TEMPLATE ANALYSIS FOR THE MAGIC TELESCOPES

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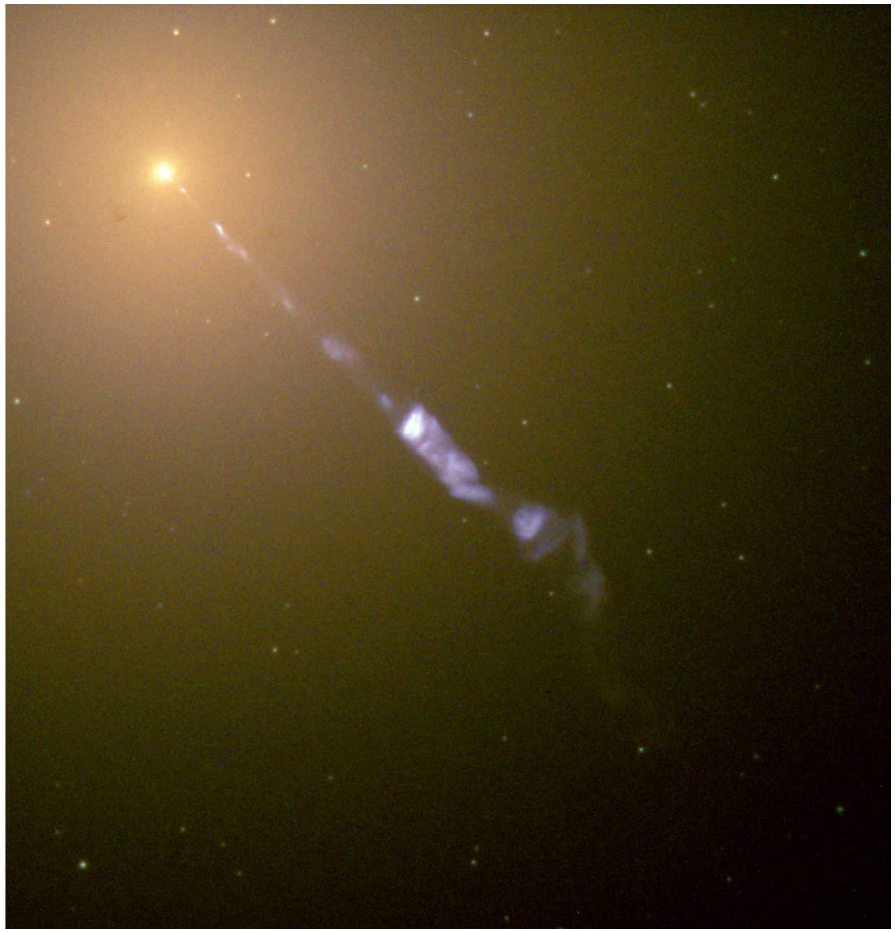
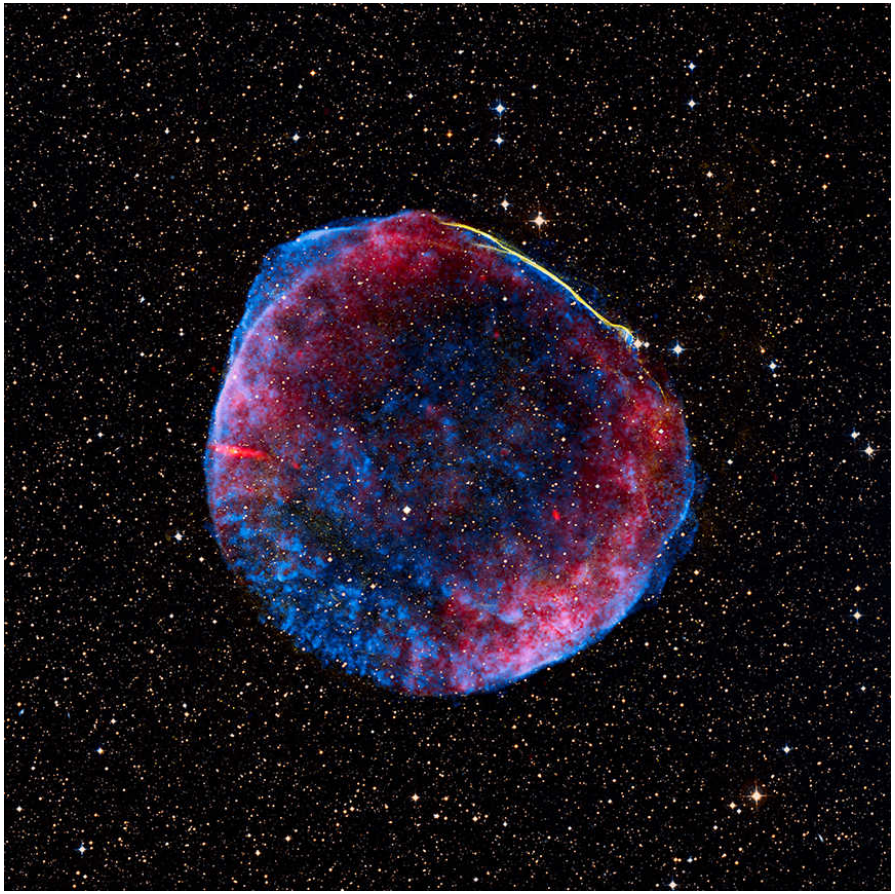
Outline

- Imaging Air Cherenkov Technique (IACT)
- Standard analysis of MAGIC
- My work - Template analysis

Examples of Gamma-ray Sources



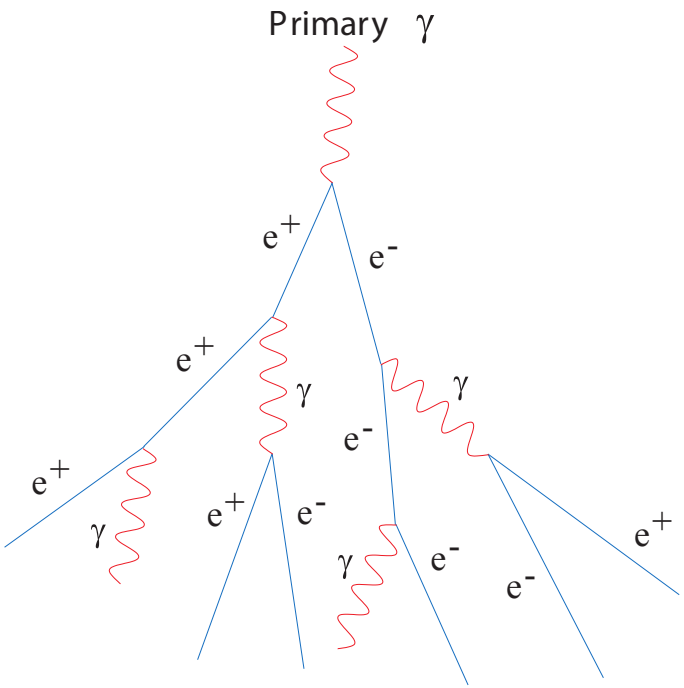
Active galactic nucleus



Supernova remnant

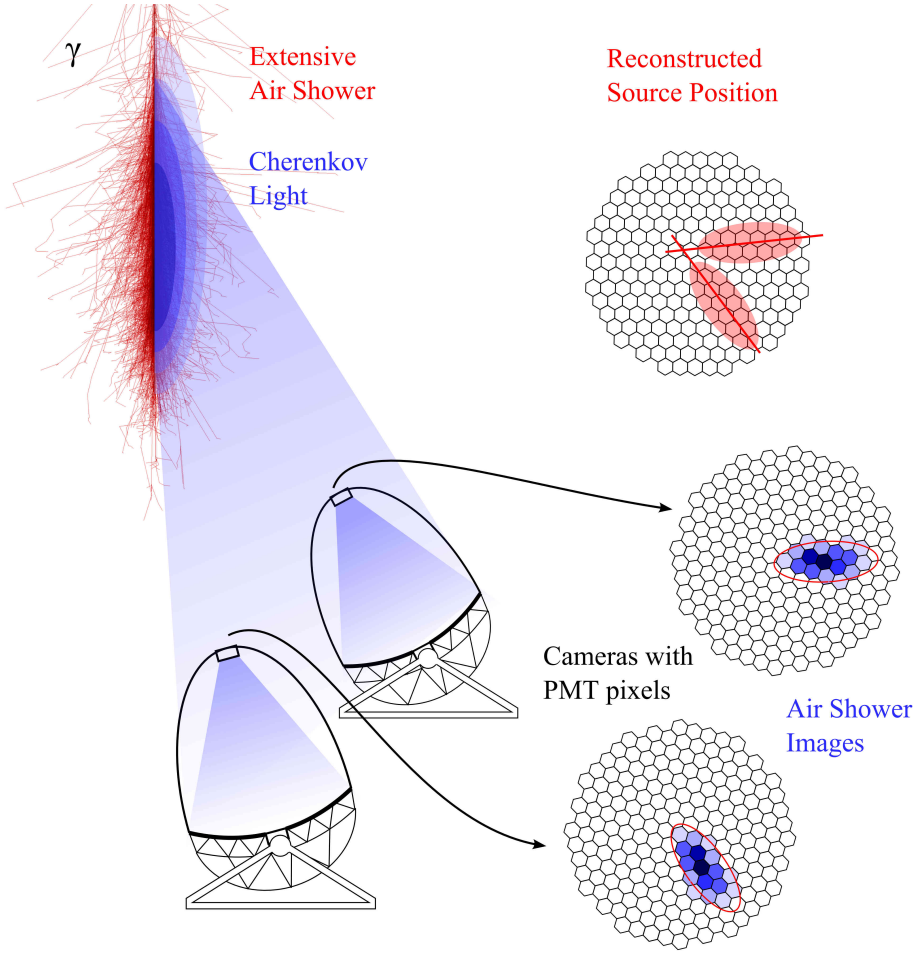
Extensive Air Showers

Electromagnetic shower



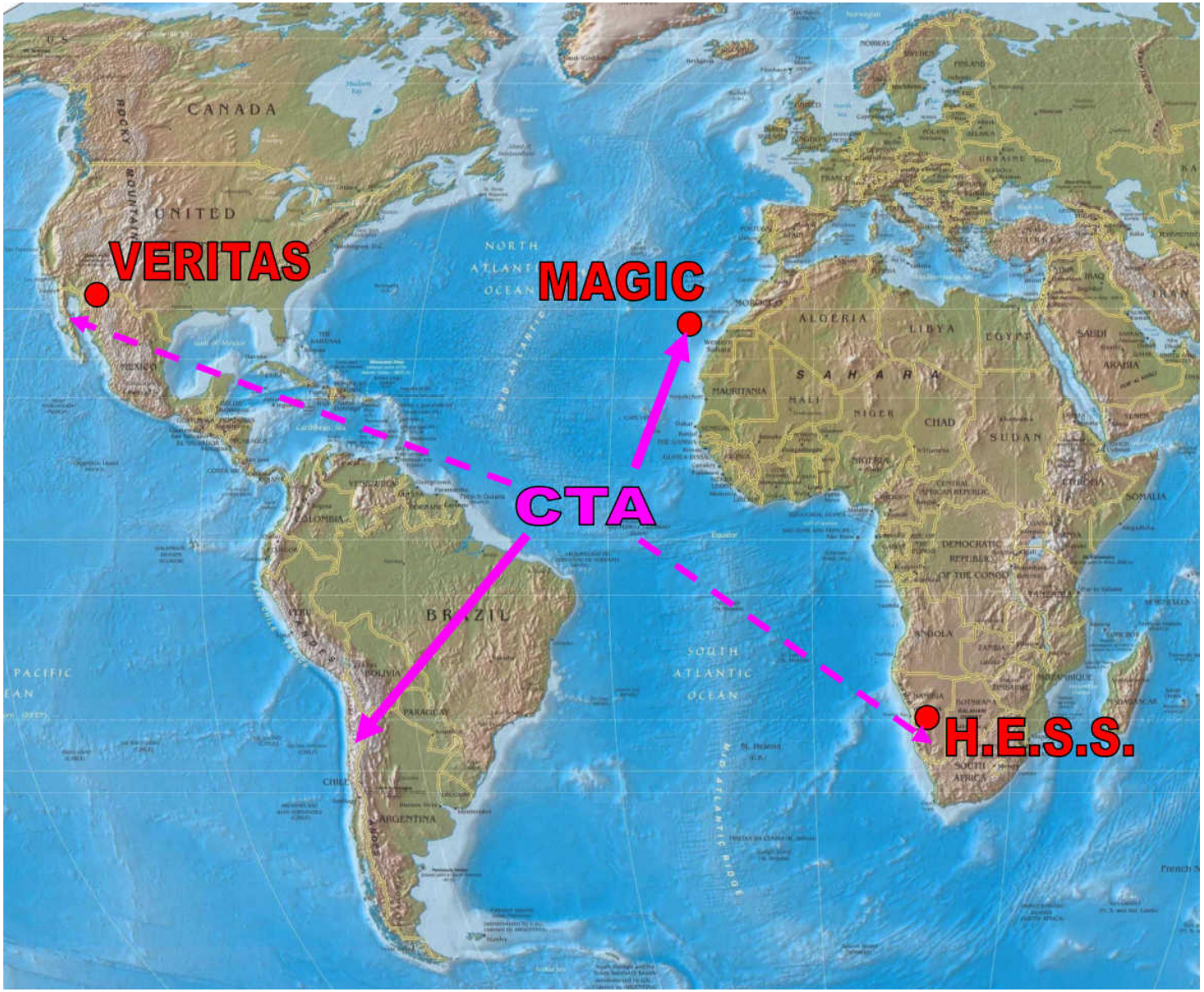
- particle cascade with
  - pair production
  - bremsstrahlung
- charged particles, faster than speed of light in air
  $\Rightarrow$ Cherenkov radiation

Imaging Air Cherenkov Technique

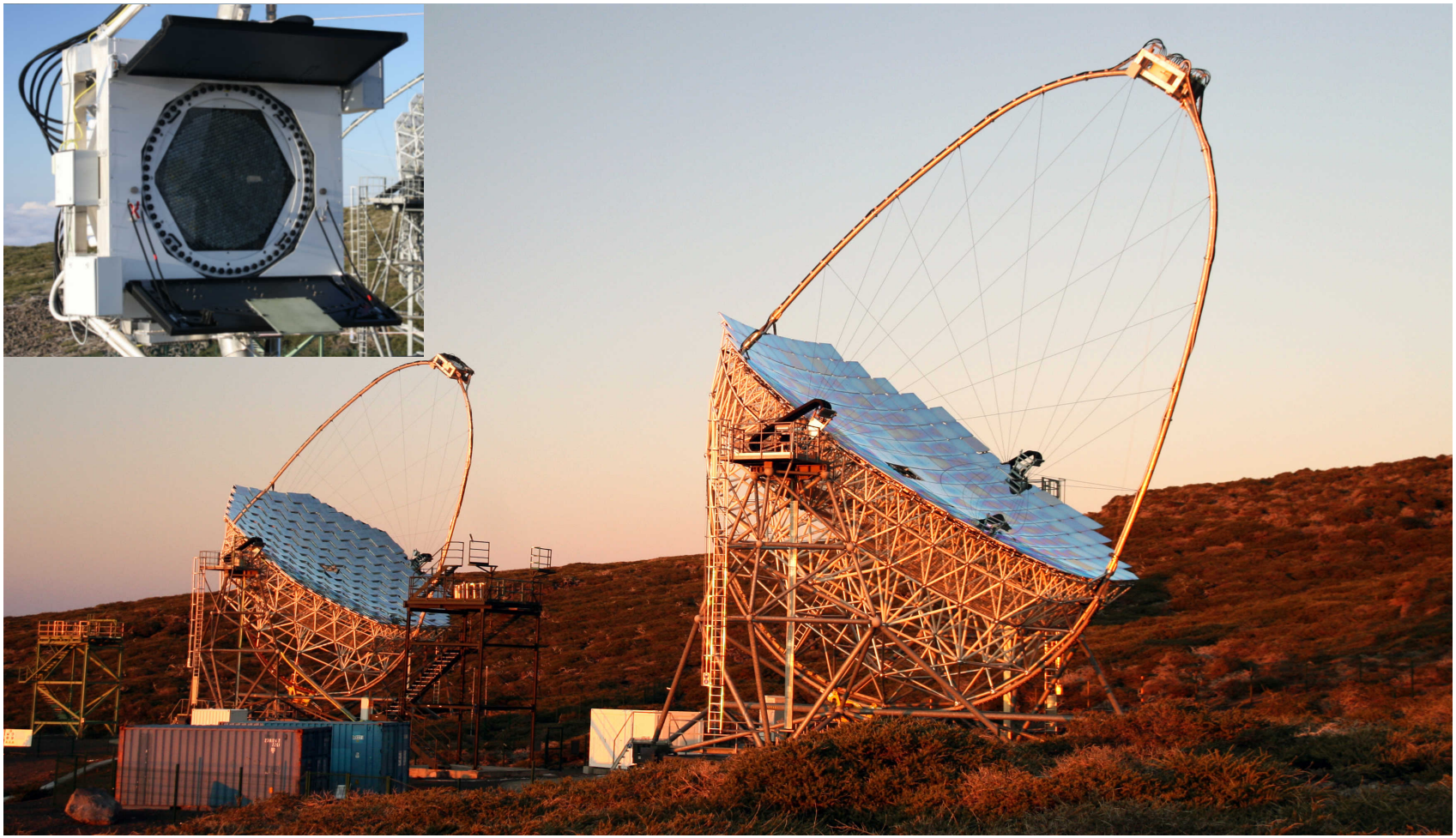


- image with elliptic shape
- stereo for better reconstruction
- background from cosmic rays, ~factor 1000

Main Imaging Air Cherenkov Telescopes



The MAGIC telescopes



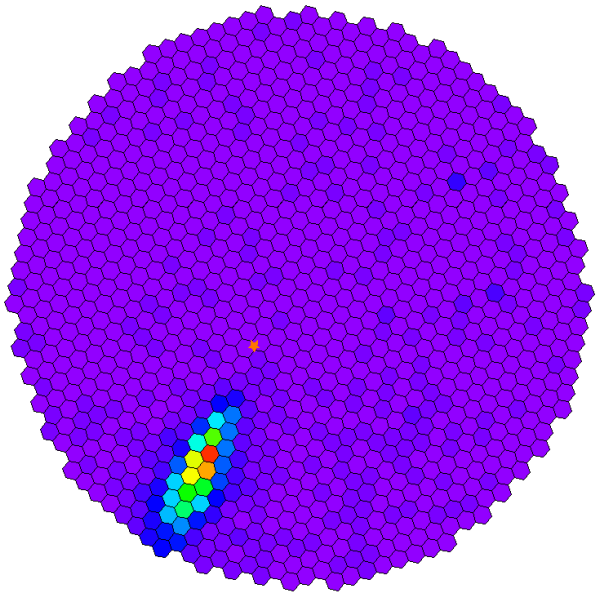
- 2200 m above sea level
- 2 telescopes, 85 m apart
- parabolic dish: 17 m diameter
- focal length: 17 m

Cameras

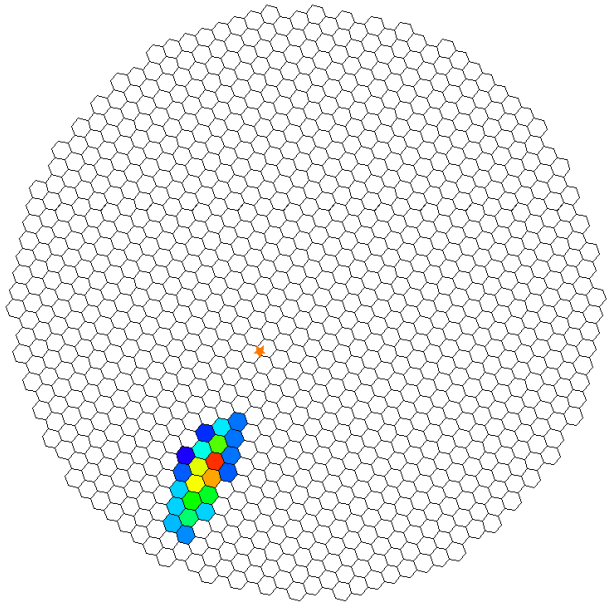
- 3.5° FOV
- 1039 PMTs

Standard MAGIC Analysis

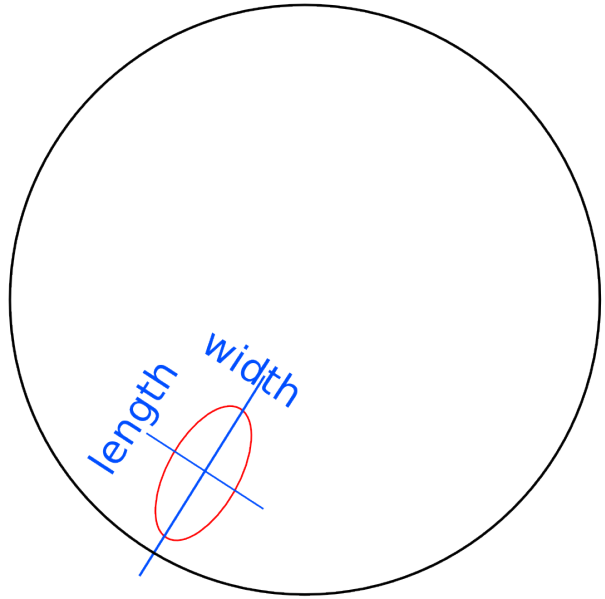
- calibrate: get number of photo electrons and arrival time for each pixel
- clean image: select pixels with enough signal
- parametrize: determine momenta and other parameters
- compare parameters with Monte Carlo simulations
  $\rightarrow$ get energy, direction, haddronness of primary particle



calibrated image



cleaned image



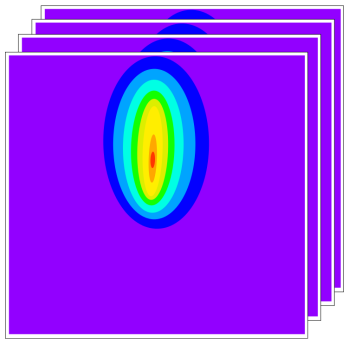
parametrized image

Alternative analysis method: Template Analysis

General Idea

current analysis: parametrization
template analysis: compare images on pixel basis

- need model images



- need method to compare images
- possible improvements for MAGIC
  - better angular resolution
  - better energy resolution
  - better sensitivity

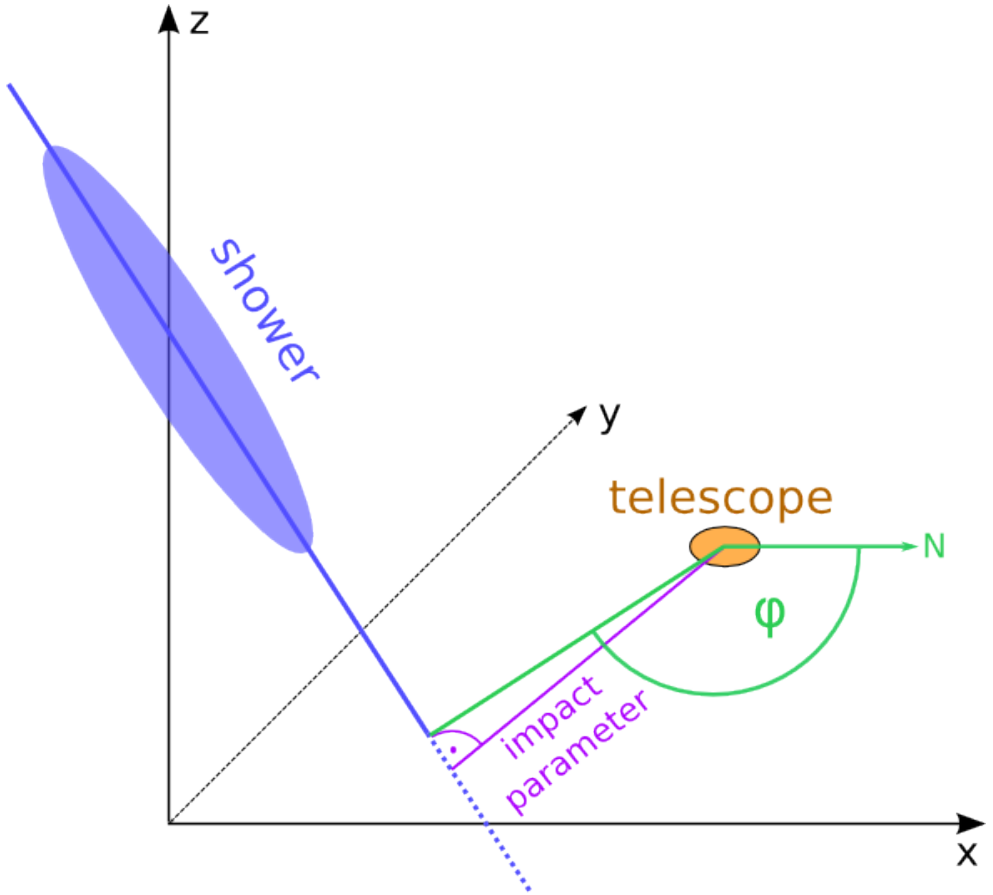
Template database

parameters that change the image:

- energy
- azimuth
- zenith angle
- impact parameter
- impact angle (φ)
- first interaction height

$\Rightarrow$ 6D-database

+ pointing: $(x_{cam}, y_{cam})_{source}$

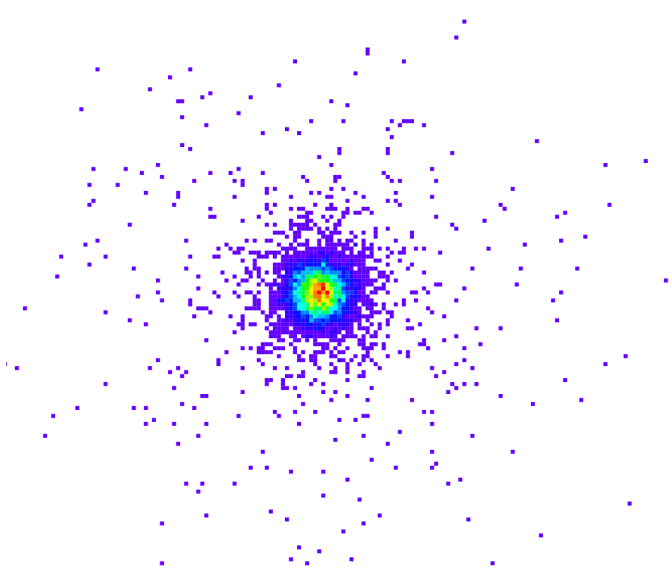


- average of many showers with same parameters
- save mean signal and rms in fine bins (< pixel size)

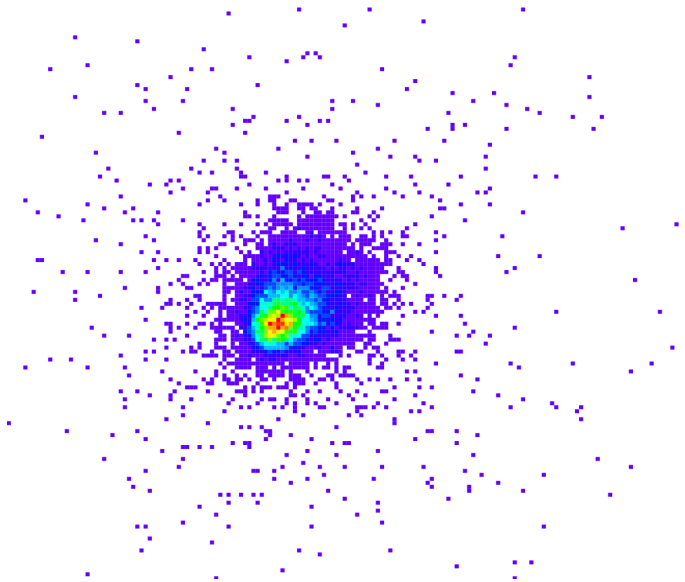
Instrument Response

- photon detection efficiency (including atmospheric absorption)
- optical point spread function (PSF)
  - parabolic mirror $\rightarrow$ comatic aberration
  - ray-tracing simulations:

0° from center

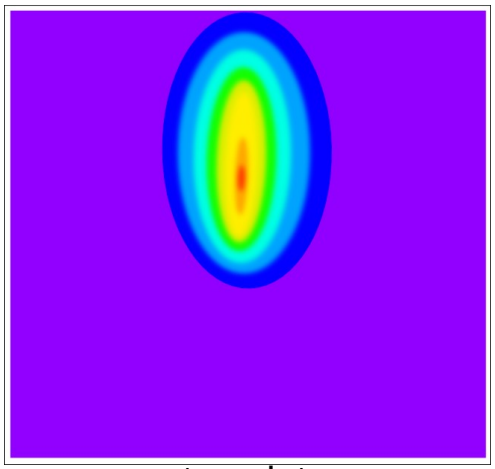


1.25° from center

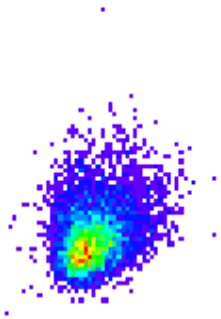


Camera Image

- separate pure template from telescope response


template

+

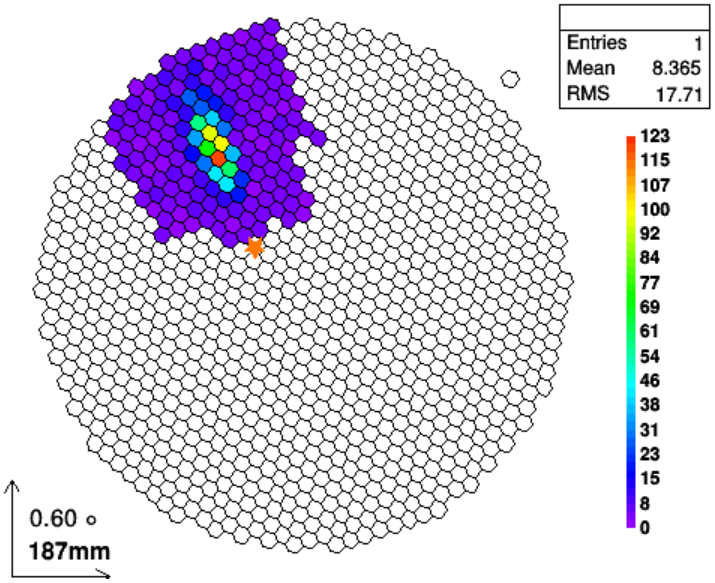

optical PSF

+

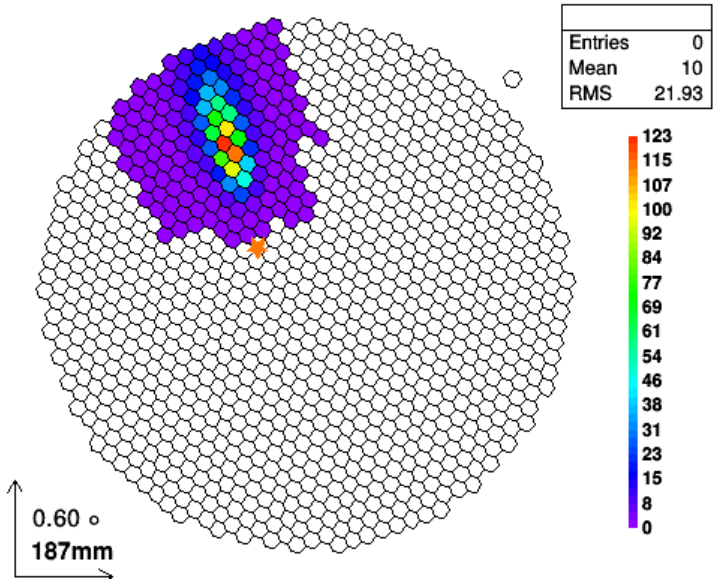
absorption
reflectivity
pixel shape

- convolve during gamma-parameter fitting
  $\rightarrow$ no need for 8D-database
- also include pixelization

Comparison of images



measurement (standard MC)



template

- create a likelihood function
  $\rightarrow$ probability that a template image results in the observed data
- maximize pixel-based likelihood (including both telescopes)
- template with maximum likelihood
  $\rightarrow$ parameters of primary gamma-ray (energy, direction, . . .)

Status

- shower simulation based on CORSIKA
- separated PSF simulation
- template database mostly finished
- simplified likelihood and maximization implemented

Future

- add atmospheric absorption and other losses
- include noise and night sky background in likelihood
- test on standard Monte Carlo gamma-ray showers
- apply to real data