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Modified Effective Solid Angle Code for the Efficiency Calculation of Volume Sample

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1. Introduction

It is relatively easy to determine the full energy peak efficiency by experiment in the case that the point source is away from the detector, but it would be a boring and difficult work in the case of volumetric source in close geometry. And it is not practical to prepare the standard sample emitting gamma-rays with the same geometry with the actual samples. Hence, the calculation is sometimes preferred and many works have dealt with various methods [1,2,3]. Moens et al. suggested the concept of effective solid angle by taking the attenuation effect of gamma-ray in the source and detector materials. The procedure to determine the peak efficiency for the source of arbitrary shape. 1) Determination of absolute peak efficiency for the standard point source away from the detector so that the coincidence summing of gamma-rays is negligible. 2) Calculation of effective solid angle for the volume and point sources. 3)Conversion of the peak efficiency for the point source to that for the volume source using the ratio of effective solid angles.

Effective Solid Angle Code has been used for years in the actual counting condition using an extended volume sample [3]. In this study, we modified the code to take into account the detail structure of the detector like insensitive region within crystal, detector end radius, end cap and mount holder geometry and so on.

2. Methods

2.1 Effective solid angle code

Effective solid angle is calculated from the following 3 conditions. 1) There is no energy attenuation in a source and adjacent absorption layers, 2) Interacting photon deposits all the energy to the sensitive region and it is recorded as a full energy absorption event. Incomplete charge collection is not considered here. And 3) Coherent scattering doesn't make energy absorption and its path variation is negligible in the energy range of interest. Hence, attenuation coefficient without coherent scattering is used.

Fig. 1 shows a generalized detection geometry with a gamma-ray source with an arbitrary shape. For volume source, effective solid angle considering gamma-ray attenuation in source detector and adjacent absorbers is given as

$$\overline{\Omega} = \int_{z_s}\int_{y_s}\int_{x_s}\int_{y_{cf}}\int_{x_{cf}} \frac{G_{att} H_{eff} z_s\, dx_{cf}\, dy_{cf}\, dx_s\, dy_s\, dz_s}{[(x_s-x_{cf})^2+(y_s-y_{cf})^2+(z_s-z_{cf})^2]^{\frac{3}{2}}}, \quad \textbf{(1)}$$

where G_{Att} is an attenuation factor representing the gamma-ray attenuation in air, end cap window, insensitive region and so on. And H_{eff} is an efficiency factor representing a probability that gamma-ray interacts with a sensitive region. Modified ESA code was coded with Compaq Visual Fortran 6.1 and the photon attenuation coefficients were obtained from XCOM software [4].

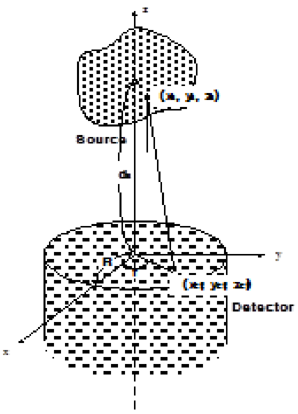

Fig. 1. Generalized gamma-ray detection geometry.

2.2 Detector End Radius

Fig. 2 shows an example of detail layout of the detector and source geometry with cylindrical shape. In this study, the thickness of insensitive layer is fine-tuned and the detector end radius is taken into account.

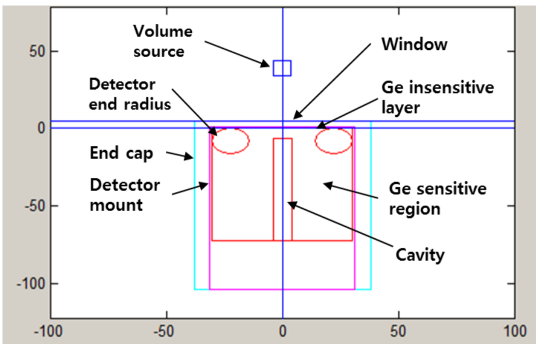

Fig. 2. Detail of detector and source geometry

Fig. 3 shows a variation of the pathlength of gamma-ray according to the angle incident on the Ge crystal when the source is 30 mm away from the surface of the end cap window. When the detector end radius increases, efficiency factor H_{eff} decreases because the pathlength in that sensitive region decreases.

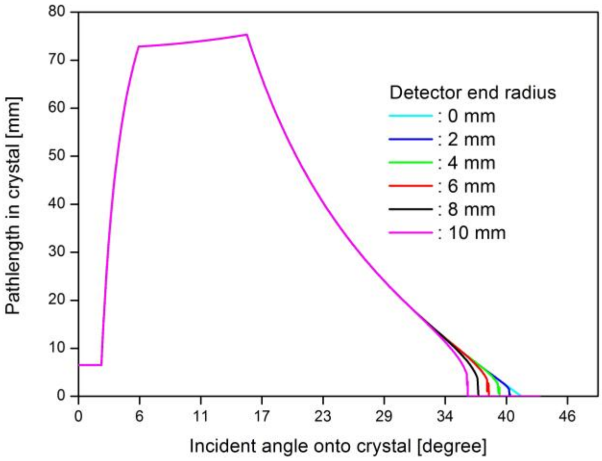

Fig. 3. Pathlength of the gamma-ray in the sensitive region according to the incident angle on the crytal by varying the detector end radius.

2.3. Effective solid angle

Full energy peak efficiency for volume source (ε_{vol})is converted from that for point source(ε_{pt}) using the ratio of the effective solid angle like

$$\varepsilon_{vol} = \varepsilon_{pt} \cdot \frac{\overline{\Omega}_{vol}}{\overline{\Omega}_{pt}} \tag{2}$$

, where $\overline{\Omega}_{vol}$ is an effective solid angle for volume source and $\overline{\Omega}_{pt}$ is that for point source, respectively. Fig. 4 shows the effective solid angle ratio between volume and point sources according to the photon energy. Volume source has a diameter of 15 mm and a length of 10 mm. As shown in the figure, the ratio decreases when the photon energy becomes low. For the sample made of Ce element, the ratio is much lower rather than that for the Al sample because the gamma-ray self-absorption in the Ce is much higher.

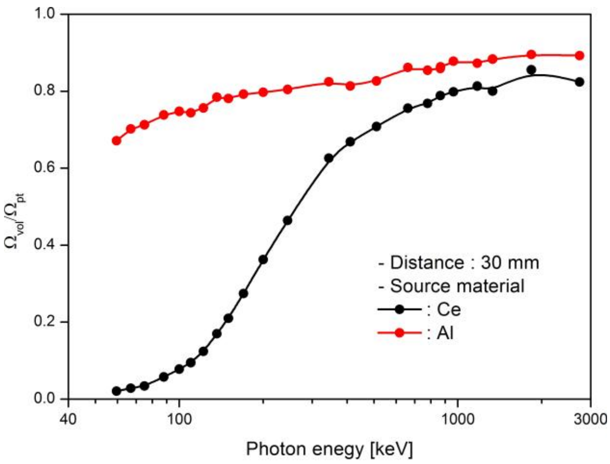

Fig. 4. Effective solid angle ratio between volume and point sources according to the photon energy.

3. Conclusions

In this study, we modified the effective solid angle code by introducing fine tuning method of the insensitive layer and the detector end radius. Pathlength of the gamma-ray is affected by the detector end radius, which means the efficiency factor is varies according to the detector end radius. And the effective solid angle ratio is strongly affected by the photon energy. Especially in the lower energy gamma-rays, the peak efficiency for the volume source is carefully calculated by considering the source and detector geometries and the associated attenuation factors in the absorbing media such as source, air, end cap window, insensitive layer and so on. The modified effective solid angle code can be widely utilized for the source with an arbitrary shape besides the cylindrical shape.

Acknowledgements

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REFERENCES

[1] L. Moens, J. De Donder, Lin Xi-lei, F. De Corte, A. De Wiselaere, A. Simonits and J. Hoste, Nucl. Instr. And Meth. 187 (1981) 451.

[2] G.M. Sun, H.D. Choi, Calculation of the Absolute Peak Efficiency of the HPGe Detector by using Point Detector Concept, Transactions of the Korean Nuclear Society Autumn Meeting, Daejeon, Korea, October 26~27, 2000.

[3] G.M. Sun, H.D. Choi, Development of Effective Solid Angle Code for the Calculation of Absolute Peak Efficiency, ANPG Annual Report, Department of Nuclear Engineering, Seoul National University, 2000.

[4] "http://physics.nist.gov/PhysRefData/Xcom, XCOM : Photon Cross Sections Database"