PASSIVE MULTIPLICITY COUNTING WITH THE NUCLEAR MATERIALS IDENTIFICATION SYSTEM FOR PLUTONIUM

T. E. Valentine, R. B. Perez, J. A. Mullens, and J. T. Mihalczo
Oak Ridge National Laboratory
P. O. Box 2008, Oak Ridge, Tennessee 37831 U.S.A.

Abstract

Passive multiplicity measurements with the Nuclear Materials Identification System (NMIS) may provide a means to determine the mass of a plutonium sample. Neutron and gamma radiation detectors with the NMIS provide additional information that is not achievable with standard multiplicity measurements. To investigate the use of NMIS, a Monte Carlo code was modified to simulate active and passive multiplicity measurements. The Monte Carlo calculations can be used to design a passive neutron and gamma multiplicity counter using the Nuclear Materials Identification System and determine the sensitivity of the NMIS active and passive multiplicity measurements.

INTRODUCTION

Use of non-destructive methods to assay nuclear material is often necessary because of either lack of information about a container of nuclear material or to satisfy accountability requirements. Fissile mass and isotopic composition are required for most accountability programs. Isotopic composition is commonly determined using gamma spectroscopy measurements whereas the fissile mass can be obtained from a variety of measurements. Passive coincidence and multiplicity measurements are commonly used for plutonium assay.[1,2] Coincidence and multiplicity measurements are time correlation measurements that provide measured quantities that can be related to the spontaneous fission rate, induced fission rate, alpha decay rate, and the detection efficiency. Models developed by Boehnel[3] and Hage and Cifarelli[4,5] have been used to relate the multiplicity moments to the spontaneous fission rate, induced fission rate, alpha decay rate, and the detection efficiency. An extension of passive multiplicity measurements would incorporate the use of prompt gamma radiation from fission. Perez et al[6] developed a rigorous stochastic theory for inclusion of active and passive multiplicity measurements with the Nuclear Materials Identification System (NMIS). NMIS uses detectors that are sensitive to both fast neutrons and gamma radiation.

This paper describes the simulation of passive multiplicity measurements with NMIS. The Monte Carlo code MCNP-DSP[7] is used for passive multiplicity simulations and a description of the code and processing algorithms is provided. This code can be used to design a passive NMIS multiplicity counter and determine the sensitivity of the NMIS active and passive multiplicity measurements.

MCNP-DSP

The Monte Carlo code MCNP-DSP was developed from MCNP4a[TM,8] to simulate active and passive subcritical measurements. This code includes detailed options for inherent spontaneous fission sources and several detector options. Models of actual detectors are included in the MCNP-DSP simulation. The detector responses are accumulated and the resulting sequences segmented into data blocks. A data block is a sample of the detector response for a specified time period. The sampling rate and the number of time bins per data block determine the time period. Currently, the MCNP-DSP simulation only includes spontaneous fission as an inherent source and does not include α-n reactions. The MCNP-DSP code modifications to include a simulation of the multiplicity measurement to simulate the multiplicity measurement are described below.

The structure of the multiplicity calculation is based on an outer and an inner loop. The outer loop controls the number of blocks of data (*bks*) to be calculated. The average number of source events per data block (*scd*) controls the inner loop. Because spontaneous fission is a Poisson process, the number of disintegration events per block (*ncdis*) is calculated from a Poisson distribution with mean *scd* for the source events per block. The average number of source events per data block relates to the actual source size by the following relation

$$scd = \frac{mR_{sf}\,ntbn}{f_s}, \tag{1}$$

where m is the mass of the source in micrograms, R_{sf} is the spontaneous fission rate of the source per gram, *ntbn* is the number of points per block, and f_s is the sampling rate. Using this expression, the source specified in the calculation can be related to the actual source used in the measurements.

The time of the source disintegration is sampled randomly within the data block because the data acquisition in NMIS is started using the computer clock. Once the source starting time has been selected, the locations of the spontaneous fission events are selected randomly within a geometric region specified by the user. The number of neutrons and gamma rays produced for each spontaneous fission event is sampled from appropriate distributions. Likewise, the energy spectra for the neutrons and gamma rays are sampled from appropriate distributions. Tracking of the source particles begins with one neutron while the other neutrons and gamma rays are stored in a bank for tracking. The progeny if any of the first neutron are then tracked before source particles are retrieved from the bank. The particles are then tracked until they are either absorbed or escape from the system. After all source particles and progeny for a given data block have been tracked, the block counter is incremented, the detector response are accumulated, and the process repeats until all blocks have been accumulated.

[TM] MCNP is a trademark of the Regents of the University of California, Los Alamos National Laboratory

In these Monte Carlo calculations, the detector material, type, and any energy thresholds are specified. There are three types of detectors available in these calculations: capture, scatter, and fission detectors. NMIS measurements are preformed using plastic scintillation detectors that are simulated as scatter detectors. The detector response is segmented into time bins for each data block whose width is specified. The time period as determined by the sampling rate and number of time bins is the interval over which the multiplicity data is acquired. The simulation determines both the detector triggered and random number of counts for each data block. The distribution for random counts is determined as the number of counts that occur in the data block. The distribution for triggered counts is obtained by determining the number of counts after the trigger count for the same time interval. Hence, the time period for triggered counts is potentially twice as long as that for the random counts. Therefore, particles are tracked for twice the period of the data block.

This process is best described using the illustration in Fig. 1. The illustration in Fig. 1 represents one sample of the detector response where the arrow is the time period of one data block. In this case, four counts occurred in the time interval. Therefore, the distribution histogram for four random counts would be incremented by one. Four trigger counts are obtained for this sample of the detector response. The counts in the next data block after the current must also be determined to create the triggered distribution. The triggered distribution for five counts would be incremented by three: one for the first trigger interval, one for the second trigger interval, and one for the third trigger interval because five counts occur within the sample time interval after the trigger event. Finally, the trigger distribution for four counts would be incremented by one for the fourth trigger interval. This process is repeated over many samples of the detector response to obtain triggered and random distribution histograms. Note that these “multiplicity” distributions do not count the trigger pulse as one of the events. These “multiplicity” distributions can then be processed using the methods described by Hage and Cifarelli.

SUMMARY

A general purpose Monte Carlo program has been created to simulate passive multiplicity measurements. Simulation of passive multiplicity measurements using the Nuclear Materials Identification System allows for the investigation of the sensitivity of this system to plutonium mass. The simulation and the NMIS measurement include not only neutrons but also gamma rays. The inclusion of the gamma rays may provide additional information that is not obtainable using conventional multiplicity measurements.

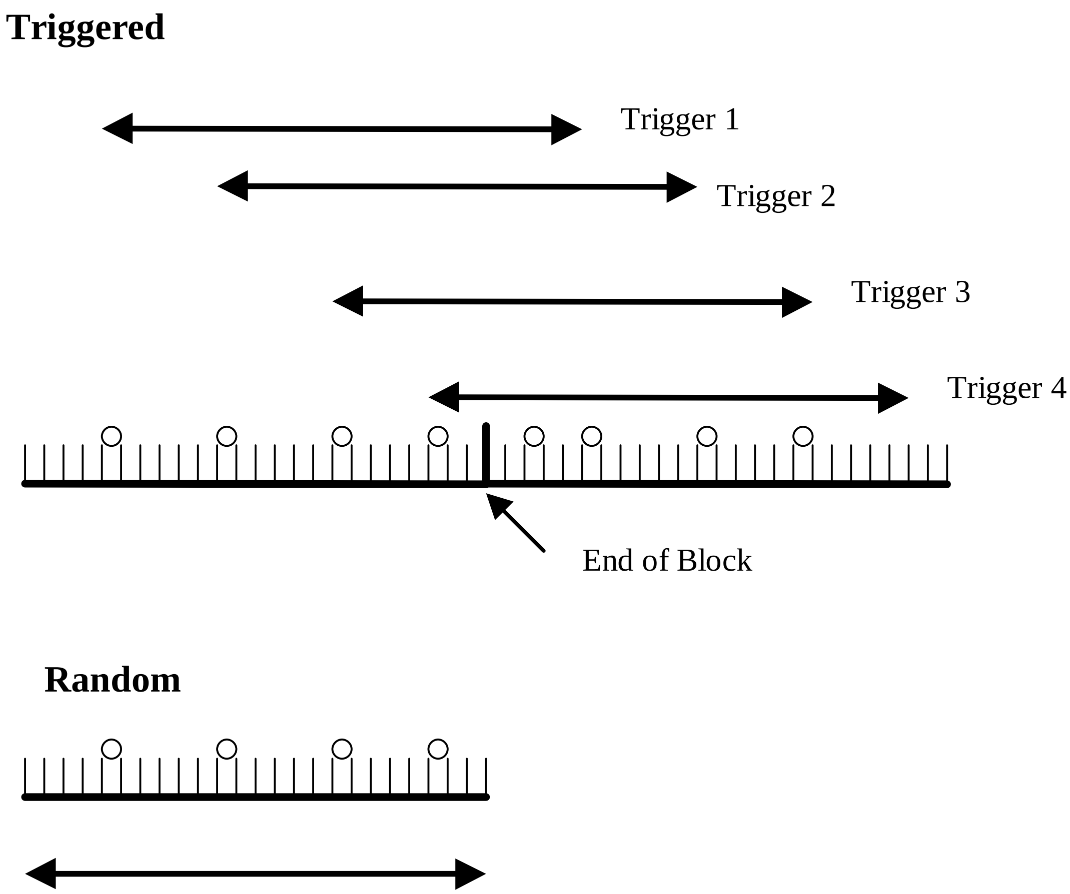

Figure 1. Diagram of multiplicity simulation.

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