Calculations of an HPGe Detector Peak Efficiency Curve up to 11 MeV with EGS4 and GEANT4

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We determined an efficiency curve of an HPGe detector in the energy range of 0.3 - 11 MeV within 0.5 % accuracy with the measured data of the $^{14}N(n,\gamma)^{15}N$ reaction and the aid of the Monte Carlo cords EGS4 and GEANT4.

1. Introduction

A precise efficiency curve up to 11 MeV is needed for the precise measurements of intensities of prompt γ-rays. Methods of the determination of peak efficiency curves of HPGe detectors have been studied. The typical method is by fitting the measured data sets. Raman et al. [1] determined an efficiency curve by using fitting functions with 2 % accuracy in the energy range of 0.1 - 11 MeV (Fig.1). Recently, Helmer et al. [2] determined one by using the CYLTRAN code within 0.2 % in the energy range of 0.2 - 1.4 MeV (Fig.2). In this study, we extended to 11 MeV with the measured data of the $^{14}N(n,\gamma)^{15}N$ reaction. We attempt to determine the efficiency curve in the energy range of 0.3 - 11 MeV within 0.5 % accuracy by using of the Monte Carlo codes EGS4 [3] and GEANT4 [4].

2. Experiments and calculations

2.1 measured efficiencies

The peak efficiencies of a 22 % coaxial HPGe detector were measured by using decay γ-rays from the ^{24}Na, ^{56}Co, ^{88}Y, ^{133}Ba and ^{152}Eu sources in the energy range of 0.3 - 3 MeV. The distances from the detector face to the sources were 10 cm. The efficiencies also measured by prompt γ-rays from the $^{14}N(n,\gamma)^{15}N$ reaction up to 11 MeV with a 22 cm distance at KURRI. The intensities of prompt γ-rays from this reaction have errors of 2 % in previous papers; we used our recent data to obtain more precise measured efficiencies within 0.5 %. We ascertained that the effect of the different distances between 10 cm and 22 cm is negligible above 1.5 MeV with EGS4.

2.2 calculations

Figure 3(a) shows the initial physical parameters of the detector used in

EGS4. These parameters are provided by the manufacturer (Geometry A in Fig4(a)). The EGS4 values calculated were compared with the measured efficiencies (Fig.4(b)). The values were not agreement with the measured ones. The slopes which constructed by the plots of open circles in Fig.4(b) indicate that the sensitive volume of the detector is smaller than the Geometry A. Therefore, we adjusted length and diameter of the detector for that the EGS4 values agree with the measured efficiencies (Fig.4(a),(c)). We calculated the values with the Geometry B, D and E and compared with the measured ones (Fig.4(b),(c)). As a result, the values with the Geometry E reproduced the measured ones relatively in the wide energy range. Therefore, the Geometry E was adopted for the final detector parameters used in calculations (Fig.3(b)).

We also calculated by using the GEANT4 with the same procedure. The detector parameters used in GEANT4 were a bit different than that used in EGS4.

3. Results

Figure 5 shows the comparison of the calculation values and the measured efficiencies. The calculated values with EGS4 agree with the measured efficiencies below 2 MeV. Above 2 MeV, the values become smaller than the measured ones. On the other hand, the calculated values with GEANT4 agree with the measured efficiencies below 6 MeV. Above 6 MeV, the values become larger than the measured ones. However, we found that the deviation between the values and the measured ones can be taken as a simple function of the energy. Therefore, we could determine the calculated values corrected by using the function.

Figure 6 shows the differences between the calculated values and the measured efficiencies. The calculated values are corrected by the deviation from EGS4. These differences were within 0.5% in the range of 0.3 - 11 MeV. Similarly, correcting the values with GEANT4 was needed. The result is also within 0.5 %

4. Conclusions

The calculation values with EGS4 do not agree with the measured efficiencies above 2 MeV, and the values with GEANT 4 did not agree with the measured ones above 6 MeV. However, we can correct these values with simple functions of energy. Differences between the calculated values and the measured efficiencies are within 0.5 %. Therefore, we can determine an efficiency curve of an HPGe detector within 0.5 % in the energy range of 0.3 - 11 MeV.

We can determine an precise efficiency curve up to 11 MeV with 0.5 % accuracy by the resent measured data of the $^{14}N(n,\gamma)^{15}N$ reaction and the aid of the codes EGS4 and GEANT4.

References

[1] S. Raman, C. Yonezawa, H. Matsue, H. Iimura, N. Shinohara, *Nucl. Instr. Meth.,* A 454 (2000) 389-402

[2] R. G. Helmer, J. C. Hardy, V. E. Iacob, M. Sanchez-Vega, R. G. Nelson, J. Nelson *Nucl. Instr. Meth.,* A511 (2003) 360-381

[3] W. R. Nelson, H. Hirayama, D. W. O. Rogers, SLAC Rep. 265 (1985)

[4] S. Agostinelli *et al*, *Nucl. Instr. Meth.,* A506 (2003) 250-303

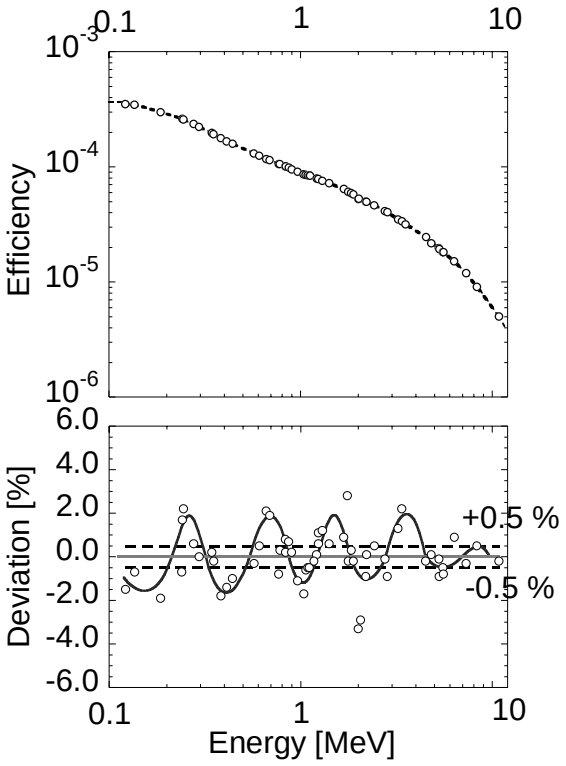

Fig.1 An efficiency curve determined by using the fitting functions up to 11 MeV [1]. In the lower panel, the oscillation caused by the non-physical fitting is shown.

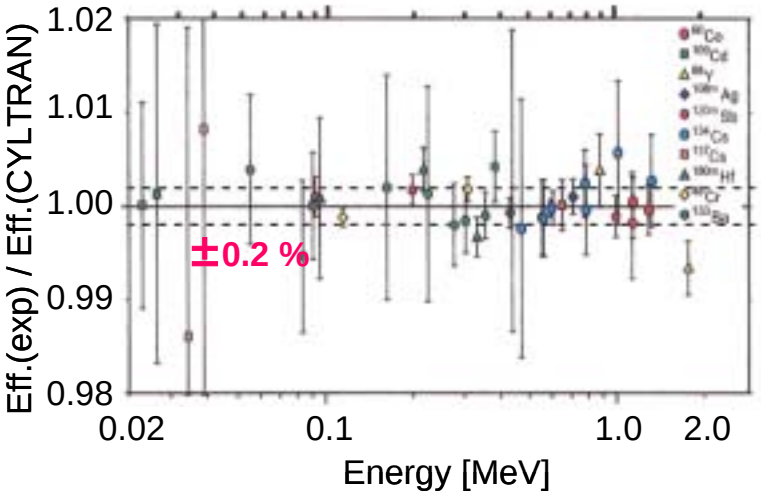

Fig.2 Comparison of the CYLTRAN values with the measured efficiencies up to 1.4 MeV [2]

Fig.3(a) 22 % HPGe detector parameters from manufacturer (Geometry A)

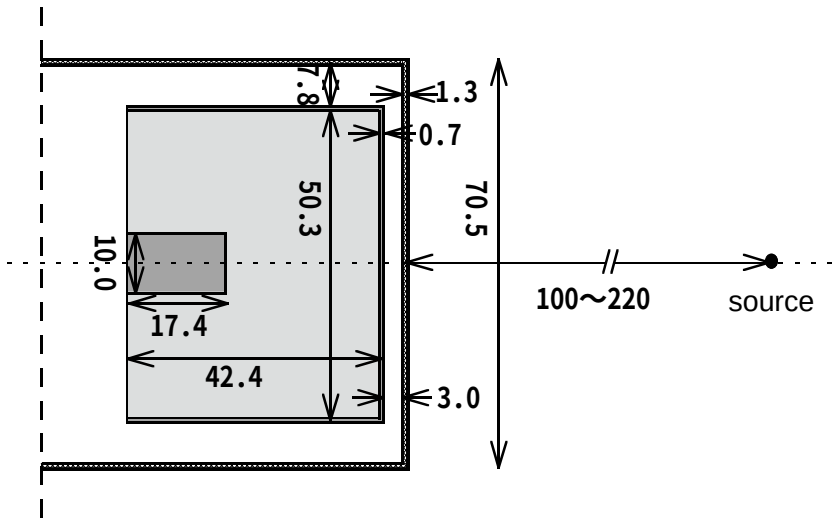

Fig.3(b) The final detector parameters used in EGS4 (Geometry E)

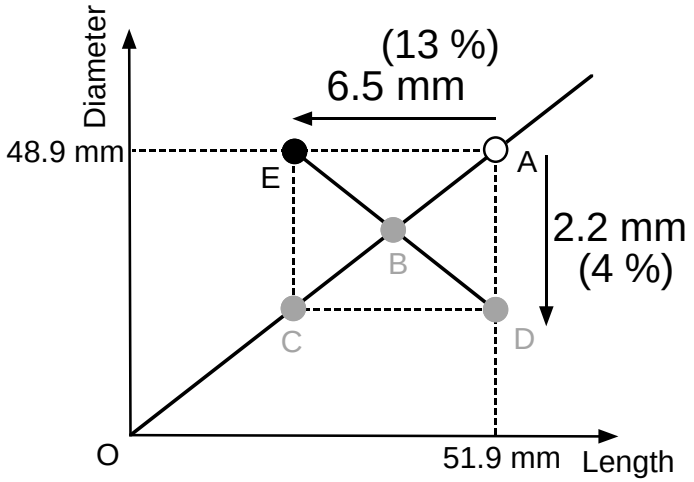

Fig.4(a) Adjustment of the detector length and diameter

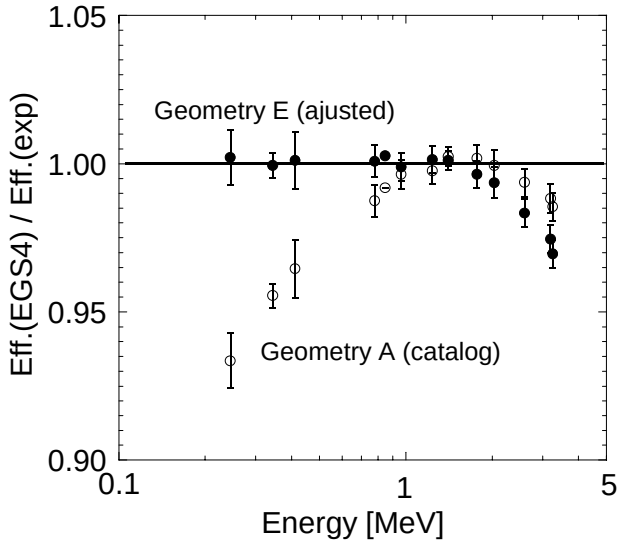

Fig.4(b) The ratio of EGS4 values to measured efficiencies

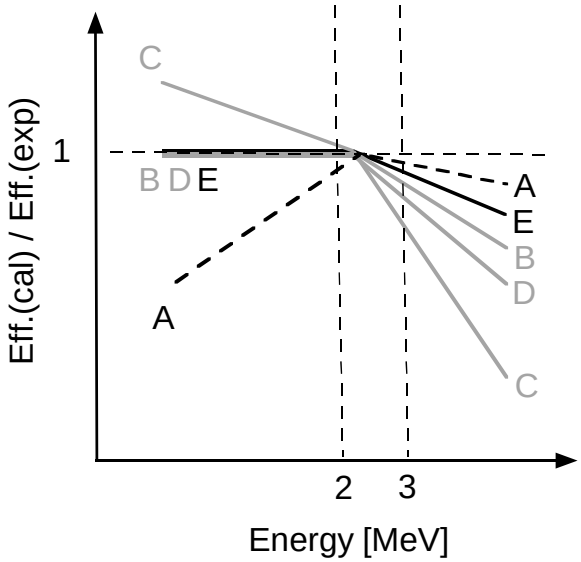

Fig.4(c) The ratio calculated with adjusted detector parameters. The Geometry E is the final parameters.

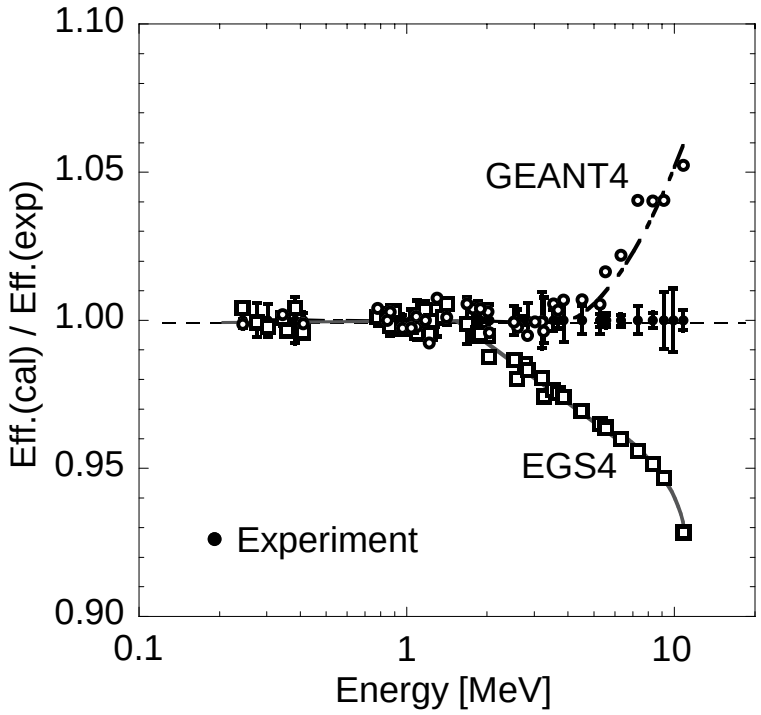

Fig.5 The ratio of the calculation values with EGS4 and GEANT4 to the measured efficiencies. The lines are eye guides.

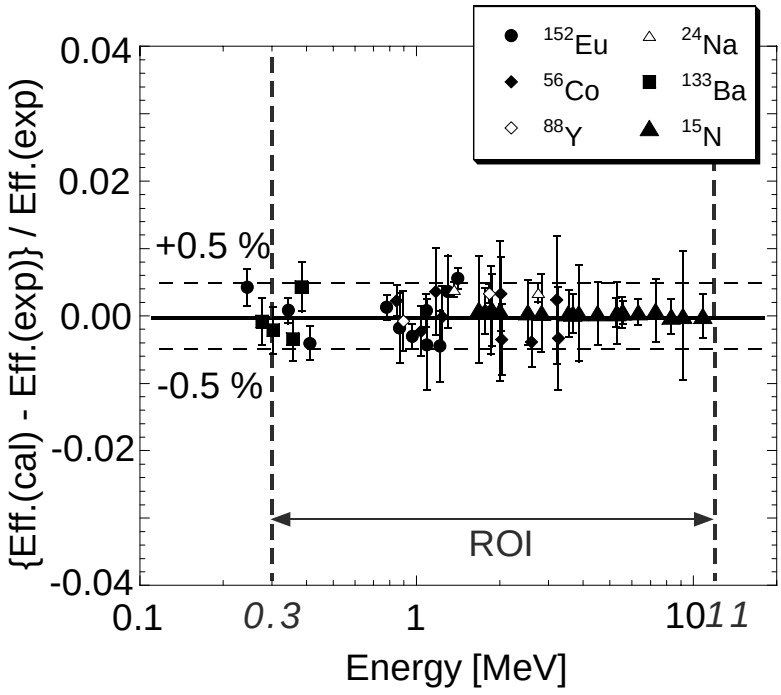

Fig.6 Differences between the calculated values and the measured efficiencies. The calculated ones are corrected by the deviation from EGS4.