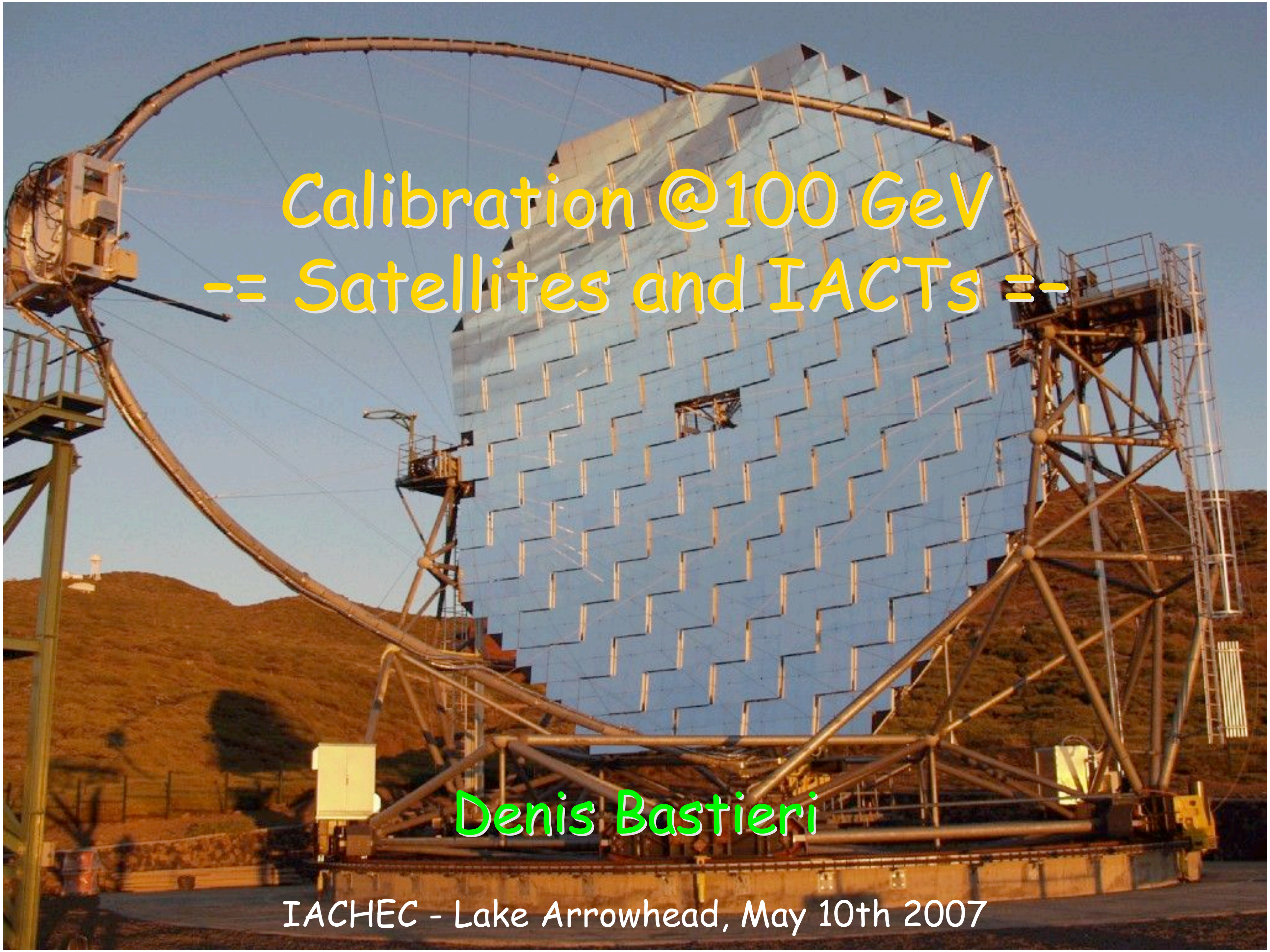
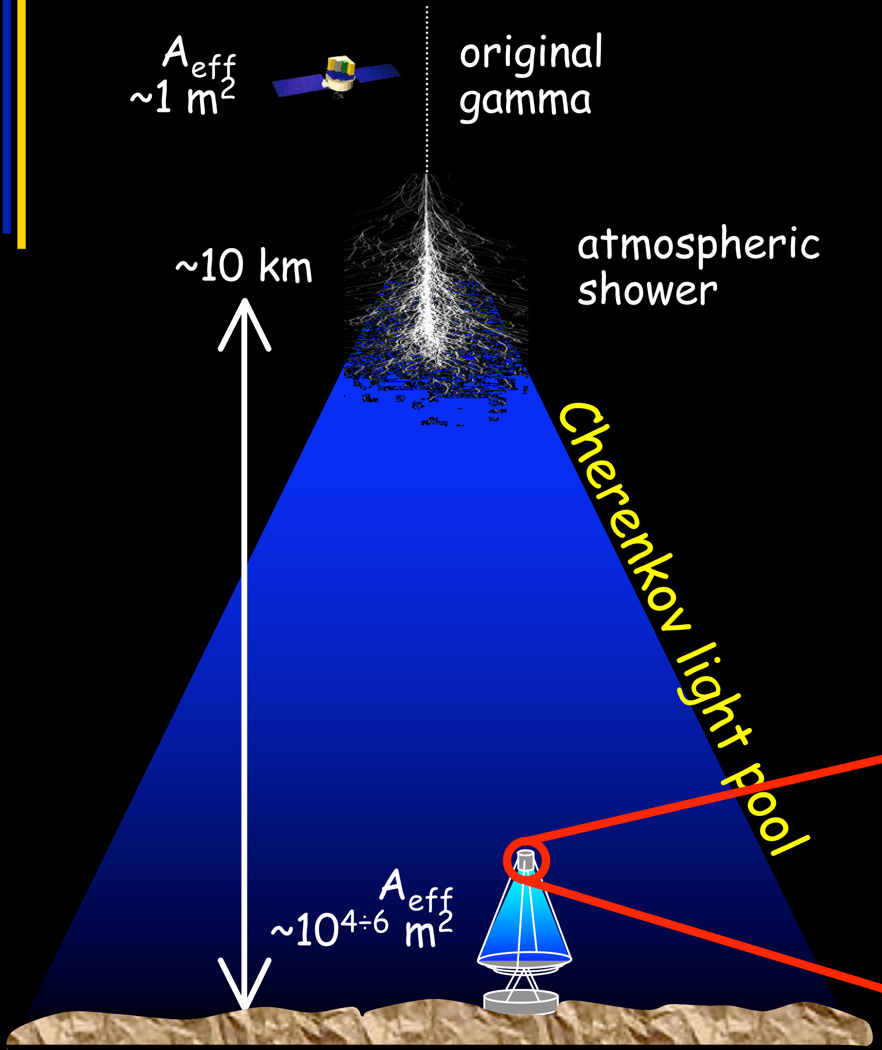
Calibration @100 GeV
-= Satellites and IACTs =-



Denis Bastieri

IACHEC - Lake Arrowhead, May 10th 2007

Imaging Atmospheric Cherenkov Technique



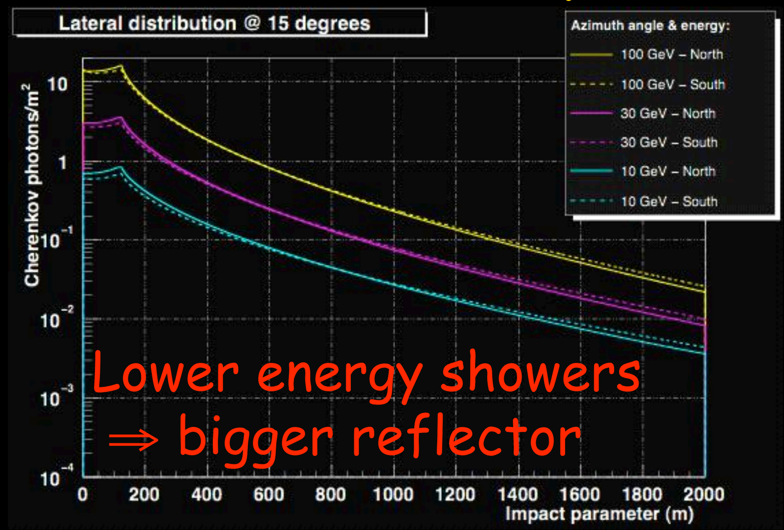
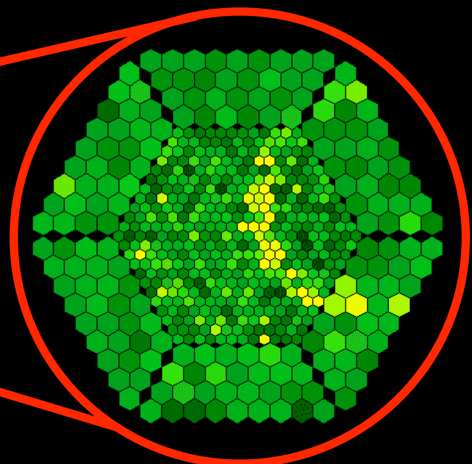
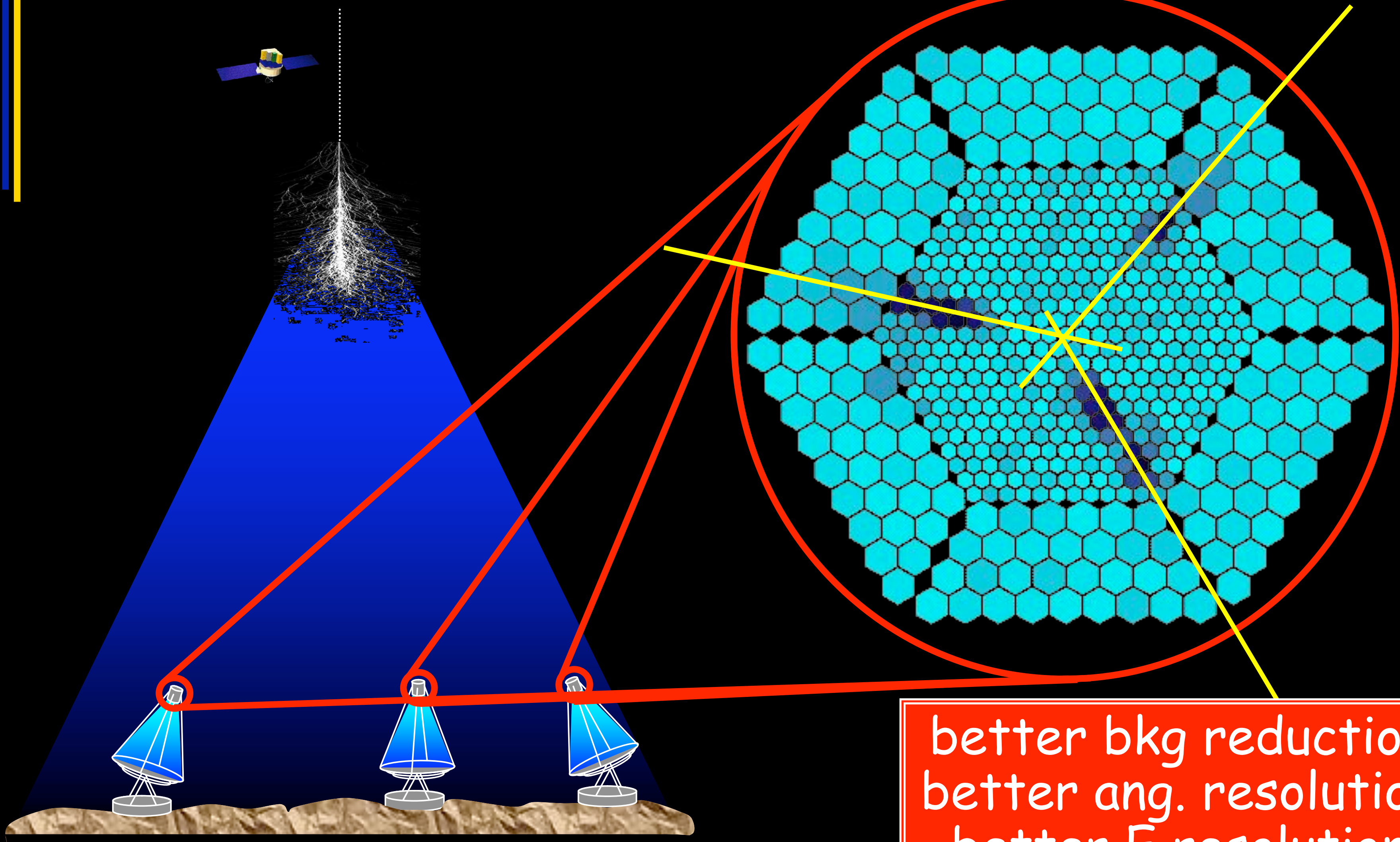


Image analysis
direction, energy and shower kind



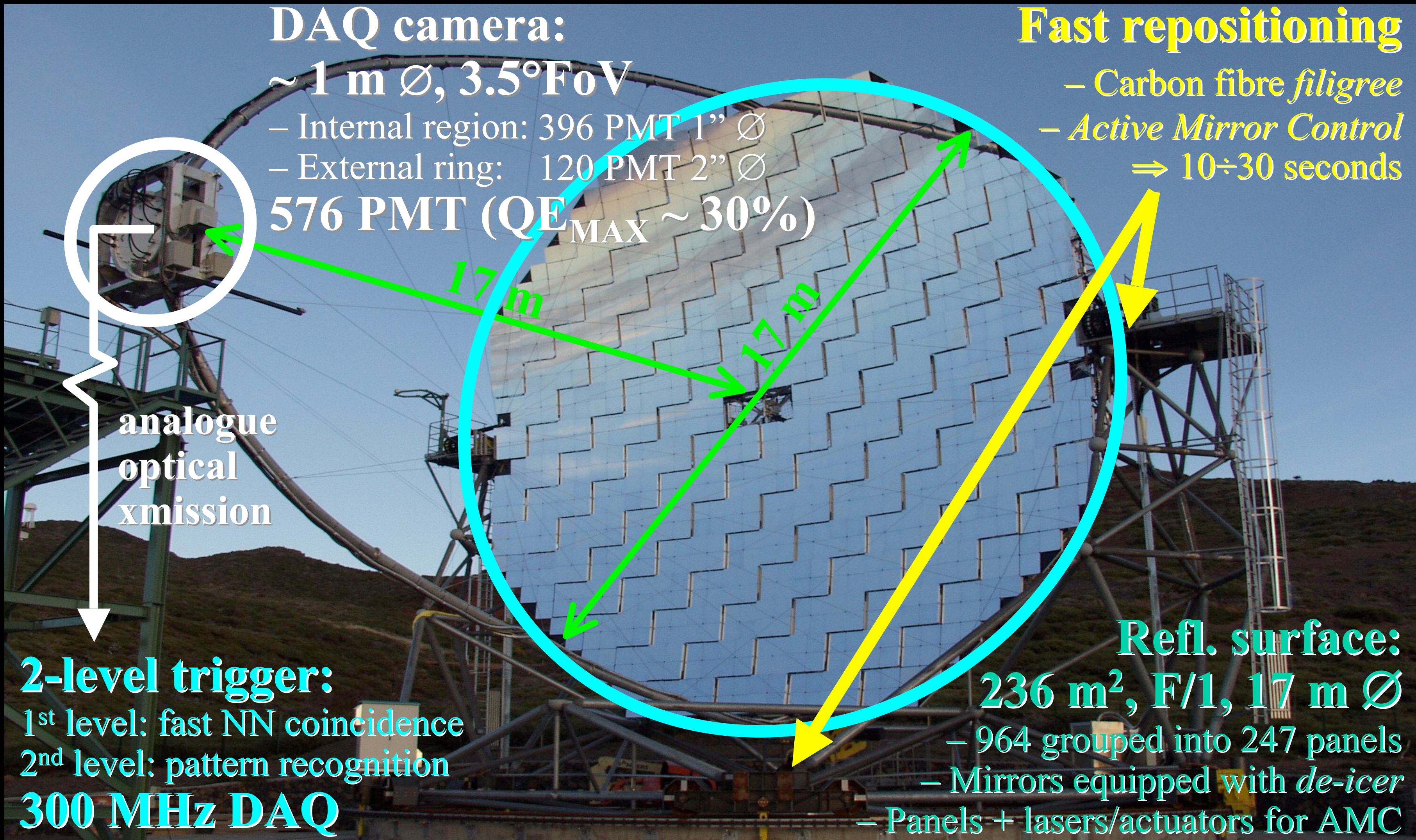
muon

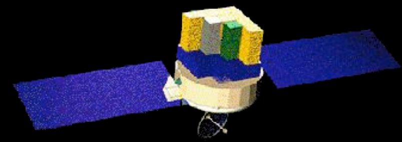
IACT - System of Cherenkov Telescopes



better bkg reduction
better ang. resolution
better E resolution

MAGIC - A general overview





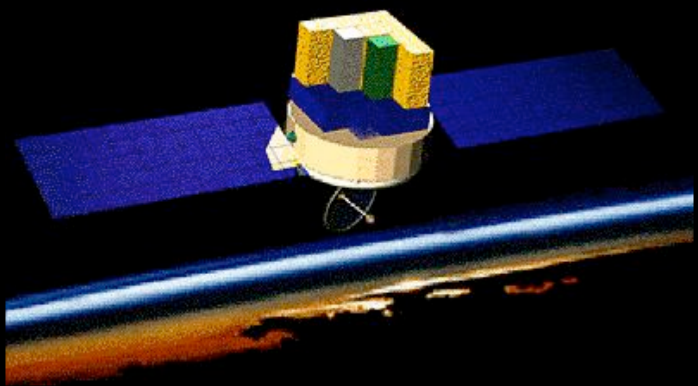
Satellites vs. Cherenkov

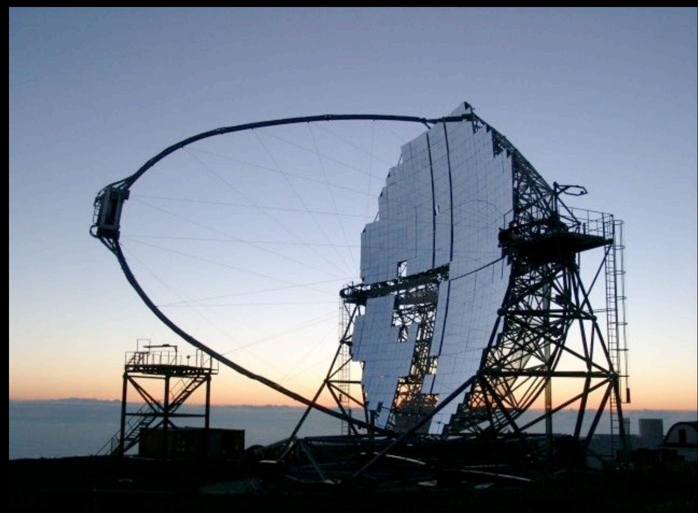
Satellite experiments

- Primary detection
  - Test beam
  - Low background
- Energy < 300 GeV
- Effective area ~ m^2
- Duty-cycle ~ 100%
- Field of view ~ 1 sr
- High cost

Cherenkov experiments

- Secondary detection
  - Strong MC dependence
  - High background
- Energy > 60 GeV
- Effective area ~ $10^{4\div5}m^2$
- Duty-cycle ~ 20%
- Field of view ~ 0.01 sr
- Low cost

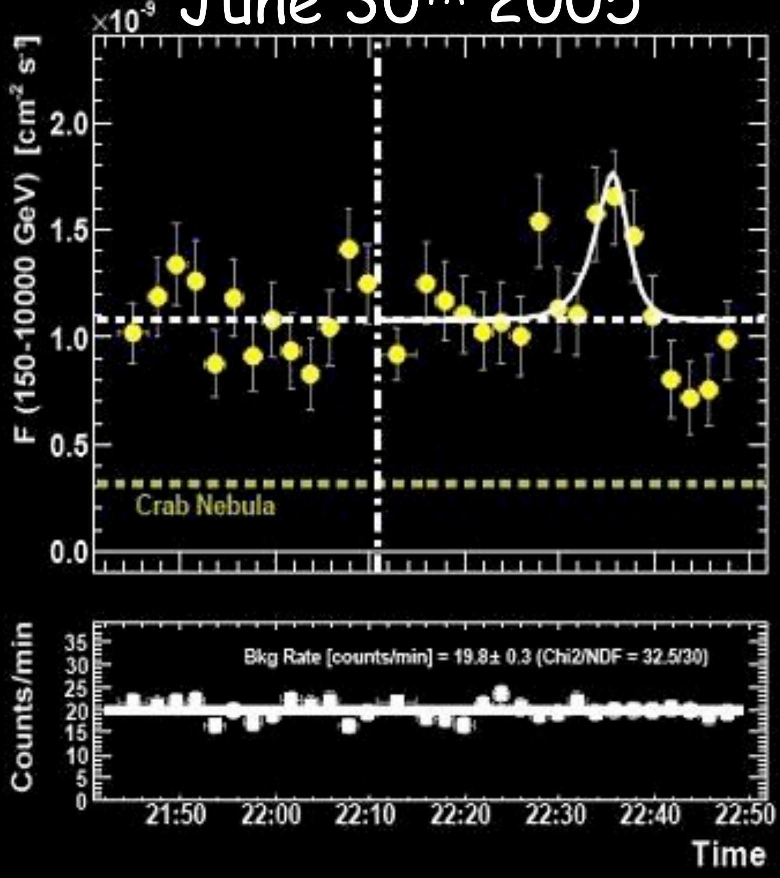




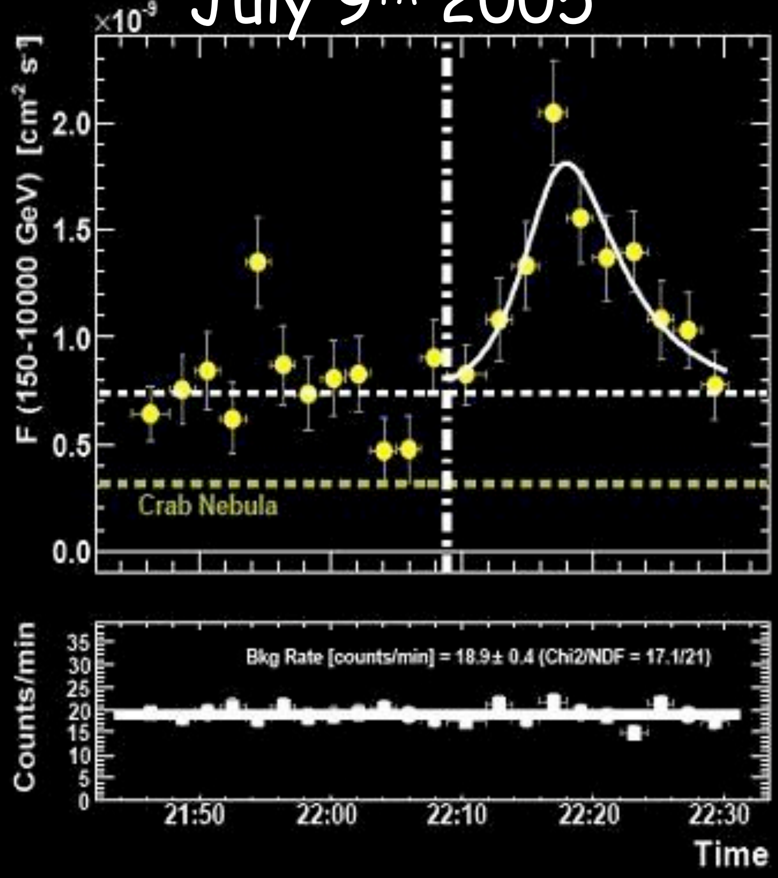
Mkn501 - Multiwavelength

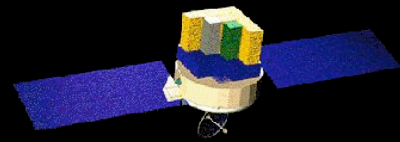
Highly variable emission

June 30th 2005



July 9th 2005





Satellites vs. Cherenkov

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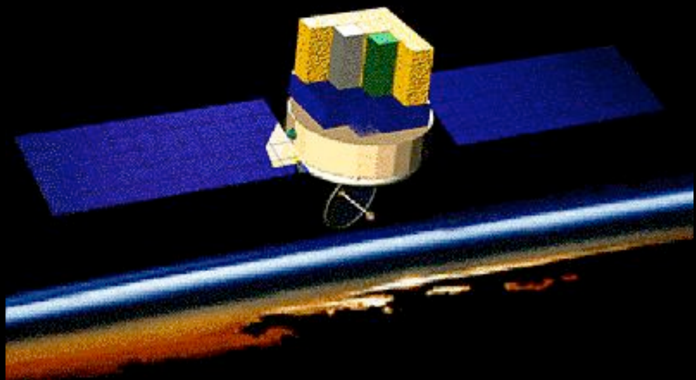

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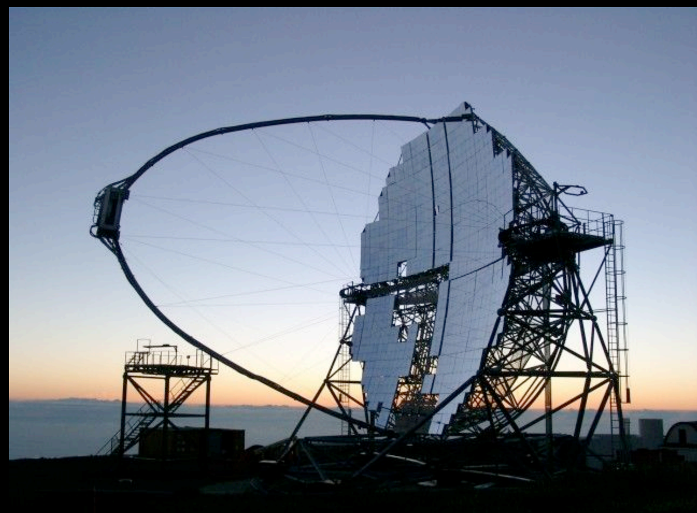
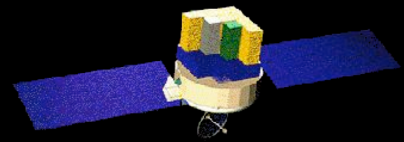
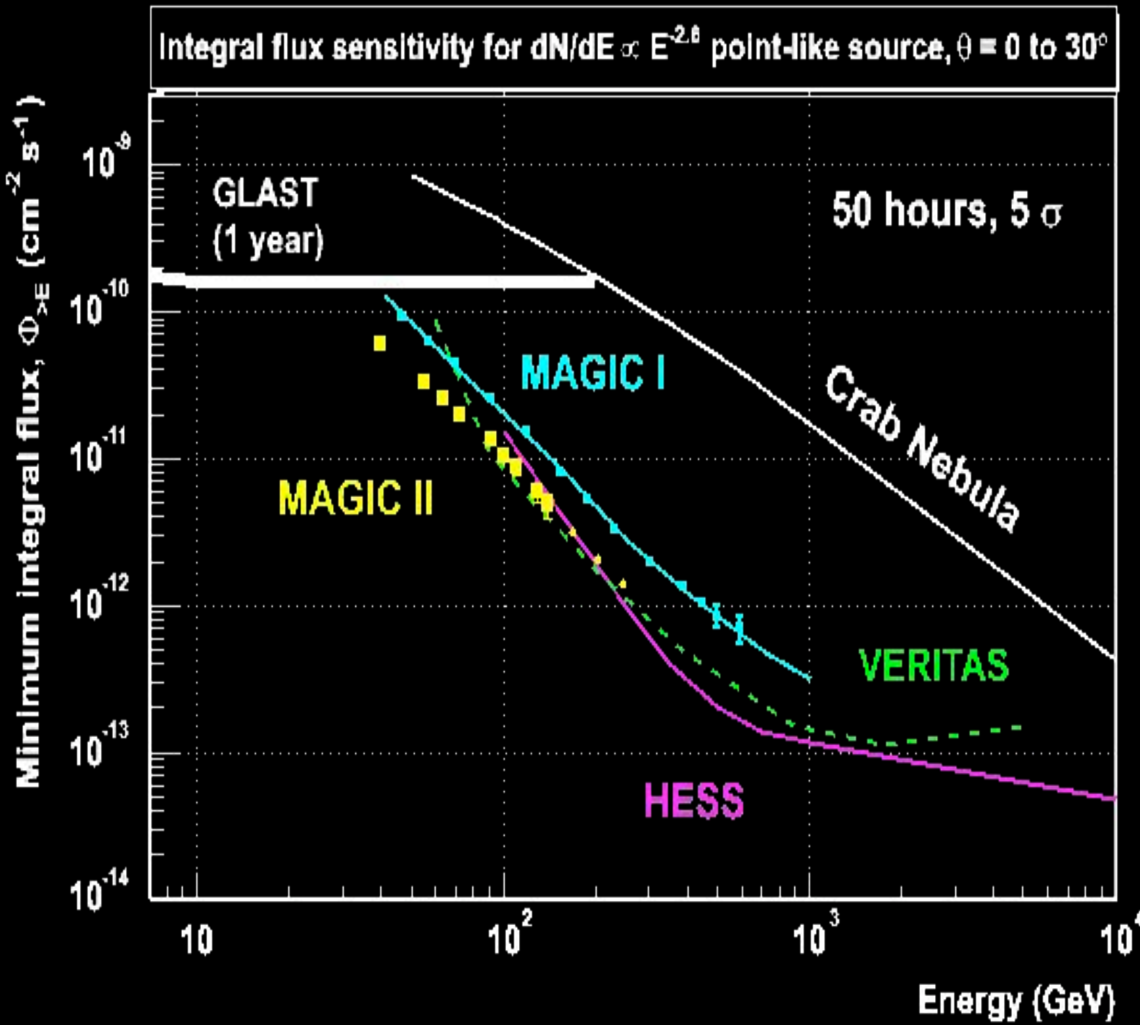


IACT - Synergy with GLAST

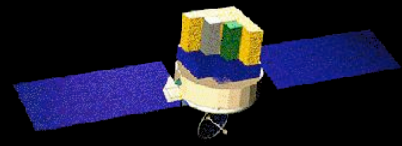


- GLAST is calibrated using a test-beam.
- IACTs have a wide overlap with GLAST

⇒ Use GLAST to calibrate IACTs!

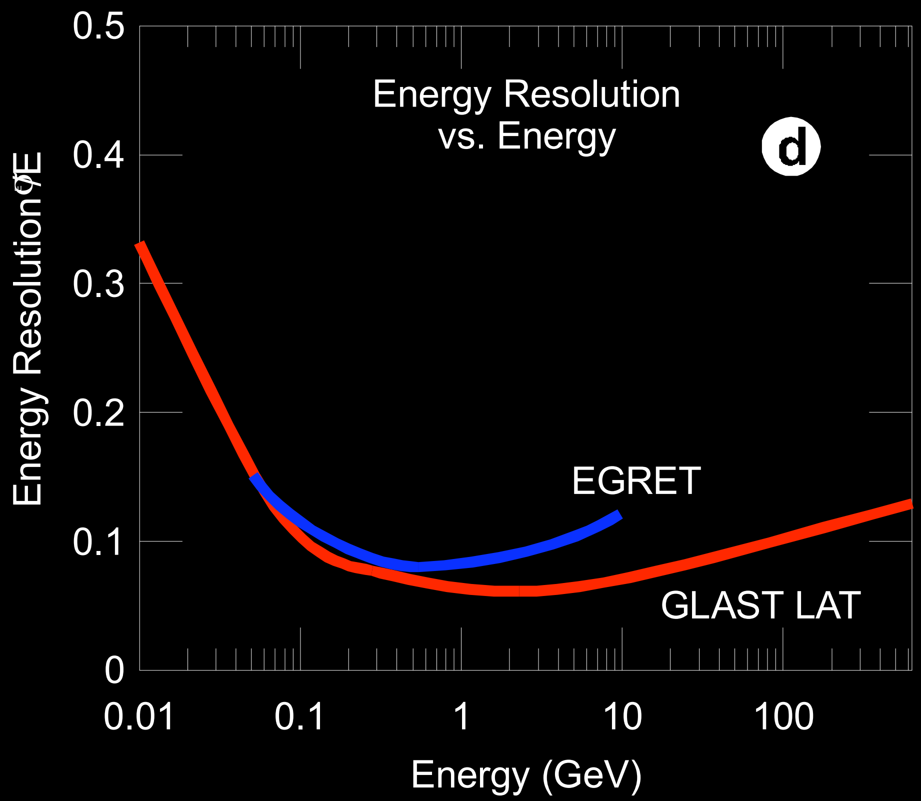


Energy reconstruction by GLAST



- Satellites as GLAST (or AGILE), contrary to IACTs, are calibrated in a well-controlled laboratory environment, using test beams of electrons and gammas,

⇒ relative uncertainties of ~ 10% or better is expected



Energy resolution vs. Energy

GLAST and EGRET compared

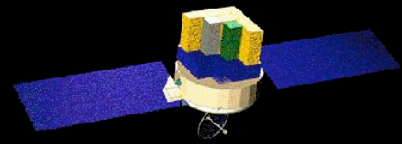
Energy reconstruction by IACTs

Measuring spectral features:

- Intrinsic energy resolution $\lesssim$ 5%
- Absolute energy scale quite elusive: energy rec. in the 50÷300 GeV range
  - dominated by uncertainties on Monte Carlo simulations
  - dominated by uncertainties on atmospheric models
  - dominated by atmospheric variations

?? ~30%

LIDAR

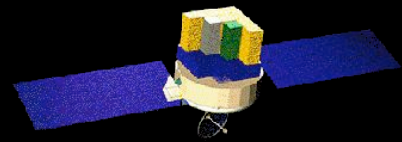


The Object: Crab Nebula

To reduce the abs. E scale uncertainty

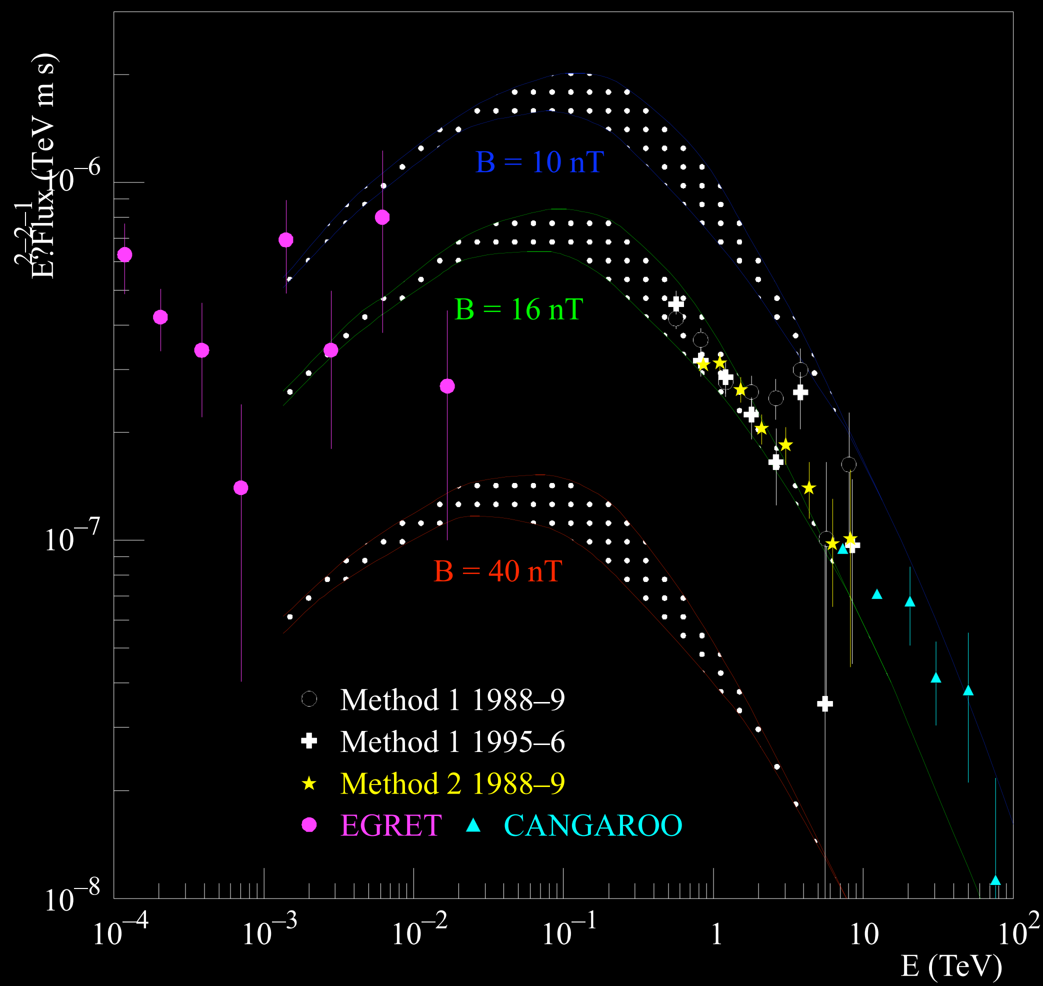
$\Rightarrow$ observe the Crab Nebula!

- Because the Crab Nebula is steady
- Because it will be observed intensively by GLAST already in the first year
- Because it will have been observed, in 2008, quite a lot by IACTs



The spectrum of the Crab Nebula

The spectrum of the Crab Nebula in the overlap region is poorly known, but under different hypotheses on the magnetic field in a Inverse Compton scenario looks like the figure on the right.



Tackling spectral features of the Nebula

The spectrum can be parameterised as a two-slope spectrum:

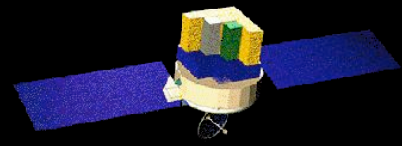
- Spectral index = 2.0 for $E < E_{brk}$
- Spectral index = 2.7 for $E > E_{brk}$

$E_{brk} \sim 100$ GeV and depends on the model assumed

A bigger difference between indexes will mark even more the spectral feature and make the determination of E_{brk} easier

The position of this spectral break
WELL DETERMINED BY GLAST
can be used to calibrate IACTs

GLAST: Crab observation (1st year)



Gammas from Crab Nebula between 30 and 300 GeV detected in the first year by GLAST in survey mode as a function of E_{brk}, with 90 % data efficiency, taking into account:

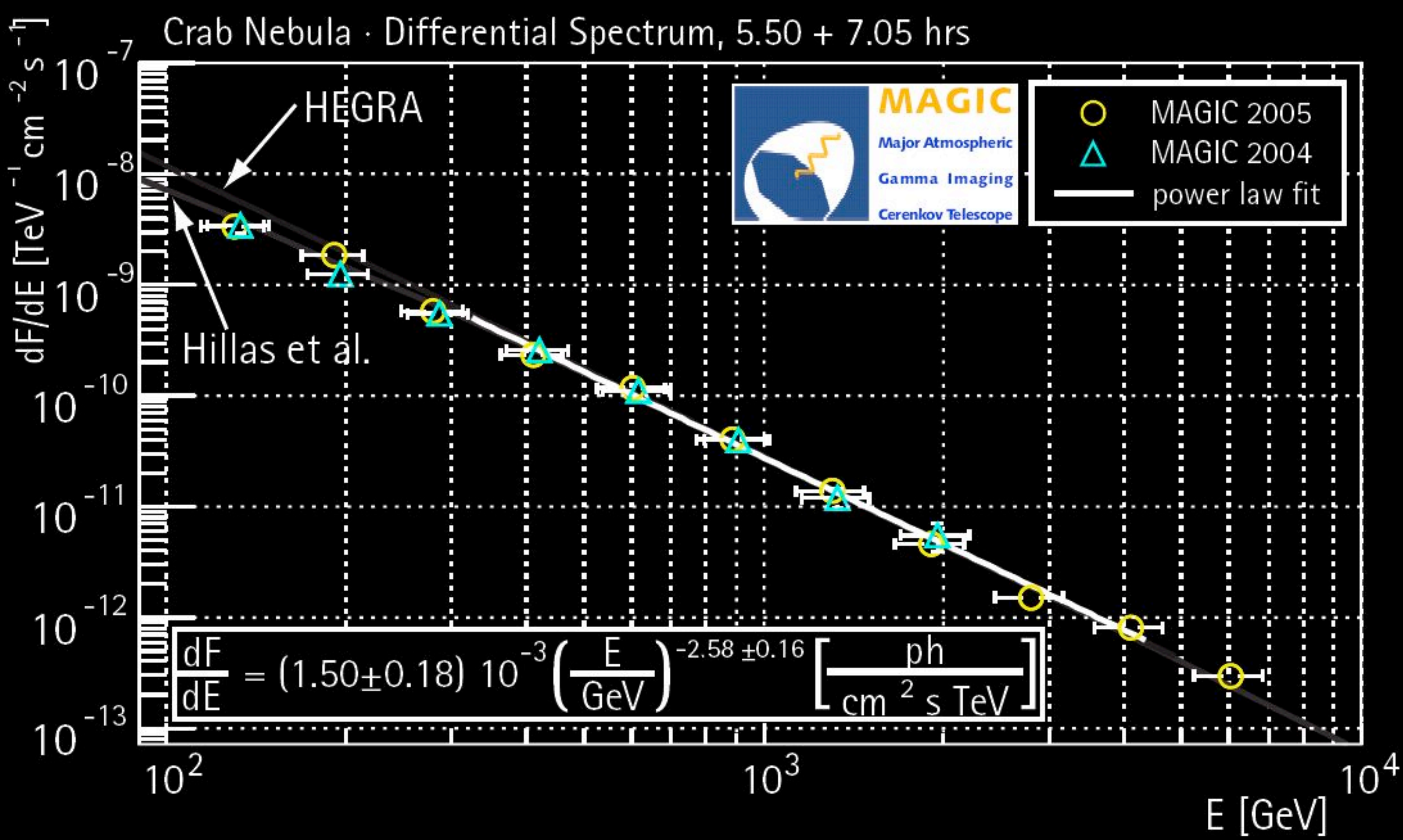
- South Atlantic Anomaly
- Data downlink failures
- Scheduled maintenances

E_{brk} fitted assuming the actual E resln. of GLAST.

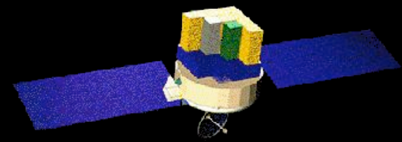
E_{brk}	Gammas seen by GLAST	$\frac{\delta E_{brk}}{E_{brk}}$
50	3763	6.2%
100	3249	8.2%
150	2988	12.7%
200	2818	17.2%

IACTs: The Crab (Nebula) spectrum

Toward the Inverse Compton peak



IACTs & GLAST: Results



- The error on E_{brk} is the spread of the estimate obtained from 100 indep. MC
- The value of E_{brk} as determined by IACTs should be offset to match GLAST one
- The absolute scale uncertainty between 30 and 200 GeV will not exceed GLAST one: it will go from about 6% to 17%

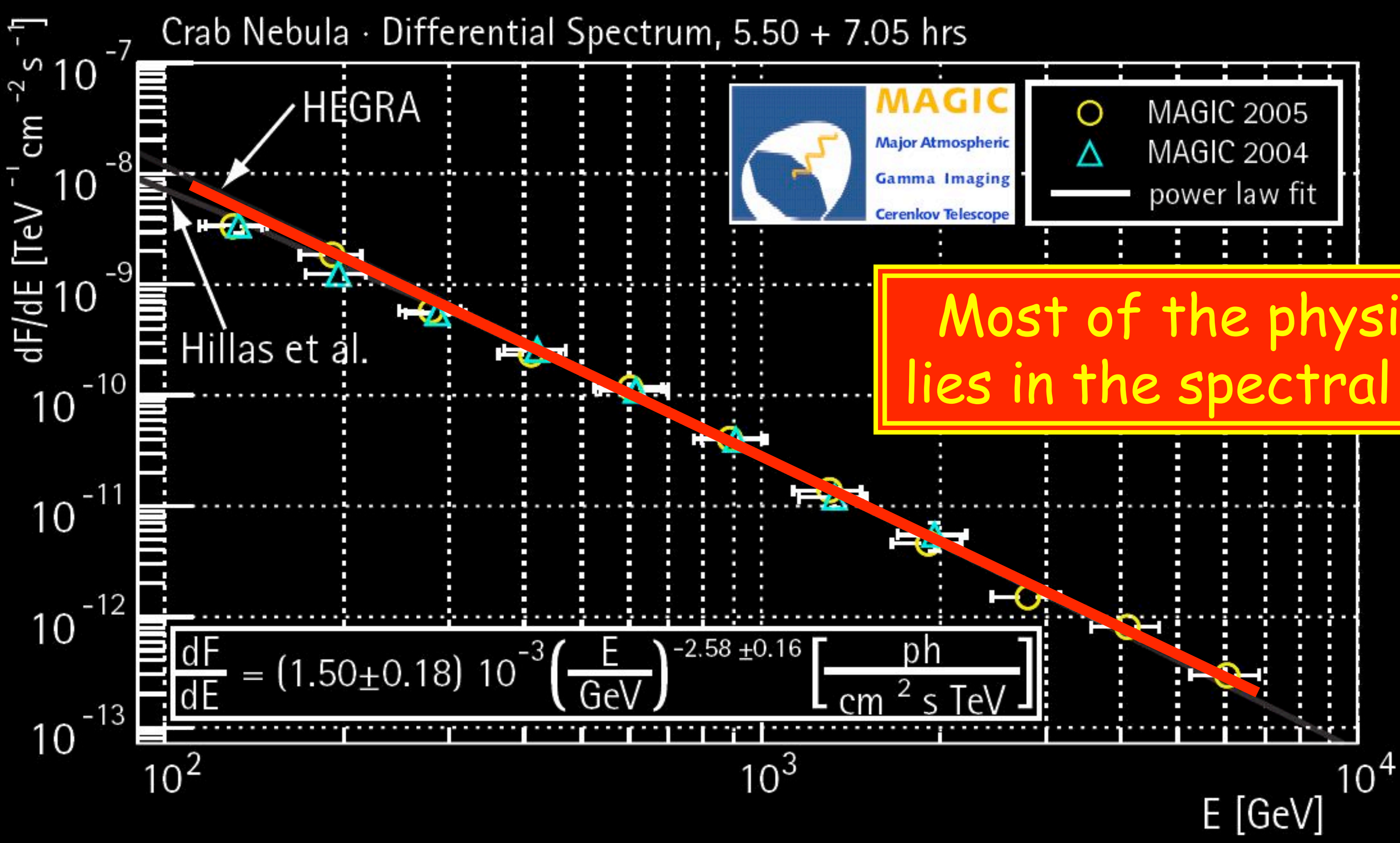
⊕ 30 %

E_{brk}	Gammas seen by GLAST	$\delta E_{brk}/E_{brk}$ GLAST		$\delta E_{brk}/E_{brk}$ IACTs
50	3763	6%	⊕	4%
100	3249	8%	⊕	3.5%
150	2988	13%	⊕	3%
200	2818	17%	⊕	5%

… or …

MAGIC – The Crab (Nebula) spectrum

Toward the Inverse Compton peak



Most of the physics lies in the spectral idx

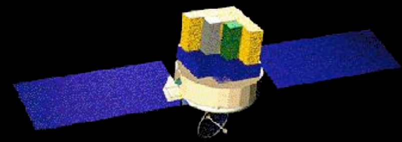
Looking for spectral features: AGNs

- AGN spectra: a power-law folded with an exponential cutoff due to the absorption by the Metagalactic Radiation Field.
- The position of this cutoff, if reconstructed both by GLAST and IACTs, can be used to reduce the absolute scale uncertainty as in the case of the Crab.
- Important per se: observational cosmology

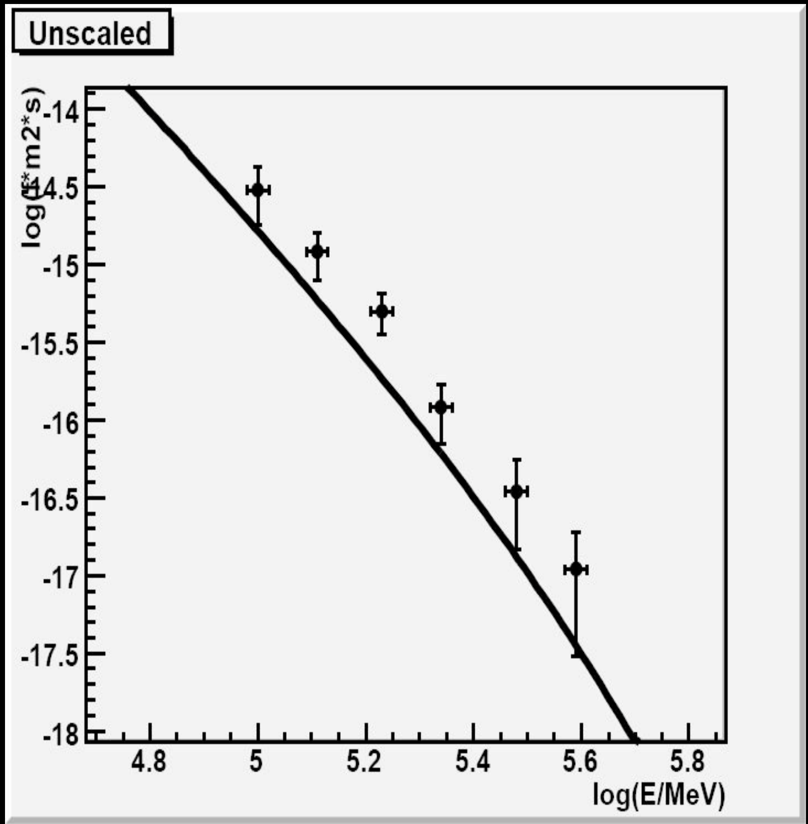
  >> Has to be very well calibrated <<

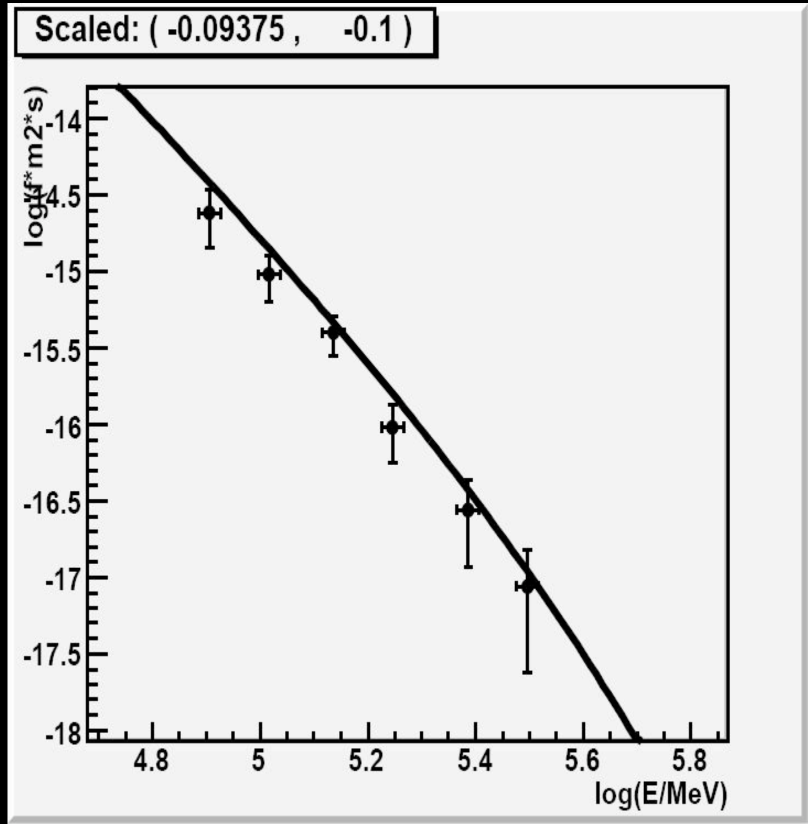
- Power law + exponential: reduce other systematic misbehaviors, such are the scaling errors in reconstructing the fluxes or the energies.
- Just two AGNs (PG1553+113 and 1ES1218+304) and the Crab Nebula enough to constrain these factors with uncertainties comparable with the actual ones.

Spectrum of PG 1553+113



Actual MAGIC data … and scaled ones



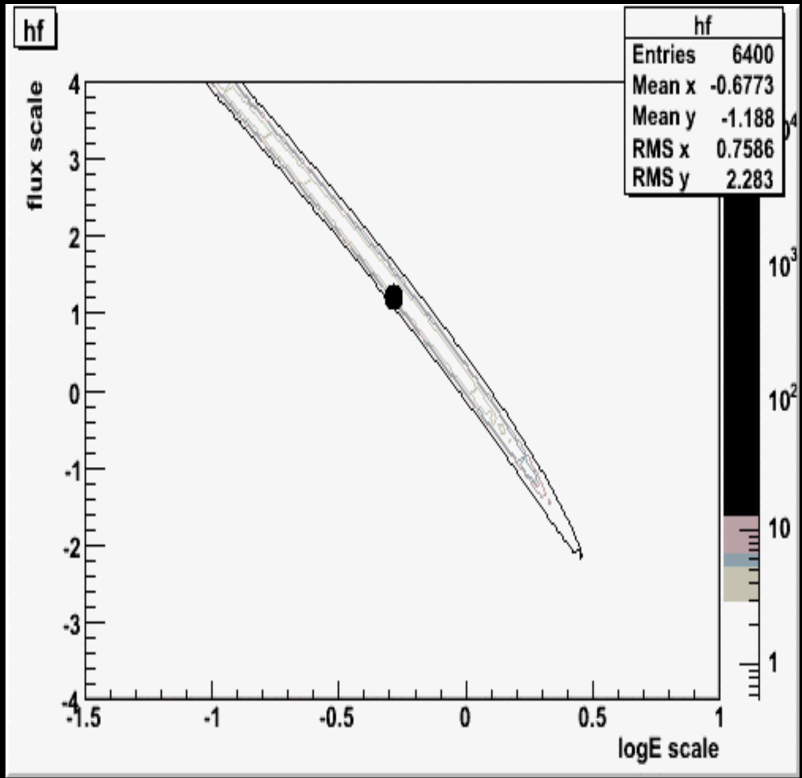


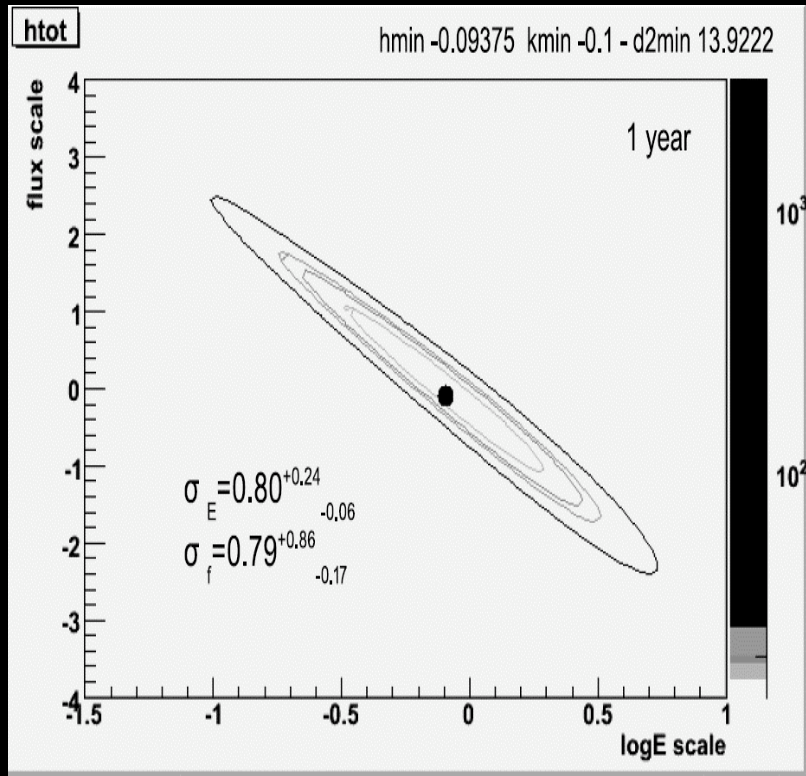
Line: GLAST simulation

Constraints on scale factors

PG 1553+113 alone …

+ 1ES 1218+30.4
+ Crab Nebula





Conclusions

- GLAST observations of steady gamma sources, as the Crab Nebula, can be used to calibrate the absolute energy scale of IACTs and reduce its uncertainty, at around 100 GeV, to <10%.
- Other spectral features, as the exponential cut-off of AGNs, are also well-suited for IACT calibration.
- This approach, beside the far-reaching cosmological implications, is comparable with the current estimates of the systematic errors in IACT.
- As the GLAST catalogue will embrace more and more sources, these errors will get smaller allowing us to observe the sky at very high energies with unprecedented precision.