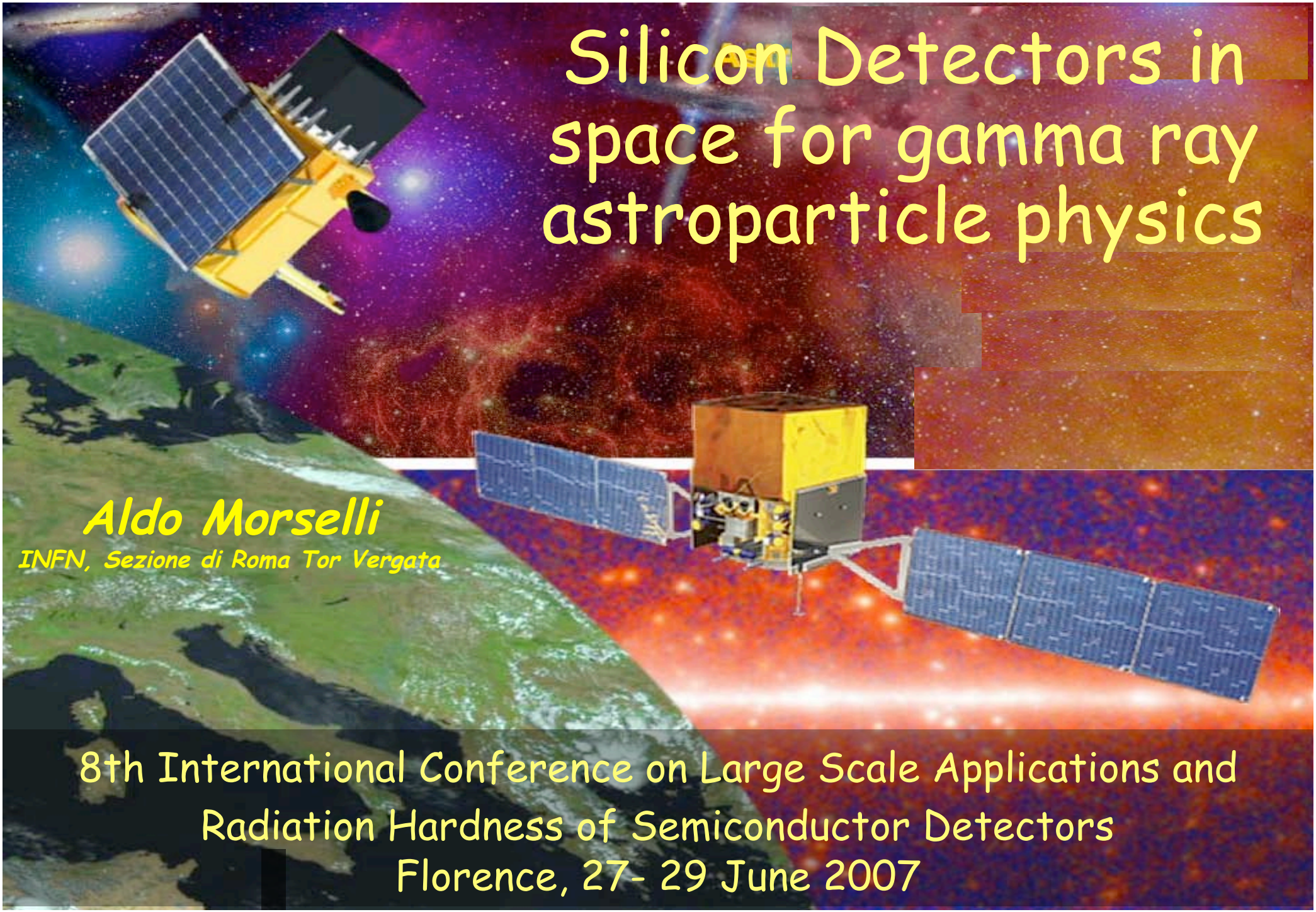
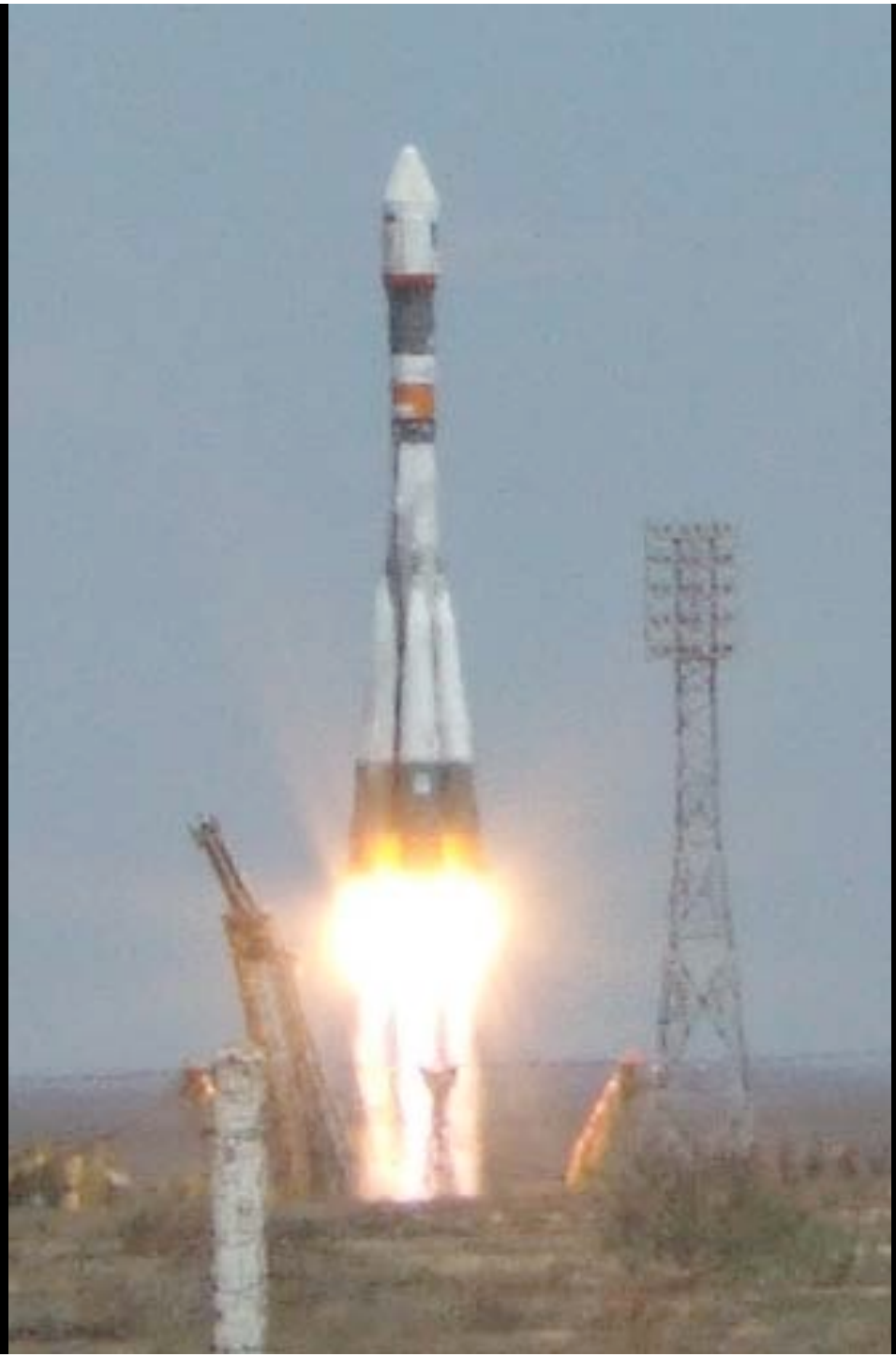

Silicon Detectors in space for gamma ray astroparticle physics
Aldo Morselli
INFN, Sezione di Roma Tor Vergata
8th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors
Florence, 27- 29 June 2007

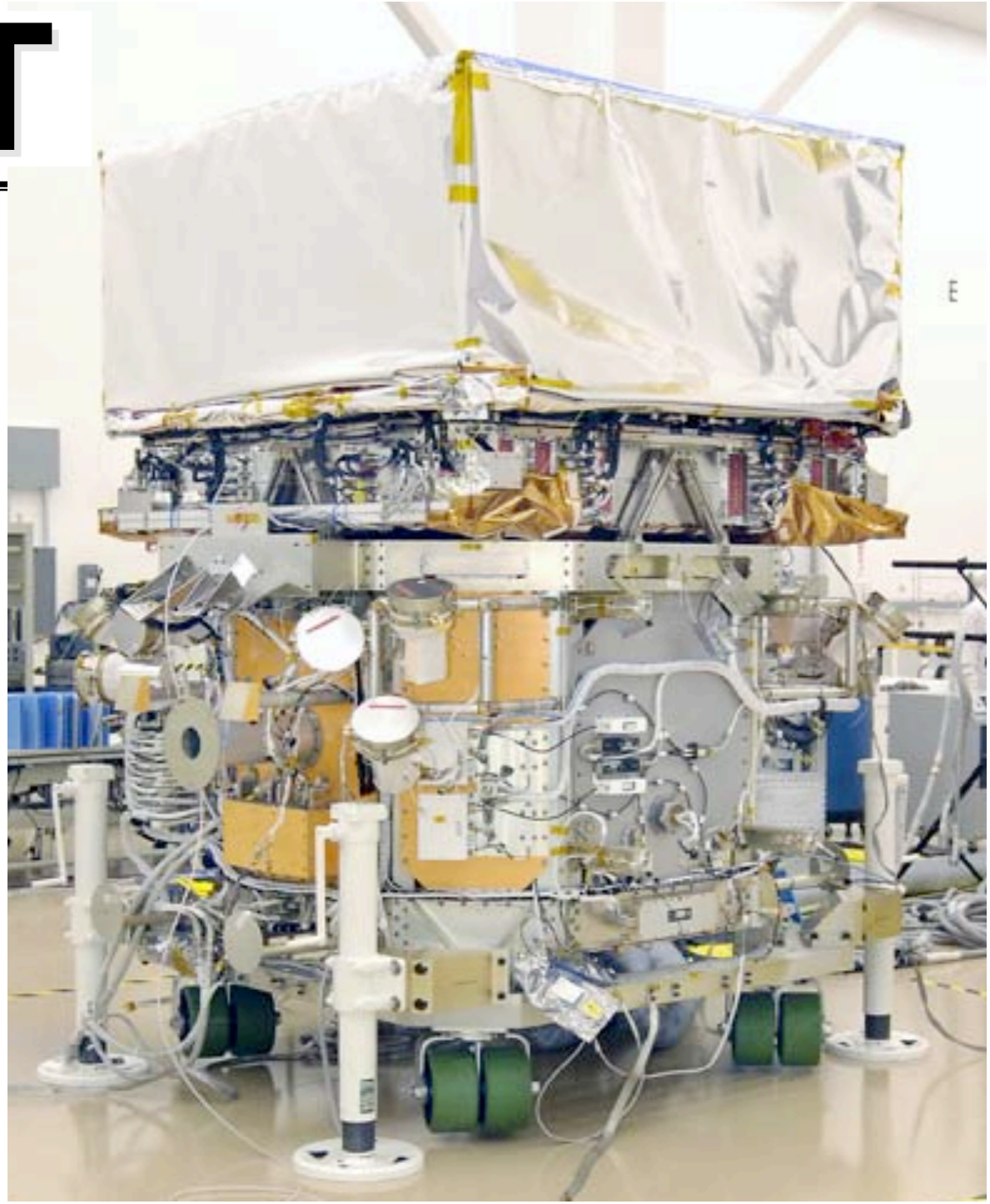
PAMELA Launch
15/06/06

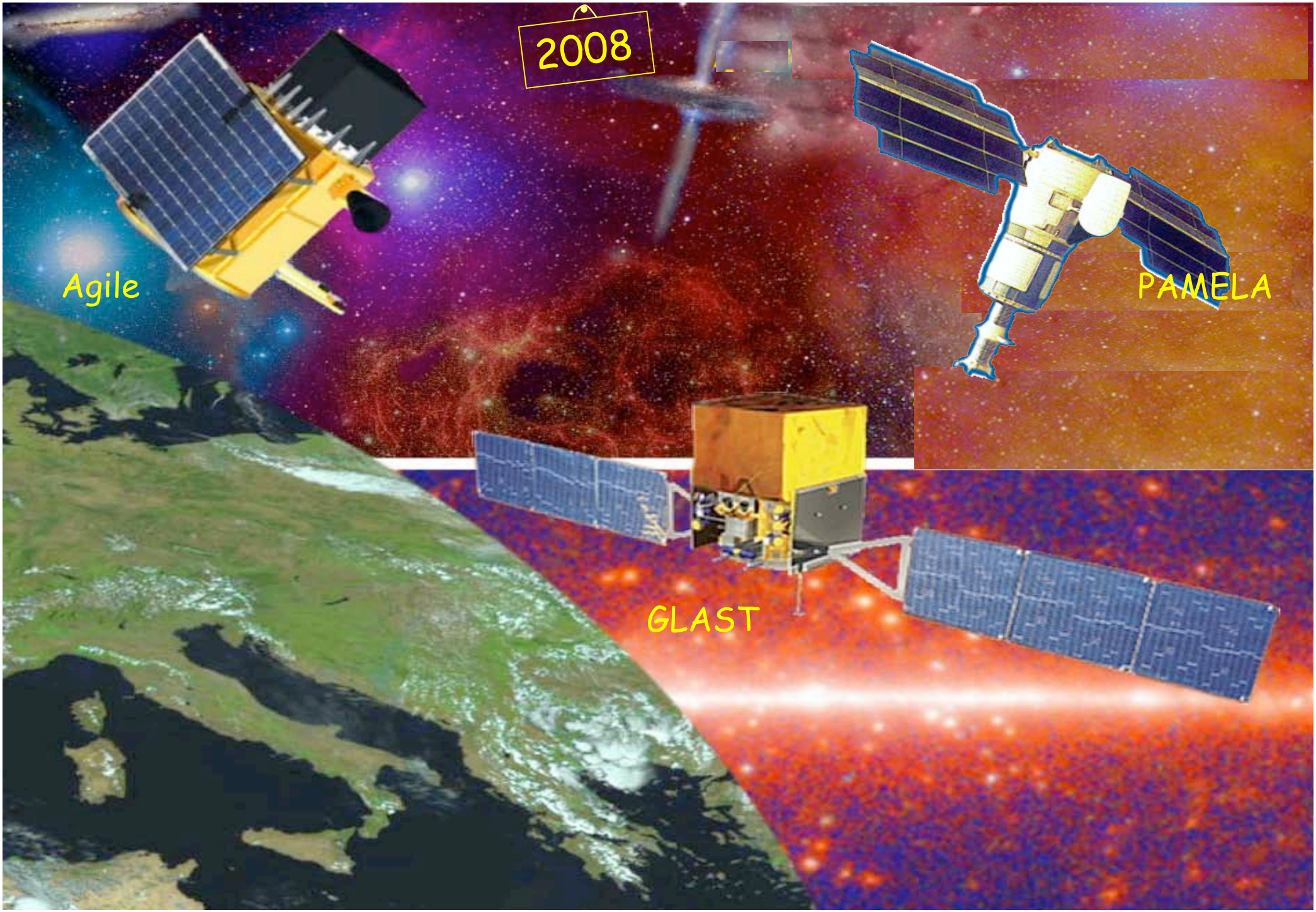


23 April 12 o’clock
Roma time : Launch

GLAST

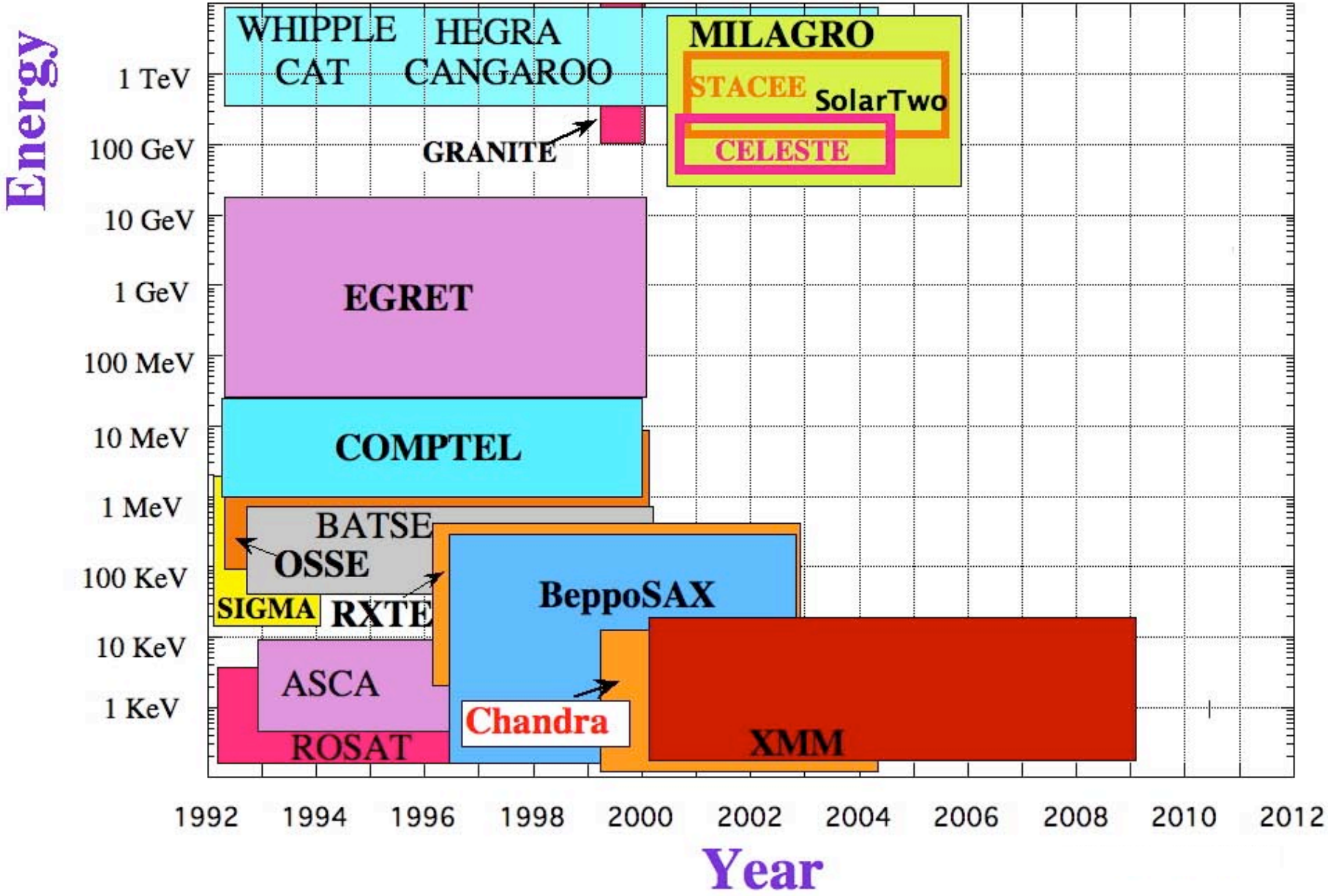
Launch : Jan 2008 !!




2008
Agile
PAMELA
GLAST

High Energy Gamma Experiments

~1993



ELSEVIER

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

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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]

[a] *Dept. of Physics, Univ. of Trieste and INFN, Italy*
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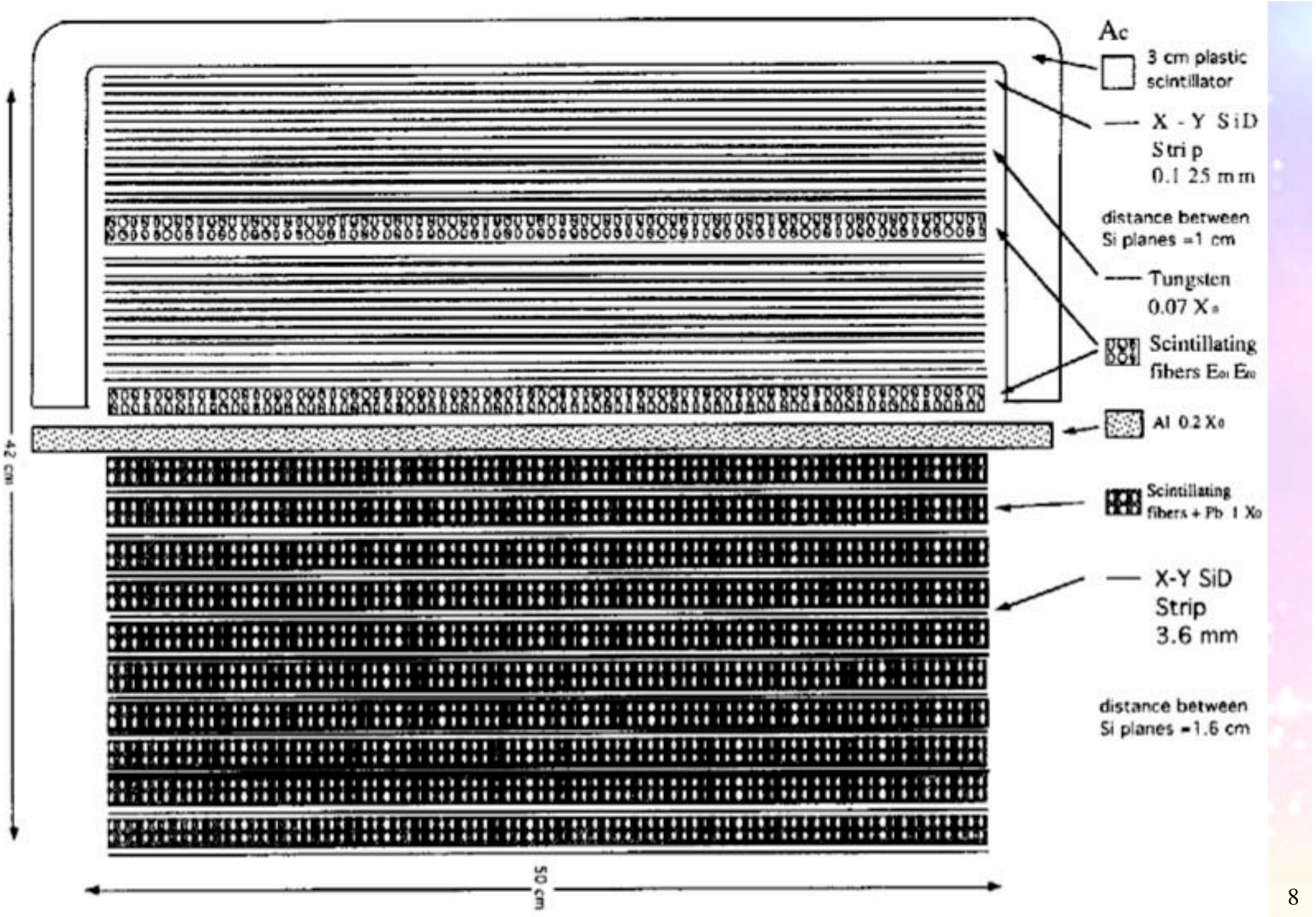
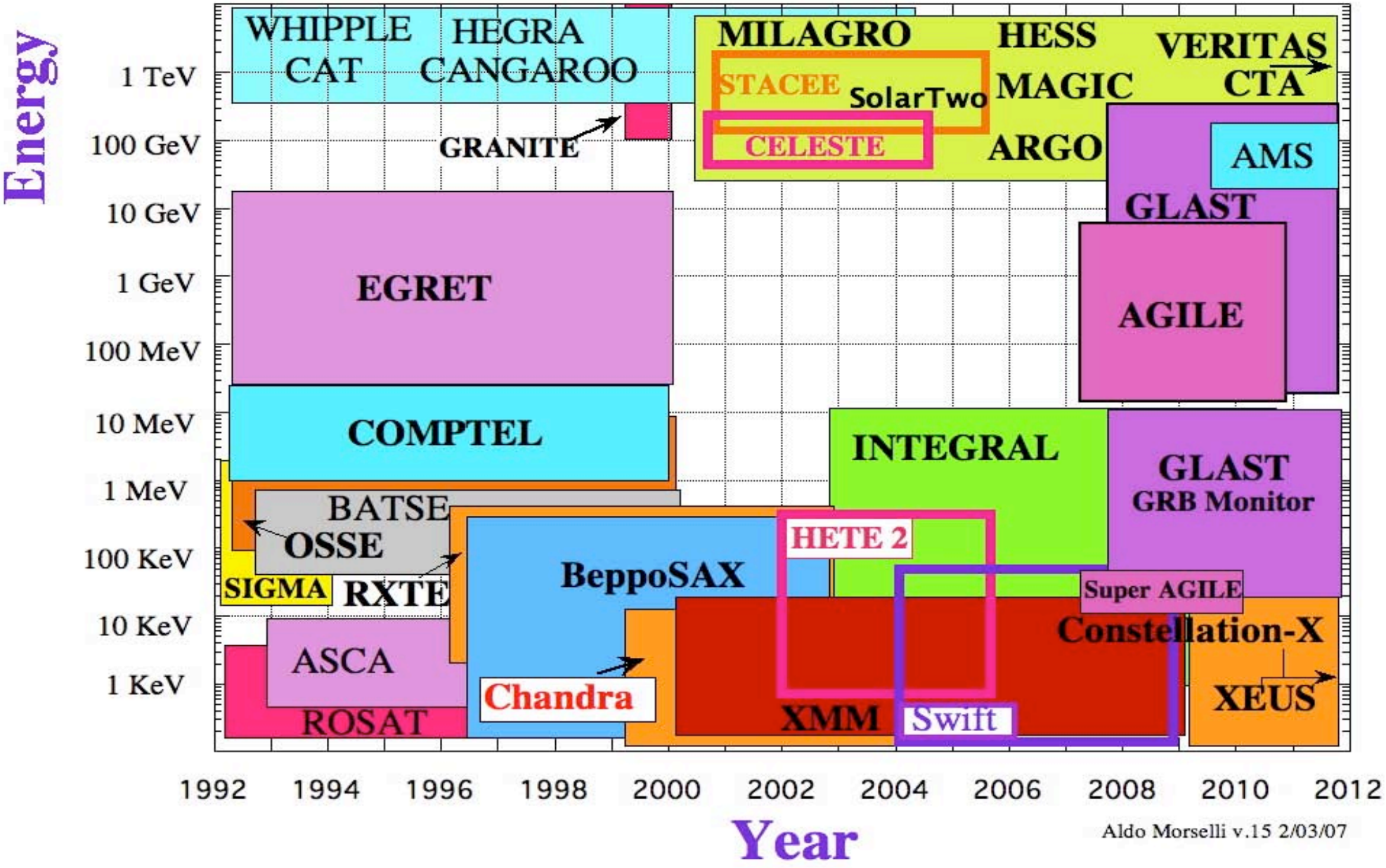
Received 5 August 1994

Abstract

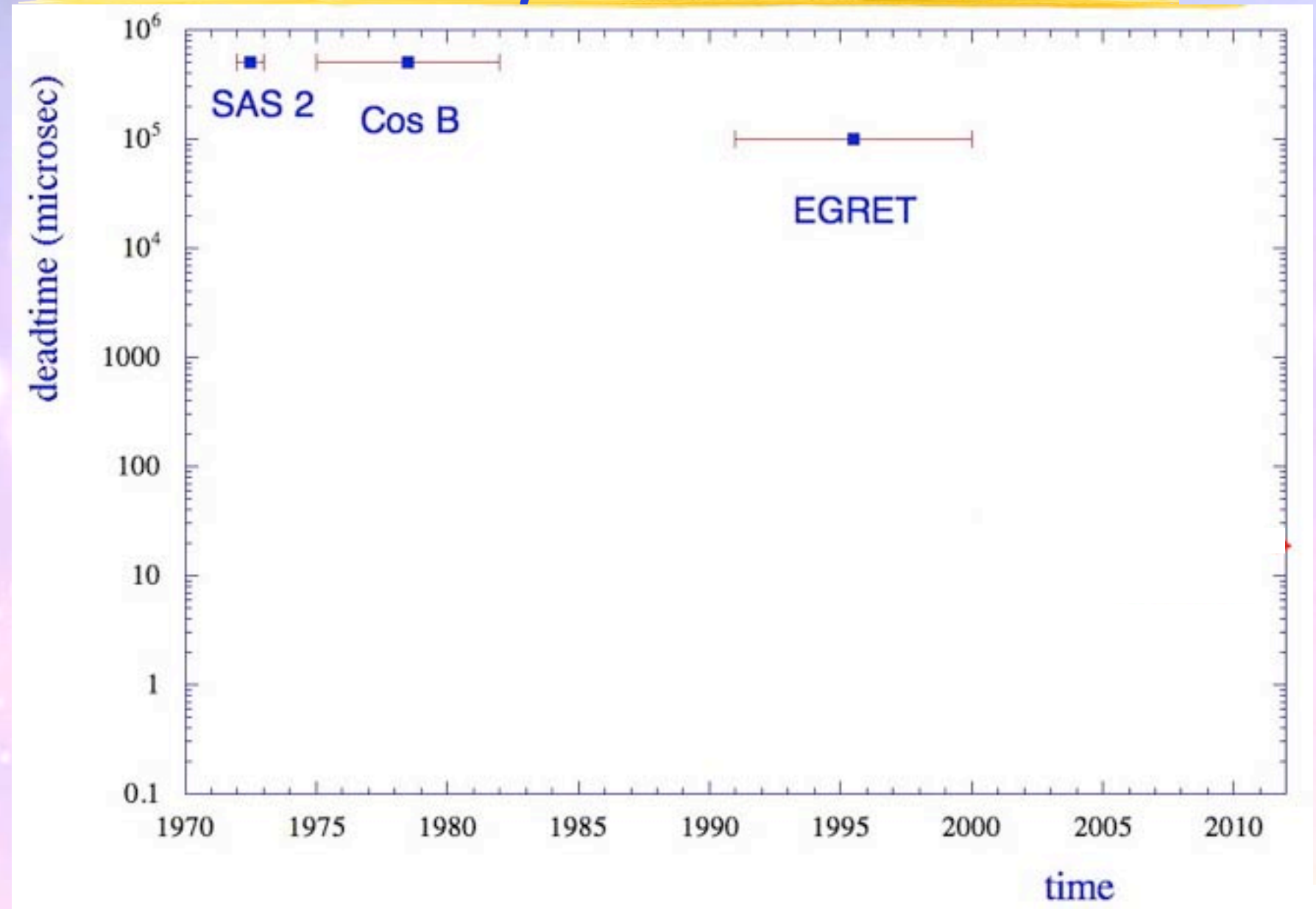
In this article a new technique for the realization of a high energy gamma-ray telescope is presented, based on the adoption of silicon strip detectors and lead scintillating fibers. The simulated performances of such an instrument (GILDA) are significatively better than those of EGRET, the last successful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


Ac
3 cm plastic scintillator
X - Y SiD Strip 0.125 mm
distance between Si planes =1 cm
Tungsten 0.07 X0
Scintillating fibers
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

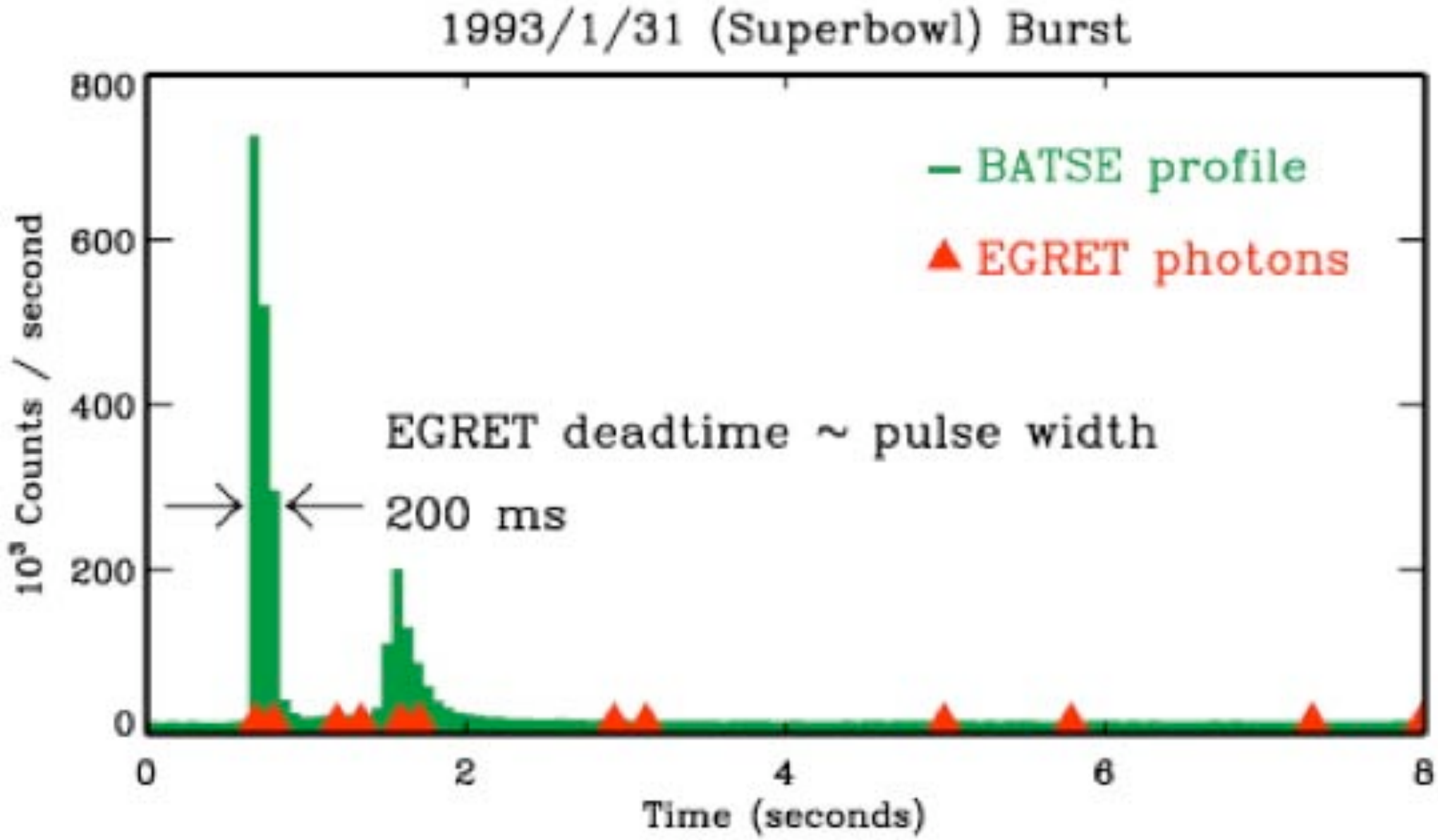
High Energy Gamma Experiments



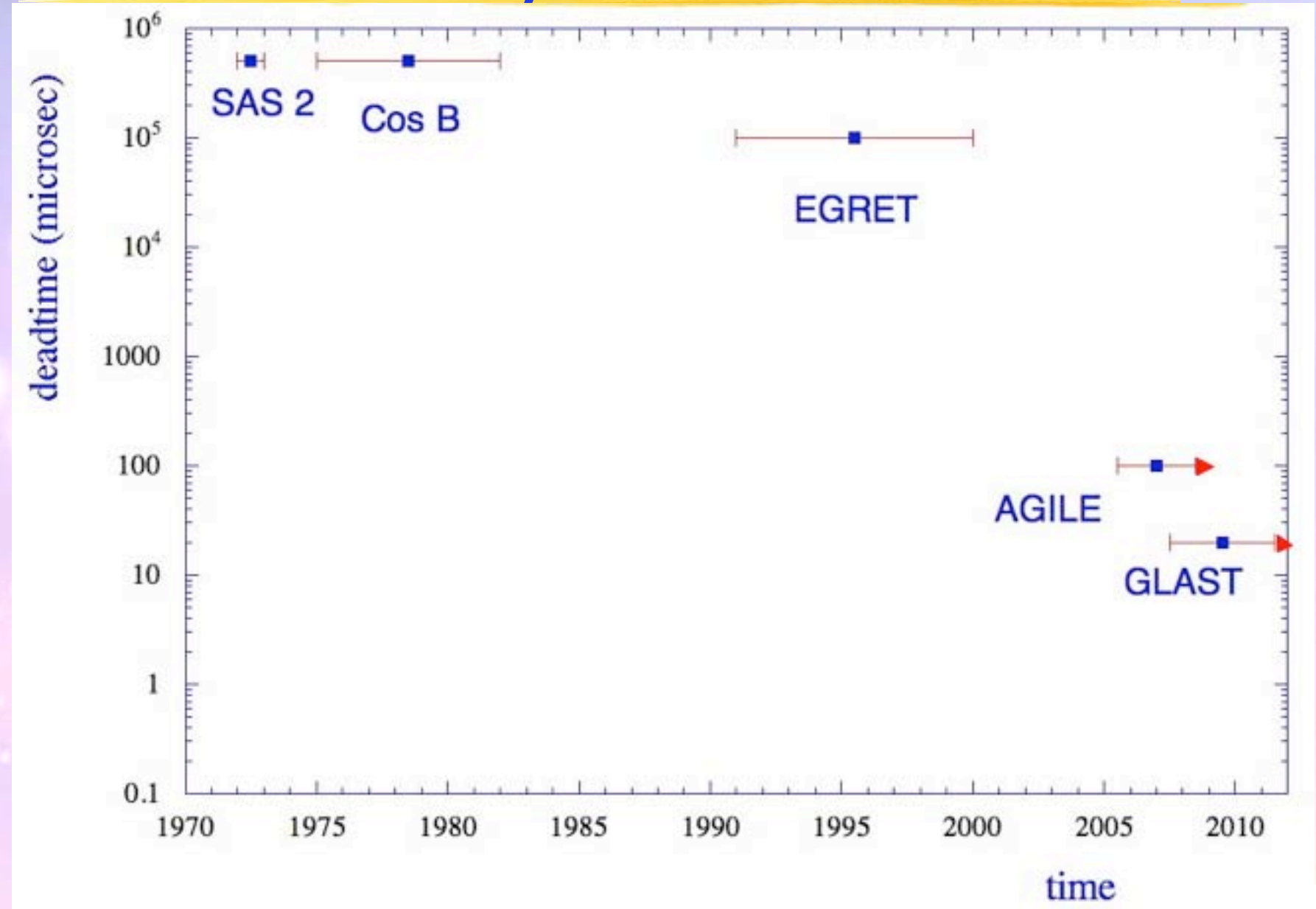
Gamma -ray mission deadtime



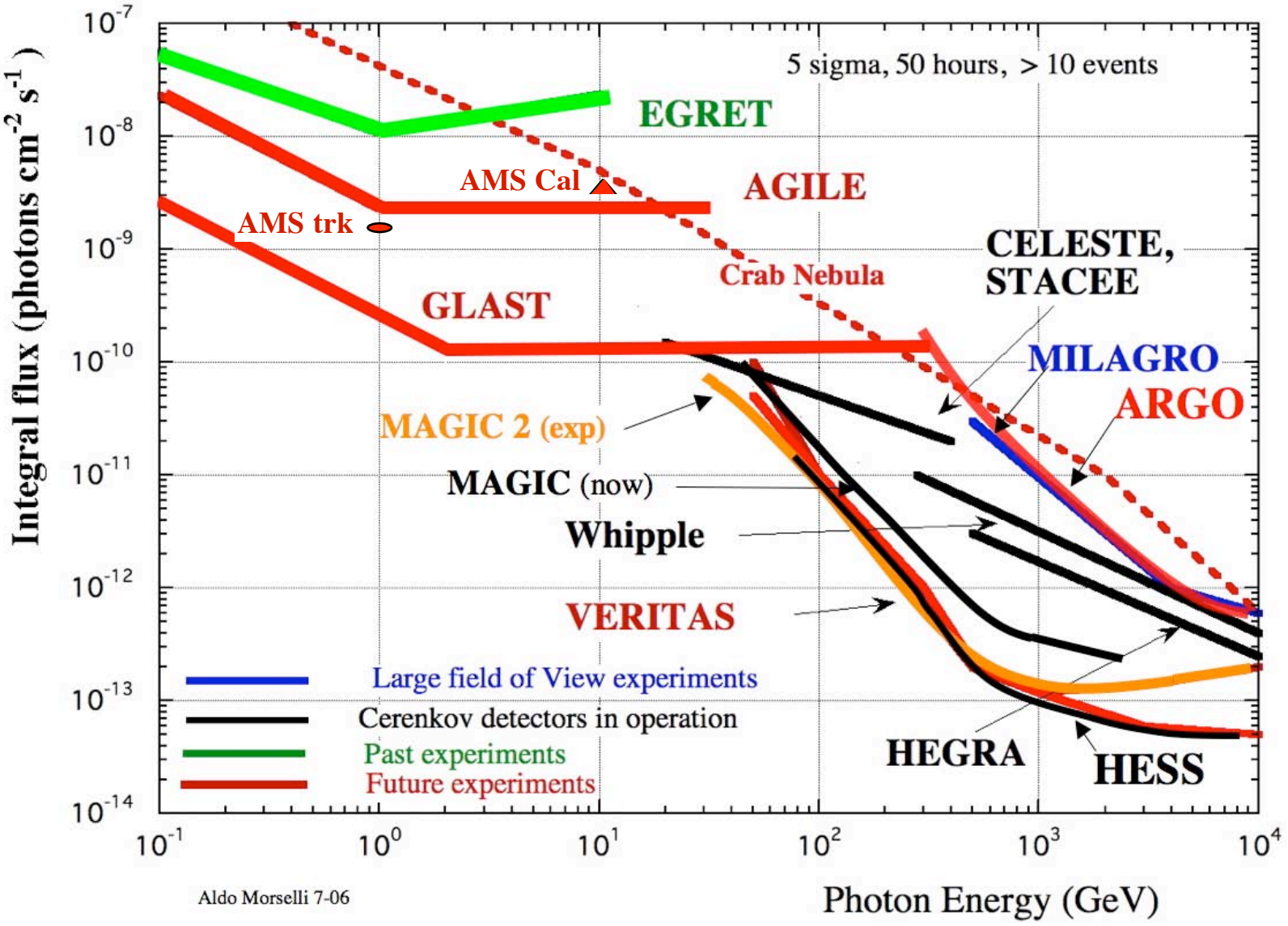
EGRET Superbowl Gamma Ray Burst



Gamma -ray mission deadtime

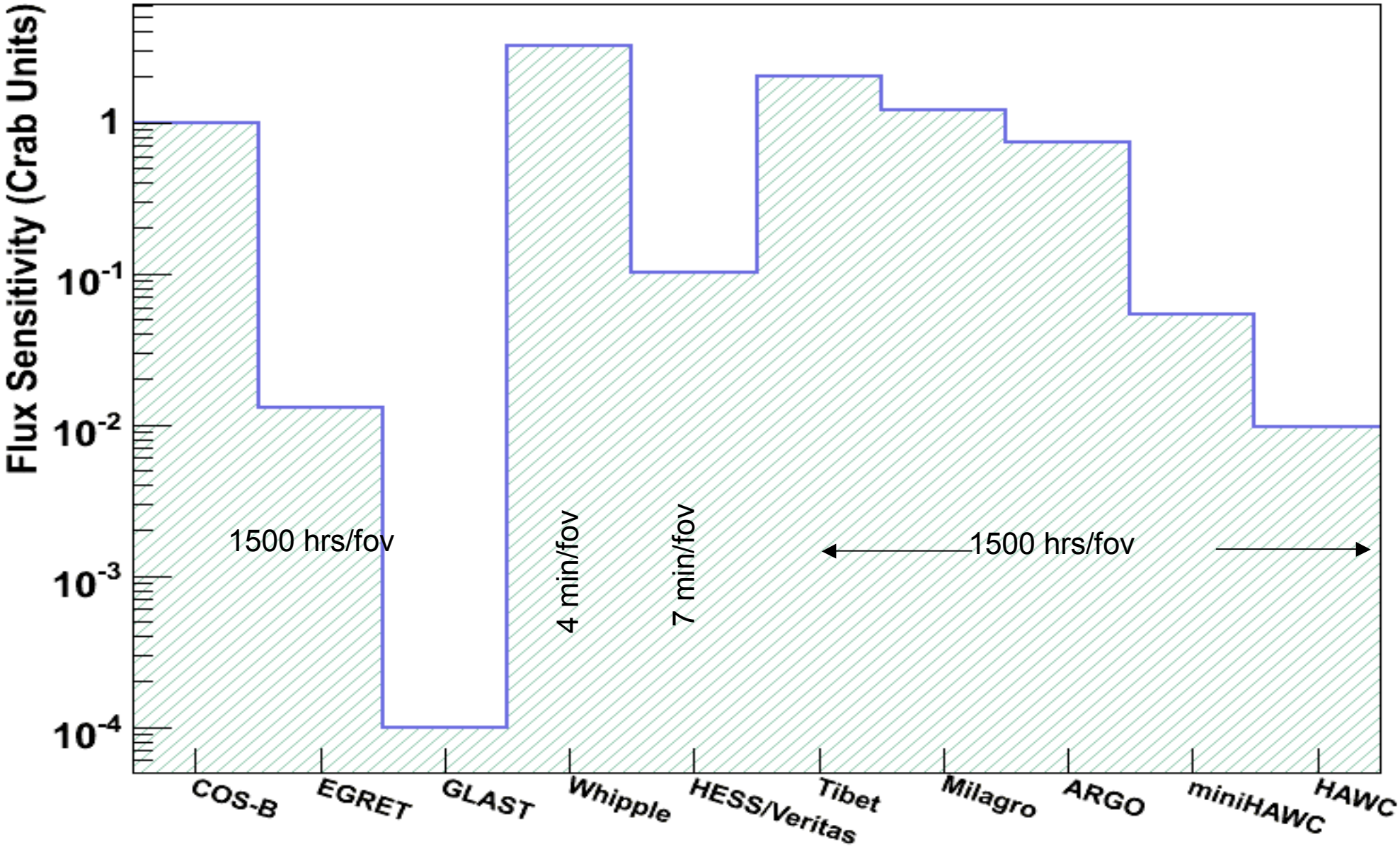


Sensitivity of γ-ray detectors



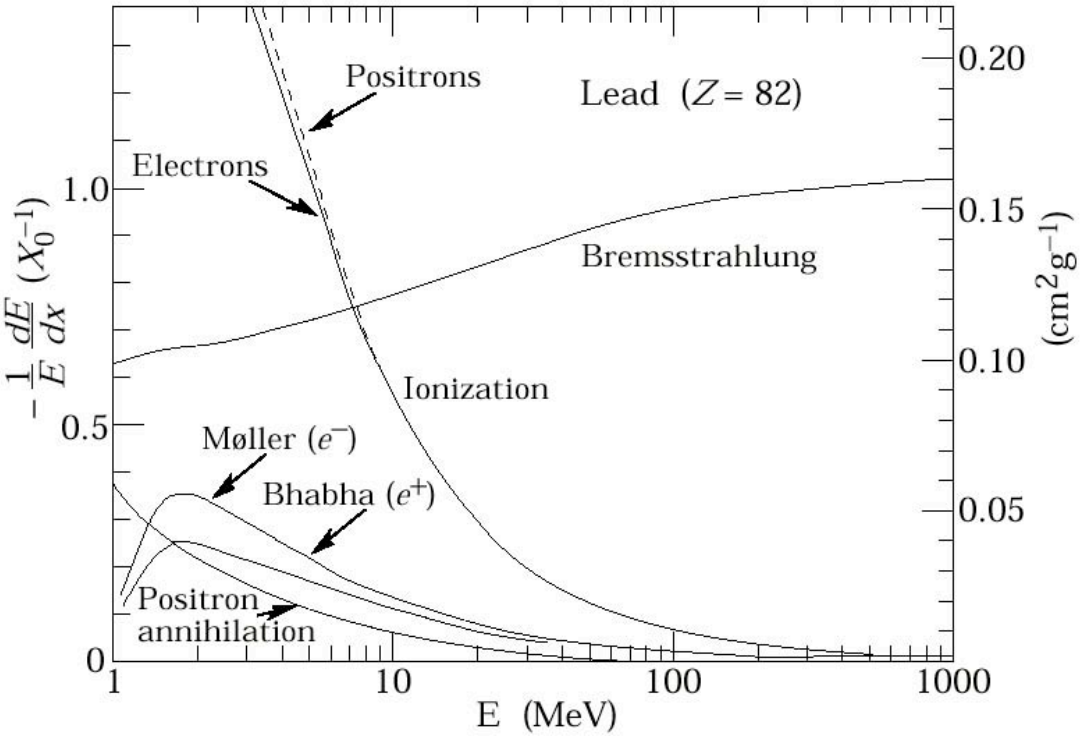
High galactic latitudes(Φ_b=2 10^{-5} γ cm^{-2} s^{-1} sr^{-1} (100 MeV/E)$^{1.1}$). Cerenkov telescopes sensitivities (Veritas, MAGIC, Whipple, Hess, Celeste, Stacee, Hegra) are for 50 hours of observations.Large field of view detectors sensitivities (AGILE, GLAST, Milagro, ARGO, AMS) are for 1 year of observation.

One Year Survey Sensitivity

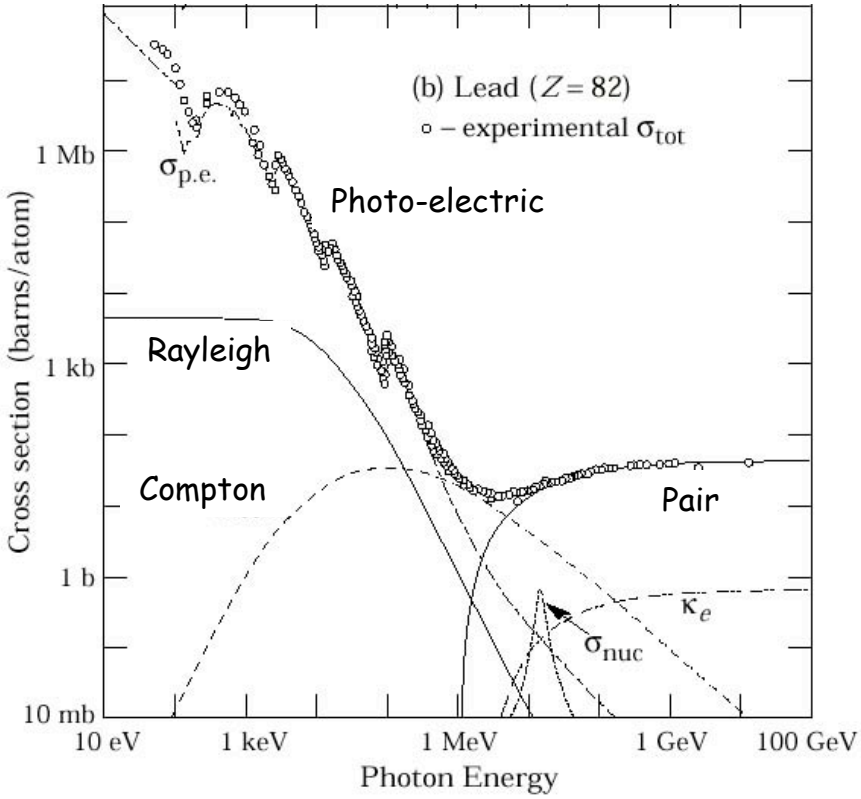


Interaction of electrons and photons with matter

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



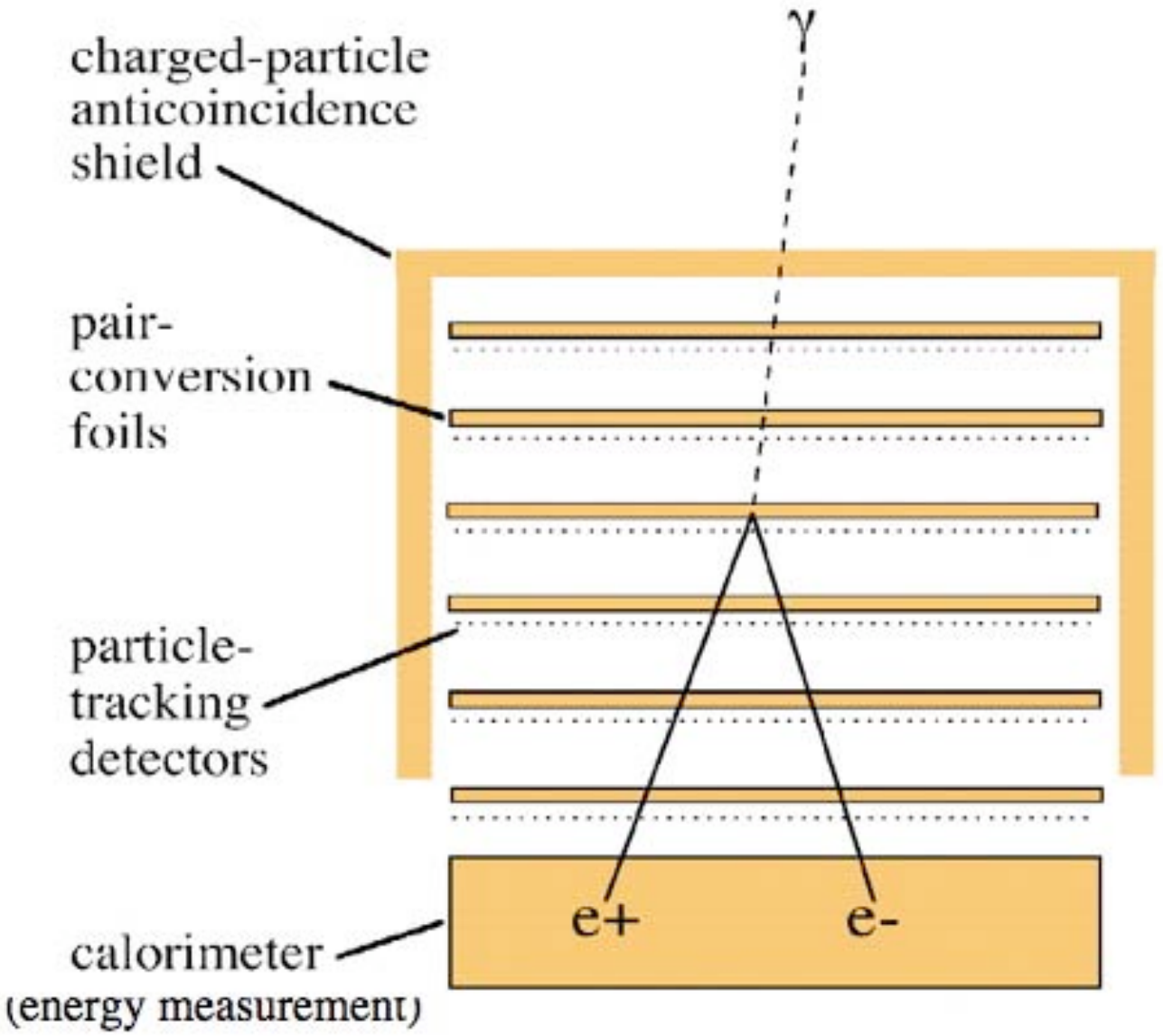
Photon total cross sections



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

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

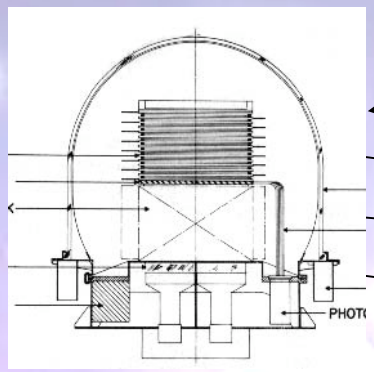
Elements of a pair-conversion telescope



- 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

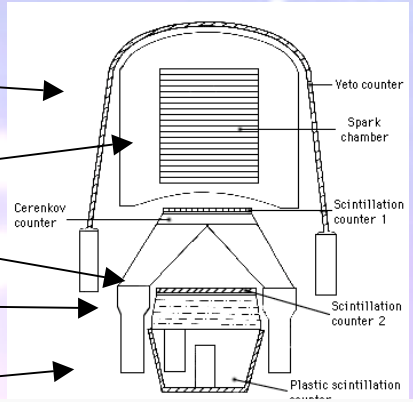
Anti-Coincidence Dome

Spark Chamber

Trigger Telescope

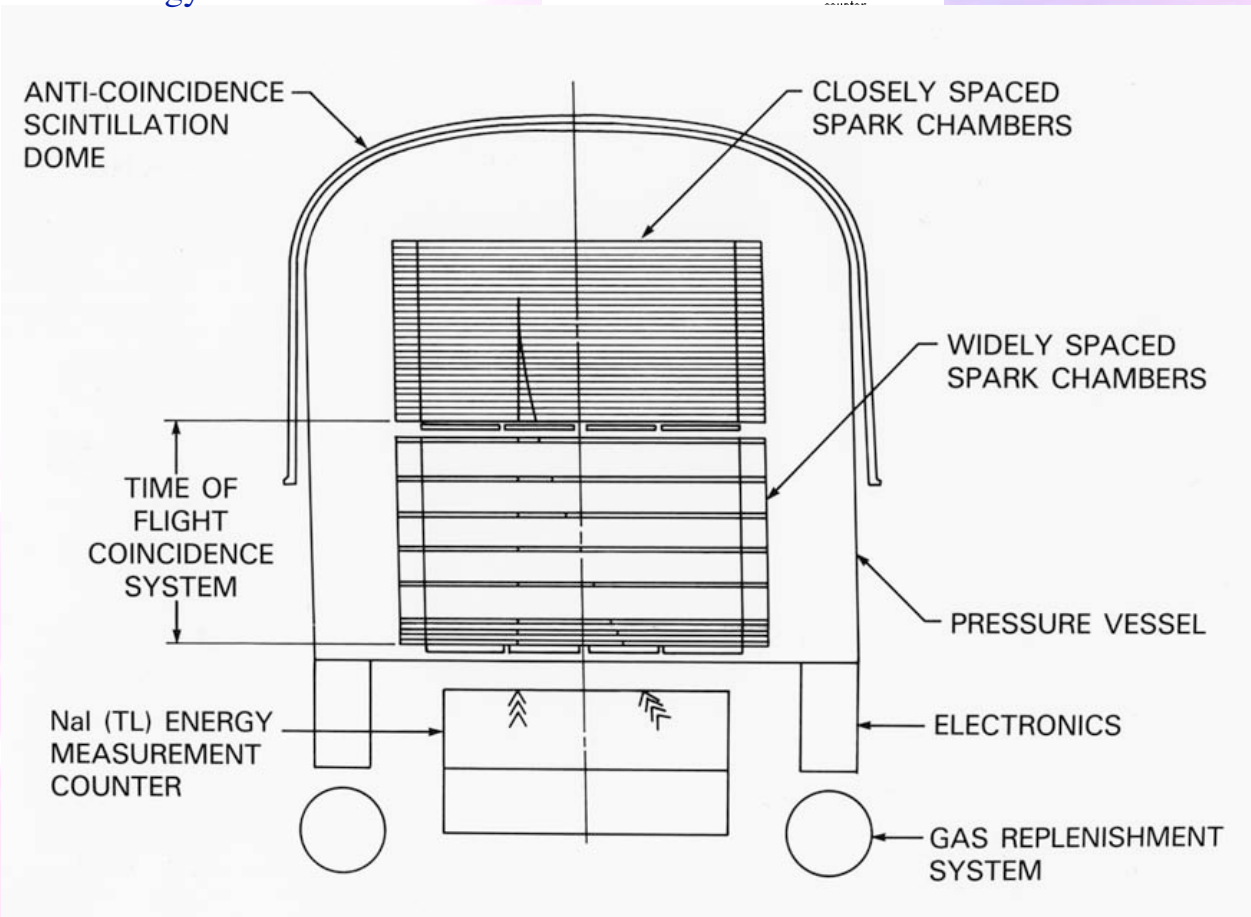
Cerenkov Counter

Energy Calorimeter



Cos-B
8/1975-4/1982

EGRET
4/1991-1999



agile

Astro-rivelatore Gamma a Immagini Leggero

asi agenzia spaziale italiana
INAF
INFN
Alenia
telespazio

THE AGILE MISSION

AGILE

Super Agile Mask

Super Agile Silicon plane

AntiCoincidence

Photomultipliers
Top: 0.5cm plastic scintillator
Lateral: 12 panels 0.6 cm

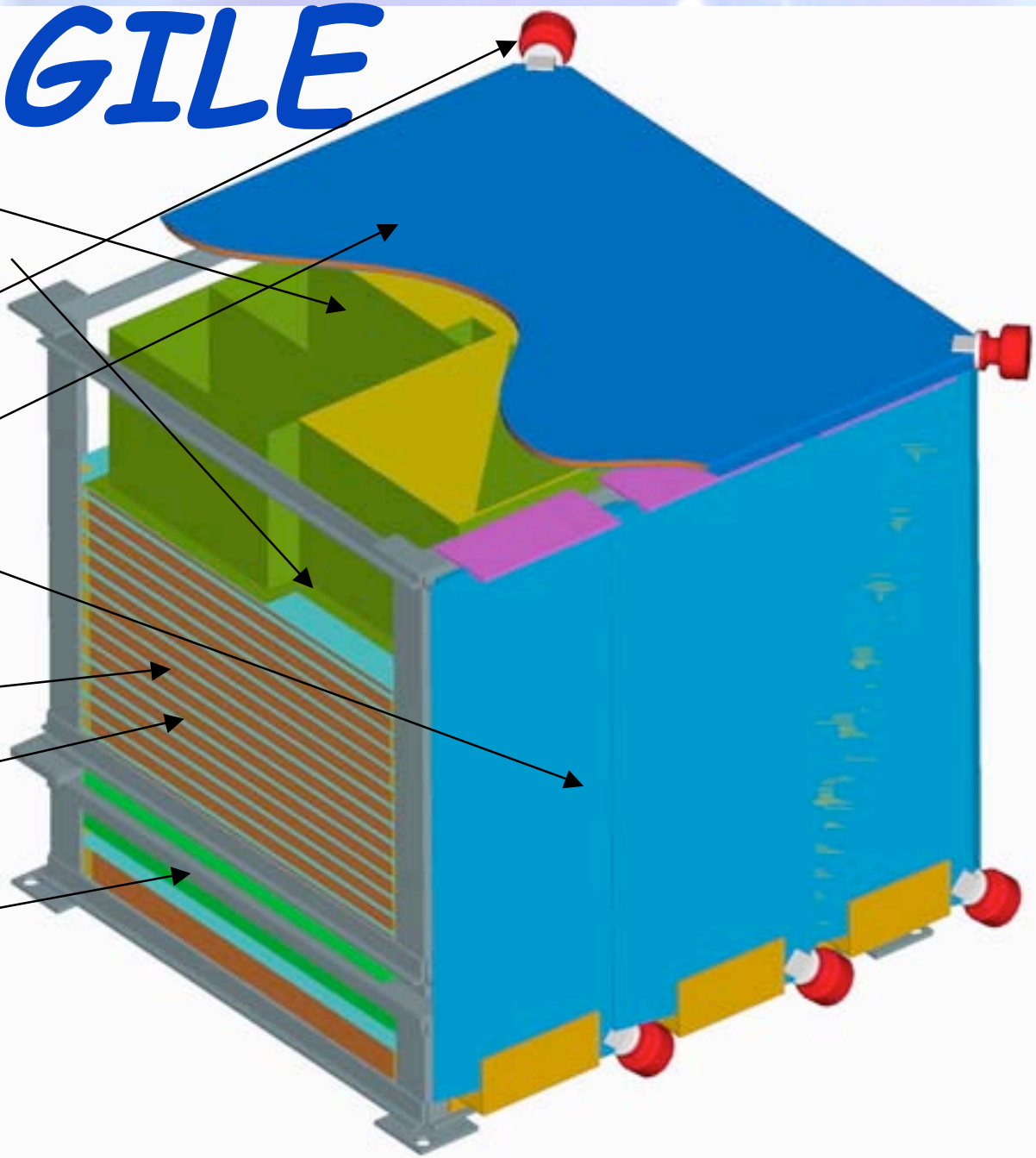
Tracker , 14 X/Y planes

W 0.07 X_0

X/Y plane, 121 mm pitch
distance between planes 1.6cm

Calorimeter

1.5 X_0 CsI Calorimeter
1.4*2*40 cm^3 bars



The Silicon Tracker

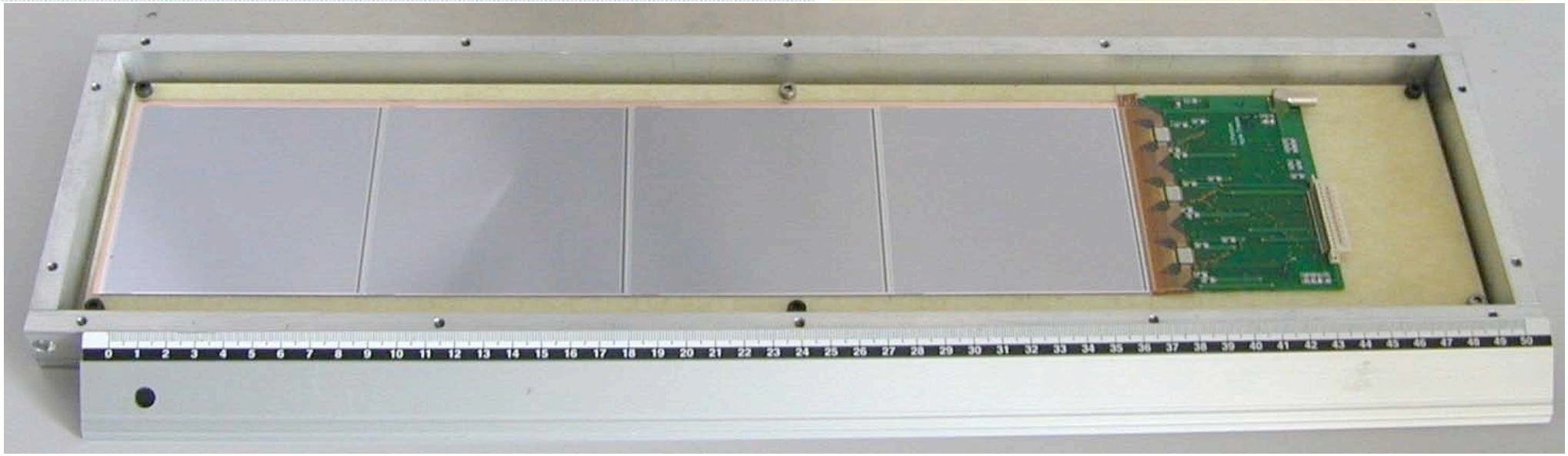
The AGILE silicon detectors

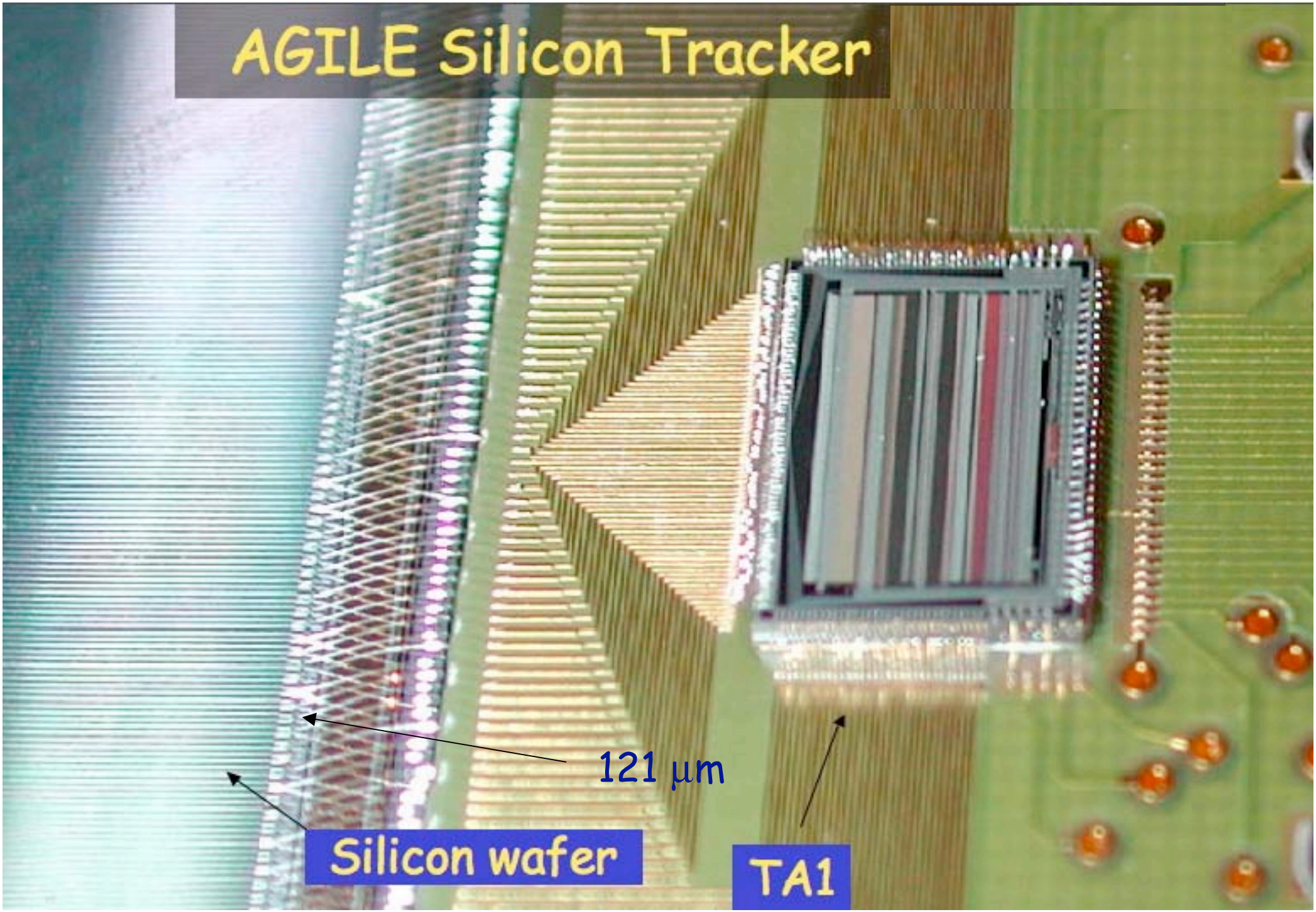
Detector specifications:

- dimension: 9.5x9.5 cm^2
- thickness: 410 μm (6 inch technology)
- readout pitch: 242 μm;
  physical pitch: 121 μm (one floating strip)
- number of strips/ladder: 384
- Single side and AC-coupled
- leakage current: 2 nA/cm^2 at Vbias=2.5*V_{FD} =200 V
- polarization resistor: 40 MΩ
- coupling capacitor: 55 pF/cm
- Al strip resistance: 4.3 Ω/cm
- max number of bad strips: <1%
- average number of bad strips: <0.5%

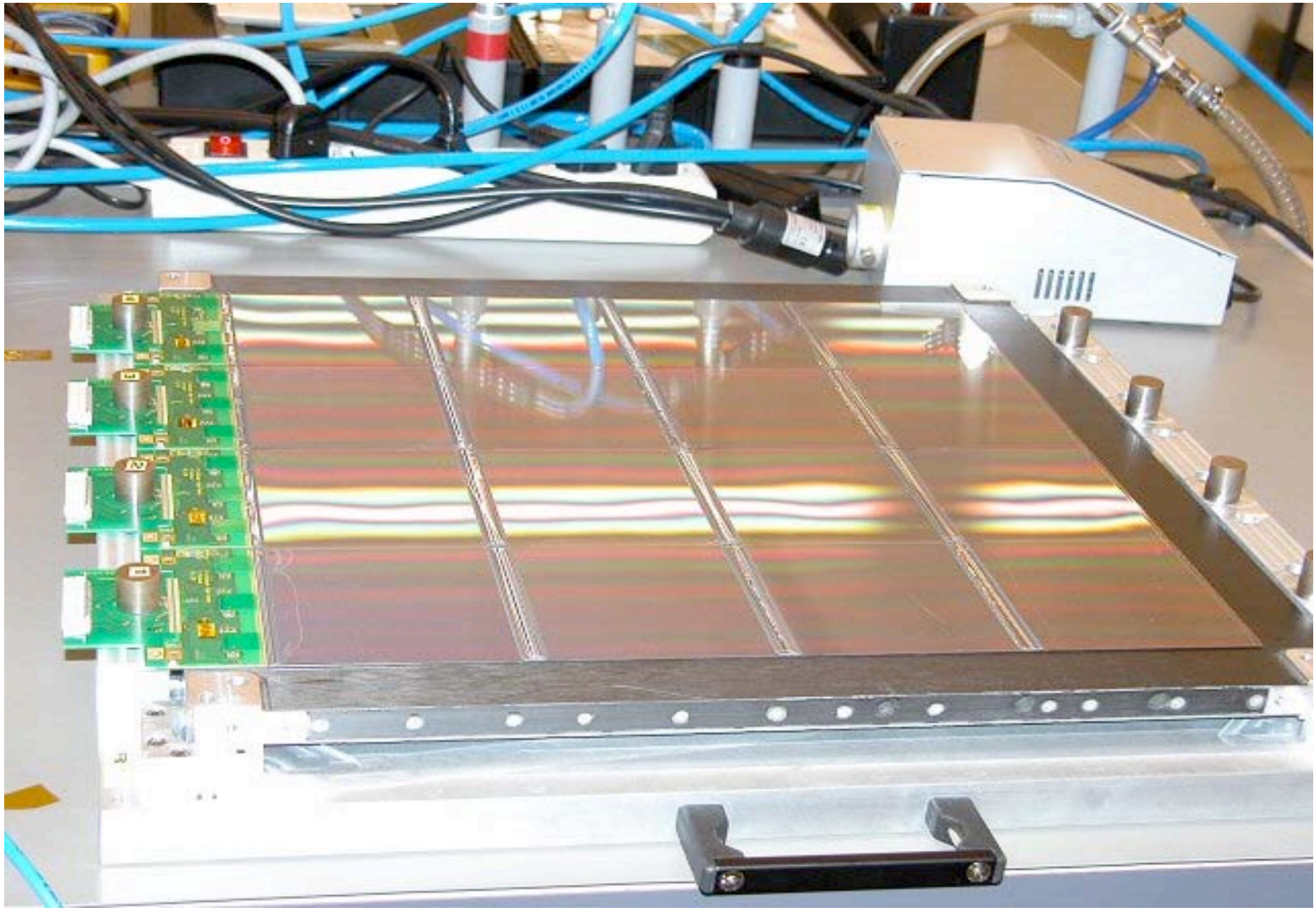
The AGILE frontend chip: TA1 → TAA1

- low noise, low power, SELF-TRIGGERING
- technology: 1.2 μ CMOS, double poly, double metal (final: 0.8 μ BiCMOS on epitaxial layer)
- features:
  - 128 channels
  - gain: 25 mV/fC; range: 18 fC
  - noise (e^-rms): 165+6.1/pF for T_{peak}=2 μs
  - power: <0.4 mW/channel
  - power rails: ±2 V
  - readout frequency: 5 Mhz
  - gain spread: <1.5%
  - threshold offset spread (TA1): 20% (in TAA1 will be implemented a 3 bit DAC per channel)

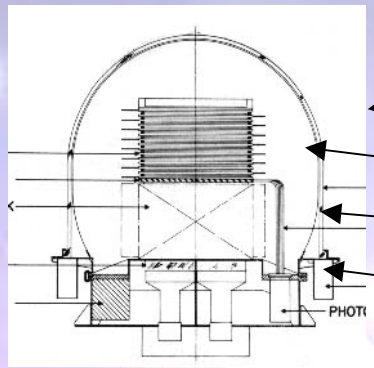



AGILE Silicon Tracker
121 μm
Silicon wafer
TA1

The Silicon Tracker



The Silicon Tracker



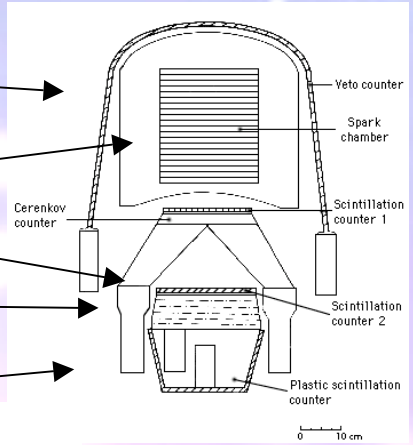
Anti-Coincidence Dome

Spark Chamber

Trigger Telescope

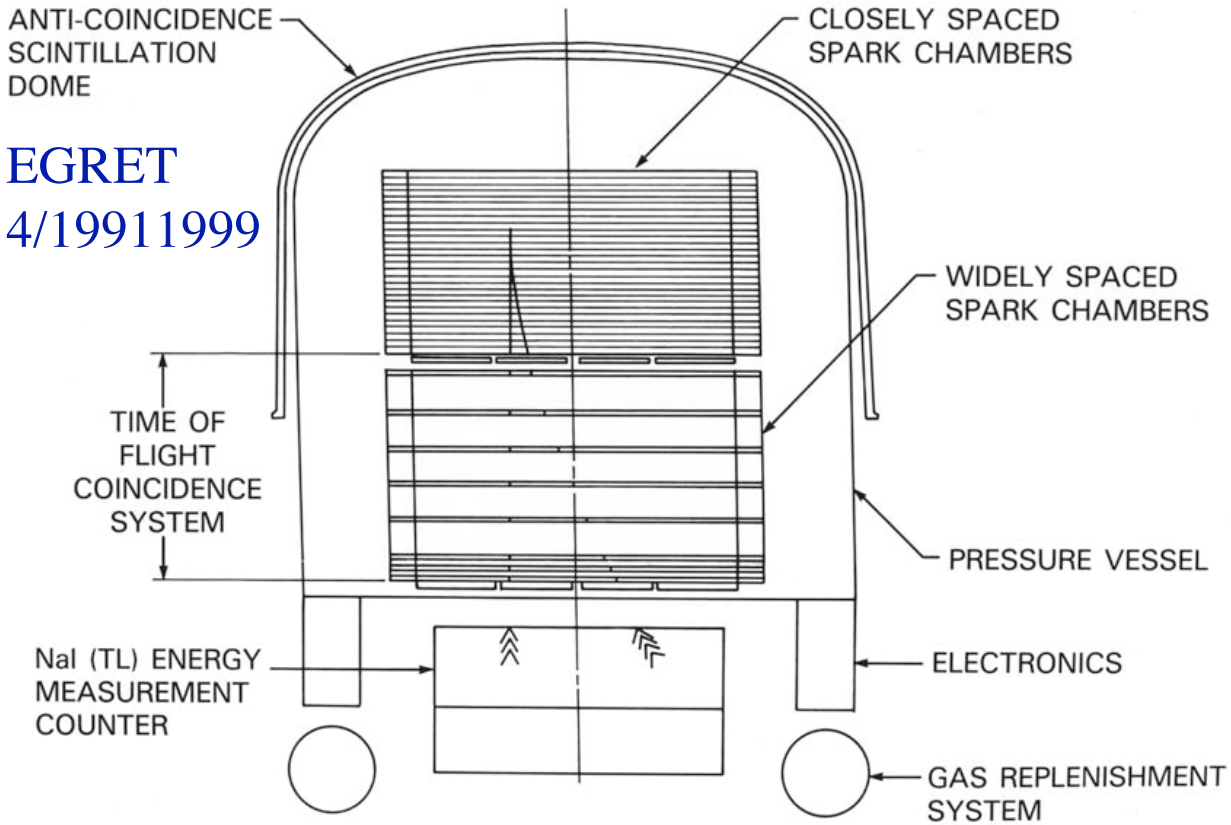
Cerenkov Counter

Energy Calorimeter

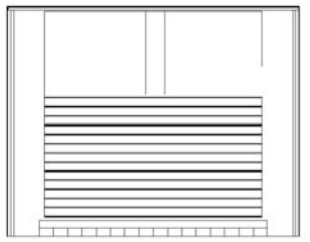


SAS-2
11/1972-7/1973

Cos-B
8/1975-4/1982

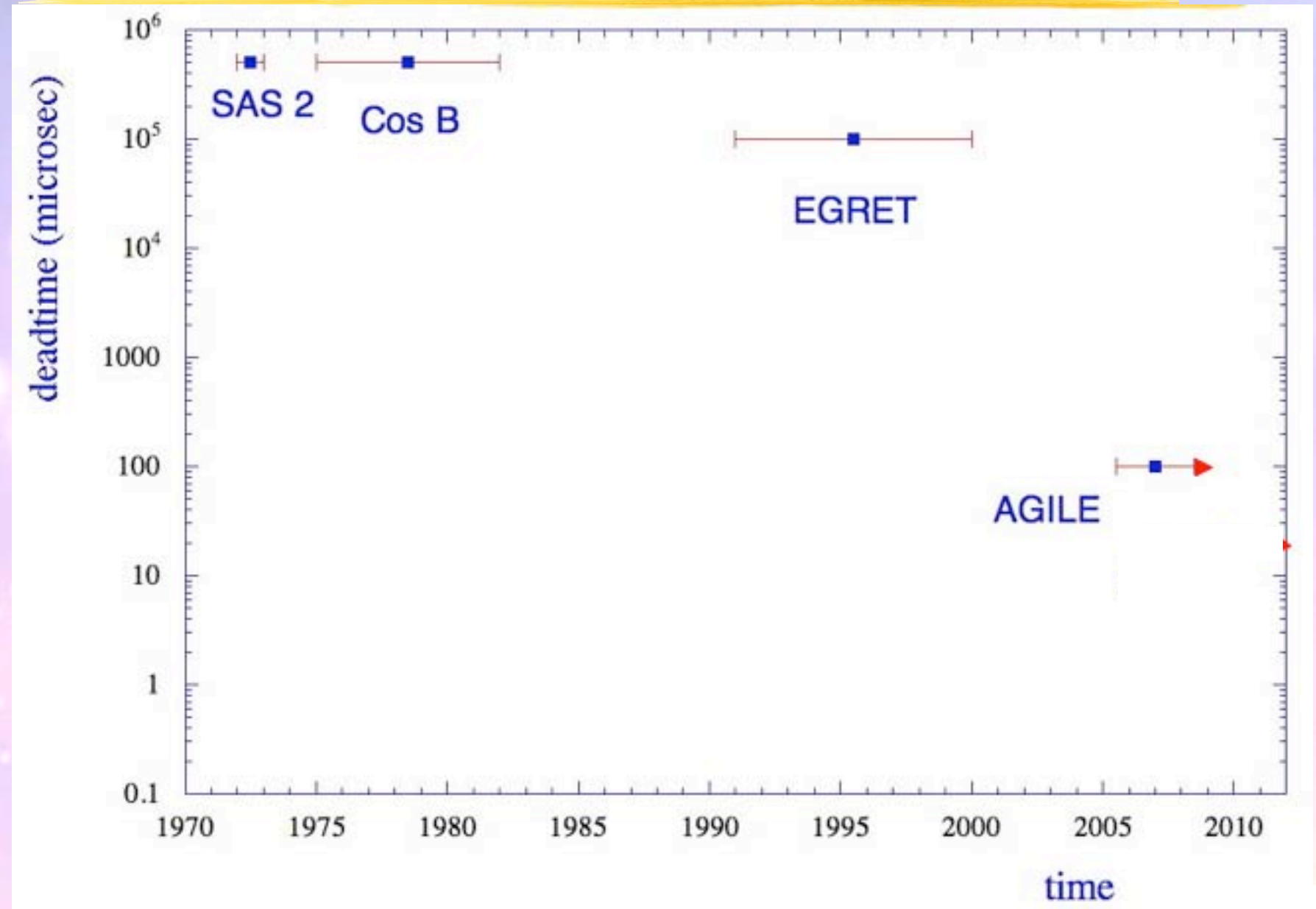


EGRET
4/19911999

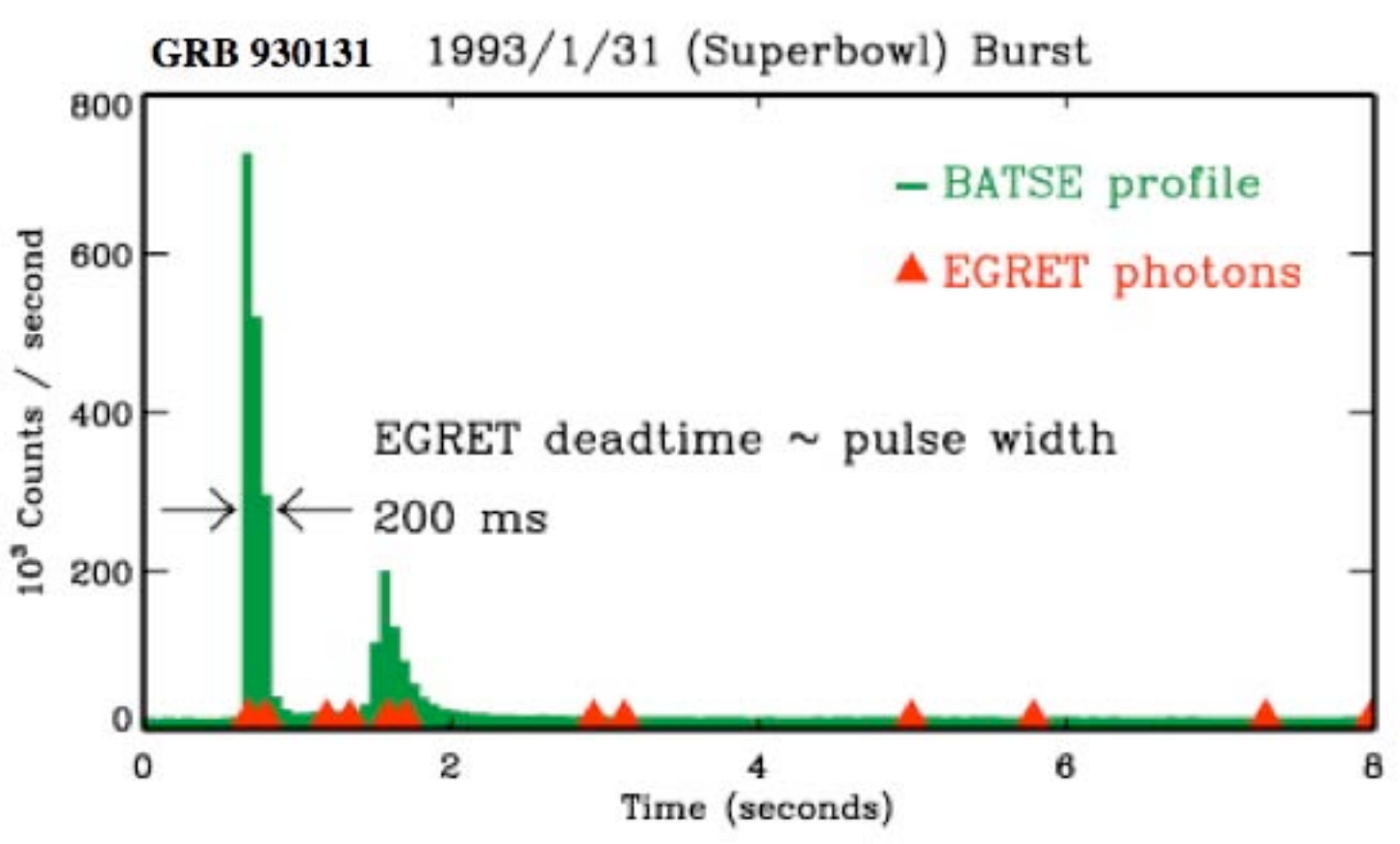


AGILE
2006-

Gamma -ray mission deadtime



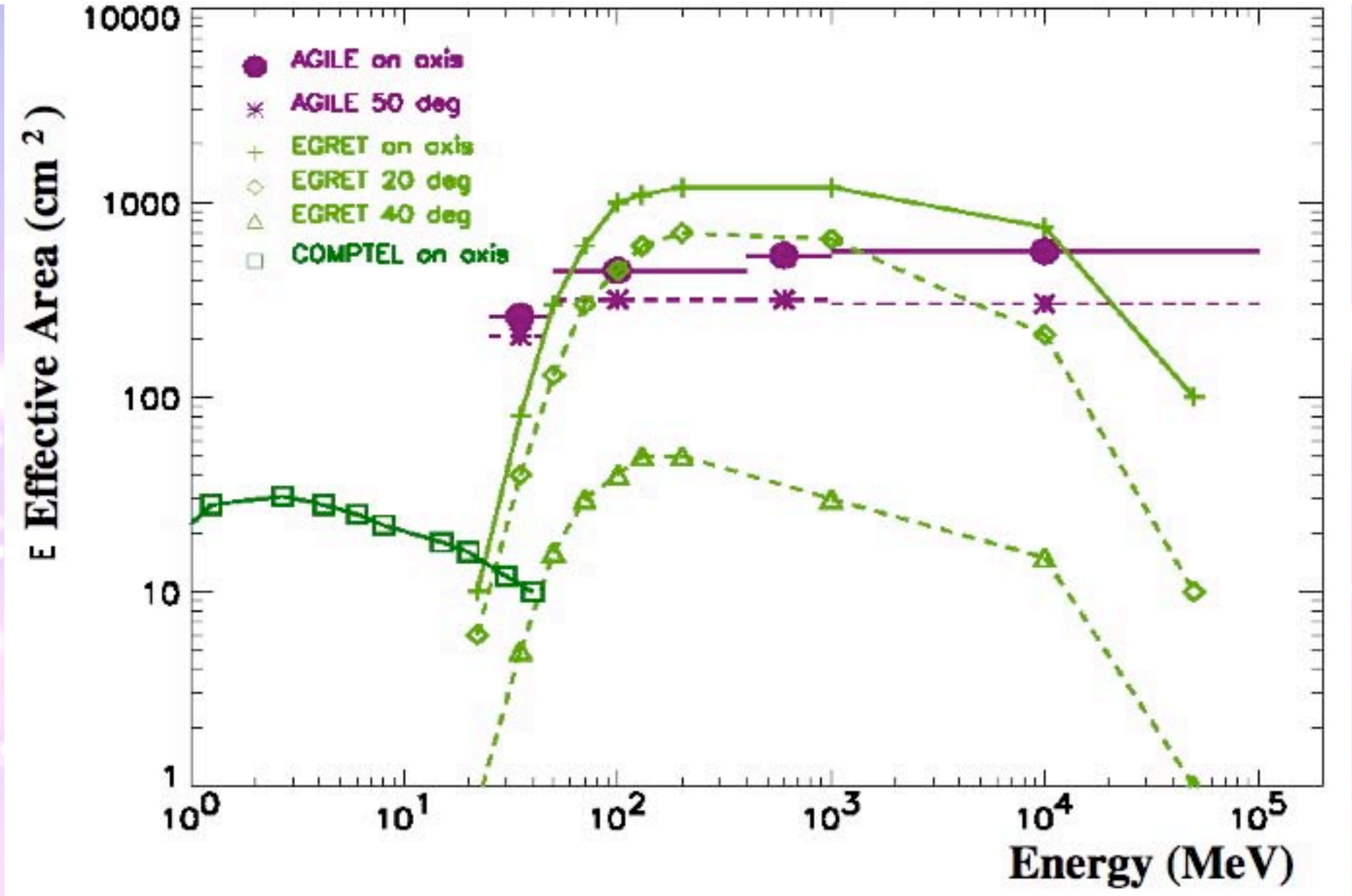
GRB studies with AGILE



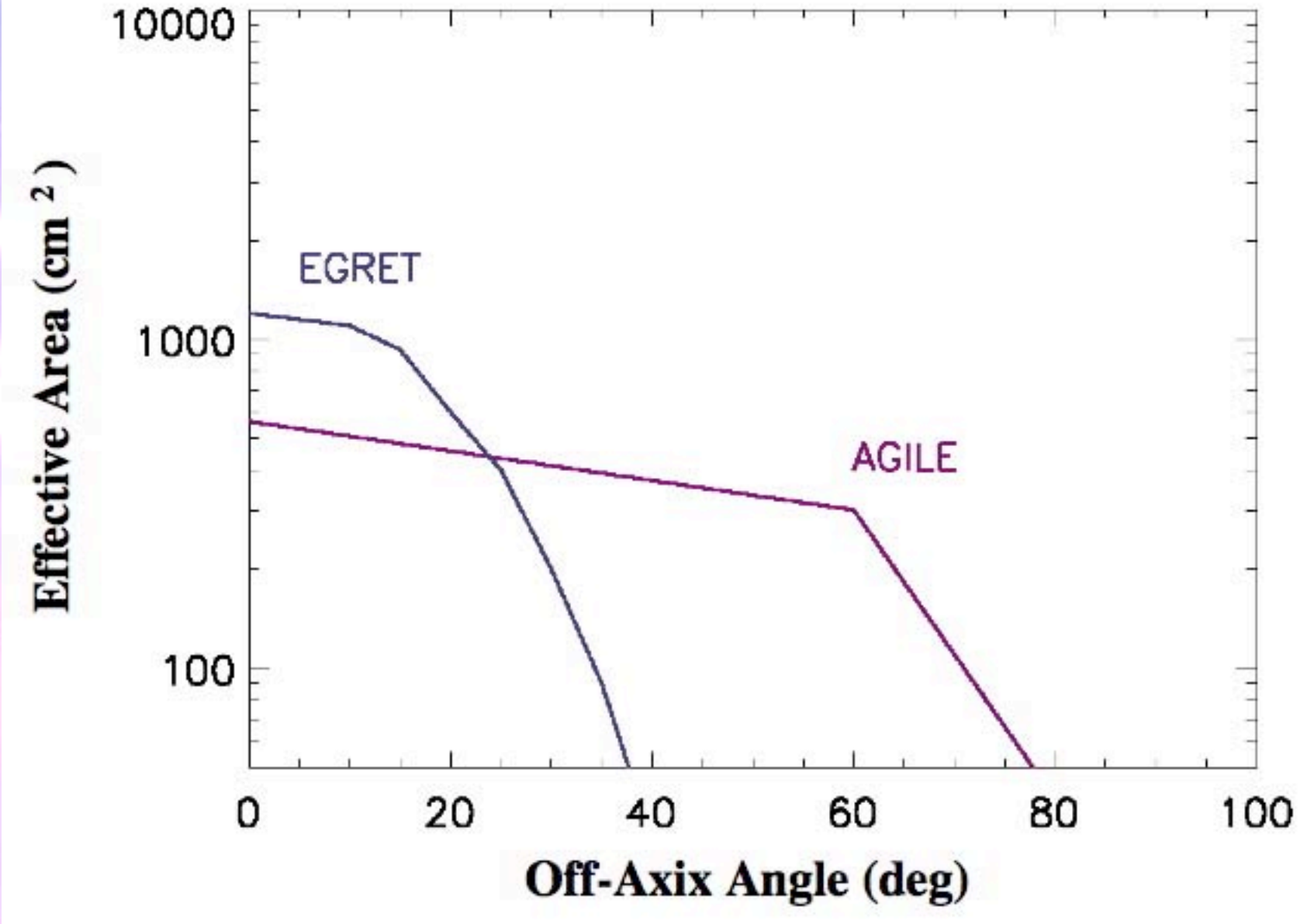
- Study of the initial impulsive phase: $\Delta t < 1$ ms
- Expected detection rate (above 50 MeV): 5-10 yr^{-1}

- Expected detection rate (above 50 MeV): 5-10 yr-1
- Broad band spectral information: ~ 200 keV - 30 GeV
- Rapid communication of GRB quicklook results

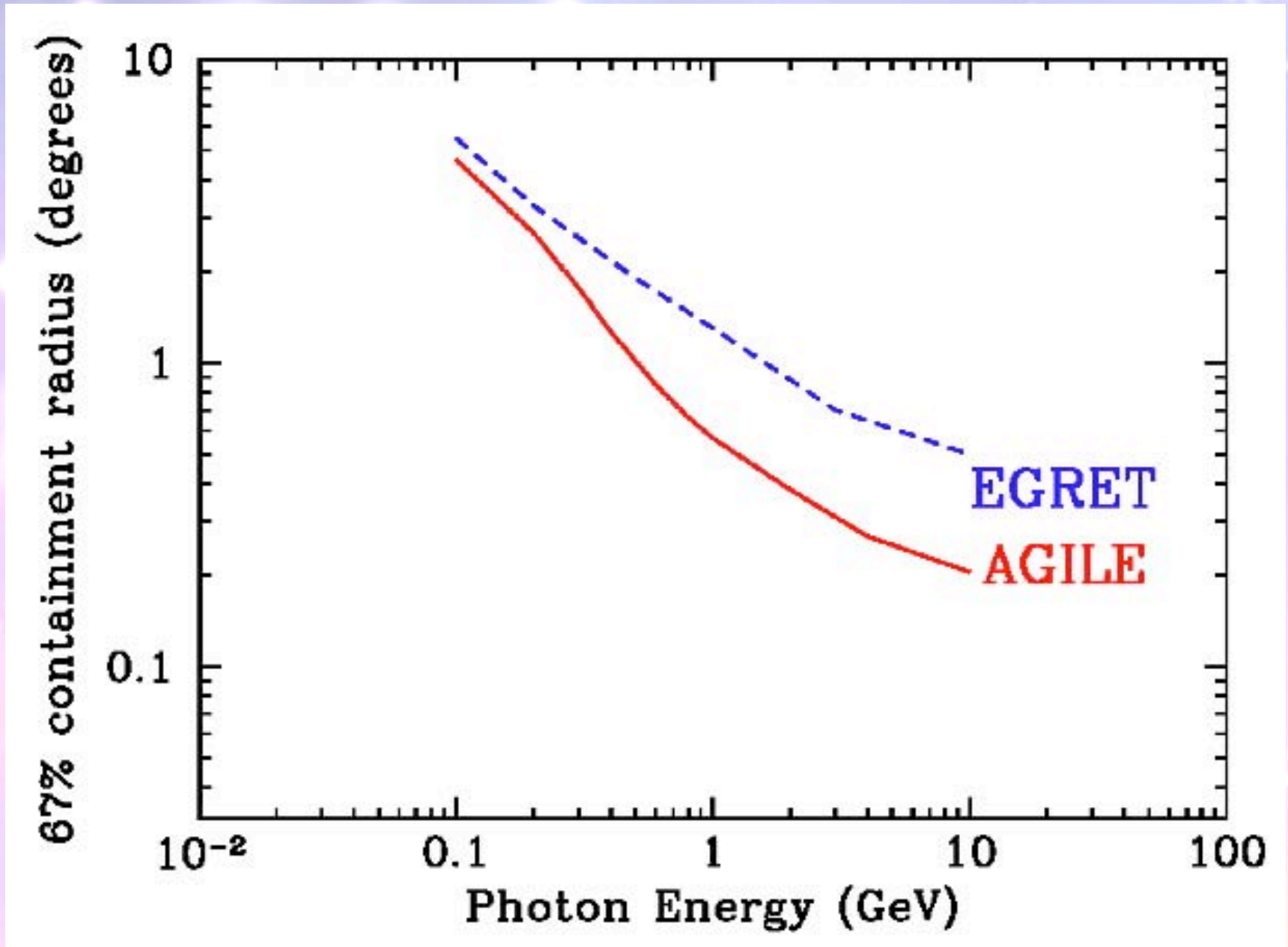
AGILE, EGRET & COMPTEL effective areas

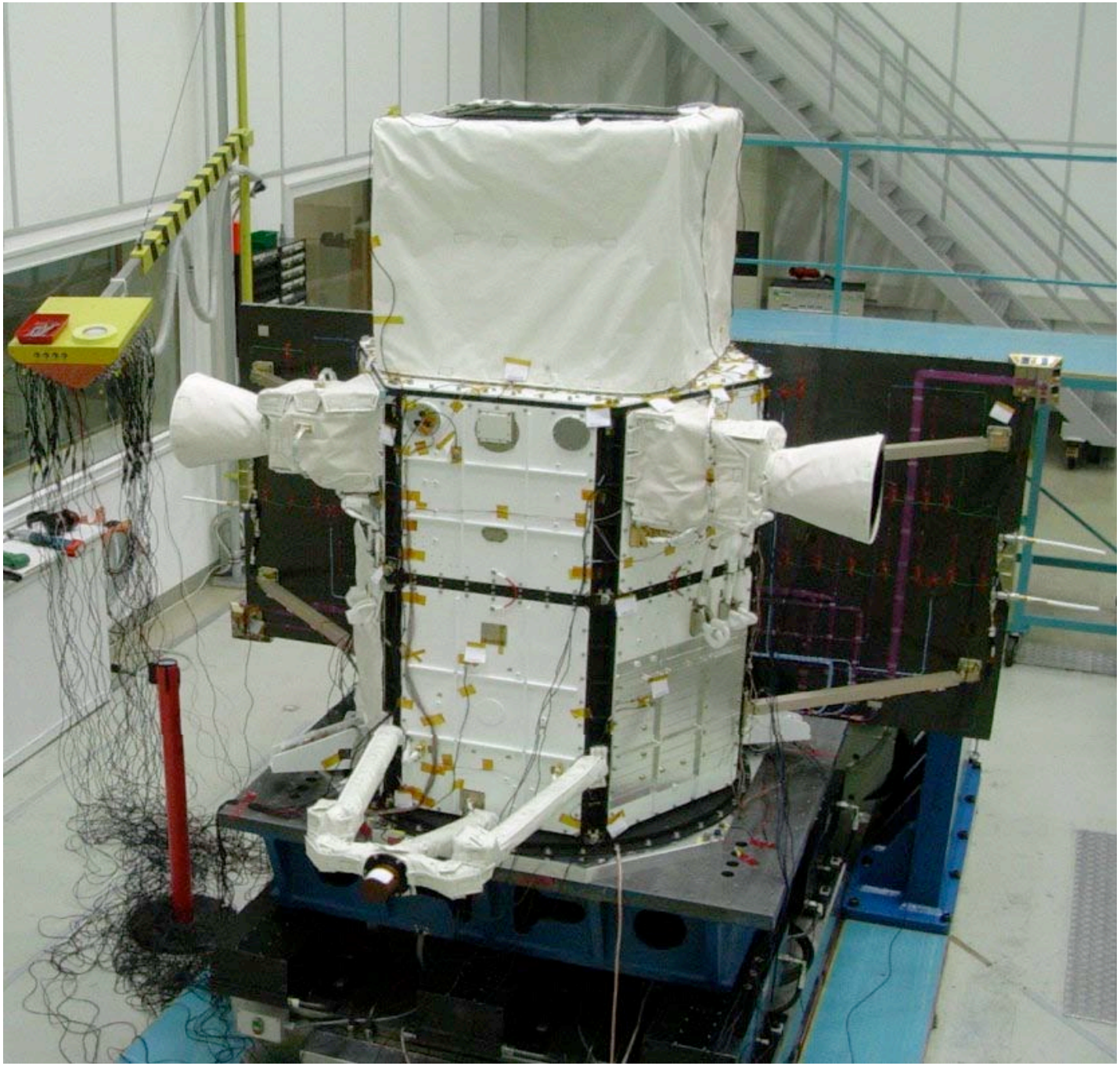


Off-Axis Effective Area at 1 GeV



Three dimensional PSF as a function of photon energy for AGILE and EGRET.





AGILE Satellite (IABG, Munich June 16, 2006)

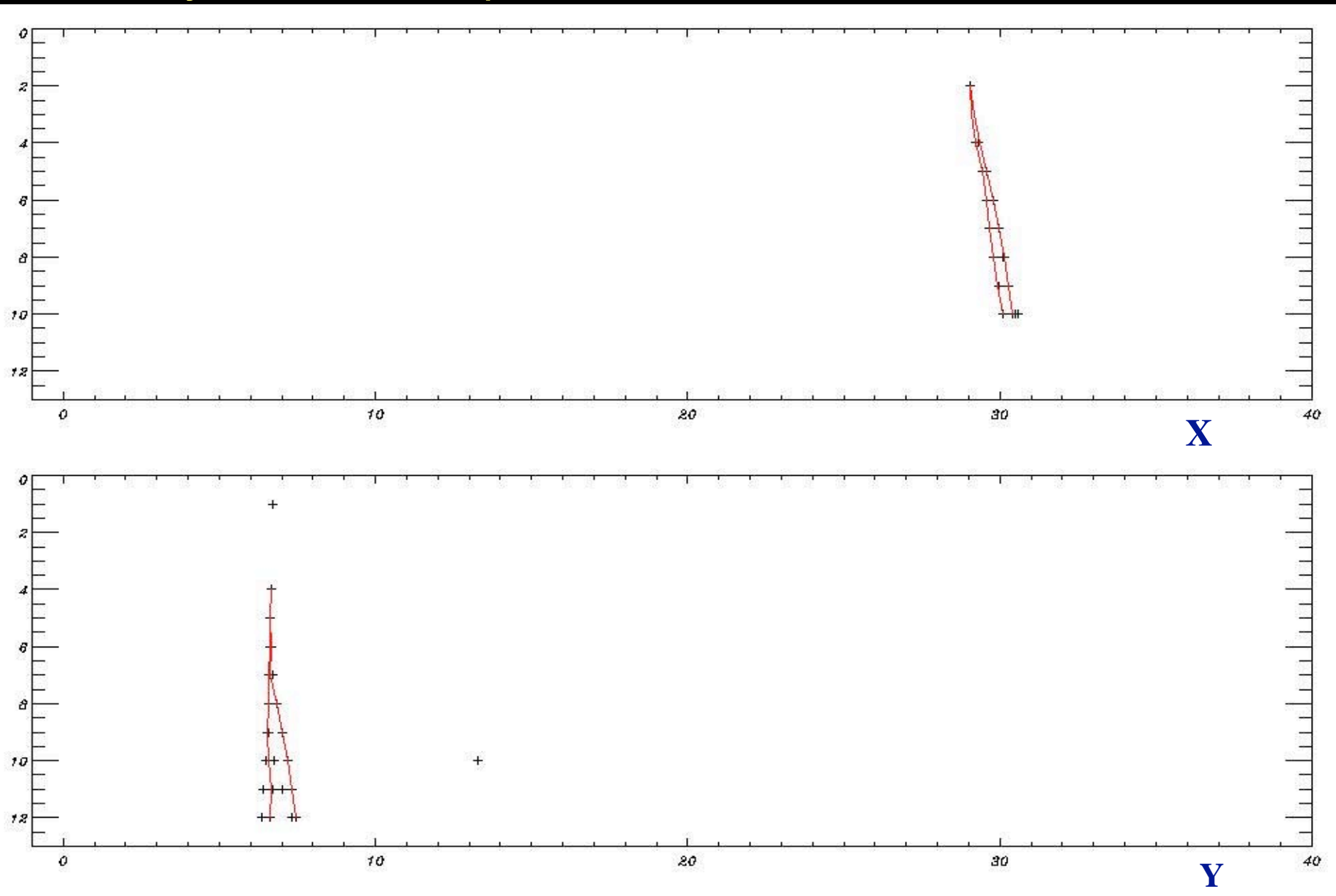

IABG
N
REMOVE BEFORE FLIGHT

17 April 2007
closing the payload
AGILE mounted on the PSLV rocket, inside the Vehicle Assembly Building of Sriharikota

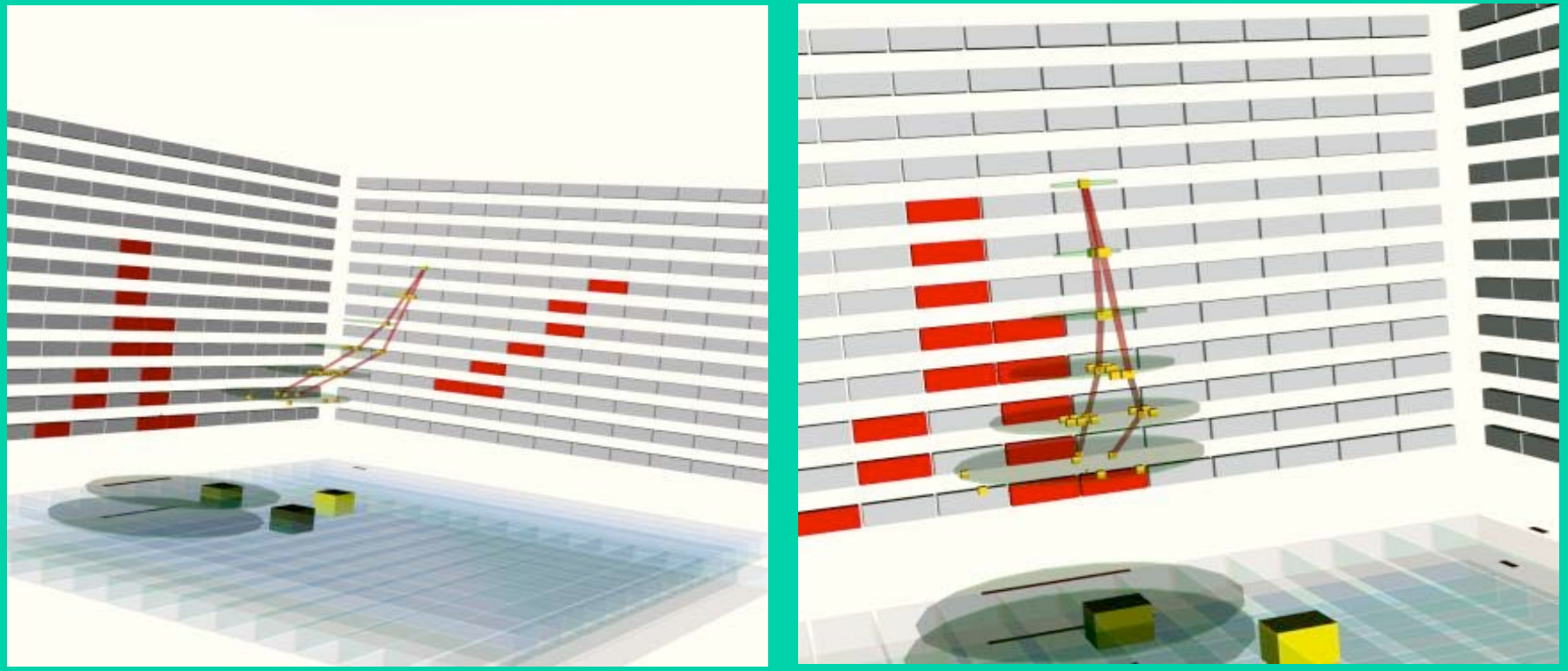
22 April
The rocket
PSLV
ready for
the launch

23 April 12 o’clock
Roma time : Launch

8 May 2007 first photon received from AGILE in orbit

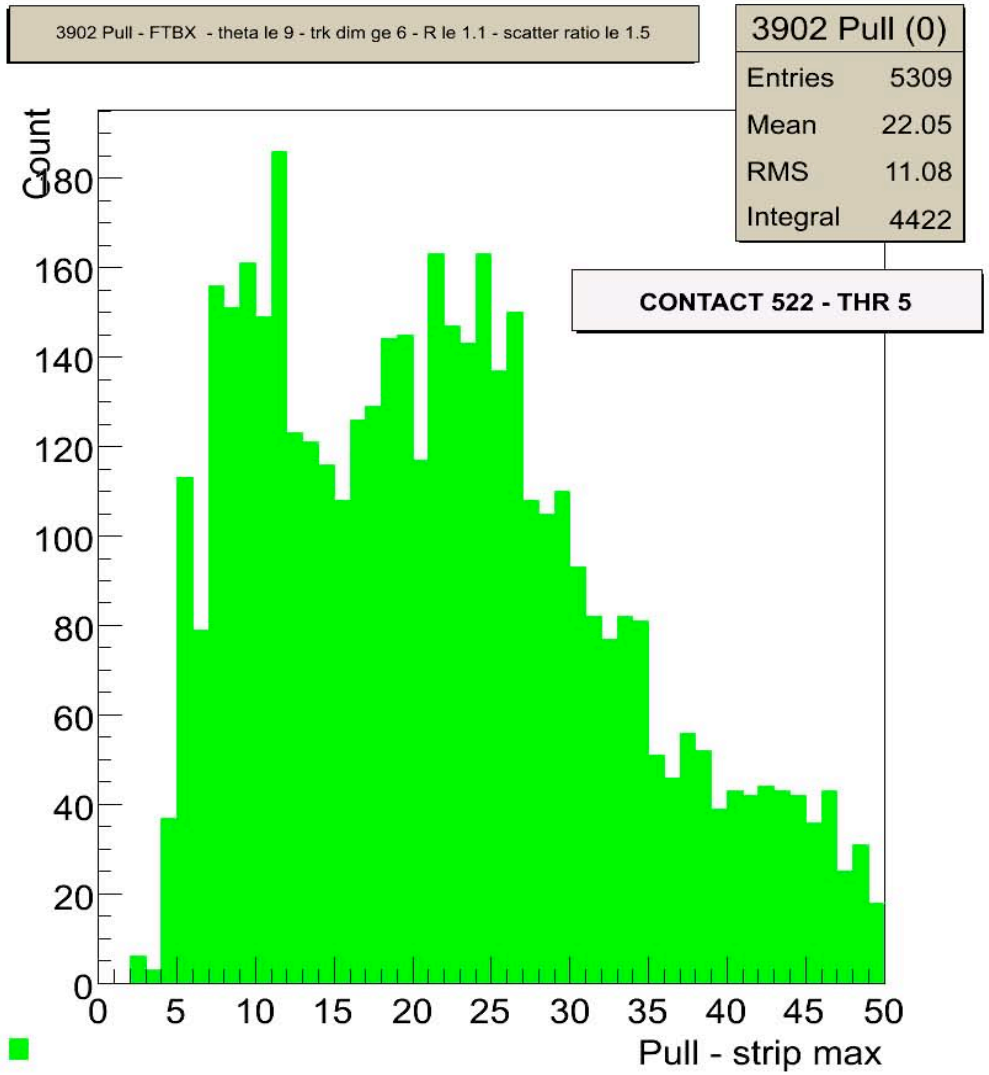


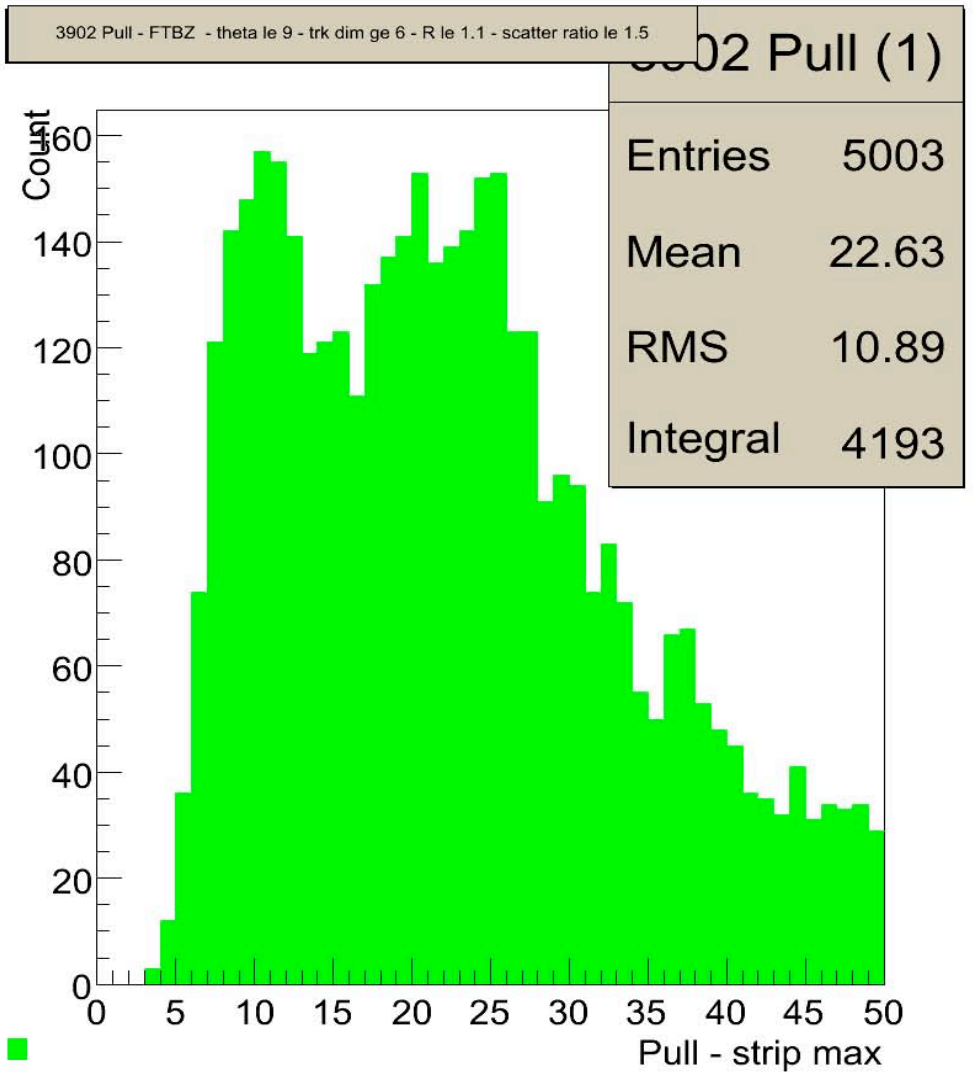
First gamma-ray photon detected by AGILE on Orbit



AGILE Tracker: on-axis (0-9 degrees) Pull

[central strip “charge”/noise (pedestal sigma)]

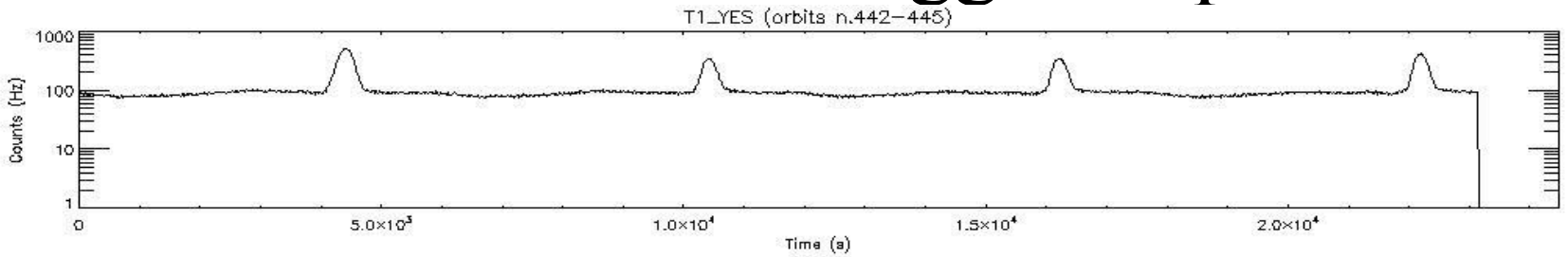




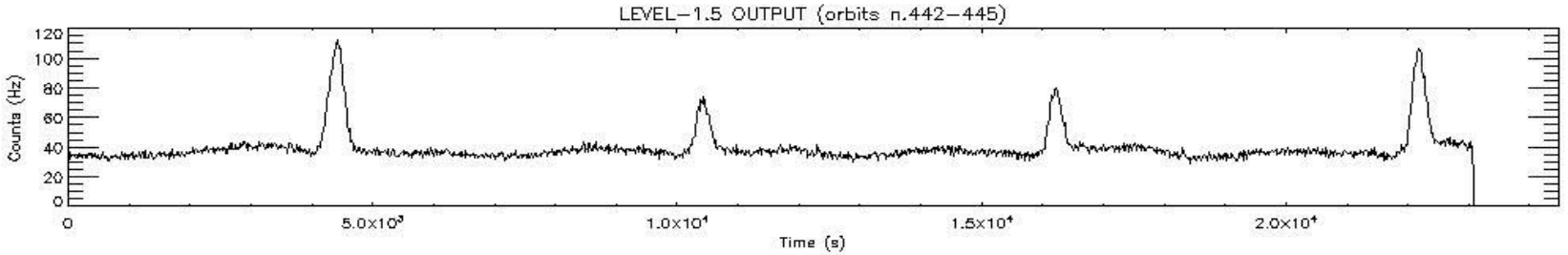
PULL ON AXIS WITH THR 5 - CONTACT 522

On Orbit AGILE Grid Trigger sequence

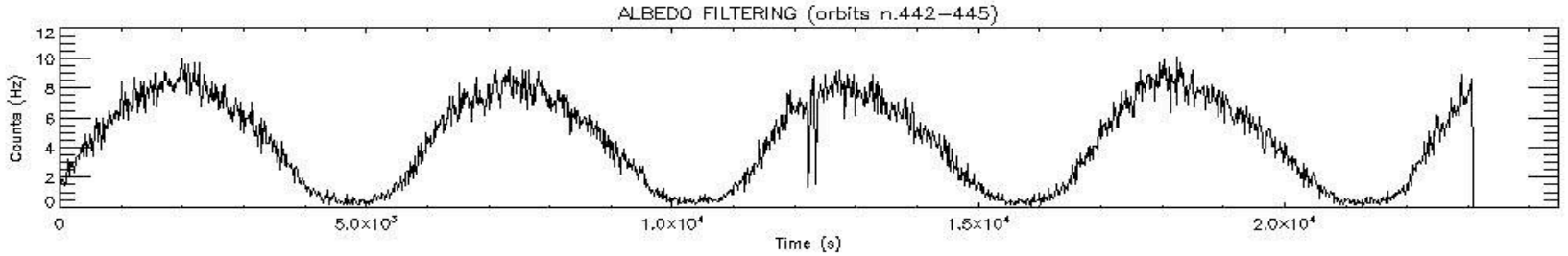
L0



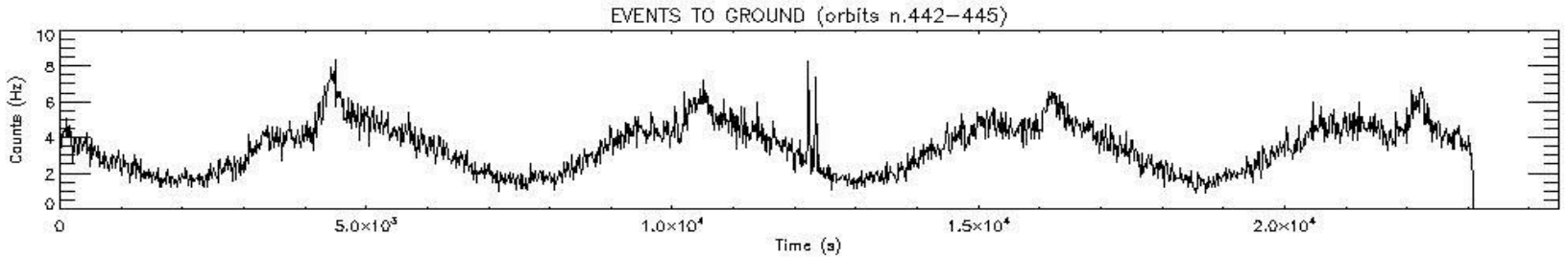
L1



Filter



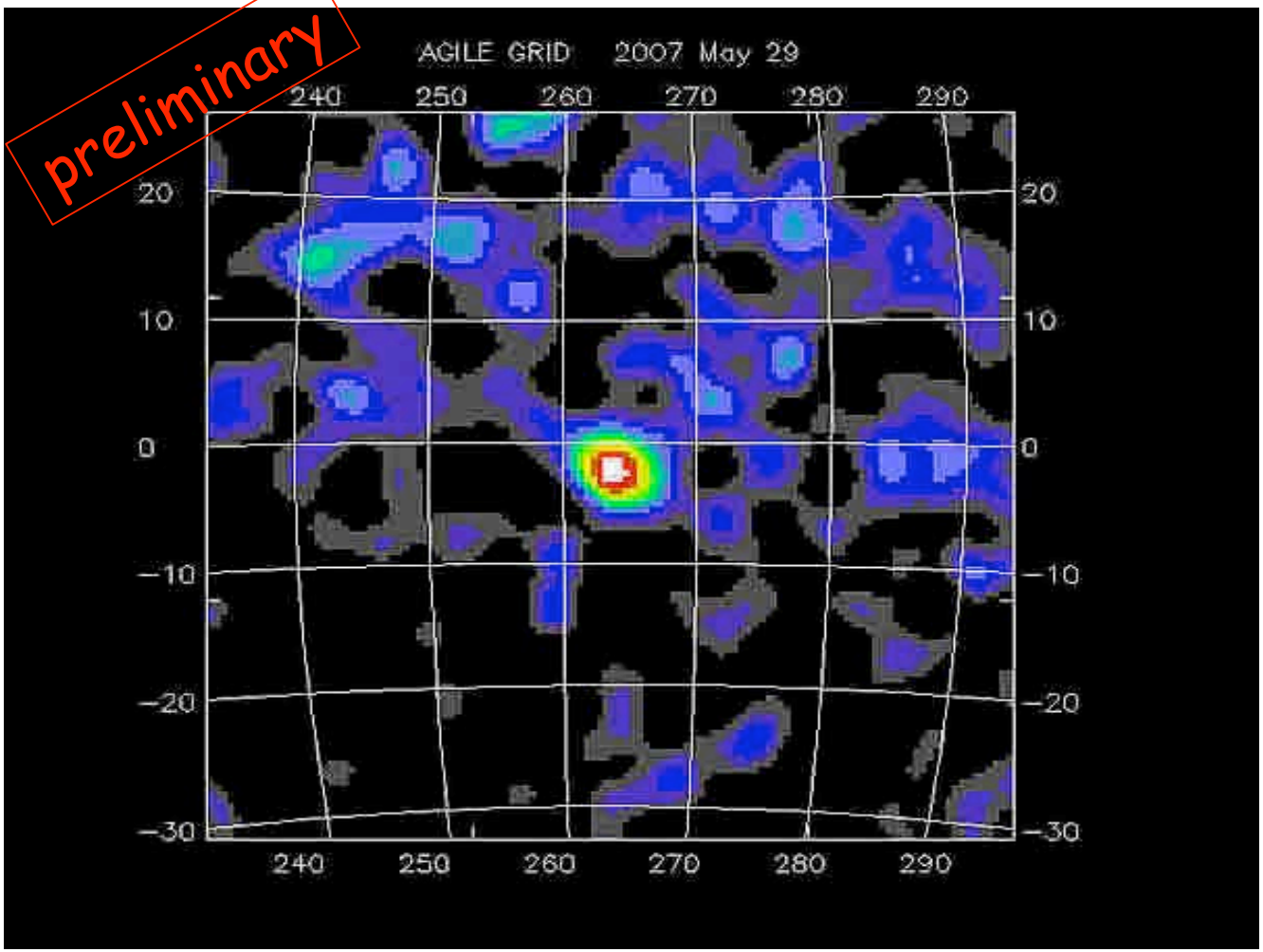
L2



AGILE Tracker efficiency (0-9 degrees) (physical calibration)

ORBITAL CONTACT NUMBER	*TR-FEE Threshold (and strip-mask)*	*TM TYPE*	*Pull-X*	*Pull-Z*	*% EVT < 3 CL*	*% C3 < 100 ADC*	*Single track efficiency (detection in the 3rd plane out of 4 aligned planes with the other 3 planes with detected hits)*
Run 11119 (IABG, Munich)	7 (6)	phys	16.7	16.2	1%	0%*	Efficiency -Z 0.97 +/- 0.02 Efficiency- X 0.95 +/- 0.02
253	20 (6)	phys	16.7	16.7	1.50%	0.20%	Efficiency -Z 0.83 +/- 0.03 Efficiency -X 0.80 +/- 0.03
510	6 (6)	phys	18.1	17.4	5%	2.30%	Efficiency -Z 0.97 ± 0.01 Efficiency -X 0.96 ± 0.01
522	5 (7)	phys	17	17.4	13%	2.50%	Efficiency -Z 0.97 ± 0.01 Efficiency- X 0.96 ± 0.02
535 (FVC – 1 plane)	5 (8)	phys	17	17.2	7.50%	2%	Efficiency -Z 0.98 ± 0.03 Efficiency -X 0.95 ± 0.03

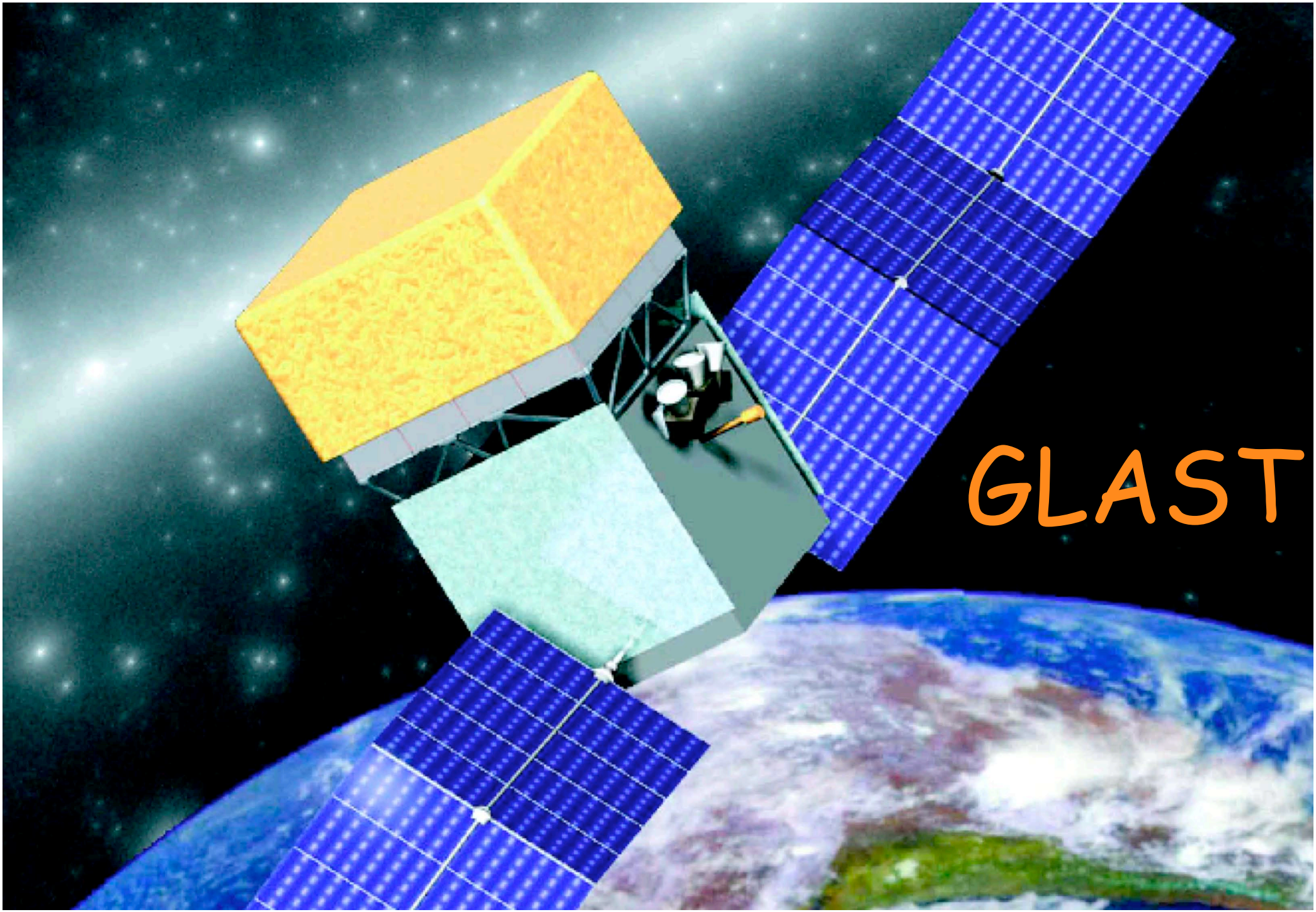
First Results:the VELA pulsar



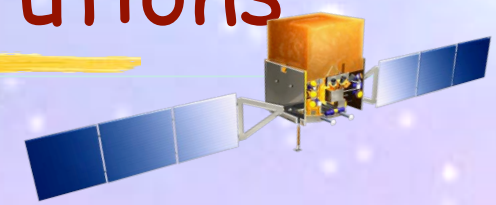
The picture shows a preliminary count map (Galactic coordinates) of photons with energy above 100 MeV of the Vela Pulsar region. The observation duration is approximately half a day (7 orbits) between May 29 and 30, 2007.
This image represents only the central part of the AGILE gamma-ray imager field of view and was built from data with a preliminary background rejection taken with an instrument configuration that is not yet optimized.

AGILE in flight

- AGILE is working nominally in orbit with the widest Field of View for a gamma-ray detector!
- The Silicon Tracker is performing in a stable way, with very low noise and small particle background
- AGILE is currently in the Commissioning Phase until the end of June
- The Science verification phase will start in July


GLAST

The GLAST Participating Institutions



American Institutions

SU-HEPL Stanford University, Hanson Experimental Physics Laboratory , ,
SU-SLAC Stanford Linear Accelerator Center, Particle Astrophysics group
GSFC-NASA-LHEA Goddard Space Flight Center, Laboratory for High Energy Astrophysics
NRL - U. S. Naval Research Laboratory, E. O. Hulburt Center for Space Research, X-ray and gamma-ray branches
UCSC- SCIPP University of California at Santa Cruz, Santa Cruz Institute of Particle Physics
SSU- California State University at Sonoma, Department of Physics & Astronomy , WUStL-Washington University, St. Louis
UW- University of Washington , TAMUK- Texas A&M University-Kingsville, Ohio State University

Italian Institutions INFN - Istituto Nazionale di Fisica Nucleare and Univ. of Bari, Padova, Perugia, Pisa, Roma2, Trieste, Udine
ASI - Italian Space Agency
IASF- Milano, Roma

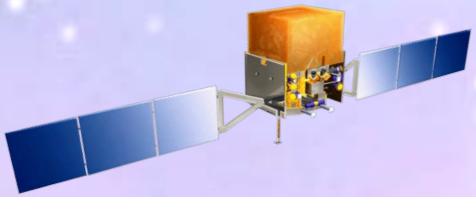
Japanese Institutions University of Tokyo
ICRR - Institute for Cosmic-Ray Research
ISAS- Institute for Space and Astronautical Science
Hiroshima University

French Institutions CEA/DAPNIA Commissariat à l'Energie Atomique, Département d'Astrophysique, de physique des Particules, de physique Nucliaire et de l'Instrumentation Associée, CEA, Saclay
IN2P3 Institut National de Physique Nucléaire et de Physique des Particules, IN2P3
IN2P3/LPNHE-X Laboratoire de Physique Nucléaire des Hautes Energies de l'École Polytechnique
IN2P3/PCC Laboratoire de Physique Corpusculaire et Cosmologie, Collège de France
IN2P3/CENBG Centre d'études nucléaires de Bordeaux Gradignan
IN2P3/LPTA Laboratoire de Physique Theorique et Astroparticules, Montpellier

Swedish Institutions KTHRoyal Institute of Technology
Stockholms Universitet

Collaboration members:	**~225**
Members:	**77**
Affiliated Sci.	~80
Postdocs:	23
Graduate Students	32

Current GLAST Collaboration Science Groups and their Coordinators



1a. **Catalog**
Seth Digel (SU-SLAC); Isabelle Grenier (CEA/ Saclay)

1b. **Diffuse (Galactic and Extragalactic) and Molecular Clouds**
Seth Digel (SU-SLAC); Isabelle Grenier (CEA/ Saclay)

2. **Blazars and Other AGNs –**Paolo Giommi (ASI), Benoit Lott (Bordeaux)

3. **Pulsars, SNRs, and Plerions** - Roger Romani (Stanford); David Thompson (GSFC)

4. **Unidentified Sources, Population Studies, and Other Galaxies**
Patrizia Caraveo (IASF); Olaf Reimer (Stanford)

5. **Dark Matter and New Physics** - Elliott Bloom (SU-SLAC); Aldo Morselli (INFN–Rome)

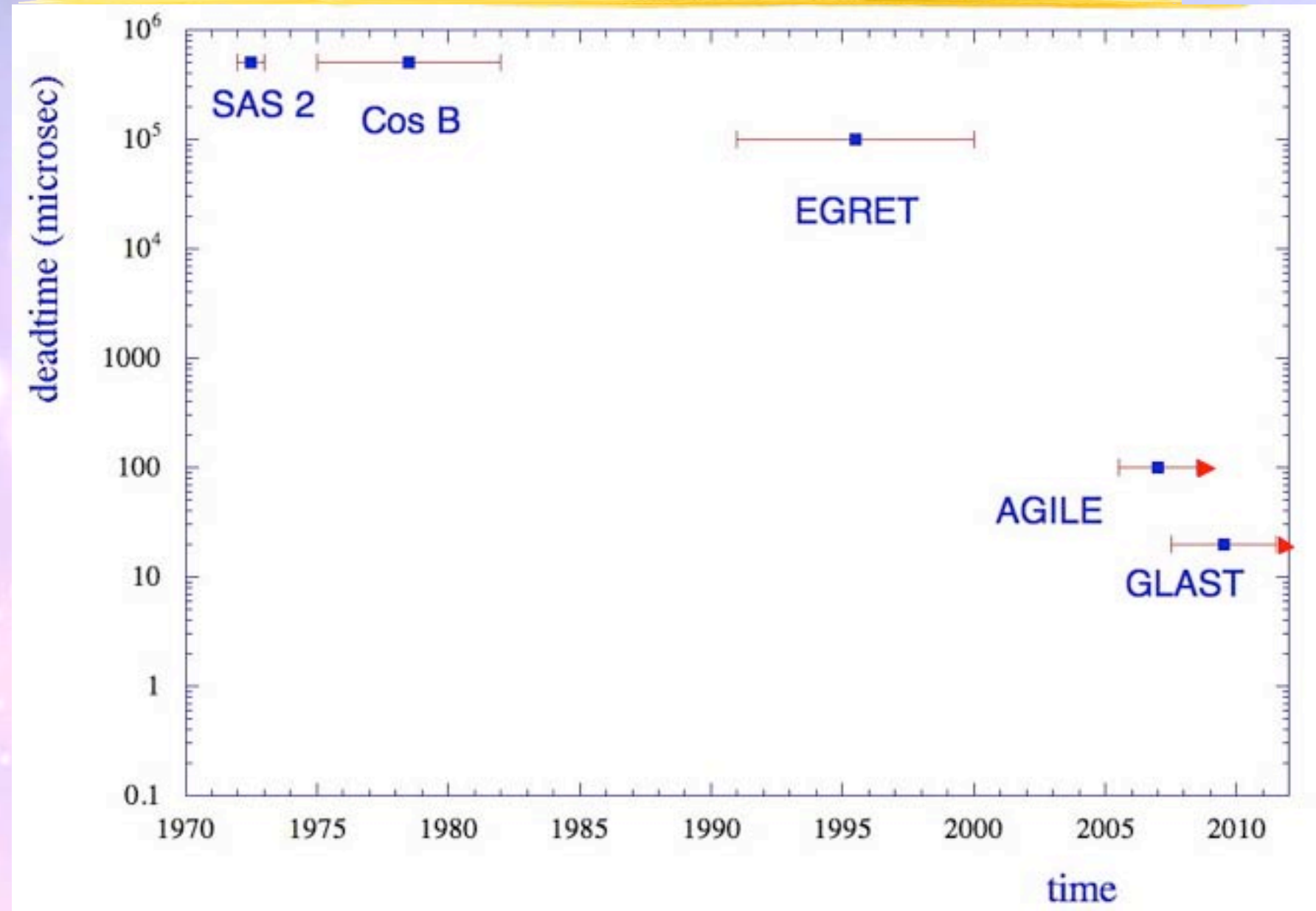
6. **Gamma-Ray Bursts** - Jay Norris (GSFC); Nicola Omodei (INFN-Pisa)

7. **Solar System Sources** - Gerry Share (NRL)

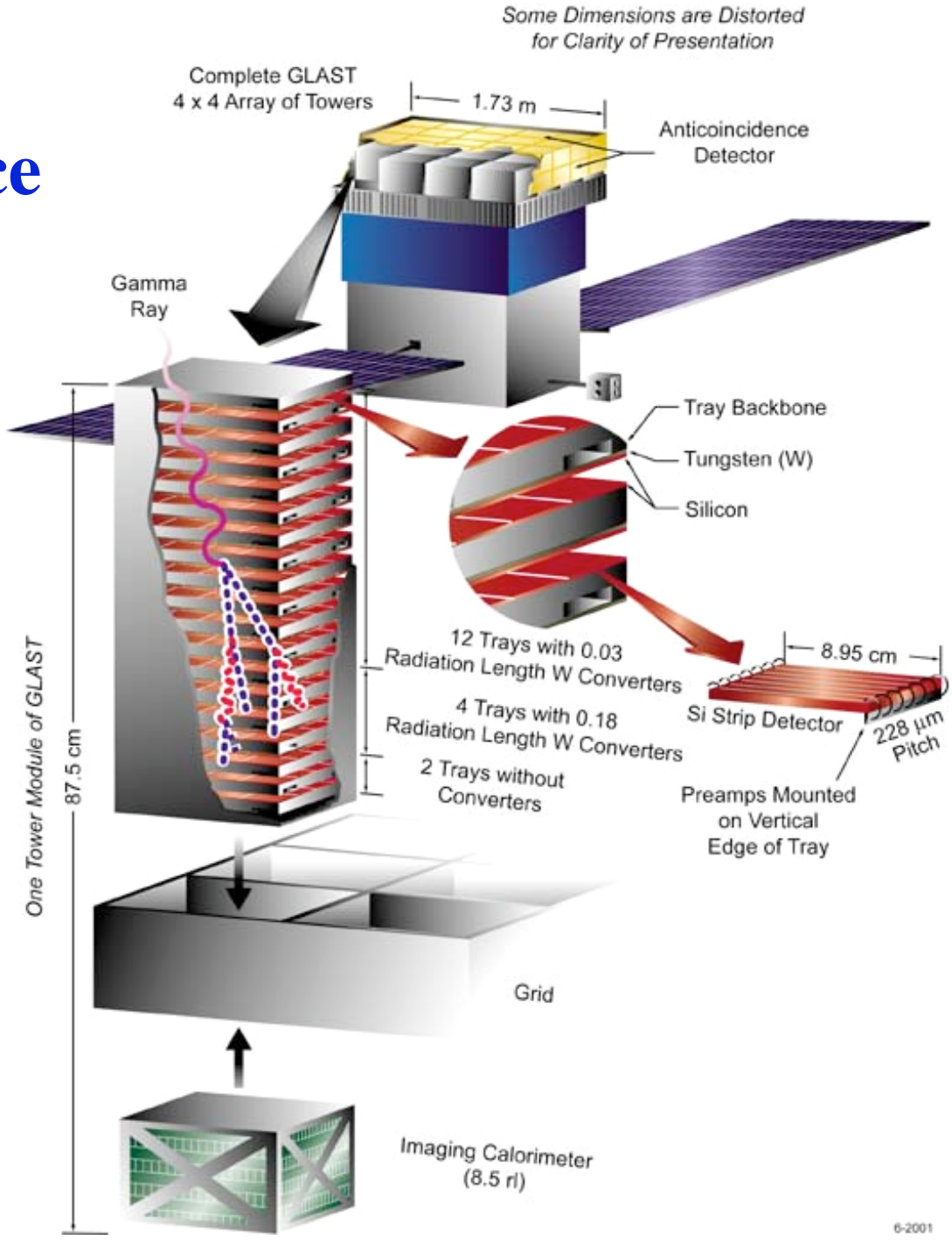
8. **Calibration and Analysis Methods** - William Atwood (UCSC); Steve Ritz (GSFC)

9. **Multiwavelength Coordination Group** – Roger Blandford (SU – KIPAC); David Thompson (GSFC)

Gamma -ray mission deadtime



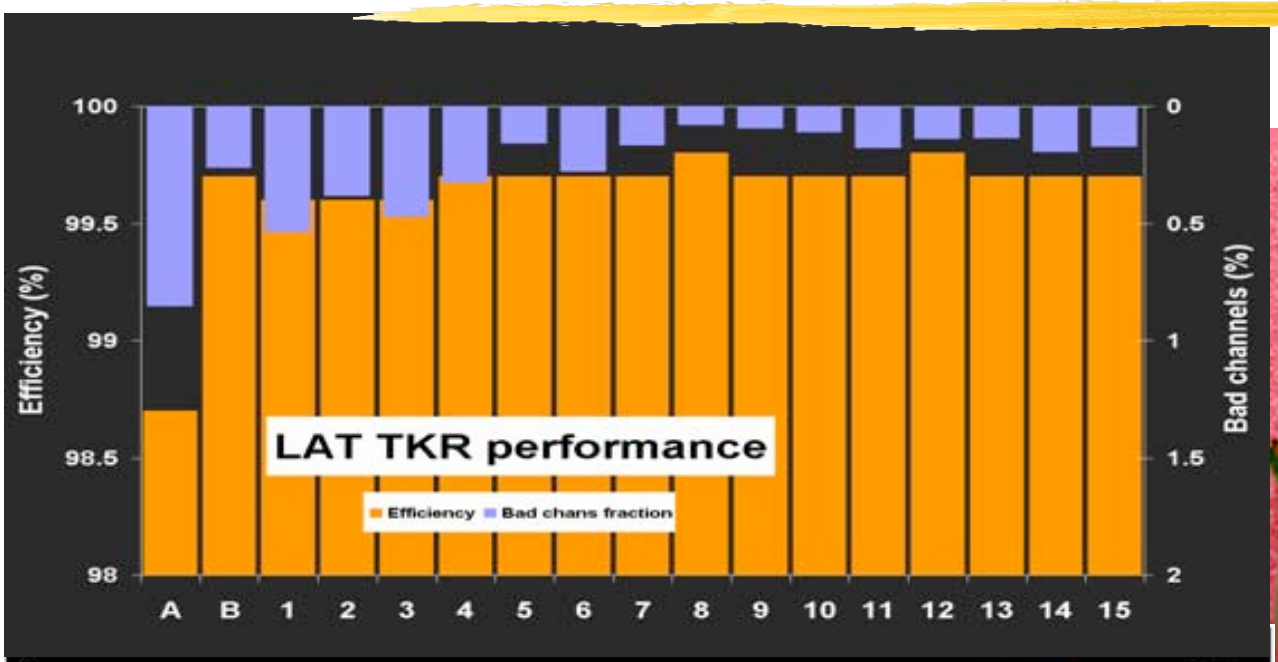
Gamma-Ray Large Area Space Telescope

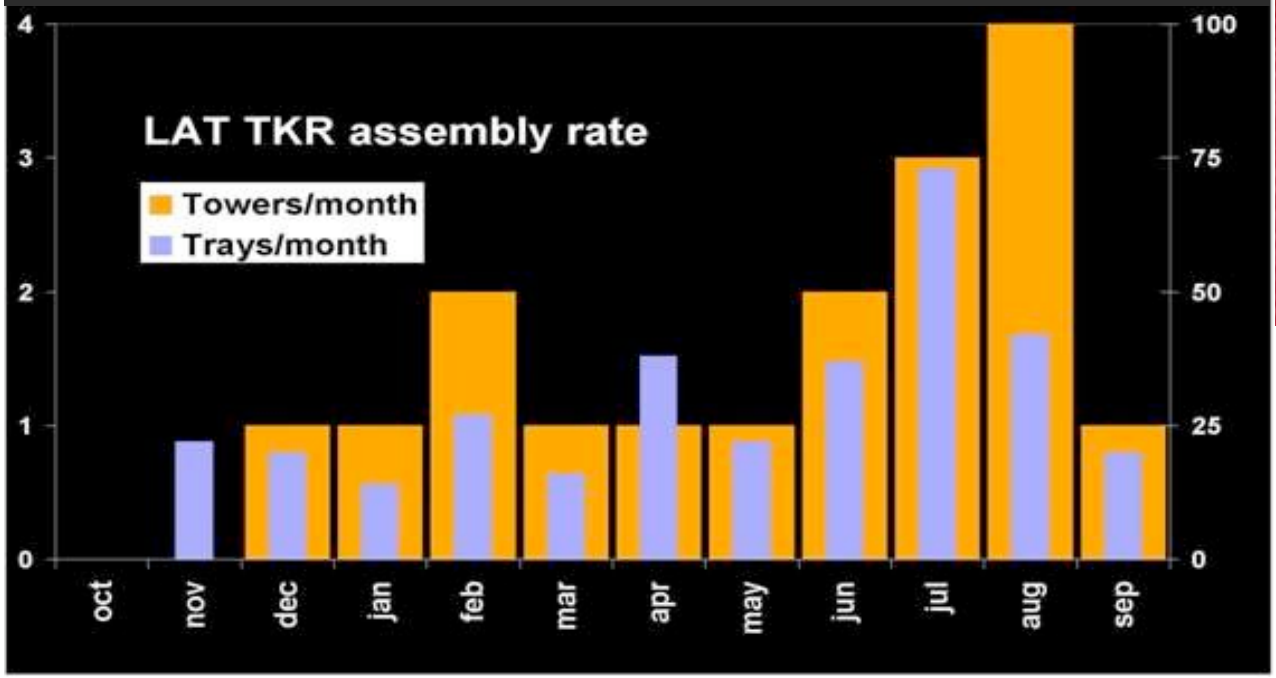


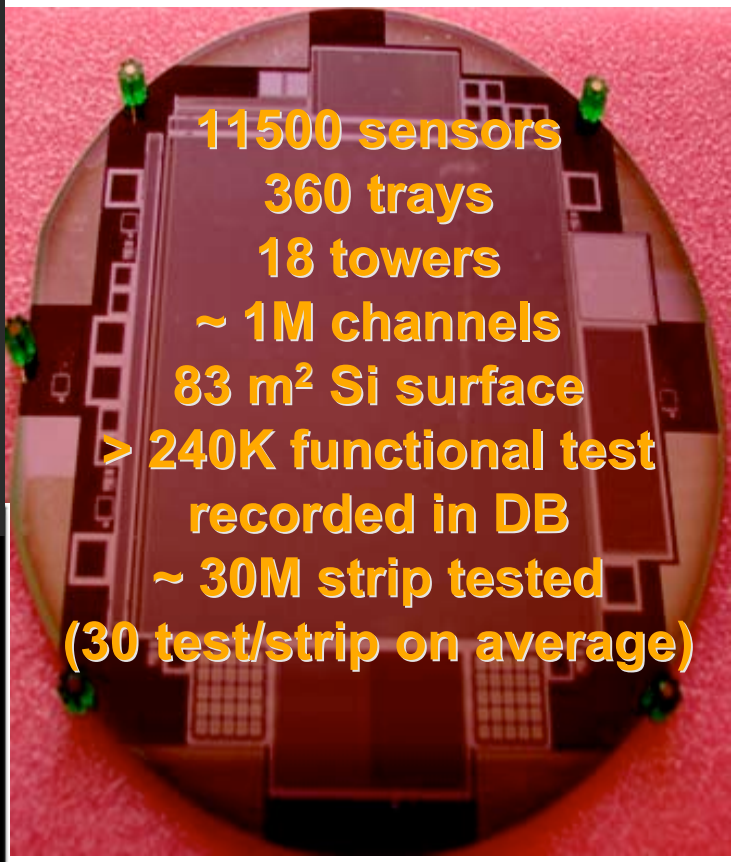

GLAST @ SLAC
12/16 Towers in the GRID on 7/10/05


GLAST @ SLAC
16/16 Towers in the GRID on 20/10/05

The LAT Tracker numbers

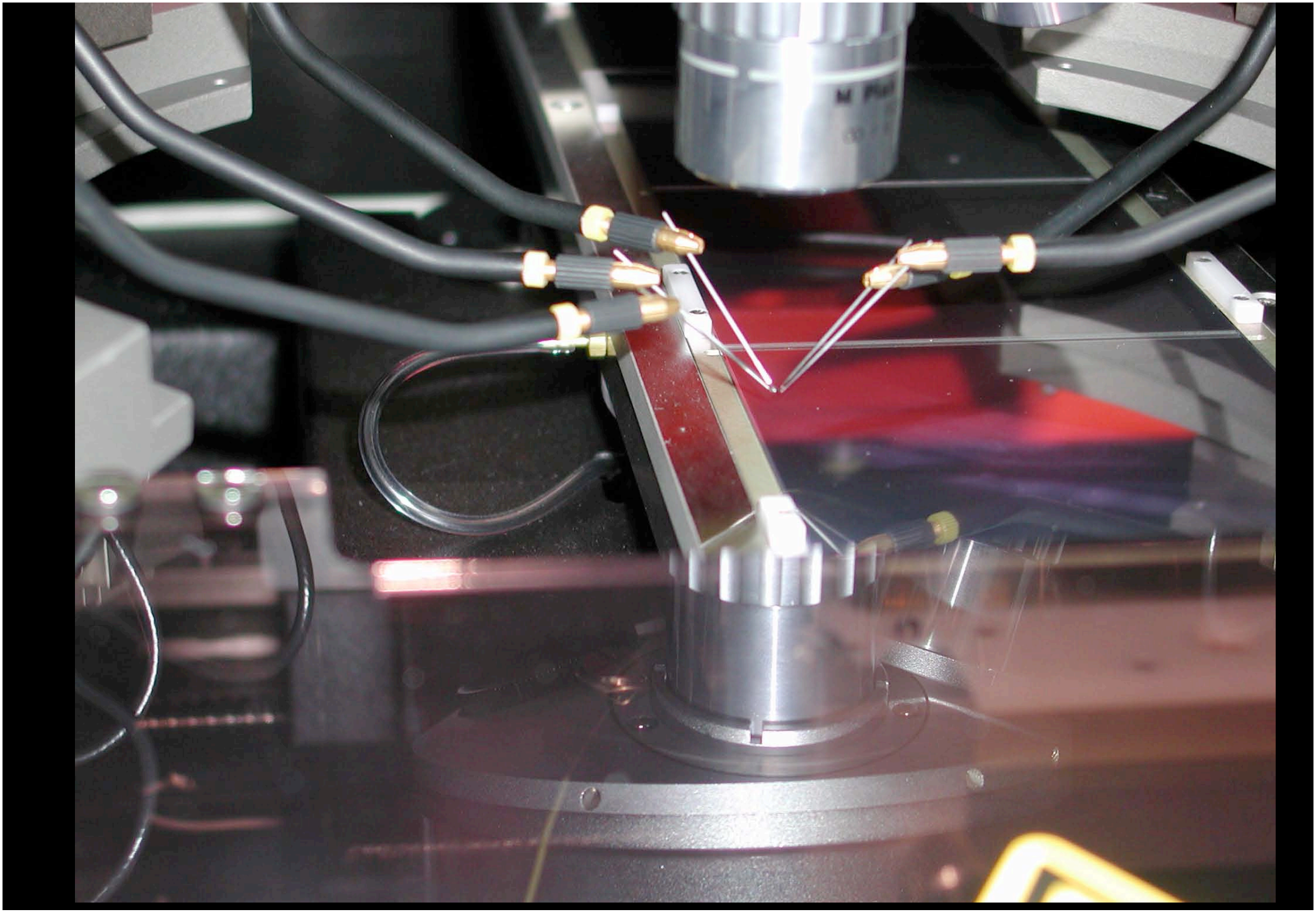


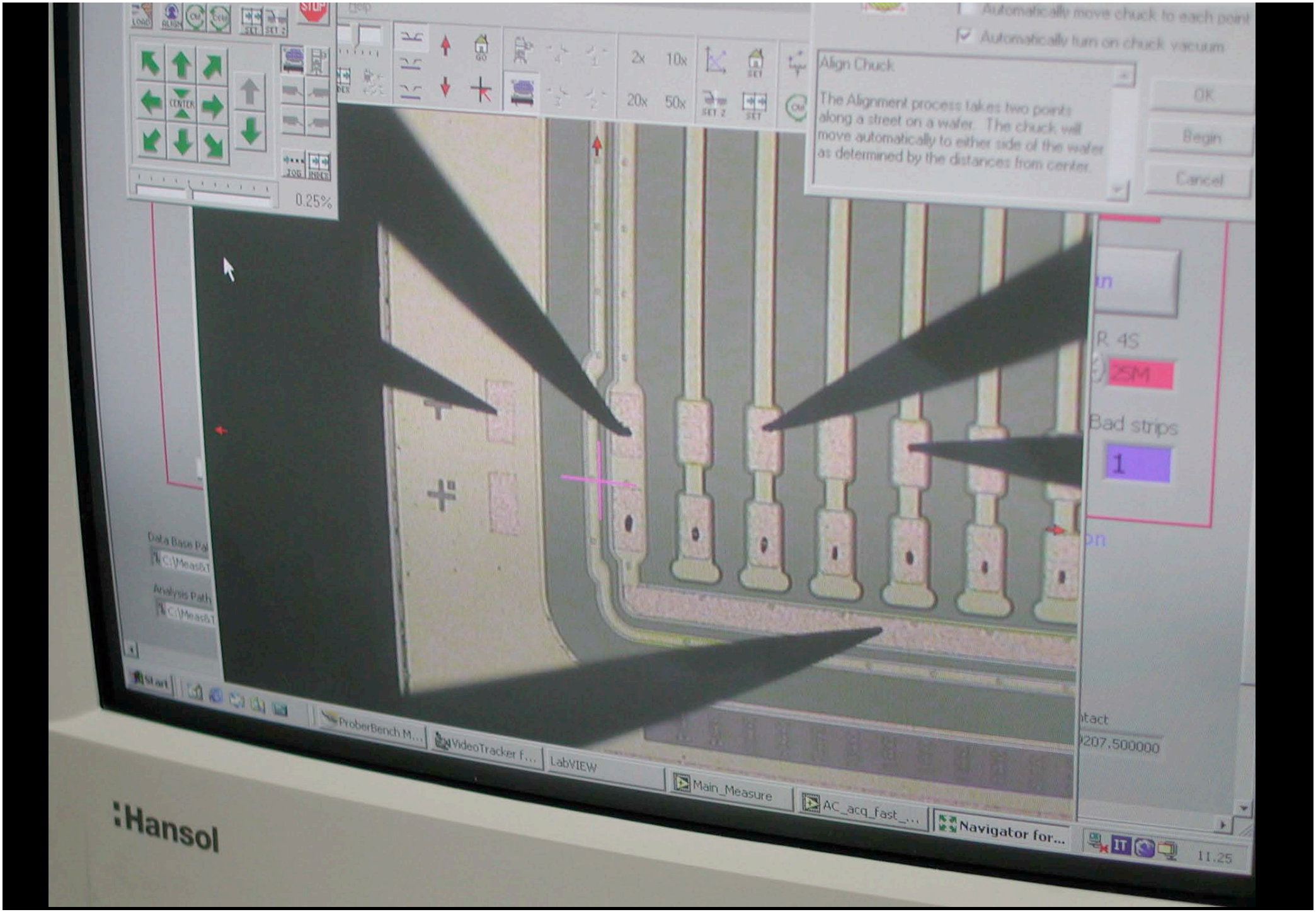




> 60 physicist and engineers involved in the italian teams from INFN (Trieste, Udine, Padova, Pisa, Perugia, Roma2, Bari) in partnership with ASI


EMERGENCY STOP

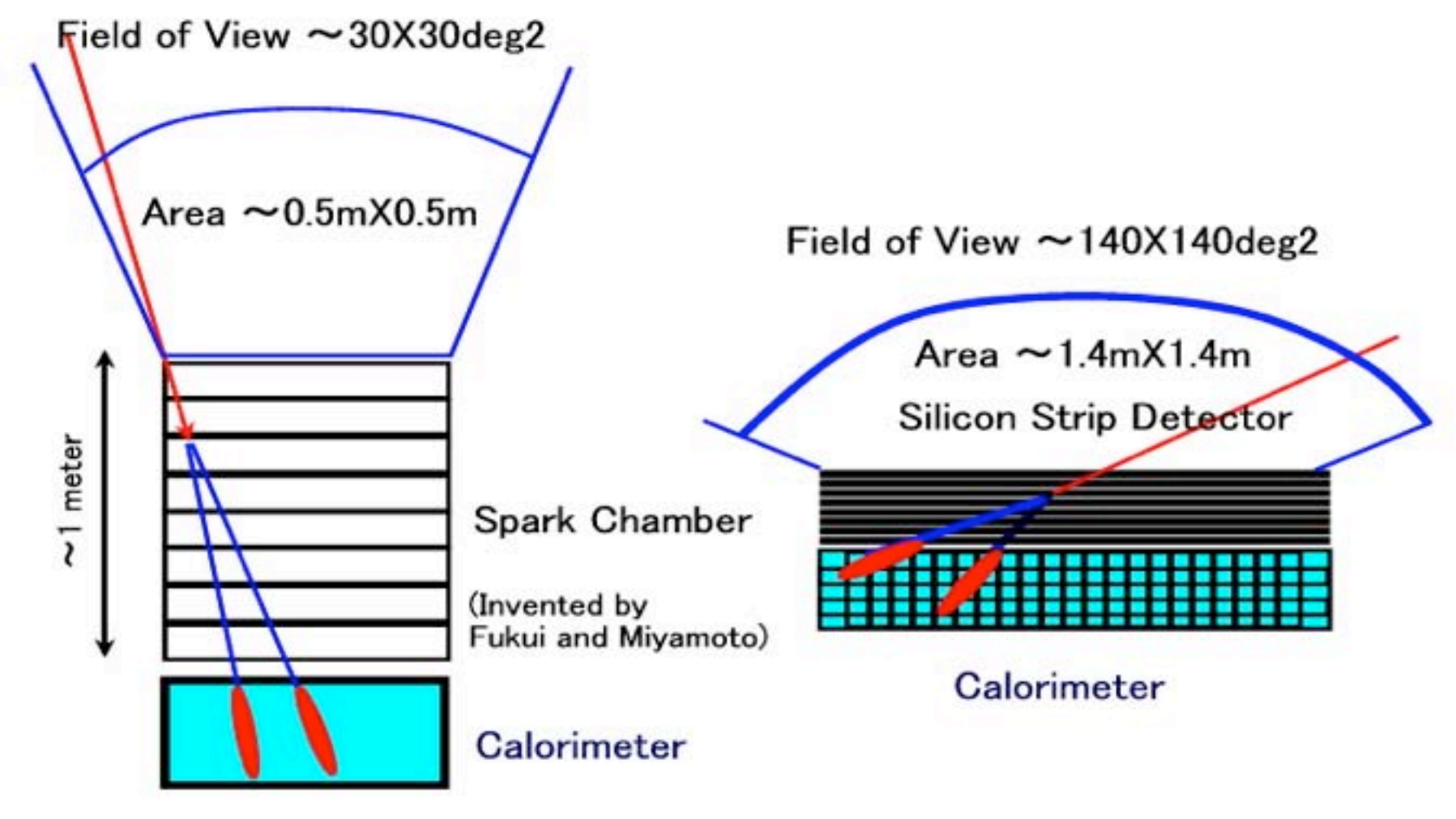



Align Chuck
The Alignment process takes two points along a street on a wafer. The chuck will move automatically to either side of the wafer as determined by the distances from center.
OK
Begin
Cancel
Automatically move chuck to each point
Automatically turn on chuck vacuum
2x
10x
20x
50x
0.25%
Bad strips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

Celebrations for the end of Tracker construction

52 attendees from INFN, ASI, SLAC, NASA, italian industrial partners

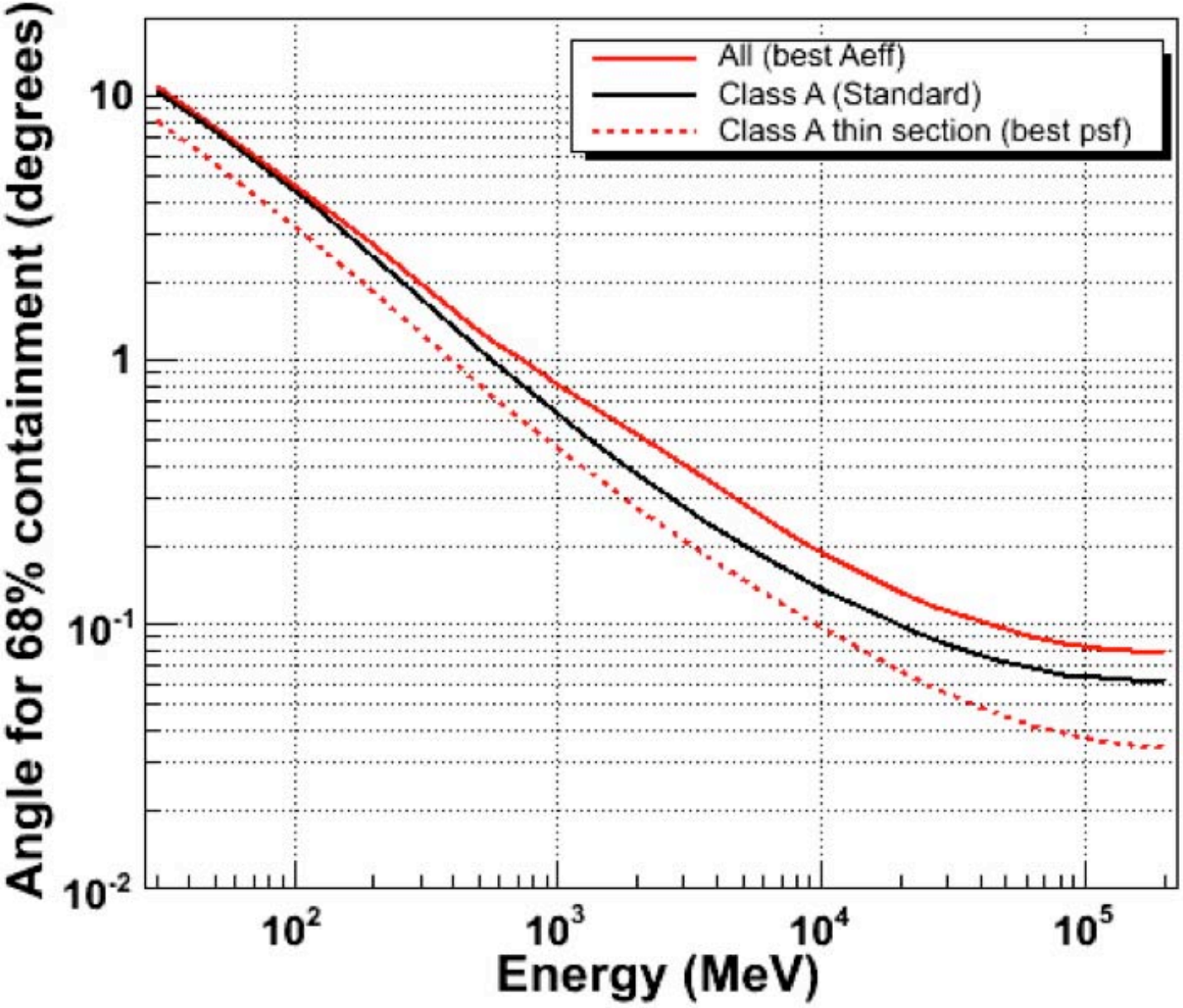
EGRET (Spark Chamber) VS. GLAST (Silicon Strip Detector)



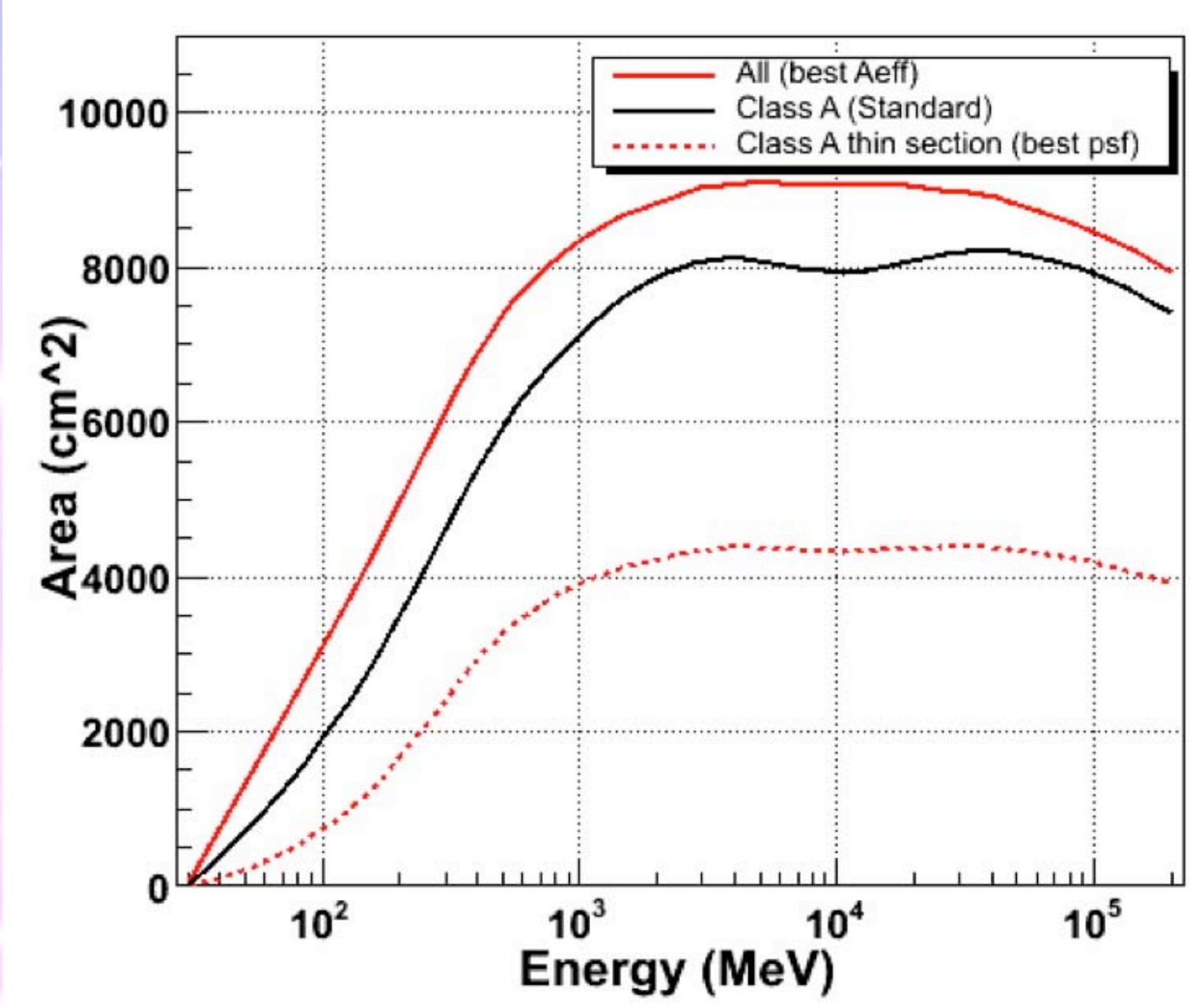
EGRET on Compton GRO (1991-2000)

GLAST Large Area Telescope (2007-2015)

GLAST Angular Resolution

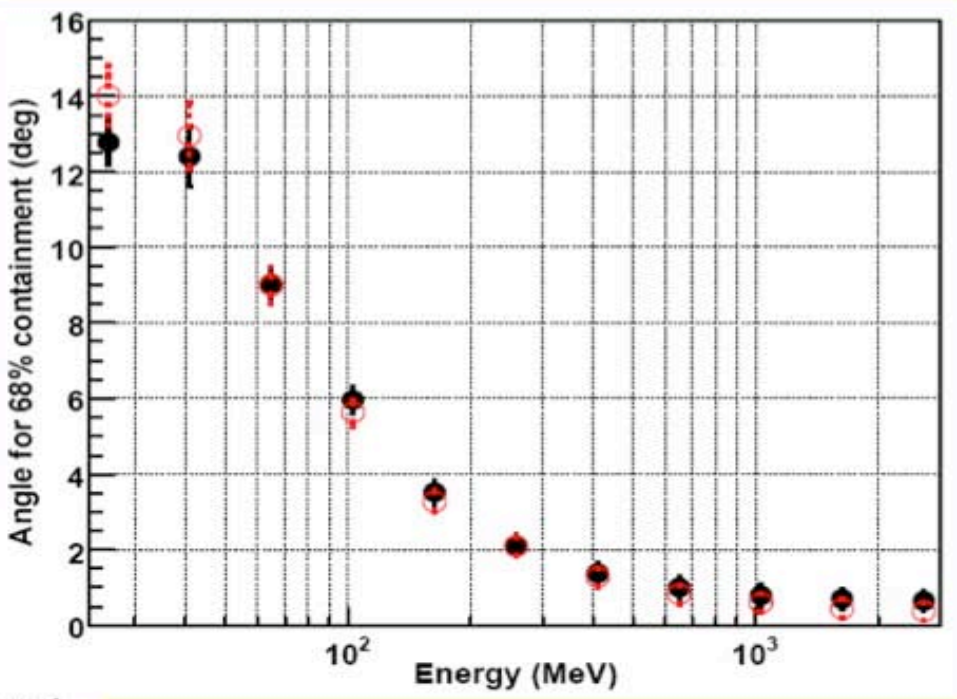


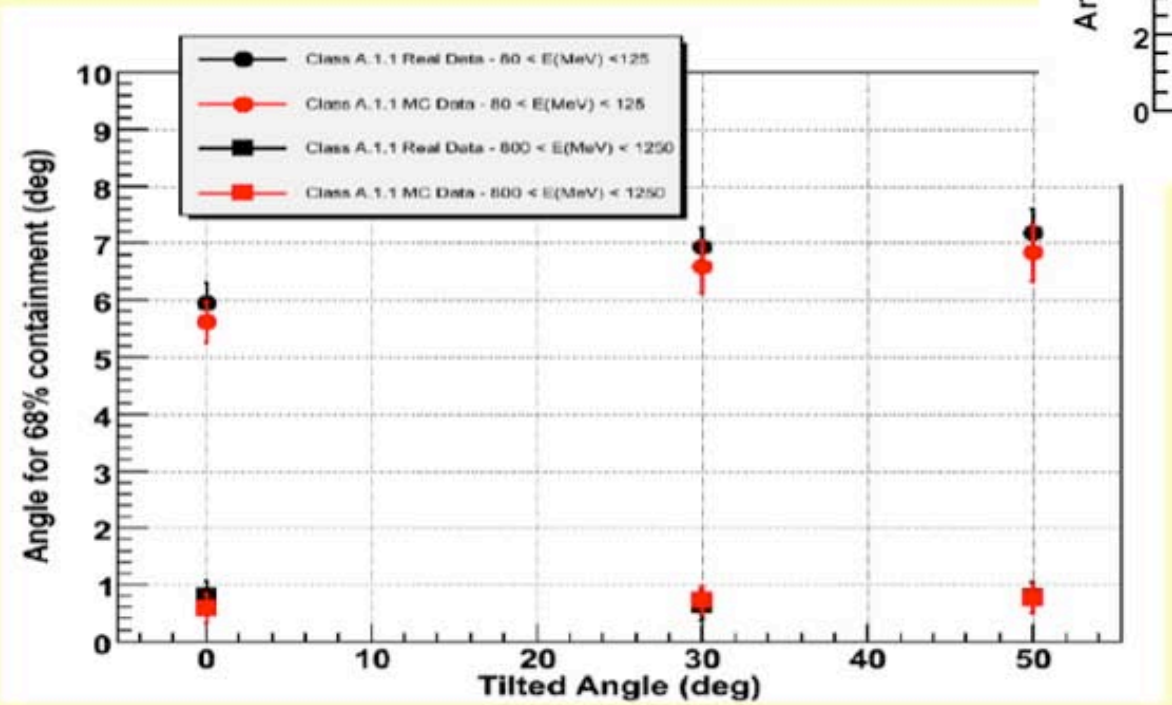
GLAST Effective Area



TKR Performance – Angular Resolution

- 68% angular dispersion for vertex events
- Good Data/MC agreement
- Comparable results from tagged photon runs





GLAST Master Schedule

- **August 2004**

Assembling of first tower completed

- **Middle of October 2005**

Completion of the LAT – *Environmental testing*

- **February 2006**

Delivery to NRL-

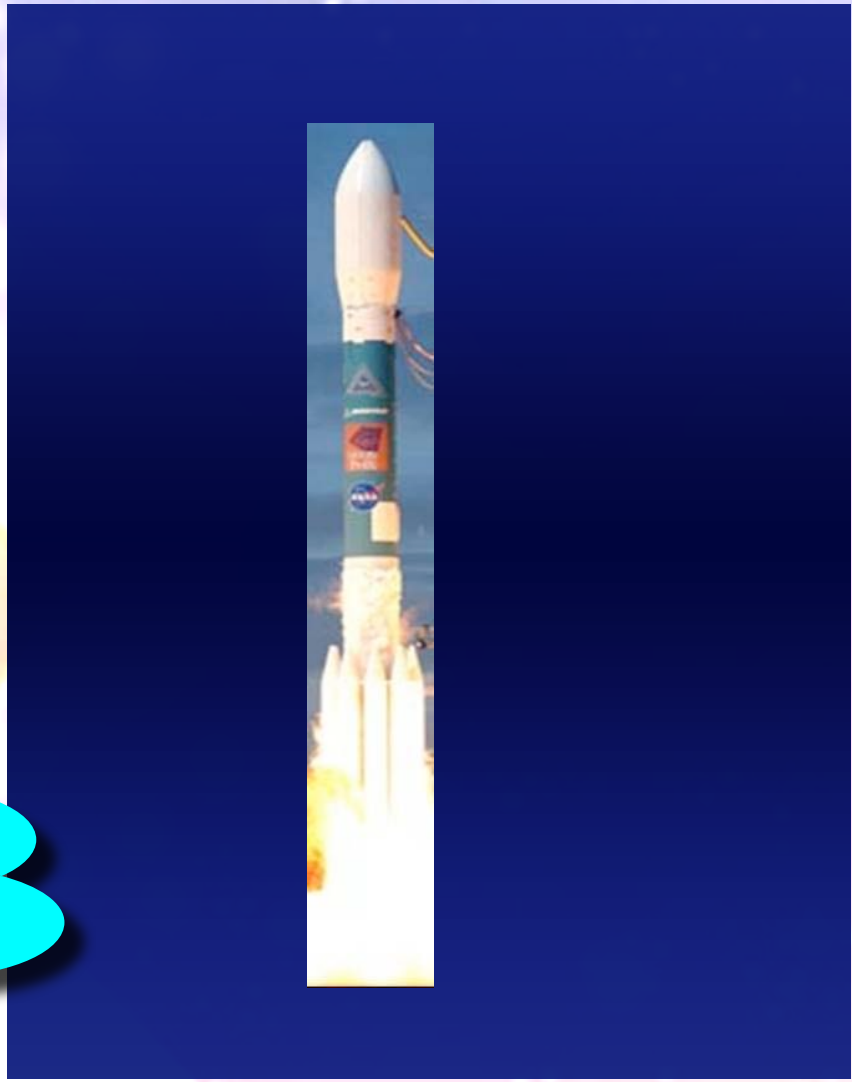
- **Dic.2007 -Feb. 2008**

Kennedy Space Flight Center

LAUNCH

- **June 2008**

Science operation begins!



more info : http://people.roma2.infn.it/glast/

What we can do in the future ?

CTA : The Cherenkov Telescope Array facility

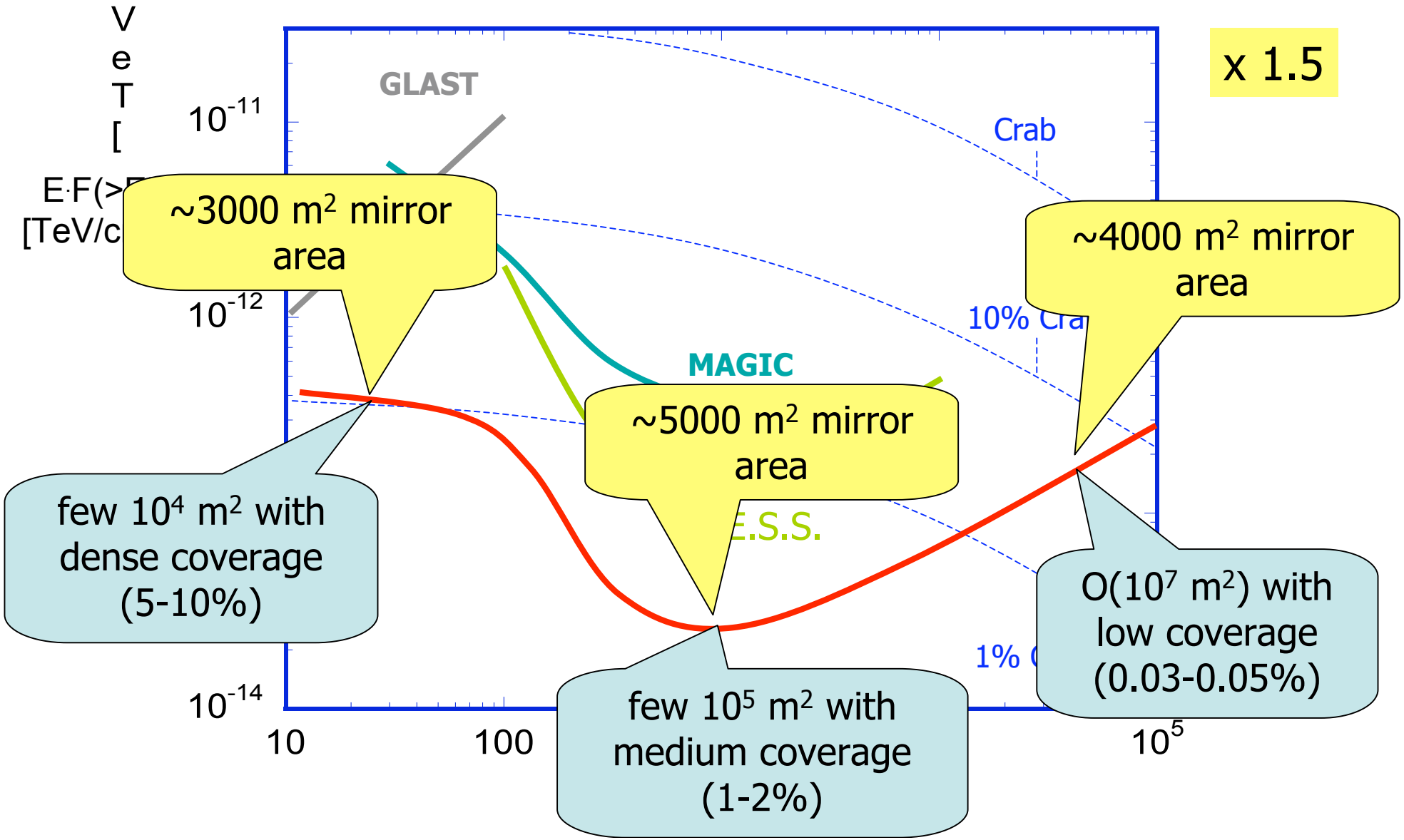
aims to explore the sky in the 10 GeV to 100 TeV energy range

Not to scale !

Possible CTA sensitivity

CTA

An advanced facility for ground-based high-energy gamma ray astronomy



Stages

CTA

An advanced facility for ground-based high-energy gamma ray astronomy

- Letter of Intent (spring 07)
  - Establishs physics case
  - Discusses basic performance needs
  - Lists possible sites and key characteristics
  - Gives examples for array configurations
  - Gives options for technical implementation
  - Lists areas where further design is needed
- Proposal (summer/fall 08)
  - Re-iterates physics case
  - Gives detailed performances for (few) array layouts
  - Gives details for (few) implementation options
  - More on site options, organization options
  - Gives cost estimates
- Design report (fall 09)
  - Final Array layout
  - Telescope implementation choices and details
  - List of final few candidates sites {not clear if final site choice}
  - Proposal for organization, governance, operation

Design study structures in Work Packages

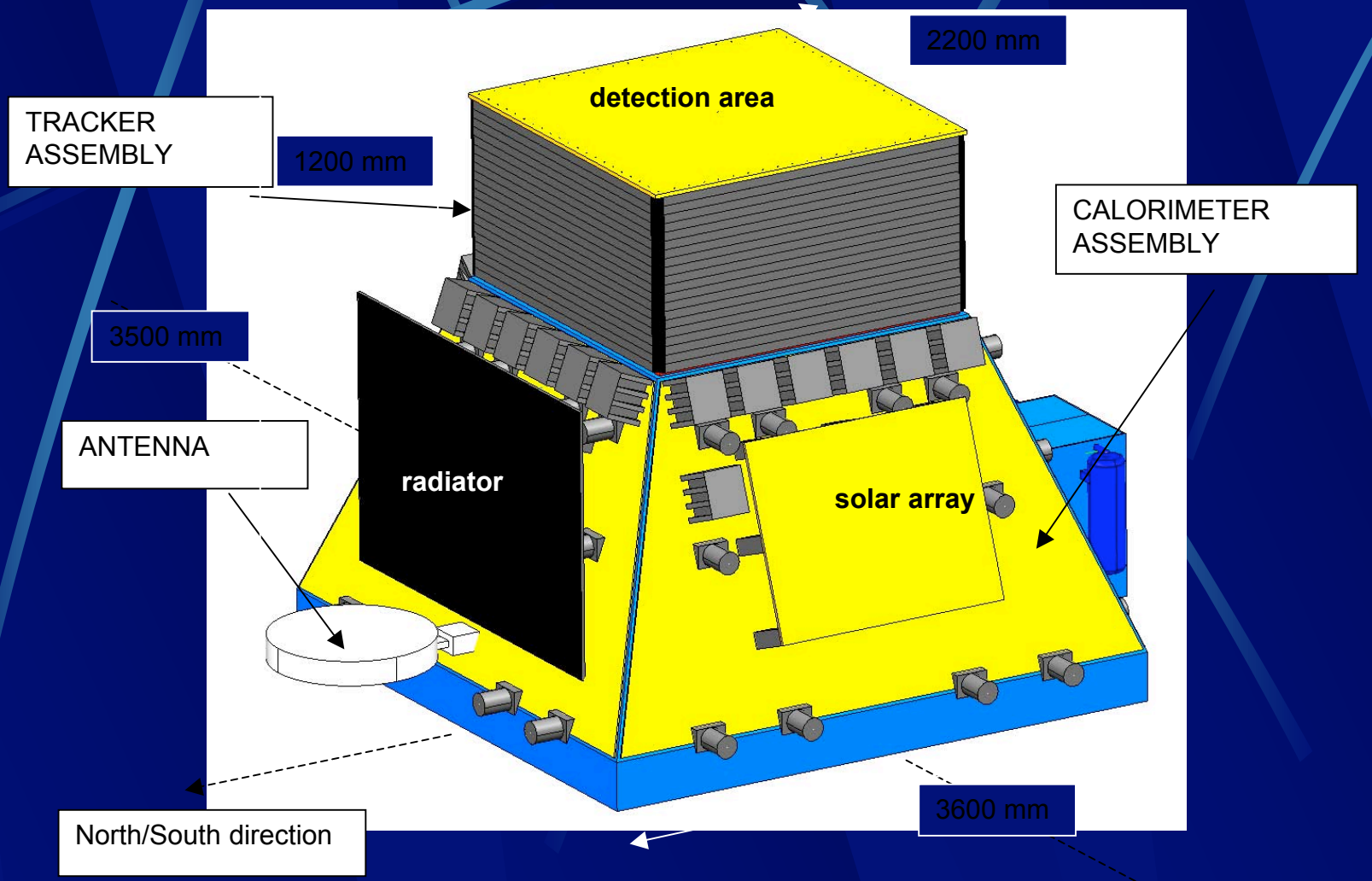
CTA

An advanced facility for ground-based high-energy gamma ray astronomy

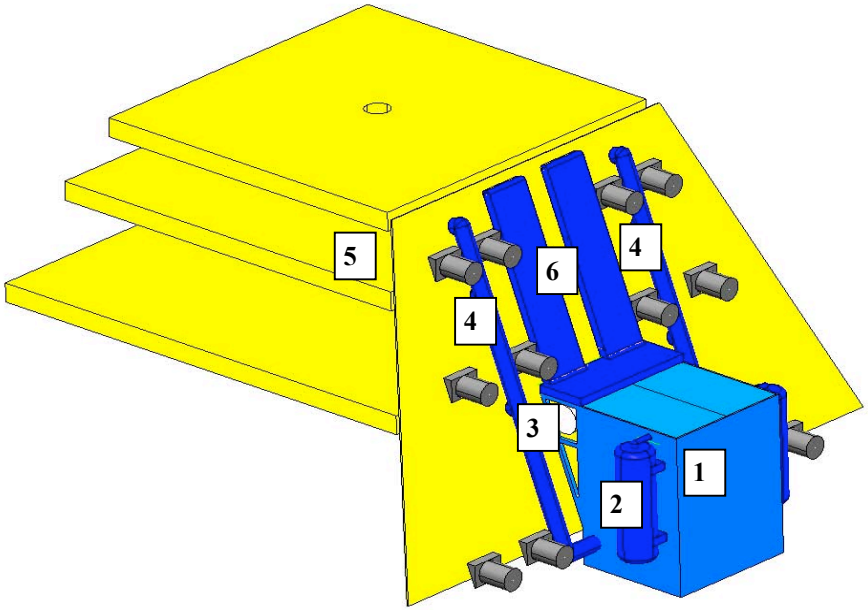
WP1	Management of the design study
WP2	Astrophysics and astroparticle physics
WP3	Optimization of array layout, performance studies and analysis algorithms
WP4	Site selection and site infrastructure
WP5	Telescope optics and mirror
WP6	Telescope structure, drive, control
WP7	Photon detectors and focal plane
WP8	Readout electronics and trigger
WP9	Instrument calibration and analysis algorithms {merge with WP10?}
WP10	Atmospheric monitoring and associated science
WP11	Observatory operation and access (TOC + SOC)
WP12	Data handling, data processing, data management and data access (SDC)
WP13	Risk assessment and quality assurance, production planning (?)
WP14	Resource exploration

Silicon detectors on the moon ?

Traker and Calorimeter configuration

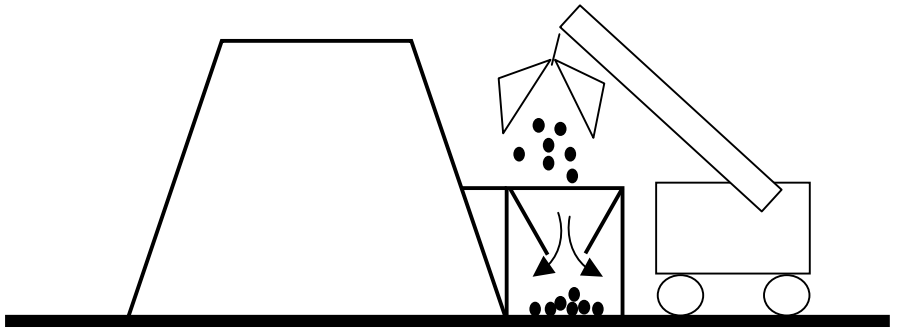


Regolite Loading Unit



1. Storing device
Pressurization device
Compressor
4. Pressurized inlet circuit
5. Filters
6. Pressurized outlet circuit

courtesy AAS-I
LABEN



Conclusion

- **from 23 April 2007 AGILE is in the sky !**
- **Jan. 2008 : GLAST** will be launched from Kennedy Space Flight Center

Silicon detectors are the core of two instruments that has been constructed for the study of the gamma ray sky in the pair production regime (above 10 - 20 MeV)

Very successful goals of the original idea

The future ?

Thank you !!!