Studies on effect of coincidence time window on intrinsic energy resolution of NaI(Tl) Detector

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Introduction

Scintillators are widely used in areas such as nuclear physics, medical science, space exploration, etc. Energy resolution is one of several parameters that determines the usefulness of a scintillator. One of the important parameters that contributes to the overall energy resolution of scintillator is its intrinsic energy resolution. Studies have been done on intrinsic energy resolution using a technique called Compton Coincidence Technique (CCT) [1,2]. This technique was proposed by Valentine and Rooney in 1994, to study the non-proportionality and intrinsic energy resolution of scintillators [3]. In this technique, signals from two detectors are recorded only when both the signals arrives under a pre-defined time interval called Coincidence Time Window (CTW). Till now, no data is available on the dependence of CTW on intrinsic energy resolution. The present work aims to understand the dependence of intrinsic energy resolution of a 2"×2" NaI(Tl) detector on CTW.

Experimental Details

A 2"×2" NaI(Tl) detector was placed opposite to 2.19"×2.36" HPGe detector at a distance of 2 cm. The detectors were kept very close to each other to maximize the number events as shown in Fig.1. The gamma source Cs-137 which emits 661.6 keV gamma photons was placed in between the two detectors. Pixie-4, an advanced system for data acquisition was used to record events when the signal from both detectors arrived in the time interval of CTW. Next, the Compton scattering events of gammas that deposited 477.3 keV energy in NaI(Tl) are filtered out by gating on events in HPGe. Consequently, the remaining energy of 184.3 keV out of total 661.6 keV will be deposited in HPGe. It should be noted that excellent energy resolution of HPGe allows to have a very precise control over the energy gating.

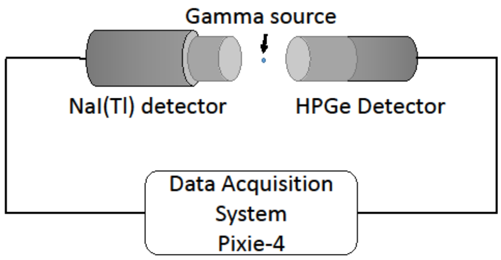

Fig. 1. Experimental setup of CCT.

Results and Discussion

The coincidence of events gives rise to two peaks in the spectrum of both detectors. The spectrum in case of NaI(Tl) is shown in Fig. 2. Two peaks at 184.3 keV and 477.3 keV were obtained due to Compton scattering of gamma photons in detectors. The third peak corresponding to photoelectric effect is due to accidental coincidences. The corresponding 2D-spectrum is shown in Fig. 3. The two clusters of points in the 2D-spectrum corresponds to the two peaks at 184.3 keV and 477.3 keV. The spectrum of NaI(Tl) after energy gating is shown in Fig. 4. It shows a single peak corresponding to gamma photon that scattered at 180° from NaI(Tl) and deposited 477.3 keV energy.

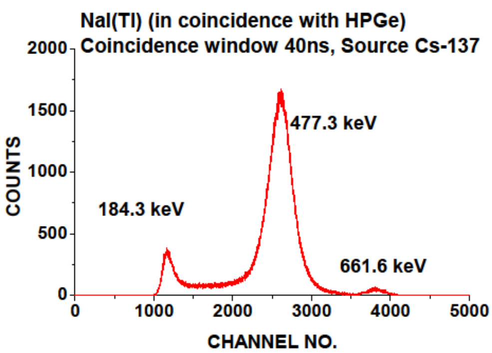

Fig. 2. Coincidence spectrum of NaI(Tl).

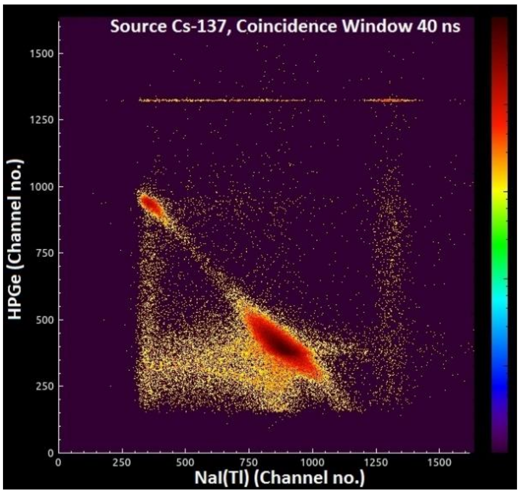

Fig. 3. 2D-spectrum of CCT experiment.

Intrinsic energy resolution was obtained by subtracting the photomultiplier tube (PMT) contribution δ_{pmt} from overall energy resolution. In the present work, δ_{pmt} is calculated using the relation:

$$\delta_{pmt} = 2.355 \times \sqrt{\frac{1+\varepsilon}{N_{phe}}}$$

where ε denotes the variance in gain of PMT and N_{phe} is number of photoelectrons whose values are taken from [1].

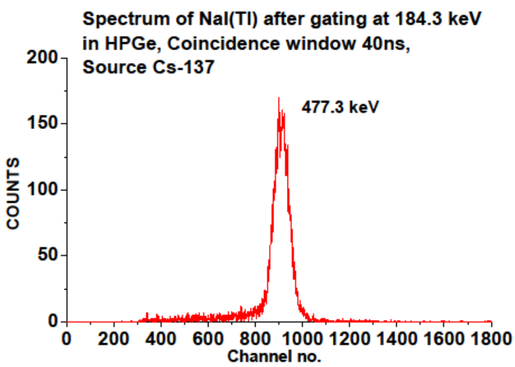

Fig. 4. Gated spectrum of NaI(Tl) at 477.3 keV.

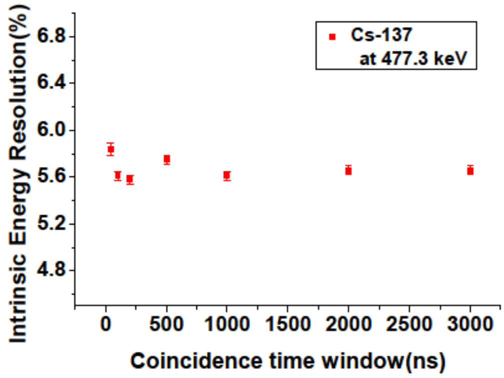

Fig. 5. Plot of Intrinsic energy resolution vs CTW.

Seven different values of CTWs were chosen for experiment, namely, 40 ns, 100 ns, 200 ns, 500 ns, 1000 ns, 2000 ns and 3000 ns. The intrinsic energy resolution vs CTWs is plotted in Fig. 5. The intrinsic energy resolution is found to be largely independent of coincidence time window after 1 µs. Work is in progress to find the dependence of intrinsic energy resolution on coincidence time window for different gamma energies.

References

[1] M. Moszýnski *et al.*, Nucl. Instr. Meth. A 484 (2002) 259-269.

[2] K. Roemer *et al.*, 2010 IEEE Nucl. Sci. Symp. Conf. Record., N20-7.

[3] John D. Valentine, Brian D. Rooney, Nucl. Instr. Meth. A 353 (1994) 37-40.