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Comparison of the Photo-peak Efficiencies between the Experimental Data of ^{137}Cs Radioactive Source with Monte Carlo (MC) Simulation Data

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Abstract: *We have carried out an experiment of semiconductor detector (Germanium, Ge detector) using γ rays emitting source ^{137}Cs at nuclear astrophysics laboratory of Okayama University in Japan. Now a days, Ge detectors are very important tools for γ ray's studies and nuclear spectroscopy research. We have measured the photo-peak efficiencies using the radioactive source ^{137}Cs. We have created the Monte Carlo simulation with the help of GEometry ANd and Tracking (Geant4) successfully. The photo-peak efficiencies of MC simulation were calculated. We have compared our simulation data with the experimental data. We have found fair agreement between MC data and experimental data and it within 77%.*

1. INTRODUCTION

We know that atomic nuclei emitγ rays of energy between 0.1-20 MeV. Now a days, semiconductor Ge detectors are the detectors of first choice for γ rays detection when we need high resolution for the experiment. Ge detector was first introduce in 1962. This detector was collected the charges produced by the ionization of the detector matrial, when a charge particle passes through the detector material. It is well known that the energy required to produced one electron-hole pair is about 3 eV energy [1]. Scientists are trying to detect γ rays accurately and need to find out best detctor with good accuracy. The experiment of detection of γ rays and photo-peak was carried out at the experimental nuclear astrophysics laboratory, Okayma University, Japan using standard radioactive source ^{60}Co using Ge detector. The photo-peak efficiencies are very important for detection technology. The detection of γ rays depends on the type of interaction of γ ray detctor matter. This interactions type are important in detector design. The photo-peak efficiecnies were measured using experimental data of radioactive source ^{137}Cs. The Monte Carlo simulation for this experiment was made with the help of Geant4 [2,3]. We have calculated the photo-peak area and then calculated the photo-peak efficiencies of the γ rays spectrum of MC data.

We have compared the photo-peak efficiencies of MC were calculated accurately and compared with the experimental data. We have found good maching between experimental data and MC data and which is about 75%.

2. GERMANIUM (GE) DETECTORS

Ge detector is a semiconductor detector [4]. It is a kind of device which is usually uses a semiconducting material to measure the energy loss of ionization from effect of incident charged particles or photons [4,5]. These types semiconductor detectors are the detectors of choice for the γ-ray's studies in modern times. This type of detectors is mainly used in an experiment where we need high resolution. These types of detector directly collect the charges produced by the ionization of the semiconductor material when a charged particle passes through. The energy required to produced one electron-hole pair is about 3 eV energy [1].

3. EXPERIMENT WITH HPGE DETECTORS

3.1. Experimental Set up

We have carried out an experiment of gamma ray's studies from radioactive source ^{137}Cs at experimental nuclear astro-physics laboratory, Okayama University, Japan. Figure 1. is the figure of the experimental setup of an experiment with radioactive source ^{137}Cs.

Figure1. *Experimental Set-up for Ge detector*

In our experiment, we have placed the γ rays source^{137}Cs at 115m from the surface of the Ge detector. We have carried out our experiment at 1100V.

3.2. Data Acquisition System

In our experiment, the Data Acquisition System (DAQ) is very important for γ ray's detection. It has to handle so may signals from Ge semiconductor detector that is why it is so important. This DAQ system is required to have high time resolution and high speed to get good accuracy. It also required to have good energy resolution at wide rage for analysis of discrete γ rays which need to effectively apply energy gates on them. In Figure 2, we can see the block diagram of DAQ system of our experiment.

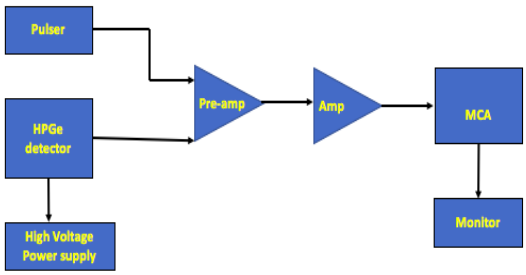

Figure2. *Data acquisition system for Ge detector*

In DAQ system, it required to have a High Voltage Power supply, a Pulser or Analog to Digital Converter (ADC), an Amplifier, a Multichannel Analyzer (MCA) and a computer monitor.

3.3. Data Analysis

We have collected the data of γ rays by Ge detector using MCA. This detected raw data was collected as counts per channel. This data has analyzed by two different ways: (1) Background subtractions (2) Energy calibration.

3.3.1. Background Subtraction

We have carried out an experiment without any radioactive source and collected data without radioactive sources i.e. empty source and then compared with data with radioactive source. Then we have subtracted the background data from the raw data.

3.3.2. Energy Calibration

We need to calibrate the energy for our experimental data. Energy calibration was done with the help of equation 2.

$$E = a \times ch + b \quad (1)$$

where ch is the channel, a is the linear scale (keV/channel) or slopes, b is the intercept and E is the energy. The calibration sources information is shown in Table 1.

Table1. *Calibration sources information*

Source	*Peak energy [keV]*	*I_g [%]*
^{137}Cs	661.66	85.1

3.4. Measurement of the Photo-peak Efficiency

From the decay scheme of ^{137}Cs, we get that the branching ratio for decaying γ –ray is 85.1%.

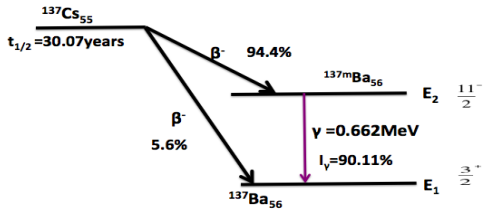

Figure3. *γ rays decay scheme of ^{137}Cs.*

Figure 3 shows the γ spectrum of ^{137}Cs radioactive source. The number of events N_i can be written as

$$N_i = 0.851\beta T_L\, \eta\varepsilon \tag{2}$$

where β= activity for ^{137}Cs, ηε= photo-peak efficiency, T_L=live time =r_L T, where T is the measurement time, r_L is the dead time correction factor =0.94 (as dead time is 6%). The efficiency can be written as

$$\eta\varepsilon = \frac{N_i}{0.851 \times \beta T_L} \tag{3}$$

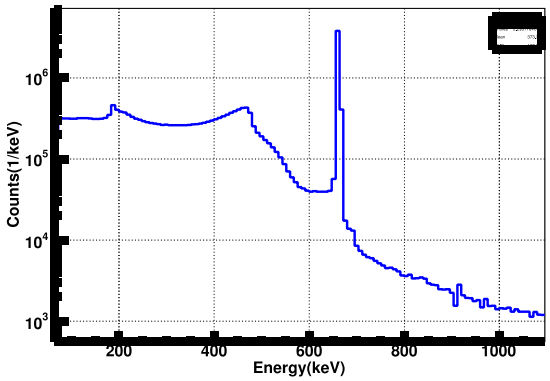

Figure4. *γ rays spectrum of radioactive source ^{137}Cs*

Figure 4 shows the γ rays spectrum of ^{137}Cs. We have calculated the photo-peak efficiencies by using Eq.3. The photo-peak efficiency for 1173 is about 0.09%.

4. GENAT4 (MONTE CARLO) SIMULATION FOR GE DETECTOR

Geant4 is the short form of GEometry ANd Tracking and it is a platform for the simulation of the passage of particles through matter using the well-known Monte Carlo (MC) method.

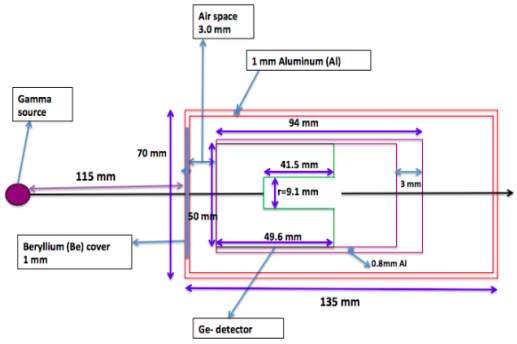

Figure5. *Block diagram of real size of Ge detector*

In Figure 5, we can see the block diagram of real size of the Ge detector for our experiment. The detector is cylindrical type and it has co-axial is circular. The length of this Ge detector is 135mm and diameter of this Ge detector is 70mm. The thickness of aluminum cover of this detector is 1mm with length 135mm and 70mm diameter. This Ge-detector with 50mm diameter and 49.6mm length inside the air space.

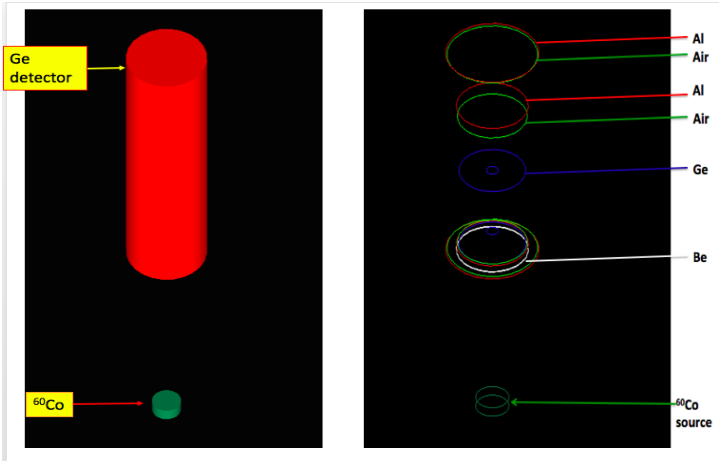

Figure6. *Block diagram of MC simulation of Ge detector.*

There is a 0.5mm Beryllium cover in front of the Ge detector. In this Ge detector, there is electrode hole right side of the Ge-detector. The hole with 9.1mm diameter and 41.3mm length. Figure 6. Shows the block diagram of MC simulation of Ge detector of our experiment.

We have generated the Geant4 (MC) program environment for our experiment. We have generated the gamma rays for different energies. We have successfully generated the γ rays for radioactive source of ^{137}Cs. Then, the γ ray's spectrum of experimental data and MC (Geant4) has compared and found fair agreement between the experimental data and MC (Geant4) data. Figure 7 shows that the comparison of the γ rays spectrum between experimental data and MC (Geant4) data.

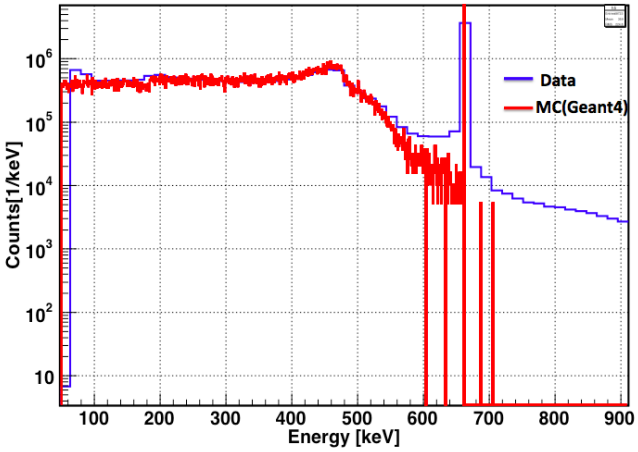

Figure7. *Comparison of the* γ ray's *spectrum between experimental data and MC data.*

For each energy ray, we have generated the γ rays of radioactive source ^{137}Cs. We have calculated the total number of rays and the number of γ rays detected by the Ge-detector inside the photo-peak area. Then, the detector efficiencies for the MC simulation can be calculated by using Eq. 4.

$$MC\ efficiency = \frac{N_c}{N_s} \times 100\% \quad (4)$$

Where N_C is the number of rays detected by the Ge detector. N_S is the total number of rays generated.

Then the photo-peak efficiencies of the γ of MC (Geant4) data were compared with the photo-peak efficiencies of experimental data.

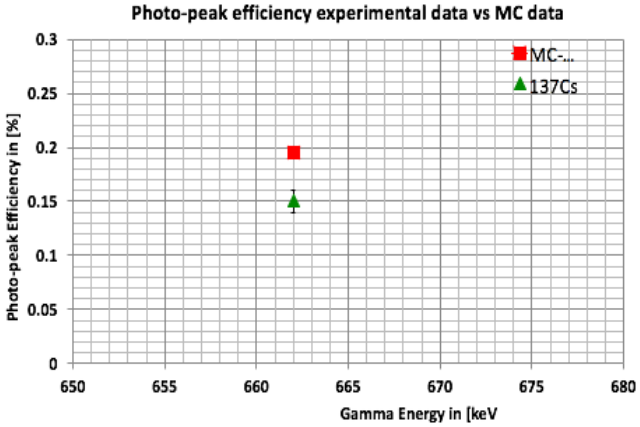

Figure8. *Comparison of the photo-peak efficiencies between experimental data and MC data for ^{137}Cs*

In Figure 8, we can see that the comparison of the photo-peak efficiencies between the experimental data of ^{137}Cs and the MC (Geant4). From this figure, we can say that MC data has a good agreement with experimental data. We found that our MC (Geant4) data are in good agreement with the experimental data and it is about 77%.

5. CONCLUSION

We have carried out an experiment for studying the characteristics of Ge semiconductor detector using the standard radiation source ^{137}Cs at astro-particle laboratory, Okayama University, Japan. We have study the γ ray spectrum of ^{137}Cs. We have measured the full energy photo-peak efficiency of Gedetector. We have measured the photo-peak efficiency with the help of the standard radioactive sources ^{137}Cs successfully. We have compared our experimental data with the MC(Geant4) data. The agreement between data and MC (Geant4) is about 77%. From this result, we can conclude that in reality there is no perfect detector.

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