GLAST LAT Calibration Unit beam tests at CERN

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Abstract

The Gamma-ray Large Area Space Telescope (GLAST) is a next generation gamma-ray satellite, designed to operate in energies ranging from 10 keV to 300 GeV. The scheduled launch is in the beginning of 2008 from the Kennedy Space Center in Florida, USA. This poster describes the GLAST satellite, the two major beam test campaigns at CERN in 2006, performed by the GLAST LAT collaboration, and preliminary results from the analysis of the collected beam test data.

GLAST

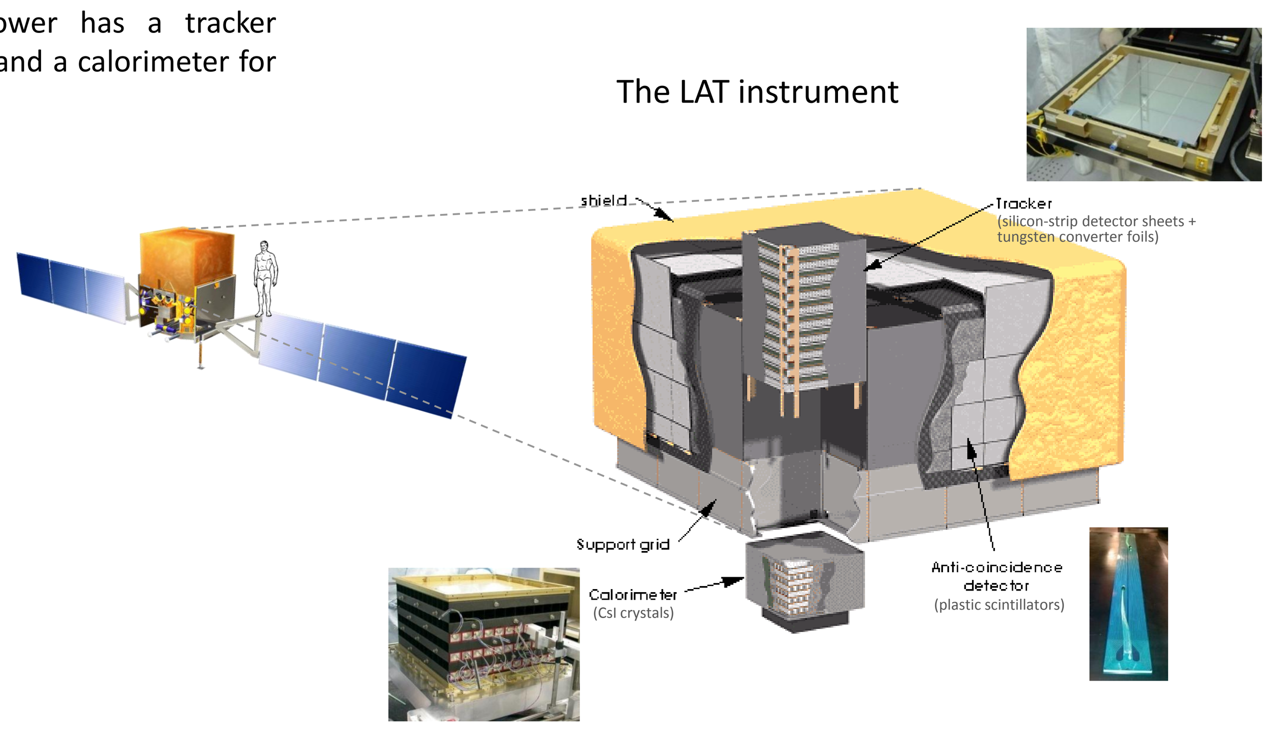
The Gamma-ray Large Area Space Telescope (GLAST) mission is a next generation high-energy gamma-ray observatory designed to make observations of celestial gamma-ray sources in the energy range extending from 10 keV to about 300 GeV. The expected launch is in the beginning of 2008.

Its predecessor was the CGRO-EGRET experiment, which was operational between 1991 and 1999. With respect to this experiment, GLAST promises many improvements such as a much shorter deadtime and a much higher sensitivity.

The GLAST experiment is a large international effort with members from USA, Germany, France, Italy and Sweden and consists of two instruments, Large Area Telescope (LAT) and Gamma-ray Burst Monitor (GBM). LAT is the main instrument and consists of 16 identical towers arranged in a 4x4 array, covered by anti-coincidence tiles for background rejection. Each tower has a tracker module for direction determination and a calorimeter for energy measurements.

Quantity	LAT (Minimum Spec.)	EGRET
Energy Range	20 MeV - 300 GeV	20 MeV - 30 GeV
Peak Effective Area[1]	> 8000 cm^2	1500 cm^2
Field of View	> 2 sr	0.5 sr
Angular Resolution[2]	< 3.5° (100 MeV) < 0.15° (>10 GeV)	5.8° (100 MeV)
Energy Resolution[3]	< 10%	10%
Deadtime per Event	< 100 µs	100 ms
Source Location Determination[4]	< 0.5'	15'
Point Source Sensitivity[5]	$< 6 \times 10^{-9}$ cm^{-2} s^{-1}	$\sim 10^{-7}$ cm^{-2} s^{-1}

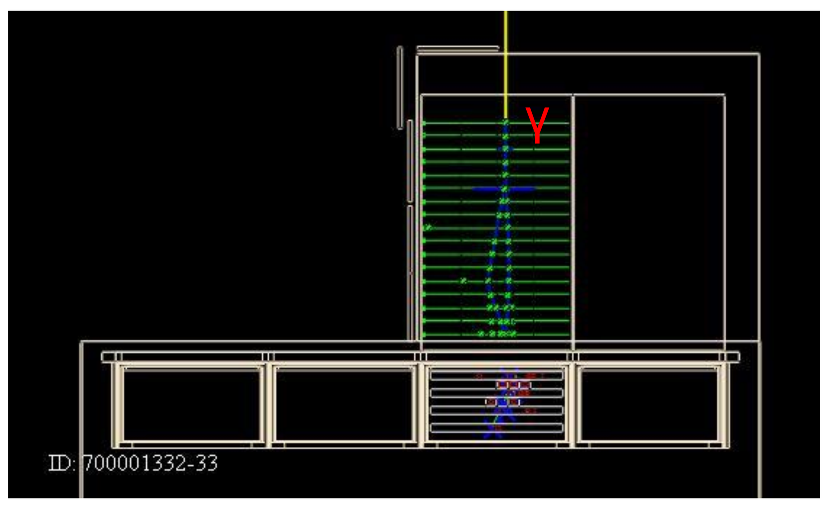
[1] After background rejection
[2] Single photon, 68% containment, on-axis
[3] 1-σ, on-axis
[4] 1-σ radius, flux 10^{-7} cm^{-2} s^{-1} (>100 MeV), high $|b|$
[5] > 100 MeV, at high $|b|$, for exposure of one-year all sky survey, photon spectral index -2



Analysis

Many analysis topics are possible with the collected beam test data. One important topic is the study of the different sources of background that the LAT will encounter in orbit. There, only a small fraction of the signals are due to gamma-rays. The science requirements for LAT demand a rejection power of 10^6 to 1 at 10 GeV. The following areas have therefore been studied using the collected beam test data:

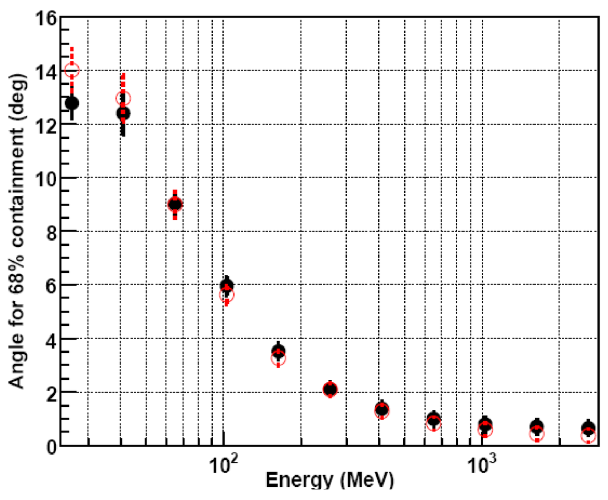
- **Albedo gamma-rays**
  These are gamma-rays produced when cosmic rays interact with the atmosphere of the Earth and enter the LAT from the side and back. Some of these can mimic a gamma-ray with normal incidence.
- **Hadronic interactions**
  Protons can interact with the instrument or the spacecraft, generating a hadronic cascade that can mimic an electromagnetic shower in the CAL. To reject this type of events, the transverse size of the shower and the distance between the first hit in the tracker and the ACD are used.
- **Charged particles interacting in the MicroMeteoroid Shield**
  If a charged particle enters the instrument, the ACD can be used to reject it. However, if the charged particle interacts with the MMS, photons can be produced within the LAT field of view.
- **Heavy ions**
  Heavy ions deposit a well known amount of energy through ionization in the CAL and the ACD. Therefore, these subdetectors can be calibrated with heavy ions.



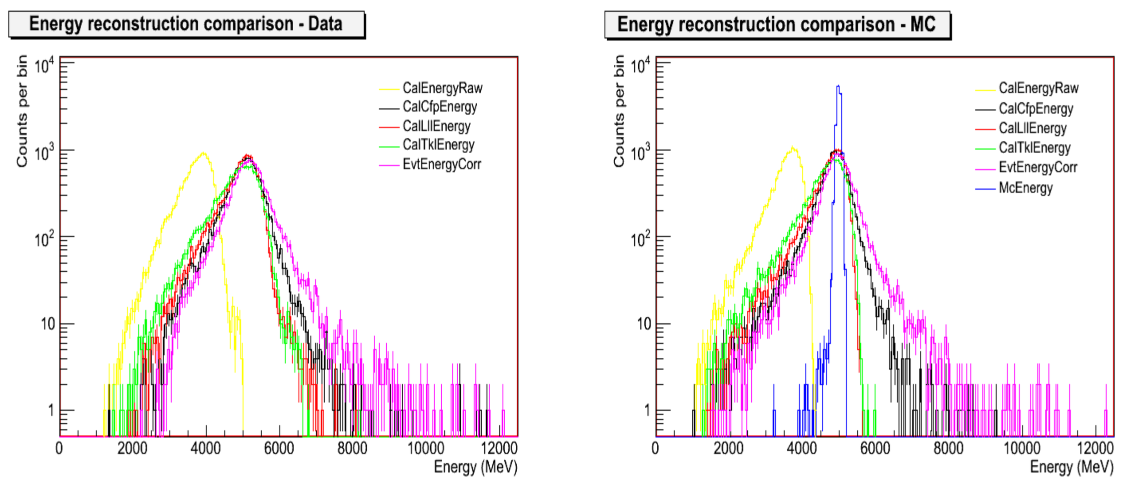
Event display showing an interacting photon in the Calibration Unit.

The Swedish interests in this analysis have been directed towards the following topics:

- **Monte Carlo validation**
  - Direction, position and energy reconstruction
  - CAL only events
  - Variables used in classification trees for energy reconstruction
- **Calorimeter studies**
  - Assymmetry curves for calorimeter crystals
  - Trigger efficiencies
- **Electronics validation**
  - Validation of a previous discrepancy in the autorange readout mode of the integrated circuit in the CAL



Angular dispersion at 68% containment. Black is data, red is Monte Carlo. From Baldini et al., *Preliminary results of the LAT Calibration Unit beam tests*, Proc. The First GLAST Symposium, Feb 2007.



Energy reconstruction for a 5 GeV electron run with 0 degree incoming angle, showing the raw energy measured by the CU in yellow and the four available methods to reconstruct energy in the other colors except blue. (*Left*) The resulting energy reconstruction from the CERN PS data. (*Right*) The resulting energy reconstruction from simulation, with true energy shown in blue.

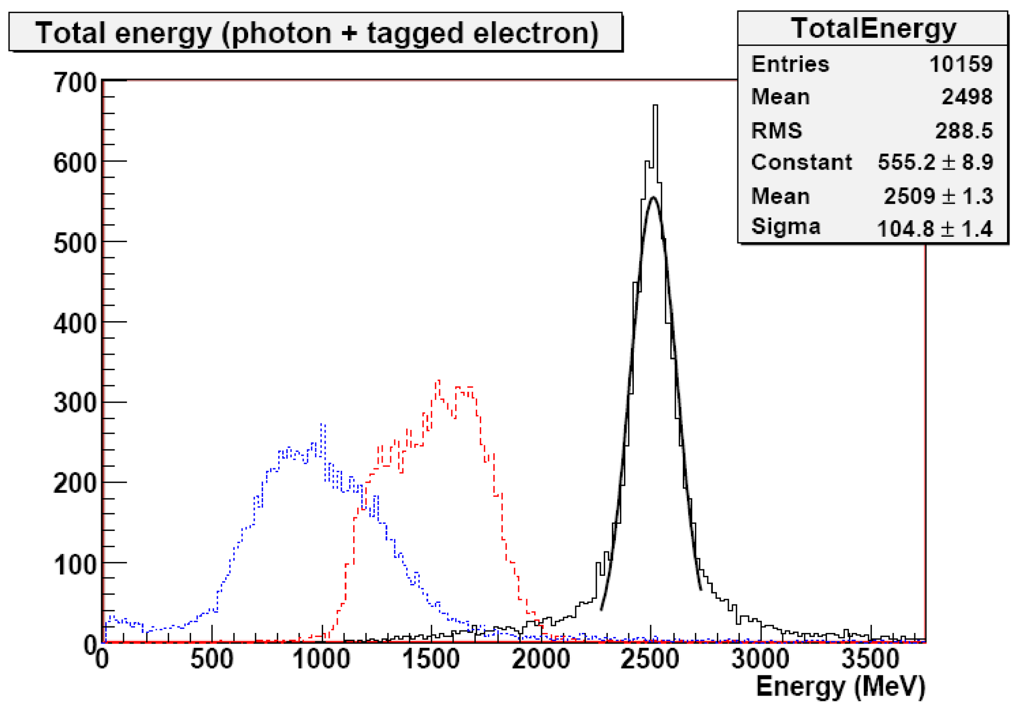
Beam tests at CERN

During the year 2006, two beam tests were performed at CERN by the GLAST-LAT collaboration, the first one in the Proton Synchrotron (PS) facility in July and the second one in the Super Proton Synchrotron (SPS) facility in September.

The tests were performed on the LAT Calibration Unit (CU), which consists of spare flight modules and flight electronics. Two full towers, with a tracker (TKR) module and a calorimeter (CAL) module, an additional calorimeter, and a few anti-coincidence detector (ACD) tiles were included in the CU. At CERN it was exposed to a variety of beams, representing the different signals that LAT will detect in space. A beam of photons was, however, not directly available at CERN. Therefore one was created by deflecting electrons with a magnet, thereby leaving only bremsstrahlung photons created in the detectors upstream. Gas threshold Cherenkov counters (C1, C2) were used for particle identification, plastic scintillators (S0, S1, S2, S4, Sh, Sv1, Sv2, Sv3, Sv4) were used for triggering and vetoing and in the PS beam test, Silicon Strip Detector (SSD) hodoscopes were used for photon tagging.

The CU was later also used in a third beam test at GSI in Darmstadt, Germany (not described in this poster), where it was exposed to beams of different heavy ions. This test was of importance since part of the calibration procedure of LAT in orbit involves measuring heavy ions.

The purpose of the whole campaign was to validate the advanced Monte Carlo simulation of the LAT, which is based on the Geant4 package, before the actual launch of the GLAST satellite. By measuring the physical processes occurring in the detector, the processes in the Monte Carlo simulation can eventually be fine-tuned.



The different energy distributions in tagged photon mode. Blue is the photon energy as measured by the CU. Red is the deflected electron energy as measured with the tagger spectrometer. Black is the total energy. From Baldini et al., *Preliminary results of the LAT Calibration Unit beam tests*, Proc. The First GLAST Symposium, Feb 2007.