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Gamma-ray Large Area Space Telescope (GLAST)

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ACD Performance Monitoring and In-Flight Calibration

05/08/02 - DRAFT by Dave Thompson, with comments by Alex Moiseev, Bob Hartman, and Eduardo do Couto e Silva

ACD Performance Monitoring and In-Flight Calibration - What Do We Need and How Do We Get It?

1. Introduction

Of the many parameters that characterize the ACD, the scientific performance is largely determined by two level III requirements: (1) the efficiency for signaling the passage of charged particles (requirement 0.9997 averaged over the surface except for the lowest row of side tiles); and (2) the ability to reject backsplash effects at high energies (< 20% loss at 300 GeV). The other requirements on the ACD are essentially all related to obtaining these performance characteristics. By contrast, parameters like energy resolution and point spread function, which are critical in the tracker and calorimeter, are largely irrelevant to the ACD. The focus of testing and in-flight calibration is on monitoring the ACD performance in these two critical areas.

2. Detection Efficiency and Related Parameters

Although the charged particle detection efficiency is the crucial parameter, this quantity is fairly difficult to measure in flight, requiring analysis of track fits. It is also not something that is directly adjustable. For this reason, the related measurable quantities of rate, pedestal, electronics response to known charge, Minimum Ionizing Particle (MIP) peak position, MIP peak Full Width Half Maximum (FWHM), threshold, and HV need to be tracked (threshold and HV being the commandable ones that may require adjustment). The position of the MIP peak in particular is a good measure of the end-to-end performance. Many of these parameters are directly read out or easily derived, so that they could be included in a monitoring (on-line, or EGSE) system. The derived parameters are ones that require additional analysis and would be thought of as calibration parameters.

We have to remember that the ACD efficiency is not uniform – it is lower around the tile edges than in the center. But still the performance of the entire ACD can be derived from the performance of its parts – electronics, tiles, and the fiber ribbons.

For monitoring in real-time, we expect to have data display pages and graphics, with formats to be defined. For calibration, we will maintain a table of these parameters (averaged over each tile by tube) as a function of time, and perhaps some or all of these can be included in Eduardo's Web-based database system. A sample table is given at the end of this document.

Here is how we might obtain each of these (see Fig. 1 for a schematic):

Rate (Hz) - This simple parameter, which is sampled and read out by the AEM for each tube, is a surprisingly powerful diagnostic of first-order changes in performance. The first thing we will want to look at in every test is the set of rates from the tubes, comparing them with a reference set and with each other. This parameter is used in both real-time monitoring and in calibration.

Since these rates vary a lot over an orbit, and also over a day, some care is needed to compare with a reference set. Perhaps use averages over ~5 minutes, then use for comparison the minimum during a 24-hour period. The maximum is less attractive because of solar flares and trapped particle precipitation. Even the minimum could be distorted if a flare occurs around the time the minimum should occur.

Pedestal (in units of PHA or ADC channels) – We may need a special mode for this test where the Zero-Suppression will be shut down. Accumulate a pulse height analysis (PHA) spectrum for each tube, under any operating condition. Fit a gaussian or other functional form to the large peak in the lowest non-zero channels. The pedestal is the channel value at the maximum of this fitted peak. Remark: after the qualification test of electronics we will determine the limitations on the pedestal's sigma and on the range of pedestal value change (significant pedestal shift will signal that something is changing in the system). For real-time monitoring, we will want to accumulate a PHA spectrum for each tube. The analysis for the pedestal value is probably simple enough to do in the EGSE, but it seems unnecessary to do such analysis on board.

Electronics response (in units of channels) - Run the ACD in charge injection mode for TBD min (perhaps during one SAA passage per TBD) with HV for the phototubes turned down. Inject charge nominally corresponding to 1 MIP. Record the channel(s) where this peak appears in the PHA spectrum for each tube, and the width of this peak. Note that this mode requires an ACD-only trigger for the LAT.

MIP Position and MIP FWHM (in values of channels) - During normal operation, most of the triggers that contain useful information for determining these parameters will not be sent to the ground. In principle, these PHA spectra could be accumulated on board, but we have not requested this mode. The best information will probably come from the unbiased data sample that will be collected regularly, or from dedicated ACD calibration runs (calibration modes designed to measure tracker and calorimeter performance are not likely to have enough events in the side ACD tiles to be useful). From this unbiased sample, accumulate PHA spectra for each tube using the following selection process. For each target tile, define one or more trigger tiles that are approximately in a normal direction to the given tile. Collect PHA values for the target tile (each tube separately) only for those triggers in which a signal (above TBD) is seen in one of the tubes on the trigger tiles. Fit the accumulated PHA spectra with a Landau function to determine the peak and Full Width Half Maximum. An alternative approach using processed data would be to accumulate the PHA spectra for tiles to which the tracker shows a single straight track pointing. Real-time monitoring includes accumulating PHA spectra and probably simple fitting analysis. The calculated values can go into the calibration data base.

Threshold (in channels) - This is a commanded value. If the command units are mV, convert to channels using the scaling for that tube. The commanded value can be displayed in real time.

In addition to the command, we need to determine the actual threshold, in channels. This would be easy if we could self-trigger on the LLD, then read out pulse heights and presence/absence of VETO. However, I don't think that is possible in the present electronics design. The charge injection pulser can give a rough estimate, 0.1 MIP steps. This will require stepping through the range of the threshold, recording the fraction of pulses triggering VETO at each setting. Special runs and off-line analysis are probably required for this function, which then becomes part of the calibration database.

High Voltage (in V) - This is a commanded value. It is also read back. We probably want to monitor both the command and the value read back.

Both the command and the readback should be included in real-time monitoring displays and in the calibration database.

Efficiency (fraction of charged particles for which a tile or ribbon produces a signal) - This is the ultimate parameter, but it is a derived one. What is needed for a given tile is a large sample of triggers for which a single charged particle hits the tile within TBD degrees of normal. This sample can be derived from events with a single visible track in the tracker and at least one ACD tile along the direction of the track showing a PHA value consistent with a MIP. The efficiency is the fraction of such events pointed toward a given tile that produce a signal in the VETO_HITMAP (the only readout that has the full efficiency) - assuming the VETO_HITMAP comes from the "or" of signals from the two tubes on a tile (need to verify that). As the work by Kamae and Mizuno on the BFEM has shown, this is not a trivial analysis. Separating true "leaks" from pair conversions in or near the tiles might involve looking for energy deposit consistent with a single charged particle, either in the calorimeter or in another ACD tile. The carefully-analyzed efficiency is then part of the calibration database. As work by Alex Moiseev has shown, the efficiency can also be measured to good approximation by plotting the fraction of pedestal-subtracted signals as a function of threshold, using the PHA distributions (see reports by Alex). This efficiency calculation might be done in the real-time EGSE monitoring system.

3. Backsplash Rejection

This parameter should be derivable from the standard data products. Recognized gamma-ray events with high energy are likely to be accompanied by backsplash signals in some ACD tiles. Events in which the backsplash hits the entering tile will be rejected, but many events will be seen in which the backsplash is seen only in other ACD tiles. From those we should be able to confirm the backsplash energy spectrum (at least that visible above tube noise) and angular distribution. This analysis is probably only practical offline. Remark: we probably need some sort of guide-line for how the VETO threshold effects the backsplash rejection. Such information will be obtained during the beam calibrations using the ACD Calibration Unit, but it can also be derived from the PHA data during routine operations.

4. Other Calibration Data

Two other calibration data sets of interest:

1. Electronics linearity table for each tube (done by charge injection in 64 charge value steps). Eduardo suggests a table. The calibration input pulse height is defined in terms of DAC counts and the output is expressed as an average ADC value of the muon peak. The conversion is accomplished by using a look-up table where adjacent points are linearly interpolated.

	Tile or ribbon	**Peak Number**	**DAC**	**ADC**
	0	0 -100	0 to 10^4	0 to 10^4
Type	int	double	double	double

Table 1. One possible version of ACD electronics linearity table.

Tile	**Tube**	**Step 0**	**Step 1**	**Step 2**	**Step 3**	**• • •**	**Step 61**	**Step 62**	**Step 63**
000	0								
000	1								
001	0								

Table 2. A second possible version of the ACD linearity table.

2. A map of the apparent "leaks" in the ACD, so that the Science Analysis Software group would have the option of including that information in the analysis software (for example, not accepting events with MIP-like energies that have a straight track that is seen in all layers of the tracker pointing to a region of the ACD known to have lower efficiency than average). This map would be derived from the same analysis used for efficiency - looking for straight tracks that penetrate ACD tiles and/or ribbons with no signal - but on a finer spatial scale. Possible areas of weaker performance are the corners.

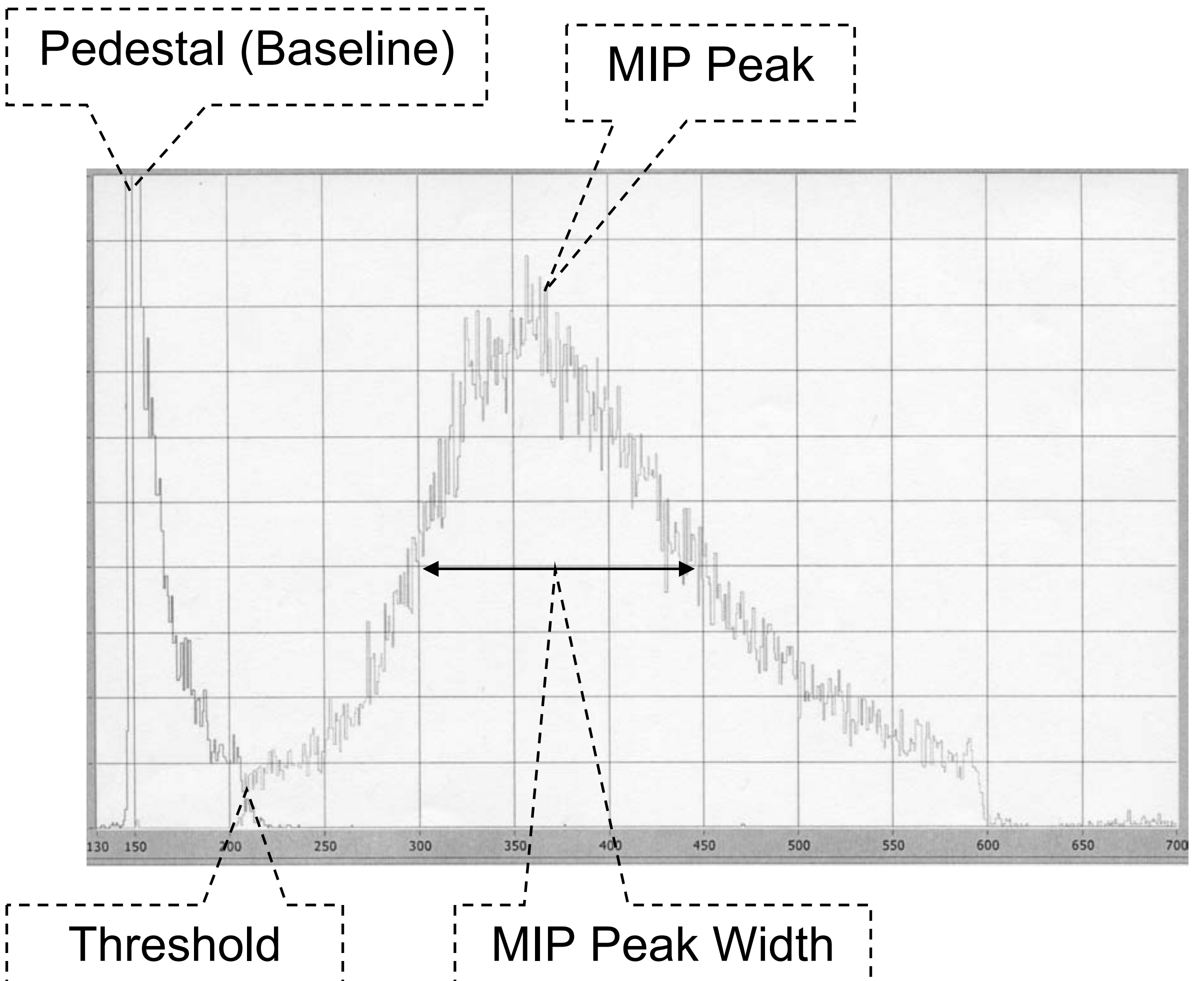

Fig. 1 – Schematic of calibration parameters derived from the ACD data, particularly the Pulse Height Analysis (PHA).

Item	Number of tiles+ribbons	PMT	Energy range	Output data	Words	Type	Bytes/type	Kbits
Detection efficiency	89+8			Value, error	97	Float	4	5.6
Veto Threshold	89+8			Value, error	97	Float	4	5.6
MIP position	89+8			Value at peak, FWHM	97	Float	4	5.6
Pedestals	89+8	2	2	Centroid, width	388	Float	4	22.3
Electronics Response	89+8	2	2	Value at peak, FWHM	97	Float	4	5.6
Electronic Linearity	89+8	2	2	Peak, DAC,ADC	388	Float	4	44.5

Table 3. Eduardo's candidate table of ACD calibration

Time: 01/01/2007 12:00:00 UT

Tile	Tube	Rate (Hz)	Pedestal	Elec. Resp.	MIP Pos.	MIP FWHM	Thresh. command	Thresh. (derived)	HV command	HV readout	Effic. (derived)
000	A	350	125	1000	1200	300	440	450	1050	1050	.9998
	B										
001	A										
	B										

Table 4. Another possible format for an ACD calibration table.