# Simulation study on the four-scintillator detectors to identify gamma-emitting radionuclides

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## Abstract

In this study, we derived the relationship between the SLO ratios, and the gamma-ray energies based on the physical properties of the scintillators. The derived relationship between the SLO ratio and the gamma-ray energy can be divided into three regions with a quasi-linearity. Five different kinds of radionuclides that emit poly-energetic gamma-rays can be identified with derived relationship.

## Introduction & Experimental setup

- The scintillation detector is one of conventional radiation detectors used in various applications such as radiation monitoring, medical imaging, and the industrial field. It is preferred due to its cost competitiveness and simplicity.
- However, it is still hard to identify gamma-ray emitting radionuclides with small volume scintillators due to the penetrability of gamma-ray. It is known that the energy resolution decreases as the volume of the scintillator decreases because the scintillator cannot fully absorb the incident gamma-ray. Therefore, it seems like traditional scintillation detector is unsuitable for small size of Personal Radiation Detectors (PRDs) that adopt general gamma spectroscopy technique.
- In previous studies, we suggested the gamma-ray energy estimation algorithm based on the ratio of scintillation light output (SLO). We compared the SLO ratios from Monte Carlo N-Particle (MCNP) simulations and experimental results. Based on the derived relationship, the energy of $^{137}$Cs can be estimated without gamma spectroscopy.
- In this study, we derived the relationship between the SLO ratios, and the gamma-ray energies based on the physical properties of the scintillators. The relationship between the SLO ratios and the gamma-ray energies according to inorganic scintillators can be divided into three regions with a quasi-linearity.
- Based on Beer-Lambert law, different kinds of scintillators such as BGO ($Z_{eff}$=84), GAGG:Ce ($Z_{eff}$=54.4), $CaF_2$:Eu (Eljen EJ200 equivalent, $Z_{eff}$=17.1) and plastic scintillator ($Z_{eff}$=5.7) are selected. They are modeled in the form of cylinder with 15 mm length, and 3 mm diameter. The brass is selected for frame of sensor. The overall geometry is shown in Figure 1.

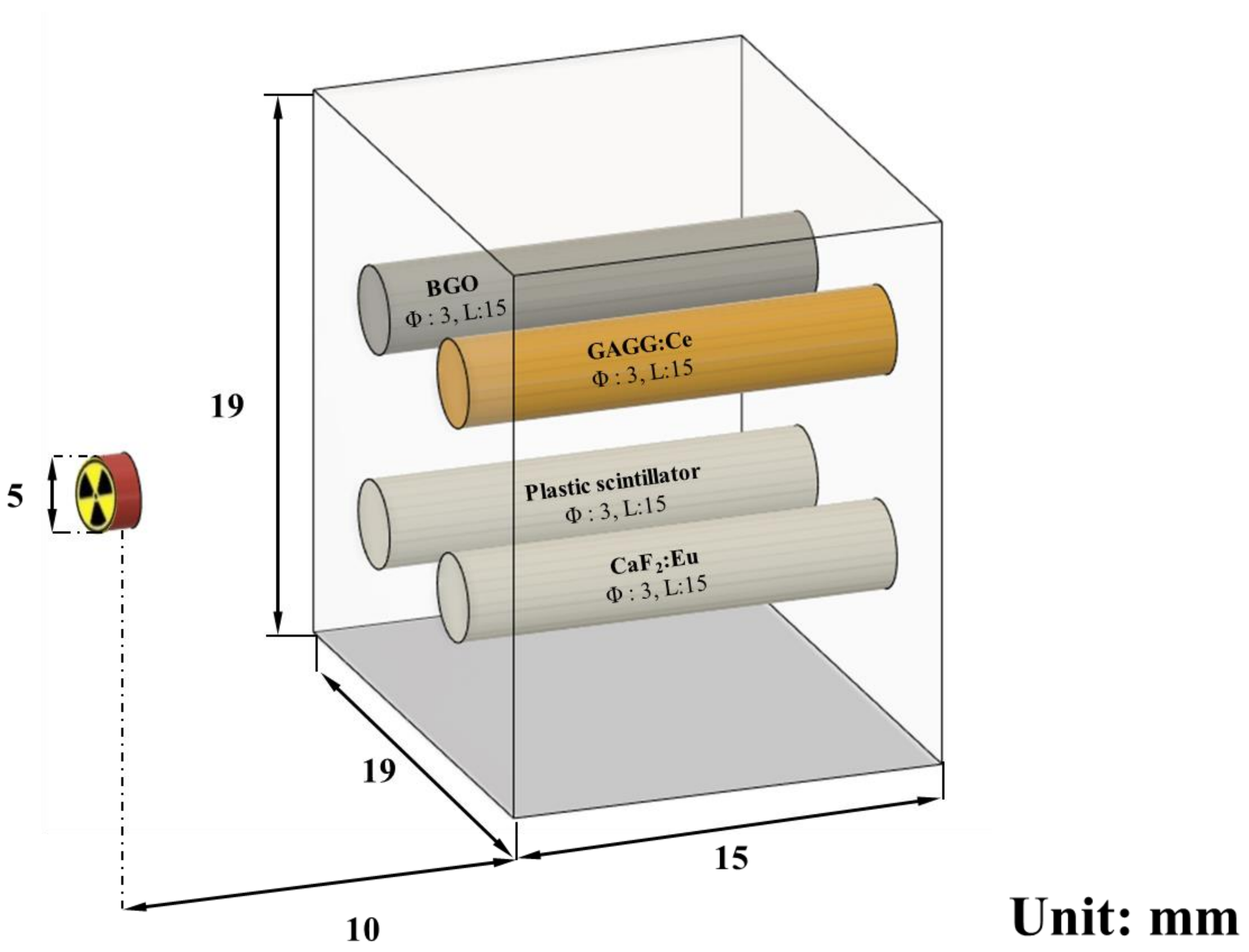


**Fig. 1.** Geometry for MCNP simulation

## Experimental results

- Fig. 2 shows the total energy deposition (TED) in each scintillator with gamma-ray energy. In cases of BGO and GAGG:Ce, the amount of TED increases in the low-energy regions where photoelectric absorption is dominant since the largest energy is transferred with photoelectric absorption. On the other hand, the amount of TED increases gradually as gamma-ray energy increases in both $CaF_2$:Eu and plastic scintillators.

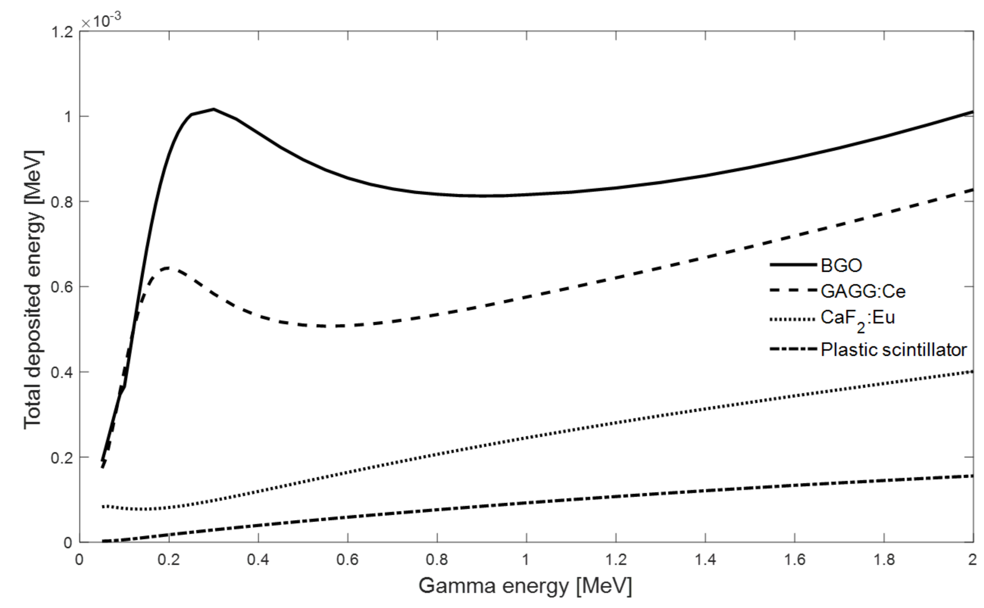


**Fig. 2.** Energy depositions in inorganic scintillator as a function of the energy of gamma-ray

- Fig. 3 shows the calculated SLO ratios between inorganic and plastic scintillators. Since the amount of energy deposition depends on the physical properties of scintillator as shown in Fig. 2, each peak and slope in the graphs also depend on the physical properties of scintillators.

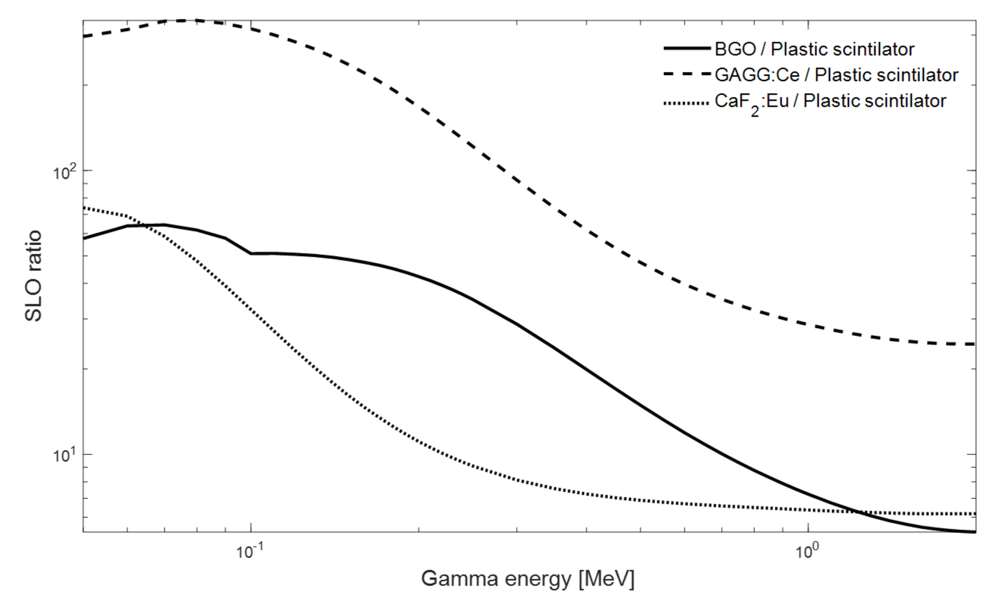


**Fig. 3.** SLO ratio as a function of the energy of gamma-ray

- The energy of gamma-ray can be divided into three regions considering the discontinuity due to the K-edge of scintillation material, peak, and slope. And five different kinds of radionuclides that emit poly-energetic gamma-rays can be identified with derived relationship. as shown in Fig 4.

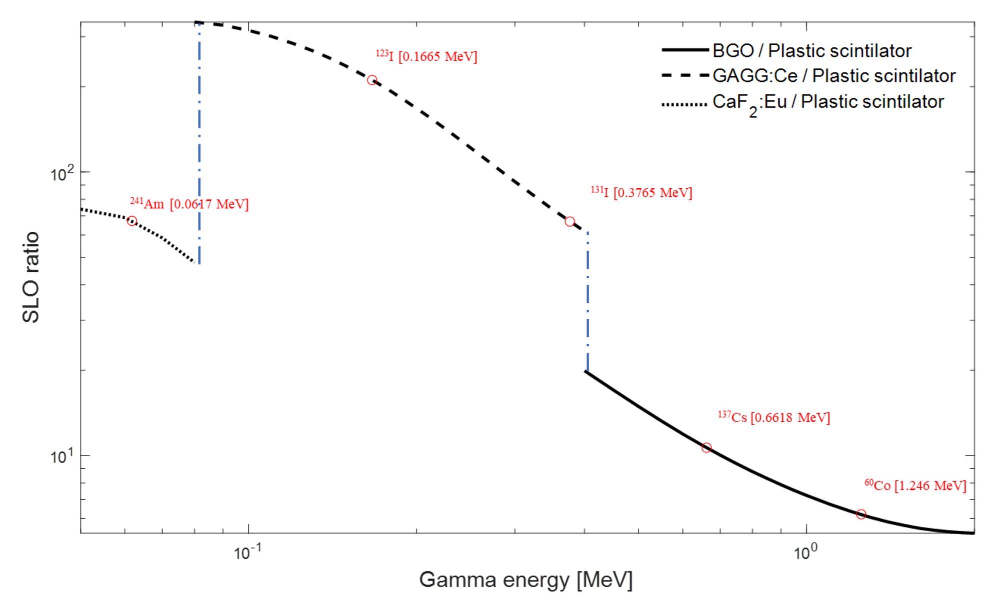


**Fig. 4.** SLO ratio to determine the energy of incident gamma-ray

## Conclusions

In this study, SLO ratios are calculated with MCNP simulation. Since the SLO depends on the energy deposition that is affected by physical properties of scintillator, the gamma-ray energy can be divided into three regions with a quasi-linearity. In further study, the energy of gamma-ray except for 137Cs can be also estimated with derived relationship between SLO ratio and energy of gamma-ray.

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