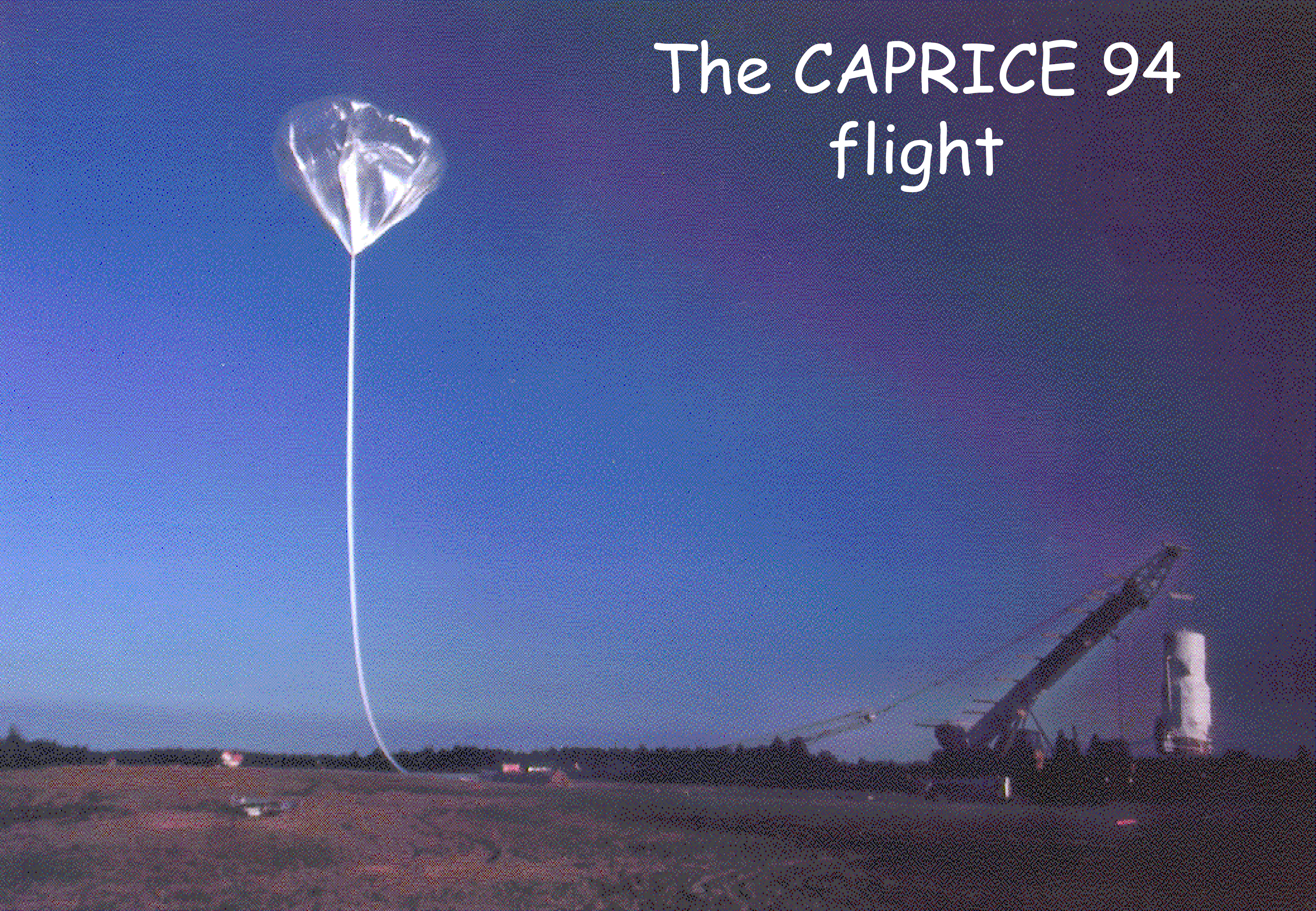
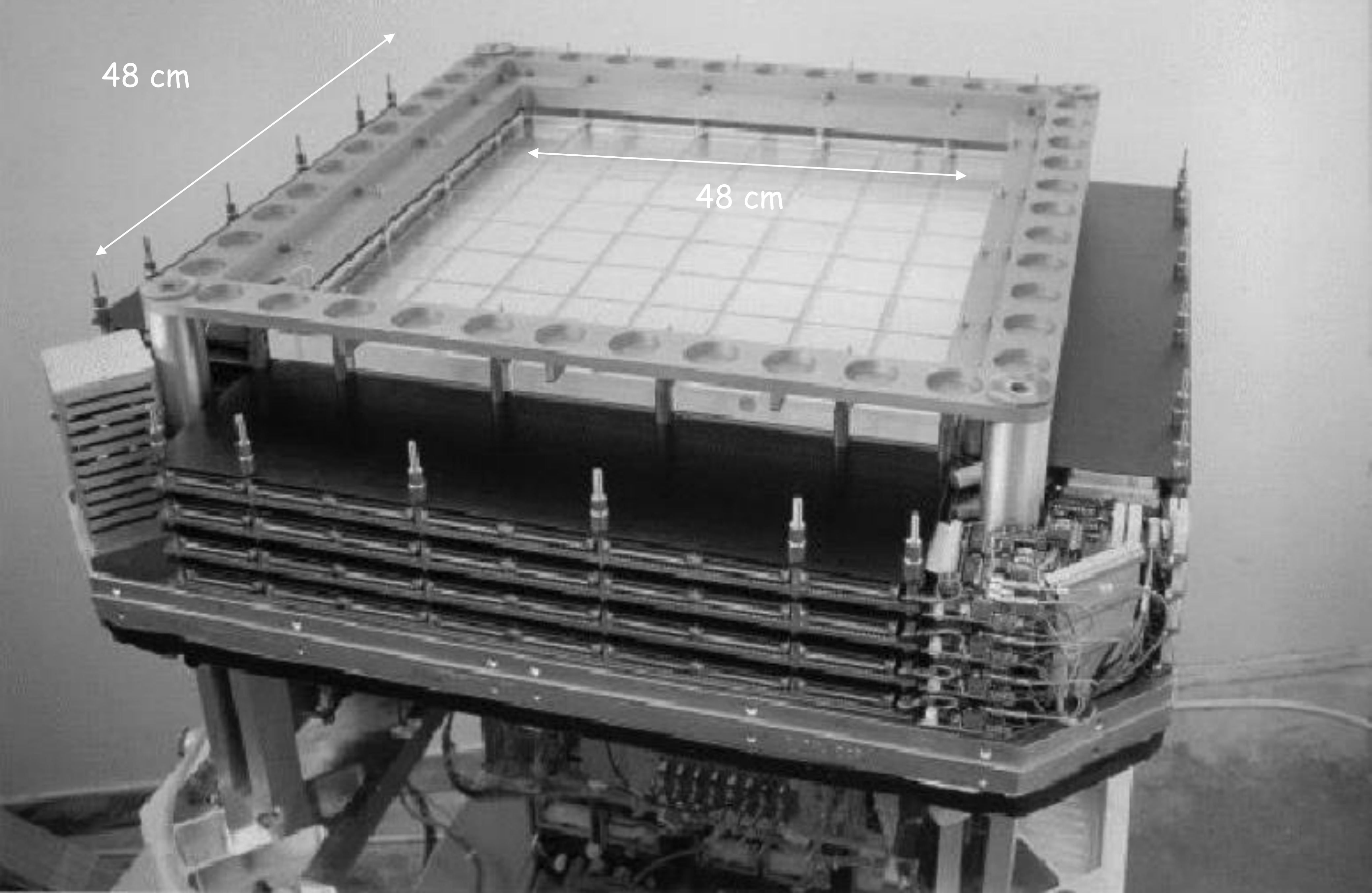

Raggi gamma da satellite, gli esperimenti AGILE e Fermi
Aldo Morselli
INFN Roma Tor Vergata
Celebrazione per i 70 Anni dell'INFN
Roma 11 Maggio 2022


The CAPRICE 94
flight

The TS93 and CAPRICE silicon-tungsten imaging calorimeter.



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]

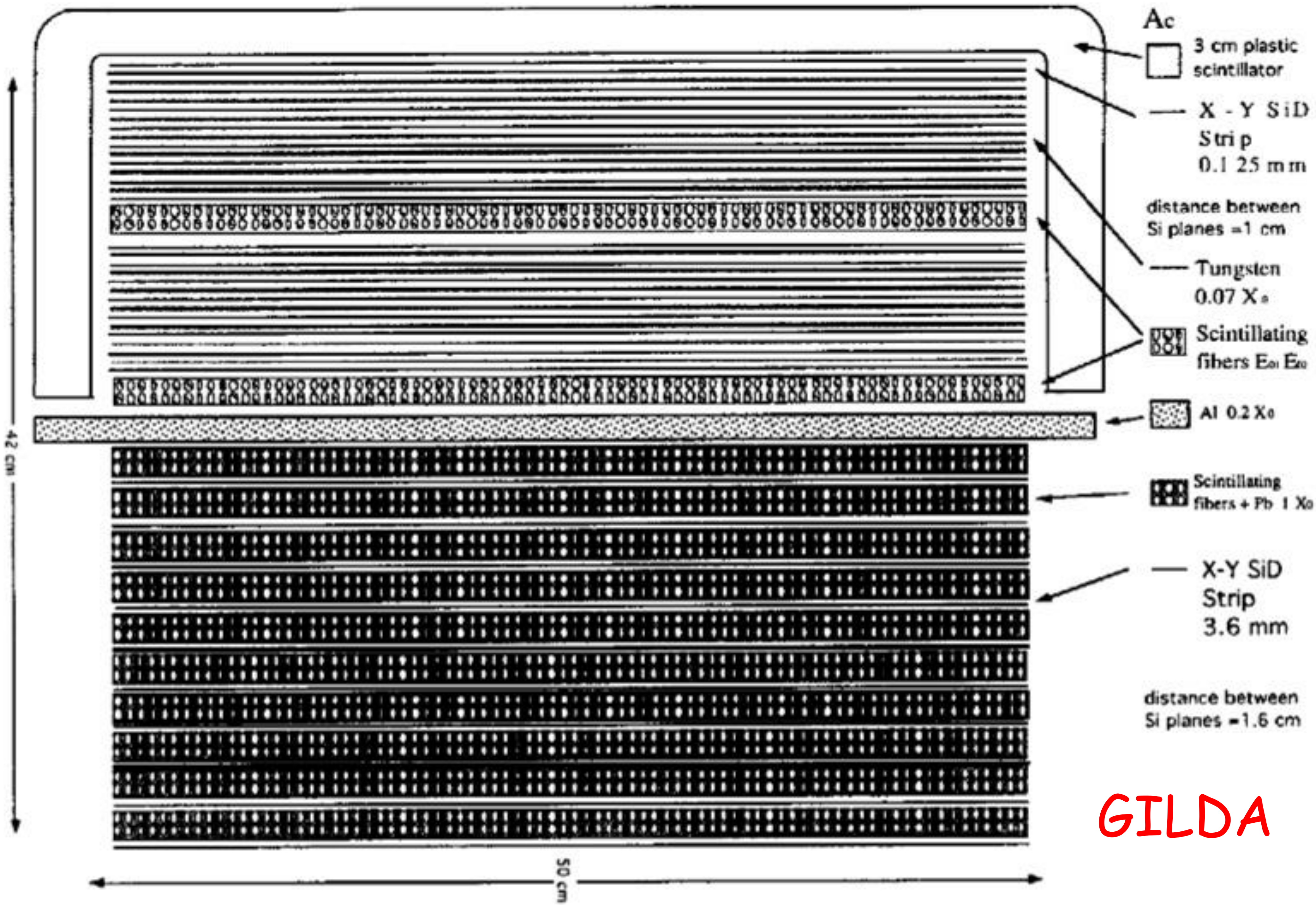
[a] *Dept. of Physics, Univ. of Trieste and INFN, Italy*
[b] *Dept. of Physics, II Univ. of Rome "Tor Vergata" and INFN, Italy*
[c] *Dept. of Physics, Univ. of Firenze and INFN, Italy*
[d] *INFN Laboratori Nazionali di Frascati, Italy*

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 0.125 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

GILDA

Quindi eravamo pronti per rispondere alla Call for Ideas ASI per Piccole Missioni (Scienze dell'Universo) 26 giugno 1997
e rispondemmo con due proposte:

- GILDA 40

e

- AGILE

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.

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

AGILE: Rivelatore a immagini gamma leggero

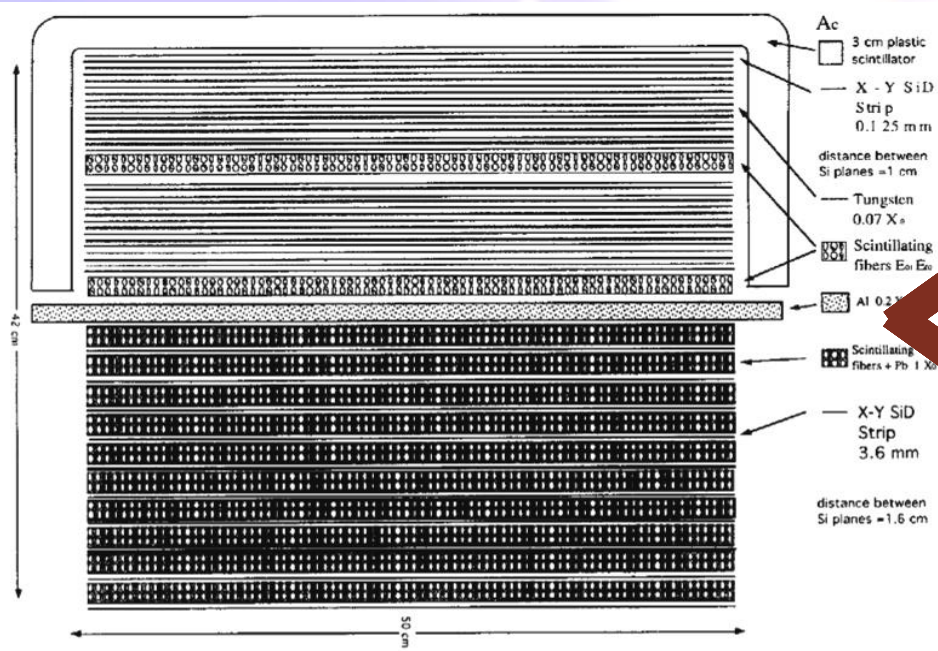
M. Tavani[1,2], G. Barbiellini[3], M. Boezio[3], P. Caraveo[1], M. Casolino[4], M. P. De Pascale[4], S. Mereghetti[1], A. Morselli[4], A.Perrino[4], P. Picozza[4], P. Schiavon[3], R. Sparvoli[4], A. Vacchi[3]

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

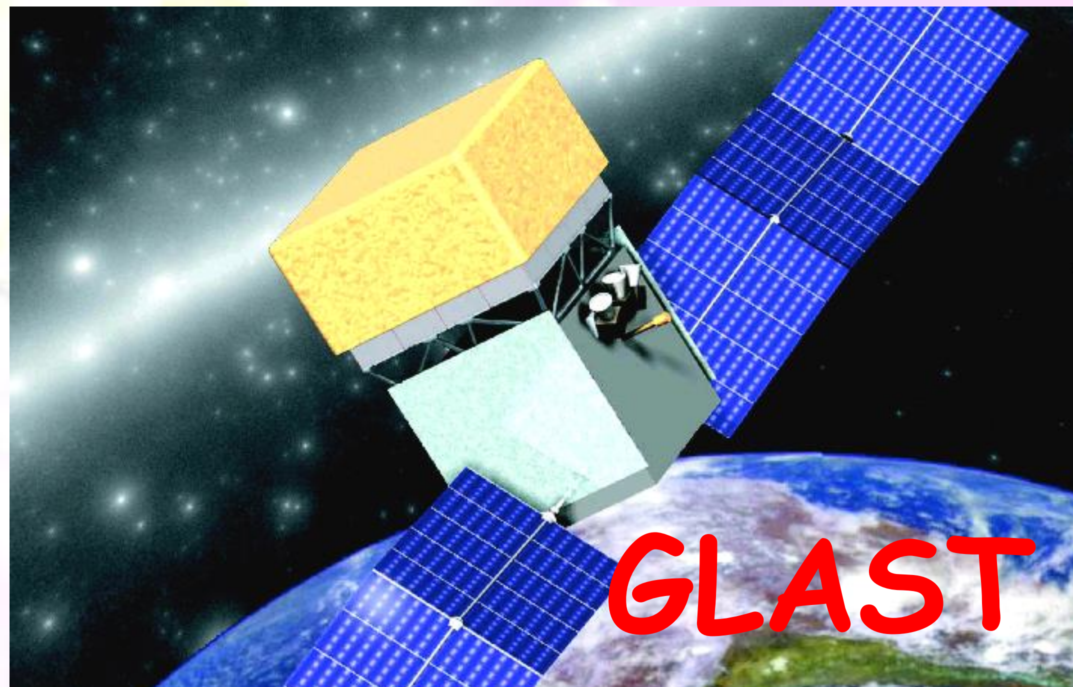
L'astrofisica gamma delle alte energie nella banda 30 MeV–10 GeV beneficierebbe enormemente durante i primi anni del 2000 dall'esistenza di un rivelatore al silicio a largo campo e con sensibilita' e accuratezza confrontabili o migliore di EGRET. Presentiamo qui il concetto di tale missione leggera, 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.

GILDA



Ac
3 cm plastic scintillator
X - Y SiD Strip 0.125 mm
distance between Si planes =1 cm
Tungsten 0.07 X_0
Scintillating fibers
Scintillating fibers + Pb
X-Y SiD Strip 3.6 mm
distance between Si planes =1.6 cm
42 cm
50 cm

agile
Astro-rivelatore Gamma
a Immagini Leggero
INAF
INFN



GLAST


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

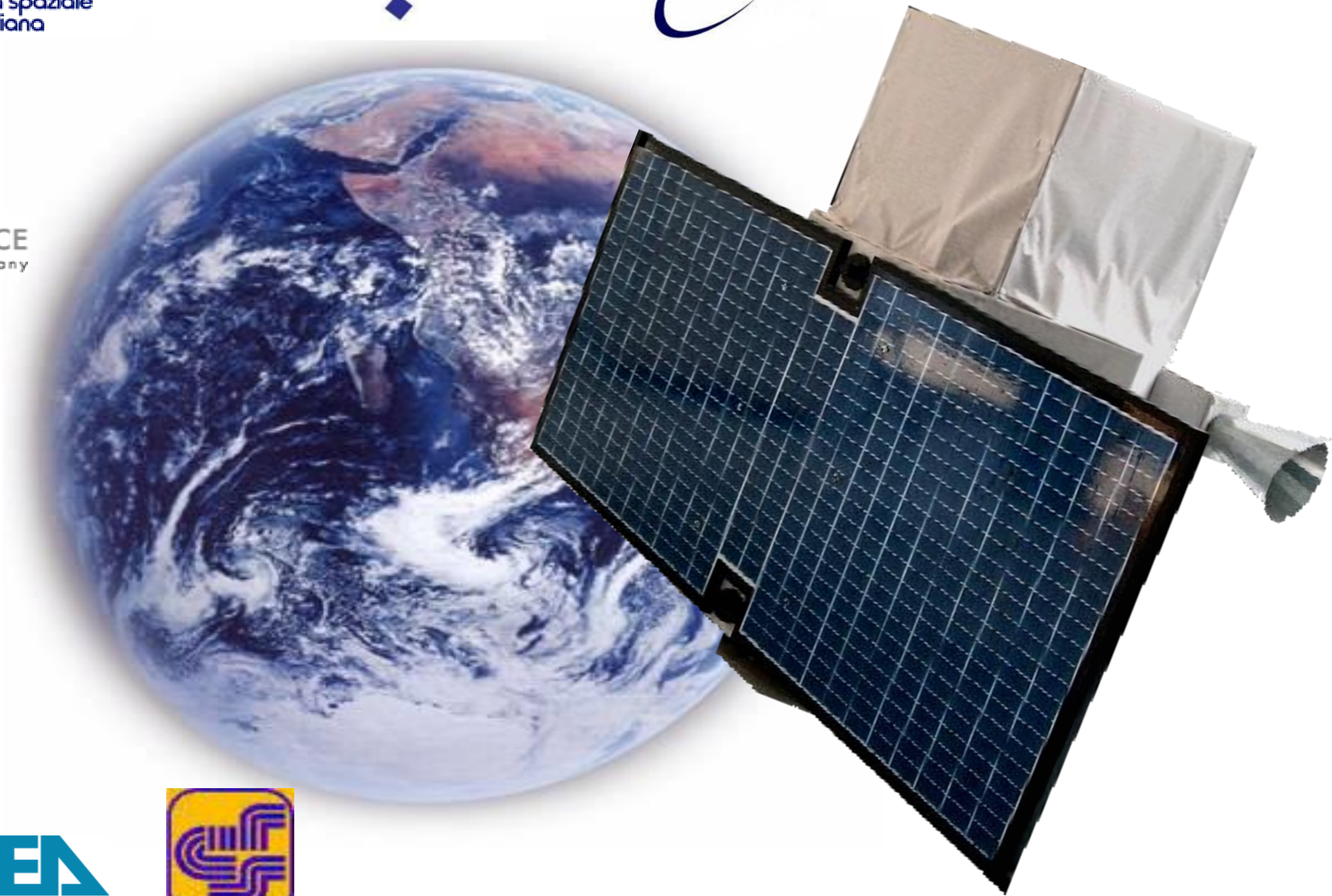
OERLIKON CONTRAVES

telespazio
A Finmeccanica/Alcatel company

Galileo Avionica

MIPOT

ENEA



April 23, 2007: Launch!

SHAR base (Chennai), India

Equatorial orbit: 550 Km, < 3° inclination angle

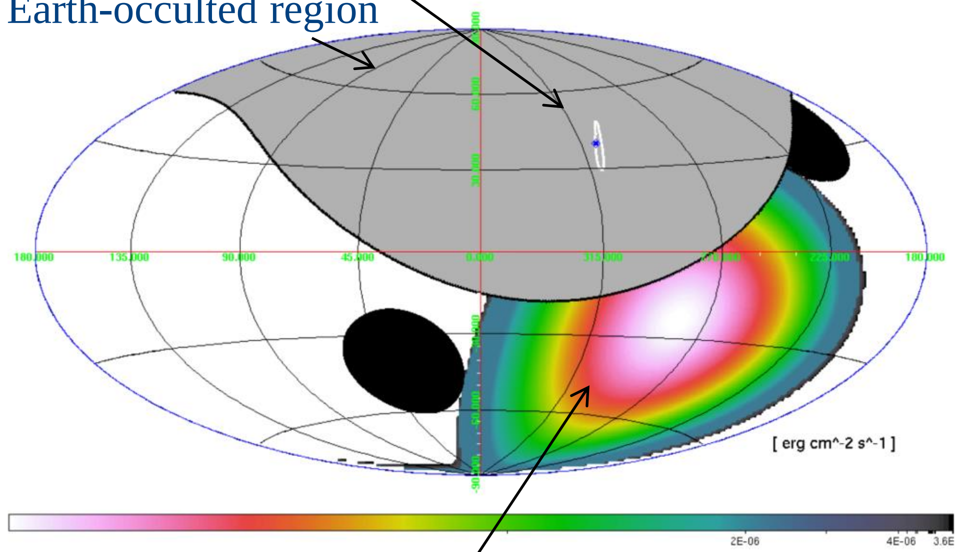

AGILE
23 April 2007
Happy 15th Birthday Agile !!
e' diventata la missione scientifica italiana piu' duratura


AGILE
23 April 2007
Happy 15th Birthday Agile !!

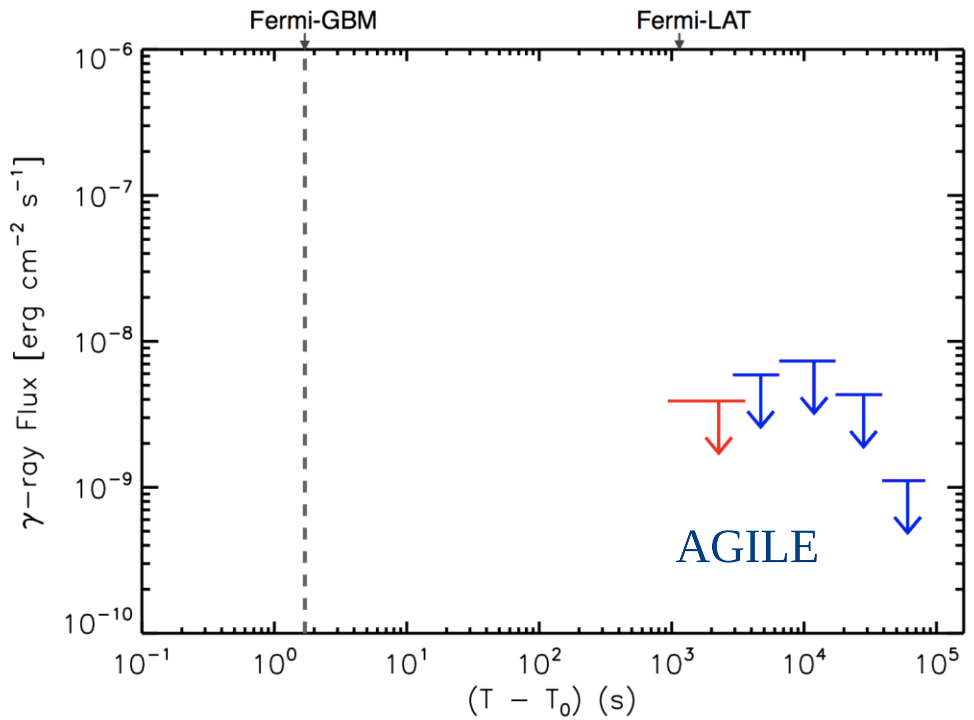
AGILE and GW170817

GW170817

Earth-occulted region



AGILE exposure at T_0



- At T_0 GW170817 was occulted by earth but AGILE instrument collected useful data before and after the GW/GRB event providing useful constraints on the precursor and delayed emission properties of the NS-NS coalescence event.
- Bright prospects for future events

F. Verrecchia, et al, (AGILE Coll.) ApJL 850 L27 2017 arXiv:1710.05460

AGILE and Fast Radio Bursts

nature astronomy

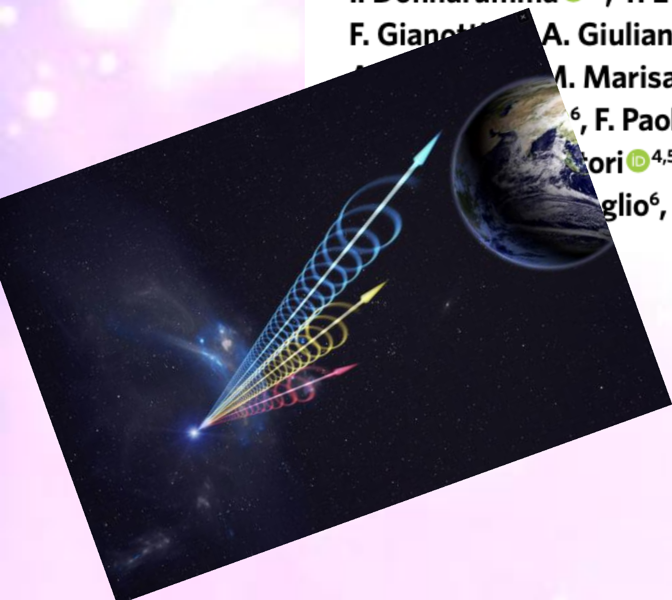
ARTICLES

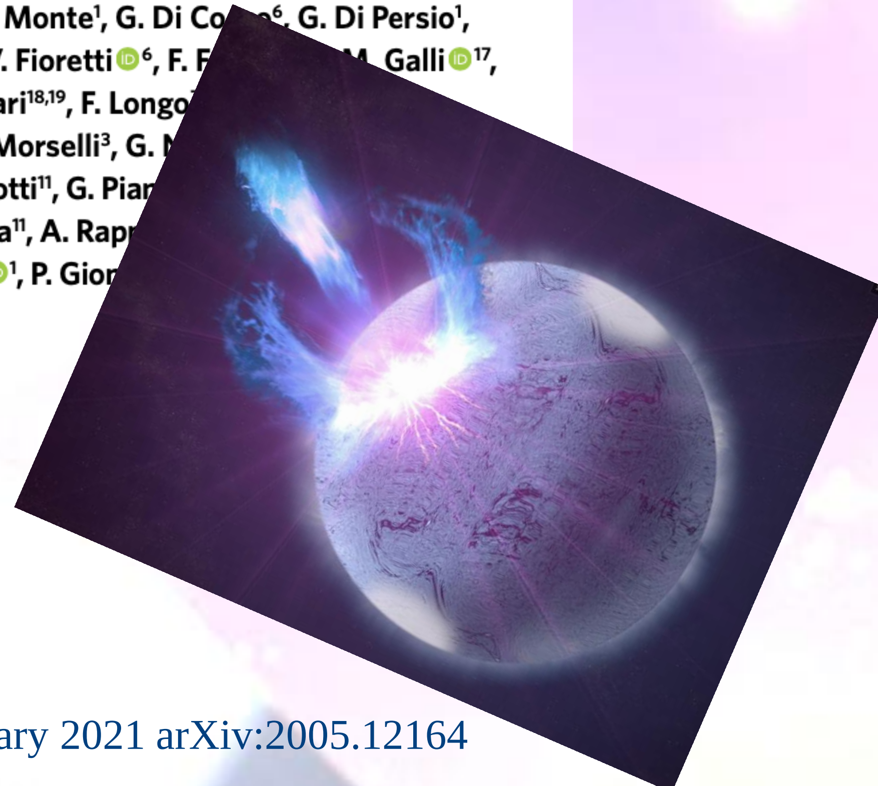
https://doi.org/10.1038/s41550-020-01276-x

Check for updates

An X-ray burst from a magnetar enlightening the mechanism of fast radio bursts

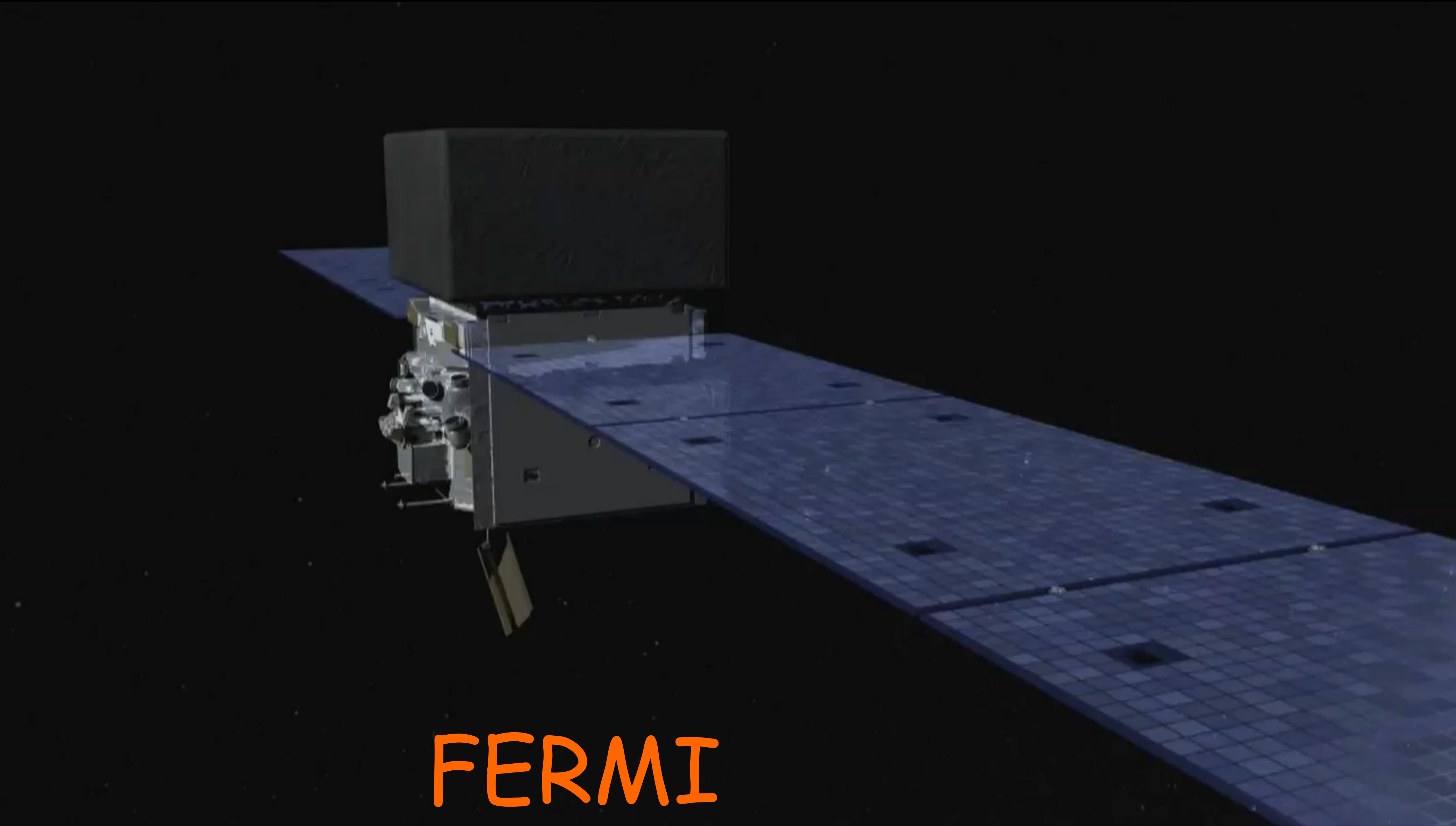
M. Tavani[1,2] ✉, C. Casentini[1,3], A. Ursi[1], F. Verrecchia[4,5], A. Addis[6], L. A. Antonelli[5],
A. Argan[1], G. Barbiellini[7,8], L. Baroncelli[6], G. Bernardi[9,10], G. Bianchi[9], A. Bulgarelli[6], P. Caraveo[11],
M. Cardillo[1], P. W. Cattaneo[12], A. W. Chen[13], E. Costa[1], E. Del Monte[1], G. Di Co...[6], G. Di Persio[1],
I. Donnarumma[14], Y. Evangelista[1], M. Feroci[1], A. Ferrari[15,16], V. Fioretti[6], F. F... ...M. Galli[17],
F. Gian... A. Giuliani[11], C. Labanti[6], F. Lazzarotto[1], P. Lipari[18,19], F. Longo...
...M. Marisaldi[6,21], S. Mereghetti[11], E. Morelli[6], A. Morselli[3], G. M...
...[6], F. Paoletti[22], A. Pellizzoni[23], M. Perri[4,5], F. Perotti[11], G. Pian...
...tori[4,5], S. Puccetti[14], G. Pupillo[9], M. Rapisarda[11], A. Rap...
...glio[6], A. Trois[23], S. Vercellone[25], V. Vittorini[1], P. Gior...





M.Tavani, et al, (AGILE Coll.) Nature Astronomy 18 February 2021 arXiv:2005.12164

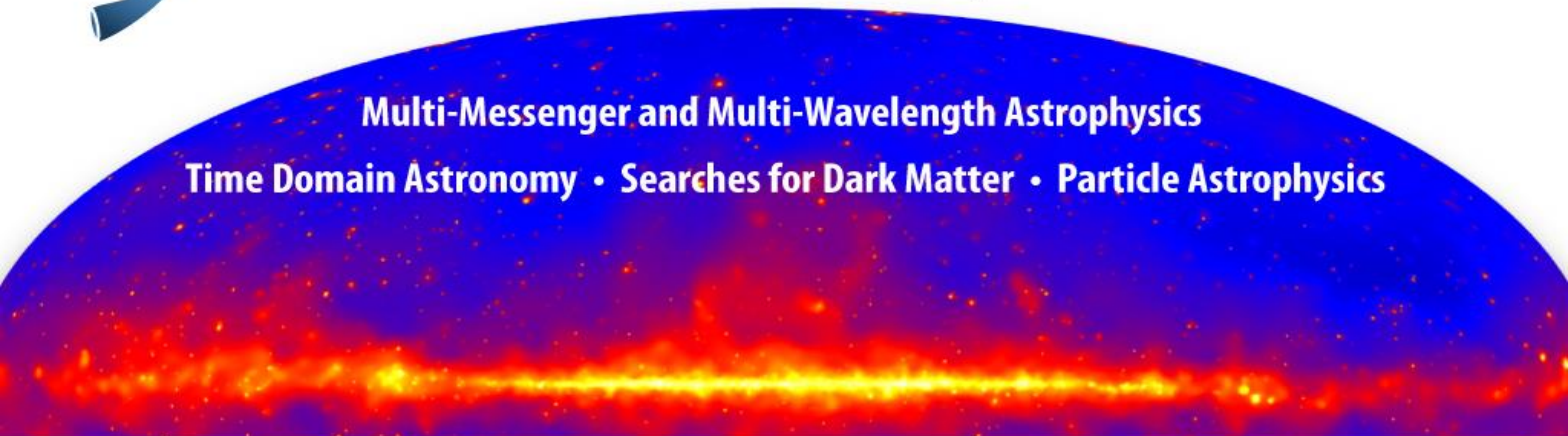
You can follow AGILE with AGILE Science App.

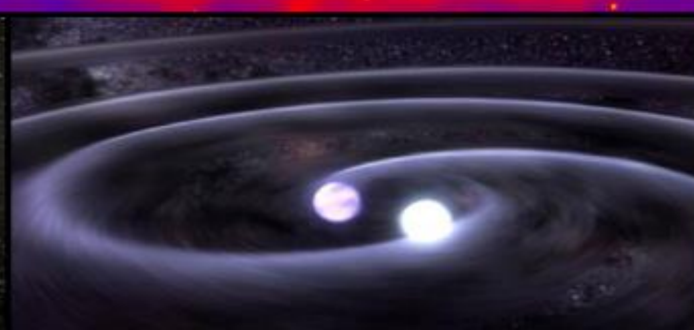


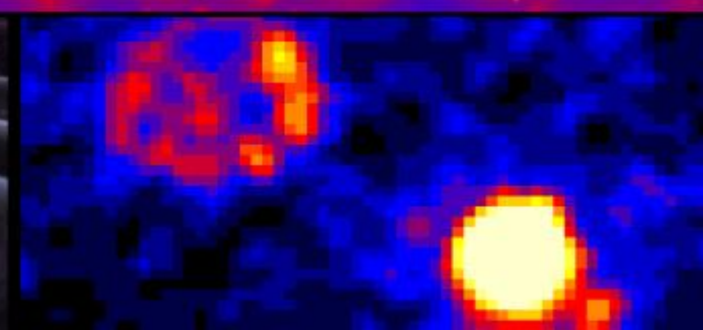
FERMI

Large Area Telescope

Fermi Gamma-Ray Space Telescope

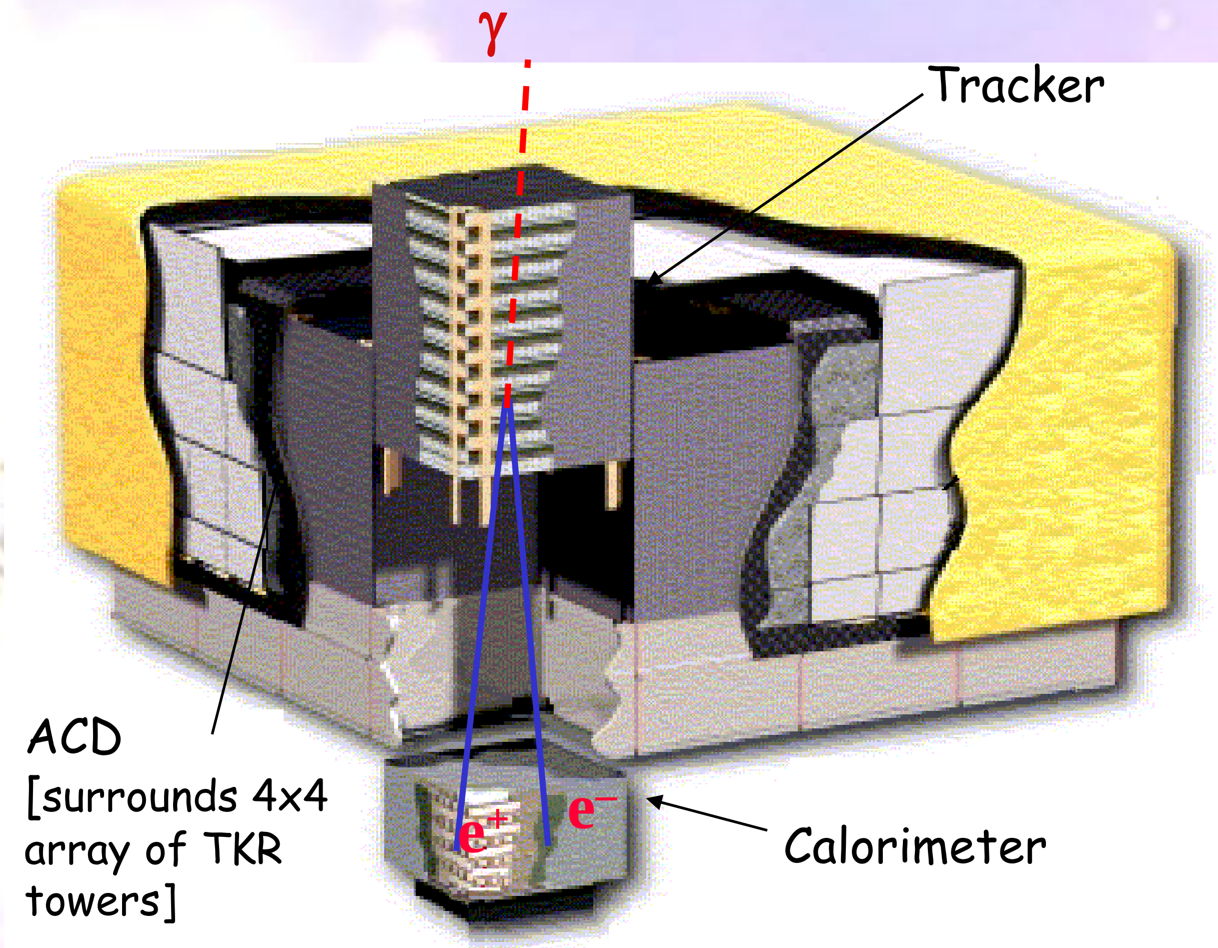




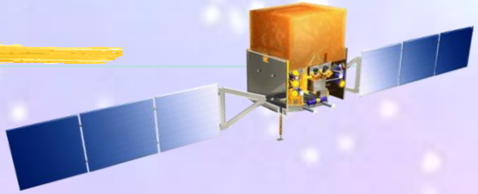


Fermi LAT: A Telescope Without Lenses

- 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.



The Fermi LAT 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

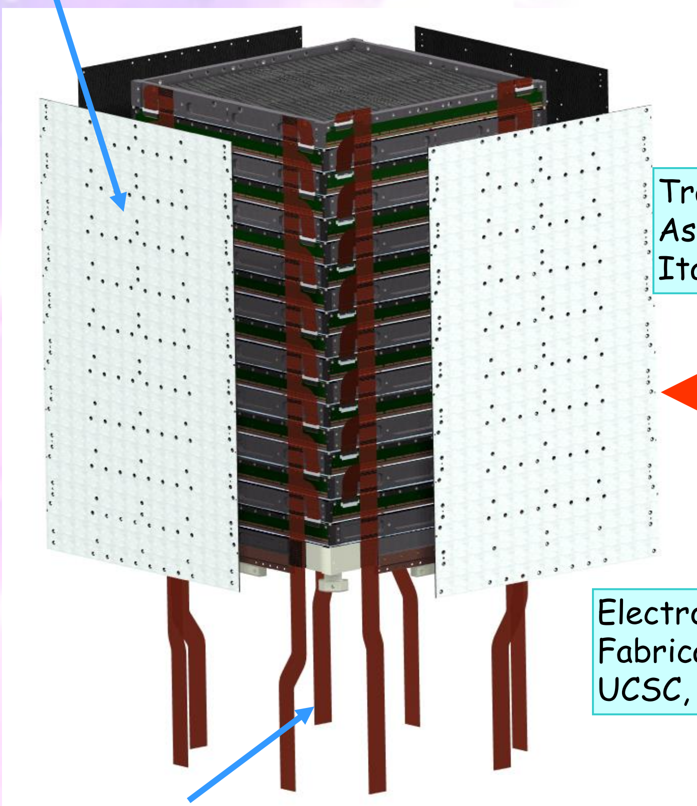
Swedish Institutions

KTHRoyal Institute of Technology
Stockholms Universitet

Collaboration members:	**~270**
Members:	**95**
Affiliated Scientists	~90
Postdocs:	37
Graduate Students	48

Tracker Production Overview

Module Structure (walls, flexures, thermal-gasket, fasteners)
Engineering: SLAC, Italy (Hytec)
Procurement: SLAC, Italy



Readout Cables
UCSC, SLAC

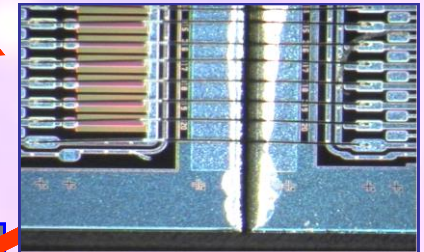
Tracker Module Assembly and Test
Italy

18

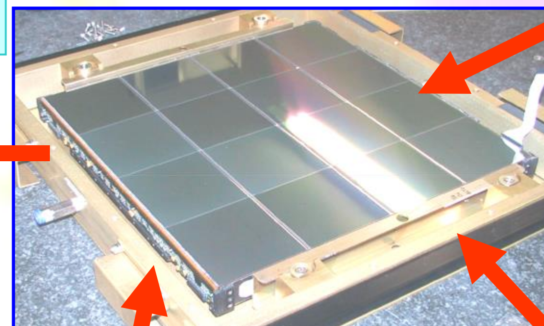
SSD Procurement, Testing
Japan, Italy, SLAC

10,368

SSD Ladder Assembly
Italy (G&A, Mipot)



2592

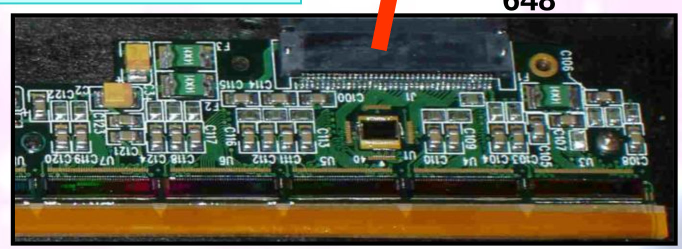


Tray Assembly and Test
Italy (G&A, Mipot)

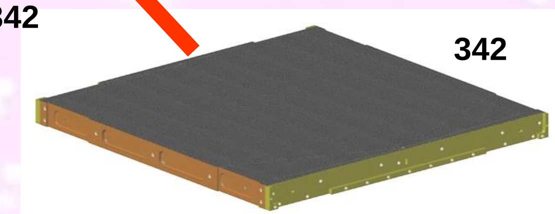
342

Electronics Design, Fabrication & Test
UCSC, SLAC (Teledyne)

648

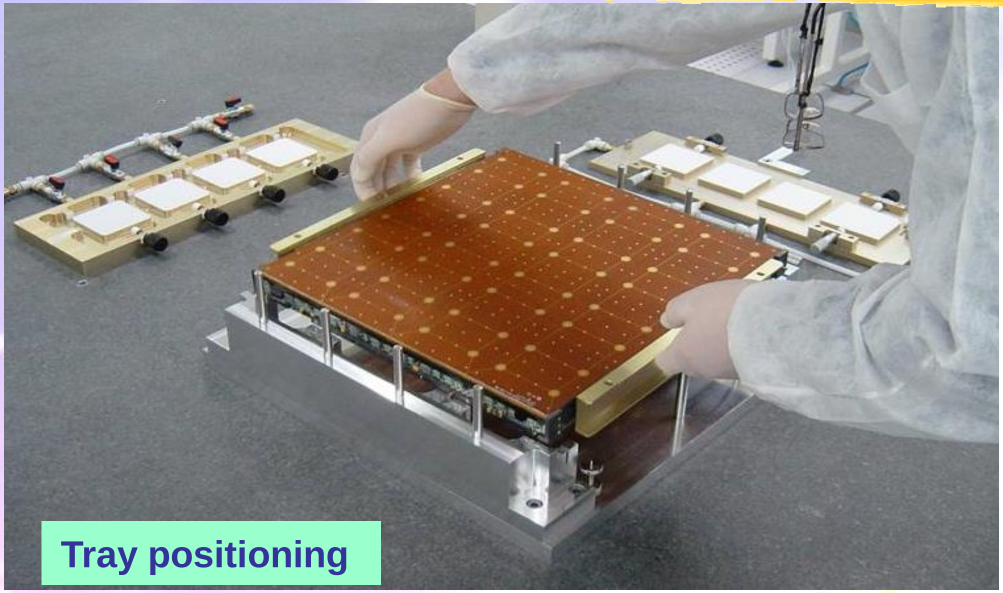


342

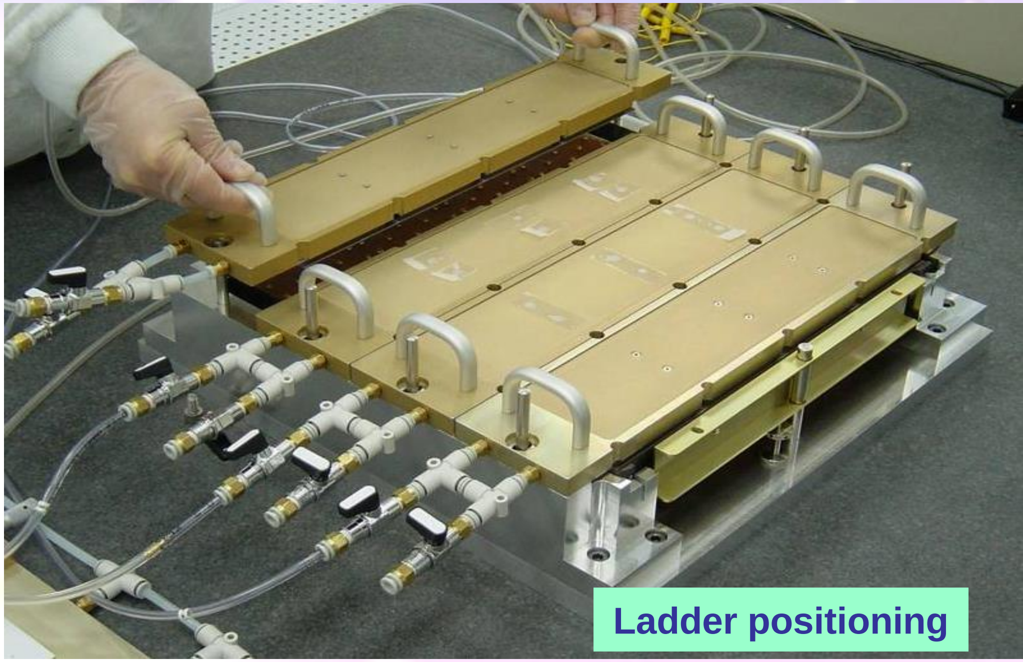


Composite Panel & Converters
Engineering:
SLAC, Italy (Hytec, COI)
Procurement: Italy (Plyform)

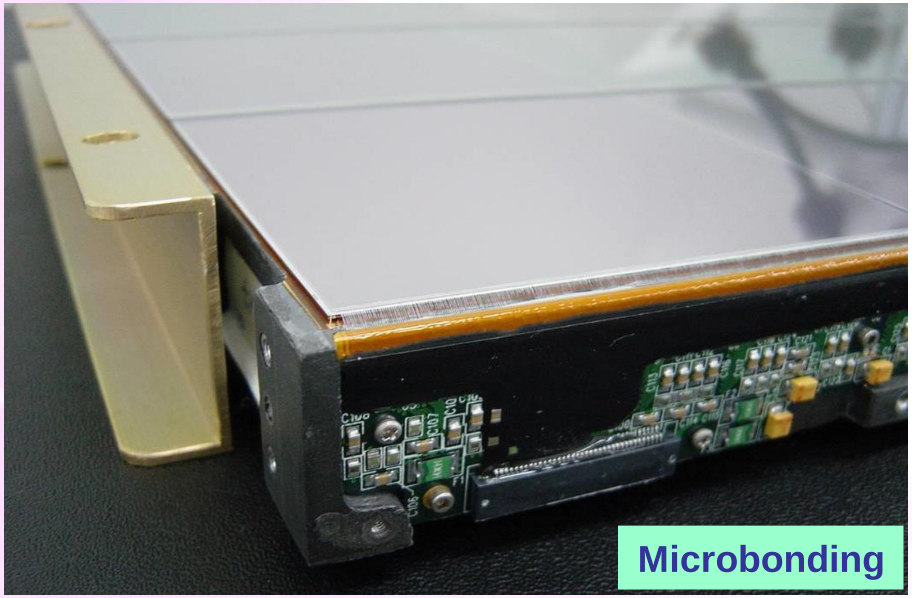
Tray assembly in G&A



Tray positioning



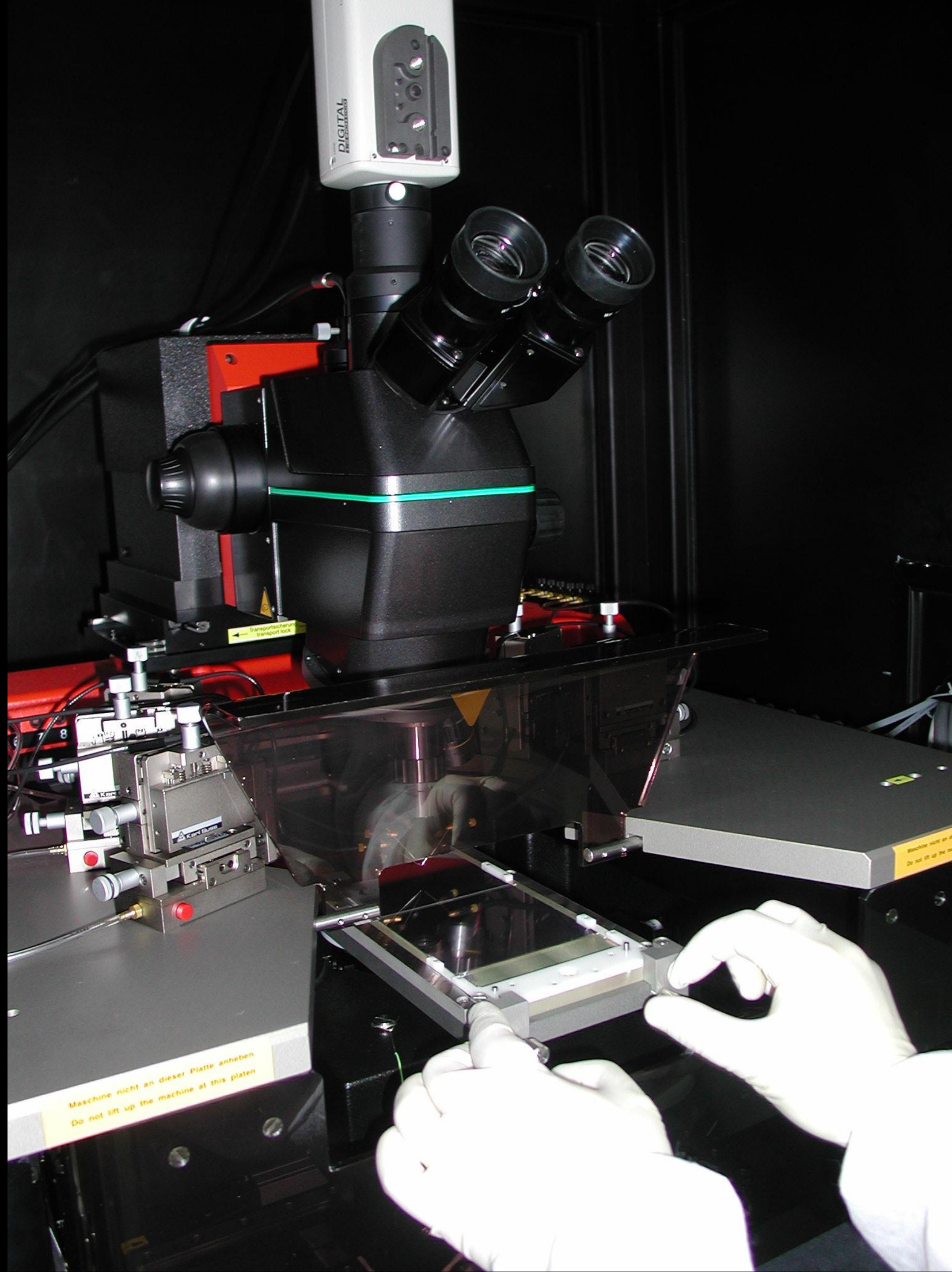
Ladder positioning



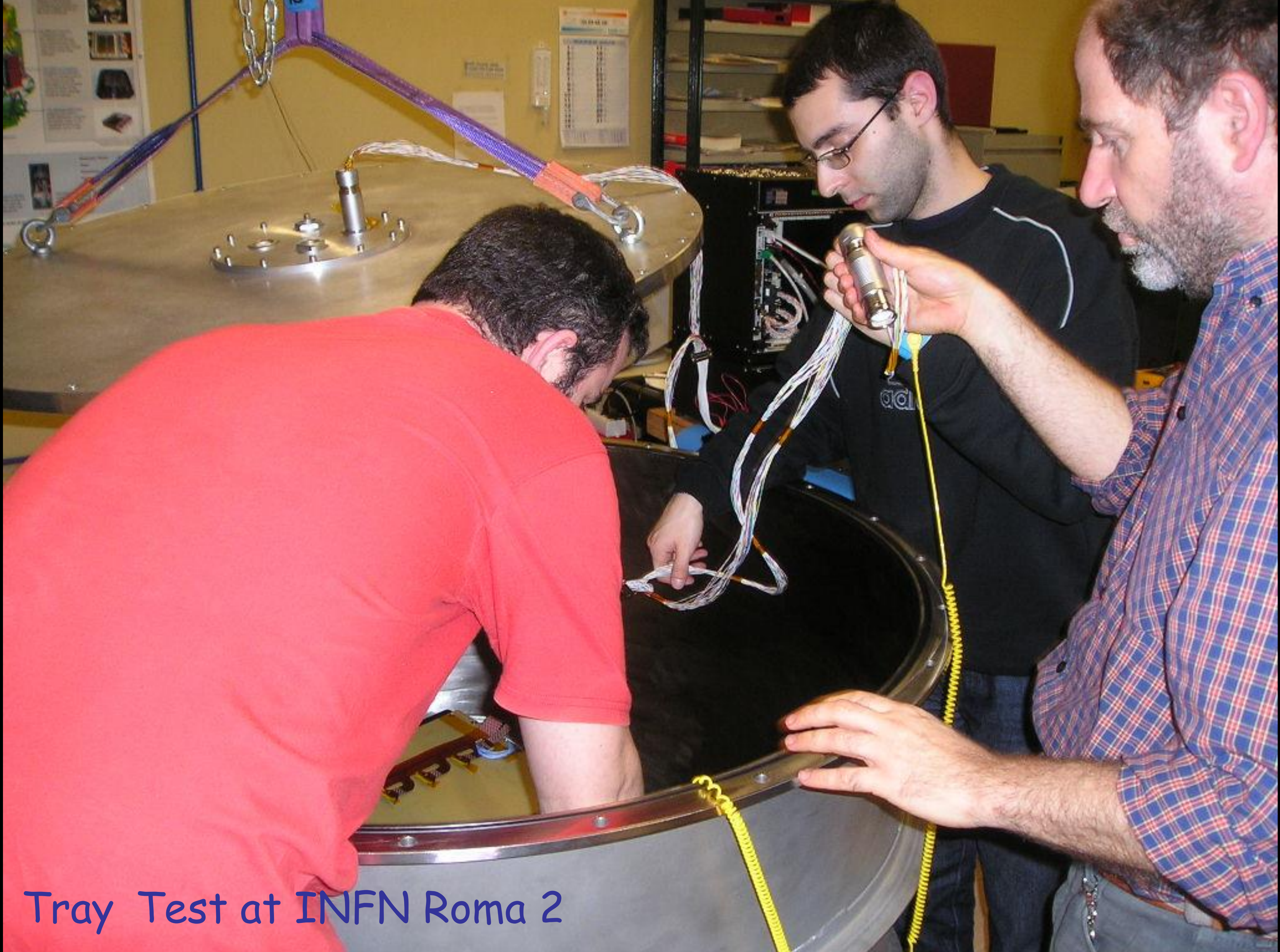
Microbonding

- 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


DIGITAL
Maschine nicht an dieser Platte anheben
Do not lift up the machine at this platen

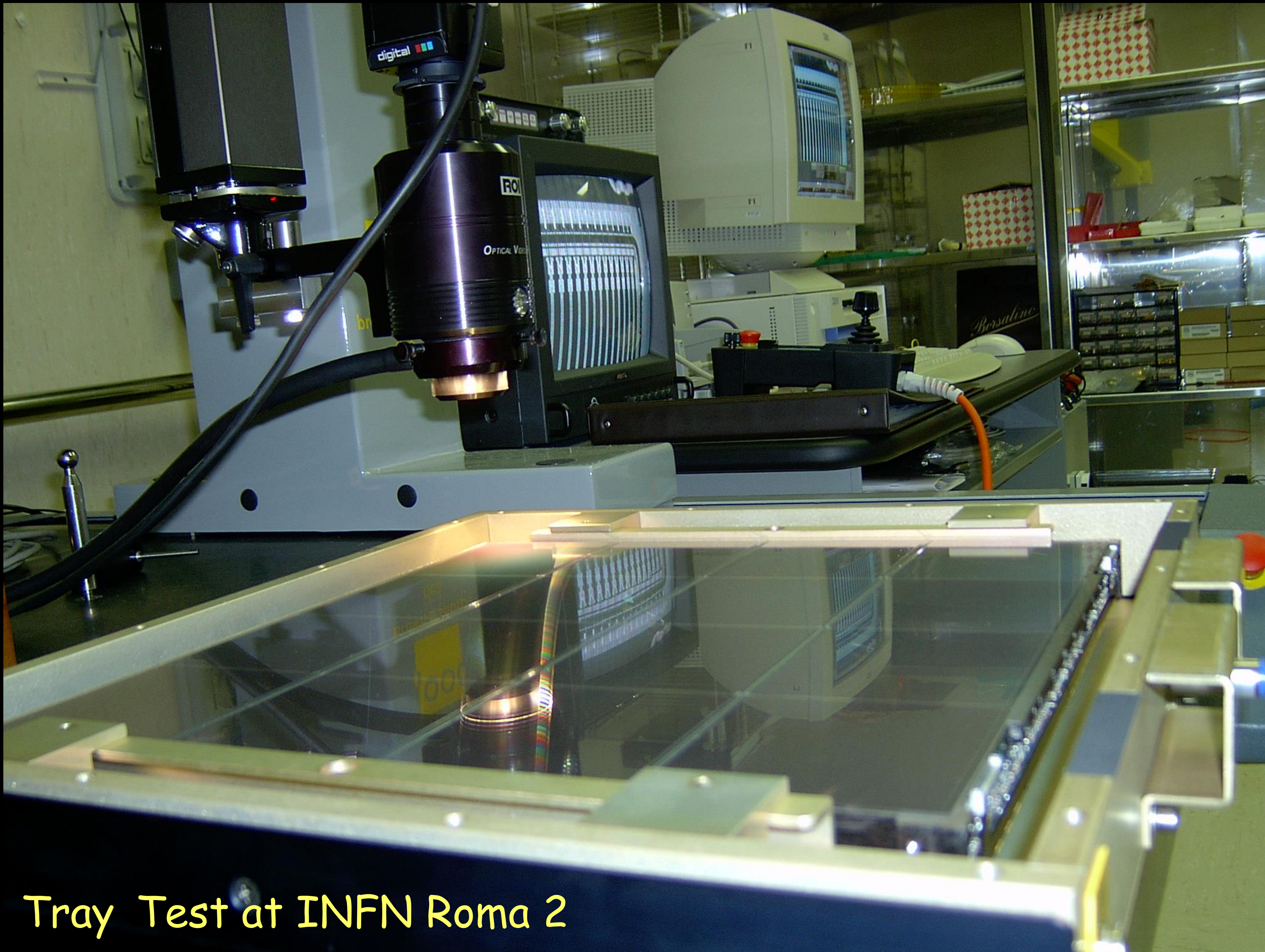

LAMINAR FLOW
ASALAIR 1200
LAMINAR FLOW
1200FLV
PROIBITO
FUMARE
VIETATO
L'ACCESSO
a chi non è
autorizzato



Tray Test at INFN Roma 2

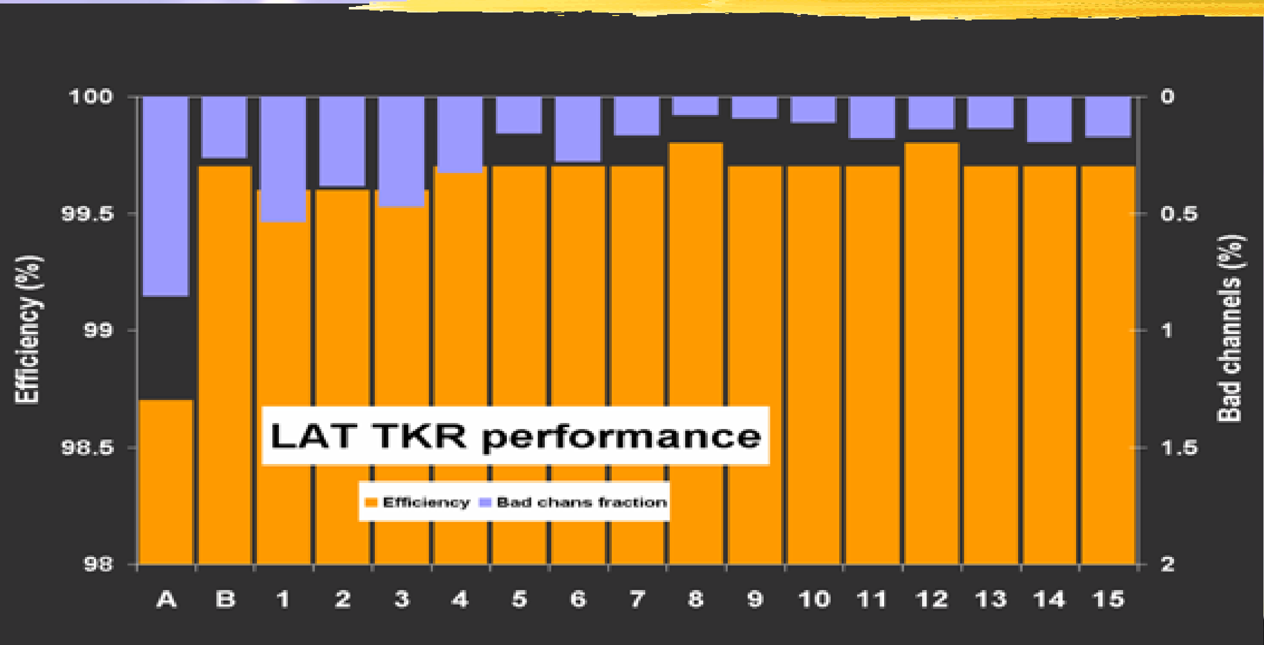
Tray Test at
INFN Roma 2

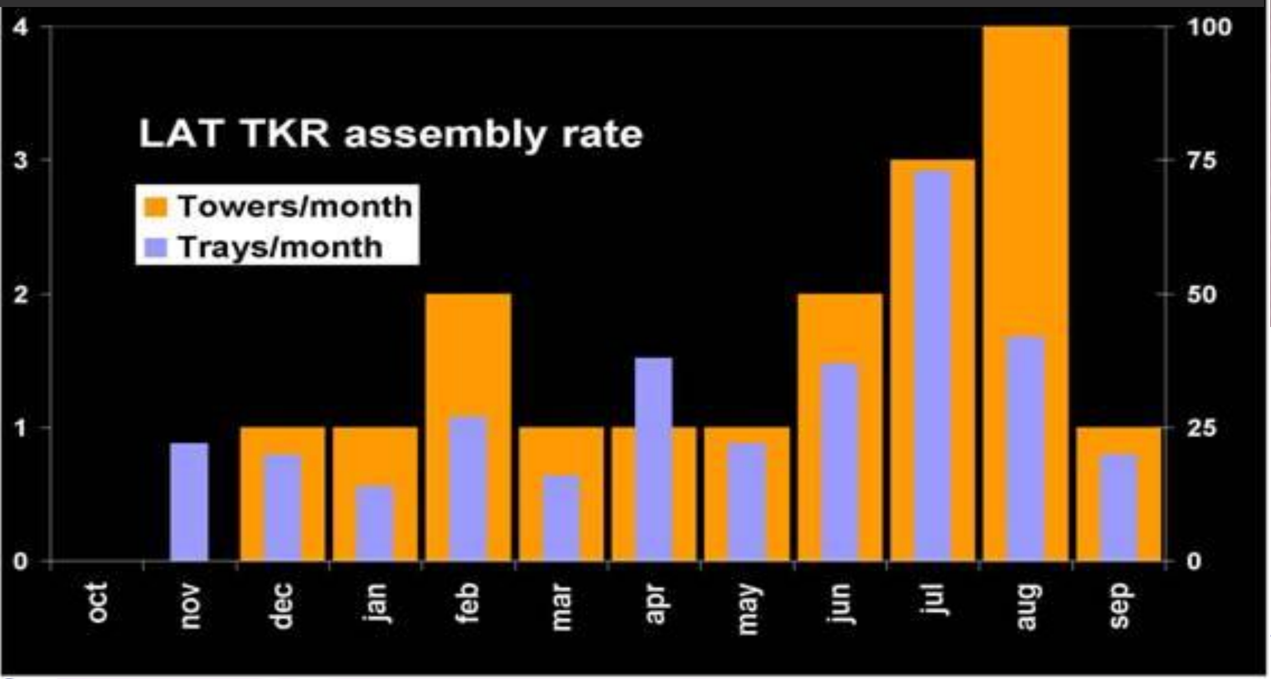
Tray Test at INFN Roma 2

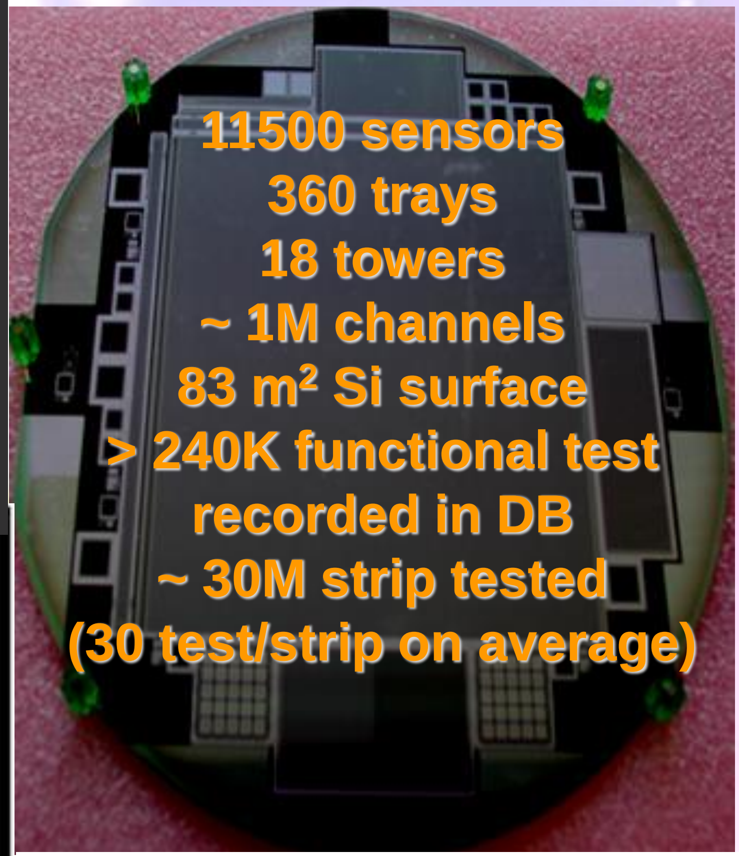


Tray Test at INFN Roma 2

The LAT Tracker numbers







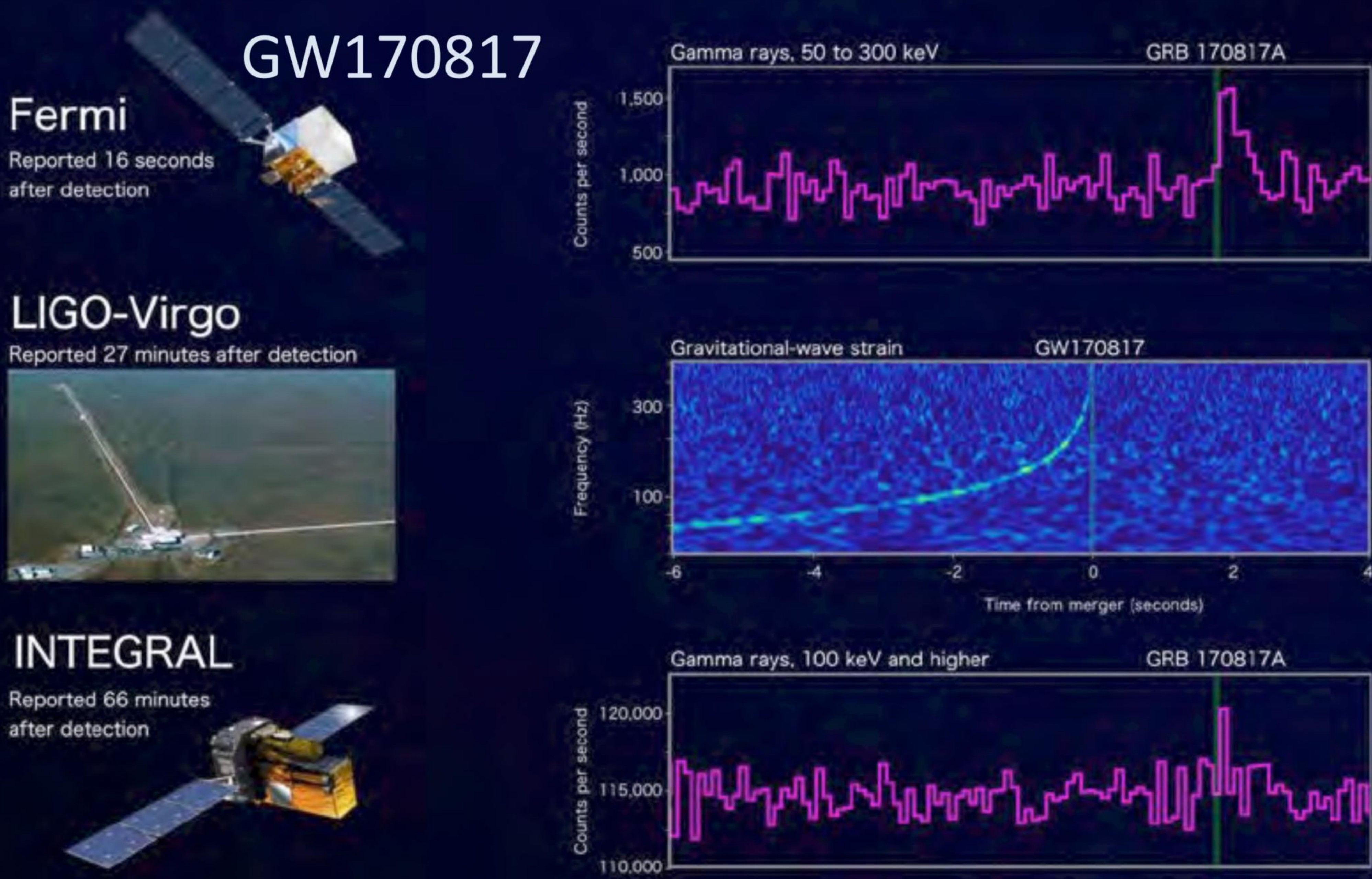
Fermi
Gamma-ray Space Telescope

11 June 2008

Fermi
Gamma-ray Space Telescope

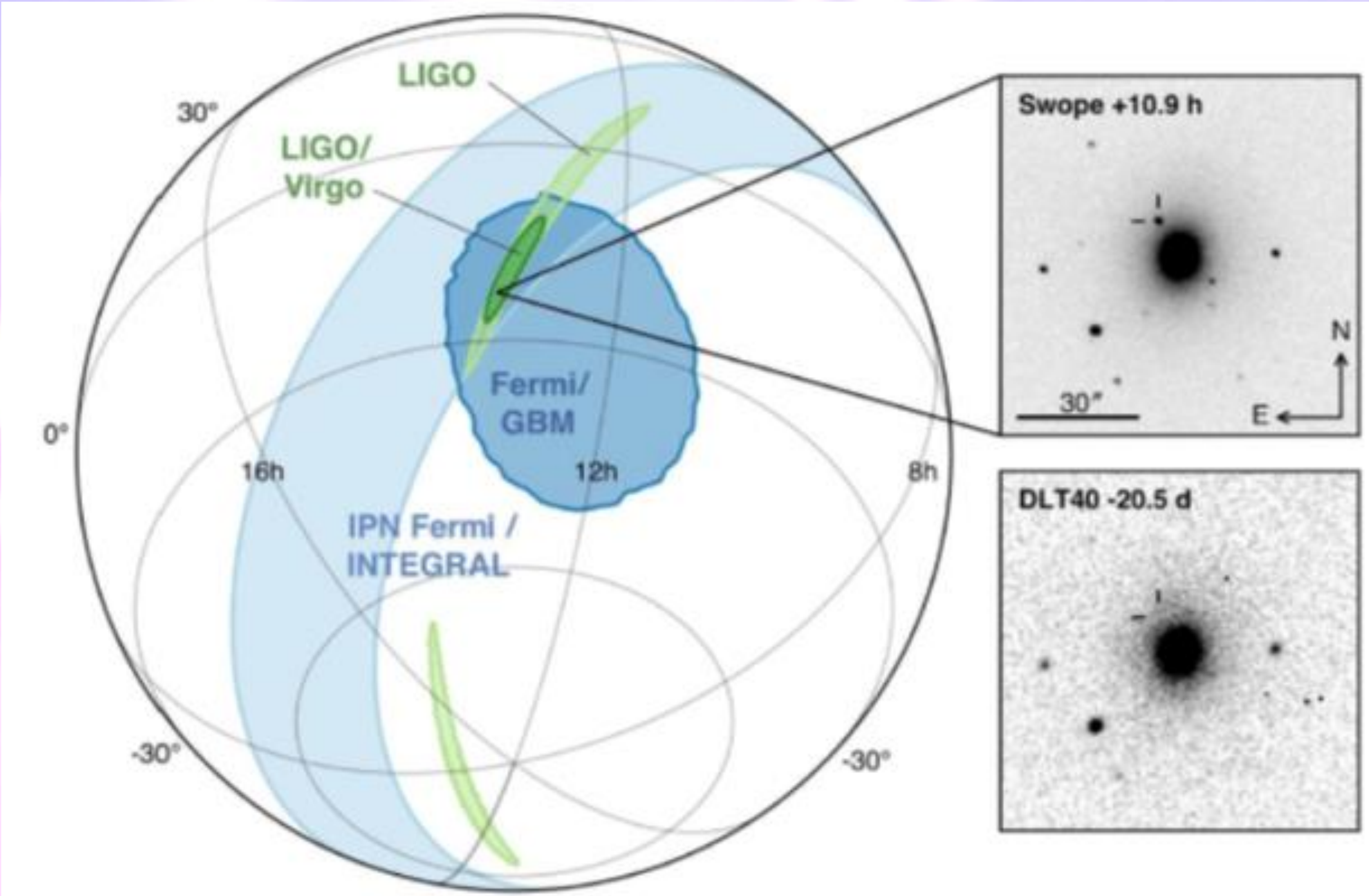
Happy 14th Birthday Fermi !!

11 June 2008



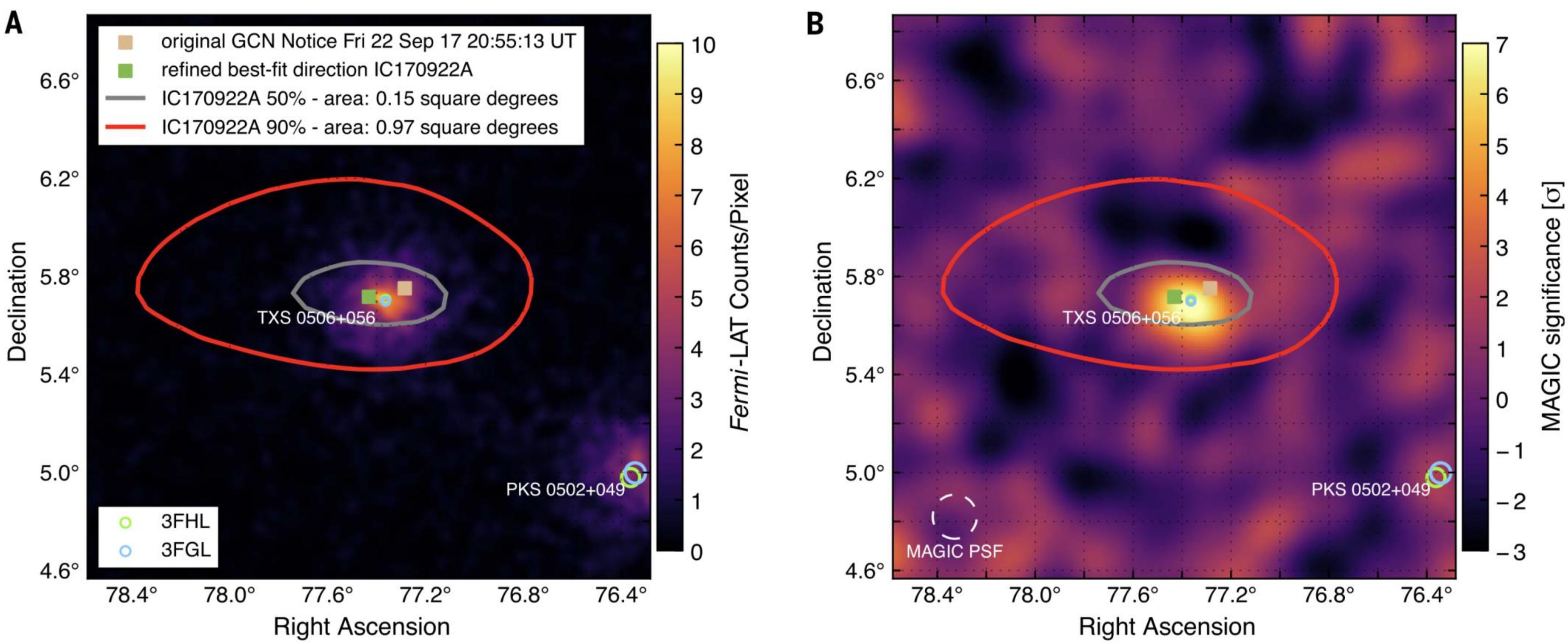
Multi-messenger Observations of a Binary Neutron Star Merger ApjL 848 L12 2017 [arXiv:1710.05833] 3656 authors !

GBM e Onde Gravitazionali: 17 08 2017



Astronomia multimessaggero: neutrini

- I buchi neri delle galassie attive sono le sorgenti dei neutrini e quindi dei raggi cosmici di altissima energia (UHECR) ?
- Il caso di EHE 170922 (TXS 0506 +056)



Fermi-LAT and MAGIC observations of IceCube-170922A's location.

Science 361, eaat1378 (2018) 12July

Sommario pubblicazioni Fermi INFN team nel periodo Gen.2015-Ago.2021

91

Pubblicazioni su giornali referati:
(refereed journals: Science, Physical Review Lett., Physical Review D, Astrophys. Journal, Astrophys. Journal Letters, Astrophys. Journal Supplement, Astronom. Journal, Mont. Not. Royal Astron. Soc., Astron. & Astroph., Astropart. Phys., Journ. HE Astroph., Galaxies, Universe)

30

Atti di convegno (proceedings), note brevi, white papers, (*) **:**
(journals: Proc. of Science, Proc. of IAU, AIP Conf. Prof., ICRC web page proc., arXiv eprint only)

(*) in più 19 abstracts (non papers), cmq indicizzati in database pubblicazioni ADS-NASA: **totale 49.** Alcuni proceedings elencati (<10) sono referati.

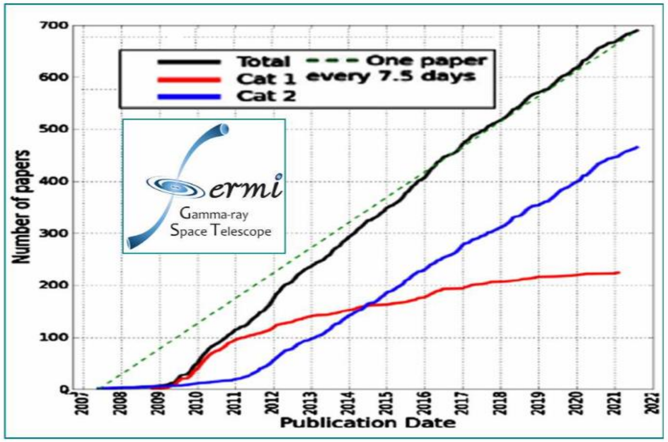
112

Comunicazioni e note rapide

- **104** Astronomer's Telegrams (ATel)
- **8** GRB Coordinates Network, Circular Service (GCN)

Settembre 2019 -- Agosto 2021:

- **21 Pubblicazioni su giornali referati**
- **5 Atti di convegno (proceedings), note brevi, white papers**
- **52 Comunicazioni e note rapide** (51 ATel & 1 GCN)



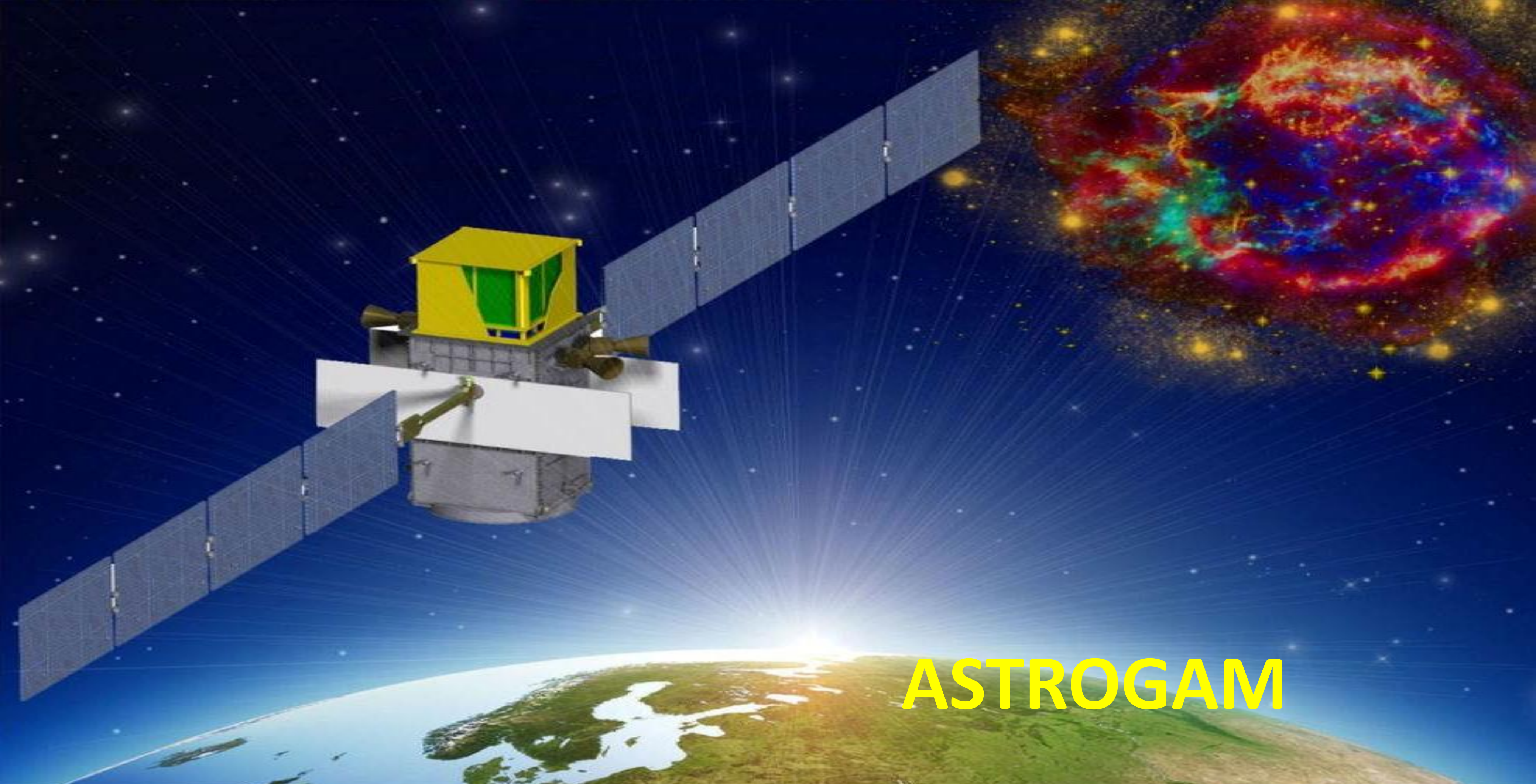
Senior Review of Operating Missions
SR 2022 timeline
- Proposals Due: January 2022
- Panel meets: March 2022
- Panel Report: April 2022
- HQ Response to Panel Report: July 2022

Example: Refereed paper published in Gen.-Aug. 2021

86. Ajello M et al., First Fermi-LAT Solar Flare Catalog, ApJS 252 (2021) 13
87. Acciarri V A et al., VHE gamma-ray detection of FSRQ QSO B1420+326 and modeling of its enhanced broadband state in 2020, A&A 647 (2021)
88. Komossa S et al., X-ray spectral components of the blazar and binary black hole candidate OJ 287 (2005-2020), MNRAS 504 (2021) 5575
89. Komossa S et al., Project MOMO: Multiwavelength Observations and Modeling of OJ 287, Universe 7 (2021) 261
91. Baldini L et al., Fermi-LAT Collaboration, Catalog of Long-Term Transient Sources in the First 10 Years of Fermi-LAT Data, ApJS, 256 (2021), 13
92. Ajello M et al., Fermi-LAT Collaboration, Fermi Large Area Telescope Performance After 10 Years Of Operation, ApJS 256 (2021), 12

I cinque articoli Fermi LAT più citati di sempre

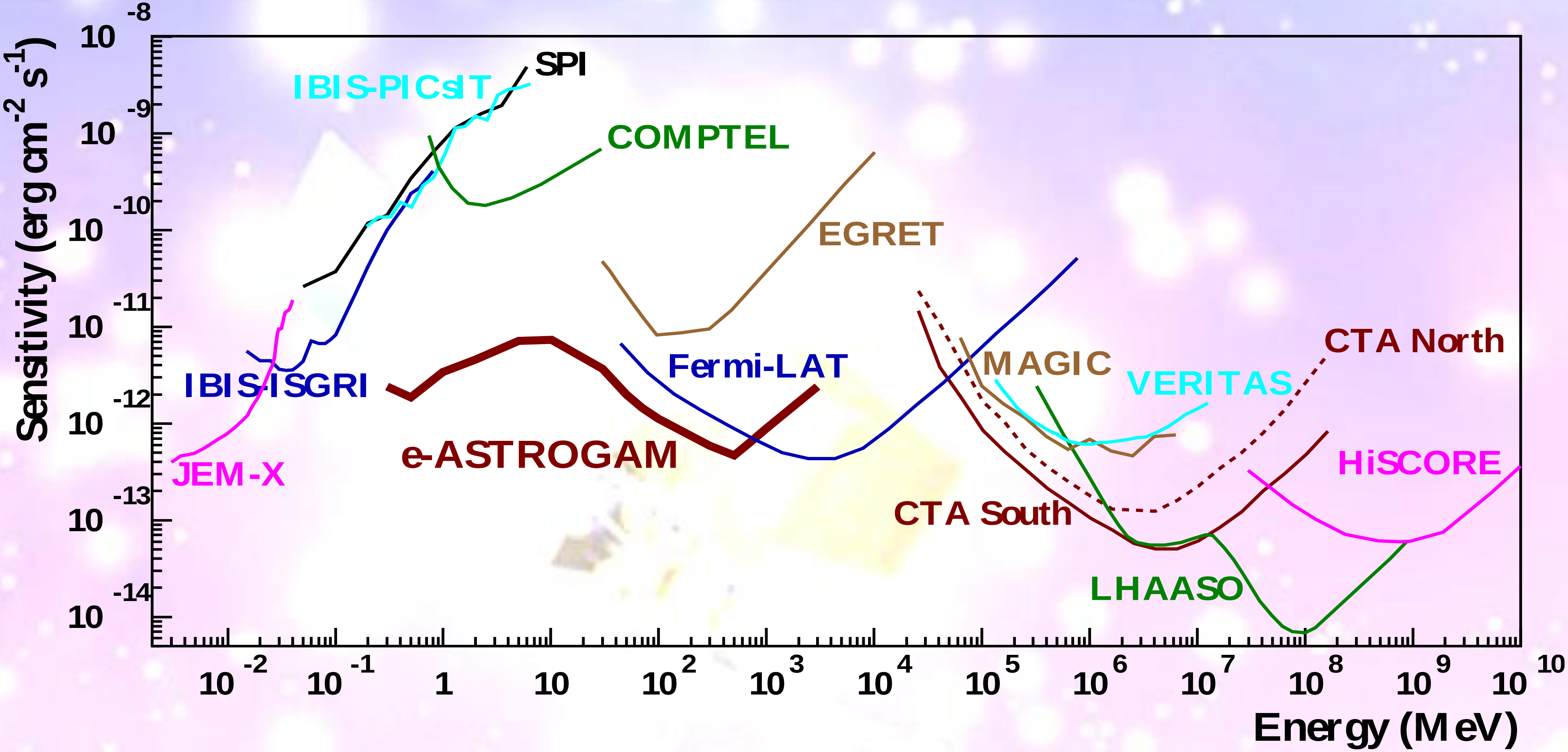
- **The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission** ApJ *2009/06* cited: 2699 — Fermi SSDC team (ASI-INAF acc. & affil.)
- **Multi-messenger Observations of a Binary Neutron Star Merger** ApJ *2017/10* cited: 1969 — Fermi SSDC team (ASI-INFN acc. & affil.)
- **Fermi Large Area Telescope Third Source Catalog** ApJS *2015/06* cited: 1304 — Fermi SSDC team (ASI-INFN acc. & affil.)
- **Fermi Large Area Telescope Second Source Catalog** ApJS 2012/04 cited: 1232 — Fermi SSDC team (ASI-INAF acc. & affil.)
- **Searching for Dark Matter Annihilation from Milky Way Dwarf Spheroidal Galaxies with Six Years of Fermi Large Area Telescope Data** PhRvL *2015/12* cited: 882 — Fermi SSDC team (ASI-INFN acc. & affil.)



This proposal is the result of the merging of the ASTROMEV and GAMMA-LIGHT groups that submitted two separate LoIs.
The proposal is presented on behalf of the ASTROGAM Collaboration by:

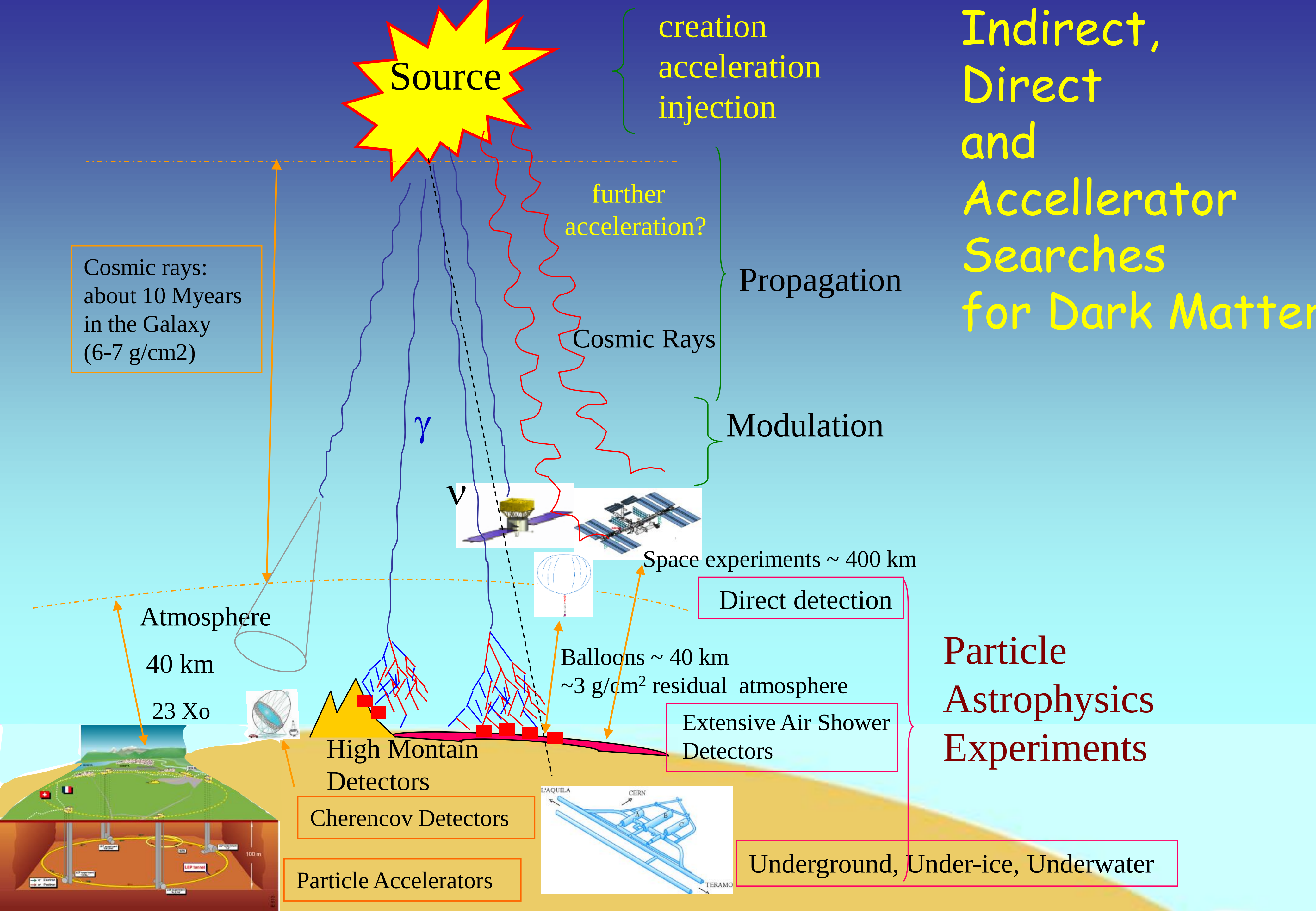
M. Tavani (INAF and University of Rome Tor Vergata, Italy)
V. Tatischeff (CSNSM, France)
P. von Ballmoos (IRAP, France)
C. Budtz-Jorgensen (DTU Space, Lyngby, Denmark)
A. Bykov (Ioffe Institute, St. Petersburg, Russia)
L. Hanlon (University College Dublin, Ireland)
D. Hartmann (Clemson University, USA)
M. Hernanz (ICE/CSIC-IEEC, Barcelona, Spain)
J. Isern (ICE/CSIC-IEEC, Barcelona, Spain)
G. Kanbach (MPI, Garching, Germany)
P. Laurent (APC, France)
J. McEnery (NASA, USA)
S. Mereghetti (INAF-IASF, Milano, Italy)
A. Morselli (INFN, Italy)
K. Nakazawa (The University of Tokyo, Japan)
U. Oberlack (Univ. of Mainz, Germany)
R. Walter, (Univ. of Geneva, Switzerland)
A. Zdziarski (NCAC, Poland)
A. Zoglauer (UC Berkeley, USA)

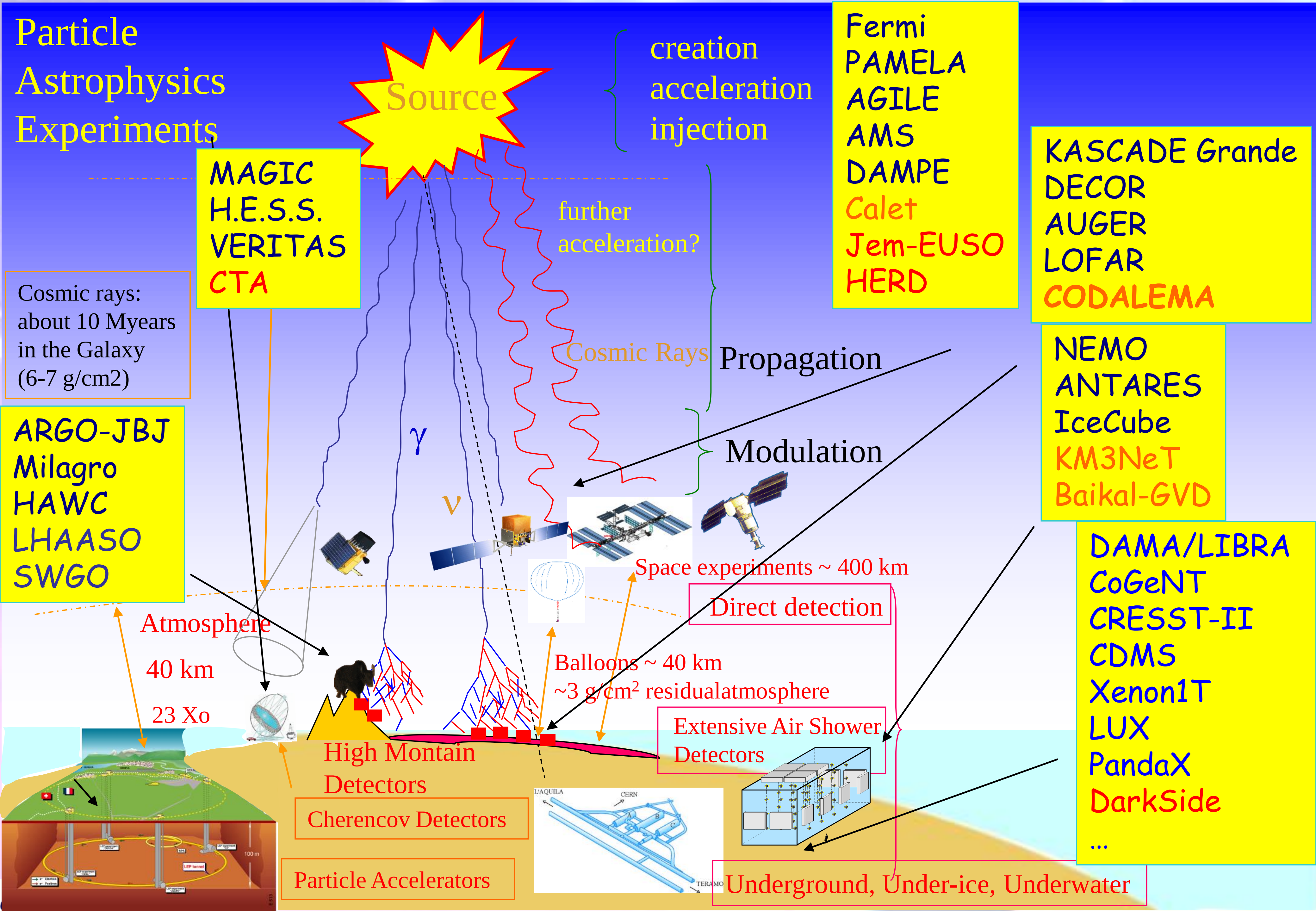
ASTROGAM Sensitivity



Selezionato per la fase 2 dell'ESA M7 Call

Prototipo in costruzione nell'ambito di H2020 AHEAD


Indirect, Direct and Accellerator Searches for Dark Matter
Source
creation
acceleration
injection
further acceleration?
Propagation
Cosmic Rays
Modulation
Cosmic rays: about 10 Myears in the Galaxy (6-7 g/cm2)
γ
ν
Space experiments ~ 400 km
Direct detection
Atmosphere
40 km
23 Xo
Balloons ~ 40 km
~3 g/cm² residual atmosphere
Extensive Air Shower Detectors
High Montain Detectors
Cherencov Detectors
Particle Accelerators
L'AQUILA
CERN
TERAMO
Particle Astrophysics Experiments
Underground, Under-ice, Underwater


Particle
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Source
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Fermi
PAMELA
AGILE
AMS
DAMPE
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HERD
KASCADE Grande
DECOR
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H.E.S.S.
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Cosmic Rays
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ANTARES
IceCube
KM3NeT
Baikal-GVD
ARGO-JBJ
Milagro
HAWC
LHAASO
SWGO
γ
Modulation
ν
Space experiments ~ 400 km
DAMA/LIBRA
CoGeNT
CRESST-II
CDMS
Xenon1T
LUX
PandaX
DarkSide
...
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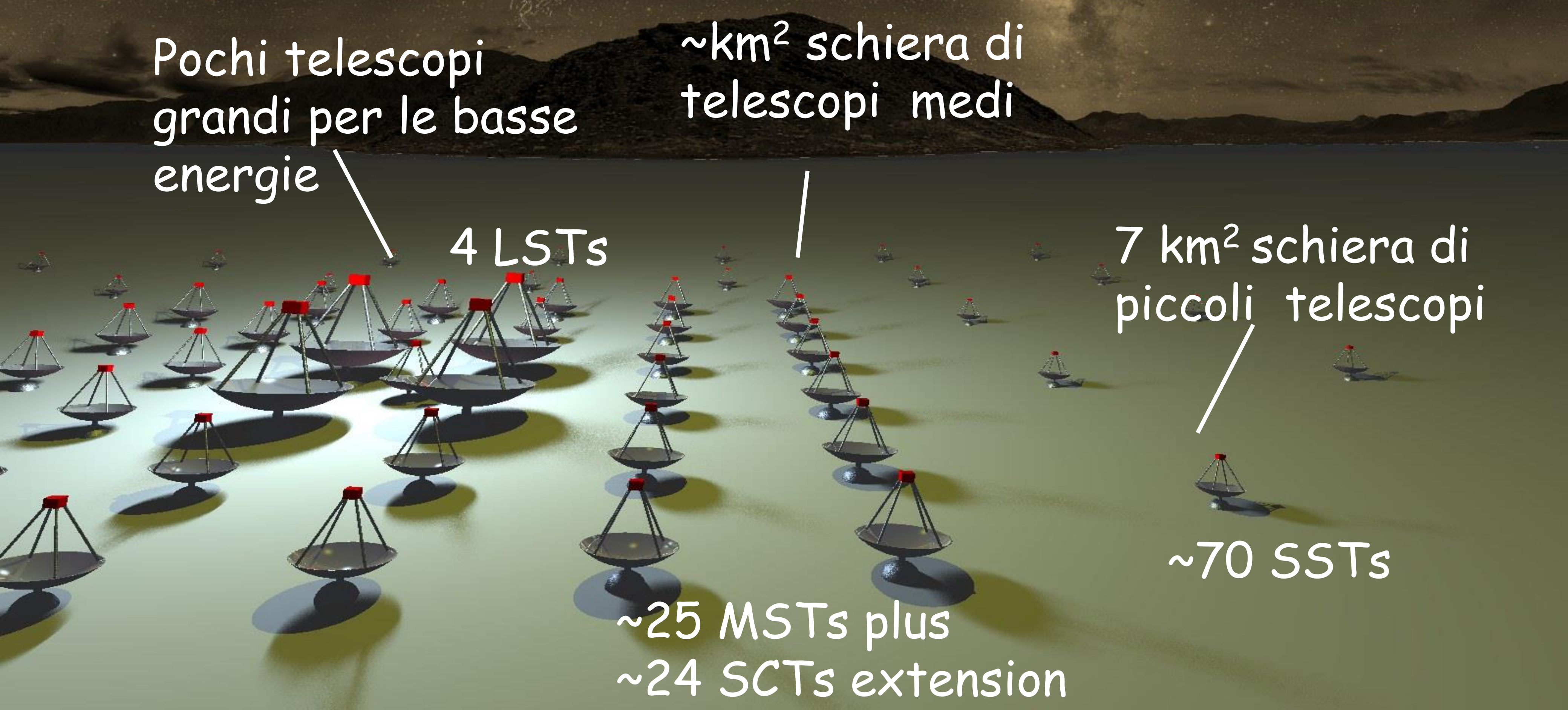
Extensive Air Shower
Detectors
High Montain
Detectors
Cherencov Detectors
Particle Accelerators
L'AQUILA
CERN
TERAMO
Underground, Under-ice, Underwater

Una schiera di telescopi Cherenkov **COME ?**

- γ di bassa energia sono tanti ma producono segnale debole
  ➜ ci vogliono telescopi molto grandi
- γ di alta energia sono pochi ma producono segnale forte
  ➜ specchi piccoli sparsi su grande area



CTA 1st LST construction

Camera Support Structure Installed
21 June

CTA 1st LST construction

Inauguration 10 October 2018

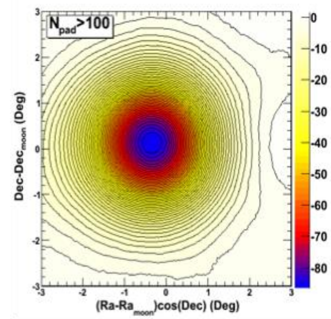
The ARGO-YBJ experiment

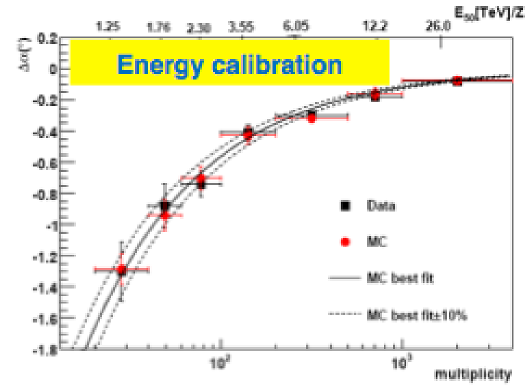

RPC

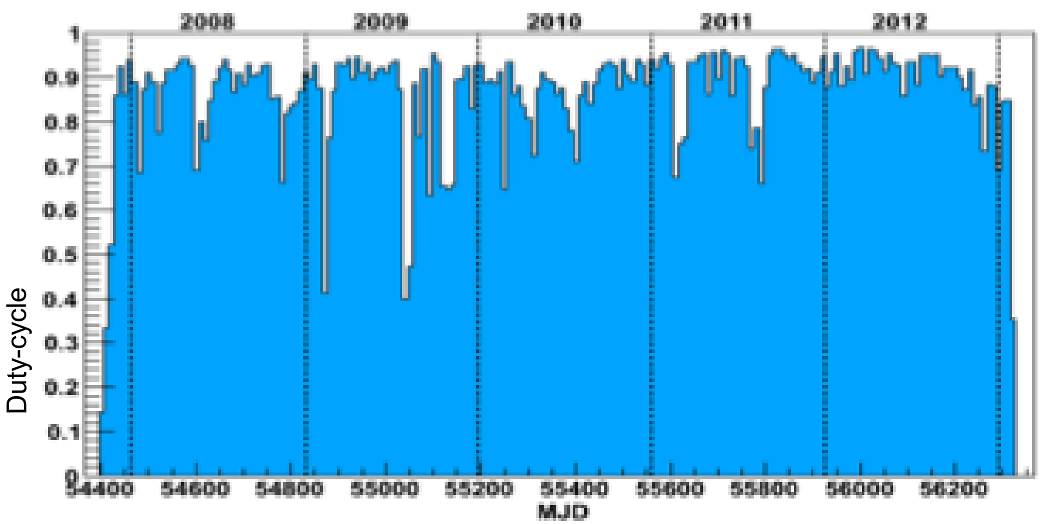
Performance

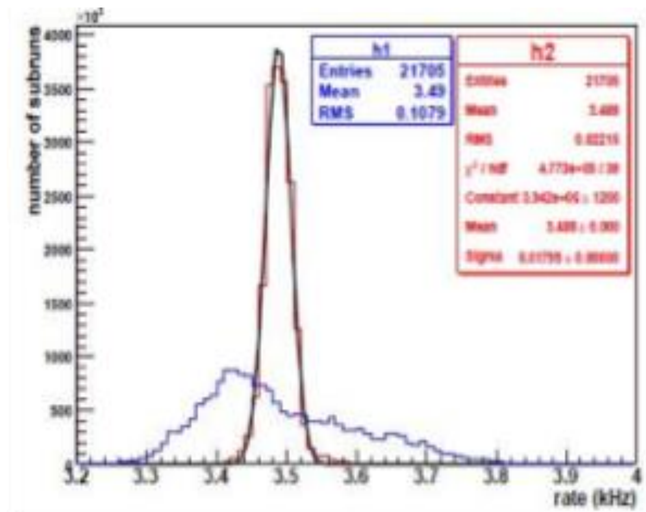
- In observation since July 2004 (with incresing portions of the detector)
- Stable data taking since November 2007
- End/Stop data taking: January 2013
- Very modest maintenance in a hostile environment

- Average duty cycle ~87% Dead time mostly due to frequent cuts of electric power
- Trigger rate ~3.5 kHz @ 20 pad threshold
- N. recorded events: ≈ $5 \cdot 10^{11}$ from 100 GeV to 10 PeV
- 100 TB/year data









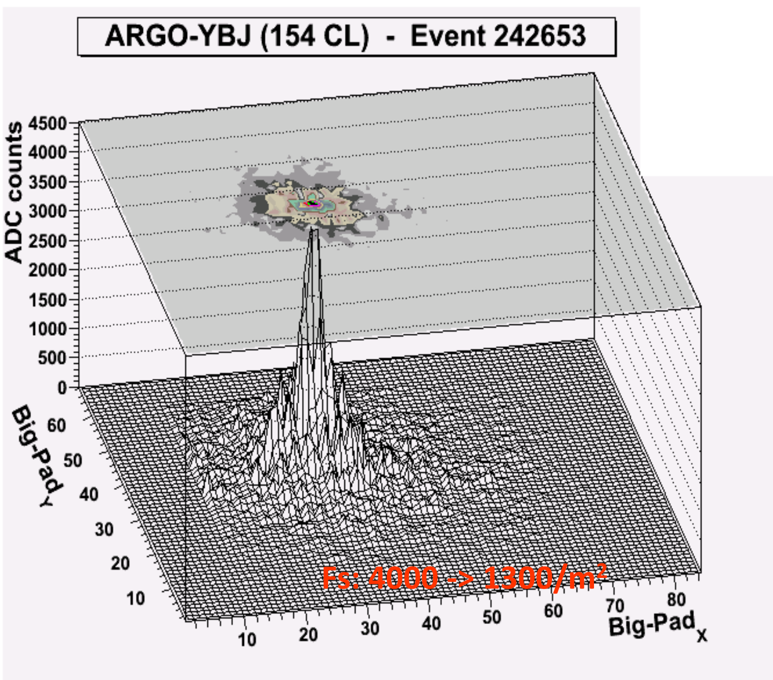
Intrinsic Trigger Rate stability 0.5% (after corrections for T/p effects)

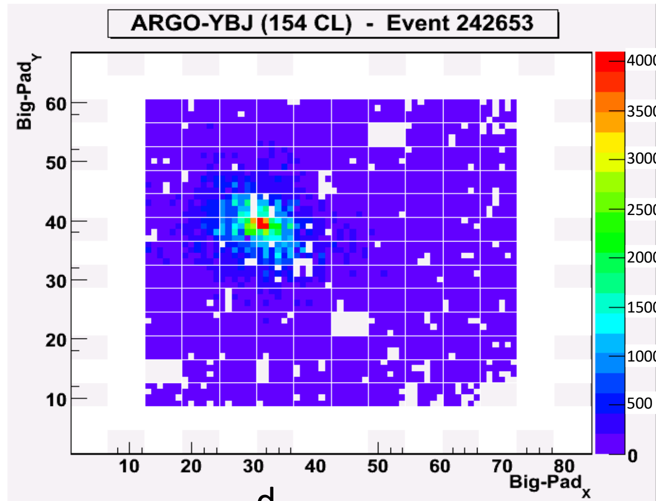
The RPC analog readout

Extending the dynamical range up to PeV

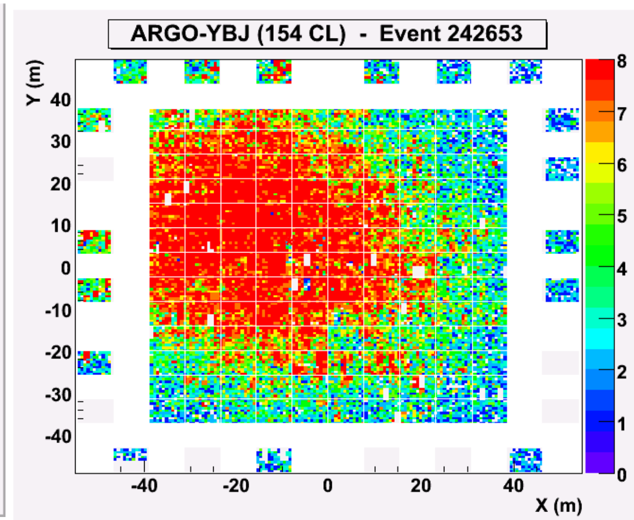
- Is crucial to extend the covered energy range above 100 TeV, where the strip read-out saturates
- Max digital density ~20/m^2
  Max analog dens ~10^4/m^2
- Access the LDF in the shower core
- Sensitivity to primary mass
- Info/checks on Hadronic Interactions

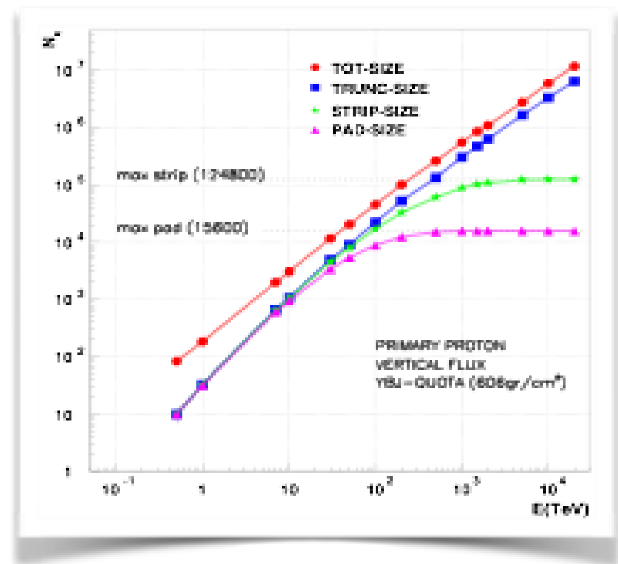
ARGO event





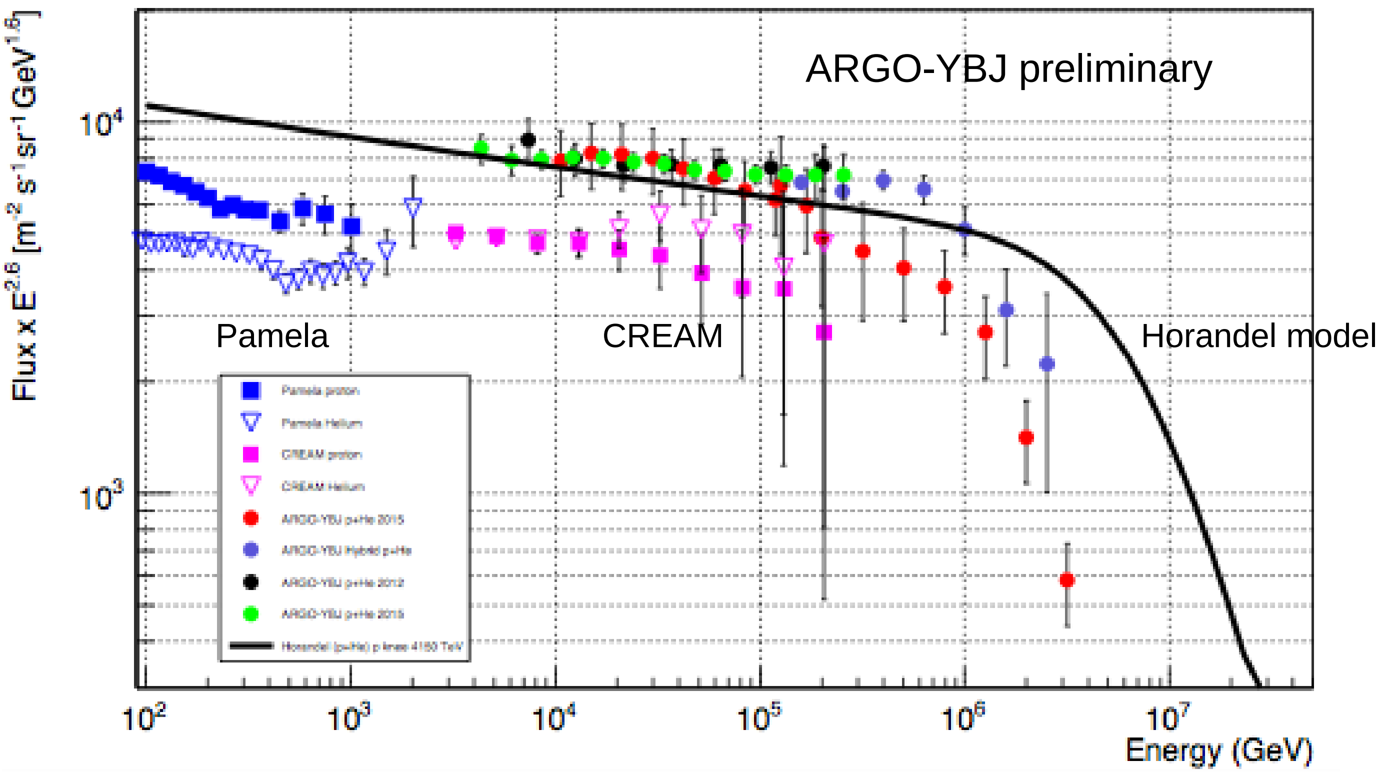
d





Light component spectrum (3 TeV - 5 PeV) by ARGO-YBJ

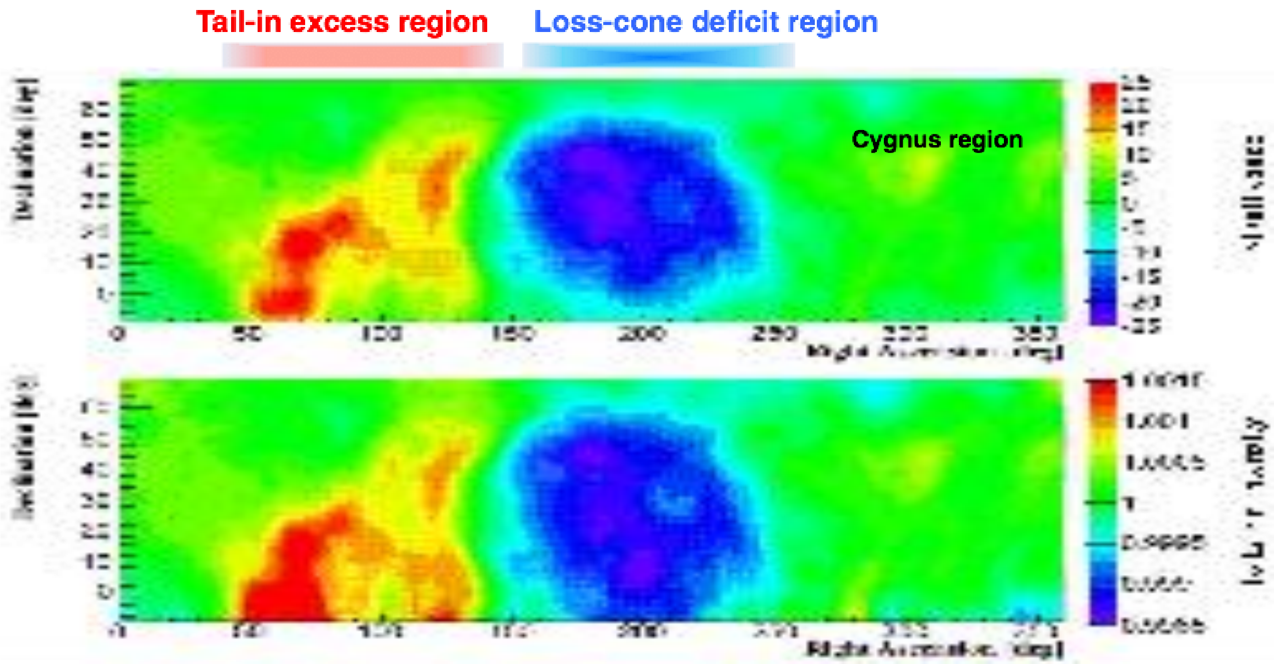
ARGO-YBJ reported evidence for a proton knee starting at about 650 TeV
and not at 4 PeV (“standard model”)



Large scale anisotropy by ARGO-YBJ

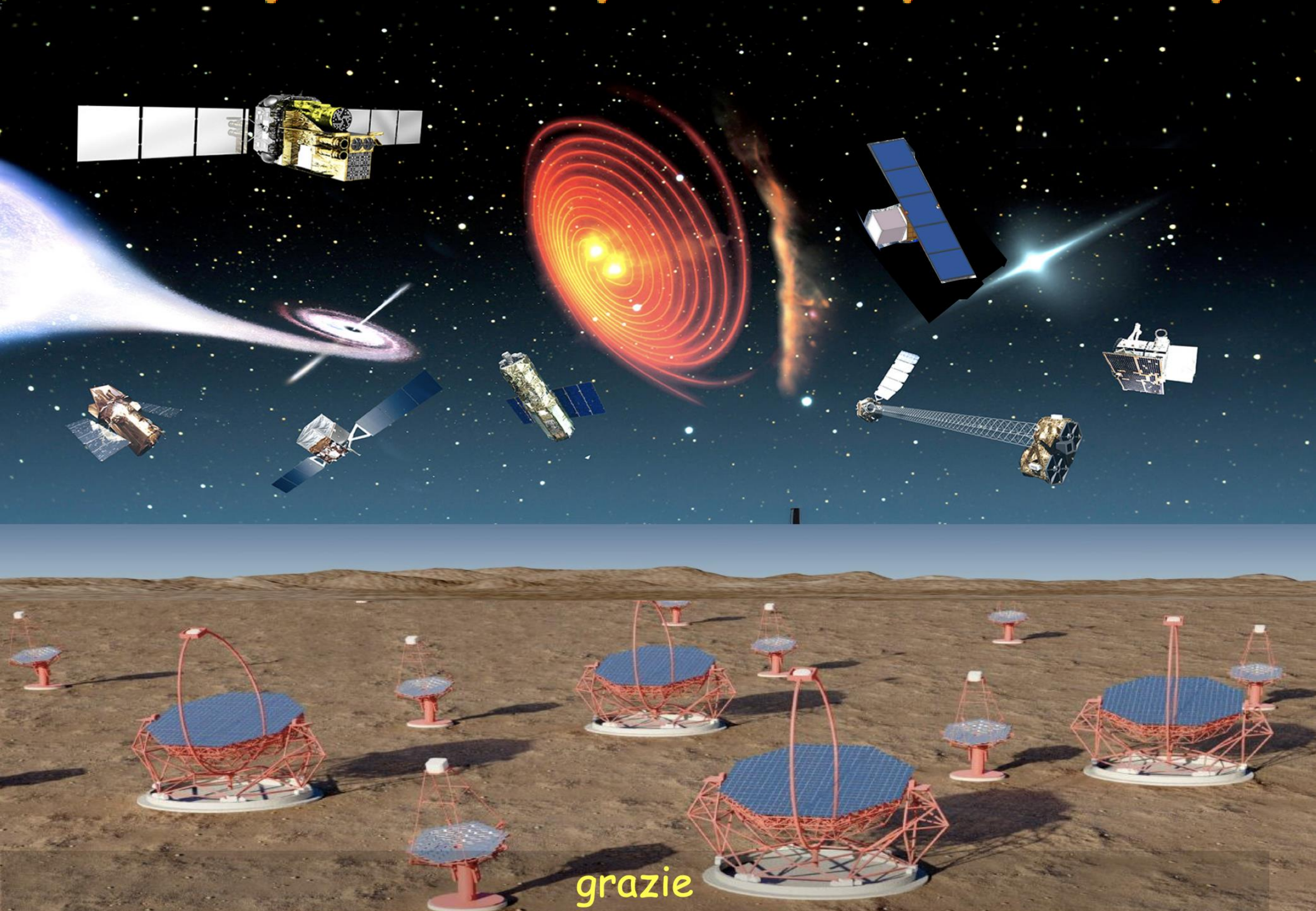
2 years data: 2008 - 2009, during minimum of solar activity

E ≈1 TeV, 3.6×10^{10} events in the declination band $-10^\circ < \delta < +70^\circ$



Uno sguardo al futuro

Nell'ambito del PNRR CTA+ una collaborazione INAF-INFN prevede la creazione di un rivelatore di test ibrido RPC- Water Cherenkov di ~ 500 m² in previsione di un grande osservatorio complementare a CTA nell'emisfero Sud (SWGO)


grazie