Determination of Detection Efficiency for Voluminous Gamma-ray Sources at Collimation Geometry

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1. Introduction

For the various types of γ-ray sources considering the geometrical effect and attenuation, determination of the full energy absorption peak(FEP) efficiency(detection efficiency) is one of the important processes of the γ-ray activation analysis. To calculate detection efficiency for arbitrary volume sample, we developed and verified the EXVol (Efficiency calculator for eXtended Voluminous source) code which is based on effective solid angle method[1]. The procedure for semi-empirical determination of the FEP efficiency for the arbitrary volume sources and the calculation principles about EXVol code were validated in previous study [2].

In this study, we extended and verified the performance of the EXVol code. The previous EXVol only determined the detection efficiency of the source-detector coaxial structure for the whole volume source. After expansion of the performance, EXVol can calculate both coaxial and asymmetric structure. In addition, the introduction of a collimator made it possible to reduce the radiation intensity of a high radiation source. And it is possible to determine the precise detection efficiency according to the energy of a γ-ray at a specific position of the volume source.

2. Methods

The volume source was described as 3- dimensional (x,y,z) cylindrical source at a asymmetric geometry. It is shown in Figure 1. A collimator was placed between source and detector to consider the scanning and detecting at a specific position in a large volume source. The input values for defining the collimator include matter, density (g/cm3), hole diameter (mm) and thickness (mm) of a collimator.

To calculate the asymmetric structure, the radial direction of the volume source was assumed to be uniform. The x- coordination of the detector center was set to 0 and translation of the detector was considered by the direction and distance of movement. If the detector is moved to the left side of the source, minus value of the translated distance is entered to the EXVol code and if the detector is moved to the right side of the source, plus value of the translated distance is entered to the EXVol code.
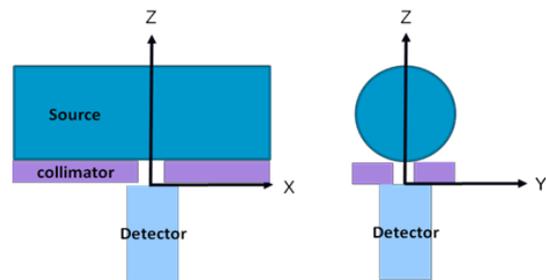

Fig. 1. Coordinate system of asymmetric geometry.

To verify the performance of the EXVol, a high resolution gamma spectroscopy system was constructed and measurement and analysis were performed. Measurements were performed on coaxial, asymmetric and collimated structures with standard point source and standard volume source (1 L, liquid medium, cylindrical) and HPGe detector (efficiency 40%, N-type). And a collimator was installed between the source and the detector. So detector was scanning in the height direction of the volume source. The source and detector used in the experiments are shown in Figure 2.

The measured results were compared with the calculation results of EXVol. We calculated the same situation as the experiments. And comparison of experimental and measured values was confirmed by relative deviation. The calculated value minus the measured value was divided by the measured value.

Fig. 2. Standard sources (point: left, volume: middle) and Measurement environment(right).

3. Results

The relative deviation of the measurement and calculation in the coaxial (without collimator) geometry was less than $\pm10\%$. It is shown in Figure 3. And the relative deviation of the measurement and calculation in the coaxial and asymmetric (with collimator) geometry was less than $\pm20\%$. It is shown in Figure 4. The comparison between the measured and calculated results while the detector moves in the height direction of the source is shown in Figure 5 and Figure 6.
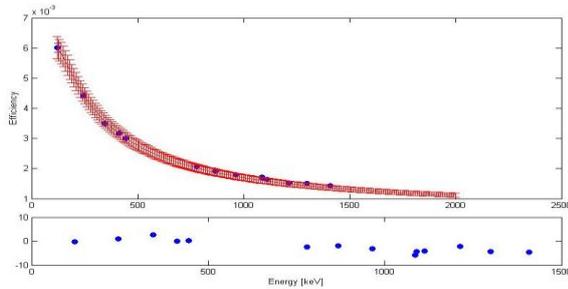

Fig. 3. The detection efficiency(upper box) and a relative deviation(down box) about EXVol calculation(red line) and the experimental value(blue dot) at a coaxial geometry(without collimator).
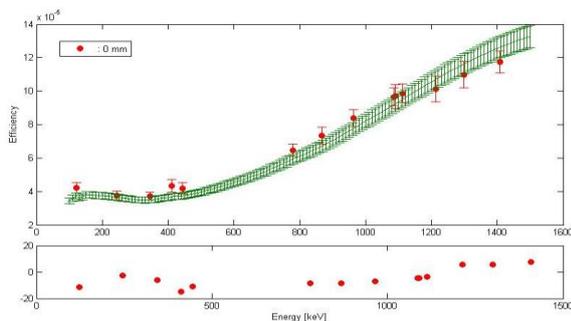

Fig. 4. The detection efficiency(upper box) and a relative deviation(down box) about EXVol calculation(green line) and the experimental value(red dot) at a coaxial geometry(with collimator) at a center point of height.
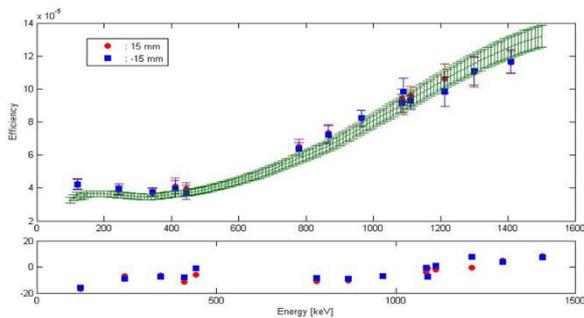

Fig. 5. The detection efficiency(upper box) and a relative deviation(down box) about EXVol calculation(green line) and the experimental value(blue square and red dot) at a coaxial geometry(with collimator) at ±15 mm translated position from the center point of height.
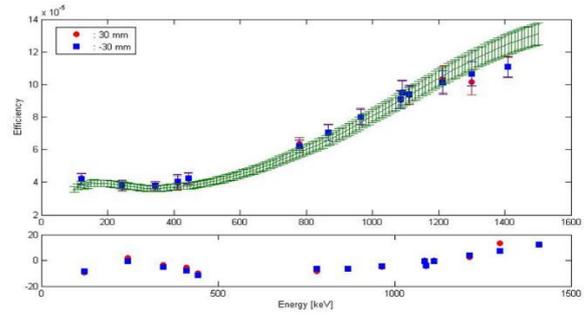

Fig. 6. The detection efficiency(upper box) and a relative deviation(down box) about EXVol calculation(green line) and the experimental value(blue square and red dot) at a coaxial geometry(with collimator) at ±30 mm translated position from the center point of height.

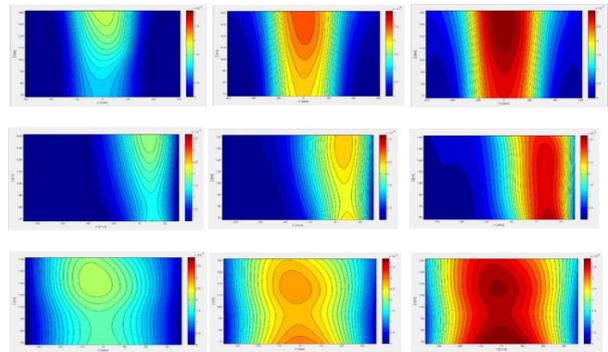Figure 7 shows the contour plot of detection efficiency distribution.

Fig. 7. Picture of detection efficiency distribution at zx plane. First row shows the detection efficiency distribution at a center position. Second row shows detection efficiency distribution of ±15 mm translated position and third row shows detection efficiency distribution of ±30 mm translated position. And from left to right, energy is 500, 1000, 1500 keV respectively.

4. Conclusions

We have established a method for calculating the detection efficiency of the differential volume corresponding to a specific position in the large volume source. As a result of this study, γ-ray detection efficiency and radiation distribution were obtained.

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