

Development of DRFWAVE Code for Easy Design and Evaluation of Phoswich Detector

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1. Introduction

The general Monte Carlo codes such as MCNP4C¹⁾ and EGSnrc have been widely used for the analysis of the design characteristics and the response functions of a detector. Especially, precise reproduction of detector response functions (DRFs) is essential to the detector design. But it is difficult to precisely reproduce DRF since the energy resolutions of the detector components and the electronic noise influence the amount and the energy range of light output generated from the crystal.

However, most of the Monte Carlo codes are so complicated that it is not easy to appropriately use for beginners. It is, therefore, to develop a code system in order for easily designing a phoswich detector and analyzing its design characteristics through a graphical user interface without a detailed way of using the Monte Carlo codes.

2. Methods and Results

2.1 Components of the Detector Response Function

The Monte Carlo codes cannot directly consider the each contribution of detector component by the energy resolution because they can just calculate the amount of energy deposition absorbed in scintillator²⁾. But the γ -ray response function obtained from the MCA (Multi-channel Analyzer) includes the effect of energy resolution of detector components as well as the noise of electronic devices.

The total energy resolution δ_{total} of the full-energy peak measured with a scintillator coupled to a photomultiplier can be described as:

$$\delta_{\text{total}}^2 = \delta_{\text{intrinsic}}^2 + \delta_{\text{transfer}}^2 + \delta_{\text{PMT}}^2$$

where $\delta_{\text{intrinsic}}$ is the intrinsic resolution of the scintillator, δ_{transfer} is the transfer resolution, and δ_{PMT} is the PMT contribution to the resolution as shown in Figure 1. The transfer component of energy resolution in modern scintillation detectors can often be neglected. Some processes are additionally needed for considering the resolution of the detector components and correcting the Monte Carlo results.

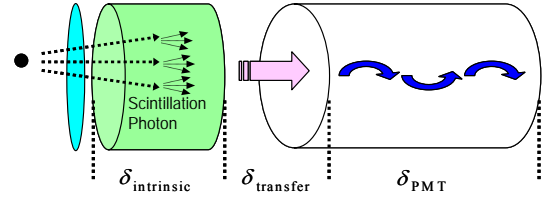


Figure 1. The energy resolution of each component of the phoswich detector

The full-energy peak has a tendency to be broadened by the energy resolution reflecting the inherent characteristics of each component. The σ_{total} (total standard deviation), which was used for Gaussian spread of the spectra generated by Monte Carlo code, can be obtained from δ_{total} . The spectra for applying Gaussian broadening $G(E_{C,i} \rightarrow i)$ is obtained from the following formula:

$$G(E_{C,i} \rightarrow i) = \int_{E_i}^{E_i + \Delta E_i} \frac{1}{\sqrt{2\pi}\sigma(E)} \exp\left(-\frac{(E_{C,i} - E)^2}{2\sigma^2(E)}\right) dE$$

where $E_{C,i}$ is the pulse height in i th channel and $\sigma(E)$ is the σ_{total} according to the incident γ -ray energy.

2.2 Development of DRFWAVE Code System

In this work, a code system using MCNP4C and PV-WAVE, which was named DRFWAVE, was developed to conveniently design the specific phoswich detectors and analyze its design characteristics. MCNP4C was used for photon transport in CsI(Tl) scintillator, and PV-Wave³⁾ was used to provide the environment for graphical user interface and the module for applying the resolution of the detector.

The phoswich detector designed by KAERI was used as the standard model in this study. It consists of CsI(Tl) and plastic scintillator for detecting the γ and β -ray, respectively. The DRFWAVE provide the environment to easily change the thickness, length, and diameter of CsI(Tl) scintillator as well as the housing of the detector for designing the new phoswich. Figure 2 shows the

screen shot that the new phoswich detector is designed and analyzed using the DRFWAVE.

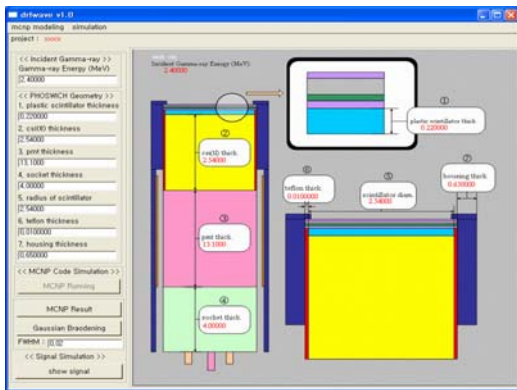


Figure 2. The screen shot of an application (DRFWAVE) for reproducing the phoswich DRF

Using the DRFWAVE code system, people can easily reproduce the phoswich DRF and analyze the design characteristics of the new model according to the change of the detector design and incident γ -ray energy. Figure 3 shows the DRF without Gaussian broadening (solid line) and the broadened spectra (dotted line) calculated by using Gaussian broadening module of the DRFWAVE.

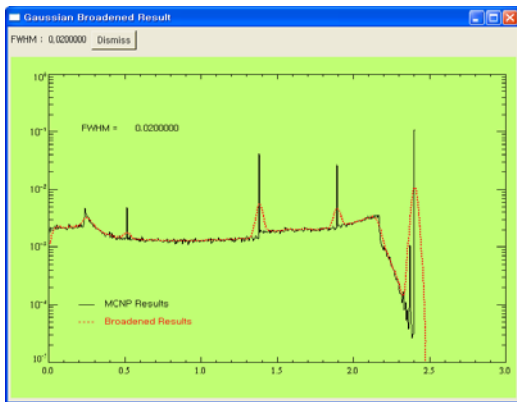


Figure 3. Analysis of phoswich DRF using DRFWAVE

2.3 Reproduction of the Dynamic signal from MCA

The DRFWAVE also provided the simulation module for reproducing the dynamic signal from MCA, which sort out incoming pulses according to pulse height and keep count of the number at each height in a multi-channel memory.

The PTRAC card of MCNP4C enables us to obtain the information about every particle event, individually. The MCA module of the DRFWAVE read the output file generated from PTRAC card and produce the pulse height

tallies every 1000 history like a MCA of real detector system. Figure 4 is the pulse height tallies according to the energy deposition in crystal produced by the MCA module.

The reproduction of dynamic signal from MCA simulation module is based on the amount of the energy deposition in crystal.

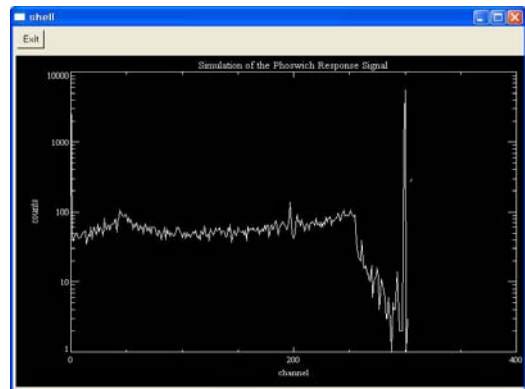


Figure 4. The simulation of the signal generated from MCA of the phoswich detector system

3. Conclusion

The DRFWAVE code was constructed for designing new phoswich detector and analyzing its design characteristics without a detailed way of using the Monte Carlo code. In the DRFWAVE code, the MCNP4C code was coupled with PV-WAVE to provide the GUI and support the precise calculation of the phoswich DRF. Using DRFWAVE code system, it is possible to design the specific phoswich detector and easily evaluate its design characteristics even for beginners of complicated Monte Carlo codes.

Acknowledgement

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