Pass 8 Overview

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on behalf of LAT collaboration

Overview

- Introduction
- Event reconstruction
- Data/simulation agreement
- Event selection
- Performance
- Validation

What does Pass mean?

- Each pass corresponds to a version of the Fermi LAT data
- It implies a whole package:
  - Intrument simulation
  - Reconstruction code
  - Event selection
  - Instrument Response Functions (IRFs)
  - Systematic uncertainties
  - Isotropic template (which includes the cosmic-ray residual background)
  - And sometimes more (Galactic diffuse model, Earth limb template, Sun+Moon template)
- It’s only when we have validated the whole package that we can release it to the public.

From Pass 6 to Pass 8

- Pass 6 (launch time)
  - Pass 6 reconstruction
  - Pass 6 selection
  - Based on pre-launch instrument simulation
  - First data revealed the issue of out-of-time pile-up (aka ghosts)
  - New: instrument simulation with ghosts -> correct IRFs

- Pass 7
  - Pass 6 reconstruction
  - New: Pass 7 selection optimized with simulations with ghosts

- Pass 8
  - New: improved instrument simulation
  - New: Pass 8 reconstruction, as ghost-proof as possible
  - New: Pass 8 selection

Pass 8 improvements

- Ghost handling
  - Tracker: ignoring ghost hits
  - ACD: partial deghosting
  - Calorimeter: clustering and cluster classification

- Improved direction measurement
  - Tree-based track finder

- Improved energy measurement
  - Extension of the energy range: from ~10 MeV to ~3 TeV

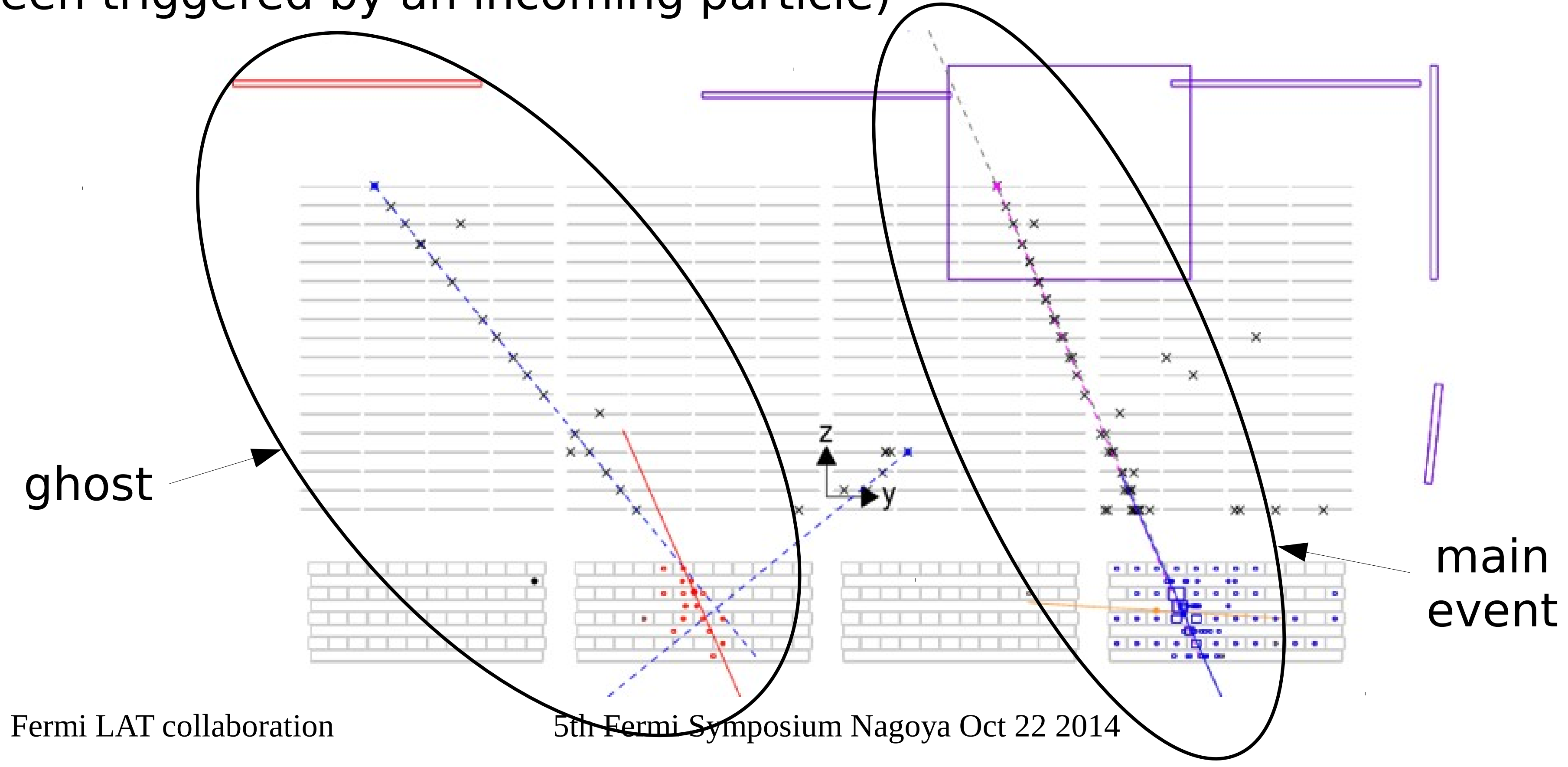
- Improved track/ACD matching information
  - Using the uncertainty of the tracker direction

- Improved event selection
  - Using the ROOT TMVA package (tmva.sourceforge.net)

- Additional sub-classes of events

Out-of-time pile-up

- The slow signal characteristic time is: ACD=4μs, CAL=3.5μs, Tkr=10μs
- The cosmic-ray rate up to 10kHz induces signals from out-of-time particles (aka ghosts)
- This is taken into account in the simulation by overlaying on each simulated event a on-orbit periodic trigger (2Hz) event (event that has not been triggered by an incoming particle)

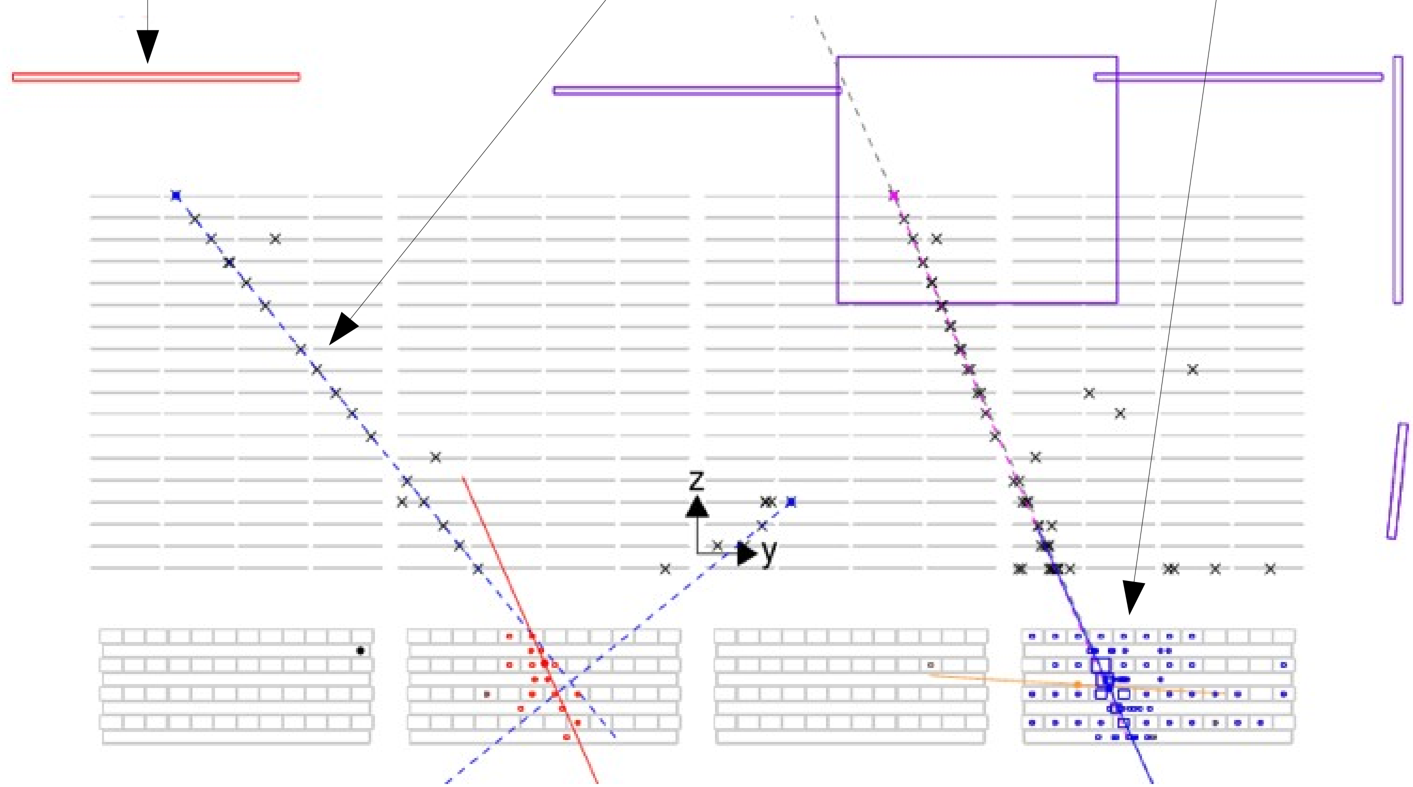


De-ghosting

ACD
Remove tiles with no trigger veto (based on fast signal) but with a signal that should have fired the veto

Tracker
Remove hits from time-over-threshold information

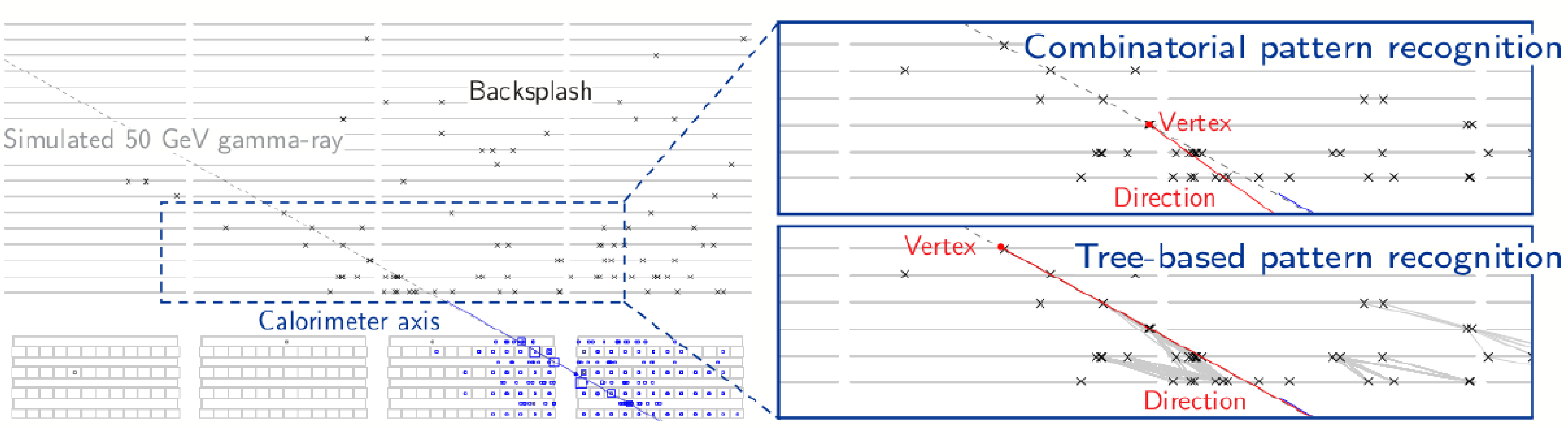
Calorimeter
Perform clustering and cluster classification and keep the most gamma-like



Tracking

- Pass 7: track-by-track combinatorial pattern recognition
  - Returns the optimum trajectory for each track
  - Need a good seed: strong dependence on the CAL
  - Track confusion and errors in high-multiplicity events

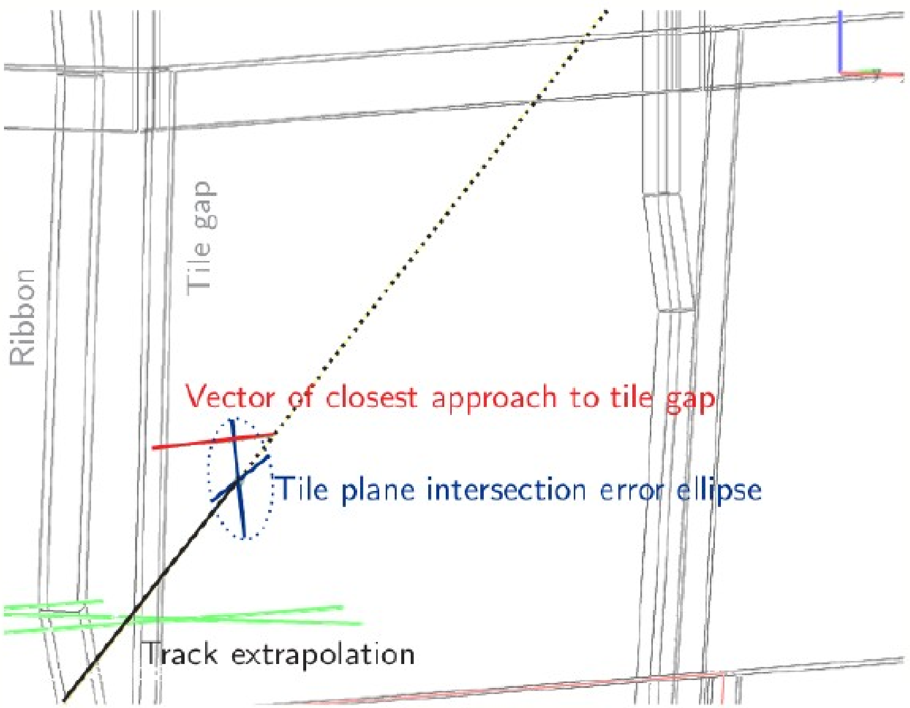
- Pass 8: global tree-based approach to track finding
  - Reduce mistracking, improve the high energy PSF
  - Provide additional information for background rejection
  - No dependence on CAL



ACD

• The ACD is responsible for providing 0.9997% rejection power for charged particle entering the top or sides of the LAT
• It must avoid self-vetoes from backsplash of high energy gamma rays.

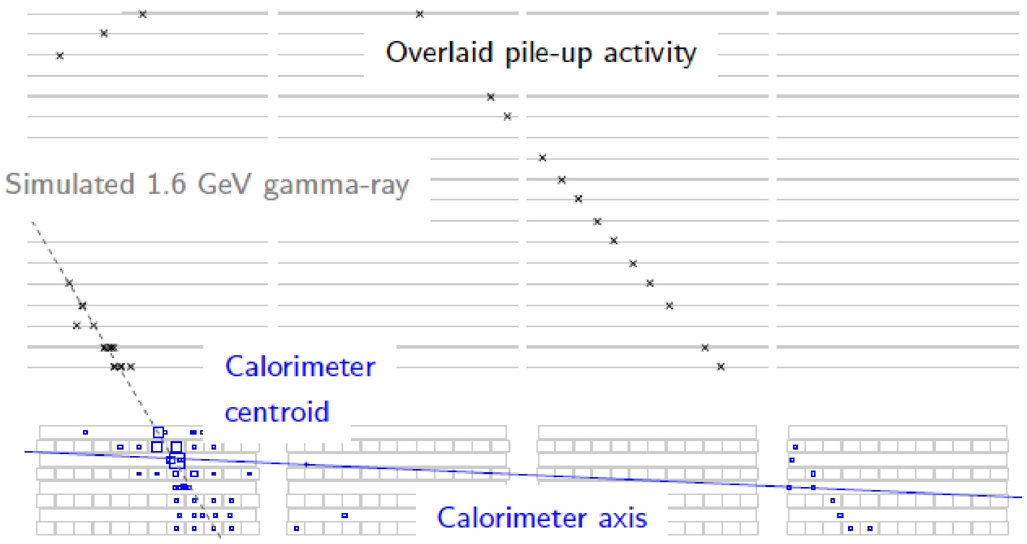
• Pass 8: track and ACD tile association based on track covariant error propagation to the tiles

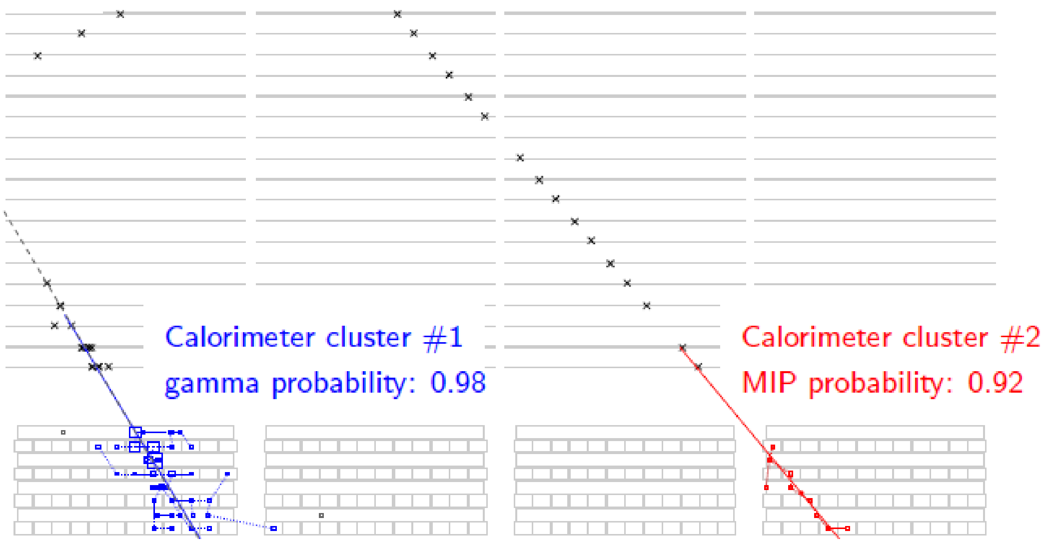


Calorimeter clustering

- Pass 7 reconstruction assumes only one particle
  - All crystals grouped in one cluster
  - Small energy deposit by ghosts can have a large impact on cluster direction and transverse size.

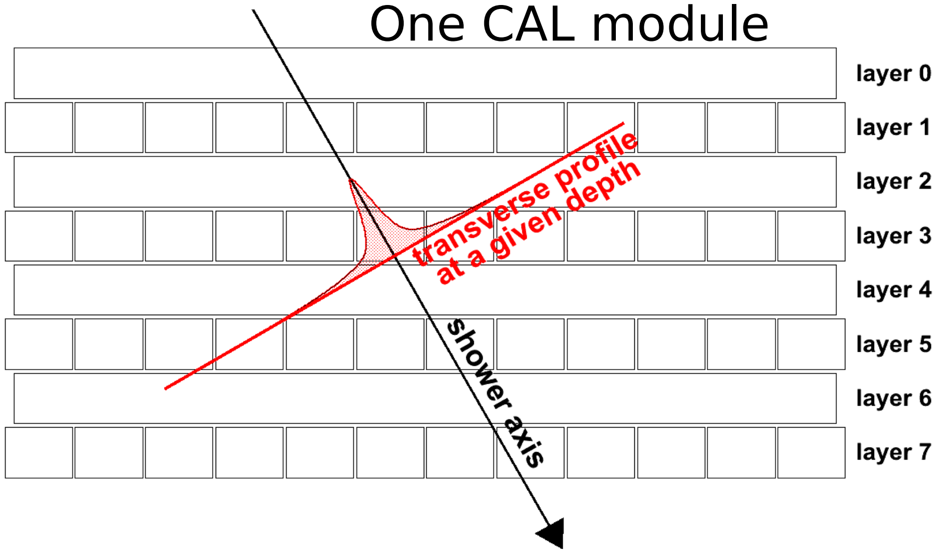
- Pass 8 starts by performing a clustering, optimized such that:
  - A gamma-ray event is not split
  - Ghosts are found as near as possible to the main event cluster
  - Hadronic showers are not subdivided in too many clusters (in order not to decrease rejection power)

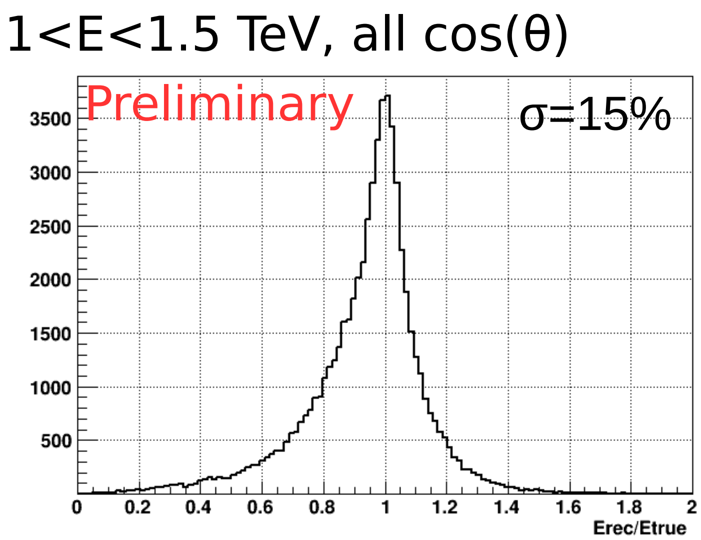




Energy reconstruction

- Pass 8 increases the LAT energy range:
  - Down to E<50 MeV, by reconstructing events that do not reach the calorimeter. For these events the energy measurement is solely based on the number of hits in the tracker.
  - Up to several TeV, by improving the shower profile fit:
    - New parameterization of shower development parameters as a function of energy up to 10 TeV thanks to dedicated simulations
    - Phenomenological model of energy losses in gaps between towers
    - Crystal saturation handling thanks to a full 3D shower modeling





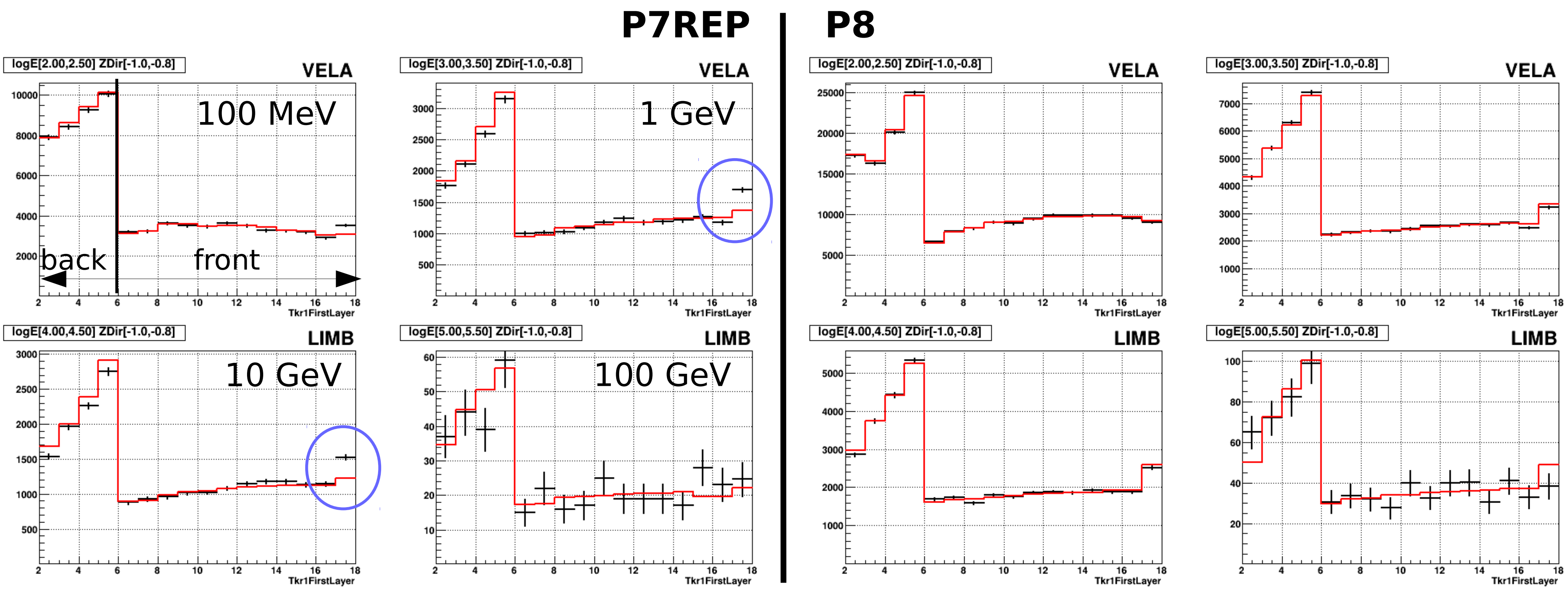
Data/simulation agreement

- The development of Pass 8 has been an opportunity to improve the data/simulation agreement.
- The goal is:
  - to have reliable variables that we can use for background rejection and quality subclasses selection
  - to minimize the systematics uncertainties on the effective area
- In Pass 7, we had to apply an ad hoc correction based on data/simulation comparison:
  - Effective area correction in order to get a correct Front/Back ratio at low energy (energy dependent correction)
  - In-flight PSF correction (the high energy prediction by the simulation was too small)
- Thanks to the improvement of the data/simulation agreement, there is no need of such ad-hoc corrections in Pass 8.

- The data/simulation comparison is performed using:
  - The Vela pulsar
  - The 30 brightest AGN
  - The Earth limb

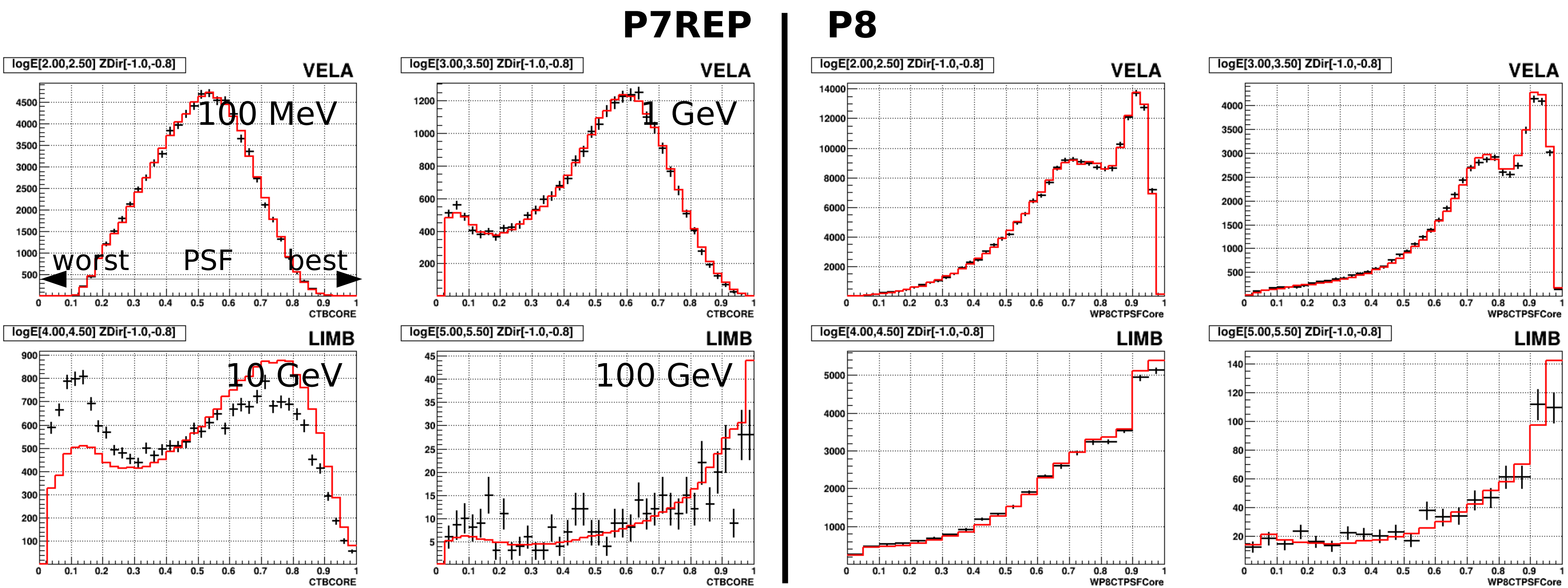
Conversion point

• The instrument simulation under-predicted the fraction of events converting in the first TKR plane. It implied that the amount of passive material between the ACD and TKR was slightly under-estimated.
• We added to the simulation instrument model the amount of passive material (<1% X0) that gave the best data/simulation agreement.



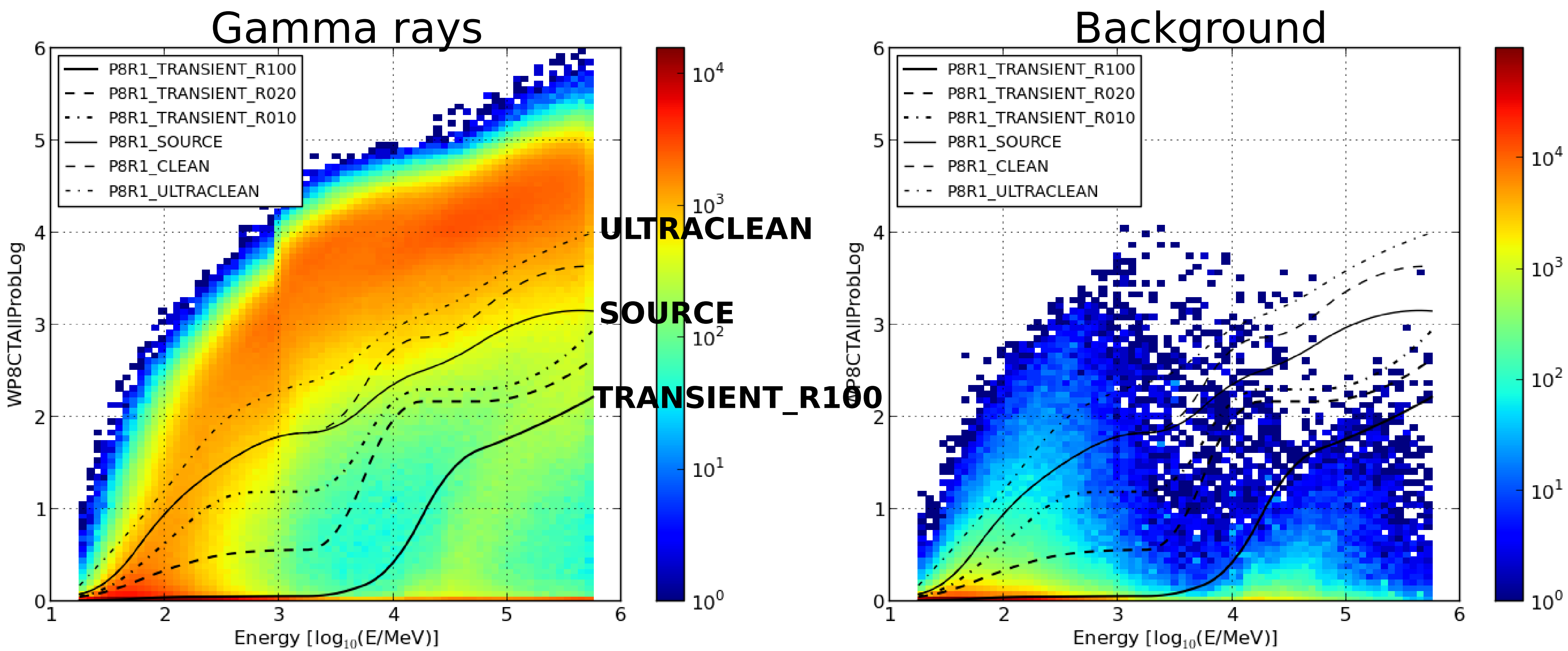
PSF at high energy

- The PSF is very sensitive to the alignment of the planes in the tracker towers. The mis-alignments are corrected thanks to an alignment calibration derived from flight data.
- Using slightly different (within measurement uncertainties) alignment calibrations during simulation and reconstruction allowed us to predict correctly the PSF at high energy



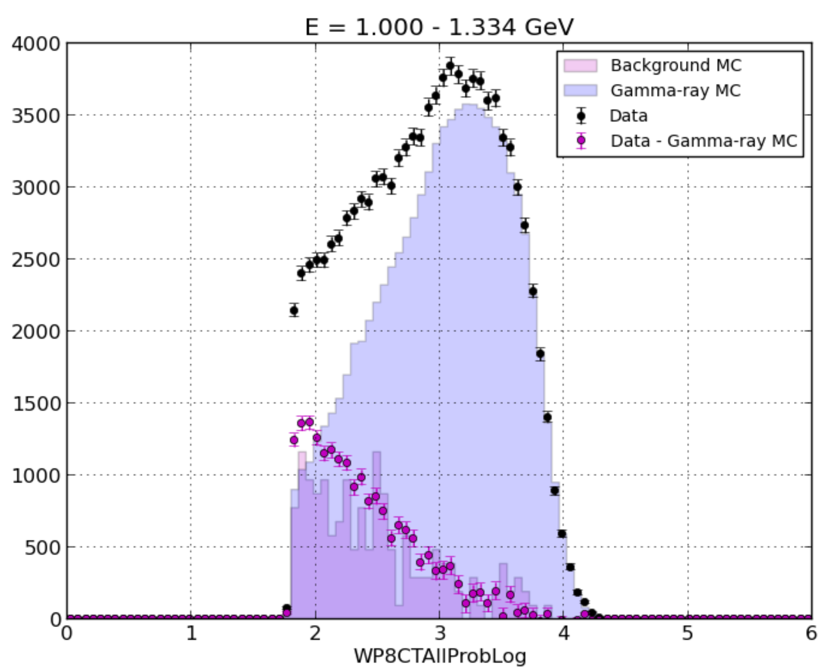
Selection optimization (1)

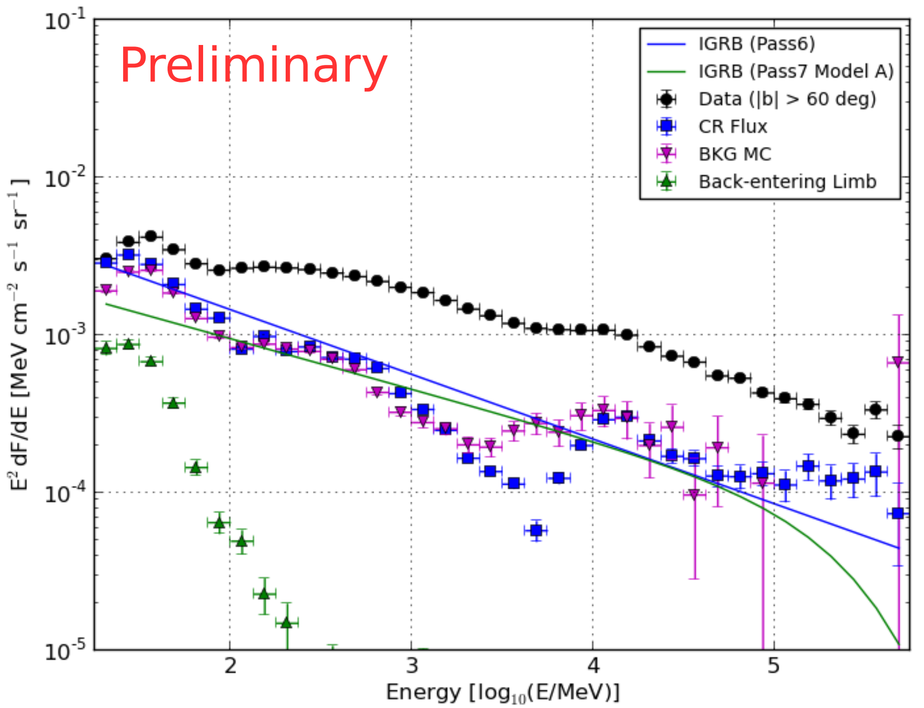
- The event selection is performed thanks to multivariate classification technique (using the TMVA package and Boosted Decision Trees)
- This technique outputs a variable that is used to define the selection cuts
- The power of this technique depends a lot on the data/simulation agreement



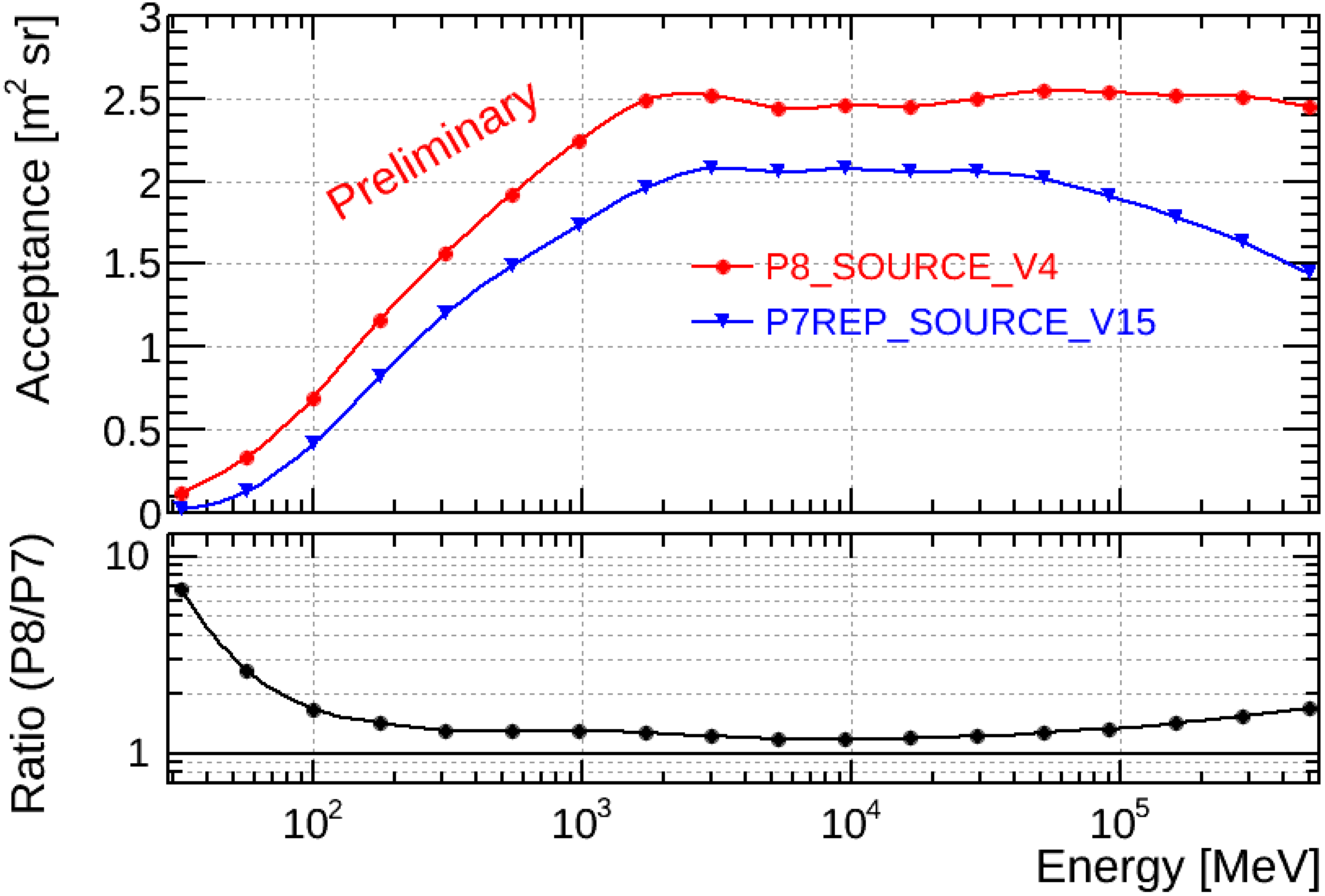
Selection optimization (2)

- We use the simulation to produce templates for gammas and background
- These templates are used to derive the background contamination in high-latitude data
- The selection cuts are chosen such that the residual background contamination is a given fraction of the EGB (~60% for the SOURCE class) while keeping a smooth effective area as a function of energy
- In Pass 8, we also developed a CT variable to reject back-entering photons

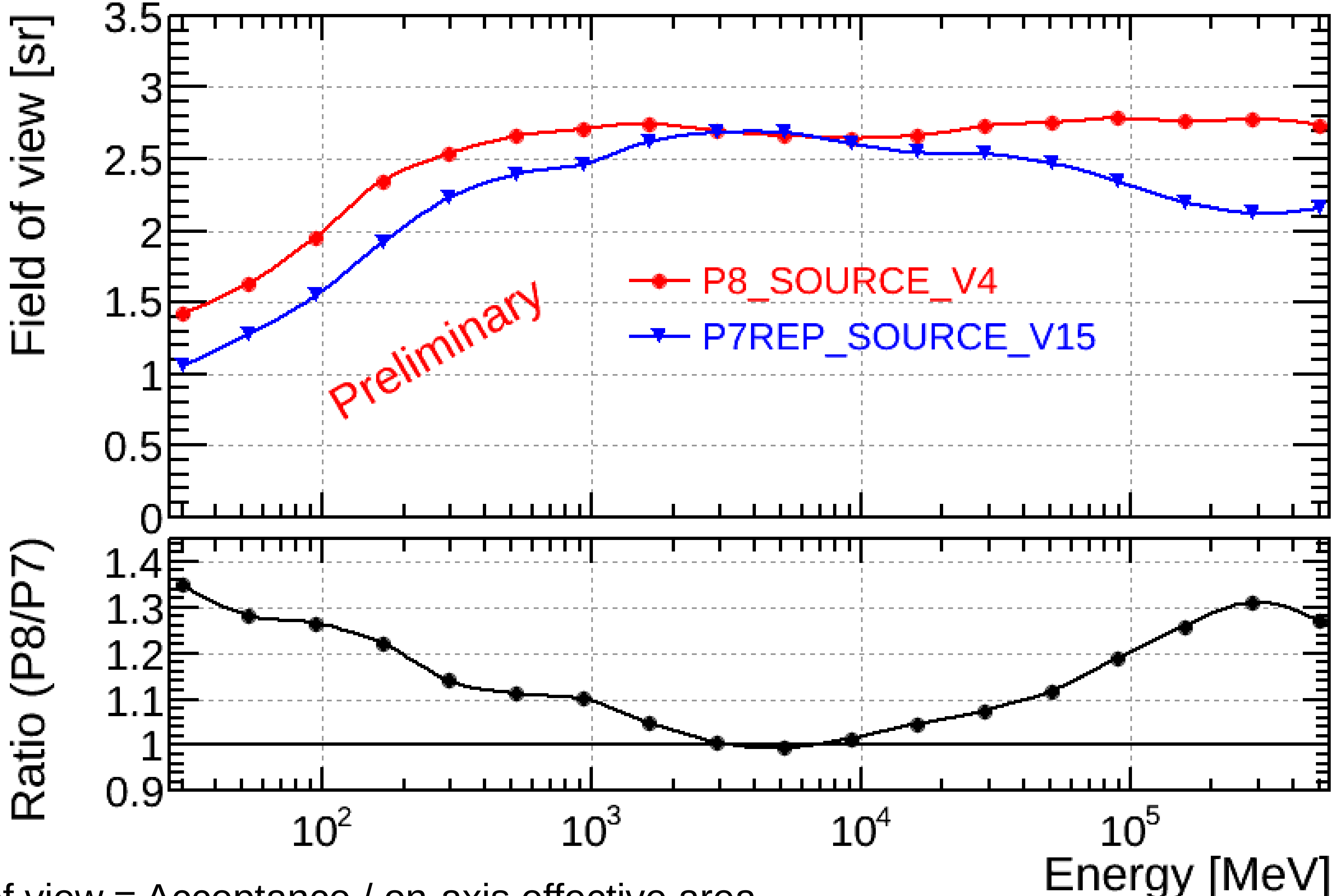




SOURCE class acceptance

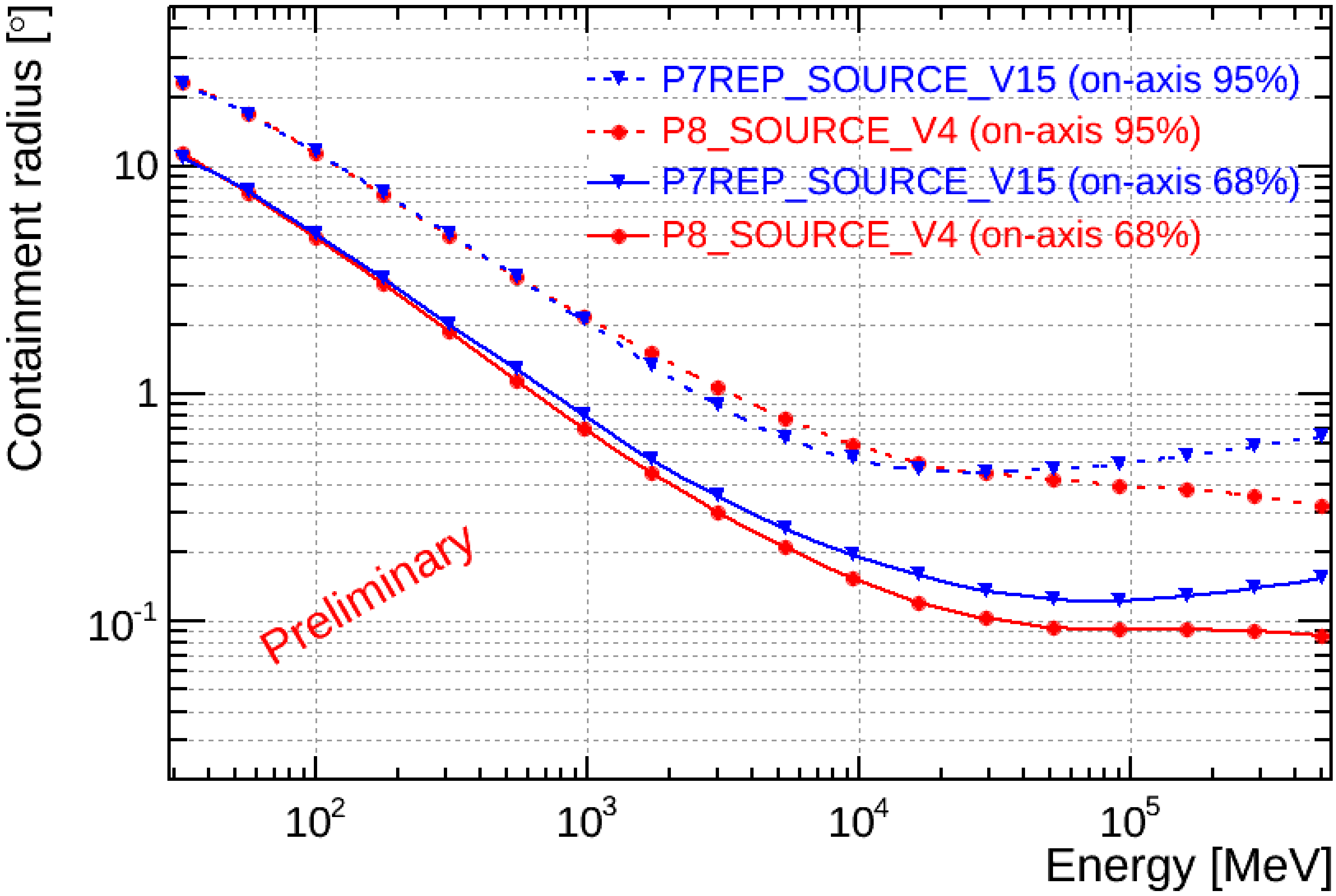


Field of view

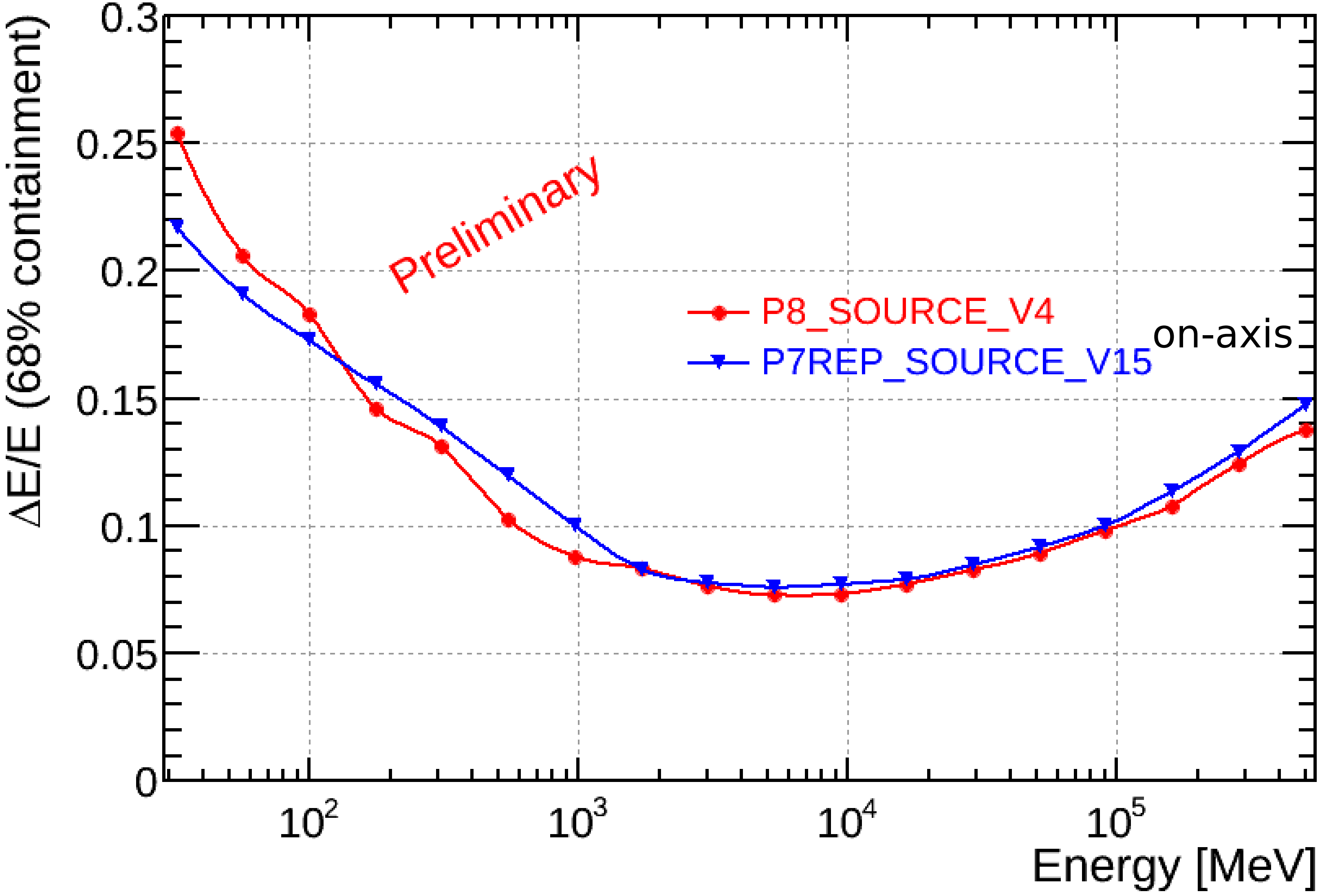


Field of view = Acceptance / on-axis effective area

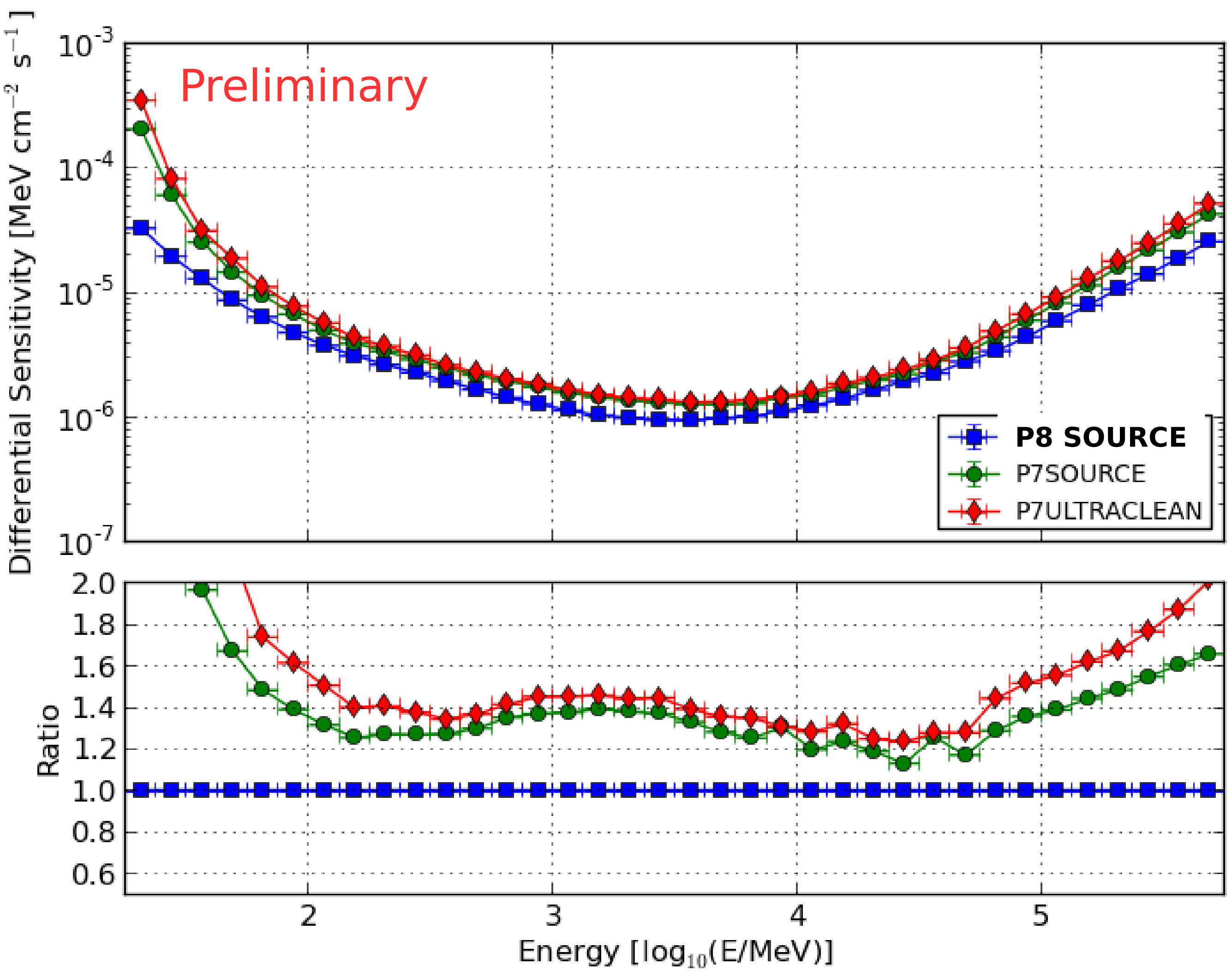
PSF


P7REP_SOURCE_V15 (on-axis 95%)
P8_SOURCE_V4 (on-axis 95%)
P7REP_SOURCE_V15 (on-axis 68%)
P8_SOURCE_V4 (on-axis 68%)
Preliminary
Containment radius [°]
10
1
10^{-1}
10^2
10^3
10^4
10^5
Energy [MeV]

Energy resolution

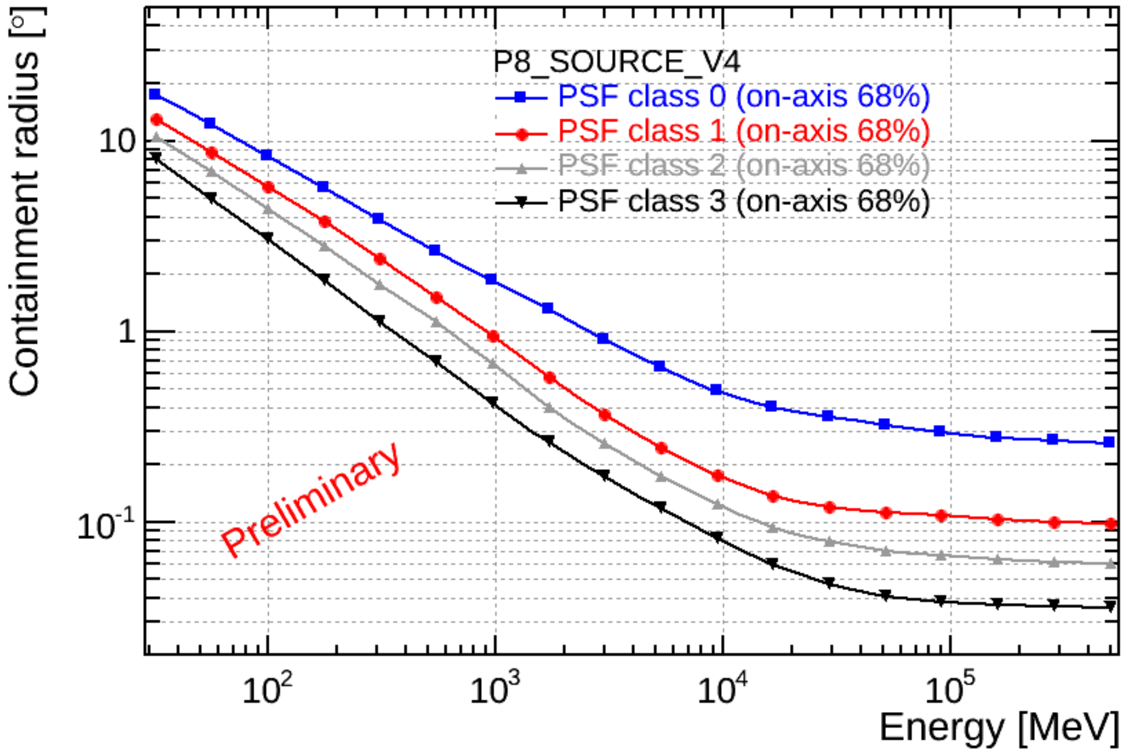


Source sensitivity



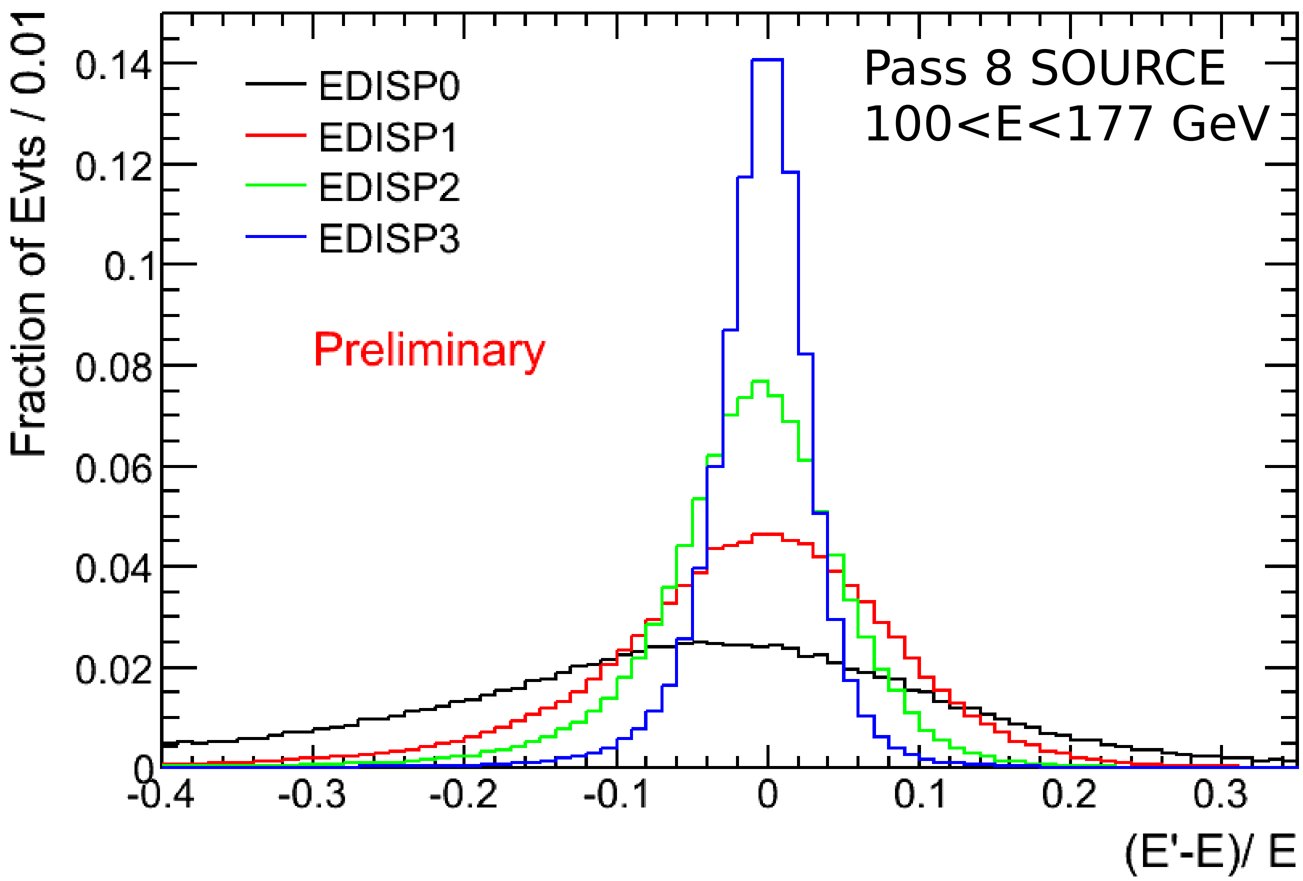
PSF event types

- Split the data in 4 event types:
  - with increasing quality of the PSF
  - with equal acceptance
- The optimal is to use the event types in a joint likelihood analysis (5-10% gain in sensitivity)
- Using >4 event types does not improve the sensitivity.



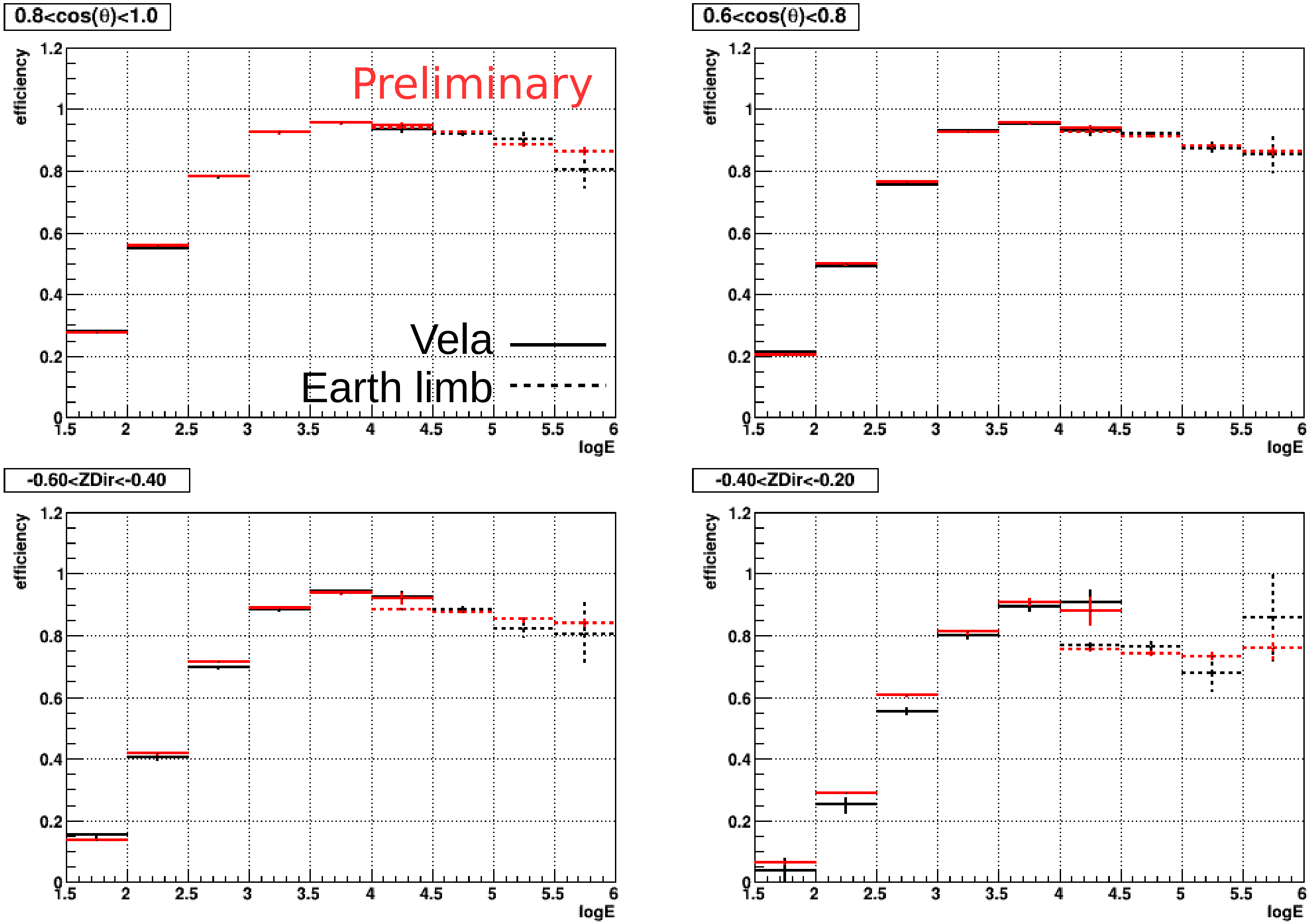
Energy disp. event types

- Split the data in 4 event types:
  - with increasing quality of the energy resolution
  - with equal acceptance



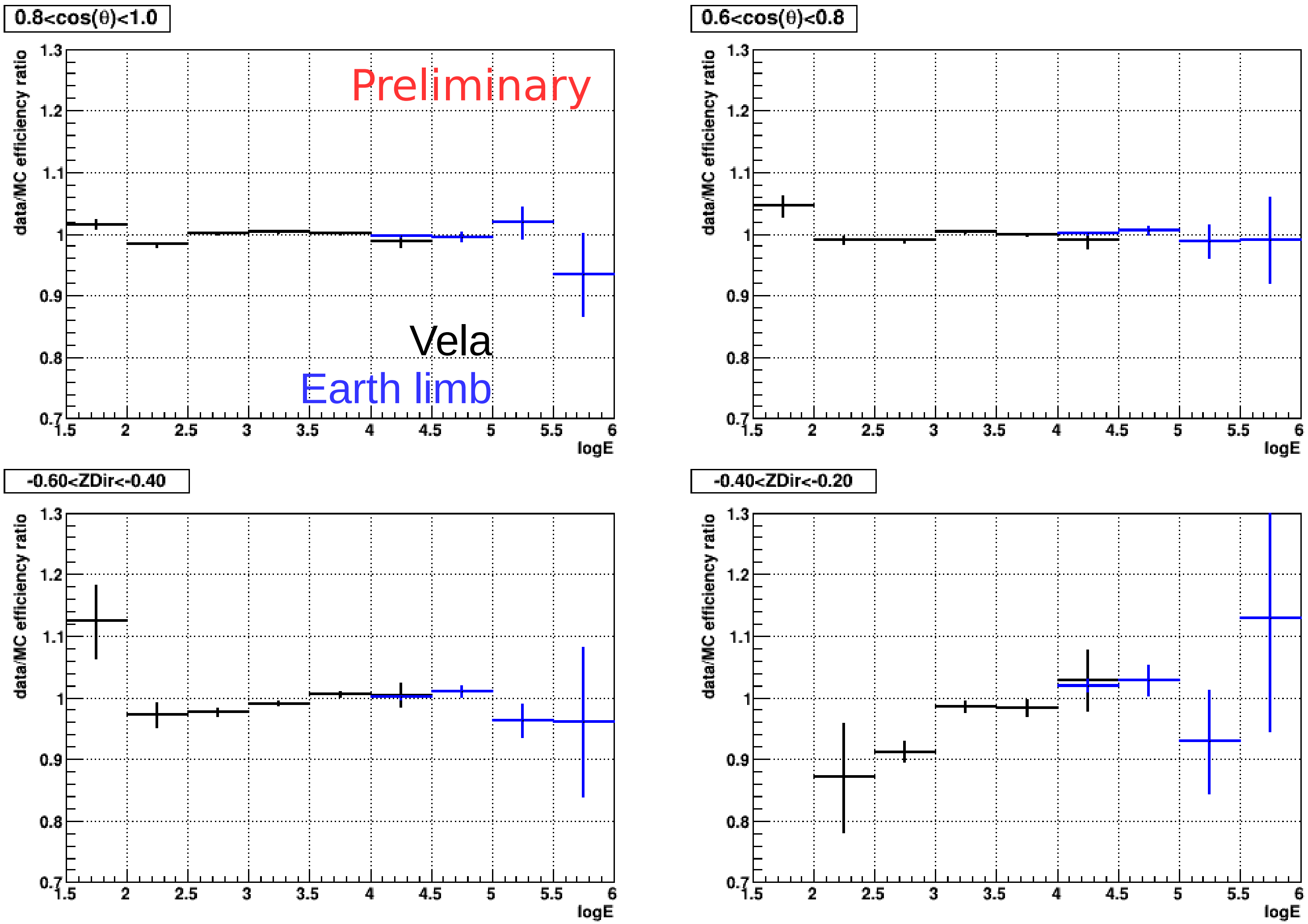
Validation: acceptance

- We measure the efficiency from a very loose selection to the SOURCE class selection for data (black) and the simulation (red)



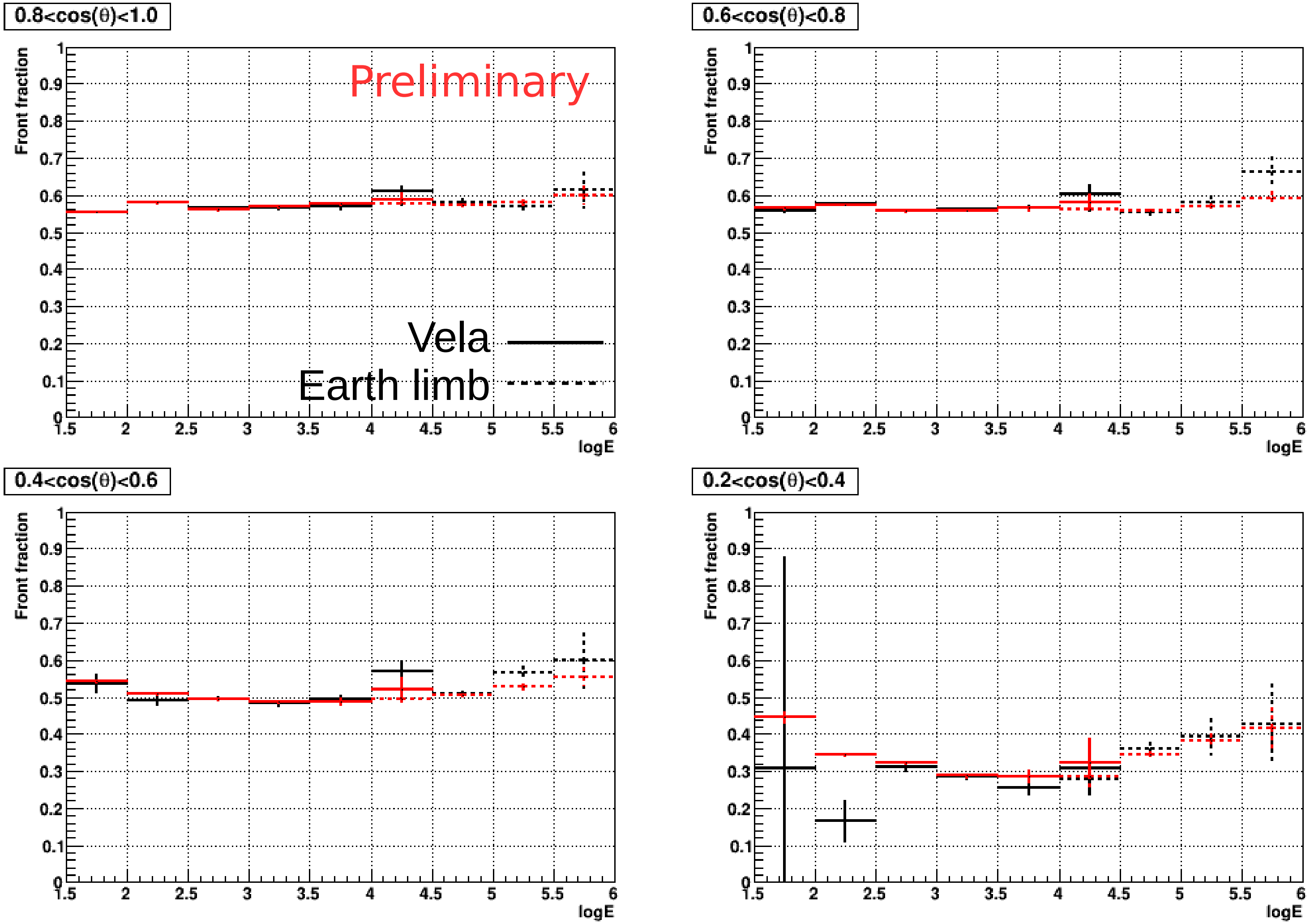
Validation: acceptance

- We compare the data and simulation efficiencies:



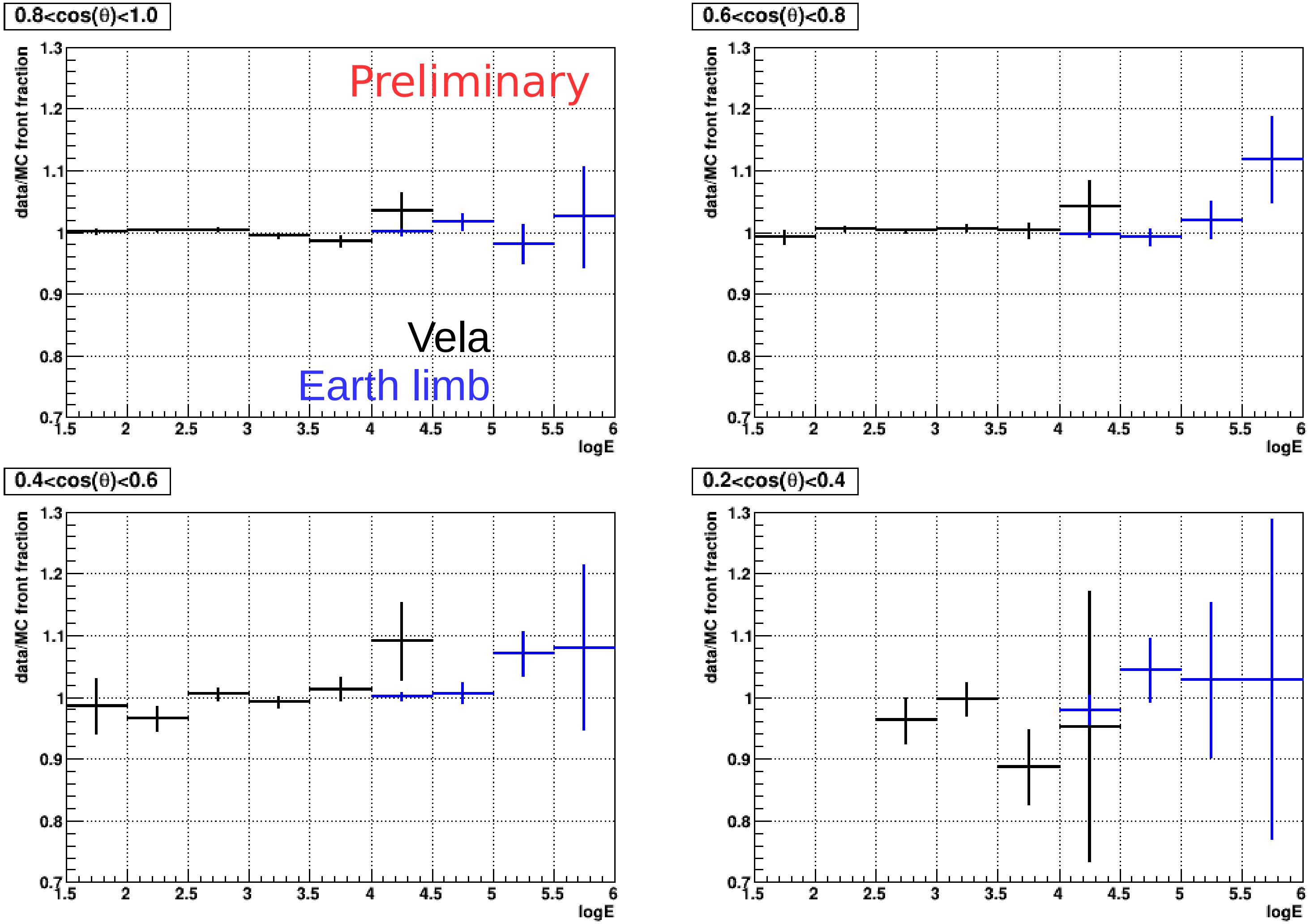
Validation: Front/Back

• We measure the fraction of Front events in the SOURCE class selection for data (black) and the simulation (red)



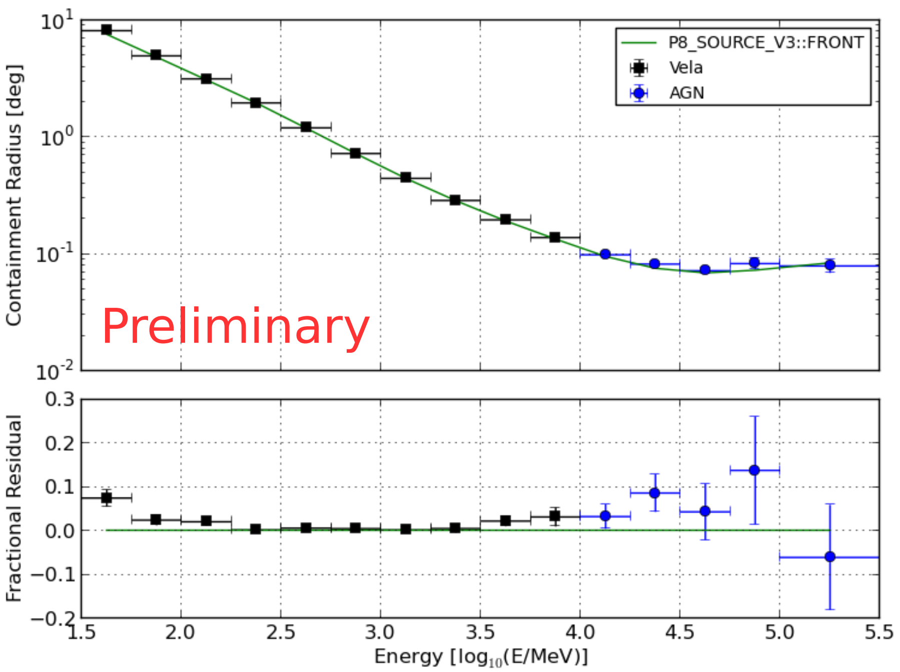
Validation: Front/Back

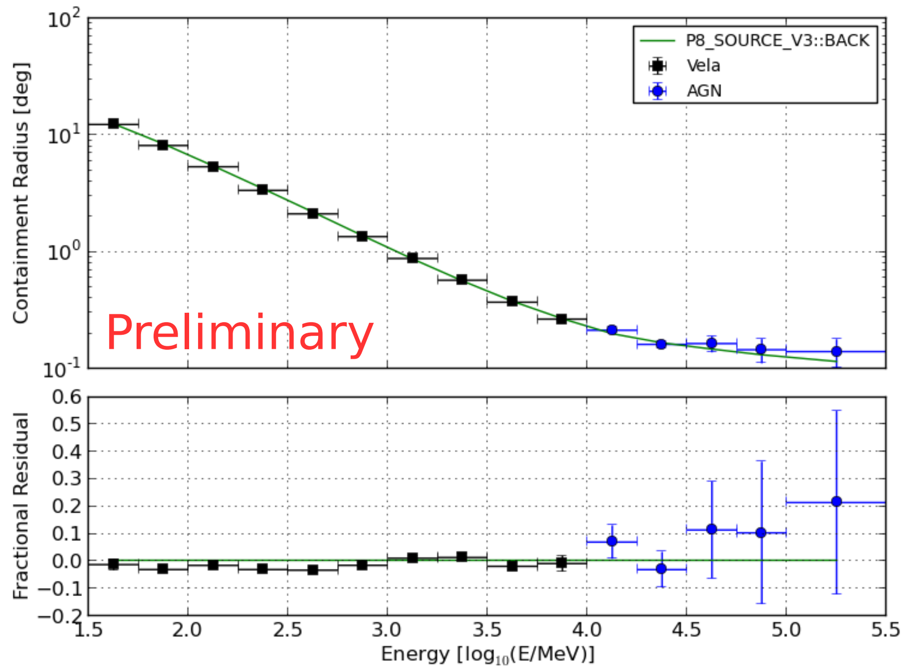
- We compare the data and simulation fractions of Front events:



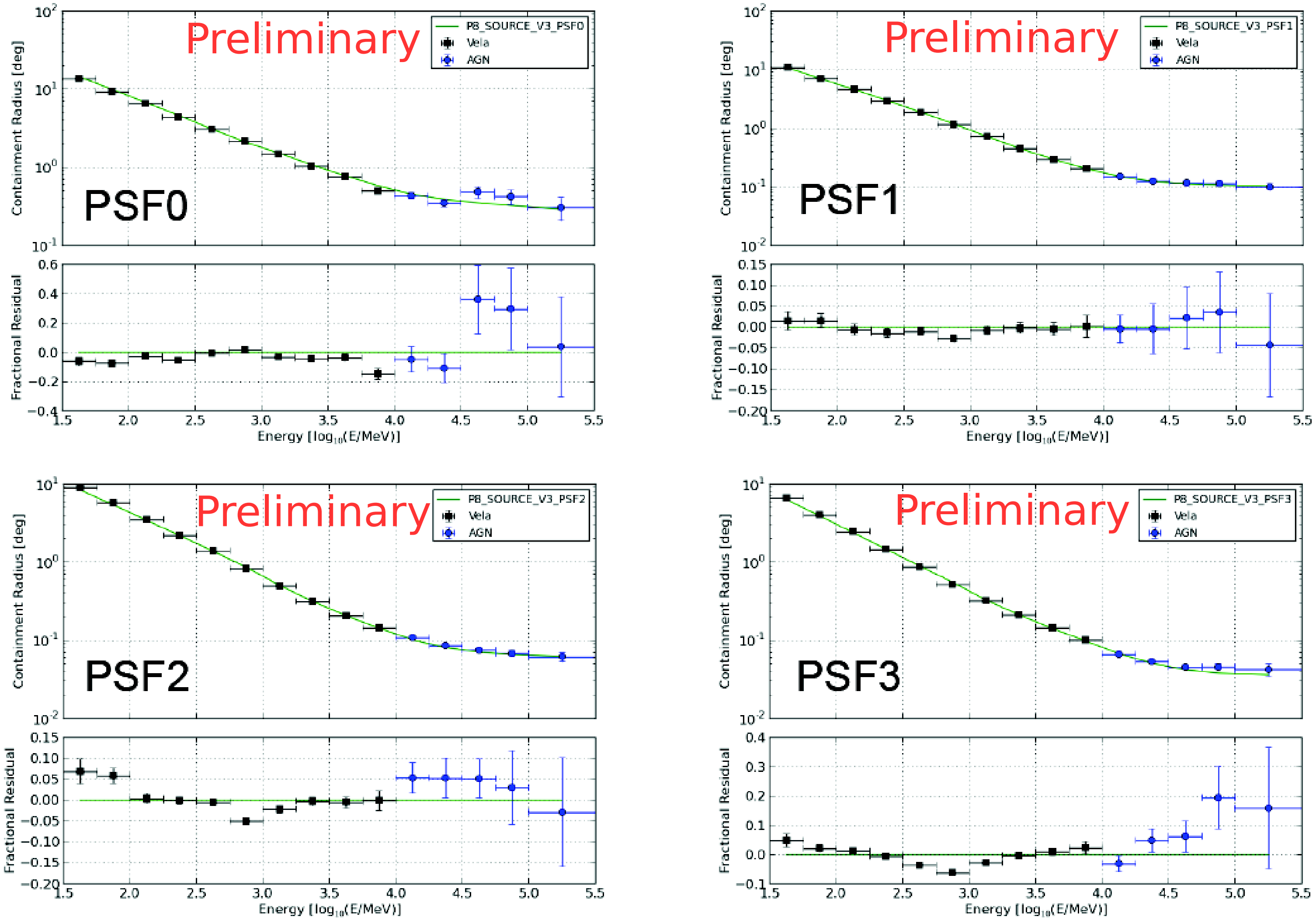
Validation: PSF

- Using Vela and the brightest AGN, we can compare the PSF measured from flight data to the one predicted by the simulation (and stored in the IRFs)

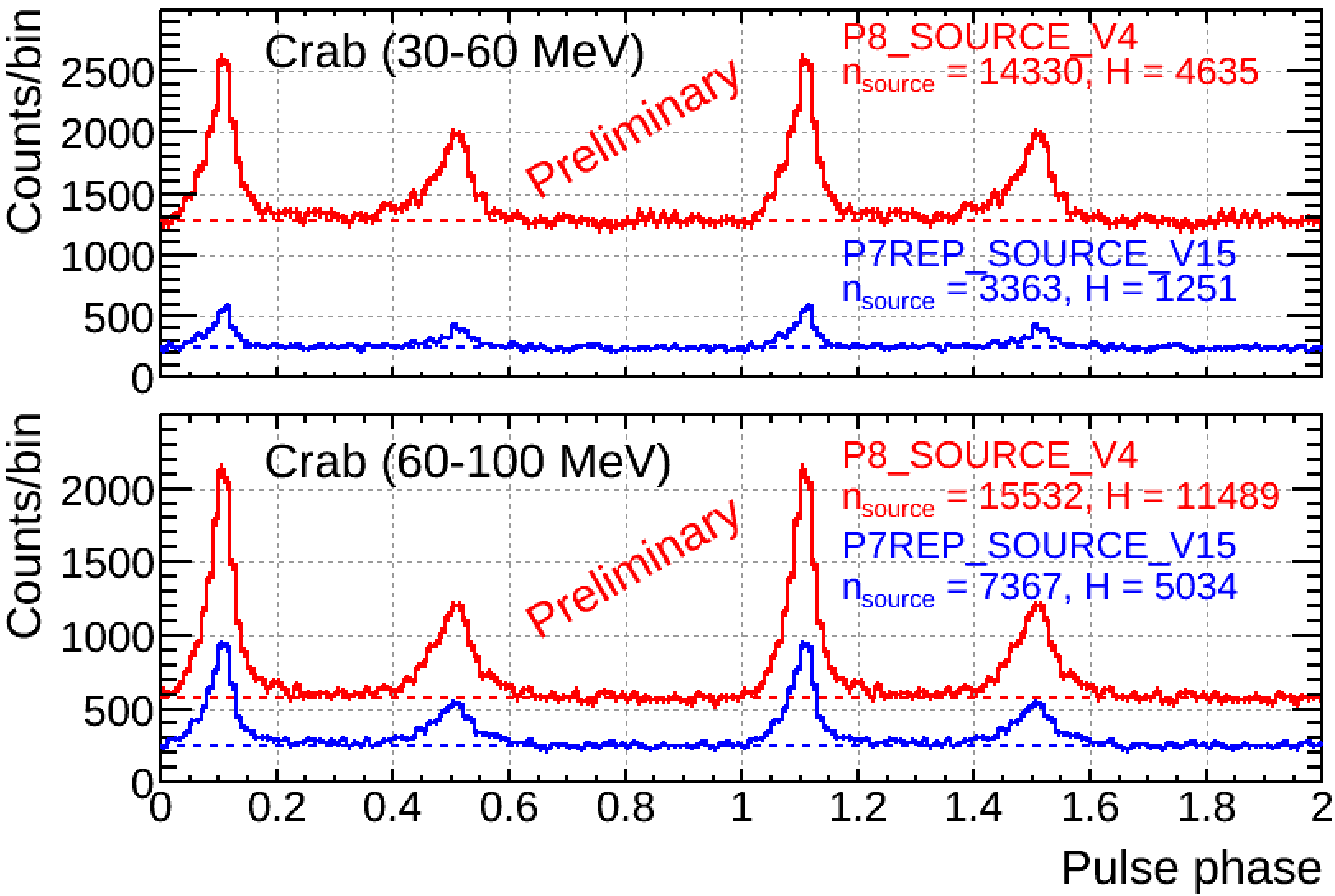




Validation: PSF event types

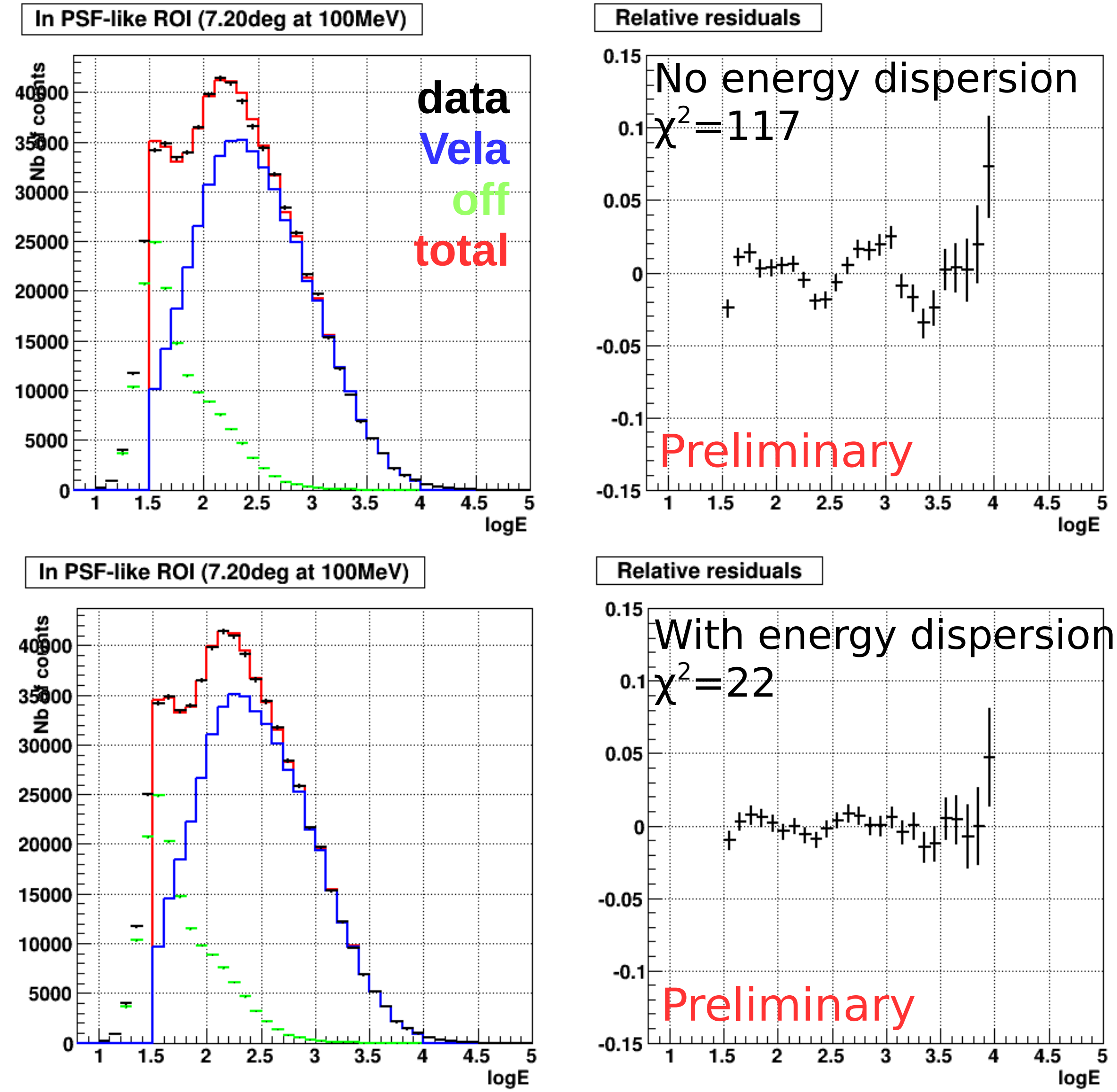


Pass 8 at low energy: Crab



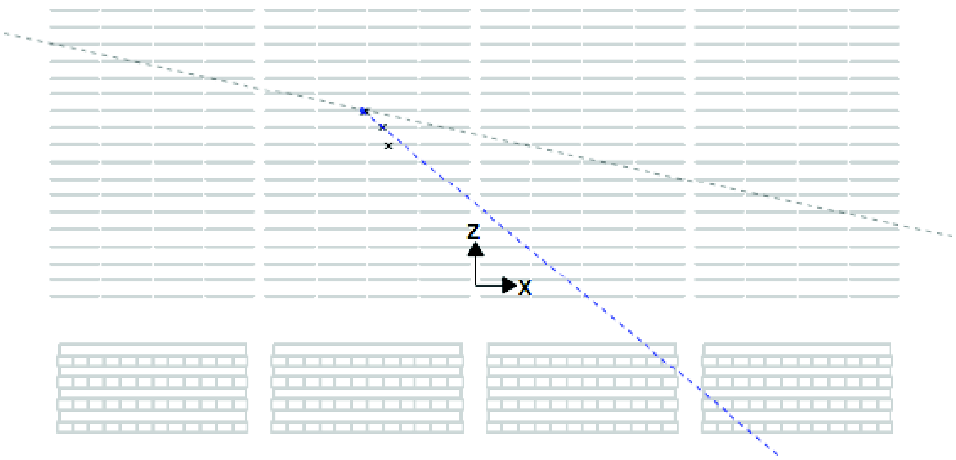
Validation at low energy

- In order to check how low in energy we can go, we perform a Vela ON-OFF spectral fit
- It allows a validation of the IRFs >30 MeV
- Taking into account energy dispersion allows us to:
    - get a better fit
    - decrease the systematics

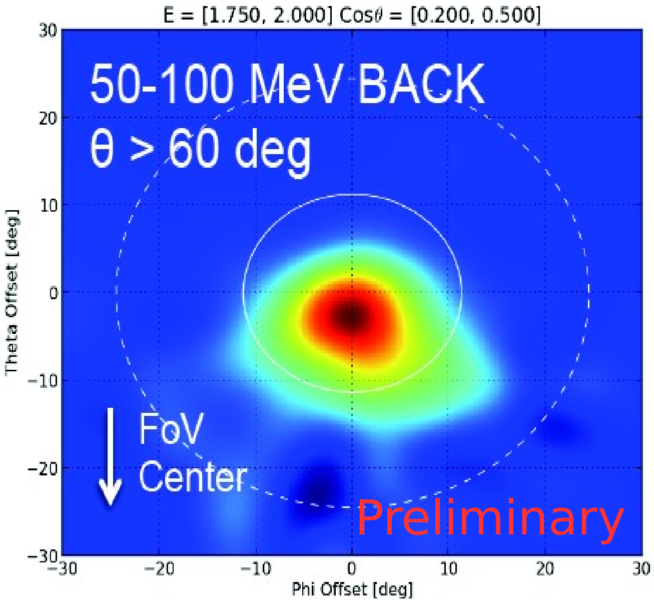


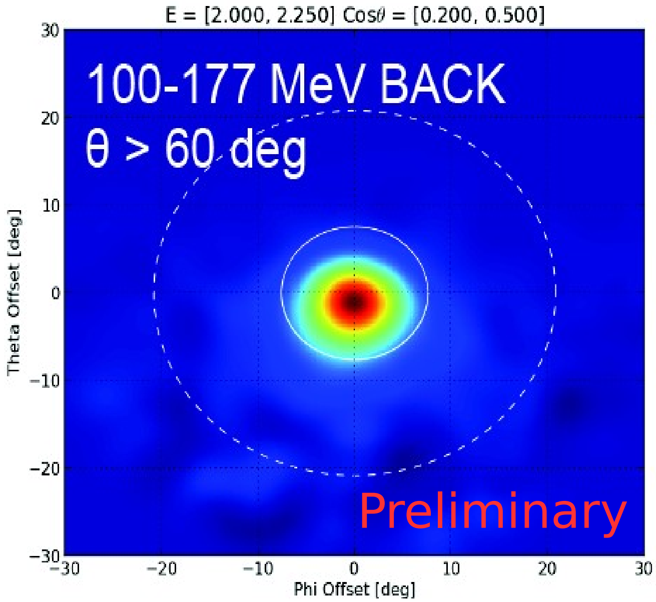
Fish-eye effect

• Particles that scatter towards the center of the FoV are preferentially. triggered/reconstructed causing a bias in the PSF at low E and high theta.
• Transients may be observed with a narrow range of phi angles resulting in a large bias.
• A correction is in development.



Vela in instrument coordinates





Pass 8 package

- The Pass 8 data and a first reliable version of the IRFs have been validated

- We are now producing the rest of the Pass 8 package:
  - Diffuse model: for now we have rescaled the Pass 7 model for energy dispersion distortion
  - Isotropic template
  - Earth limb
    - The large Pass 8 field of view implies that we are more sensitive to the residual Earth limb
  - Systematic uncertainties:
    - P7REP: 5% between 316 MeV and 10 GeV
    - Pass 8 goal: <2% between 100 MeV and 100 GeV

Conclusions

- Pass 8 looks good and very promising
- First science results at presented at this Symposium
- We are currently finalizing the Pass 8 package
- Public release: ~mid 2015