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Semi-empirical Determination of Detection Efficiency for Voluminous Source by Effective Solid Angle Method

M.Y. Kang[a], J.H. Kim[a], H.D. Choi[a] and G.M. Sun[b]
[a]*Department of Nuclear Engineering, Seoul National University, Seoul, Korea*
[b]*Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea*
vandegra@plaza.snu.ac.kr

1. Introduction

In the field of γ-ray measurements, the determination of full energy (FE) absorption peak efficiency for a voluminous sample is difficult, because the preparation of the certified radiation source with the same chemical composition and geometry for the original voluminous sample is not easy. In order to solve this inconvenience, simulation or semi-empirical methods are preferred in many cases [1-4].

Effective Solid Angle (ESA) Code which includes semi-empirical approach has been developed by the Applied Nuclear Physics Group in Seoul National University. ESA code converts FE absorption peak efficiency determined by using reference point γ–ray sources into that for a volume source such as a cylinder or a Marinelli beaker shape.

In this study, we validated ESA code by using Marinelli type voluminous KRISS (Korea Research Institute of Standards and Science) CRM (Certified Reference Materials) sources and IAEA standard γ–ray point sources. And semi-empirically determined efficiency curve for voluminous source by using the ESA code is compared with the experimental value.

2. Method

The procedure for semi-empirical determination of the FE efficiency for the arbitrary volume sources converted from that for the point source is explained in previous studies [2-4]. ESA code calculates the effective solid angle considering attenuation of γ-rays in source, medium, detector and adjacent materials. γ-ray generated in the source region are transported to the detection area (Ge crystal), and FE absorption events are simulated at each medium. Incomplete charge collection is not considered. ESA code can deal with various source shapes like point, disk, cylinder, sphere, Marinelli container and the volume sources larger than the detector diameter. ESA code is written in Matlab language and the attenuation coefficients were obtained from NIST X-COM code [5].

3. Experiment

The absolute FE efficiency of the standard IAEA point source (ε_{pt}) is determined at 25cm distance from the detector. And KRISS certified reference material (CRM) voluminous γ-ray sources were also measured on top of the detector head to compare the semi-empirically calculated efficiency curve for voluminous source (ε_{vol}).

Radionuclides are dissolved in a dilute HCl solution and a solid medium (agar) in polyethylene Marinelli container. The information of source and detector used in this study is shown in table 1 and 2, respectively, and the Marinelli container and the detection geometry is shown in figure 1.

Table 1. List of γ-ray sources

Source	Classification	Contents
IAEA standard point source	Nuclide	^{60}Co, ^{137}Cs, ^{152}Eu, ^{133}Ba, ^{241}Am
KRISS CRM volume source	Nuclide	^{60}Co, ^{137}Cs, ^{113}Sn, ^{109}Cd, ^{241}Am, ^{139}Ce, ^{51}Cr, ^{85}Sr, ^{88}Y, ^{57}Co
	Volume	450ml
	Type	Marinelli beaker
	Medium	0.1M HCl solution 0.1M HCl agar

Table 2. Specification of detector and the experimental condition

	Contents
Detector	n-type coaxial HPGe (ORTEC) Relative efficiency : 31.7%
Location	Pb shield
Time	2 hours
Source to detector distance	IAEA point source : 25 cm KRISS CRM volume source : 0 cm

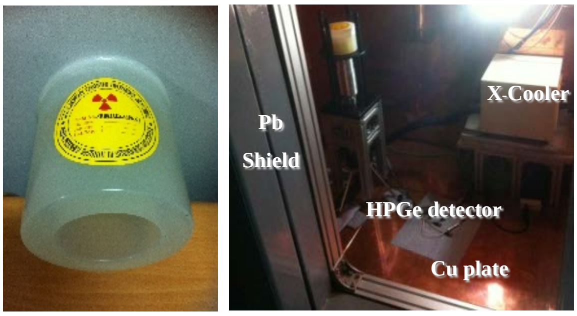

Fig.1. KRISS volume source and the detection geometry

4. Analysis and Result

HyperGam code [6] was used to analyze the area of peaks in spectra. The detection efficiency curve for point sources at 25 cm from the detector window was determined by measurement. And this value was used as input data for the determination of that for voluminous source. Figure 2 shows the measured and calculated result of FE efficiencies. ESA code calculates the effective solid angle and absolute FE efficiency curve at the result window for voluminous source as shown in figure 3. The efficiency curve can be calculated for two case of with or without coherent scattering attenuation coefficient. The curve without coherent scattering (blue line) is commensurate with measured curve in the lower energy region.

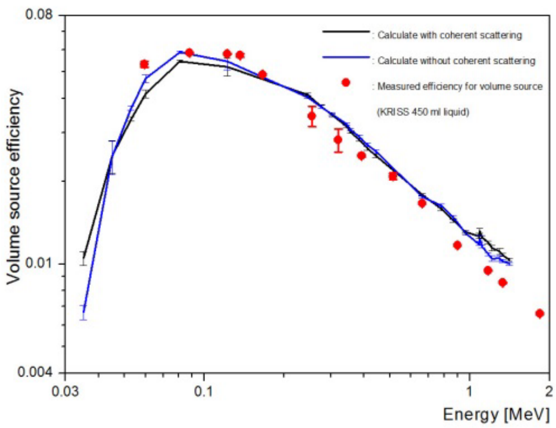

Fig.2. Comparison of efficiency curve for voluminous source between calculation and the experimental value.

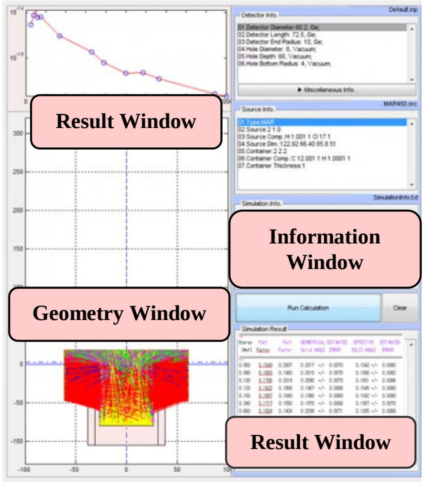

Fig.3. Result window of ESA code.

5. Conclusion and Further Work

We calculated the efficiency curve of voluminous source from the measured efficiency of standard point source by using the ESA code. We will carry out the ESA code validation by measurement of various CRM volume sources with detector of different efficiency.

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