Full energy peak efficiency of composite detectors for high energy gamma-rays

Ritesh Kshetri*
Department of Physics, Sidho-Kanho-Birsha University, Ranchi Road, P.O. Sainik School, Purulia 723104, West Bengal, INDIA

Introduction

Experiments involving radioactive beams demand high detection efficiencies. One of the ways to obtain high detection efficiency without deteriorating the energy resolution or timing characteristics is the use of composite detectors which are composed of standard HPGe crystals arranged in a compact way [1]. Two simplest composite detectors are the clover and cluster detectors [1–3]. The TRIUMF-ISAC Gamma-Ray Escape-Suppressed Spectrometer (TIGRESS) [4] comprises of 16 large-volume, 32-fold segmented HPGe clover detectors, where each detector is shielded by a 20-fold segmented escape suppression shield (ESS).

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 [5]. The β^- decay of ^{11}Be ($\tau_{1/2}$ = 13.81(8) sec) produces high energy gamma-rays up to 7974 keV [6]. Among the seven TRIGRESS detectors, four detectors were displaced at 90^0, while the other three were arranged at 135^o with respect to the beam axis. The faces of the detectors were 14.5 cm from the target, covering $\approx 27\%$ of the full solid angle. A 1 mm thick annular double-sided silicon detector of the BAMBINO detector [7], was mounted 19.4 mm downstream of the target position (see inset of figure 1), and used for detection of the electrons in coincidence with the gamma-rays from the clover detectors. During the β^- decay of ^{11}Be, high energy electrons (up to 10.5 MeV) are emitted which interact with surrounding materials including the TIGRESS HPGe detectors. The use of BAMBINO detector helped in minimizing the contribution of the continuum arising from the interaction of high energy electrons with the detectors. The effect can be clearly observed in figures 2(A) and 2(B) where the experimental spectra from ^{11}Be β^- decay are shown for data with and without the coincidence condition. These spectra also demonstrate the effect of passive and active shielding.

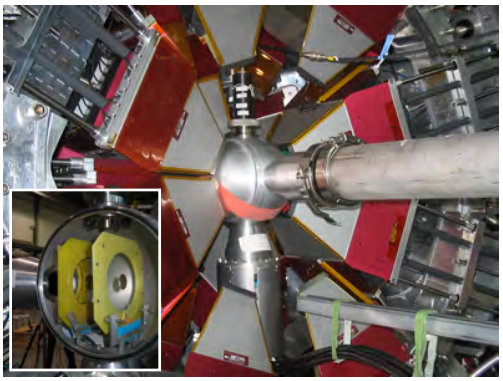

FIG. 1: The TIGRESS array with the BAMBINO detector. Inset shows the BAMBINO detector.

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.

Full energy peak efficiency

The experimentally obtained relative full energy peak efficiency of the array with seven TIGRESS detectors (in addback mode with the coincidence condition) is plotted in figure

*Electronic address: ritesh.kshetri@gmail.com

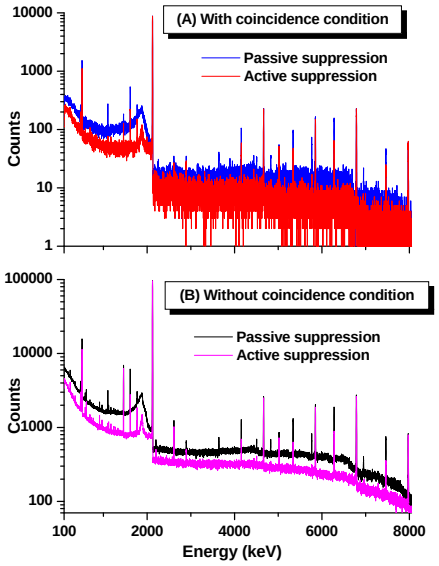

FIG. 2: Comparison of data in addback mode and different suppression cases from a single TIGRESS detector (see text). Spectra for cases with and without the coincidence condition are shown in (A) and (B), respectively.

3. A deviation in the experimental curve is observed at 4665 keV, which might be due to a reported incorrect relative intensity of 4665 keV from ^{11}Be β^- decay. The experimental absolute efficiencies at 1332 keV and 7974 keV are 3.94(1)% and 0.69(6)%, respectively. These measured efficiencies will be useful for performing data analysis and planning gamma-ray spectroscopy experiments for energies above 3.5 MeV, which could be obtained using a standard ^{56}Co source.

Figure 3 also shows a comparison of relative efficiencies of the TIGRESS, Euroball cluster [3] and a clover detector of standard geometry [2] in addback mode for energies up to 10.6 MeV. The efficiencies are normalised at an energy of 344 keV. The relative efficiency of TIGRESS detectors at high energy is found to be greater than the clover detector but lower than the cluster detector. This is mainly due to the difference in active volumes of these detectors and their different distances of operation. The cluster detector has a volume $\approx$ 2000 cm^3, while the TIGRESS and a standard clover detector have volumes $\approx$ 930 cm^3 and $\approx$ 470 cm^3, respectively. The clover, cluster and TIGRESS detectors were kept at respective distances of 22 cm, 25.7 cm and 14.5 cm from the target position.

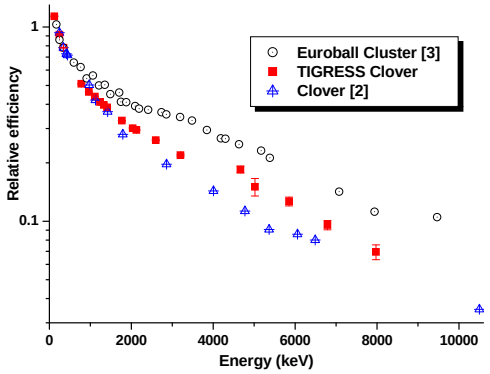

FIG. 3: Comparison of relative efficiencies in addback mode (normalised at 344 keV) of the TIGRESS array (from coincidence data of present work), the clover [2] and cluster [3] detectors. The error bars of efficiencies for clover and cluster detectors are not shown.

References

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