Supporting documentation

Photofission Signatures in the Prompt Regime for Special Nuclear Material Identification

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The interrogation of actinides and non-actinides using high-energy bremsstrahlung photons has been investigated in the past [1-2]. Recently, the study of prompt emissions from photonuclear events induced in the various materials has gained interest in the research community [3-4]. These prompt methods are based on the fact that different photonuclear reactions occur for different materials when they are interrogated with the same endpoint energy bremsstrahlung beam. For example, photons of sufficient energy induce (gamma, n), (gamma, 2n), and (gamma, fission) reactions on actinides whereas they induce only (gamma, n) reactions on lead (Pb; a common benign material). The energy distributions of the prompt neutrons emitted by these reactions depend on the energy of the incident photon and on the type of photonuclear reaction. In the case of photofission, the energy of the outgoing neutrons depends weakly on the energy of the incident photon and the shape of the neutron spectrum is essentially maxwellian - similarly to neutron-induced fission. In the case of (gamma, n) and (gamma, 2n) reactions, the energy of the outgoing neutrons depends strongly on the Q-value of the reaction and on the energy of the incident photon. These considerations on the photonuclear interactions physics can be used to discriminate actinides from non-actinides, and perhaps also to perform characterization of the actinides.

Figure 1 shows the MCNPX [5] simulation of the outgoing neutron spectrum following interrogation with 10 MeV endpoint energy bremsstrahlung photons from two materials of interest: depleted uranium (DU) and Pb. The neutron energy spectrum from DU is significantly different from the neutron energy spectrum emitted by Pb. The DU spectrum is harder and extends up to 18 MeV, whereas the Pb spectrum extends to neutron energies of only 4 MeV, approximately.

Figure 2 shows the simulation of the outgoing neutron spectrum following interrogation with 20 MeV bremsstrahlung photons from DU and Pb. In this case, the difference in the neutron energy spectra is not as pronounced as in the 10 MeV case; the neutrons emitted by DU have essentially the same energy distribution as shown in Fig. 1, whereas those emitted by Pb have a harder distribution than in Fig. 1, as is expected by the kinematics of the interaction.

In the full paper, we will analyze the response of organic scintillation detectors to prompt neutrons emitted by photonuclear events. We will show that it is possible to distinguish between actinides (HEU, DU) and non-actinides (Pb) by analyzing neutron pulse height distributions measured with the detectors. A preliminary attempt at isotope characterization will also be described. This research has application in the areas of nuclear nonproliferation and homeland security.

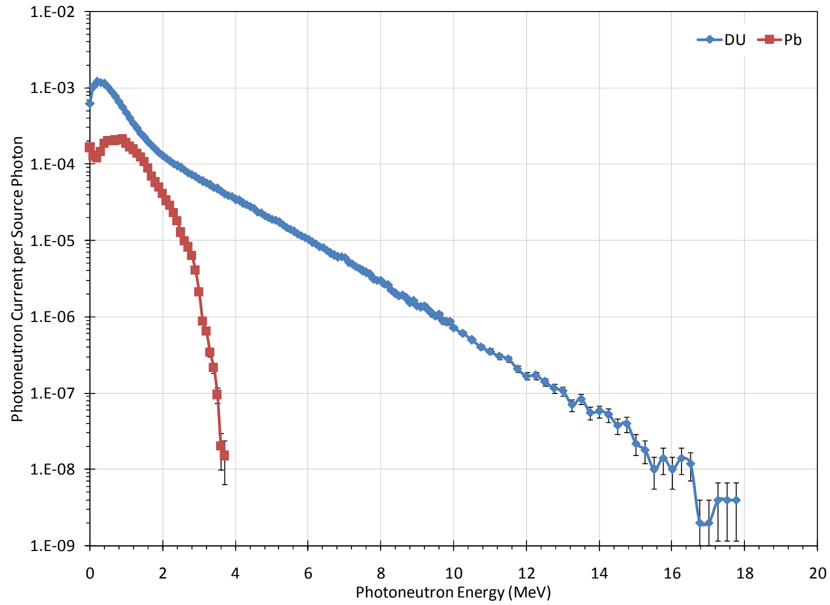

Figure 1. Photoneutron spectra from DU and Pb targets following interrogation with 10-MeV bremsstrahlung photons.

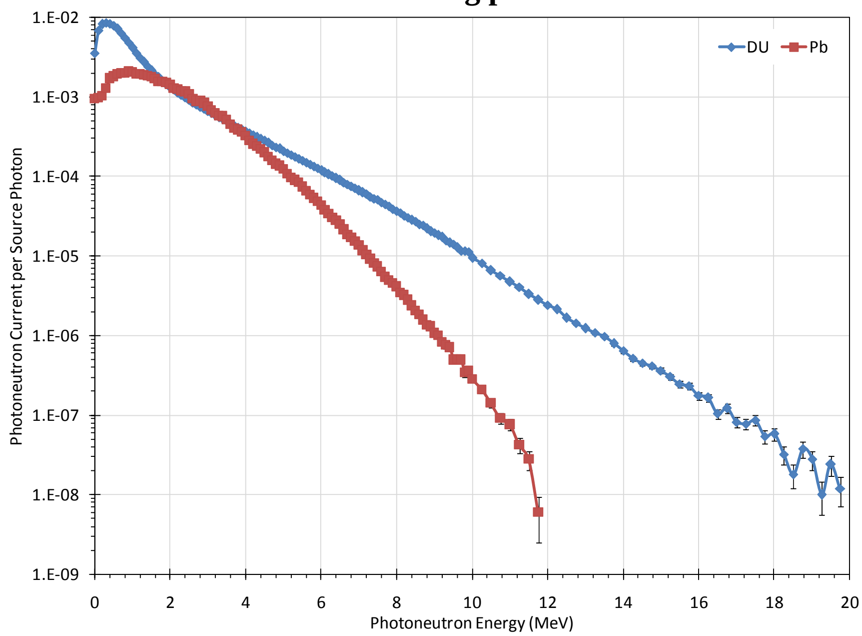

Figure 2. Photoneutron spectra from DU and Pb targets following interrogation with 20-MeV bremsstrahlung photons.

References

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