Gamma Ray Astronomy at MPE

GLAST Burst Monitor

Understanding the GLAST Burst Monitor detector calibration.
A detailed simulation of the calibration including the environment

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The GLAST Burst Monitor (GBM) is the secondary instrument on NASA's next Gamma-ray mission GLAST. It will enhance the capabilities of GLAST by locating and detecting cosmic gamma-ray bursts at lower energies by the use of

12 NaI detectors (10 keV to 1 MeV)

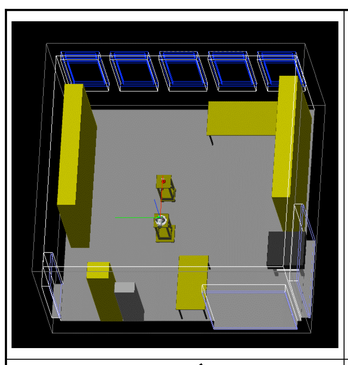
and

2 BGO-detectors (150 keV to 30 MeV).

The angular and energy response of each GBM detector has been calibrated using various radioactive sources at different incidence angles relative to the detector in a laboratory environment at the MPE in 2005. To facilitate the understanding of the reconstruction of the detector response, a detailed simulation of the whole laboratory environment and the calibration source setup was performed using a modified version of the CERN GEANT4 simulation software (provided by LANL).

Here we summarize the results of a detailed comparison and analysis of the calibration measurements and the simulation. Emphasis is given to disentangle the contribution of the various components of the environment (furniture, source holder, detector holder, floor etc.) to the measured spectra. Components that contribute significantly to the measured spectra are identified. This results are important to derive the best calibration and response determination of our instrument and may be of interest for the calibration of future experiments.

Please see also the 4 other posters that are related to this GBM calibration and simulation: P19.17 (Hoover), P19.35 , P19.36 (v. Kienlin), 19.44 (Kippen)



Calibration Setup

The full environment (laboratory) of the calibration setup was modeled. All components (walls, windows, furniture, floor, ceiling etc.) could be activated or deactivated for interactions of the radiation.

The radioactive sources used for the calibration were placed onto a source holder at a fixed position near the middle of the room.

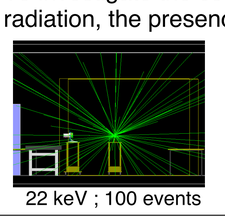
The detector mounting could be rotated around three axes to change the angle of the incident radiation.

The distance between detector and radioactive source was 1.16m.

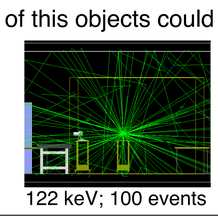
Scattering of Radiation

A significant part of the radiation emitted isotropically by a source is scattered in various objects in the laboratory, including the air.

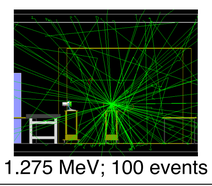
To investigate the contribution of the various objects to the scattered radiation, the presence of this objects could be turned on/off.



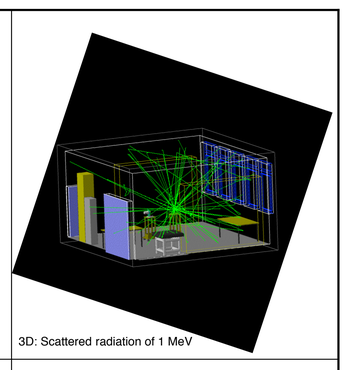
22 keV ; 100 events



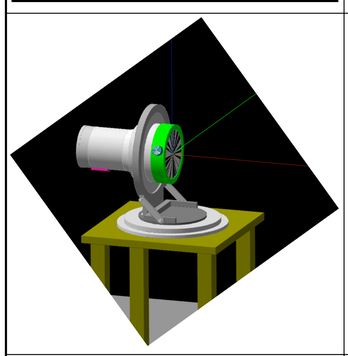
122 keV; 100 events



1.275 MeV; 100 events



3D: Scattered radiation of 1 MeV



NaI Detector

A complete detailed model of a NaI detector and its mounting brackets (materials, components, and geometry) as it is used on the spacecraft was created.

In addition, the complex holding structure, which enabled a rotation of the detector around all three axes during the calibration was modeled. The holding structure consisted of Aluminum and was mounted on a wooden stand raising it about one meter above the laboratory floor.

All this was modeled with great care as this material is close to the detector!

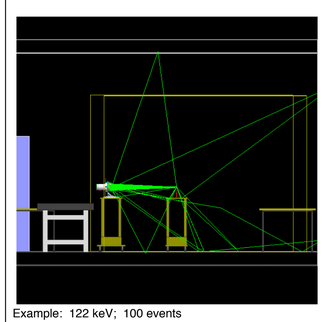
Radiation Scattered into Detector

With increasing energy of the radiation, an increasing fraction of the scattered radiation reaches the detector and contributes to the "source background" (i.e. background induced by the isotropic radiation of a source present).

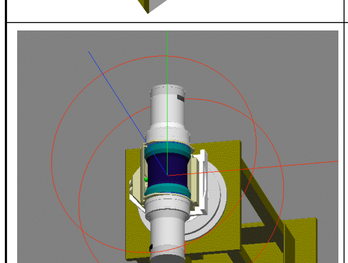
At 22 keV, only few percent of the detected radiation are scattered photons. Most photons reach the detector directly. But at 1.275 MeV a significant part of the detected radiation is from scattered photons.

Percentage of detected photons direct / scattered (%):

22 keV: 94 / 6; 122 keV: 91 / 9; 1.275 MeV: 75 / 25



Example: 122 keV; 100 events



BGO Detector

A complete detailed model of a BGO detector and its complex mounting bracket (materials, components, and geometry) as it is used on the spacecraft was created.

In addition, the holding structure, which enabled a rotation of the detector around all three axes during the calibration, was modeled. The holding structure consisted of Aluminum and was mounted on a wooden stand raising it about one meter above the laboratory floor.

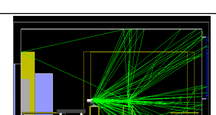
All this was modeled in great detail as this material is very close to the detector!

Modified Radiation Geometry

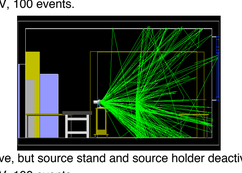
Two methods have been applied to derive the relative contribution of objects to the detected radiation:

- The radiation geometry could be modified to radiate certain directions and objects only;
- the presence of objects in the simulation could be switched off.

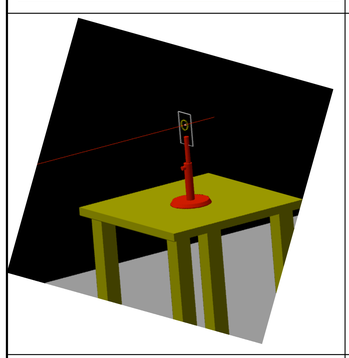
This was done in many test runs to determine the relative contribution of the components of the environment to the measured spectra.



modified radiation geometry: radiation only to the right; 122 keV, 100 events.



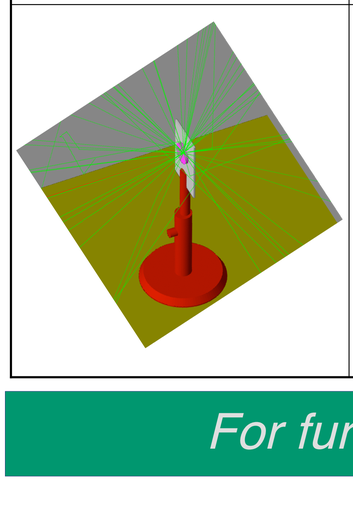
as above, but source stand and source holder deactivated; 122 keV, 100 events.



Source Holder

The source holder was built entirely from PVC. The disc containing the radioactive material was glued with an adhesive tape to the source holder. Great care was taken to place the source directly in front of (as seen from the detector) a small hole in the holding plate. This hole was meant to avoid direct backscatter and to guide as an "on-axis" marker. Like the detectors, the source holder rested on a wooden stand.

A detailed modeling was done as the components were close to the radiating source.



Radioactive Calibration Sources

The radioactive material of the calibration sources was contained in a sphere of about 1 mm diameter in the center of a flat plastic disc of about 3 mm thickness and 1 cm radius.

Sources used and simulated (main energies in MeV):

^{109}Cd (0.022), ^{241}Am (0.059), ^{57}Co (0.122, 0.134), ^{203}Hg (0.279), ^{137}Cs (0.662), ^{51}Mn (0.835), ^{22}Na (0.511, 1.275), ^{88}Y (0.898, 1.836)

Summary of Results

To achieve good statistics, almost all simulation runs have been made with 10 000 input photons (photons emitted by the source).

	NaI			BGO
component	**22 keV**	**122 keV**	**1.275 MeV**	**4.43 MeV**
direct infall	94.0 %	91.0 %	75.0 %	70.0 %
scattered rad. total	6.0 %	9.0 %	25.0 %	30.0 %
walls	< 0.1 %	0.6 %	12.0 %	13.0 %
source holder	4.6 %	7.5 %	3.0 %	2.0 %
source stand	0.1 %	< 0.1 %	< 0.1 %	< 0.1 %
detector stand	<0.1 %	< 0.1 %	2.0 %	< 0.1 %
floor	< 0.1 %	0.8 %	8.0 %	15.0 %
other furniture	< 0.1 %	< 0.1 %	< 0.1 %	< 0.1 %
air	1.3 %	< 0.1 %	< 0.1 %	< 0.1 %

A collimator would have simplified the environmental model but would probably have little effect to the measurements. This, however, should be tested in a future application of the simulation software and the existing model by simulating the presence of a collimator!

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Poster #19.33; First GLAST Symposium, Stanford University, CA, USA, 2007-02-05/08 *hs*