Fermi-LAT measurement of cosmic-ray electron spectrum with Pass 8

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on behalf of the Fermi LAT collaboration

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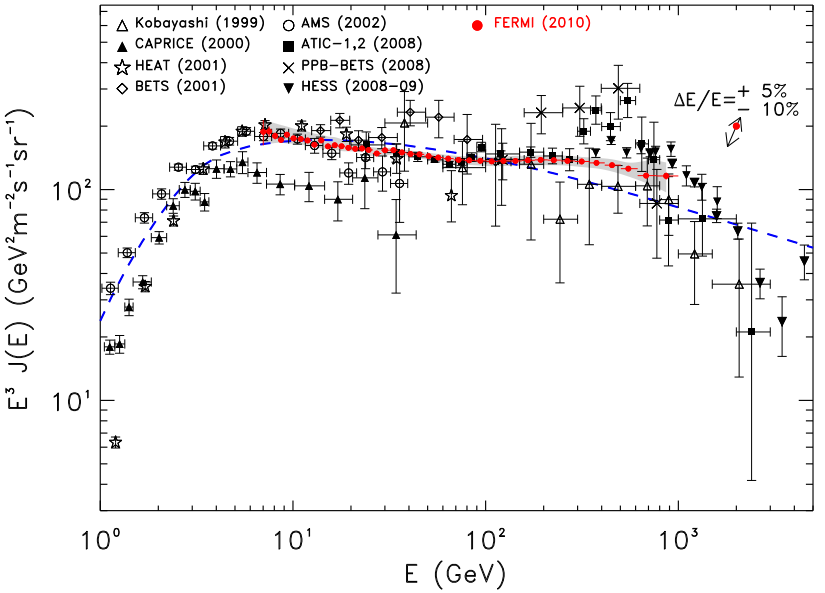
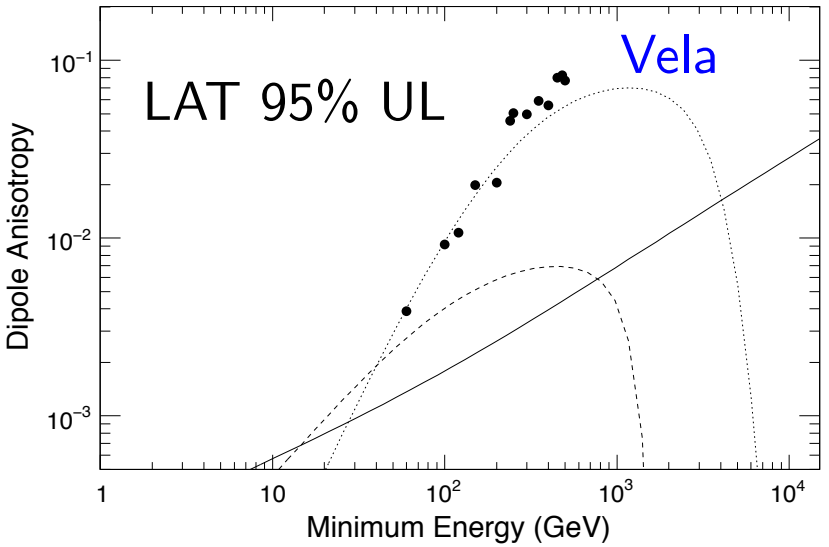
The LAT as electron telescope

- The LAT is designed for E. M. showers
  - Naturally including electrons $(e^+ + e^-)$
  - No direct charge separation
- Triggering on (almost) every particle that crosses the LAT
- Sending to ground all events depositing more than 20 GeV in the CAL
- Electron identification
  - Dedicated event selection
- CRE spectrum and limits on anisotropy already published
- The goal of Pass 8 electron analysis is:
  - Update the results with a superior event level analysis
  - Extend the energy range

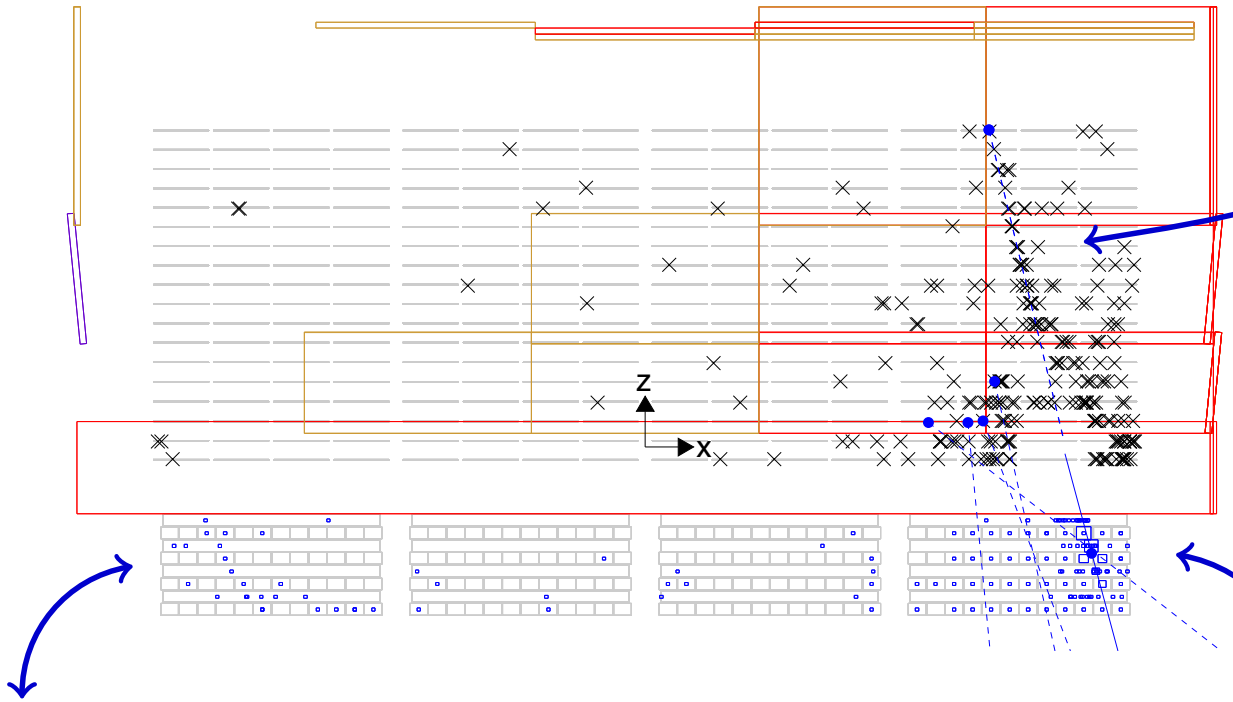




The new event reconstruction package: Pass 8

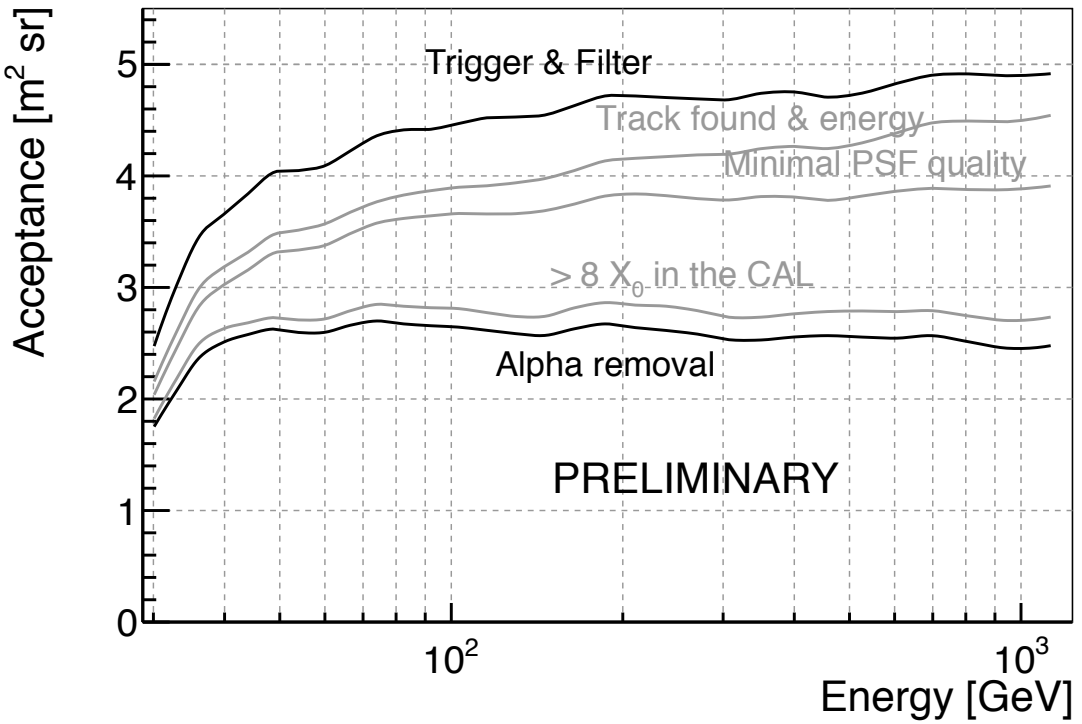
- Pass 8 is a complete rework of the entire event level analysis
  - See Philippe Bruel talk (in session 10B) for details
- Effectively a new instrument, with superior performance

- Tree-based tracking pattern recognition



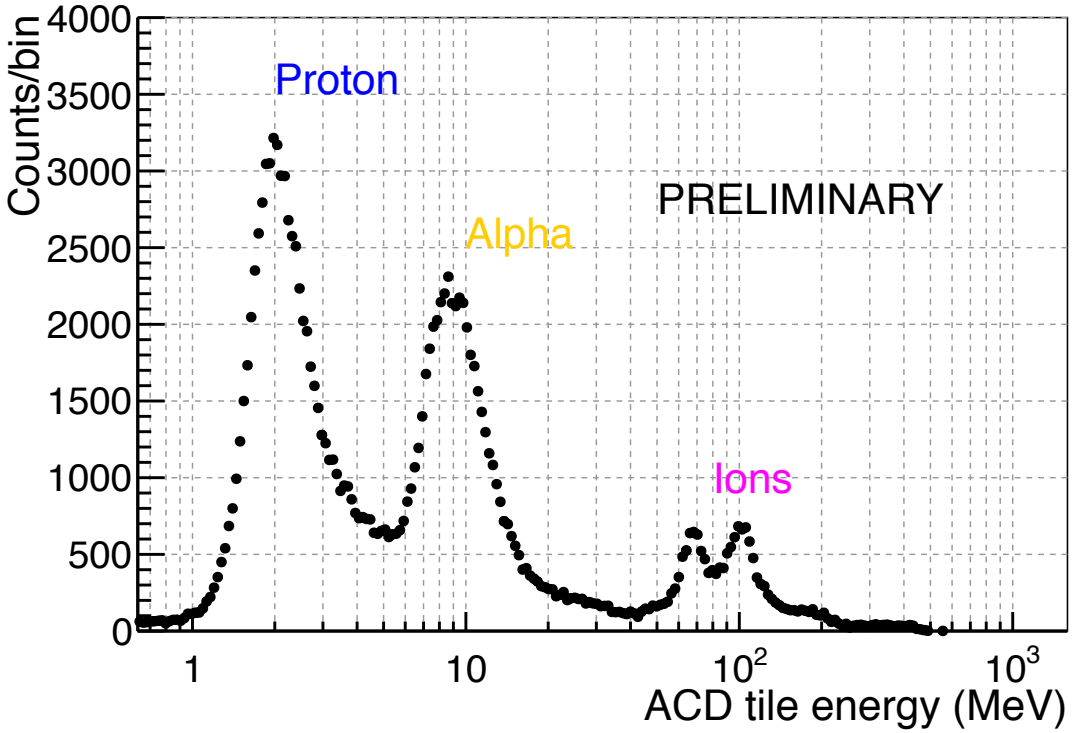
- Calorimeter clustering to handle "ghost" events
- Improved shower profile fit for energy reconstruction

Introduction to the new analysis



- Basic quality cuts:
  - At least a reconstructed track and 5 GeV of energy deposition in the CAL
  - A loose selection on the PSF quality (using the same handle as in γ-ray analysis)
  - At least 8 radiation length in the CAL
- Alpha and heavier particles are removed using simple selections (next slide)
- Field of view is limited to 60°
- Using all runs in survey mode available up to now: $\sim$3.9 year of livetime

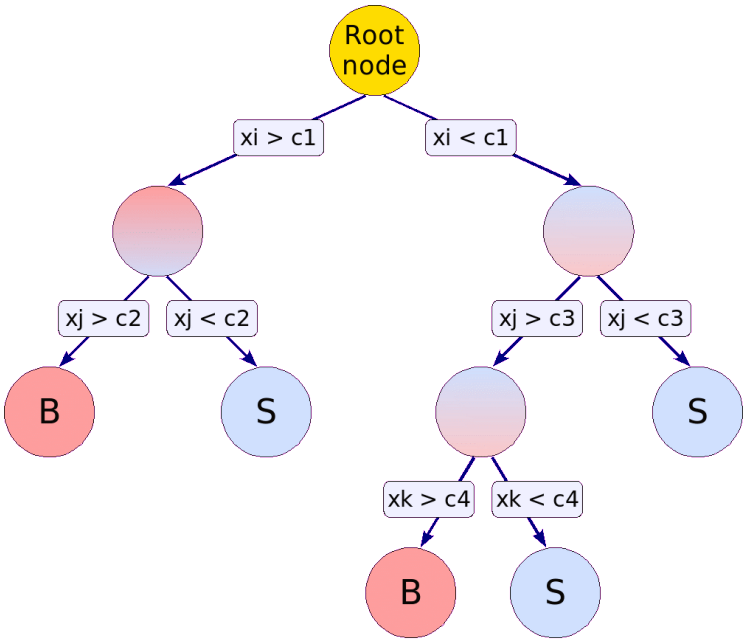
Alpha particle removal



- Alpha and ions are relatively easy to separate using, e.g., the pulse height information in the ACD and the tracker
- Their hadronic interactions are comparatively hard to simulate
- We have a series of simple cuts to bring down the alpha/ion contamination to a negligible level
  - In the following stages of the event selection we are essentially dealing with only two classes of events (electrons and protons)

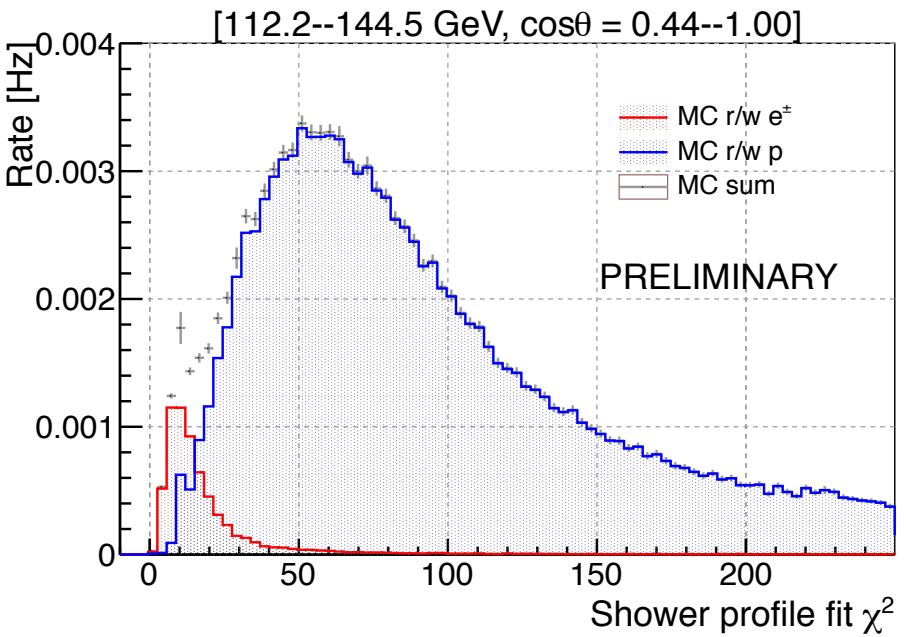
Electron identification: event classification

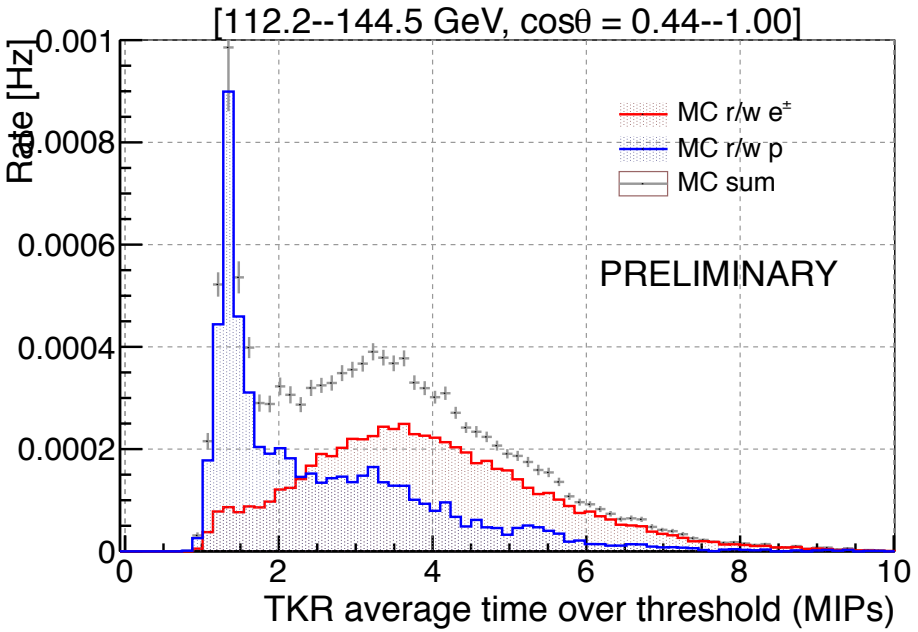
- Take advantage of the experience with γ rays
  - Select $\gamma/e^{\pm}/etc.$ candidate at different background level
  - Assess the quality of the reconstructed direction and energy
- Extensive use of multivariate classification technique
  - Exploiting the TMVA package (`http://tmva.sourceforge.net`)
  - Boosted Decision Trees (BDT) provide the best performance
- Several combination of training setting tested
  - BDT parameters (tree depth, boosting, etc...)
  - Input variables



- Decision Tree:
  - Sequential application of cuts splits the data into nodes, where the final nodes classify an event as Signal or Background
  - Well known in "data mining", becoming popular in Physics

Relevant quantities in the subsystems

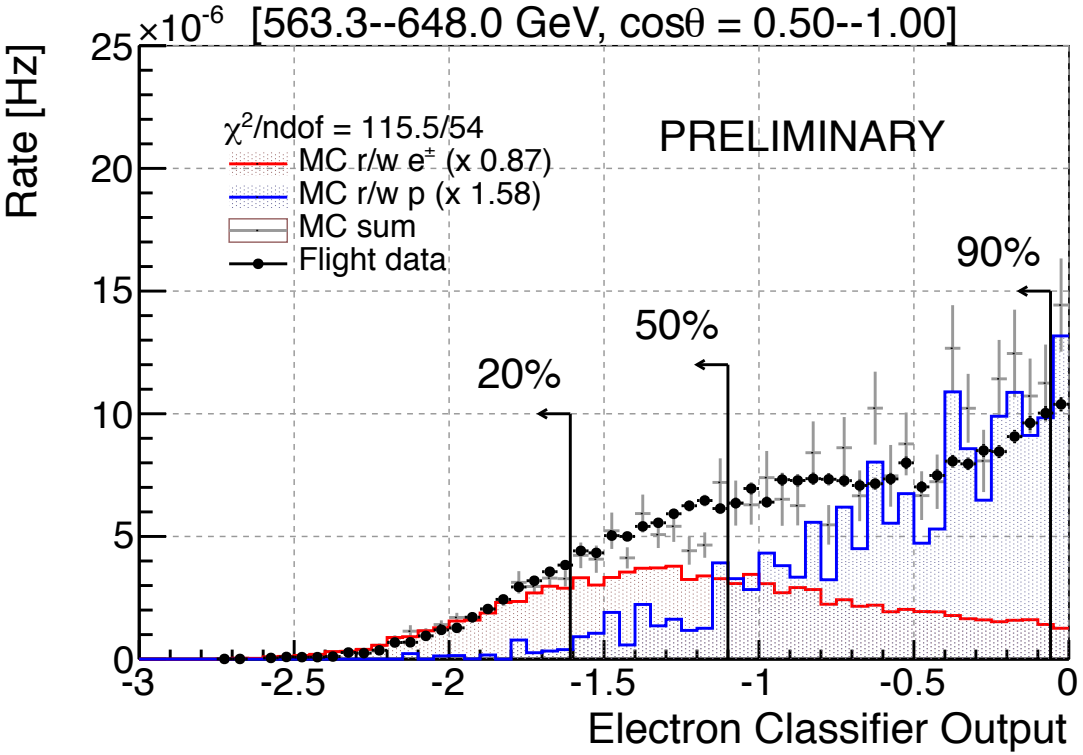




- Shower transverse size
- Shower profile fit χ^2
- ...

- Time Over Threshold: energy deposition in the TKR
- Extra hits around the main track
- ...

Output of the classifier

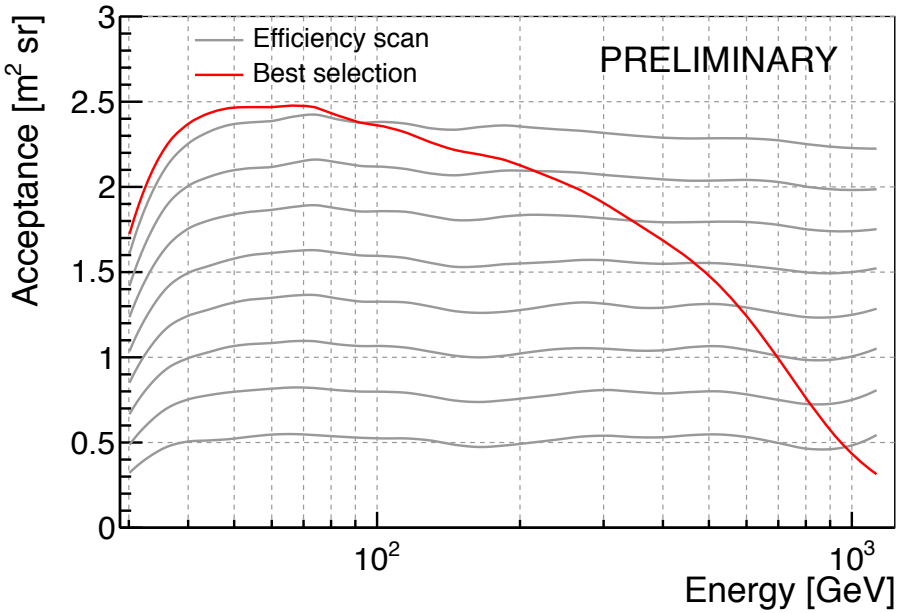


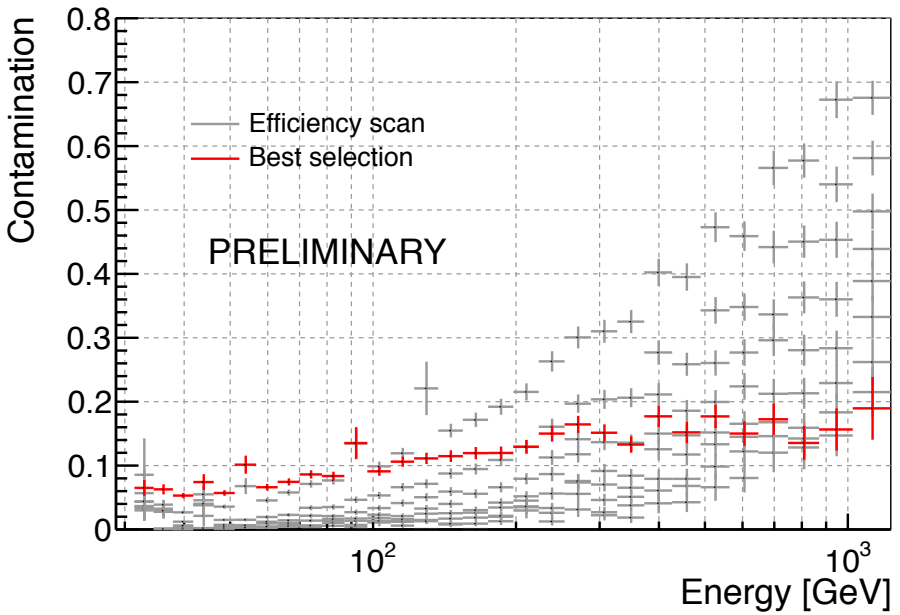
- Example of one of the BDT we are using
- Others classifier configurations under evaluation, with same procedure

- Compared with flight data
  - Testing the data-MC agreement
  - Using MC with a realistic energy spectrum
    - Fitting only normalization
  - Estimating signal directly from the fit
  - Estimating the residual background correction

- Event selection done with a cut on this quantity
  - Scanning several efficiency level
  - Testing stability of the spectrum
  - Residual contamination corrected with fit result

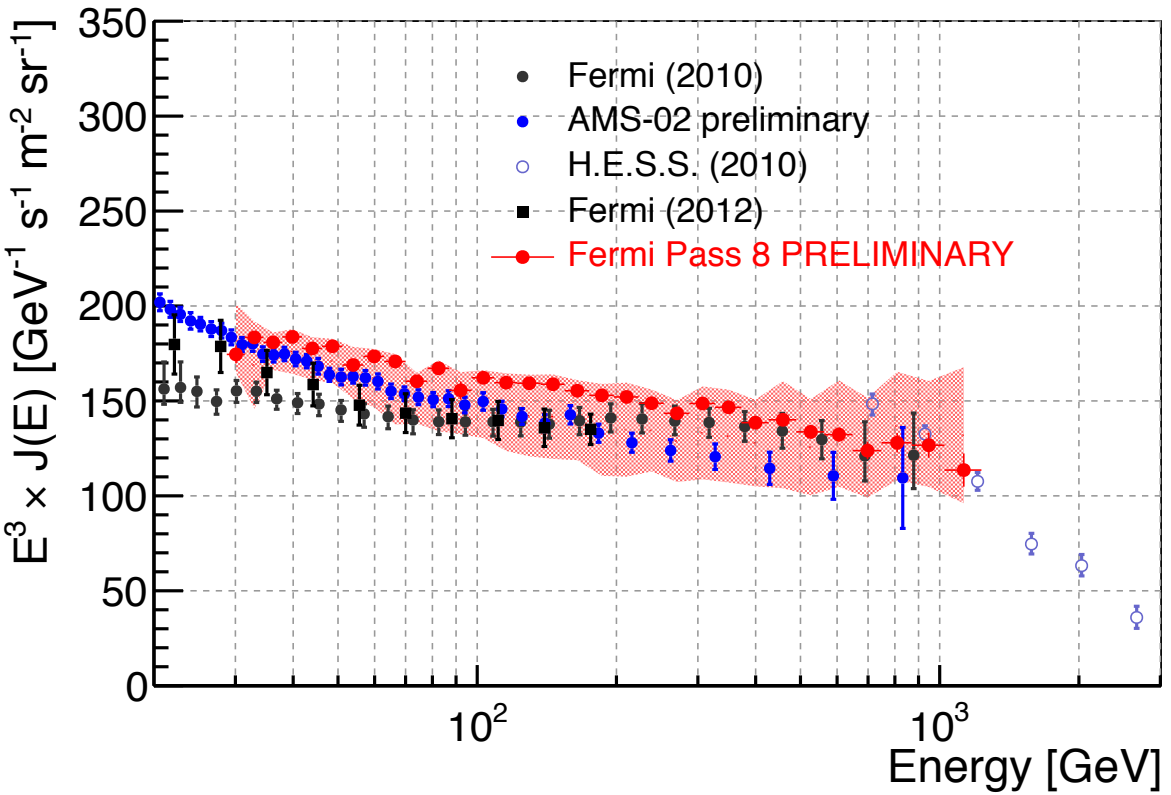
Instrument response





- Testing the stability of the spectrum in this very wide range
  - Spectrum variation likely relate to data-MC disagreement
- Form 90% to 20%, (almost) energy-independent
  - Maybe a too wide...
- Average acceptance (after cuts) for this scan shown on the left
- "Best" cut can be evaluated using the MC-based ROC, as the point in which the slope goes above a defined threshold
- Bottom plot shows the corresponding residual contamination
  - Can be very large at high energy

Preliminary $e^+ + e^-$ spectrum



- Shaded region includes the maximum variation of the spectrum in the efficiency scan
- Central points from the "best" cut
- Result from template fit within uncertainties

- Effect of absolute energy scale uncertainty not included in the plot
- We have evidence that at least a significant part of the difference with our 2010 result is due to "ghost" signal
  - This was not taken into account in the acceptance in our first analysis
  - Subsequent studies (e.g. the control region in the positron analysis) suggest an overestimation of acceptance by 10–15% at ~ 10 GeV
  - Pass 8 is designed to be insensitive to "ghost"

Conclusions

- A new measurement of the $e^+ + e^-$ spectrum with ~ 6 years of data and extending to 1.2 TeV is presented
- The new Pass 8 event reconstruction and selection performs very well
  - Better rejection power than the previous analysis
  - No sign of dependence from "ghost" signal
- Pass 8 is still young also for electron analyses
  - Results are preliminary
  - Working on improvements for energy extension, angle-resolved analyses, reduced systematics