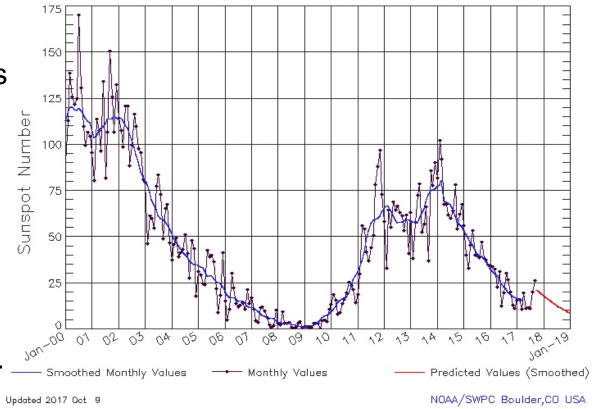
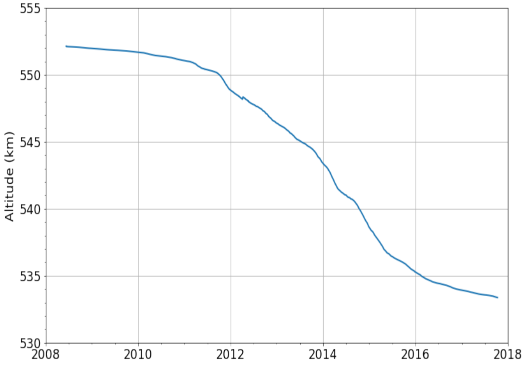
Fermi Orbital Environment

The *Fermi* charged particle environment is strongly influenced by the 11-year Solar cycle. *Fermi* launched at the minimum of the Solar cycle in 2008, followed by a mild Solar cycle maximum peaking in 2014-2015.



Recent Solar Activity showing the Solar Cycle

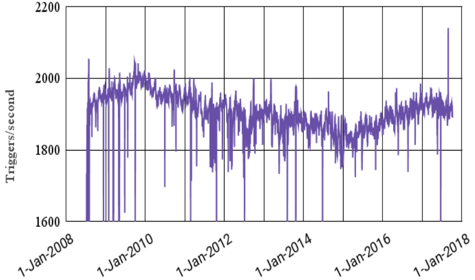
The orbital altitude of *Fermi* decayed relatively slowly in the early mission, attributed to low atmospheric drag during the minimum of the Solar cycle. The rate of decay of orbit altitude increased during Solar maximum around 2014-2015, but decreased after the Solar maximum was passed.



Trend of the *Fermi* orbital altitude

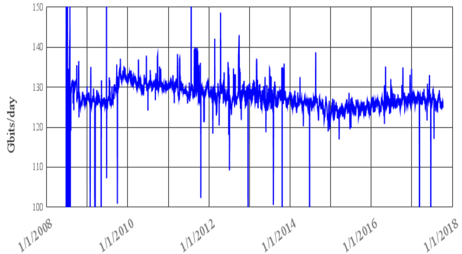
LAT Trigger and Data Flow

The LAT event trigger rate is apparently influenced by the Solar cycle. The trigger rate decreases with increasing Solar cycle activity, as the atmosphere is heated to a larger scale height, and depleting trapped charged particles in the *Fermi* orbit.



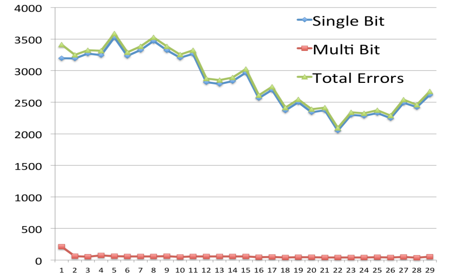
Trend of LAT Daily Average Trigger Rate

The long-term trend of the LAT downlinked data rate also shows changes similar to the LAT trigger rate, having a minimum around the time of Solar maximum.



LAT output, downlinked data rate

Changes in *Fermi*'s charged particle environment are also revealed through the memory upset rate in the flight computers operating in the LAT. The memory upset rate shows a minimum around the time of Solar maximum.

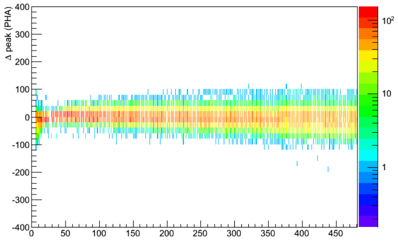


Trend of LAT Memory Errors in 10 Ms periods.

Anti-Coincidence Detector

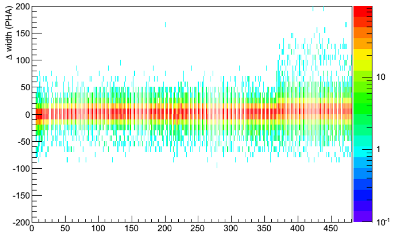
- ❑All 89 ACD scintillator tiles and both readout channels from all ACD tiles are well behaved. Some noise is seen infrequently on one PMT readout of one ACD tile.
- ❑One ACD ribbon end (of 8 scintillator ribbons between ACD tiles) has been non-responsive since 2008.
- ❑Electronic pedestals drift is about 0.01% per year.
- ❑Electronic gain drift is about 0.3% per year.

- ❑No PMT bias voltage change has been performed since launch, and no bias voltage change is planned in the foreseeable future.



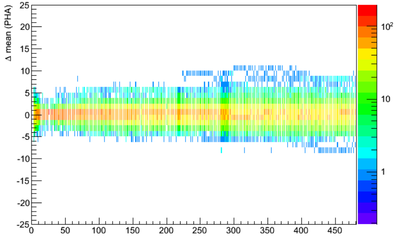
Time (weeks since launch)

ACD channel MIP peak shifts



Time (weeks since launch)

ACD channel MIP peak width changes



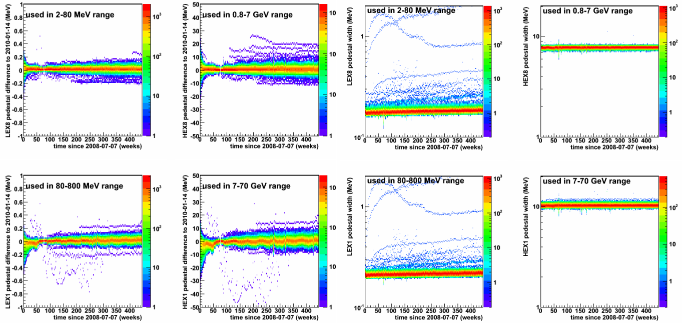
Time (weeks since launch)

ACD channel electronic pedestal changes

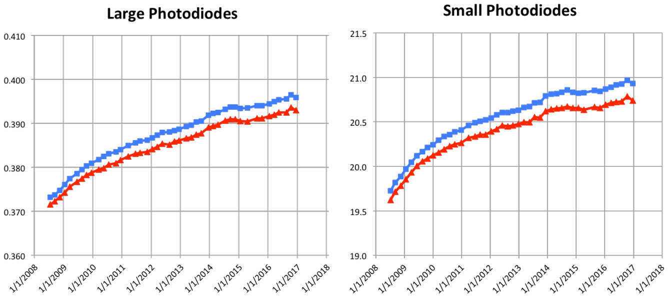
Calorimeter

- ❑All 1536 CsI crystal logs in the Calorimeter (CAL) are alive and calibrated
- ❑One pre-amplifier of 6144 is dead, since July 2010: for a HE photodiode, and so only affects energy depositions >1 GeV in a single crystal
- ❑All trigger and data suppression discriminators are alive and set with correct thresholds
- ❑Only 12 of 6144 readout channels show excessive front-end noise; 5 channels with >2x median noise.

- ❑ Decrease of light yield in CsI crystals in the CAL due to cumulative radiation dose since launch has produced ~5% CAL gain change. Gain changes, in “MeV per DAC unit”, are calibrated over time and compensated for in ground processing of CAL data.



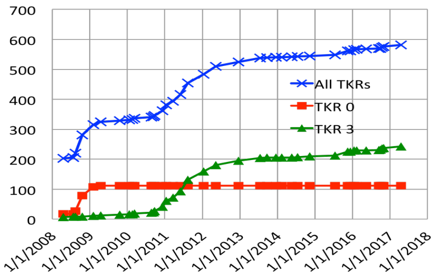
Trends of CAL pedestal and pedestal width changes, showing few noisy channels



Trends of average (blue) and median (red) “MeV per DAC unit” gain calibrations for CAL large and small photodiodes

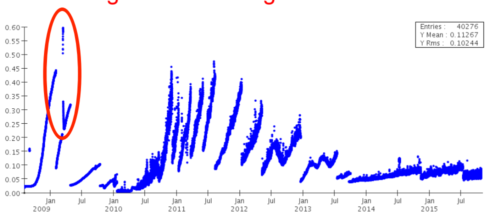
LAT Tracker

- 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.
- TKR readout uses 15000 ASICs, with only 1 failed ASIC (which failed before launch).
- Noisy strips are electronically masked off in the LAT. 203 strips were masked on the LAT before launch, and 382 more strips have been masked since launch, mostly in Tower 0 (early mission) and in one quarter of Layer 35 in Tower 3.



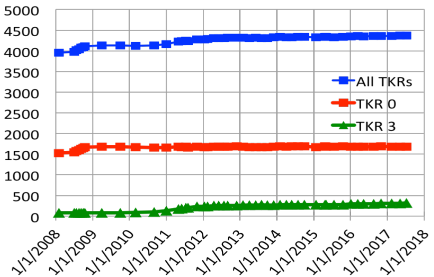
History of LAT Tracker On Board Masked Strip Count

Trending of Noise Occupancy for layer 35 of TKR Tower 3 shows early mission noise due to a few very noisy Si strips, then increasing noise since 2010, reduced by mask updates



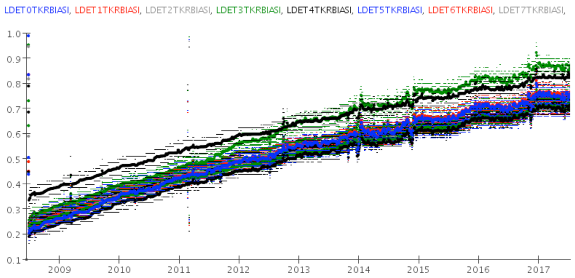
Trend of Noise Occupancy in LAT T3L35

- The LAT also has dead strips, due to disconnected or unresponsive pre-amplifiers.
- LAT calibration shows 4367 dead or noisy strips, 0.49% of the TKR, starting at 3957 before launch.
- Tower 0 (Flight Model A), the first tower made, has the most bad strips, but still met requirements.



History of LAT Tracker Masked Strip Count in ground calibration

A slow increase in Tracker leakage current (mA) is seen over the mission duration, due to cumulative radiation dose in the Si layers. The leakage current has increased the most in TKR tower 3, since 2010.


Trend of bias current in the 16 Tracker towers

The Future

Both Fermi and the LAT are performing extremely well after 9 years in orbit. Expectations are high for no near term problems, and for future years of good operational capability. Looking at a mission beyond 10 years, preparations are underway for NASA and the international LAT Collaboration to take on larger fractions of the support of LAT operations. This transition is also being exploited as an opportunity to strategically plan upgrades of LAT support ground systems to more current technologies than those in place at launch, to better ensure the longevity and maintainabiity of LAT operations systems in the future mission.

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