The Large Area Telescope: Performance Monitoring And Calibrations

Anders W. Borgland (SLAC)
on behalf of the
LAT Instrument Science Operations Center (ISOC)

Abstract The Large Area Telescope (LAT) is one of the two instruments onboard the Gamma ray Large Area Space Telescope (GLAST), the next generation high energy gamma ray telescope. It contains sixteen identical towers in a four-by-four grid, each tower containing a silicon-strip tracker and a CsI calorimeter that together will give the incident direction and energy of the pair-converting photon. The instrument is covered by an Anti-Coincidence Detector (ACD) to reject charged particle background. Altogether, the LAT contains more than 864k channels in the trackers, 1536 CsI crystals and 97 ACD tiles and ribbons.

The LAT was integrated and tested at the Stanford Linear Accelerator Center (SLAC) in 2005-2006, underwent Thermo-Vacuum (TVAC) testing at the Naval Research Lab (NRL) in the summer of 2006 and is currently being integrated with the Spacecraft at General Dynamics/Spectrum Astro Space Systems in Arizona. GLAST is due to be launched in Fall of 2007.

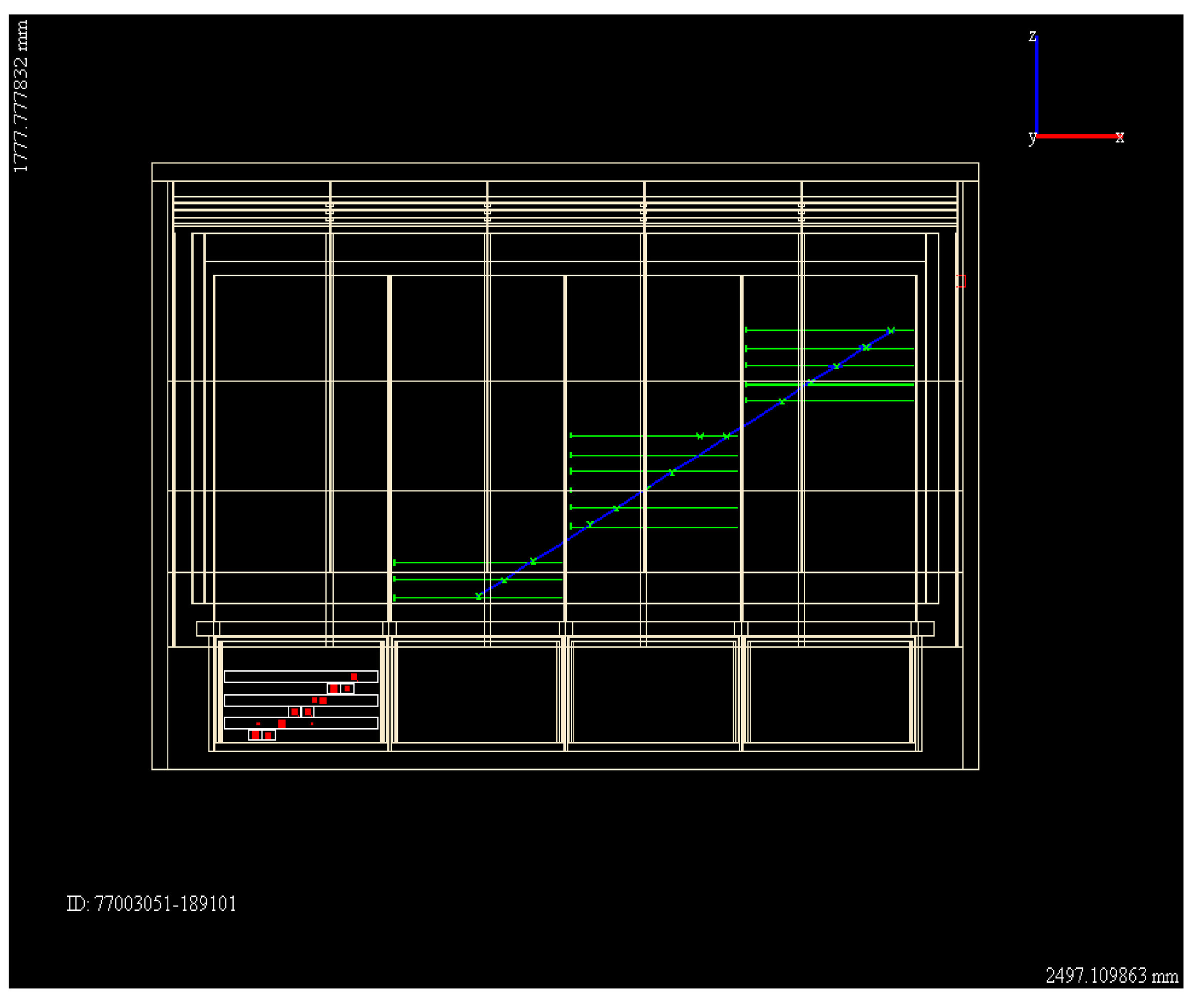
This poster details some of strategies and methods for calibrating the instrument, including both particle based calibrations, using Galactic Cosmic Rays (GCR) events, and charge injection, that will be necessary to ensure a satisfactory performance of the LAT in its full energy range from 20 MeV to 300 GeV. It will also detail how we are planning to monitor the instrument performance, including both low level detector monitoring and more high level analysis based monitoring using astrophysical sources. Both calibrations and monitoring draws on the extensive experience gained from Integration and Test of the instrument.

The LAT Instrument

The Large Area Telescope (LAT) is made up of a four-by-four grid of sixteen identical towers. Each tower consists of a silicon-strip tracker (TKR), a CsI calorimeter (CAL) and a Tower Electronics Module. An Anti-Coincidence Detector (ACD) covers the instrument. Finally, there is a very flexible Global Trigger.

All events that pass the first level hardware trigger are passed on to an onboard software filter for further processing and selection. Thus, the initial rate - expected to be about 5kHz -is reduced to about 300 Hz which is the limit set by the downlink capacity.

The energy range of the LAT is 20 MeV to 300 GeV. Please see poster 18.07, 'The LAT on the GLAST', for further details on the instrument performance. The following event display shows a real cosmic ray event taken with the LAT. The track crosses three different trackers and enters the calorimeter in a fourth tower.



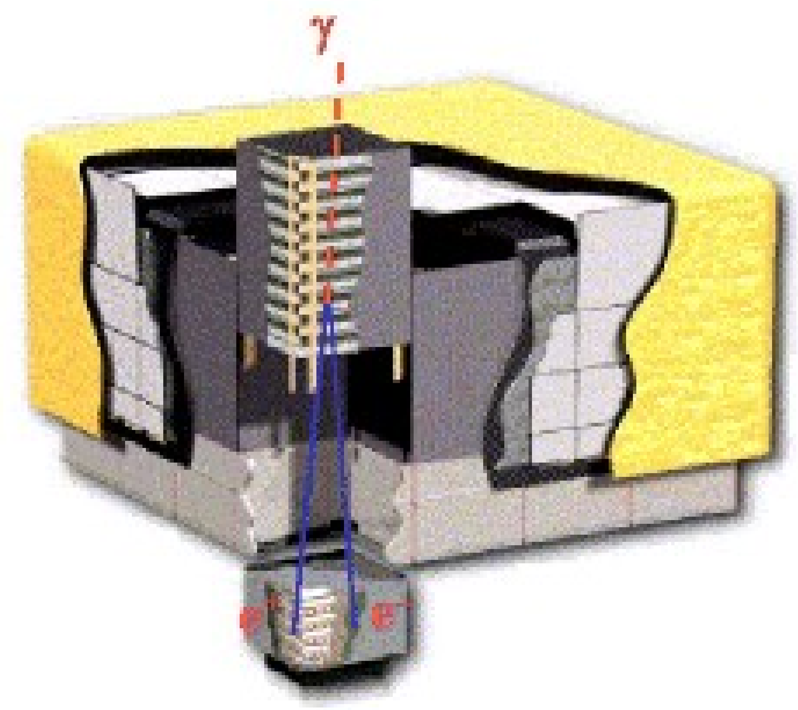
Here are some details about the LAT that are relevant for instrument monitoring and calibrations:

TKR:
- Thirty-six alternating X- and Y-layers for position information
- 1536 strips per layer for a total of 54k channels per TKR:
  - Total of 864k channels for all sixteen trackers!
- Provides Time-Over-Threshold (TOT) information:
  - Can be used for particle identification purposes

CAL:
- Eight alternating perpendicular layers:
  - Twelve CsI crystals per layer
  - Each crystal bar is read out on two sides:
    - Light asymmetry gives position information along the bar
- Total of 8.4 radiation lengths for normal incidence
- Energy resolution in the range 100 MeV to 10 GeV: <10%

ACD:
- Eighty-nine plastic scintillator tiles
- Eight plastic scintillator ribbons to cover gaps
- Highly segmented system to reduce self-veto at higher energies
- Required efficiency for rejecting charged particles: 0.9997
- Provides a Carbon-Nitrogen-Oxygen (CNO) trigger

Triggers: Different combinations of
- TKR: 6 hits in a row
- CAL Low: >100 MeV in a single CAL crystal
- CAL High: >1 GeV in a single CAL crystal
- CNO: >20 MIPs in an ACD tile



Performance Monitoring

The Large Area Telescope (LAT) is really a standard particle detector, but in space, and the instrument monitoring reflects this duality. We will both have monitoring of basic detector quantities like occupancies and use astrophysical sources.

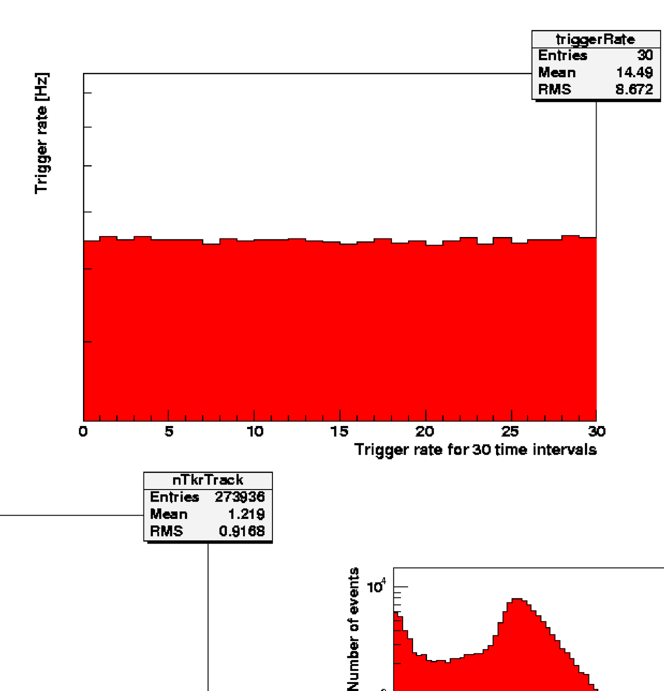
The monitoring will both be done on an orbit-by-orbit basis to quickly catch any large problems, and aggregated over several orbits to catch more subtle ones. More sophisticated trending of quantities versus time and orbit location will also be used.

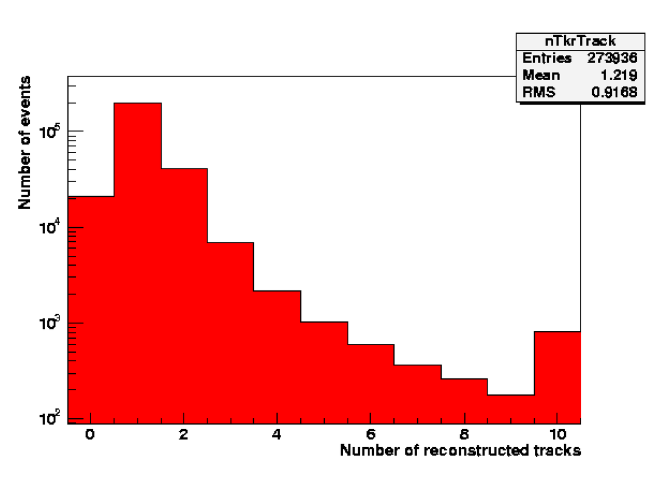
Basic detector monitoring:
- Unpacking of raw detector information from electronics space to physical space
- Detector occupancies including TKR dead and hot strips
- Tracker Time-over-Threshold (TOT)
- Trigger rates and Instrument deadtime

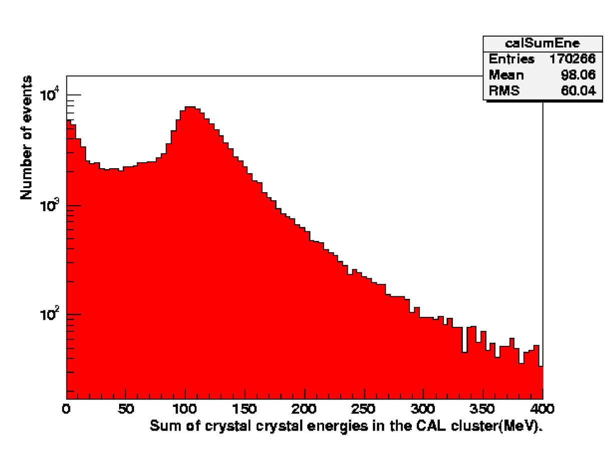
Reconstructed quantities:
- Depends on reconstruction algorithms and uses offline calibrations
- Number of tracks, track position and direction
- Calibrated CAL energy in MeV and ACD energy in MIPs
- Extrapolate TKR tracks into the CAL: TKR-CAL 'alignment'
- Extrapolate TKR tracks into the ACD: ACD efficiency
- Monitoring of configuration settings like zero-suppression and trigger thresholds.

Astro-physical quantities:
- Source monitoring like Timing of pulsars
- Background rates and categorization
- High level monitoring of Instrument Response Functions

The plots below show the time dependent trigger rate, the number of tracks and the calibrated energy in the CAL in MeV from real cosmic ray events taken with the LAT. We see that the number of tracks is peaked at one and the CAL energy has a peak around 100 MeV, both as expected from MIPs.







Configurations and Calibrations

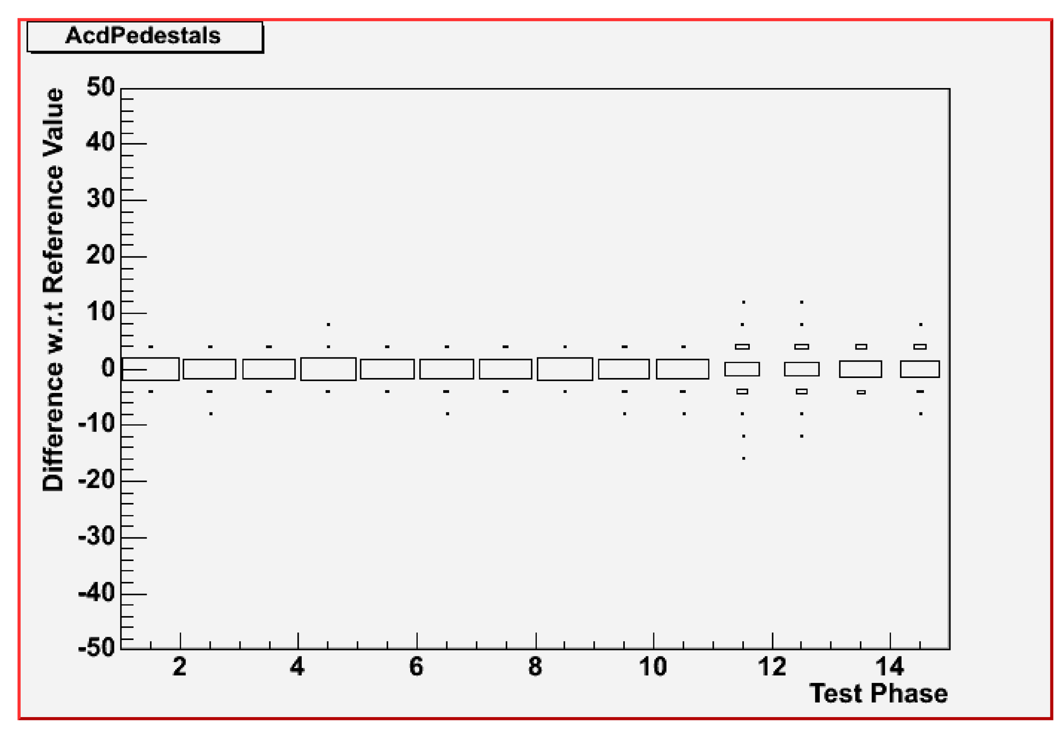
The LAT is a sophisticated instrument with many different detector elements. It requires a multitude of onboard configuration settings and offline calibration quantities. Both intra- and inter-tower alignment will also be necessary. This is in addition to the LAT-Spacecraft alignment.

Different calibration quantities will change over very different time scales! As much as possible, we try to let through a small sample of calibration events during normal physics runs to better represent the varying conditions and to optimize data taking efficiency. For example, we will take pedestals once a second during normal data taking. This is possible because of the flexible Global Trigger that permits different readout of the detector on an event-by-event basis. We will also have different algorithms like Galactic Cosmic Ray (GCR) and Alignment filters running in the Onboard filter for calibration purposes.

In addition, special Charge Injection runs are taken to characterize the front-end electronics.

The onboard settings include zero-suppression thresholds for the CAL and the ACD, hit discriminator thresholds in the TKR, trigger thresholds (CAL LO, CAL HI and CNO) and ACD Veto thresholds. In addition, all the subsystems have to be timed in.

Experience from on ground operations have shown that configuration and calibration quantities are very stable over time. As an example, see the plot below of ACD pedestals (with respect to a reference value) over many months at SLAC and NRL.



We have extensive experience calibrating the LAT on ground. However, on orbit some things will be different. For example, on ground we use MIPs to calibrate the Calorimeter. A MIP leaves about 11.2 MeV in a crystal. For on orbit operations we need to measure energies up to 50-100 GeV in a single crystal .... However, on orbit we will use Galactic Cosmic Rays. The plot below shows results from a simulation study looking at dE/dX in the CAL for Carbon, which leaves about 216 MeV/cm (Mark Strickman et al). Similarly, the ACD will use CNO events for the MIP calibration.