GLAST Large Area Telescope:
IA Workshop
July 14, 2005
AntiCoincidence Detector (ACD) Subsystem

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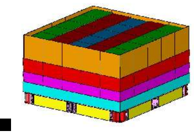
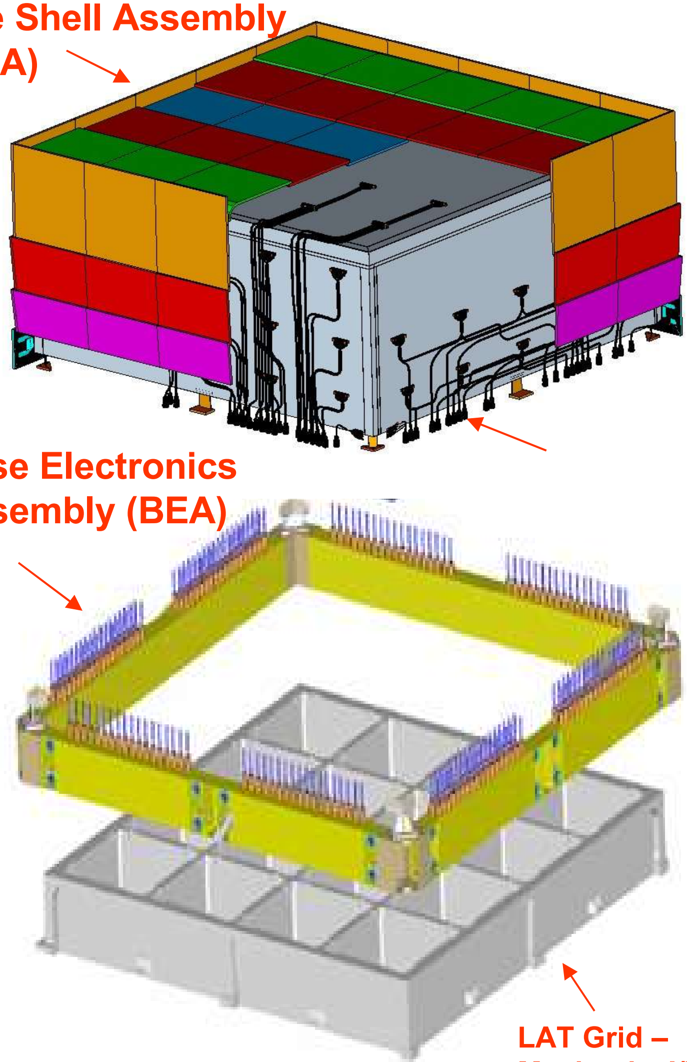
INSTRUMENT OVERVIEW - ACD





- **TILE SHELL ASSEMBLY**
  - 89 Plastic scintillator tiles – 1 cm thick (5 tiles are 12 mm thick), various sizes
  - Waveshifting fiber light collection (with clear fiber light guides for long runs)
  - Two sets of fibers interleaved for each tile
  - Tiles overlap in one dimension
  - 8 scintillating fiber ribbons cover gaps in other dimension – 4.5 mm x 12 mm x ~ 3 m
  - Supported on self-standing composite shell
  - Covered by thermal blanket + micrometeoroid shield (not shown)

- **BASE ELECTRONICS ASSEMBLY**
  - 194 photomultiplier tube sensors (2/tile)
  - 12 electronics boards (two sets of 6), each handling up to 18 phototubes. Two High Voltage Bias Supplies on each board.

ACD Geometry

Scintillating fiber ribbons under these joints

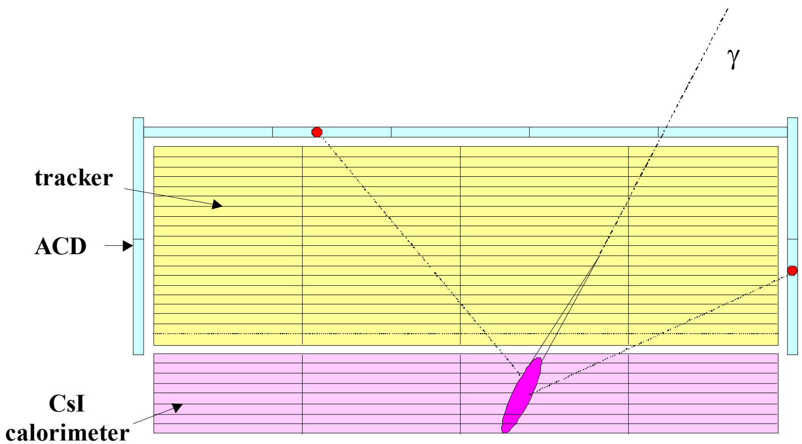
Bottom edge of ACD scintillator is 2 mm above the level of the CsI in the Calorimeter but ~10 cm away horizontally. This gap is not covered by active detectors.

What ACD does?

- LAT will have to identify cosmic gamma-rays from 4-5 orders of magnitude more intense background of charged cosmic rays
- The majority of the rejection power against cosmic rays will be provided by ACD

- **Required efficiency for charged particle detection for the ACD is 0.9997 over the entire area**

- EGRET has experienced the efficiency degradation by 50% at 10 GeV in respect to that at 1 GeV due to backsplash caused self-veto in ACD



- **Our goal is to approach at least 300 GeV maintaining at least 80% of the maximum efficiency**

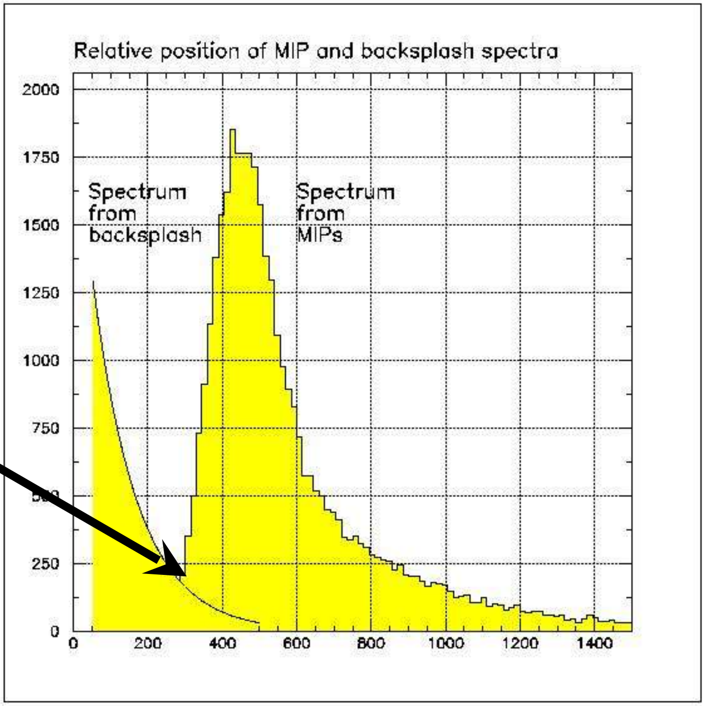
Why we so care about threshold?

The solution - segmented detector

Efficiency ↔ Backsplash trade-off

Designing to minimize backsplash and maximize efficiency are competing requirements - where to set a threshold to please both of them?

Pulse-height distribution for *MIP*s and backsplash



ACD has to issue a VETO if signal in a tile exceeds this threshold – this is ACD main responsibility

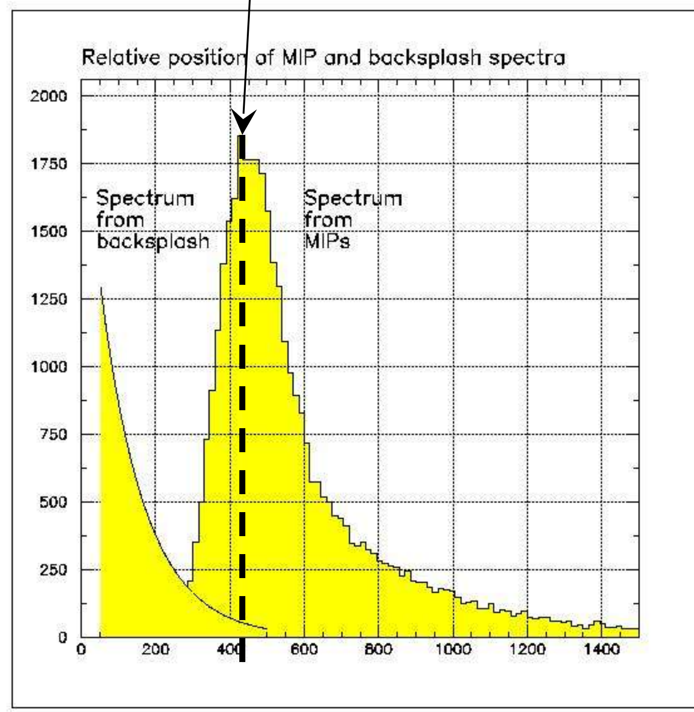
Key Definition - *MIP*

We will be operating with the term "*MIP*"

This is a most probable value (MPV) of energy deposition (or analog signal coming out of the detector, or ADC bin) from minimum ionizing relativistic particle in ACD tile. When I say "0.3 *MIP*" – I mean energy deposition (analog signal, ADC bin) which is 0.3 of its MPV

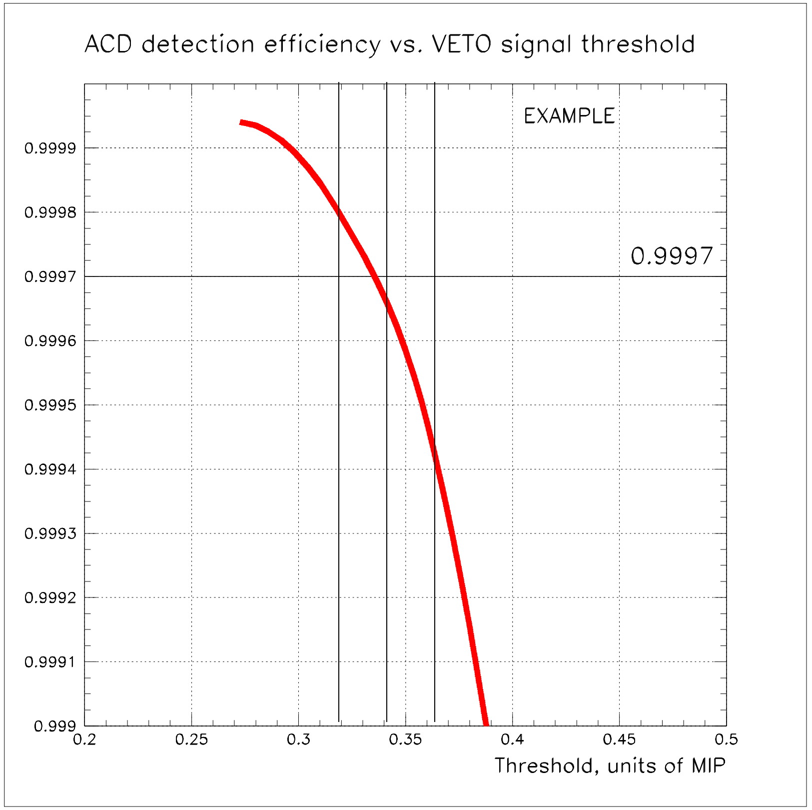
This is our key value; it does not depend on any calibration etc.

MIP



Threshold setting precision

An error of 0.01 *MIP* in threshold setting causes 0.0001-0.00015 error in the efficiency – we need to set (actually to know what we had set) VETO threshold with the precision better than 0.01 *MIP*



ACD Data – Discriminator Pulses (only THROTTLE YET)

The ACD sends two types of discriminator pulses to the GASU (GEM) on dedicated wires:

2. **VETO pulses from individual phototubes, with a nominal threshold of 0.3 MIP (desirably higher).**

3. **CNO pulses, one from each of the 12 Front End Electronics (FREE) cards, with a nominal threshold of about 30 MIP.**

The VETO pulses from the two phototubes on each ACD tile or ribbon are OR'ed in the GEM. These signals can then be used as a "throttle" on the hardware trigger. **VETO PULSES SENT TO THE GASU ARE NOT PRIMARY ACD DATA. THE FIXED (SHORT) PULSE WIDTH ALLOWS HIGHER INEFFICIENCY THAN THE LAT CAN TOLERATE (possible pile-up). ONLY *ACD PHA PLUS DIGITAL HIT MAP MEETS LAT REQUIREMENT.***

The CNO pulses (sometimes call High Level Discriminator or HLD) can be used as a trigger to alert the Calorimeter of a possible heavy particle passage. **THE CNO PULSES SERVE NO OTHER PURPOSE AND ARE THEREFORE SECONDARY TO THE FUNCTION OF THE ACD.**

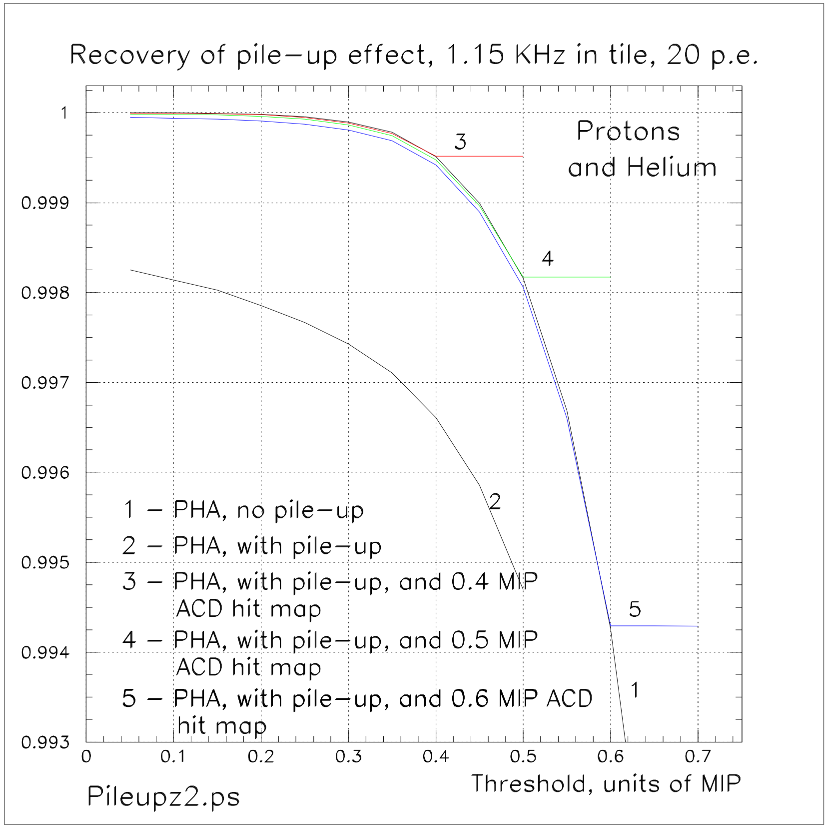
ACD Data – Digital Data (Real Efficiency)

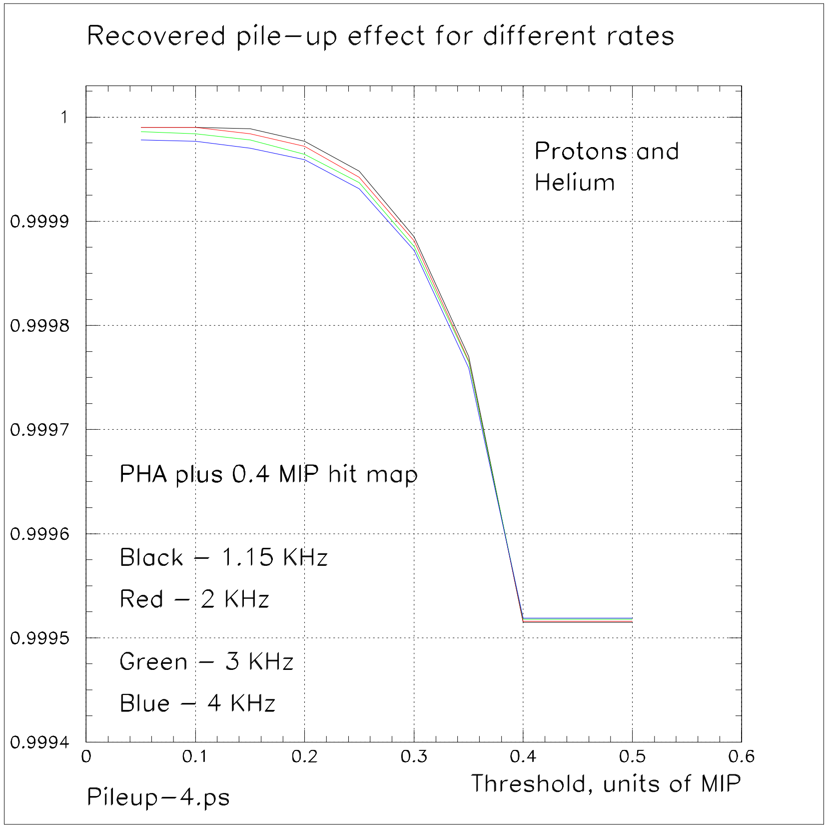
When a TACK is received, the ACD sends event data to the GASU (AEM, which is similar to a TEM). The most important data elements are:

2. A map of which individual phototubes had signals above a nominal threshold of 0.3 MIP (Hit Map). Because these discriminator pulses are not truncated, this map can have higher efficiency than the VETO signals sent directly to the GEM.
3. A series of Pulse Height Analysis (PHA) words, one for each phototube with a signal above the Zero Suppress Threshold (also called PHA threshold). The PHA threshold is nominally 0.1 MIP.

The PHA data provide the maximum information (individual values), but the deadtime associated with readout of the PHA (~10 microsec) is larger than the deadtime of the discriminator signals. The **maximum efficiency of the ACD** is achieved by using a combination of the PHA and Hit Map data, and **ONLY OFF-LINE!**

Pile-up effect





Summary

ACD

CNO – just flag

Threshold ~ 30 MIP

Hard-wired VETO; only Throttle in L1T

VETO “High” Threshold > 0.3 MIP

Do not enter backsplash area

Digital Data for ground analysis

Hit-map with VETO “High” thresholds

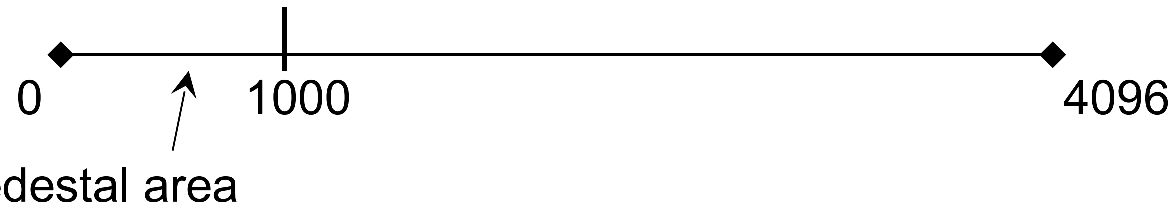
PHA data; software VETO threshold

All VETO thresholds (both for hard-wired and for off-line PHA analysis)are set individually **in units of MIP** for every PMT, depending on the purpose

ACD PHA

194 ADC channels (each PMT)

ACD ADC – 4,096 bins



PMT High Voltage is chosen to have a *MIP* peak of the weakest PMT on FREE board to be separated by ~400 bins from the pedestal

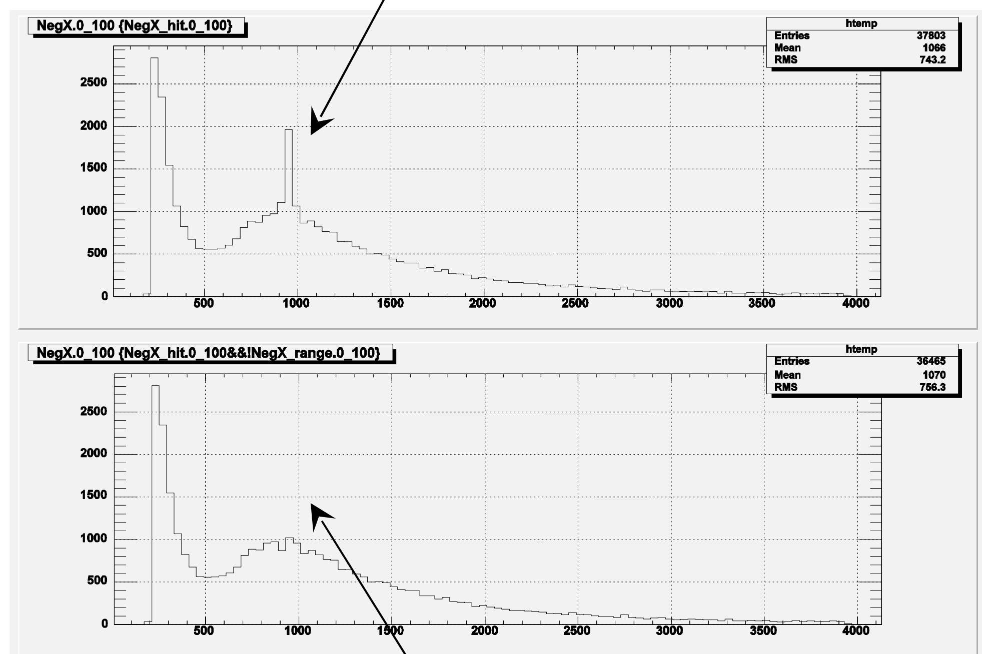
As was said earlier, we need threshold set precision to be ~0.01 MIP, or ~ 4 bins! But this is average for 185 channels (all tiles except long ones and ribbons), so the individual threshold setting precision is ~ 50 bins! Better!

More about ACD PHA

Placing MIP signal in channel ~400, the full ADC range will be 6-8 mips.

When signal from PMT exceeds ~ 5 MIP (High Level Discriminator, or HLD), GAFE gain switches to low, allowing for up to 1000 MIP signals to be digitized in ADC range

Both ranges events together.
These are High range events



Here High range events are removed

What do we have to Monitor and Calibrate?

There is only one the most important thing – **find MIP peak position** (for every PMT) and be sure that the **ADC is linear in the bin range from the pedestal to the MIP peak.** This secures that simple calculation of the threshold to be set (just needed fraction of MIP peak bin number) works right.

To determine MIP peak position:

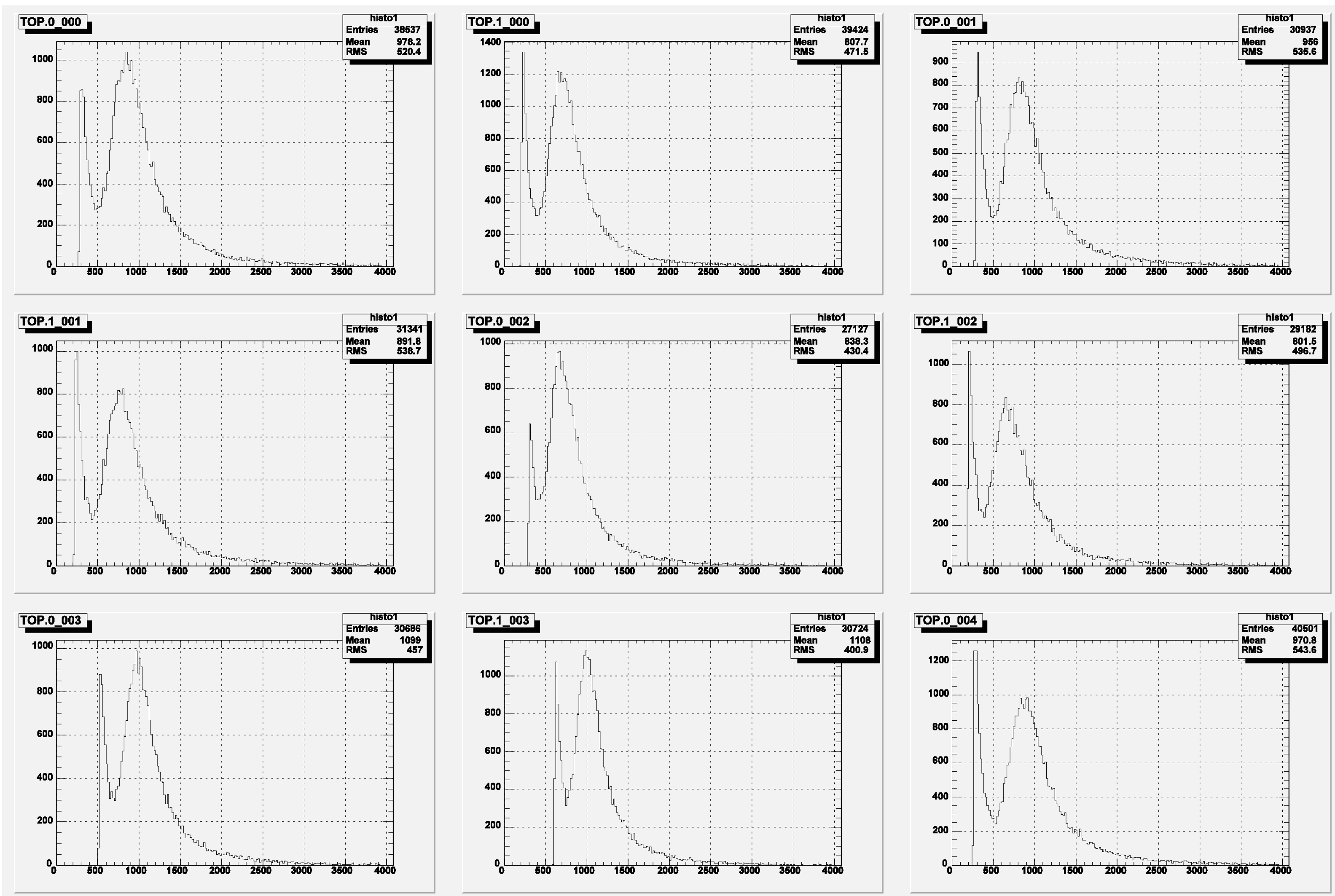
- On the ground – muons (free!) are the BEST tool. Proper event selection provides vertical events. Muon flux angular distribution (~ $\cos^3 \theta$) is very favorable in this case

- In flight – use tracker

-**MIP peak position has to be Monitored** (TBD how often)

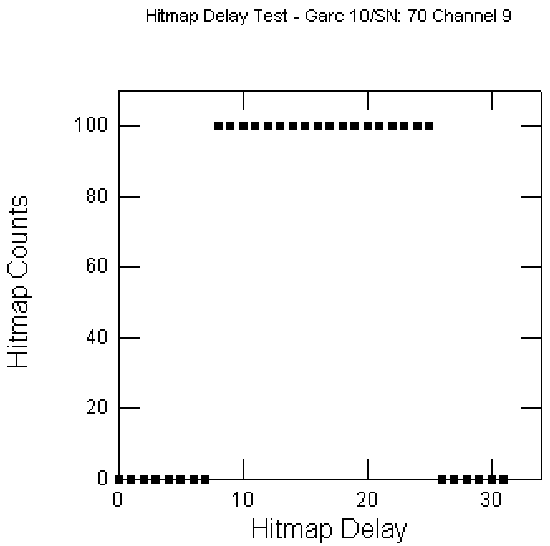
-Next thing – we need to know the correspondence between actual threshold position (in ADC bins) and threshold setting. **To be Calibrated**

Muon histograms in ACD, July 10, 2005

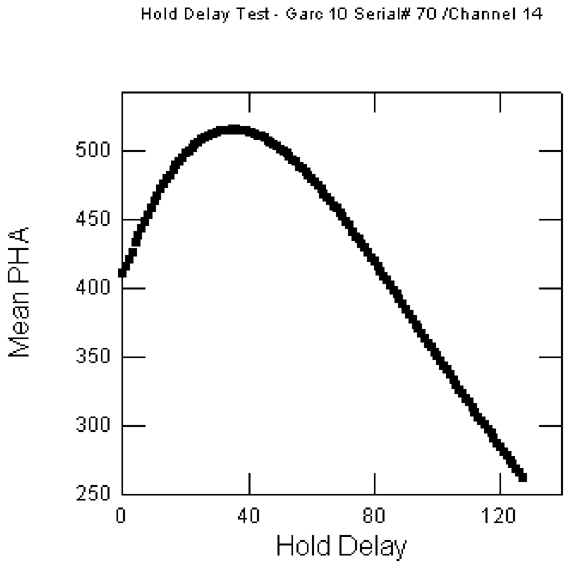


ACD timing

- ACD is a relatively fast detector.
- ACD has a number of “knobs” to adjust timing, including delays and pulse widths. (See the ACD Interface Control Document for details)
- Our test modes using plastic scintillator and TCIs for triggering are probably not a good emulation of the LAT timing.
- The trigger group will need to time in the ACD using the real LAT trigger.

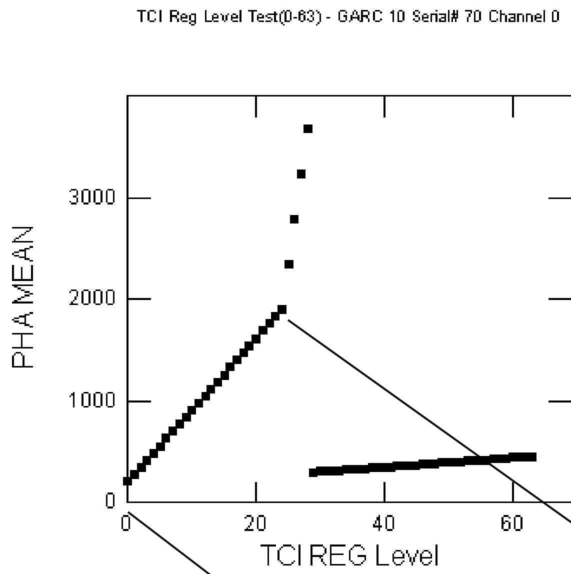


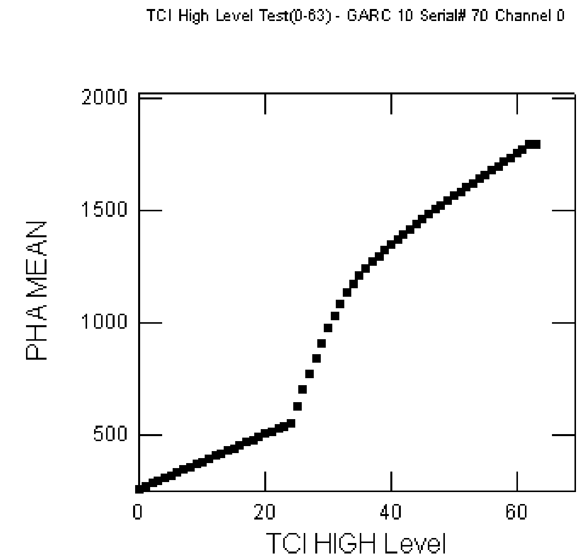
Examples – Hit Map delay (left) and PHA hold delay (right) scans for TCI.



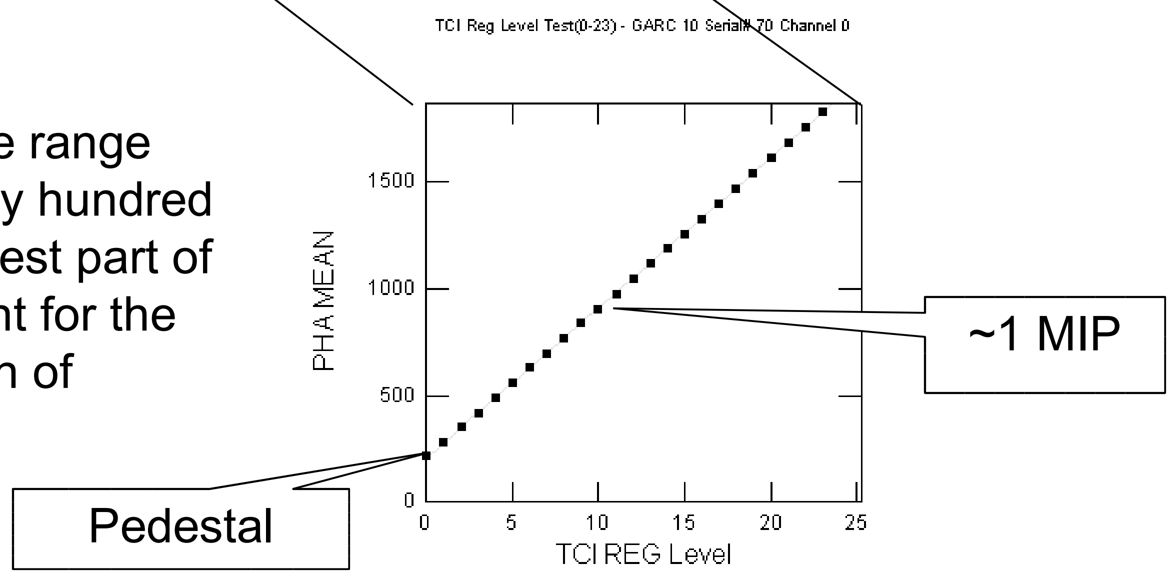
ACD Data – TCI Calibrations

Test Charge Injection for ACD has two levels, each with two ranges.





TCI covers a charge range representing 0-many hundred MIPs. Only the lowest part of this range is relevant for the single-MIP detection of greatest interest.



ACD Science Simulations

• Some important requirements flow through a science simulation, because direct measurement is impractical (no calibrated source of cosmic rays).

ACD Simulation **Measured** Input Parameters

Active elements
- Tile performance
- PMT performance
- Ribbon performance
- Flight configuration channel light through-put

Passive elements
- Clear fiber performance
- Wave shifting fiber performance
- Fiber connectors performance

Dead area
- Gaps between tiles and at corners

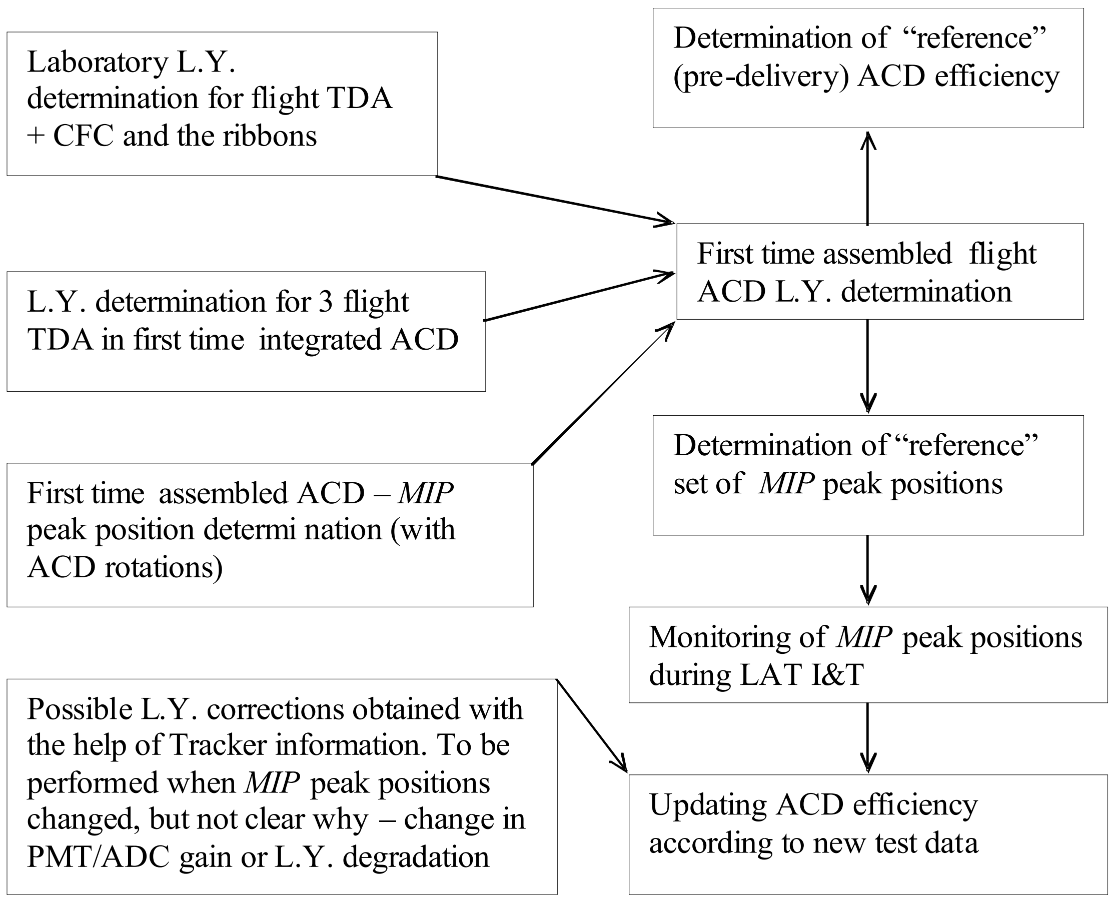
ACD Science Instrument Simulation

Key Requirement #1:
ACD 0.9997 overall efficiency

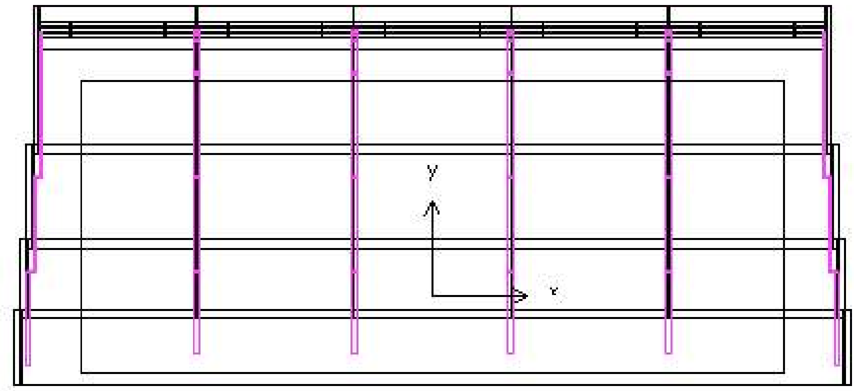
ACD Performance Determination

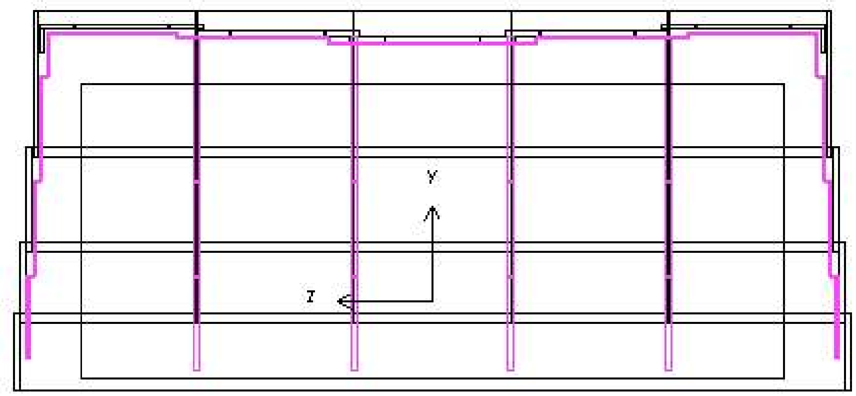
We have to propagate ACD detectors performance obtained in the laboratory before integration to that after integration.

Very limited time is given for assembled ACD tests!

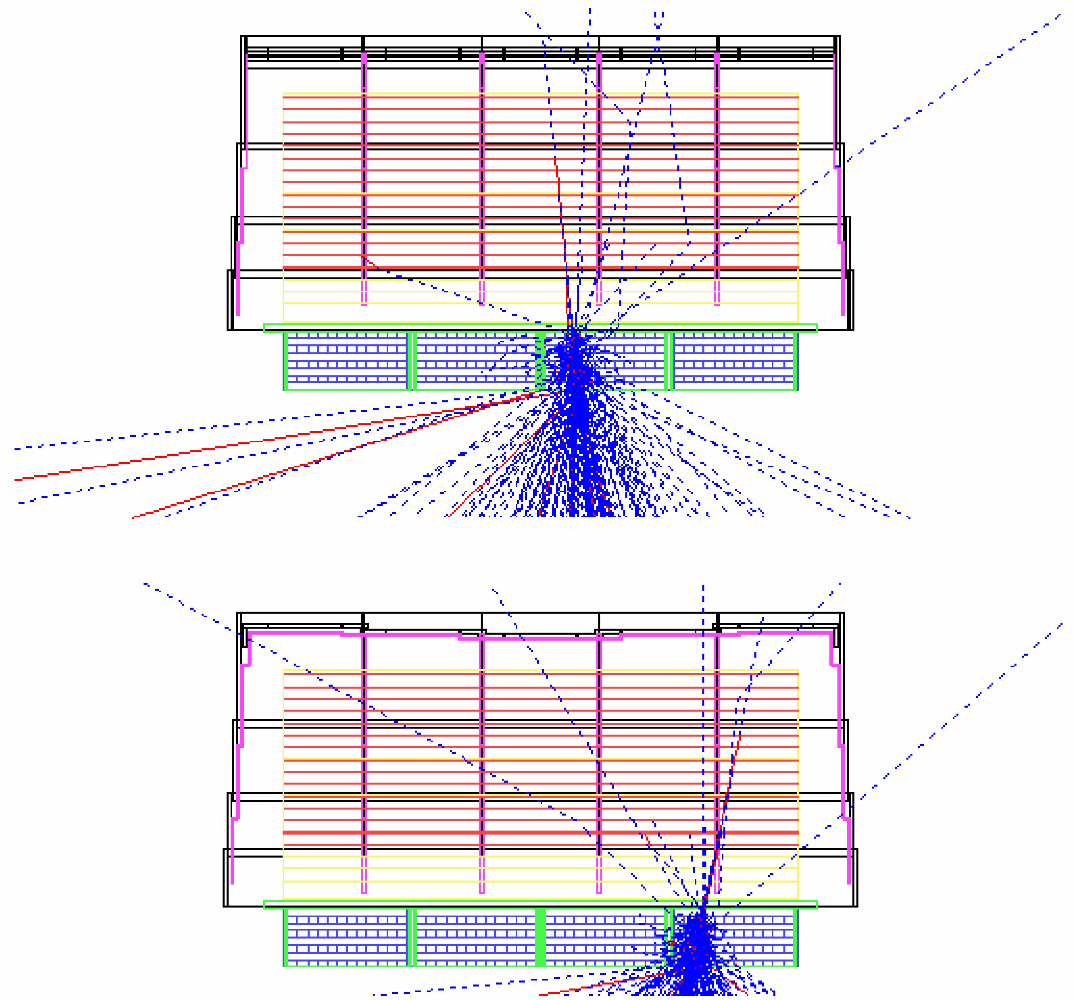


ACD Simulations





ACD Simulations

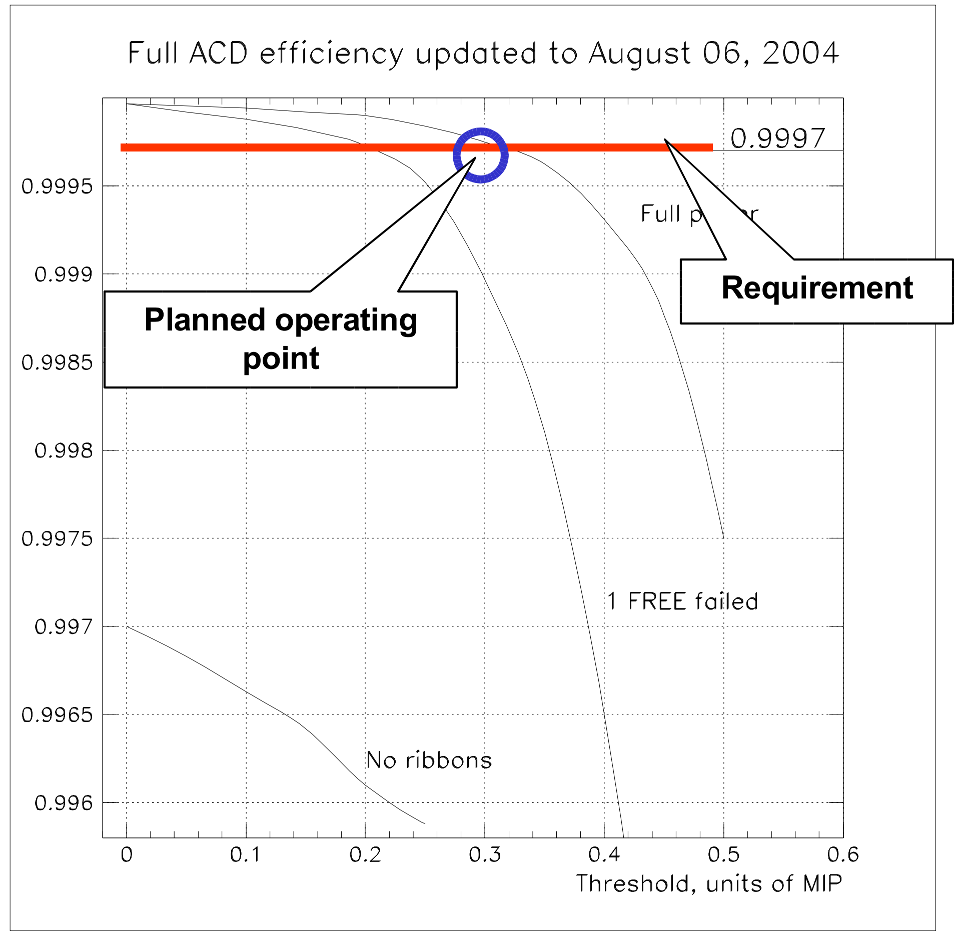


ACD Data Table

PMT (channel)	Average Rate, Hz	ADC Pedestal / width, bins	MIP peak position / width, measured, bins (pedestals subtracted)	MIP peak position correction factor (directional part)	MIP peak position correction factor (ADC gain change part)	MIP peak position for normal incidence, derived, bins	MIP peak position, reference, bins	MIP peak position change ratio	Light Yield, reference, p.e.	Light yield, current, derived, p.e.	High Voltage, readout / HV nominal, Volts
	Determined in this test	Determined in this test. Width is monitored	Determined in this test	Provided by ACD group	Determined in this test in electronics test	Determined in this test. Used for VETO threshold setting	Provided by ACD group	Determined in this test, monitored	Provided by ACD group	Determined in this test. Used for efficiency calculation	Readout determined in this test; nominal provided by ACD group
A	B	C	D	E	F	G	H	I	J	K	L
0-000	350	120/3	380/72	0.94	1.02	364	370	0.984	18.4	18.1	780/780
1-000		170/3	420/78	0.94	1.05	414	412	1.005	19.5	19.6	779/780
0-001		250/4	340/66	0.96	0.97	317	310	1.023	20.2	20.7	782/780
1-001		520/4	395/76	0.96	1.	379	386	0.982	18.8	18.5	780/780
…… ….											

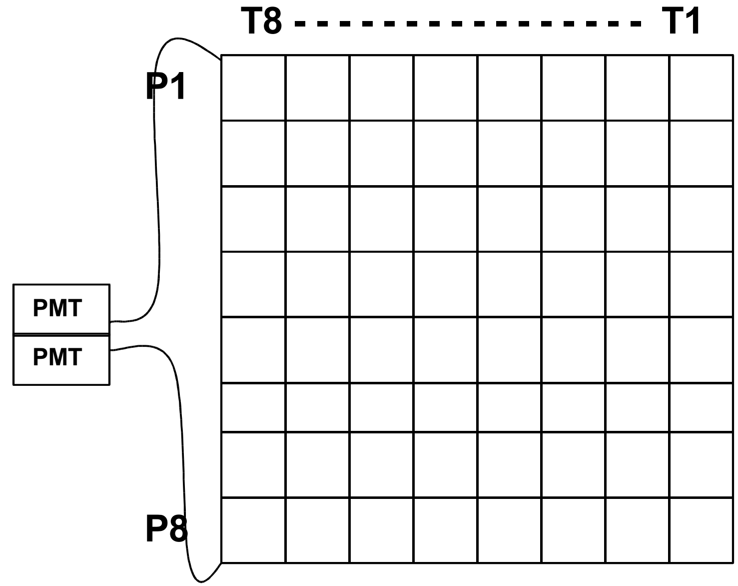
ACD Science Requirements Verification

- Performance of all detector elements has been measured in a laboratory setup, using ground-level muons as a source.
- These measurements were compared to a simulation of the same geometry.
- The same simulation was used for the ACD geometry, based on measurements during assembly.
- The calculated efficiency meets the requirement at the planned operating point.
- Margin for loss of detector signals is obtained by operating at a lower threshold.

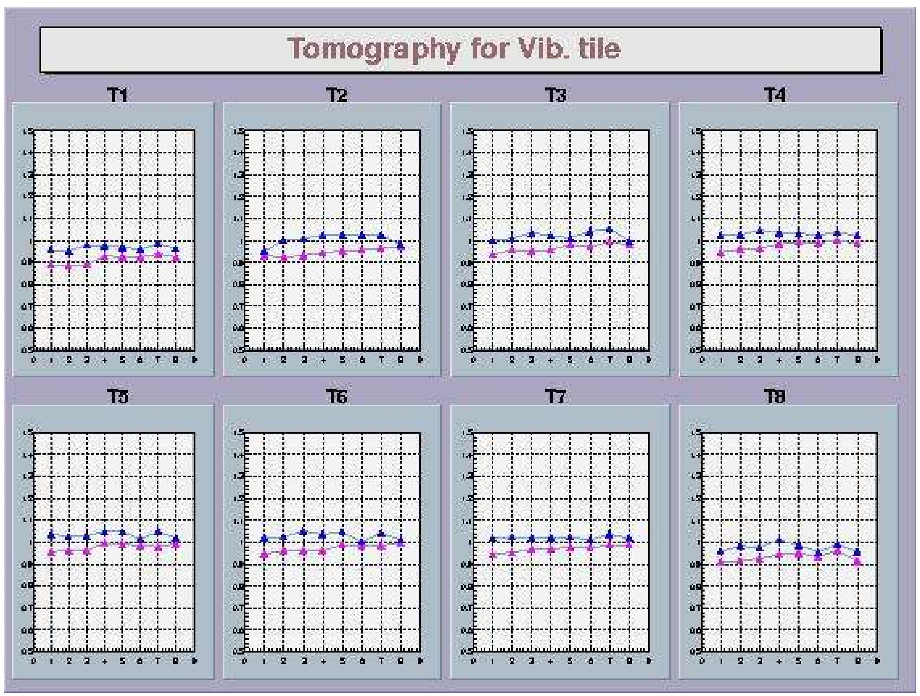


GLAST LAT ACD FULL PERFORMANCE ANALYSIS REPORT, ACD-RPT-000271

Tomography Test



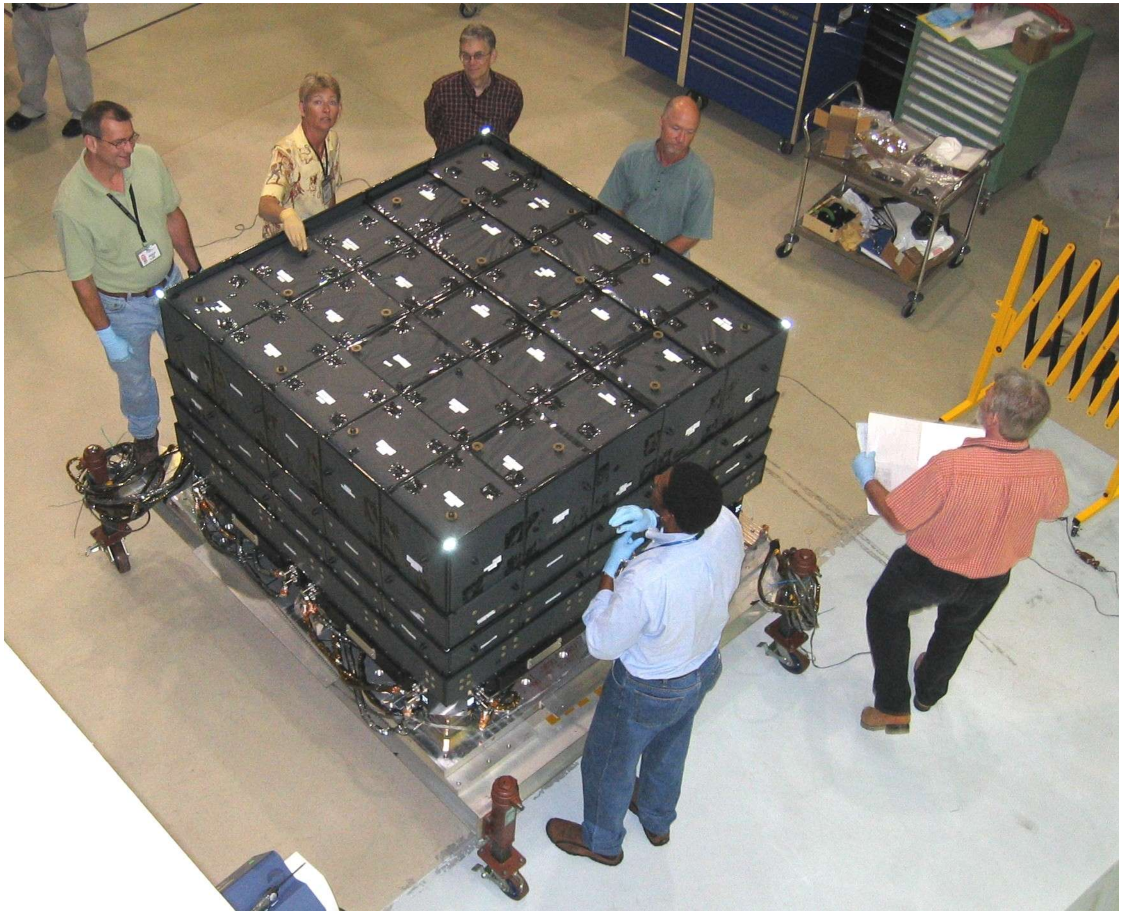
One advantage of the wavelength shifting readout is the uniformity of the output of the Tile Detector Assemblies (TDA). Each TDA was checked using an 8 x 8 muon hodoscope (right). This "tomography" showed that the light output is not a strong function of the position in the detector (below).



Data Analysis with ACD @ SLAC prior to integration in the grid

- ACD will be at SLAC for ~2 months before integration into the LAT
  - We hope to continue running tests in stand-alone mode
  - Final choices for thresholds will be set
  - We want to run ACD data through the pipeline to verify the process and learn about LAT analysis
    - Eduardo says, “We are expecting it not to be so smooth but we are working together…”
- We would be glad to have more people look at the cosmic rays we will be taking at SLAC at this stage, or the data we have taken during testing at Goddard (which are on the Web as LDF files – password required).
  - Try the analysis methods being used by I&T group

Just before MMS installed



MMS is ON!!! Hopefully forever!

ACD after assembly in the LAT

- Most tests seem fairly straightforward
  - ACD needs to be timed-in with the system.
    - We assume the trigger group will do this
  - Need to do a quick test with ACD setting it to veto cosmic rays, i.e. use it in “throttle” mode
    - And we should see very little leaking (the ACD is not perfect, remember)
  - Need cosmic rays triggering on side tiles (ACD trigger)
    - This requires ROI setup for coincidences between different regions of the ACD, such as opposite sides or top and sides. One ACD test script does this now.
  - Need mapping of tracks back to the ACD to look for weak areas (such as corners) where leaks might be more probable.
    - Might be worth considering a map of such areas for data analysis
    - This is an area where the ACD team could really use help from the analysis group.

Timeline

- ACD has just started environmental testing:
- Passed all 3 axis vibration
- In acoustic test today
- Go to thermal-vacuum chamber on Monday

- Delivery to SLAC is scheduled for mid-August
- Next Instrument Analysis Workshop is at the end of August during Collaboration meeting
  - The ACD should be at SLAC but not integrated onto the LAT
  - We need to learn more about how the IA group handles data and what tools are being developed for analysis.