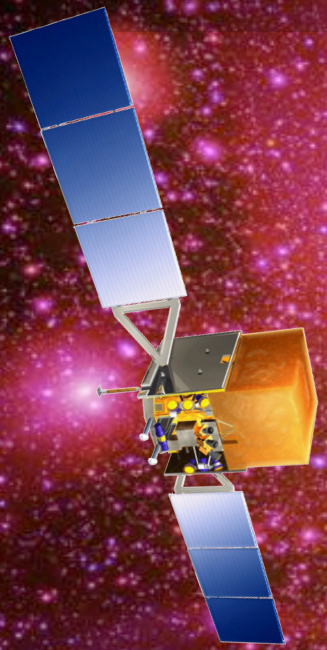
Silicon in space: cosmic rays and astrophysics



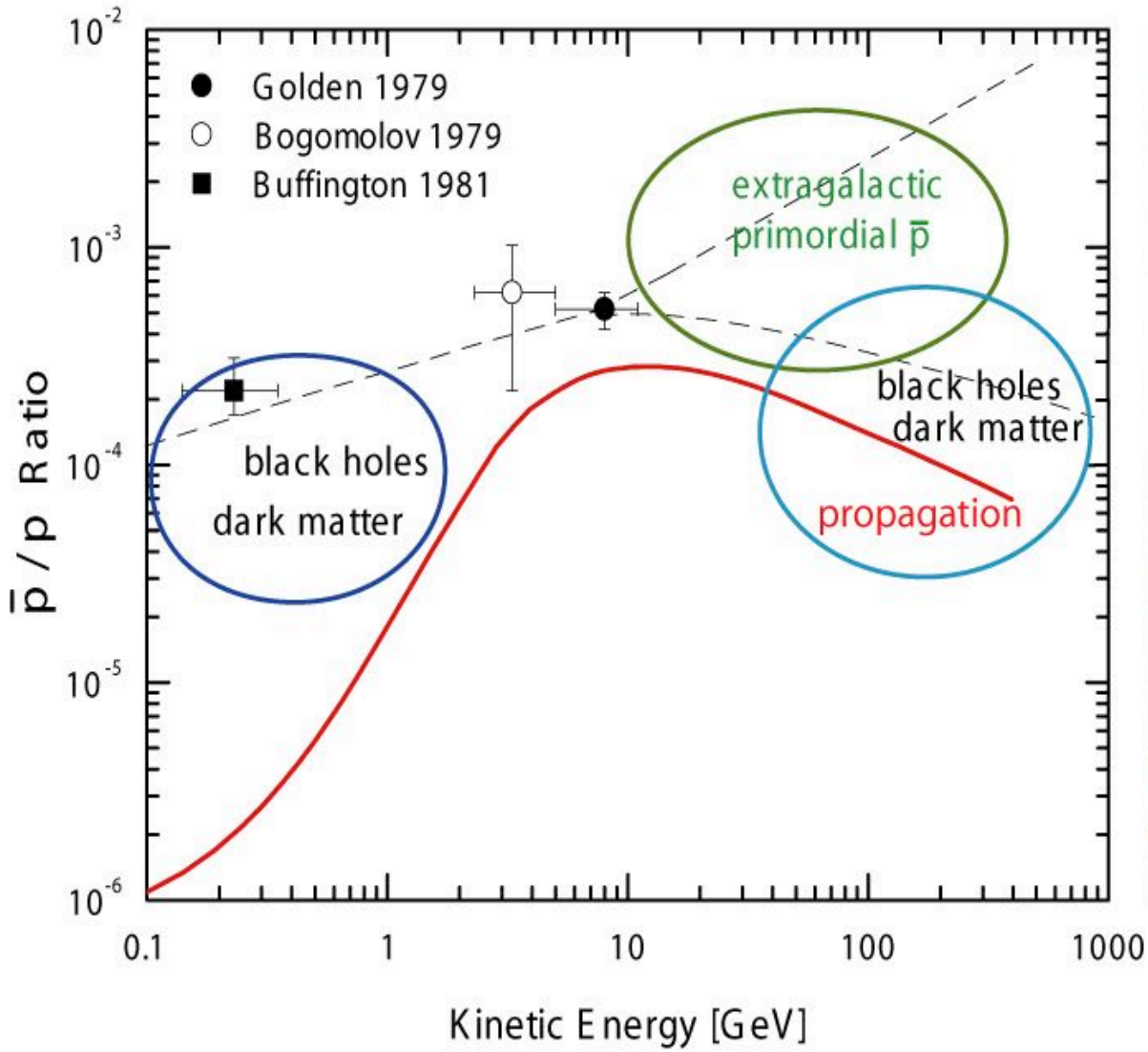
Aldo Morselli

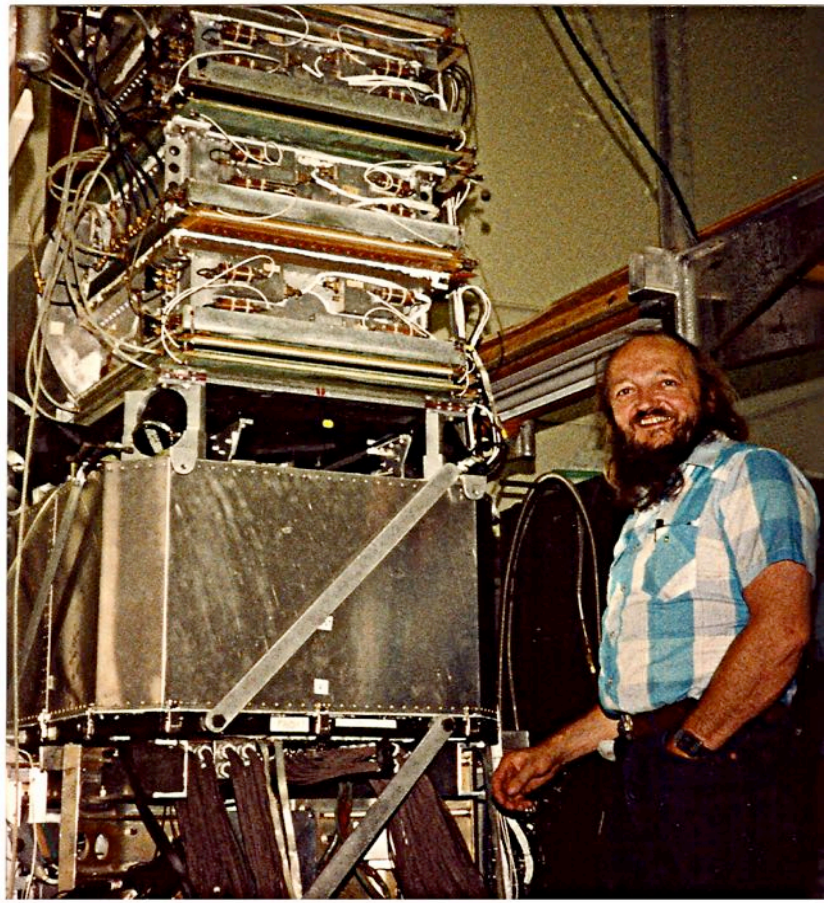
INFN Roma Tor Vergata

ASI

Roma 20 Giugno 2016

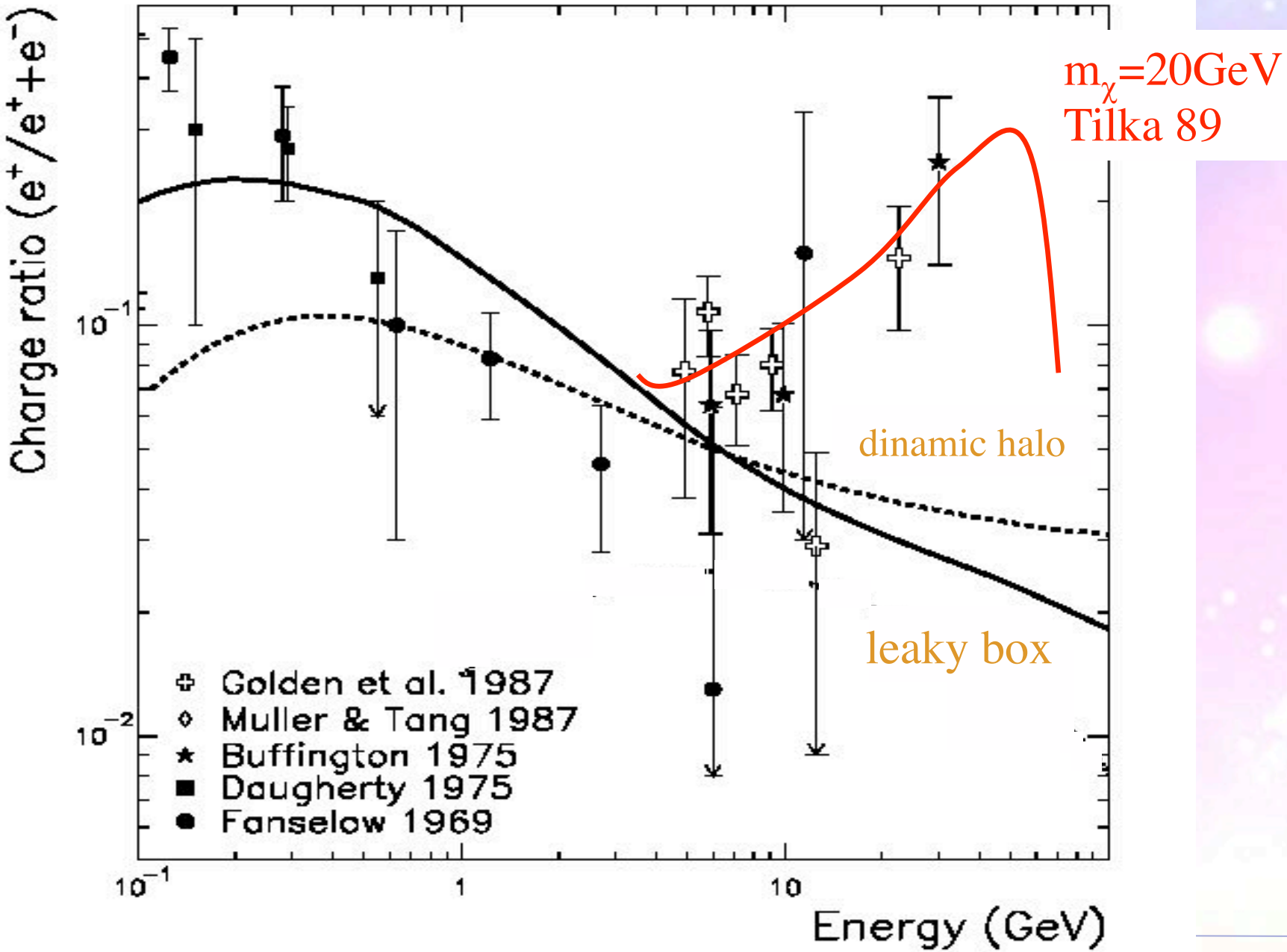
The first historical measurements of the $\bar{p}/p$ - ratio and various Ideas of theoretical Interpretations



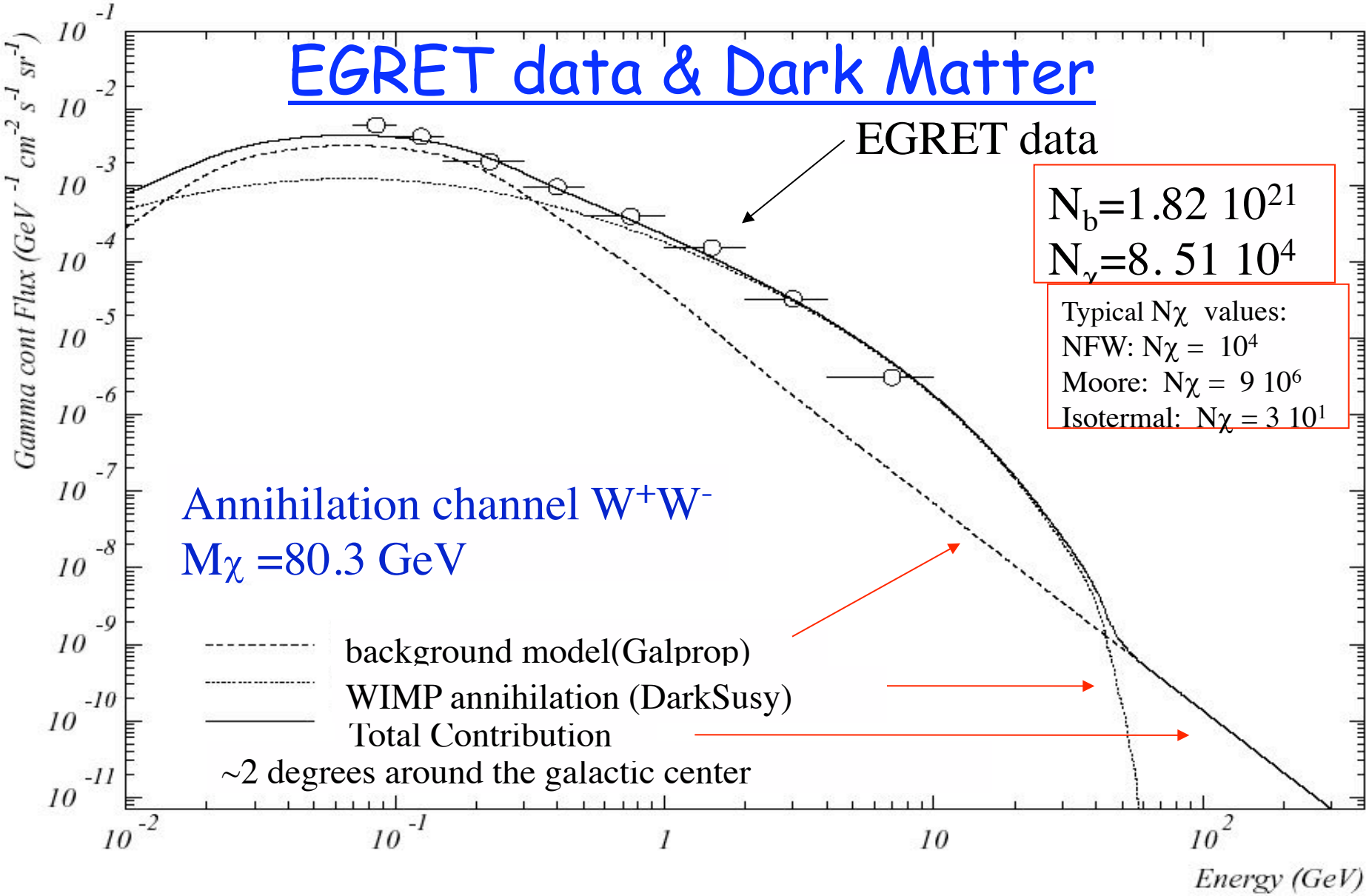


Robert L. Golden

Balloon data : Positron fraction before 1990



EGRET data & Dark Matter



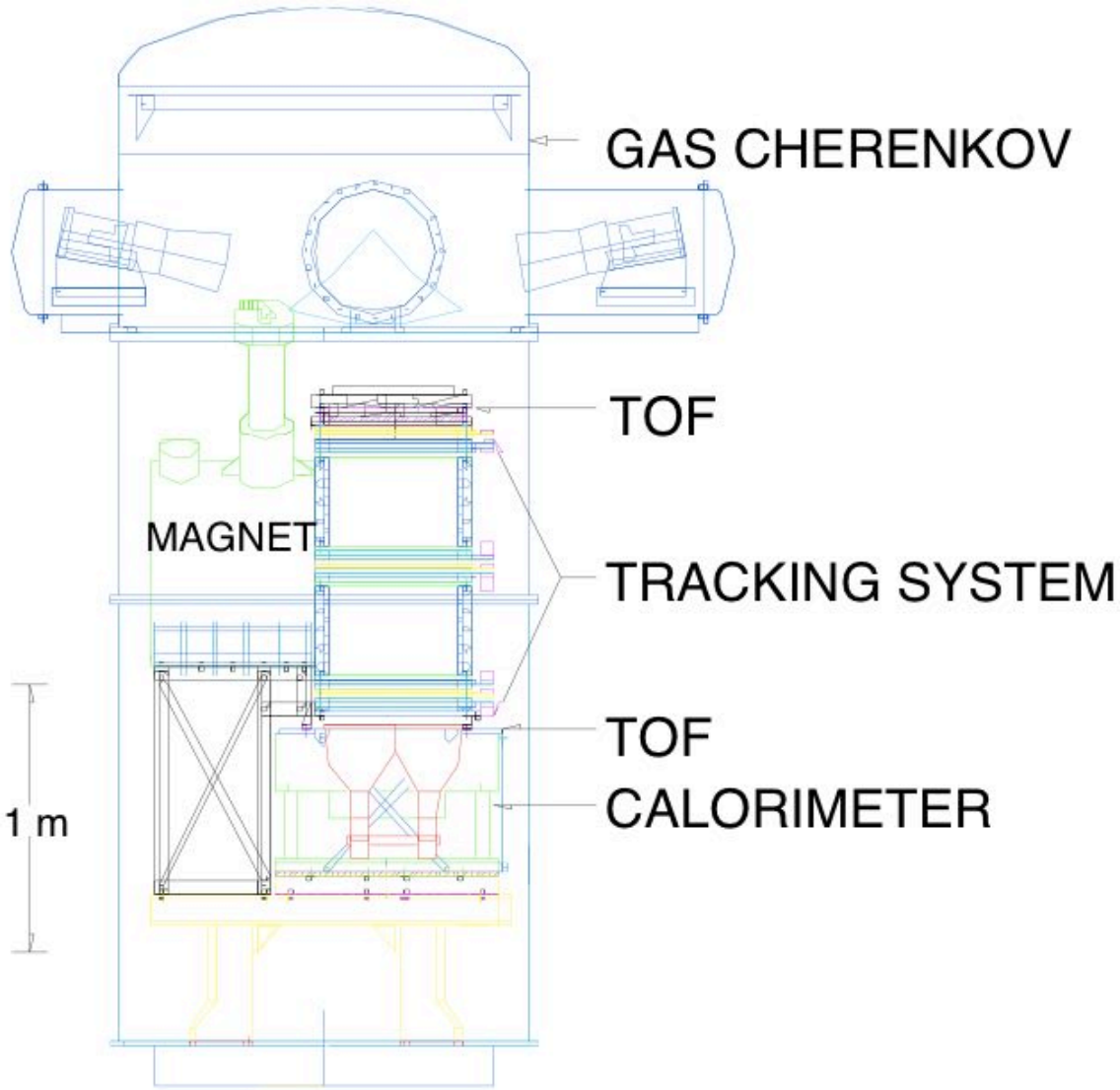
A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, Nucl. Phys. B 113B (2002) 213-220 [astro-ph/0211327]

Neutralino WIMPs

Assume χ present in the galactic halo

- χ is its own antiparticle **=>** can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)
- So, any extra contribution from exotic sources (χ χ annihilation) is an interesting signature
- ie: χ χ --> anti p + X
- Produced from (e. g.) χ χ **-->** q / g / gauge boson / Higgs boson and subsequent decay and/ or hadronisation.

MASS Matter Antimatter Space Spectrometer



5 September 1989

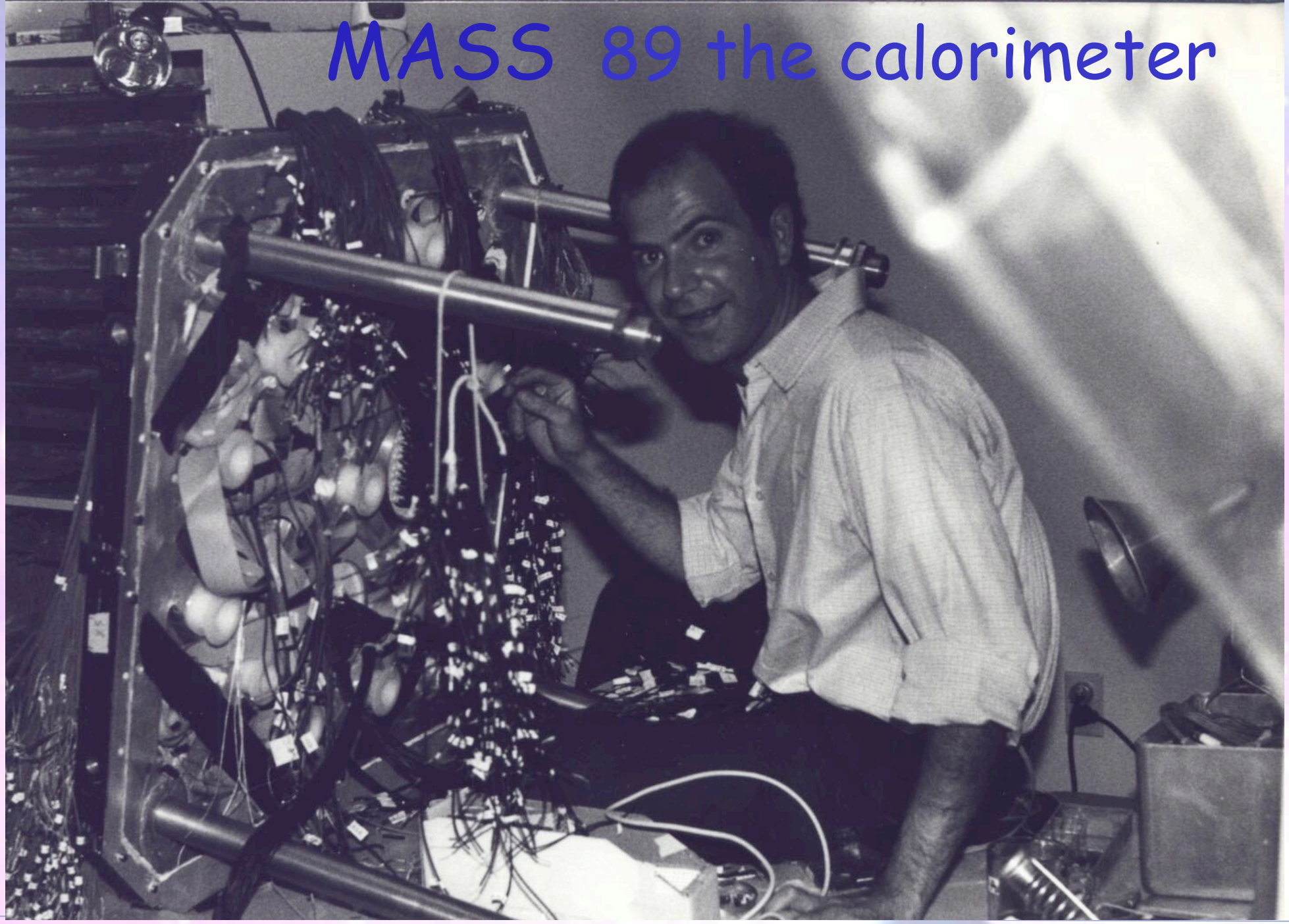

HOLD


MASS 89 flight

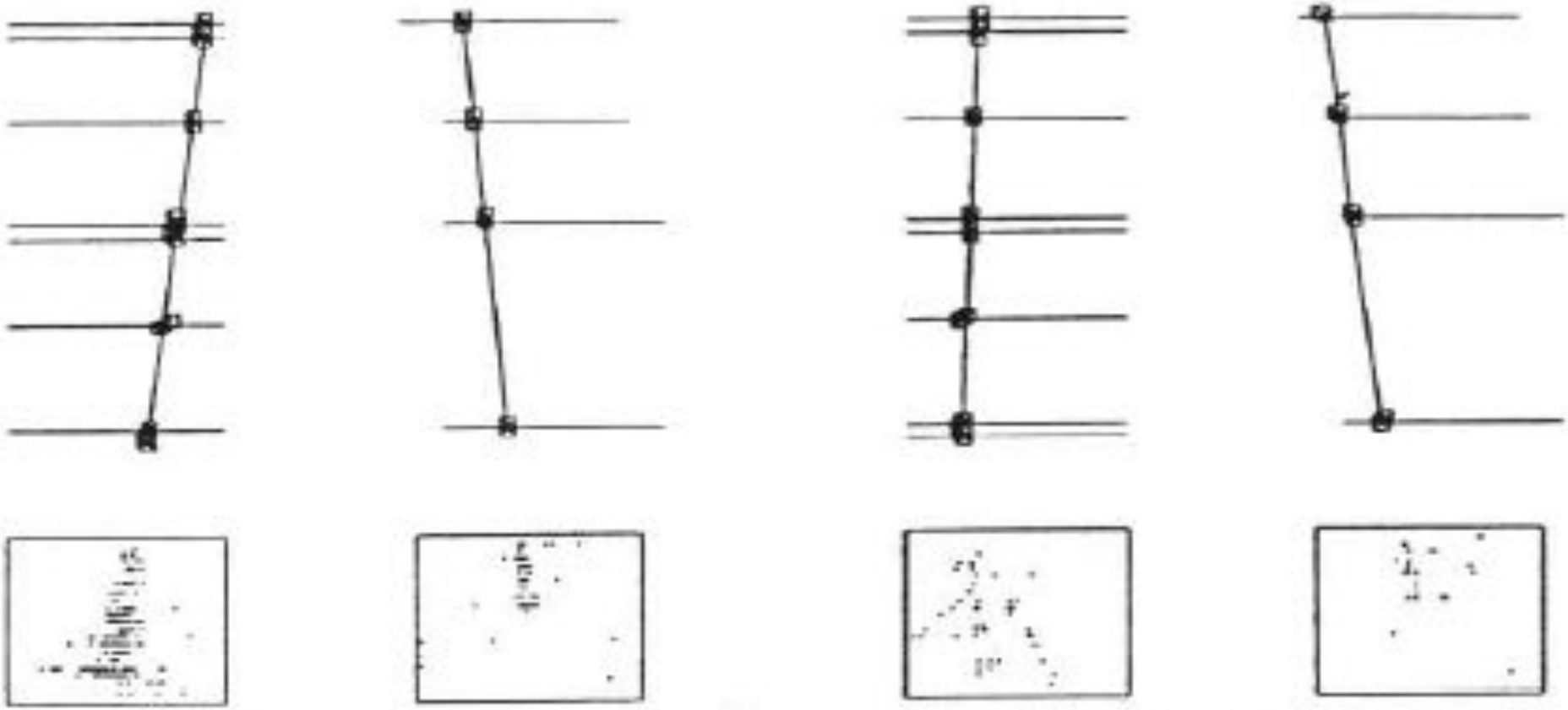

MASS 89 flight


MASS 89

MASS 89 the calorimeter



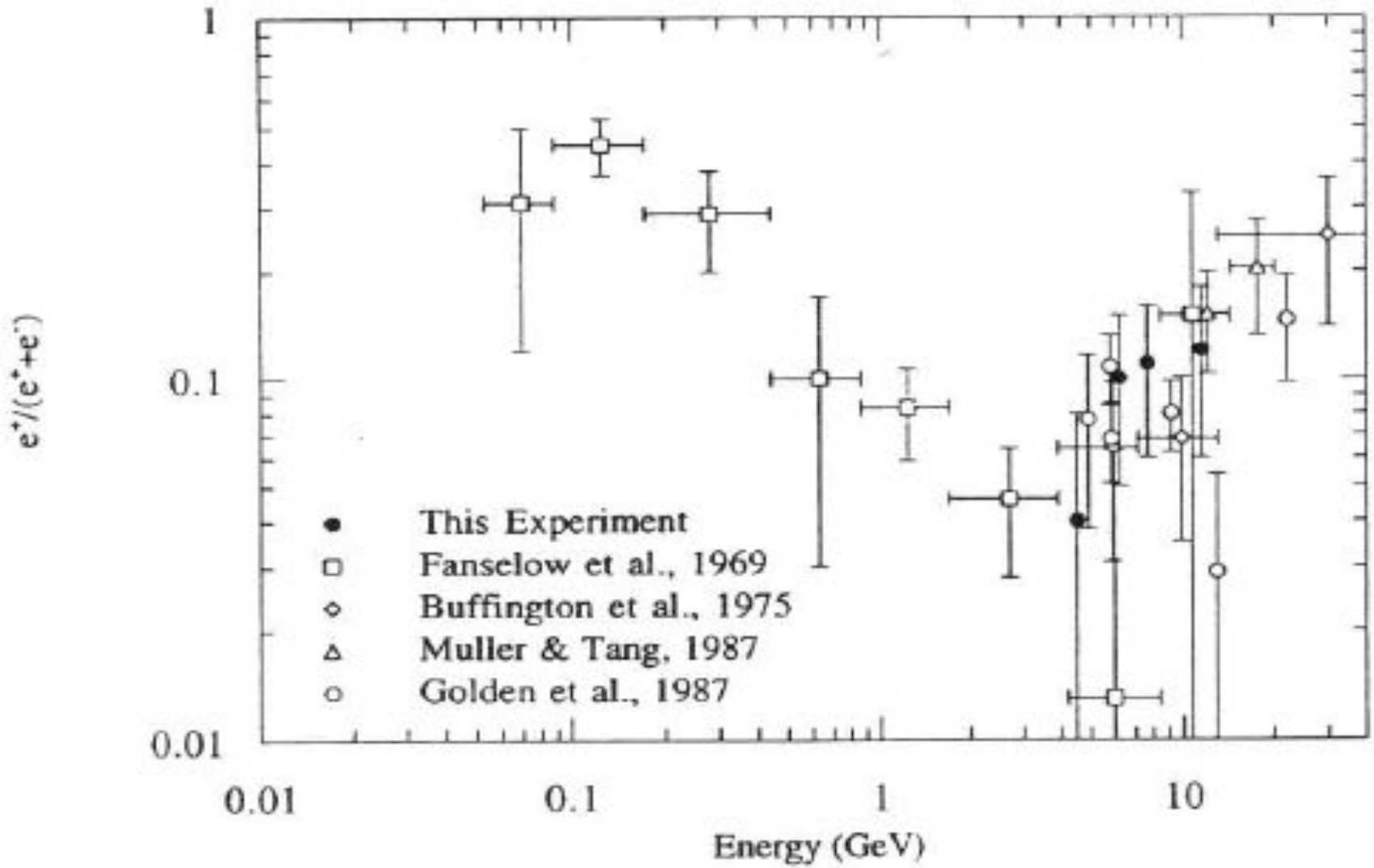
MASS 1989



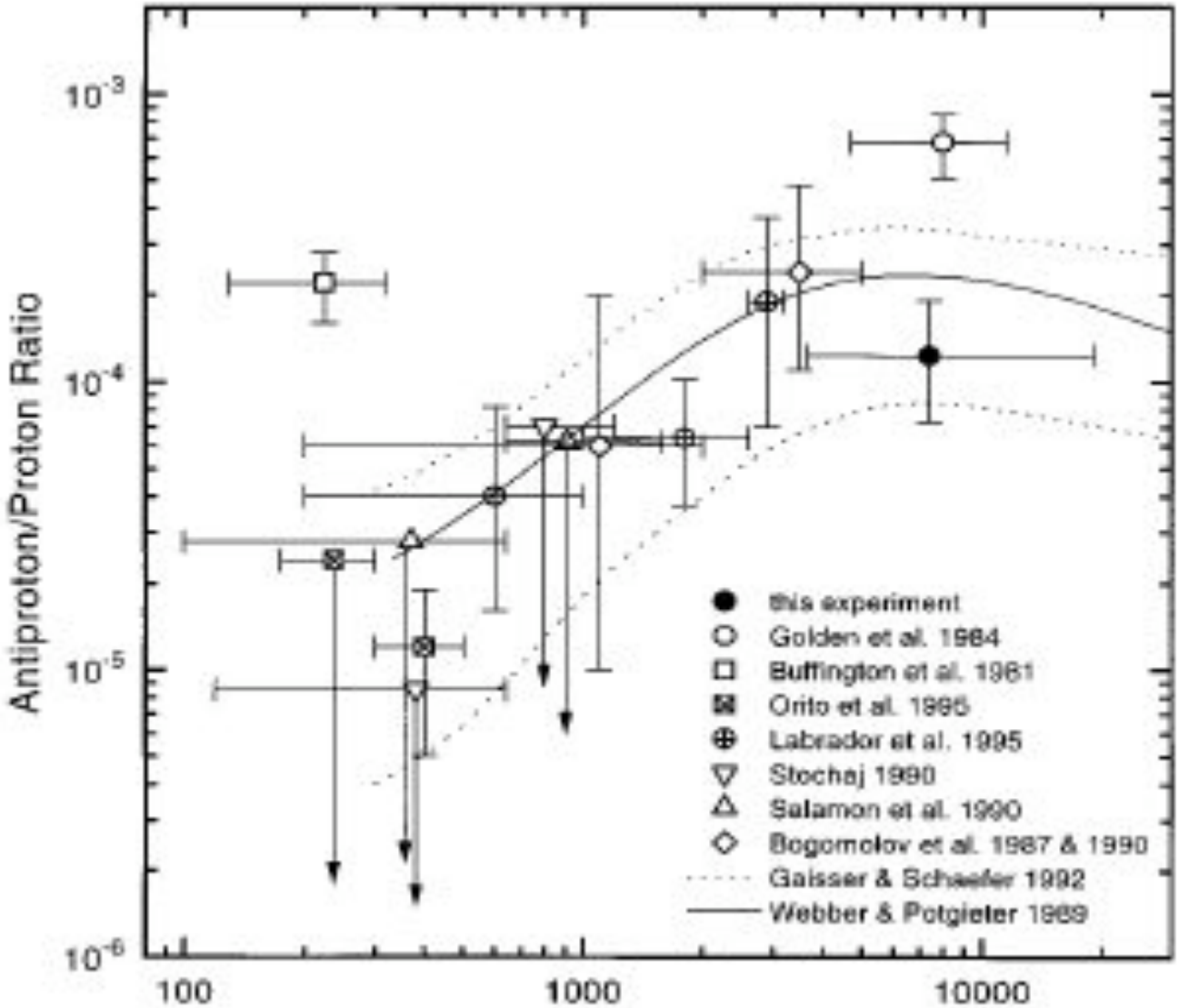
electron

proton

MASS 1989
Positron to electron ratio



MASS 1991
antiproton to proton ratio



The Turning Point

Nuclear Instruments and Methods in Physics Research A 333 (1993) 560–566
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

A silicon imaging calorimeter prototype for antimatter search in space: experimental results

M. Bocciolini, F. Celletti, A. Perego and P. Spillantini
Dipartimento di Fisica dell'Università di Firenze and Sezione INFN di Firenze, Firenze, Italy

G. Basini, F. Bongiorno [1], F. Massimo Brancaccio and M. Ricci
Laboratori Nazionali di Frascati dell'INFN, Frascati, Italy

M.T. Brunetti, A. Codino, M. Menichelli, M. Miozza and I. Salvatori
Dipartimento di Fisica dell'Università di Perugia and Sezione INFN di Perugia, Perugia, Italy

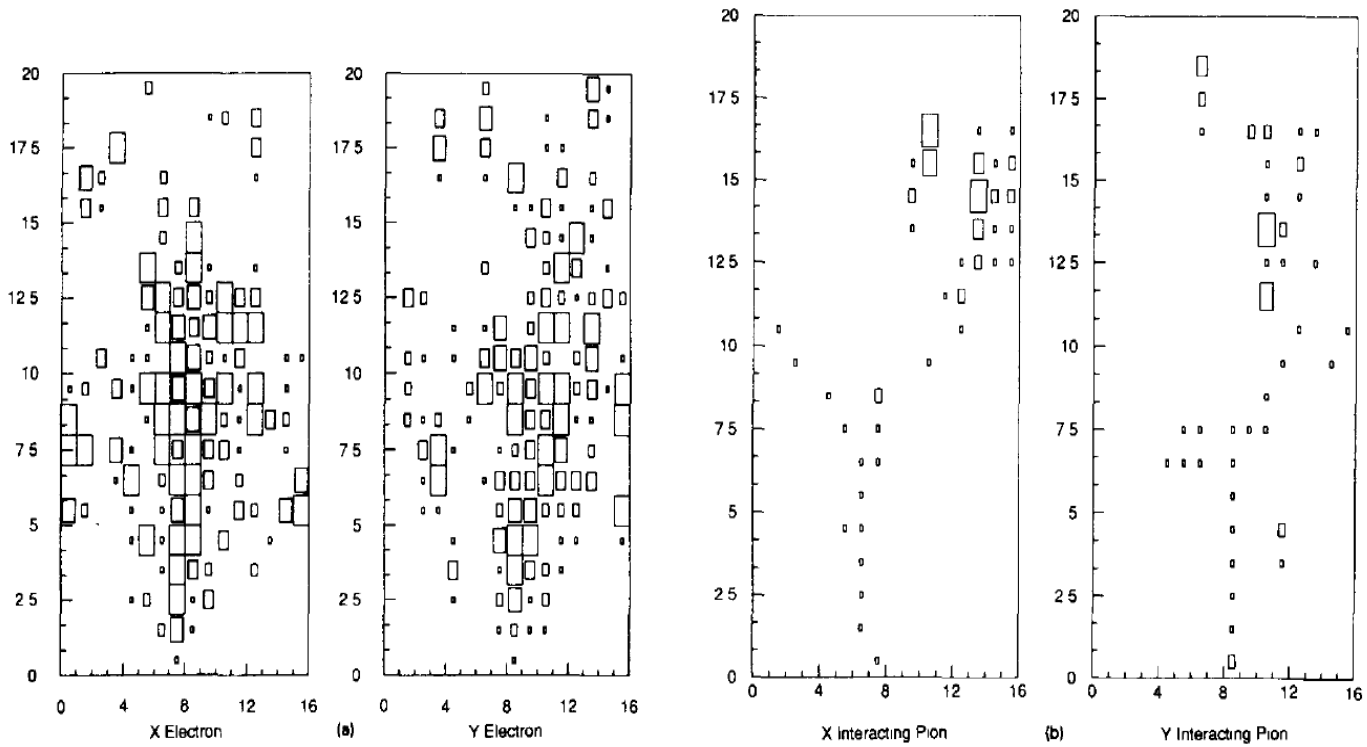
V. Bidoli, M. Candusso, C. De Fabritiis, M.P. De Pascale, A. Morselli and P. Picozza
Dipartimento di Fisica dell'Università "Tor Vergata", Roma and Sezione INFN di Roma II, Roma, Italy

A. Buccheri, A. Incicchitti and D. Prosperi
Dipartimento di Fisica dell'Università "La Sapienza", Roma and Sezione INFN di Roma, Roma, Italy

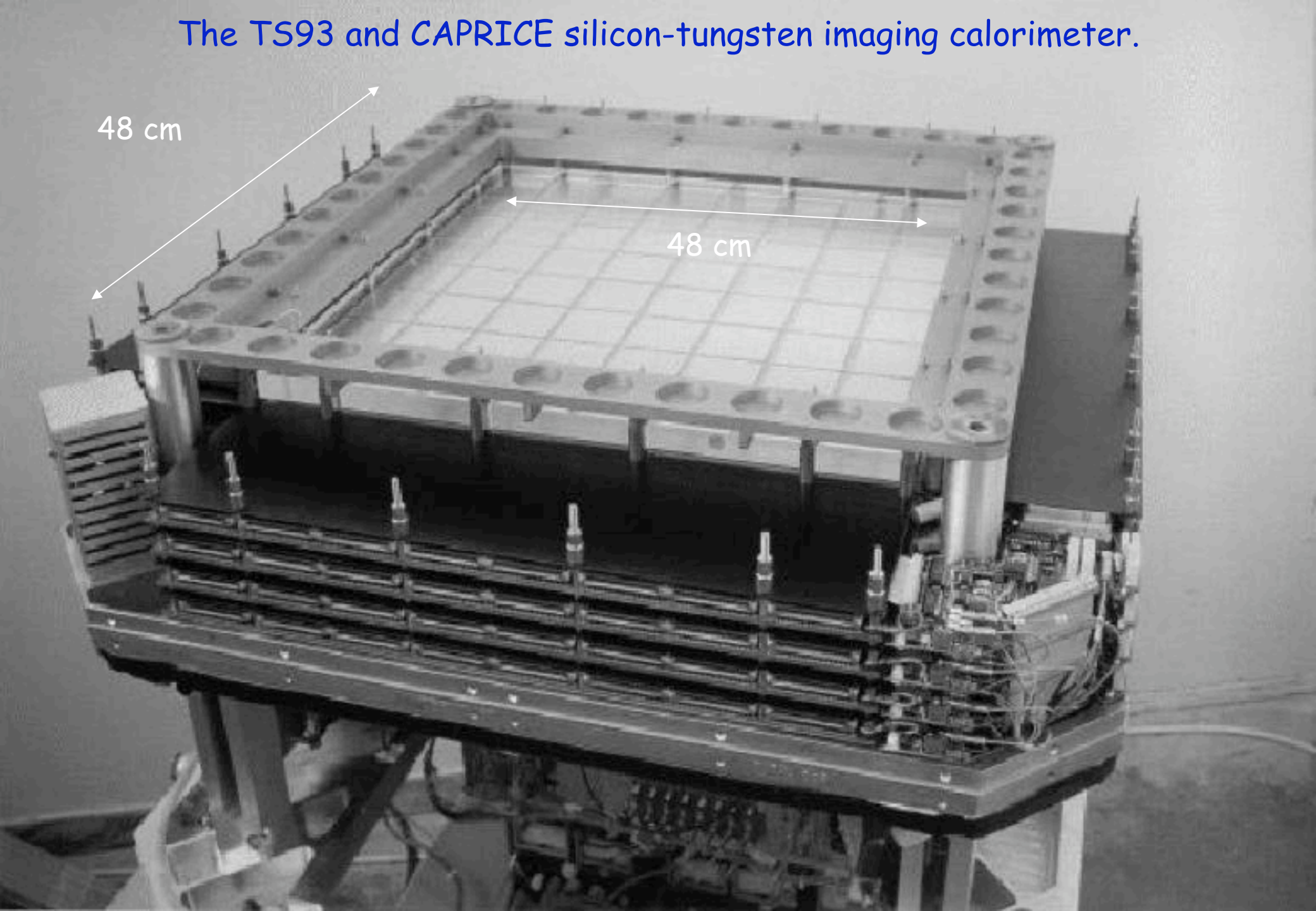
G. Barbiellini, M. Boezio, F. Fratnik, P. Schiavon, A. Vacchi and N. Zampa
Dipartimento di Fisica dell'Università di Trieste and Sezione INFN di Trieste, Trieste, Italy

Received 3 August 1992 and in revised form 19 January 1993

This report presents the results obtained with a prototype silicon–tungsten (Si–W) electromagnetic calorimeter, conceived as a fine-grained imaging device to carry out studies of the antimatter component in primary cosmic radiation. The calorimeter prototype contains 20 x, y sampling layers interleaved with 19 showering material planes. One sensitive layer is obtained with two silicon strip detectors (Si-D) (60×60) mm^2, each divided into 16 strips, 3.6 mm wide; the two detectors are assembled back to back with perpendicular strips. This allows the transverse distributions of the shower in both coordinates at each sampling (0.5 X_0) to be pictured. The basic characteristics of the design and the experimental results obtained on a test beam at the CERN proton synchrotron (PS) for electrons and pions are reported. The main results presented are the response of the calorimeter to the electron at various energies (1–7 GeV), and the transverse shower profiles at different calorimeter depths as well as the patterns of the electromagnetic shower and those of the interacting and non-interacting pions. The capability of the calorimeter in measuring the direction of the incoming electromagnetic particle from the pattern of the shower has been evaluated at different energies. These results are encouraging in view of the possible use of this detector to search for high-energy γ sources in space.



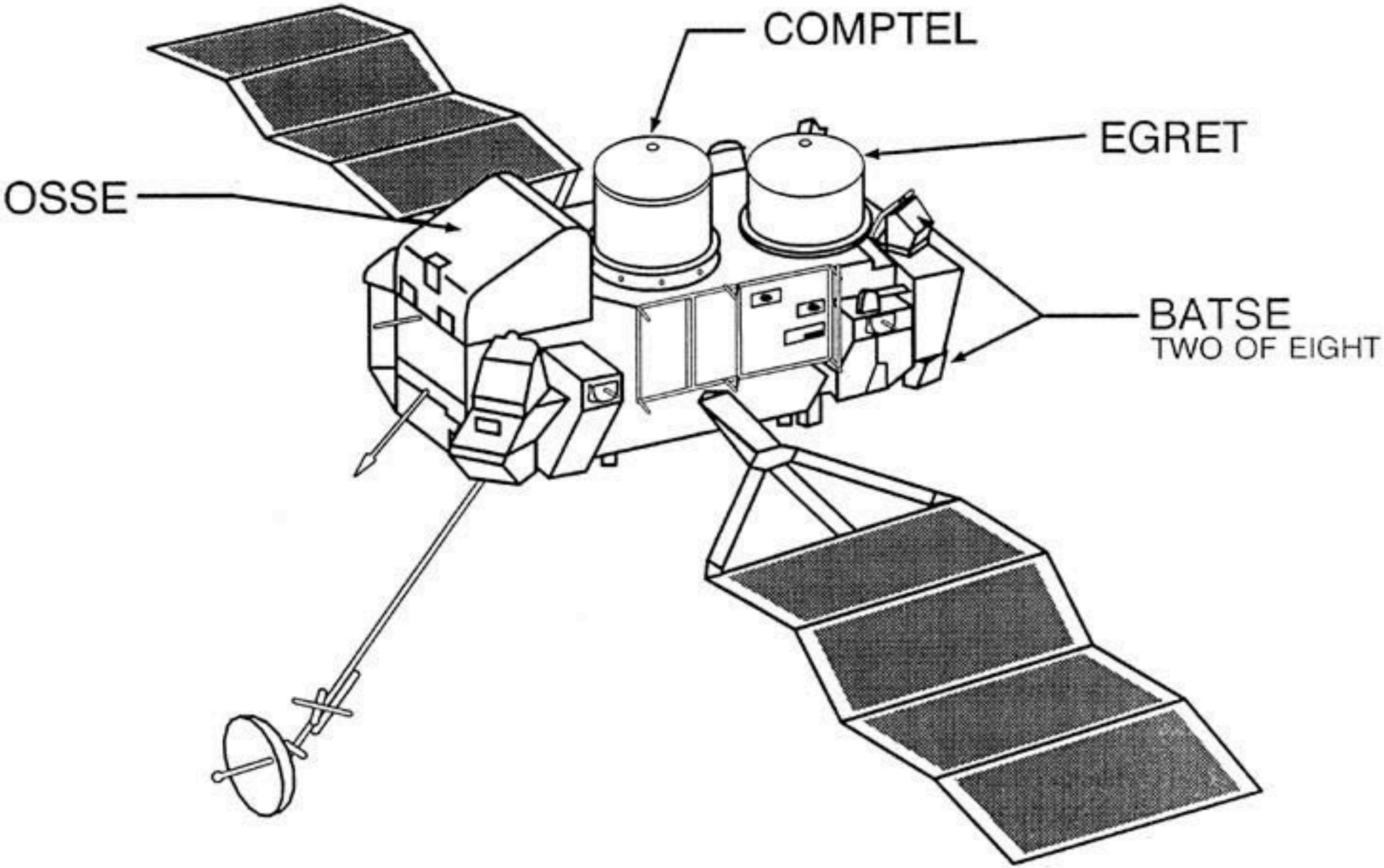
The TS93 and CAPRICE silicon-tungsten imaging calorimeter.




The CAPRICE 94
flight

Silicon detectors : useful non only for cosmic rays

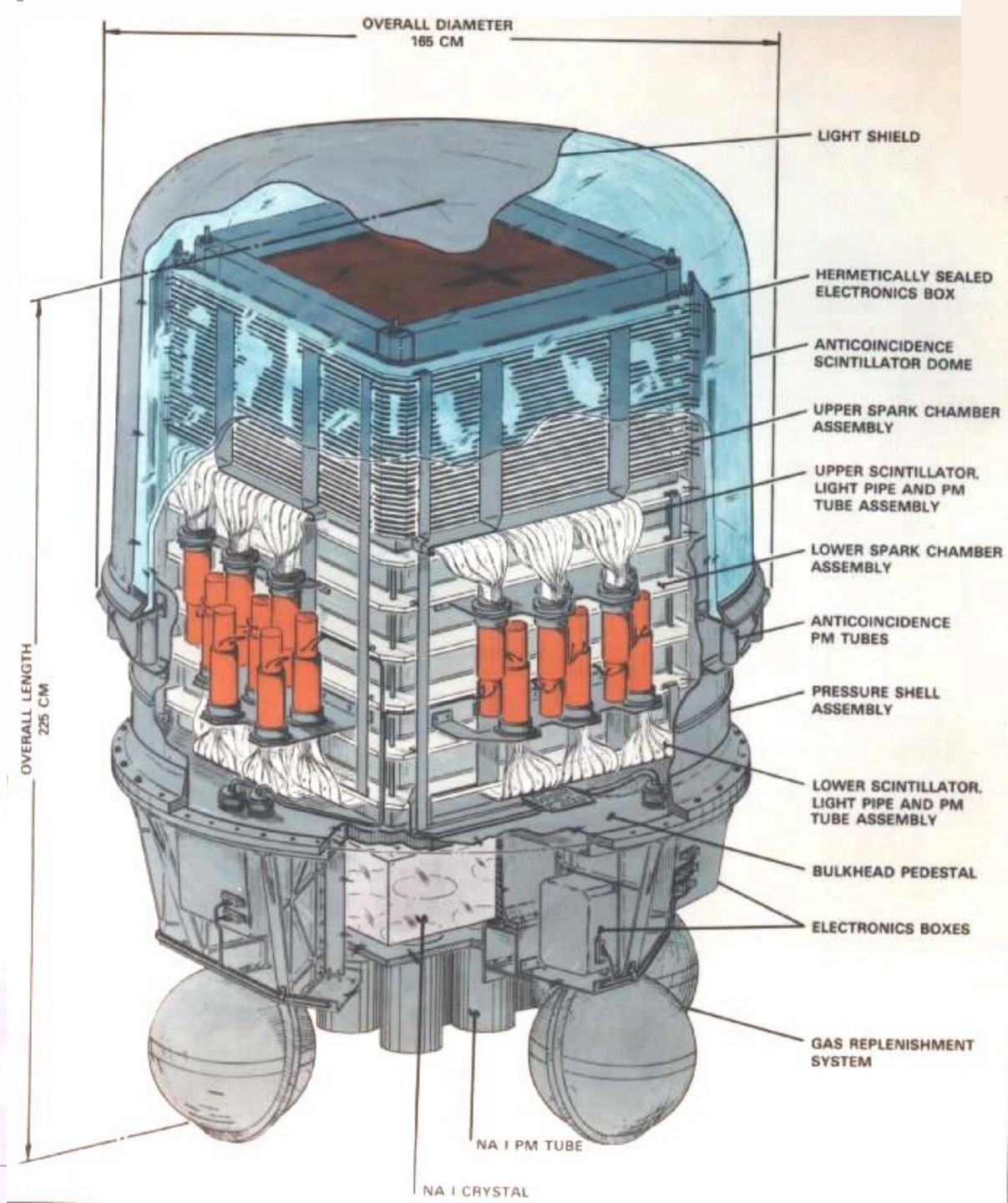
COMPTON OBSERVATORY INSTRUMENTS

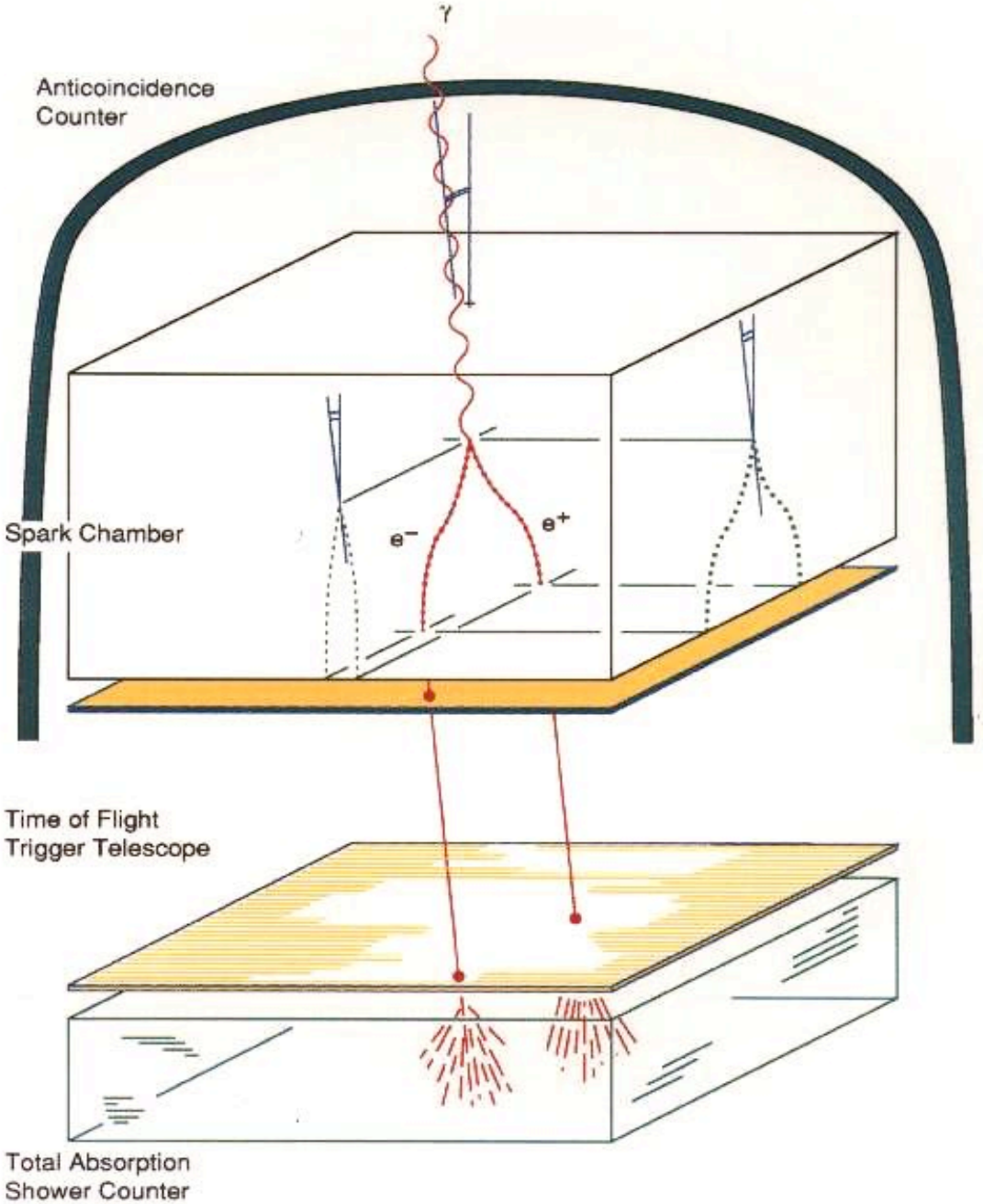


EGRET:the detector

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°

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

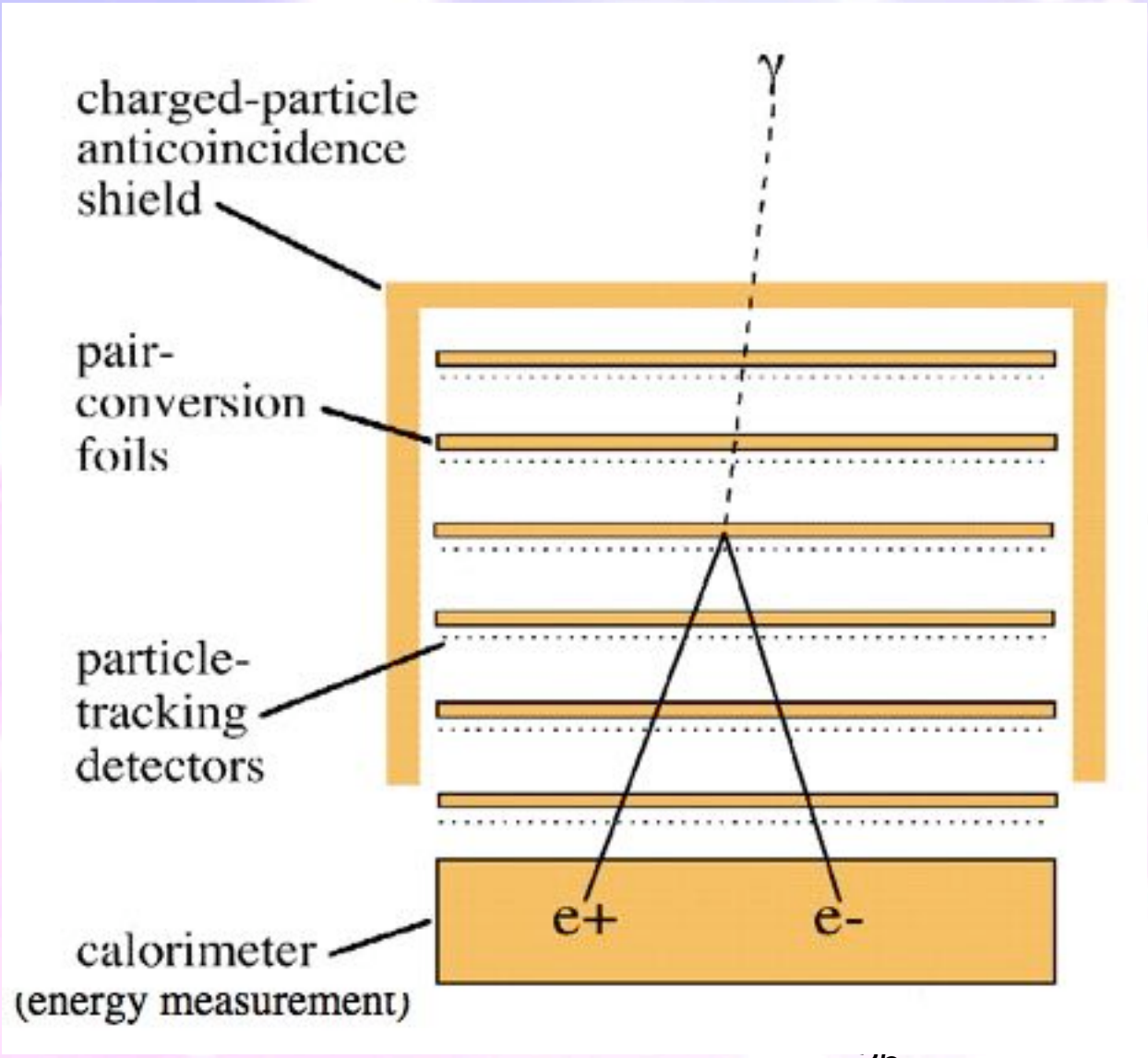
EGRET – Principle of gamma ray detection

A γ-ray 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 time-of-flight 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 electron-positron 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.

Elements of a pair-conversion telescope



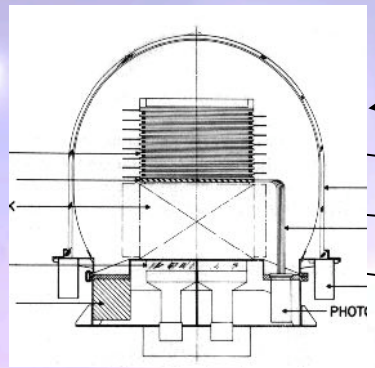
- photons materialize into matter-antimatter pairs:

  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

26

The gamma-ray missions



SAS-2
11/1972-7/1973

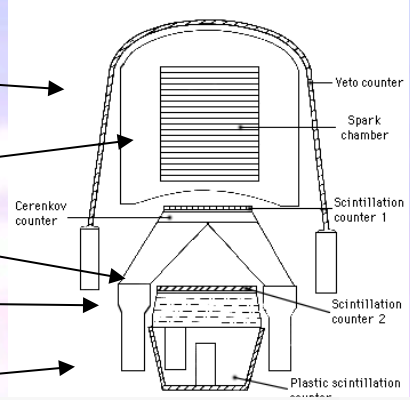
Anti-Coincidence Dome

Spark Chamber

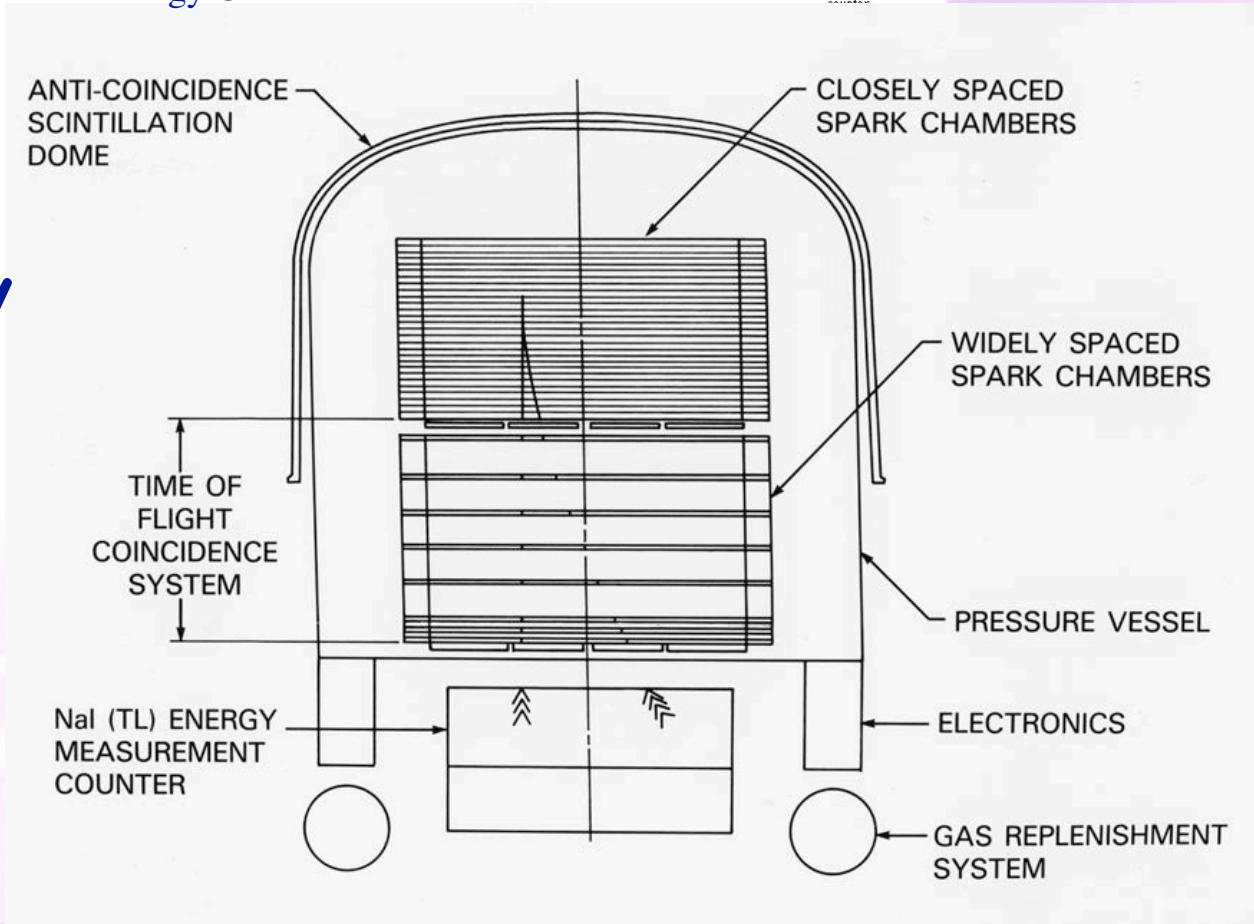
Trigger Telescope

Cerenkov Counter

Energy Calorimeter

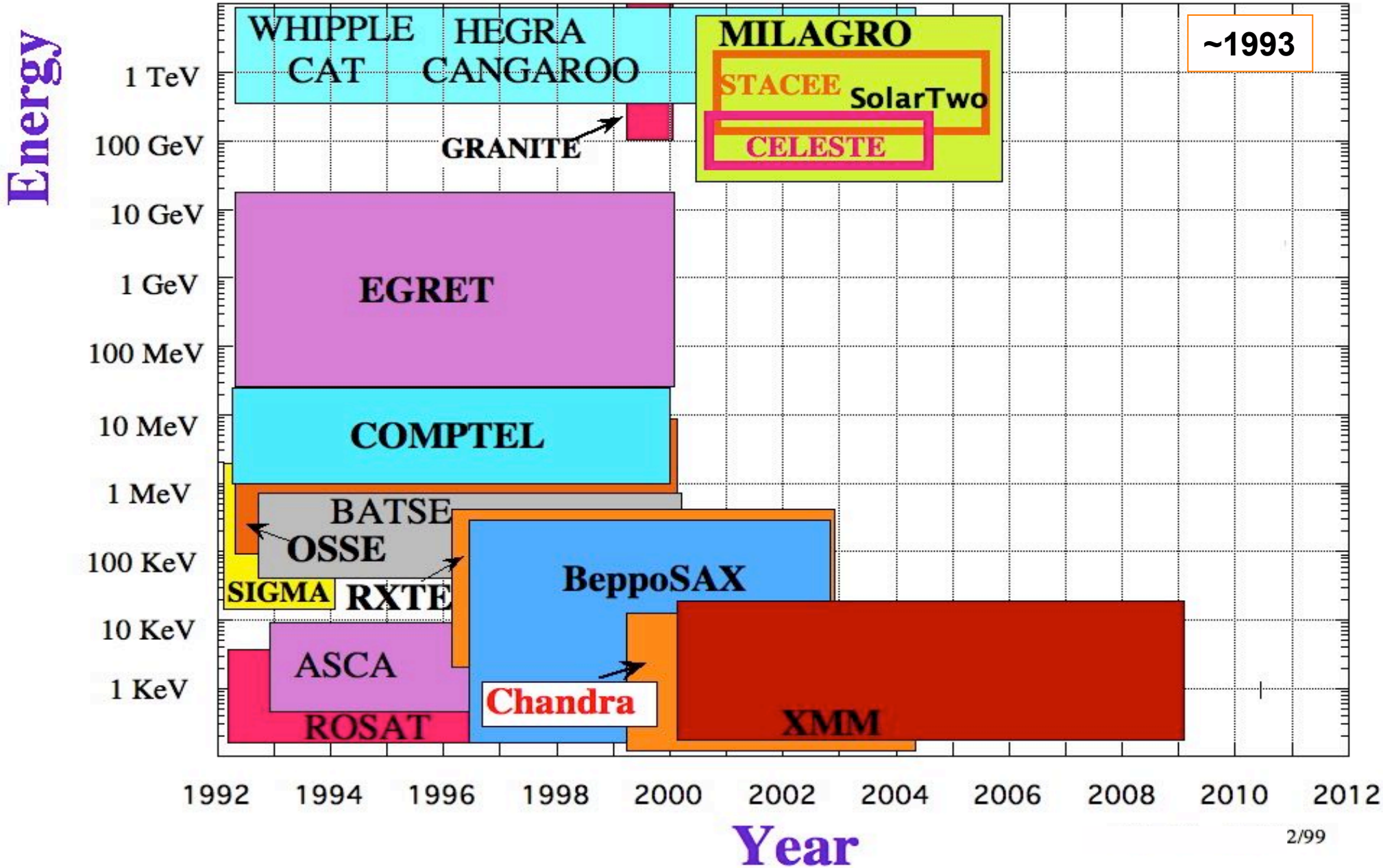


Cos-B
8/1975-4/1982



EGRET
4/1991-1999

High Energy Gamma Experiments Experiments



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]

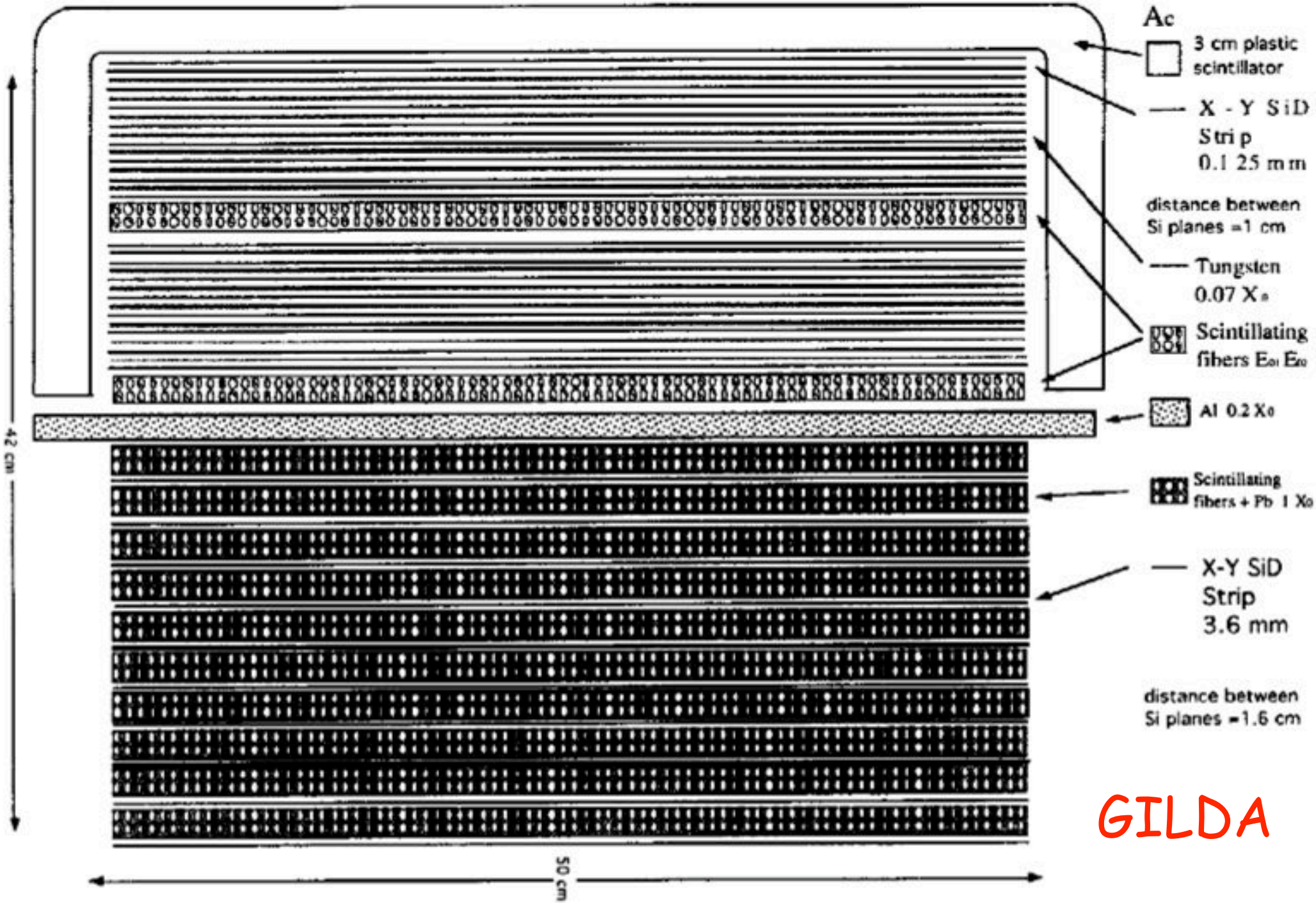
[a] *Dept. of Physics, Univ. of Trieste and INFN, Italy*
[b] *Dept. of Physics, II Univ. of Rome "Tor Vergata" and INFN, Italy*
[c] *Dept. of Physics, Univ. of Firenze and INFN, Italy*
[d] *INFN Laboratori Nazionali di Frascati, Italy*

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 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

So we were ready to respond to the Call for Ideas for Small Missions ASI (Universe Sciences) June 26, 1997 and we responded with two proposals:

- 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 (1μs) 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

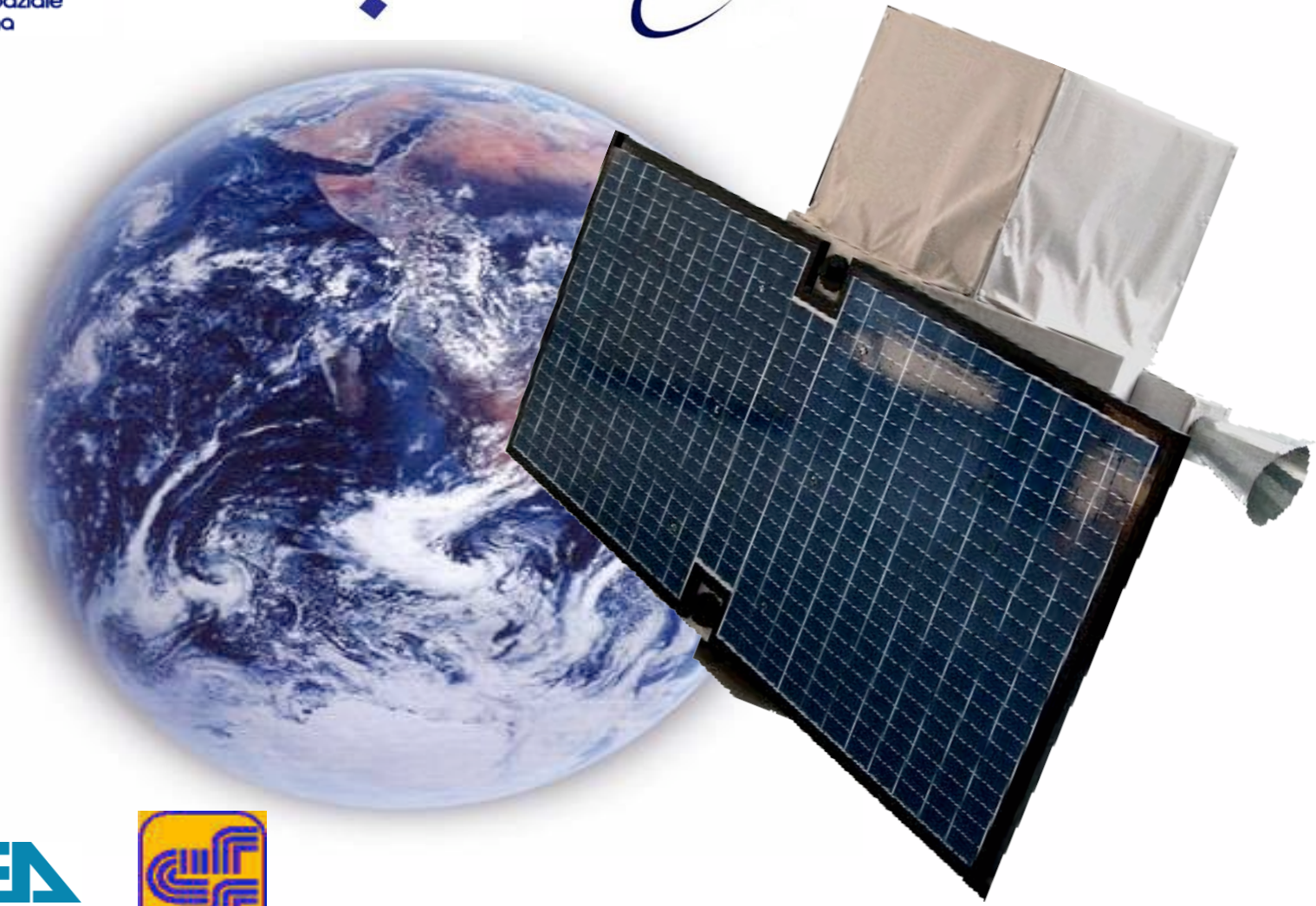
L'astrofisica gamma delle alte energie nella banda 30 MeV–10 GeV beneficierebbe enormemente durante i primi anni del 2000 dall'esistenza di un rivelatore al silicio a largo campo e con sensibilita' e accuratezza confrontabili o migliore di EGRET. Presentiamo qui il concetto di tale missione leggera,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

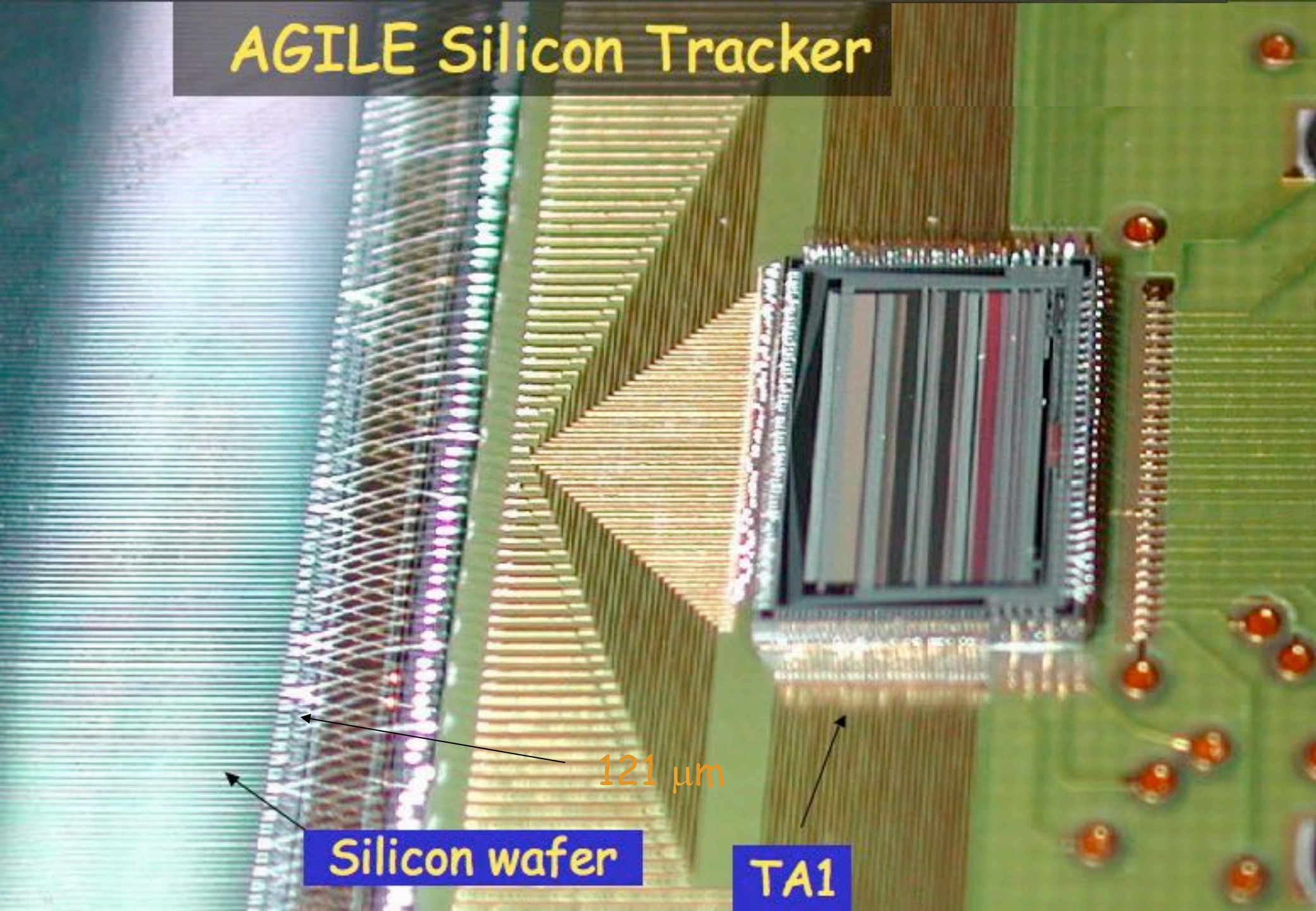
agile

Astro-rivelatore Gamma a Immagini Leggero

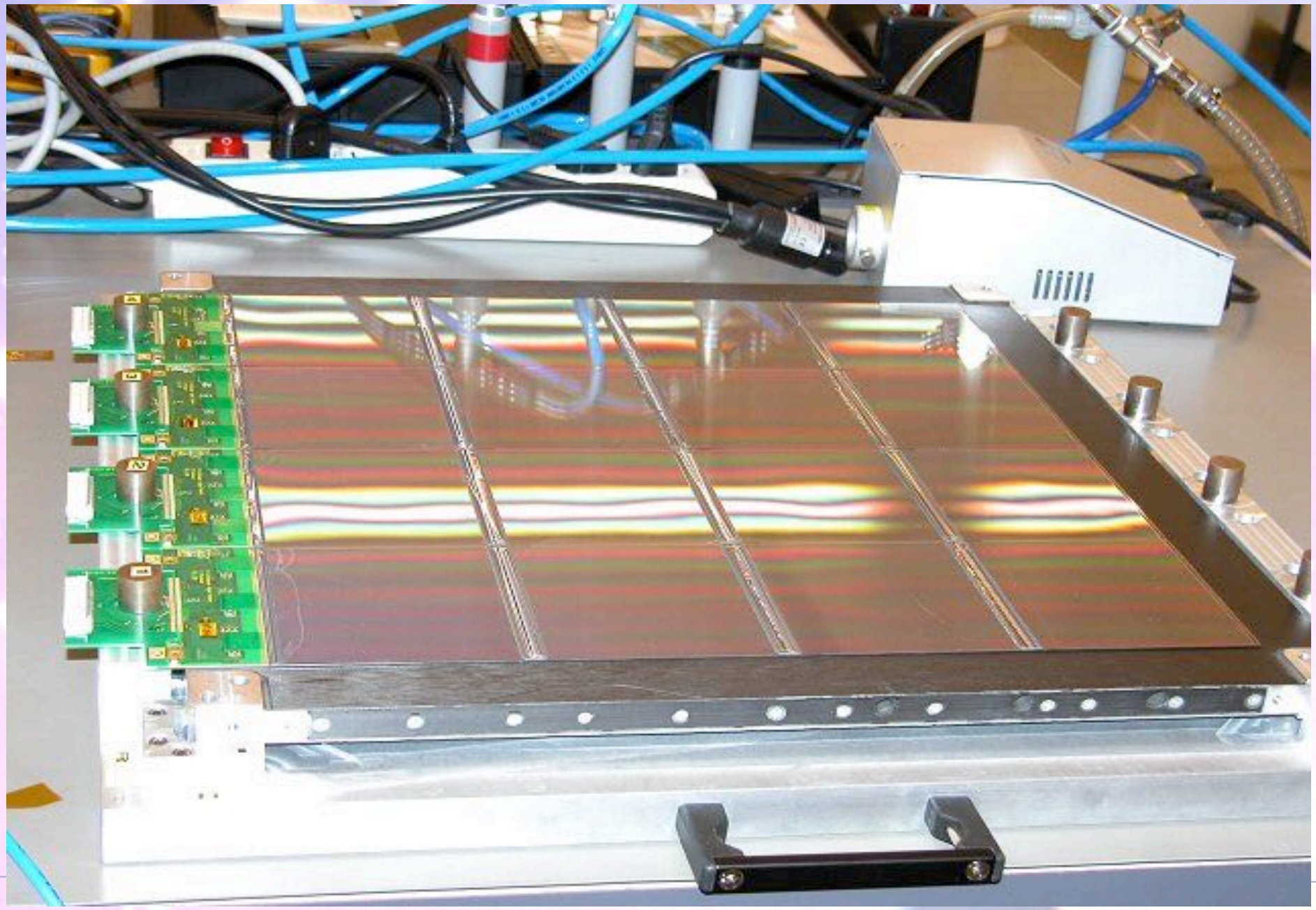
asi agenzia spaziale italiana · INAF · INFN · Alenia · telespazio

THE AGILE MISSION




AGILE Silicon Tracker
121 μm
Silicon wafer
TA1

The Silicon Tracker



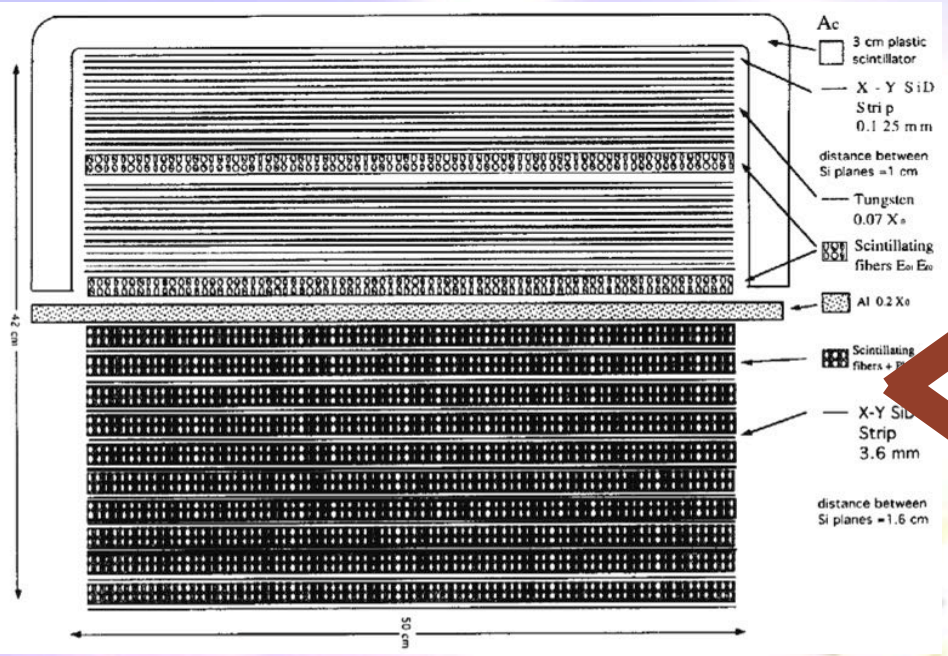
The Silicon Tracker

April 23, 2007: Launch!

Equatorial orbit: 550 Km, < 3° inclination angle

SHAR base (Chennai), India

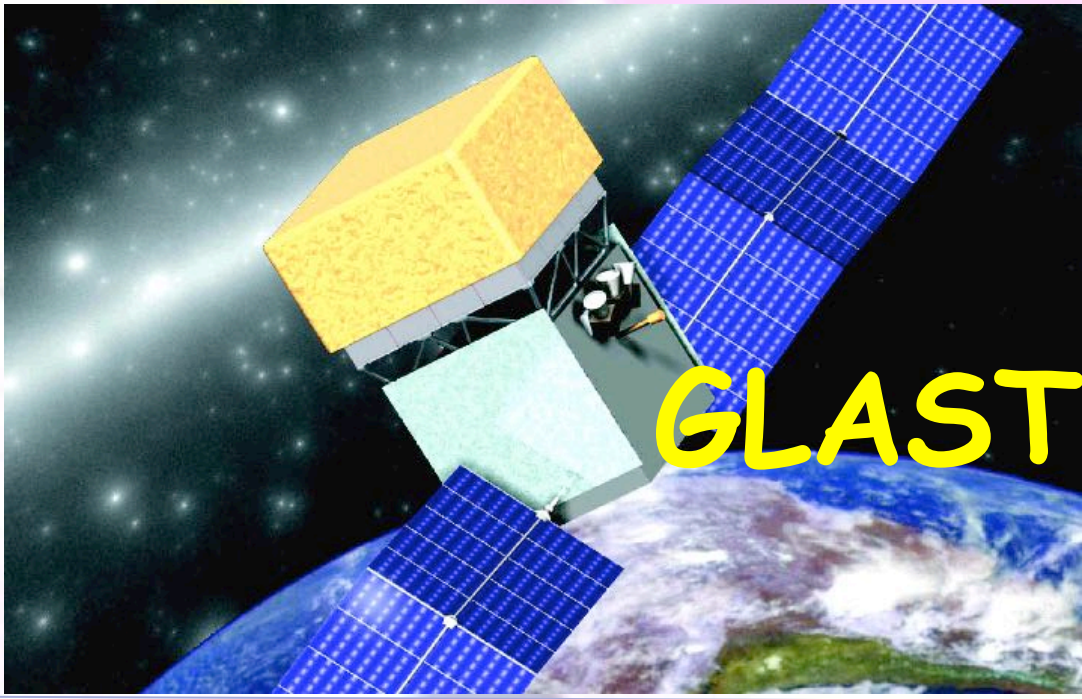
GILDA



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

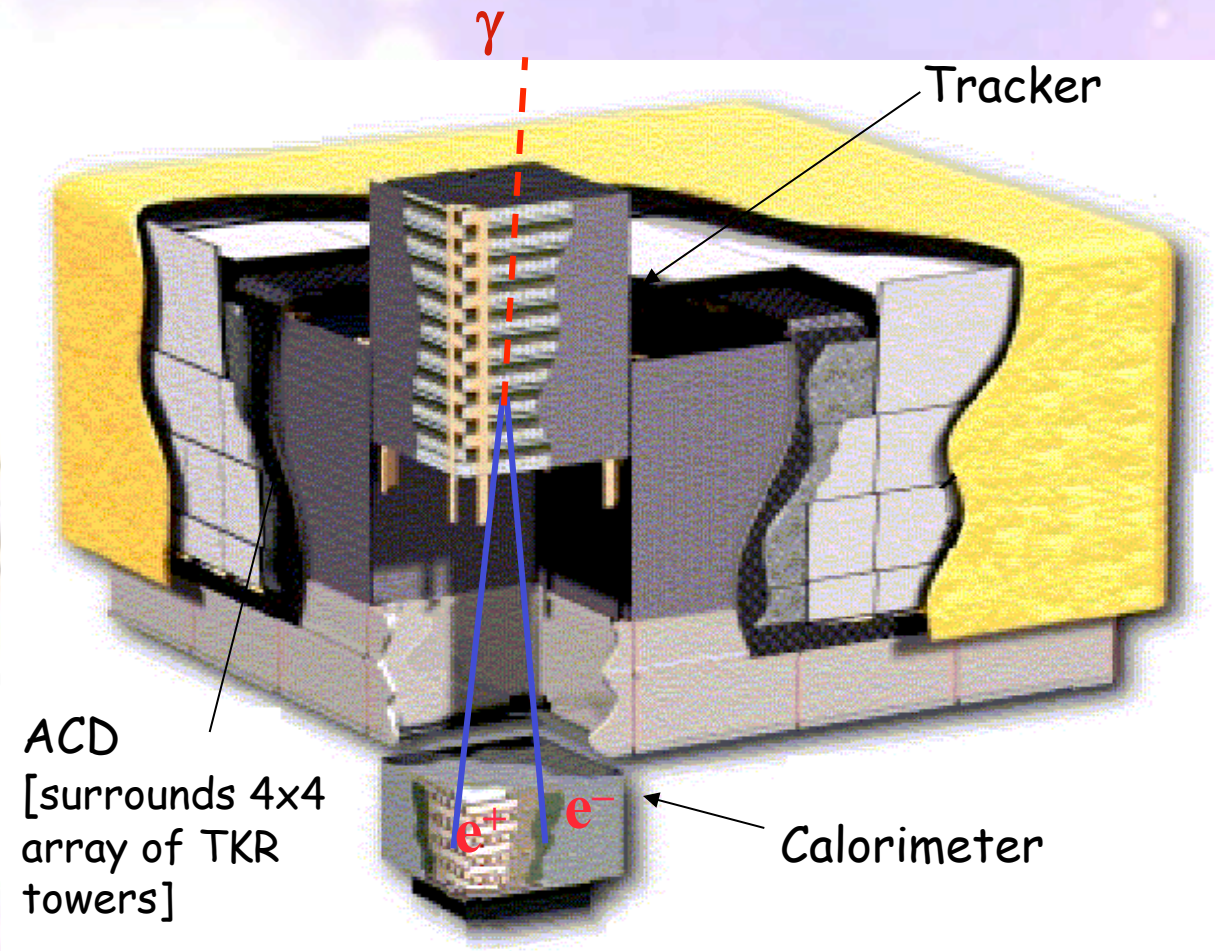



August 98 beam test @ CERN on Silicon tracker prototype


FERMI
Large Area
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

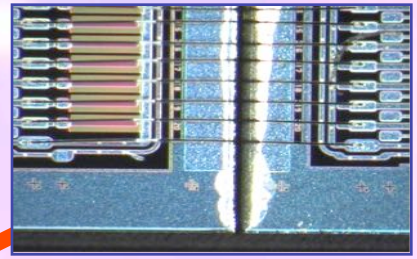
Tracker Production Overview

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

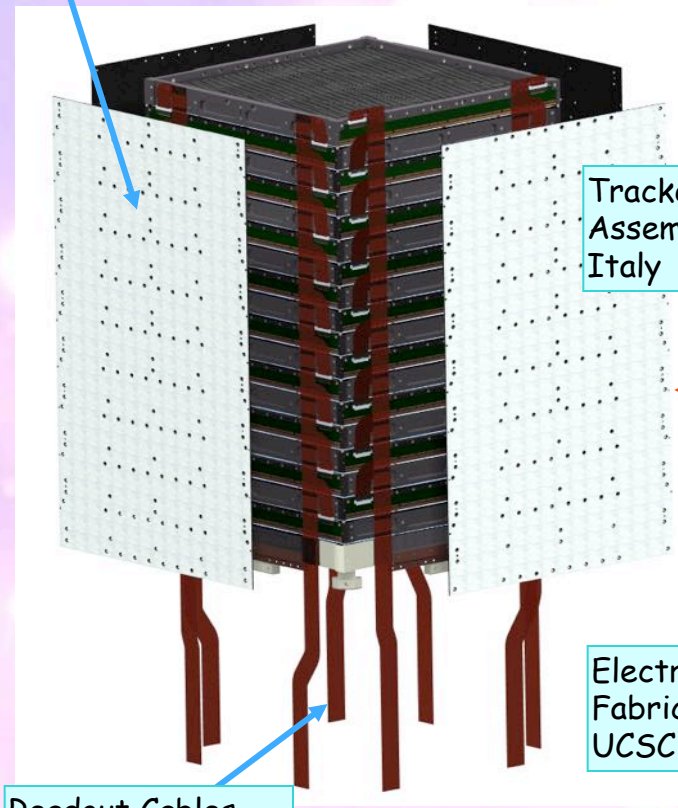
SSD Procurement, Testing
Japan, Italy, SLAC

10,368

SSD Ladder Assembly
Italy (G&A, Mipot)

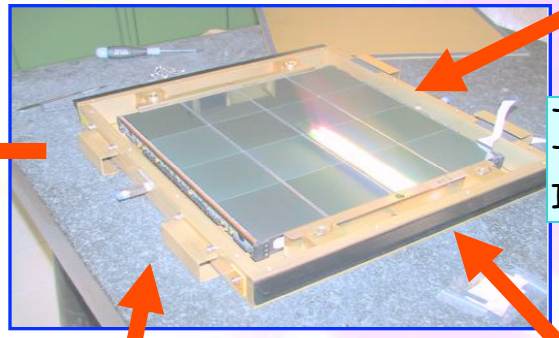


2592



Tracker Module
Assembly and Test
Italy

18

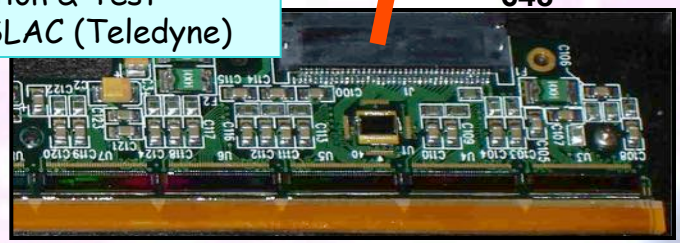


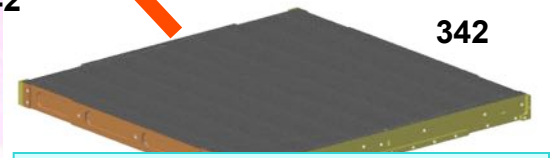
342

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

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

648



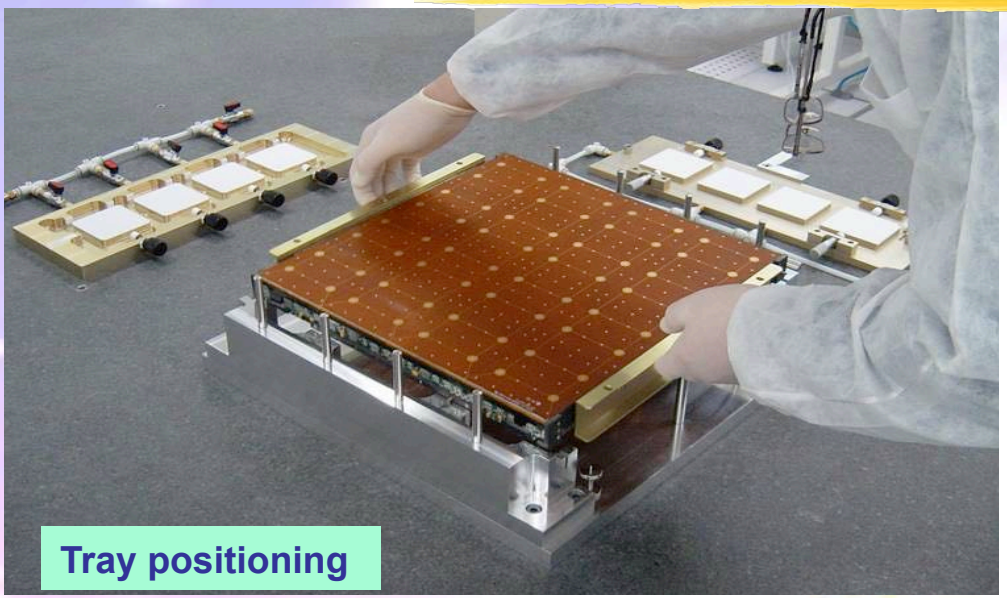


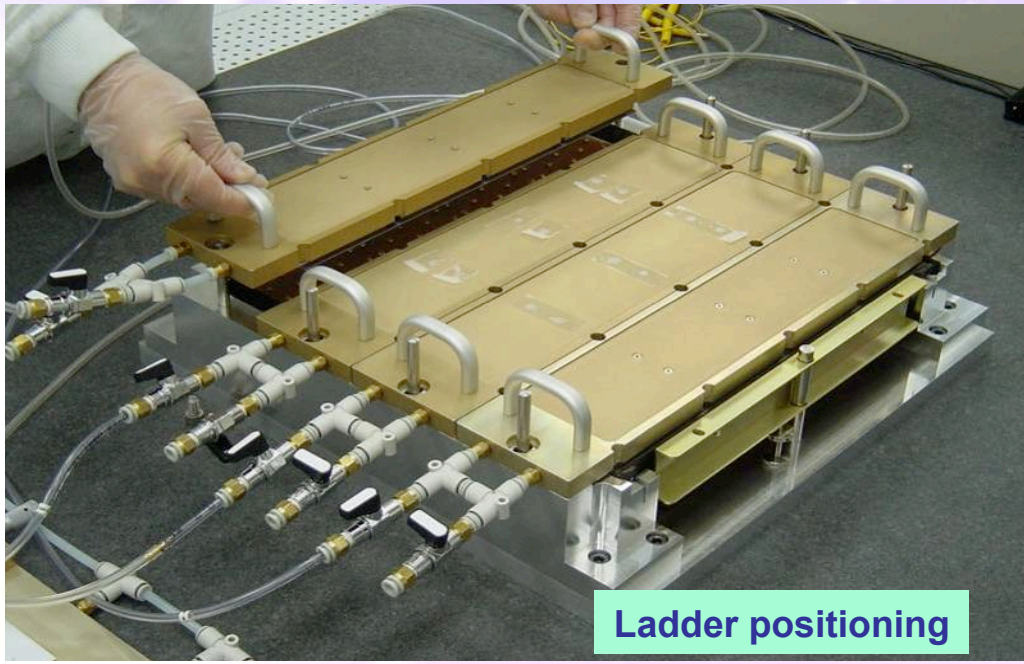
342

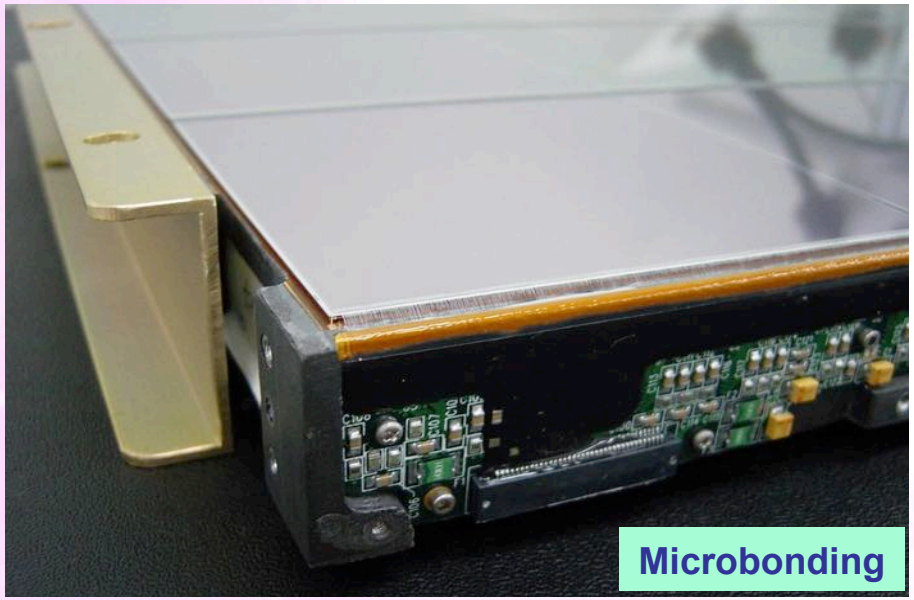
Composite Panel & Converters
Engineering:
SLAC, Italy (Hytec, COI)
Procurement: Italy (Plyform)

Readout Cables
UCSC, SLAC

Tray assembly in G&A

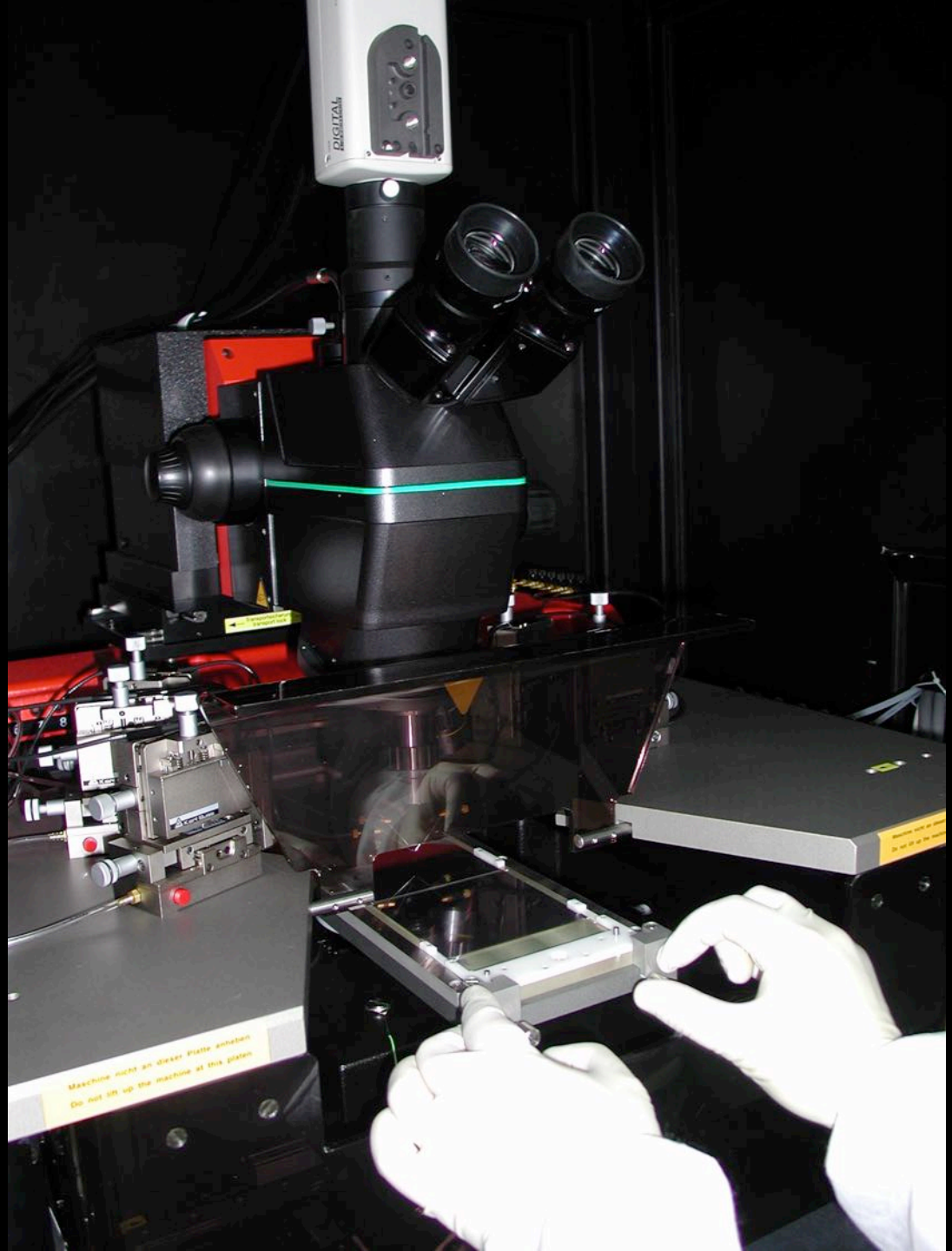


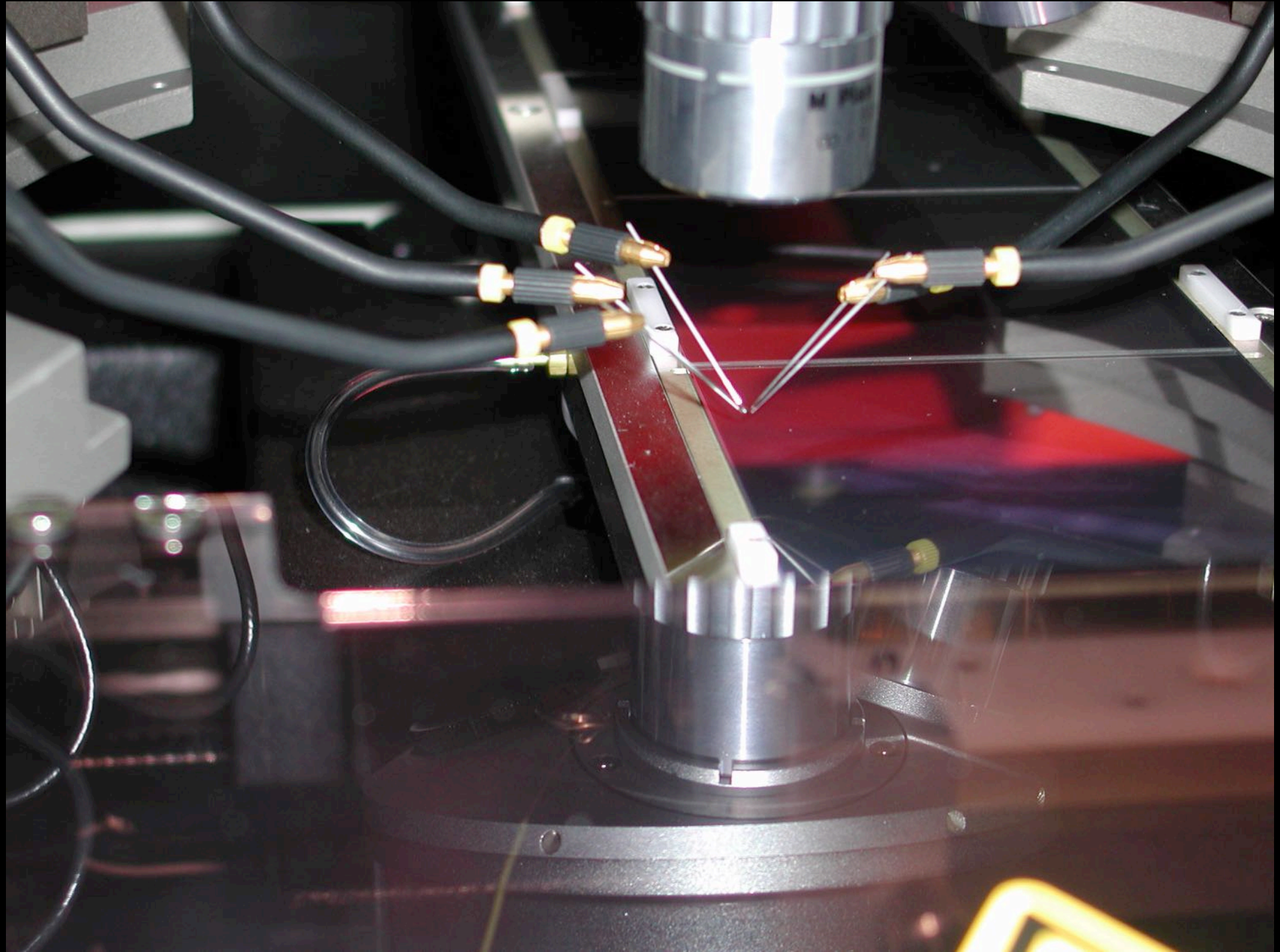


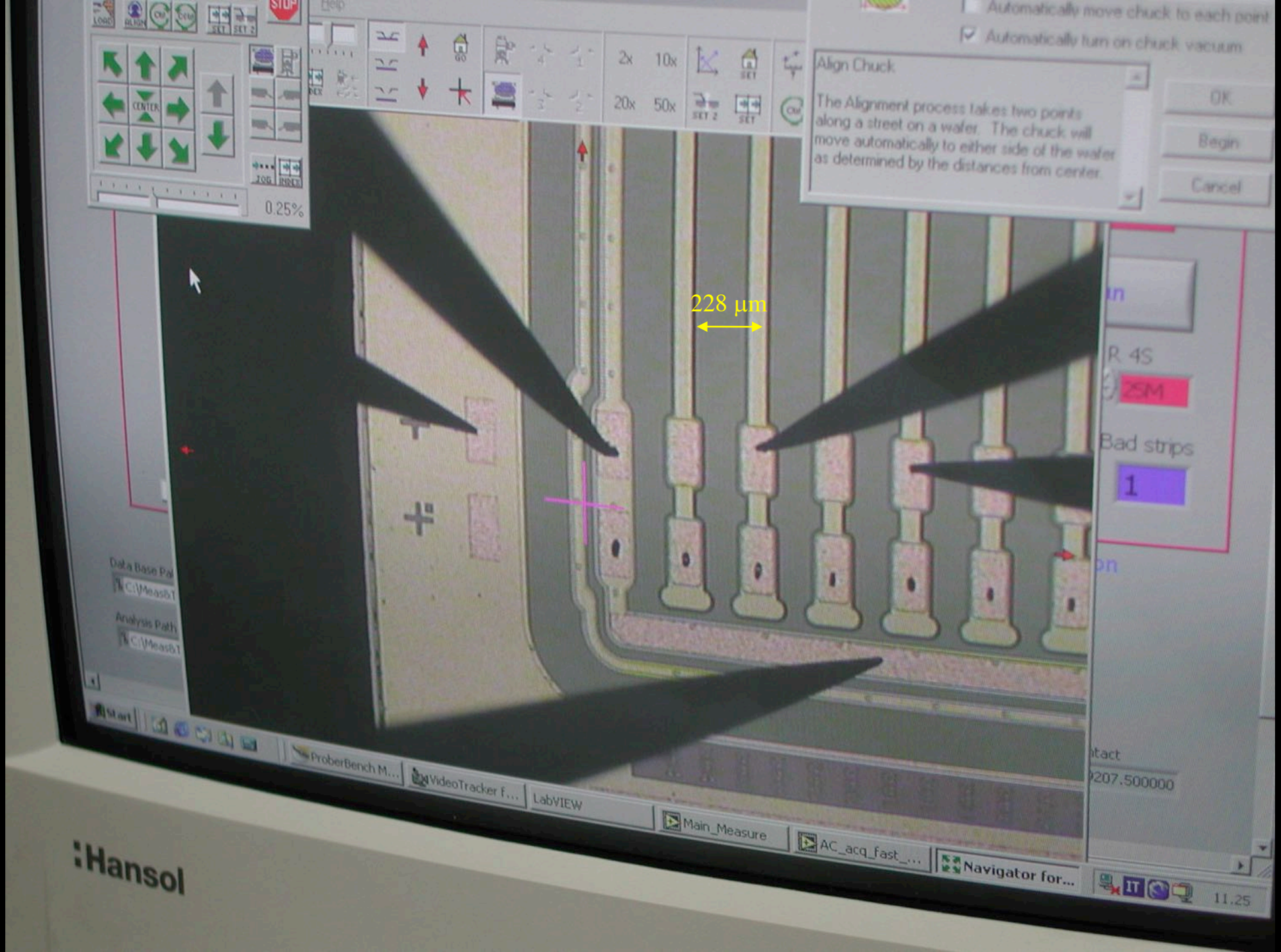


- 160 bare panels produced
- 100 tested and qualified for integration with ladders
- completed trays for 3.3 towers
- 6 assembly chain ready
- Max assembly rate : 3 trays/day/shift

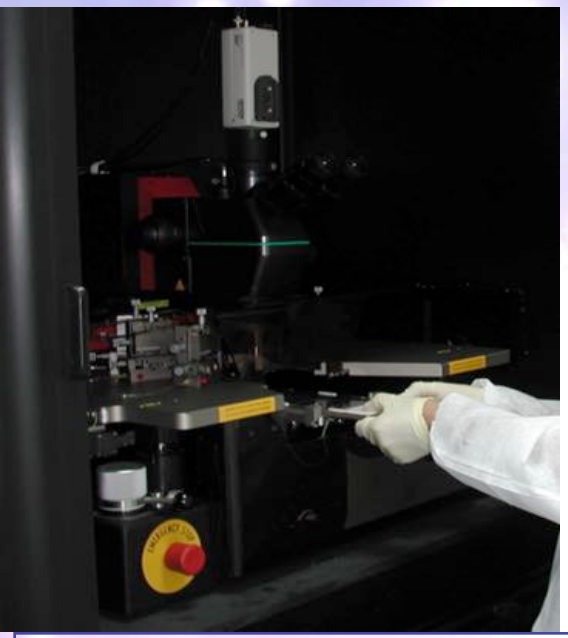

EMERGENCY STOP


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

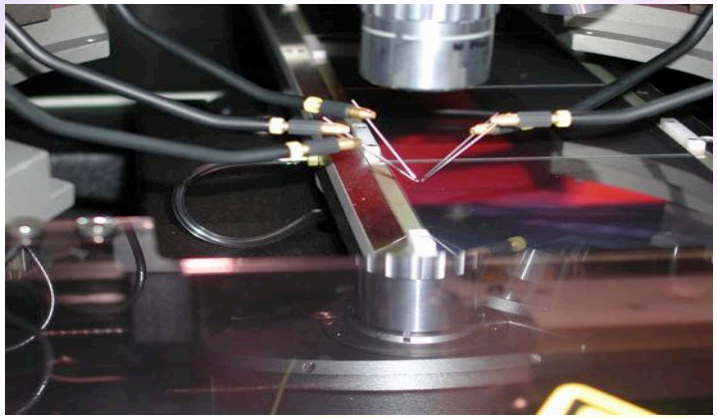


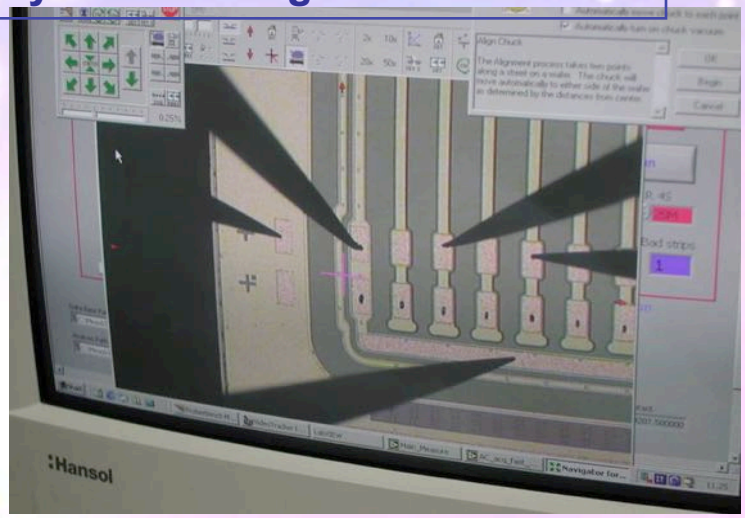

228 µm
Align Chuck
The Alignment process takes two points along a street on a wafer. The chuck will move automatically to either side of the wafer as determined by the distances from center.
OK
Begin
Cancel
Automatically move chuck to each point
Automatically turn on chuck vacuum
Bad strips
1
Hansol

Ladders testing



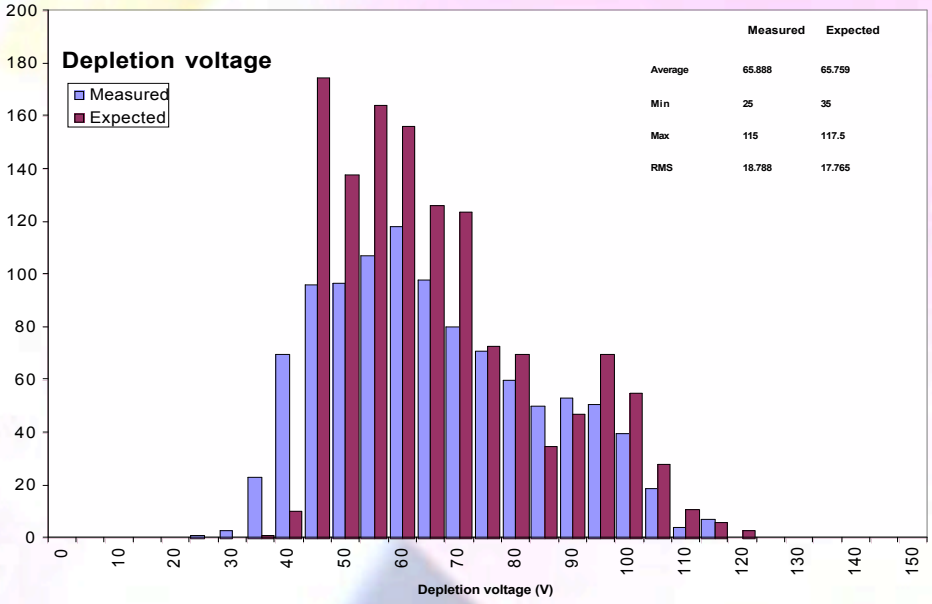
Ladders probe station: 5 probes are used to measure body and single strip I, C to check sanity of each single channel





Flight ladders production status:

- Completed and tested (INFN BA/RM2/PG) 1900
- Under construction 800
- rejected ~ 1%
- 0.016% bad chans caused by bonding or probing
- 2μm RMS alignment spread
- All results in good agreement with what expected from SSDs



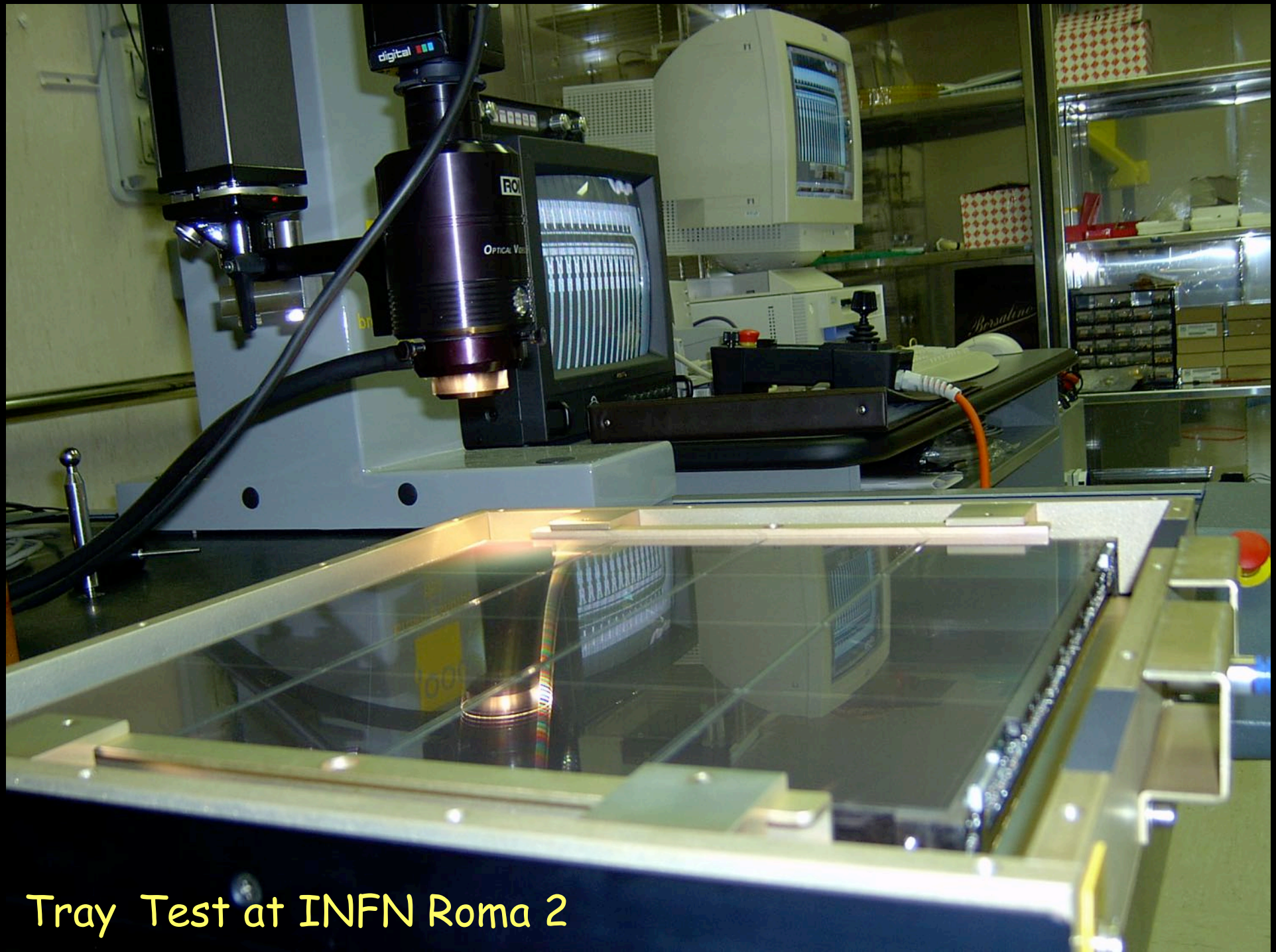
Tray Test at INFN Roma 2


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

Tray Test at INFN Roma 2

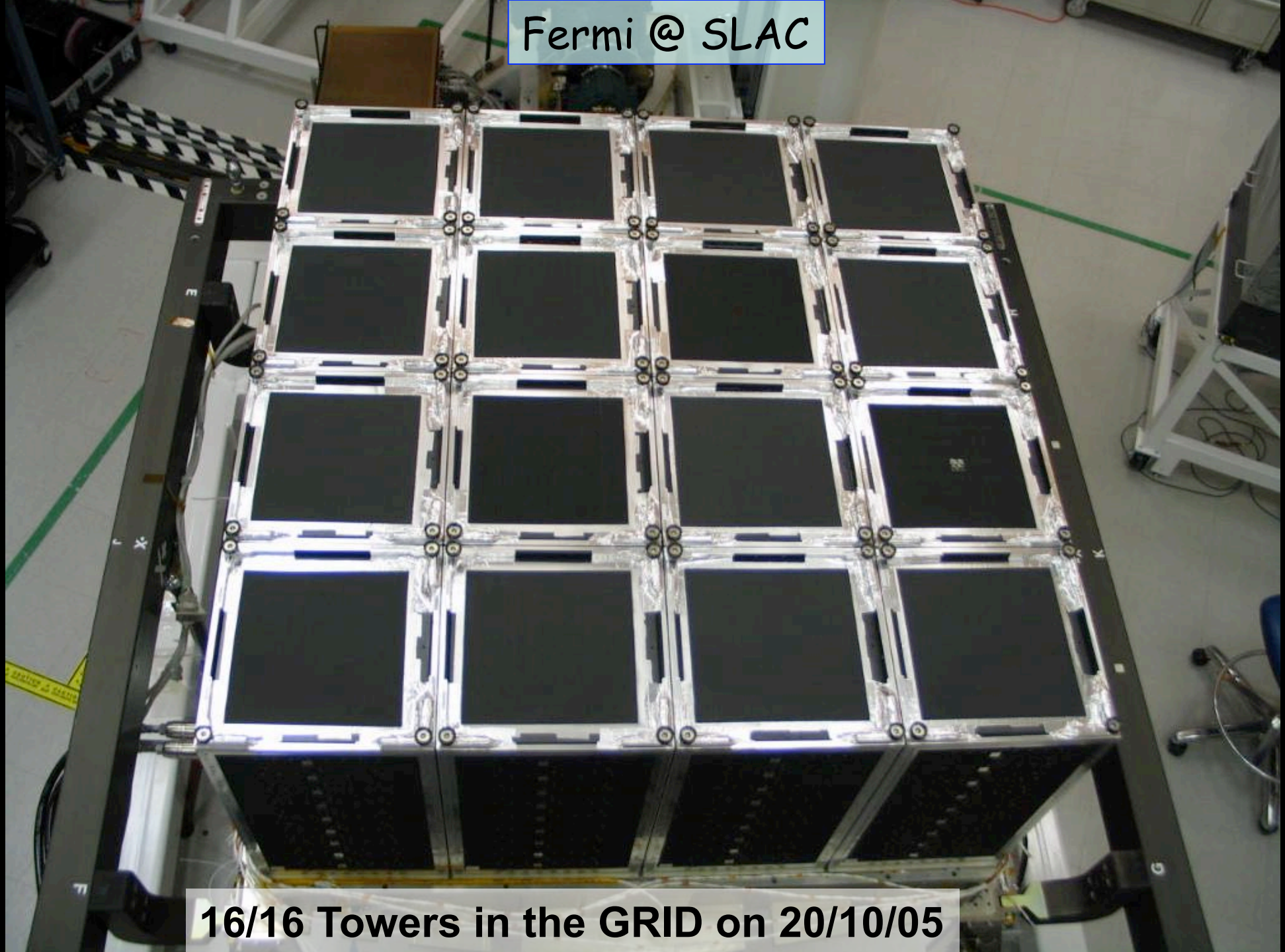
Tray Test at
INFN Roma 2

Tray Test at INFN Roma 2

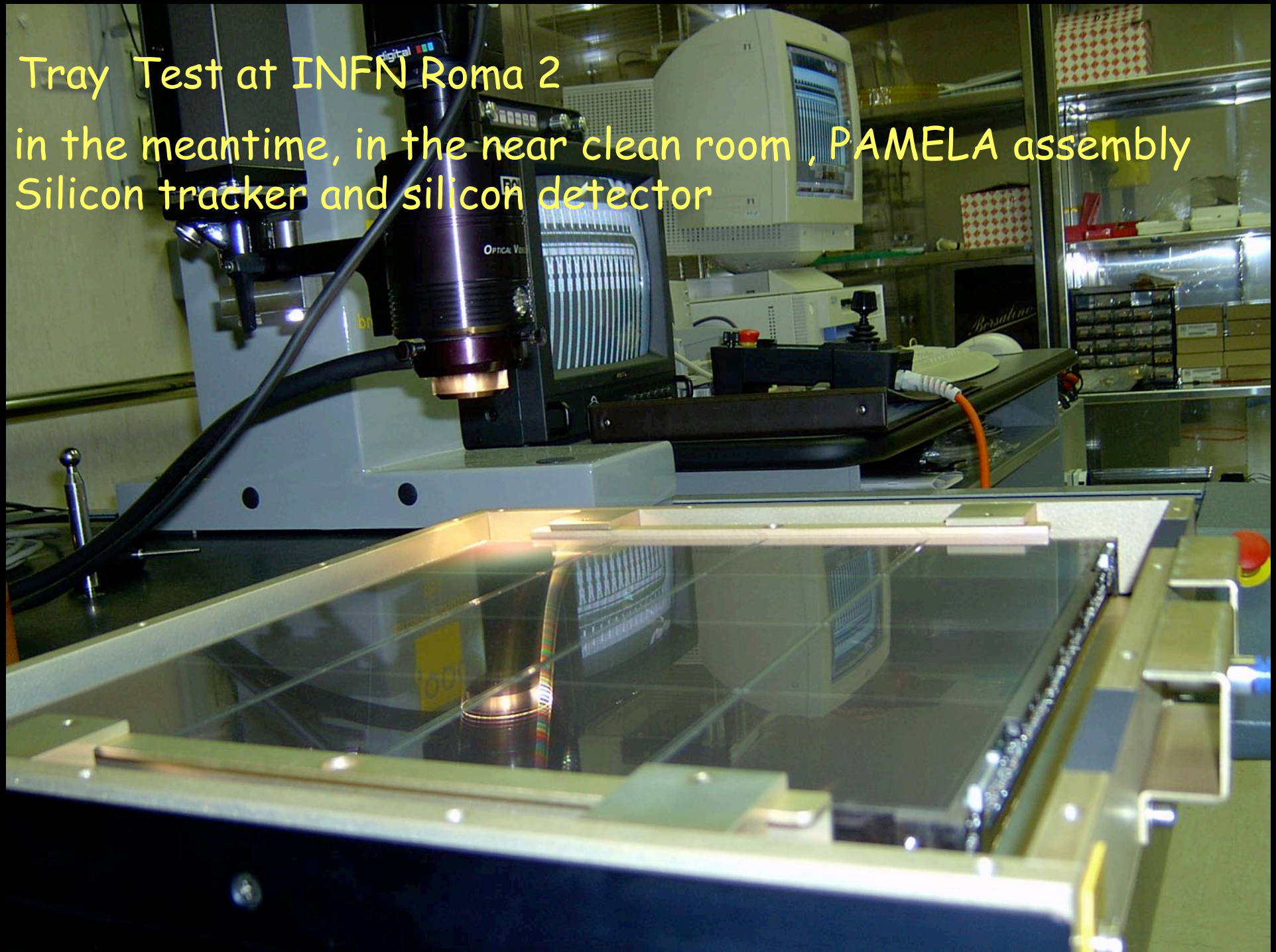


Tray Test at INFN Roma 2


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

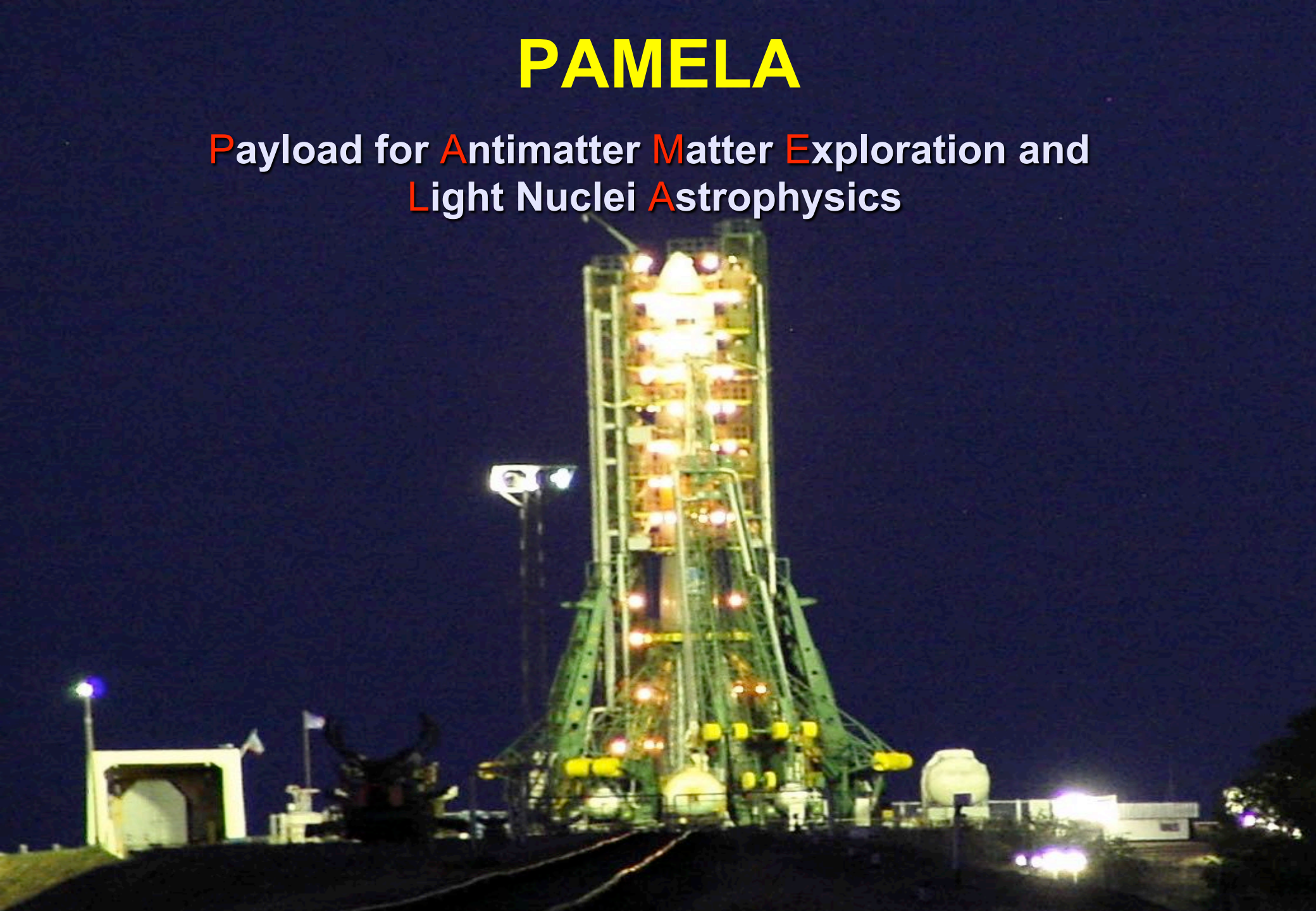

Fermi @ SLAC
16/16 Towers in the GRID on 20/10/05


Fermi
Gamma-ray
Space Telescope
Happy 8th Birthday Fermi !!
11 June 2008


Tray Test at INFN Roma 2
in the meantime, in the near clean room , PAMELA assembly
Silicon tracker and silicon detector

PAMELA

Payload for Antimatter Matter Exploration and Light Nuclei Astrophysics



long list of attempts before Pamela

- Wizard on Astromag

C.De Marzo, R.Bellotti, F.Cafagna, M.Calicchio, O.Erriquez, N.Giglietto, B. Marangelli, E.Spinelli, P.Spillantini, M.Bocciolini, M.Meschini, A.Perego, G.Basini, E.Bonaviri, F.Bongiorno, M.Occhigrossi, M.Ricci, A.Codino, C.Federico, C.Grimani, M.Menichelli, E.Rongoni, I.Salvatori, D.Prosperi, M.De Sanctis, A.Incicchitti, P.Picozza, M.P.De Pascale, A.Morselli, P.Galeotti, G.Barbiellini, L.Lanceri, P.Poropat, P.Schiavon, A.Vacchi, S.P.Ahlen, J.J.Beatty, H.J.Crawford, P.J.Lindstrom, J.F.Ormes, R.E.Streitmatter, C.R.Bower, R.M.Heinz, S.Mufson, T.G.Guzik, J.P.Wefel, A.Stephens, J.H.Adams, K.E.Krombel, A.J Tylka, M.Simon, K.D.Martin, R.Golden

Proposal of the Wizard experiment presented to the Italian Space Agency, June 1989
Il Nuovo Cimento 103B, 625-634, (1989)

- WiZard-Sat

R.Bellotti, G.De Cataldo, C.De Marzo, N.Giglietto, B.Marangelli,P.Spinelli,M.Bocciolini, E.Pace, P.Papini, A.Perego, P.Spillantini, A.Codino, C.Grimani, M.Menichelli, I.Salvatori, M.Candusso, M.P.De Pascale, A.Morselli, P.Picozza, G.Basini,F.Bongiorno, M.Ricci, R.Bertoni, M.Dardo, P.Galeotti, P.L.Ghi, F.Aversa, G.Barbiellini, M.Boezio, G.Cantatore, A.Colavita, P.Schiavon, A.Vacchi, S.Venkataraman

Proposal for a satellite experiment to observe antimatter, gamma-rays and other topics in cosmic rays, June 1993

.....

The earliest evidence

24th International Cosmic Rays Conference (Rome), 1995, v. 3, p.591

$e^{\pm}/p^{\pm}$ separation and some li
PAMELA experiment will be
on board of the Earth-Observa
at the end of 1988.

The Magnetic Spectrometer PAMELA for the Study of Cosmic Antimatter in Space

O. Adriani[1], B. Alpat[2], G. Barbiellini[3], L.M. Barbier[4], S. Bartalucci[5], R. Bellotti[6], G. Basini[5], M. Bocciolini[1], M. Boezio[3], F.M. Brancaccio[1], U. Bravar[3], F. Cafagna[6], M. Candusso[7], R. Cardarelli[7], P. Carlson[8], M. Casolino[7], M. Castellano[6], G. Castellini[1], M. Circella[6], E.R. Christian[4], A.J. Davis[9], G. De Cataldo[6], C.N. De Marzo[6], M.P. De Pascale[7], E. Fiandrini[2], N. Finetti[2], T. Francke[8], C. Fuglesang[8], A.M. Galper[10], F. Giannini[7], N. Giglietto[6], R.L. Golden[11], M. Hof[12], S.V. Koldashov[10], M.G. Korotkov[10], J. Krizmanic[4], M.L. Lamorte[5], M. Lanfranchi[2], P. La Riccia[2], B. Marangelli[6], L. Marino[5], R.A. Mewaldt[9], V.V. Mikhailov[10], J.W. Mitchell[4], A.A. Moiseev[10], A. Morselli[7], J.F. Ormes[4], J.V. Ozerov[10], P. Papini[1], A. Perego[1], S. Piccardi[1], P. Picozza[7], M. Ricci[5], P. Schiavon[3], S.M. Schindler[9], M. Simon[12], R. Sparvoli[7], P. Spillantini[1], P. Spinelli[6], S.J. Stochaj[11], R.E. Streitmatter[4], O. Toker[2], A. Vacchi[3], V. Vignoli[1], S.A. Voronov[10], N. Weber[8], N. Zampa[3]

[1] *Università and INFN, Firenze, Italy.* [2] *Università and INFN, Perugia, Italy.* [3] *Università and INFN, Trieste, Italy.* [4] *NASA Goddard Space Flight Center, Greenbelt, USA.* [5] *Laboratori Nazionali INFN, Frascati, Italy.* [6] *Università and INFN, Bari, Italy.* [7] *II Università and INFN, Roma, Italy.* [8] *Royal Institute of Technology, Stockholm, Sweden.* [10] *Moscow Engineering and Physics Institute, Moscow, Russia.* [11] *Particle Astrophysics Lab, New Mexico State University, Las Cruces, USA.* [12] *Universität Siegen, Fachbereich Physik, Siegen, Germany.*

Abstract

In the framework of the Russian Italian Mission (RIM) program, PAMELA is the experiment devoted to the accurate measurement of the positron and antiproton spectra from the very low energy threshold of 100 MeV up to more than 50 GeV, and to hunt antinuclei with sensitivity better than 10^{-7} in the antihelium/helium ratio. A permanent magnet equipped by microstrip silicon sensors, measures the particle momentum with MDR=400 GV/c on GF=25 cm^2 sr. An accurate ToF system, a 19 X_0 deep imaging calorimeter, an aerogel Cherenkov counter and a TRD detector complement the spectrometer in order an efficient $e^{\pm}/p^{\pm}$ separation and some light isotope identification capability. The PAMELA experiment will be carried out on a 700 km high polar orbit, on board of the Earth-Observation Meteor-3A satellite, to be launched at the end of 1988.

References

[1] "Objectives and feasibility of the Russian-Italian Mission program in Astroparticle Physics", November 1993.

PAMELA

Payload for **A**ntimatter **M**atter **E**xploration and **L**ight Nuclei **A**strophysics

In orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour launch site.

First switch-on on June 21 2006

From July 11 Pamela is in continuous data taking mode

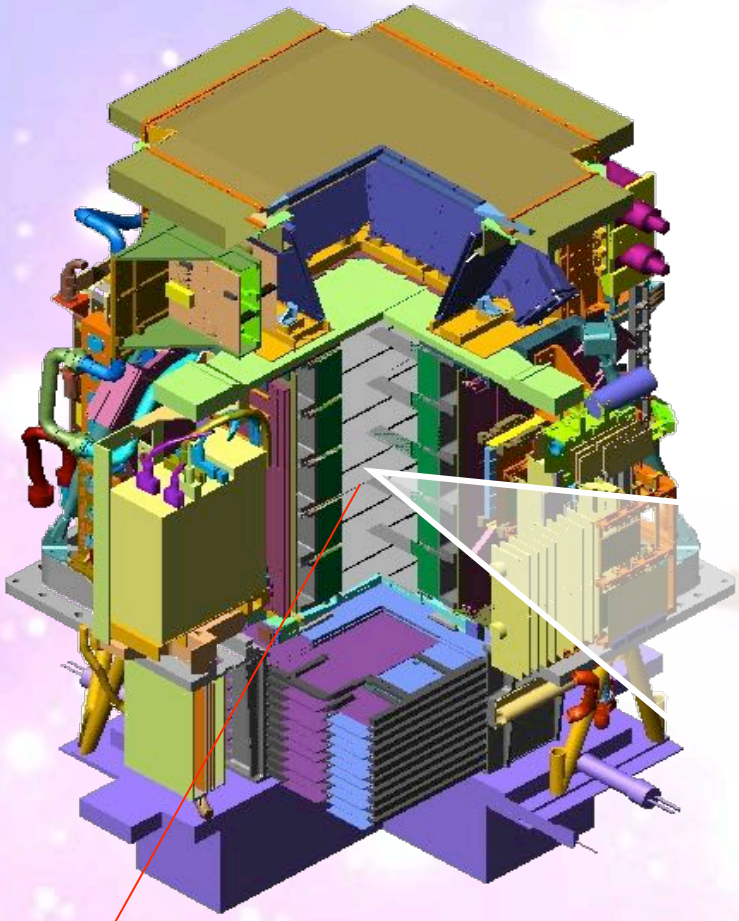
PAMELA Instrument

GF ~21.5 cm^2sr

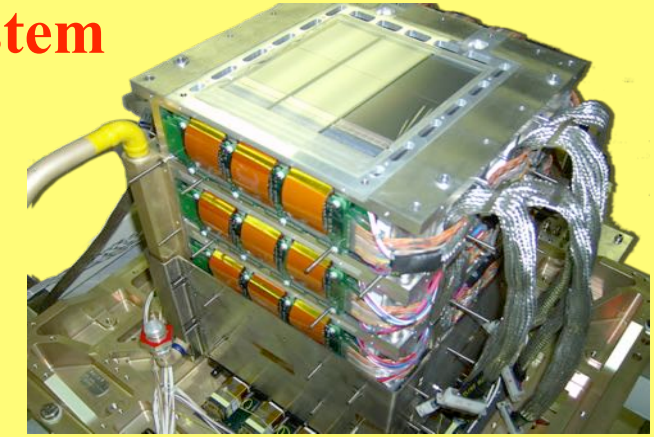
Mass: 470 kg

Size: 130x70x70 cm^3

PAMELA



The tracking system



Main tasks:

- Rigidity measurement
- Sign of electric charge
- dE/dx

Characteristics:

- **6 planes double-side (x&y view) microstrip Si sensors**
- 36864 channels
- Dynamic range 10 MIP

Performances:

- Spatial resolution: **3÷4 μm**
- **MDR ~1.2TV** (from flight data)

Nuclear Instruments and Methods in Physics Research A 333 (1993) 560–566
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

A silicon imaging calorimeter prototype for antimatter search in space: experimental results

M. Bocciolini, F. Celletti, A. Perego and P. Spillantini
Dipartimento di Fisica dell'Università di Firenze and Sezione INFN di Firenze, Firenze, Italy

G. Basini, F. Bongiorno [1], F. Massimo Brancaccio and M. Ricci
Laboratori Nazionali di Frascati dell'INFN, Frascati, Italy

M.T. Brunetti, A. Codino, M. Menichelli, M. Miozza and I. Salvatori
Dipartimento di Fisica dell'Università di Perugia and Sezione INFN di Perugia, Perugia, Italy

V. Bidoli, M. Candusso, C. De Fabritiis, M.P. De Pascale, A. Morselli and P. Picozza
Dipartimento di Fisica dell'Università "Tor Vergata", Roma and Sezione INFN di Roma II, Roma, Italy

A. Buccheri, A. Incicchitti and D. Prosperi
Dipartimento di Fisica dell'Università "La Sapienza", Roma and Sezione INFN di Roma, Roma, Italy

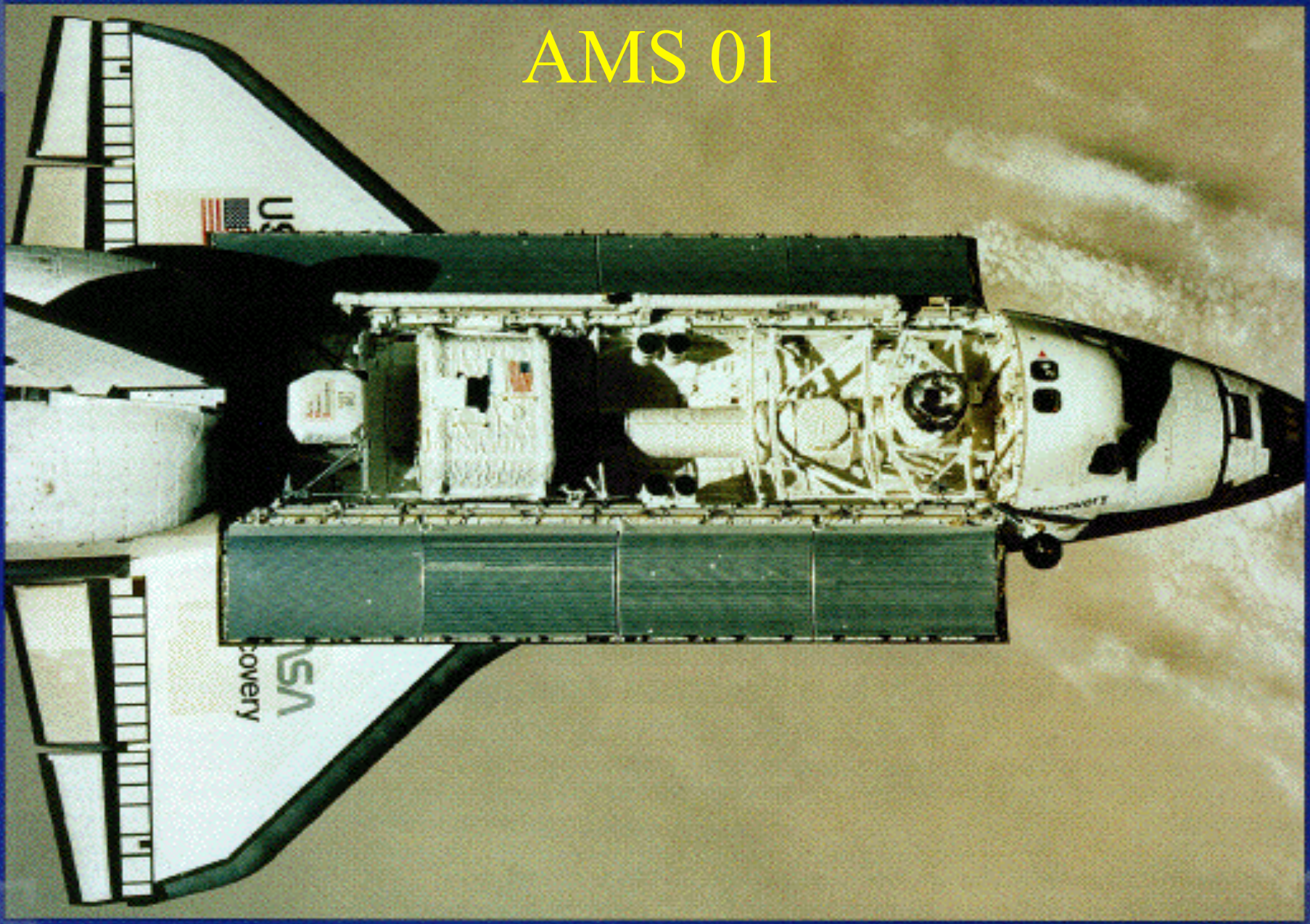
G. Barbiellini, M. Boezio, F. Fratnik, P. Schiavon, A. Vacchi and N. Zampa
Dipartimento di Fisica dell'Università di Trieste and Sezione INFN di Trieste, Trieste, Italy

Received 3 August 1992 and in revised form 19 January 1993

Selected Elements of AMS History

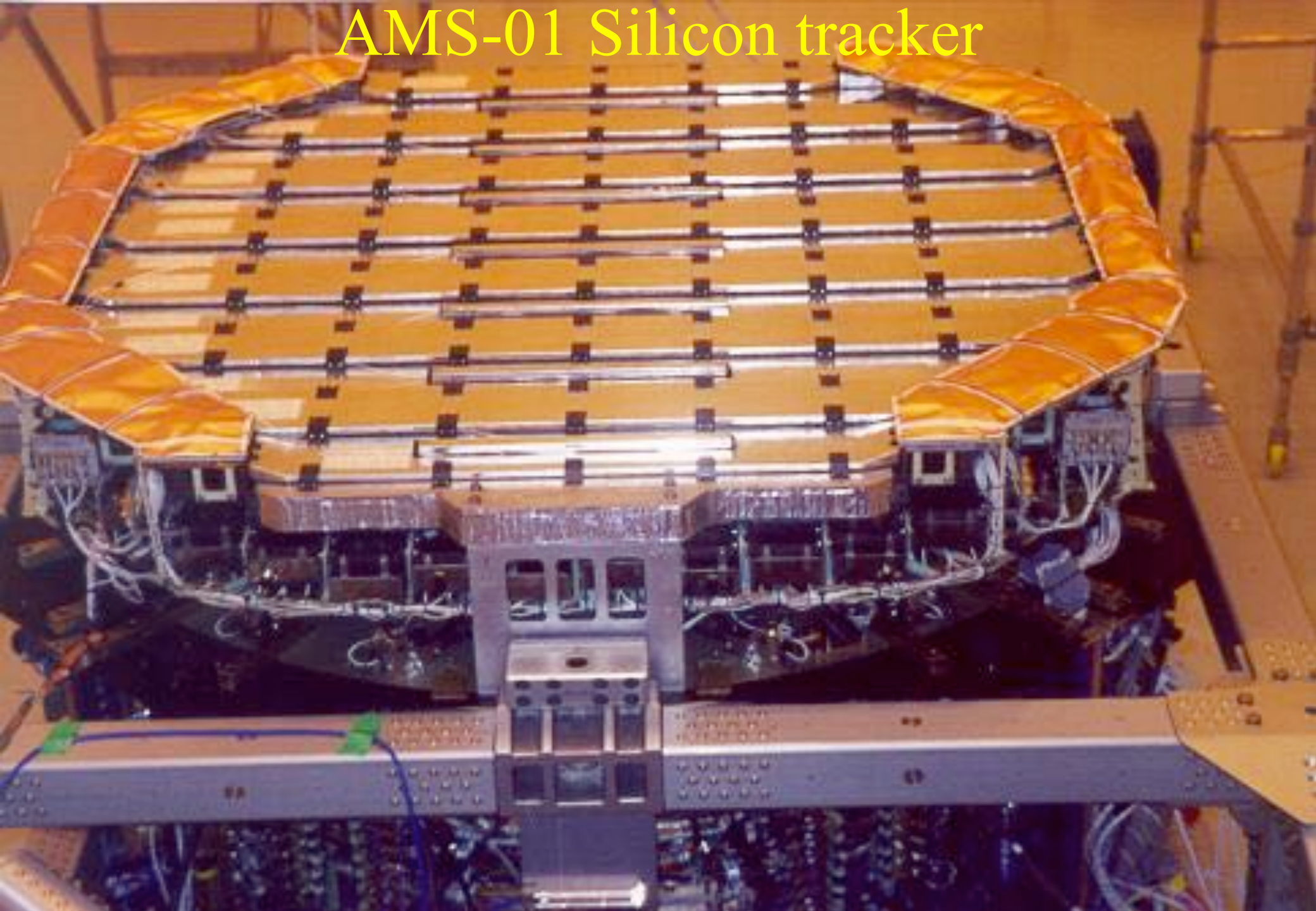
- 1994:
  - AMS concept development begins
  - Prof. Ting visits the NASA Administrator, (Dan Golden) to explore NASA interest in AMS
  - AMS first proposed to DOE
- April 1995: first DOE-AMS Committee Review ("Blue Ribbon Panel")
- 1997: AMS becomes a "recognized experiment" at CERN
- June 1998: AMS-01 "engineering test" Space Shuttle flight
- March 1999: second DOE-AMS Committee Review
- September 2006: third DOE-AMS Committee Review
- January 2010: NASA-DOE Implementing Arrangement signed: NASA delivers payload, provides ISS services; DOE responsible U.S. science effort.
- **May 2011**: AMS-02 arrives at ISS, is installed, taking data within 5 hours
- September 2013: fourth and most recent DOE-AMS Committee Review
  - Chair report endorses continued operation onboard the ISS at least to 2020, at which point statistical errors will be have been halved.

AMS 01

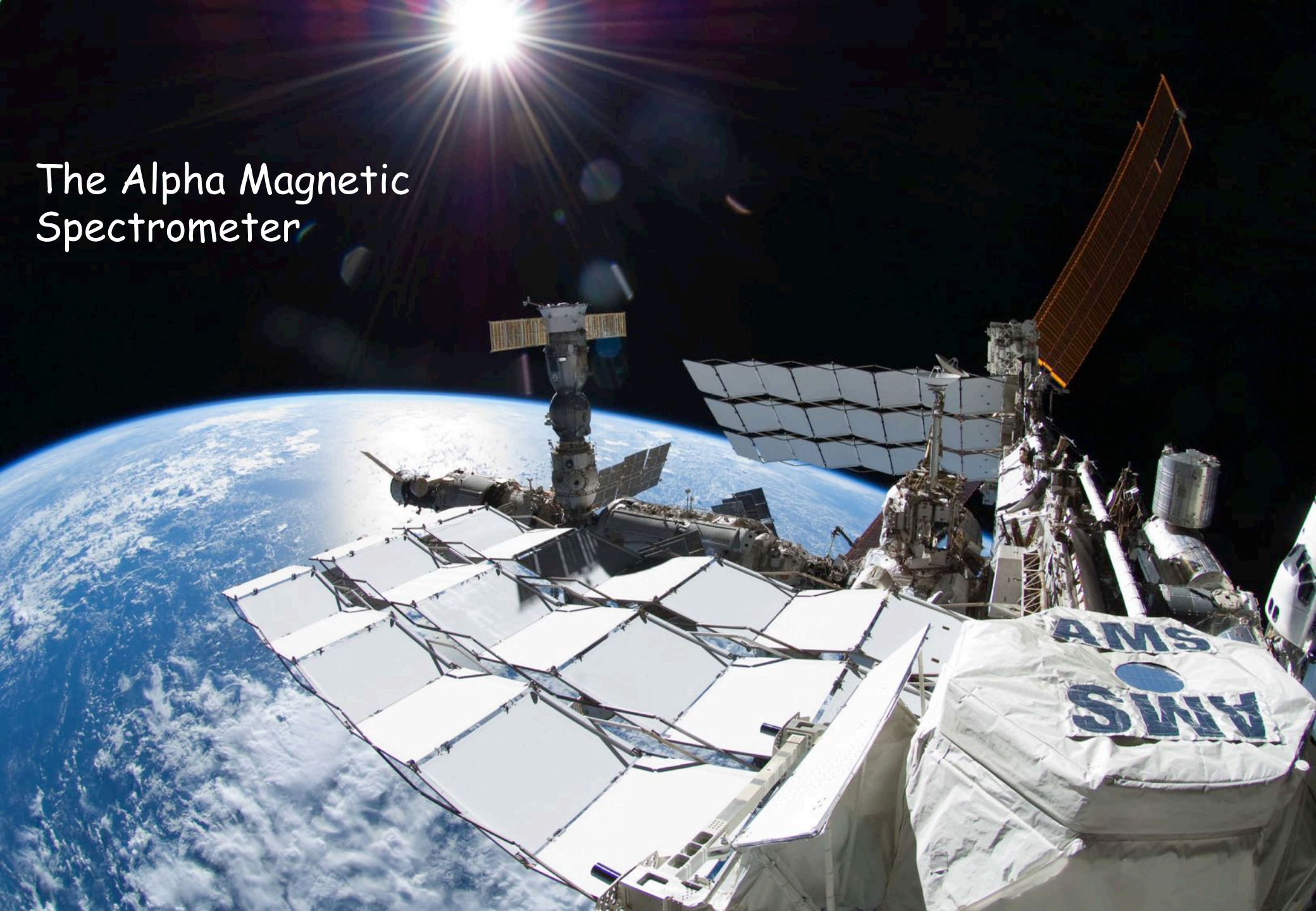


Particle physics detector in space

AMS-01 Silicon tracker



The Alpha Magnetic Spectrometer



New gamma projects in space

- e-AstroGam 300 KeV- GeV (Proposal to ESA for M5)
- Gamma-light (Proposed to ESA but not approved)

http://agenda.infn.it/getFile.py/access?contribId=67&resId=0&materialId=slides&confId=4267

- Gamma-400 launch foreseen by 2020

100 MeV – 3 TeV, an approved Russian γ-ray satellite. Energy resolution (100 GeV) ~ 1 %. Effective area ~ 0.4 m^2. Angular resolution (100 GeV) ~ 0.01°.

Science with Gamma-400 Workshop http://cdsagenda5.ictp.it/full_display.php?ida=a1311

- DAMPE: An approved Chinese γ-ray satellite with italian contribution. Launched 17/12/2015.

- HERD: Instrument on the planned Chinese Space Station.

Energy resolution (100 GeV) ~ 1 %. Effective area ~ 1 - 2 m2. Angular resolution (100 GeV) ~ 0.01°. Planned launch around 2020.

All new project include silicon detectors

MG 1997

Many Thanks

Guido!

Aquila School
2001