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Investigation of triple-discriminating plastic scintillators for the detection of SNM in active measurements by photofission at 7 MeV

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Many developments are currently in progress towards new threat detection technologies for security-related applications. In particular, the photofission technique can be applied to detect Special Nuclear Material (SNM) hidden inside cargo containers, which can potentially be used to make nuclear weapons or “dirty bombs”. This technique relies on detecting prompt and delayed neutrons and gamma rays emitted by the photofission reaction for which the energy threshold is around 6 MeV for plutonium and uranium isotopes. In the frame of the H2020 ENTRANCE project and following the H2020 C-BORD project, CEA List is investigating the performance of the photofission technique using a linear electron accelerator (linac) operated at 7 MeV, *i.e.* delivering photons with energies not far above the threshold of the reaction of interest. One of the aim is to couple the photofission technique with compact linacs embeded in mobile X-ray scanning systems used by customs for control at borders. Moreover, we investigate the potentialities of triple-discriminating plastic scintillators for the detection of SNM with such systems. These detectors are manufactured by the laboratory and are based on ^{6}Li-doped plastic scintillators which allows them to discriminate between gamma-rays, thermal neutrons and fast neutrons by Pulsed Shape Discrimination (PSD). Thus, they could potentially measure simultaneously both the neutron and gamma signatures from SNM and enable to overcome the challenges met when measuring the low signals expected due to the fact that the photofission cross-section values reach a few millibarns between 6 and 7 MeV. First, the PSD capabilities and scintillation yields of these new detectors are characterized in the laboratory environment using a ^{252}Cf source. Then, we perform measurements at the SAPHIR platform located at CEA Paris-Saclay with the 9 MeV linac available and several SNM samples. Neutron sensitivity as well as detection limits are then compared to reference measurements carried out with a high-density polyethylene detection block housing five 150NH100 ^{3}He detectors. In parallel, we implemented an MCNP6 Monte Carlo simulation model of the experimental setup at 9 MeV. Once validated, this model is used to assess the performance of triple-discriminating plastic scintillators for photofission measurements carried out at 7 MeV. In collaboration with Smiths Detection, field tests are planned in 2023 at the seaport of Rijeka, Croatia, with different cargo matrices and a 7 MeV mobile X-ray scanner equipped with triple-discriminating plastic scintillators.