The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization
IAEA International Atomic Energy Agency

SMR/1842-19

International Workshop on QCD at Cosmic Energies III

28 May - 1 June, 2007

Lecture Notes

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VHE gamma astroparticle physics: MAGIC results and the future

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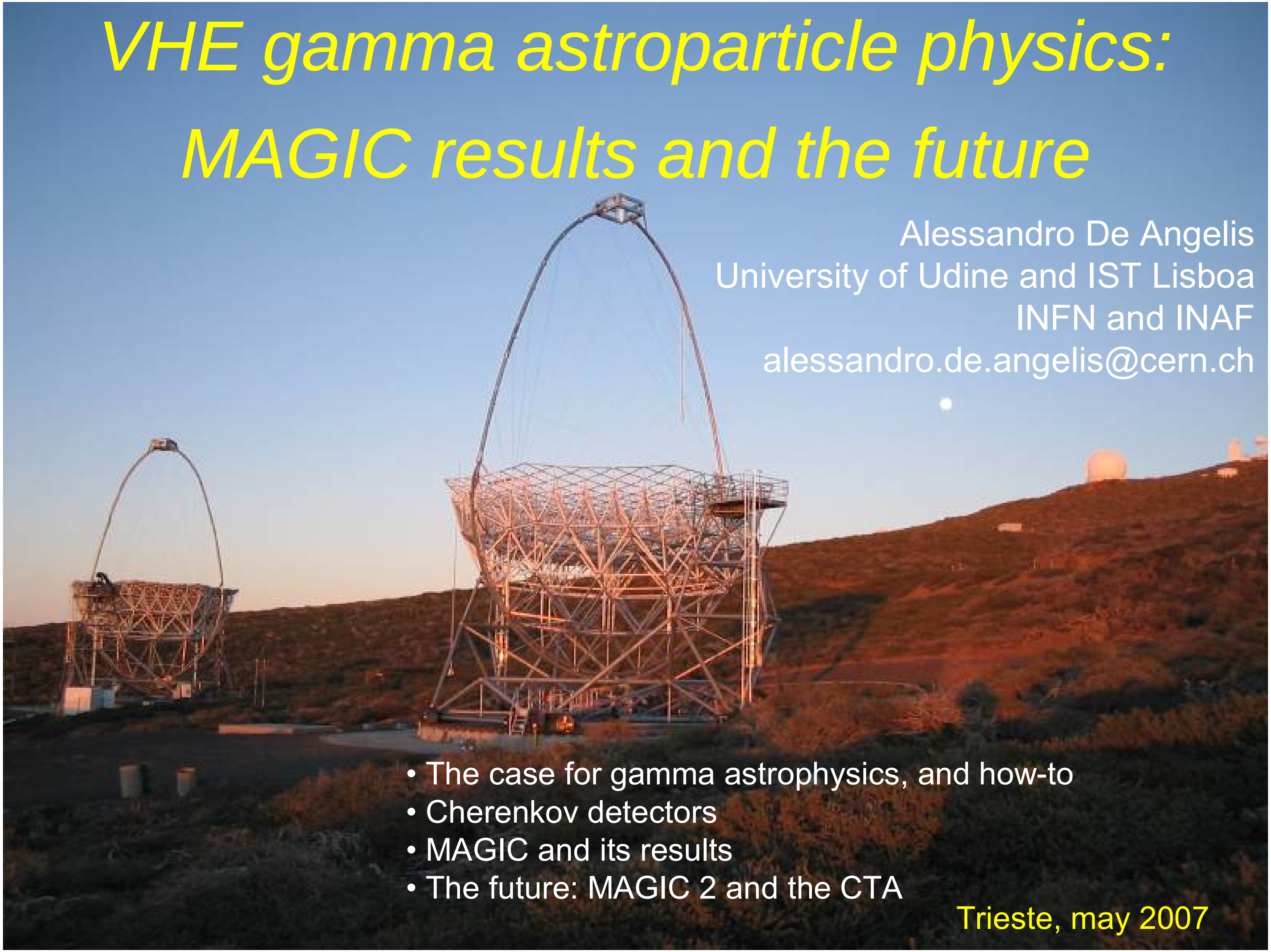


- The case for gamma astrophysics, and how-to
- Cherenkov detectors
- MAGIC and its results
- The future: MAGIC 2 and the CTA

Trieste, may 2007

Motivations for the study of gammas

- Probe the most energetic phenomena occurring in nature
  - Nonthermal
    - Nuclear de-excitation/disintegration
    - Electron interactions w/ matter, magnetic & photon fields
    - Matter/antimatter annihilations
    - Decay of unstable particles

⇒ Clear signatures from new physics

⇒ Insighs on the acceleration mechanisms

⇒ Relation gamma/hadrons

Motivations for the study of gammas - II

Penetrating

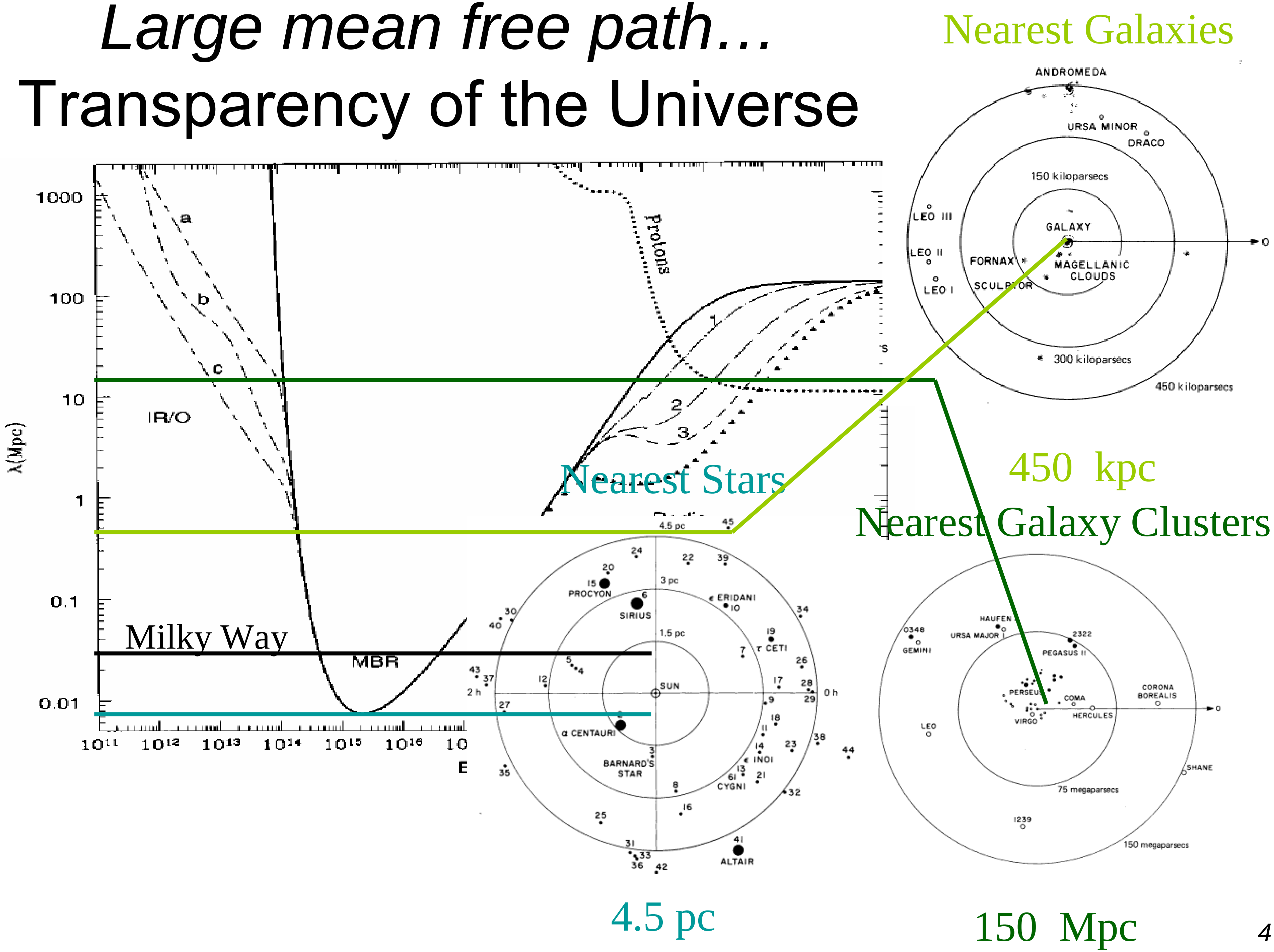
- No deflection from magnetic fields, point ~ to the sources
  - Magnetic field in the galaxy: ~ 1μG
    R (pc) = 0.01p (TeV) / B (μG)
    => for p of 300 PeV @ GC the directional information is lost

- Large mean free path

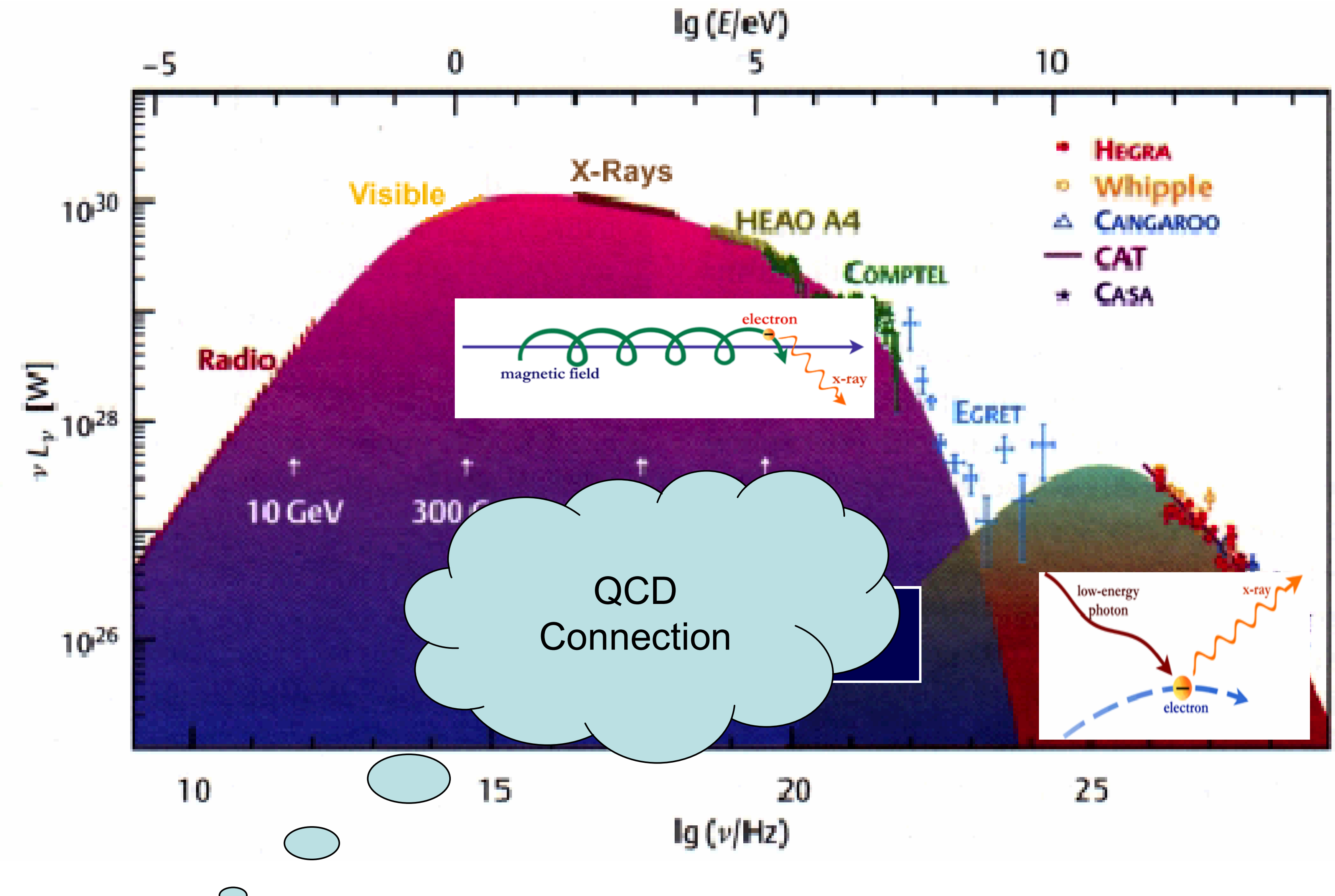
- Regions otherwise opaque can be transparent to X/γ

- We know how to detect them with a reasonable efficiency

Large mean free path…
Transparency of the Universe



Physics of the emission: the SSC

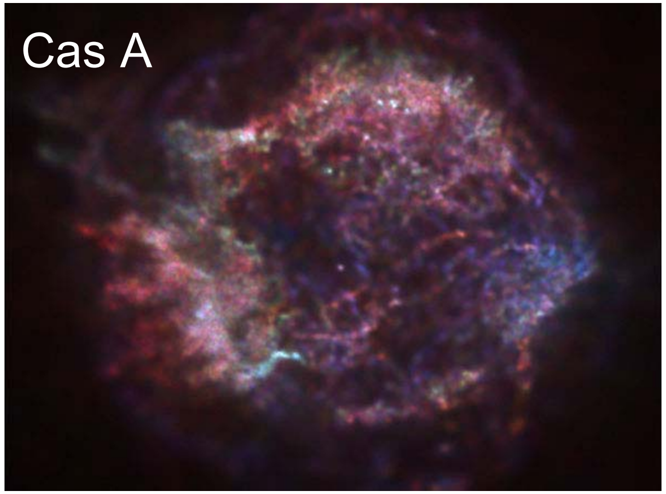


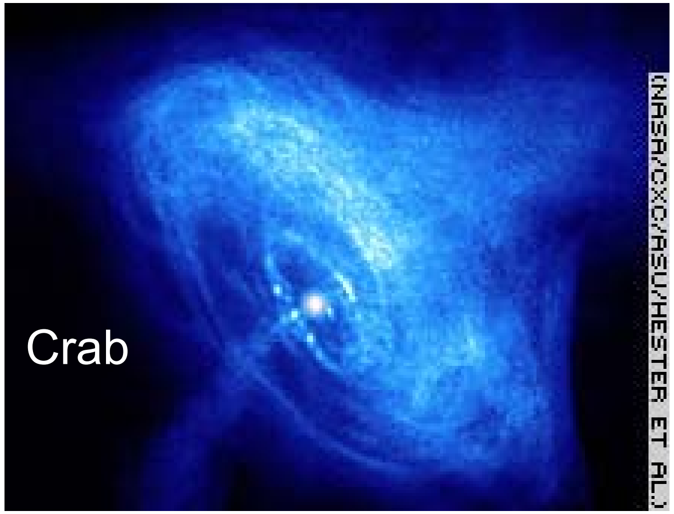
Plus hadronic reactions (cosmic rays?) – Clear signature in gamma
- Morphology

Possible CR sources - I

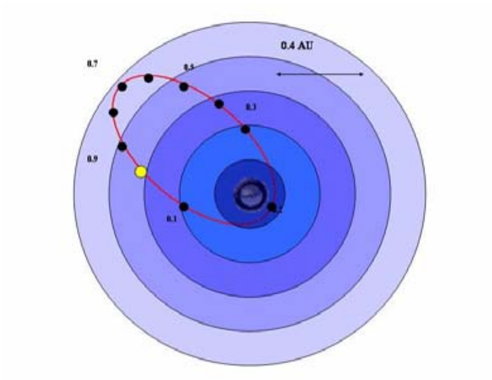
A large variety of sources has been proposed to feed nonthermal particle populations in the universe.

- **Supernovae.** The shock wave launched into the circumstellar medium after the collapse of a star, that has burnt its nuclear fuel, can very efficiently accelerate particles. Models predict that 10% or more of the kinetic energy of the explosion is transferred to high-energy particles.
- **Pulsars and pulsar nebulae.** Pulsars - rapidly rotating neutron stars left over, e.g., after a supernova explosion - exhibit large electric and magnetic fields and act like dynamos accelerating particles.





Possible CR sources - II



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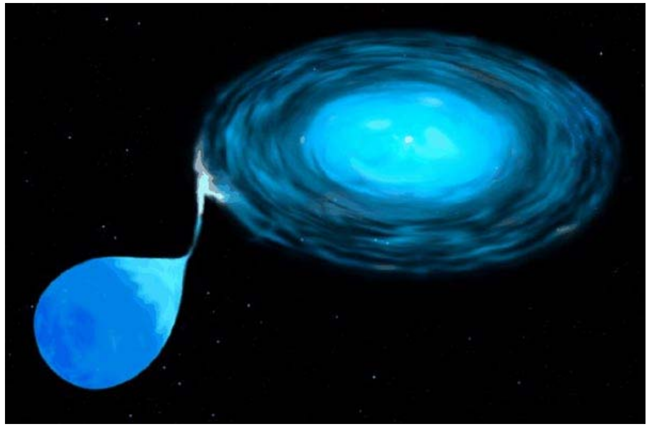
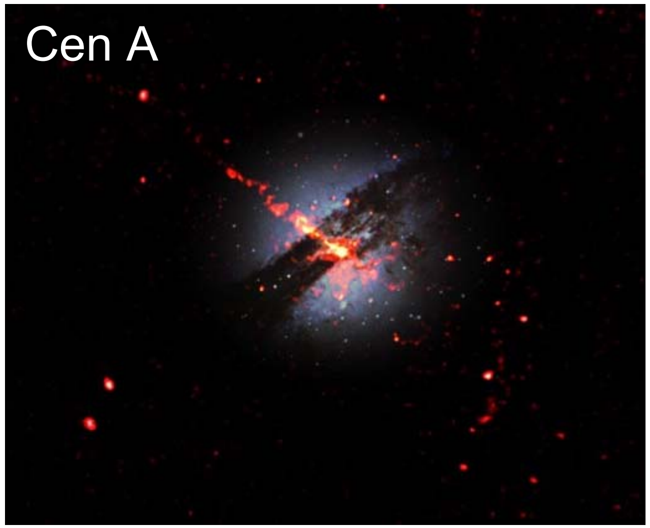
- **Binary systems** (one object accretes matter from the other) with the accretion disk surrounding the central massive object. The accreting object could either be a neutron star, or a black hole
- **Black holes in the centers of active galaxies.** Active galaxies are currently, together with the Crab Nebula, the best-explored sources of TeV gamma-rays, exp. due to the two objects Markarian 421 and 501, which show a large and highly time-variable gamma-ray flux.
- **Heavy relics of the Big Bang**, such as monopoles of cosmic strings, are predicted to have been generated in the Big Bang, and some of them might have survived until now. Decays of such objects could be the sources of the highest energy cosmic rays, and would also generate a steady flow of gamma-rays.
- **Gamma-Ray Bursts (GRB)**

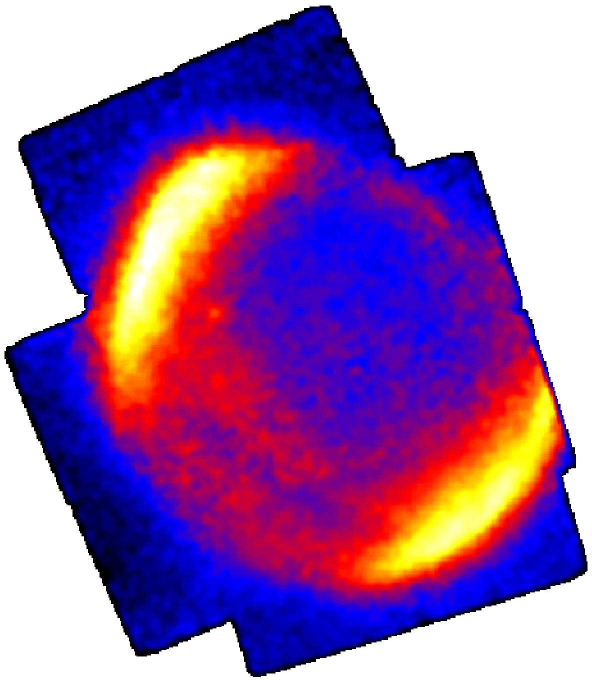




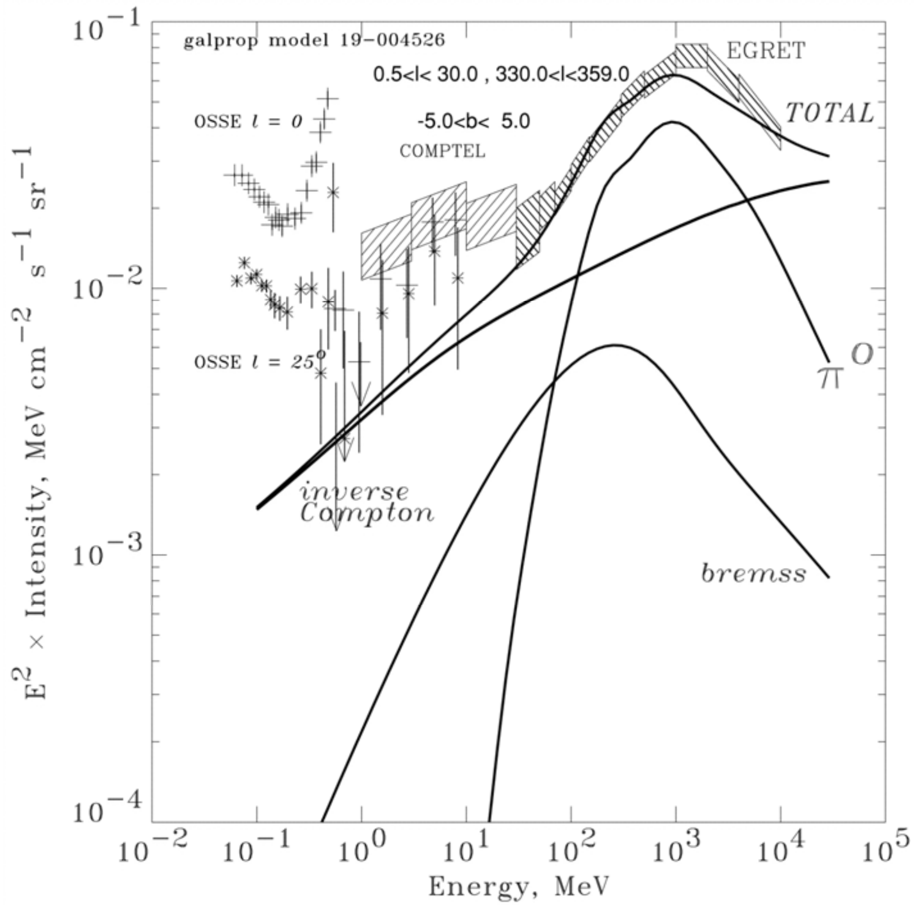
How to probe CR emission from SNRs
I – π^0

$$p + N_{ISM} \rightarrow \pi^o + X \rightarrow 2\gamma$$

- π^o gamma-ray bump near 70 MeV at SNRs, as seen in the diffuse galactic γ-radiation (Ginzburg and Syravotskii 1964; Hayakawa 1969)



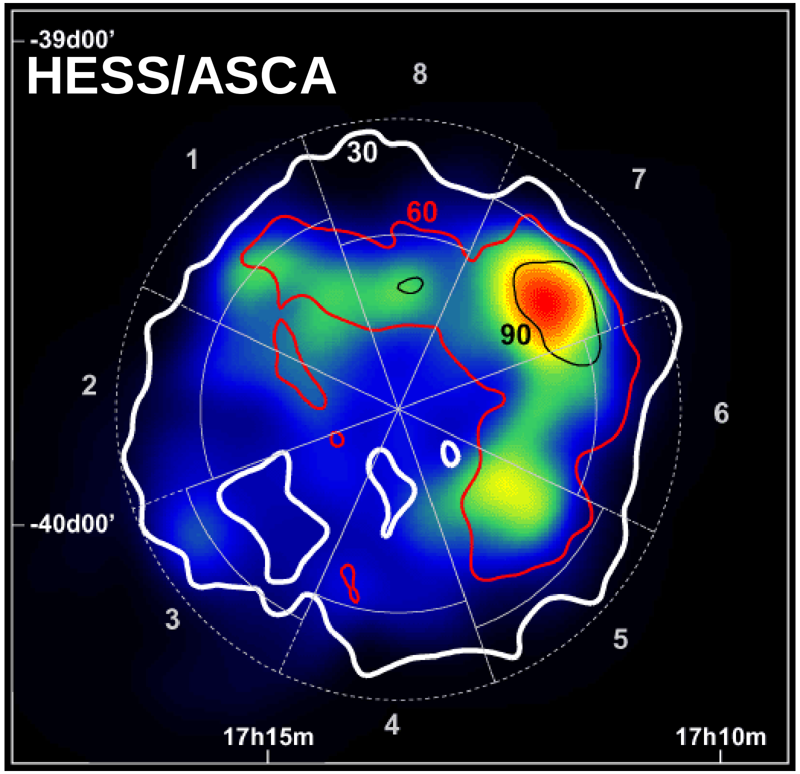
Evidence for nonthermal electron acceleration in SN 1006



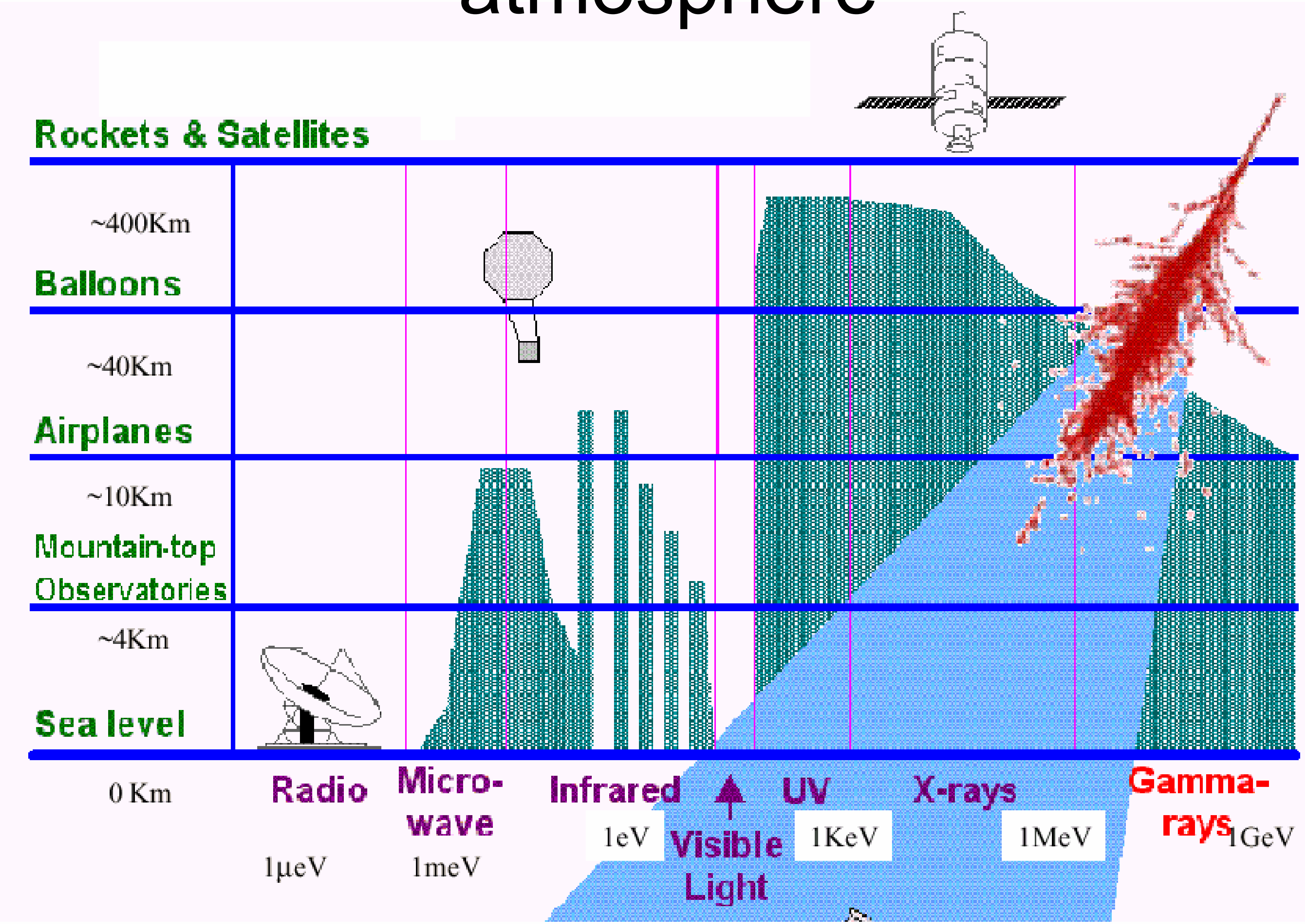
(Strong, Moskalenko, & Reimer 2000)

How to probe CR emission from SNRs
II – Source morphology

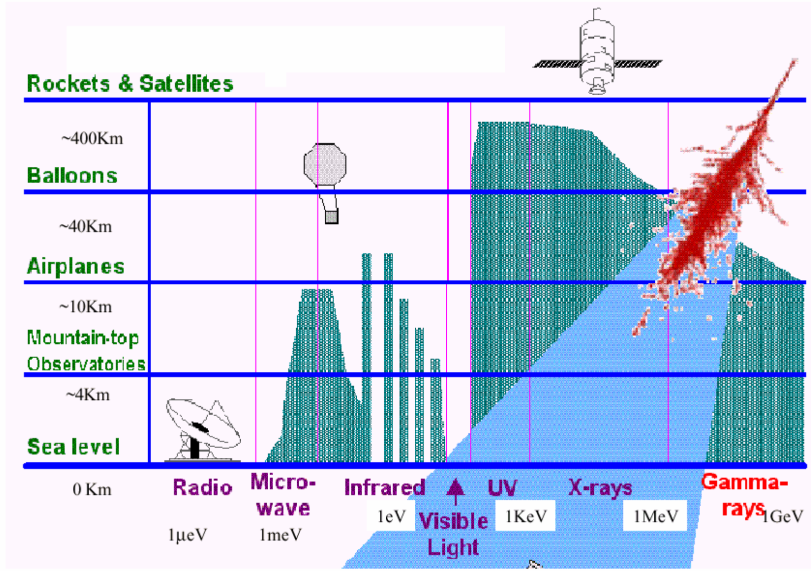
- HESS TeV gamma-ray observation of RX J1713-3946
  - Evidence for particle acceleration > 100 TeV.
  - Morphological similarity with X-ray observation.
  - Suggest leptonic origin?



Detection problem: opacity of the atmosphere



Consequences on the techniques



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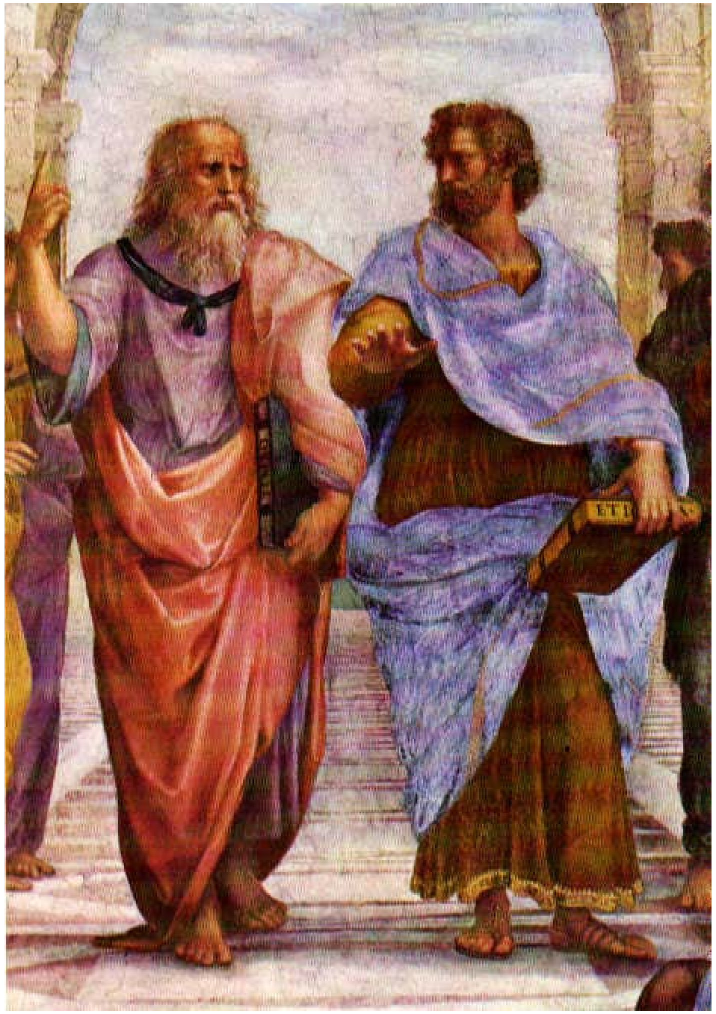
- The earth atmosphere (28 X_0 at sea level) is opaque to γ => **only sat-based detectors can detect primary γ**
- The fluxes of h.e. γ are low and decrease rapidly with energy
  - a perfect $1m^2$ detector would detect only 1 photon/2h above 10 GeV from the strongest sources

  => **with the present space technology, VHE and UHE gammas can be detected only from atmospheric showers**
  - Earth-based detectors, atmospheric shower satellites
- The flux from high energy charged cosmic rays is much larger

Space- and ground-based instruments



- primary detection
- small effective area ~1m^2
  - lower sensitivity
- large angular opening
  - search
- large duty-cycle
- large cost
- low energy
- low bkg

(GLAST, AGILE)

- secondary detection
- huge effective area ~10^4 m^2
  - Higher sensitivity
- small angular opening (IACT)
- small duty-cycle
- low cost
- higher energy
- high bkg

(MAGIC, HESS, VERITAS)

Satellites and atmospheric: complementary, w/ moving boundaries

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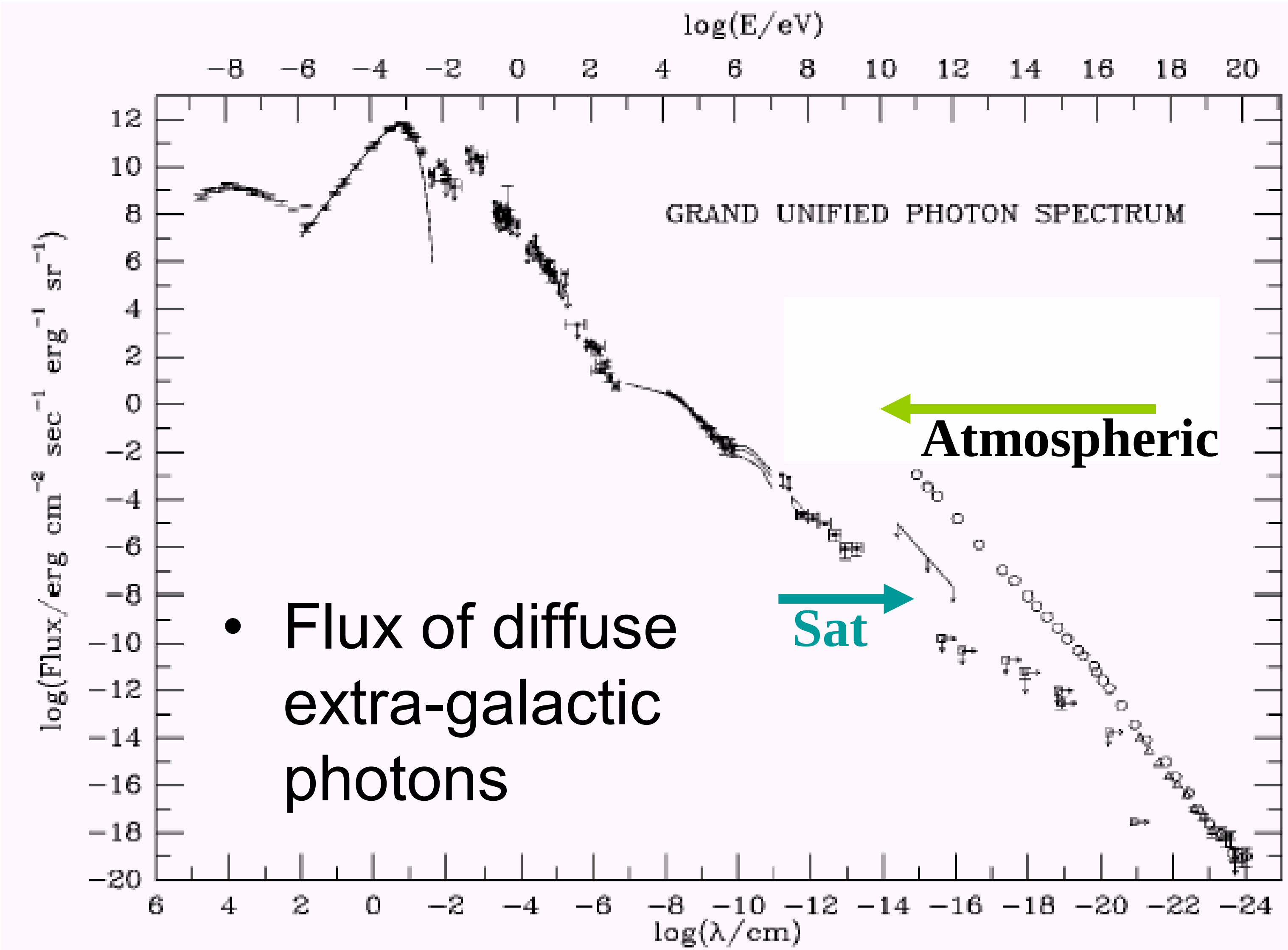
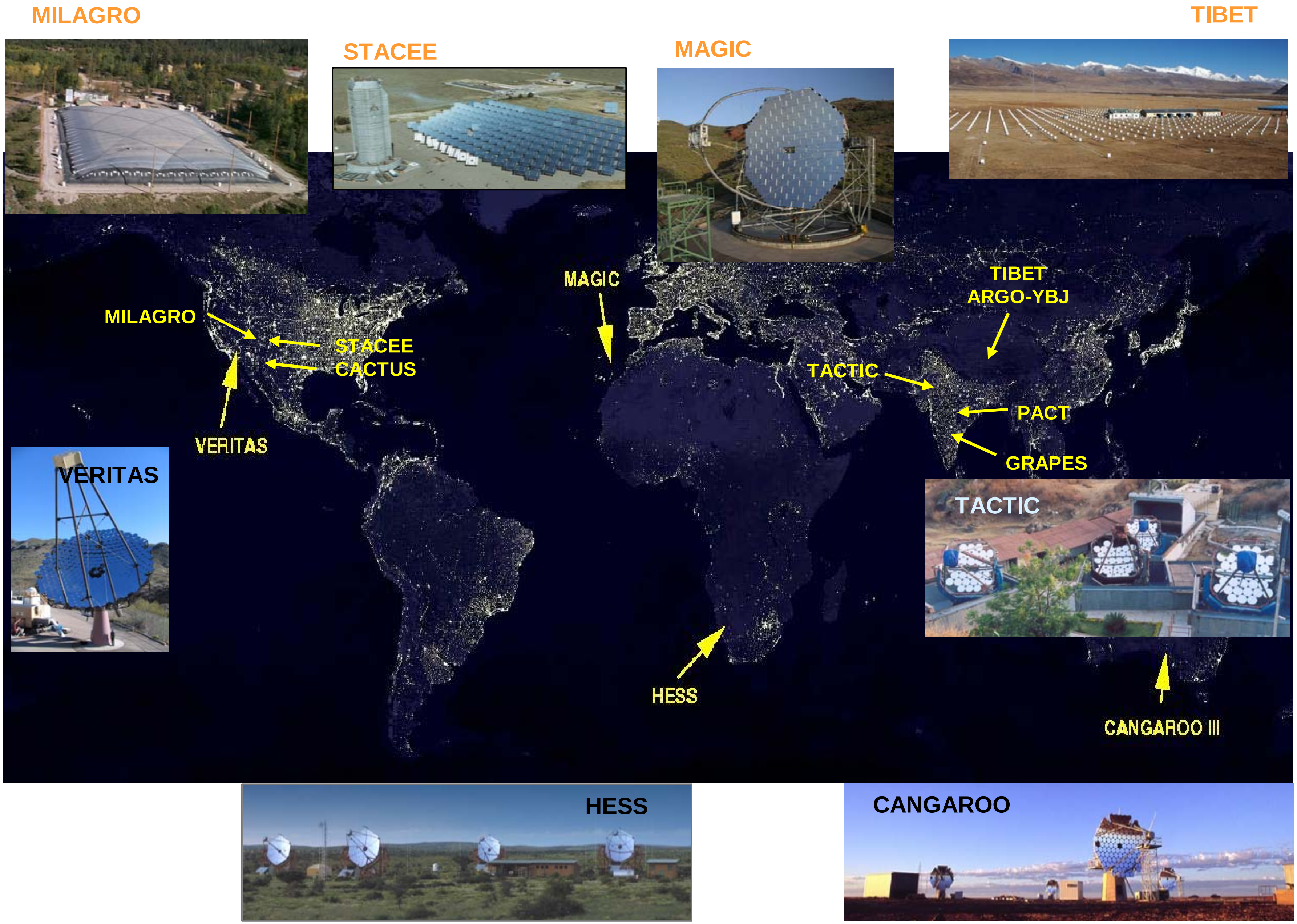


- Flux of diffuse extra-galactic photons

The Experimental VHE World (in progress)



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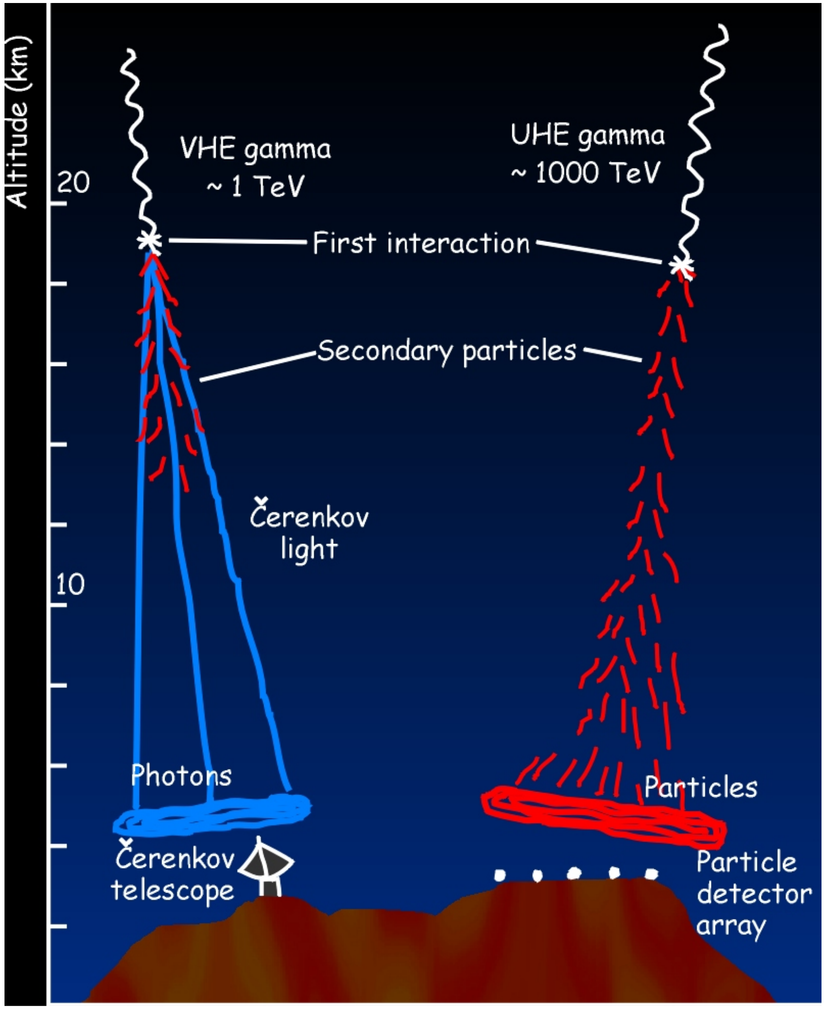
Ground detectors: EAS vs. IACT



- EAS (Extensive Air Shower): detection of the charged particles in the shower

  High altitude, threshold ~500 GeV

=> A posteriory, we know that ~5 sources only can be seen with a sensitivity ~ 1 Crab

- Cherenkov detectors: (IACT): detection of the Cherenkov light from charged particles in the atmospheric showers

Ground-based detectors: Cherenkov telescopes

- Breakthrough in high-energy astrophysics:

  IACTs established as astronomical tools

- Big step within last 2 years:
  - quantitative (x 10 number of detected sources)
  - qualitative (unprecedented high quality)

COMING OF (GOLDEN?) **AGE FOR CHERENKOV TELESCOPES !**

Cherenkov (Č) detectors
Cherenkov light from γ showers

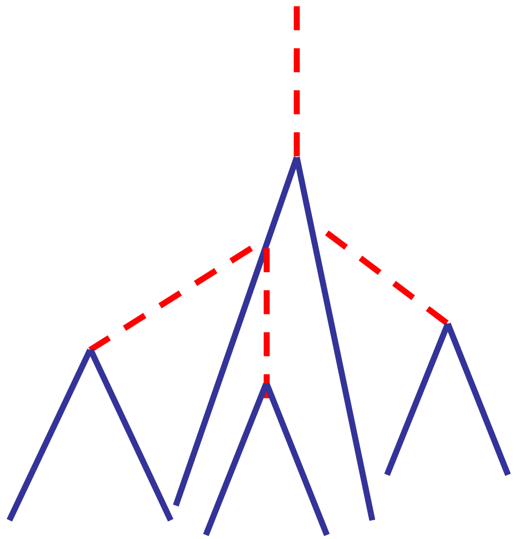
- Č light is produced by particles faster than light in air
- Limiting angle cos $\theta_c \sim 1/n$
  - $\theta_c \sim 1.3^o$ at sea level, 1^o at 8 km asl
  - Threshold @ sea level : 21 MeV for e, 44 GeV for μ

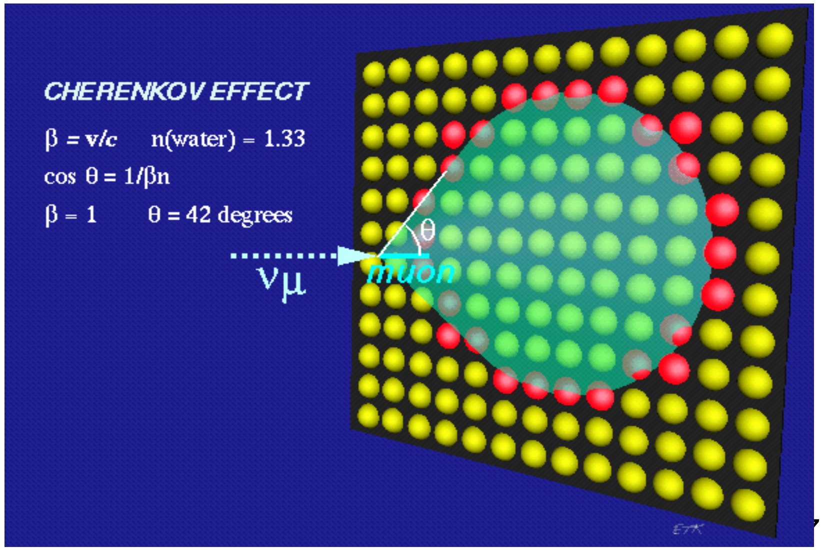
Maximum of a 1 TeV γ shower ~ 8 Km asl

200 photons/m^2 in the visible

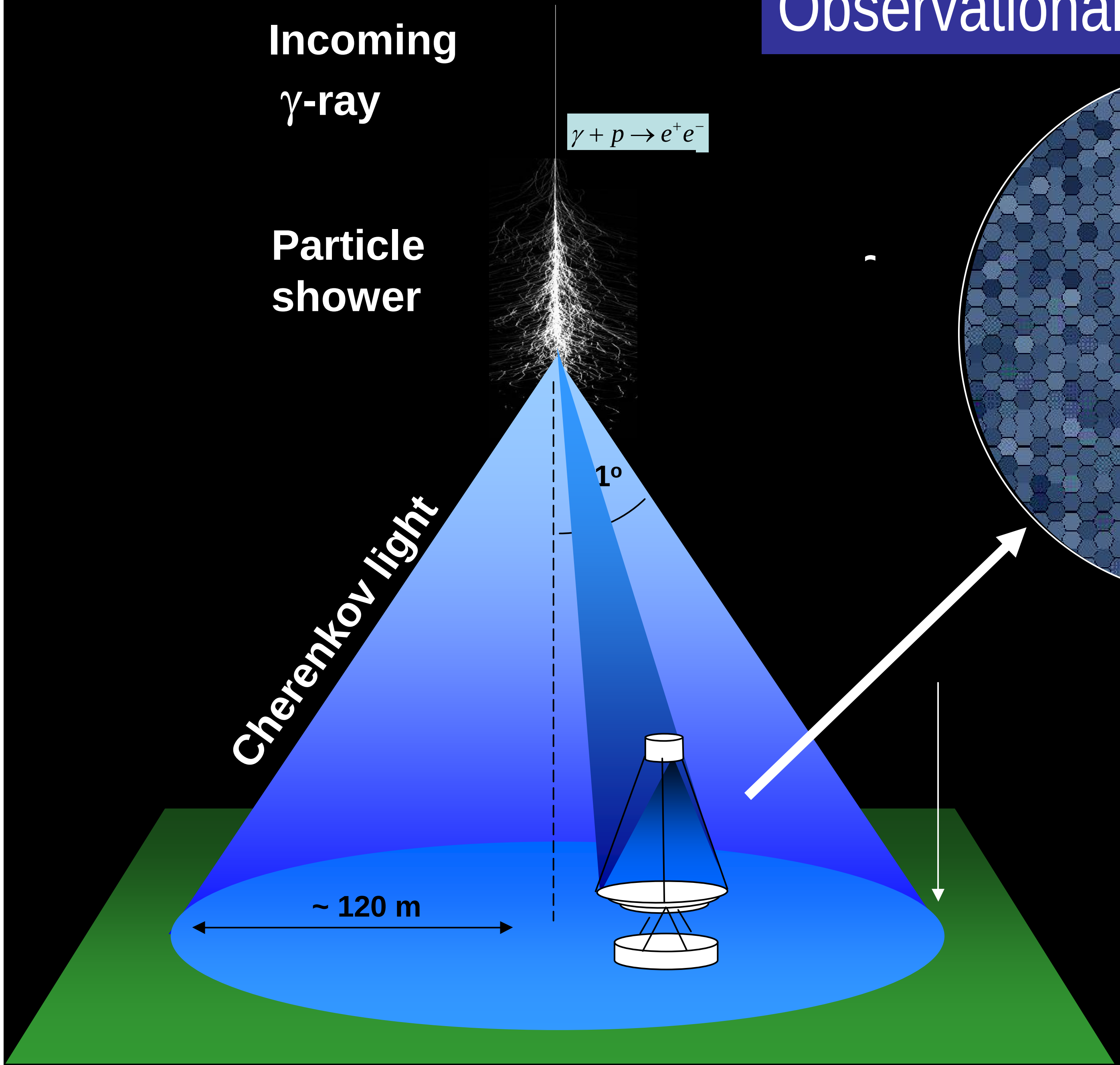
Duration ~ a few ns

Angular spread ~ 0.5º





Observational Technique



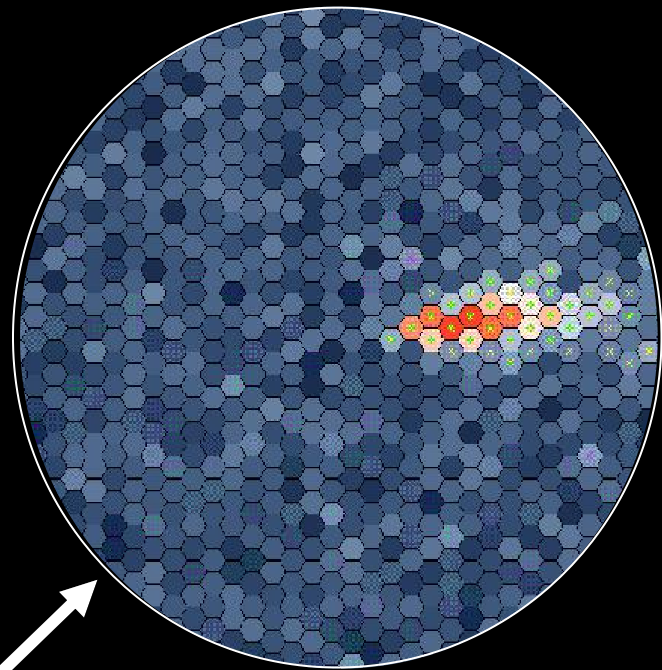
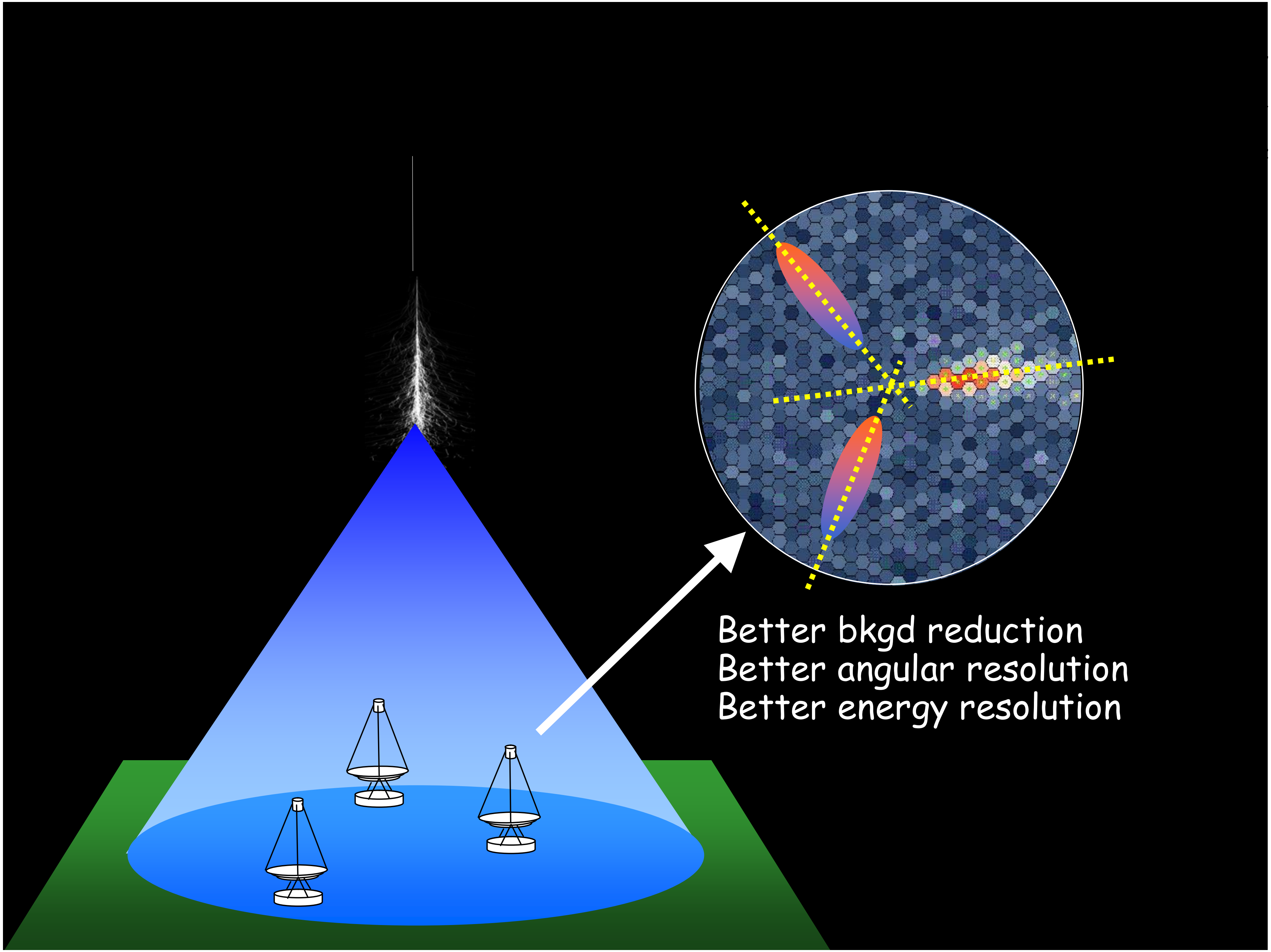


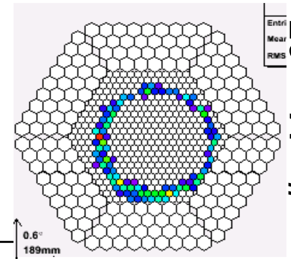
Image intensity
➔ Shower energy

Image orientation
➔ Shower direction

Image shape
➔ Primary particle


Better bkgd reduction
Better angular resolution
Better energy resolution

Gamma / hadron separation μ



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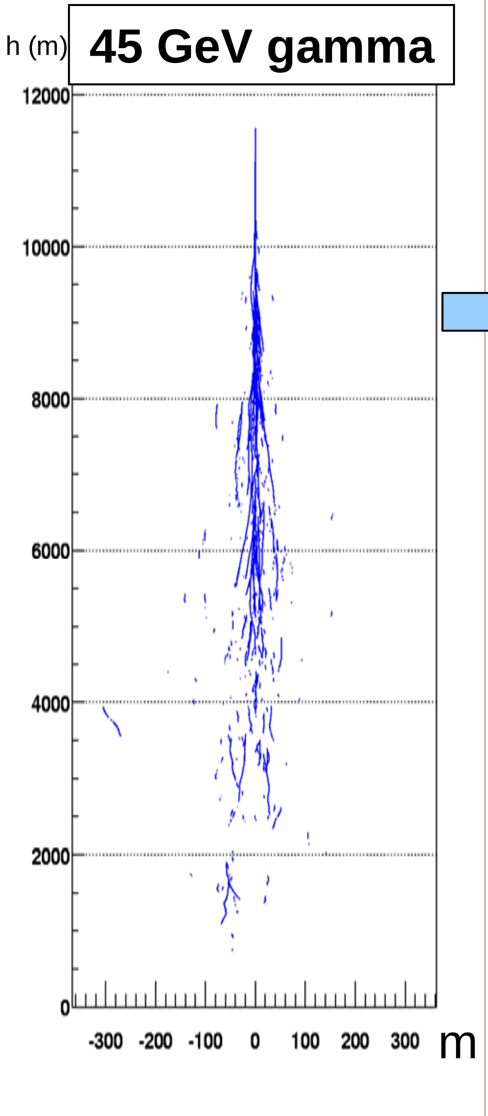
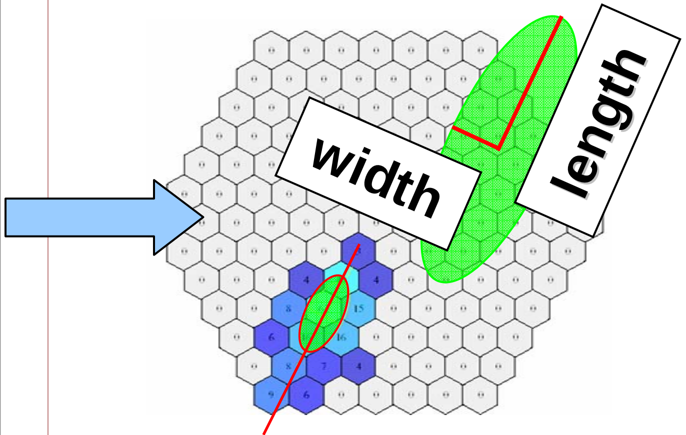
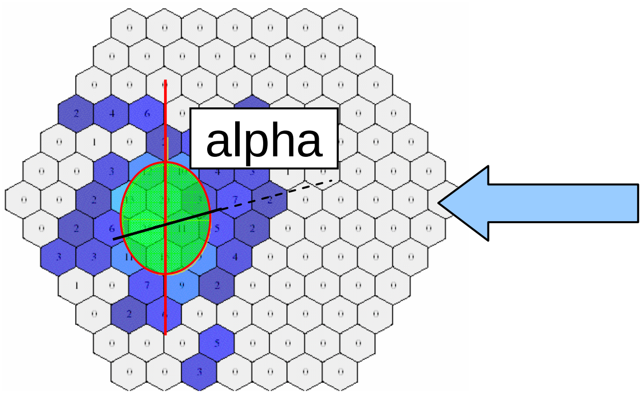
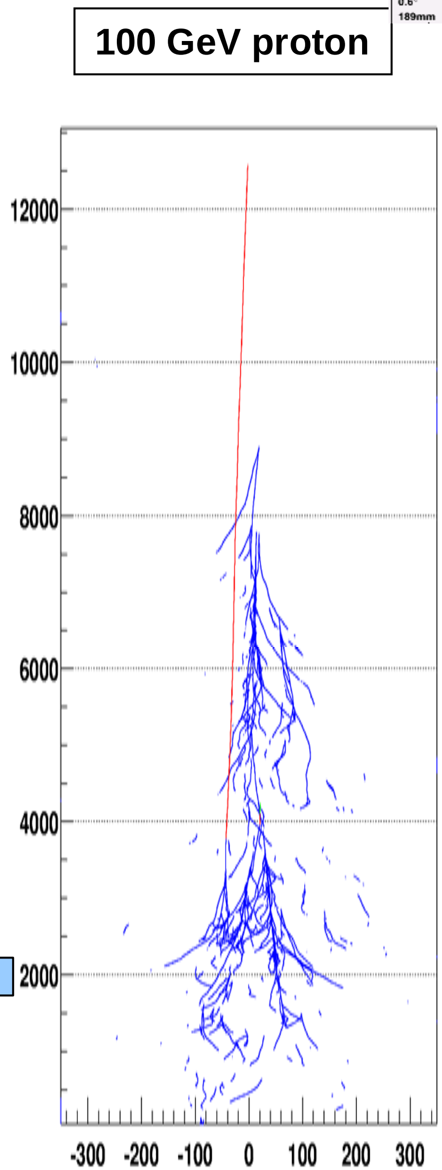


Gamma shower
(narrow, points to source)

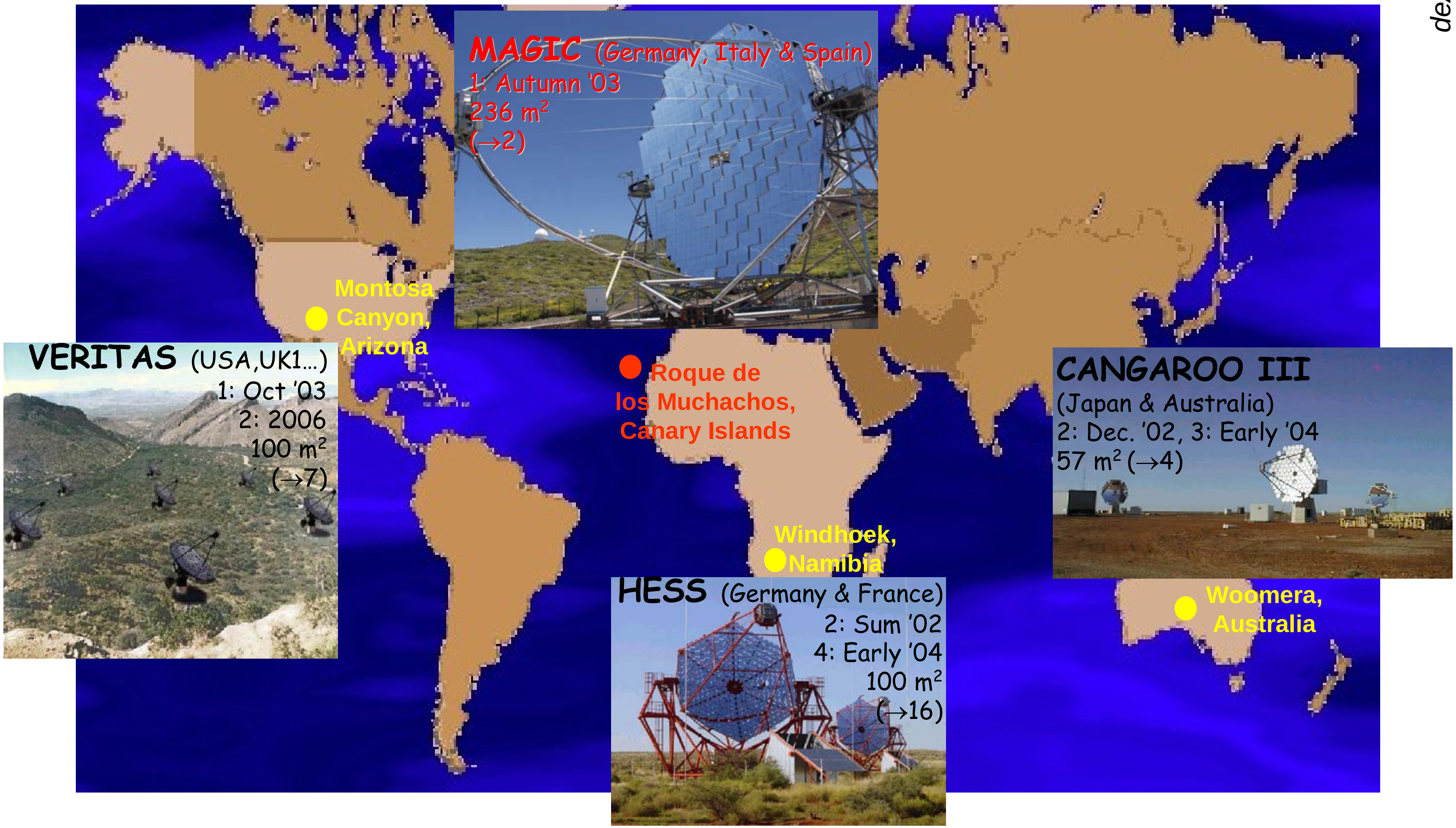


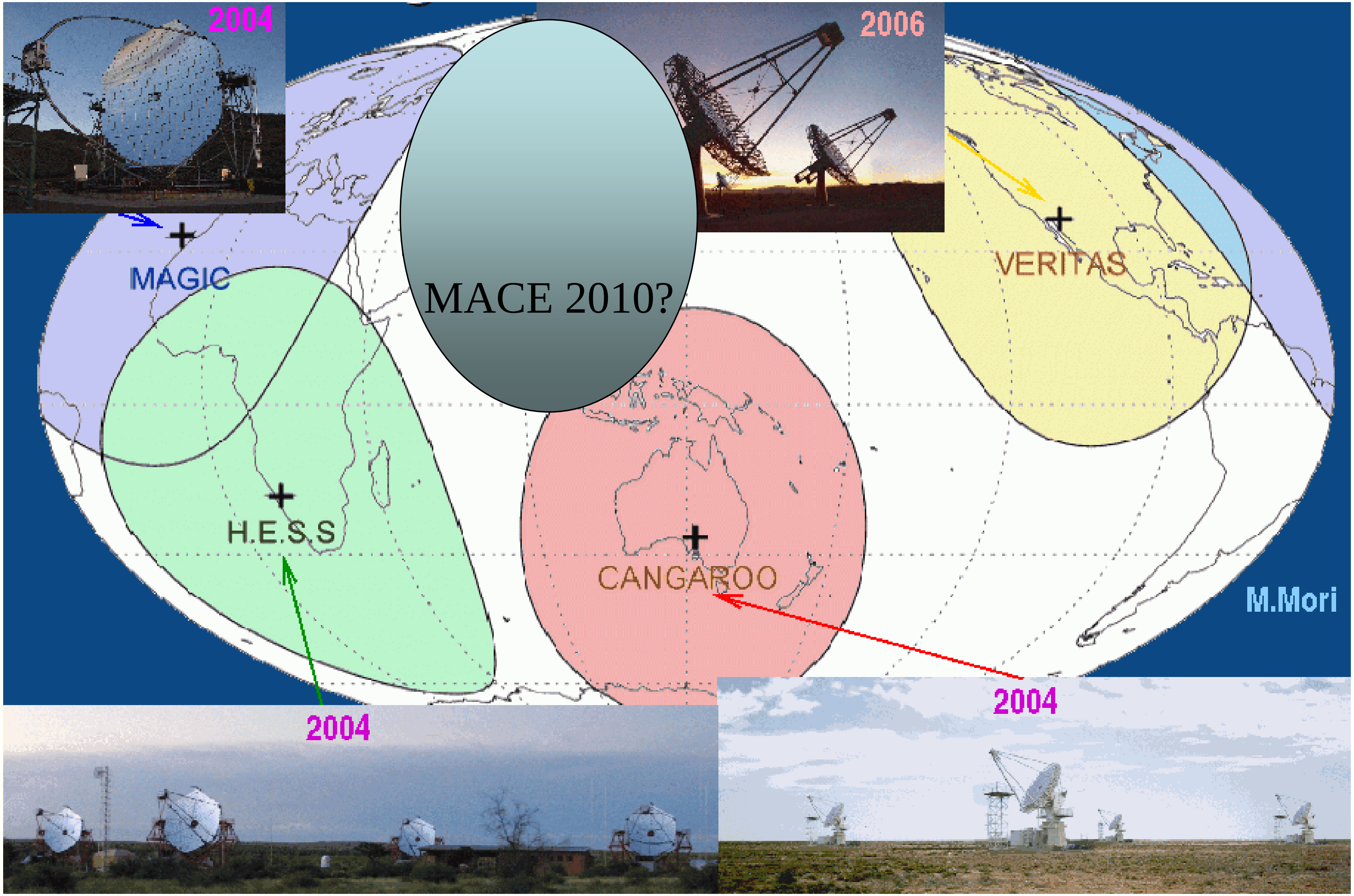
Proton shower
(wide, points anywhere)





Present IACTs: the "Big Four"



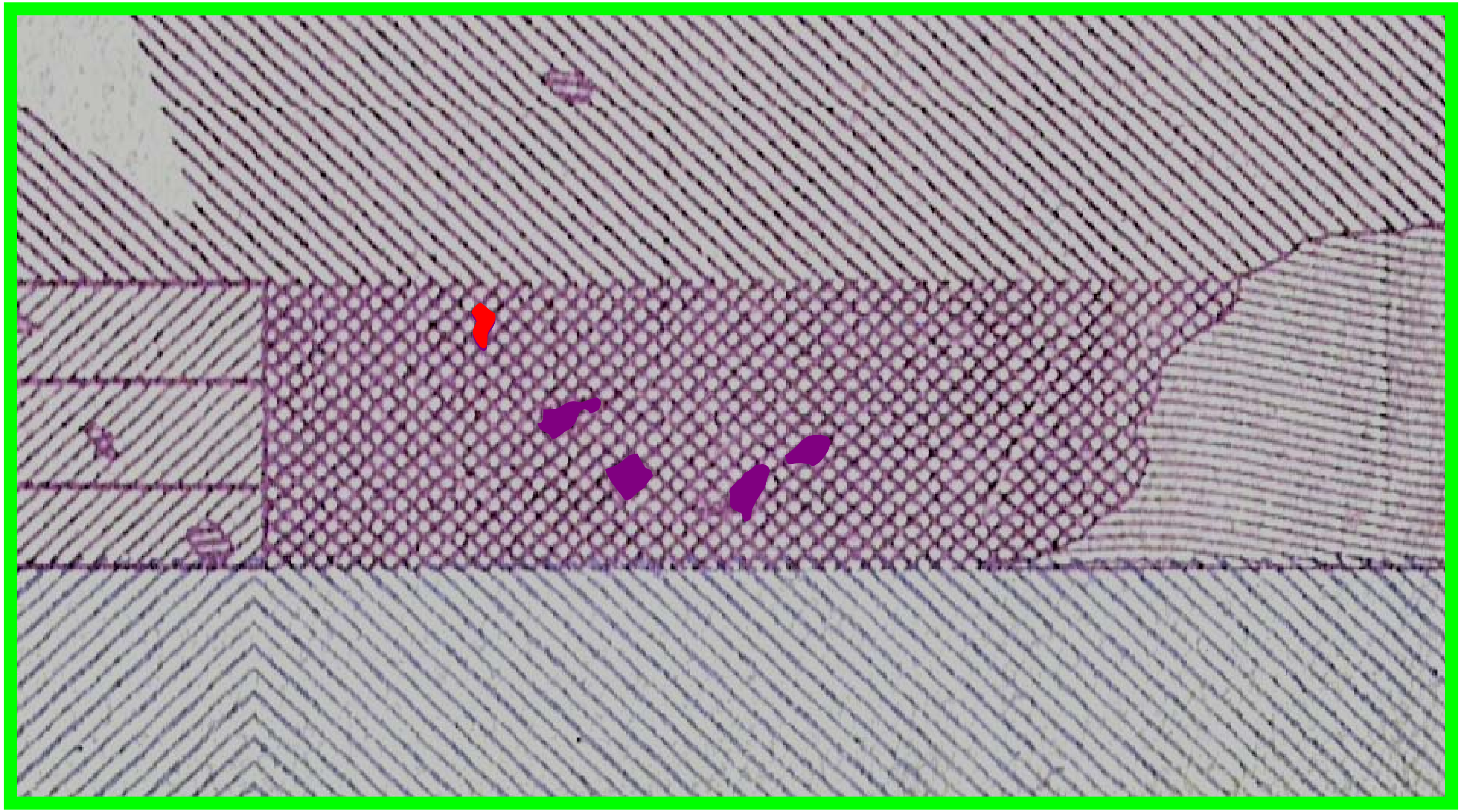


Overlap of the 'Big4' allows for ~continuous observations

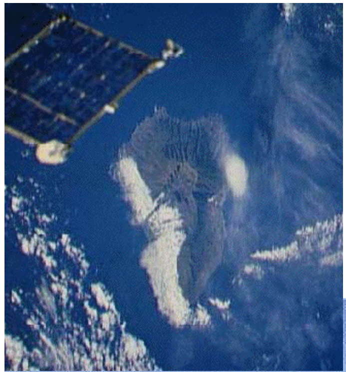
In progress: MoU to balance between competition and cooperation

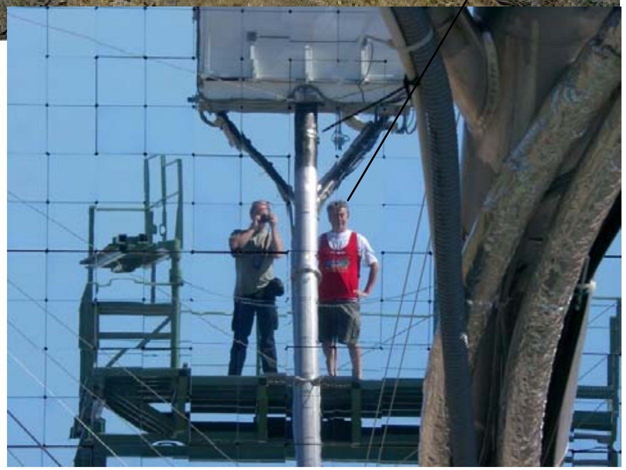
MAGIC

MAGIC



The MAGIC site





Telescopio
Nazionale Galileo

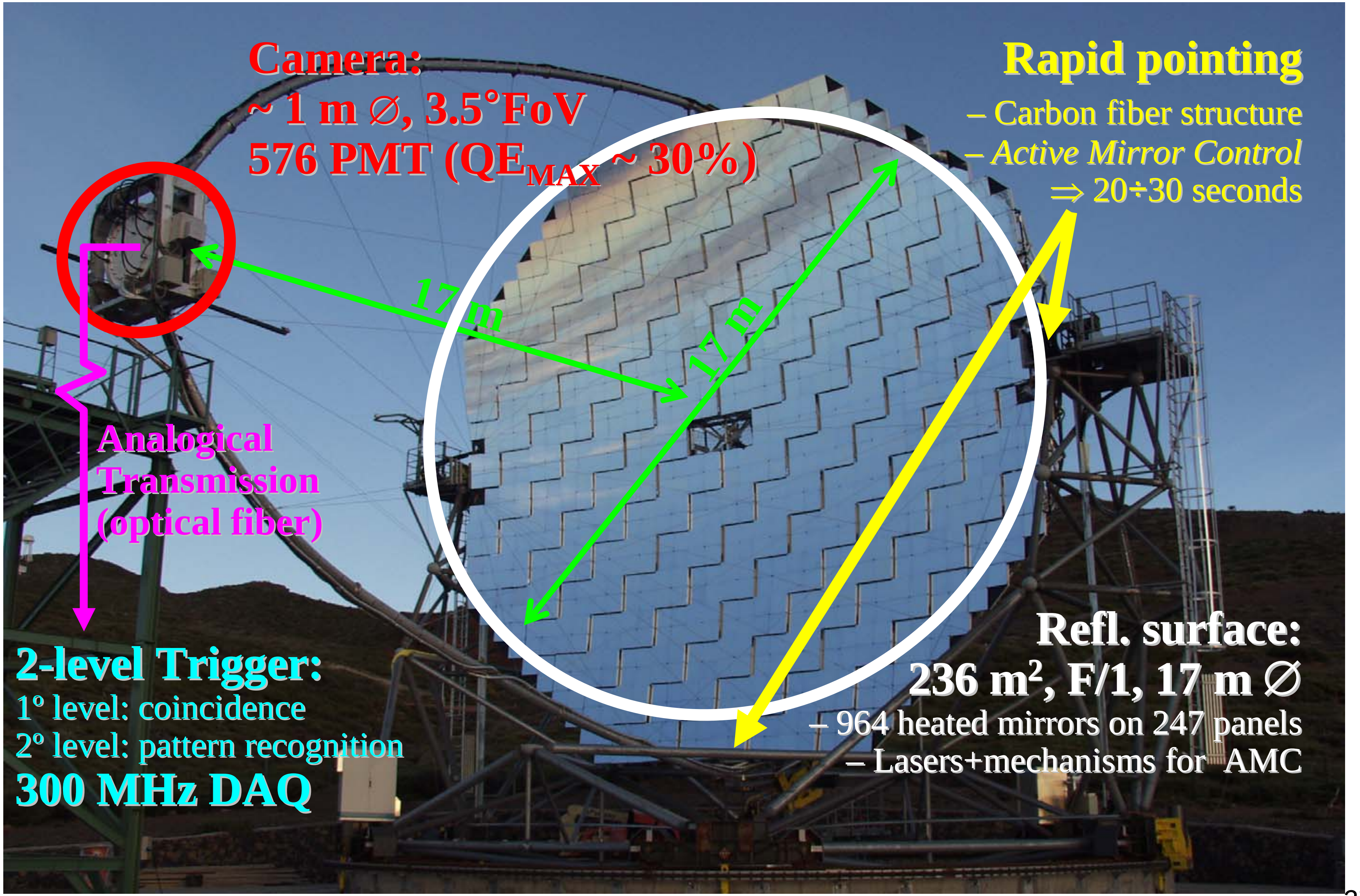
MAGIC

The MAGIC Collaboration

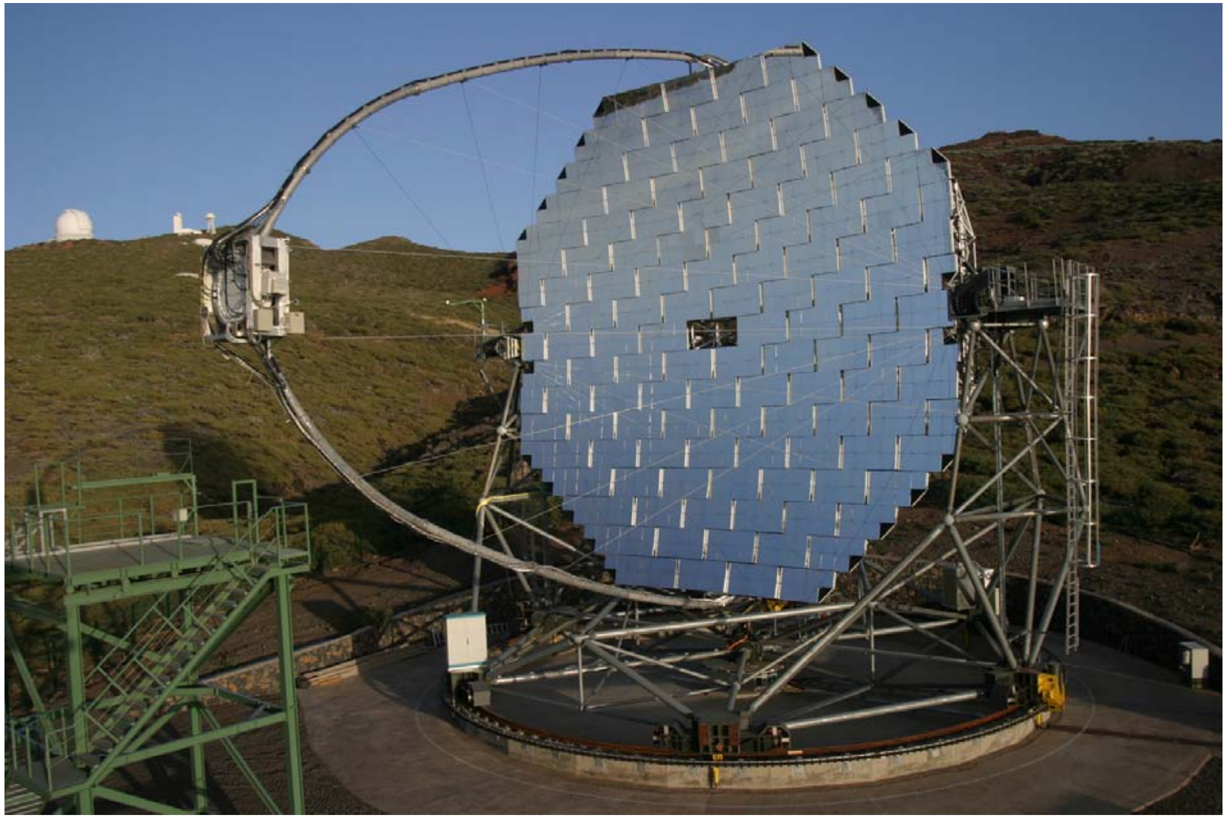
Archaiologia

- First presentation in 95 at the ICRC, Rome, (*Bradbury et al.*)
- Design study spring 1998
- Approval of funding late 2000
- Start of construction in 2001 in ORM, La Palma (2200 m a.s.l.)
- Inauguration October 10th in 2003
- First detections of Crab Nebula and Mrk421 February 2004
- Commissioning until fall 2004 (completion in Sept 2004)
- Regular observations since winter 2004/2005

MAGIC



Camera:
~ 1 m ∅, 3.5°FoV
576 PMT (QE$_{MAX}$ ~ 30%)
Rapid pointing
– Carbon fiber structure
– *Active Mirror Control*
⇒ 20÷30 seconds
17 m
17 m
Analogical Transmission (optical fiber)
2-level Trigger:
1º level: coincidence
2º level: pattern recognition
300 MHz DAQ
Refl. surface:
236 m^2, F/1, 17 m ∅
– 964 heated mirrors on 247 panels
– Lasers+mechanisms for AMC



After upgrade of the optics in July 2004 the telescope is in its final shape

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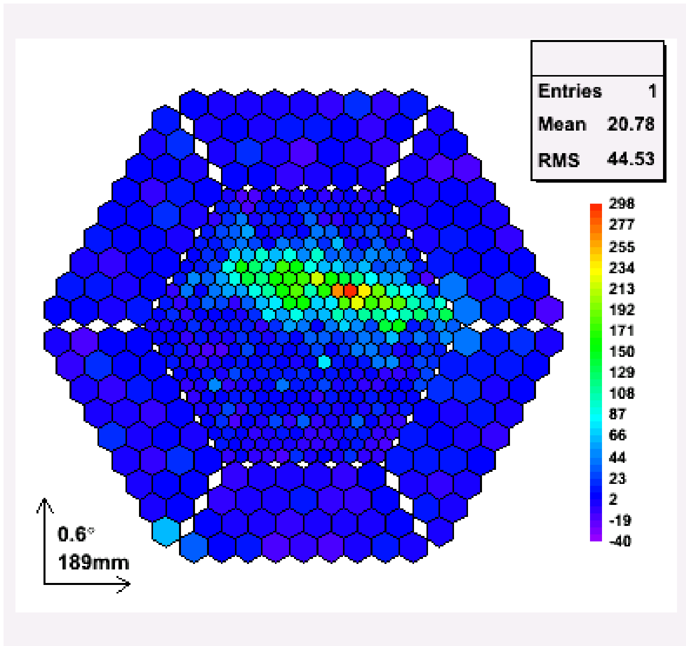
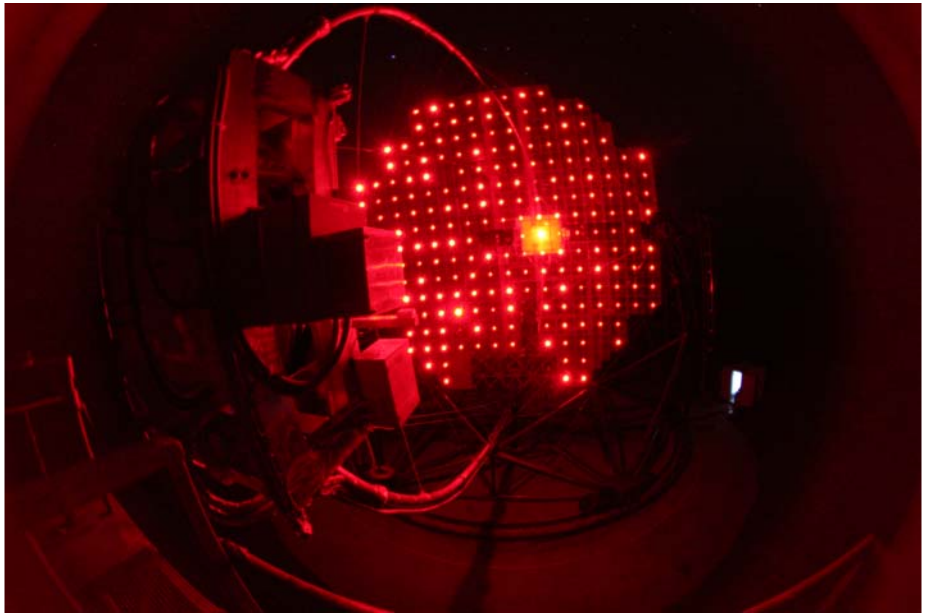
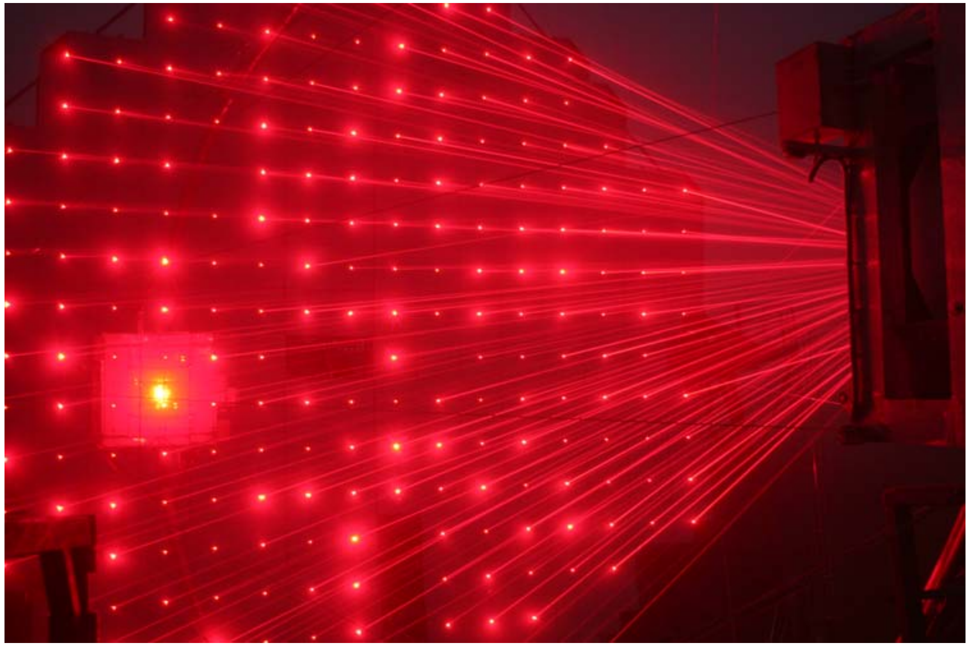


~300Hz shower rates
E_{th} ~40GeV

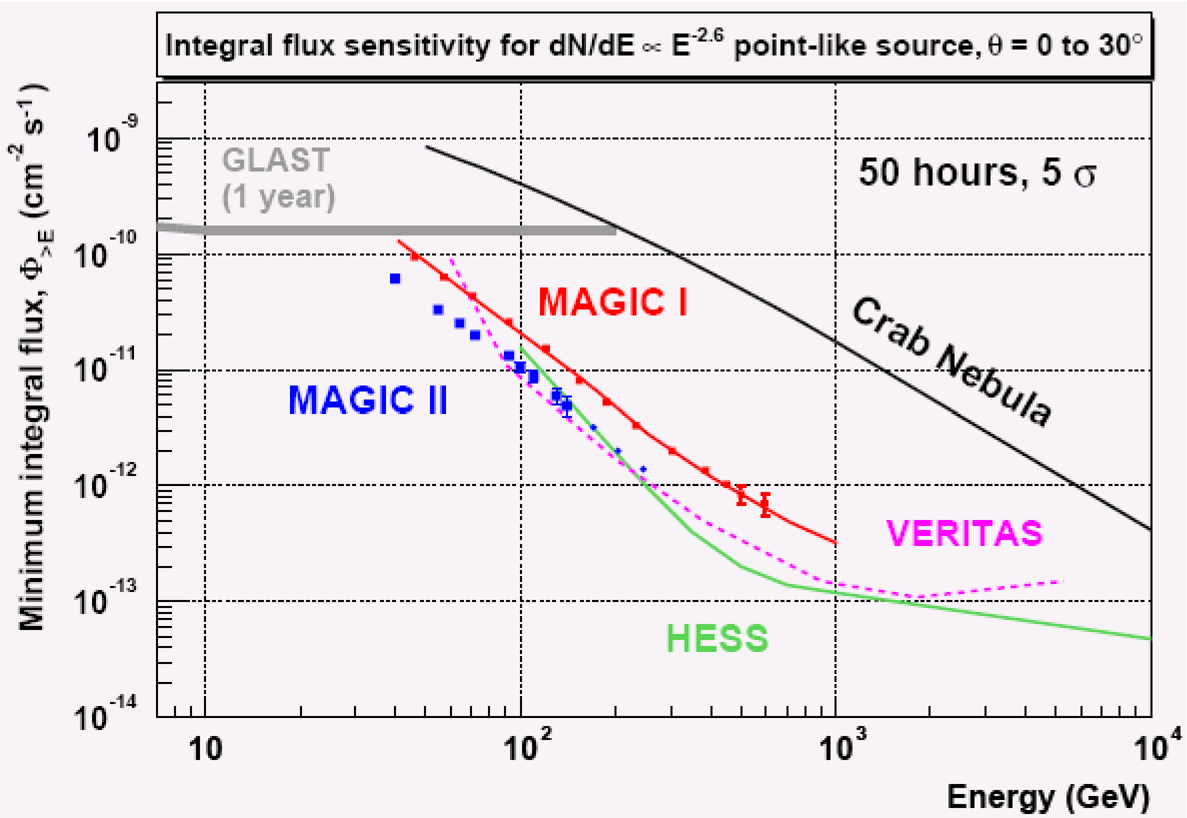
the Active Mirror Control laser beams





Photograph of the 576-pixel imaging camera of MAGIC-I. In the central part one can see the 396 high resolution pixels of 0.1° size. Those are surrounded by 180 pixels of 0.2°.

The Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) telescope: parameters

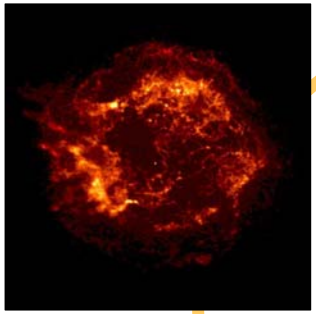


956 0.5m x 0.5m aluminum mirrors
Parabolic shape
Diameter: 17m – area: 240 m2
f/D = 1
Al mirrors + *C* fiber → low weight
Slew time ~ 20 s
Hexagonal camera: FOV: 3.8°

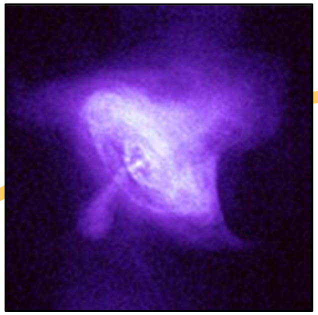
E(threshold) ~ 50 GeV
Sensitivity: 0.05 Crab in 50 hrs
Angular resol.: 0.1 deg
Energy resol.: 30%

World's largest IACT => lowest threshold

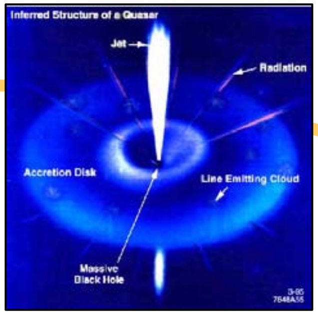
The Physics Program



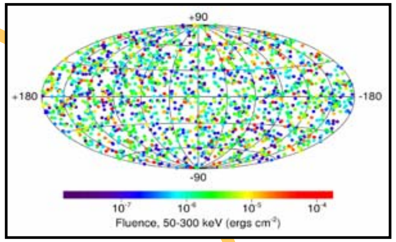
SNRs



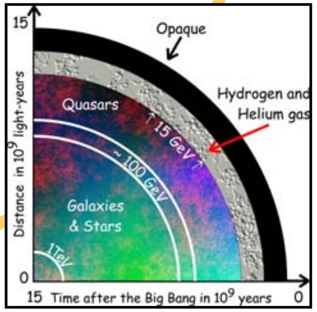
Pulsars



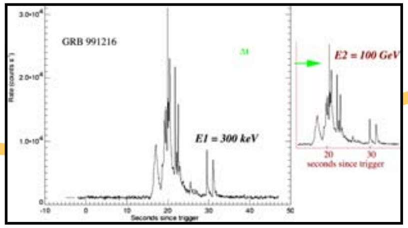
AGNs



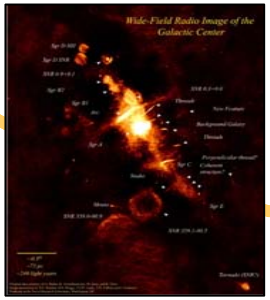
GRBs



cosmological
γ-Ray Horizon



Quantum Gravity
effects



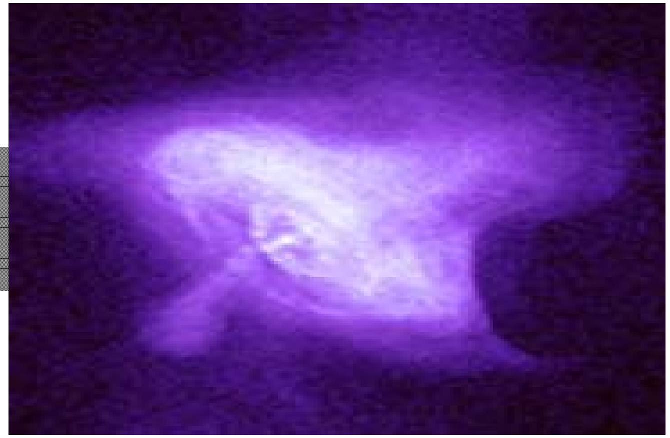
Cold Dark
Matter

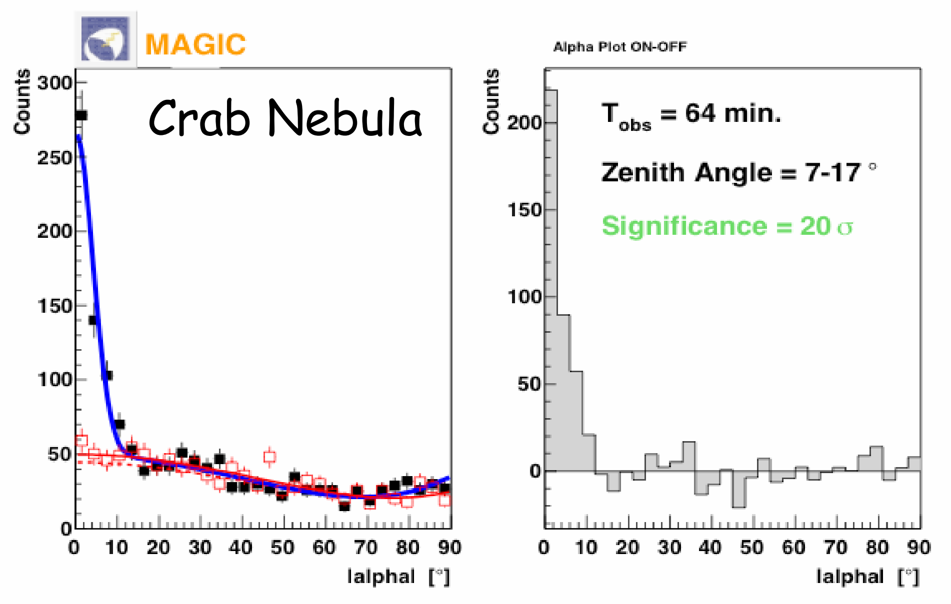
Origin of
Cosmic Rays

Crab

Crab

Stable γ source GeV/TeV (Whipple '89).
Standard candle for gamma astronomy

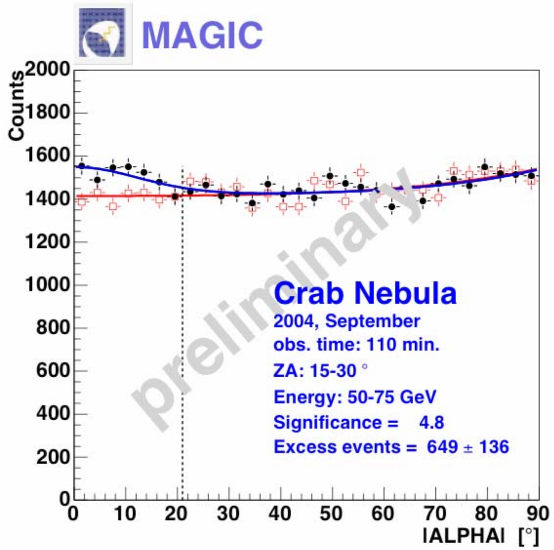




$$\text{HESS} :\sim 30\sigma \times \sqrt{\text{Time(h)}}$$

$$\text{MAGIC} :\sim 20\sigma \times \sqrt{\text{Time(h)}}$$

3% Crab @ 5σ in 25-50 hrs



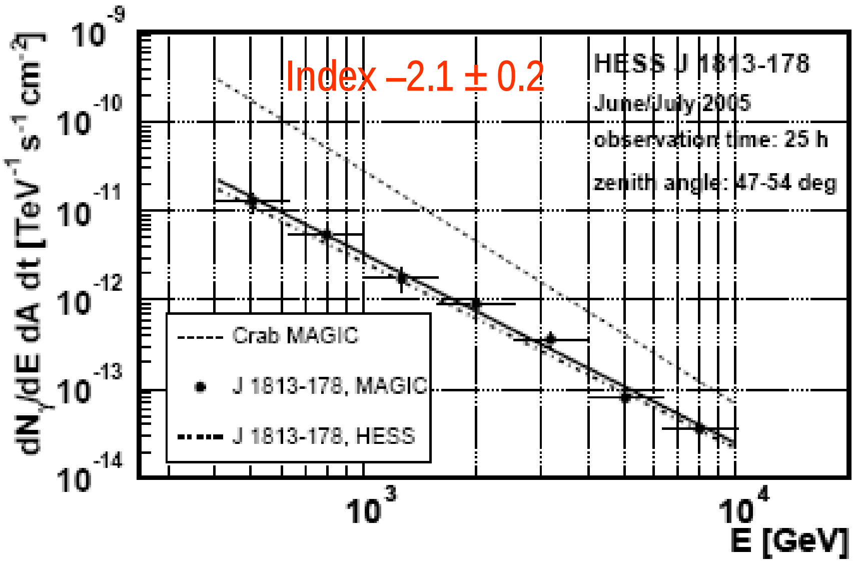
MAGIC: Significant signal starts at 50GeV (2h of observation).

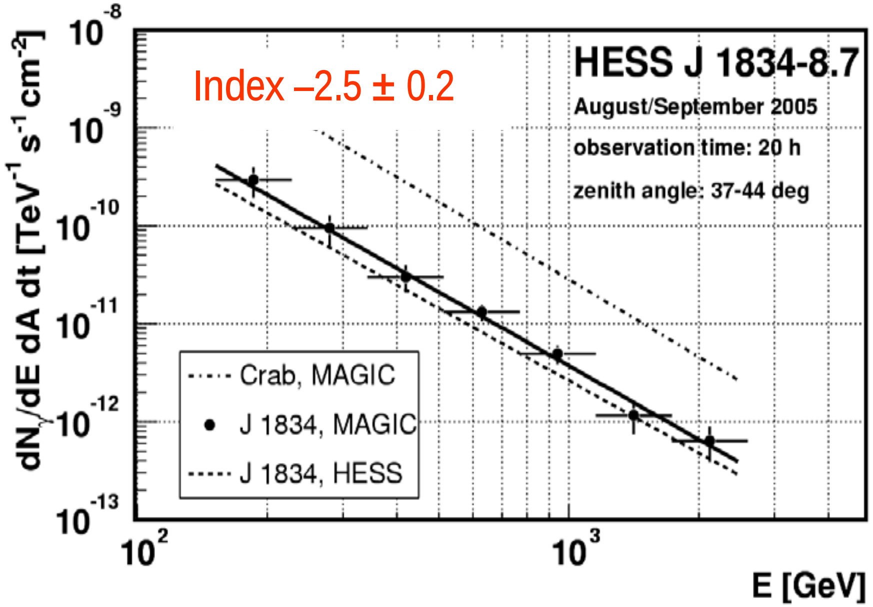
MAGIC Cycle1-2 (Mar 2005-May 2007)

- Statistics of physics runs:
  - ~2000 hours dark time for physics, efficiency ~60% (85% after subtracting bad weather)
    - Moon time increasing to an asymptotical value ~1/3: ~300 hours/year
  - ~200 hours ToO (with some important results)
    - will increase with the increased number of collaborations
      - Suzaku, Swift, GLAST, AGILE, …
- All data of cycle 1 analyzed, 70% of Cycle2
    - >20 papers published or in publication from Nov 2005 to now
- 4 GRB observations during the primary burst
- MAGIC Catalog opened (MAGIC Jxxx-yyy)

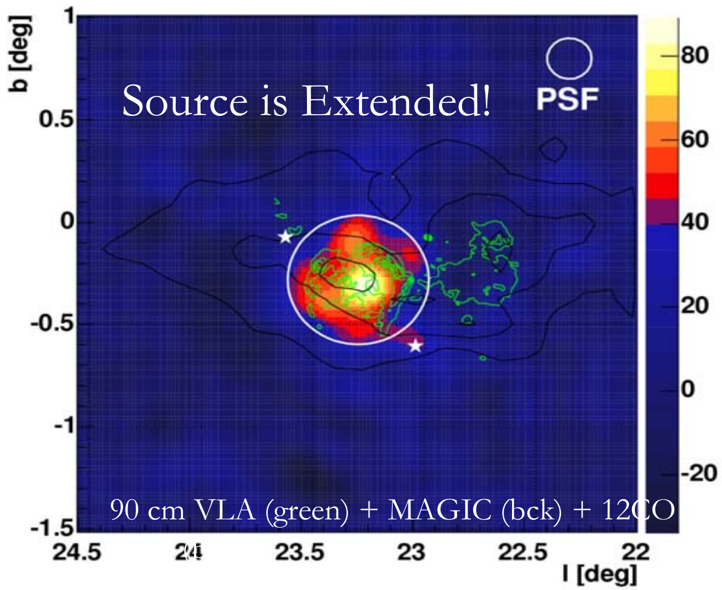
Galactic Sources I: SNRs

- "MAGIC observations of VHE γ -rays from HESS J1813-178", ApJ Lett. 637 (2006) 41.

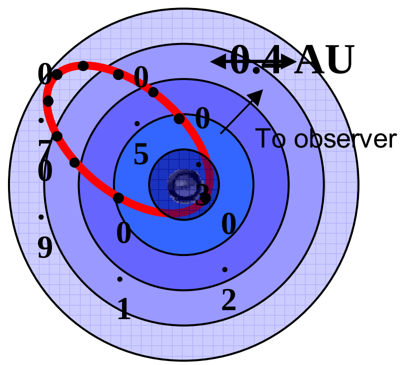




- "Observation of VHE γ radiation from HESS J1834-087/W41 with MAGIC", ApJ Lett. 643 (2006) 53.
- MAGIC J0616+225 (May 2007)

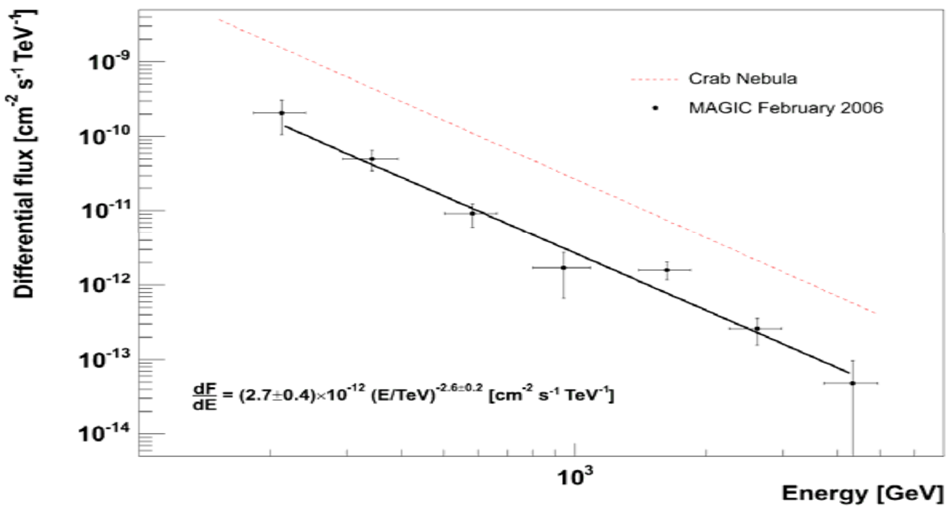


Galactic Sources II: μQSR (?)



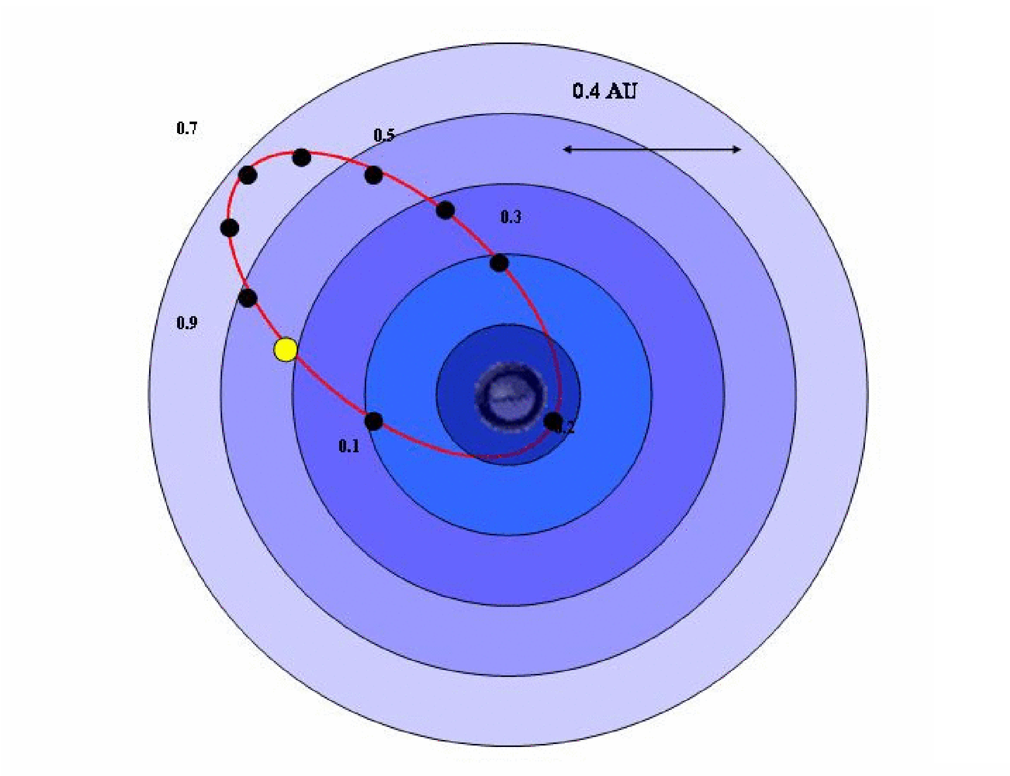
deAngelis, May 07

- **LS I +61 303:**
  - High Mass x-ray binary at a distance of 2 kpc
  - Compact object probably a neutron star
  - High eccentricity or the orbit (0.7)
  - Modulation of the emission from radio to x-rays with period 26.5 days attributed to orbital period



- **MAGIC** has observed LS I +61 303 for 54 hours from November 2005 to March 2006 (6 orbital cycles)
- **A point-like source** (E>200GeV) detected with significance of ~9σ consistent with LSI position ⇒ **identification of γ-ray source**

- **MAGIC** has observed LS I +61 303 for 54 hours from November 2005 to March 2006 (6 orbital cycles)
- **A point-like source** (E>200GeV) detected with significance of ~9σ consistent with LSI position $\Rightarrow$ **identification of γ-ray source**



- The source is **quiet at periastron** passage and at relatively **high emission level** (16% Crab Nebula flux) at later phases [0.5-0.7]
- Hint of periodicity

Science 312, 1771 (2006)

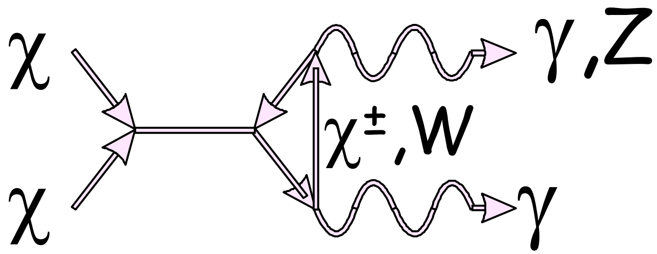
The Galactic Center and Dark Matter

- meV candidates: non-directional, indirect (and subtle)
  - Might have implications on gamma rays [Bignami et al. 2005]
- GeV/TeV candidates:
  - direct (nondirectional) if we live in a sea of DM
  - indirect (directional) mostly through photons: where to look for?
- Photons are the main character of this story
  - Interaction between astrophysicists and experimentalists is the key

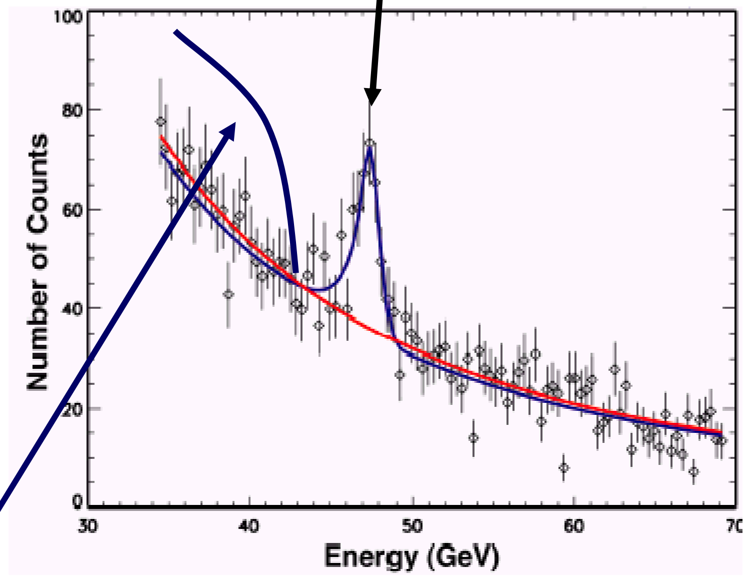
The main field of research:
Heavy WIMPs, indirect: self-annihilation

Good energy resolution in the few % range is needed

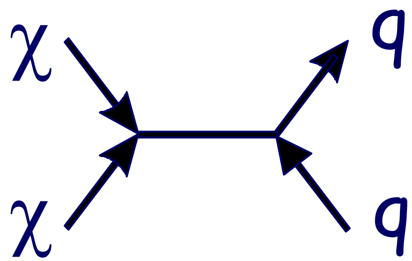
- annihilation



  into γγ or γZ:
  $E_\gamma = m_\chi$ / $m_\chi - m_Z^2/4\,m_\chi$
  => clear signature at high energies
  but: loop suppressed



- annihilation into qq -> jets -> n γ's
  => continuum of low energy gammas
  difficult signature but large flux

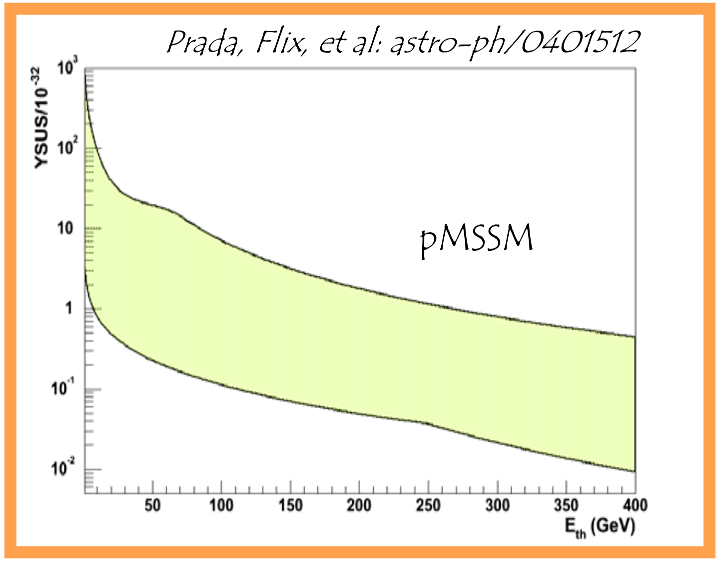


- But also: antimatter (positrons), neutrinos

γ-Flux from χ-Annihilation

$$\frac{dN_\gamma(\Omega,E)}{dt\,dA\,dE\,d\Omega} = \frac{\alpha}{M_\chi^2} \cdot \int \rho_{DM}{}^2(l)\,dl(\Omega)$$

- **Particle physics:**
  SUSY models
  fragmentation functions
- **Astrophysics:**
  γ-ray flux ~ ρ^2
  => search for CDM clumps



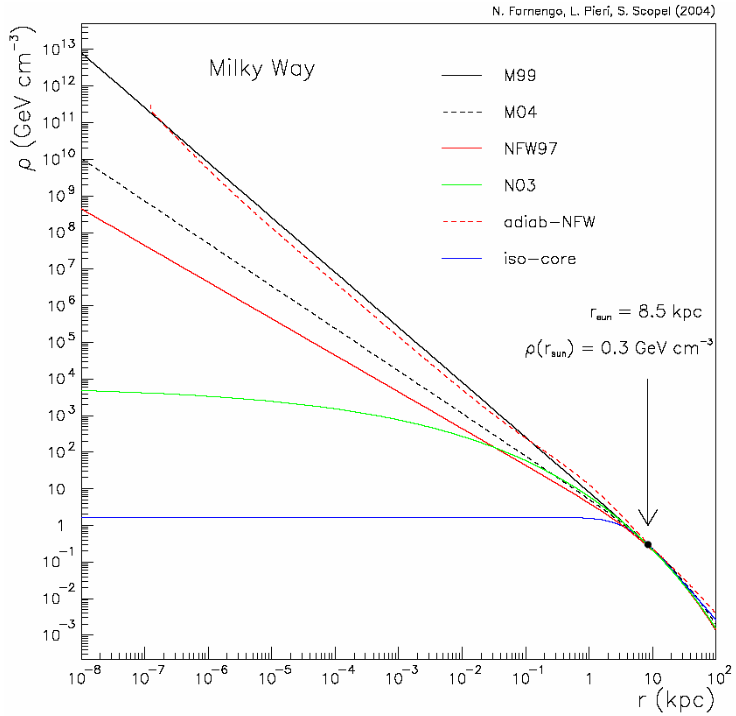
DM density profiles: Cusp, Core, Clumps…

- **gamma-flux dependence ρ^2 => inner, high ρ_{DM} region dominating**
- **CDM simulations: uncertainties**

$$\rho(r) = \rho_o \frac{r_s}{r^\alpha}\left(1+\frac{r}{r_s}\right)^{3-\alpha}$$

  - **Navarro,Frenk & White (1996):** $\alpha_{NFW} = 1$
  - **Moore (1998):** $\alpha_{Moore} = 1.5$
  - **Stoehr (2004)** $\alpha < 1$

controversial

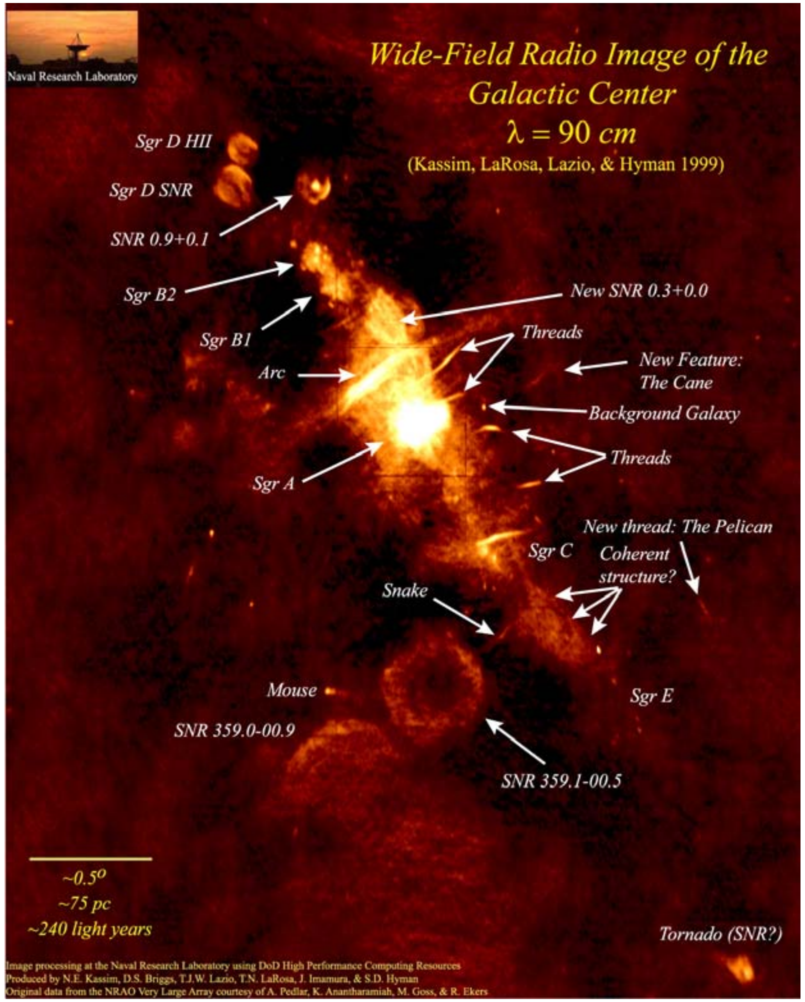


- **experimental data for GC (rotation curves, microlensing data, ..)**
  - **no evidence for cuspy profile**
  - **cusp not unambiguously ruled out**

predictions for $\int \rho_\chi^2(l)dl$ differ by orders of magnitude

Targets for DM search

Highest DM density candidate
Close by
Not extended
Not associated with known astrophysical object



Galactic Center

Distance (7.5 kpc) →
GC best candidate for indirect DM searches ?

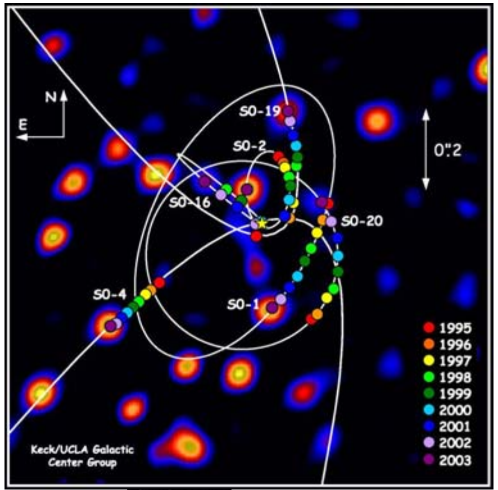
BUT:

– other γ-ray sources in the FOV, i.e. SNR Sgr A East

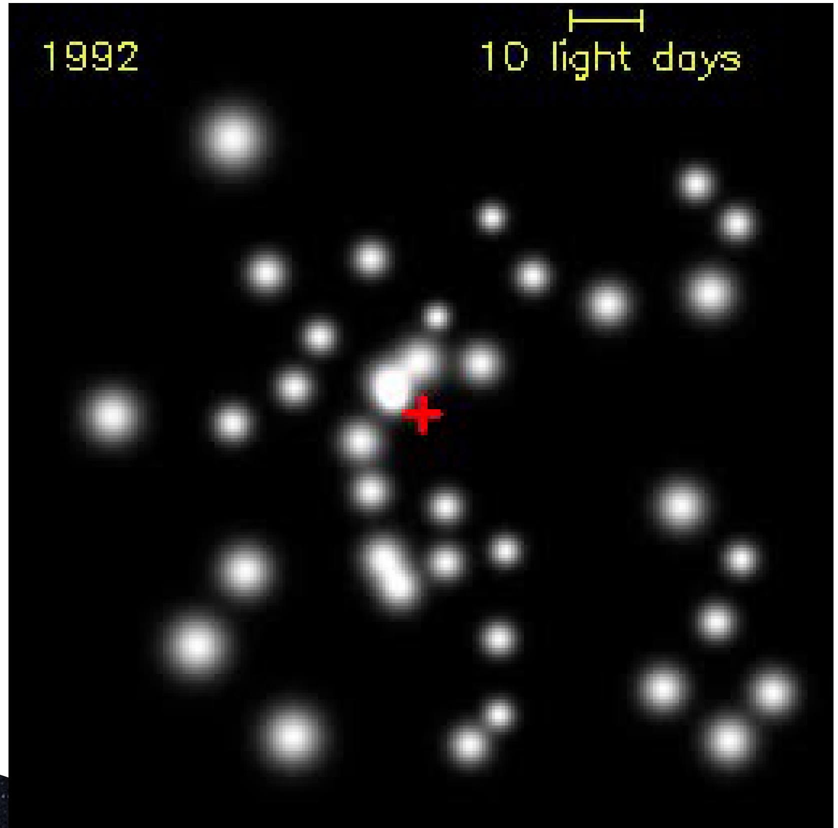
– competing plausible scenarios

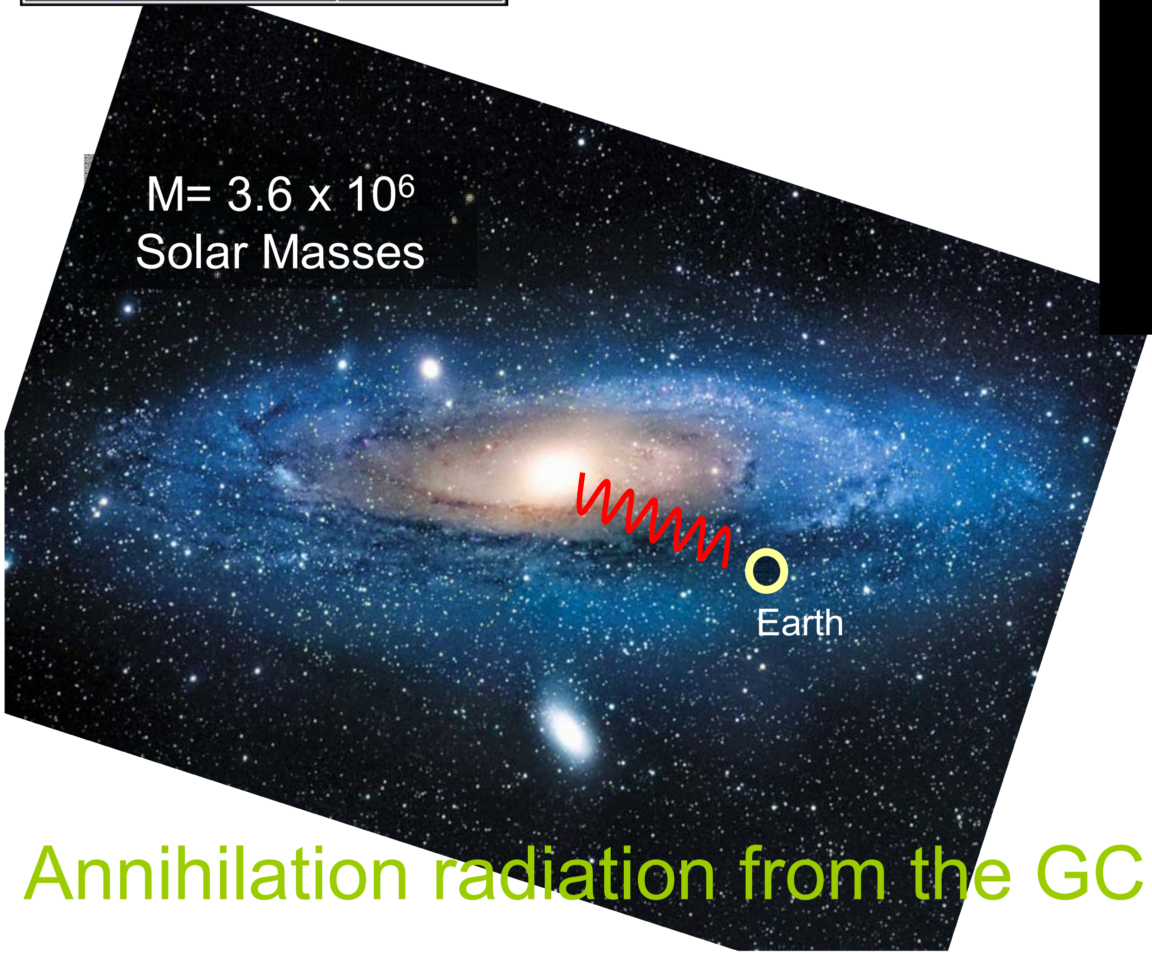
- central halo DM density vs L relation: $\rho_0 \propto L^{-1}$

- halo core radius: extended vs point-like



The Galactic Centre





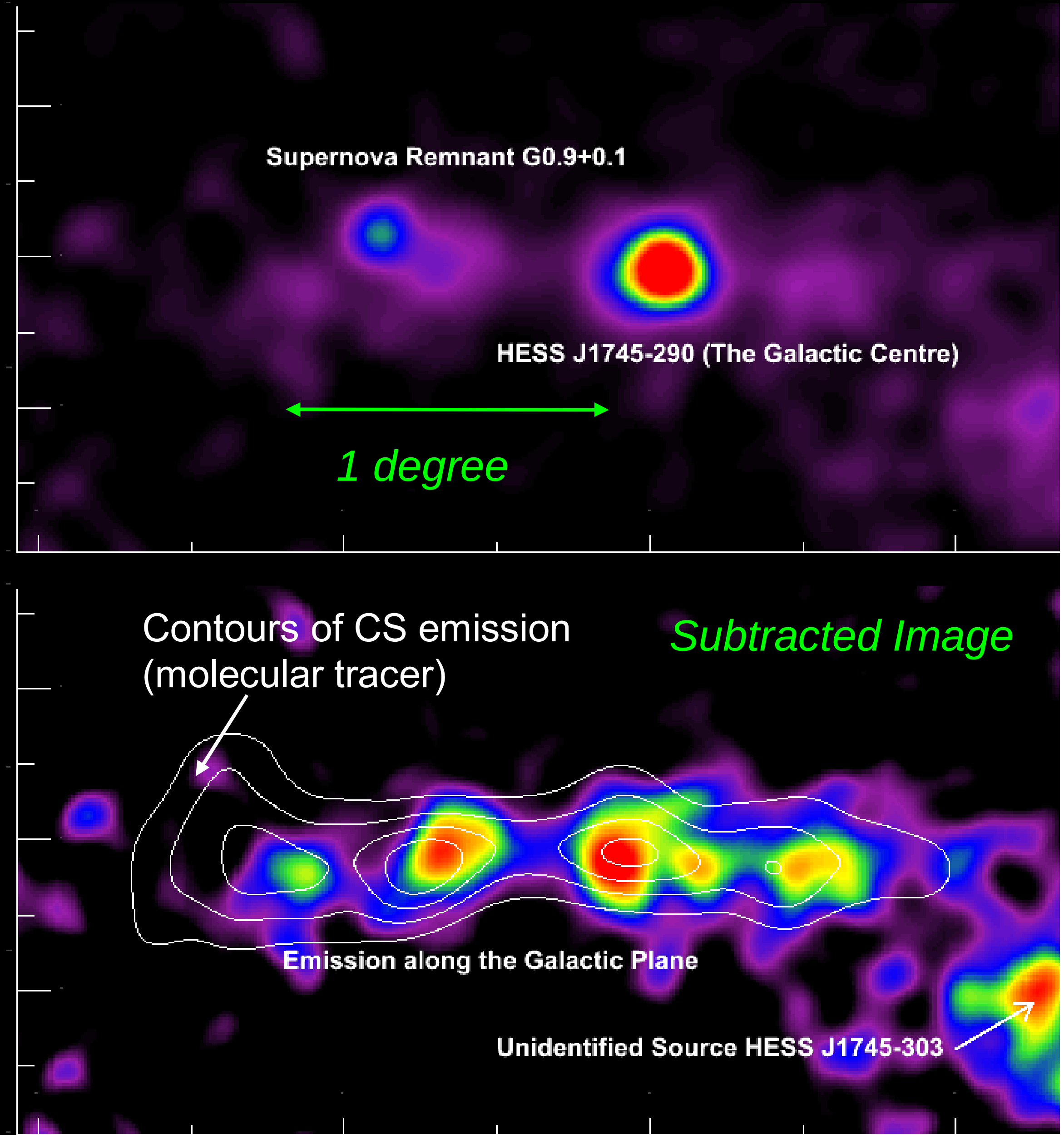
Prime osservazioni di raggi gamma: 2004/05

Annihilation radiation from the GC

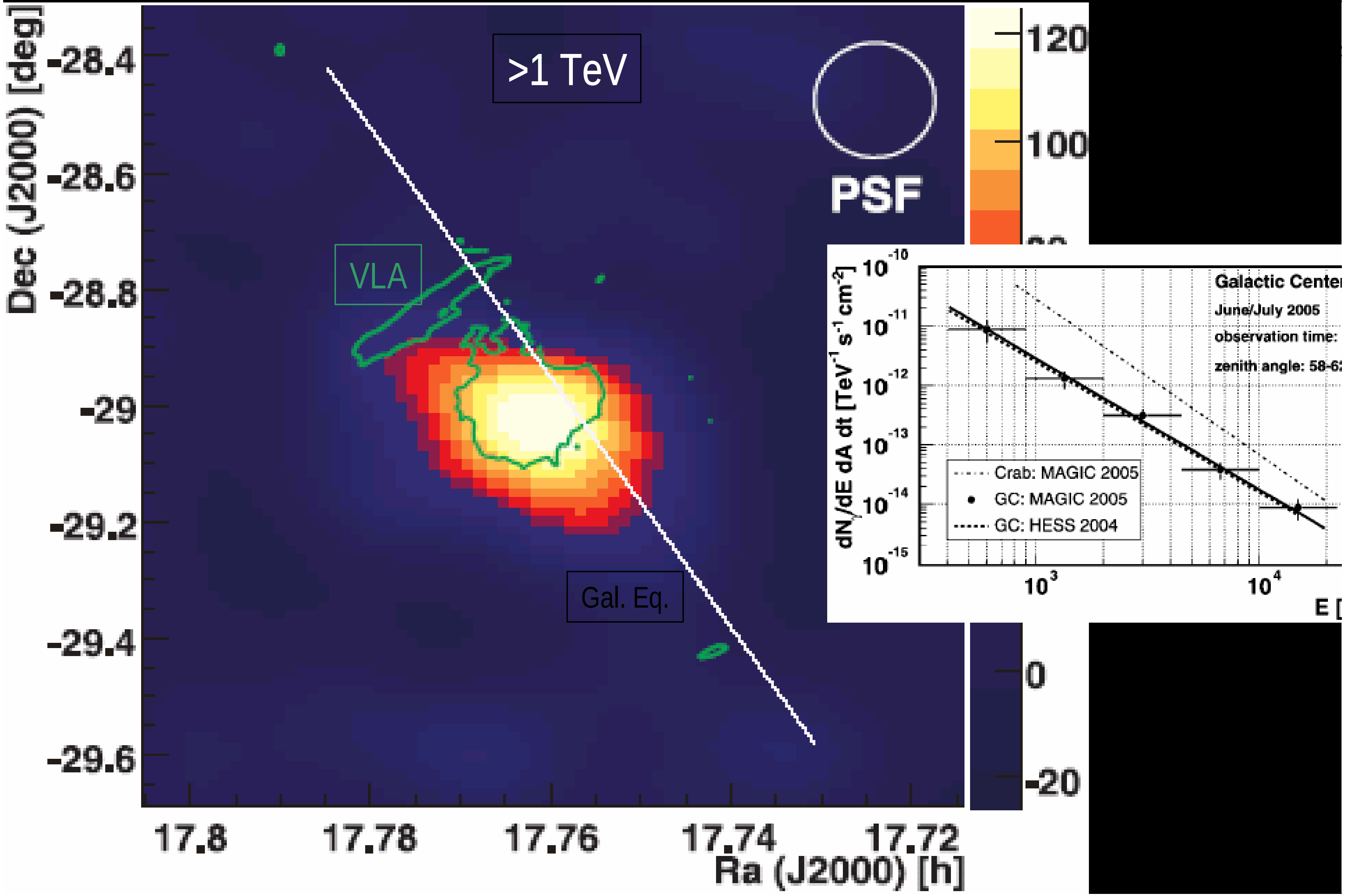
The Galactic Center

HESS

- – Source coincident with supermassive black hole Sgr A*
- ***Diffuse Emission***
  - – Emission along the plane is revealed by subtraction of strong sources...
  - – Correlation with molecular material
    - Cosmic rays interacting with molecular clouds



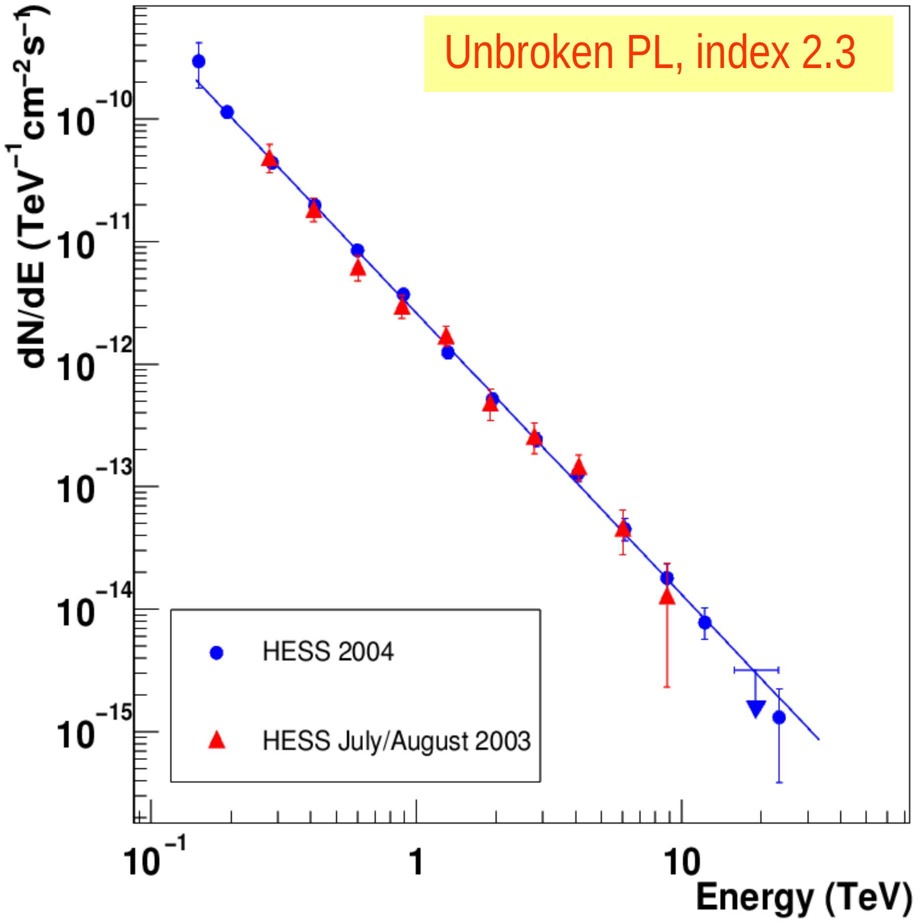
The Galactic Center

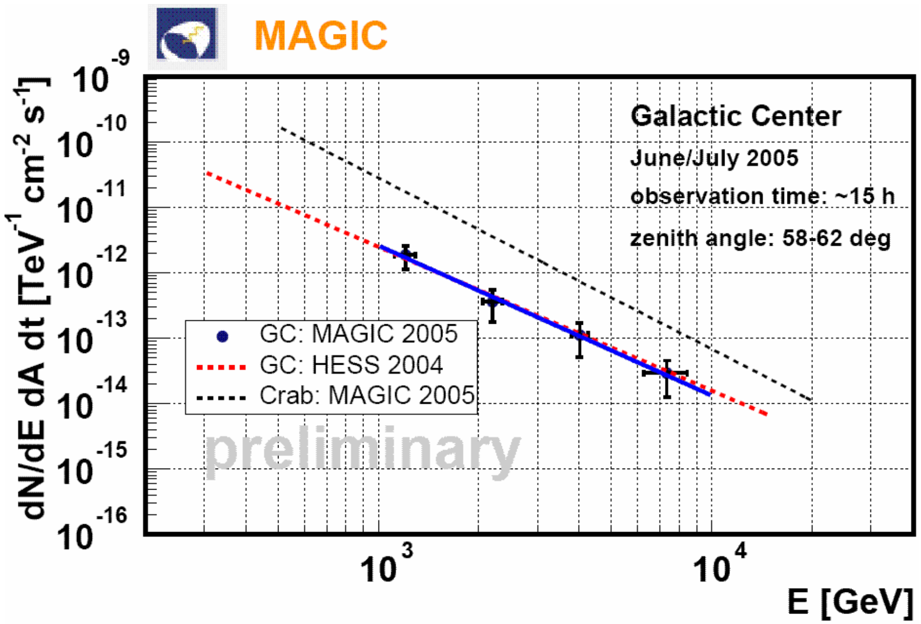


Galactic Center: MAGIC

MAGIC

deAngelis, May 07





Good agreement between HESS and MAGIC (large zenith angle observation)

⇒ strong γ-ray source to outshine DM signal ?

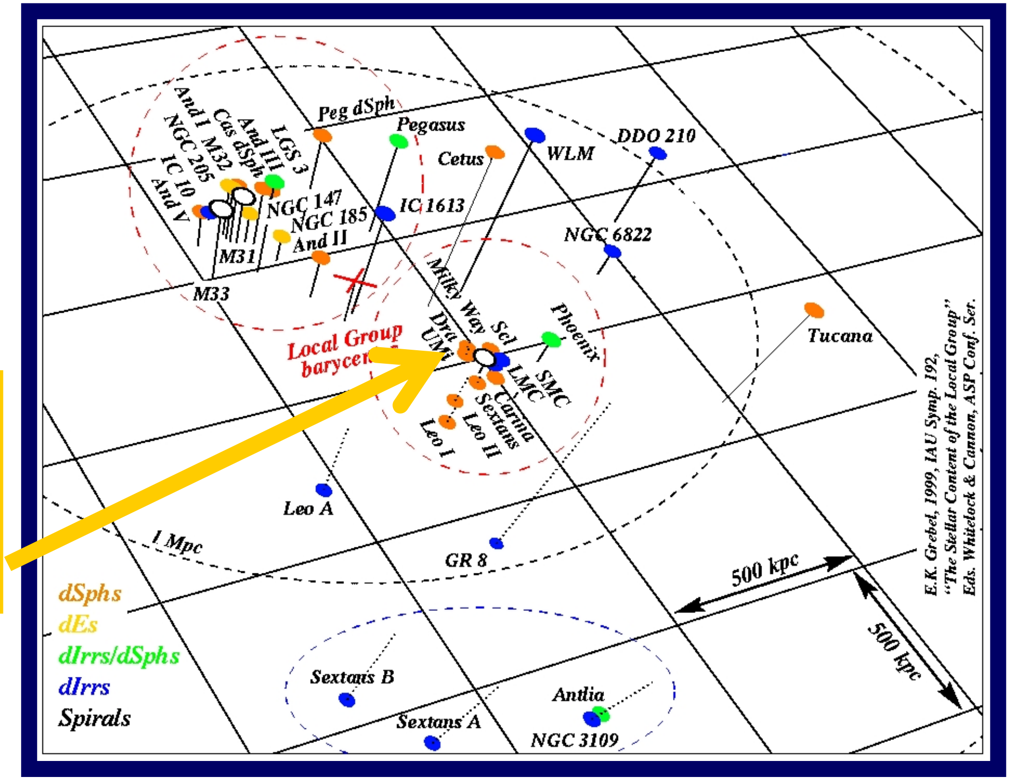
⇒ most SUSY scenarios: cutoff in DM spectrum at a few TeV → ??

DRACO dSph : Motivations

- Milky Way surrounded by small, faint companion galaxies

DRACO highest M/L dwarf

Northern source



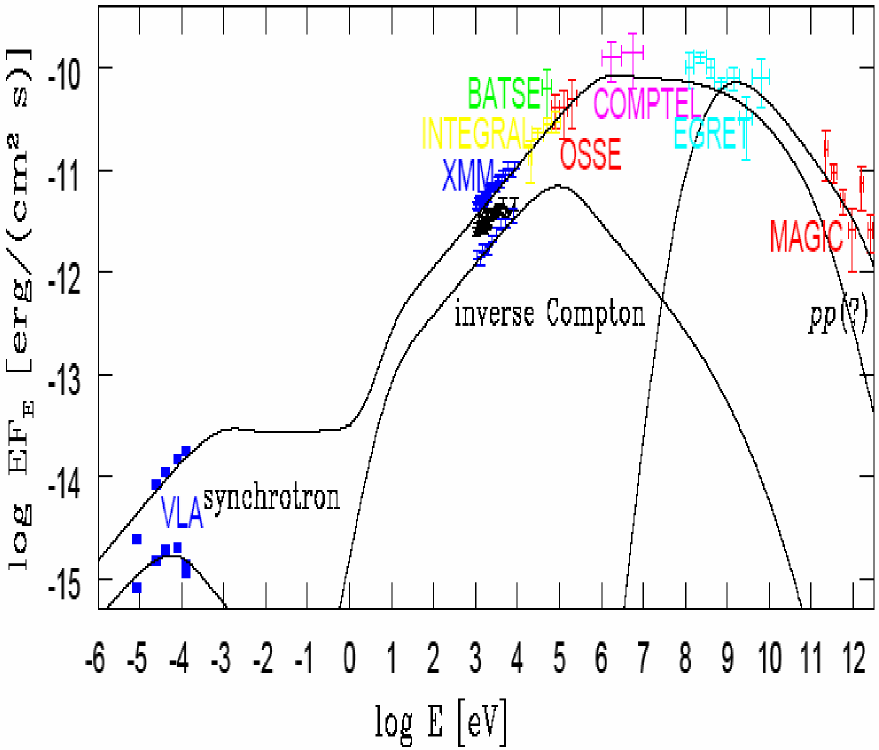
- dSph's → very DM-dominated objects
- Distances, M/L ratios 16<D/kpc<250, 30<M/L<300
- detection most likely?

Extragalactic (AGN)

- 10 AGNs detected

Mrk 421	z=0.030	astro-ph /0603478
Mrk 501	z=0.034	astro-ph 0702008
1ES2344+514	z=0.044	astro-ph /0612383
Mrk 180	z=0.045	ApJL 648 (2006) 105
1ES1959+650	z=0.047	ApJ 639 (2006) 761
BL Lac	z=0.069	astro-ph/0703084
1ES1218+308	z=0.182	ApJL 642 (2006) 119
PG1553+113	z>0.09	ApJL 654 (2007) 119

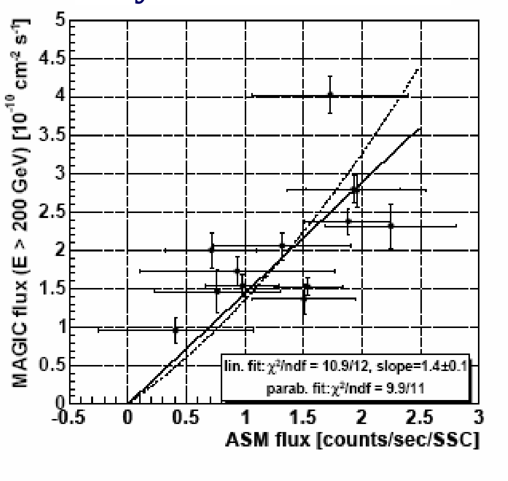
  – 3 more in press (0.03-0.2)

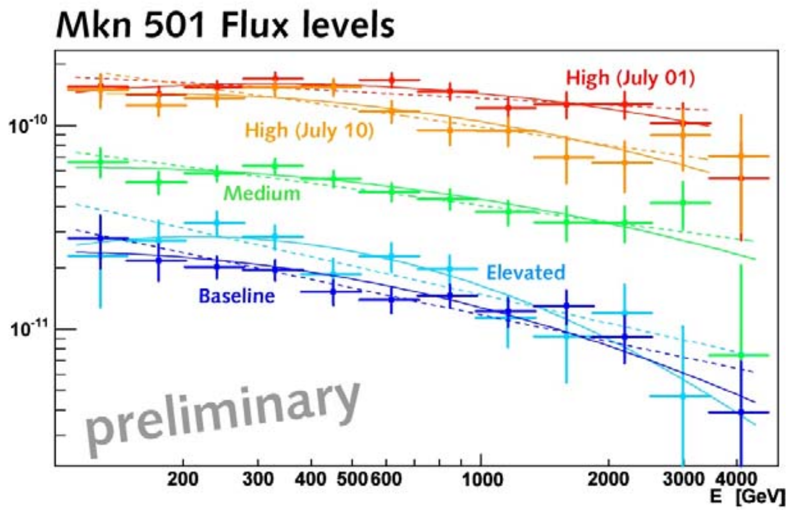


Mkn 421 (z=0.030) & Mkn 501 (z=0.034)

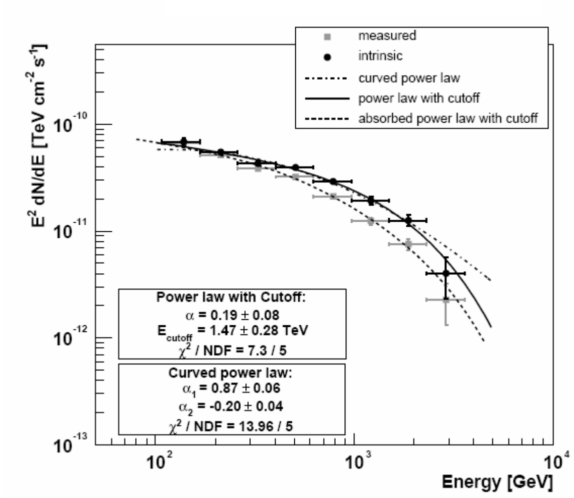
- Two very well studied sources, highly variable
  - >40k excess photons in MAGIC
  - TeV-X Correlation

Mkn421 TeV-X-ray-correlation



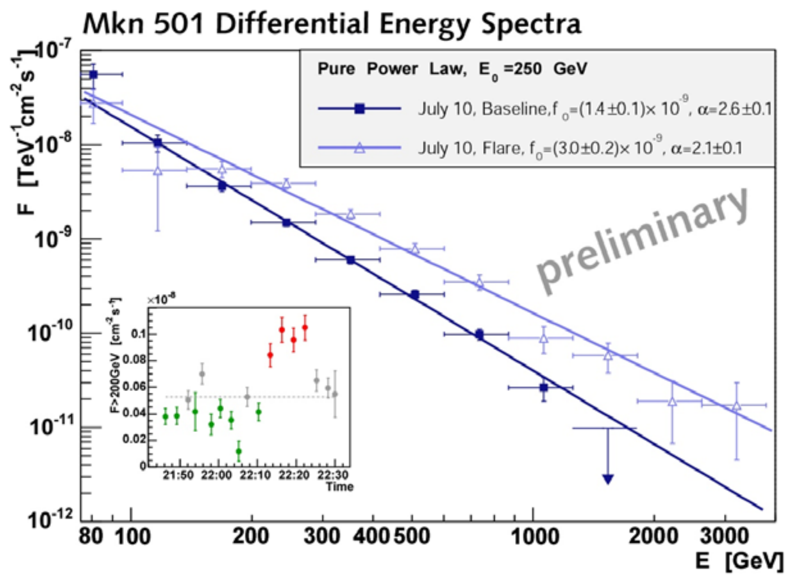


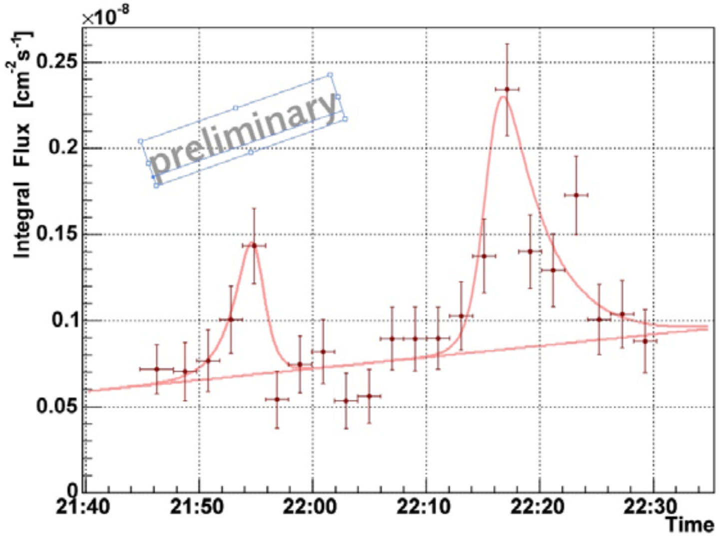
Mkn421

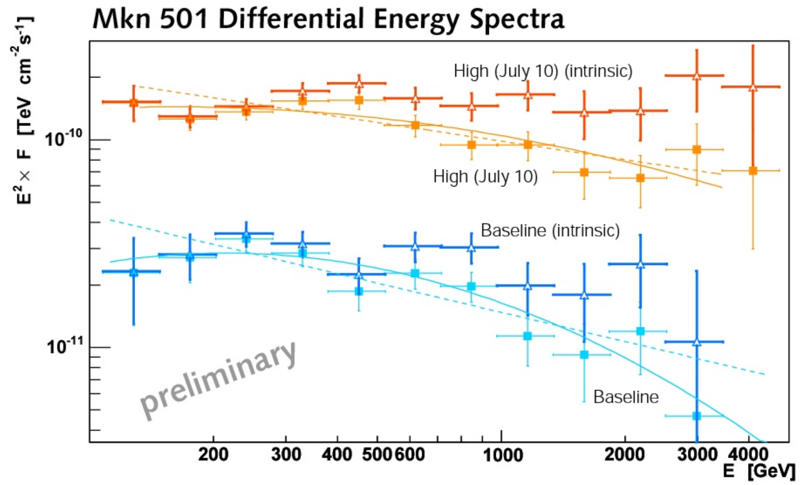


Mkn 501 giant flare

- Flare on 9 July 2005
- Doubling time ~ 5 min.
- Spectrum shape changes within minutes
  - Implications on the dispersion relation for light, see later
- IC peak detected
- Shape energy dependent







A nontrivial dispersion relation for light in vacuum
(e.g., Quantum Gravity effects?)

- From a phenomenological point of view, the effect can be studied with a perturbative expansion. In first order, the arrival delay of γ–rays emitted simultaneously from a distant source should be proportional to their energy difference and the path L to the source:

$$\Delta t \sim \frac{\Delta E}{E_{QG}} \frac{L}{c}$$

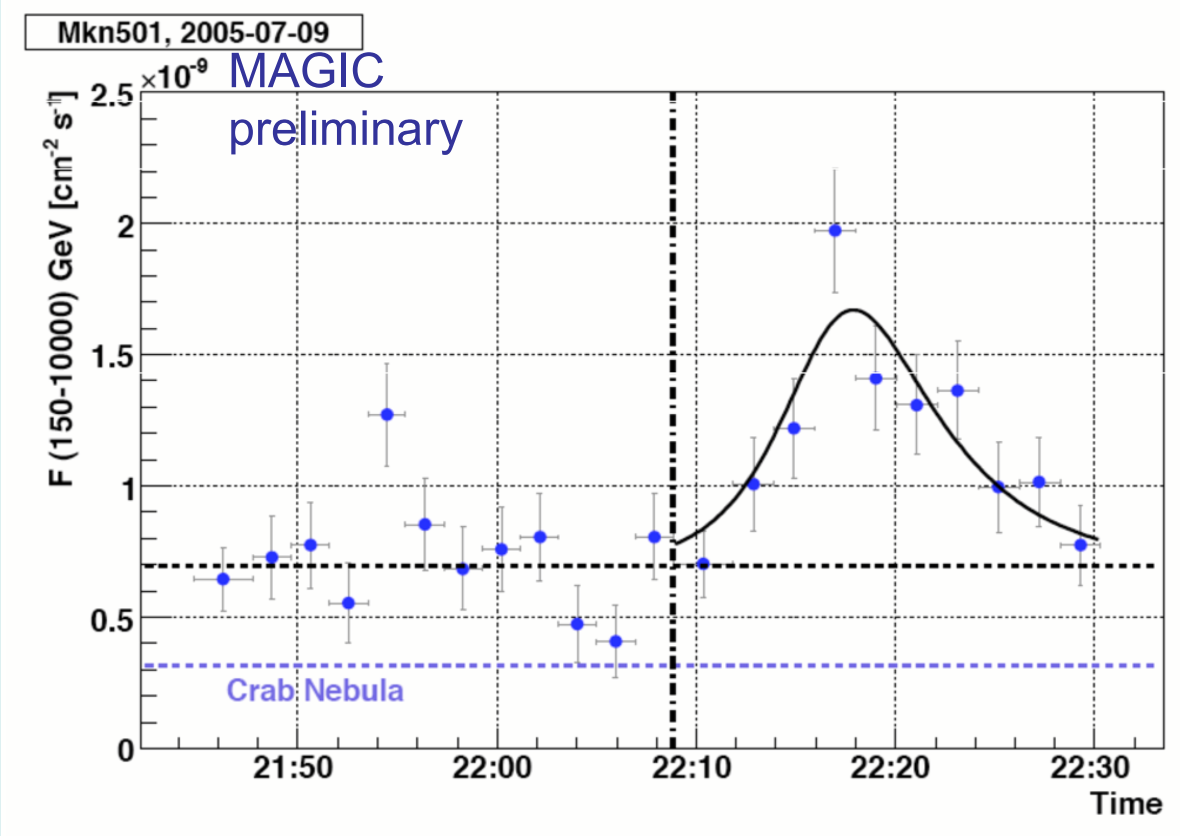
- The expected delay is very small and to make it measurable one needs to observe very high energy γ-rays coming from sources at cosmological distances.

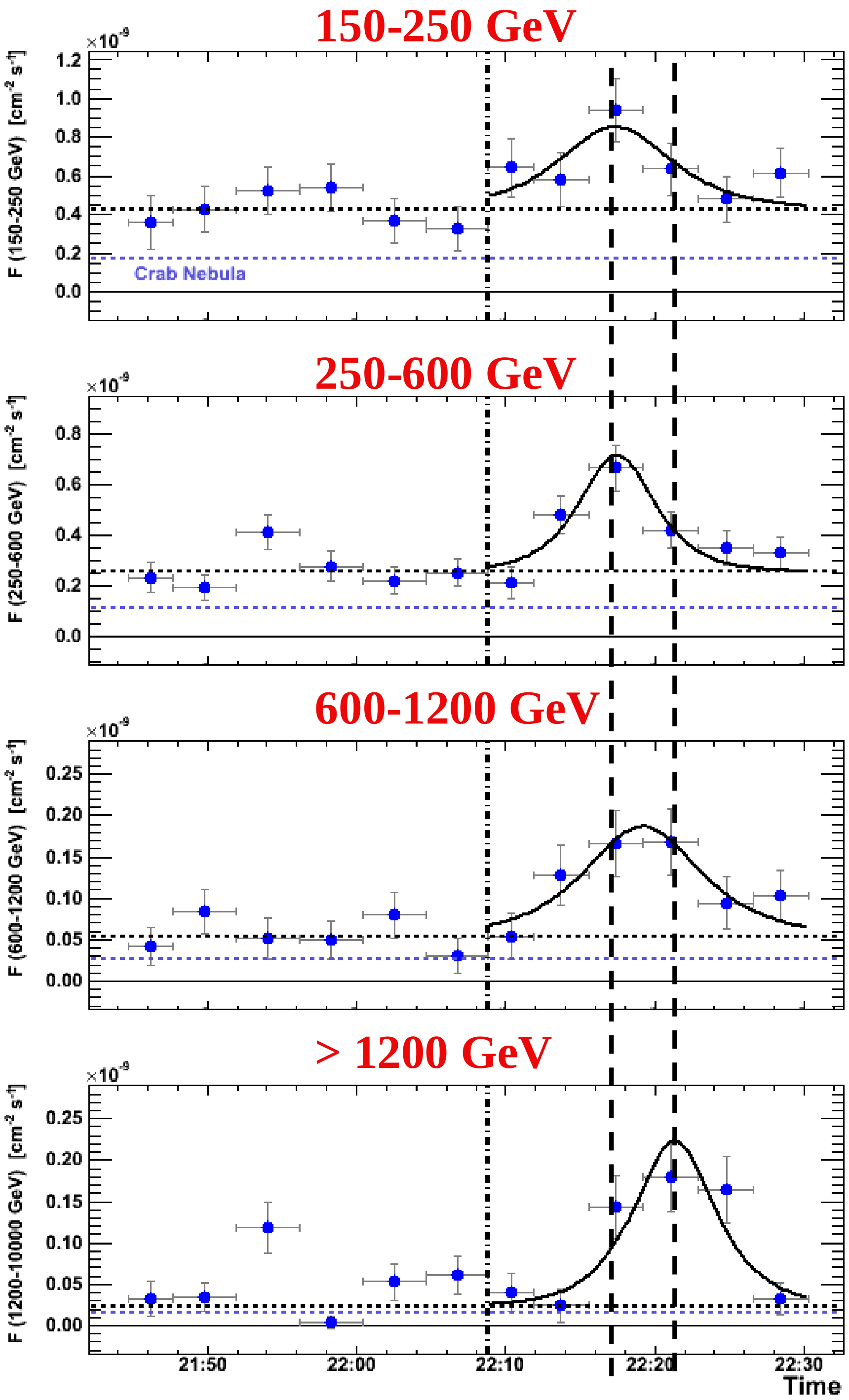
High time-resolution study of AGN flare

- Huge Mkn 501 flare in July 2005: 4 Crab intensity, signal more than doubled wrt baseline

- Intensity variation recorded in 2 minute bins => new, much stronger, constraints on emission mechanism and light-speed dispersion relations (effective quantum gravity scale).

- O (M_p/100) reached





LCs for different energy ranges (4 min bins)

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Flare is seen in all energy ranges

Time delay of 4 ± 1 minute between highest and lowest energy ranges

Flux variations larger at the largest energies

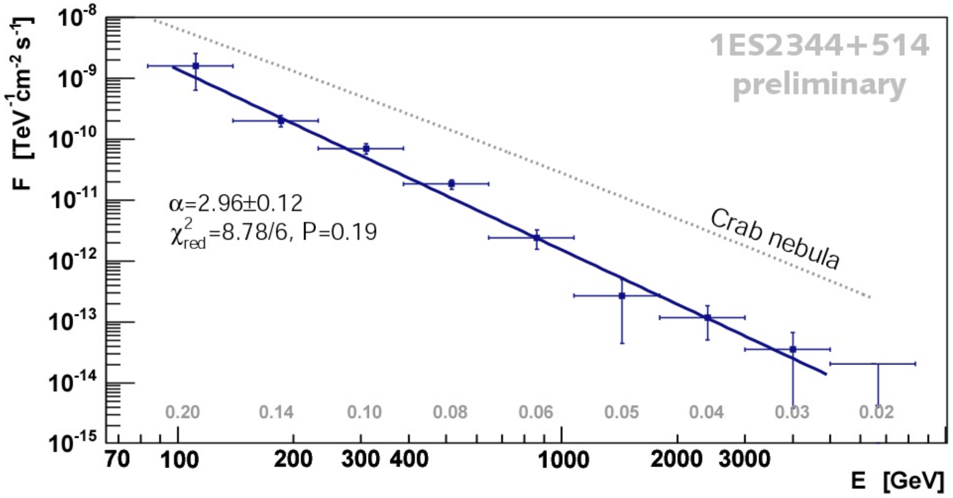
First time in VHE !!

IF

Photons at different energies were emitted simultaneously

$\Delta T = 4 \pm 1$ min; $\Delta E \sim 1$ TeV

$$E_{QG} = \frac{L}{c} \cdot \frac{\Delta E}{\Delta t} = (0.6 \pm 0.2) \cdot 10^{17}\,\mathrm{GeV}$$

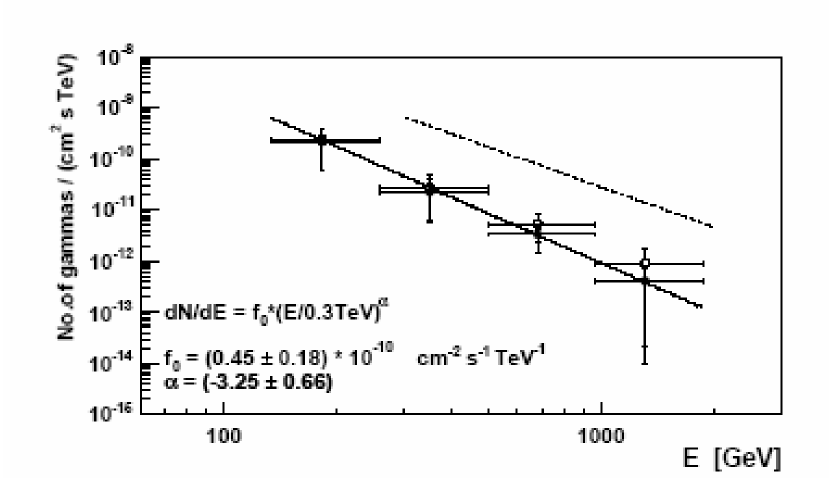


1ES2344+514 (z=0.044)

Clear detection, ~9σ

No variability

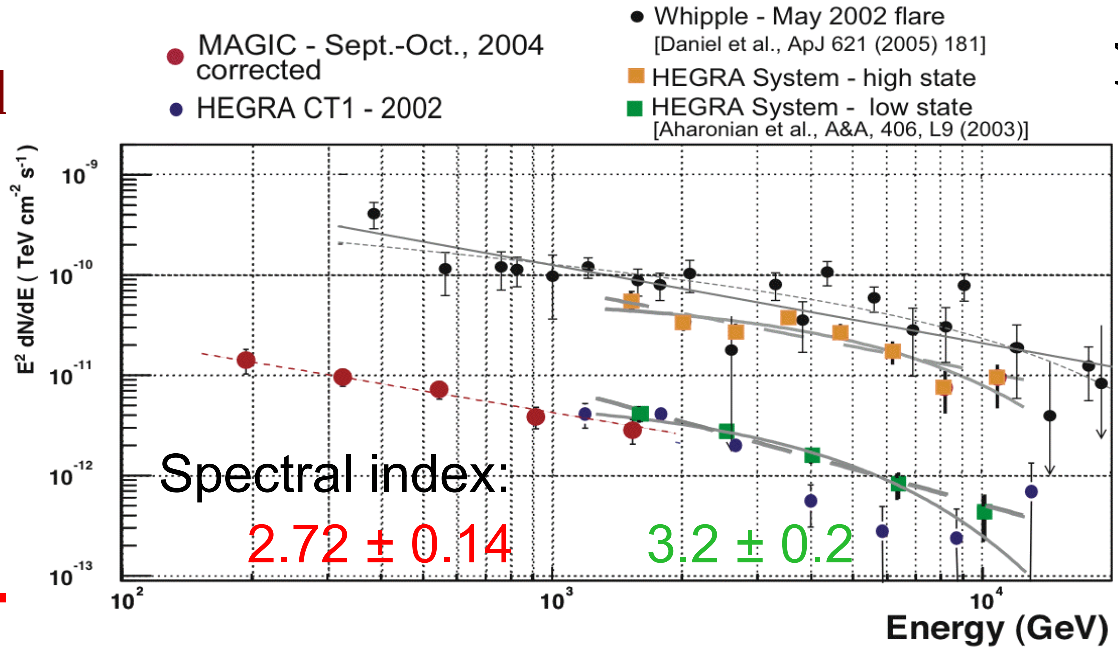
Mkn 180 (z=0.045)



- Upper limits from HEGRA, WHIPPLE
- MAGIC: DISCOVERY!
  - April 2006, 11.1 h -Triggered by optical flare
  - 5.5 σ, index: -3.3 ± 0.7

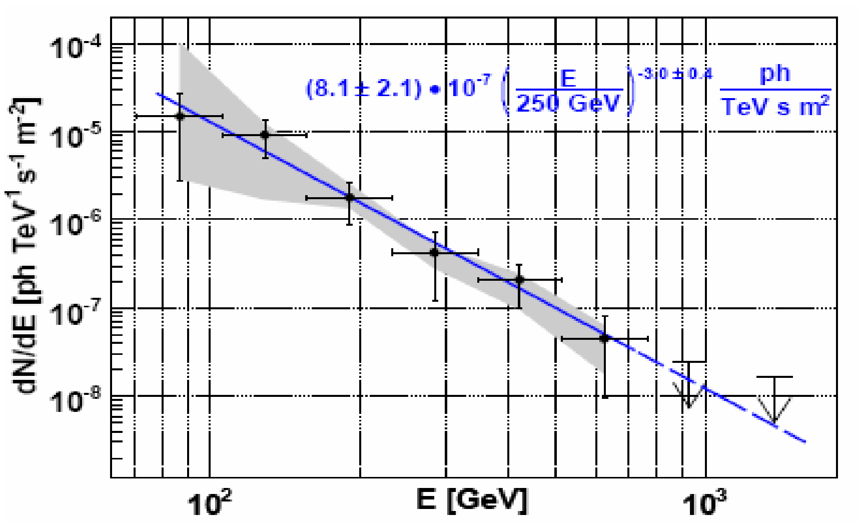
1ES1959+650 (z=0.047)

- MAGIC: Significant signal in only 6h of observation
  ApJ 639 (2006) 761



1ES1218+304 (z=0.182)

- Upper limits from HEGRA, WHIPPLE
- MAGIC: DISCOVERY!
  - Jan 2005, 8.2 h
  - 6.4 σ, index: -3.0 ± 0.4
  - No signs of variability

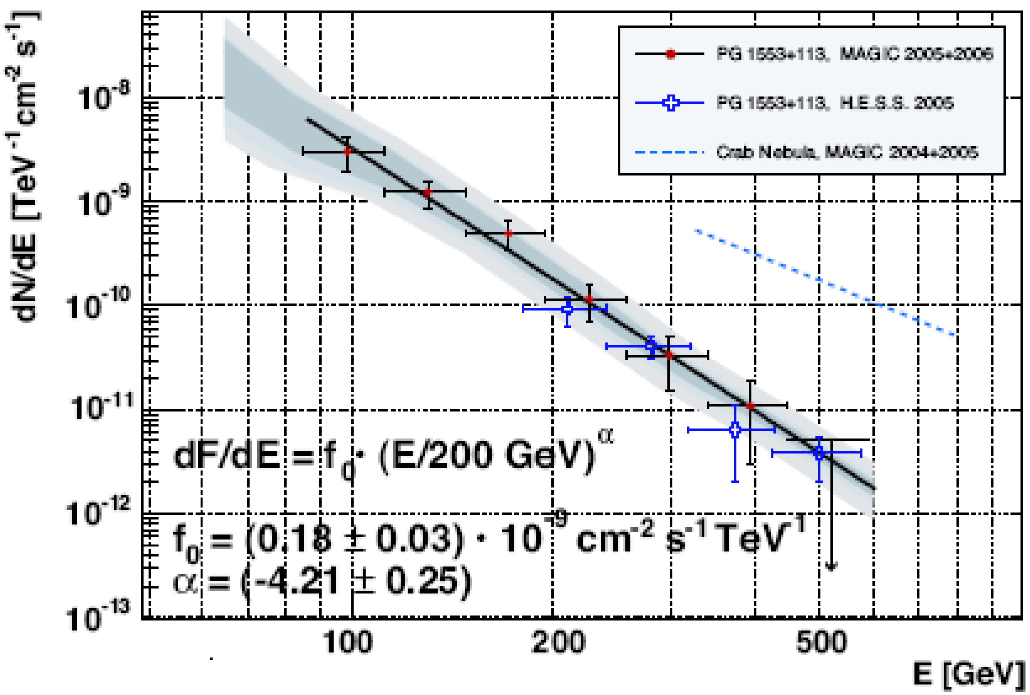


ApJ L 642, L119 (2006)

deAngelis, May 07

PG1553+113 [z~0.3? (>0.09)]

- Observed 18.8h in 2005-06
- H.E.S.S.: 4.0σ hint
  (A&A 448L (2006), 43)
- MAGIC: ApJL submitted, astro-ph/0606161
- 8.8σ, firm detection.



- If (a) intrinsic slope not harder than 1.5 (b) intrinsic spectrum has just one peak

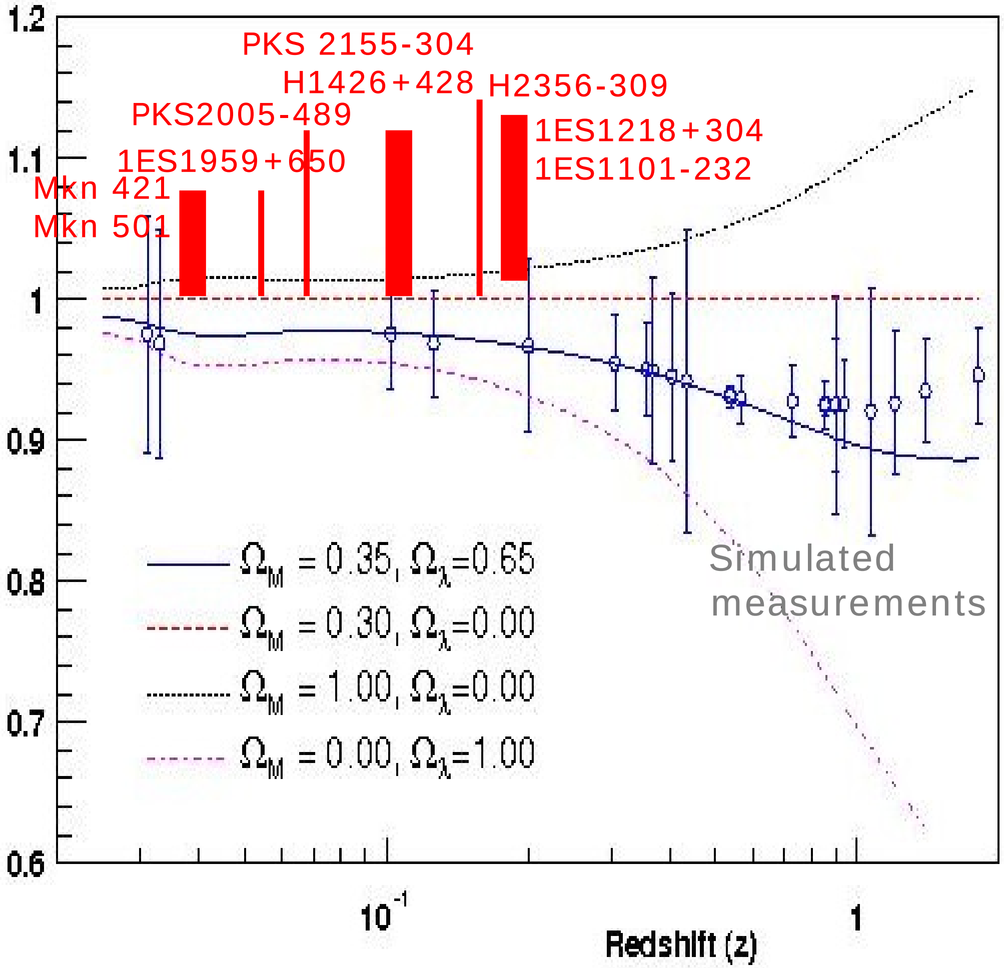
  => z < 0.78 (MAGIC only) or z < 0.42 (MAGIC+HESS)

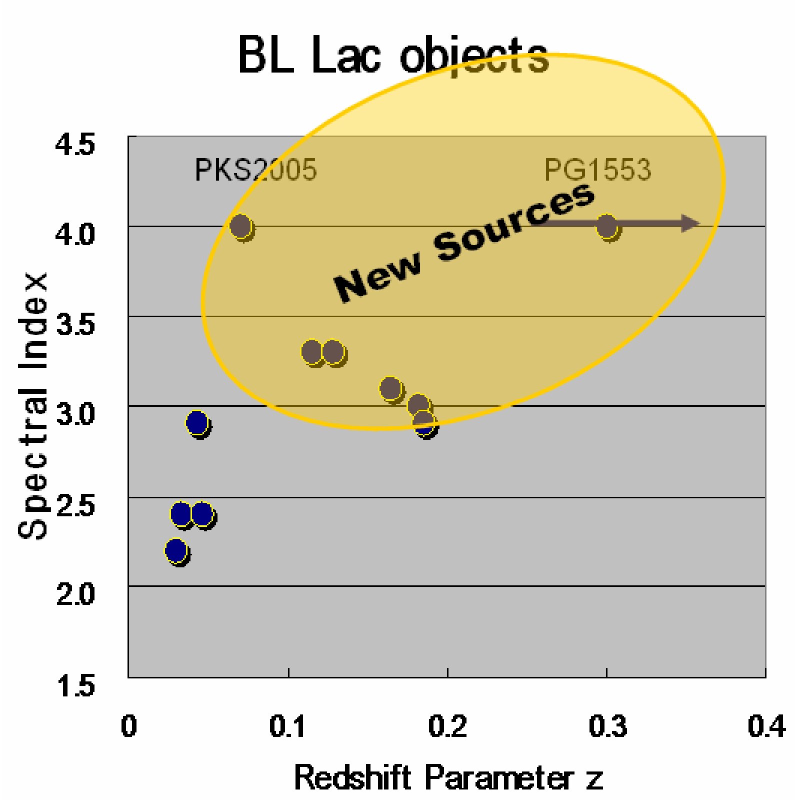
AGN: conclusions

- There are 15 AGNs above 100 GeV established
- MAGIC detected 8 of them; 3 of them discovered by MAGIC, 1 co-discovered with HESS
- Fast, giant flare of Mkn501 recorded with unprecedented time resolution. Physics?
- Hard constraint on the redshift of PG1553+113 to $z<0.42$ in case there is one peak above 100 GeV. If $z>0.42$, first observation of multipeak structure of a blazar above 100 GeV.
- Variation of spectra with distance. Physics?

AGN at a glance

Source	Redshift	Spectral Index	Type	Detection (>5σ)	Confimation
M87	0.004	2.9	FR I		HESS
Mkn 421	0.031	2.2	BL Lac	Whipple	Many
Mkn 501	0.034	2.4	BL Lac	Whipple	Many
1ES 2344+514	0.044	2.9	BL Lac	Whipple	HEGRA,MAGIC
1ES 1959+650	0.047	2.4	BL Lac	Tel. Array	Many
PKS 2005-489	0.071	4.0	BL Lac	HESS	
PKS 2155-304	0.116	3.3	BL Lac	Mark VI	HESS
H1426+428	0.129	3.3	BL Lac	Whipple	Many
H2356-309	0.165	3.1	BL Lac	HESS	
1ES 1218+304	0.182	3.0	BL Lac	MAGIC	
1ES 1101-232	0.186	2.9	BL Lac	HESS	
PG 1553	>0.25	4.0	BL Lac	MAGIC	



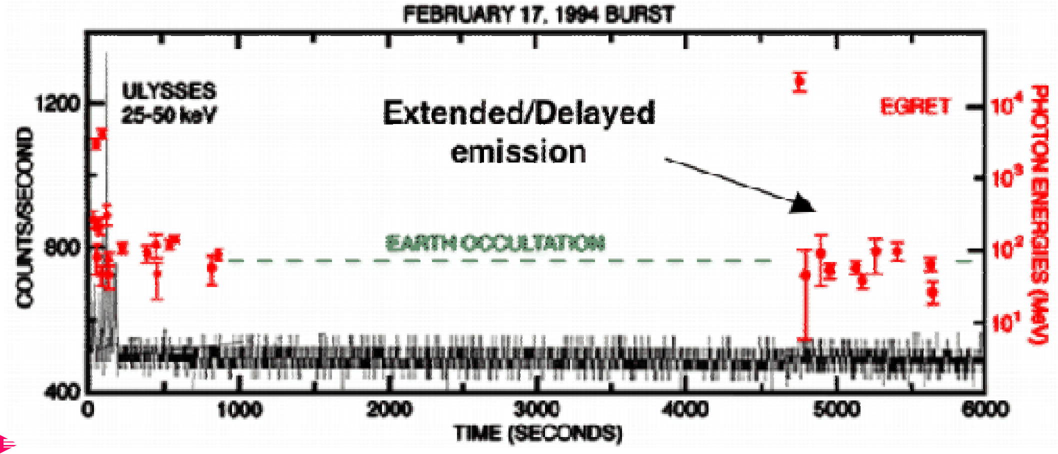


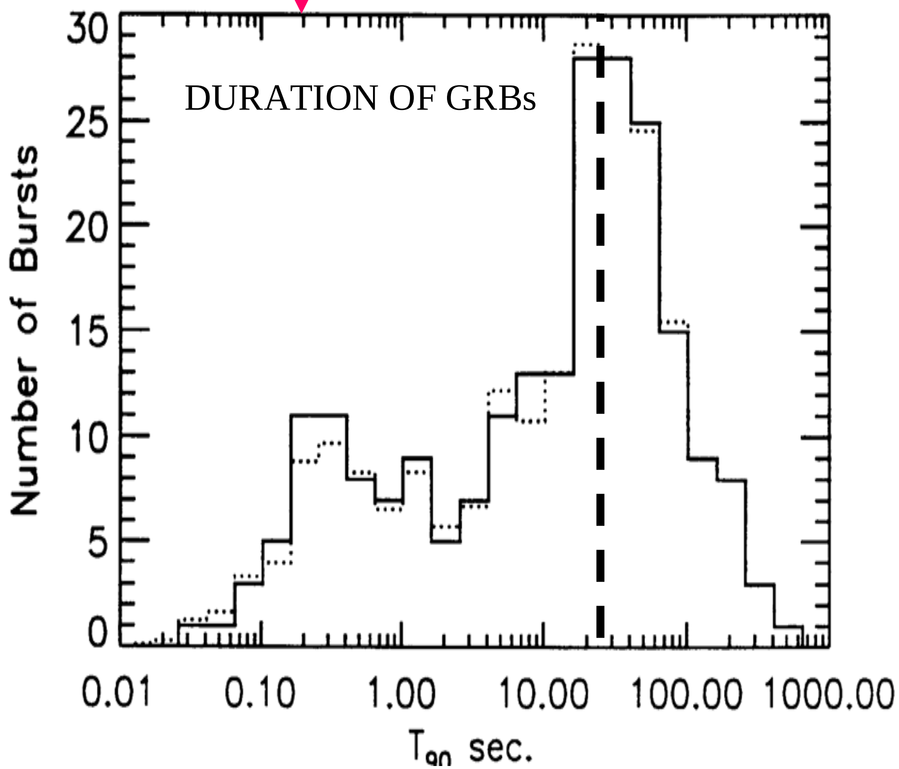
At least a handle on EBL, but also the possibility of accessing cosmological constants (Martinez et al.) could become reality soon (maybe including X-ray obs.)

GRBs

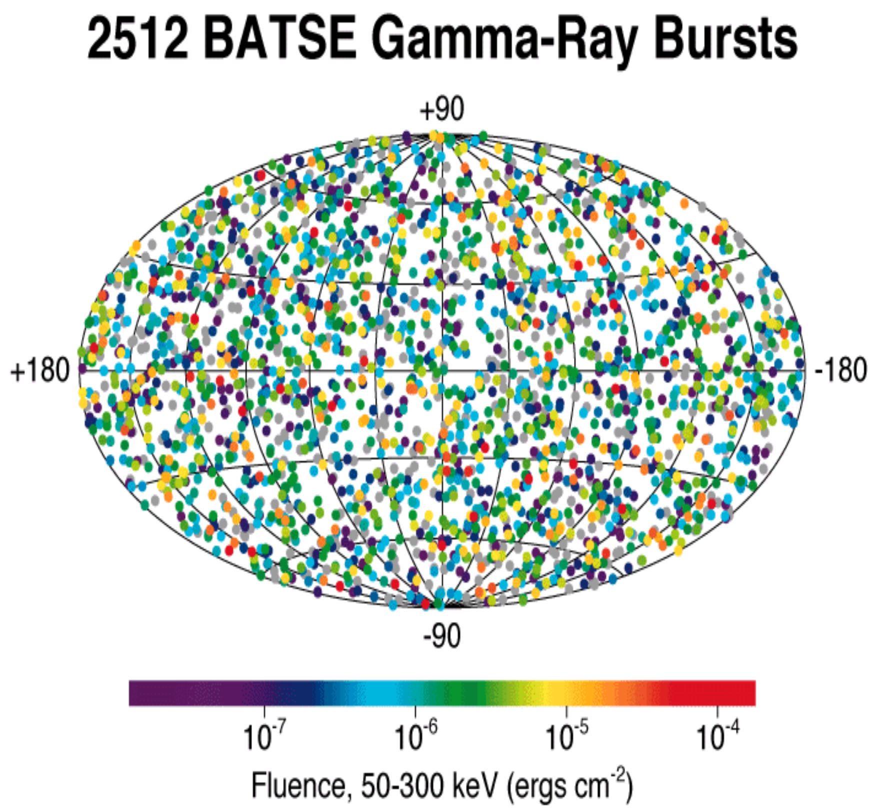
Only to be seen by all sky monitor detectors

Acc. by MAGIC During clear nights



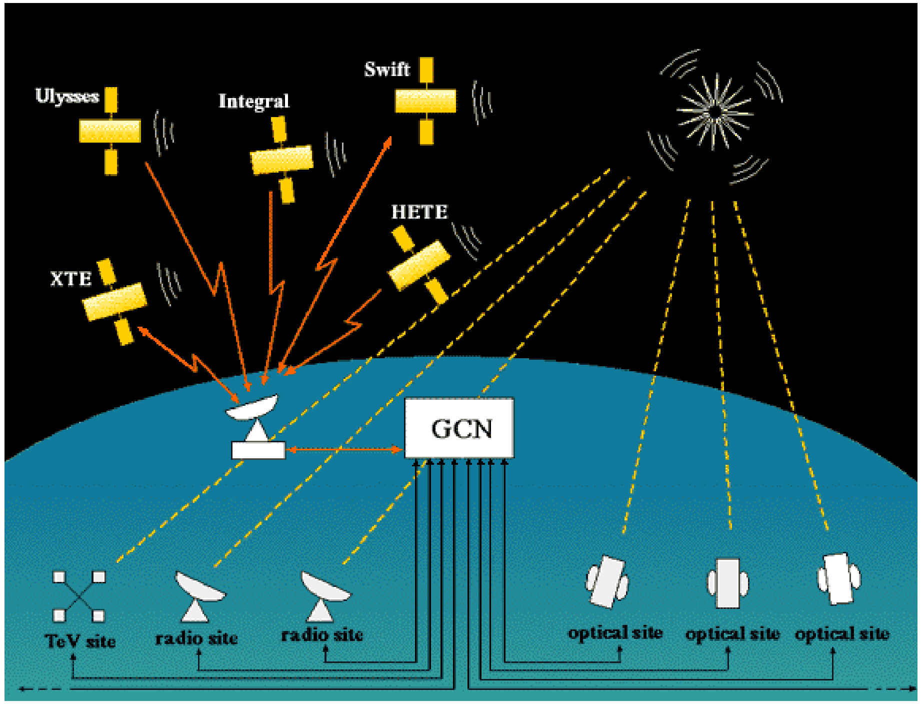


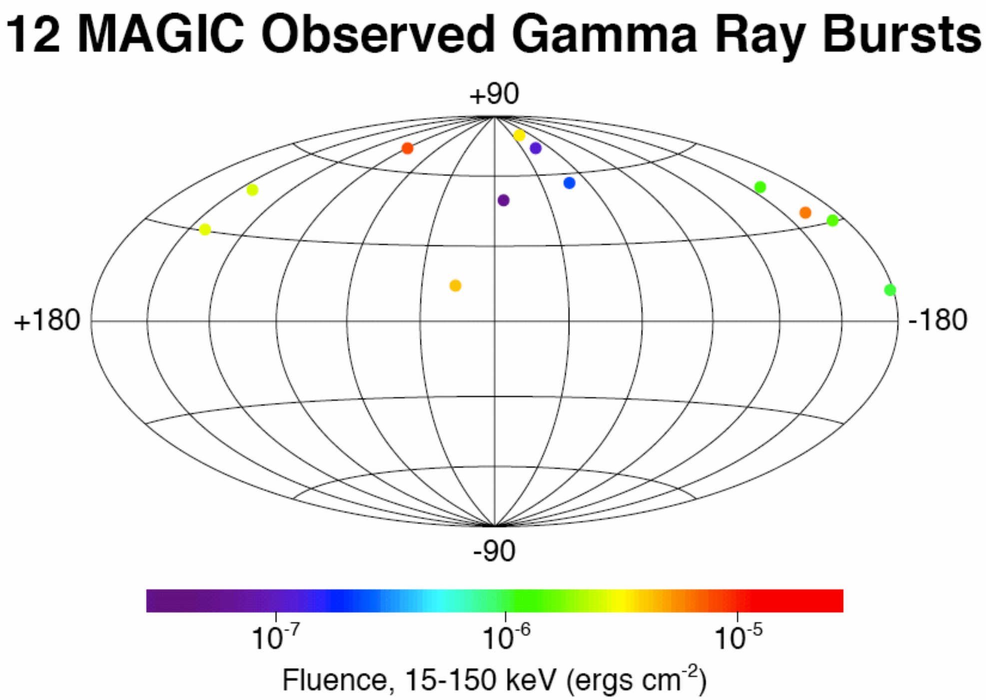
GRB Positions in Galactic Coordinates, BATSE



GRBs and MAGIC

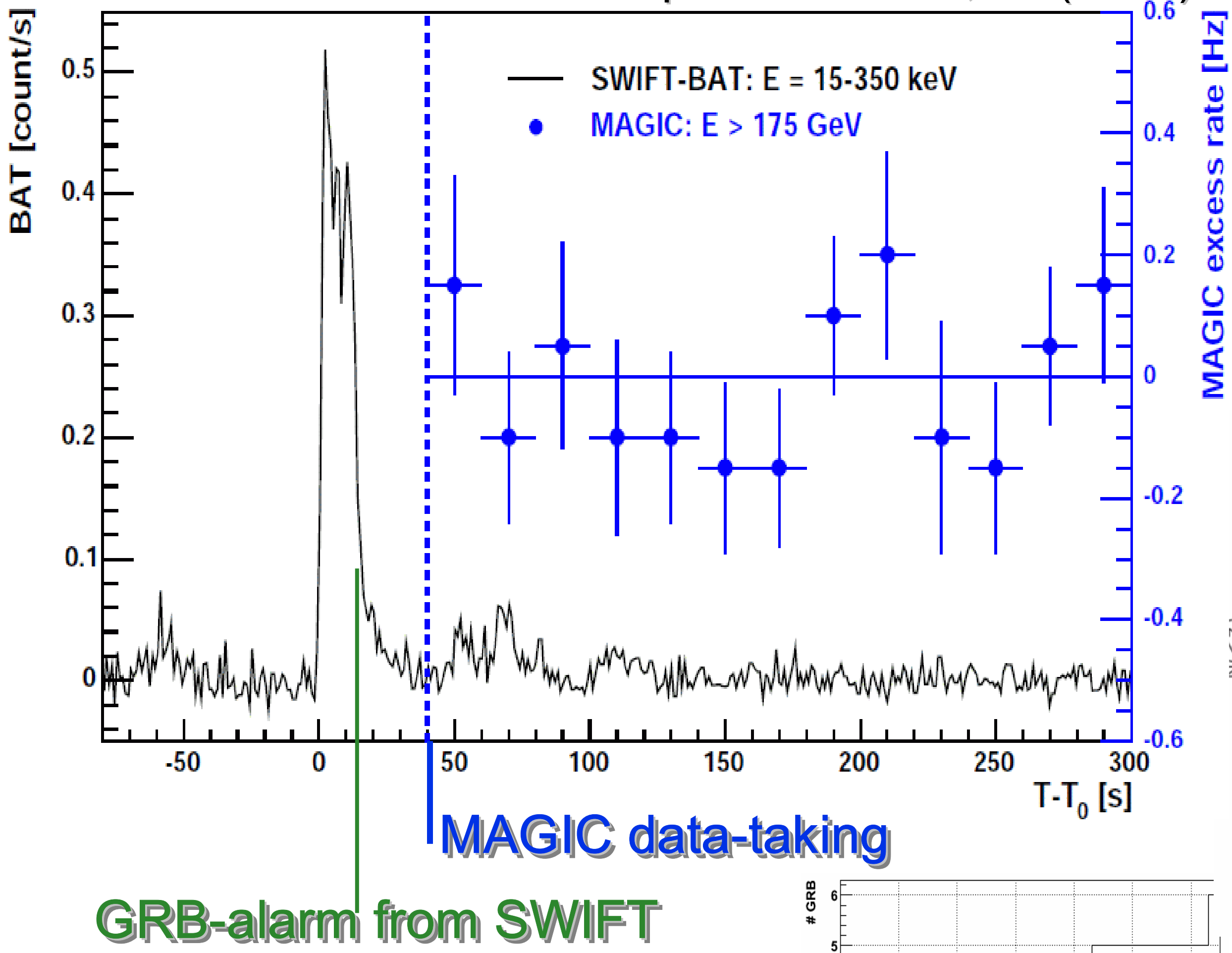
- MAGIC is the right instrument, due to its fast movement & low threshold
  - MAGIC is in the GCN Network
  - GRB alert active since Apr 2005

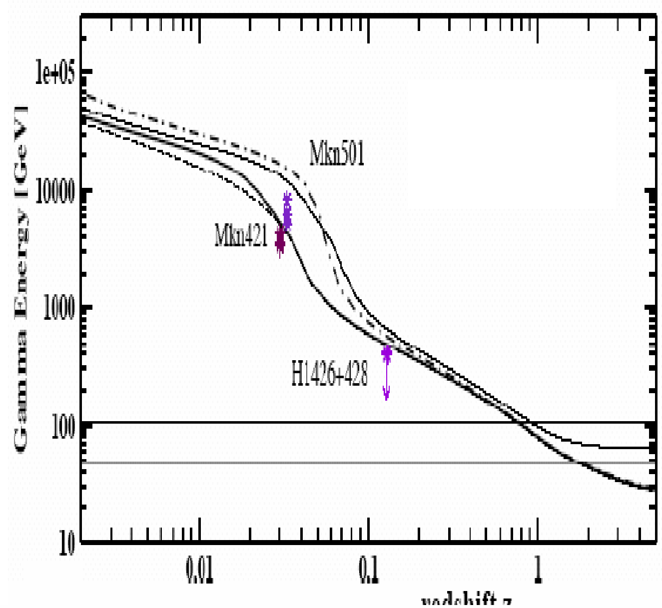


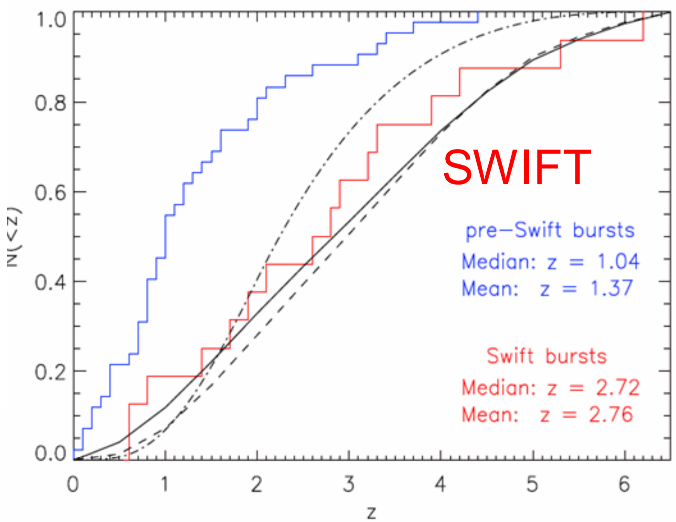


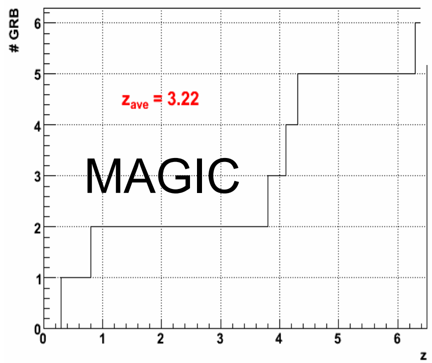
GRB observation with MAGIC: GRB050713a

ApJ Letters 641, L9 (2006)









We are on the track!

No VHE γ emission from GRB positively detected yet...
(all other observed GRB very short or at very high z)

The threshold

- We are publishing with a threshold of 60 GeV
- We detect significant signal above 40 GeV
- Understanding our efficiency towards the goal of 40 GeV. Preliminary physics results at 50 GeV
  - Substantial improvement on DM studies and determination of cosmological constants

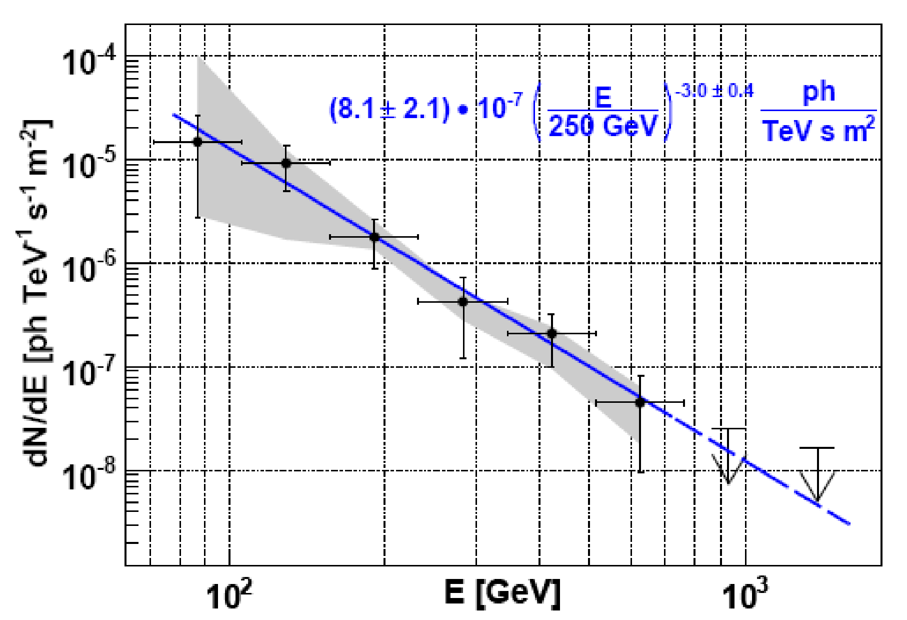
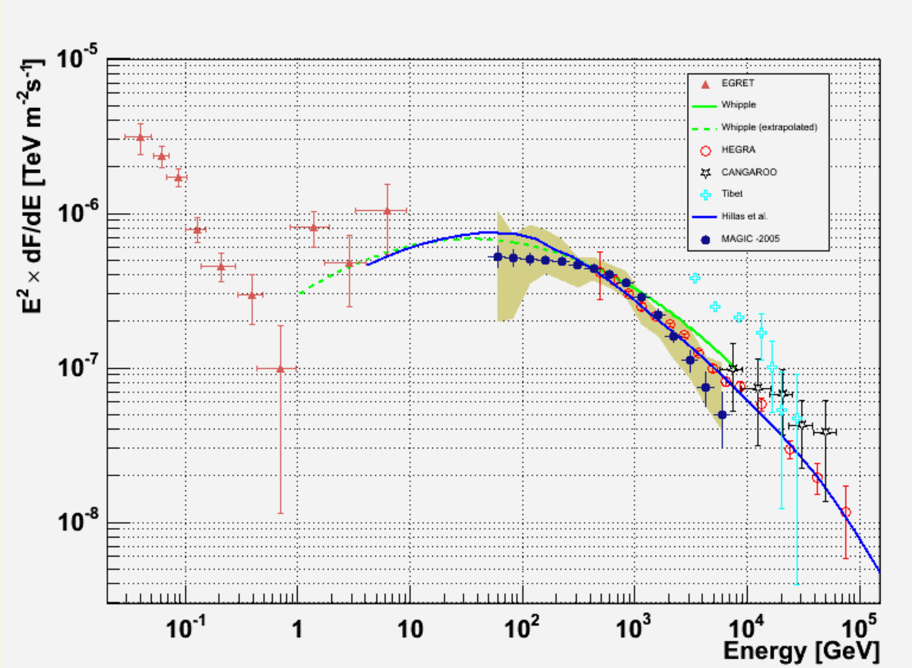


Fig. 3. Differential energy spectrum of 1ES 1218+30.4. The upper limits correspond to a 90% confidence level.

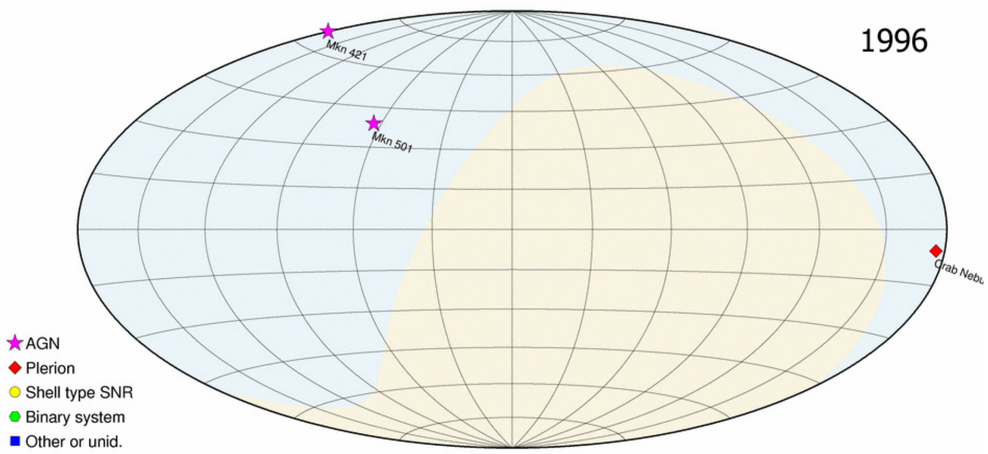


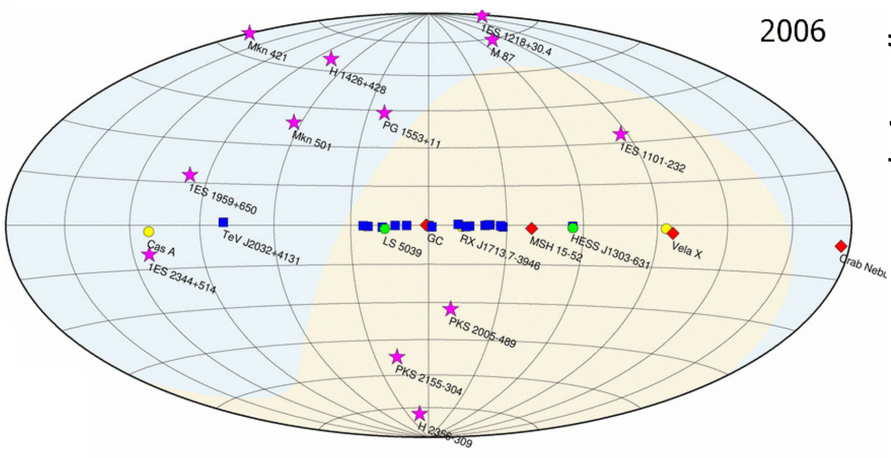
deAngelis, May 07

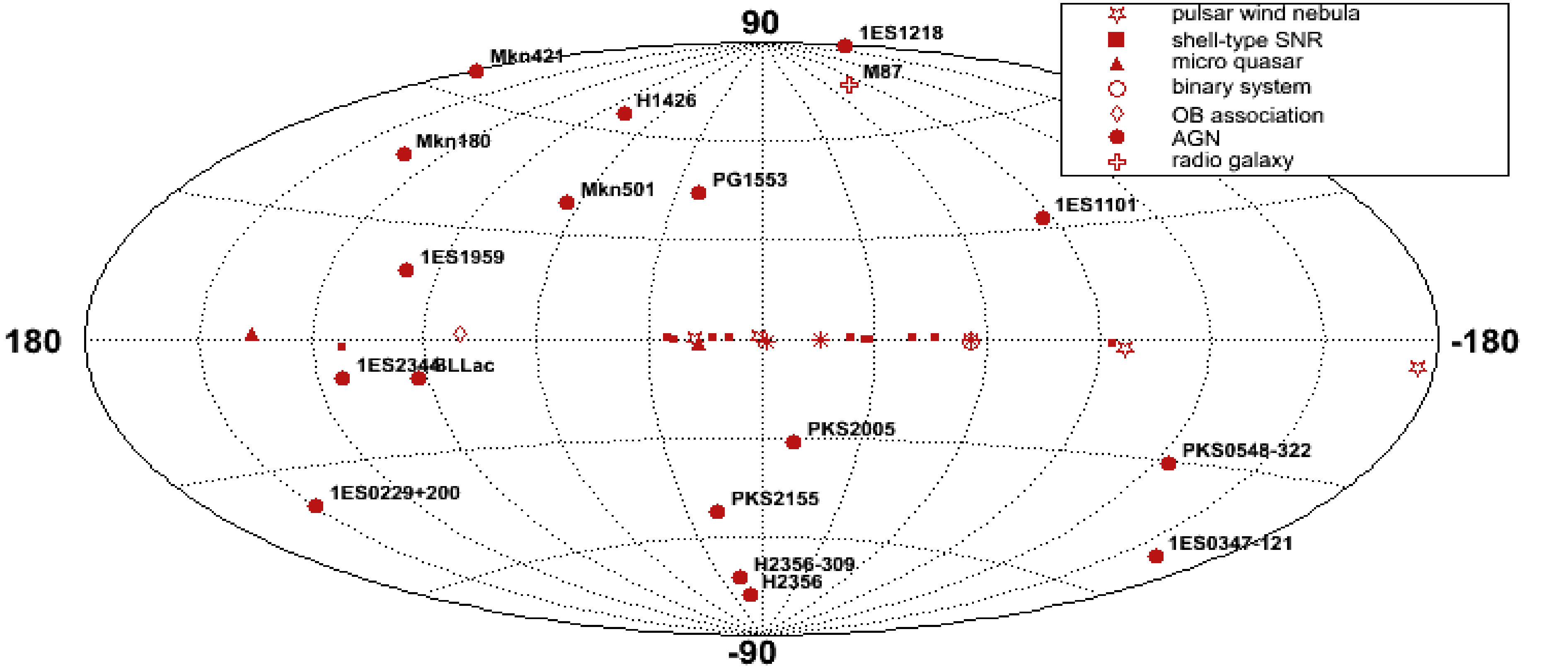
Conclusions on MAGIC I

- MAGIC is close to the design performance for 1 telescope
  - Threshold of 60 GeV for physics analysis; hope to understand down to 50 GeV, and signal from 40 GeV
- MAGIC is delivering very good physics results
  - >20 papers published or submitted (one in Science), with 8 new sources; 6 papers in the pipeline
  - Cycle 2: important commitment to test more fundamental physics (DM, Lorentz violation, …)
  - And the second telescope will see the first light soon…

The sky above 100 GeV







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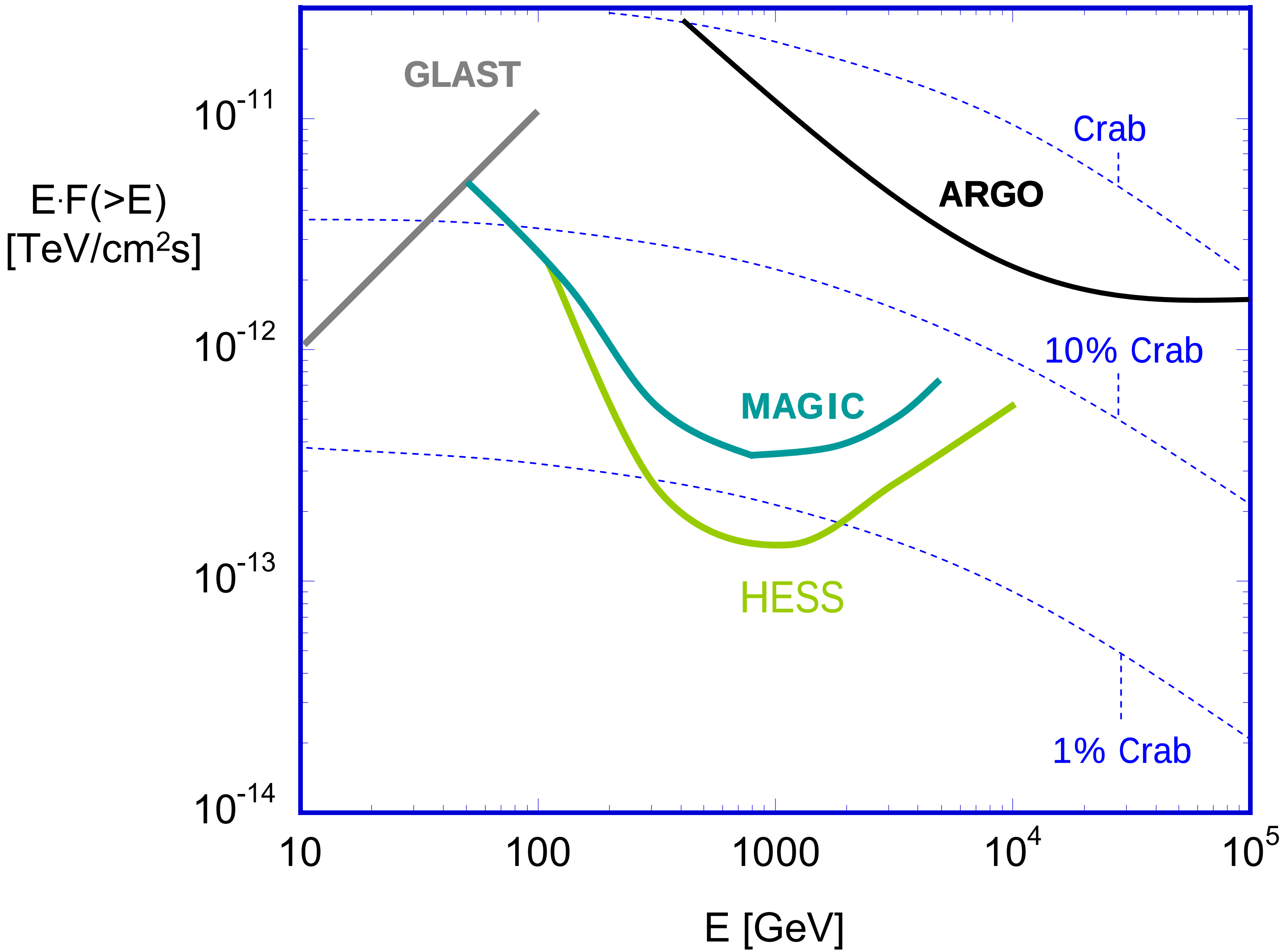
Performance of MAGIC in 2006



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Outlook: What next ? 1.

Cherenkov Telescopes

VERITAS

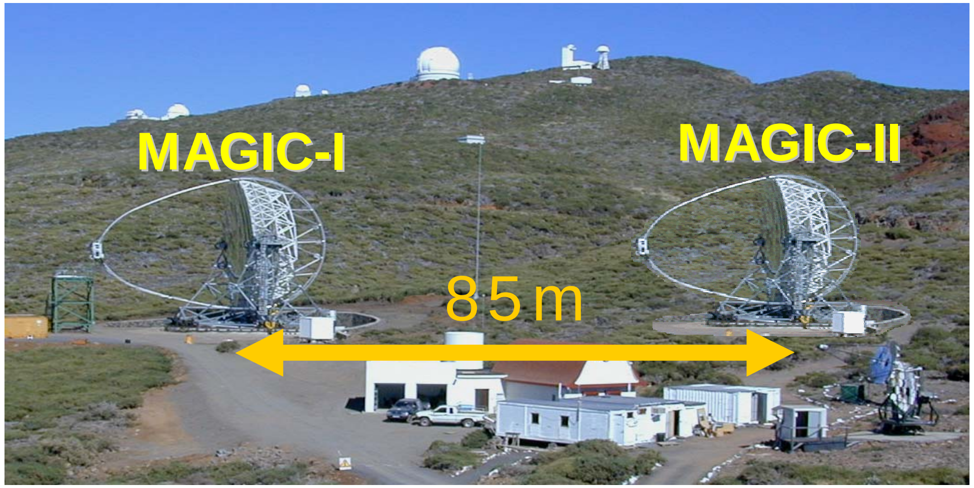
- 4x 12m telescopes at Kitt-Peak in 2007 (2 now)

MAGIC-II

- Improved 17m telescope.
- Faster FADCs and a high-QE camera.
- First light in 2007.

HESS-II

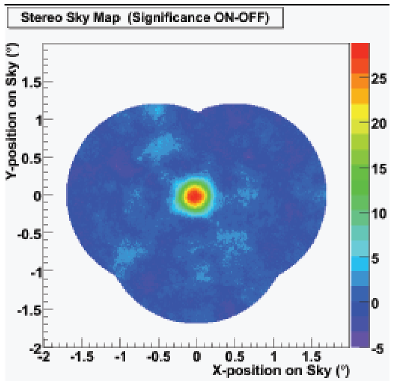
- New 28m telescope.
- 2048 pixel camera.
- Lower energy threshold (30 GeV?)
- First light in 2008 or 2009



VERITAS

Present status: reproducing MAGIC results w/ 3 telescopes

Sensitivity will be comparable to Magic1



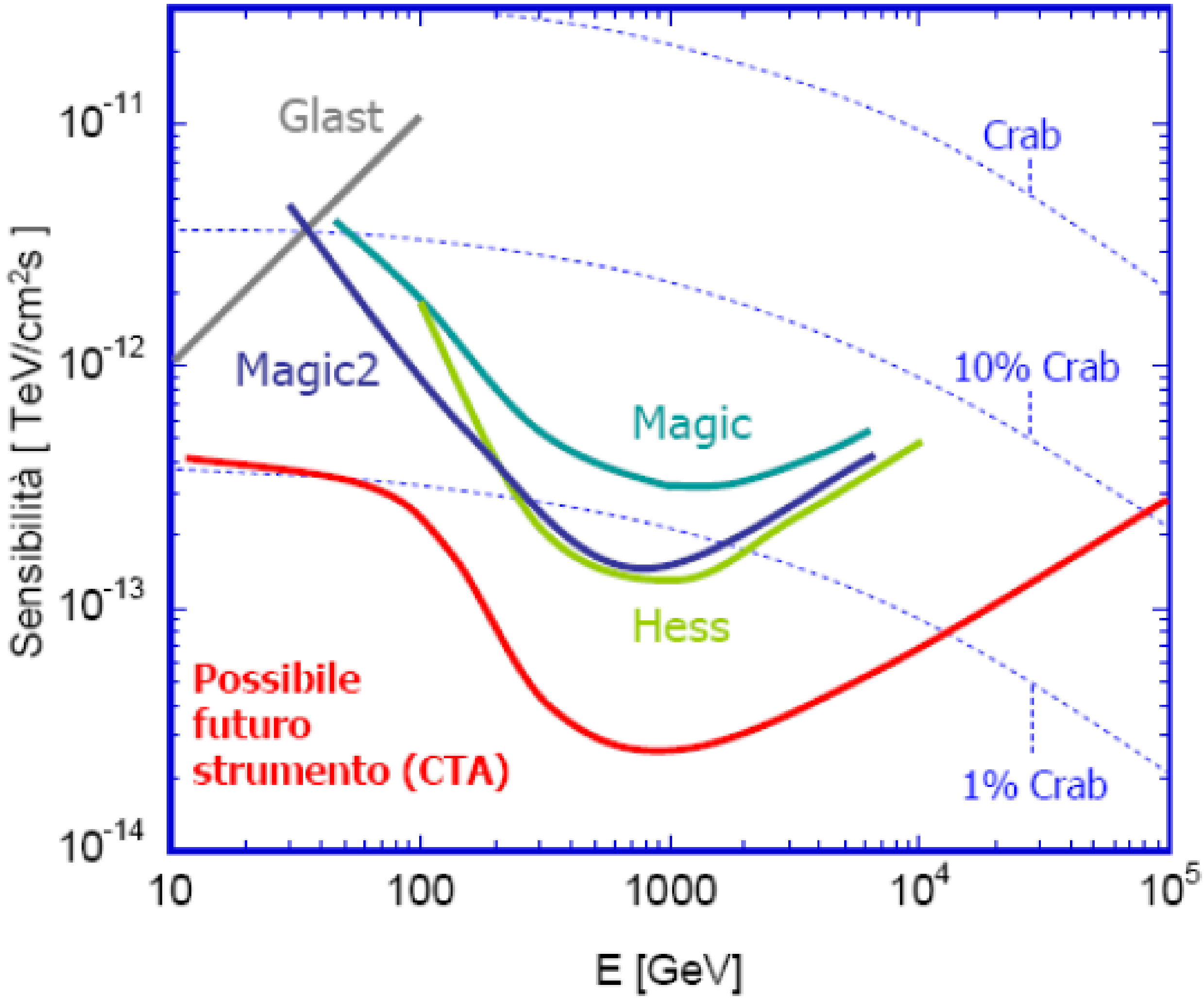
The second MAGIC telescope

News: Electronics, mirrors

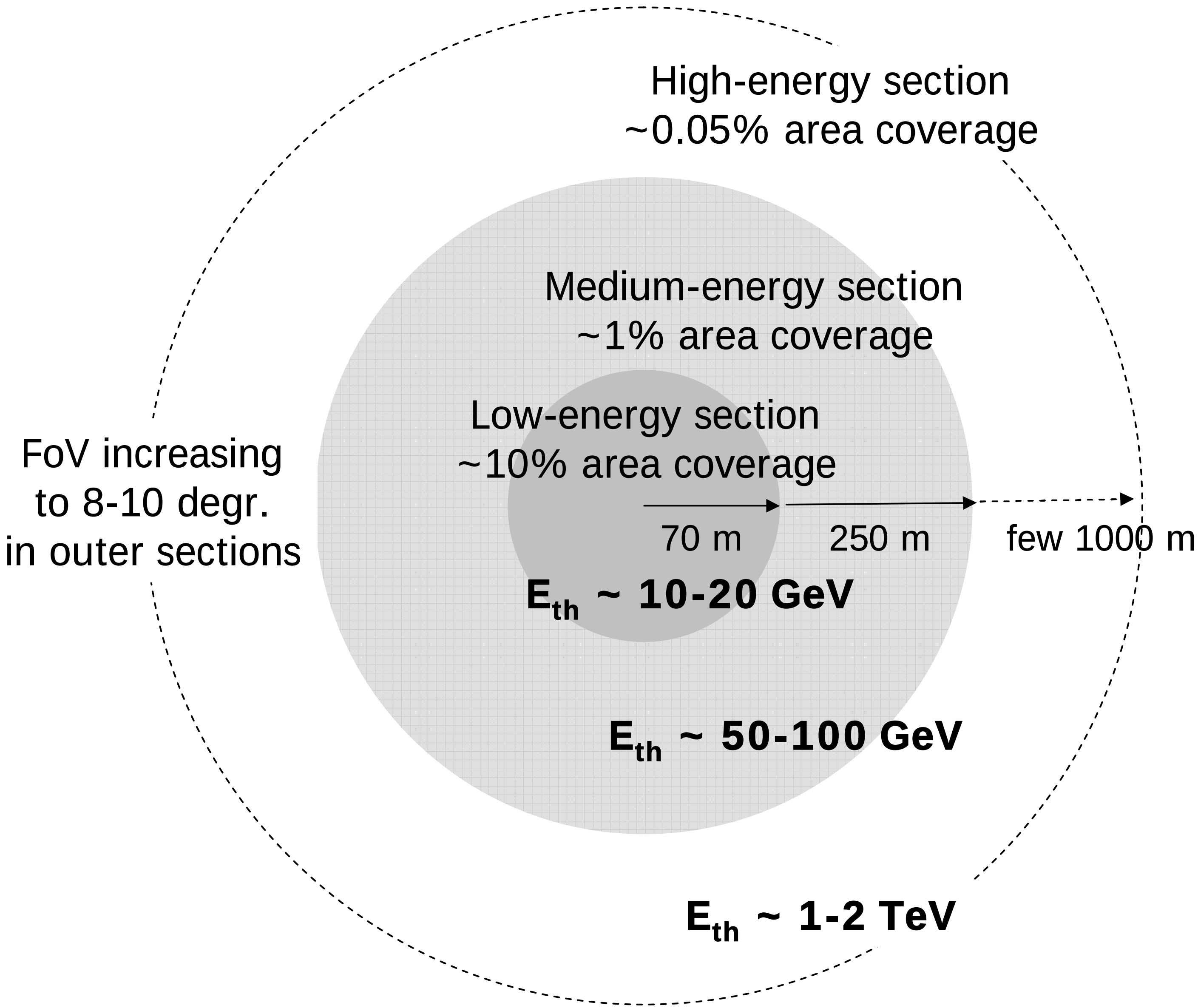
Calendar (tentative)

- *Nov '05 → Prototypes mounted*
- *Jun '06 → New test mirrors*
- *June-September '06 → Tooling realization*
- *September '06 → Starting production first INFN mirrors*
- Feb '07 → Prototypes of INAF mirrors
- Aug '07 → First INFN batch installation
- Feb '08 → Production INAF complete; installation starts
- Apr '08 → Reflector completed ?

What’s new – 2 : the CTA



Array layout: 2-3 Zones



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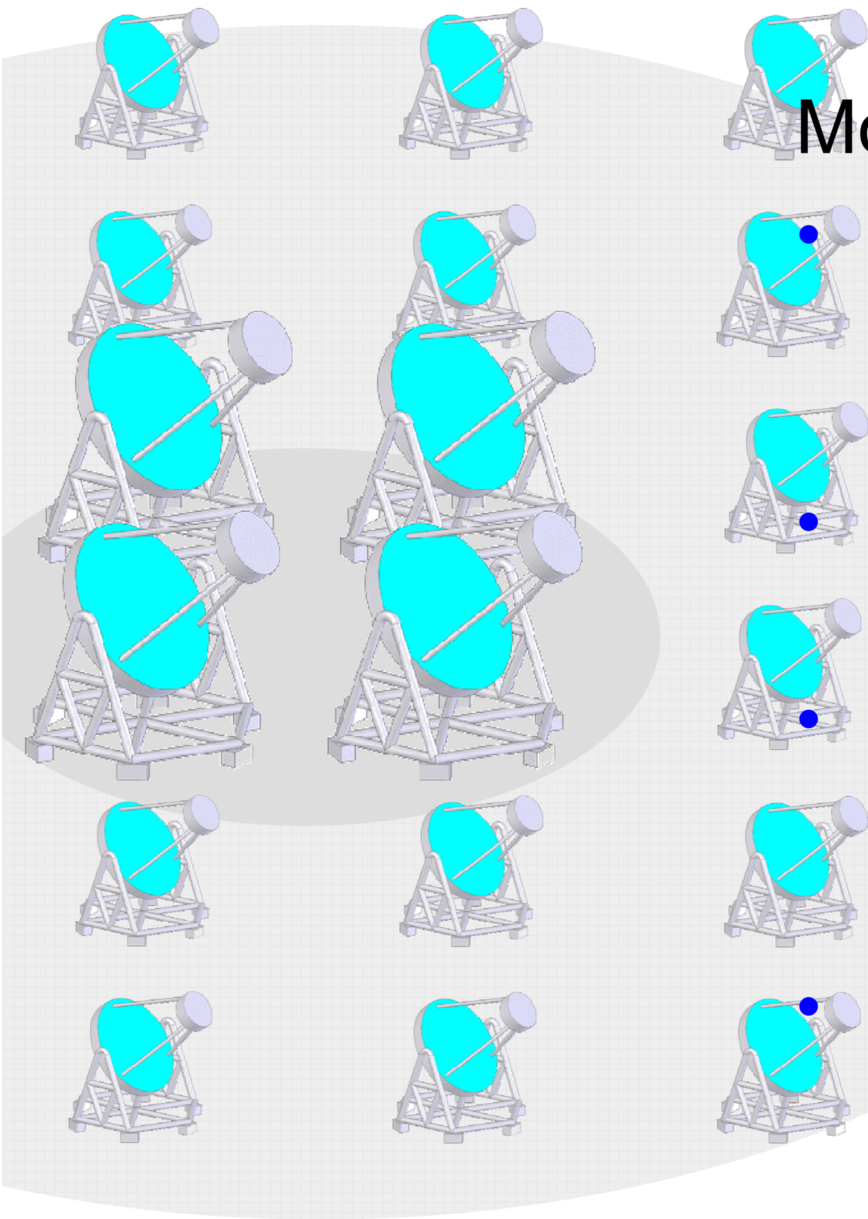
Option “off the shelf”: Mix of telescope types



Not to scale !

Modes of operation

- Deep wide-band mode: all telescopes track the same source
- Survey mode: staggered fields of view survey sky
- Search & monitoring mode: subclusters track different sources
- Narrow-band mode: halo telescopes accumulate high-energy data, core telescopes hunt pulsars

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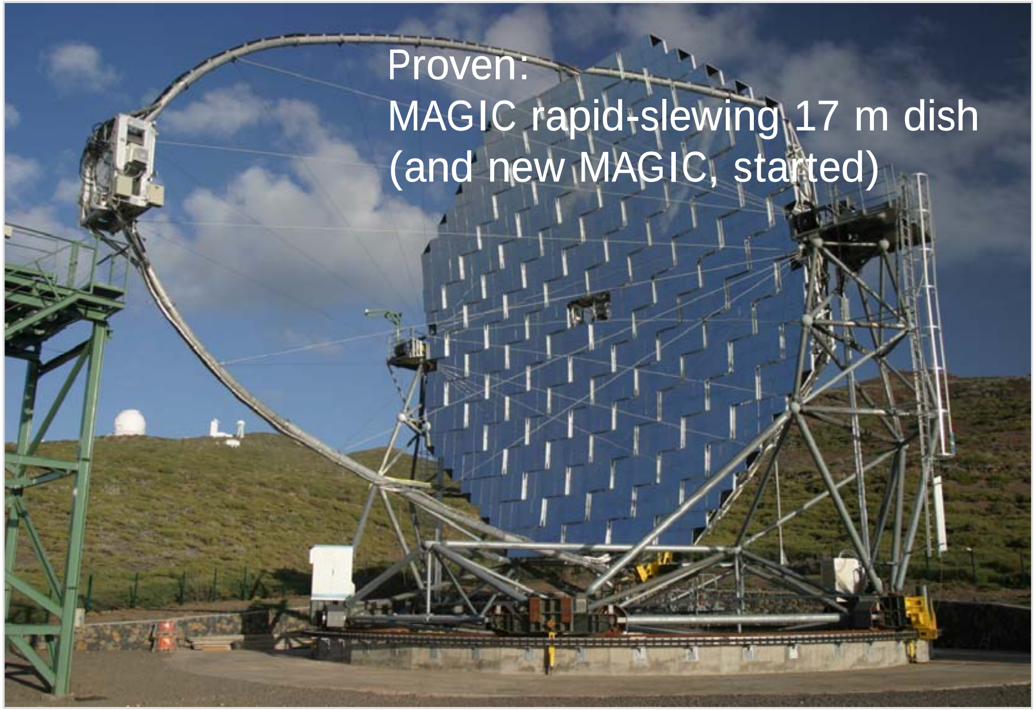
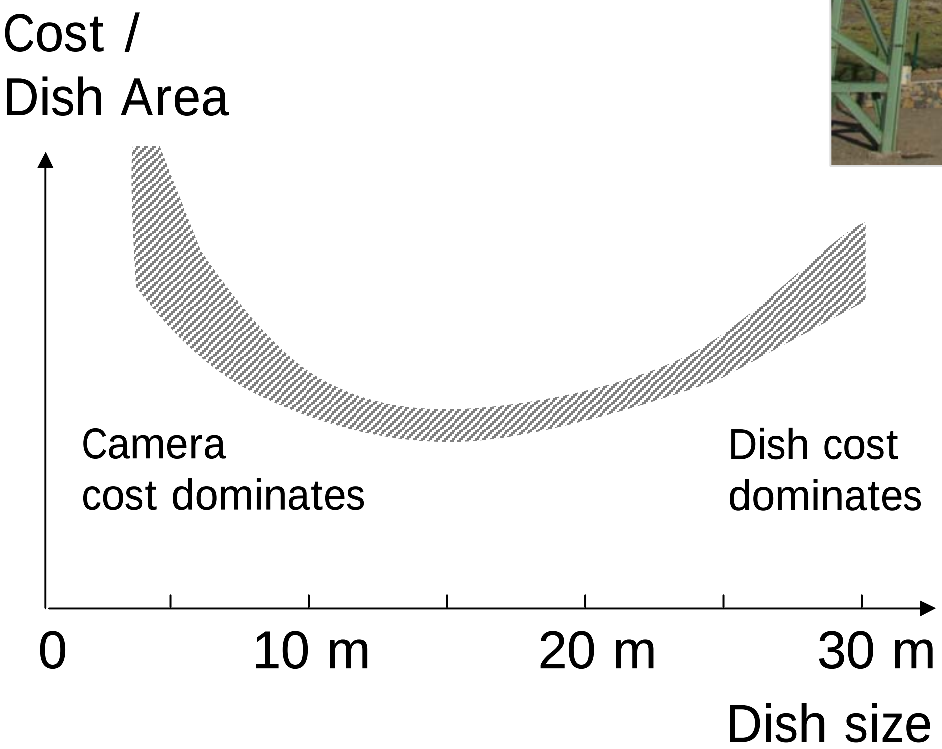
Telescope structure "off the shelf" (but new ideas for large-field are welcome)

Telescope structure “off the shelf” (but new ideas for large-field are welcome)





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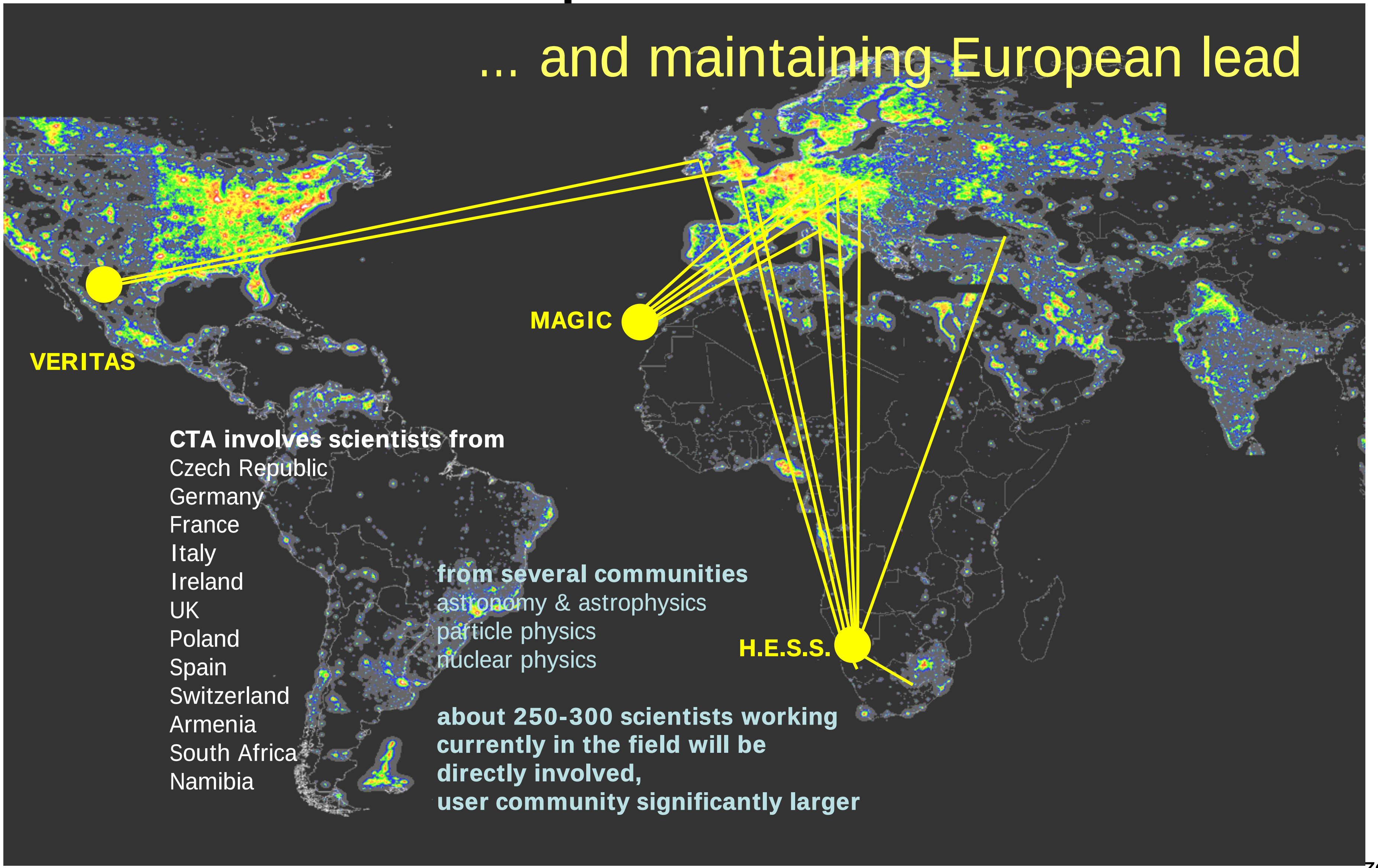
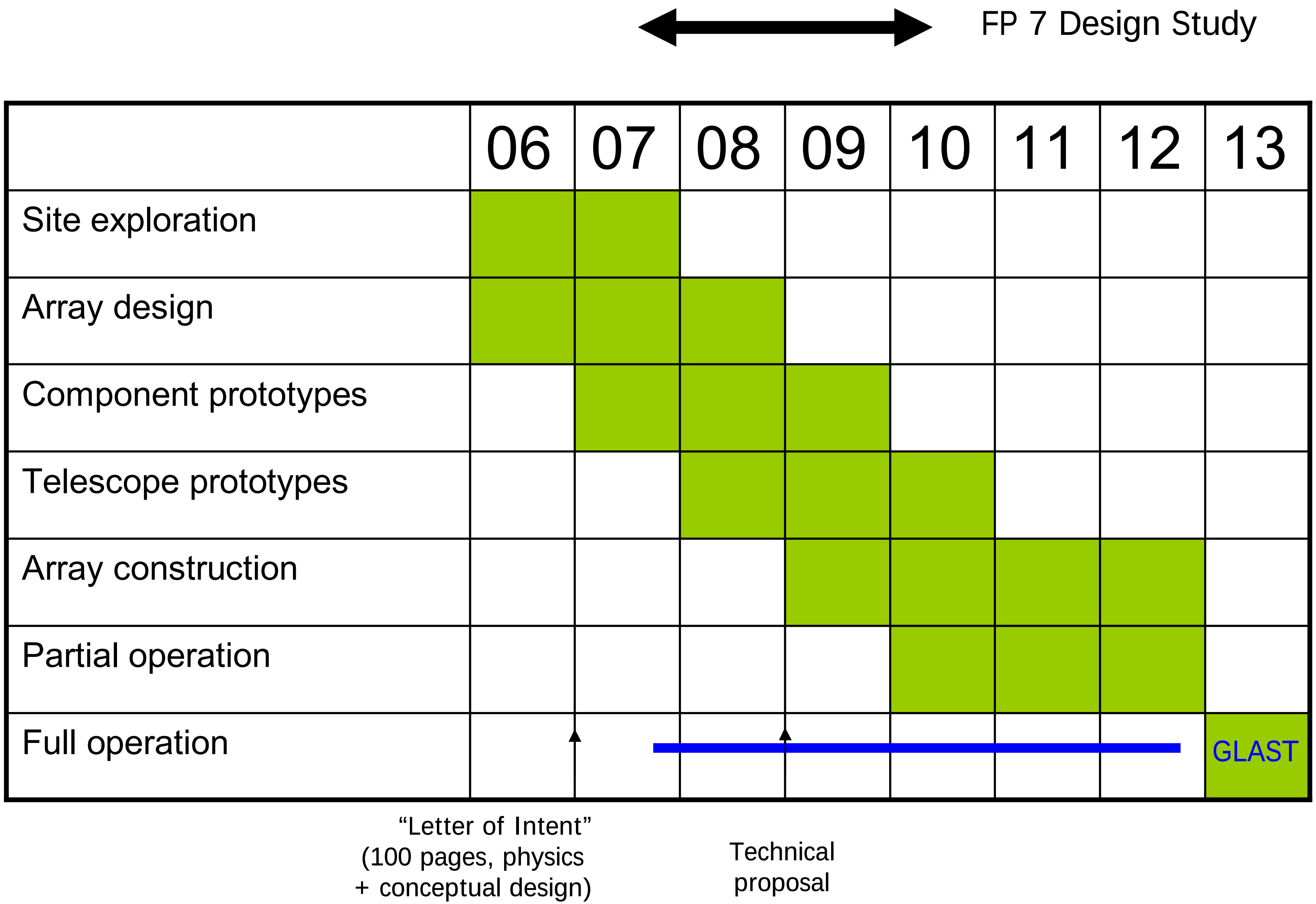
- Typical angular resolutions will be 0.3 deg at 20 GeV, 0.05-0.1 deg at 1 TeV and beyond.
- The performance curve has 3 regions:
  - low energy (10-100 GeV),
  - medium energy (100 GeV - few TeV) with excellent sensitivity (~10x HESS)
  - high energy (beyond 10 TeV).

  Both at low and high energy sensitivity will be reduced compared to the ~1 TeV region.
- We would need a judgement as to how important the various regions are (e.g. a matrix of physics topics vs energy range), and if there is a clear priority for implementation in case parts of the instrument have to be staged.

Strong support from EU: European lead…



(Very optimistic) Schedule



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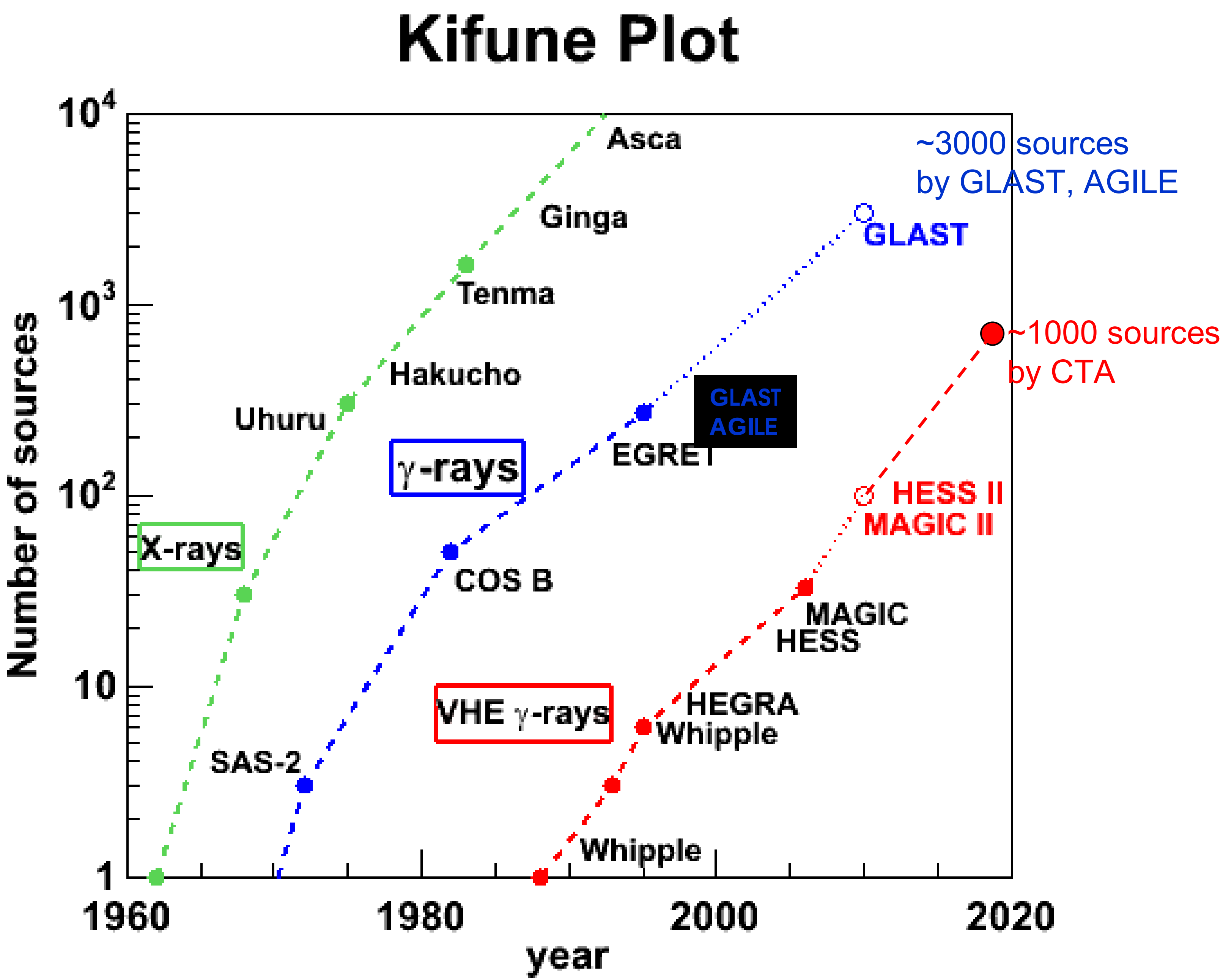
- Working groups started meeting in June 06
  - **Physics**: A. De Angelis and L. Drury (convenors), M. Persic, G. Lamanna, F. Aharonian, M. Teshima, K. Mannheim, D. Torres, G.F. Bertone, M. Punch, B. Giebels, …
  - **MC**: K. Bernloher and E. Carmona (conv.), G. Hermann, G. Lamanna, S. Nolan, C. Bigongiari, A. Moralejo, W. Rhode, …
  - **Photon detector**: T. Schweizer and P. Vincent (conv.), P. Goret, M. Punch, M. Teshima, E. Lorenz, N. Turini, …
  - **Choice of the site**: B.K. and M. Teshima (conv.), G. Vasiliades, J. Cortina, …
  - **Mechanics and mirrors**: M. Mariotti and M. Panter (conv.), E. Lorenz, A. Biland, P. Chadwick, O. de Jager, …
  - **DAQ and computing**: A. Biland and U. Schwanke (conv.), F. Goebel, L. Drury, T. Brez, G. Cabras, …

Final physics document ready in May 07 (space for "exotic" additions…)



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CTA - conclusions

- The time to decide the weight of Italy is now
  - Design is open…
    - $10^4 – 10^5$ m^2 surface ! Good market for mirror technology…
    - Frontier technology for electronics
    - New design (Newton?)
  - Negotiation for R&D to be concluded within April
    - Italy got the optical surface, and…

GENERAL Conclusions

- Great results from Cherenkov telescopes: number of VHE sources increased by one order of magnitude in 3 years
- Another factor of 3 with MAGIC2, HESS2
  - And crucial improvement in resolution
- Subjects of fundamental physics become accessible
  - Acceleration mechanisms
  - Lorentz violation
  - Dark matter
  - Transparency of the Universe
- Another order of magnitude can be gained with CTA
  - And more: room for new ideas…

- A safe sector, with some expectation for the unexpected !!!
  - Also for anomalous events…

  - **Please contact me if you have ideas!**