Study of Intrinsic Photo peak Efficiency of NaI(Tl) Detectors at 662 KeV

Supriti Sen[1†], Anirudh Chandra[2], Dibyadyuti Pramanik[3], M.Saha Sarkar[4]*
[1]Lady Brabourne College, Kolkata- 700017, INDIA
[2]National Institute of Technology, Tiruchirappalli 620015, INDIA
[3] Bengal Engineering and Science University, Shibpur,Howrah - 711103, INDIA
[4] Saha Institute of Nuclear Physics, Kolkata-700064, INDIA
*email: maitrayee.sahasarkar@saha.ac.in

Introduction

Uncharged radiations like gamma rays or neutrons are detected only after a significant amount of interaction within the detector. As a result these detectors can never detect 100% of incident radiation. Efficiency calibration therefore constitutes an important prelude to gamma ray spectroscopy. Depending on the particular usage of the detector in a particular experiment, there are several ways [1] of defining the efficiency.

The efficiency of a gamma detector depends primarily on the detector material, the radiation energy, the physical thickness of the detector in the direction of the incident radiation along with the source to detector distance and geometry. Usually intrinsic efficiency (ε_{int}) of a detector is defined as the ratio of the number of pulses recorded in the detector to the number of radiation quanta incident on it. It is more convenient to compare the intrinsic efficiencies of the different detectors as these are weakly dependent on the geometric factors. In most of the cases intrinsic efficiency is considered as a constant quantity for a particular detector for a specific energy. However, it is known [1] that intrinsic efficiency varies at smaller source to detector distances and finally attains a constant value depending on the detector crystal dimension. For detectors of larger dimensions, this variation should be studied to determine the minimum distance beyond which a source should be placed to utilise the full potential of the detector.

†Present address: Department of Physics, Calcutta University, 92 Acharya Prafulla Chandra Road, Kolkata 700009.

NaI(Tl) scintillator is one of the most widely used detectors for gamma ray detection. It has been accepted as the standard scintillation material for routine gamma ray spectroscopy. In the present work the variation of the intrinsic photo peak efficiencies of two NaI(Tl) detectors of different dimensions have been studied as functions of source-detector distance (*d*). The efficiency calibration was done using 662 keV gamma ray emitted from a ^{137}Cs radioactive source placed at various distances from the detector. The intrinsic photo peak efficiencies for various distances (*d*) have also been calculated analytically using the average path length (l) traversed by the gamma quanta within the active volume of the detectors.

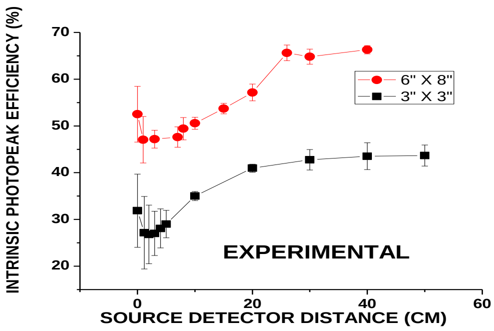

Fig.1 Variation of intrinsic photopeak efficiency

Experiment

The ^{137}Cs source was placed at different on - axis distances (*d*) from a BICRON 6″x8″ NaI(Tl) detector. A bias voltage of 800 V was applied to the detector and an ORTEC amplifier (Model No. 672) was used to process the signal from the detector. The data were taken for live time of 1800 sec with a shaping time of 3μs. The

ADC range was set to 8k. Data were also accumulated for background radiations before and after source data. For each data set, respective background spectra were subtracted from the source spectra and the resulting spectra were analysed for the counts under the photo peak. Corrections for dead-time, thickness of the Al casing of the detector, etc have been included in the calculations.

The experiment was repeated using a BICRON 3″x3″ NaI(Tl) detector. The live time for this setup was set to 3600 sec.

Results and Discussion

The experimental data on variation of intrinsic efficiencies of the detectors with source -detector distances are shown in Fig.1. It is seen that for 6″x8″ crystal, intrinsic photo peak efficiency reaches a minimum at d≈ 3 cm and at d≈ 2 cm for the 3″x3″ crystal.

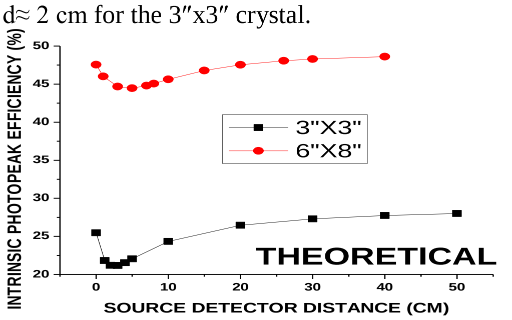

Fig.2 Variation of intrinsic photopeak efficiency

Theoretical Calculations

Absolute efficiency of a detector is given by [2]: ε_{abs} = G x I x M, where, G is the geometric solid angle factor, I the fraction of photon transmitted by the intervening materials that reach the detector and M is the fraction of photons absorbed by the detector, which is calculated by using the average path length that the photons traverse through the detector.

Now, $\varepsilon_{int} = \varepsilon_{abs}/G$. Therefore, intrinsic photo peak efficiency is given by: $\varepsilon_{p,int}=\varepsilon_{int}$ P/T, where, P/T is the peak to total ratio for the incident gamma energy.

We have calculated analytically [3] the variation of average path length of the gamma quanta inside the detector's active volume, with varying source-detector distances. The efficiencies of the detectors have been calculated using the simple relations mentioned above. The efficiencies (Fig. 2) match qualitatively with the trend shown by the experimental data (Fig. 1). However, the absolute values of the efficiencies do not match exactly. Further modifications in the calculations are being included to improve the prediction.

It has been found that the average path length (l) of the gammas within the active volume of the crystal, initially decreases with source - detector distance (d), reaches a minimum value and increases thereafter reaching a saturation. For large d, l gradually approaches L, the length of the crystal. The calculated efficiencies are found to vary smoothly with the average path length (l) of the gammas within the active volume of the crystal (Fig.3).

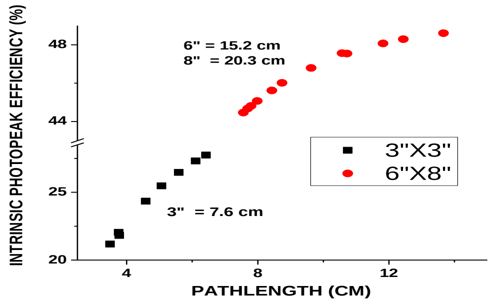

Fig.3 Variation of intrinsic photopeak efficiency with average path length

Conclusion

From the present work, it is found that, at a given energy, the relationship between intrinsic photo peak efficiency and the source detector distance is dominated by the average path length of gamma quanta in the active volume of the detector. Longer the path length of the gamma rays within the detector, higher the efficiency.

References

[1] G.F. Knoll, Radiation Detection and measurement.
[2] Bicron, "Efficiency Calculation for Selected Scintillators".
[3] F.O. Ogundare, E.O. Oniya and F. A. Balogun, Pramana **70**, 863 (2008).