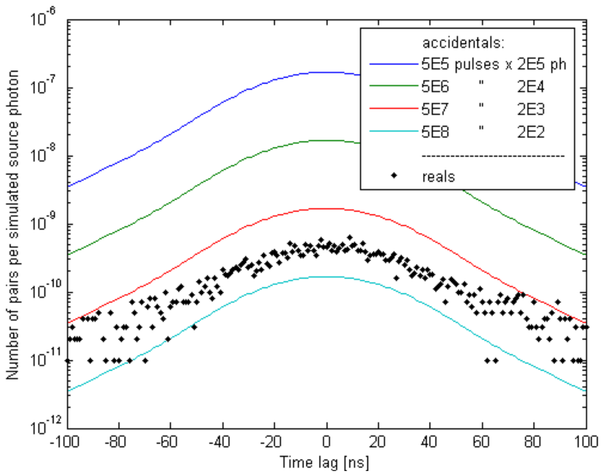

Fig. 2. Distribution of real and accidental coincidences for a depleted uranium target.

Clearly, the number of photons per accelerator pulse has a dramatic effect on the number of accidental coincidences. In fact, the case of 5×10^8 pulses of 2×10^2 photons is the only one in which the number of accidental coincidences is less than the number of real coincidences. Such a measurement would take approximately 83 minutes with an accelerator operating at 100 kHz.

The preliminary results shown here clearly illustrate the importance of considering accidental coincidences for a system relying on coincident detection in conjunction with a pulsed source. In fact, these accidentals can very easily dominate the signal from the target material. It is therefore crucial that these effects be quantified and understood in preparation for performing such measurements.

REFERENCES

1. S. A. POZZI, E. PADOVANI, ET AL., *Nucl. Instr. and Meth. A*, **513**: 550–558 (2003).
2. S. A. POZZI, Oak Ridge National Laboratory Internal Report, ORNL/TM-2004/299 (2004).