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#6-266 Evaluating the performance of a photofission prompt neutron detection system based on threshold activation scintillation coupled with a 9 MeV electron accelerator

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Photofission prompt neutron detection methods are of great interest for research and development in the field of nuclear instrumentation and measurement, whether for nuclear waste package characterization, border control and homeland security, but also fundamental nuclear physics. The photofission reaction is generally induced by a linear electron accelerator (LINAC), converting electrons into Bremsstrahlung photons, by slowing them on heavy atomic nuclei target, as tungsten or tantalum for instance. Yet, when those high-energy photons (> 6 MeV) interact with actinides, i.e., U-235, U-238, Pu isotopes, etc., photofission reactions may occur and emit prompt and delayed neutrons and delayed gammas. Prompt neutrons are emitted instantaneously while the measurement system and electronics, commonly He-3 proportional counters, are saturated by the intense photon flash delivered by the LINAC. Thence, applications regarding photofission particles emission mostly concern delayed neutrons and delayed gammas whereas 99% of the emitted neutrons are prompt. In addition, their detection after Active Photon Interrogation (API) is relevant for actinide quantification when matrix effects can complicate the measurement by thermalizing delayed neutrons, attenuating and self-absorbing gamma signatures. In this work, we evaluate the performance of a photofission prompt neutron detection system coupled with a 9 MeV LINAC, with the aim of investigating the use of a third photofission signature, in addition to delayed neutrons and delayed gamma rays. This, to reduce uncertainties in the detection of shielded actinides or contained in large hydrogenated volumes, as well as to quantify and differentiate them. In a first step, we performed Monte Carlo simulations to assess the parameters of a setup designed for the photofission prompt neutron detection, based on an indirect method. It consists in delaying the detection of prompt neutrons, by activating a radionuclide and then measuring the decay of the reaction product. The detection of the 6.131 MeV gamma radiation emitted by N-16, resulting from (n, α) reactions with F-19, has been deployed since the earliest advancements in neutron detection for nuclear reactors. Developments with pentafluorostyrene plastic scintillator and CaF2 threshold activation detectors have led to more recent progress in this area. Based on this approach, we can avoid the photon flash of the LINAC and a strong background noise of photoneutrons, created in the conversion target. In a second step, we conducted experimental tests with a 9 MeV electron accelerator, Linatron® M9A designed by Varex Imaging Corp., at the SAPHIR platform (CEA Paris-Saclay, France). The photofission experiment is simulated using PHITS and MCNP6 Monte Carlo codes and the respective nuclear data libraries: ENDF/B-VIII.0 and JENDL-5. First, we evaluate the photoneutron background produced in the tungsten of the accelerator. Considering the (γ, n), (γ, 2n) and (γ, Xn) cross-sections and reaction threshold, the photoneutron production happens to be 90 times higher for a LINAC operated at 15 MeV compared to 9 MeV. Then, the calculation of the photofission reaction rate in uranium leads to the conclusion that the signal-to-noise ratio is optimal for an accelerator operated at 9 MeV, i.e., for a photoneutron production about 40 times higher than the prompt neutron yield. Second, we machined polytetrafluoroethylene layers to be disposed against a bismuth germanate scintillator and we irradiated a depleted UMo sample. Finally, by designing and optimizing a photofission prompt neutron detection system, and investigating the use of a third photofission signature, we are enhancing the API technique for border control of cargo containers and particularly in cases where terrorists would use shielding around hidden Special Nuclear Materiel (SNM). This work should help to push back the frontiers of the API developments

and contribute to the advancement of the associated research community.

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