Contribution ID: **117** Type: **Poster**

#4-117 Photon flux characterization of a 15 MeV electron linear accelerator in the CINPHONIE irradiation facility

Tuesday, June 10, 2025 4:55 PM (5 minutes)

Electron linear accelerators (LINACs) are versatile and powerful X-ray sources, which can be used in medical radiotherapy as well as in various industrial applications including non-destructive testing, imaging and security inspection. LINACs accelerate electrons by passing them through a series of oscillating electric fields within a vacuum tube. These high-energy electrons are then directed toward a metallic target, producing X-rays (bremsstrahlung radiation) when they decelerate upon impact.

In the field of non-destructive radioactive waste characterization, high-energy photon imaging (radiography, tomography) is used on large cemented radiological waste containers, with a volume of the order of 1 m3, to check their integrity and assess their content [1][2]. However, for such packages, passive gamma-ray spectroscopy, passive neutron counting and even active neutron interrogation fail in measuring nuclear materials, like plutonium and uranium. Therefore, high-energy photon interrogation techniques is being studied to detect and quantify nuclear materials through the detection of induced-photofission particles.

For the past years, CEA has been developing high-energy imaging [3] and photon interrogation techniques [4] in CINPHONIE irradiation bunker (CHICADE facility, CEA IRESNE, Cadarache, France). CINPHONIE was recently upgraded with a new K15 VARIAN accelerator, reaching a maximum dose rate of 130 Gy/min at 1 m from the target. The stability of the dose rate, as well as the reproducibility was greatly improved compared to the previous setup with a legacy SATURNE LINAC [4]. New features are also available: two operation modes (9 MeV or 15 MeV), online dose rate monitoring and beam shaping thanks to high-density collimation blocks.

For advanced techniques (high-energy photon and photoneutron activations, photofission, bi-energy imaging), it is paramount to simulate precisely the irradiation field. For that purpose, a numerical model of the LINAC internals was built (with MCNP 6.3). It aims at simulating photon and neutron fields in view to calculate dose rates and reaction rates in irradiation samples, waste packages, but also in the whole casemate (background).

A thorough characterization campaign carried out to validate and calibrate this MCNP model against various experiments will be reported, including dose rate measurements in a water tank and delayed gamma-ray spectroscopy of thin gold and nickel foils activated in the X-ray beam. These experimental results will be used to fine-tune the electron source energy distribution, in view to model as reliably as possible the X-ray energy spectrum. Its high-energy part is indeed particularly crucial for photofission studies, and modeling properly the whole spectrum shape at 9 MeV and 15 MeV is of utmost importance for bi-energy studies. We will also check consistency of the simulated spectrum intensity with the experimental LINAC current.

[1] B. Pérot, et al., "The characterization of radioactive waste: a critical review of techniques implemented or under development at CEA, France, "EPJ Nuclear Sciences & Technologies, 4, 3 (2018). doi.org/10.1051/epjn/2017033
[2] M. Kistler, et al., "Simulated performances of very high energy detectors for nondestructive computed tomography characterization of large objects."IEEE Transactions on Nuclear Science, 65(9):2527–2532, 2018.
[3] N. Estre, et al., "High-Energy X-Ray Imaging Applied to Nondestructive Characterization of Large Nuclear Waste Drums,"IEEE Transactions on Nuclear Science, 62(6), 3104–3109, (2015). doi.org/10.1109/TNS.2015.2498190
[4] M. Delarue, et al., "New measurements of cumulative photofission yields of 239Pu, 235U and 238U with a 17.5 MeV Bremsstrahlung photon beam and progress toward actinide differentiation,"Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1040, 167259, (2022). doi.org/10.1016/J.NIMA.2022.167259

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Session Classification: #04 - Research Reactors and Particle Accelerators

Track Classification: 04 Research Reactors and Particle Accelerators