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Optimization of Compton-suppression and summing schemes for the TIGRESS HPGe detector array

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Abstract

Methods of optimizing the performance of an array of Compton-suppressed, segmented HPGe clover detectors have been developed which rely on the physical position sensitivity of both the HPGe crystals and the Compton-suppression shields. These relatively simple analysis procedures promise to improve the precision of experiments with the TRIUMF-ISAC Gamma-Ray Escape-Suppressed Spectrometer (TIGRESS). Suppression schemes will improve the efficiency and peak-to-total ratio of TIGRESS for high γ-ray multiplicity events by taking advantage of the 20-fold segmentation of the Compton-suppression shields, while the use of different summing schemes will improve results for a wide range of experimental conditions. The benefits of these methods are compared for many γ-ray energies and multiplicities using a GEANT4 simulation, and the optimal physical configuration of the TIGRESS array under each set of conditions is determined.

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Keywords: Tigress; Segmented HPGe detectors; Compton suppression

1. Introduction

The TRIUMF-ISAC Gamma-Ray Escape-Suppressed Spectrometer, or TIGRESS (Fig. 1) [1–4], is a new γ-ray detector array being developed in order to take advantage of the radioactive ion beams to be delivered by the new ISAC-II [5] facility at TRIUMF. When complete, TIGRESS will consist of twelve large-volume 32-fold segmented HPGe clover detectors, each consisting of four HPGe crystals in which the outer electrical contacts will be segmented in four ways longitudinally and two ways transversely. Each HPGe clover will also be fitted with a 20-fold segmented Compton-suppression shield.

Due to the low production rates of nuclei far from stability at radioactive ion beam (RIB) facilities, high detection efficiencies and peak-to-total ratios are essential

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for high-precision experiments [6]. One method of improving the overall performance of the array is to tailor its physical configuration to particular experiments. To allow this, the TIGRESS detectors can be arranged in two ways: *HPGe Forward*, which enhances the efficiency by close packing the detectors 11.0 cm from the source, and *HPGe Back* (Fig. 1) at a distance of 14.5 cm, which enhances the peak-to-total ratio by using the front suppression shields [3]. In addition, dense metal collimators can be placed on the front shields, giving a total of three physical configurations.

In order to allow further experiment-specific optimization, several methods of data analysis have been explored, considering different suppression and summing schemes. These methods have been compared and tested using a GEANT4 [7] simulation of the TIGRESS array.

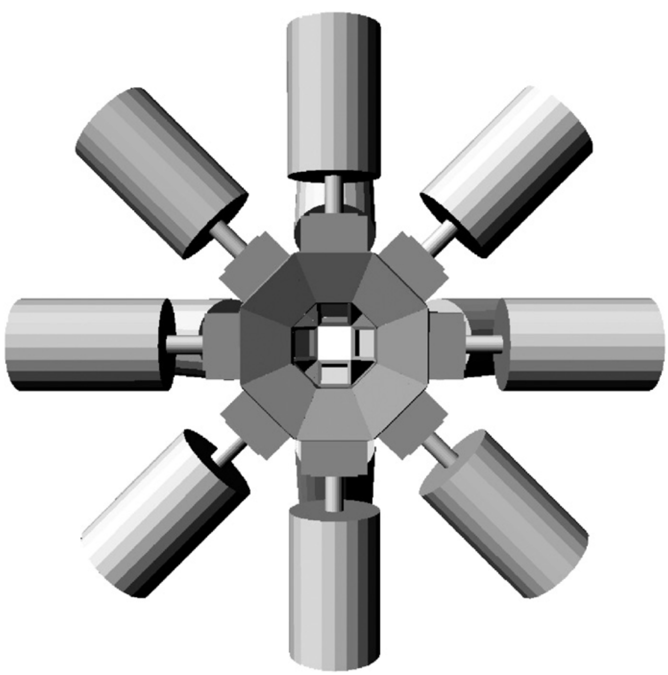

Fig. 1. The TIGRESS Compton-suppressed, segmented HPGe clover detector array.

As described in Ref. [4], data from a variety of γ-ray sources were collected using the prototype TIGRESS detector and Compton-suppression shield. The apparatus was then simulated, and data were generated using simulated γ-rays of the same energies as those of the real sources. The resulting spectra are compared in Fig. 2. The validated single-detector simulation was then scaled to create a simulation of the 12-detector array.

Using this simulation, at each of a large number of γ-ray energies (ranging from 40 keV to 10 MeV) and multiplicities (ranging from 1 to 40), the best combination of suppression scheme, summing scheme, and configuration was determined in order to explore the practicality of these methods and to determine the magnitude of the improvement that can be expected from their use.

2. Suppression and summing schemes

Suppression schemes address the problem of false suppression related to high-multiplicity events, such as those examined in high-spin studies. As the γ-ray multiplicity increases, suppressor segments which are distant from a HPGe crystal with an observed energy deposition become more likely to absorb energy from a second γ-ray than from Compton scattering of the first, observed, γ-ray. At these multiplicities, results can be improved by suppressing events selectively based on the locations of energy depositions in the suppression shield. To examine their effectiveness, five suppression schemes were examined in which the locations of the interactions were determined by noting which optical segments recorded energy depositions. These are shown schematically in Fig. 3.

Summing the energies observed in the HPGe crystals within each detector recovers many γ-rays which Compton scatter between crystals. Likewise, summing energies over multiple detectors can recover additional Compton-scattered γ-rays. At high multiplicities, this summation is very likely to add energies from multiple γ-rays, so results can be improved by summing selectively based on the positions of the energy depositions. The summing schemes tested ranged from complete summation to no summation of crystals, and included: (a) "full array", which sums energies

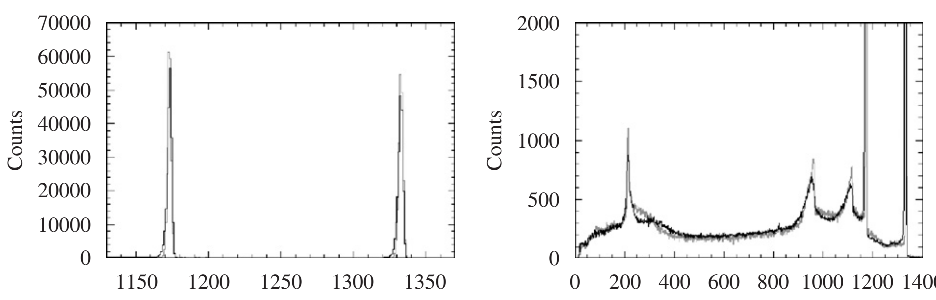

Fig. 2. Experimental (black) and simulated (grey) energy spectra for the peaks (left) and Compton continua (right) for ^{60}Co in the HPGe Back configuration, without collimation.