# On-Orbit Operation and Performance of the Fermi Large Area Telescope

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**on behalf of the Fermi Large Area Telescope Collaboration**

Summary: We summarize the on-orbit operation and performance of the Large Area Telescope on *Fermi*, and also the performance of the LAT Instrument Science Operations Center at the SLAC National Accelerator Laboratory

## Abstract

The Large Area Telescope (LAT) on *Fermi* is now in its seventh year of on-orbit operations. We present some key measures and statistics for the on-orbit performance of the LAT, and summarize plans and expectations for future on-orbit changes of the LAT. We also describe the status, performance and plans for the ground-based control, processing and monitoring of the LAT at the Instrument Science Operations Center (ISOC) at the SLAC National Accelerator Laboratory at Stanford University.
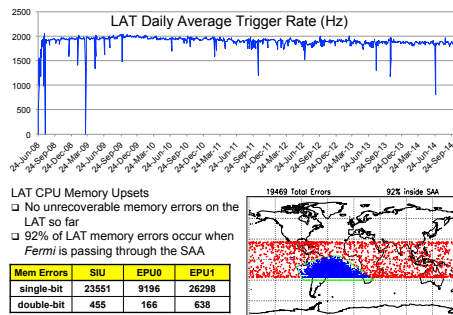
## ISOC Summary

- The LAT ISOC is organized to:
  - Maintain and safely operate the instrument
  - Process and deliver LAT event data and limited science data
- Main Functions of the ISOC:
  - Command planning and construction
  - Instrument health and safety monitoring
  - Maintain and modify FSW and the LAT Testbed
  - Instrument performance verification and optimization
  - Process and archive LAT data
  - Maintain the software that produces science data
- ISOC supports the *Fermi* mission and the LAT Collaboration
  - ISOC partners with the LAT Collaboration to ensure world-wide monitoring for instrument and science support

## LAT Operations Summary

- The LAT is performing well, now over 6 years into the mission
- Over 99% efficiency for routine data-taking during the science mission
- No major hardware failures.
- 19 LAT FSW updates since launch: Calibration and Configuration and GRB detection improvements, fix for LAT CPU resets (fixed in 2009), minor bug fixes
- One LAT FSW update is still planned, to be completed in 2014
  - B3-2-0 : significant speedup of on-board charge injection calibration of Tracker Time over Threshold (ToT), from several hours to about 1 hour
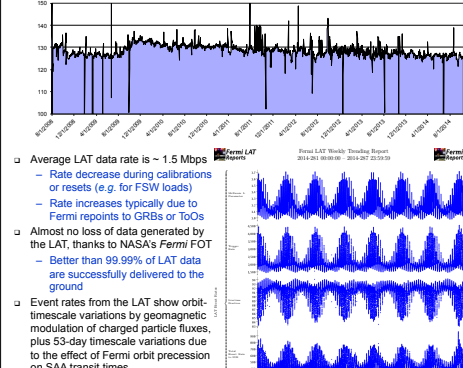
## LAT On-board Processing

- 380 billion event triggers on the LAT since launch. Average trigger rate ~ 2kHz.
  - On-board FSW filtering of triggered event readouts reduces average rate of events delivered to the ground to about 400 Hz
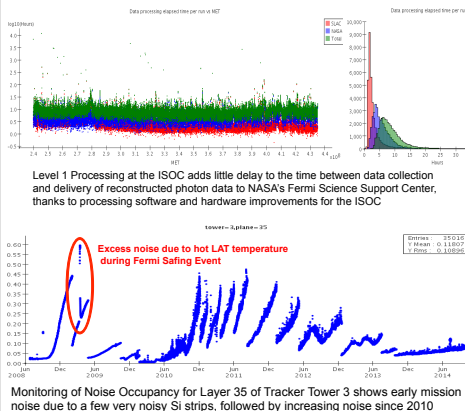  - 76 billion LAT event readouts have been sent to the ground

### LAT Daily Average Trigger Rate (Hz)

LAT CPU Memory Upsets
- No unrecoverable memory errors on the LAT so far
- 92% of LAT memory errors occur when *Fermi* is passing through the SAA

19469 Total Errors    92% inside SAA

| Mem Errors | SIU | EPU0 | EPU1 |
|---|---|---|---|
| single-bit | 23551 | 9196 | 26298 |
| double-bit | 455 | 166 | 638 |

## LAT Event and Data Rates

The LAT generates about 125 Gbits/day, sent to the ground for analysis at the ISOC

- Average LAT data rate is ~ 1.5 Mbps
  - Rate decrease during calibrations or resets (*e.g.* for FSW loads)
  - Rate increases typically due to *Fermi* repoints to GRBs or ToOs
- Almost no loss of data generated by the LAT, thanks to NASA's *Fermi* FOT
  - Better than 99.99% of LAT data are successfully delivered to the ground
- Event rates from the LAT show orbit-timescale variations by geomagnetic modulation of charged particle fluxes, plus 53-day timescale variations due to the effect of Fermi orbit precession on SAA transit times

## ISOC Science Operations

- Level1 data processing + Automated science processing
  - Level 1 processing and Automated Science Processing (ASP) are performed automatically at the ISOC, after each of the ~10 Level 0 data deliveries from NASA per day
  - LAT Collaboration members provide Data Quality checking of all Level 1 data
    - Over 100,000 data quality measurements are calculated, with alarm limits on ~5000 measurements
  - L1 processing in the ISOC transitioned to P7REP processing on 5 November 2013. Updating Level 1 processing to Pass 8 is expected sometime in 2015.
  - Over 397 million source-class photons and 2.4 billion transient-class events have been delivered to NASA for public release, and to the LAT Collaboration
  - Automated Science Processing performs blind search for GRB candidates and monitoring and daily and weekly light curve generation for variable sources

Level 1 Processing at the ISOC adds little delay to the time between data collection and delivery of reconstructed photon data to NASA's Fermi Science Support Center, thanks to processing software and hardware improvements for the ISOC

Excess noise due to hot LAT temperature during Fermi Safing Event

Monitoring of Noise Occupancy for Layer 35 of Tracker Tower 3 shows early mission noise due to a few very noisy Si strips, followed by increasing noise since 2010

## LAT Detectors

### Tracker

- Each Tracker (TKR) tower has 36 Si strip layers, with each layer having 1536 strips, for a total of 884,736 TKR strips in the LAT
- Strips which become noisy can be electronically masked off
  - 203 strips were masked on the LAT at launch, and another 340 strips have been masked since launch, mostly in Tower 0 (early mission) and one part of Layer 35 in Tower 3 (since 2010). The LAT also has dead strips, with 4338 dead or noisy strips in total. 4338 strips in 884,736 = 0.49% of the TKR.
- A slow increase in TKR leakage current is also seen over the mission time. It is expected and due to cumulative radiation dose in the Si layers

History of LAT Tracker On-Board Masked Strip Count
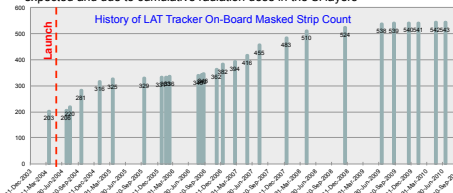
### Calorimeter

- Yellowing of CsI in the CAL from radiation dosage since launch is producing slow, small gain changes
- Only 3 of 6144 CAL readout channels show excessive electronic noise
- 1 channel failure: in July 2010, for Tower 4 CAL, Layer X1, Column 4, +Face, HE diode

CAL Small Photodiodes

CAL Large Photodiodes
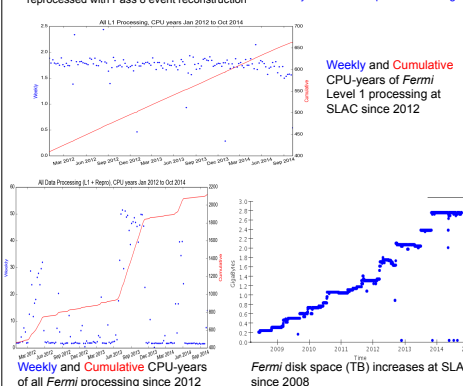
### Anti-Coincidence Detector

- All 89 ACD tiles are well behaved
- No PMT bias change since launch
- One ACD ribbon end (of 8 ACD ribbons between ACD tiles) has been non-responsive since 2008

CAL "MeV per DAC unit" shows decreasing light from CsI crystals
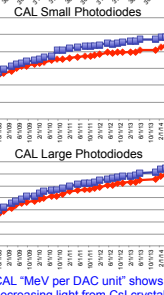
## Computing Systems

Computing resources at SLAC for the ISOC and the LAT Collaboration are integrated with and make use of SLAC Computer Farm infrastructure

- SLAC resources
  - CPU: 3000 cores
  - Storage: 2.8 PB disk + 3.6 PB tape
  - Level 1 processing:
    - 26 TB disk storage per month
    - 10 CPU-years per month
    - 125 cores time-averaged use
  - NASA-facing ISOC servers are on SLAC High Availability systems, with available backup power during power outages
- Lyon resources
  - 1500 - 1700 cores, used for Monte-Carlo simulations
- Over 6 years of LAT mission data has been reprocessed with Pass 8 event reconstruction

A day of SLAC Computer Farm usage

Weekly and Cumulative CPU-years of *Fermi* Level 1 processing at SLAC since 2012

Weekly and Cumulative CPU-years of all *Fermi* processing since 2012

*Fermi* disk space (TB) increases at SLAC since 2008

More information on LAT operations is available at the LAT ISOC website:
http://glast-isoc.slac.stanford.edu
Scan this QR code to visit the ISOC website.

A summary of the LAT instrument response performance is available at:
http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm
Scan this QR code to visit the LAT performance website.