Simulation of Gamma detection using GEANT4

Abhishek Nag
Indian Institute of Science Education & Research Kolkata

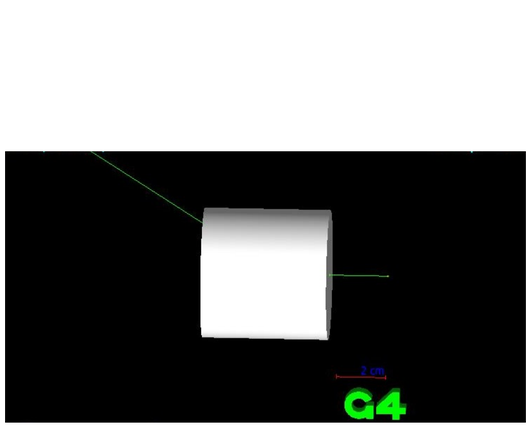
Introduction

- **Aim** To simulate gamma detection using **GEANT4**[1] and the scintillation process using **R**[2] to obtain the MCA spectrum of Co^{60}.
- **GEANT4** is an object-oriented toolkit for the Monte Carlo simulation of the passage of particles through matter.
- **R** is a programming language and software environment for statistical analysis, graphics representation and reporting.

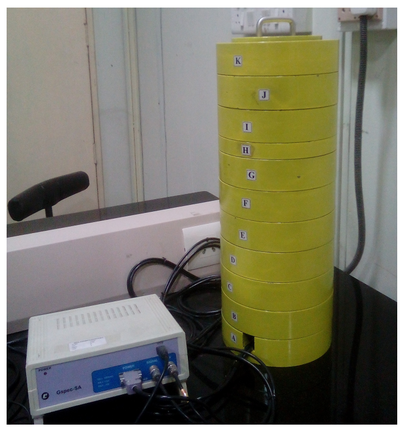
Method

- A solid cylindrical detector of material NaI of radius 25.5 mm and length 51 mm is simulated.
- A particle gun emits gamma particles of energy 1.173 MeV and 1.33 MeV in all directions.
- The above setup is placed inside a lead cylindrical shield, and energy deposited in the NaI is simulated by GEANT4.
- The number of photons produced by the NaI scintillator due to the energy deposited is statistically generated such that each photon require 17.2 ± 0.4 eV [3].
- The number of electrons collected at the anode of the PMT is statistically generated corresponding to the energy and number of photons hitting the photocathode.
- The calibrated spectrum is obtained corresponding to electrons giving the pulse and compared with the real data.

Results and Observation

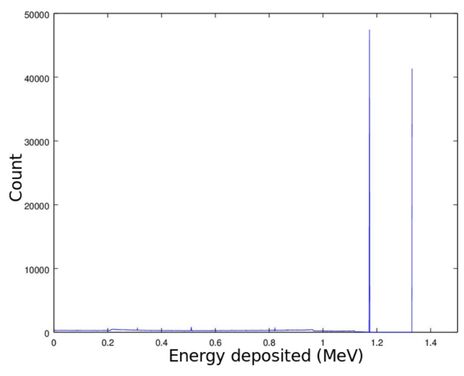


(a) Image of the detetcor as built in GEANT4

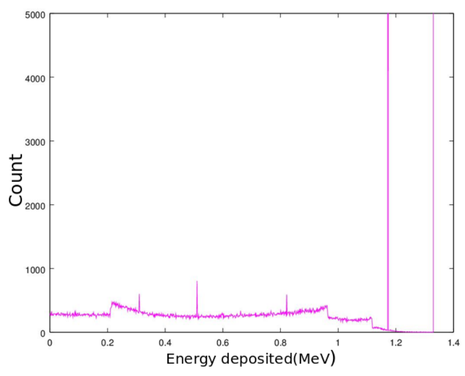


(b) MCA setup in laboratory

Figure 1: Experimental setup

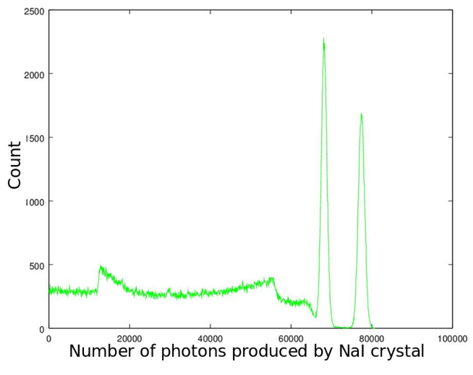


(a) Spectrum of Energy deposited in NaI crystal

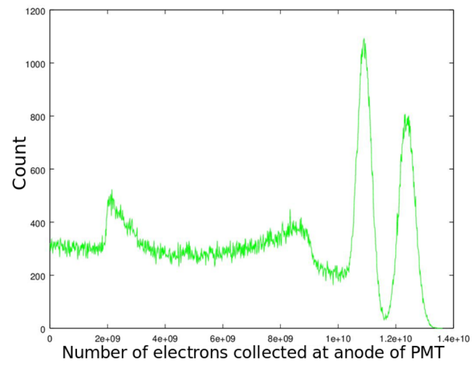


(b) Zoomed in at lower counts

Figure 2: Energy deposition simulation results from GEANT4



(a) Spectrum of scintillation photons



(b) Spectrum of PMT electrons

Figure 3: Scintillation and PMT simulation results from R

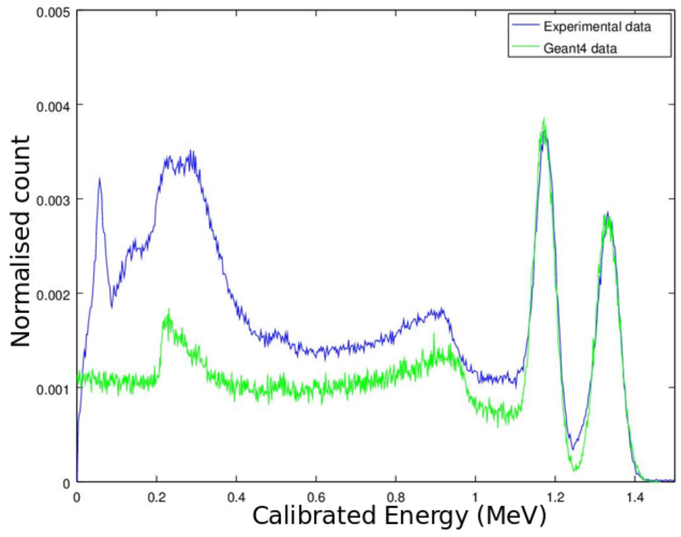


Figure 4: Normalised MCA Spectrum of Co^{60} source from simulation and experiment

Comparing the spectrum for different size of the NaI crystal.

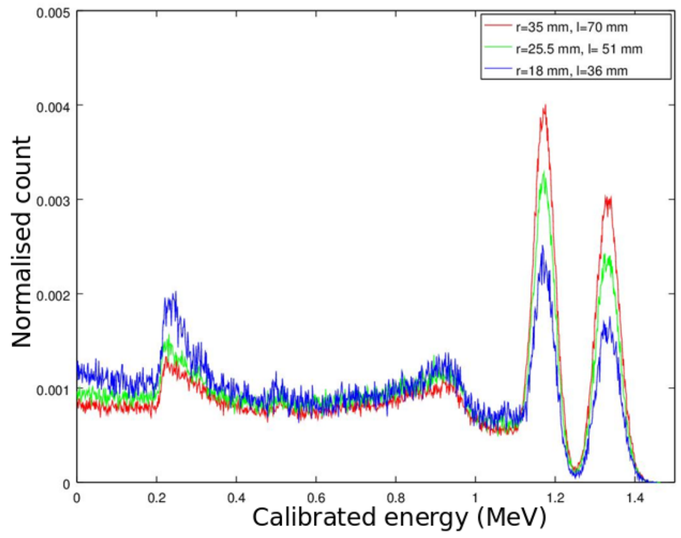


Figure 5: Normalised Spectrum of Co^{60} source with different size of NaI crystal

Discussion

- We see that the simulated data and the experimental data match quite well.
- The spread in the photopeak region is mainly due to the the spread in the number and energy of photons produced in the NaI crystal.
- The height of compton plateau decreases and that of photopeak increses with increase in size of detector, which is expected.
- **Further improvements**
  - While taking the experimental data, the background data could be removed.
  - The lead cylindrical shield should have same dimensions as that in the experiment.

References

1. Geant4, a toolkit for the simulation of the passage of particles through matter, `http://geant4.web.cern.ch/geant4/`
2. The R Project for Statistical Computing, `https://www.r-project.org/`
3. Number of scintillation photons produced in NaI(TI) and plastic scintillator by gamma-rays, M. MIYAJIMA, S. SASAKI, H. TAWARA, *IEEE Transactons on Nuclear Science (Volume: 40, Issue: 4, Aug 1993)*

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