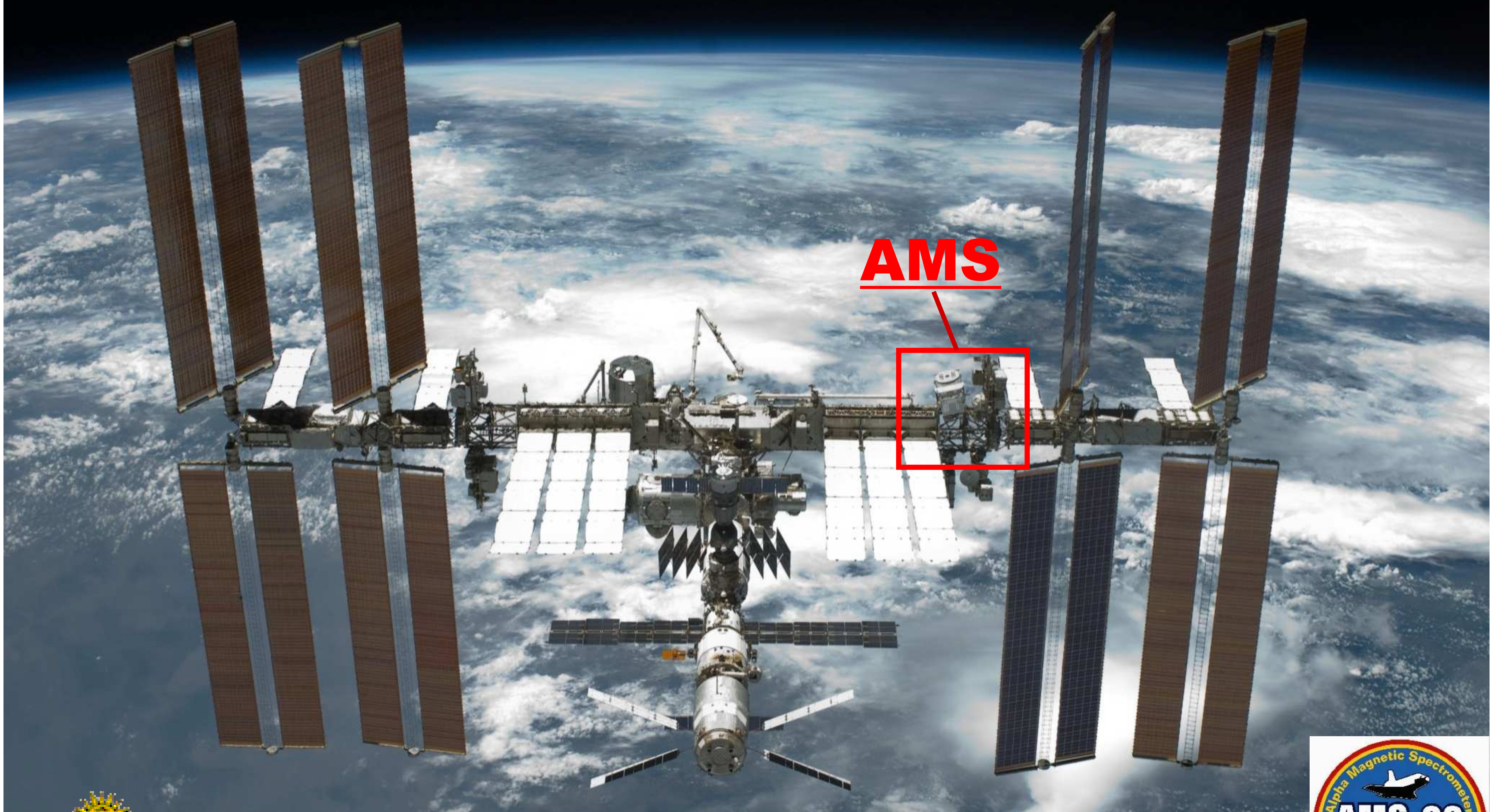
AMS: *First Year on ISS in SPACE*



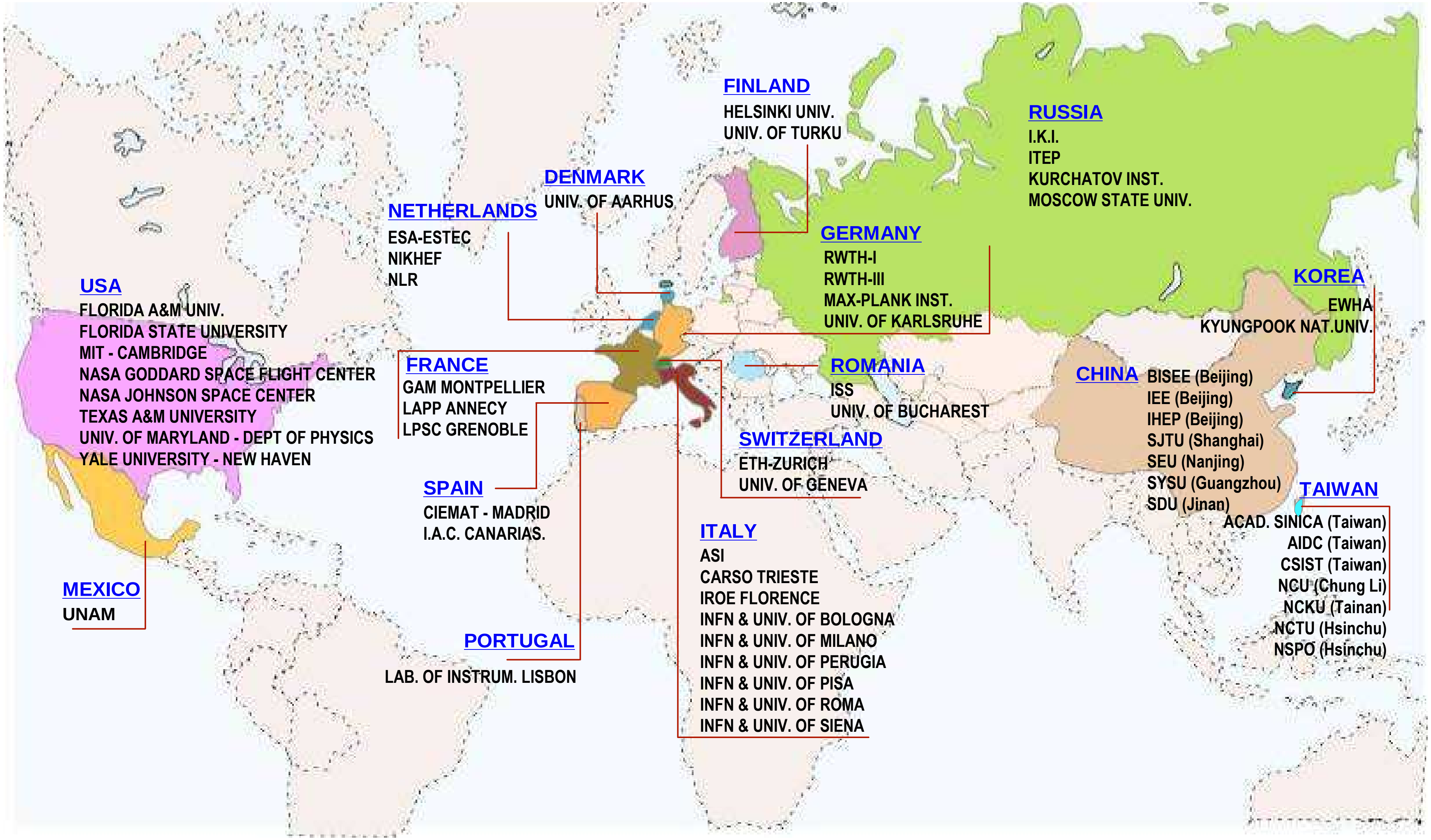
Divic RAPIN

D.P.N.C. *Université de Genève*

Journée de réflexion du DPNC, *BOSSEY 18 juin 2012*

AMS International Collaboration

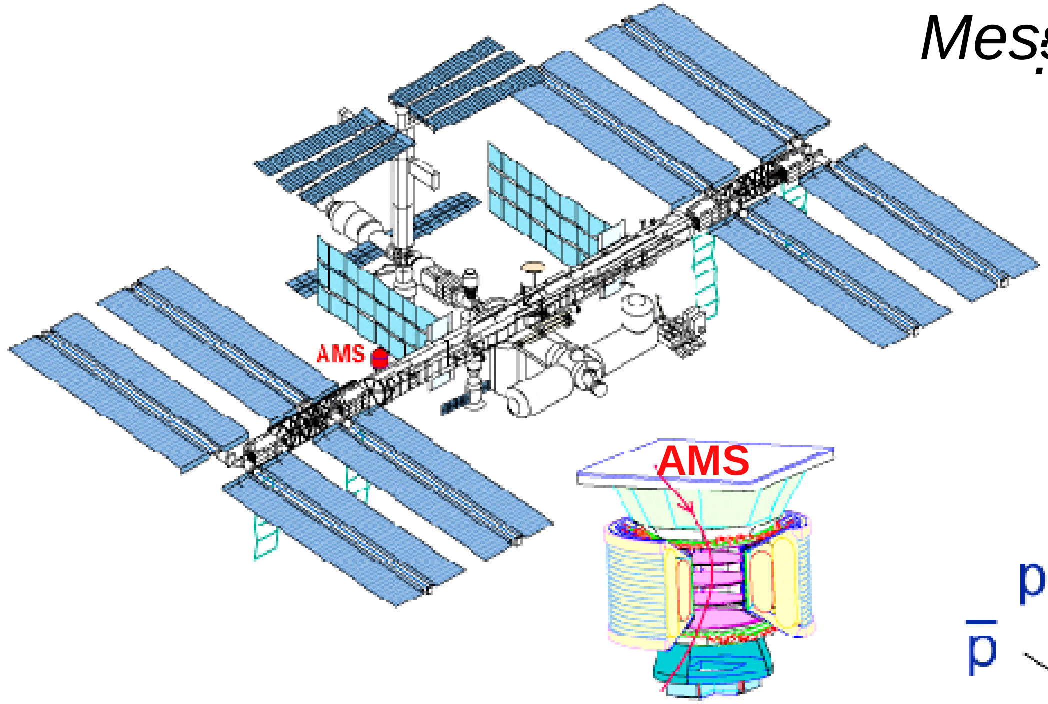
16 Countries, 60 Institutes and 600 Physicists



Project and design based on NASA's commitment to deploy AMS on the ISS

Fundamental Science on the International Space Station

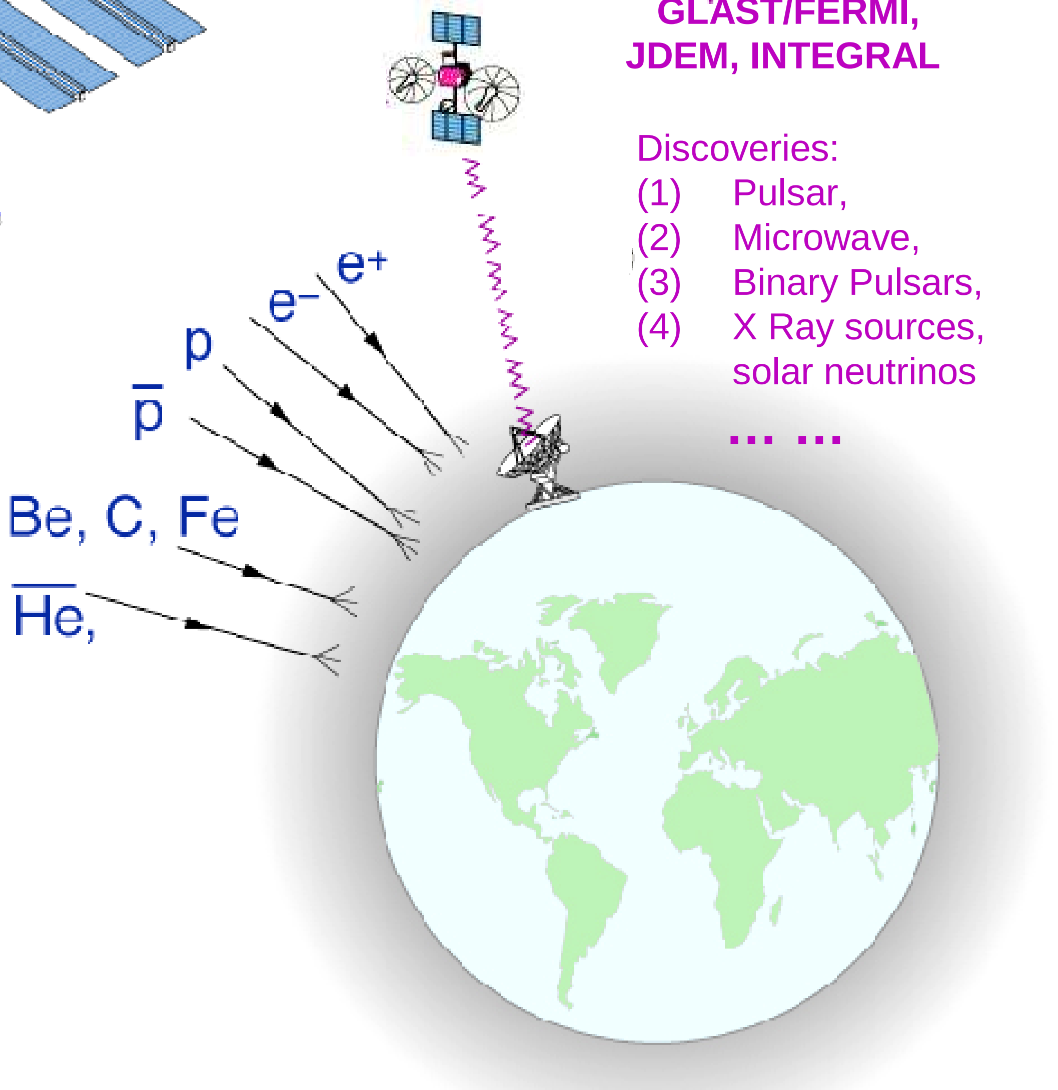
Messengers: 1- Neutral component: γ, ν



Hubble, Chandra, GLAST/FERMI, JDEM, INTEGRAL

Discoveries:
(1) Pulsar,
(2) Microwave,
(3) Binary Pulsars,
(4) X Ray sources, solar neutrinos

… …



2- Charged component: He, Be, C, Fe

AMS Physics Case:

- Anti-matter in Universe
- Precise study of Cosmic Ray
- Dark Matter
- Surprises ?

ANTI-MATTER

Questions and problems:

- No signal of presence of antimatter in Universe is presently seen. (No annihilation signals of sufficient intensity)
- If antimatter existed, where is it? Very far?
- Are there relics in the local Universe?
- What is the limit of its non existence

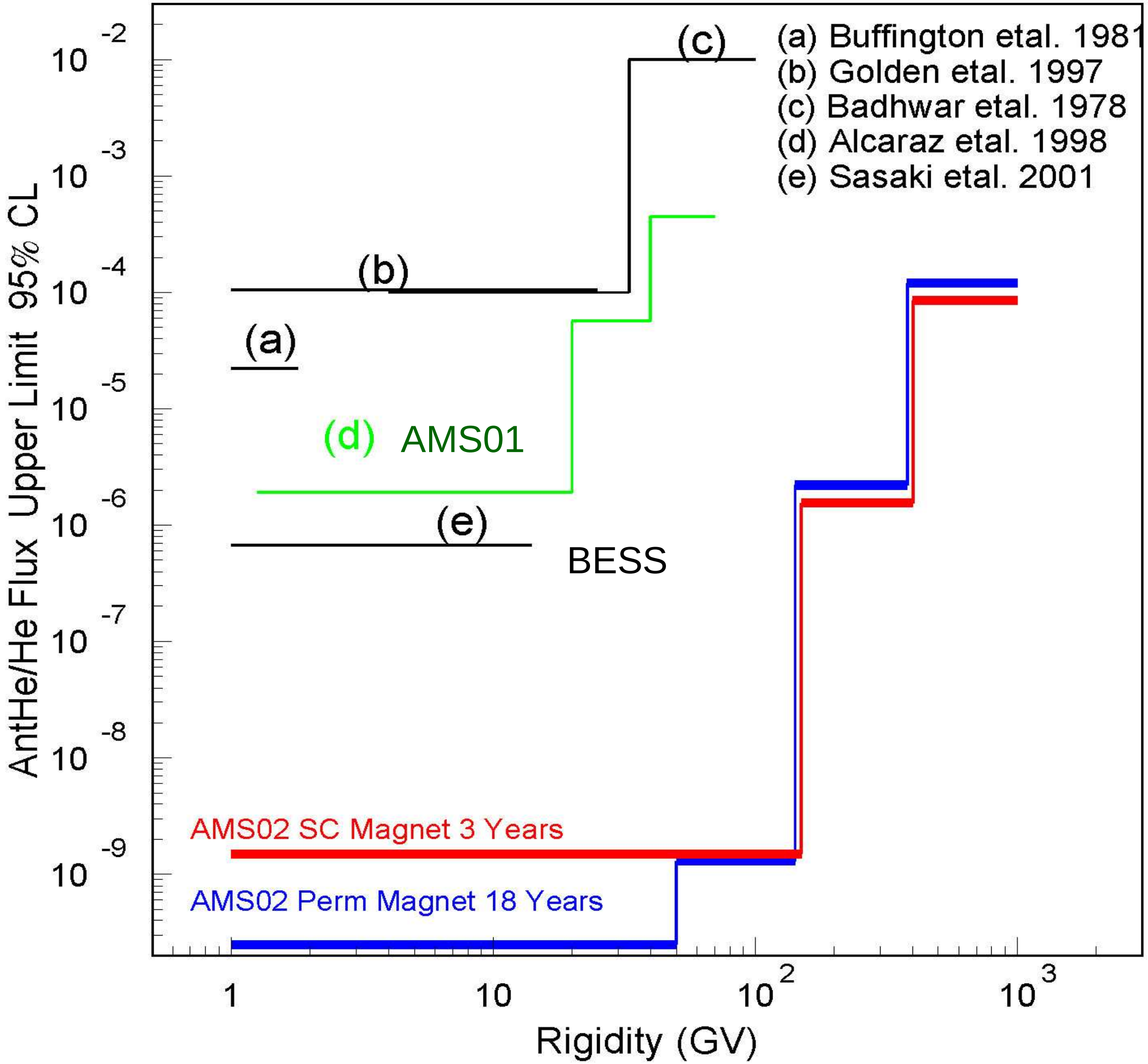
Sakharov Conditions: for a baryogenesis (with no anti-baryons)

- Out of thermal equilibrium (***yes)***
- Violation of symmetries C ***(yes)*** and CP ***(too small)***
- Baryon number (nb of quarks) violation.***(no)***

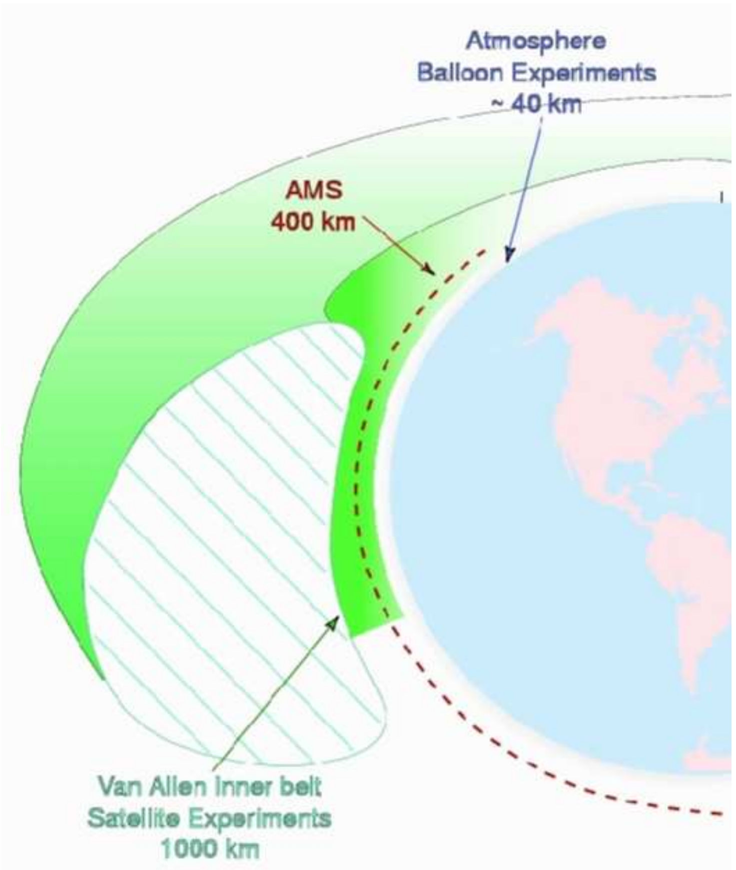
The physics applying to the firsts instants of Big-Bang is not yet known.

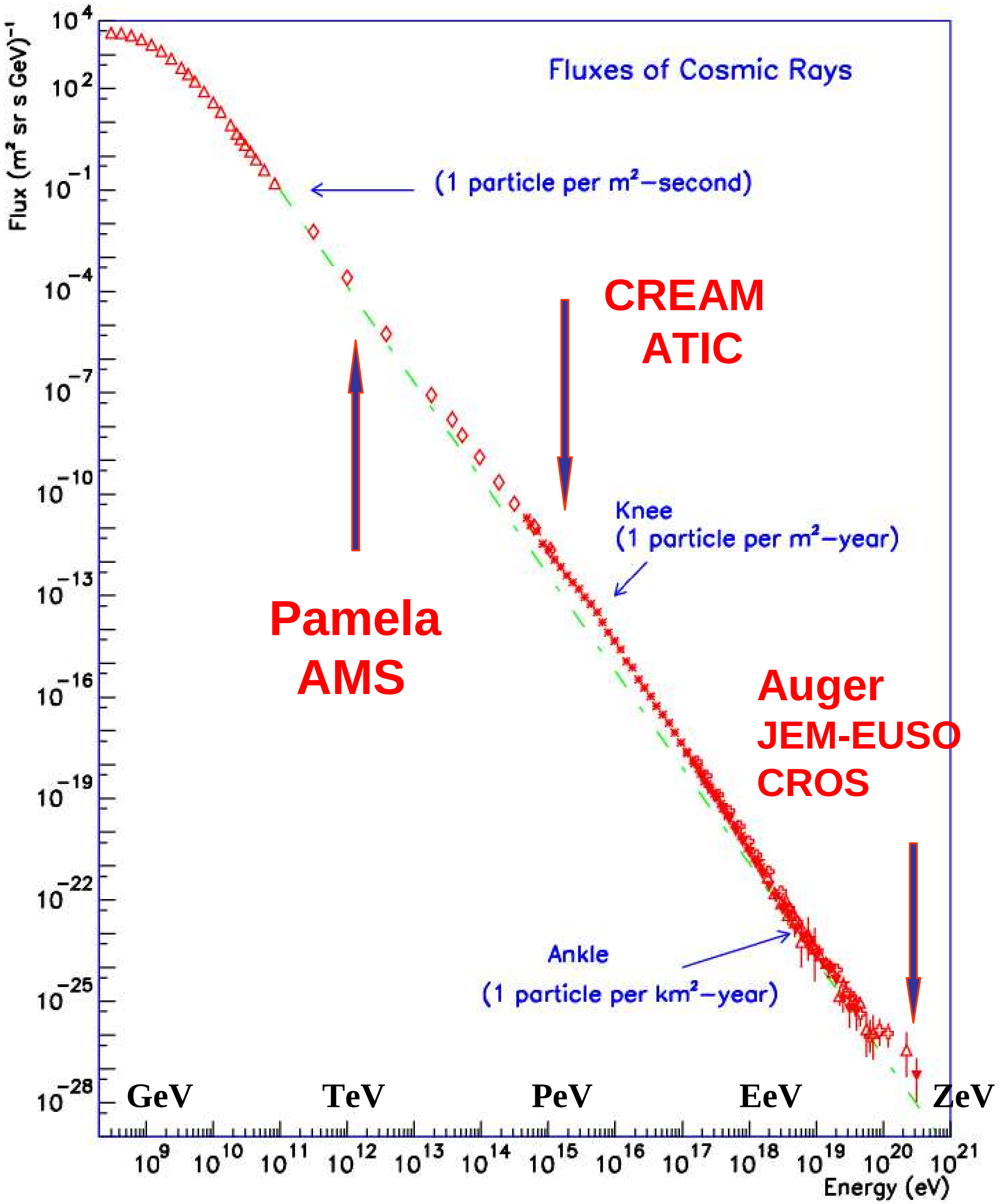
AMS: Search for anti-nuclei in cosmic ray

AMS goal: Limits on anti-Helium in cosmic rays



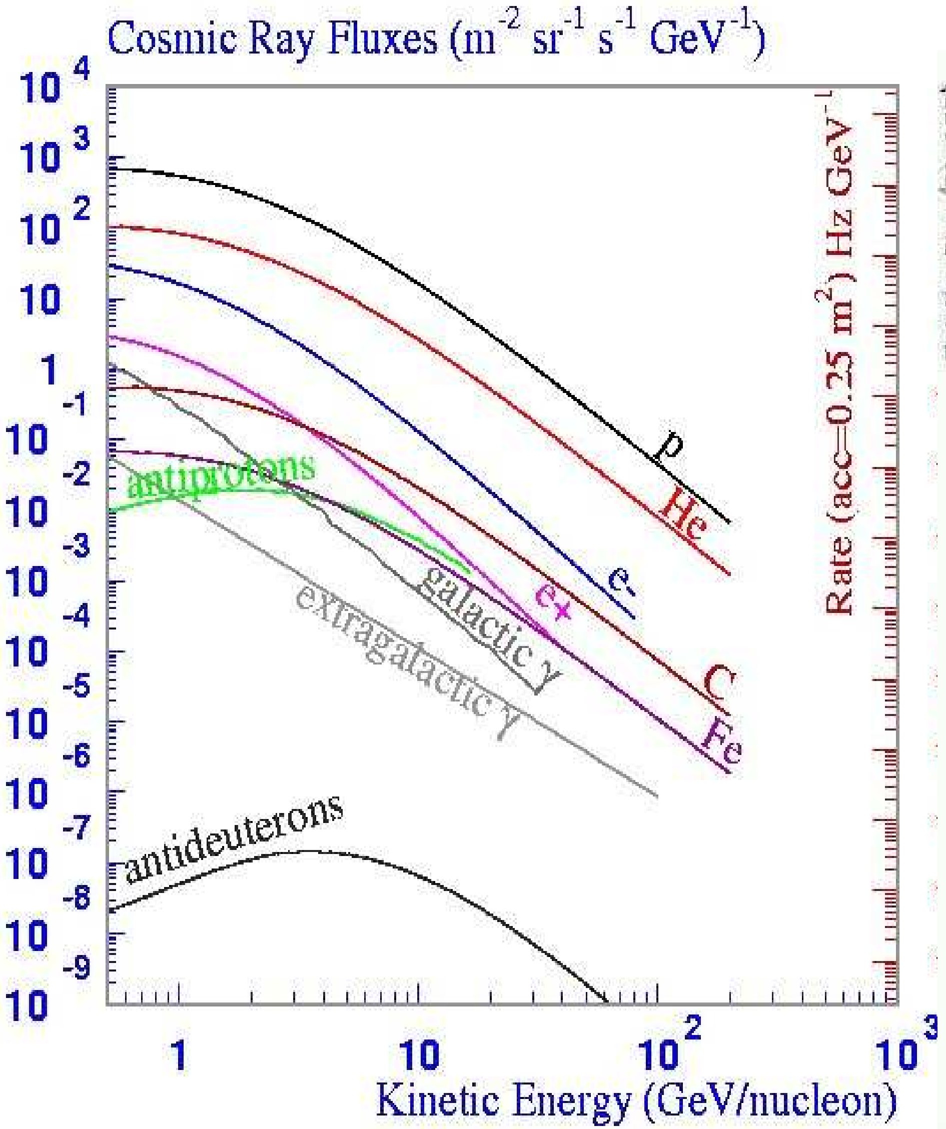
Large number of orders of magnitude in energies and intensities of CR

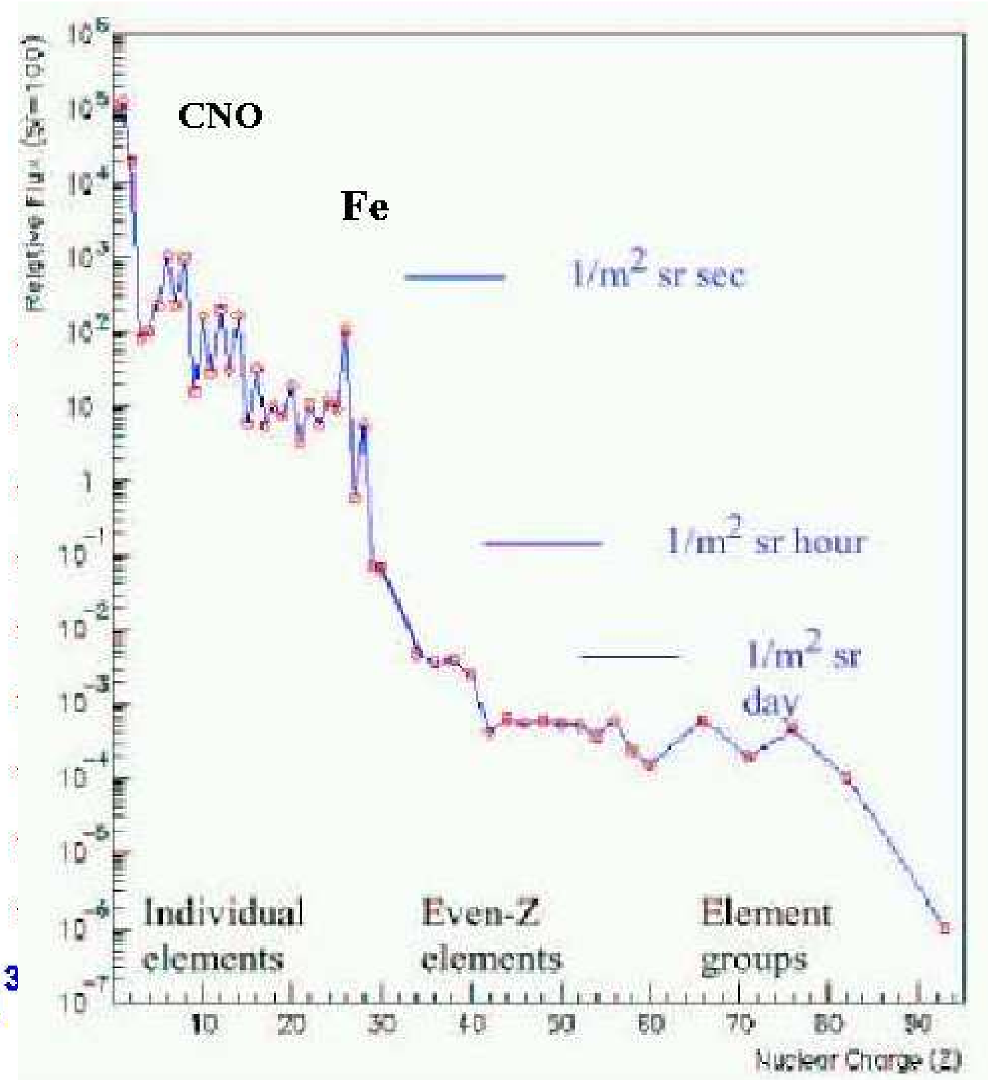




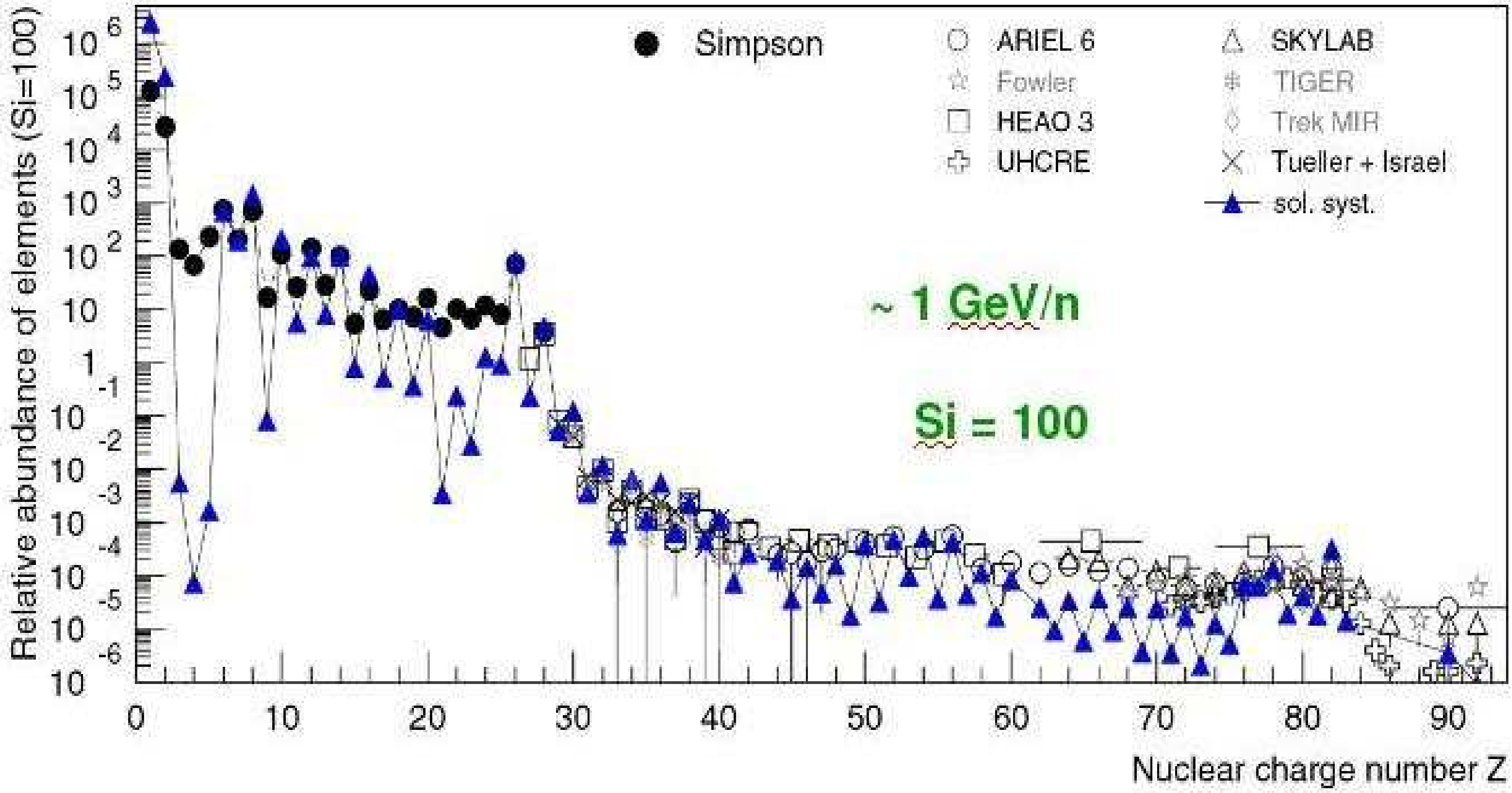
Abundances of various particles (➔ *identification)*

Abundance of various nuclei (elements) in CR





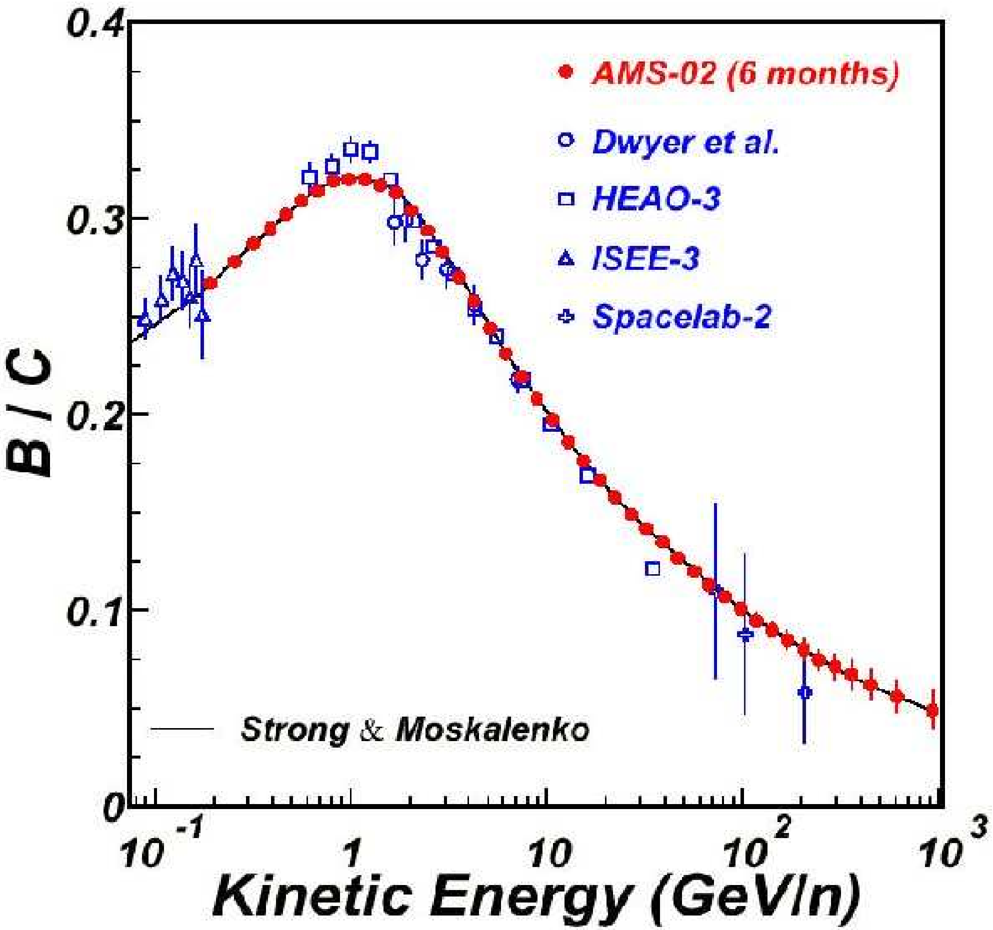
Relative abundance of elements in CR and in solar system

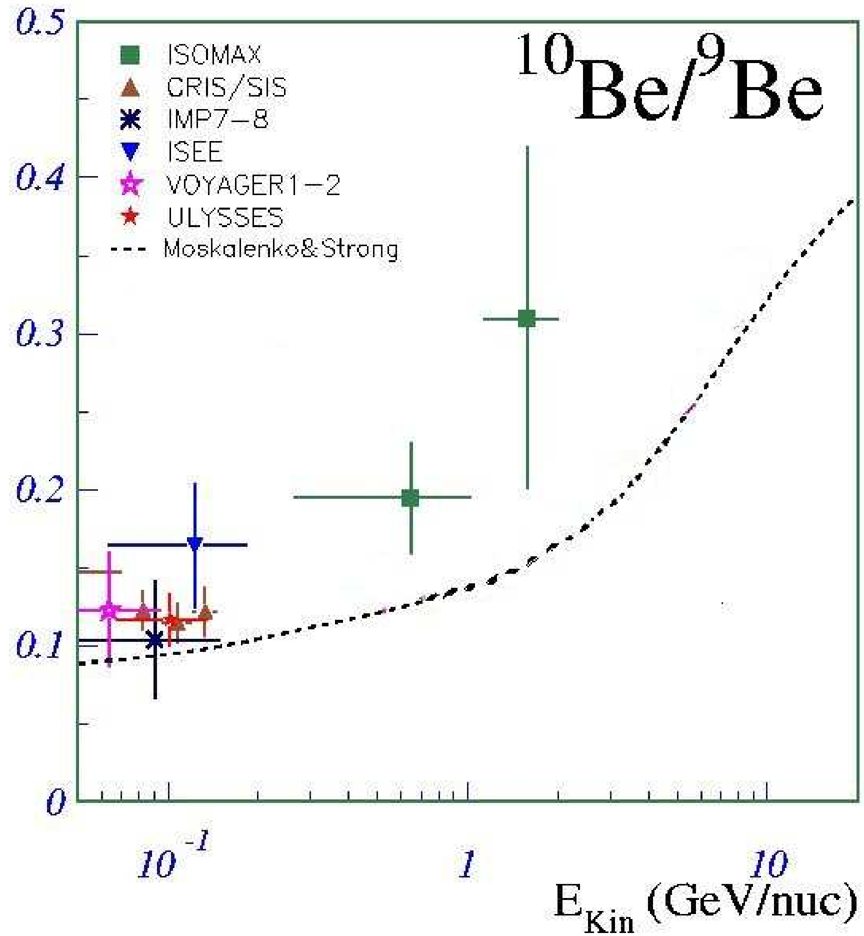


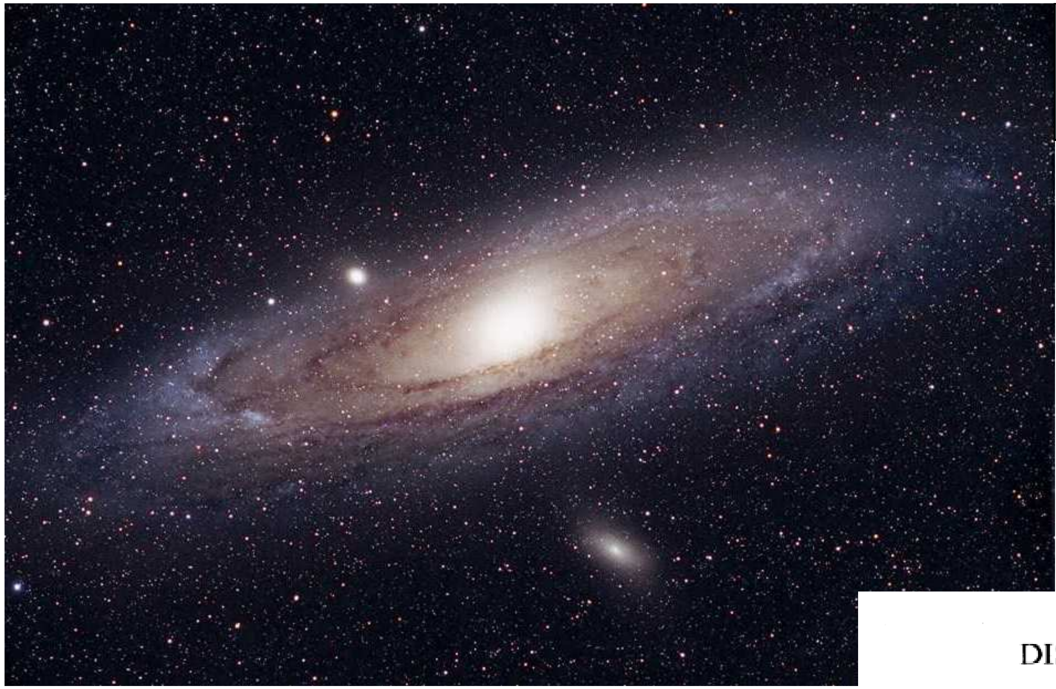
➔ Interaction of cosmic ray with interstellar medium by fragmentation ➔ Confinement time

Tests of CR propagation models using secondaries and ratios

Li, Be, B nuclei come from CNO spallation. Radio-active secondary nuclei like ^{10}Be (τ = 2 x 10^6 y) are *cosmic clocks.* Chemical composition and isotope ratios depend on cosmic ray confinement time and density of the interstellar medium.





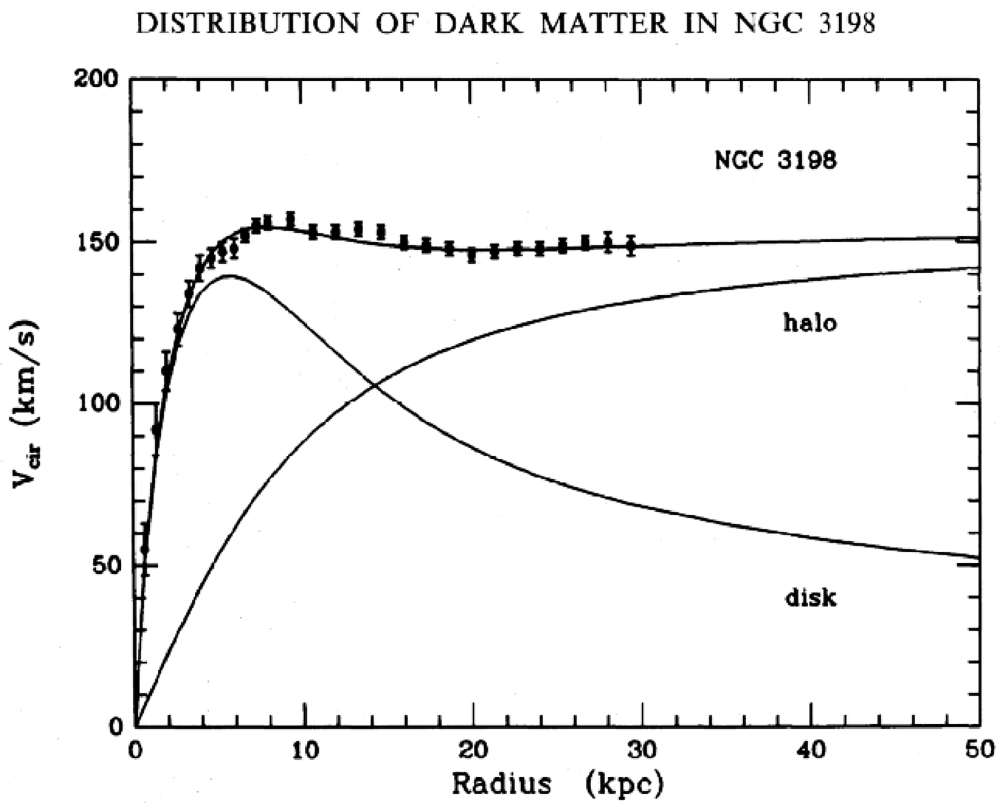


Dark Matter

Dark Matter manifests its existence through its gravitational effects:

-Rotational velocities of stars at the edge of the disk galaxies.

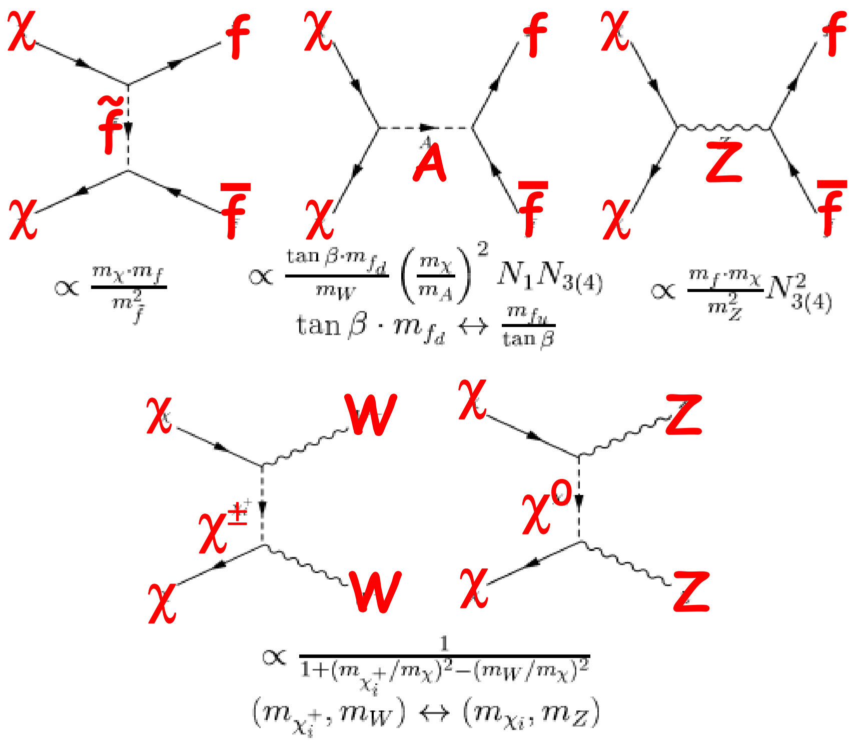
-Gravitational lensing

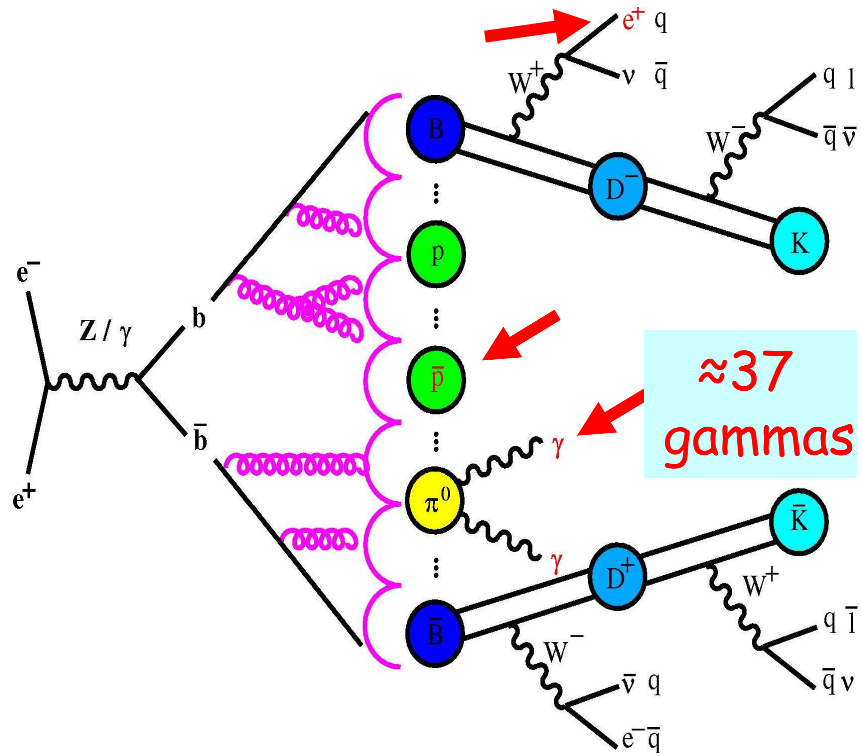


From the many hypothesis on the nature of DM, two are related to particle physics:

- Supersymmetric particles χ_o
- Kaluza-Klein Boson (B)

DM Annihilation in Supersymmetry





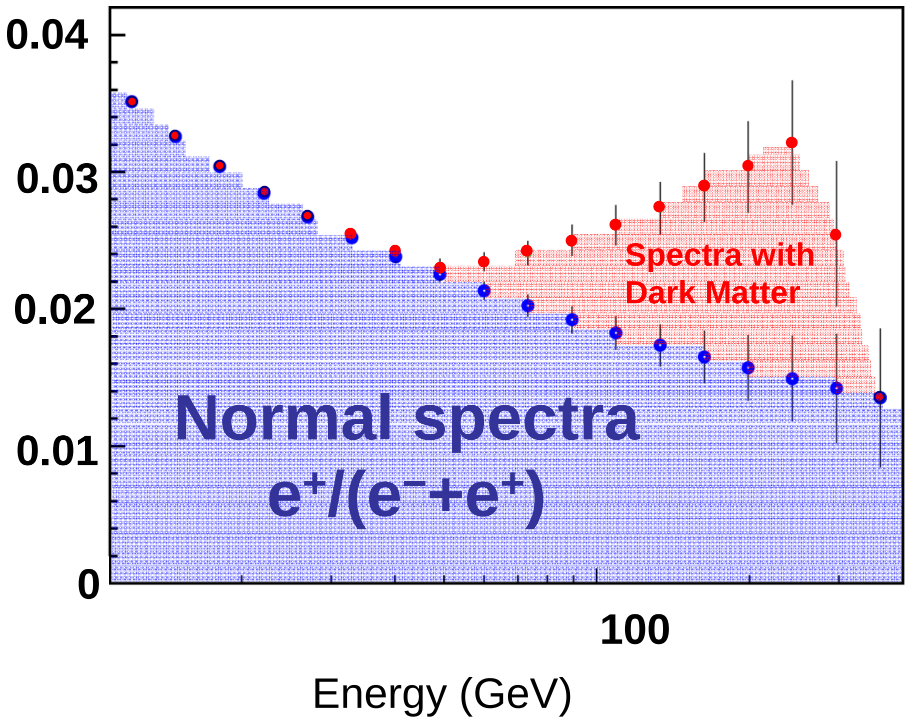
Dominant

$\chi + \chi \Rightarrow A \Rightarrow$ b bbar quark pair

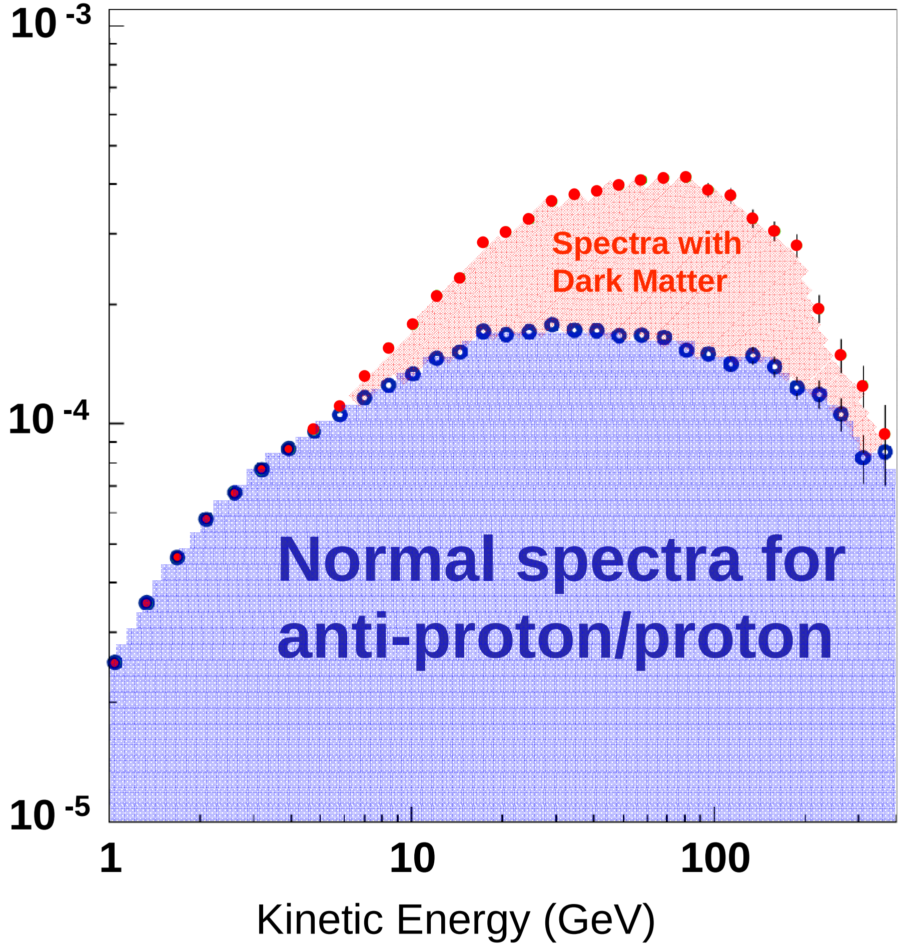
B-Fragmentation known!
Hence Spectra of Positrons,
Gammas and Antiprotons known!

Two leading theoretical candidates

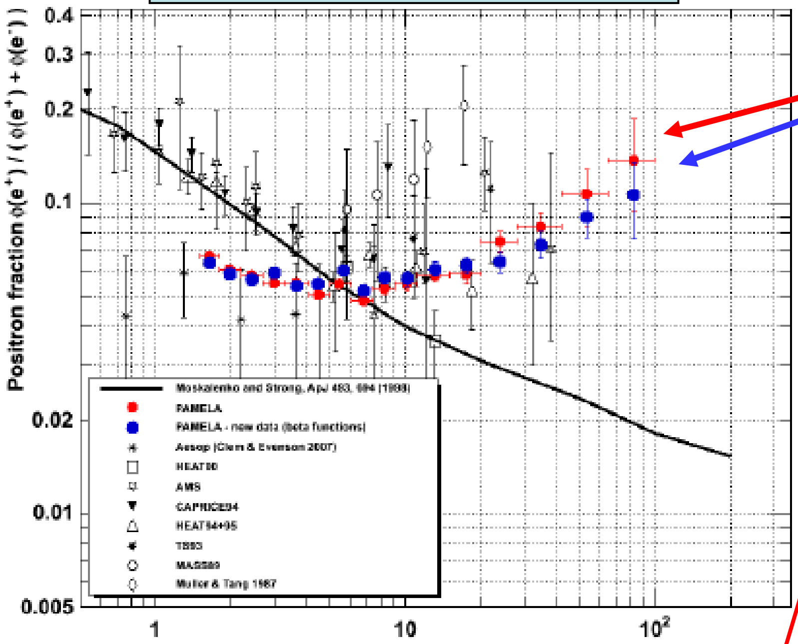
Dark Matter is a Kaluza-Klein Boson (B)
- assumes extra dimensions -
with a typical mass of
M_B = 300GeV

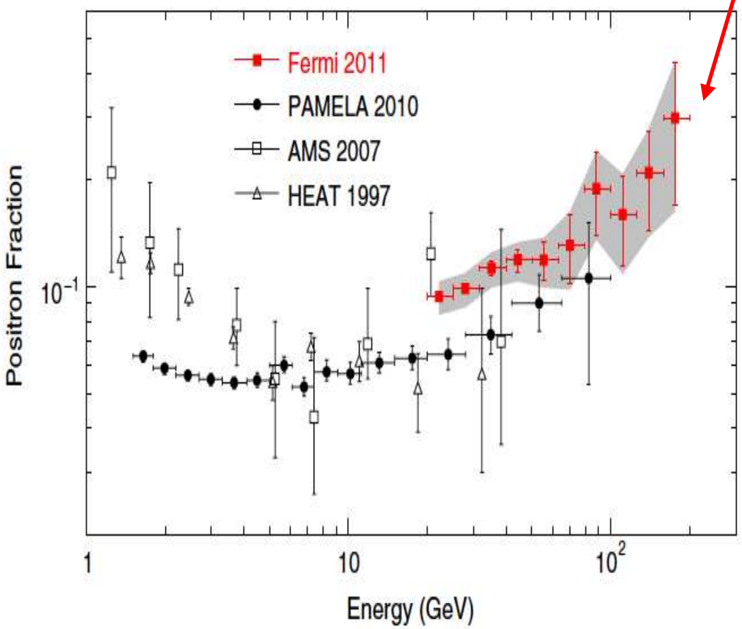


Dark Matter is a supersymmetric particle with Mχ = 840 GeV.
This is not accessible to the next accelerator (LHC)



$e^+ / (e^+ + e^-)$



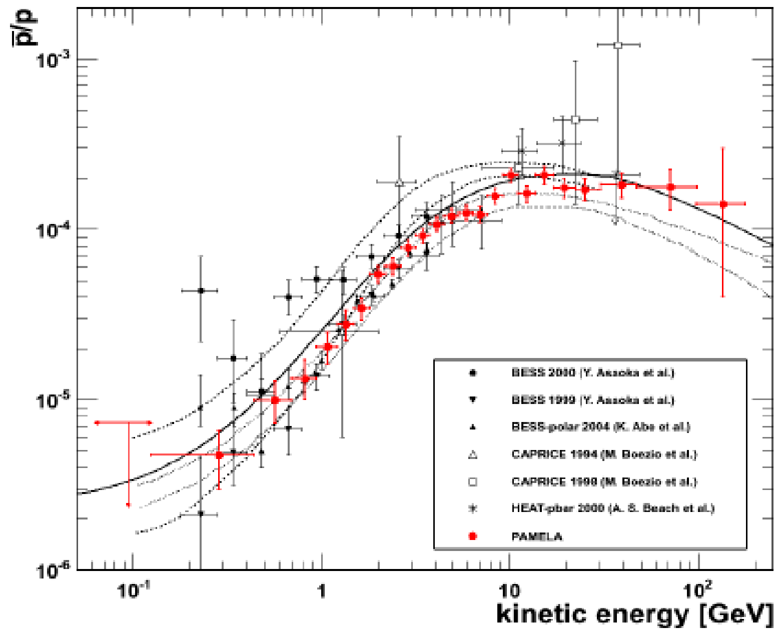


PAMELA has seen a e^+ signal...

~confirmed by *FERMI*

... but no signal on the anti-protons

p_{bar} / p

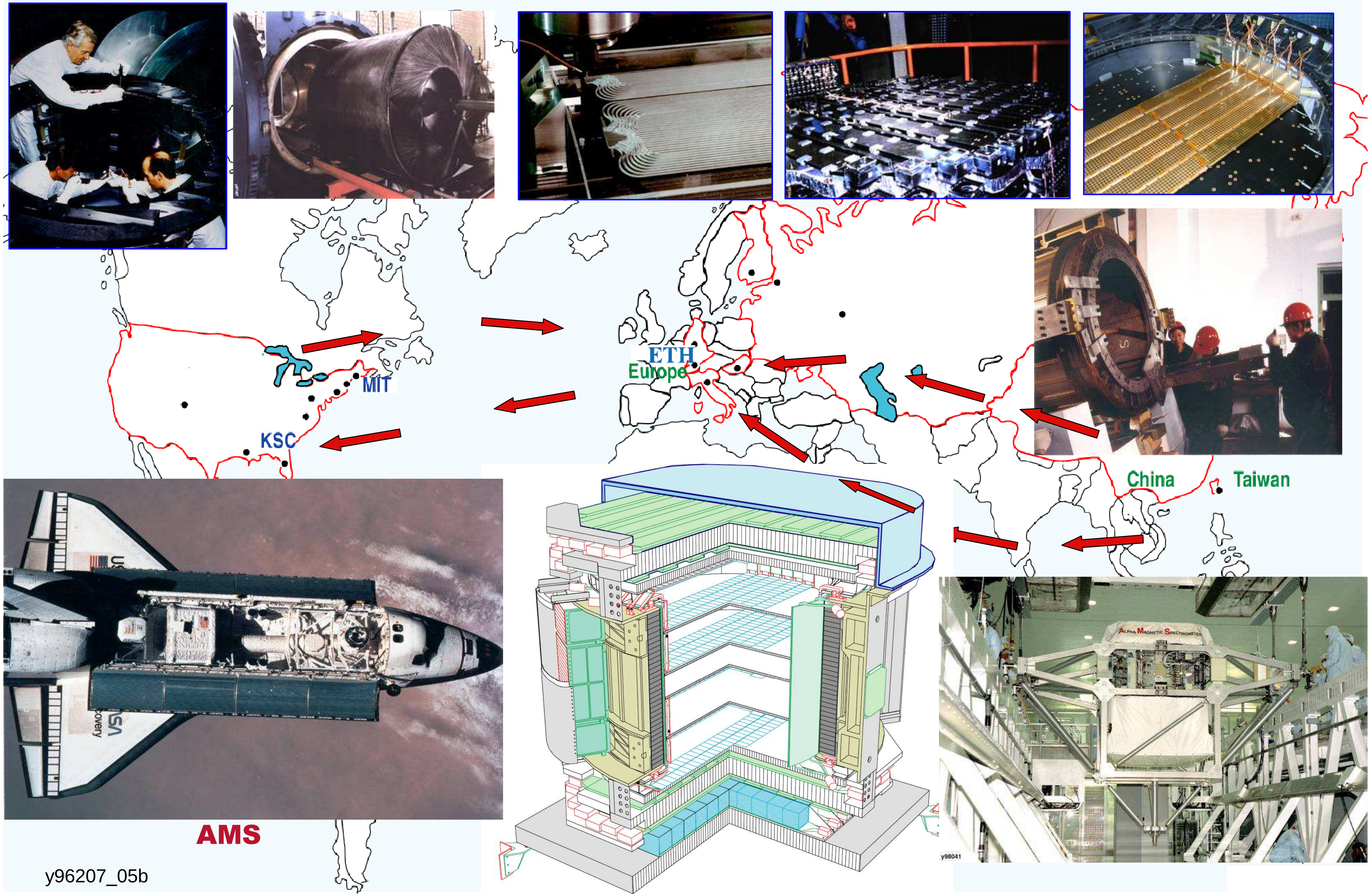


E.Mocchiutti, W.Mitthumsiri, *Positron Workshop, Mürren, 2012*

AMS experiment

First flight AMS-01 (STS-91 Docking to MIR)

Approval: April 1995, Assembly: December 1997, Flight: 10 days in June 1998

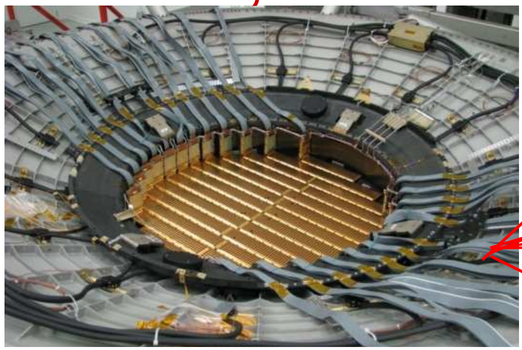


y96207_05b

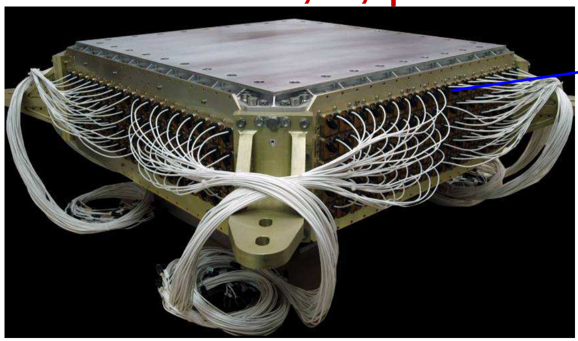
AMS: A TeV precision, multipurpose spectrometer

TRD
Identify e^+, e^-

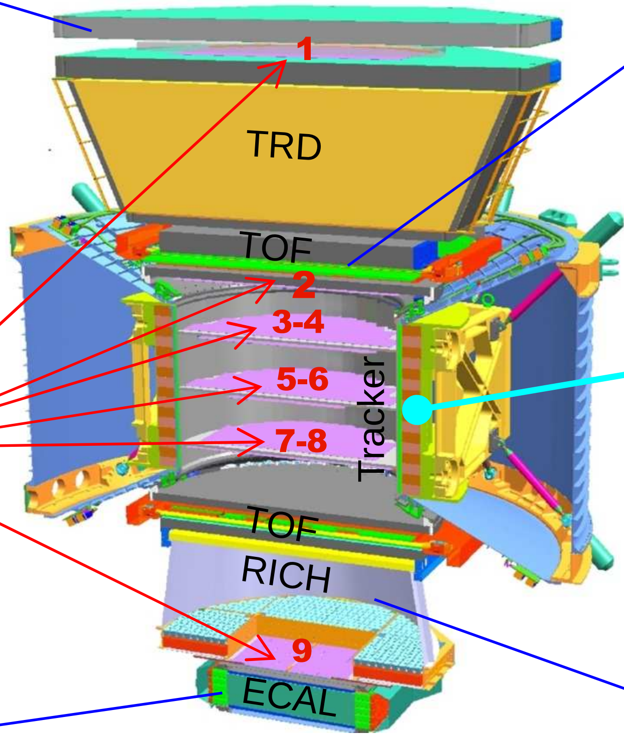
Silicon Tracker
Z, P



ECAL
E of e^+, e^-, γ



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

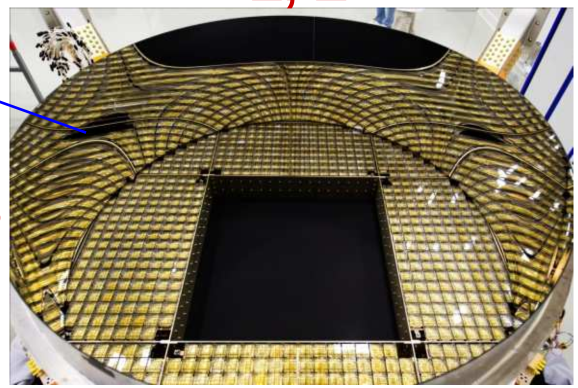


Z, P are measured independently by the Tracker, RICH, TOF and ECAL

TOF
Z, E

Magnet
±Z

RICH
Z, E



AMS: A TeV precision, multipurpose spectrometer

TRD
Identify e+, e-

- 20 layer radiator/straw tubes
- Xe/CO_2 80%/20% gas
- 5284 channel

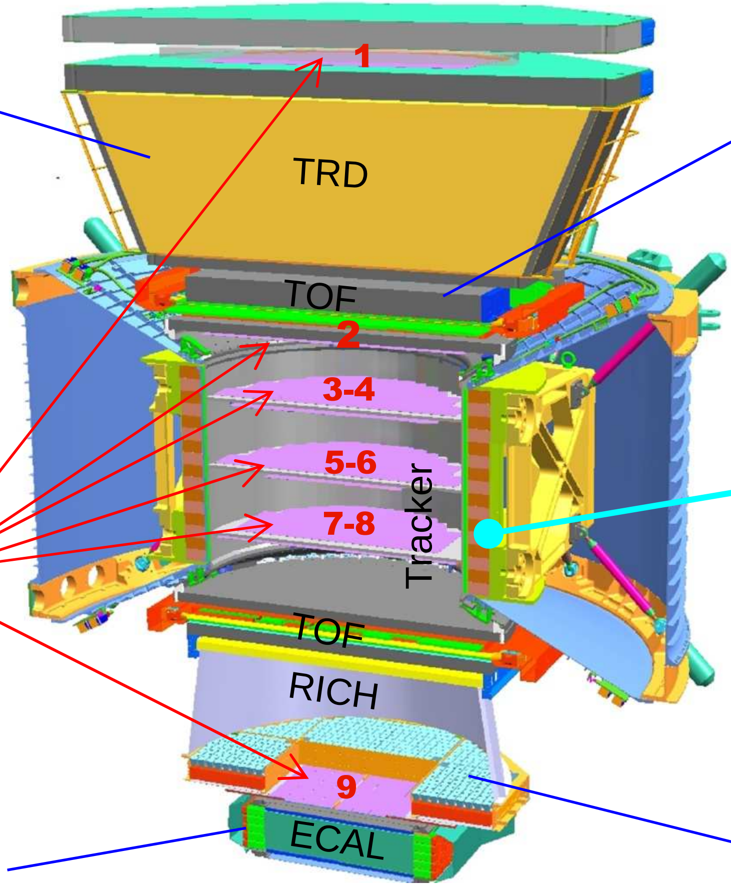
Particles and nuclei are defined by their charge (Z) and energy (E ~ P)

TOF
Z, E

- 4 layer scintillators
- 48 PM
- 1536 channels
- V. Bindi poster

Silicon Tracker
Z, P

- 9 layer double sided detector
- 192000 high dyn. range readout channel
- low material budget



Magnet
±Z

- B ~ 0.14 Tesla
- 640 Nd-Fe-B blocks
- 1900 Kg

ECAL
E of e+, e-, γ

- 3D sampling calorimeter
- 17 X_0
- 9 superlayer lead/fibers
- 324 MAPMT
- 2916 channels

RICH
Z, E

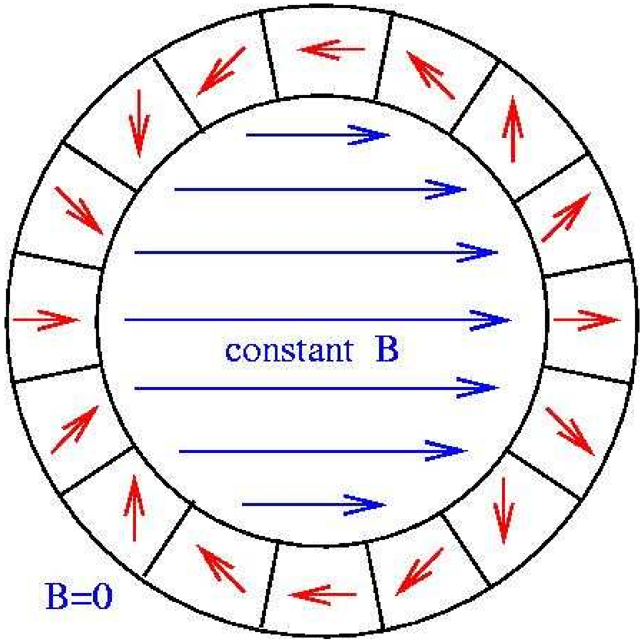
- Areogel and NaF radiator
- 680 MAPMT
- 21726 channels

Z, P are measured independently by the Tracker, RICH, TOF and ECAL

AMS-01 permanent magnet

Torques are forbidden on spacecrafts

➔ The total magnetic moment MUST BE ZERO



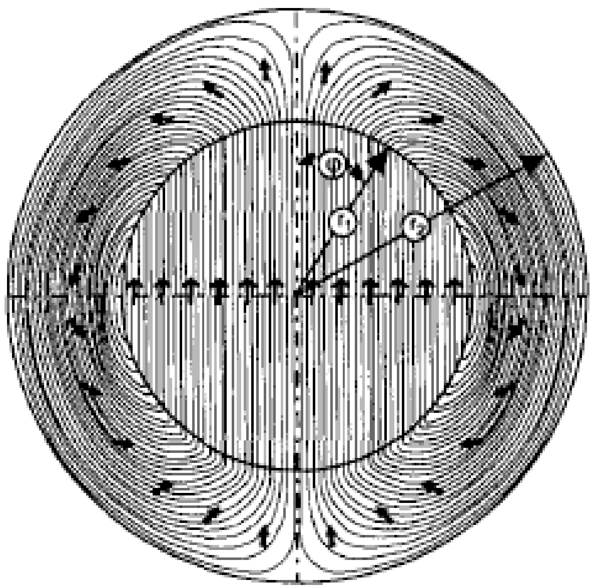
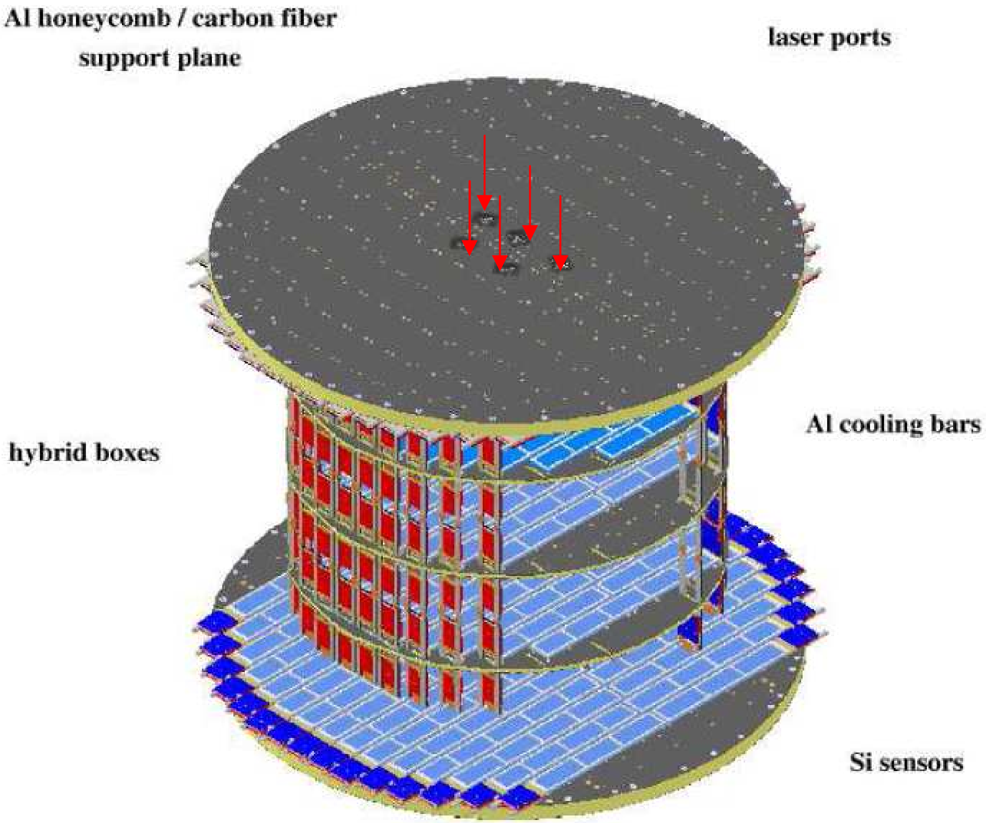


Fig. 6. Magnetic field distribution at a cross-section of the center of the magnet.

B=0.14 T

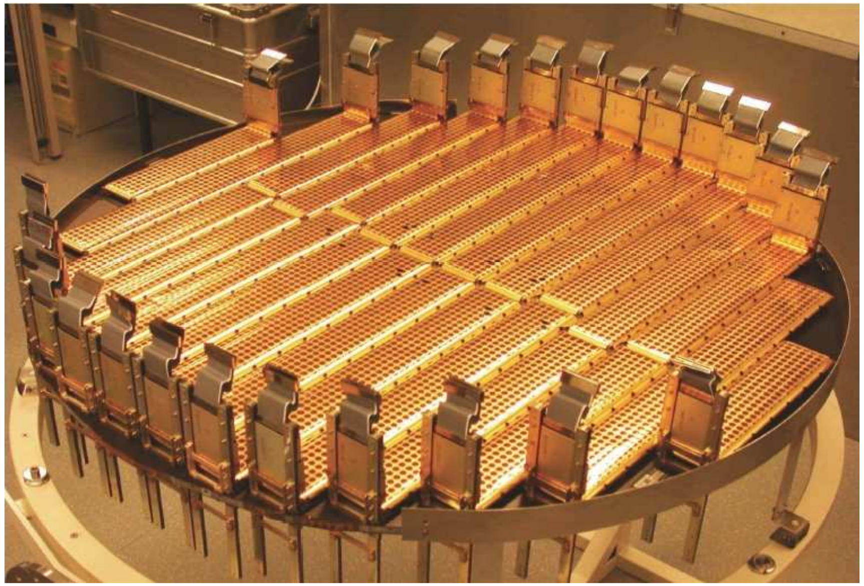
L= 1 m

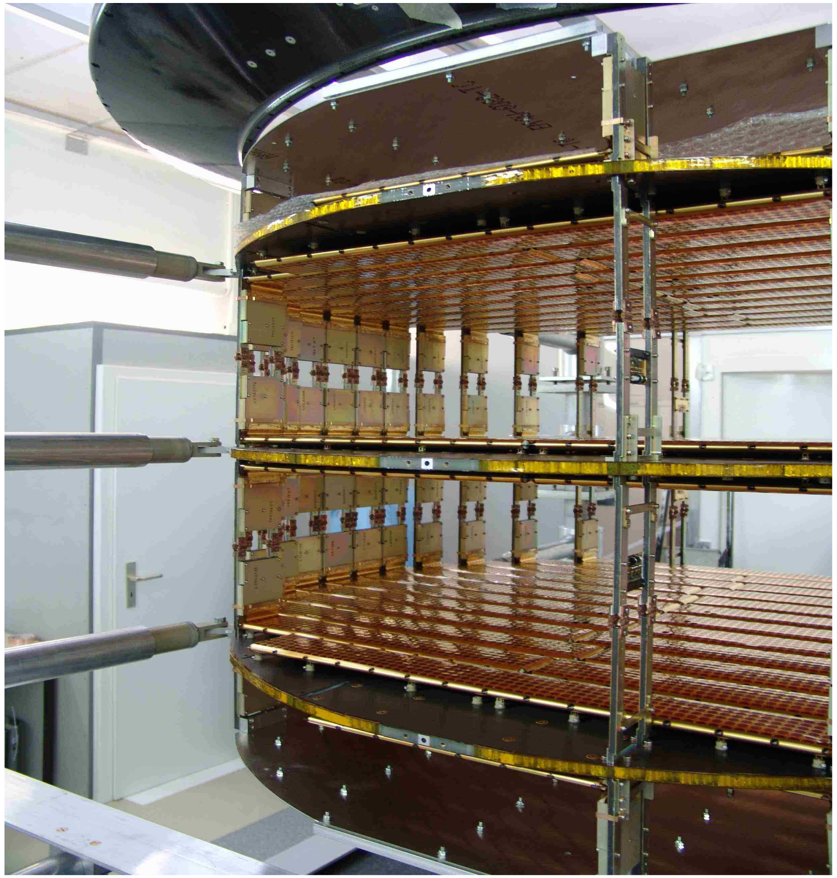


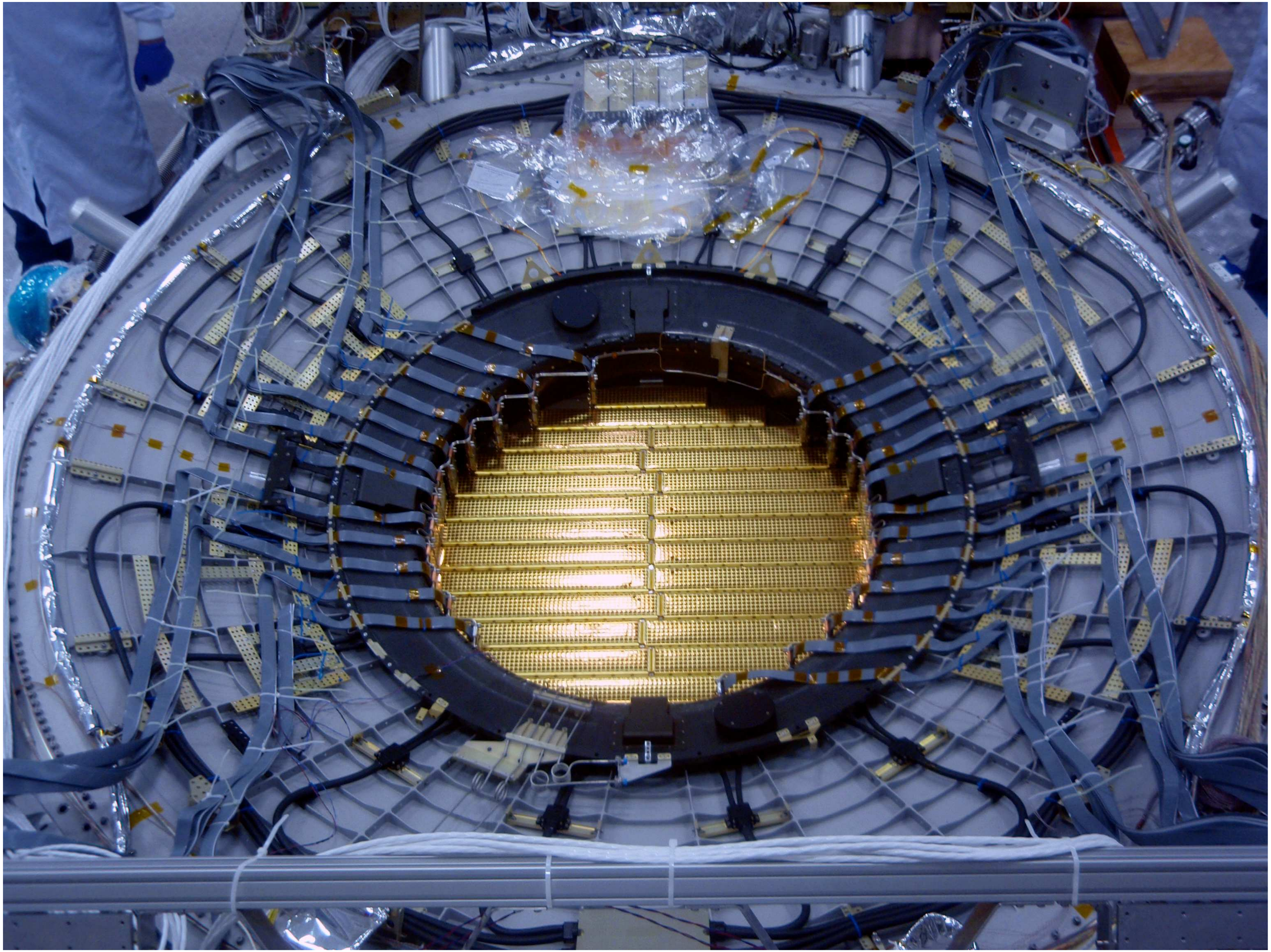
• 9 layers of XY sensors (7 m^2 total)

• 7 inner layers (in magnet bore) + two external layers(top and bottom)

•Cooling of the front-end electronics by *thermal bars* and two phases CO_2 circuit at 50 bar pressure.

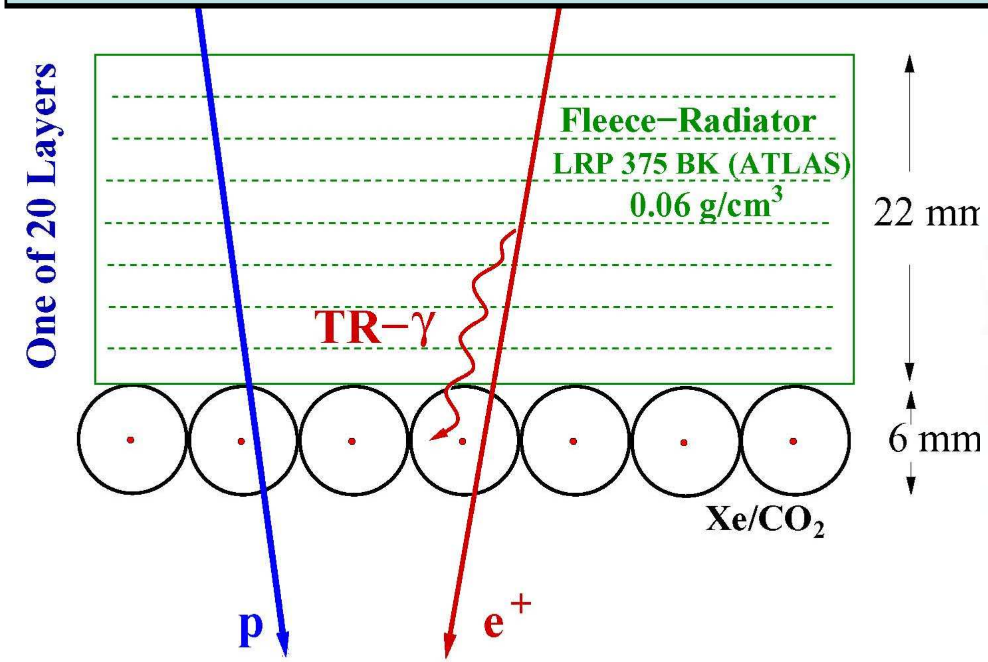




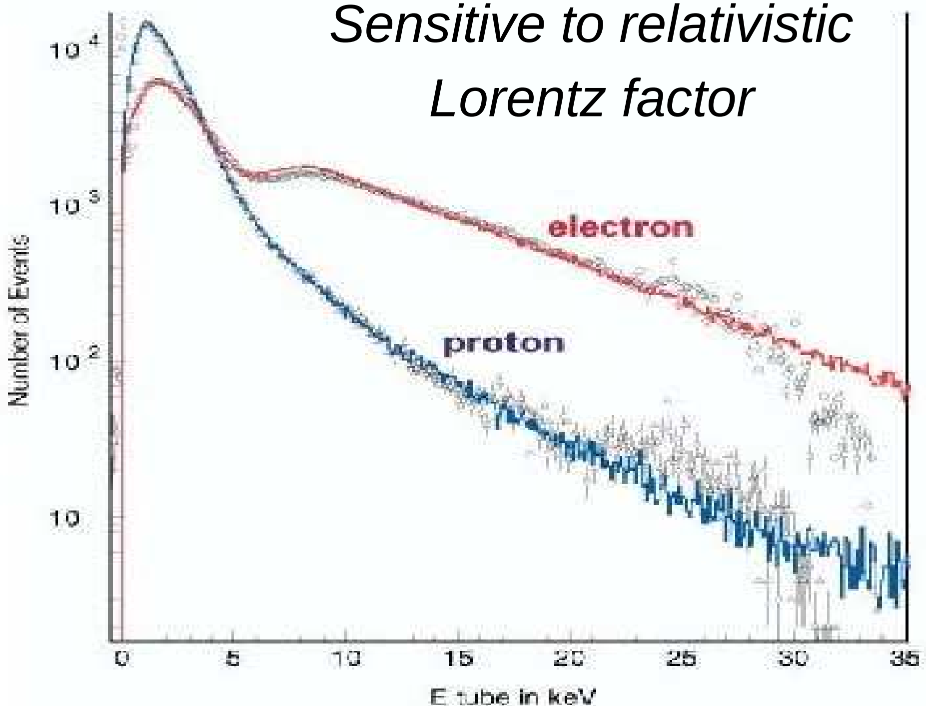


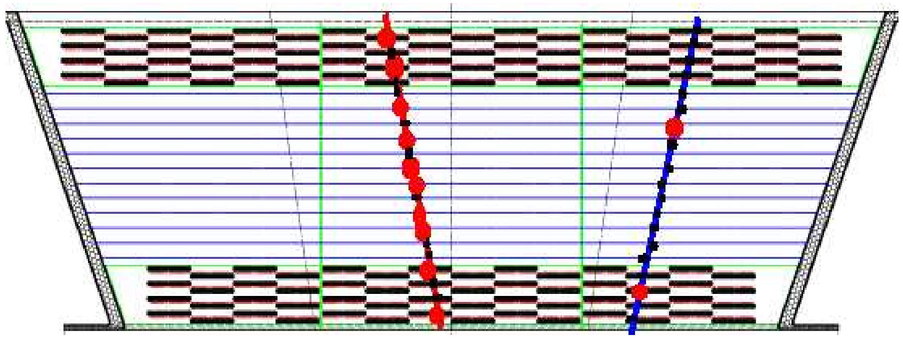
Transition Radiation Detector: TRD

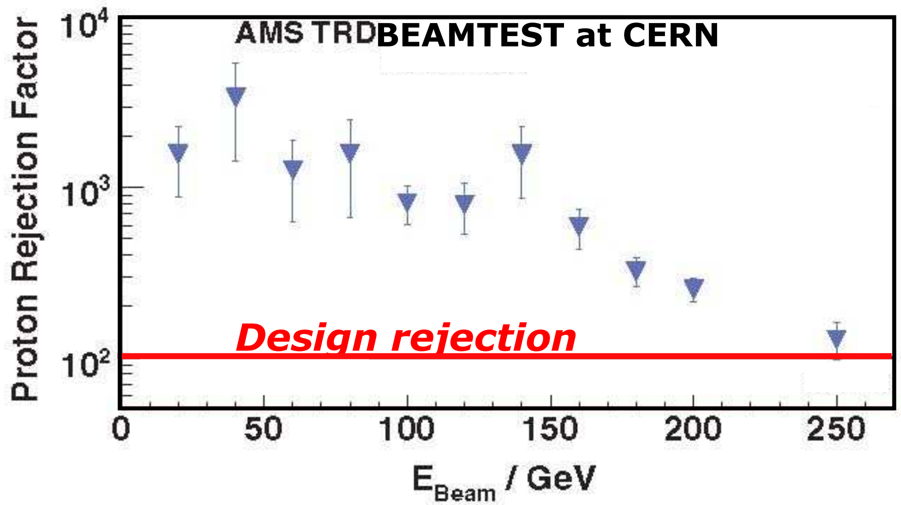
Identify electrons/positron



Sensitive to relativistic Lorentz factor

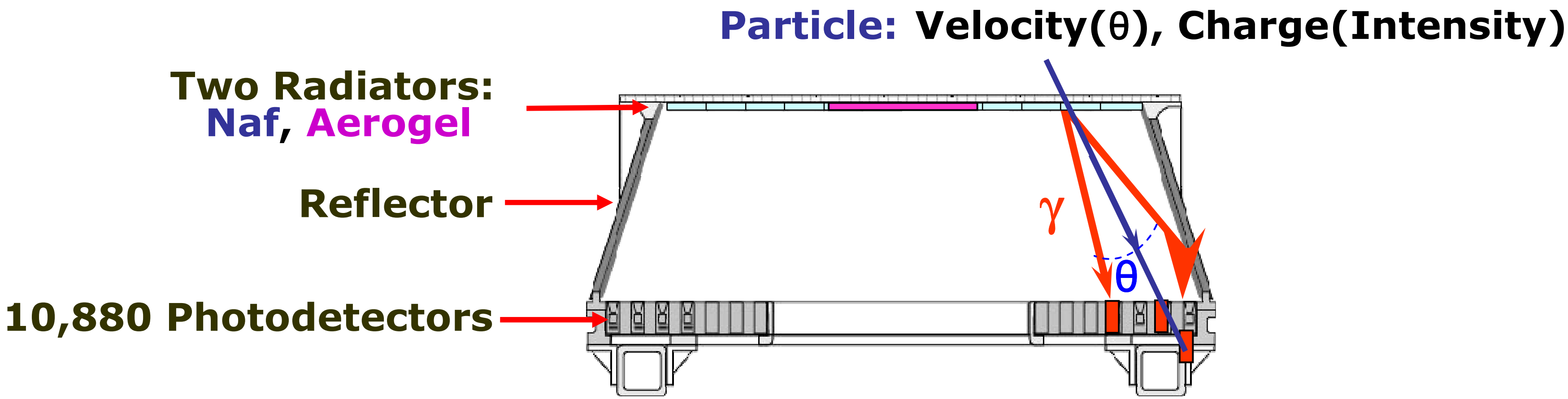


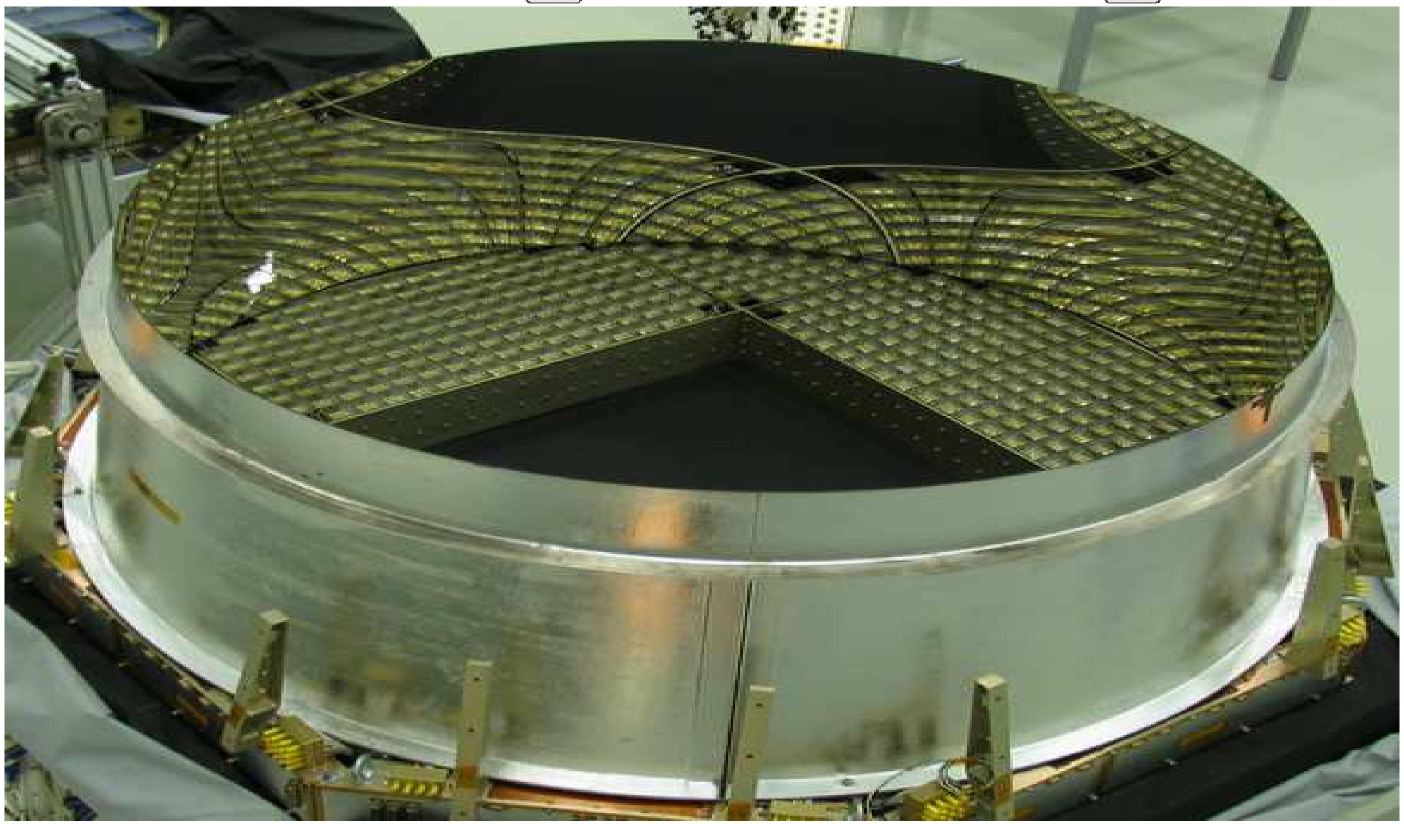




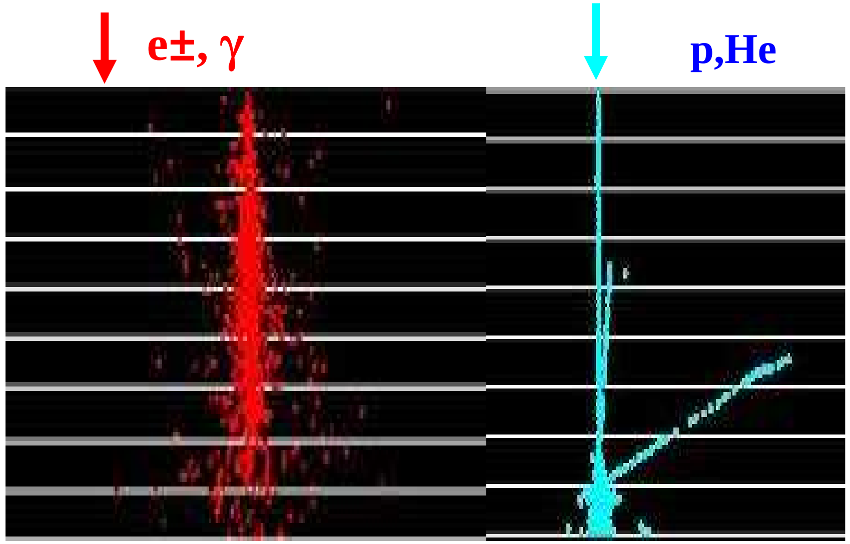
12 layers in the bending plane
8 layers in the non-bending plane

Ring Imaging Cerenkov Counter (RICH)

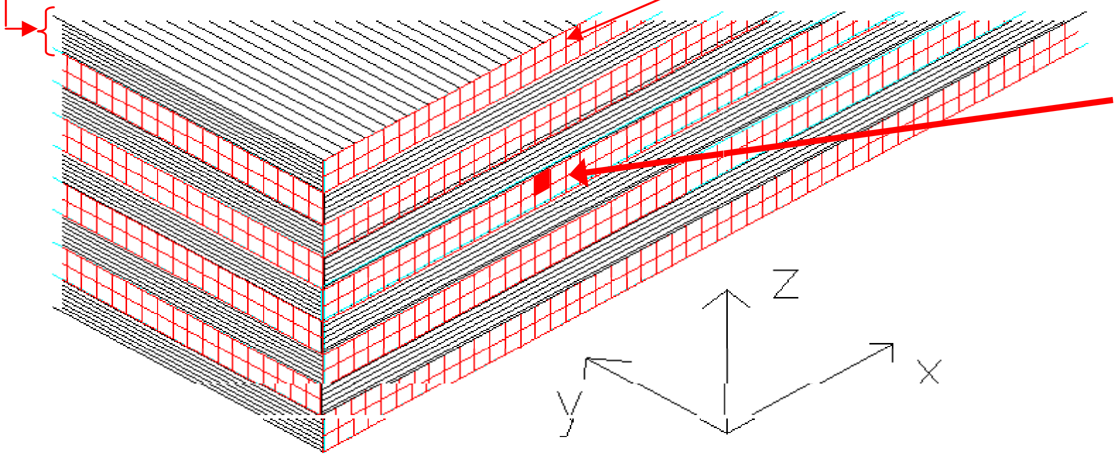


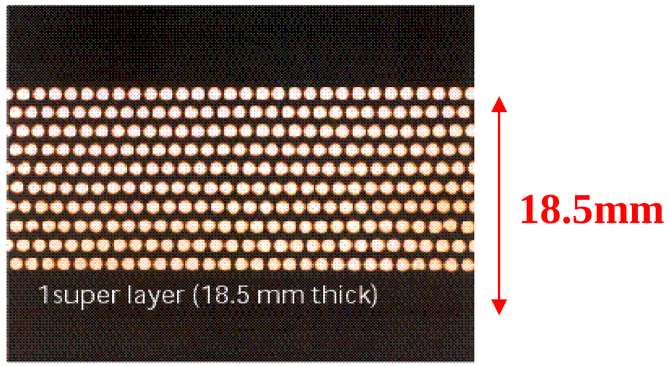


ECAL: electromagnetic calorimeter

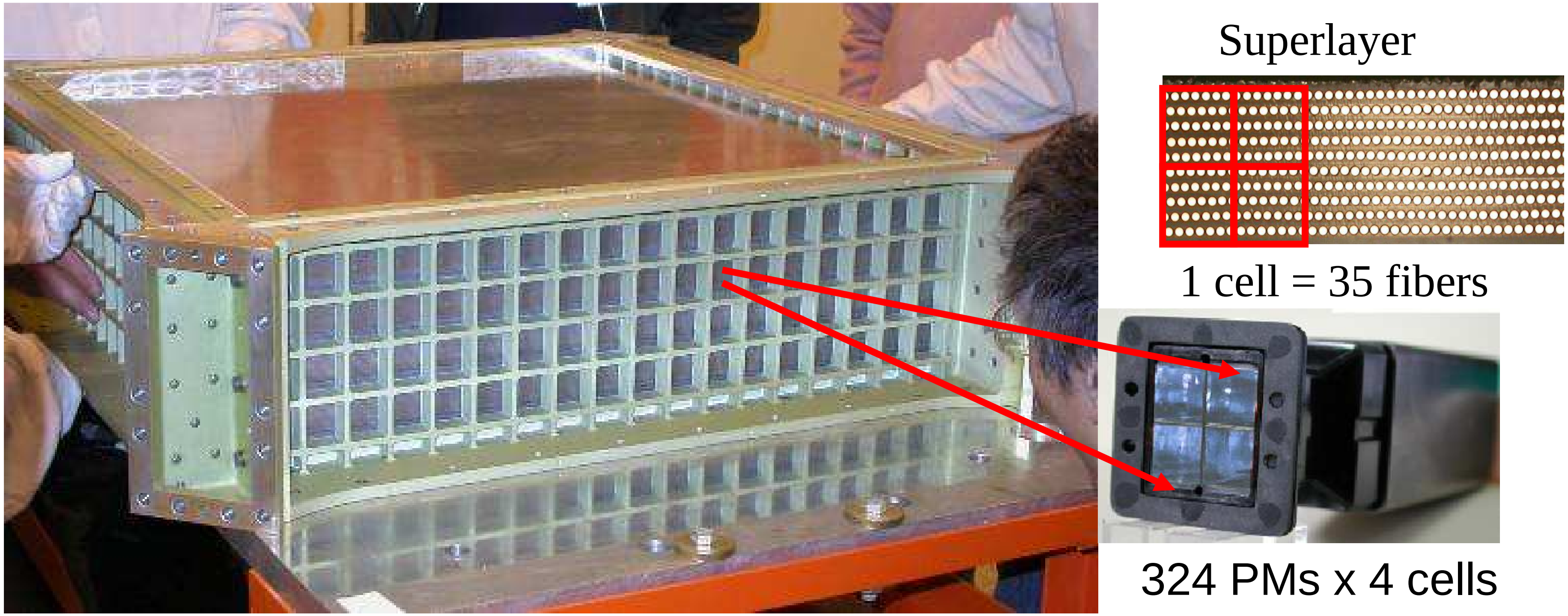


- Pb/scintillating fibers sandwich (640 kg) with 3D sampling by 9 crossed superlayers (18 layers, 5 pairs in X, 4 pairs in Y)
- Segmentation: *long:~ 1 X_0, lat: ~ 0.5 R_M*
- Length: ***~ 17 X_0 ,≈ 1 λ_R .***
- Angular resolution: *~1°*
- ΔE/E = *10%/√E + 2.6%*
- Proton suppression up to 10^4 at 500 GeV. (10^6 with TRD)

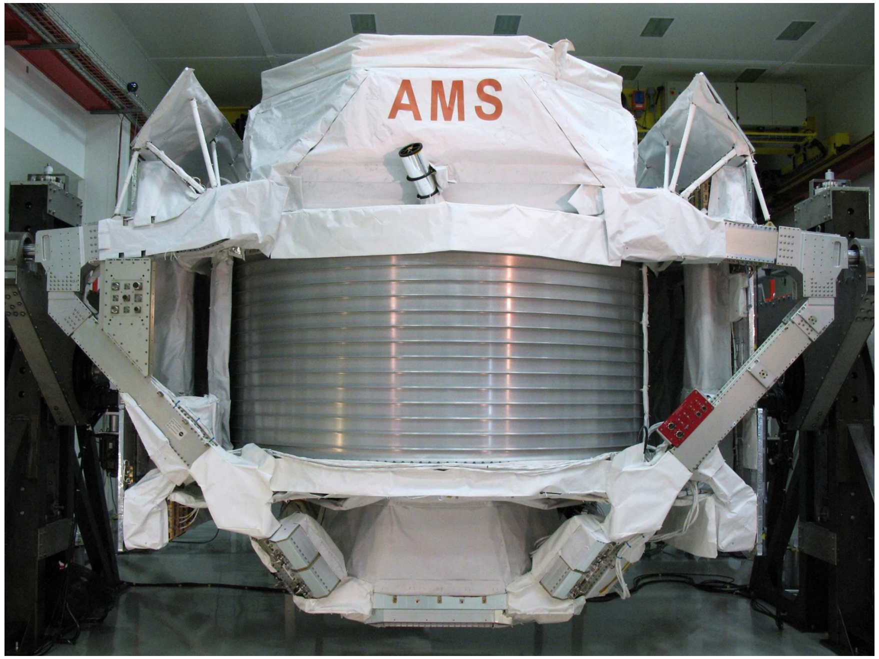




Imagerie 3D

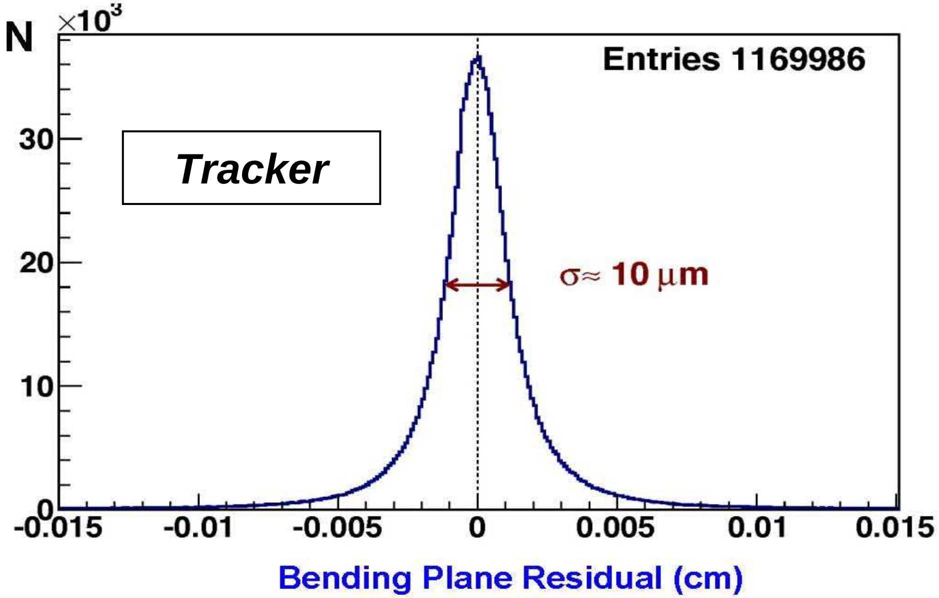

Superlayer
1 cell = 35 fibers
324 PMs x 4 cells

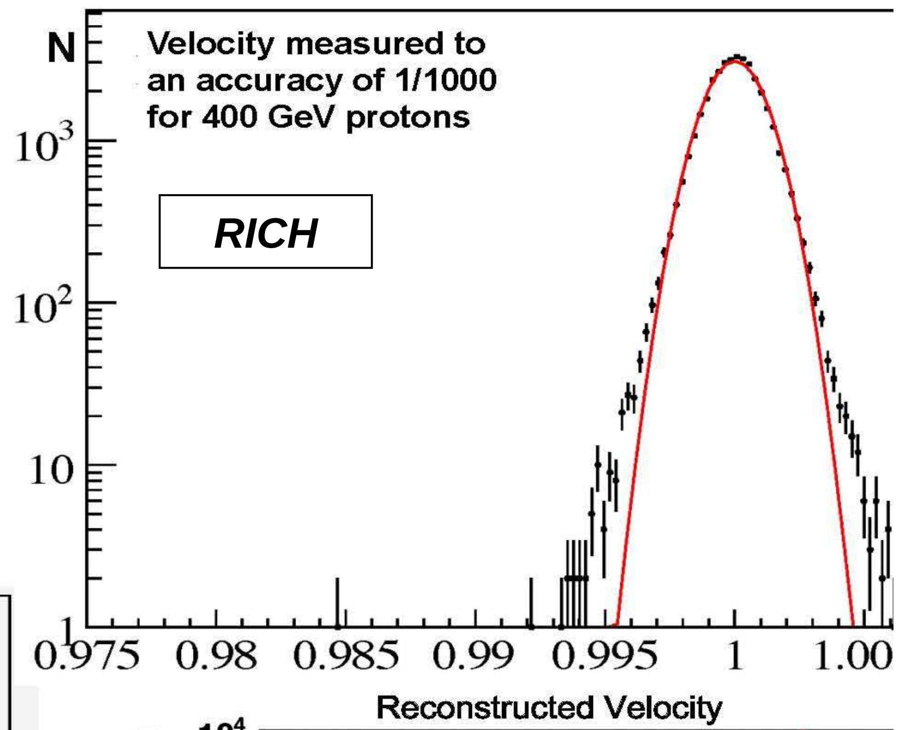
Integration of AMS: at CERN in a specially built clean room

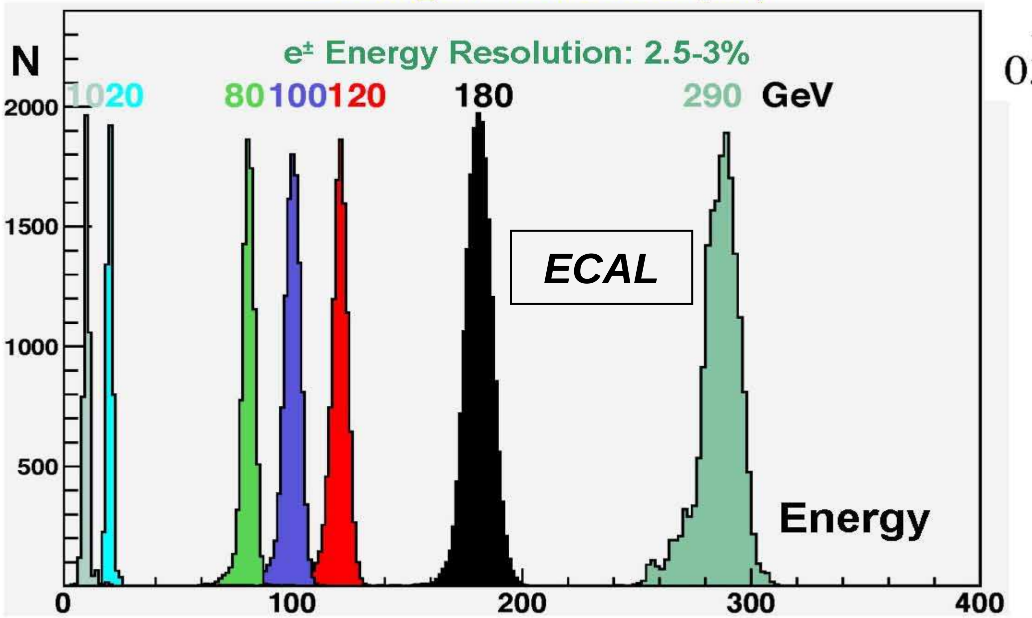


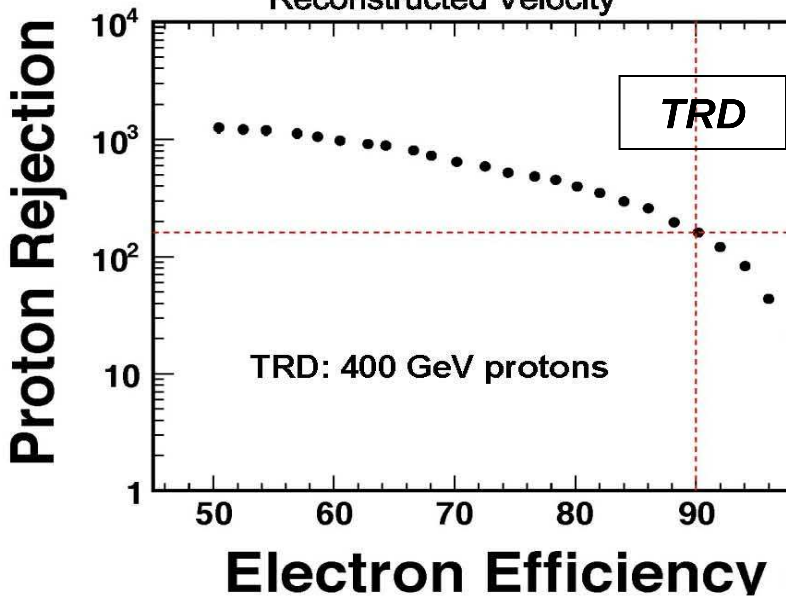
- 2007-08: pre-integration with spare vacuum case (waiting for the SC magnet)
- Dec 2008: arrival of magnet
- Sep 2009: integration with SC magnet
- Feb 2010: *Test beam*
- Mar 2010: EMI & TVTest @ESTEC
- Apr 2010: Change configuration to permanent magnet.
- Aug 2010: *Test beam* and move to KSC (Cape Canaveral) Tests, integration @NASA
- May 2011: Launch & install on ISS

Test beam results with permanent magnet 8-20 Aug 2010

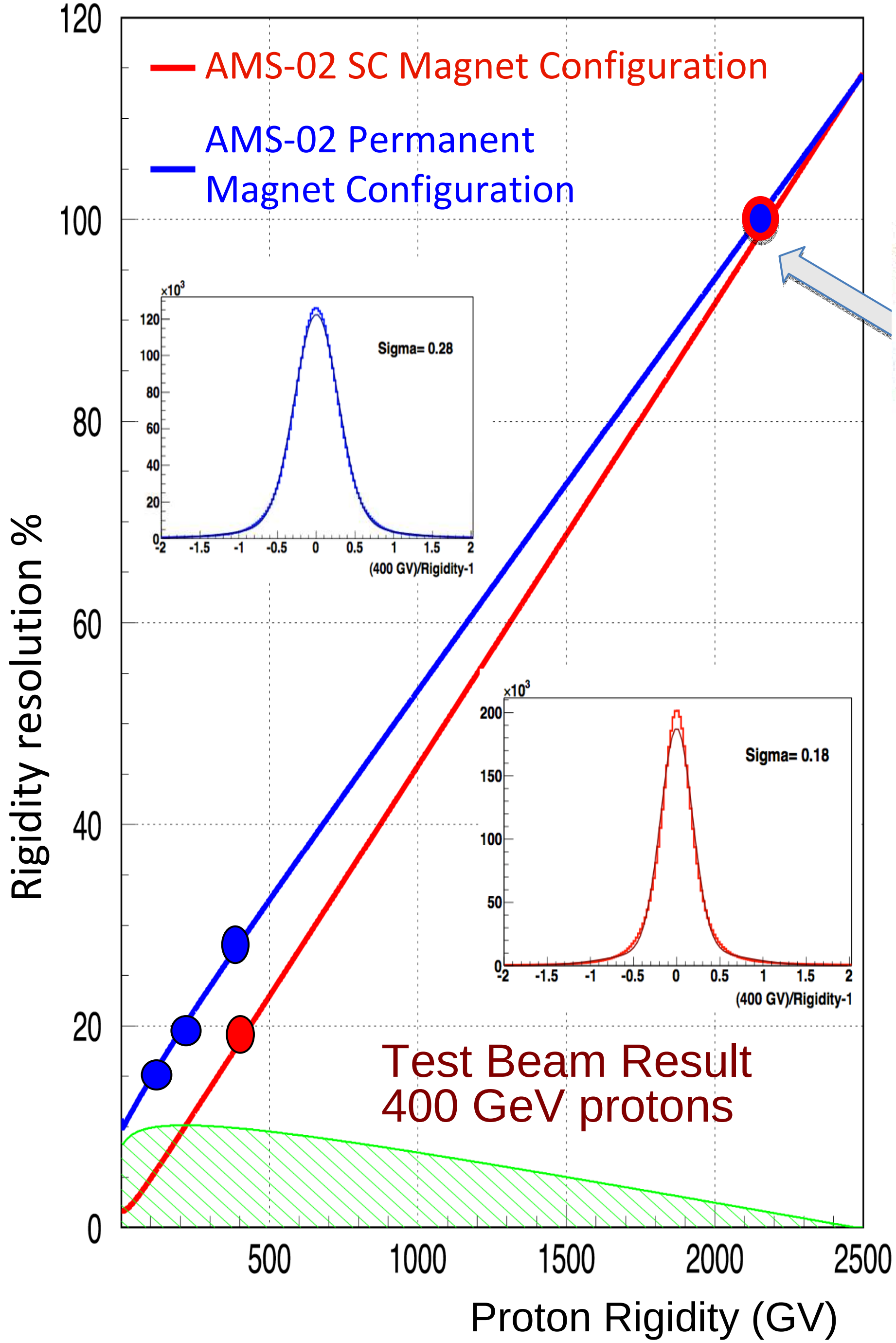




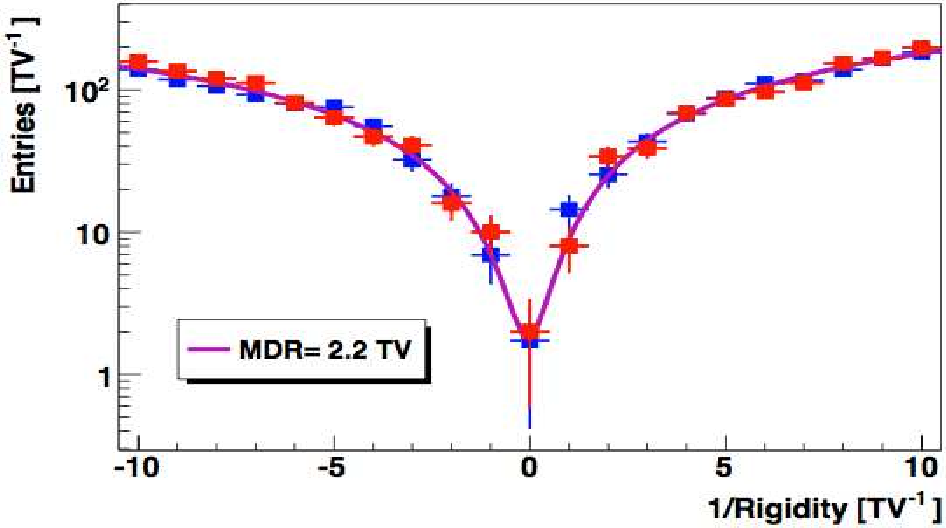




Measured combined rejection power @400 GeV: $e^{+}/p = 10^{-6}$

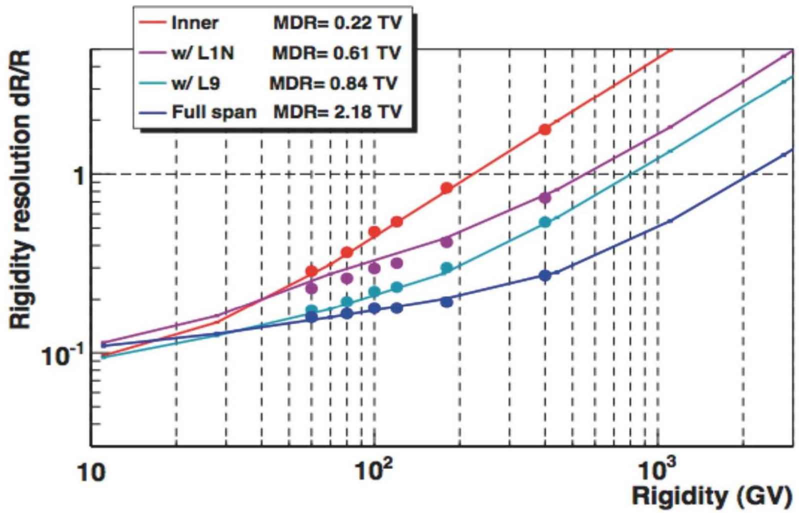


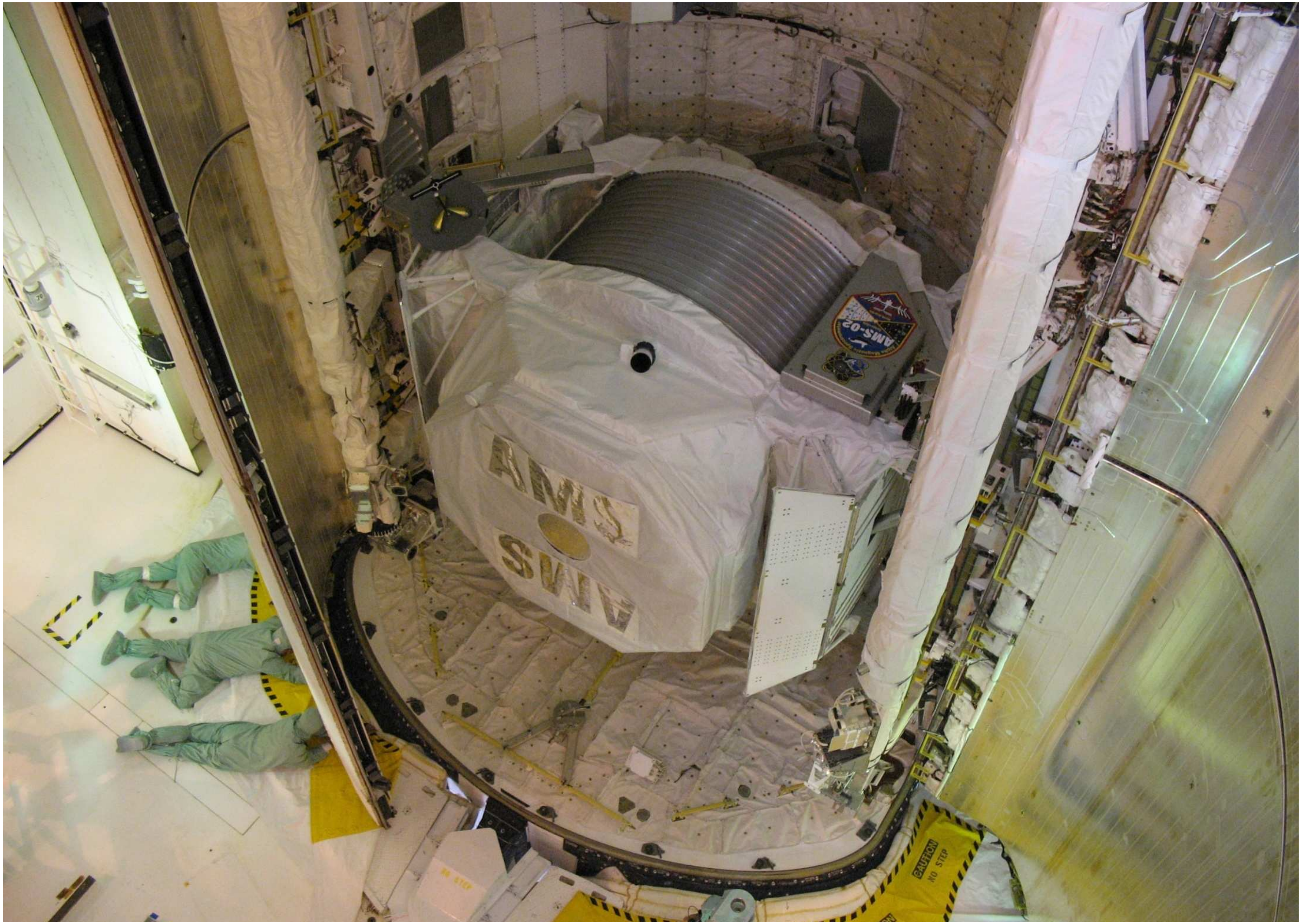
Tracker Performances with Test Beam and Atmospheric Muons



Comparison between TB and MC

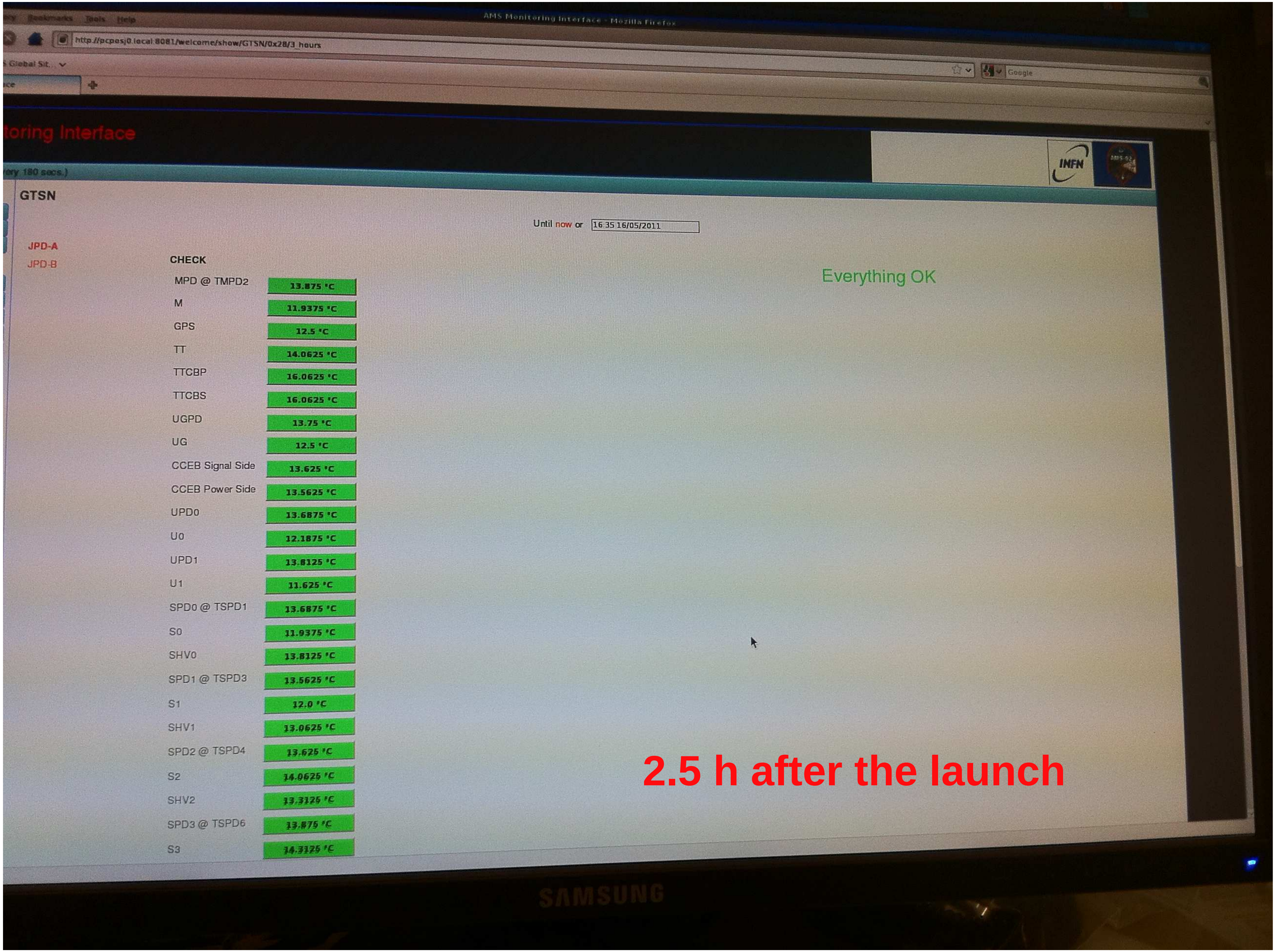
p/pi 60, 80, 100, 120, 180 and 400 GeV





Closing Endeavour's Payload Bay Doors at the Launch Pad to Prepare for Launch


JAXA
May 16, 2011 @ 08:56 AM



2.5 h after the launch

FROM SHUTTLE TO ISS

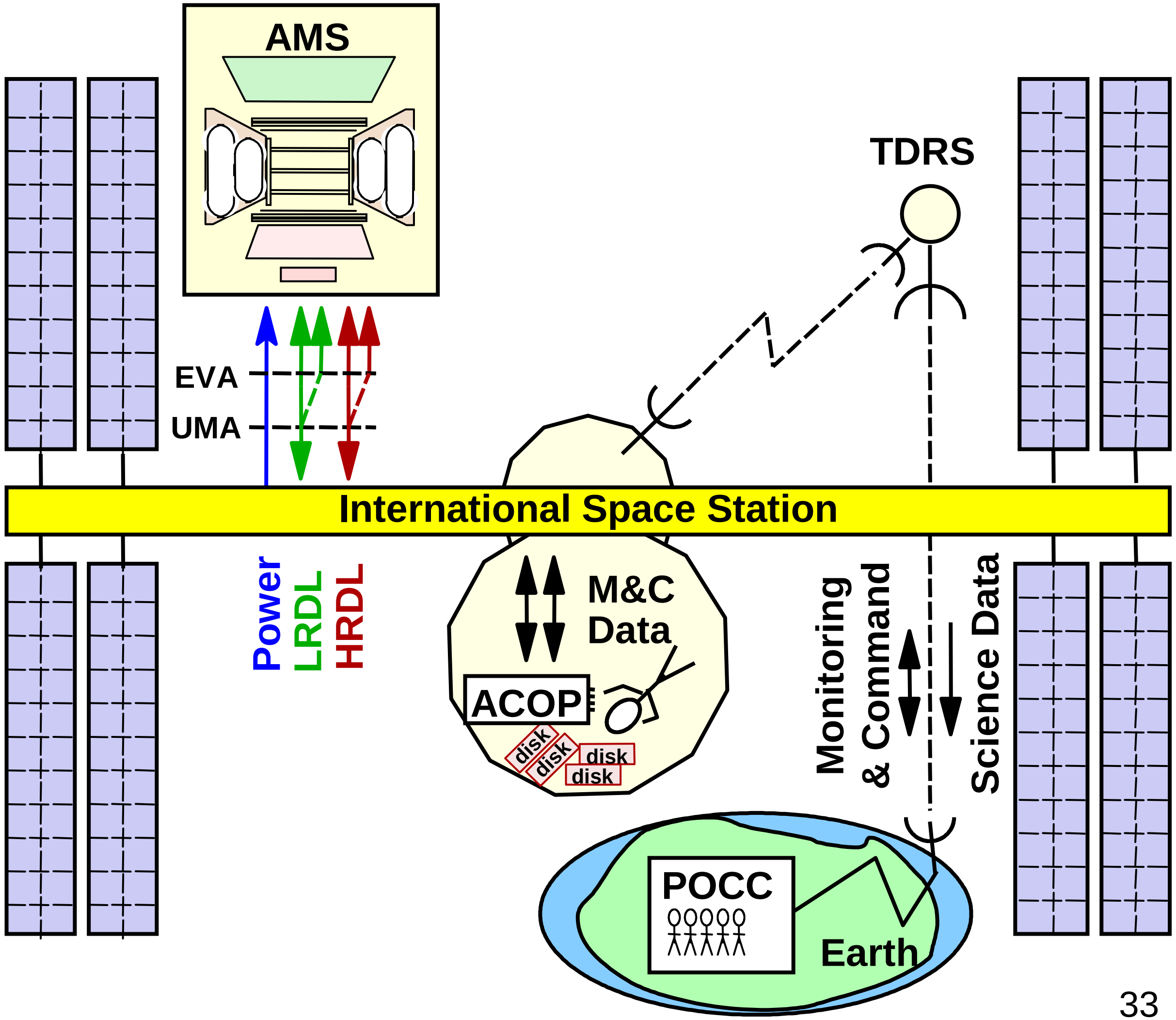
ON ISS

AMS Electrical Interfaces on ISS

Power:
- 109-124VDC
- ~2KW

LRDL
- for Cmd & Mon
- 1553B Bus
- 1 Kbit/s in
- 10 Kbit/s out
- 10 B/sec CHD

HRDL
- for Event Data
- Taxi F/O
- <13Mbit/s>$_{orbit}$

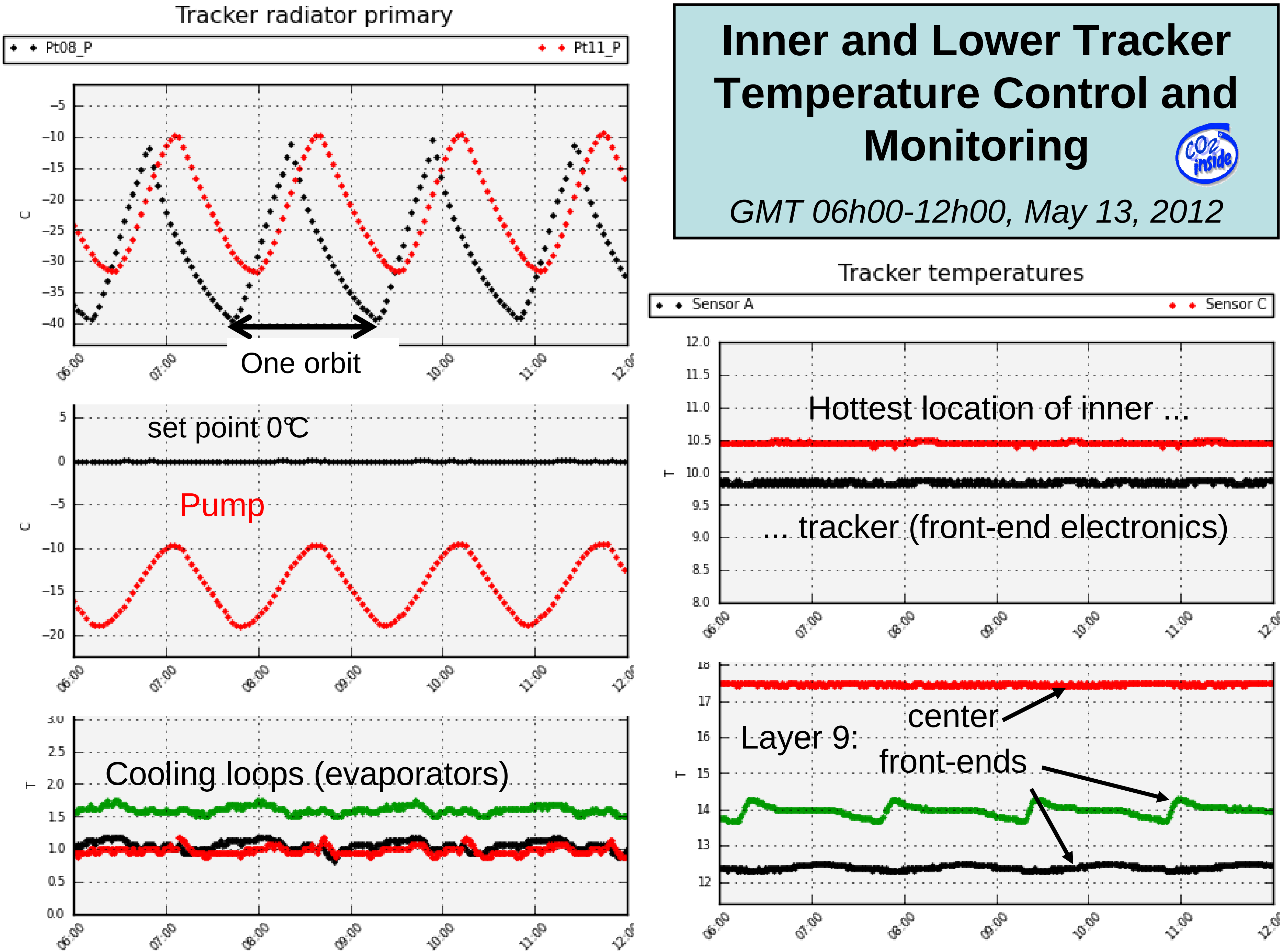


xRDL: Duty cycle ~50-70%

G.Ambrosi

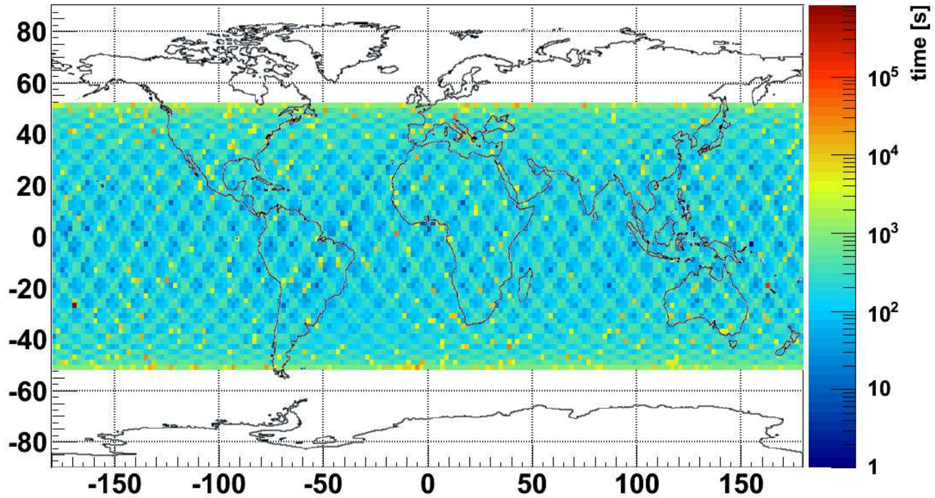
Inner and Lower Tracker Temperature Control and Monitoring

GMT 06h00-12h00, May 13, 2012

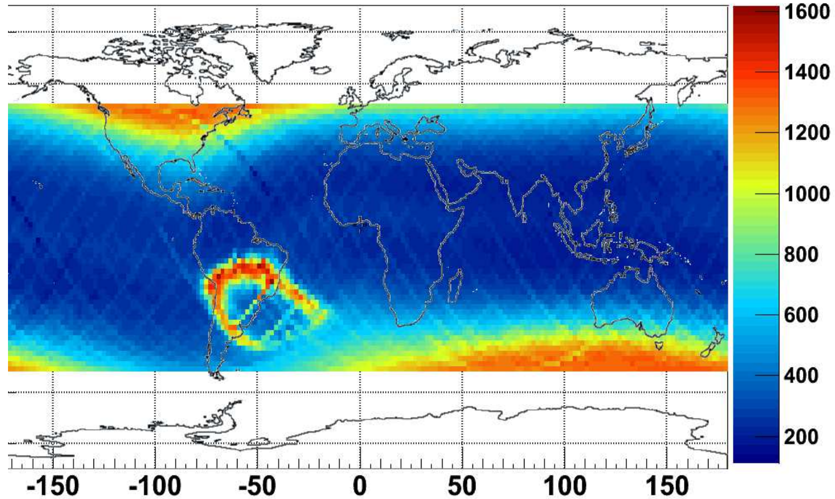


Orbital DAQ parameters

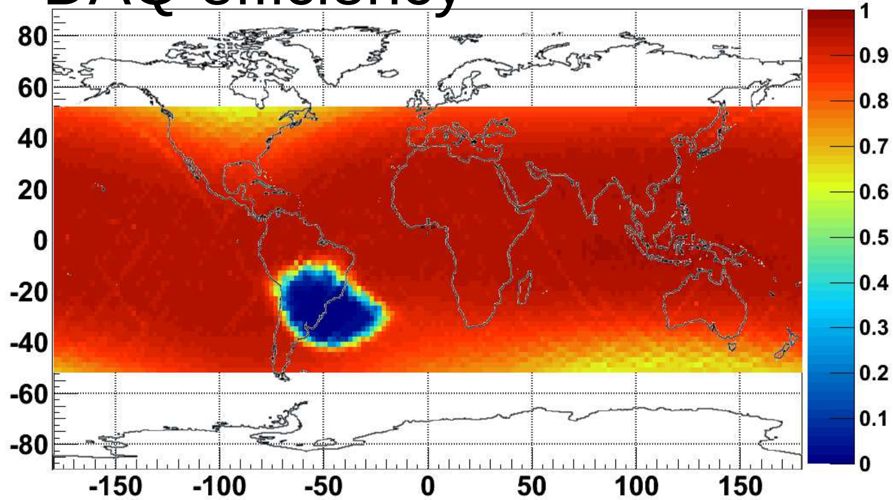
Time at location [s]



Acquisition rate [Hz]



DAQ efficiency

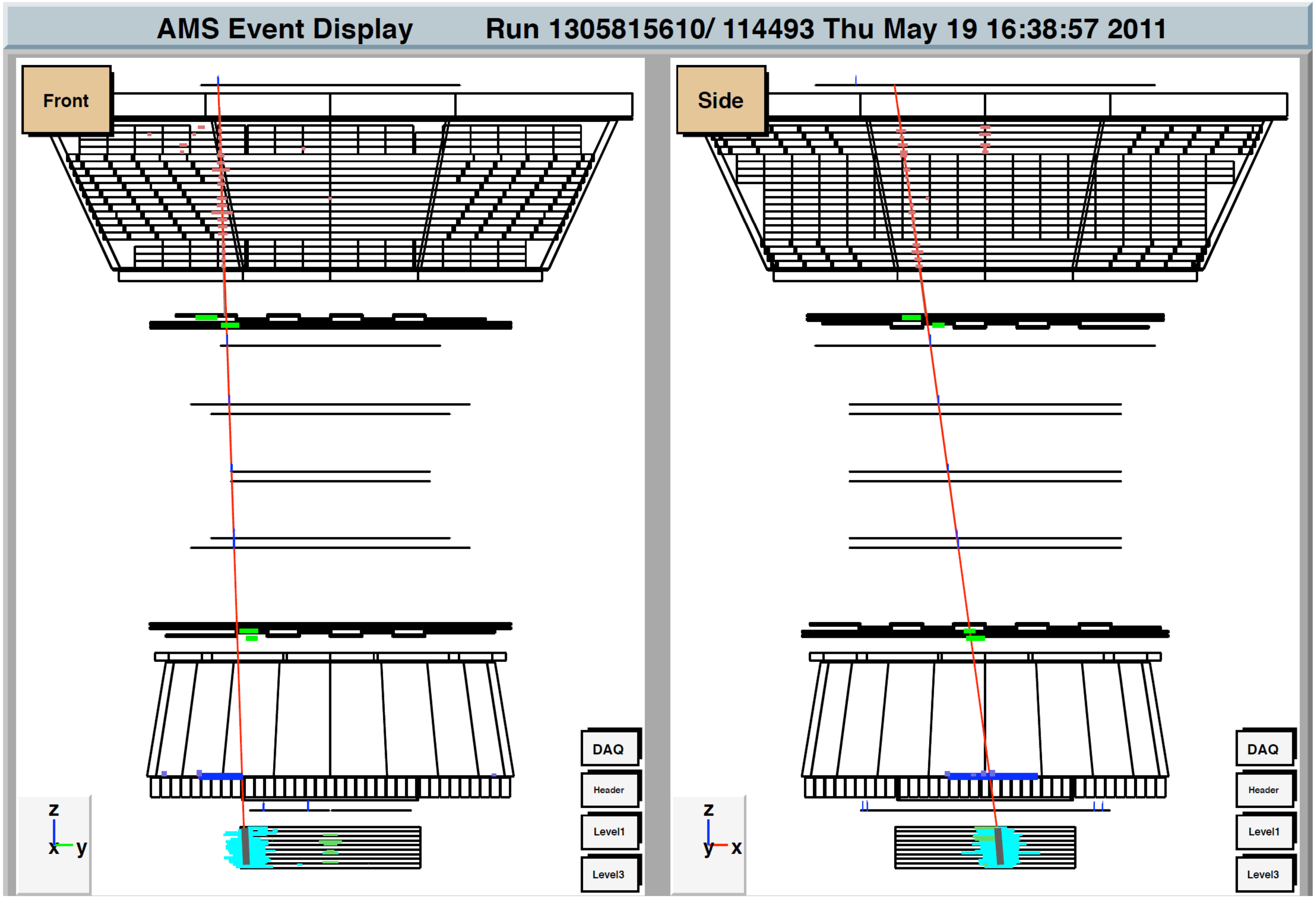


Particle rates: 200 to 2000 Hz per orbit

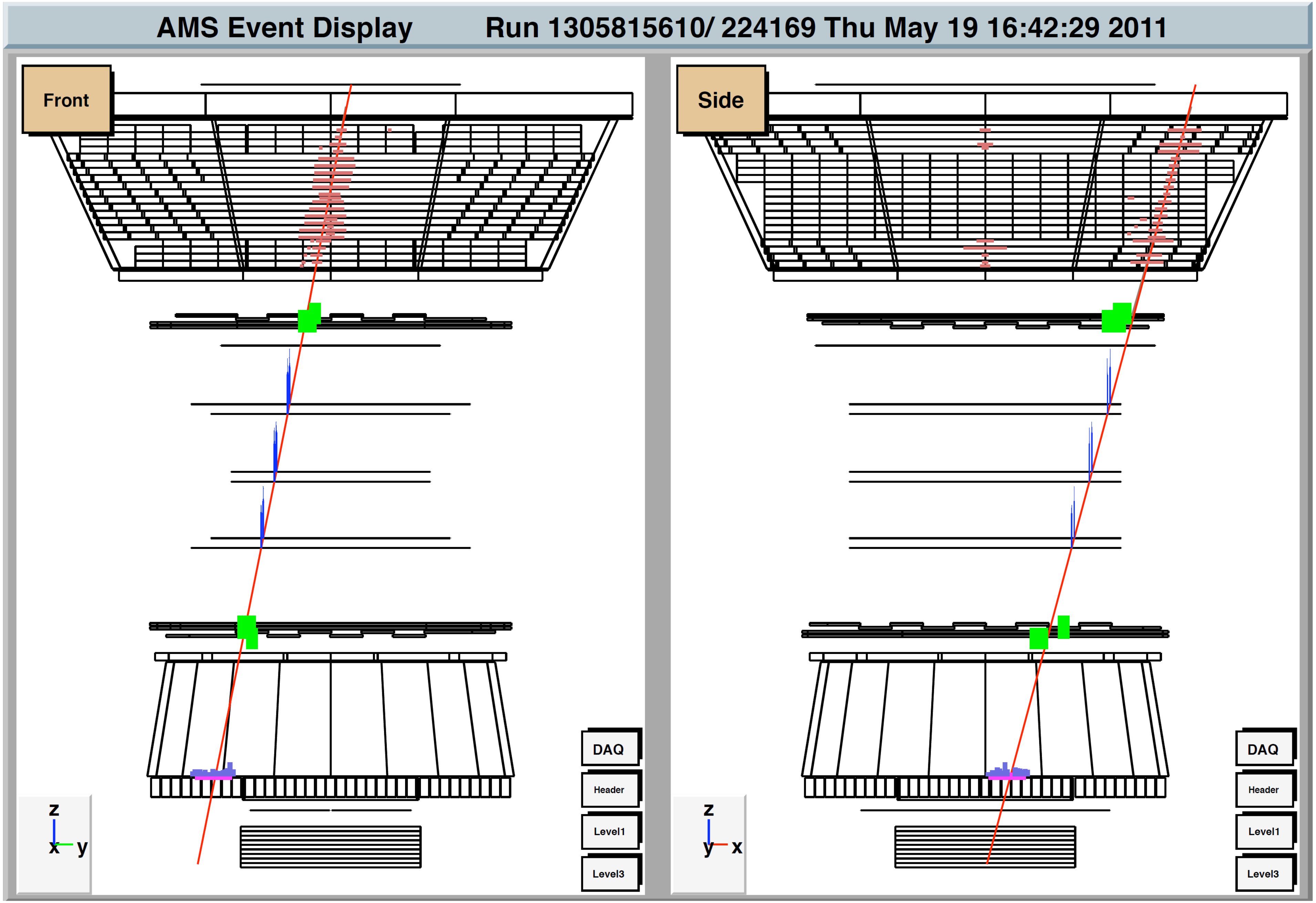
Orbit average: DAQ efficiency 85%
DAQ rate ~530Hz

1 year of data: 1.6 10^{10} events
35 TB raw events

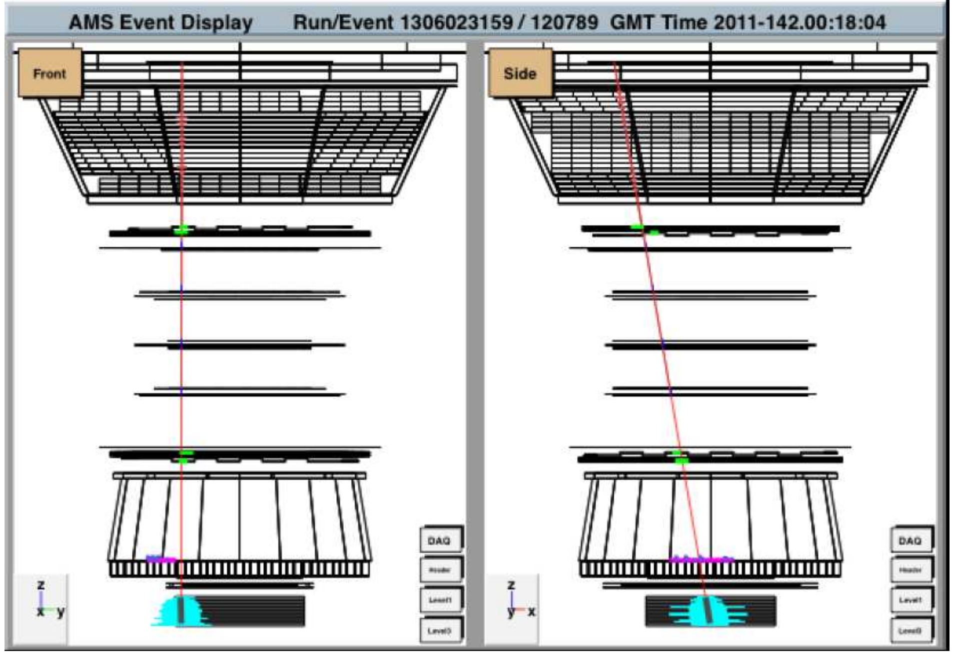
Data from the 1st few minutes – 20 GeV Electron, 19 May 2011



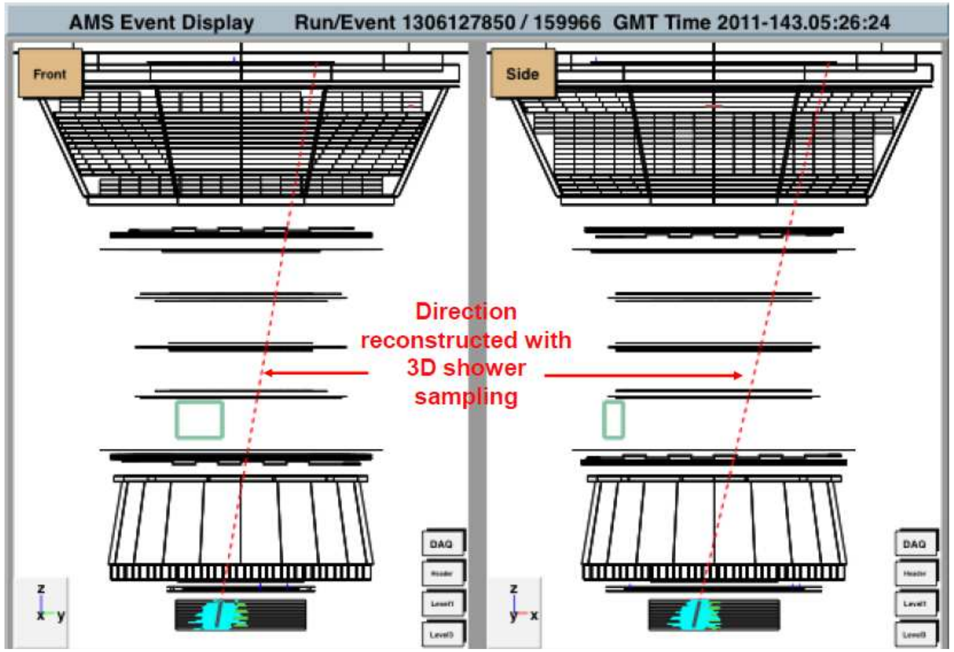
Data from the 1st few minutes – 42 GeV/c Carbon, 19 May 2011



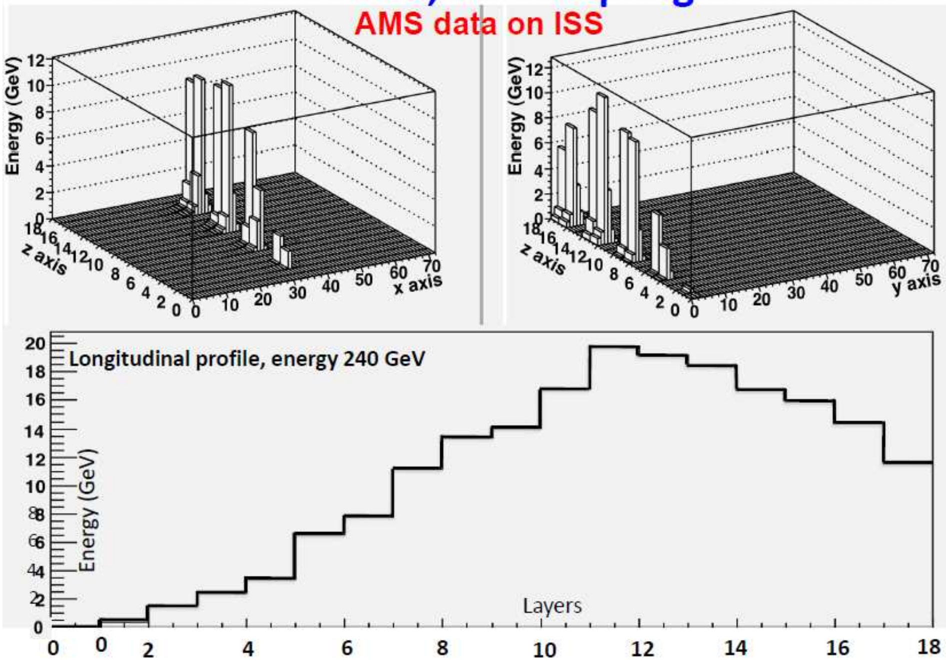
AMS data on ISS **Electron 240 GeV, 22 May**



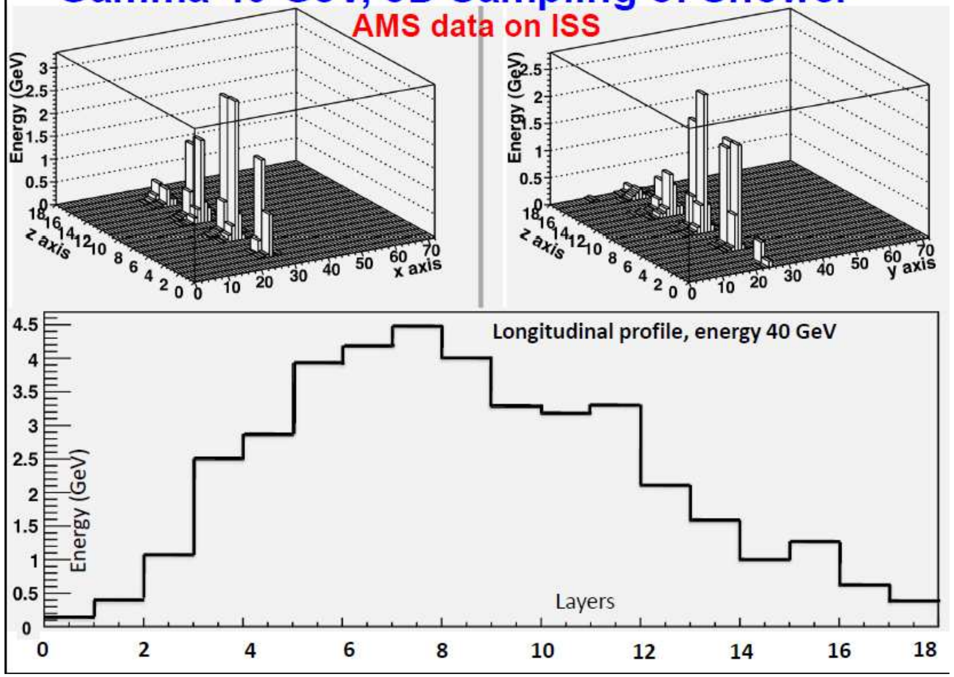
AMS data on ISS **Photon 40 GeV, 23 May**



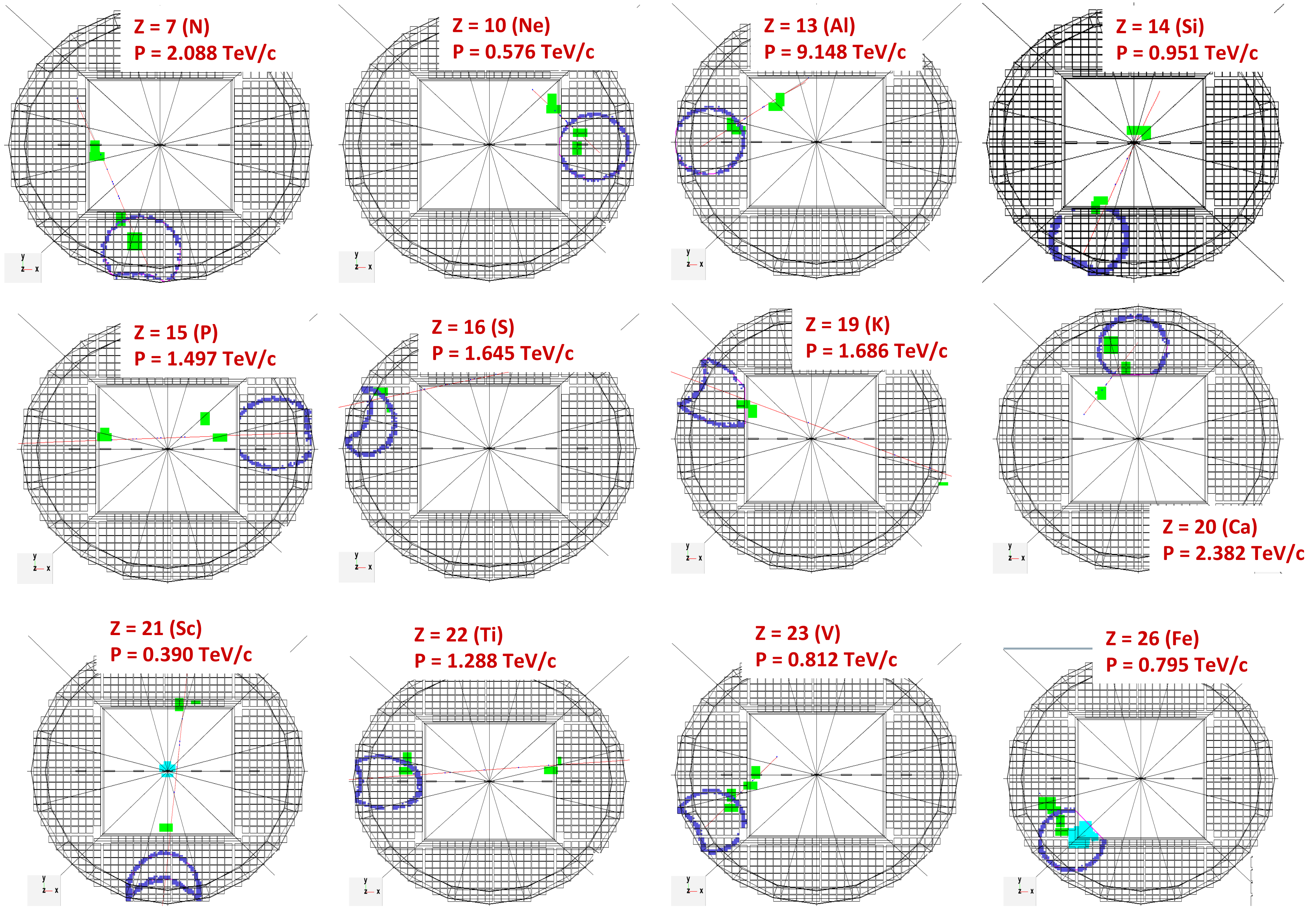
240 GeV Electron, 3D Sampling of Shower



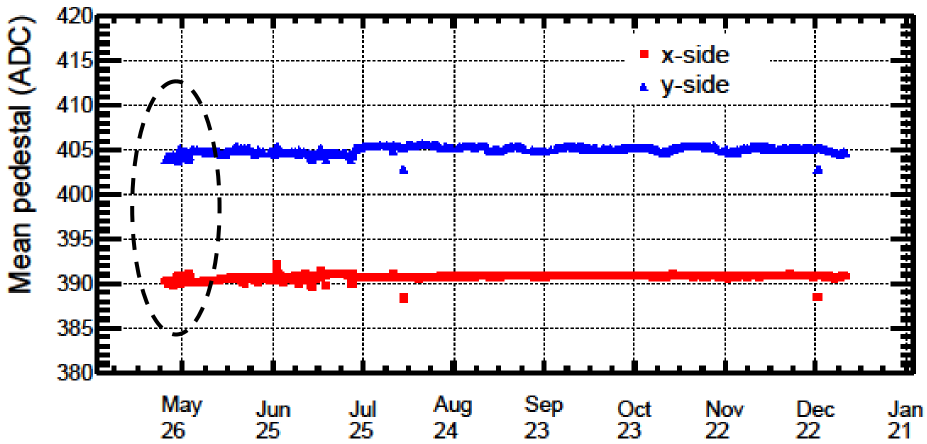
Gamma 40 GeV, 3D Sampling of Shower

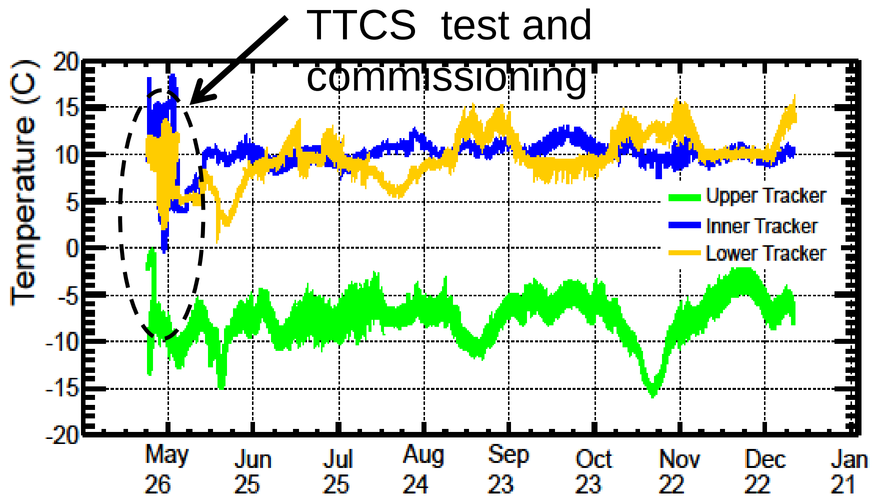


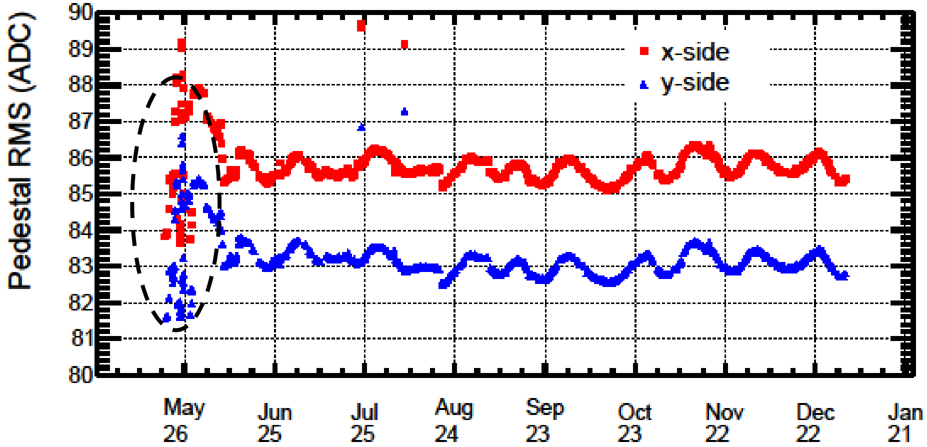
AMS data: Nuclei in the TeV range *(RICH)*

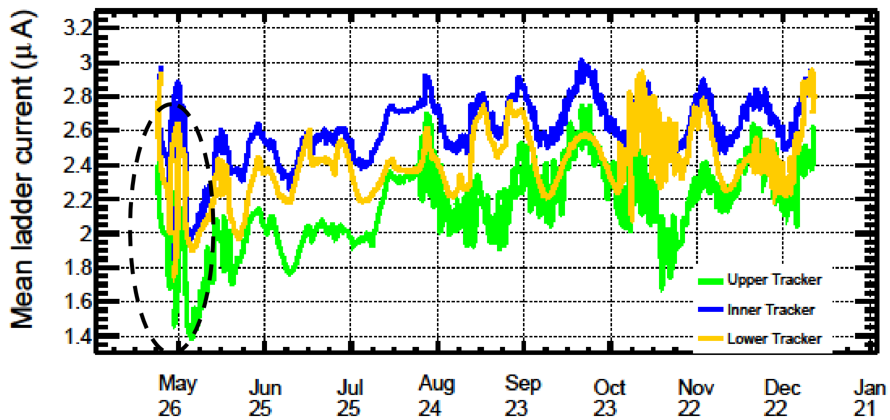


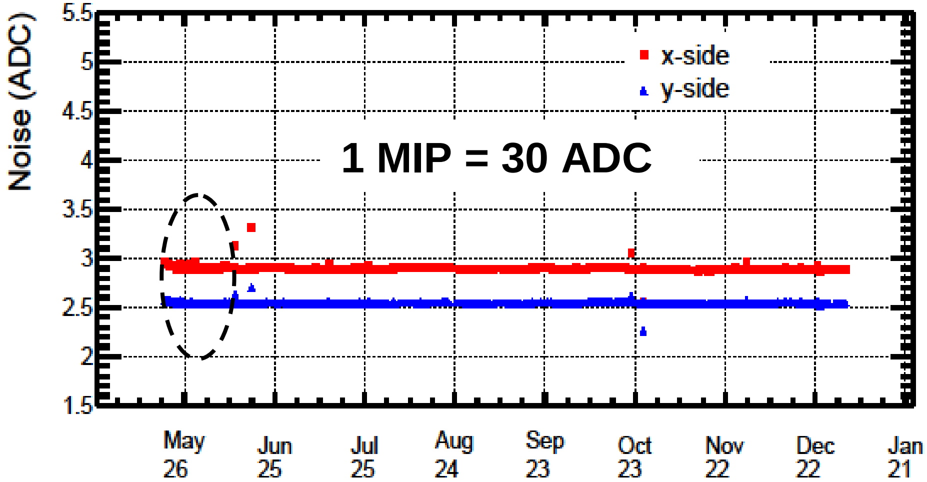
Tracker Environmental Conditions and Stability



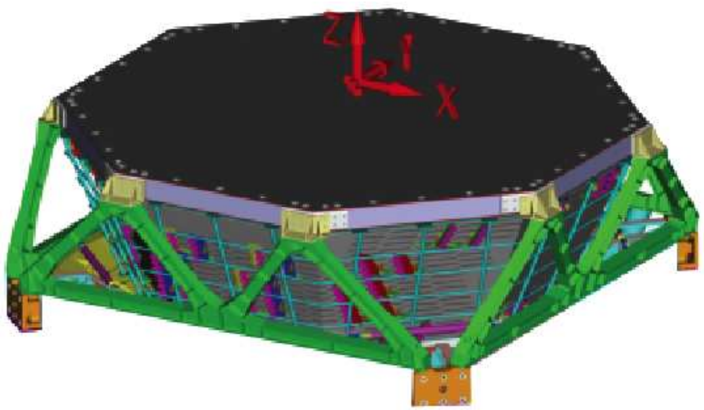


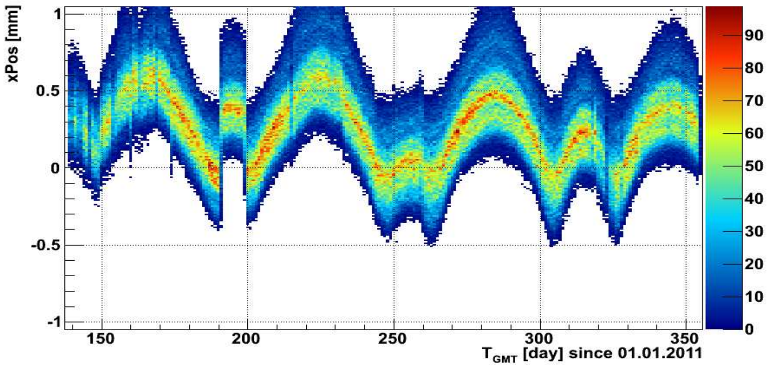


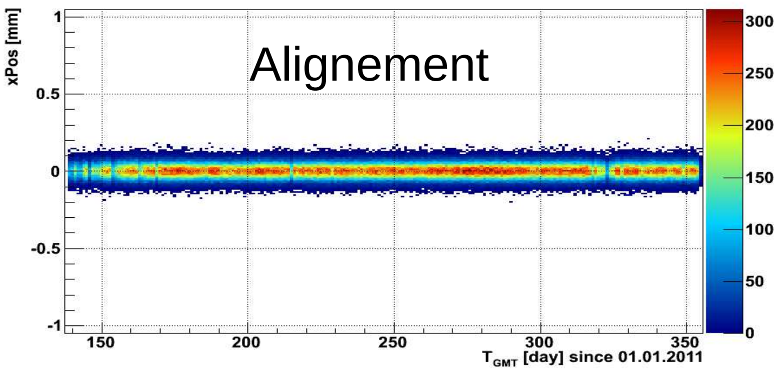


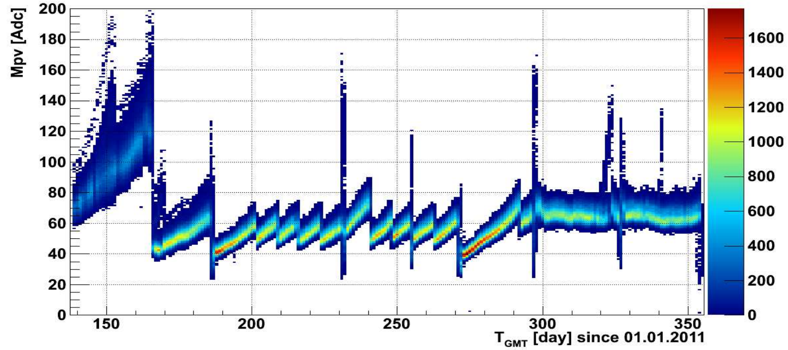


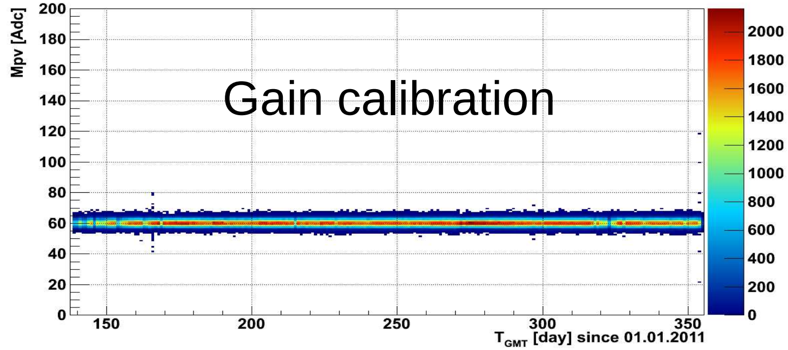
TRD on ISS

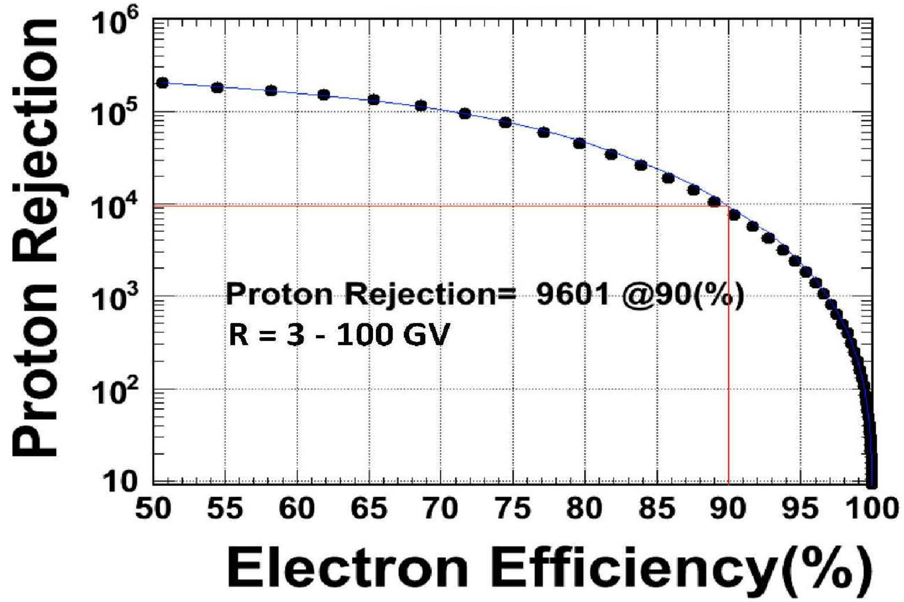

Z
Y
X


xPos [mm]
T_{GMT} [day] since 01.01.2011


Alignement
xPos [mm]
T_{GMT} [day] since 01.01.2011

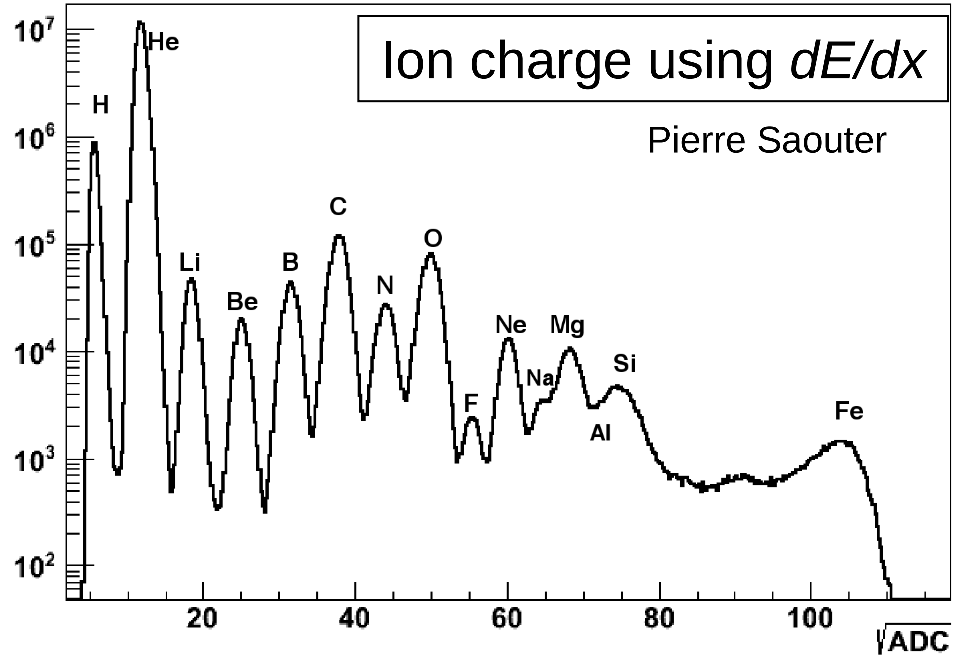

Mpv [Adc]
T_{GMT} [day] since 01.01.2011


Gain calibration
Mpv [Adc]
T_{GMT} [day] since 01.01.2011


Proton Rejection
Electron Efficiency(%)
Proton Rejection= 9601 @90(%)
R = 3 - 100 GV

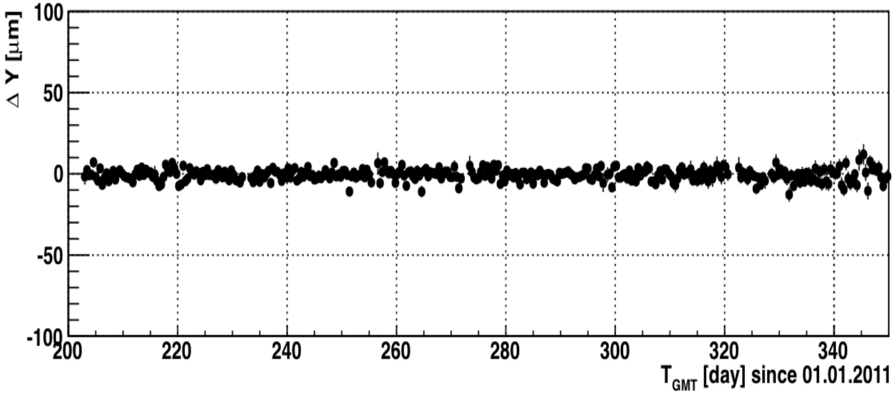
Tracker on ISS

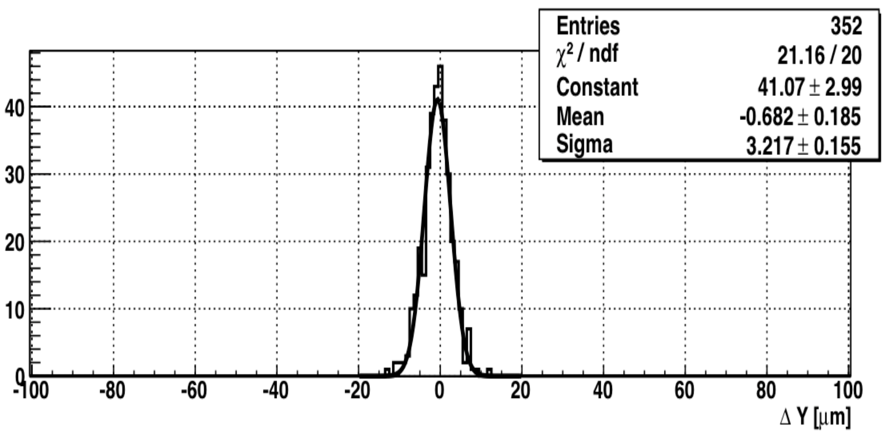
(after calibration)

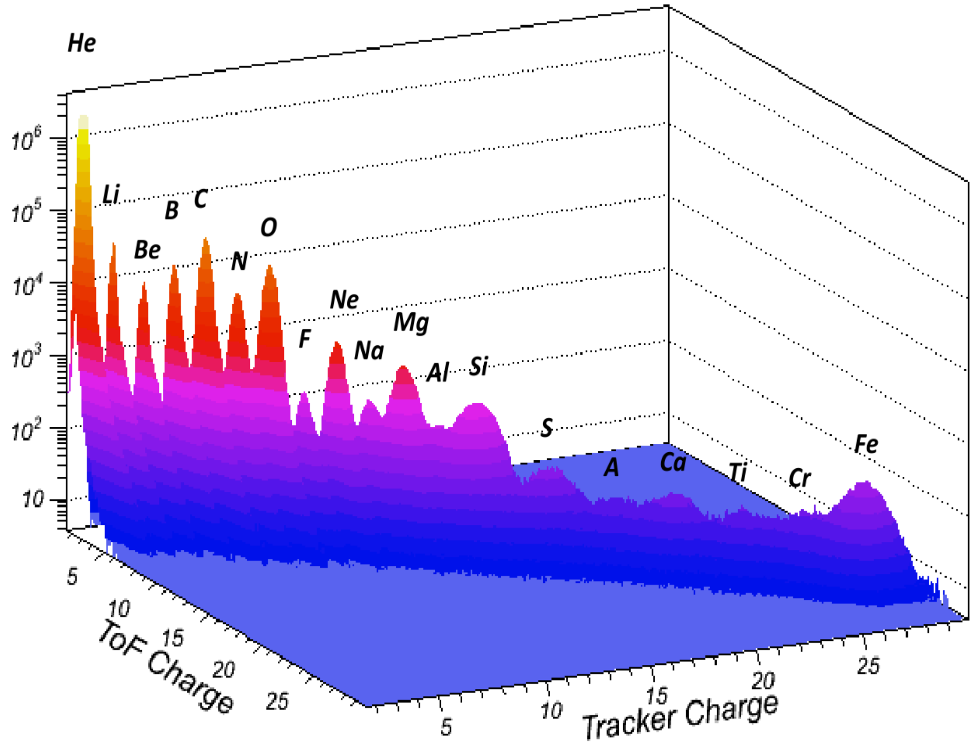


Alignement stability

(Averages of residues on layer 1 vs time)

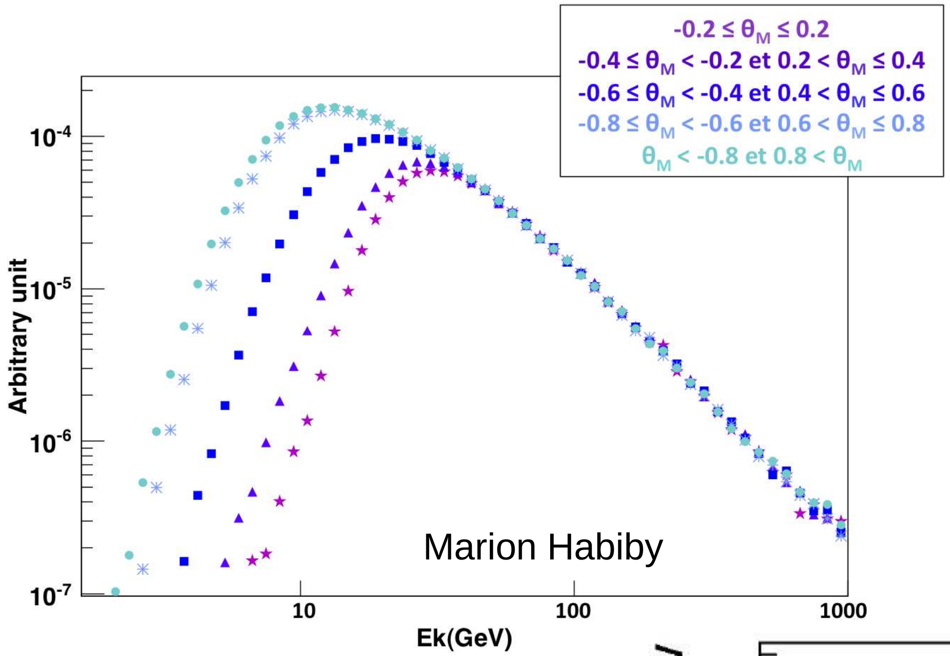


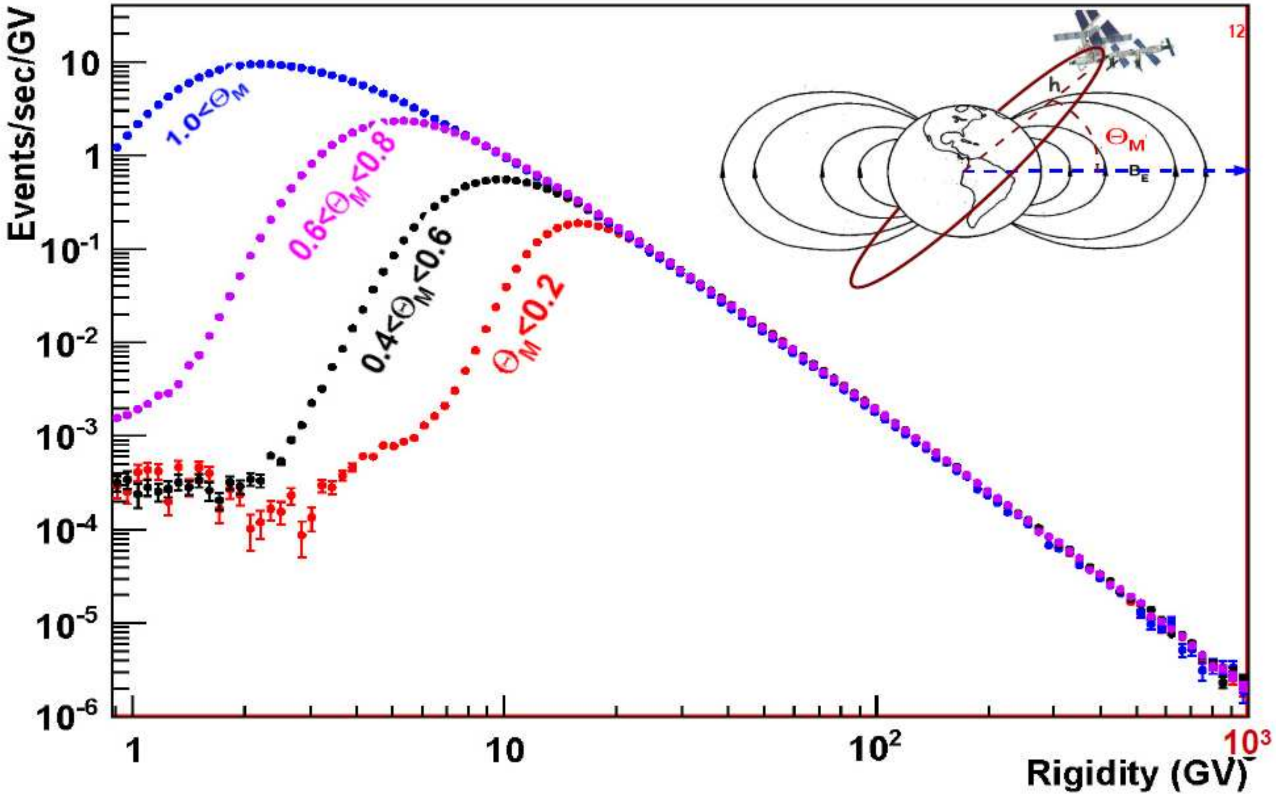




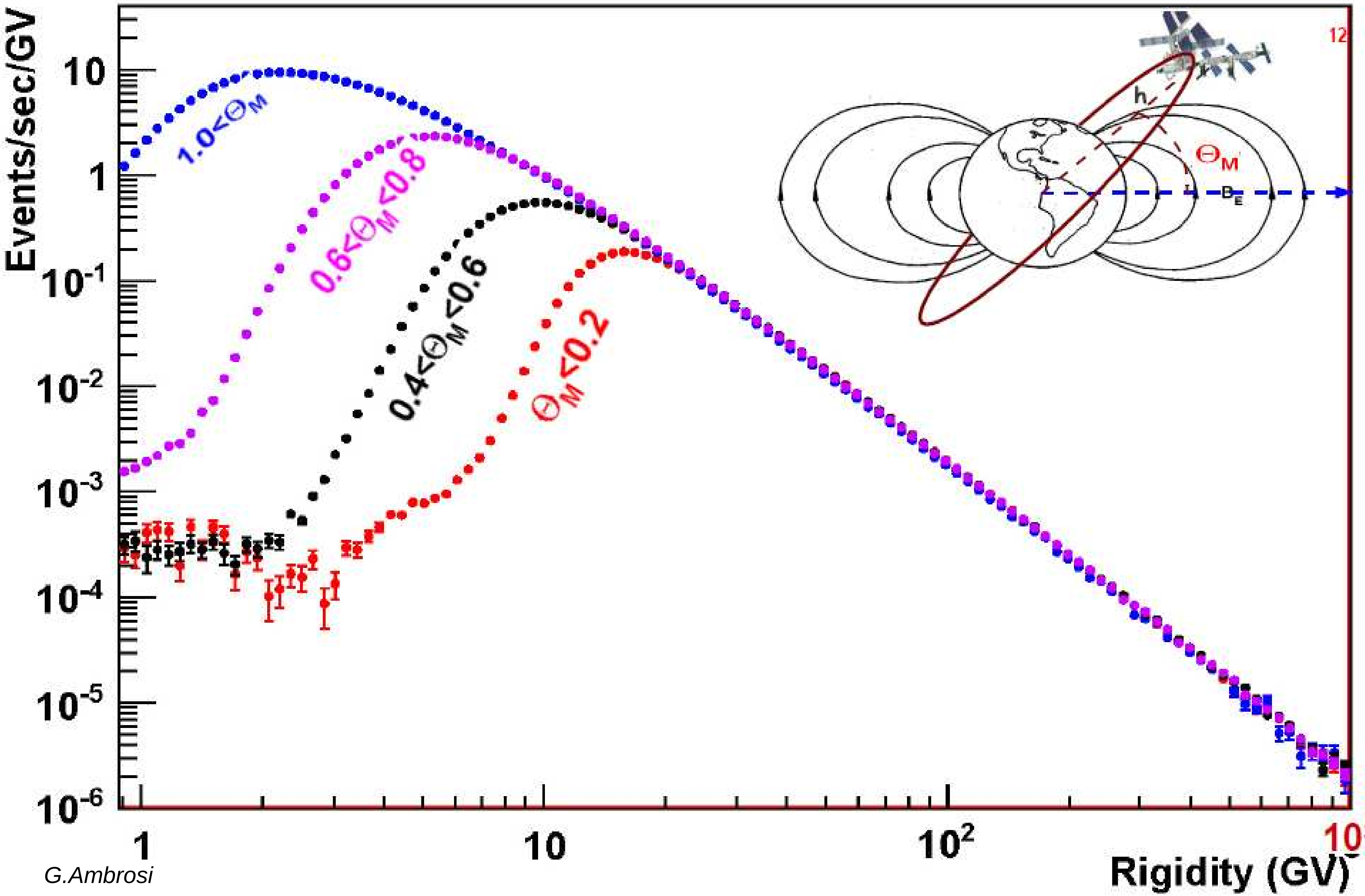
AMS data on ISS:

Helium

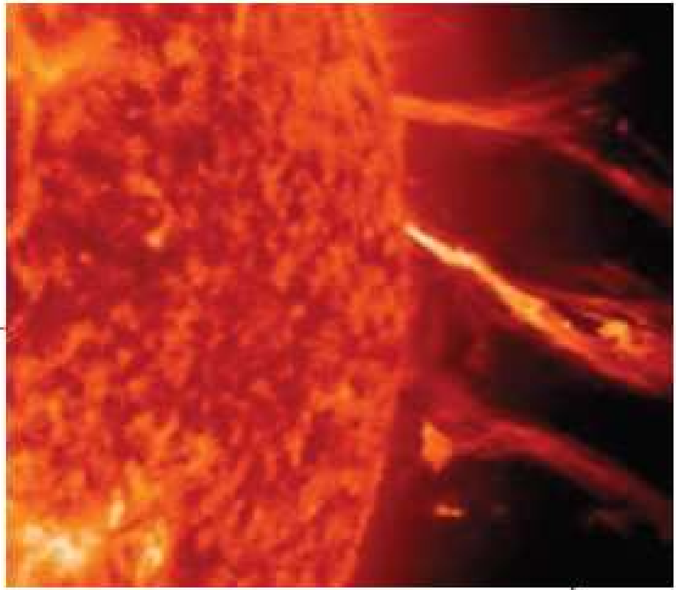


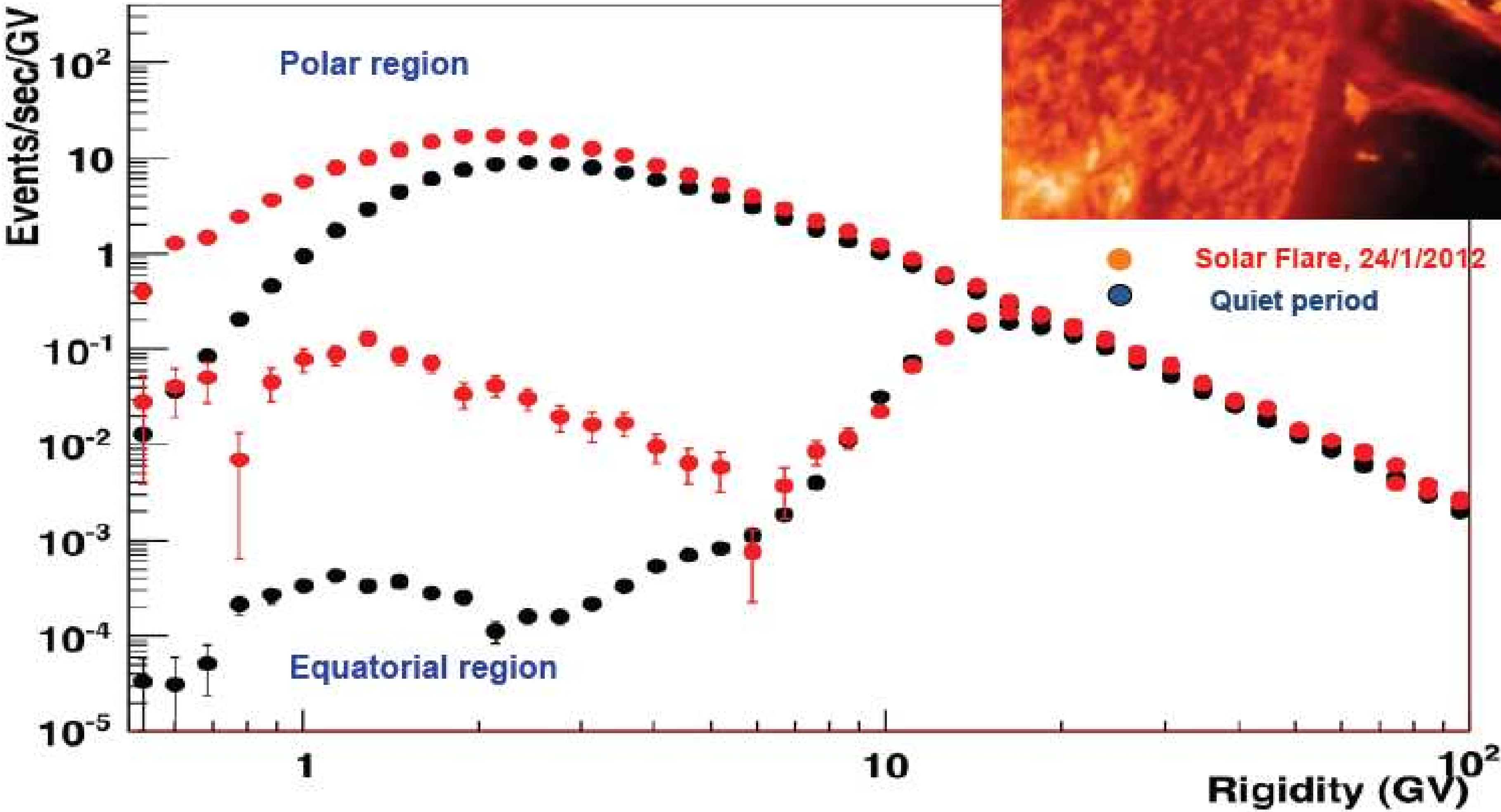


AMS data on ISS: **He rate**



AMS data: He rate and solar flare

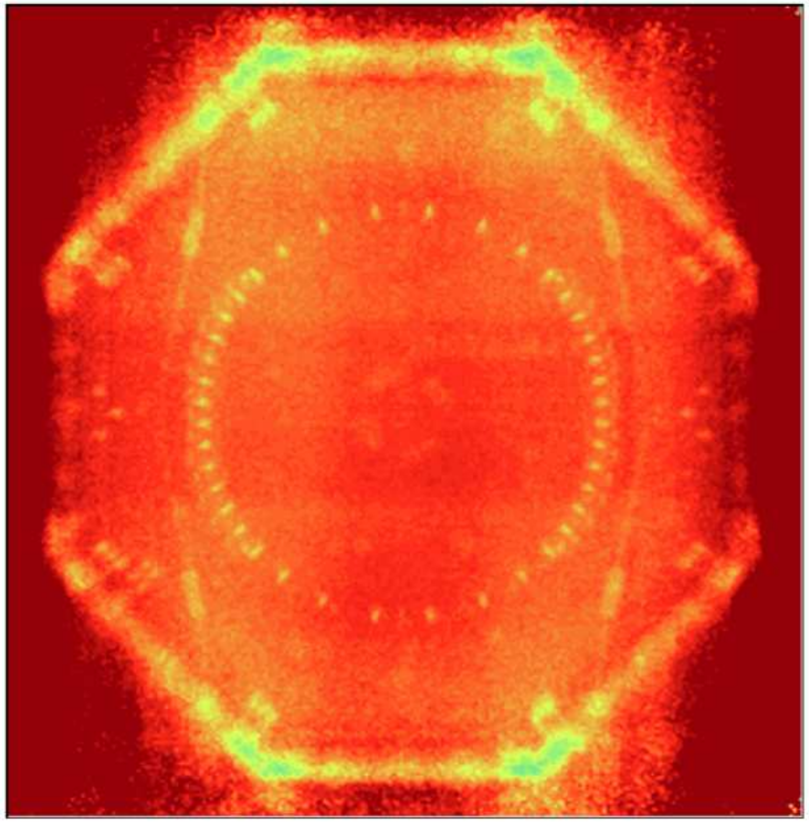


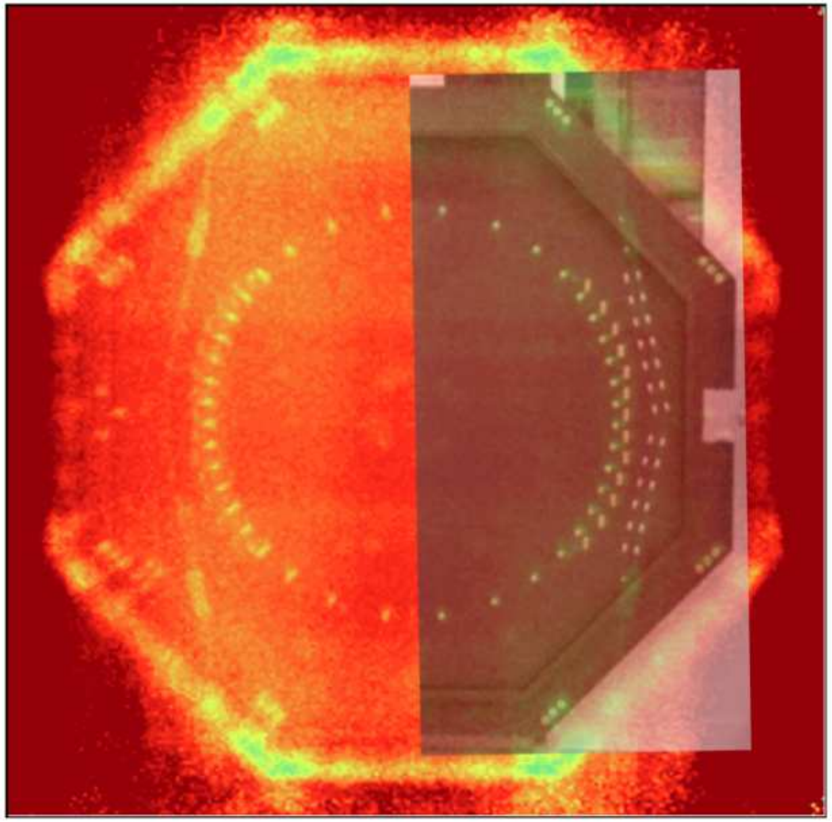


G.Ambrosi

Tomography of support plane with *Helium deficit*

He missing particles extrapolated to the first mechanical Tracker support

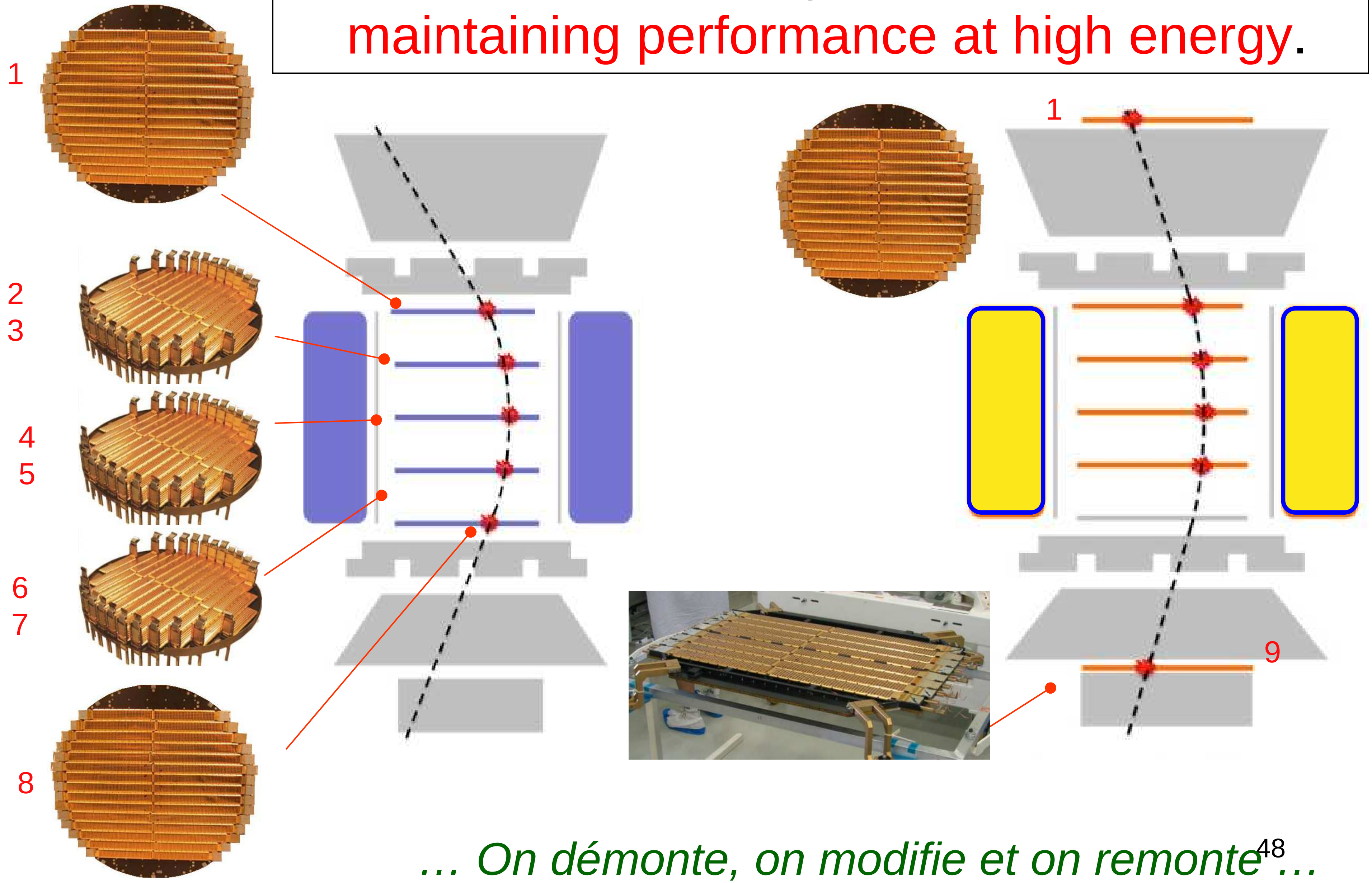




Conclusion

- AMS02 is in orbit since May 16th 2011
- No visible damage due to the launch stress or to the space environment, all the system are working in both the primary and redundant part
- All the detectors are properly functioning with DAQ in nominal conditions since May 19th 2011
- Minor failures
- Thermal behavior needs attention
- Ground operations (POCC and SOC) run smoothly
- Detector calibrations (alignment, e/p rejection, charge id, etc.) are well advanced
- 10+ years on board the ISS: *Precision measurements → discovery potential*

Tracker geometry is modified in order to increase the lever arms to compensate the lower field, maintaining performance at high energy.



… On démonte, on modifie et on remonte …

Superconducting Magnet

- *Cooled with superfluid Helium.*
- *2500 liters He for ~~3~~ years operation*

B=0.7 T
L= 1 m