Validation of the Monte-Carlo efficiency calculation of the LOENIEv2 long counter for delayed neutron measurements

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Abstract: LOENIEv2 is a long counter detector designed by CEA for delayed neutron (DN) yield ν_d and group constant (a_k,λ_k) measurements. It is composed of sixteen ^{3}He tubes embedded in a cylindrical high-density polyethylene (HDPE) matrix. The general formulation linking ν_d to the detector counting rate requires a prior knowledge of the DN energy spectra χ_d(E) as a weighting function of the detection efficiency $\varepsilon(E)$. As these data are poorly known, except for the 20 most abundant DN precursors, it is recommended to minimize the energy dependence of $\varepsilon(E)$, so that their contribution vanishes. Design calculations of the LOENIEv2 detector were performed with the TRIPOLI-4® Monte-Carlo to meet this requirement. Thanks to a special arrangement of the ^{3}He tubes in three concentric rings, variations of the total efficiency as low as 2% can be reached over the [0.1 – 1 MeV] energy range. The purpose of this paper is to confirm these design calculations thanks to calibrated neutron source measurements, performed at the NPL institute. These sources are in the form of small cylinders containing either a spontaneous fission material (^{252}Cf) or a radioactive material producing neutron through (α,n) reactions (AmLi, AmB, AmF, AmBe). These sources are well characterized in emission rate, spectrum and anisotropy so that they can used as standards for efficiency calibration. Moreover, the availability of several sources of the same materials with a diversity of emission rates, provides a convenient way to validate the dead-time correction model up to 5.10^4 c/s. The study concludes that the agreement between the TRIPOLI-4® simulated and measured efficiencies is better than 1% and that the best agreement is reached with the JEFF-3.3 library. The impact of the nuclear data cross section and thermal scattering data is tested with the JEFF-3.1.1, JEFF-3.3, JENDL-4.0 and ENDF/B-VIII.0 libraries and is shown to be low. At last, the TRIPOLI-4® model of LOENIEv2 is applied to compute the detection efficiency for delayed and prompt neutron measurement from the thermal neutron induced fission of ^{235}U. A Total Monte-Carlo approach is applied to propagate the uncertainty due to the energy spectra and due to the technological data of the long-counter.