Performance of the clover detector considering the effects of pair production

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Introduction

Gamma rays having sufficient energy to produce positron-electron pairs in a detector generate three peaks in the energy spectrum, corresponding to the full gamma-ray energy, and this gamma-ray energy minus 511 and 1022 keV because of the single and double escape of the 511 keV annihilation quanta [1]. The escape peaks are frequently used to extend the precision of energy calibration, simply by providing additional spectral peaks at well-known energies.

At energies around 6 MeV, the pair production process dominates over other gamma interaction processes in germanium. It has been observed that the intensity of the single and double escape peaks (SEP and DEP) for gamma-rays around these energies increases rapidly [1]. This results in a difficulty to correctly identify new gamma-rays, which is crucial for precision gamma-ray spectroscopy that involves mostly the use of tapered cylindrical germanium detectors.

Experimental details

A radioactive ^{11}Be beam with an energy of 16.5 MeV, produced and delivered by the ISAC-II facility at TRIUMF, was implanted in a thick gold foil, placed in the target position at centre of the array [2]. The β^- decay of ^{11}Be ($\tau_{1/2}$ = 13.81(8) sec) produces high energy gamma-rays up to 7974 keV [3]. A 1 mm thick annular double-sided silicon detector of the BAMBINO detector, was mounted 19.4 mm downstream of the target position and used for detection of the electrons in coincidence with the gamma-rays from the seven TIGRESS detectors. The master trigger allowed data to be collected either in Ge singles mode or with a Ge-Si coincidence condition. Standard sources of ^{152}Eu and ^{56,60}Co were also used to obtain low energy data.

Experimental Results

A. During the addback mode, what happens to the single escape peak ?

We have compared the ratio of SEP areas in addback mode with that of single crystal mode to study if the SEP gains or loses counts due to addback mode. Results have been shown in figure 1. It is observed that SEP areas from single crystal mode and addback mode spectra are similar, which indicates equal compensation, i.e, the SEP gains and loses similar counts due to addback process.

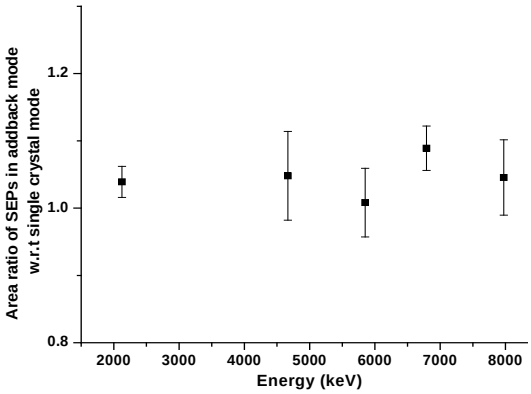

FIG. 1: Ratio of SEP areas in addback mode with that of single crystal mode from ^{11}Be β^- decay data

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B. Comparison between TIGRESS and standard clover detector

A measure of the deterioration of the spectrum quality is given by the ratio R which is defined for a gamma-ray of energy E_γ as follows:

$$R(E_\gamma) = \frac{area\ of\ SEP\ (E_\gamma)\ +\ area\ of\ DEP\ (E_\gamma)}{area\ of\ FEP\ (E_\gamma)} \quad (1)$$

Studies on conventional germanium detectors have shown that the ratio R increases with gamma energy [4]. We have observed similar behaviour for our sophisticated detector. In figure 2, we have compared the ratio R for gamma-rays covering an energy range from 2 MeV to 8 MeV. Data from TIGRESS (^{11}Be β^- decay data) and clover detectors [5] have been compared. Our observation are as follows:

- The TIGRESS data with passive shielding in single crystal mode shows that the ratio is higher than 1 at energies above 5 MeV. With active shielding, the escape peaks are already suppressed to some extent in the single crystal spectrum. The ratio in figure 2 for the single crystal spectra is never higher than 1 and reaches $\simeq$ 0.8 at 8 MeV. For data with active shielding in addback mode, the ratio reaches 0.35 at 8 MeV. The ratio of the slopes (from polynomial fits to data) for addback mode-active suppressed to single crystal mode-active suppressed to single crystal mode-passive suppressed cases is 1.0 : 2.6 : 6.5. These results quantify the advantage gained in using active suppression and addback mode over passive suppression and single crystal mode.

- Compared to the TIGRESS detector, the clover detector [5] has higher value of ratio R for both single crystal and addback modes. This shows that the TIGRESS detector perform better than a standard clover detector in reducing the escape peaks. This is due to the larger detector volume and presence of additional CsI(Tl) back catcher in the escape suppression shield of TIGRESS detectors.

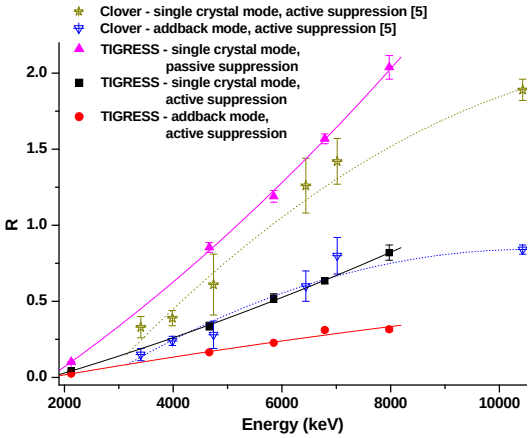

FIG. 2: Variation of the ratio R as a function of gamma energy for TIGRESS and clover detectors [5]. The lines represent polynomial fits to data.

References

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