Overview of the Calorimeter Reconstruction for the Fermi LAT

C. Sgrò[1], L. Baldini[1], J. Bregeon[1], and M. Pesce-Rollins[1]
on behalf of the Fermi Large Area Telescope Collaboration
[1]Istituto Nazionale di Fisica Nucleare, sezione di Pisa

Summary: Overview of the calorimeter (CAL) reconstruction in the framework of the "Pass 8" project, aimed at maximizing the science return from the Fermi Large Area Telescope through a radical revision of the event-level analysis.

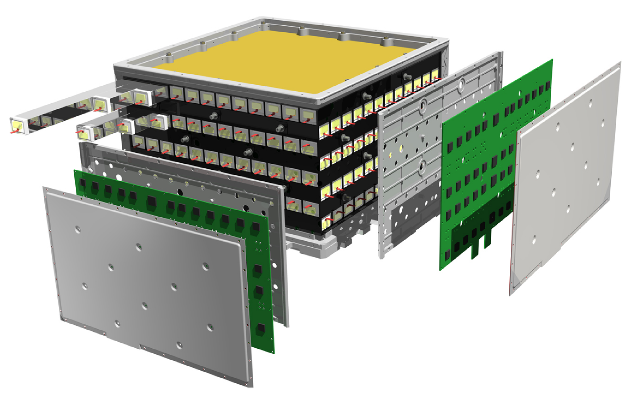
The calorimeter subsystem of the Fermi-LAT instrument provides information about the type, direction and energy of detected particles. The calorimeter portion of "Pass 8", the development version of the LAT event reconstruction and analysis, has been extensively revised from Pass 7, the current production version, which is largely unchanged since launch.
In particular, in order to properly handle the signals from nearly coincident background particles in the calorimeter, we added a clustering stage based on a Minimum Spanning Tree (MST) algorithm. In addition to that, we developed a multivariate classification technique based on a Naive Bayes Classifier (NBC) algorithm, with the aim of making the full topological information from the calorimeter available to the following stages of the event reconstruction. Finally, we improved the accuracy of the calorimeter direction measurement, and recovered for science analysis a substantial fraction of the "CAL-only" events, for which there is no usable tracker information.
Here we present a comprehensive overview of the Pass 8 calorimeter reconstruction, provide a summary of the current performance and discuss the prospects for using the LAT calorimeter as a stand-alone gamma-ray telescope.

The LAT calorimeter

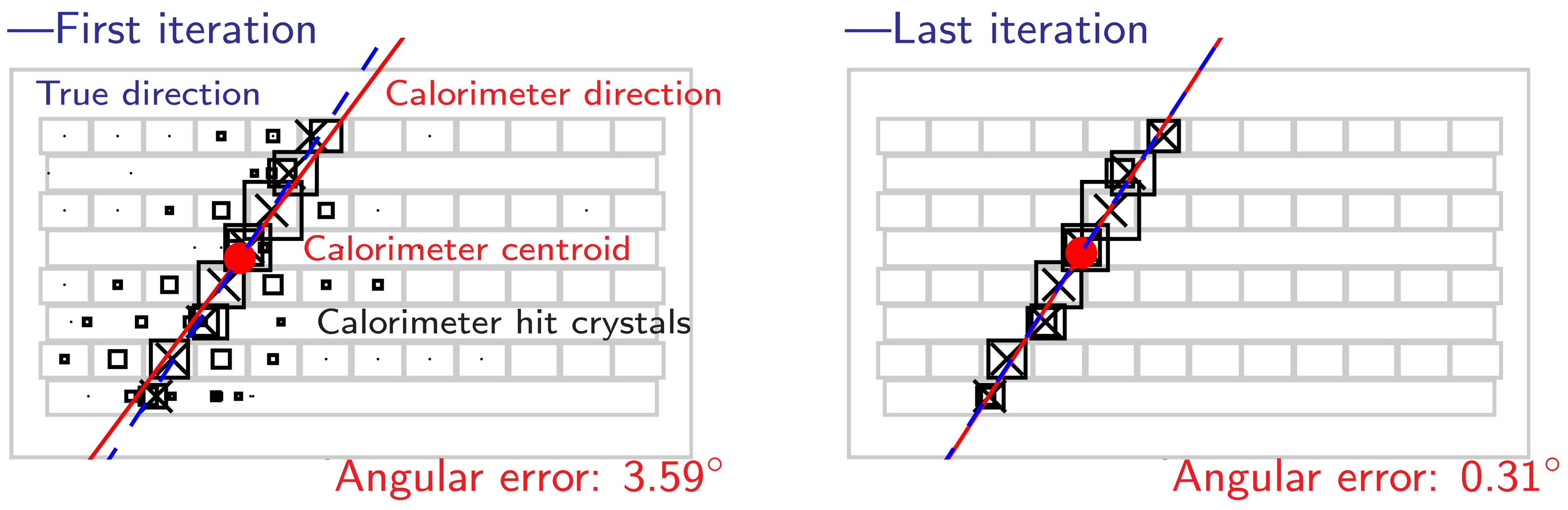
Hodoscopic array of CsI(Tl) crystals readout from both ends providing 3-dimensional hits

- 4×4 arrays of modules
- 8 layers of 12 crystals in each module

See [1, 2] for more information



Calorimeter direction reconstruction



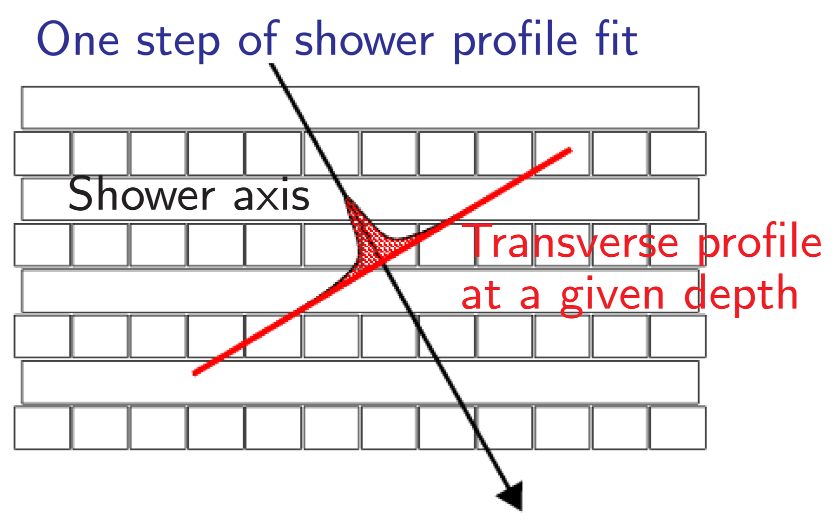
The calorimeter direction is determined through a three-dimensional moments analysis:

- Principal axes of the energy deposit determined by diagonalizing the corresponding inertia tensor
- Iterative process in which the calorimeter hits far from the axis are progressively discarded

Energy reconstruction

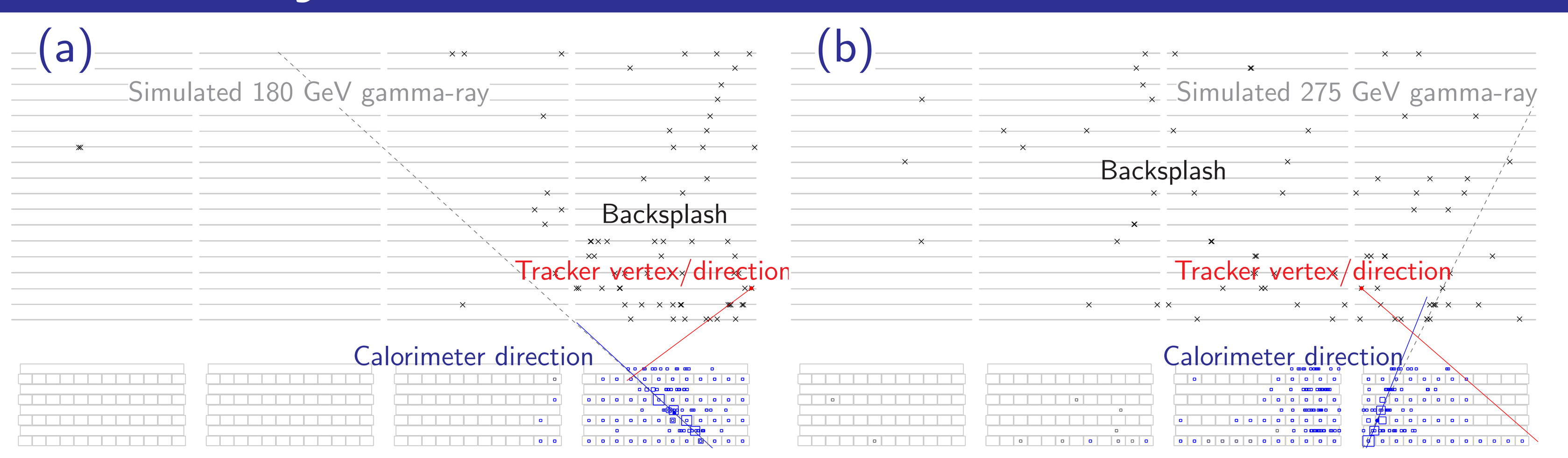
The gamma-ray energy is reconstruced via two different algorithms

- A parametric correction to the calorimeter energy
  - Use energy centroid depth along the showed axis
  - Corrects for energy losses
  - Best at *low energy*
- A shower profile fit
  - Uses a shower axis as reference
  - Full 3D fit of energy deposition
  - Best at *high energy*



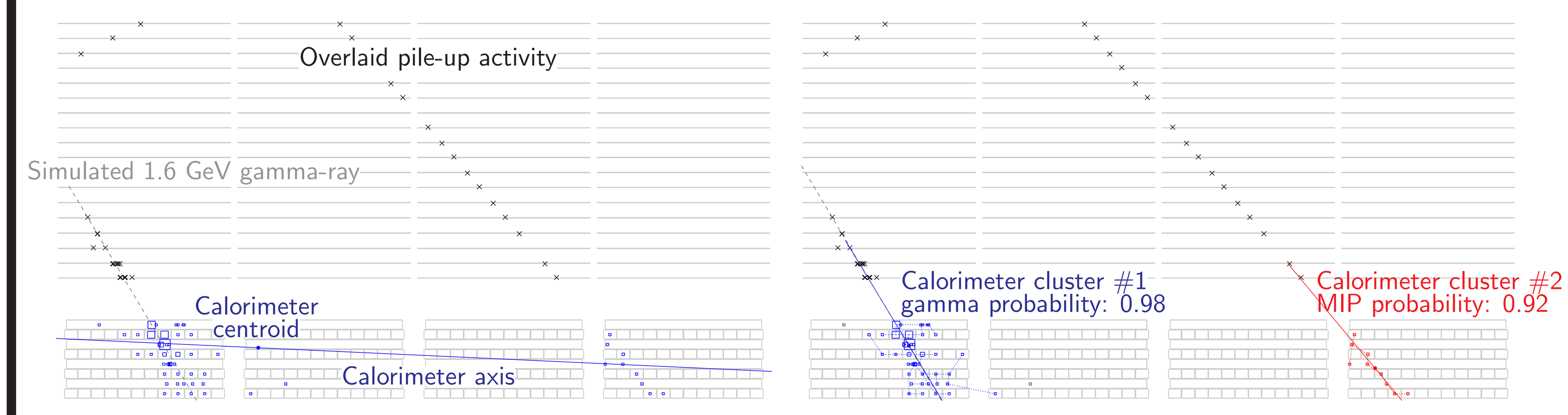
Given a trajectory direction, a model of the shower transverse profile at a given depth is used to compute the fraction of energy deposited in each CAL layer. See [3] for details

CAL-only events



Sample events with no usable tracker direction information: (a) a γ-ray converting in the calorimeter and (b) a γ-ray converting in the tracker being mistracked due to the backsplash. We call events like these "CAL-only".

Calorimeter clustering



Current framework: all hits in CAL are considered part of a single shower

- Background rejection compromised by instrumental pile-up
- No chance to see multi-photon events

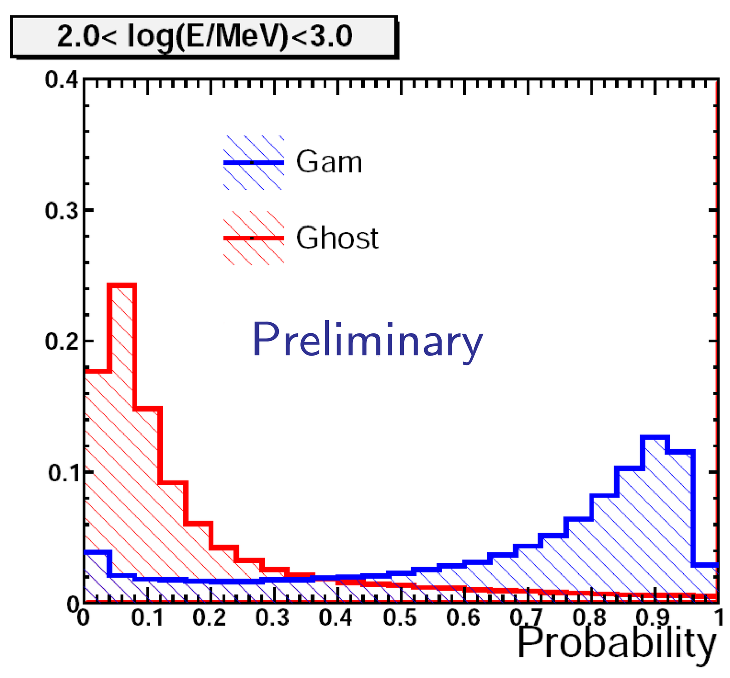
Pass 8: clustering stage added at the beginning of the reconstruction chain

- Separate the pile-up activity from the genuine gamma-ray signal
- Provide topology information to the following reconstruction steps

CAL cluster classification

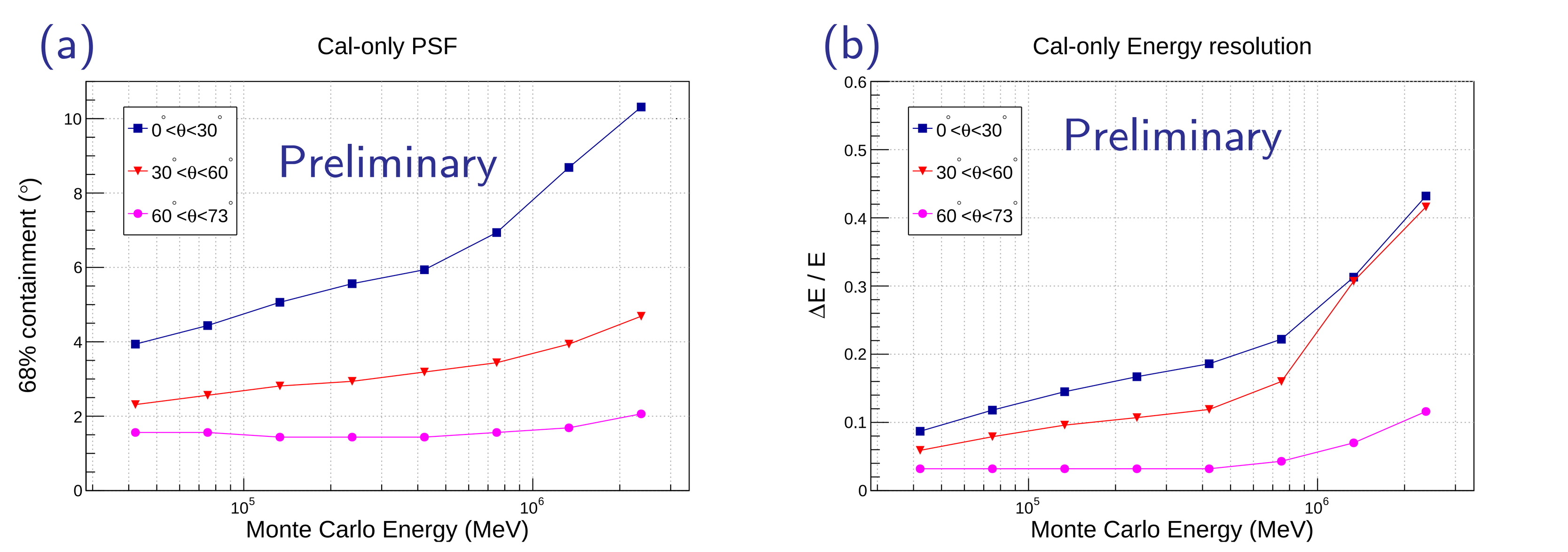
A classification algorithm is applied to identify and separate pile-up activity

- Based on Naive Bayes Classifier
- Uses quantities from clustering and moment analysis stage
- Cluster are classified in 4 classes
  - Gamma-ray
  - Ghost (pile-up activity)
  - Hadron
  - Non-interacting ionizing particle (like MIPs)
- Particularly important at low energy where pile-up events can constitute most of the signal in the CAL



Preliminary tests with flight data indicate that we can resolve and remove a significant fraction of "ghost" clusters

CAL-only performance



The calorimeter axis can be used to estimate the incoming direction of γ-rays and as a reference axis for energy recontruction. The plots shows the performance for a sample of simulated events after CAL-only and minimal event selection: (a) calorimeter pointing resolution and (b) energy resolution (half-width of 68% dispersion containment) using CAL axis.

[1] Atwood, W. B. et al., *The Large Area Telescope on the Fermi Gamma-ray Space Telescope Mission*, ApJ, 697, 1071 (2009)
[2] J. E. Grove and W. N. Johnson, *The calorimeter of the Fermi Large Area Telescope*, Proc. SPIE 7732, 77320J (2010)
[3] Ph. Bruel, *Extending the Fermi energy range above 1 TeV*, Poster at this Symposium