

High Purity Germanium Detector Characterization by Means of Monte Carlo Simulation through Application of Geant4 Toolkit

Authors : Milos Travar, Jovana Nikolov, Andrej Vranicar, Natasa Todorovic

Abstract : Over the years, High Purity Germanium (HPGe) detectors proved to be an excellent practical tool and, as such, have established their today's 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 are 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 a 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 the 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 initially performed an adequate full-energy peak (FEP) efficiency calibration of the used equipment. 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 calibration 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 the 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 well-established and described specifications of the detector. Unfortunately, the documentation that manufacturers provide alongside the equipment is rarely sufficient enough for this purpose. Furthermore, certain parameters tend to evolve and change over time, especially with older equipment. Deterioration of these parameters consequently decreases the active volume of the crystal and can thus affect the efficiencies by a large margin if they are not properly taken into account. In this study, the optimisation method of two HPGe detectors through the implementation of the 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 experimental data that falls under an average statistical uncertainty of $\sim 4.6\%$ for XtRa and $\sim 1.8\%$ for BEGe detector within the energy range of 59.4–1836.1 [keV] and 59.4–1212.9 [keV], respectively.

Keywords : HPGe detector, γ spectrometry, efficiency, Geant4 simulation, Monte Carlo method

Conference Title : ICNPP 2022 : International Conference on Nuclear and Particle Physics

Conference Location : San Francisco, United States

Conference Dates : September 27-28, 2022