The GLAST Burst Monitor Instrument Response Simulation System

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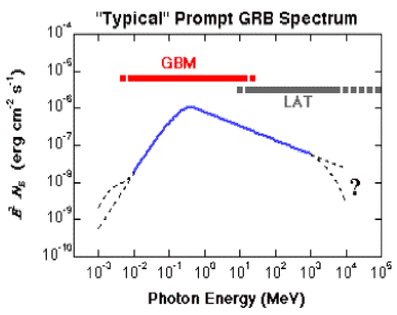
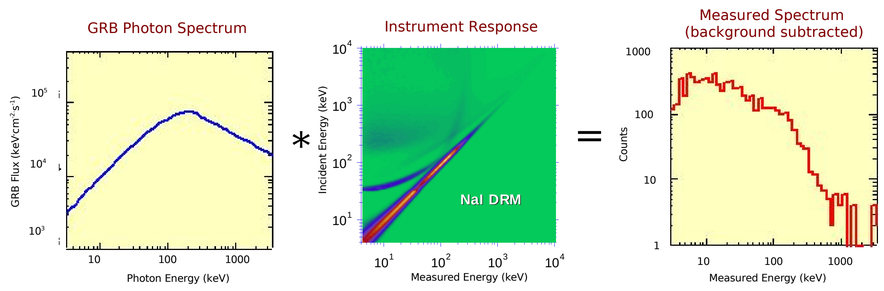
The Gamma-ray Large Area Space Telescope (GLAST) will study the cosmos in the 10 keV - 300 GeV energy range. The Large Area Telescope (LAT) is the main instrument, and will cover the 20 MeV - 300 GeV energy range. A second instrument, the GLAST Burst Monitor (GBM), is designed to provide wide field of view observations of gamma-ray bursts from 10 keV to 25 MeV, overlapping with the lower limit of the LAT range. The GBM is composed of twelve NaI and two BGO detectors that are widely dispersed about the GLAST spacecraft. Reconstructing burst locations and energy spectra from these separated detectors requires detailed knowledge of the response to direct and scattered burst radiation. A simulation software package based on the GEANT4 Monte Carlo toolset is being developed to fulfill this requirement. Our main task is to understand the GBM detector response for direct source photons, photons scattering from the instrument and spacecraft body, and photons scattering from the earth's atmosphere. We will discuss the architecture of our simulation system, present preliminary comparisons between simulation results and laboratory measurements, and use these results to evaluate the scientific capabilities of the GBM.

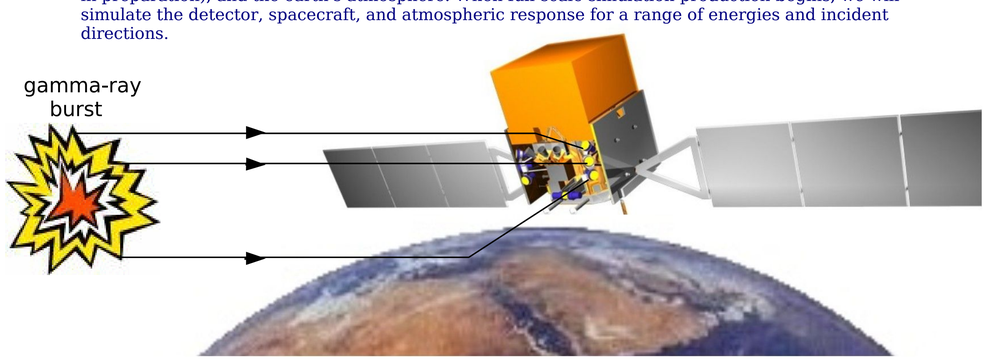
The GBM complements the LAT in the low-energy region, allowing for comparison between the well understood low-energy region and the unknown high-energy region.



The detector response matrix (DRM) describes how the detector responds to a source photon spectrum. Accurate simulation of the DRM is critical for the data analysis process, where the DRM is used to unfold the original source spectrum from the measured spectrum. The quality of scientific return from the GBM relies on this simulation.

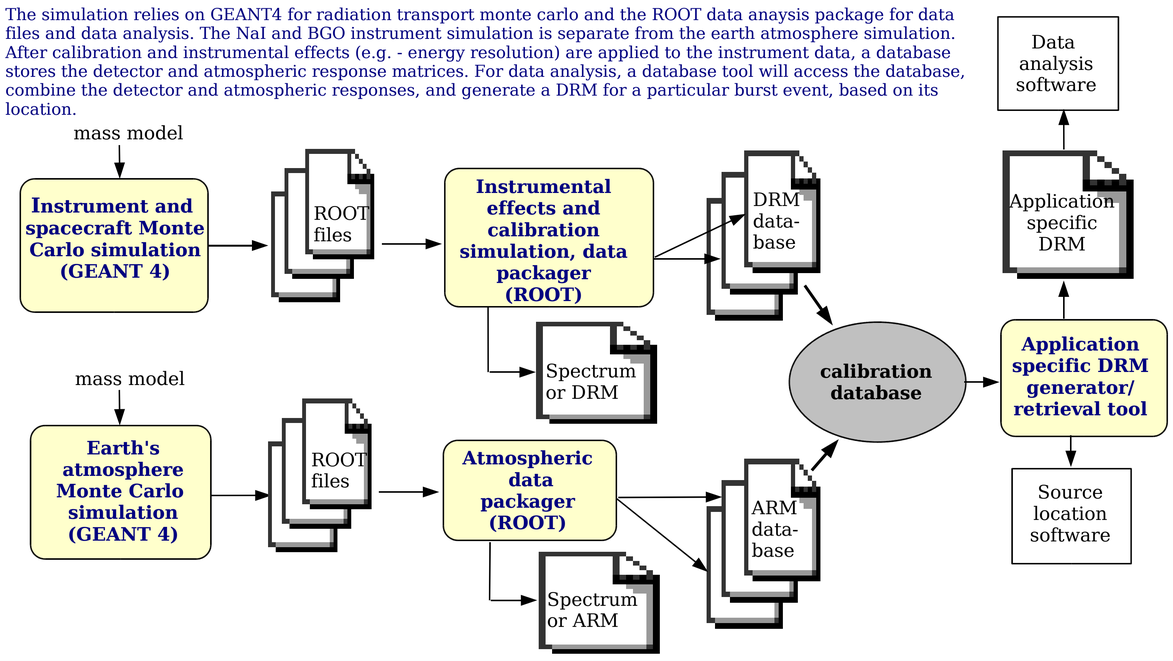


The simulation software must determine the response of the GBM detectors from several possible sources: 1) source photons which hit the detector directly and may scatter inside the detector itself, 2) source photons which scatter off the spacecraft before entering the detector, 3) source photons which scatter off the earth's atmosphere (and possibly the spacecraft also) before entering the detector. The simulation uses full-scale, detailed models of the NaI and BGO detectors, the spacecraft (currently in preparation), and the earth's atmosphere. When full-scale simulation production begins, we will simulate the detector, spacecraft, and atmospheric response for a range of energies and incident directions.

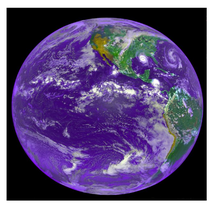


Software architecture

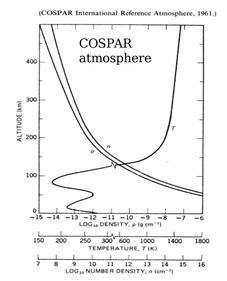
The simulation relies on GEANT4 for radiation transport monte carlo and the ROOT data anaysis package for data files and data analysis. The NaI and BGO instrument simulation is separate from the earth atmosphere simulation. After calibration and instrumental effects (e.g. - energy resolution) are applied to the instrument data, a database stores the detector and atmospheric response matrices. For data analysis, a database tool will access the database, combine the detector and atmospheric responses, and generate a DRM for a particular burst event, based on its location.

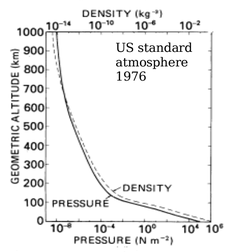


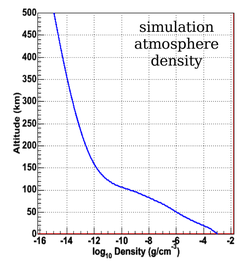
Earth atmosphere model

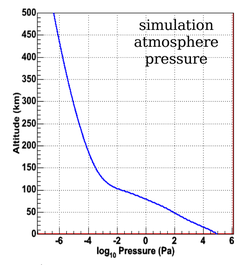


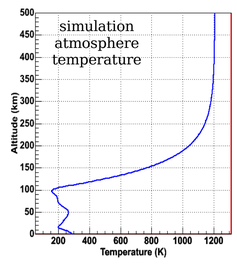
A full-scale simulation of the earth's atmosphere was constructed from concentric spherical shells, with each shell having a unique temperature, density, pressure and element composition. The number and thickness of the layers is arbitrary and easily changed. The NRLMSISE-00 atmospheric model is used, and covers from 0-1000 km. The density, pressure, temperature, and composition of the simulation atmosphere, shown below, agree well with the COSPAR and US Standard atmosphere data.

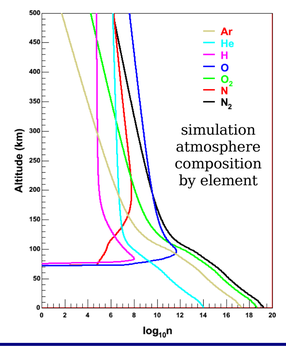


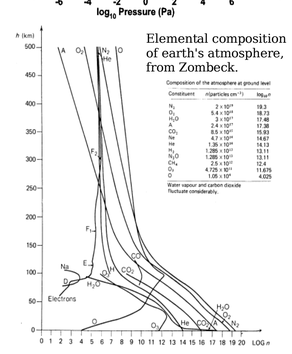




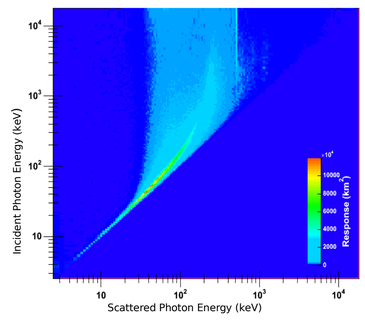








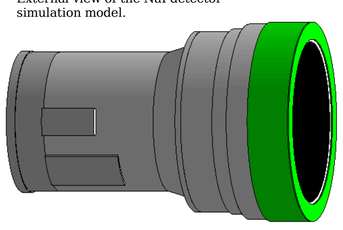
Simulated atmospheric response matrix.



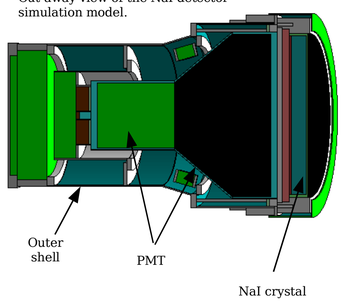
NaI detectors

There are 12 NaI detectors distributed around the spacecraft in groups of three. Each NaI crystal is 12.7 cm in diameter and 1.27 cm thick. The NaI detectors cover the 10 keV to 1 MeV range. To generate a proper DRM, a high degree of precision and accuracy is required in the simulation model of these detectors, particularly around the NaI crystal and its interface to the photomultiplier tube.

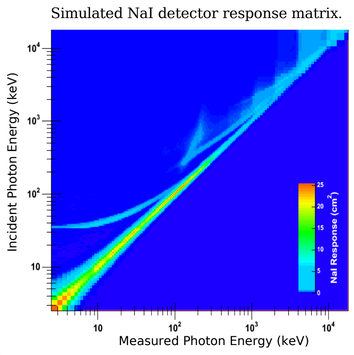
External view of the NaI detector simulation model.



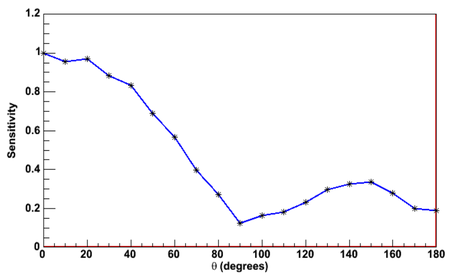
Cut-away view of the NaI detector simulation model.



Simulated NaI detector response matrix.



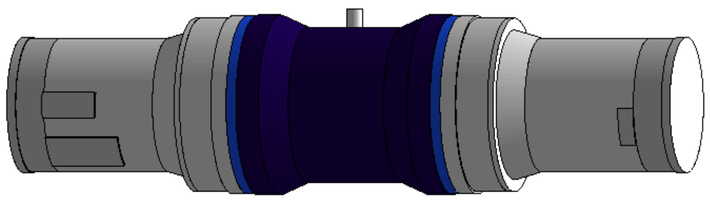
NaI detector sensitivity to a plane wave, Band function source as a function of incident photon angle (Band function parameters used: α=-1, β=-2.3, E_{peak}=230 keV). Normal incidence is 0 degrees. Data is normalized by the normal incidence value. The detector shows some sensitivity even for sources located behind the detector's look direction.



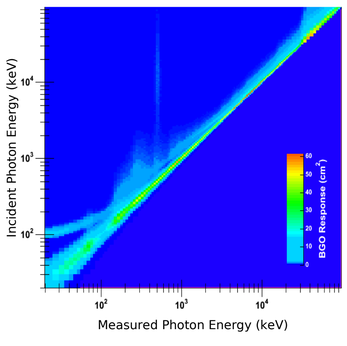
BGO detectors

The 2 BGO detectors cover the 150 keV to 25 MeV range, providing good overlap with the NaI detectors and the LAT. Each BGO crystal is 12.7 cm in diameter and 12.7 cm thick, and viewed by two photomultiplier tubes.

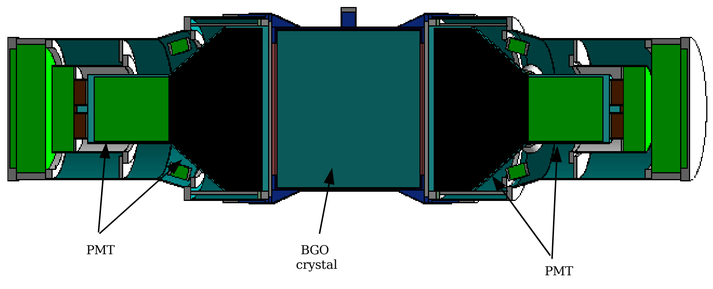
External view of the BGO detector simulation model.



Simulated BGO detector response matrix.

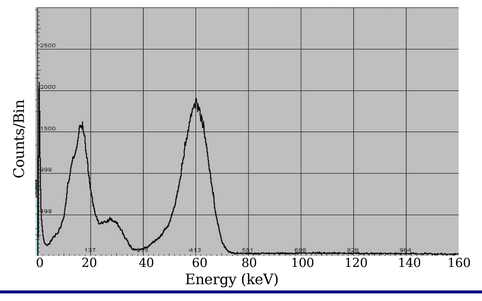


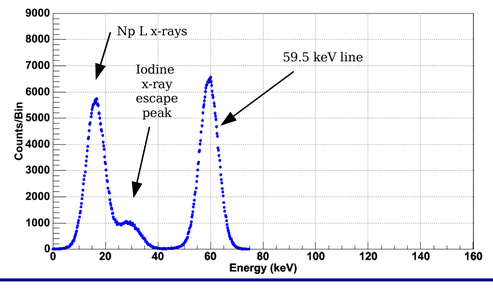
Cut-away view of the BGO detector simulation model.



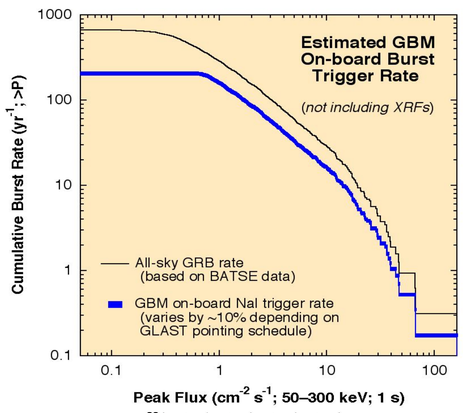
Preliminary comparison to calibration data

Americium-241 spectrum taken with a prototype NaI detector (left), and spectrum obtained with the simulation (right). The prototype model is similar but not identical to the simulation model, so only general agreement is to be expected. The simulation included the 59.5 keV (36%) and 26.3 keV (2.4%) lines, and Neptunium-237 L shell x-rays (38%) modeled as one line at 16.2 keV. The Iodine x-ray escape peak is visible near 30 keV.

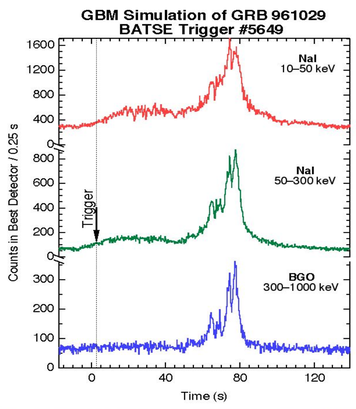


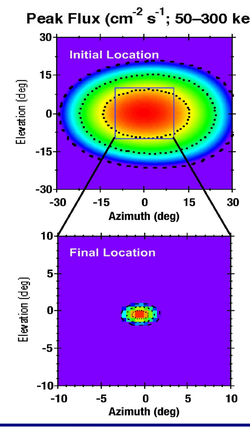


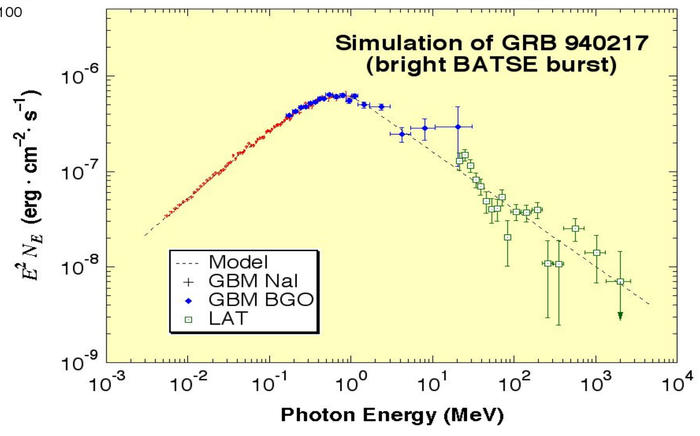
GBM expected performance



We expect to trigger on approximately 200 bursts per year, and determine the burst location for the brightest bursts with an error of < 15° after on-board analysis and 3° after ground-based analysis.







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