The MAGIC Telescope Project. *Status and Results.*

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for the

MAGIC Collaboration

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The MAGIC telescope

Major Atmospheric Gamma-Ray Imaging Cherenkov Telescope

- **Largest Imaging Air Cherenkov Telescope** for γ-ray astronomy (17 m mirror dish)
- Design optimized for:
  - low energy threshold **E_γ = 30 GeV**
  - fast repositioning **t_R<30 sec**

Collaboration: > 100 physicists, 18 institutes, 11 countries:
Barcelona IFAE, Barcelona UAB, HU Berlin, Crimean Observatory, U.C. Davis, U. Dortmund, U. Lodz, UCM Madrid, INR Moscow, MPI München, INFN/ U. Padua, INFN/ U. Siena, Sofia, Tuorla Observatory, Yerevan Phys. Institute, INFN/ U. Udine, U. Würzburg, ETH Zürich

The unexplored spectrum gap

- γ–ray sources observed with EGRET satellite (E < 10 GeV)
- 271 sources (171 unidentified)

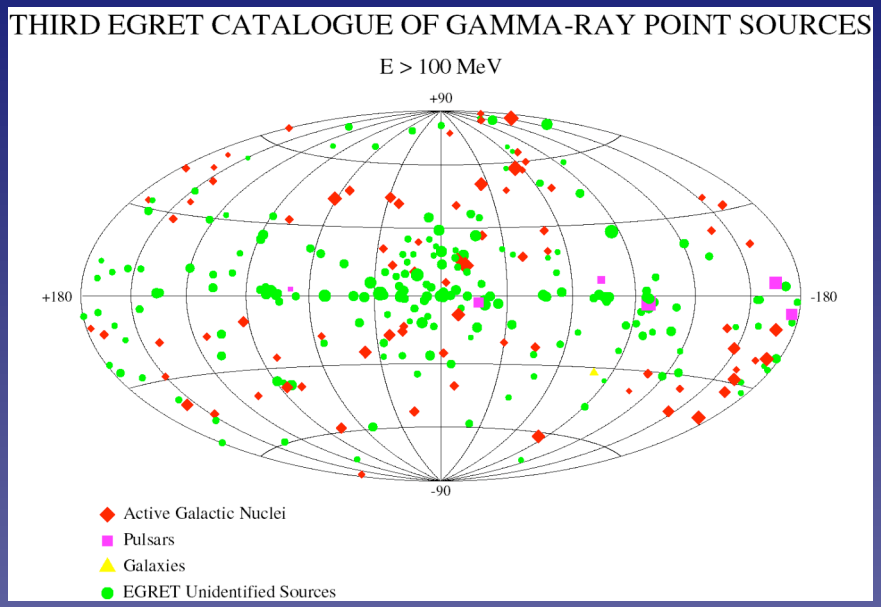
Satellite effective area < 1 m^2

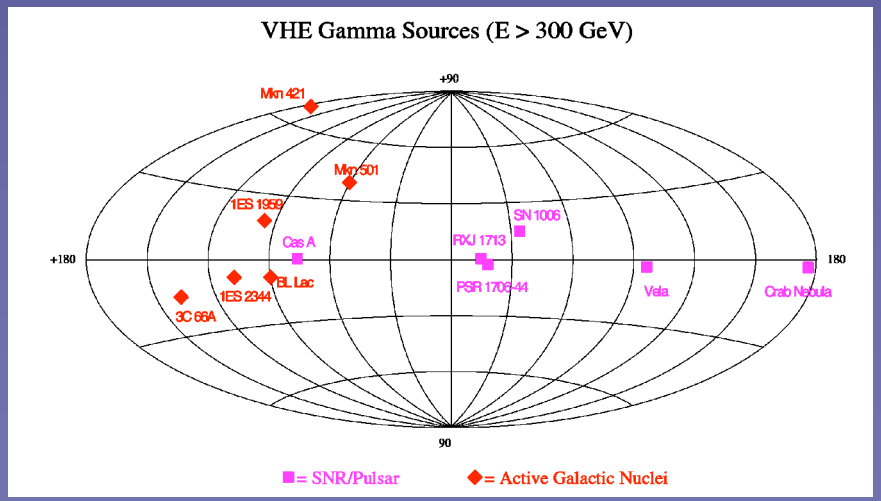
- Old generation ground-based experiments observe few sources with E > 300 GeV.

Effective area > 10^4 m^2

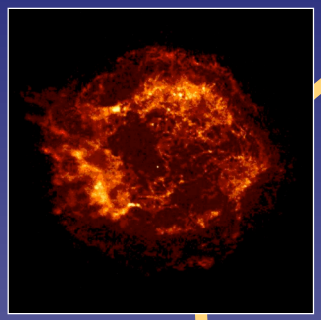
Strong cutoff in γ-spectrum for 10 Gev < E < 300 GeV

Explore energy gap with MAGIC

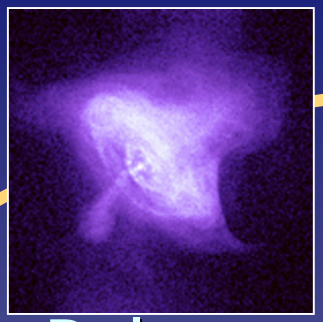




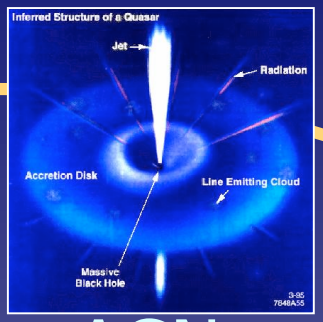
The MAGIC Physics Program



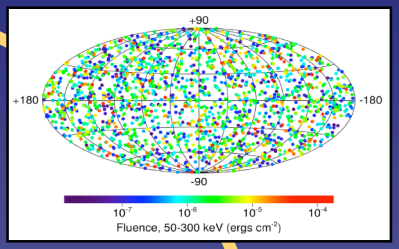
SNRs



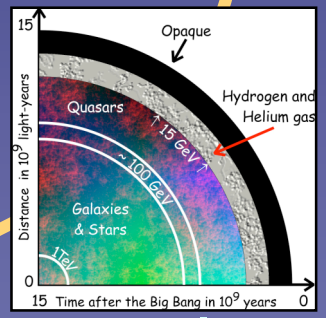
Pulsars



AGNs



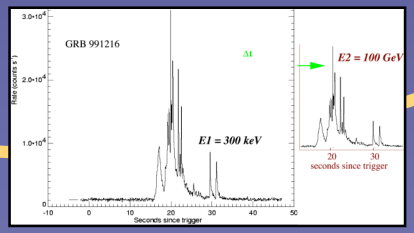
GRBs



cosmological γ-Ray Horizon

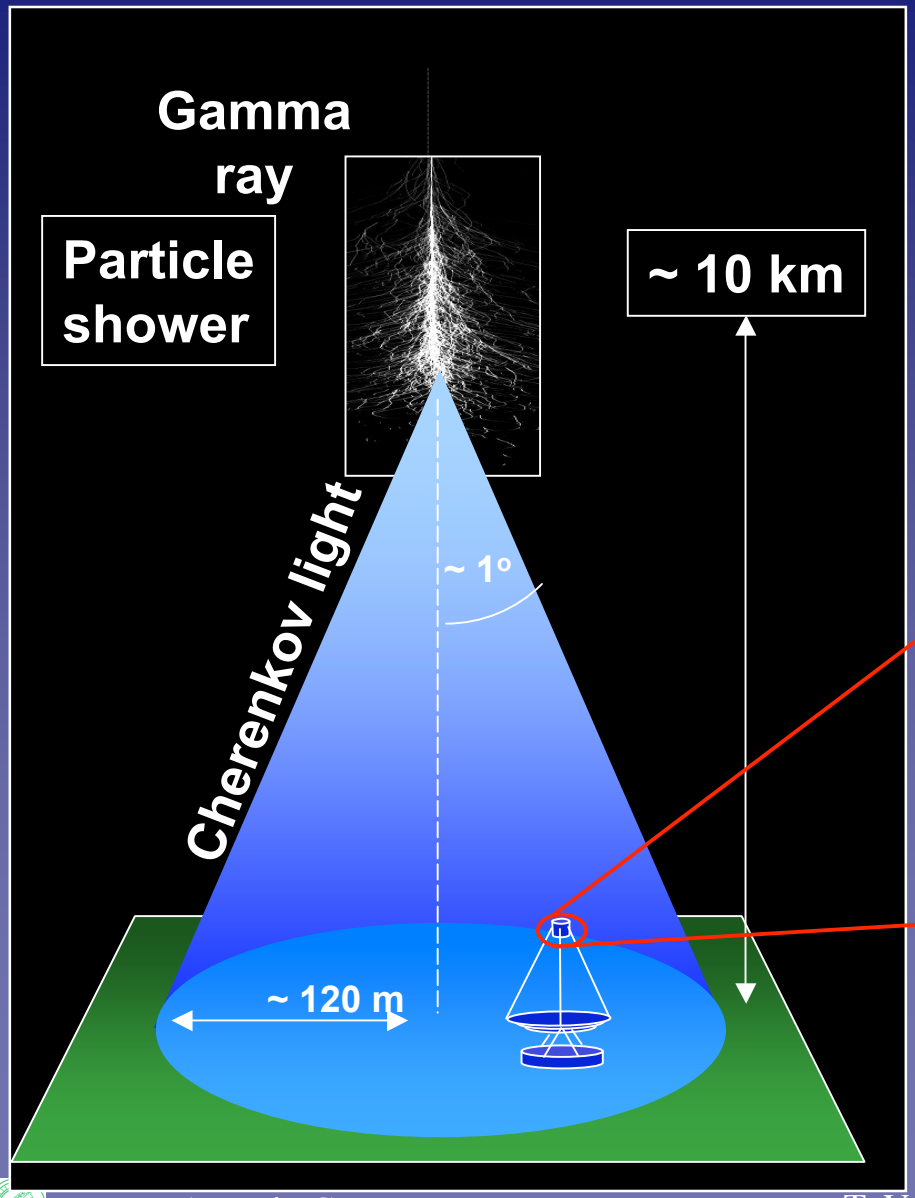
Origin of Cosmic Rays

Cold Dark Matter

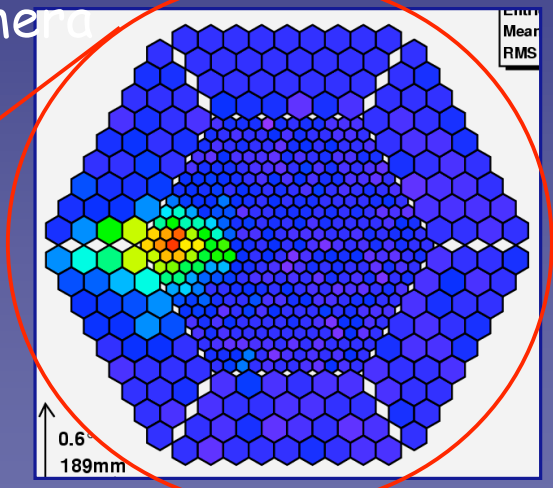


Quantum Gravity effects

Imaging Air Cherenkov Telescopes

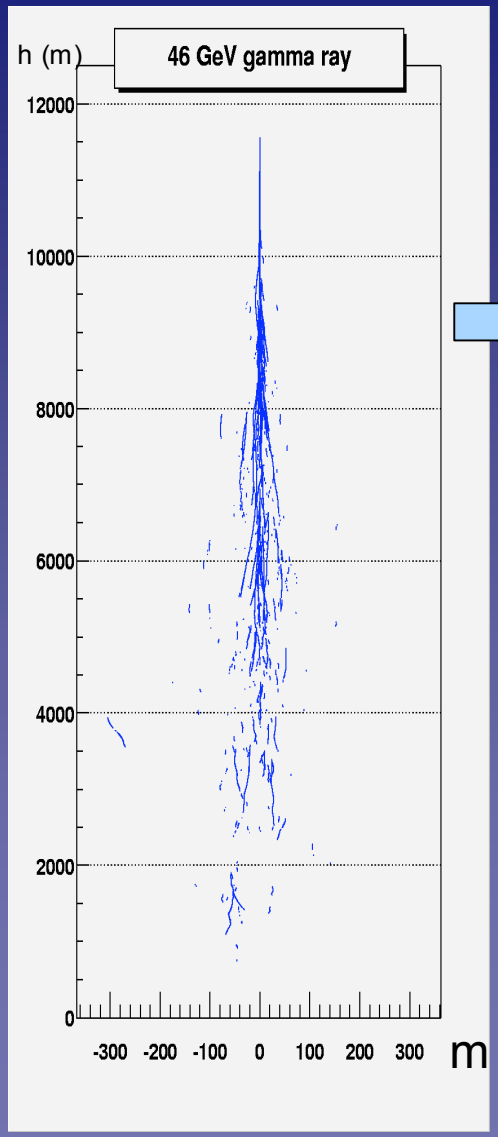


Cherenkov light Image of particle shower in telescope camera

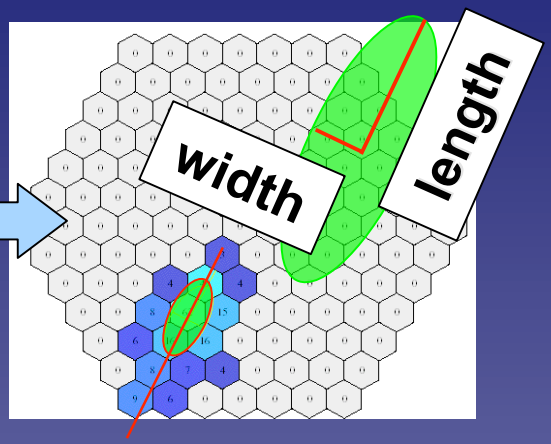


- reconstruct: arrival direction, energy
- reject hadron background

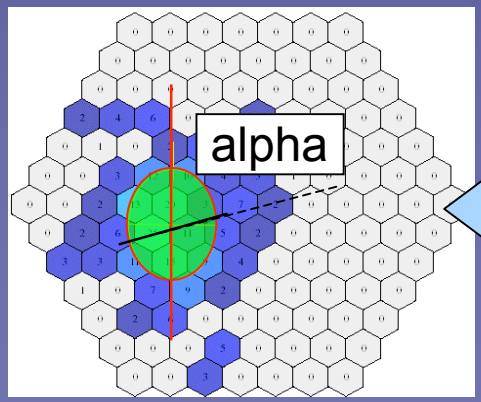
Gamma / hadron separation

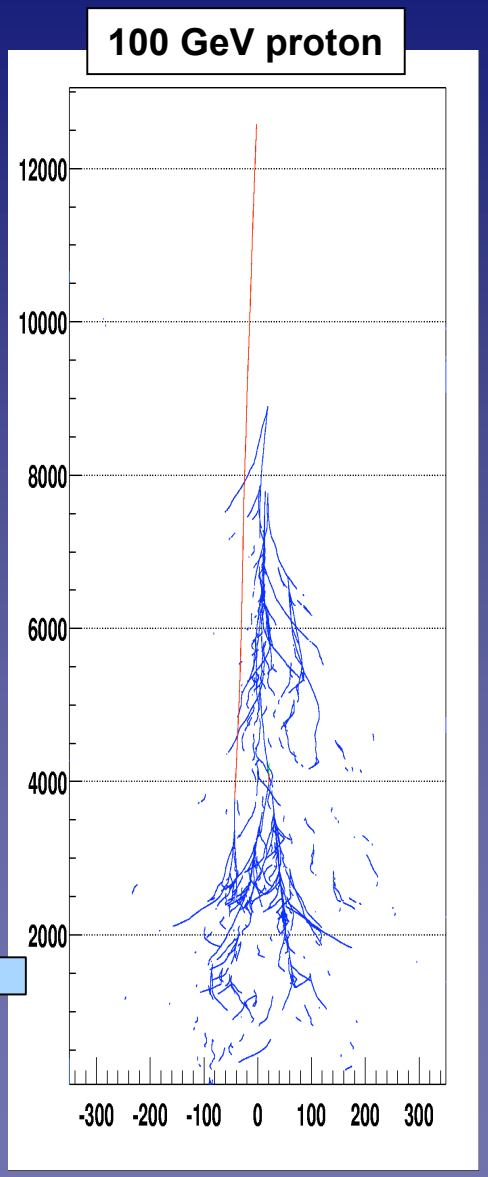


Gamma shower
(narrow, points to source)

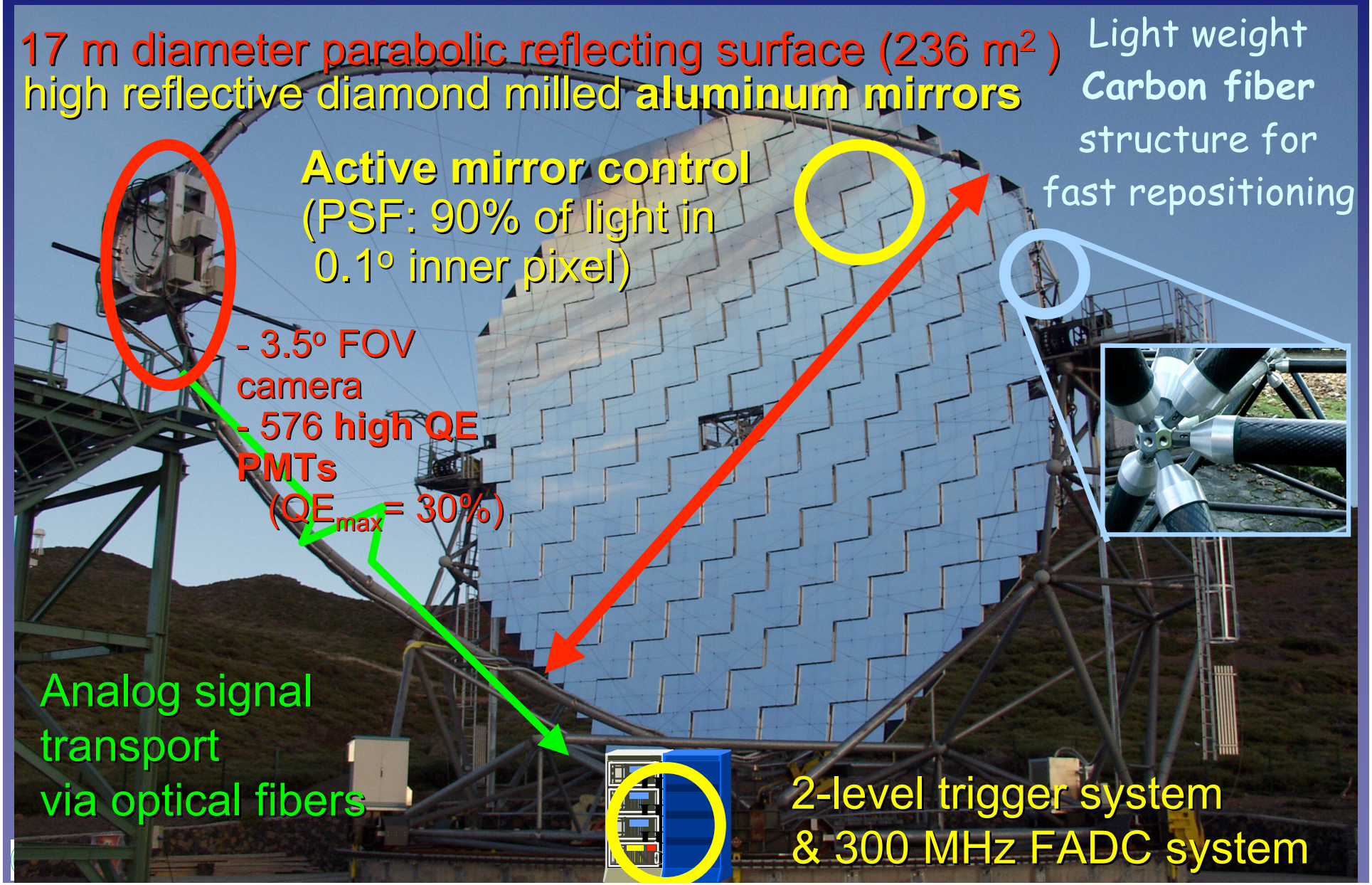


Proton shower
(wide, points anywhere)



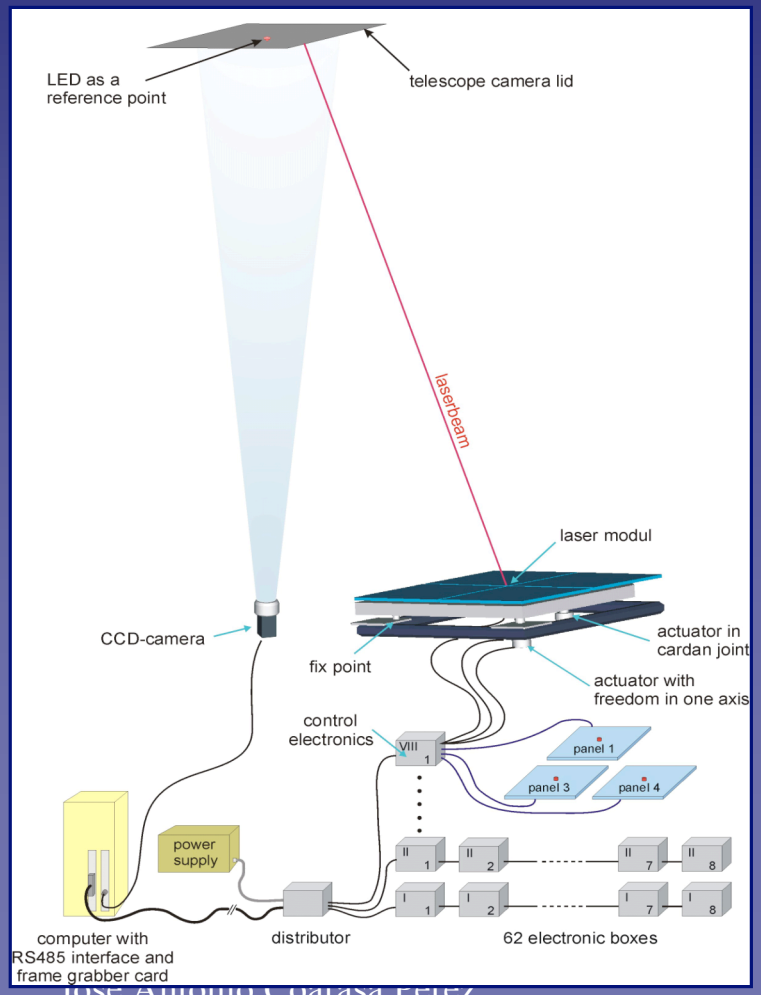


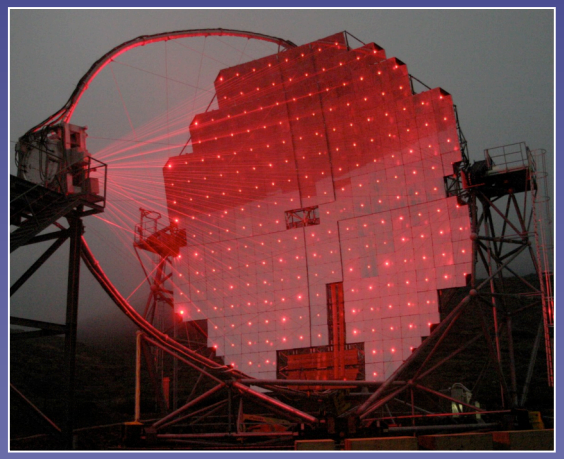
Key technological elements for MAGIC

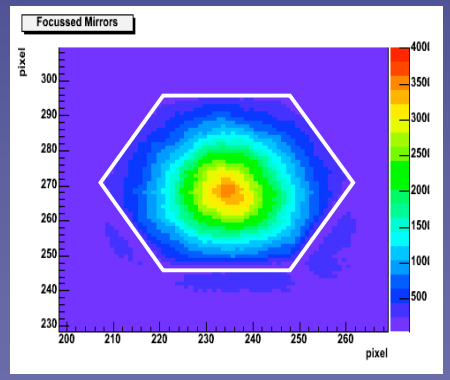


Active Mirror Control

light weight structure requires corrections for small residual deformations of mirror







achieved PSF:

90% of light contained in

0.1° inner pixel

High QE Camera

- Matrix of 576 PMTs
- Field of View: 3.5^0

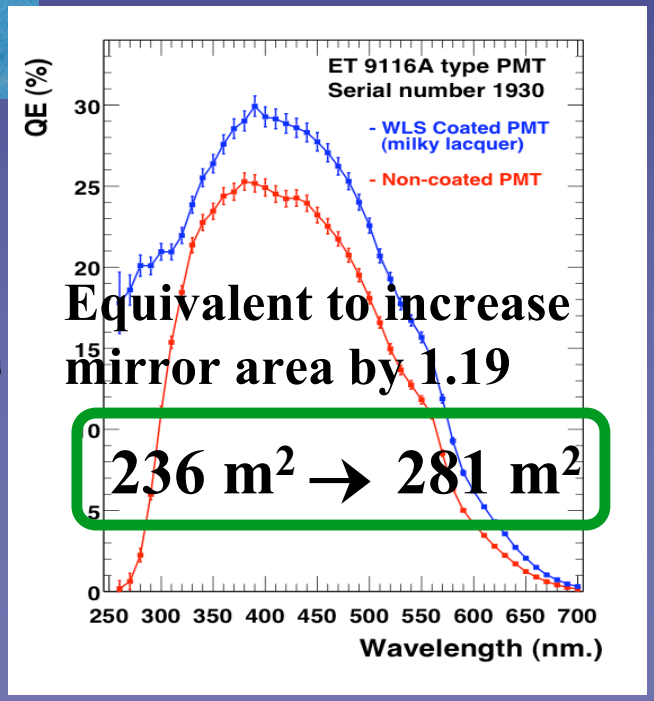
6 stage PMTs (low gain)

- ET 9116A (1") : 0.1^o
- ET 9117A (1,5") : 0.2^o

Quantum Efficiency increased up to 30 % with diffuse scattering coating

➠Increase in detection efficiency by (19±2)%

extended UV sensitivity using wavelength shifter coating

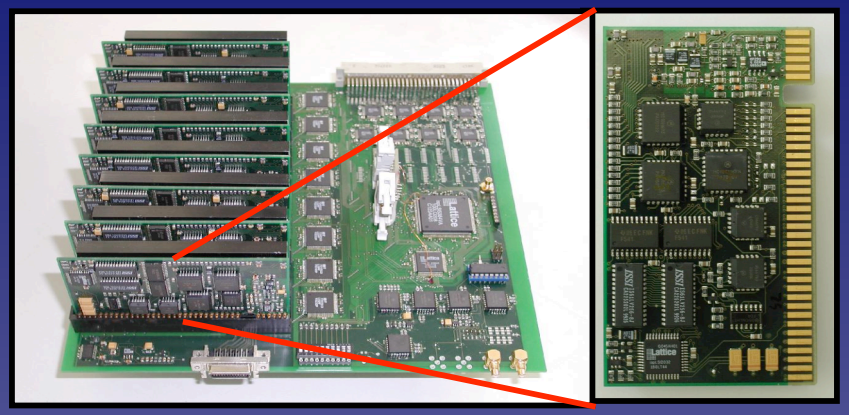


Signal Processing

- Analog signals transmitted over 162 m long optical fiber

  => no signal dispersion

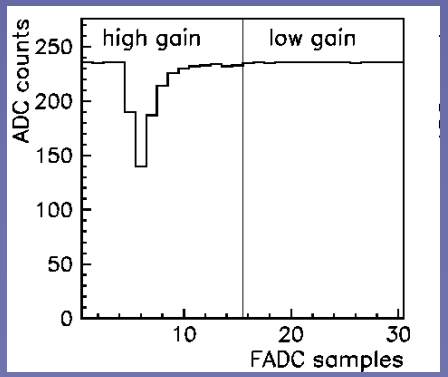
- Stretch pulse to 6 nsec
- Split to high & low gain (dynamic range > 1000)
- 300 MSamples/s 8 bit FADCs (upgrade to 2GSamples/s this year)

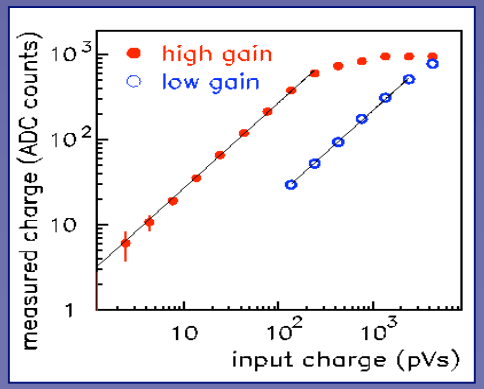


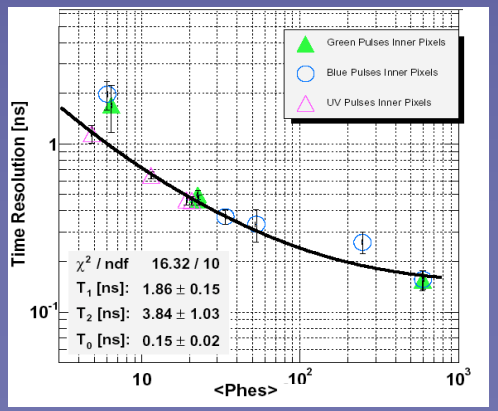
optimized signal reconstruction

- time resolution < 1 nsec
- small integration time

  => improved S/N







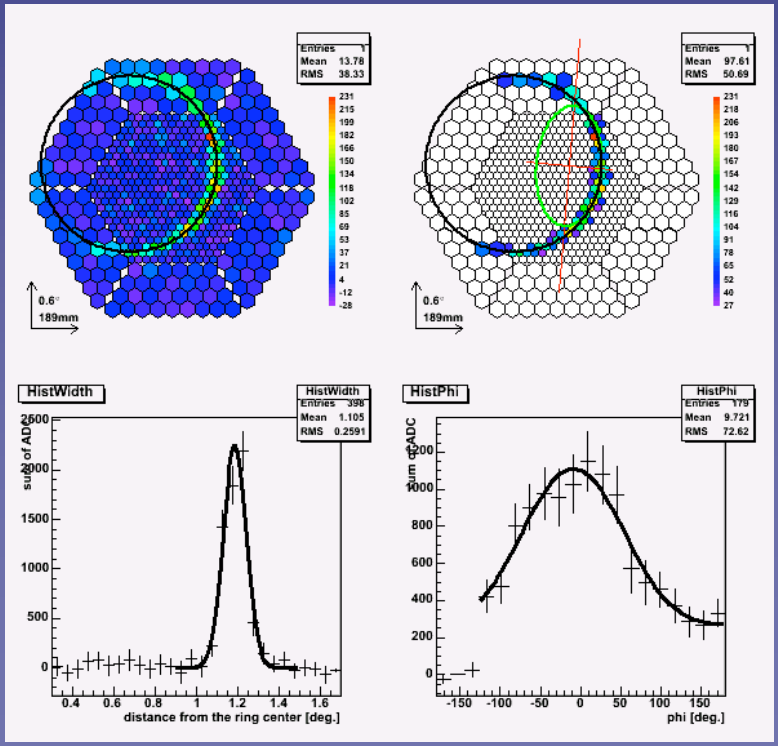
Status of MAGIC

- October 2003: Inauguration
- until August 2004: Commissioning
- July 2004: Installation of last Mirrors
- September 2004:
  Start of regular data-taking
  - data-taking efficiency gradually improving, reaching 80-90% in January 2005 (nice weather)
- February 2005:
  - weather is not always nice
  - missed first 2 observable GRBs alarms from SWIFT

Calibration

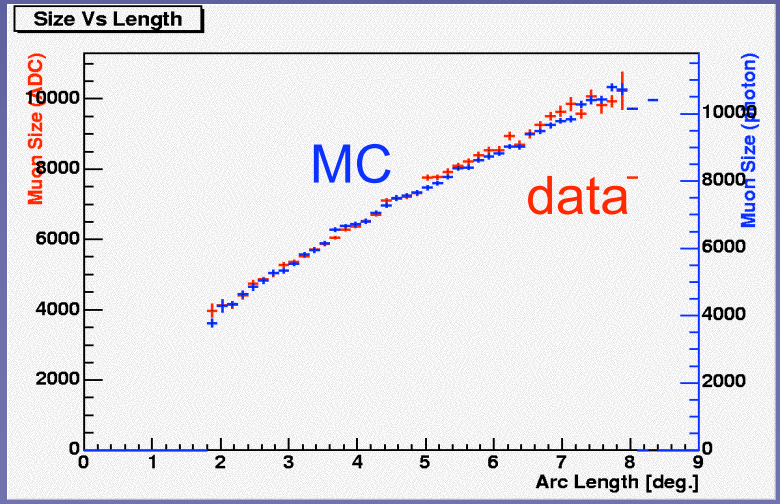
Standard calibration

- light pulses illuminating camera uniformly
- allows calibration in PEs



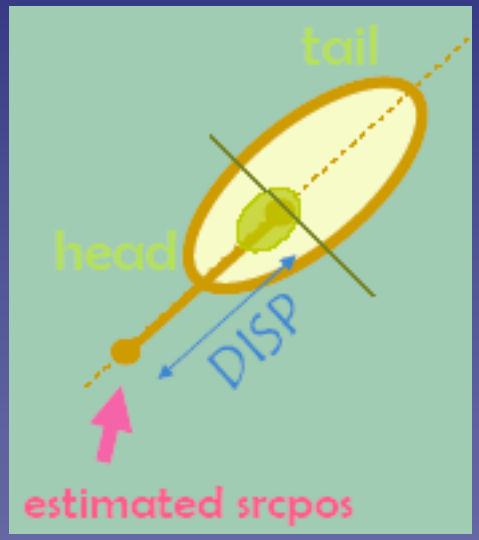
Muon calibration

- select set of clean muons (2.3 Hz)
- comparison of measured and expected muon signal
- allows absolute calibration of photon collection efficiency of detector (mirror + PMTs + ..)

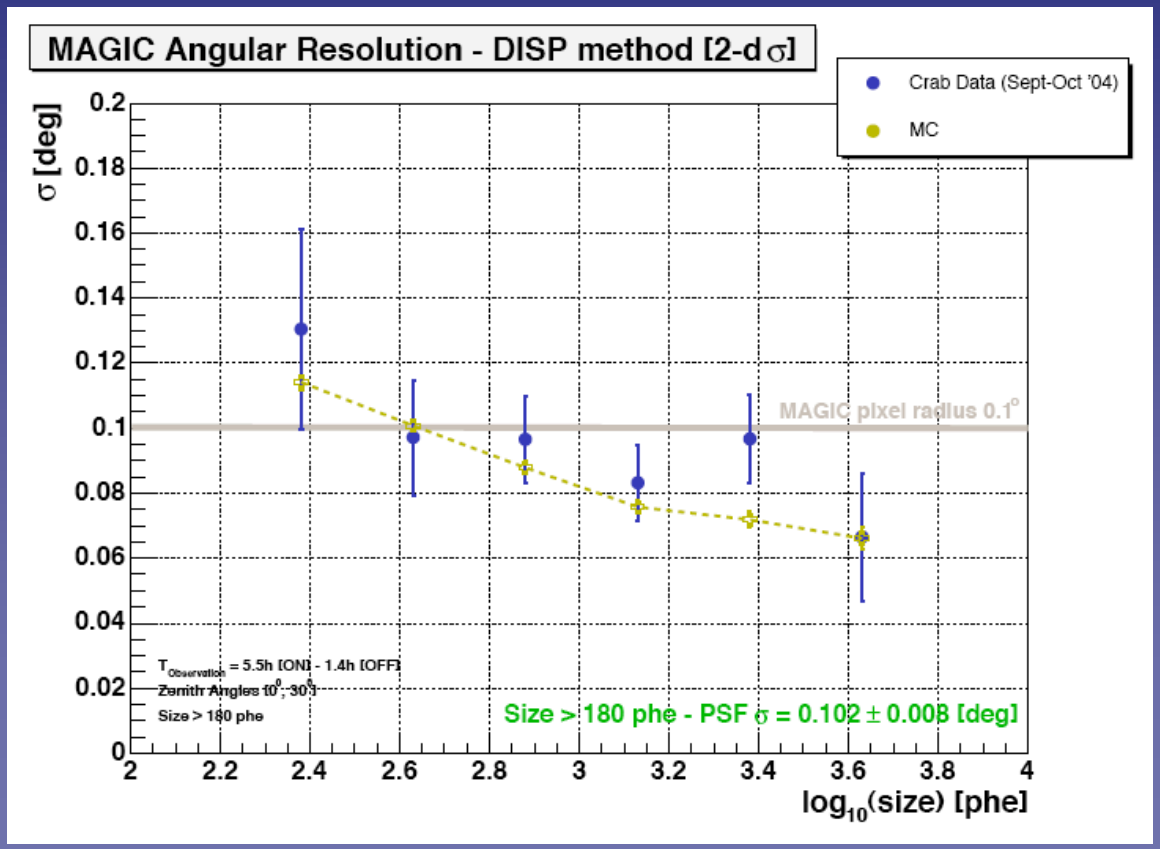


Source Position reconstruction

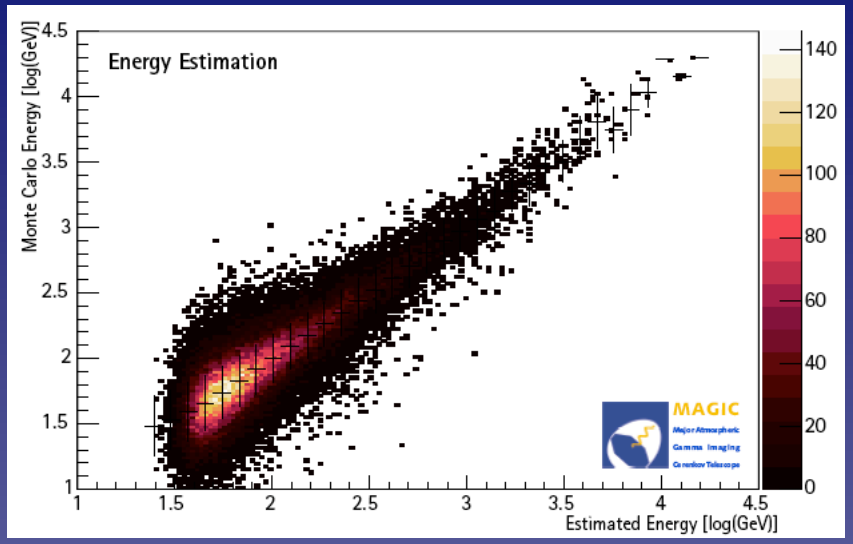
- DISP method
- angular resolution: 0.1º

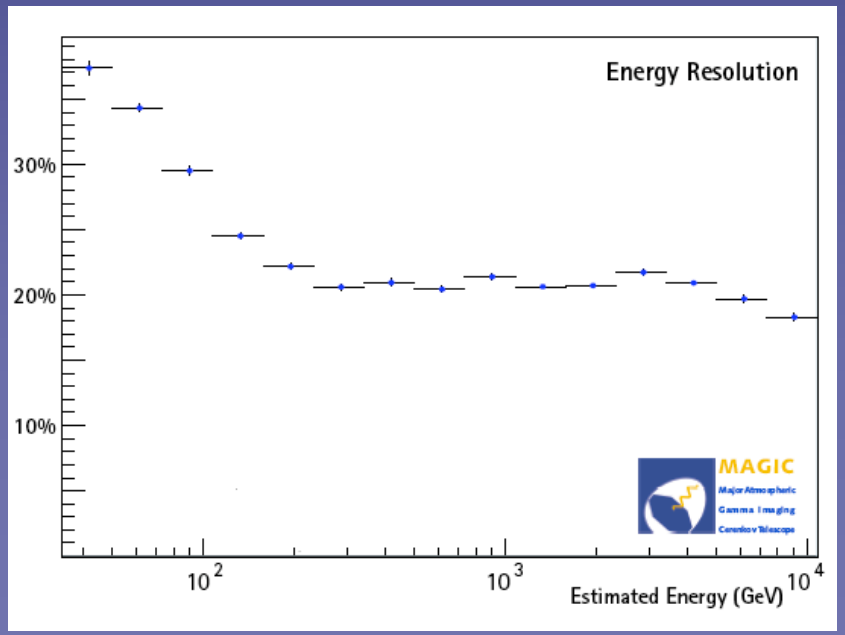


$$DISP = \xi(Size) \bullet (1 + \frac{width}{length})^{-1}$$



Energy resolution



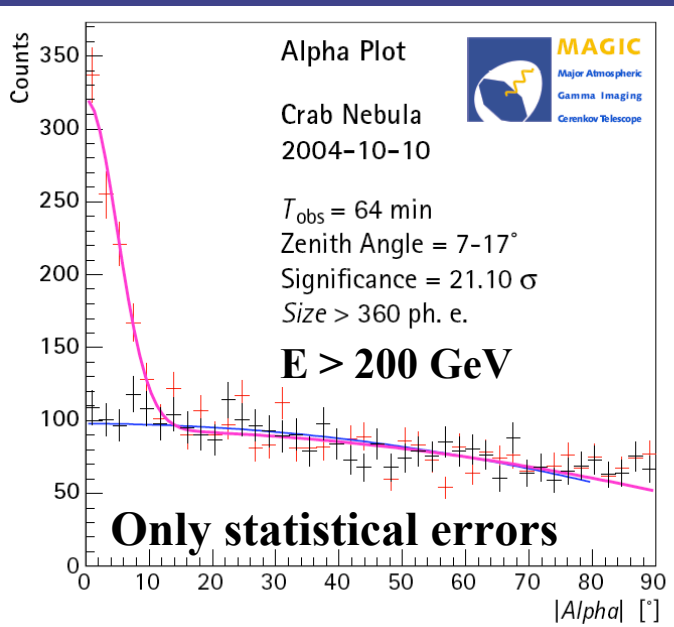


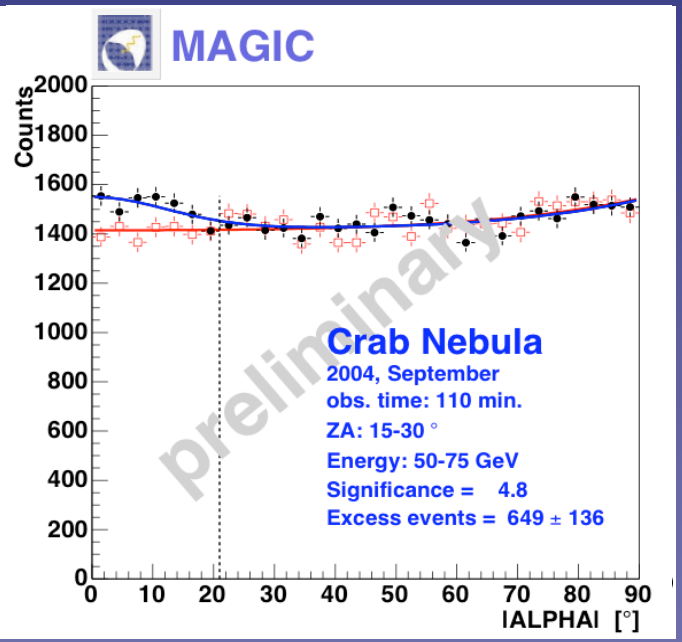
- SIZE (total number of PEs) simplest energy estimator
- improve energy estimation including other image parameters
- optimized estimator using Random Forest technique
- 20% (30%) @ 1 TeV (100 GeV)

Crab Pulsar: The standard candle

- strong steady source of GeV/TeV gamma rays (Whipple '89)

=>Standard candle to test performance Cherenkov Telescopes





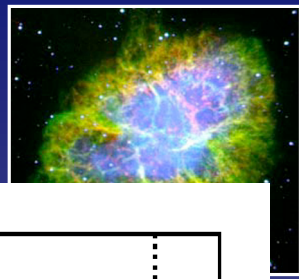
- below 100 GeV standard γ/h separation not very efficient
- Nevertheless, significant signal extracted in 50 -75 GeV bin

$$21\sigma \bullet \sqrt{time(h)}$$

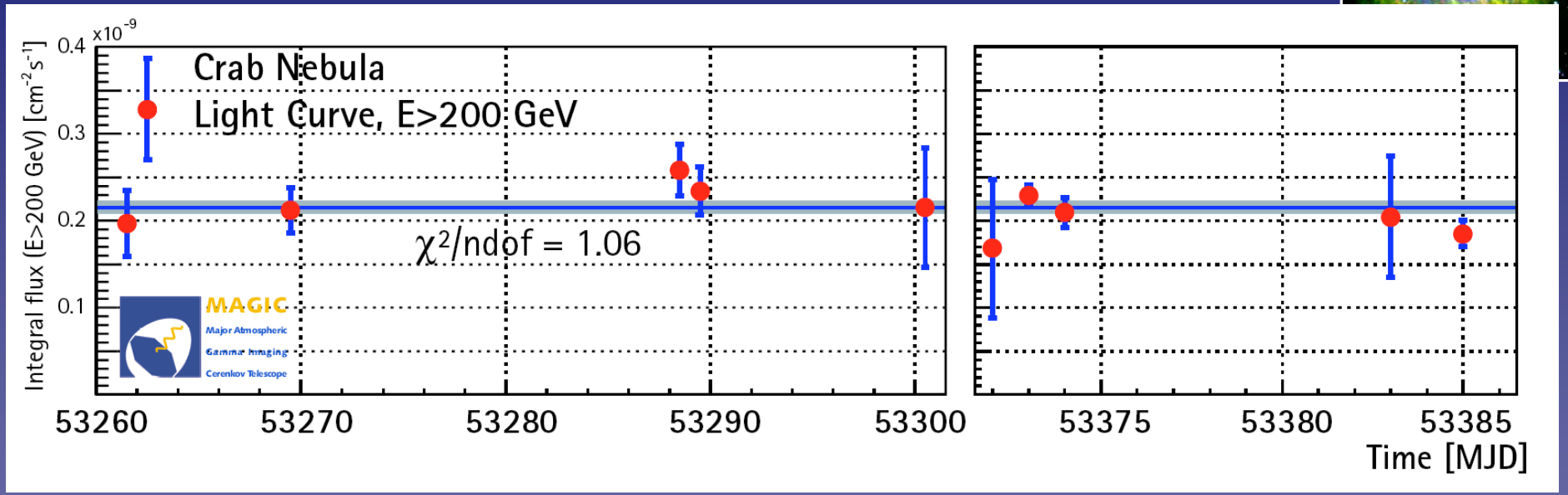
=> 5 σ detection in 3.5 min

Wagner et al, 29th ICRC, August 2005

Crab Pulsar: The standard candle



2004; September, October **2005**; January



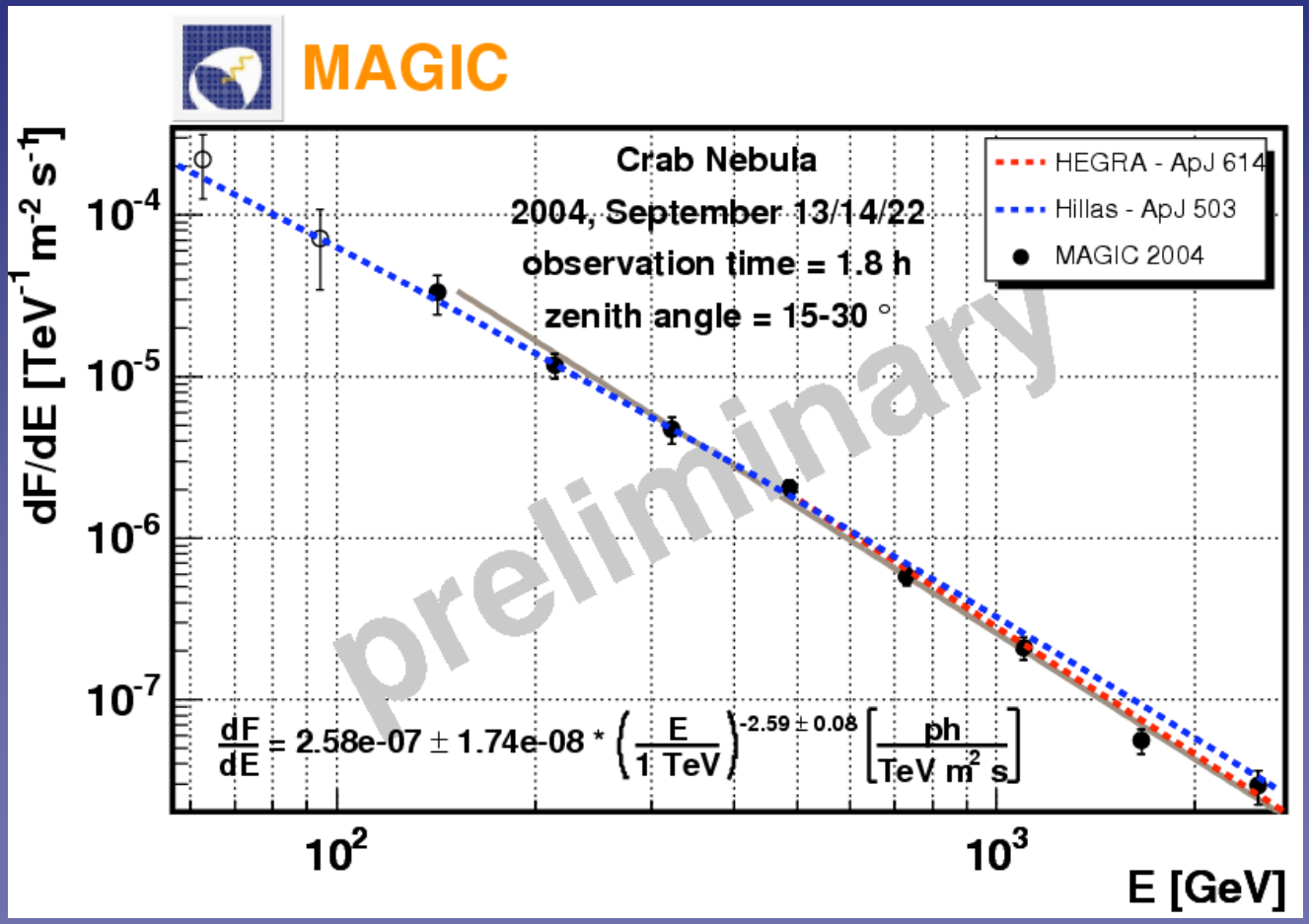
- Indead stable

=> Even after hardware changes in January

=> We understand the performance of the telescope

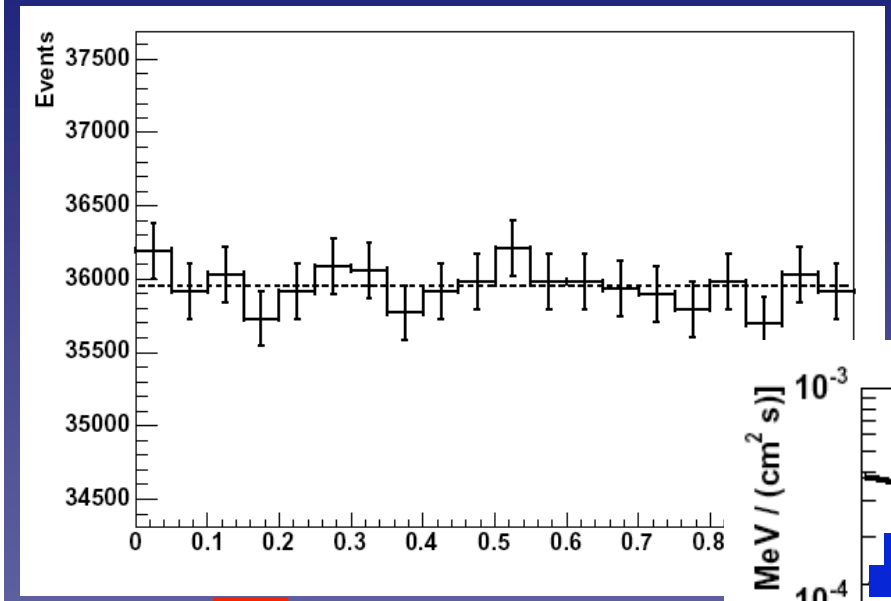
Energy Spectrum of Crab Nebula

Extending the Crab spectrum towards the inverse compton peak



Systematic errors below 100 GeV under investigation

Crab Pulsar

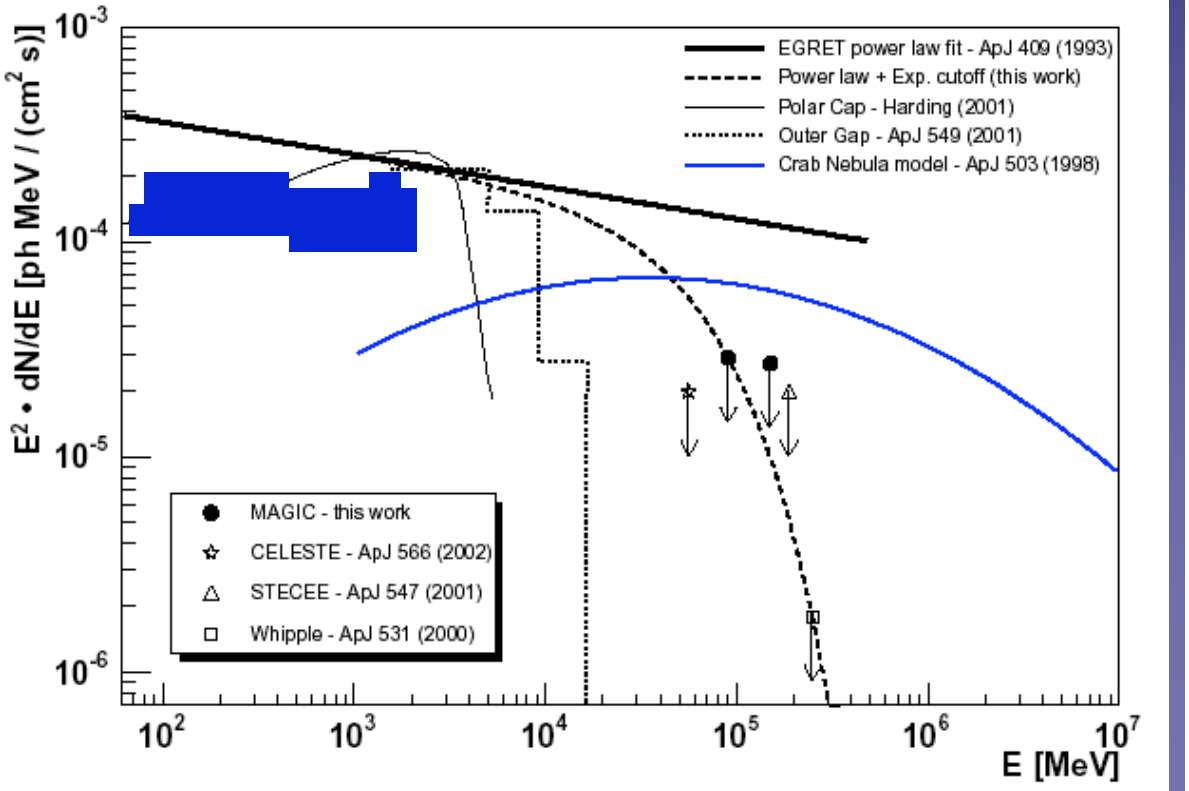


NO PULSATION DETECTED AT ENERGIES > 100 GeV

Limit to Exponential cut-off

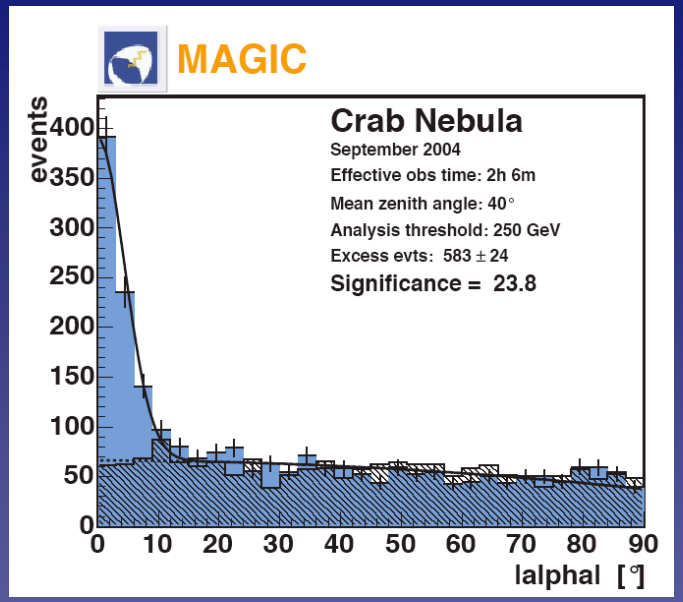
$E_{cut} < 60$ *GeV*

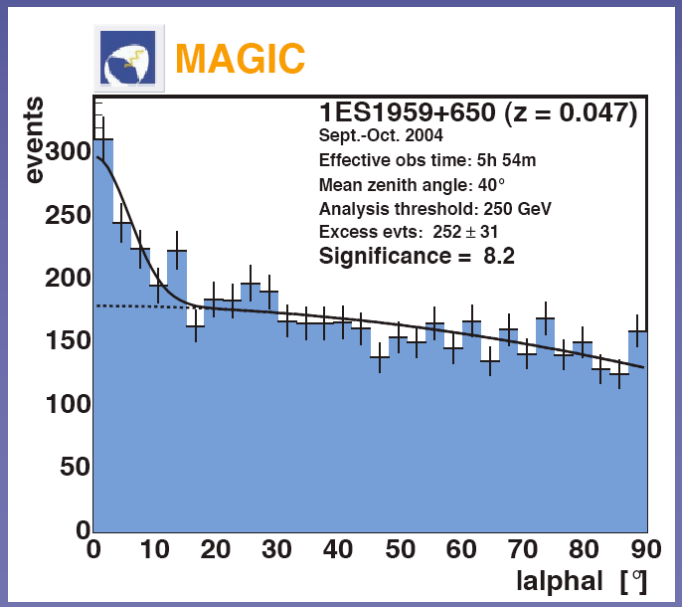
Agreement with CELESTE

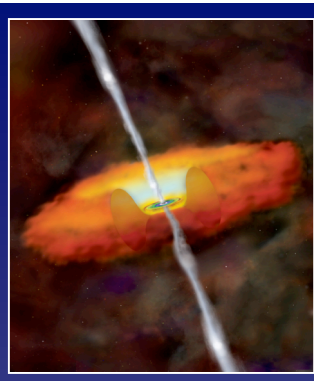


1ES1959+650

- AGN @ z=0.047
- previously seen by Seven Telescope Array, Whipple, HEGRA
- 6.5 h observation by MAGIC in Sept - Oct 2004
- @ High ZA
- 8.2 σ detection
- ~ 10 % Crab level compatible with previous measurements

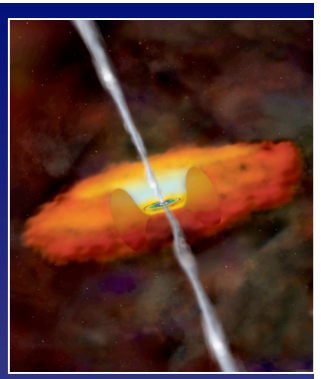






Tonello et al, **29th ICRC, August 2005**

1ES1959+650

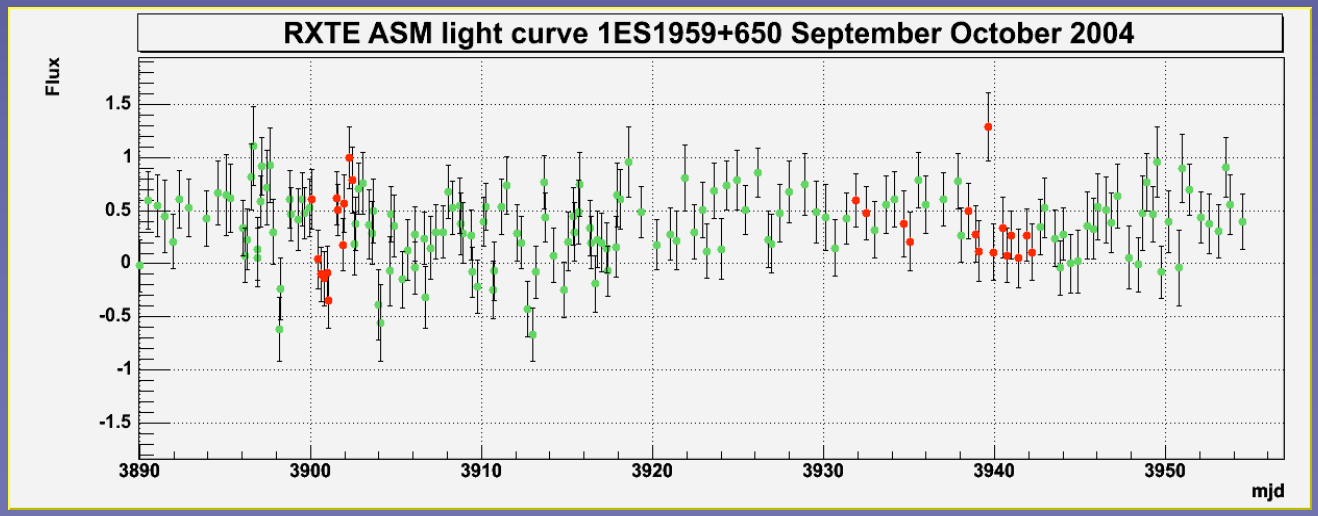


No significant time variation of gamma-ray activity

Days	Obs time	Significance	Excess	Rate (phot/min)
September 6,7	121 min	3.6	42.8 ± 11.8	0.35 ± 0.09
October 7,10,15	110 min	4.0	49.5 ± 12.3	0.45 ±0.11
October 16, 17	137 min	5.0	64.0 ± 12.8	0.46 ± 0.09

Tonello et al, 29th ICRC, August 2005

No significant time variation in the X-ray activity



Mrk421

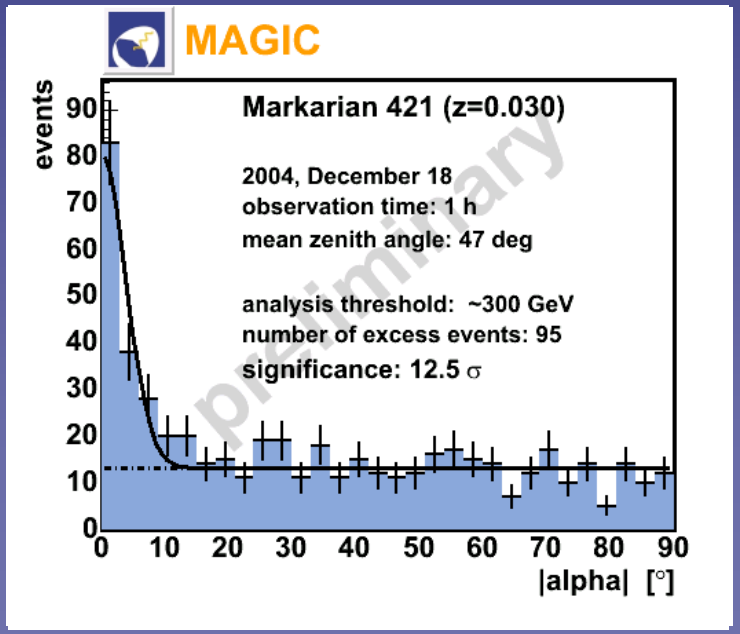
sample	on time	zenith [°]	mode	E_{thr}[GeV]	N_{on}	N_{off}	N_{excess}	sigma
I	4.70 h	9.3 - 31.2	ON	100	7458	5084.0 ± 59.3	2374.0 ± 102.1	23.26
II	1.41 h	42.4 - 55.0	ON	300	593	315.9 ± 14.9	277.1 ± 27.3	10.13
III	7.88 h	9.2 - 27.5	ON	100	8116	5089.8 ± 59.4	3026.2 ± 104.5	28.96
IV	9.57 h	9.4 - 32.4	wobble	100	9296	5668.3 ± 45.1	3627.7 ± 98.3	36.89

- During whole period found to be in a moderate to high state resulting in clear signals in all four data sets.
- December 2004: flare observed by RXTE
- Simultaneous observation with HESS on 18 Dec '04 allows (High ZA)

-Cross calibration

-Observation under different zenith angles => different energy ranges

=> larger energy scope coverage



Mazin et al, 29th ICRC, August 2005

Mrk421:Variability

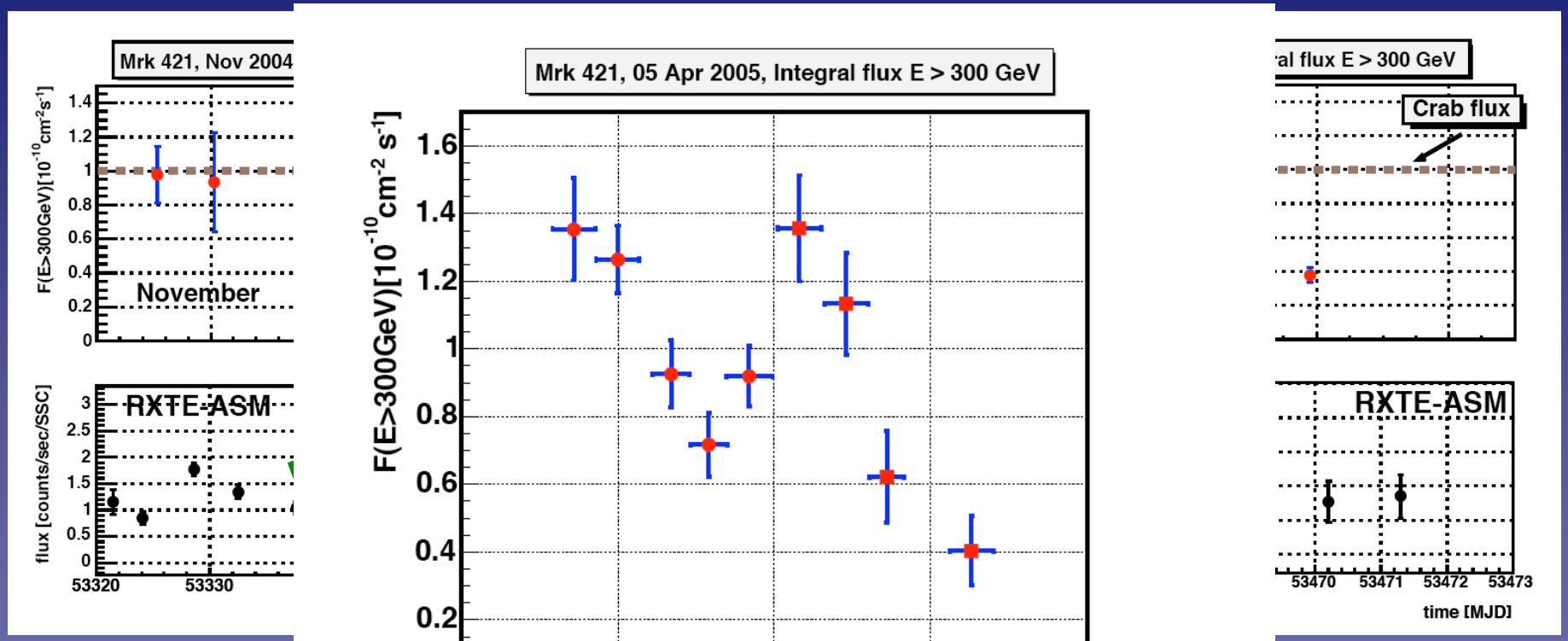


Figure 4. Light-curve for the night MJD 53465 in bins of 20 minutes (sample III: circles, sample IV: squares)

Galactic Center

Bartko et al, 29th ICRC, August 2005

- Galactic Center observable from La Palma at zenith > 58°

=> difficult observation conditions

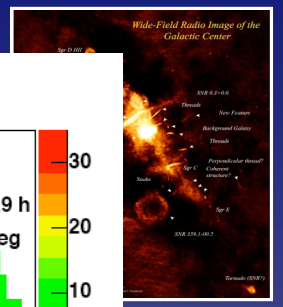
=> high energy threshold (E_{thr}~O(1 TeV))

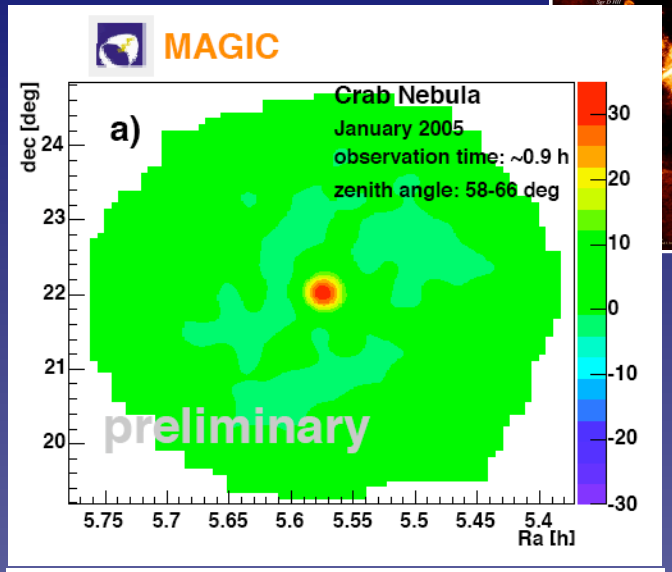
=> large effective collection area

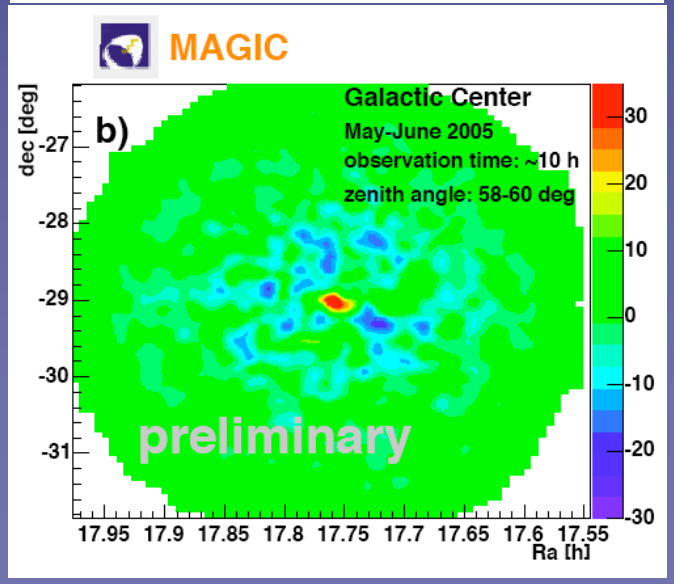
- observed Galactic Center in September 2004 for ~3 hours under test conditions and 28 hours in May-June 2005

⇨ We see a clear signal

⇨ Energy domains of ~10 TeV could be accessible

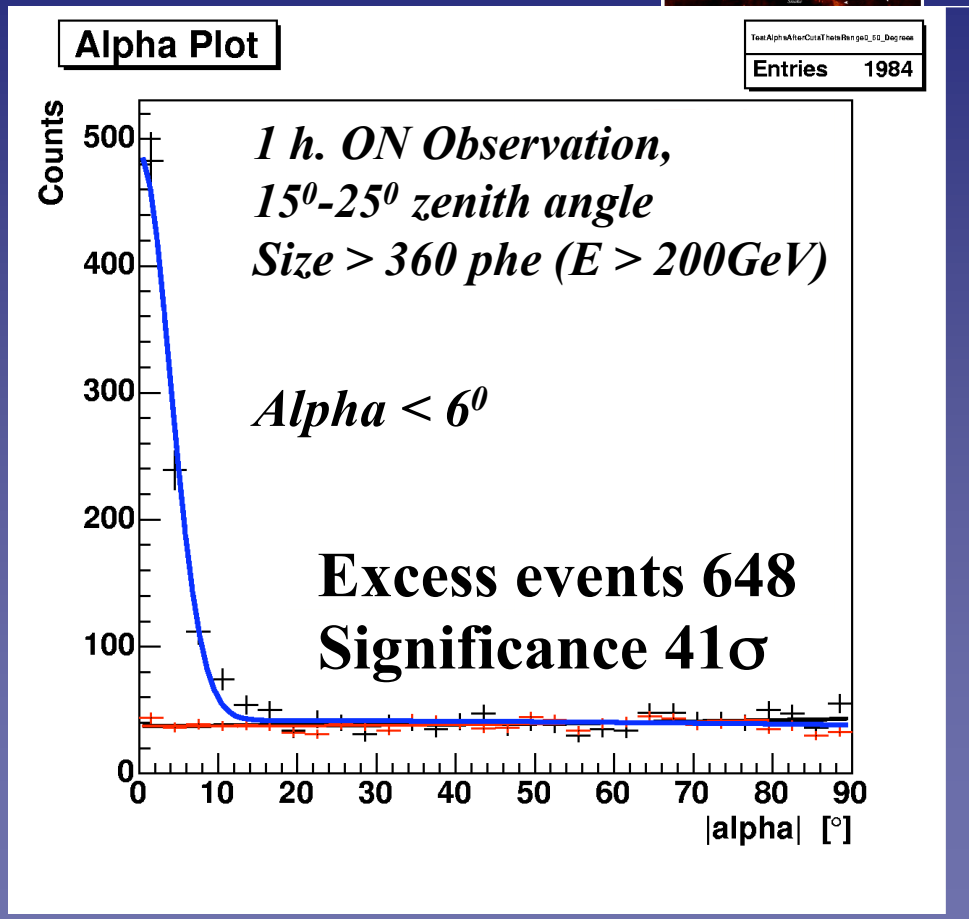






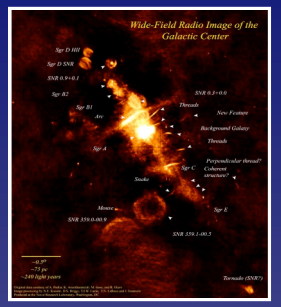
Mrk 501

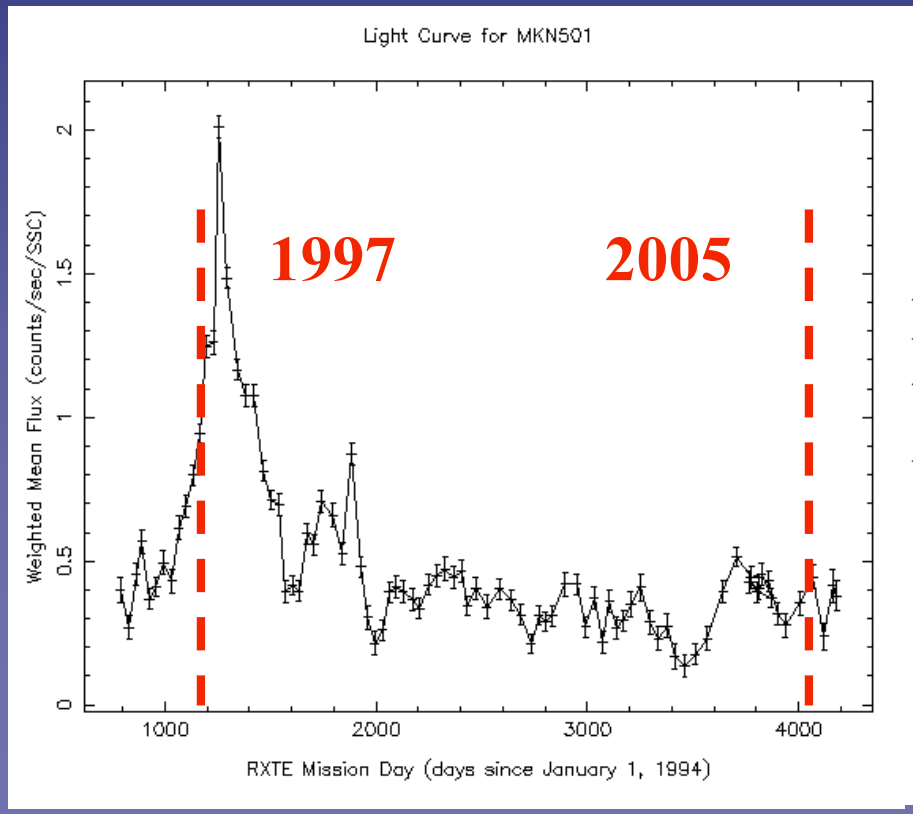
- Observed during May, June, July 2005 (not all data analyzed yet)
  - ➢ Source mostly in *quiescent* state (0.3-0.5 Crabs above 200 GeV).
  - ➢ 5 σ signal in less than 1/2 hour.
  - ➢ On 1st of July

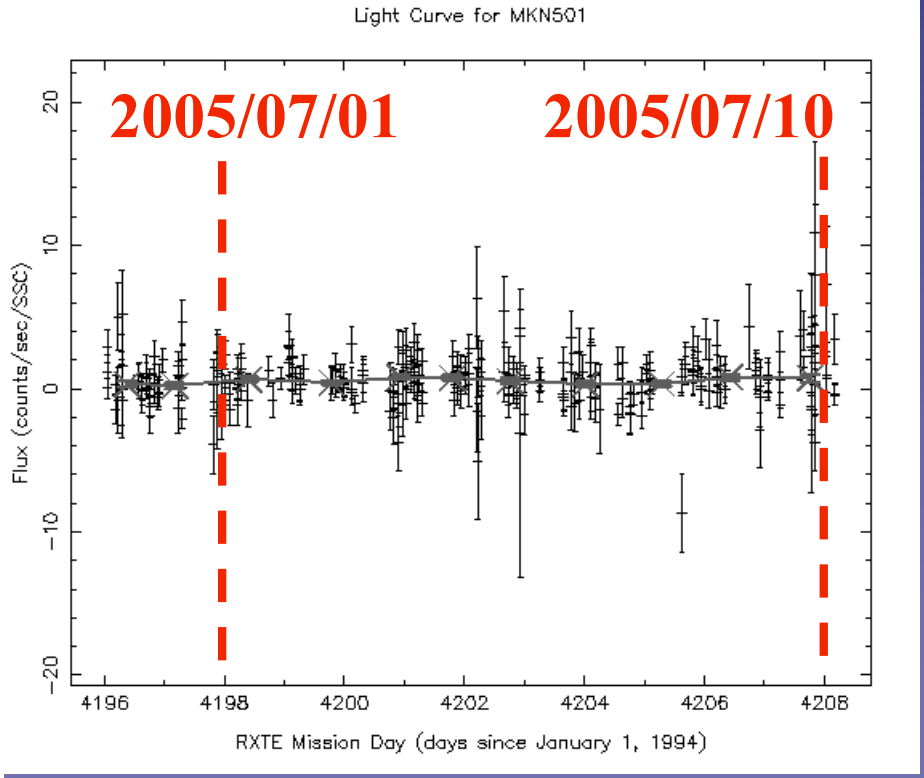


http://wwwmagic.mppmu.mpg.de/physics/mkn501flare05/index.html

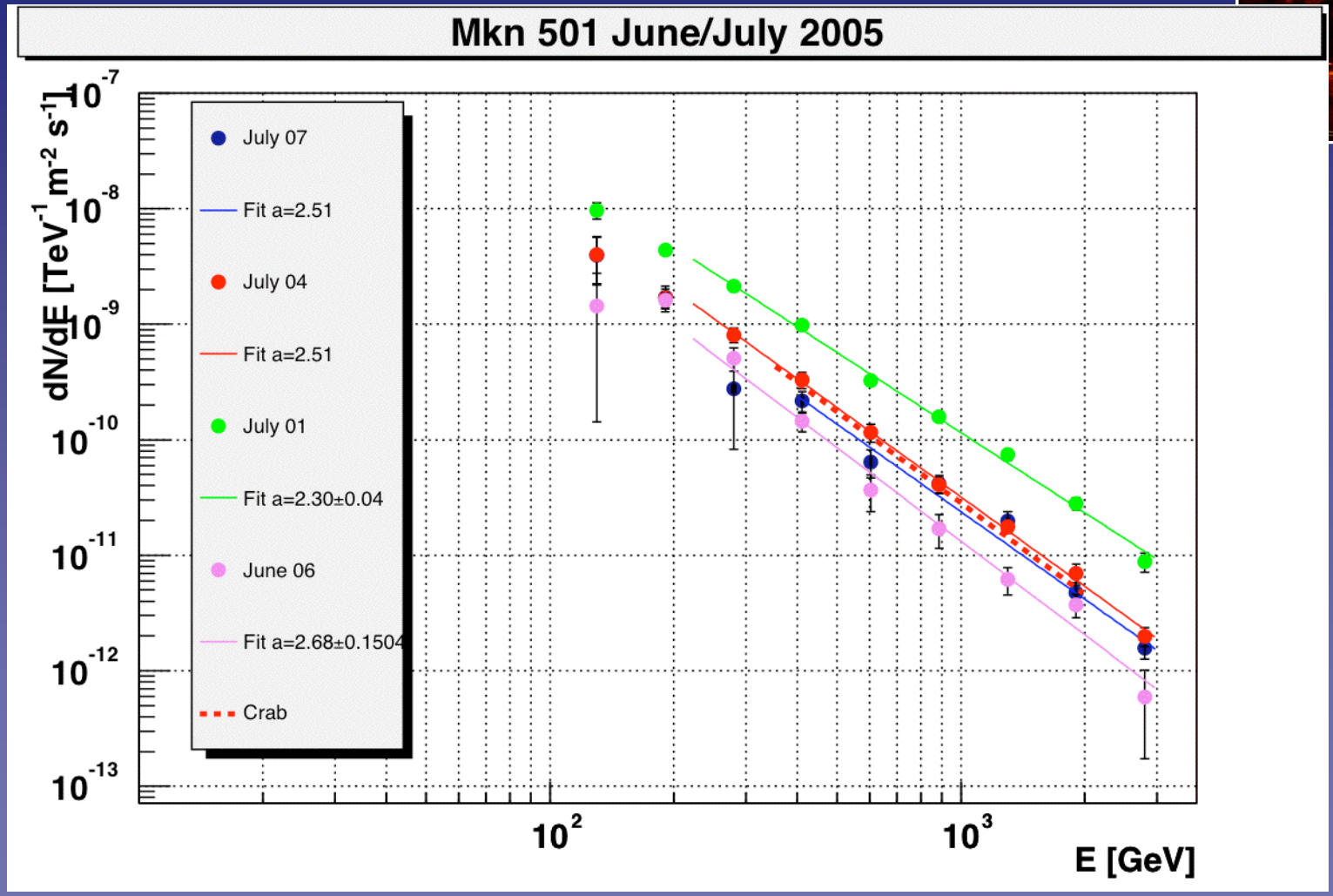
Mrk 501 Light curve







Mrk 501 Preliminary Spectrum



Conclusions & Outlook

- MAGIC is a producing results
- Expect many more results in the near future
- The MAGIC collaboration has started to build a second telescope

MAGIC II will

- increase the sensitivity of the observatory
- further push for lower energy threshold
  - equip camera with high QE HPDs
  - upgrade to 2GSamples/s FADCs (this year for MAGIC I)