Analysis of Correlated Neutron and Gamma Detection from Photofission

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We describe Monte Carlo simulations of the photon interrogation of uranium and plutonium metal samples of varying mass and composition. The simulations are performed using a Monte Carlo tool that consists of modified versions of the codes MCNPX and MCNP-PoliMi. The codes simulate the neutron and photon field generated by interrogating fissile (and non-fissile) material with a high energy photon source. Photo-atomic and photo-nuclear collisions are modeled, and time-correlated detections are computed, both for photon beam on and photon beam off operation. The signal obtained in photon beam on operation consists of correlated particles emitted by the primary photo-fissions, whereas the signal obtained in photon beam off operation consists of correlated particles emitted by secondary fissions induced by the delayed neutrons from photo-fission. The cross-correlation functions measured by the detectors consist of correlated neutron and gamma detections. In the first part of our paper, these physical mechanisms are described, and the ability of the resulting correlation signatures to characterize special nuclear material (SNM) is discussed.

The second part of our paper illustrates a methodology based on Monte Carlo simulations and artificial neural networks (ANN) that is aimed at determining the characteristics of the fissile material. In the simulations, we modeled a simple geometry consisting of fissile material with shielding of various thicknesses, such as lead and polyethylene, placed between two plastic scintillation detectors. A 15 MeV mono-energetic photon source was used as the interrogation beam. Uranium and plutonium masses ranging from one to ten kilograms were simulated in spherical and cylindrical configurations. Select features of the correlation functions were used as inputs to an ANN. The outputs of the ANN were chosen to be the k_{eff}, radius, material, and shape of the fissile samples. The choice of input parameters will be optimized, and the effect of noise and other experimental effects will be discussed. We will show that the combined stochastic and artificial intelligence methodology allows the prediction of the mass and composition of the SNM samples with reasonable accuracy. The proposed methodology has application in the fields of nuclear nonproliferation and homeland security.