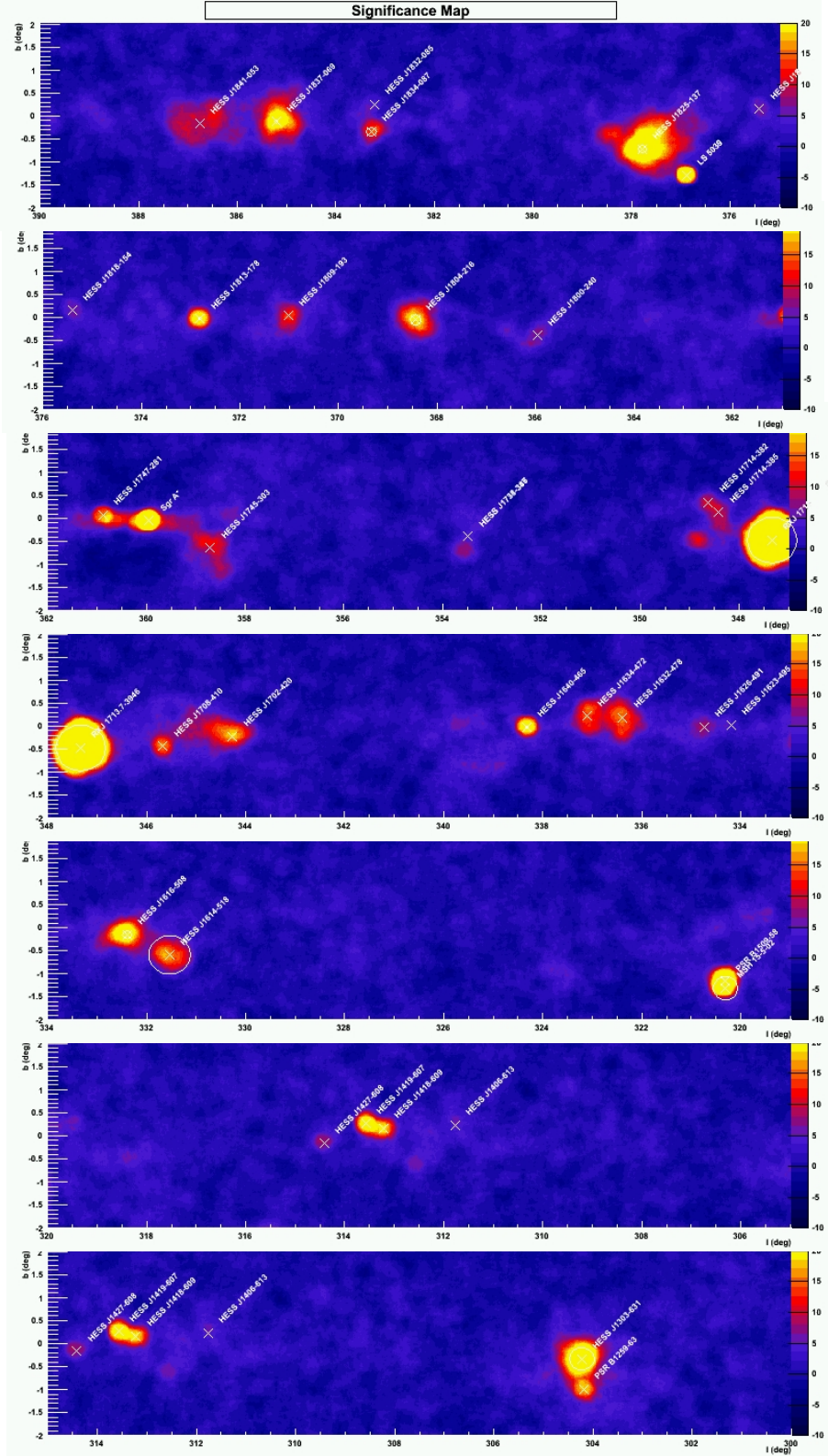
MPI Kernphysik, Heidelberg
Humboldt Univ. Berlin
Ruhr-Univ. Bochum
Univ. Hamburg
LSW Heidelberg
Univ. Tübingen
Ecole Polytechnique, Palaiseau
APC Paris
Univ. Paris VI-VII
Paris Observatory, Meudon
LAPP Annecy
LAOG Grenoble
LPTA Montpellier
CEA Saclay
CESR Toulouse
Durham Univ.
Dublin Inst. for Adv. Studies
Charles Univ., Prague
Yerewan Physics Inst.
North-West Univ., Potchefstroom
Univ. of Namibia, Windhoek

High Energy Stereoscopic System: Status and Results (Summer 2006)

J.P. Tavernet for the HESS collaboration
L.P.N.H.E. - Paris VI university -

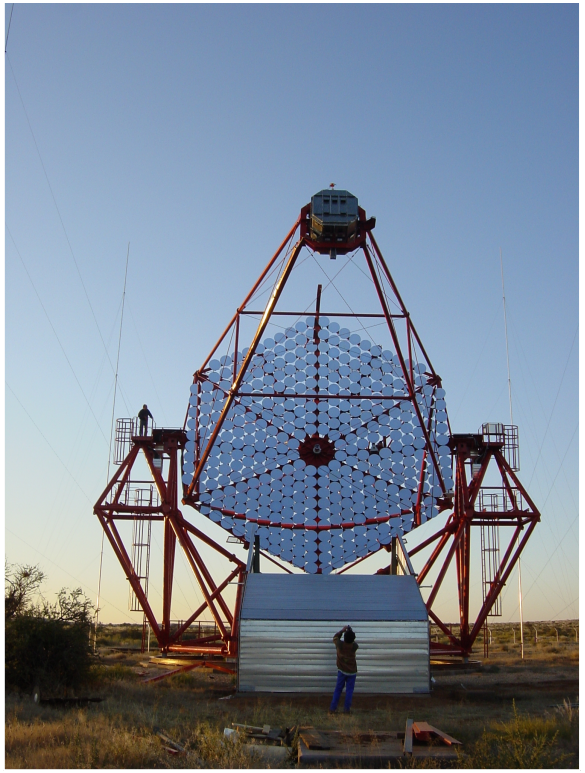
6th Rencontres du Vietnam

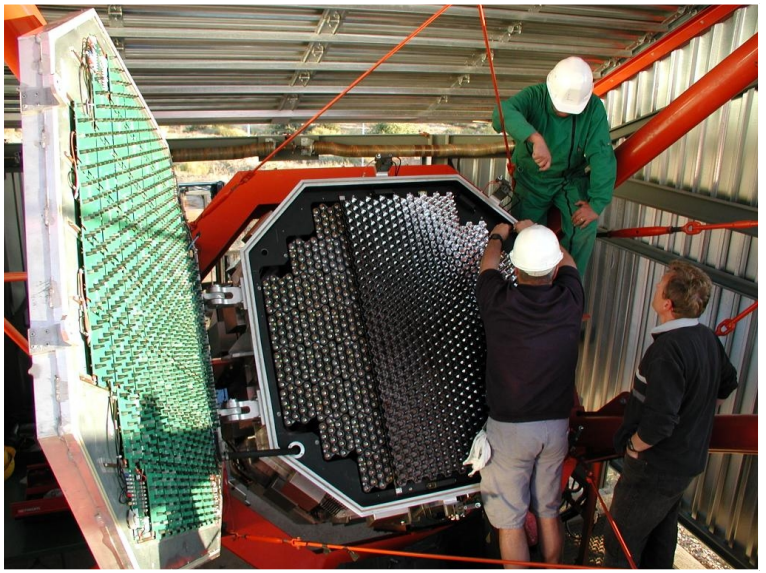


Outline :

- **H.E.S.S. Status 1**
  - **Calibration and Methods**
  - **Crab Nebula**
- **Galactic sources**
- **Extragalactic sources**
- **H.E.S.S. Status 2**
  - **Phase 2 of the project**

H.E.S.S. galactic plane survey





Outline :

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Array of 4 Atmospheric Cerenkov:

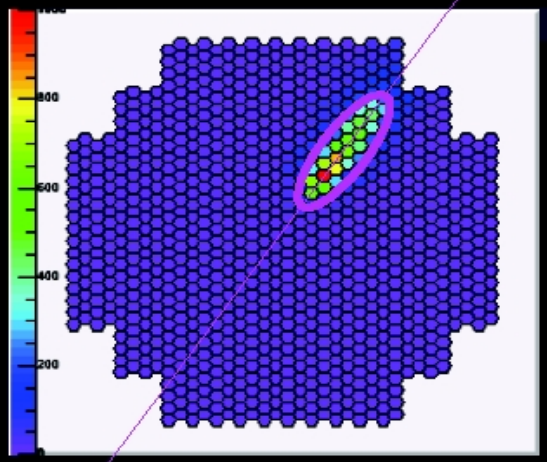
- Telescopes in Namibia

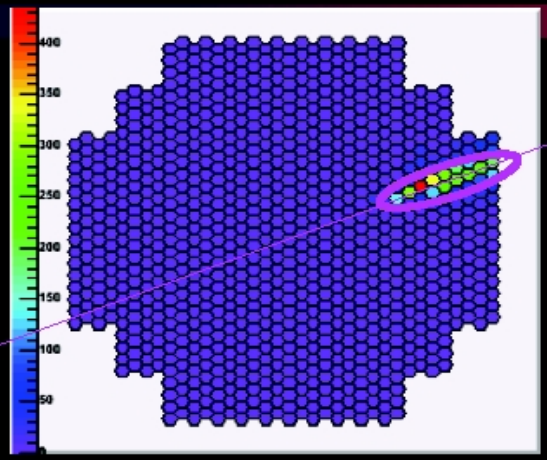
  (23°16'18'' South, 16°30'00' East)'
- Large dishes (107 m^2)
- Fast camera (1ns integration) of 960 pixels
- field of view 5°
- observations in moonless night 1000h/year
- Fully operational since Dec. 2003

Performances;

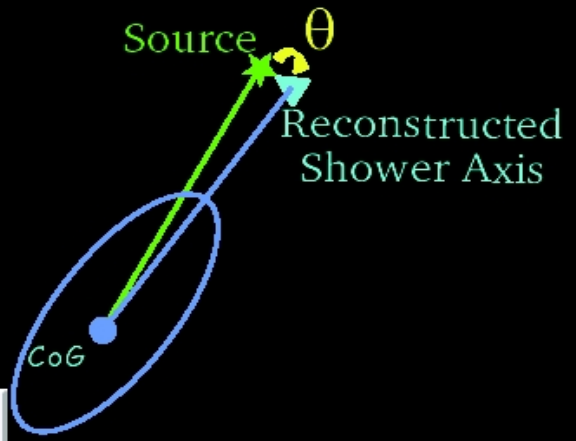
- Trigger threshold 100 GeV @ zenith
- Angular resolution < 0.1°
- Energy resolution ~ 15%
- Effective area > 10^5 m^2
- 1 Crab @ zenith in 30 s (vs 1 h for previous generation)
- 1% Crab in 25 h

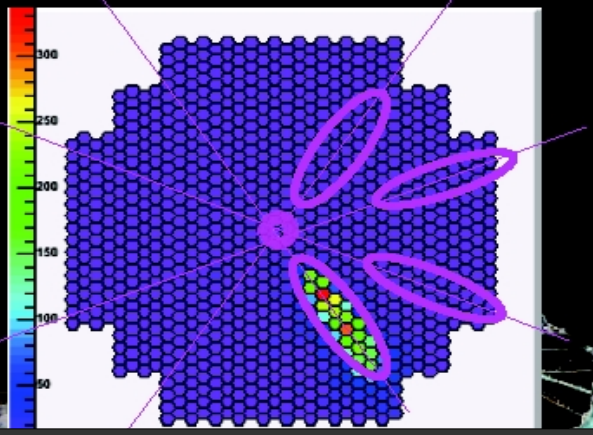
Stereo: Tells where the shower came from

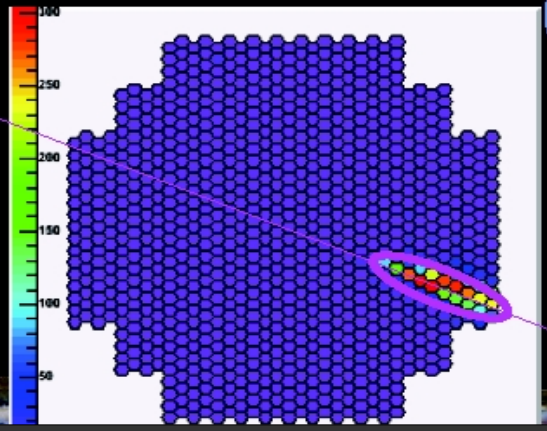




Geometrical determination of
the source position in the camera
... HESS angular resolution 0.10→0.06° per photon

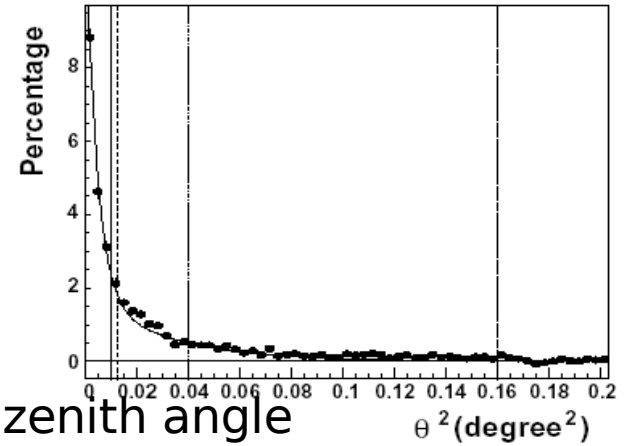






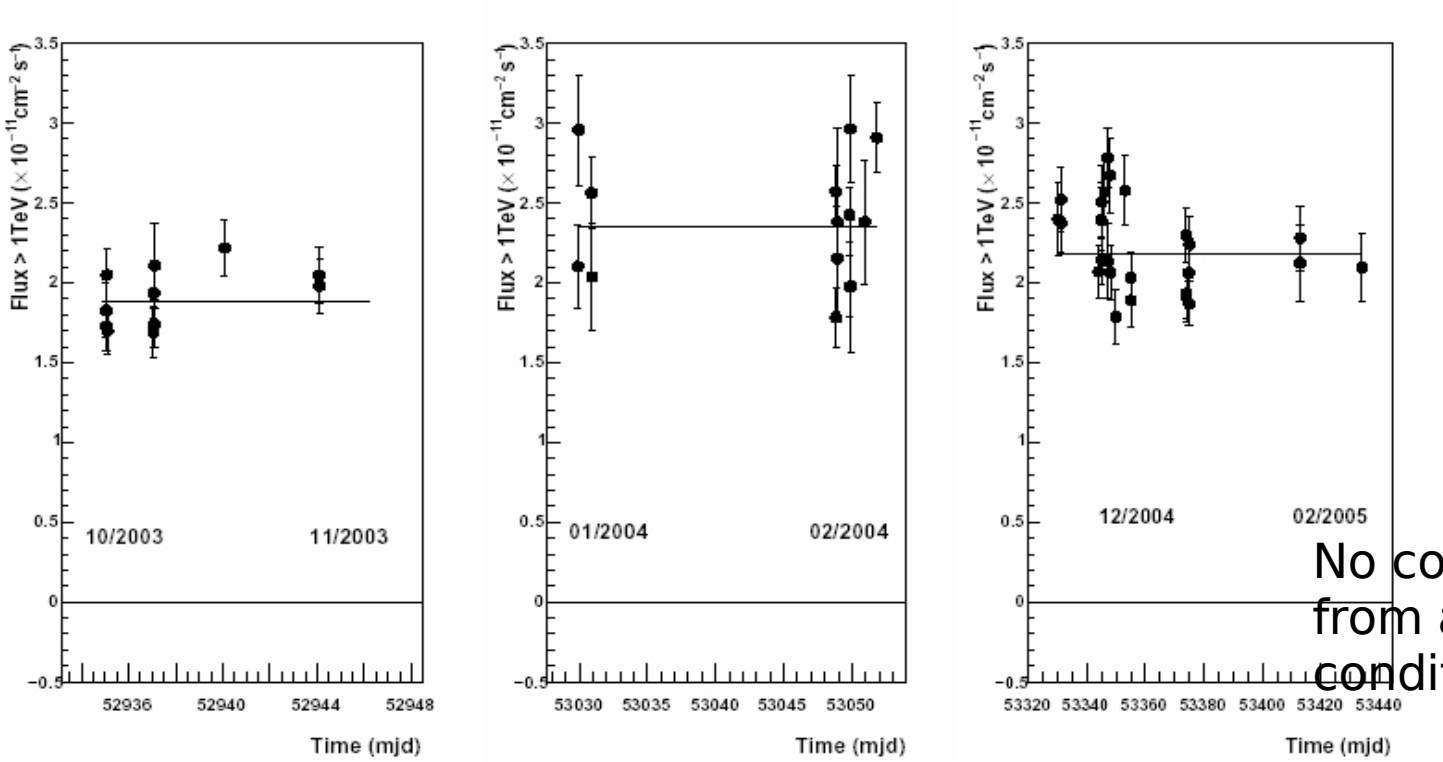
- **Geometrical determination the shower impact on ground**
  => resolution of the energy/ impact parameter degeneracy
- **0.10 -> 0.06° : allows source morphology studies**

Crab Nebula



- Standard reference source for VHE astronomy
- Point source for H.E.S.S.
- At H.E.S.S. latitude, it culminates at 45°, so at a large zenith angle

run by run light curve



No correction, from atmospheric conditions

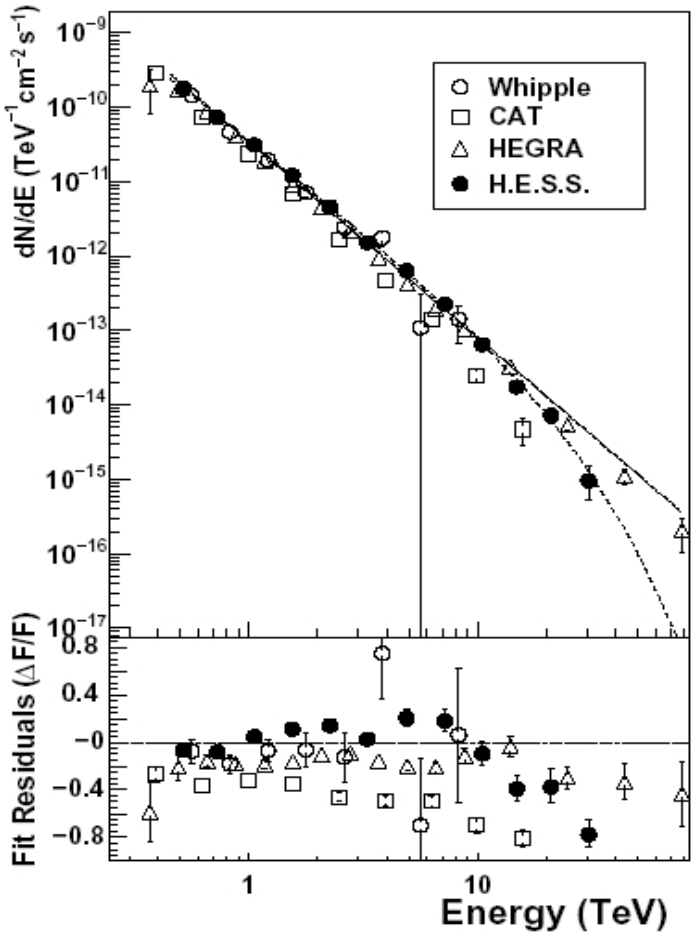
period 1 (~5h): 3 telescopes

period 2 (~6h): 4 telescopes

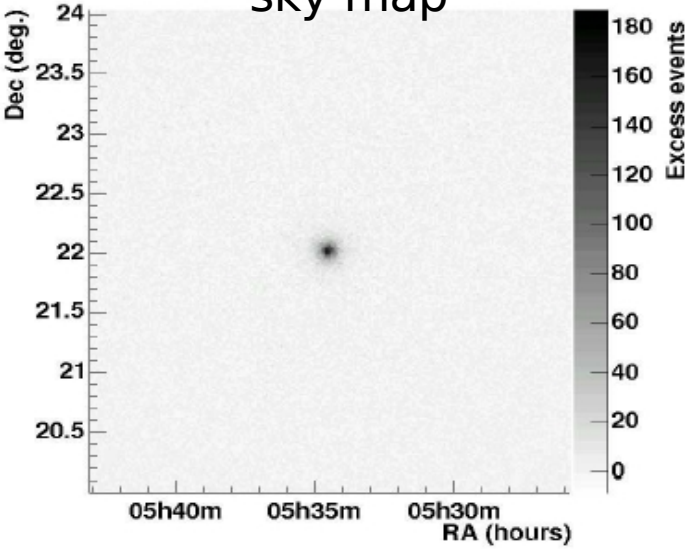
period 3 (~11h): 4 telescopes

long term stability (period 2 and 3 flux is 10% higher, but difference is smaller than the rms spread).

Crab Nebula: spectrum and sky map



sky map



Uncertainty	Flux	Index
MC Shower interactions	1%	
MC Atmospheric sim.	10%	
Broken pixels	5%	
Live time	1%	
Selection cuts	8%	0.08
Background est.	1%	0.01
Run-by-run variability	15%	-
Data set variability	-	0.05
Total	20%	0.09

systematic error

$dN/dE = I_o\ (E/1\ TeV)^{-\Gamma} \exp(-E/E_c)$ with

$I_o = (3.76 \pm 0.07) \times 10^{-11}\ cm^{-2} s^{-1} TeV^{-1}$

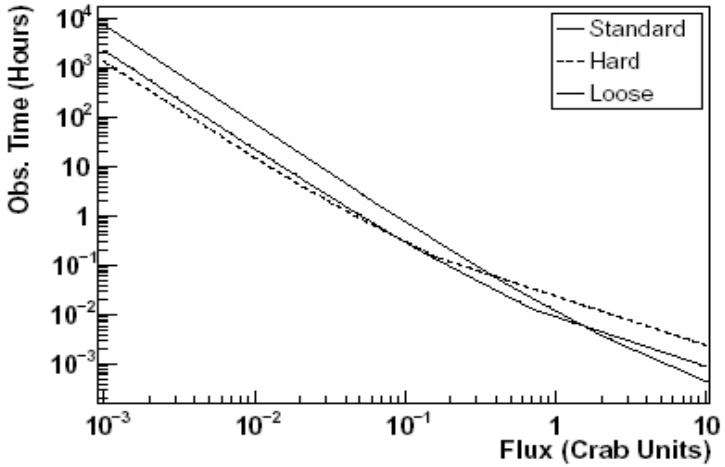
$\Gamma = 2.39 \pm 0.03$

$E_c = 14 \pm 2$ TeV (stat. only)

Our calibration source (Crab nebula) is observed with :

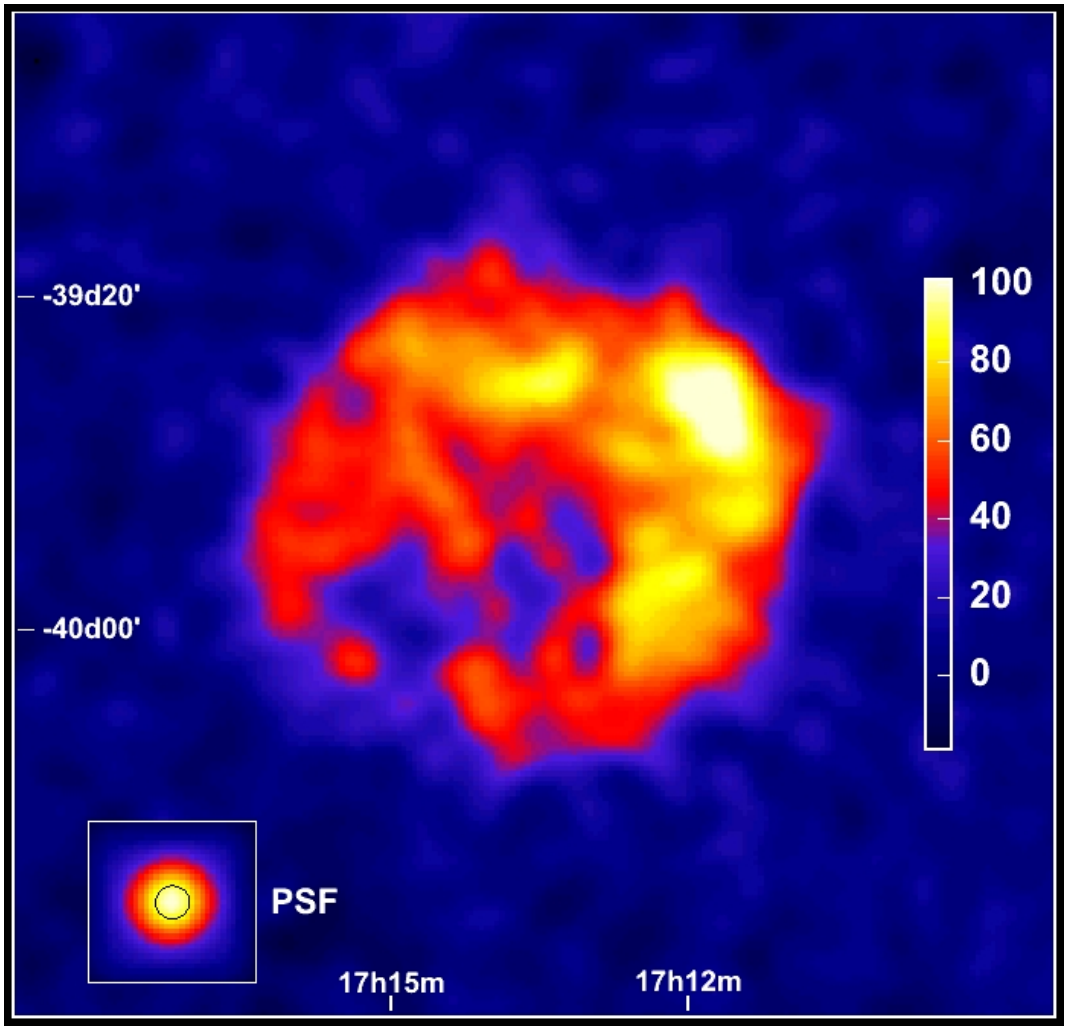
- For standard selection :
  - 6.0 γ min^{-1}
  - significance of 27/√t(hr^{-1})
- long term stability shows that instrument, calibration and analysis methods are well understood

=> more confident for the old and future results.



Time as function of signal strength required for a 5σ detection at 20° zenith angle for standard cuts :

- 30 seconds for source with a flux of the Crab
- 25 hours : 1% of flux of the Crab



RXJ1713.7-3946 (See talk of U. Schwanke !!)

Outline :

- H.E.S.S. Status 1
  - Calibration and Methods
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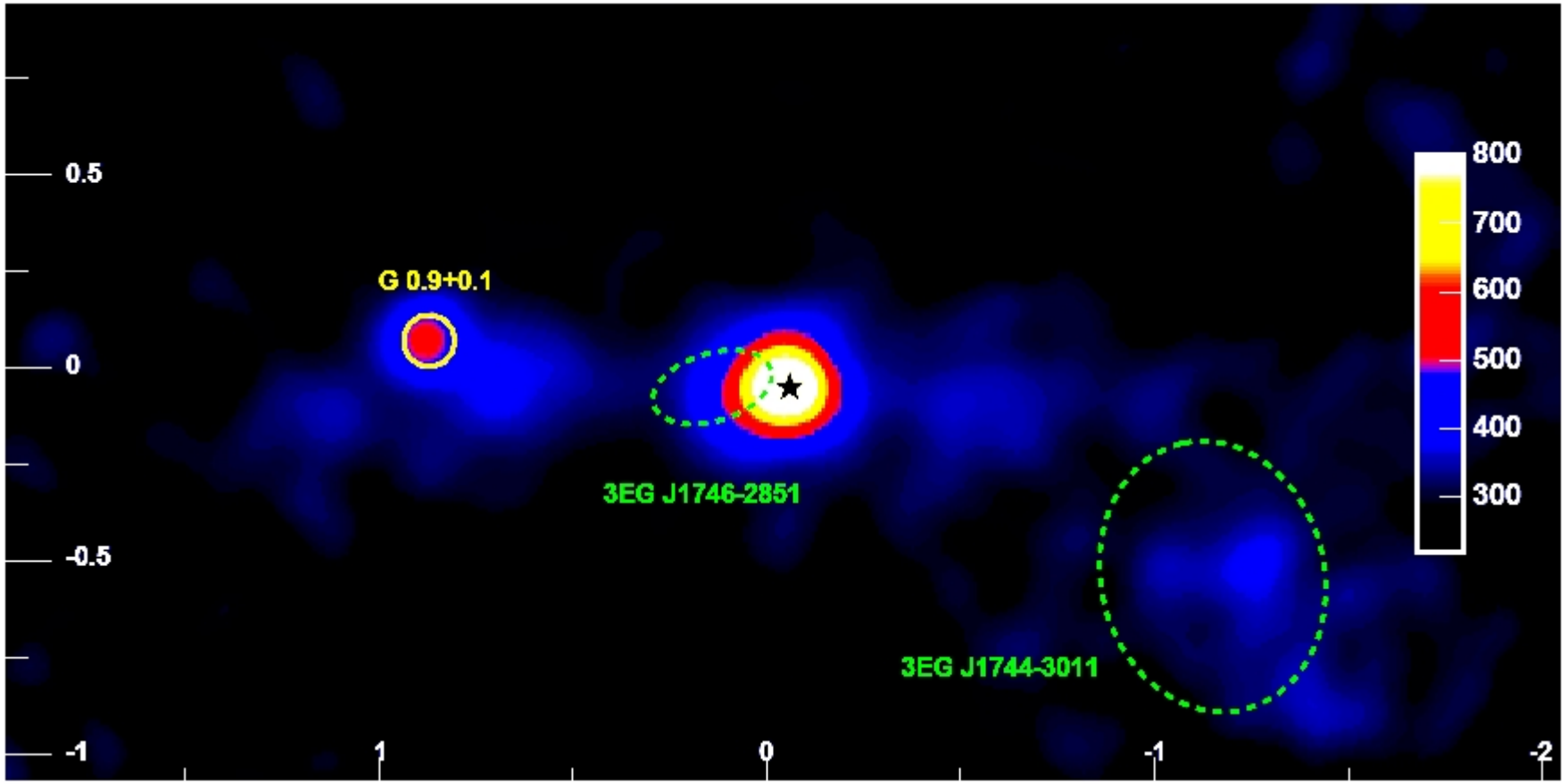
- **Galactic sources**
  - **Galactic center**
  - **LS5039**
- Extragalactic sources
- H.E.S.S. Status 2
  - Phase 2 of the project

Galactic center region:

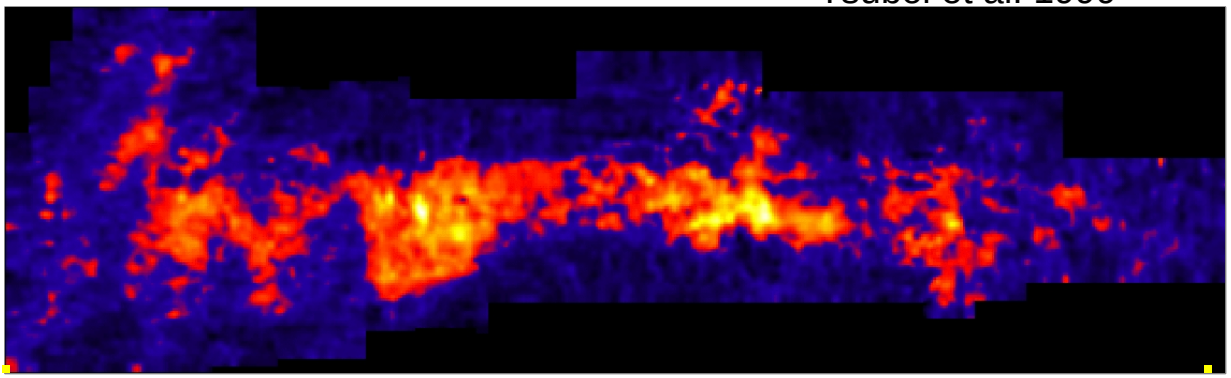


Observations:

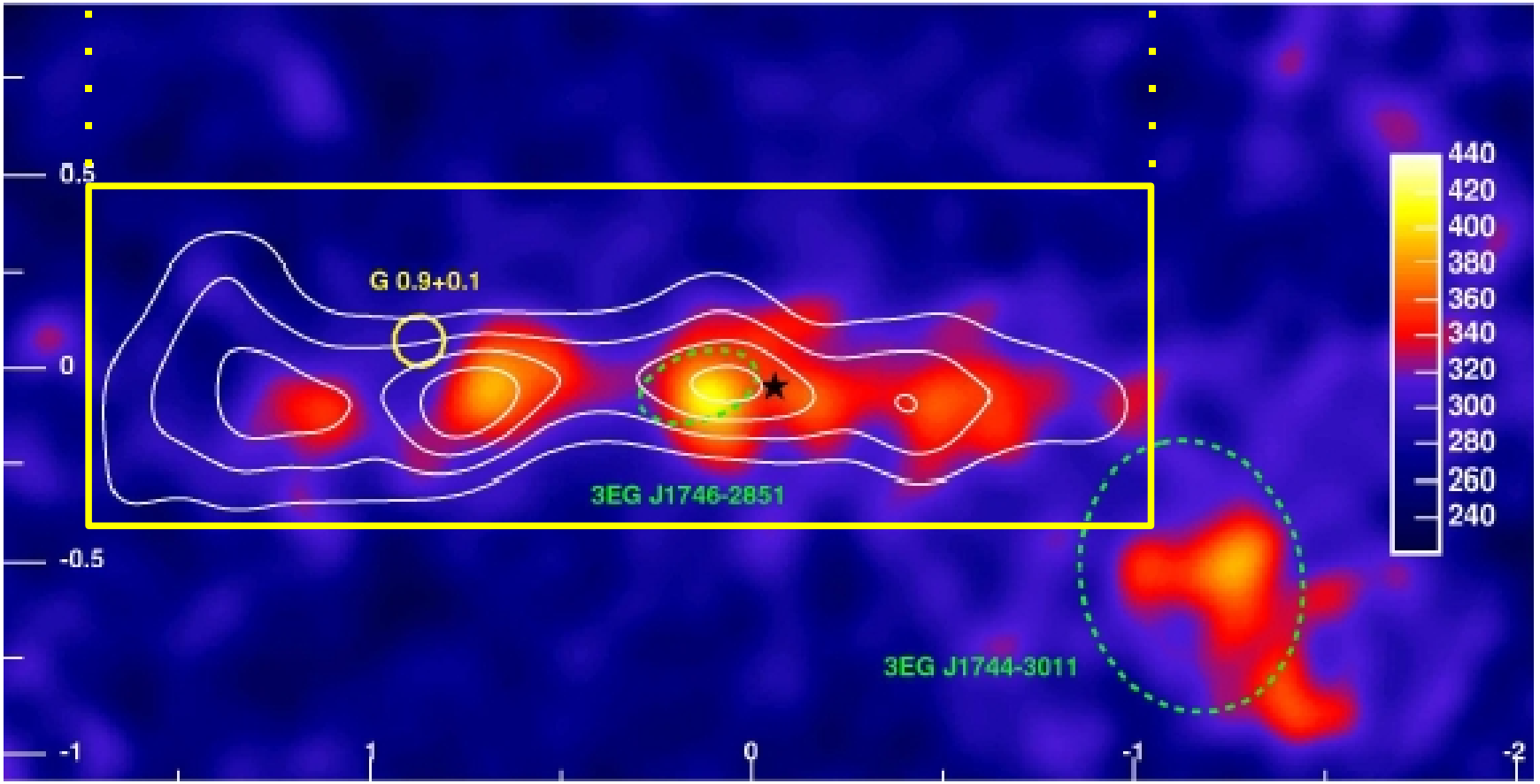
- a point-like source of VHE γ-rays at the gravitational center of the Galaxy
- the supernovae remnant/pulsar wind nebula G0.9+0.1
- structures under these two sources signal

GC molecular clouds

Tsuboi et al. 1999

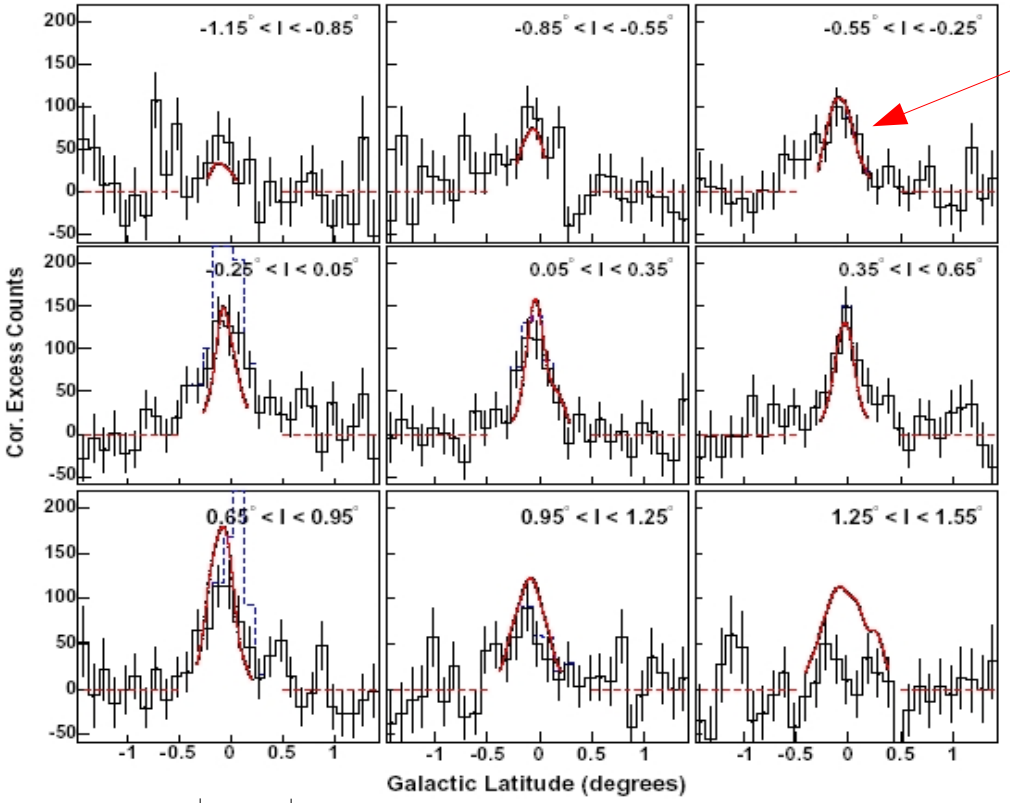


•Excellent correlation with molecular clouds



Galactic γ-rays map after subtraction

Diffuse emission from the galactic center region



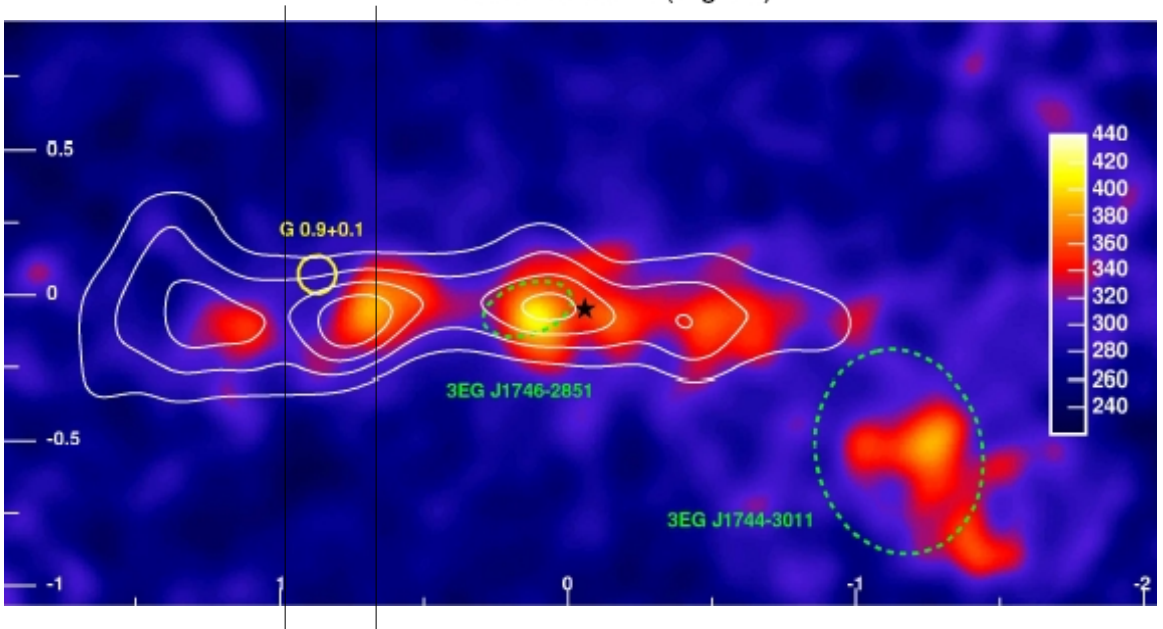
density of molecular gas

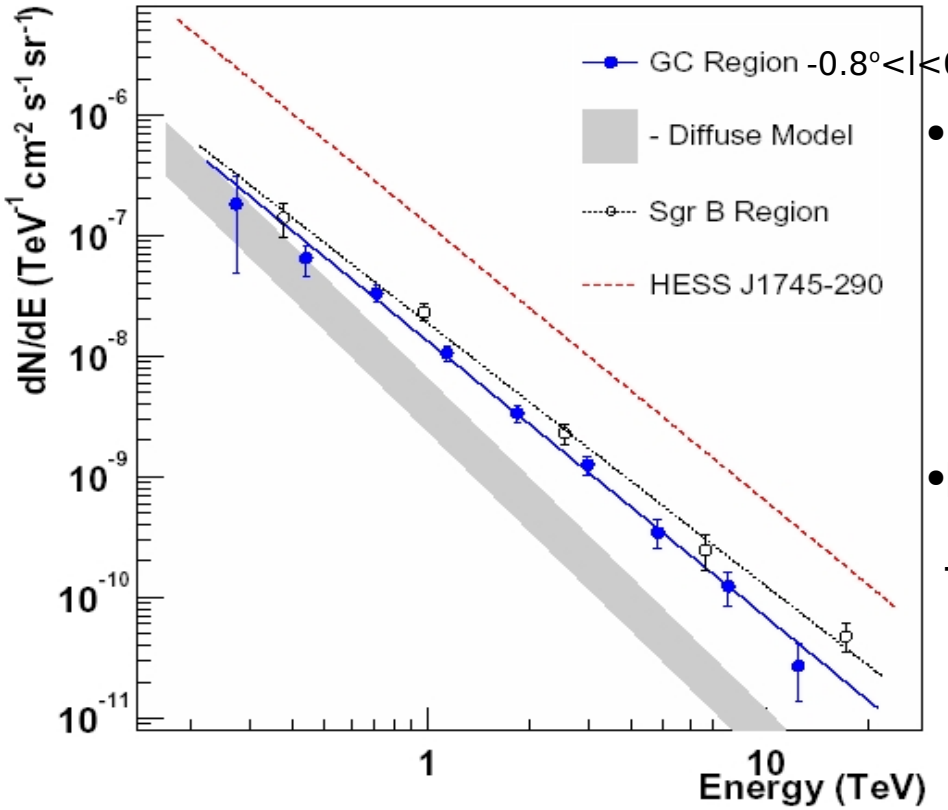
Strong correlation between VHE γ-rays distribution and molecular clouds (traced by CS emission):

indication for VHE emission coming from interactions of CRs with molecular clouds

rather uniform CR density in GC

in case of a power law energy distribution, spectral index of the γ-rays ≈ spectral index of the CRs





- Power law spectrum with
  Γ = 2.29 ± 0.07±0.20
  ≠ Γ=2.75 'classical' CR spectrum
  ➔probable proximity of particle accelerators

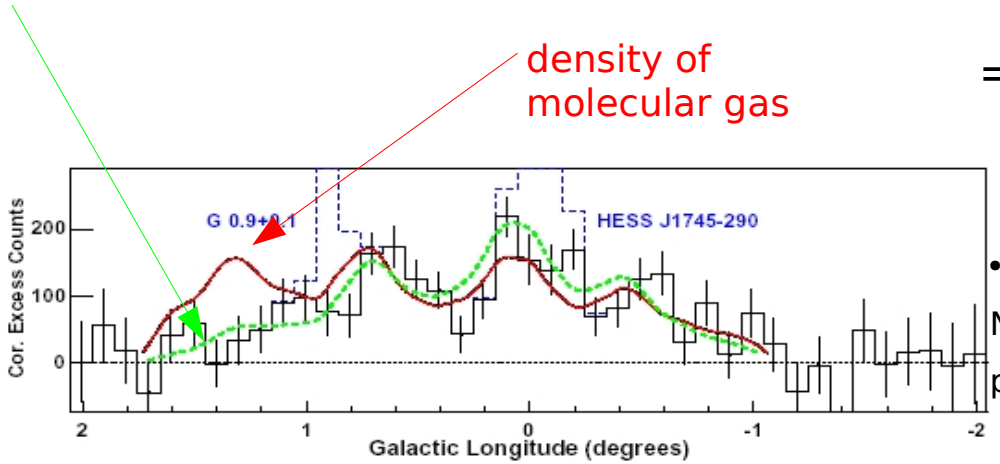
•Diffuse Model :

- γ-rays flux with 'classical' CRs spectrum (Γ=2.75) and a total target mass estimated from CS measurement
- Additional component to GC RCs needed
  - Energy of a single SNR is enough
  - Morphology+proton diffusion time-scale

  => possible sources near the center around 10 kyr (SNR Sgr A East or black hole Sgr A*)

γ-rays flux expected if CR density described by a Gaussian centered at l=0°, and rms=0.8°

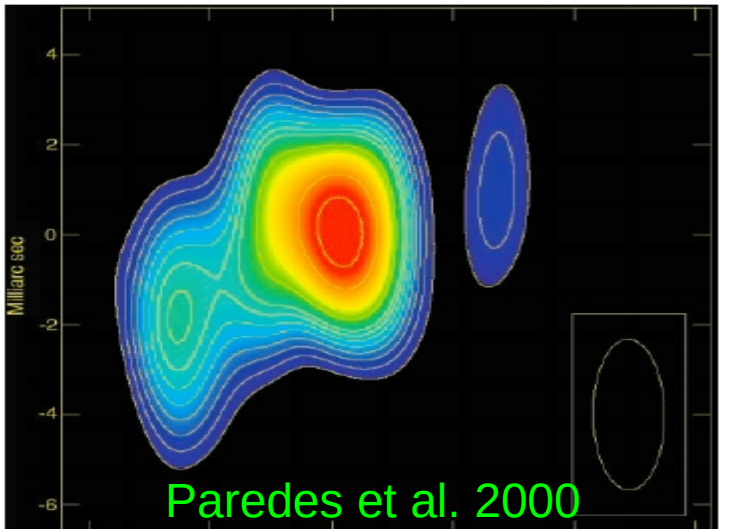
density of molecular gas



• VHE γ-rays emission via IC scattering of accelerated electrons
No ! TeV electron would lose their energy rapidly due to intense photon field and high magnetic fields.

A microquasar: LS 5039

(compact object fed by a massive star)



- massive O6.5V star
- unidentified compact object

  1.5 -> 5 $M_{\odot}$ (casares et al. 2005)

- Orbital period ~3.9 days – Inclination [15°,65°]?
- Eccentric orbit (e~0.3) binary separation 2->4.5 R_{*}

  ➔ binary system

- Radio emission possibly from jet (Paredes et al. 2000)

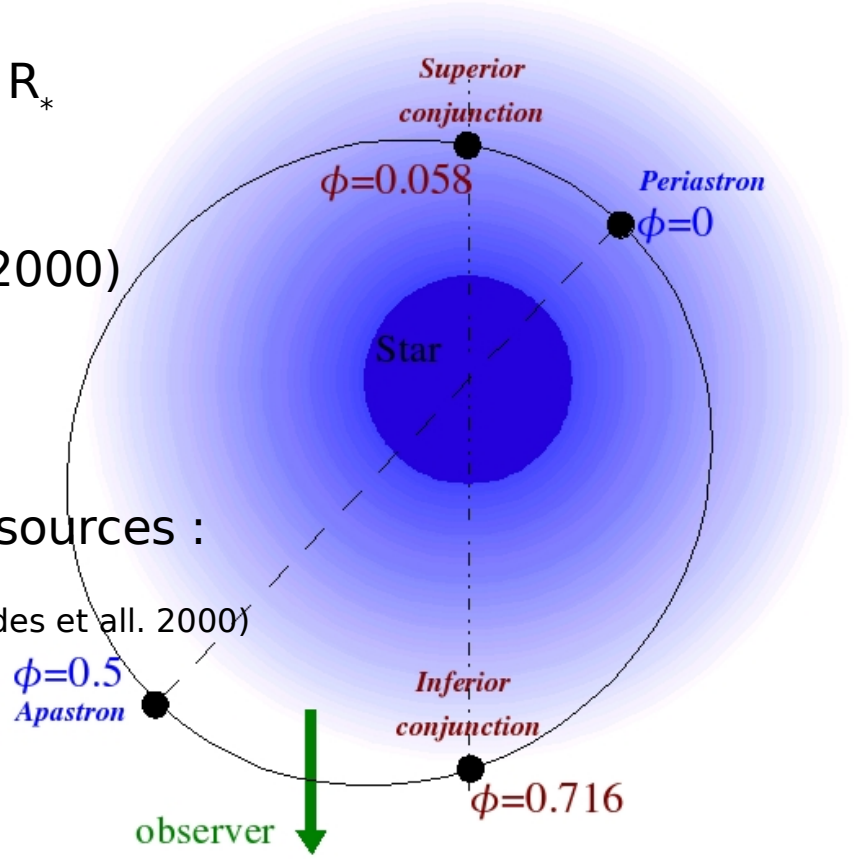
  extension ~1000 AU, v ~ 0.2 c

  ➔ microquasar

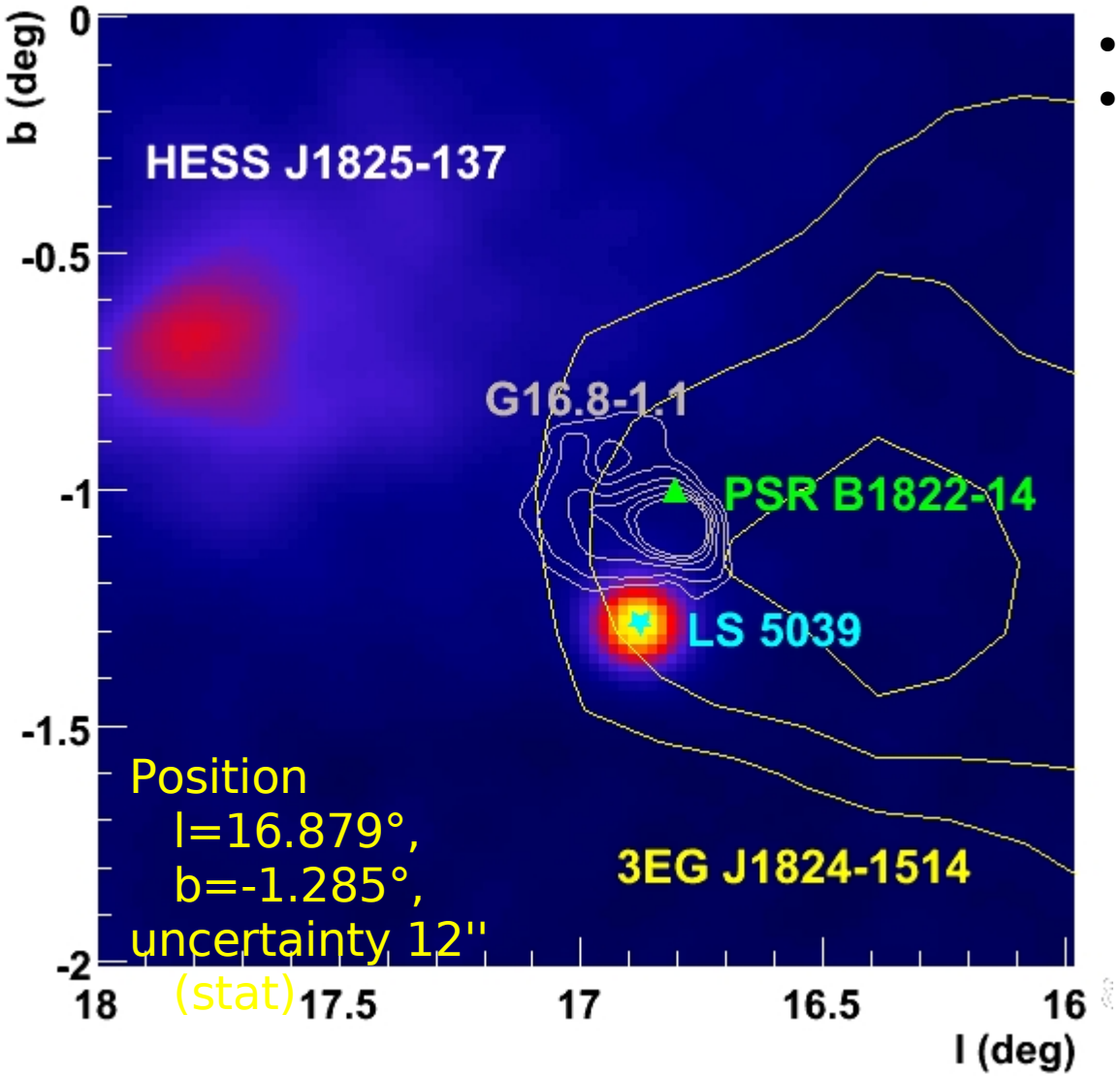
- Possible association with the MeV to GeV γ-rays sources :

  CRO J1823-12 (Collmar 2003), 3EG 1824-1514 (Paredes et all. 2000)

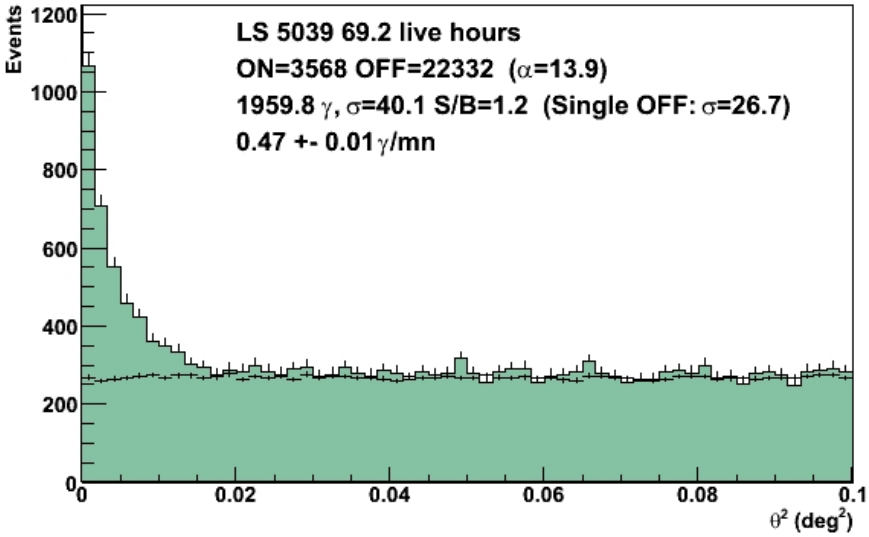
  ➔ indication of multi-GeV particles



LS 5039: HESS observations

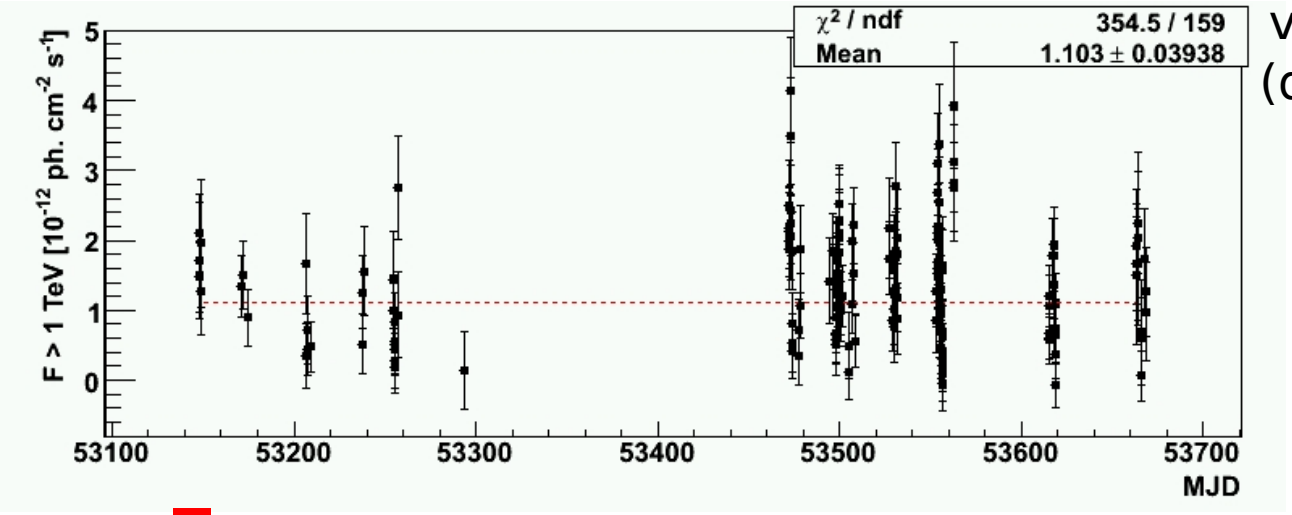


- Detection during galactic scan (2004)
- Deep observation in 2005



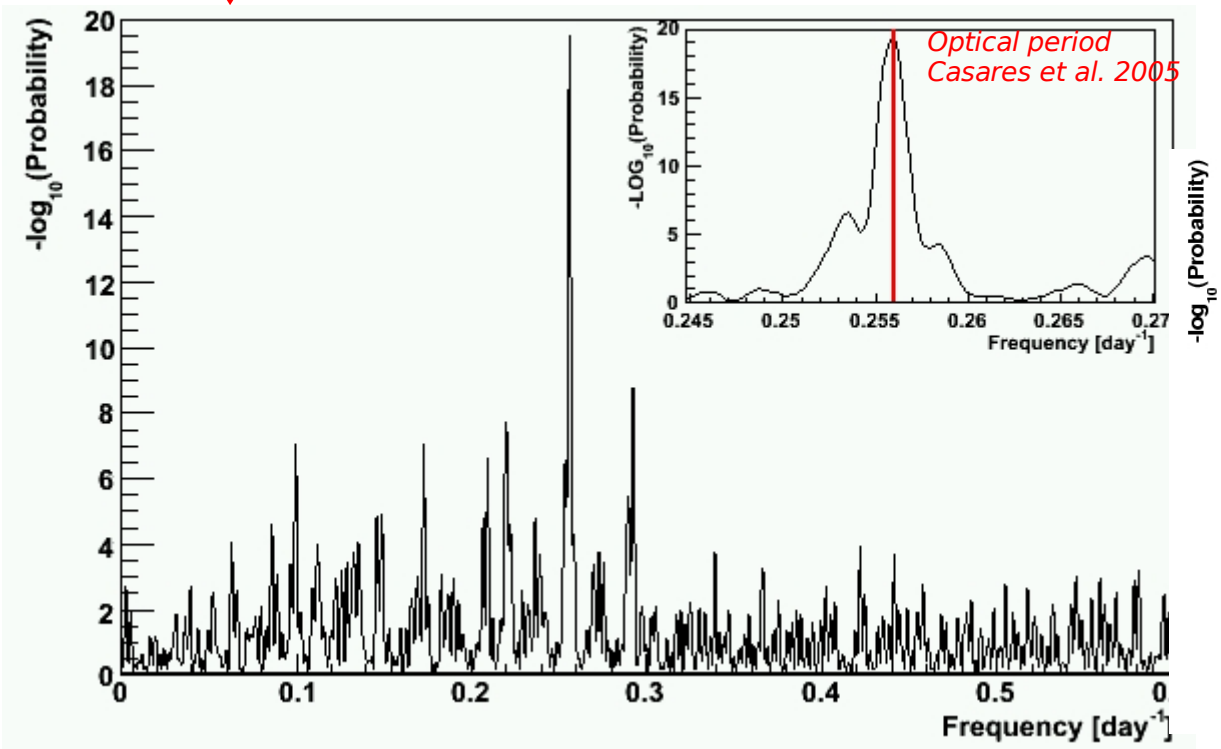
LS 5039 only X/radio source in FoV

LS 5039: HESS results

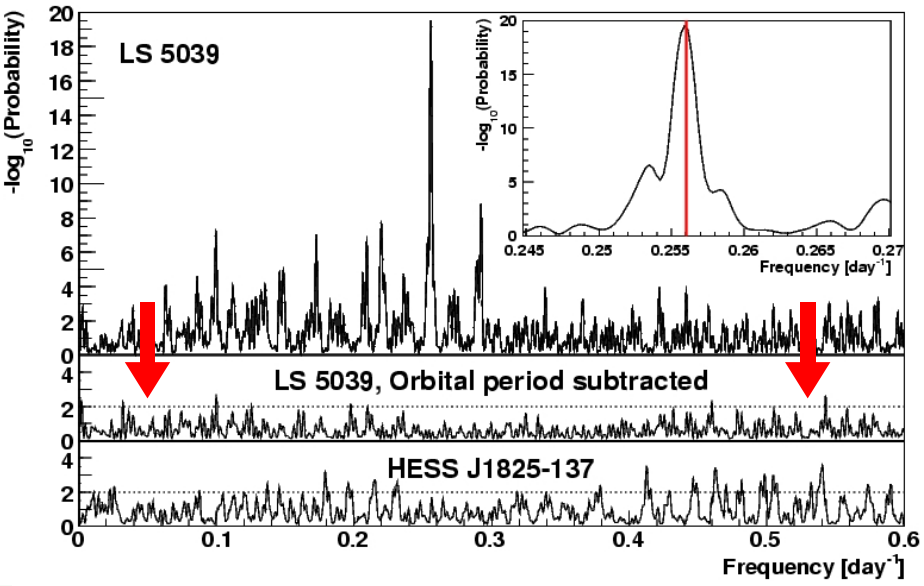


variable source
(data length ~ 1000 days)

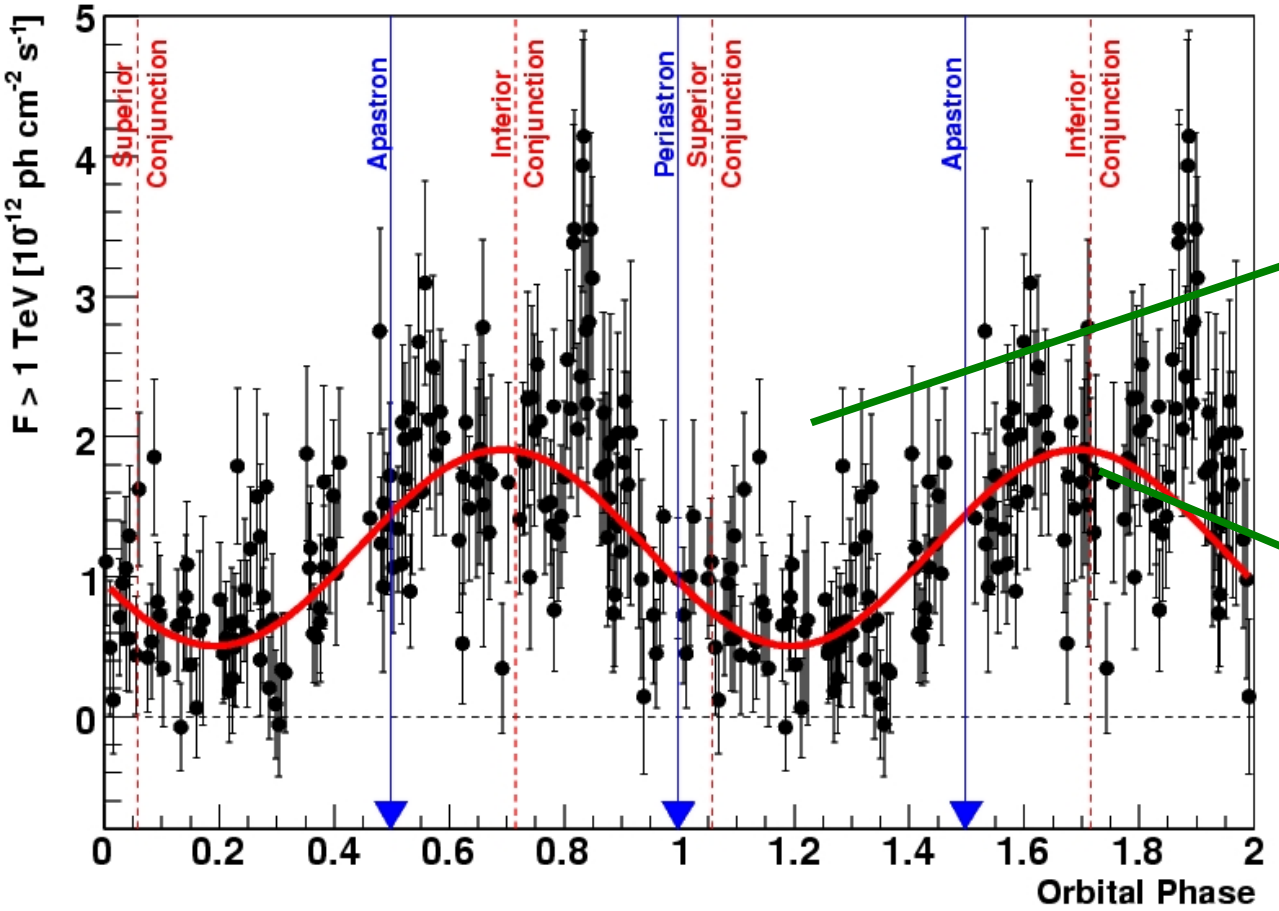
Lomb-Scargle Test (Scargle 1982) or
Normalised Rayleigh Statistic (deJager 1994)

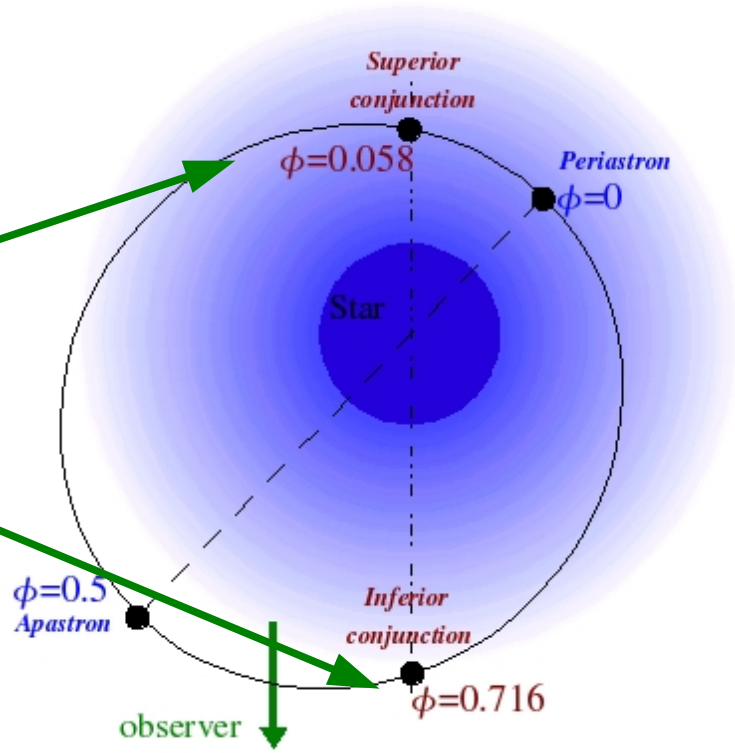


- peak at 3.9078±0.0015 days compatible with orbital period
- statistical fluctuation < 10^{-15}



LS 5039: HESS results

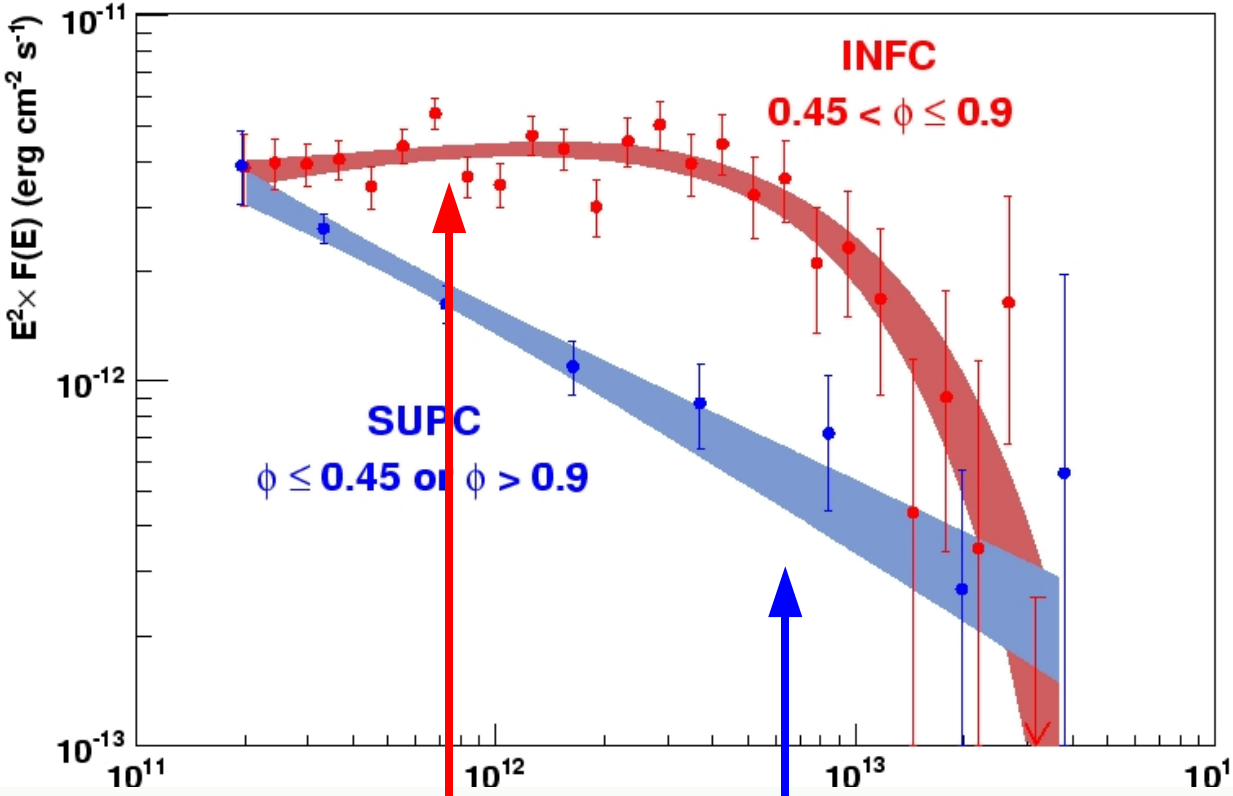


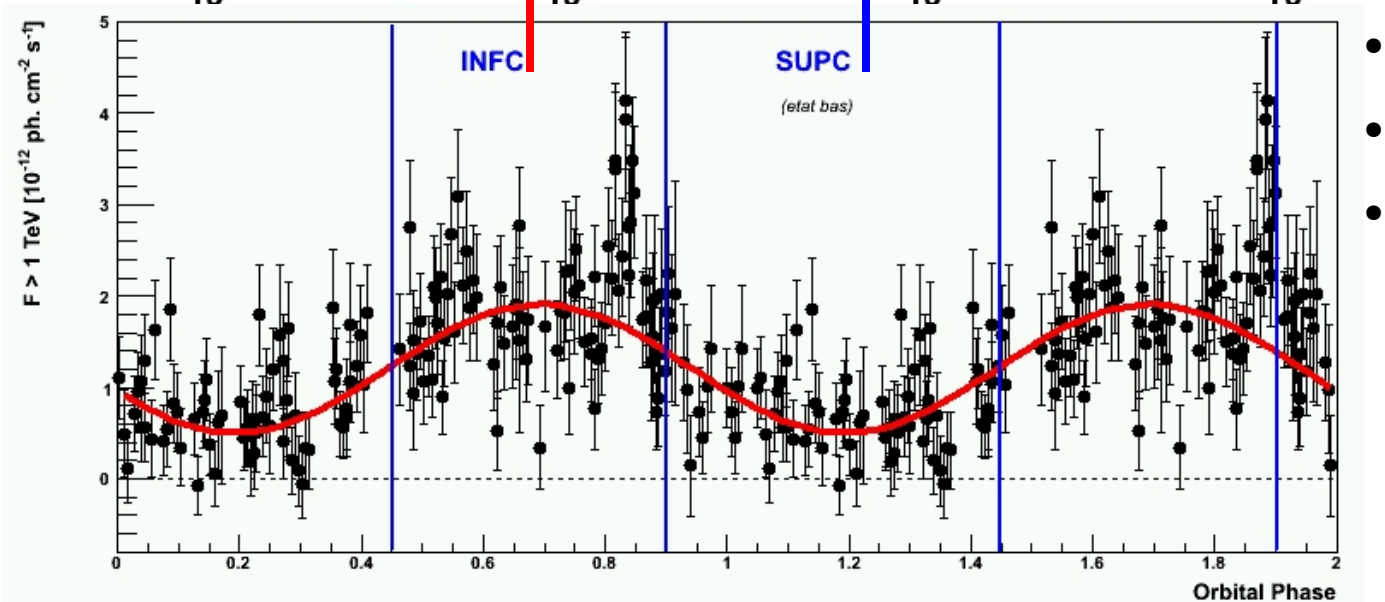


- VHE maximum flux with inferior conjunction
  (Star-compact object-observer alignment)
- VHE minimum flux with Φ~0.2

➔ **not compatible with a simple absorption model**

LS 5039: HESS results and conclusions





- Strong spectral modulation

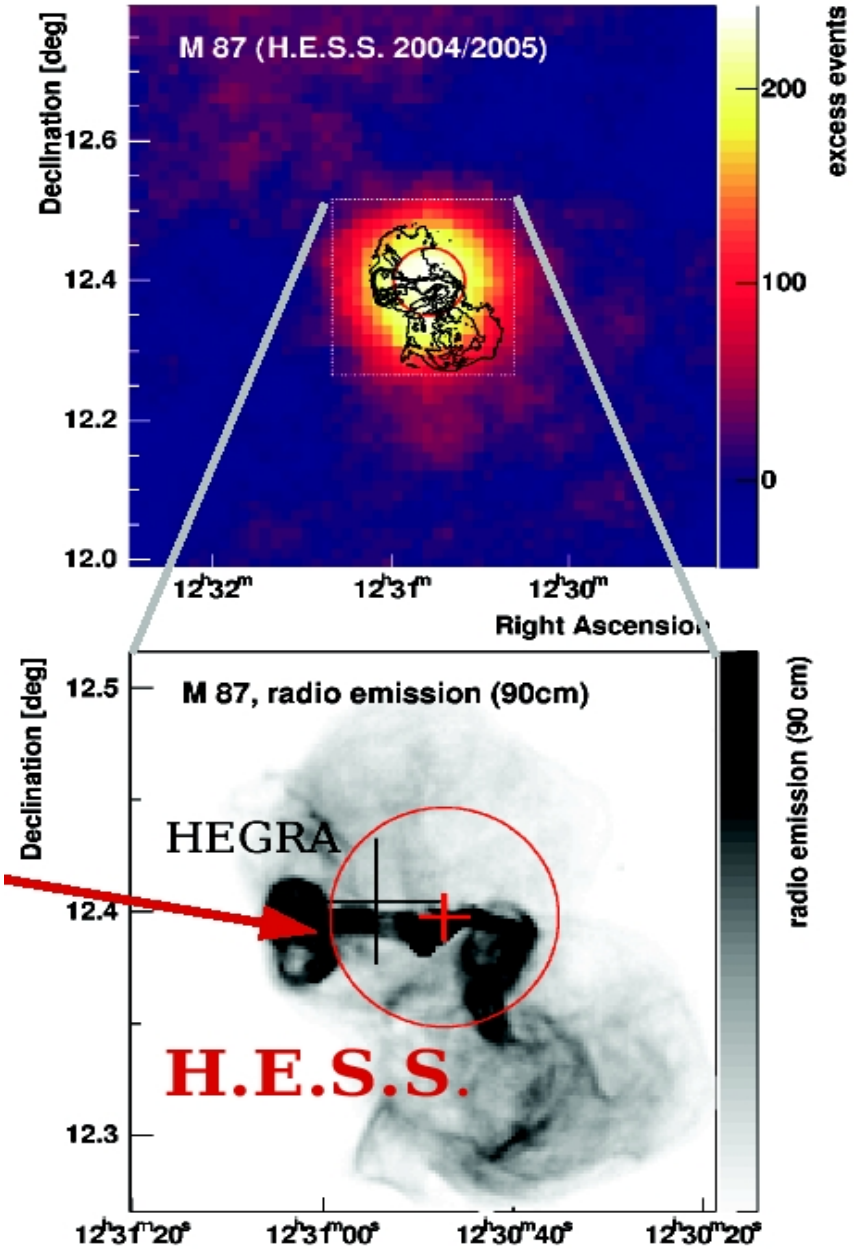
  $\Gamma = 2.53 \pm 0.07$

  and

  $\Gamma = 1.85 \pm 0.06$

  $E_{cut} = 8.7 \pm 2$ TeV

- First periodic signal in TeV
- Emission region constraint
- Emission from jet disfavored
- Model : Absorption + production processes



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- **Extragalactic sources**
  - **E.B.L.**
  - **M87**
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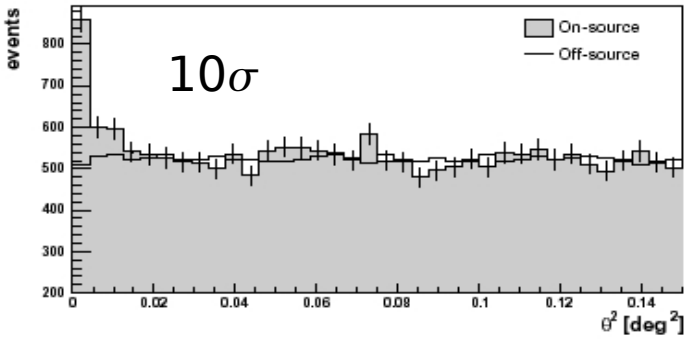
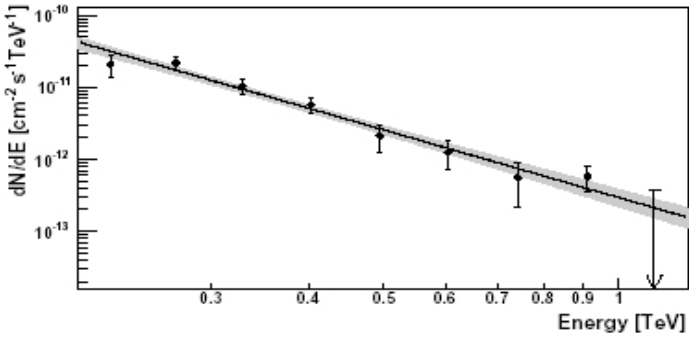
  - Phase 2 of the project

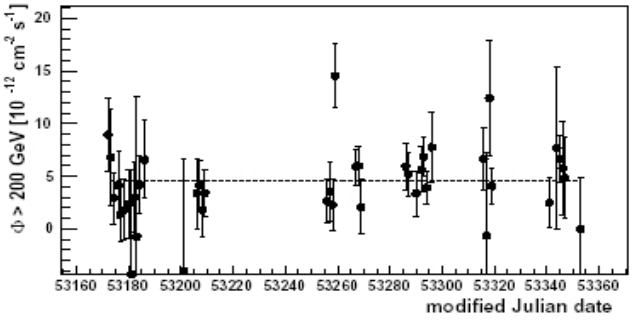
Legend:
discovered by H.E.S.S.
seen by H.E.S.S.

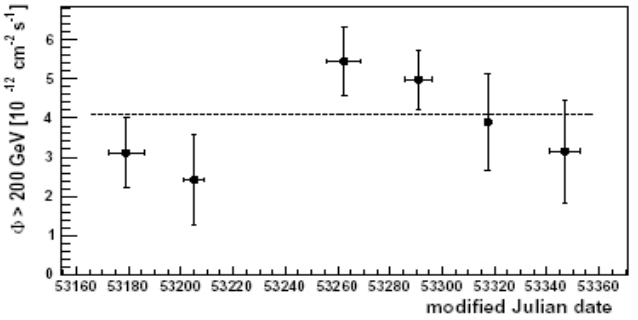
Name	redshift	reference
M 87	0.004	Aharonian et al, A&A, 403, L1 (2003)
Markarian 421	0.030	Punch et al., Nature, 358, 477 (1992)
Markarian 501	0.034	Quinn et al., ApJ, 456, L83 (1996)
1ES 2344+514	0.044	Catanese et al., ApJ, 501, 616 (1998)
Markarian 180	0.045	Albert et al., astro-ph/0606630 (2006)
1ES 1959+650	0.047	Nishiyama et al., 29th ICRC, 3, 370 (1999)
PKS 2005-489	0.071	Aharonian et al, A&A, 436, L17 (2005)
PKS 2155-304	0.116	Chadwick et al., ApJ, 513, 161 (1999)
H 1426+428	0.129	Horan et al., ApJ, 571, 753 (2002)
H 2356-309	0.165	Aharonian et al, Nature, 440, 1018 (2006)
1ES 1218+304	0.182	Albert et al., ApJ, 642, L119 (2006)
1ES 1101-232	0.186	Aharonian et al, Nature, 440, 1018 (2006)
PG 1553+113	>0.25?	Aharonian et al, A&A, 448, L19 (2006)

H2356-309, z=165



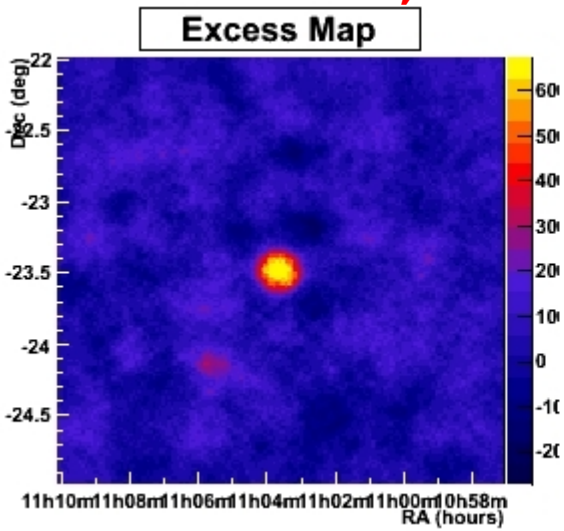


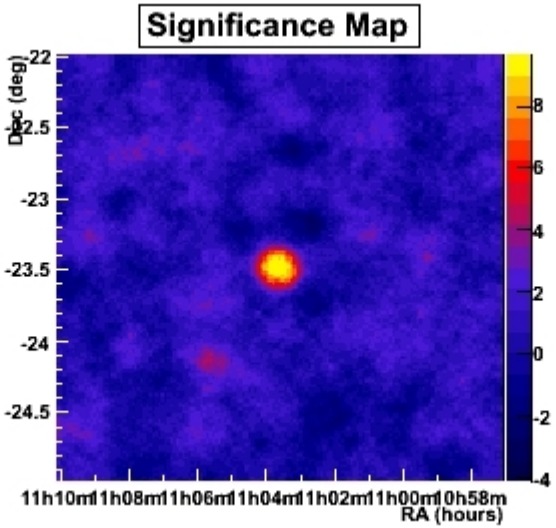


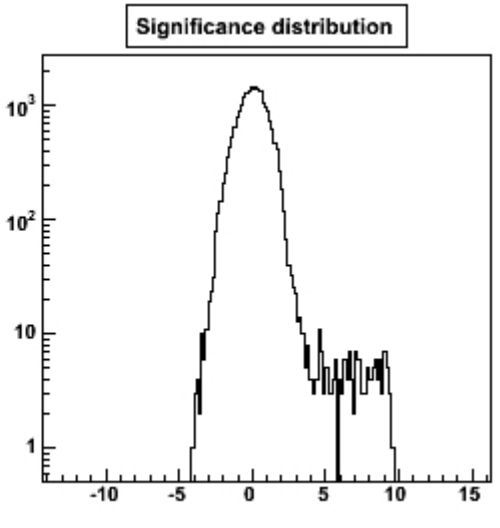


	Γ	N_0 $[10^{-13}\,\mathrm{cm^{-2}s^{-1}TeV^{-1}}]$	$P(\chi^2)$
(1)	$3.09 \pm 0.24_{\mathrm{stat}} \pm 0.10_{\mathrm{sys}}$	$3.00 \pm 0.80_{\mathrm{stat}} \pm 0.31_{\mathrm{sys}}$	0.47
(2)	$3.06 \pm 0.21_{\mathrm{stat}} \pm 0.10_{\mathrm{sys}}$	$3.07 \pm 0.75_{\mathrm{stat}} \pm 0.31_{\mathrm{sys}}$	0.60

1ES1101-232, z=0.186

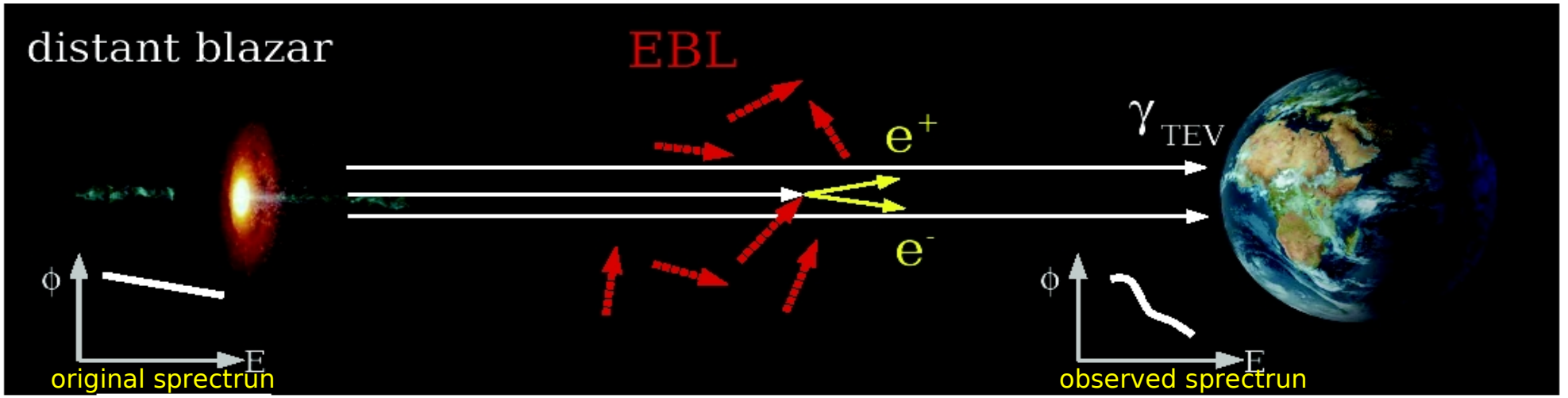




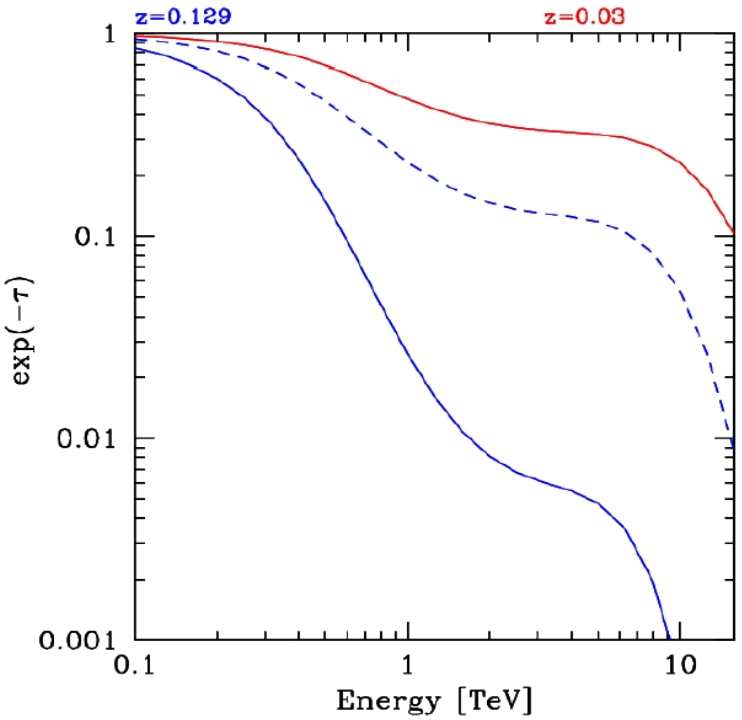


- Most distant sources for which spectra have been measured at TeV energy
- Hard spectra
- Strong implications on Extragalactic Background Light (ELB)

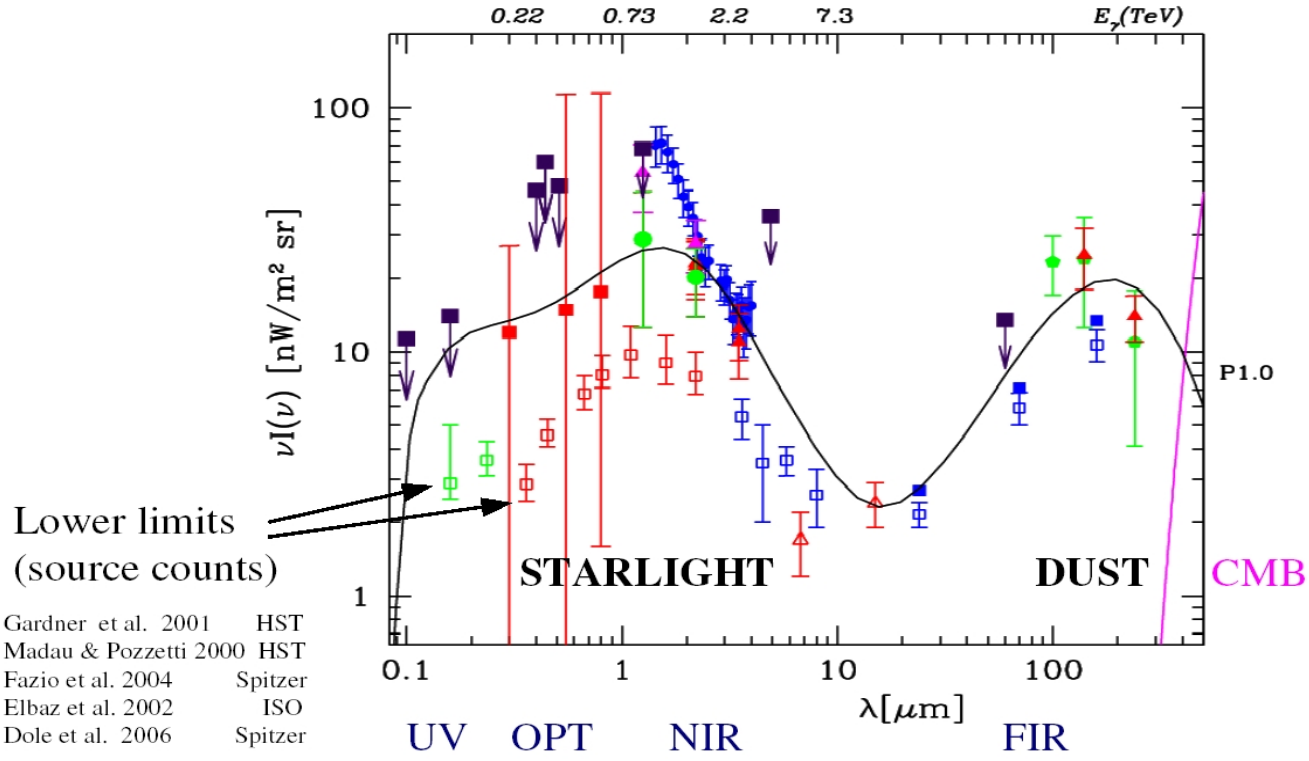
- **EBL:** Extragal. background light: TeV γ–absorption



$$F_{obs}(E) = F_{intr}(E) \times e^{-\tau(E)}$$

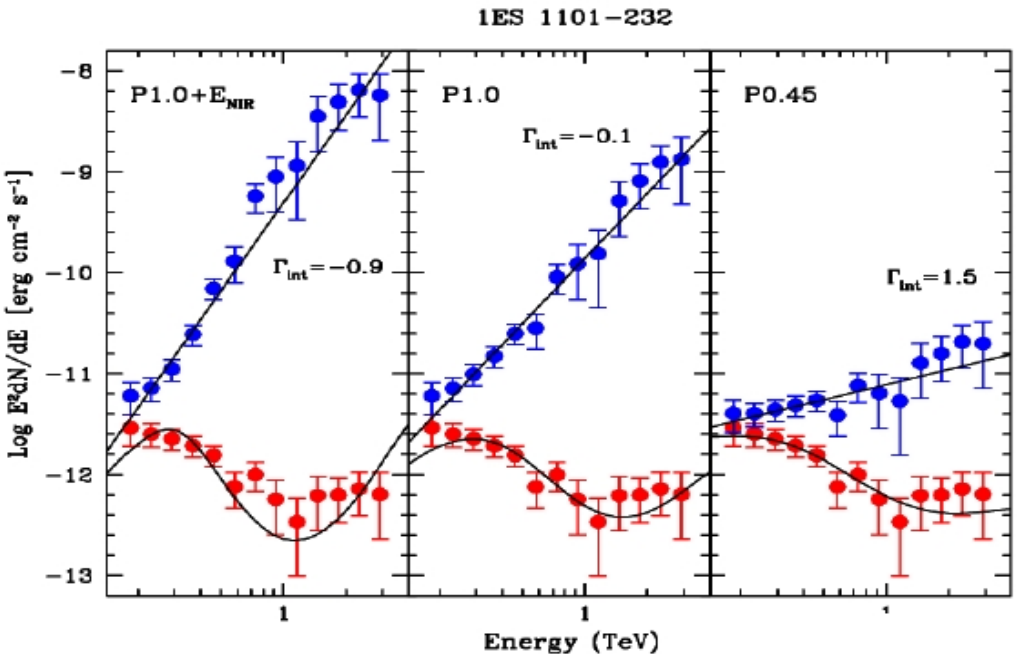


optical depth

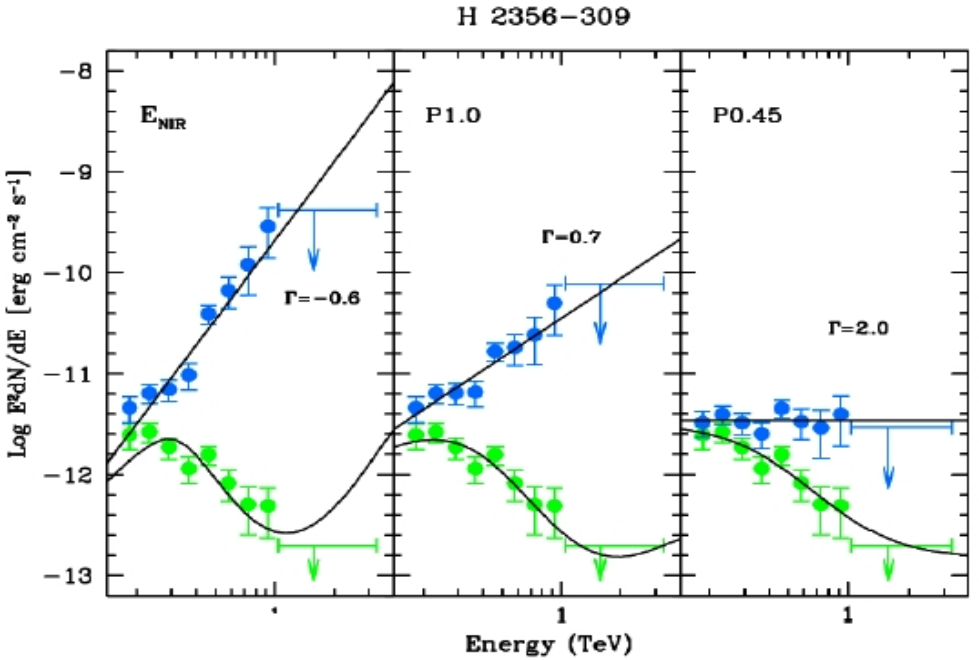


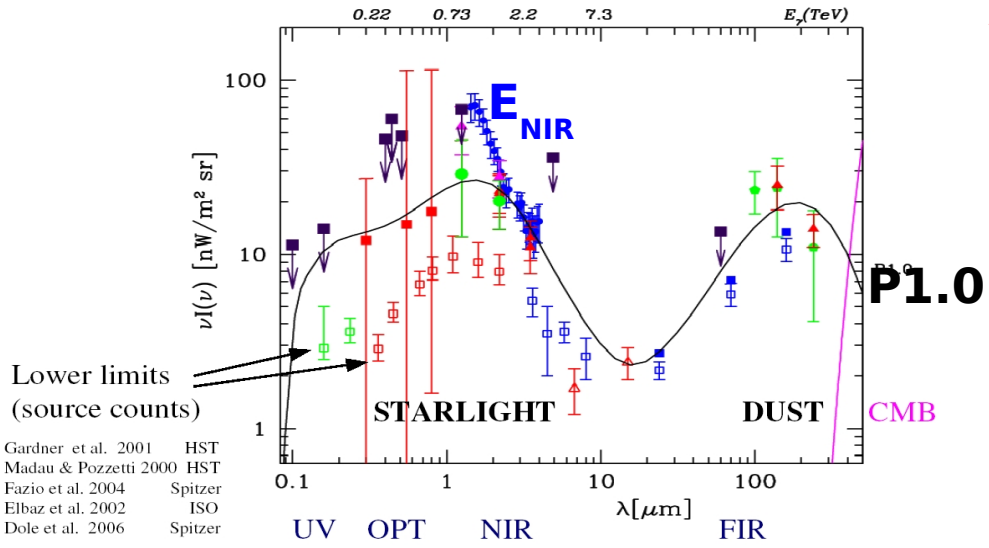
Gardner et al. 2001	HST
Madau & Pozzetti 2000	HST
Fazio et al. 2004	Spitzer
Elbaz et al. 2002	ISO
Dole et al. 2006	Spitzer

1ES 1101-232



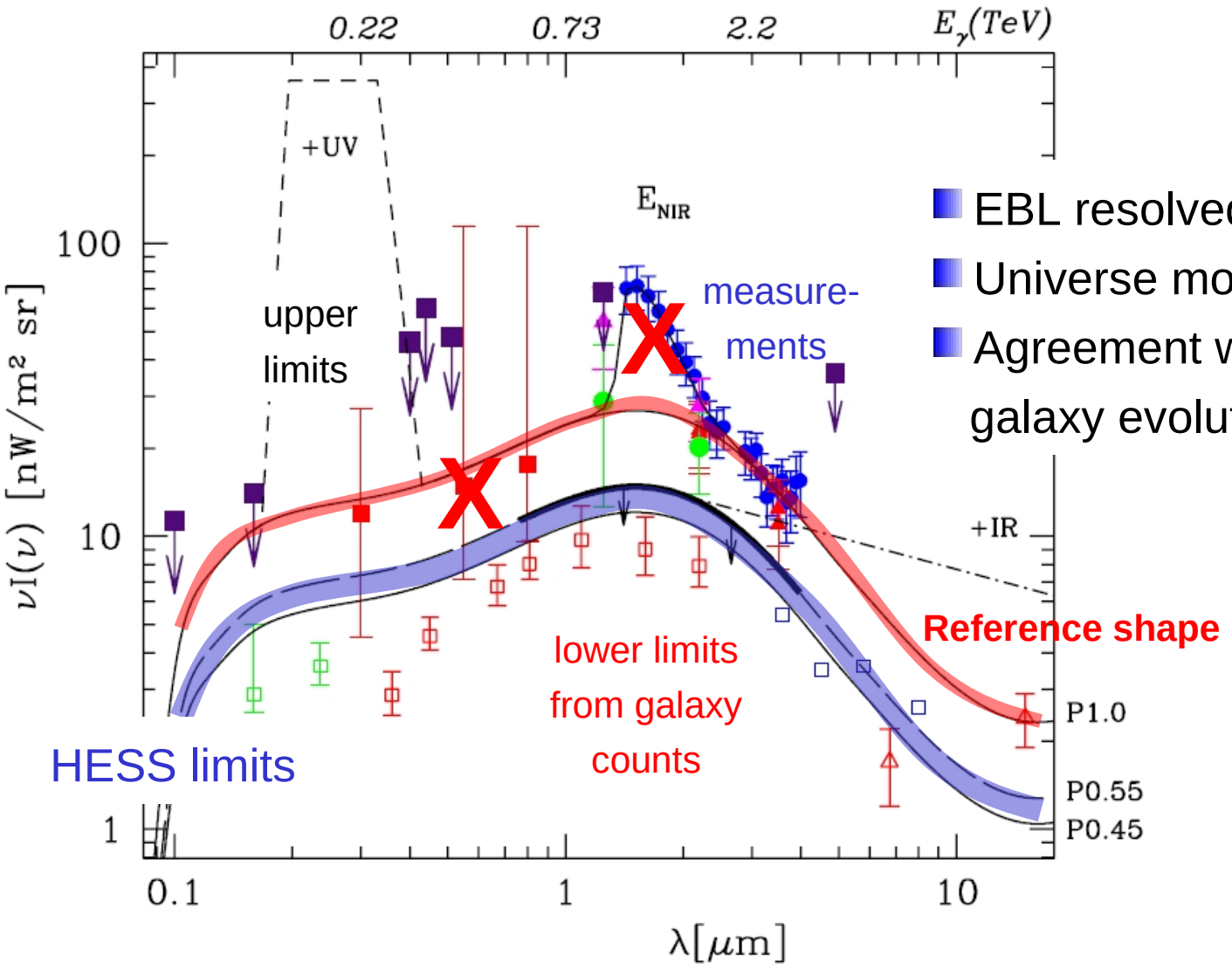
H 2356-309





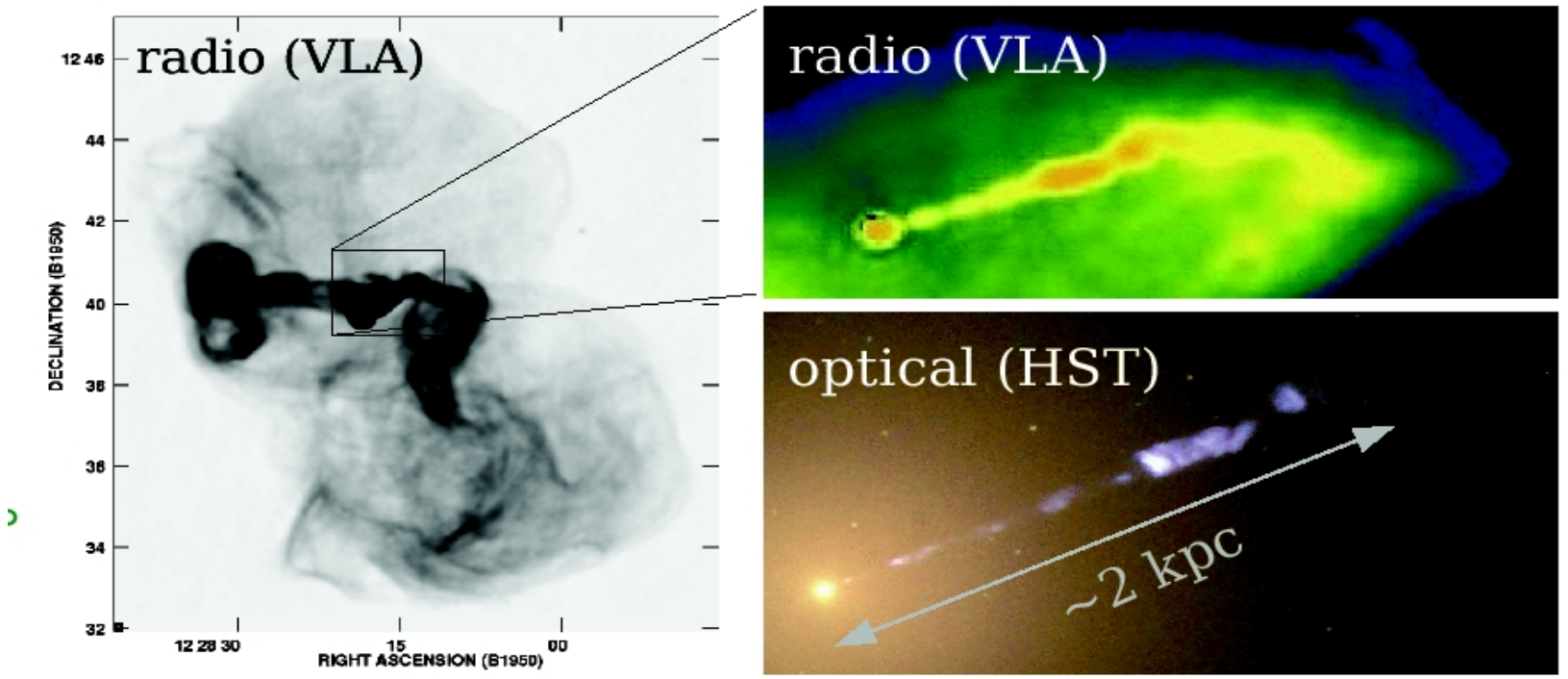
Assumption: original spectrum index not harder than 1.5

$\Gamma \geq 1.5$ does not need to change the known blazar physics scenario to agree with observations (SSC or proton acceleration)



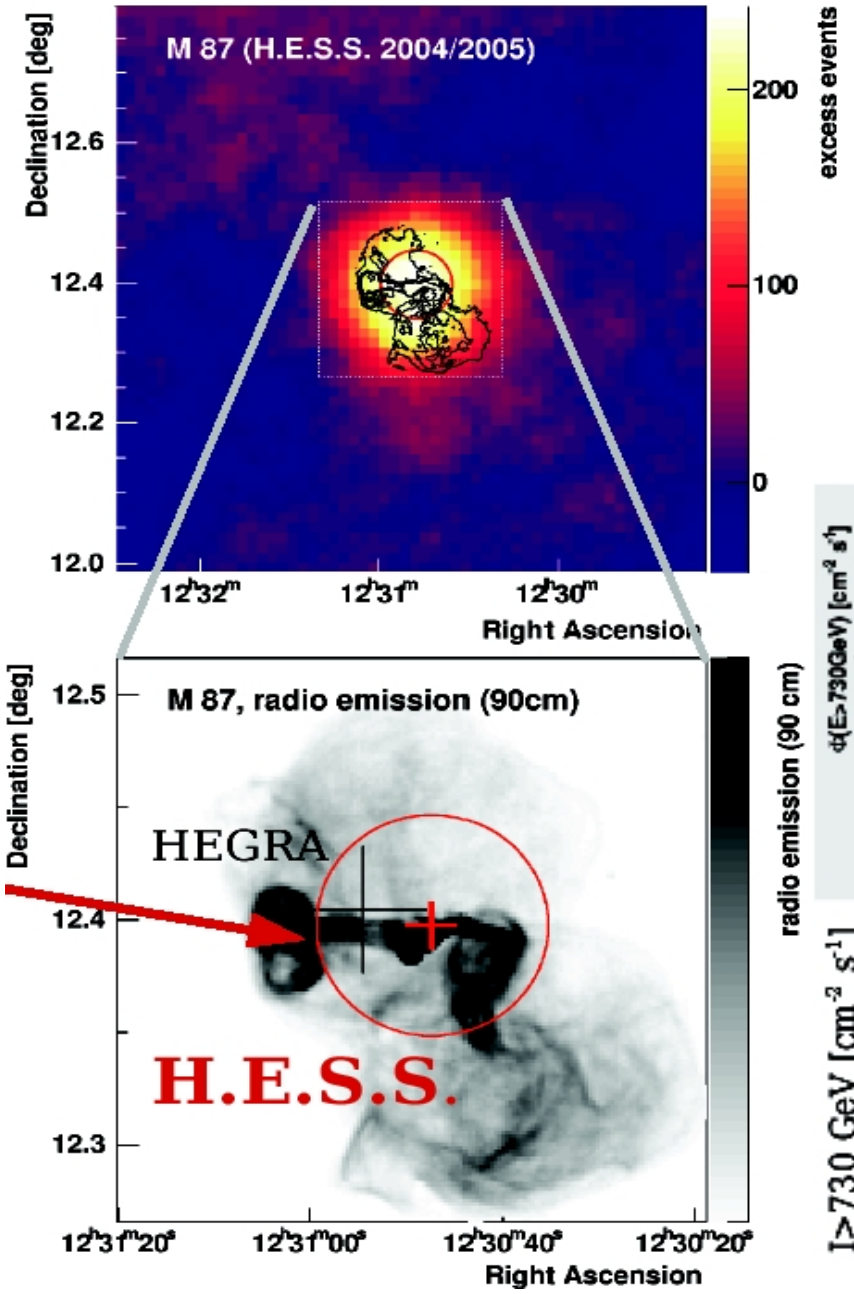
- EBL resolved
- Universe more transparent
- Agreement with standard galaxy evolution model

The Giant Elliptical radiogalaxy M87

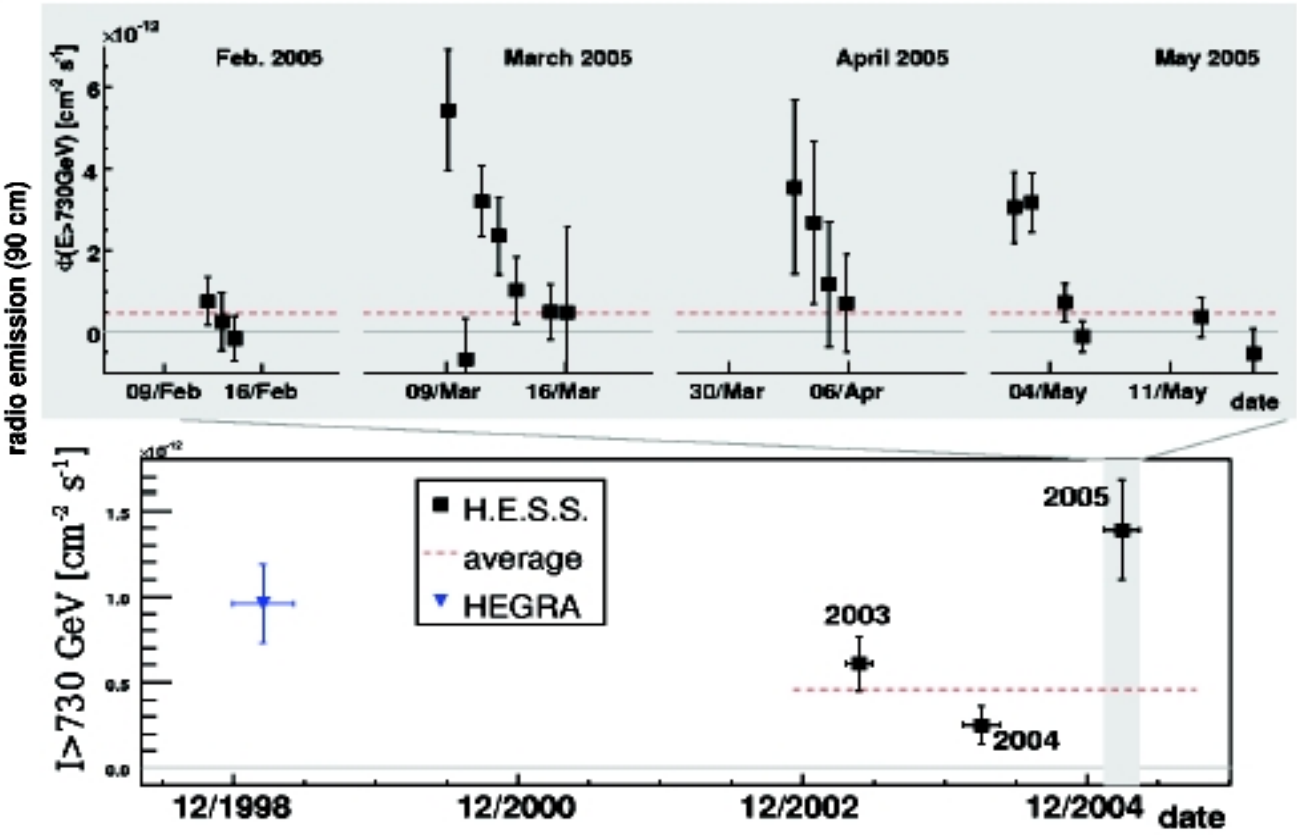


- Distance : z=0.00436 (~16 Mpc)
- Central BH
- Jet angle ~ 30º
  - ➔ not a blazar !
- First detection at TeV energies by HEGRA (2003, A&A, 403,L1)

M87 : HESS observations



- Observations by HESS:
  - ~19h in construction phase
  - ~52h in 2004/05
- Point-like source:
  - compatible with M87 nucleus
- Long-term variability
- Short term variability:
  - size of emission region (R ~ 5x10^{15} δ cm

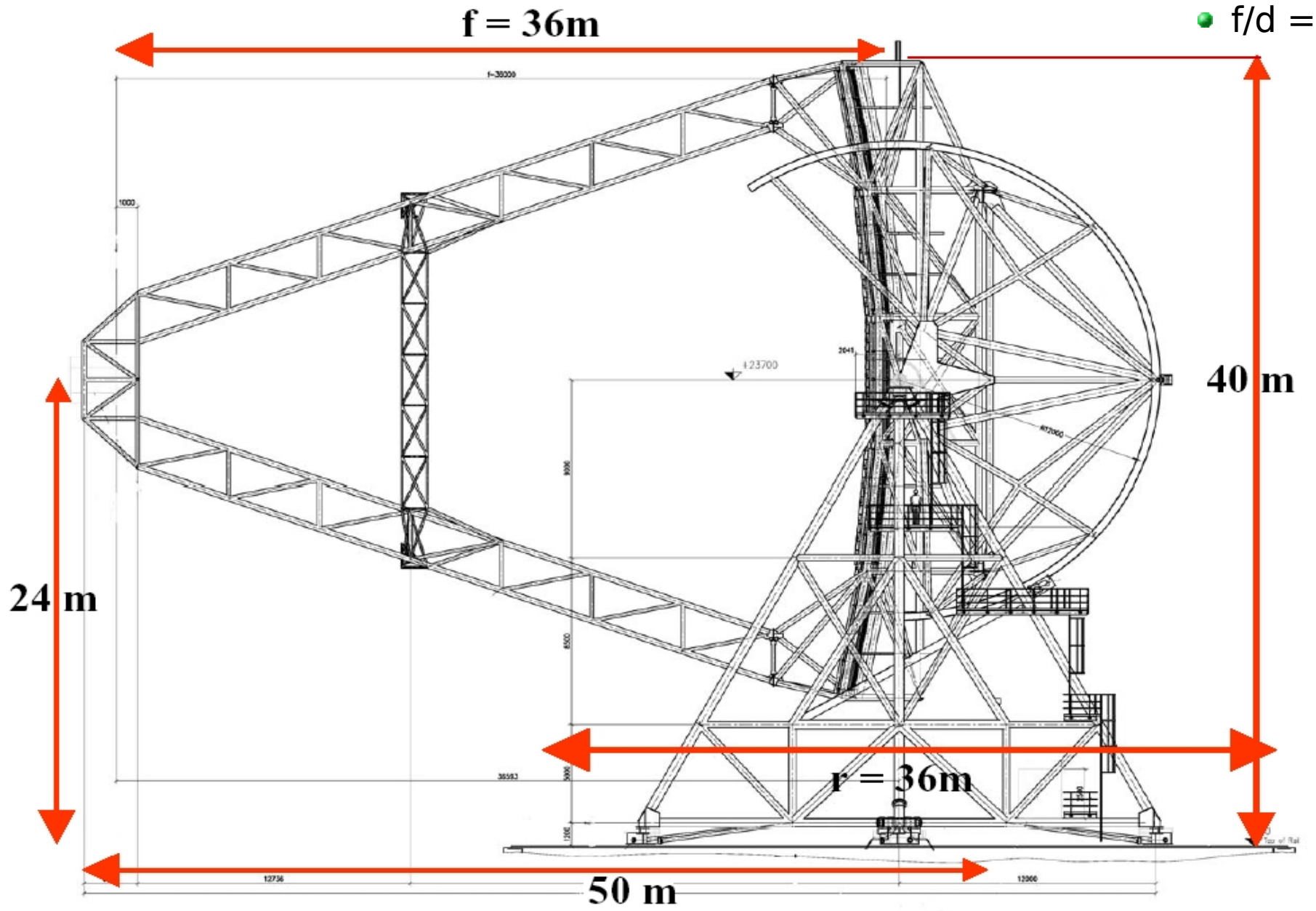


Outline :

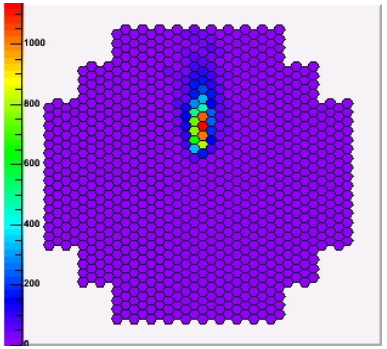
- H.E.S.S. Status 1
  - Calibration and Methods
  - Crab Nebula
- Galactic sources
- Extragalactic sources
- **H.E.S.S. Status 2**
  - **Phase 2 of the project**

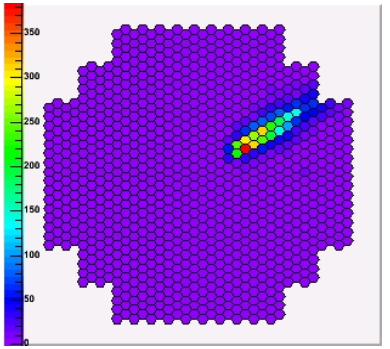
HESS-2: Dimensions

- steel structure
- Alt-az mount
- parabolic mirror
  - 596 m^2
  - f/d = 1.2

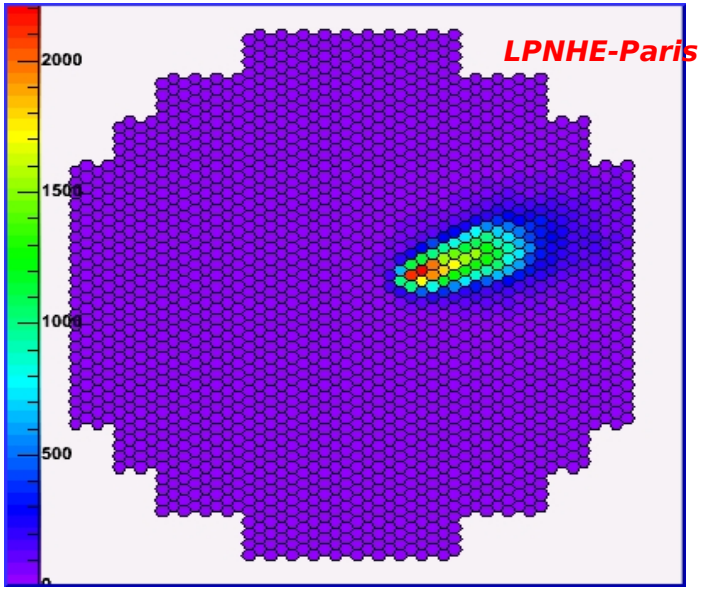


A sample 5 TeV Hybrid HESS - I&II event





For the same energy, better definition of the shower image



2048 pixels

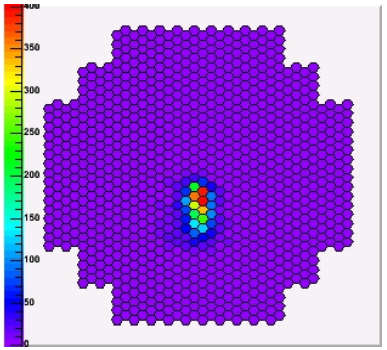
~ 3.5° Field of View

Same technology as HESS-I

Same Physical PM size

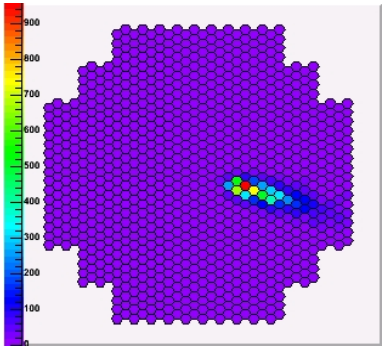
Angular pixel size ~0.07°

Same NSB (Night-Sky Background)

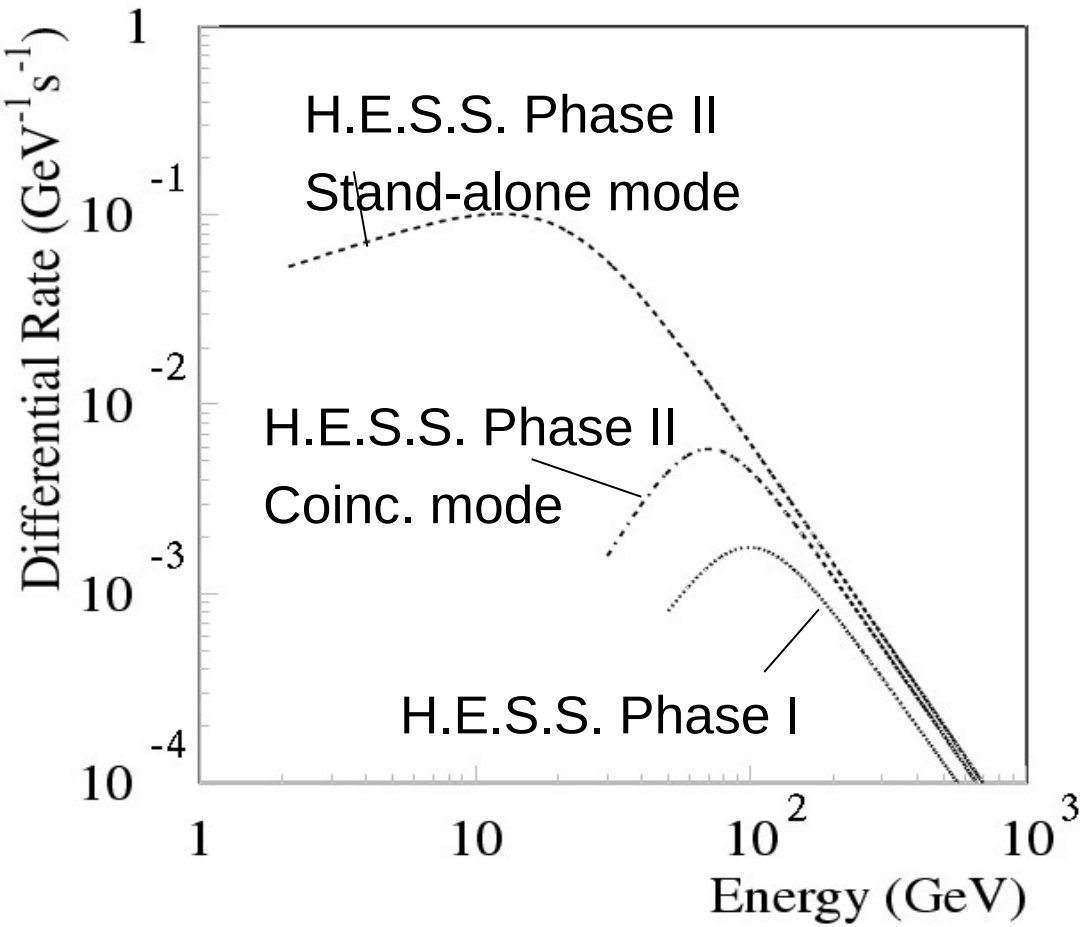


Camera to fit in ~ cylinder

r=1.9m, ϕ=2.5m, 3000 kg



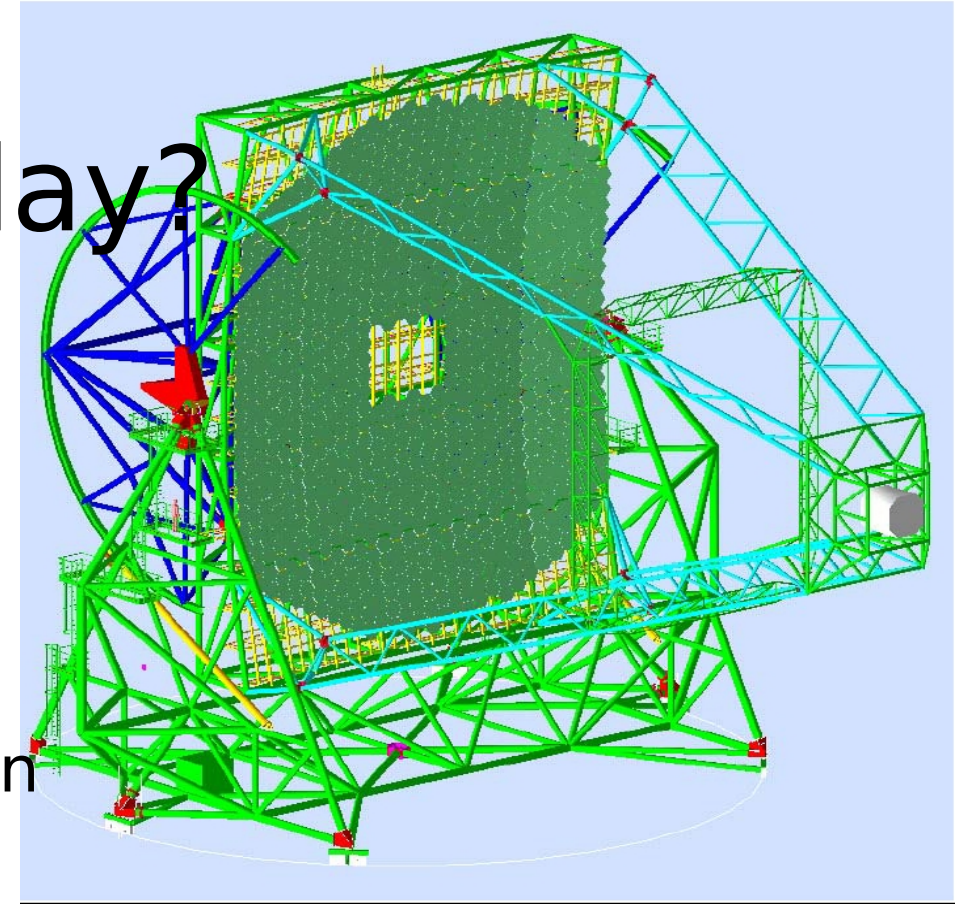
Projected Performance for HESS-II and Hybrid



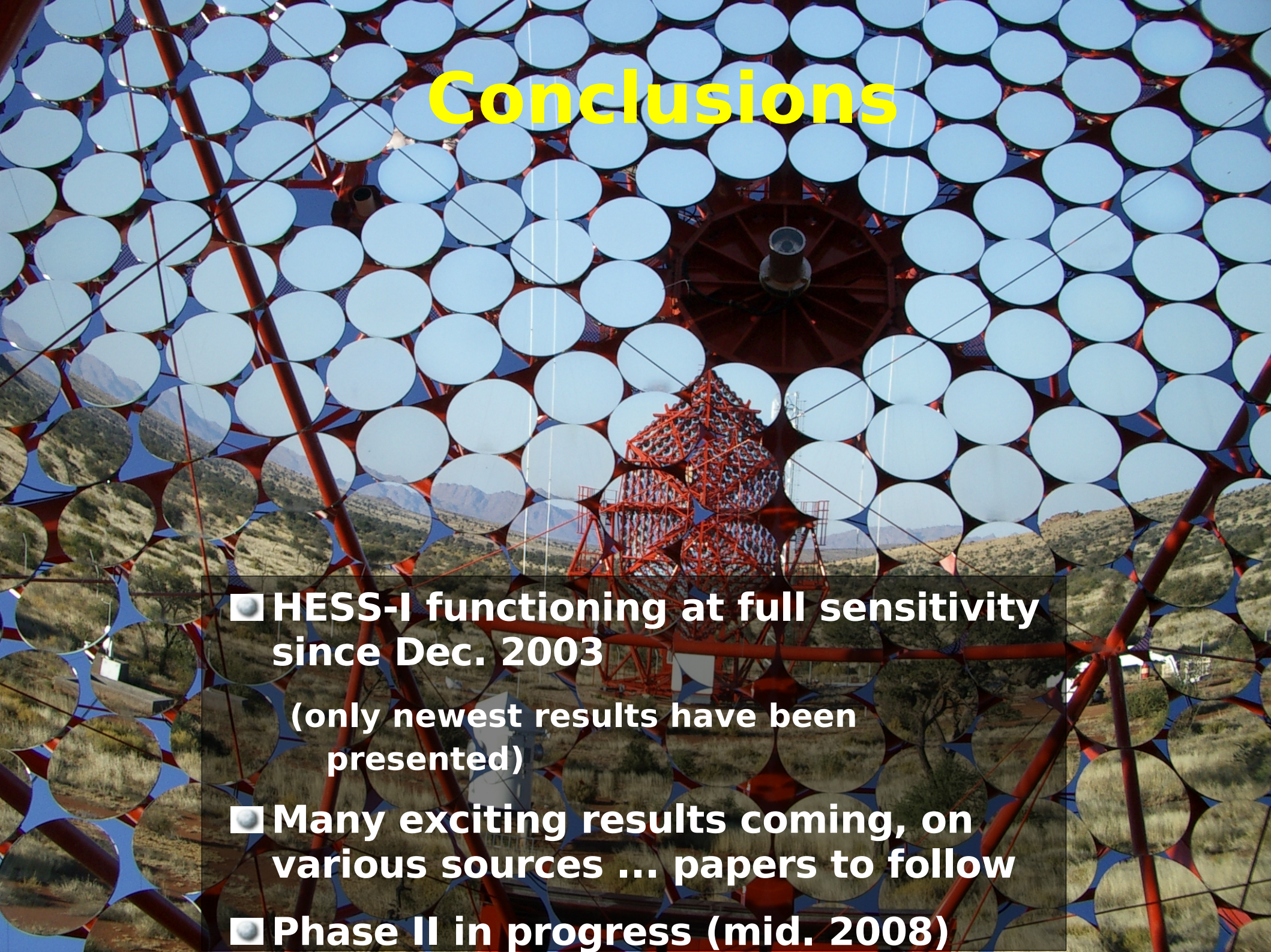
Coincidence Threshold in the region of 50 GeV

Standalone Threshold in the region of 20 GeV

HESS-2:
Where are you today?



- Steel Structure: company chosen
- Foundation: started soon
- PMTs: call of tender is opened, and will be closed on October 10th
- Camera Structure
- Electronic: ~same HESS-1 with better performances
- First light: middle of 2008



Conclusions

- HESS-I functioning at full sensitivity since Dec. 2003

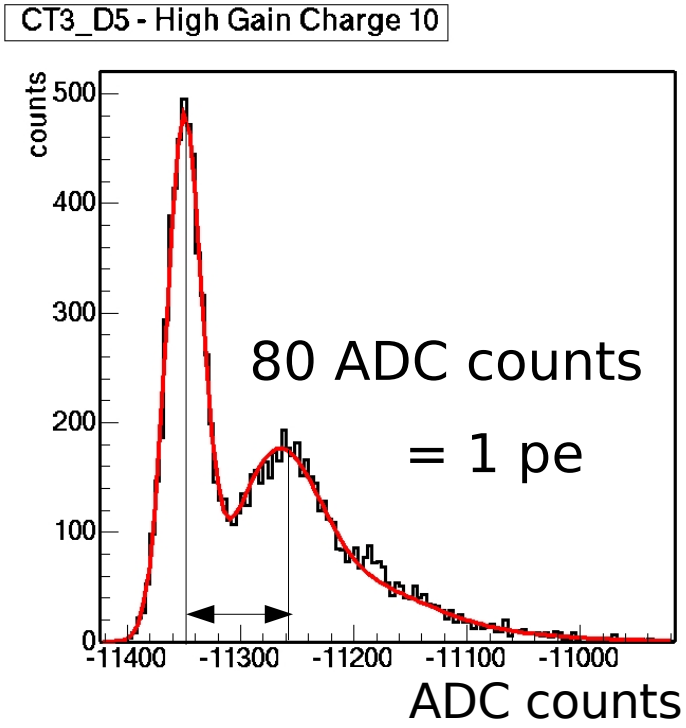
  (only newest results have been presented)

- Many exciting results coming, on various sources ... papers to follow

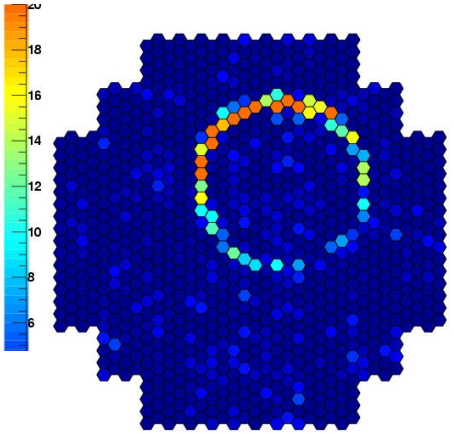
- Phase II in progress (mid. 2008)

Backup

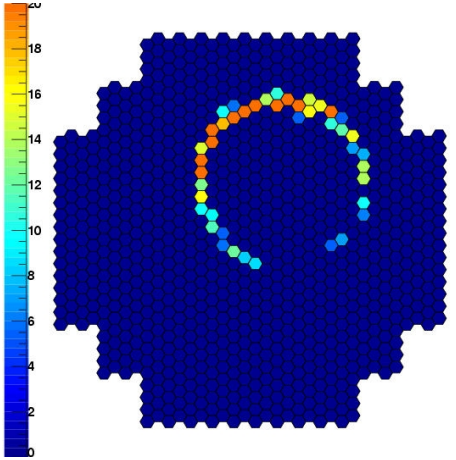
SinglePE distribution



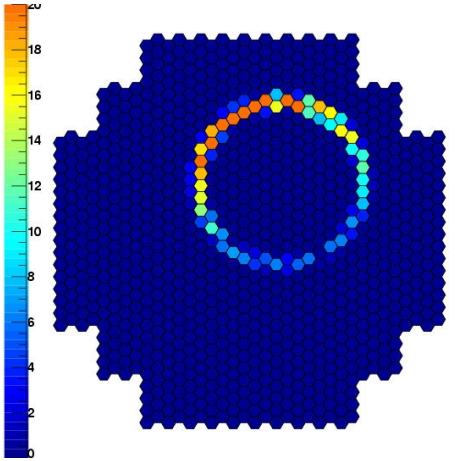
electronic noise : 0.18 p.e.



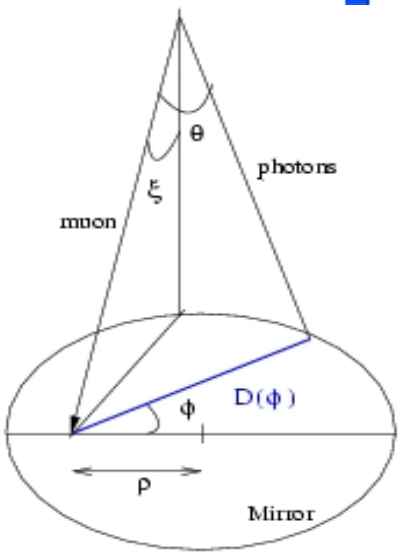
data

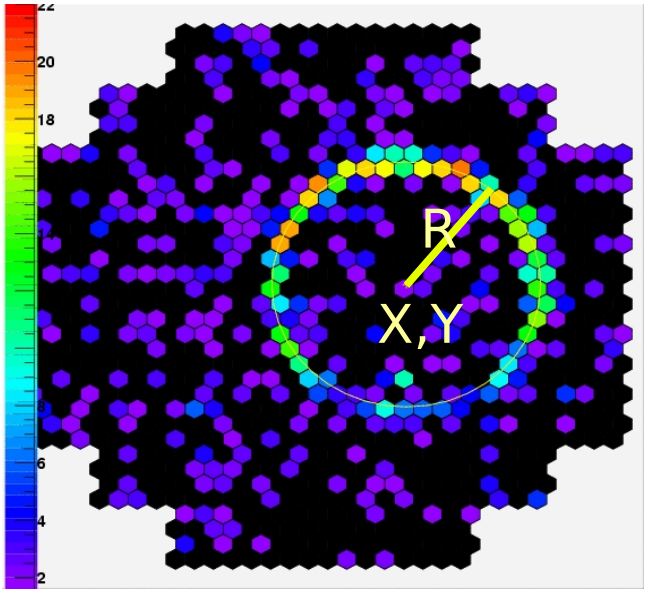


cleaned data



theoretical data

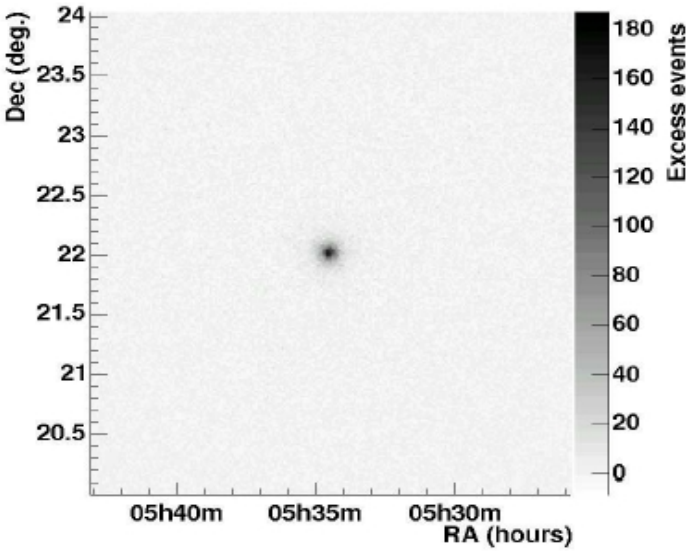


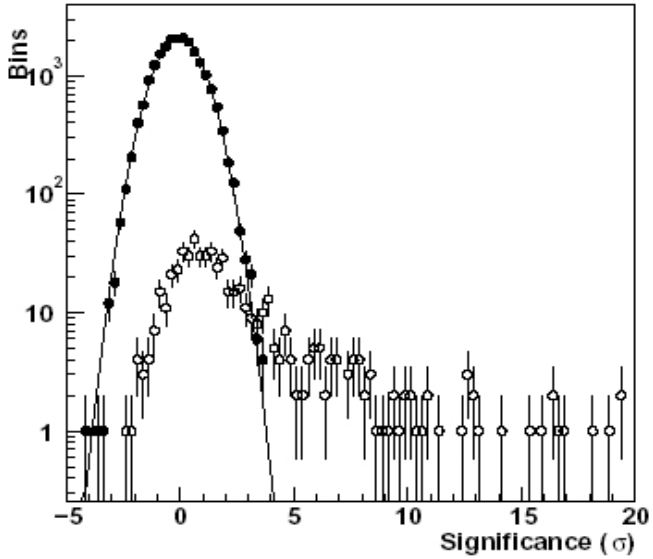


For each Pixel :

$$I(\phi) \propto \sin(2\theta_c) D(\phi) \epsilon$$

Sky map (Crab nebula)



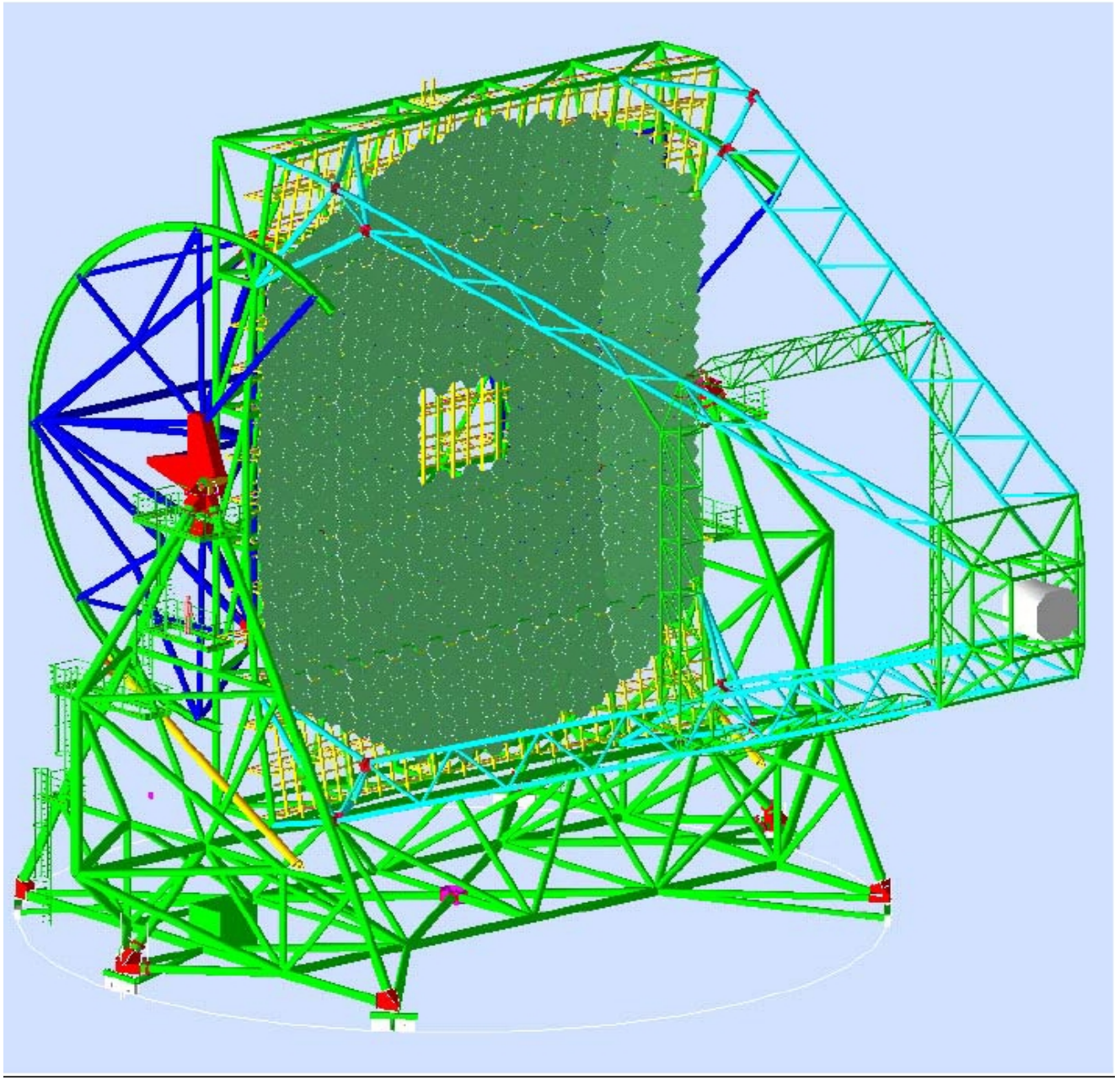


Filled circles represent points further from the source

Gaussian fit :

mean=0.04+/-0.006

sigma=0.98+/-0.004



Calibration Systems

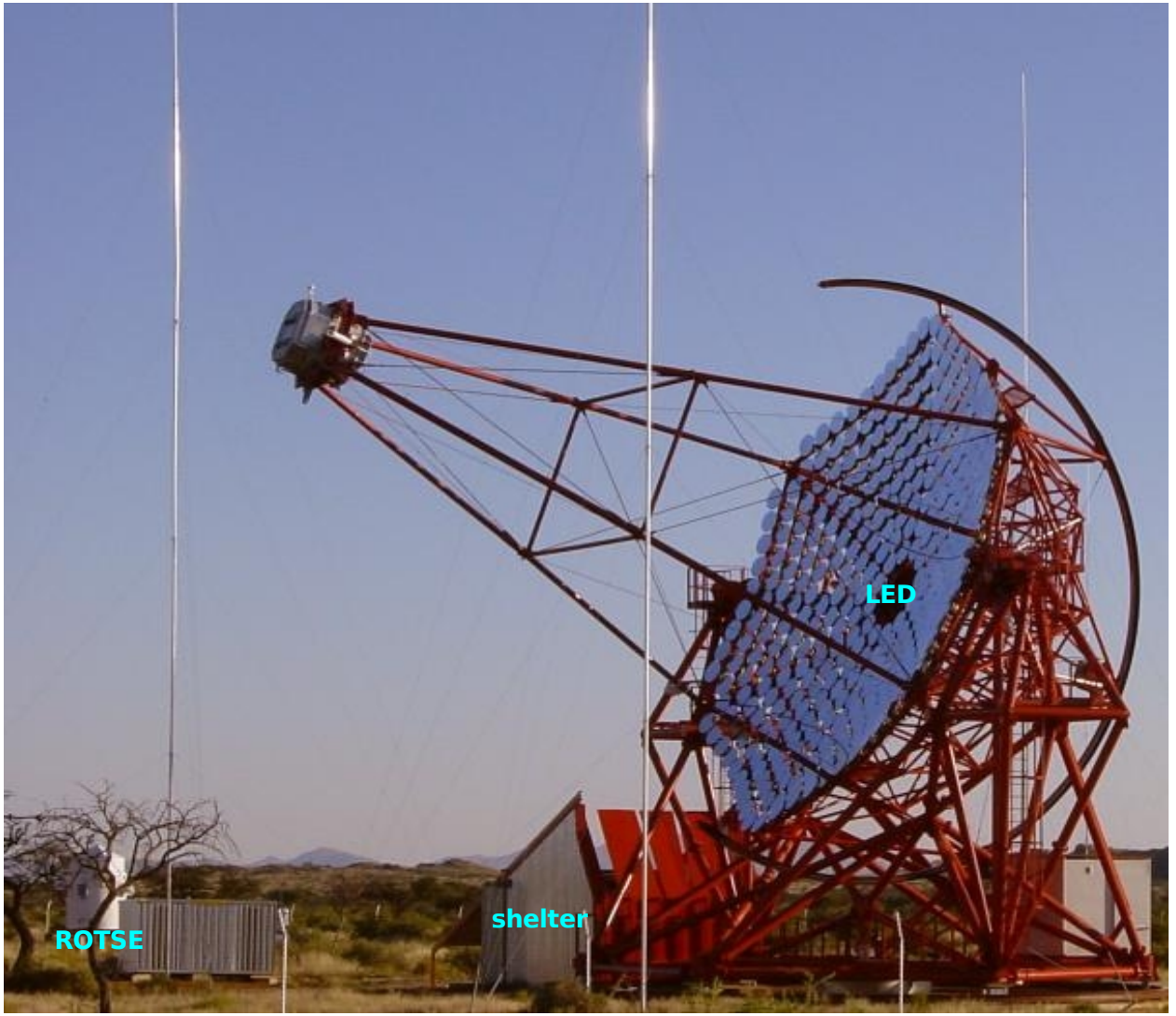
In the shelter:
LED: SinglePE distribution to monitor the gain

In the centre of the dish:
LED: to homogenize the PMT response

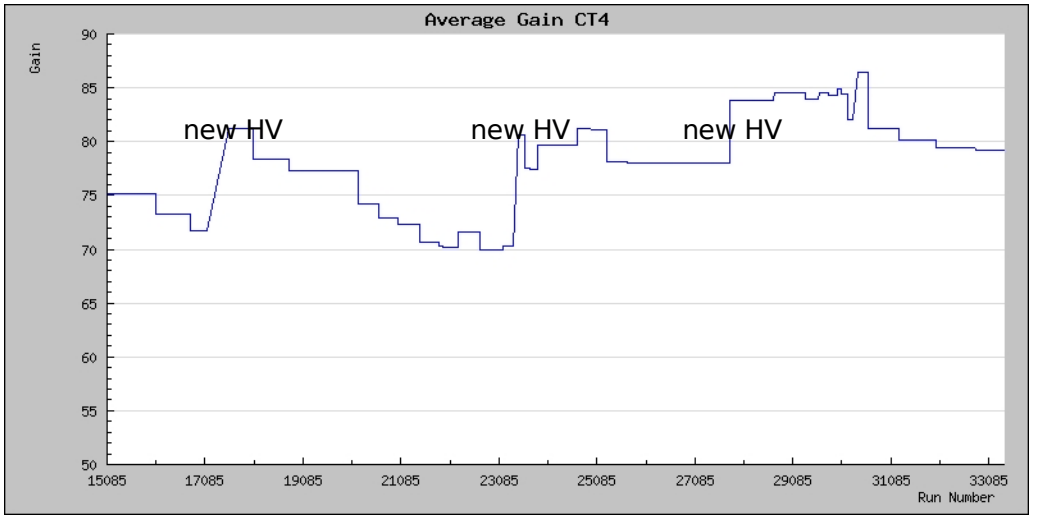
Muons:
to get the global optical efficiency

Pointing:
CCDs or stars in the f.o.v.

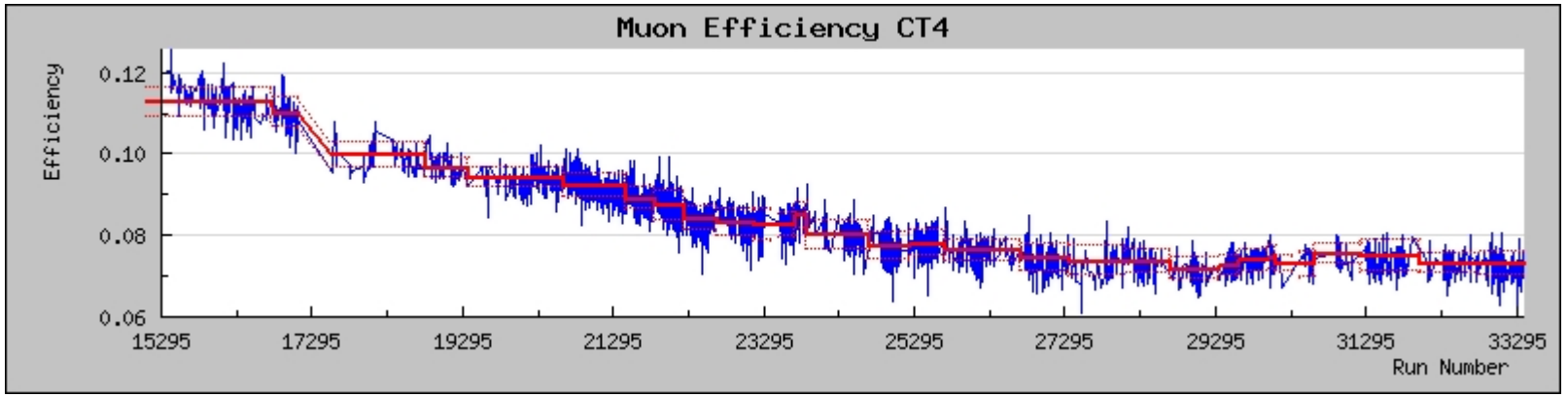
Atmosphere:
Ceilometer, ...
LIDAR in the future



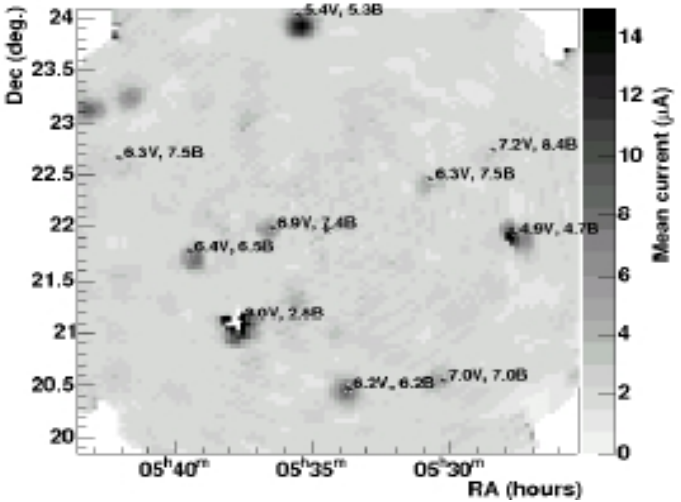
Examples:



Sept 2003 Sept 2004 June 2006

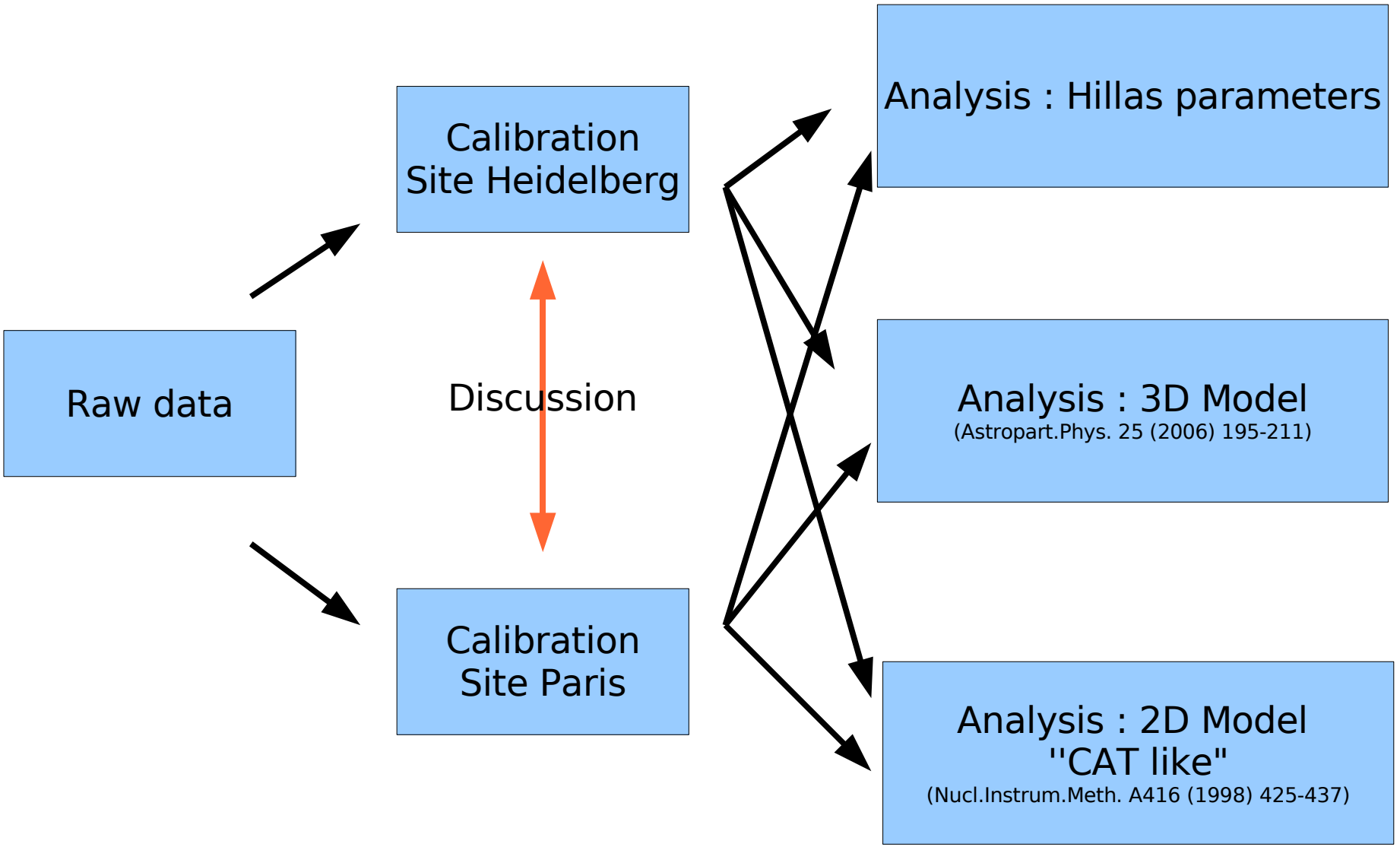


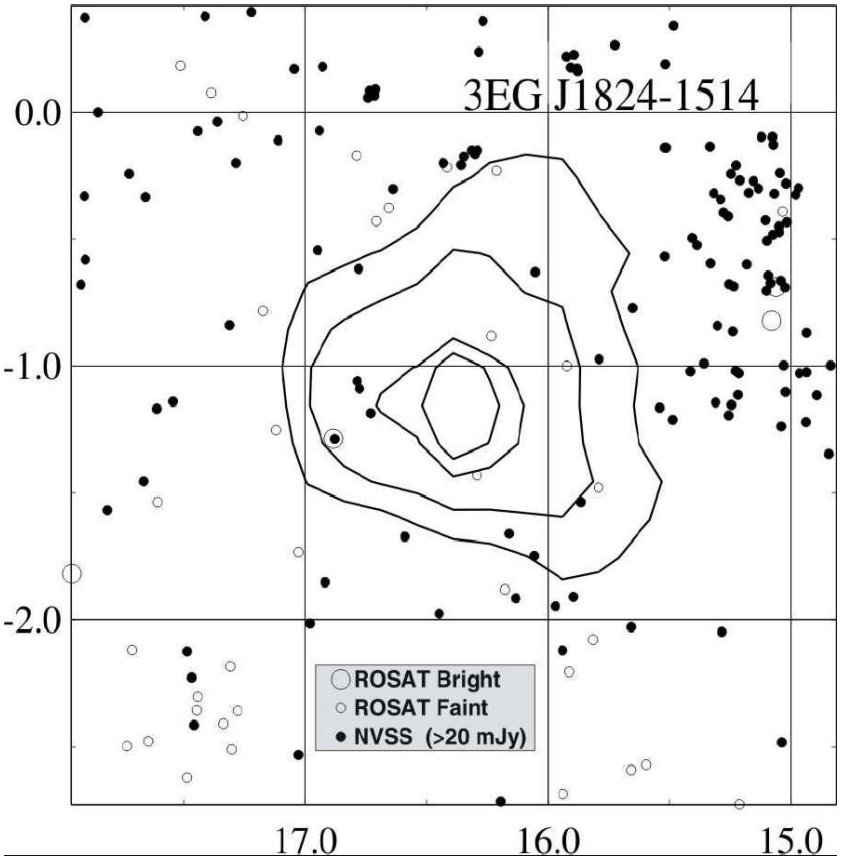
change over time - degradation in mirror reflectivity, cone reflectivity,..



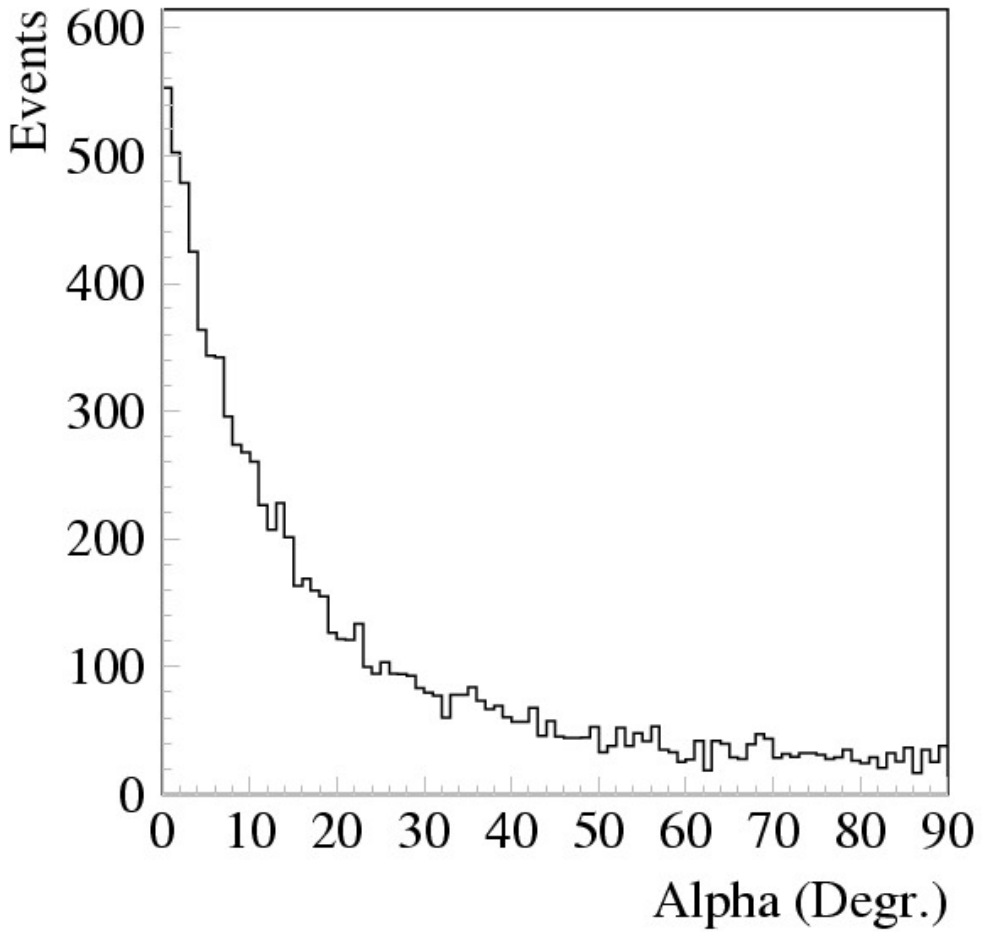
Stars in the Crab nebula region

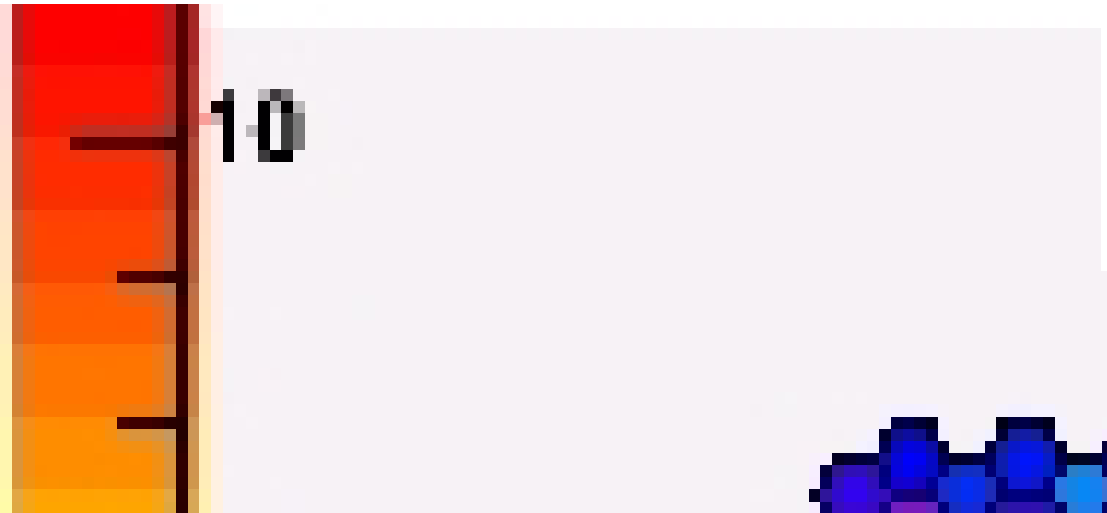
Analysis Scheme

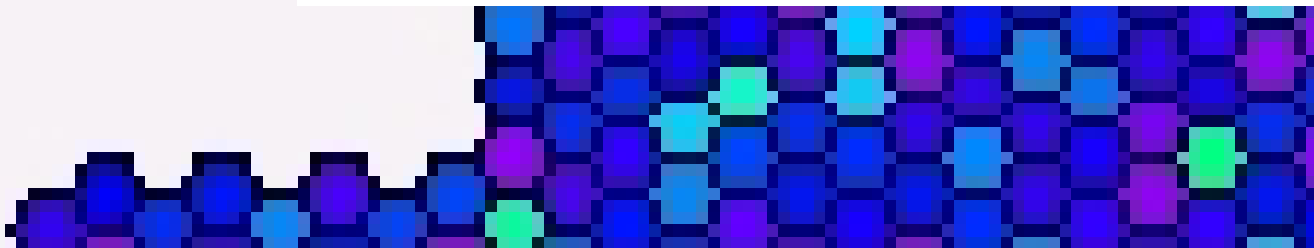


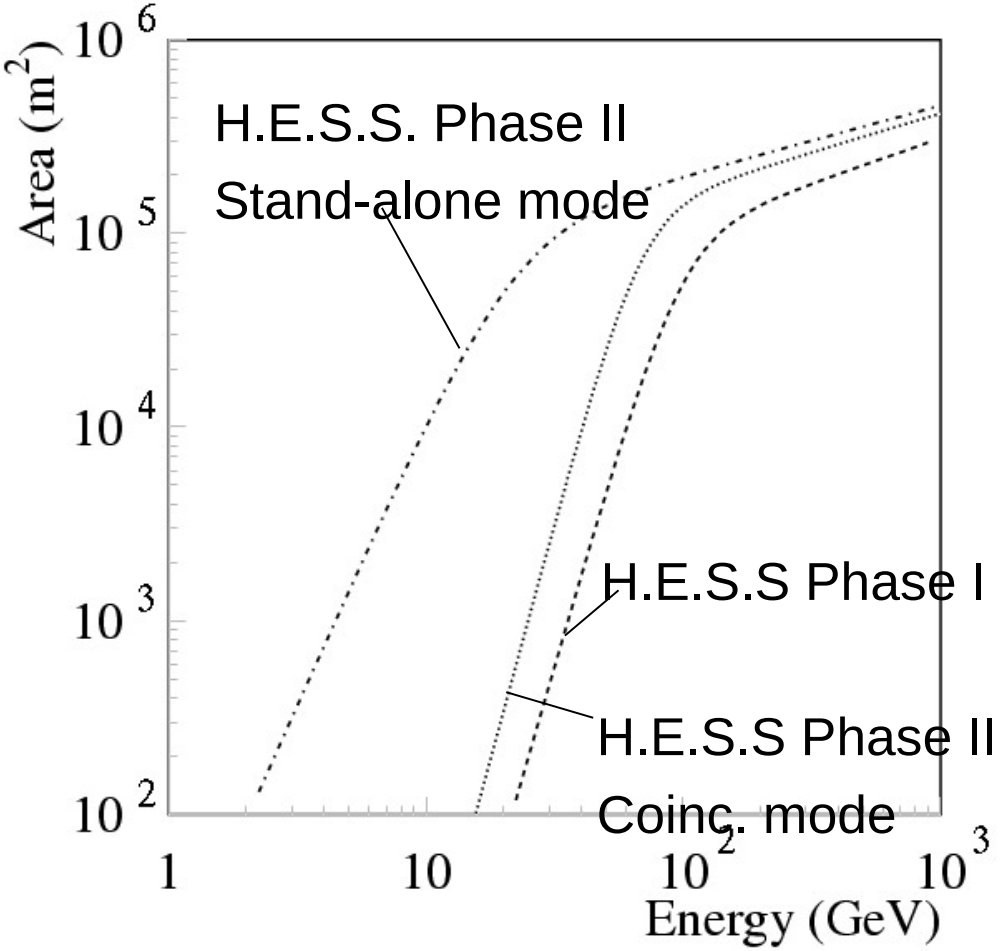

3EG J1824-1514
0.0
-1.0
-2.0
17.0
16.0
15.0
ROSAT Bright
ROSAT Faint
NVSS (>20 mJy)

Samples of 20 GeV HESS-II events








Area (m^2)
10^6
10^5
10^4
10^3
10^2
1
10
10^2
10^3
Energy (GeV)
H.E.S.S. Phase II
Stand-alone mode
H.E.S.S Phase I
H.E.S.S Phase II
Coinc. mode