True Coincidence Summing Correction in Scintillations Detectors: Measurements and Simulations

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Introduction

In gamma spectroscopy, when gamma-rays from a single decay interacts with the active volume of the detector and deposit all their energy within a time that is short compared with the response time of detector results in a sum peak in the spectrum. This is known as true coincidence summing due to which there is loss of counts from individual peaks which give rise to the sum peak. Therefore, in order to calculate the full energy peak efficiency and total detection efficiency accurately, coincidence summing correction method is needed [1-5]. Moreover, coincidence summing correction provides enough number of efficiency values resulting in a better efficiency calibration curve for any detector. The present work aims to carry out experimental measurements and realistic simulations of coincidence summing correction factors in NaI(Tl) and $LaBr_3$(Ce) scintillation detectors. The studies have been made for different source-detector separations.

Theory

A simple method is described by Vidmer *et al.* [1] for coincidence summing correction under the close geometry with HPGe detector. This method of correction is based upon imposing the constraints on the system of equations which determine the number of counts registered in individual peaks in their spectra. The constraints are based upon sound physical ground and it also gives both of full energy peak and total detection efficiencies directly for two-step cascade emission of gamma rays. We have used a source of ^{60}Co which is double gamma emitter to determine the total detection and full absorption efficiencies in NaI (Tl) as well as $LaBr_3$ detectors The full energy peak efficiency corresponding to 1.173 MeV gamma emitted by ^{60}Co is calculated by [1]

$$\varepsilon_1 = \frac{\varepsilon_{\max} + \varepsilon_{\min}}{2} \quad \text{where,}$$

$$\varepsilon_{\min} = \frac{[(\alpha_1^{app} - \alpha_2^{app}) + ((\alpha_1^{app} - \alpha_2^{app})^2 + 4A\alpha_{12})^{1/2}]}{2A}$$

and

$$\varepsilon_{\max} = \frac{\alpha_1^{app}\alpha_{12}}{A\alpha_2^{app}}$$

where, ε_1 is photo peak efficiency of gamma of energy E_1. α_{12} is the count rate under the sum peak. α_1^{app} and α_2^{app} are the apparent count rates for the first and second peak of ^{60}Co source. *A* is the activity of the source. Similarly, full energy peak efficiency of second gamma of 1.332 MeV can also be calculated.

Experimental Details

We have made measurements of coincidence summing correction factors using a calibrated point source of ^{60}Co with NaI(Tl) detector of size 1.5''x 1.5'' and $LaBr_3$(Ce) detector of size 1''x 1'' for source-detector separations of 0.0, 0.5, 1.0 and 1.5 cm.

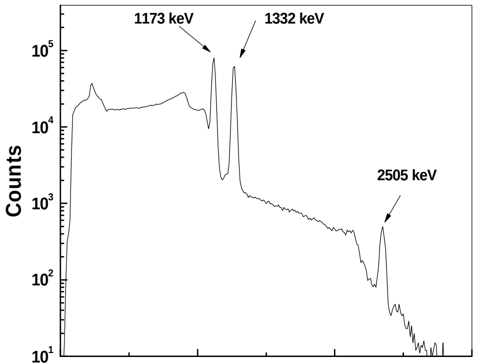

Fig.1. A typical ^{60}Co energy spectrum recorded using $LaBr_3$(Ce) detector at source-detection separation of 1.0 cm.

The branching ratios of both the transitions of ^{60}Co considered were set to 100% in the calculation. We have assumed that angular correlations between the directions of emission of two gamma-rays are neglected. The spectrum acquisition was done by CASSY lab software installed in a personal computer.

Results and Discussion

Table 1 shows the measured photo peak efficiencies corresponding to two gamma rays emitted by ^{60}Co using Nal(Tl) detector. Clearly, the peak efficiency of gamma of higher energy is lower than that of lower energy which is a well know fact that the peak efficiency decreases with the increase in gamma energy.

Table 1: Absolute peak efficiencies (in %) of Nal(Tl) detector corresponding to two gamma rays emitted by ^{60}Co.

Distance (in cm)	Peak Efficiency (ε_1)	Peak Efficiency (ε_2)
0.0	0.0236	0.0202
0.5	0.0183	0.0154
1.0	0.0129	0.0106
1.5	0.0098	0.0082

These results have been compared with realistic GEANT4 simulations. These simulations were carried out taking into account all possible experimental parameters and physics processes occurring in the active volume of the detector. The results are found to be in good agreement with the experimental results. Prior to comparison of measured results with simulated results, we have verified the GEANT4 code by measuring the absolute efficiency of the detector using a calibrated point source of mono-energetic gamma source ^{137}Cs. The simulated efficiencies for ^{60}Co have been corrected for coincidence summing and the corrected values are also found to be in good agreement with the experimental values. The uncertainties associated with the simulated efficiencies have also been calculated using the uncertainty components associated with the detector geometry as provided by the manufacturer.

We have also generated simulated spectra for the number of events determined by the calibrated source strength and the duration of measurement using low-energy EM model of GEANT4. It has been found that the inclusion of the supporting table in our simulation reproduced the backscattered peak well. In addition, the energy-resolution model could successfully reproduce the observed response of the detector for the whole energy region of the measured spectrum for each detector. The results of measurements and simulations will be presented and discussed in detail.

References

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