The Large Area Telescope

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on behalf of the GLAST LAT Collaboration

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Outline

- The Large Area Telescope (LAT): a pair conversion telescope
- LAT performance
- Subsystems
  - tracker
  - calorimeter
  - anticoincidence detector (ACD)
  - trigger and data acquisition system
- LAT simulation & testing
- analysis software development
GLAST LAT Collaboration

United States
- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Stanford University HEPL, KIPAC, and SLAC)
- Texas A&M University – Kingsville
- University of Washington

France
- CEA/Saclay
- IN2P3

Italy
- ASI
- INFN
- INAF

Japan GLAST Collaboration
- Hiroshima University
- Institute for Space and Astronautical Science
- RIKEN

Swedish GLAST Consortium
- Royal Institute of Technology (KTH)
- Stockholm University

Cooperation between NASA and DOE, with key contributions from France, Italy, Japan, and Sweden
LAT instrument construction managed by the Stanford Linear Accelerator Center
Remembering two early sources of inspiration and support

Herbert Gursky (NRL)        Joe Ballam (SLAC)

Joe Ballam (SLAC)
Components of the LAT

- **Precision Si-strip Tracker (TKR)**
  - 18 XY tracking planes with tungsten foil converters. Single-sided silicon strip detectors (228 μm pitch, 900k strips) Measures the photon direction; gamma ID.

- **Hodoscopic CsI Calorimeter (CAL)**
  - Array of 1536 CsI(Tl) crystals in 8 layers. Measures the photon energy; image the shower.

- **Segmented Anticoincidence Detector (ACD)**
  - 89 plastic scintillator tiles. Rejects background of charged cosmic rays; segmentation mitigates self-veto effects at high energy.

- **Electronics System**
  - Includes flexible, robust hardware trigger and software filters.

The systems work together to identify and measure the flux of cosmic gamma rays with energy \( \sim 20 \text{ MeV} \rightarrow \sim 300 \text{ GeV} \).
the real LAT

ACD [surrounds 4x4 array of TKR towers]
Key (Level 2) Science Performance Requirements Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SRD Value</th>
<th>Current Best Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Effective Area (in range 1-10 GeV)</td>
<td>&gt;8000 cm²</td>
<td>~9000 cm²</td>
</tr>
<tr>
<td>Energy Resolution 100 MeV on-axis</td>
<td>&lt;10%</td>
<td>~10%</td>
</tr>
<tr>
<td>Energy Resolution 10 GeV on-axis</td>
<td>&lt;10%</td>
<td>&lt;6%</td>
</tr>
<tr>
<td>Energy Resolution 10-300 GeV on-axis</td>
<td>&lt;20%</td>
<td>&lt;8%</td>
</tr>
<tr>
<td>Energy Resolution 10-300 GeV off-axis (&gt;60°)</td>
<td>&lt;6%</td>
<td>~5%</td>
</tr>
<tr>
<td>PSF 68% 100 MeV on-axis</td>
<td>&lt;3.5°</td>
<td>&lt;3.2°</td>
</tr>
<tr>
<td>PSF 68% 10 GeV on-axis</td>
<td>&lt;0.15°</td>
<td>.1</td>
</tr>
<tr>
<td>PSF 95/68 ratio</td>
<td>&lt;3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>PSF 55°/normal ratio</td>
<td>&lt;1.7</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>Field of View</td>
<td>&gt;2sr</td>
<td>&gt;2 sr</td>
</tr>
<tr>
<td>Background rejection (E&gt;100 MeV)</td>
<td>&lt;10% diffuse</td>
<td>&lt;10% (after residual subtraction)</td>
</tr>
<tr>
<td>Point Source Sensitivity(&gt;100MeV)</td>
<td>6x10⁻⁹ cm⁻²s⁻¹</td>
<td>4 x 10⁻⁹</td>
</tr>
<tr>
<td>Source Location Determination</td>
<td>&lt;0.5 arcmin</td>
<td>&lt;0.4 arcmin</td>
</tr>
<tr>
<td>GRB localization</td>
<td>&lt;10 arcmin</td>
<td>&lt;5 arcmin</td>
</tr>
<tr>
<td>Instrument Time Accuracy</td>
<td>&lt;10 µsec</td>
<td>&lt;&lt;10 µsec (current 1σ = .7 µs)</td>
</tr>
<tr>
<td>Dead Time</td>
<td>&lt;100 µsec/evt</td>
<td>26.5 µsec/event nominal</td>
</tr>
<tr>
<td>GRB notification time to spacecraft</td>
<td>&lt;5 seconds</td>
<td></td>
</tr>
</tbody>
</table>
LAT performance summary

LAT performance plots available at
www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm

or google “LAT performance”
LAT Silicon Tracker

team effort involving physicists and engineers from the United States (UCSC & SLAC), Italy (INFN & ASI), and Japan

11,500 sensors
350 trays
18 towers
~10^6 channels
83 m² Si surface

LAT TKR performance

Efficiency (%)

Bad channels (%)

Efficiency Bad chans fraction

spec

LAT TKR performance

spec

98

100

99.5

99

98.5

98
LAT Calorimeter

team effort involving physicists and engineers from the United States (NRL), France (IN2P3 & CEA), and Sweden

1,728 CsI crystal detector elements
18 modules
First Flight Tower in I&T

March 2005
First Integrated Tower – Muon Candidate Event

- Tracker planes
- XZ projection
- Calorimeter crystals
- YZ projection
First integrated tower: Gamma-ray pair conversion
LAT Flight Hardware Integration at SLAC

Preparation of flight grid for TCS integration

Flight Tracker in Cleanroom

LAT Integration stand with PAP ready for proof test

Flight Calorimeter
team effort involving physicists and engineers from Goddard Space Flight Center, SLAC, and Fermi Lab
LAT complete

assembly and environmental testing complete: September 2006
LAT Data Acquisition System Testbed
16 tower LAT
rate: ~ 500 Hz
Components of Simulation & Analysis

Simulation

- gamma-ray sky model
- background fluxes
- Instrument Response (Digitization), Formatting
- Trigger and Onboard Filter (wrapped FSW)
- Particle Generation and Tracking
- Detector Calibration
- Event Reconstruction
- Event Classification
- Performance
- High-level Science Analysis
GLAST LAT Simulation

High energy $\gamma$ interacts in LAT

Geometry Detail
- > 500k Volumes
- Includes Tracker Electronics Boards
  - Mounting Holes in ACD Tiles!
- Spacecraft details
  - and much, much more

Geant 4 Interaction Physics
- QED: based on original EGS code
- Hadronic: based Geisha (can use FLUKA as well as others)

Propagation
- Full treatment of multiple scattering
- Surface-to-surface ray tracing.

Connection to detector Response
- Energy deposits in Active Volumes
- Parametric Detector response based on energy and location
The GLAST-LAT Calibration Unit

- 2.5 towers, ~1/8 of the LAT
- 110k Si strip
- 288 CsI logs

CU integration completed at INFN may 2006
The CERN campaign

- 4 weeks at PS/T9 area (26/7-23/8)
  - Gammas @ 0-2.5 GeV
  - Electrons @ 1.5 GeV
  - Positrons @ 1 GeV (through MMS)
  - Protons @ 6.10 GeV (w/ & w/o MMS)
- 11 days at SPS/H4 area (4/9-15/9)
  - Electrons @ 10,20,50,100,200,280 GeV
  - Protons @ 20,100 GeV
  - Pions @ 20 GeV
- Data, data, data…
  - 1700 runs, 94M processed events
  - 330 configurations (particle, energy, angle, impact position)
  - Mass simulation
- A very dedicated team
  - 60 people worked at CERN
  - Whole collaboration represented
Tested many configurations..
Comparisons with MC Simulation

PSF

280 GeV electrons at 30 deg

preliminary

ACD
Backsplash
Data Challenges

Data challenges provide excellent testbeds for science analysis software.

Full observation, instrument, and data processing simulation.

Team uses data and tools to find the science. “Truth” revealed at the end.

- A progression of data challenges.
  - DC1 in 2004: 1 simulated week all-sky survey simulation.
    - find the sources, including GRBs
    - a few physics surprises
  
  - DC2 in 2006: 55 simulated days all-sky survey.
    - first catalog
    - source variability (AGN flares, pulsars) added. lightcurves and spectral studies. correlations with other wavelengths. add GBM. study detection algorithms. benchmark data processing/volumes.
DC2 Point Source Catalog

Catalog analysis pipeline (Saclay) runs a source detection algorithm and then runs likelihood analysis to produce a table of the basic gamma-ray properties of each source.

Released at the beginning of DC2, it provided a starting point for a large fraction of the more detailed source analysis and was a reference for population/source detection type studies.

380 sources
Systematic studies: SNR

Set of simulations of SNR RXJ 1713.7-3946 each with a different spectral model
GRB Spectral Models

- Developing methods to measure spectral features and using systematic simulation studies to evaluate performance
Pulsar simulations and analysis

• Razzano and Harding - simulations to illustrate the ability of LAT observations to distinguish between pulsar emission models.
• Develop analysis methods to quantify this.
• Additional simulation improvements
  – Adding models for binary pulsars
  – Including noise and glitches

1 week (left) and 1-month Vela observation and 1 year Vela observation.
Pulsar Wind Nebula Studies

- Simulations of the kookaburra region which contains a pulsar and a pulsar wind nebula, illustrating how phase resolved spectral studies or energy resolved spatial studies can distinguish between the two components.
1 year sky simulation

- the movie
Launch:  t – 10 months and counting