VERITAS

Imaging Calorimetry at Very High Energies

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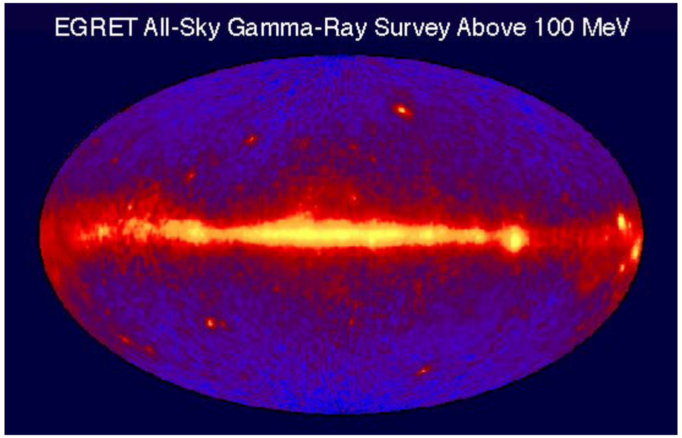
Array System

- Description and status of VERITAS
- Air showers and the stereoscopic imaging technique
- Background rejection of hadronic showers
- Energy resolution

Astrophysics above 50 GeV



Probing galactic and extragalactic acceleration processes, particle populations, and interactions

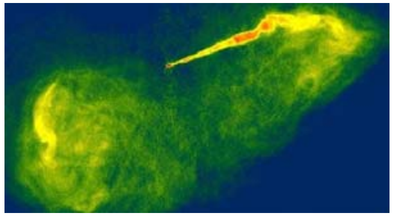
????

Dark Matter?

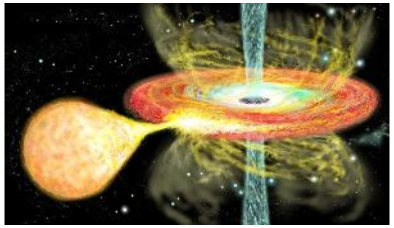
GRBs?

Galactic Clusters?

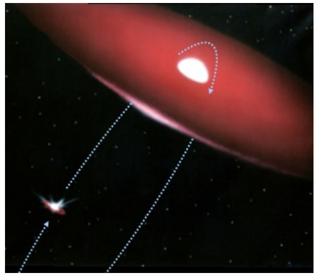
Blazars



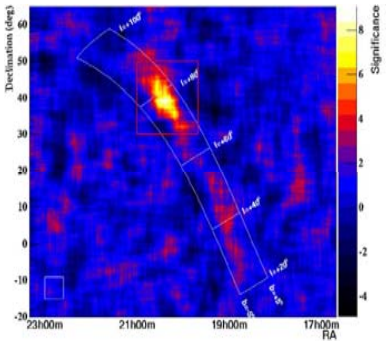
Microquasars

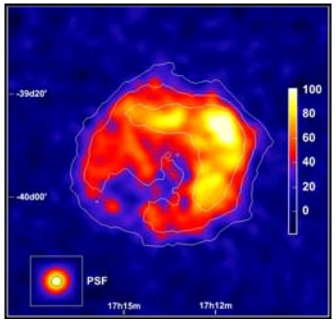


Compact Binary Systems

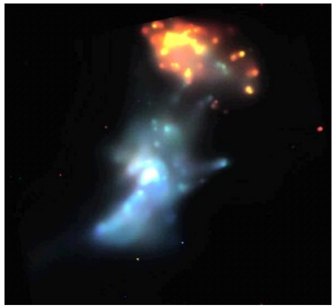


Diffuse Galactic Emission





Supernova Remnants

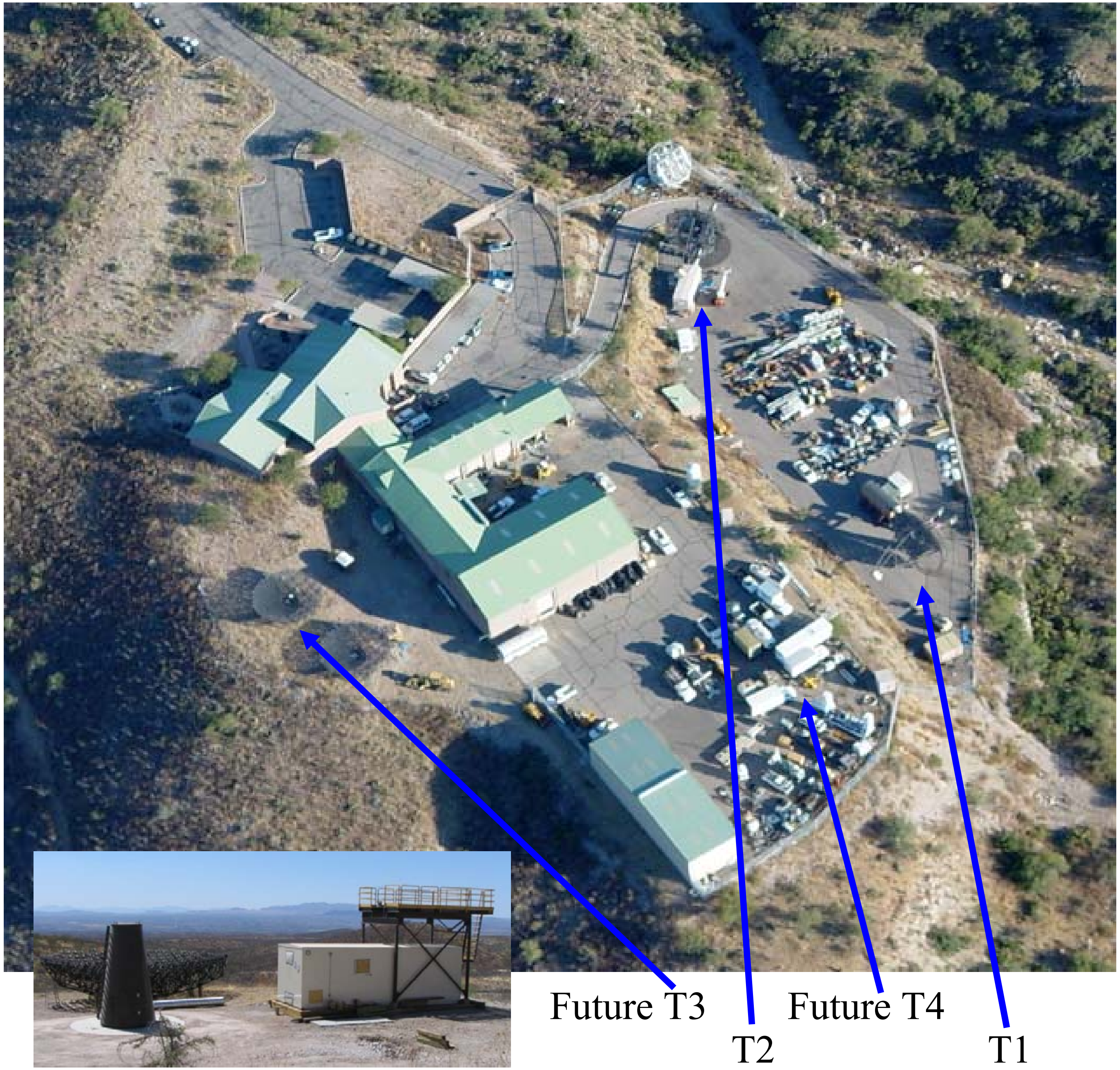


Pulsar Wind Nebulae

VERITAS

- System of 4 imaging air Cerenkov telescopes to detect γ-rays above >50 GeV
  - 12-m reflectors, 110 m^2 area
  - 499 PMT cameras, 3.5° fov, 0.15° pixel spacing
  - 500 MHz FADC
  - 3 level trigger
    - **channel**: constant fraction discriminators, ~5 PE threshold
    - **telescope**: pattern of neighboring channels
    - **array**: coincident telescope triggers

VERITAS Status

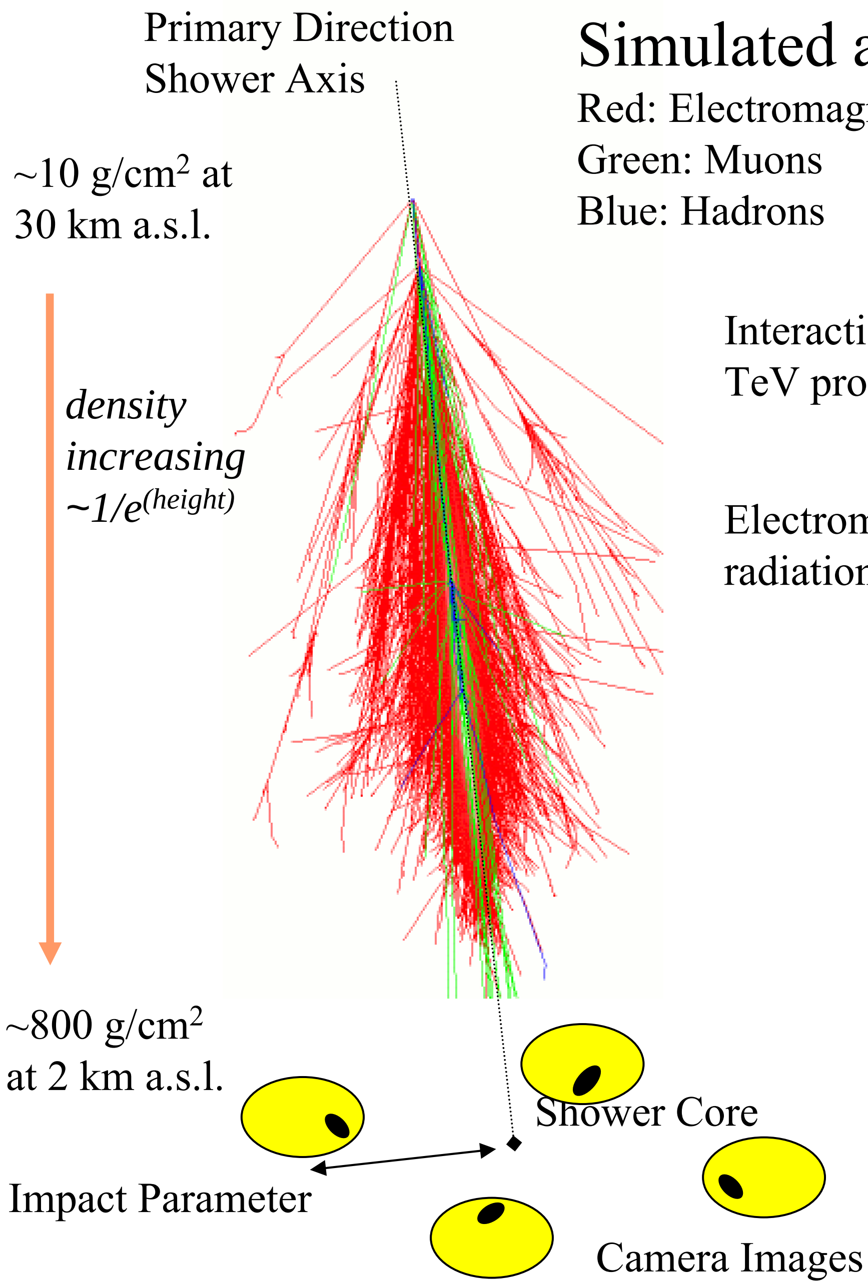


- Constructing array at the basecamp of Mt Hopkins in AZ
- Running 2 telescopes now using array level trigger
- Will complete the array in Fall 2006
- Will run the 4 telescope array at Mt Hopkins for 2 years

Imaging Air Showers

Simulated air shower using Corsika

Red: Electromagnetic
Green: Muons
Blue: Hadrons



Interaction length
TeV proton - air
~80 g/cm^2

Electromagnetic
radiation length
~34 g/cm^2

Shower Parameters

- Primary Type
- Primary Direction
- Primary Energy
- First Interaction Depth
- Shower Core Location
  - intersection of shower axis with detector plane

Cerenkov telescopes record 2D projections in angular space of the track of the shower through the atmosphere.

Image shape, orientation, and intensity depend on the shower parameters.

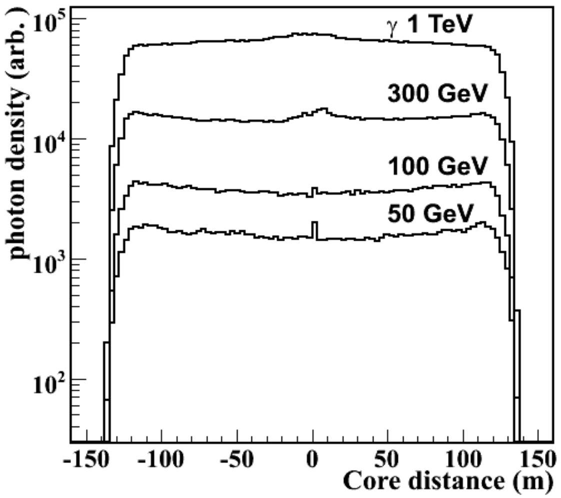
Shower Development

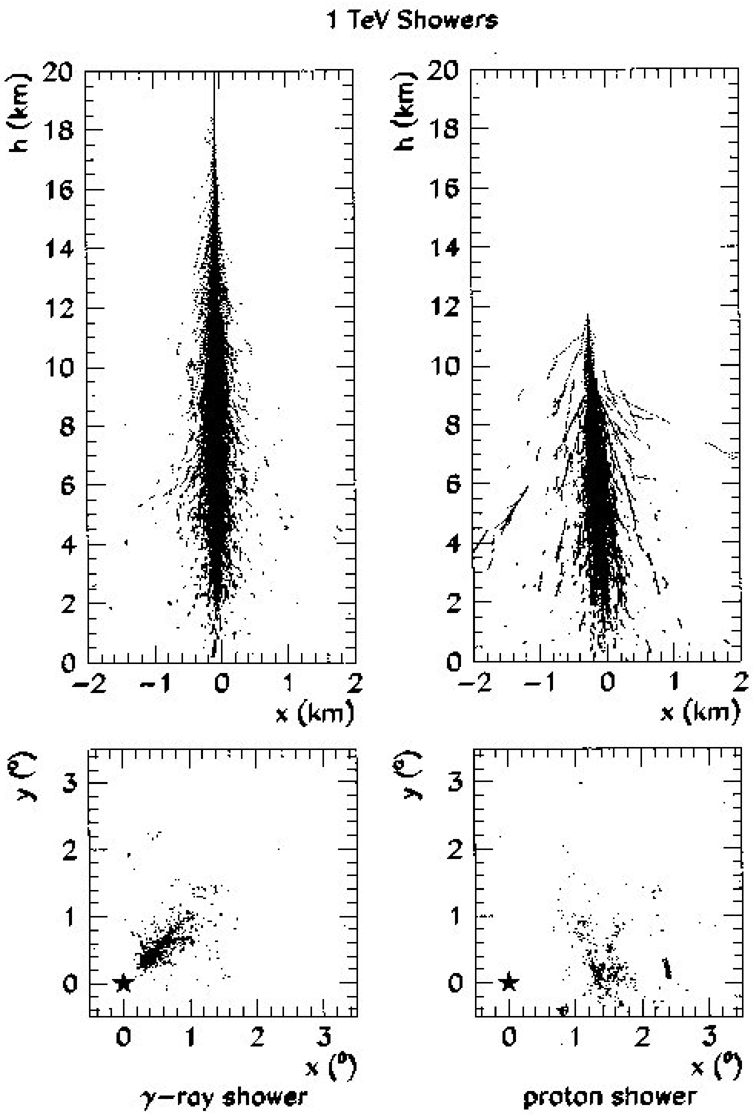
Gamma Ray

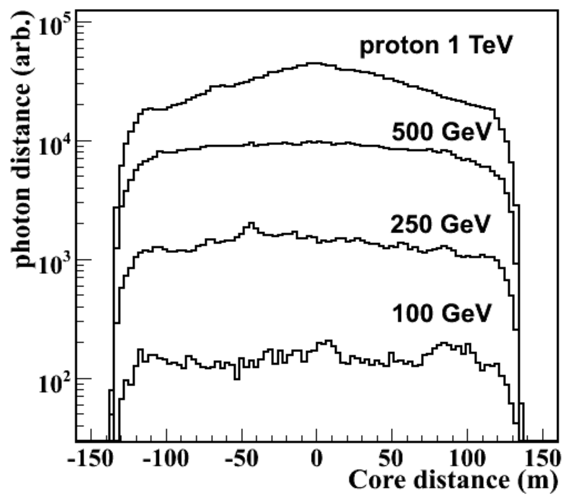
- uniform shower development
- higher Cerenkov light intensity
- relatively symmetric
- compact images without large fluctuations

Proton

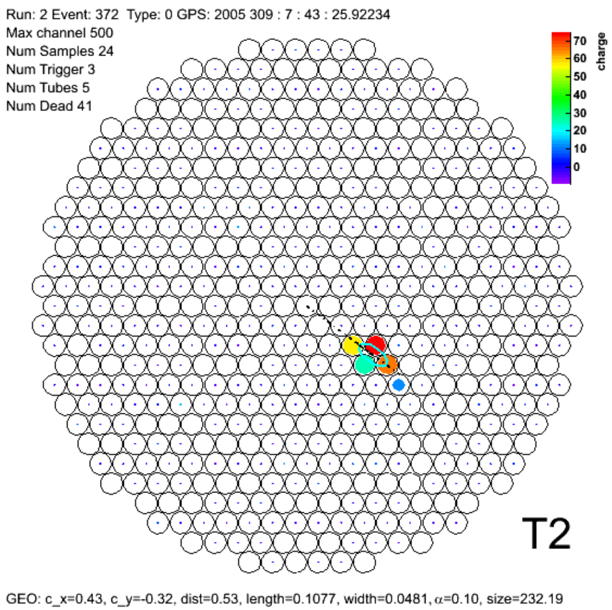
- large fluctuations in shower development
- lower Cerenkov intensity
- less symmetric than electromagnetic shower
- Laterally broader with fluctuations

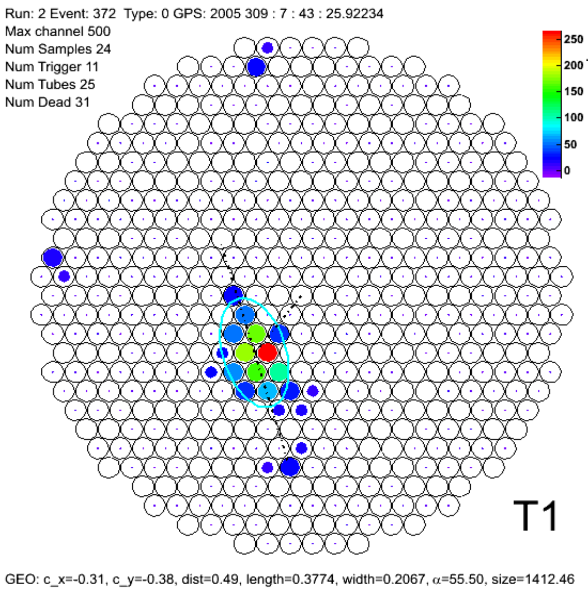






Imaging Air Showers: Mono





Single telescope allows

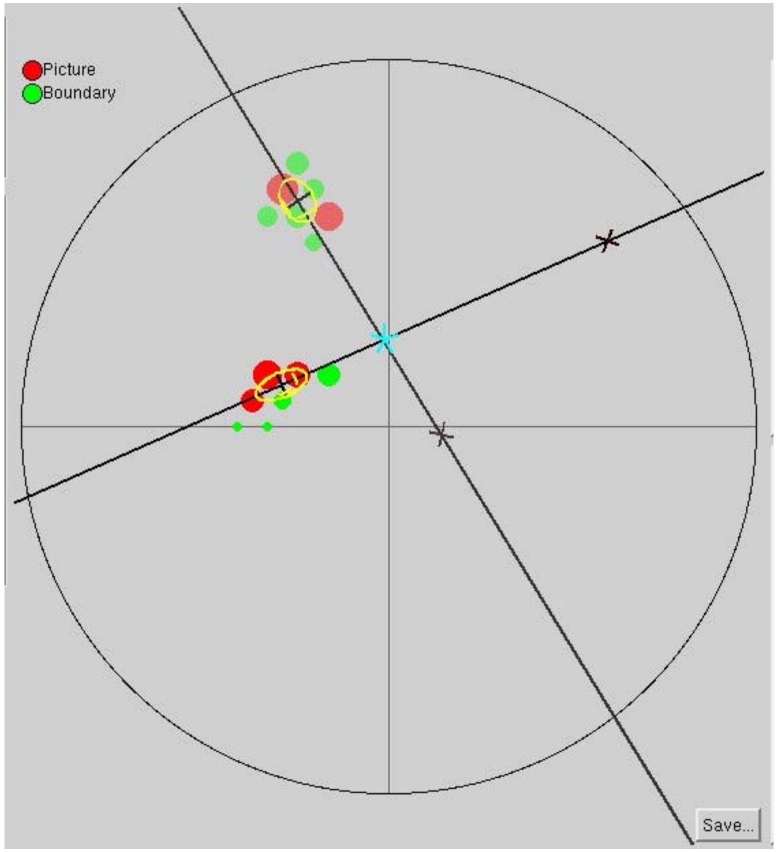
Good constraint of primary direction, but determined statistically

Best fits for elliptical showers, R~50-100 m, higher energy

Some knowledge of core location

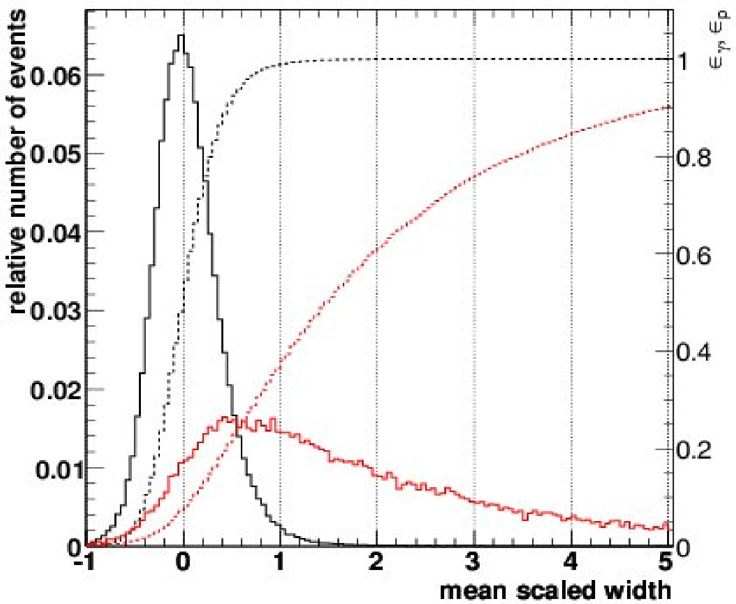
Energy resolution ~30%

Imaging Air Showers: Stereo



- Array trigger eliminates local muon background
- Core Resolution ~10m
  - improves data quality cuts
  - hadron rejection
  - energy resolution 15-20%
- Multiple images not 100% correlated
  - array provides several images favorable for determining shower parameters
  - Fits improve substantially for 3 telescopes in event
- Primary direction determined per event
  - Reconstruction resolution ~0.1°
- Primary energy, type, interaction height and shower max statistical

Background Rejection



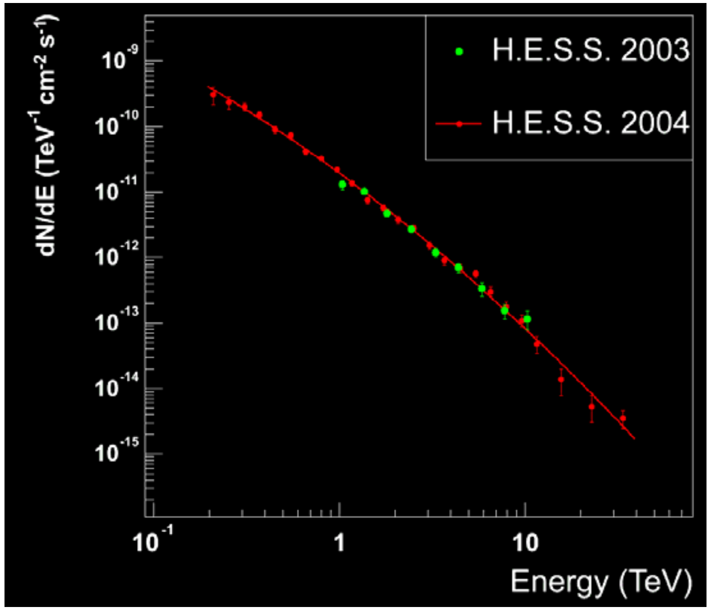
Orientation still a powerful tool for point source analysis.

What about extended or diffuse sources?

- Rejection in trigger and image cleaning
  - Hadronic showers of same energy produce less Cerenkov light than electromagnetic showers (loss to μ and ν)
- State of the art rejection still based on shape
  - Knowledge of the shower core improves things substantially
- Additional rejection potential
  - Shower symmetries (widths, lateral density profile...)
  - Timing

Energy Parameterization

$$N_c \propto \ln(E)$$



Differential flux for Supernova remnant RX J1713-394 from H.E.S.S.

But...this is only approximate. The atmosphere as a calorimeter is inhomogeneous and the Cerenkov angle varies with height.

And there are fluctuations in interaction height for gamma rays of a given energy.

Shower core and number of telescopes fitting the shower have a big impact.

Conclusions

- VERITAS already capable of stero observations and full array completed soon
- Stereoscopic imaging allows excellent determination of
  - primary direction
  - shower core
- Hadron rejection significantly improved
  - ongoing work for improved methods without use of direction
- Additional methods still to be exploited