Full Spacecraft Source Modeling and Validation for the GLAST Burst Monitor

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Abstract. The GLAST Burst Monitor (GBM) consists of 12 NaI detectors and 2 BGO detectors mounted on two sides of the spacecraft. This provides detection capability for energies between 10 keV and 30 MeV, and sensitivity to all directions in the sky. Extensive measurements using radioactive sources have been performed on the isolated detectors. Simulations of these measurements using the GEANT4 Monte Carlo radiation transport simulations toolset have also been preformed. For gamma-ray burst the spacecraft itself will have a significant impact on the detector response, therefore the final stage of validations involves measuring the detector response to radioactive sources after the spacecraft is fully assembled, and validating the results using simulation. Details of these simulations will be given in this paper.

Keywords: GLAST, burst monitor, simulations, validation
PACS: 95.55.Ka, 98.70.Rz

INTRODUCTION

The GLAST mission is the next major NASA mission to explore the high-energy universe. Its primary payload, the Large Area Telescope (LAT), is designed to measure gamma-rays between 20 MeV and 300 GeV. The secondary payload, the GLAST Burst Monitor (GBM), is designed to fill in the gap between 10 keV to 30 MeV. The GBM will provide the critical bridge between the almost completely unexplored high-energy regime the that LAT is designed for, and the previously studied low-energy regime.

Gamma-rays in the energy range between 10 keV and 30 MeV will have a significant cross section for interaction within the GLAST spacecraft. It is therefore critical to properly account for this effect when interpreting the data in the GBM detectors from a transient source.

In order to do this a detailed mass model of the full spacecraft has been built using GEANT4 and incorporated in the GBM Response Simulation System (GRESS). The goal is then to validate the model by comparing calibration data using radioactive sources and simulations of those sources. Once this validation is done, response functions for each of the detectors can be calculated from the simulations and used for proper reconstruction of astrophysical sources.

CALIBRATION SOURCE MODEL

For calibrations of the full spacecraft two high intensity radioactive sources were purchased. The first, a ^{137}Cs source, produces a 662 keV gamma-ray, the second, a ^{60}Co source produces gamma-rays at 1173 keV and 1333 keV. A thick lead collimator was designed and built to hold these sources and minimize scatter from gamma-rays not directly incident on the spacecraft. For calibrations there will be a floor, walls, and a ceiling all near the spacecraft which would not be present in its natural operating conditions in orbit. We therefore try to minimize gamma-rays scattering with this collimator. The collimator will have an effect on the gamma-ray spectrum hitting the spacecraft as scattering will occur in the lead, therefore a model of the source collimator is also required.

CP921, *The First GLAST Symposium*
edited by S. Ritz, P. Michelson, and C. Meegan

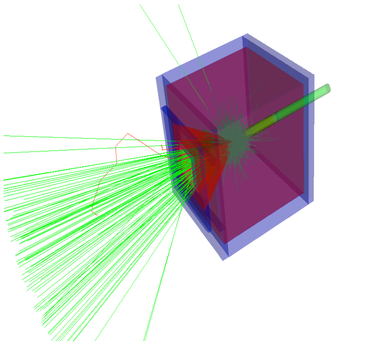

FIGURE 1. GEANT4 model of calibration source holder

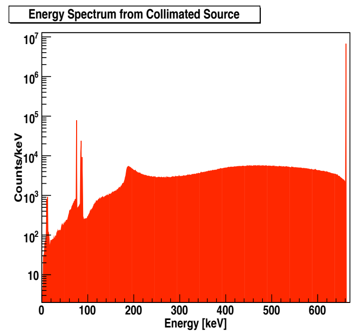

FIGURE 2. Energy distribution of gamma-rays leaving the source holder

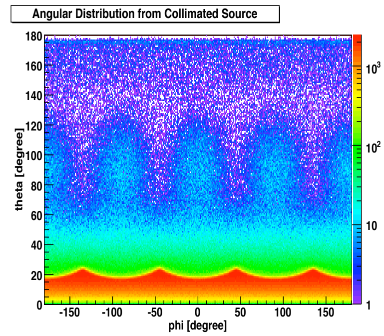

FIGURE 3. Angular distribution of gamma-rays leaving the source holder

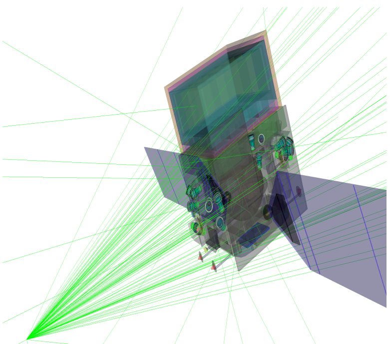

FIGURE 4. Simulation of Source with Satellite

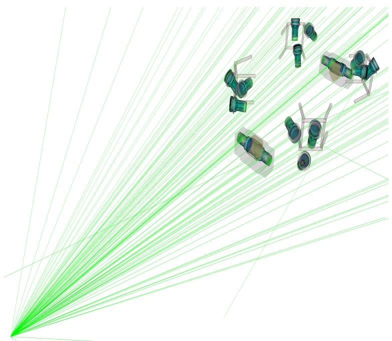

FIGURE 5. Simulation of Source without Satellite

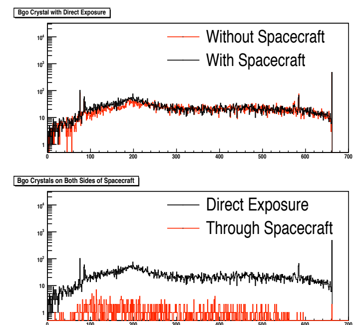

FIGURE 6. Simulated Energy Spectrum in BGO detector

Simulations using the full spacecraft model are computationally rigorous and therefore it would be prohibitively slow to add the 4π source and collimator directly to the GRESS package. The source with collimator was therefore modeled independently. From the output of these simulations a source was built in GRESS that would generate the appropriate angular and energy distribution.

The source collimator is shown in Figure 1. The inner region is made of lead. The outer shell is made of aluminum. There is a stainless steel source holder inserted from the back. The source is attached to the front of the stainless steel piece which is at the entrance of a 30 degree by 30 degree opening. The size is about 6" x 6" x 6" and weighs about 60 lbs. Figure 1 shows 3000 simulated gamma-rays inside the collimator. A simulation was done using about 250 million primary gamma-rays. The output energy and angles were recorded and used to model a source with similar energy and angular distribution but only throwing those gammas that escape. The output from the source model is shown in Figures 2, 3. Approximately 9 million gamma-rays per second are emitted. The modeled source is binned into 16 phi distributions based on theta and 64 different energy distributions based on the theta and phi.

Source in GRESS

In order to understand to effect the spacecraft mass has on the detector response, simulations using the source model were performed with the full spacecraft, as well as without but with detectors in their proper locations.

Figures 4 and 5 show the two configurations simulated. The first is the spacecraft in its flight configuration, the second figure is only the GBM detectors. Figure 6 is the energy spectrum for the two BGO detectors with and without the spacecraft. The top figure is for the BGO on the side of the source. The bottom figure shows both BGO crystals with the spacecraft present.

After completion of the source calibrations the mass model can be adjusted to match the simulations and experimental data. This will conclude the validation of the simulation software. Final response DRMs can then be generated.