Calorimeter-only analysis of the Fermi Large Area Telescope

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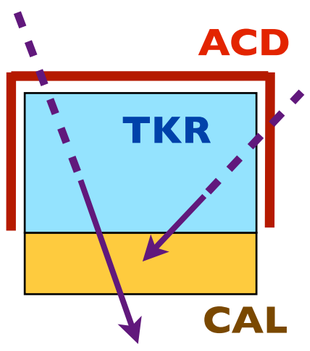
Calorimeter-only analysis provides a new class of events without usable tracker information, which potentially can increase the instrument acceptance above few tens of GeV. Here we explain the concept and report some preliminary characteristics of this novel analysis.

Regular Fermi-LAT analysis

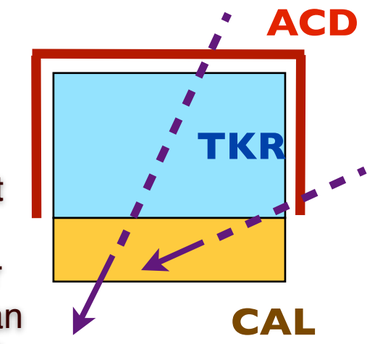
The LAT has three detectors, namely, the Anti-Coincidence Detector (ACD), the Tracker (TKR) and the Calorimeter (CAL). The regular event classes require usable information from the TKR, otherwise, the events are rejected.



Calorimeter-only (CalOnly) Fermi-LAT analysis

The CalOnly adds a new class of events, where events with no usable TKR information can be utilized if sufficient information from the CAL is available. This may occur for events going through the onboard high-pass filter, which have energies larger than 20-30 GeV.

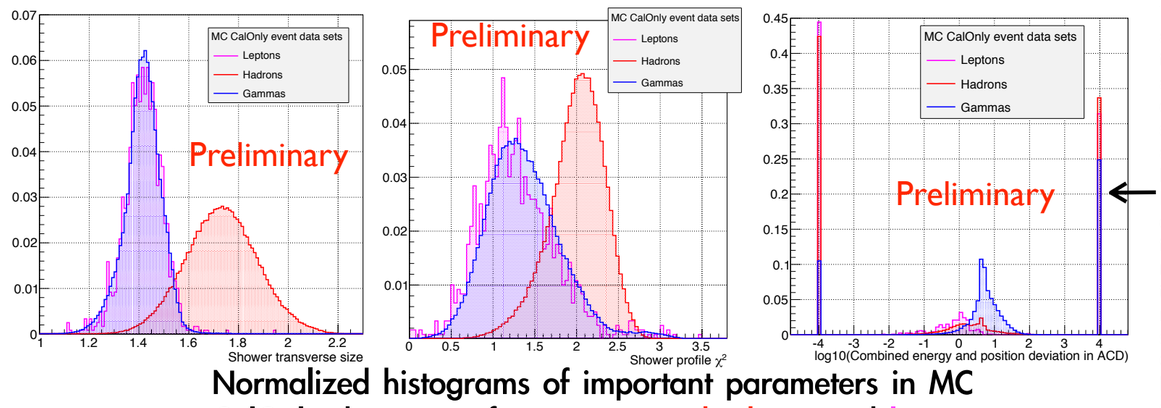
Through the CalOnly analysis one can recover valuable gamma-ray events that are not converted in the TKR. CalOnly events are expected to have a worse signal/background separation and angular resolution with respect to the regular event classes. However, the gamma-rays recovered by the CalOnly analysis can be very valuable above few tens of GeV, where the performance of Fermi-LAT for doing astronomy is photon-statistics limited.



Signal / Background separation

The rejection of the background cosmic-ray events in the CalOnly analysis is based on the different topology of electromagnetic and hadronic showers, and the ACD signals produced by the charged particles.
Pass 8 provides a number improvements with respect to Pass 7, which are crucial for the development of the CalOnly analysis

- CAL cluster analysis
- Improvement in the CAL direction reconstruction
- Improved algorithms for association of tracks and clusters to ACD tiles

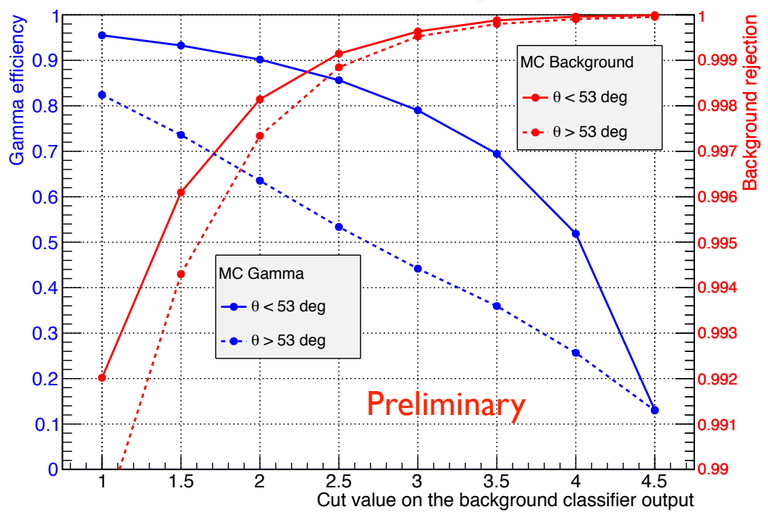


Normalized histograms of important parameters in MC CalOnly data sets of gamma-rays, hadrons and leptons.

The variable "Combined energy and position deviation in ACD" is the number of sigmas less than an expected MIP signal, combined with the number of sigmas the track propagation is away from tile or ribbon most likely to veto the first CAL cluster. If the value of this combined quantity is zero, then the log10 of this quantity is set to -4. This is more likely to happen to MIPs than for gamma-rays. If there are no tracks associated to ACD signals, this quantity is set to +4. Charge particles are likely to have smaller values than the gamma-rays.

Multi-variate analysis

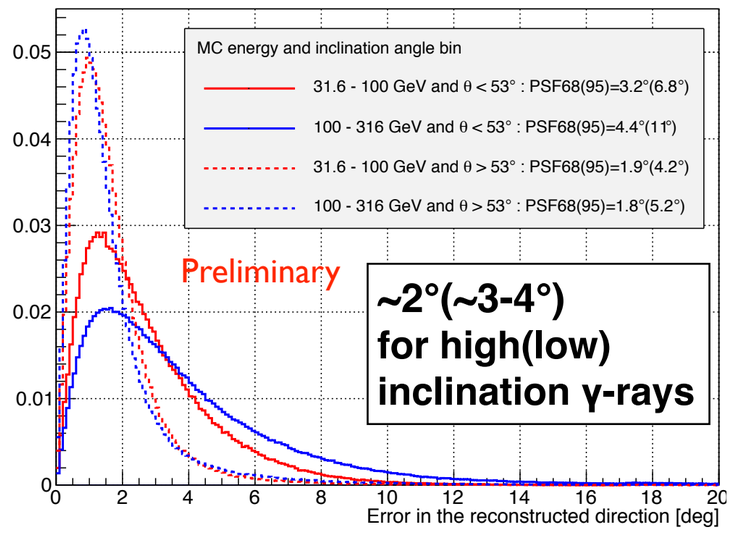
For effective background rejection, we applied **the Boosted Decision Tree**, one of the methods of multi-variate analysis.
In this method, we train many classification trees with Monte Carlo data. Then we make them evaluate gamma-likeness of each event and combine their results. We are using the ROOT-based TMVA package to train the classification tree analysis.



Efficiency of MC gamma events and rejection of MC background events vs. cut value of a classifier output.

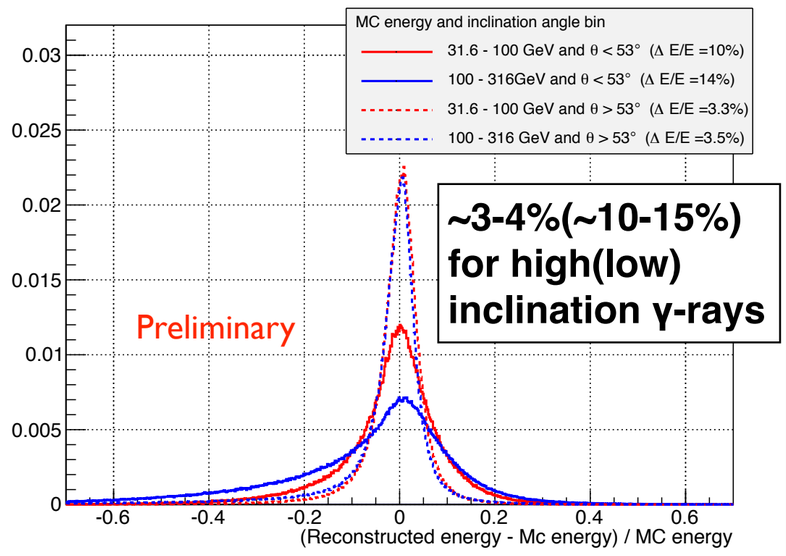
Resolution

Angular resolution



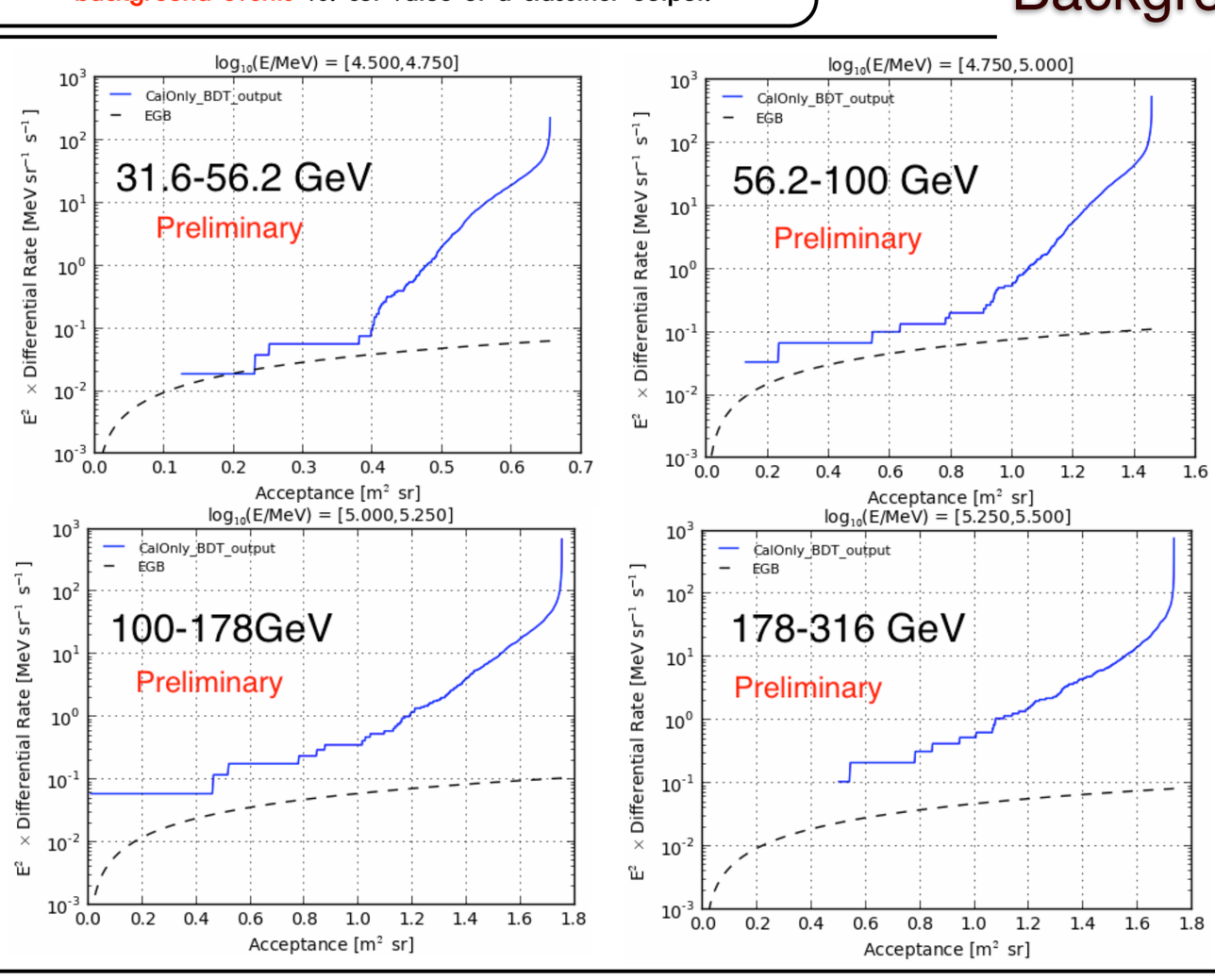
Normalized histograms of the distances between reconstructed and MC direction of CalOnly events in 2 inclination angle x 2 energy bins

Energy resolution



Normalized histograms of the dispersions in the reconstructed energy of MC CalOnly events in 2 inclination angles x 2 energy bins

Background rate vs. acceptance



The blue curves show background rate vs. acceptance of the CalOnly CT output variable in four energy bins (31.6-56.2 GeV, 56.2-100GeV, 100-178GeV, 178-316GeV). The broken curves show the differential rate of the Extragalactic Gamma-ray Background (EGB) which is an irreducible background for Fermi-LAT analysis.

Conclusions

- Pass 8 provides an unprecedented framework to develop an analysis that uses events without usable TKR information. This novel analysis (CalOnly) is currently under development within the Fermi-LAT collaboration.
- The CalOnly analysis could be used to increase the acceptance of Fermi-LAT above few tens of GeV (where the performance is photon statistics limited). Particularly, it may impact the LAT science output in two areas:
  - Search for line-signals potentially coming from Dark Matter annihilation (because of the larger number of events and the excellent energy resolution for the large-incident angle events)
  - Study of transient events like GRBs and AGN flares (because of the larger number of events and the valuable increase in the temporal coverage of the source)