An investigation of alternative configurations of the readout controllers of the Fermi LAT tracker

Leon Rochester (SLAC National Accelerator Laboratory)
on behalf of the Fermi Large Area Telescope Collaboration

In events with many hits in the LAT tracker, the limitations of the data-acquisition system can lead to hit loss. We explore some simple measures to reduce this effect.

The Fermi Large Area Telescope (LAT) [1] consists of 16 towers, each incorporating a tracker made up of a stack of 18 pairs of orthogonal silicon strip detectors (SSDs), interspersed with tungsten convertor foils. The strip numbers of the struck strips in each SSD are collected by two readout controllers (RCs), one at each end, and nine RCs are connected by one of eight cables to a cable controller (CC).

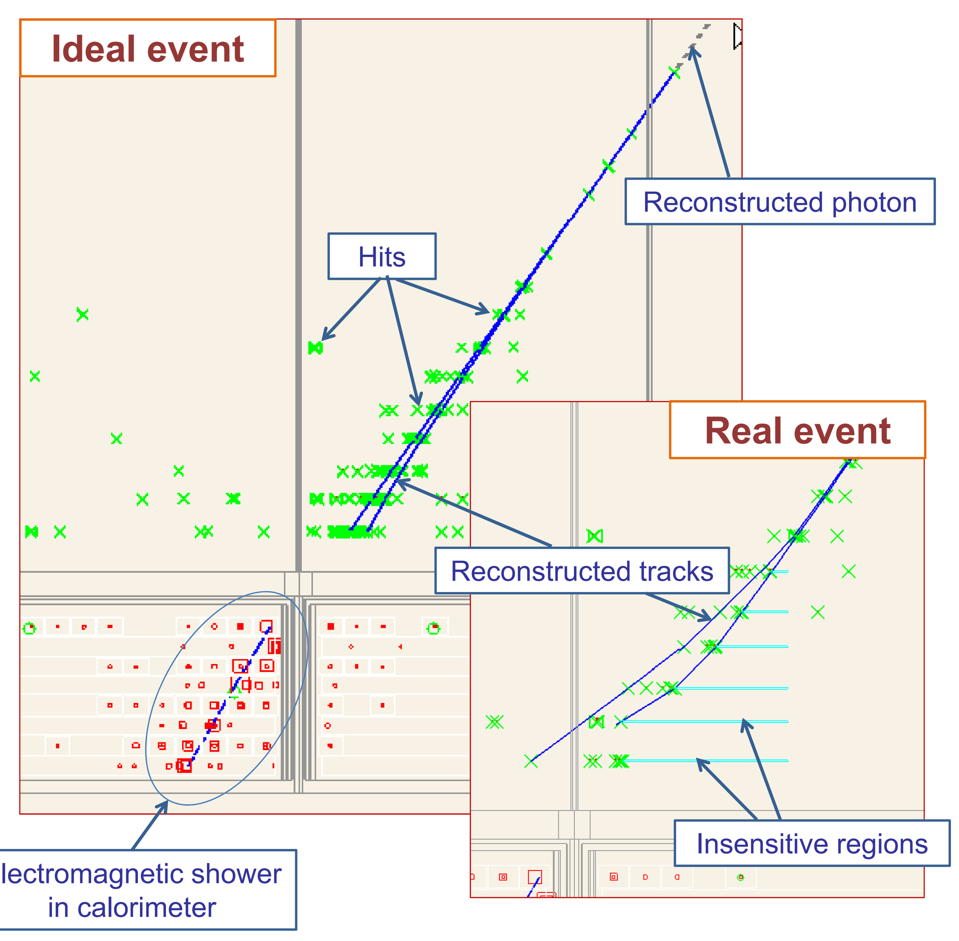
The tracker readout electronics limits the number of strips that can be read out. Although each RC can store up to 64 hits, a CC can store maximum of only 128 hits. To insure that the photon shower development and backsplash in the lower layers of the tracker don't compromise the readout of the upper layers, we artificially limit the number of strips read out into each RC to 14, so that no CC can ever can see more than 126 hit strips.

In this contribution, we explore other configurations that will allow for a more complete readout of large events, and investigate some of the consequences of using these configurations..

Hit truncation in the tracker data buffers

The problem

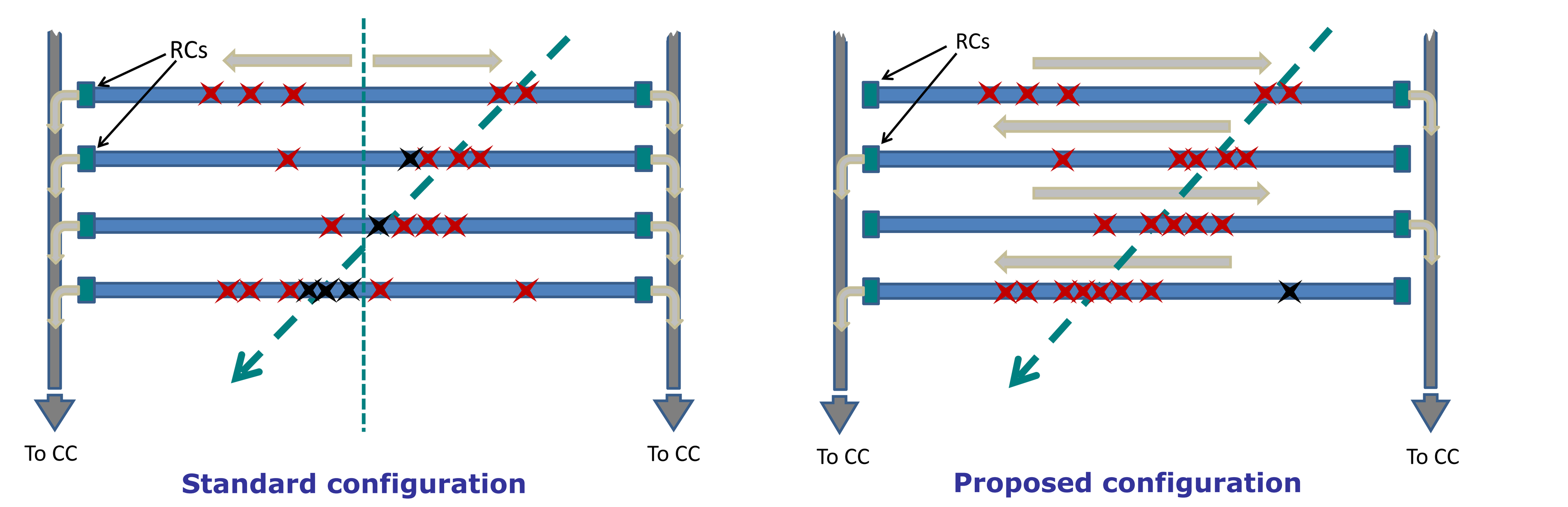
- The hit strips in each of the tracker layers are read out into buffers in two read controllers (RCs), one at each end of the layer, and nine RCs are read into a buffer in a cable controller (CC), where the data are stored for assembly into the complete event.
- Each RC can accommodate up to 64 strips, but the CC can only accept the first 128.
- If there are more than 128 hits, those from the top layers are lost first, leading to a serious loss of resolution on the recon-structed photon direction.
- So we limit the number of hits in each RC so that the CC buffer is never completely filled. For events with many hits, this strategy tends to confine the hit loss to the lower layers, where the photon has started to shower, and where the tracker is sensitive to backsplash due to low-energy photons from the calorimeter, just below the tracker.



This simulated event shows a high-energy photon showering in the tracker, with no limits on the number of hits read out. This can be done in simulation, but not in the real detector. As the shower develops, the number of hit clusters (green x's) in each layer increases. The blue lines indicate the tracks found by our newest pattern recognition software [2].

The inset shows the same event, but now the hit buffers are truncated as they would be in the standard configuration of the LAT readout electronics. (*See next panel*.) Many of the hits in the lower layers are lost; the teal bars show the regions that become insensitive. Because of the missing hits, the lower parts of the tracks are displaced, and this contributes to a shift in the reconstructed direction of the found tracks away from the true direction, and thus in the inferred photon direction. For this event, the shift is 0.03º.

A proposed configuration [3] with fewer lost hits



On the left is a schematic representation of the standard configuration of the tracker readout. Note the two read controllers on each layer, each of which reads out the hits in half of the layer. All the layers are configured in the same way.

In the actual readout, each read controller can accept 14 hits; here, for illustration, we set the buffer limit to three. In this event, the dark green arrow represents a photon showering in the tracker. The red x's are the hits. The grey arrows indicate the direction of the information flow. We show the lost hits in black. Note that the hits towards the center of the layer are the ones affected.

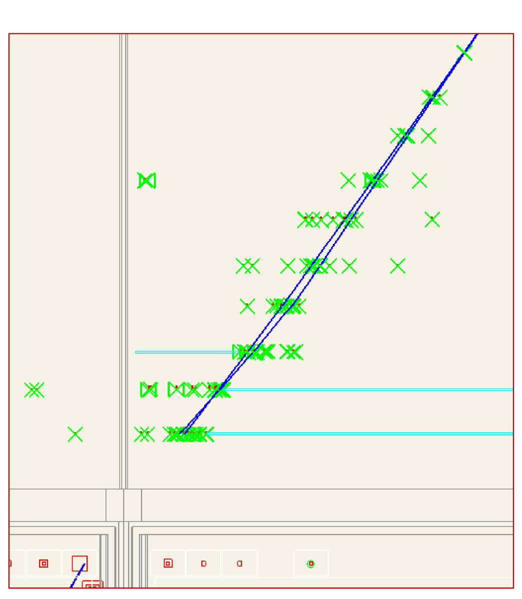
The proposed configuration on the right , takes advantage of the fact that the width of the shower in a tracker layer is typically much smaller than the half-width of the layer, so that the hits tend to fall into one half or the other. Instead of splitting the layer, we read out all the hits at one end, and double the buffer size. In the next layer, all the hits are read out at the other end. The maximum number of hits presented to each cable controller stays the same, but we now can use the currently often wasted capacity of the end farthest from the hits.

In this example, we recover four of the five lost hits in the new configuration. The remaining lost hit falls outside of the shower core, and so will not affect the tracking. This is a general feature of this configuration, since the hits are lost from the ends, rather than from the middle of the layer.

As a variation of this configuration, we can "taper" the buffer limits, so that the buffer size is smaller at the top of the tracker, where there are fewer hits, allowing us to use the extra capacity at the bottom. The example we will use below tapers from 12 hits at the top to 49 at the bottom.

Readout configurations are defined in the onboard software, and can be uploaded to the orbiting instrument.

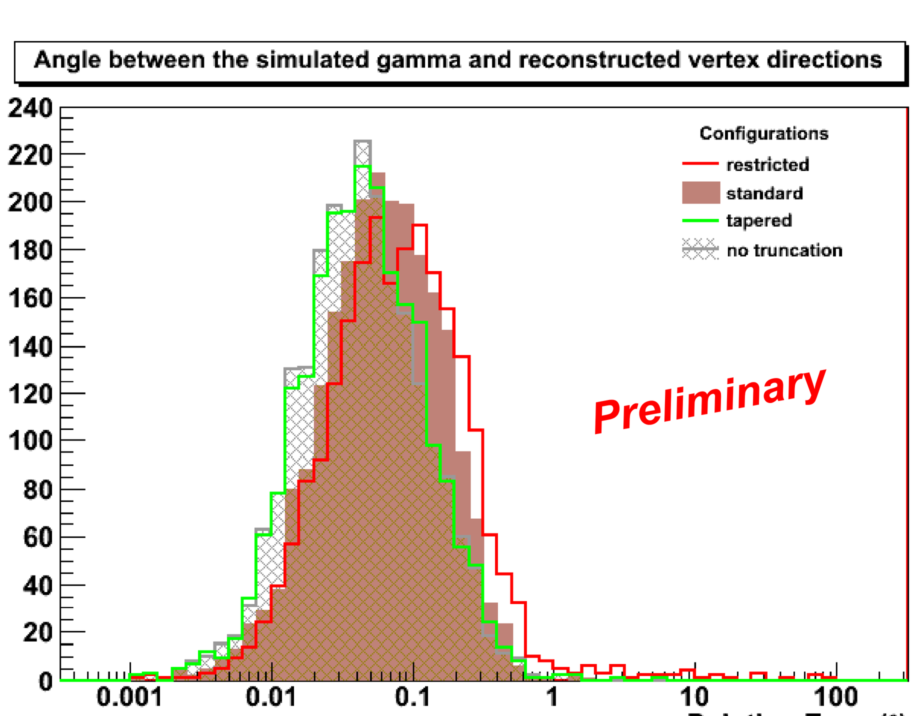
Improvement in angular resolution



To the left we show the original event, read out with a tapered configuration, as described above. Note that even though there are still lost hits, the overall situation is much closer to the ideal one.

In the figure below, we compare the angular deviations of the reconstructed tracks from the true direction ("PSF"s), for the configurations discussed above, for an event sample consisting of photons with an $(\text{energy})^{-1}$ spectrum (uniform in $\log_{10}(\text{energy})$), and incident on the LAT at 45 degrees to the vertical, and with a minimal cut on the overall quality of the reconstruction. We select the subsample with energies between 10 and ~300 GeV that convert in the upper ("thin radiator") section of tracker. The energy, angle and conversion point are all chosen to maximize the truncation effect.

To make the plot, we choose all events for which the PSF for the standard configuration is below two degrees. Since there are only three events between one and two degrees, the exact location of this cut is not crucial.



We plot one additional configuration. This one, called "restricted," is similar to the standard one, except that we limit the read-controller buffers to eight, rather than fourteen hits. We expect this configuration to have the poorest PSF of all. But it will be useful, because we can compare the distributions of simulated events to those of existing real data, by removing hits from the real data.

In the figure, the standard configuration is shown with brown fill; the tapered one as a green line, the restricted one as a red line, and the ideal configuration with hatched fill. The simple alternating configuration with 28-hit buffers has been omitted for clarity; its PSF is slightly worse that of the tapered one.

The PSF of the tapered configuration is better than that of the standard one; indeed it's almost as good as the ideal resolution. The restricted configuration significantly degrades the PSF.

Quantitative results and discussion

To make a quantitative comparison, we take the means of the distributions in the previous panel, cutting the distributions off at five degrees. The qualitative conclusion doesn't depend on this cut. The results of this simple study, shown in the table below, indicate that there is definitely something to be gained by adopting one of the proposed configurations.

Before making a serious proposal, we need to do a more realistic study, using photons at all angles, and background events. We should also compare the simulation to real data, first by using the restricted configuration with existing data, and eventually by running tests on-orbit with the proposed configuration(s).

Finally, we need to consider other effects of such a change. Some possibilities are:

- degradation of the hardware trigger, principally through possible changes in timing,
- decreased ability to identify out-of-time tracks (ghosts), because of loss of granularity of the detailed trigger information, and
- increased time to reconstruct the events offline, which can be significant for our combinatoric algorithm.

Finally, now that we're aware of this issue, it may be possible to tune our reconstruction algorithms to mitigate the effect of the missing hits on performance.

Configuration	Average Angular Deviation
Ideal (no truncation)	0.071º
tapered	0.074º
alternate 28	0.077º
standard	0.092º
restricted	0.144º

References

[1] Atwood, W. B., et al., *The Large Area Telescope on the Fermi Gamma-ray Space Telescope Mission*, ApJ **697**, 1071 (2009), 0902.1089.

[2] Tracy Usher, *Tree-Based Tracking – a global approach to track finding and Gamma-Ray reconstruction in the Fermi LAT*, poster, this symposium.

[3] Luca Baldini originally suggested this idea.