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Evaluation of different software codes for the analysis of gamma spectra for the potential use in nuclear forensics

Gamma spectrometry plays an important role as a non destructive method in nuclear forensics. In this work an evaluation of the analysys of different uranium containing materials, measured on two High Purity Germanium (HPGe) detector types (planar and coaxial) and analyzed using four software packages is presented. For the purpose of the analysis efficiency transfer software Angle and EFFTRAN were used in comparison to Geant4 and MCNP simulation codes. Both EFFTRAN [1] and Angle [2] present dedicated detection efficiency calculation software, and are based on the efficiency transfer (ET) method. The mechanism of this method is calculating the ratio of the efficiencies for the sample of interest and for the calibration sample and by multiplying it with the measured Full Energy Peak Efficiency (FEPE) of the latter. Monte Carlo simulation, based on Geant4 simulation package [3], has been developed to obtain the response of germanium detectors, with the aim to reproduce experimental spectra of detectors in a wide range of applications in gamma spectroscopy measurements. In the present work, the Geant4 software (version 4.9.5.) was used to obtain the detection efficiencies for different geometries of voluminous sources placed in front of the HPGe detector. As an addition to the Geant4 simulation results, the detection efficiencies were also computed using the MCNP Monte Carlo transport code version 6.2 [4].

Detector 1 is a HPGe low background extended range coaxial detector made by ORTEC with a serial mark GMX-20190. It is an N-type coaxial detector, with a crystal that has a radius of 28.0 mm, a height of 65.2 mm, and an active volume of 160 cm3. Being extended range type, it has a beryllium window which is 99.8 % pure and is 0.5 mm thick. The detector has a 32.4 % relative efficiency, an energy resolution (FWHM) of 1.92 keV at 1.33 MeV, and a Peak to Compton ratio of 54.1. Detector 1 is shielded with multi-layer lead, tin, and copper shielding. The shielding is composed of an outer 120 mm layer of refined low background Pb, 3.5 mm of Sn, and an inner layer of 0.5 mm of a high purity Cu.

Detector 2 is a HPGe planar detector, made by CANBERRA with a serial mark GL2020R. It has a 2000 mm2 active crystal area and 50.5 mm active diameter, with a detection range from 10 keV to 1200 keV. Detector crystal height is 20 mm. The nominal resolution (FWHM) at 122 keV is 680 eV.

Uranium containing samples were measured on both detectors and the obtained spectra were analyzed by EFFTRAN and ANGLE software. The obtained results of the efficiencies and activity concentrations were compared with the simulation results of Geant4 and MCNP. The advantages and disadvantages of the use of different detector types (coaxial and planar) were discussed as well as suitability of the use of mentioned software codes in the analysis.

The results supported the improvement of gamma spectroscopy spectrum analysis methods for the application as a non-destructive tool in nuclear forensics analysis. As an outcome of the project, a close scientific collaboration between research teams from neighbouring states (Serbia and Hungary) was established.

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