Characterization Of Compton-Suppressed TIGRESS Detectors For High Energy Gamma-rays

R. Kshetri[1,2], C. Andreoiu[1], G.C. Ball[2], D.S. Cross[1], T. Drake[3], M. Djongolov[2], N. Galinski[1], A.B. Garnsworthy[2], G. Hackman[2], J.N. Orce[2], C. Pearson[2], D. Smalley[4], C.E. Svensson[5], S. Triambak[2], S.J. Williams[2]

[1]*Simon Fraser University, Burnaby, BC, CANADA*

[2]*TRIUMF, Vancouver, BC, CANADA*

[3]*Physics Department, University of Toronto, Toronto, ON, CANADA*

[4]*Department of Physics, Colorado School of Mines, CO, USA and*

[5]*Department of Physics, University of Guelph, Guelph, ON, CANADA*

Introduction

The TRIUMF-ISAC Gamma-Ray Escape-Suppressed Spectrometer (TIGRESS) will consist of 12 large-volume, 32-fold segmented HPGe clover detectors [1]. Each detector is shielded by a 20-fold segmented Compton suppression shield. For performing discrete gamma-ray spectroscopy of light mass nuclei with TIGRESS, we need information about full energy peak efficiency, resolution and lineshape of full energy peaks for high energy gamma-rays. However, suitable radioactive sources having decay gamma-rays of energies greater than $\approx$ 3.5 MeV are not easily available. So the characteristics of gamma spectrometers at energies higher than 3.5 MeV are usually determined from simulation data. Predictions from GEANT4 simulations (experimentally validated from 0.3 to 3 MeV) indicate that TIGRESS will be capable for single 10 MeV gamma-rays of absolute detection efficiency of 1.5% for backward configuration of the array [2]. It has been observed experimentally that simulation results work well up to certain energies and might deviate at higher energies. So, it is essential to check the validity of simulation results for energies above 3.3 MeV. We have investigated the high energy performance of seven TIGRESS detectors up to 8 MeV.

Experimental Details

The β decay of ^{11}Be was used to produce high energy gamma-rays up to 8 MeV. A radioactive ^{11}Be beam of energy 16.5 MeV, produced and delivered by the TRIUMF cyclotron, was implanted in a thick Au foil at target position. Seven Compton-suppressed Clovers of the TIGRESS array [1] were arranged around the target chamber. Four detectors were at 90^o, while three were at 135^o. The faces of the detectors were 14.5 cm from the target, covering approximately 27% of the full solid angle. An annular double-sided 1mm thick silicon detector, BAMBINO, was mounted 19.4 mm downstream of the target position, perpendicular to the beam direction, and was used for detection of the electrons (emitted during the β decay) in coincidence with the Clover detectors. This minimised the continuum arising from interaction of high energy electrons (up to 10.5 MeV) in germanium. Standard sources of ^{152}Eu and ^{56,60}Co were also used to obtain low energy data.

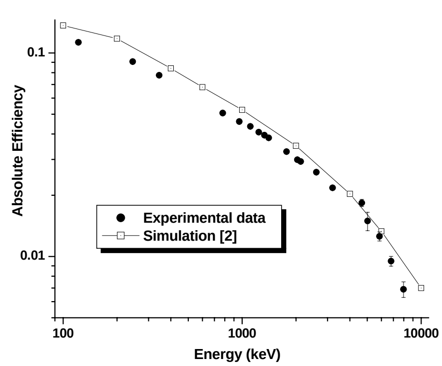

FIG. 1: Absolute efficiency of TIGRESS array with seven detectors. Comparison of experimental data with simulation is shown.

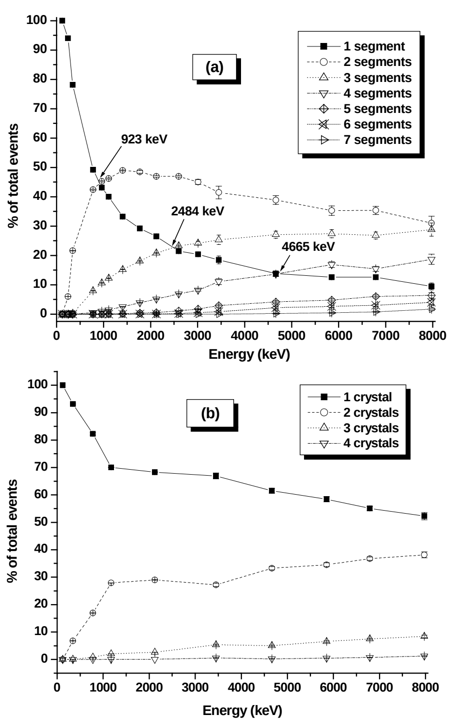

FIG. 2: Experimental hit pattern distributions are shown for (a) segment and (b) core.

Results

The experimentally obtained absolute efficiency of the array with seven TIGRESS detectors (in addback mode) is shown in figure 1 along with the simulation results [2]. The simulation slightly overestimates the experimental data, which shows a similar trend. However unlike simulation, a kink is observed at 4665 keV, which might be attributed to incorrectly reported relative intensity of 4665 keV from ^{11}Be decay. The experimental absolute efficiency at 1332 keV and 7974 keV are 3.94(1) % and 0.69(6) %, respectively. The ratio of efficiency at these two energies is 5.7, which is lower than the value of 6.8, obtained for a Eurogam type Clover detector [3]. The comparatively higher efficiency for TIGRESS detectors is due to larger crystal size.

The experimental hit pattern distributions at segment and core levels are shown in figure 2 (a) and (b), respectively. Both indicate that the single hit distribution decreases with increasing energy while the distribution for multiple hits increases. The single and double hit pattern distributions change rapidly up to $\simeq$ 1 MeV after which the change is more gradual. This is related to the relatively sharper decrease of the linear attenuation coefficient for the photoelectric effect compared to that for the Compton scattering at energies from 50 keV to 1200 keV. At the segment level (figure 2(a)), the single hit distribution crosses double, triple and quadruple hit distributions at 923, 2484 and 4665 keV, respectively. Above 1 MeV, the full energy peak efficiency is dominated by double hit events. This shows the relative importance of double hit events, for instance in gamma-ray position reconstruction. Figure 2(b) shows that the addback factor (= total events / single hit events) slowly increases from 1 and attains a value of 1.91(8) at 7974 keV. There appears no indication of a saturation.

The peak-to-total ratio (in addback mode) for unsuppressed and fully-suppressed ^{11}Be data are 0.126(1) and 0.212(2), respectively. The escape peak efficiency have been extracted for both unsuppressed and fully-suppressed cases. Details of the results will be presented in the symposium.

Conclusion

We have studied the response of an array of seven TIGRESS detectors up to 8 MeV using ^{11}Be decay and source data. The measured efficiencies will be useful for future TIGRESS experiments.

The authors would like to thank R. Churchman, H. AlFalou for help in experimental set up, H. Leslie, C. Sumithrarachchi for discussions and the operations staff of TRIUMF for providing the beam.

References

[1] C.E. Svensson *et al.*, Nucl. Instr. Meth. A **540** (2005) 348; H.C. Scraggs *et al.*, Nucl. Instr. Meth. A **543** (2005) 431.

[2] M.A. Schumaker *et al.*, Nucl. Instr. Meth. A **570** (2007) 437.

[3] M. Saha Sarkar *et al.*, Nucl. Instr. Meth. A **556** (2006) 266.