Characteristics and performance of the GAW experiment for a large field of view Cerenkov gamma-ray telescope

C. Delgado on behalf of GAW collaboration

What is GAW?

GAW is a path-finder experiment for γ-ray astronomy (above 0.7 TeV), to test the feasibility of a new generation of IACT (Imaging Atmospheric Čerenkov telescopes), which join high sensitivity with large Field of View.

Why GAW?

GAW will perform deep sky survey, search for counterparts of X and γ-ray sources, search for serendipity and transient sources,...

When will GAW be ready?

GAW is an R&D experiment under development; a first part of the array should be completed and operative within winter 2008.

Where will it be placed?

GAW is planned to be located at Calar Alto Observatory, Spain, ~2150 m a.s.l..

Who is involved in this experiment?

VHE Astronomy and IACT Telescopes

Presently, the existing and planned ground-based Imaging Atmospheric Čerenkov Technique IACT observatories aim to fulfil two main objectives:

Lower Energy Threshold, up to few tenths of GeV.
Higher Flux Sensitivity in the entire VHE region).

This allows:

Excellent Background Rejection *High Resolution Energy Spectra*
Studies of known sources *Survey of limited sky region*
Discover serendipitous sources

However their small FOV (3^0 to 5^0) makes

Survey of large regions of sky very costly.
Low detection probability for serendipity transient sources or stable sources far from the galactic plane

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Enlargement of FOV is the main aim of GAW

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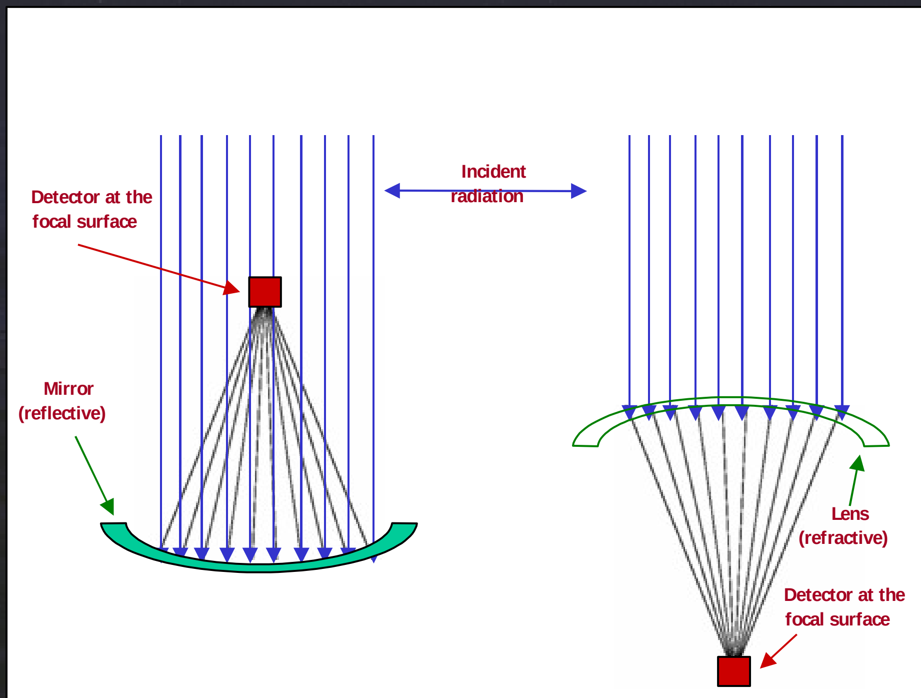
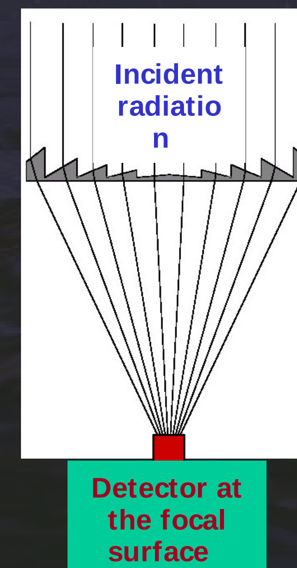
How to enlarge the FOV?

Gaw Proposes the use of refractive optics to increase the FOV and avoid the camera shadow



Fresnel Lens

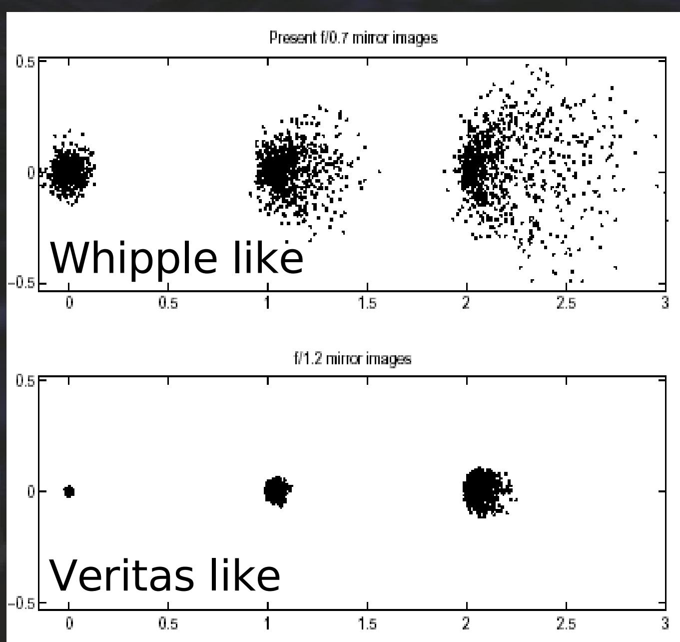


A "refractive" Fresnel lens can work as an efficient light collector for IACT

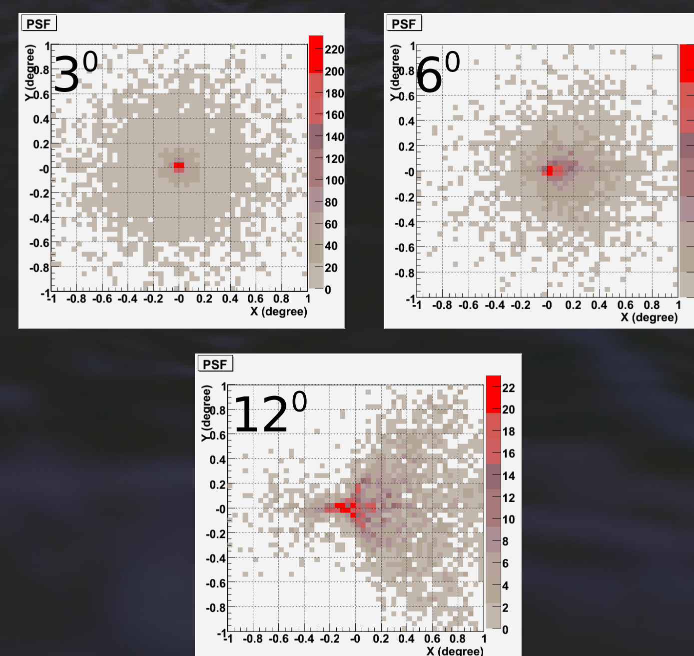
Small thickness *Good transmittance*
Easy replication *No camera shadow*
Large FoV

How to enlarge the FOV?

Standard approach

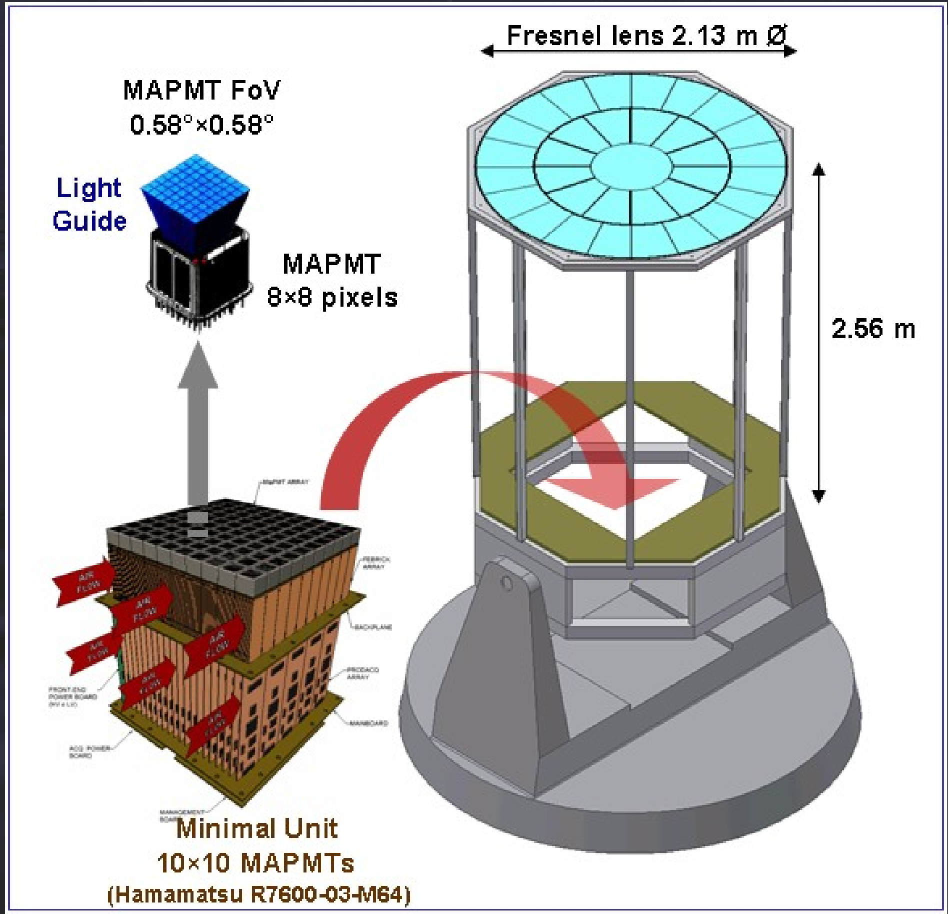


GAW solution



GAW Telescope unit

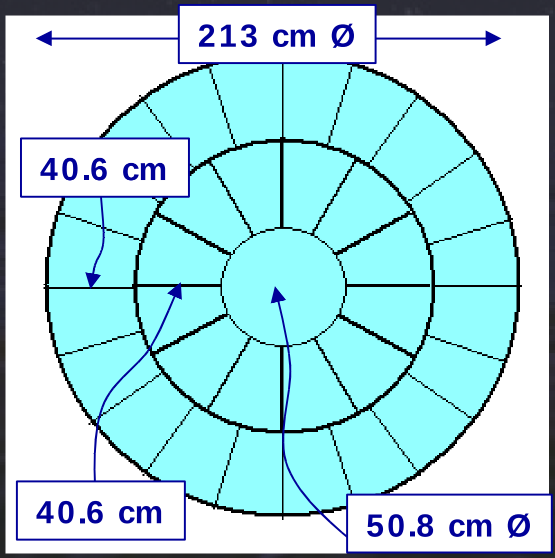
GAW is conceived as an array of three identical telescopes with alt-az mounting, disposed at the vertexes of an equilateral triangle, 80 m side, working in stereoscopic mode.



GAW Optical System

Non-commercial Fresnel lens as light collector:

Baseline Optics Module for GAW prototype	
Lens	Flat single-sided
Diameter	2.13 m
Focal Length	2.56 m
f/#	1.2
Material	UV Transmitting Acrylic
Refraction Index	1.517 (at 350 nm)
Standard Thickness	3.2 mm
Trasmittance	~95% (330-550 nm)
Manufactured by Fresnel Technologies Inc.	

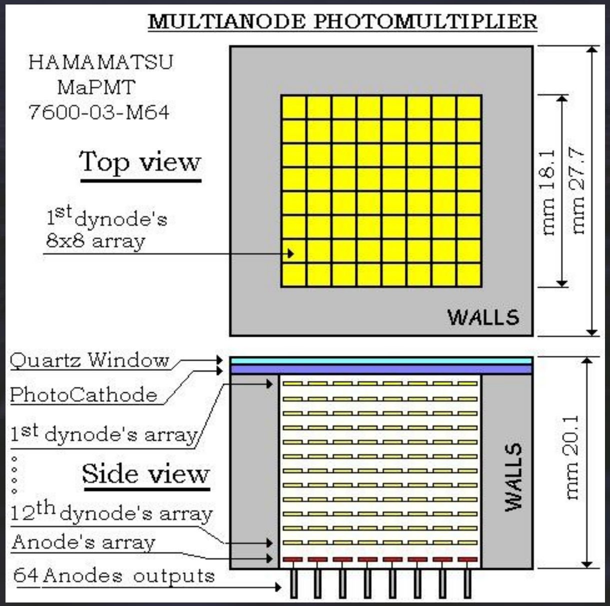


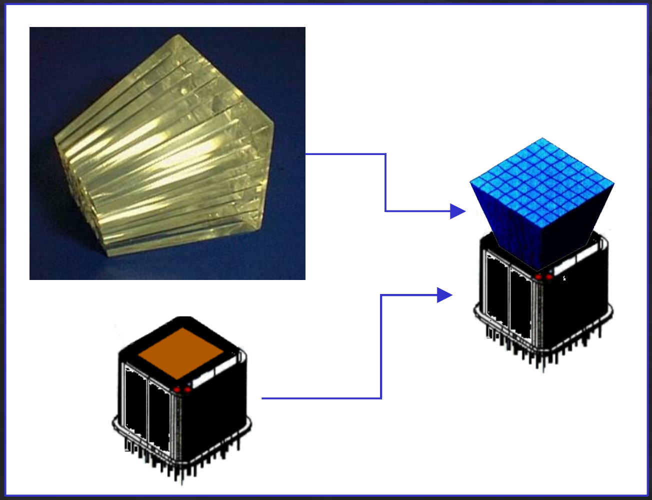
Lens composed by a central core surrounded by an intermediate corona of 12 petals and an outer corona of 20 petals. A spider support will maintain all the pieces together.

Lens be optimized to have at 360 nm a spatial resolution suitable to the requirement of the Čerenkov imaging and as much as possible uniform up to +/- 12°.

GAW detector

Formed by a grid of MultiAnodePhotoMultiplierTubes, MAPMT Hamamatsu R7600-03-M64, 8×8 pixels each *(baseline),* coupled with light guides to avoid the death area, increasing the detector uniformity.
The resulting pixel area is 4x4 arcmin^2.





10x10 MAPMT are clustered in the so called minimal units.
Each telescoped is equiped with a minimal unit in a first phase, and 16 minimal units during a second phase.

GAW detector operation mode.

Instead of the usual charge integration method, GAW front-end electronics design is based on *single photoelectron counting mode*.

This:

- Keeps negligible the electronics noise and the PMT gain differences.
- Strongly reduces the minimum number of photoelectrons, *p.e.*, required to trigger the system.

Requiring pixel size small enough to minimize photoelectron pile up within intervals shorter than sampling time (10ns).

With current camera design

We estimate a threshold of 14 p.e per sample (sampling time 10ns) per trigger-cell (2x2 MAPMT) for triggering the telescope.

The expected NSB contribution is 3 p.e. per sample per trigger-cell.

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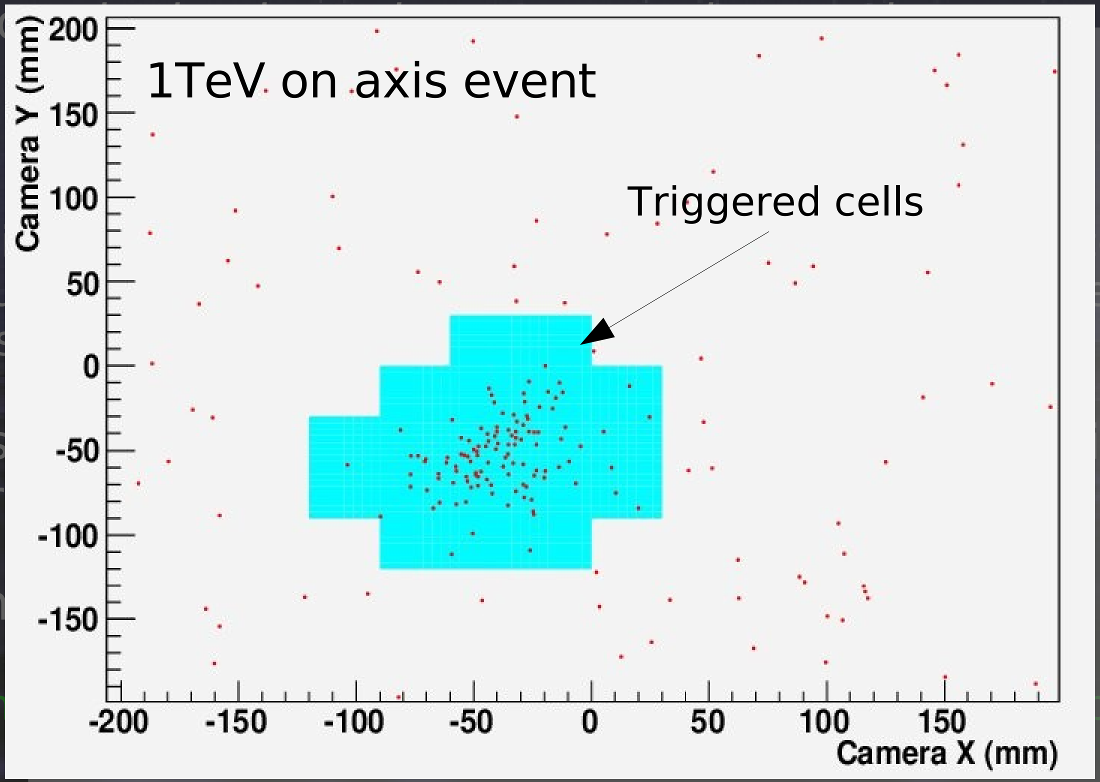

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GAW project summary.

The instrument is an array of three identical telescopes disposed at the vertexes of an equilateral triangle, 80 m side, at Calar Alto observatory.

Phase 1 (2007-2008): GAW in testing configuration, 6°×6° FoV.

Moving the detector along the FoV, the sensitivity of GAW will be tested observing the Crab Nebula with on-axis and off-axis pointing up to 12° with energy threshold of 700 GeV.

Phase 2: If phase 1 is successful, GAW with Large Field of View,24°×24° FoV

Pointing along different North-South directions, GAW would reach a survey of 360°×60° sky region.

Possible technological improvements (Flat panels, high quantum efficiency PMTs...)

GAW Expected performance.

Based mainly in preliminary MC simulations by M.C. Maccarone and B. Sacco from IASF-Palermo, Italy.

All results should be considered **preliminary.**

Simulation

CORSIKA used to generate the Čerenkov light, at level of single photons, associated to air showers induced by gamma and proton primaries.

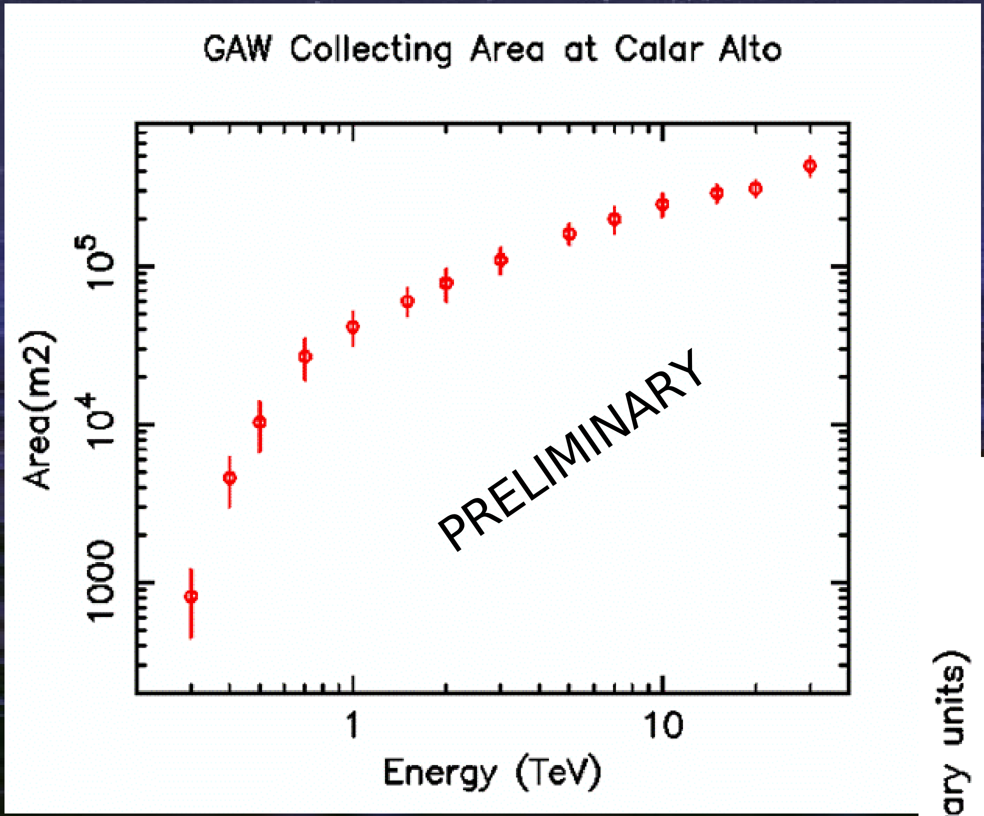
More than 12 000 simulated air showers in the energy range 0.3-30 TeV.

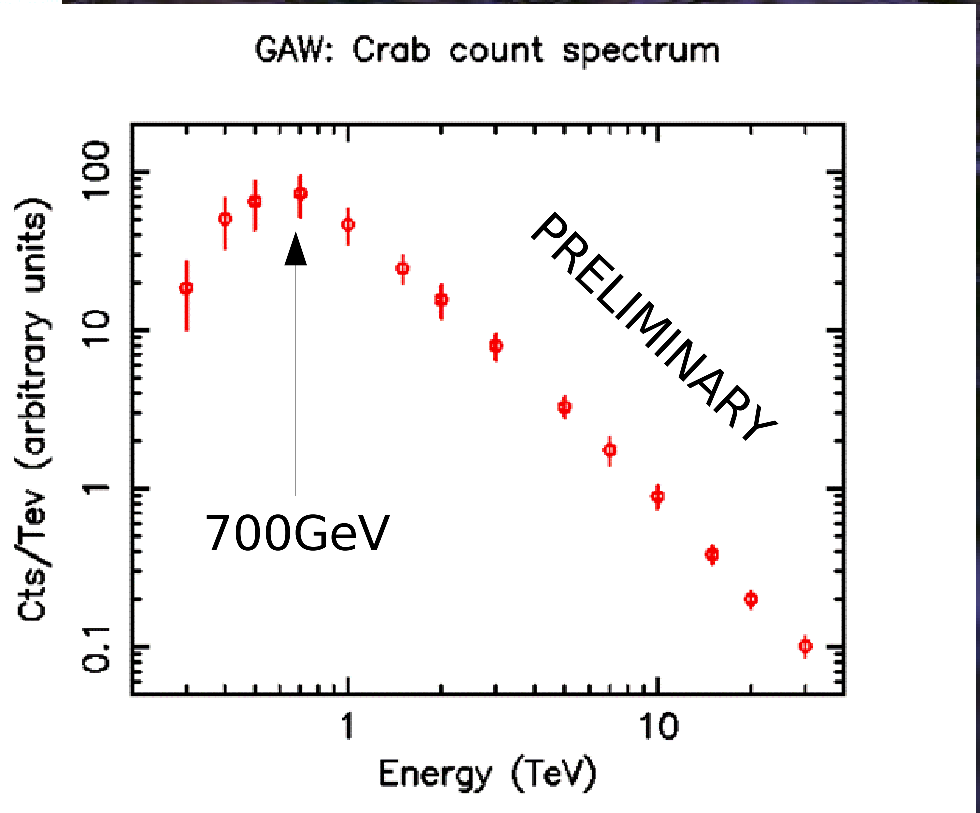
Cores of the events were randomly distributed in the large fiducial area of 1520×1520 m^2 around the position of the GAW set of telescopes.

Effects of the atmospheric absorption and a set of detector parameters values, considered nominal at this stage of the project, are included.

Trigger simulated according to current configuration.

Collecting Area





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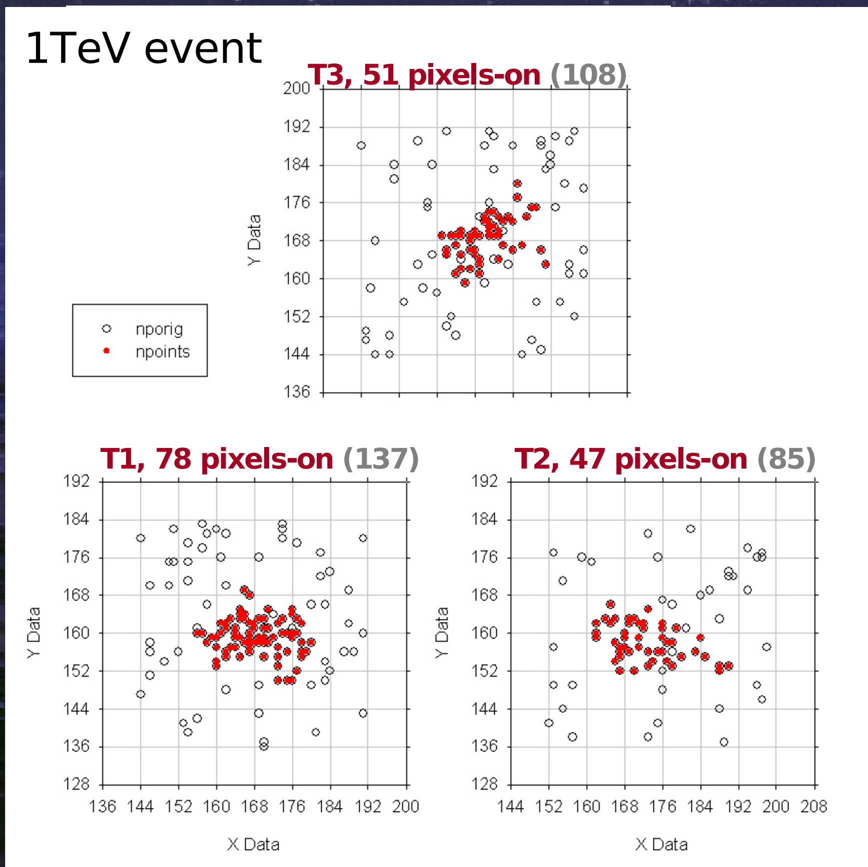
Determination of source position.



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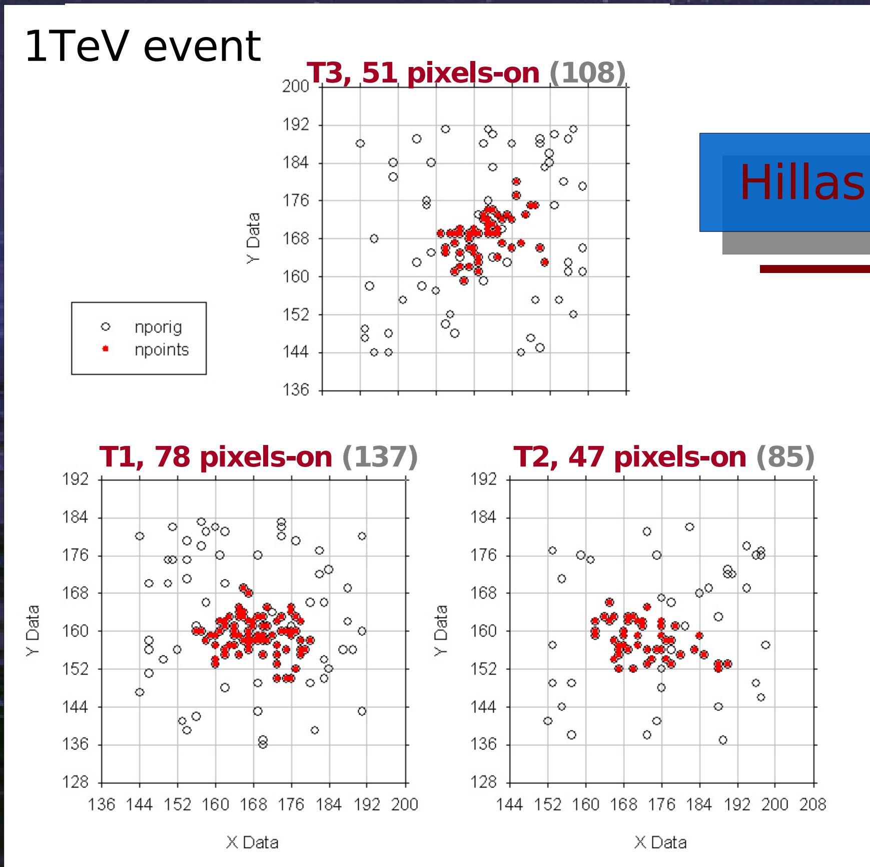
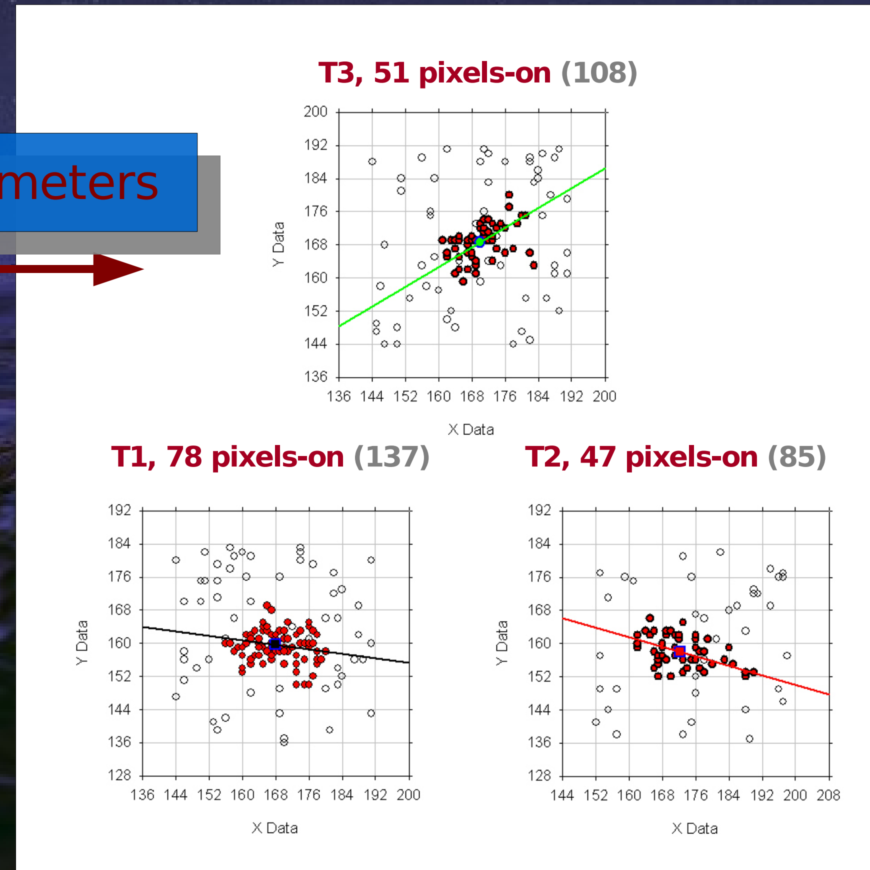


Hillas parameters



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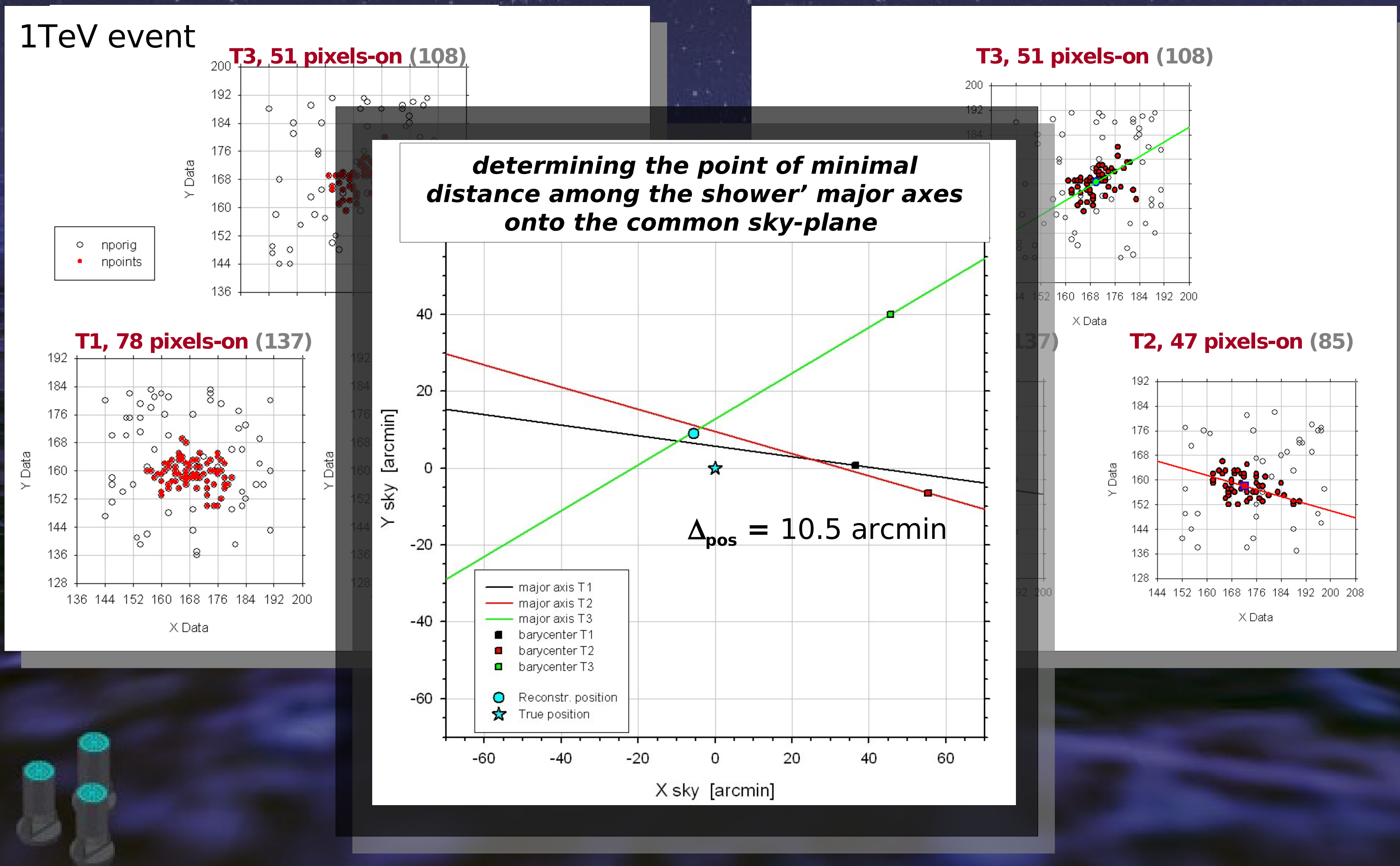

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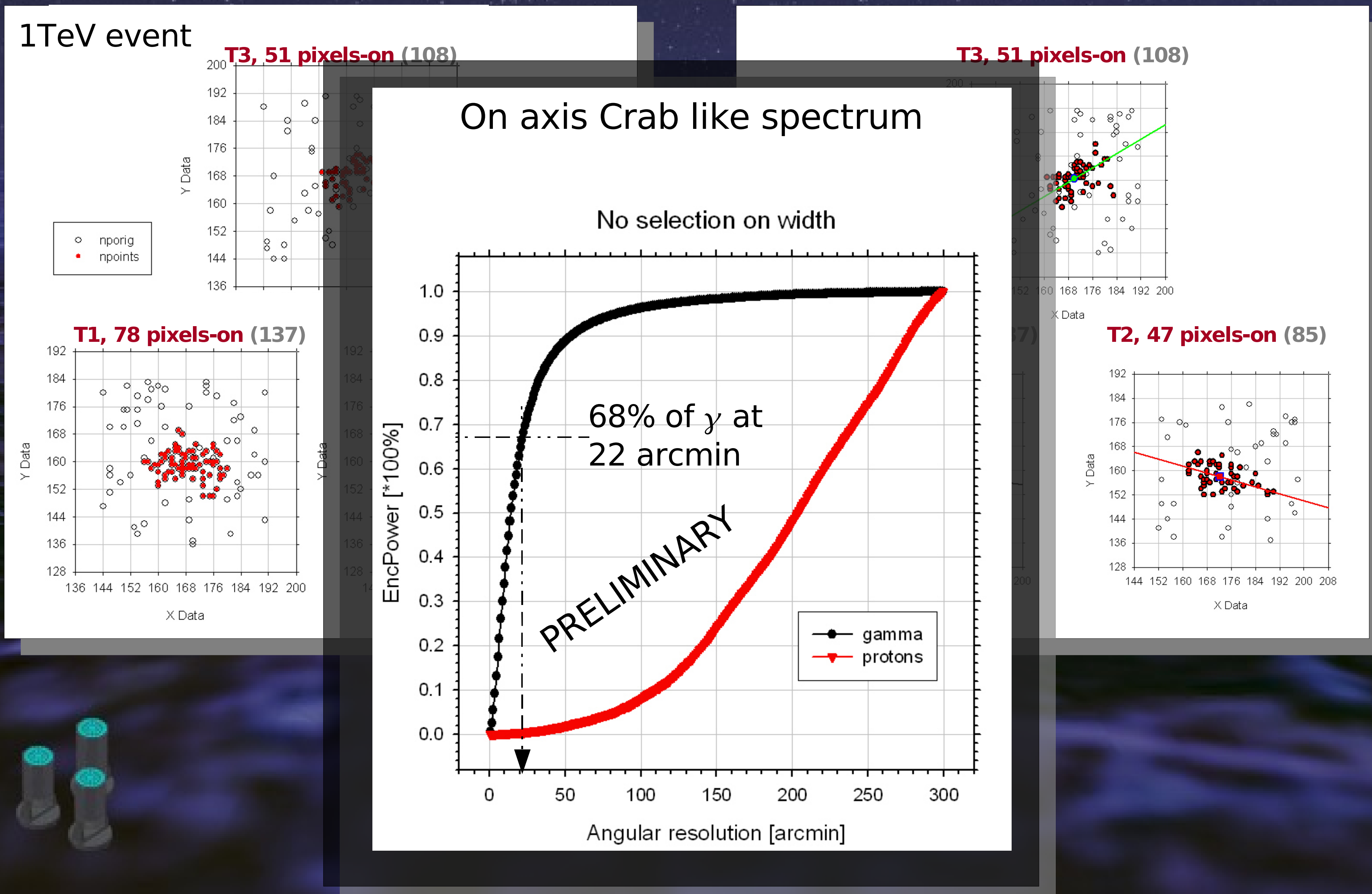

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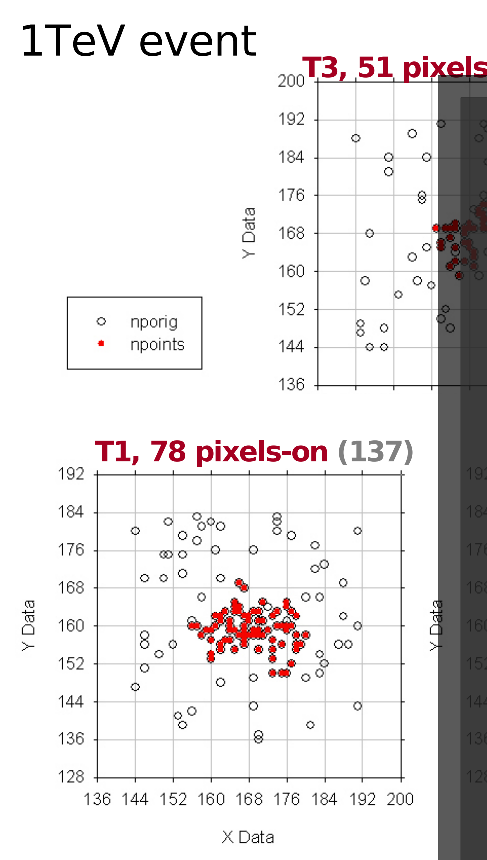

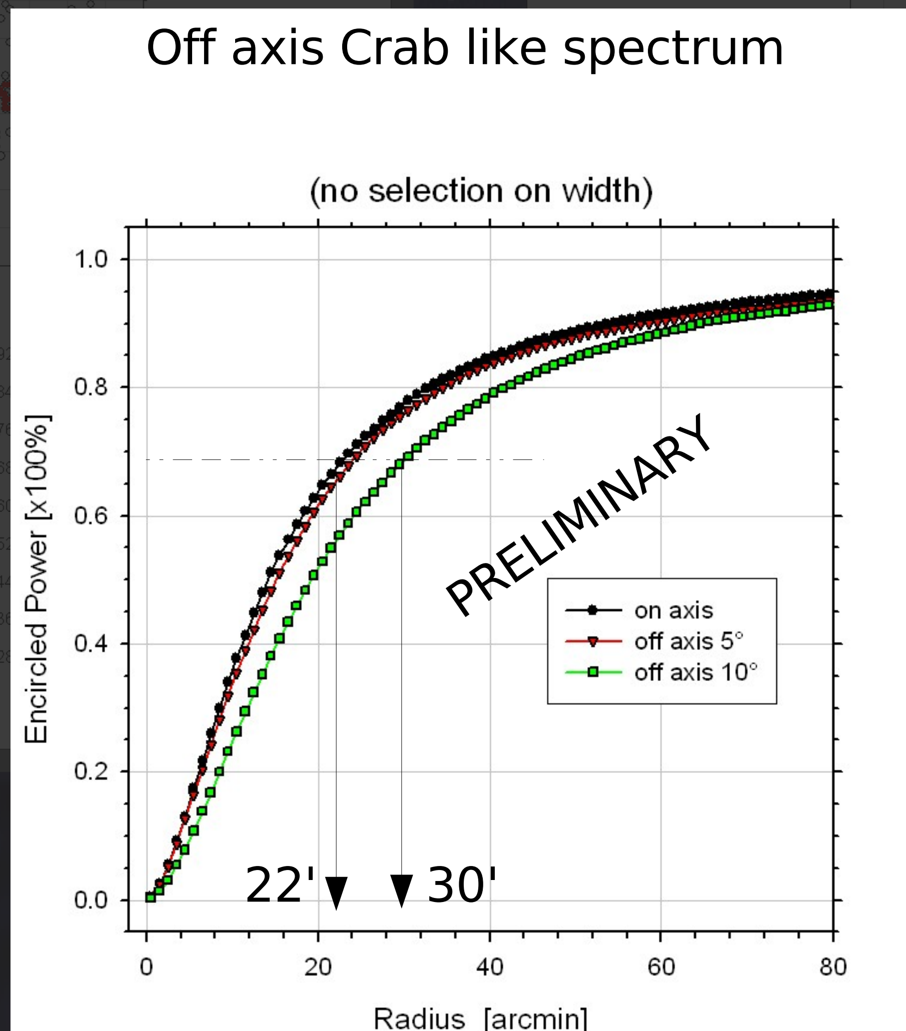

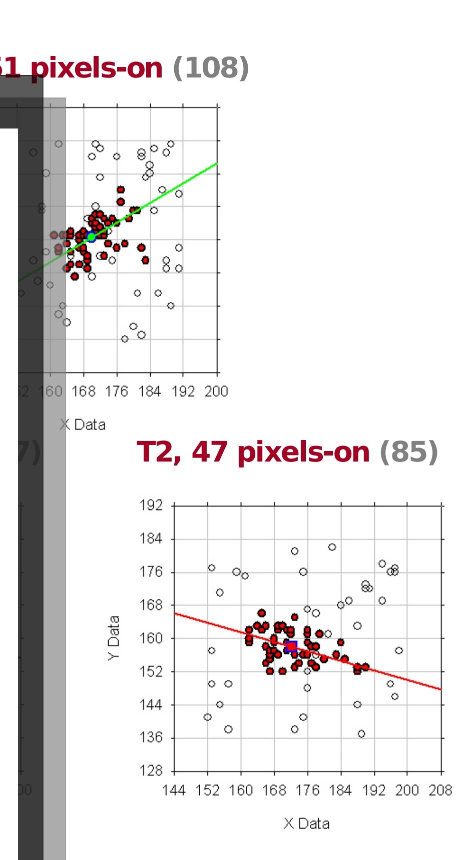

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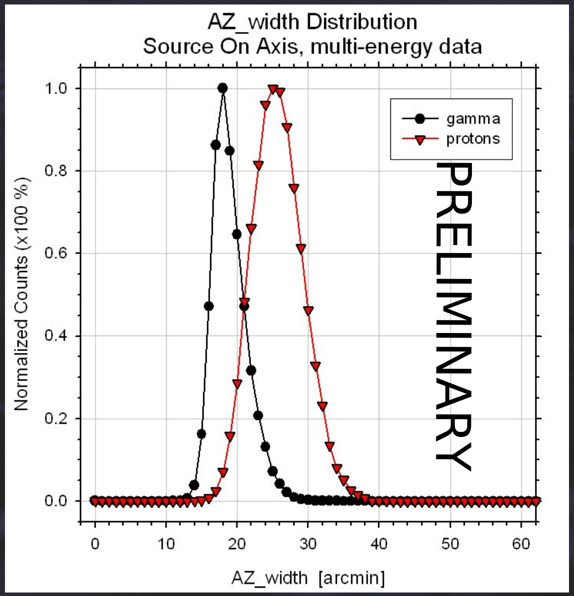
γ-hadron separation

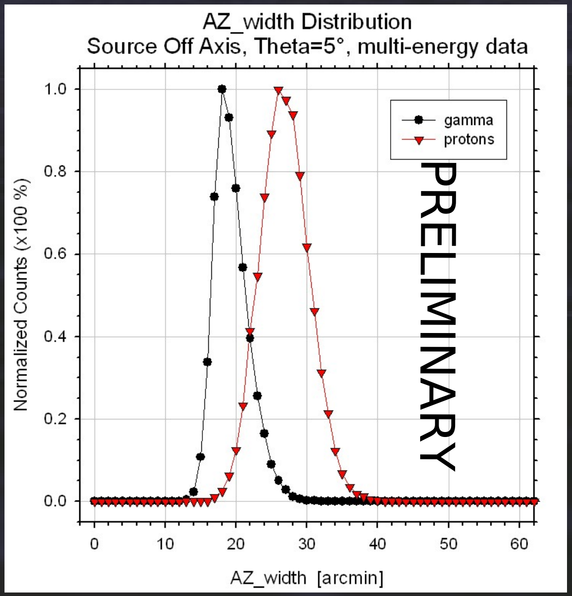
Most useful variable found: Azimuthal width

RMS of the distribution of detected p.e. projected on the axis perpendicular to the line joining the image centroid and the source position.

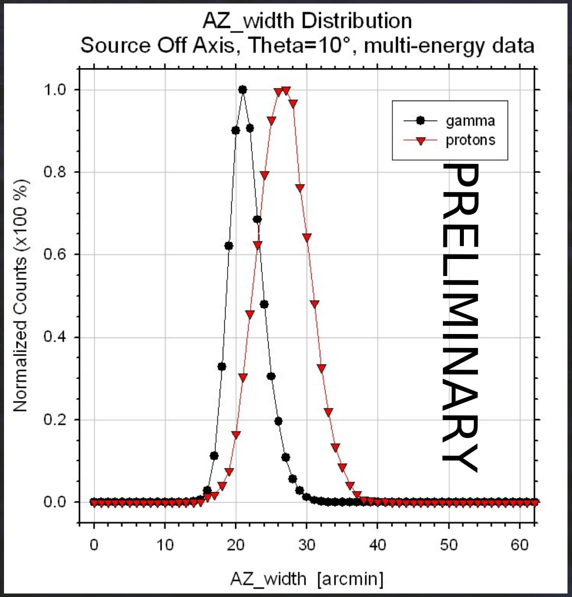
Source at $\theta = 0°; \phi = 0°$



Source at $\theta = 5°; \phi = 30°$



Source at $\theta = 10°; \phi = 30°$



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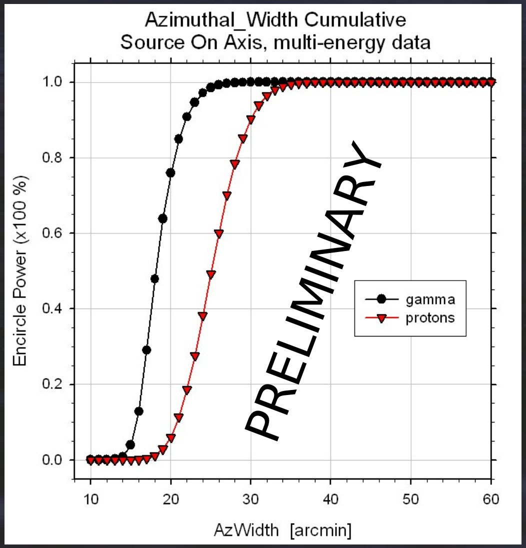

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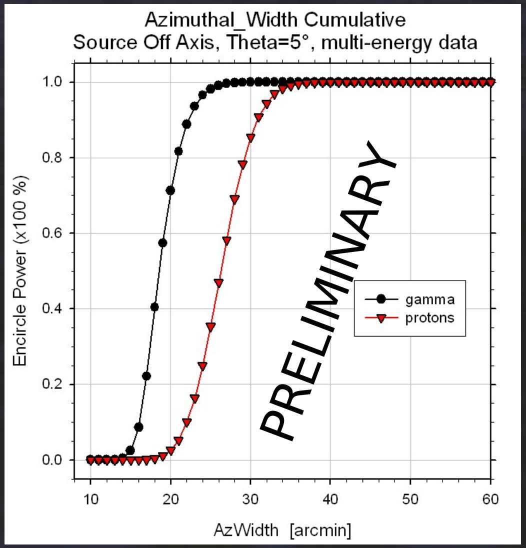

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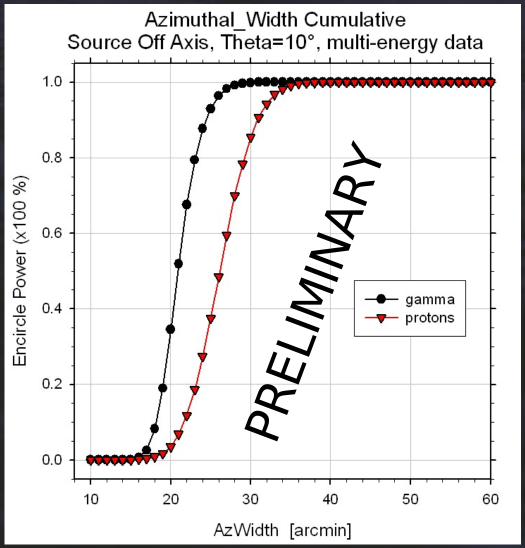


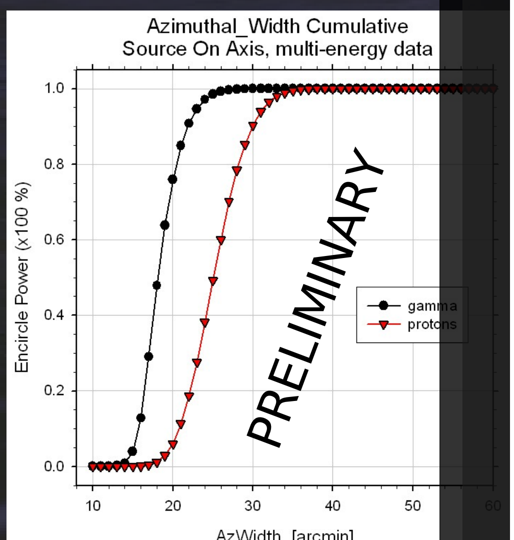
Exploratory analysis methods (neural nets, Random Forest...) under consideration.

γ-hadron separation

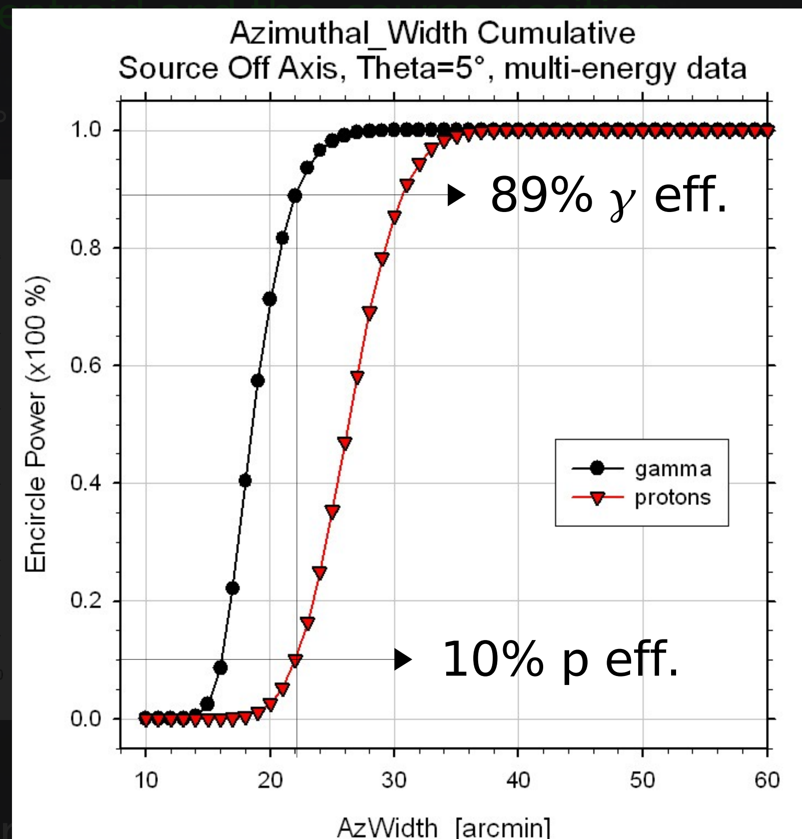
Most useful variable found: Azimuthal width

RMS of the distrib… perpendicular to the line joining the image …

Source at $\theta = 0°; \phi = …$



Source at $\theta = 5°; \phi = 30°$



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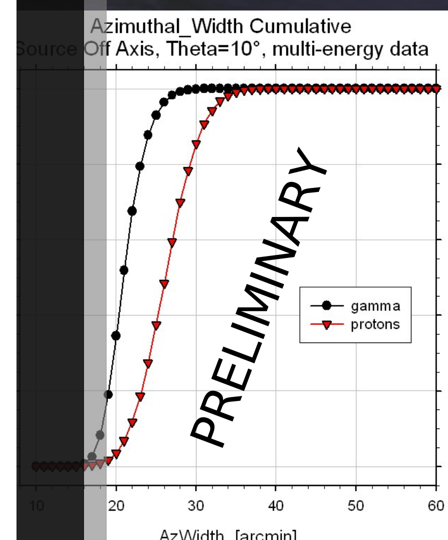
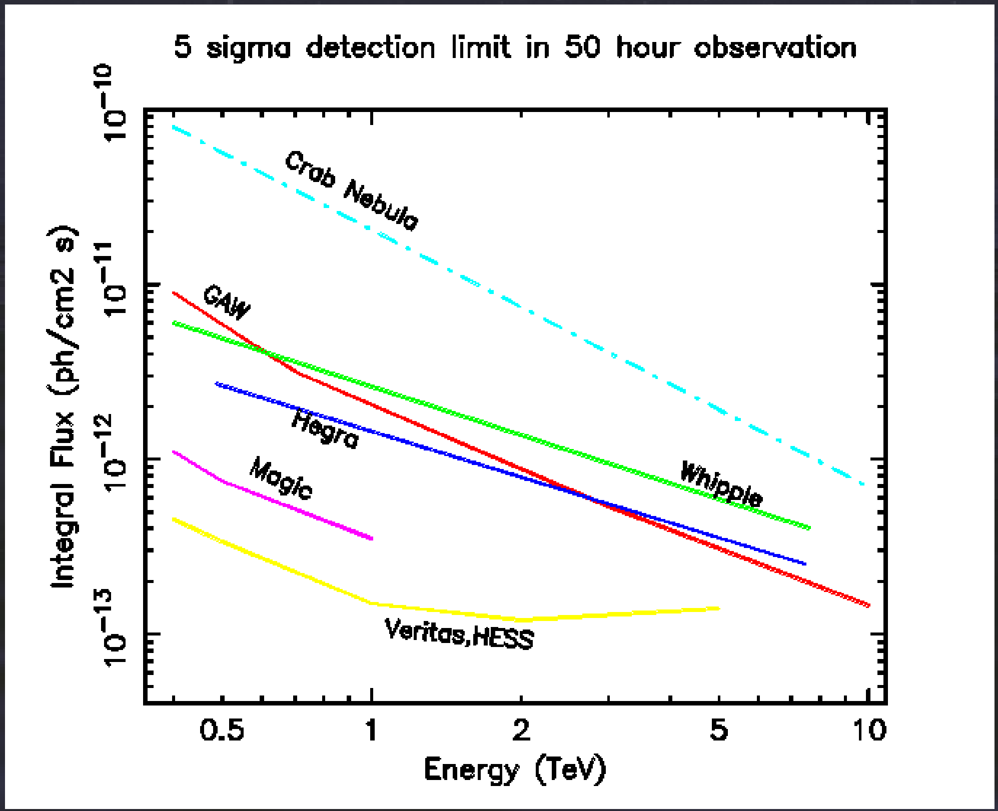


Exploratory analysis … …) under consideration.

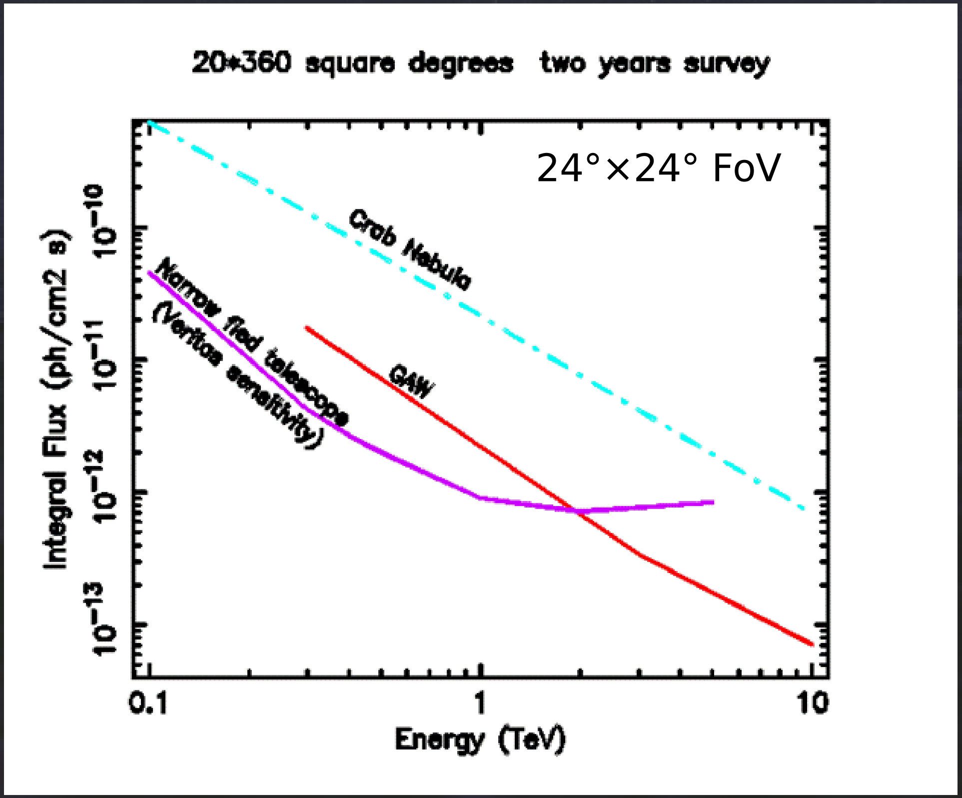
Sensitivity

GAW sensitivity with 6°×6° FoV. (phase 1), evaluated with a Crab-like spectrum source.



Sensitivity

GAW sensitivity for two years sky survey wit 24°×24° FoV. (phase 2), evaluated with a Crab-like spectrum source.



Despite of the small dimension of GAW light collector, GAW is competitive thanks to the gain of a factor more than 30 in the useful FoV w.r.t. current IACTS; this allows GAW to observe the same sky region for longer exposure time in the same amount of time as narrow FOV IACTS.

Conclusions

- GAW proposes two innovative steps to perform observations of VHE gamma rays above 700 GeV with a large FOV:
  - Use of fresnel lens as light collector.
  - Use of single photoelectron counting mode to decrease the noise.
- The expected sensitivity of the resulting array is 5σ Crab in 1.6 hours, covering a sky region of 24^0x24^0 during phase two.
- GAW could detect any ateady source at the 10% Crab level in a 7200 squared degrees in the sky in 2-3 years of observation time.
- It also could be more sensitive to transient phenomena thanks to its FOV, thus could be used as a monitoring system to trigger observations with other telescopes.