Direct CR measurements & Indirect DM searches

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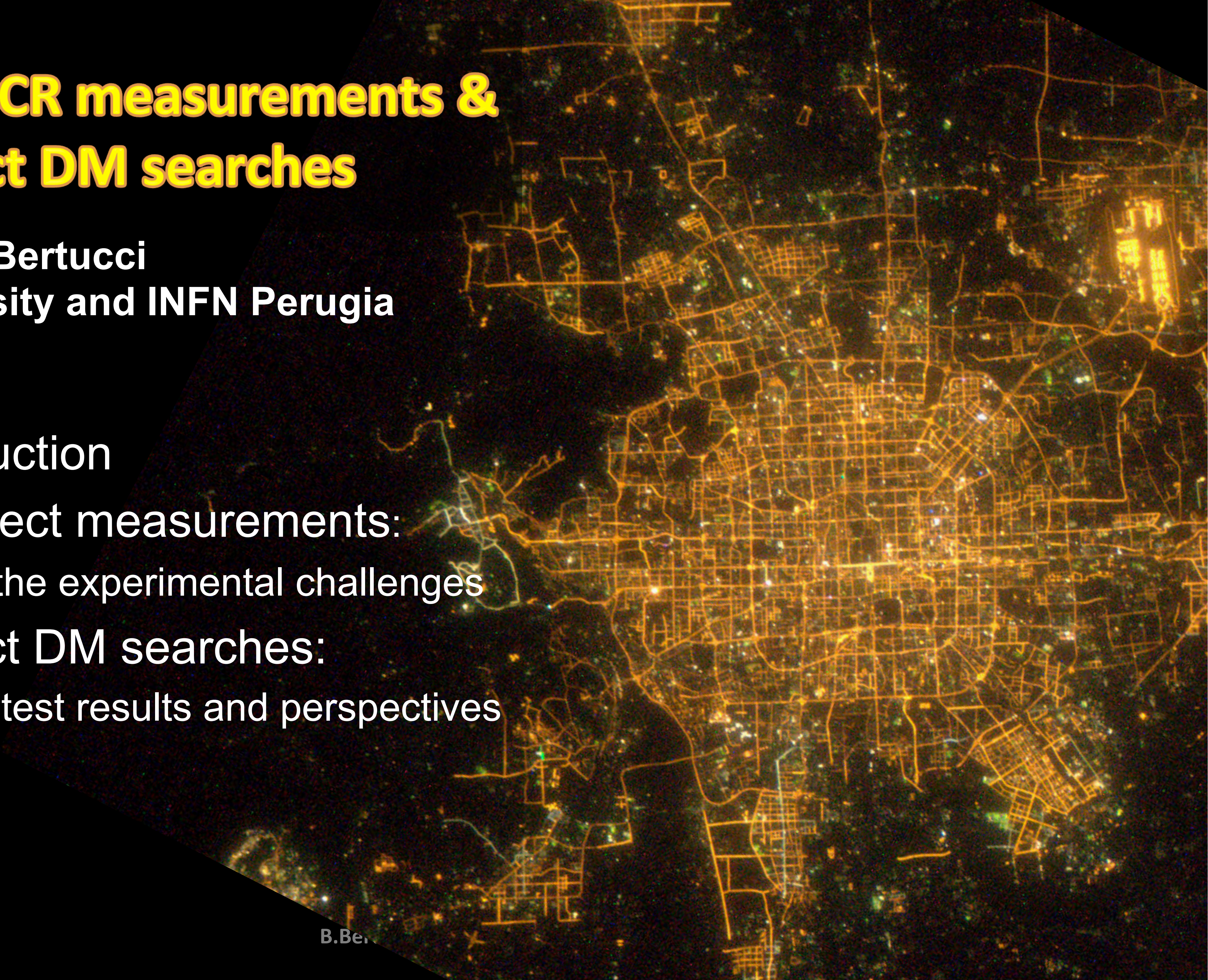
Introduction

CR direct measurements:

→ the experimental challenges

Indirect DM searches:

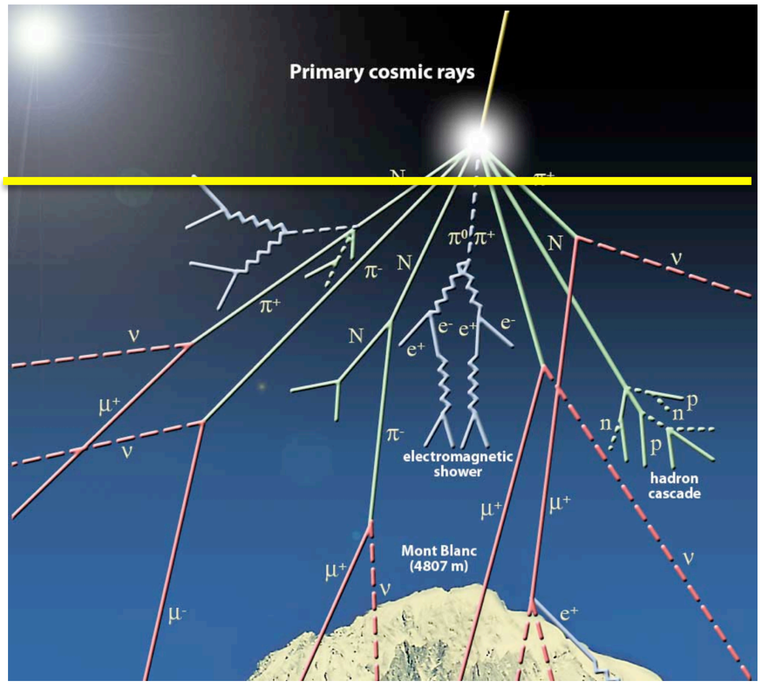
→ latest results and perspectives

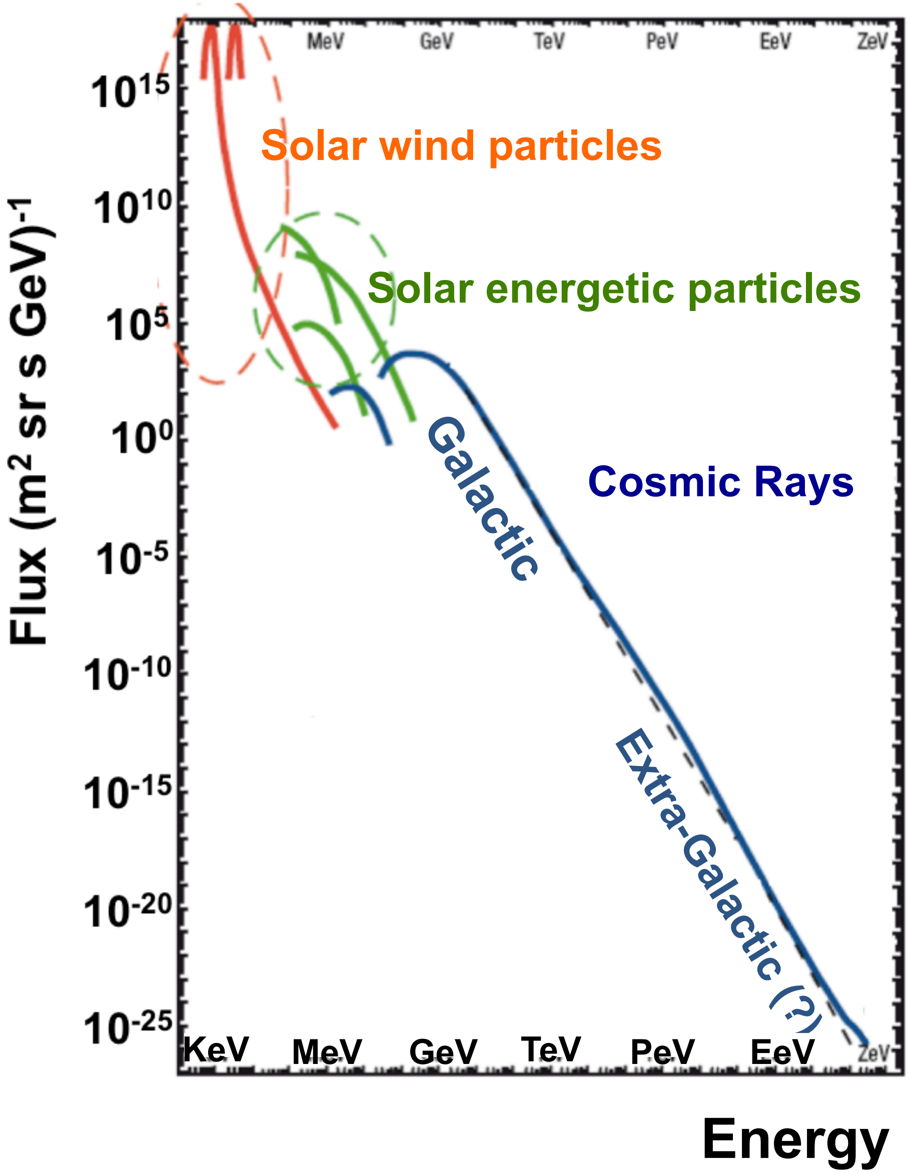


The cosmic ray flux

Direct CR measurements :

- ✓ **Particle identification**
- ✓ **Energy measurement**
- ✓ **Charge sign (anti-particles)**

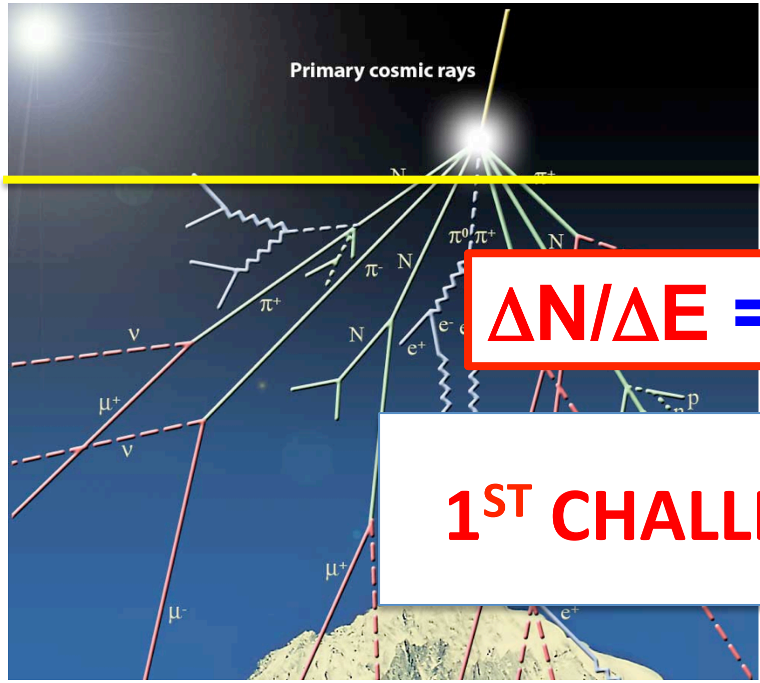


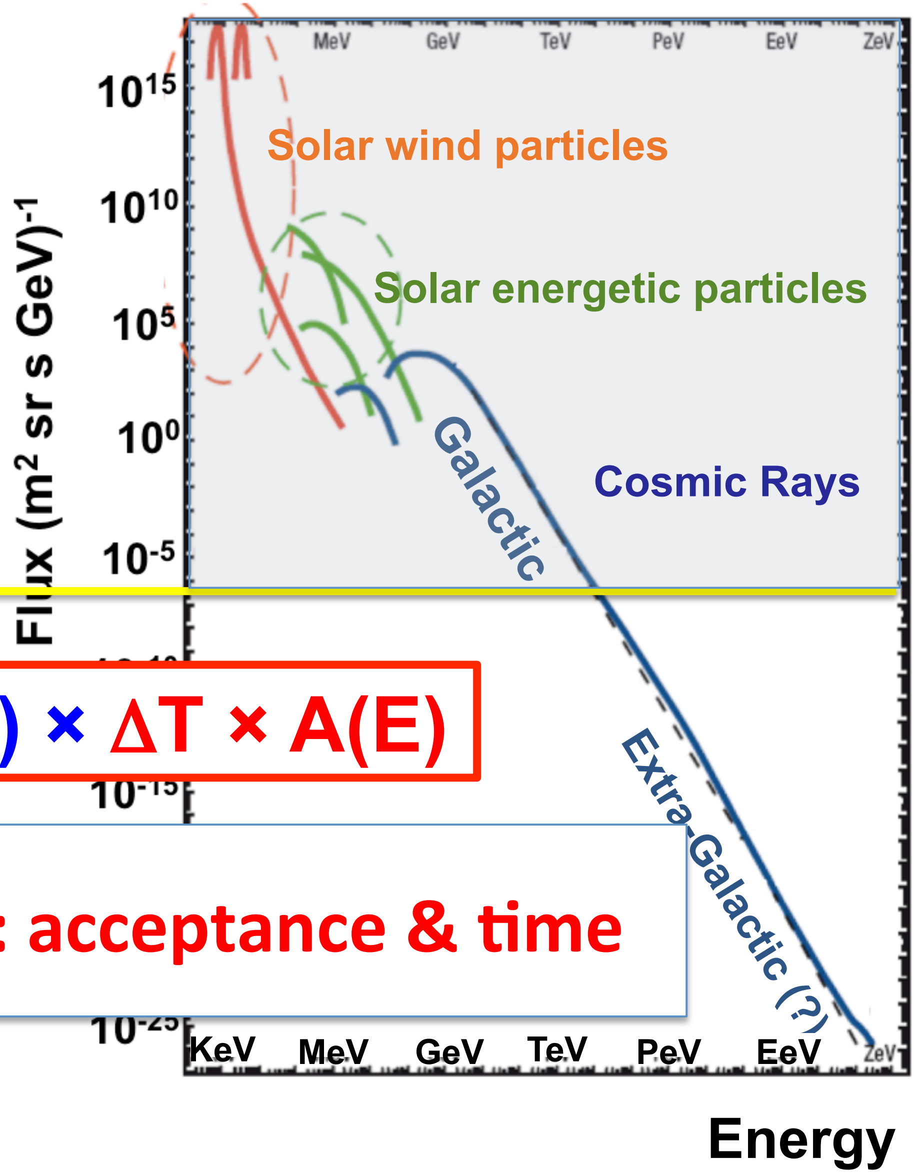


The cosmic ray flux

Direct CR measurements :

- ✓ Particle identification
- ✓ Energy measurement
- ✓ Charge sign (anti-particles)

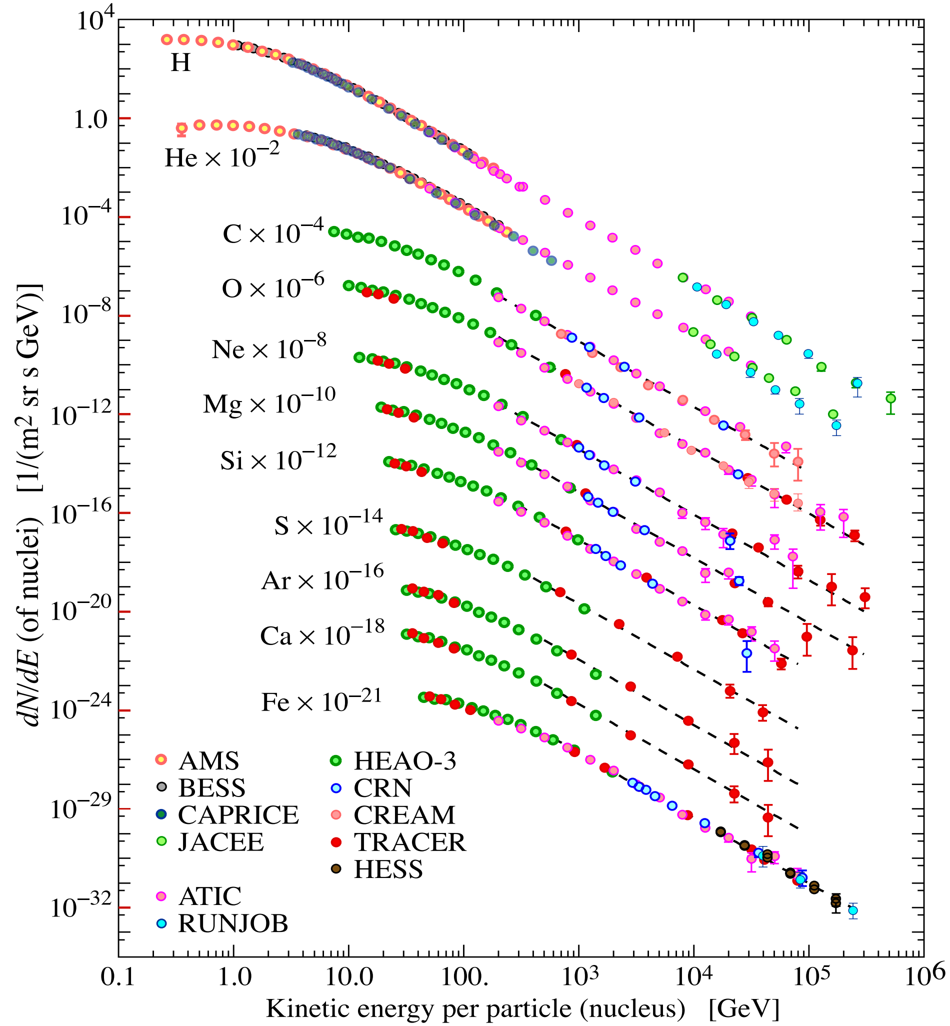




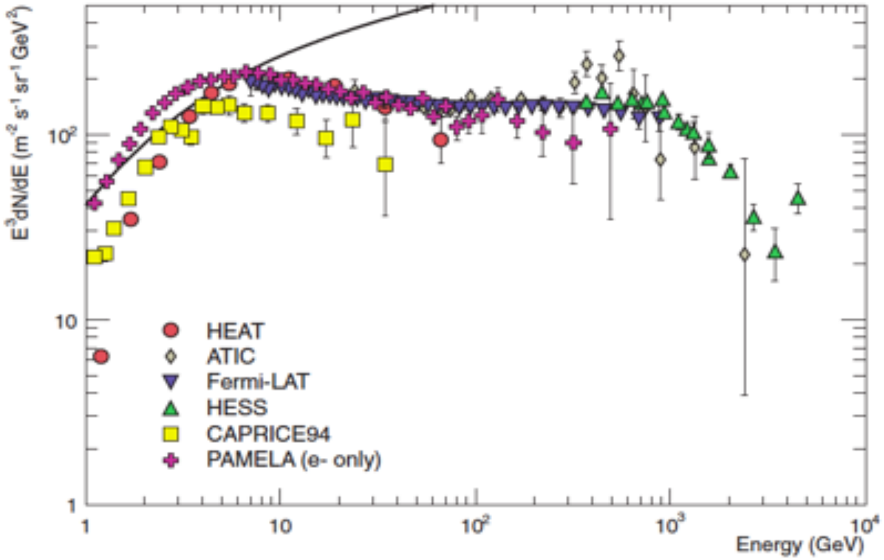
$$\Delta N/\Delta E = \Phi(E) \times \Delta T \times A(E)$$

1ST CHALLENGE: acceptance & time

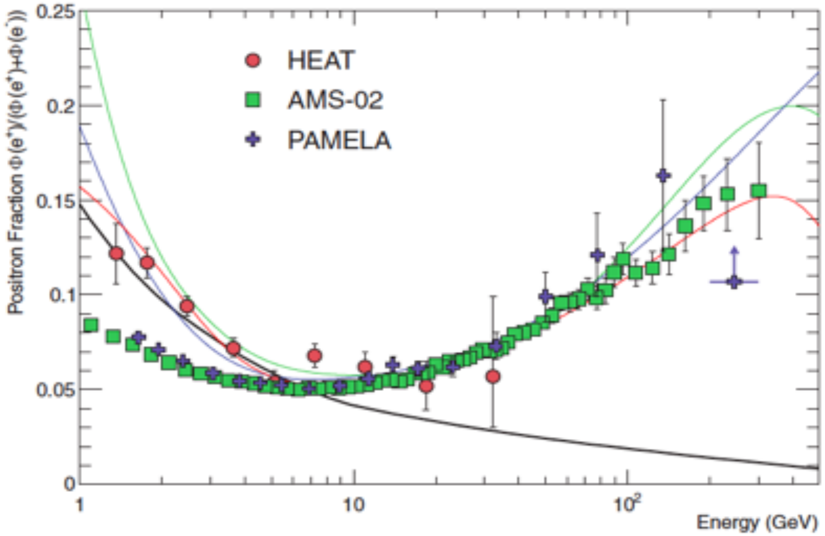
Different channels to explore for different (and complementary) objectives : from CR origin in the galaxy to new exotic sources….



The e± component

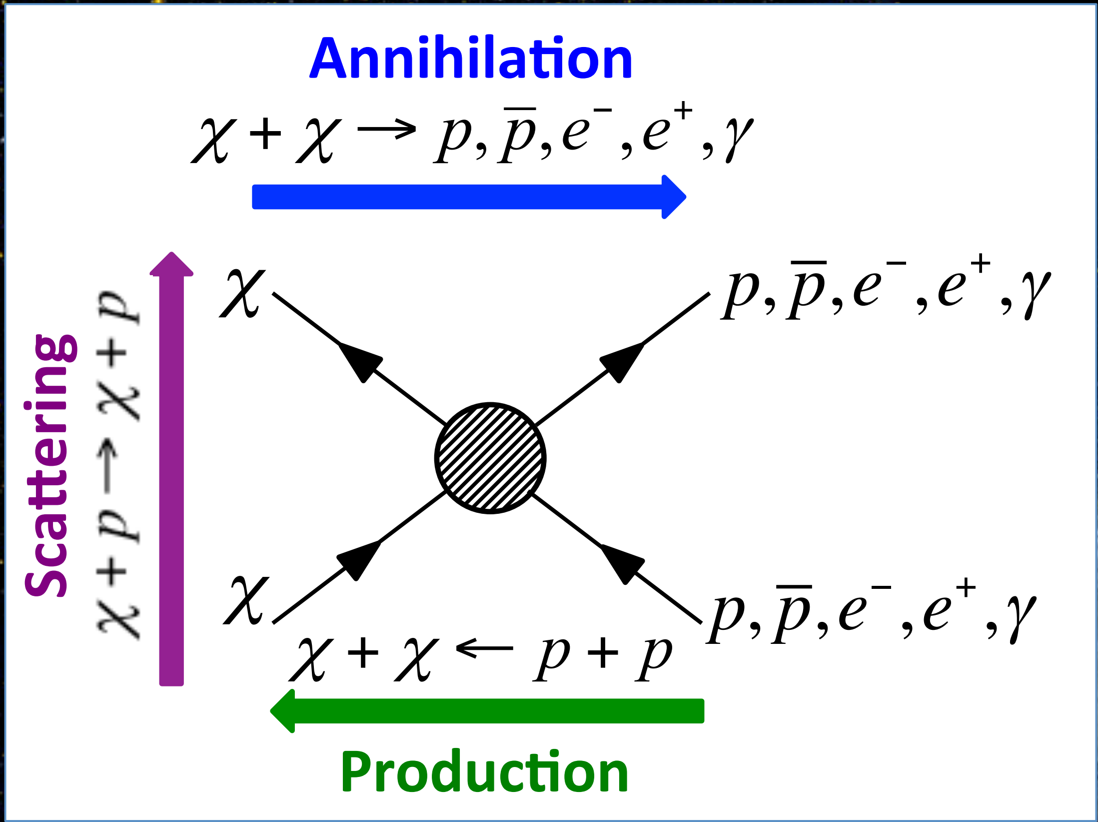


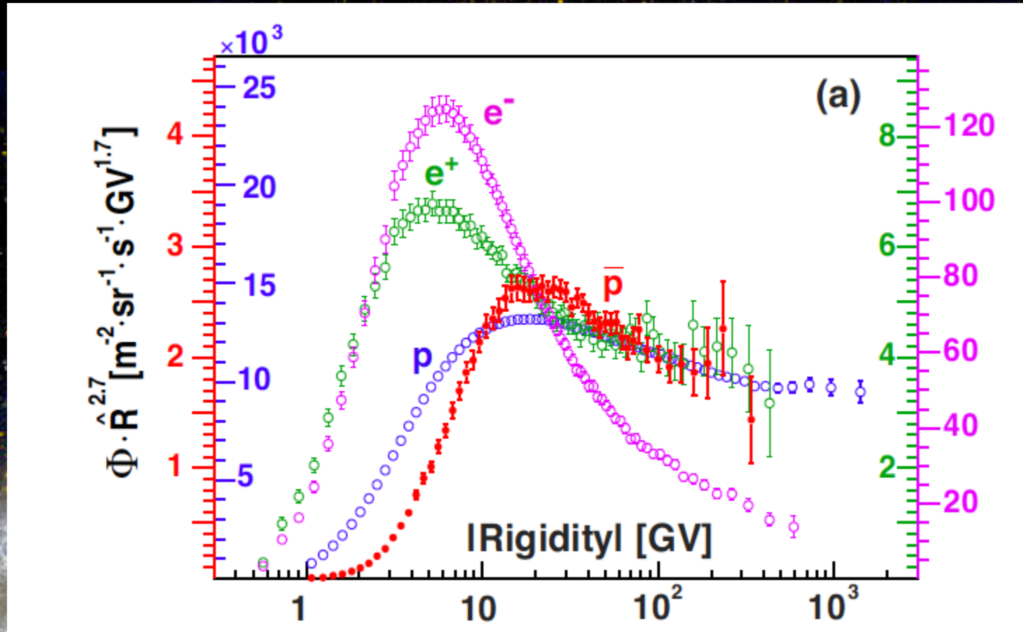
Anti-particles: e.g. the $e^+/e^+ + e^-$ fraction

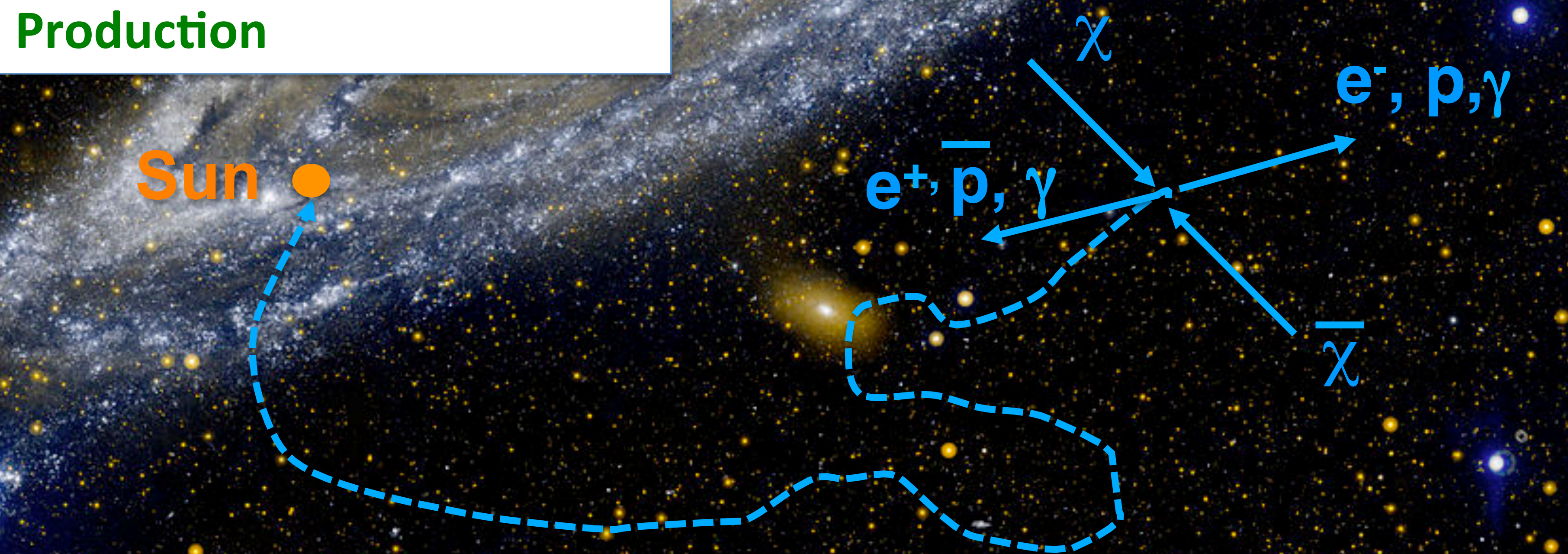


Chemical composition energy spectra of primary (and secondary)

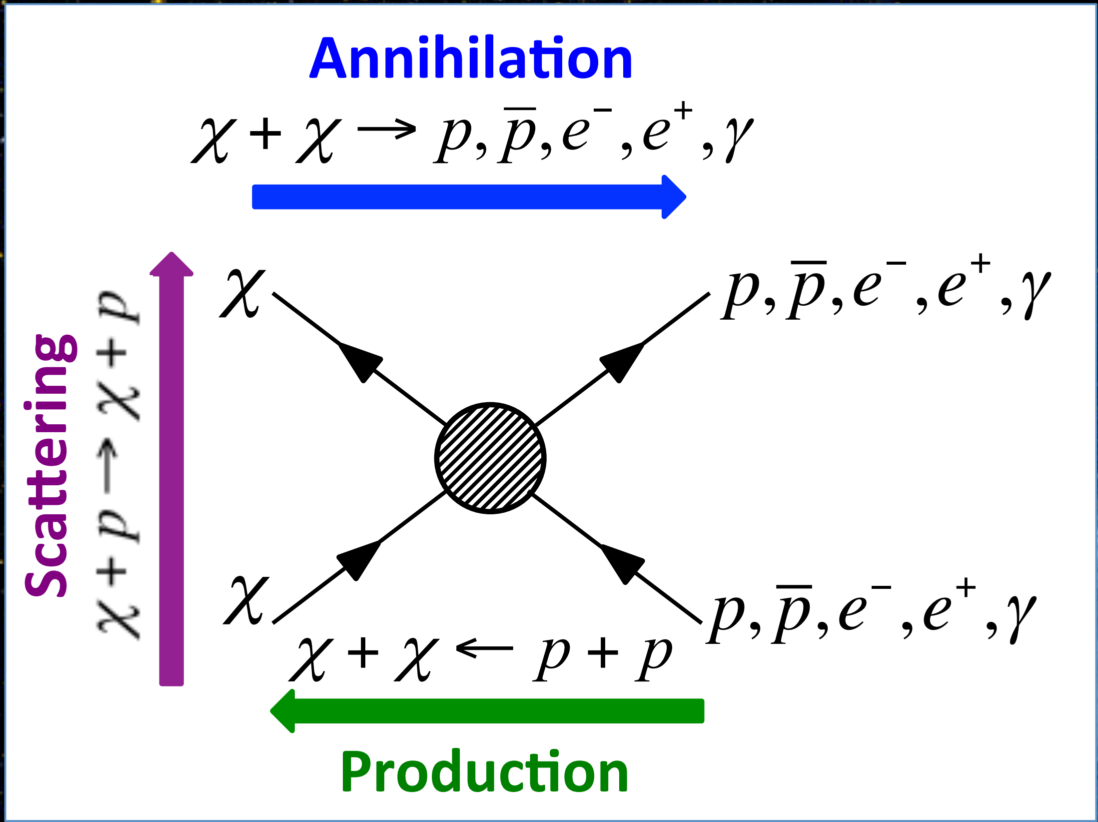
The quest for Dark Matter

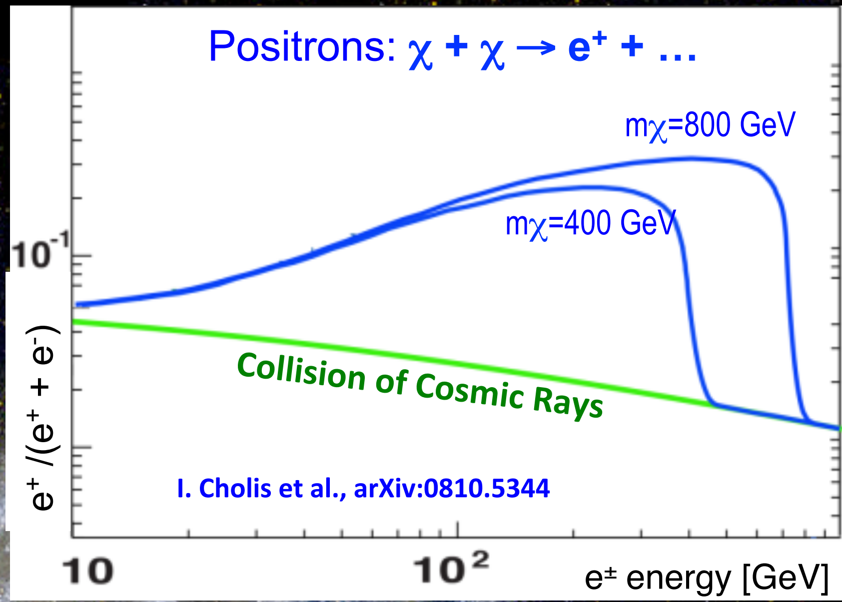


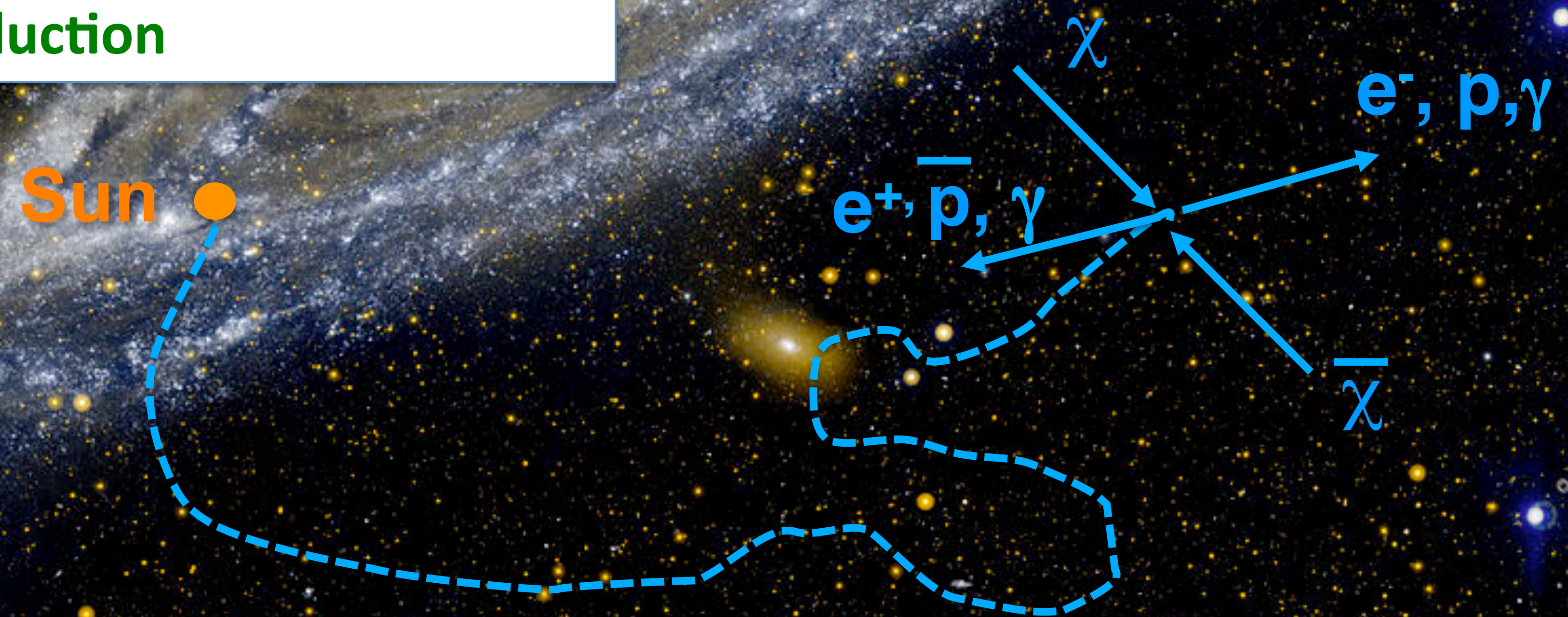




The quest for Dark Matter

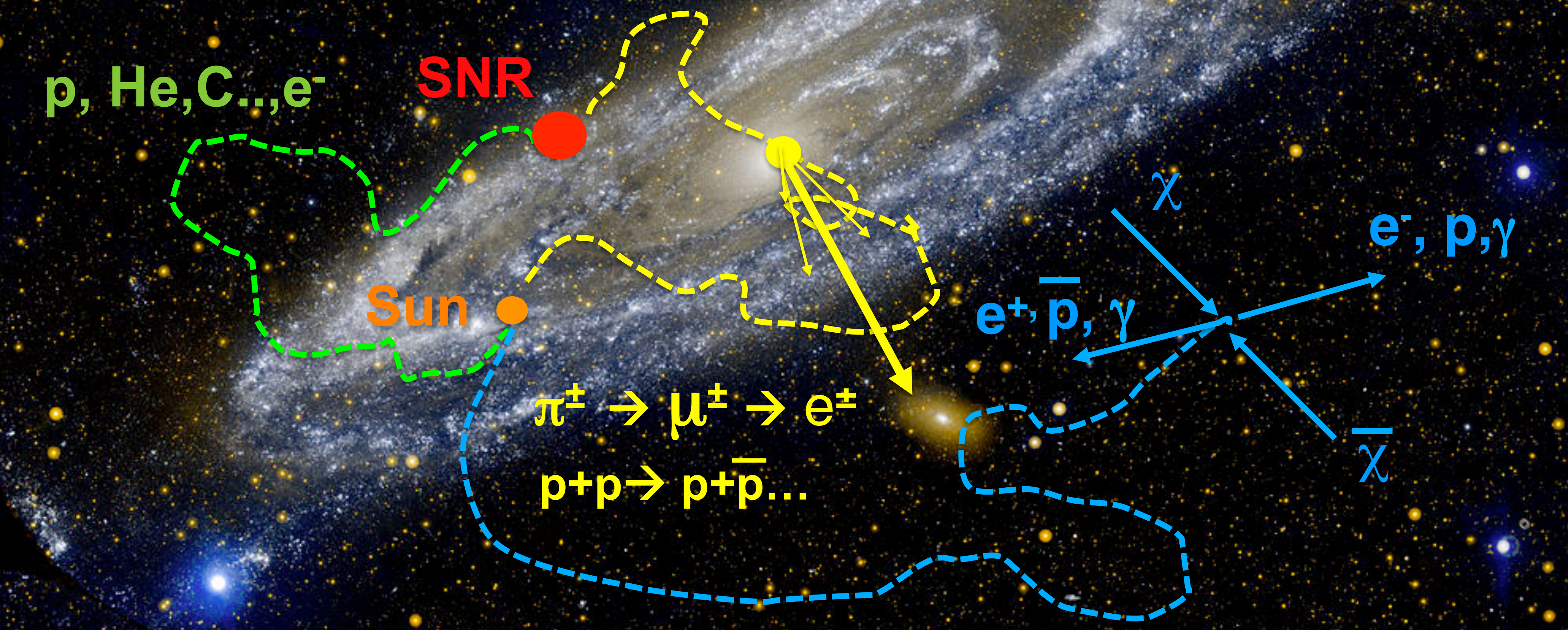






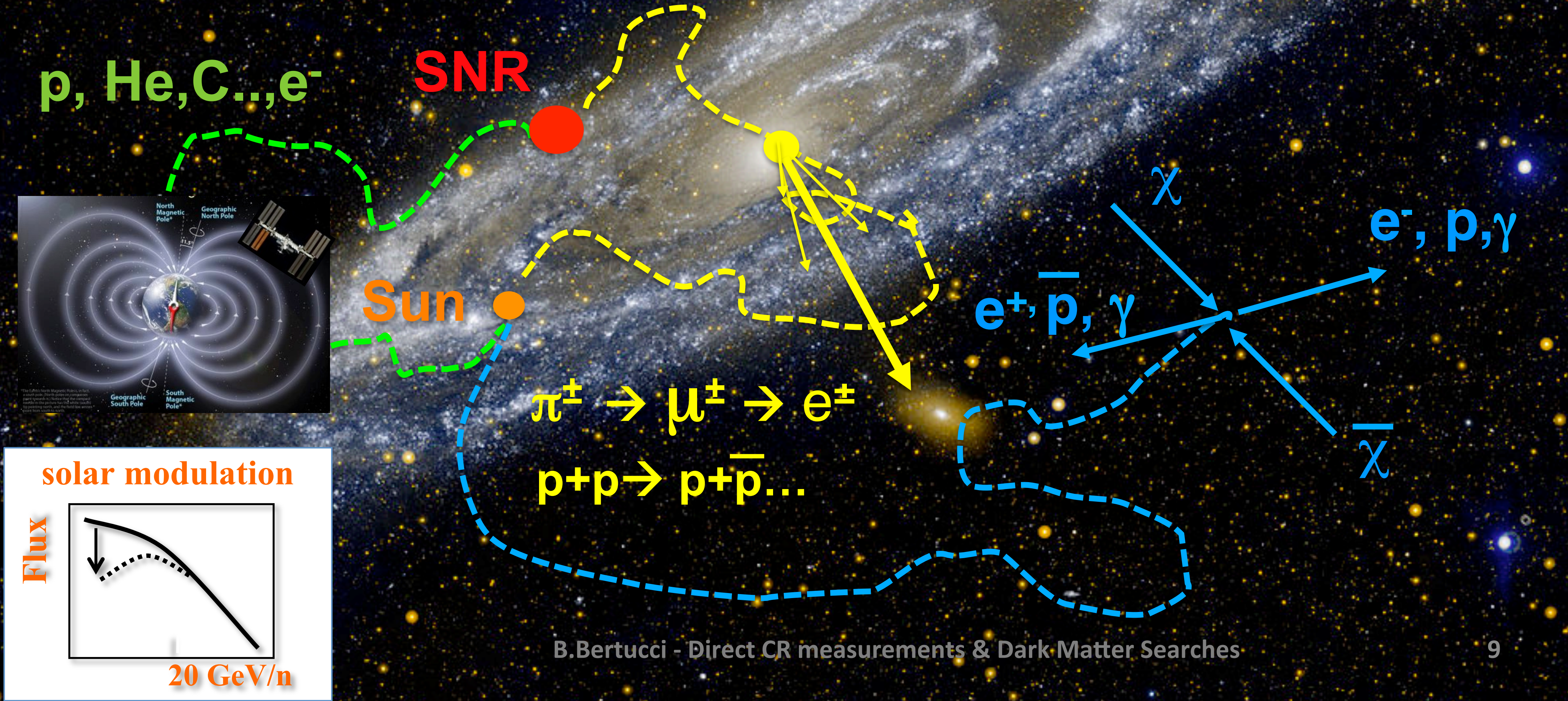
The Astrophysical Background:

Origin, propagation and production of CRs and their secondaries in the galaxy



The Astrophysical Background:

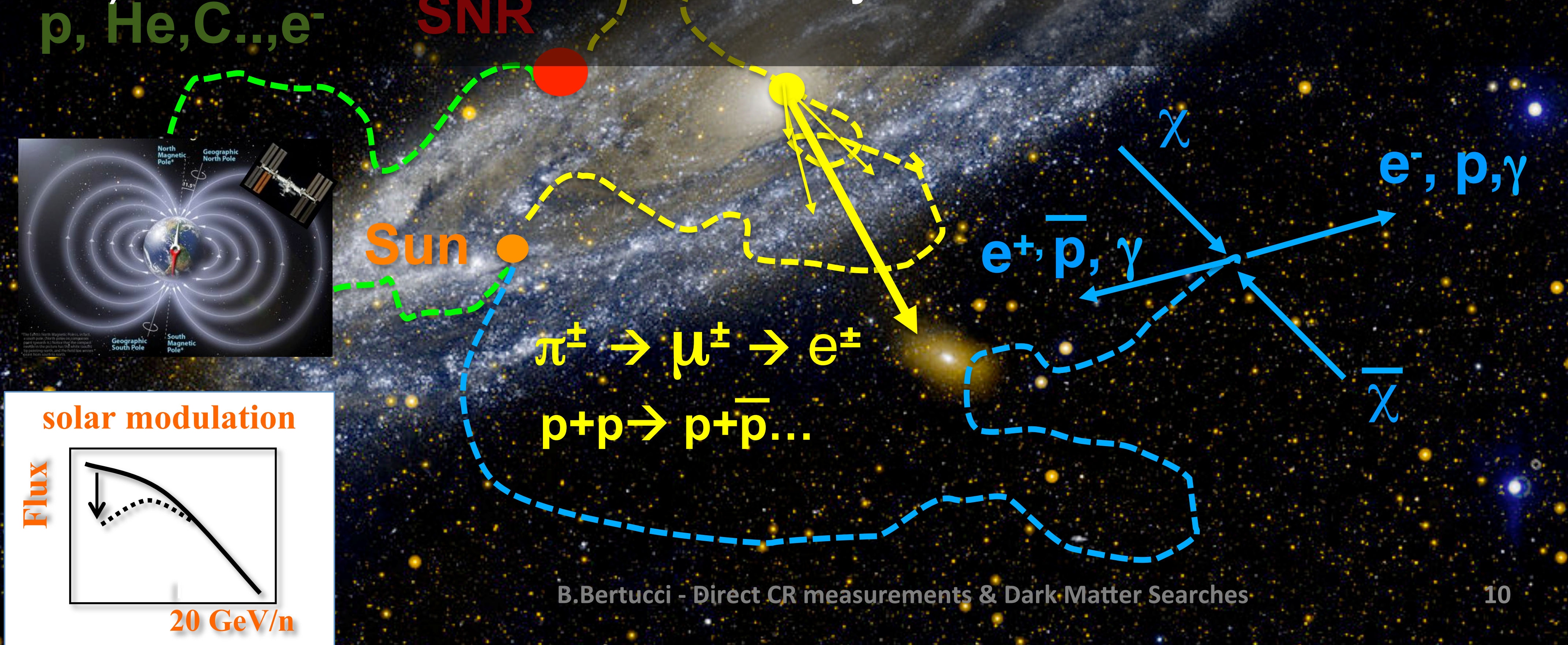
Origin, propagation and production of CRs and their **secondaries** in the galaxy
+ heliospheric / magnetospheric effects…



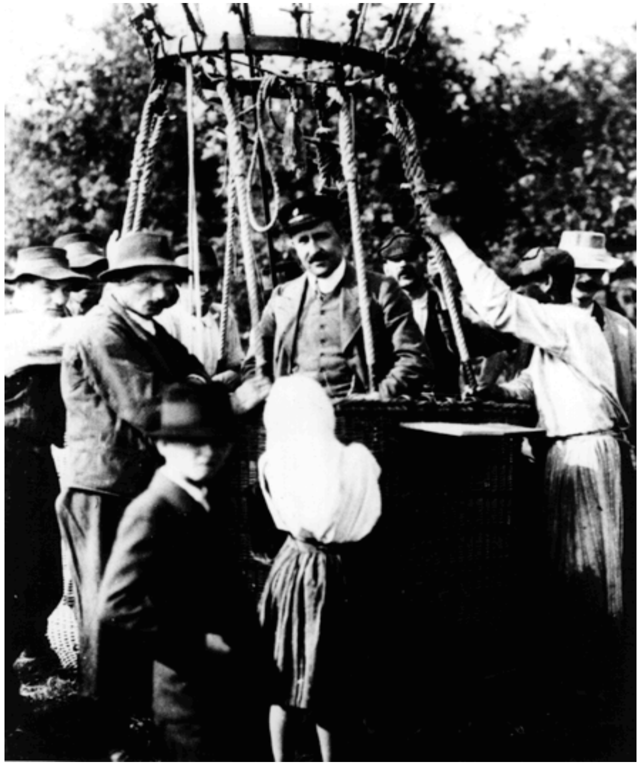
The experimental challenge

Hunt rare signals and provide accurate flux measurements of the CR components to constraint astrophysical models

1) DESIGN : state of the art detectors providing redundant particle measurements
2) TEST: test and calibration on ground
3) OPERATION in Space: monitoring and calibration
4) DATA ANALYSIS: unknown luminosity of the cosmic collider !



Part 1:
Direct CR measurements :
(some of) the experimental challenges



Requirement:
No atmosphere ⇒

- Stratospheric Balloons
- Space

Stratospheric Balloons: from few hrs to months

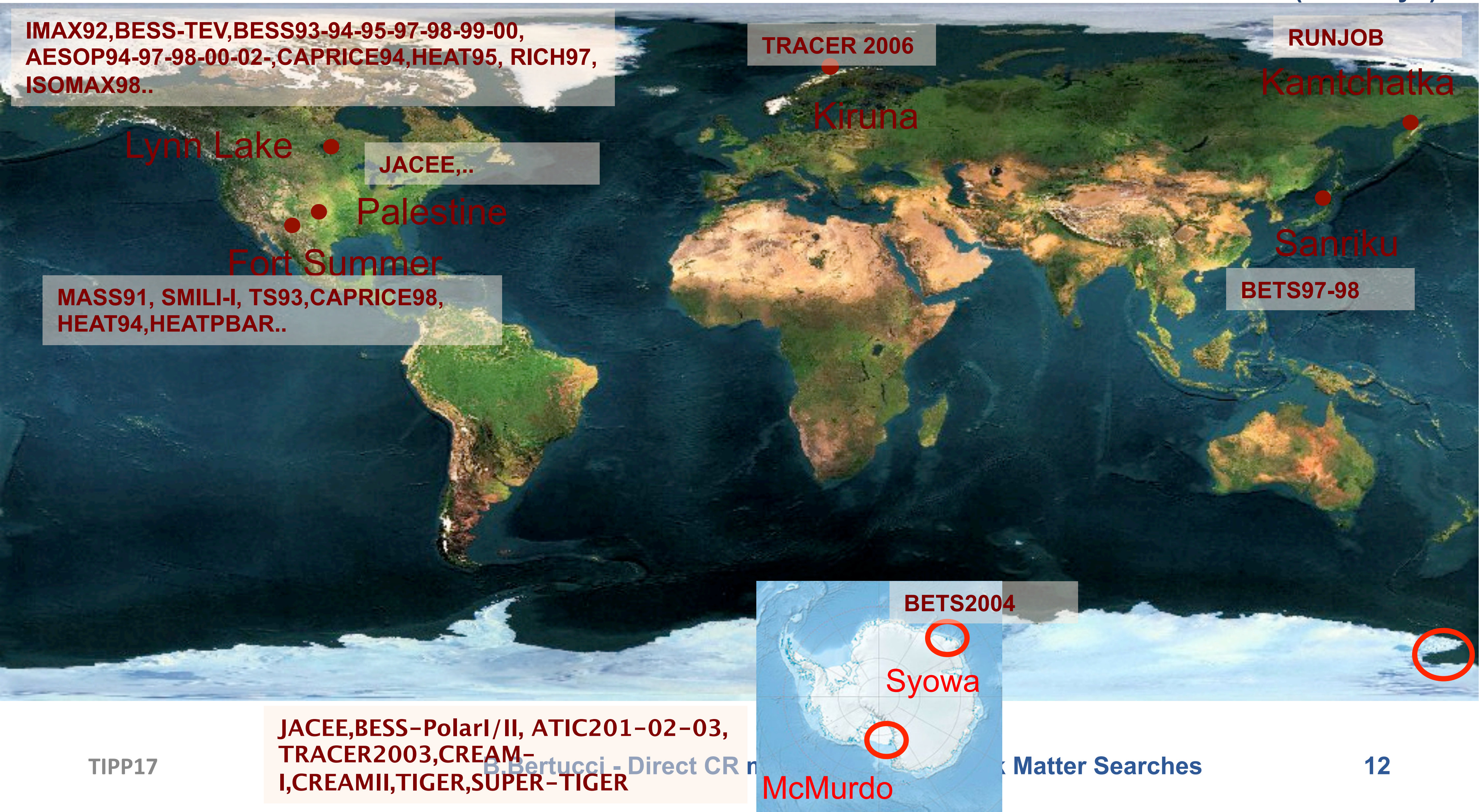
Magnetic Spectrometers

…

BESS/POLAR/TEV (9 Flights)
WIZARD (6,Flights)
HEAT/PBAR (4,Flights)

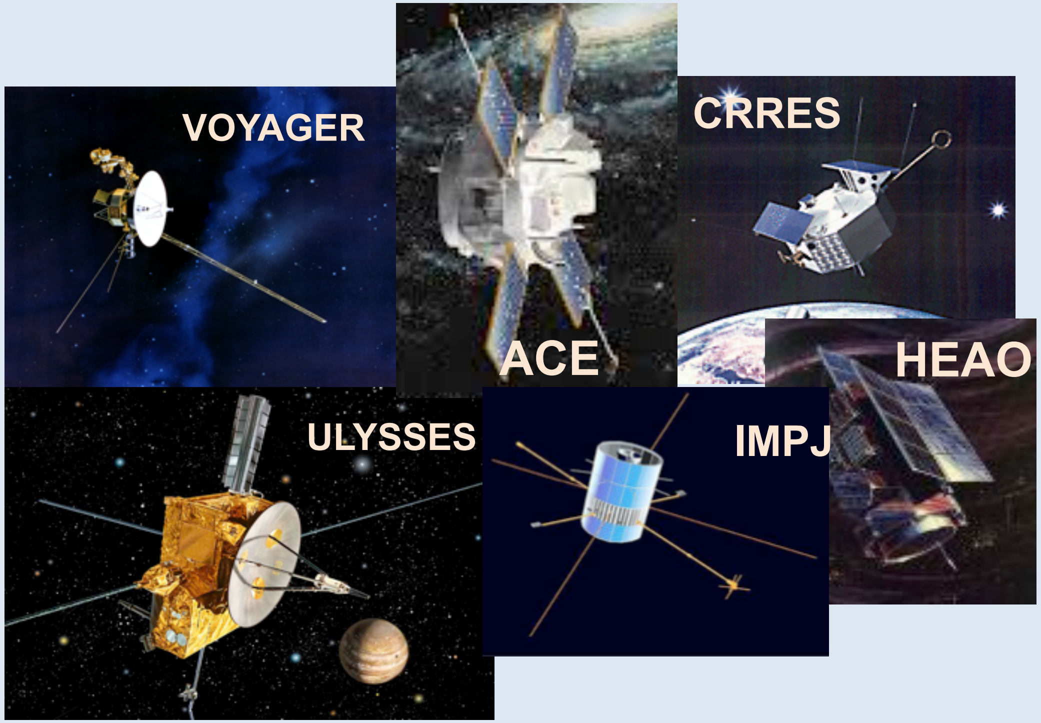
Calorimetry, TRD +..

RUNJOB (62 day, 10 Flights)
TRACER (18 days, 3 Flights)
CREAM (161 days,6 Flights)
ATIC (53 days, 3 Flights)
TIGER/S-TIGER (2/55 days)



JACEE,BESS-PolarI/II, ATIC201-02-03, TRACER2003,CREAM-I,CREAMII,TIGER,SUPER-TIGER

Space:



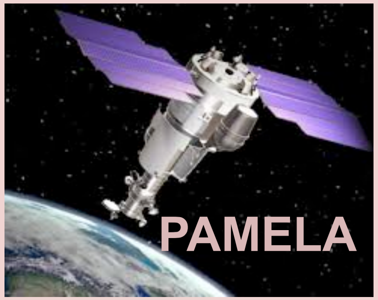
Long missions (years)
Small payloads
Low energies..

IMP series < GeV/n
ACE-CRIS/SIS Ekin < GeV/n
VOYAGER-HET/CRS < 100 MeV/n
ULYSSES-HET (nuclei) < 100 MeV/n
ULYSSES-KET (electrons) < 10 GeV
CRRES/ONR < (nuclei) 600 MeV/n
HEAO3-C2 (nuclei) < 40 GeV/n

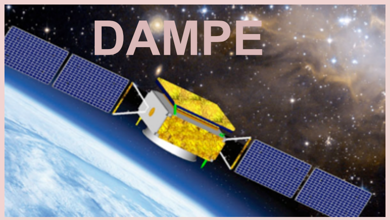
Short missions (days)/ Larger payloads

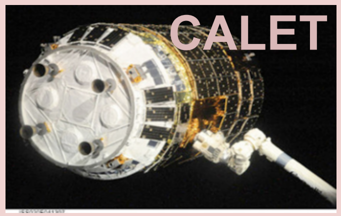
CRN on Challenger
(3.5 days 1985)

AMS-01 on Discovery
(8 days, 1998)

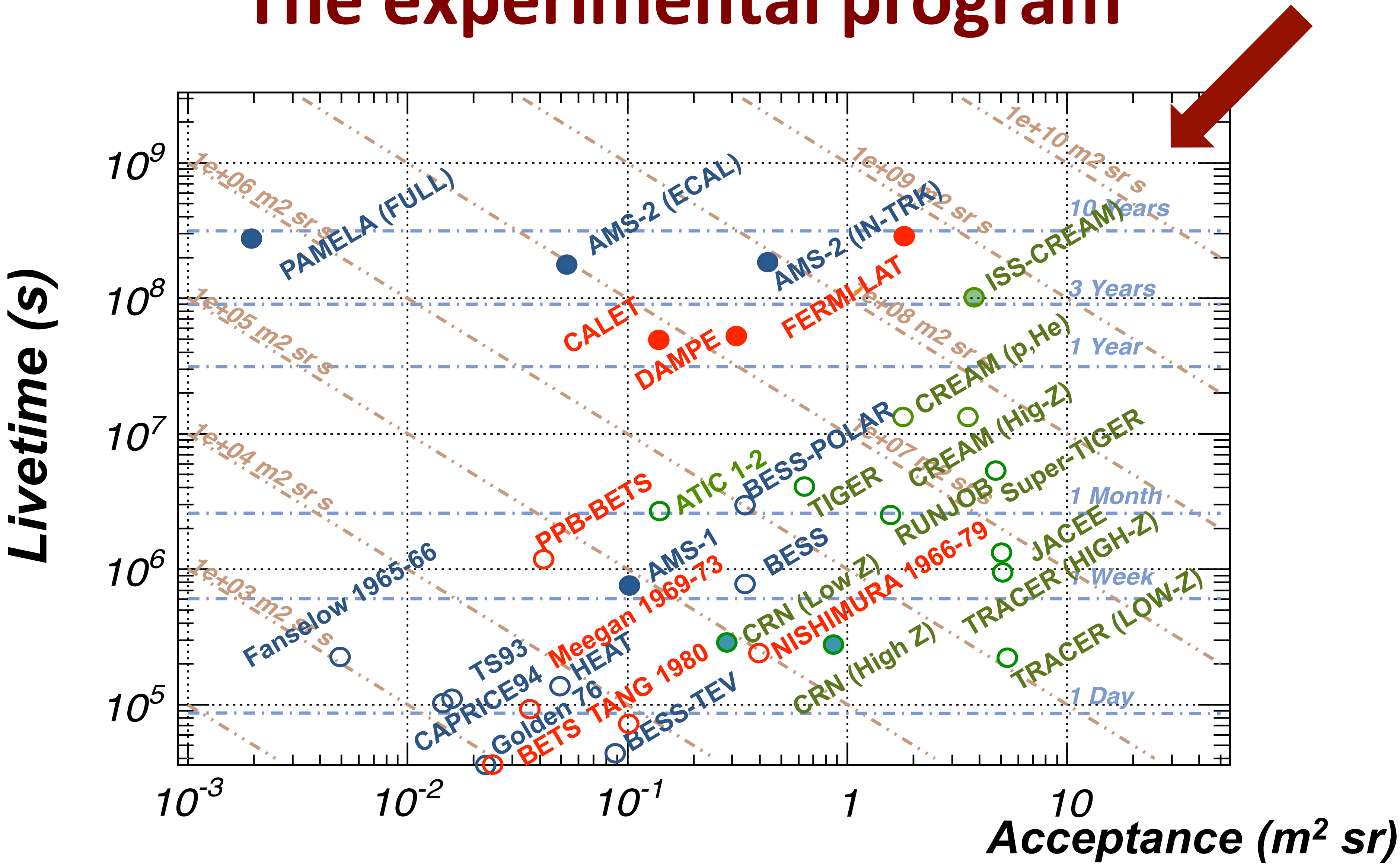


Long missions
Large payloads





The experimental program



No B field, different techniques with main focus on Z

No B field, different techniques with main focus on e,γ

Magnetic spectrometers

Balloon

Space

Space (planned)

The experimental challenge

No atmosphere: Stratospheric Balloons
Space

⇓ Limits on size / weight / time

- Detector design focused on specific measurements

p,He,e^-,anti-particles

⇓

<u>Magnetic spectrometers</u>
Energy reach on anti-particles limited by Maximum Detectable Rigidity

Primary spectra, Nuclei, $e^{\pm}$

⇓

<u>Calorimeters</u>
Energy reach limited by statistics

Calorimetric CR detectors

Now on orbit:

→ **Fermi** (2007): γ-rays, electrons($e^{\pm}$)
→ **CALET** (2015) : electrons($e^{\pm}$), nuclei
→ **DAMPE** (2015): electrons ($e^{\pm}$), light nuclei, γ-rays

Ready to launch:
→ ISS-CREAM (2017 !!) : nuclei

Magnetic spectrometers

→**PAMELA** (2006-2016) : anti-particles, e^{-}, p, He, light nuclei

Now on orbit:
→ **AMS-02** (2011): anti-particles,e- p, He ...nuclei (up to Fe..)

The experimental challenge

No atmosphere: Stratospheric Balloons
Space

⇩ Limits on size / weight / time

- Detector design focused on specific measurements

p,He,e^-,anti-particles ⇩

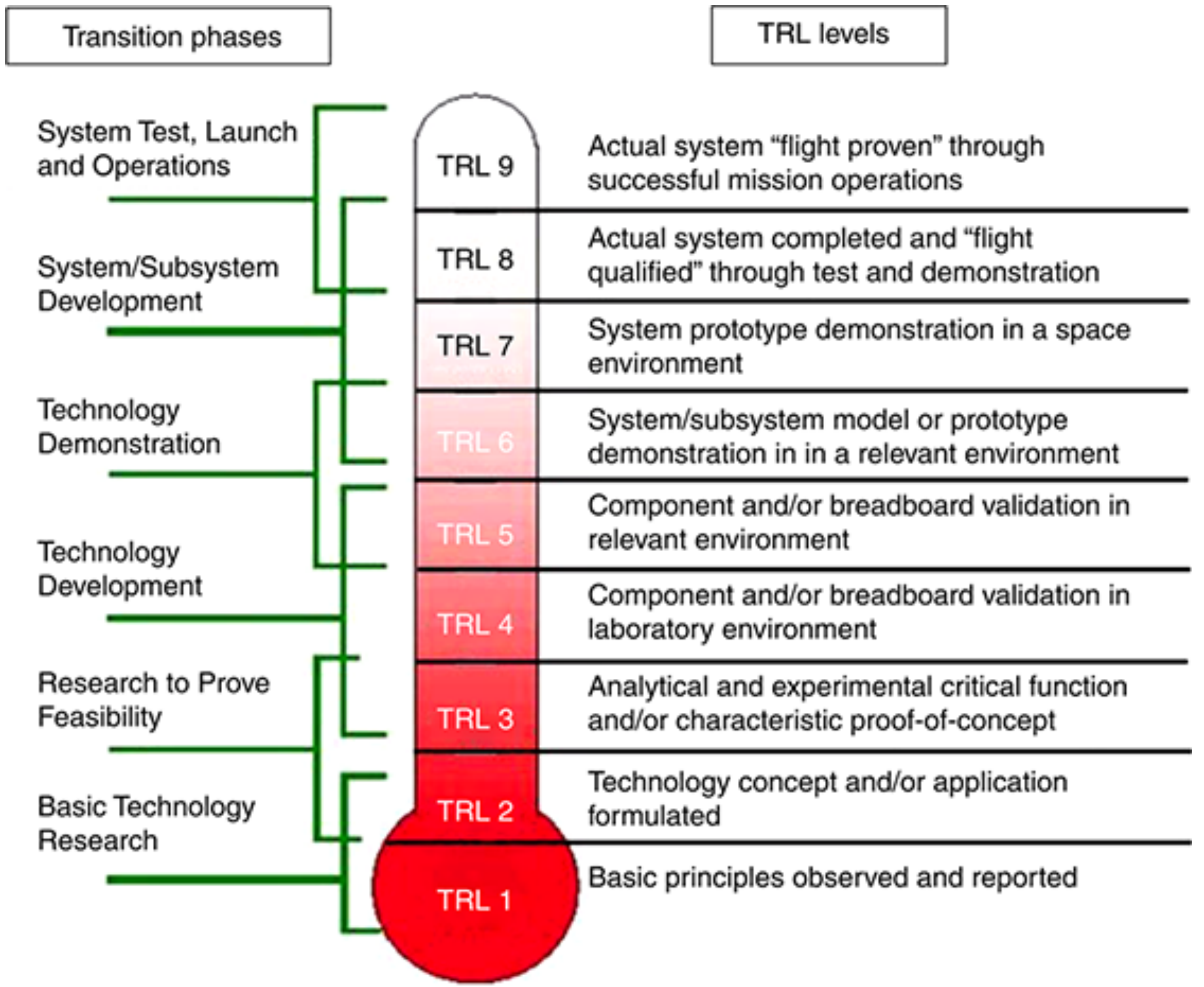
Magnetic spectrometers
Energy reach on anti-particles limited by Maximum Detectable Rigidity

Primary spectra, Nuclei, $e^\pm$ ⇩

Calorimeters
Energy reach limited by statistics

→ HEP detectors adapted to space !

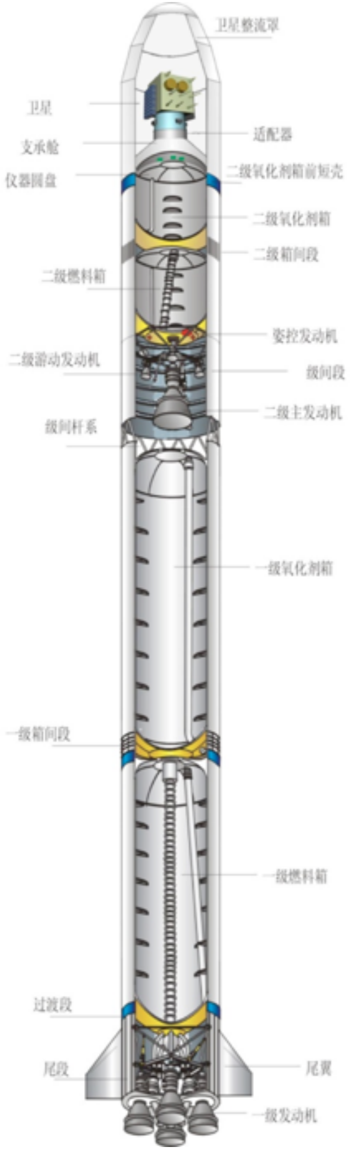
Technology Readiness Level



Source: Adapted from NASA and Mankins (1995)

Exported to space

Well established technology on ground



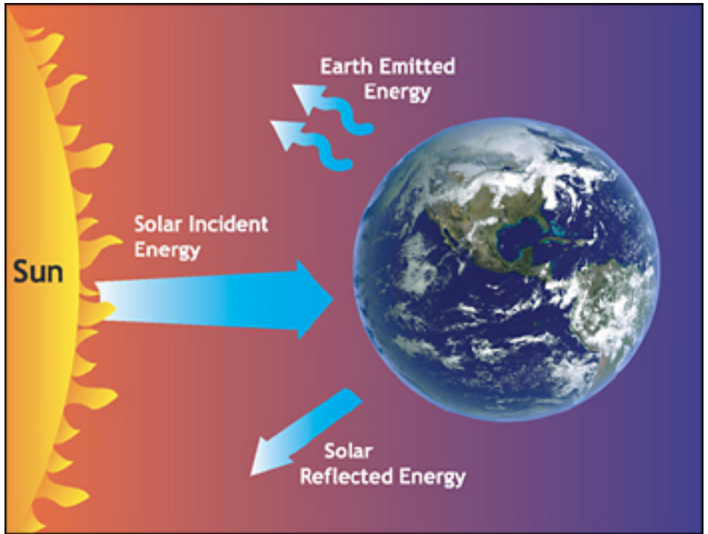
HEP detectors in Space

Mechanical stress at launch:

- Static acceleration
- Random vibration
- Sinusoidal vibration
- Pyroshock

Life in space:

- **Thermal stresses due to Sun-light (seasonal / day-night effects)**
- **Vacuum**



Careful Design, Model validation and Qualification are needed to ensure *highest possible reliability*

As a space payload: qualification tests before and after assembly

Full space qualification sequence before launch:

- Operational tests after stress
- Verification of dynamical behaviour
- Verification of thermal model

Thermal Stress → Functional check → Mechanical Stress → Functional check →

Thermal cycles in Vacuum → Functional check

EMC

x 2
Qualification Model & Flight Model

e.g. AMS & silicon microstrip detectors in space

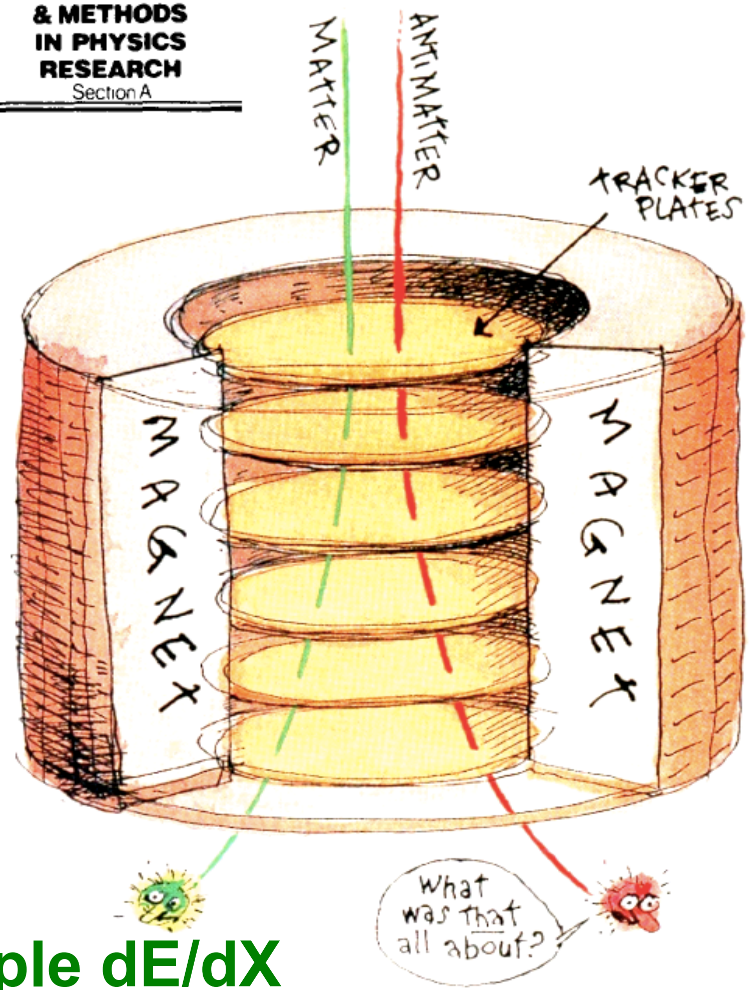
Nuclear Instruments and Methods in Physics Research A 350 (1994) 351–367
North-Holland

An antimatter spectrometer in space

Antimatter Study Group

S. Ahlen [f], V.M. Balebanov [a], R. Battiston [l], U. Becker [g], J. Burger [g], M. Capell [g], H.F. Chen [p], H.S. Chen [o], M. Chen [g], N. Chernoplekov [b], R. Clare [g], T.S. Dai [g], A. De Rujula [f,*], P. Fisher [d], Yu. Galaktionov [c], A. Gougas [d], Gu Wen-Qi [n], M. He [q], V. Koutsenko [c], A. Lebedev [c], T.P. Li [o], Y.S. Lu [o], D. Luckey [g], Y. Ma [o], R. McNeil [e], R. Orava [j], A. Prevsner [d], V. Plyaskine [c], H. Rubinstein [m], R. Sagdeev [h], M. Salamon [i], H.W. Tang [o], S.C.C. Ting [g], I. Vetlitsky [c], Y.F. Wang [g], Xia Ping-Chou [n], Z.Z. Xu [p], J.P. Wefel [e], Z.P. Zhang [p], B. Zhou [f], A. Zichichi [k,*]

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A



Tracking with silicon microstrip detectors : heritage of LEP experiments (L3) :

Main advantages:

→ Excellent spatial resolution
→ Absolute charge measurement from multiple dE/dX
→ Light weight / minimum material along track trajectory
→ No HV

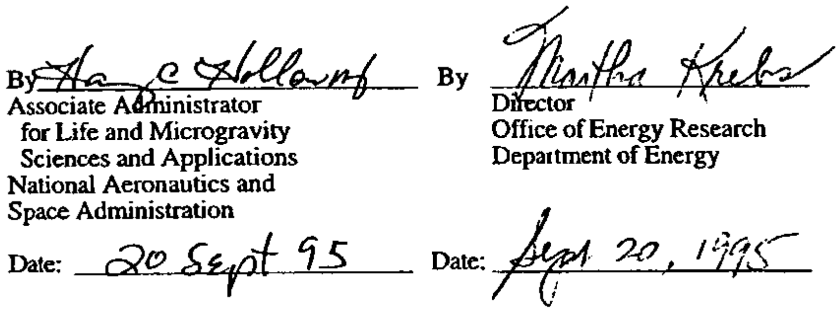
e.g. AMS & silicon microstrip detectors in space

Open questions in 1995:

→ **Never operated in space**
→ **300 μm thick detectors will survive the stress of the launch?**
→ **Assembly precision should match the resolution: do we really know their position ? Alignment after launch?**
→ **Many readout channels: electronics?**

Answer:

- **Proposal in 1994**
- **Agreement with NASA 1995 :**

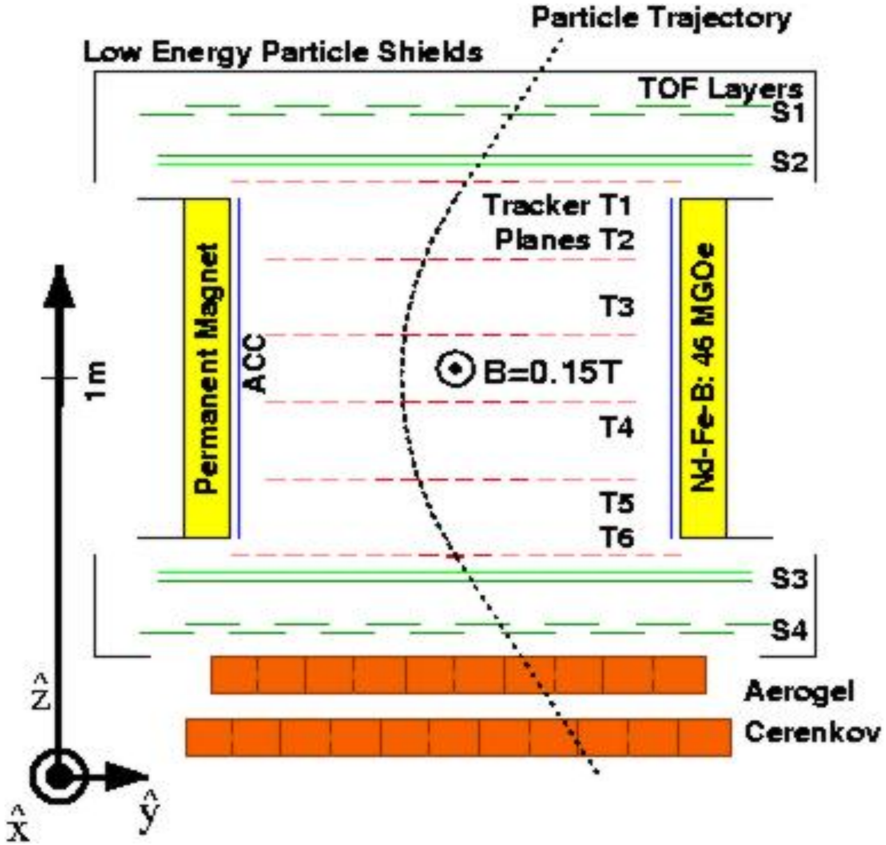

By [signature]
Associate Administrator
for Life and Microgravity
Sciences and Applications
National Aeronautics and
Space Administration
Date: 20 Sept 95

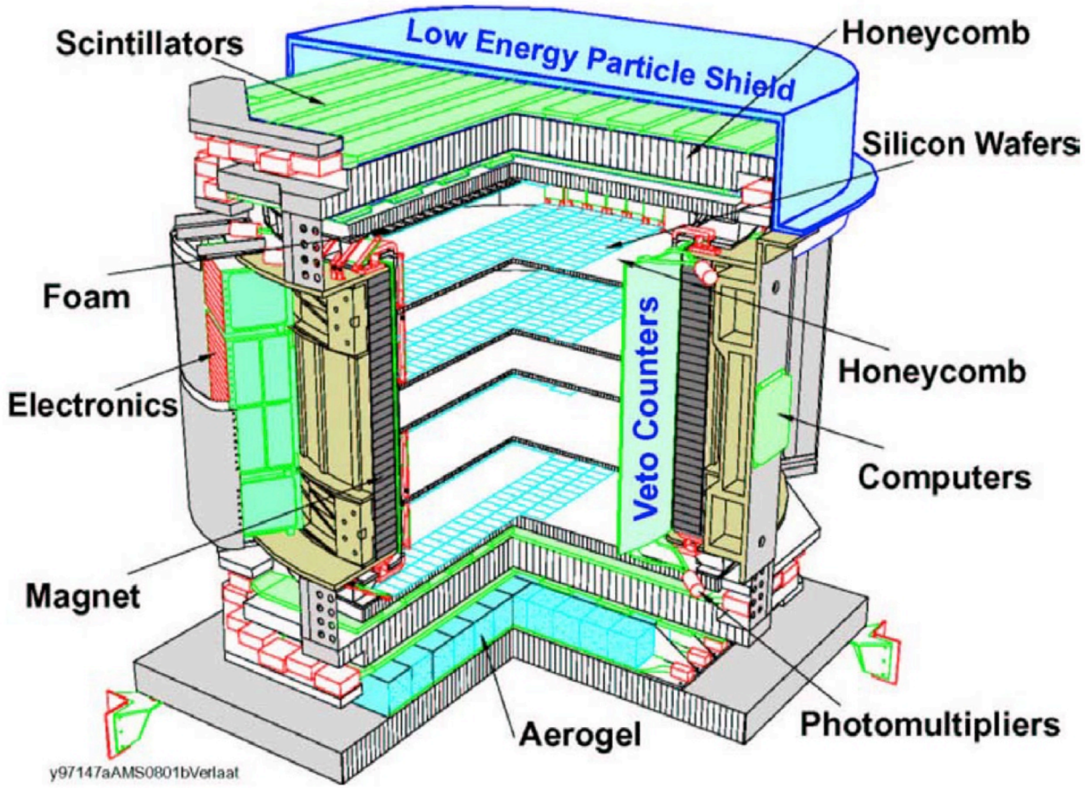
By [signature] Martha Krebs
Director
Office of Energy Research
Department of Energy
Date: Sept 20, 1995

AMS-01 : to prove technical design

AMS-02: for physics…

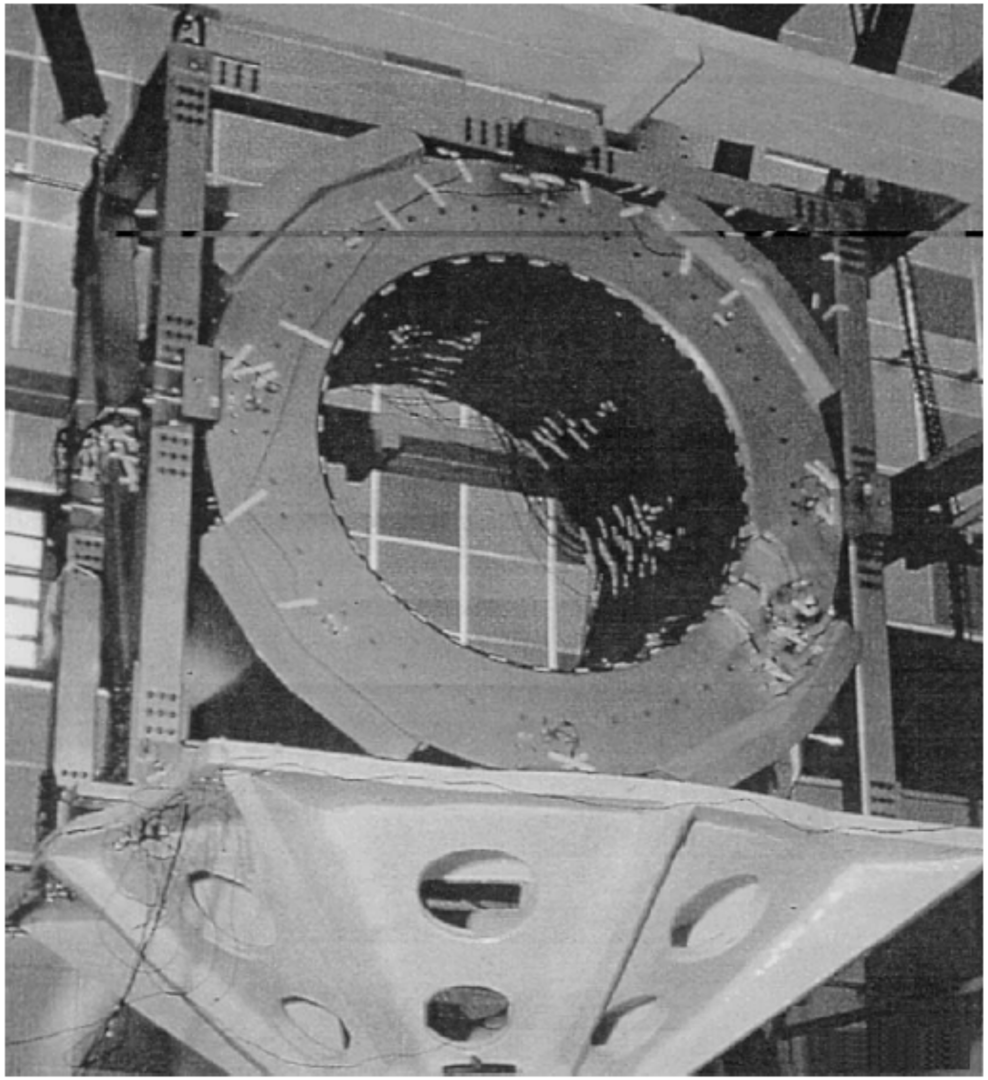
AMS-01:
First space borne spectrometer with a silicon tracker



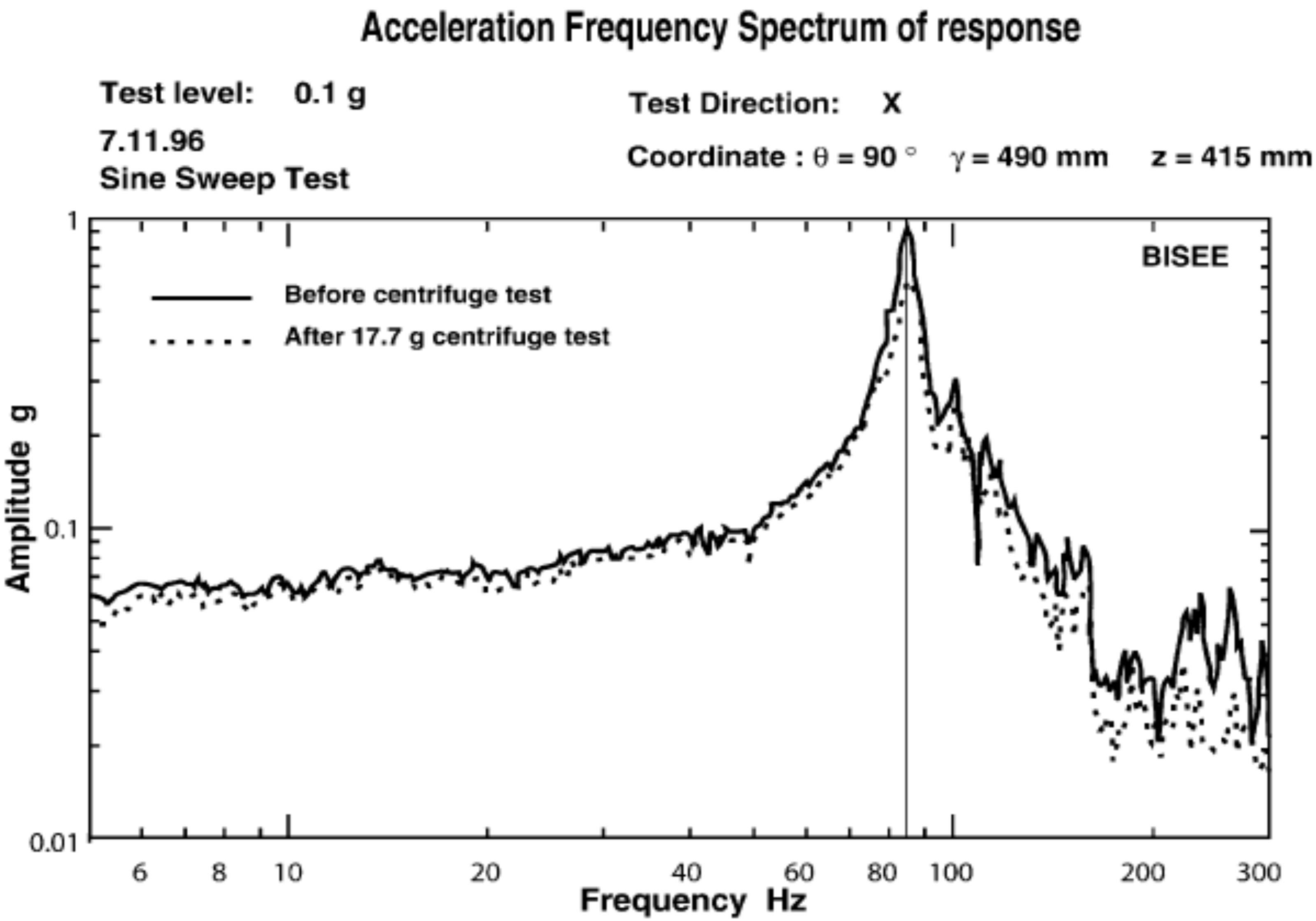


Time Of Flight : measure time → velocity, arrival direction, dE/dX → Z
Magnet: 2.2 Ton of Nd-Fe-B blocks providing a 15kGauss field inside, < 2 Gauss outside
Tracker: 2m^2 of silicon sensors arranged in 6 planes
Aerogel Cerenkov threshold counter: discrimination of e/p based on cerenkov emission

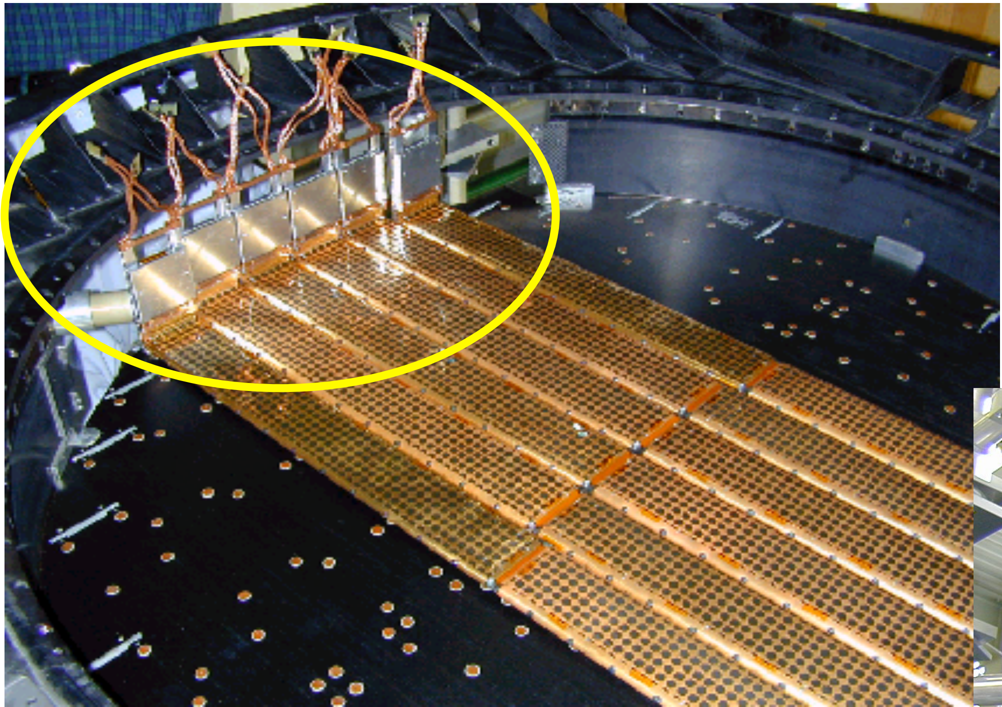
The Magnet before going to space.....



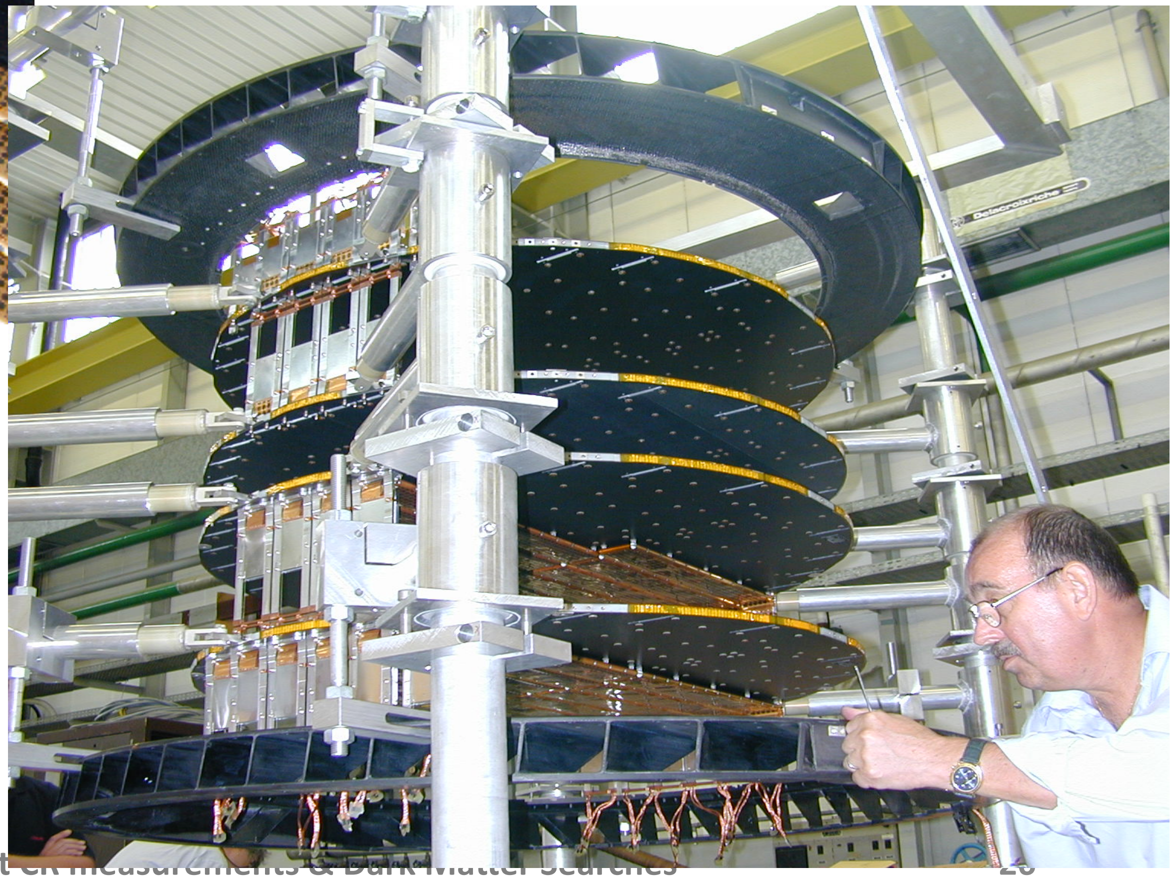
Before going to space.....



AMS-01 Silicon Tracker

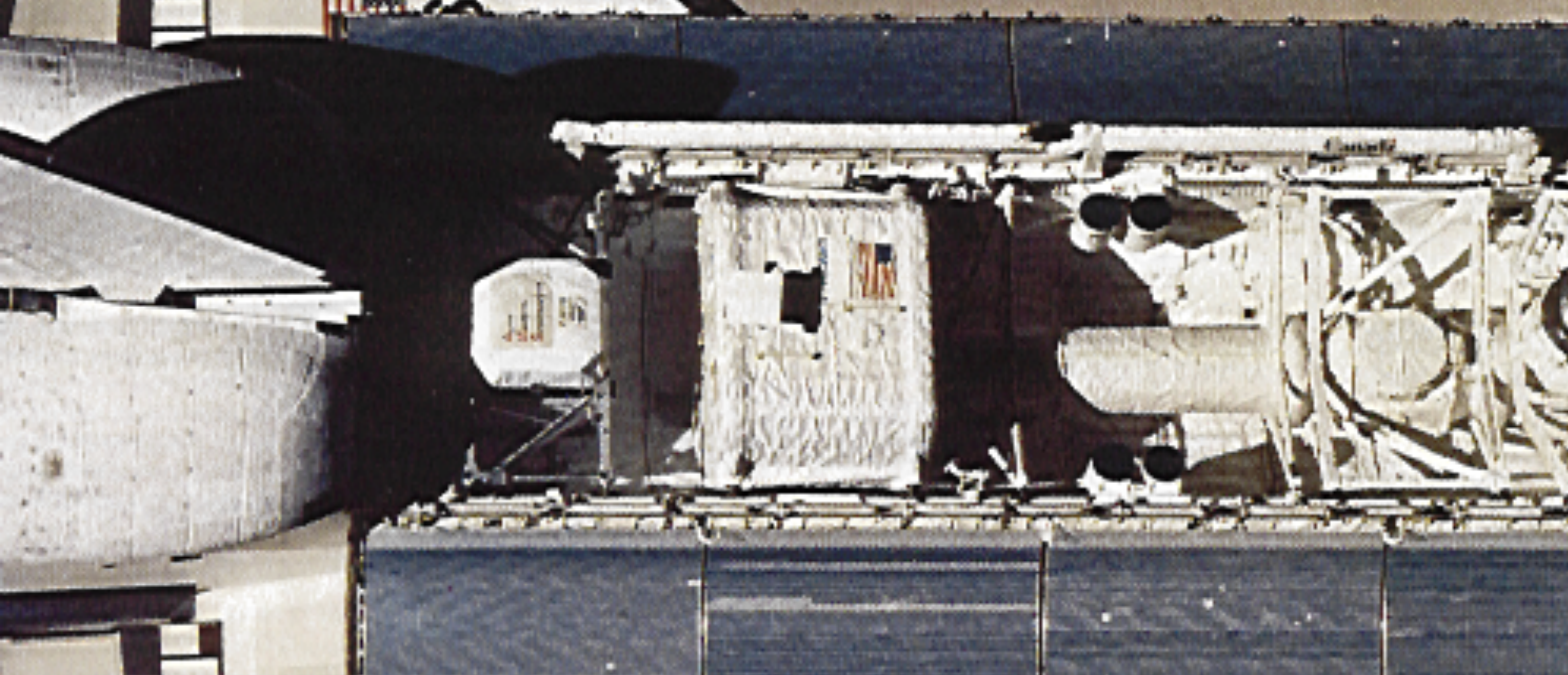


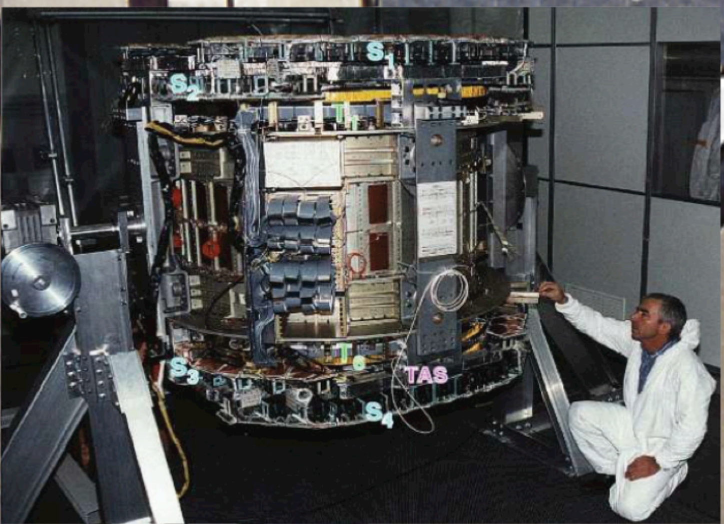
- ✓ Aluminum honeycomb + carbon fiber reinforcement layers
- ✓ Front end electronics disposed vertically on the edge of the plane to save acceptance
- ✓ Thermal bars to dissipate the power on the magnet mass outside

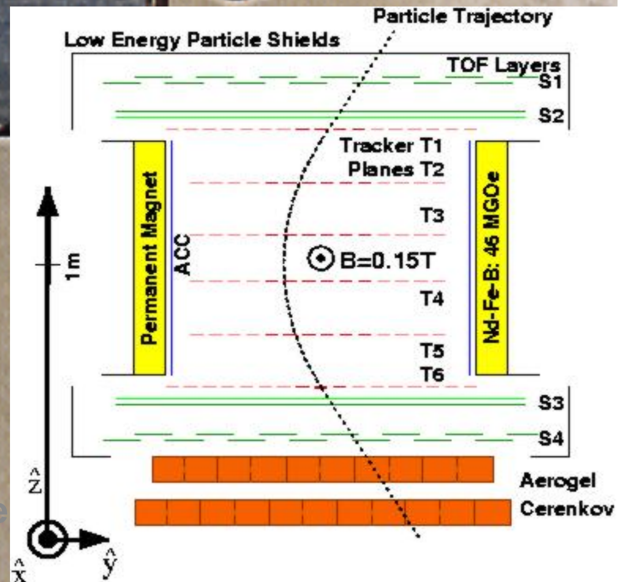


Lightweight carbon fiber shell to hold the planes

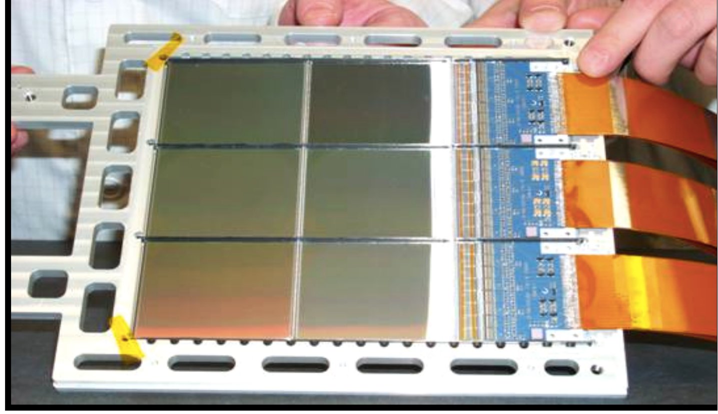
Alpha Magnetic Spectrometer on STS-91
AMS-01 (1998)
First silicon tracker in space



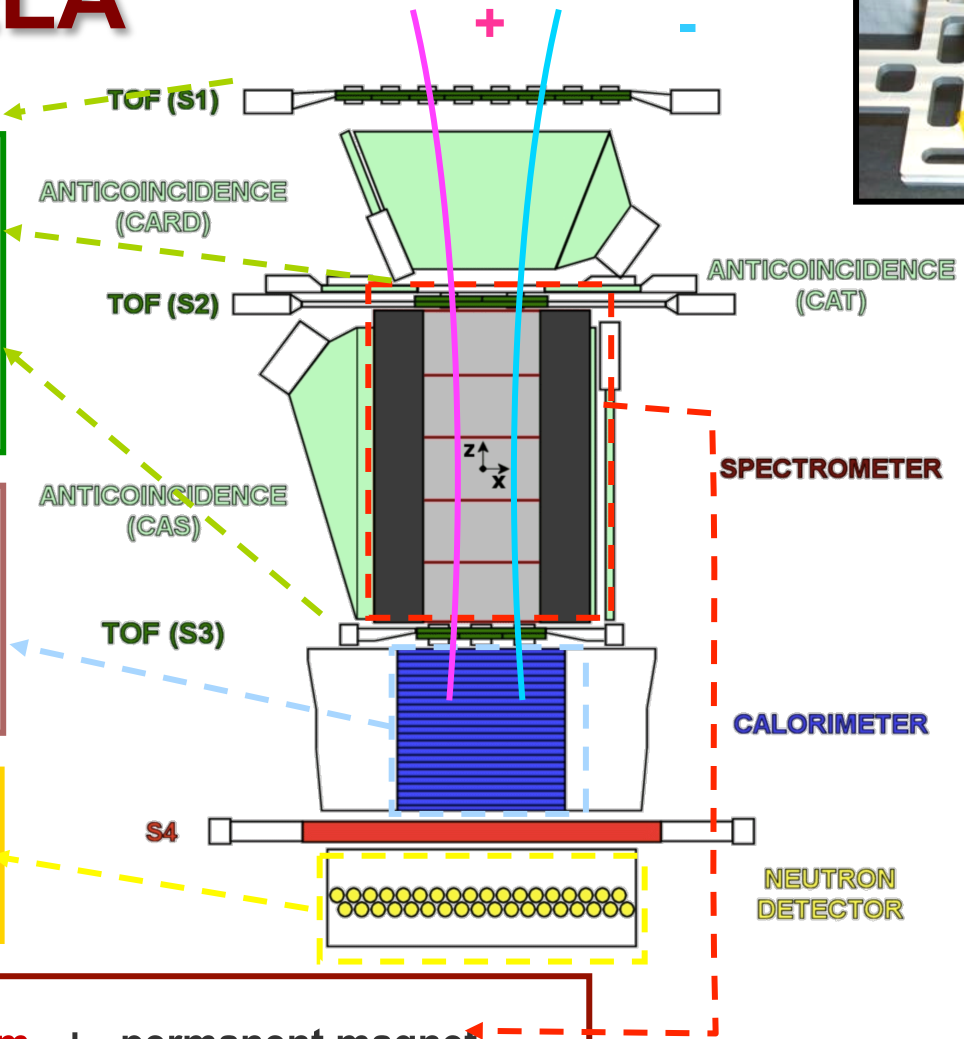




2006: PAMELA



Silicon detectors with electronics: 6 layers in a cavity 13x16 cm²



Time-Of-Flight
plastic scintillators + PMT:
- Trigger
- Albedo rejection;
- Mass identification up to 1 GeV;
- Charge identification from dE/dX.

Electromagnetic calorimeter
W/Si sampling (16.3 X0, 0.6 λI)
- Discrimination e+ / p, anti-p / e^- (shower topology)
- Direct E measurement for e^-

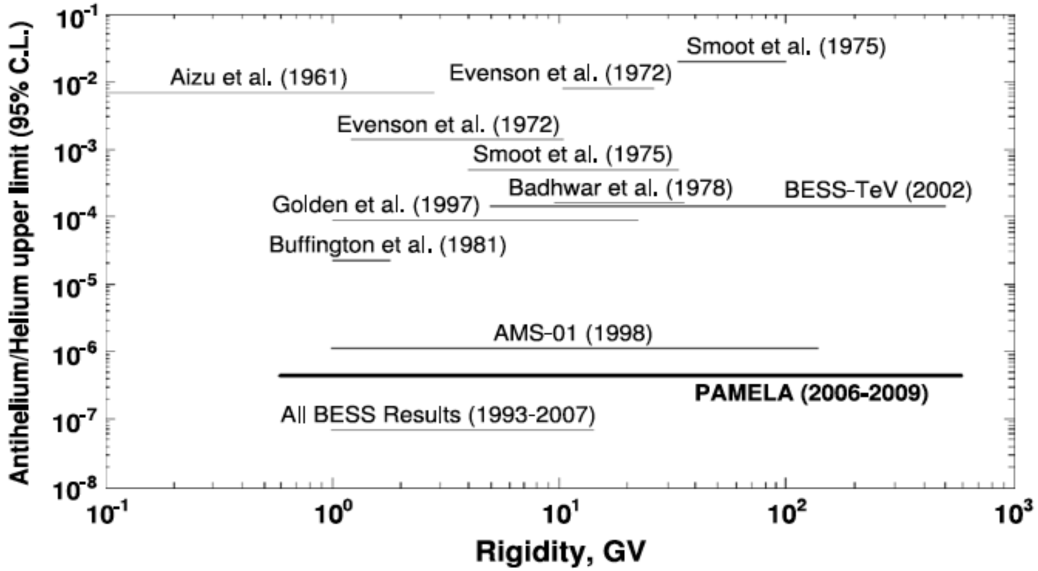
Neutron detector
36 He^3 counters :
- High-energy e/h discrimination

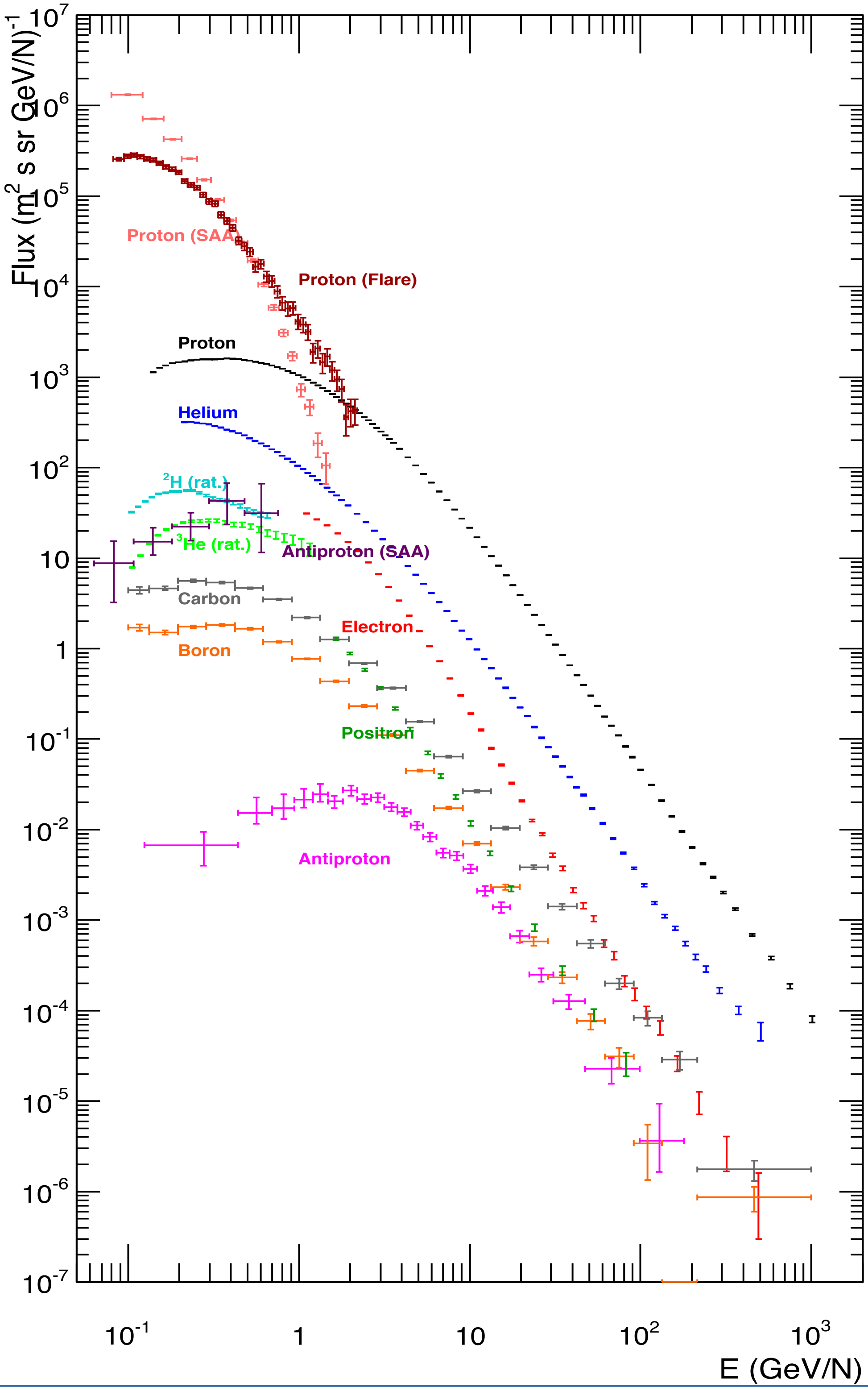
Spectrometer
microstrip silicon tracking system + permanent magnet
It provides:
- *Magnetic rigidity* → R = pc/Ze MDR≈1(0.25) TV
- *Charge sign*
- *Charge value from dE/dx*

GF: 21.5 cm^2 sr
Mass: 470 kg
Size: 130x70x70 cm^3
Power Budget: 360W

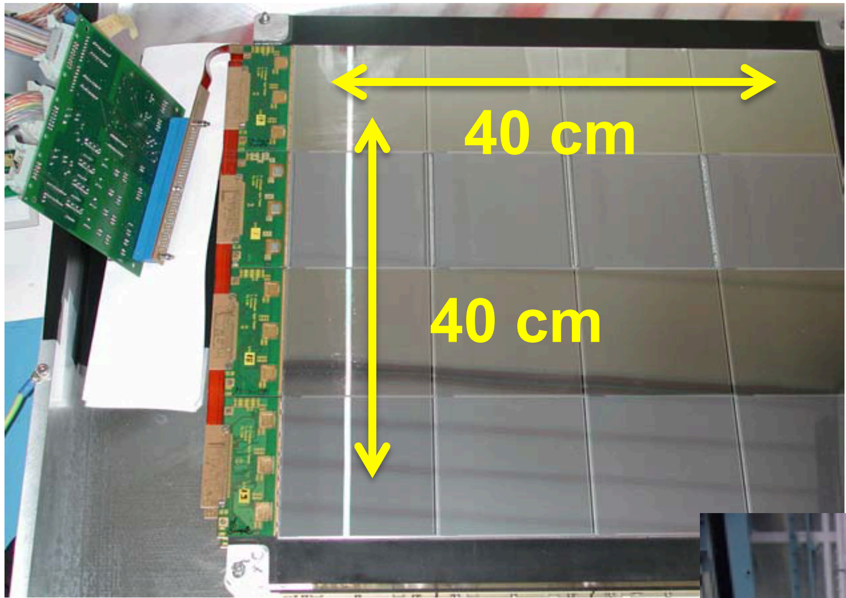
All particle results

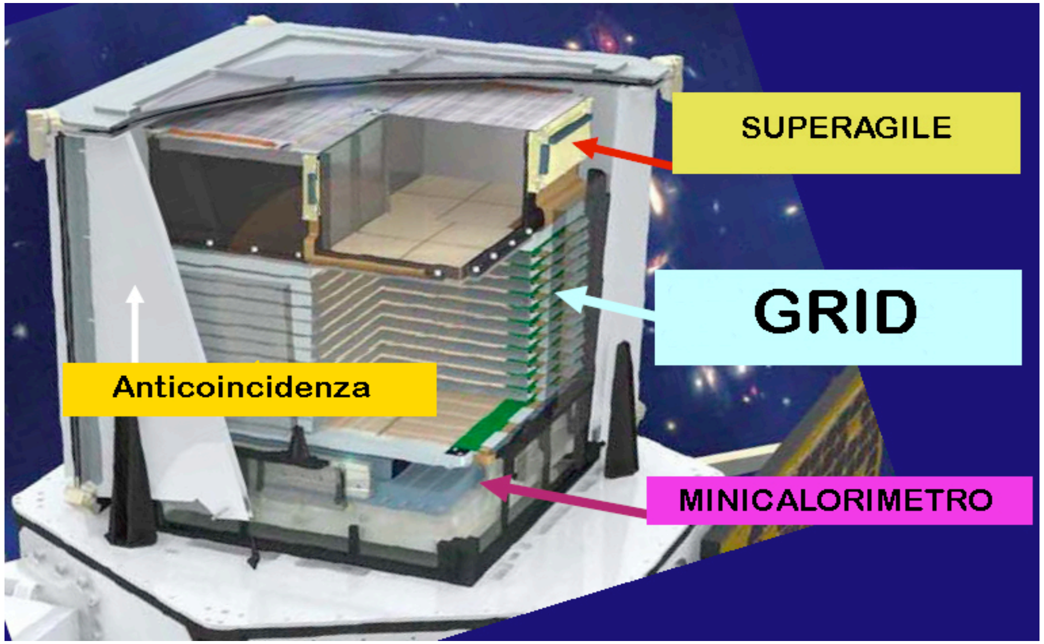
- → Antiparticles
- → Galactic CR
- → Solar Physics
- → Particles in Earth's magnetosphere

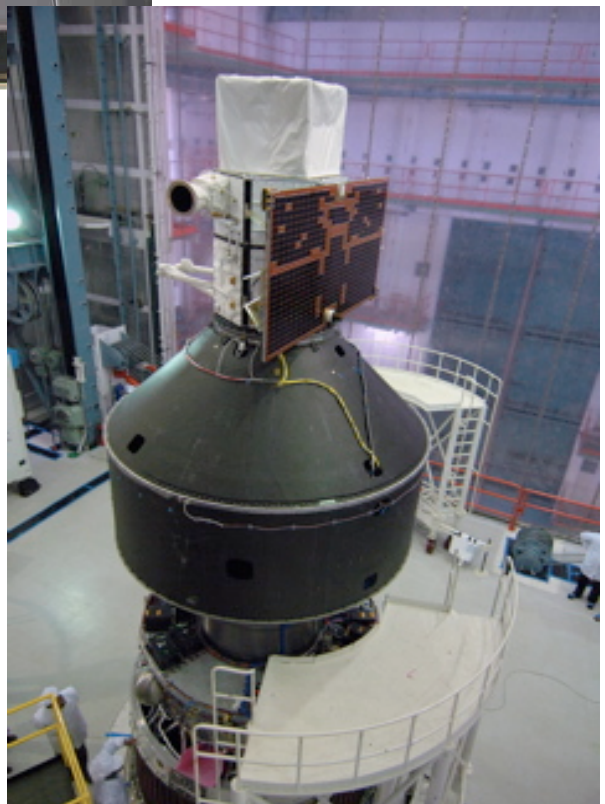


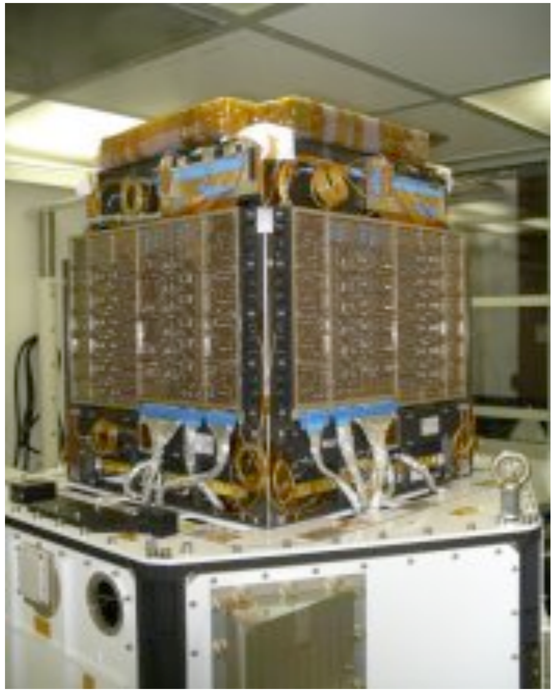


AGILE 2007 (x,γ)

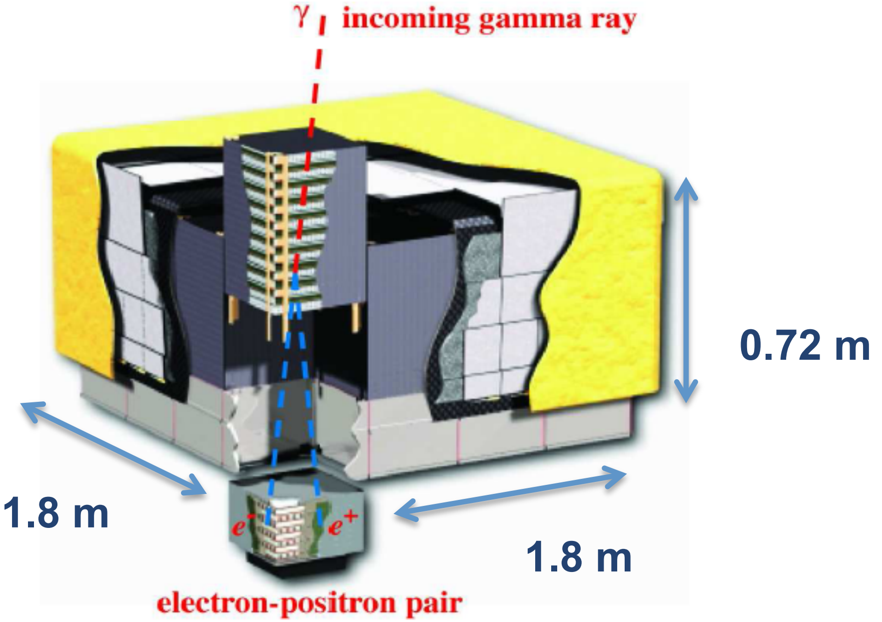


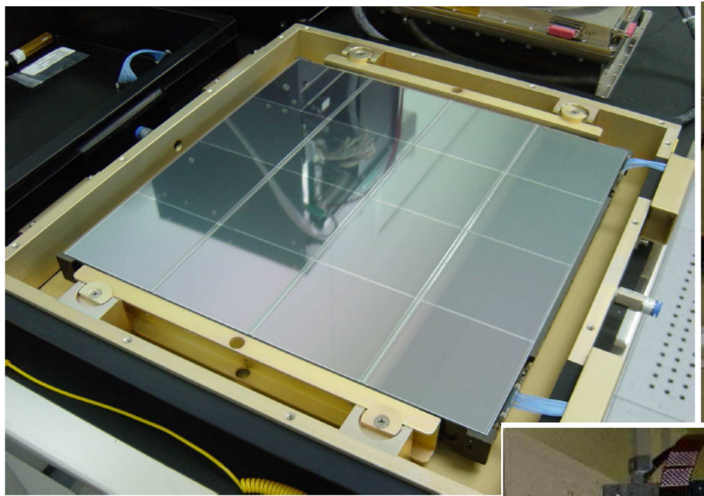


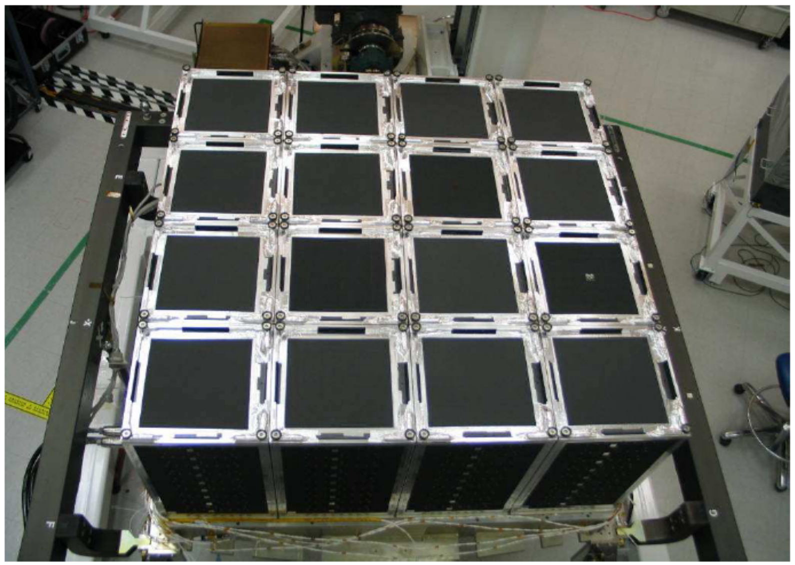


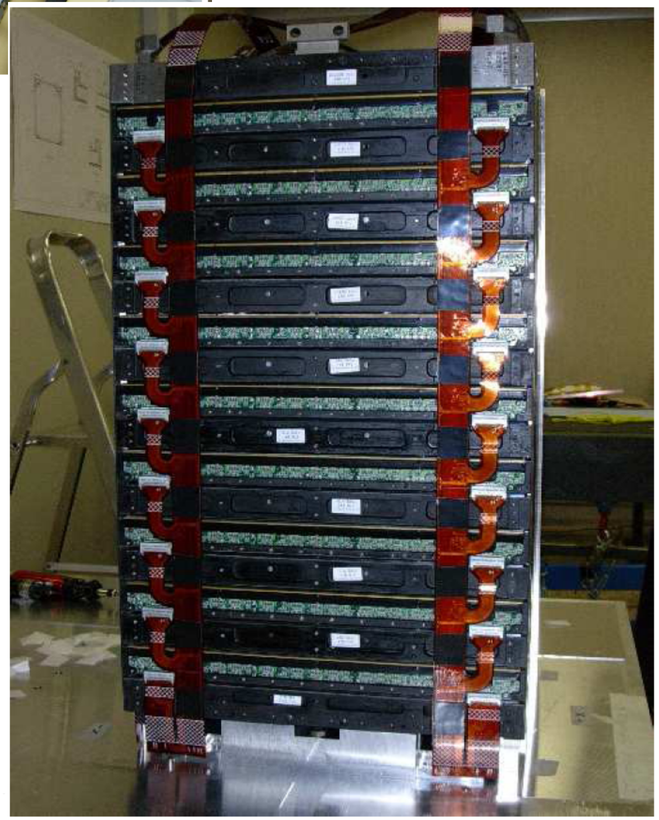


FERMI 2008 : 73 m² of silicon sensors

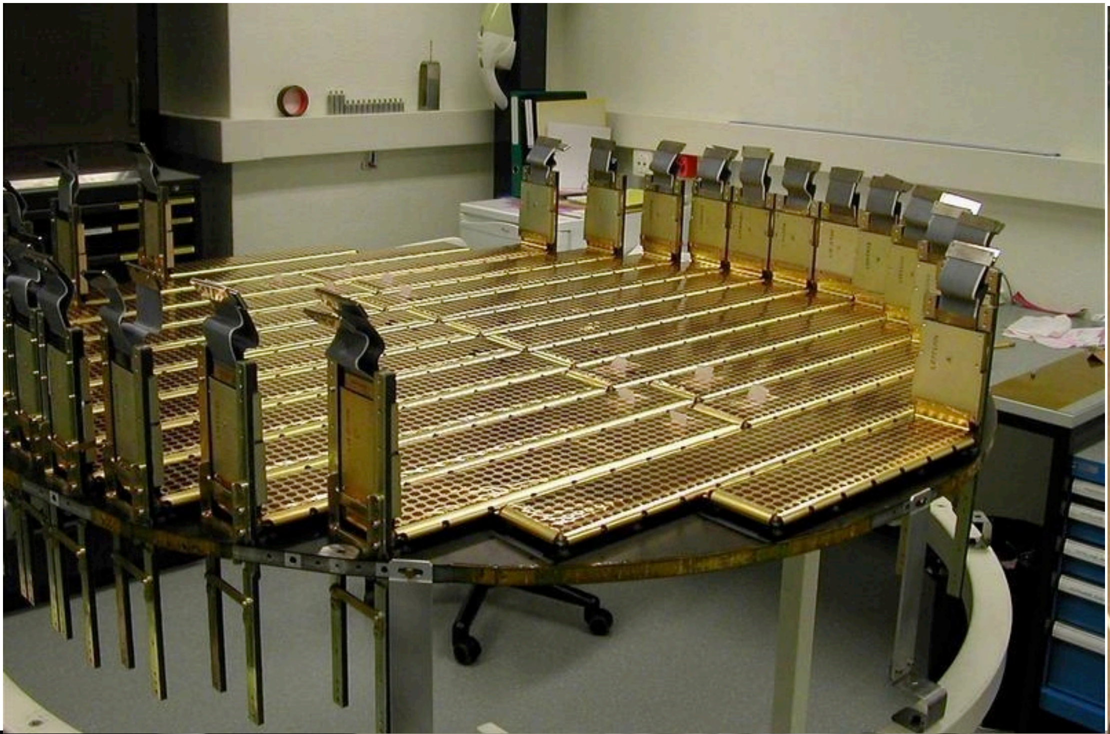


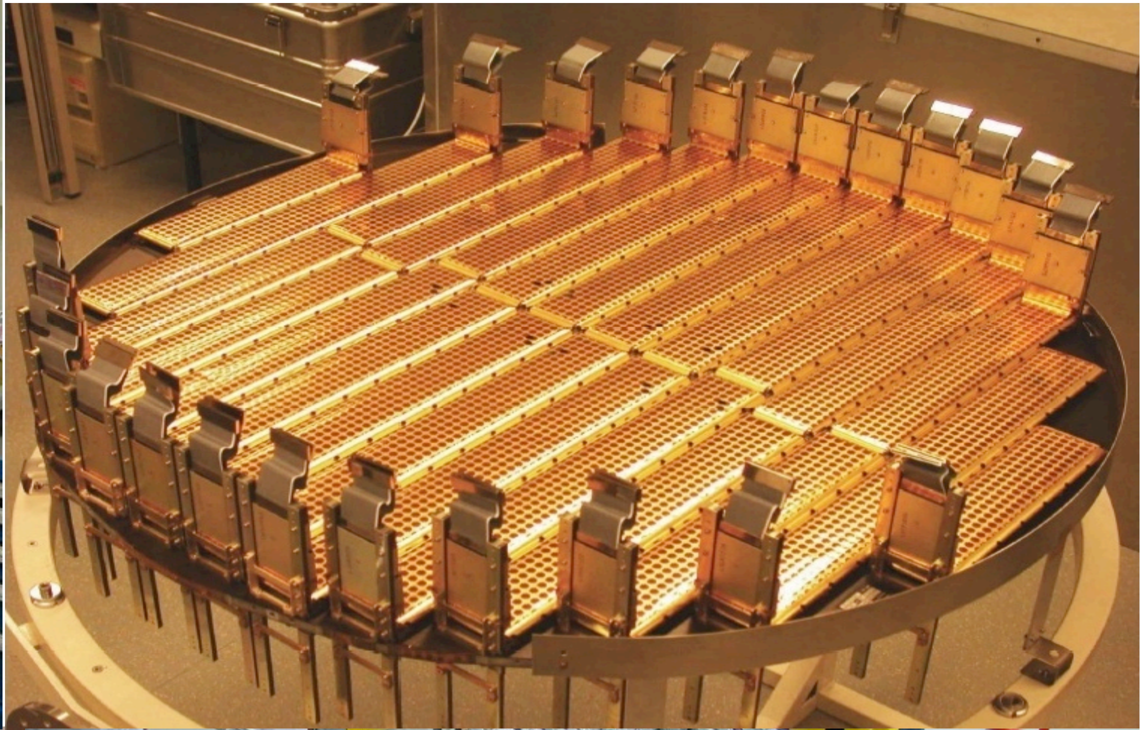


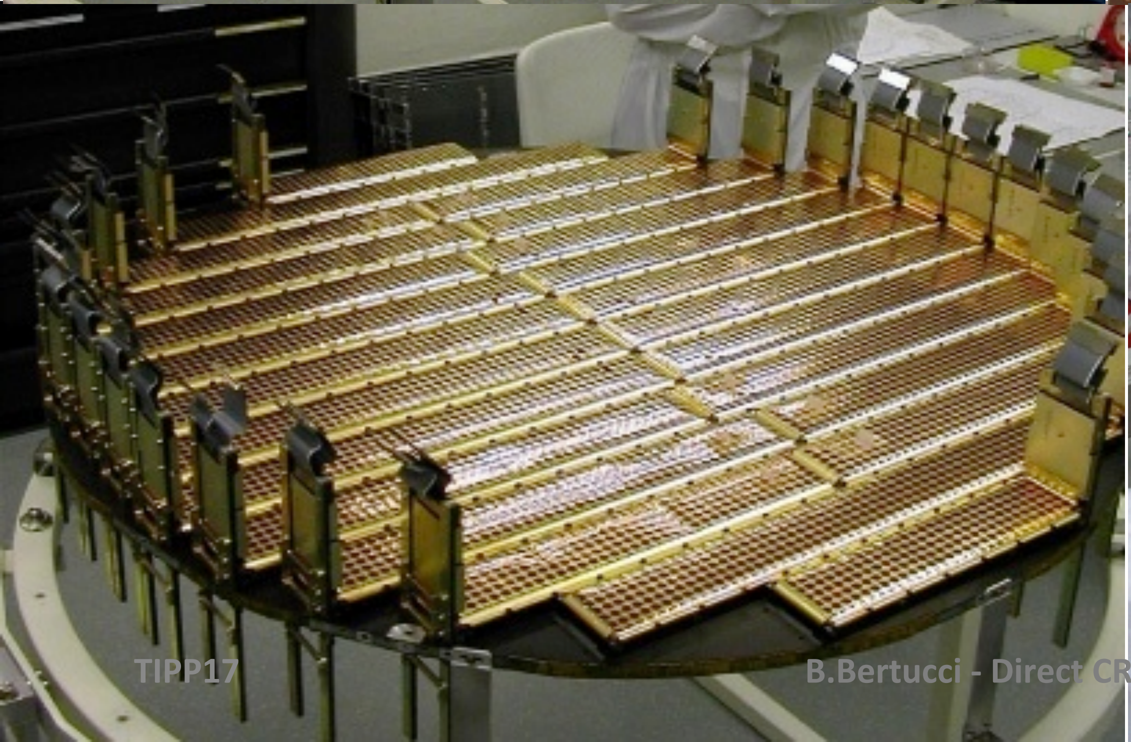




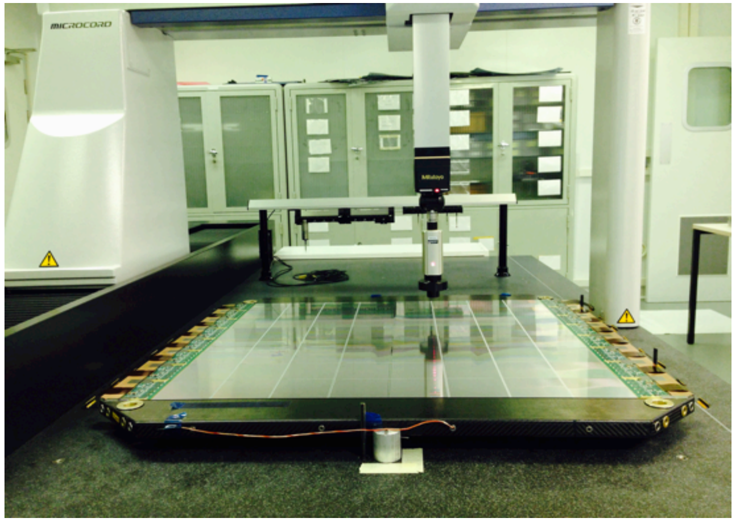
2011 AMS-02: 9 planes (6.4 m^2)

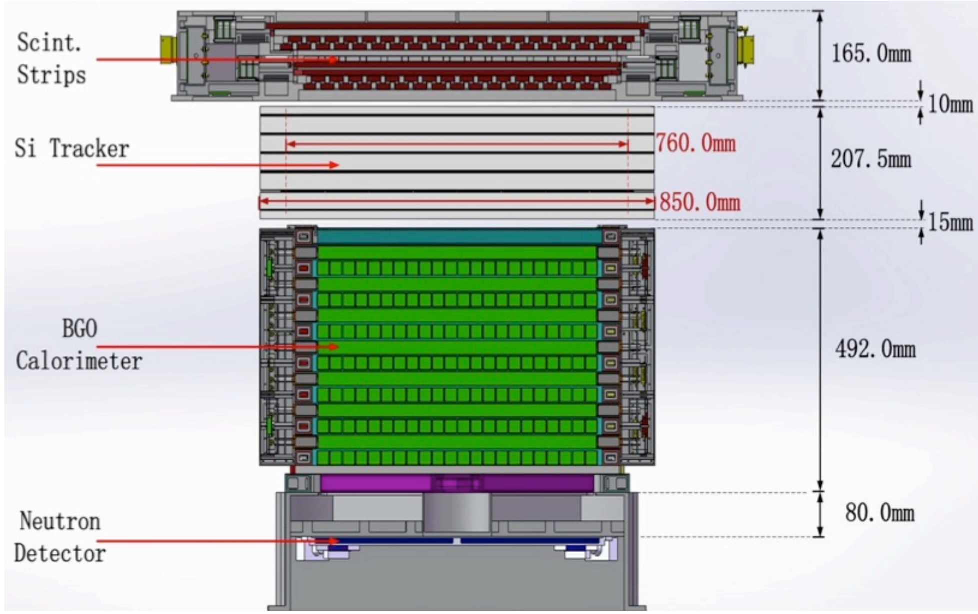


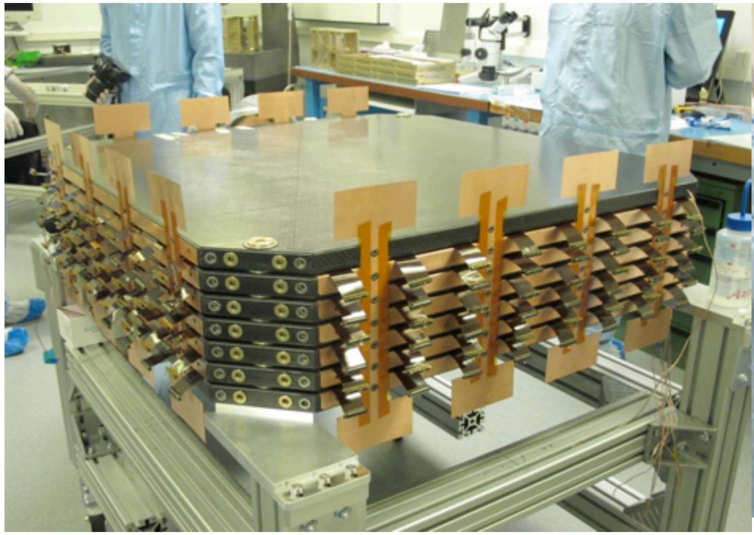


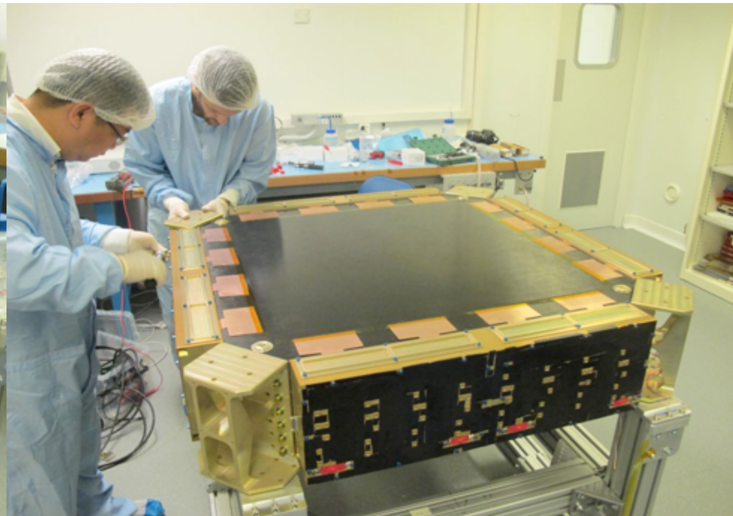


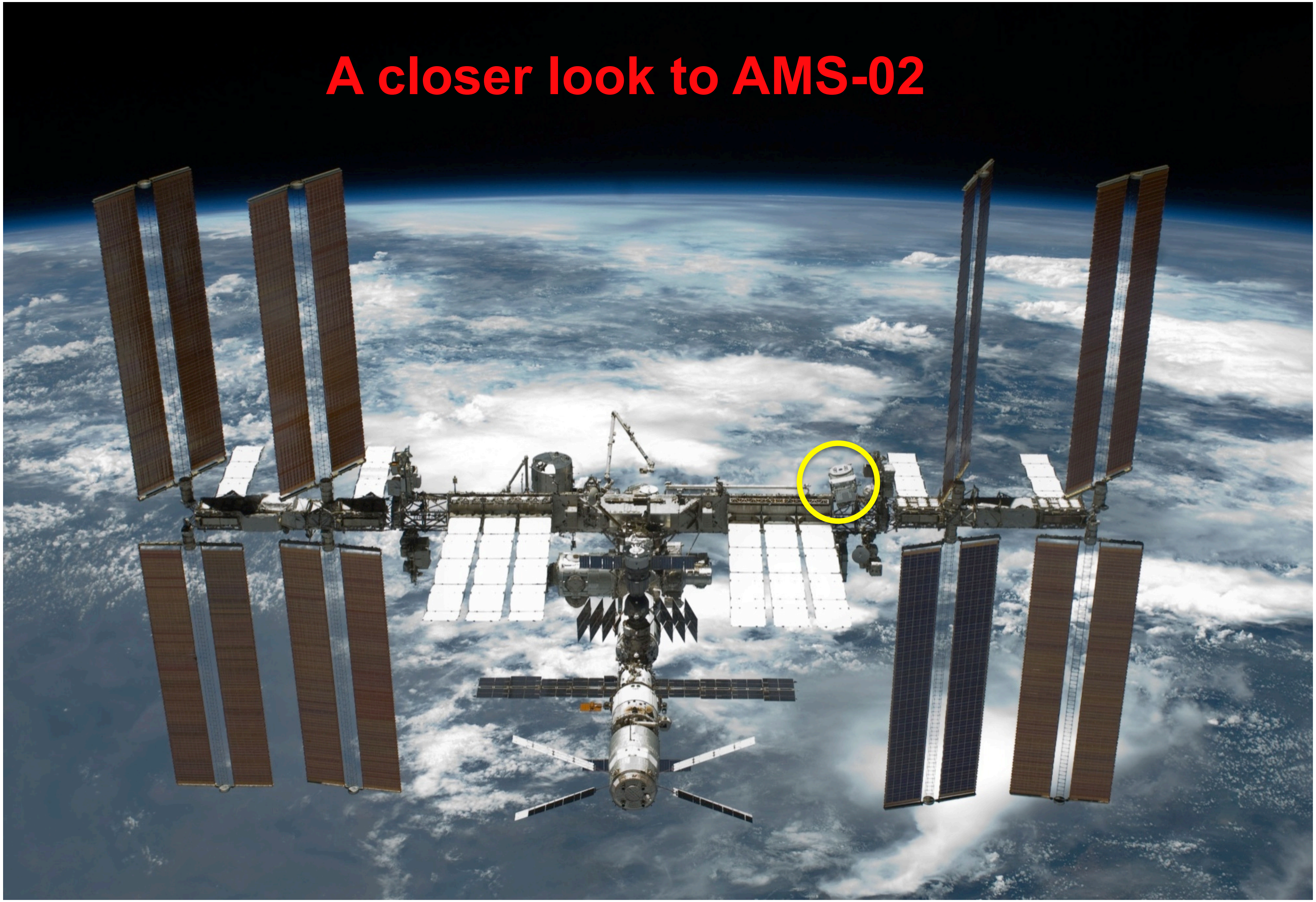
2015 : DAMPE
7.7 m^2 of silicon sensors





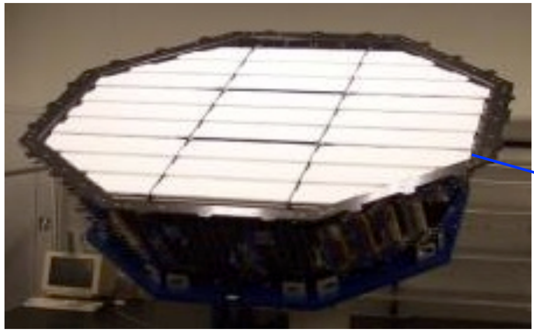




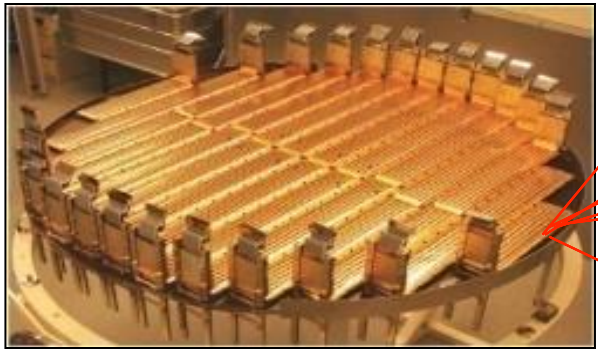

A closer look to AMS-02

AMS-02: A TeV precision, multipurpose spectrometer

Transition Radiation Detector (TRD)
Identify e^+, e^-

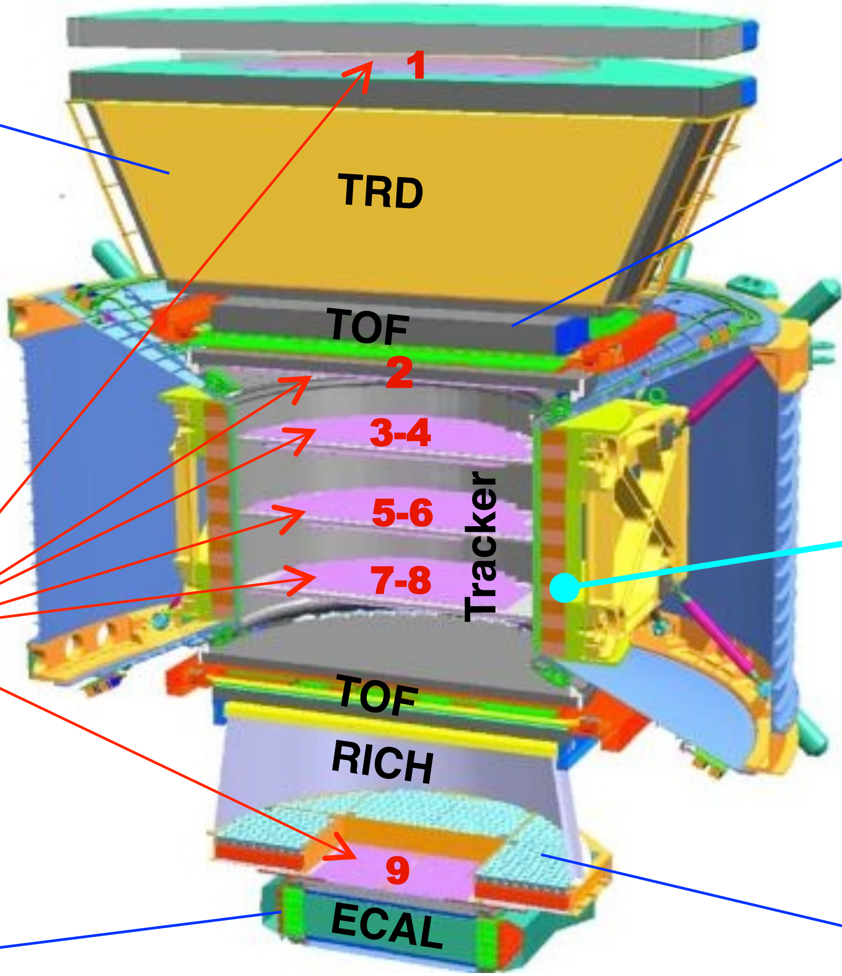


Silicon Tracker
Z, P



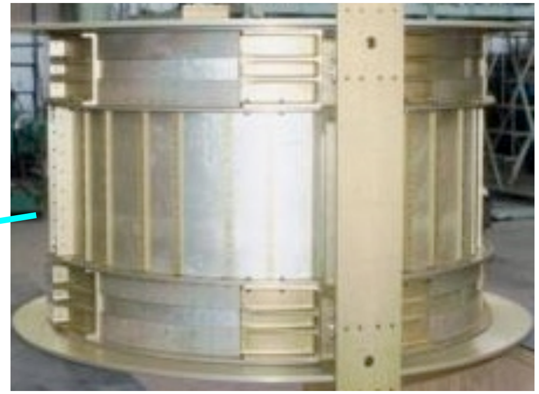
Electromagnetic Calorimeter (ECAL)
E of e^+, e^-, γ

Particles and nuclei are defined by their charge (**Z**) and energy (**E**)



Time of Flight (TOF)
Z, E

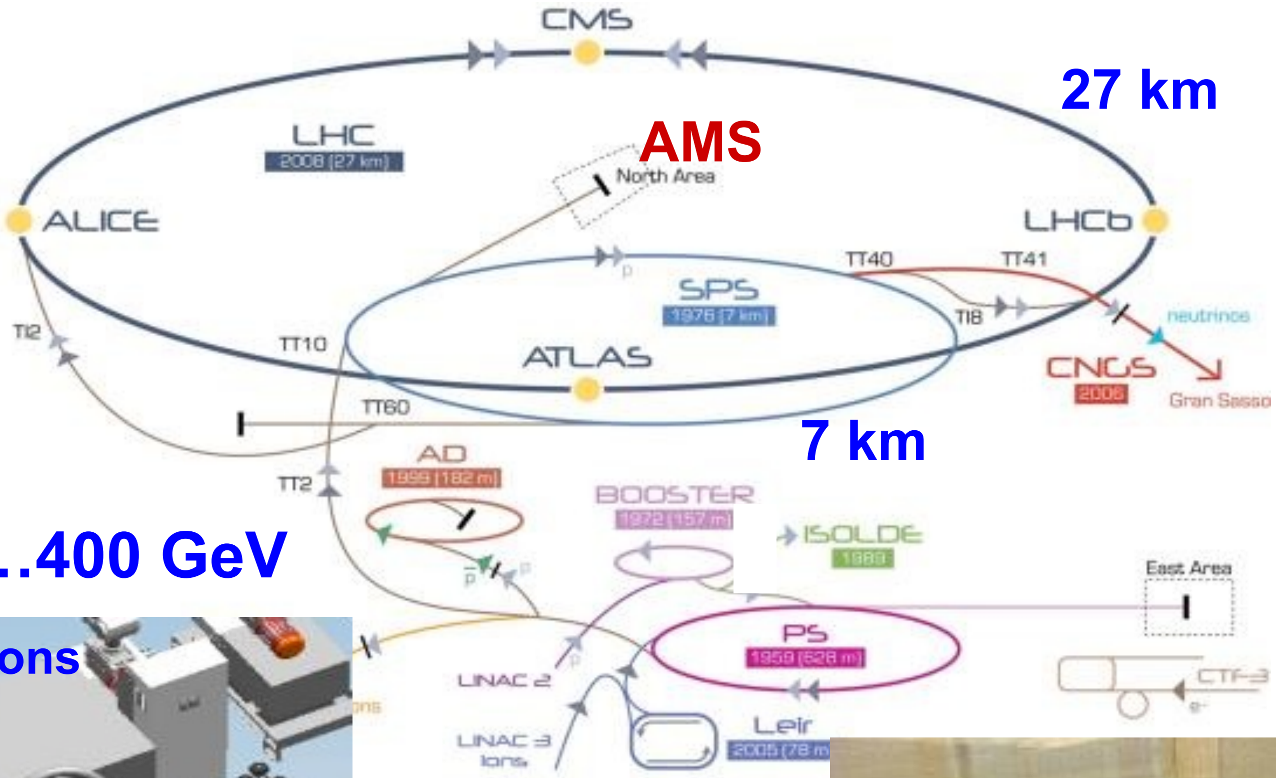
Magnet (0.15 T)
±Z



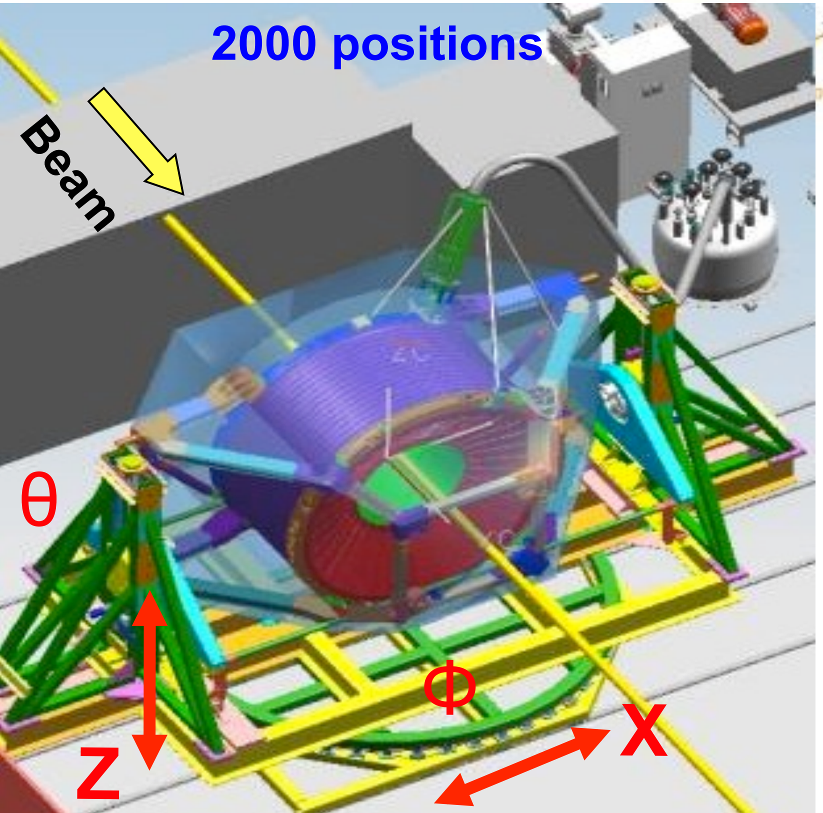
Ring Imaging Cherenkov (RICH)
Z, E

Z, E, R, β
are measured independently by the Tracker, RICH, TOF and ECAL for the same CR

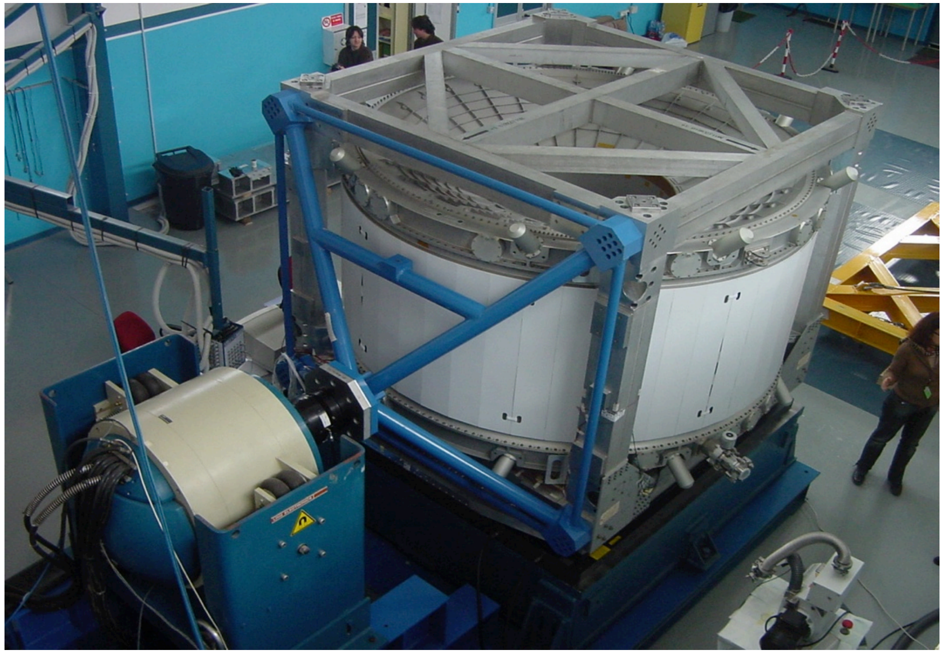
As any HEP experiment: beam test calibration @ CERN

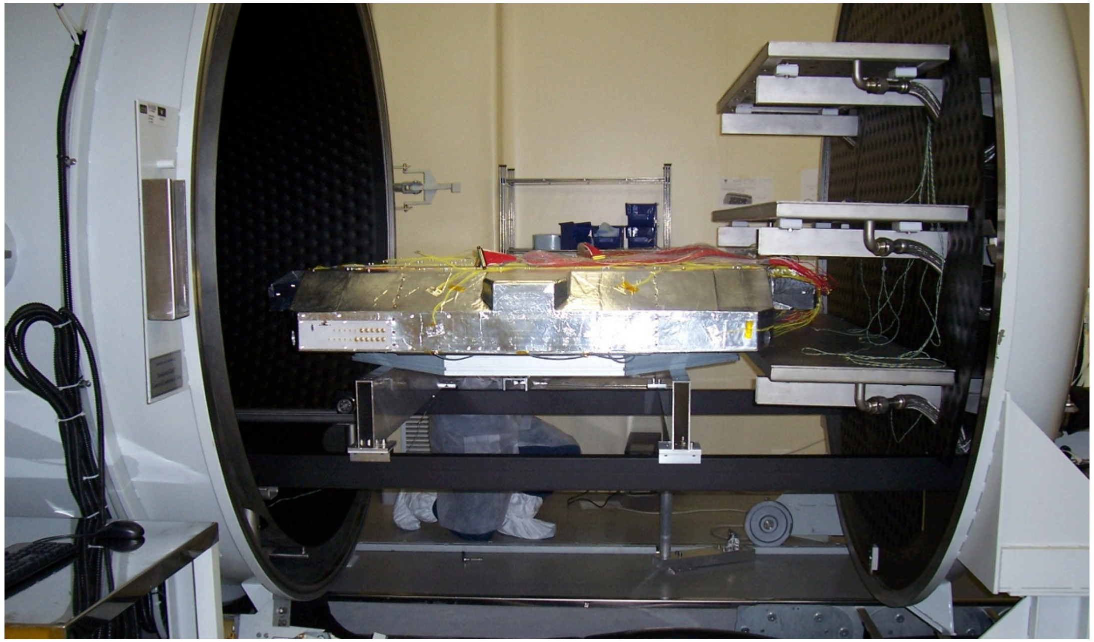


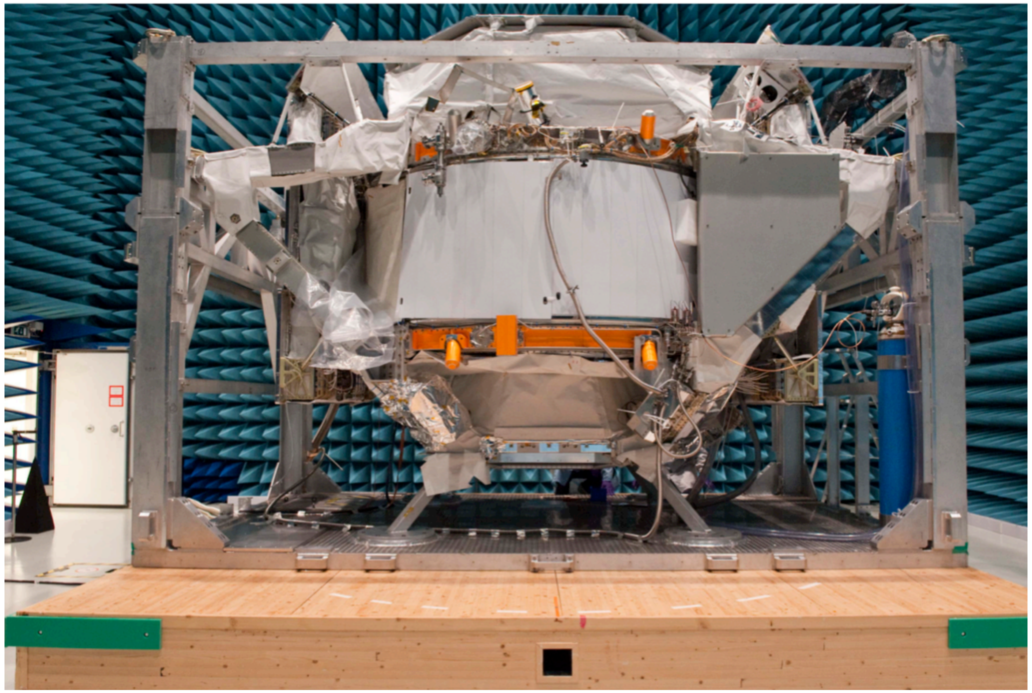
p, e$^+$, e$^-$, π 20…400 GeV

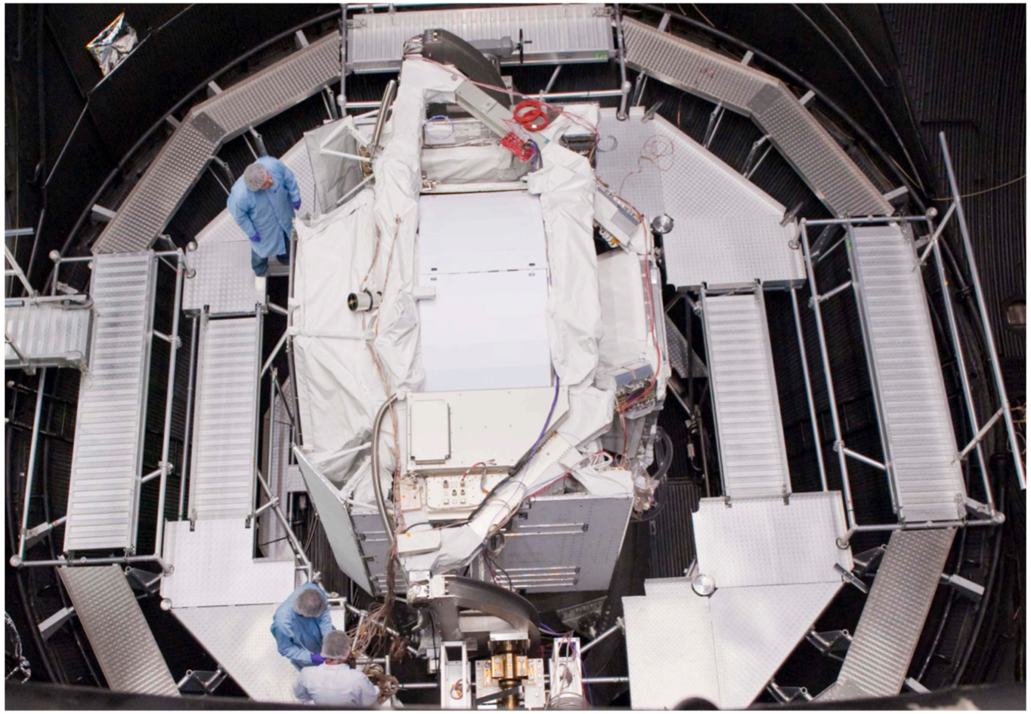


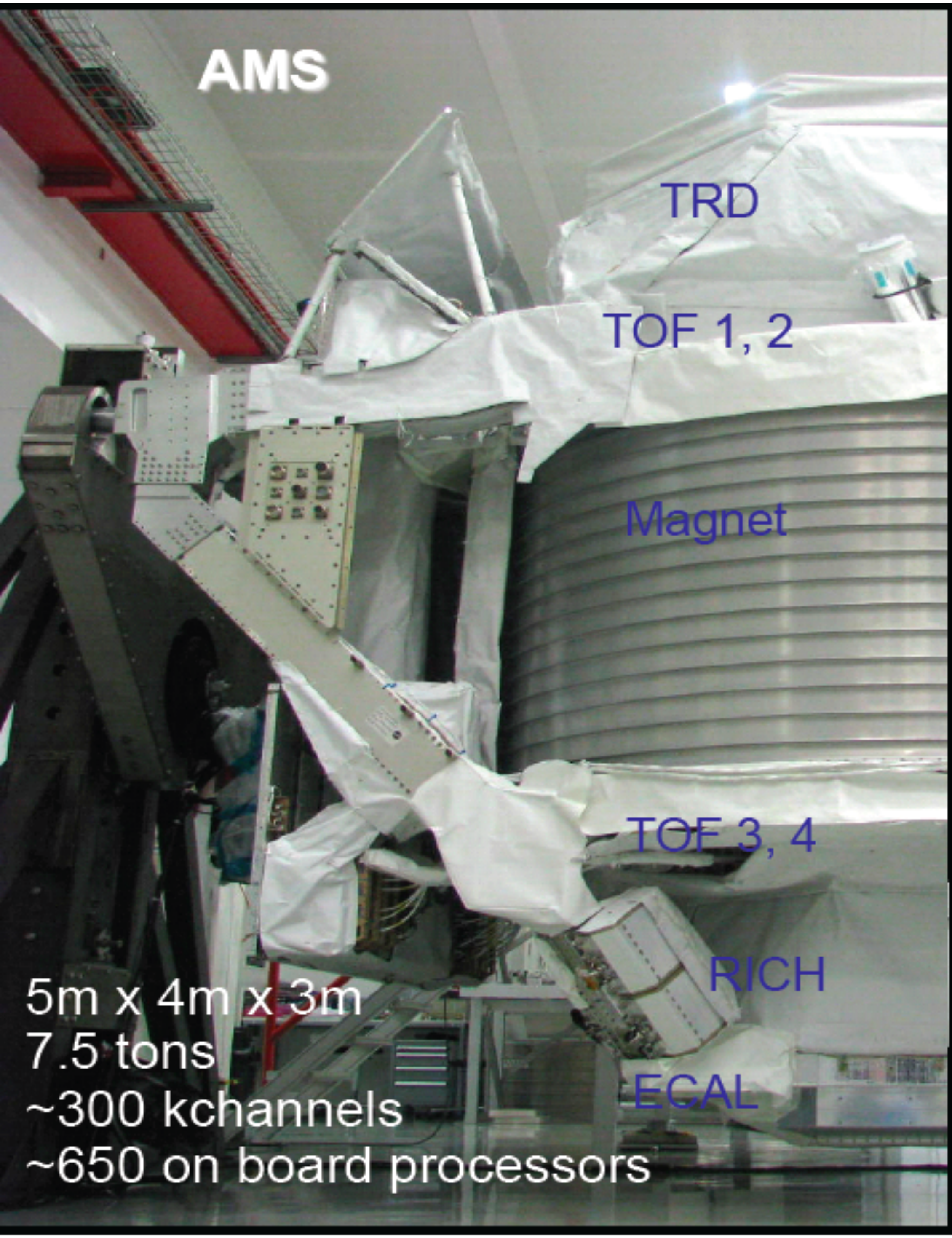
As a space payload: qualification tests before and after assembly

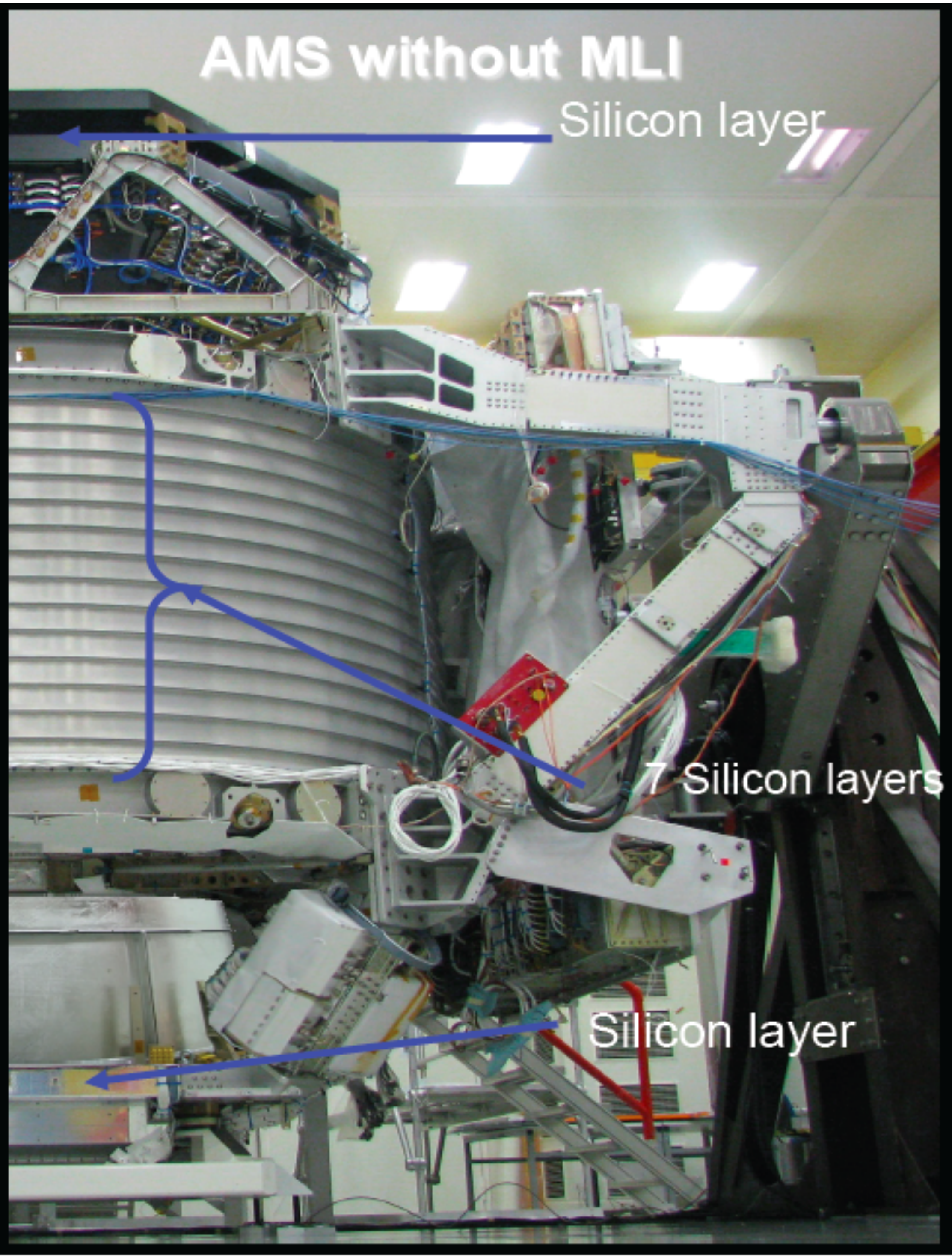






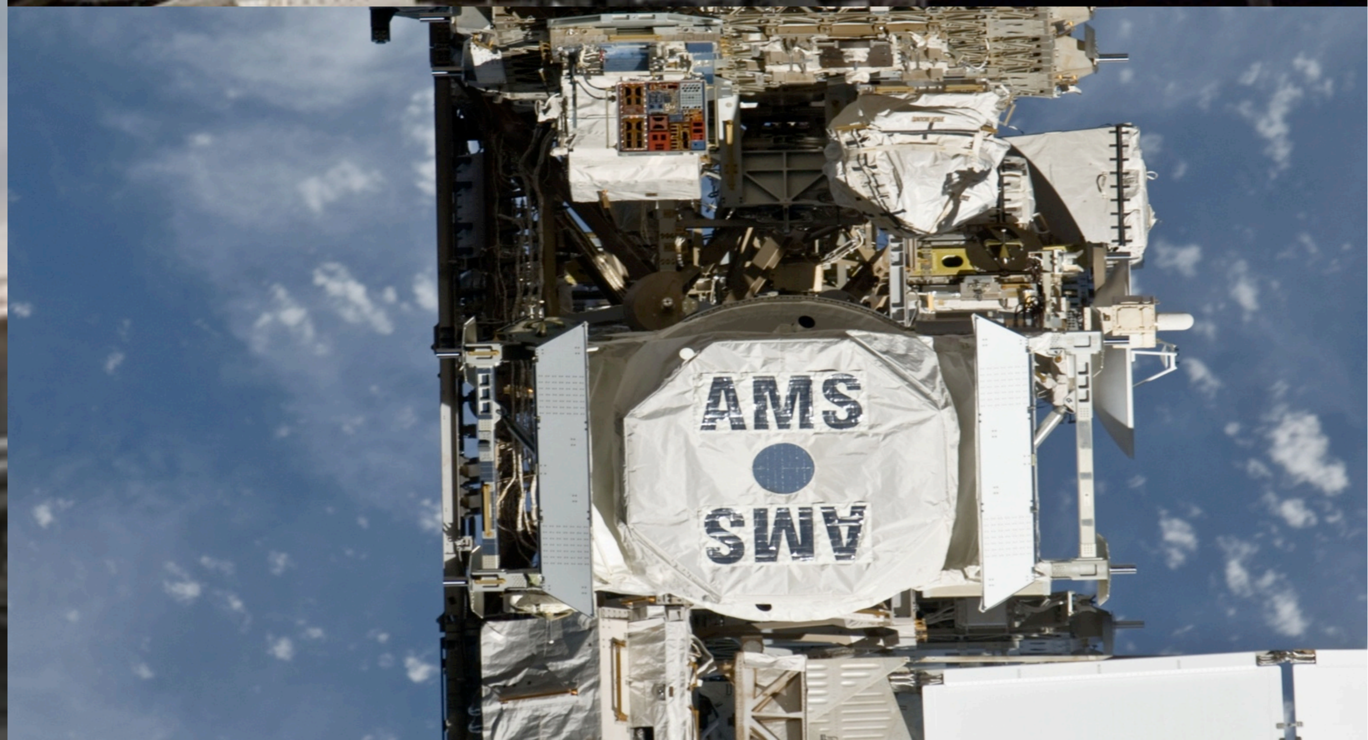



AMS
TRD
TOF 1, 2
Magnet
TOF 3, 4
RICH
ECAL
5m x 4m x 3m
7.5 tons
~300 kchannels
~650 on board processors

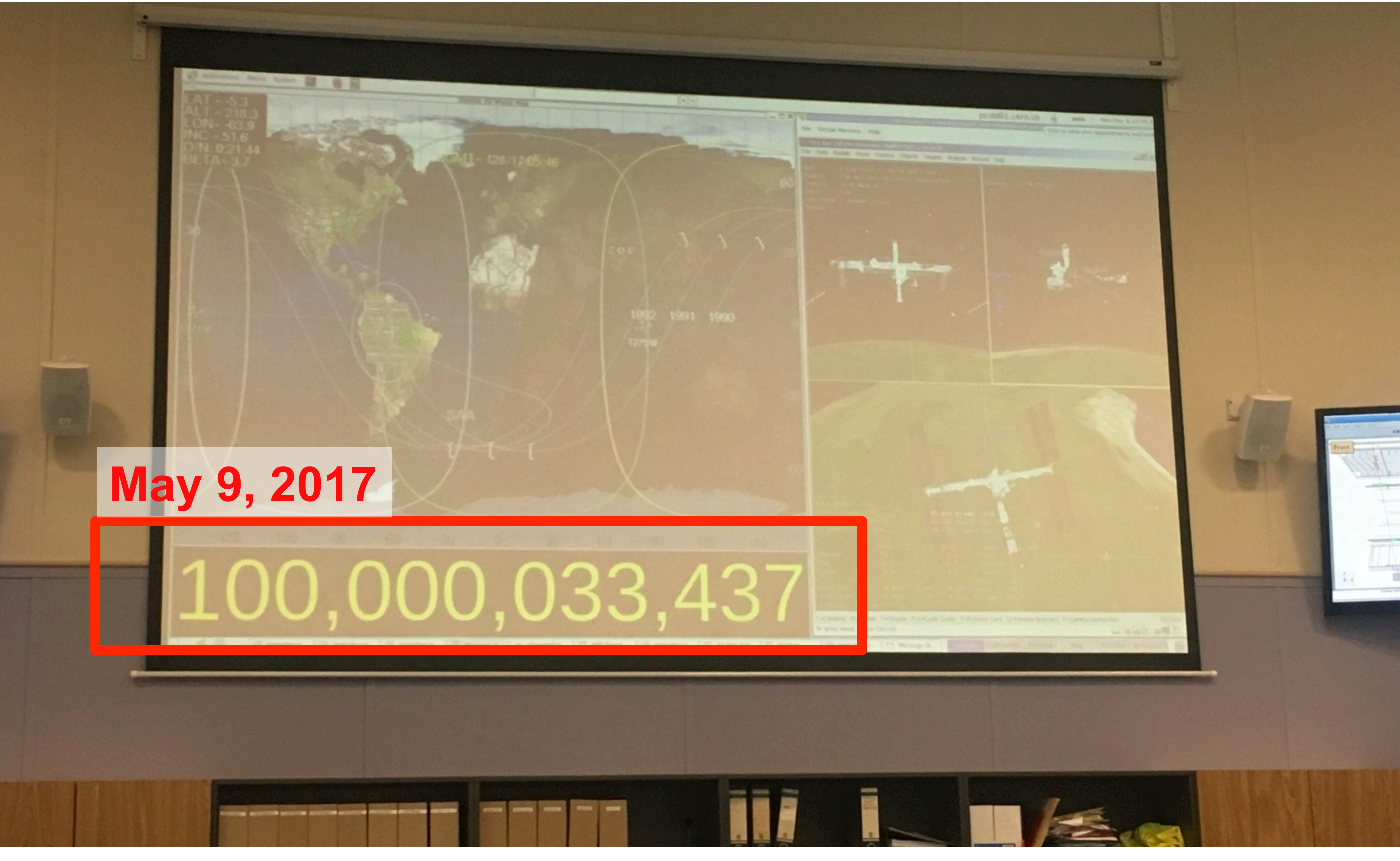

AMS without MLI
Silicon layer
7 Silicon layers
Silicon layer


Launch of AMS
May 16, 2011

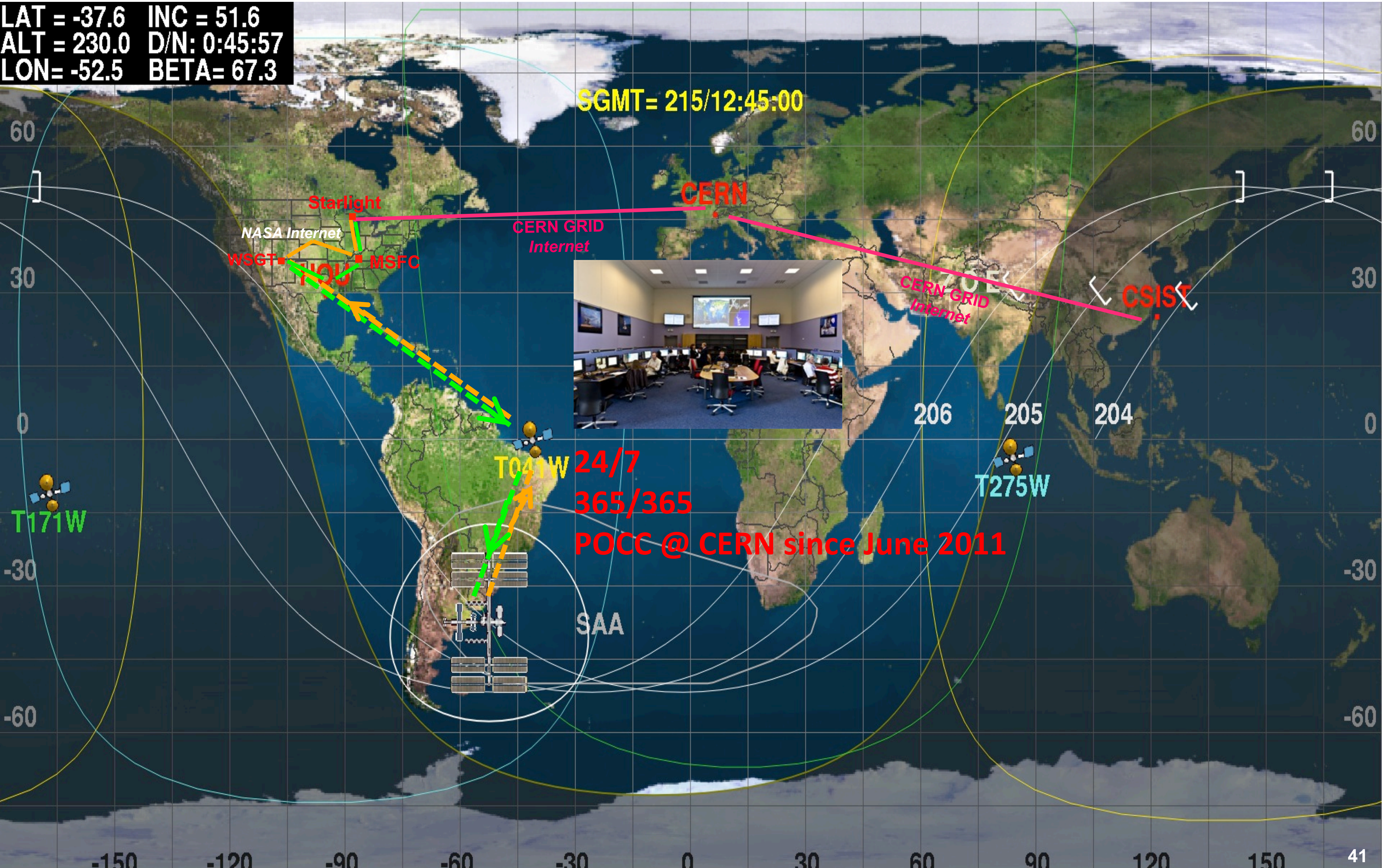

AMS on ISS
May 19, 2011


AMS

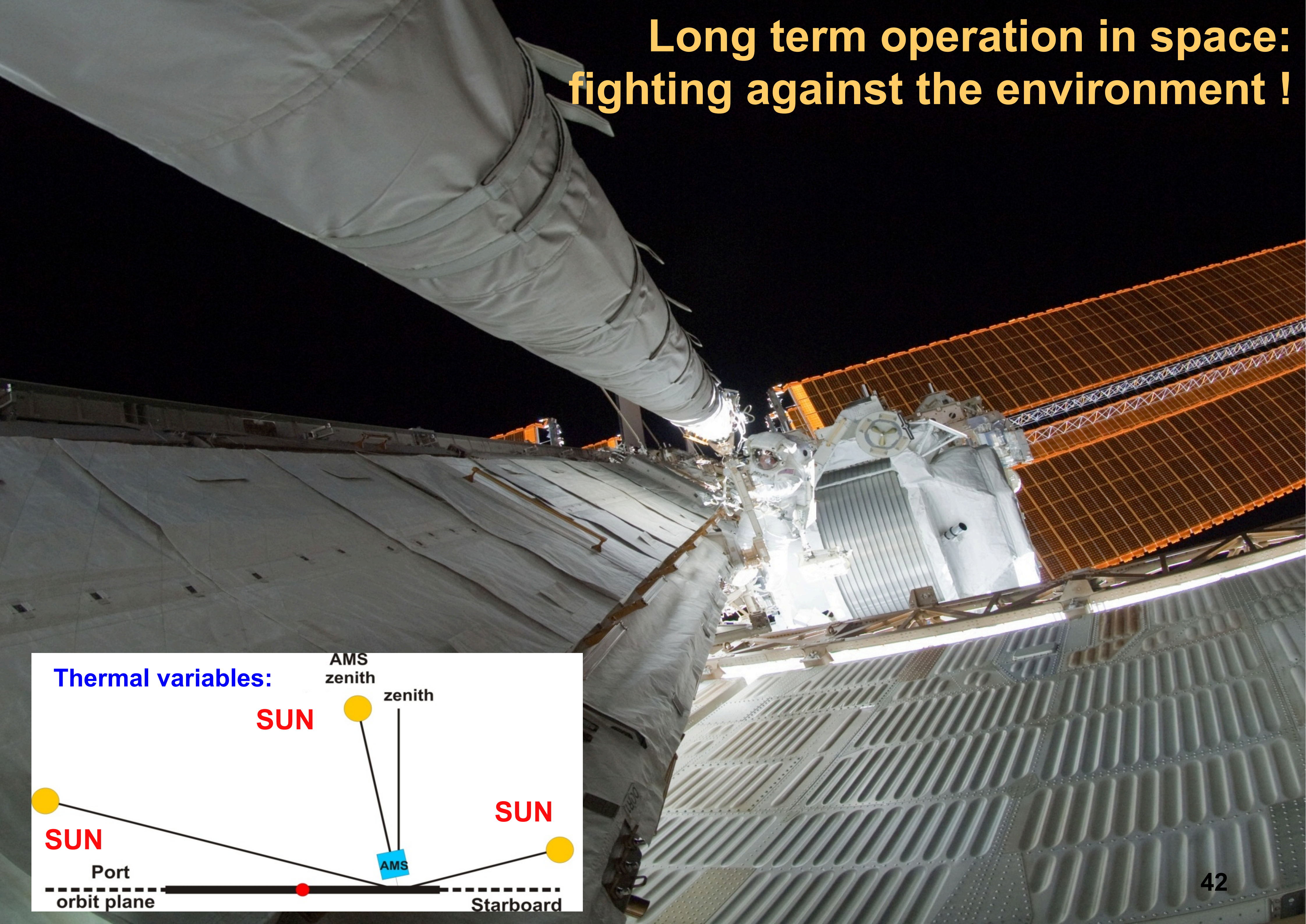
Operation in Orbit



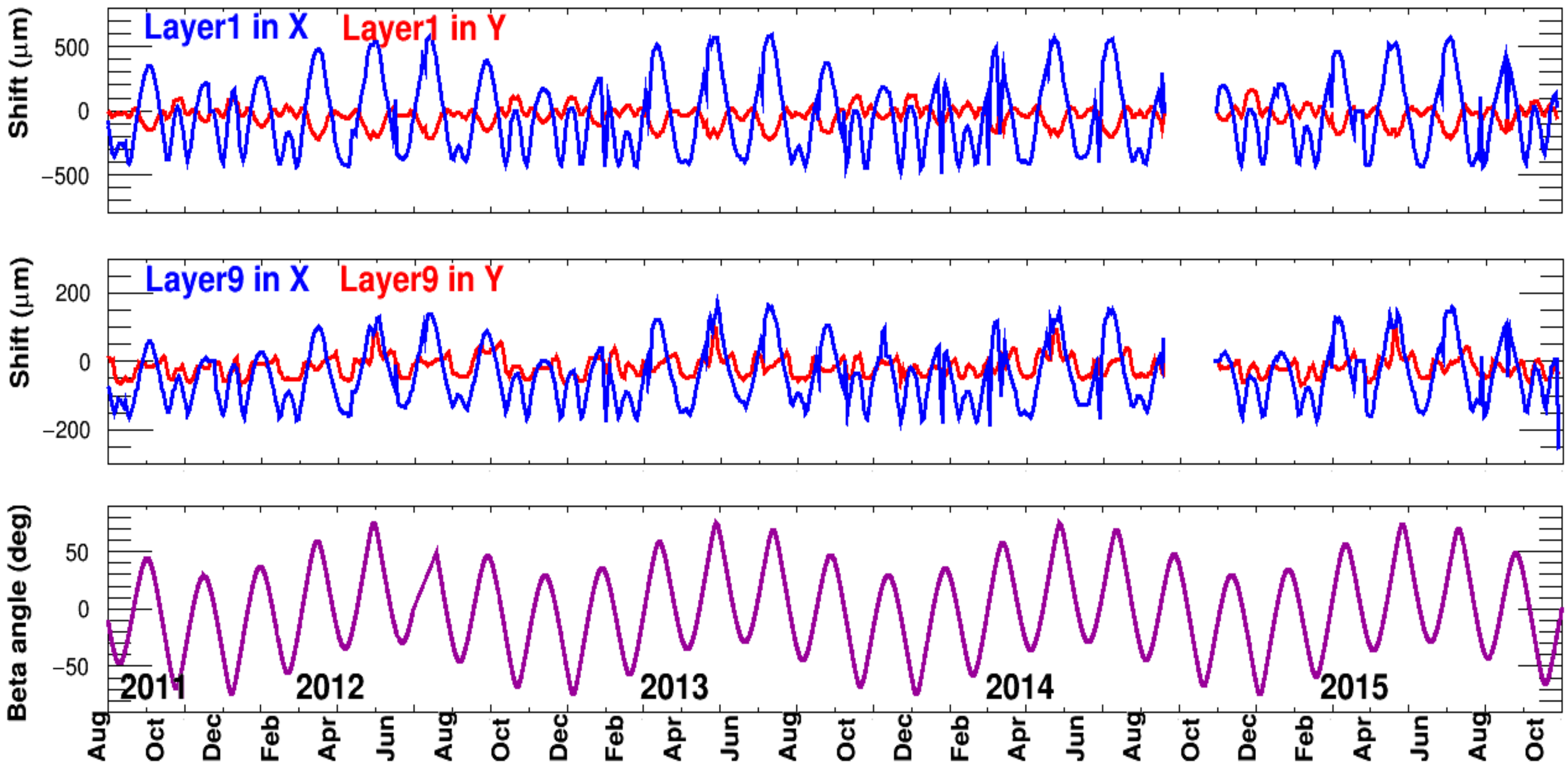
Operation in Orbit



Long term operation in space: fighting against the environment !



Temperature & Tracker displacements

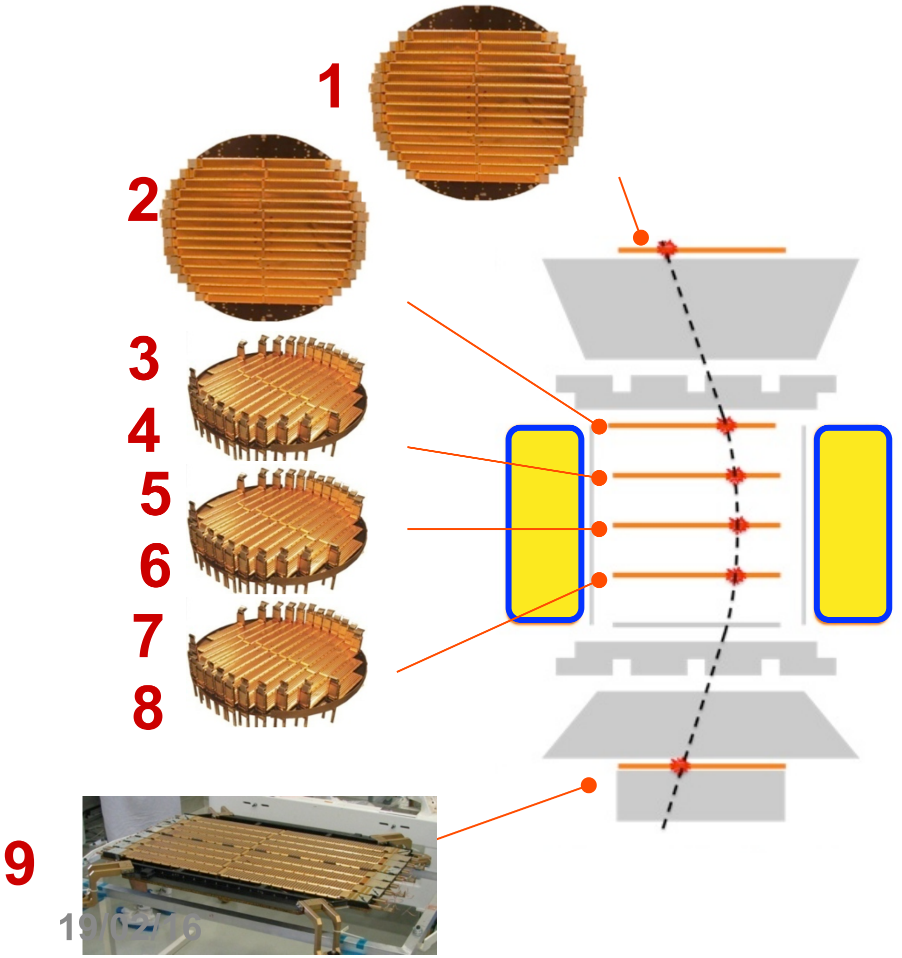


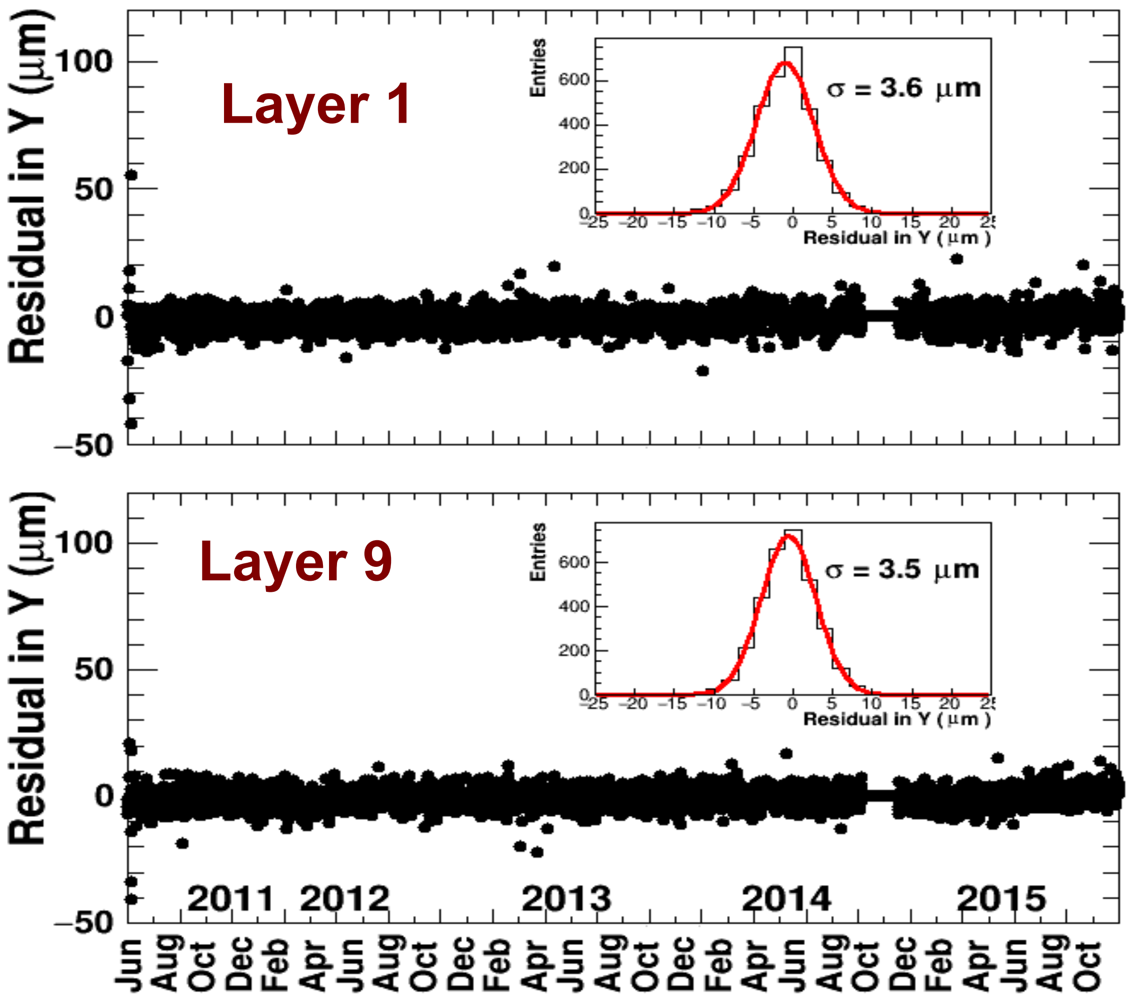
Tracker alignment

9 layers of double sided silicon microstrip detectors to reconstruct the particle trajectory with 10 μ resolution in the bending plane

→ **20 –UV Lasers to monitor inner tracker alignment**

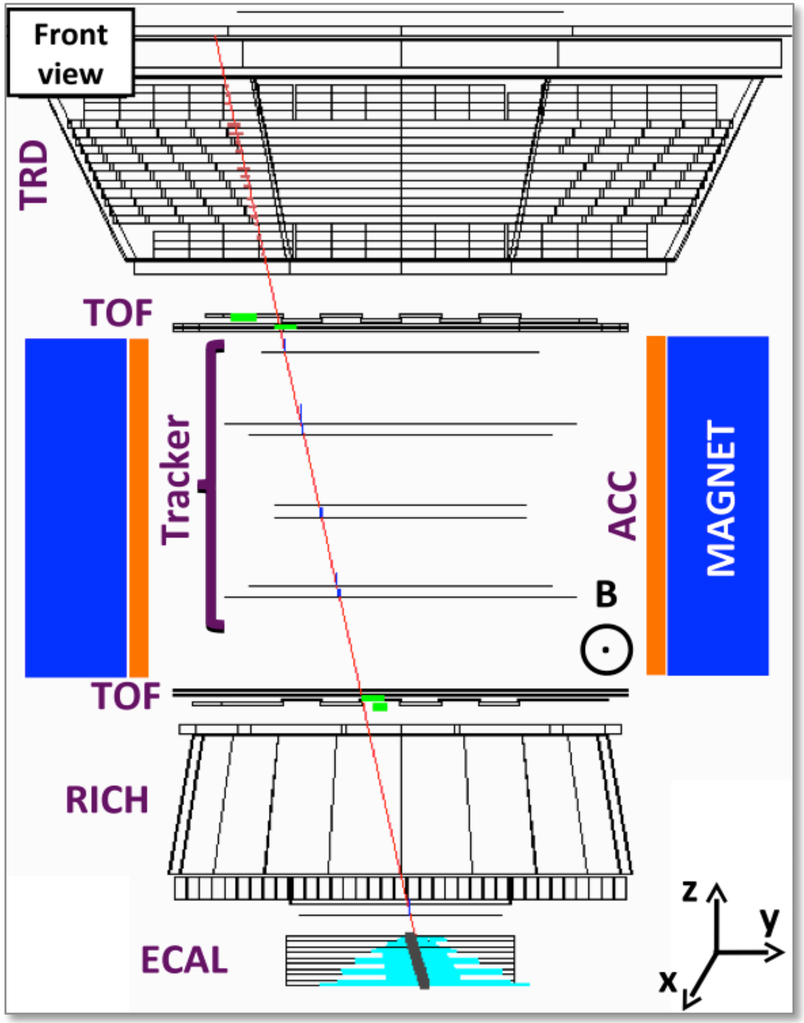
→ **Cosmic rays to monitor outer tracker alignment**

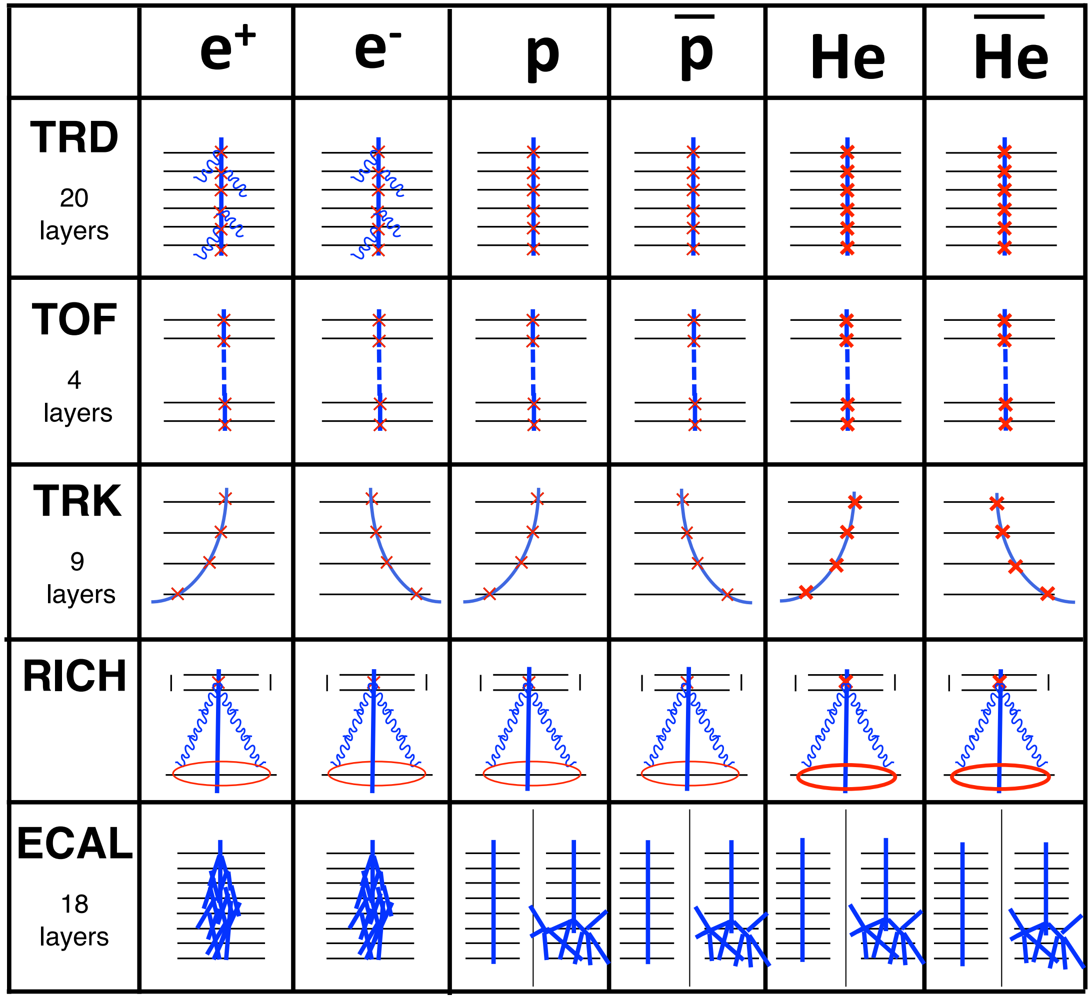




Full coverage of anti-matter & CR physics

600 GeV electron





e/p separation
charge (|Z|)

trigger
velocity (β)
charge (|Z|)

momentum (p)
sign (±Q)
charge (|Z|)

velocity (β)
charge (|Z|)

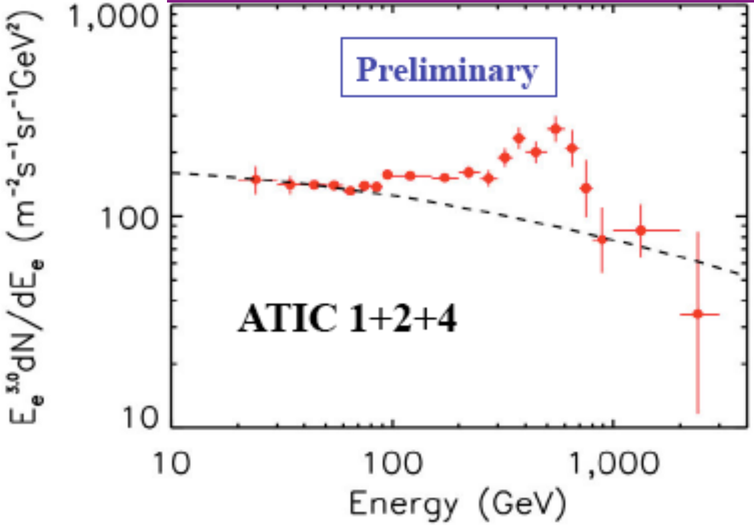
$e^{\pm}$ energy
e/h separation
γ trigger

Part 2:
Indirects Dark Matter searches: latest results and perspectives

- ✓ **Measurements of e^+,e^-,$e^\pm$**
- ✓ **anti-protons**

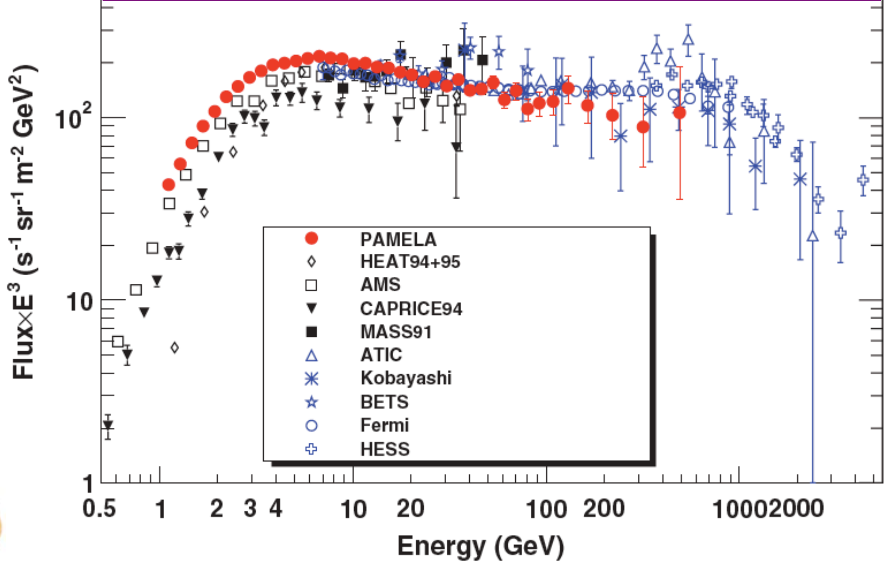
The electron/positron puzzle

2008: e± eccess in ATIC data

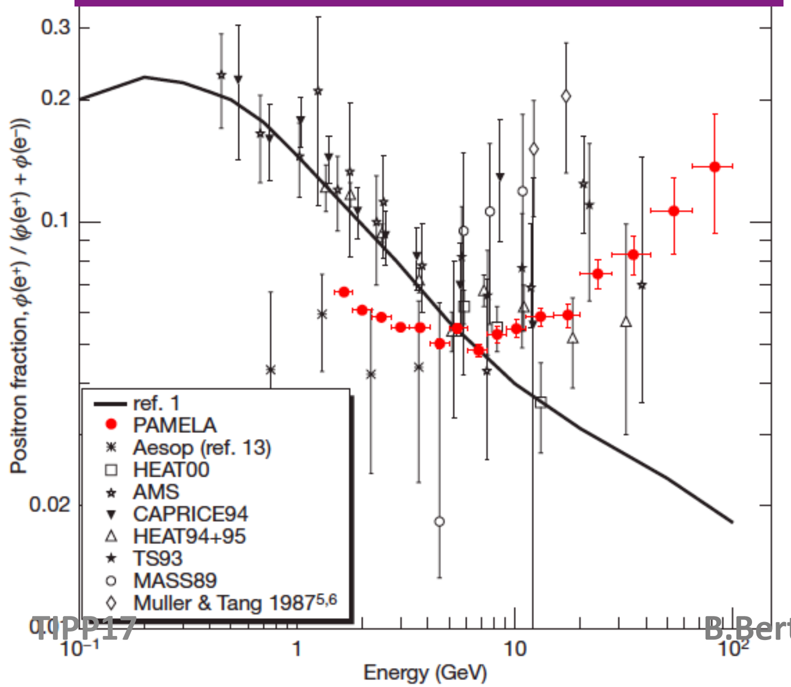


2009: No excess in Fermi e±

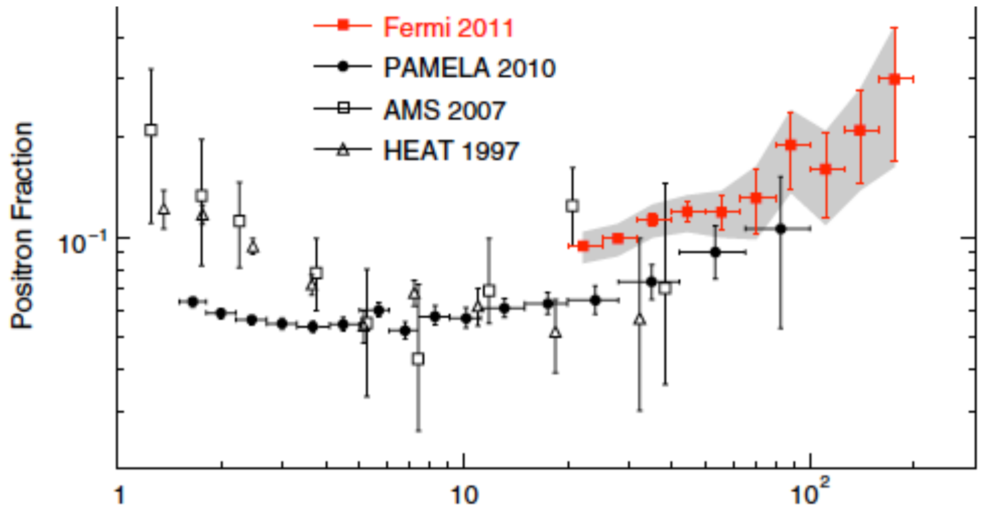
2011: No excess in e- from PAMELA



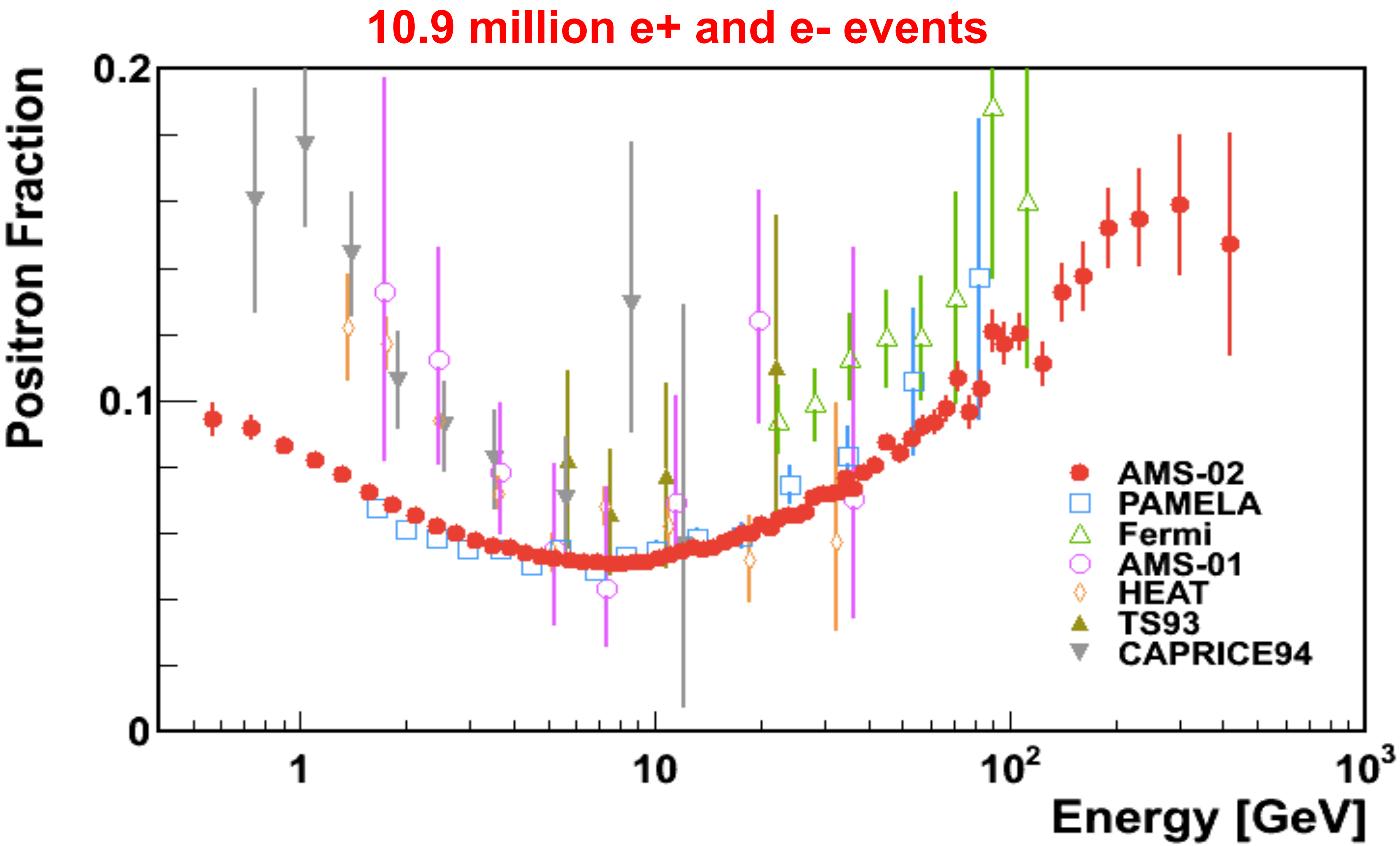
2008: e+ excess in PAMELA data



2011: Confirmed by Fermi

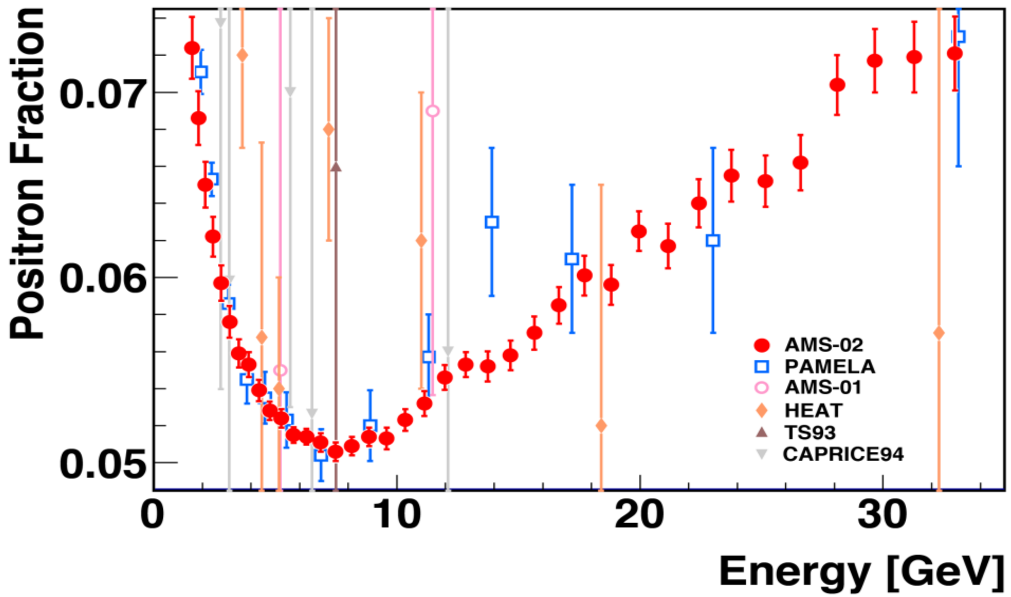


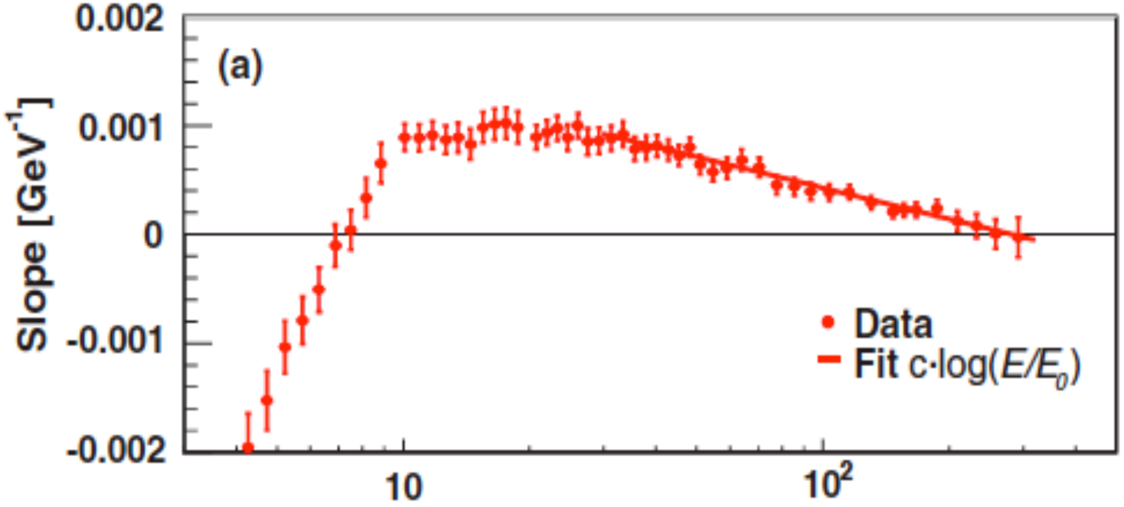
Positron fraction with 2.5 years of AMS data

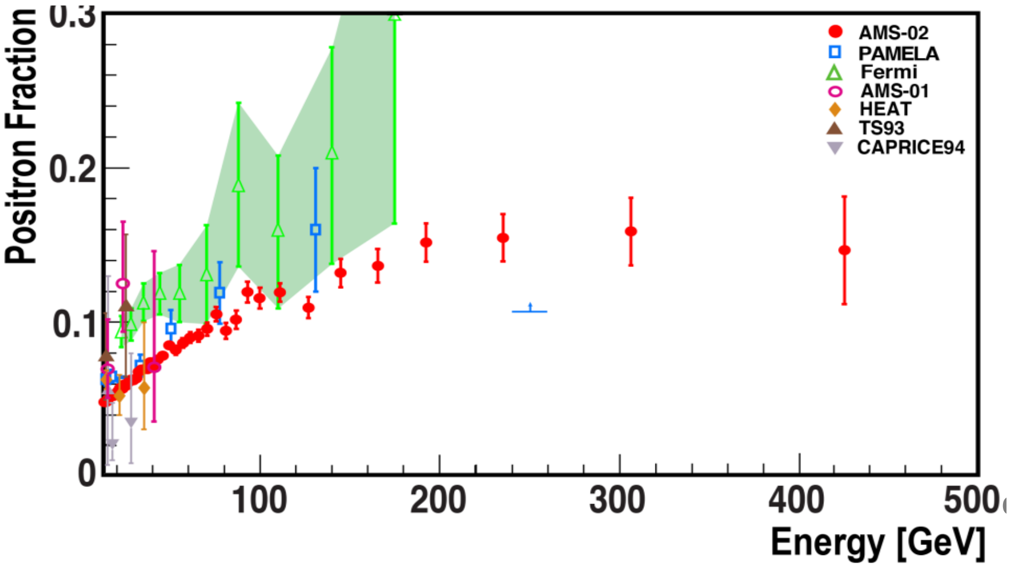


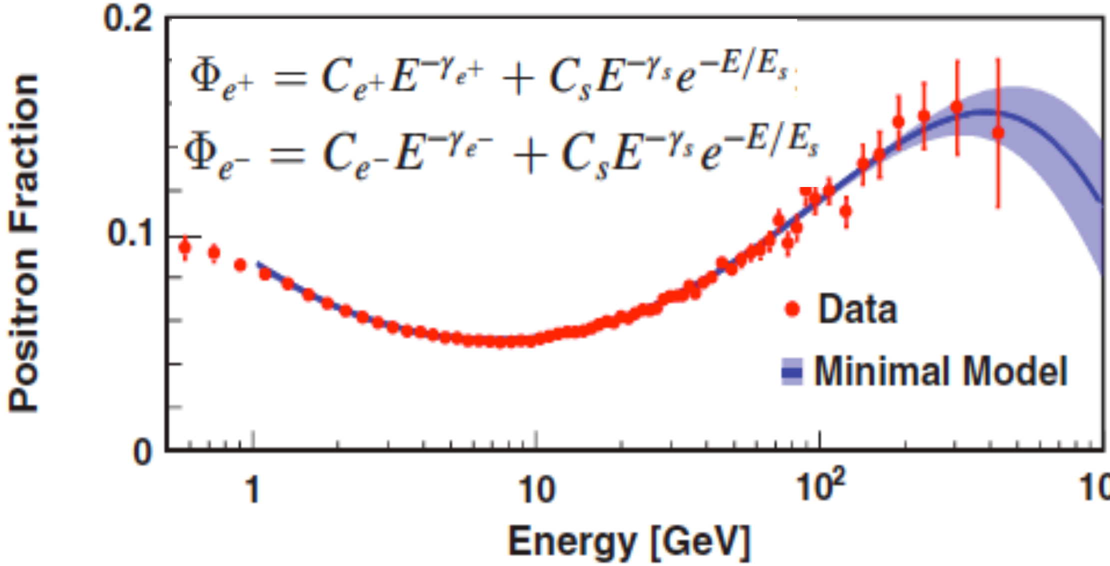
Positron fraction with 2.5 years of AMS data

- ✓ No sharp structures
- ✓ Steady increase of the positron content up to ≈ 275 GeV
- ✓ Well described by an empirical model with a common source term for e^+/e^-





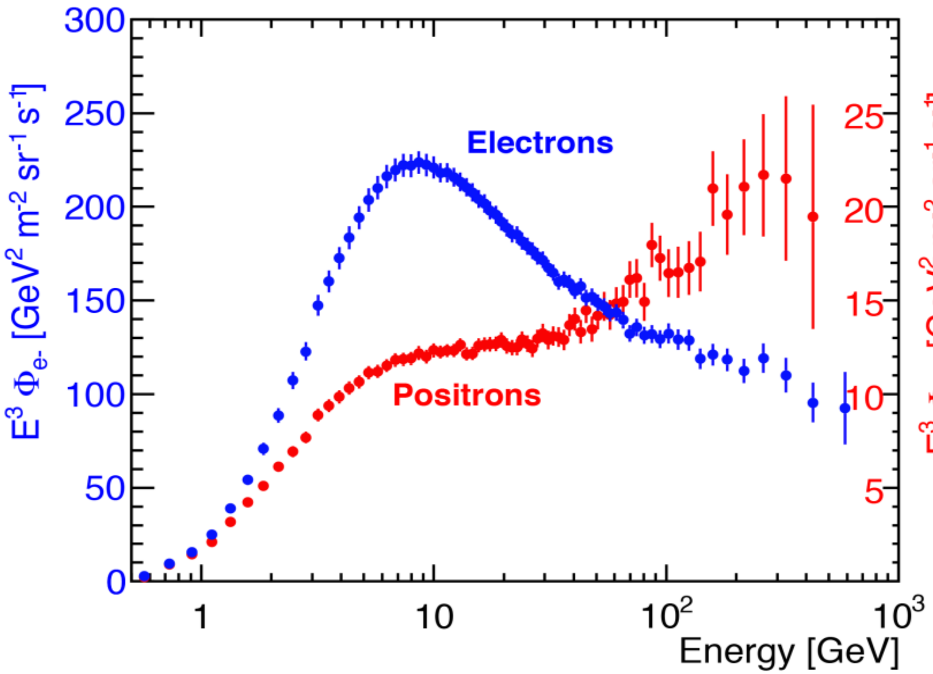


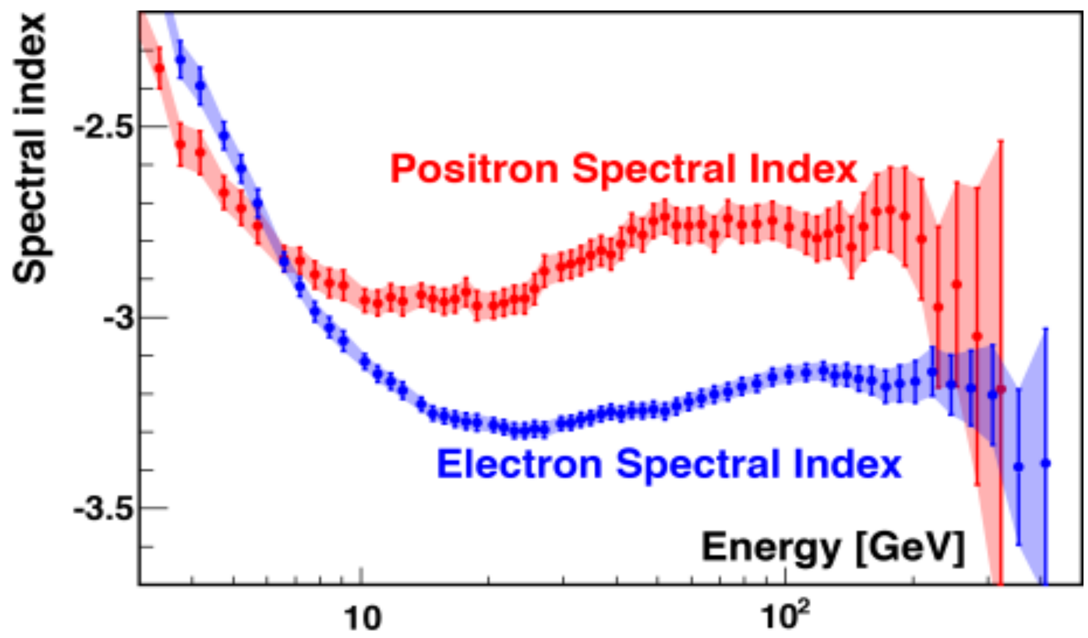


Electron/Positron fluxes with 2.5 years of AMS data:

For the first time a detailed study of the spectral index variation with energy :

$$\gamma_{e^\pm} = d[\log(\Phi_{e^\pm})]/d[\log(E)]$$

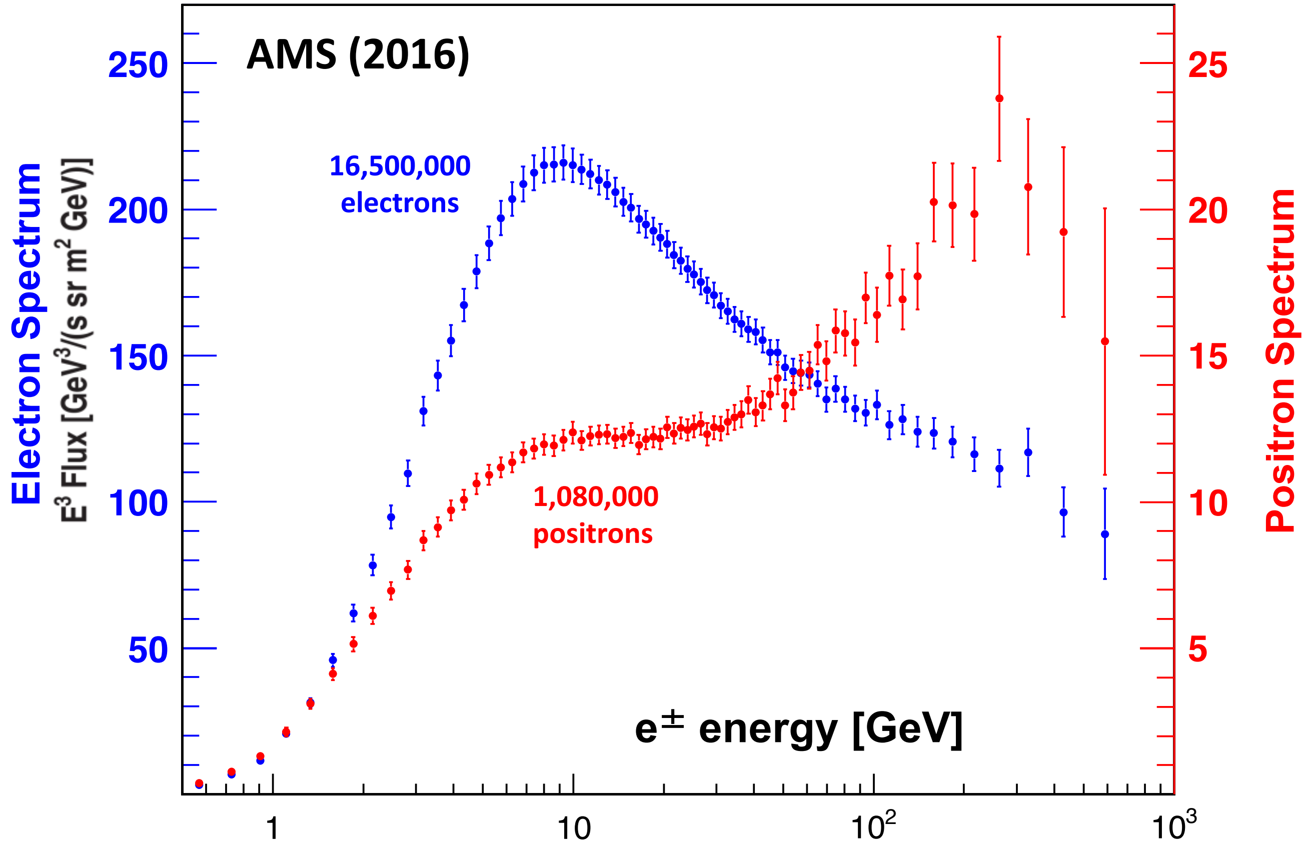




Hardening of the positron spectrum is at the origin of the positron fraction increase…

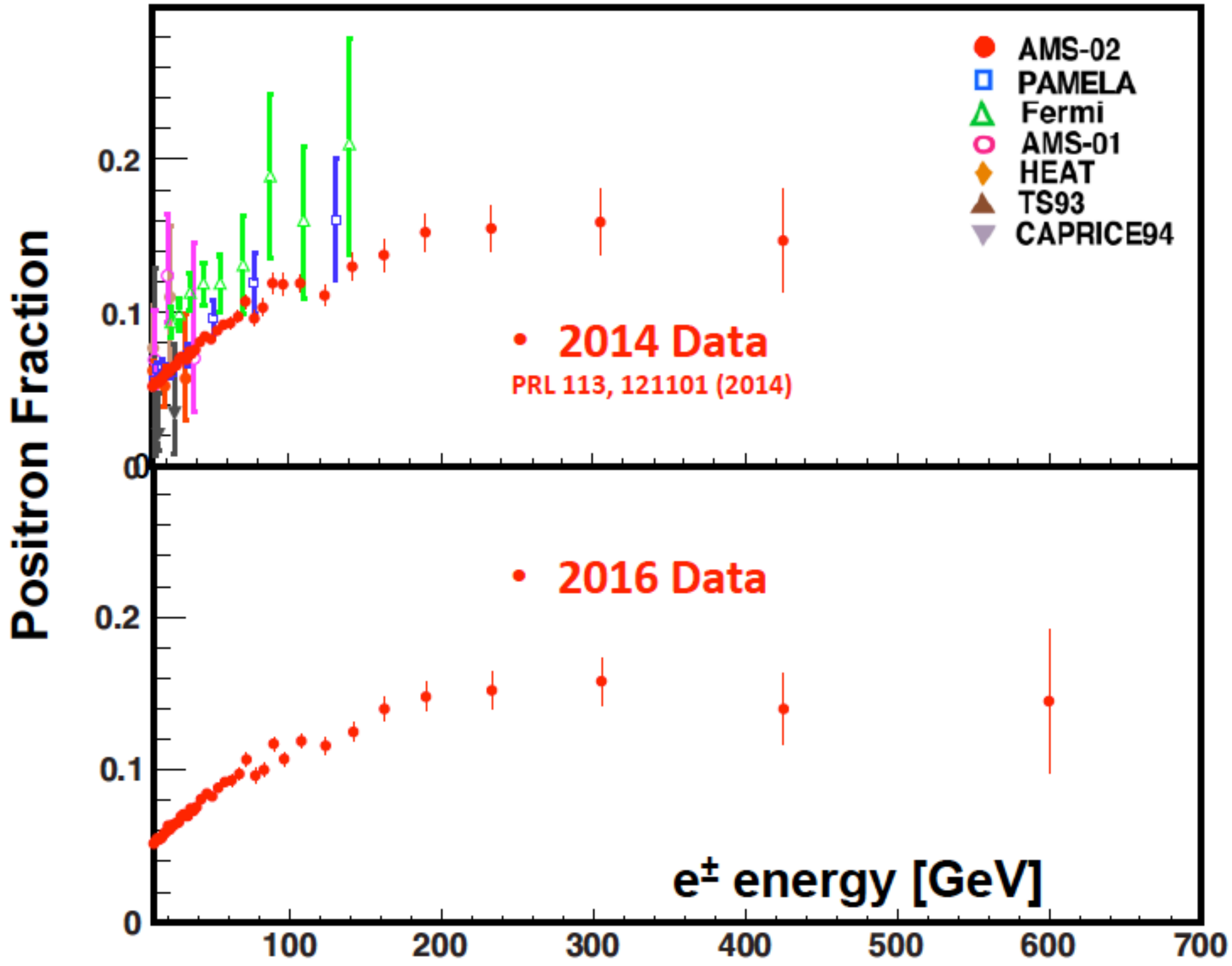
AMS-02 Positrons/electrons : status report* with 5 years of data

60 months
~ 17.5 million e⁻/e⁺ events



*** Not to be quoted before publication!**

AMS-02 positron fraction: status report* with 5 years of data

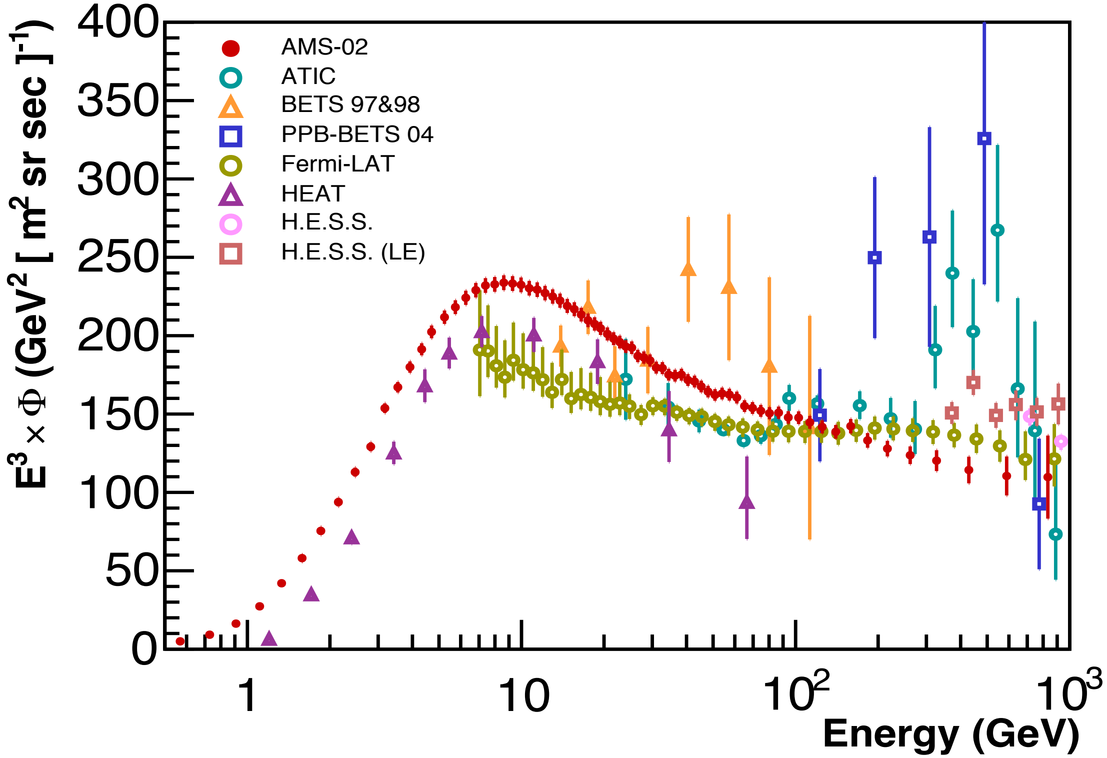


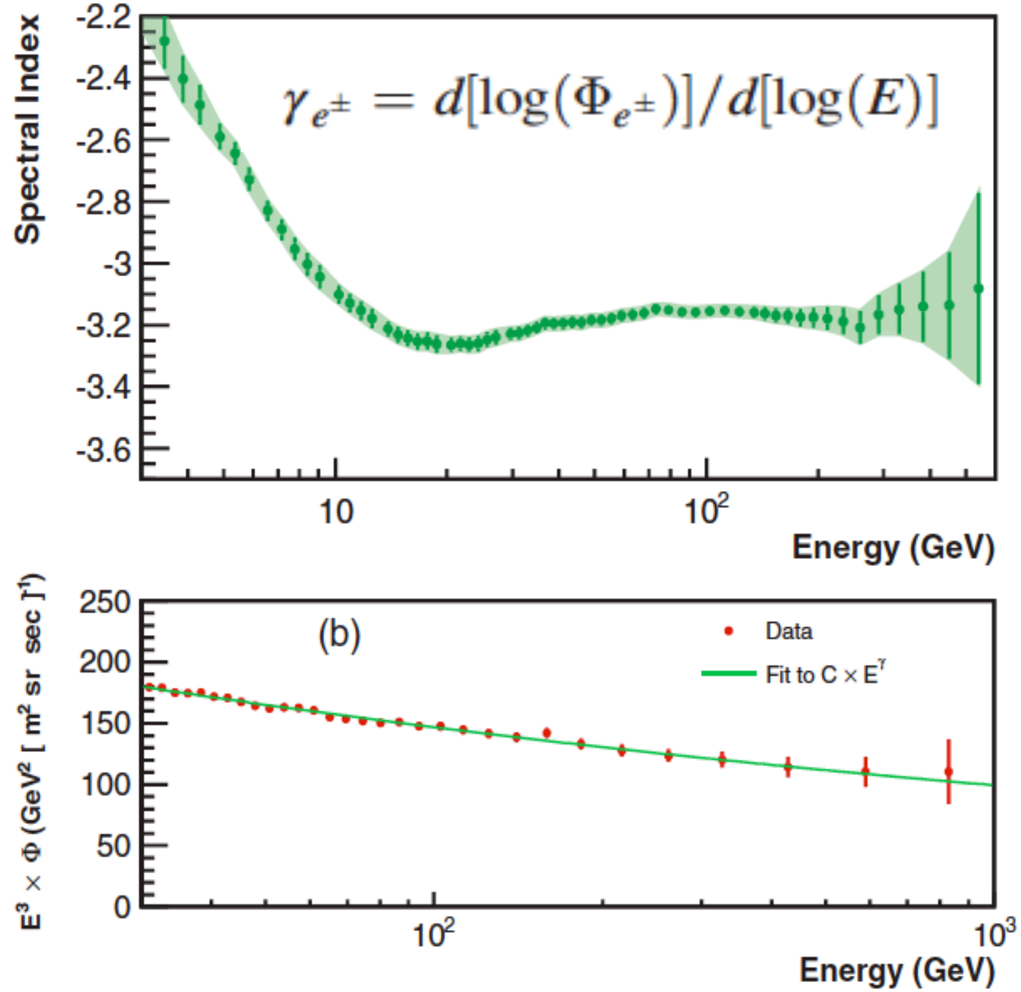
*** Not to be quoted before publication!**

Electron + Positron flux with 2.5 years of AMS data:

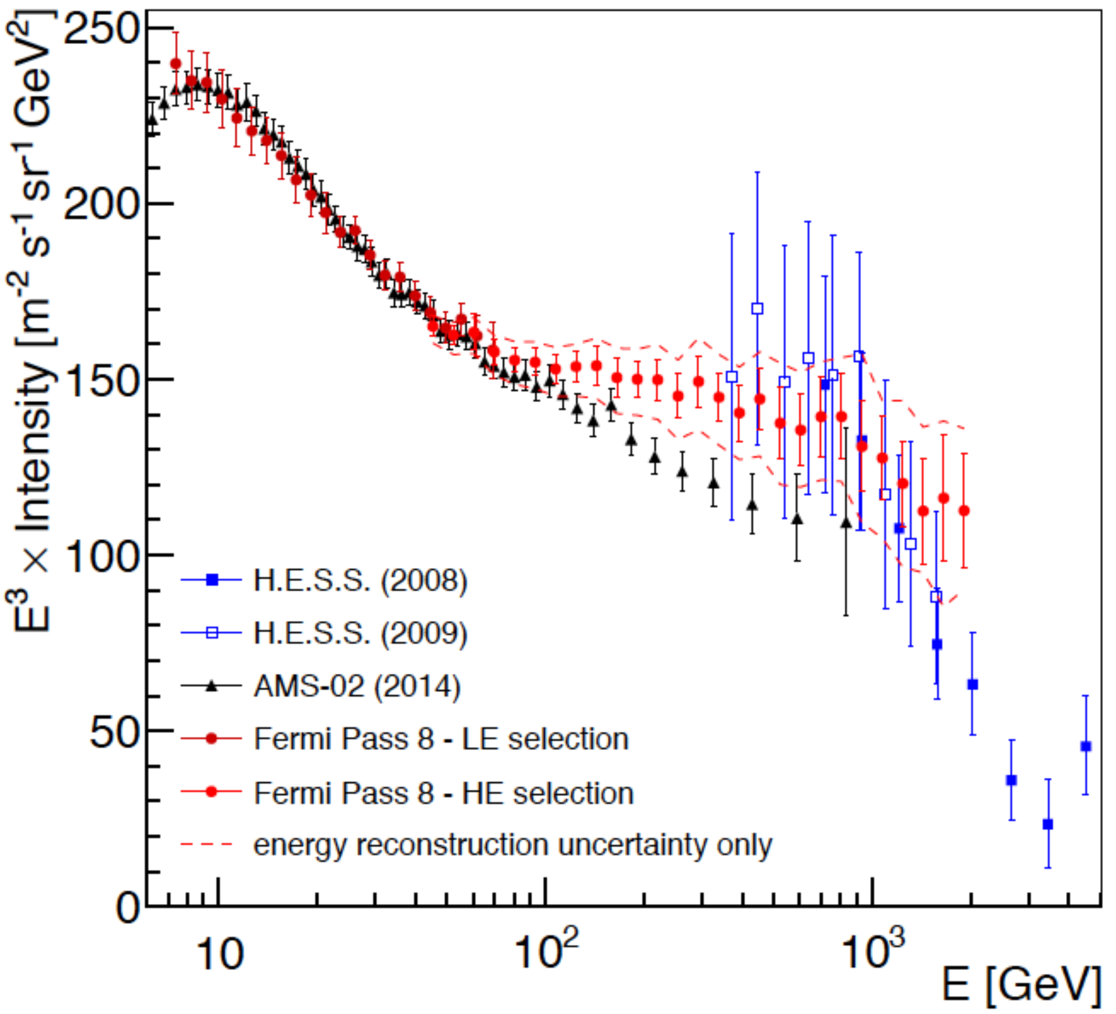
Charge insensitive measurement →
higher energy, directly comparable with previous experiments

- ✓ No sharp structures
- ✓ A single power low describes the spectrum after 30 GeV





Electron + Positron flux: Fermi 2017



New measurement:

→ agreement with AMS up to ≈ 100 GeV

→ different (smooth) spectrum above

What is AMS observing?

From Dark Matter

1) J. Kopp, Phys. Rev. D 88, 076013 (2013);
2) L. Feng, R.Z. Yang, H.N. He, T.K. Dong, Y.Z. Fan and J. Chang Phys.Lett. B728 (2014) 250
3) M. Cirelli, M. Kadastik, M. Raidal and A. Strumia ,Nucl.Phys. B873 (2013) 530
4) M. Ibe, S. Iwamoto, T. Moroi and N. Yokozaki, JHEP 1308 (2013) 029
5) Y. Kajiyama and H. Okada, Eur.Phys.J. C74 (2014) 2722
6) K.R. Dienes and J. Kumar, Phys.Rev. D88 (2013) 10, 103509
7) L. Bergstrom, T. Bringmann, I. Cholis, D. Hooper and C. Weniger, PRL 111 (2013) 171101
8) K. Kohri and N. Sahu, Phys.Rev. D88 (2013) 10, 103001
9) P. S. Bhupal Dev, D. Kumar Ghosh, N. Okada and I. Saha, Phys.Rev. D89 (2014) 095001
10) A. Ibarra, A.S. Lamperstorfer and J. Silk, Phys.Rev. D89 (2014) 063539
11) Y. Zhao and K.M. Zurek, JHEP 1407 (2014) 017
12) C. H. Chen, C. W. Chiang, and T. Nomura, Phys. Lett. B 747, 495 (2015)
13) H. B. Jin, Y. L. Wu, and Y.-F. Zhou, Phys.Rev. D92, 055027 (2015)
14) M-Y. Cui, Q. Yuan, Y-L.S. Tsai and Y-Z. Fan, arXiv:1610.03840 (2016)
15) A. Cuoco, M. Krämer and M. Korsmeier, arXiv:1610.03071 (2016)

From Astrophysical Sources

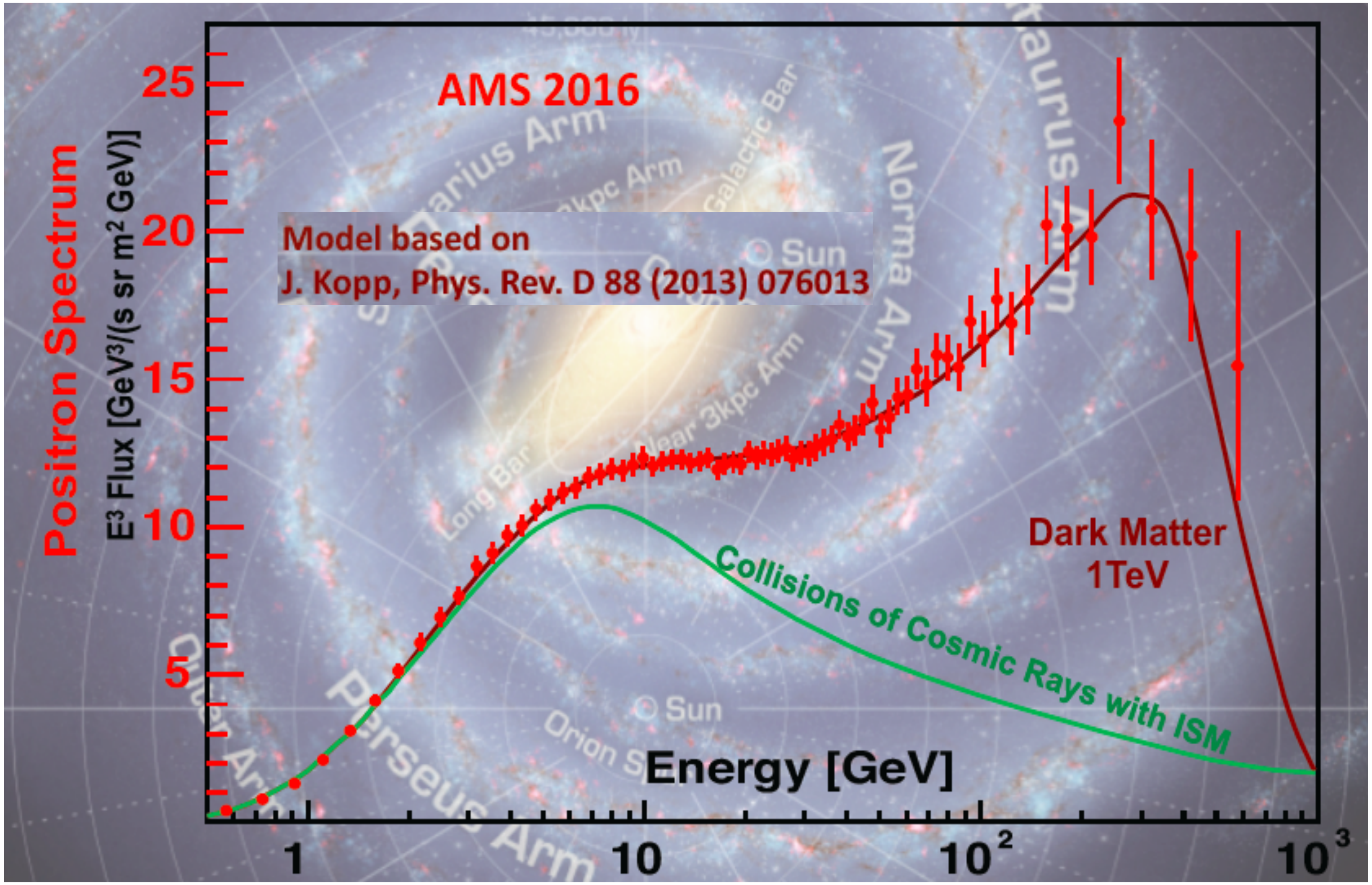
1) T. Linden and S. Profumo, Astrophys.J. 772 (2013) 18
2) P. Mertsch and S. Sarkar, Phys.Rev. D 90 (2014) 061301
3) I. Cholis and D. Hooper, Phys.Rev. D88 (2013) 023013
4) A. Erlykin and A.W. Wolfendale, Astropart.Phys. 49 (2013) 23
5) P.F. Yin, Z.H. Yu, Q. Yuan and X.J. Bi, Phys.Rev. D88 (2013) 2, 023001
6) A.D. Erlykin and A.W. Wolfendale, Astropart.Phys. 50-52 (2013) 47
7) E. Amato, Int.J.Mod.Phys.Conf.Ser. 28 (2014) 1460160
8) P. Blasi, Braz.J.Phys. 44 (2014) 426
9) D. Gaggero, D. Grasso, L. Maccione, G. DiBernardo and C Evoli, Phys.Rev. D89 (2014) 083007
10) M. DiMauro, F. Donato, N. Fornengo, R. Lineros and A. Vittino, JCAP 1404 (2014) 006
11) K. Kohri, K. Ioka, Y. Fujita, and R. Yamazaki, Prog. Theor. Exp. Phys. 2016, 021E01 (2016)

From Secondary Production

1) R.Cowsik, B.Burch, and T.Madziwa-Nussinov, Ap.J. 786 (2014) 124
2) K. Blum, B. Katz and E. Waxman, Phys.Rev.Lett. 111 (2013) 211101
3) R. Kappl and M. W. Winkler, J. Cosmol. Astropart. Phys. 09 (2014) 051
4) G.Giesen, M.Boudaud, Y.Gènolini, V.Poulin, M.Cirelli, P.Salati and P.D.Serpico, JCAP09 (2015) 023;
5) C.Evoli, D.Gaggero and D.Grasso, JCAP 12 (2015) 039.
6) R.Kappl, A.Reinertand, and M.W.Winkler, arXiv:1506.04145 (2015)

What is AMS observing?

Something **"different"** with respect "conventional" models of e^+ production by collisions of CR hadrons with the interstellar matter



What is AMS observing?

Something **"different"** with respect "conventional" models of e^+ production by collisions of CR hadrons with the interstellar matter:

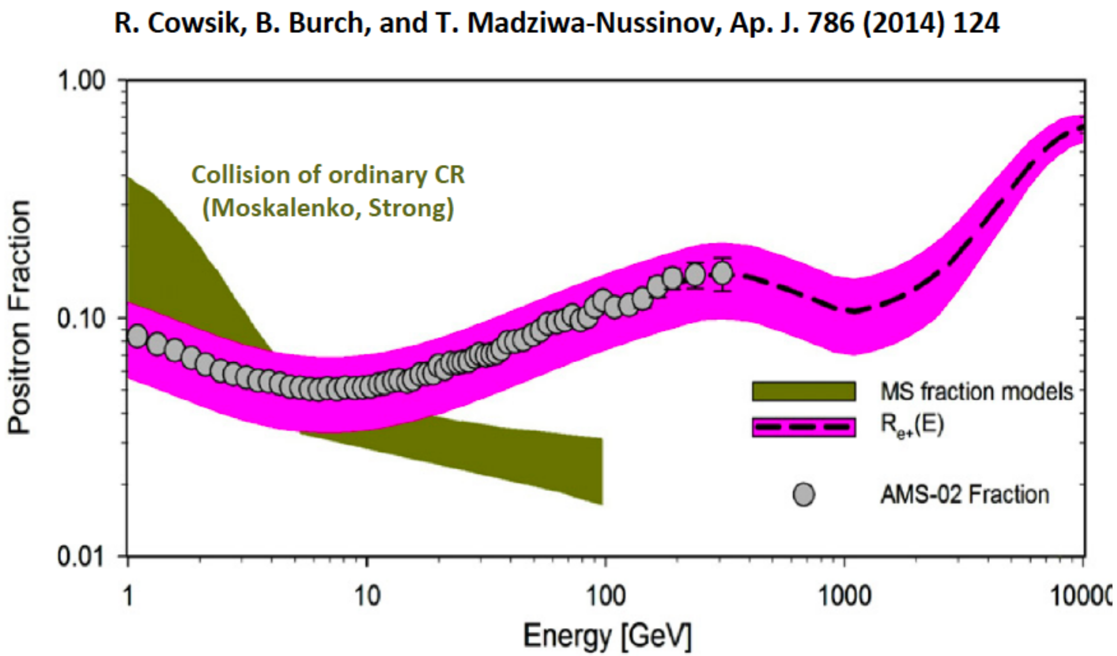
Astrophysical Sources:

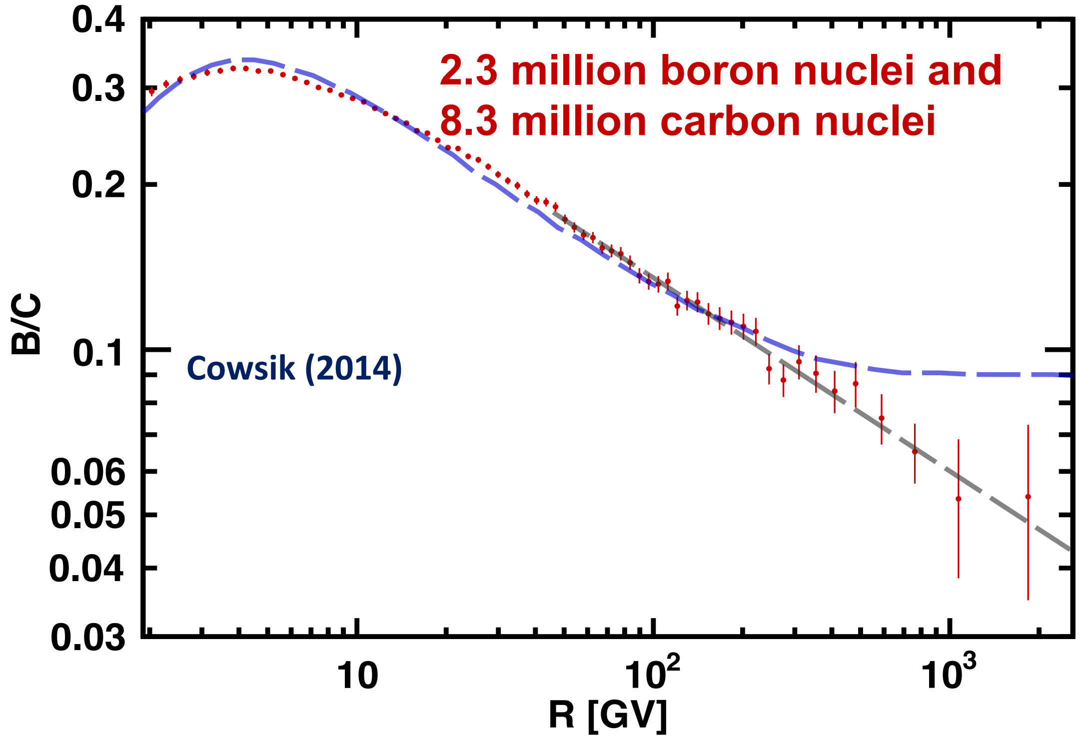
- Local sources as pulsars (slow fall at high energies, anisotropy..)
- Interactions of CR hadrons in old SNR (but this should affect also other secondary species as anti-protons, B/C)
- purely secondary production in non-conventional models

Dark matter:

- The mass of the DM particle could give a sharp cutoff with energy
- Isotropic distribution
- Effects also on anti-p

Secondary production:

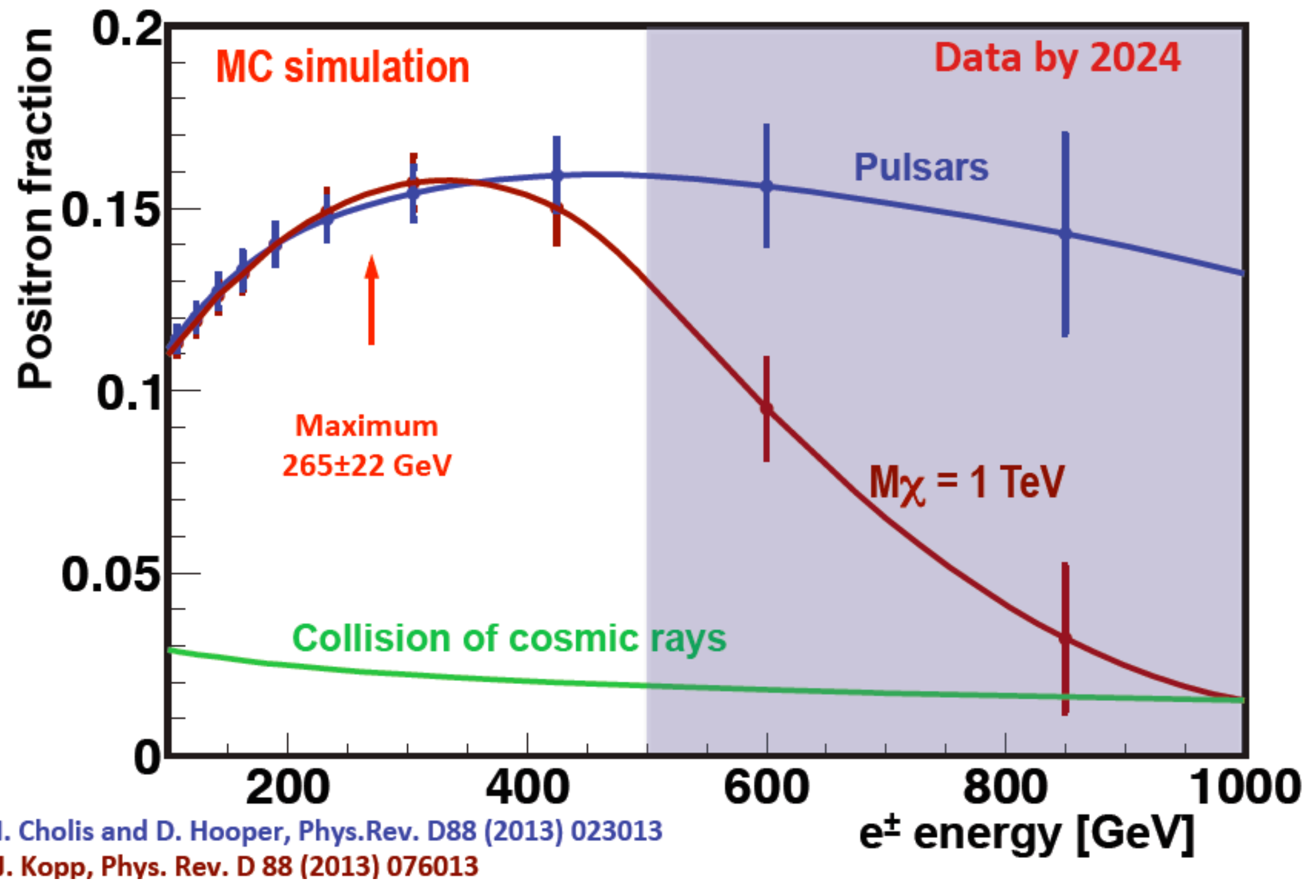




ok
for positron fraction

fails in other channels !

We have to wait….



- ✓ **Increase statistics & energy range**
- ✓ **Better understanding of astrophysical background from other measurements (nuclei)**
- ✓ **Study other anti-particle channels….**

Anti-proton/proton in the past millennium..

the early times (1984)

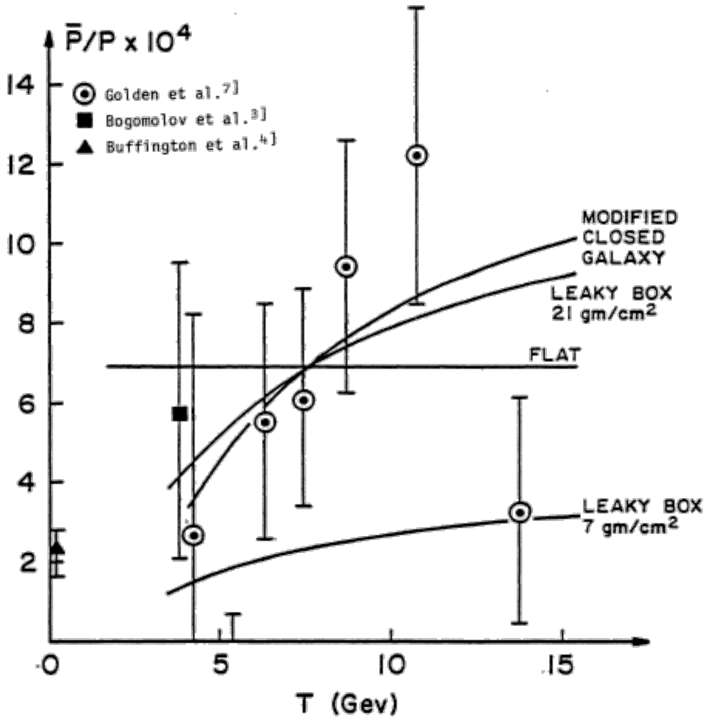
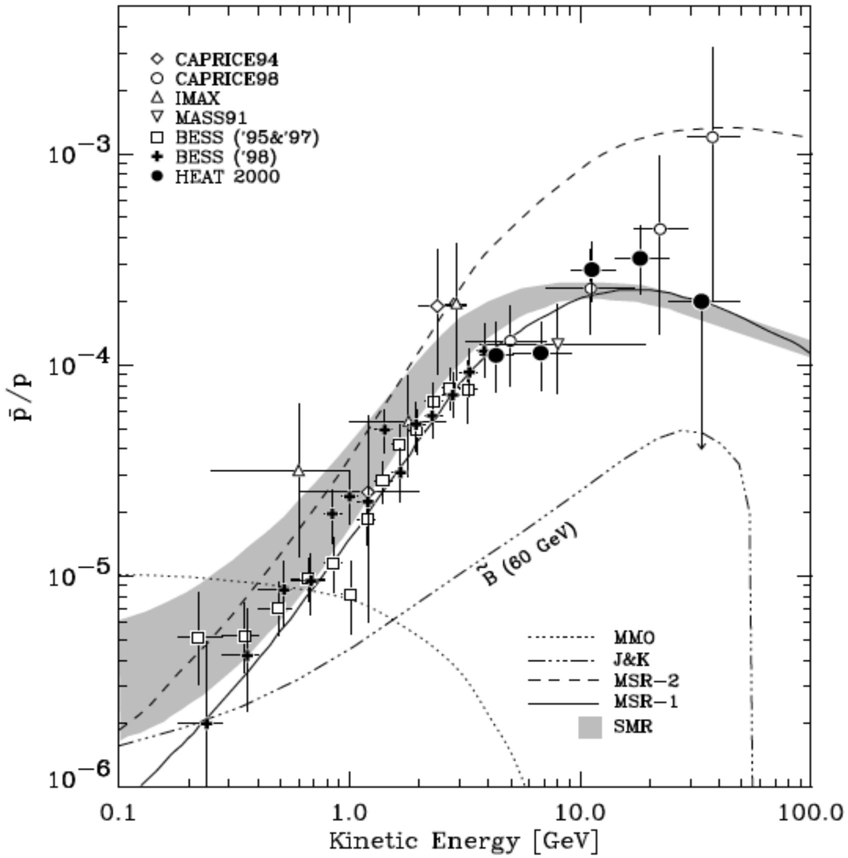


Figure 1. Antiproton Observations and Predictions

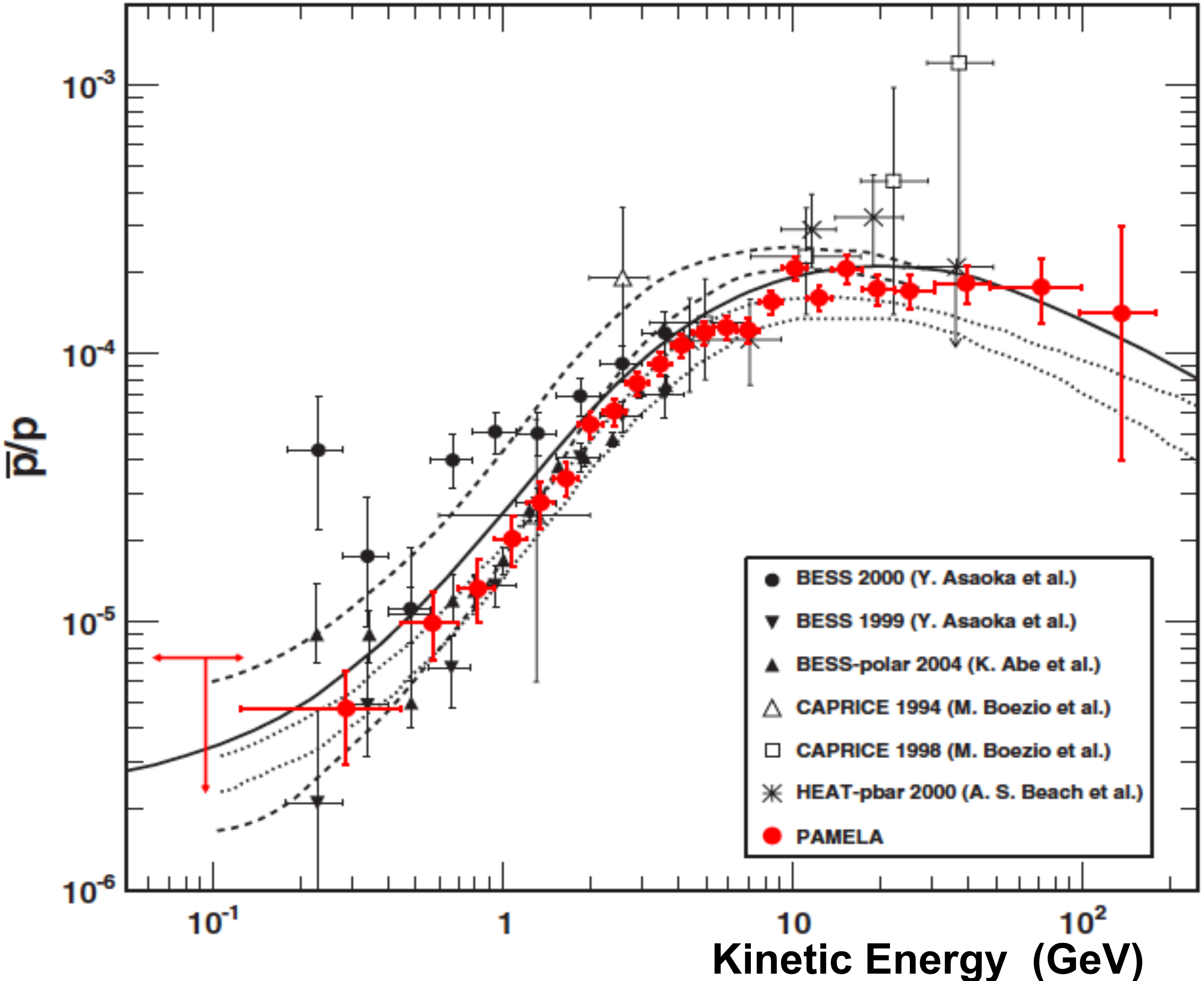
...around 2000



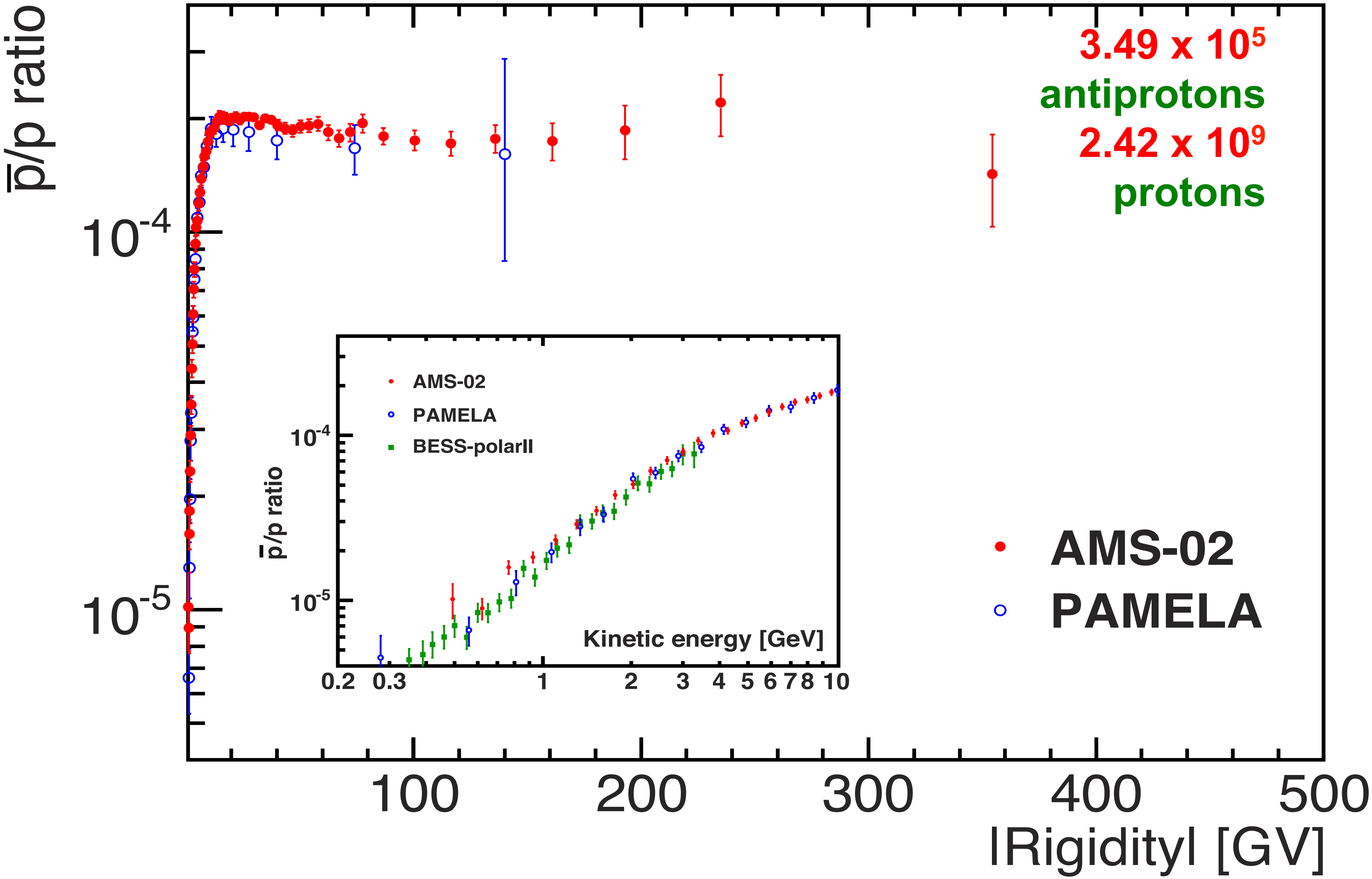
HEAT ≈ 70 events
CAPRICE ≈ 31 events

Anti-proton/proton : 2010

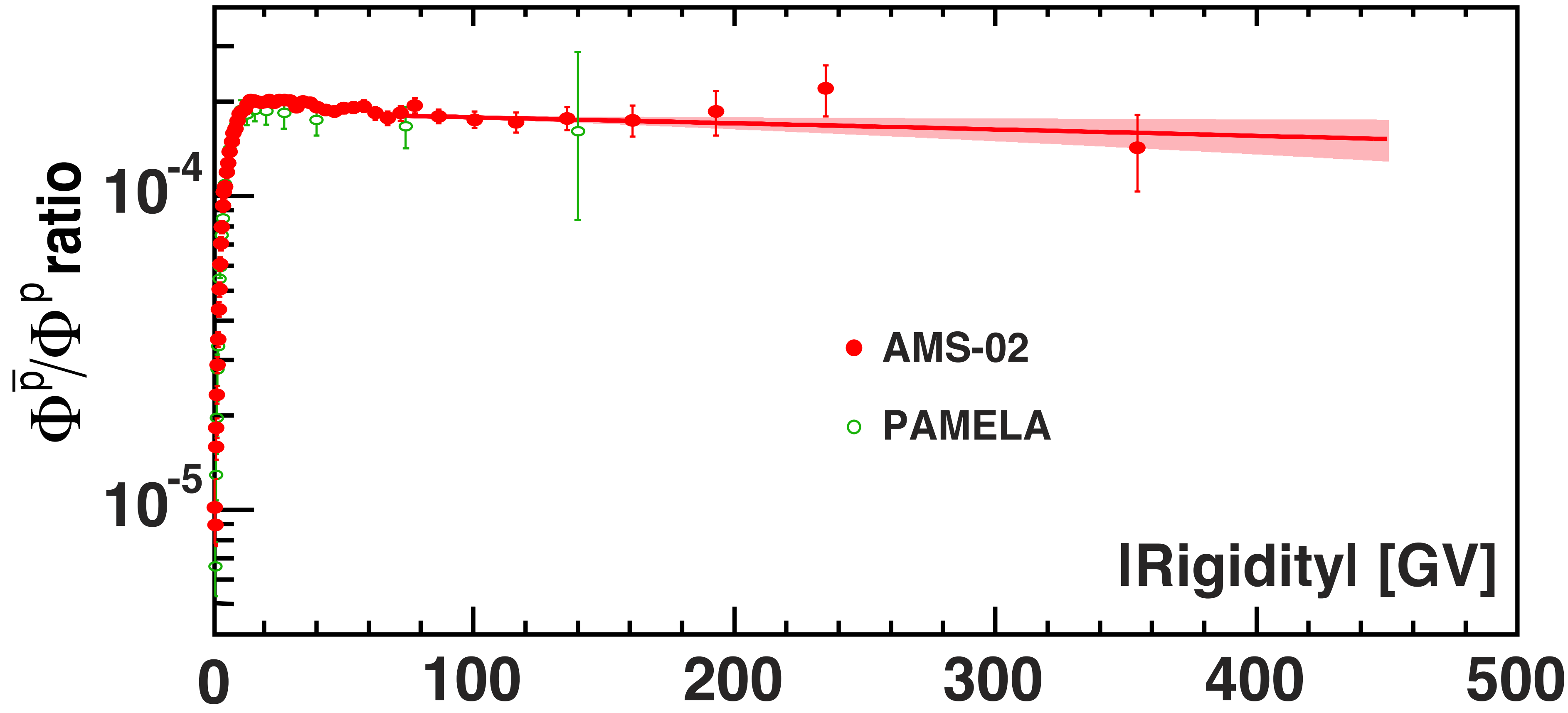
BESS-POLAR (2004) ≈ 1520 events < 4.2 GeV
PAMELA (2006-2009) ≈ 1500 events



AMS results on the $\bar{p}/p$ flux ratio

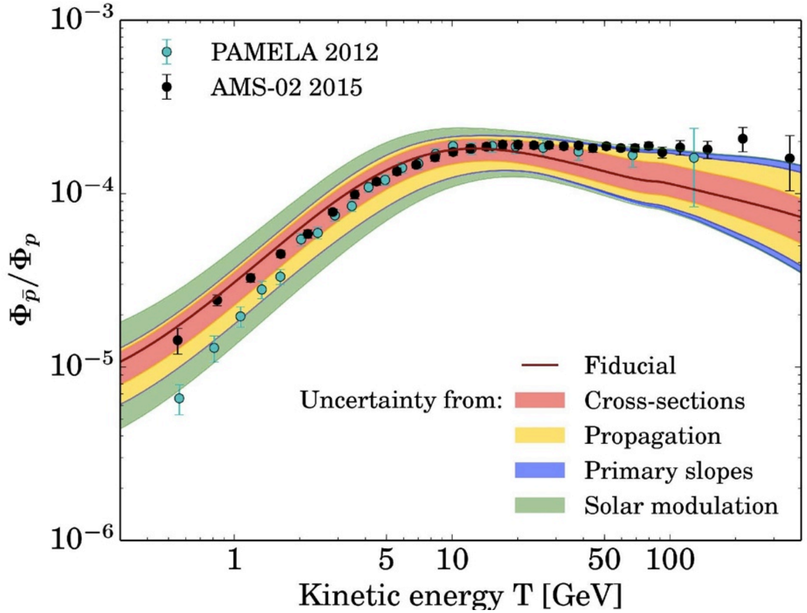


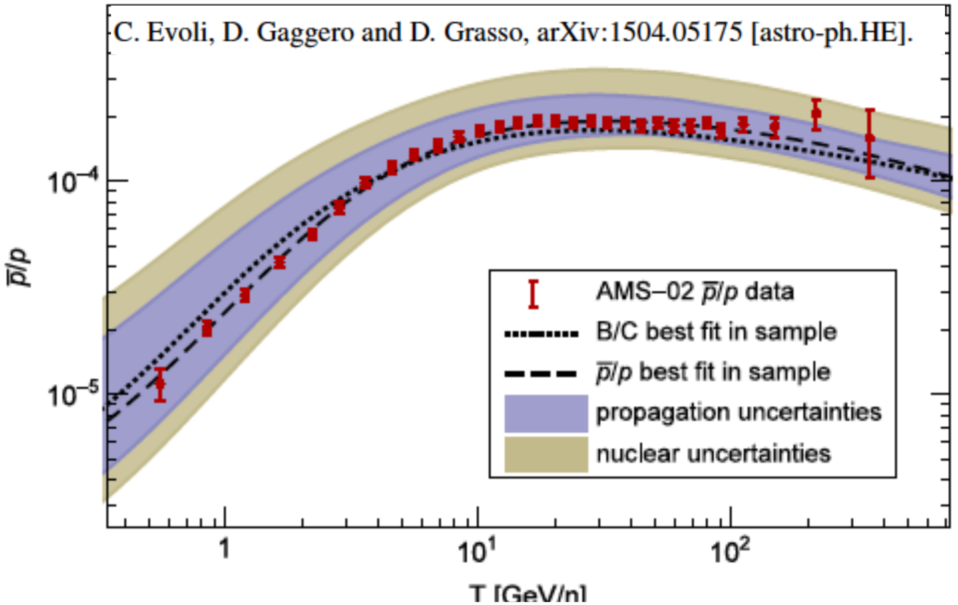
The pbar/p ratio flattens above 60 GeV..

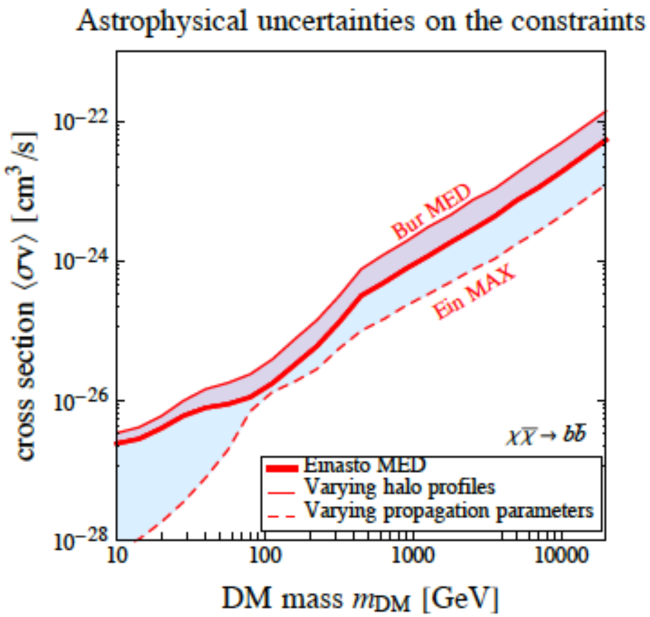


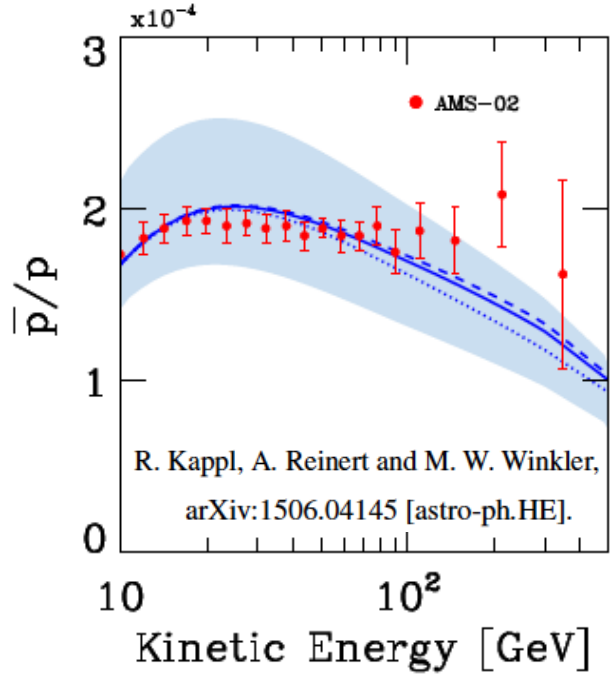
What is AMS observing?

The accuracy of the AMS measurement challenges current knowledge of cosmic background !









XSCRC2017: Cross sections for Cosmic Rays @ CERN

29 Mar 2017, 14:00 → 31 Mar 2017, 19:00 Europe/Zurich

503-1-001 - Council Chamber (CERN)

Description New space borne experiments are ushering us into the era of precision direct measurements in cosmic ray physics. However, a poor knowledge of several particle physics and nuclear physics inputs - such as antiproton production or spallation cross sections - can seriously limit the relevant astroparticle physics information that can actually be extracted from these data, for instance for Galactic propagation parameters or indirect dark matter searches. The goal of the workshop, bringing together different communities, is to review theoretical motivations for the measurements of key processes, current galactic models and recent advances in cosmic ray observations that crucially depend on some of these inputs. The workshop also strongly aims at presenting current efforts and discussing forthcoming perspectives for particle/nuclear measurement campaigns.

Duration: The workshop will start Wednesday, March 29 in the late morning, and will end Friday, March 31 at about 4pm.

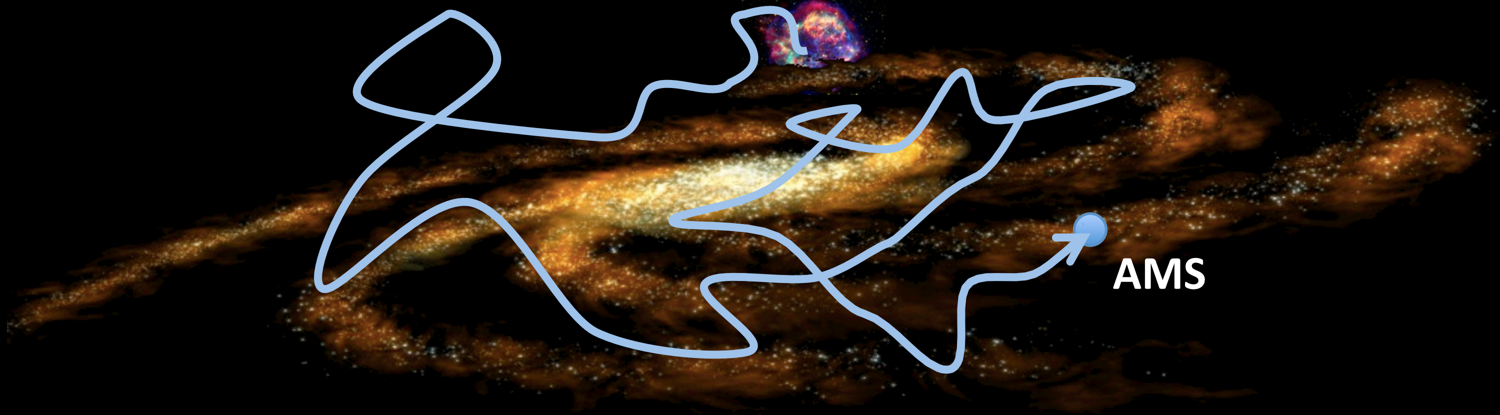
Organizing Committee: Bruna Bertucci (Perugia University), F. Donato (Torino University, chair), G. Giudice (CERN), Giovanni Passaleva (INFN, Florence), P. D. Serpico (LAPTH, Annecy, co-chair)

Scientific Advisory Committee: Oscar Adriani (Univ. and INFN, Firenze), Luca Latronico (INFN, Torino), Julie McEnery (Goddard NASA), Nadia Pastrone (INFN, Torino), Pierre Salati (LAPTH, Annecy), Andy Strong (MPE, Munich), Samuel C.C. Ting (MIT, Cern), Guy Wilkinson (Oxford Univ)

Invited Speakers: AMS Collaboration, Compass Collaboration, LHCb Collaboration, Alfredo Ferrari, Nicolao Fornengo, Guðlaugur Jóhannesson, Vladimir Ivanchenko, Tune Kamae, David Maurin, Nicola Mazziotta, Igor Moskalenko

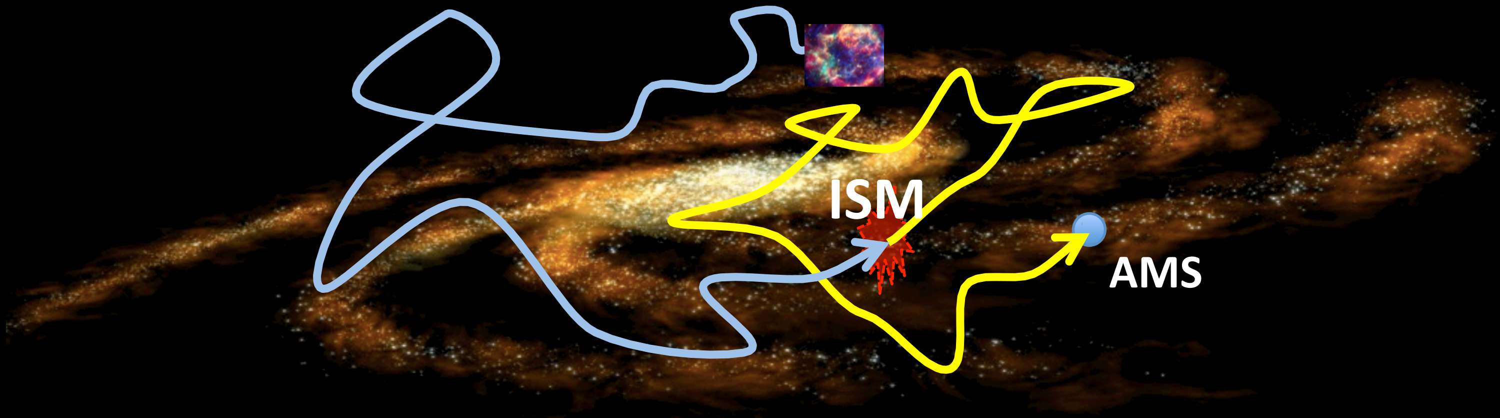
Registration *This event is open to new participants.* Register

A comprehensive set of measurements is needed to constrain astrophysical background:



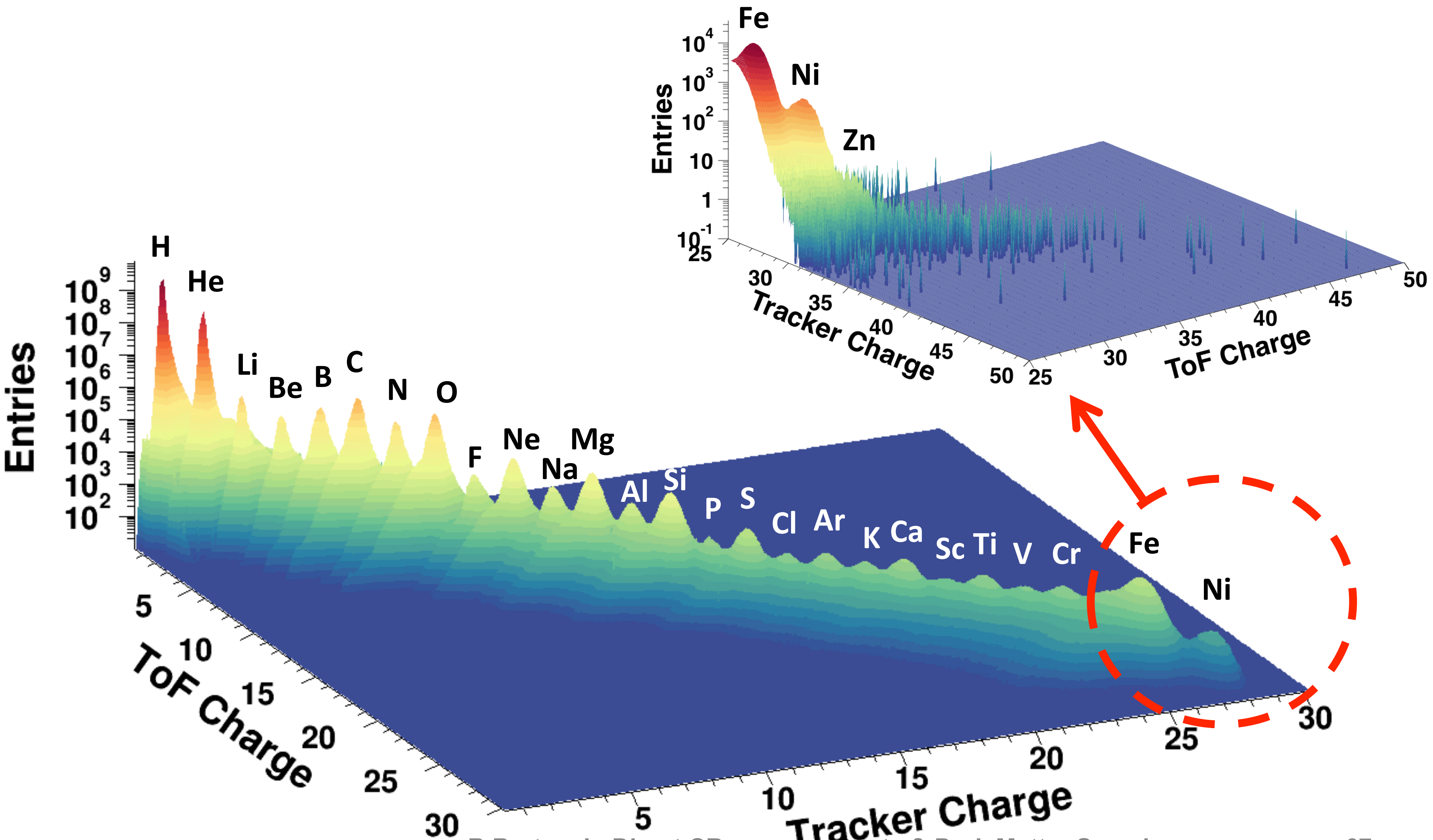
Primary Cosmic Rays (p, He, C, O, …)

C, O, …, Fe + ISM → Li, Be, B + X



Secondary Cosmic Rays (Li, Be, B, …)

Cosmic ray composition with AMS



Conclusions & Perspectives

- ✓ Stratospheric balloon program is still relevant for specific measurements (GAPS for anti-d ....)

- ✓ Space is giving an important contribution to direct CR measurements…
  - ✓ PAMELA did a great job…
  - ✓ AMS-02 has just started to release impressive results..and more will come in the next future
  - ✓ CALET and DAMPE just launched…
  - ✓ ISS-CREAM is close to launch ()

- ✓ But we need more….

China’s Space Station Program

2022

Phase -III

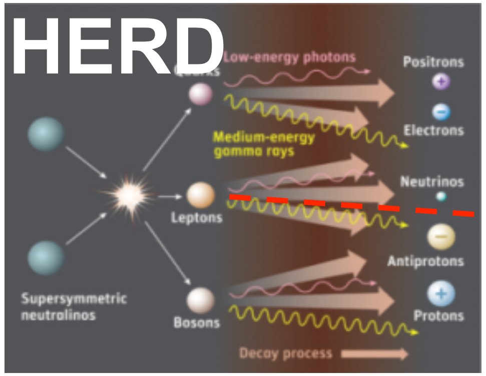
2018

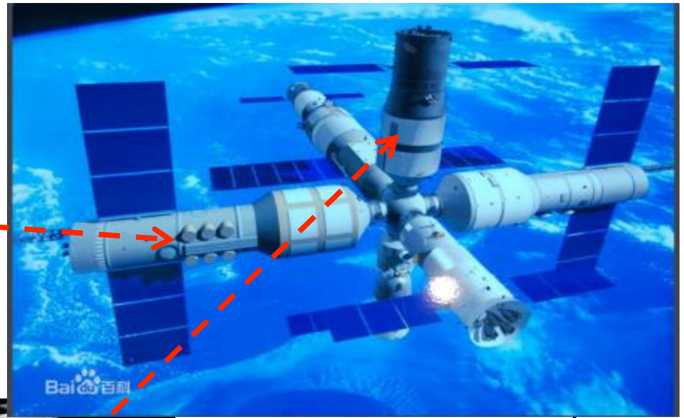
Phase -II

2011

Phase -I

2003



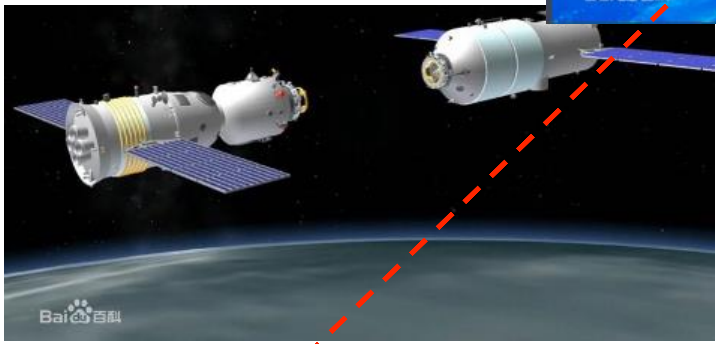


Space Station

3 large modules

+ 2 m telescope

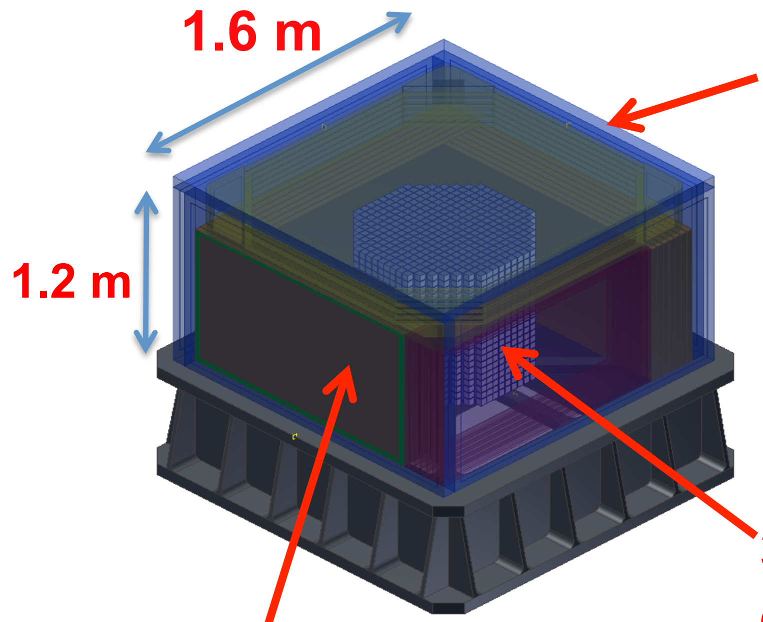
~10-year lifetime



Space lab: no living cabin

10 astronauts in 5 flights → space walk

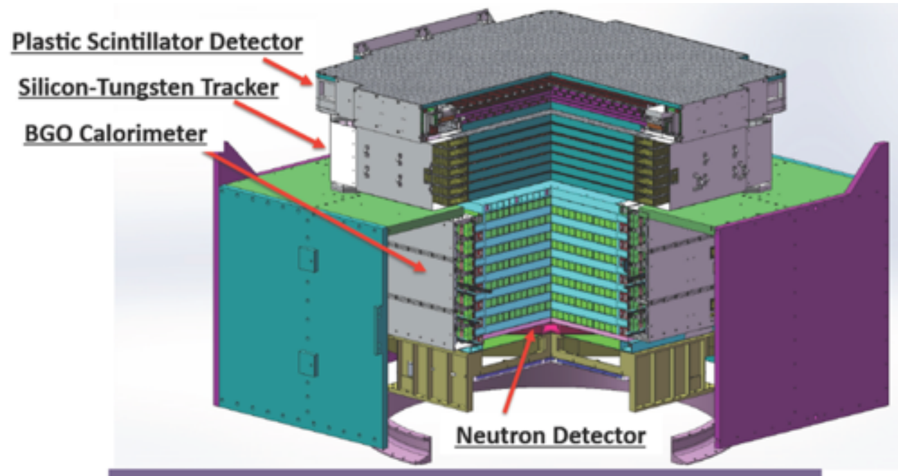
HERD: High Energy Cosmic Ray Detector



PSD, five sides
low energy Gamma Id
Charge

3D CALO
e/γ/CR energy
e/p discrimination

STK(SSD+W),five sides
Charge
Trajectory
Gamma tracking

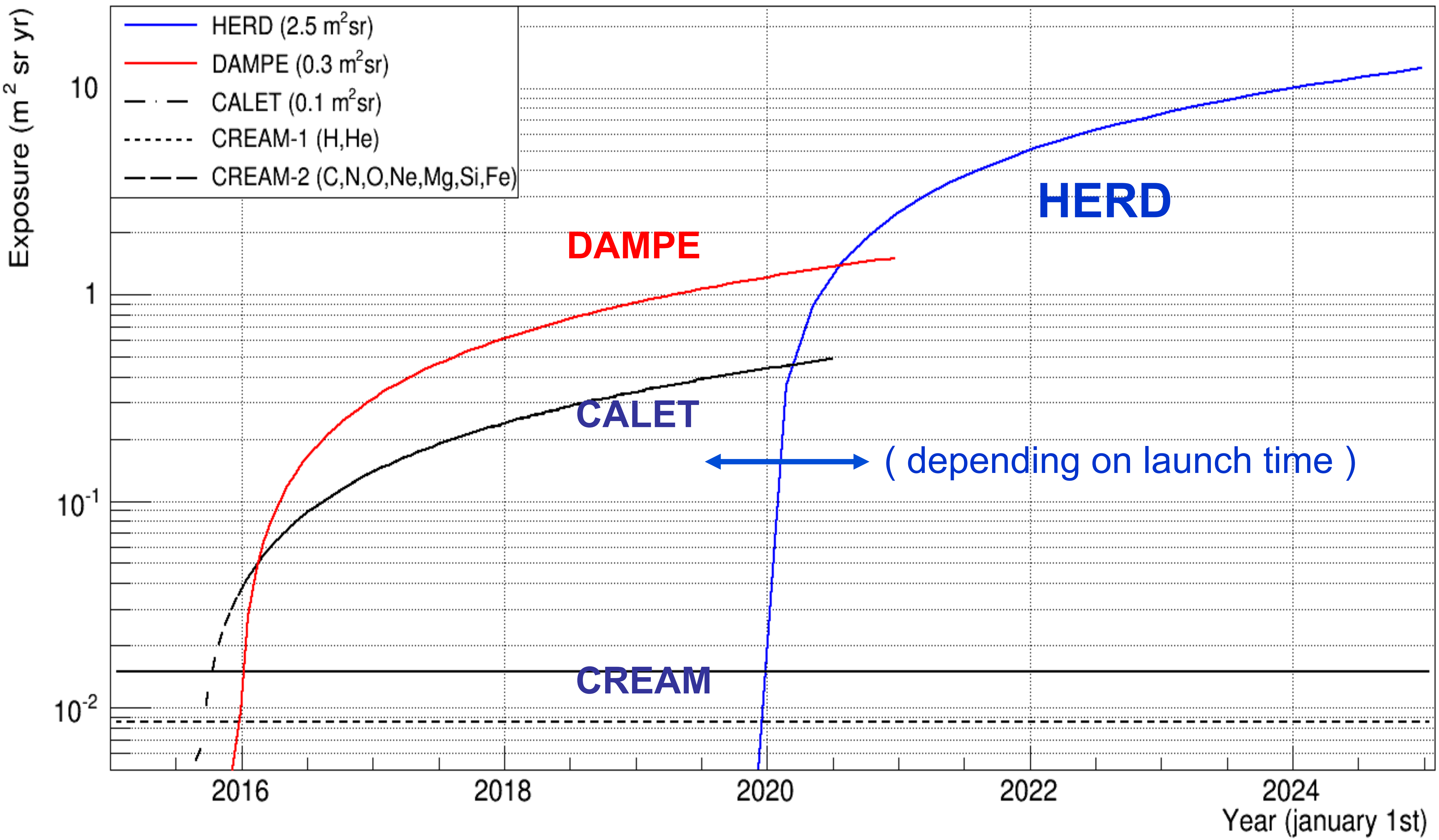


W converter + thick calorimeter (total 33 X_0)
+ precise tracking + charge measurement ➡
high energy γ-ray, electron and CR telescope

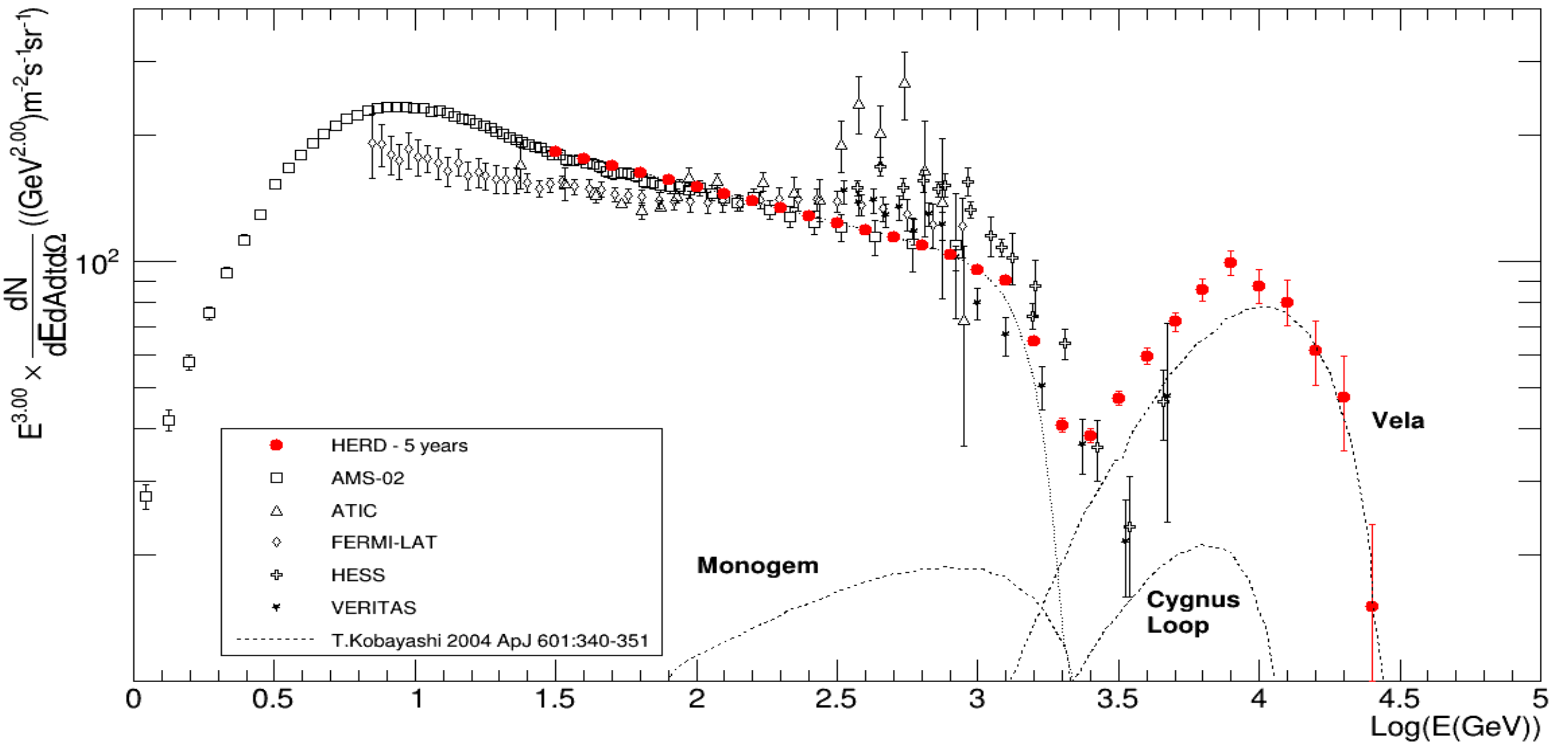
Working mode

- Normal trigger mode
  - PMT trigger (E_{dep}>30 GeV)
  - PMT trigger (E_{dep} >0.5GeV) + PSD veto
- Calibration mode
  - PMT trigger (1.2 GeV>E_{dep}>0.6 GeV)

Exposure（assuming GF=2.5m²sr）



Expected HERD Spectra for electrons



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- ✓ in 10 years a large acceptance space based calorimetric experiment insuring good overlap with ground based (indirect) measurements

For a real advance in DM searches: Anti-matters matters
A long term plan (with R&D development) is needed for a new antimatter large acceptance detector in orbit ..


Thanks for your attention
&
Greetings from Perugia !