Energy Response of CdZnTe Detectors in the BAT onboard Swift Satellite

M. Suzuki¹, M. Tashiro¹, G. Sato², K. Nakazawa¹, T. Takahashi², S. Watanabe¹, Y. Okada¹, H. Takahashi³, S. Barthelmy⁴, J. Cummings⁵, N. Gehrels⁶, D. Hullinger⁶, H. Krimm⁶, C. Markwardt⁶, A. Parsons⁶, J. Tueller⁶, E. Fenimore⁶, D. Palmer⁶, D. Willis⁶

¹Saitama University, Japan; ²Institute of Space and Astronautical Science (ISAS/JAXA), Japan; ³University of Tokyo, Japan; ⁴NASA/Goddard Space Flight Center, USA; ⁵Los Alamos National Laboratory, USA; ⁶University of Southampton

1. Introduction

Swift is the Gamma-Ray Bursts (GRBs) explorer, that is scheduled for launch in May of 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 Cd₃Zn₇Te₄ detectors (4×4 mm², 2 mm thick) that have a total detector area of 5240 cm². CdZnTe materials have a large band gap which allows them to operate at room temperatures, and also have a high average atomic number which makes them sensitive to hard x-rays (15 ~ 150 keV).

So we investigate the energy response of the BAT detector mainly to study the spectroscopy and imaging in the observations of the burst's afterglow.

2. Model fitting method

Electron-Hole drift

\[ \text{Hecht equation} \]

\[ \eta(x) = \frac{\exp\left(-\frac{x-E_0}{\tau}\right)}{1+\exp\left(-\frac{x-E_0}{\tau}\right)} \]

\( \eta(x) \) is the amount of charge collected from a CZT detector depends on the depth of the photon interaction. The holes, in particular, have a small mobility and a short lifetime, so they are not all collected. The Hecht equation describes the amount of charge that is collected. It depends on the \( \mu \) product for electrons (\( \mu_e \)) and the \( \mu \) product for holes (\( \mu_h \)). These quantities together completely characterize the charge transport properties of a detector.

3. sim-SwiMM (Swift Mass Model)

Mask-weighting Method

Before the spectra are summed, each one is first multiplied by a “mask-weighting” factor that lies somewhere between -1 and 1. If the “mask-weighting” factor for a particular detector is -1, that means the detector is entirely in the shadow of a lead tile (that is, the “shadow” that is cast by the source). If the “mask-weighting” factor is 1, that means the detector does not lie in the shadow of a lead tile at all. A “mask-weighting” factor between -1 and 1 means that the detector lies partially in the shadow of a lead tile.

Response builder

In order to make a GRB spectrum, it takes long time to apply to the all 32 k \( \mu \) values in each detector. So, we devised the above gpusces plot panel in grids with equal interval in log-scale. For each grid, a fraction of number of detectors in the total number (26,301) is calculated and those more than 0.1 % are shown in the red color. To construct spectral model for summed spectrum, we firstly calculate “\( \mu \) model” for each 36 grid with \( \mu \) products at the center of the grid, and sum them up with the fraction of the grid as a weight, we call this “multi-\( \mu \) model.”

Summary

3. We estimated the BAT detector characteristic features by measuring \( \mu \) values for 32k CdZnTe.

4. On sim-SwiMM, we can reconstruct the measured \( ^{57}\text{Co} \) spectrum in the full array test.

5. We will develop the sim-SwiMM to BAT response builder in the near future.