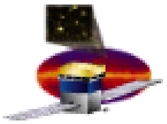
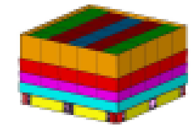




GLAST Large Area Telescope:

Collaboration Meeting
September 15-18, 2003

AntiCoincidence Detector (ACD) Subsystem
WBS: 4.1.6

David J. Thompson, Subsystem Manager
Thomas E. Johnson, Instrument Manager
Alex A. Moiseev, Lead Scientist
NASA Goddard Space Flight Center

Anti-Coincidence Detector

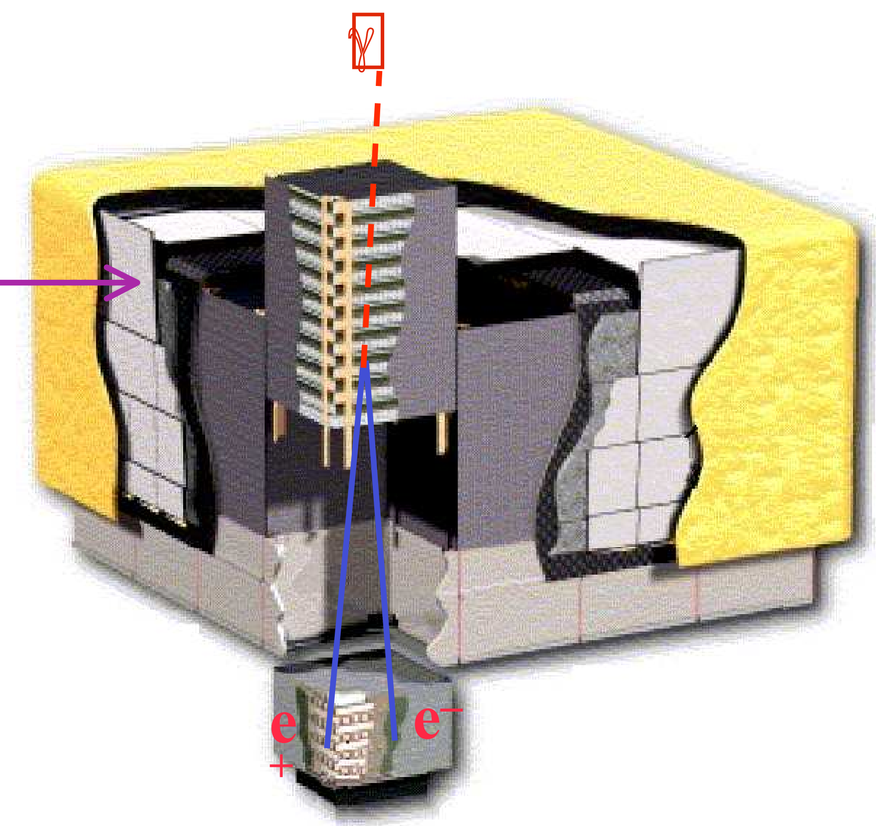
ACD has been presented many times in detail from different aspects.

Now I will give you a brief summary of:

- what we are building,
- why we are building the ACD as is,
- where we are now with 73 people associated with the ACD (Don't worry; most are not being paid by LAT)

ACD Task

- ACD is the outermost LAT detector which surrounds the top and sides of the tracker.
- The purpose of the ACD is to detect incident charged particles which outnumber cosmic gamma rays by up to 4 orders of magnitude.



ACD Main Requirements

1. ACD has to have 0.9997 average detection efficiency for singly charged relativistic particles (*mip*) over its area

→ to contribute to the needed ~x10^6 charged particle background rejection at the LAT level

2. The false veto due to calorimeter backsplash must be no more than 20% of all 300 GeV photon events.

→ to provide high efficiency of LAT for photons extending to 300 GeV and higher. EGRET experienced 50% efficiency degradation at 10GeV (relative to that at 1GeV) due to backsplash effect

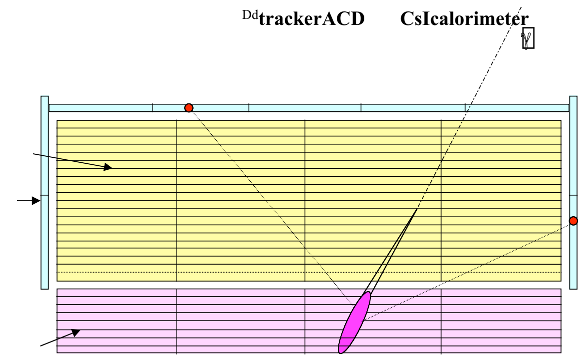
Approach to the Design - Backsplash

Let's start with the backsplash problem:

We found that the only way to suppress self-veto caused by backsplash is to segment the ACD

 An event is vetoed only if a signal was present in the tile crossed by the reconstructed event trajectory.

 Trade-off study: What should the segmentation be to meet the requirement with the fewest number of segments?



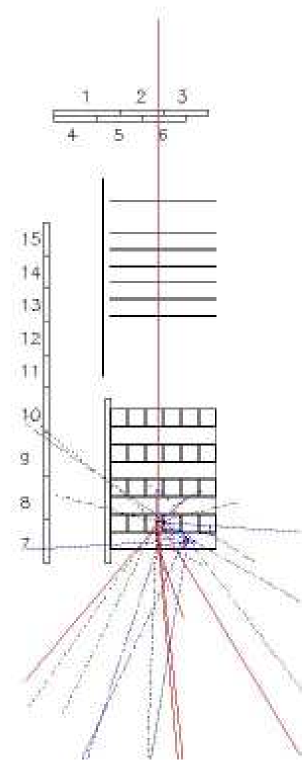
 How to do the segmentation optimization - can we trust the simulations if we need to simulate a process in which the primary photon is several hundred GeV, and the signal we are looking at in the ACD is ~100 keV ?

Backsplash study

We decided to do a beam experiment to measure the backsplash, compare it with the GEANT simulations, and optimize ACD segmentation using both - simulations and experimental results

Approach:

- Use an electron beam due to the similarity of the showers created by electrons and photons
- Use a segmented scintillator array, similar to the ACD approach, to study the angular distribution of backsplash
- Use a calorimeter prototype, with material similar to the LAT calorimeter, to produce similar backsplash

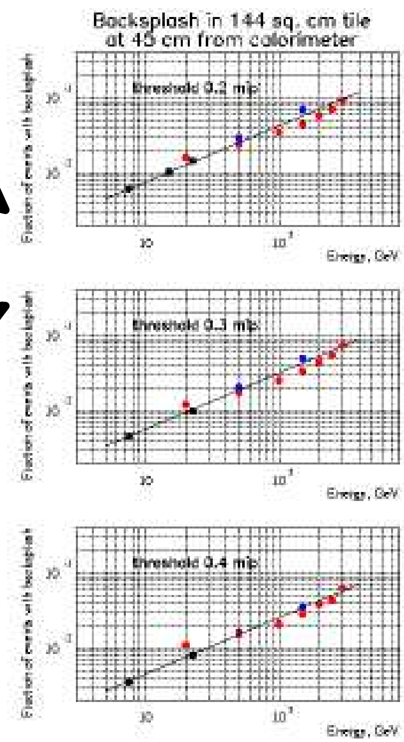


Backsplash study (cont.)

We ran 3 beam experiments with ACD-like segmented detectors designed specifically for these tests. Special care was given to the background rejection.

1. SLAC (December 1997) - γ-beam with max energy 25 GeV, ~40K events. Mainly qualitative measurements

2. CERN (July 1999) - Electron beam from 20 GeV to 300 GeV, ~250K events. Backsplash vs. energy measurements



From these tests we obtained a formula

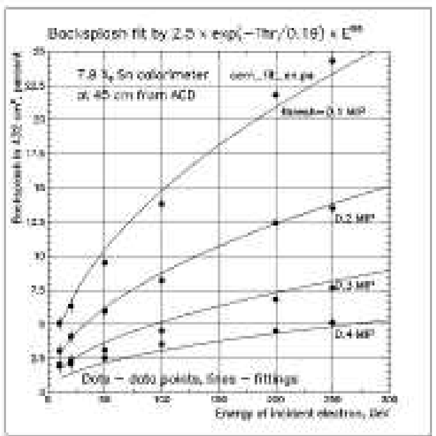
$$P_{backsplash} = \left(0.85\cdot\frac{0.3}{E_{thr}} + 0.15\right)\cdot 10^{-3}\cdot\frac{A}{144}\cdot\left(\frac{55}{x+10}\right)^{2}\cdot E^{0.75}$$

where $P_{backsplash}$ is the probability of backsplash-caused signal with pulse-height above E_{thr} (units of mip) occurring in A[cm^2] area tile with ACD placed at x[cm] from the calorimeter face. Incident energy is E[GeV]

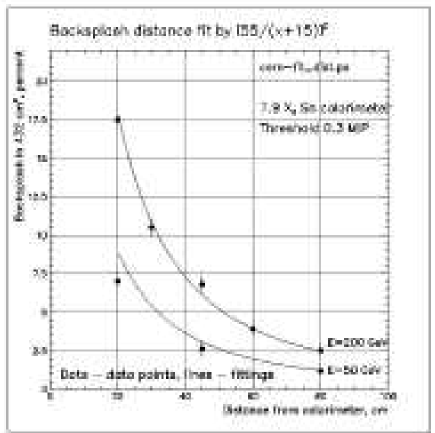
Backsplash study (cont.)

3. CERN (July 2002) - Electron beam from 10 GeV to 250 GeV, 51 runs, ~500K events. Precise energy, angular, position, calorimeter Z measurements

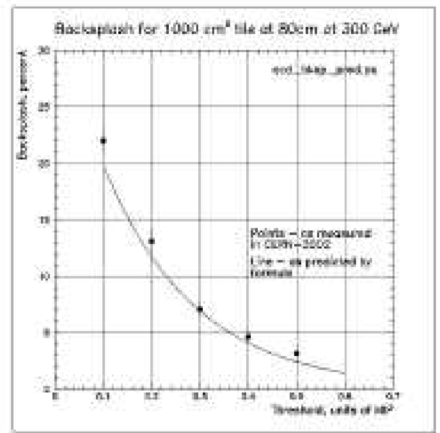
$$P_{backsplh} = 2.5 \cdot \exp\left(-\frac{E_{thr}}{0.19}\right) \cdot \left(\frac{A}{432}\right) \cdot \left(\frac{55}{x+15}\right)^{2} \cdot \sqrt{E}$$



Fitting for energy and signal pulse-height



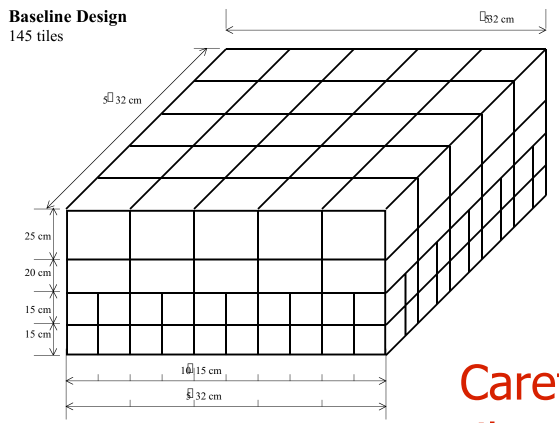
Fitting for the distance between ACD and calorimeter



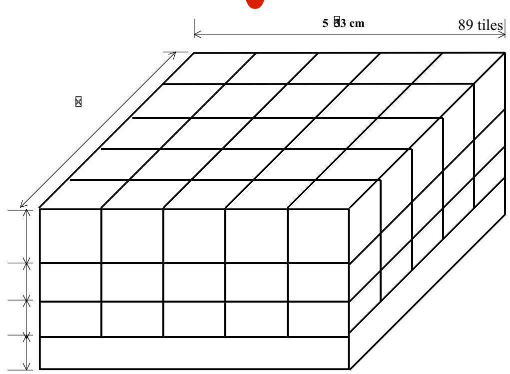
Backsplash prediction for LAT ACD

Use of this formula makes segmentation optimization much easier - go ahead!

Segmentation trade study



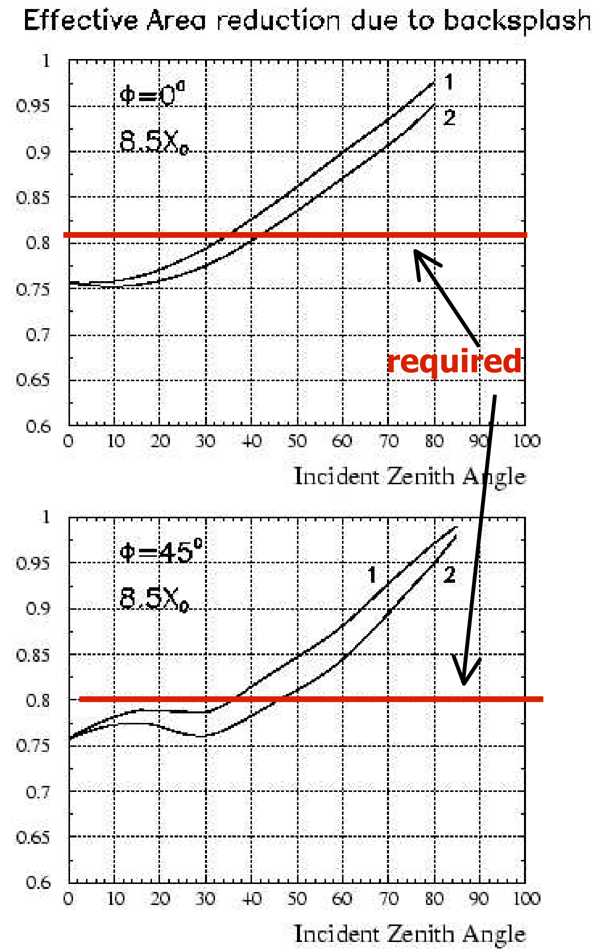
Current design



Careful optimization of the tile sizes allowed us to significantly reduce the number of elements.

1 - baseline design

2 - current design



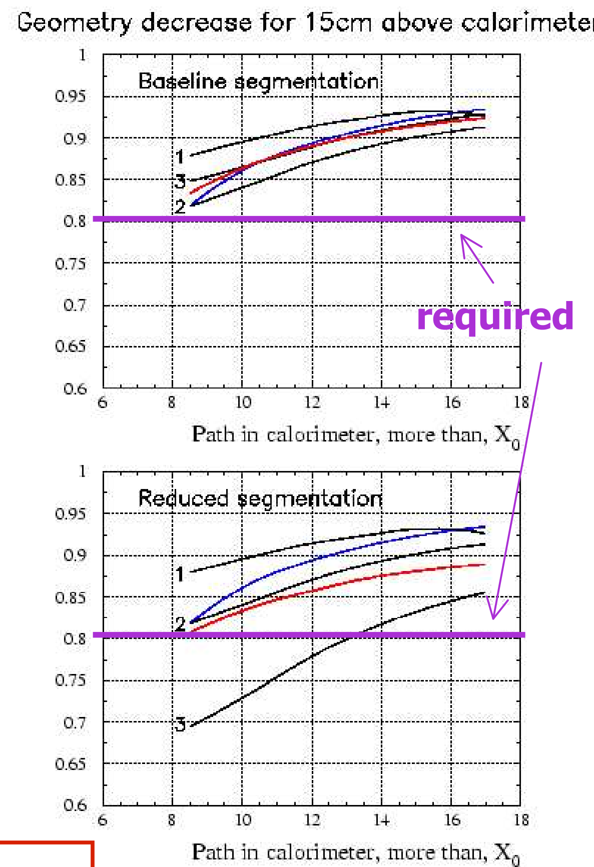
Segmentation trade study (cont.)

Bottom tile rows are closer to the source of backsplash - calorimeter, so they should be smaller

Blue line - Geometrical factor for events entering only through the top

Lines 1,2, and 3 - side tile rows, from top to bottom

Red line - result for all trajectories



ACD was optimized to meet self-veto requirement with fewest number of channels

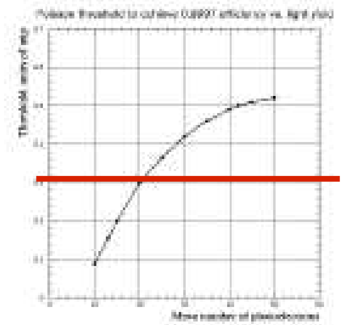
Efficiency provisions

0.9997 detection efficiency over entire area for singly charged relativistic particles (*mip*)

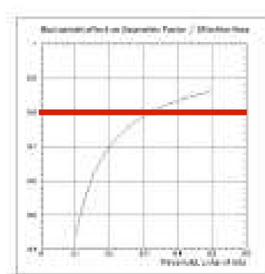
Main problems:

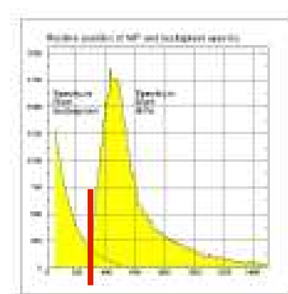
- To reduce signal fluctuations (origin of inefficiency), we need as much light yield as possible from the tiles.
- Mechanical tile arrangement with
  - minimal gaps between tiles to minimize particle leak through them
  - **but** gaps between tiles big enough for thermal expansion / contraction
- Signal threshold setting - **conflict** with backsplash self-veto requirement - decided on 0.3 *mip* threshold to meet both requirements.

How much of the light do we need?



What signal threshold to set?





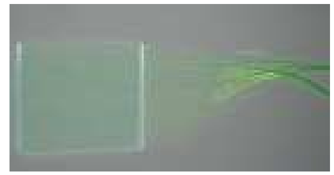
Efficiency provisions (cont.)

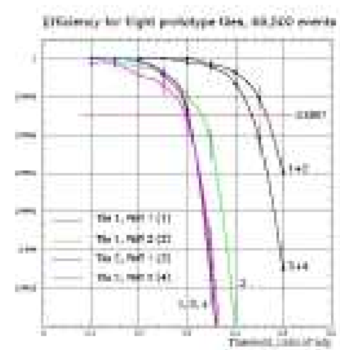
▪ Light yield from tiles was maximized as a result of a 2-year study:

- scintillator tile readout choice
- scintillator and fiber choice
- fiber spacing and groove depth
- wrapping material
- fiber end finishing

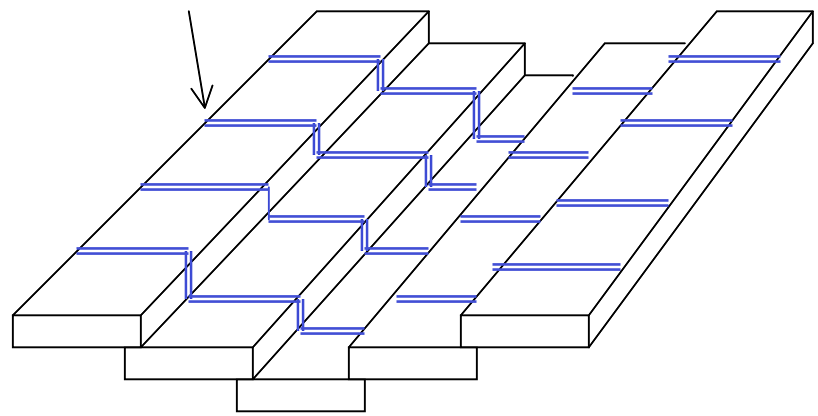
* Resulted in more than 50 photoelectrons per tile (split between 2 fiber bundles)

▪ ACD Hermeticity is provided by overlapping tiles in one direction and sealing gaps in the other direction with multi-layer scintillating fiber ribbon.





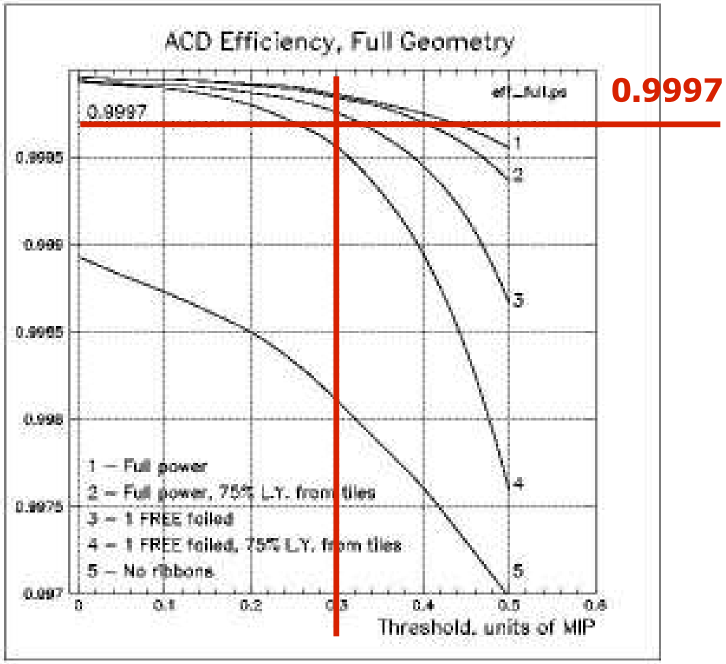
Measured tile efficiency



(top of ACD)

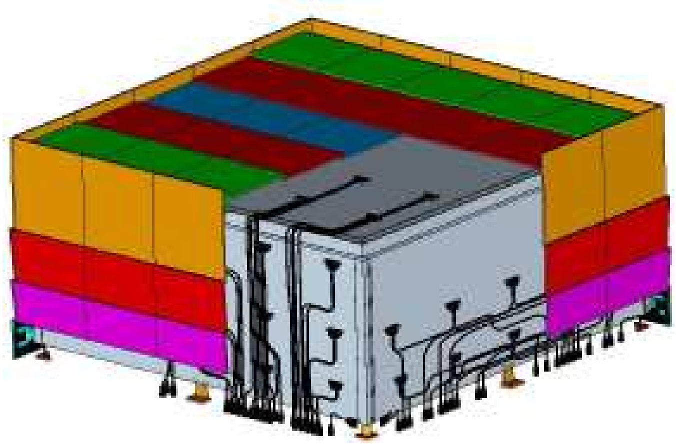
Efficiency provisions (cont.)

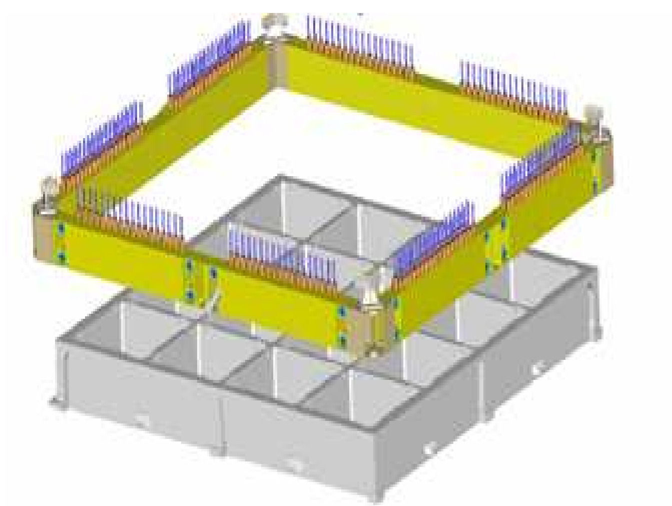
 To determine the resulting efficiency, the entire ACD was simulated, with carefully estimated light yield (different for each tile and fiber ribbon) and tile gaps corresponding to the expected ACD operating temperature of -20C°.



 Possible failure cases were analyzed - light reduction due to scintillator degradation and electronics/PMT failures - ACD can tolerate the loss of a full FREE board (up to 17 PMT channels), and light loss up to 25%. ACD also can tolerate the loss of several fibers per tile without significant change in performance.

Design Overview





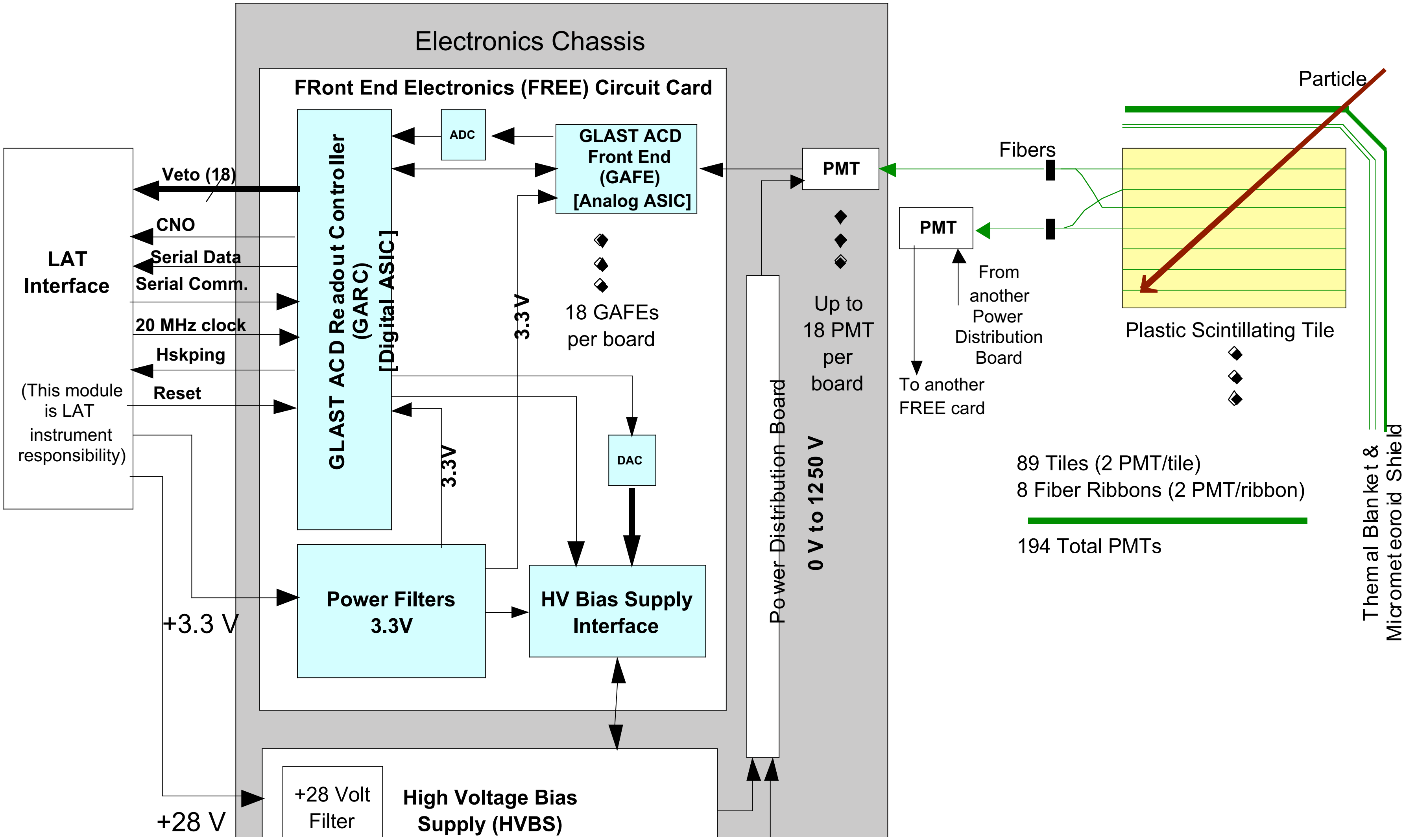
TILE SHELL ASSEMBLY

- 89 Plastic scintillator tiles (8.6 m^2 total)
- Waveshifting fiber light collection, with clear fiber light guides for long runs (6.7 km total)
- Two sets of fibers interleaved for each tile
- Tiles overlap in one dimension
- 8 scintillating fiber ribbons cover gaps in other dimension (not shown)
- Supported on self-standing composite shell
- 376 composite flexures support tiles
- Covered by thermal blanket + micrometeoroid shield (not shown)

BASE ELECTRONICS ASSEMBLY

- 194 photomultiplier sensors (2 per tile or ribbon)
- 12 electronics boards (two sets of 6), each handling up to 17 phototubes.
- Two (redundant) High Voltage Bias Supplies for each board.
- 24 electrical interface connectors (1600 pins total)

ACD Electrical Topology



Design Qualification

All ACD components passed design performance tests

Fiber ribbon prototype

TDA vibration test

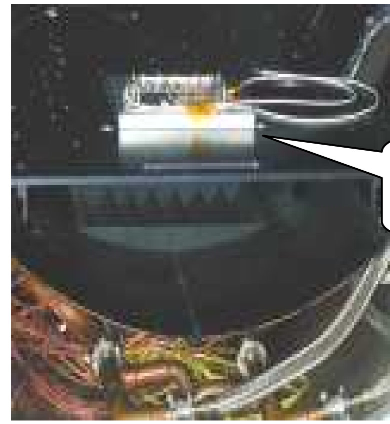
TDA uniformity test

TDA thermal-vacuum test

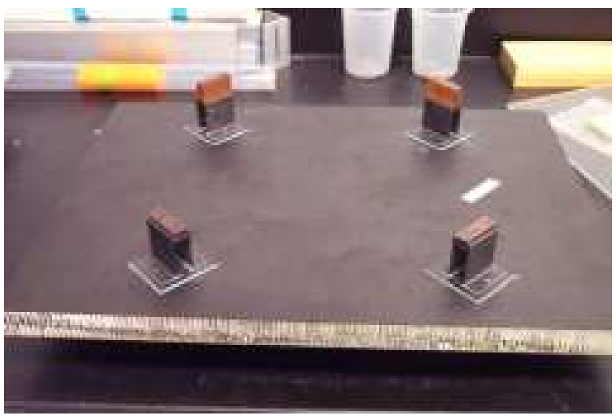
Front-end electronics test

Design Qualification (cont.)

Electronics chassis fit test



High Voltage Bias Supply thermal-vacuum test



Composite shell panel prototype with TDA flexures

Light-tight PMT assembly in vacuum chamber for corona test

ACD Current Status

- ACD design is essentially complete.

  Some mechanical interference issues are being resolved.

- Detector/Electronics End-to-End testing

  Required performance was confirmed with flight-type scintillator Tile Detector Assembly (TDA), phototubes (PMT), High Voltage Bias Supply (HVBS), Front End Electronics (FREE) card.

- Fabrication of mechanical structure and other ACD components is underway.

Issues and Concerns

- Flight ASICs need performance tests, plus screening and qualification
- Mechanical interference in TDA layout needs to be resolved
- TDA fabrication at Fermilab - reduction of support could cause some delay
- Late delivery of G3 Test Stand requires work-arounds for electronics chassis testing
- ACD cost has increased over original baseline, currently working on a re-baseline plan