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Calculation of Peak-to-Total Ratios for Airborne Gamma-ray Spectrometer

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1. Introduction

The aerial gamma-ray spectrometry system is an important tool in response to incidents involving the release of mixed fission products, the threat or actual explosion of a RDD (Radiological Dispersal Device), and the loss or theft of a large industrial source.

In South Korea, recently, the airborne gamma-ray spectrometer was introduced from Sweden for the purpose of building the aerial radiological survey system. The spectrometer was equipped with a NaI scintillation detector that had a dimension of 4″x4″x20″.

The aim of this paper is to assess the intrinsic response functions of the NaI detector using the MCNP5 code at the combination of various photon energies (0.662, 1.275, 1.460, 1.765, and 2.614MeV) and source-spectrometer distances (10cm, 1m, and 5m).

2. Methods and Results

2.1 Computer Code System

Since the MCNP5 code contains a tally (F8) that is specific for detector pulse-height determination, it has been proven that the code is very effective in modeling the detector response providing that the detection system can be simulated accurately.[1]

In this work, the MCNP5 code was used to determine the response function of the NaI detector with the following photon energies and source-spectrometer distances.

- Photon energy emitted from a point source: 0.662, 1.275, 1.460, 1.765, and 2.614MeV
- Distance (From source to base of the spectrometer): 0.1, 1.0, 5.0m

2.2 Spectrometer Model

The spectrometer geometry was modeled with the MCNP5 code, which simulated the detection process to obtain spectrum peaks. Figure 1 shows the geometry of the spectrometer that was modeled.

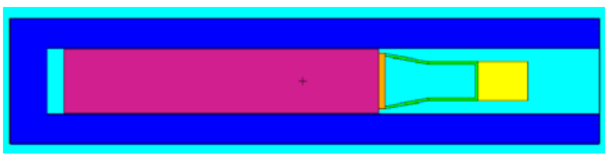

Fig. 1. Modeling of the spectrometer – Vertical cut

2.3 Material Compositions and Cross-section Library

For the calculation, it is required the data on density and isotopic composition of each material – NaI crystal, optical window, photomultiplier tube, metal shield, filling, casing, and etc. Detailed information used is omitted in this paper.

The cross-sections used for photons and electrons are from MCPLIB04 and EL03, respectively.

2.4 Pulse Height Tally

The F8 (especially called 'pulse-height') tally was employed to simulate the total energy deposited in a NaI crystal by all tracks of a history. The energy deposition was calculated using 128 bins within the energy of 0~3MeV.

In all cases simulated, no variance reduction technique was used. Electron transport was turned on using the mode card (i.e. Mode p e).

In order to achieve a statistically reasonable and accurate result, the number of particle history set to be fairly large. For each run, statistical behavior of the result was assessed by checking the associated tables in the tally fluctuation chart bin.

2.4 Results

The intrinsic response functions were calculated for an isotropic point source that emitted various energies of photon at 0.1m, 1m, and 5m from the base of the spectrometer. According to the combination of photon energies and distances, 15 cases were run in our simulations.

The peak-to-total ratio of simulated spectrum can be easily determined by simply integrating and comparing the area under the peak and the entire spectrum.[2] Figures 2 through 4 provide the calculated peak-to-total ratios versus incident photon energy at 0.1m, 1m, and 5m, respectively.

3. Conclusions

In this paper, the intrinsic efficiency of NaI detector with the source-spectrometer distance was simulated for different gamma-ray energies by using the MCNP5 code. Based on the simulated results, the peak-to-total ratios were calculated.

The overall results are shown in Figure 5. From the figure, it is clear that the peak-to-total ratio is monotonously decreased with the incident photon energy. It is presumed that this is due to the increase of effects (i.e. characteristic X-ray, Compton scattering, annihilation, and etc.) of surrounding materials. It is judged that the results can be used in building the aerial gamma-ray spectrometry system.

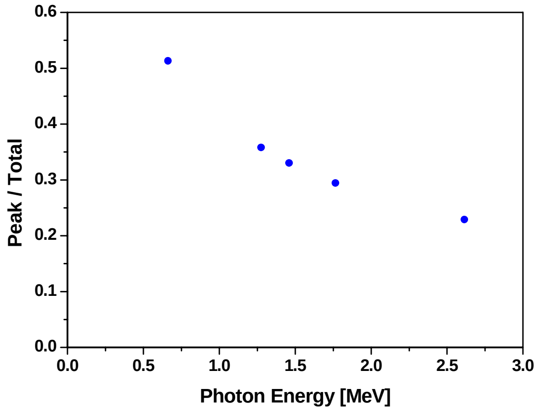

Fig. 2. Calculated peak-to-total ratios versus incident photon energy at 0.1m

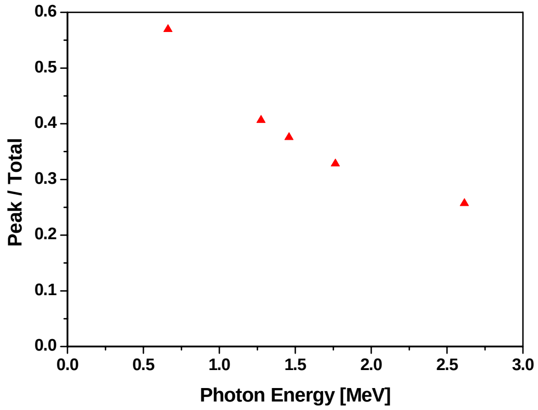

Fig. 3. Calculated peak-to-total ratios versus incident photon energy at 1.0m

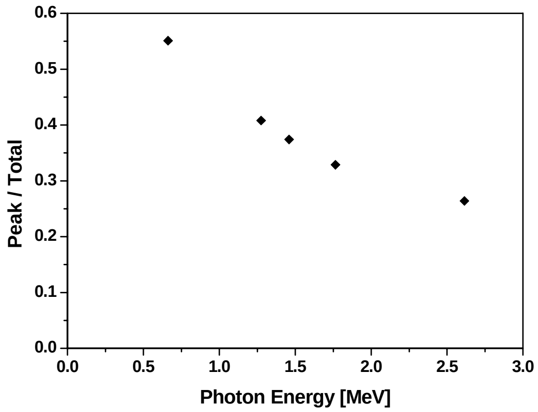

Fig. 4. Calculated peak-to-total ratios versus incident photon energy at 5.0m

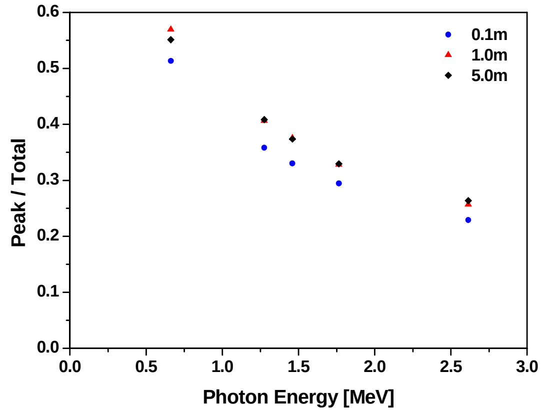

Fig. 5. Calculated peak-to-total ratios versus incident photon energy at various source-spectrometer distances

REFERENCES

[1] MCNP-A General Monte Carlo N Particle Transport Code, Version 5, LA-UR-03-1987, Release 1.40, November 2005.
[2] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, pp.612-613, 1999.