The GAW project

A R&D experiment for a very large field-of- view Imaging Atmospheric Čerenkov Telescope

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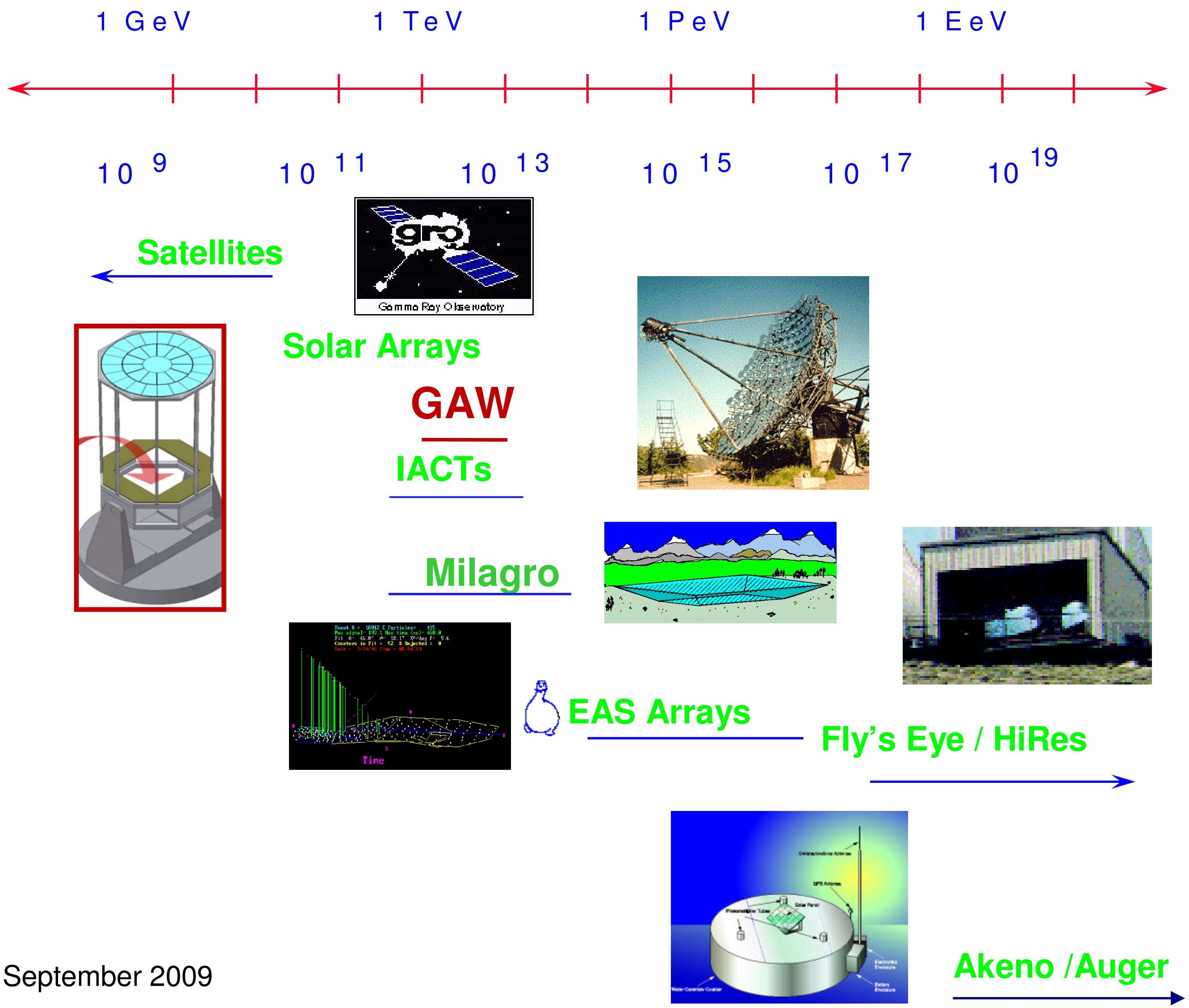
on behalf of the GAW collaboration

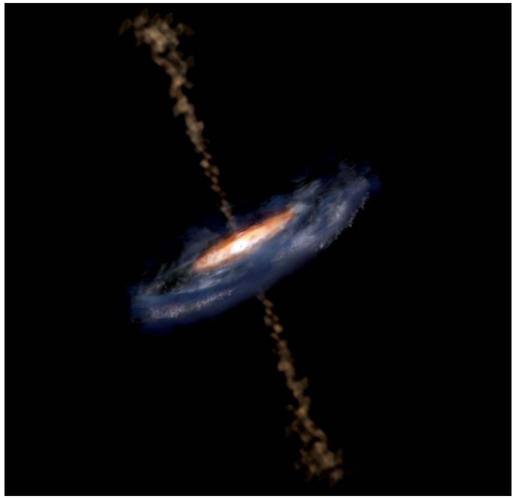
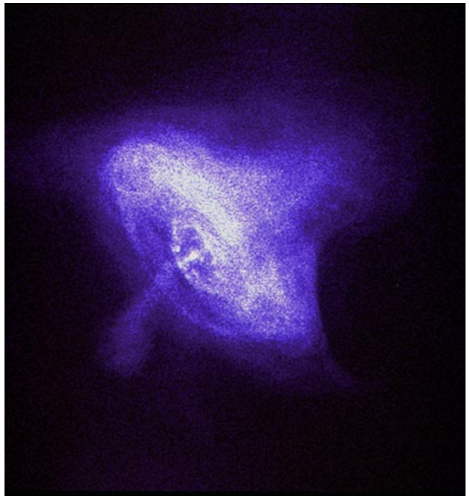
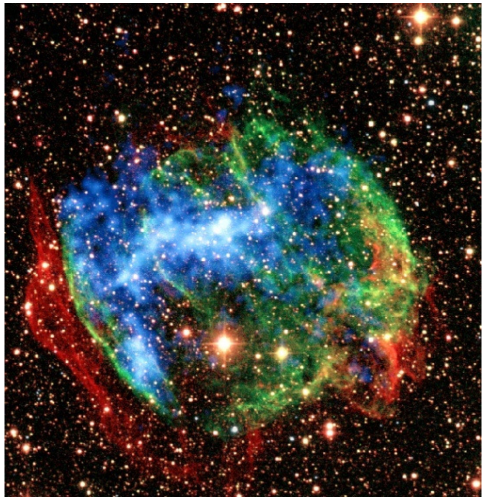
LIP – Laboratório de Instrumentação e Física Experimental de Partículas

Observing the High Energy Sky



Scientific Motivation

- VHE gamma-ray astronomical events can occur at unknown locations and/or randomly in time.
- High sensitivity surveys of large sky regions are limited by the capability of the current observatories.

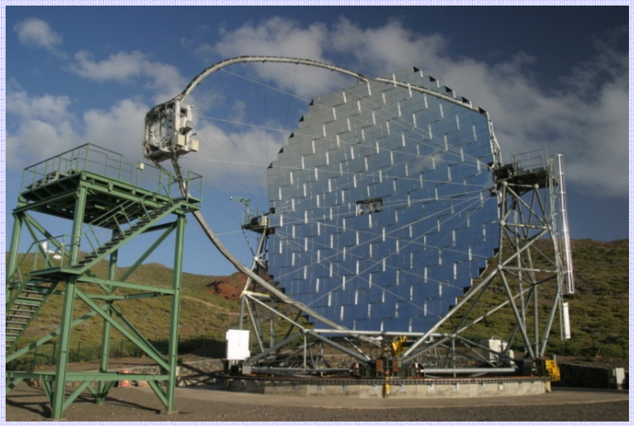




The existing and planned ground-based observatories aim to fulfill three main objectives:

- ❖ Lower Energy Threshold (few tenths of GeV),
- ❖ Improve Flux Sensitivity (in the entire VHE region),
- ❖ Full sky coverage.

Current gamma-ray detection techniques

- **IACT Telescopes** as CANGAROO III, HESS, MAGIC, VERITAS, … have
  - large collection area
  - reflective optics
  - high spatial resolution;
    - ☺ excellent background rejection;



which allow…

- ☺ wide energy range of γ-rays: from tens of GeV to TeV;
- ☺ good sensitivity to sources;

but …

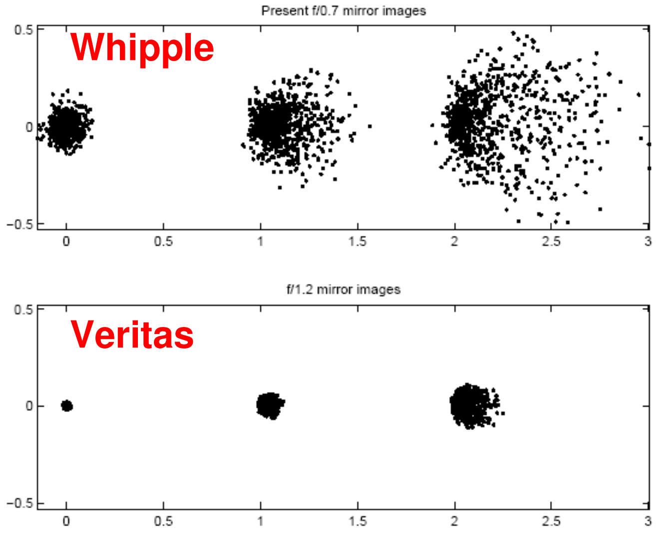
- ☹ survey of small sky areas;
- ☹ low detection probability for serendipity transient sources or stables sources far from the galactic plane;
  - ☹ **Small field of view (3º-5º)**

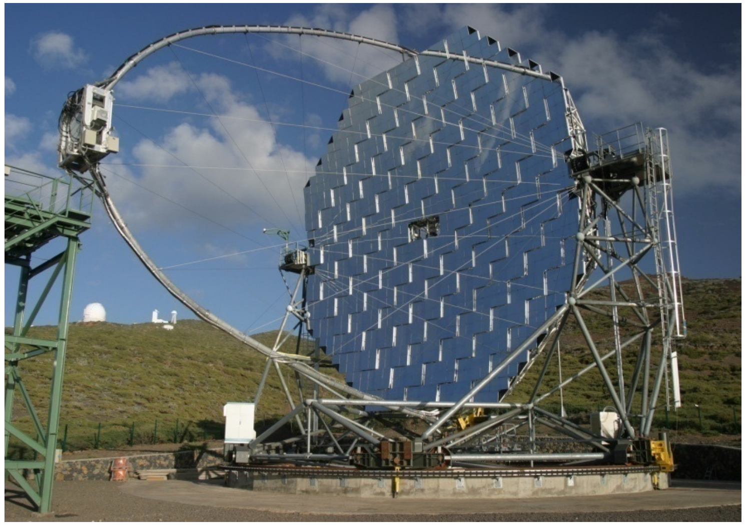
- **Shower particles arrays** ARGO, Tibet-HD and Milagro
  - ☺ very large FoV, more than one steradian
  - ☺ large duty cycle
  - ☹ sensitivity is some order of magnitude worse than IACT and achieved with much longer exposure.

FOV increase in IACTs: limitations

Large reflector mirrors (up to 17 m Ø) are used by the current IACTs.
Field of View enlargement is compromised due to:

- image degradation for off-axis imaging





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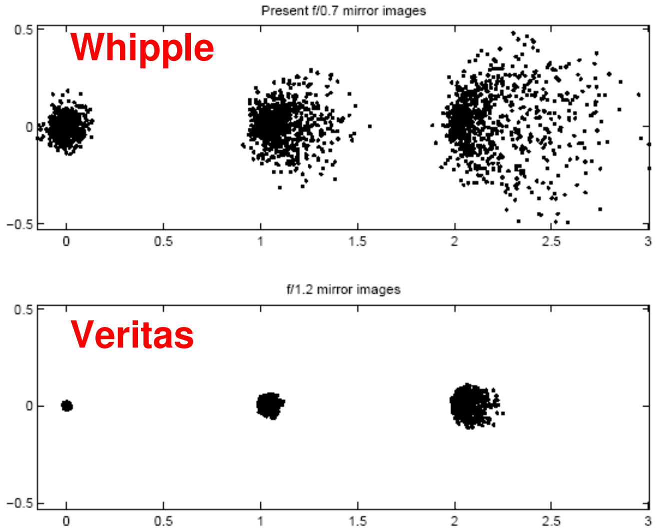
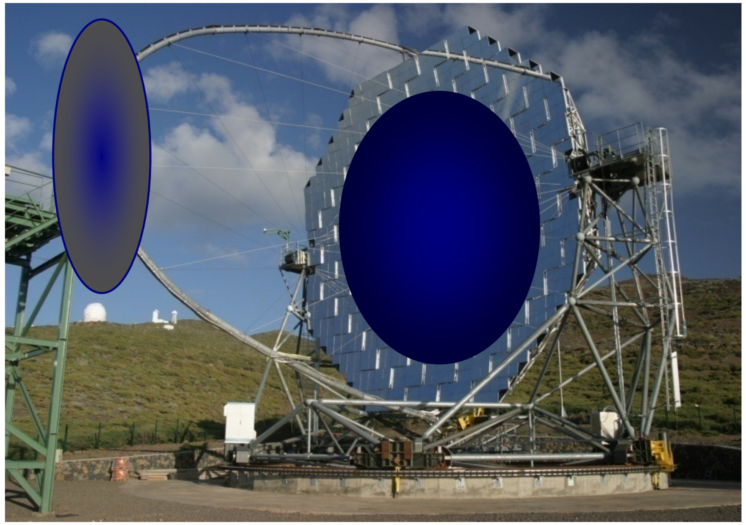


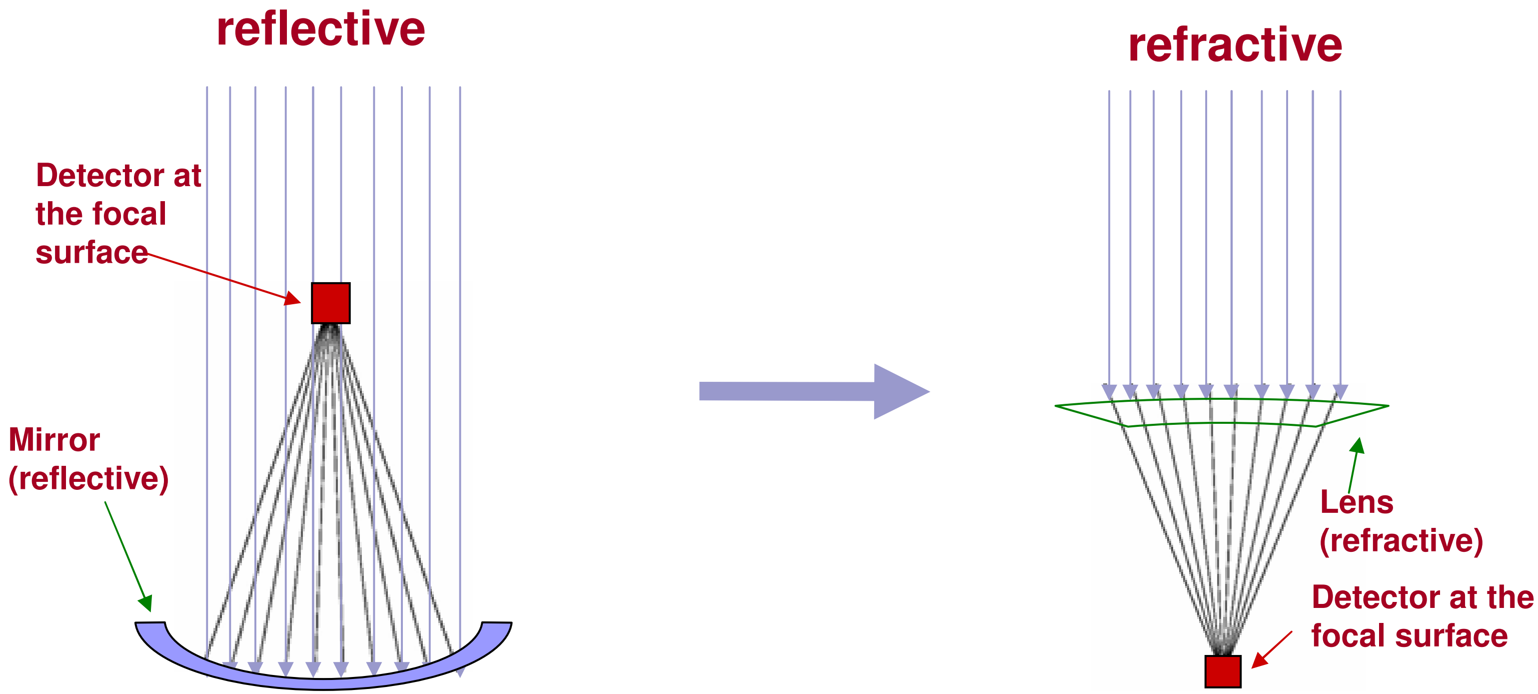
- the shadow of the focal surface increase



It is necessary to review the current geometry of the IACTs!

The GAW concept: Optics

➢ GAW proposes the usage of refractive optics to increase the FOV and to avoid the camera shadow



<u>Novel technique using Fresnel lenses</u>: a “refractive” Fresnel lens can work as an efficient light collector!

small thickness
good transmittance
easy replication –> low cost solution!

no shadow
large FoV

<u>Requirements</u>:
Cromaticity should be controlled at level <0.1º

The GAW concept: Focal Plane

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

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

Requirement: pixel size small enough to minimize p.e. pile up within intervals shorter than sampling time (10ns).

The MAPMT R7600-03-M64 chosen as baseline for GAW satisfies such a requirement.

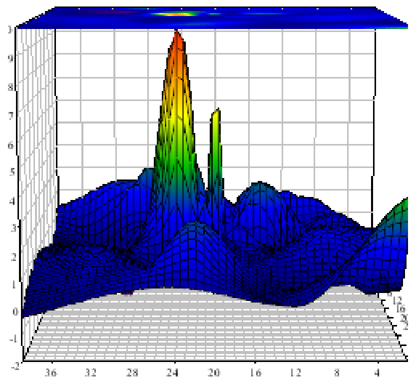
With current camera design is confortable with:

Threshold of 14 p.e per sample per trigger-cell (2x2 MAPMT)

Expected NSB contribution is 2-3 p.e. per sample per trigger-cell.

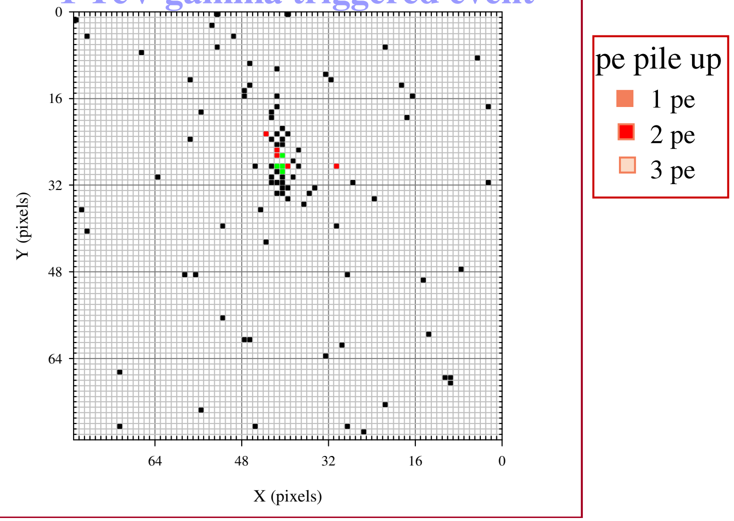
Charge Integration (Analog)

• 1 TeV gamma triggered event

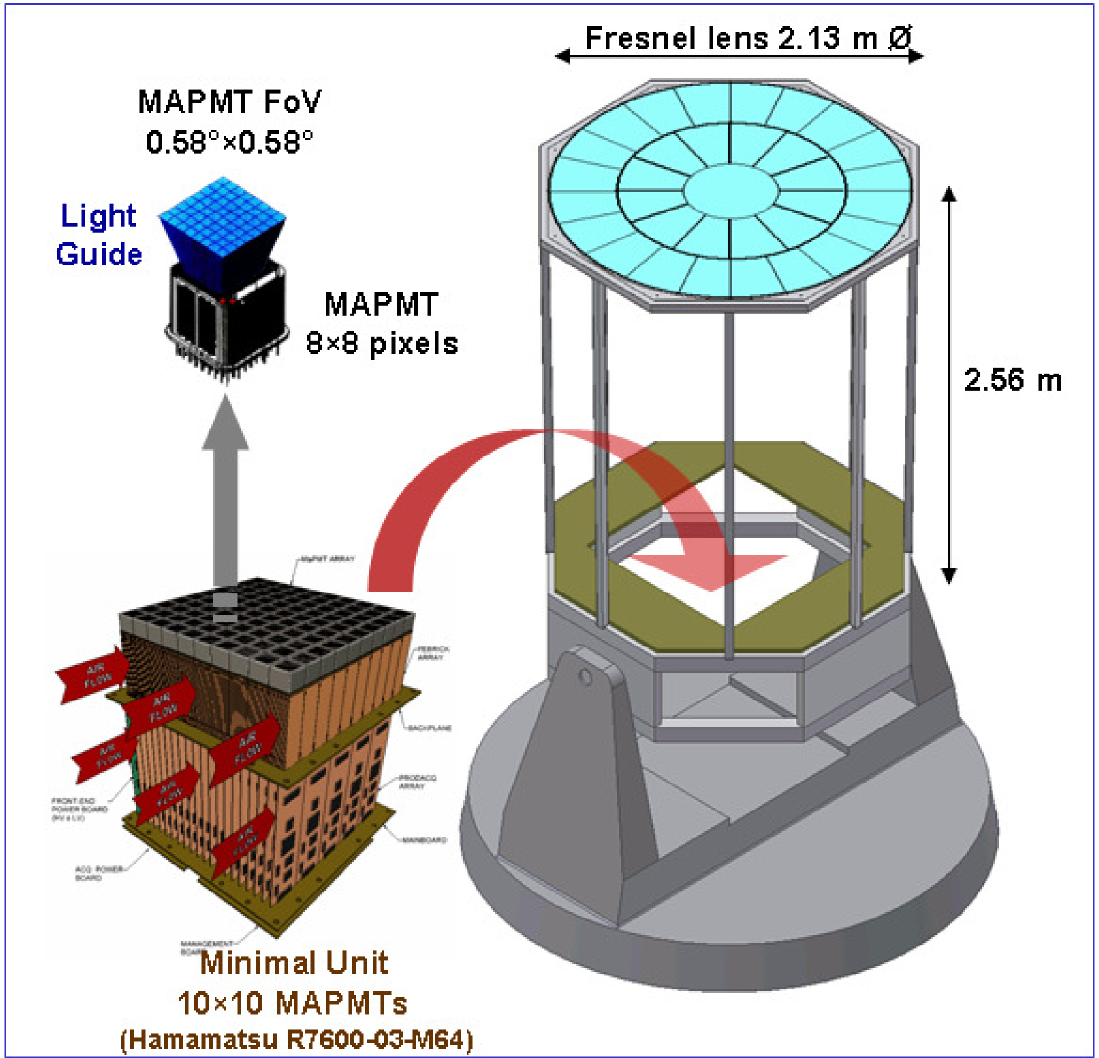


Single Photon Counting (Digital)

• 1 TeV gamma triggered event



GAW telescope design



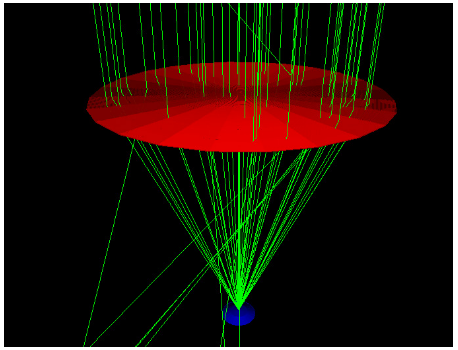
- GAW is a pathfinder gamma-ray experiment, sensitive in the 1-10 TeV energy region.
- Colaboration between institutes in Italy (IASF, Palermo), Portugal (LIP, Lisbon) and Spain (CIEMAT, Granada, Sevilla).
- The R&D telescope is planned to be located at Calar Alto Observatory (Sierra de Los Filabres - Almeria Spain), at 2168 m a.s.l.

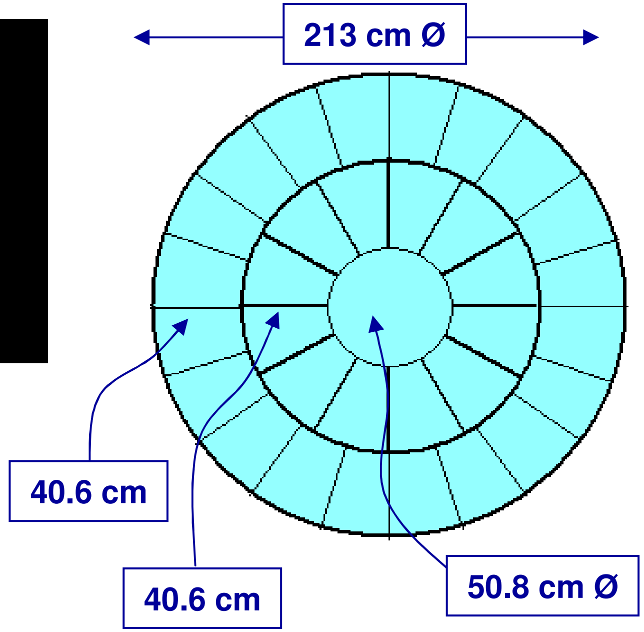
The telescope is equipped with

- a Fresnel lens
- a focal surface detector formed by a grid of 10x10 MultiAnode pixelized (8x8) PhotoMultiplier Tubes coupled to light guides.

GAW optics

✓ GAW uses a non-commercial Fresnel lens as light collector (by NANOSHAPE).
✓ Optimized for maximum of photon detection (λ = 360 nm).





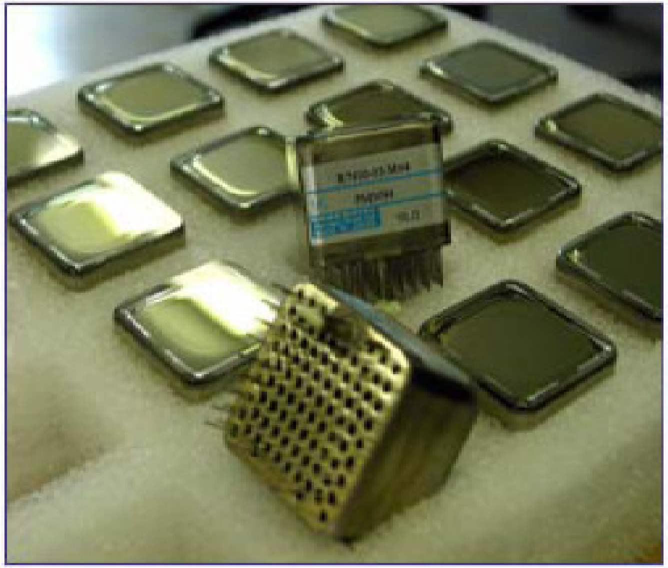
central core
+ 12 petals
+ 20 petals
+ spider support will maintain all the pieces together.

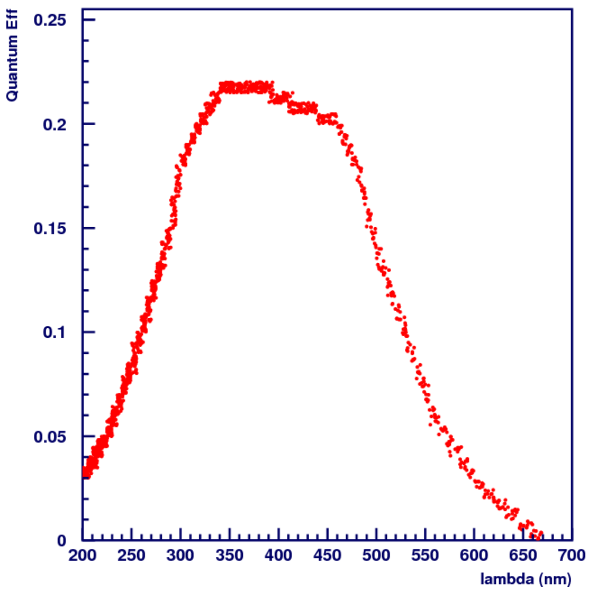
Baseline Optics Module for GAW prototype	
Lens	Flat single-sided
Diameter	2.13 m
Focal Length	2.56 m
f/#	1.2
Material	**UV Transmitting Acrylic**
Refraction Index	1.517 (at λ = 350 nm)
Standard Thickness	3.2 mm
Transmittance	~95% (330-600 nm, from UV to Near Infra Red)

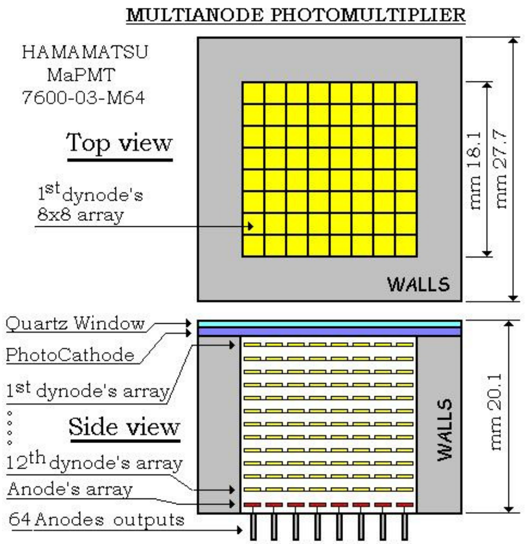
GAW detection matrix: photomultipliers

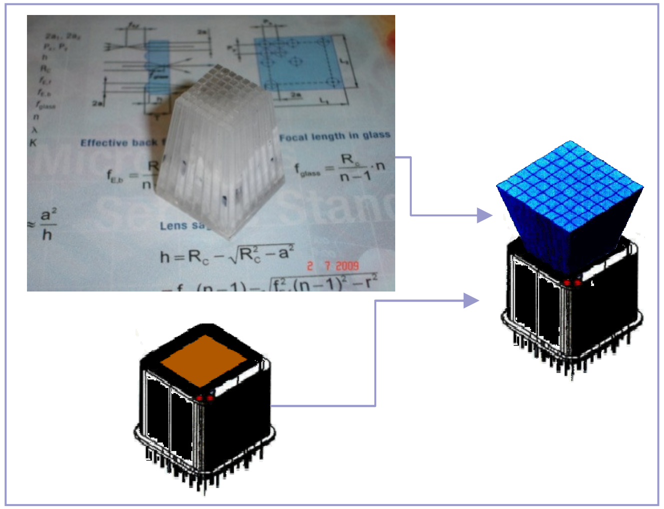
- MAPMT 8 × 8 (Hamamatsu R7600-03-M64)
- UV sensitive [200,680] nm
- Effective area 18.1 mm x 18.1 mm

  • Spatial granularity (~0.1º) suitable for Cherenkov imaging
- Good quantum efficiency for λ > 300 nm (>20% @ 420 nm)
- High gain ~3×10^5 for 0.8 kV voltage, low noise
- Fast response (< 10 ns)

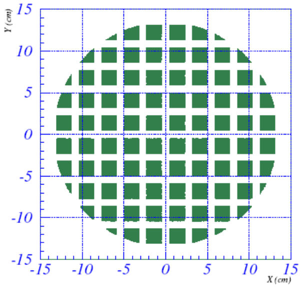


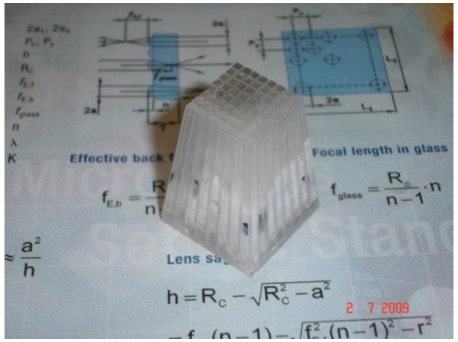




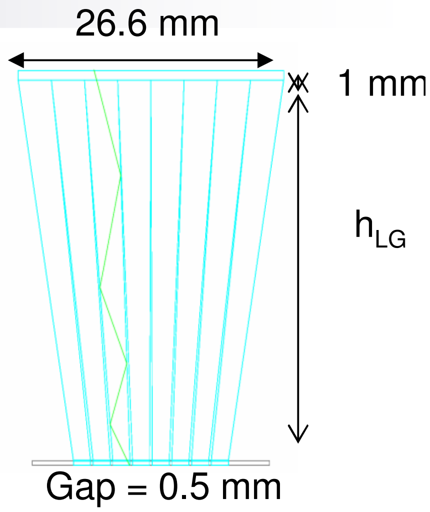


Detection matrix: light guides

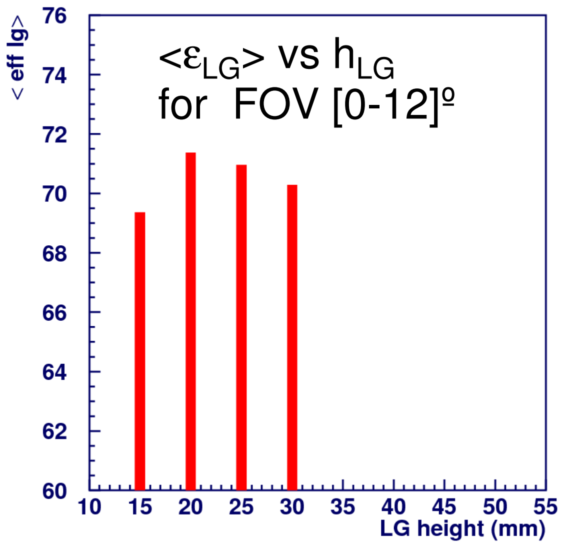


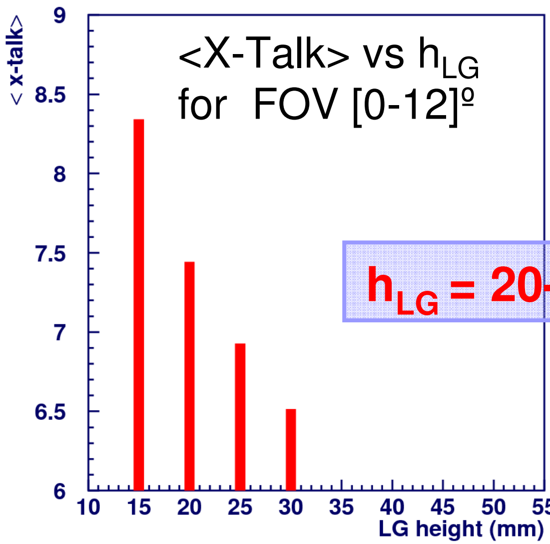


- ~55% of the photons would be lost without any guiding device
- LG are made of 8x8 independent acrylic plastic tubes glued on a plastic plate
- Tubes:
    - pyramidal polyhedron shaped
    - material: PMMA from Fresnel Technologies (n=1.4893)
- Pieces hold together by 1mm layer on the top made of anti-reflective PMMA



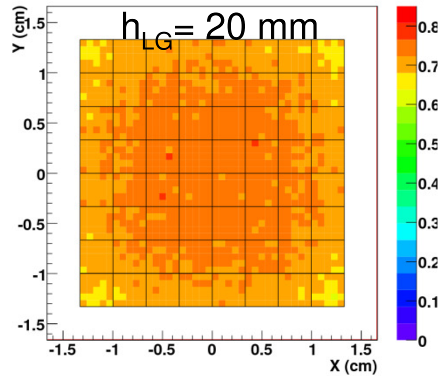
PMMA Fresnel

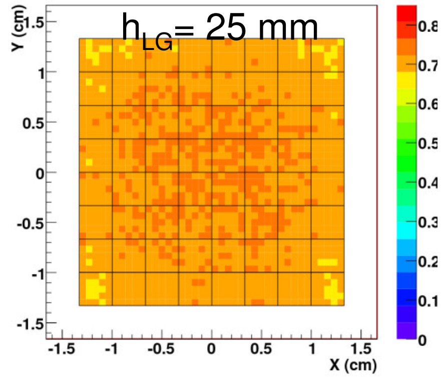




h_{LG} = 20-25 mm

ε_{LG} vs (X,Y) for θ<32º

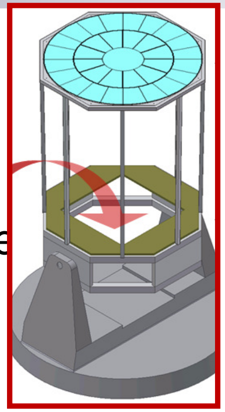




GAW timeline

2005 - 2007

Telescope Design and site choice



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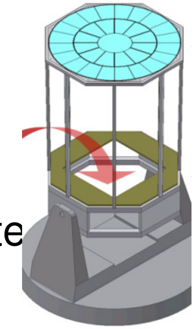
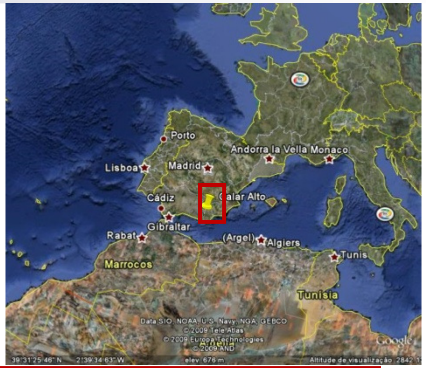




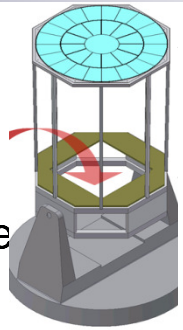
2005 - 2007	Telescope Design and site choice
2007	Project proposal approved (Phase 1 approved)

GAW
Gamma Air Watch

A very large field of view Imaging Atmospheric Cherenkov Telescope

Concept Design and Science Case

GAW timeline

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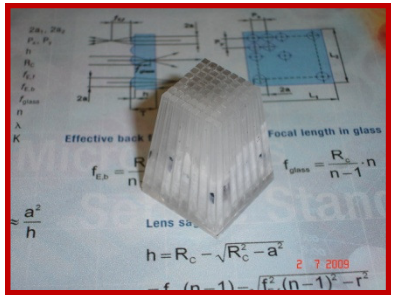

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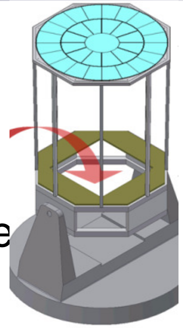
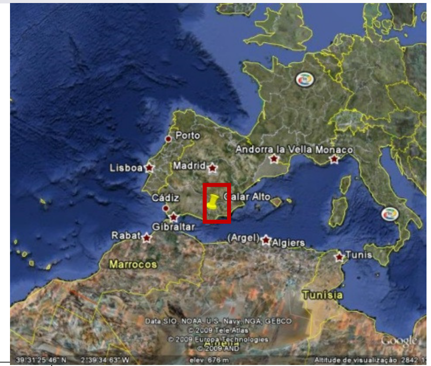

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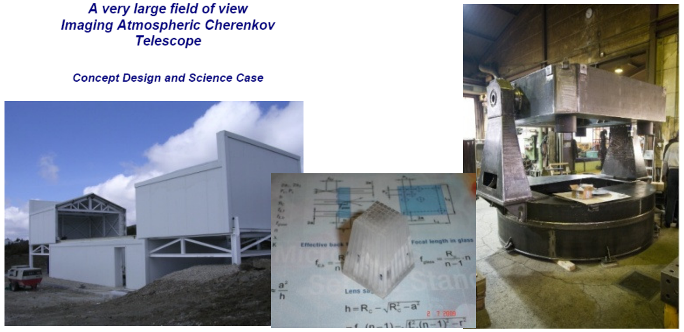
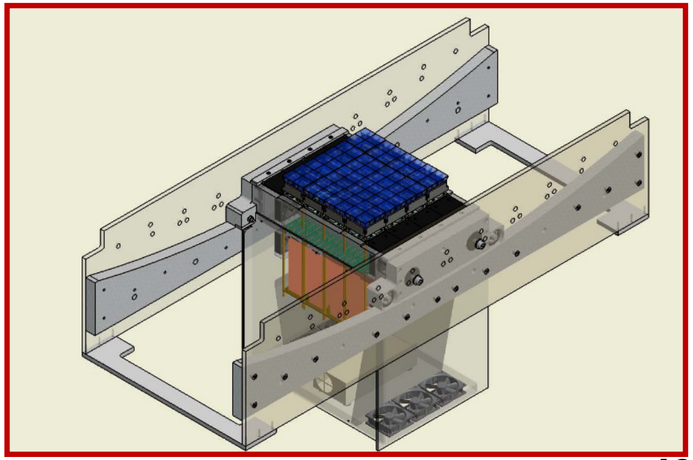
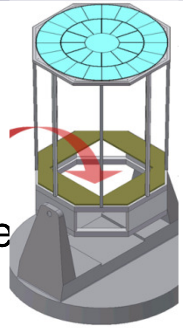
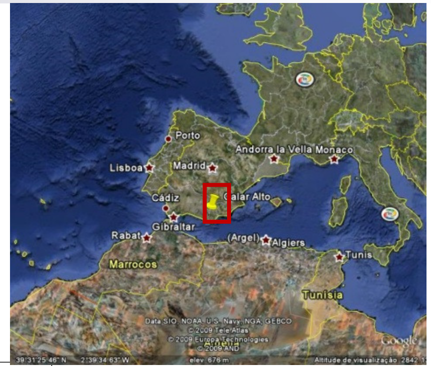




GAW timeline





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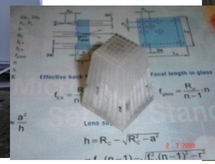
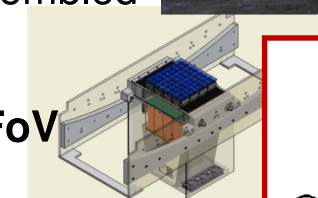
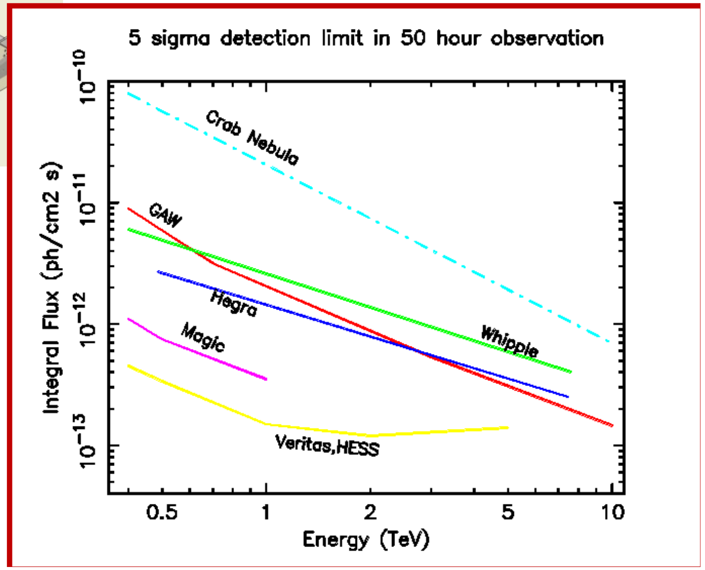


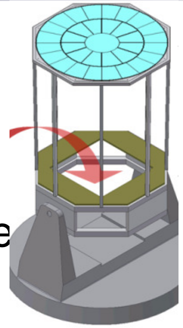
2010 — Test full apparatus:
1 telescope **6°×6° FoV**

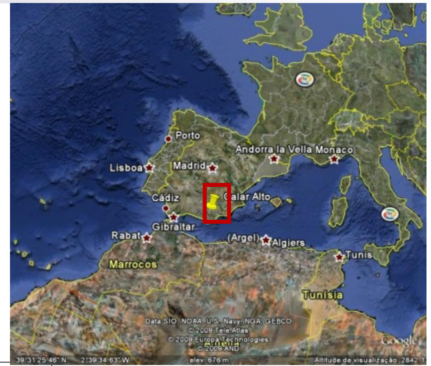


2011 — Results on R&D
Test bench for new technological solutions for the focal plane

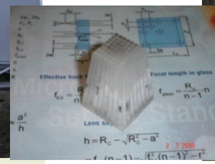


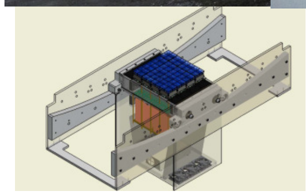
GAW timeline

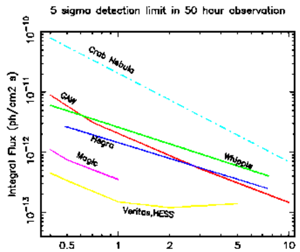


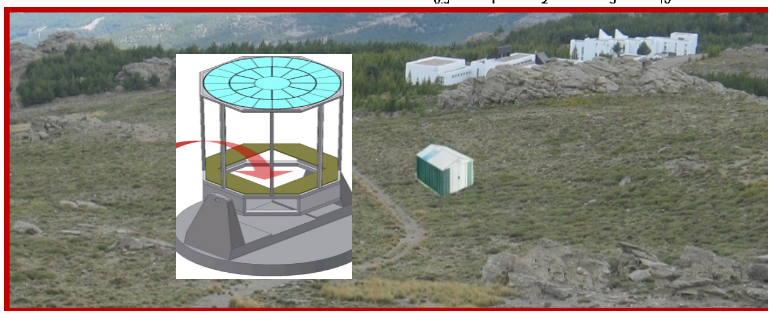


2005 - 2007	Telescope Design and site choice
2007	Project proposal approved (Phase I approved)
2008 - 2009	Construction and begin of installation Lens purchase: lens design First light guide assembled
2010	Test full apparatus: 1 telescope **6°×6° FoV**
2011	Results on R&D Test bench for new technological solutions for the focal plane
2012	Phase II **24°×24° FoV**









Conclusions

- ✓ IACT challanges for the next years:
  - ✓ Improve sensitivity
  - ✓ Lower the threshold for γ rays detection
  - ✓ Higher FOV

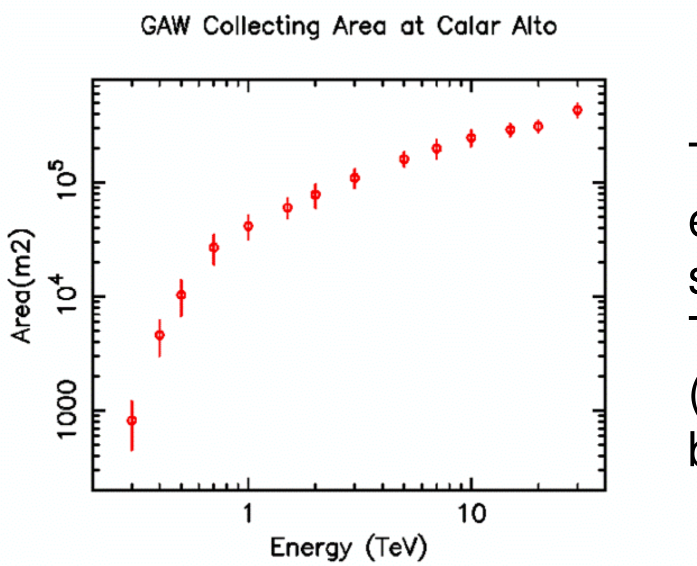
✓GAW intends to proof that it is possible to combine both good sensitivity with large FOV. GAW will use:

- ✓ a Fresnel lens as a refractive light collector,
- ✓ single photoelectron counting mode as detection working method.

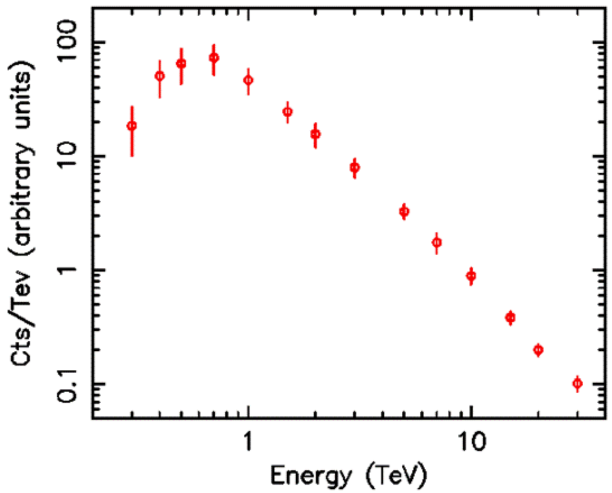
- ✓ 2009 Mechanical telescope structure built already in place
- ✓ 2010 Detector prototype commissioning phase:
  - ✓ test Fresnel lens
  - ✓ test electronic and readout matrix
- ✓ 2011 Results proving the feasibility of the technique. Good test bench for IACTs improvement.

BACKUP Slides

GAW prospects: collecting area



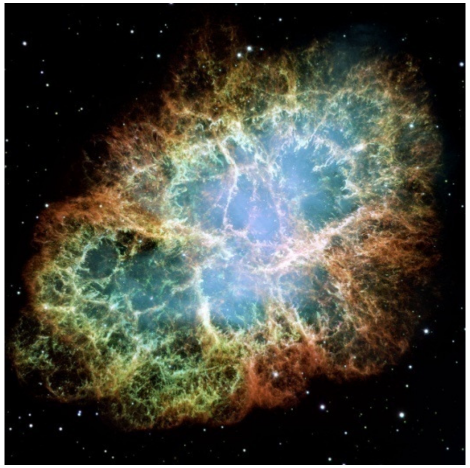
The collecting area is evaluated for mono-energetic γ-ray events coming from an on-axis source (zenith angle=0°) and with a 3-Fold Telescopes trigger coincidence: the fiducial area (1520×1520 m^2) is multiplied by the ratio between the detected and generated events.



<u>GAW and the Crab Nebula.</u>

GAW collecting area has been convolved with a Crab-like spectrum.

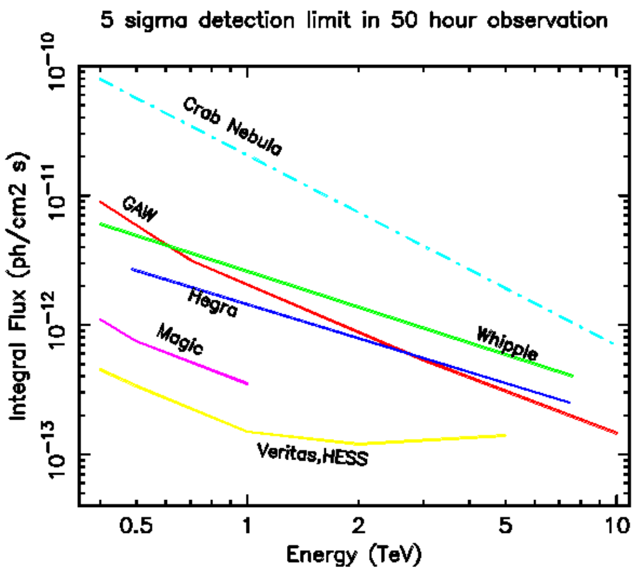
The figure shows the differential detection rate of the Crab Nebula vs energy, which peaks at 0.7 TeV.



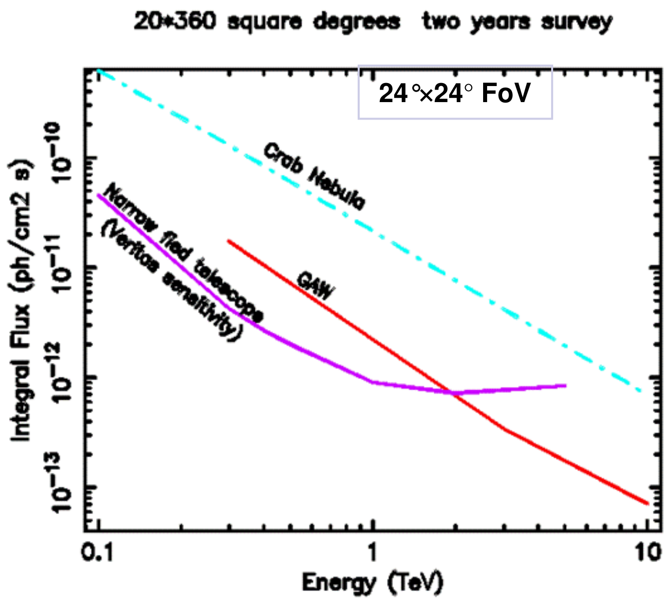
GAW prospects: sensitivity

The sensitivity limit is evaluated using a source with a Crab-like spectrum.

GAW sensitivity with 6°×6° FoV. **"Phase 1"**



GAW sensitivity with 24°×24° FoV. **"Phase 2"**



GAW/VERITAS
GAW light collector (2.13 m Ø) / VERITAS (12 m Ø)
GAW is competitive, mainly at higher energies, thanks to the gain of a factor more than 100 in the useful FoV
-> GAW will observe the same sky region for longer exposure time in the same clock-time interval.