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Simulation of The Compton Suppression Gamma-ray Spectrometer by MCNPX

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1. Introduction

A new gamma-ray spectrometer with Compton suppression system (CSS) was installed for an instrumental neutron activation analysis in KAERI.

The Compton continuum in a gamma-ray spectrum from an HPGe detector is generated primarily by gamma-rays that undergo one or more scatterings in the detector followed by the escape of the scattered photons from the active volume. In a CSS, the background originated from Compton scattered gamma-rays is reduced by surrounding a primary HPGe detector with a guard scintillation detector like NaI(T1) or BGO. Only events which occur in the primary detector without simultaneous observation of scattered photon in the surrounding guard detector are accepted.

Simulation for the CSS was carried out for optimization of layout geometry of the system by using a MCNPX code.

2. Methods and Results

In this section, the technique used to model and simulate the CSS is described. Further optimization of this model to achieve the optimal model has done.

2.1 The CSS Modeling

Based on the parameters and dimensions of the CSS performed at an NAA lab (KAERI), the CSS model was created by using some tools such as MCNP Visual Editor and SimpleGeo [2].

The modeling of the CSS is necessary for the simulation process. It is therefore important to declare correctly these parameters and dimensions. By using some tools that supply design geometry for MCNP code , it can be easy to do.

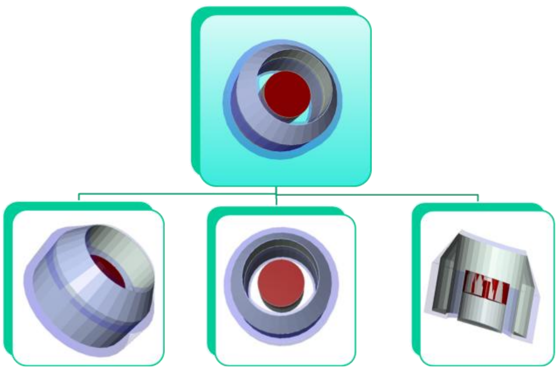

Fig. 1. The layout geometry of the CSS model

2.2 The CSS Simulation

We used MCNPX version 2.5e for these simulations. In these simulations, tally cards with coincidence option [3] were used to handle coincidence events between the HPGe and BGO detector. The detail of modeling geometry is shown in a Fig. 1.

Editing and modification of the MCNPX input code for simulation will generate the resultant gamma-ray spectra for the primary HPGe of the CSS in normal and anticoincidence modes. The suppression factor is defined (1):

$$Suppression\_factor = \frac{PNS}{PS} \quad (1)$$

PNS: Peak-to-Compton ratio without suppression
PS: Peak-to-Compton ratio with suppression

Peak-to-Compton suppression is defined as a ratio of the counts in the highest photopeak channel to average counts in the associated Compton continuum region.

For a simulated gamma-ray spectrum, the full energy peak appears at a position of the source energy. But the problem is that only a single value is calculated and deposited in the tally without any peak broadening. There is no statistical fluctuation exhibited in the spectrum. In order to simulate the real observed spectrum, one needs to modify the simulated spectrum to account for the statistical fluctuation, which yields a broadened peak and a smoothed spectrum.

The MCNPX approach to this problem is to broaden the peak by changing the energy before the simulated particle is deposited in the tally bin. In MCNPX, this is done by replacing the original energy with a random sampled energy from a Gaussian distribution, which is centered at the original particle energy and has a particular standard deviation. To determine this Gaussian distribution, one needs to know the mean which is the original particle energy and the standard deviation (σ) [4]. The formula used in a MCNPX for calculating σ is given as eq. (2):

$$\sigma = a + b(E + cE^2)^{(1/2)} \quad (2)$$

For the HPGe detector, we assume that a, b and c constants are 73.56×10^{-5}, 85.95×10^{-5} and 48.98×10^{-2}, respectively. For the BGO detector, these are -1.47×10^{-2}, 10.55×10^{-2} and 0.0, respectively.

This CSS model has been simulated using several standard sources such as ^{60}Co and ^{137}Cs to getting the gamma-ray spectra from an HPGe detector in normal and anti-coincidence modes.

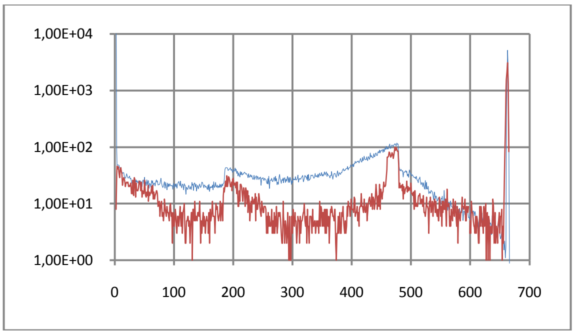

Fig. 2. The simulation gamma-ray spectrum of ^{137}Cs in normal anti-coincidence modes

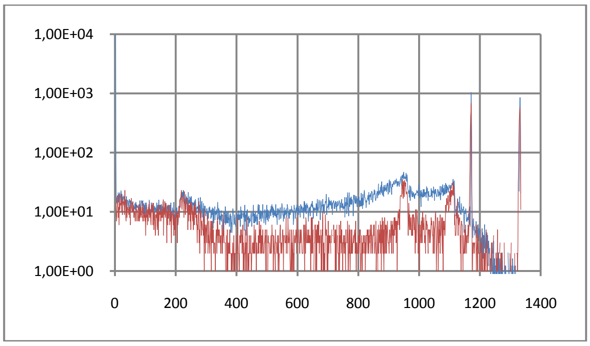

Fig. 3. The simulation gamma-ray spectrum of ^{60}Co in normal anti-coincidence modes

2.3 The Optimal CSS

The some parameters of this CSS model such as the correlative position between HPGe and BGO detectors should be changed to find the best Suppression factor. Then, based on these results one can optimize the correlative position of the BGO detector with the primary HPGe detector.

3. Conclusions

Simulation techniques using MCNPX code are useful tools for designing CSS modeling. It also is useful to generate the gamma-ray spectra of the CSS modeling with normal and coincidence modes.

Therefore, MCNPX code has been used to calculate the gamma-ray spectra and optimize the CSS geometry for NAA application.

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