Gamma-Ray Space Missions

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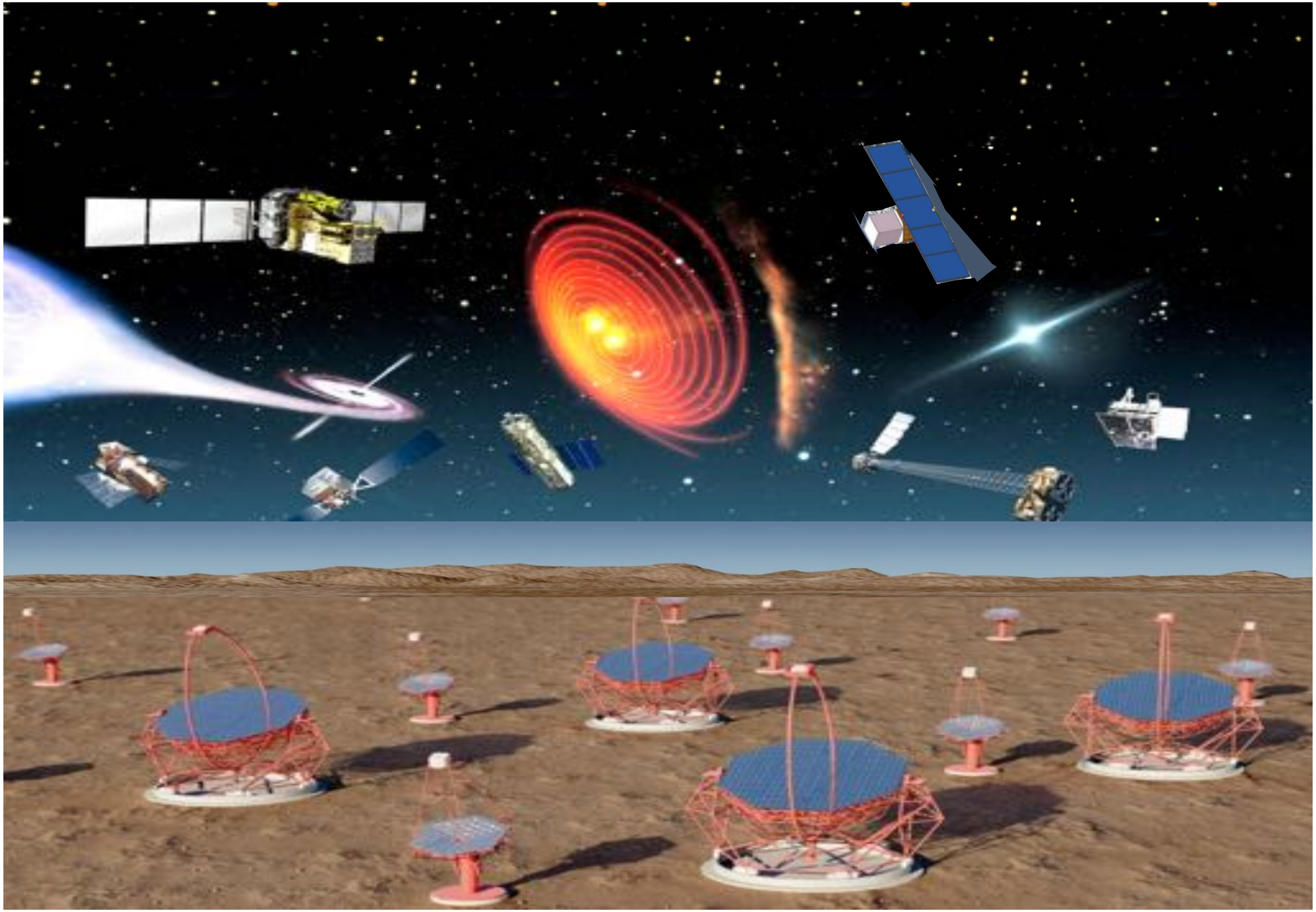
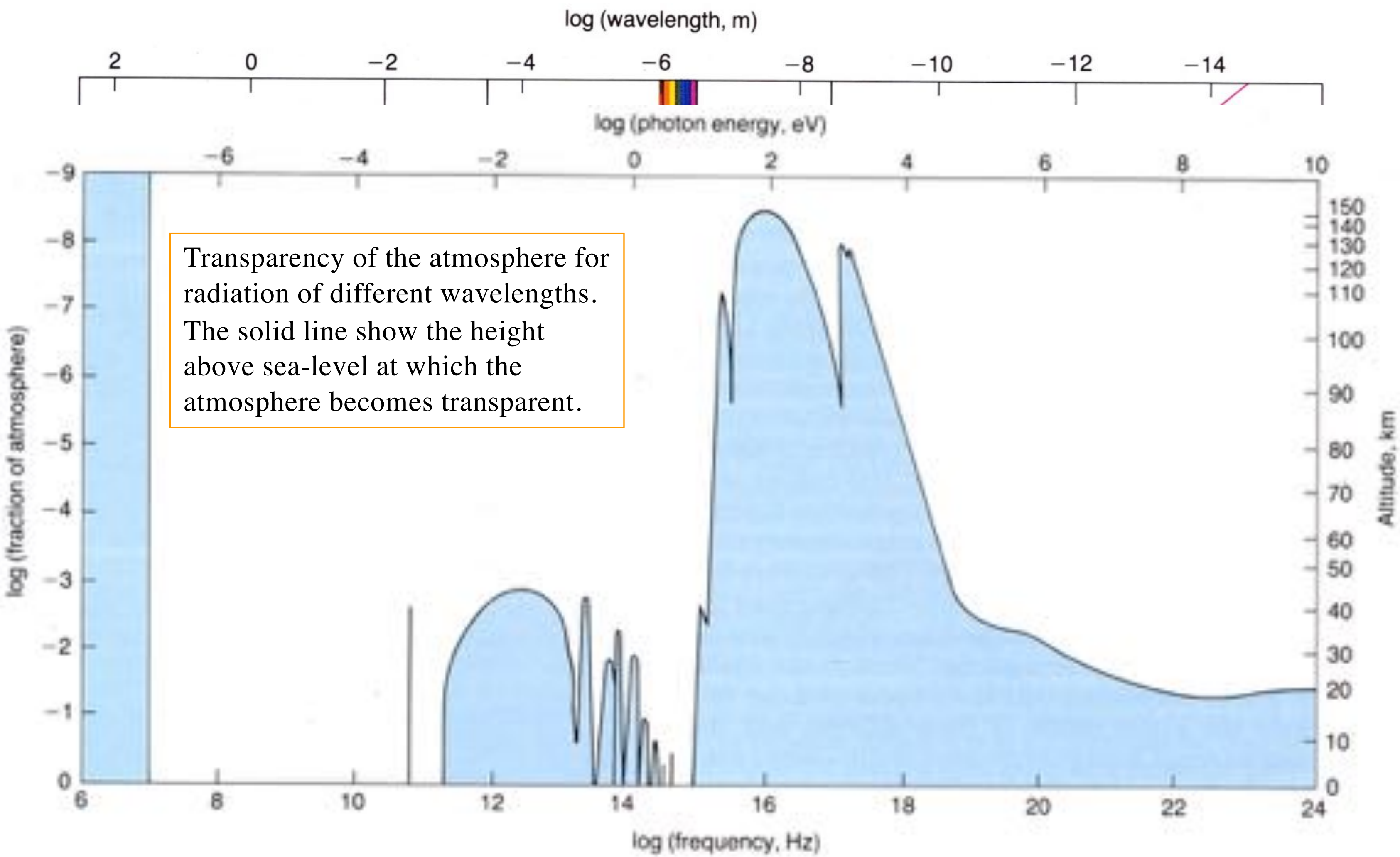
Max-Planck-Institute for Physics

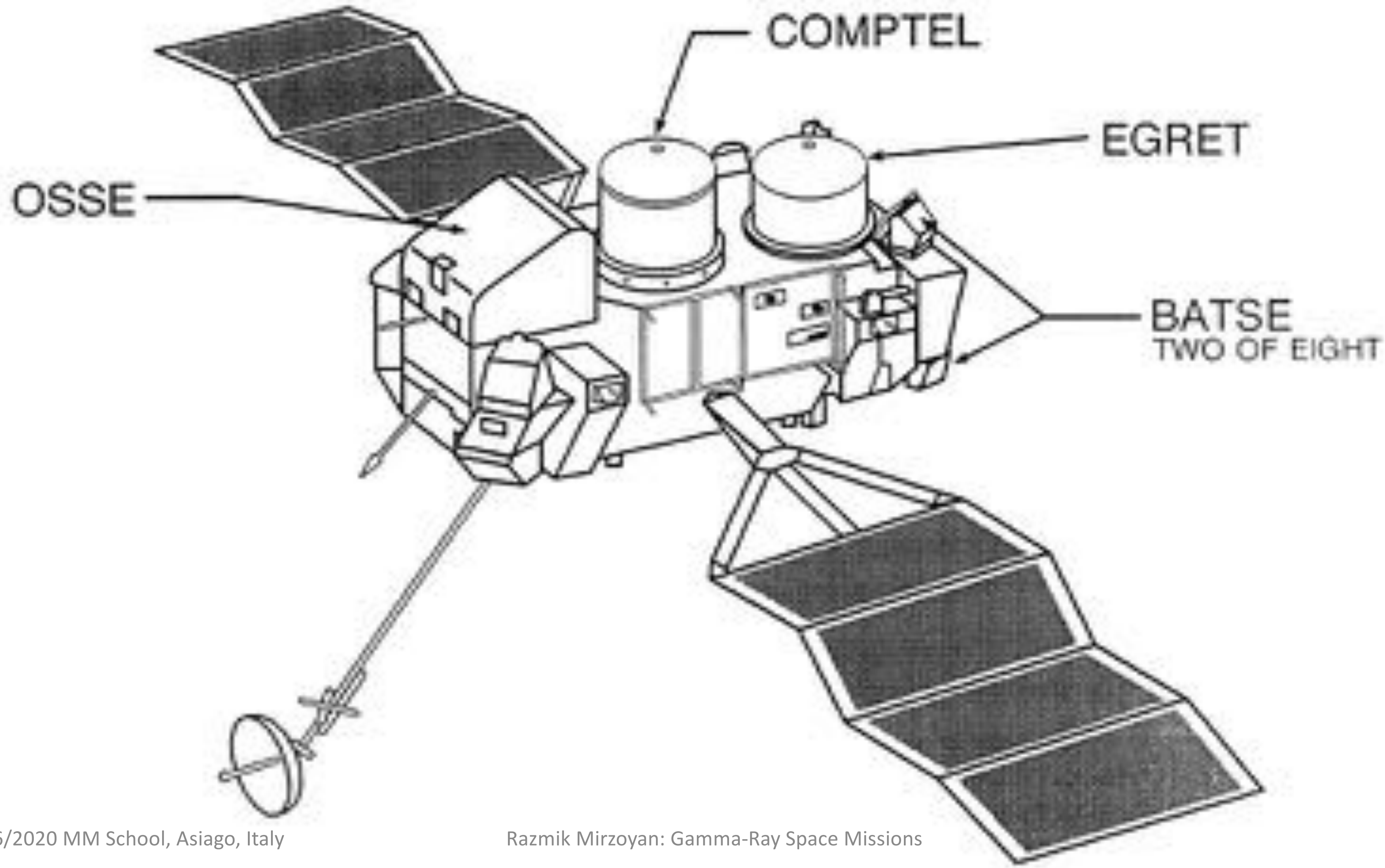
(Werner-Heisenberg-Institute)



Gamma ray attenuation



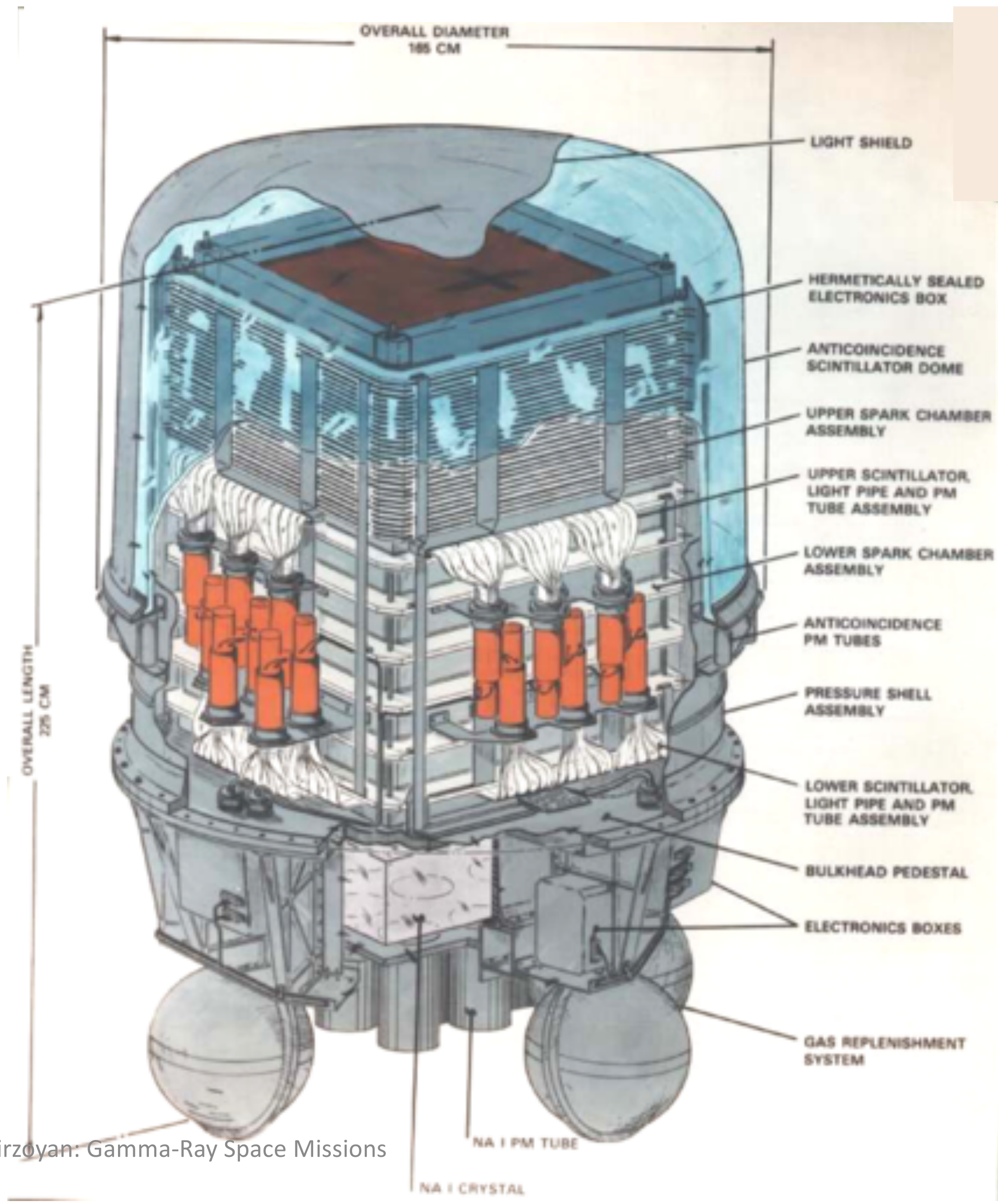
COMPTON OBSERVATORY INSTRUMENTS

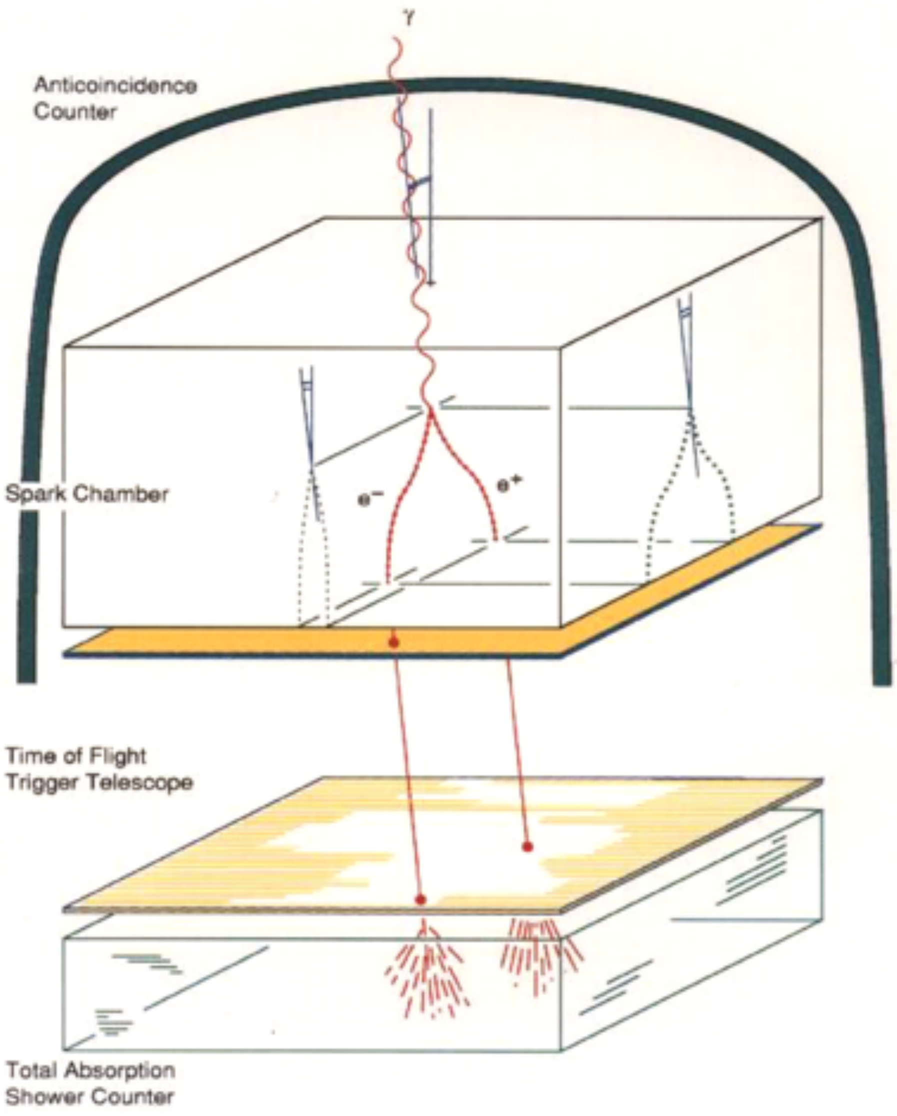


EGRET:the detector

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

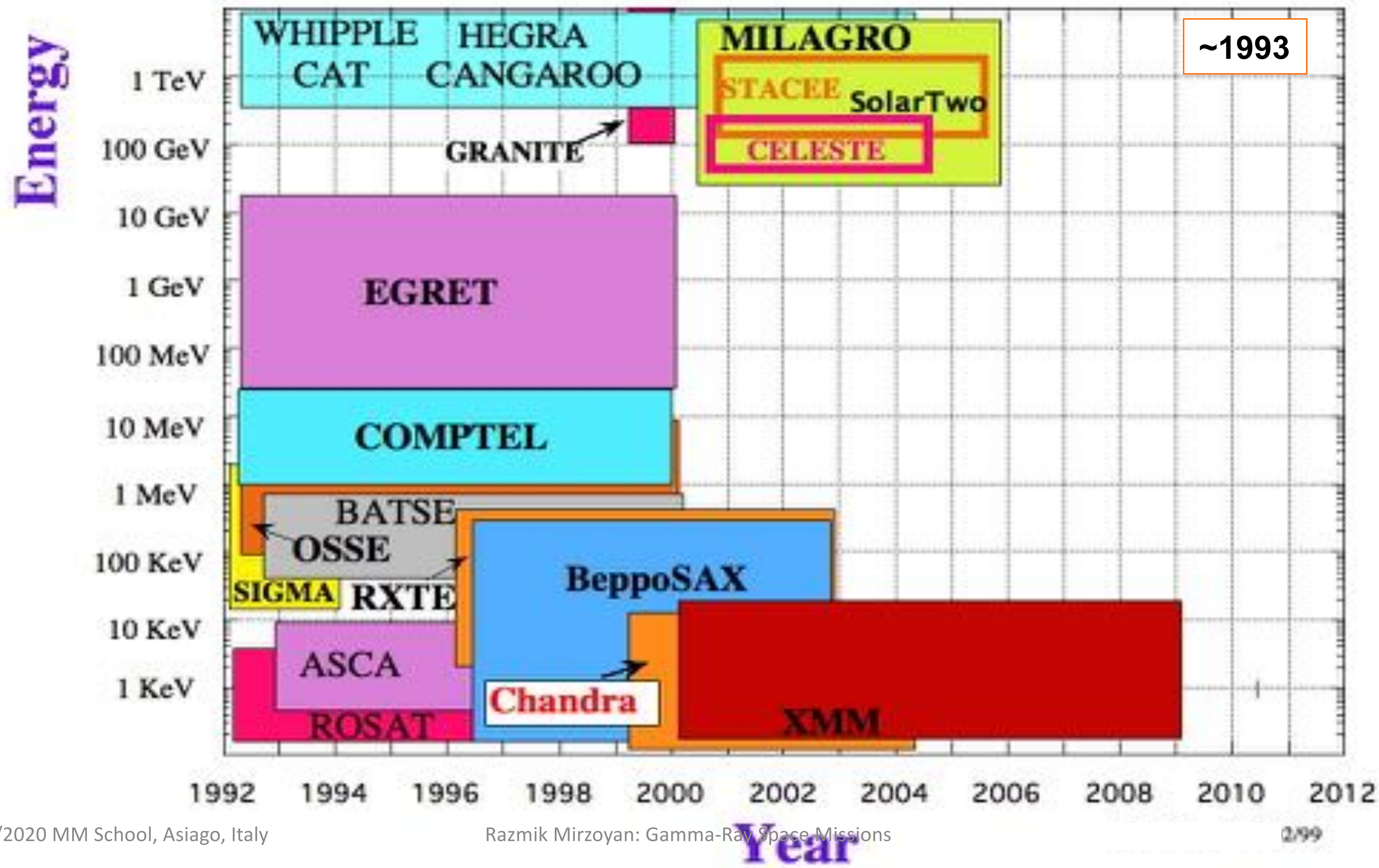
EGRET – Principle of gamma ray detection

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 electron positron pair in one of the thin tantalum (Ta) sheets interleaved between the 28 closely spaced spark chambers in the upper portion of the instrument.

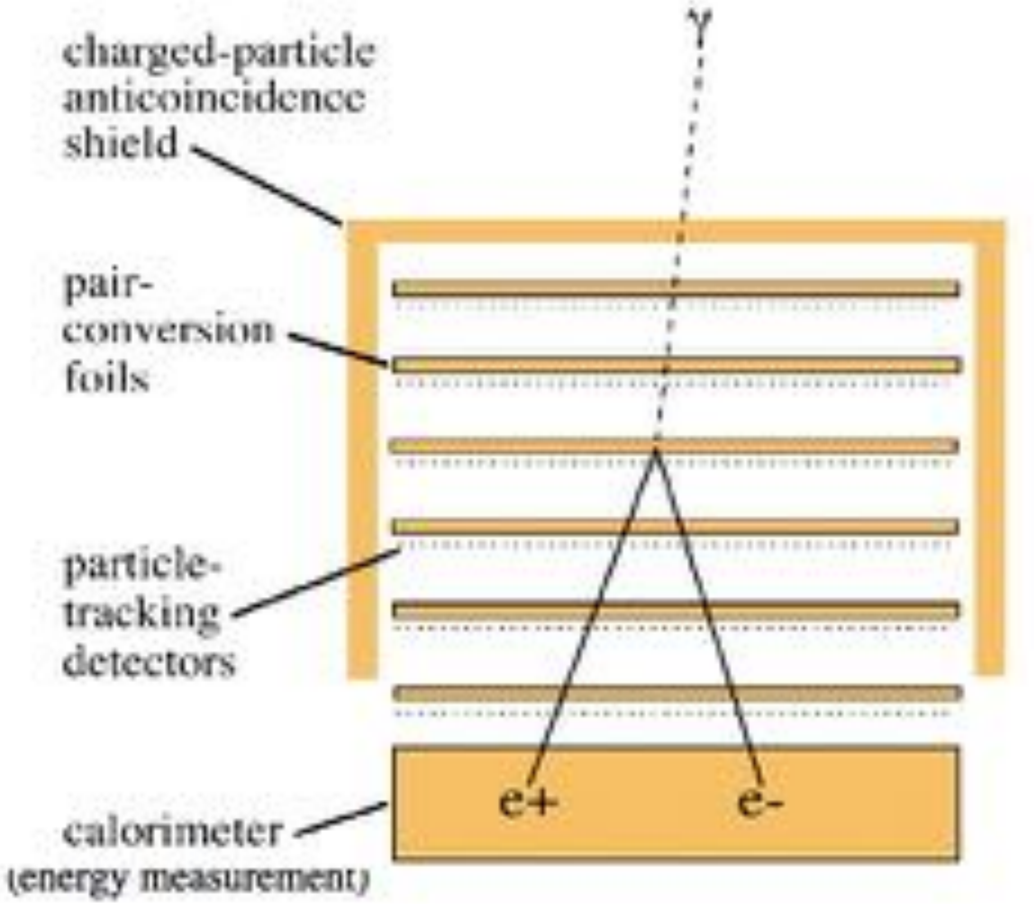
Below the conversion stack are two 4 x 4 arrays of plastic scintillation detector tiles spaced 60 cm apart which register the passage of charged particles. If the timeofflight delay indicates a downward moving particle which passed through a valid combination of upper and lower scintillator tiles, and 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.

High Energy Gamma Experiments



Elements of a pair-conversion telescope

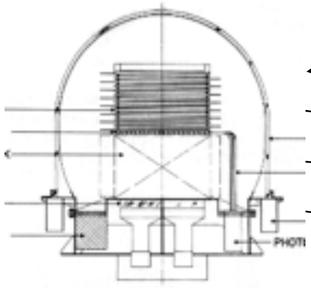


- photons materialize into matter-antimatter pairs:

  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

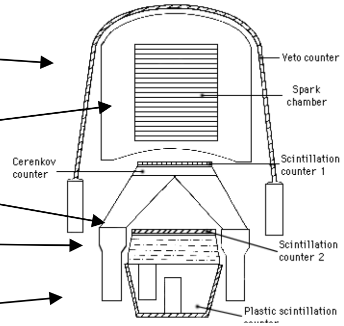
Anti-Coincidence Dome

Spark Chamber

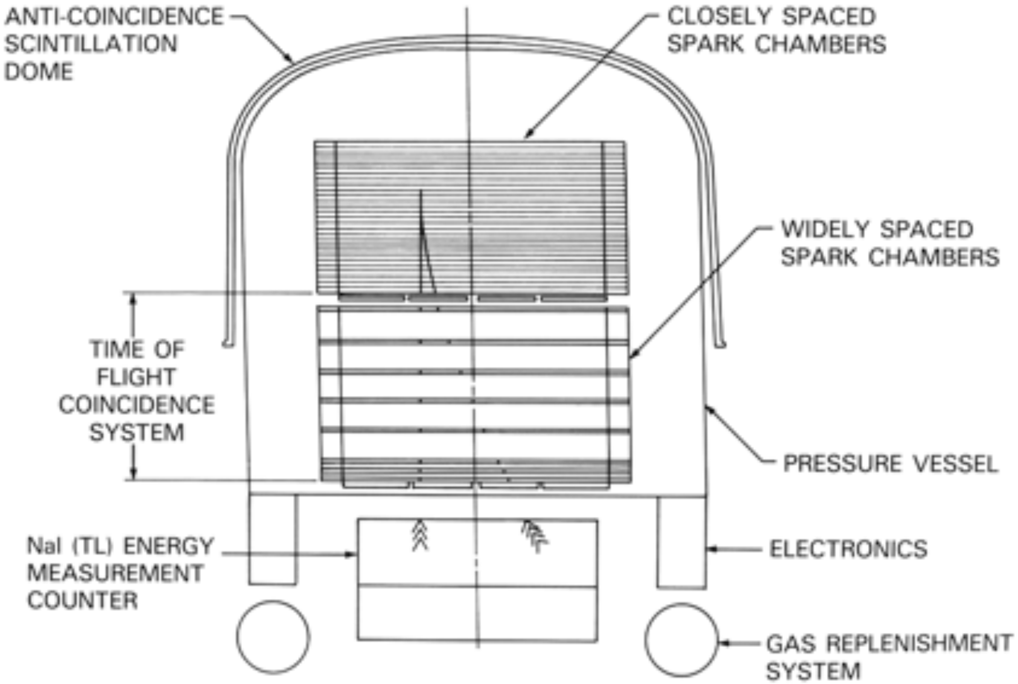
Trigger Telescope

Cerenkov Counter

Energy Calorimeter



Cos-B
8/1975-4/1982

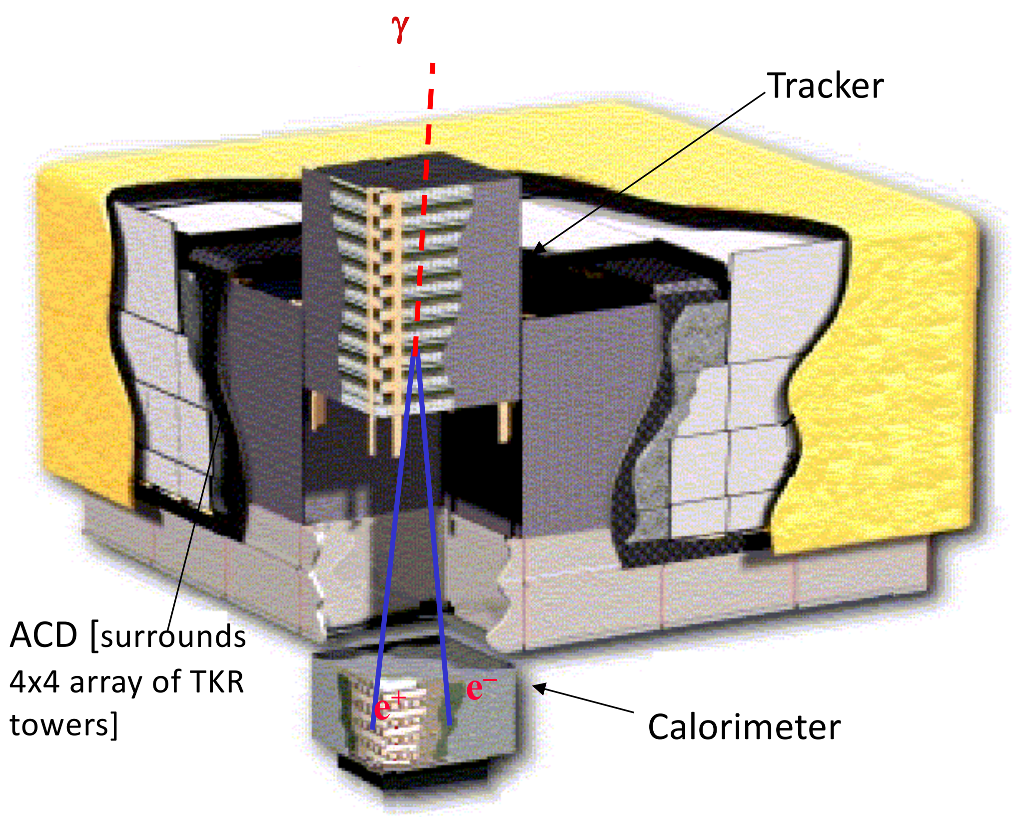


EGRET
4/1991-1999


AGILE
23 April 2007
Happy 11th Birthday Agile !!

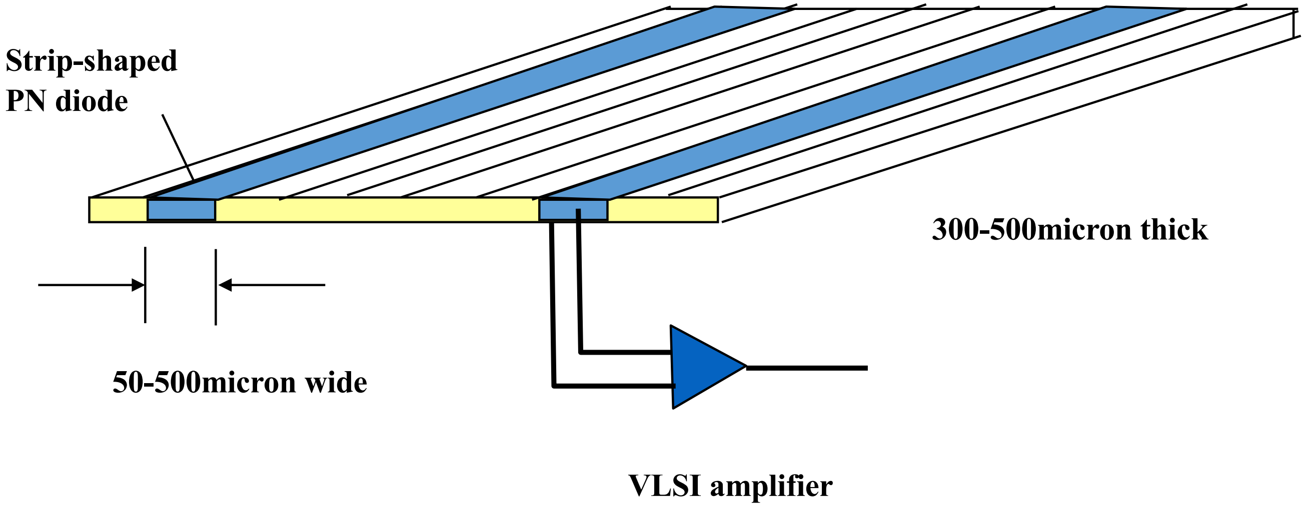
Fermi LAT: A Telescope Without Lenses

- 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.



New Detector Technology

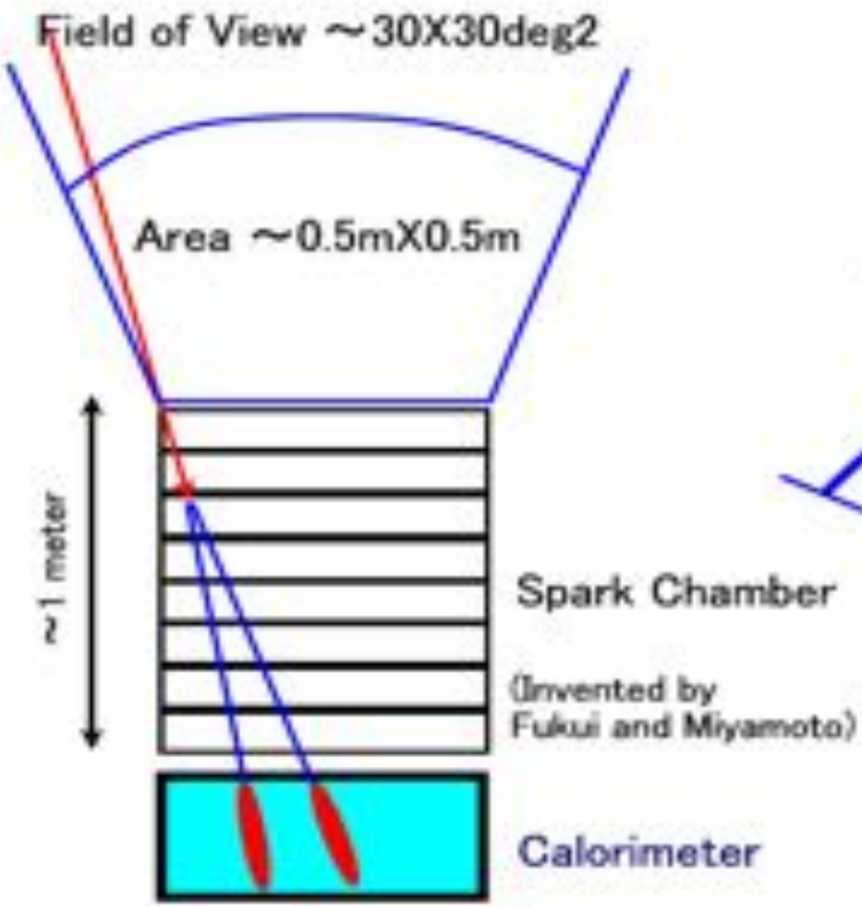
- <u>Silicon strip detector</u>



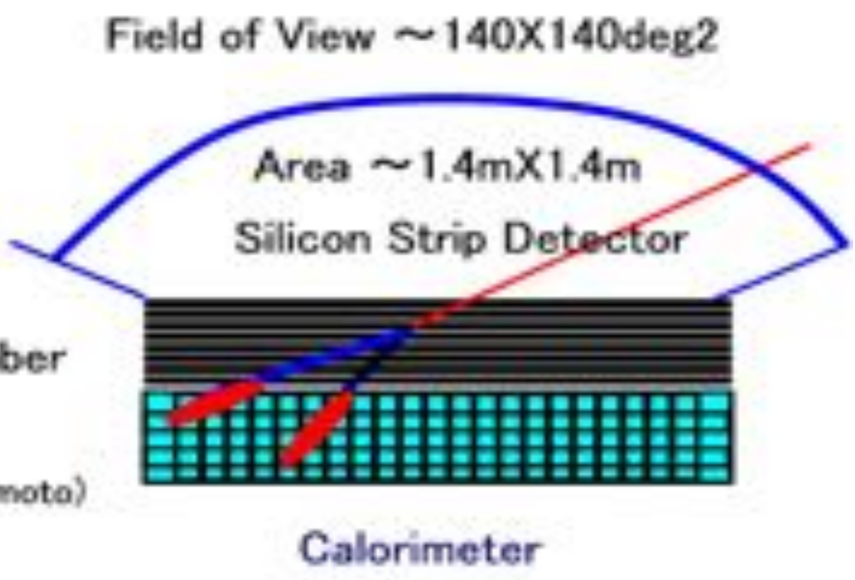
Stable particle tracker that allows micron-level tracking of gamma-rays

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)

EGRET(Spark Chamber) VS. Fermi LAT (Silicon Strip Detector)

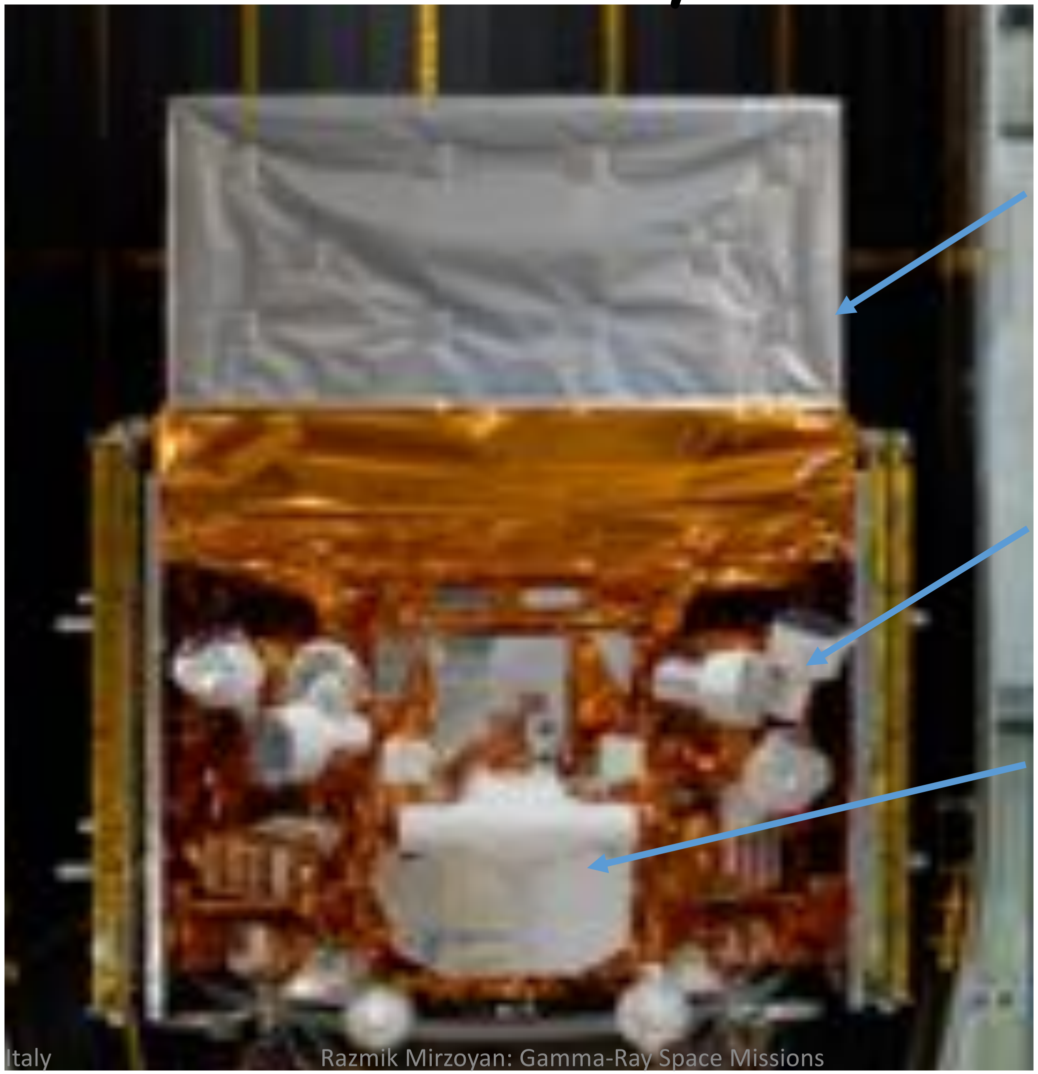


EGRET on Compton GRO (1991-2000)



Fermi Large Area Telescope (2008-2018)

The Fermi Observatory

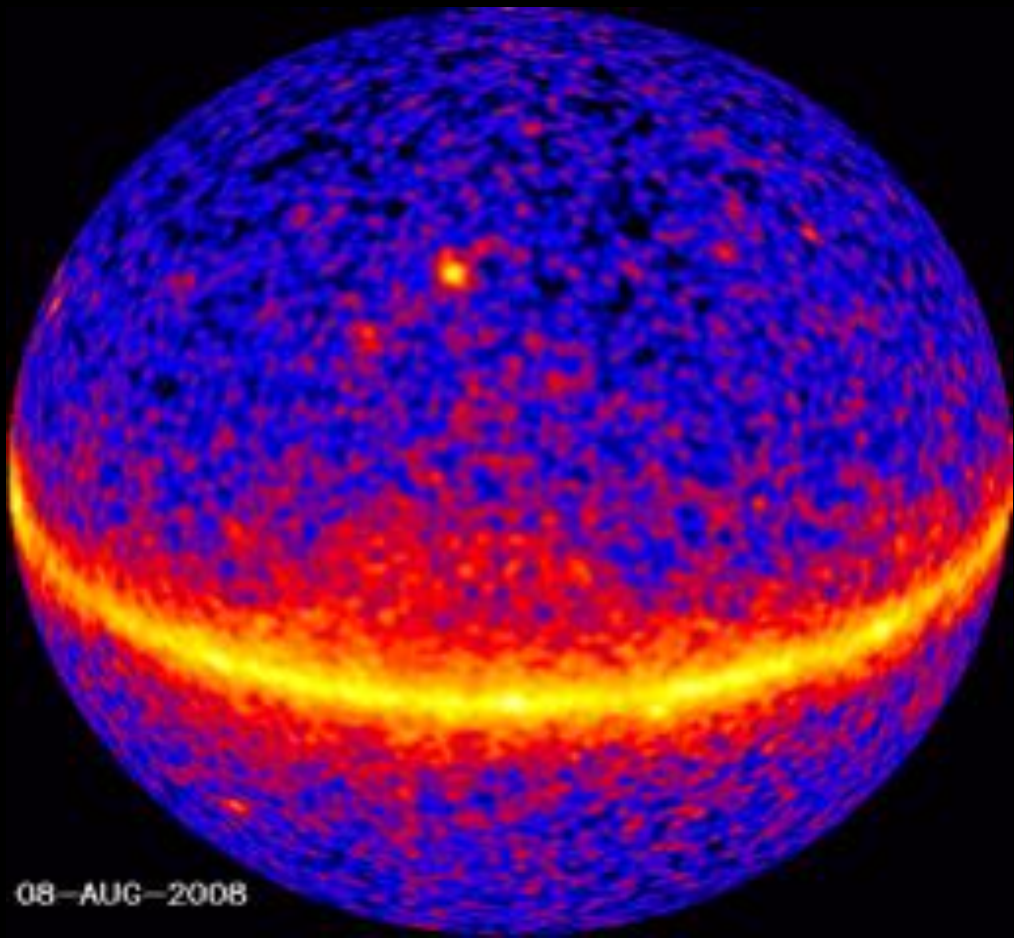


LAT
Large
Area
Telescope

GBM
Sodium Iodide
Detector

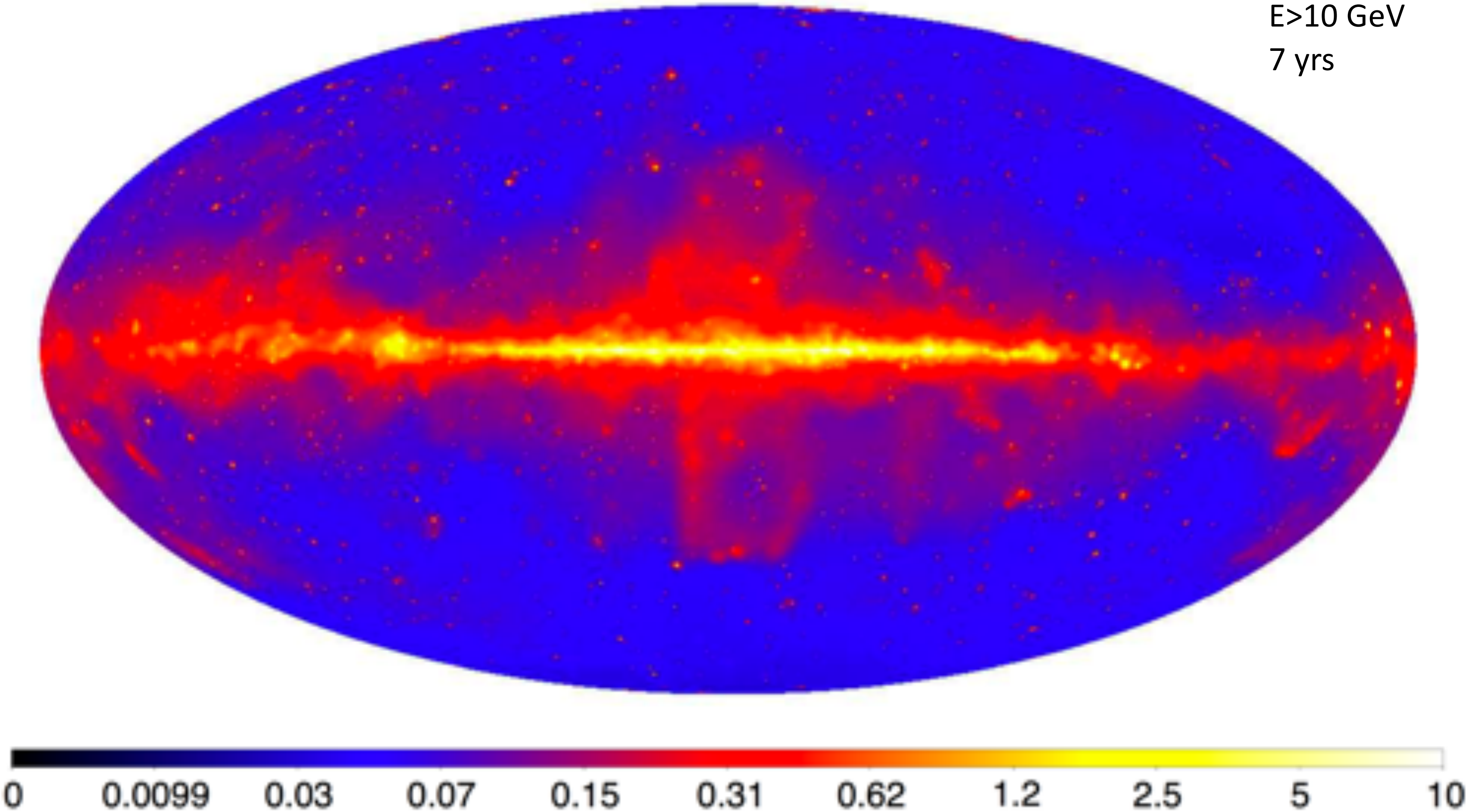
GBM
Bismuth
Germanate
Detector

Daily Gamma-ray Sky



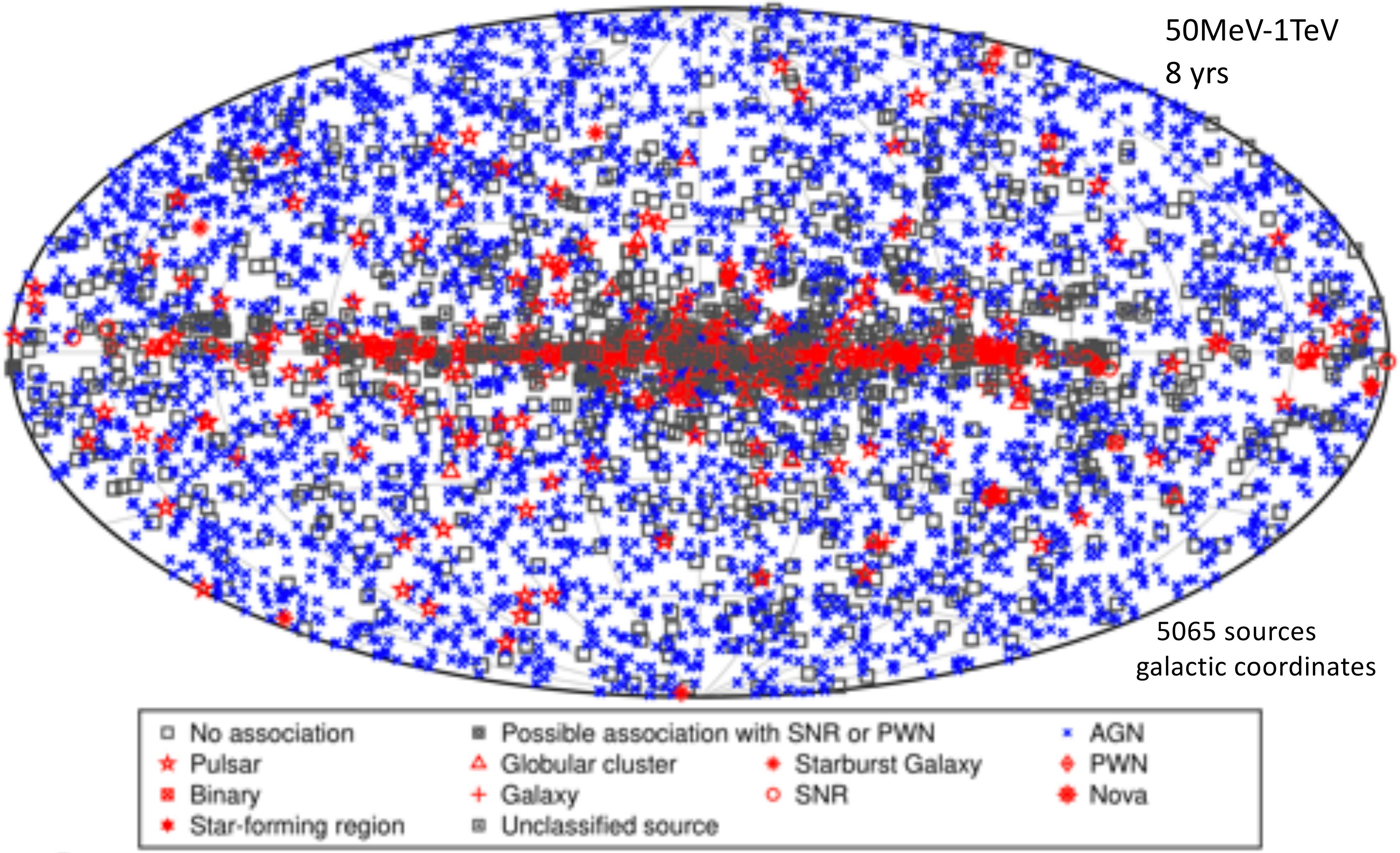
The sky in gamma-rays

E>10 GeV
7 yrs



M.Ackermann et al. [Fermi Coll.] 3FHL: The Third Catalog of Hard Fermi-LAT Sources ApJS 2017 232 arXiv:1702.00664

The sky in gamma-rays 4^{th} source catalog

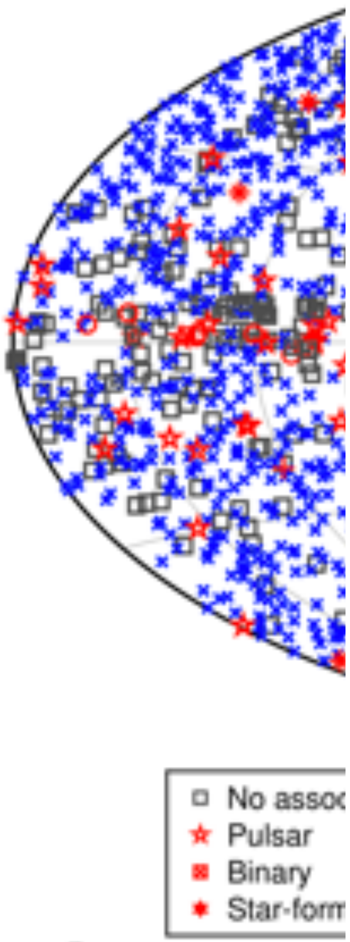


50MeV-1TeV
8 yrs

5065 sources
galactic coordinates

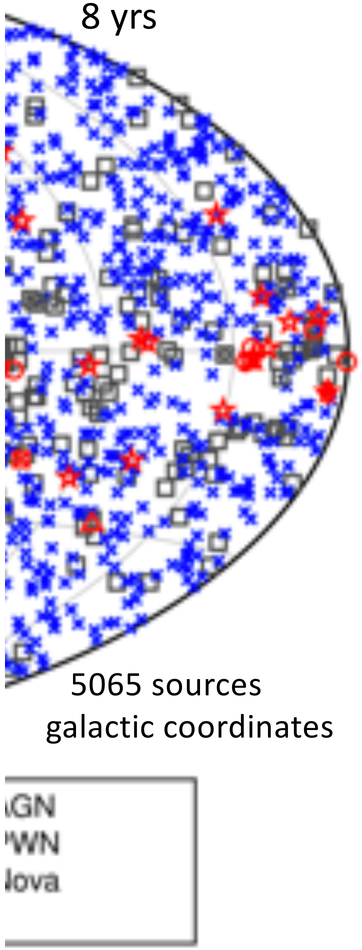
Fermi Fouth Source Catalog, arXiv:1902.10045_v3

The sky in gamma-rays 4th source catalog



Description	Identified		Associated	
	Designator	Number	Designator	Number
Pulsar, identified by pulsations	PSR	229	...	...
Pulsar, no pulsations seen in LAT yet	...	...	psr	10
Pulsar wind nebula	PWN	12	pwn	6
Supernova remnant	SNR	24	snr	16
Supernova remnant / Pulsar wind nebula	SPP	0	spp	90
Globular cluster	GLC	0	glc	30
Star-forming region	SFR	3	sfr	0
High-mass binary	HMB	5	hmb	3
Low-mass binary	LMB	1	lmb	1
Binary	BIN	1	bin	0
Nova	NOV	1	nov	0
BL Lac type of blazar	BLL	22	bll	1094
FSRQ type of blazar	FSRQ	42	fsrq	644
Radio galaxy	RDG	6	rdg	36
Non-blazar active galaxy	AGN	1	agn	17
Steep spectrum radio quasar	SSRQ	0	ssrq	2
Compact Steep Spectrum radio source	CSS	0	css	5
Blazar candidate of uncertain type	BCU	3	bcu	1327
Narrow line Seyfert 1	NLSY1	4	nlsy1	5
Seyfert galaxy	SEY	0	sey	1
Starburst galaxy	SBG	0	sbg	7
Normal galaxy (or part)	GAL	2	gal	2
Unknown	UNK	0	unk	92
Total	...	356	...	3388
Unassociated	...	...	...	1323

NOTE—The designation 'spp' indicates potential association with SNR or PWN. Designations shown in capital letters are firm identifications; lower case letters indicate associations.

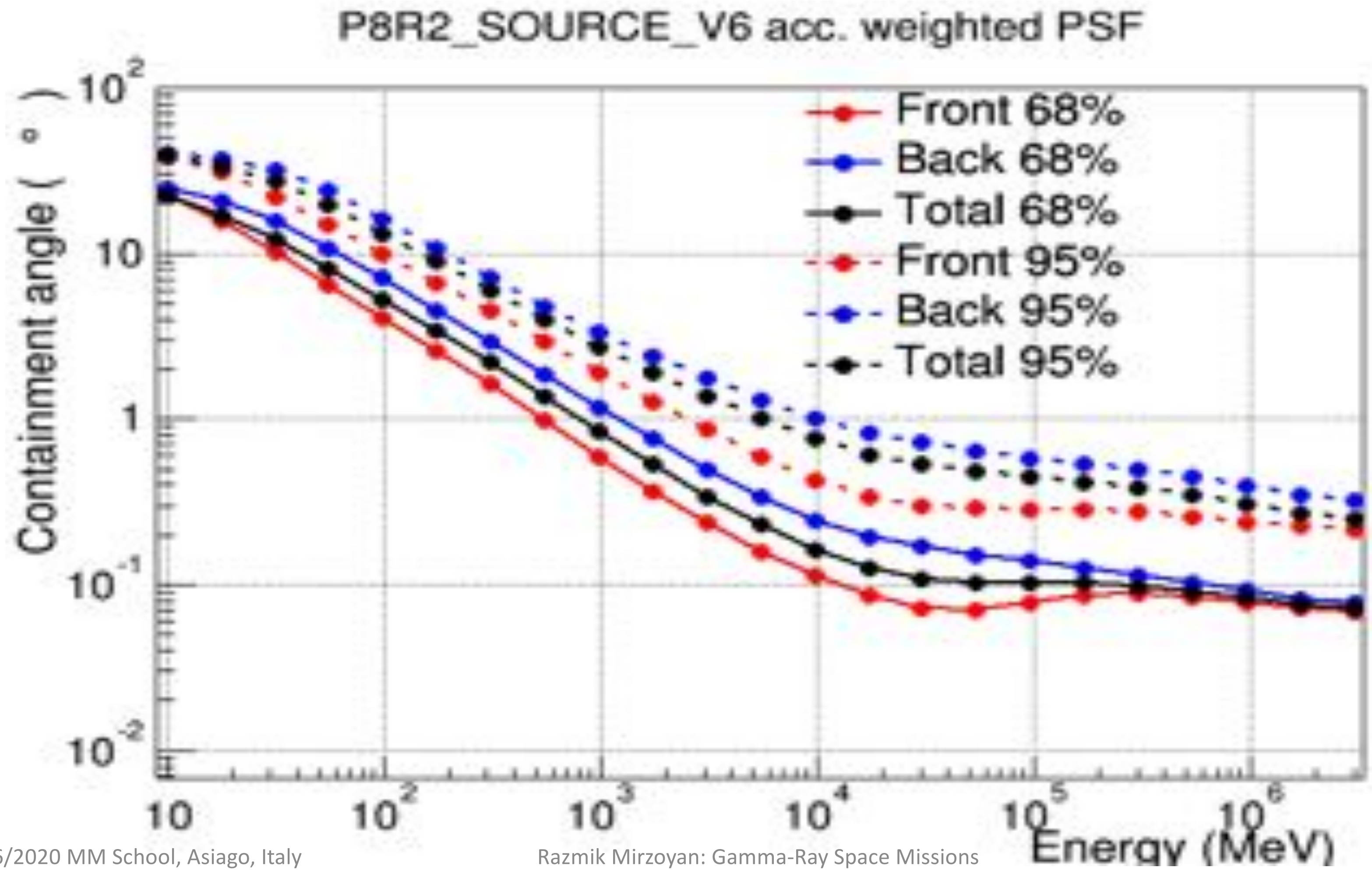


50MeV-1TeV
8 yrs

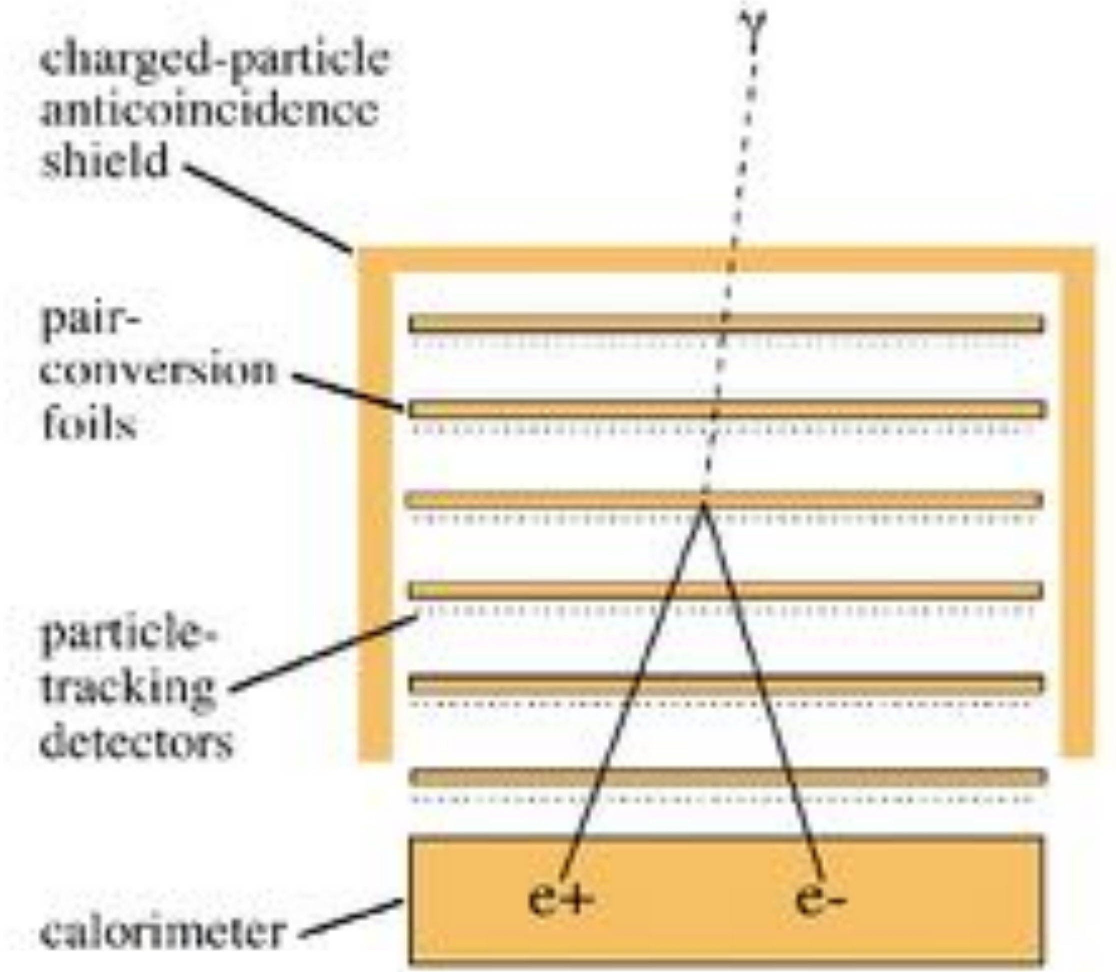
5065 sources
galactic coordinates

Fermi Fouth Source Catalog, arXiv:1902.10045_v3

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



Elements of a pair-conversion telescope



(energy measurement)

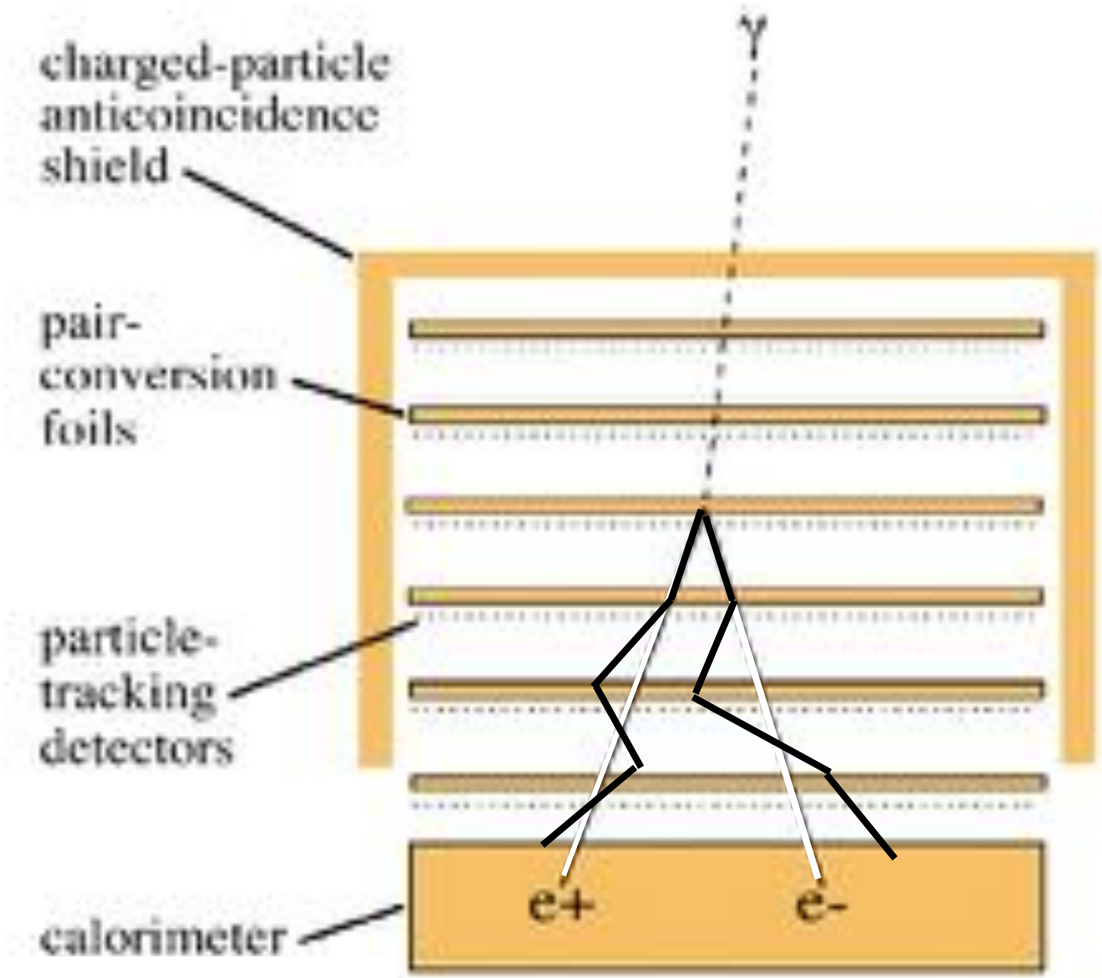
- photons materialize into matter-antimatter pairs:

  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)



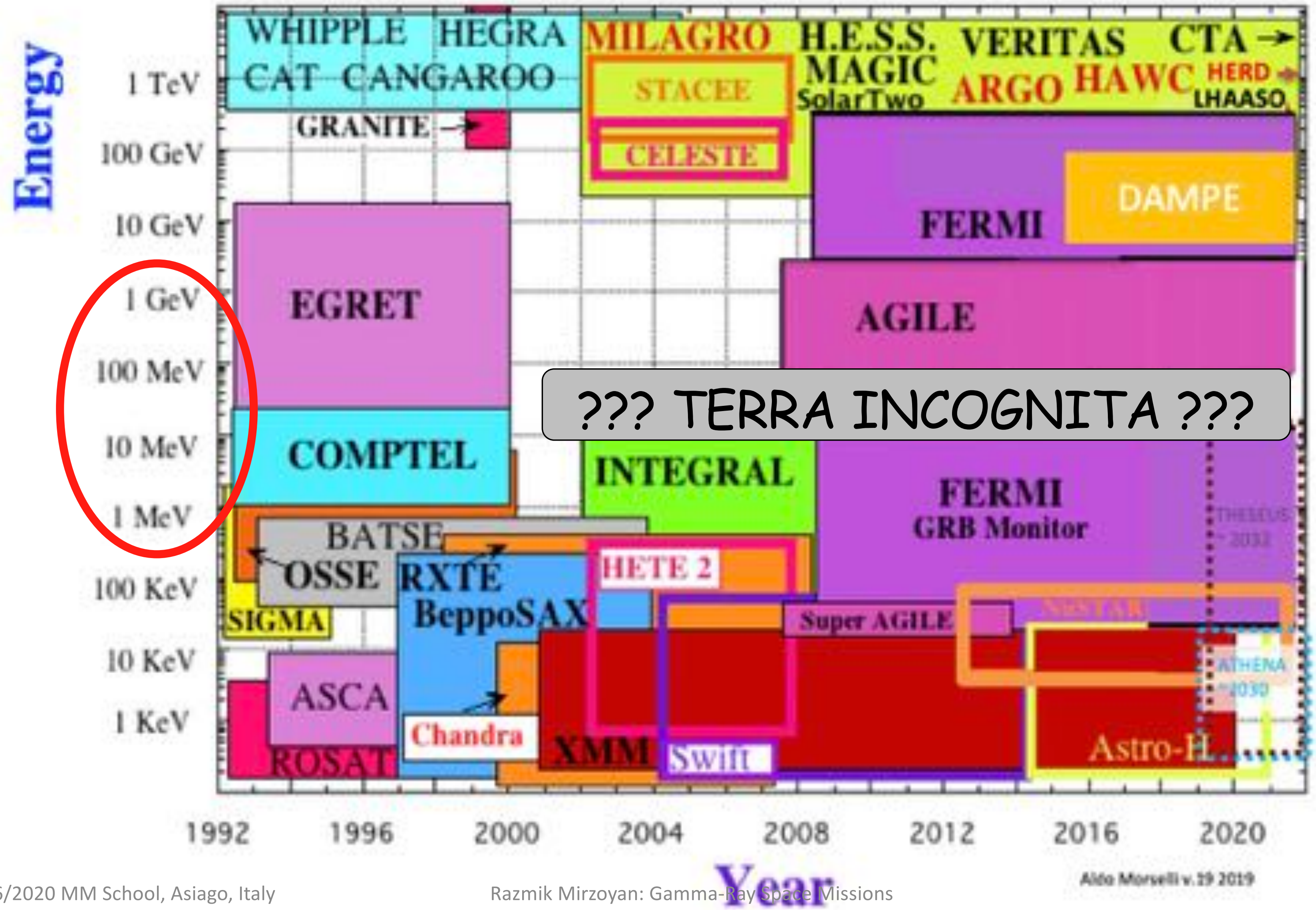
(energy measurement)

- photons materialize into matter-antimatter pairs:

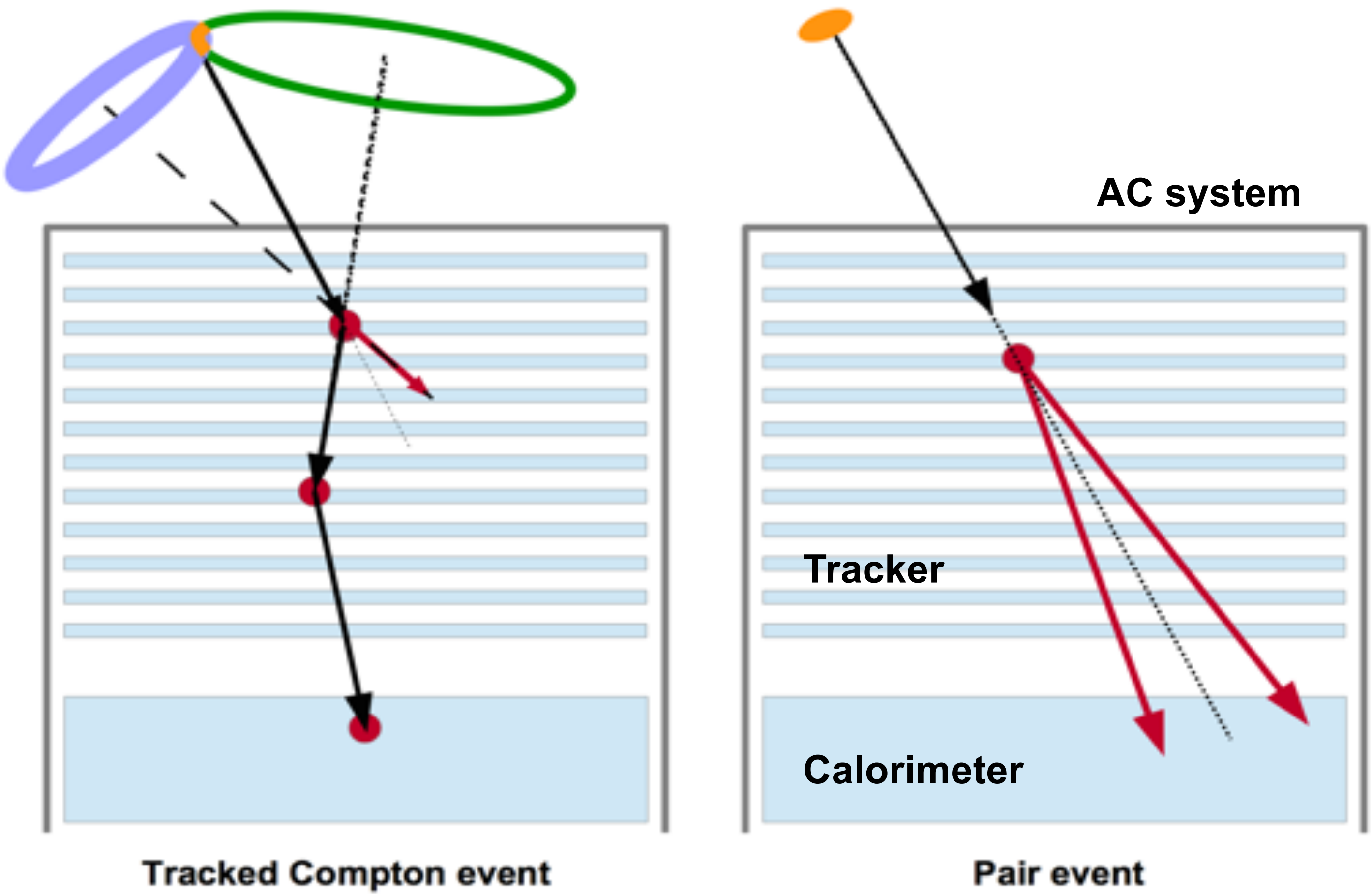
  E_γ --> $m_{e+}c^2 + m_{e-}c^2$

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

m

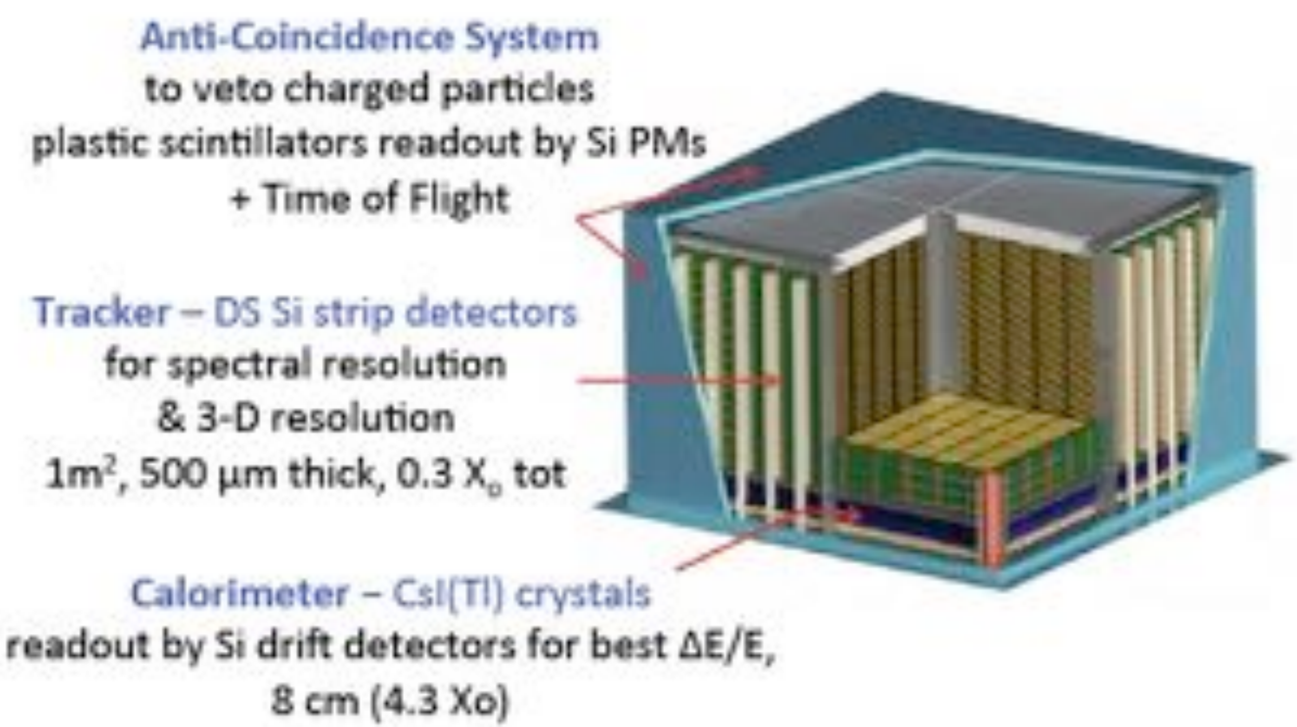

??? TERRA INCOGNITA ???
Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE
HEGRA
CAT
CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
ARGO
HAWC
CTA
HERD
LHAASO
FERMI
DAMPE
EGRET
AGILE
COMPTEL
INTEGRAL
FERMI
GRB Monitor
BATSE
OSSE
SIGMA
RXTE
BeppoSAX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

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 (213 pages)

e-ASTROGAM



ASTROGAM is made of 56 Silicon planes, about 1 m^2 each, which record Compton interactions and pair production events induced by cosmic photons, by an anticoincidence detector and by a calorimeter.

Core science motivation

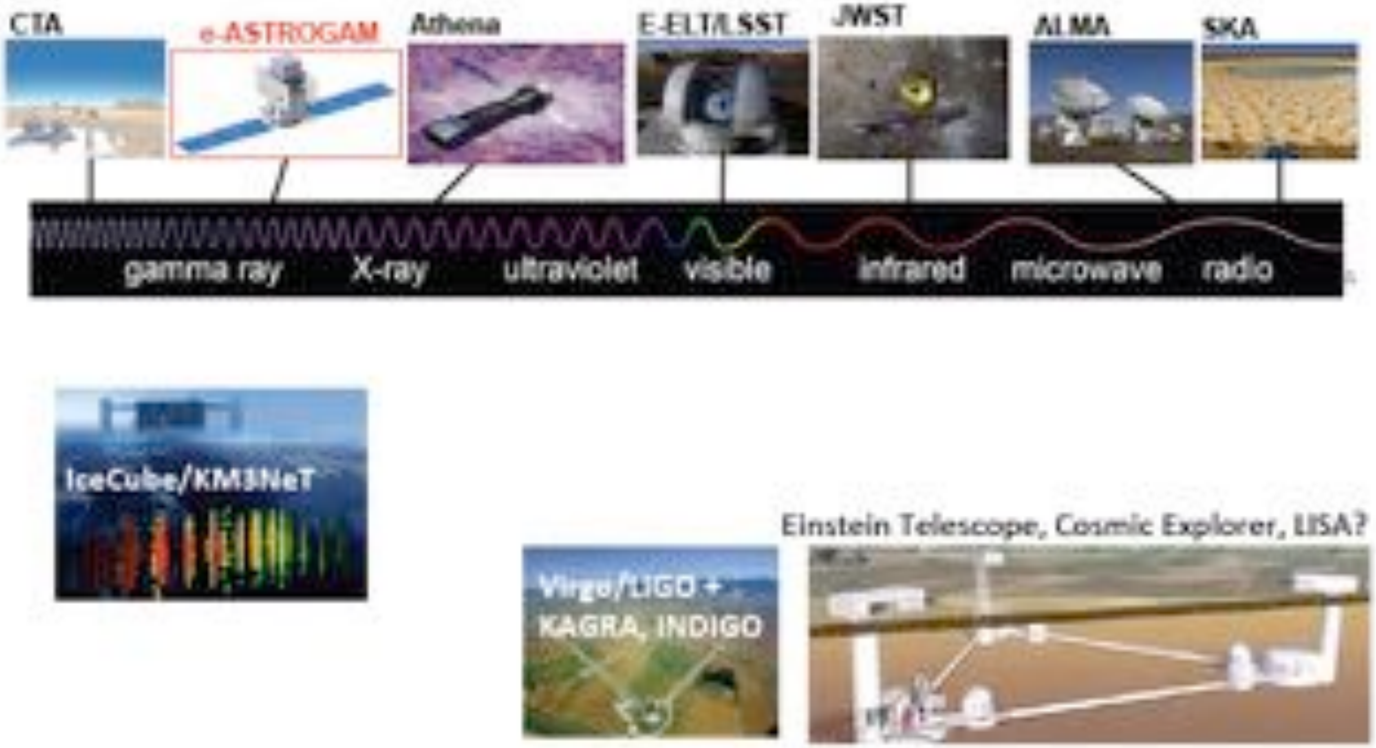
1. Processes at the heart of the extreme Universe (AGNs, GRBs, microquasars): prospects for the Astronomy of the 2030s
   - Multi-wavelength, multi-messenger coverage of the sky (with SKA, JWST, E-ELT, Athena, CTA, ν and GW detectors…), w/ special focus on transient phenomena

2. The origin of high-energy particles and impact to galaxy evolution, from cosmic rays to antimatter

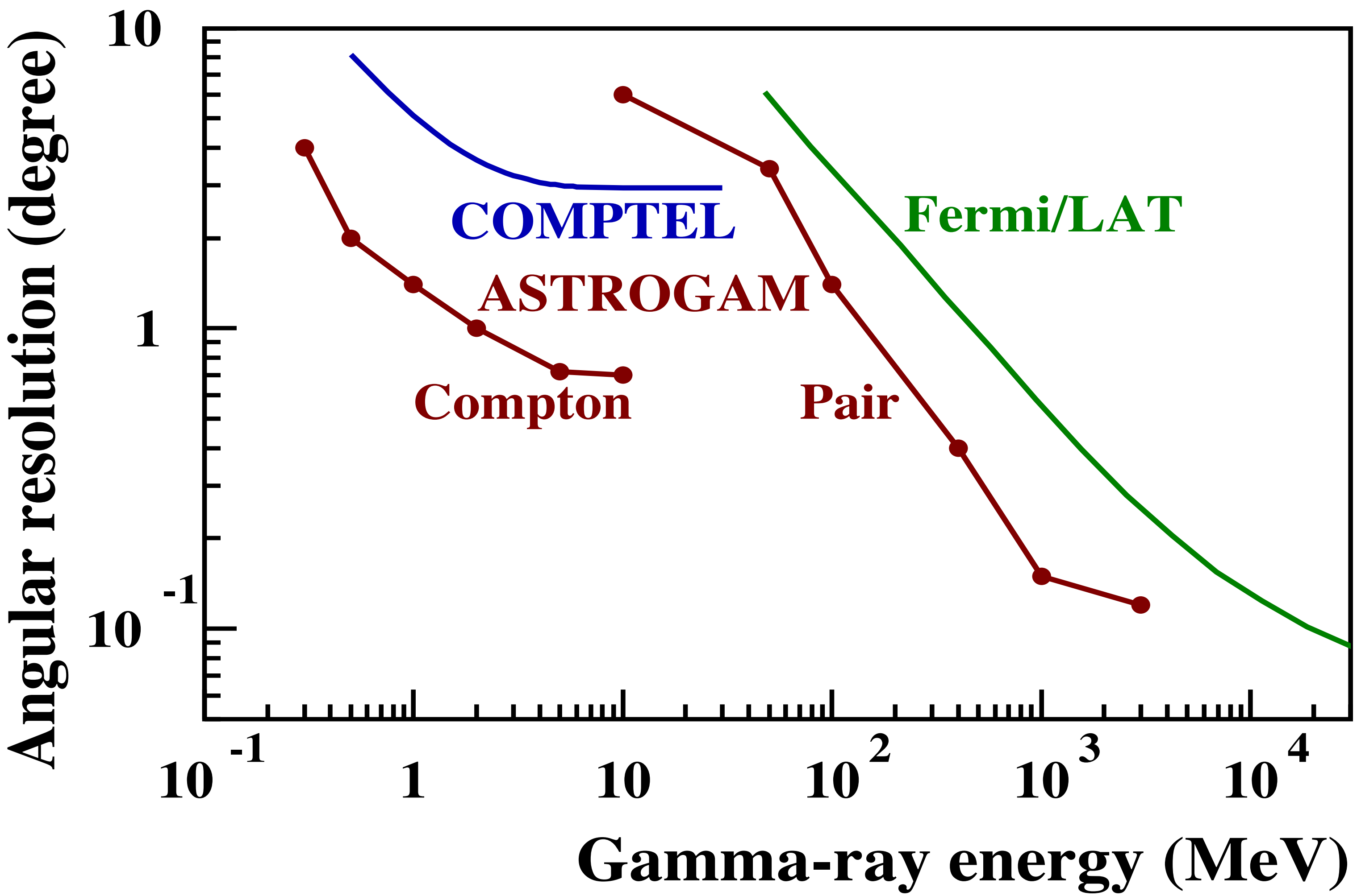
3. Nucleosynthesis and the chemical enrichment of our Galaxy

A unique Observatory integrated with future astrophysics

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

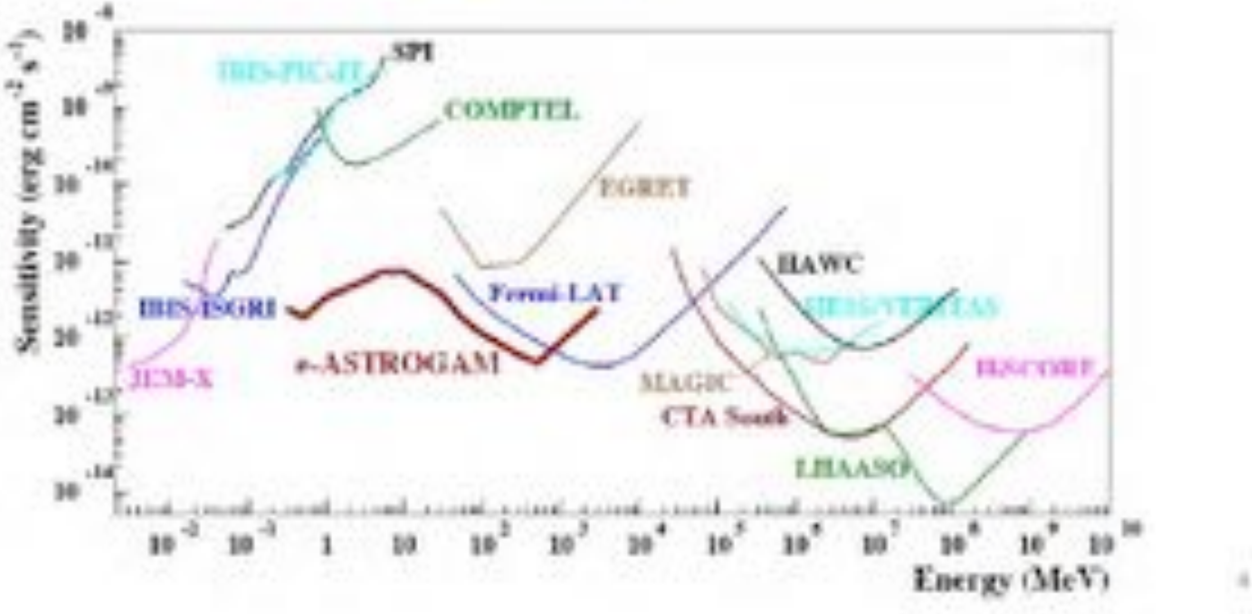


ASTROGAM Angular Resolution



e-ASTROGAM Performance assessment

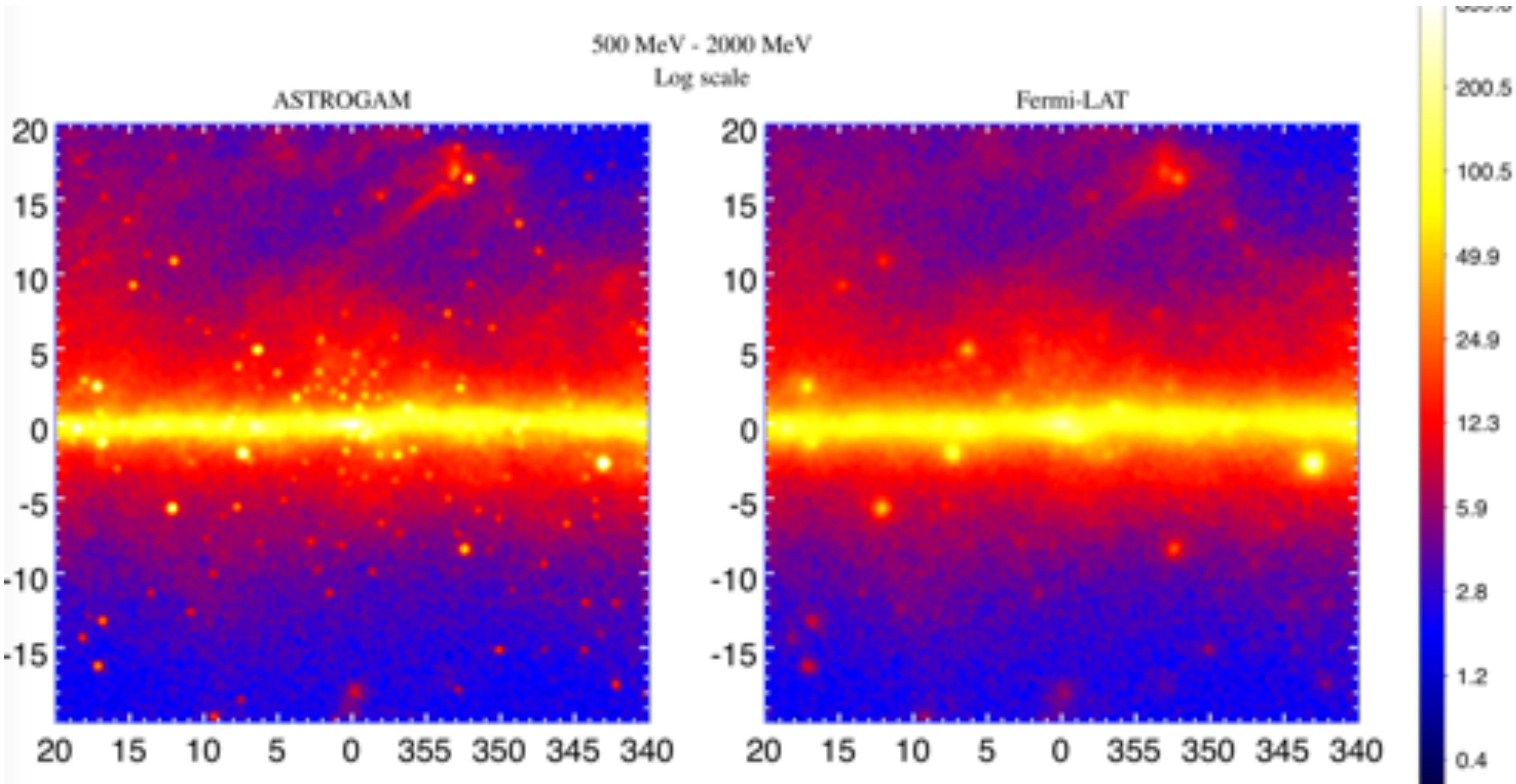
1. Excellent sensitivity in the 1-50 MeV energy range
2. γ-ray polarization for both transient and steady sources
3. Unprecedented angular resolution (e.g., ~ 10' at 1 GeV)
4. Large field of view (~ 2.5 sr) ⇒ efficient monitoring of the γ-ray sky
5. Sub-millisecond trigger and alert capability for transients



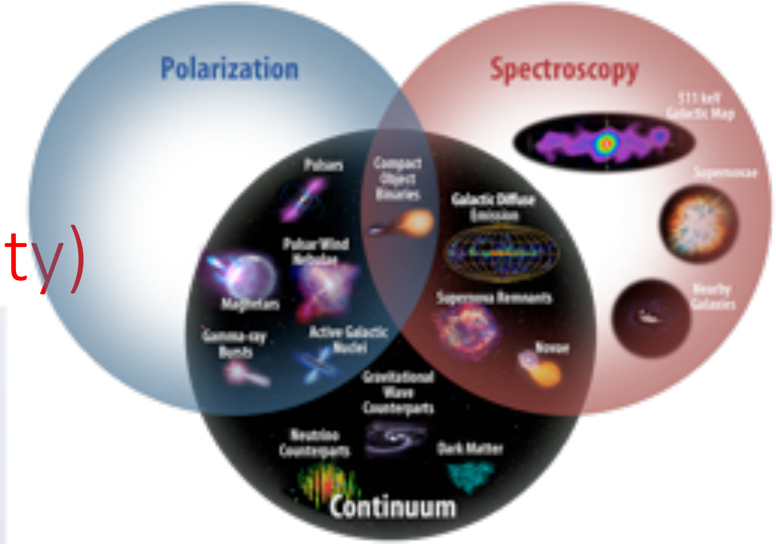
e-Astrogam: arXiv:1611.02232

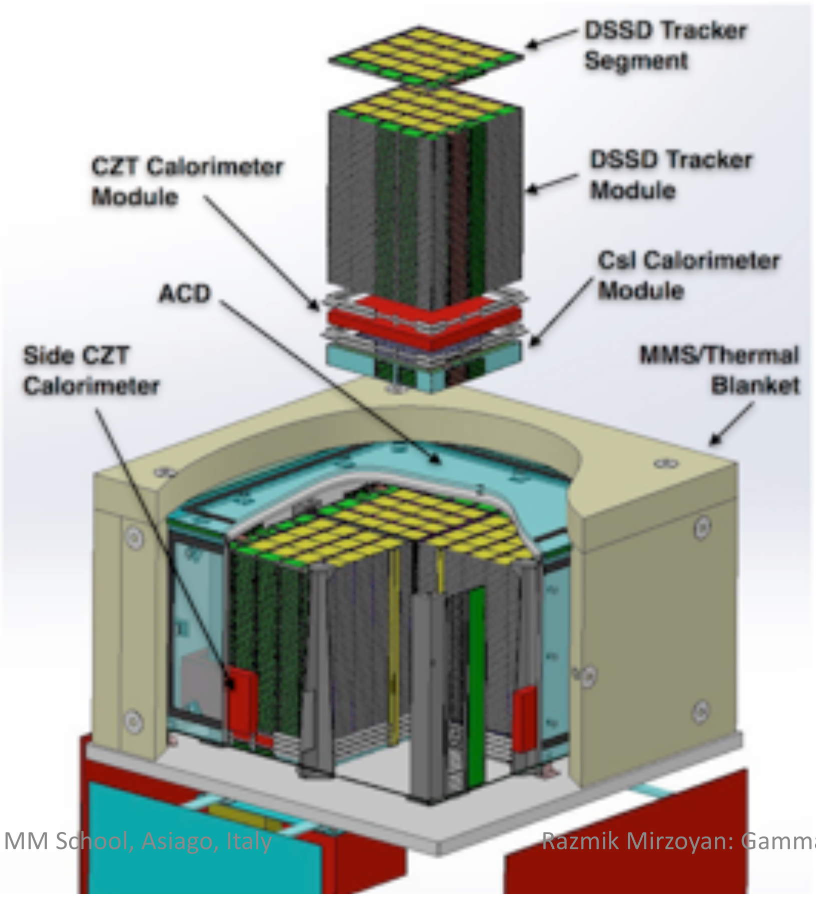
Fermi PSF Pass7 rep v15 source

Galactic Center Region 0.5-2 GeV



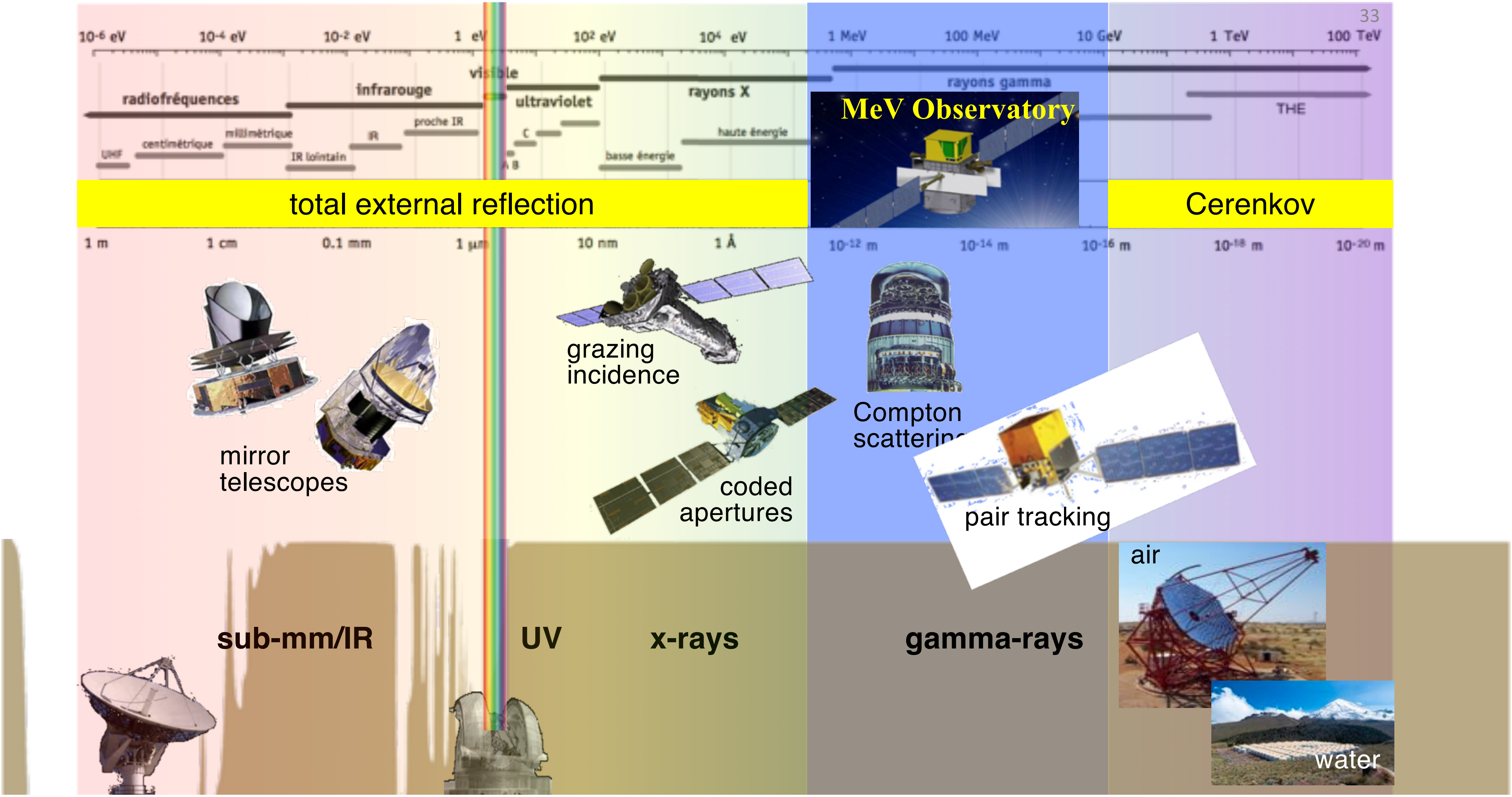
A sister experiment: AMEGO (NASA)
(two brands, one community)



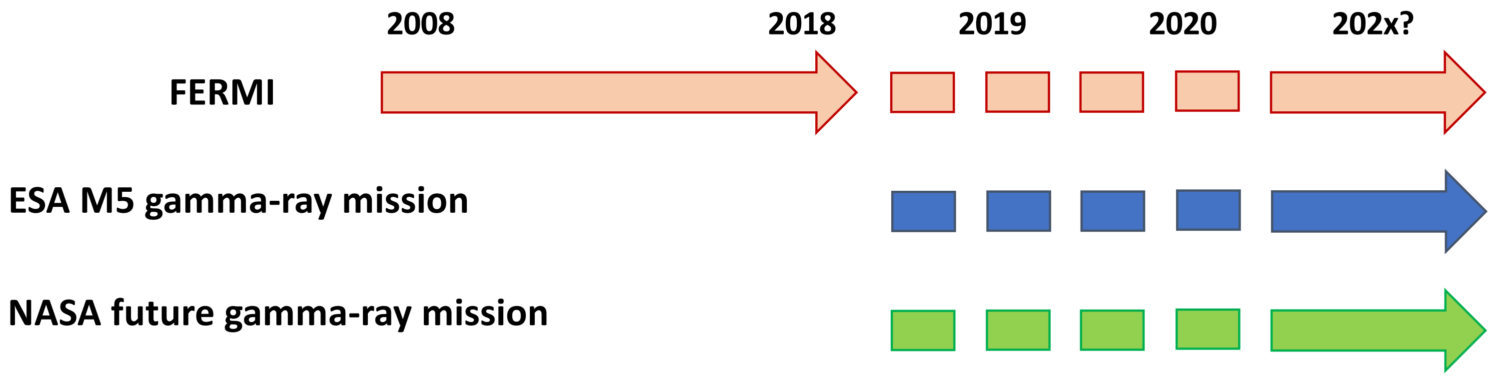


- ~20% smaller tracker
- CZT calorimeter layer

An instrument to complete the coverage of the electromagnetic spectrum



Space-based high energy gamma ray plan



- M5 Phase A selection
  - 7 May 2018: ESA selects three new mission concepts for study:
    - A high-energy survey of the early Universe (Theseus), an infrared observatory to study the formation of stars, planets and galaxies (Spica) , and a Venus orbiter (EnVision) are to be considered for ESA's fifth medium class mission in its Cosmic Vision science programme, with a planned launch date in **2032**
  - e-ASTROGAM not selected for ESA M5
    - Excellent report, though; stressed challenging technical solutions
- Next chances:
  - AMEGO
  - Discussions for a possible integration in HERD
  - Discussions for a possible Russian launcher

Disclaimer

In this report I got the permission to use slides from Aldo Morselli shown at the TMEX-2020 (Rencontres du Vietnam) conference in Vietnam (January 5-11, 2020)