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HPGe detector characterisation by means of Monte Carlo simulation through application of Geant4 toolkit

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Over the years High Purity Germanium (HPGe) detectors proved to be an excellent practical tool and as such have established their todays wide use in low background γ-spectrometry. One of the advantages of gamma ray spectrometry is its easy sample preparation as chemical processing and separation of the studied subject in not required. Thus, with a single measurement one can simultaneously perform both qualitative and quantitative analysis. One of the most prominent features of HPGe detectors, besides their excellent efficiency is their superior resolution. This feature virtually allows researcher to perform a thorough analysis by discriminating photons of similar energies in the studied spectra where otherwise they would superimpose within a single-energy peak and as such could potentially scathe analysis and produce wrongly assessed results. Naturally, this feature is of great importance when identification of radionuclides, as well as their activity concentrations, is being practiced where high precision comes as a necessity. In measurements of this nature, in order to be able to reproduce good and trustworthy results, one has to have intially performed an adequate full energy peak (FEP) efficiency callibration of the used equipement. However, experimental determination of the response i.e. efficiency curves for a given detector-sample configuration and its geometry is not always easy and requires a certain set of reference callibration sources in order to account for and cover broader energy ranges of interest. With the goal of overcoming these difficulties, a lot of researches turned towards the application of different software toolkits that implement Monte Carlo method (e.g. MCNP, FLUKA, PENELOPE, Geant4, etc.), as it has proven time and time again to be a very powerful tool. In the process of creating a reliable model, one has to have a well-established and described specifications of the detector. Unfortunately, the documentation that manufacturers provide alongside of the equipment are rarely sufficient enough for this purpose. Furthermore, certain parameters tend to evolve and change over time, especially with older equipement. Deterioration of these parameters consequently decrease the active volume of the crystal and can thus affect the efficiencies by a large marginbif they're not properly taken into account. In this study, the optimisation method of two HPGe detectors through implementation of Geant4 toolkit developed by CERN is described, with the goal of further improving simulation accuracy in calculations of FEP efficiencies by investigating the influence of certain detector variables (e.g. crystal-to-window distance, dead layer thicknesses, inner crystal's void dimensions, etc.). Detectors on which the optimisation procedures were carried out were a standard traditional co-axial extended range detector (XtRa HPGe, CANBERRA) and a broad energy range planar detector (BEGe, CANBERRA). Optimised models were verified through comparison with experimentally obtained data from measurements of a set of point-like radioactive sources. Acquired results of both detectors displayed good agreement with exeperimental data that falls under an average statistical uncertainty of ~ 4.6% for XtRa and ~ 1.8% for BEGe detector within the energy range of 59.4–1836.1 [keV] and 59.4–1212.9 [keV], respectively.

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