The impact of the Calorimeter-only photons in the Fermi-LAT analysis of VHE sources

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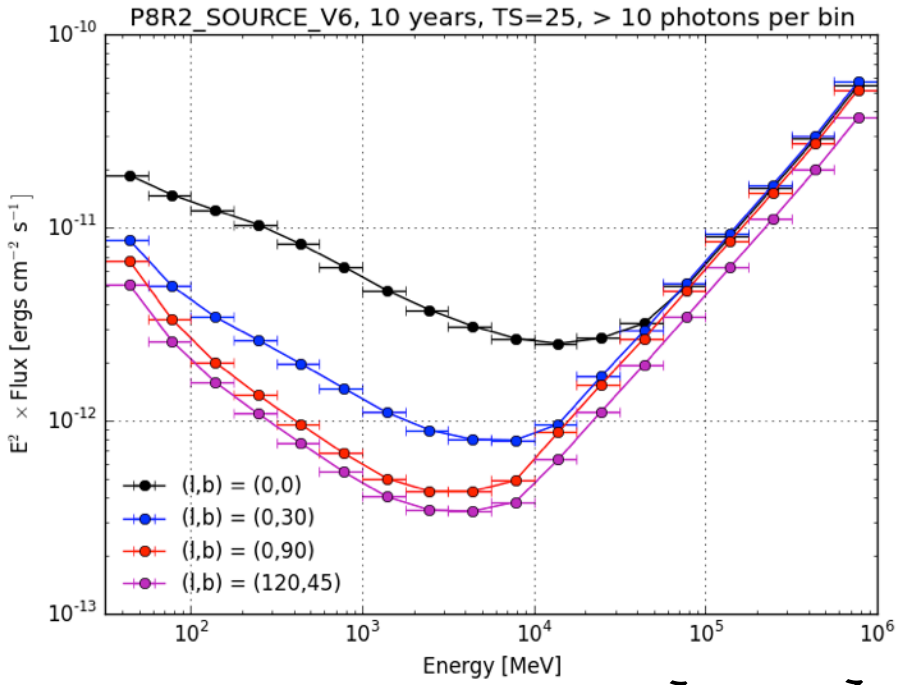
Gamma-ray observation above tens of GeV

- **Fermi-LAT Pass8 provides a large acceptance, ~2.5m²sr above 1 GeV**
- **The steep falling photon flux with energy of most γ-ray sources results in a substantial sensitivity limitation above few tens of GeV**

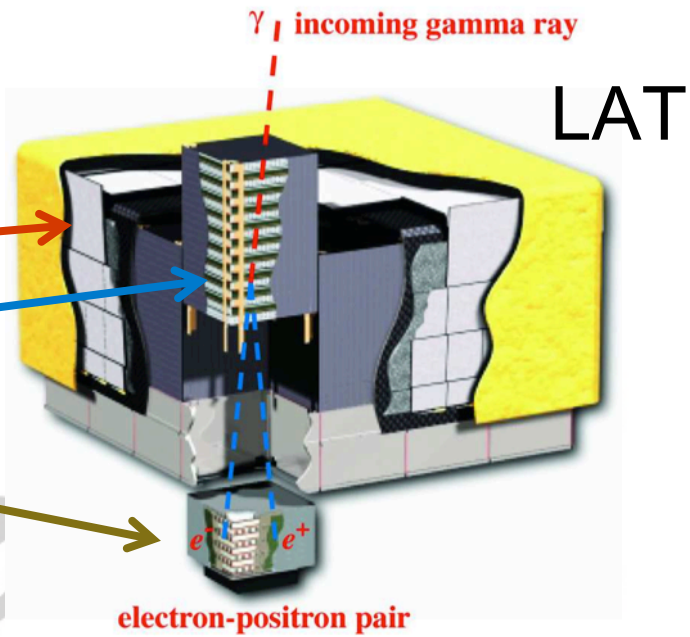
Pass8 SOURCE class sensitivity

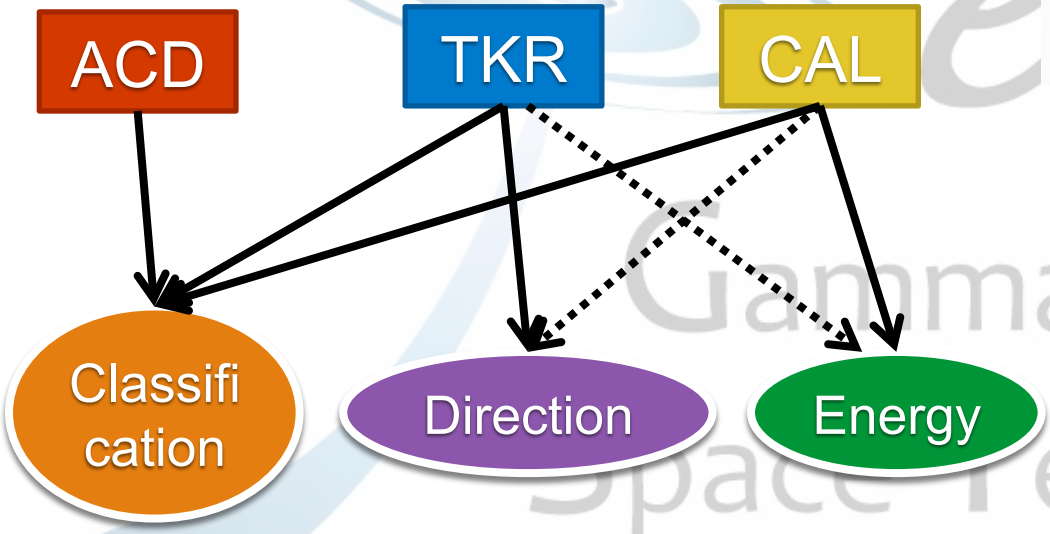


At the Fermi-LAT highest energies, sensitivity is photon-statistics limited

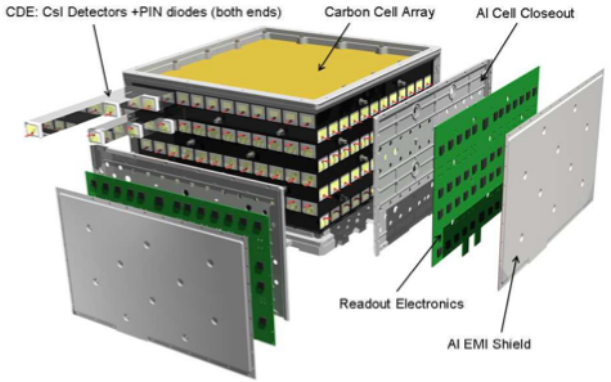
Three detectors of the Fermi-LAT

- **The Fermi-LAT is composed of three kinds of detectors**
  - **Anti-Coincidence Detector (ACD)**
  - **Tracker (TKR)**
  - **Calorimeter (CAL)**



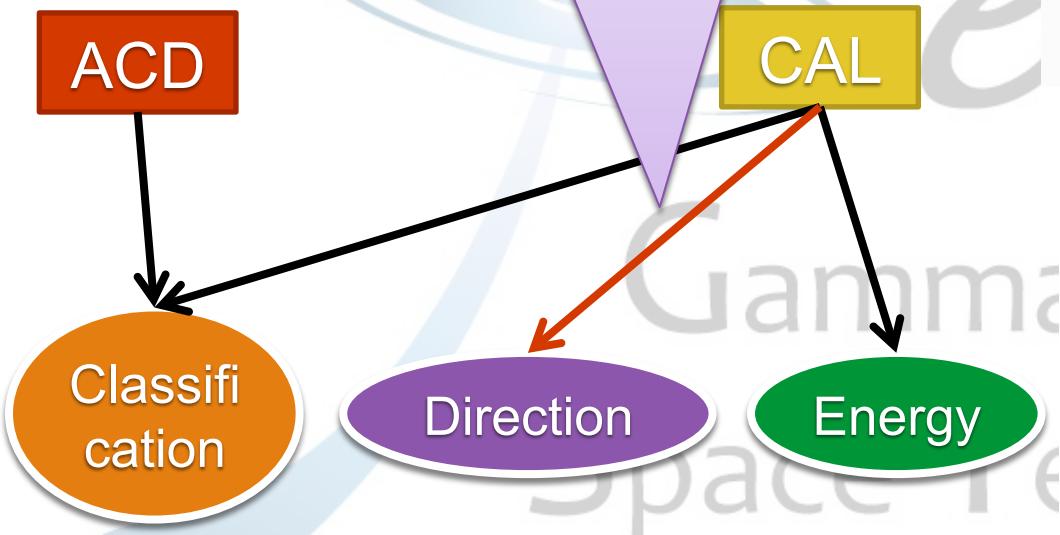


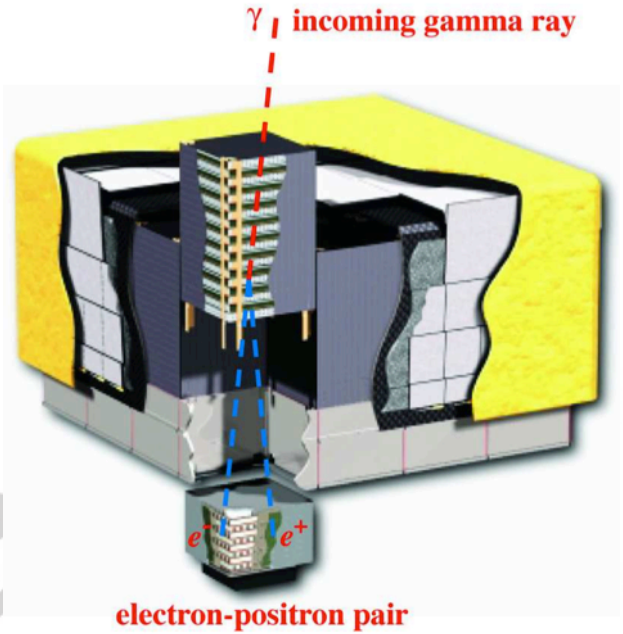
Calorimeter

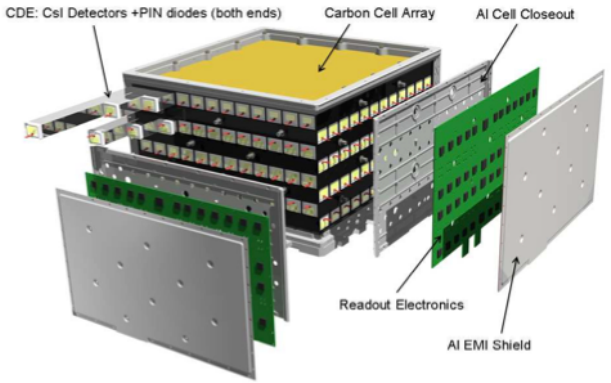


Three detectors of the Fermi-LAT

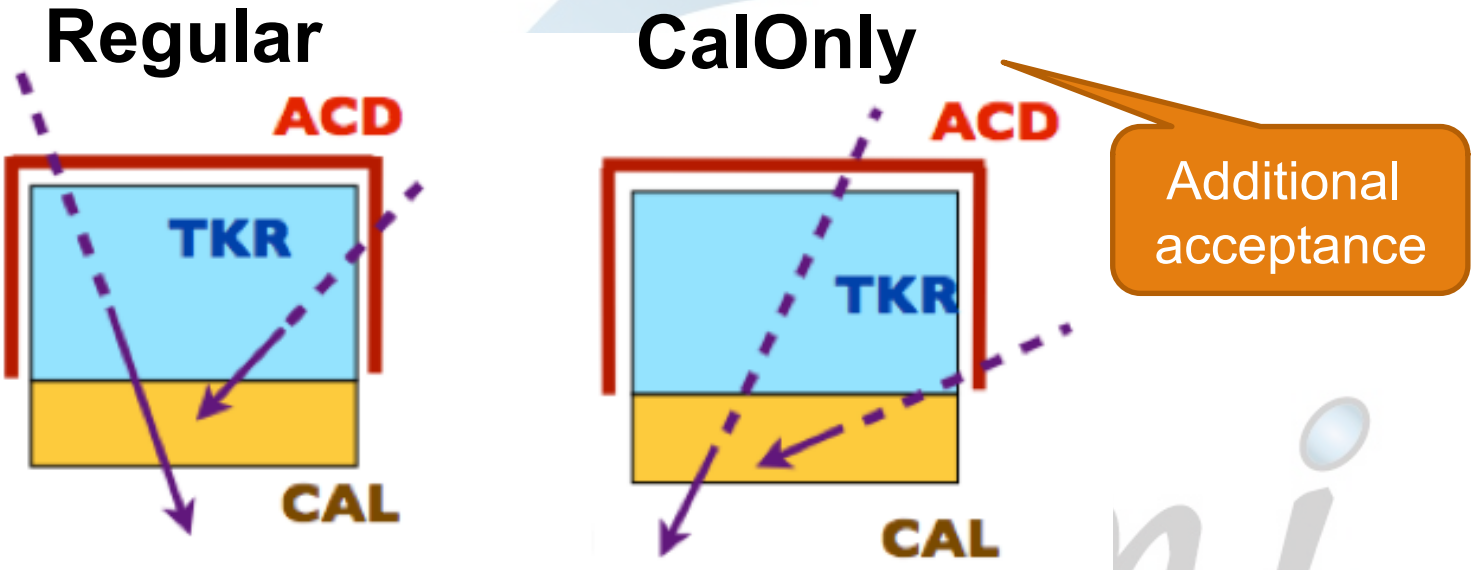
Pass8 made possible the reconstruction of high-energy events without usable TKR information, dubbed “CalOnly” events







Idea of the Calorimeter-only (CalOnly) analysis



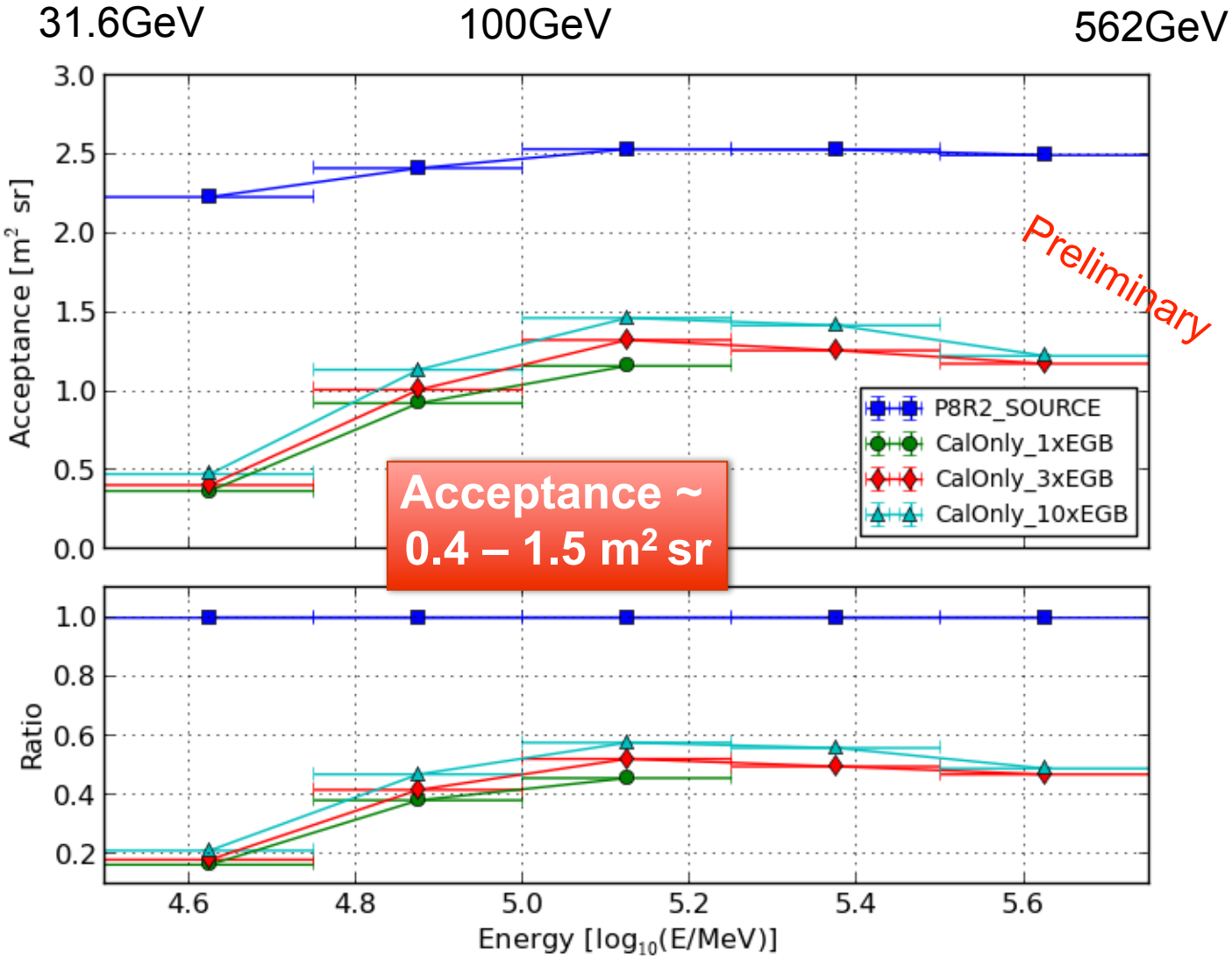
- **The CalOnly analysis can recover valuable gamma-ray events that are not converted in the TKR, *i.e.* side-entering or TKR-passing events**
  - Provides an increase in acceptance at few tens of GeV, where sensitivity is limited by photon statistics
  - CalOnly events expected to have somewhat worse angular resolution and signal/bkg separation
- **Once fully developed and validated, the CalOnly event class could be added to the distributed photon data**

Rejection of backgrounds

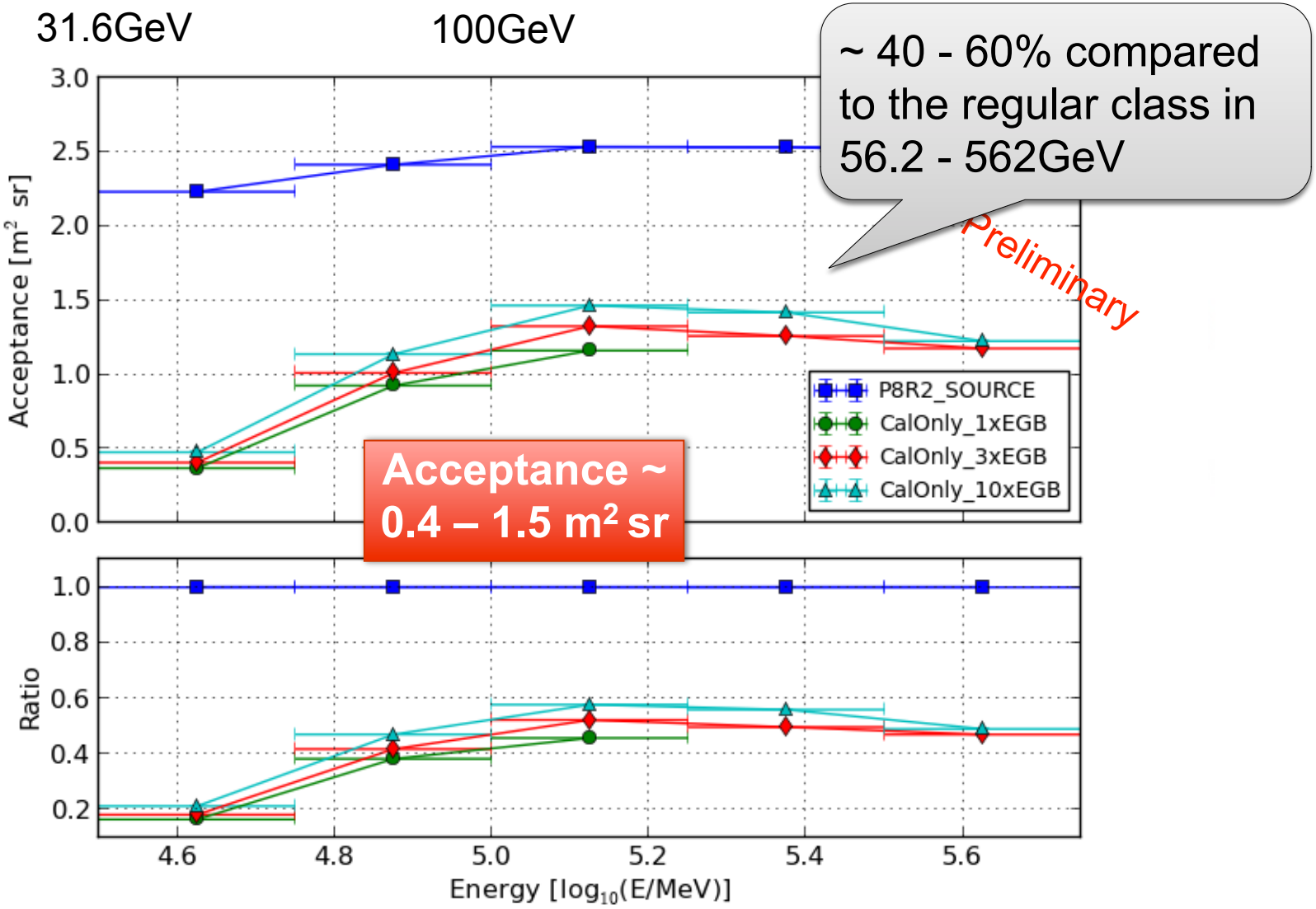
- **γ-ray and bkg are separated with multi-variate analysis (MVA)**
  - Similar to the regular LAT analysis; but the MVA should be optimized for events without usable TKR information
- **A tighter cut class has less events**
- **Signal/bkg separation algorithm is designed to have a residual bkg comparable to the Extragalactic Background (EGB), while keeping the largest possible number of signal events**
- **Three classes are produced**
  - **~1x EGB level**
  - **~3x EGB level**
  - **~10x EGB level**
- **Further improvement is being investigated**

Comparison of the performance of the CalOnly analysis with MC

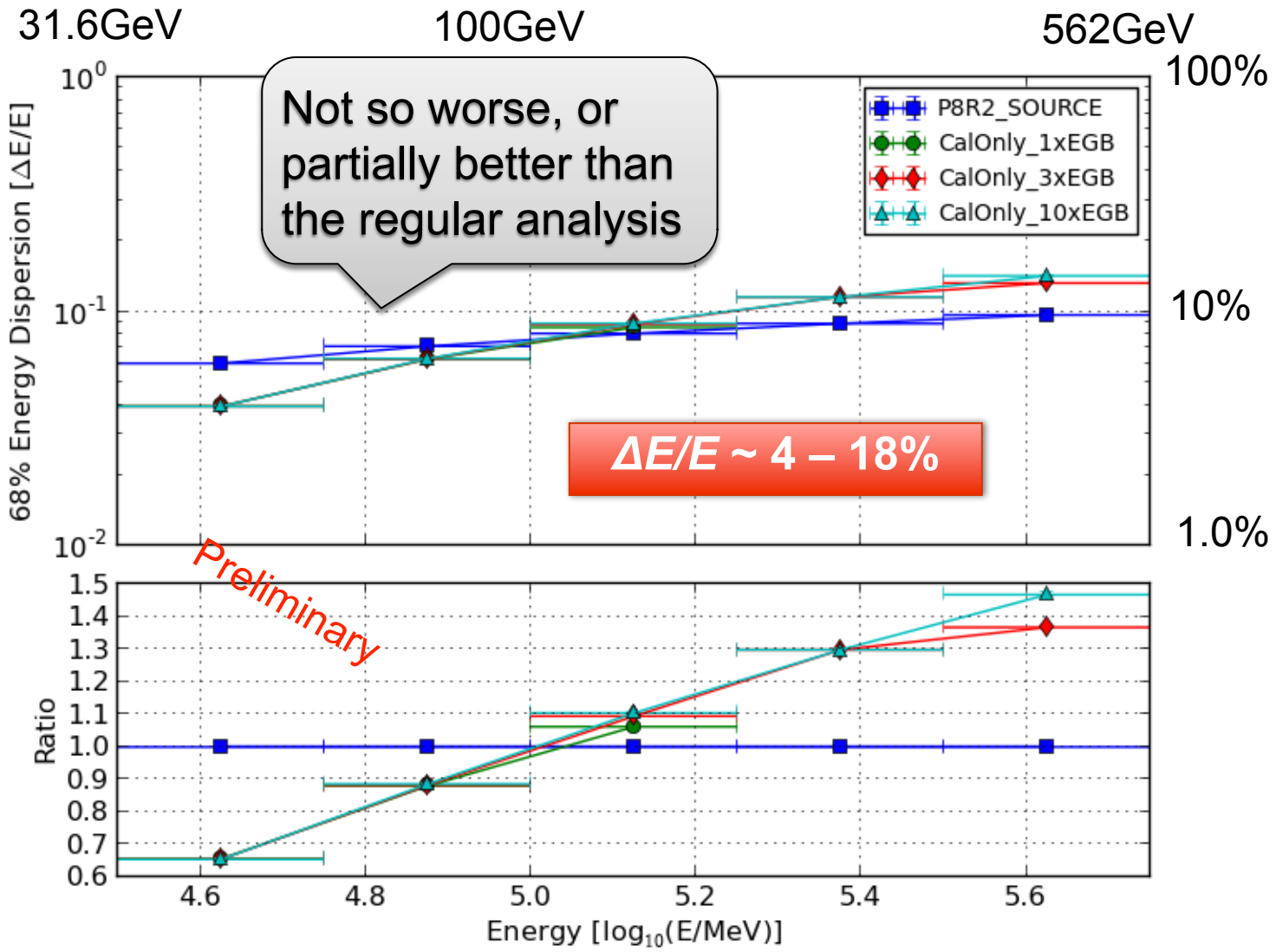
Acceptance vs. energy



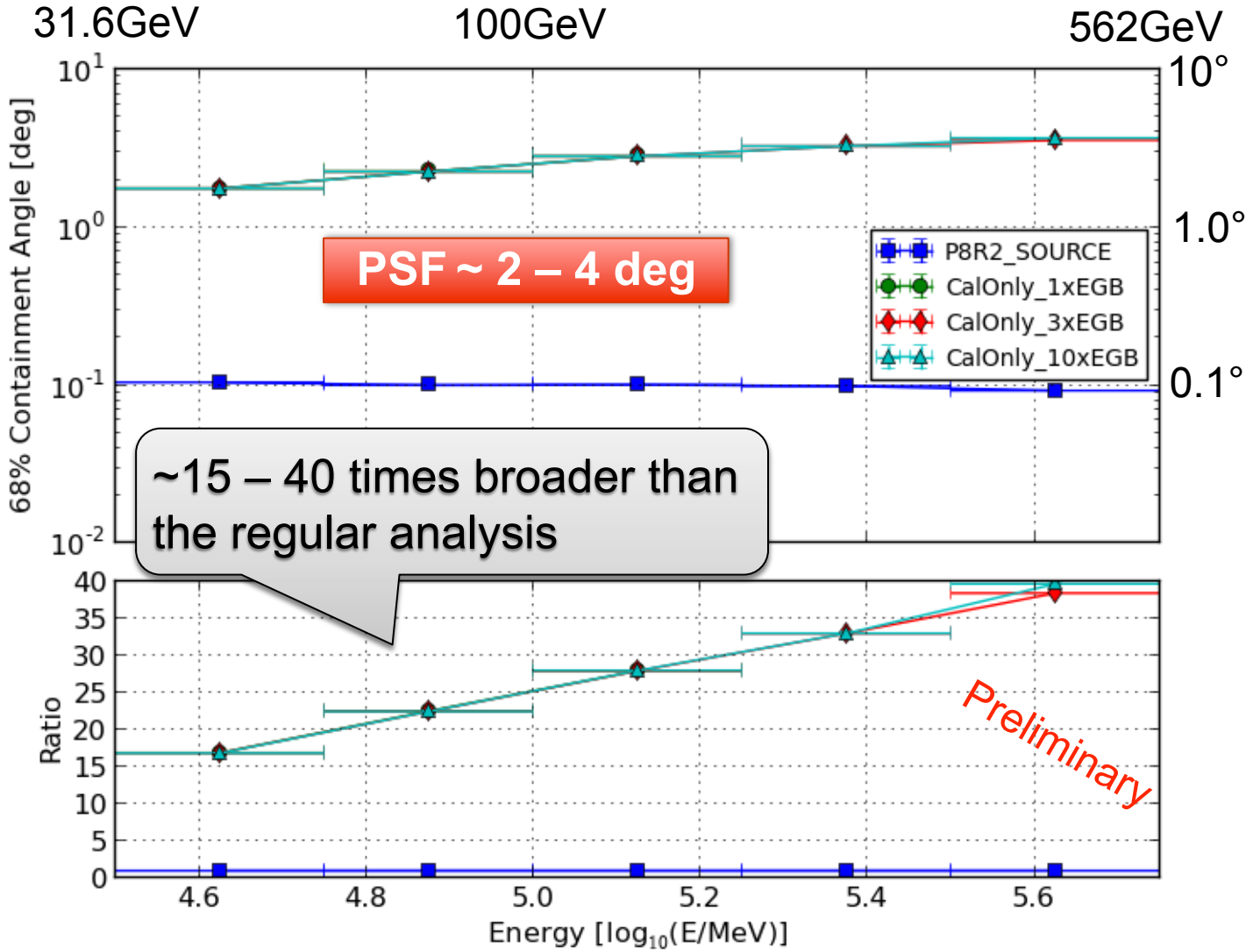
Acceptance vs. energy



Energy dispersion (68% containment)



PSF (68% containment)

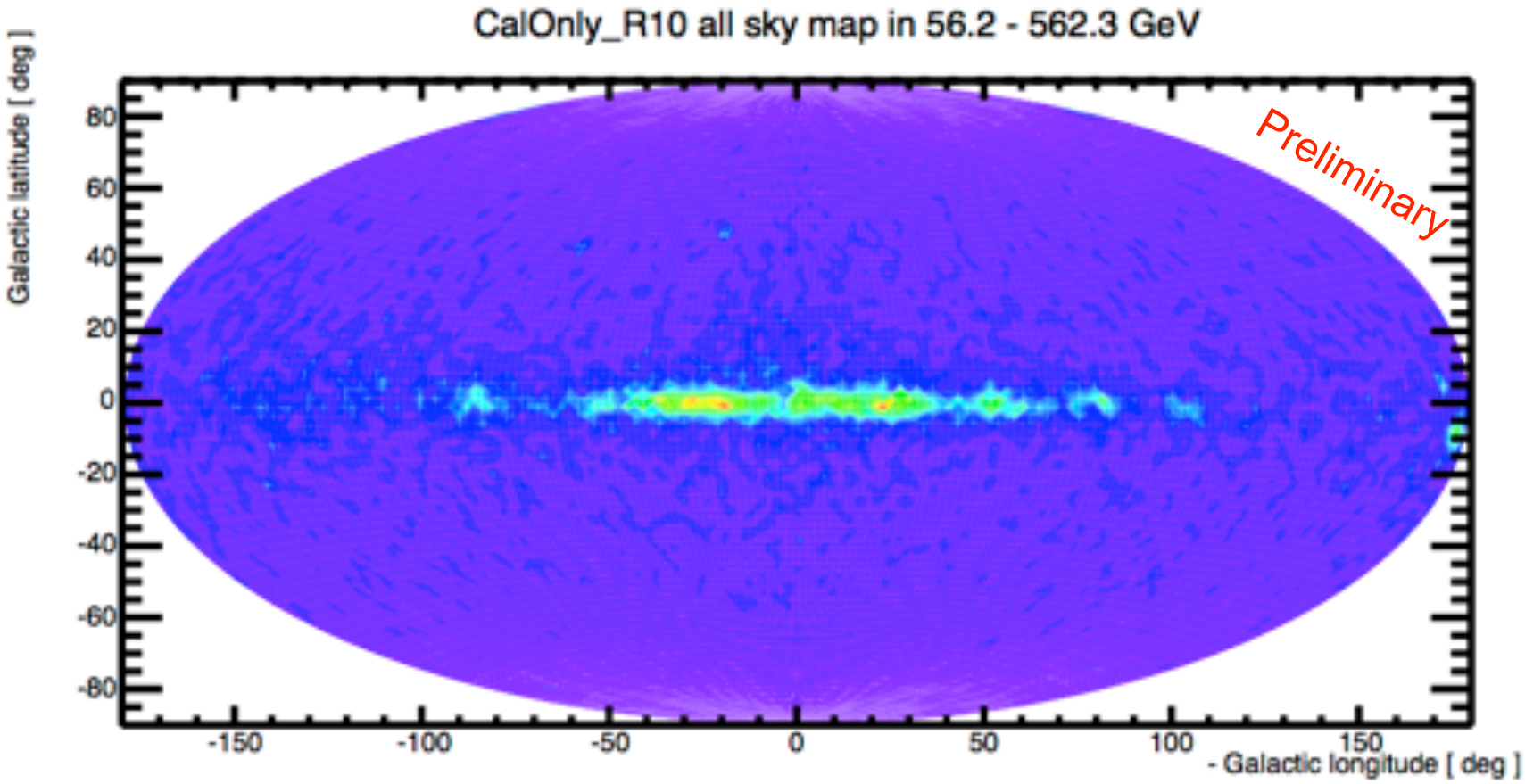


Characteristics of the CalOnly analysis

- **The energy resolution is roughly comparable to the regular one**
- **The angular resolution is more than an order of magnitude worse**
- **Both of the energy and angular resolution strongly depend on the energy and inclination angle**
  - Sub-classes of events with better energy and/or angular resolution should be possible
- **The field of view is larger than the regular analysis**
- **Promising targets for the CalOnly analysis**
  - Transients
    - Background is further suppressed by the temporal information of the flare
    - SED of AGN flares
    - >30GeV photons from GRBs
  - Sources where good angular resolution is not required
    - Search for Dark matter in diffuse/extended regions at the highest Fermi-LAT energies

The CalOnly analysis of real data

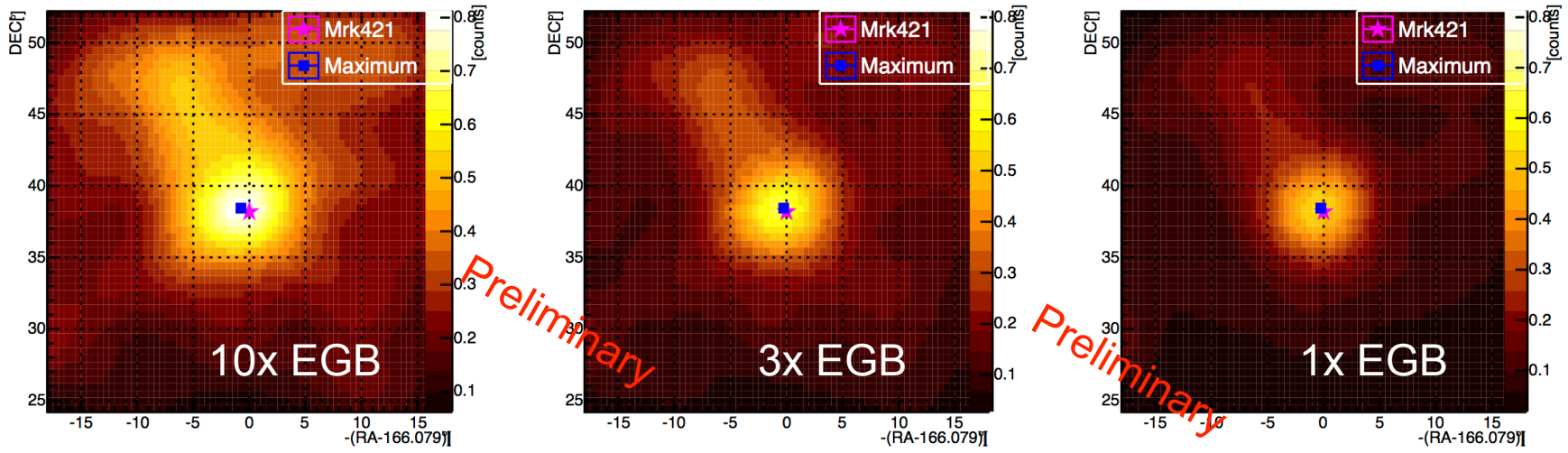
The CalOnly Universe over five years data



- **Count map in linear-scale**
  - Making the exposure map is ongoing hence no flux data yet
- **56.2 - 562 GeV**
- **Jan 1, 2009 – Dec 31, 2013**

Mrk421 over five years

Smoothed count map in 56.2-562GeV

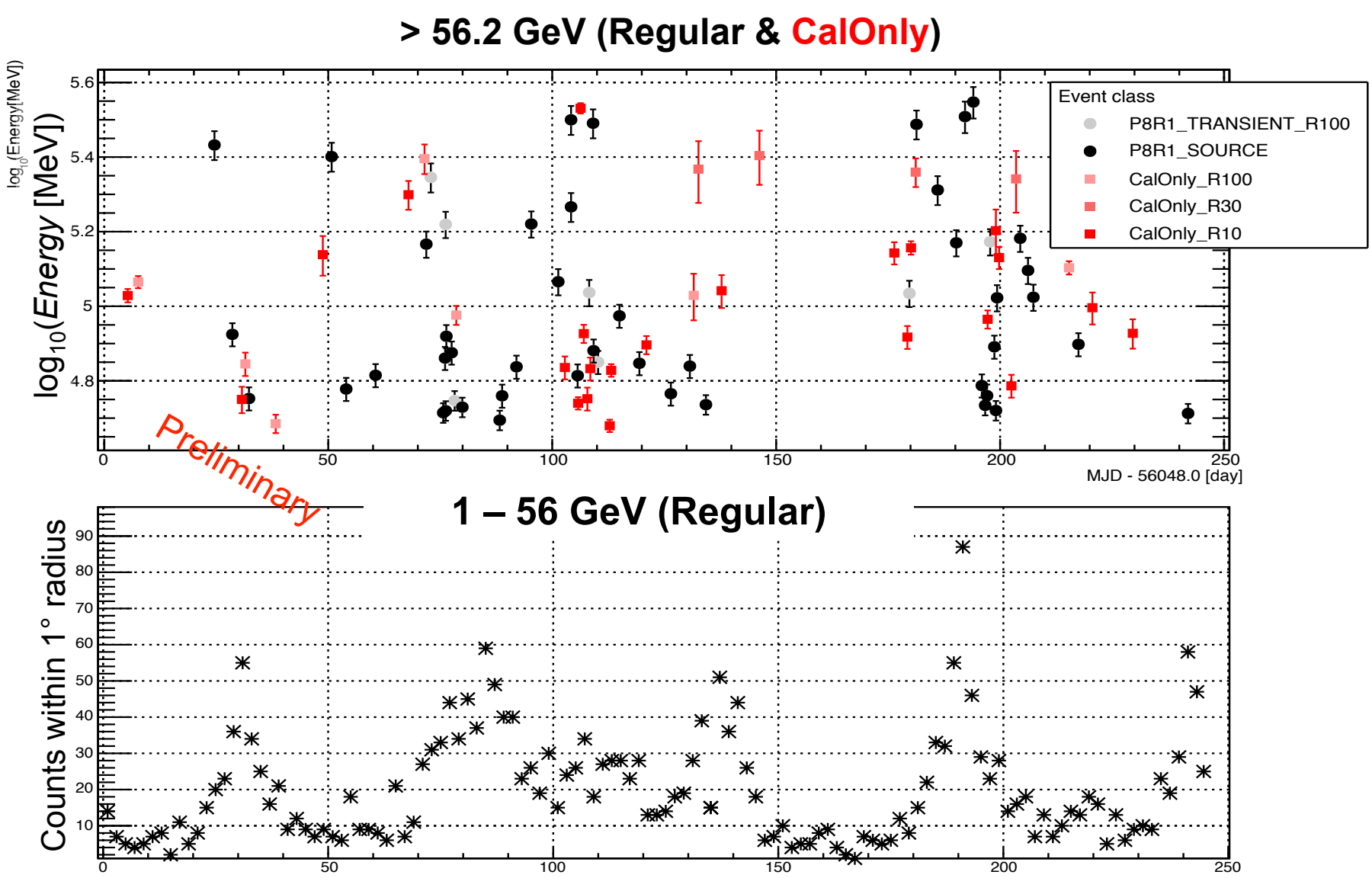


Milder cut ⟷ **Tighter cut**

CalOnly	CalOnly 10xEGB	CalOnly 3xEGB	CalOnly 1xEGB
Counts within 1.5σ PSF	150	120	95
Expected background	57.4	34.3	19.4
Regular	**TRANSIENT**	**SOURCE**	
Counts within 1.5σ PSF	190	178	
Expected background	0.41	0.03	

- **Signal excess clearly seen from the location of Mrk421, despite a S/B ratio substantially worse than for the regular analysis**
  - Mostly due to the limited angular resolution

Mrk421 over 8 months
(One of the most active periods, May 1 – Dec 31, 2012)



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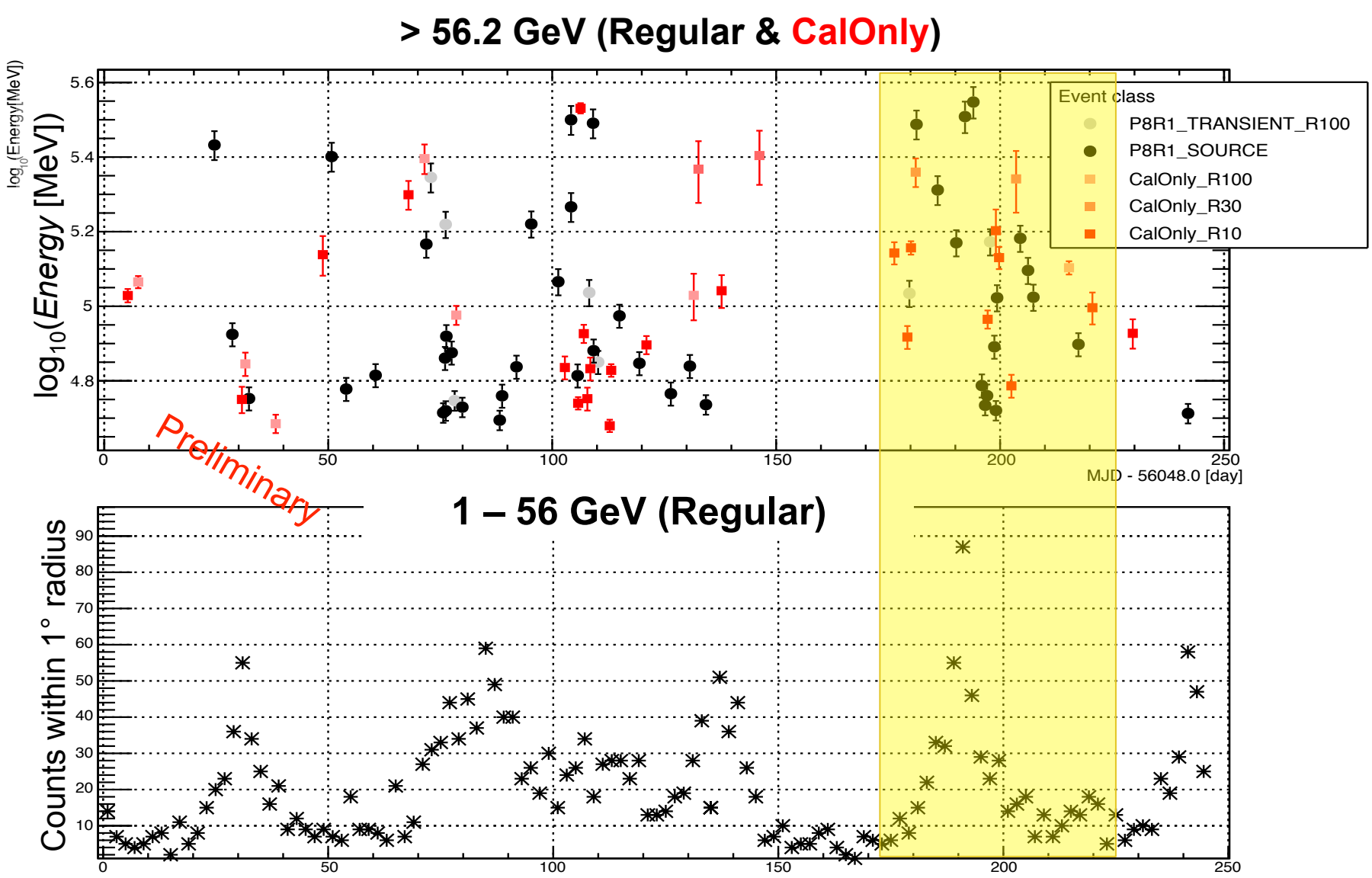
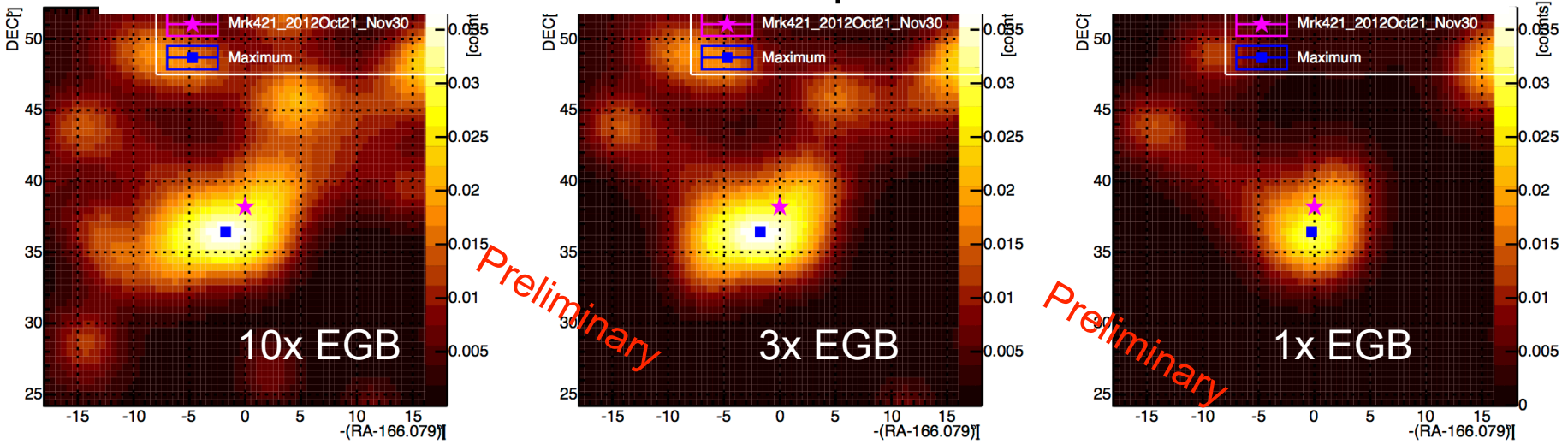


Mrk421 over 40 days (21 Oct - 30 Nov)

Smoothed count map in 56.2-562GeV



Milder cut ⟵ ⟶ **Tighter cut**

CalOnly	CalOnly 10xEGB	CalOnly 3xEGB	CalOnly 1xEGB
Counts within 1.5σ PSF	9	9	7
Expected background	1.2	0.76	0.44
Regular	**TRANSIENT**	**SOURCE**	
Counts within 1.5σ PSF	14	12	
Expected background	0.0097	0.0009	

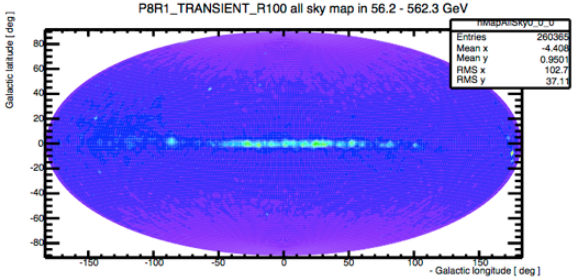
- **The bkg can be suppressed for a limited time-domain**
  - AGN flares and GRBs are good targets for CalOnly

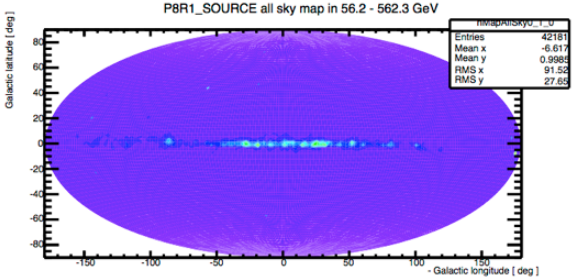
Summary

- **Above tens of GeV, γ-ray observations with the Fermi-LAT are often dominated by limited photon (signal) statistics**
- **Pass8 made possible the reconstruction of high-energy "CalOnly" events without usable TKR information**
- **Overall, the CalOnly event class can add ~40-50% of events above ~50 GeV**
- **The PSF is ~ 2 - 4 degrees**
  - More than one order of magnitude worse than the regular analysis
- **The energy dispersion is ~ 4 - 18%**
  - Comparable to that of the regular analysis
- **The energy and angular resolution depend on the energy and inclination angle**
  - Sub-classes with better resolution are being investigated
- **Beneficial for scientific topics related to**
  - Transients (AGN flares and GRBs)
  - Largely extended sources (*e.g.* search for DM)
- **The analysis based on MC is being verified with real flight data**

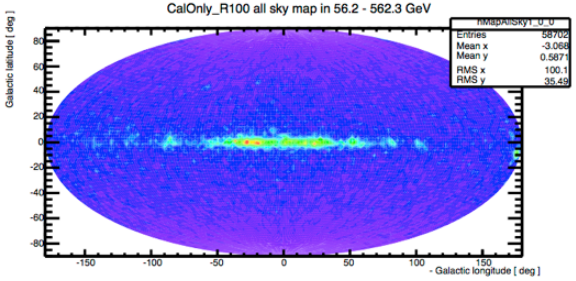
Fermi Gamma-ray Space Telescope

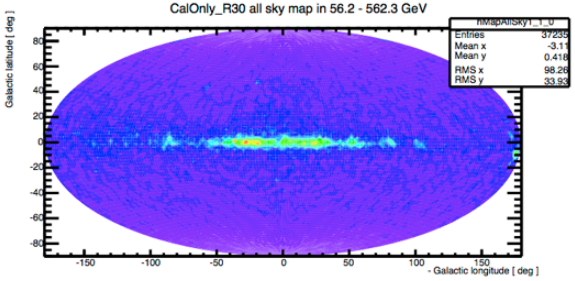
Backup

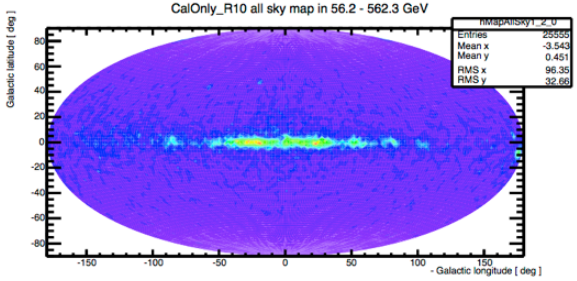




Preliminary







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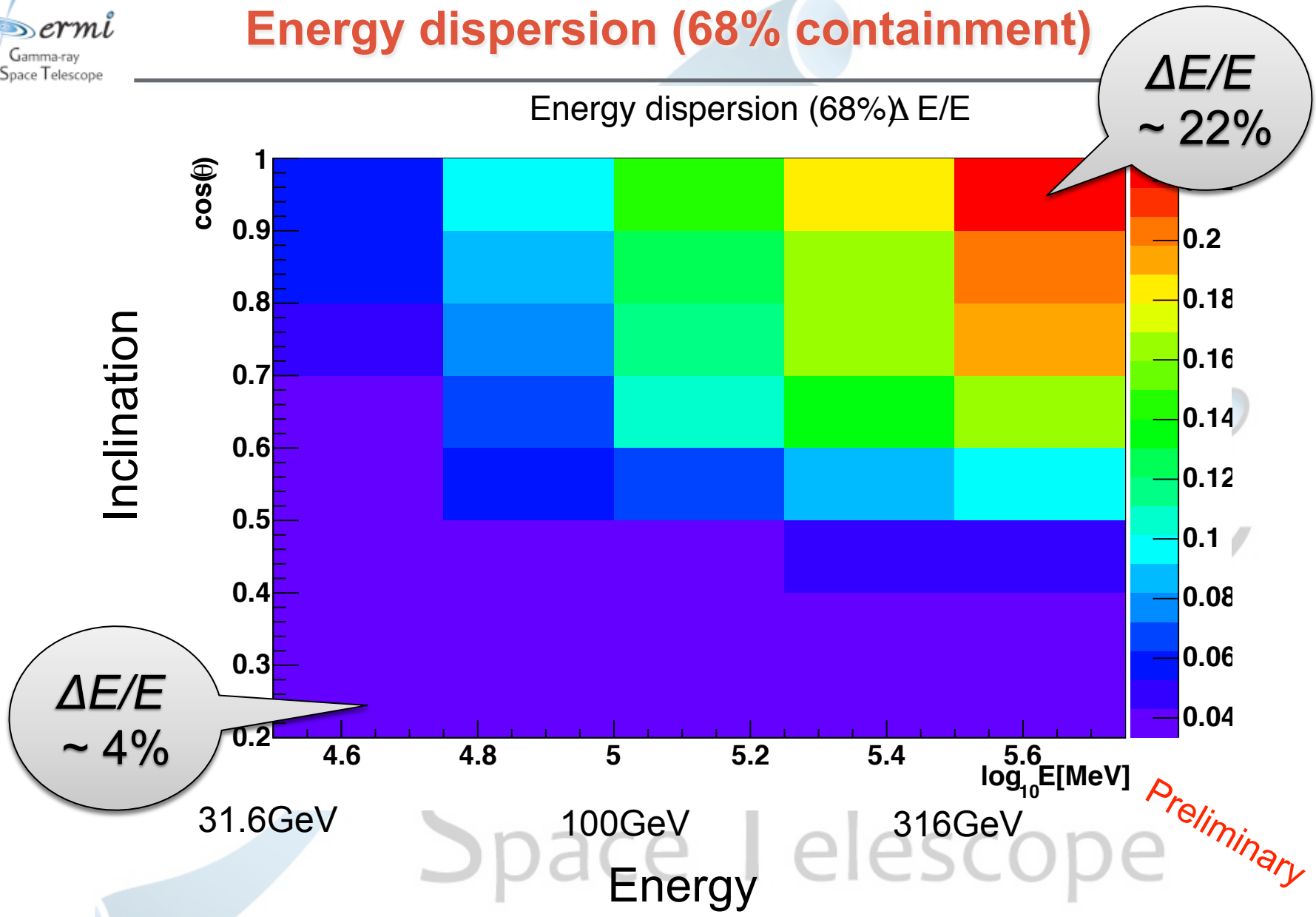

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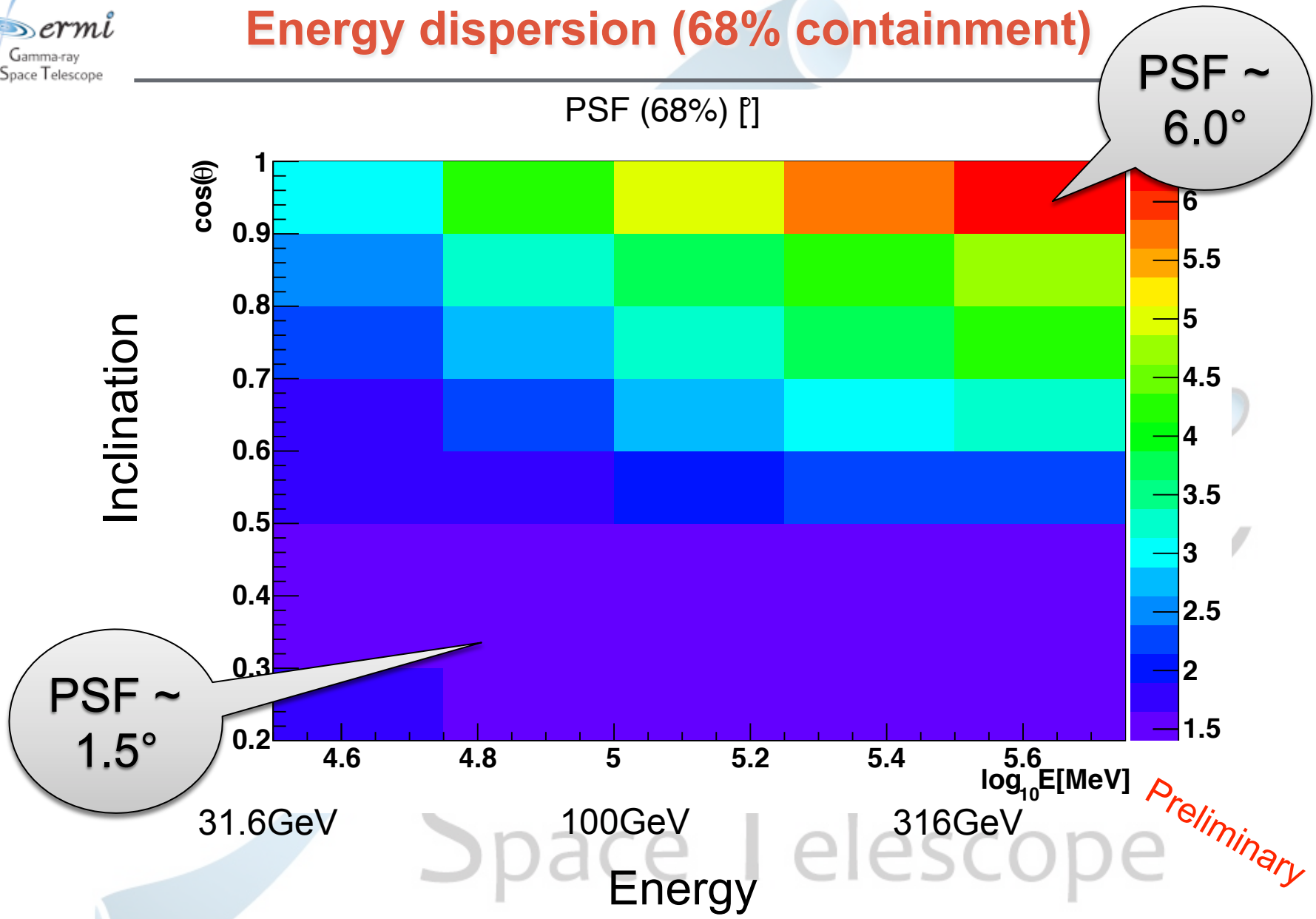

What to do for scientific analysis

- Processing of data in 2008, 2014 and 2015
- Fine tuning of the multi-variate analysis
- Event sub-classes of better energy or angular resolution
- Make of an exposure map and calculation of the flux
- Summarize to high-level data