

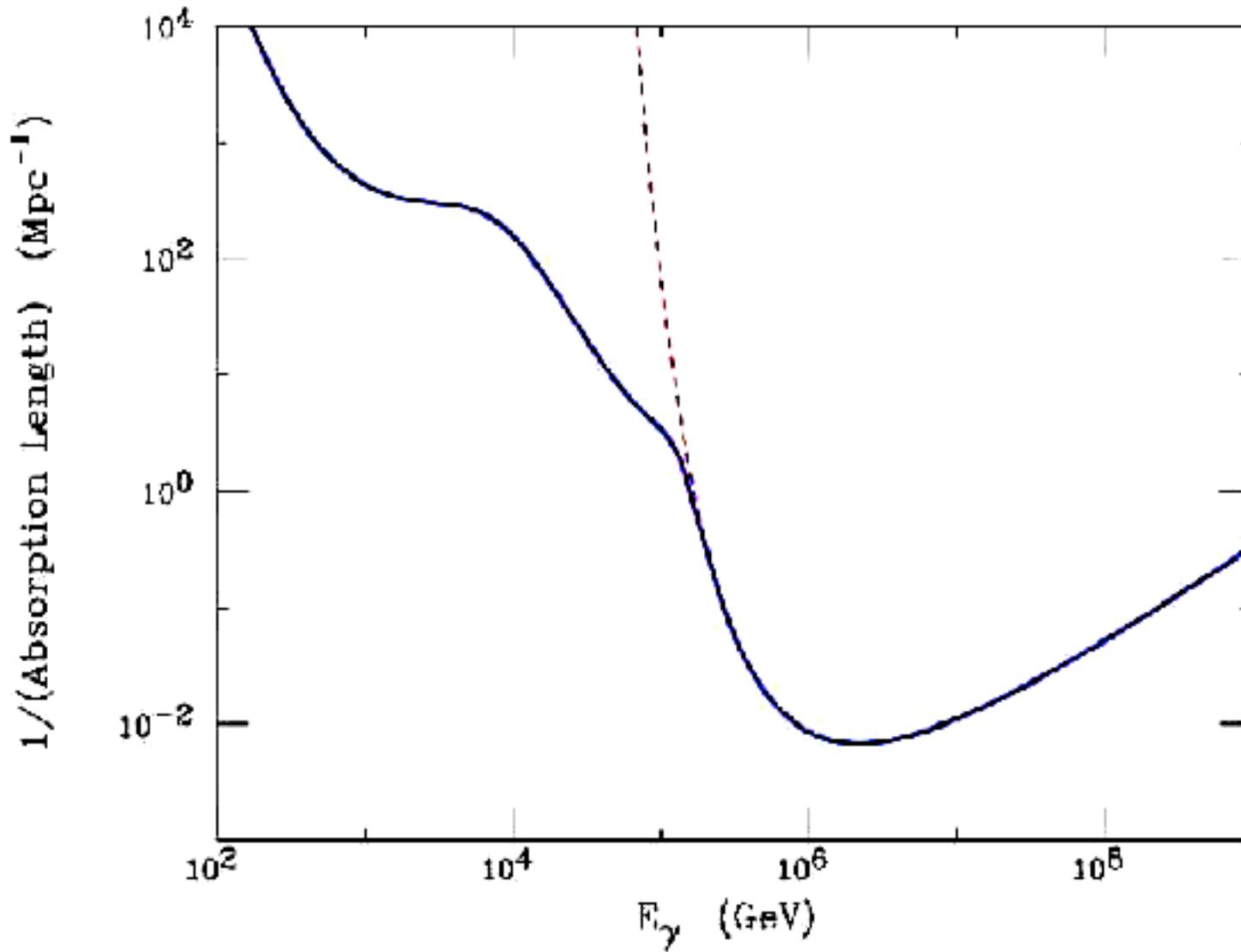
Astrofisica e particelle elementari

aa 2007-08

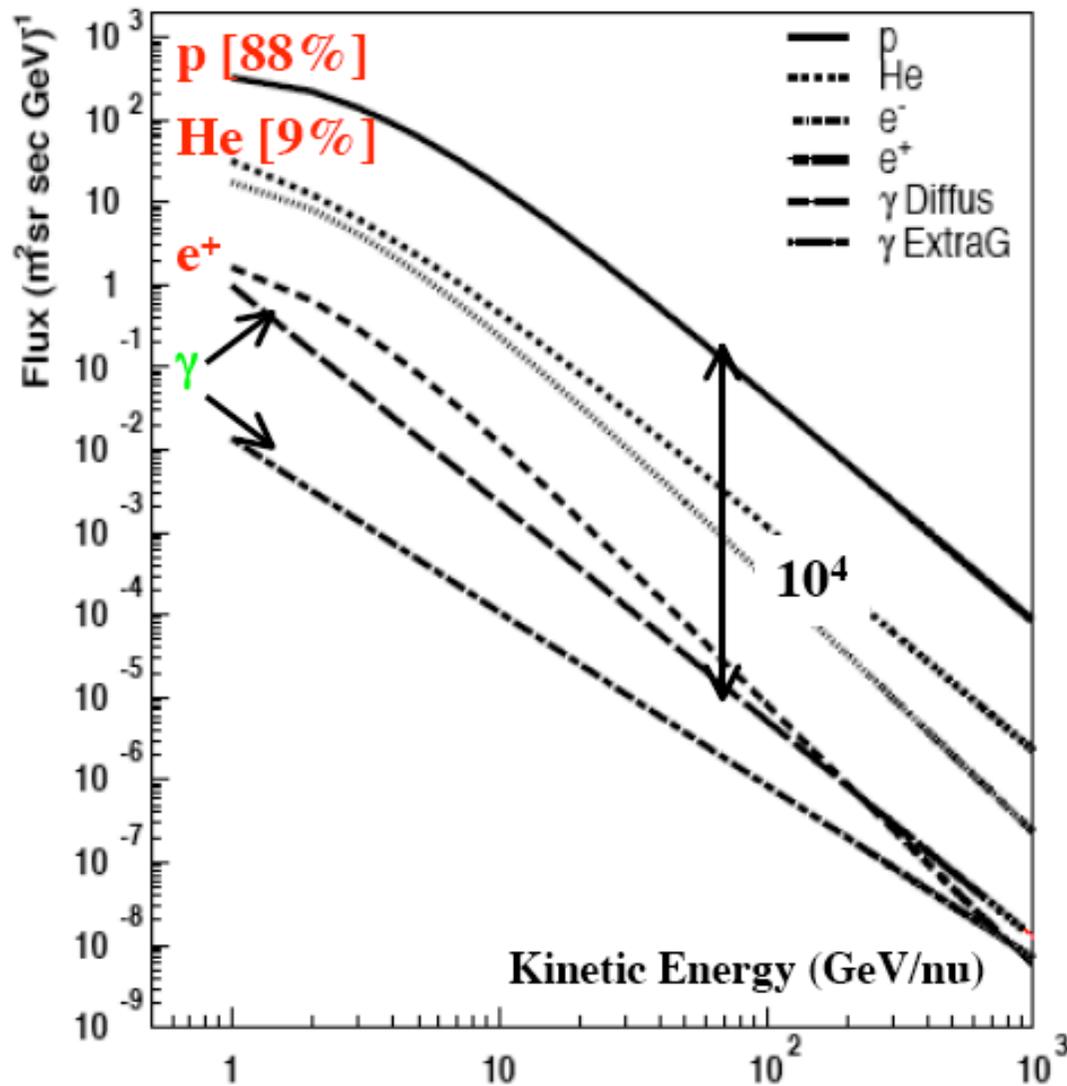
Lezione 11

Bruno Borgia

γ : LUNGHEZZA DI ASSORBIMENTO



GAMMA COSMICI



- per ottenere un rapporto fondo/segnale $\approx 1\%$ occorre raggiungere una reiezione del fondo per un fattore 10^6
- fondo per conversione coppia e⁺ e⁻: protoni + raggi δ
- fondo calorimetro em: protoni

ORIGINE DEI GAMMA COSMICI

Le sorgenti dei gamma cosmici non possono essere di origine termica in quanto richiederebbero temperature al di sopra di 10^9 K, ovvero $kT > 1$ MeV.

1. *Bremsstrahlung*. I gamma possono essere emessi da elettroni relativistici nel campo coulombiano di particelle cariche. L'energia persa dagli elettroni è per unità di materia attraversata (ρx , grammi/cm²) $dE/d\rho x = -E/X_0$ dove X_0 è la lunghezza di radiazione. La radiazione è emessa predominantemente in un intervallo angolare $m_e c^2/E$.

2. *Scattering Compton inverso*. Un elettrone relativistico può trasferire una parte considerevole della sua energia a fotoni di bassa energia. Fotoni di energia media E_γ ricevono in media un'energia

$$E_\gamma \approx E_e \gamma (E / m_e c^2)^2$$

Ad esempio un elettrone di 60 GeV/c può trasformare un fotone del CMB di 6×10^{-4} eV in un gamma di 10 MeV.

3. *Collisioni anelastiche* $p + p \rightarrow \pi^0 + X$. Protoni al di sopra della soglia di energia possono produrre pioni neutri che decadono in 2×10^{-16} s in due gamma con energia nel c.m. di $m_\pi/2$.

4. *Annichilazione* $e^+ e^- \rightarrow \gamma \gamma$.

5. *Radiazione di sincrotrone*. Emessa da elettroni relativistici in campo magnetico. Questo processo è importante nelle pulsar che hanno un campo magnetico molto elevato dell'ordine di $10^6 - 10^8$ T. La potenza irradiata dagli elettroni è $P \propto (B_\perp \beta \gamma)^2$ dove B_\perp è il campo magnetico, $\beta=v/c$, $\gamma=E/m_e$ dell'elettrone. Lo spettro di emissione ha un massimo per

$$\nu_m = 0.29(3/4\pi)eB_\perp \gamma^2 / m_e$$

6. *Linee spettrali nucleari*. Transizioni tra livelli nucleari emessi nei decadimenti radioattivi o in seguito all'eccitazione dei nuclei da parte di particelle energetiche.

AGN

L'osservazione dei nuclei delle galassie mostra che esistono somiglianze tali da supporre che i fenomeni abbiano una origine comune, anche se le attività differiscono quantitativamente. Le caratteristiche delle attività dei nuclei, AGN, sono:

- presenza di un nucleo compatto brillante
- spettro continuo di radiazione dall'infrarosso alla regione X
- emissione di righe spettrali
- emissione radio non-termica
- variabilità del continuo o delle linee di emissione.

Il modello consiste dei seguenti elementi:

1. al centro una black hole con $10^6 - 10^{10} M_{\odot}$
2. un disco di accrescimento "piccolo" intorno alla black hole che emette nel continuo
3. nuvole di gas ionizzato intorno alla black hole che emette righe
4. toro di gas e polvere nel piano della galassia opaco alla radiazione ottica che emette nell'infrarosso
5. due jet molto stretti emessi dalla regione centrale lungo la direzione dell'asse di rotazione. Questi jet emettono radiazione di sincrotrone.

BLACK HOLE + STELLA



QUASAR

Oggetti di brillantezza superficiale elevata a grandi distanze, $z \approx 5$. Fenomeni avvenuti in stadi primitivi delle galassie. Associati a black hole di $10^6 - 10^8 M_{\odot}$. Il buco nero sarebbe circondato da un disco di materiale galattico di accrescimento che alimenta la sua crescita. In questo processo il materiale subisce violente oscillazioni e le particelle cariche sono accelerate ad altissime energie e sfuggono sotto forma di due jet lungo l'asse minore del disco. Poiché ai jet di particelle è associato un campo magnetico, gli elettroni emettono radiazione di sincrotrone.

La magnitudo visibile dei quasar sorpassa quella delle galassie giganti per un fattore anche fino a 100.

La distribuzione spettrale ha una forma di potenza, con il flusso grossolanamente

$$F \propto \nu^{-\alpha}$$

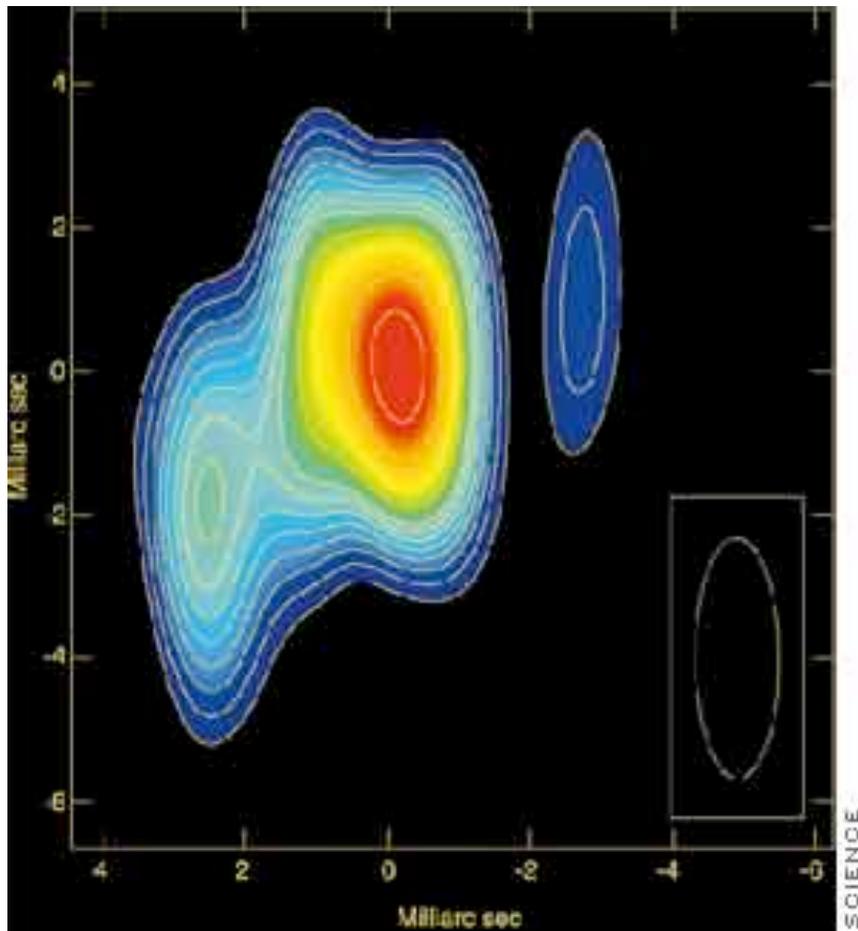
con $\alpha \approx 1$

Lo spettro ha sostanzialmente due zone, una parte di radiazione termica ed una parte non-termica nella regione delle radiofrequenze, dei raggi X e raggi gamma. I fotoni energetici X e gamma non sono di origine di radiazione di sincrotrone ma provengono dal Compton inverso di fotoni meno energetici su elettroni di alta energia.

La struttura dei quasar, osservata dai radiotelescopi, mostra che la maggior parte è composta di due o più oggetti, usualmente una zona centrale compatta ed una più estesa lunga e sottile.

L'energia totale può essere stimata dalla radiazione termica del disco di accrescimento e dalla radiazione di sincrotrone. In totale si trova un'energia caratteristica di 10^{55} J, che corrisponde ad una massa relativistica Mc^2 di diverse $10^8 M_{\odot}$. L'emissione tipica di un quasar è circa 4×10^{40} W, per cui la riserva di energia può durare al più $10^7 - 10^8$ anni.

MICROQUASAR



Mappa dell'emissione radio da un microquasar in cui un buco nero "succhia" una stella compagna.

I "microquasar", alcuni dei quali relativamente vicino alla Terra, sono una versione più piccola dei quasar, che si trovano usualmente al centro delle galassie.

I microquasar emettono luce nel visibile, onde radio, raggi X, gamma e jet di materia lunghi 2-3 miliardi di km.

Il "motore" dei microquasar dovrebbe essere o un piccolo buco nero, $\approx 2 M_{\odot}$ o una stella di neutroni che risucchia materia da una stella vicina.

I buchi neri usualmente hanno una emissione intensa di raggi X, ma i microquasar hanno una emissione modesta di raggi X.

I microquasar potrebbero essere le sorgenti dominanti delle particelle di alta energia e dei fotoni prodotti nella nostra galassia.

La stessa area dove si trovano i microquasar produce emissione persistente di gamma che sono stati rivelati da EGRET.

EGRET ha individuato più di 100 oggetti emettitori di gamma non identificati.

PULSAR

Scoperte nel 1967 con radiotelescopio. Emettono segnali brevi, periodici con periodo T tra 1 ms a 8 s. La durata del segnale è circa $3\%T$.

Crab Nebula emette segnali nell'ottico, X e gamma con $T=33.2$ ms. Si è formata nel 1054 AD nell'esplosione di una supernova. La stella "residua" (remnant) è una stella di neutroni che pulsa con periodo T .

Nella regione dei poli magnetici viene emesso plasma che ruota con la stella raggiungendo velocità c in un cilindro di raggio $R=cT/2\pi$, cilindro luce. Nella Crab $R=1580$ km. Il raggio delle stelle di neutroni è ≈ 10 km.

Se una stella come il Sole che ha inizialmente $T=25d$ collassa in una stella di neutroni, assumendo che conservi totalmente il momento angolare, il periodo diverrebbe $T=1$ ms.

Se inizialmente $B \approx 5 \times 10^{-4}$ T, le linee di forza sono compresse con un rapporto pari \approx al rapporto delle superfici e $B \approx 10^6$ T. Per emettere radiazione gamma col meccanismo della radiazione di sincrotrone occorrono campi $\approx 10^8$ T.

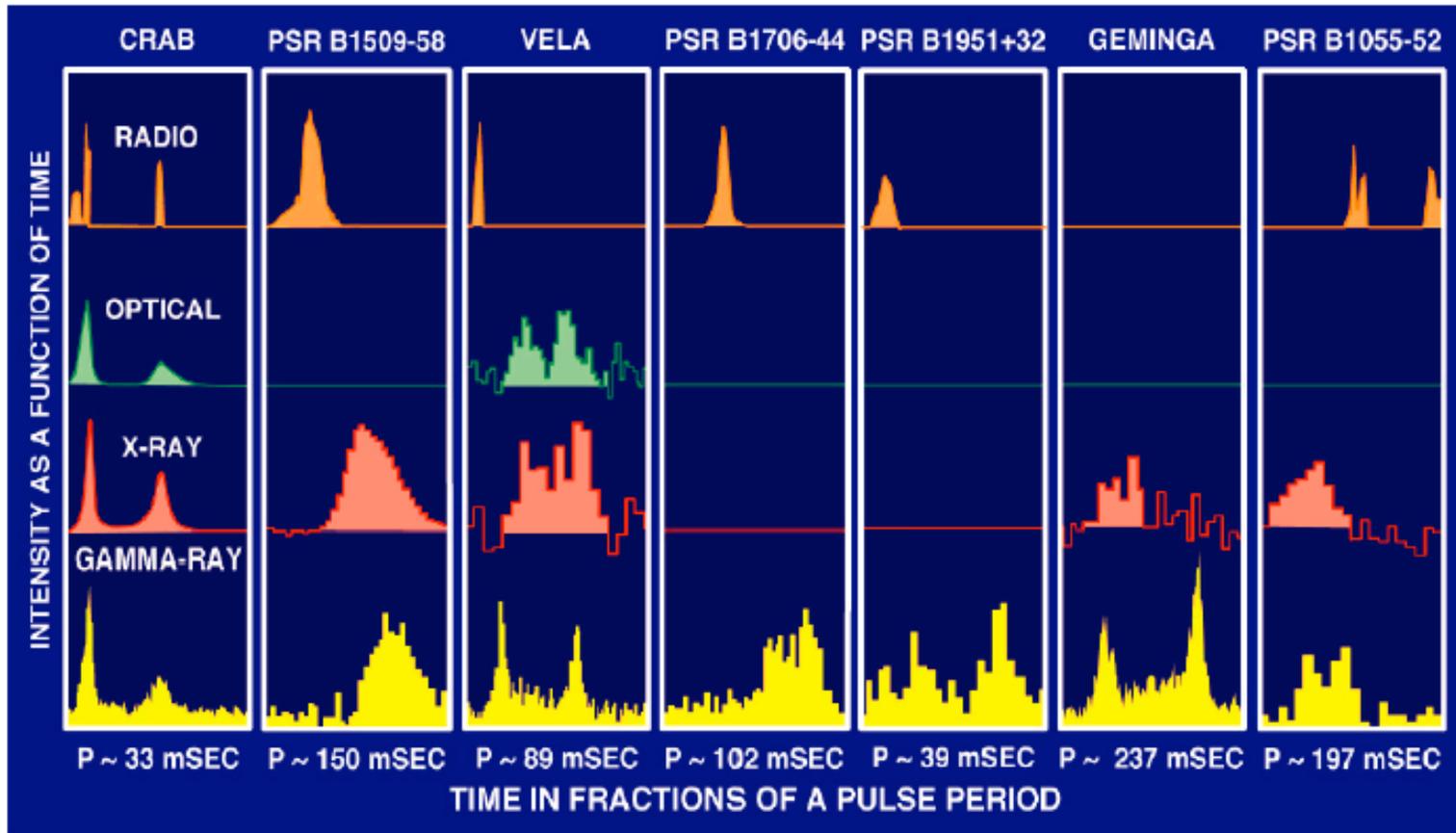
Storicamente le pulsar sono chiamate radio pulsar perché scoperte con i radiotelescopi. In realtà le misure nella regione dei gamma ha mostrato che la potenza emessa dalle pulsar in radiazione gamma è maggiore che nella regione radio per parecchi ordini di grandezza.

Sostanzialmente esistono due modelli di emissione:

- "polar cap": la regione di emissione è intorno ai poli entro qualche raggio stellare
- "outer gap": la regione di emissione è nella zona di linee di forza del dipolo più chiuse.

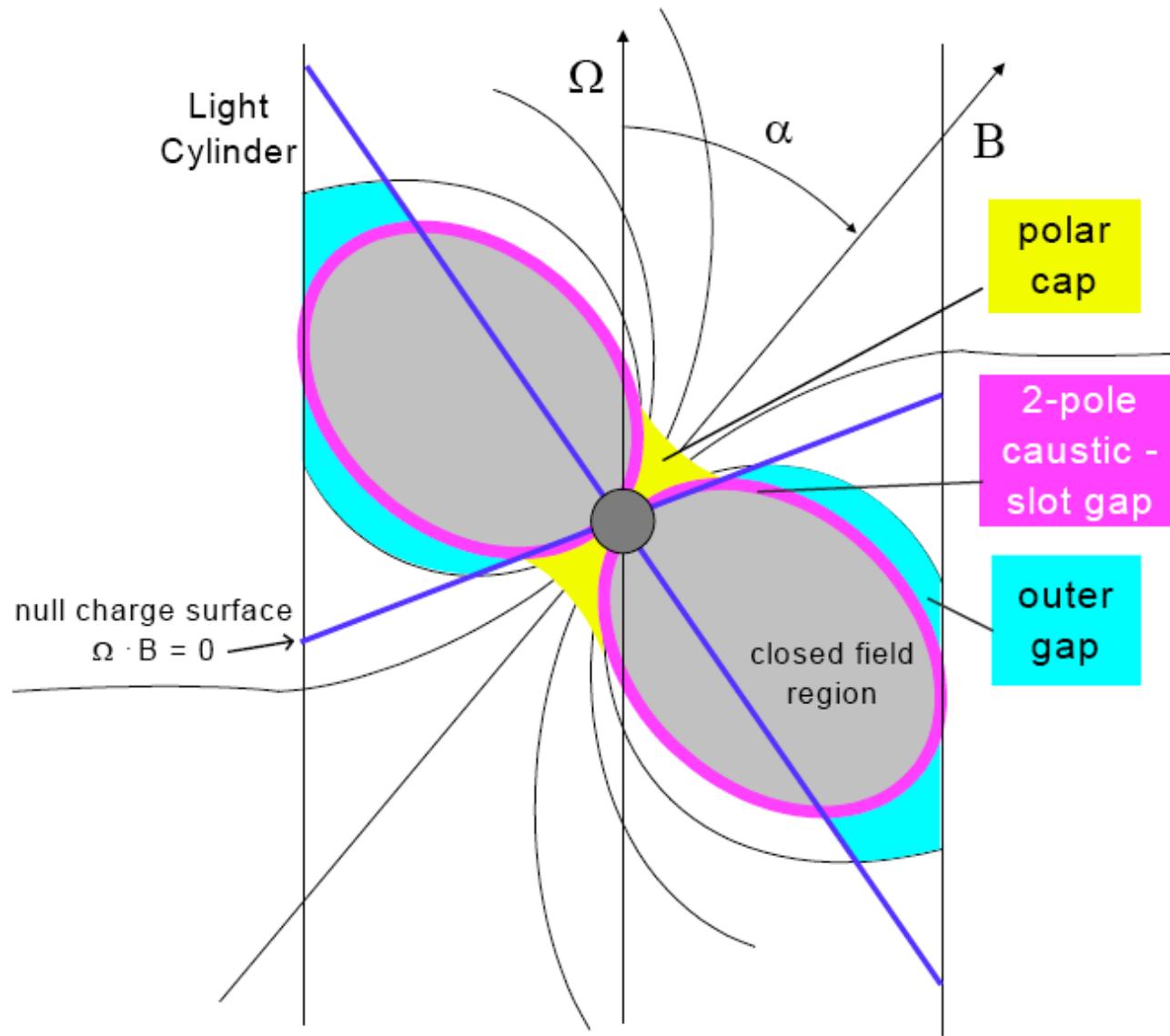
RADIAZIONE EM DA PULSAR

P
U
L
S
A
R
S

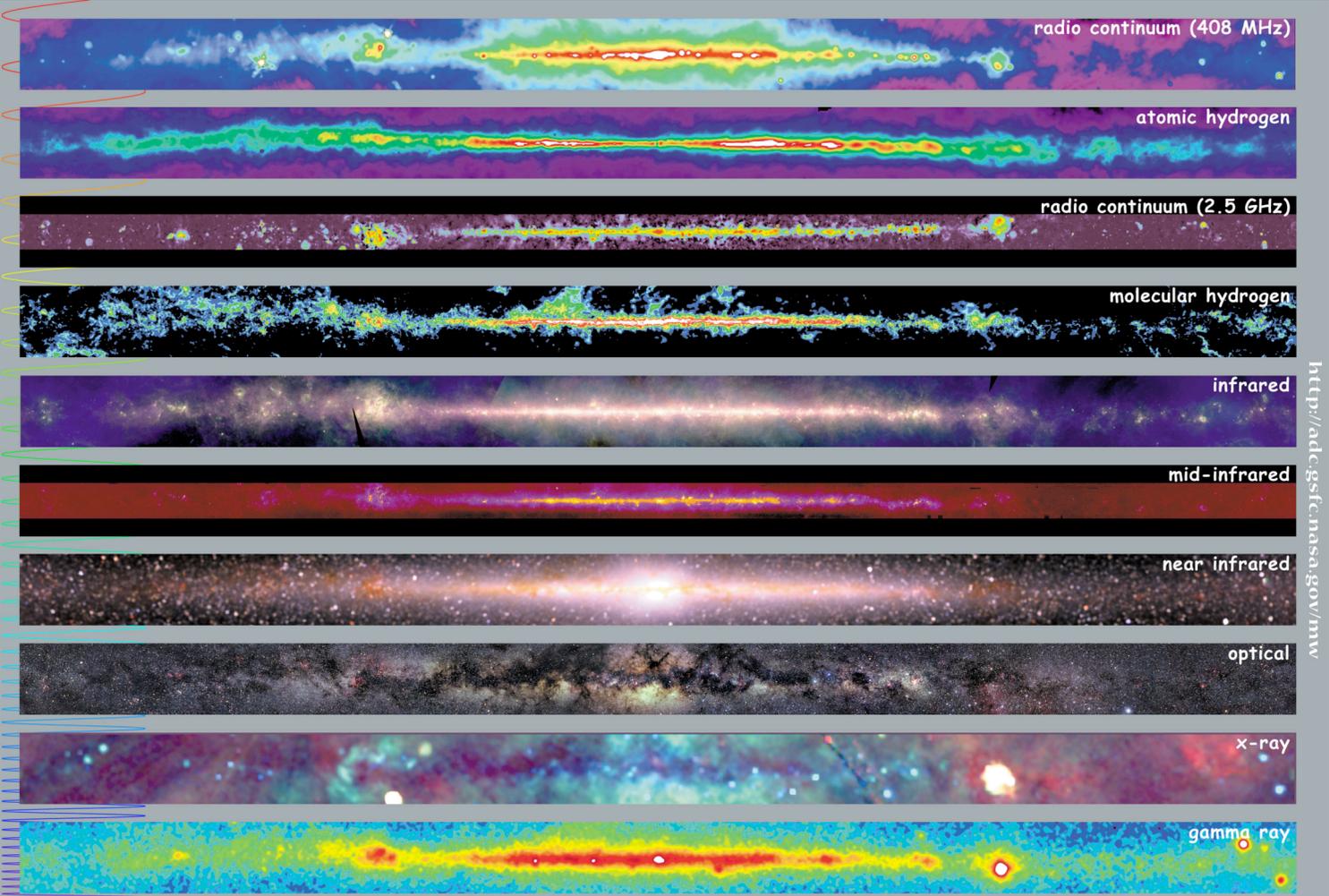


Multiwavelength light curves of the seven pulsars detected by GRO.

PULSAR: MODELLI EMISSIONE



The Galaxy – I



<http://adc.gsfc.nasa.gov/mw>

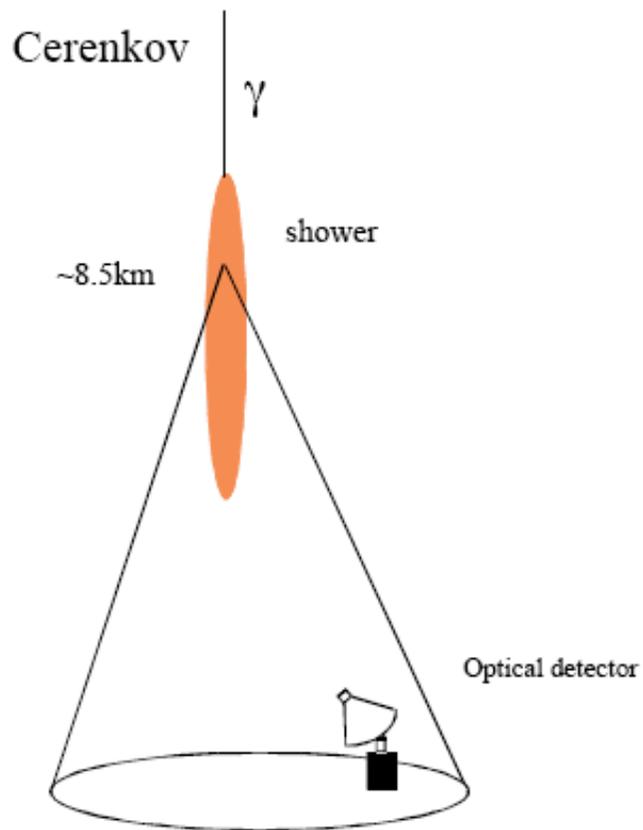


Multiwavelength Milky Way

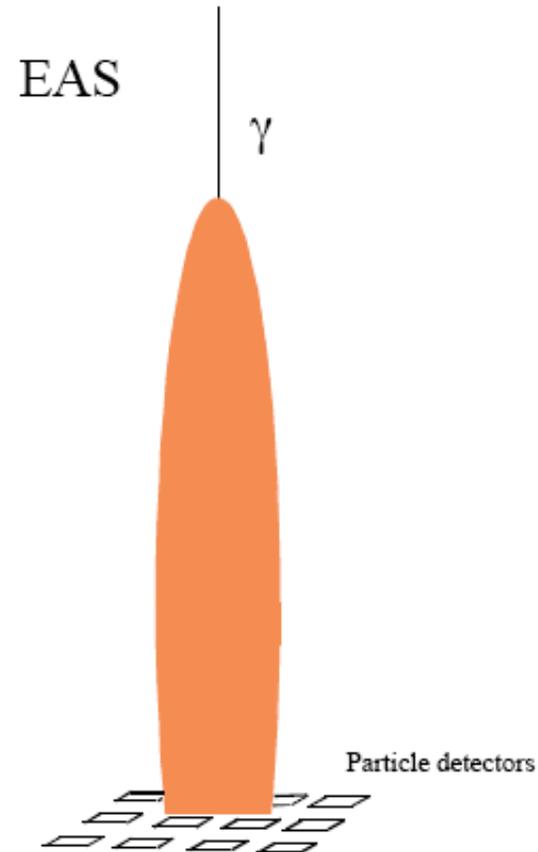
Esperimenti

SCIAMI IN ATMOSFERA

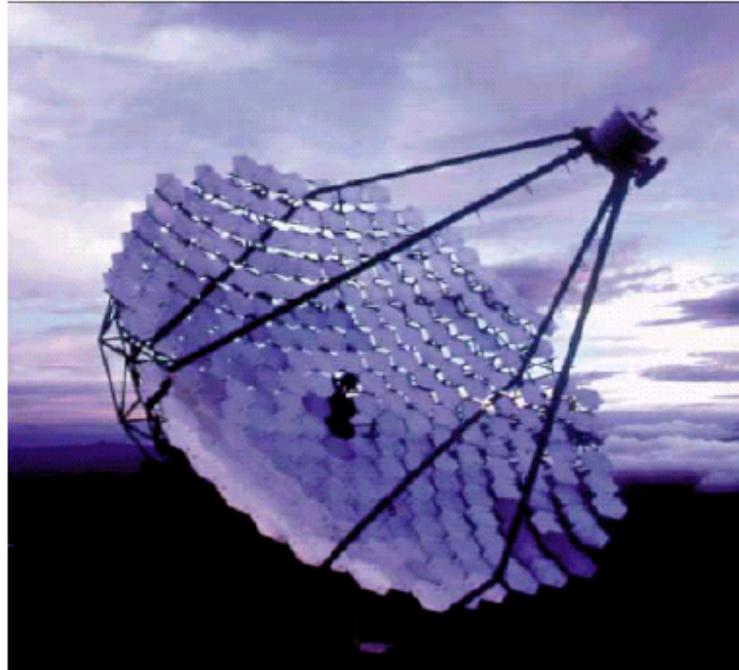
Cerenkov and Extensive air shower (EAS) gamma ray telescope concepts



$\sim 40.000\text{ m}^2$, but no anticoincidence shield !



CERENKOV



Whipple: diametro=10m, $E > 350$ GeV

The Whipple collaboration, which pioneered the Imaging Atmospheric Cherenkov Technique for the detection of very high energy (VHE) gamma rays, is based at the Fred Lawrence Whipple Observatory in Southern Arizona, in the United States. **The primary emphasis of the collaboration's research effort is the search for and study of celestial sources of gamma-rays in the energy range of 100 GeV - 10 TeV.**

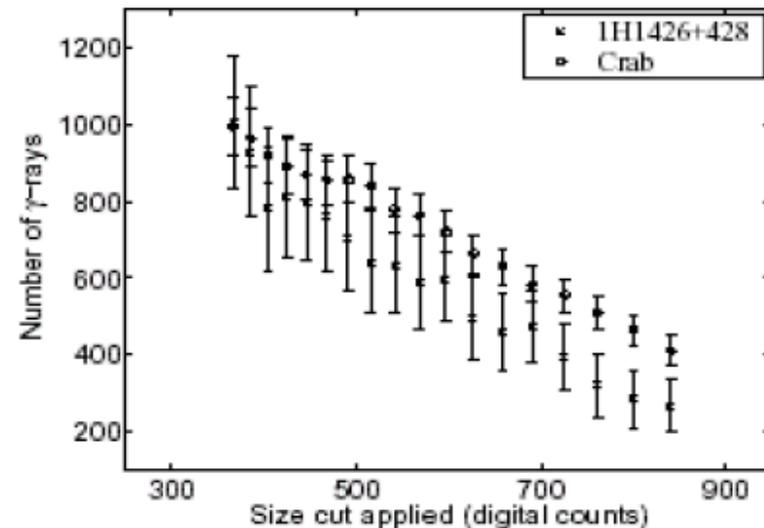
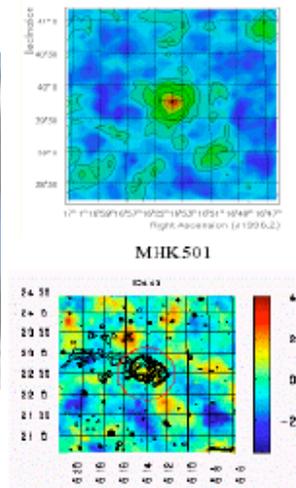
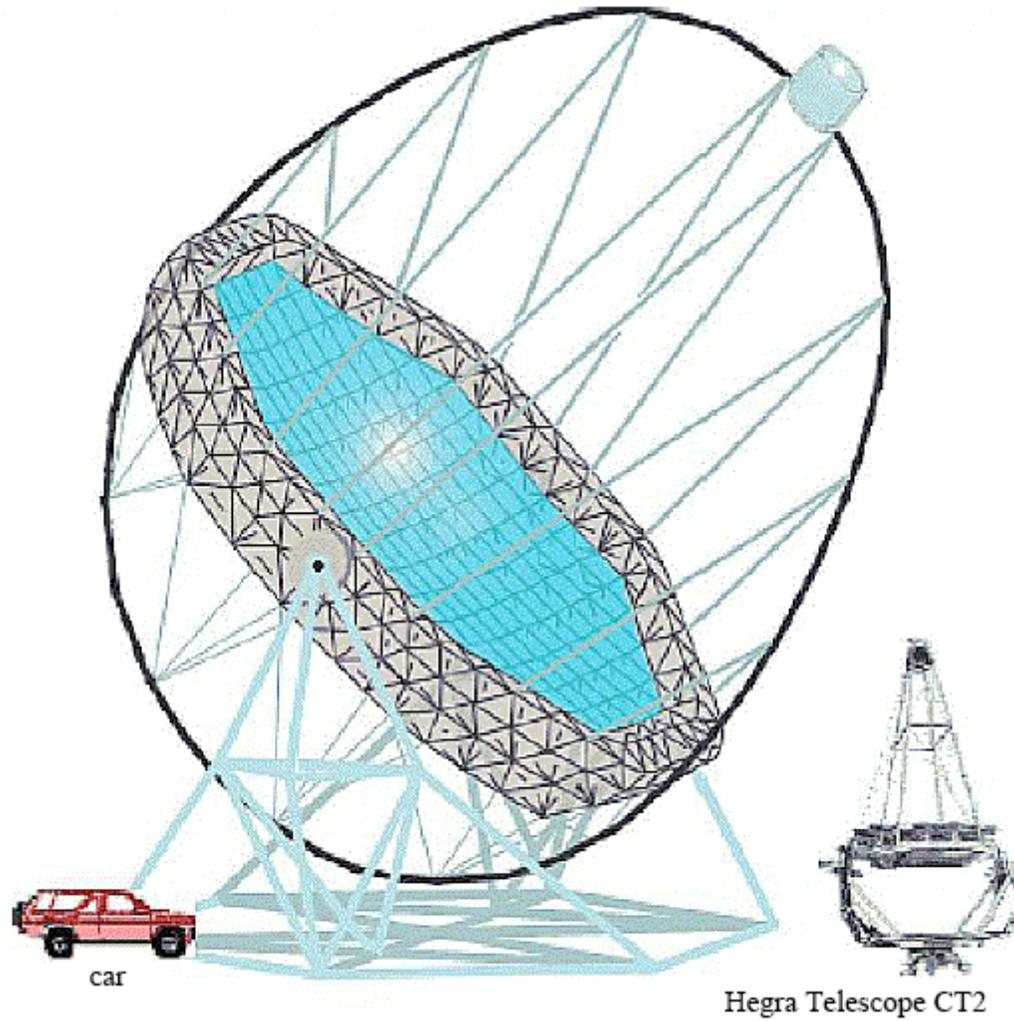


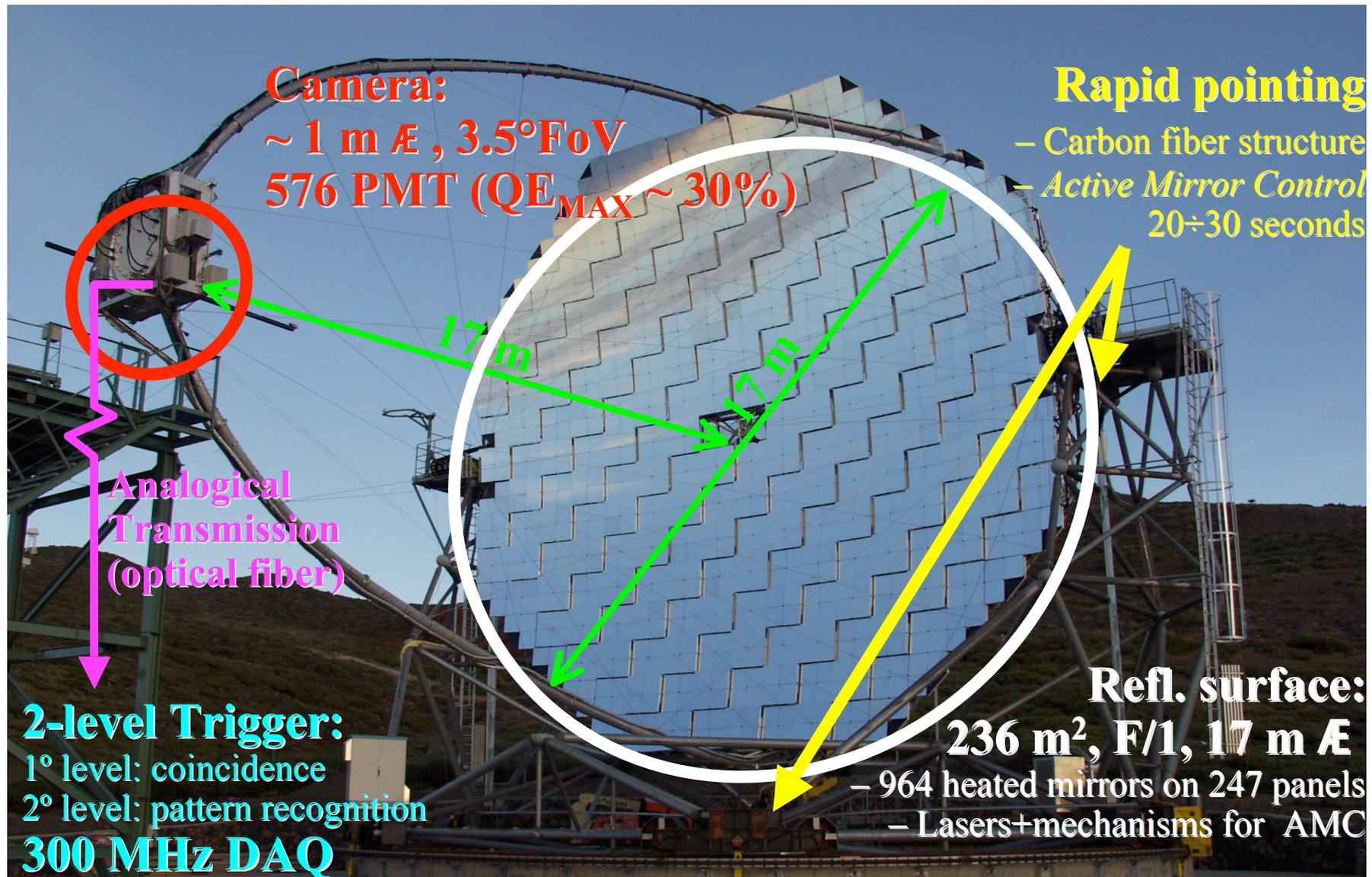
Fig. 4.— Integral excess events observed by the Whipple telescope from the directions of 1H1426+428 (crosses) and the Crab Nebula (open circles) during 2001 as a function of integrated Cherenkov light in the shower image. Exposure on the Crab Nebula was adjusted to match the total excess of 1H1426+428 at the lowest size cut applied, 366 digital counts. One photoelectron corresponds to ~ 3.6 digital counts.

MAGIC

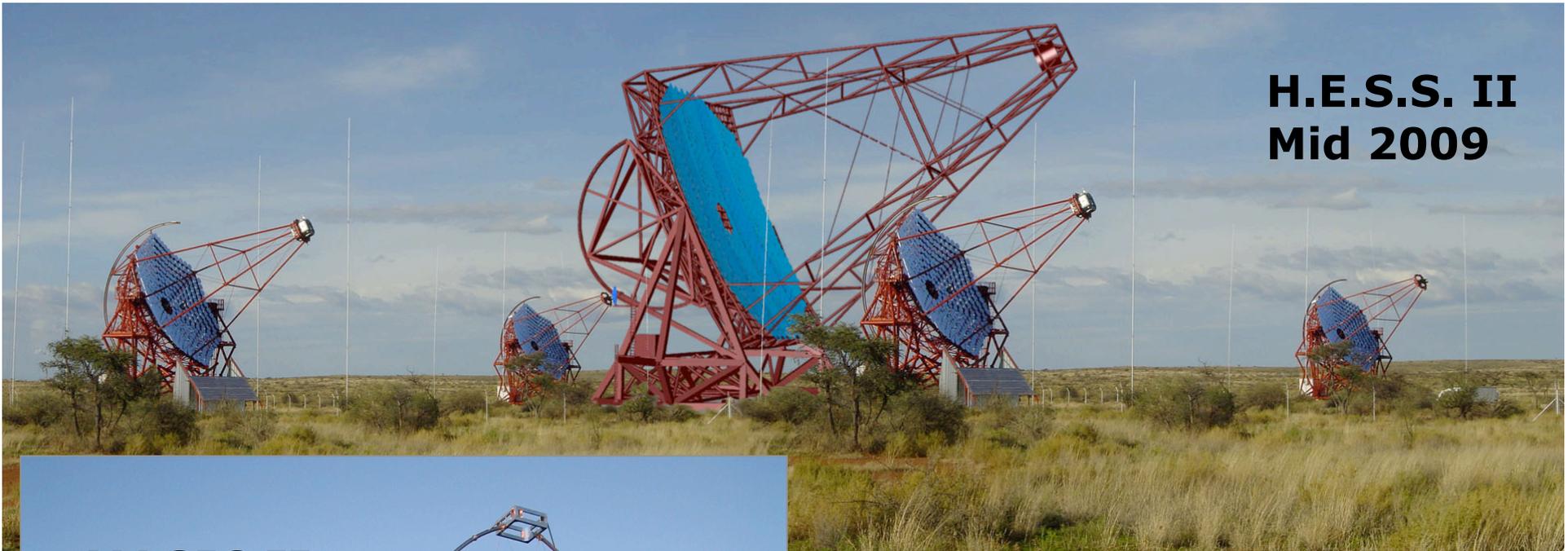
220 m²
E: 10-300 GeV
La Palma



MAGIC



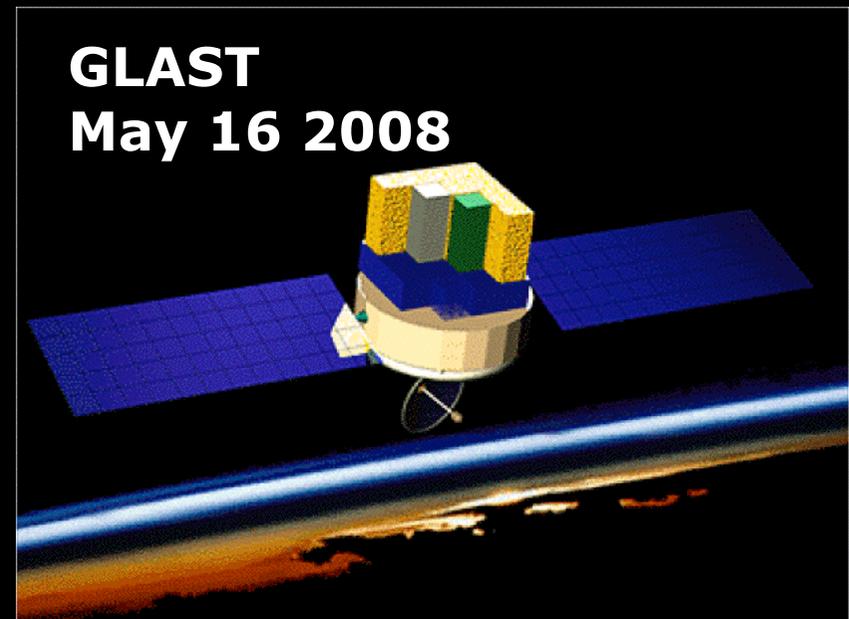
**H.E.S.S. II
Mid 2009**



**MAGIC II
September 21, 2008**



**GLAST
May 16 2008**



CERENKOV

H.E.S.S.

H.E.S.S. is a next-generation system of Imaging Atmospheric Cherenkov Telescopes for the investigation of cosmic gamma rays in the 100 GeV energy range. The name H.E.S.S. stands for **High Energy Stereoscopic System**, and should also remind of **Victor Hess**, who received in 1936 the **Nobel Prize in Physics for his discovery of cosmic radiation**. The acronym also emphasizes two main features of the proposed installation, namely the **simultaneous observation of air showers with several (3 to 4) telescopes, under different viewing angles, and the combination of multiple (up to 16) telescopes to a large system to increase the effective detection area for gamma rays**. With telescopes of over 100 m² mirror area, the proposed system provides a

- **detection threshold of about 40 GeV,**
- **full spectroscopic capability above 100 GeV, an**
- **angular resolution for individual showers of 0.1 degrees**
- **energy resolution of about 20%.**

It will allow to explore gamma-ray sources with intensities at a level of a few thousandth parts of the flux of the Crab nebula. H.E.S.S. is located in Namibia, near the Gamsberg, an area well known for its excellent optical quality. The first four H.E.S.S. telescopes (Phase I of the H.E.S.S. project) are under construction and are expected to successively go into operation between early 2002 and 2003



The H.E.S.S. technology



Christopher van Eldik from Germany and Eben Tjingaete from Namibia checking mirror facets



Just like big optical telescopes, the H.E.S.S. Cherenkov telescopes consist of a mirror which focuses the incident light, and a light detector (the 'camera') to record the images. A mount allows the telescope to rotate and to track celestial objects as they move across the sky.

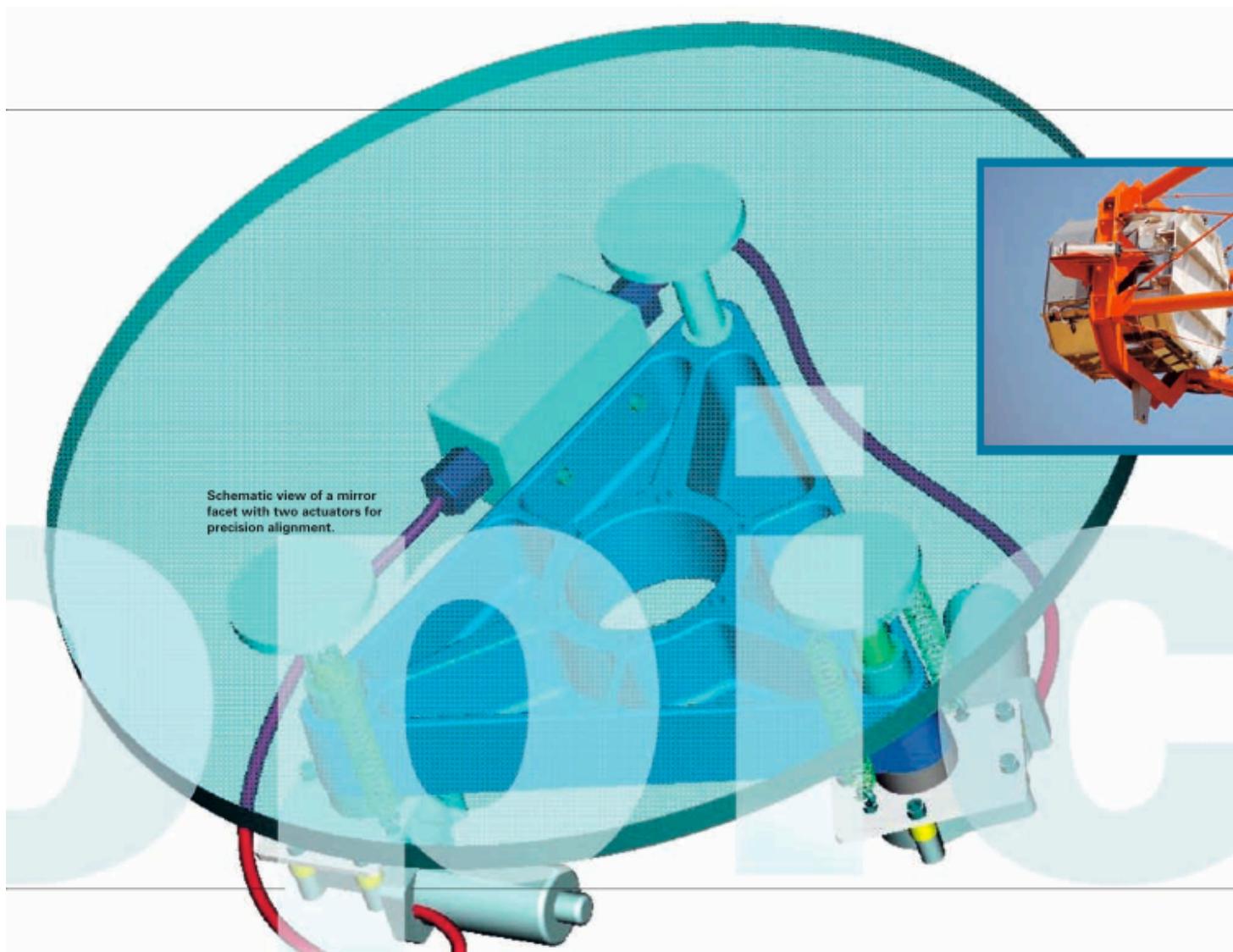
Mount and mirror dish

Mount and dish are sturdy steel structures, designed for high rigidity. The steel structure weighs 60 tons; it was designed in Germany and fabricated in Namibia. Computer-controlled drive systems steer the telescopes with high precision.

Mirrors

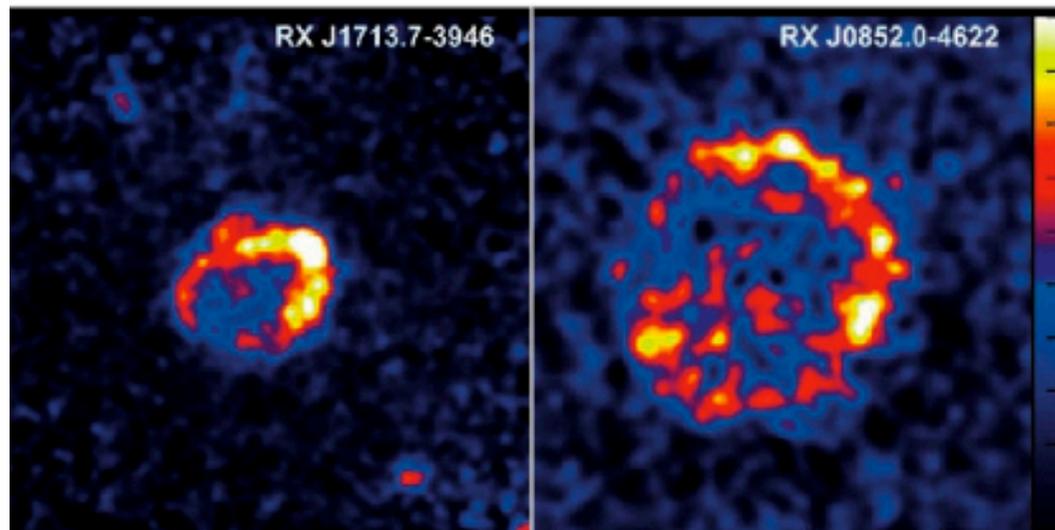
The diameter of the dish is more than 12 m, and the mirror area 107 m². Mainly for cost reasons, the mirror is composed of 380 individual facets, made of ground glass and aluminised for best reflectivity. Each facet can be aligned under remote control using two motor-driven actuators, with a precision of a few thousandth of a millimeter.

HESS



HESS

Supernova explosions ...



If supernova explosion waves are cosmic accelerators - as long suspected by scientists - they should be clearly visible in gamma rays. Indeed, H.E.S.S. images resolve the ring-like shock fronts for the first time and show them glowing in high-energy gamma rays.

One of the first highlights of the H.E.S.S. observations was the discovery of high-energy gamma rays from two supernova explosion shells, whose 'names' RX J1713.7-3946 and RX J0852.0-4622 refer to their celestial coordinates and the fact that they were first seen as X-ray sources. The H.E.S.S. telescopes were able to resolve the spatial structure of the gamma-ray source; as predicted, gamma rays were found to exactly trace the supernova shell. This discovery proves conclusively that supernova explosion waves work as cosmic accelerators, at least up to energies of 100 million million electron volts ('electron volt' is a unit characterising the energies of particles and radiation; visible light has 2 to 4 electron volts).

Background

Our entire Galaxy is permeated by cosmic rays - atomic nuclei accelerated to very high energies. The existence of cosmic rays was discovered by Victor Hess in 1912, almost 100 years ago. Throughout this time, the origin of cosmic rays was heavily debated: Somewhere in our Galaxy must be cosmic particle accelerators capable of creating particle energies many orders of magnitude beyond the biggest man-made accelerators on Earth.

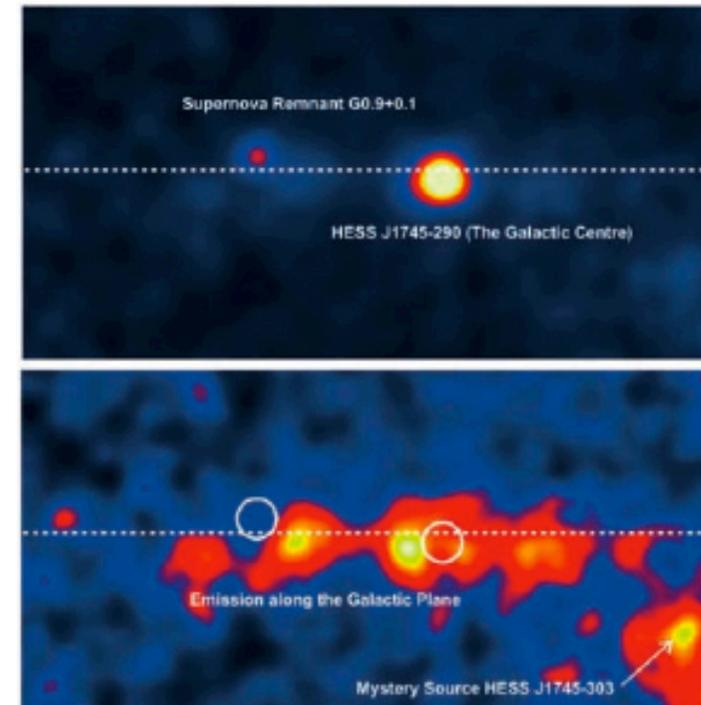
HESS

... in high-energy gamma rays

observed by H.E.S.S. From the fact that very distant gas clouds do not shine in gamma rays, one concludes that this accelerator is active since some 10 000 years, and particles have not had sufficient time to reach the more distant clouds.

Could this source at the Galactic Centre hint the long-sought annihilation of Dark Matter particles? To explain the gamma rays, the masses of the Dark Matter particles would have to be much higher than usually assumed — at least 10 tera electron volts — and their annihilation rate would have to be quite high, but models for the hypothetical Dark Matter particles are sufficiently flexible to accommodate such features. Also, initial observations showed that the angular distribution of gamma rays had a slight 'halo', as predicted for a distribution of Dark Matter particles with a peak at the Galactic Centre, but with a smooth distribution extending out into the Galaxy.

However, the recent H.E.S.S. precision data revealed that the halo is explained by the emission from the gas clouds. Another characteristic feature of Dark Matter annihilation is the energy distribution of gamma rays. Rather than the predicted annihilation spectrum with a peak energy flow at intermediate energies, the latest H.E.S.S. results show a monotonically falling energy spectrum, now measured over almost two decades in energy, in contradiction with dark-matter predictions. This pretty much rules out Dark Matter as the dominant source of the observed radiation. The exact nature of the gamma-ray source, however, remains mysterious; particle acceleration in the turbulent gas streams falling into the black hole may be the answer, and studies combining new data from different wavebands may some day provide the answer.

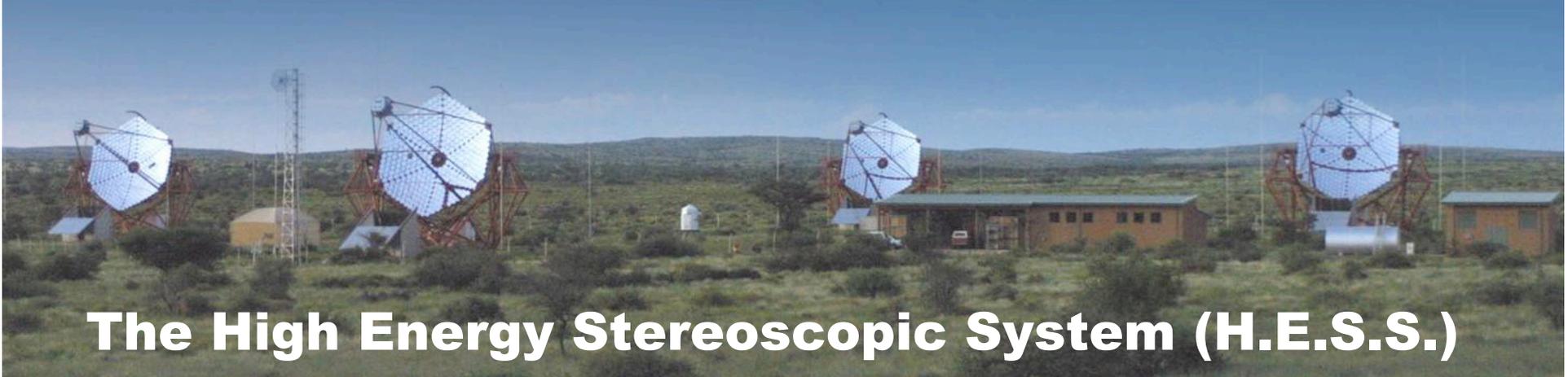


Two point-like sources – about 1° apart – dominate the gamma-ray image of the Galactic Centre region (top). After mathematical subtraction of their contribution, diffuse emission from molecular clouds becomes apparent (bottom).

VERITAS



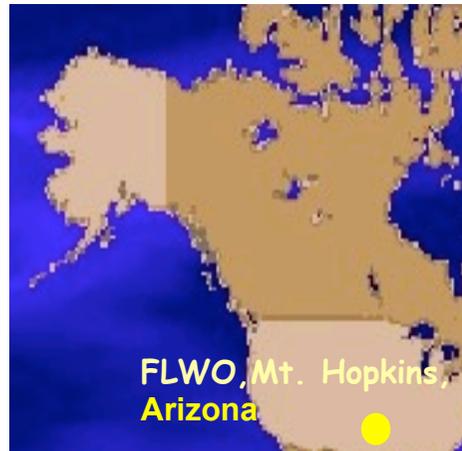
The High Energy Stereoscopic System (H.E.S.S.)



CANGAROO



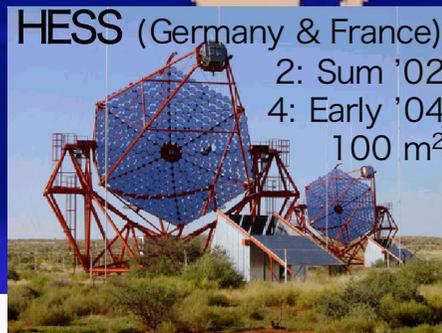
The “Big Four”



● Roque de
los Muchachos,
Canary Islands



● Windhoek,
Namibia



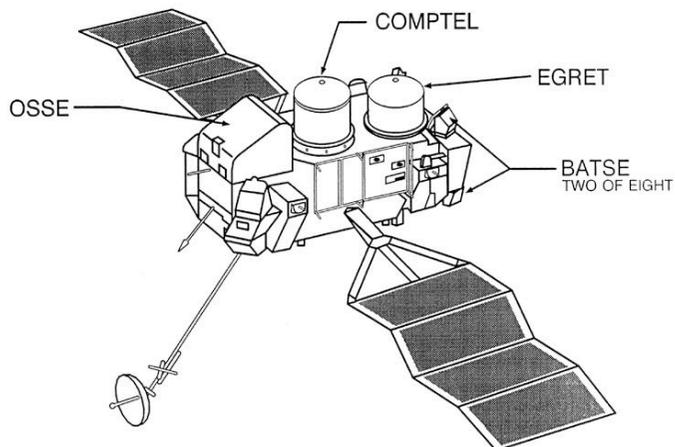
CERENKOV

Group/ Instrument	Location	Reflector(s) Number × Aperture	Camera Pixels	Threshold (GeV)	Epoch Beginning
<i>Operating Telescopes^a</i>					
Whipple	Arizona, USA	10 m	331	250	1984
Crimea	Crimea, Ukraine	6×2.4 m	6×37	1000	1985
SHALON	Tien Shen, Russia	4 m	244	1000	1994
CANGAROO	Woomera, Aust.	3.8 m	256	500	1994
HEGRA	La Palma, Sp.	5 × 3 m	5 × 271	500	1994
CAT	Pyrenées	3m	600	250	1996
Durham/ Mark 6	Narrabri, Aust.	3× 7 m	1× 109	250	1996
TACTIC	Mt. Abu, India	4× 3.5 m	1×225	300	1997
Seven TA	Utah, USA	7×2 m	7×256	500	1998
STACEE	Sandia, New Mexico	32 × 7 m	32× 1	75	1998
CELESTE	Pyrenées, France	40×7 m	40×1	50	1998
<i>Future Telescopes</i>					
CANGAROO II	Woomera, Aust.	7 m	1×512	250	1999
GRAAL/CESA-1	Almeria, Sp.	63×7.1 m	4	100	1999
Solar II	Barstow, CA	96×7.1 m	96× 1	20	2002
MAGIC	La Palma, Sp.	17 m	1×800	30	2001
HESS	Namibia	4×10 m	4×700	50	2002
CANGAROO III	Woomera, Aust.	4× 10 m	4×512	75??	2003
VERITAS	Arizona, USA	7×10 m	7×499	75	2004

^a From Catanese & Weekes 1999

EGRET

COMPTON OBSERVATORY INSTRUMENTS



The Instruments on CGRO Cover Six Orders of Magnitude in Photon Energy

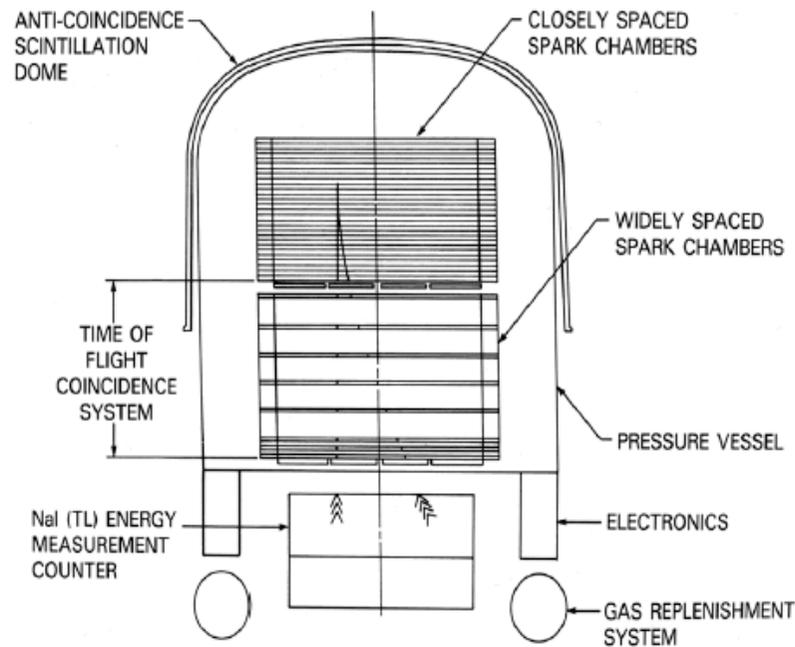
BATSE

OSSE

COMPTEL

EGRET

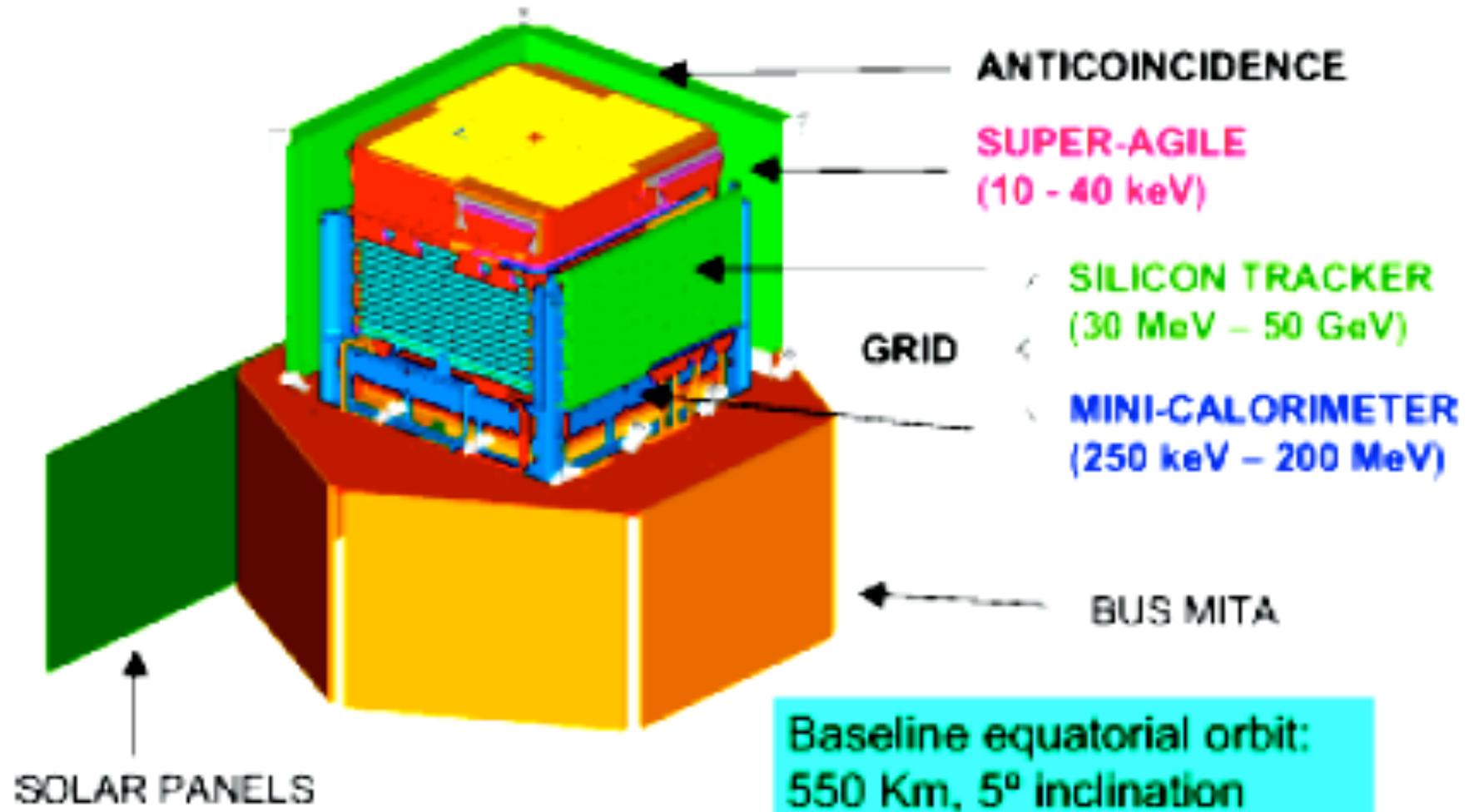
10 keV 100 keV 1 MeV 10 MeV 100 MeV 1 GeV 10 GeV 100 GeV



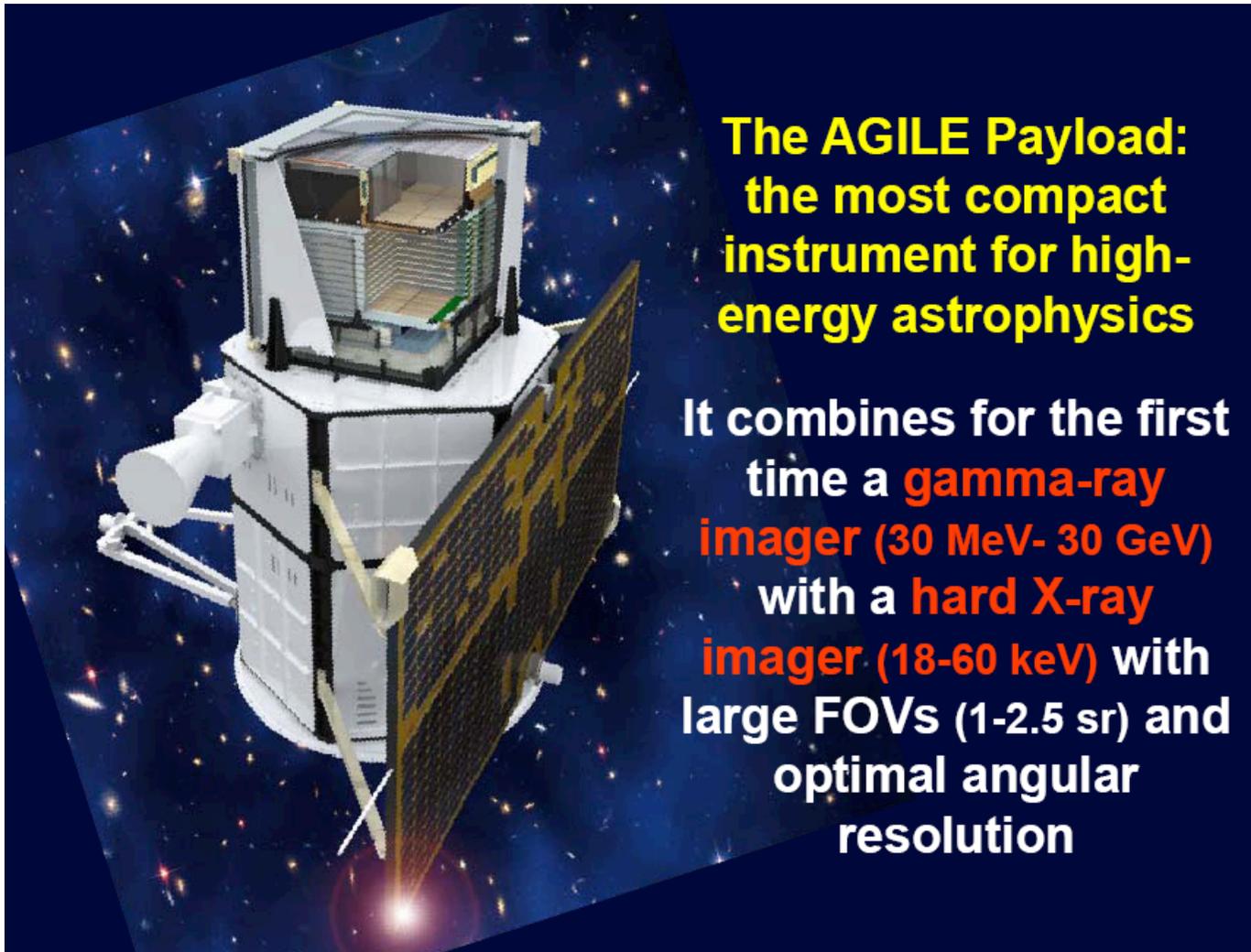
EGRET

- 1991-2000
- 30 MeV - 30 GeV
- AGN, GRB, Unidentified Sources, Diffuse Bkg

AGILE



AGILE instrument



**The AGILE Payload:
the most compact
instrument for high-
energy astrophysics**

**It combines for the first
time a **gamma-ray
imager (30 MeV- 30 GeV)**
with a **hard X-ray
imager (18-60 keV)** with
large FOVs (1-2.5 sr) and
optimal angular
resolution**

AGILE: inside the cube...

**HARD X-RAY IMAGER
(SUPER-AGILE)**

**INAF-IASF-Rm
(E.Costa, M. Feroci)**

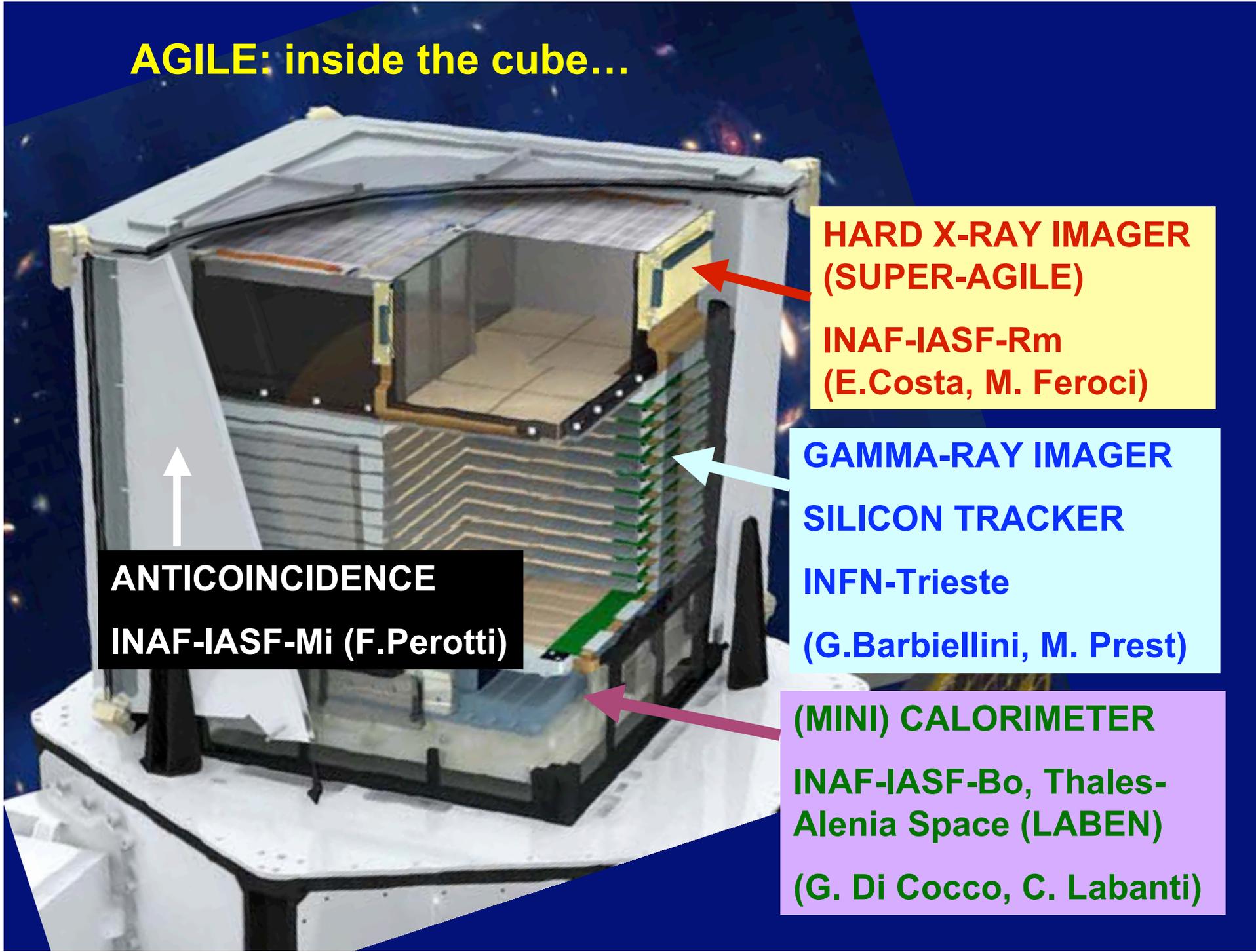
**GAMMA-RAY IMAGER
SILICON TRACKER
INFN-Trieste**

(G.Barbiellini, M. Prest)

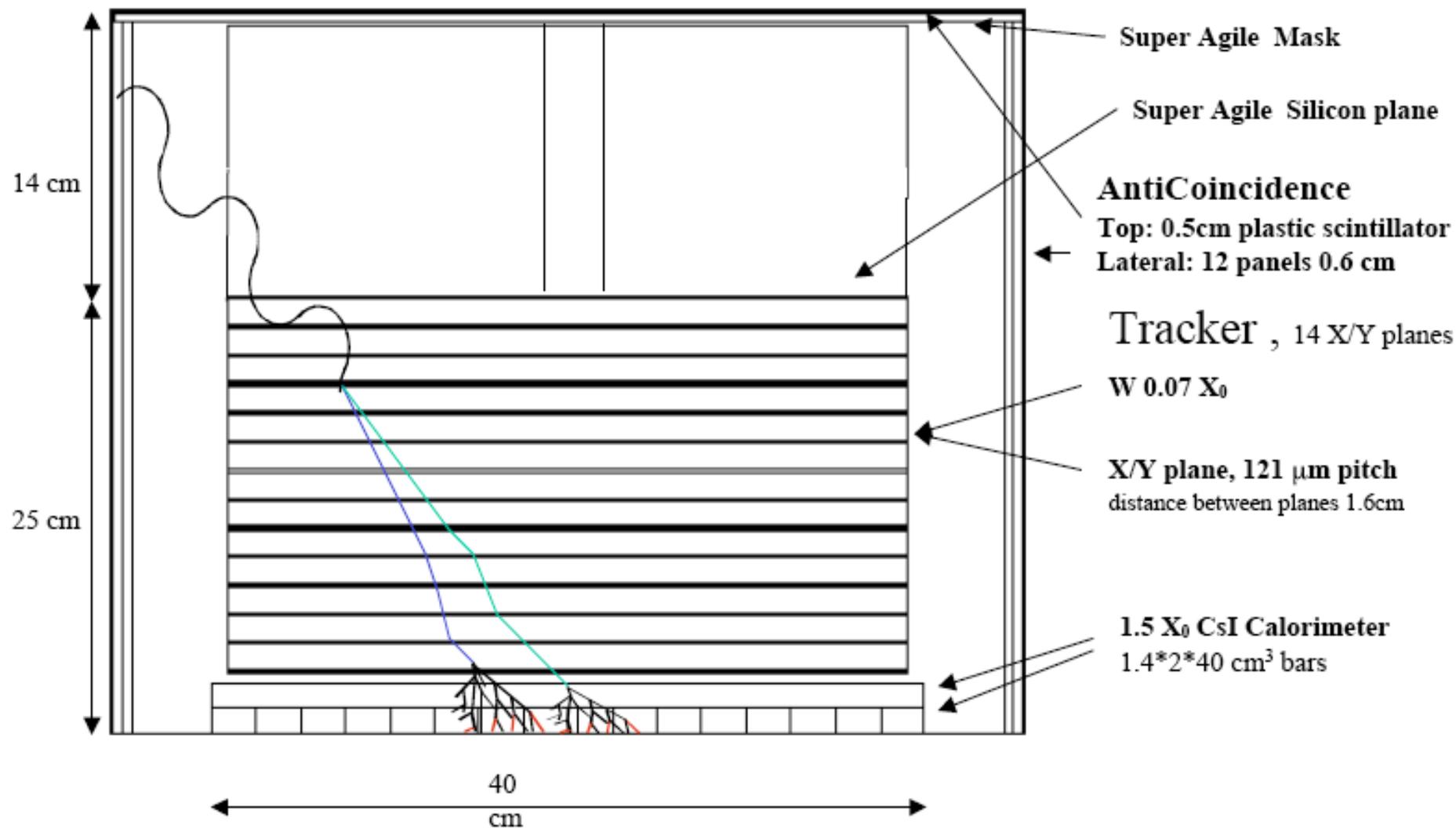
**(MINI) CALORIMETER
INAF-IASF-Bo, Thales-
Alenia Space (LABEN)**

(G. Di Cocco, C. Labanti)

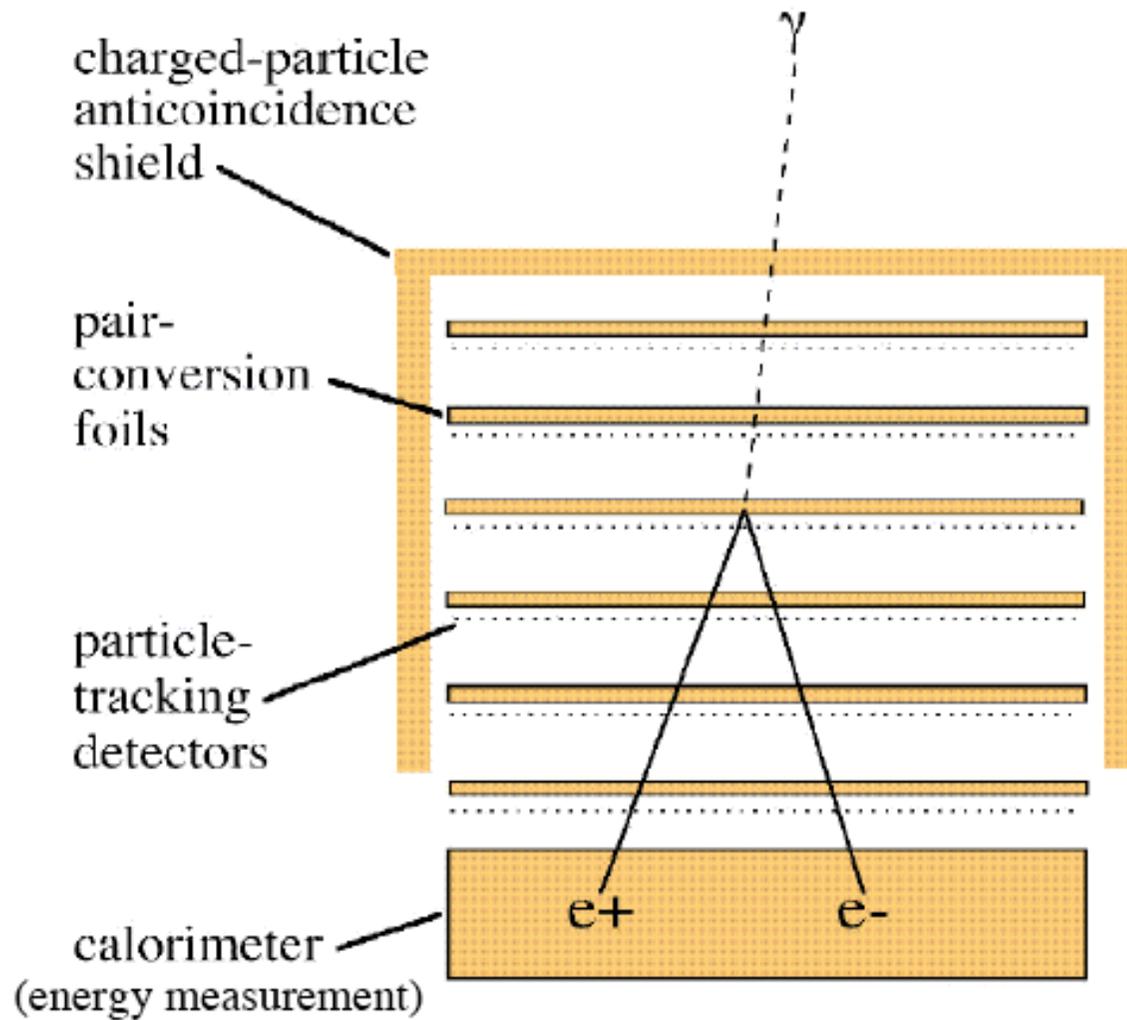
**ANTICOINCIDENCE
INAF-IASF-Mi (F.Perotti)**



AGILE



CONVERSIONE $\gamma \rightarrow e^+ e^-$



- photons materialize into matter-antimatter pairs:
$$E_\gamma \rightarrow m_{e^+}c^2 + m_{e^-}c^2$$
- electron and positron carry information about the direction, energy and polarization of the γ -ray

$$\gamma \rightarrow e^+ + e^-$$

High-energy γ -ray telescopes work on the principle of pair production. A photon passing through matter may convert into an electron-positron pair.

$$\gamma + \text{nucleus} \rightarrow e^+ + e^- + \text{nucleus}$$

The probability of such a conversion taking place is roughly independent of the energy of the incident photon above 1 GeV, and falls off at lower energies. While the full pair-production differential cross section is a complex function of incident γ -ray energy, electron and positron energy, nuclear recoil energy, opening angle, azimuthal angle, and recoil angle [1], several simplifying assumptions give simple estimates of bulk behavior [2]. For a homogeneous material the intensity of the incident γ -ray beam falls off like

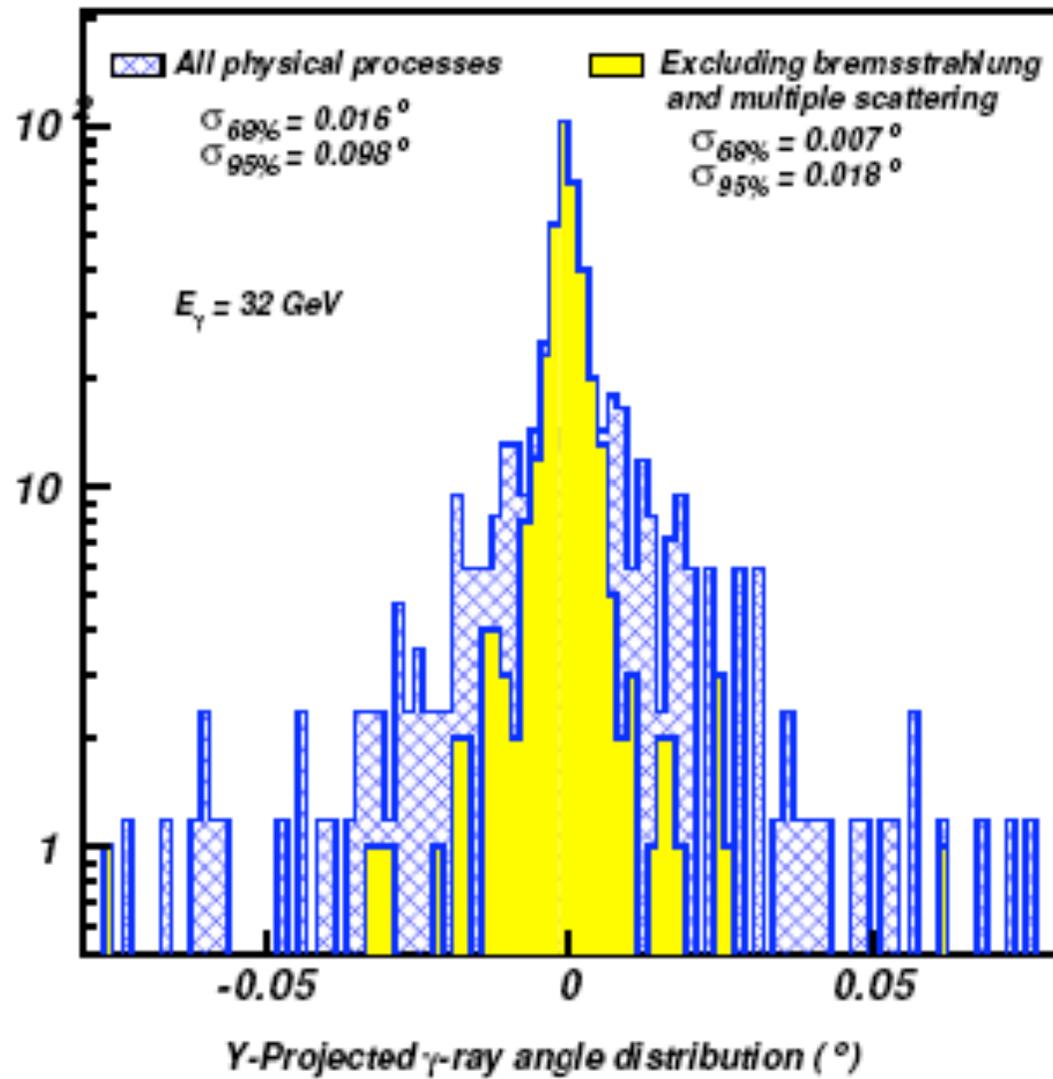
$$I = I_0 \exp\left(-\frac{7}{9}t/X_0\right), \quad (1)$$

due to all interactions, where t is the thickness of material and X_0 is the radiation length of the material. Therefore, the probability of a particular γ -ray to interact in the material is

$$P(t) = 1 - \exp\left(-\frac{7}{9}t/X_0\right). \quad (2)$$

Pair production offers an opportunity for photons detection. In fact we can estimate the incident γ -ray energy and direction by tracking the resulting e^+e^- pair. The reconstructed energy will be the sum of the e^+ and e^- energies, corrected for energy loss in the instrument, and the incident direction of the γ -ray can be obtained by the momentum-weighted average of the e^+ and e^- directions.

DISTRIBUZIONE θ_p



PAMELA

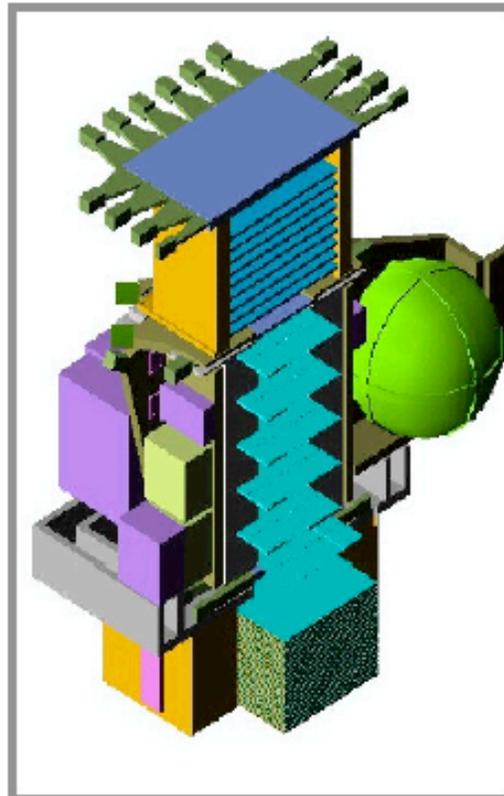
Pamela Subdetectors

TRD

- Threshold device. Signal from e^\pm , no signal from p, π
- 9 planes of Xe/Co₂ filled straws (4mm diameter). Interspersed with carbon fibre radiators \Rightarrow crude tracking.
- Aim: 10^2 separation e^- -vs- p (above 1GeV/c). NB: 10^6 with calorimeter.

Si Tracker + magnet

- Measures rigidity
- 5 Nd-B-Fe magnet segments (0.4T)
- 6 planes of 300 μ m thick Si detectors
- $\sim 3\mu$ m resolution in bending view demonstrated, ie: MDR = 740GV/c



[Acceptance $\sim 21 \text{ cm}^2\text{sr}$]

Anticoincidence system

- Defines acceptance for tracker
- Plastic scintillator + PMT
- Binary read-out

Time-of-flight

- Gives L1 trigger / detects albedos / particle identification (up to 1GeV/c) / dE/dx
- Plastic scintillator + PMT
- Timing resolution = 70ps

Si-W Calorimeter

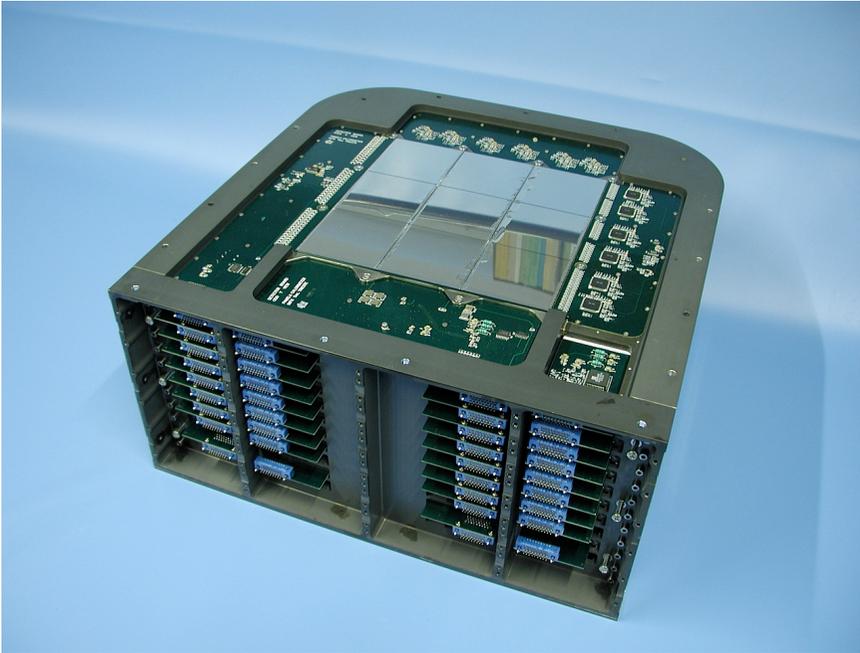
- Measures energies of e^\pm . $\Delta E/E = 15\% / E^{1/2}$.
- Si-X / W / Si-Y structure.
- 22 Si / 21 W $\Rightarrow 16X_0 / 0.9\lambda_0$
- Imaging: EM - vs- hadronic discrimination. Reconstruct long. and transverse shower profile.

PAMELA-MAGNETE



- The magnetic material used is the sintered Nd-Fe-B with a large residual magnetic induction (1.3T). The average field inside the magnet is 0.4 T, with a good homogeneity.
- The combined characteristics of the magnet and of the Si tracker will allow a Maximum Detectable Rigidity (MDR) greater than 740 GV/c.

PAMELA- CALORIMETRO EM

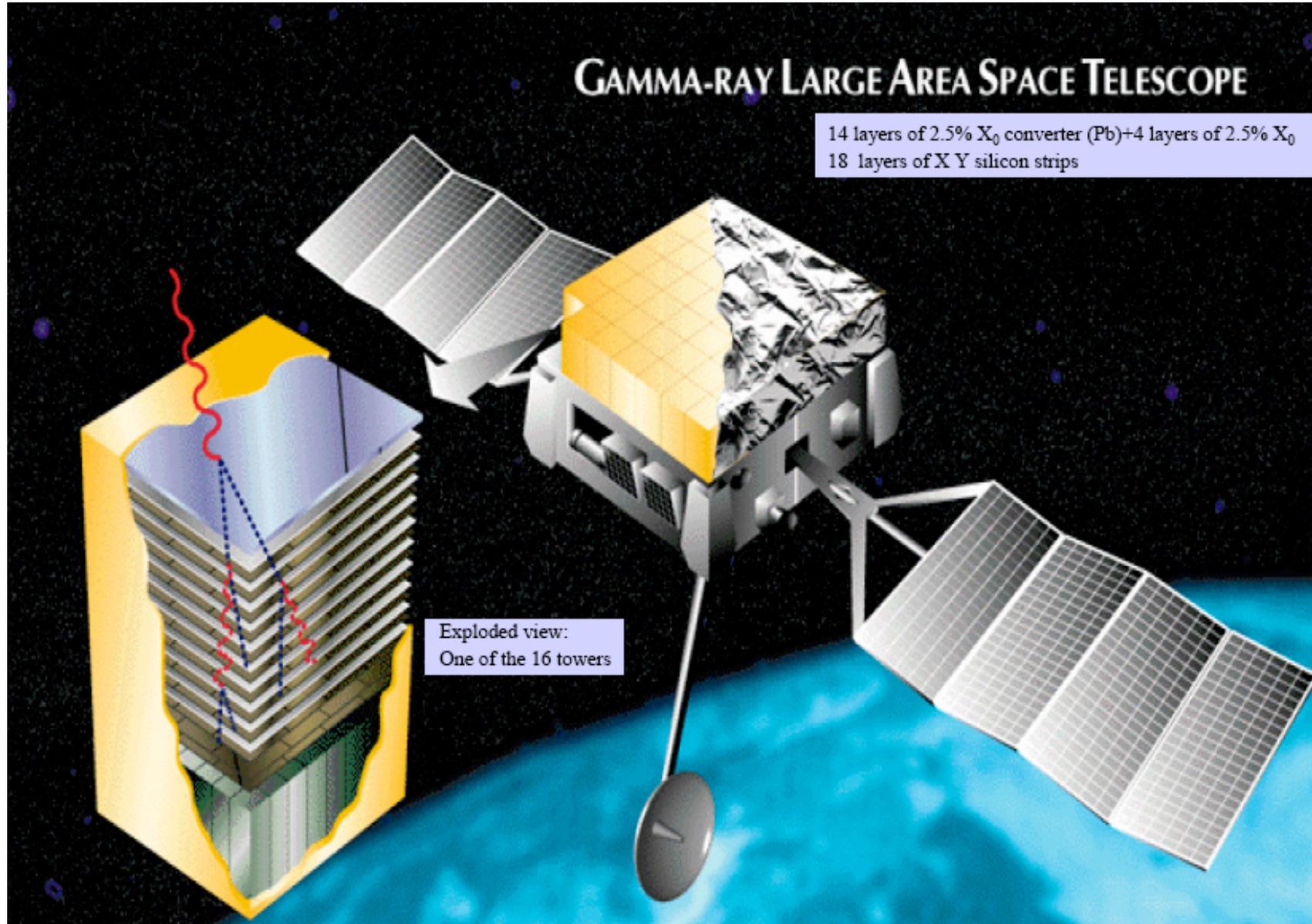


- The total thickness corresponds to 0.9 interaction lengths and 16 radiation lengths.
- The energy resolution for high energy electrons is better than 10% .

GLAST

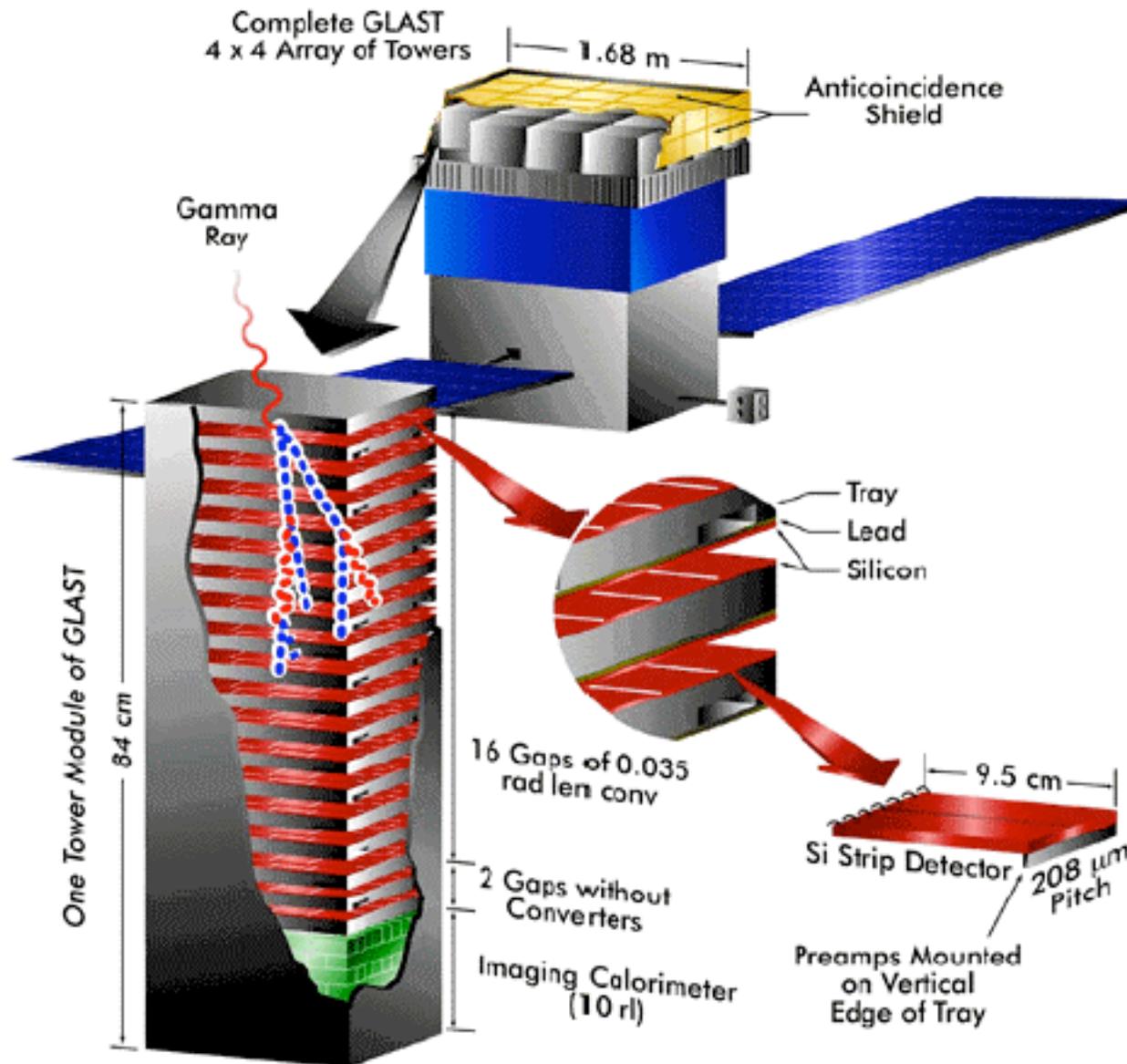
GAMMA-RAY LARGE AREA SPACE TELESCOPE

14 layers of $2.5\% X_0$ converter (Pb)+4 layers of $2.5\% X_0$
18 layers of X Y silicon strips



Exploded view:
One of the 16 towers

GLAST



GLAST Large Area Telescope

Instrument

Pair-conversion telescope

16 towers \Rightarrow modularity

height/width = 0.4 \Rightarrow large field-of-view

Calorimeter Modules

Hodoscopic Imaging Array of CsI crystals:

~ 8.5 ri depth

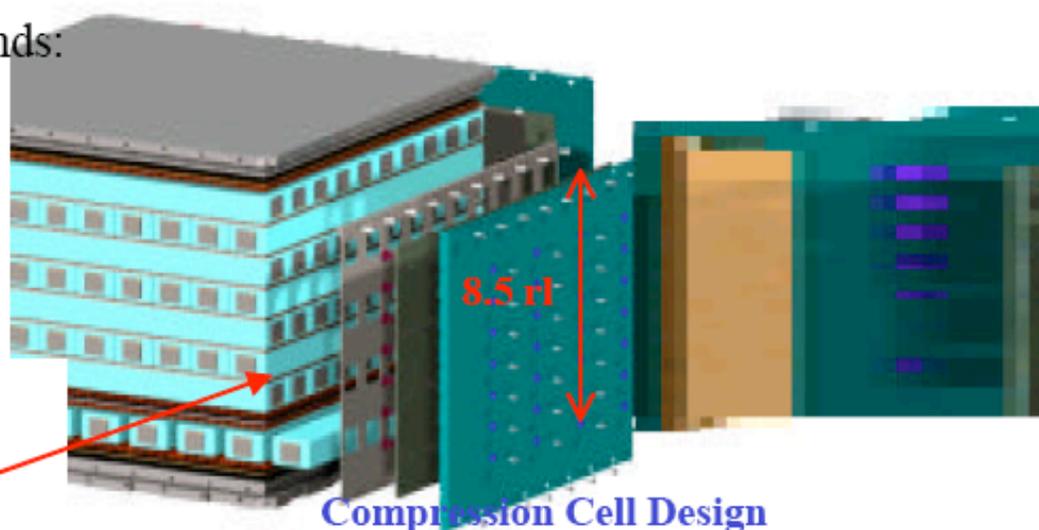
PIN photodiode readout from both ends:

2 ch/xtal x 80 xtals/mod = 2,560 ch

segmentation allows pattern recognition (“imaging”) and leakage correction

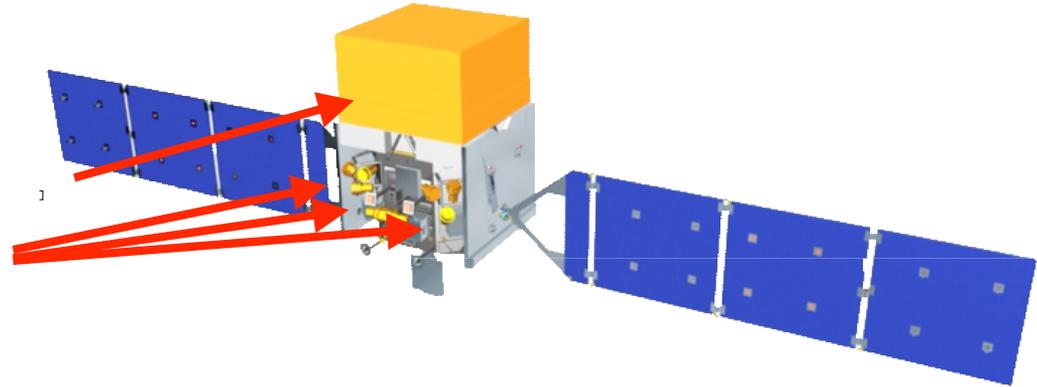


Mechanical Prototype of Carbon Cell Design



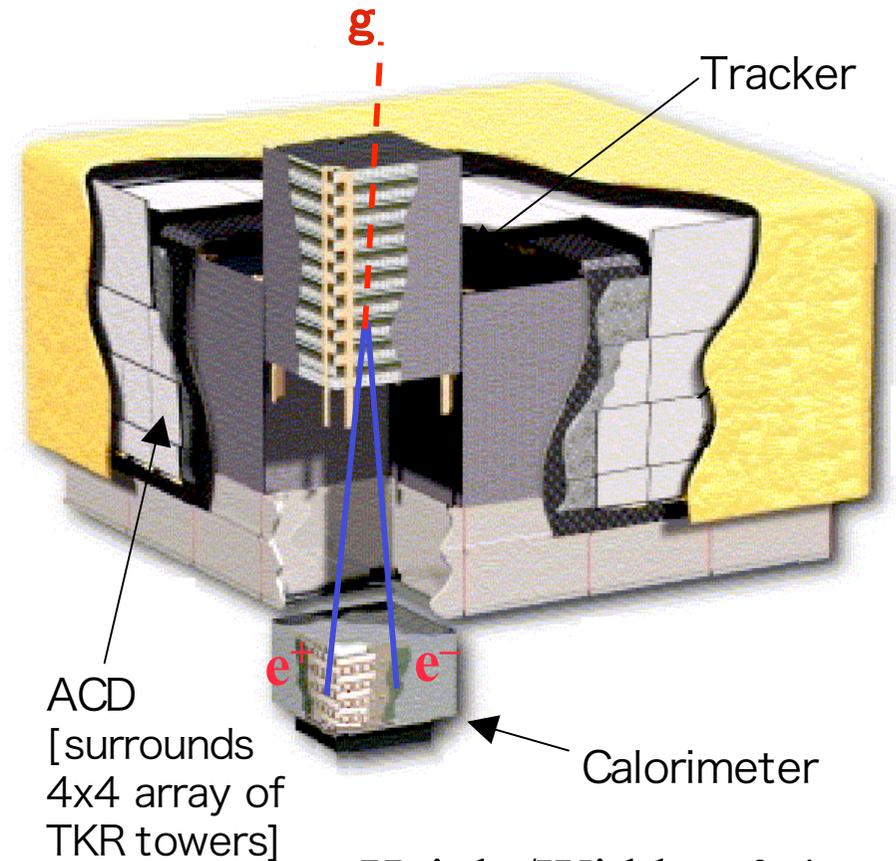
GLAST Key-Features

- Two GLAST instruments:
 - LAT: 20 MeV - >300 GeV
 - GBM: 10 keV - 25 MeV
 - Launch: 16 May 2008.
 - 565 km, circular orbit
 - 5-year mission (10-year goal)
 - International Collaboration
- Huge field of view:
 - LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours.
 - GBM: whole unocculted sky at any time.
- Huge energy range, including largely unexplored band 10 GeV- 100 GeV



The GLAST Large Area Telescope

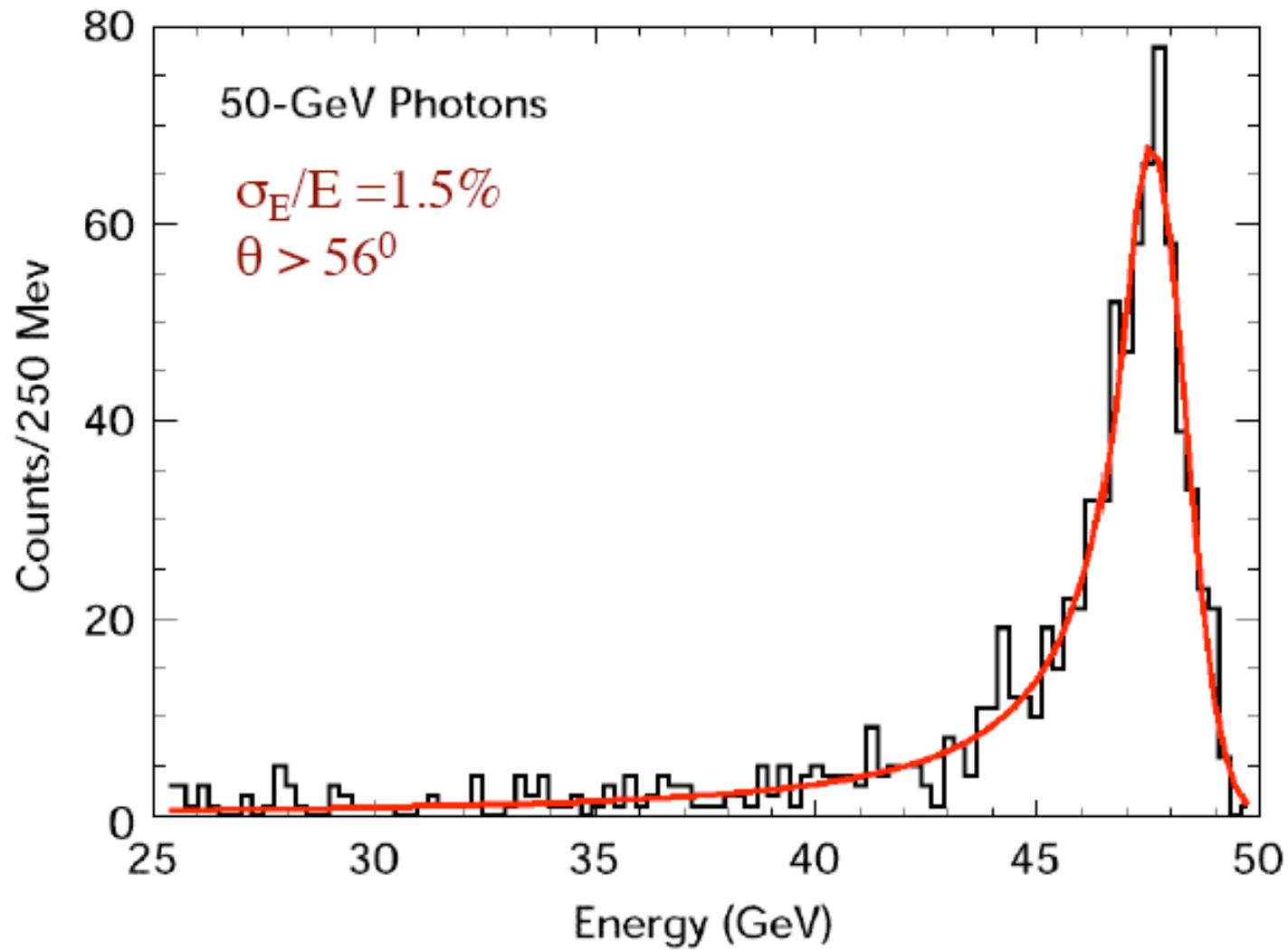
- **Precision Si-strip Tracker (TKR)**
18 XY tracking planes. 228 m m pitch). High efficiency.
Good position resolution (ang. resolution at high energy) 12 x 0.03 X_0 front end => reduce multiple scattering. 4 x 0.18 X_0 back-end => increase sensitivity >1GeV
- **CsI Calorimeter(CAL)**
Array of 1536 CsI(Tl) crystals in 8 layers.
Hodoscopic => Cosmic ray rejection.
=> shower leakage correction.
8.5 X_0 => Shower max contained <100 GeV
- **Anticoincidence Detector (ACD)**
Segmented (89 plastic scintillator tiles)
=> minimize self veto,
Reject background of charged cosmic rays;
- **Electronics System** Includes flexible, robust hardware trigger and software filters.



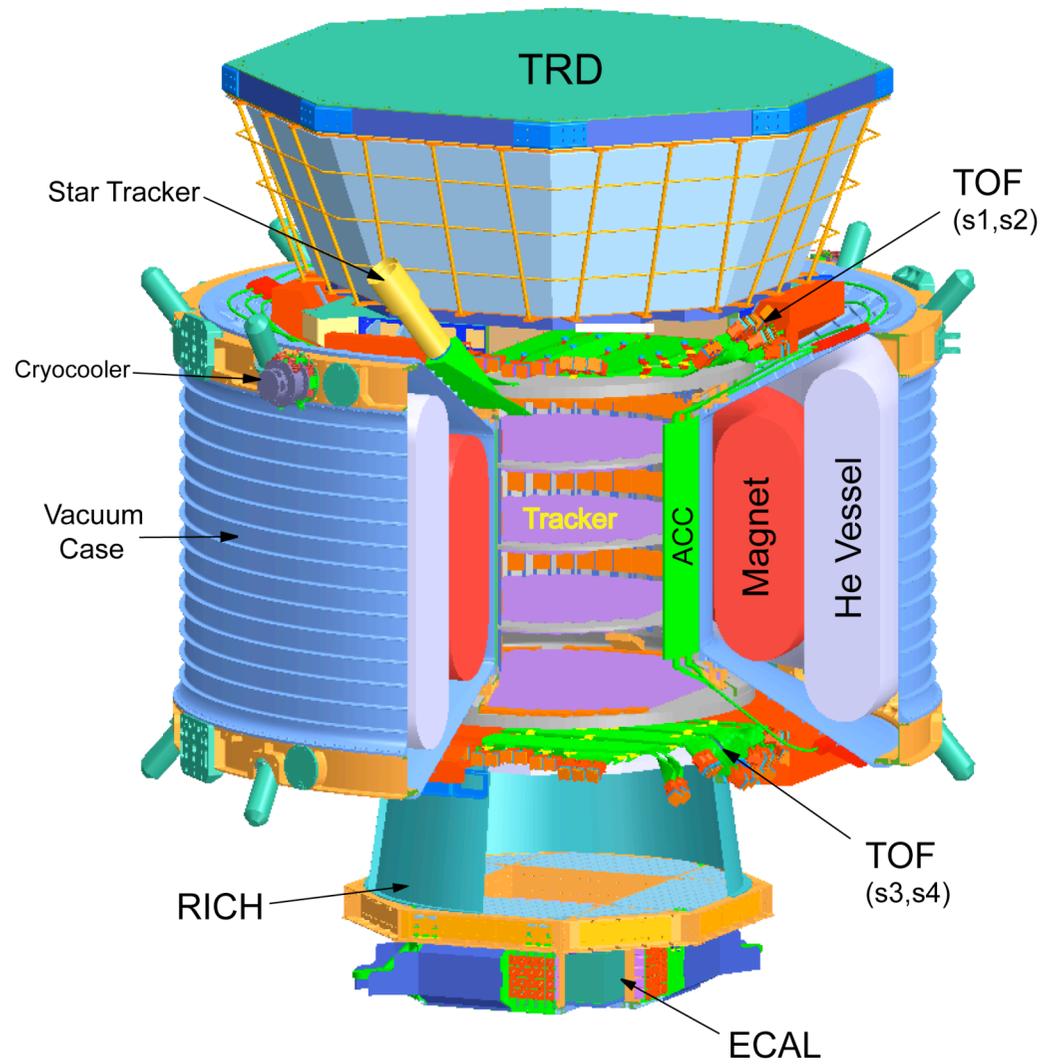
Height/Width = 0.4
=> Large field of view

Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

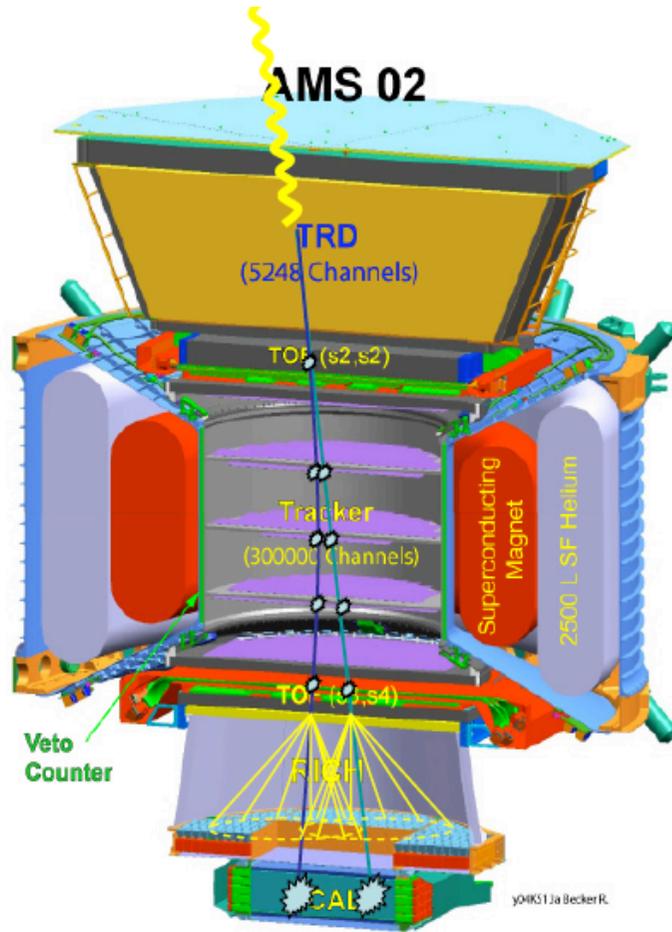
GLAST: RISOLUZIONE E



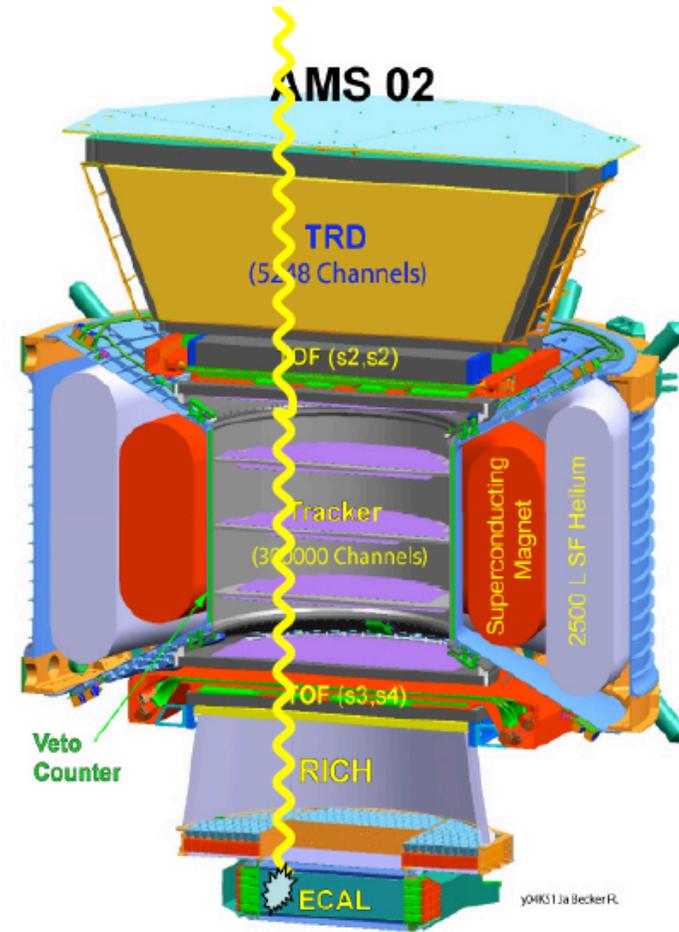
AMS



AMS2

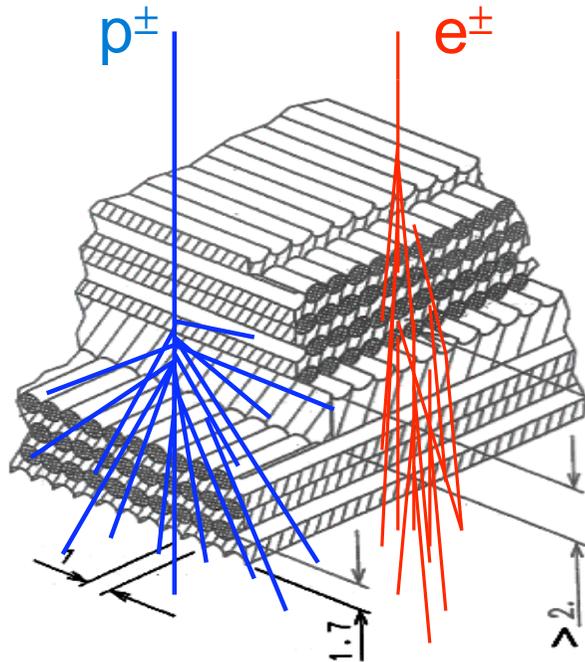


Photon conversion



Direct Photon detection

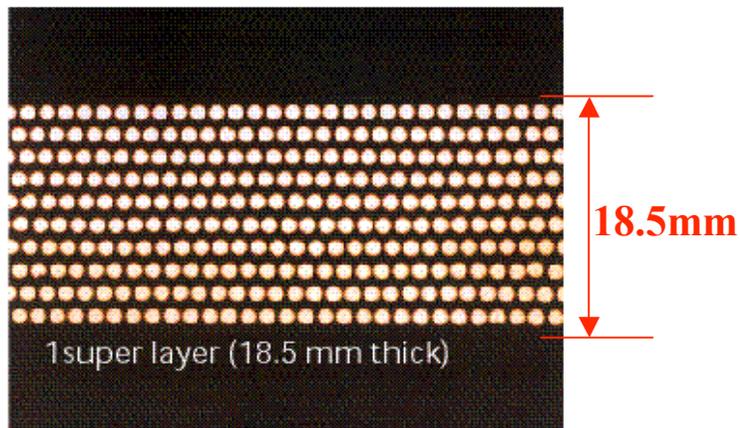
EM sampling calorimeter



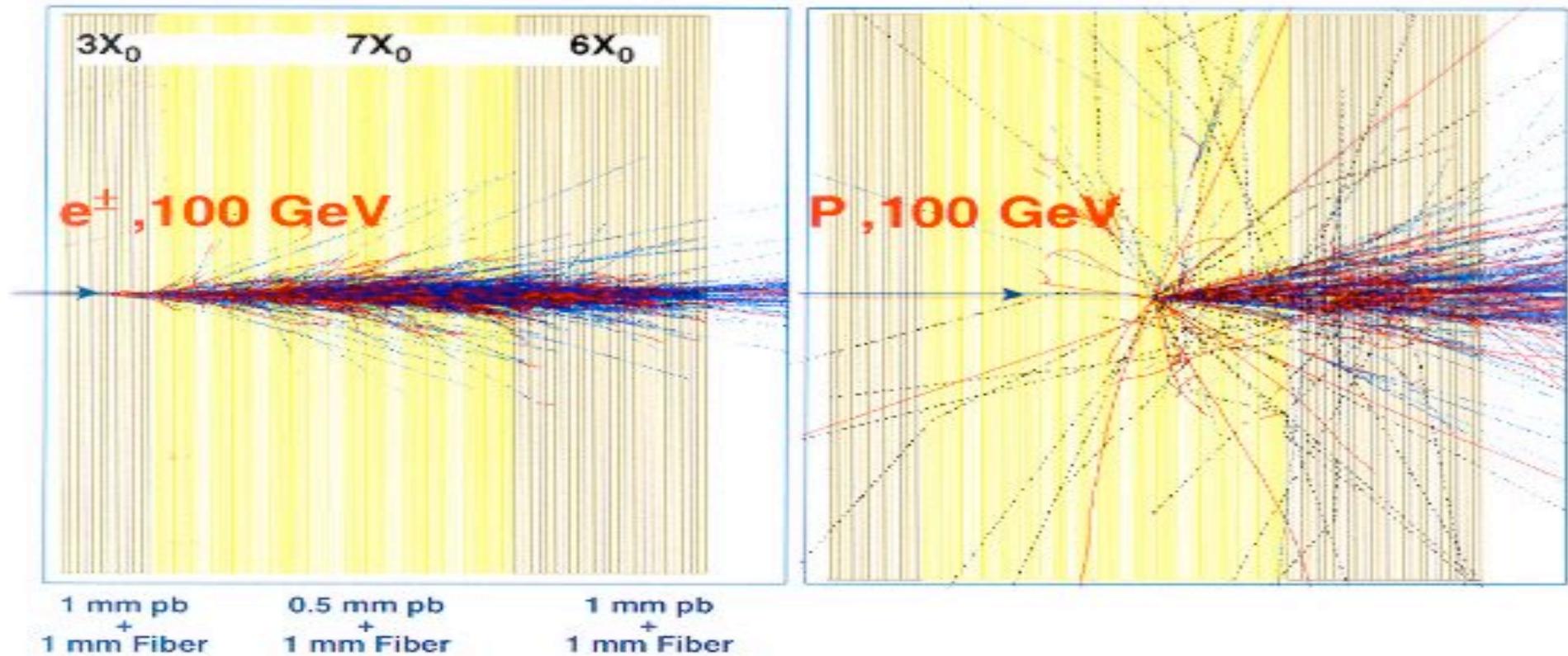
- ⇒ High granularity :
 - 0.5 Molière radius in X-Y
 - 18 samplings, $0.9 X_0$ in depth

why spaghetti?

- ⇒ best longitudinal & lateral shower reconstruction
 - ⇒ energy correction
 - ⇒ p/e separation
- ⇒ best γ angular resolution



Calorimetro Elettromagnetico



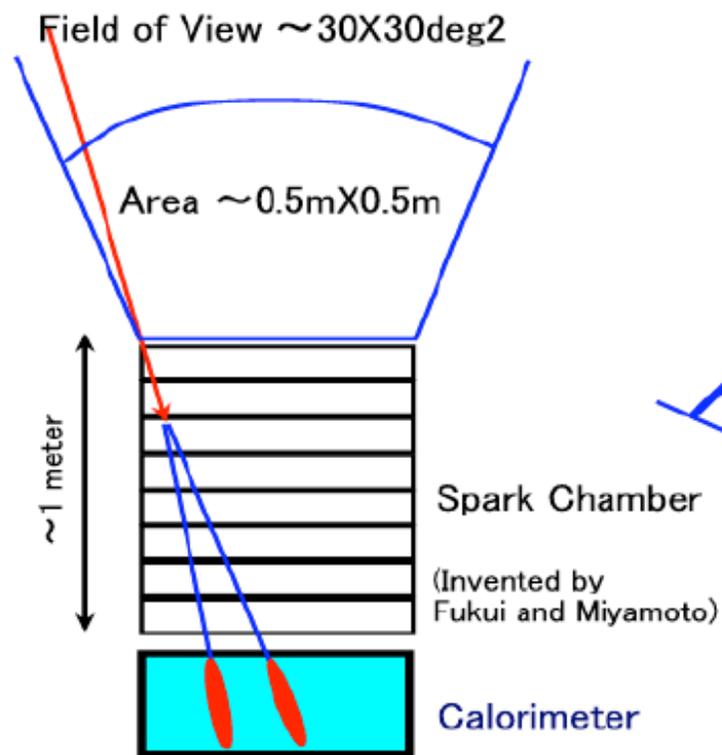
$1X_0$: probabilità $1/e$ di emettere 1γ o e^+e^-

$$\# \text{ fotoni} \propto E \quad \Delta E/E = (a/\sqrt{E}) + b$$

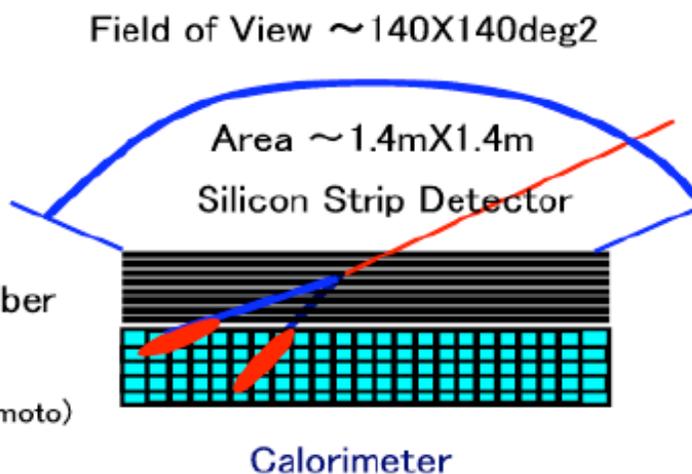
Alcune prestazioni degli esperimenti

SENSIBILITA`

EGRET(Spark Chamber) VS. GLAST(Silicon Strip Detector)

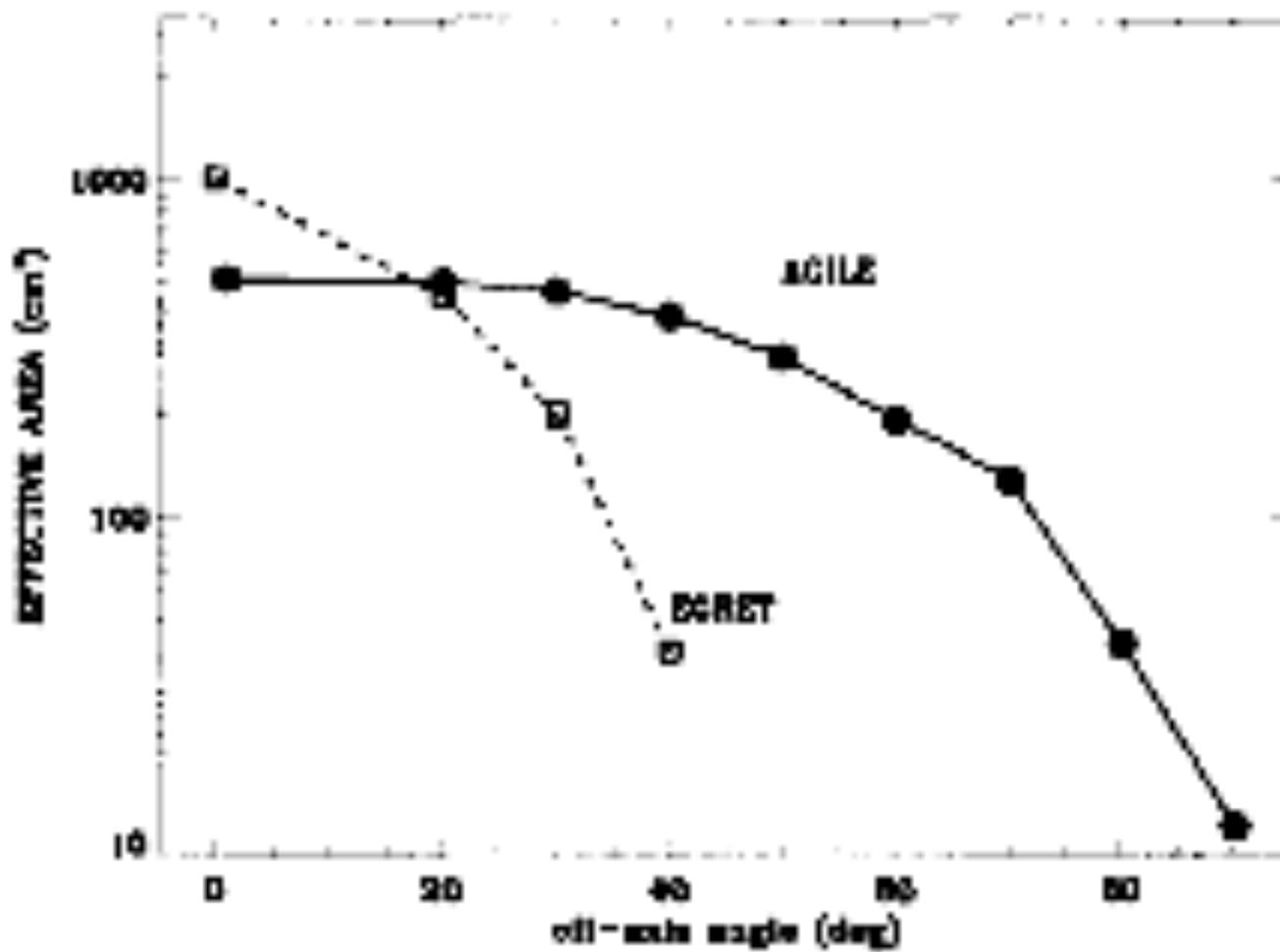


EGRET on Compton GRO
(1991–2000)



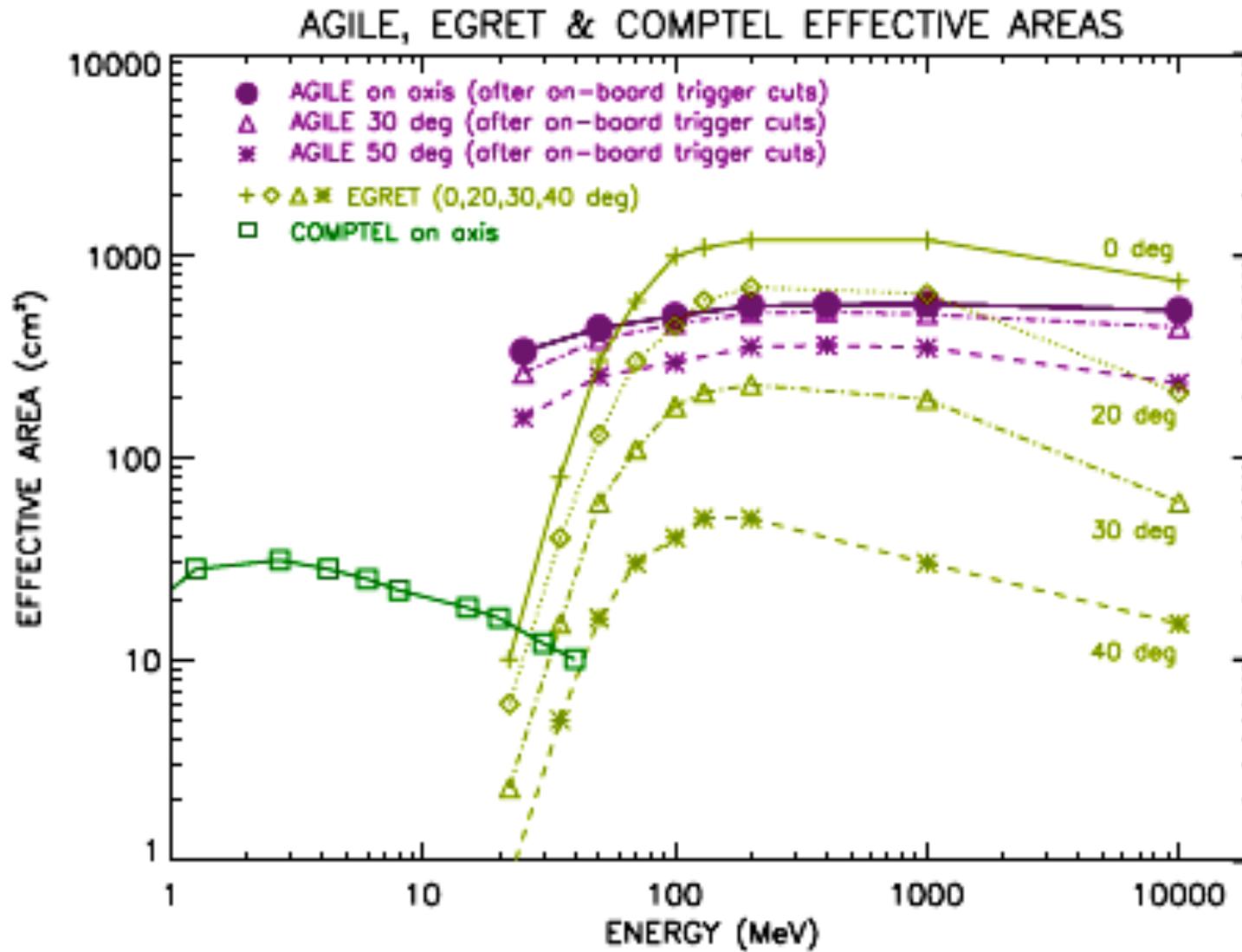
GLAST Large Area Telescope
(2006–2015)

AGILE



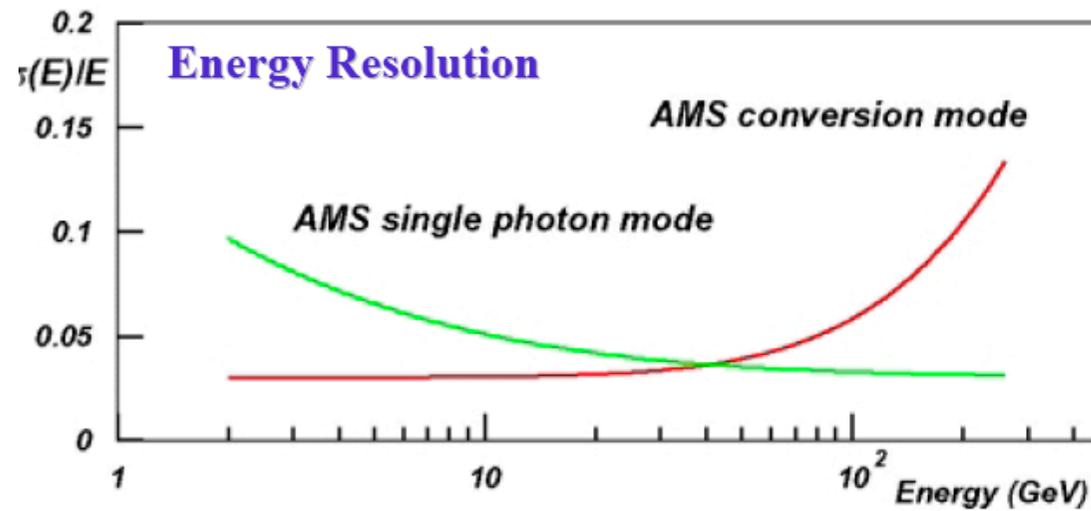
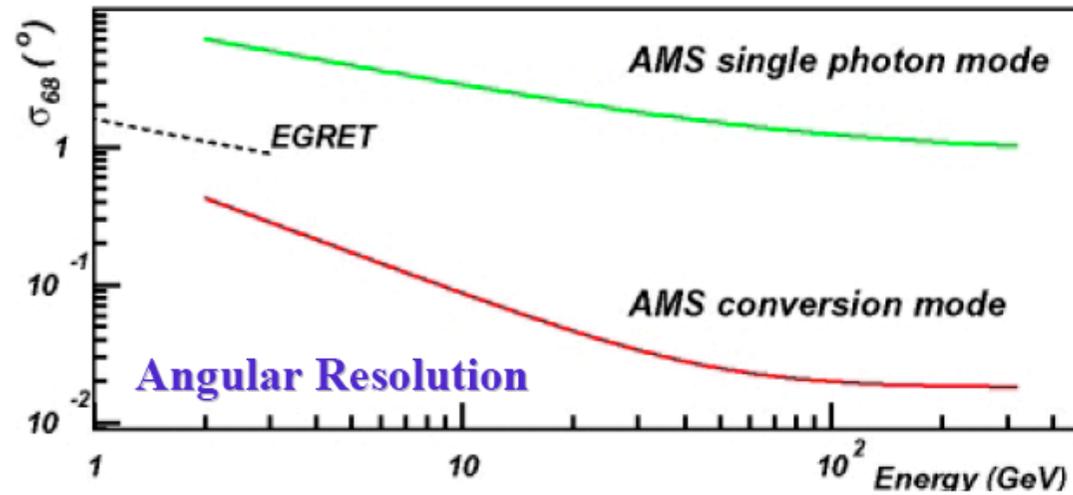
Area effettiva di AGILE a 100 MeV confrontata con EGRET in funzione della direzione di incidenza del fotone.

AGILE



Area effettiva in funzione dell'energia del fotone per diversi angoli di incidenza

AMS risoluzione γ



AMS02 Gamma

Unidentified Sources with AMS

AMS

- **Source localization:**
($E > 10$ GeV) $< 2'$

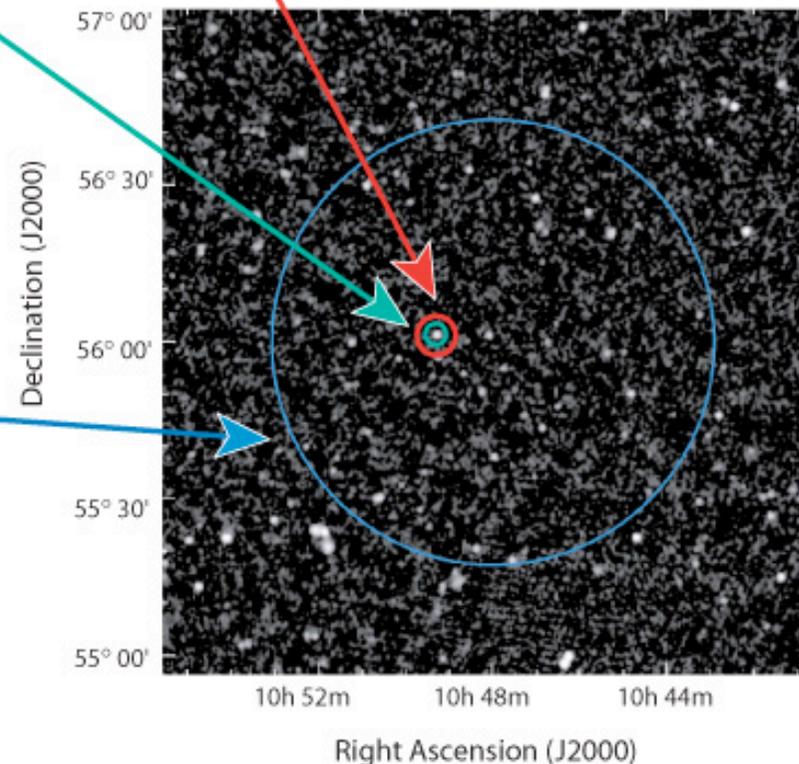
In 1 Year and for source of strength:
 $5. \times 10^{-8}$ ph $\text{cm}^{-2} \text{s}^{-1}$ ($E = 1$ GeV)

GLAST

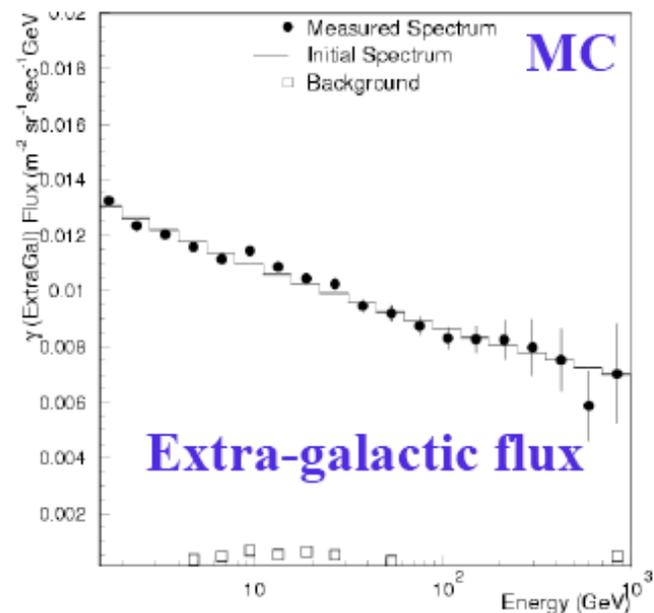
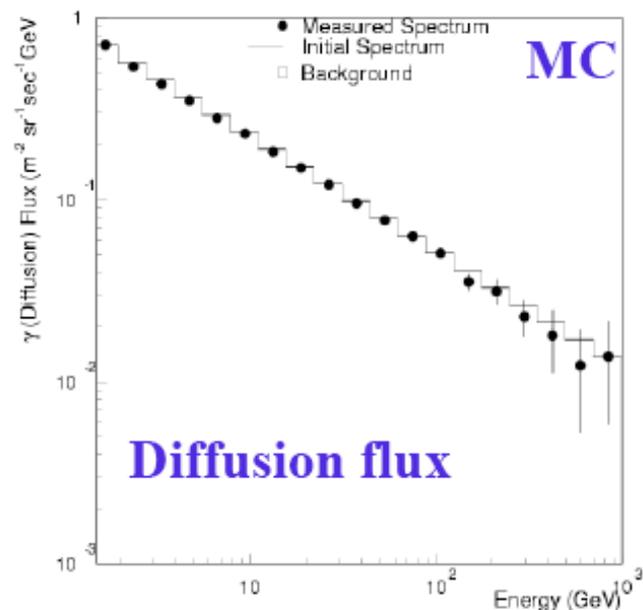
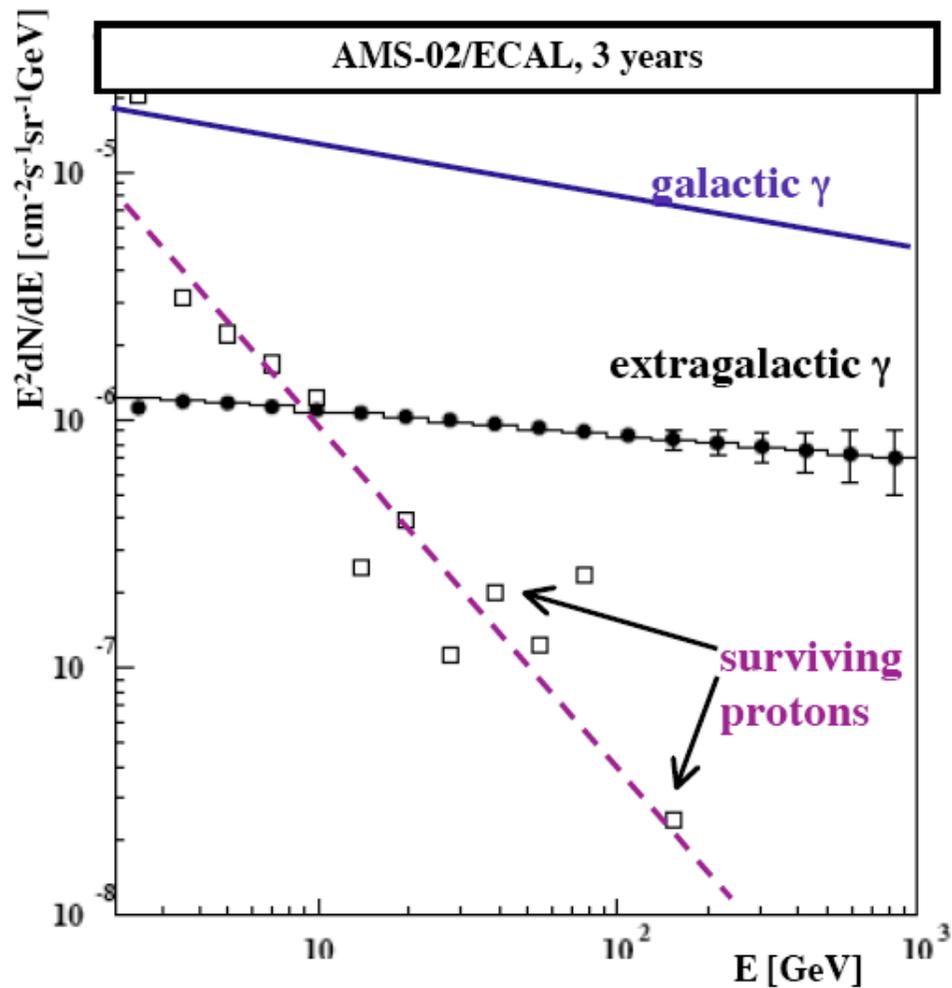
- **Source localization:**
 $< 5'$ and high sensitivity

EGRET

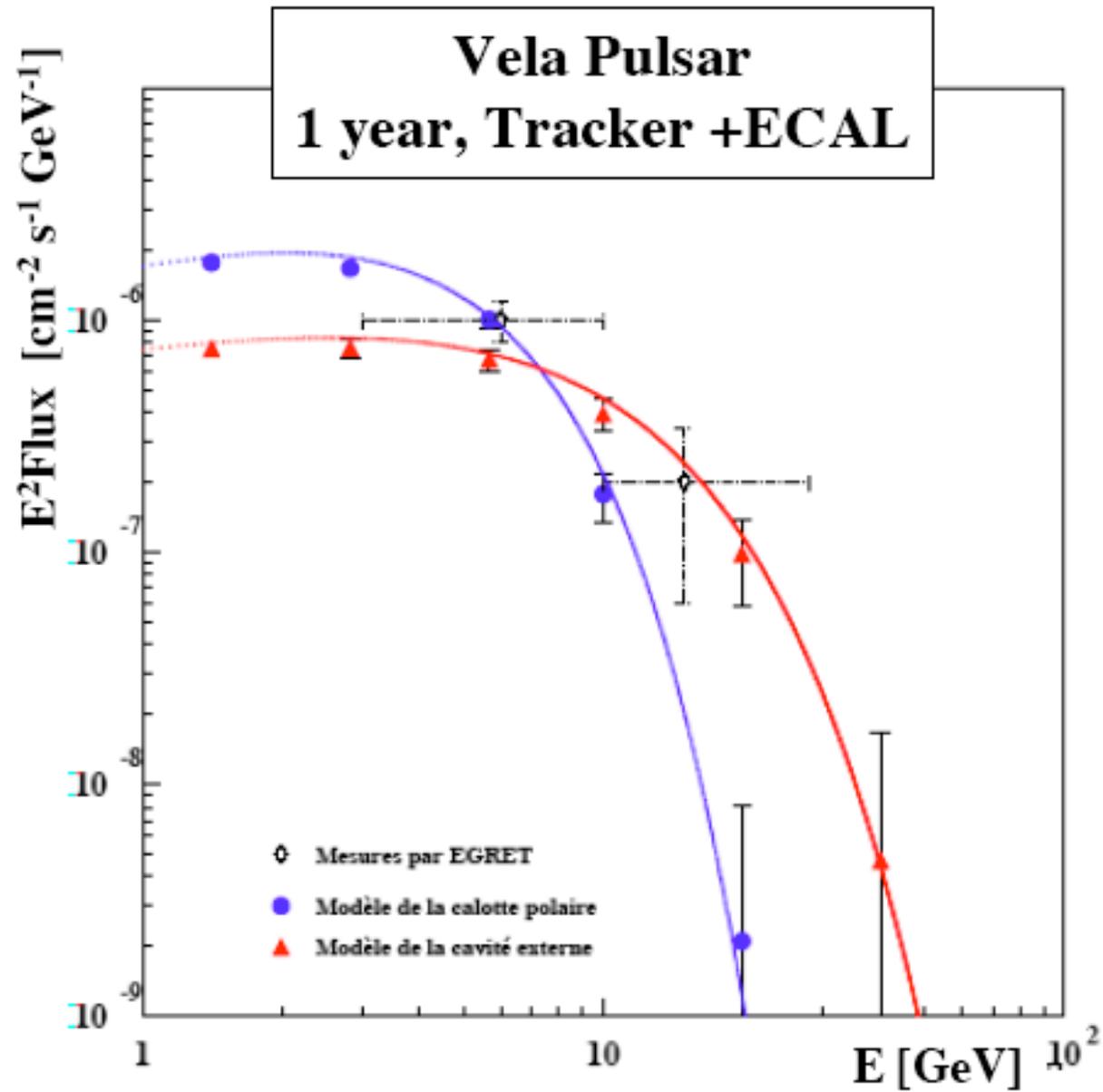
- **Source localization:**
 $< 30'$
for source of strength
 10^{-8} ph $\text{cm}^{-2} \text{s}^{-1}$
- **Limited sensitivity**
above 1 GeV



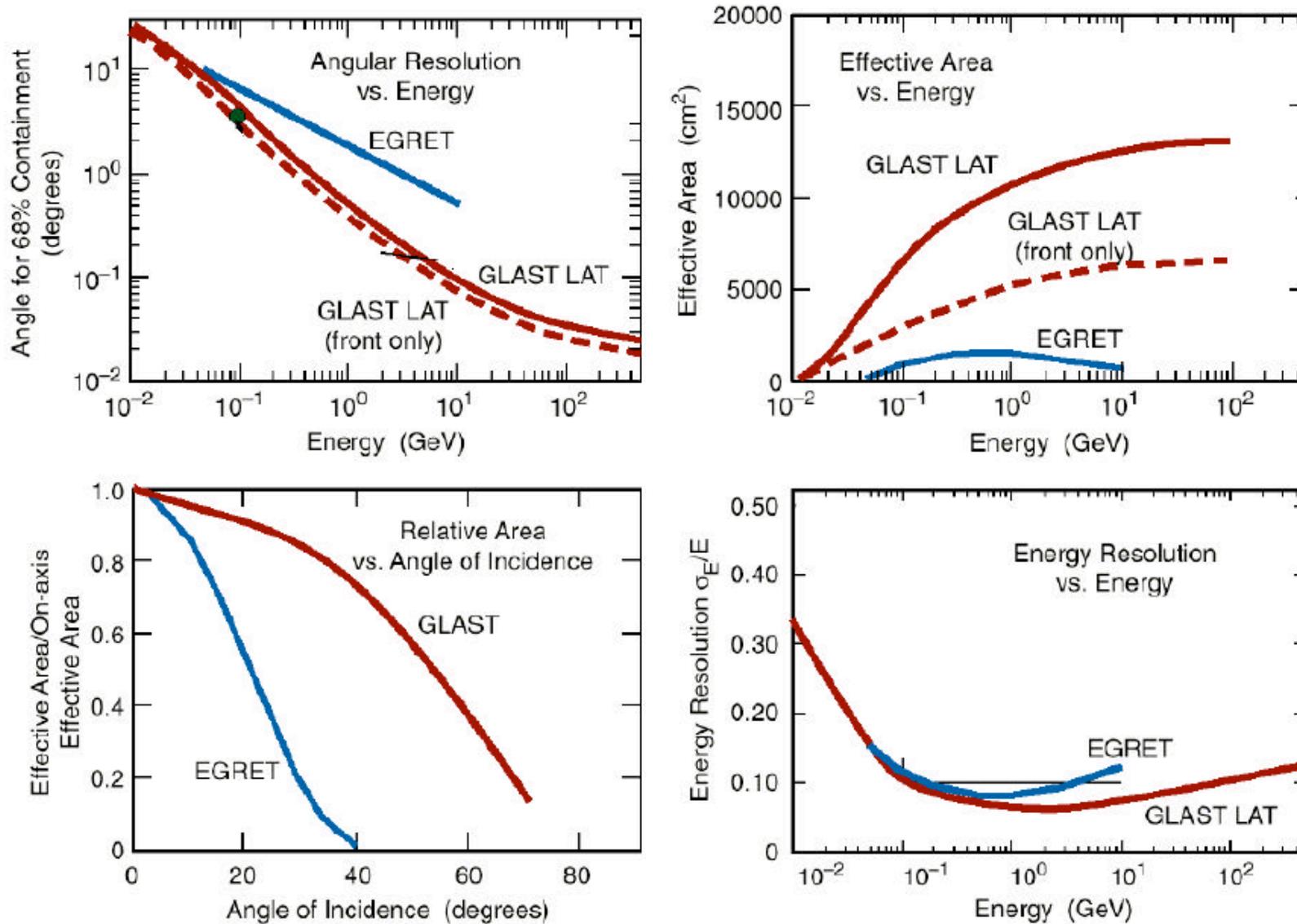
AMS: GAMMA G, EG



AMS: MODELLI PULSAR

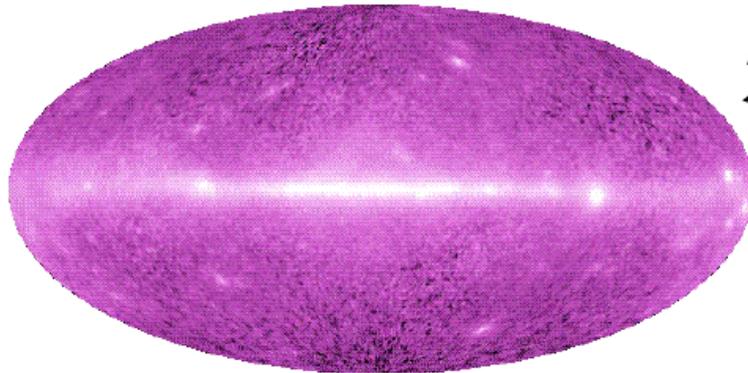


GLAST: PRESTAZIONI

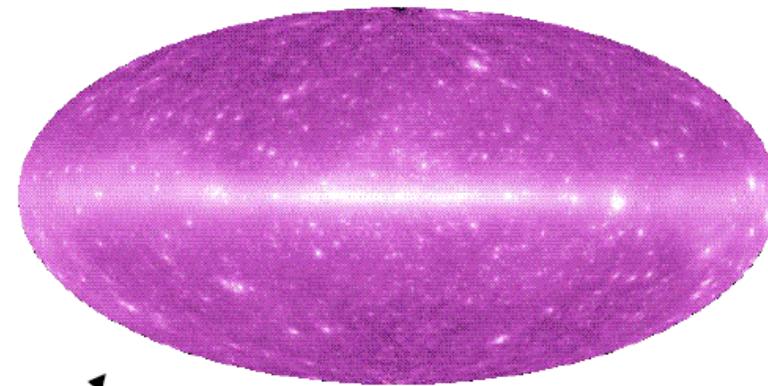


GLAST

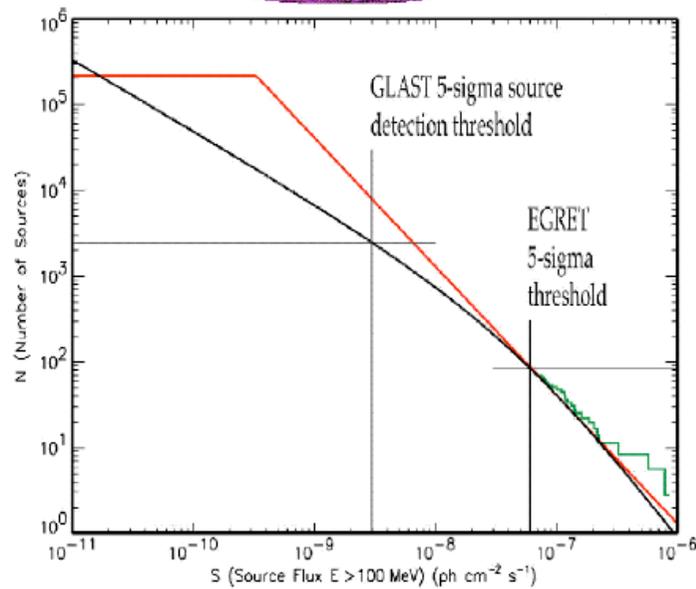
One year All-Sky Survey Simulation, $E_\gamma > 100$ MeV



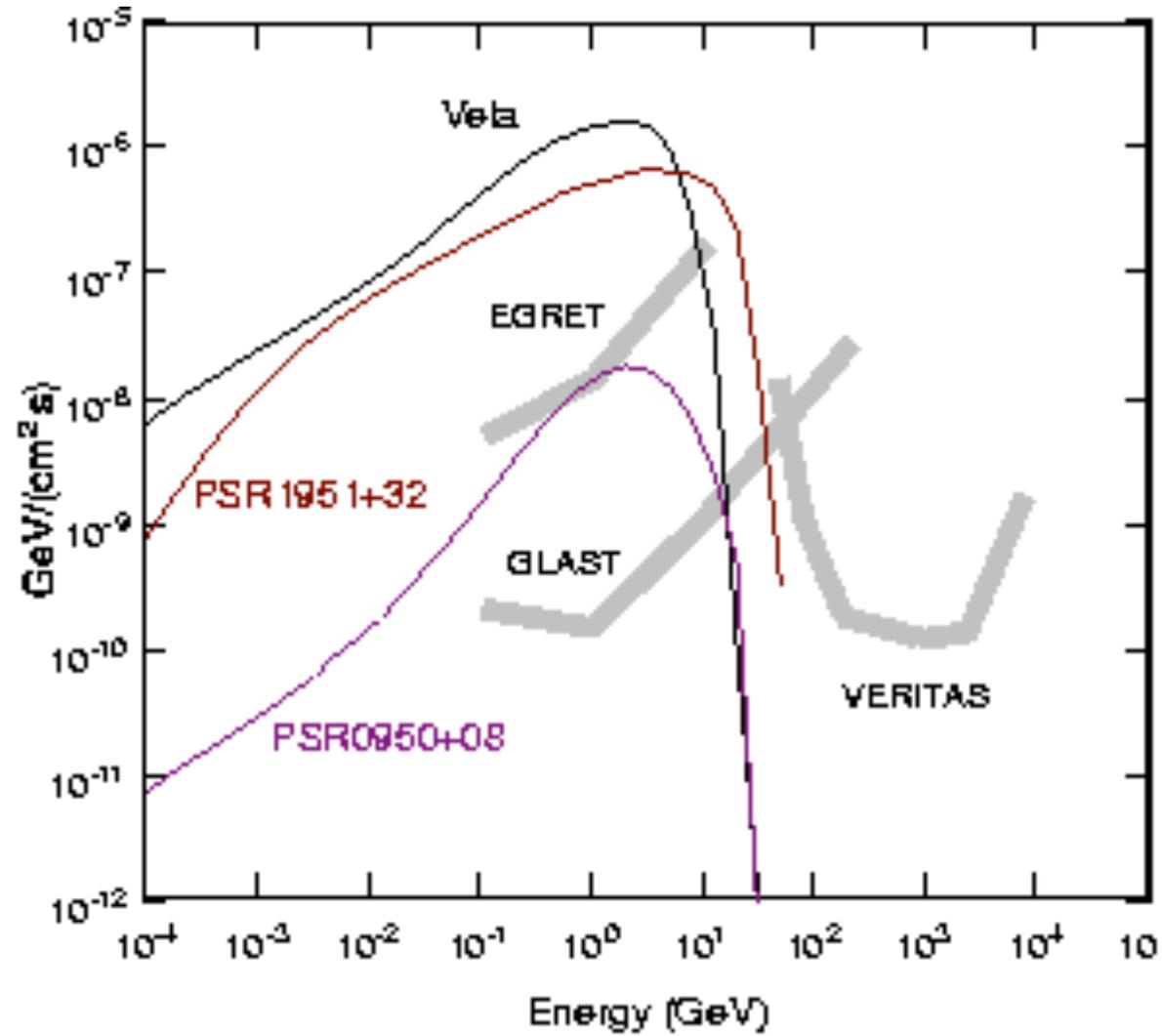
All-sky intensity map based on five years EGRET data.



All-sky intensity map from a GLAST one year survey, based on the extrapolation of the number of sources versus sensitivity of EGRET

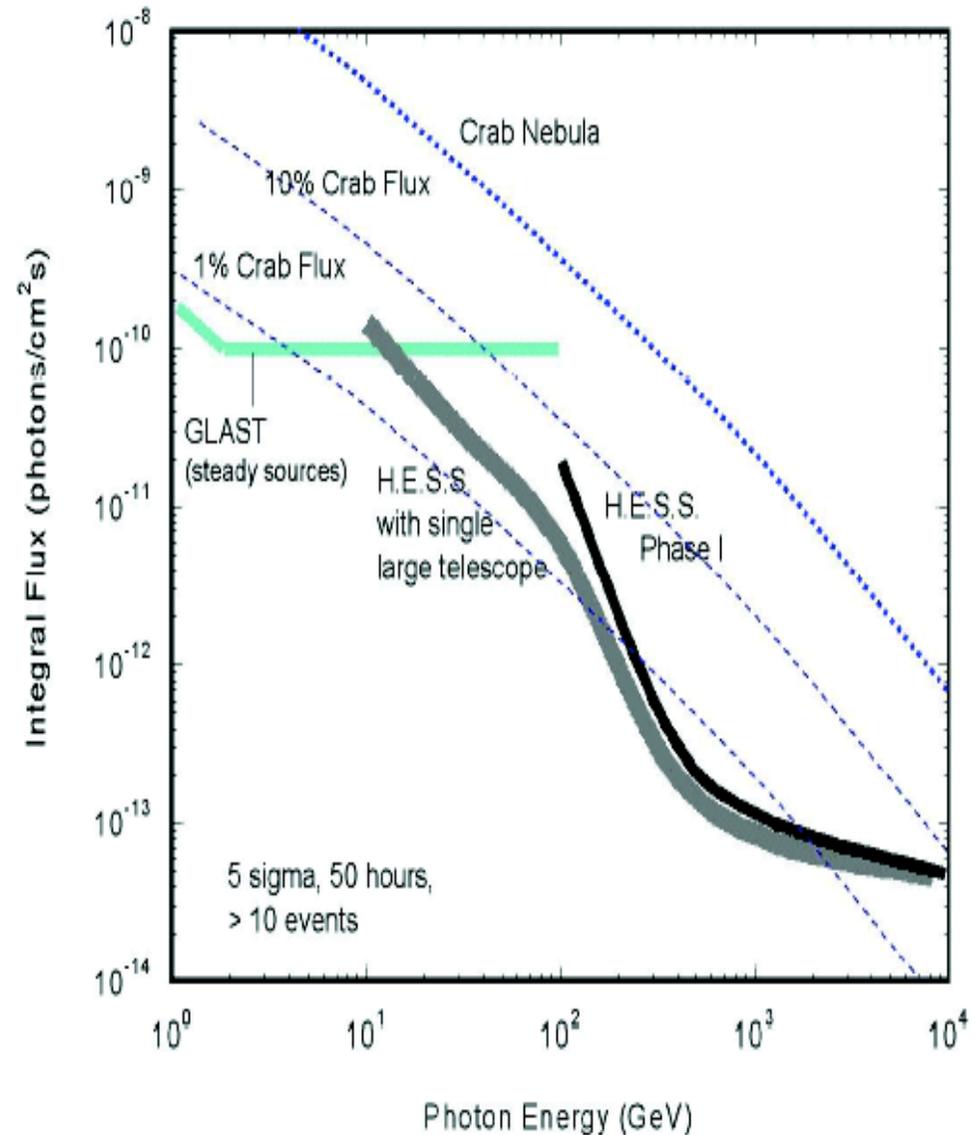


PULSAR: POLAR CAP



OSSERVAZIONE SPAZIO-TERRA

- Gli esperimenti nello spazio e a Terra sono complementari fra di loro. Nella figura è mostrata la sensibilità al flusso di gamma vs l'energia di GLAST e di HESS. Le linee blu rappresentano rispettivamente il flusso di fotoni dalla Crab Nebula e lo stesso flusso ridotto per un fattore 10 e 100.



RIVELATORI GAMMA

