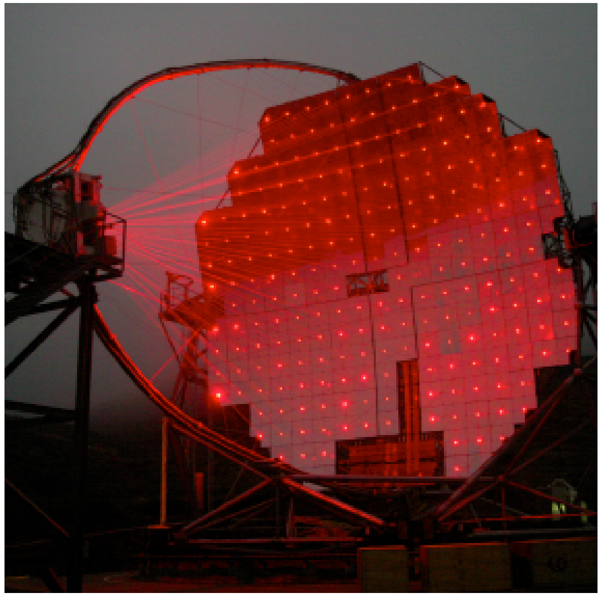
The MAGIC Telescope:
Project status and source observations

David Paneque



(Courtesy of R.Wagner)

Astronomical picture of the day (16/10/04)

OUTLINE

1- IACTs for doing gamma-ray astronomy

2- The MAGIC Telescope, a technological challenge

3- Project status and source observations

4- Conclusion

Imaging Atmospheric Cherenkov Telescopes (*IACT*) as ground-based instruments for making gamma-ray astronomy

1.0 - Introduction to IACTs and Gamma-Ray astronomy

➢ **Imaging Atmoshpheric Cherenkov Telescopes (IACTs) are instruments for performing gamma-ray astronomy**

IACTs* aim to provide experimental basis for the understanding of the *Non-thermal Universe

Acceleration, propagation and interaction of high energy particles can produce gamma rays

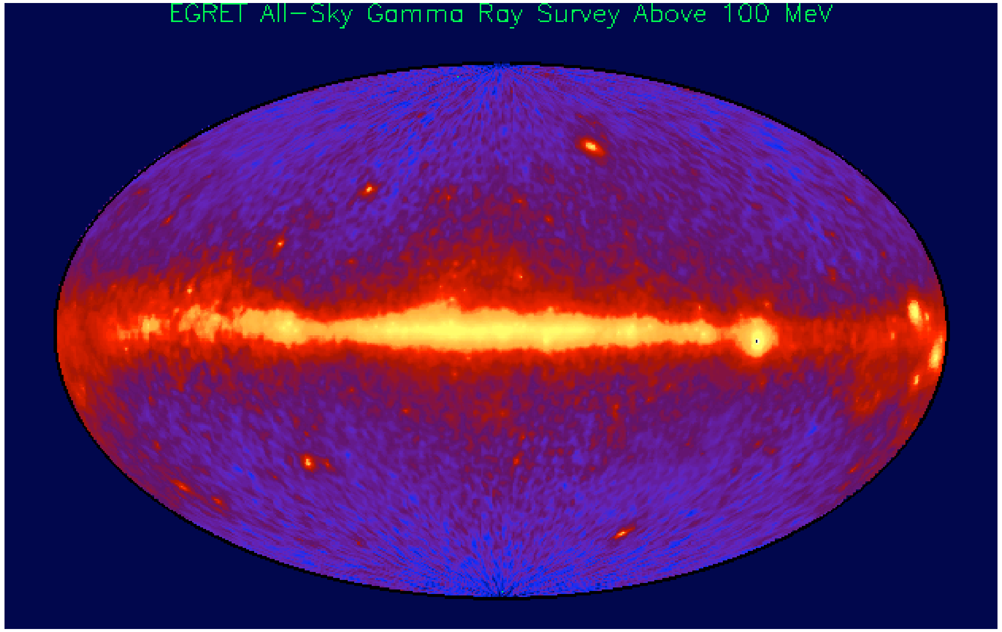
Hadronic high-energy particles → $\pi^{o} \rightarrow \gamma\gamma$
$\pi^{\pm} \rightarrow \mu^{\pm}\,\nu$

Leptonic high-energy particles → *Bremsstrahlung*
Synchrotron
Inverse Compton

Gamma rays are secondary products of the cosmic accelerators

EGRET All-Sky Gamma-Ray Survey E > 100 MeV

Gamma rays are mostly produced by the interaction of *cosmic rays* with the interstellar gas of the *Milky Way*



Information brought by the gamma quanta:

1 - Location of the high energy particles
2 - Lower limit to the energy of the high energy particles
3 - Time information

Gamma ray astronomy opens a new window to explore the Non-thermal Universe

<u>Rather young discipline</u>

	Exploration phase	Established field
satellite-borne exp.	*70s (SAS, COSB)*	*90s (EGRET)*
ground-based exp.	*80-90s (WHIPPLE, HEGRA…)*	*00s (HESS, MAGIC, VERITAS …)*

Attention: using this novel tool might have side effects

<u>Gamma-ray astronomy might lead us to some NEW knowledge in fundamental/particle physics</u>

Tycho Brahe: observations of planetary motion

Johannes Kepler: laws of planetary motion

Isaac Newton: **Gravitation (1665)**

Balmer series of hydrogen involved spectroscopic observations of violet and ultraviolet lines of hydrogen in *white dwarf stars*

Niels Bohr: **atomic structure (1913)**

Nobel Prize (1923)

Hulse and **Taylor** discovered a *binary pulsar system (1974)*

Gravitational radiation loss predicted by General Theory of Relativity

Nobel Prize (1993)

History shows *outstanding achievements in the knowledge of physics* due to the observation of the Universe

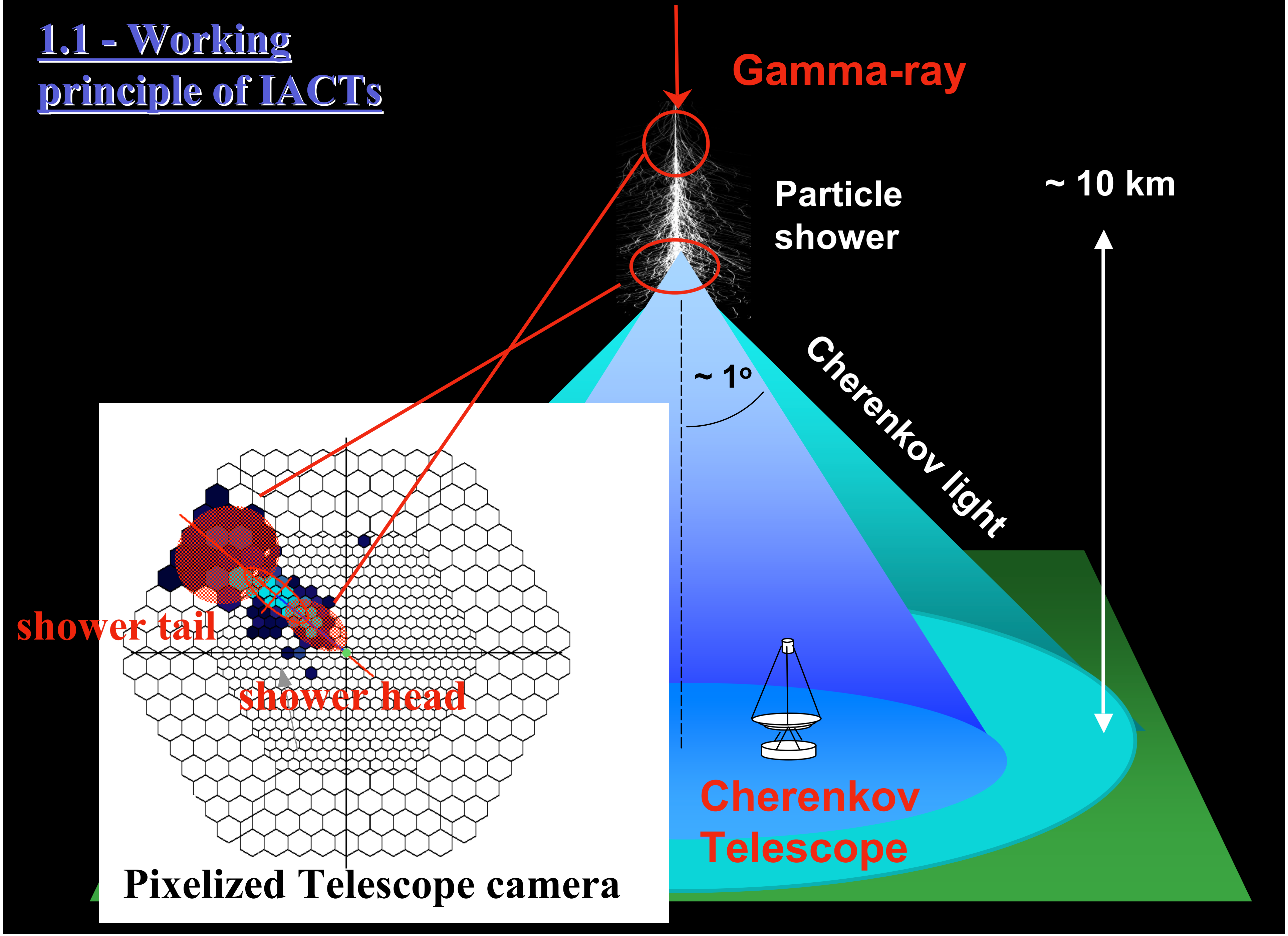
Recipe:

- ***Observation of physical environments not reproducible on Earth-based laboratories***
- ***New perspective provided by a novel instrument***
- ***!!!!!!!!   GOOD LUCK !!!!!!***

Gamma ray astronomy fulfils the first 2 conditions

One never knows about the third one…

1.1 - Working principle of IACTs



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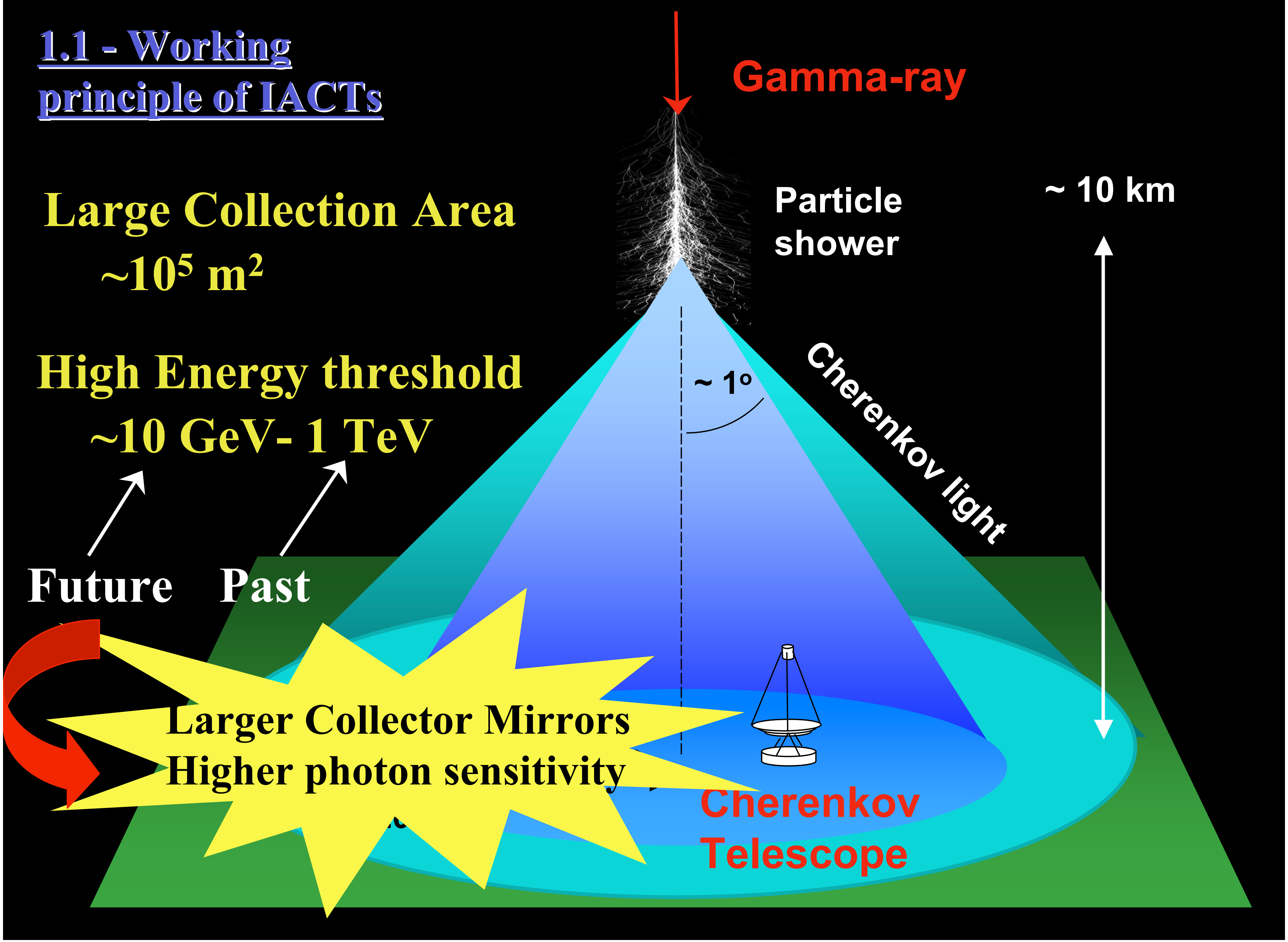
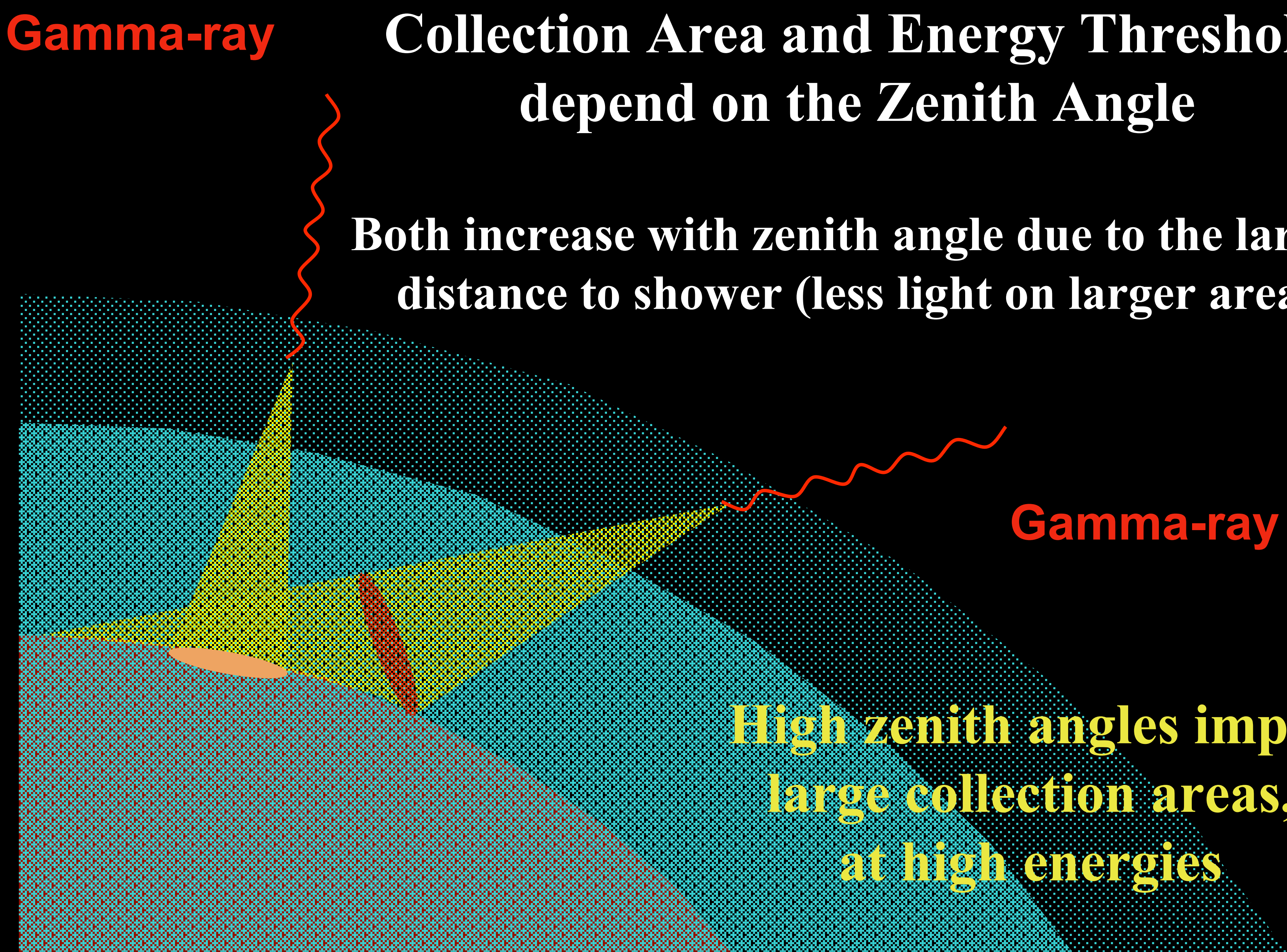


Collection Area and Energy Threshold depend on the Zenith Angle

Both increase with zenith angle due to the larger distance to shower (less light on larger area)

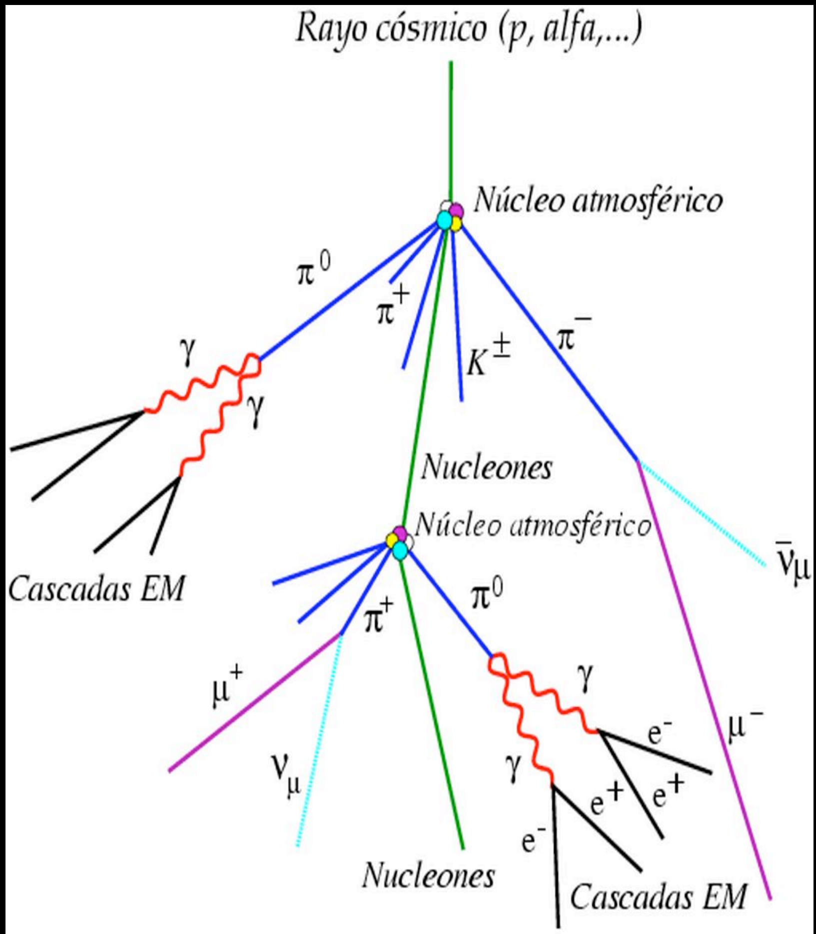


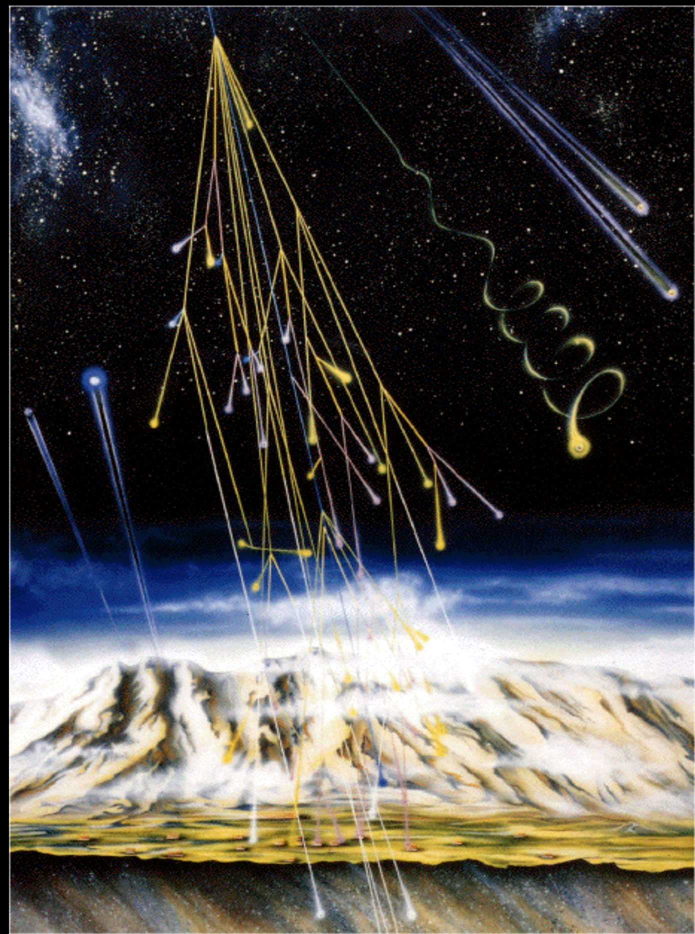
High zenith angles imply large collection areas, at high energies

Drawback of IACTs: Strong background

Cosmic nuclei also initiate air showers producing Cherenkov light

Hadrons are about 10^4 more numerous than Gammas

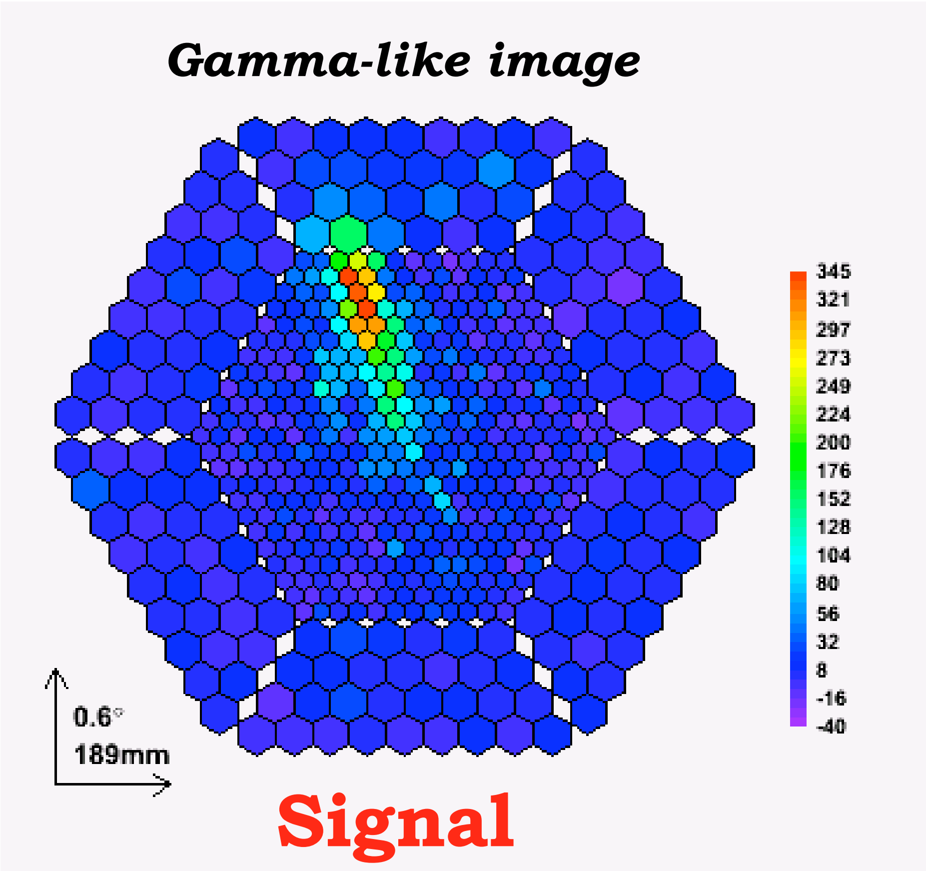


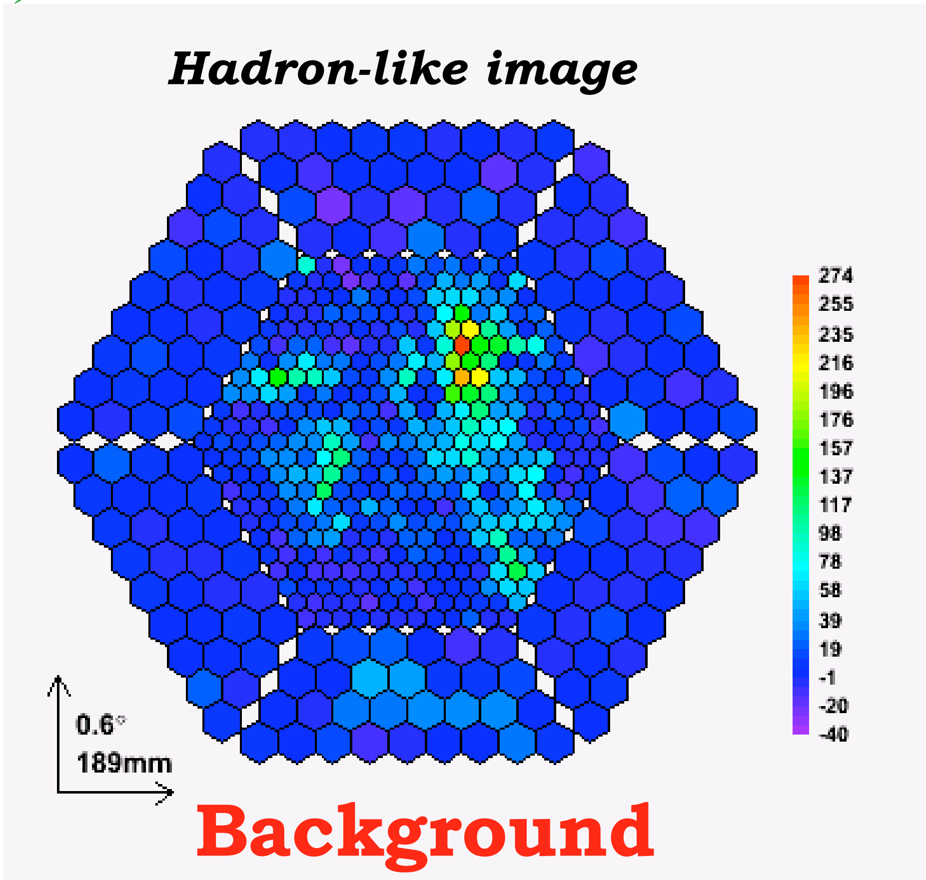


1.2 - Analysis method to select and reconstruct the gamma-rays

◆ **Analysis based on the classical Hillas parameters to perform a quantitative description of the shower images**

(Hillas, 19th ICRC, vol. 3, 445-448, 1985)





Hadrons are 10^4 more numerous than Gammas
Efficient selection cuts in Hillas parameters are required

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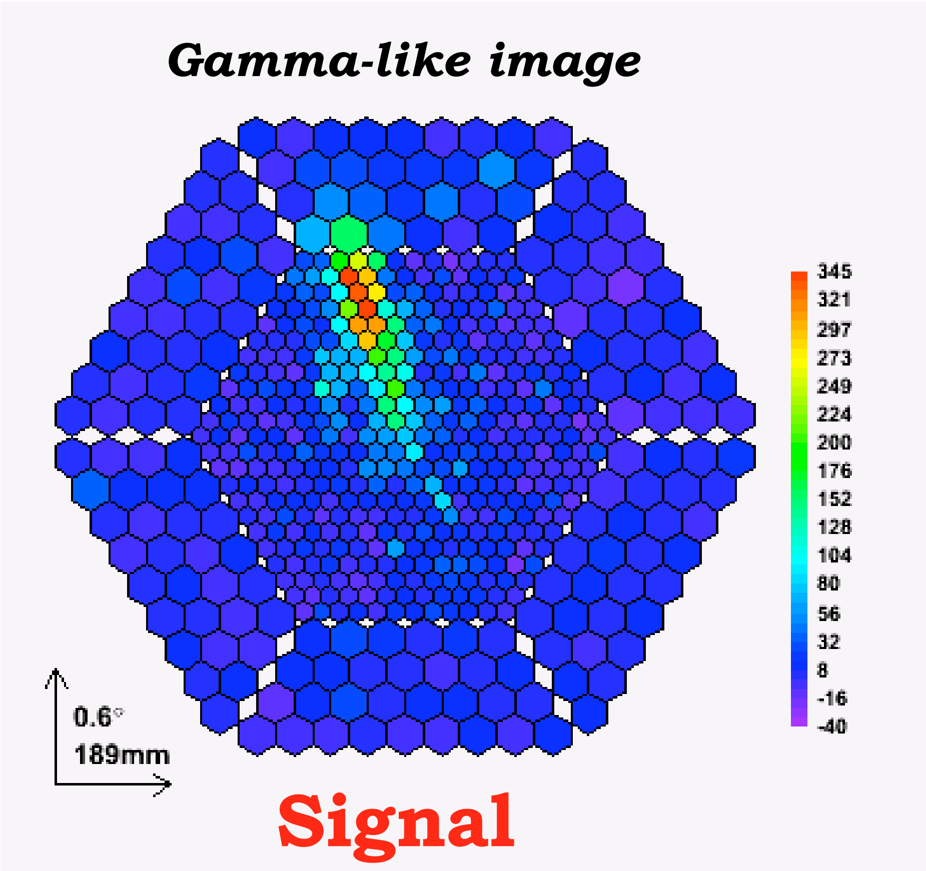


Shape of image → **Nature of primary particle**

Orientation of image → **Incoming direction of primary particle *and bkg rejection***

Intensity of image → **Energy of primary particle**

Hadrons are 10^4 more numerous than Gammas
Efficient selection cuts in Hillas parameters are required

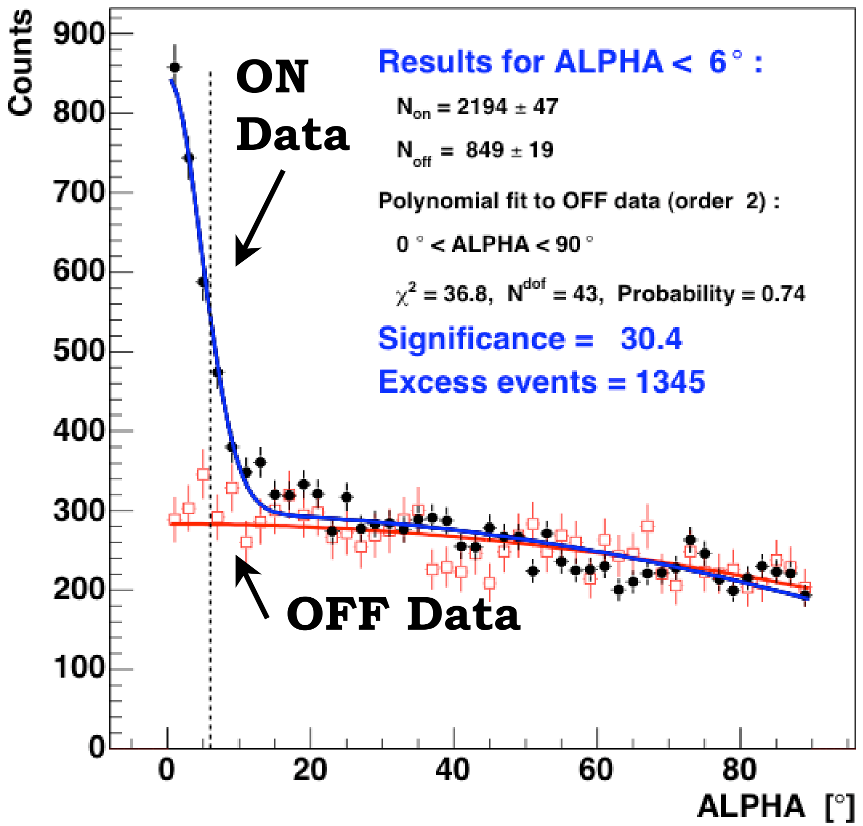
◆ **Several methods can be used to obtain a set of selection cuts**

Classic	*New*
Static cuts	Linear discriminant analysis
Dynamical cuts	Neural Networks
Scaled cuts	Random Forest
	3D-Model (only for stereo)
	Semi-analytical models

Currently used in MAGIC data analysis

Some MAGIC people working on that

Le Bohec et al, NIM A 416 (1998) *It does not use the Hillas parameters*



◆ **Signal shows up in the distribution of the ALPHA parameter after the selection cuts (*ALPHA plot*)**

MAGIC Mkn421 data from 14-15/02/2004

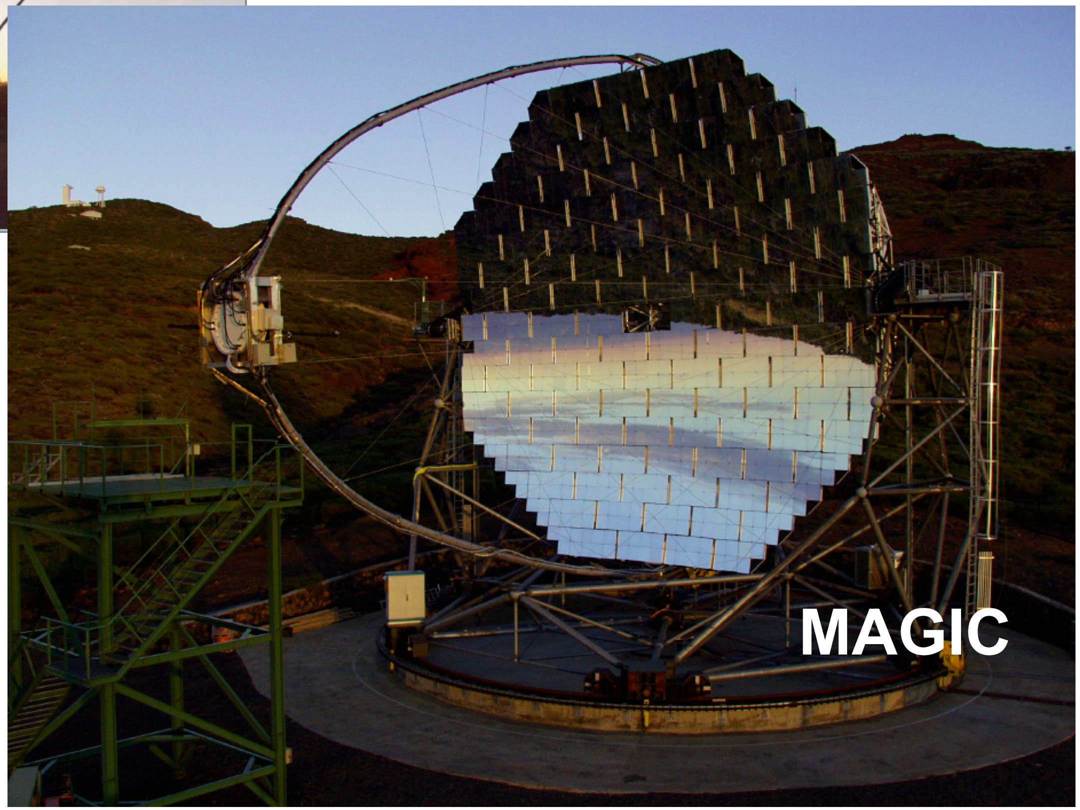
(105 minutes ON observation)

1.3 - The new generation of IACTs

SOUTHERN HEMISPHERE

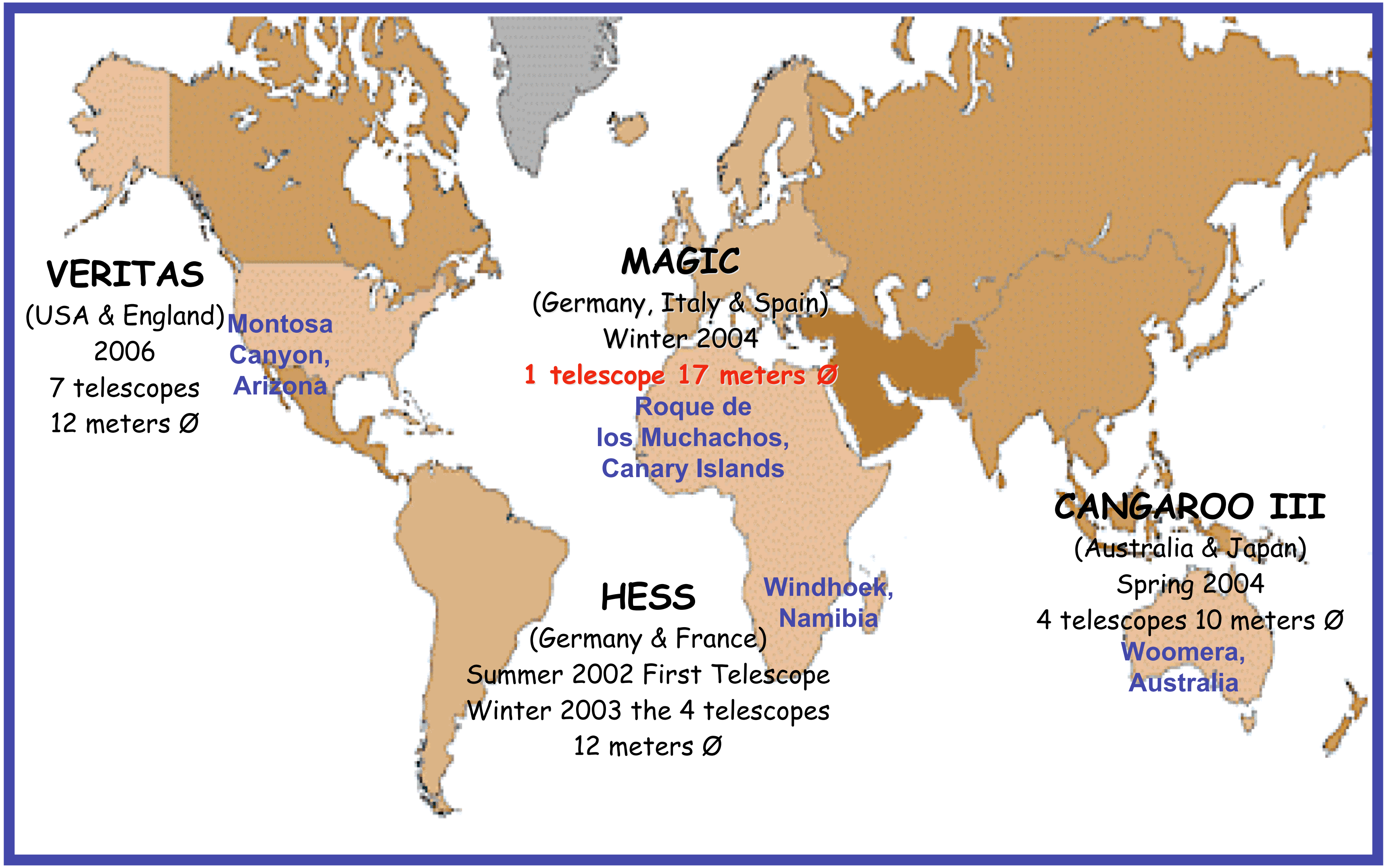
1.3 - The new generation of IACTs

NORTHERN HEMISPHERE



1.3 - The new generation of IACTs

"THE BIG 4"



1.3 - The new generation of IACTs

Location of these 4 observatories is perfect to follow up of sources. Specially important for *transient* sources (*AGN, GRB*).

Do not miss details of a source flare

Observe sources simultaneously at *low zenith angle* (low energy threshold) and *large zenith angles* (high energy events with good statistics)

Perform simultaneous *multiwavelength* observations. Correlation of TeV and GeV gamma-rays with x-rays, optical and radio.

Joint observations with the GLAST Satellite are particularly interesting due to the overlapping energy region (*30-300 GeV*). Exploit *performance differences* between IACTs and satellite-based detectors. Coordinated actions are required:

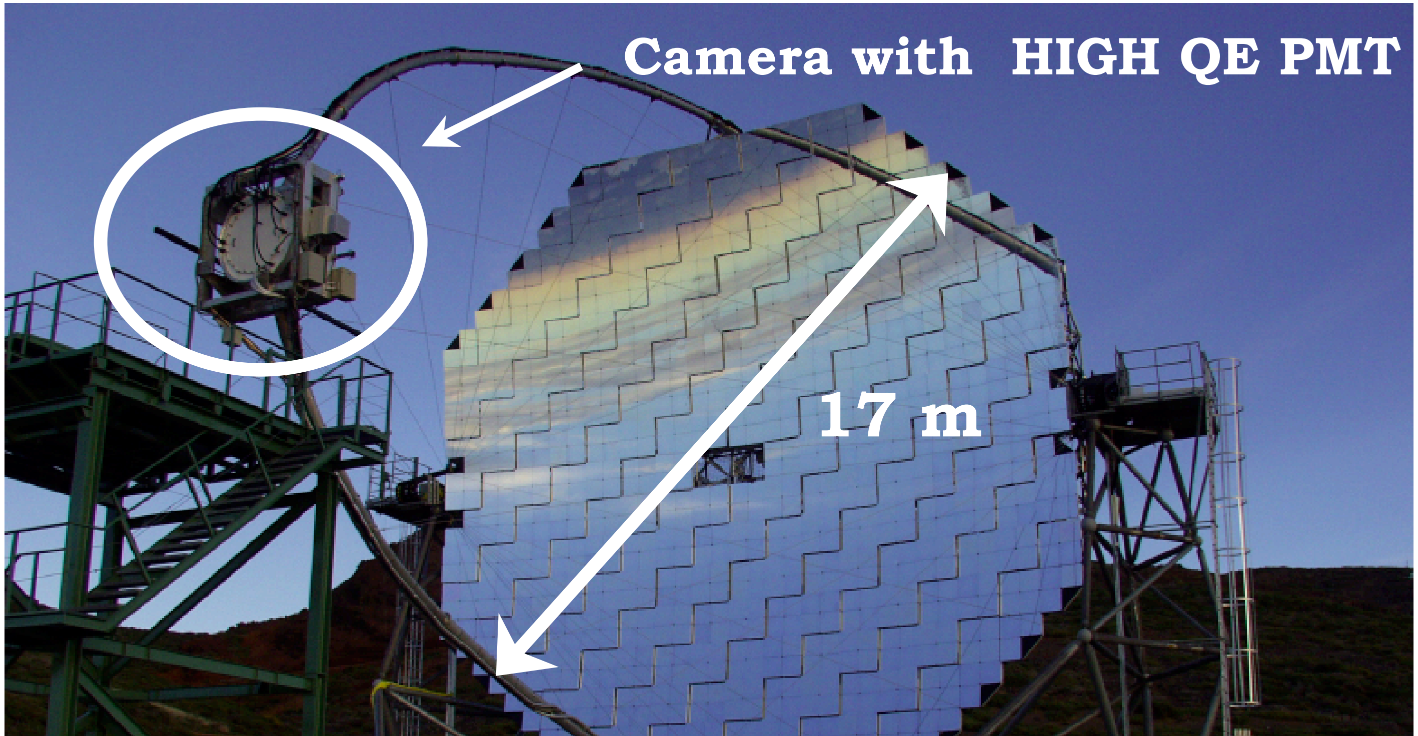
GLAST GeV-TeV Symposium (September 2004, SLAC)

The MAGIC Telescope, a technological challenge

2.1 - Motivation for building MAGIC

- **Largest** Imaging Air Cherenkov Telescope (***IACT***) world-wide
- **Lowest energy threshold**; γ-ray astronomy in the range **30 GeV-30 TeV**

30-300 GeV was still unexplored



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

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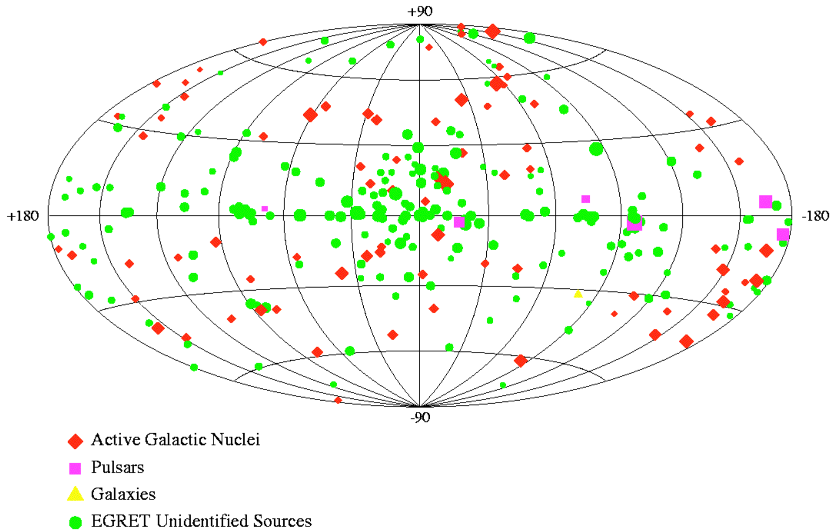
2.1.1 - Observations in this energy range are very valuable

Sources observed with EGRET

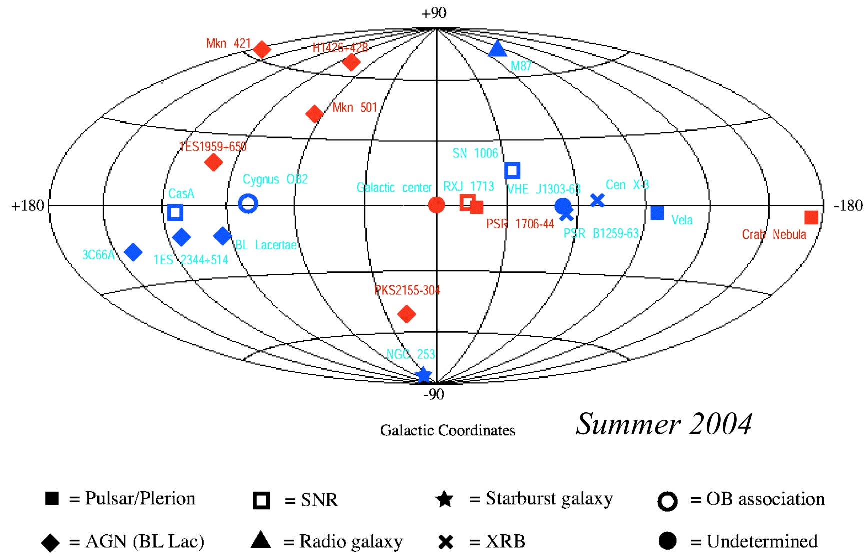
100 MeV < E ≤ 10 GeV



271 sources, from which
170 are still unidentified

Sources observed with *IACTs*

E > 300 GeV



21 sources; 9 established,
12 need further confirmation

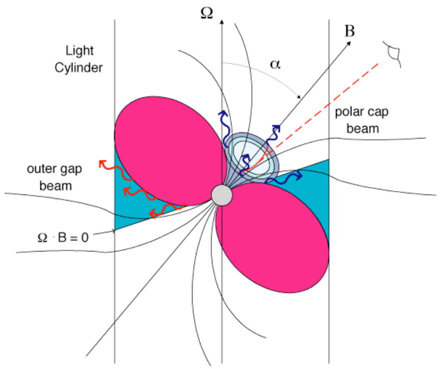
Existence of strong cut-offs in the γ-spectra in the range 10-300 GeV

2.1 - Motivation for building MAGIC

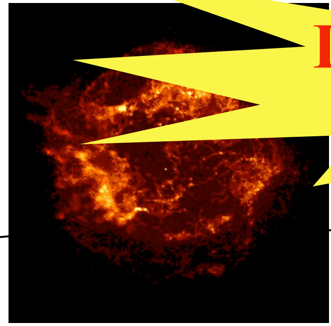
- **Largest** Imaging Air Cherenkov Telescope (***IACT***) world-wide
- **Lowest energy threshold**; γ-ray astronomy in the range **30 GeV-30 TeV**

30-300 GeV was still unexplored

2.1.2 - Main astrophysical targets for the MAGIC Telescope



Pulsars



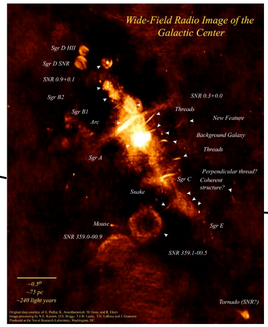
Supernova Remnants (SNR)

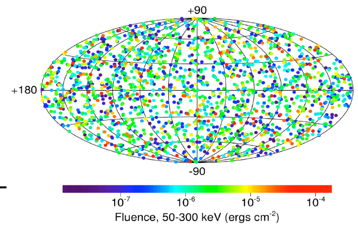
Leptonic or hadronic acceleration ????

EBL indirect measurements

Active Galactic Nuclei (AGN)

Annihilation of Dark Matter Particles





Gamma Ray Bursts (GRBs)

2.2 - Development of technologies never used in IACTs

2.2.1 - Carbon fiber tube frame with light-weight aluminium mirrors

2.2.2 - Development of an Active Mirror Control (AMC)

2.2.3 - Enhancement of the PMT sensitivity by a special coating

2.2.4 - Development of an optical system with large dynamic range to transmit the analogue PMT signals

2.2.5 - Trigger providing online background rejection

2.2.6 - Development of a DAQ with 8bits 300 MSample/s FADCs

Enhancement in the PMT sensitivity by a special coating

3 - Enhancement of the PMT sensitivity by a special coating

Camera of MAGIC

576 Photomultipliers (PMTs)
(Electron Tubes 9116/17)

Bialkali photocathode
6 dynodes

3 - Enhancement of the PMT sensitivity by a special coating

High conversion of Cherenkov photons to photoelectrons is mandatory in reducing the Energy threshold (E_{th}) of the telescope

$$E_{th} \quad \frac{1}{A_{mirror} \; R \; LC_{eff} \; QE}$$

(*Mirzoyan, Proc. Towards a Major Atmospheric Cherenkov Detector, 1997*)

A_{mirror} ; Area of the mirror dish
R ; Reflectivity of the mirrors
LC_{eff} ; Efficiency of the light collectors
QE **; Quantum Efficiency of the PMTs**

Increase in PMT QE decreases the telescope E_{th}

<u>Photomultipliers used in the camera of MAGIC</u>

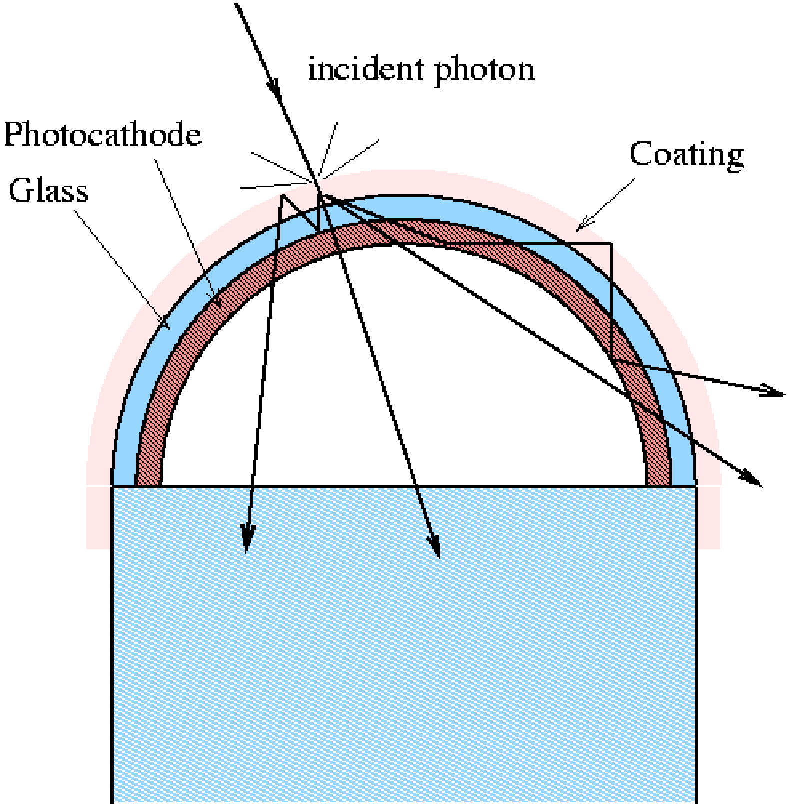
Electron Tubes 9116A (25mm ∅), **9117A** (38mm∅)

- Hemispherical borosilicate window
- Bialkali semitransparent photocathode (*PhC*), *25% peak QE*
- Dynode system with 6 stages

A substantial sensitivity enhancement was achieved by SCATTERING the photons by a SPECIAL COATING before they get into the *PhC*

Scattering surface on the hemispherical window of a PMT

QE



$n^{coating} = n^{glass} = 1.5$

$n^{photocathode} \sim 2.5$

- Photons scattered in a way that their trajectories cross the *PhC* twice ↑
- Photons scattered so that they get trapped between the *PhC* and the Coating ↑
- Reflectivity of coating larger than that of the glass ↓
- Photons scattered back in coating after being reflected off in the *PhC* ↑

Additional increase in the UV sensitivity was obtained by including a Wavelength Shifter (*WLS*) in the coating

3.1 - Method used to get the scattering layer

Technique based on a standard procedure to coat PMTs with a *WLS* *(Eigen and Lorenz, NIM A 167, 405 (1979))*

Non-coated PMT **Coated PMT**

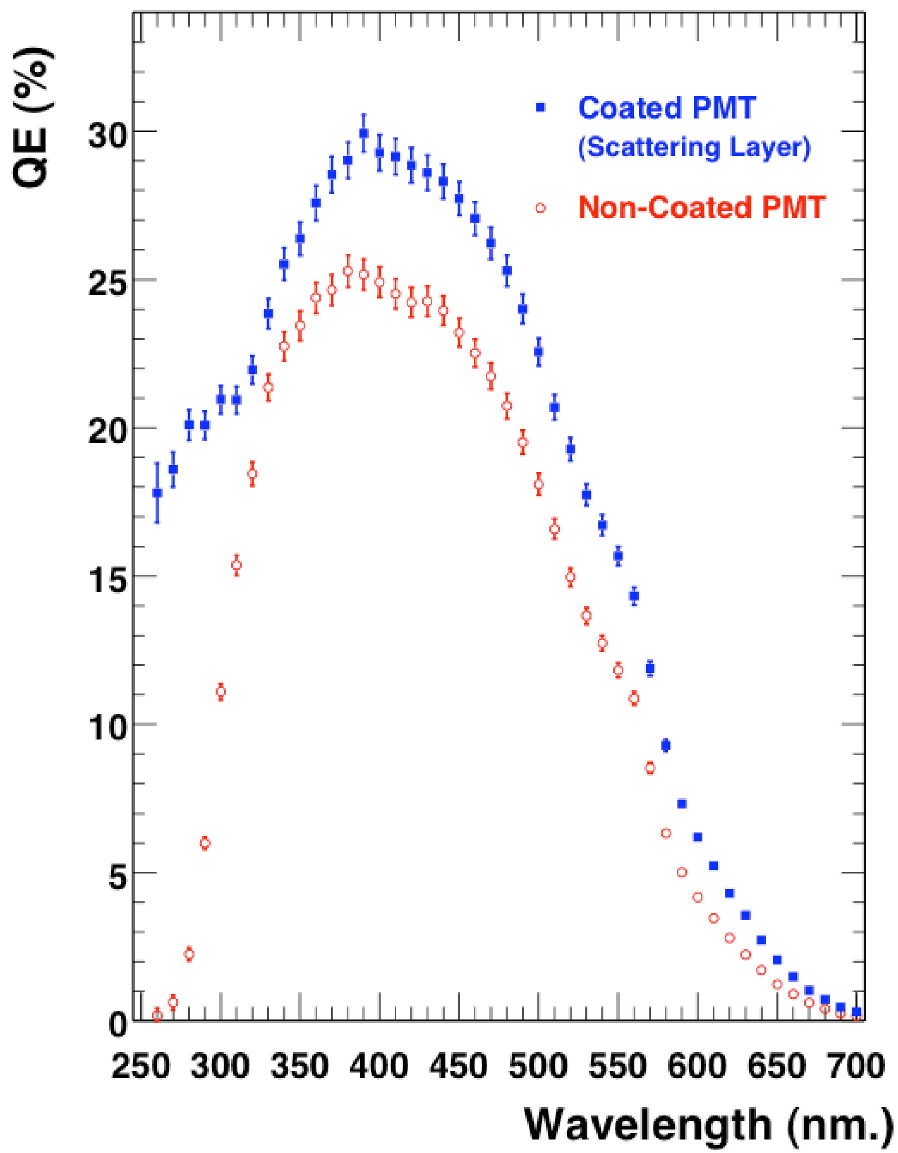
◆ PMT is dipped 2-3 times in *Paraloid B-72* and *1,4 p-Terphenyl (PTP)* dissolved in *Dichloromethane*

◆ *Rapid evaporation results in diffuse (milky) layer*

Paneque et al, Nucl. Instr. Meth A 504: 109-115, 2003

Paneque et al, Nucl. Instr. Meth A 518: 619-621, 2004

3.2 - Enhancement in QE achieved by this technique



Increase in QE is produced in the full wavelength range

Paneque et al, Nucl. Instr. Meth A 504: 109-115, 2003

Paneque et al, Nucl. Instr. Meth A 518: 619-621, 2004

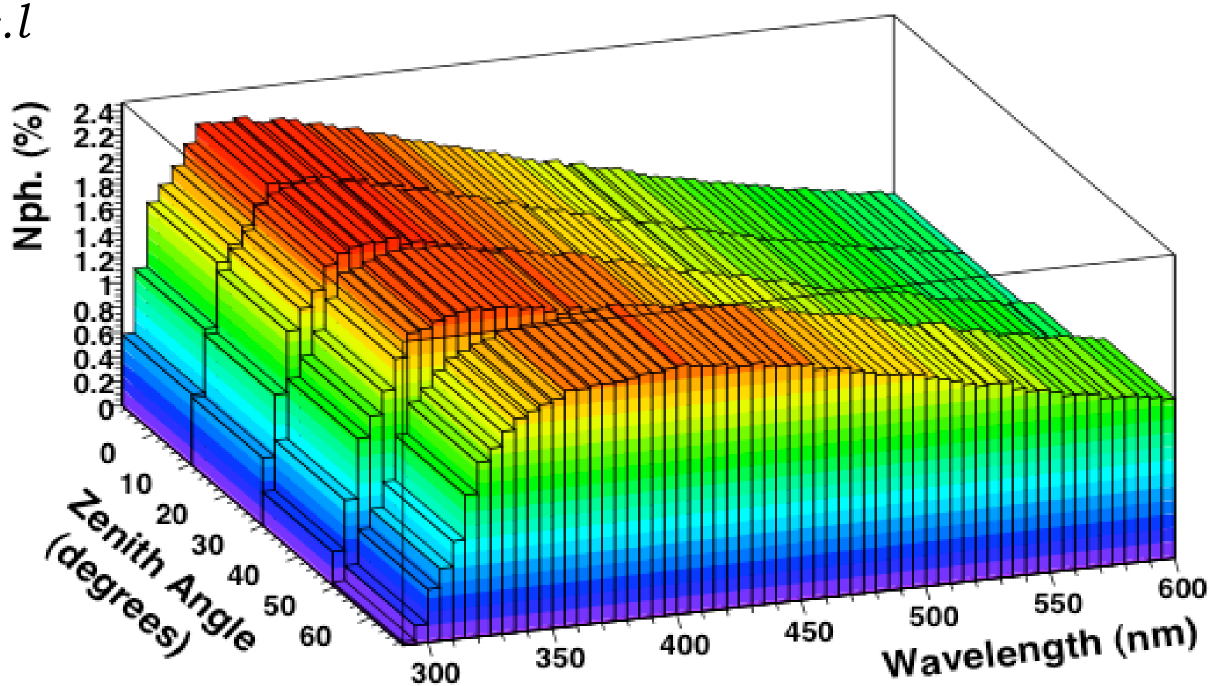
3.3 - Increase in the detection efficiency of an IACT

◆ In order to quantify the enhancement, one needs to fold the *“new QE”* with the *Cherenkov Photon Spectrum* and compare it with the *“old QE”*

$$QE_{eff} \equiv \frac{\int QE(\lambda) N_{ph}^{C}(\lambda) d\lambda}{\int N_{ph}^{C}(\lambda) d\lambda}$$

◆ Cherenkov photon spectrum expected from 10GeV-30TeV showers at 2200 m *a.s.l*

(obtained with CORSIKA 6.019)



3.3 - Increase in the detection efficiency of an IACT

The technique increases QE_{eff} of MAGIC by 19%
Equivalent to increase mirror area by 19% (from 239 m^2 to 284 m^2)

$$E_{th} \qquad \frac{1}{A_{mirror} \square R \square LC_{eff} \square QE}$$

E_{th} of MAGIC is reduced by a factor ~1.19

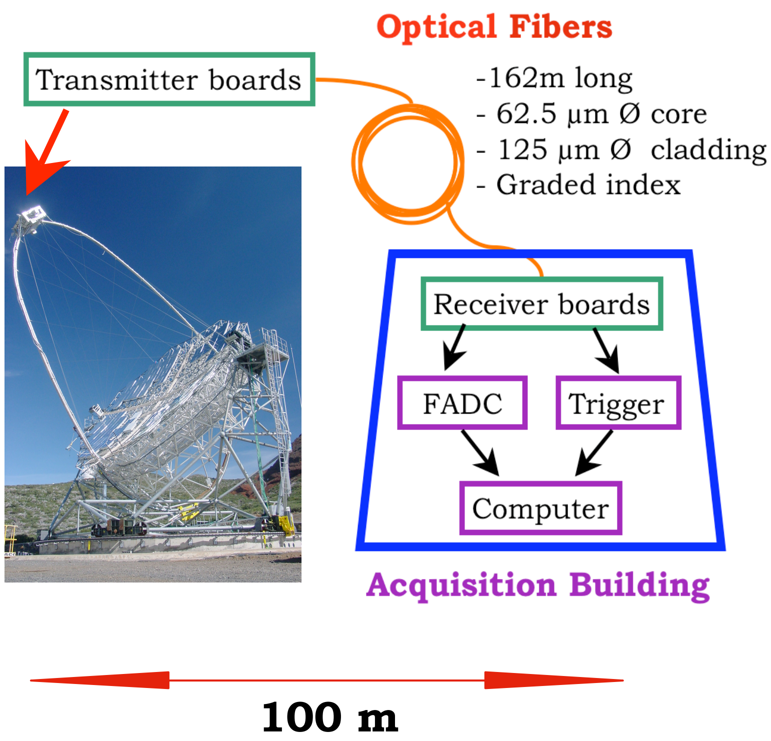
The MAGIC collaboration decided to apply this special coating to all the PMTs of the telescope camera

Technique can be used in any other application where the PMT is not optically coupled to its light source

Development of an optical system based on VCSEL drivers to transmit the PMT signals

4 - Development of an optical system based on VCSEL drivers to transmit the PMT signals

4.1 Why do we use an optical system instead of coaxial cables?



Cherenkov light flashes; 2-3 ns

In MAGIC, PMT signals have typically **2-3ns FWHM**

Reduction in signal attenuation and distortion

Important to keep signals short to reduce Night Sky Background

- Attenuation in RG58C:

  17dB/100m @ 100 MHz

- Attenuation in our fibers:

  0.3dB/100m @ 500 MHz

Optical link system is less bulky

- Single RG58C cable: 5 *mm Ø*
- Bundle of 72 fibers: 16 *mm Ø*

Optical fibers are lighter (x10) than coaxial cables

No crosstalk among channels, neither pickup nor grounding problems

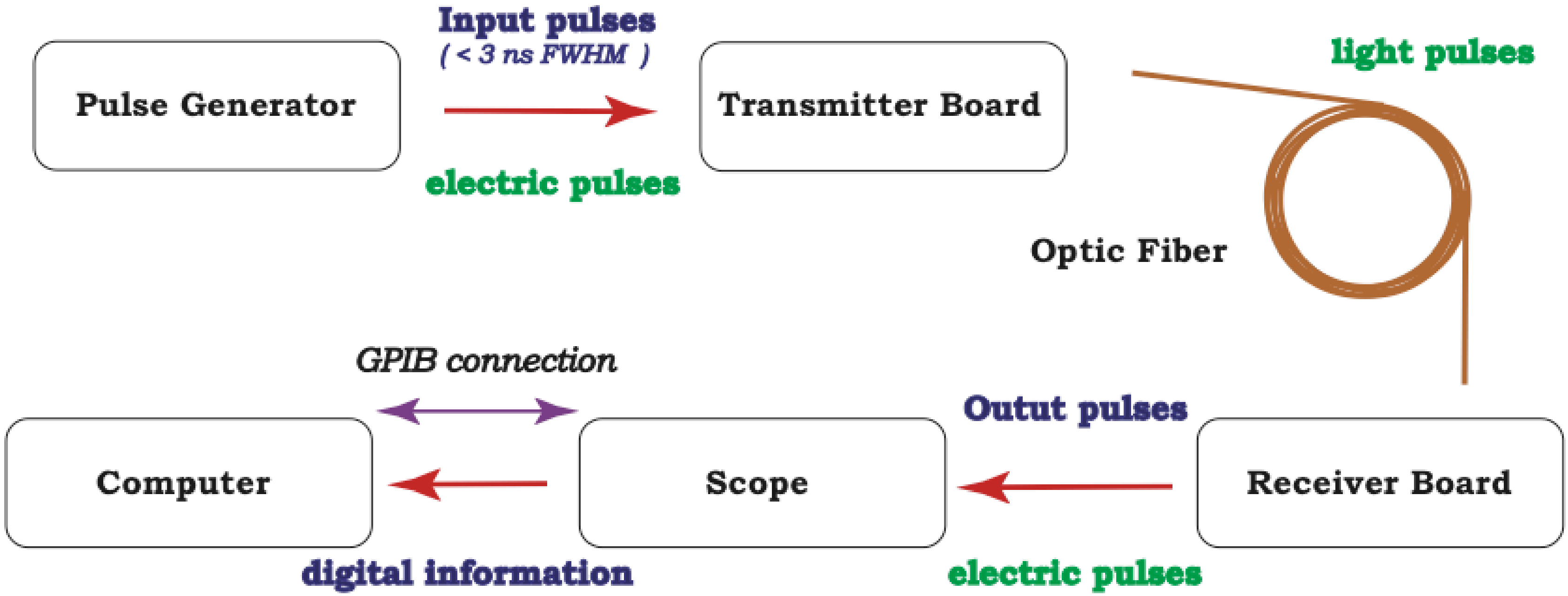
4.2 Evaluation of the optical link system

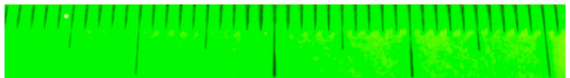
Optical system uses Vertical Cavity Surface Emitting Lasers (VCSEL)

So far, VCSELs used basically ONLY in DIGITAL communications

Experimental SETUP used to test the optical link system

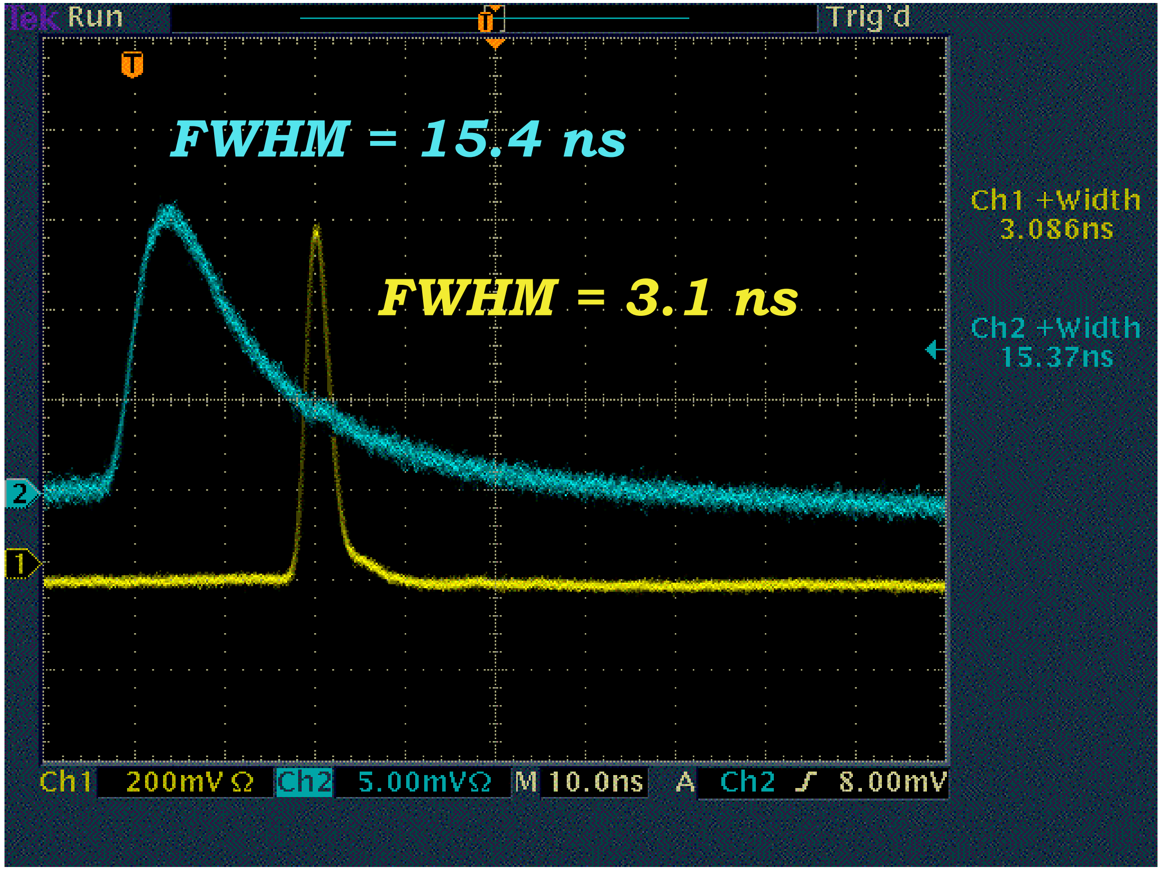
➢ Low divergent (15º) circular beam





The optical link system is evaluated by studying the area under the *output pulses* vs time and vs the amplitude of the *input pulses*

Pulses on the screen of an oscilloscope after travelling 160 meters



The used initial pulse had a *FWHM = 2.7 ns.*

After 156 m long RG58C coaxial cable

After 160 m long optical fiber

The system is able to transfer pulses of <3 ns FWHM with low distortion

The system provides substantial reduction of Night Sky Background

4.2 Evaluation of the optical link system

Noise and instabilities in the transmitted pulse were found.
Attributed to ***mode hopping*** in the multimode **VCSELs**

Performance of the optical system depends very much on the bias current used drive the VCSELs

At low bias currents (<7 mA) VCSELs are typically less noisy

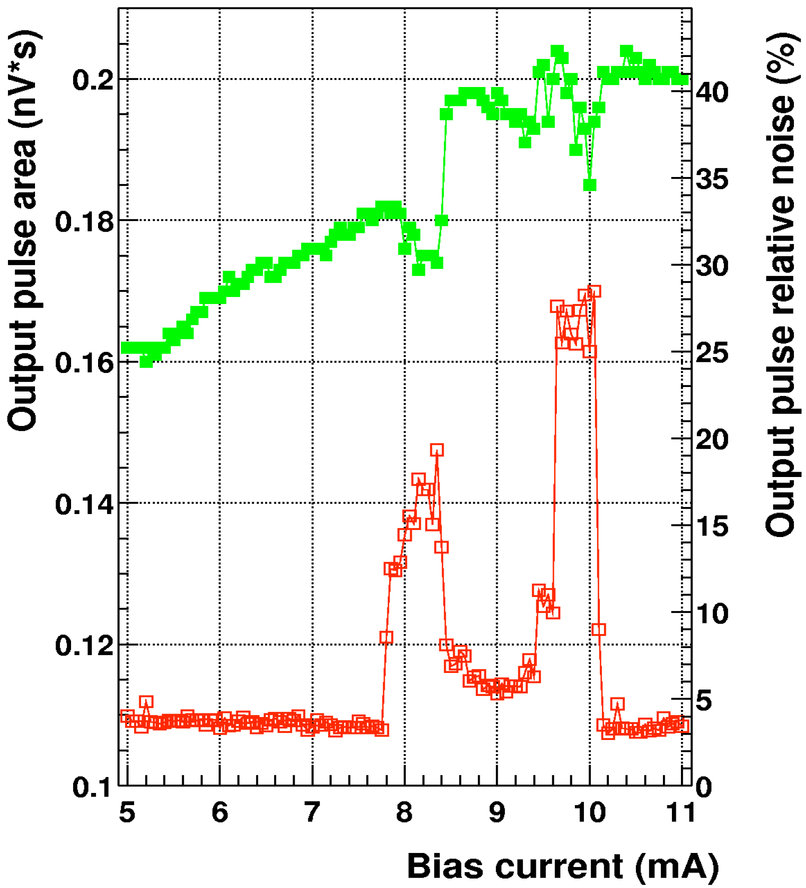
Performance of the optical links depends very much on the size of the transmitted pulse

Relative fluctuations in the output pulse decrease when increasing the amplitude of the input pulse

There is some spread in the performance of the used VCSEL type

Output pulse area (green) and relative noise (red) vs the bias current

Input pulse amplitude; 40 mV



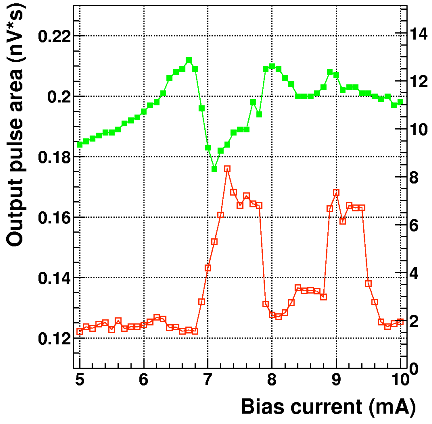
The area is the mean of the measured area of 120 pulses, and the relative noise is the computed sigma divided by the mean

VCSEL gain and noise can change significantly when varying the bias current

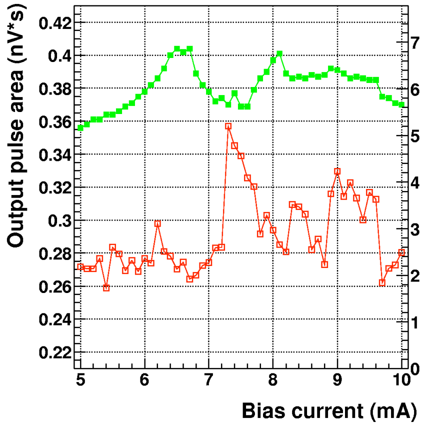
Each VCSEL has its characteristic dependence on the bias current; yet, in general, sudden changes of gain and high noise are less frequent at low bias currents

Output pulse area and relative noise vs bias current at several input pulse amplitudes

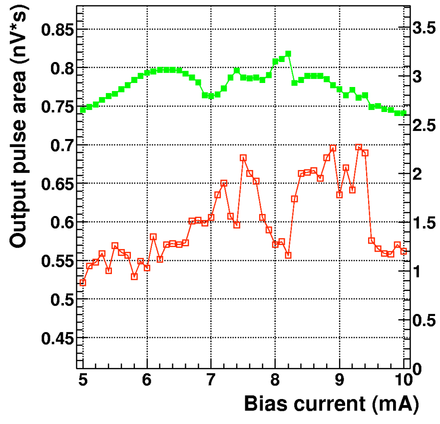
40 mV



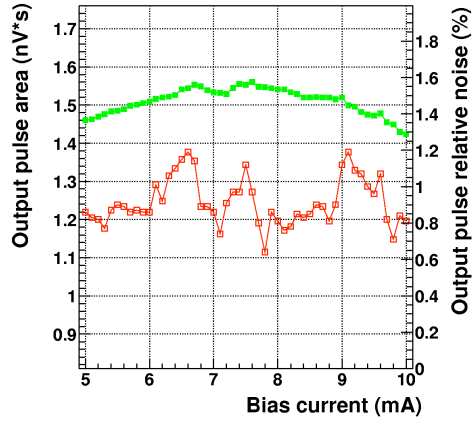
80 mV



156 mV



312 mV



Sudden changes of VCSEL gain and high noise appear ONLY at low *input pulse* amplitudes

Activation/deactivation of transverse modes affect the beam divergence angle and the polarization of the light, thus producing variations in the amount of light focused and, later on, transmitted by the optic fiber.

There is a wide spread in the performance of the used VCSEL type

4.3- SOLUTIONS to the previously presented problems

4.3.1- Signal amplification by a factor 4 before it is fed into the VCSEL

4.3.2- Bias current set to 6.0 mA for all VCSEL

4.3.3- Study and selection of ALL VCSEL used in the camera of MAGIC

Bias Current Scan: 5-7 mA in steps of 0.05 mA
Long Time Test: @ 6.0mA during more than 10 hours time
Input pulse used: 10 mV amplitude, 2.7ns FWHM

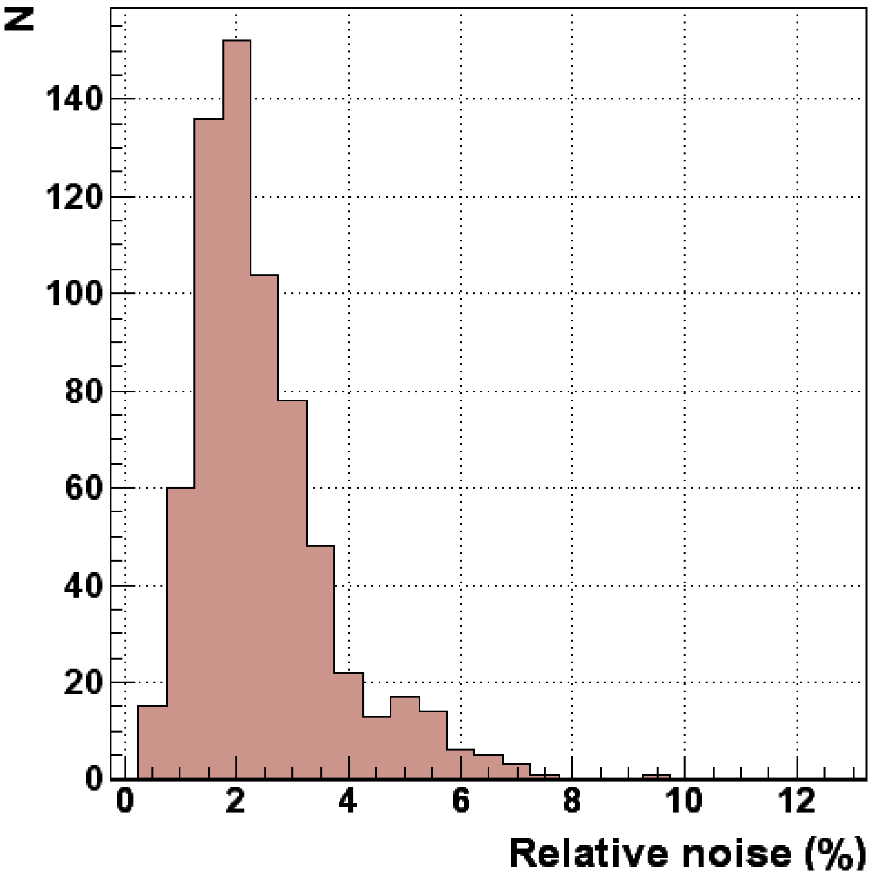
Very tight selection criteria were applied in order to ensure excellent performance of all the VCSELs to be used in MAGIC

970 VCSEL were measured; **670** (70%) passed the selection

4.4 - Measured performance of the optical links (*after selection*)

4.4.1 - Relative noise (measured in the long time test) for all VCSELs that passed the selection

Input pulse: ***10 mV*** *ampl;* ***2.7ns*** *FWHM*



The *input pulse* used corresponds to a pulse produced by **~10 phe** in the pixel chain of MAGIC

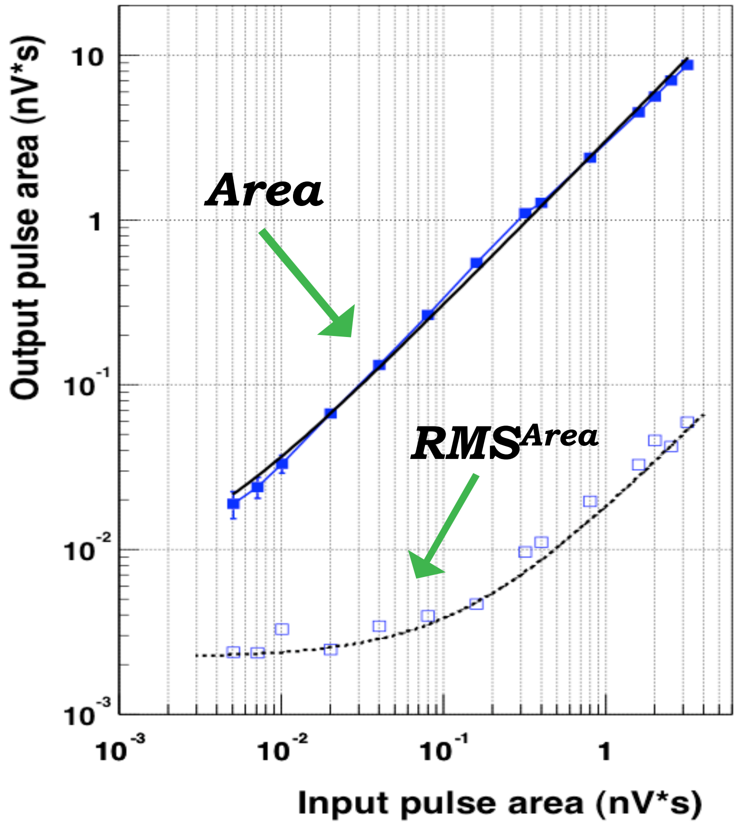
Note: *statistical fluctuation in PMT signals produced by 10 phe is*

$$\frac{\sigma_Q}{\langle Q \rangle} = \frac{1}{\sqrt{\langle m_{phe} \rangle}} \bullet F = \frac{1}{\sqrt{10}} \bullet 1.15 \approx 36\%$$

The noise performance of the optical link channels is well below the level of the statistical *phe* fluctuation in the *PMT* signals

4.4 - Measured performance of the optical links (*after selection*)

4.4.2 - Measured linearity of the optical link system



The lowest and the highest point of the plot relates to an *input pulse* of 2.7ns FWHM and 1.5 mV and 940 mV amplitude, respectively

Deviation from a perfect linear behaviour by less than 15% in 56 dB

RMS noise well below the signal in the whole range of 56 dB

Paneque et al, Proc. 28th ICRC, 2927-2930, Tsukuba 2003

MAGIC is the first detector using an optical system with VCSEL drivers to transmit analogue signals over 60 dB

The MAGIC Project,
status and source observations

5.1 - Recent history of the MAGIC Project

First presentation at the 24th ICRC, Bradbury et al, Rome (1995)

2000-2003 **Construction** of the MAGIC Telescope

Design study spring 1998

Approval of funding only late 2000

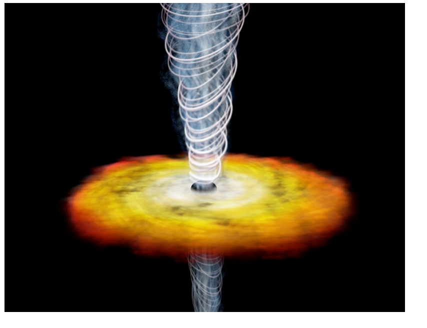
Nov 2003-Sep 2004

Commissioning and first observations:

Crab, Mrk421 ...

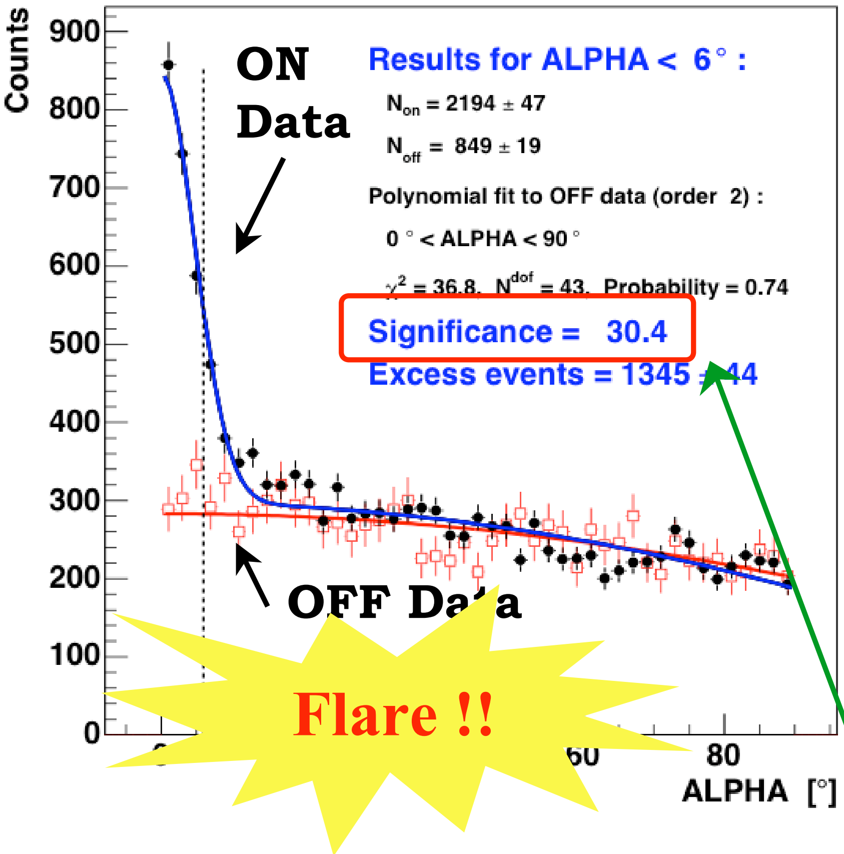
Mirror installation finished in July 2004

10 Oct 2003 **Inauguration** of MAGIC

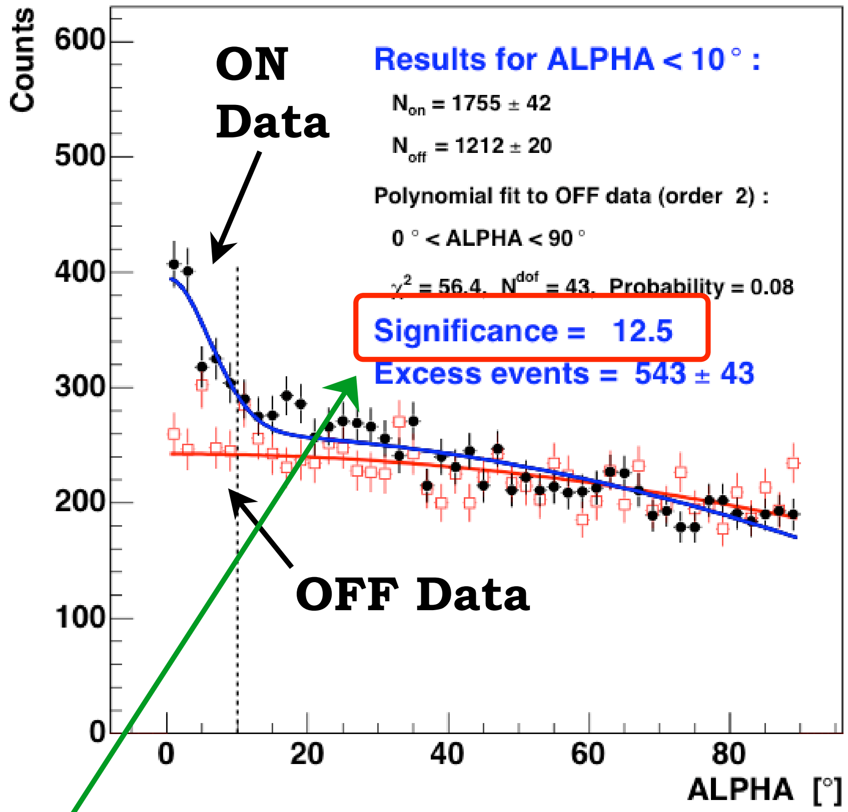


14-15 February 2004: First gamma-ray source detections

◆ Mkn421 (*z= 0.031*), 105 min ON time, mean zenith angle 20^0



◆ Crab Nebula, 85 min ON time, mean zenith angle 26^0



Despite the beginning of the telescope commissioning, the signals are very significant
(Only statistical errors considered)

5.2 - Status of the MAGIC Project

◆ **September 2004; MAGIC starts running smoothly, only few hardware interventions and some performance tests in November.**
Starting regular observation of several sources till January 2005

◆ Status after 2nd week of January 2005

People say that the weather is always good at La Palma…

… this is not always true …

◆ **Status in February 2005**

… and it can always get worse …

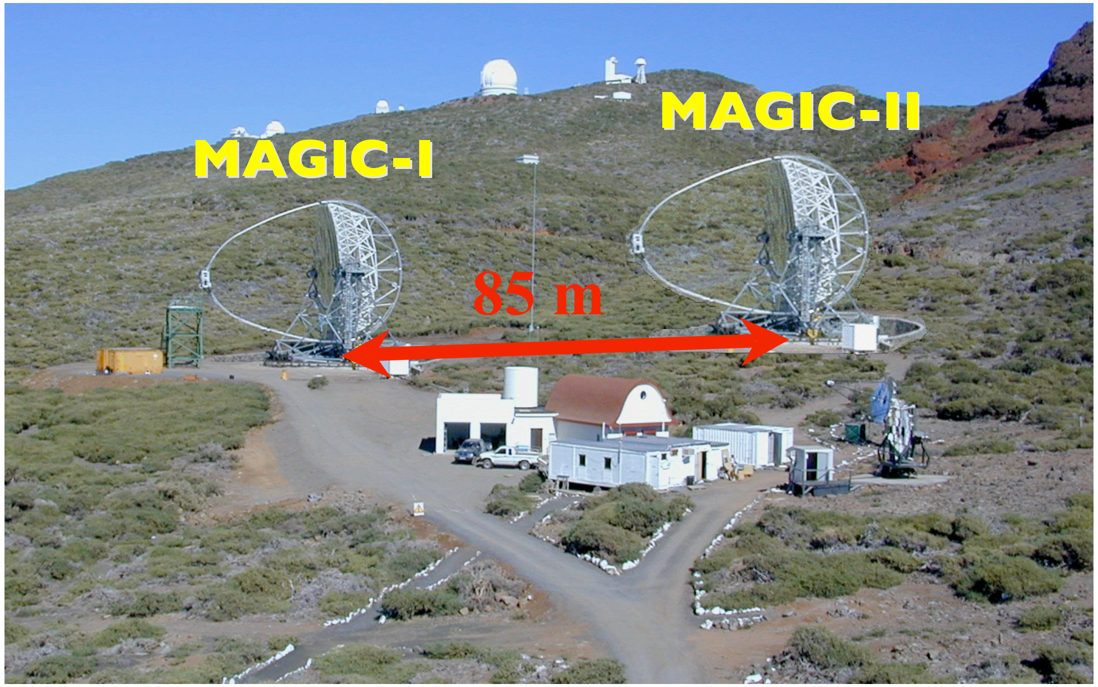
5.2 - Status of the MAGIC Project

◆ September 2004; MAGIC starts running smoothly, only few hardware interventions and some performance tests in November.
Starting regular observation of several sources till January 2005

◆ No data taken from mid January till mid March

◆ Regular observations till now

◆ Construction of the second telescope started



3.2 - Status of the MAGIC Project

◆ September 2004; MAGIC starts running smoothly, only few hardware interventions and some performance tests in November.
Starting regular observation of several sources till January 2005

◆ **No data taken from mid January till mid March**

◆ **Regular observations till now**

◆ **Construction of the second telescope started**

- Increase in sensitivity
- Better angular resolution
- Reduction of energy threshold
- Independent Obs. of two diff. Sources simultaneosly

Expected to be operational by beginning 2007


7 September 2005
FIRE !!!!!
Fire reached the observatory… 300 m from MAGIC !!
It was close… fire was controlled; MAGIC is safe…

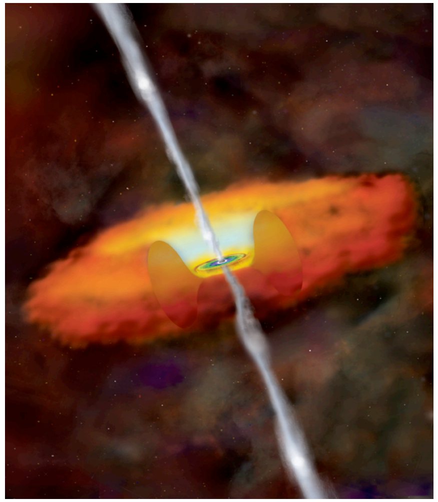
Detected sources with MAGIC (since Autumn 2004):

Crab Nebula	5 sigmas in 3 minutes *No pulse emission down to 100 GeV*
Mkn 421	Gamma ray variability with clear X-ray correlations *Simultaneous observations with HESS*
1ES1959+650	Clear detection in quiescent state
Mkn 501	Detection in quiescent state **+ flare**
Galactic center	6 sigmas detection
HESS 1813-178	11 sigmas, 1st confirmation of the HESS detection
1ES1218+304 **(z = 0.182)**	6 sigmas, **1st detection in VHE** **Good candidate for EBL studies**

5.3 - Source observations

1ES1959+650

Elliptical galaxy
Active Galactic Nucleus
z = 0.047
RA =20h00m
Dec = +65.1°
Observability at la Palma:
May-October 35°-54°



- 1998: First VHE □detection: Utah Seven Telescope Array *(Nishiyama et al, 1999)*
- Confirmed in 2002 by WHIPPLE and HEGRA *(Holder et al, 2003 - Aharonian et al, 2003)*

➢ Jets of highly energetic particles pointing towards the Earth (***Blazar***)

➢ Preferred model for the gamma ray emission; Inverse Compton

Interesting things About 1ES1959+650

1 - TeV-emission in quiescent state is very low

HEGRA System (2000-2001):

> 100 h obs. time (E_{th} > 2TeV); **5.2 σ , average integral flux ~5.3% Crab**

(Aharonian et al, A&A 406, 2003)

2 - Orphan flare in TeV-rays in June 2002

(High activity in γ-rays with low activity in X-rays)

Leptonic or hadronic acceleration ??

Hint for neutrino excess recently reported by AMANDA *(Paris, 2005)*

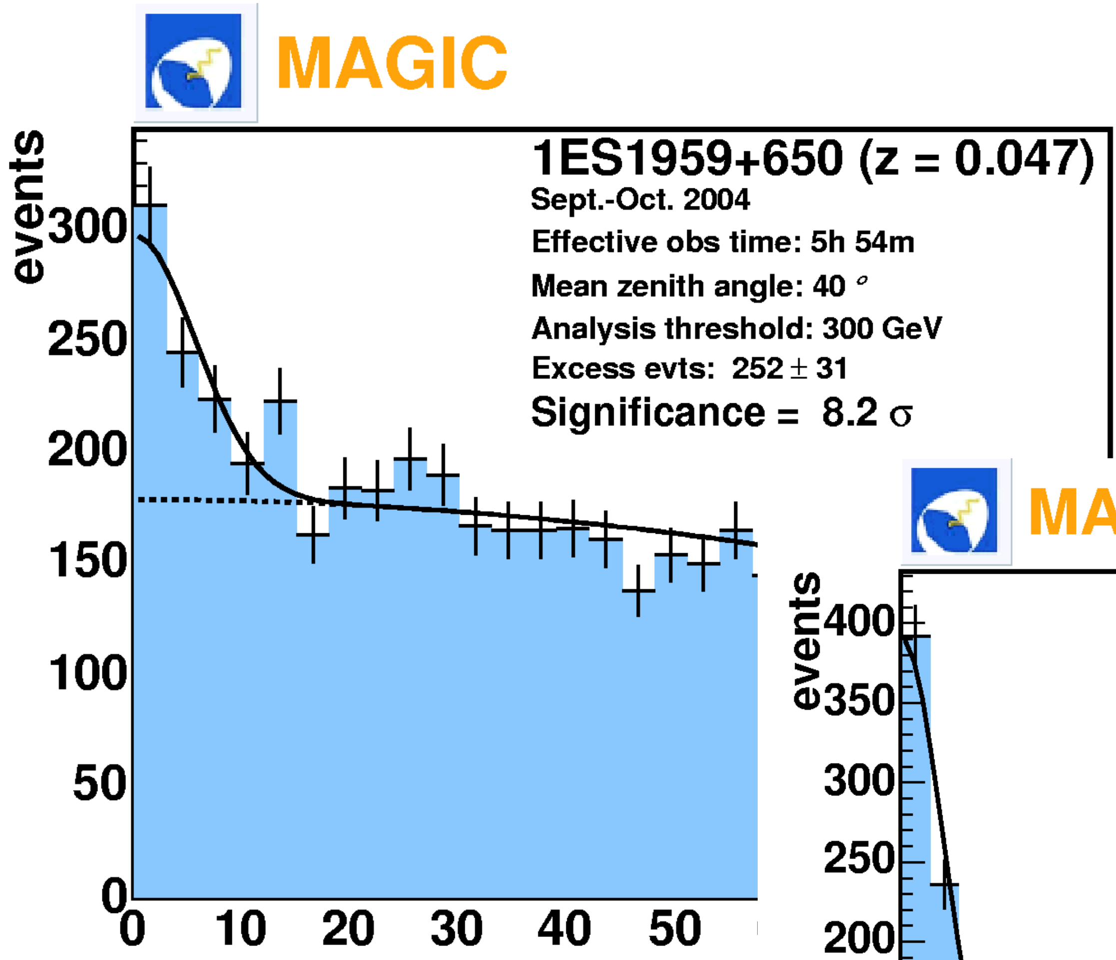
Correlation with position of a UHECR from HiRes *(astro-ph/0406654)*

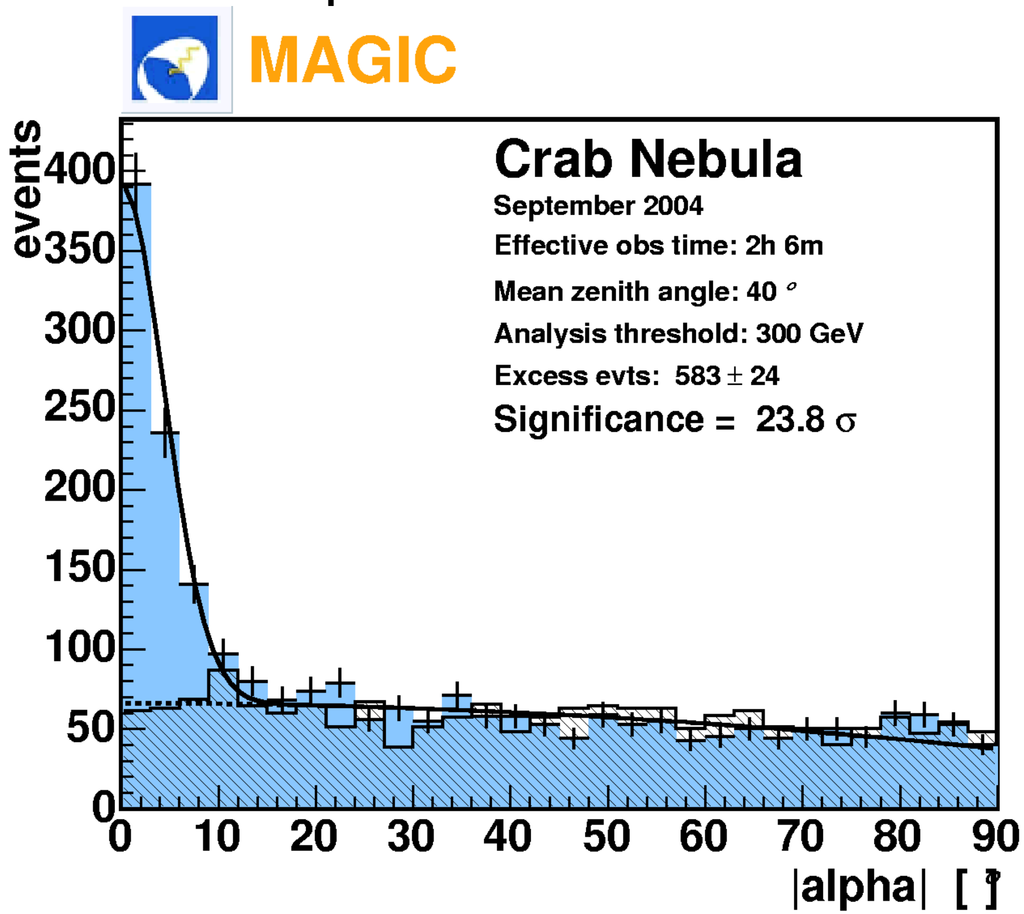
Observation with MAGIC

Days	Obs. Time	ZA range
September 2004 06, 07 **October 2004** 07, 10, 15, 16, 17	6 h 55 m 4.4 M events	min = 36° max = 47°

Analysis used was optimized on the Crab Nebula data set, which was obtained during the same period and zenith angle range

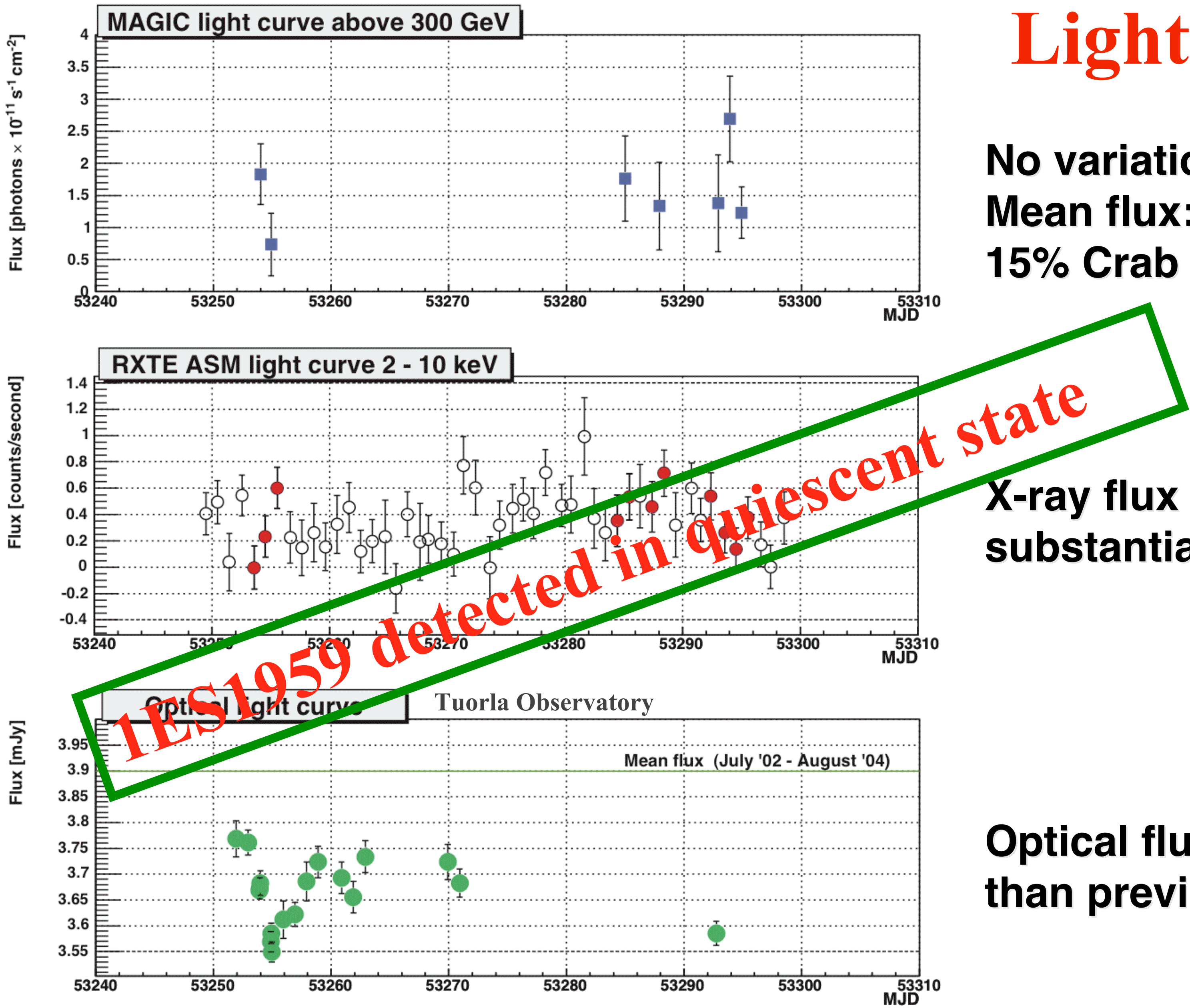
ALPHA PLOT





To be compared with Crab at medium/large zenith angle

Light curves

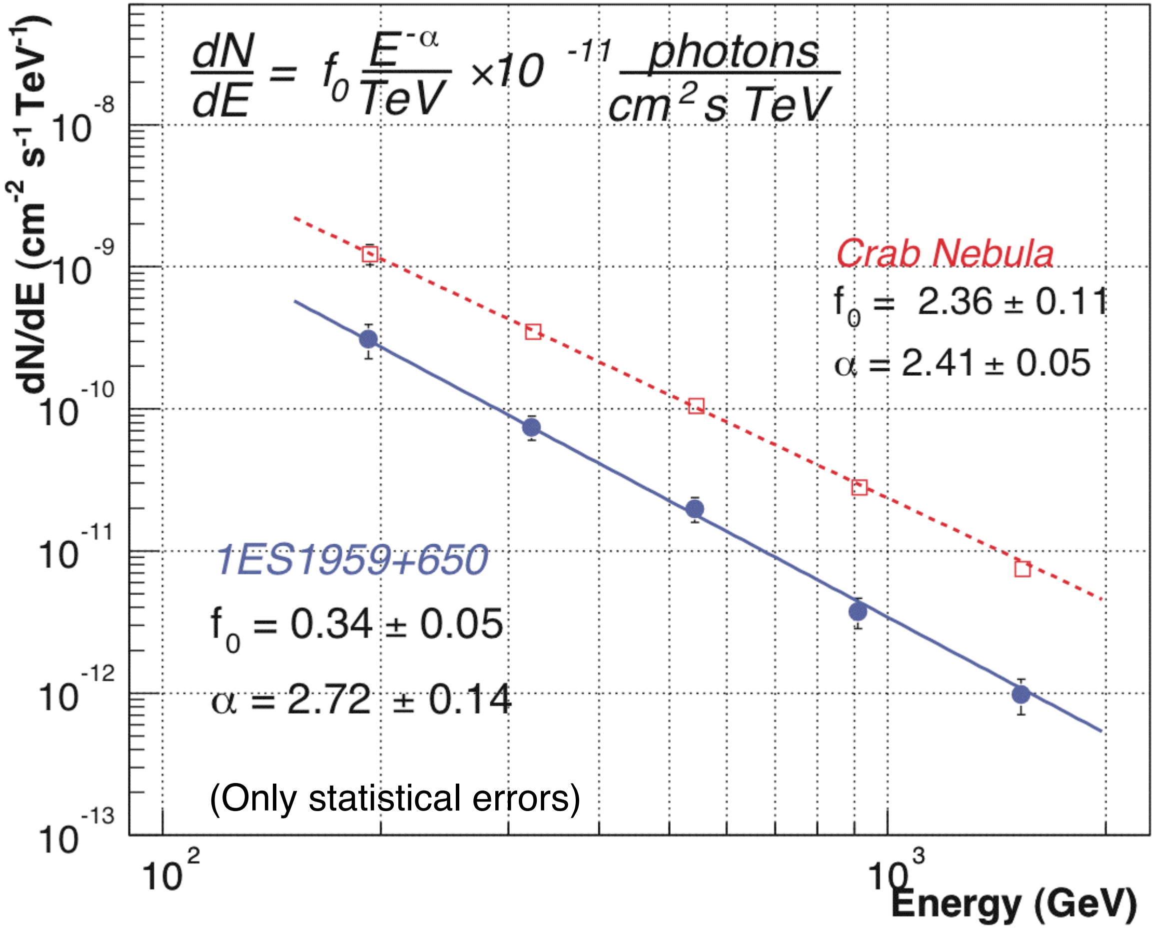


No variation observed
Mean flux:
15% Crab flux

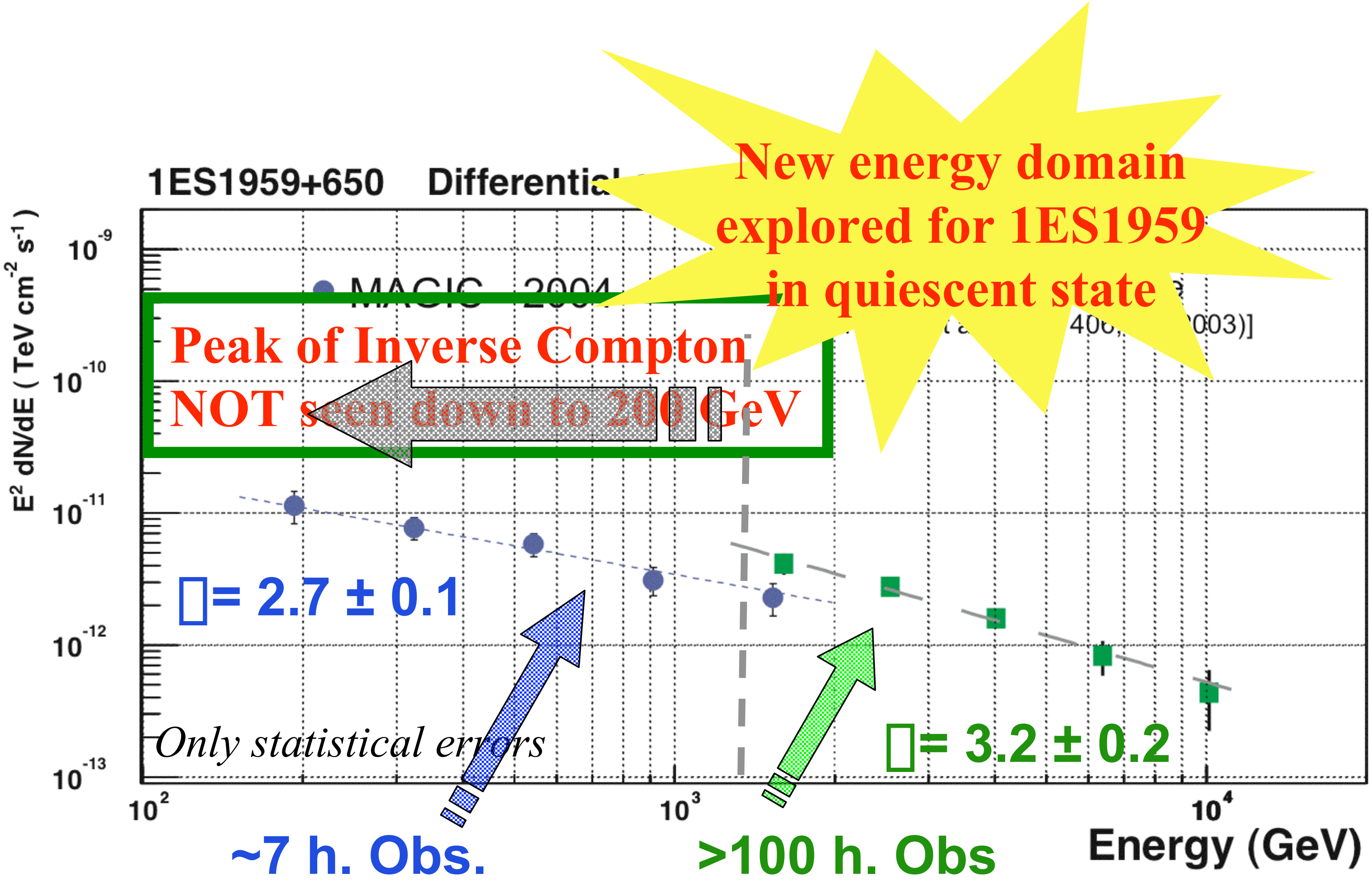
X-ray flux without substantial variations

Optical flux lower than previous period

Differential photon flux



Softter than that of Crab Nebula



Performance of the new IACT instruments allow to do VHE γ-astronomy of blazars in quiescent state

5.3 - Source observations

MARKARIAN 501

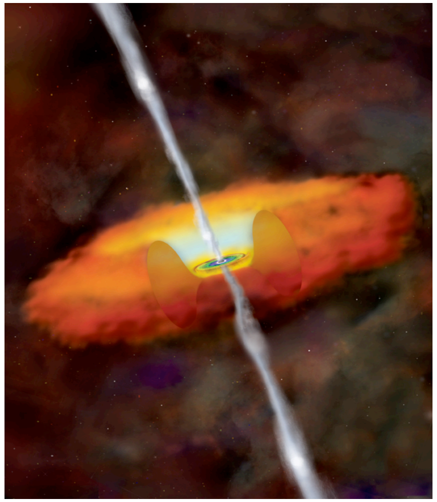
Elliptical galaxy

Active Galactic Nucleus (*AGN*)

z = 0.034

RA =16h54m

Dec = +39.8°



- First detected in VHE gamma rays by WHIPPLE (Quinn et al, 1996) and HEGRA CT1 (Bradbury et al, 1996).
  Second extragalactic detection in VHE gamma rays
  147 h. of ON observation; 5.2 sigmas detection with CT1 (quiescent state)

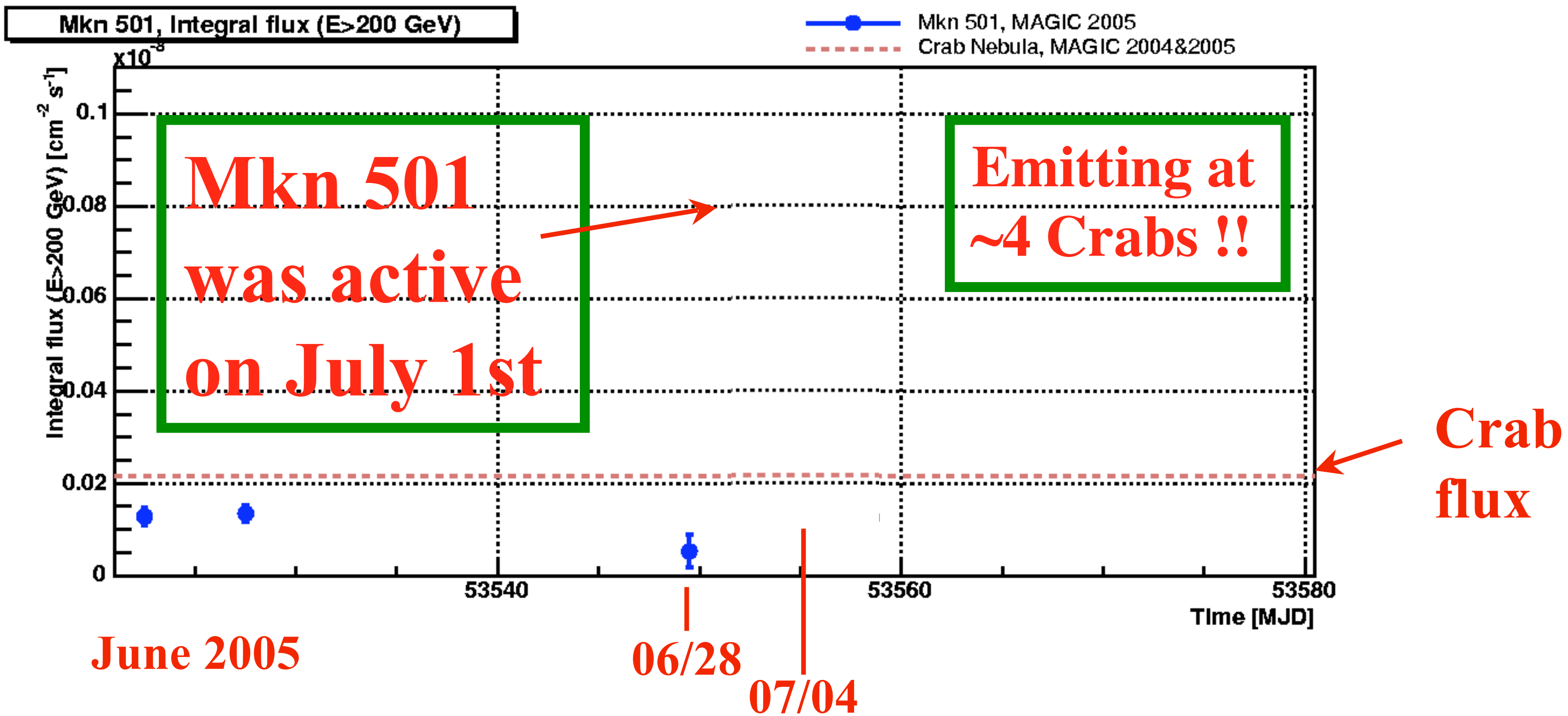
- Variable source with high correlations between gamma rays and x-rays (*Huge flare in 1997, up to 10 Crabs*)

- Jets of highly energetic particles pointing towards the Earth (***Blazar***)
- Preferred model for the gamma ray emission; Inverse Compton

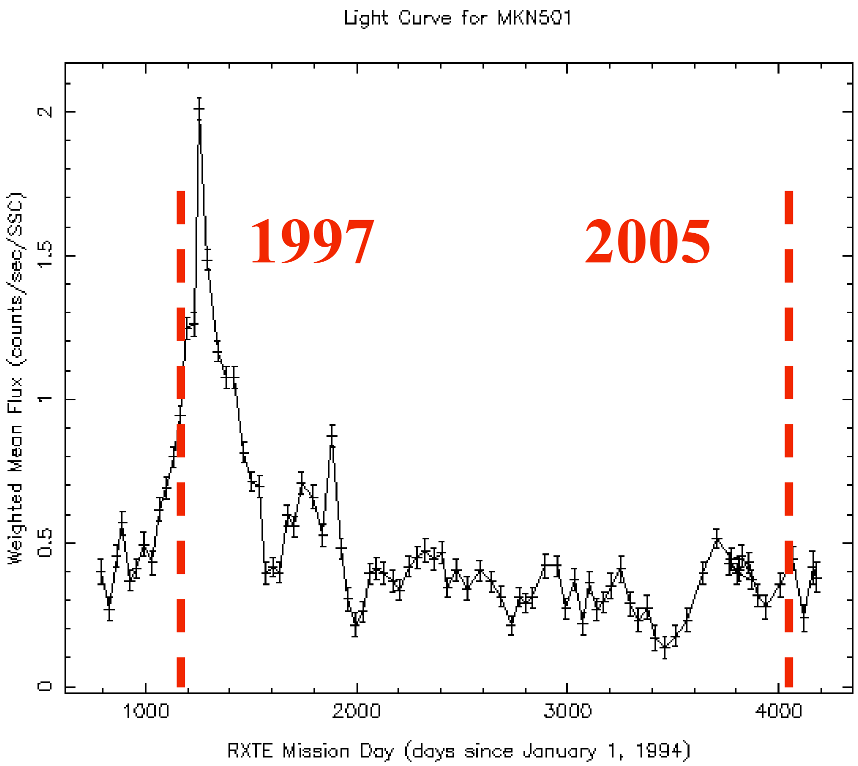
Mkn 501 was observed with MAGIC in June and July 2005

- Source found mostly in quiescent state (0.3-0.5 Crabs above 200 GeV). Not all data analyzed yet…

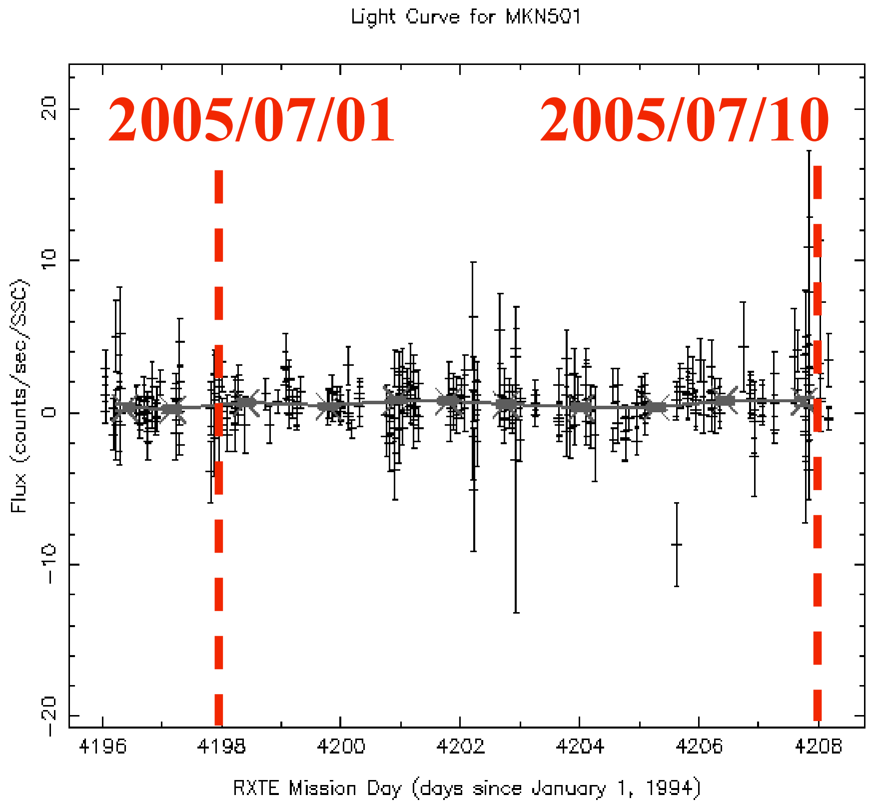
- Signal above 5 sigmas in only 1/2 hour (for 30% Crab) !!!!



X-rays measured by ASM since 1994
(average over 700 obs.)



X-rays measured by ASM
near to the flaring event



- Source was not found active by the ASM detector

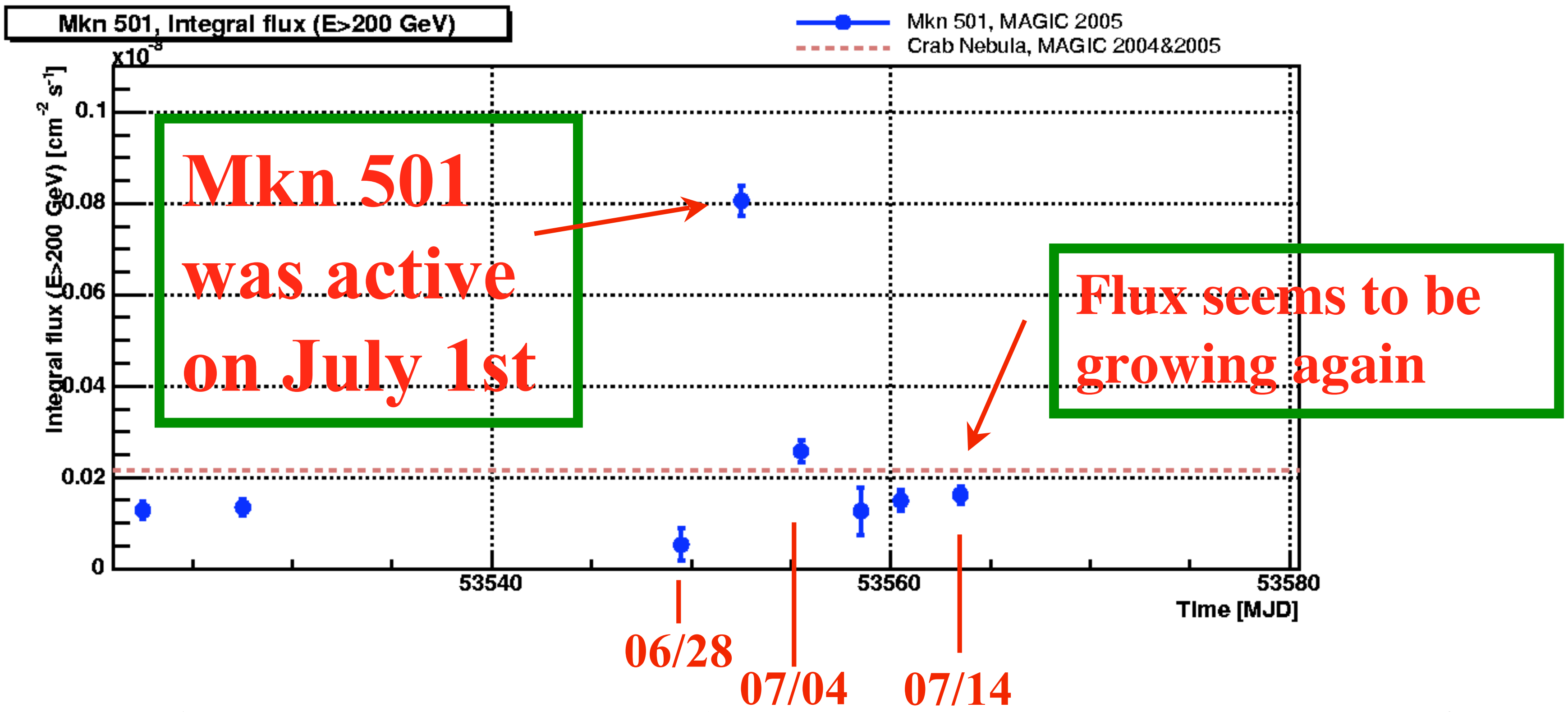
  Is it an ORPHAN flare ??????

That's getting exciting …

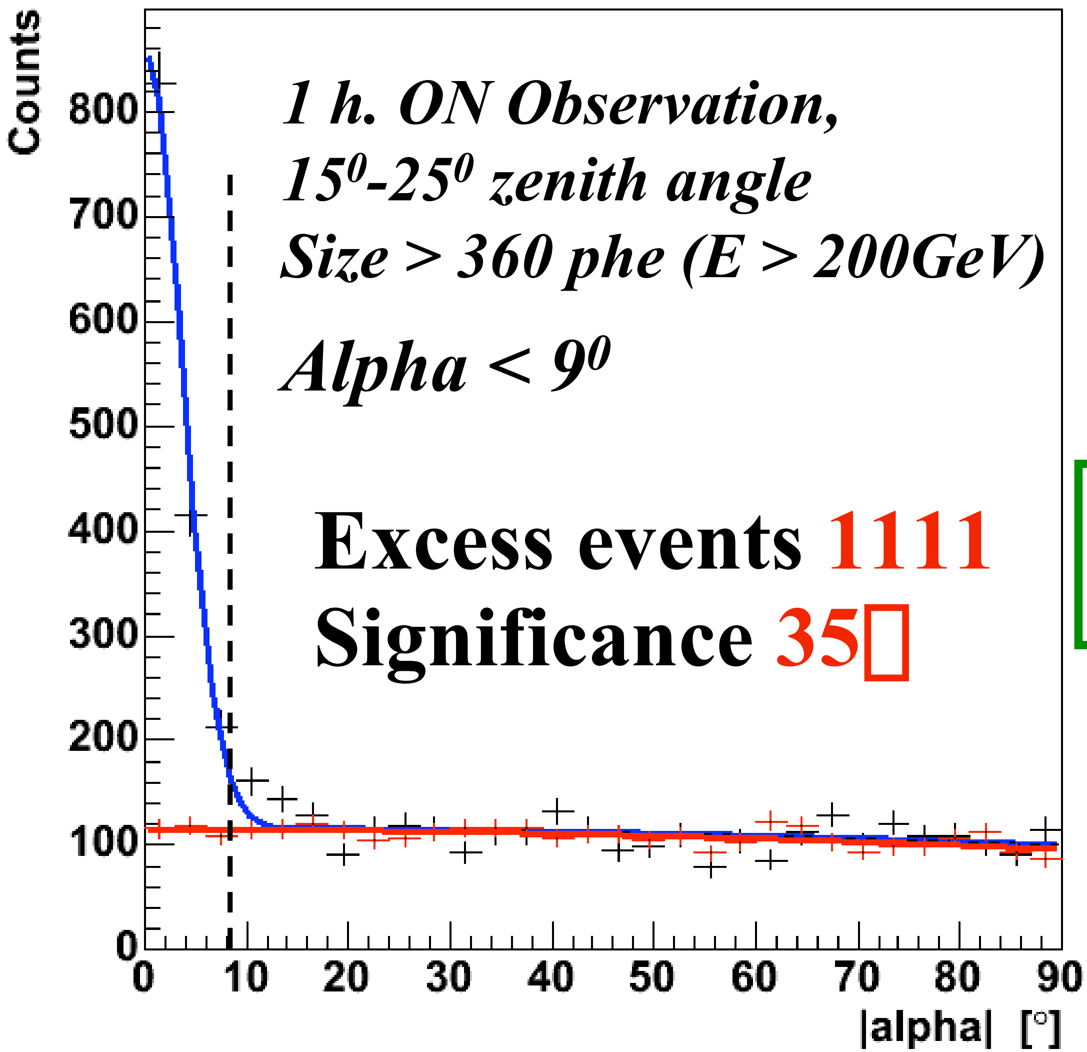
Mkn 501 was observed with MAGIC in May, June and July 2005

- Source found mostly in quiescent state (0.3-0.5 Crabs above 200 GeV). Not all data analyzed yet…

- Signal above 5 sigmas in only 1/2 hour (for 30% Crab) !!!!



Alpha plot for data from July 1st



High purity in the extracted gamma signal

Excellent for comparisons
Data - Monte Carlo

Improvement of our analysis techniques

6 - CONCLUSIONS

Construction of MAGIC was a technological challenge

MAGIC is operating regularly since fall 2004. Reasonable understanding of the telescope performance achieved.

Clear gamma-source detections down to 100 GeV have been performed with high significance

7 detections; 1 discovery

Work ongoing to:

1) ***Increase sensitivity at low energies***
2) ***Reduce further the analysis energy threshold***
3) ***Construction of the second telescope***

6 - CONCLUSIONS

The Universe in gamma-rays is more fascinating than expected.

Latest excitements (in addition to the above mentioned)…

Binary pulsar system PSR 1259 / SS2883; new type of TeV gamma-source

Unidentified TeV sources; TeV J2032 (*HEGRA*), TeV J1303 (*HESS*)

Starburst galaxy NGC 253 (CANGAROO); new type of TeV gamma-source

Radio galaxy M87 (HEGRA, confirmed by HESS)

Increasing number (*already 10*) of VHE gamma-ray blazars detected

3 new very distant blazars

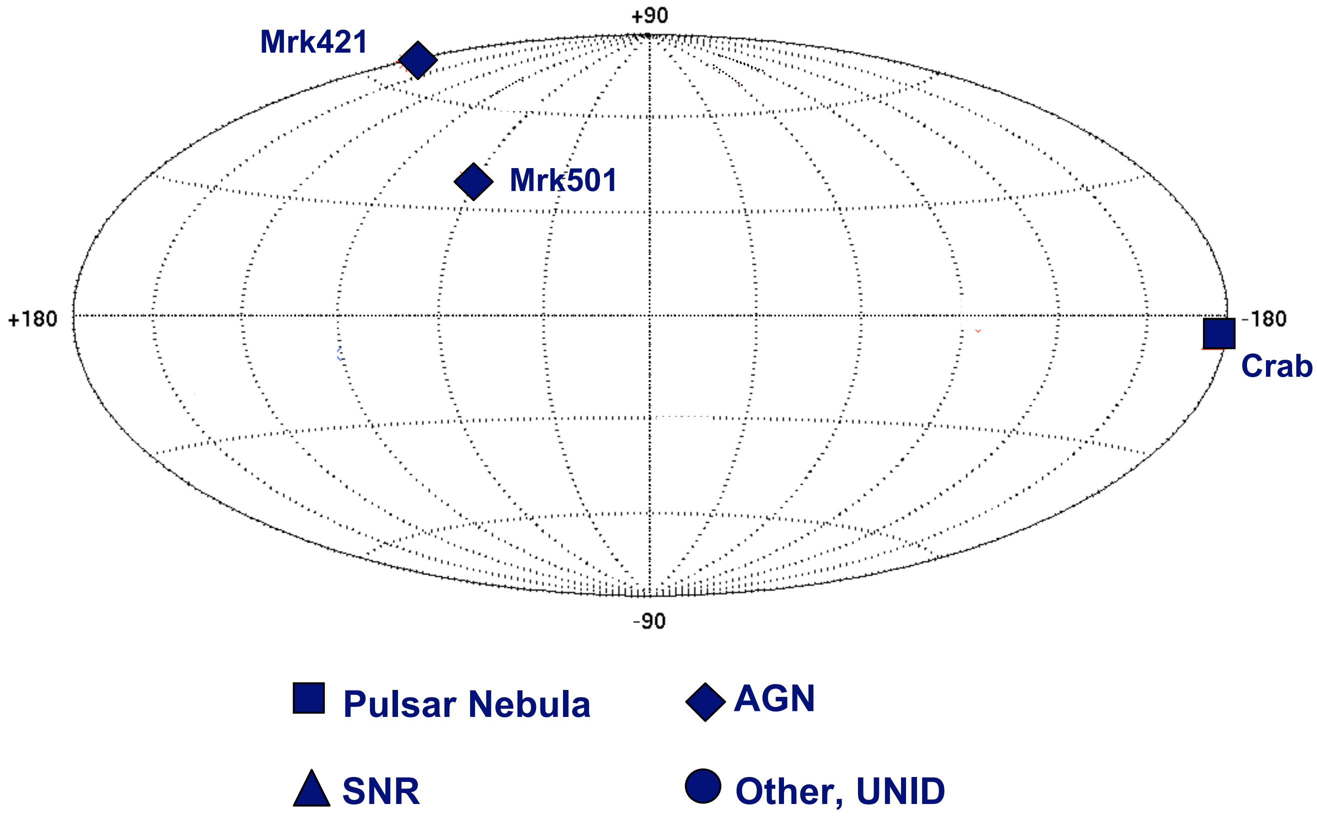
H2356-309	0.165	HESS
1ES 1218+304	0.182	MAGIC
1ES 1101-232	0.186	HESS

Galactic scan in gamma rays (HESS); 8 new sources

Micro-quasar LS 5039 (HESS); new type of VHE gamma-ray object

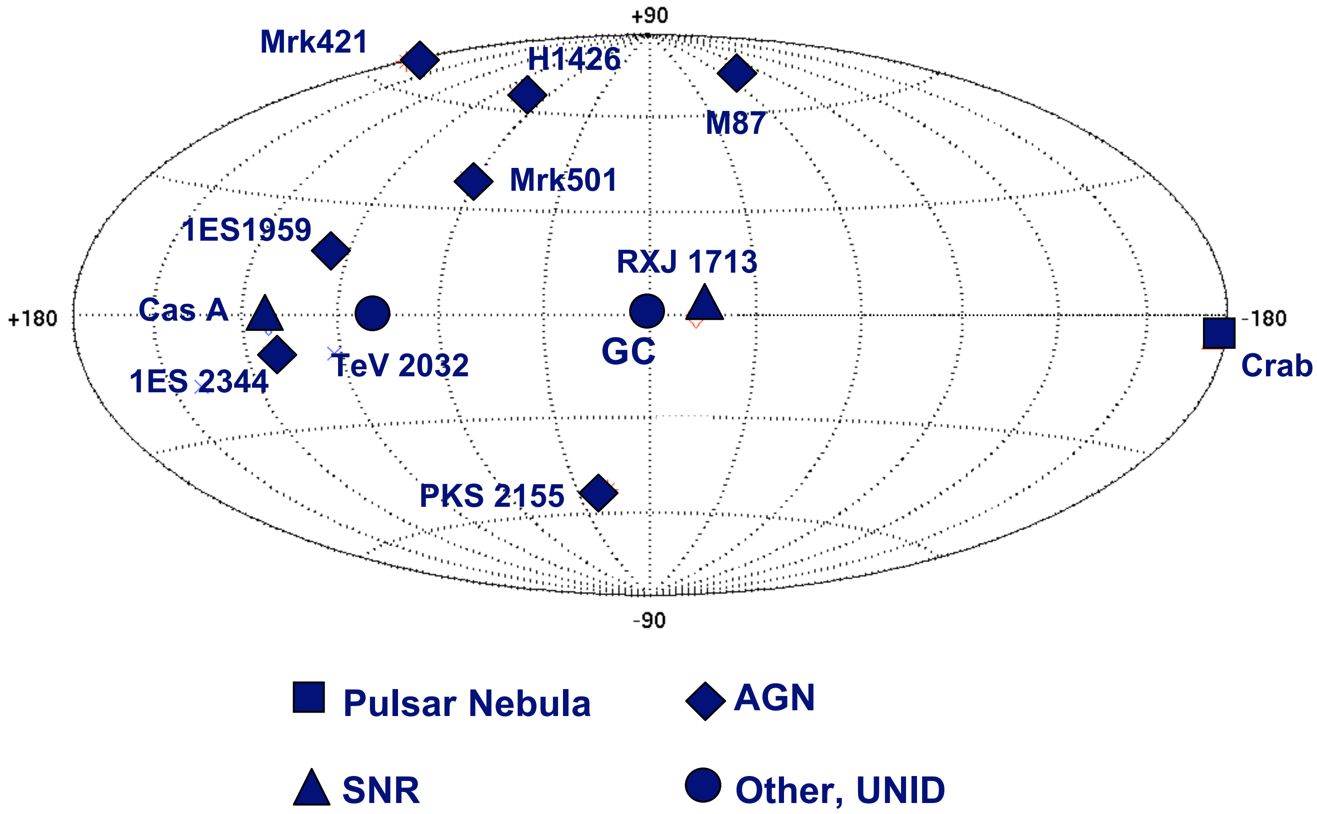
The VHE Sky - 1995

(R.A. Ong, ICRC 2005, Pune)



The VHE Sky - 2003

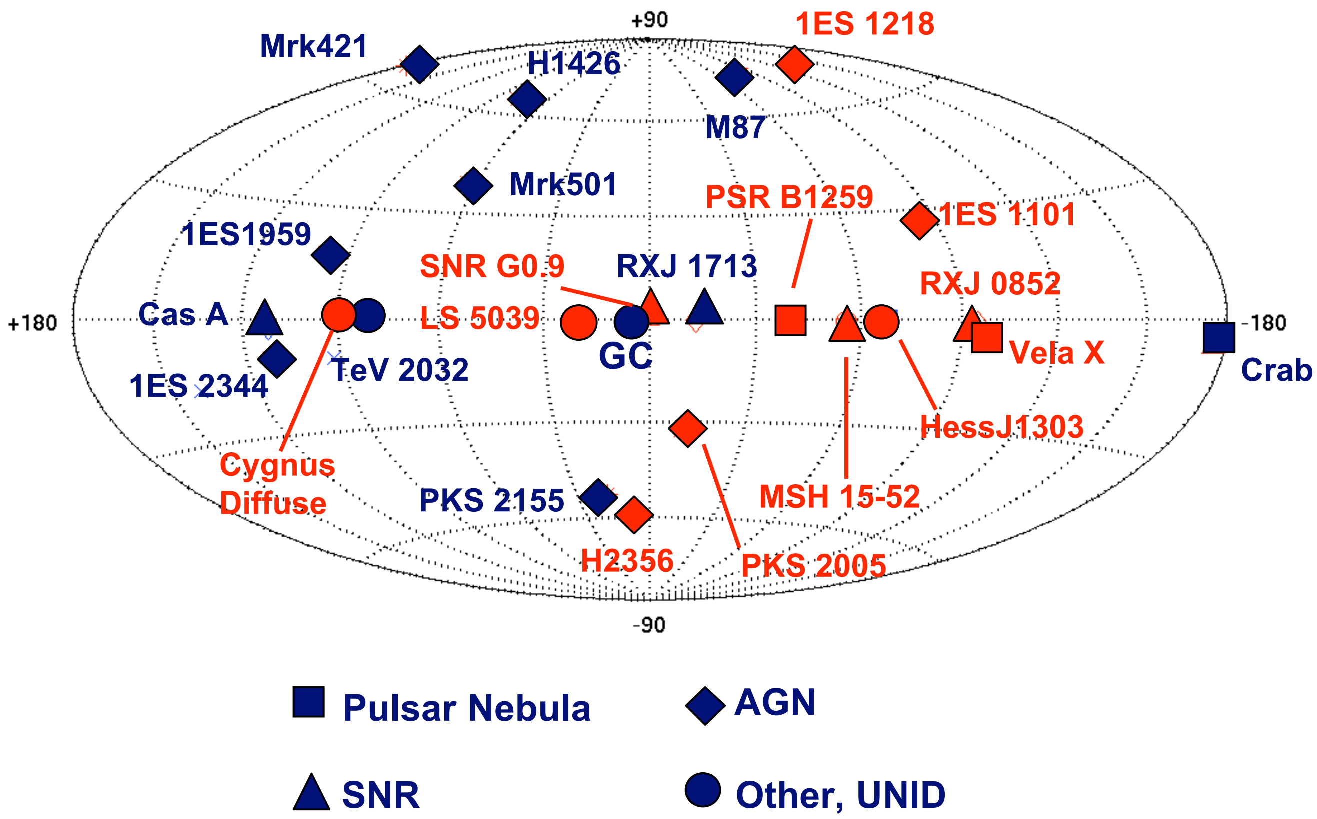
(R.A. Ong, ICRC 2005, Pune)



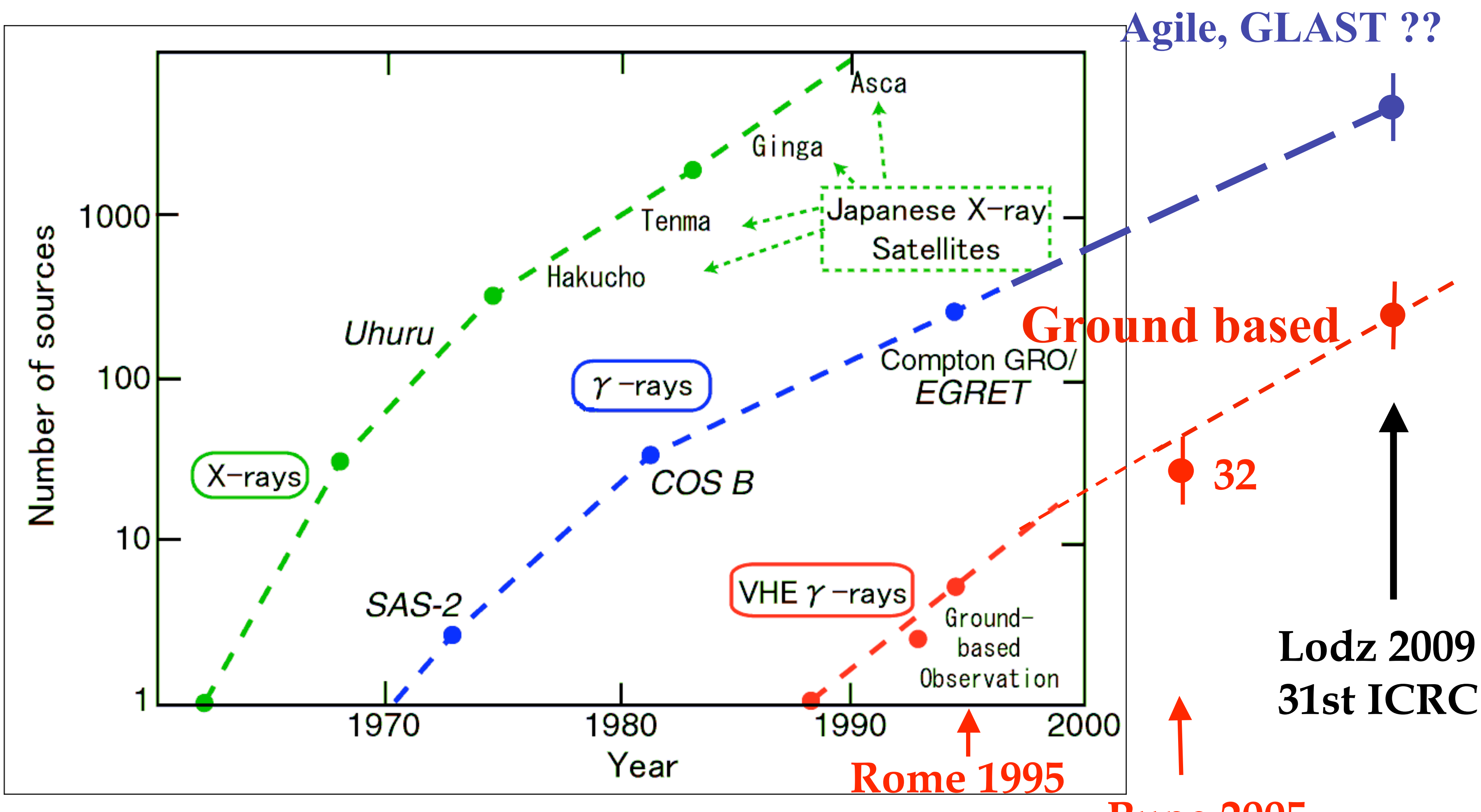
The VHE Sky - 2005

(R.A. Ong, ICRC 2005, Pune)

+ 8-15 add. sources in galactic plane.



“Kifune Plot”



Source count versus year [T. Kifune]

R.A. Ong, ICRC Pune (2005)

6 - CONCLUSIONS

MAGIC, as the other *new generation of instruments* that aim for exploring new gamma-ray energy domains, are *expected* to bring key data for understanding the "non-thermal Universe"

!!!! Very exciting time for gamma-ray astronomy !!!!

The real voyage, is not to travel to new landscapes, but to see with new eyes…

Marcel Proust
(1871-1922)