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Evaluation of light Collection in Radiation Portal Monitor with Multi PMTs using Monte Carlo simulation

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1. Introduction

The Radiation Portal Monitor (RPM) for container cargo inspection using the plastic scintillator has been used to inspect the movement of the nuclear and radioactive materials at the border, seaport, airport, etc. [1]. A plastic scintillator in the RPM is suited for the γ-ray detection of various-range energy and is the cost effective radiation detection material [2]. In order to well inspect emitted radiation from the container cargo, the radiation detection area of a plastic scintillator should be larger than other general purpose radiation detector. However, the large size plastic scintillator affects the light collection efficiency at the photo-sensitive sensor due to the long light transport distance and light collisions in a plastic scintillator [3]. Therefore, the improvement of light collection efficiency in a RPM is one of the major issues for the high performance RPM development. A method using multi-PMTs (Photomultiplier Tube) is one of methods to solve the light loss problem in a large size plastic scintillator. To develop a RPM with multi-PMTs, the consideration points are the attachment positions of the PMT on plastic scintillator and an appropriate number of a PMT. Therefore, we calculated the change of the number of collected light according to changing of the attachment position and number of PMT. To calculate the number of collected light, the DETECT2000 and MCNP6 Monte Carlo simulation software tool was used.

2. Methods and Results

2.1 Monte Carlo Simulation Model

Lights in the plastic scintillator, which is generated by γ-ray absorption, are collected by a PMT. Therefore, in order to calculate the detected light number, the absorbed energy in plastic scintillator and light collection efficiency at the light sensitive PMT have to be calculated. In order to calculate these parameters, we used the DETECT2000 light transport simulation code and the MCNP6 particle transport simulation code.

In this study, we calculated collected light number at the light detection plane (the contacting surface between scintillator and PMT) using the Monte Carlo simulation codes mentioned in the paragraph above. For the performance of simulation, we designed the model of a large area plastic scintillator with PMTs as shown in Figure 1. The simulation model is consisted with large size polyvinyl-toluene (PVT) plastic scintillator of 1800 × 700 × 50 cm^3 size and numerous light collection plane of rectangular type of 2.8x2.8 cm2 size. The refractive index and reflection coefficient of plastic scintillator in the model are 2.4 and 0.95.

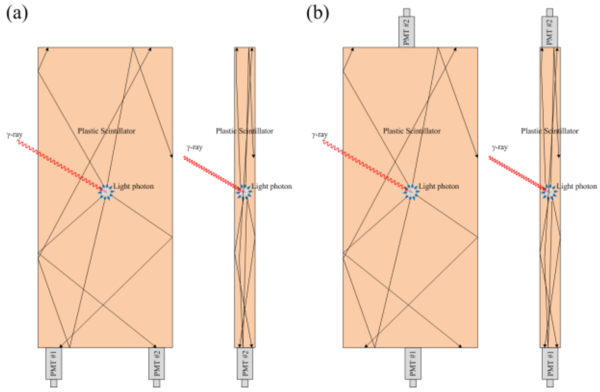

Fig. 1. Plastic scintillator with multi-PMT of Radiation Portal Monitor; (a) one side PMTs, (b) two side PMTs.

To calculate the change of the collected light number according to changing of the position of light collection plane, we performed 2 types simulation as shown in Fig. 1. The first method is that light collects on only one side as shown in Fig. 1(a) and the other is that used two side

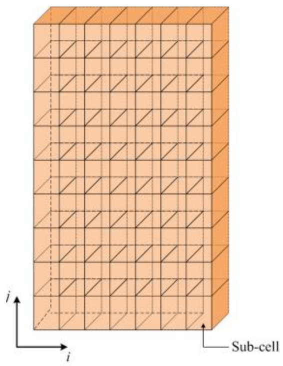

Fig. 2. Segmented large size plastic scintillator; size of sub-cell is 20 × 10 × 5 cm^3.

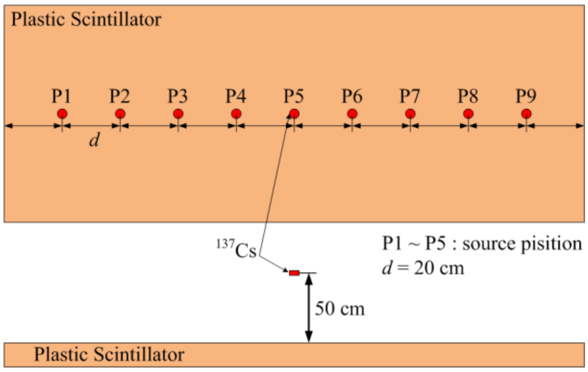

Fig. 3. Monte Carlo simulation method for calculation of collected light number.

as present in Fig. 1(b).

To accurately perform the simulation, plastic scintillator was divided into 63 sub-cells of the fixed–size of 20 × 10 × 5 cm^3 as presented in figure 2. Collection efficiency of the generated light in the scintillator is difference according to the light generating position. In order to estimate light collection efficiency of RPM according to changing of the light generation position, the light collection efficiency of lights, which is generated into each sub-cell, calculated using DETECT2000. Figure 3 presents simulation method for calculation of the absorption energy in each sub-cells using MCNP6. Used gamma-ray source is ^{137}Cs of 661keV. And the distance between source and plastic scintillator is 50 cm.

2.2 Number of Collected Light

And collected light number at each PMT was calculated using the absorbed energy in each sub-cells and light collection efficiency of generated lights in each sub-cells. The collected light number can be calculated such that

$$n = \eta \times E_{abs} \times \frac{1}{w} \qquad (1)$$

Where η and E_{abs} are light collection efficiency and absorbed energy. And w is w-value of plastic scintillator [4].

We calculated the collected light number using results of Monte Carlo simulation. Figure 4 presents results according to source position. As shown in graph, when the position of source is located center of the plastic scintillator, the number of the total collected lights of two methods is same. However, when position of source is changing, responses of two method are all more or less similar. Changing of the response signal according to changing source position using our method relatively smaller than method using one side.

3. Conclusions

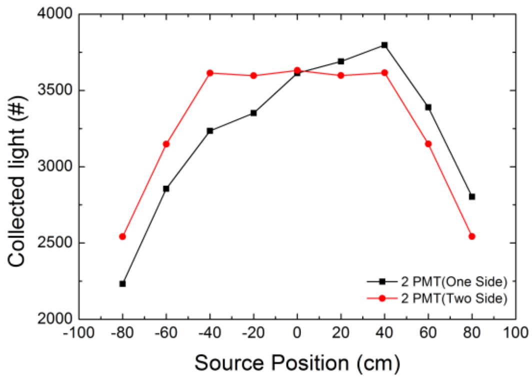

Fig. 4. Collected light number of two simulation. The black and red line present results of the one side and the two side methods.

Response signal performance of RPM system is affected by the position of the incident radiation. If the distance between the radiation source and a PMT is long, the number of loss signal is larger. Therefore, it needs to special method for high performance system. Generally, PMTs for signal detection in RPM system has been attached on one side of plastic scintillator. In contrast, RPM model in the study have 2 PMTs, which attached at the two side of plastic scintillator. We estimated difference between results using the old method and our method. According to results, uniformity of response signal was better than method using one side. Therefore, if additive simulation and experiment is performed, it will be possible to develop the improved RPM system. In the future, we will perform additive simulation about many difference RPM model.

4. Acknowledgment

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