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# #07-28 Characterization of nuclear waste packages by active photon interrogation with mobile or stationary systems based respectively on 7 or 9 MeV linacs

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Decommissioning and dismantling (D&D) operations conducted in former nuclear facilities generate a large amount of nuclear waste packages. Characterization of the latter is an important step in the management process. Active photon interrogation, based on the photofission reaction, is a well-adapted method to characterize nuclear waste packages containing concrete matrices. Indeed, with such matrices, both passive methods and the active neutron interrogation method reach their limits whereas the high-energy photon beam produced thanks to a linear electron accelerator (linac) could enable to interrogate the center of a concrete matrix package. The photofission reaction is based on two steps. First, high-energy photons induce fission reactions on actinides such as uranium and plutonium isotopes. Secondly, prompt and delayed particles are emitted. The energy threshold of the photofission reaction is close to 6 MeV for most actinides (<sup>235</sup>U, <sup>238</sup>U, <sup>239</sup>Pu, etc.). In the frame of the MICADO project, which is part of the European Union's Horizon 2020 research programme, the active photon interrogation method is assessed to characterize packages containing concrete matrices. Two different setups are studied: on the one hand a stationary system based on a 9 MeV linac; on the other hand a mobile system based on a 7 MeV linac. However, characterization of nuclear waste packages using a linac operated at an energy below 10 MeV is not straightforward. Undoubtedly, compared to 9 MeV, the challenge is even higher at 7 MeV, and will require the most effective measurement protocol and sensitive detection systems. Moreover, in both cases, the high-energy photon beam delivered by a linac would enable to gather more information on the package matrices thanks to the high-energy imaging technique. The aim of this paper is to present the recent developments in the field of active photon interrogation for nuclear waste package characterization with mobile or stationary systems based respectively on 7 or 9 MeV linacs. First, performances of the photofission technique with a 7 MeV linac will be assessed by Monte Carlo simulation using both PHITS and MCNP6 codes. Accuracy of cross-sections around the energy threshold of the photofission reaction will be discussed. Secondly, performances of the photofission technique with a 9 MeV linac will be assessed experimentally at the SAPHIR platform (CEA Paris-Saclay, France) using mock-up packages with different matrices including concrete and containing either uranium or plutonium samples. Delayed neutrons from photofission will be detected using <sup>3</sup>He-filled gas proportional counters, and high-energy delayed gamma-rays will be detected using large size plastic scintillators. Comparison between simulation and experimental results will enable to validate the MCNP6 simulation model. The latter will then be used to evaluate performances obtained with the photofission technique and a 9 MeV linac on larger packages and more complex package geometries.

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