Measuring the photopeak efficiency of the TexCAAM detector using the ^{11}Be decay and the ^{60}Co gamma source

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The Texas CsI Array for Astrophysical Measurements, TexCAAM, was built and commissioned for charged-particle gamma coincidence experiments with radioactive beams with the focus on nuclear astrophysics. The absolute photopeak efficiency of the TexCAAM detector was measured in the energy range from 1 to 8 MeV. The β decay of ^{11}Be and the ^{60}Co source were used to obtain the experimental photopeak efficiency at various energies.

TexCAAM is an array of 32 CsI(Tl) scintillators read by pin diodes. It has nearly 4π coverage and a compact geometry allowing for good passive shielding from external gamma-rays. Each scintillator has an area of 5x5 cm^2 and a thickness of 4 cm. The detectors are arranged in a box geometry. The box is composed of four sections each made by 8 closely packed scintillators. For this experiment the four sections are placed at theta angles 146°, 128°, 93° and 55° from the center of a 1 mm thick silicon detector that is used as implantation target.

The ^{11}Be beam with energy 115 MeV was produced at the MARS spectrometer line of Cyclotron Institute and implanted in the Silicon detector. The beam was pulsed with a 30 s on, 30 s off frequency. Beta particles produced by the beta decay of ^{11}Be were detected in the silicon detector and provided the trigger for the acquisition system. Gamma rays from the deexcitation of ^{11}B were detected by the TexCAAM scintillators in coincidence with the beta particles. We note that two detectors were missing in this experiment: one in the section at 93° and one in the section at 146°. The measured efficiencies are not corrected to compensate for the missing detectors.

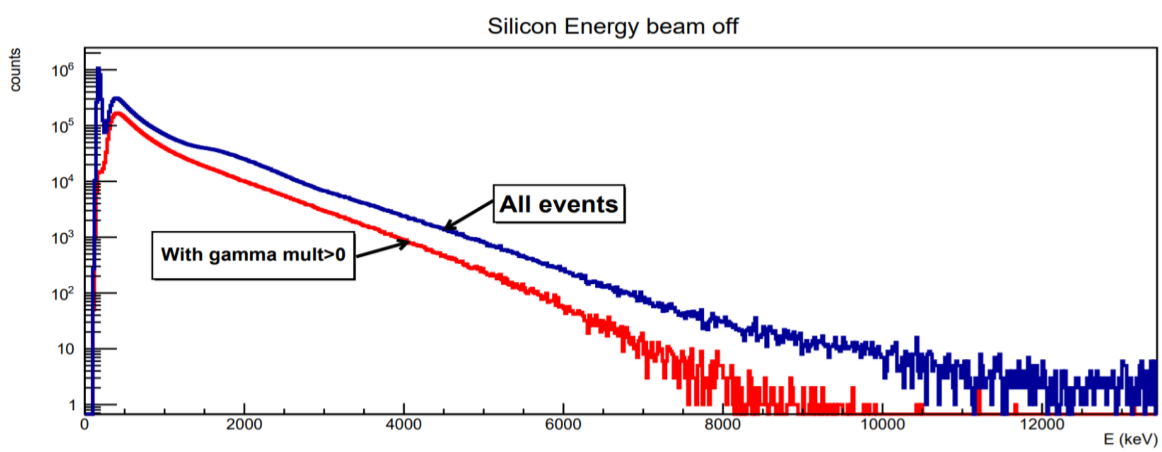

Fig. 1. Beta particle spectra measured in the beam off interval. Blue line all events, read line events with at least one gamma.

The beta particle spectrum measured in the Silicon detector during the beam off time is shown in Fig. 1, whereas the gamma spectra measured in the four sectors of the TexCAAM array are shown in Fig. 2.

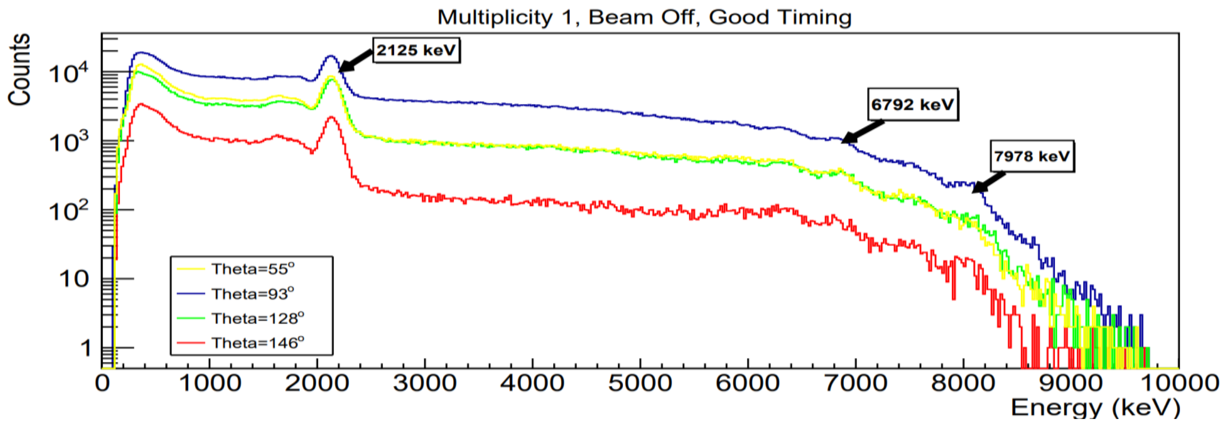

Fig. 2. Gamma spectra measured in the four sections of the TexCAAM array during beam off.

Integrating the beta spectrum from above the noise (267 keV) up to 10000 keV we measured a total of 9172520 beta decays. Looking at the gamma ray spectra in Figure 2, three peaks are clearly visible. These peaks correspond to the transitions from the excited states of ^{11}B at 2125, 6792 and 7978 keV to the ground state. After background subtraction, the integral of these peaks was used to obtain the experimental photopeak efficiency. The results are reported in Table I together with the branching ratios from ref. [1]. The efficiency obtained considering the photopeak and the first escape peak is also reported in Table I.

Table 1. Photopeak efficiency of the TexCAAM detector from 2 to 8 MeV. Branching ratios are from ref. [1].

Beta decay to ^{11}B state	Beta branching ratio %	Gamma branching ratio to the ground state %	Expected counts if 100% efficiency	Measured photopeak counts	Efficiency %	Measured photopeak + first escape peak	Efficiency %
2125 keV	31	100	2843481	211819	7.4	257850	9
6792 keV	6.5	68	405425	5464	1.3	11550	2.8
7978 keV	4	47	172443	2135	1.2	4806	2.8

A ^{60}Co gamma source was also used to measure the photopeak efficiency of TexCAAM at 1173 and 1332 keV. For this measurement the source was placed at the silicon detector position. The source spectrum obtained considering all the CsI detectors is shown in the left panel of Fig. 3. The photo-peaks were fitted with a two gaussians + linear background function to obtain the total number of counts in each peak (C_{1174} and C_{1332}). The right panel of Fig. 3 shows a two-dimensional plot of E1 vs. E2 for multiplicity two events. The energies are ordered so that the largest energy measured is always on the x axis. The integral in the 2-dimensional gate around the coincidence spot provides the number of coincidences with a 1173 keV and 1332 keV gamma, C_2. The efficiency at 1173 keV is $\varepsilon_{1332} = C_2/C_{1332}$ =24%. The efficiency at 1173 keV is $\varepsilon_{1173} = C_2/C_{1173}$ =20%. Fig. 4 shows the measured photopeak

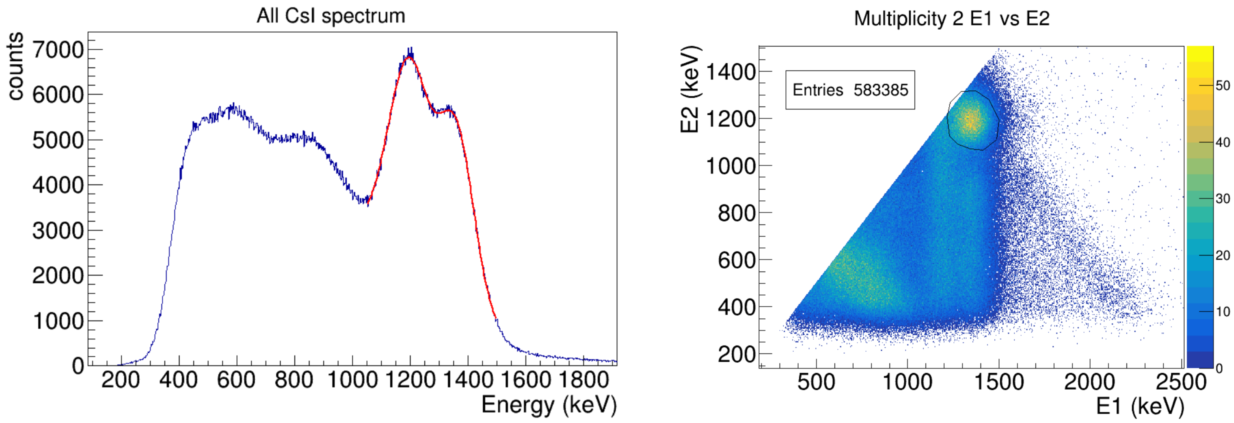

Fig. 3. Left panel: Spectrum of the ^{60}Co source. The red line shows the result of the fit with two gaussians and a linear background. Right panel: ^{60}Co source, multiplicity two events, E1 vs E2. A two-dimensional gate is plotted around the spot of 1173 keV and 1332 keV gamma ray coincidences.

efficiencies as a function of the gamma energy. The points are fitted with a simple power law function to interpolate the efficiency values in between the measured points. Fig. 4 also shows the energy resolution as a function of the gamma energy.

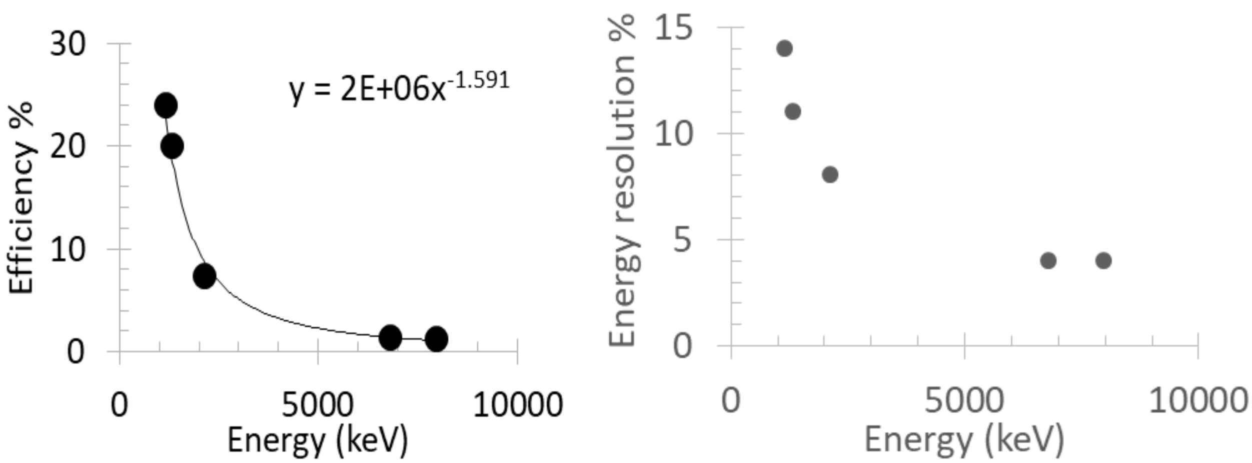

Fig. 4. Left panel: photopeak efficiency as a function of the gamma energy fitted with a power law. Right panel: Energy resolution as a function of the gamma energy.

The rather low absolute photopeak efficiency of the TexCAAM array at the highest energies makes the device not ideal for applications where high energy gamma rays needs to be detected. On the contrary, the efficiency of the assembly is high at energies below 2 MeV. This makes the detector suitable for experiments where gamma rays in the energy range from 400 to 2000 keV are produced. For example, TexCAAM could be used around an extended gas target to tag inelastic scattering events in (p, p') or (α, α') reactions. The segmentation of the detector can also provide a rough measurement of the location of the interaction point inside the gas target.

[1] D.J. Millener *et al.*, Phys. Rev. C **26**, 1167 (1982).