Study of the diffuse emissions with the H.E.S.S. experiment

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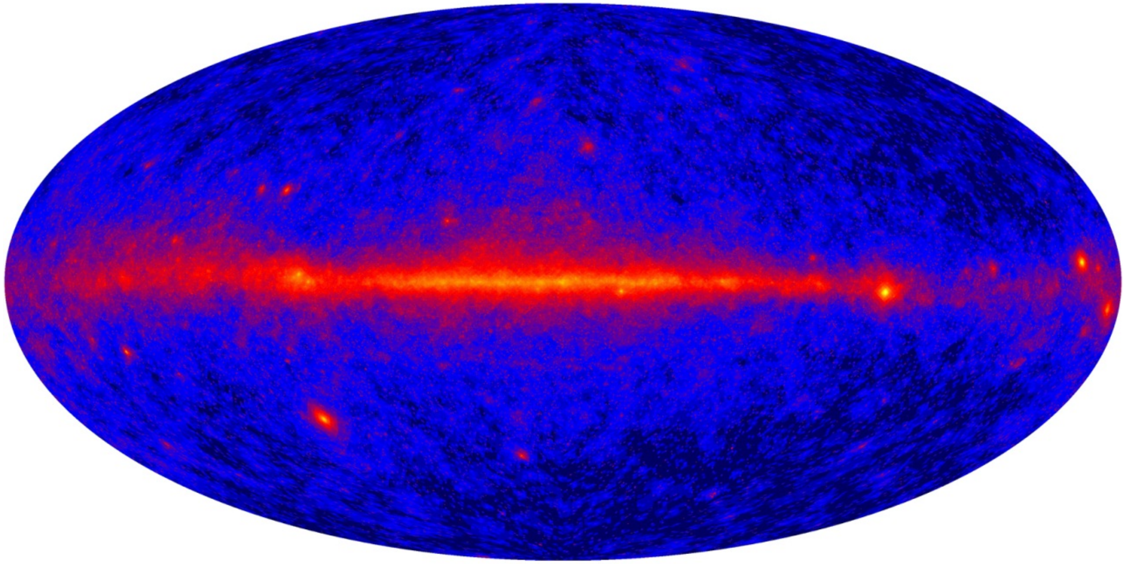
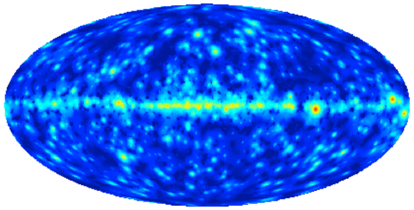
Gamma-rays



Astrophysical Sources



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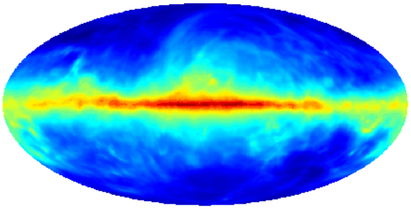
Galactic Diffuse Emission



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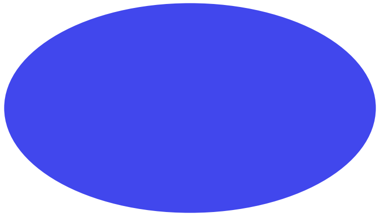
Extragalactic Diffuse Emission



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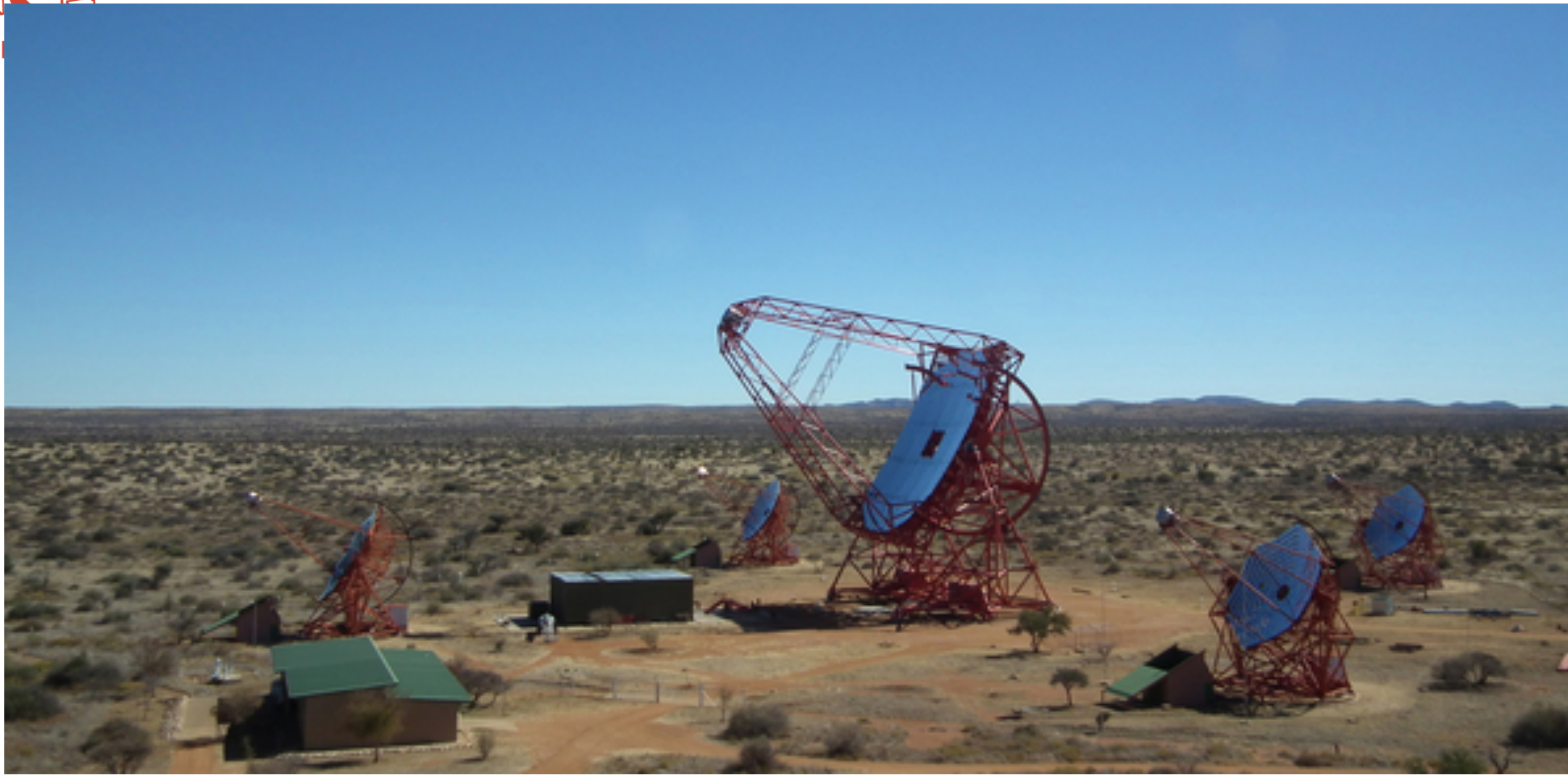
Goals

- Distinguish and study the different components of the gamma-ray emissions
- Develop analysis methods to include as much information as possible to perform an analysis which is model independent
- Look for a dark matter contribution in the reconstructed gamma and electrons

Outline

- The HESS experiment
- Development of the tools for the analysis
- Application on PKS2155-304 data

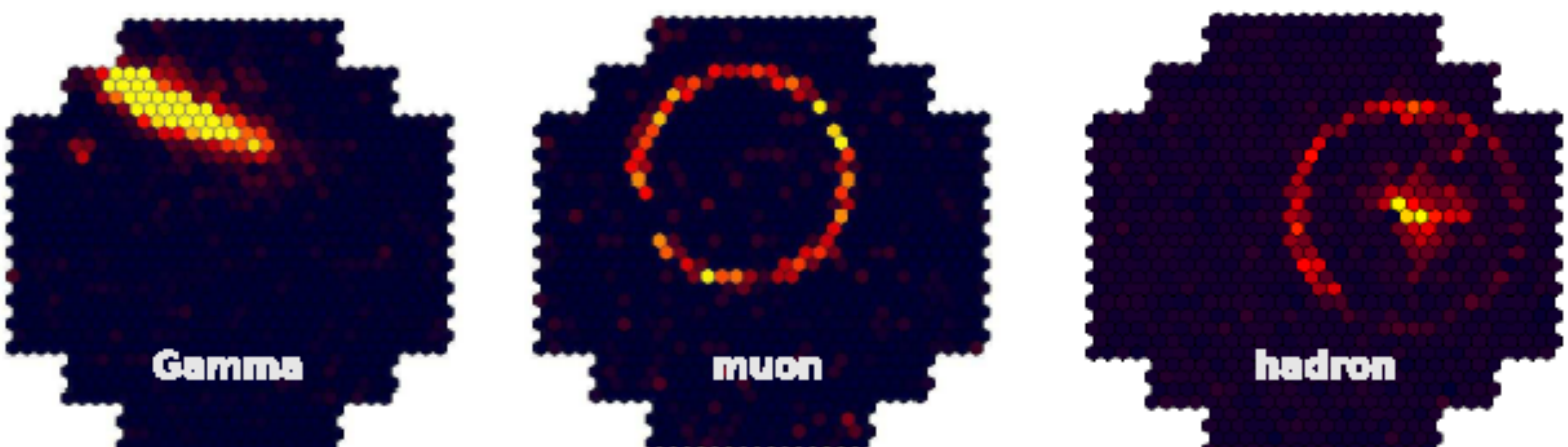


Experiment

HESS

HESS Experiment

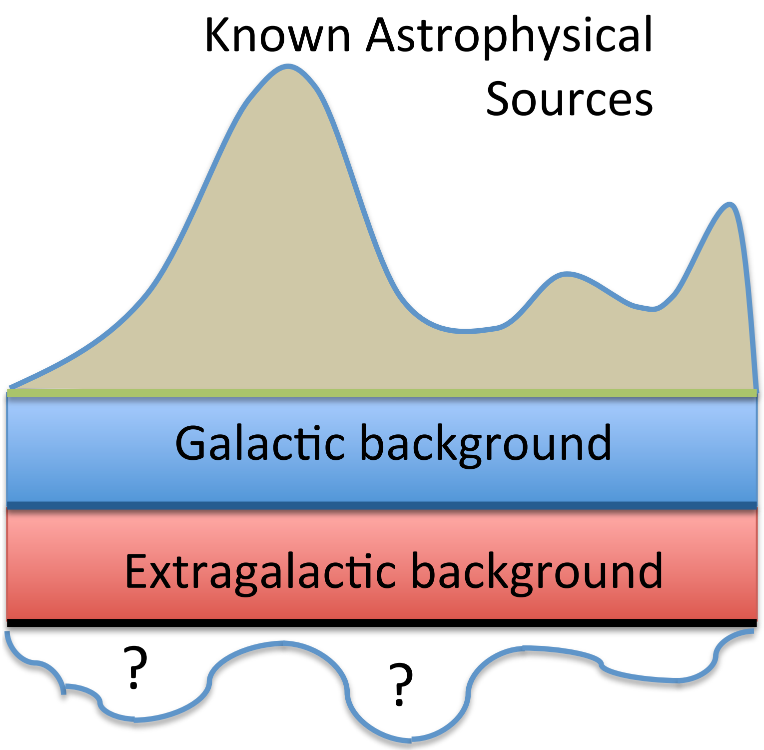
- HESS: 5 Cherenkov telescopes
  - Detection of a shower of secondary particles after the primary particle interacts with the atmosphere
  - Detected energies: 100 GeV (and ~20GeV for the fifth telescope) to a few tens of TeV
  - Resolution: 0,07˚ (HESS I)
  - Form recognition and stereoscopy



Study of the diffuse emissions with the H.E.S.S. experiment

Purpose : search for anomalies

- Study simultaneously the different cosmic-ray sources present in the field of view



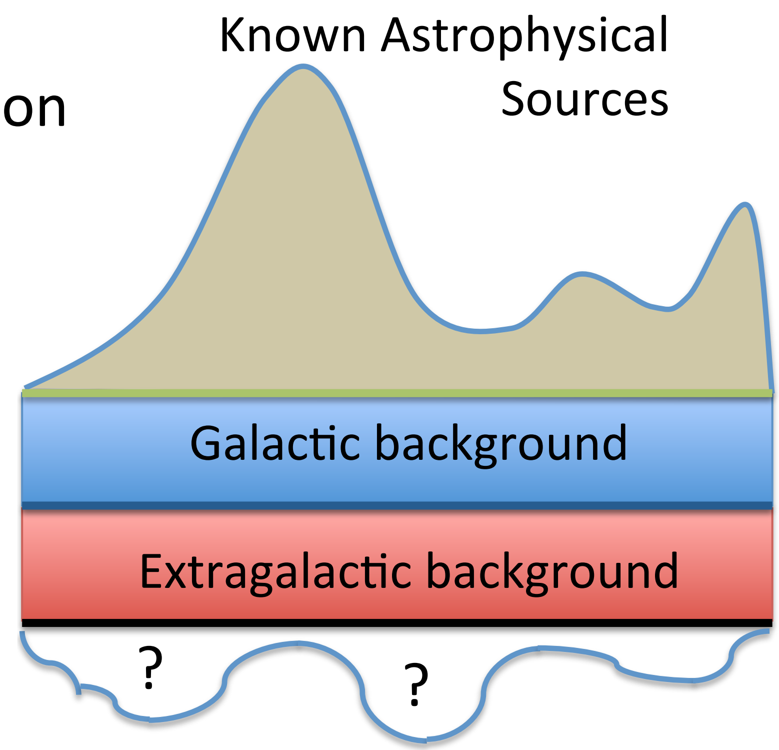
Benefits

- Whole field of view accessible
- Astrophysical sources occupy the region in the camera with the best efficiency and reconstruction
- The astrophysical source can be used as a control tool
- The method can be used for other studies (extended sources…)

Purpose : search for anomalies

- Study simultaneously the different cosmic-ray sources present in the field of view

- Weight their expected contribution to the spectrum based on component morphology



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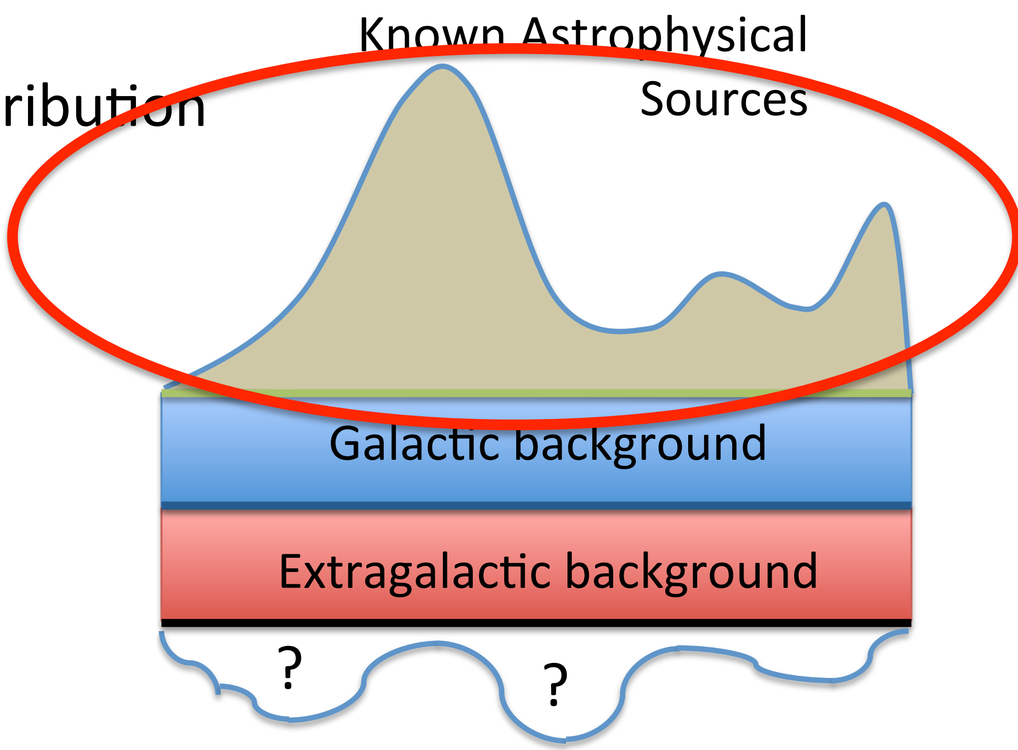


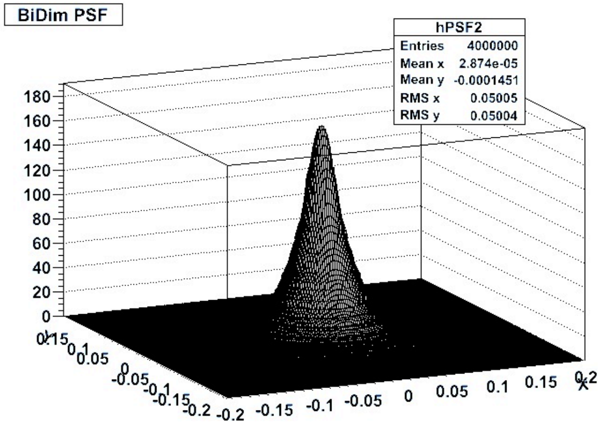
Method

Point-like source modelization

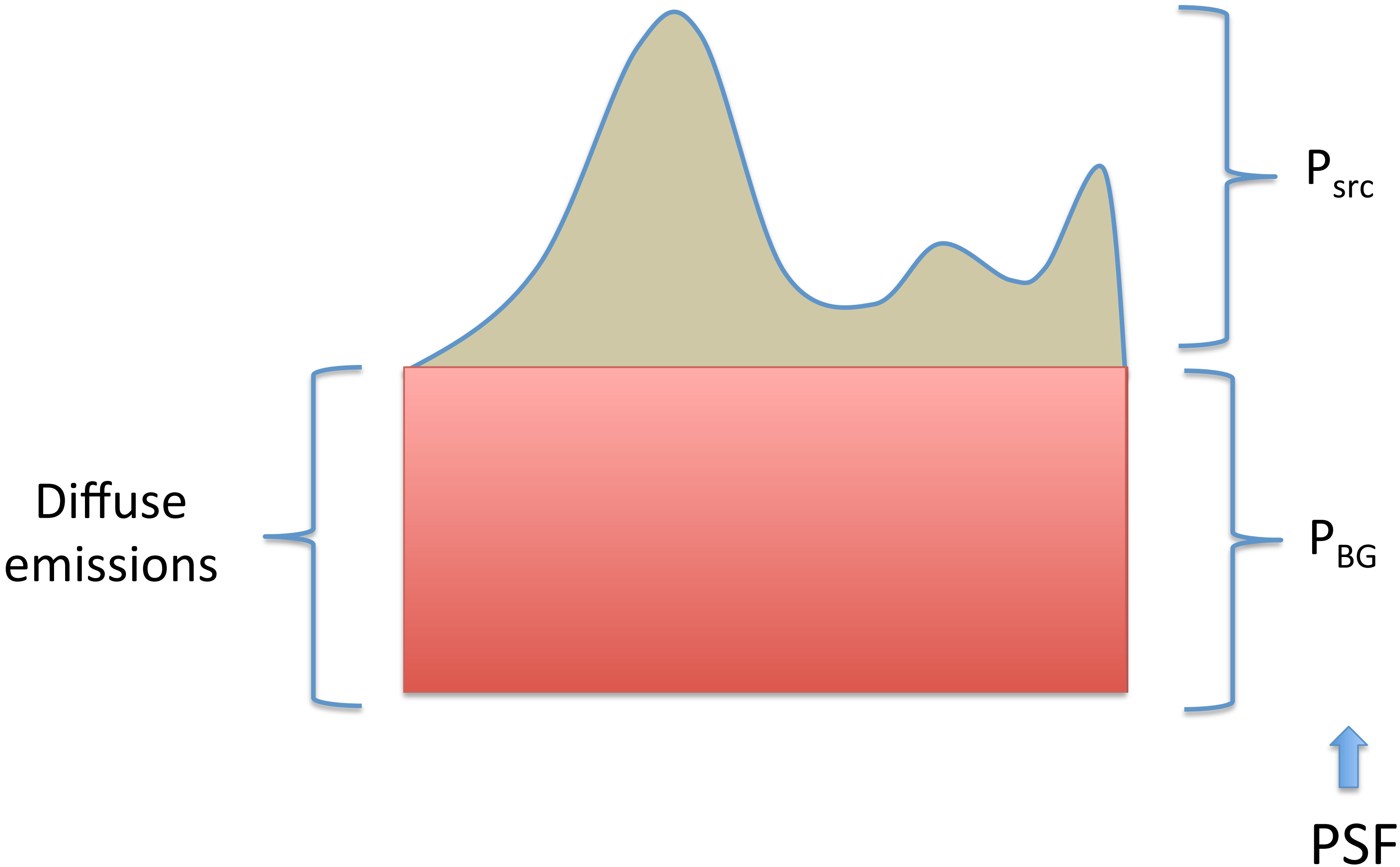
Modelling a point-like source by an enhanced PSF

- Keep the global shape of the PSF which is expected to be the best representation of a point like source
- Convoluted with Gaussian distribution to smear the distribution.

$$PSF(E, Zenith, OffAxis, OpticalEff) \circ Gauss(\sigma)$$

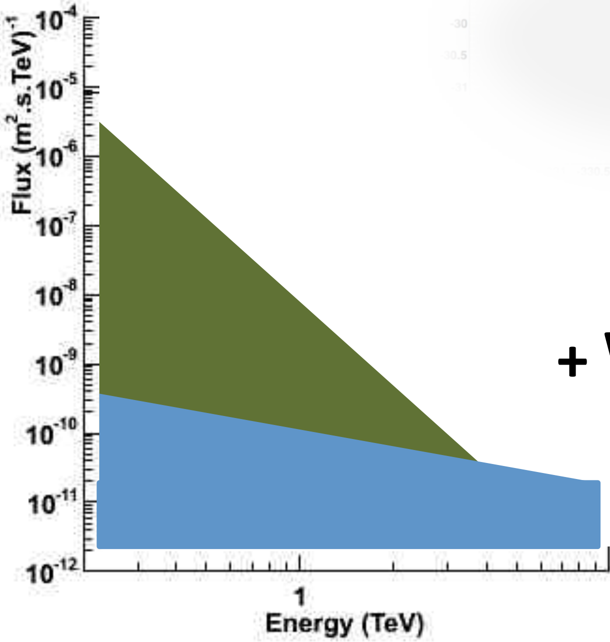


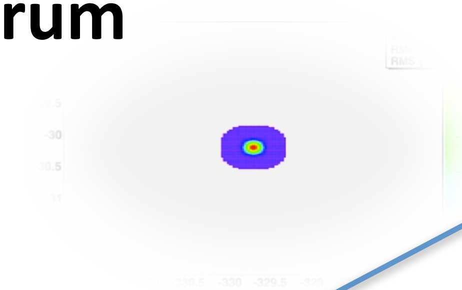
Weighting of the contributions to the spectrum



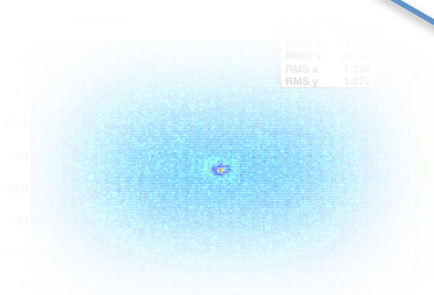
Weighting of the contributions to the spectrum

Global spectrum

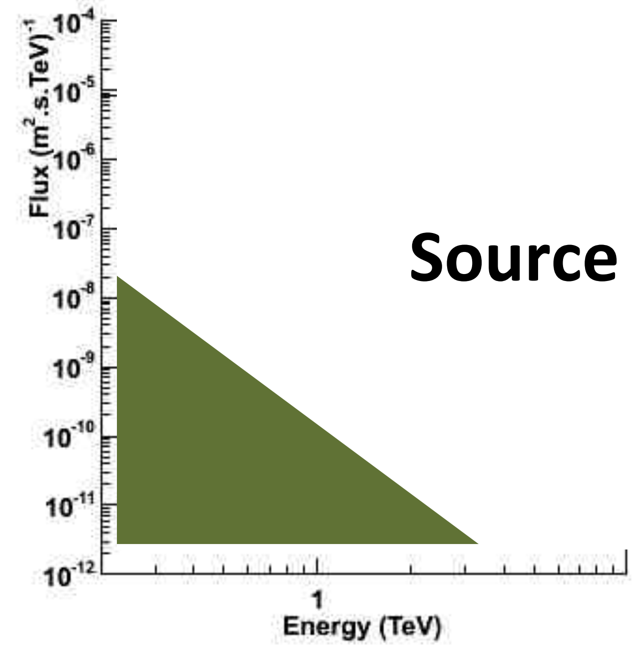




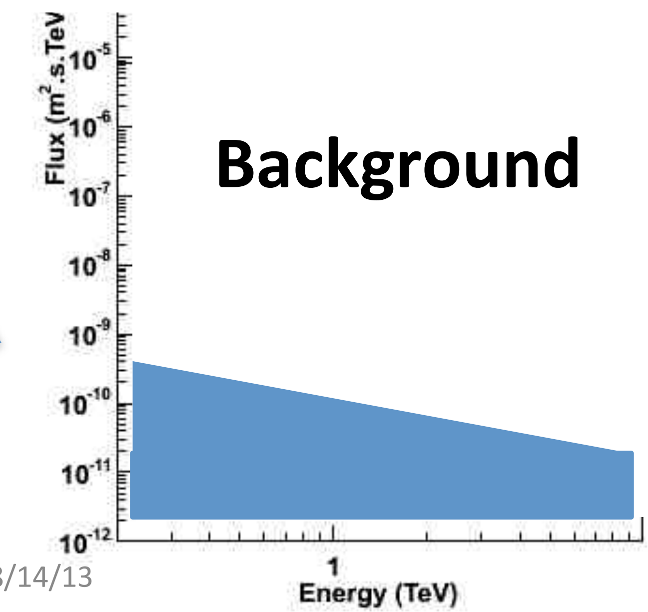
+ Weight map



Source



Background



Fitting method

- The multifit method:
  - Non-binned
  - Weighted
  - Likelihood method

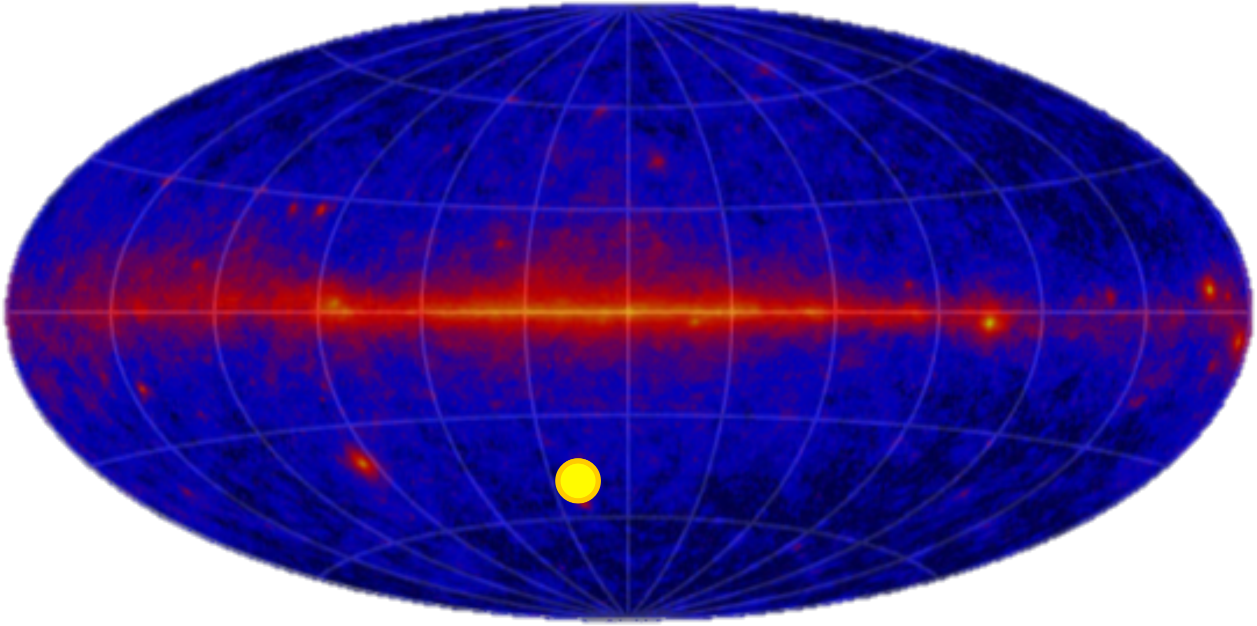
- <u>Hypothesis</u>: Powerlaws for each contribution

$$\frac{\mathrm{d}N}{\mathrm{d}E} = \Phi_0 \left(\frac{E}{E_0} \right)^{-\Gamma}$$

- Fitting the source and background contributions:

  -> spectral indices (Γ_i)

  -> flux (Φ_0)



Method : Point like source modelization

Application on PKS 2155-304

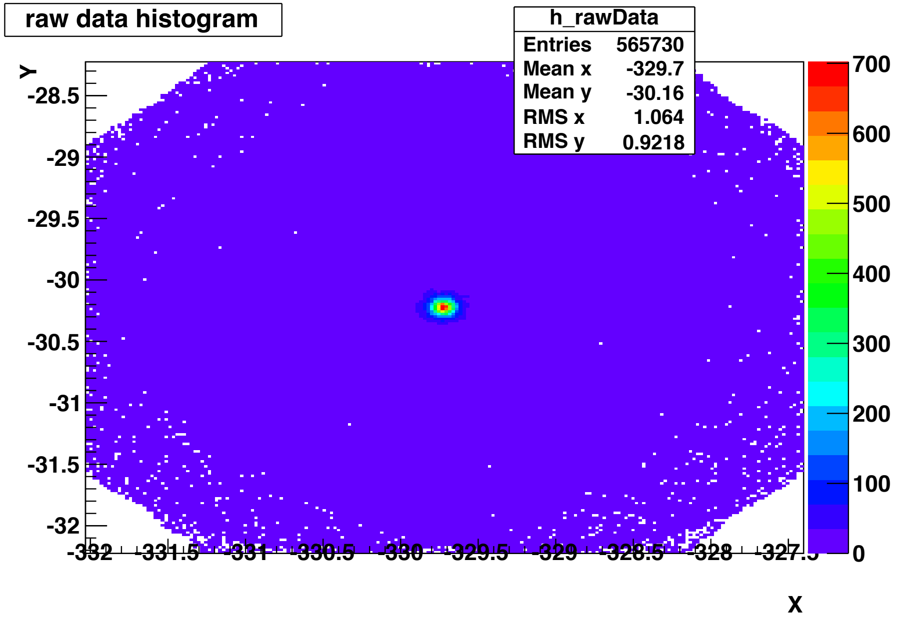
Fitting PKS 2155 – 304 during the "Chandra flare"

<u>Gamma in source</u> in a radius of 0.2˚ :

N_γ = 24 135 ± 155

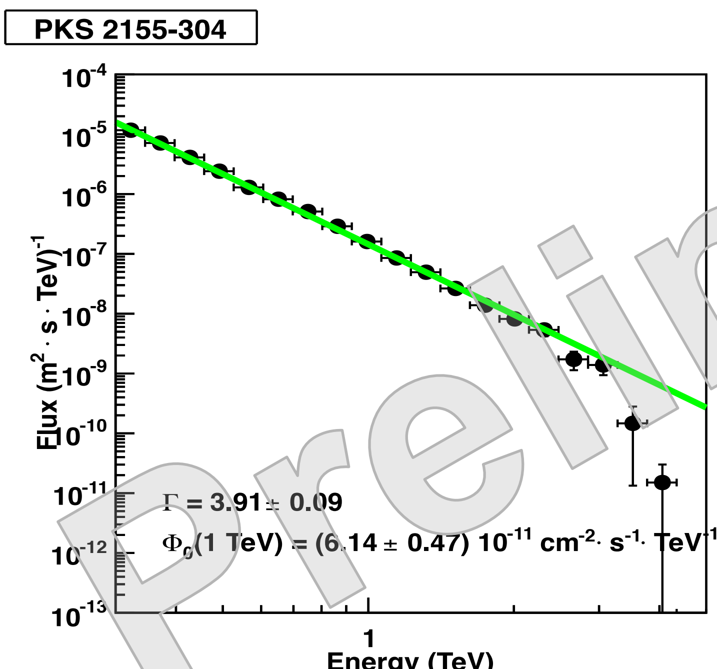
Standard method (ring background):

N_γ = 24 289 ± 156

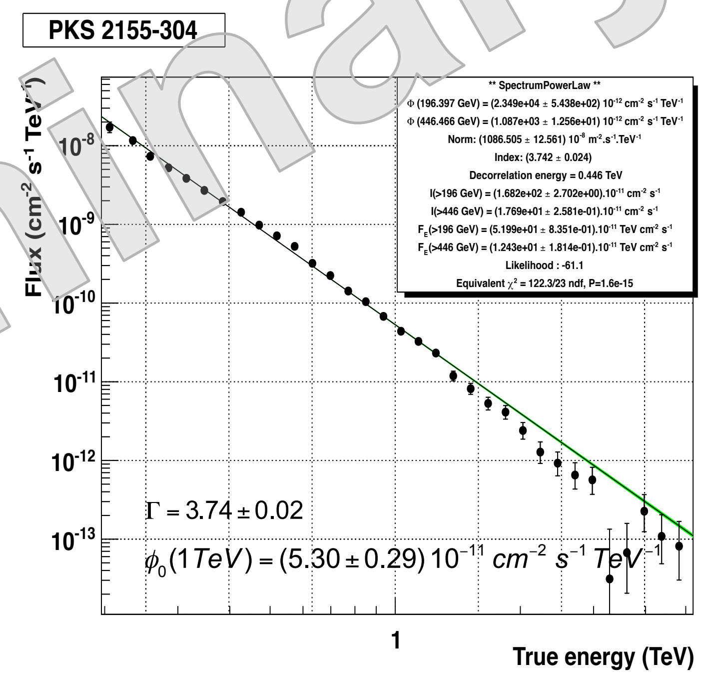


PKS 2155-304 spectrum

Convoluted PSF fit:



Standard method analysis:

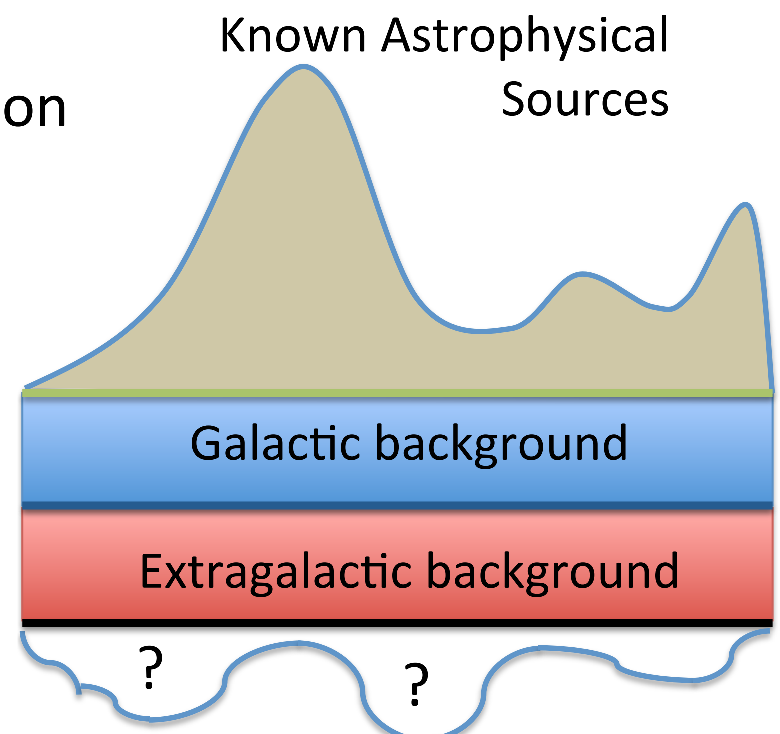


Method

Weighting the diffuse emissions

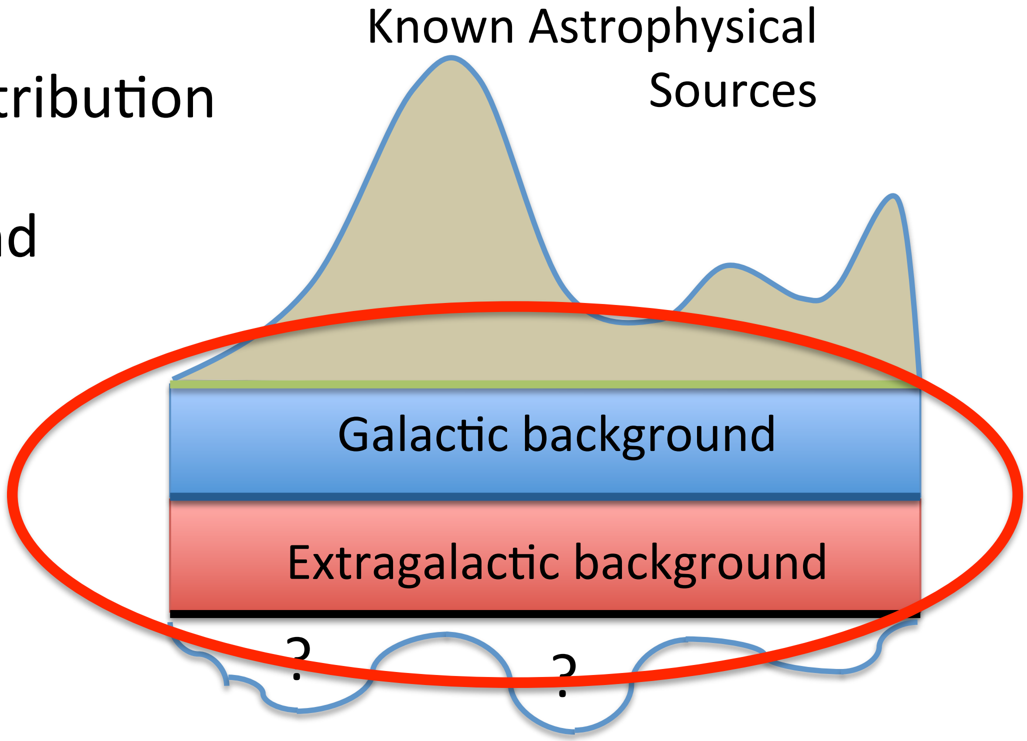
Purpose : search for anomalies

- Study simultaneously the different cosmic-ray sources present in the field of view
- Weight their expected contribution to the spectrum based on component morphology

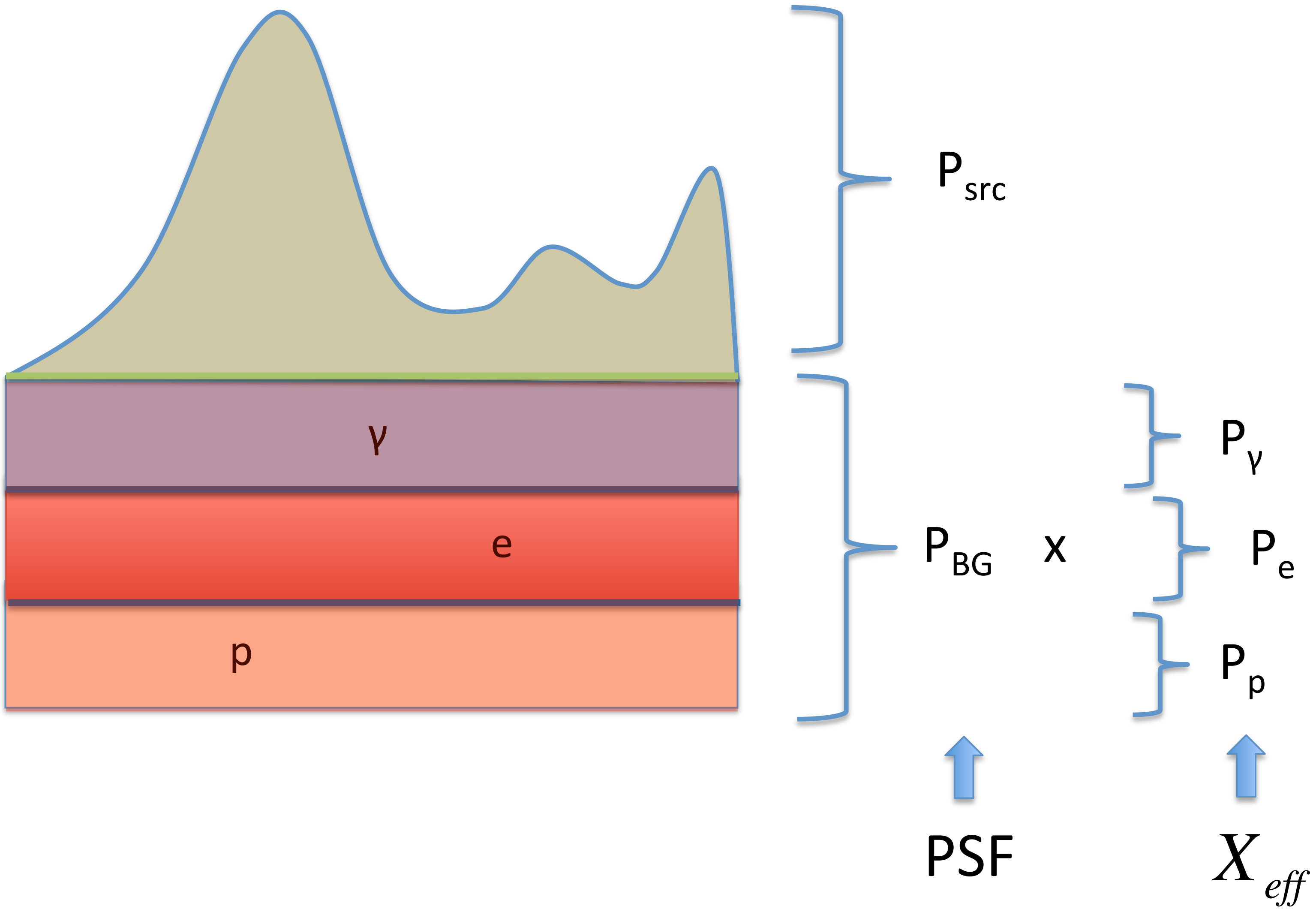


Purpose : search for anomalies

- Study simultaneously the different cosmic-ray sources present in the field of view
- Weight their expected contribution to the spectrum based on component morphology and discriminant variables



Weighting the diffuse emissions



Weighting the diffuse emissions

Background: protons + electrons + photons

-> Use of X_{eff} to separate the different components

$$X_{eff}^{i=e,p,\gamma} = \frac{\eta_i f_i}{\eta_e f_e + \eta_p f_p + (1 - \eta_p - \eta_e) f_\gamma}$$

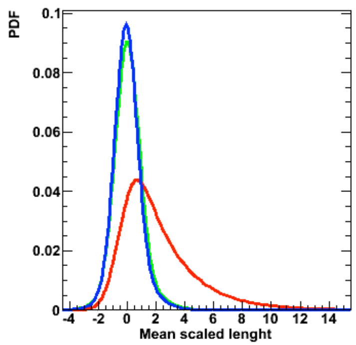
- f_e, f_γ and f_p obtained with simulations
- η_e and η_p obtained with the data

Weighting the diffuse emissions

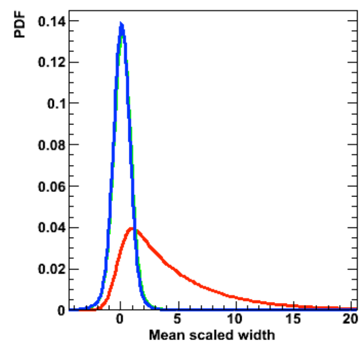
The discriminant variables

Protons vs EM :

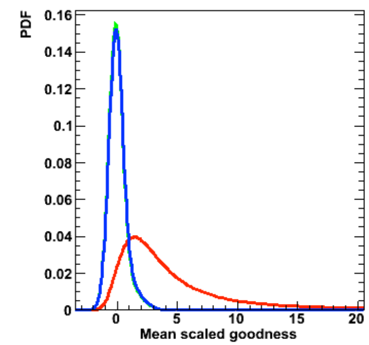
MSL



MSW

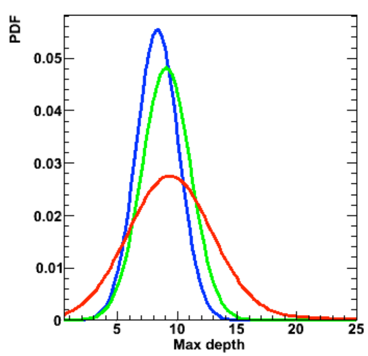


MSG

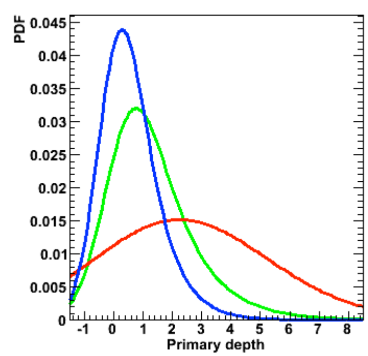


Electrons vs Gamma :

MDH



PDH



Weighting the diffuse emissions

Obtaining η_e and η_p with the data

<u>Protons vs EM</u>

$$f_{i=p,EM} = f_i(MSL) * f_i(MSW) * f_i(MSG)$$

$$L = \eta_p f_p + \eta_{EM} f_{EM}$$

$$1 = \eta_p + \eta_{EM}$$

<u>Electrons vs Gamma</u>

$$f'_{i=p,e,\gamma} = f'_i(PDH) * f'_i(MDH)$$

$$L' = \eta_p f'_p + \eta_e f'_e + (1 - \eta_e - \eta_p) f'_\gamma$$

$$\eta_{EM} = \eta_e + \eta_\gamma$$

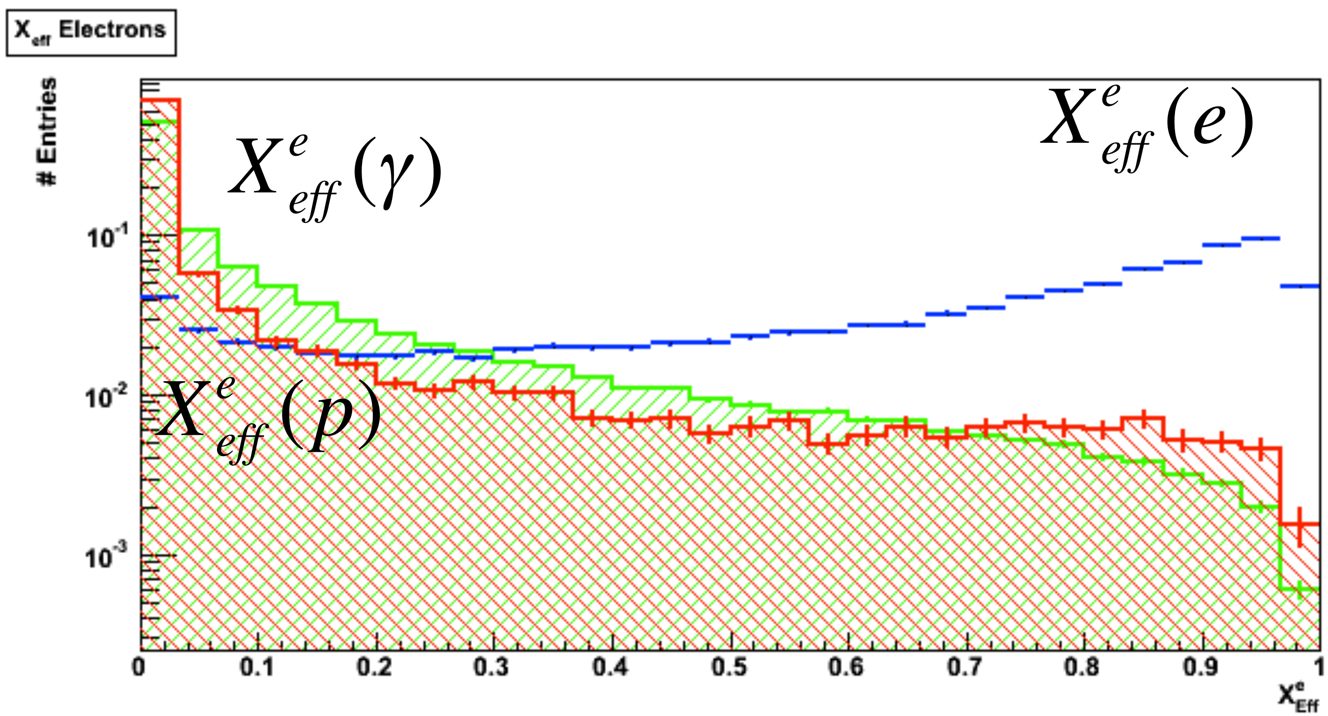
<u>Combined simultaneous adjustment on two subsamples:</u>

minimization of : $$\sum_{j=1}^{N_A} -\log(L_A^j) + \sum_{j=1}^{N_B} -\log(L_B^j)$$

Weighting the diffuse emissions

Calculating probabilities with X_{eff}

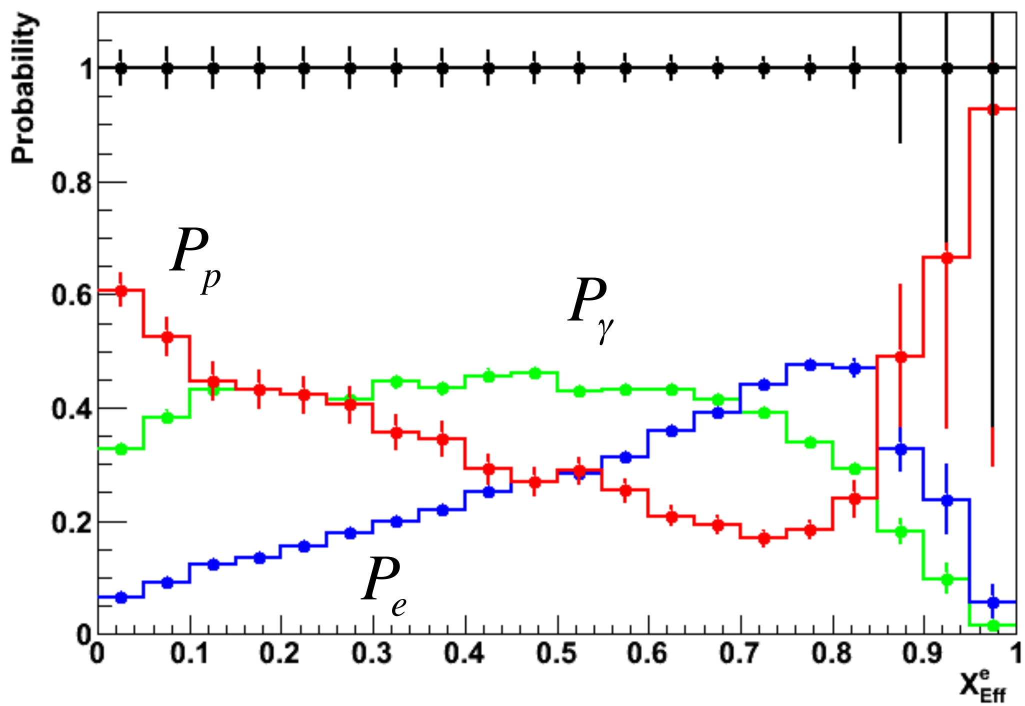
$$X_{eff}^{e} = \frac{\eta_e f_e}{\eta_e f_e + \eta_p f_p + (1 - \eta_p - \eta_e) f_\gamma}$$

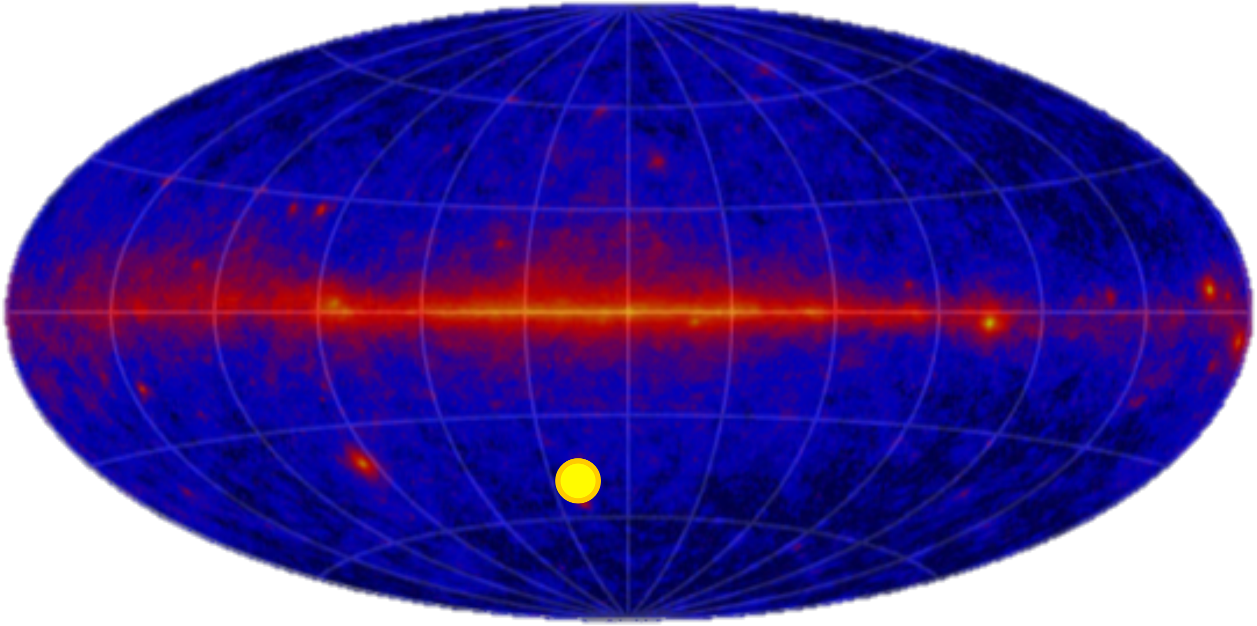


Weighting the diffuse emissions

Calculating probabilities with X_{eff}

$$P_{i=e,\gamma,p} = \frac{X^e{}_{eff}(i)}{X^e{}_{eff}(e) + X^e{}_{eff}(\gamma) + X^e{}_{eff}(p)}$$





Method : Weighting the diffuse emissions

Application on PKS 2155-304

Weighting the diffuse emissions

- <u>Concentrations of the diffuse emissions</u> :

  (excluding 0.4° around the source)

$$\eta_\gamma < 6.8\cdot 10^{-4} \quad 95\%\ \mathrm{CL}$$
$$\eta_e = (1.58 \pm 0.01)\%$$
$$\eta_p = (98.42 \pm 0.03)\%$$

It is not yet possible to conclude on the spectra, because the discriminant variables are still under study.

However, using the concentrations above and simulating a powerlaw with the same number of events, a flux can be put forward.

Hypothesis: extragalactic emission predominant, with $\Gamma = 2.41 \pm 0.05$ (Fermi, 2010)

- <u>Upper limit on the Gamma-ray flux</u> :

$$\phi_\gamma(1\,TeV) < (3.39 \pm 0.2)\ 10^{-6}\ \mathrm{m^{-2}\ s^{-1}\ TeV^{-1}\ sr^{-1}}$$

Thank you!