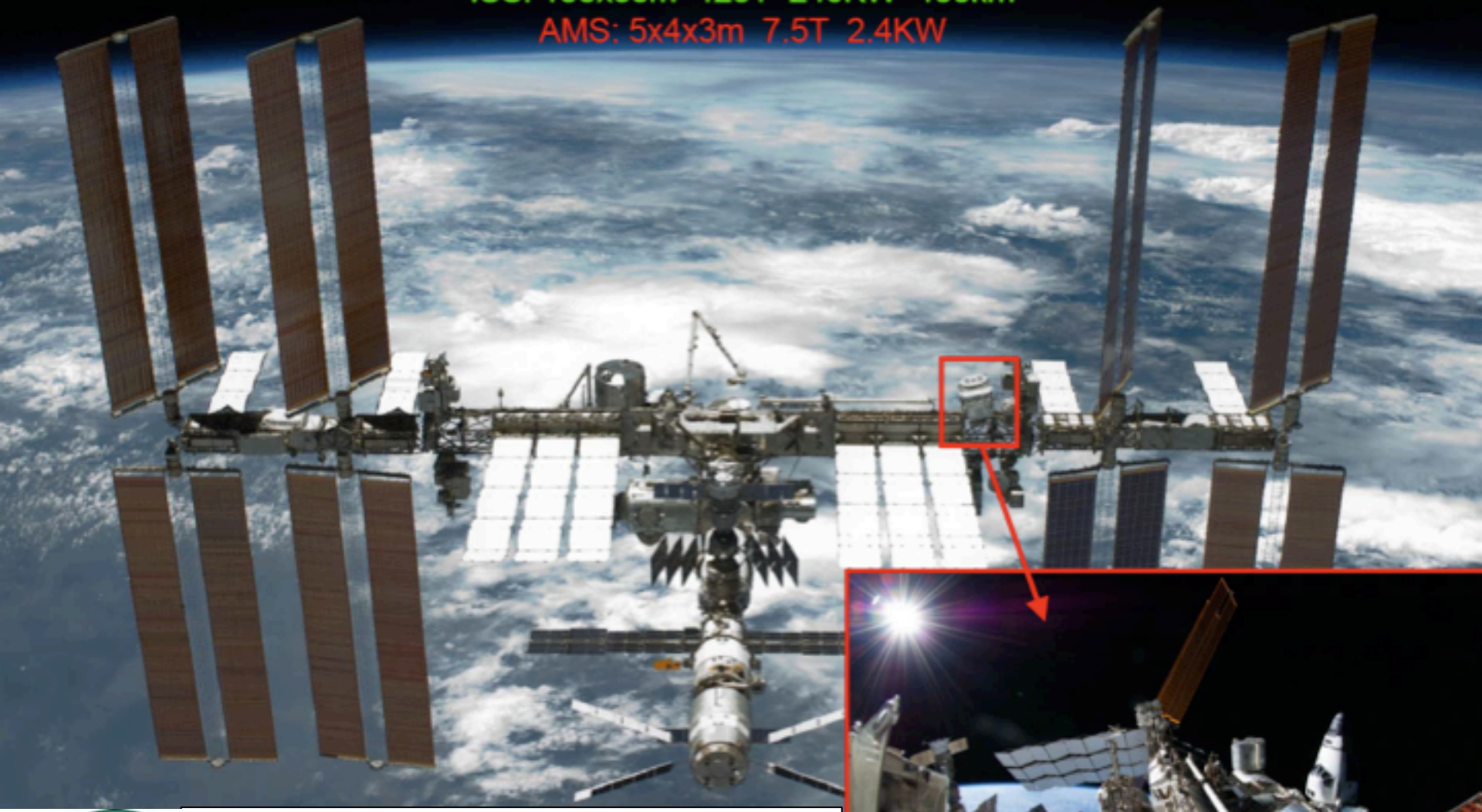
The Alpha Magnetic Spectrometer (AMS)

ISS: 108x80m 420T 240KW 400km

AMS: 5x4x3m 7.5T 2.4KW



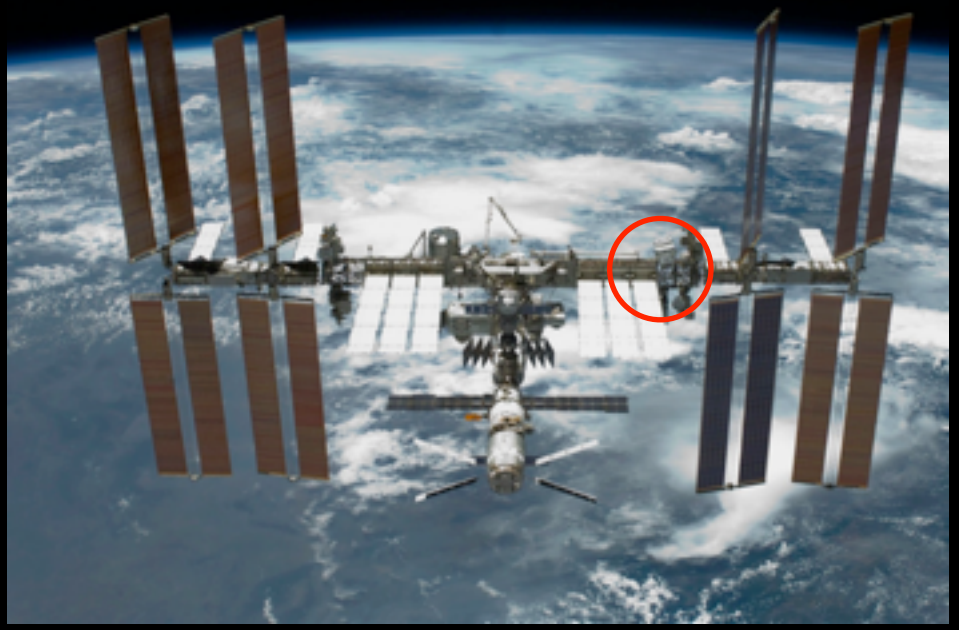
Veronica Bindi

Assistant Professor

Physics and Astronomy Department

University of Hawaii at Manoa

Scientific goals of AMS on the International Space Station

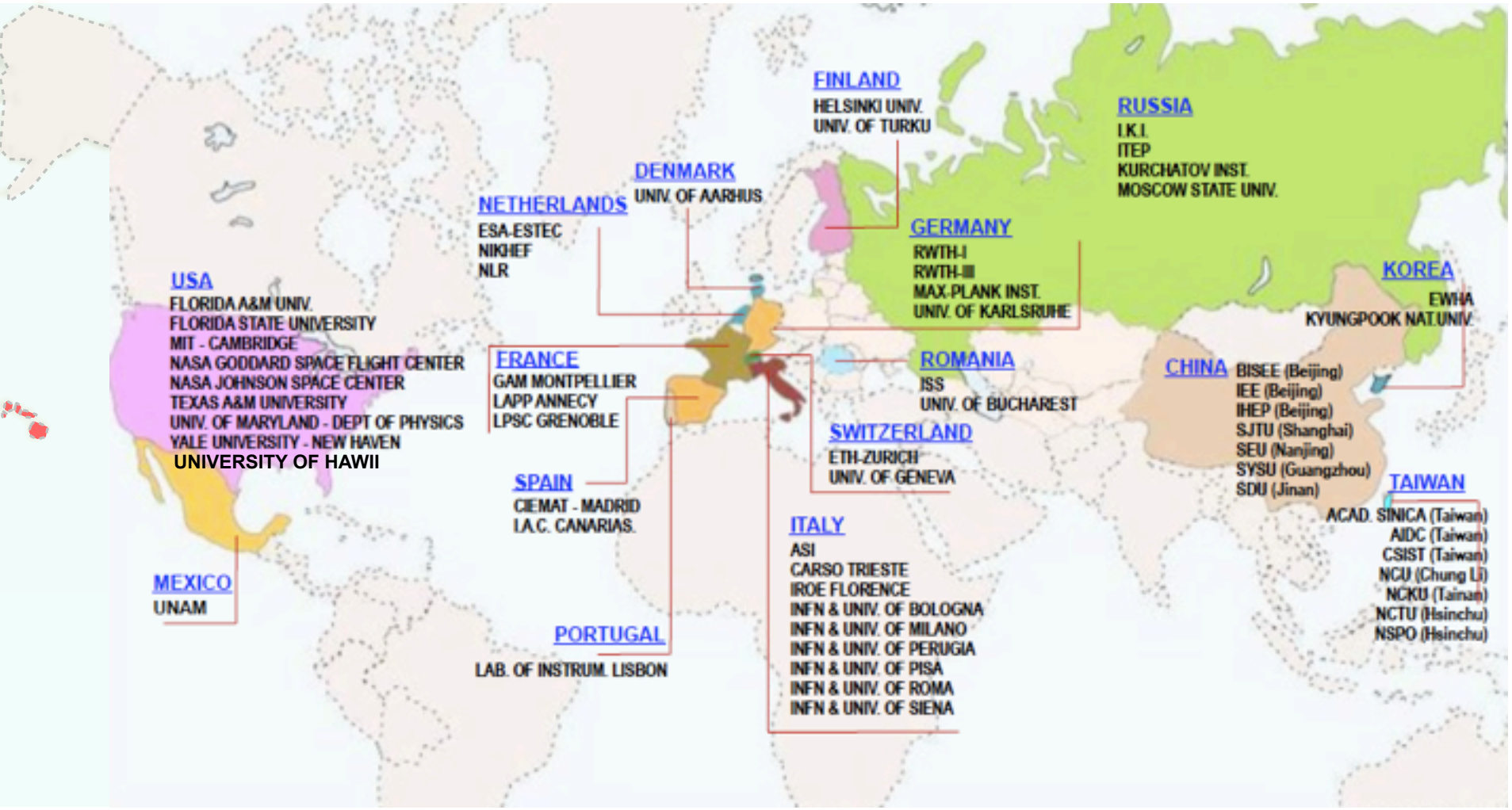


- Direct search of primordial antimatter:
  Anti-nuclei: He, C
- Indirect search of Dark Matter:
  e+ , antiprotons, ɣ, ... simultaneous observation in several signal channels
- New forms of matter:
  strangelets
- Identification of local sources of high energy photons (~TeV):
  SNR, Pulsars, PBH
- Measuring CR spectra up to the iron– refining propagation models;
- Solar modulation on CR spectra over 11 year solar cycle

AMS is a US DOE led International Collaboration

Spokesperson: Nobel laureate Prof. Dr. S. Ting from MIT

16 Countries, 60 Institutes and 600 Physicists



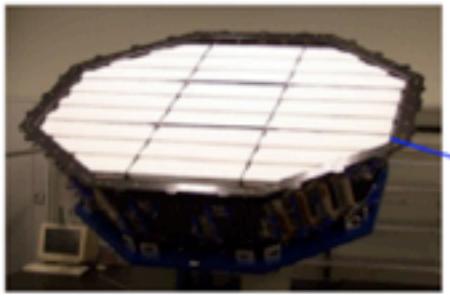
The detectors and the electronics were built all around the world and assembled in CERN, Switzerland

15ft x 12ft x 9ft
5m x 4m x 3m
7.5 tons

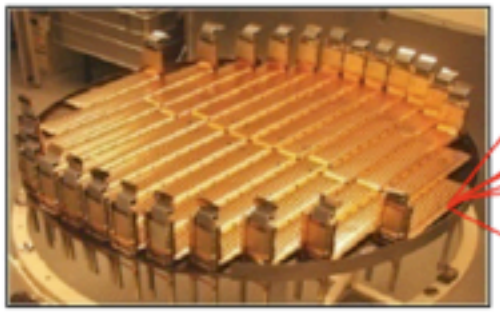
AMS is designed with the same precisions as the CERN LHC detectors the technology has been miniaturized and upgraded to work on space

AMS consists of 5 sub-detectors which provide redundant information for particle identification

TRD
Identify e+, e-

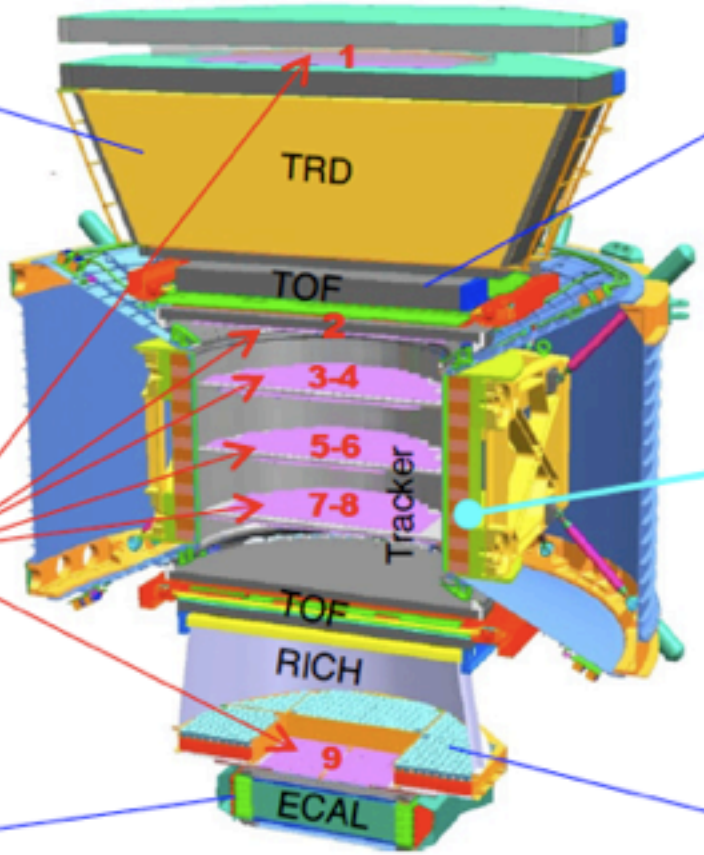


Silicon Tracker
Z, P



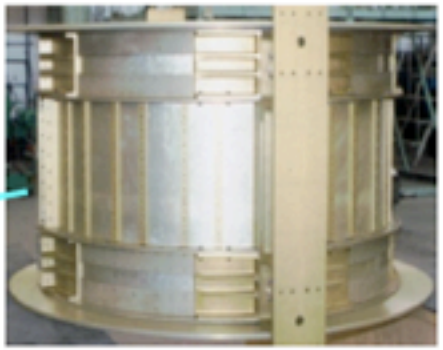
ECAL
E of e+, e-, γ

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

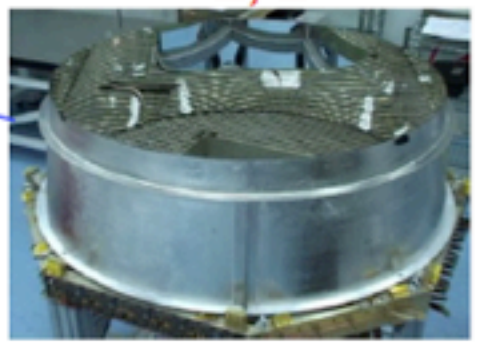


TOF
Z, E

Magnet
±Z

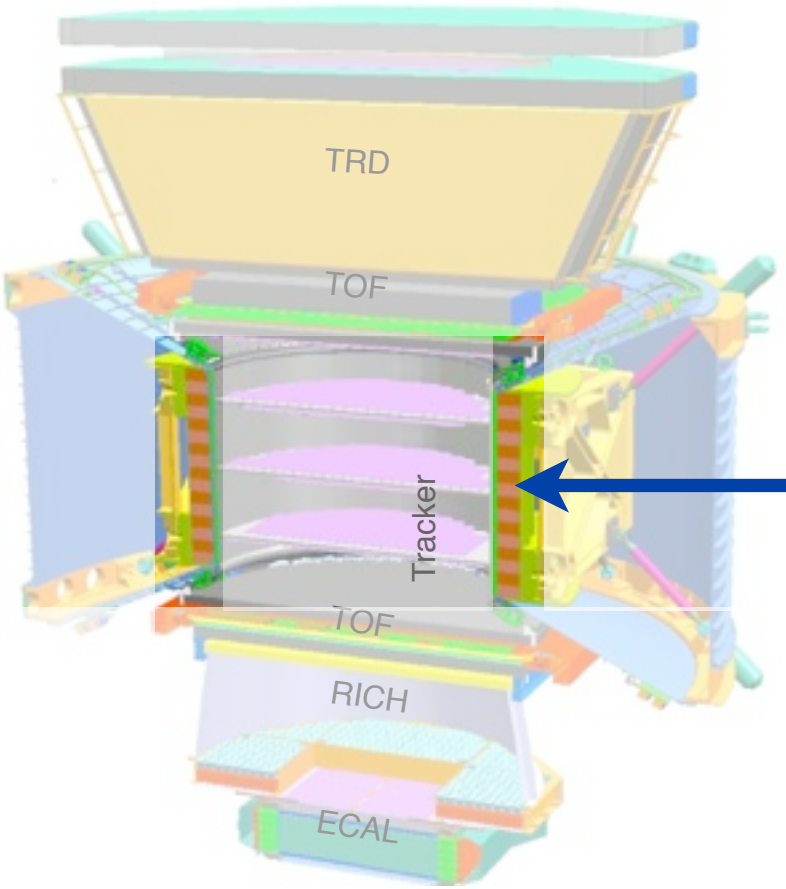


RICH
Z, E



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

A TeV precision, multipurpose spectrometer



Magnet

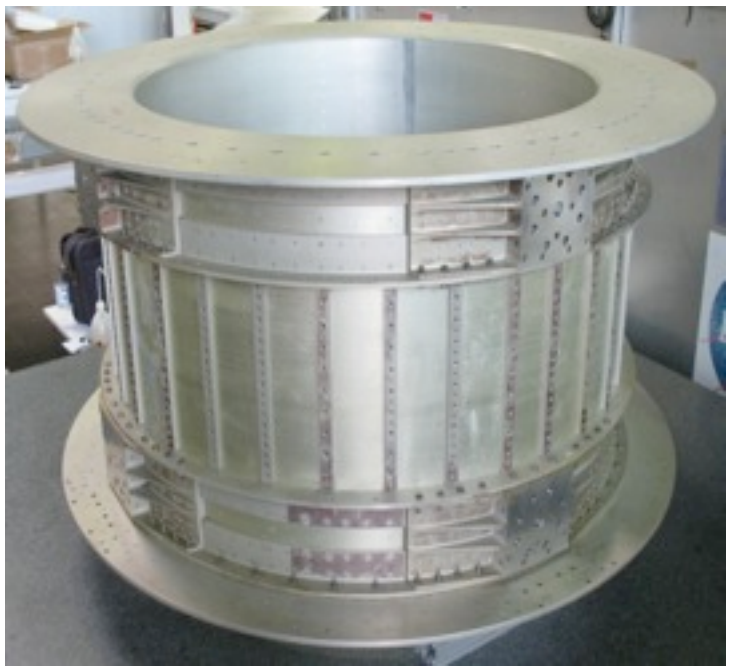
± Z

same of AMS-01

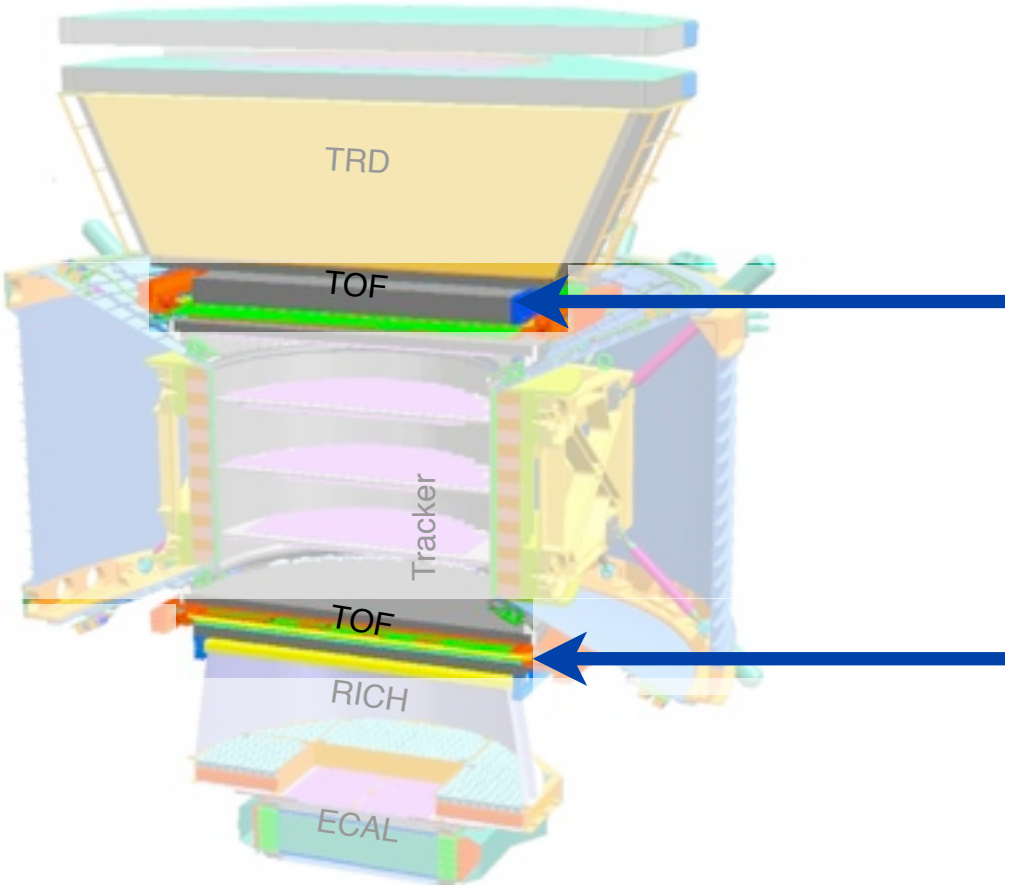
B ~ 0.14 Tesla uniform along x

no field leak outside

no torque outside



A TeV precision, multipurpose spectrometer



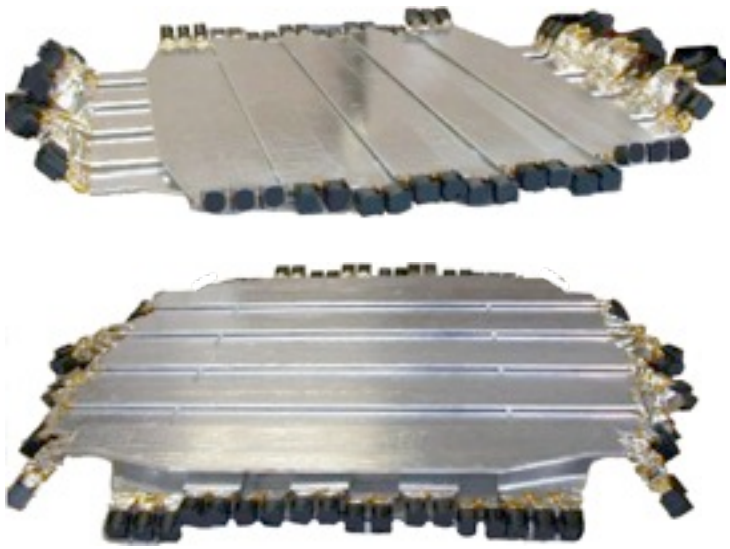
TOF

Z,E

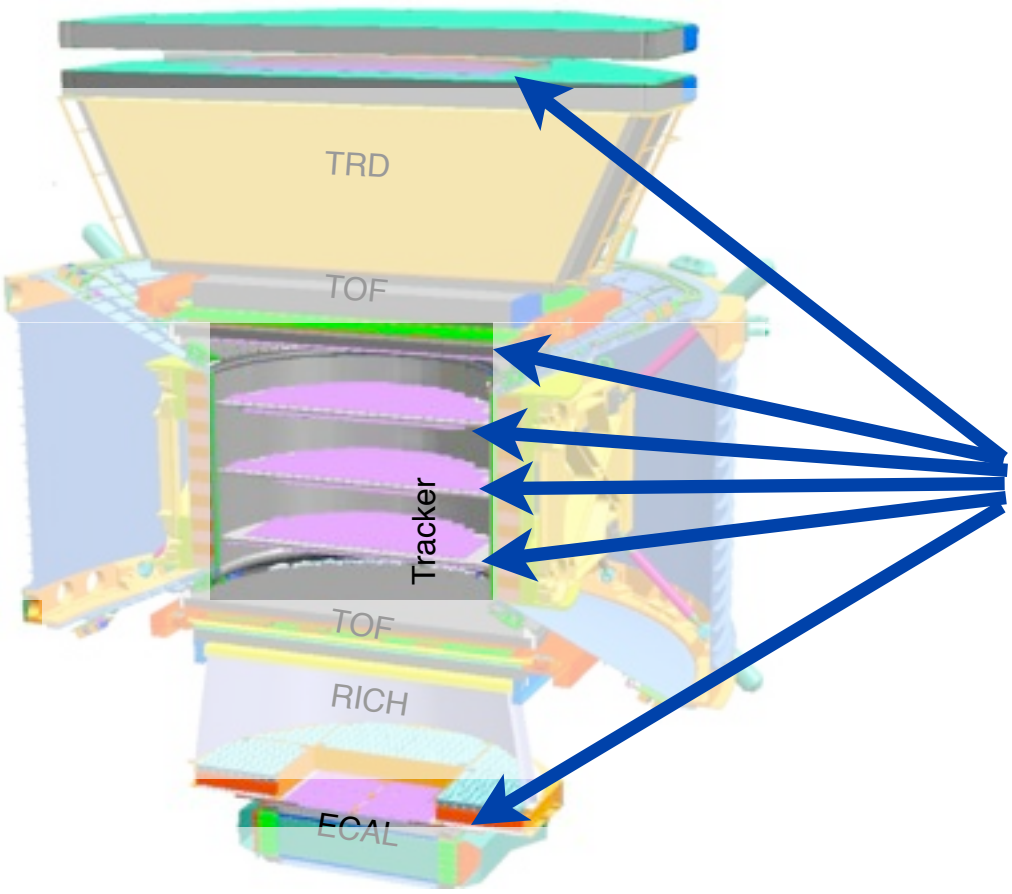
4 layer scintillators

acceptance 0.4 m^2 sr

144 photomultipliers



A TeV precision, multipurpose spectrometer



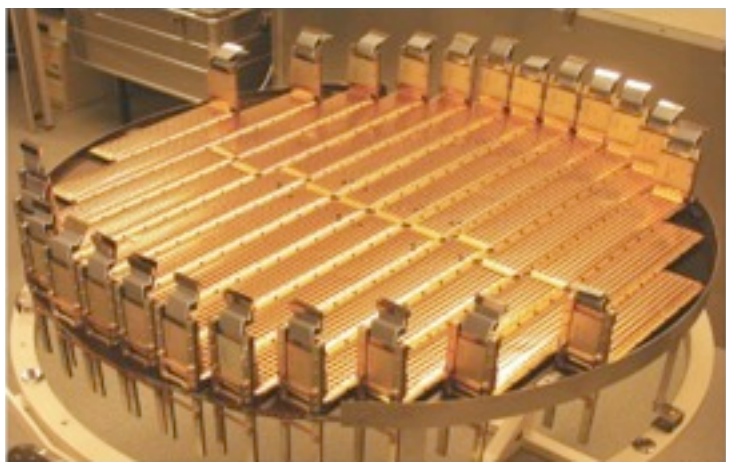
Silicon Tracker

Z, P

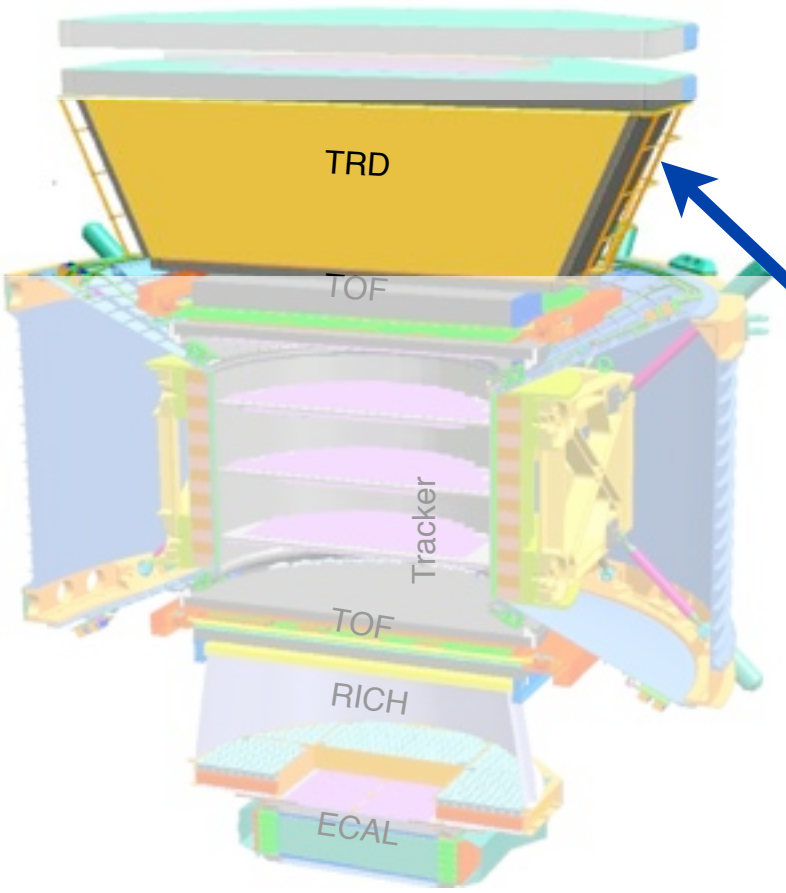
9 layers silicon

192 readout channels

resolution of 10 μm in bending direction



A TeV precision, multipurpose spectrometer

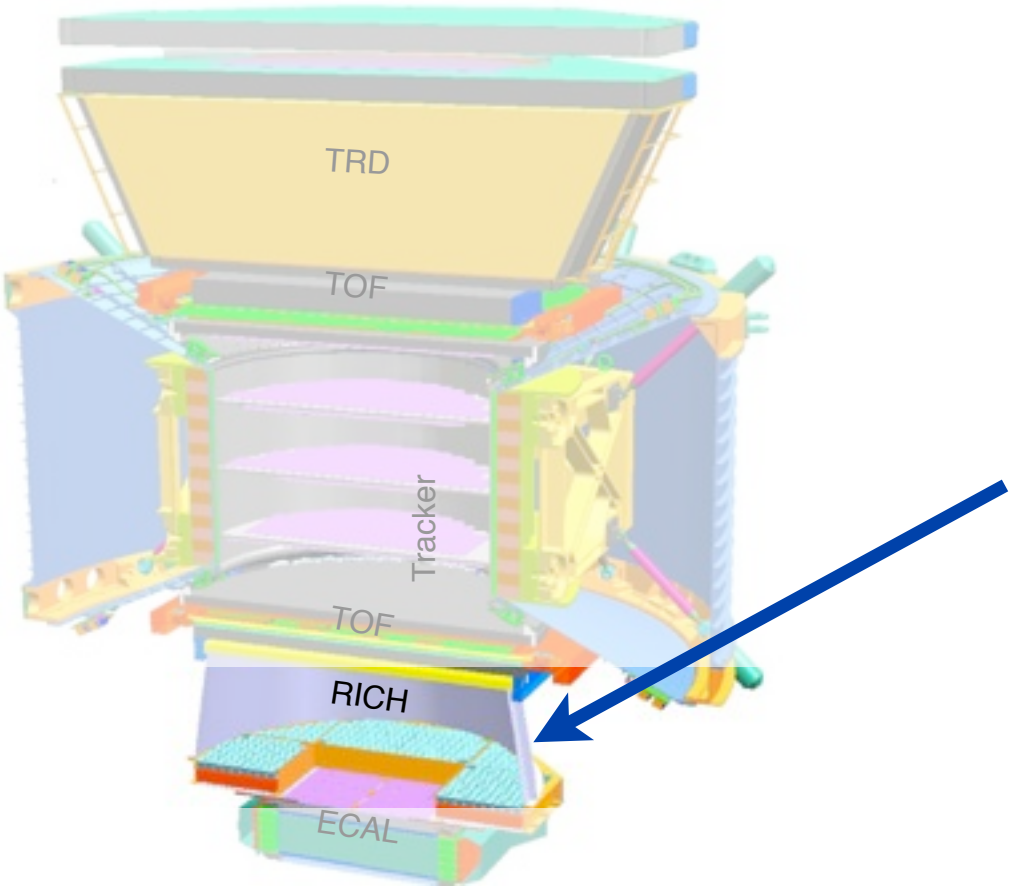


TRD

Identify e^+, e^-

20 layers of radiators
and 6mm straw tubes
Xe/CO_2 (80%/20%) gas
5248 channels

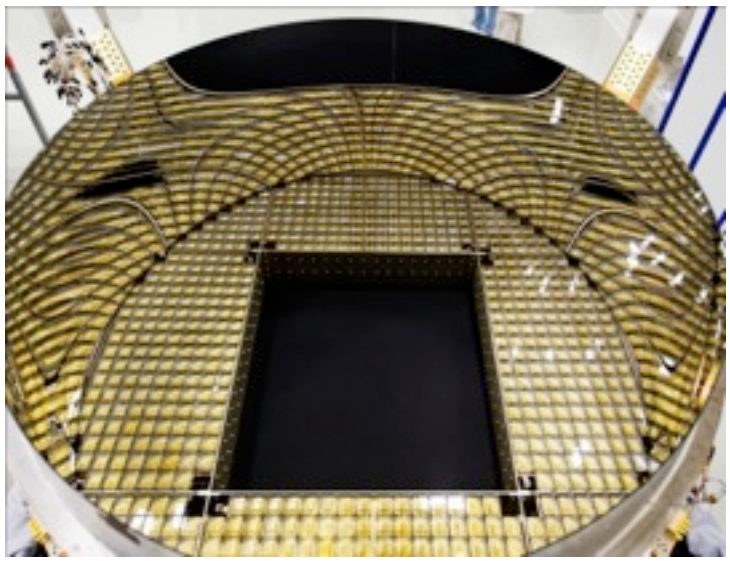
A TeV precision, multipurpose spectrometer



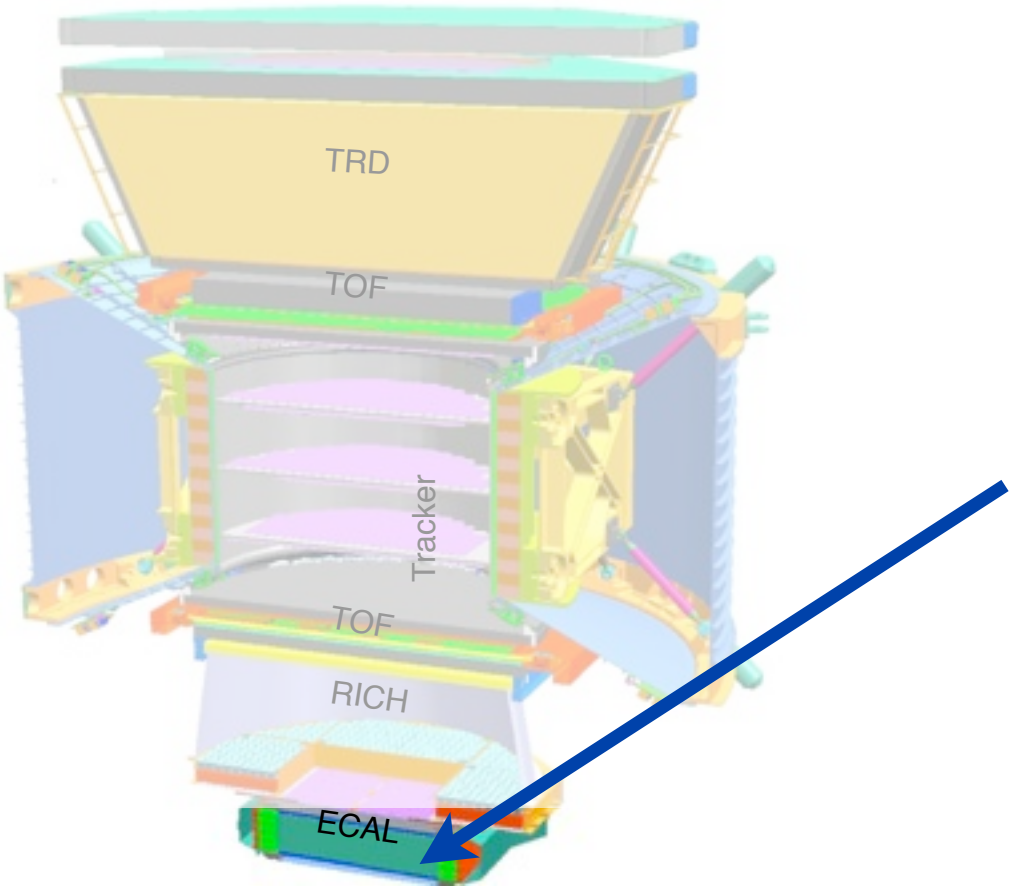
RICH

Z,E

Areogel and NaF radiators
conical reflector
10880 photosensors



A TeV precision, multipurpose spectrometer



ECAL

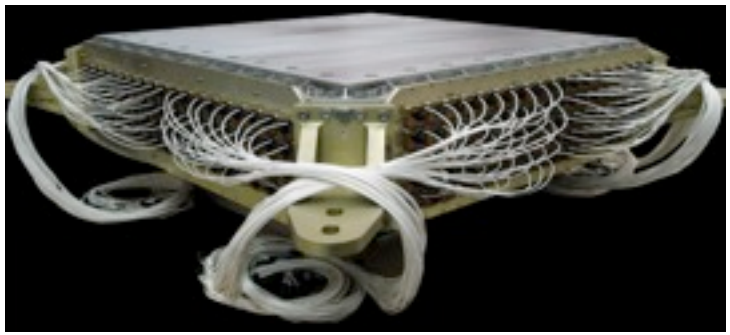
E of e^+, e^-, γ

3D sampling calorimeter

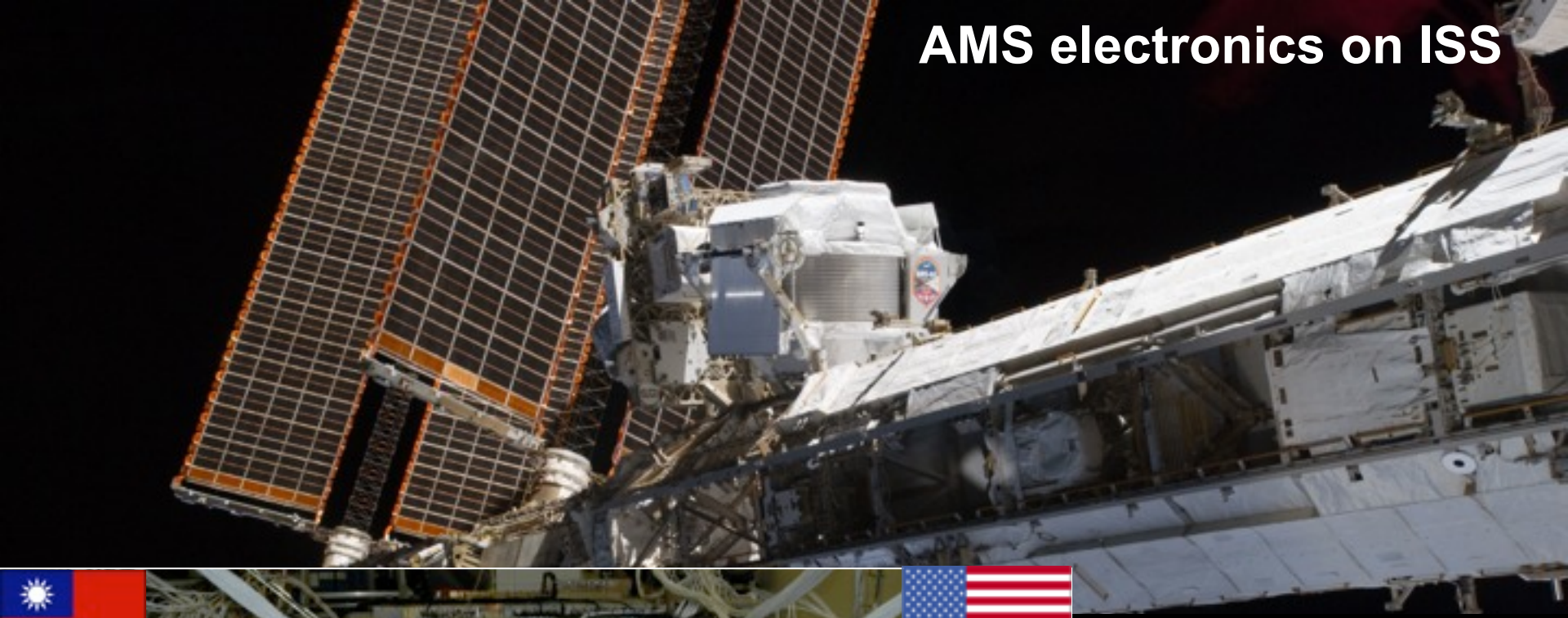
17 X0

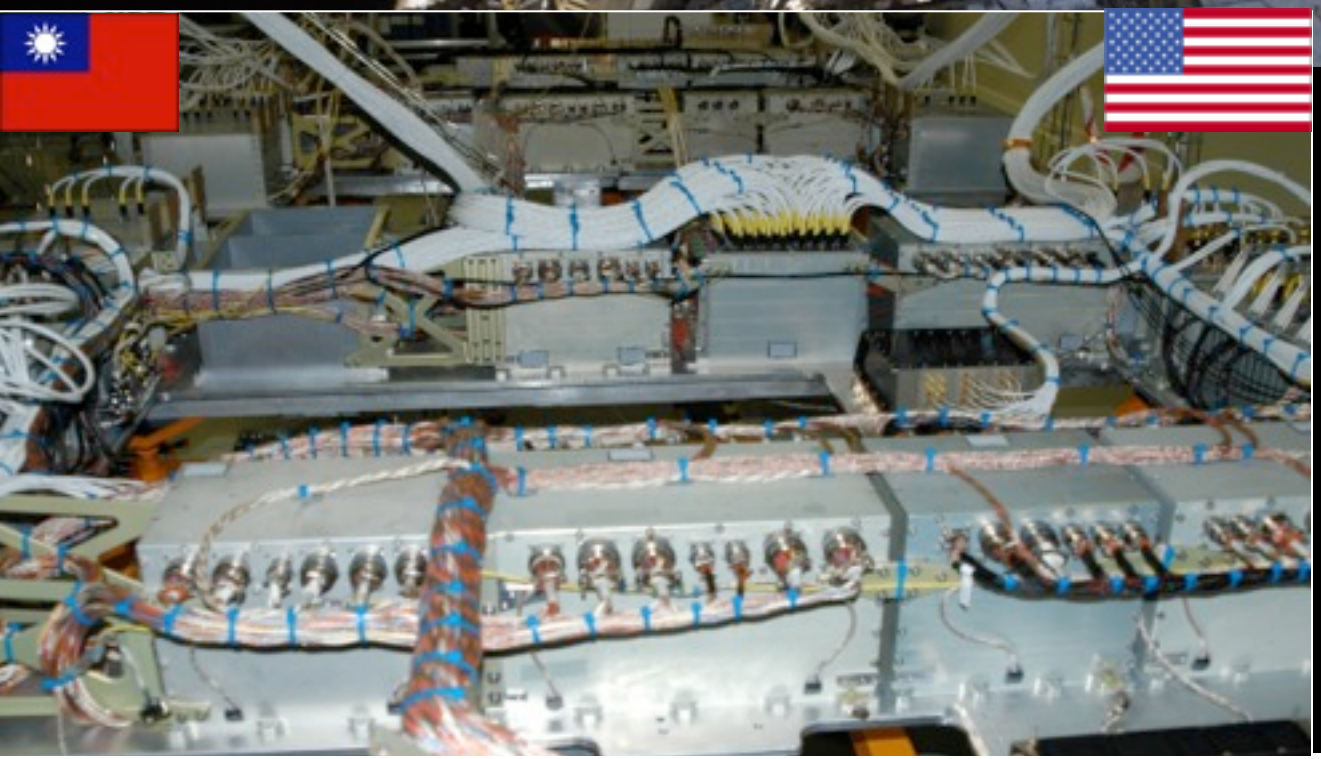
50000 fibers 1mm thick

e/p separation 10^4



AMS electronics on ISS

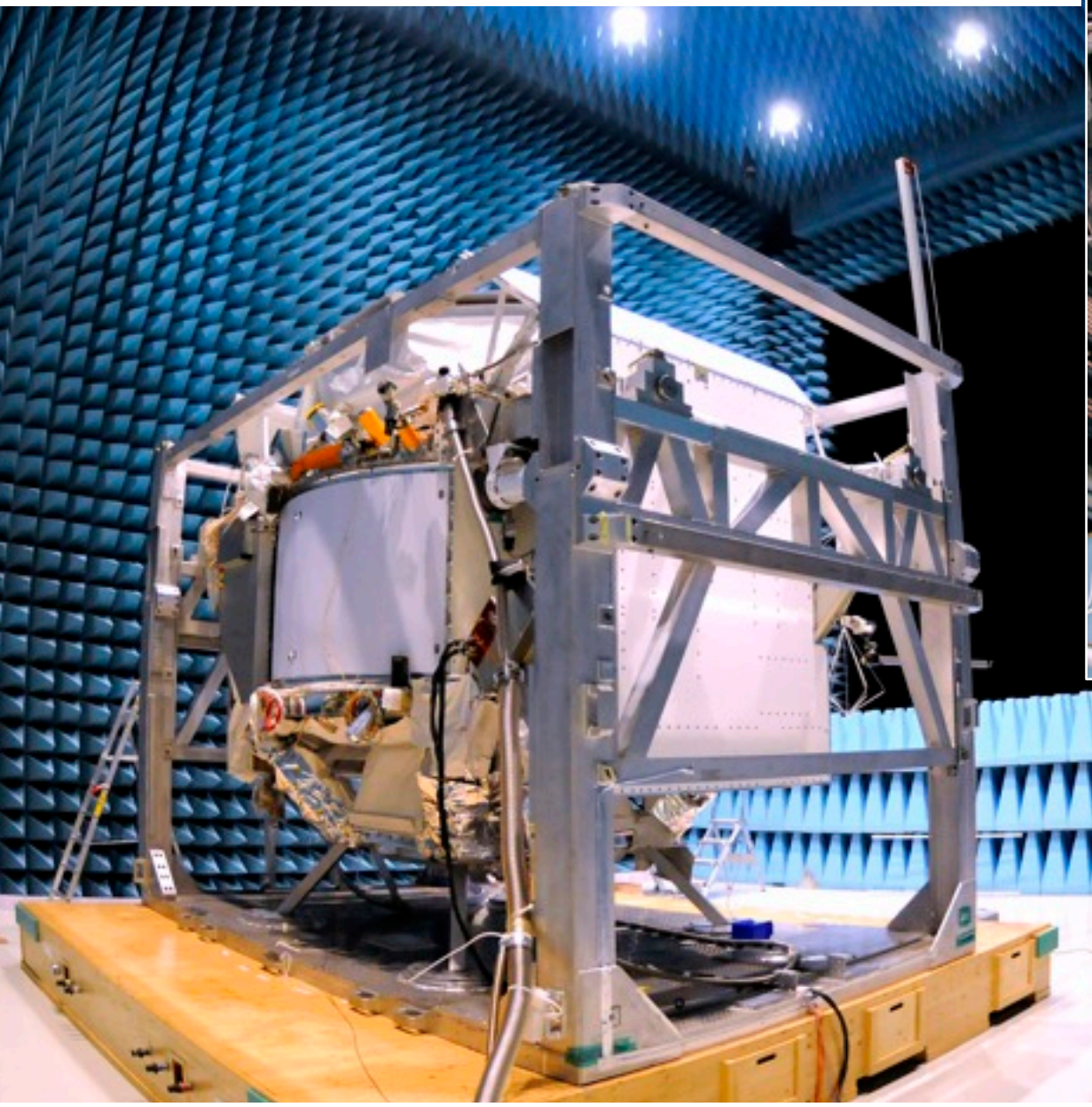


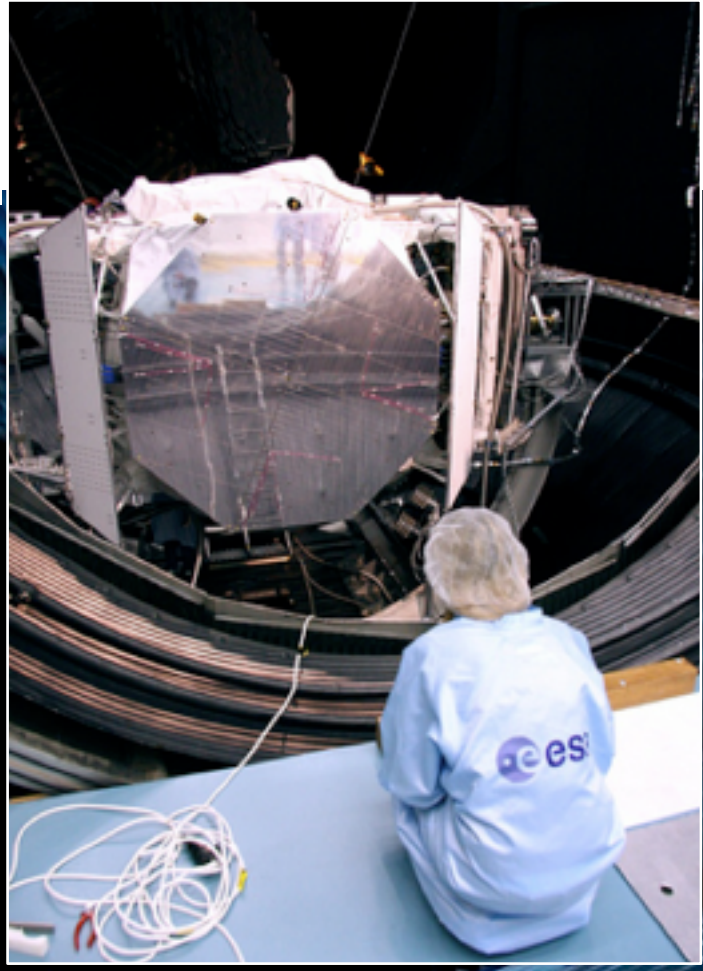


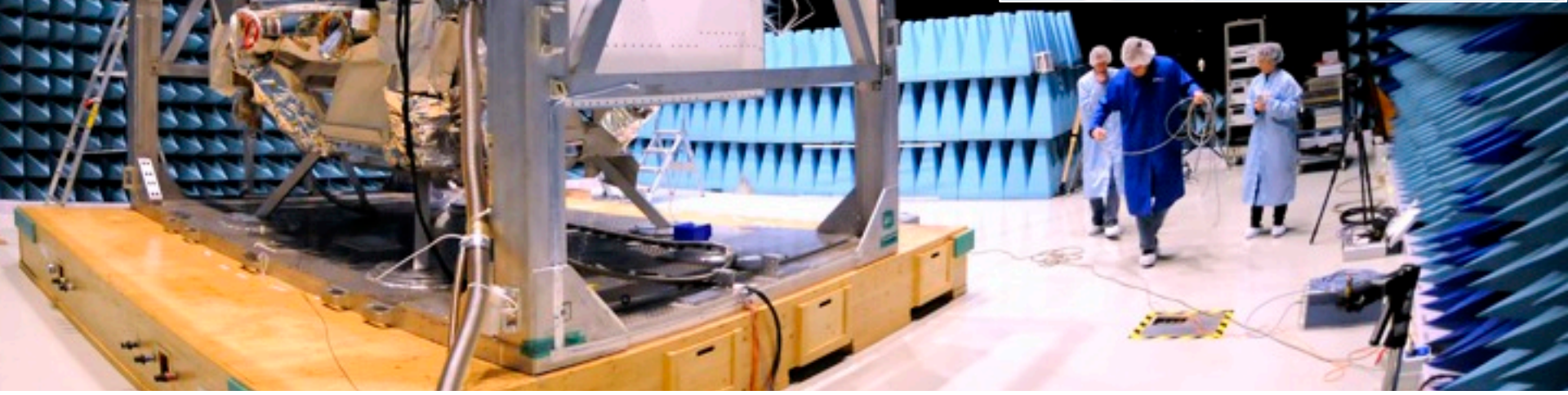
650 computers,
300,000 channels.
A ten year effort by
75 engineers
400% redundancy

AMS in the ESA

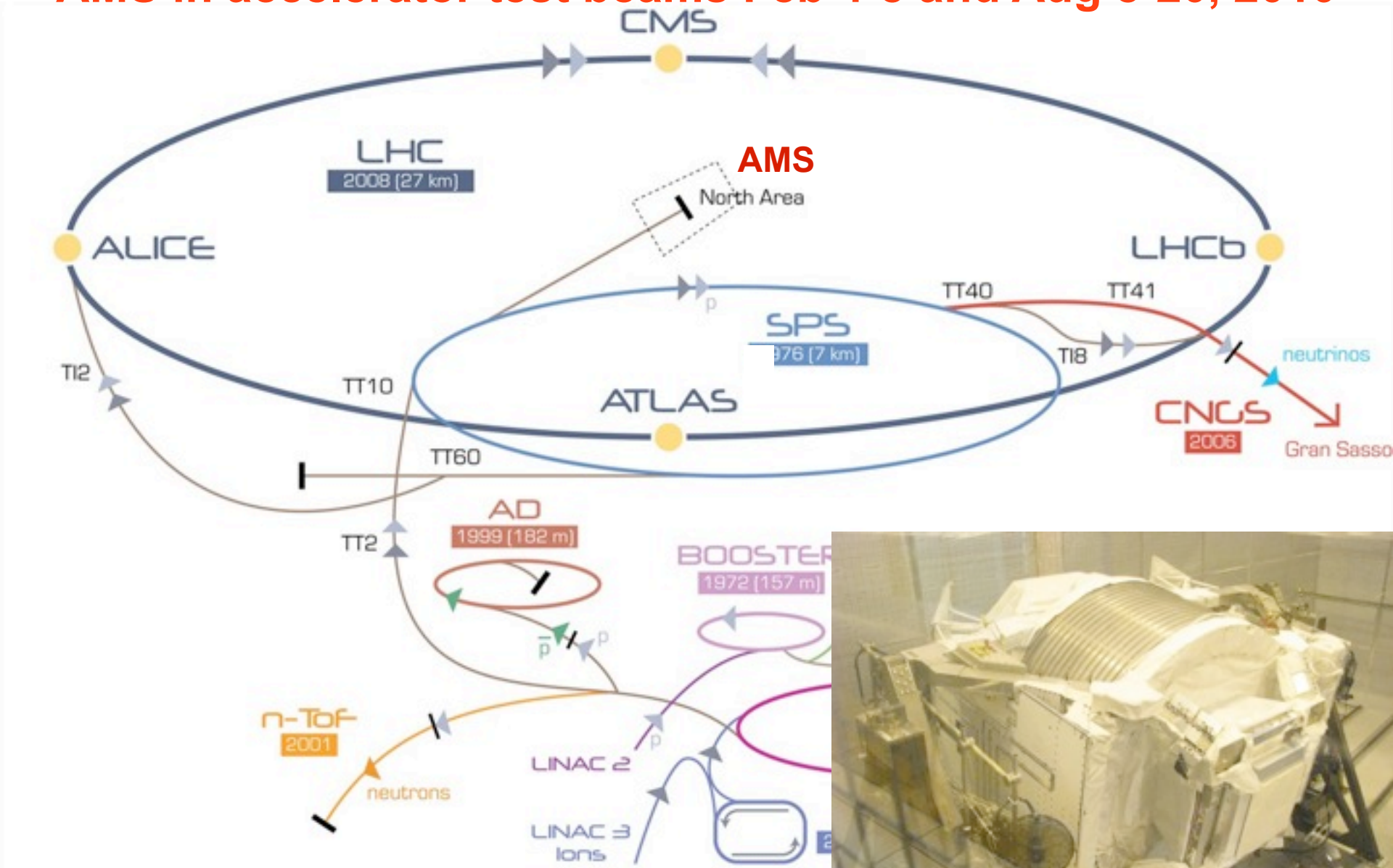
EMI and TVT tests

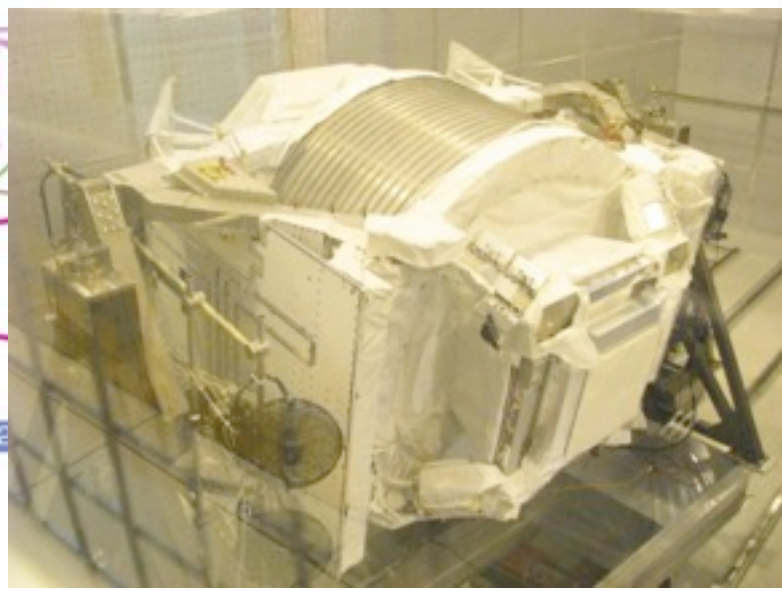




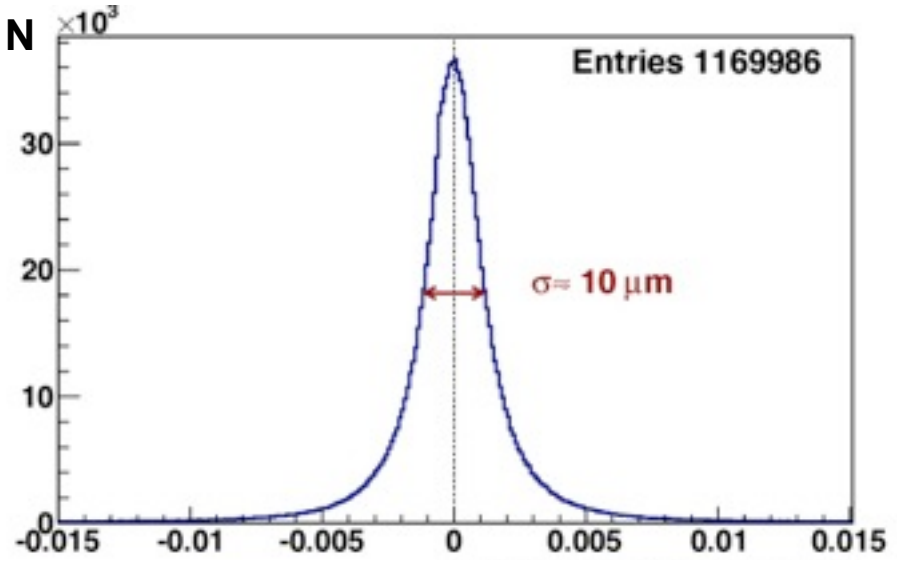


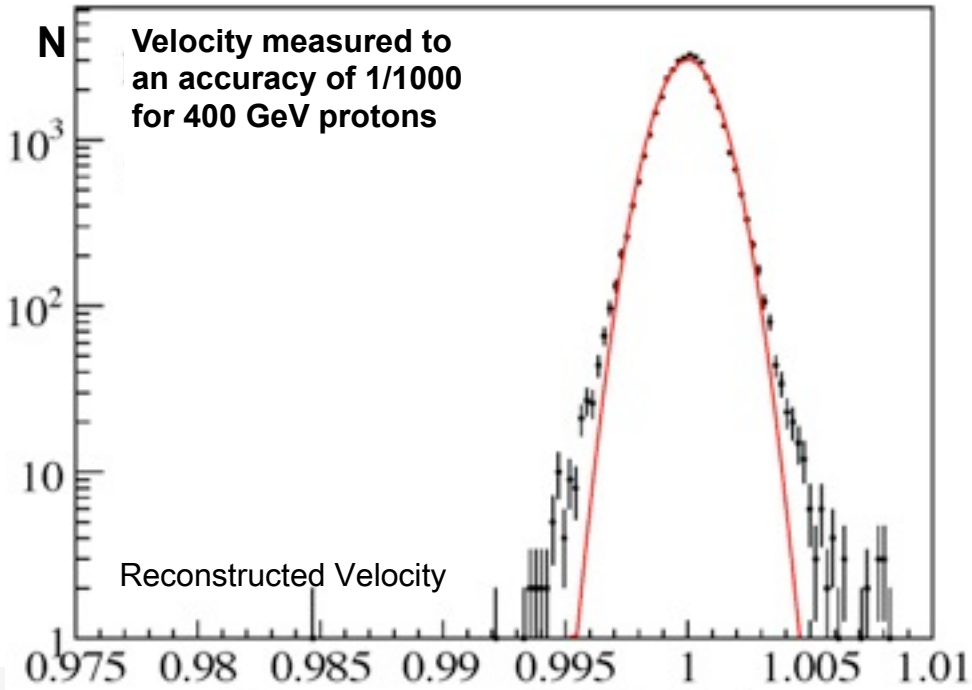
Tests at CERN
AMS in accelerator test beams Feb 4-8 and Aug 8-20, 2010

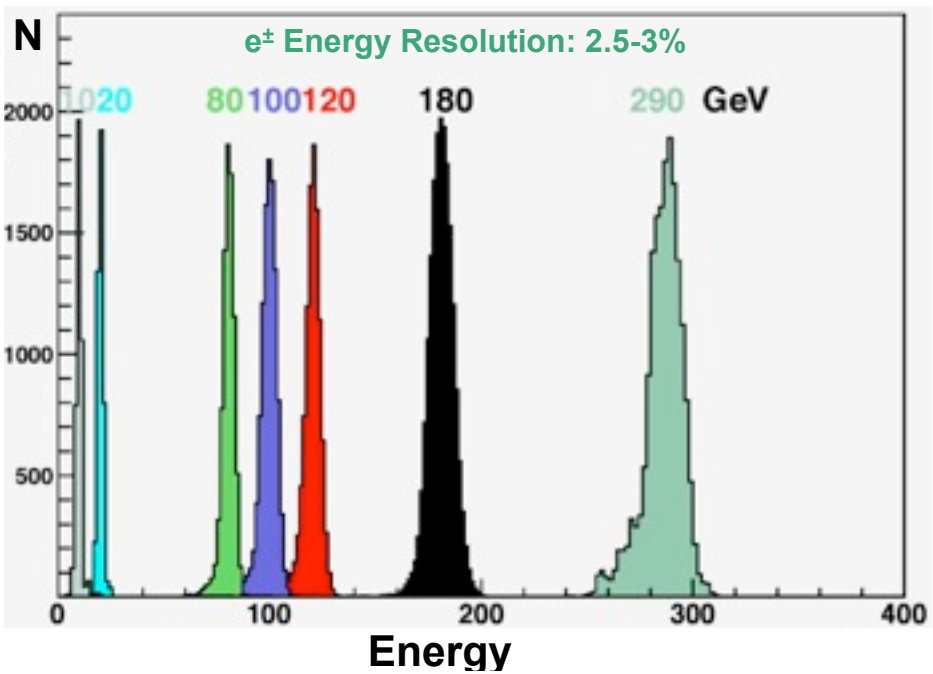


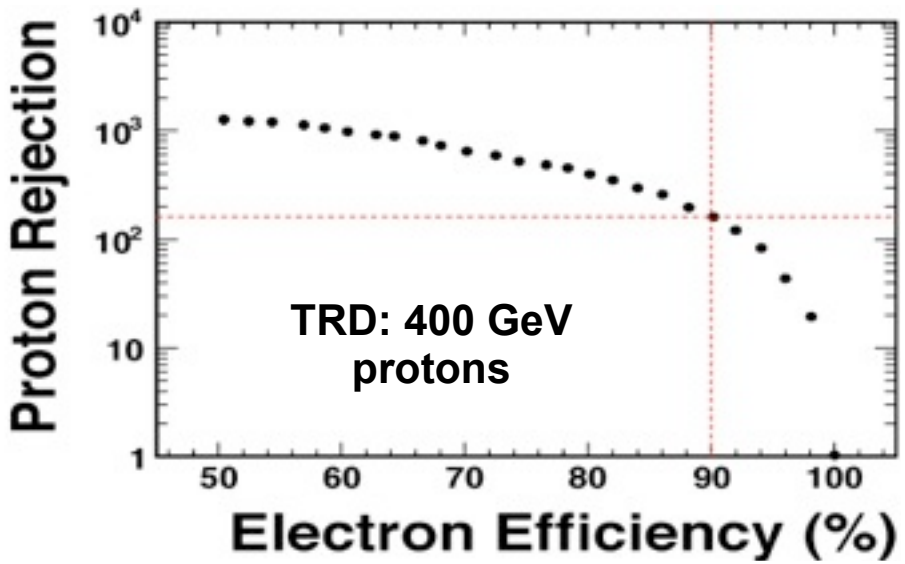


Test Beam Results



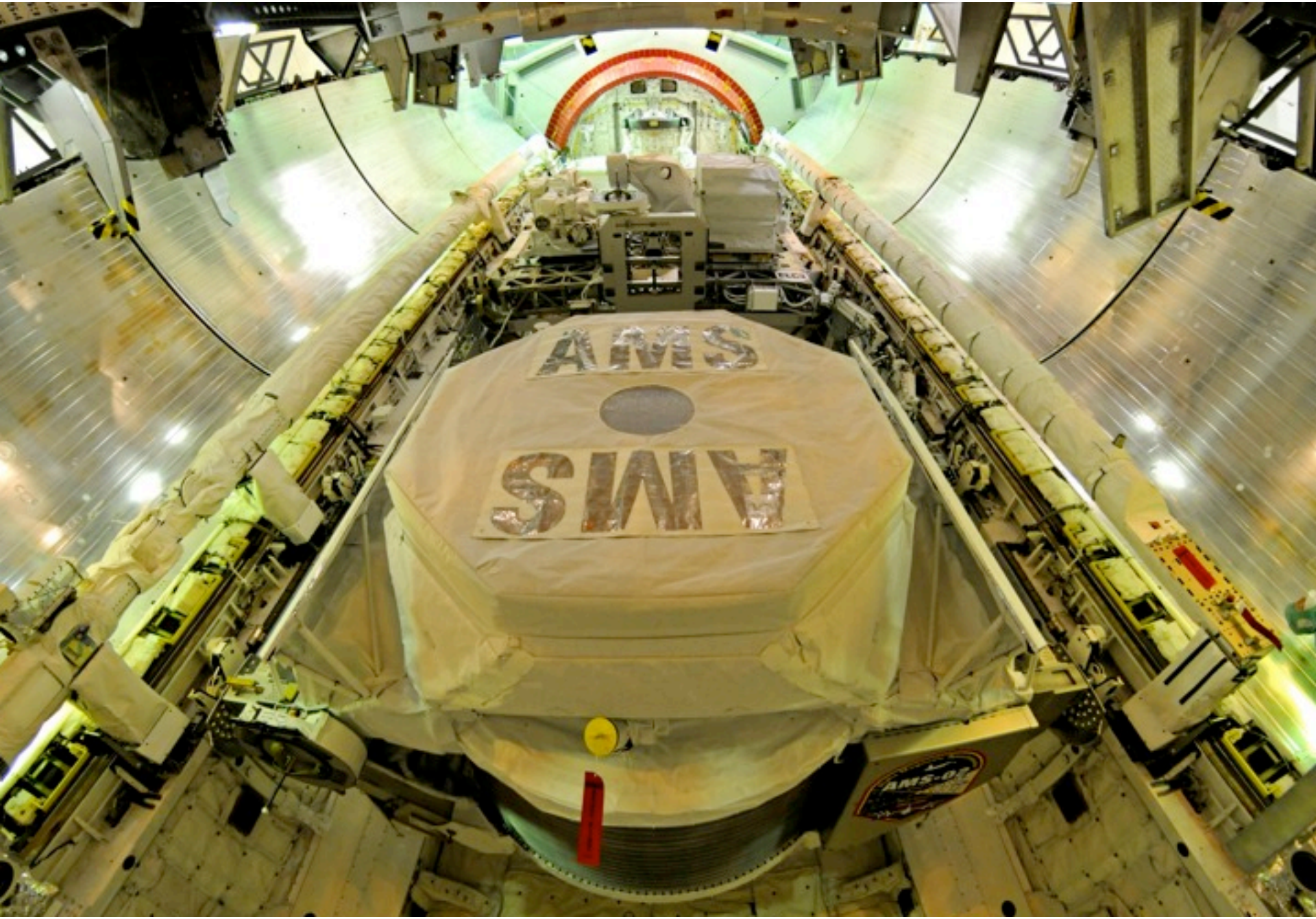






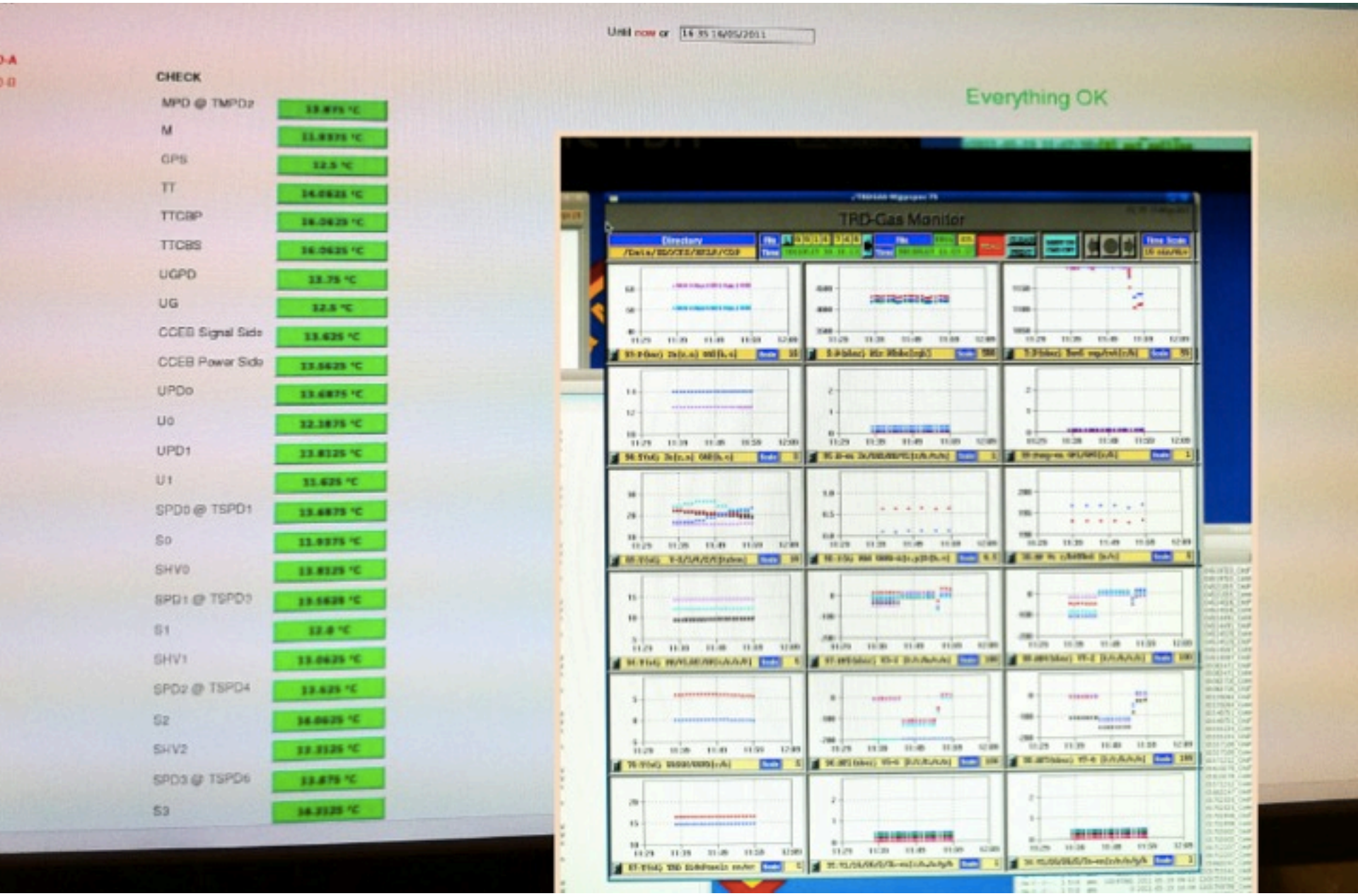
A US-AirForce C-5 Galaxy has been used for transport
from Geneva to KSC - August 25th 2010

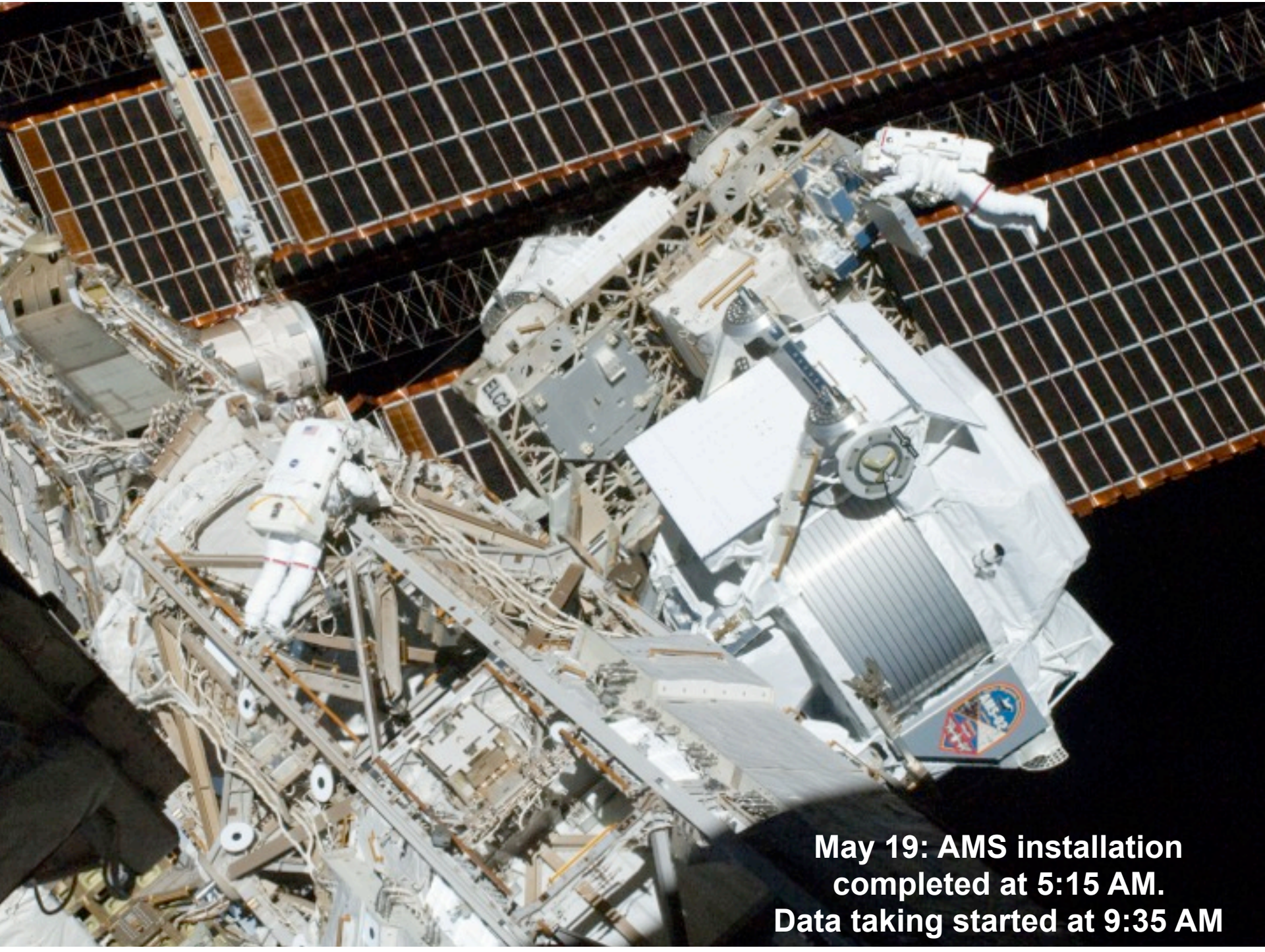
AMS in Endeavour's Payload Bay



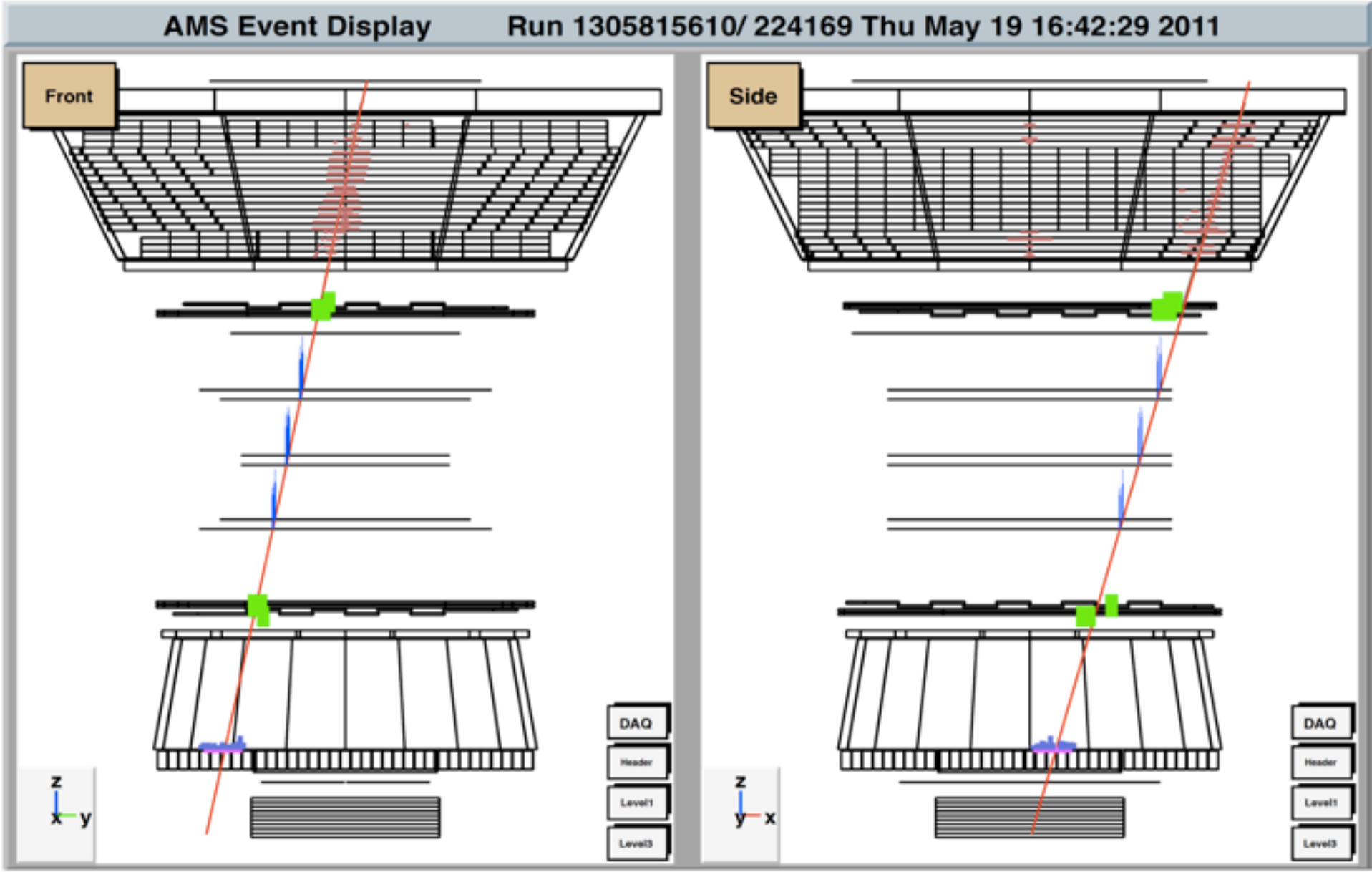
Launch of the Space Shuttle Endeavour
May 16, 2011 @ 08:56 AM

Temperatures and slow-control data monitoring started 2.5 h after the launch




May 19: AMS installation
completed at 5:15 AM.
Data taking started at 9:35 AM

42 GeV/c Carbon

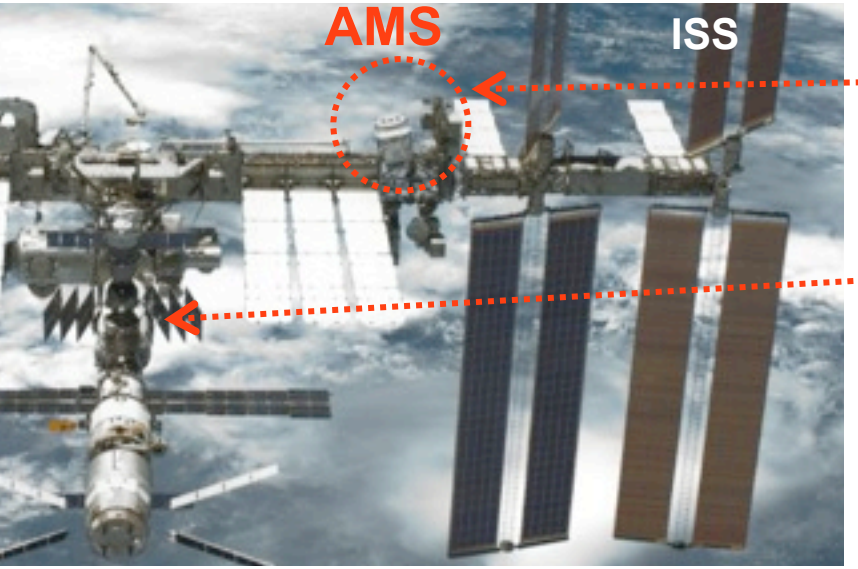


AMS installed on ISS @ 16:15 Geneva time

AMS start data taking @ 16:35 Geneva time

Johnson Space Center, May 19th 2011

AMS Operations



Ku-Band
High Rate (down):
Events:10Mbit/s

Flight Operations

Ground Operations

S-Band
Low Rate (up & down):
Commanding: 1 Kbit/s
Monitoring: 30 Kbit/s

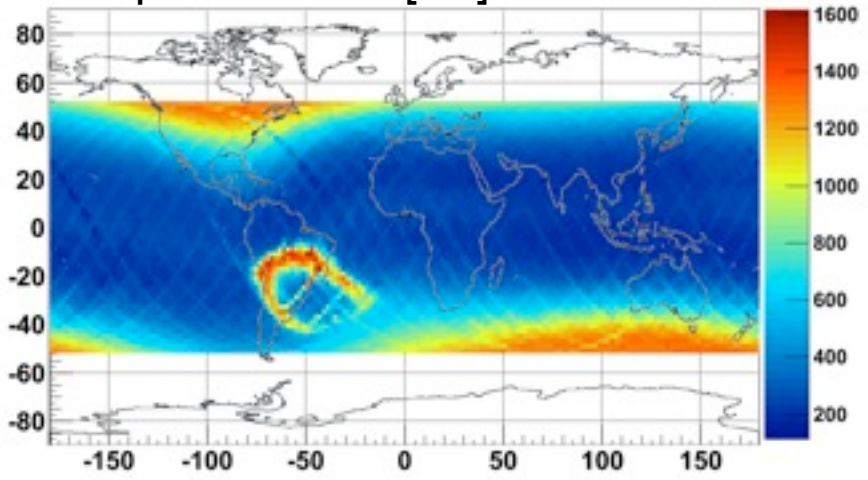
AMS Payload Operations Control and Science Operations Centers (POCC, SOC) at CERN

AMS Computers at MSFC, AL

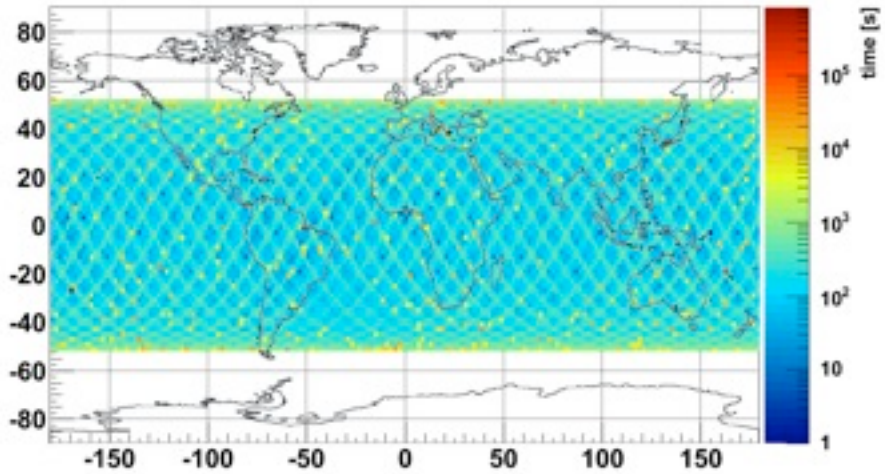
White Sands Ground Terminal, NM

Orbital DAQ parameters

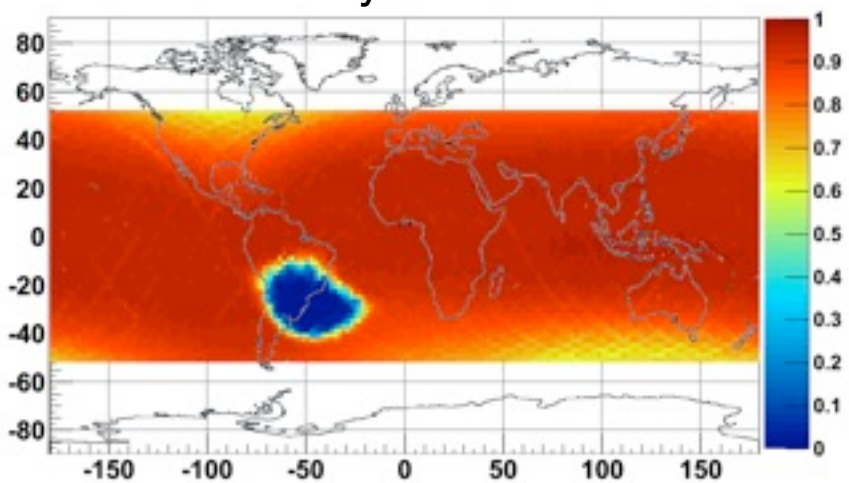
Acquisition rate [Hz]



Time at location [s]



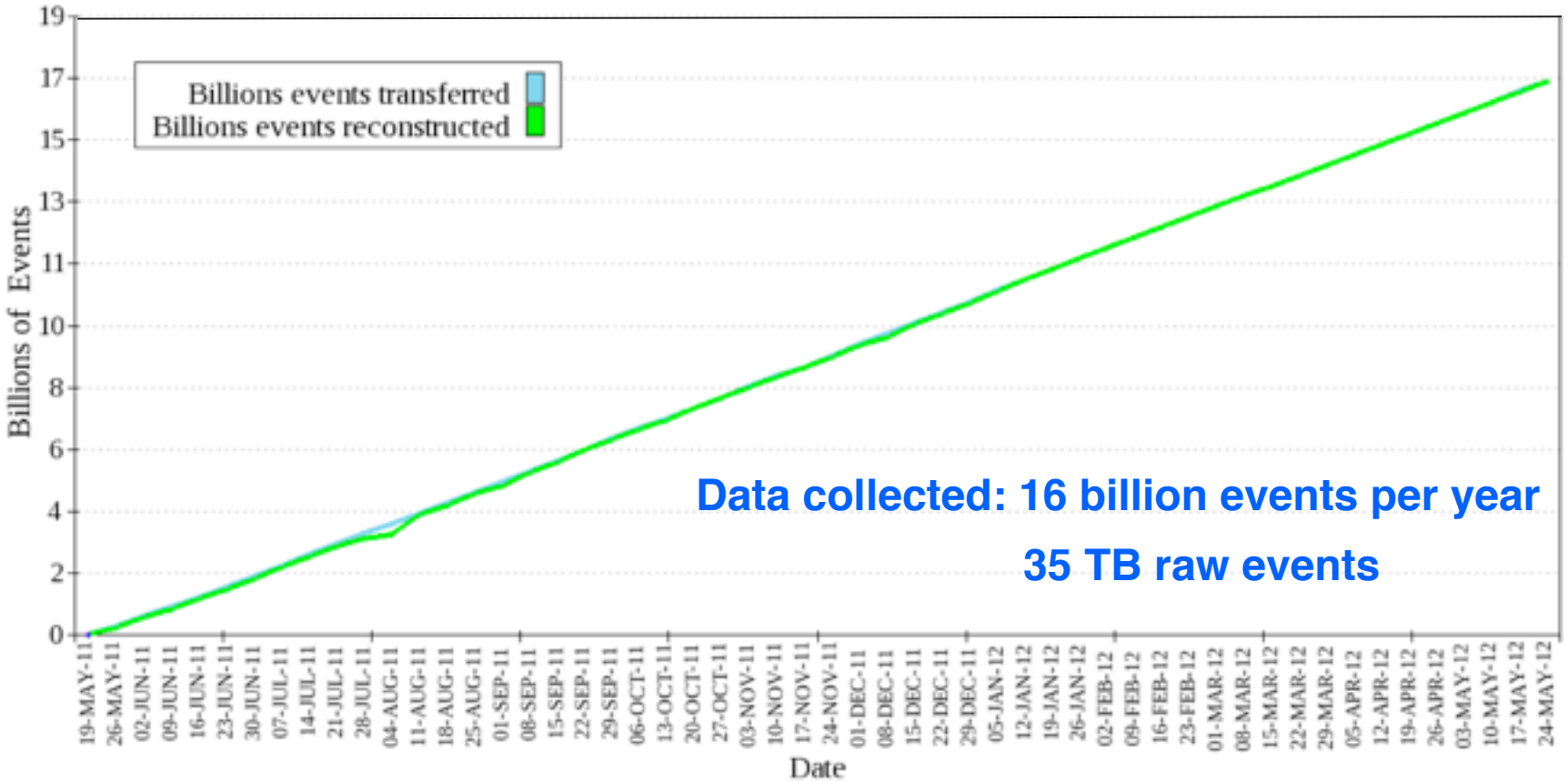
DAQ efficiency



Particle rates vary from 200 to 2000 Hz per orbit

Average DAQ efficiency 85%
Average DAQ rate ~700Hz

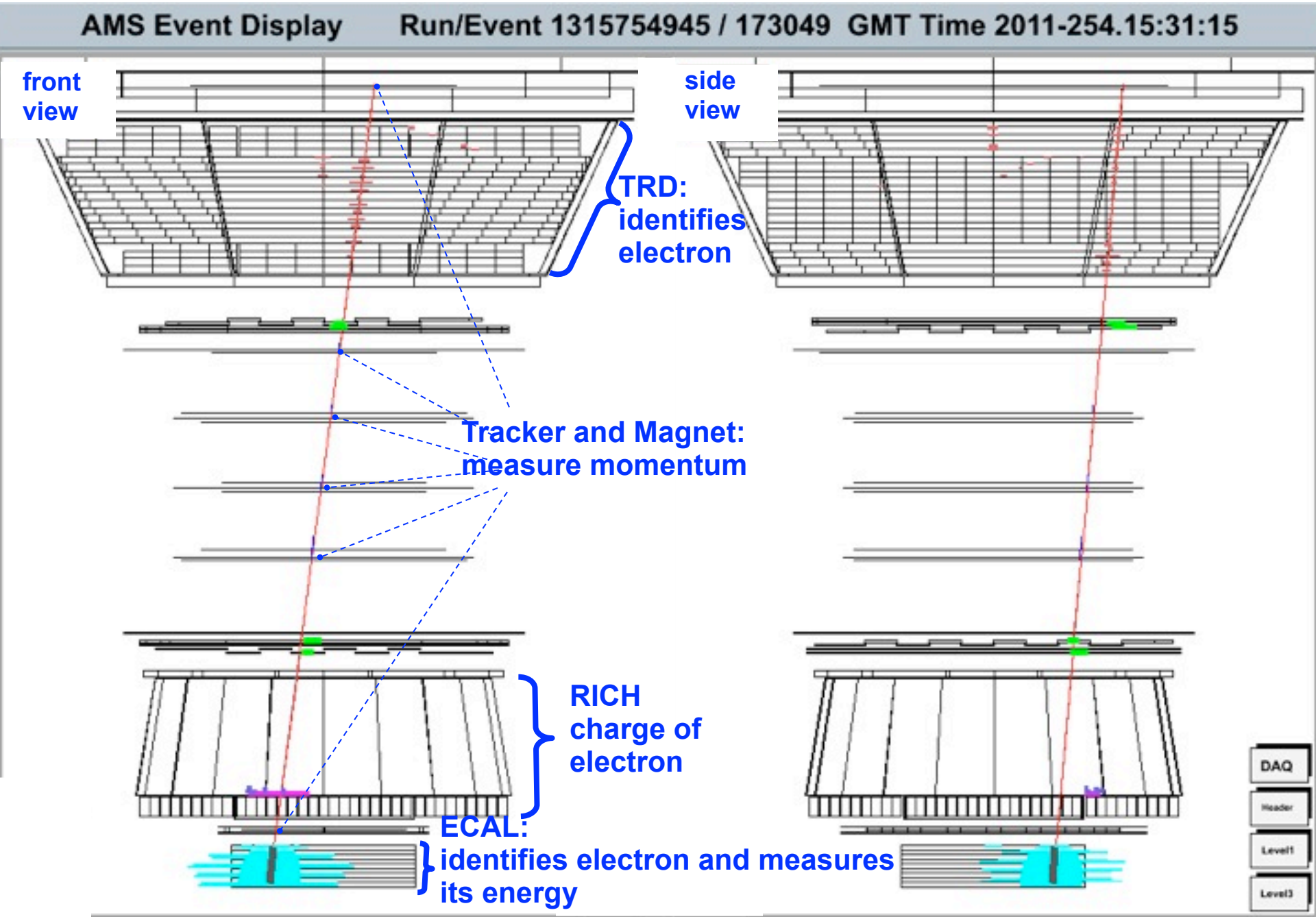
Data taking continuously active



In 10 - 20 years AMS will collect from 160-320 billion events.

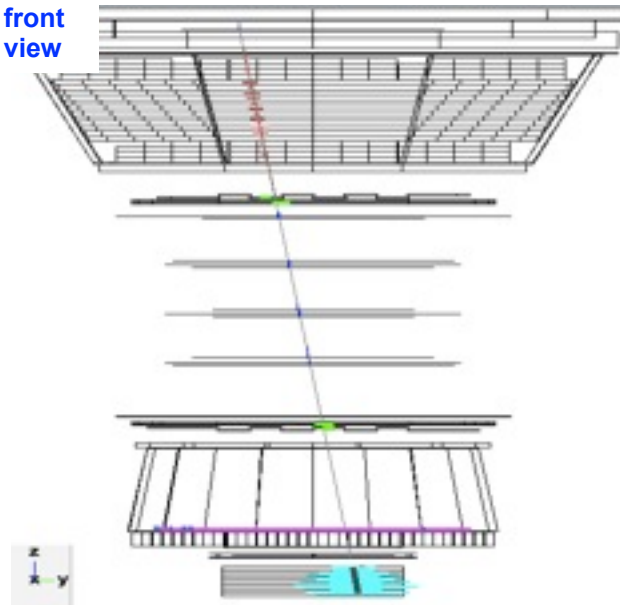
This will provide unprecedented sensitivity and statistic.

1.03 TeV electron



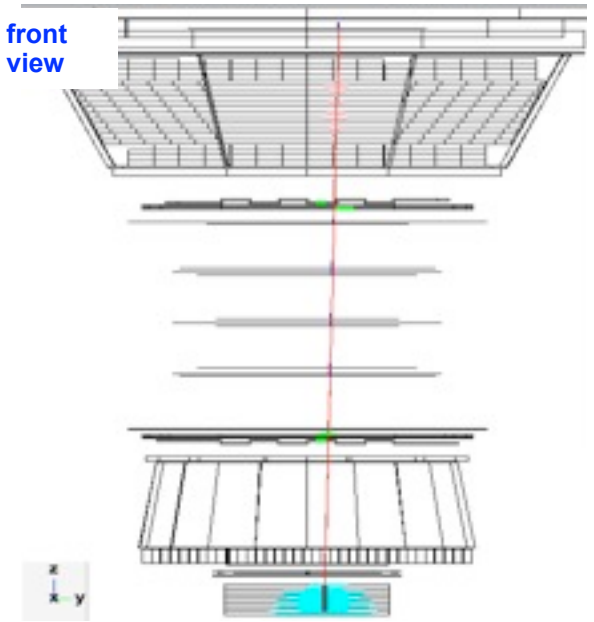
205 GeV Positron

front view



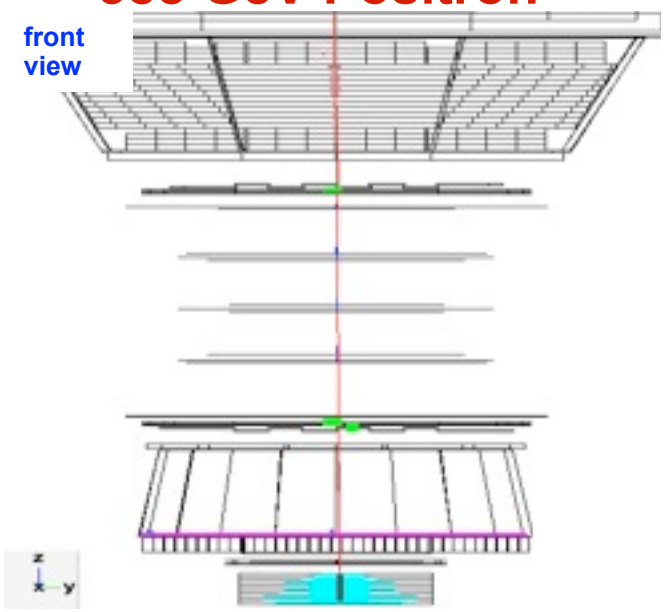
369 GeV Positron

front view



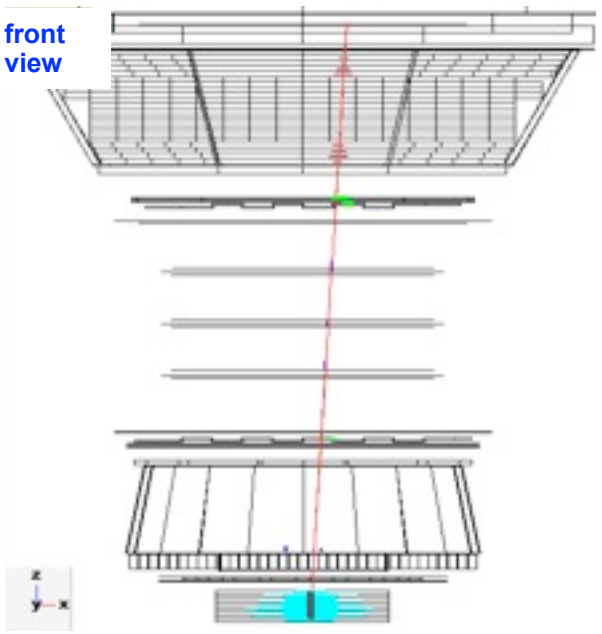
388 GeV Positron

front view



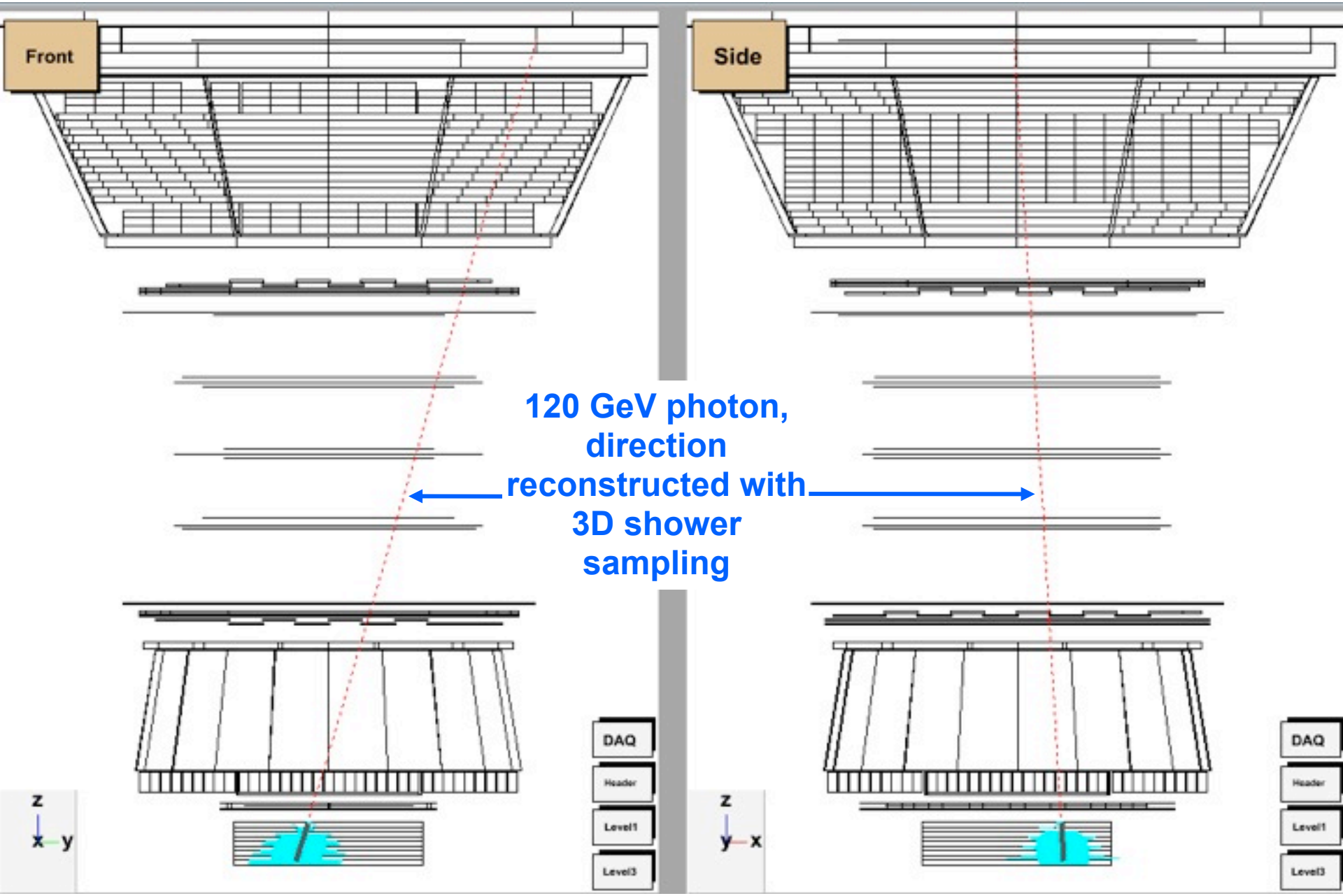
424 GeV Positron

front view

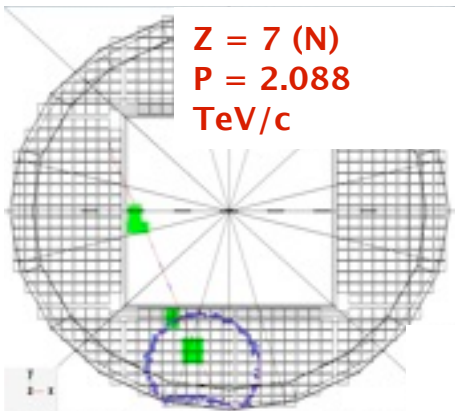


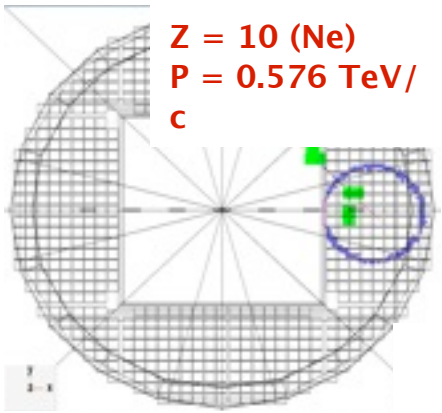
120 GeV Photon

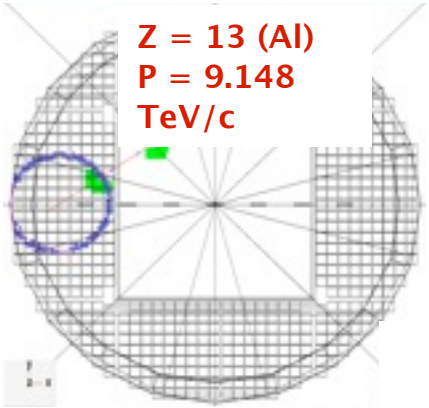
17 X_0, 3D ECAL, measure γ to 1 TeV, time resolution of 1μsec

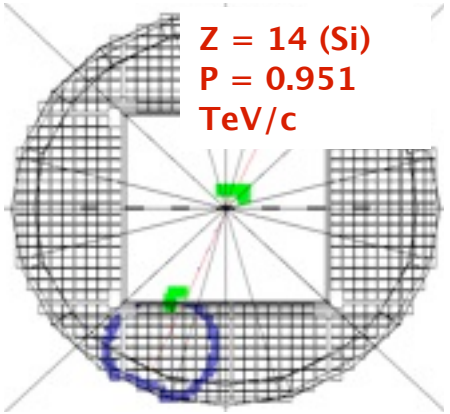


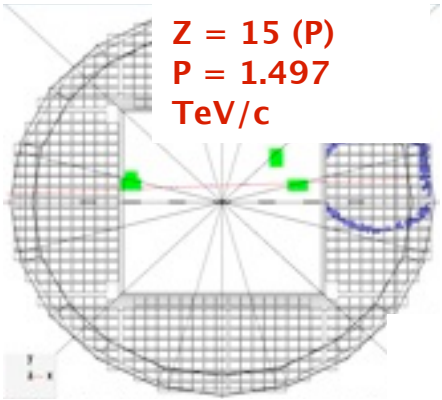
Nuclei in the TeV range

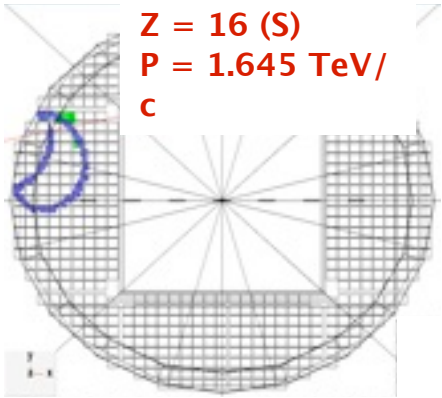


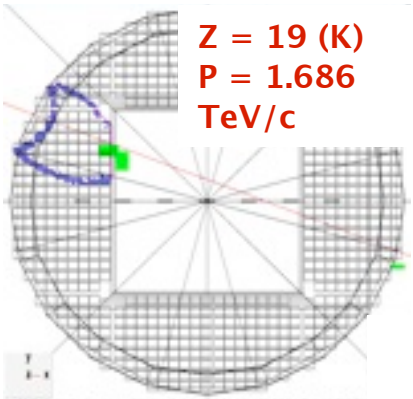


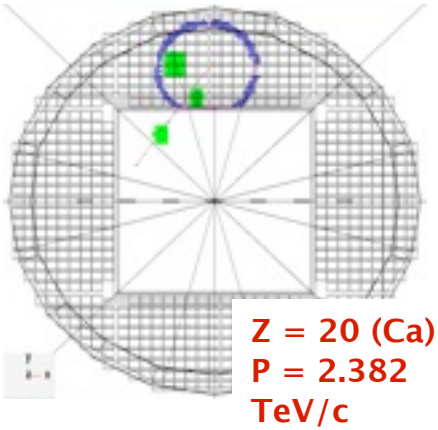


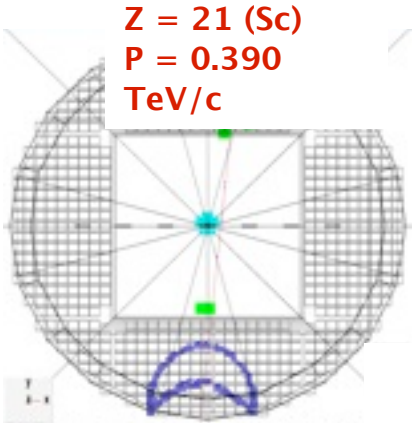


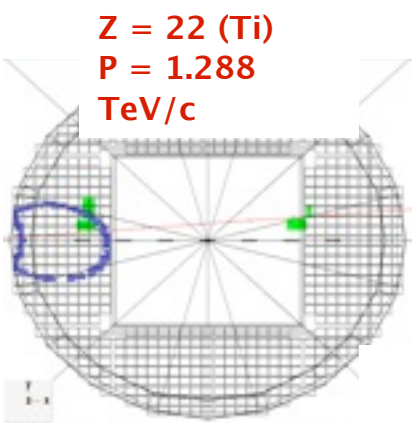


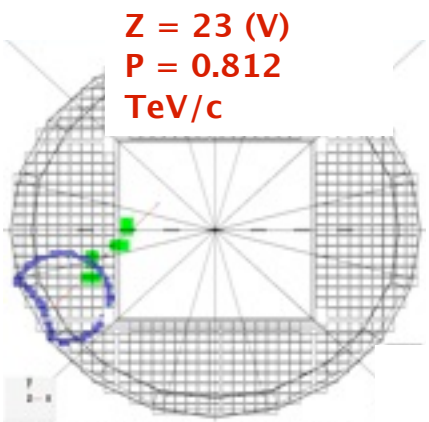


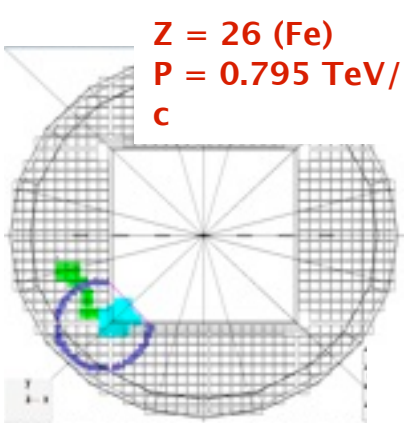








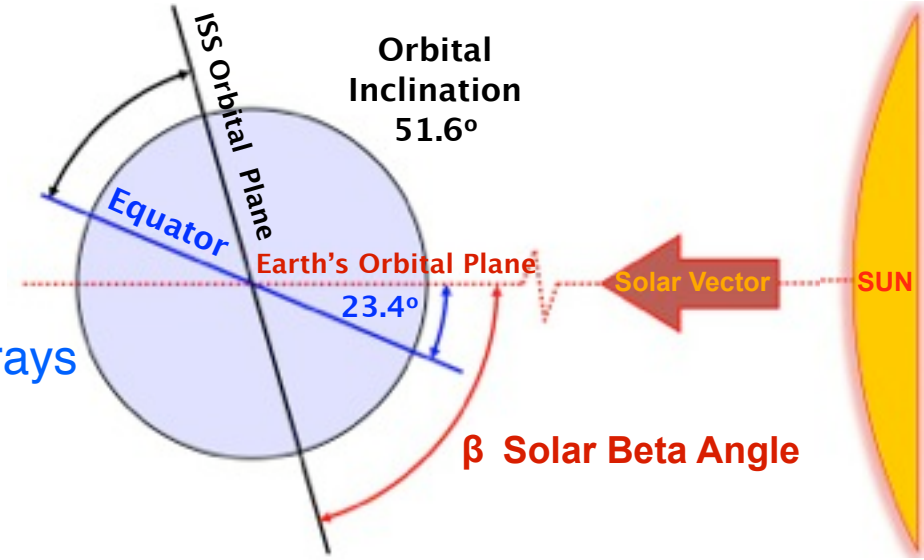




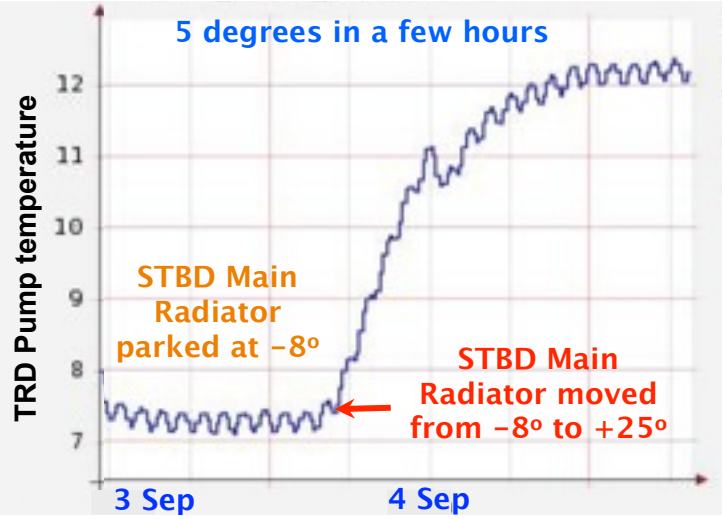
On-orbit thermal control

The thermal environment on ISS is constantly changing due to:

- Solar Beta Angle (beta)
- Position of the ISS Radiators and Solar Arrays
- ISS Attitude



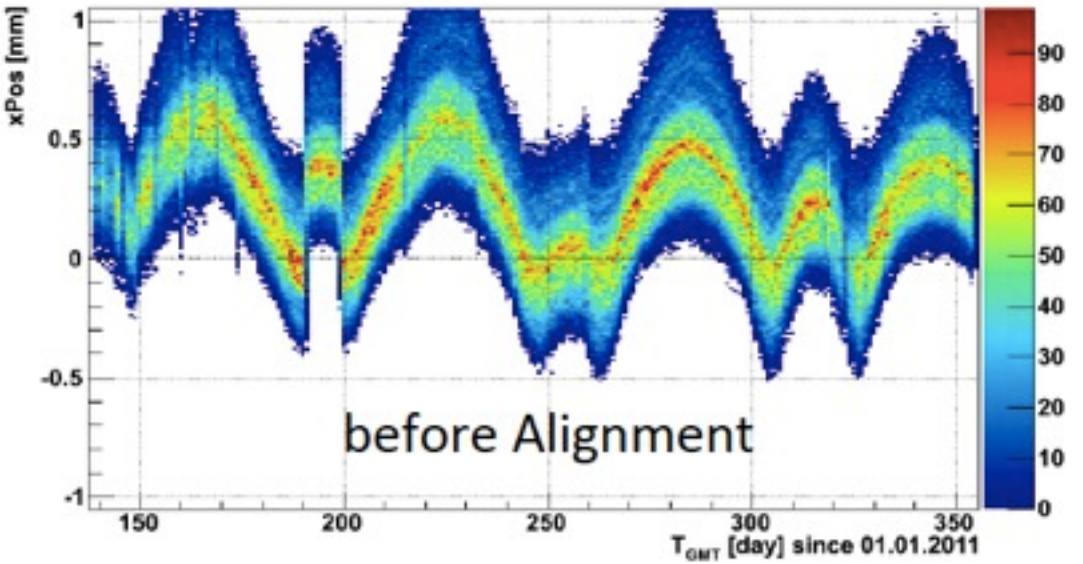
Over 1,100 temperature sensors and 298 heaters are monitored to assure components stay within thermal limits and avoid permanent damage.



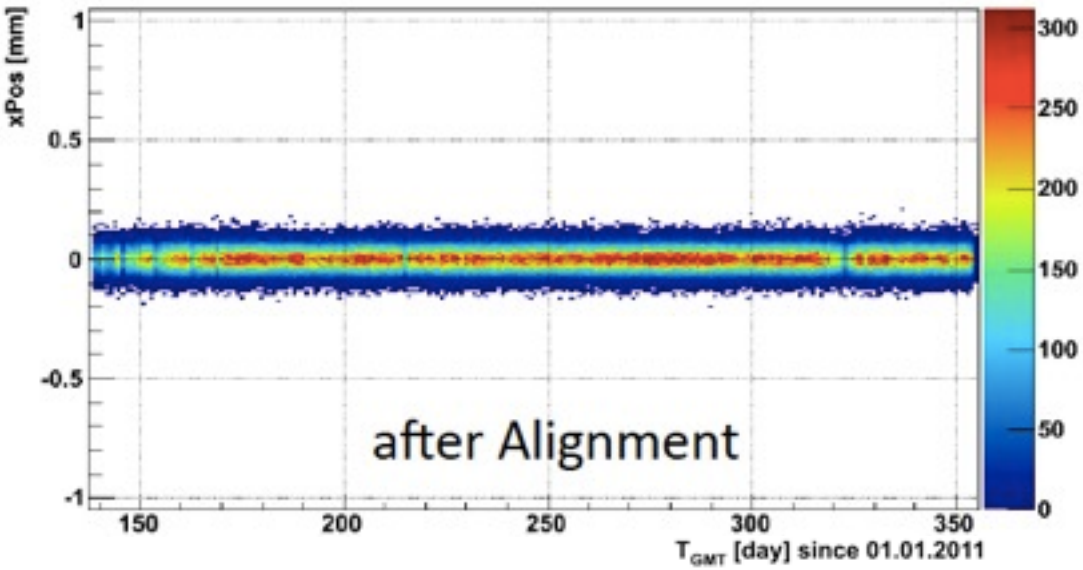
On orbit performance

TRD alignment

Due to temperature variations the TRD is moving on top of the inner tracker by up to 1 mm.



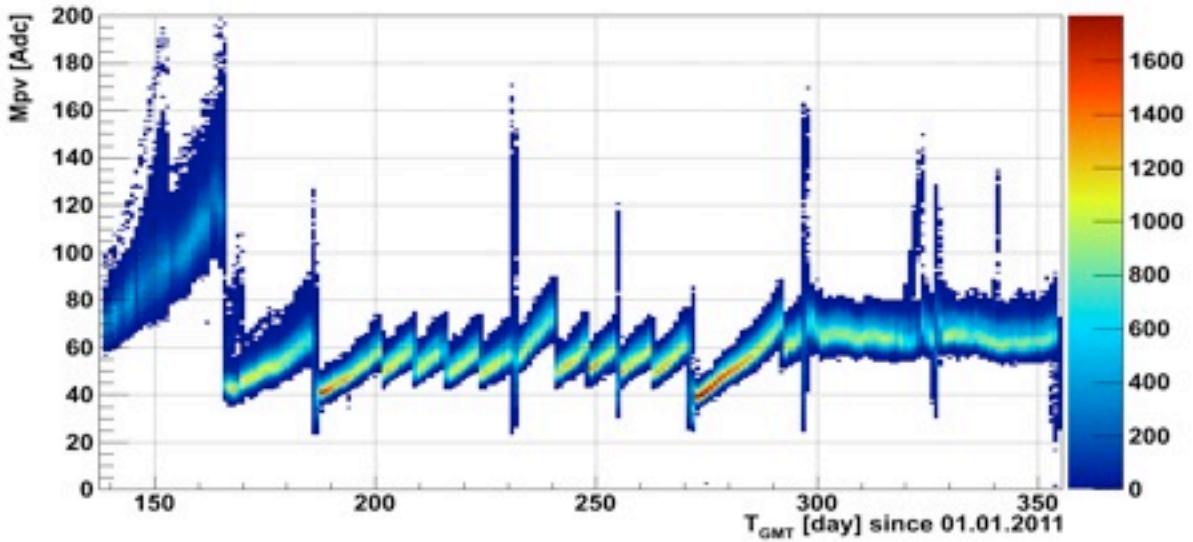
Cosmic protons are used for alignment to an accuracy of 0.04 mm for each straw module.



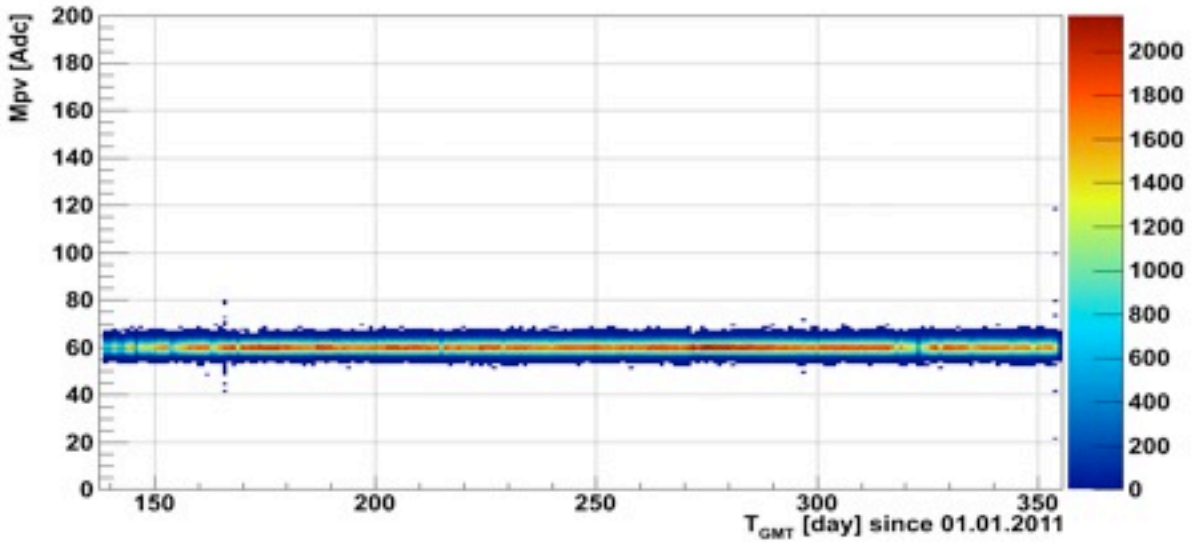
On orbit performance

TRD gain calibration

Due to temperature, pressure, gas composition and HV changes, the TRD detector response is changing.

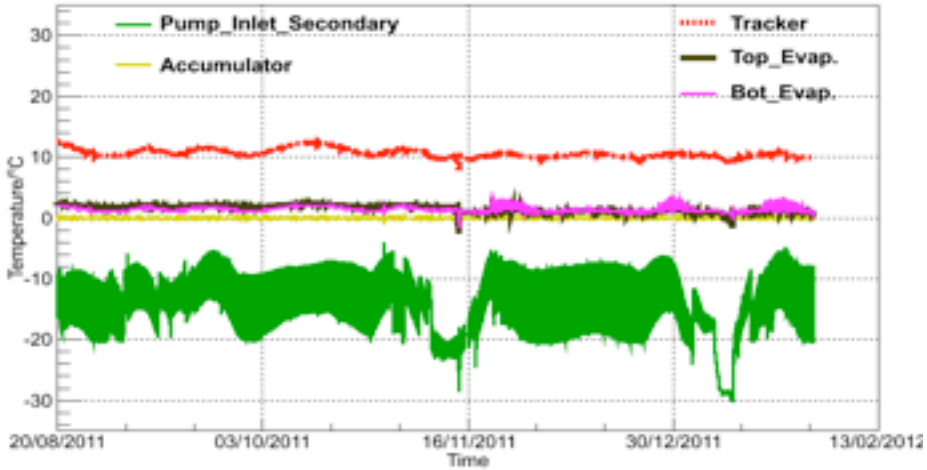


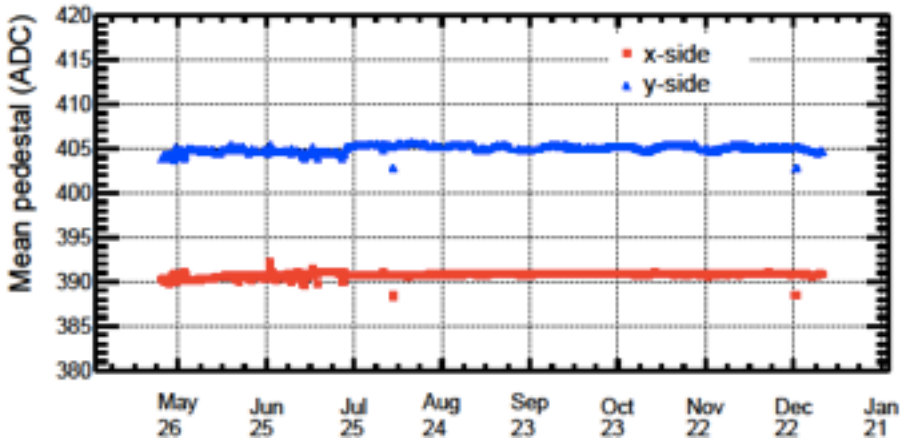
Cosmic ray protons are used to calibrate the detector response to 3% accuracy



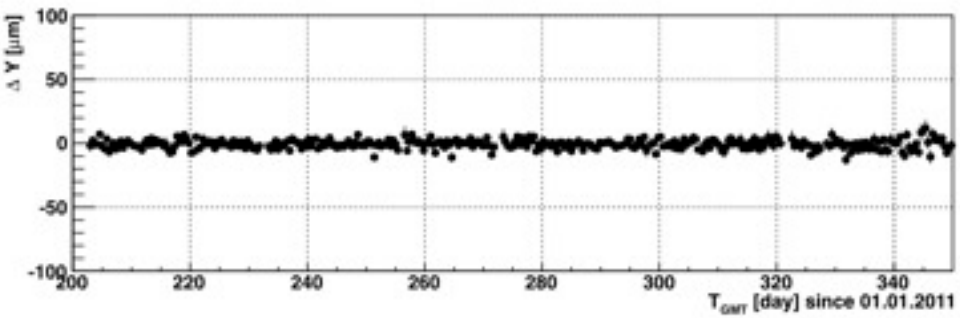
On orbit performance

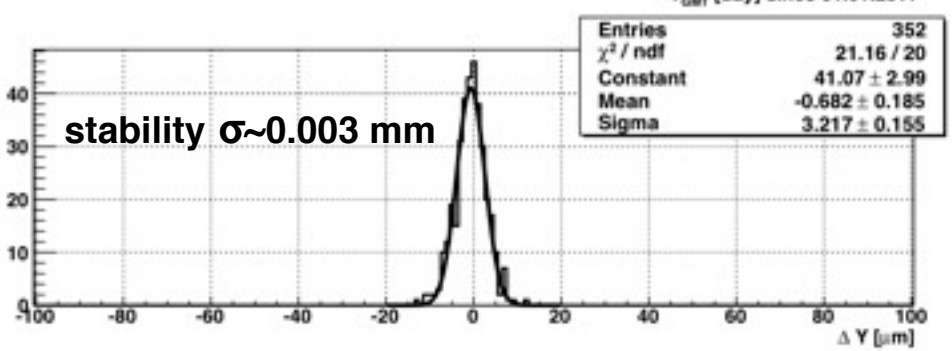
Tracker works as expected

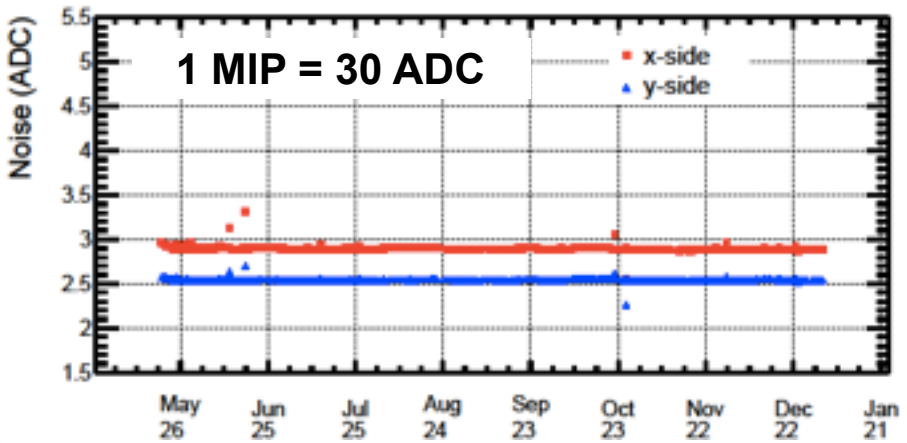




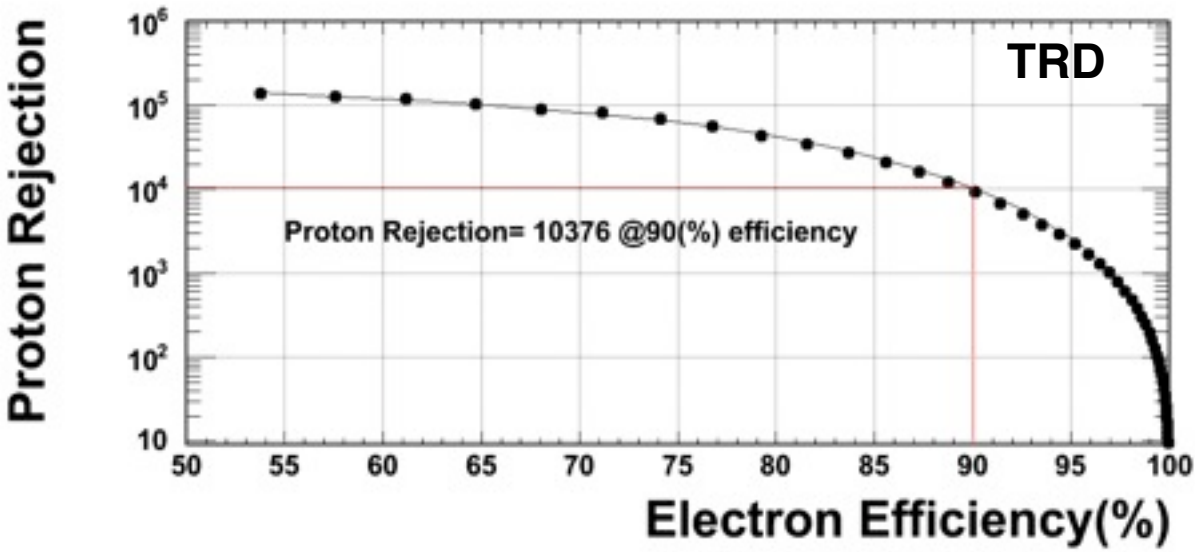
Tracker alignment stability

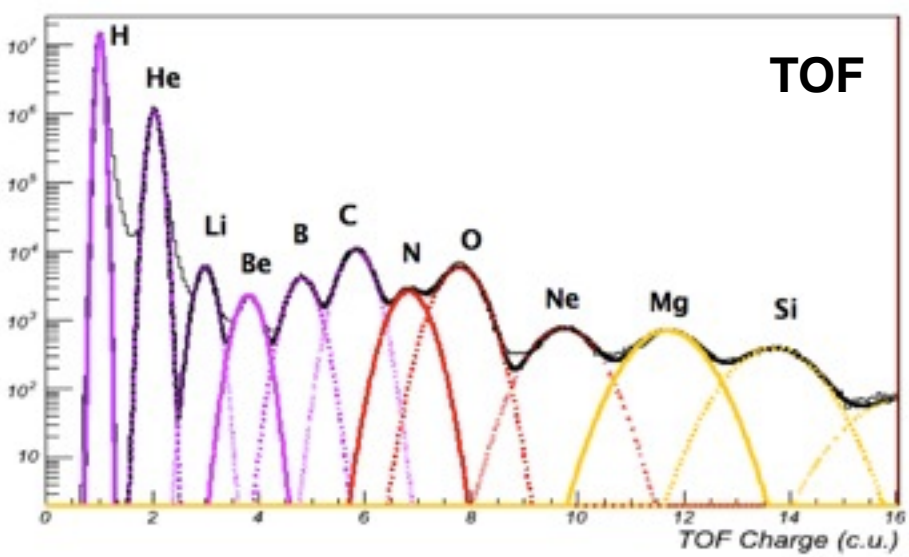


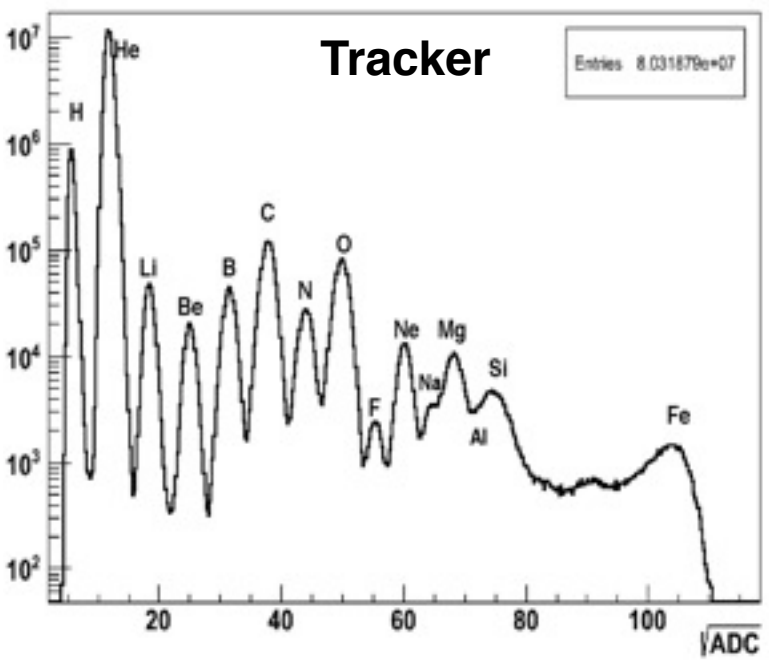




On orbit performance







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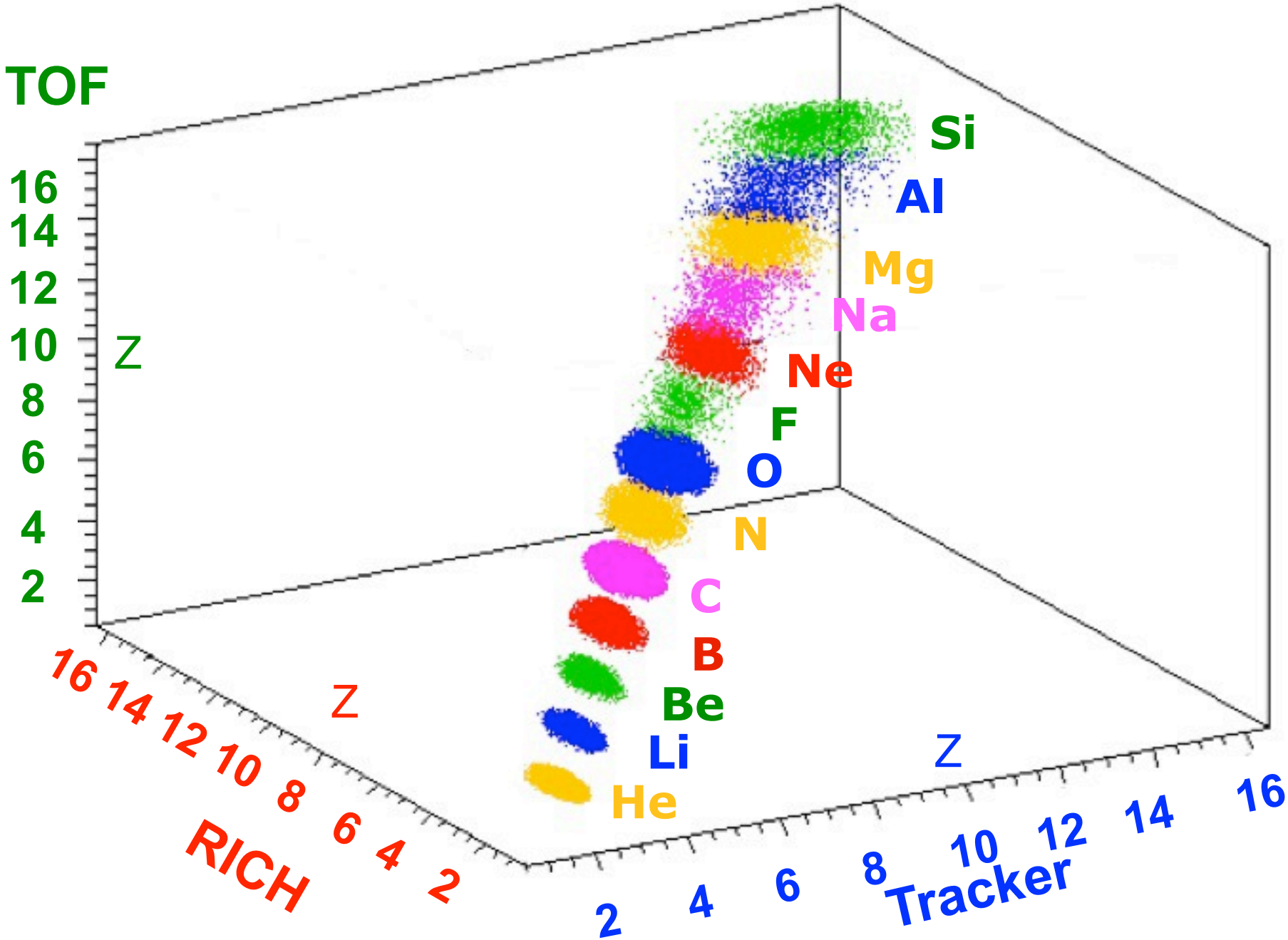
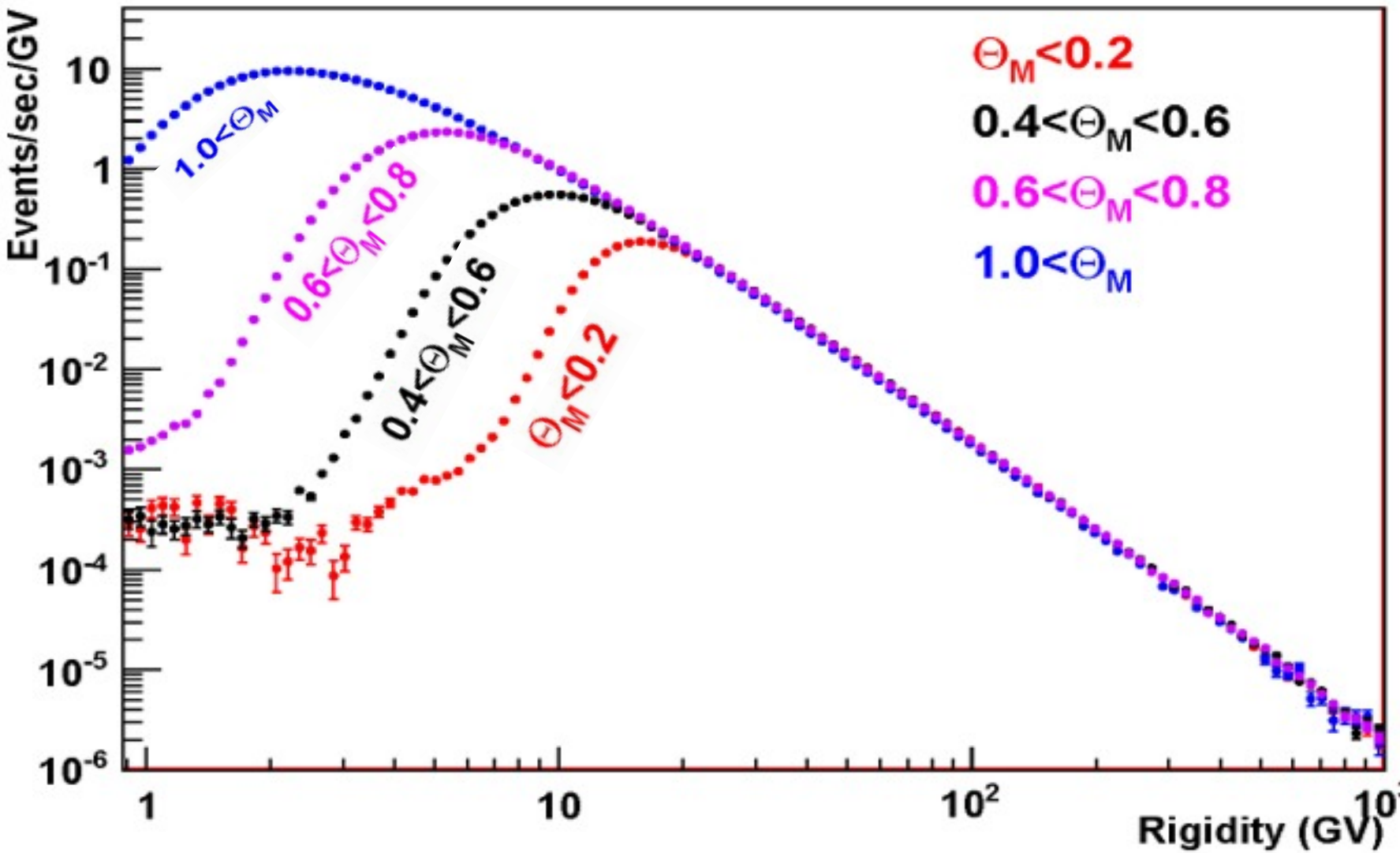
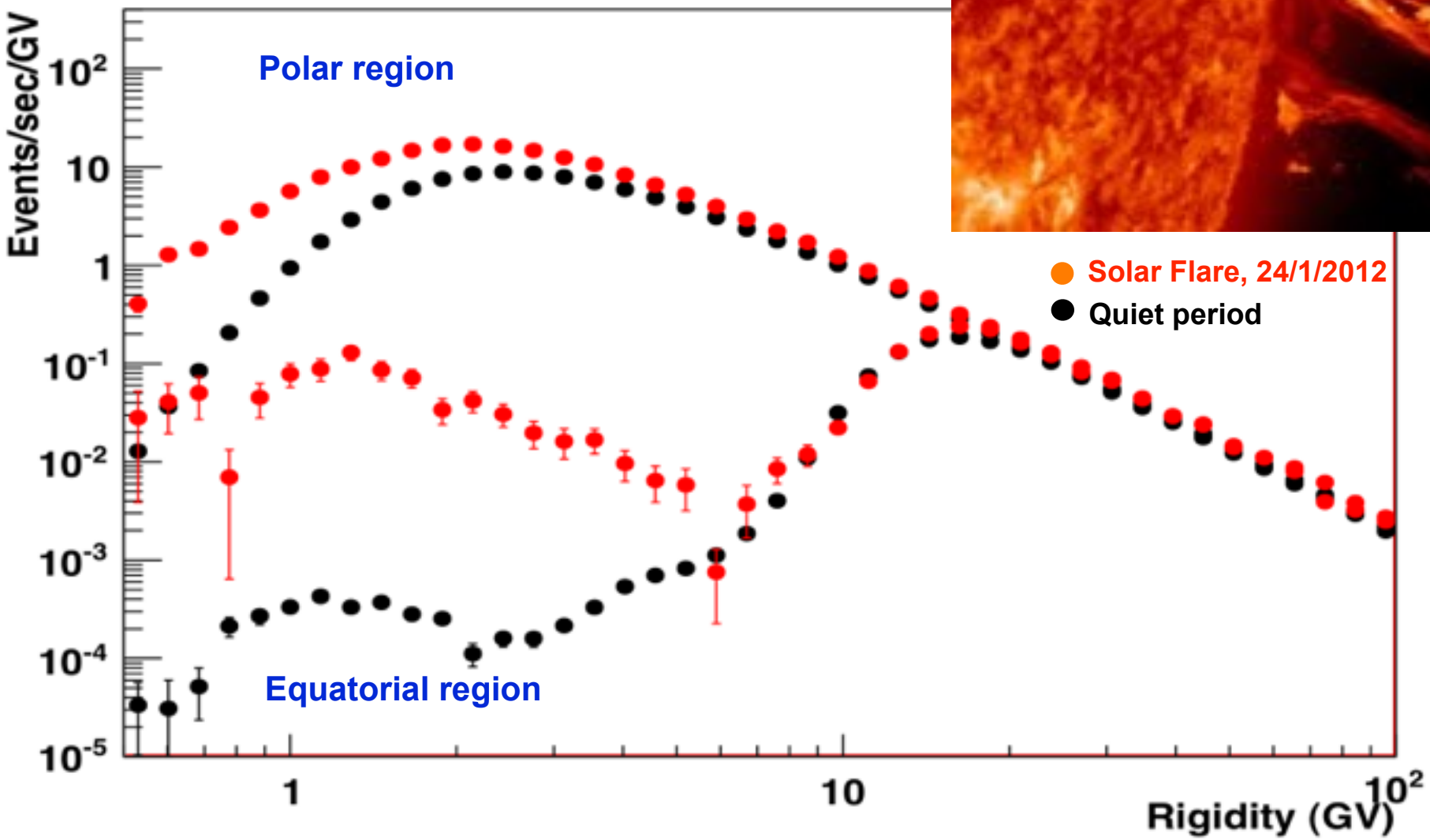
Redundant charge identification capability



He rate


Events/sec/GV
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
1
10
10^2
10^3
Rigidity (GV)
Θ_M<0.2
0.4<Θ_M<0.6
0.6<Θ_M<0.8
1.0<Θ_M
1.0<Θ_M
0.6<Θ_M<0.8
0.4<Θ_M<0.6
Θ_M<0.2

He rate and Solar Flare



Conclusions

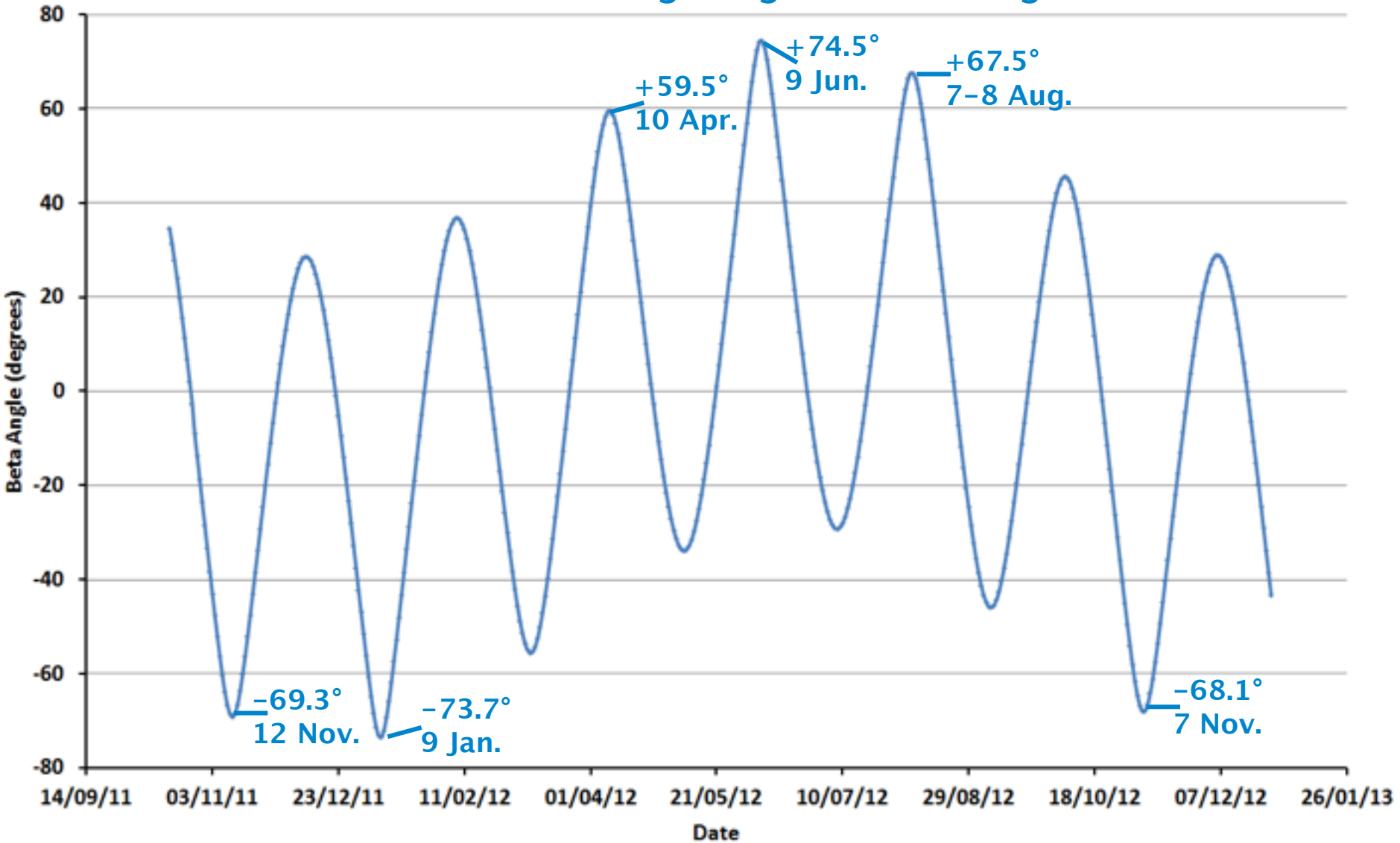
The Cosmos is the ultimate Lab: cosmic rays can be observed at energies higher than any accelerator

- AMS02 is in orbit since May 16th 2011
- All the detectors are properly functioning with DAQ in nominal conditions since May 19th 2011
- Ground operations (POCC and SOC) run smoothly
- Detector calibration (alignment, e/p rejection, charge id, etc.) are well advanced
- 10+ years on board the ISS at 16 10^9 events/year: great discovery potential

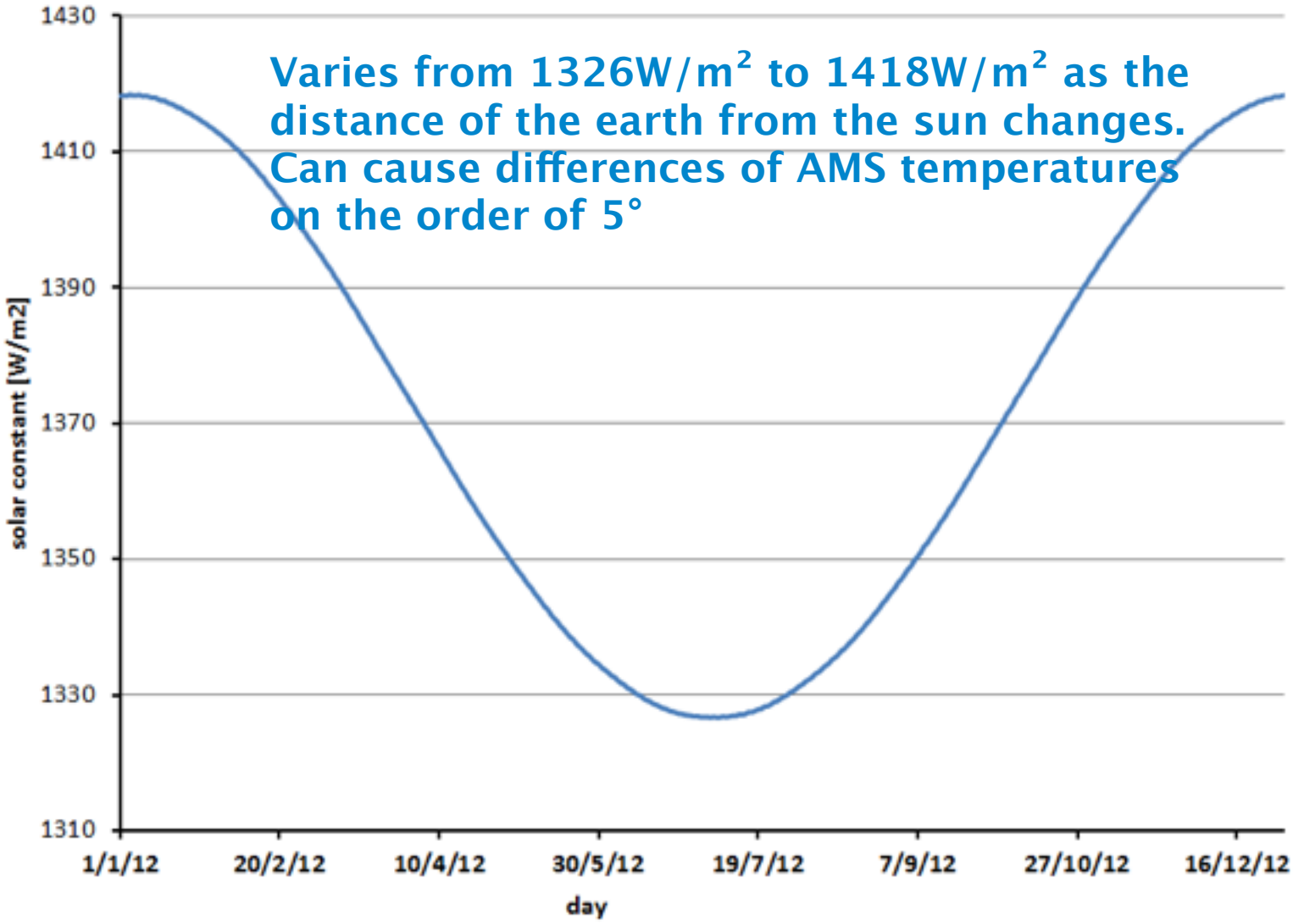
Science coming soon!!

Back-ups

Evolution of the beta angle through 2012, with dates of extreme values
At large positive values, the port side of AMS is hot and the starboard side cold.
Vice-versa for large negative beta angles



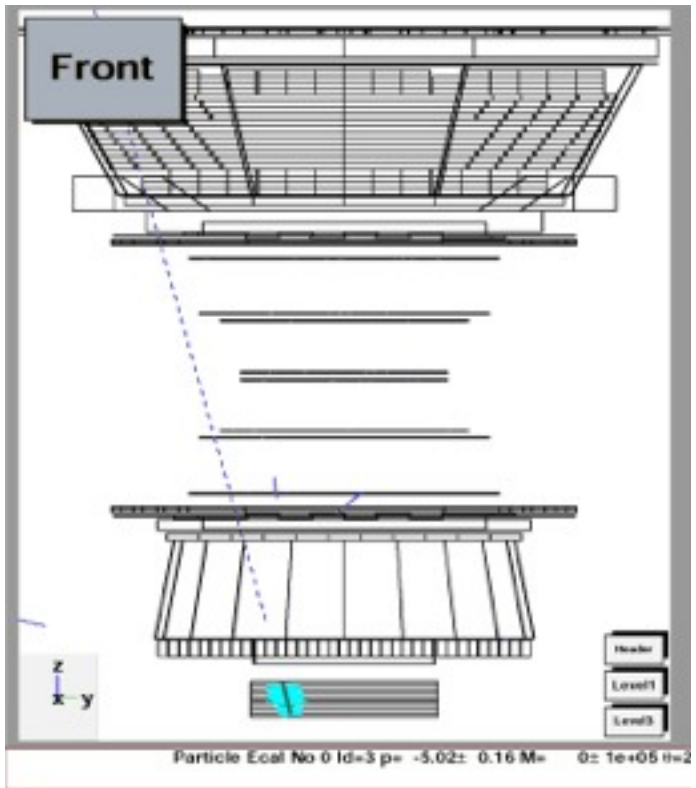
Solar Constant: illumination by the sun



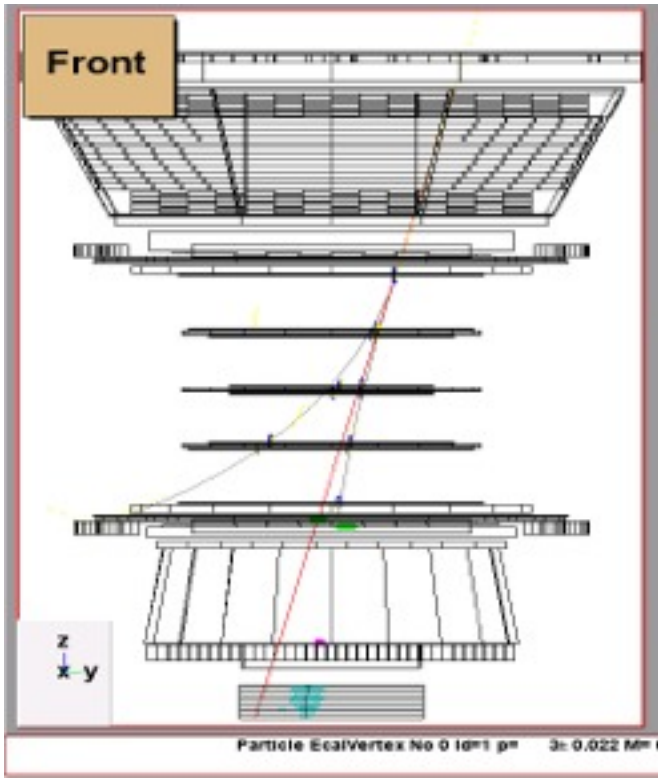
Scientific goals

γ rays astrophysics up to TeV energies

single photon mode



conversion mode



Energy spectrum for pulsars in the 100 MeV – 1 TeV and pulsar periods measured with μsec time precision.

Similar studies can be made for Blazers and Gamma Ray Bursters.

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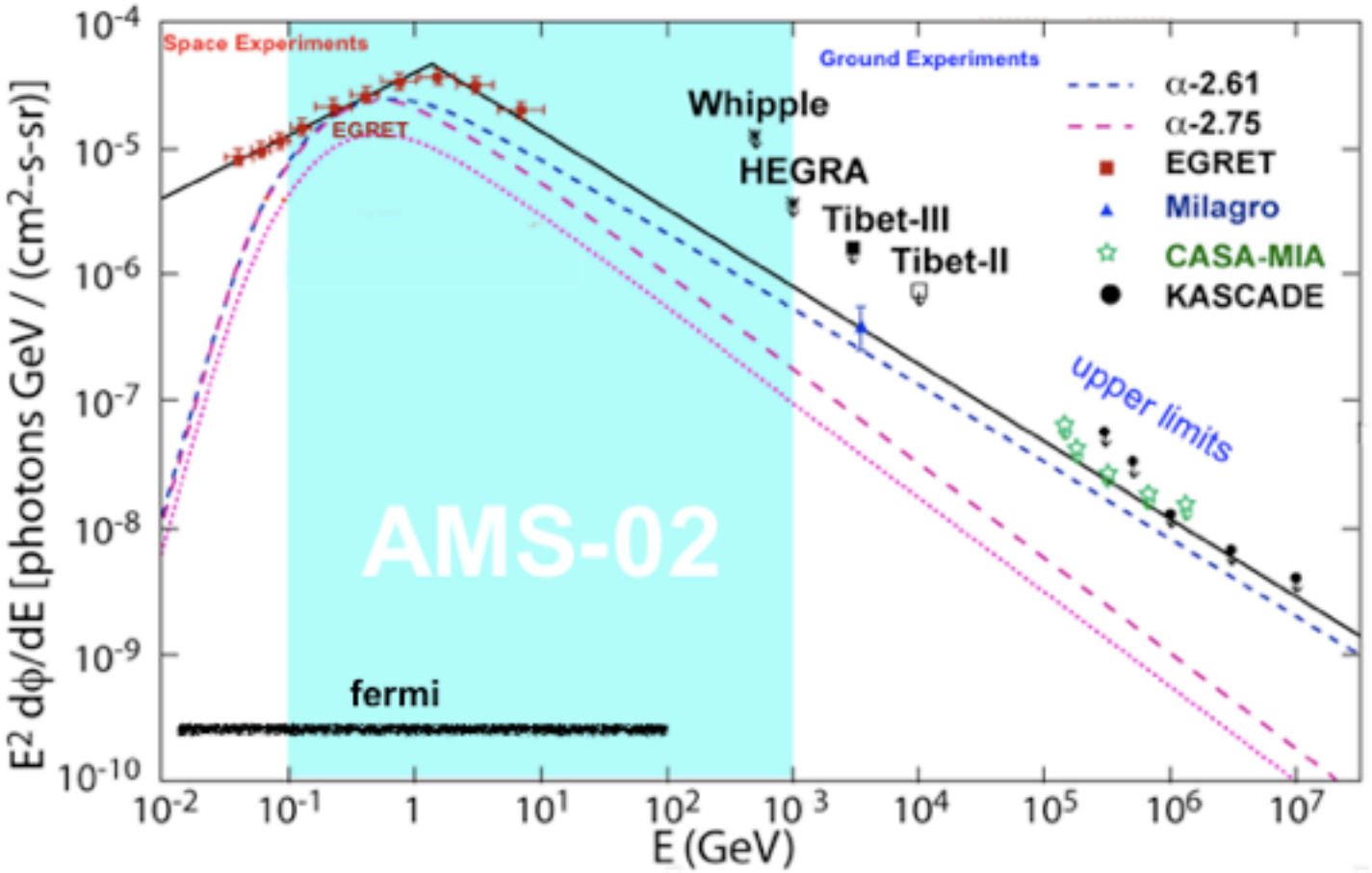
γ rays astrophysics up to TeV energies



The diffuse gamma-ray spectrum of the Galactic plane

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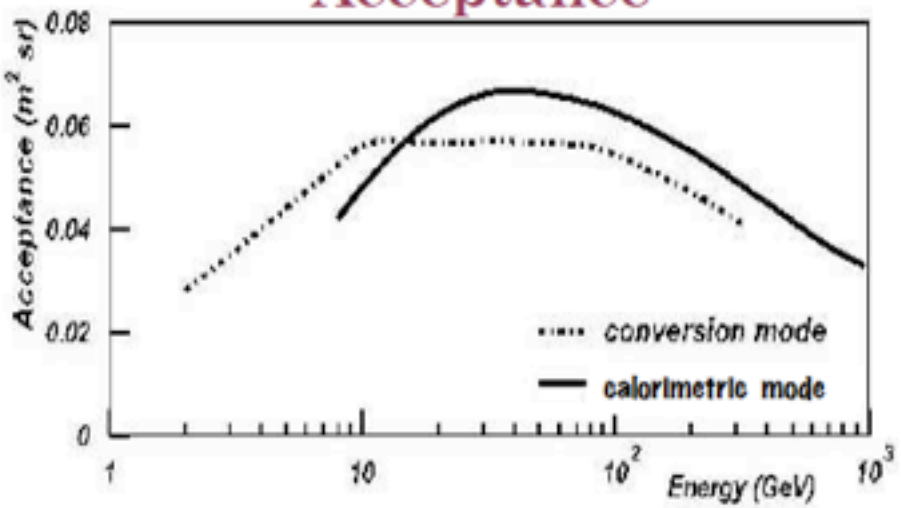
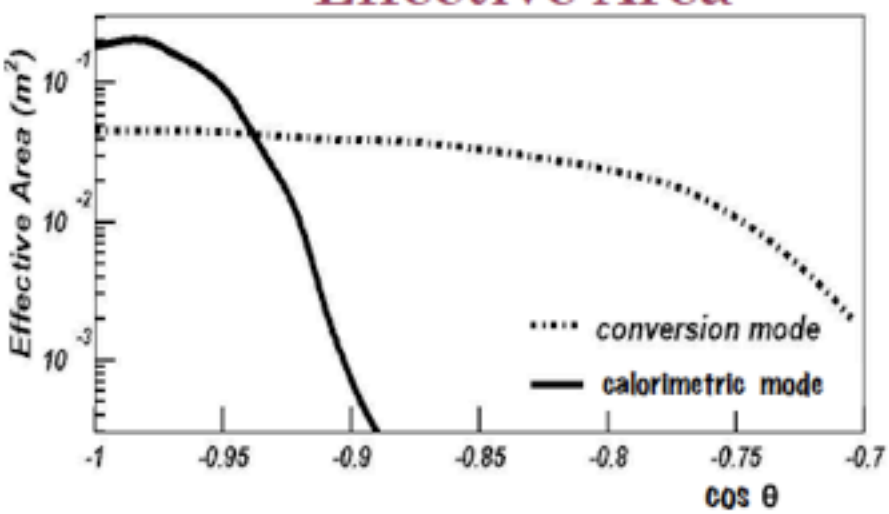
Tracker and Ecal Performances

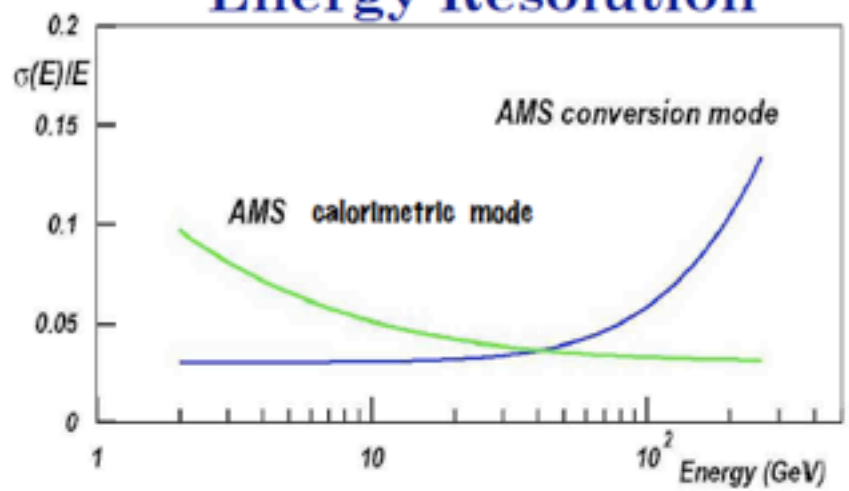
Acceptance



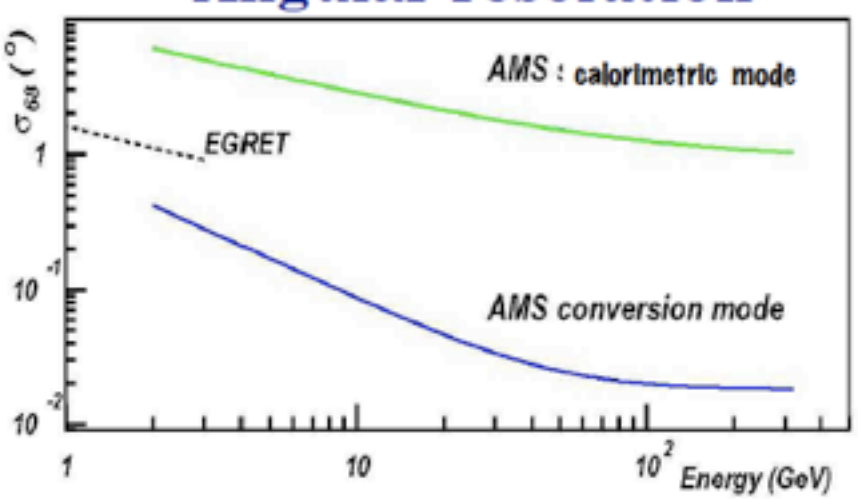
Effective Area



Energy Resolution



Angular resolution



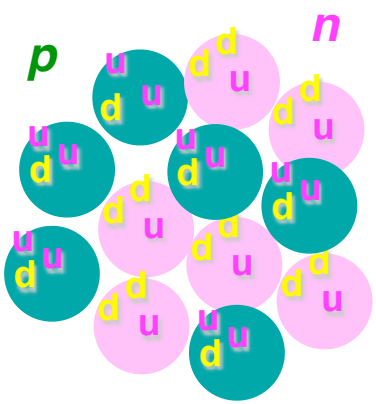
Search for New Matter in the Universe

After many years, the question of the existence of strange quark matter still remains without a definitive answer.

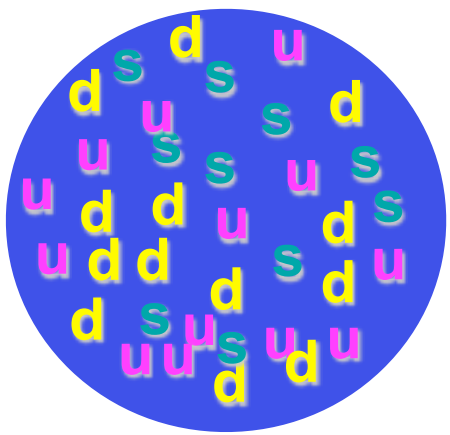
There are six types of Quarks found in accelerators (u, d, s, c, b, t).

All matter on Earth is made out of only two types (u, d) of quarks. "Strangelets" are new types of matter composed of three types of quarks (u, d, s) which should exist in the cosmos.

Carbon Nucleus
Z/A ~ 0.5



Strangelet
Z/A ~ 0.1



E. Witten, Phys. Rev. D,272-285 (1984)

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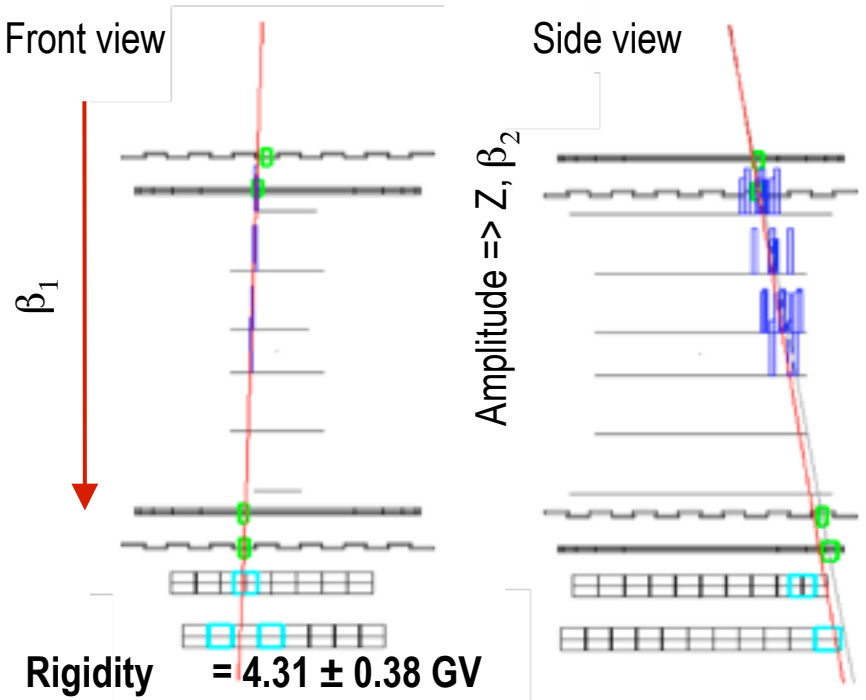
Strangelets

Jack Sandweiss (Yale) is leading the AMS search.

Candidate observed with AMS-01 5 June 1998 11:13:16 UTC



Rigidity = 4.31 ± 0.38 GV
Charge Z = 2
$\beta_1 = \beta_2$ = 0.462 ± 0.005
Mass = 16.45±0.15 GeV/c^2
Z/A = 0.114 ± 0.01
Flux (1.5 < E_K < 10 GeV) = 5x10^{-5} (m^2 sr sec)$^{-1}$

Z/A~0.1

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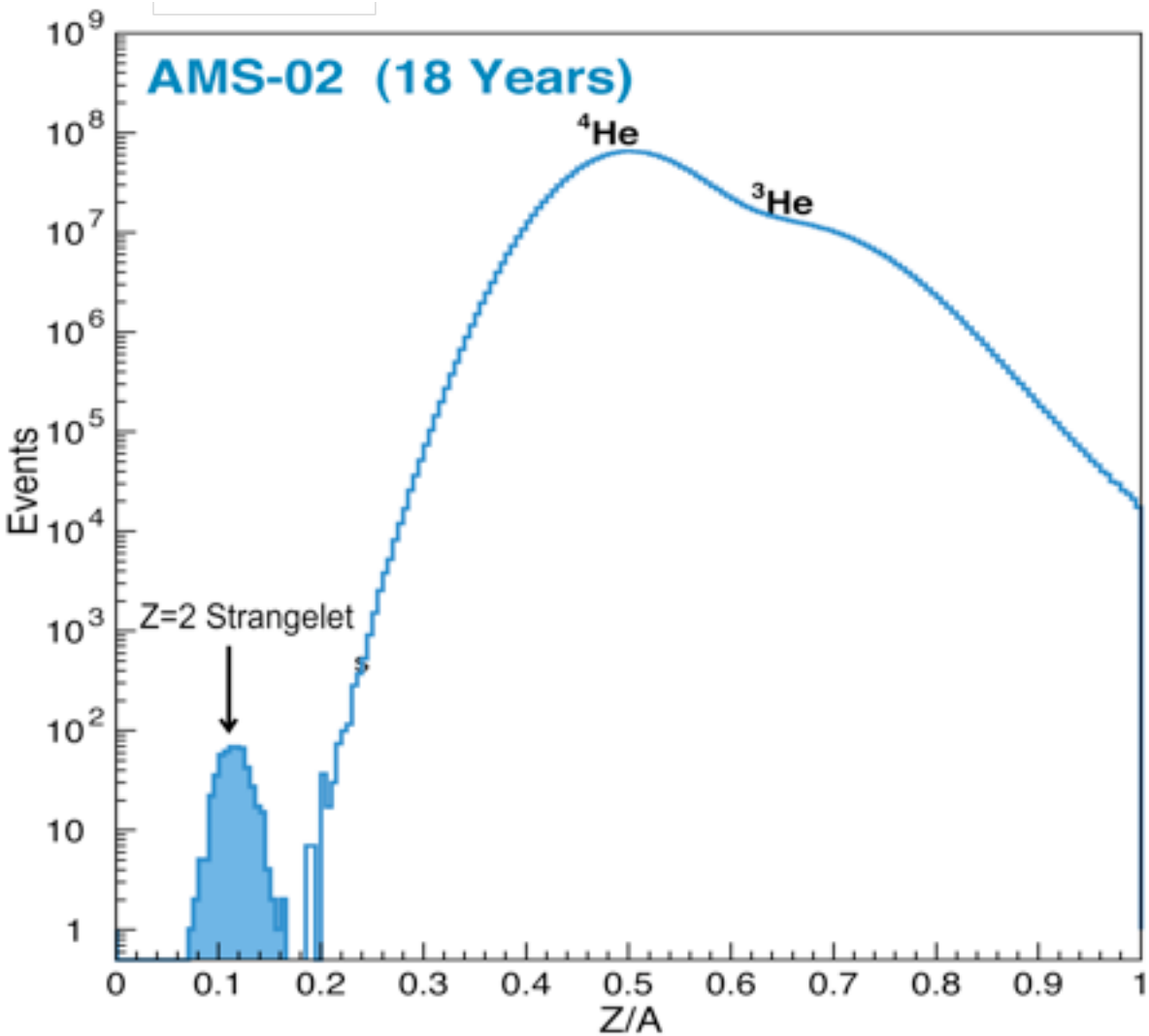
Strangelets

$\Phi_{strangelets} = 5x10^{-10}(cm^2 s\ sr)^{-1}$



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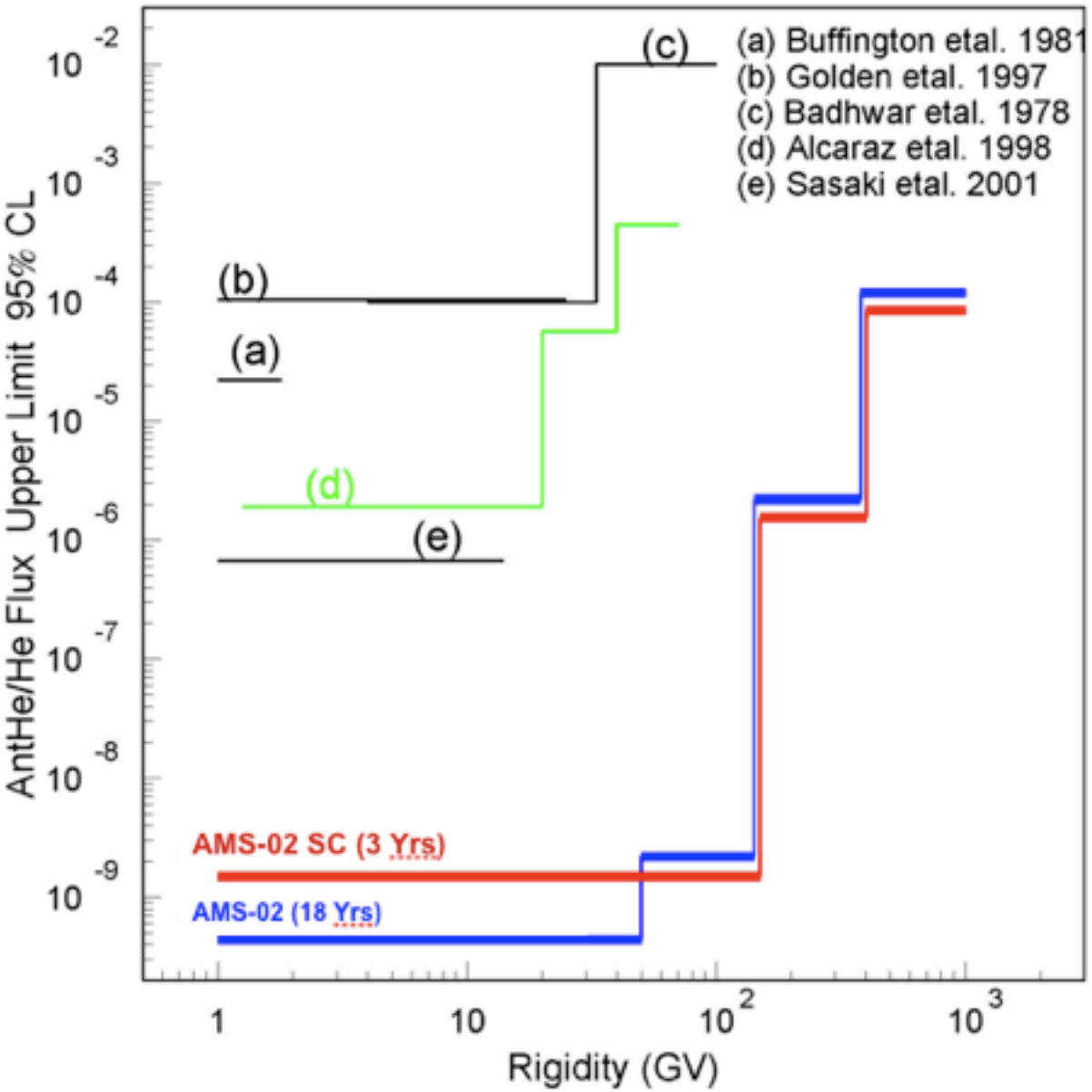
Antimatter search



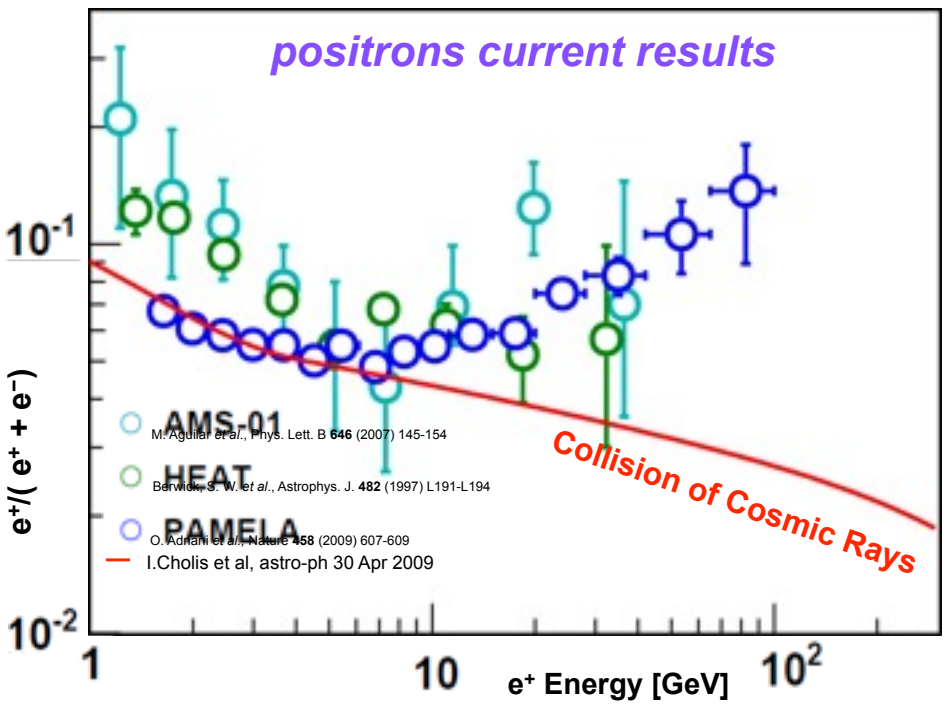
Dark Matter search: positron channel

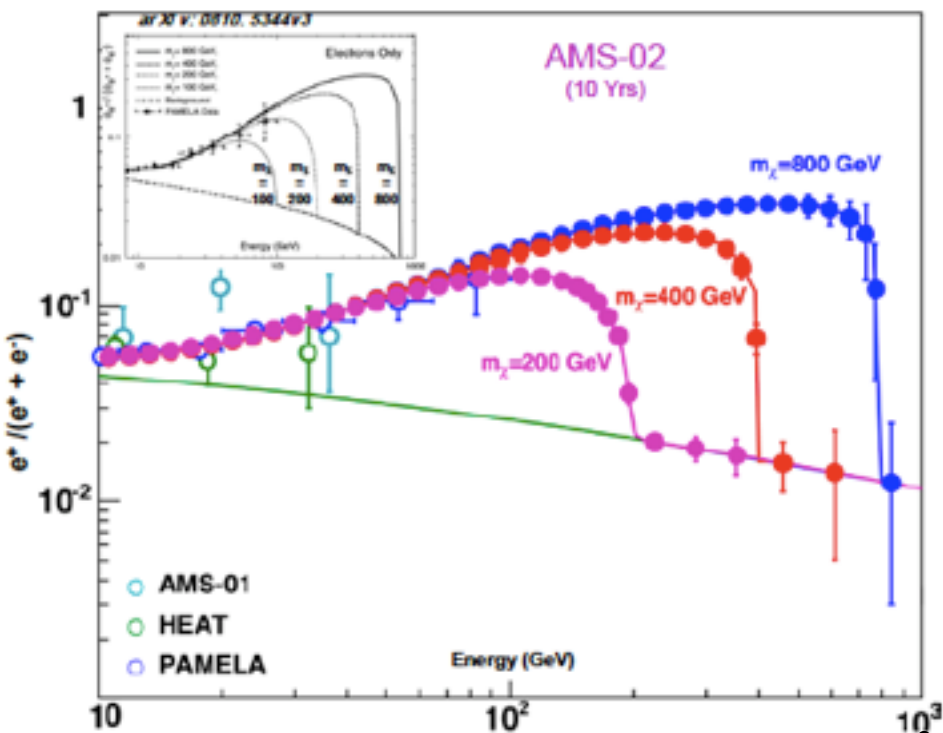
AMS will explore the indirect detection of dark matter, measuring the dark matter annihilation and collision products. Combining searches in several different channels as:

- e^+
- Photons
- p
- Antideuterons

The leading candidate for Dark Matter is a SUSY neutralino (χ^0)

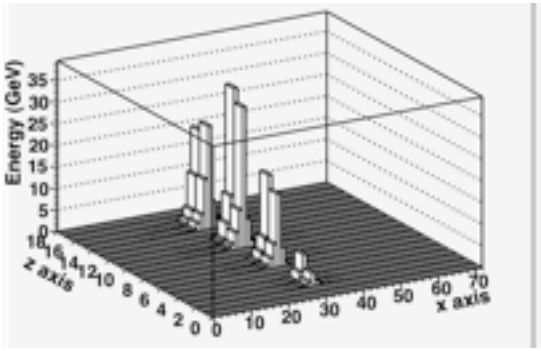
Collisions of χ^0 will produce excess in the spectra of e^+ different from known cosmic ray collisions

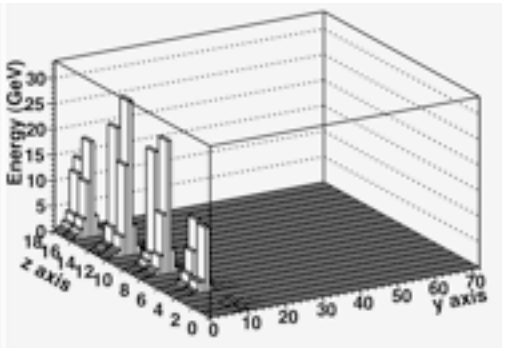


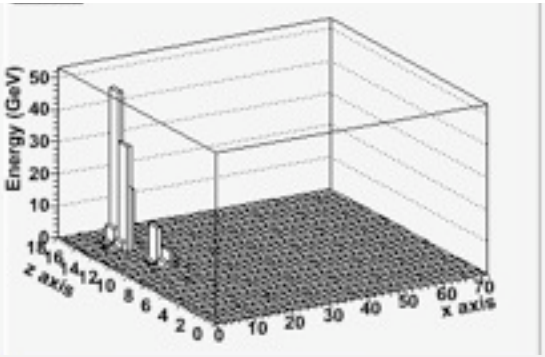


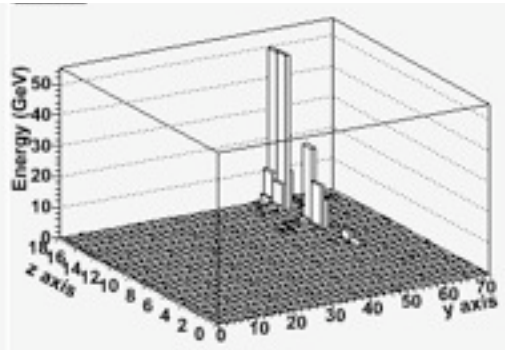
Electron 901 GeV

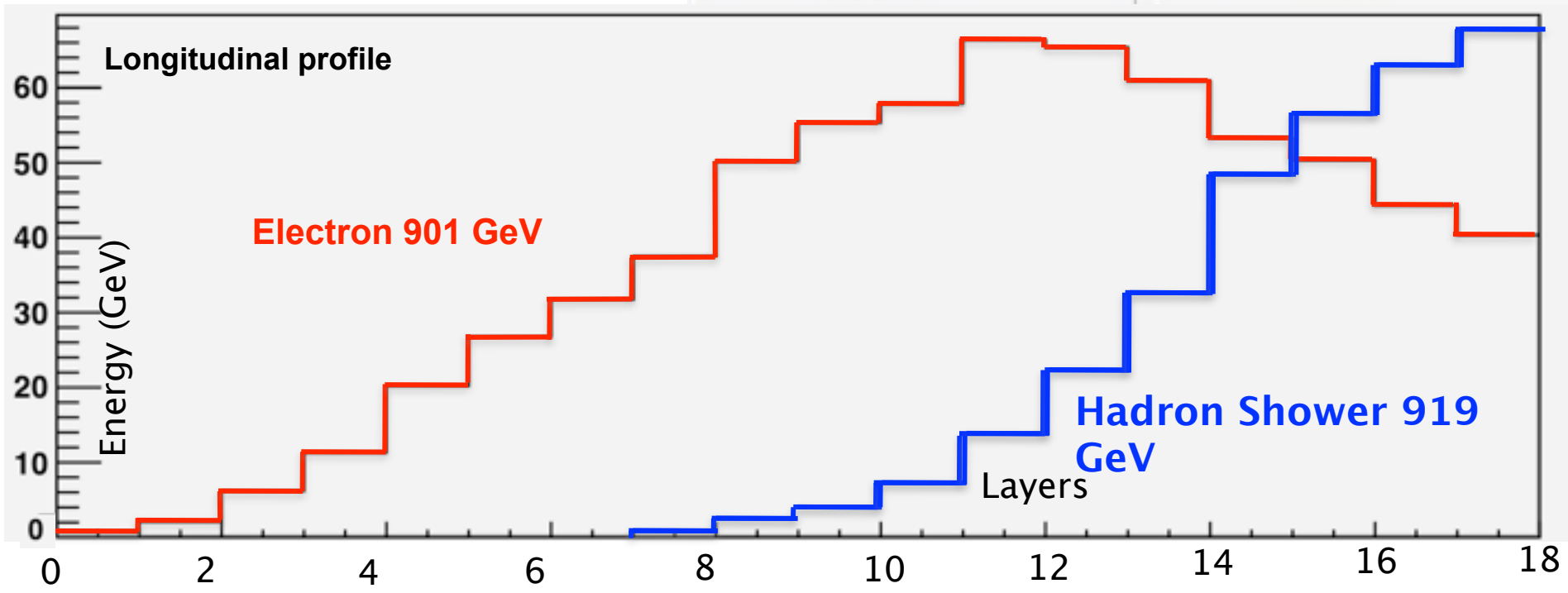
Hadron Shower 919 GeV



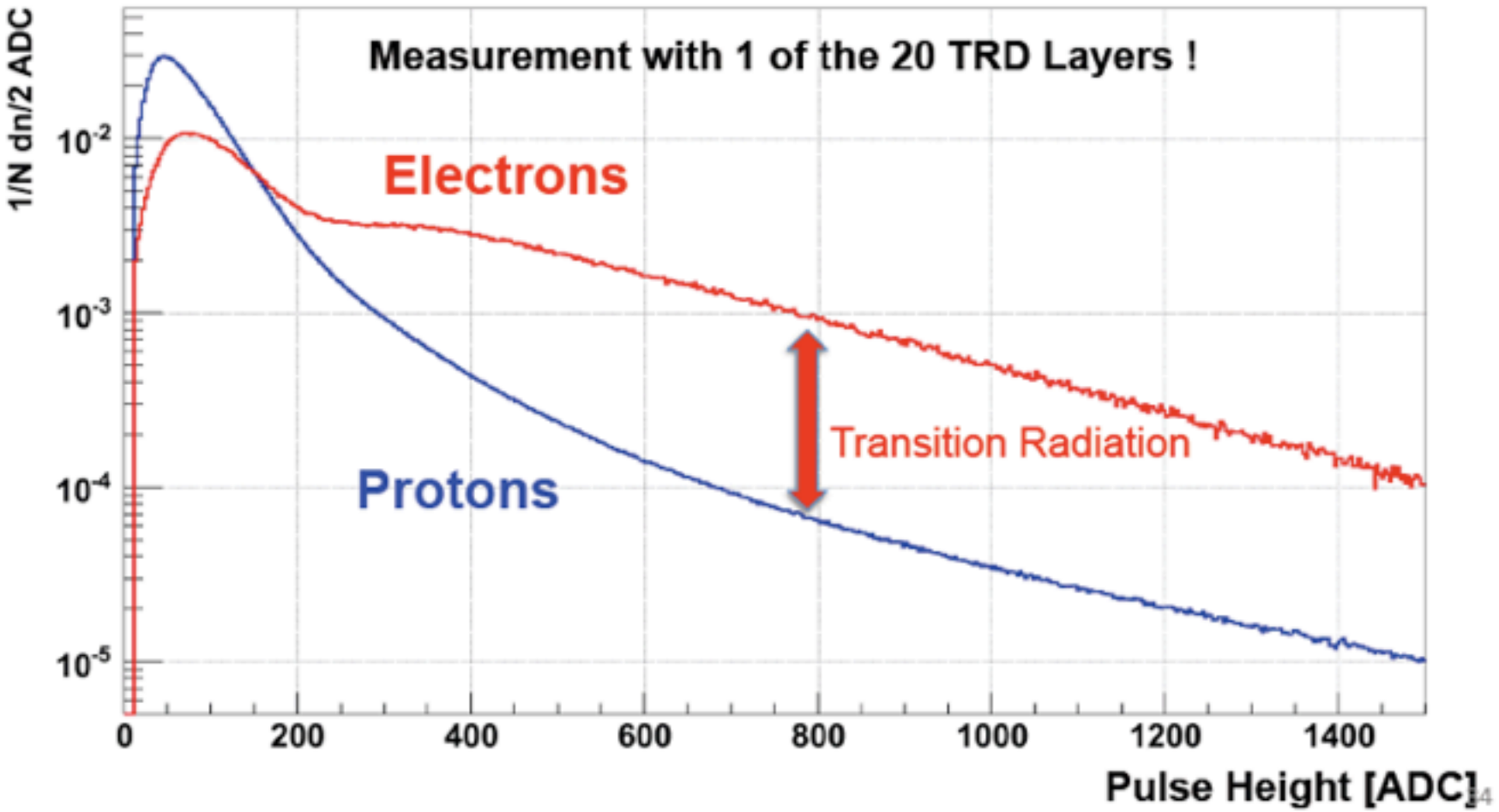






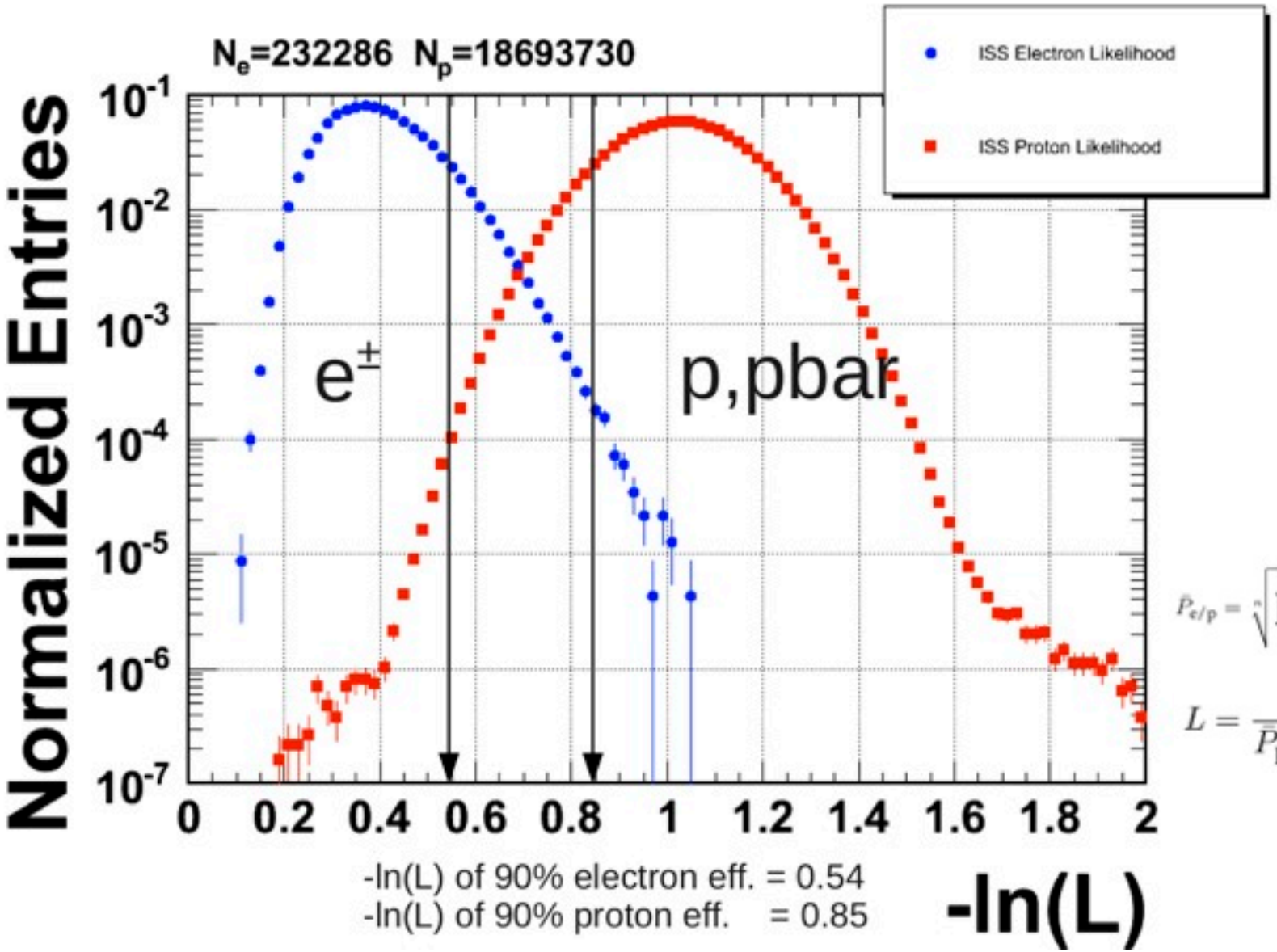


- Use the AMS Tracker and Electromagnetic Calorimeter to define a clean Electron and Proton sample.
- Study the TRD response in Space and determine the particle identification power from space data directly !



Electron vs. Proton

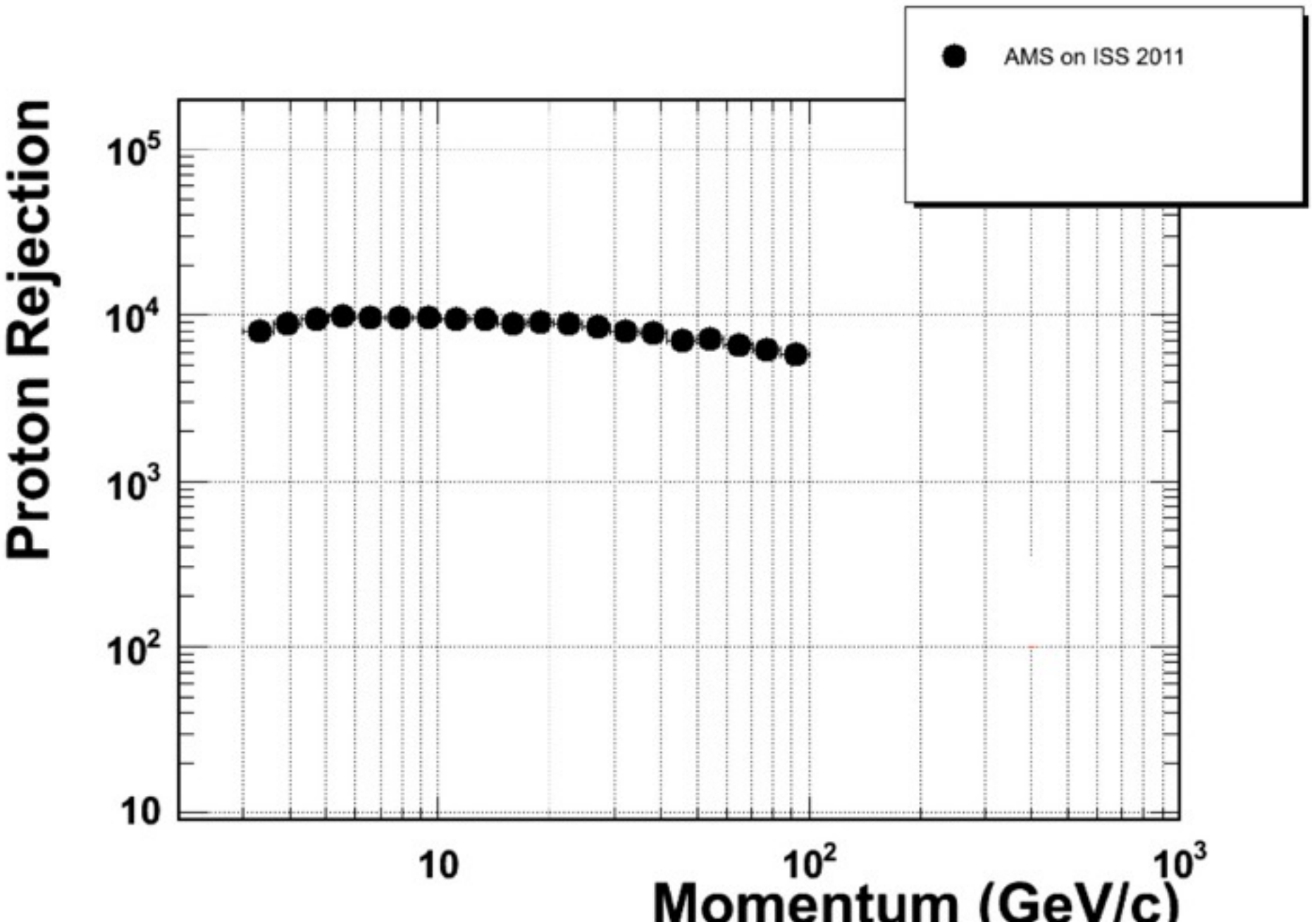
AMS TRD



$$\bar{P}_{e/p} = \sqrt[n]{\prod_i^n P_{e/p}^{(i)}(E)}$$

$$L = \frac{\bar{P}_e}{\bar{P}_p + \bar{P}_e}$$

TRD Proton Rejection at 90% Electron Efficiency

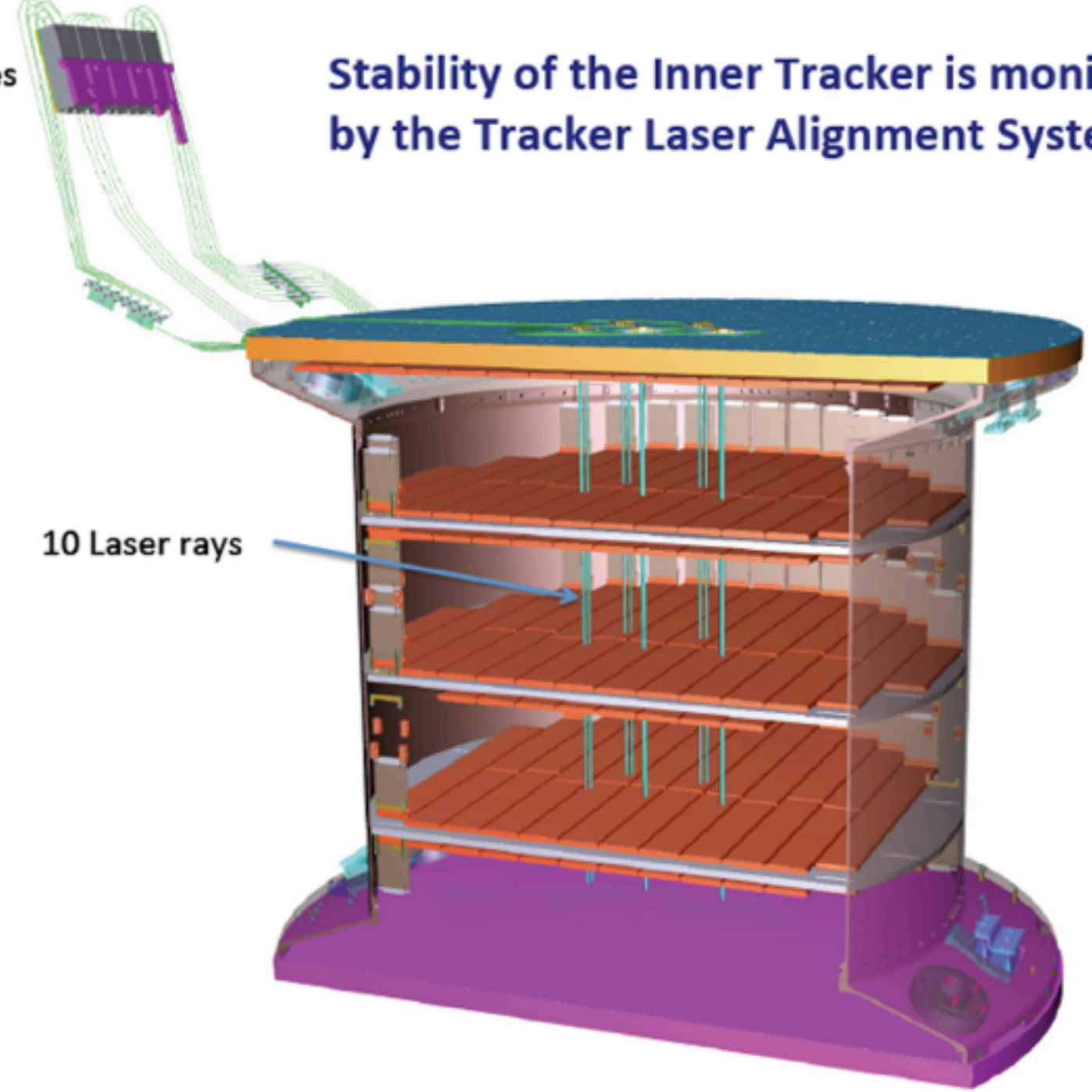


Alignment

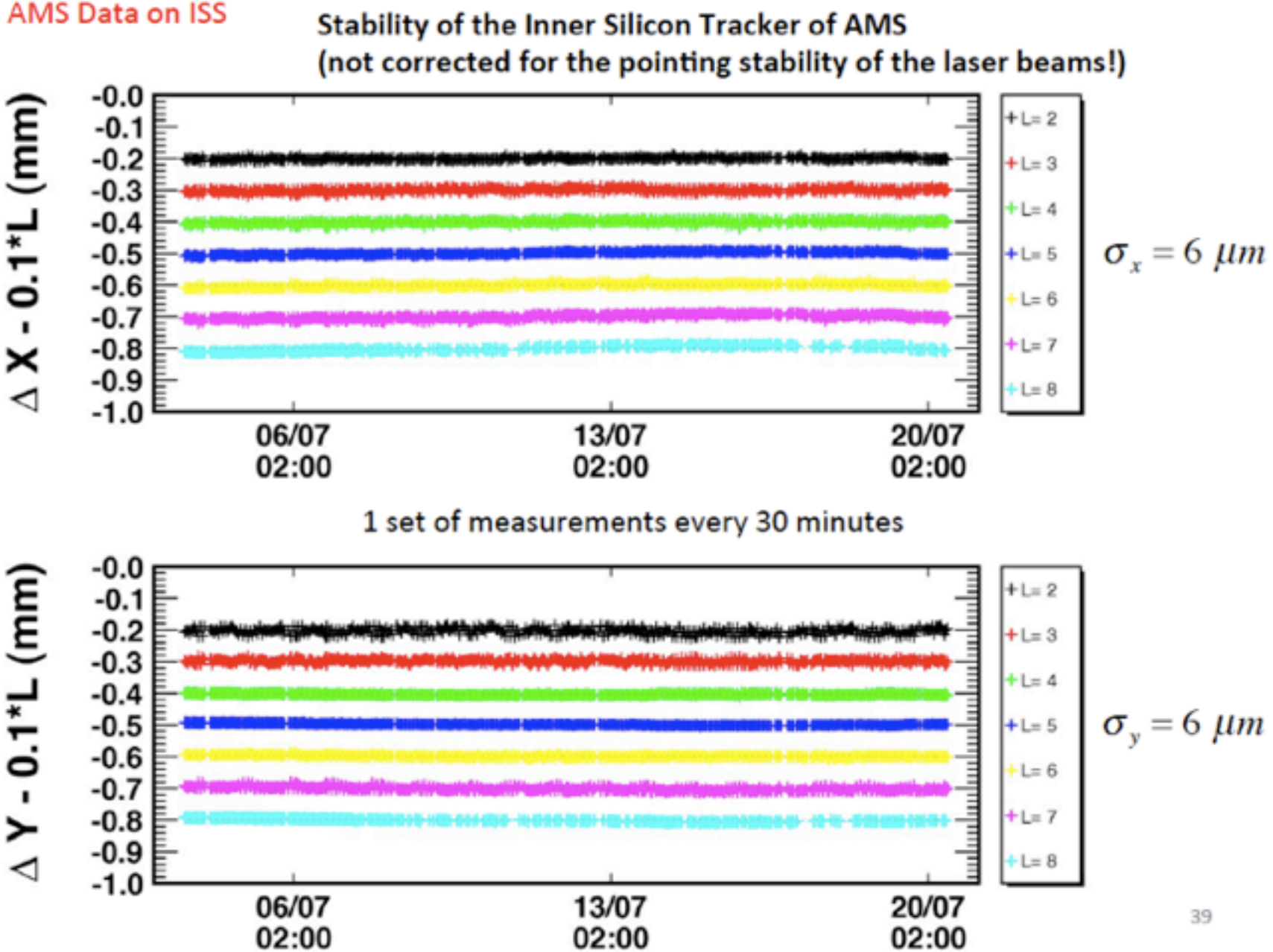
56

Laser Diodes
λ=1080 nm

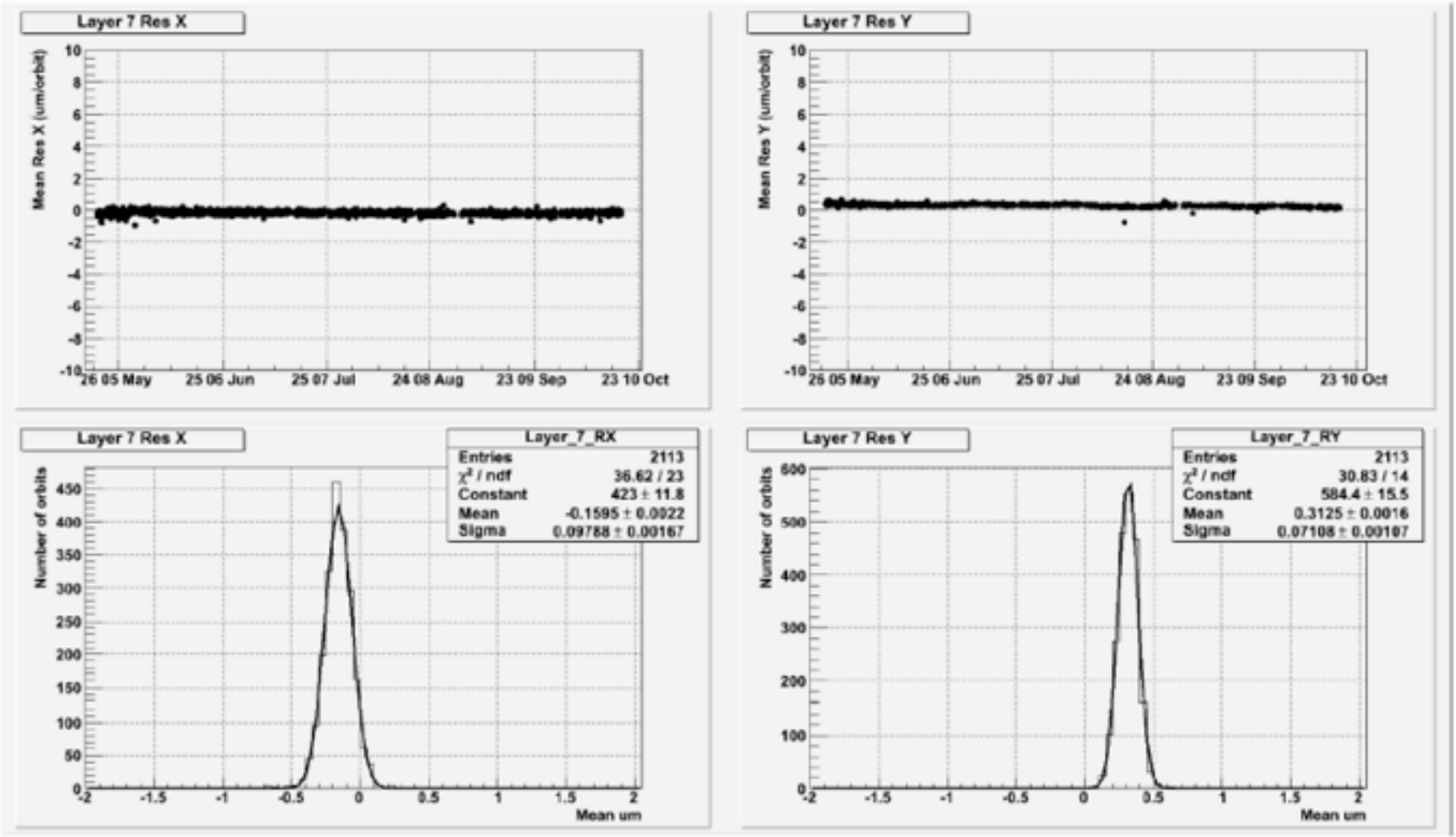
Stability of the Inner Tracker is monitored by the Tracker Laser Alignment System.



AMS Data on ISS



Typical stability of an inner tracker plane is 0.1 μm as measured with Protons on the ISS



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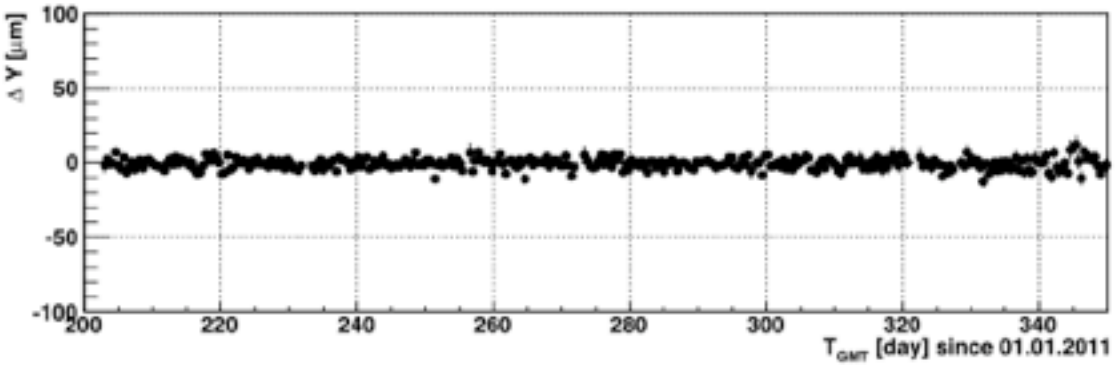
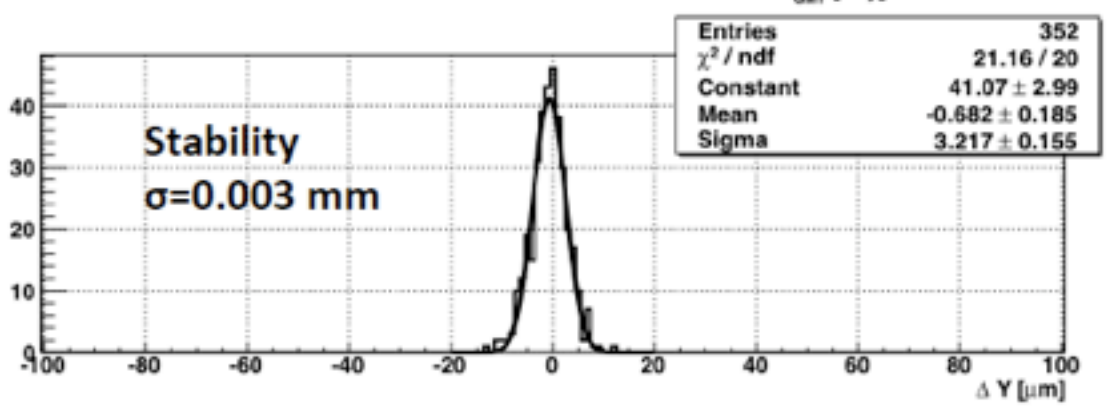
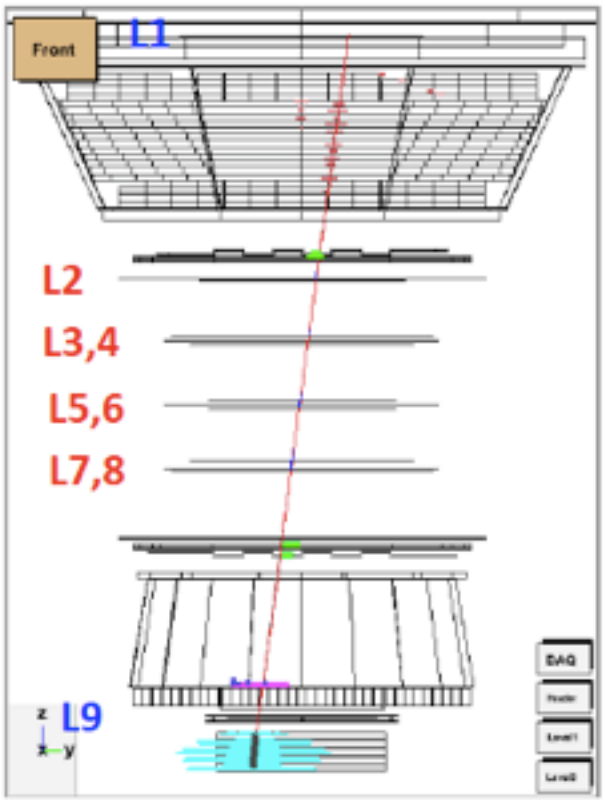
Stability of Layer 1 with respect to the Inner Tracker (bending plane)







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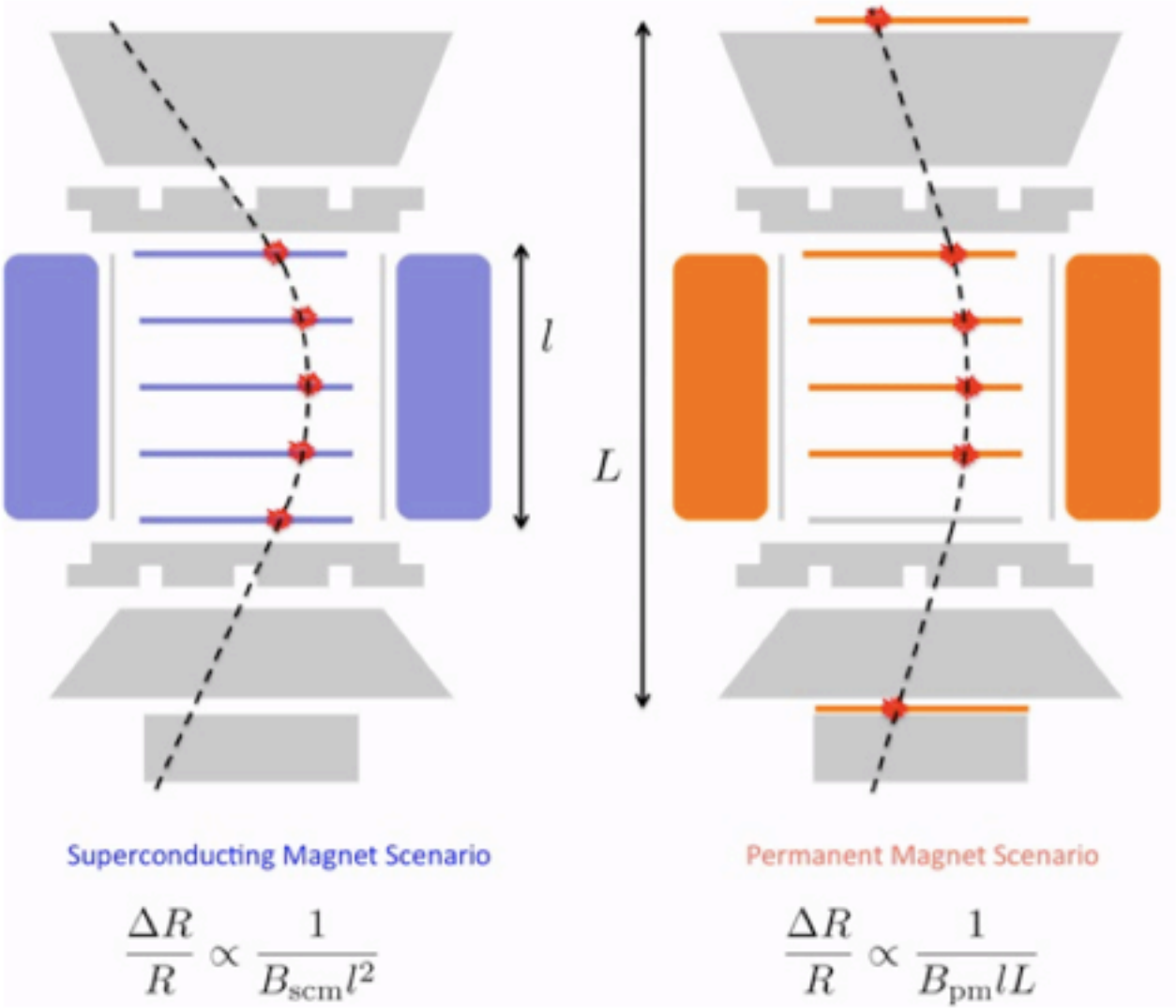
Magnet

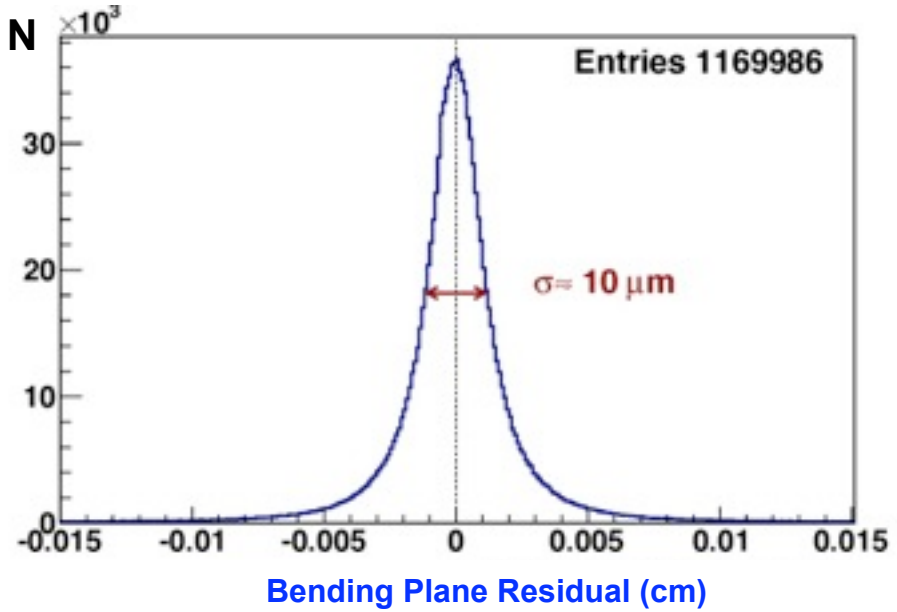
Magnets Comparison

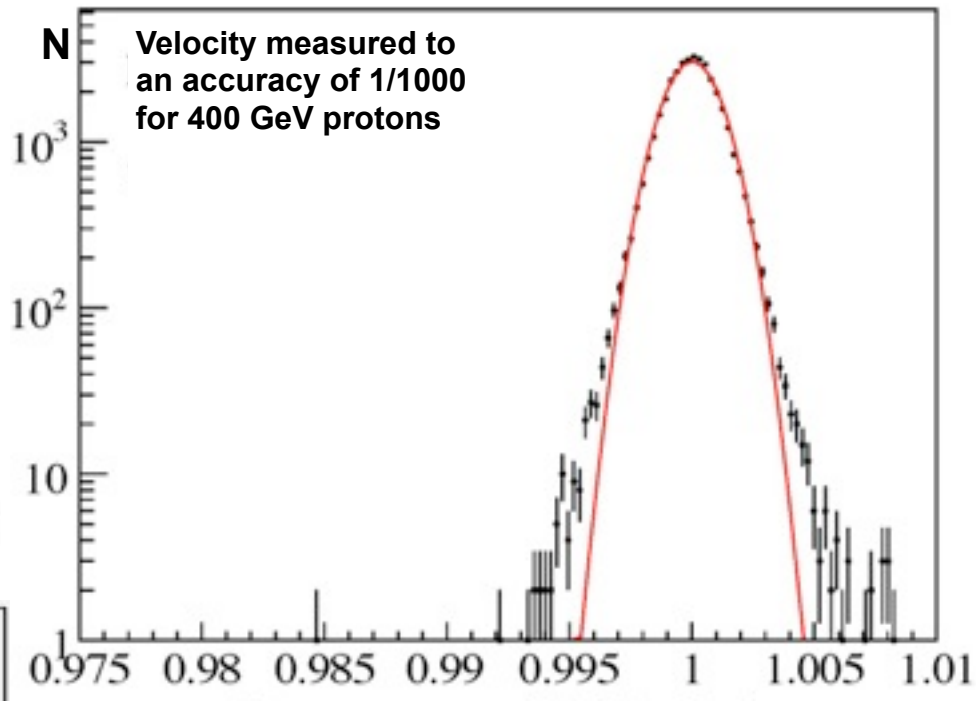


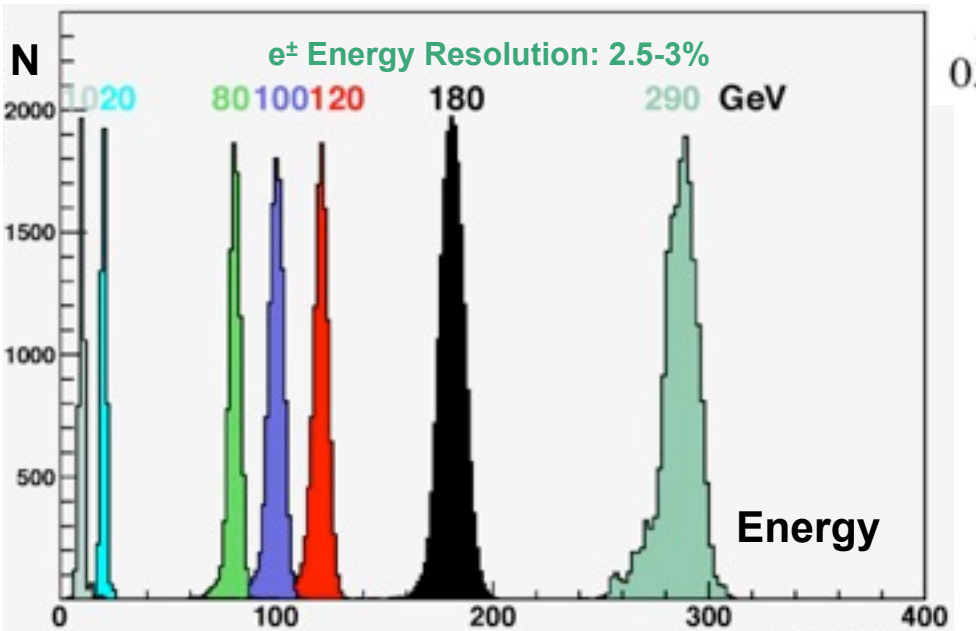
Bscm ~ 0.87 T
l ~ 1 m

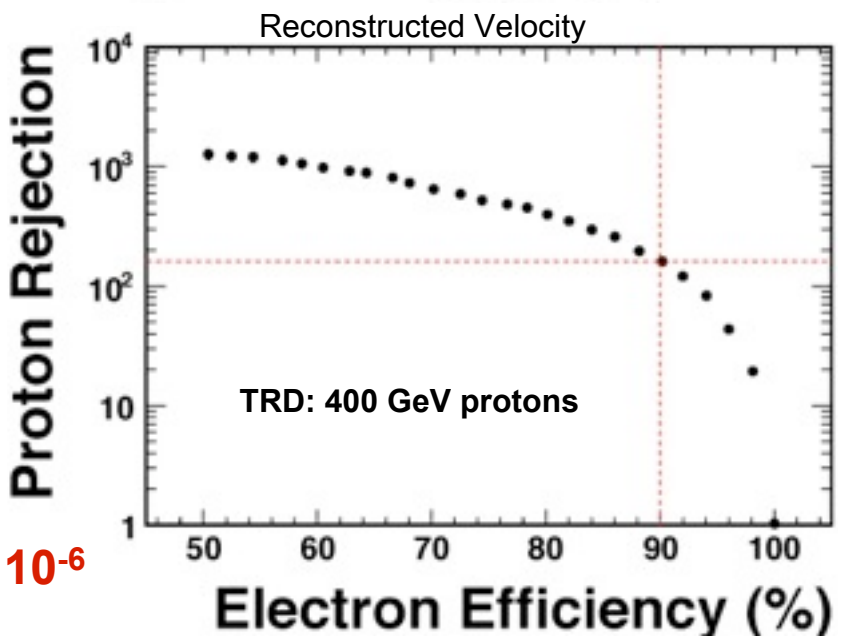
Bpm ~ 0.14 T
L ~ 4 m

Test Beam Results– 8-20 Aug 2010



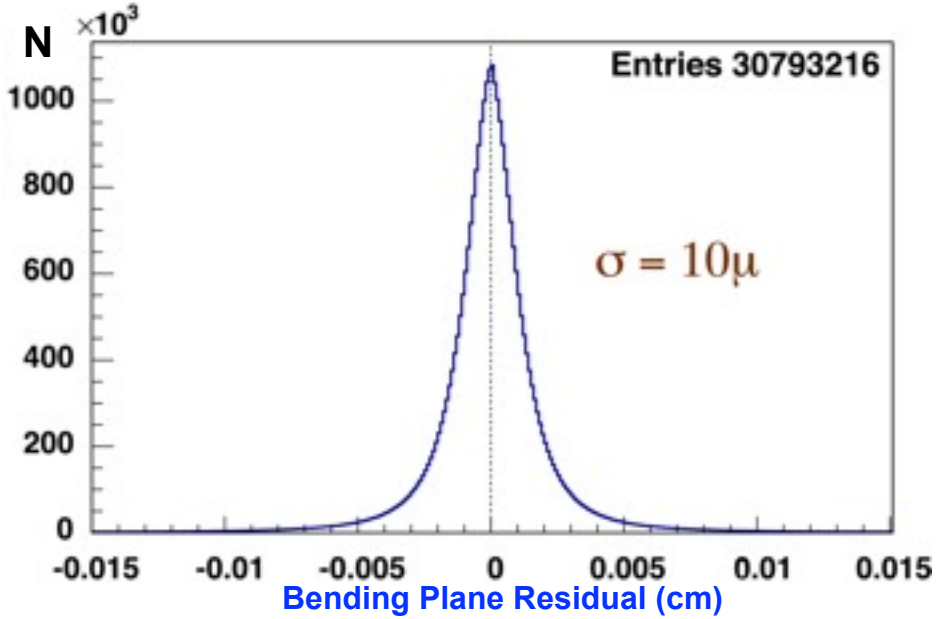


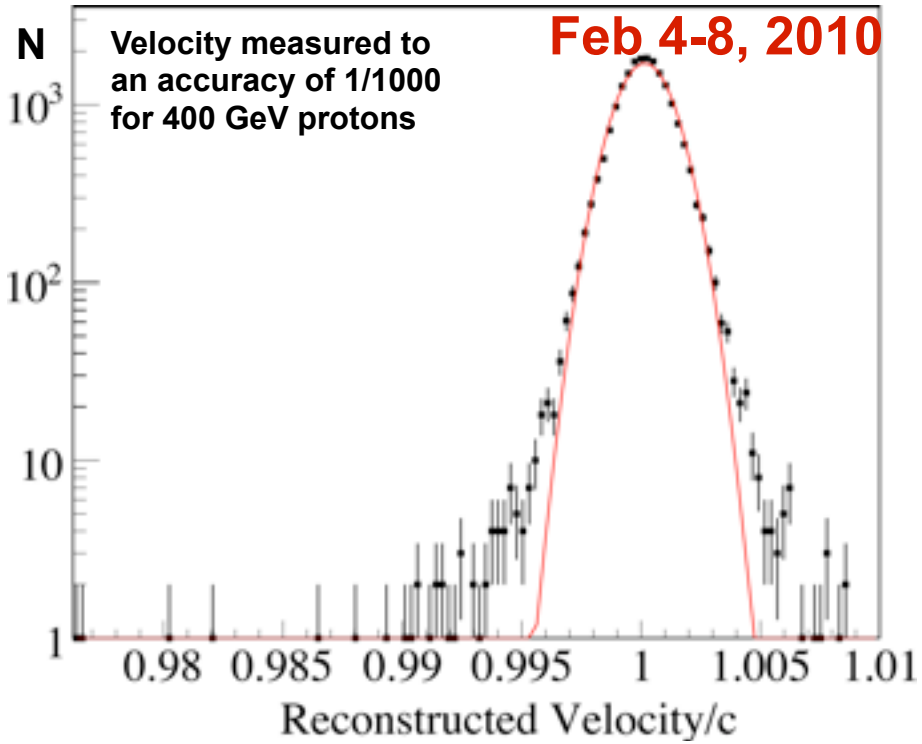


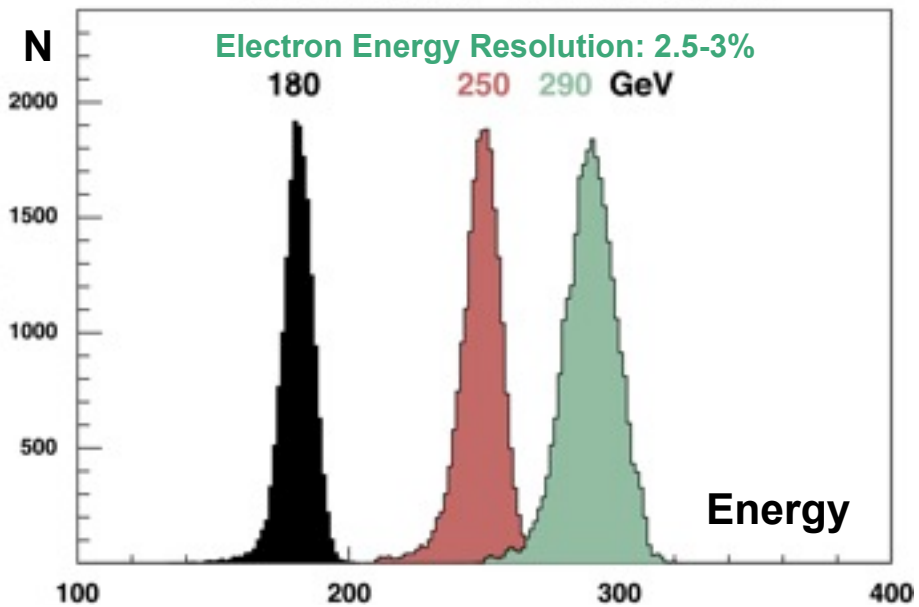


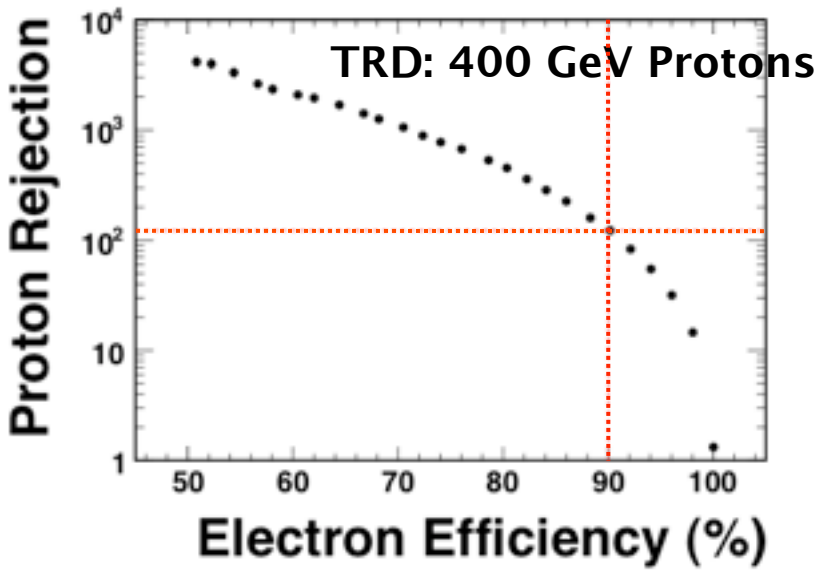
Measured combined rejection power at 400 GeV: $e^+/p = 10^{-6}$

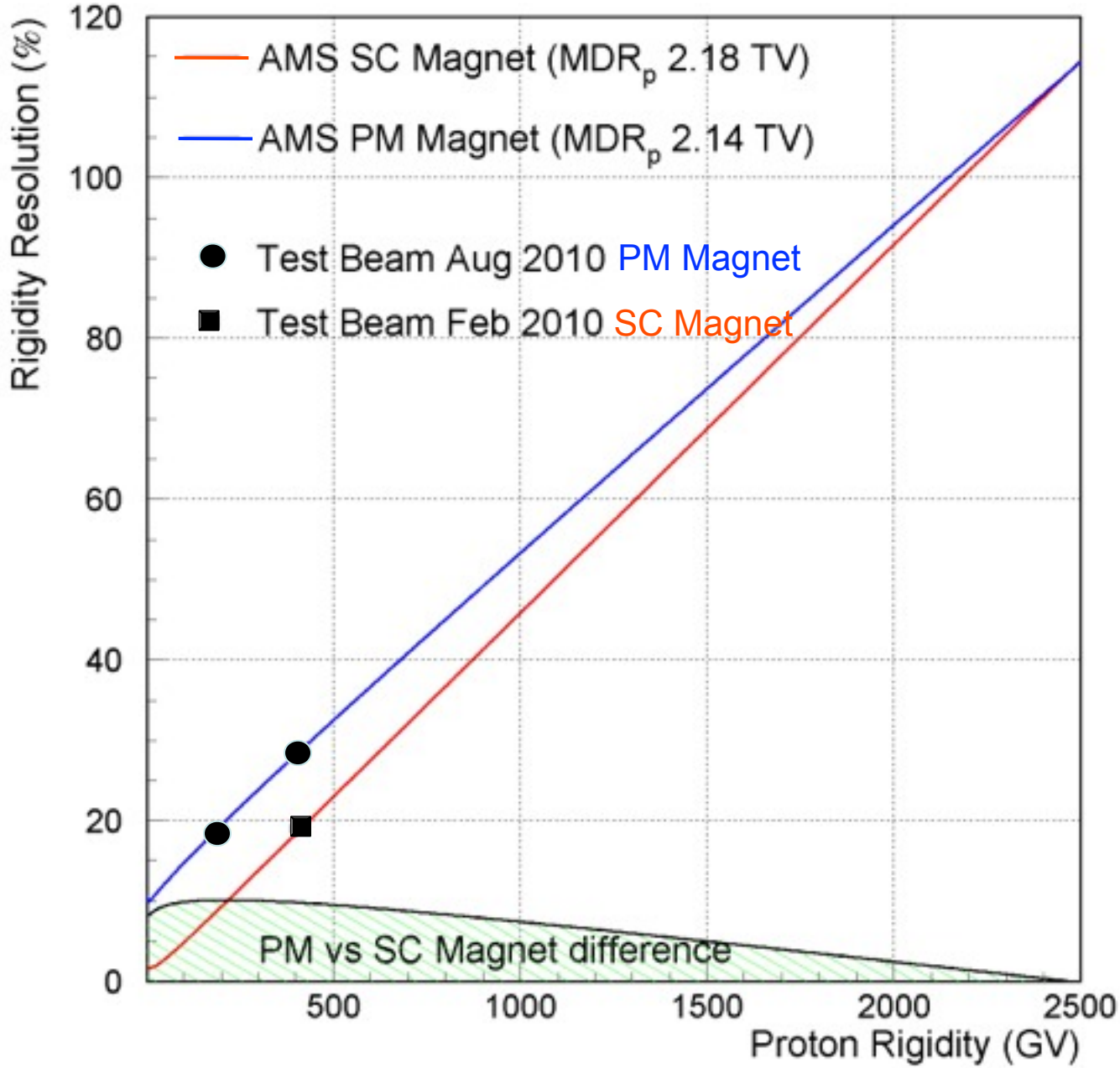
Test Beam Results of detector with superconducting magnet





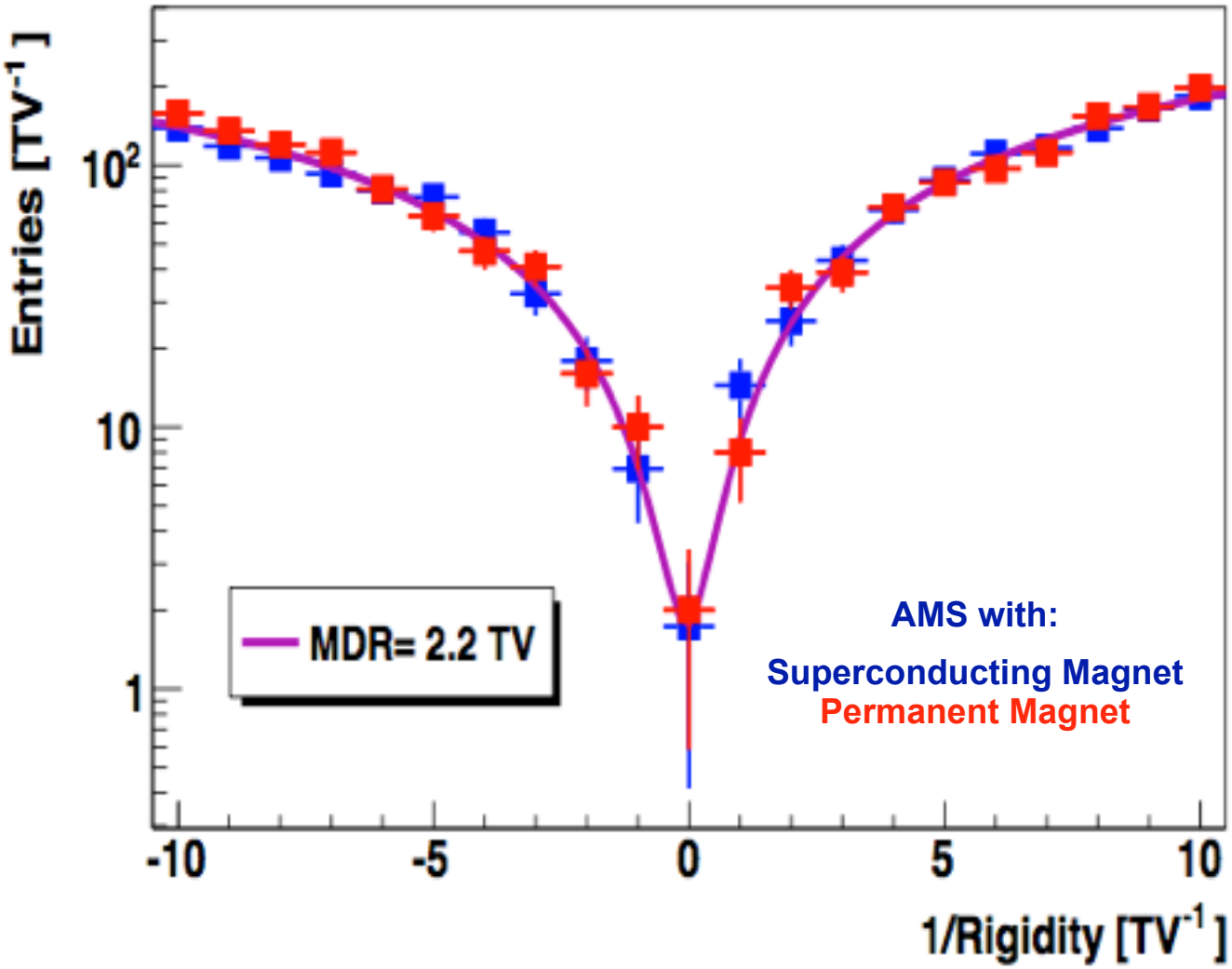






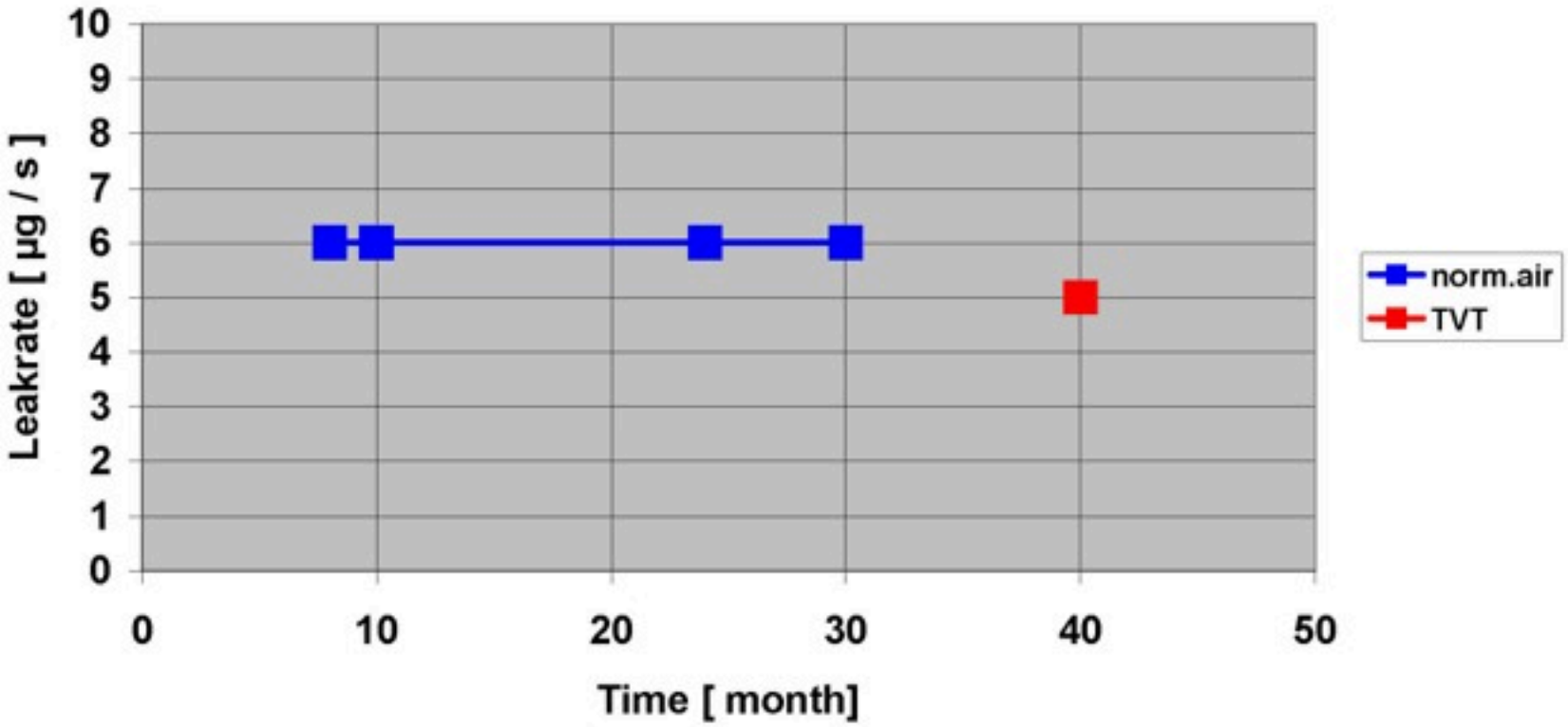
With 9 tracker planes, the resolution of AMS with the permanent magnet is equal (to 10%) to that of the superconducting magnet.

Rigidity resolution



Lifetime

A. The lifetime of consumables – TRD Leak rate



Caused by CO_2 Diffusion

CO_2 Storage at Launch: 5 kg

Leakrate of 5 µg / s corresponds to a

TRD Lifetime of 30 Years

AMS-02 data flow

AMS Data/MC Volumes Projected

DATA

Per Year Of Operation:

- 1.6×10^{10} Events
- 35 TB Raw Events
- 130 TB Reconstructed Ev.

MC

Per Year Of Operation:

- ~2 X 10^{10} Simulated Events
- ~ 200 TB Simulated Data Volume