Response of CdZnTe Detectors on the *Swift* Burst Alert Telescope

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Swift (Gehrels, 2000) is the Gamma Ray Bursts (GRBs) explorer, that is scheduled for launch in 2004. The Swift's major instrument Burst Alert Telescope (BAT) detector array sits Cadmium Zinc Telluride (CdZnTe, CZT) semiconductor devices under a coded mask. The array has 32,768 individual $Cd_{0.9}Zn_{0.1}Te_{1.0}$ detectors (4×4 mm^2 large, 2mm thick) that have a total detector area of 5240 cm^2. CdZnTe materials are able to operate at room temperature for its large band gap, and also have a high average atomic number which makes them sensitive to hard X-rays (15∼150 keV). We investigate energy response of the BAT detector for which to dedicate spectroscopy and imaging in observations of GRBs.

§1. Detector energy response

1.1. *Detector energy response*

CdZnTe and Cadmium Telluride (CdTe) semiconductor materials consist of II-VI family, which have relatively high atomic numbers ($Z_{\rm Cd}$ = 48, $Z_{\rm Te}$ = 52, $Z_{\rm Zn}$ = 30) and a wide band gap energy ($E_{\rm CdZnTe}$ = 1.6 eV, $E_{\rm CdTe}$ = 1.4 eV) which allows these materials to be operated at room temperature. CdTe/CdZnTe devices, however, have relative poor charge transfer efficiency (CTE) compared with the silicon or germanium detectors. This is because the holes, in particular, exhibit a small mobility (μ) and a short lifetime (τ), meaning that they have been trapped before being all collected. Hence, output pulse height depends on a depth of photon interaction in the detector, and the relative poor CTE makes a broad tail in the lower energy of the peak spectrum. This low-energy tail, which is caused by an interaction at the deeper position since the CZT distribution in the detector, makes the detector energy response matrix even more complicated.

1.2. *$\mu\tau$ Model fitting method*

In order to build the detector response matrix, we calculate the interaction depth distribution of the photo-electric absorption by using a Monte Carlo simulation. In addition, we evaluate the CTEs for electrons and holes which depend on the depth of energy deposits. We adopted the Hecht equation (Hecht, 1932) to describe the CTEs as functions of the $\mu\tau$ products for electron and holes. Assuming that there is a constant electric field in the detector, we modeled of the CdZnTe energy spectrum as "$\mu\tau$ model". Thus, we evaluate the $\mu\tau$ parameters for electrons and holes of the entire detectors by the spectral model fitting.

§2. BAT pre-flight calibration

We have performed the pre-flight calibration test at NASA/Goddard Space Flight Center so that we investigated the energy response of the BAT detector in 15∼150 keV gamma-rays. This calibration test is divided into two phases. The first

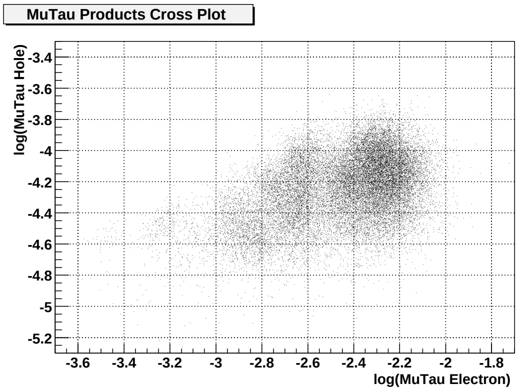

Fig. 1. Correlation the $(\mu\tau)_{\rm e}$ with the $(\mu\tau)_{\rm h}$ for 28,672 pixels after $\mu\tau$ fitting.

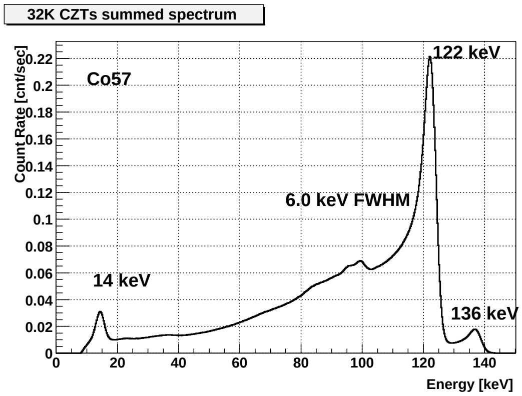

Fig. 2. The measured ^{57}Cospectrum which is summed up for 32K CZT pixels.

phase is for each "Block" with 2048 CZT pixels, and the second is for the full BAT array.

2.1. *Phase 1: Block calibration test*

In this test, we have used four different radiation sources, such as ^{241}Am, ^{57}Co, ^{109}Cd, ^{137}Cs at various bias voltages (100, 150, and 200 V), temperatures and incident angles. Then we analyzed the photopeak position and the amount of tail in each spectrum. Also, in order to determine the $\mu\tau$ parameters, we have applied the simultaneous fitting of the 122 keV photopeak of ^{57}Co spectra obtained in three different bias voltages at 20°C. We evaluated 28,672 detectors so far, and the rest is under data analysis. We succeeded to determine the $\mu\tau$ for 26581 ($\sim$ 92%) detectors. The measured $(\mu\tau)_{\rm e}$s are distributed from 5.0×10^{-4} to 1.0×10^{-2} cm^{2}V^{-1}, while $(\mu\tau)_{\rm h}$s are distributed from 1.0×10^{-5} to 1.7×10^{-4} cm^{2}V^{-1}.

2.2. *Phase 2: Full array calibration test*

After all sixteen blocks are installed on the detector array plate which is located 1 m under the coded aperture mask. In the calibration, the detector signals are modulated by the mask pattern and an active source was sat on an X-Y table held 2 m above the mask. By de-convolving the image using an FFT image reconstruction software, we achieved the angular resolution of 23.7 arcmin (FWHM) for the point source observation and also the energy resolution of 6.0 keV (FWHM) for the ^{57}Co main peak in the 32K CZT summed spectrum.

References

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