Performance of the Anti-Coincidence Detector on the GLAST Large Area Telescope

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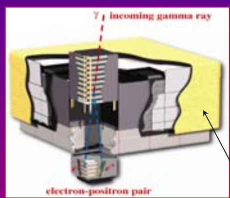
Abstract. The Anti-Coincidence Detector (ACD), the outermost detector layer in the Gamma ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT), is designed to detect and veto incident cosmic ray charged particles, which outnumber cosmic gamma rays by 3-4 orders of magnitude. The challenge in ACD design is that it must have high (0.9997) detection efficiency for singly-charged relativistic particles, but must also have a low probability for self-veto of high-energy gammas by backsplash radiation from interactions in the LAT calorimeter. Simulations and tests demonstrate that the ACD meets its design requirements. The performance of the ACD has remained stable through stand-alone environmental testing, shipment across the U.S., installation onto the LAT, shipment back across the U.S., LAT environmental testing, and shipment to Arizona. As part of the fully-assembled GLAST observatory, the ACD is being readied for final testing before launch.



1. ACD in LAT

- The LAT instrument must identify cosmic γ-rays in a background of charged cosmic rays 3-5 orders of magnitude more intense (mainly protons and electrons).
- ACD is the outermost LAT detector, surrounding the top and sides of the tracker.
- The majority of the rejection power against cosmic rays will be provided by ACD.
- The required efficiency for charged particle detection for the ACD is 0.9997 averaged over the entire area. (For entire LAT, ~0.99999)

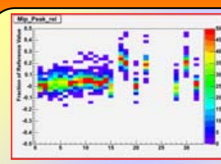
2. Design Inputs

Introduction to Backsplash Effect

- High energy photons detected by LAT create electromagnetic showers in the calorimeter.
- A small fraction of the low-energy photons (0.1 to few MeV) in the shower move backwards and can create a signal in the ACD if they produce a Compton electron.
- In some cases this signal cannot be distinguished from a charged particle signal, which indicates an event that must be rejected. This means that "good" γ-ray events, otherwise accepted, can be vetoed by this backsplash effect.
- As a result, LAT efficiency for γ-ray detection could degrade if steps are not taken to avoid this. EGRET experienced ~50% efficiency degradation at 10 GeV (relative to that at 1 GeV) due to this backsplash effect.

ACD Performance Requirements

- 0.9997 detection efficiency for singly charged relativistic particles (averaged over entire area).
- For 300 GeV photons, the probability of false veto due to calorimeter backsplash must be less than 20%.
- No more than 6% of incident γ-rays can be lost by interacting in the ACD.



MIP peak position trending plot taken for the tests from Summer 2005 through the fall of 2006. Large deviations correspond to thermal tests where we expect the MIP peak to shift at a rate of ~0.8%/degree C. The in-orbit temperature is expected to be about 0C, which will make the light signal larger than at room temperature, providing still more margin.

4. Assembled ACD Performance

Performance Verification:

- Total efficiency cannot be directly measured on the ground: no isotropic source of charged particles is available.
- We measured performance for all individual flight detectors, as well as their position measurements on the structure, and sample efficiency measurements at various locations on the array, using comic ray muons as a source.
- Detector performance measurements were combined with ACD simulations to determine the detection efficiency for singly-charged relativistic particles, as well as the final backsplash probability. The backsplash simulations were tied experimentally to results from CERN beam exposures of tile and calorimeter emulators (Moiseev et al. 2004, Astroparticle Physics 22, 275).

Tests:

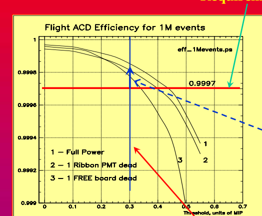
ACD successfully passed all its performance and environmental tests:

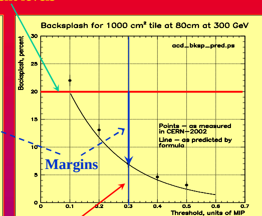
- subsystem level testing at Goddard in the summer of 2005, before integration to LAT
- at SLAC from August 2005 to May 2006, before and after integration to LAT
- LAT environmental tests at NRL in the summer of 2006
- to date with LAT on spacecraft, at General Dynamics

ACD demonstrated the required stability of performance through all these tests, over a long time interval.

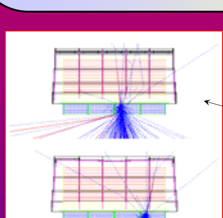
ACD meets its scientific requirements with moderate margin on detection efficiency and substantial margin on backsplash (see below).

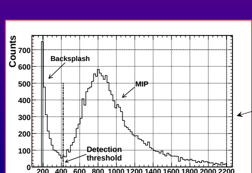
Requirement levels





Planned operational threshold





3. Design Approach

- To suppress self-veto caused by backsplash, we segment the ACD, then ignore ACD hits that are not in line with the reconstructed point of entry. Optimal segmentation was determined by simulations.
- To reduce signal fluctuations (origin of inefficiency), we need as much light yield as possible from the tiles, plus uniformity. Testing showed that 1 cm thickness of plastic scintillator is enough if we read out the signals with wavelength-shifting fibers spaced 5 mm apart.
- Also must minimize the gaps between segments (while allowing for very significant thermal expansion/contraction). Scintillator tiles overlap in one dimension; in the other direction, the gaps are covered by ribbons of scintillating fibers.
- Detector Choice: Plastic scintillator with wavelength shifting fibers and PMT readout (bent edge tile is shown, partially opened for viewing)
- Minimizing backsplash and maximizing efficiency are competing requirements:
  - Backsplash reduction implies high threshold.
  - High efficiency for particle detection implies low threshold.

5. ACD and LAT Status

- ✔ August 4, 2005 - Completion of ACD environmental and performance tests
- ✔ August 13 – ACD arrival at SLAC
- ✔ December – ACD integration into LAT
- ✔ May 2006 – Functional tests of LAT complete. Shipped to NRL for environmental tests.
- ✔ September 2006 – LAT shipped to General Dynamics for integration with the spacecraft
- Summer of 2007 – Shipment of GLAST to Kennedy Space Center for launch preparation
- November 2007 - Launch !!!

For more information on the ACD: A. Moiseev et al., The Anti-Coincidence Detector for the GLAST Large Area Telescope, Astroparticle Physics, 2007, in press