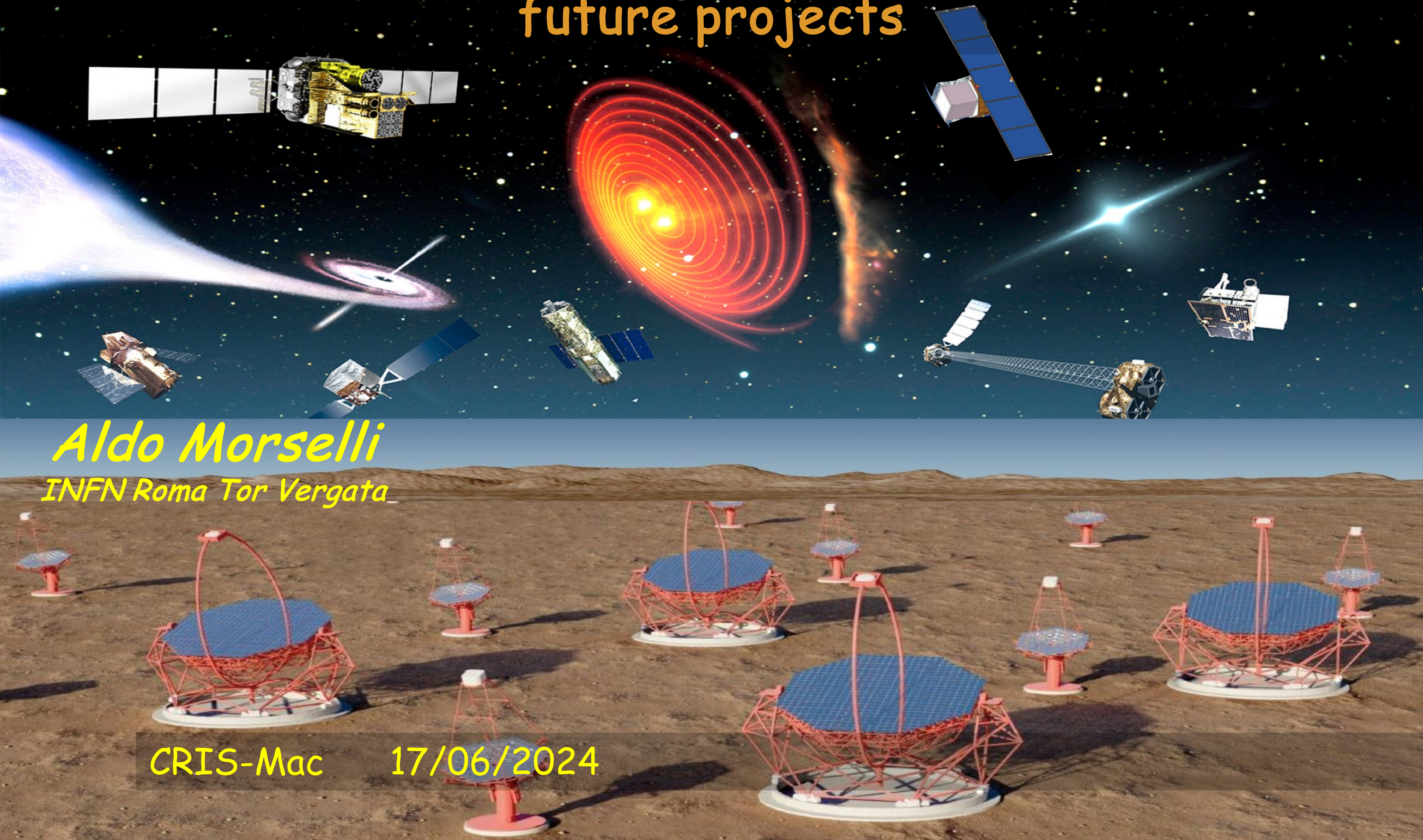
The beginning of space gamma-ray astronomy with silicon detectors: From GILDA to AGILE and Fermi and future projects

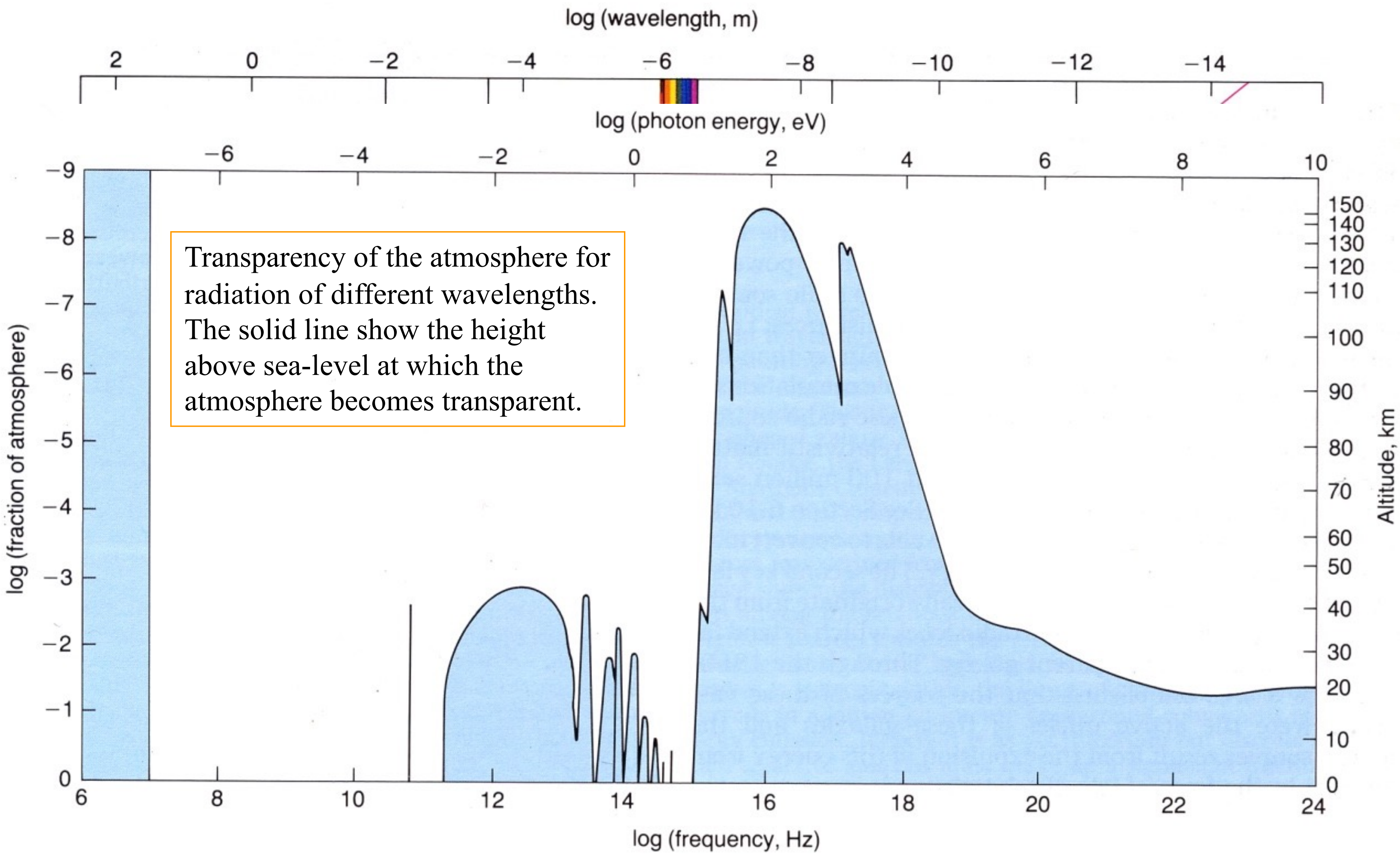


Aldo Morselli

INFN Roma Tor Vergata

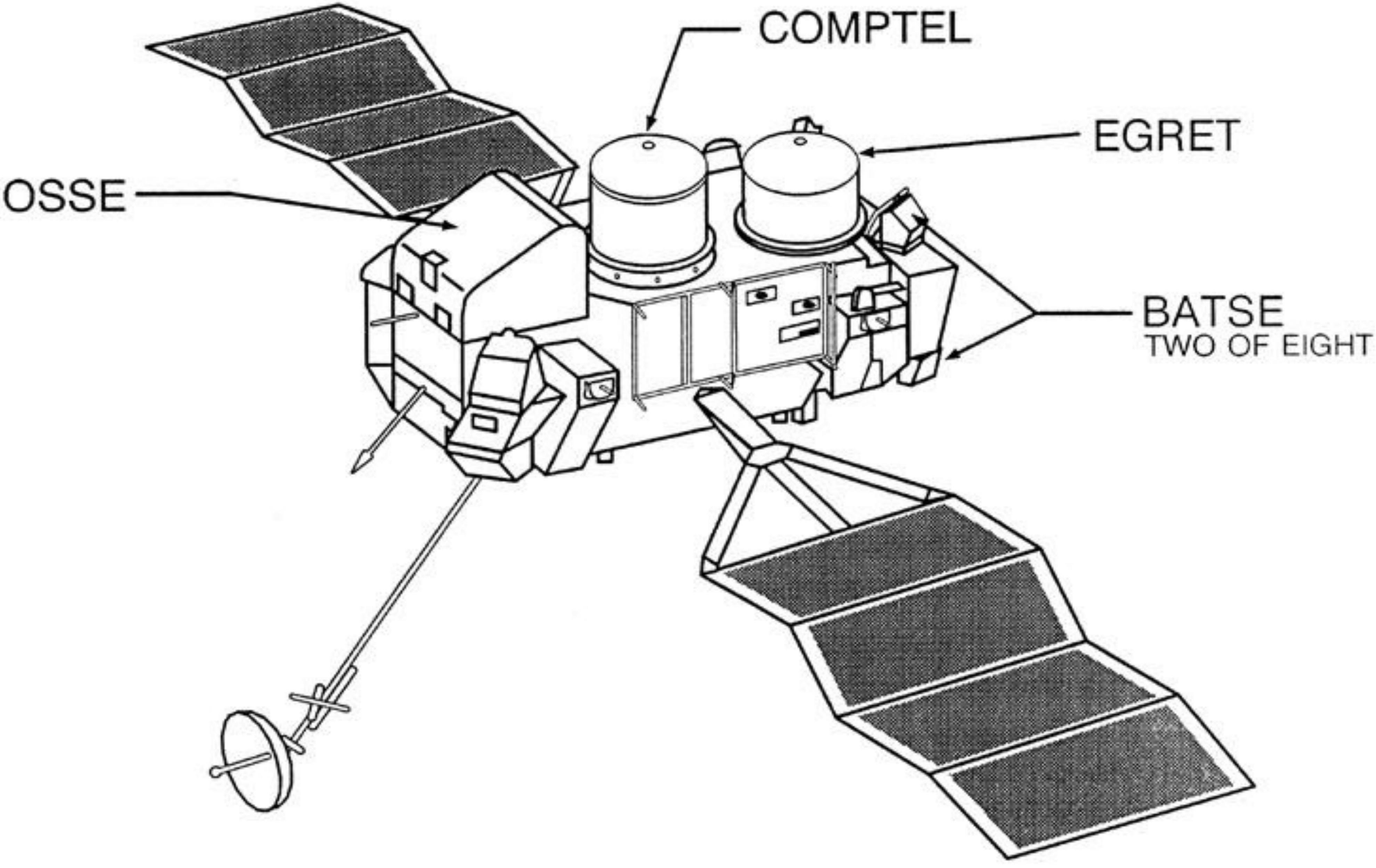
CRIS-Mac 17/06/2024

Gamma ray attenuation



Transparency of the atmosphere for radiation of different wavelengths. The solid line show the height above sea-level at which the atmosphere becomes transparent.

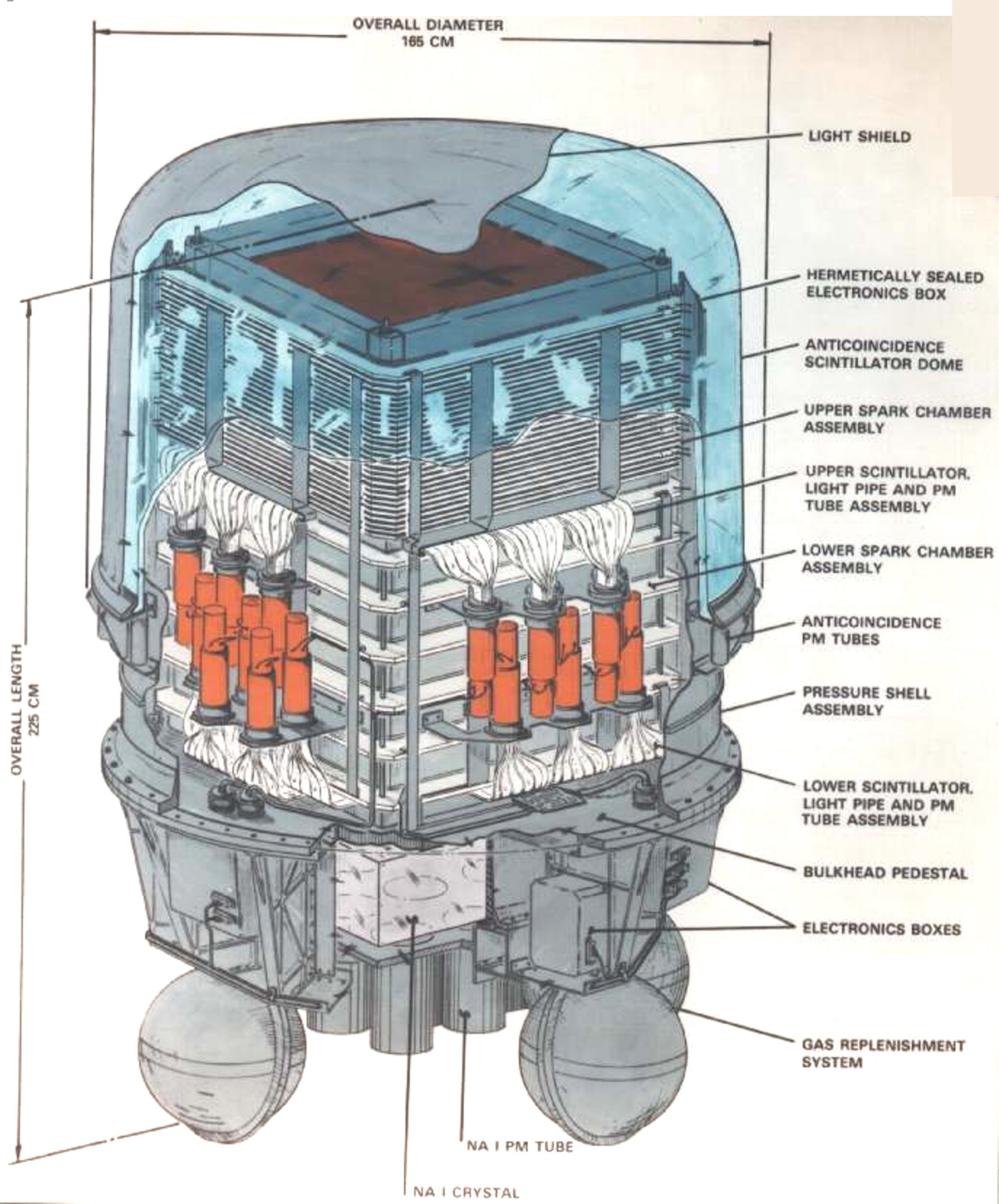
COMPTON OBSERVATORY INSTRUMENTS

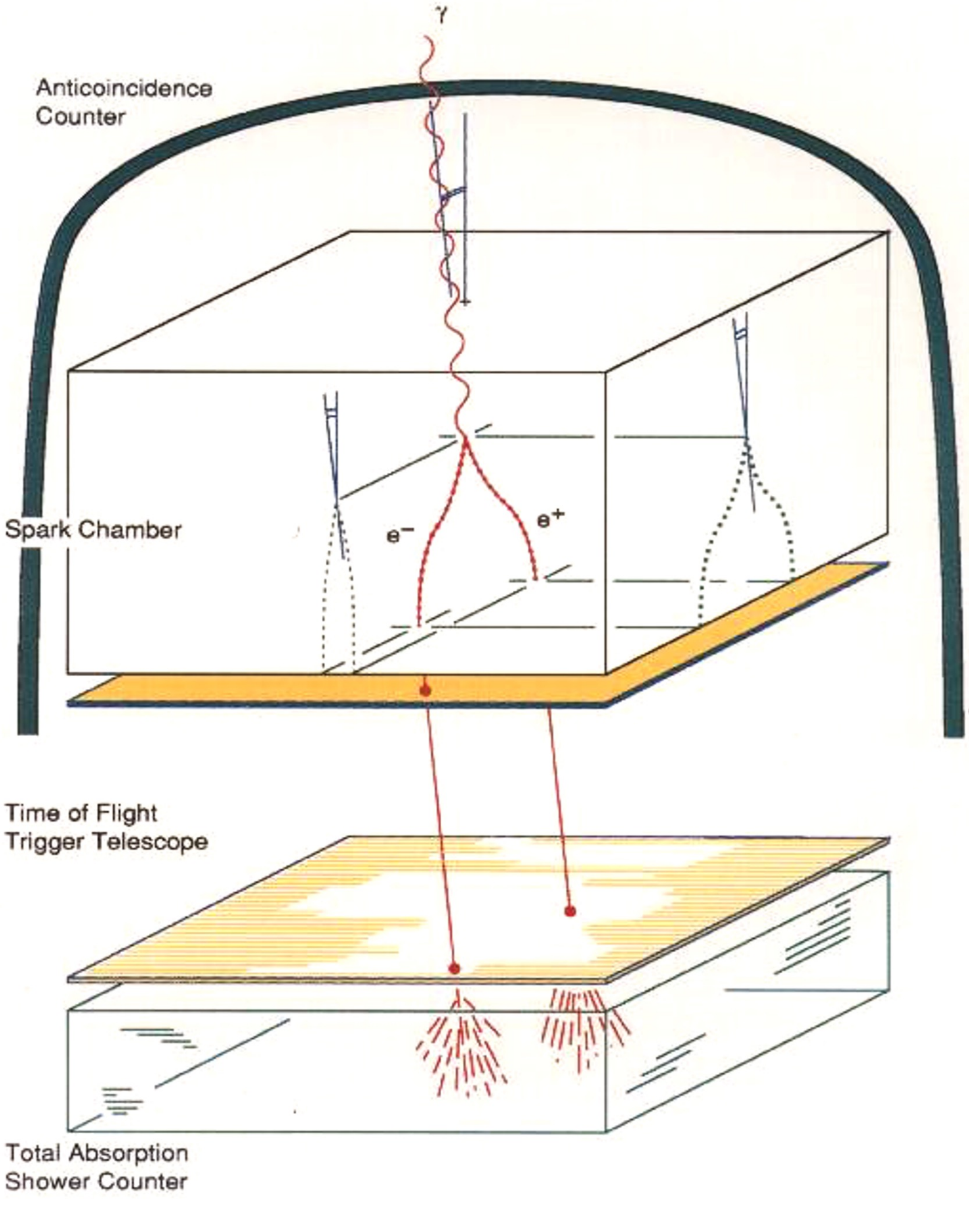


EGRET:the detector

Energy range:	20 MeV - 30 GeV
Weight:	1820 Kg
Power:	160 W
Field of view:	0. 5 sr
Dead Time:	100 ms
Effective Area (@1GeV)	1200 cm^2
Angular resolution (@100MeV)	5.8^o

Sensitivity	0.1 GeV	$5x10^{-8}$
for point	1 GeV	$1x10^{-8}$
sources	10 GeV	$2x10^{-8}$
(ph cm-2 s-1)*		





EGRET: Principle of Detection of High Energy Gamma Rays

EGRET – Principle of gamma ray detection

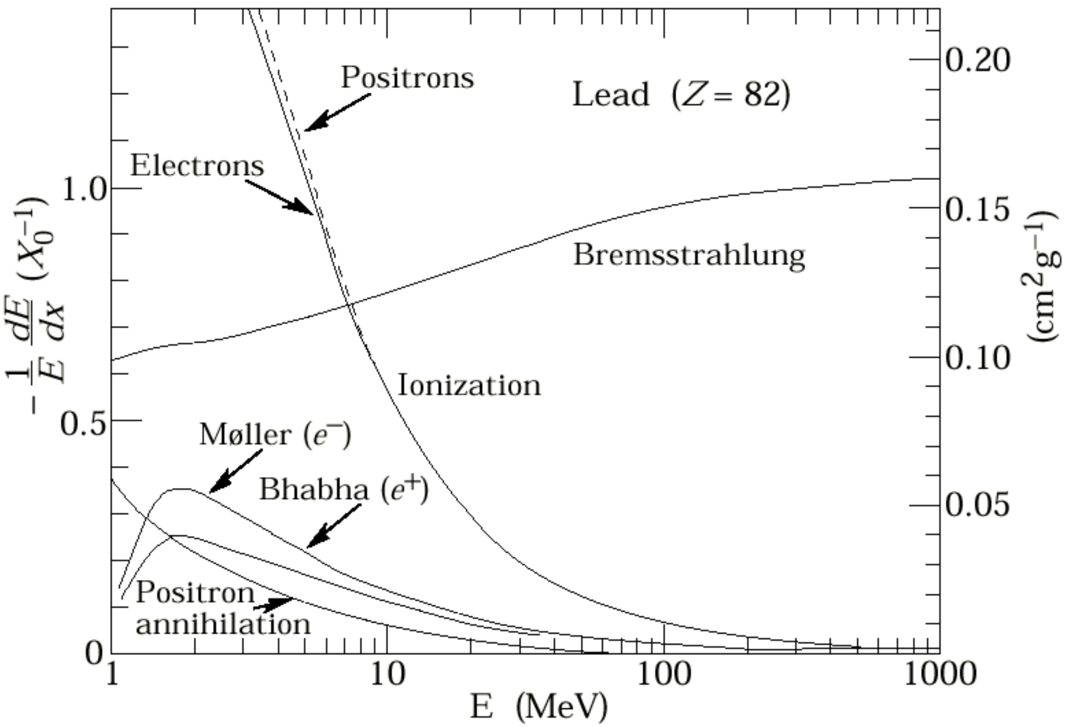
A γray which enters the top of the EGRET instrument will pass undetected through the large anticoincidence scintillator surrounding the spark chamber and has a probability 33% of converting into an electronpositron pair in one of the thin tantalum (Ta) sheets interleaved between the 28 closely spaced spark chambers in the upper portion of the instrument.

Below the conversion stack are two 4 x 4 arrays of plastic scintillation detector tiles spaced 60 cm apart which register the passage of charged particles. If the timeofflight delay indicates a downward moving particle which passed through a valid combination of upper and lower scintillator tiles, and the anticoincidence system has not been triggered by a charged particle, the track information is recorded digitally. In this manner, a three dimensional picture of the path of the electronpositron pair is measured.

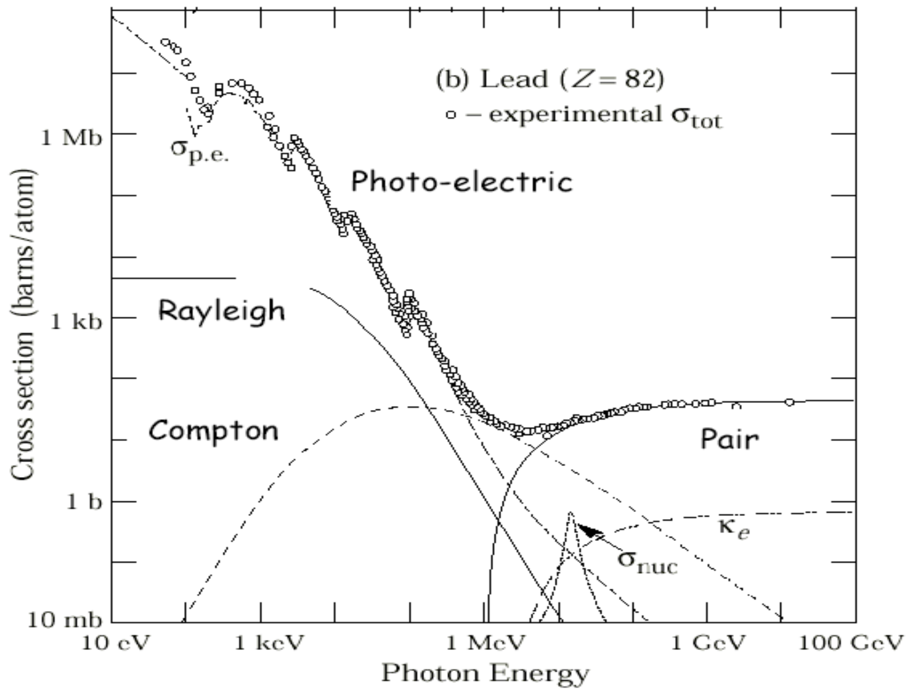
The energy deposition in the NaI(Tl) Total absorption Shower Counter (TASC) located directly below the lower array of plastic scintillators is used to estimate the photon energy.

Interaction of photons with matter

Fractional energy loss for e^+ and e^- in lead



Photon total cross sections



$$\frac{dE}{dx}_{Brems} = -\frac{E}{X_0} \Rightarrow E(x) = e^{-\frac{x}{X_0}}$$

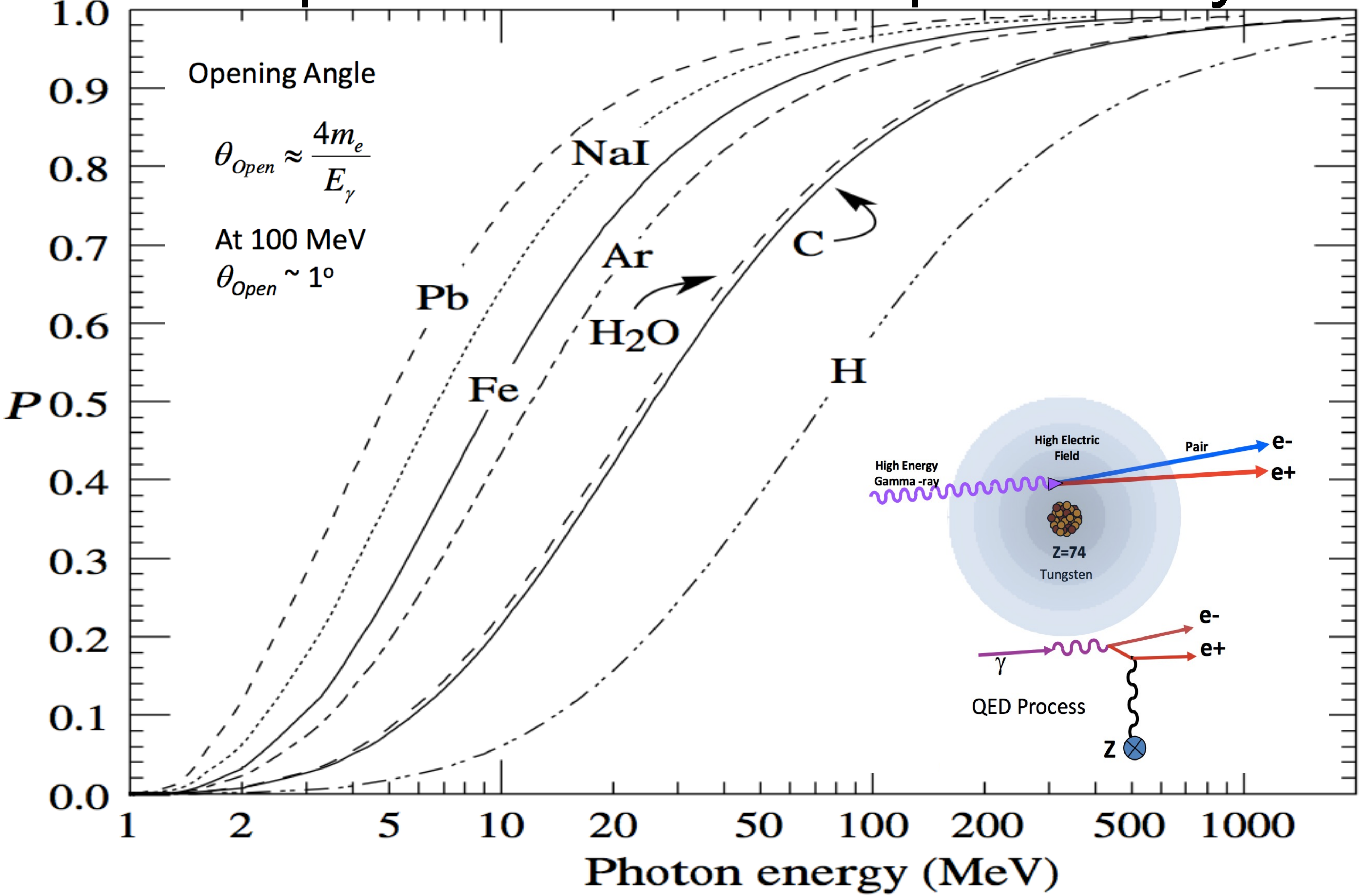
with X_0 = radiation length

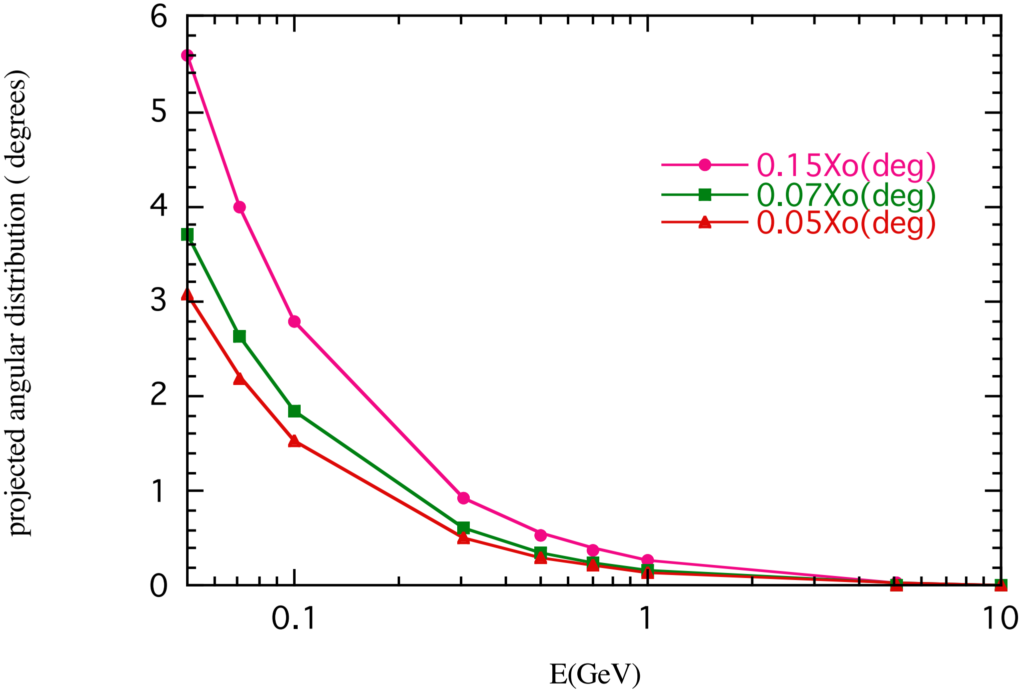
$$X_0 = 716.4 \text{ g cm}^{-2} \frac{A}{Z(Z+1)\ln\frac{287}{\sqrt{Z}}}$$

$$\text{Prob. of Int.} = 1 - \exp^{-\frac{7}{9}\frac{x}{X_0}}$$

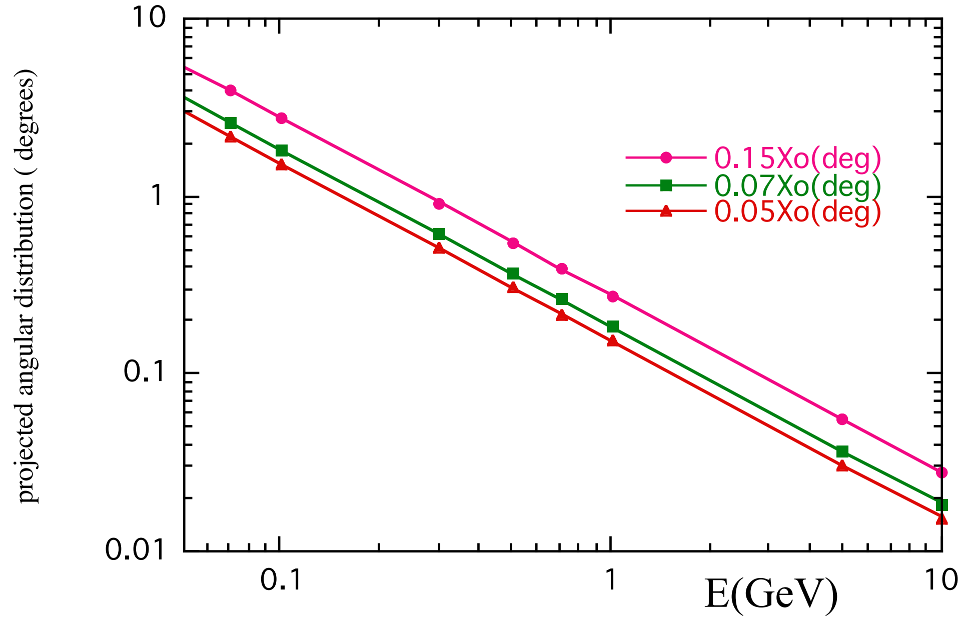
x/X_0	Prob Int.
0.5	0.40
1	0.54
2	0.79
7	0.995

Pair photon interaction probability





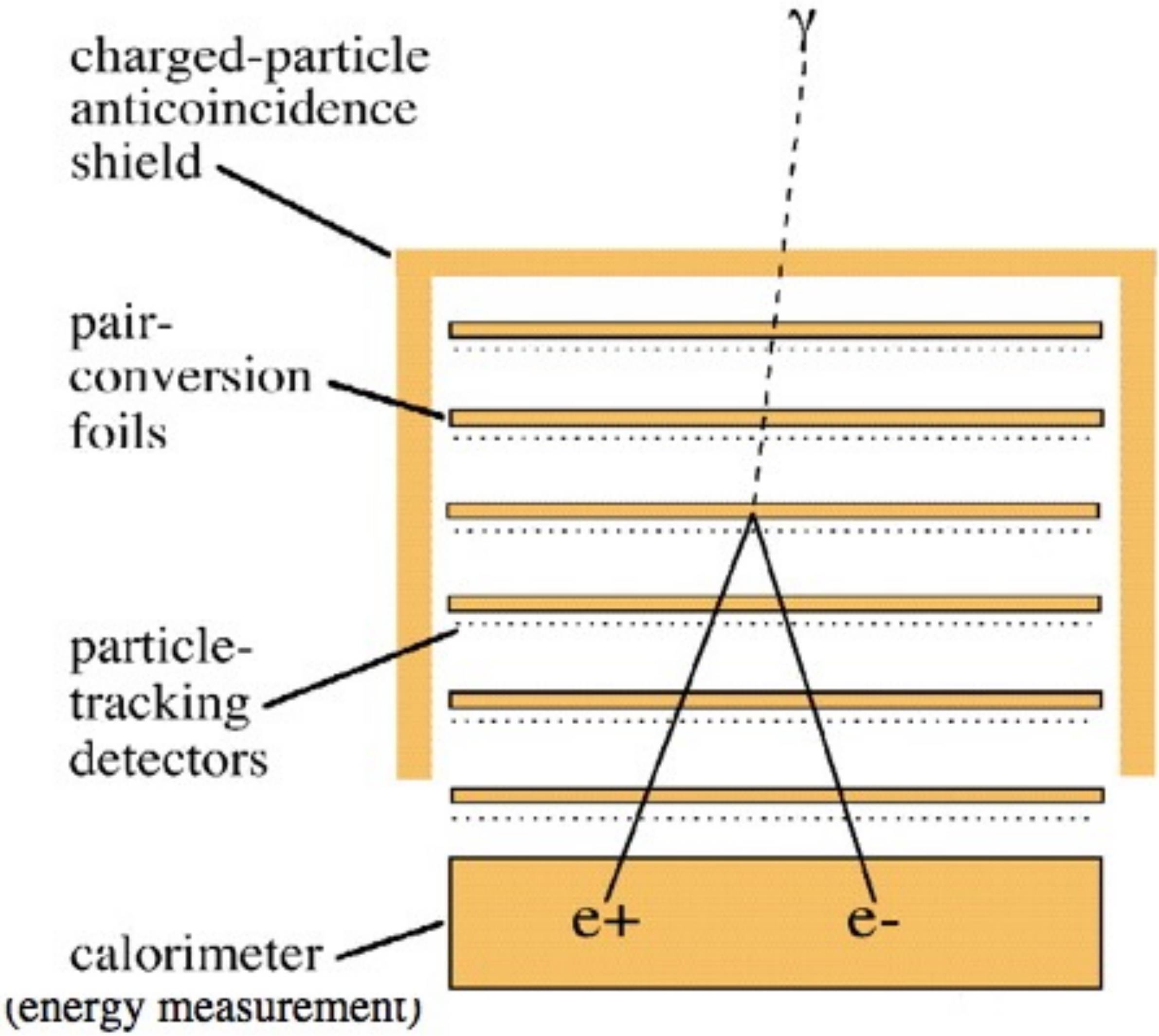
Multiple Scattering



$$\theta_0 = \theta_{plane}^{rms} = \frac{1}{\sqrt{2}}\theta_{space}^{rms}$$

$$\theta_0 = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_0}\,[1 + 0.038\ln(x/X_0)]$$

Elements of a pair-conversion telescope

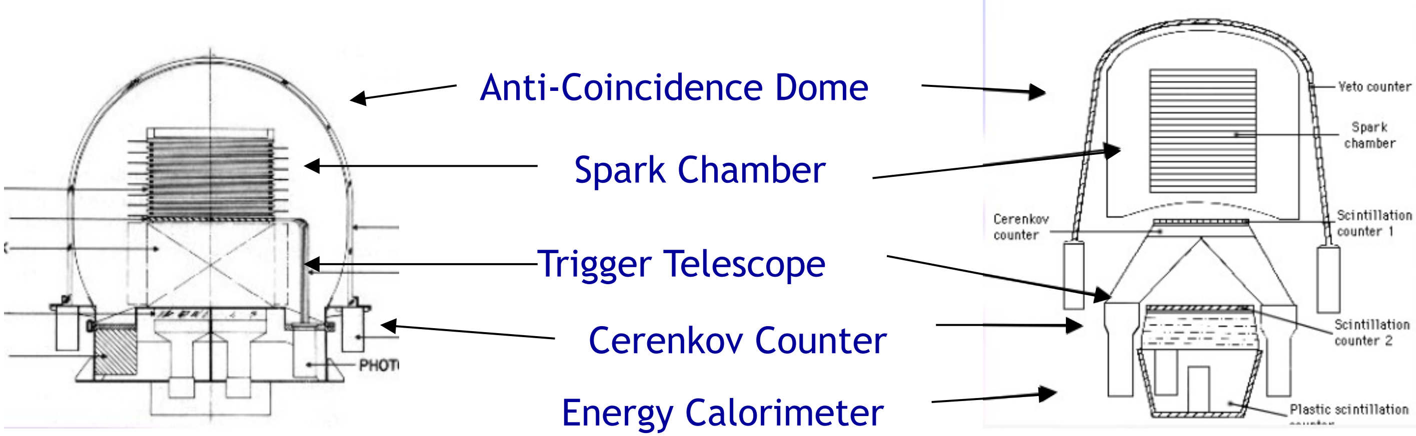


- photons materialize into matter-antimatter pairs:

  E_γ --> $m_{e+}c^2 + m_{e-}c^2$

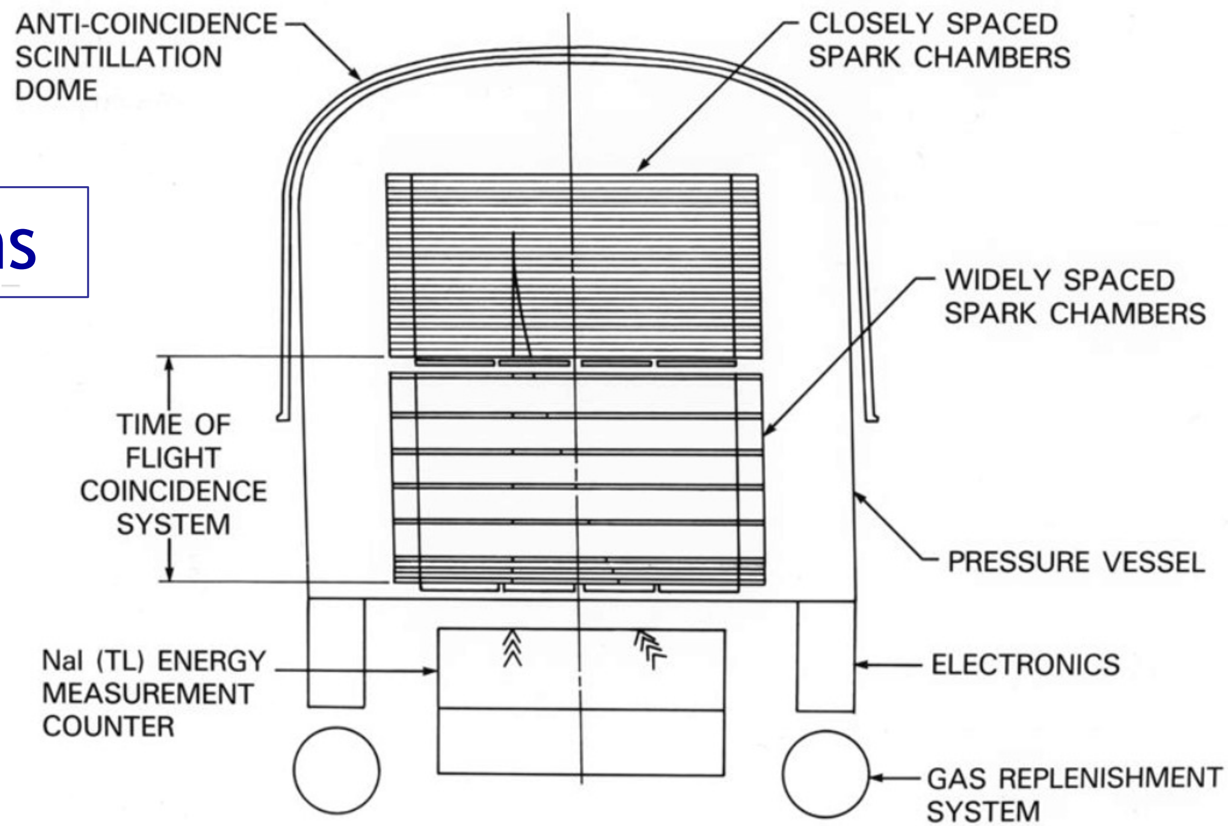
- electron and positron carry information about the direction, energy and polarization of the γ-ray

The gamma-ray missions



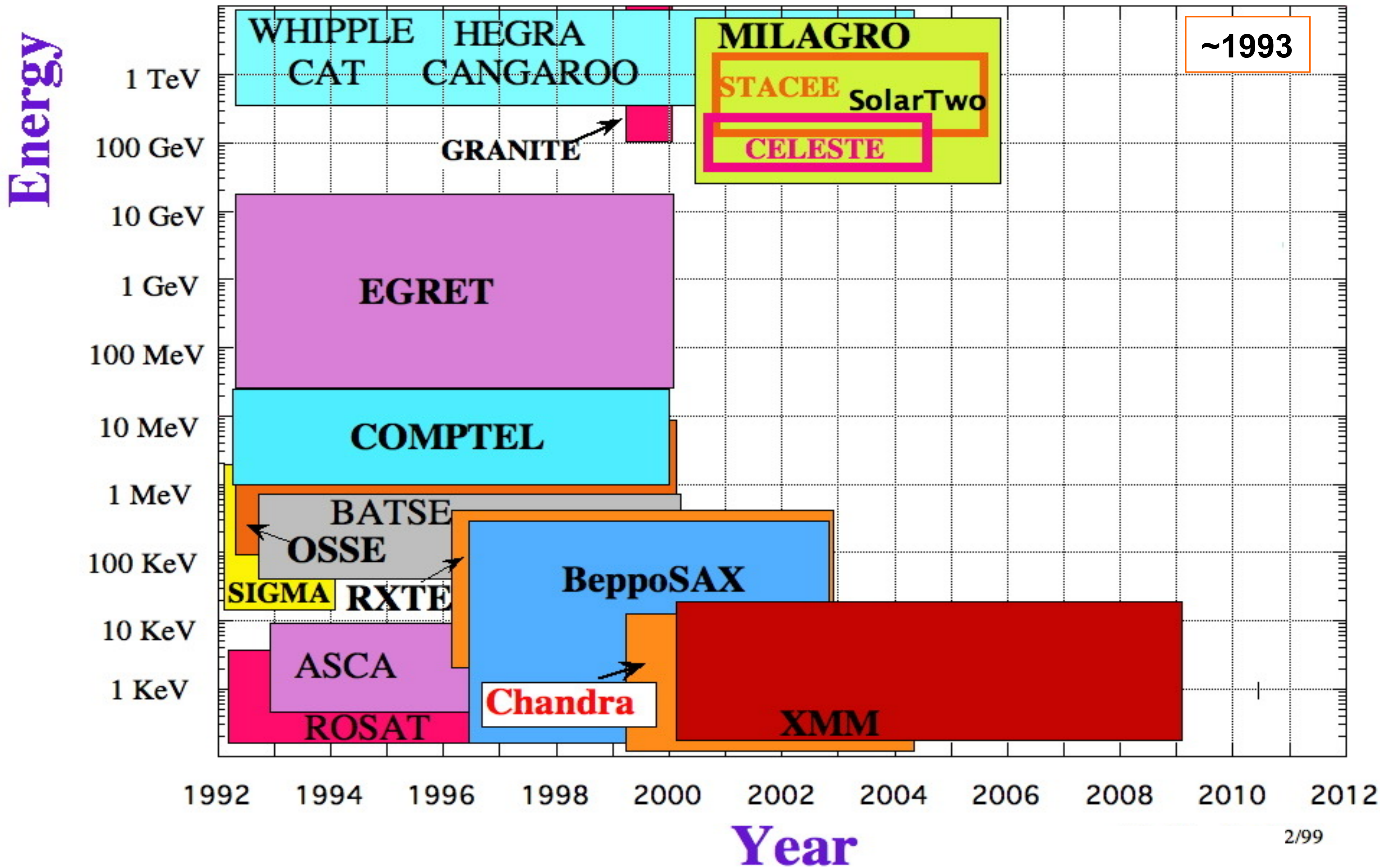
SAS-2 11/1972-7/1973

Cos-B 8/1975-4/1982



EGRET 4/1991-1999

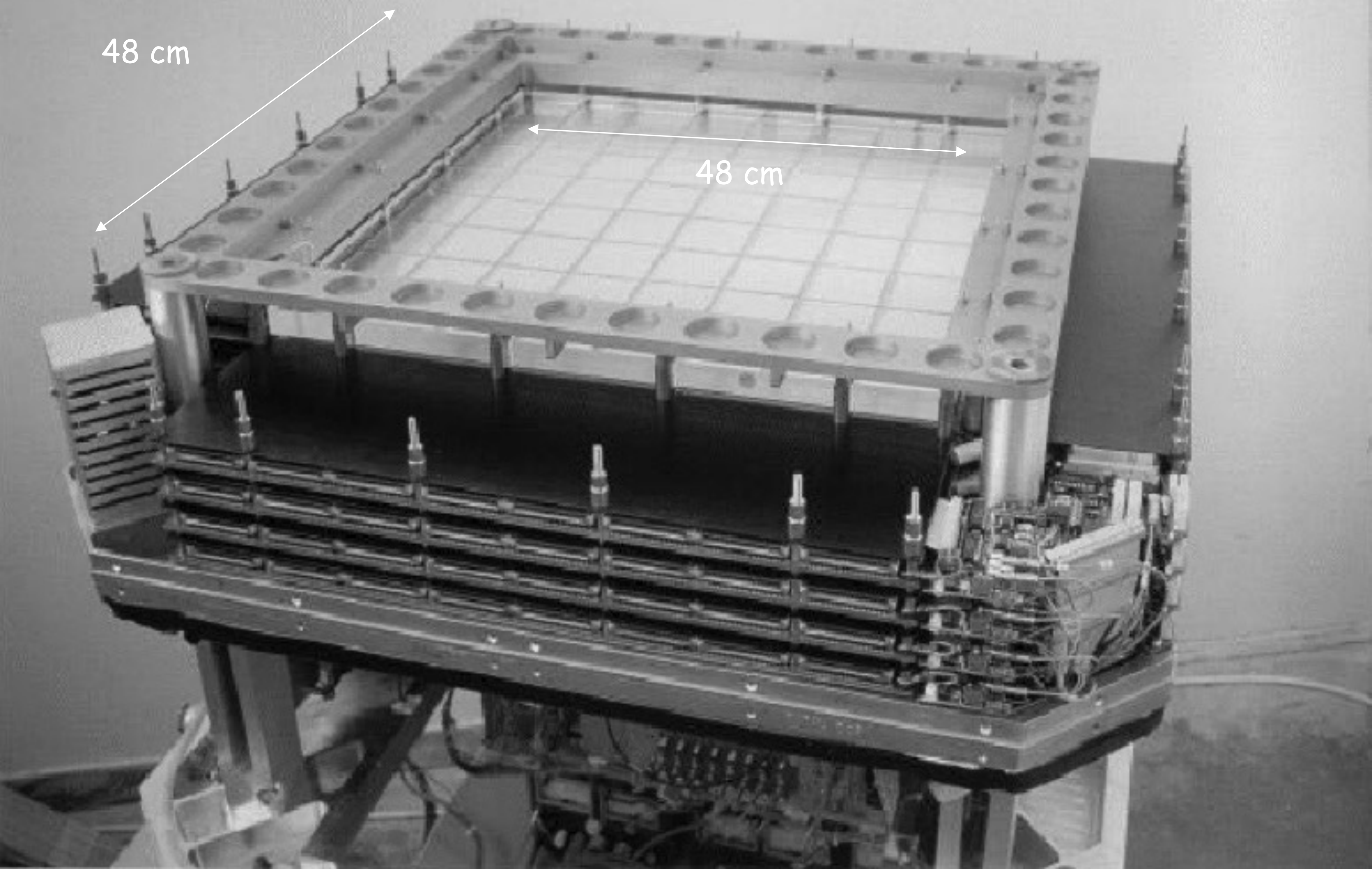
High Energy Gamma Experiments Experiments




The CAPRICE 94
flight


HOLD

The TS93 and CAPRICE silicon-tungsten imaging calorimeter.



Nuclear Instruments and Methods in Physics Research A 354 (1995) 547–552

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER

The GILDA mission: a new technique for a gamma-ray telescope in the energy range 20 MeV–100 GeV

G. Barbiellini [a], M. Boezio [a], M. Casolino [b], M. Candusso [b], M.P. De Pascale [b], A. Morselli [b,*], P. Picozza [b], M. Ricci [d], R. Sparvoli [b], P. Spillantini [c], A. Vacchi [a]

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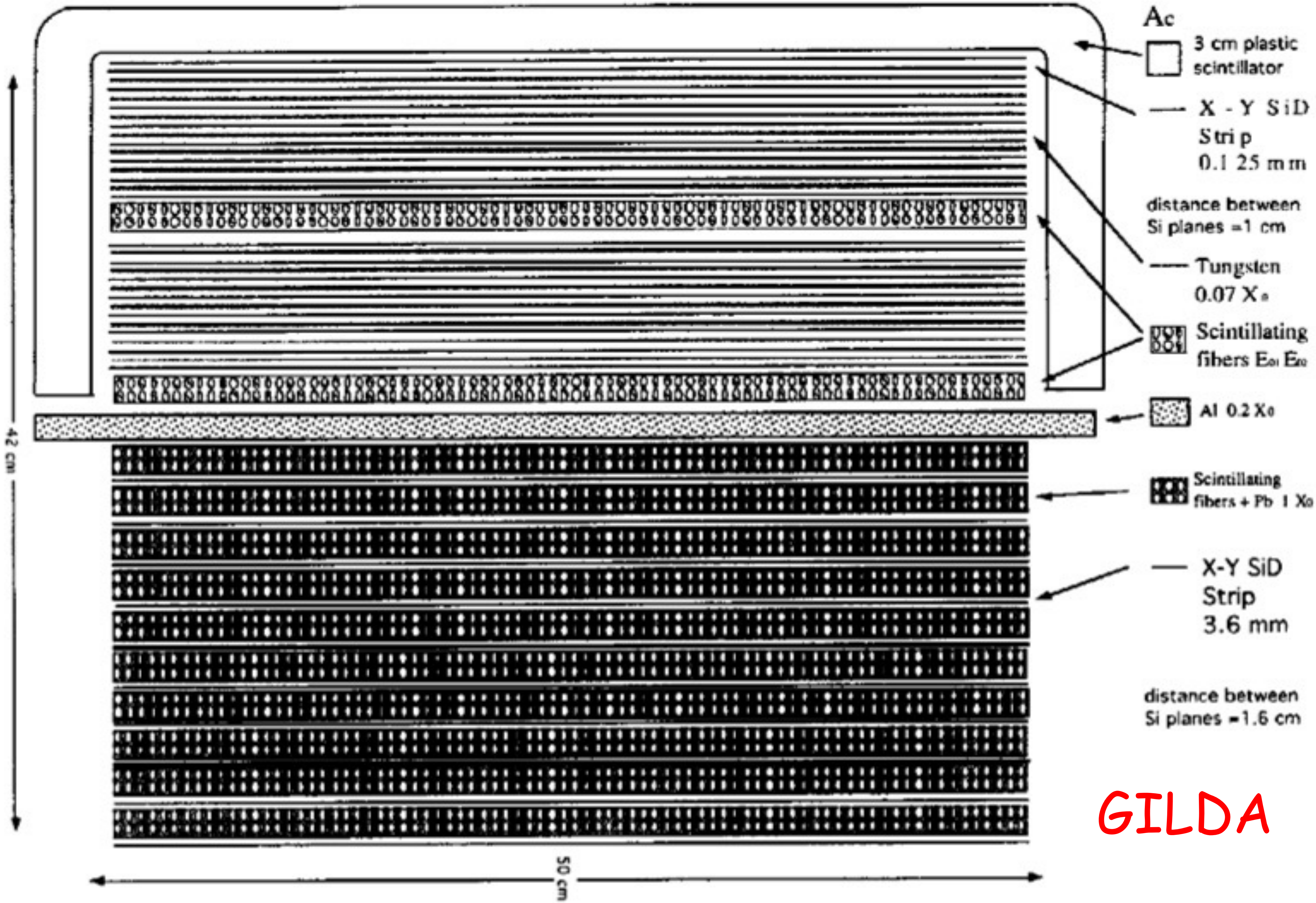
[d] *INFN Laboratori Nazionali di Frascati, Italy*

Received 5 August 1994

Abstract

In this article a new technique for the realization of a high energy gamma-ray telescope is presented, based on the adoption of silicon strip detectors and lead scintillating fibers. The simulated performances of such an instrument (GILDA) are significatively better than those of EGRET, the last successful experiment of a high energy gamma-ray telescope, launched on the CGRO satellite, though having less volume and weight.

* Corresponding author.



Ac
3 cm plastic scintillator
X - Y SiD Strip 0.1 25 mm
distance between Si planes =1 cm
Tungsten 0.07 X0
Scintillating fibers E01 E02
Al 0.2 X0
Scintillating fibers + Pb 1 X0
X-Y SiD Strip 3.6 mm
distance between Si planes =1.6 cm
42 cm
50 cm
GILDA

Proposta per la *Call for Ideas* **ASI per Piccole Missioni (Scienze dell'Universo)**
26 giugno 1997

AGILE: Rivelatore a immagini gamma leggero

M. Tavani[1,2], G. Barbiellini[3], M. Boezio[3], P. Caraveo[1], M. Casolino[4], M. P. De Pascale[4], S. Mereghetti[1], A. Morselli[4], A.Perrino[4], P. Picozza[4], P. Schiavon[3], R. Sparvoli[4], A. Vacchi[3]

1. Istituto di Fisica Cosmica e Tecnologie Relative, CNR, Milano
2. Columbia Astrophysics Laboratory, Columbia University, New York, USA
3. Dipartimento di Fisica, Universitá di Trieste e INFN
4. Dipartimento di Fisica, Universitá di Roma II, "Tor Vergata" e INFN

Introduzione

L'astrofisica gamma delle alte energie nella banda 30 MeV–10 GeV beneficierebbe enormemente durante i primi anni del 2000 dall'esistenza di un rivelatore al silicio a largo campo e con sensibilita' e accuratezza confrontabili o migliore di EGRET. Presentiamo qui il concetto di tale missione leggera, AGILE (*Astro-rivelatore Gamma a Immagini LEggero*) dalle dimensioni e peso (inferiore ai 50 kg) ridotte ma dall'elevata e unica capacita' di rivelare sorgenti gamma galattiche e extragalattiche. La tecnologia al silicio permette di rivelare radiazione gamma con enormi vantaggi rispetto a EGRET. AGILE non presenterá problemi di rifornimento di gas, non necessita di alti valori di tensione, e' caratterizzata da un tempo morto breve (1μs) e da un trigger fornito esclusivamente dai piani di silicio. L'assenza di un calorimetro non consente di avere informazione spettrale dettagliata. Tuttavia, l'enorme vantaggio di realizzare uno strumento molto leggero e dalle elevate prestazioni di rivelazione (sia di risoluzione angolare che di flusso) rende AGILE altamente competitivo rispetto a future missioni astrofisiche di alta energia. AGILE sfrutta l'esperienza del gruppo proponente nella realizzazione di satelliti astrofisici con tecnologia al silicio. L'intero rivelatore e' da realizzarsi in Italia con un costo dello strumento inferiore ai 10 miliardi e costo complessivo della missione inferiore ai 25 miliardi di lire.

Proposta per la *Call for Ideas* ASI per Piccole Missioni (Scienze dell'Universo)
26 giugno 1997

GILDA40: rivelatore di raggi gamma al Silicio

A. Morselli[1], G. Barbiellini[2], M. Boezio[2], P. Caraveo[3], M. Casolino[1], M. P. De Pascale[1], S. Mereghetti[3], A.Perrino[2], P. Picozza[1], P. Schiavon[2], R. Sparvoli[1], M. Tavani[3,4], A. Vacchi[2]

1. Dipartimento di Fisica, Universitá "Tor Vergata" e INFN.
2. Dipartimento di Fisica, Universitá di Trieste e INFN.
3. Istituto di Fisica Cosmica e Tecnologie Relative, CNR, Milano.
4. Columbia Astrophysics Laboratory, Columbia University, New York, USA.

Introduzione

La proposta del telescopio gamma GILDA40 nasce dall'attivita' consolidata della collaborazione internazionale denominata WiZard che prevede le missioni *Nina* (prevista volare per l'autunno 1997) e *Pamela* (programmata per la seconda meta' del 2000). Cio' significa che esiste un contesto scientifico in cui GILDA40 si inserisce naturalmente. Costi e tempi di sviluppo possono essere realisticamente e sensibilmente bassi visto che e' possibile attingere a tutto il lavoro di progettazione, realizzazione e test gia' esistente (vedi descrizione tecnica). Il telescopio GILDA40 fa infatti uso di rivelatori al silicio ad alta risoluzione spaziale. Questi offrono grandi vantaggi per la rivelazione astrofisica di radiazione gamma: non presentano problemi di rifornimento di gas, non necessitano di alti valori di tensione nè di fotomoltiplicatori per l'analisi del segnale, presentano un tempo morto breve ($1\mu s$) e un trigger dato esclusivamente dai piani di silicio. Lo strumento consiste in un tracciatore al silicio e di un calorimetro di dimensioni e peso opportunamente configurati in base all'orbita scelta. GILDA40 puo' volare sia su un satellite a puntamento con orbita equatoriale, che in *scanning mode* su un satellite elio-sincrono. GILDA40 puo' essere realizzata interamente in Italia entro tre anni con un costo dello strumento inferiore ai 10 miliardi di lire.

AGILE

Phase A Report
Italian Space Agency Program for Small Scientific Missions
October 1998

AGILE

Astrorivelatore Gamma a Immagini LEggero

Principal Investigator:

M. Tavani	IFC - CNR, Milano Columbia University, New York

Co-Investigators:

G. Barbiellini	University of Trieste and INFN, Trieste
P. Caraveo	IFC - CNR, Milano
S. Di Pippo	ASI
F. Longo	University of Trieste and INFN, Trieste
S. Mereghetti	IFC - CNR, Milano
A. Morselli	University "Tor Vergata" and INFN, Roma
A. Pellizzoni	IFC - CNR, Milano
P. Picozza	University "Tor Vergata" and INFN, Roma
S. Severoni	University "Tor Vergata" and INFN, Roma
F. Tavecchio	IFC - CNR, Milano
A. Vacchi	University of Trieste and INFN, Trieste
S. Vercellone	IFC - CNR, Milano

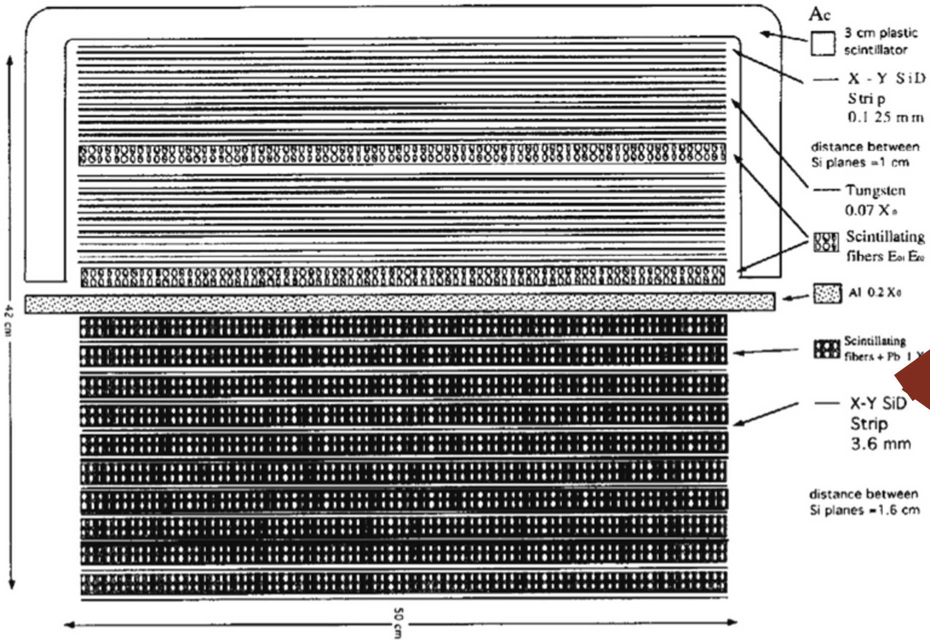
Scientific Editors:

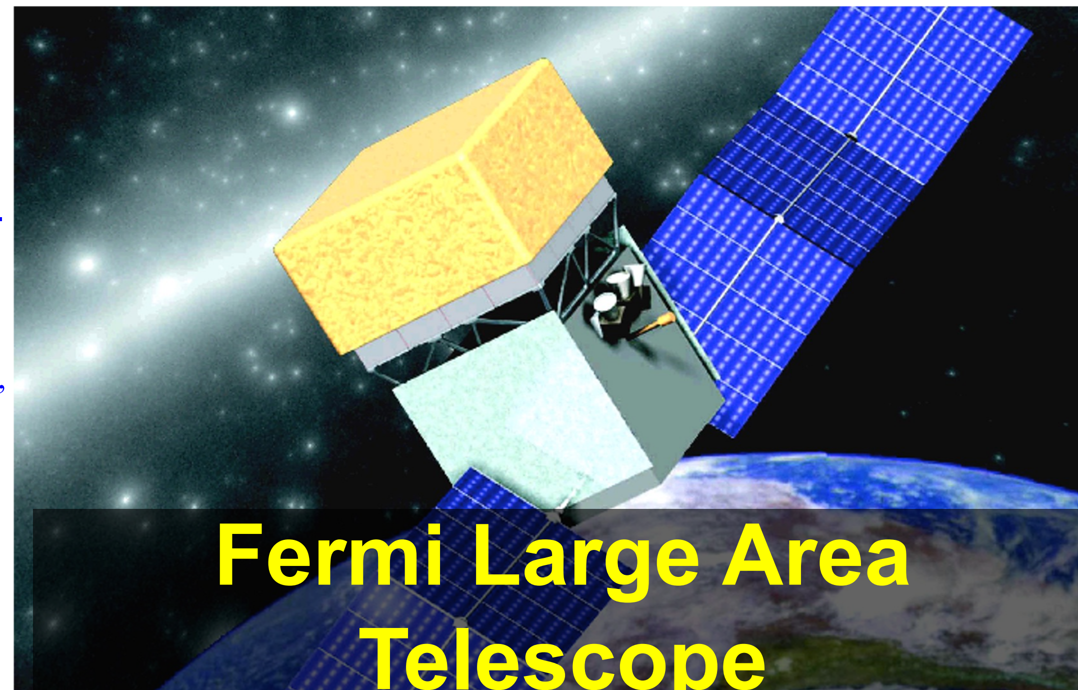
Sandro Mereghetti

Aldo Morselli

Marco Tavani

GILDA





Development of GLAST, a broadband High-Energy Gamma-Ray Telescope using Silicon Strip Detectors

P.Michelson, W.Atwood, E.Bloom, G.Godfrey, Y.Lin, P.Nolan, D.Bertsch, N.Gehrels, R.Hartman, S.Hunter, J.Norris, J.Ormes, R.Streitmatter, D.Thompson, E.Grove, P.Hertz, W.N.Johnson, M.Lovellette, G.H.Share, M.Wolff, K.S.Wood, R.Johnson, C.Couvault, R.Ong, M.Oreglia, J.Mattox, T.Burnett, C.Chenette, G.Nakano, L.Cominsky, H.A.Mayer-Hasselwander, G.Barbiellini, A.Colavita, A.Morselli, T.Kamae, K.Kasahara

Proposal presented to NASA, Space Physics Division in response to "Proposal for High Energy Astrophysics Supporting Research and Technology Program", NRA 95-OSS-17


agile
Astro-rivelatore Gamma
a Immagini Leggero
INAF
INFN
Alenia
telespazio

THE AGILE MISSION

asi agenzia spaziale italiana

INAF

INFN

CARLO GAVAZZI

Carlo Gavazzi Space SpA

ALCATEL ALENIA SPACE
An Alcatel/Finmeccanica company

OERLIKON CONTRAVES

telespazio
A Finmeccanica/Alcatel company

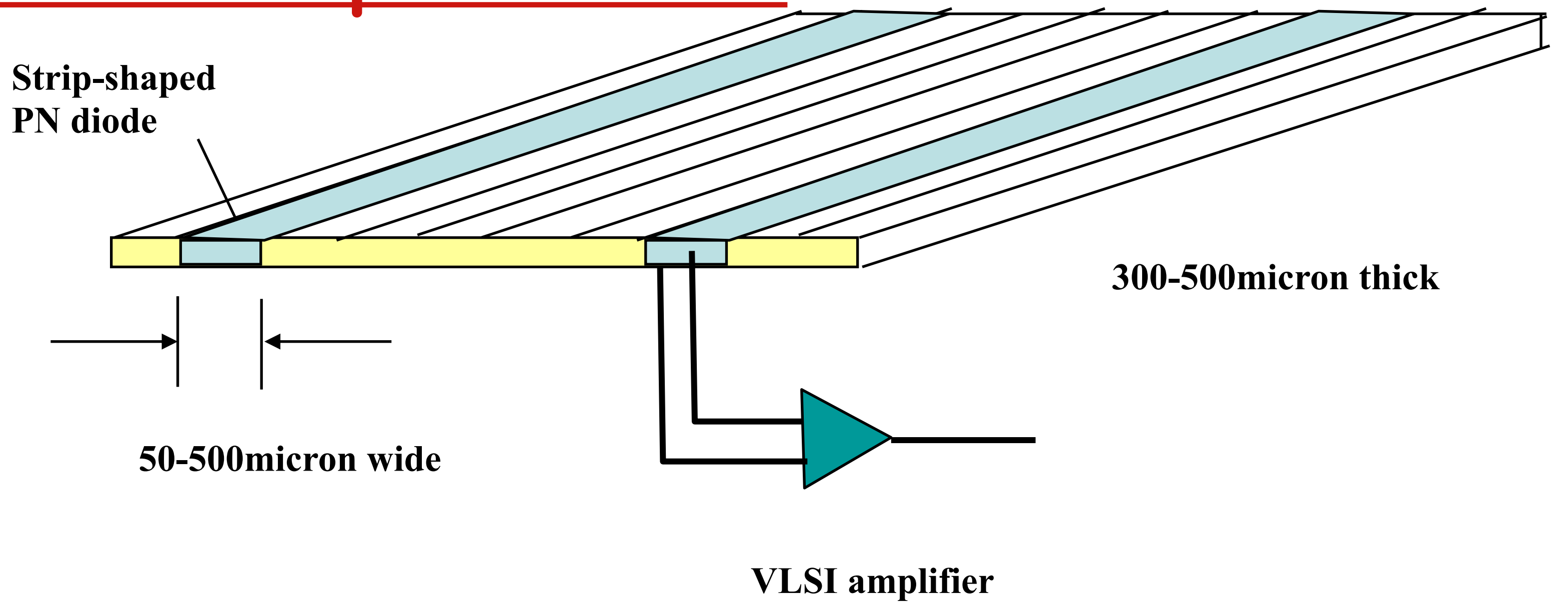
Galileo Avionica

MIPOT

ENEA

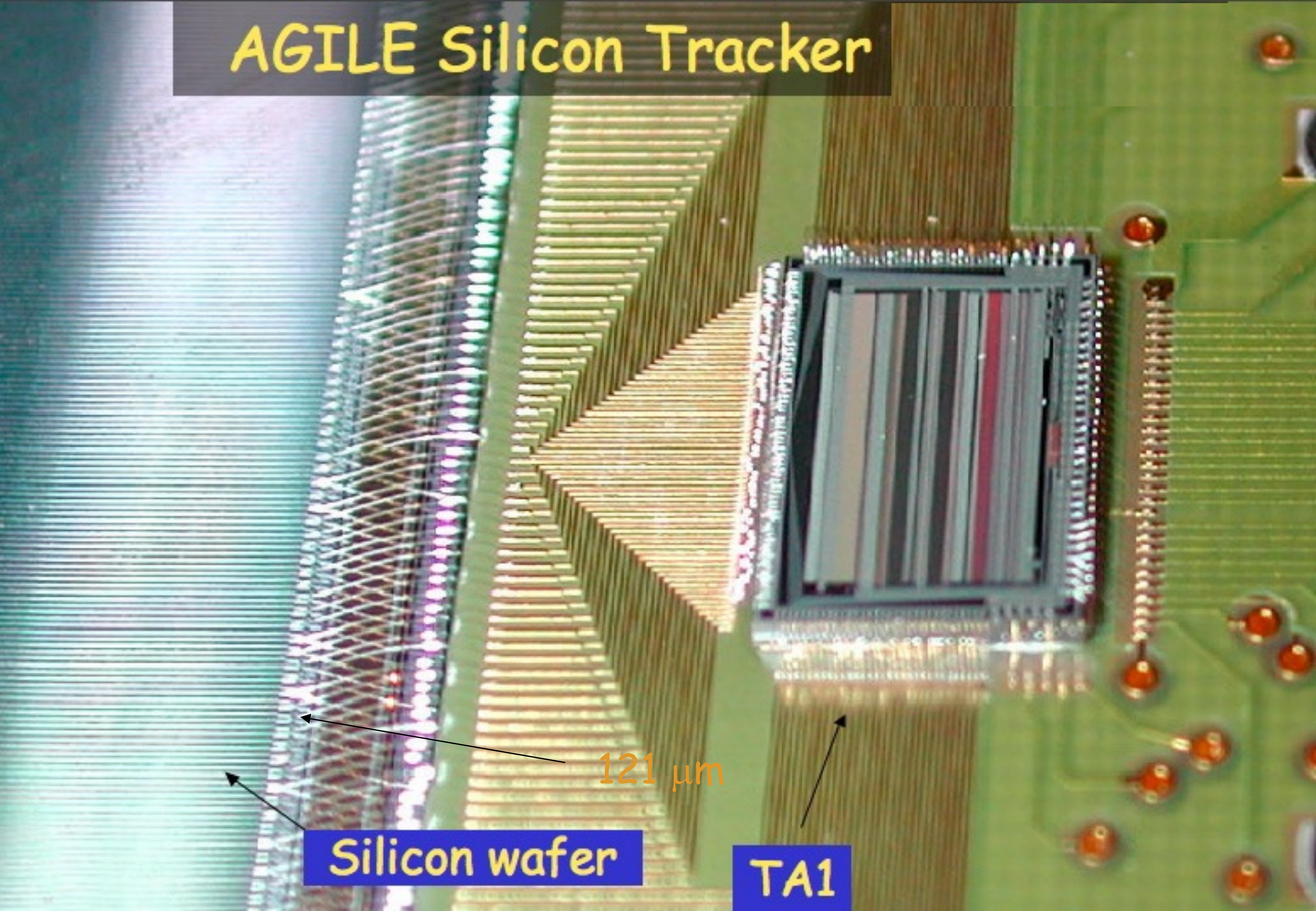
New Detector Technology

- **Silicon strip detector**

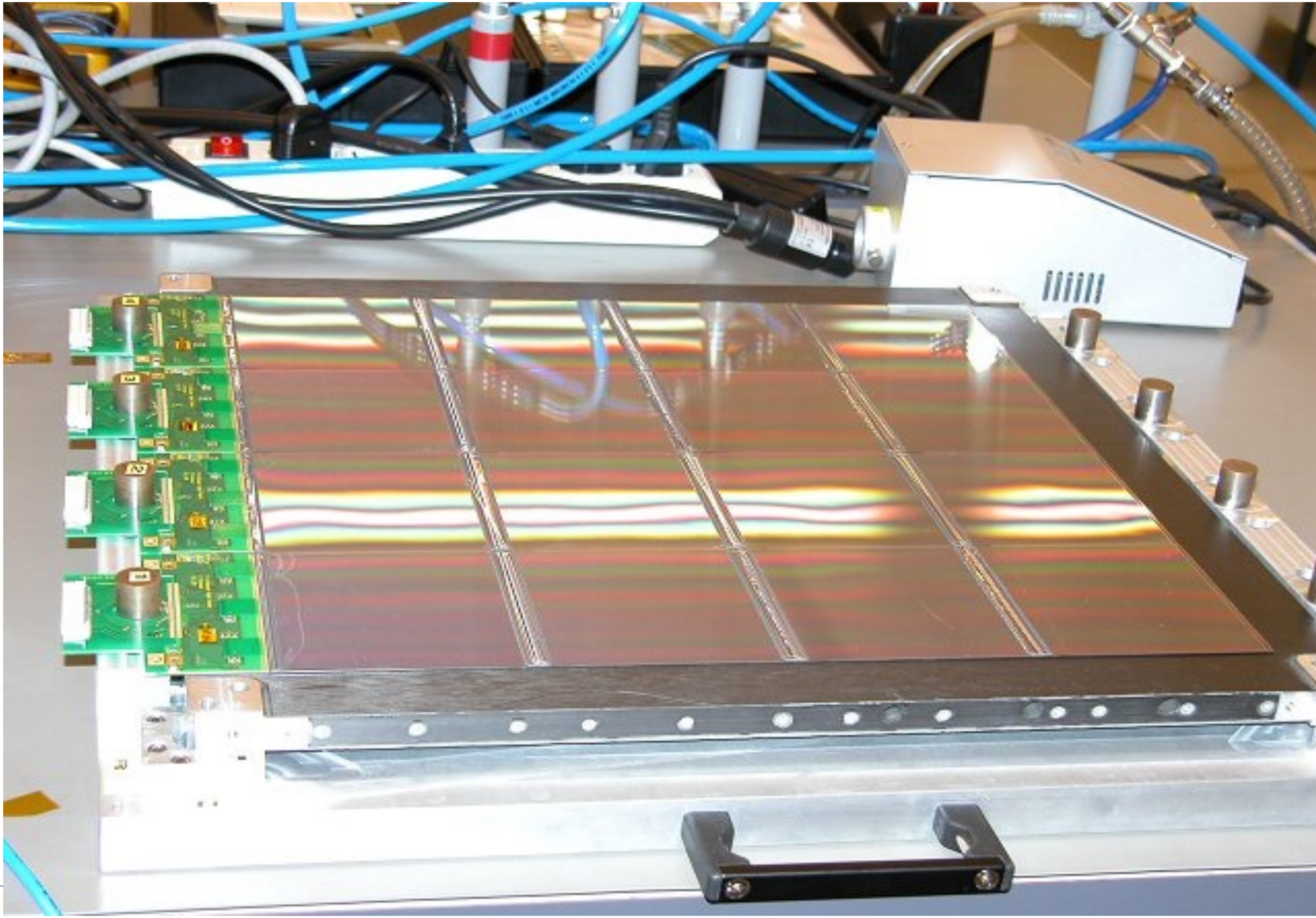


Stable particle tracker that allows micron-level tracking of gamma-rays

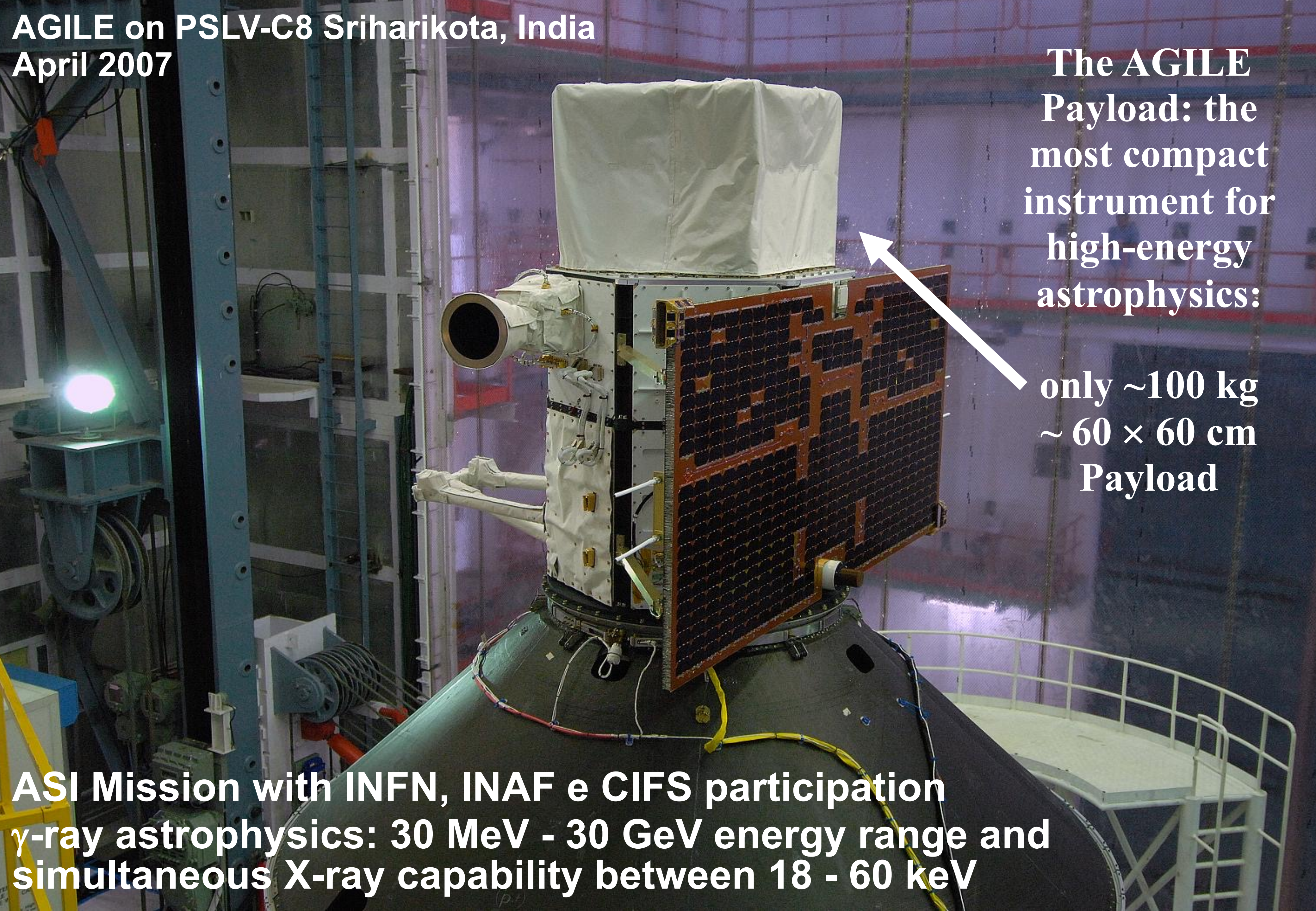
Well known technology in Particle Physics experiments.
Used by our collaboration in balloon experiments (MASS, TS93, CAPRICE), on MIR Space Station (SilEye) and on satellite (NINA)


AGILE Silicon Tracker
121 μm
Silicon wafer
TA1

The Silicon Tracker



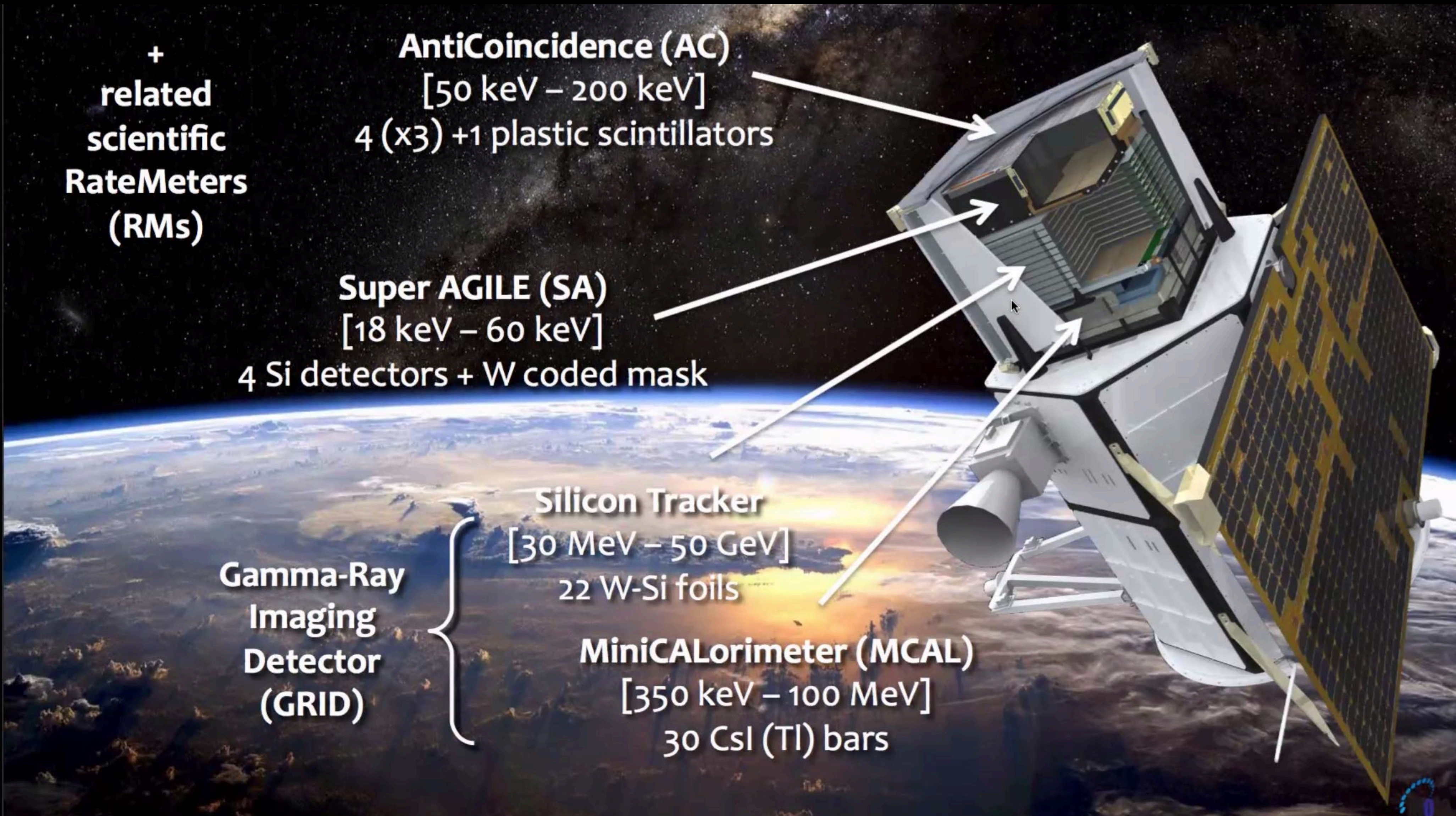
The Silicon Tracker


AGILE on PSLV-C8 Sriharikota, India
April 2007
The AGILE Payload: the most compact instrument for high-energy astrophysics:
only ~100 kg
~ 60 × 60 cm
Payload
ASI Mission with INFN, INAF e CIFS participation
γ-ray astrophysics: 30 MeV - 30 GeV energy range and
simultaneous X-ray capability between 18 - 60 keV

April 23, 2007: Launch!

SHAR base (Chennai), India

Equatorial orbit: 550 Km, < 3° inclination angle



+ related scientific RateMeters (RMs)
AntiCoincidence (AC)
[50 keV – 200 keV]
4 (x3) +1 plastic scintillators
Super AGILE (SA)
[18 keV – 60 keV]
4 Si detectors + W coded mask
Gamma-Ray Imaging Detector (GRID)
Silicon Tracker
[30 MeV – 50 GeV]
22 W-Si foils
MiniCALorimeter (MCAL)
[350 keV – 100 MeV]
30 CsI (Tl) bars

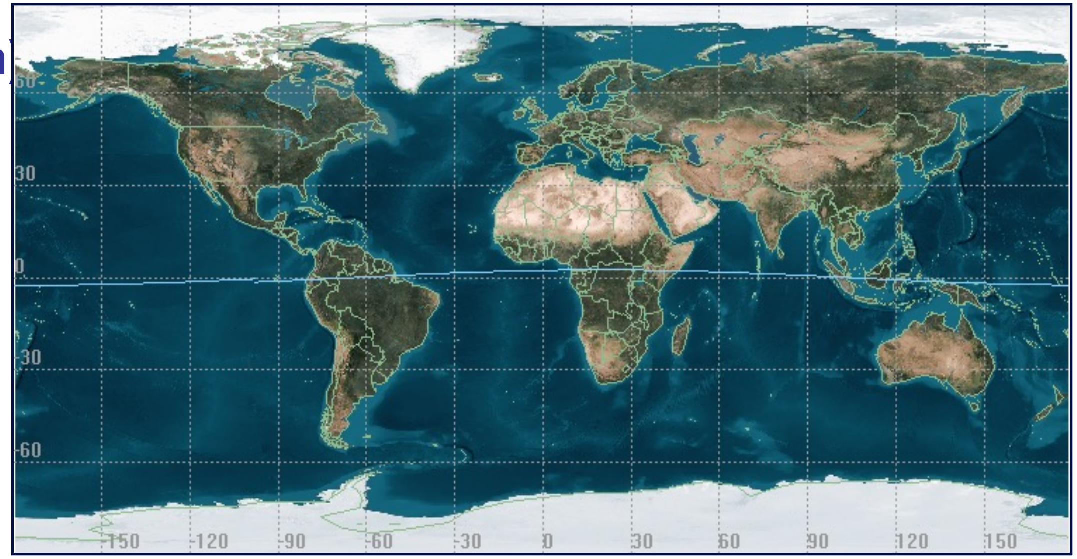
AGILE orbital parameters

Baseline equatorial orbit: 550 Km, 3° inclination

Semi-major axis: 6922.5 km (± 0.1 km)
Requirement: 6928.0 ± 10 km

Inclination angle: 2.48° (±0.04°)
Requirement: < 3°

Eccentricity: 0.002 (±0.0015)
Requirement: < 0.1°

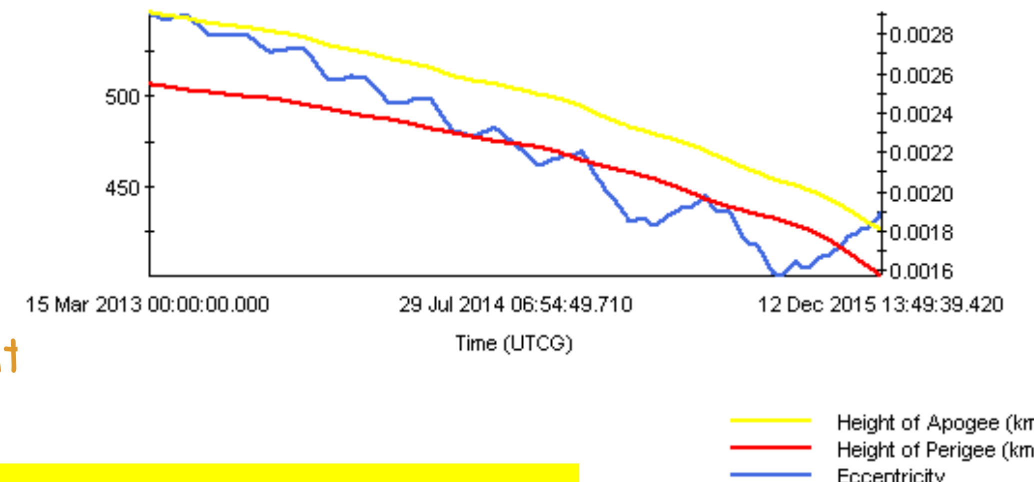


Satellite-AGILE - 28 Mar 2013 10:08:13

TPZ orbital decay estimate:
Height < 400Km on **20/04/2017**
(A/M=0.009 sqm/Kg)
Worst case (A/M=0.012 sqm/Kg):
02/11/2015
Best case (A/M=0.006 sqm/Kg):
29/04/2023

(March 2013 updated estimate, using recent solar flux “Schatten” forecasts + 2σ)

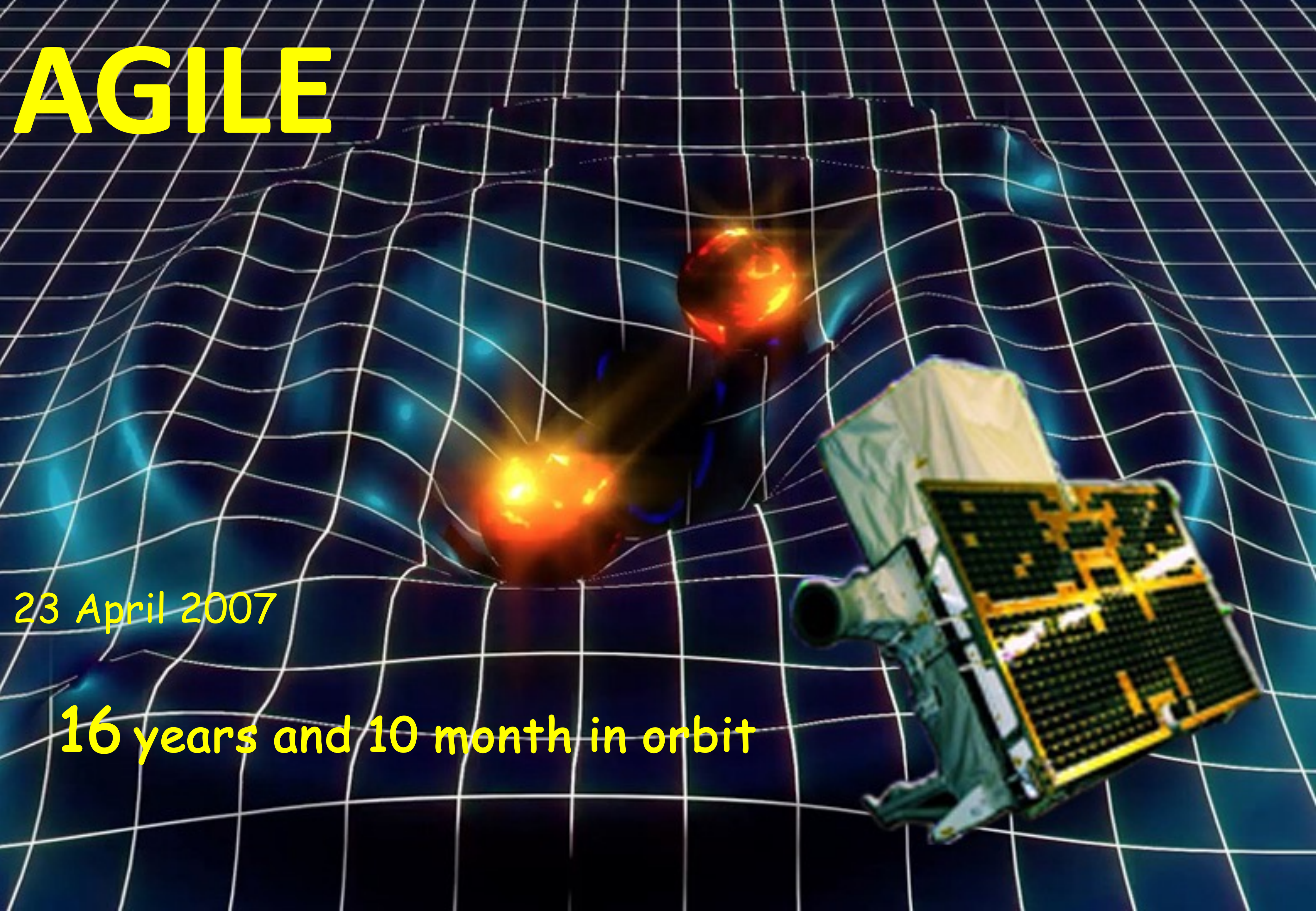
→

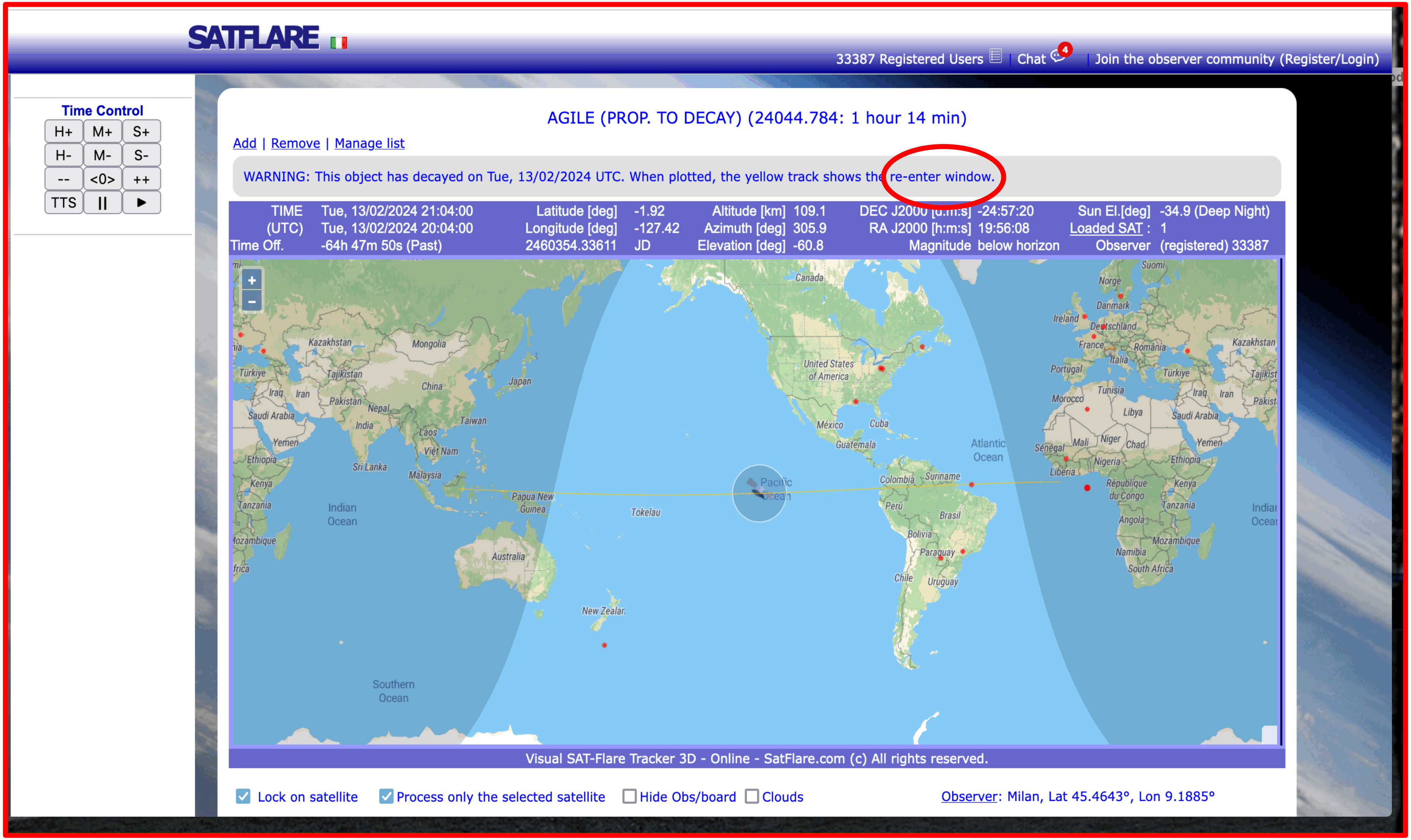


You can follow AGILE with AGILE Science App. !!

AGILE Science App. to follow AGILE (when it was in operation)


AGILE
23 April 2007- 23 April 2022
Happy 15th Birthday Agile !!
ASI
Agenzia Spaziale Italiana


AGILE
23 April 2007
16 years and 10 month in orbit


SATFLARE
33387 Registered Users | Chat | Join the observer community (Register/Login)
Time Control
H+ M+ S+
H- M- S-
-- <0> ++
TTS || ▶
AGILE (PROP. TO DECAY) (24044.784: 1 hour 14 min)
Add | Remove | Manage list
WARNING: This object has decayed on Tue, 13/02/2024 UTC. When plotted, the yellow track shows the re-enter window.
TIME Tue, 13/02/2024 21:04:00 Latitude [deg] -1.92 Altitude [km] 109.1 DEC J2000 [d:m:s] -24:57:20 Sun El.[deg] -34.9 (Deep Night)
(UTC) Tue, 13/02/2024 20:04:00 Longitude [deg] -127.42 Azimuth [deg] 305.9 RA J2000 [h:m:s] 19:56:08 Loaded SAT : 1
Time Off. -64h 47m 50s (Past) 2460354.33611 JD Elevation [deg] -60.8 Magnitude below horizon Observer (registered) 33387
Canada
United States of America
México
Cuba
Guatemala
Colombia
Suriname
Perú
Brasil
Bolivia
Paraguay
Chile
Uruguay
Atlantic Ocean
Pacific Ocean
Tokelau
Papua New Guinea
Australia
New Zealand
Indian Ocean
Southern Ocean
Kazakhstan
Mongolia
China
Japan
Taiwan
India
Nepal
Pakistan
Tajikistan
Türkiye
Iraq
Iran
Saudi Arabia
Yemen
Ethiopia
Kenya
Tanzania
Sri Lanka
Laos
Việt Nam
Malaysia
Norge
Suomi
Danmark
Ireland
Deutschland
France
România
Italia
Portugal
Tunisia
Morocco
Libya
Mali
Niger
Chad
Sénégal
Nigeria
Liberia
République du Congo
Angola
Mozambique
Namibia
South Africa
Visual SAT-Flare Tracker 3D - Online - SatFlare.com (c) All rights reserved.
Lock on satellite
Process only the selected satellite
Hide Obs/board
Clouds
Observer: Milan, Lat 45.4643°, Lon 9.1885°

Summary of AGILE results in >16 years of operations

- **Publications:** the scientific production of the AGILE Team consists of **> 800 bibliographic references in ADS, of which> 160 refereed articles.**
- The monitoring of the sky with a rapid and efficient alert system led to the publication of **>240 ATels** and **>300 GCNs**. From May 2019, **101 MCAL GCN automatic notices** have been published.

- The Quick Look system developed by INAF-OAS, distributed between the data center at SSDC and INAF-OAS in Bologna, produced **scientific results within ~ 25 min** from the data downlink to the ASI Malindi ground station: an absolute record for gamma astrophysics. The Team has also developed **AGILEScience - App on Google Play and App Store** to monitor and follow the observations of the AGILE satellite on mobile devices.

- **AGILE and the search for GW counterparts:** participation of Team members with shifts 24/7 during LIGO-VIRGO observational runs. AGILE follow-up of all **pre-O4 GW events**, with **96 GW-AGILE type GCNs published during O3** and collected in a dedicated web page in SSDC**:** *https://agile.ssdc.asi.it/news_gw.html* AGILE completed the follow-up of all GW events **up to the end of LVK O4a (first part) on Jan 16, 2024**.

- AGILE contribution to **Fast Radio Bursts** science: **very important discovery** on April 28, 2020 published in **Nature, Tavani et al. 2021** (2021NatAs...5..401T)

Three of the most important AGILE discoveries:

- **Discovery of a new acceleration mechanism inducing intense and rapid flux variations in the Crab Nebula in the energy band above 100 millions of elettronvolt!**

- **First direct evidence of cosmic ray acceleration in Supernovae remnants with the AGILE observations of the SNR W44**

- **Direct evidence that extreme particle acceleration and non-thermalized emission above 100 MeV can occur in microquasars (Cyg X-3 and Cyg X-1) with a repetitive pattern.**

THE AGILE LEGACY

AGILE archives and catalogs are available to the community through the ASI SSDC.

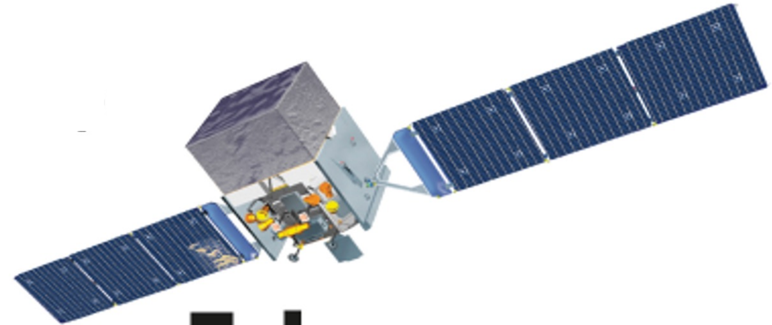
Science activities continue. We have just published on Feb. 29, 2024 all AGILE-GRID data **up to January 15, 2024. A data reprocessing is in progress.**

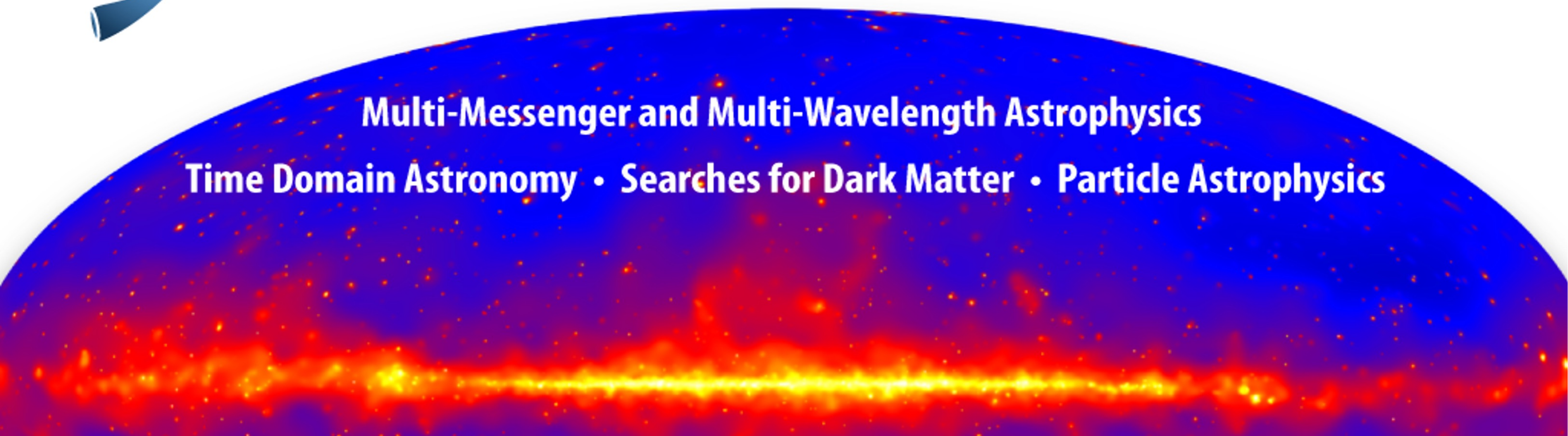
Open-source Python software package **Agilepy** (INAF-OAS) and/or **SSDC AGILE-LV3 online data analysis tool.**

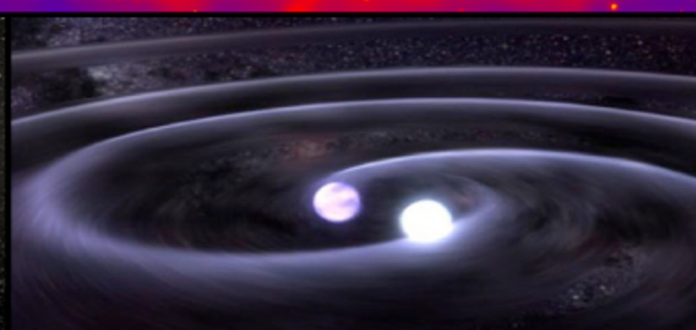
With AGILE's re-entry, the in-orbit operational phase ended, but a new phase of scientific work on the satellite legacy data archive opens.

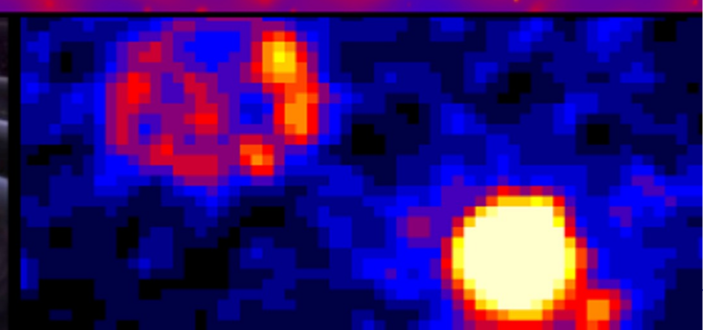
Work in progress on new catalogs with and without **Machine Learning** techniques. **Stay tuned for further results**.

Fermi Gamma-Ray Space Telescope





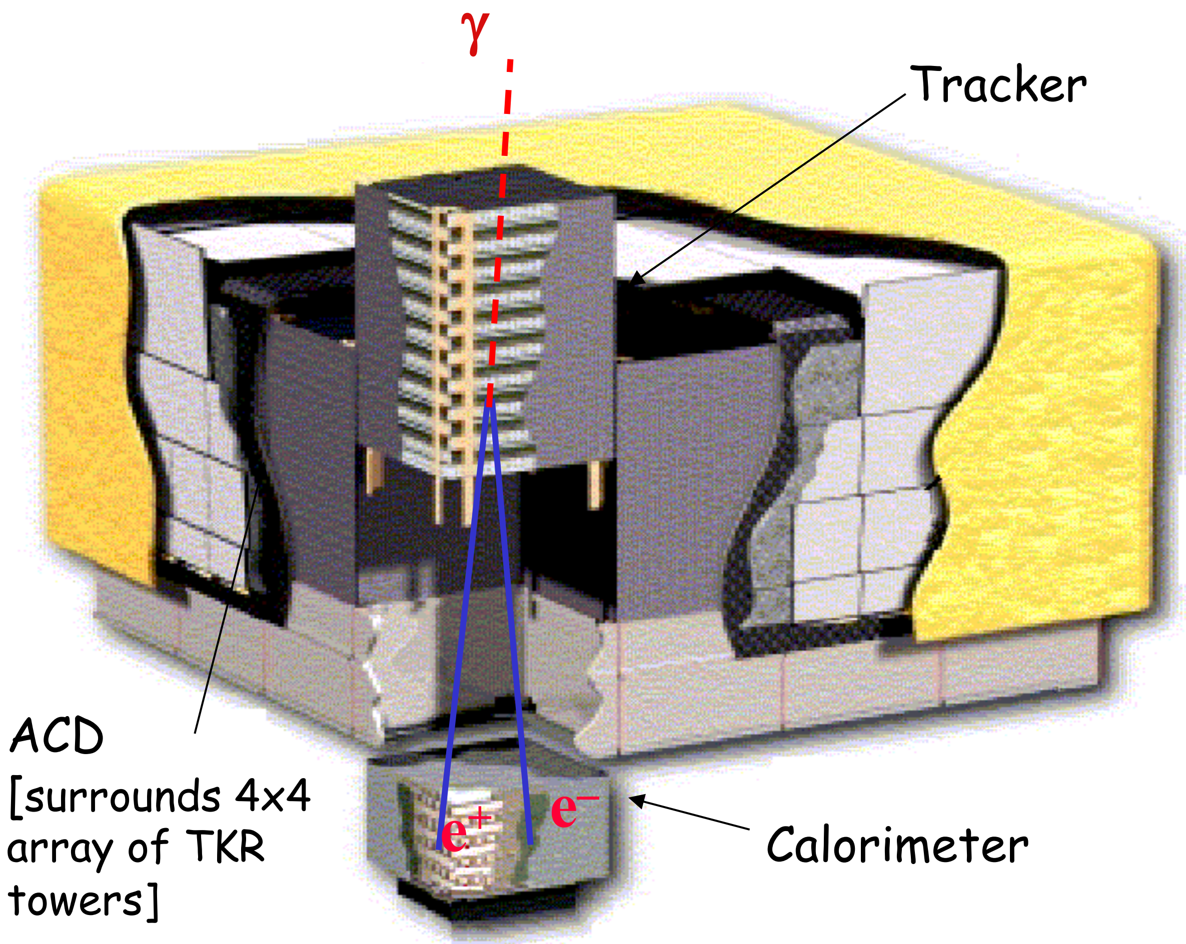




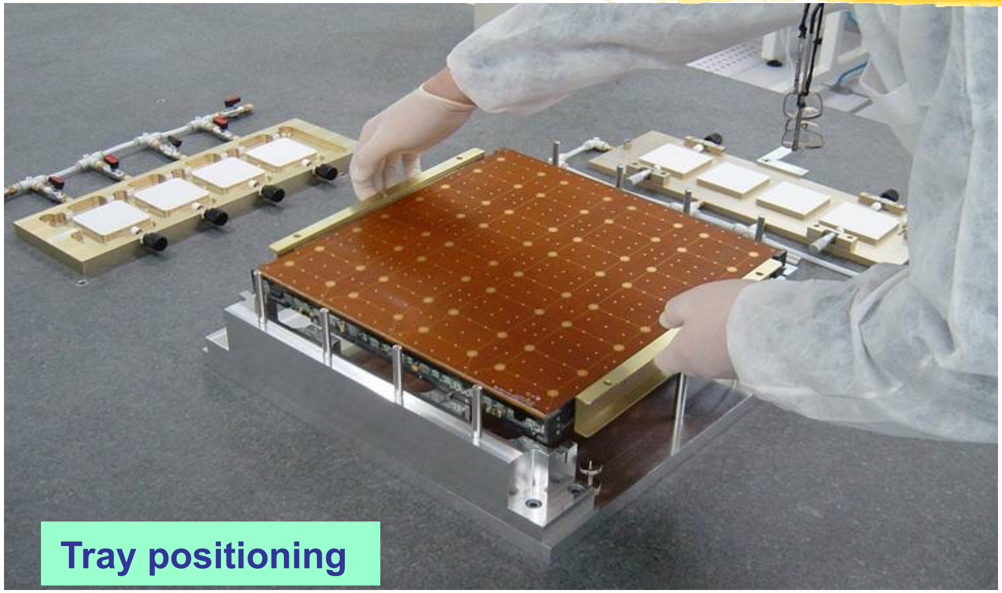

Fermi
Gamma-ray
Space Telescope
Happy 16th Birthday Fermi !!
11 June 2008
next talk by Elisabetta Bissaldi

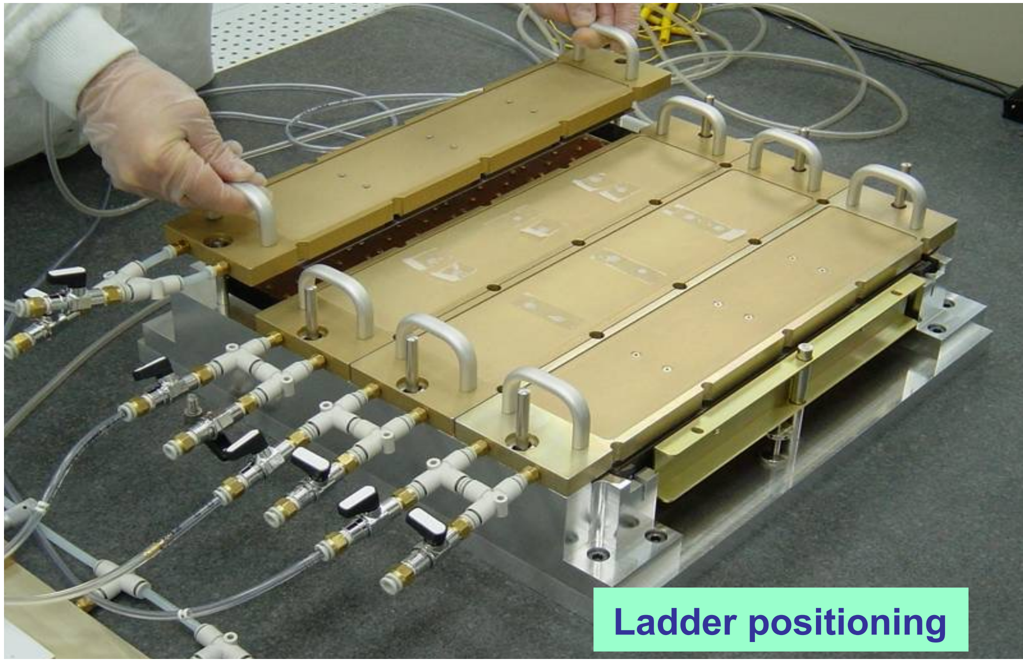
Fermi LAT: A Telescope Without Lenses

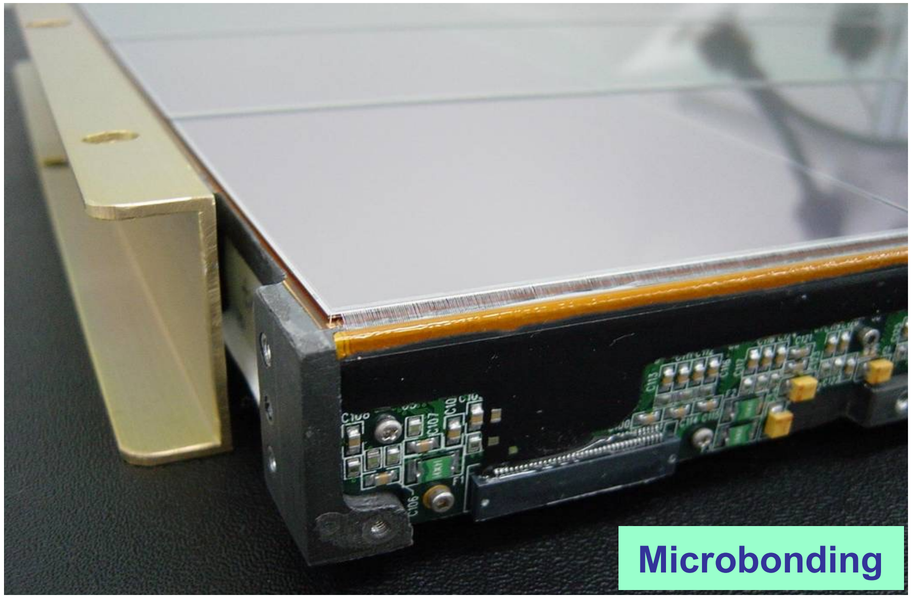
- Precision Si-strip Tracker (TKR) 70 m^2 of silicon detectors arranged in 36 planes. 880,000 channels.
- Hodoscopic CsI Calorimeter(CAL) 1536 CsI(Tl) crystals in 8 layers, total mass 1.5 tons.
- Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles.
- Electronics System Includes flexible hardware trigger and onboard computing.



Tray assembly in G&A

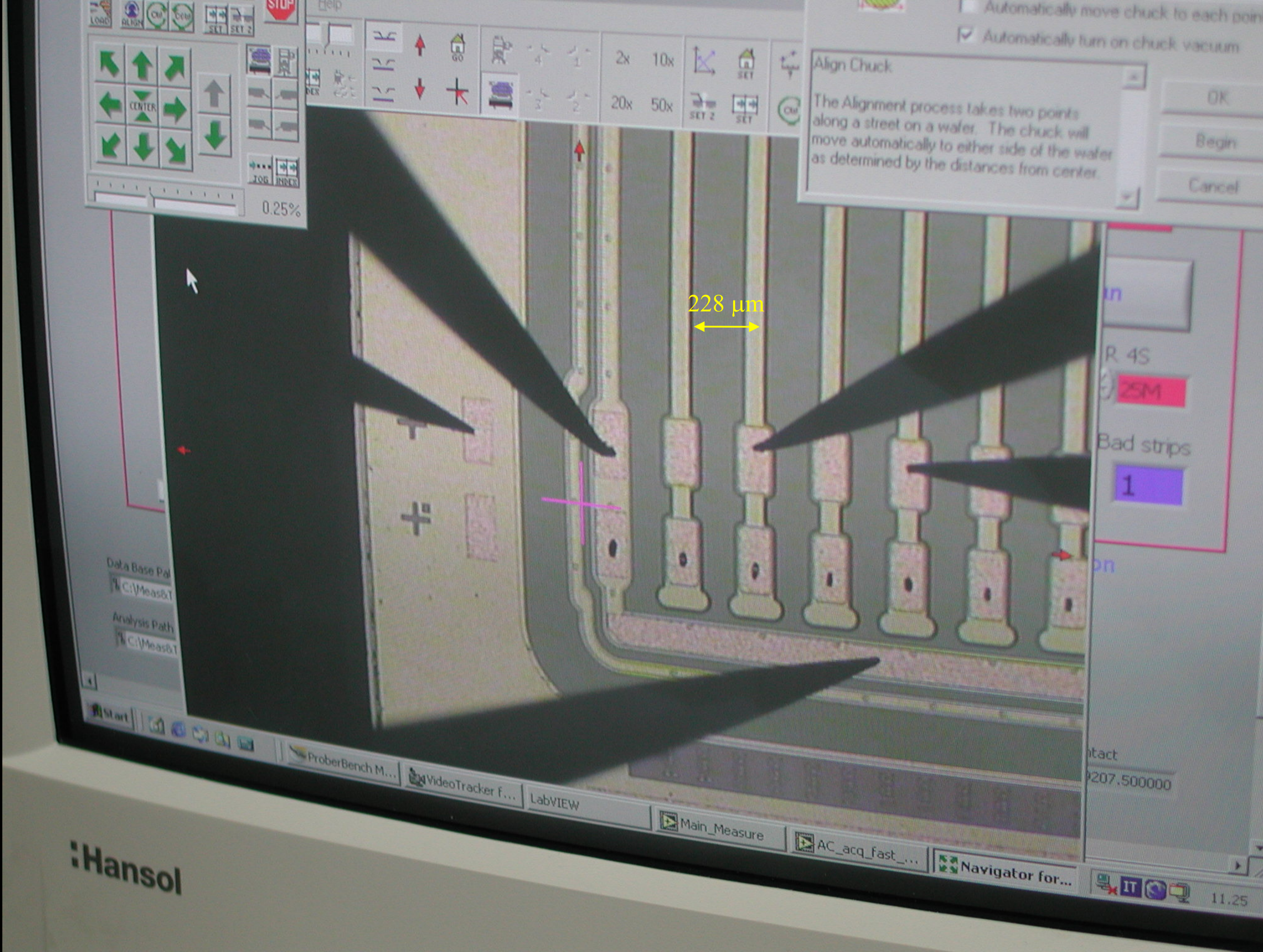




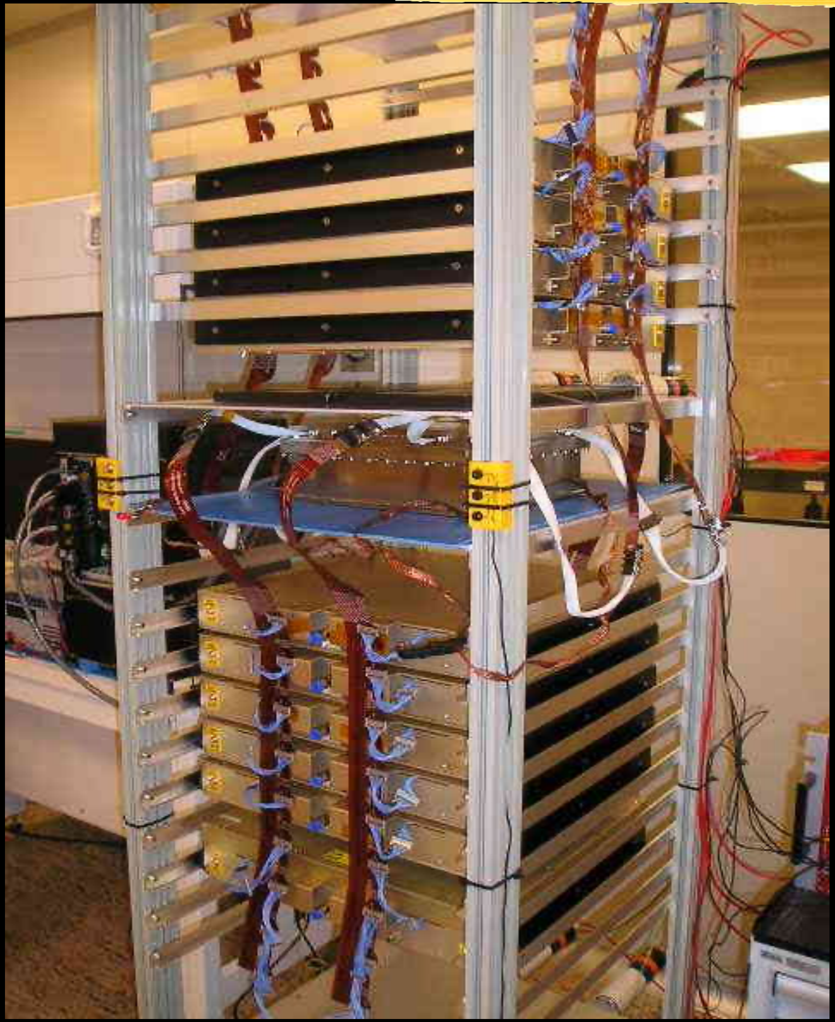


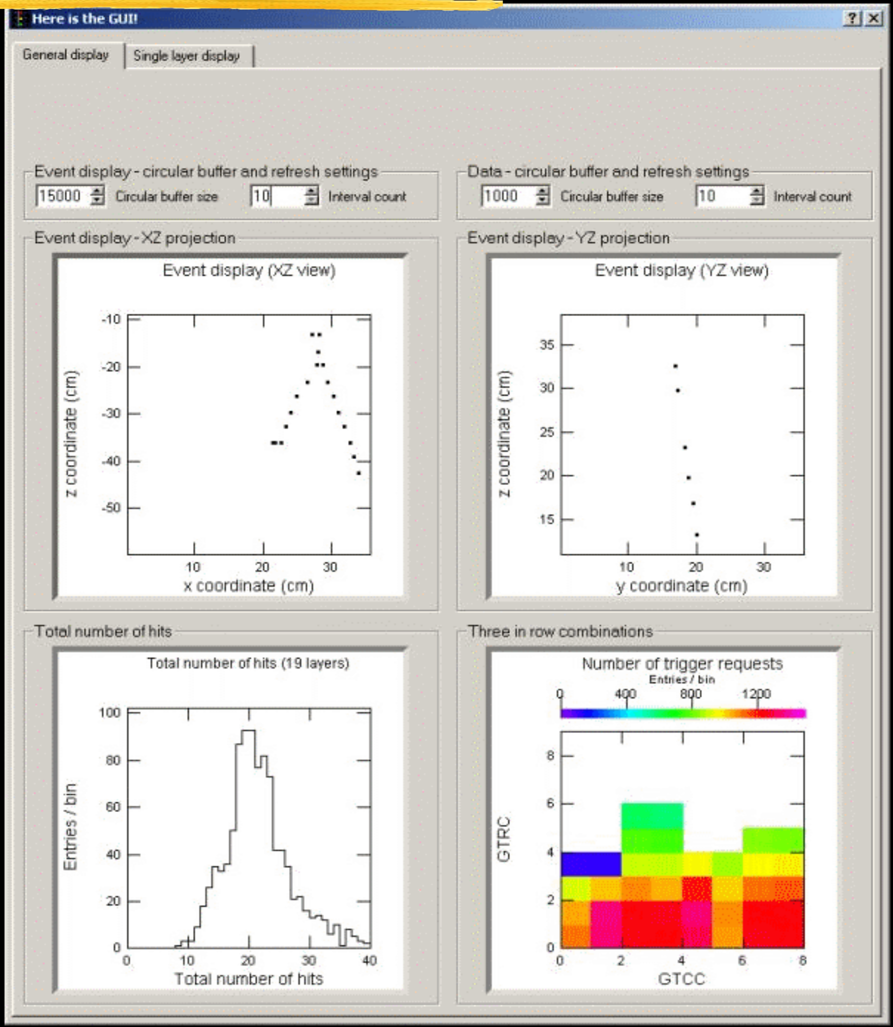
- 160 bare panels produced
- 100 tested and qualified for integration with ladders
- completed trays for 3.3 towers
- 6 assembly chain ready
- Max assembly rate : 3 trays/day/shift


EMERGENCY STOP


228 µm
Automatically move chuck to each point
Automatically turn on chuck vacuum
Align Chuck
The Alignment process takes two points along a street on a wafer. The chuck will move automatically to either side of the wafer as determined by the distances from center.
OK
Begin
Cancel
2x
10x
20x
50x
0.25%
Bad strips
1
Data Base Pa
Analysis Path
Start
ProberBench M...
VideoTracker f...
LabVIEW
Main_Measure
AC_acq_fast_...
Navigator for...
11.25
Hansol

Tray test at INFN



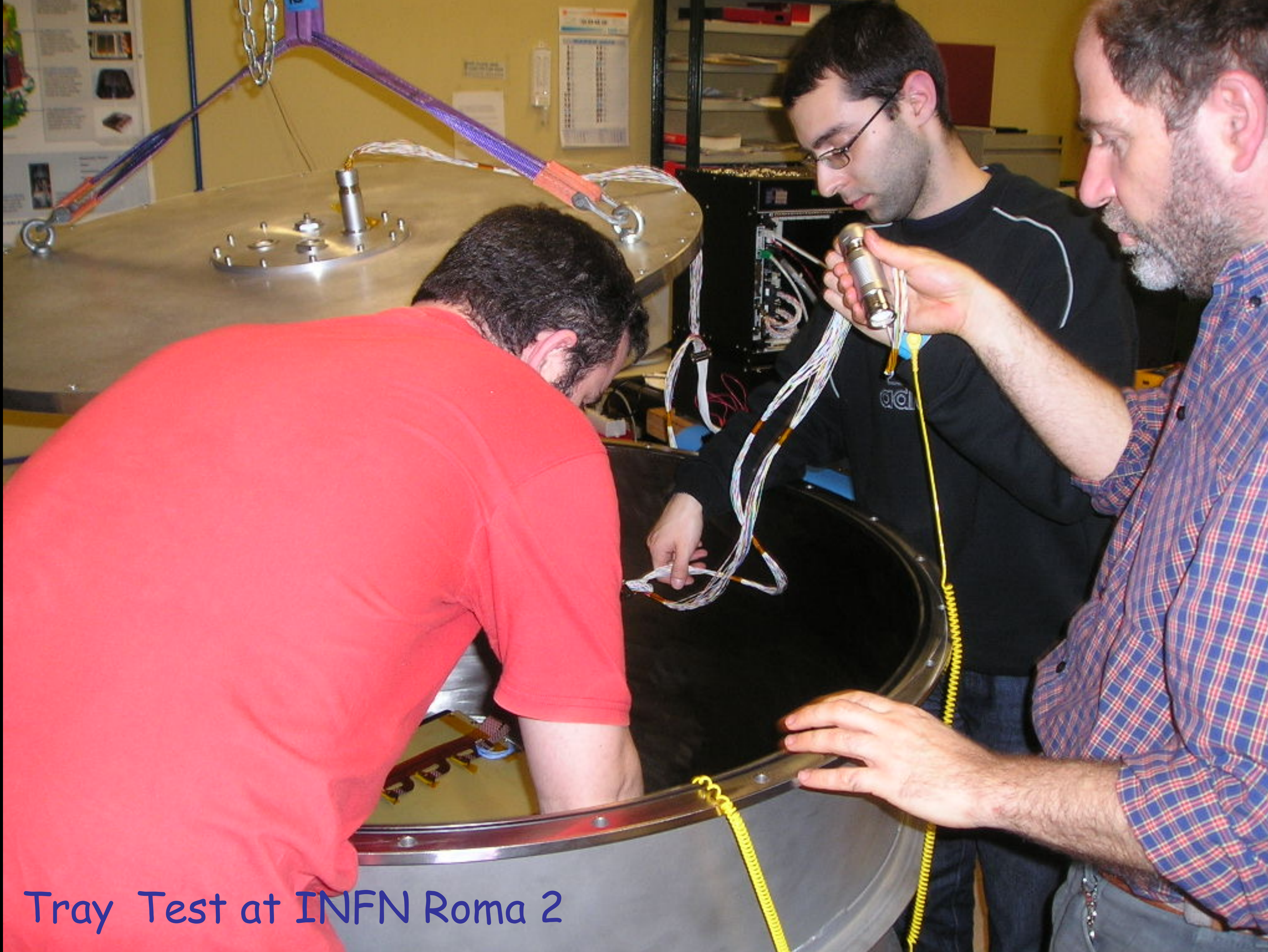


Stack of trays:

- functional tests/CR burn-in for a whole tower in parallel
- external trigger capability
- 4 stacks operating in parallel at INFN (Pi/Pg/Rm2/Ba)

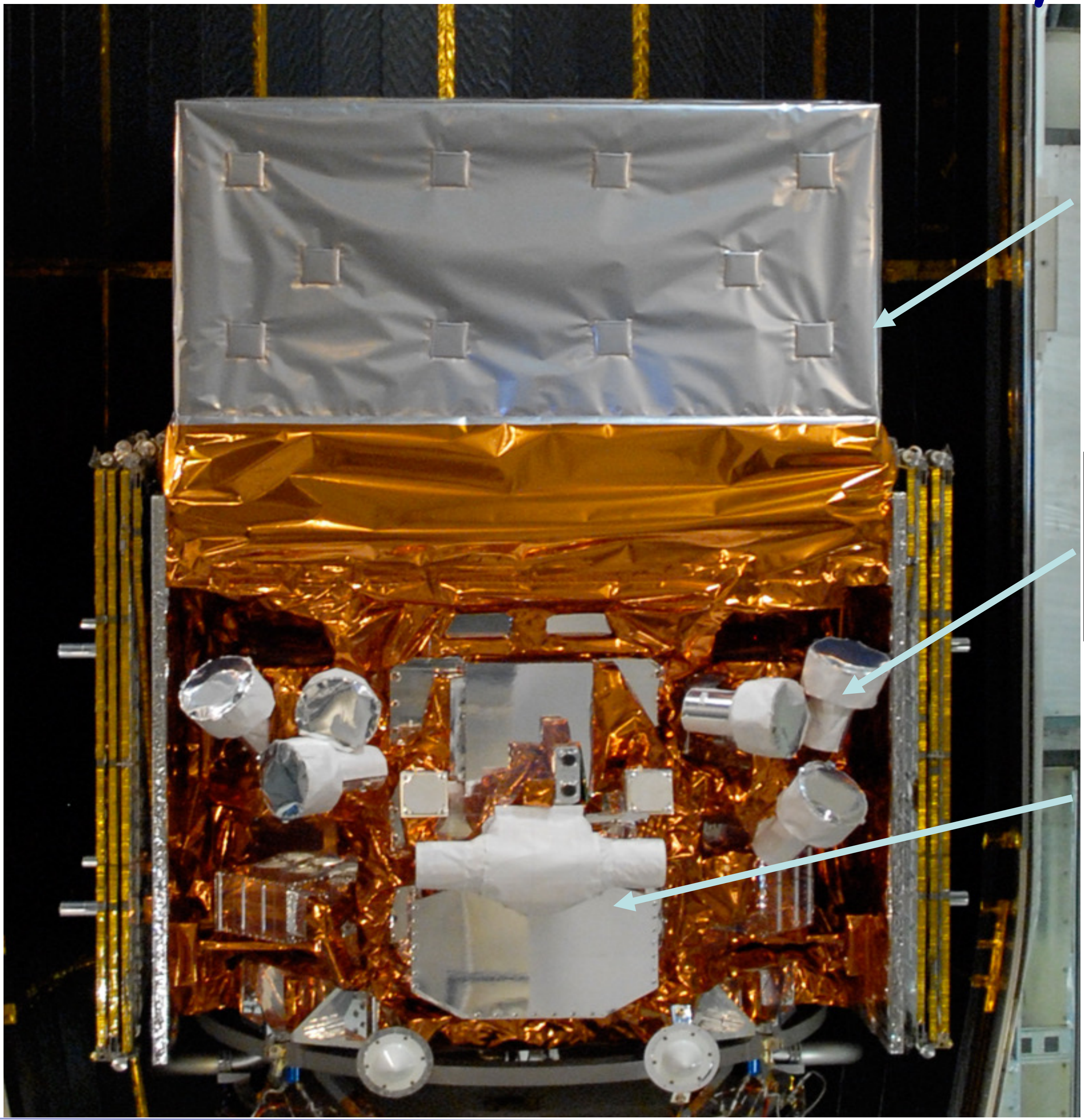
Tray Test at INFN Roma 2


LAMINAR FLOW
ASALAIR 1200
LAMINAR FLOW
1200 FLV
PROIBITO
FUMARE
VIETATO
L'ACCESSO
a chi non è
autorizzato



Tray Test at INFN Roma 2

The Fermi Observatory

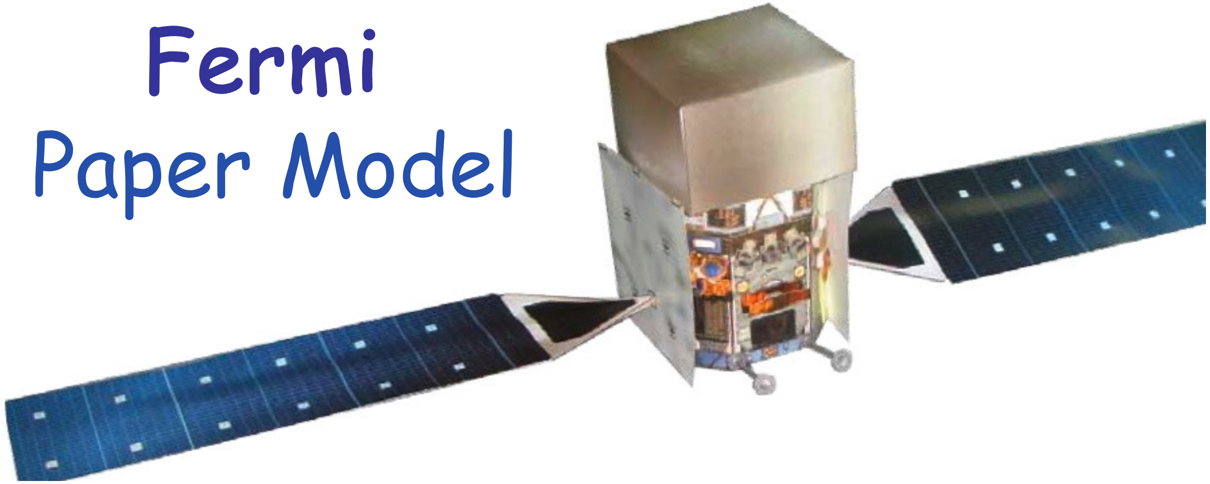


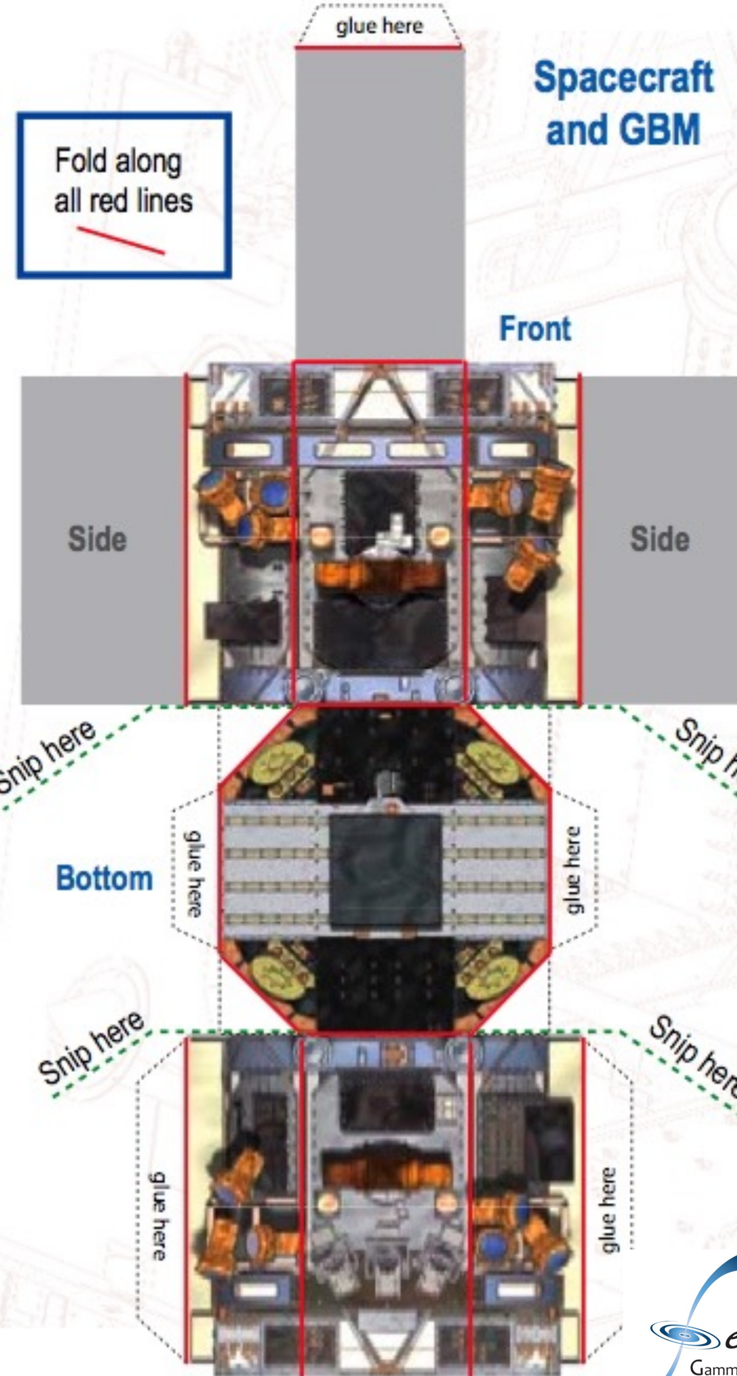
LAT
Large
Area
Telescope

GBM
Sodium Iodide
Detector

GBM
Bismuth
Germanate
Detector

Fermi Paper Model





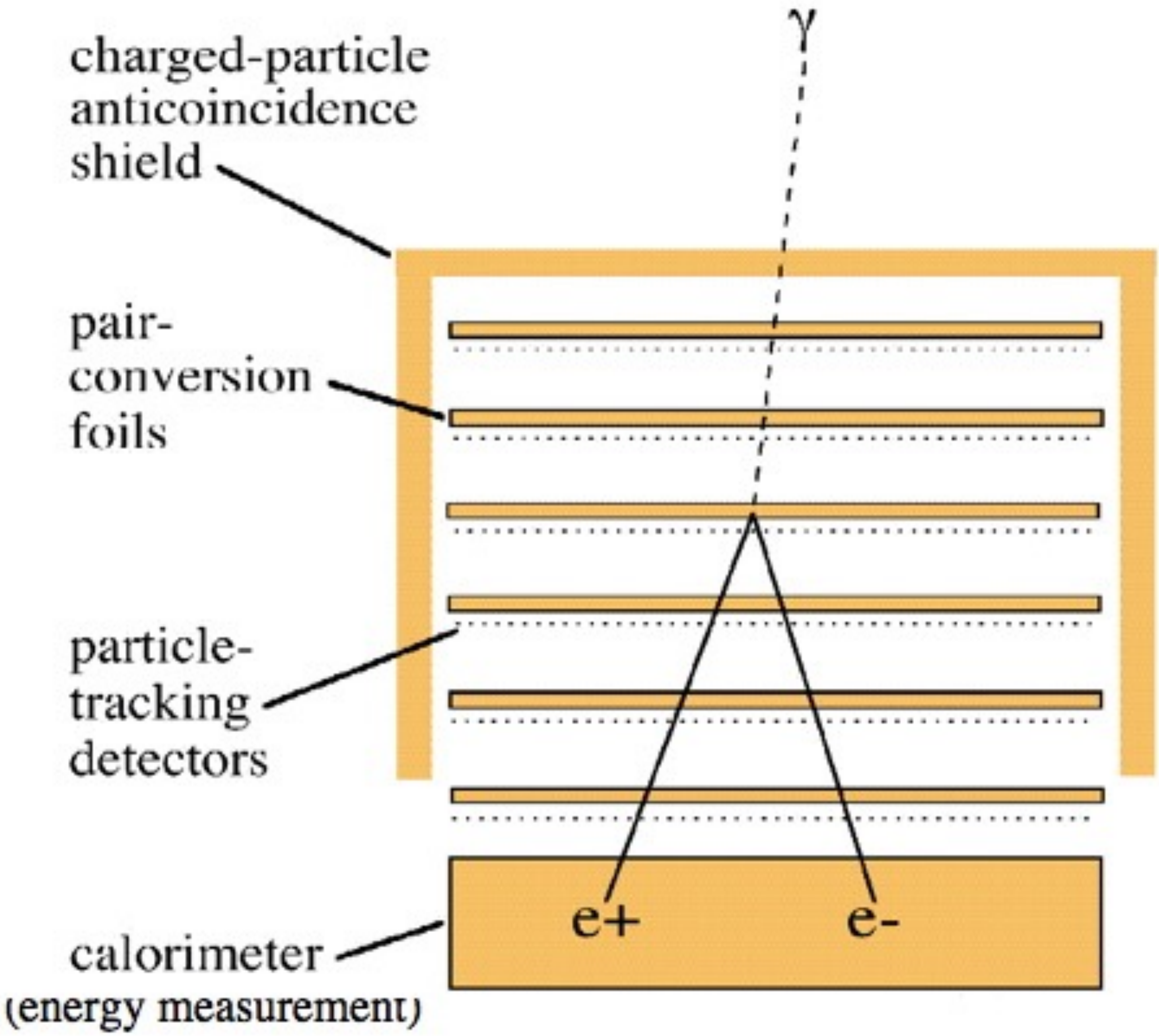
https://owncloud.roma2.infn.it/index.php/s/yvpYj8NMDV2Bip7

Fermi Gamma-ray Space Telescope


Fermi
Gamma-ray Space Telescope
Happy 16th Birthday Fermi !!
11 June 2008
next talk by Elisabetta Bissaldi

The Low Energy Frontier

Elements of a pair-conversion telescope



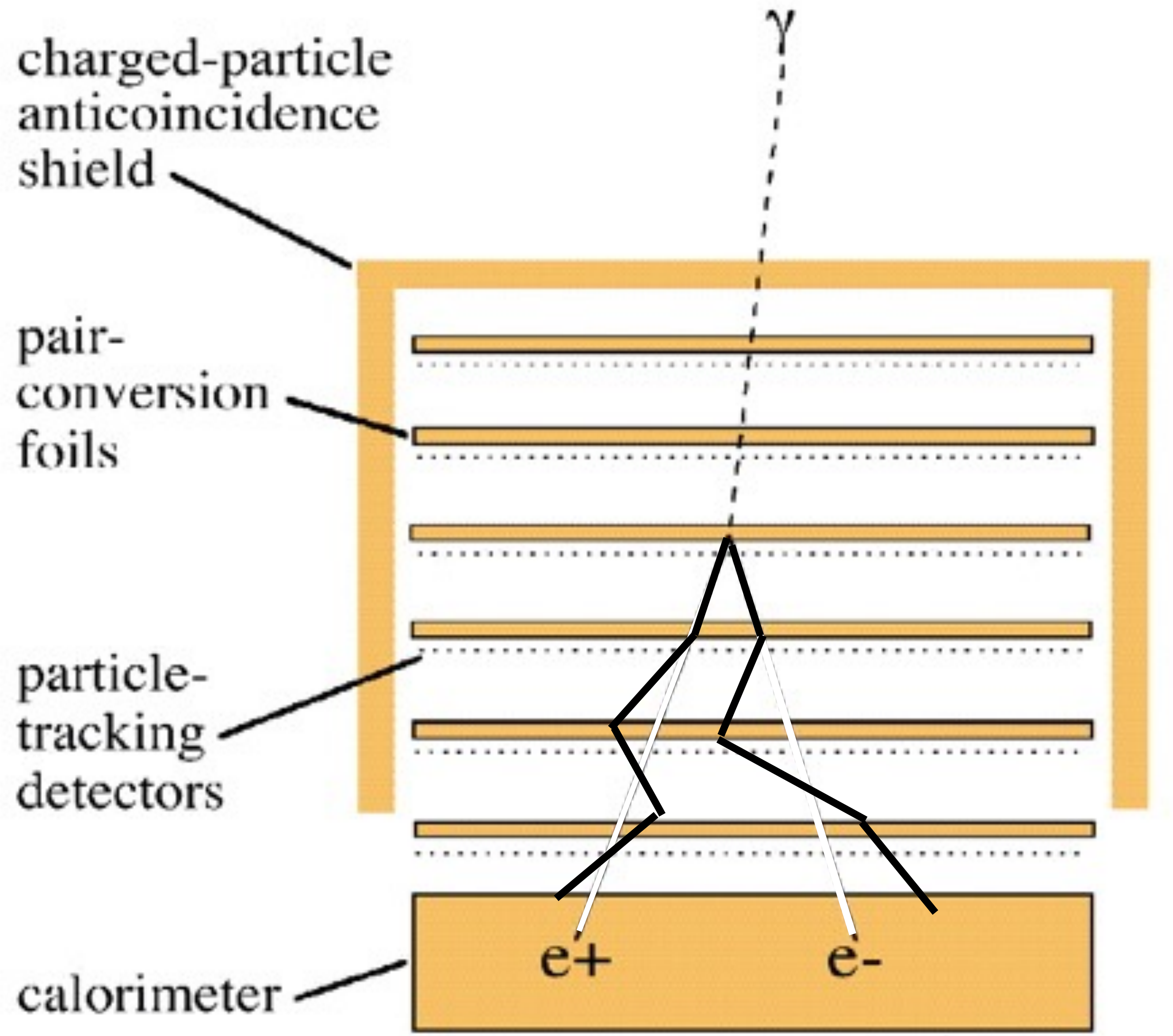
- photons materialize into matter-antimatter pairs:

  E_γ --> $m_{e+}c^2 + m_{e-}c^2$

- electron and positron carry information about the direction, energy and polarization of the γ-ray

Elements of a pair-conversion telescope

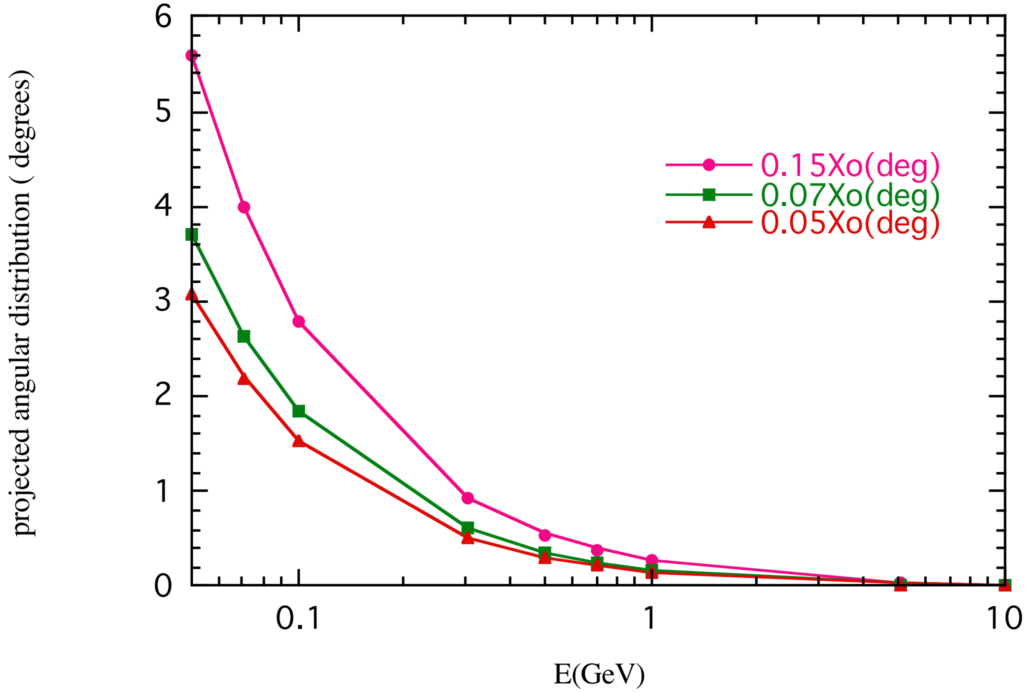
(more realistic scheme)

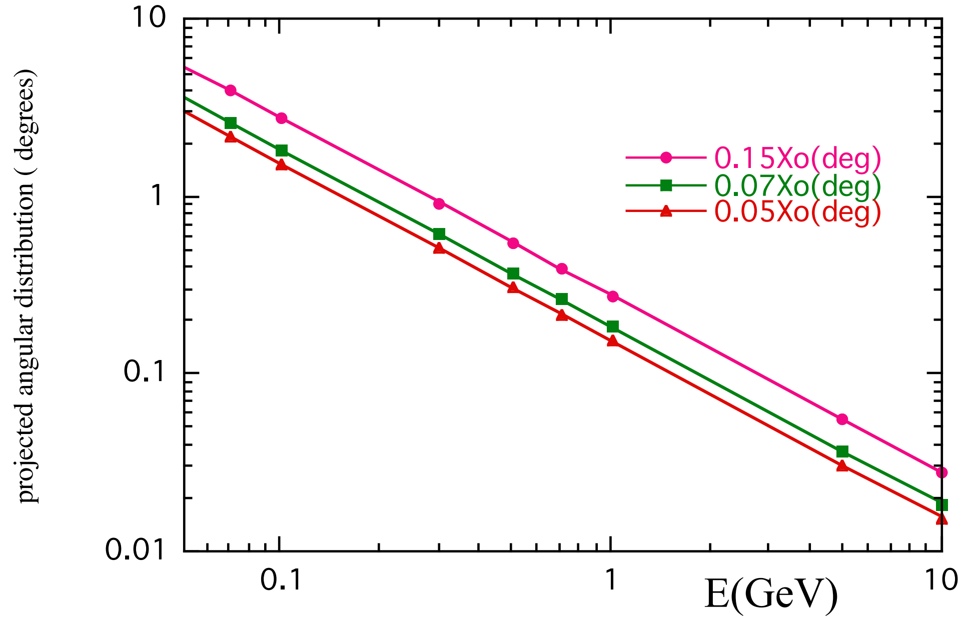


(energy measurement)

- 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

Multiple Scattering

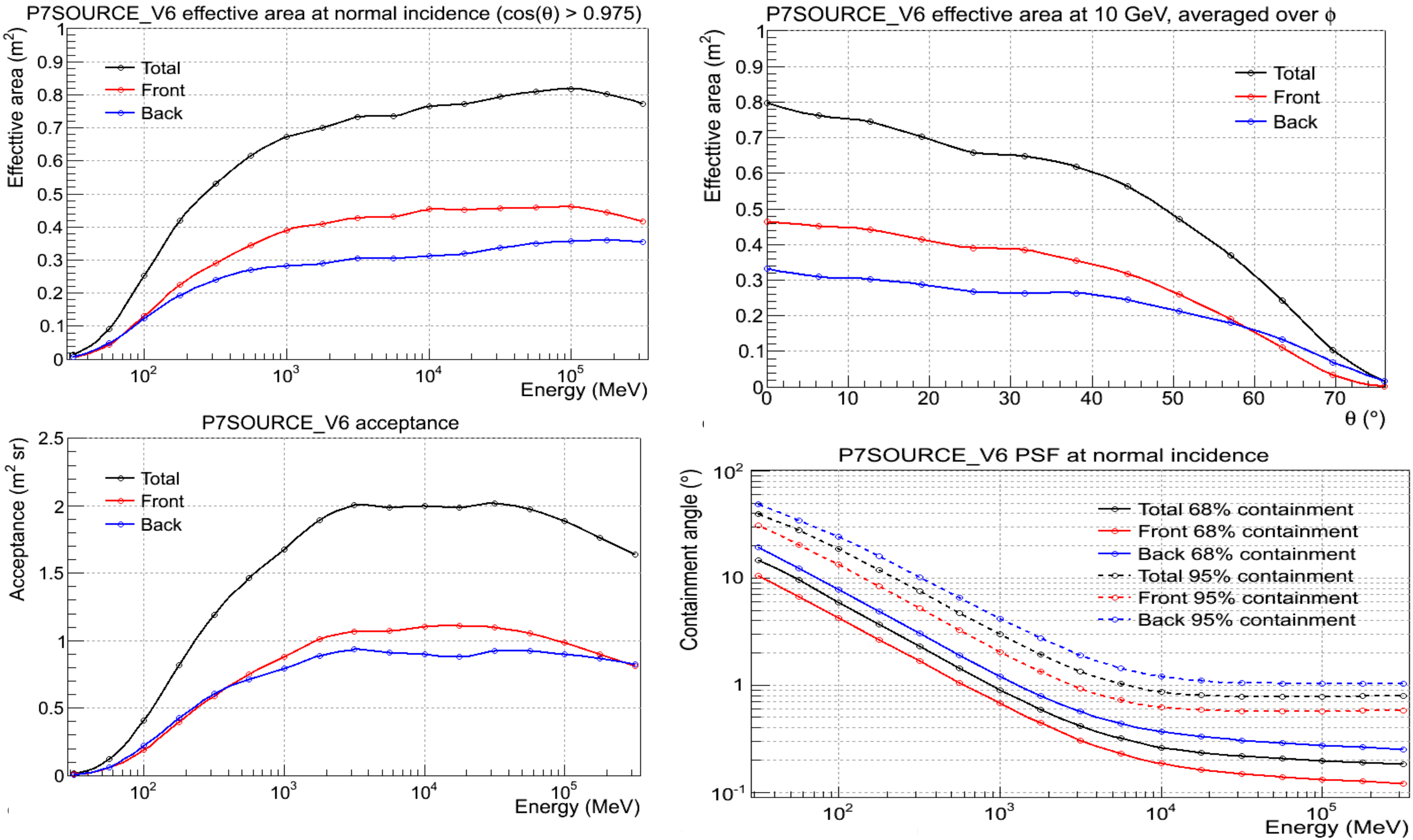




$$\theta_0 = \theta_{plane}^{rms} = \frac{1}{\sqrt{2}}\theta_{space}^{rms}$$

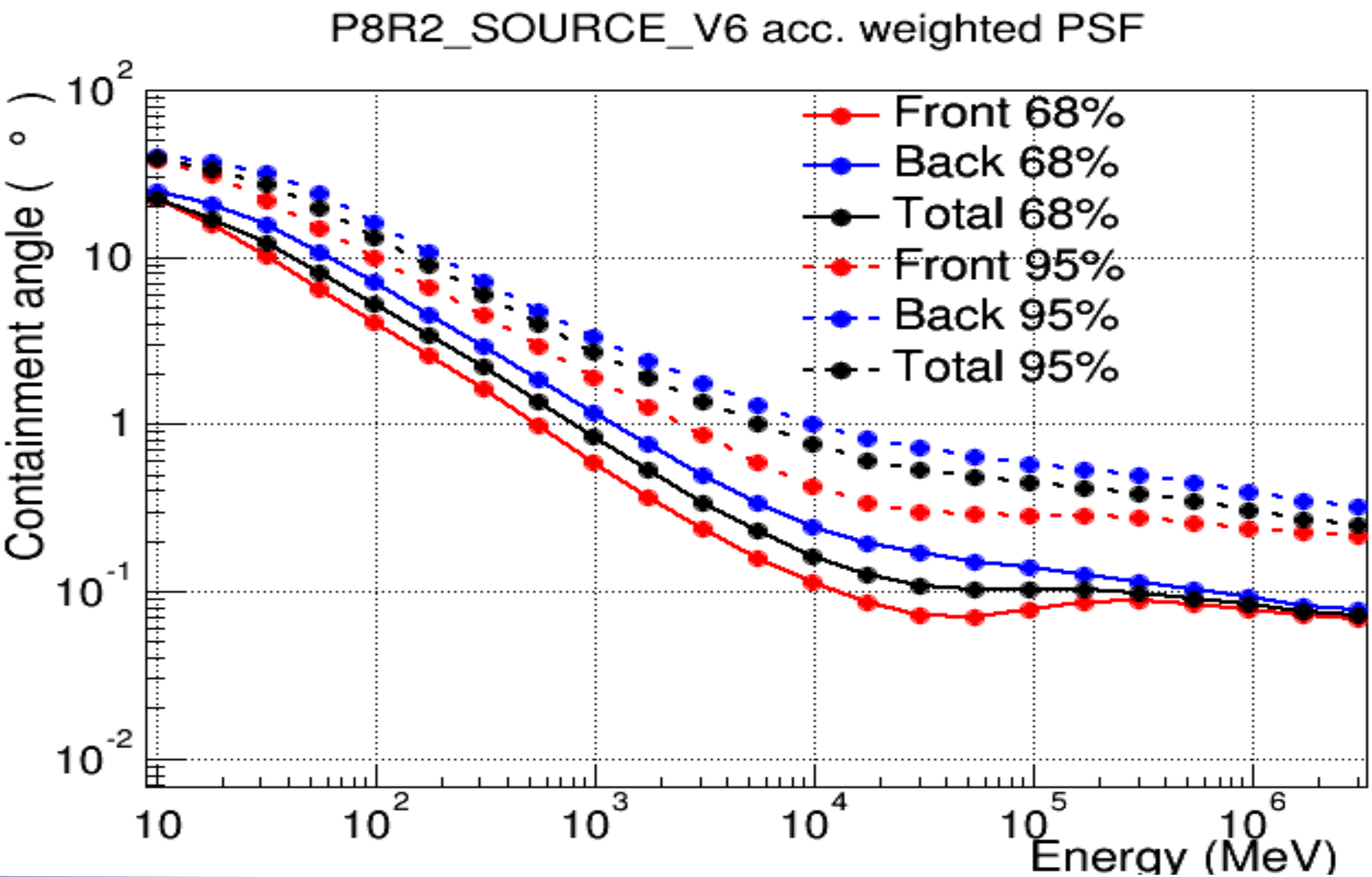
$$\theta_0 = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_0}\,\left[1 + 0.038\ln\left(x/X_0\right)\right]$$

Fermi Instrument Response Function



http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

Fermi-LAT Instrument Response Functions (Pass 8) Angular Resolution

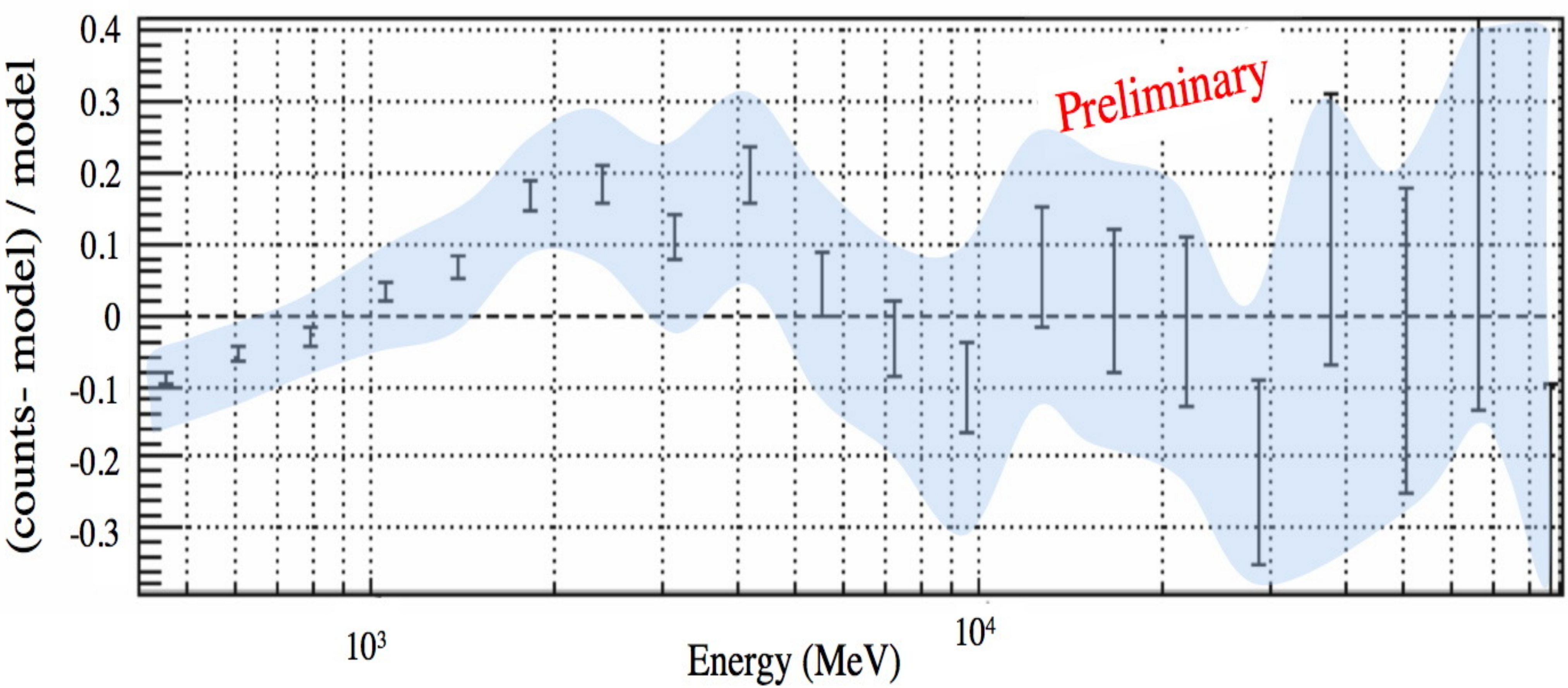


The GeV excess

7° x7° region centered on the Galactic Center

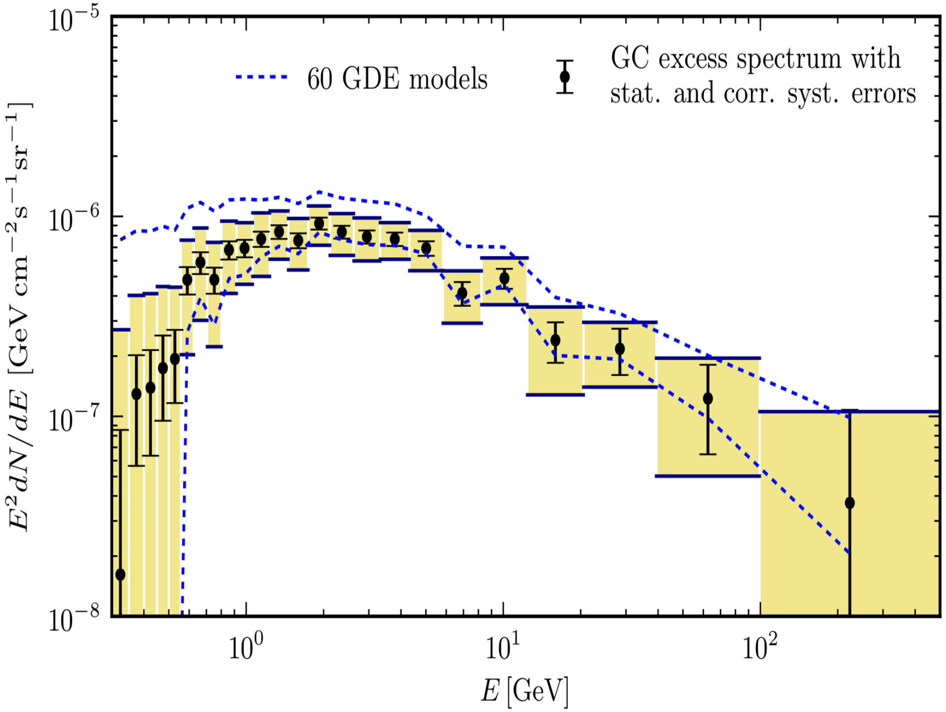
11 months of data, E >400 MeV, front-converting events analyzed with binned likelihood analysis)

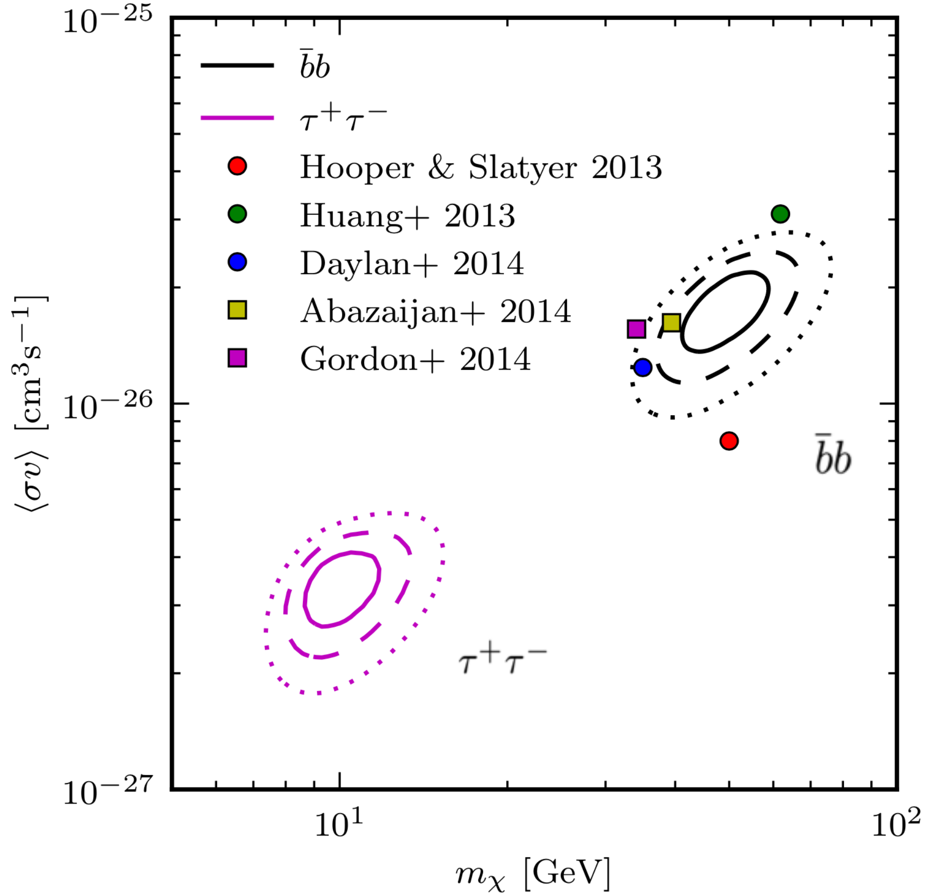
- The systematic uncertainty of the effective area (blue area) of the LAT is ~10% at 100 MeV, decreasing to 5% at 560 MeV and increasing to 20% at 10 GeV



V.Vitale, A.Morselli, Fermi Coll. 2009 arXiv:0912.3828 Fermi Symposium eConf Proceedings C091122

The GeV excess

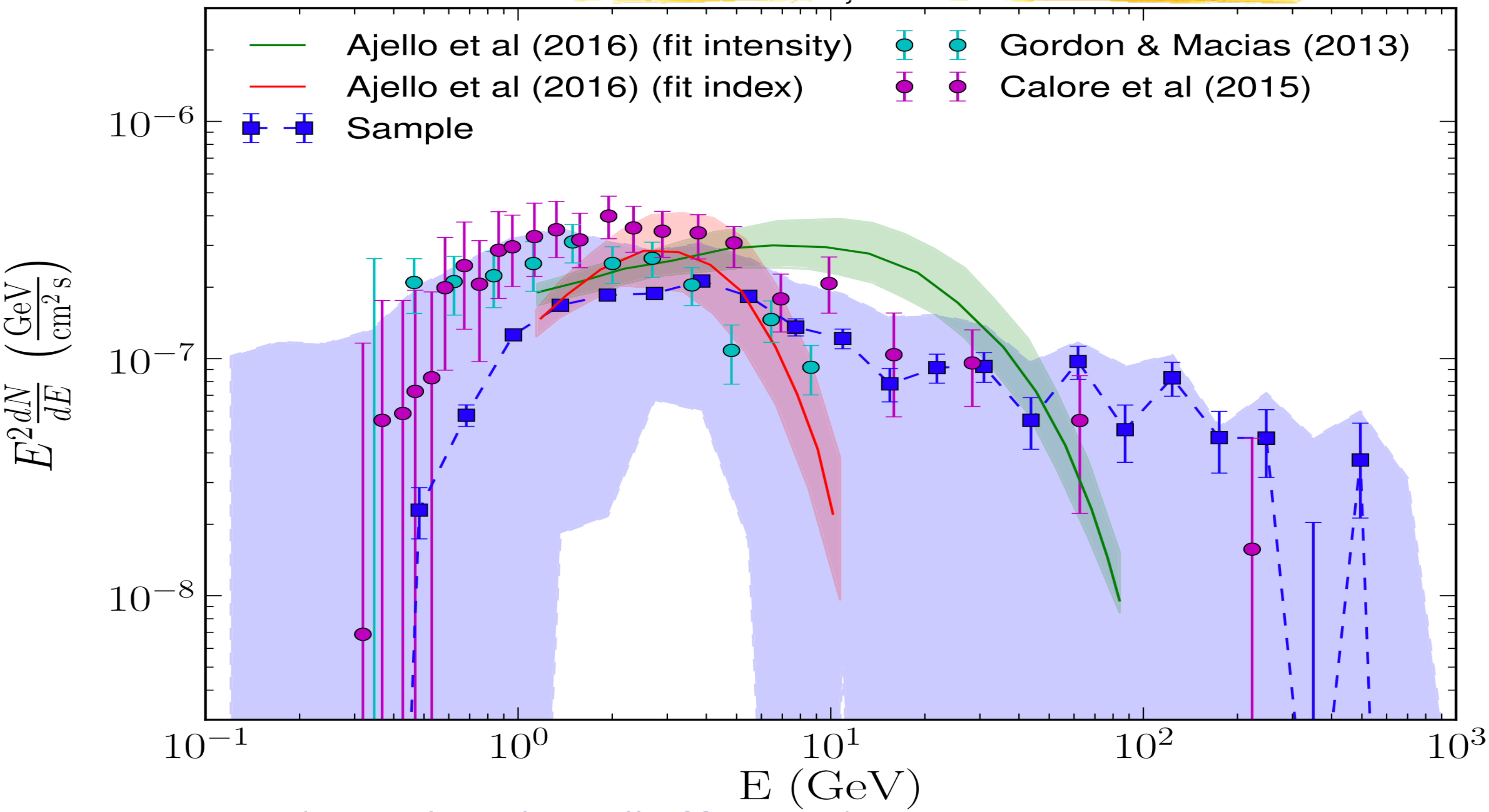




A lot of activity outside the Fermi collaboration with claims of evidence for dark matter in the Galactic Center

Calore et al., arXiv:1409.0042
Cholis et al., Phys. Rev. D 105, 103023 (2022) arXiv:2112.09706

The GeV excess (Pass8 analysis)



following uncertainties have relatively small effect on the excess spectrum

- Variation of GALPROP models – Distribution of gas along the line of sight

- **Most significant sources of uncertainty are:**

- Fermi bubbles morphology at low latitude – Sources of CR electrons near the GC

Fermi-LAT Collaboration Apj 840:43 2017 May 1 arXiv:1704.03910

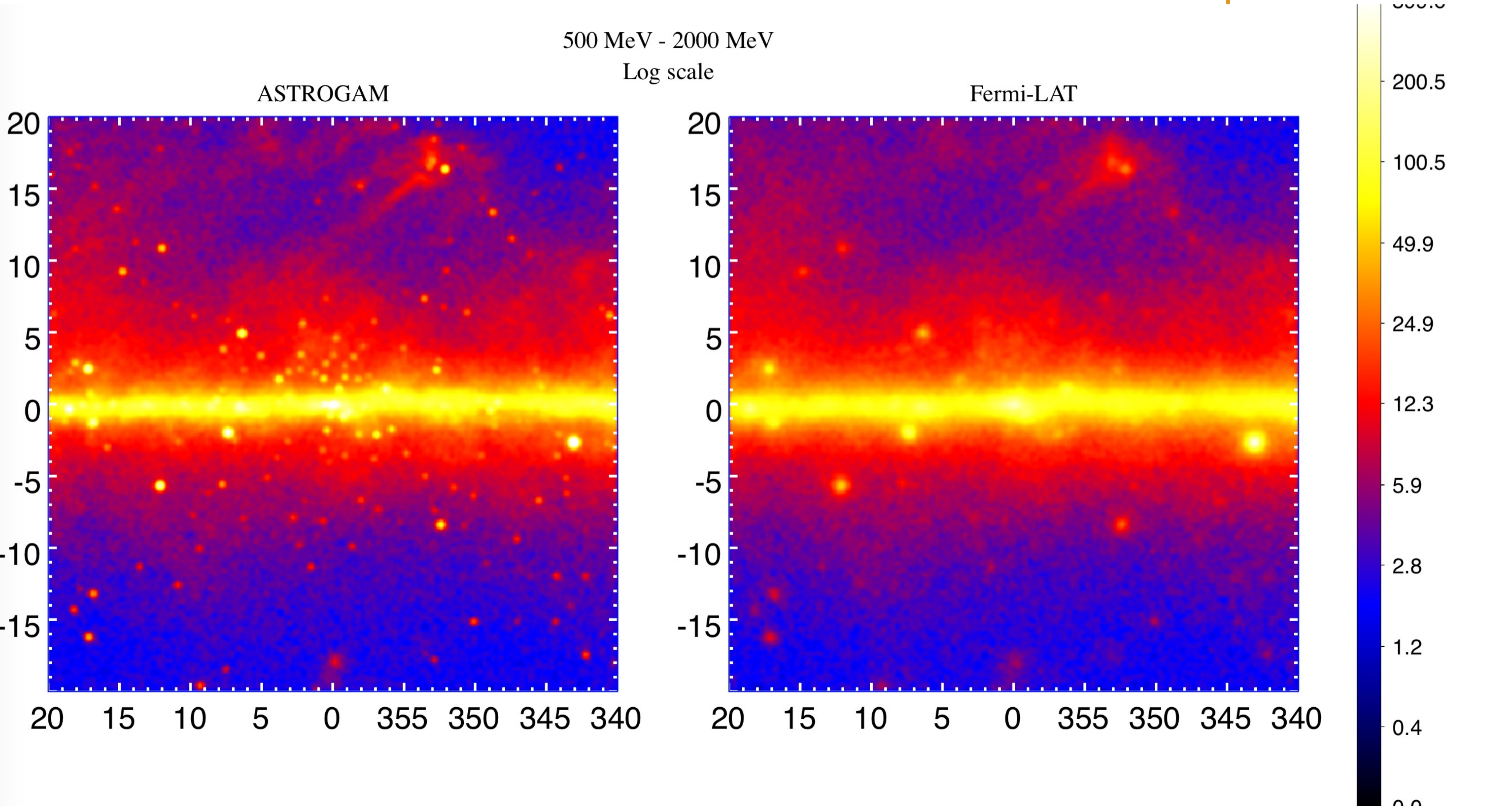
The GeV excess :

How to discriminate between the Dark Matter and the Population of pulsars in the Galactic bulge hypothesis ?

We need a new experiment with better angular resolution below 100 MeV

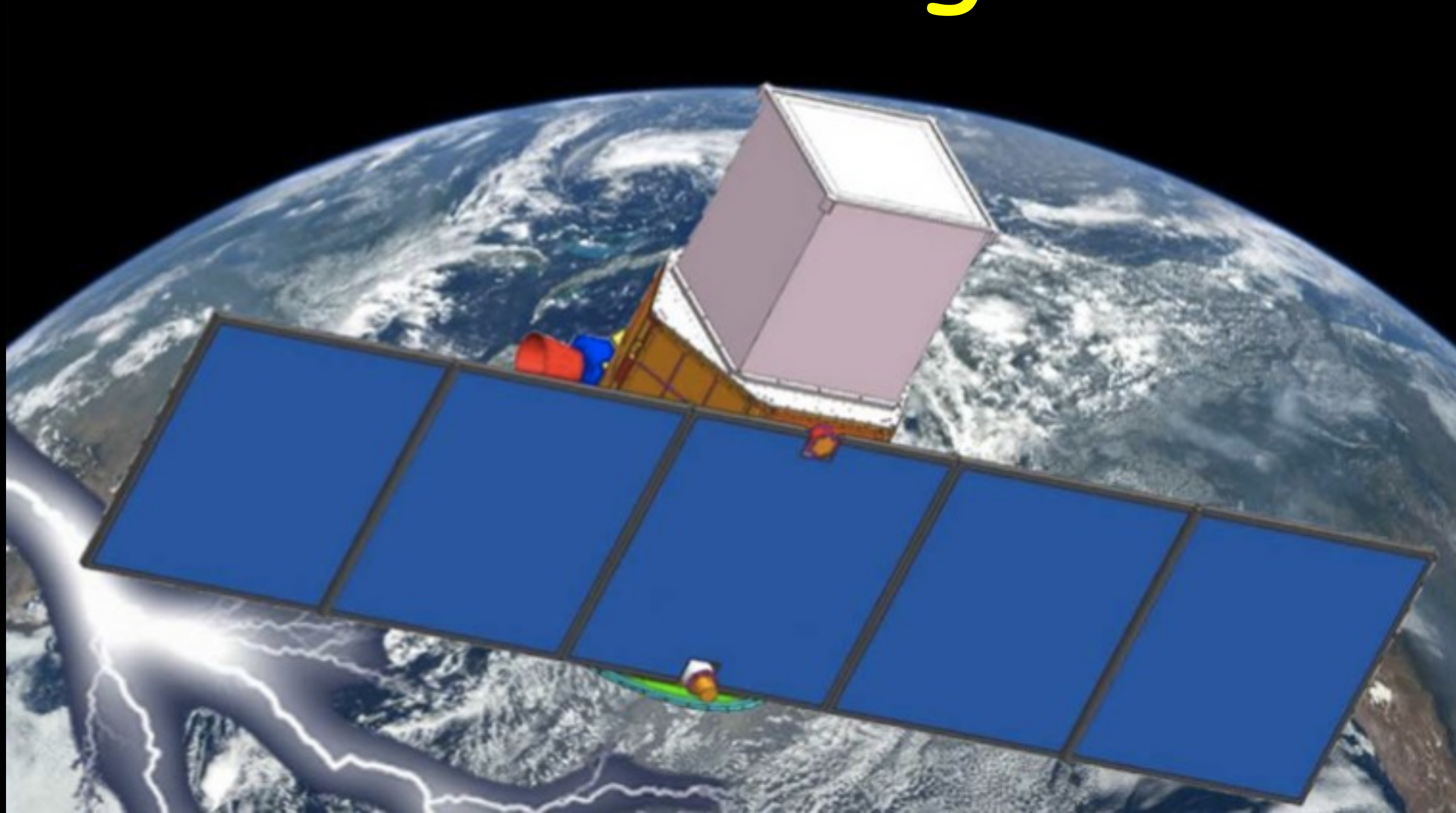
Galactic Center Region 0.5-2 GeV

Fermi PSF Pass7 rep v15 source



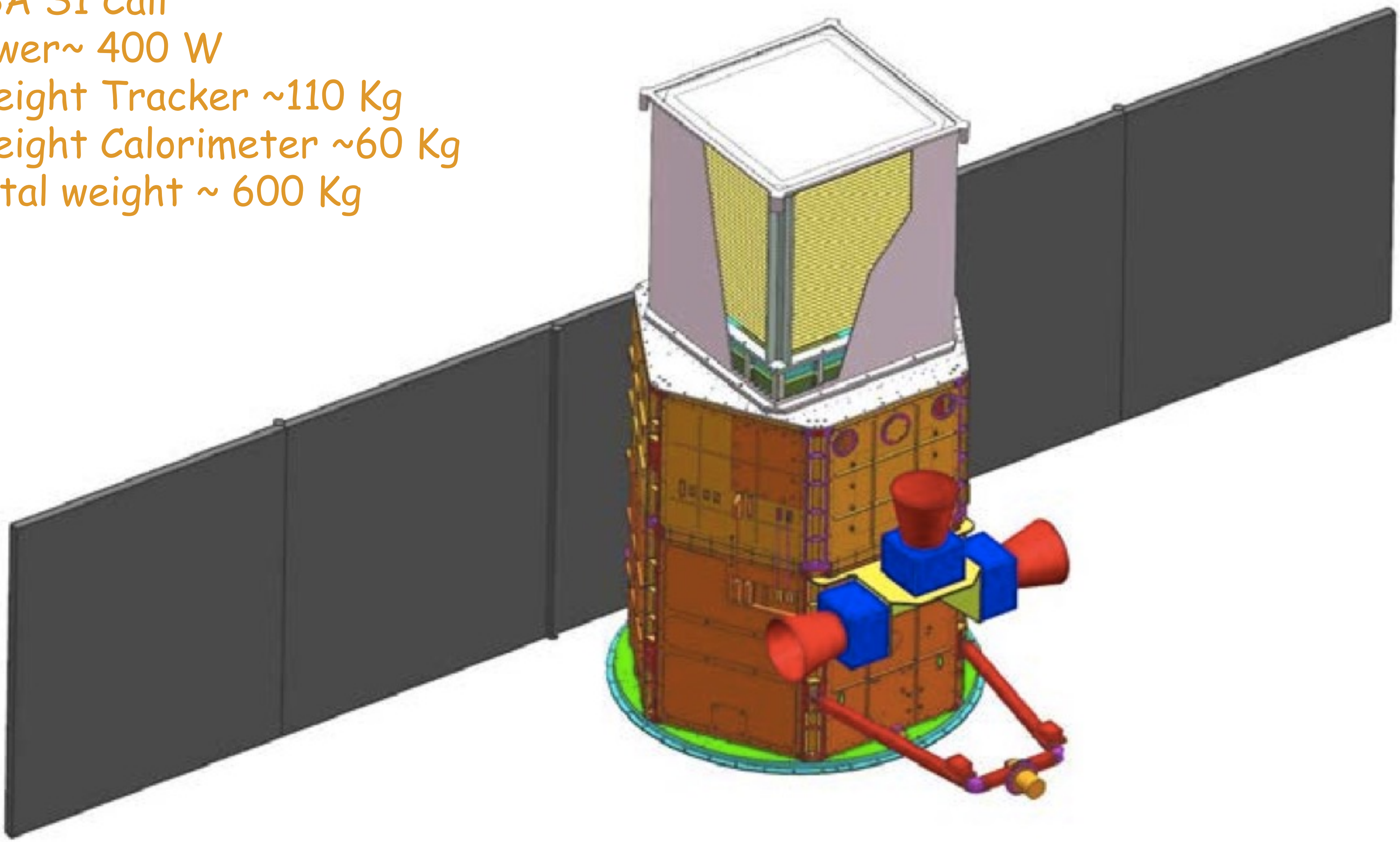
Morselli, Gomez Vargas, preliminary

Gamma-Light



Gamma-light project

ESA S1 Call
Power~ 400 W
Weight Tracker ~110 Kg
Weight Calorimeter ~60 Kg
Total weight ~ 600 Kg



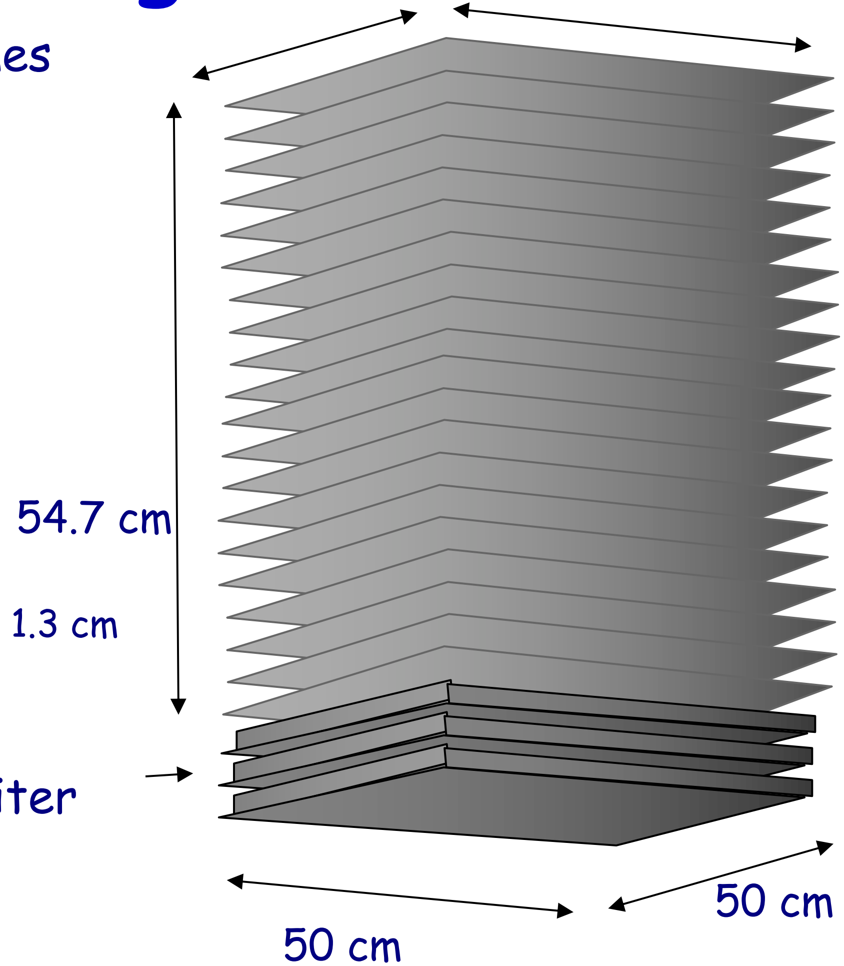
Gamma-light scheme

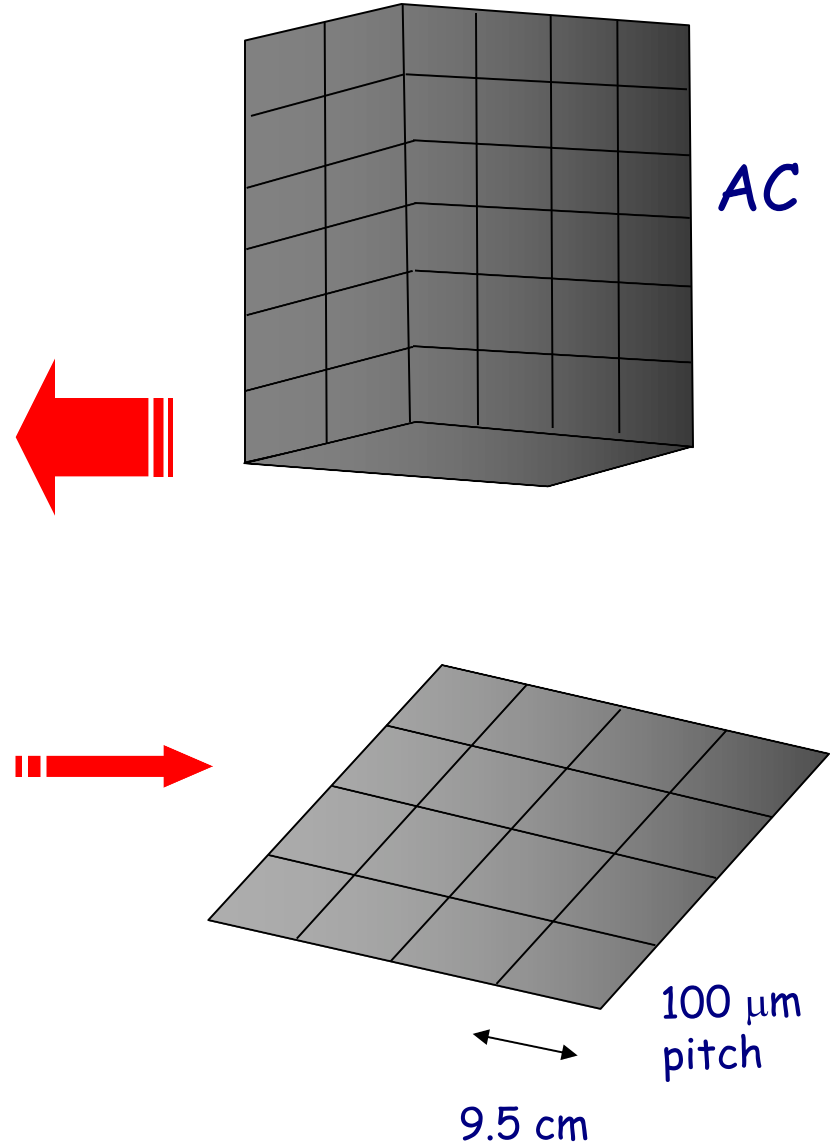
40+1 x-y planes
100 μm pitch
each
~0.025 X_0

Tot~ 1 X_0

height of a plane 1.3 cm

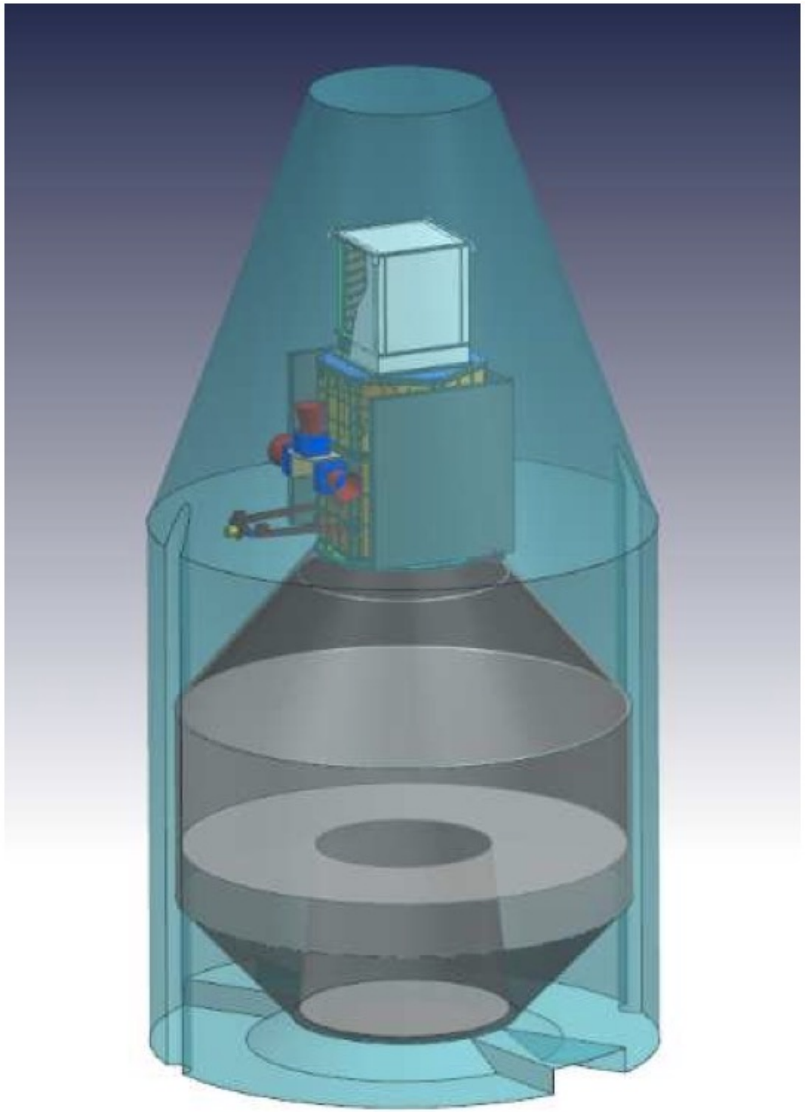
2 Xo Calorimiter

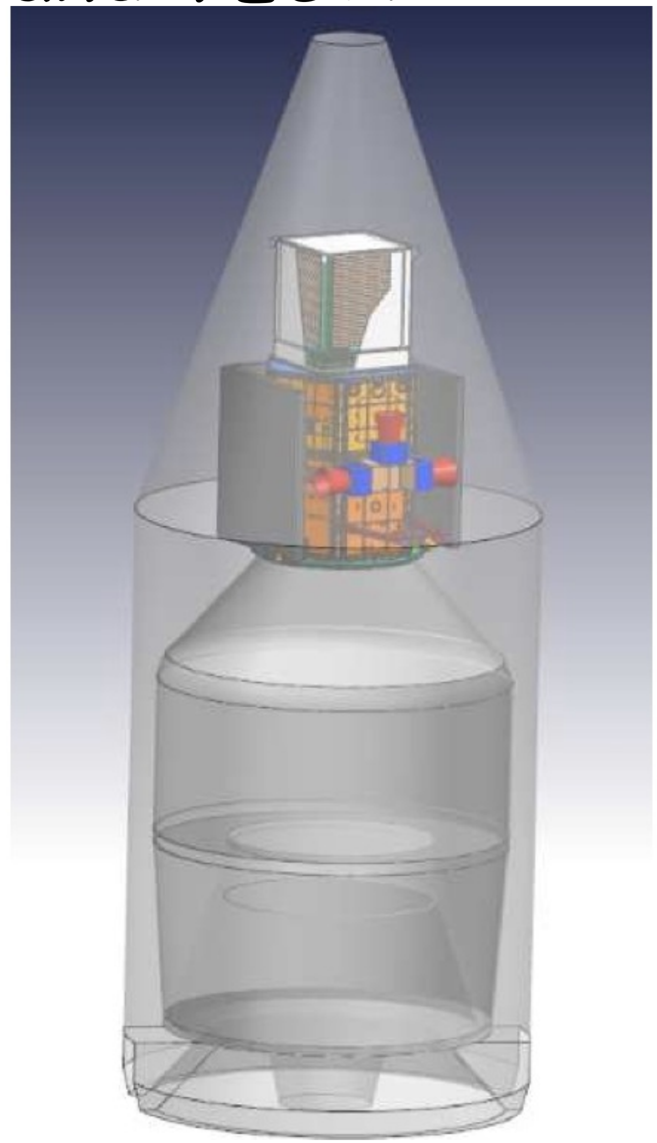




*Compton scattering **and** pair production telescope*

GAMMA-LIGHT satellite launch configurations for the PSLV and VEGA

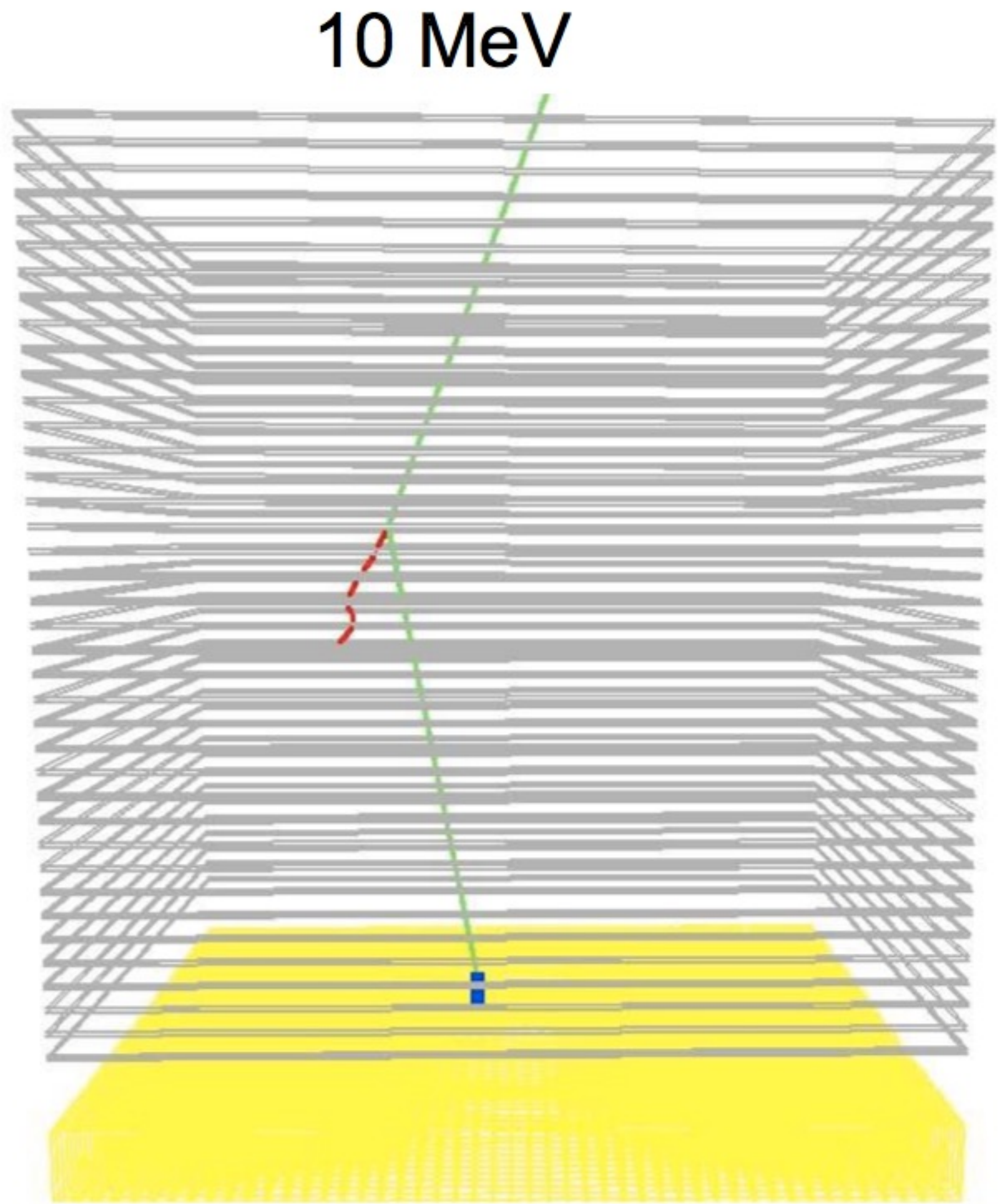




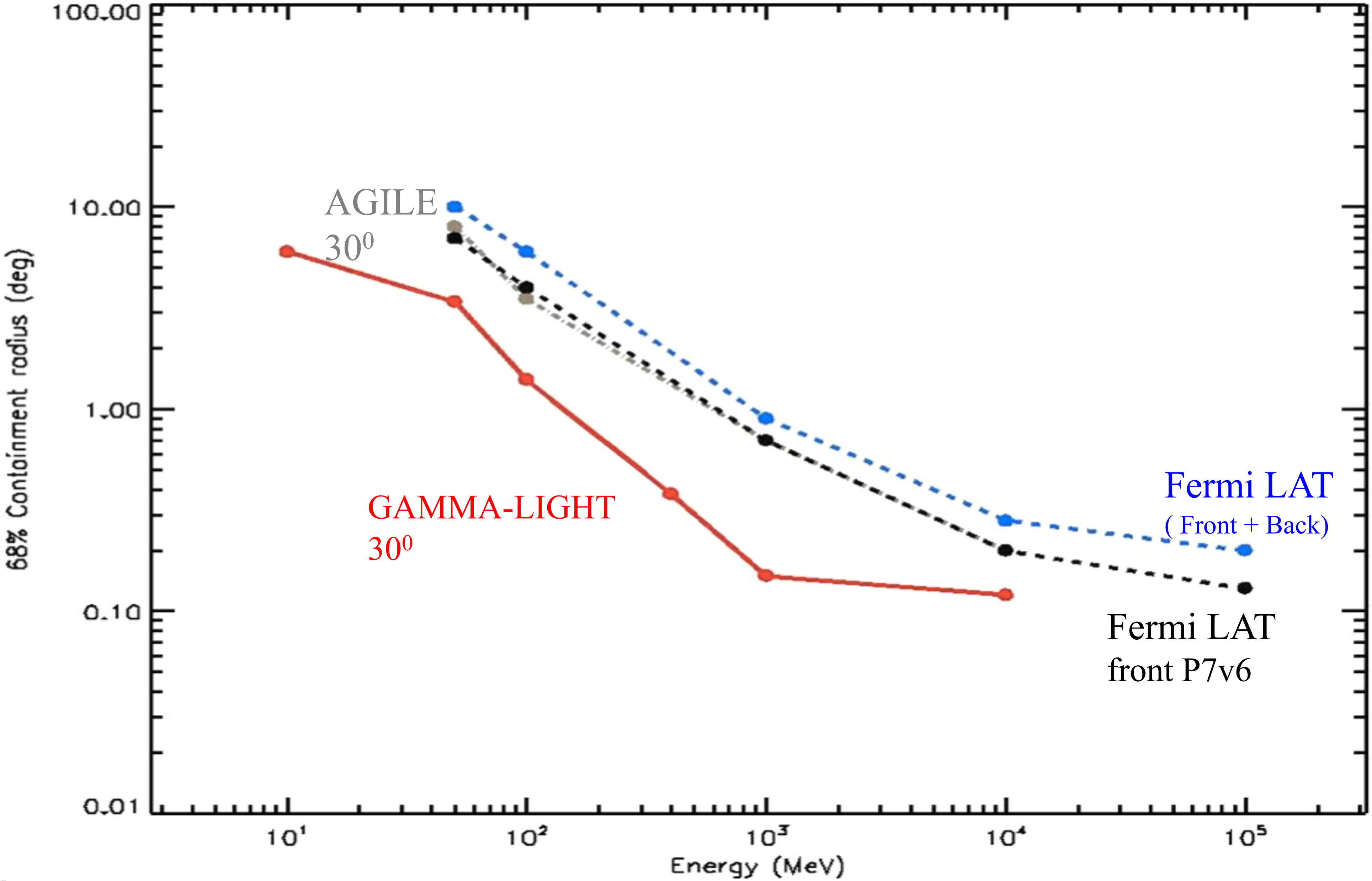
- *a companion satellite similar to G-LIGHT can be accomodated.*

G-LIGHT Simulation

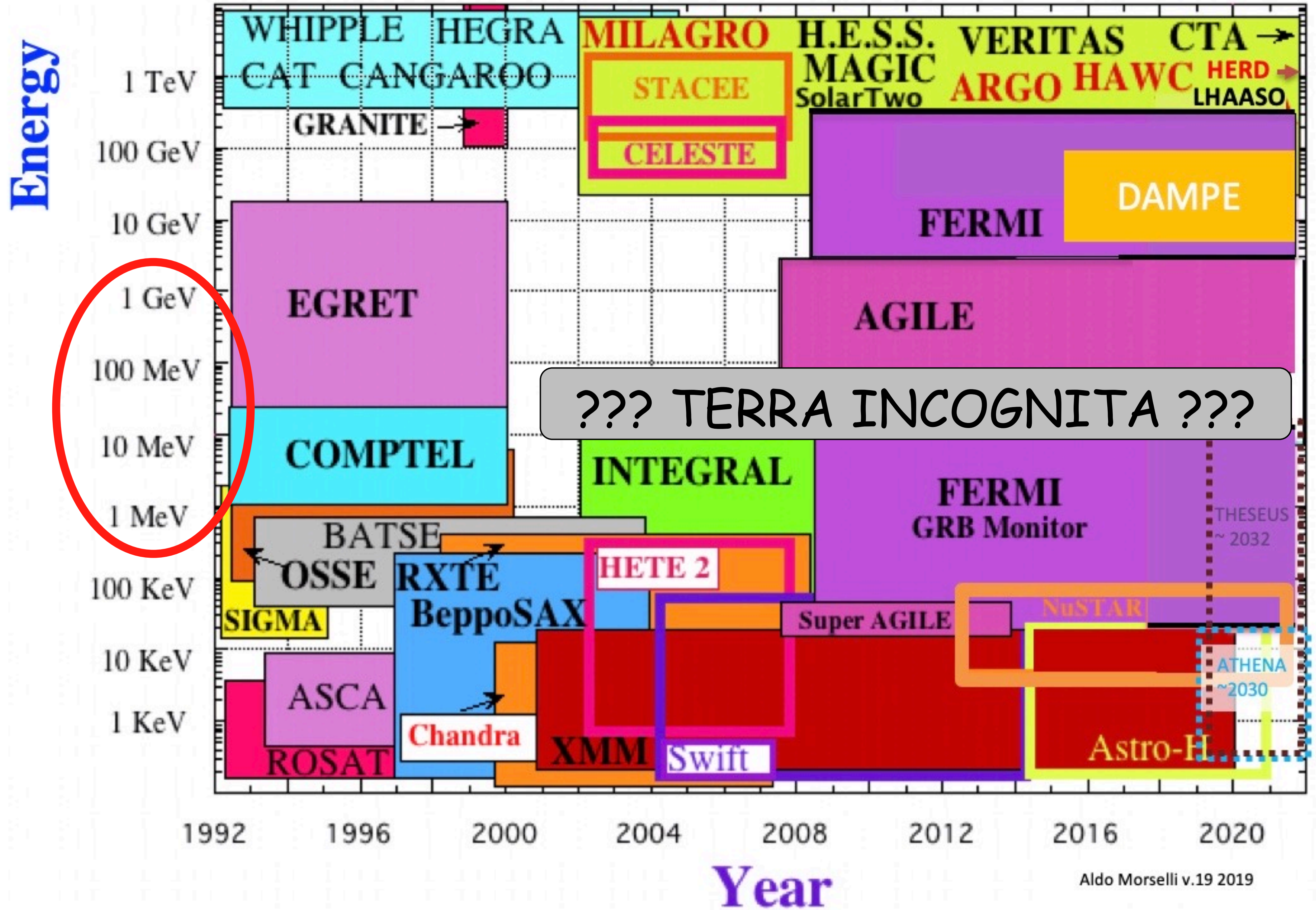
Compton interaction of a 10 MeV photon producing a low-energy single-track electron, and depositing energy in the Calorimeter for a 30^0 incidence



Gamma-Light Point Spread Function (angular resolution)



A.Morselli et al. , Nuclear Physics B Proc. Supp. 239–240 (2013) 193-198 [arXiv:1406.1071]

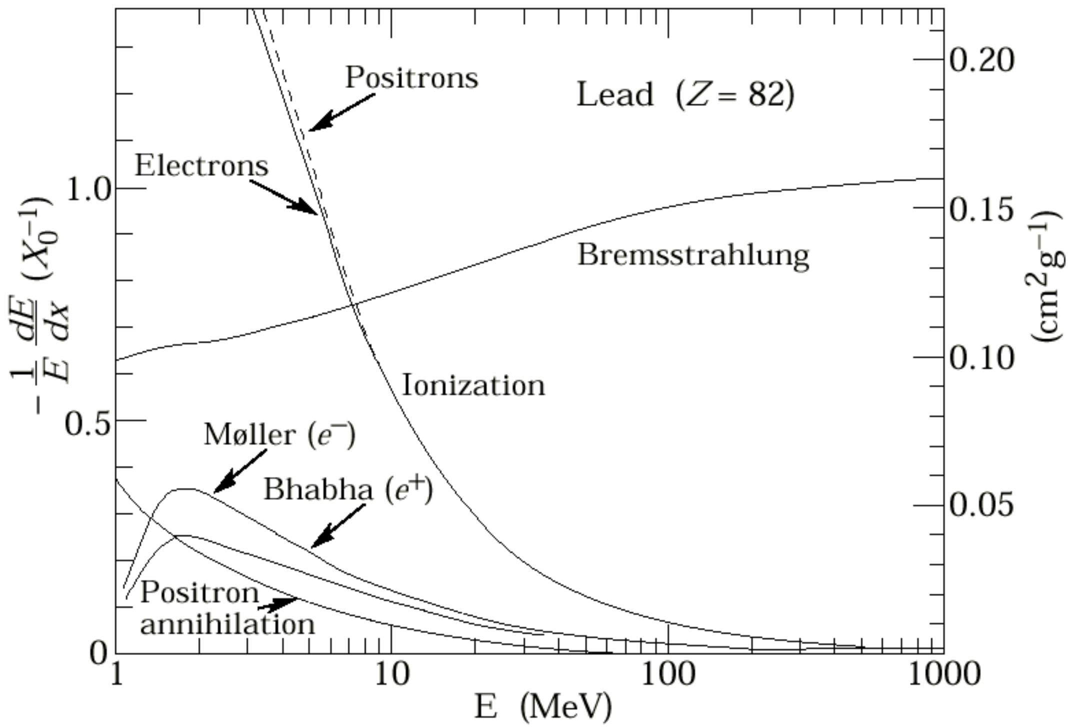


Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE
HEGRA
CAT
CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
ARGO
HAWC
CTA
HERD
LHAASO
FERMI
DAMPE
EGRET
AGILE
??? TERRA INCOGNITA ???
COMPTEL
INTEGRAL
FERMI
GRB Monitor
THESEUS
~ 2032
BATSE
OSSE
RXTE
BeppoSAX
HETE 2
SIGMA
Super AGILE
NuSTAR
ATHENA
~2030
ASCA
Chandra
XMM
Swift
Astro-H
ROSAT
1992
1996
2000
2004
2008
2012
2016
2020
Year
Aldo Morselli v.19 2019

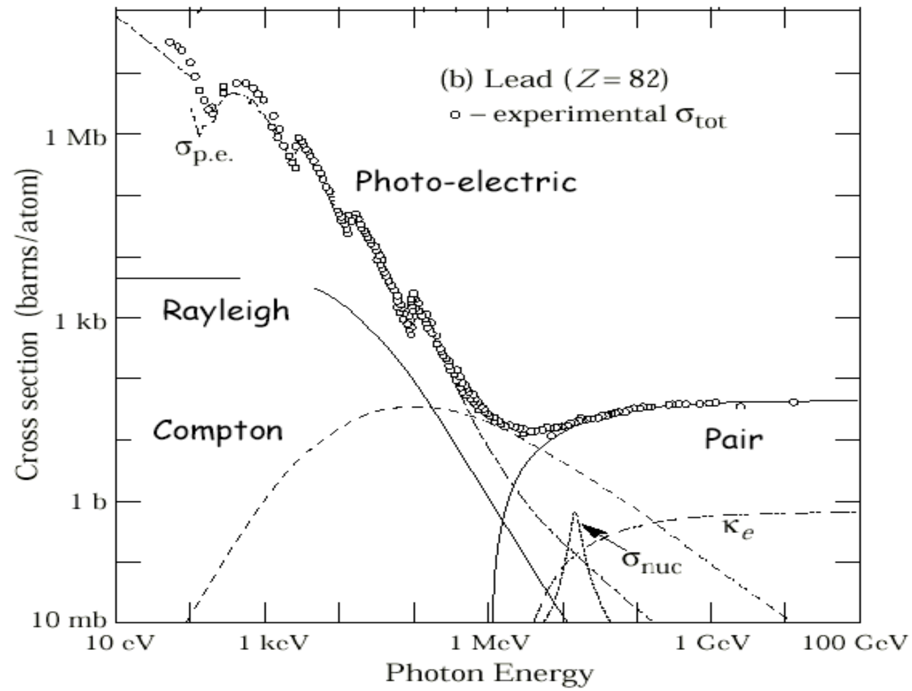
- 1-100 MeV unexplored domain for
  - Dark Matter searches
  - Galactic compact stars and nucleosynthesis
  - Cosmic rays
  - Relativistic jets, microquasars
  - Blazars
  - Gamma-Ray Bursts
  - Solar physics
- and…
  - Terrestrial Gamma-Ray Flashes

Interaction of photons with matter

Fractional energy loss for e^+ and e^- in lead



Photon total cross sections



$$\frac{dE}{dx}_{Brems} = -\frac{E}{X_0} \Rightarrow E(x) = e^{-\frac{x}{X_0}}$$

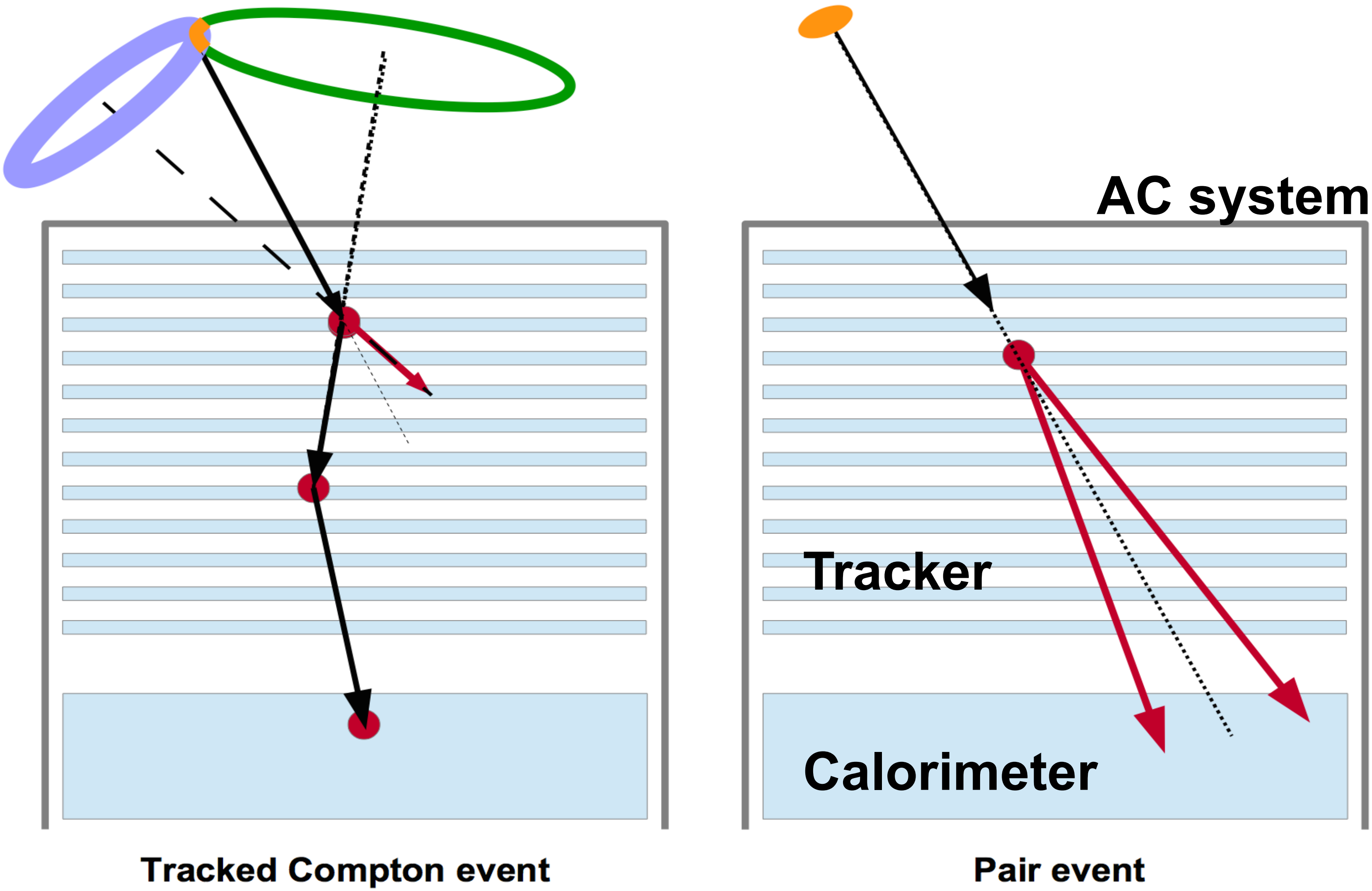
with X_0 = radiation length

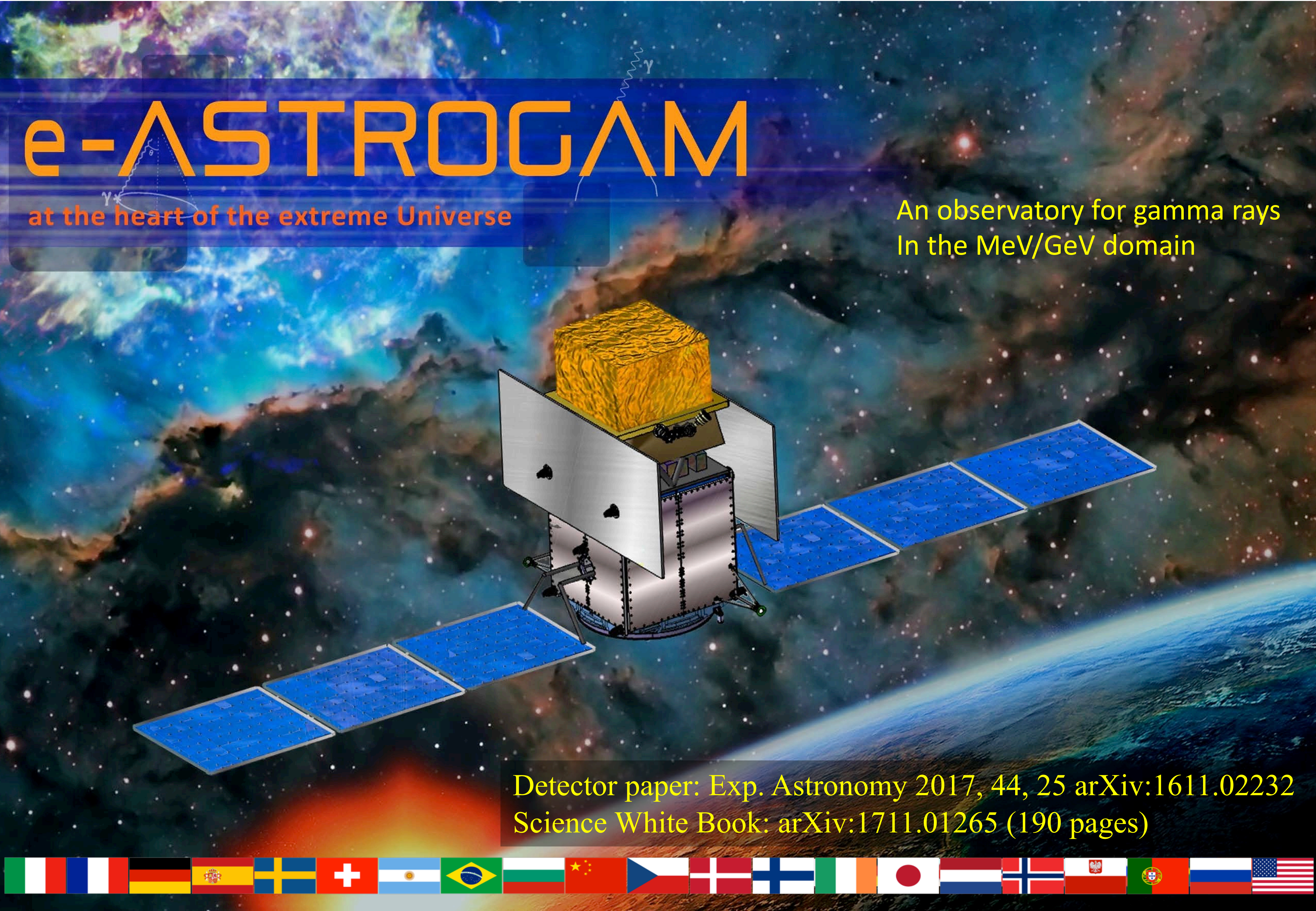
$$X_0 = 716.4 \text{ g cm}^{-2} \frac{A}{Z(Z+1)\ln\frac{287}{\sqrt{Z}}}$$

$$\text{Prob. of Int.} = 1 - \exp^{-\frac{7}{9}\frac{x}{X_0}}$$

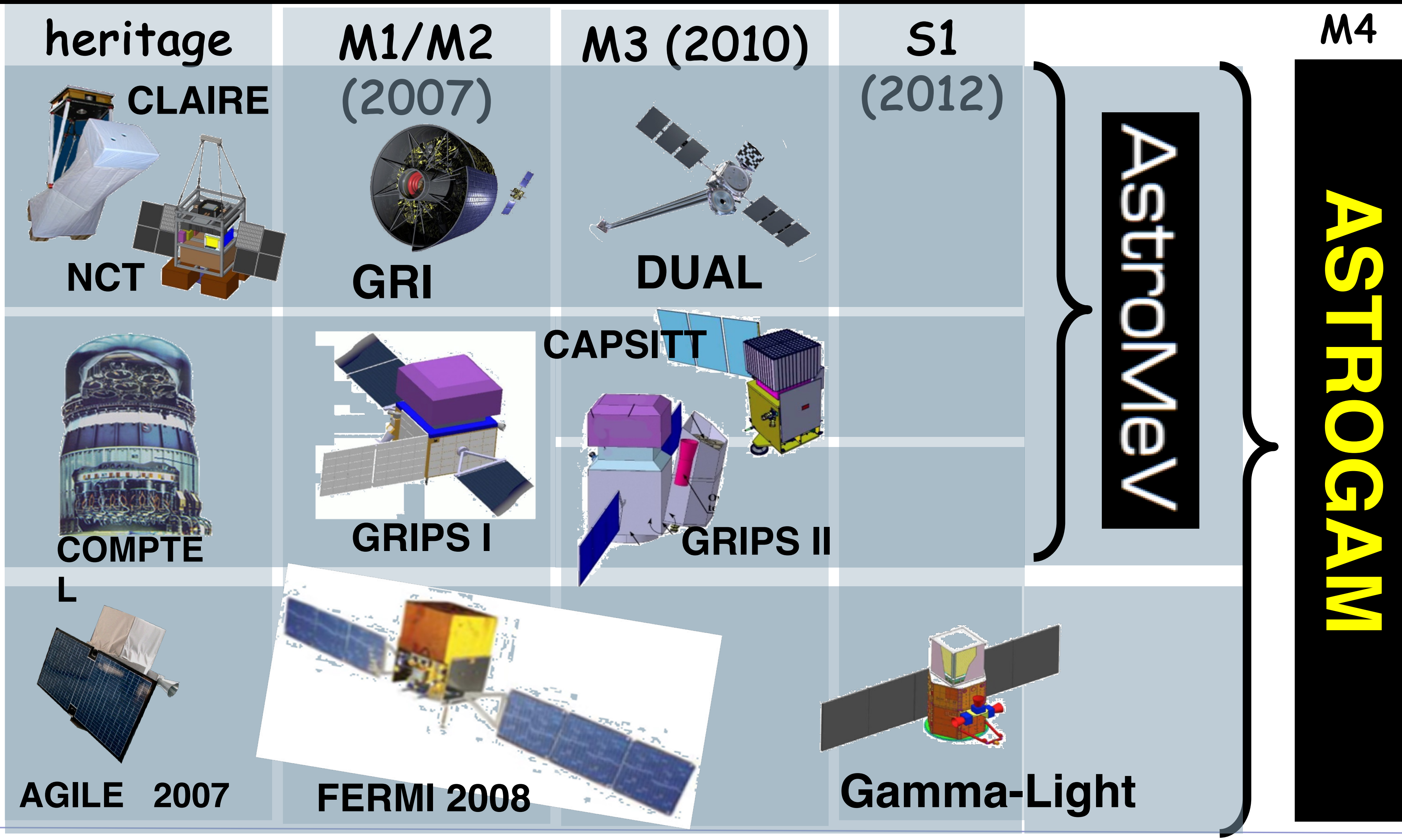
x/X_0	Prob Int.
0.5	0.40
1	0.54
2	0.79
7	0.995

An instrument that combine two detection techniques

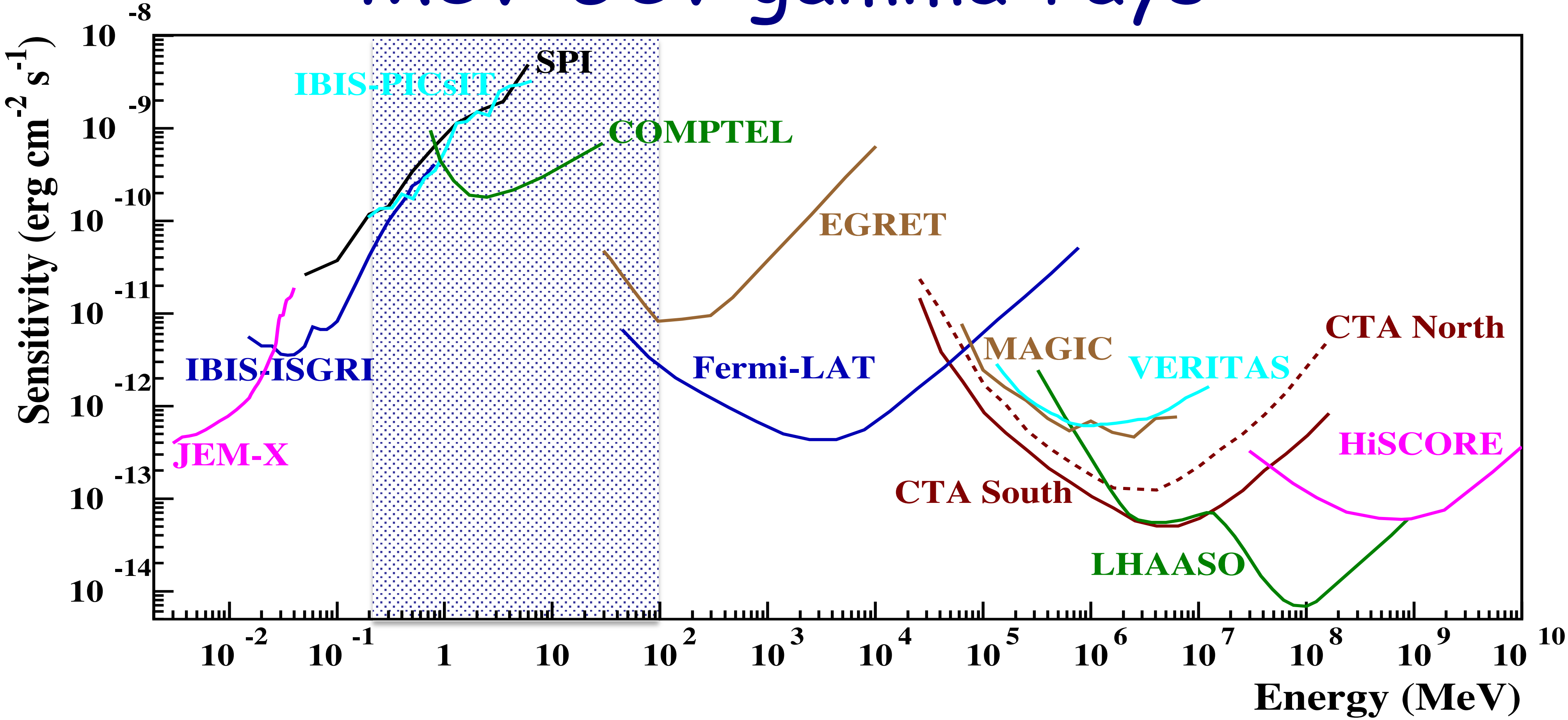



e-ASTROGAM
at the heart of the extreme Universe
An observatory for gamma rays
In the MeV/GeV domain
Detector paper: Exp. Astronomy 2017, 44, 25 arXiv:1611.02232
Science White Book: arXiv:1711.01265 (190 pages)

ASTROGAM a unified proposal from the entire gamma-ray community

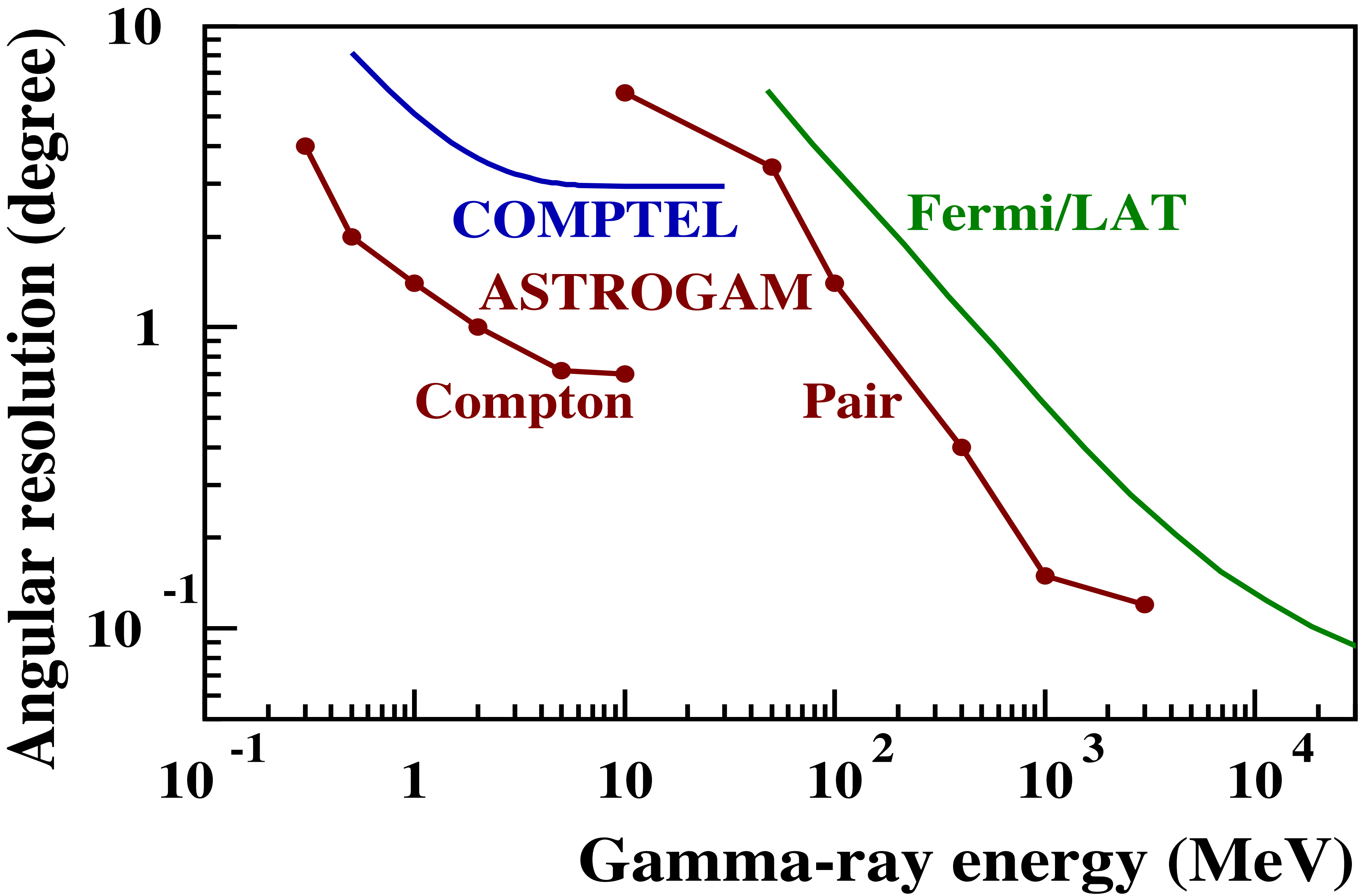


MeV-GeV gamma-rays

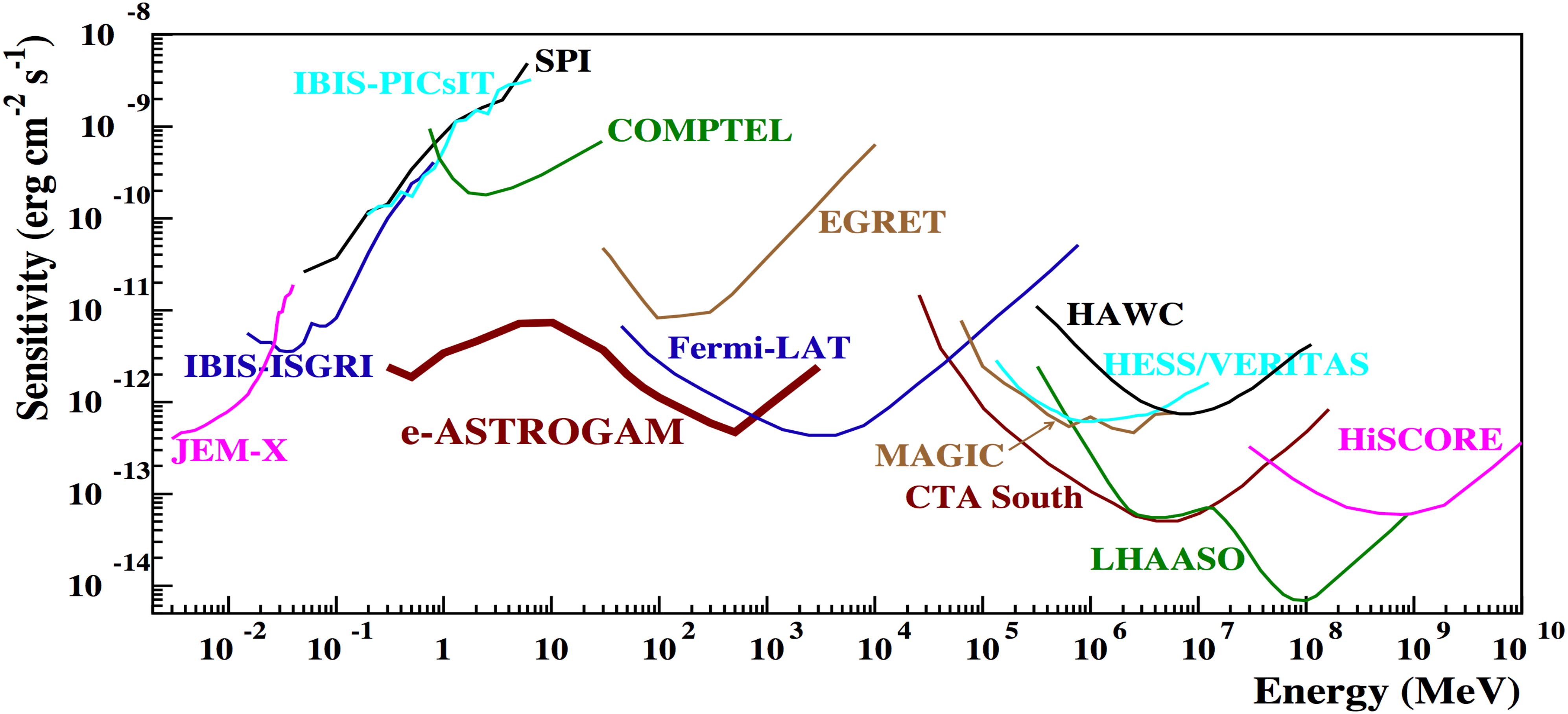


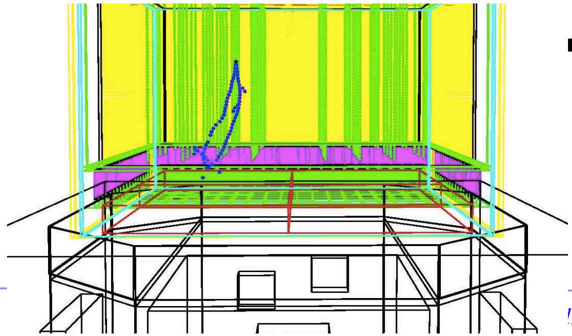
- Worst covered part of the electromagnetic spectrum in 0.1-100 MeV
- Many objects have their peak emissivity in this range (GRBs, blazars, pulsars…)
- The MeV range is the domain of nuclear gamma-ray lines (supernovae, nucleosynthesis and Galactic chemical evolution)

ASTROGAM Angular Resolution



e-ASTROGAM Performance assessment



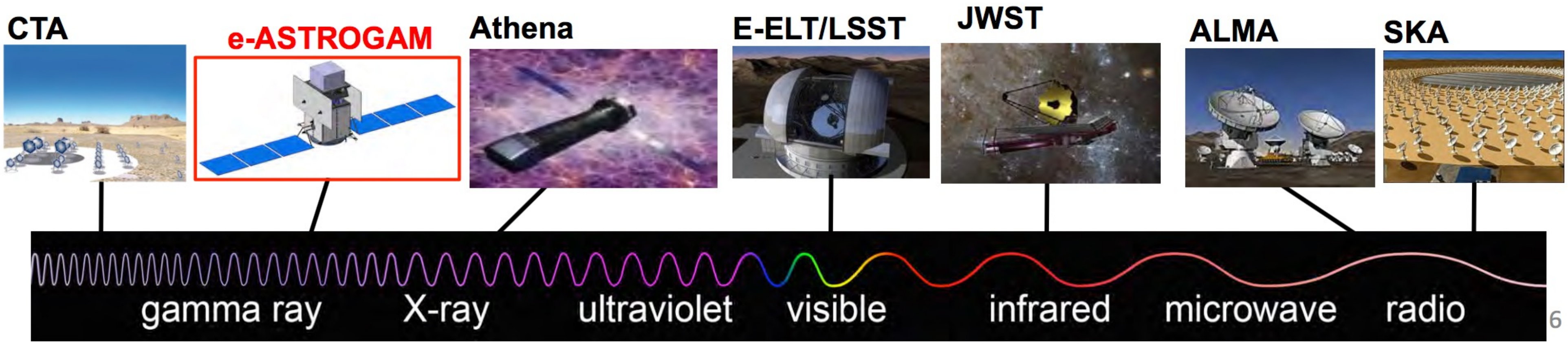


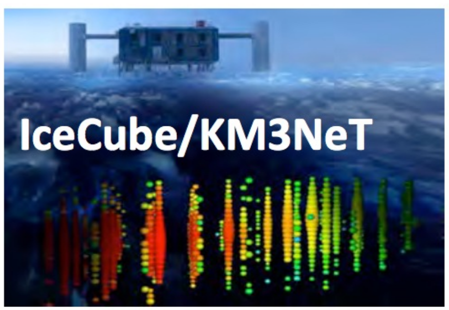
- e-ASTROGAM performance evaluated with **MEGAlib** and BoGem both tools based on Geant4 – and a detailed numerical mass model of the gamma-ray instrument

e-Astrogam: arXiv:1711.01265

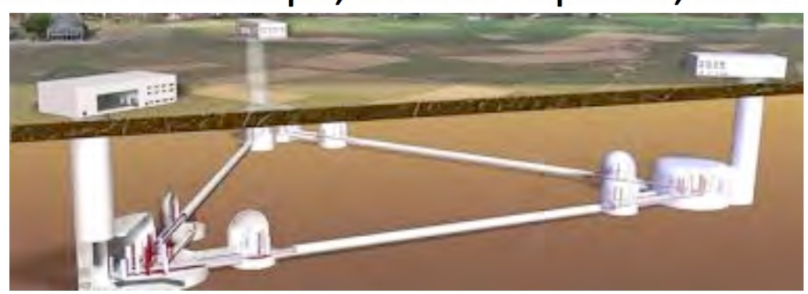
A unique Observatory integrated with future astrophysics

- Multi-messenger, multi-wavelength, well suited for transient phenomena

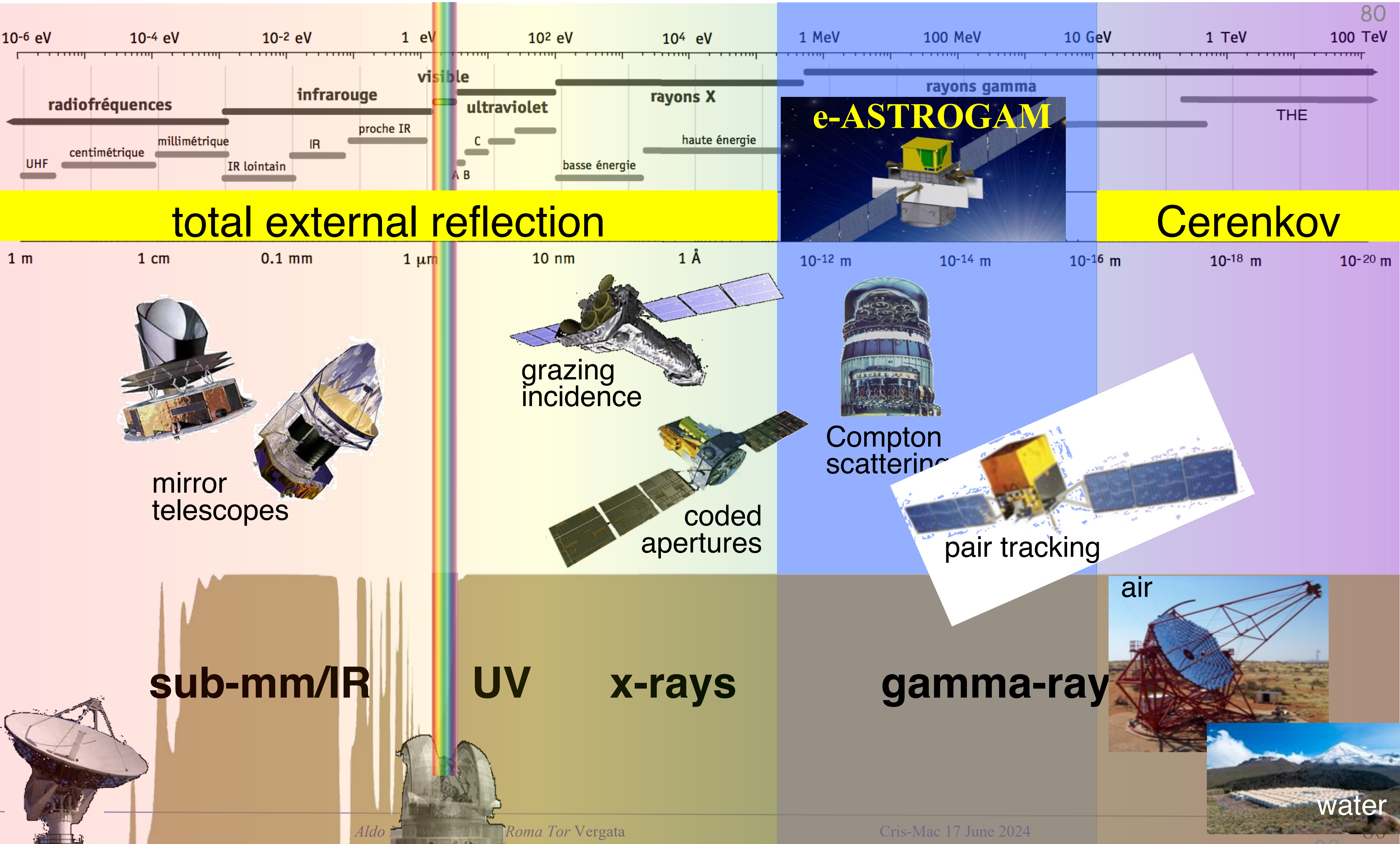




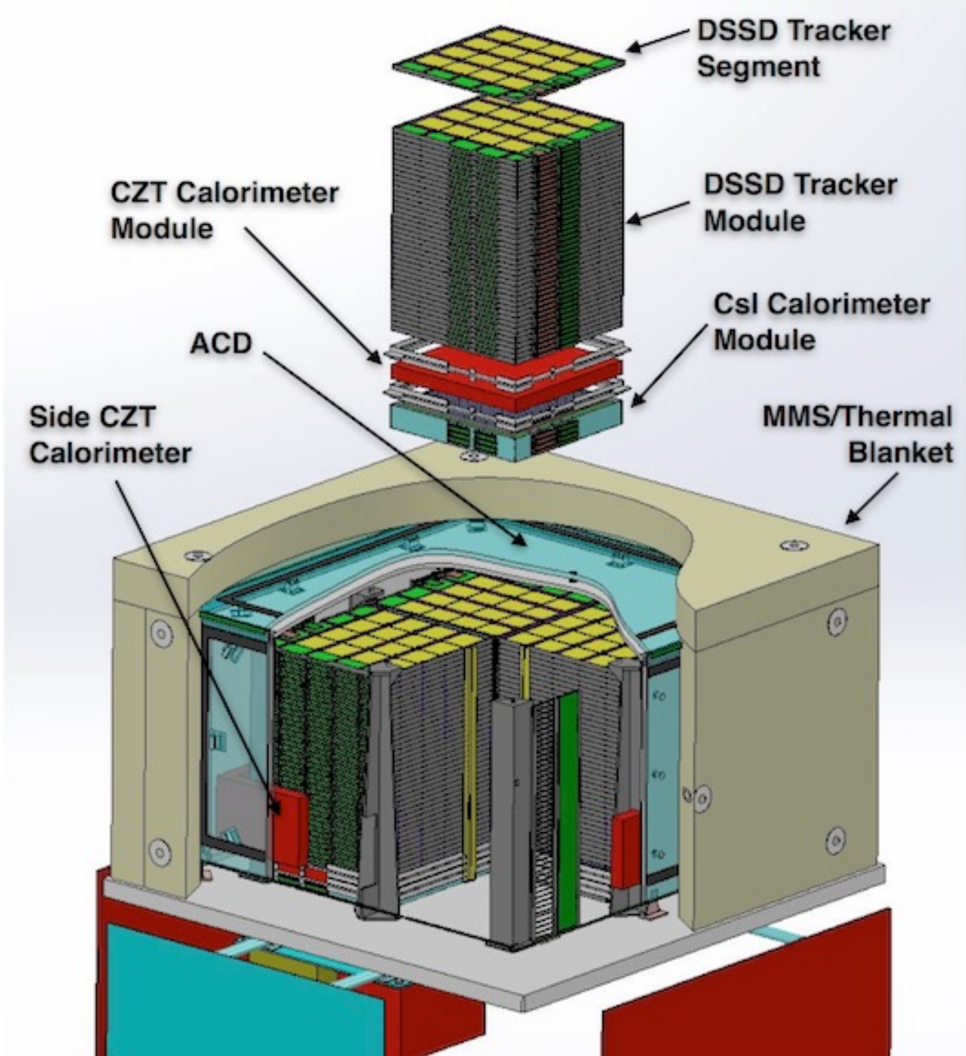
Einstein Telescope, Cosmic Explorer, LISA

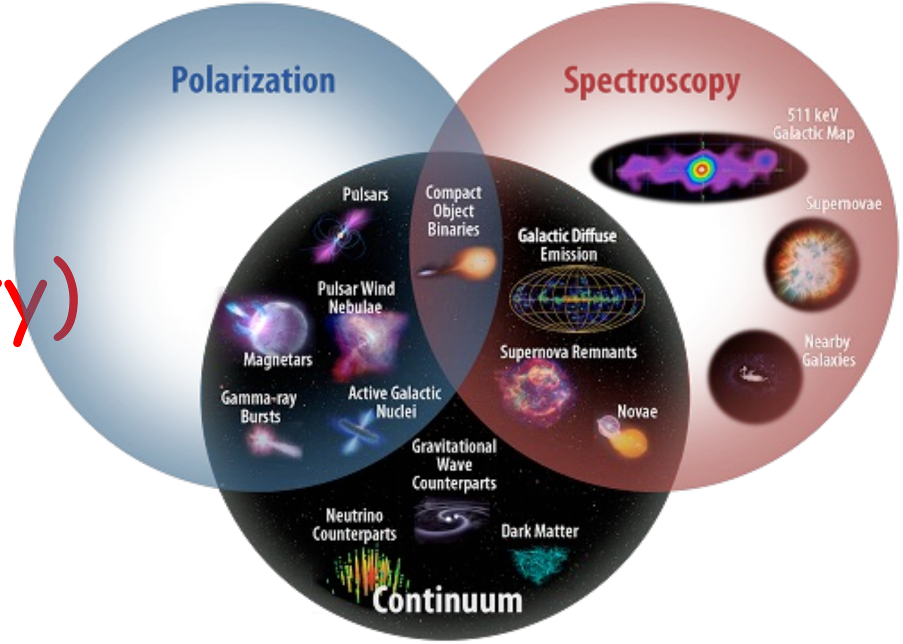


An instrument to complete the coverage of the electromagnetic spectrum



Our sister experiment: AMEGO (NASA)
(two brands, one community)

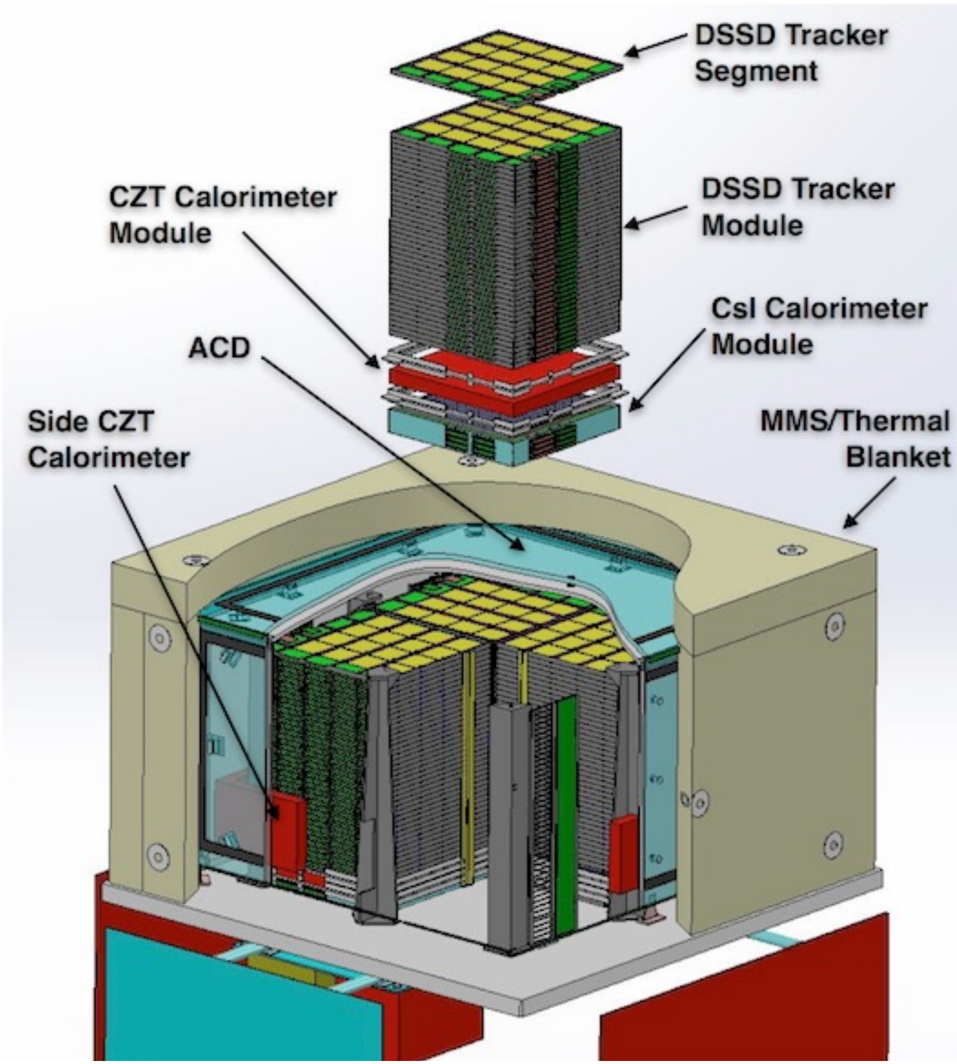




- ~20% smaller tracker
- CZT calorimeter layer

Status and Plans :
Resubmit in the next MIDEX round (~2027)

Our sister experiment: AMEGO (NASA)



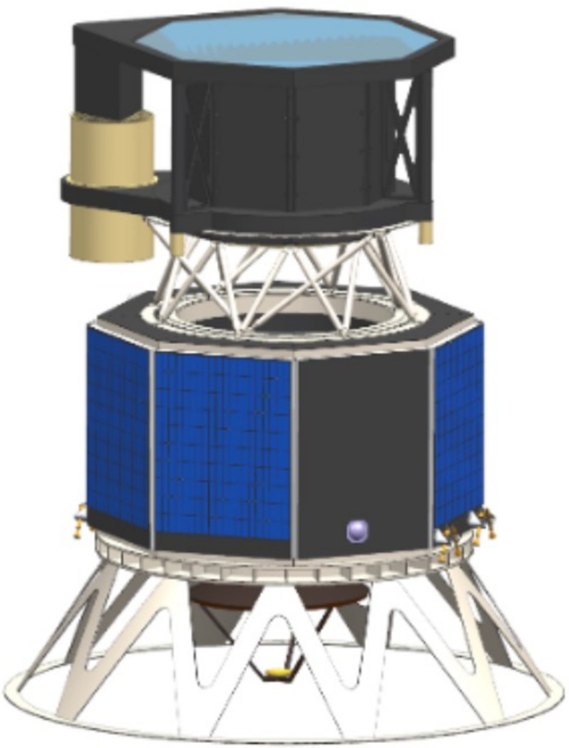
Status and Plans :
Resubmit in the next MIDEX round (~2027)

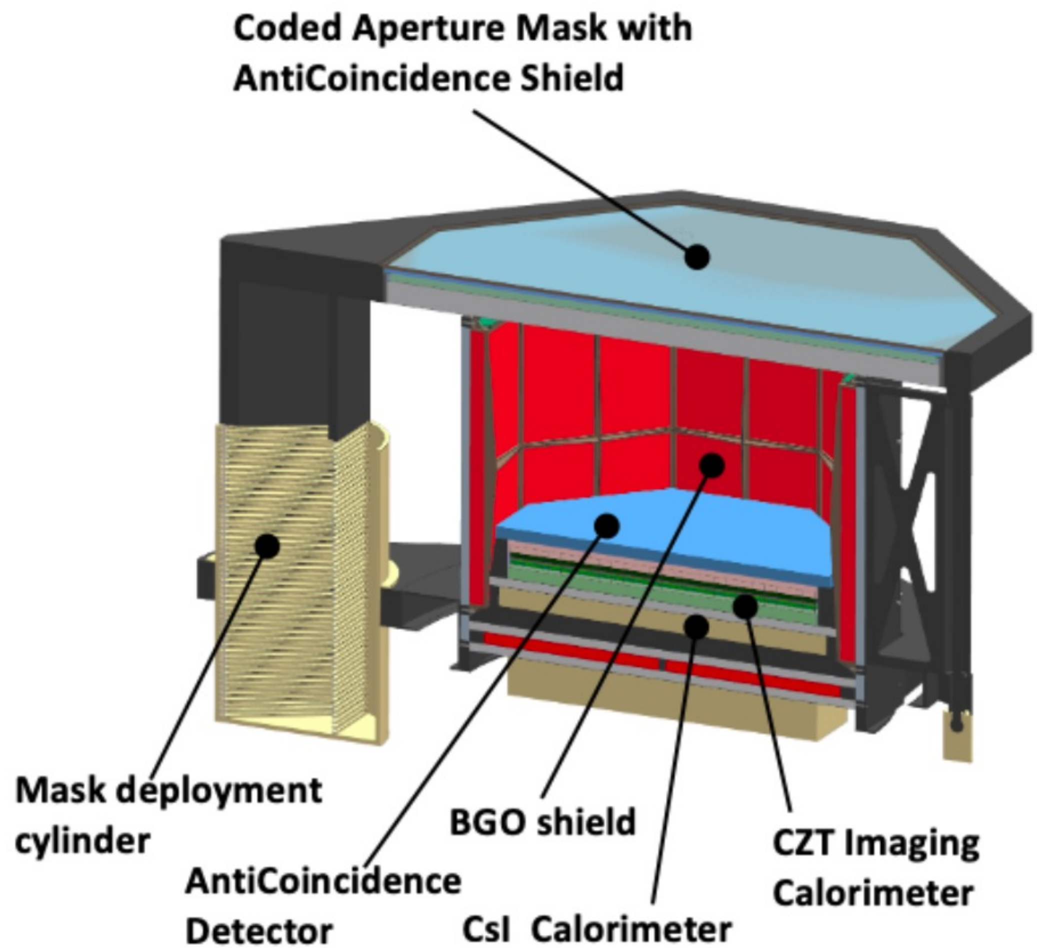
in the meantime:

Advocate to NASA via the Physics of the Cosmos Program Analysis Group (PhysPAG). This is NASA's link to the community.

- Science gaps: https://pcos.gsfc.nasa.gov/physpag/science-gaps/science-gaps.php
- Technology gaps: https://pcos.gsfc.nasa.gov/news/2024/6_Technology_Gaps_Submissions_Due.php
- Join the Gamma-ray Science Interest Group (GammaSIG)
- https://pcos.gsfc.nasa.gov/sigs/grsig.php

GECCO The Galactic Explorer with a Coded Aperture Mask Compton Telescope

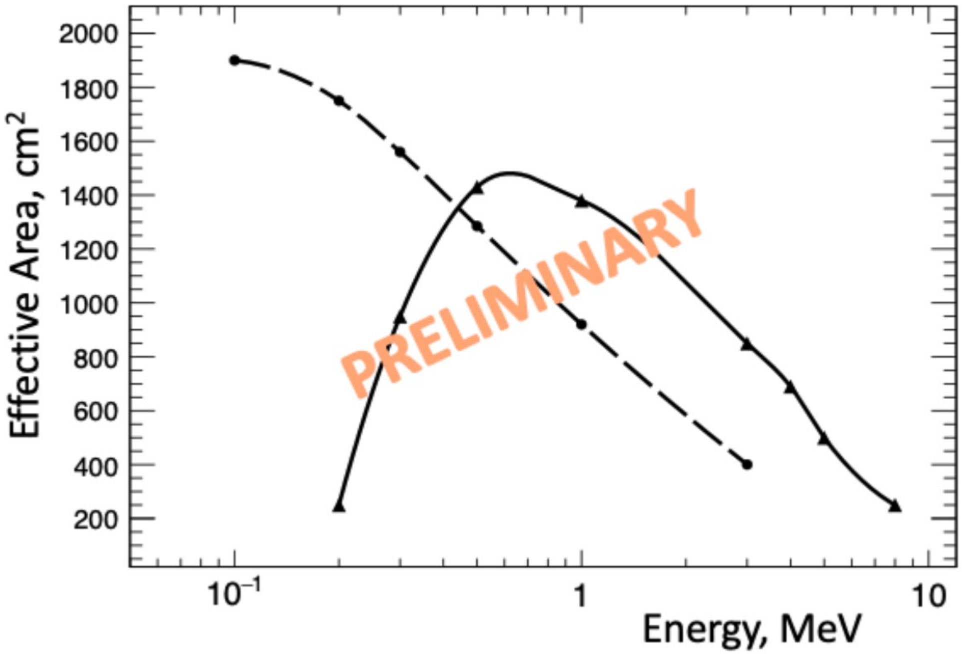




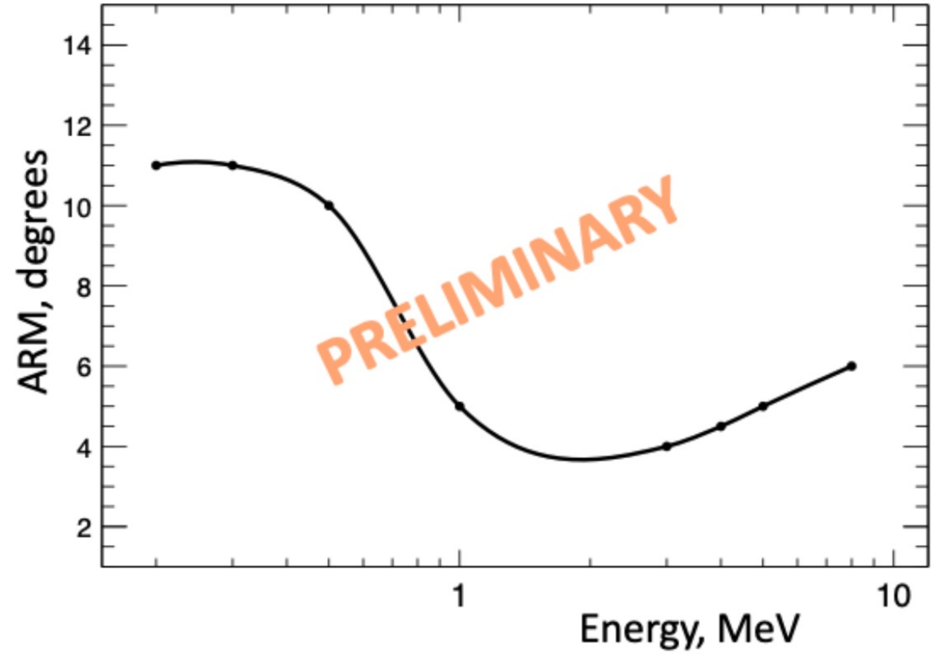
conceptual design   mask in stowed position   cutaway   diameter =90 cm

GECCO Team, JCAP07(2022)036 arXiv:2112.07190

GECCO The Galactic Explorer with a Coded Aperture Mask Compton Telescope



effective area for the CA mask imaging; the solid line is for Compton pointing used, and the dashed line is for classical mask analysis.

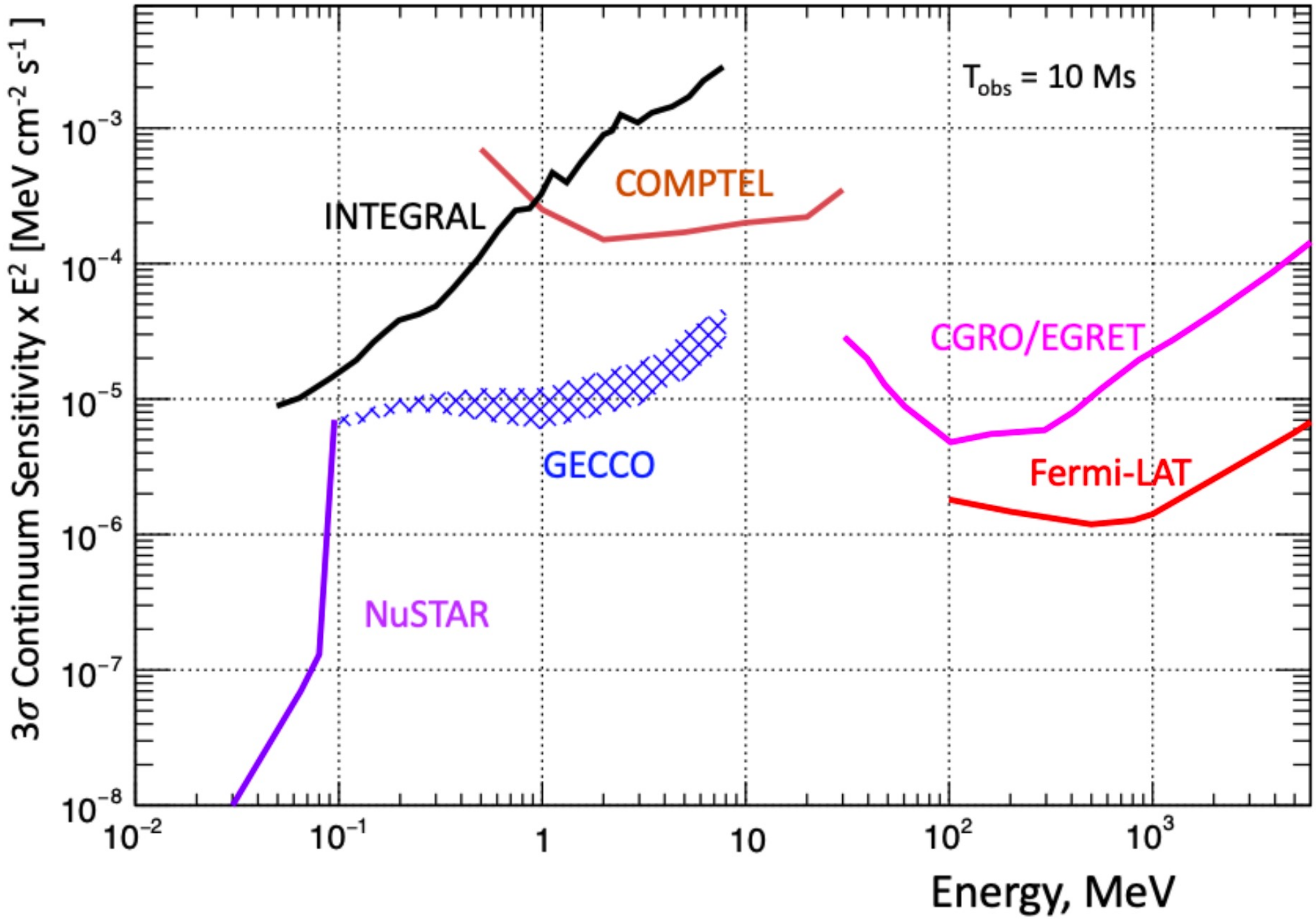


ARM (angular resolution measure) for the ImCal standalone Compton telescope.

GECCO Team, in preparation

GECCO The Galactic Explorer with a Coded Aperture Mask Compton Telescope

Sensitivity



GECCO Team, JCAP07(2022)036 arXiv:2112.07190

Summary

- AGILE ended data taking on 13 Feb 2024
- It was a very helpful mission for multimessanger observation
- Fermi is still in orbit but we need a new mission

with a focus in the low energy range (below 100 MeV)

- Because the flux is high it can be at the AGILE

scale (like Gamma-Light) i.e. also a National Space Agency (or two) can support the development and launch

thank you !