Hands-on session I

Quick intro to ctools

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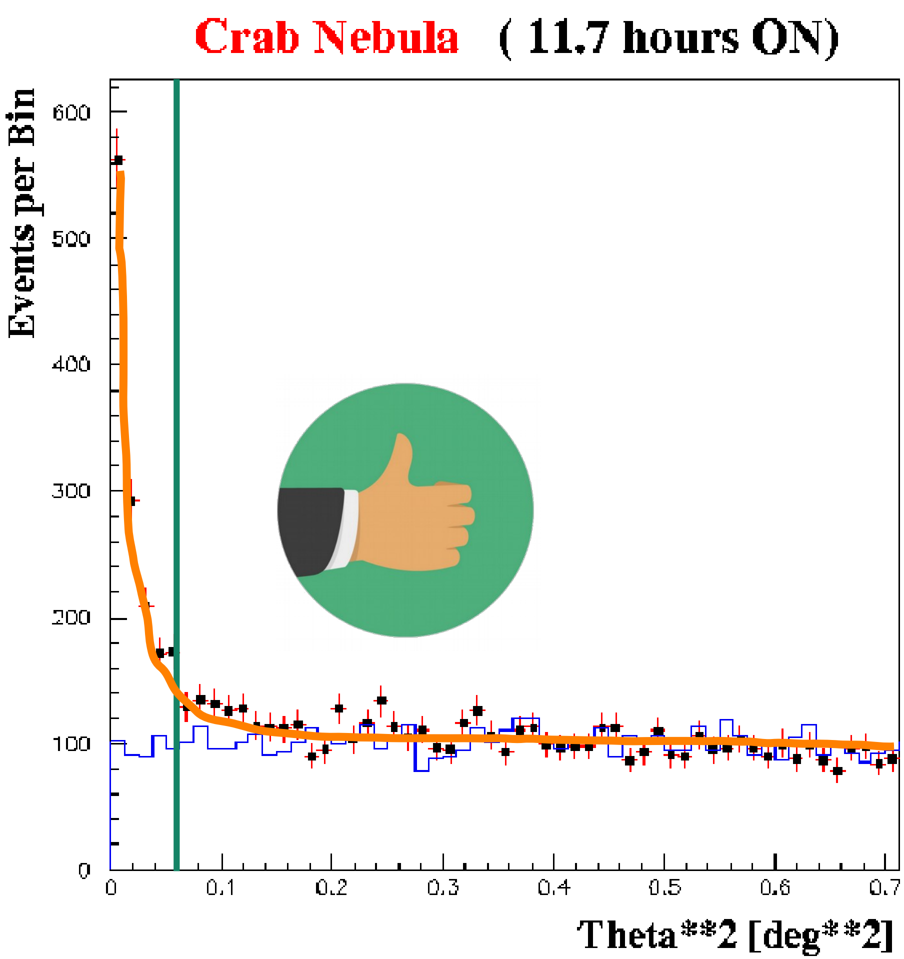
DESY

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

CTA analysis – Likelihood analysis

- Basics of CTA analysis:



1) Assume a **model**:
(e. g. point-like source)

2) **Simulate** the number of events + background

3) Compare the simulation with the data, and calculate the likelihood ratio

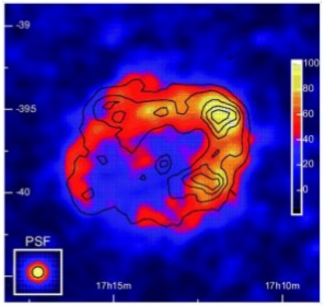
4) Iteratively repeat steps 1, 2 and 3, until you find the model better matching the data

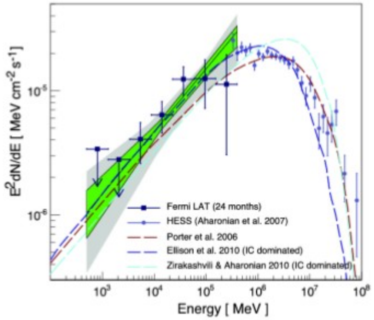
What are the ctools?

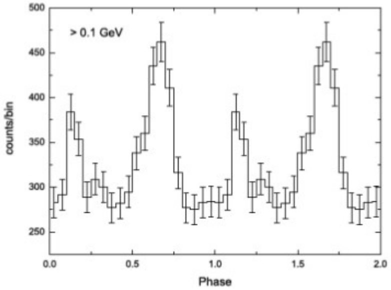
- Tools for **end users** to extract science results from Cherenkov Telescope Array event lists and instrument response functions

Background reduced event lists
Instrument response functions

Simulated event lists
Instrument response functions







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What are the ctools?

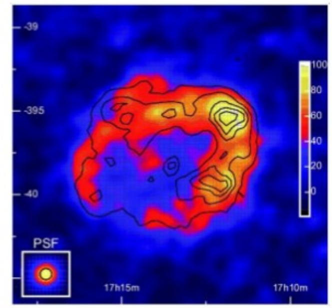
- Tools for **end users** to extract science results from Cherenkov Telescope Array event lists and instrument response functions

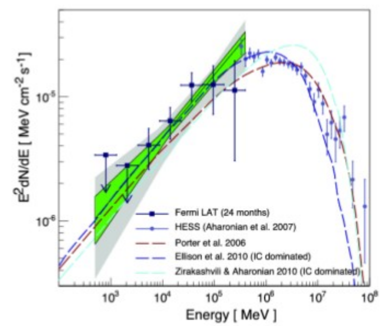
Ba ound reduc lists
Inst nt respons tions

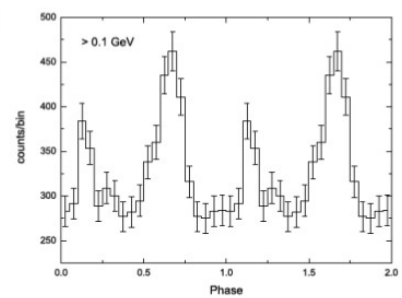
No CTA data yet… :-(

Simulated event lists
Instrument response functions

ctools
cherenkov telescope array







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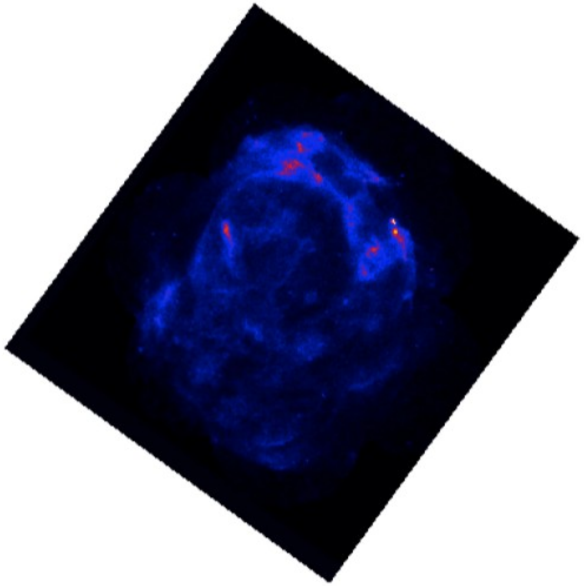
Ctools analysis – Simulating CTA data

- As there is no CTA data yet, ctools allows to simulate it:



1) Define spacial and spectral model

Ctools analysis – Simulating CTA data

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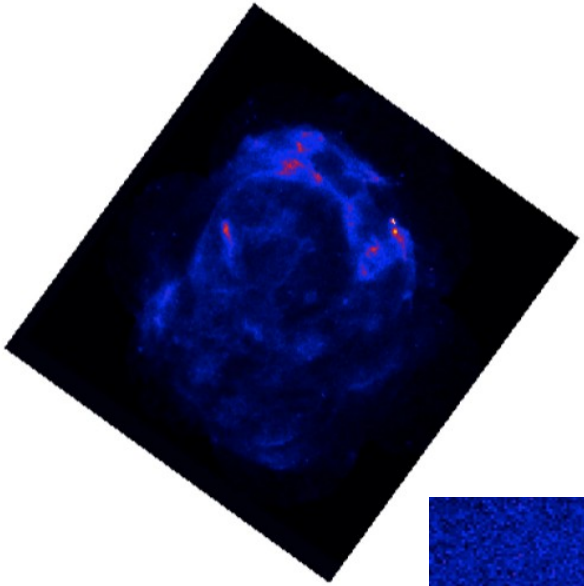

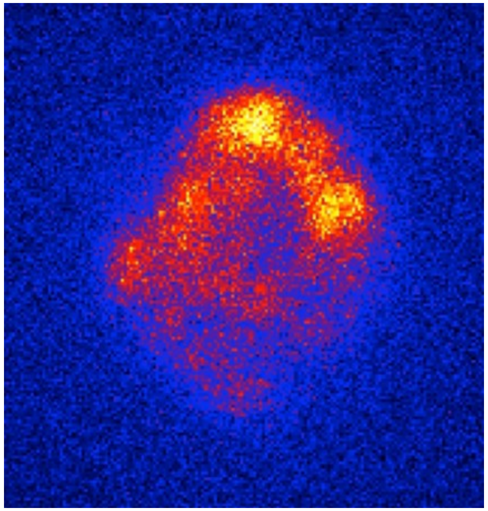

1) Define spacial and spectral model

2) Using CTA instrument response functions, simulate how CTA data would look like

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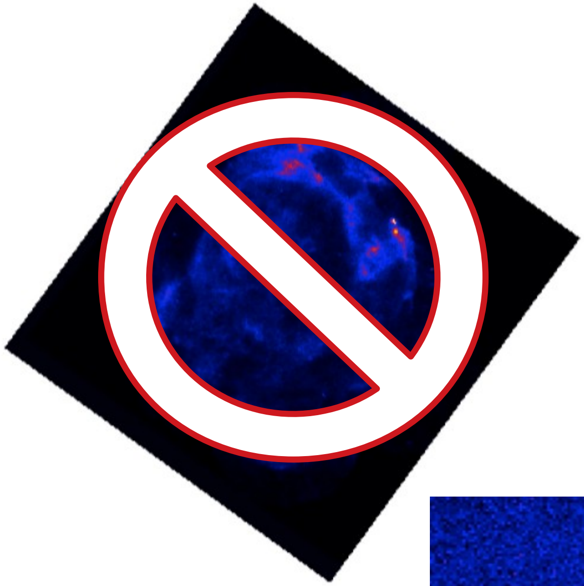

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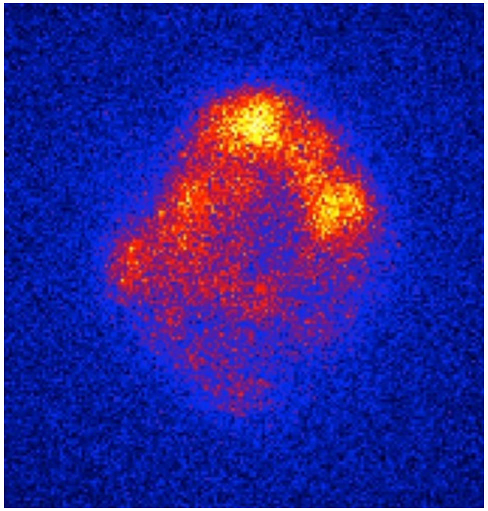

3) From this point on, treat this simulated data as real data, and study CTA performance on this scientific topic

ctools analysis – Example

Fitting with a shell model

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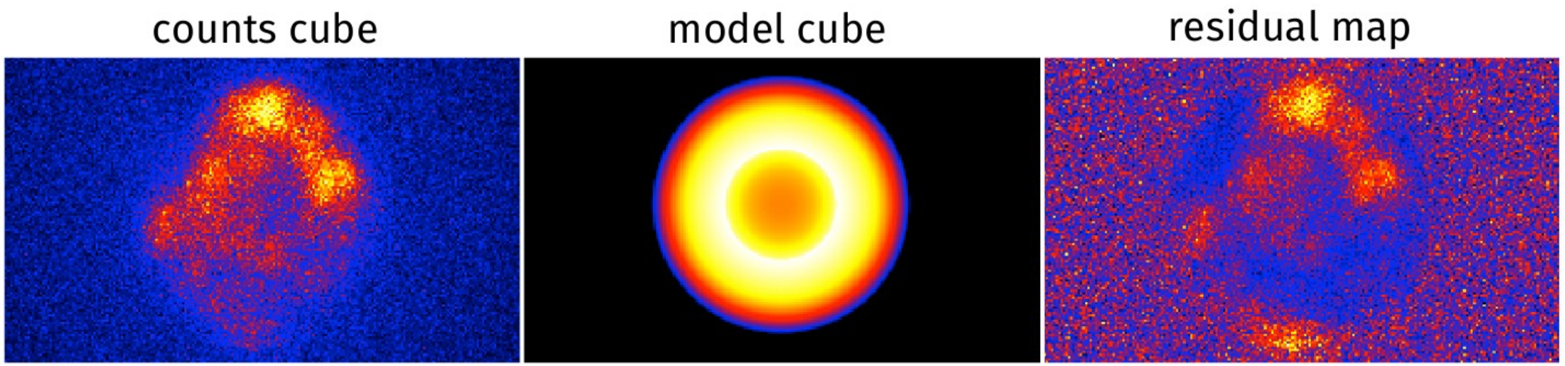

- Here, we try to fit the simulated observation to a shell model
- By computing the residual map (difference between best-fit model to data), we can have a look about the quality of the fit

ctools analysis – Example

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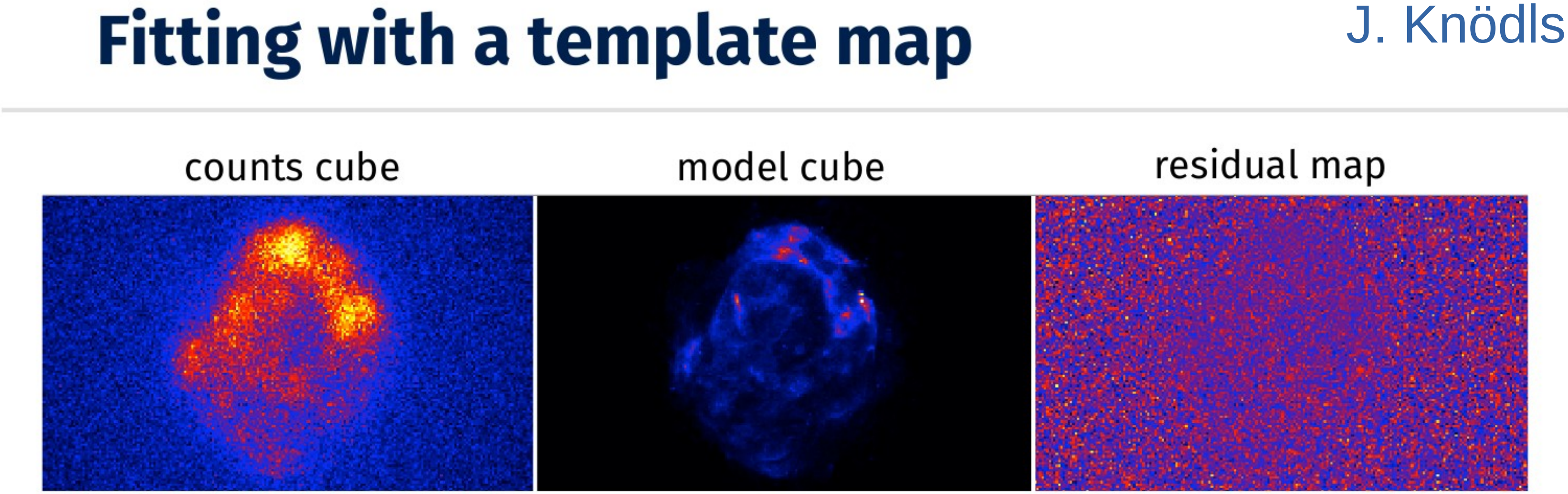

- Here, we try to fit the simulated observation to a shell model
- By computing the residual map (difference between best-fit model to data), we can have a look about the quality of the fit
- If we use as model the template we used initially, the fit should be (artificially) excellent

ctools analysis – Example

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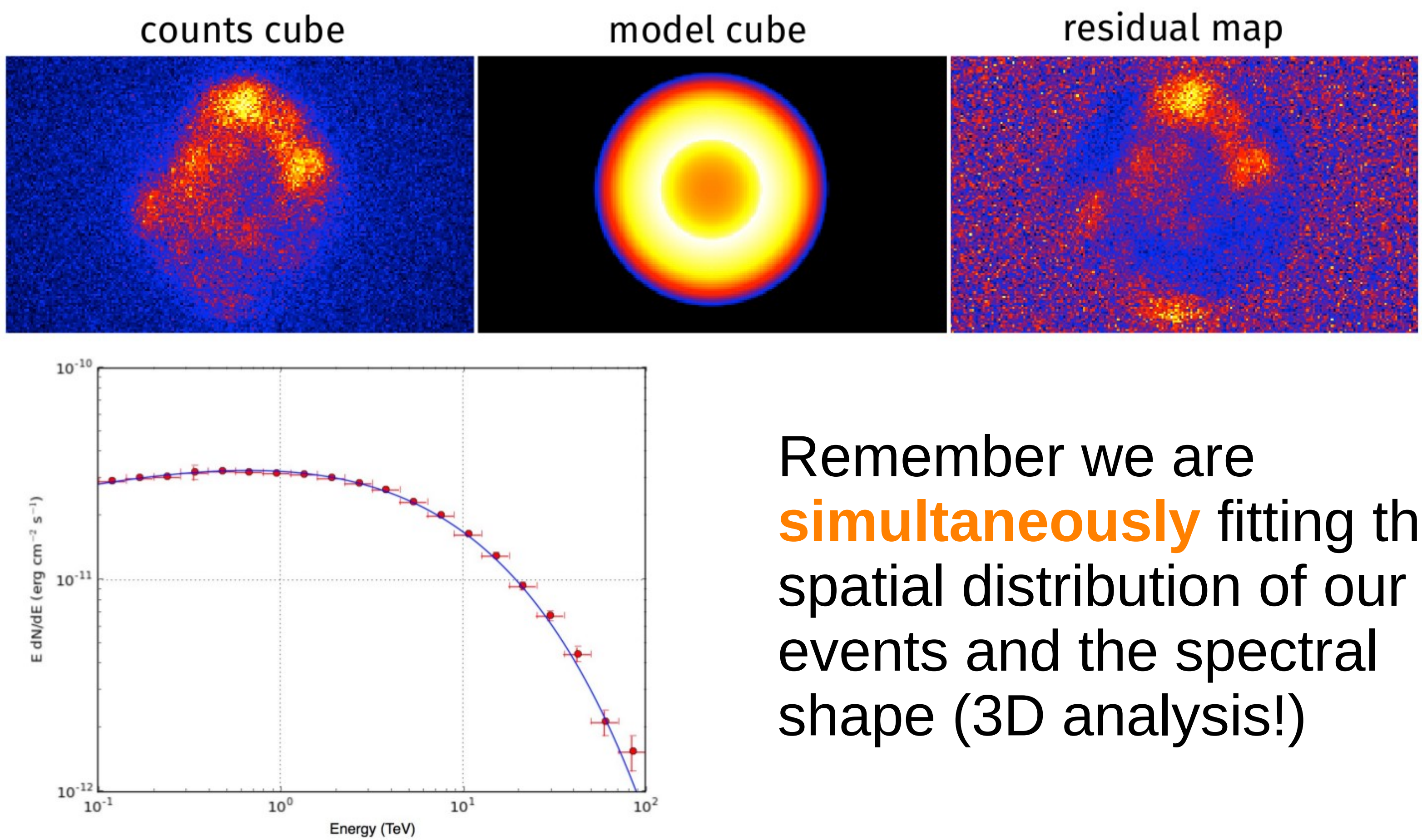
Fitting with a shell model



Remember we are **simultaneously** fitting the spatial distribution of our events and the spectral shape (3D analysis!)

Model summary

- Spatial
  - Point source
  - Radial symmetric models
    - Gaussian
    - Disk
    - Shell
  - Elliptical models
    - Gaussian
    - Disk
  - "Diffuse" models
    - Map
    - Map cubes (energy dependent maps)
    - Isotropic
- Temporal
  - Constant
- Spectral
  - Power law
  - Broken power law
  - Exponentially cut off power law
  - Super exponentially cut off power law
  - Log parabola
  - Gaussian (line)
  - File function
  - Node function
  - Constant

Everything you need is in [ctool's model documentation]

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What is in ctools?

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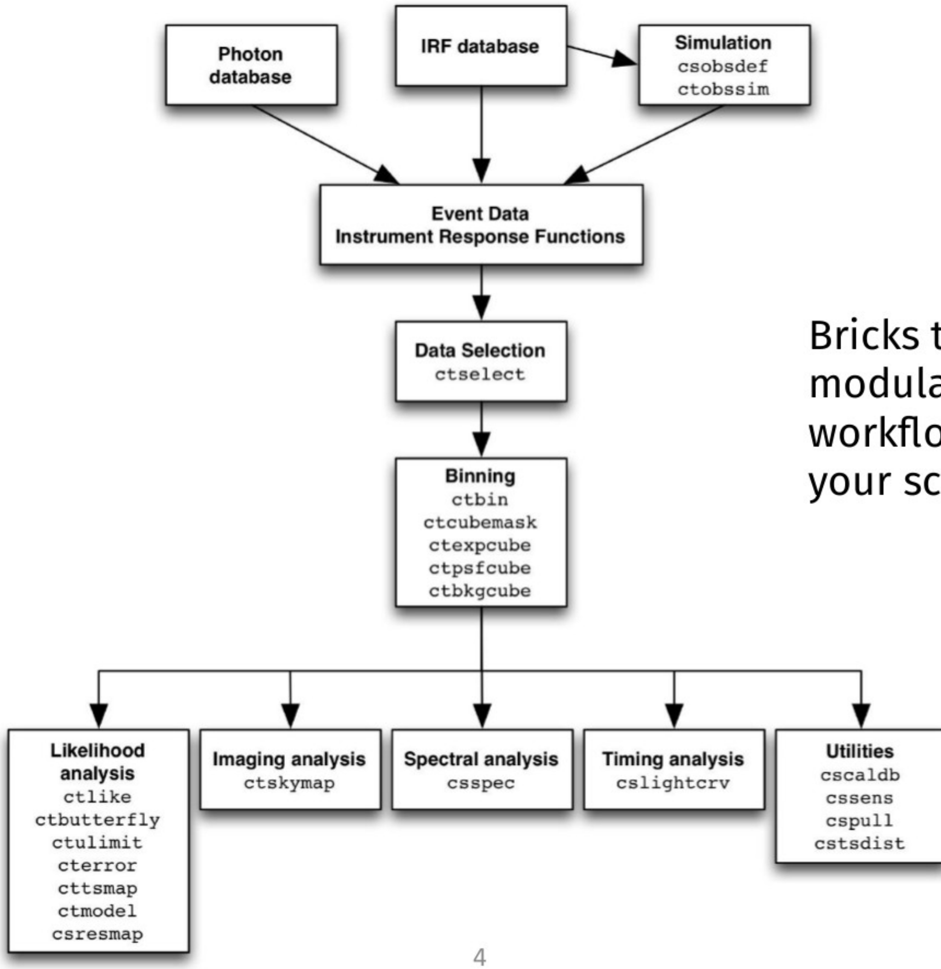


Bricks to build a modular analysis workflow suited to your science needs

Find documentation for all ctools scripts here:
http://cta.irap.omp.eu/ctools/users/reference_manual/index.html

ctools analysis – Hands-on session I

- Make sure we understand these steps:
  - Understand model definition (xml files)
  - Simulate a CTA observation
  - Understand how 3D analyses are performed


BACKUP

IACT technique – MC simulations

- The Instrument Response Function relates the array reconstructed quantities with the parameters of the source emitted photons

$$R_\gamma(\theta', \phi', E' | \theta, \phi, E) = A_\gamma(\theta, \phi, E) \times PSF(\theta', \phi' | \theta, \phi, E) \times D(E' | \theta, \phi, E)$$

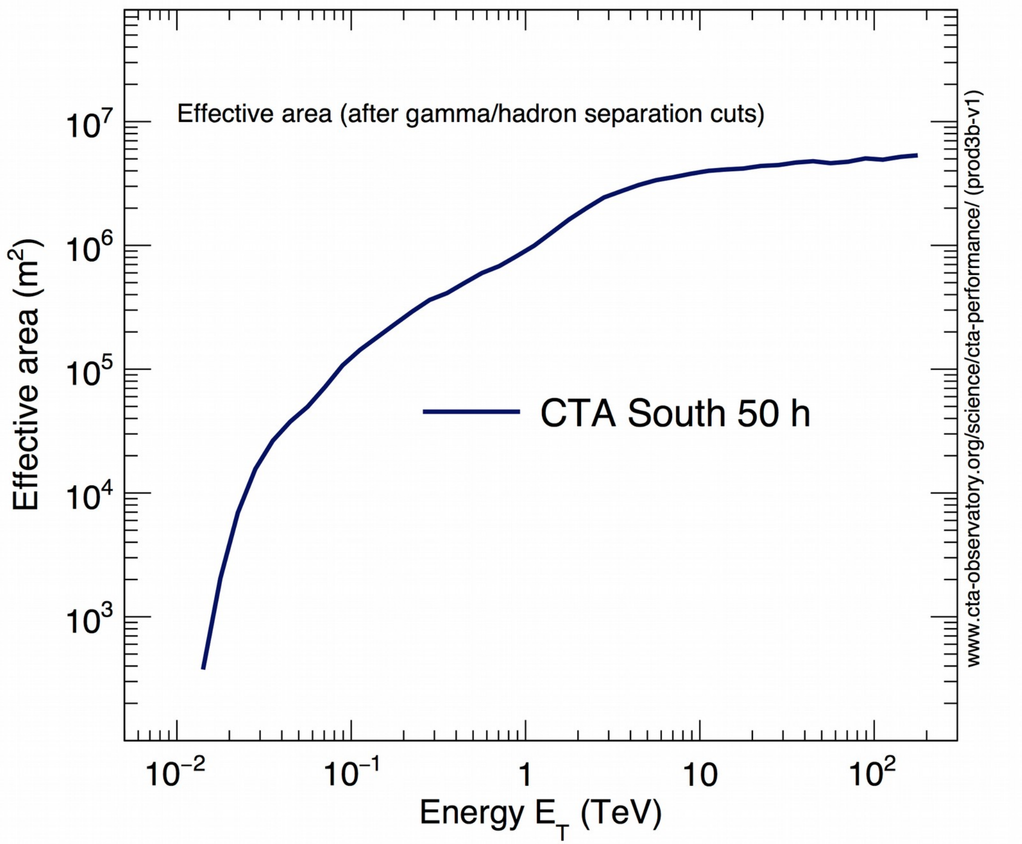
- The IRF elements are:
  - Effective area
  - Energy dispersion
  - Direction dispersion (PSF)
  - Hadronic background “acceptance”

IACT IRFs – Effective area

- If we detect X amount of gammas during Y amount of time… What is the flux of the source? → Need effective area

- $A_{sim} * N_{analysis}(E) / N_{sim}(E)$

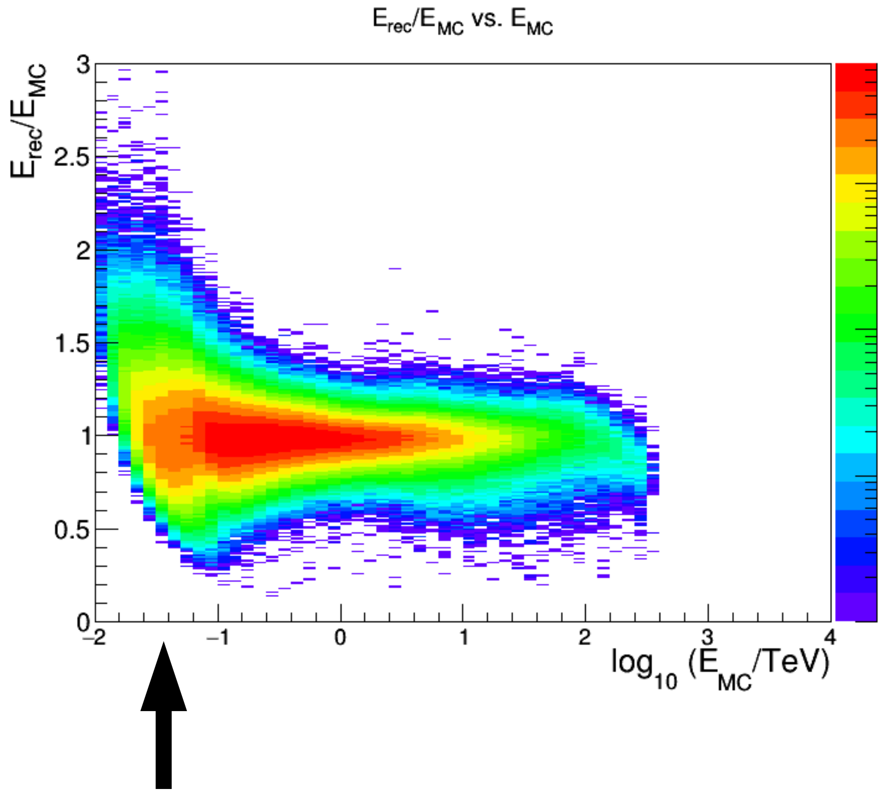
- Strongly affected by the low-level analysis

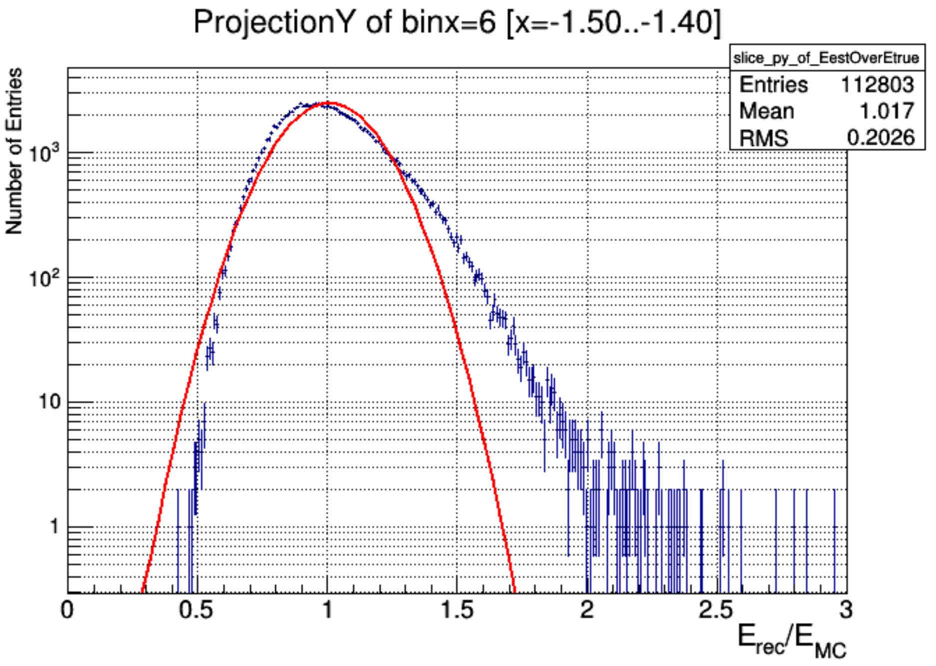


IACT IRFs – Energy migration

- Energy reconstruction is not perfect (actually, it's pretty bad…)

- Need to take into account it's dispersion in the analysis





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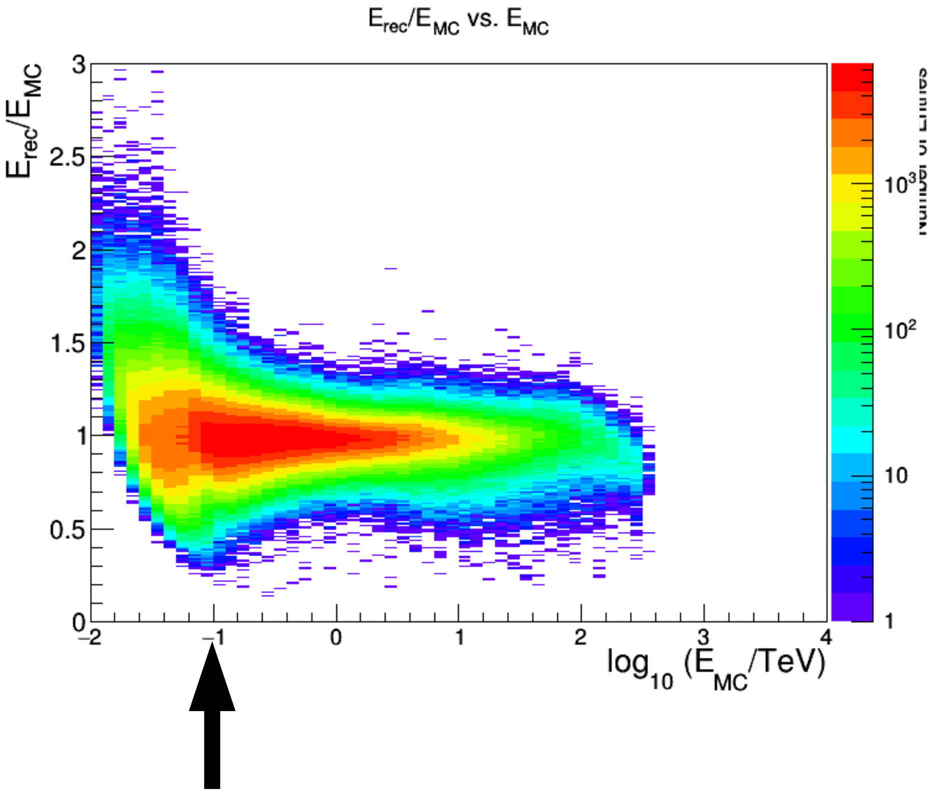

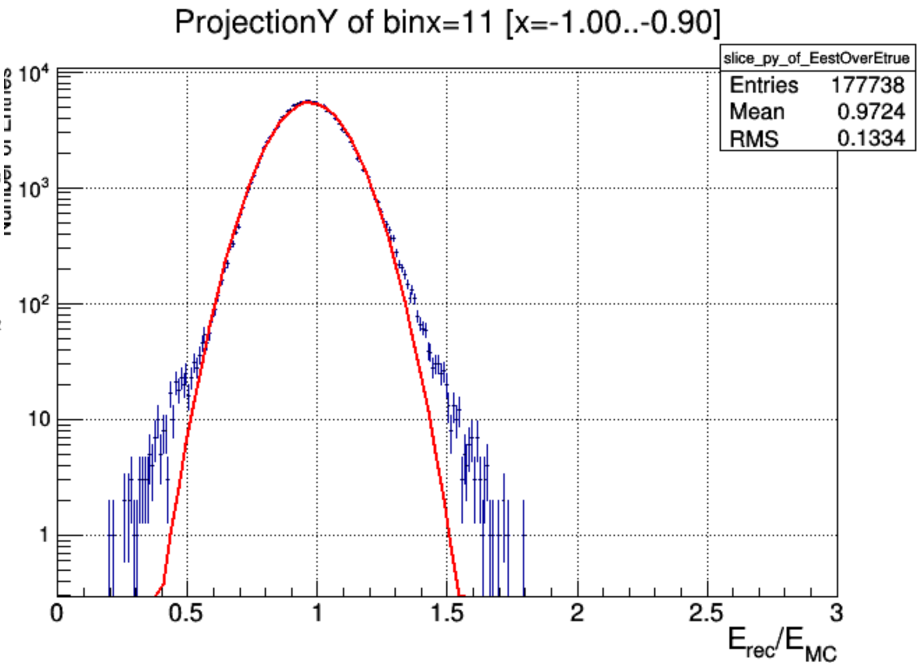

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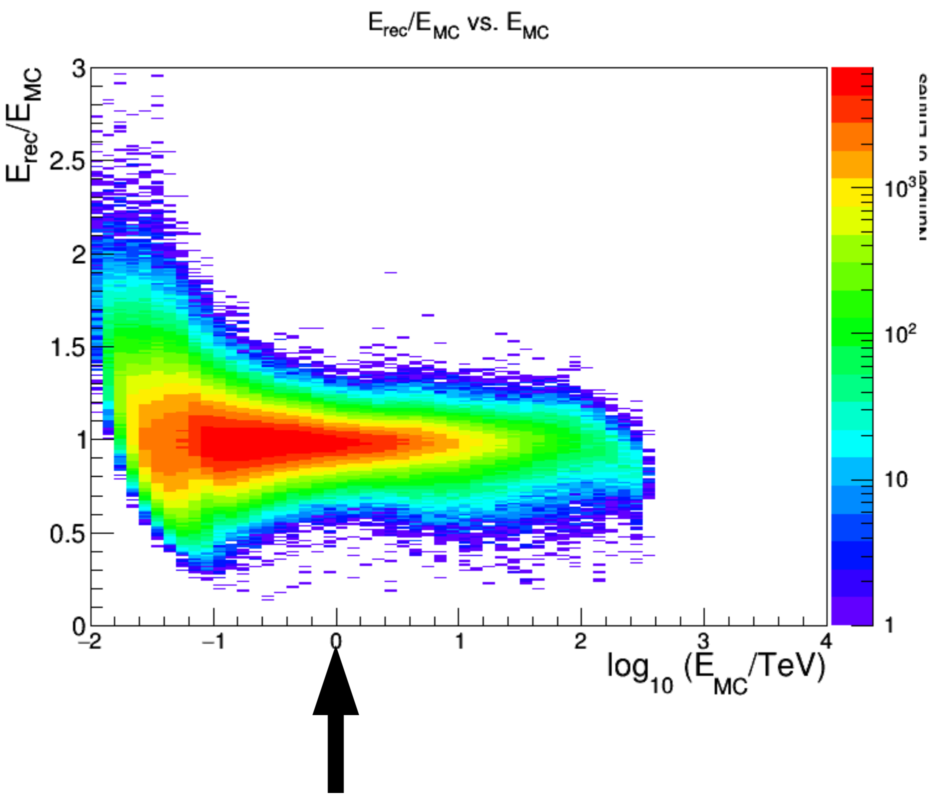

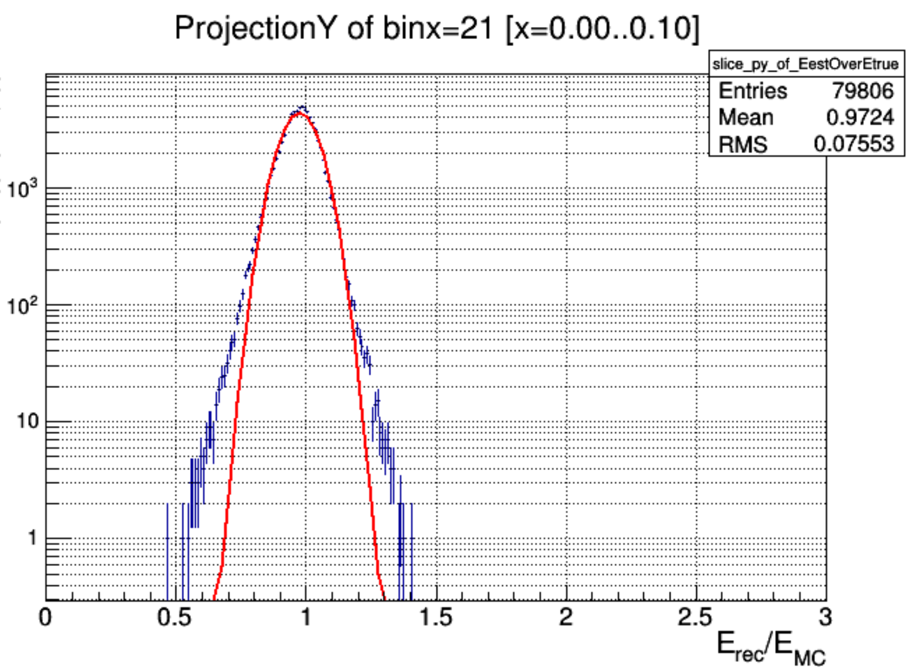

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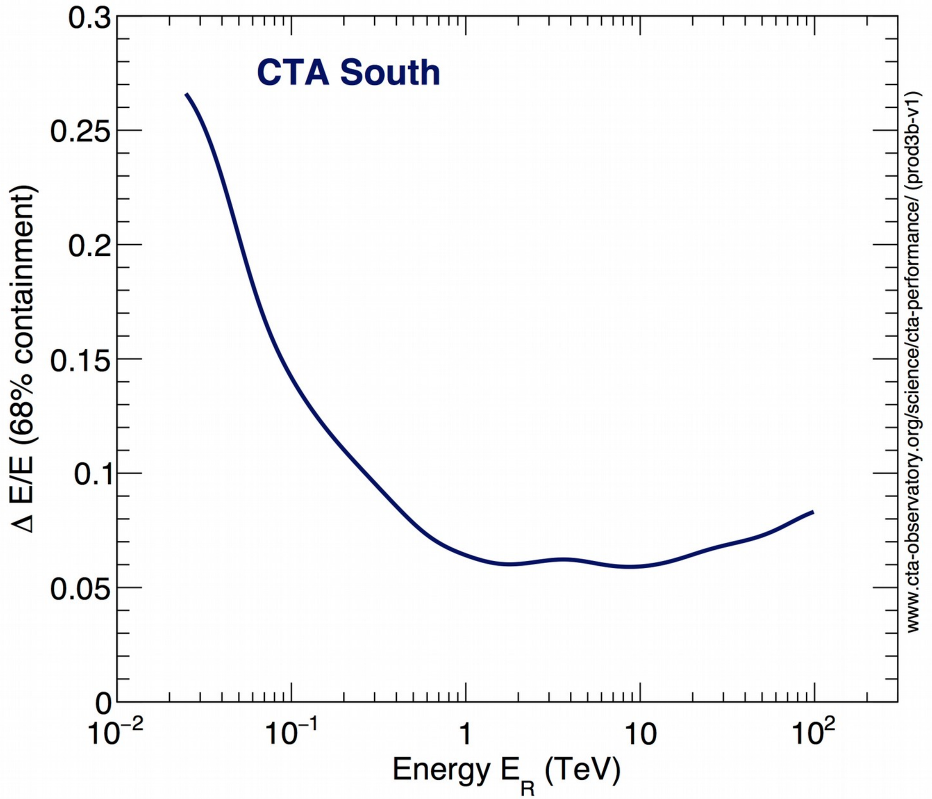

IACT IRFs – Direction reconstruction

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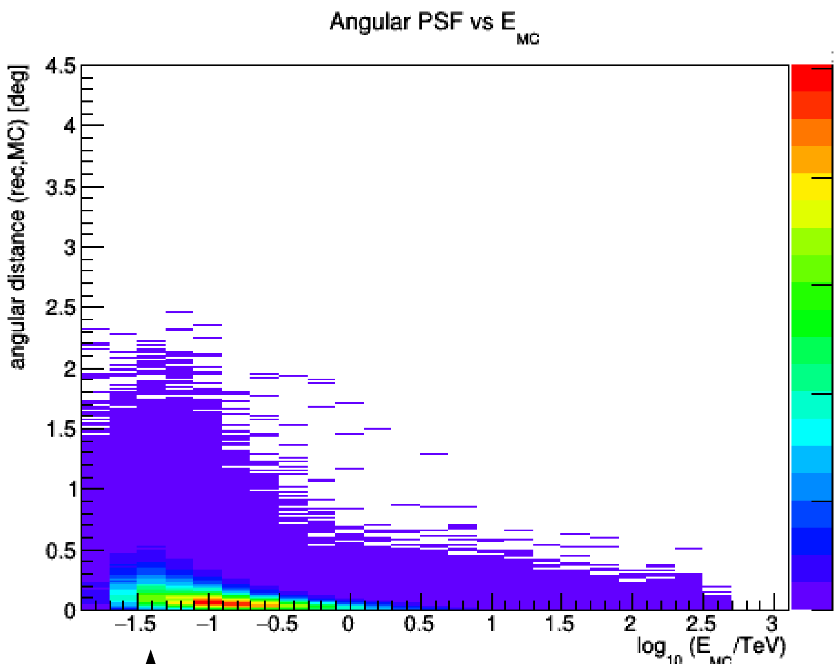
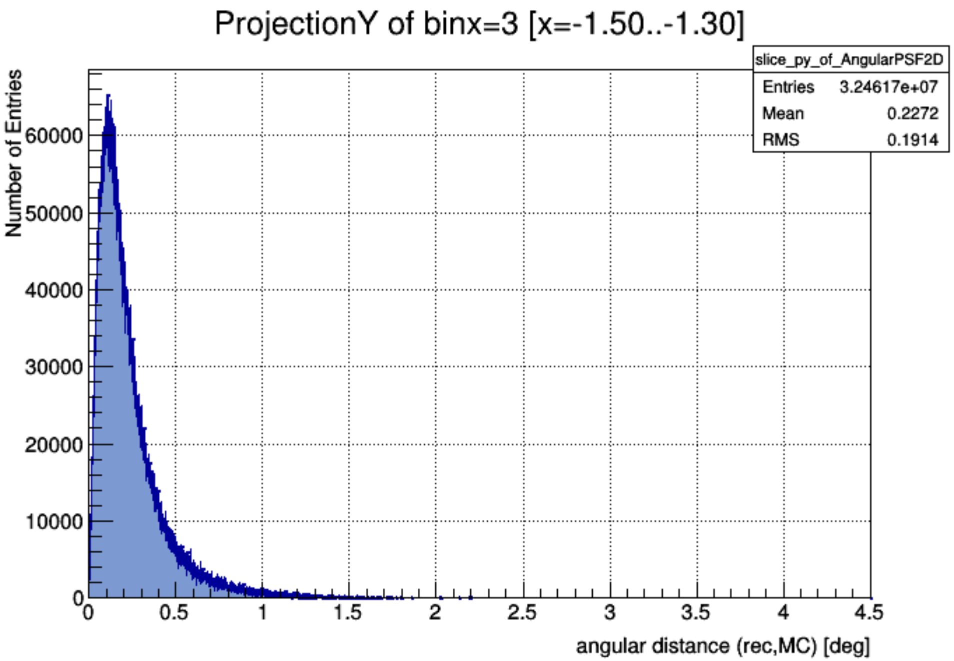
- To study source morphology, it's crucial to understand our **point spread function** (PSF)





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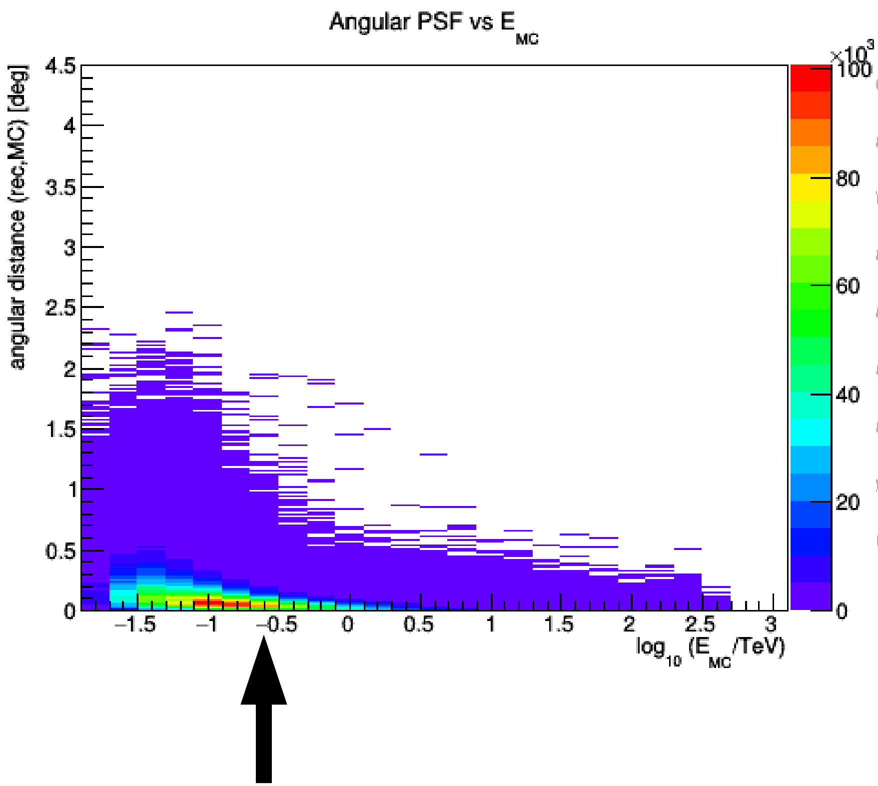

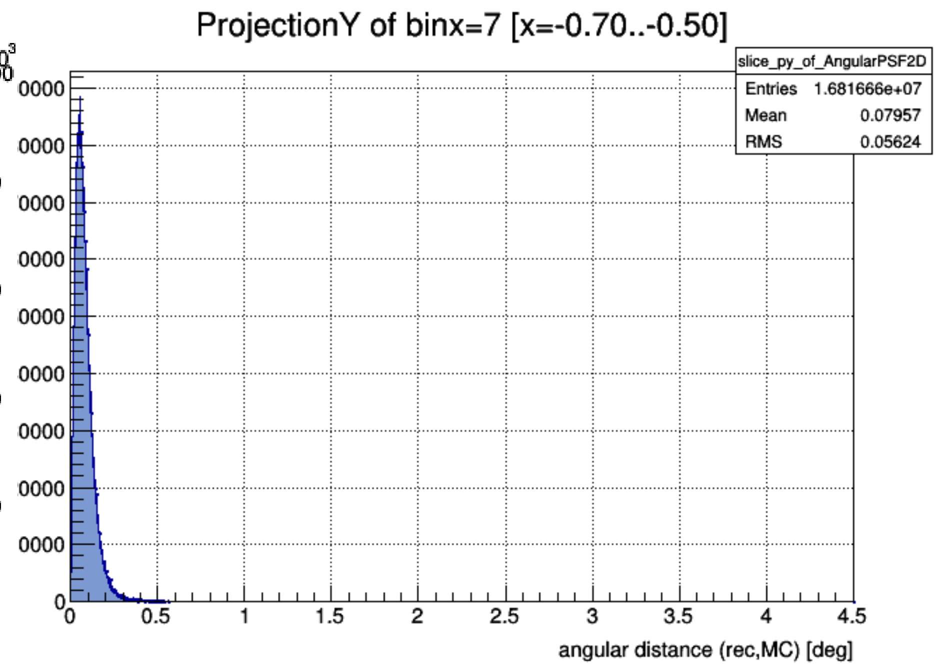

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