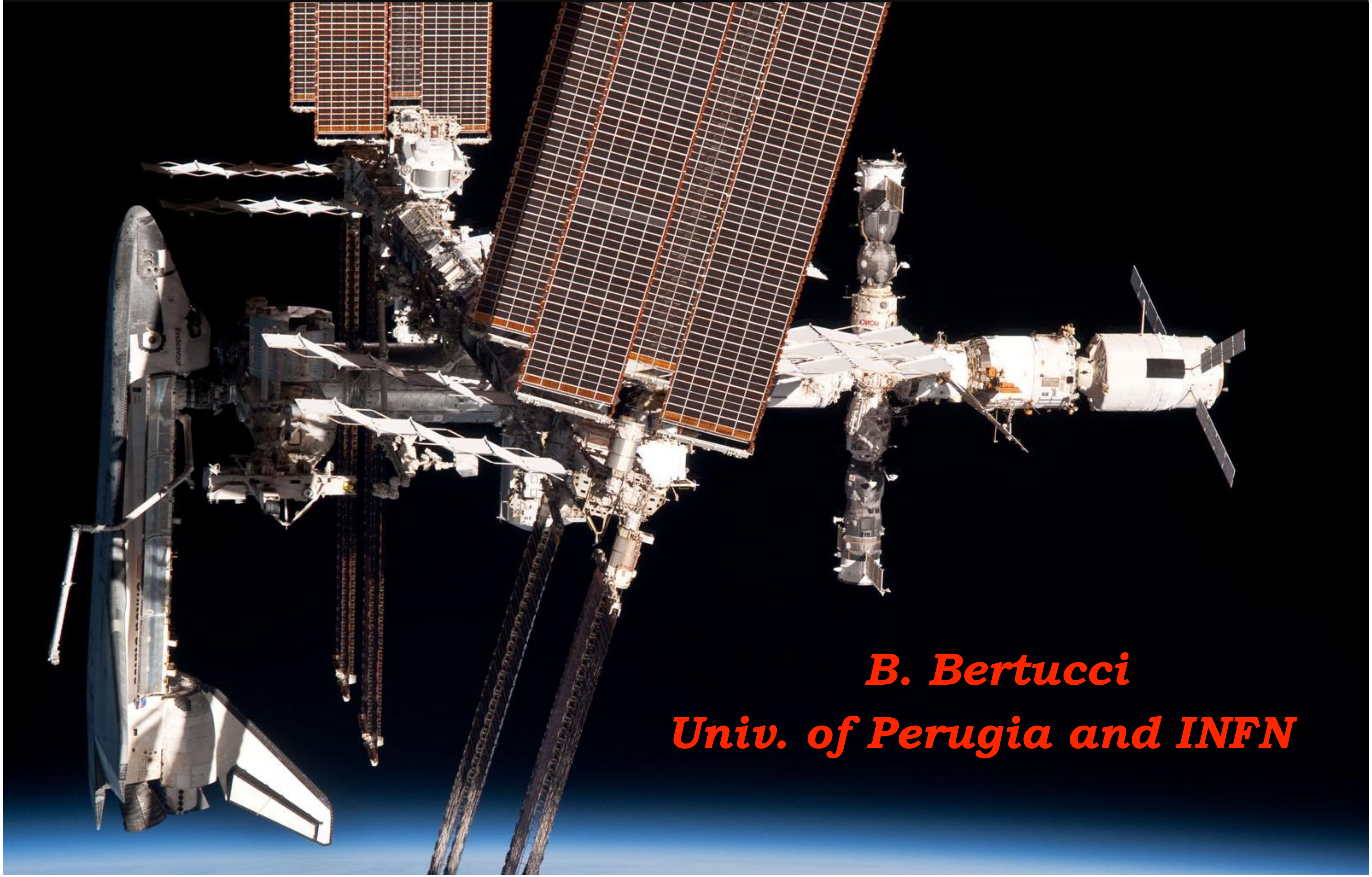
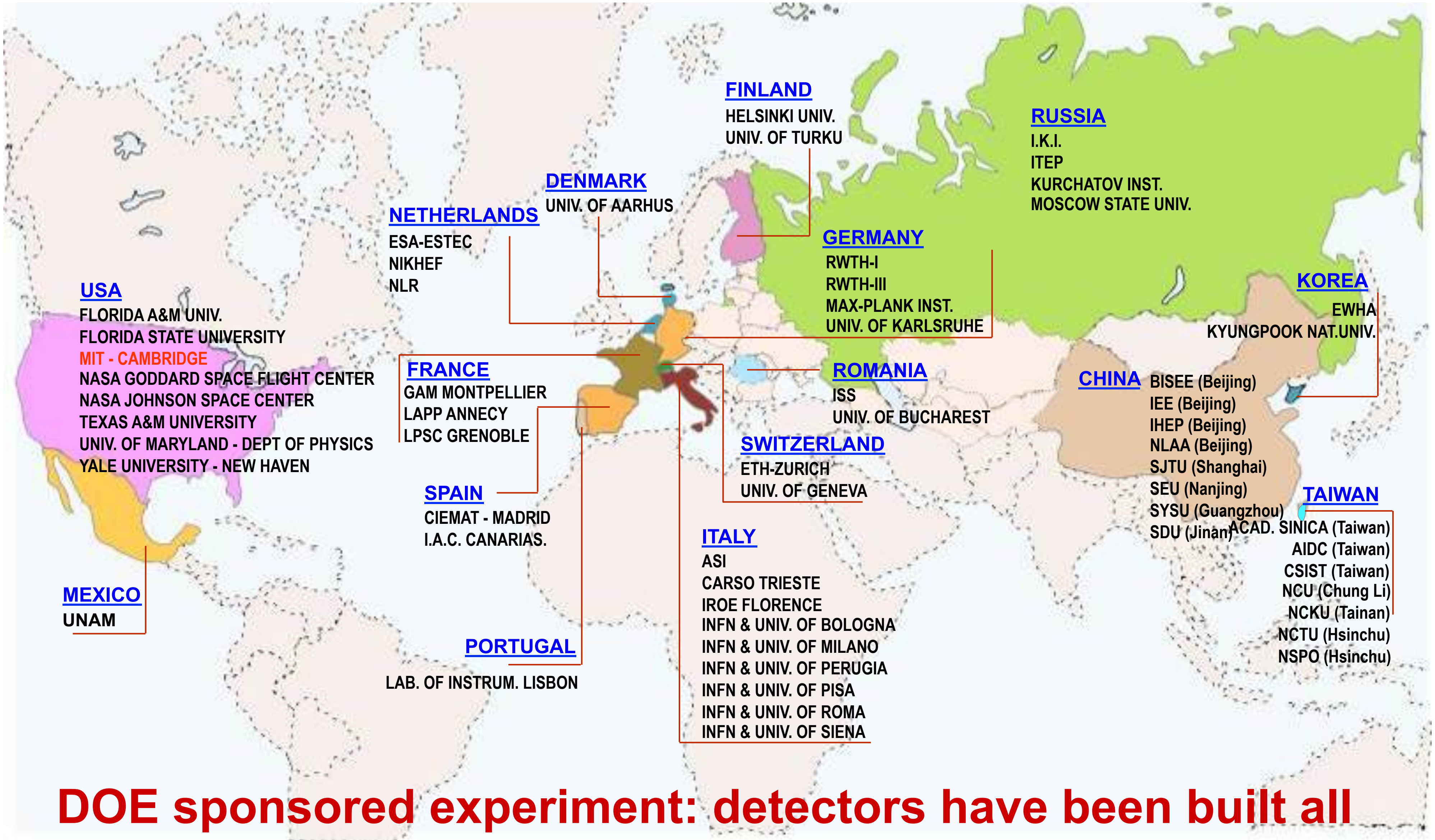
The Alpha Magnetic Spectrometer (AMS) Experiment



B. Bertucci
Univ. of Perugia and INFN

on behalf of the
AMS International Collaboration
16 Countries, 60 Institutes and 600 Physicists, 17 years



DOE sponsored experiment: detectors have been built all over the world and integrated in CERN

A smiling collaboration with the PI, Prof. S.C.C. Ting
after the first hours of operations

What is AMS?

Magnetic spectrometer conceived for the high precision study of cosmic radiation in the GV-TV rigidity range:

- ✓Search for primordial antimatter (anti-nuclei)
- ✓Indirect Search for Dark Matter (light anti-matter, gammas)
- ✓Chemical composition and energy spectra of cosmic rays
- ✓Exotic signals? (strangelets…)

Steadily taking data on the ISS since May 19th 2011

How it will fullfill its objectives?

-Same precision and detection capability as the large state-of-the-art particle physics Detectors (but fitting into the space shuttle…)

- Operation in space: on the ISS, at 400km, no backgrounds from atmospheric interactions (extensive space qualification tests…)

- Collection power:

large acceptance (≈ 0.5 m2sr)

x

exposure time (= ISS lifetime)

(extensive calibration campaigns on ground)

IMPLEMENTING ARRANGEMENT
BETWEEN
THE DEPARTMENT OF ENERGY
AND
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
REGARDING THE
ALPHA MAGNETIC SPECTROMETER IN SPACE PROGRAM

…

I. PROGRAM DESCRIPTION

The AMS is a state-of-the-art particle physics detector containing a large permanent magnet that will be designed constructed and tested by an international team organized under DOE sponsorship and that will use the unique environment of space to advance knowledge of the universe and lead potentially to a clearer understanding of the origin of the universe. Specifically, the science objectives of the AMS are to search for cosmic sources of anti-matter (i.e., anti-helium or heavier elements) and dark matter.

… On the second flight, NASA will launch the AMS on the Shuttle and transfer and install it onto the International Space Station (ISS). The AMS then will be operated as an externally attached payload on the ISS for a nominal three-year period, after which NASA will detach the AMS from the ISS, transfer it to a Space Shuttle, and return it to Earth. …

By Harry C Holloway
Associate Administrator
for Life and Microgravity
Sciences and Applications
National Aeronautics and
Space Administration

Date: 20 Sept 95

By Martha Krebs
Director
Office of Energy Research
Department of Energy

Date: Sept. 20, 1995

Michael Braukus
Headquarters, Washington
202-358-1979
michael.j.braukus@nasa.gov

March 11, 2010

RELEASE : 10-063

Heads of Agency International Space Station Joint Statement

TOKYO -- The heads of the International Space Station (ISS) agencies from Canada, Europe, Japan, Russia, and the United States met in Tokyo, Japan, on March 11, 2010, to review ISS cooperation.

With the assembly of the ISS nearing completion and the capability to support a full-time crew of six established, they noted the outstanding opportunities now offered by the ISS for on-orbit research and for discovery including the operation and management of the world's largest international space complex. In particular, they noted the unprecedented opportunities that enhanced use of this unique facility provides to drive advanced science and technology. This research will deliver benefits to humanity on Earth while preparing the way for future exploration activities beyond low-Earth orbit. The ISS will also allow the partnership to experiment with more integrated international operations and research, paving the way for enhanced collaboration on future international missions.

The heads of agency reaffirmed the importance of full exploitation of the station's scientific, engineering, utilization, and education potential. They noted that there are no identified technical constraints to continuing ISS operations beyond the current planning horizon of 2015 to at least 2020, and that the partnership is currently working to certify on-orbit elements through 2028. The heads of agency expressed their strong mutual interest in continuing operations and utilization for as long as the benefits of ISS exploitation are demonstrated. They acknowledged that a U.S. fiscal year 2011 budget consistent with the U.S. administration's budget request would allow the United States to support the continuation of ISS operations and utilization activities to at least 2020. They emphasized their common intent to undertake the necessary procedures within their respective governments to reach consensus later this year on the continuation of the ISS to the next decade.

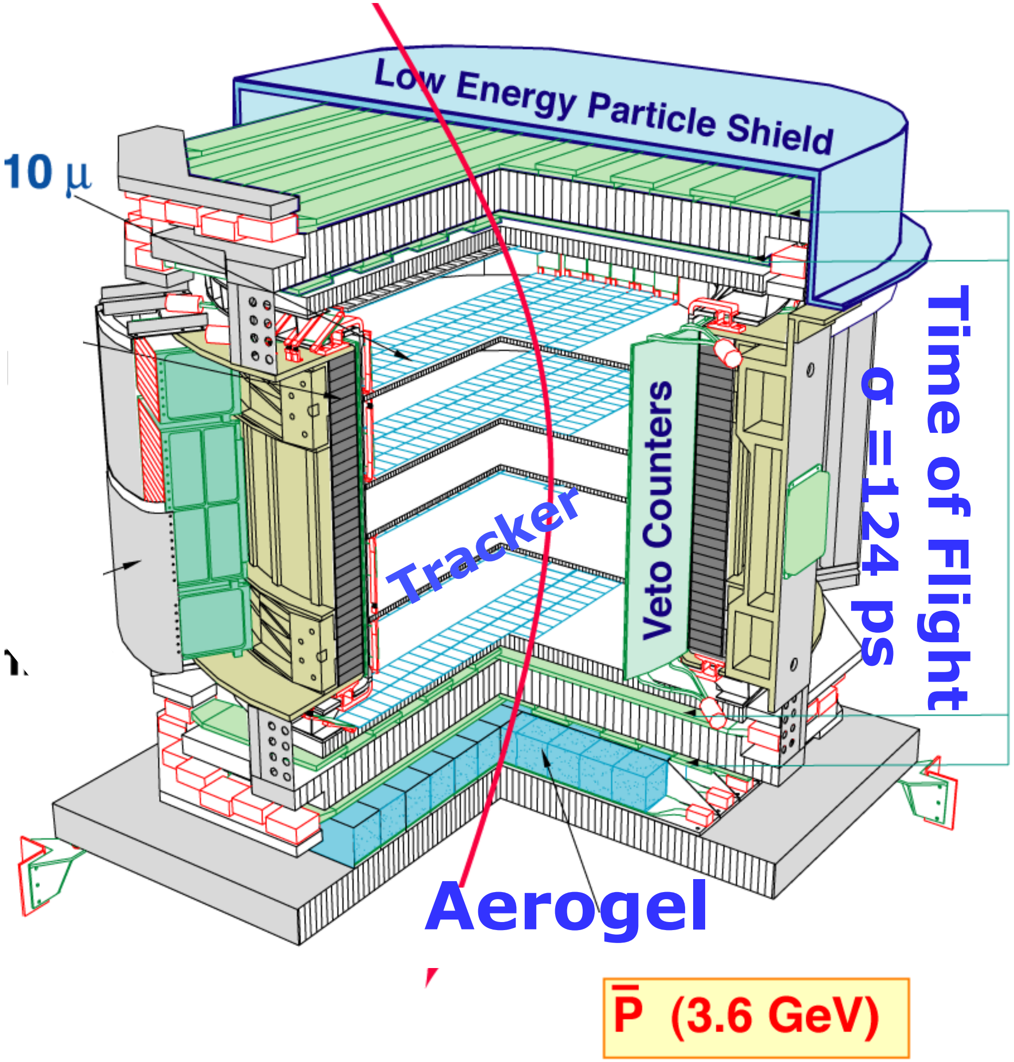
In looking ahead, the heads of agency discussed the importance of increasing ISS utilization and operational efficiency by all possible means, including finding and coordinating efficiencies across the ISS Program and assuring the most effective use of essential capabilities, such as space transportation for crew and cargo, for the life of the program.

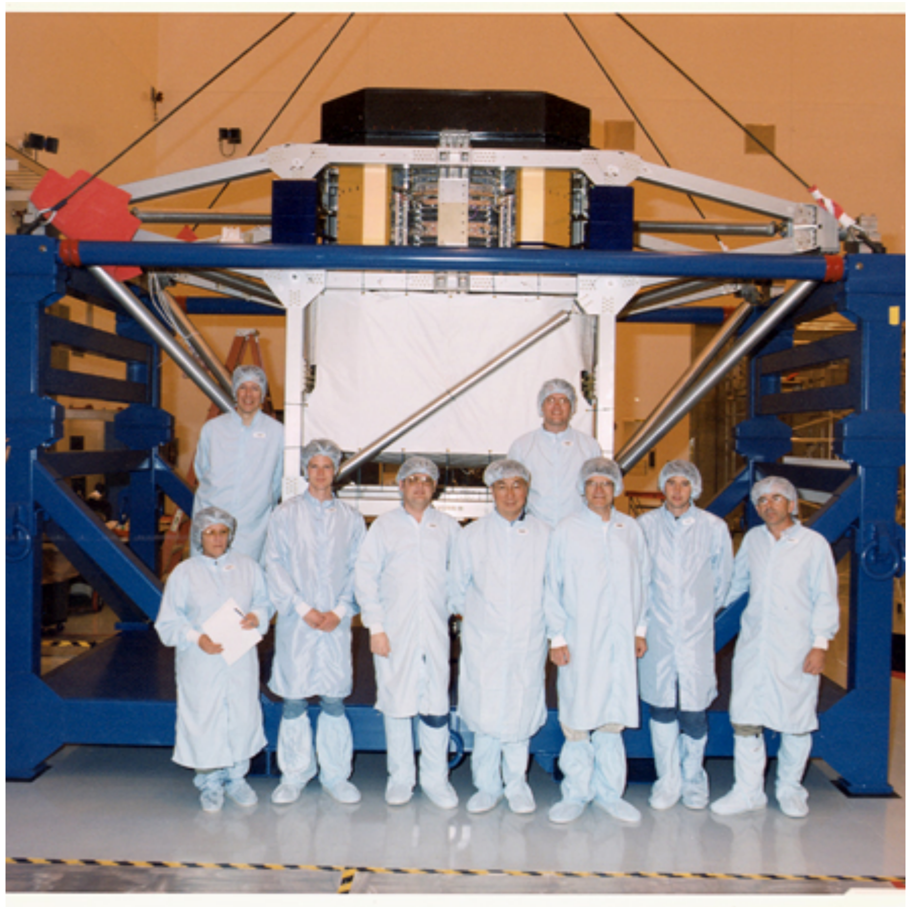
For the latest about the International Space Station, visit the Internet at: http://www.nasa.gov/station

\- end -

The AMS-01 Detector (1994-1998)

6 planes of Silicon Tracker: 3.2 % X_0, 10 μm.
BL^2 = 0.14 Tm^2, $\Delta P/P$ = 7% at 10 GeV





STS91, June 2^{nd} - 12^{th} 1998

- **10 days of data taking in orbit:**
  - **400 Km altitude**
  - **latitudes <51.7°**
  - **all longitudes**
- **10^8 events recorded**
- **Physics results**

(Phys. Rep. 366 (2002) 331)

  - **precise measurements of primary fluxes**
  - **detection of secondary fluxes (quasi trapped)**
  - **antimatter limit at 10^{-6}**
  - **light nuclei (B/C,isotopes)**

ApJ, 724:329–340, 2010 November 20

ApJ, 736:105 (11pp) 2011 August 1

The Detector

Timeline

2000-2008 : Sub-detector Construction and first mechanical integration

2009: Integration with the SC Magnet

2010: Beam test

EMI – TVT test

Integration with the Permanent Magnet

Beam test

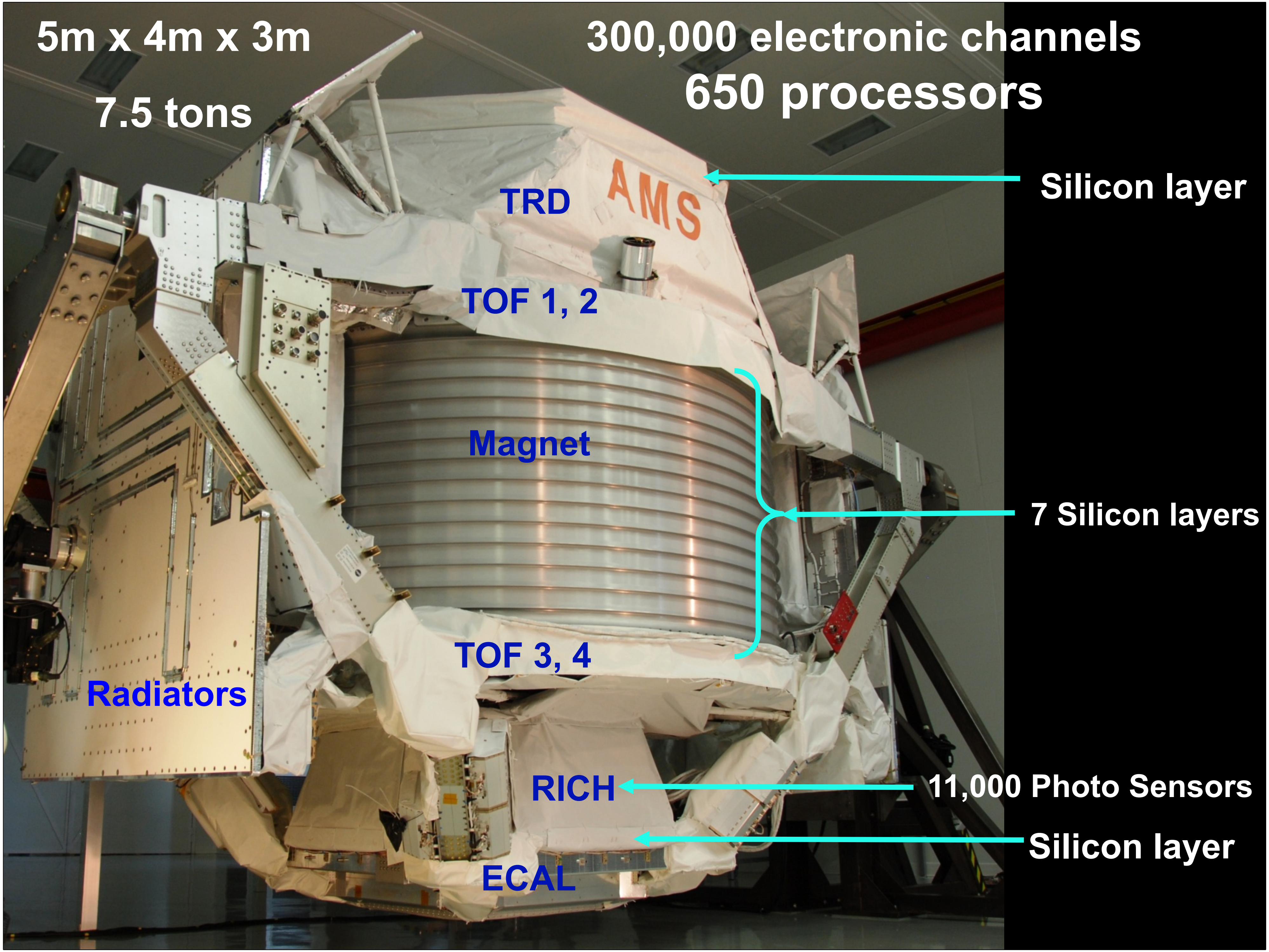
Shipment to KSC

Integration with the Shuttle and ISS interfaces

2011: Installation on the Shuttle (March)

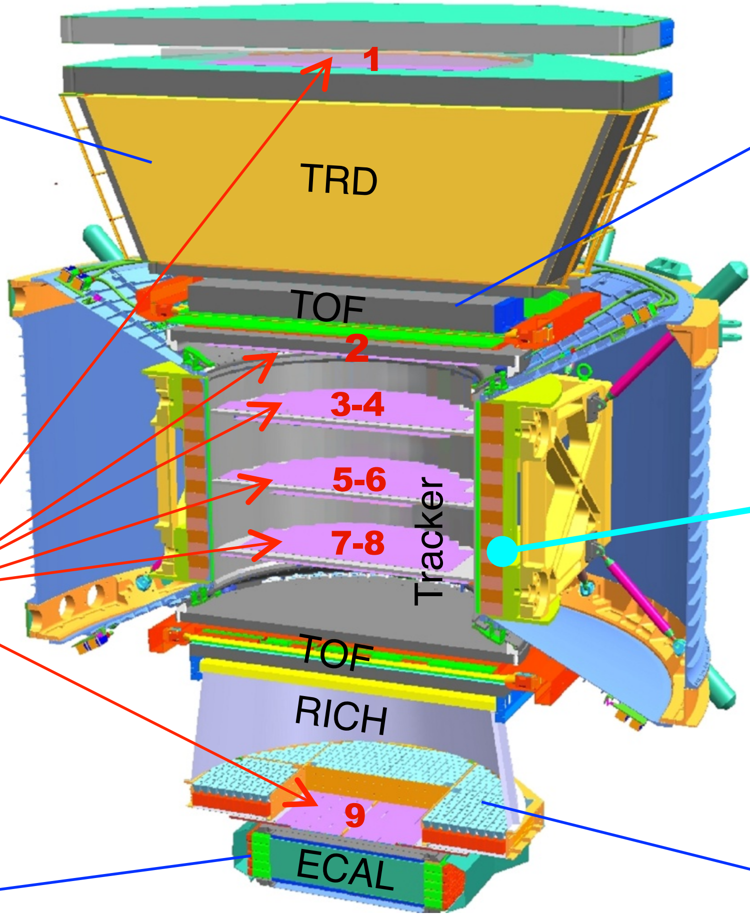
Launch (May 16)

Installation on the ISS (May 19)

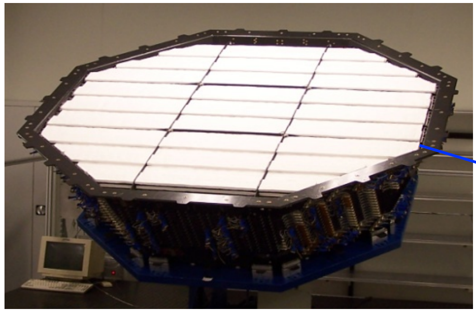

5m x 4m x 3m
7.5 tons
300,000 electronic channels
650 processors
Silicon layer
TRD
AMS
TOF 1, 2
Magnet
7 Silicon layers
TOF 3, 4
Radiators
RICH
11,000 Photo Sensors
Silicon layer
ECAL

AMS: A TeV precision, multipurpose particle physics spectrometer in space.

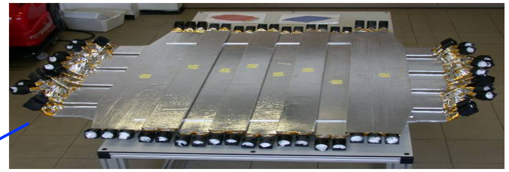
Particles and nuclei are defined by their charge (Z) and energy (E ~ P)



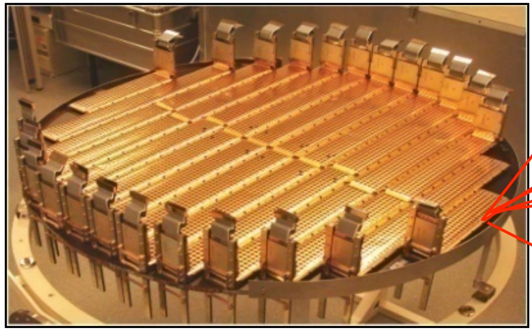
TRD
Identify e+, e-



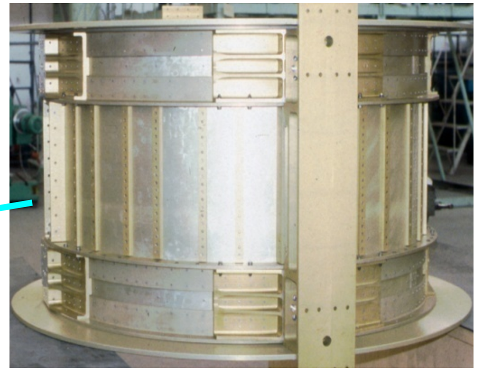
TOF
Z, E



Silicon Tracker
Z, P

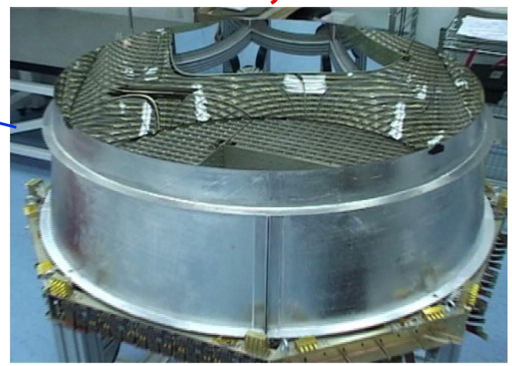


Magnet
±Z



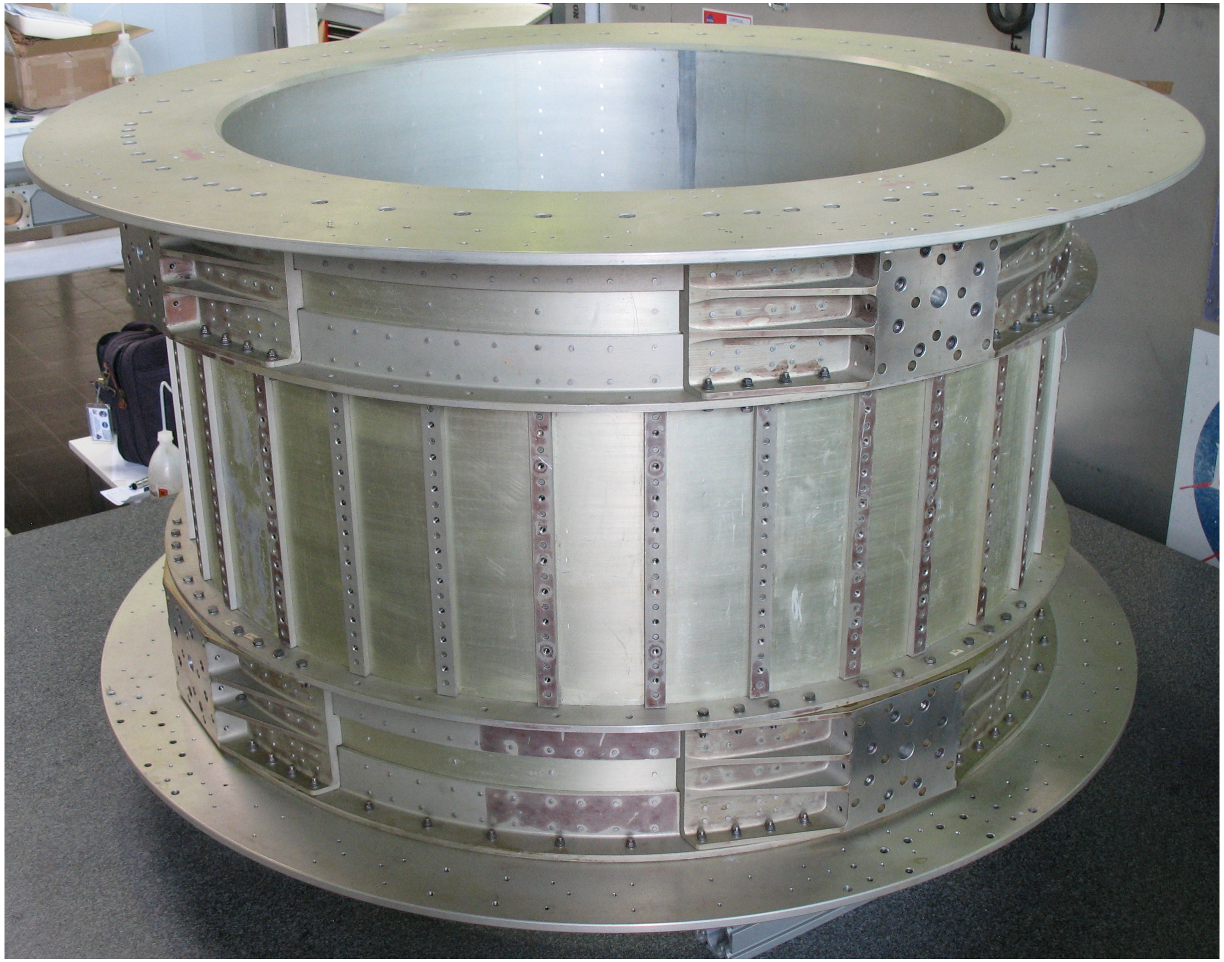
ECAL
E of e+, e-, γ

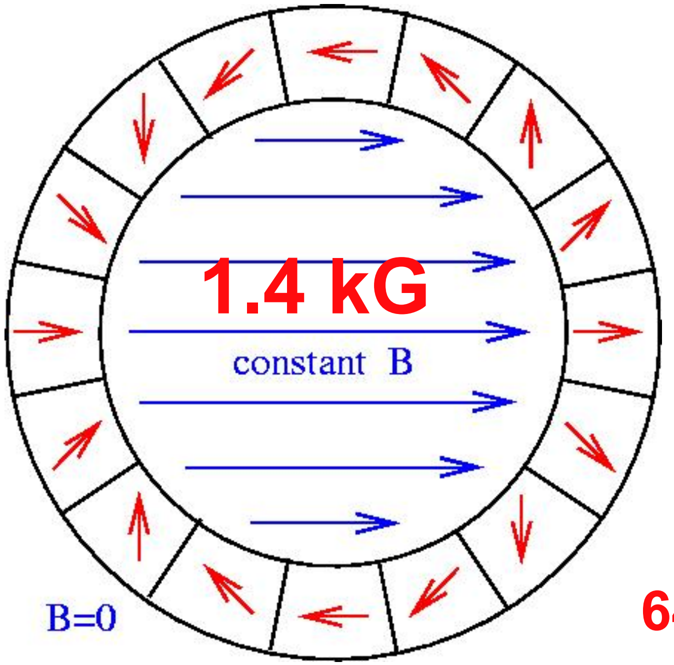
RICH
Z, E



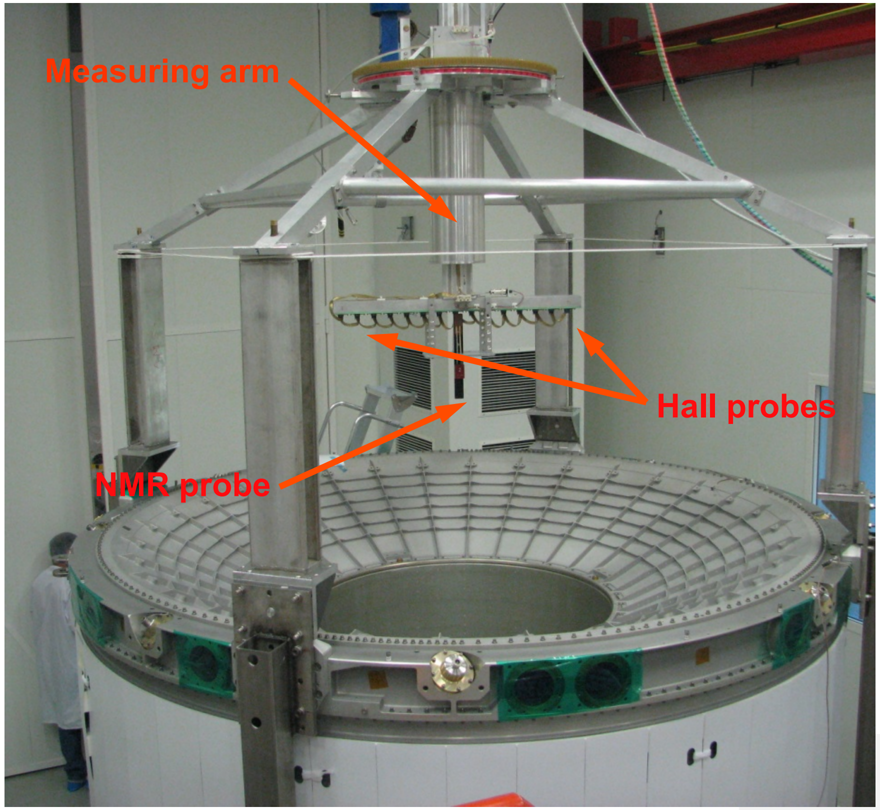
***Z, P* are measured independently by the Tracker, RICH, TOF and ECAL**

The Magnet

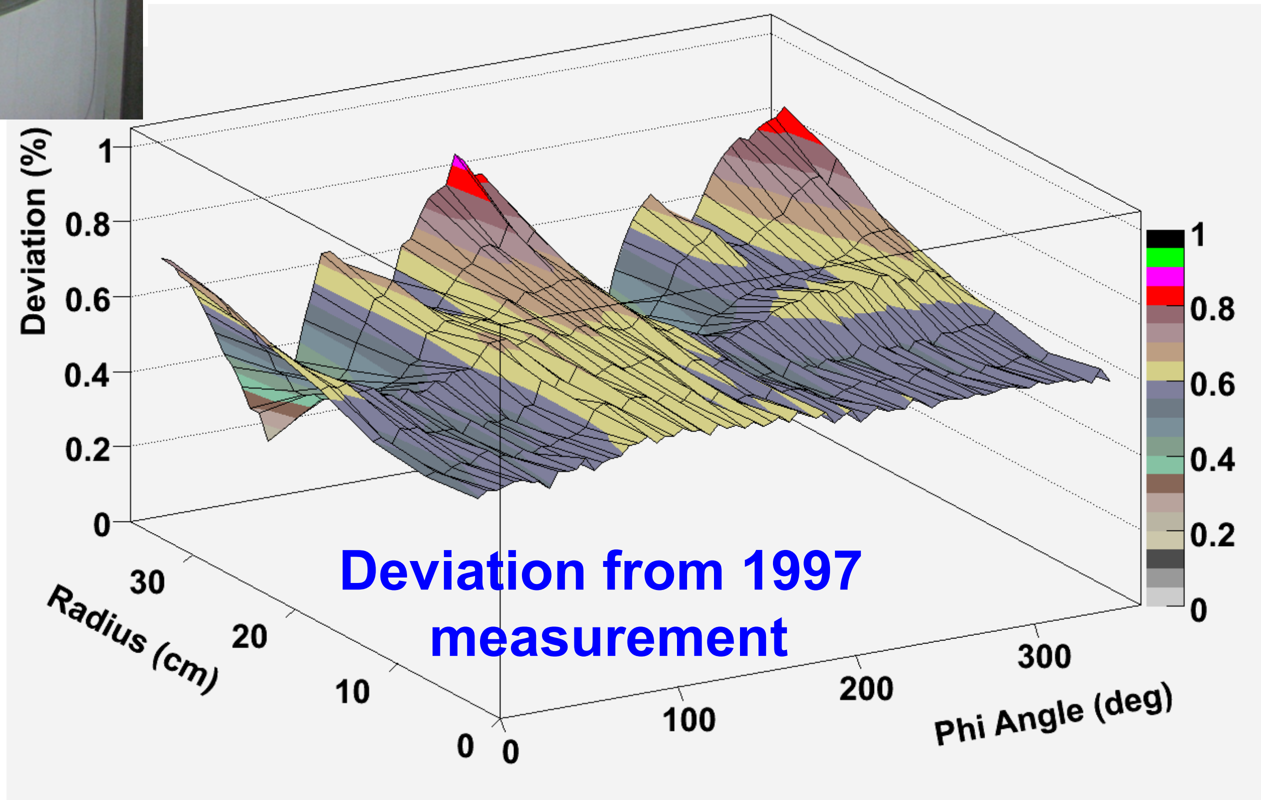




6400 high-grade Nd–Fe–B blocks

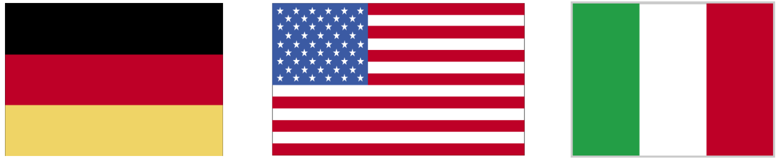


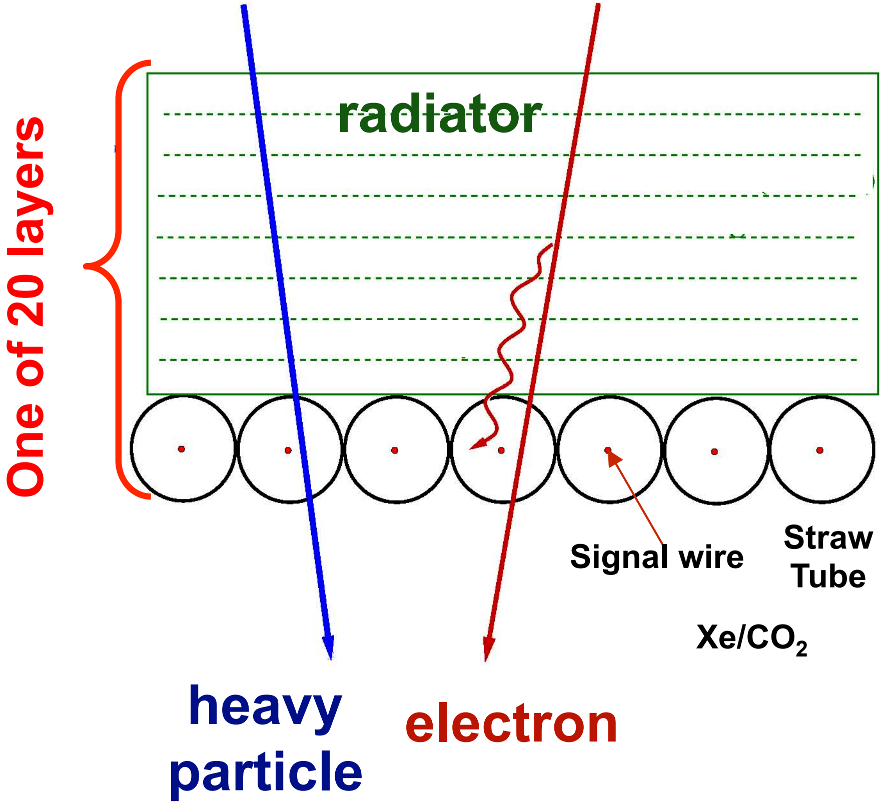
The detailed 3D field map
(120,000 locations)
was measured at CERN on
25-27 May 2010

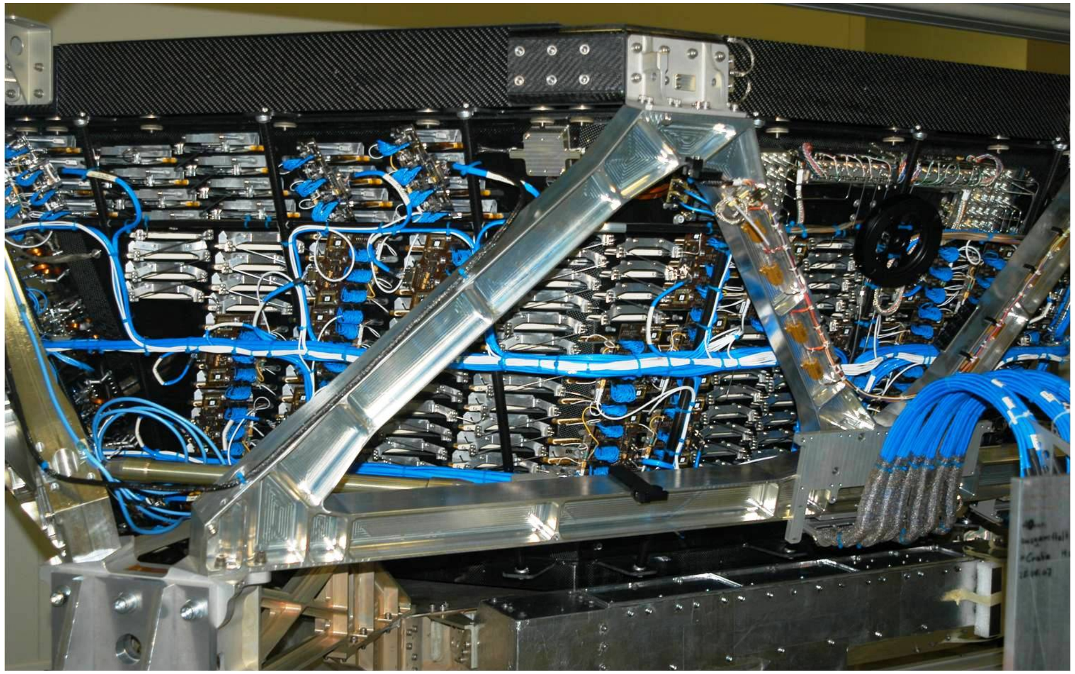


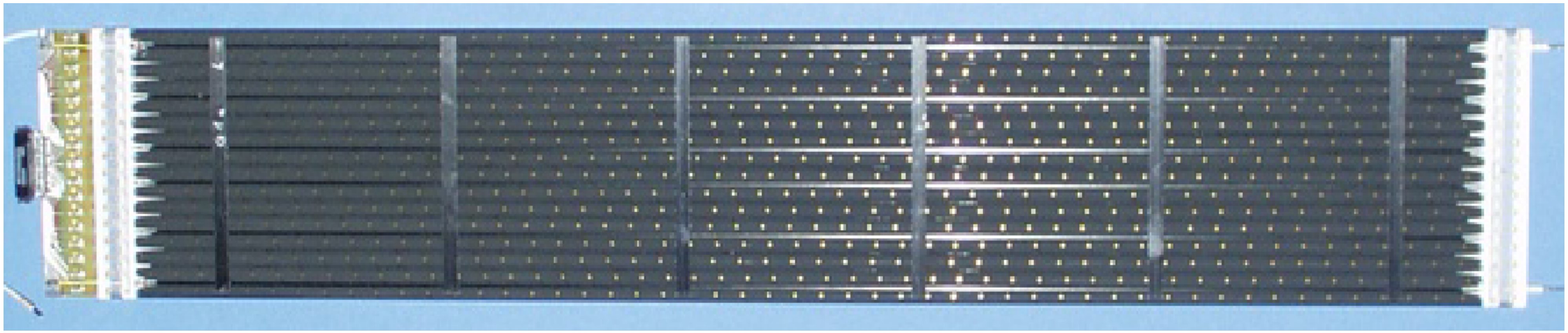
In 12 years
the field has remained
the same to <1%

Transition Radiation Detector (TRD): identifies Positron and Electron







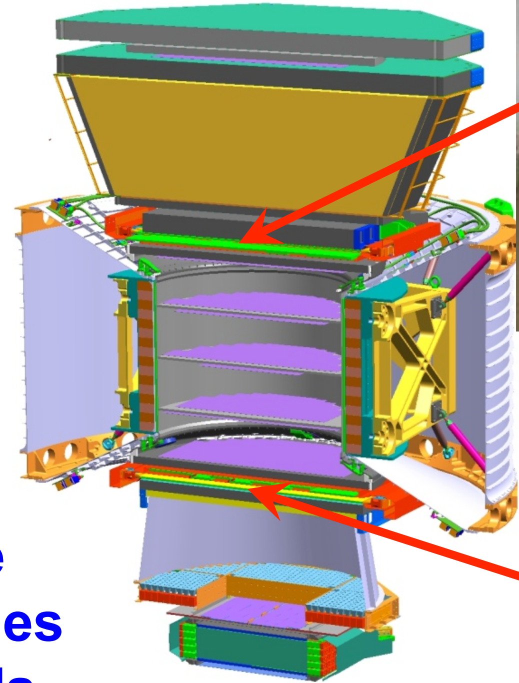


Time of Flight (TOF)

TOF

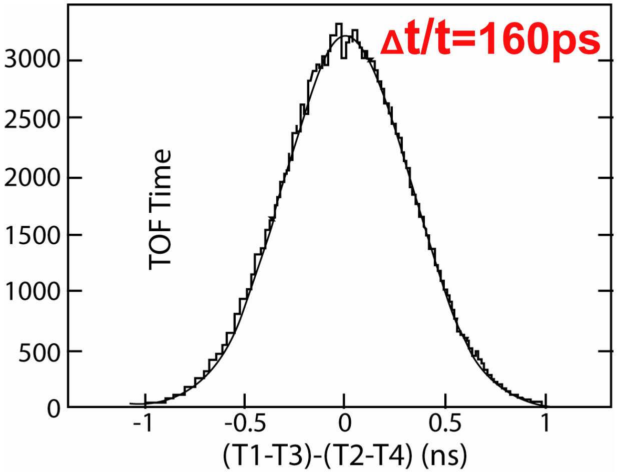
Provides trigger for charged particles

Trigger time is synchronized to UTC time to 1μs

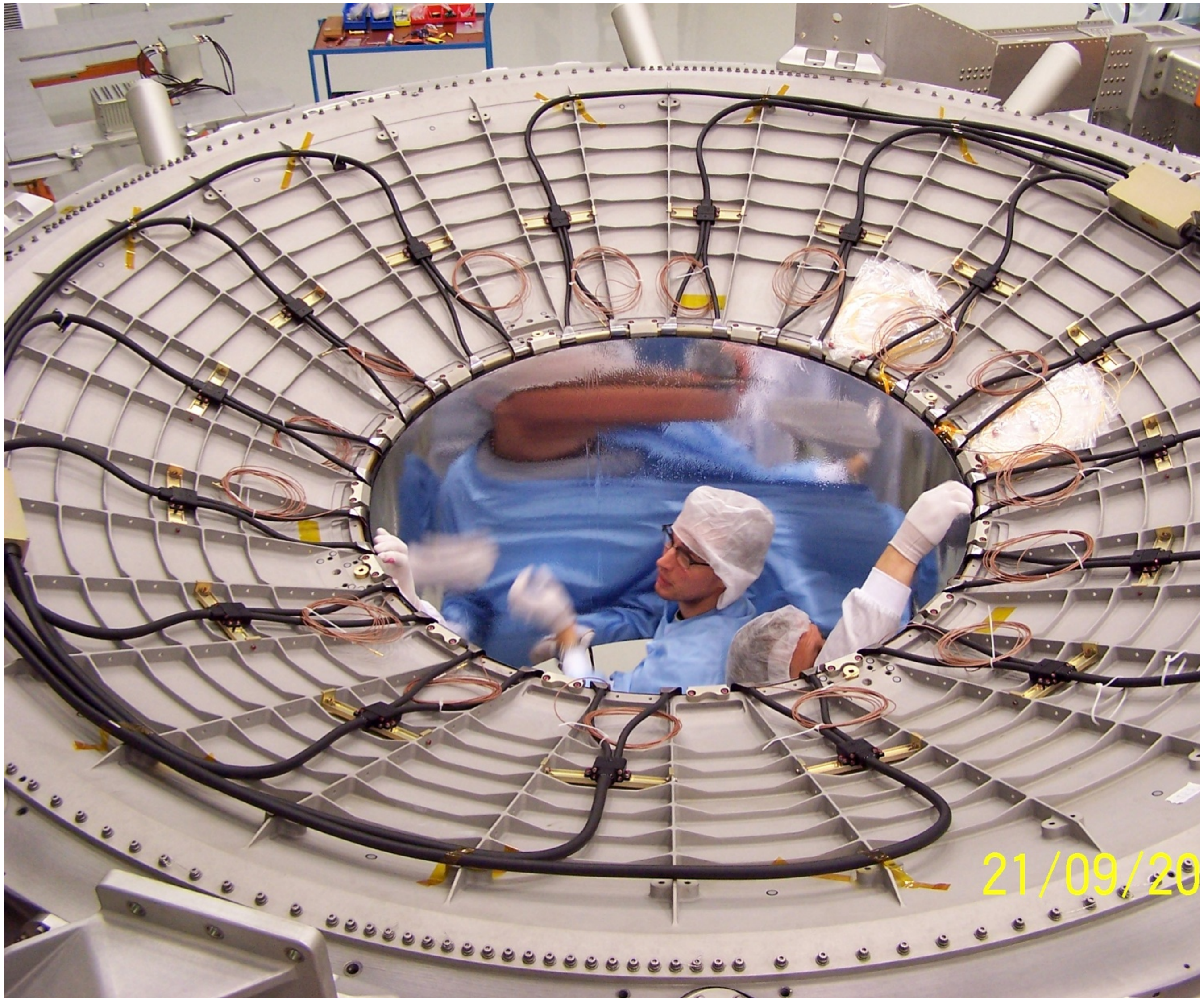


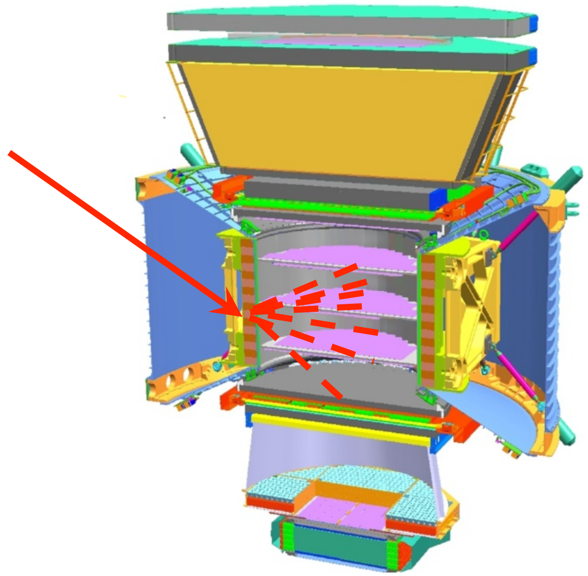
TOF

Measures the time of relativistic particles to 160 picoseconds



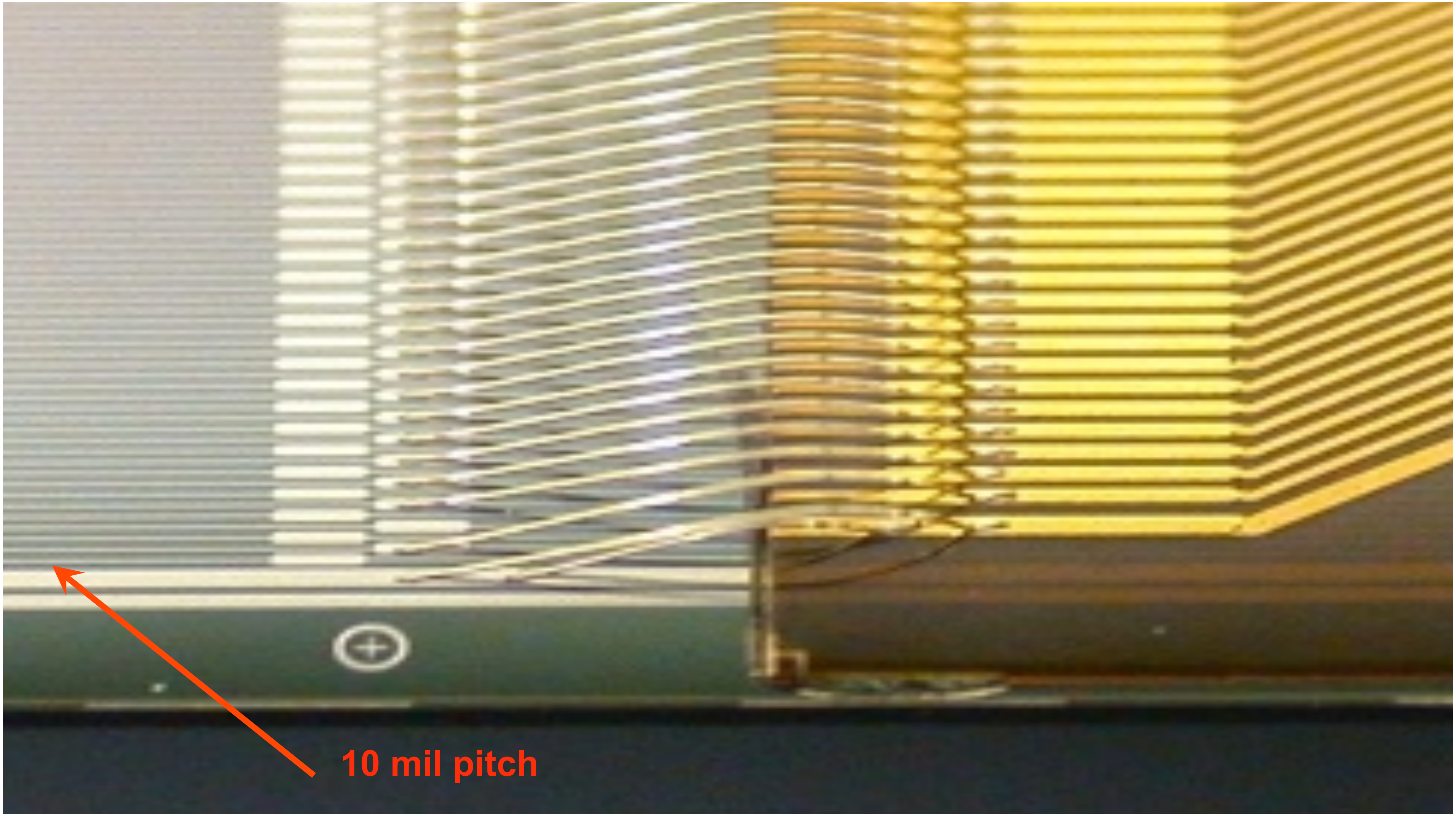
Veto System rejects random cosmic rays





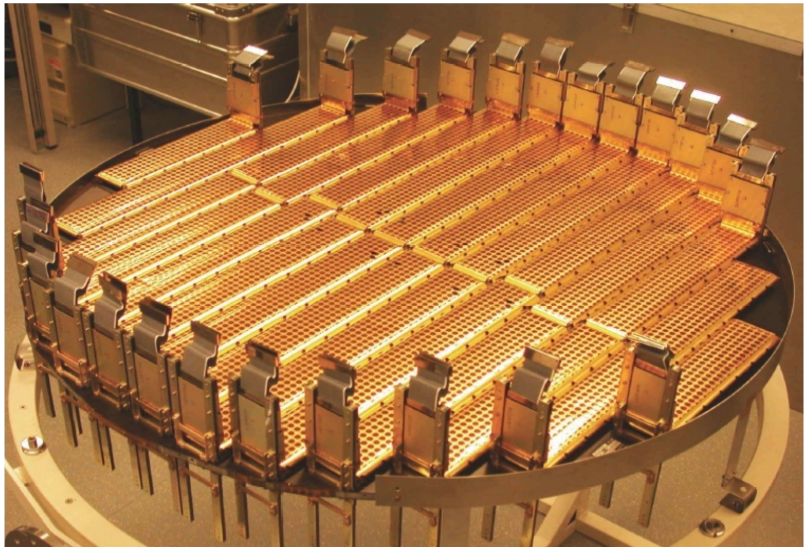
Measured veto efficiency better than 0.99999

Silicon Tracker

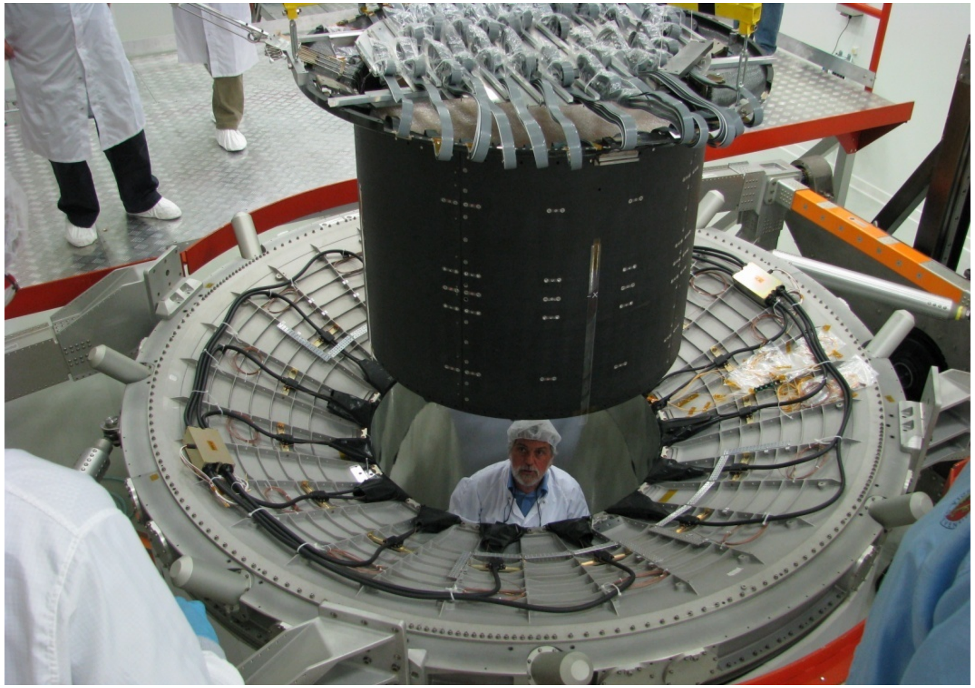


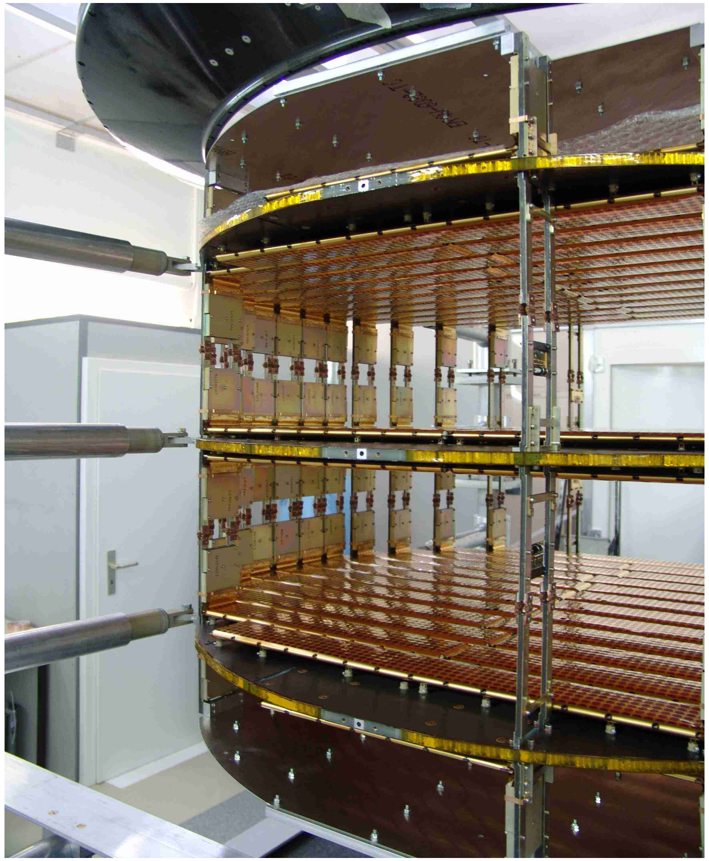
The coordinate resolution is 10 micron

Silicon Tracker

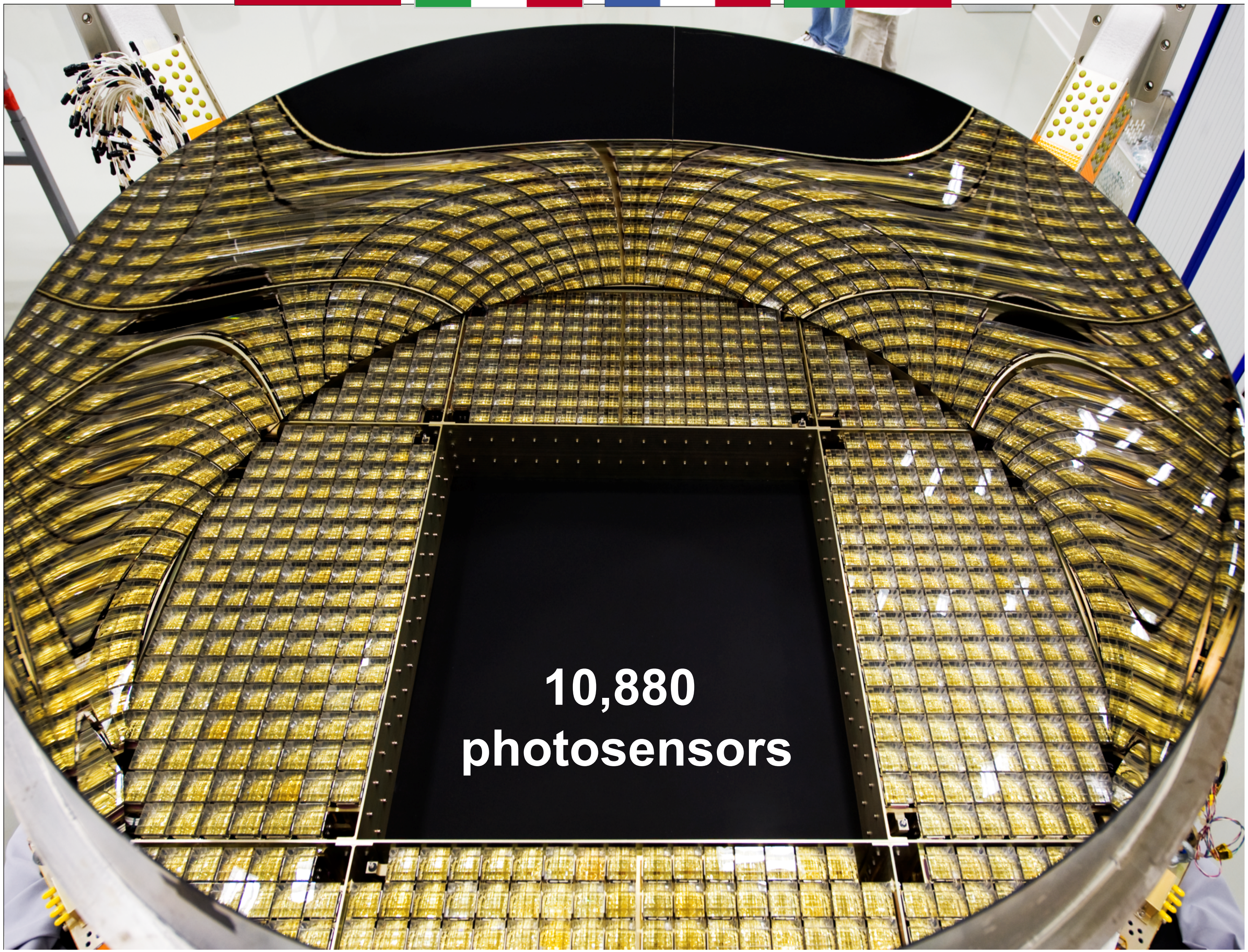


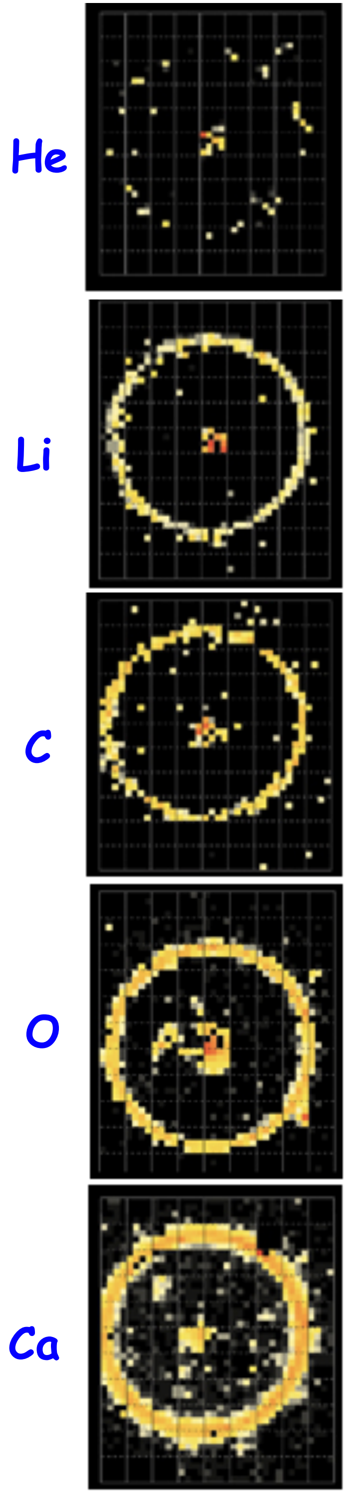
- 9 Layers of silicon microstrip detectors for an active area of 6.4m² , 3 μm mechanical alignment.
- 200k channels for 129 W of power
- high dynamic range front end for charge measurement
- wide temperature range (-20/+40 s)

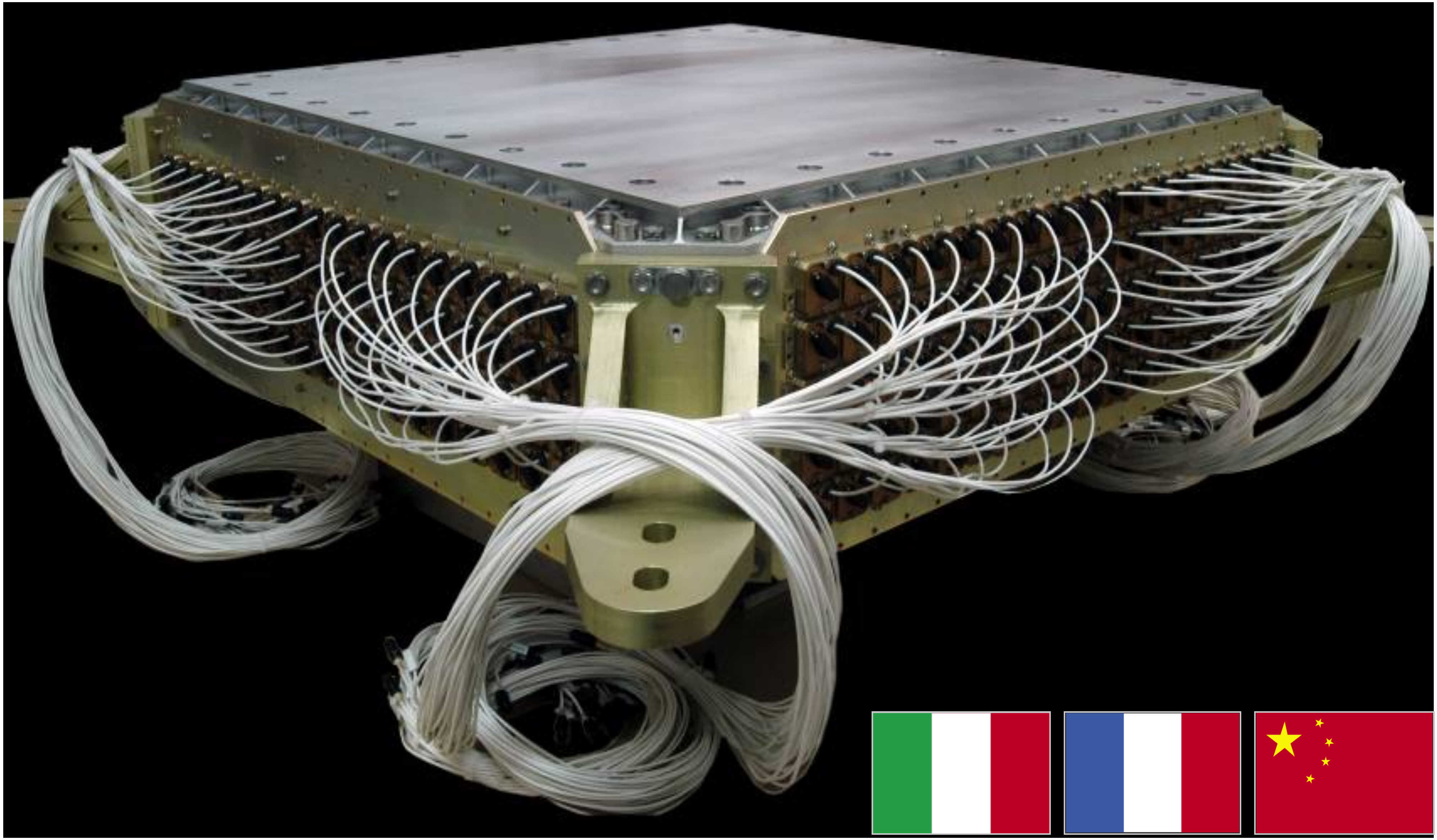




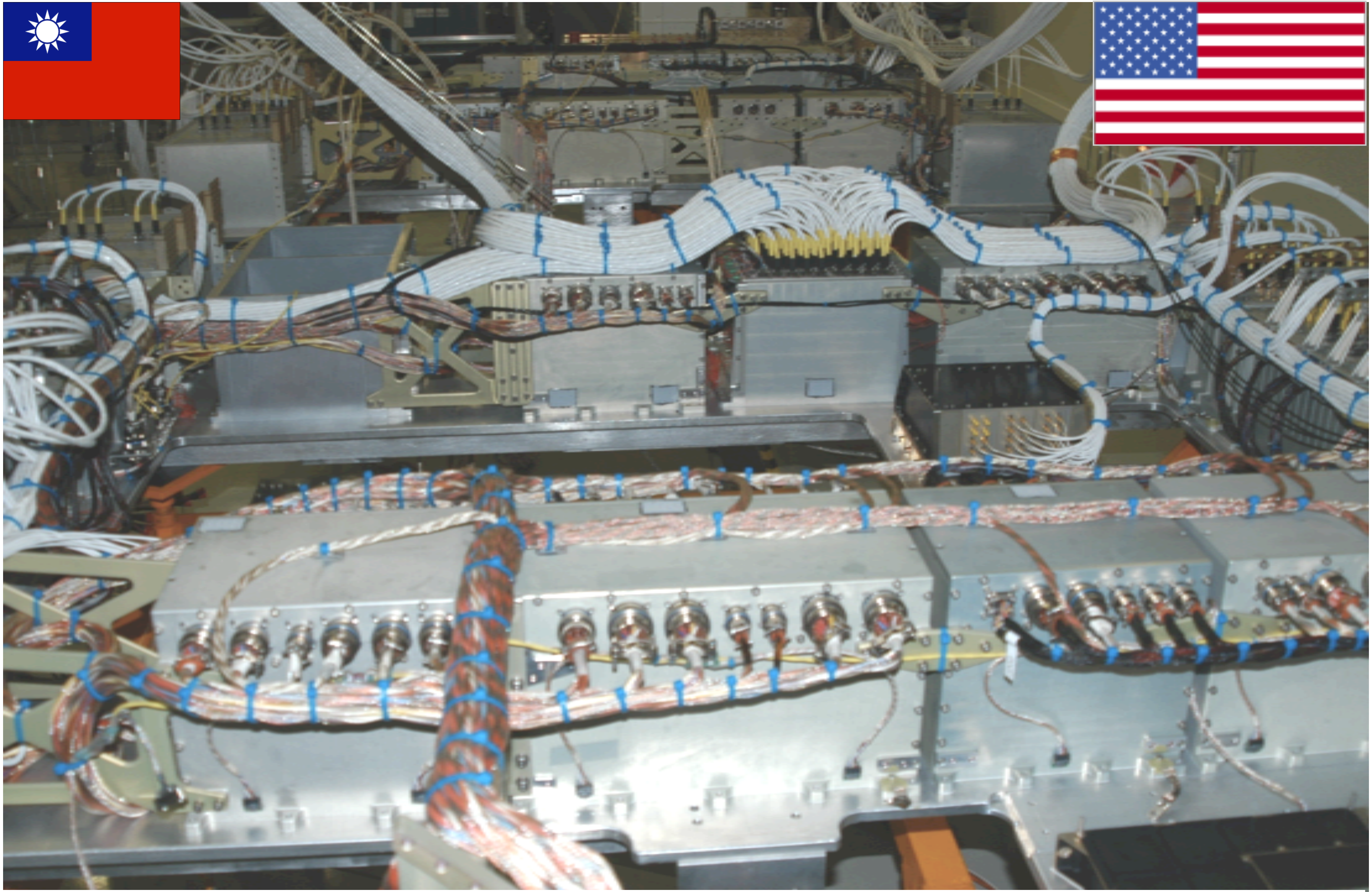
Ring Imaging CHerenkov (RICH)





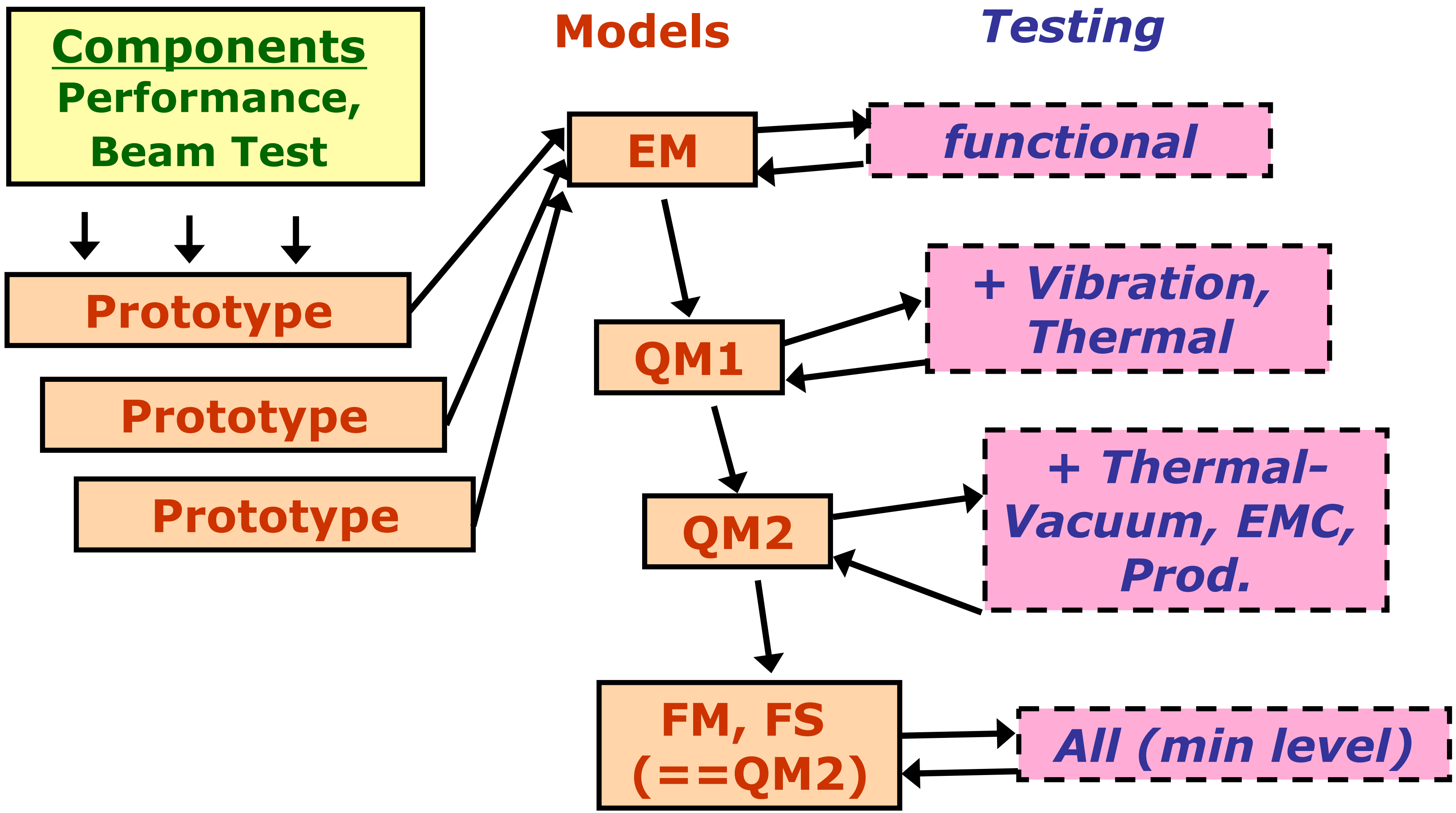


50,000 fibers, ϕ =1mm, distributed uniformly inside 1,200 lb of lead which provides a precision, 3-dimensional, 17X_0 measurement of the directions and energies of light rays and electrons up to 1 TeV

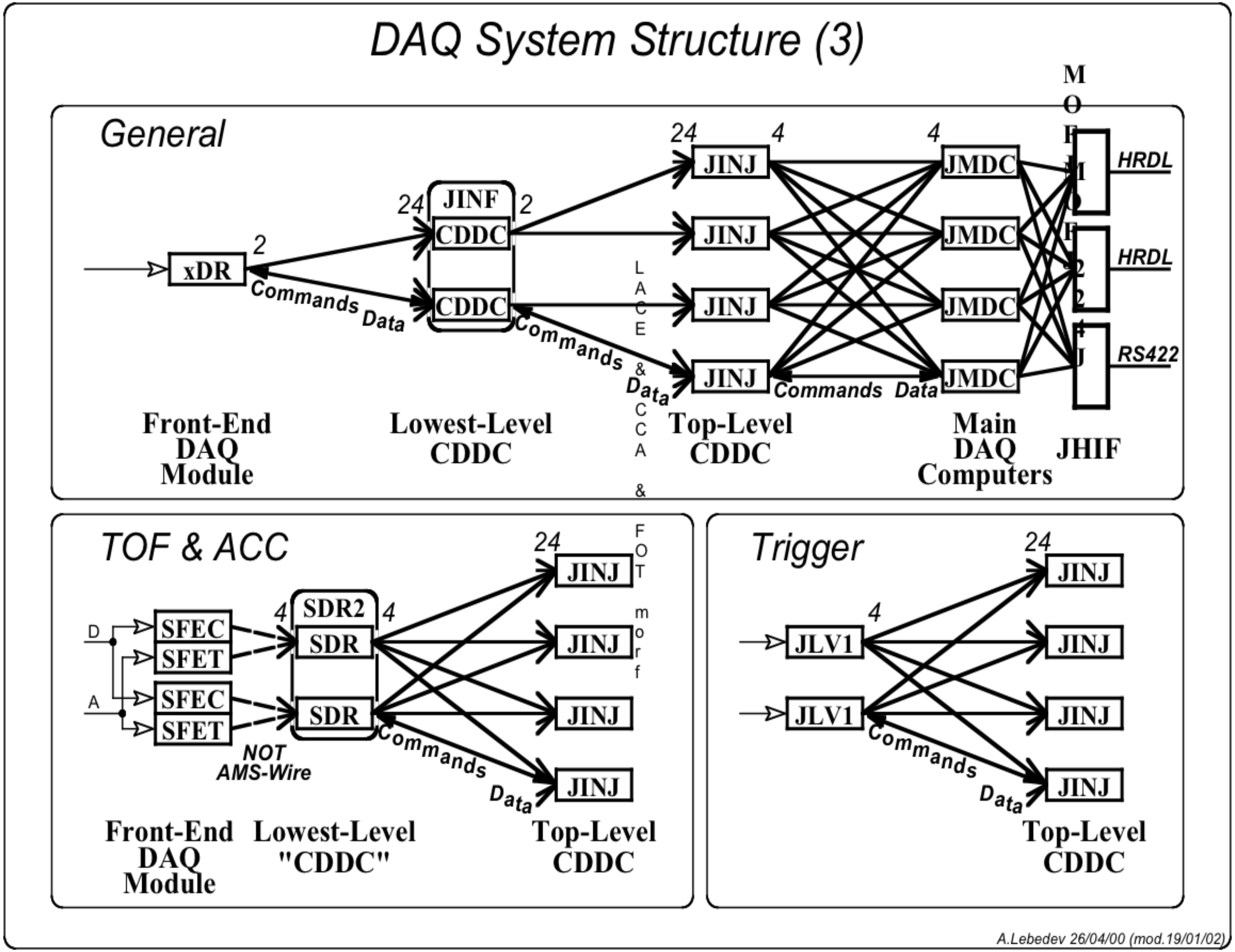


The completed flight electronics
(650 microprocessors, 300,000 channels)

High Energy Physics Electronics and Detectors to Low Earth Orbit

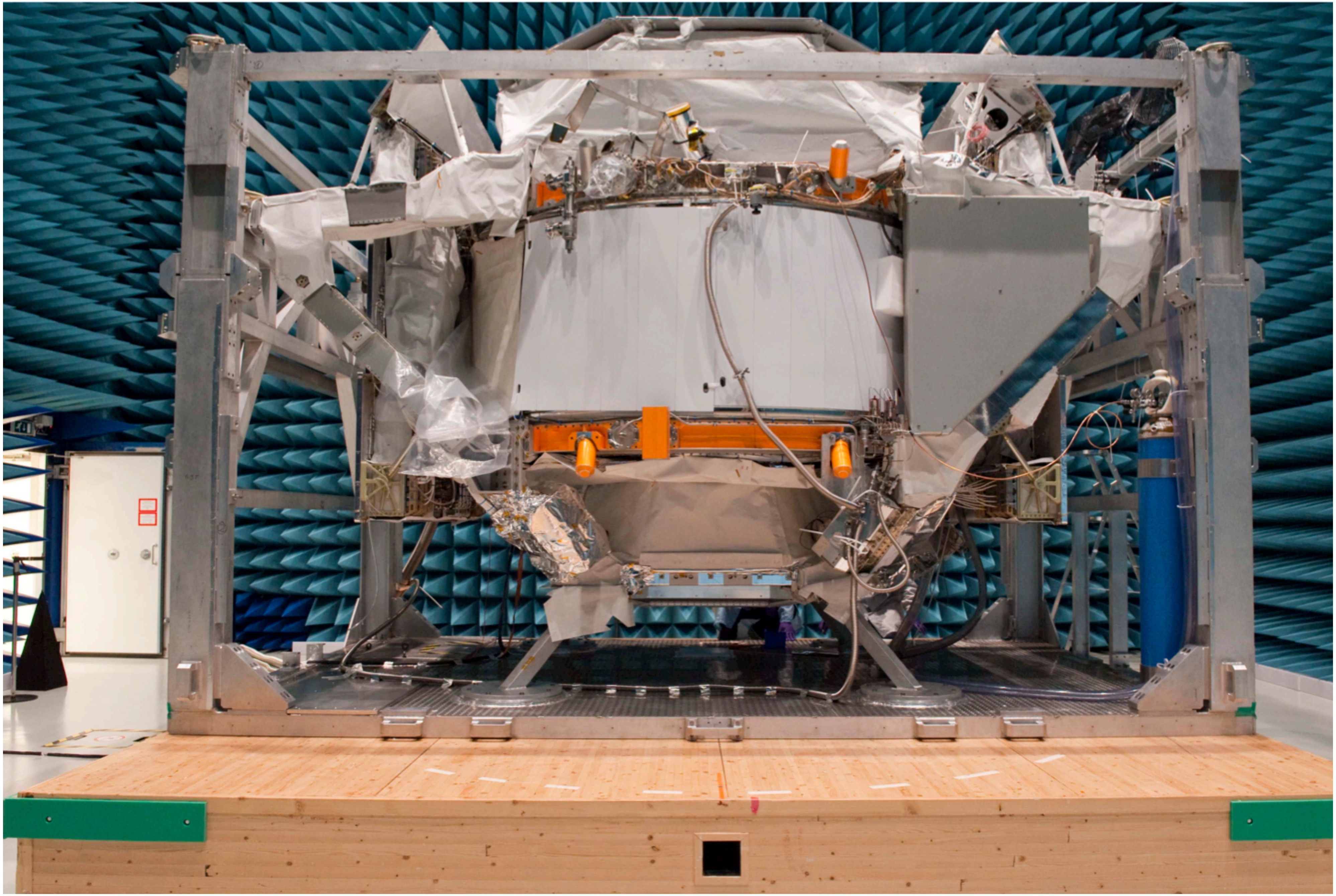


Redundancy in Design

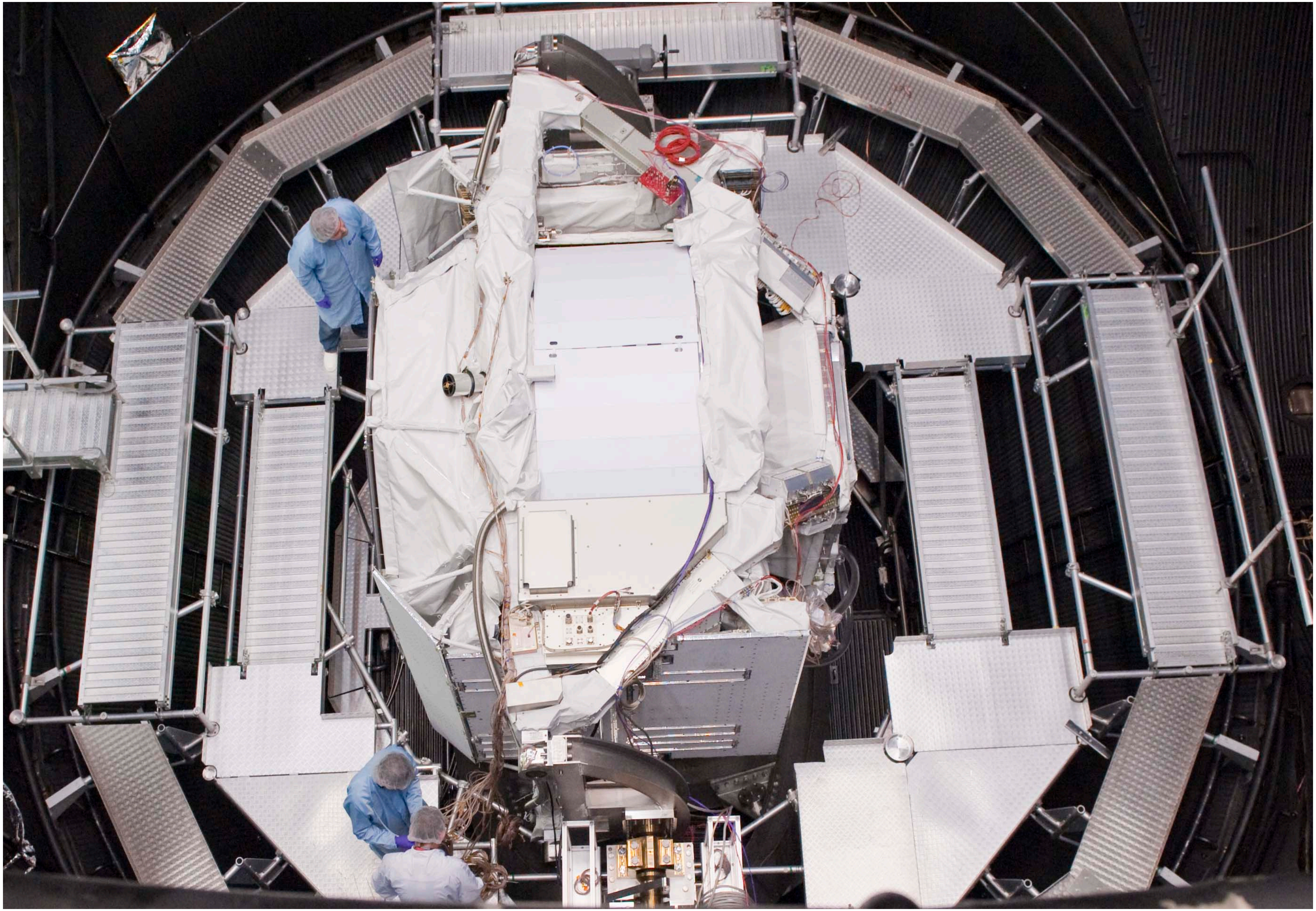


2009: AFTER 9000 hrs of TVT…THE END OF SUB-SYSTEM TESTS

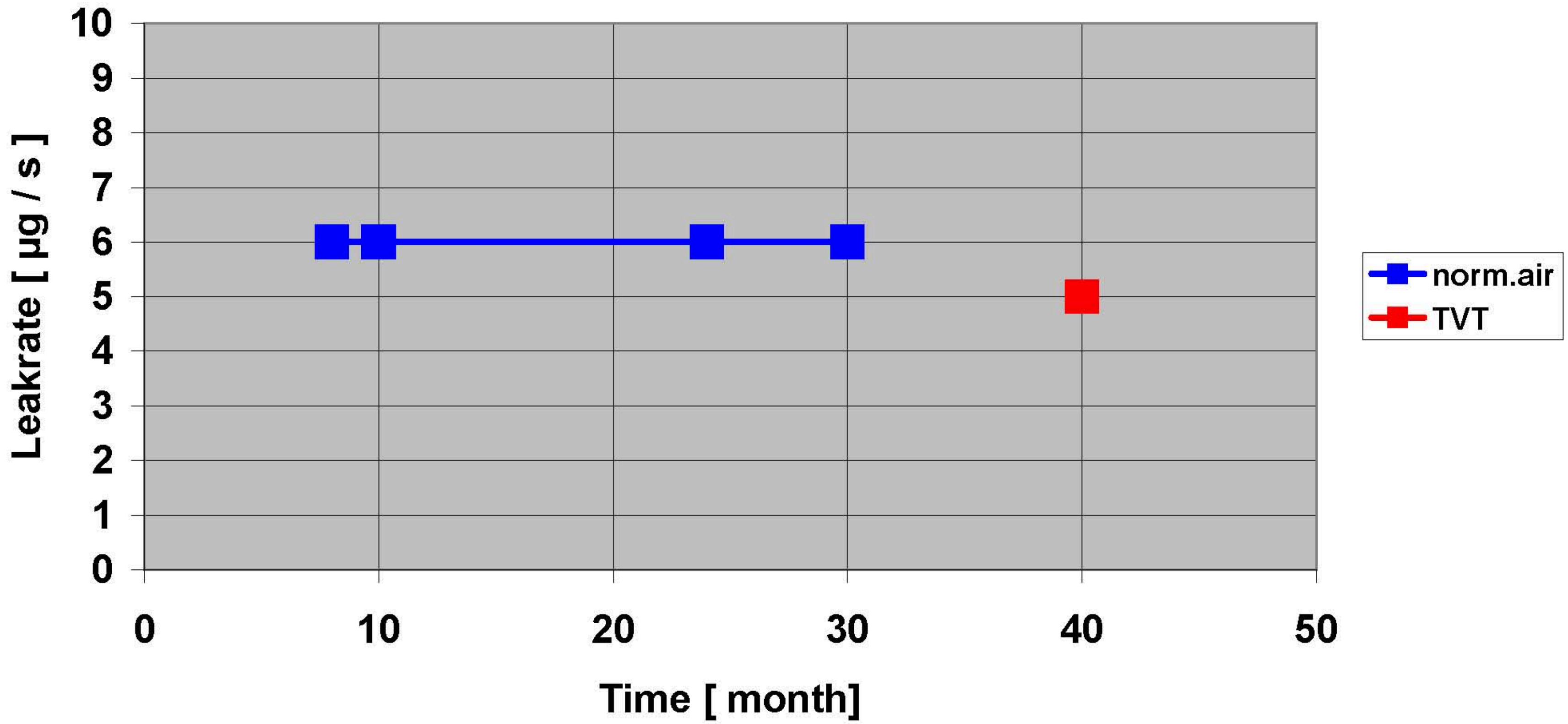
AMS in the ESA Anecoic chamber, Noordwijk, the Netherlands



AMS in the ESA Thermal Vacuum Chamber, Noordwijk, the Netherlands



Consumables lifetime – TRD Leak rate



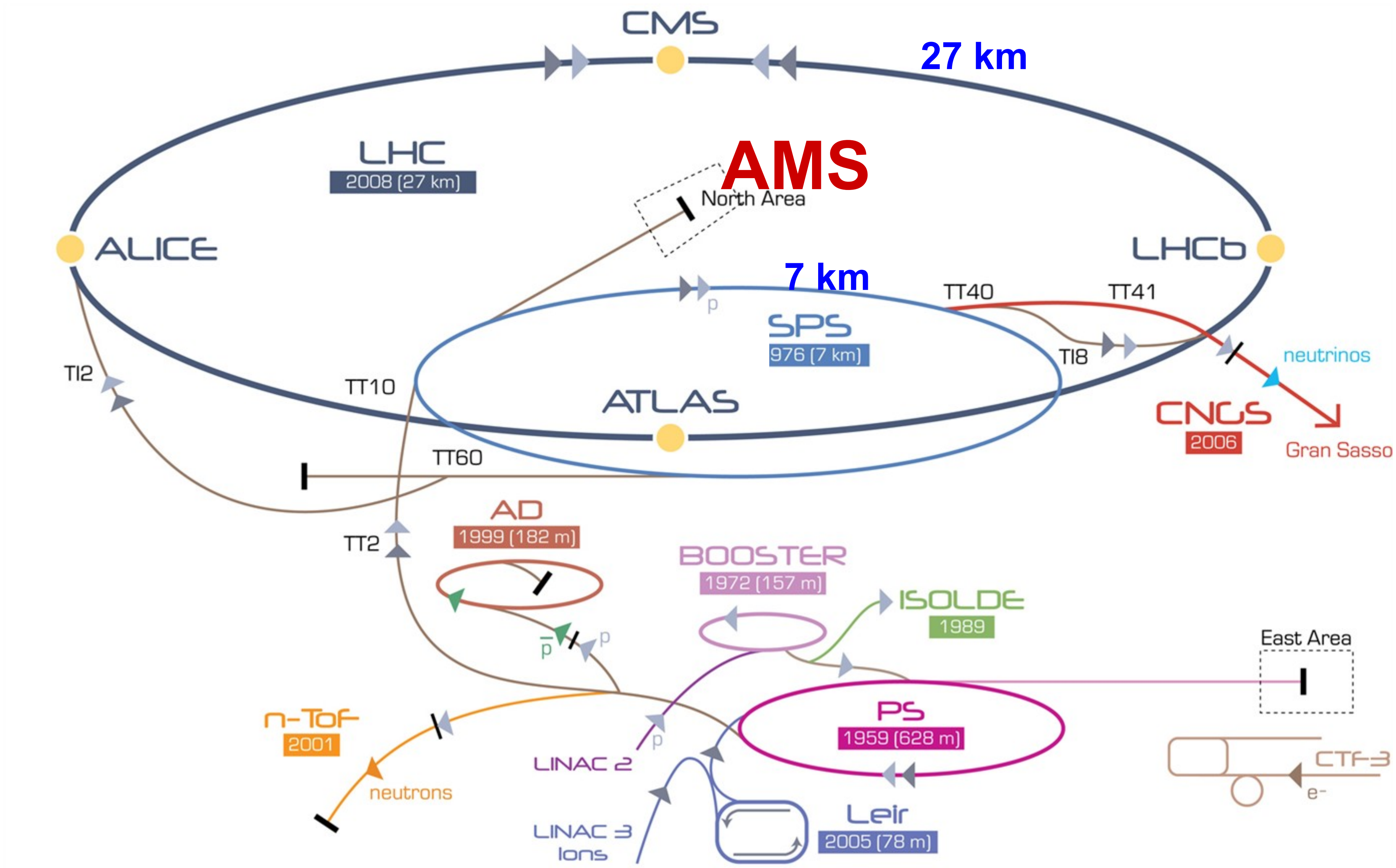
Caused by CO_2 Diffusion

CO_2 Storage at Launch: 5 kg

Leakrate of 5 µg / s corresponds to a

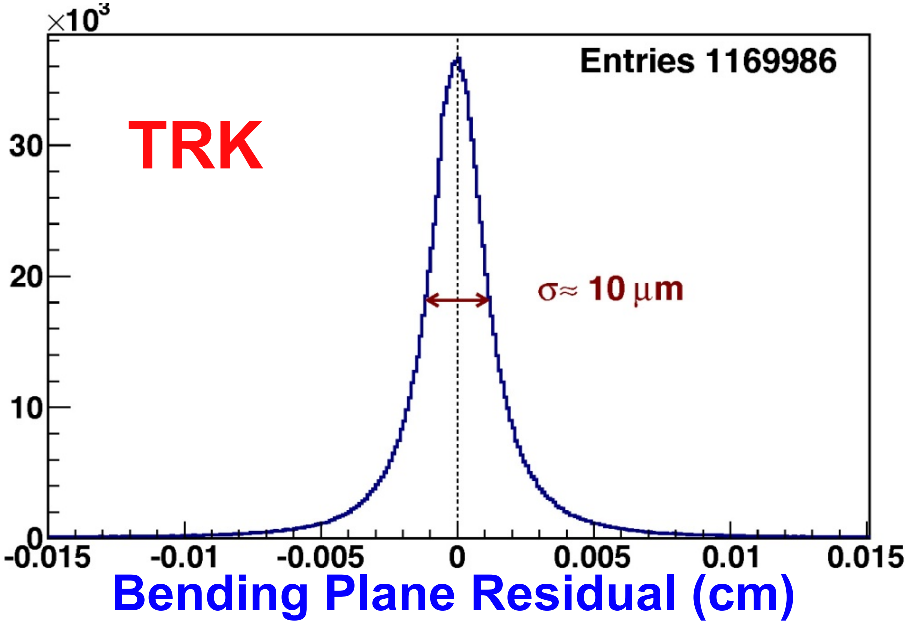
TRD Lifetime of 30 Years

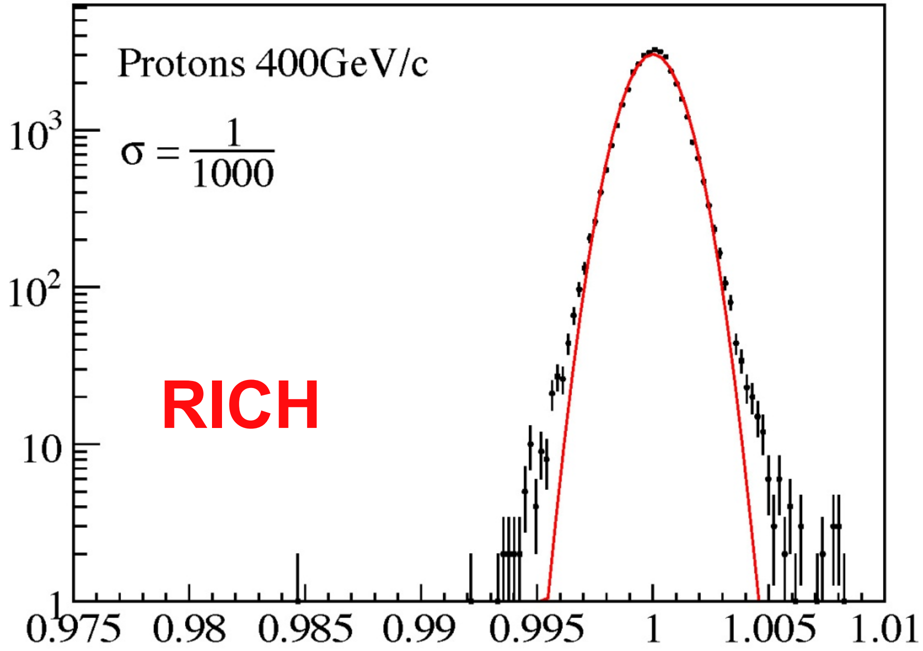
Test at CERN
AMS in accelerator test beam Feb 4-8 and Aug 8-20, 2010

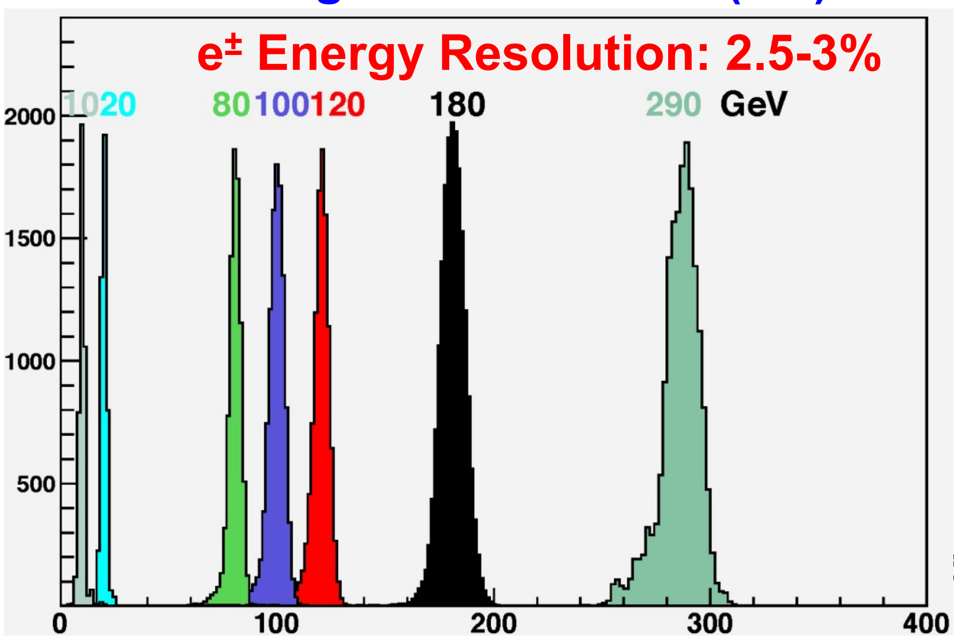


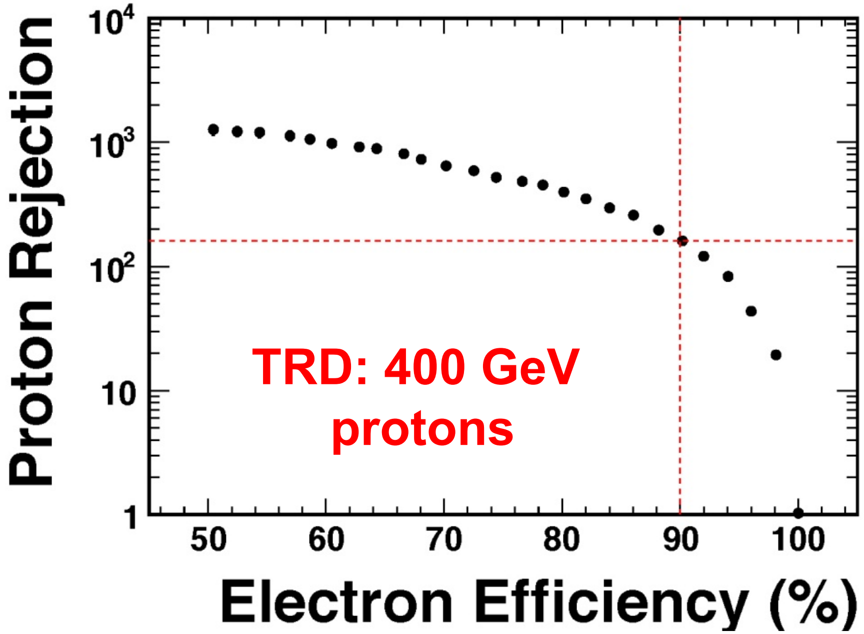
CERN Accelerator Complex

Beam test calibration









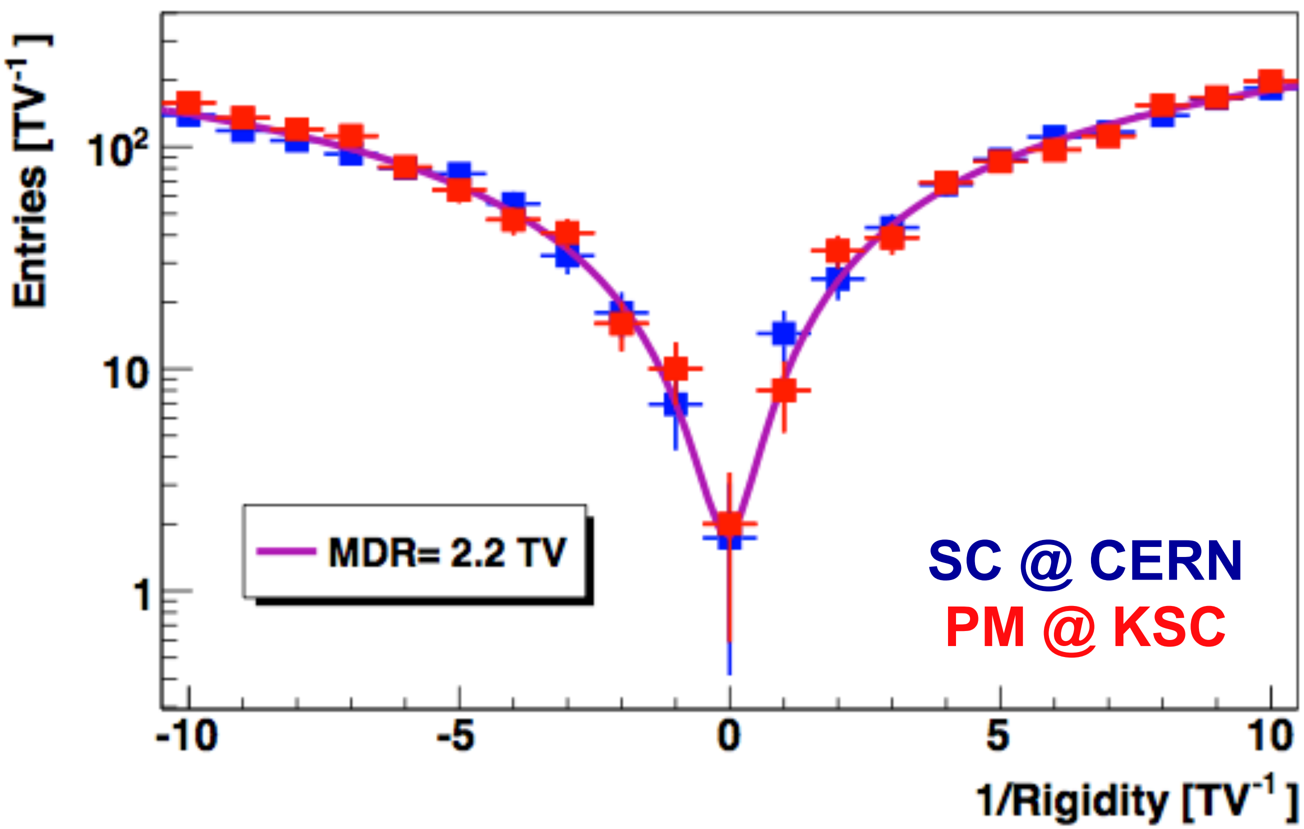
The (long) way to space

Loading of AMS into a US Air Force C5-M at Geneva Airport – 25 Aug 2010

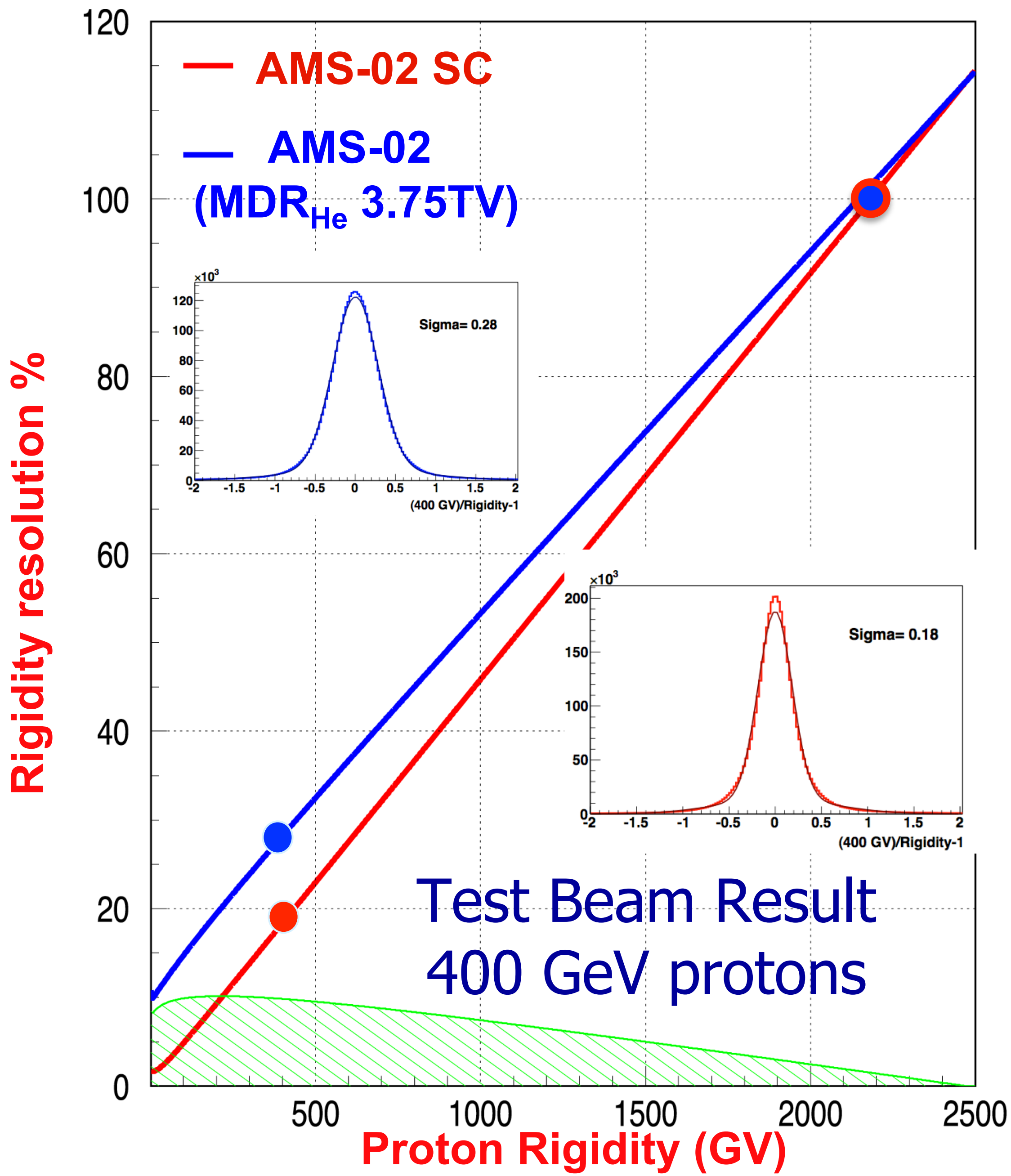
AMS C5 landing on the Shuttle runway at Kennedy Space Center – 26 Aug 2010

AMS in the Space Station Processing Facility (SSPF), ready for installation into the Space Shuttle

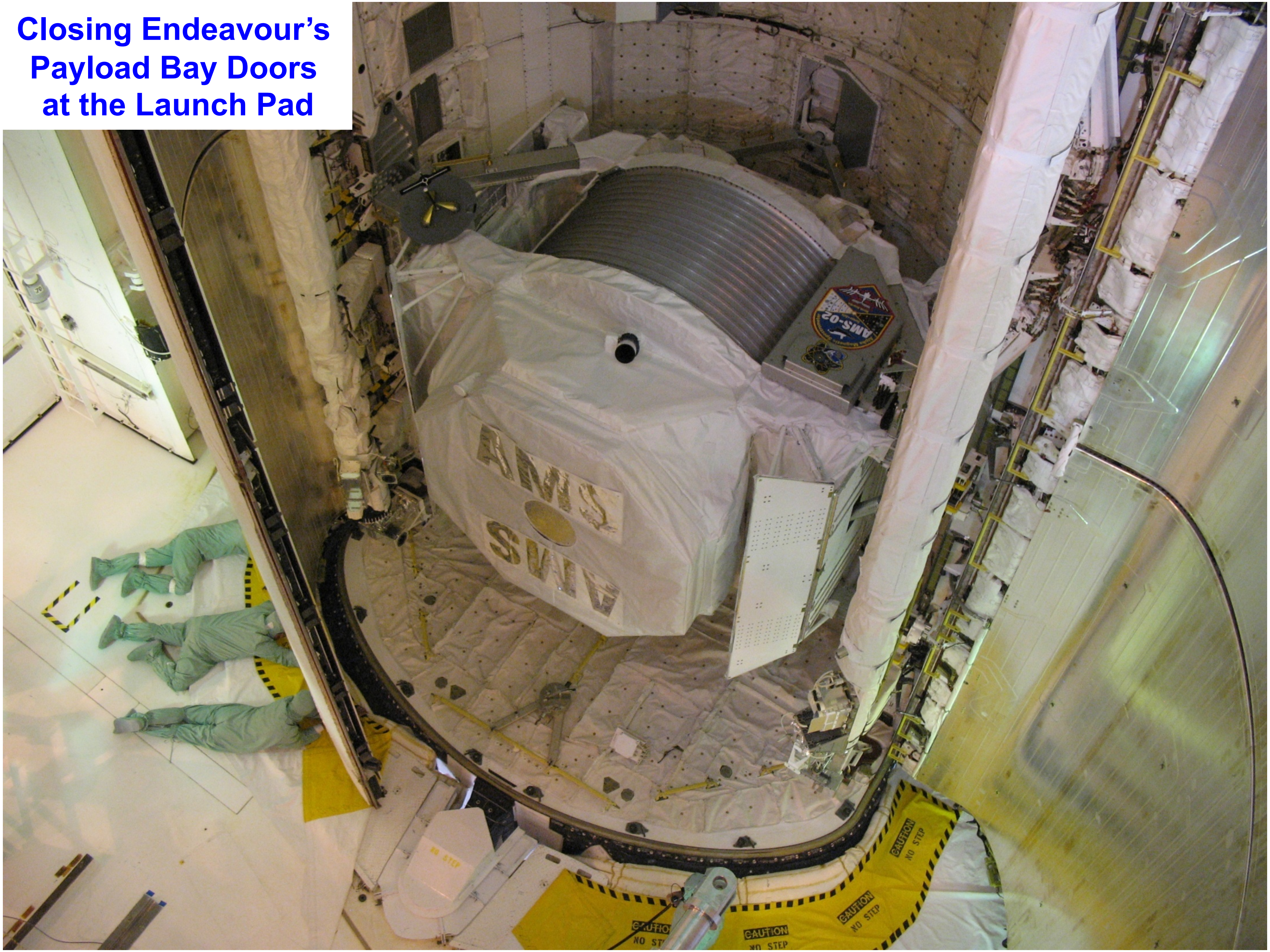
Calibration with muons



Tracker : Rigidity resolution

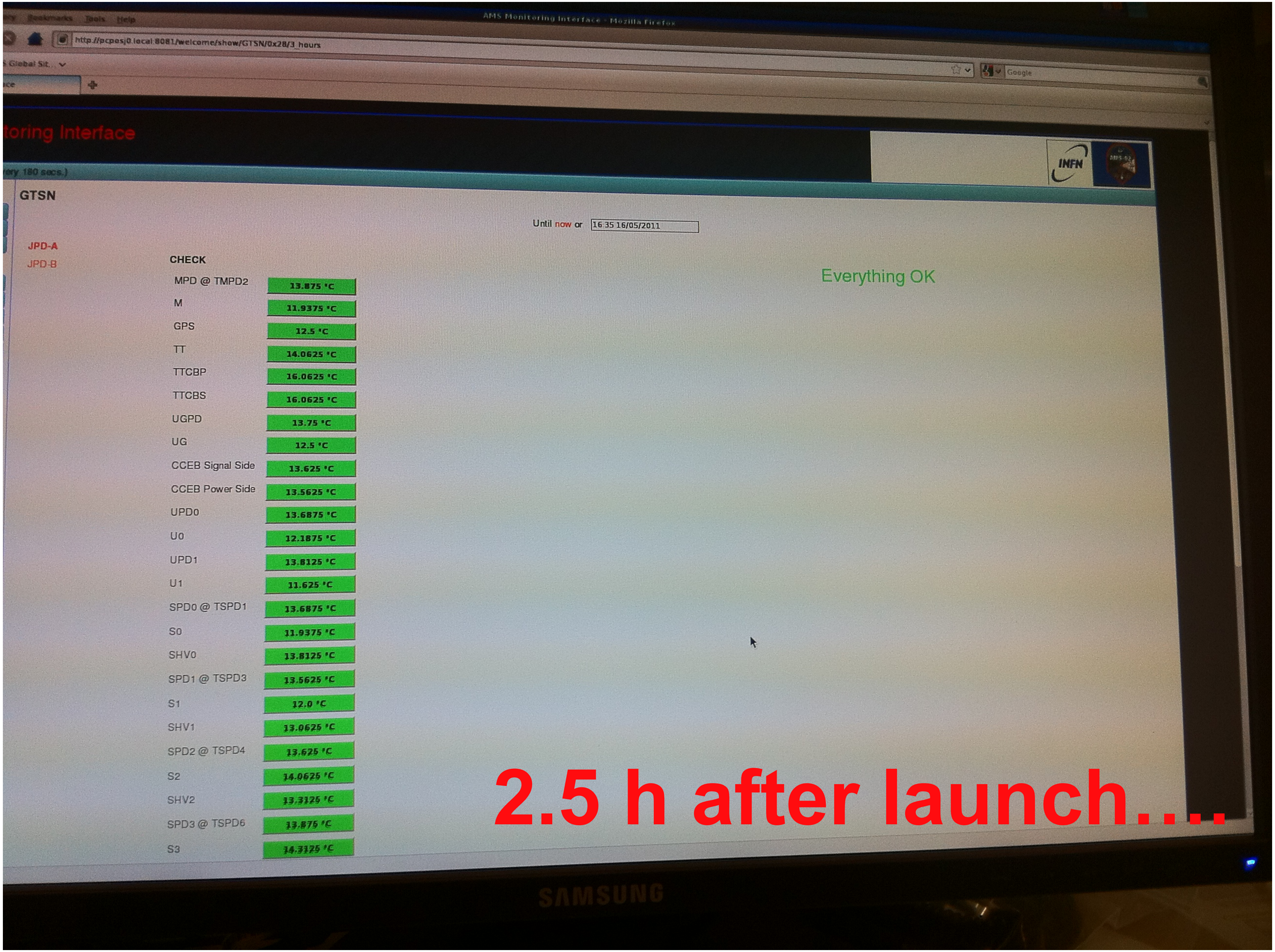


Closing Endeavour's Payload Bay Doors at the Launch Pad



Counting down to the launch of STS-134

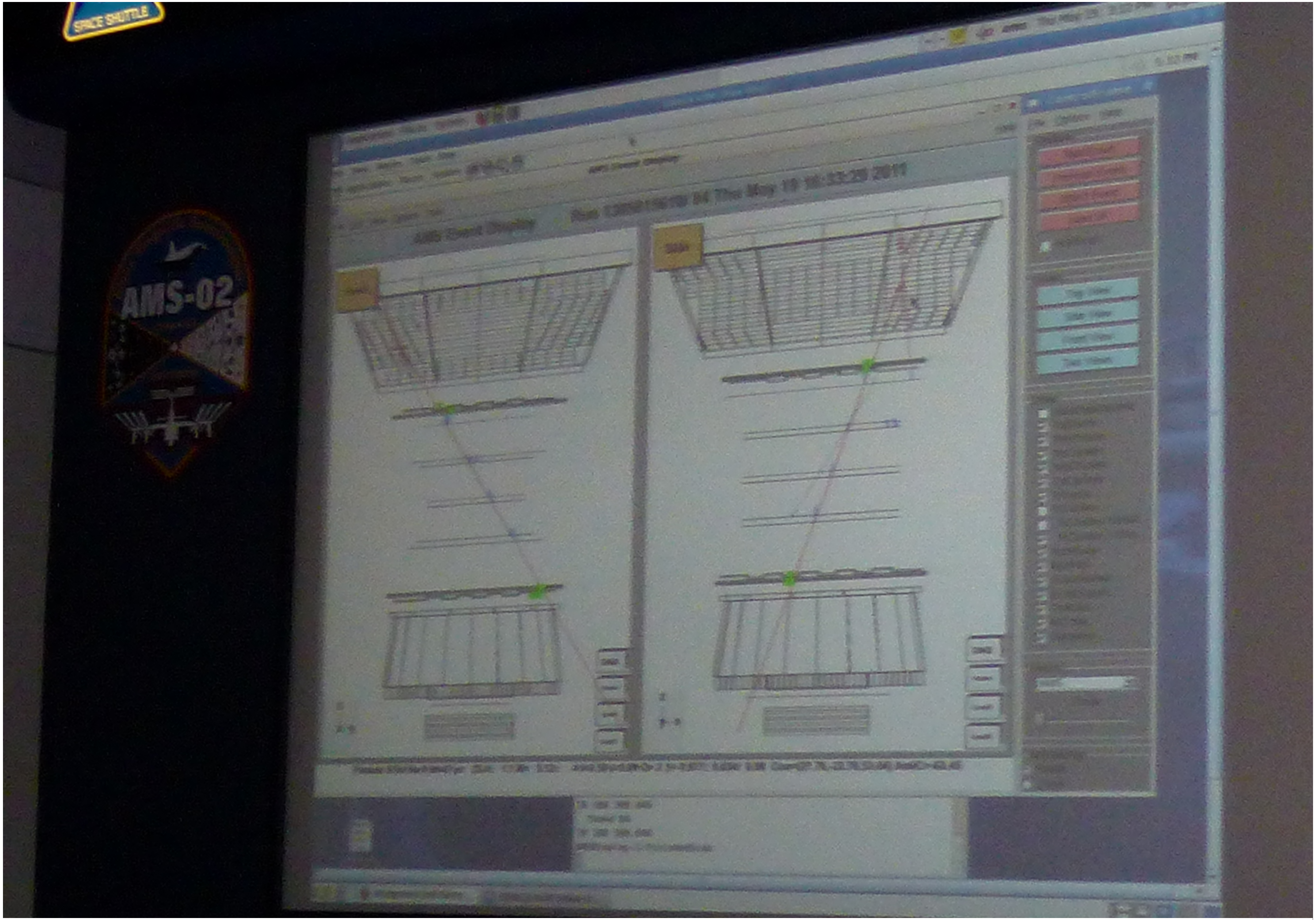
STS-134 launch   May 16, 2011 @ 08:56 AM



2.5 h after launch….

Endeavour approaches the International Space Station

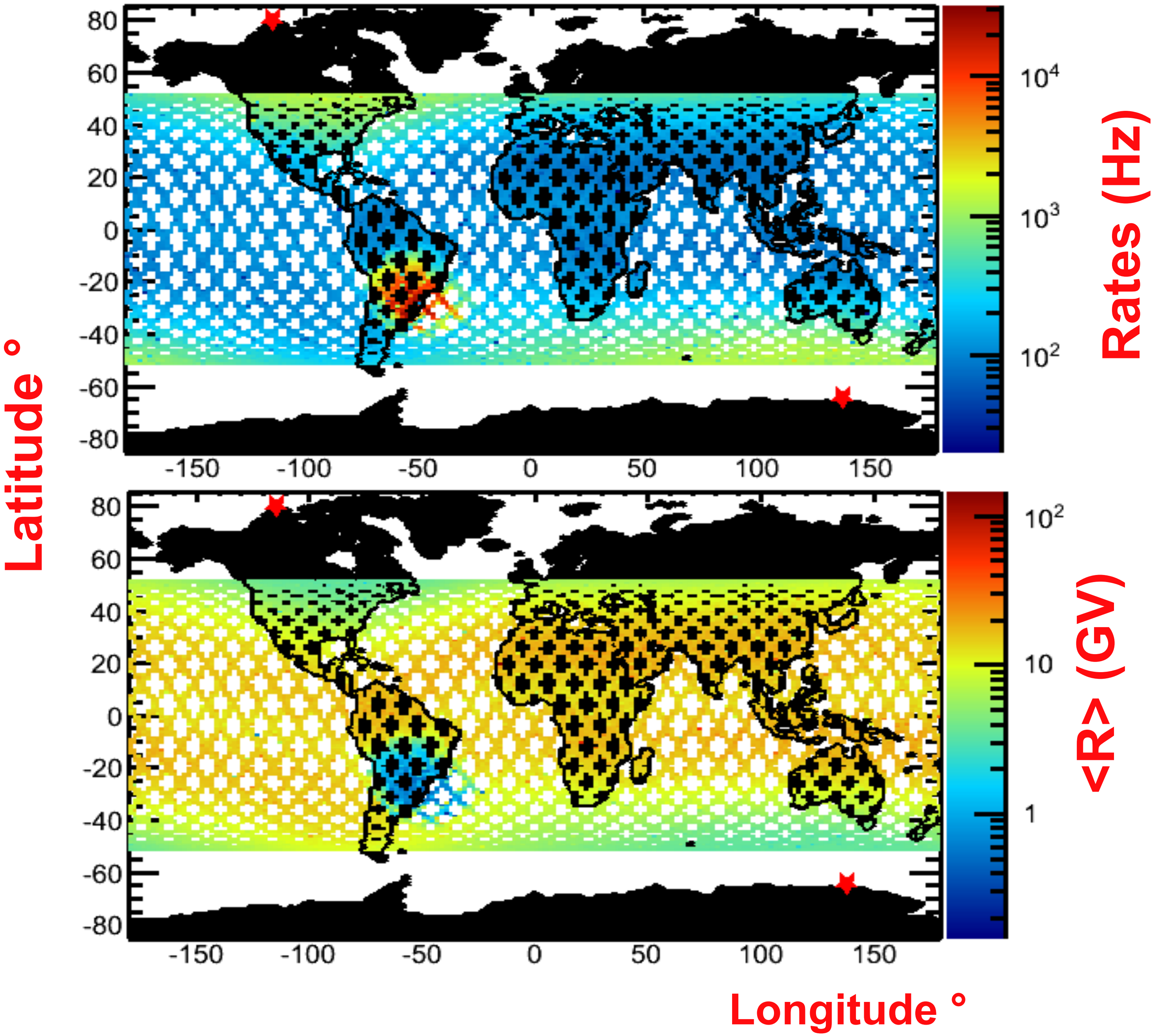
May 19: AMS installed on ISS 5:15 CDT, start taking data 9:35 CDT



One of the Firsts AMS-02 Event in Space as seen in Houston

Experience in flight

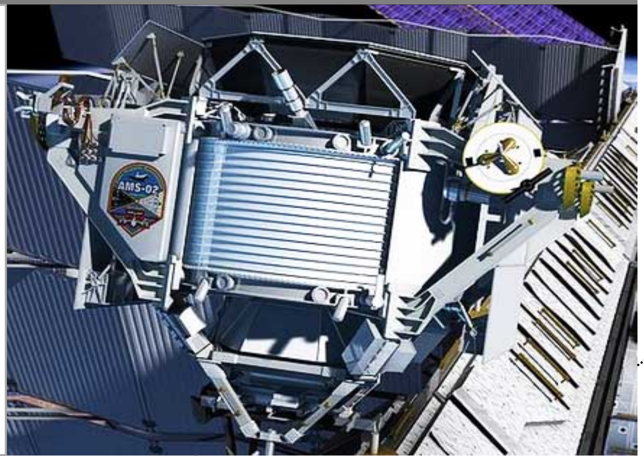
ISS orbit ≈ 390 km, 51.7°, 90 minutes



Science Data Flow

During testing at KSC, on the launch pad and on the ISS

AMS



POCC network (KSC only)

NASA channels

Internet

KSC, FL

AMS POCC (August 2010 to May 2011)

JSC, TX

AMS POCC, (February-June 2011) now backup POCC for CERN POCC

MSFC POIC, AL

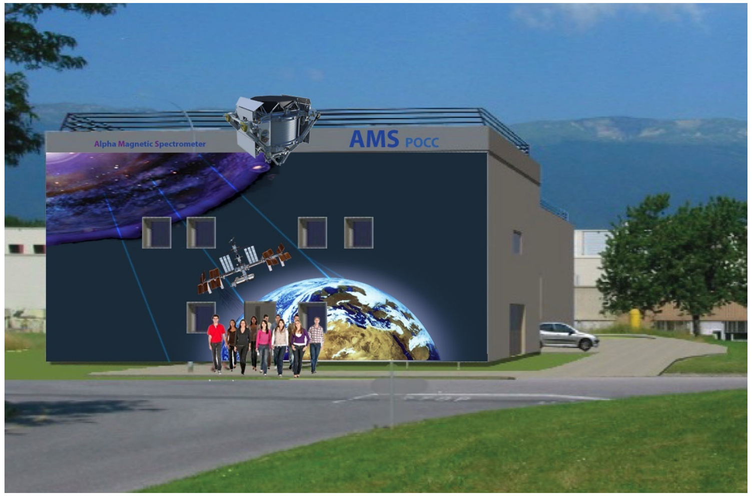
AMS GSC

CERN

AMS POCC Main operations centre (from June 23, 2011)

AMS POCC at CERN for the lifetime of the ISS

Nov. 2010

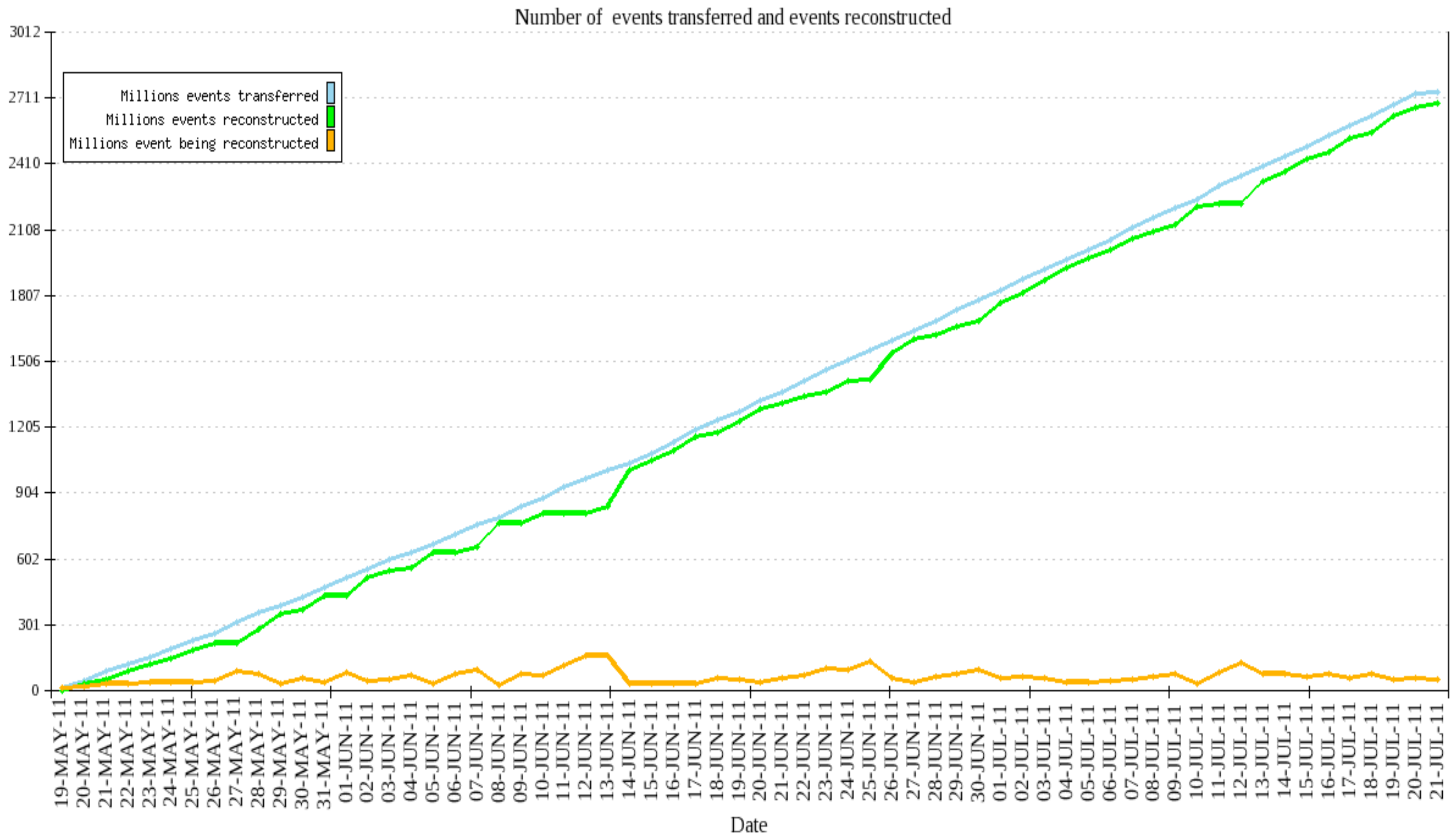


Jun.23, 2011

Jun.23, 2011

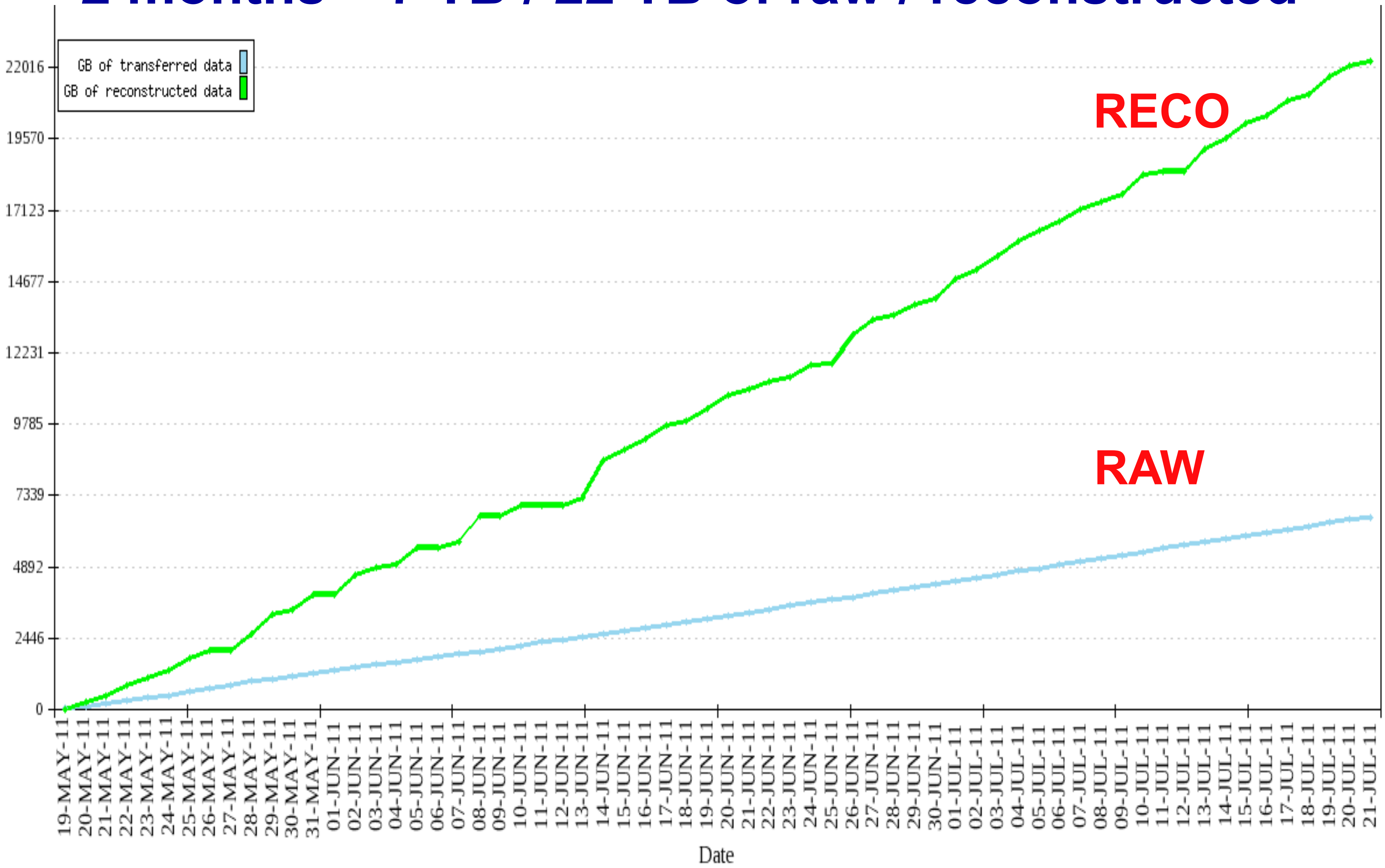
Collected and Reconstructed events

2 months ≈ 2.5 10^9 events

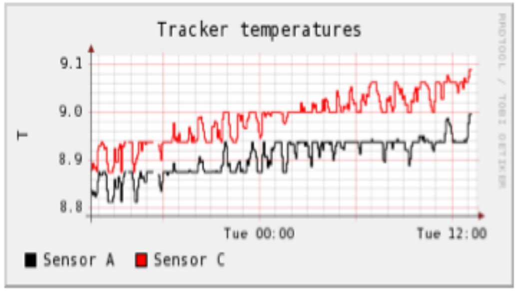


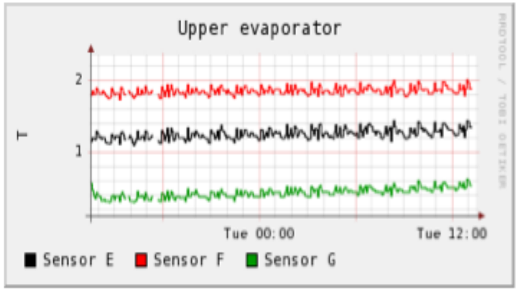
Collected data

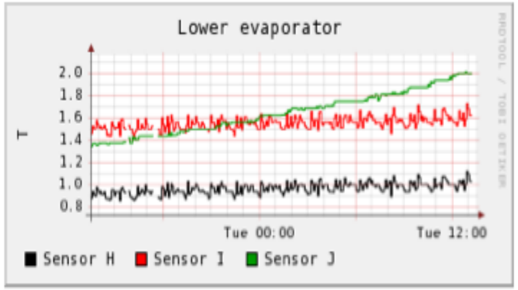
2 months ≈ 7 TB / 22 TB of raw / reconstructed

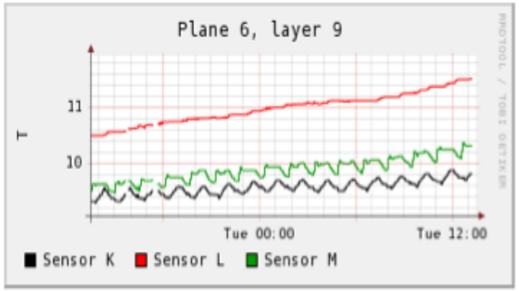


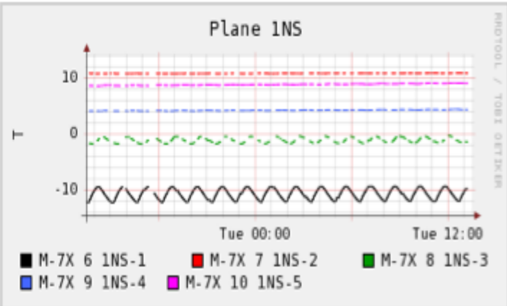
In flight experience: Tracker cooling and currents

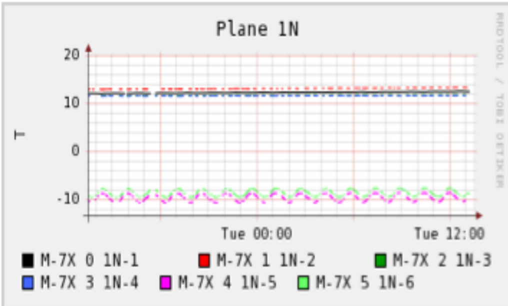


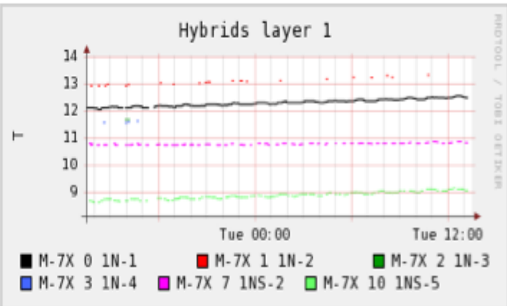


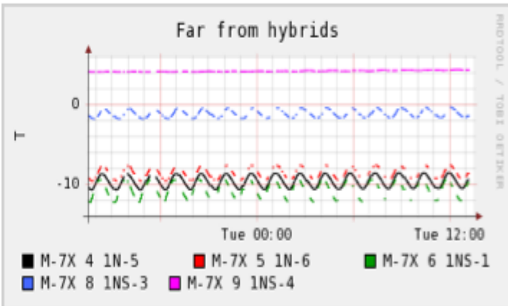


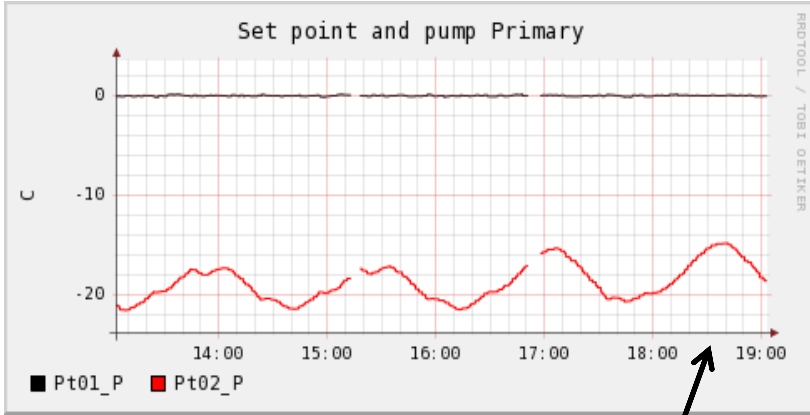






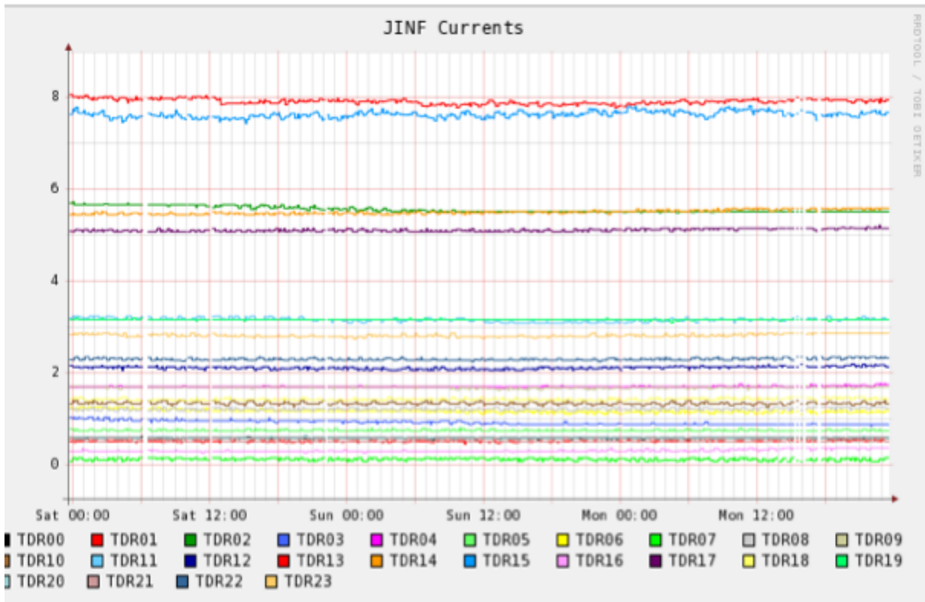




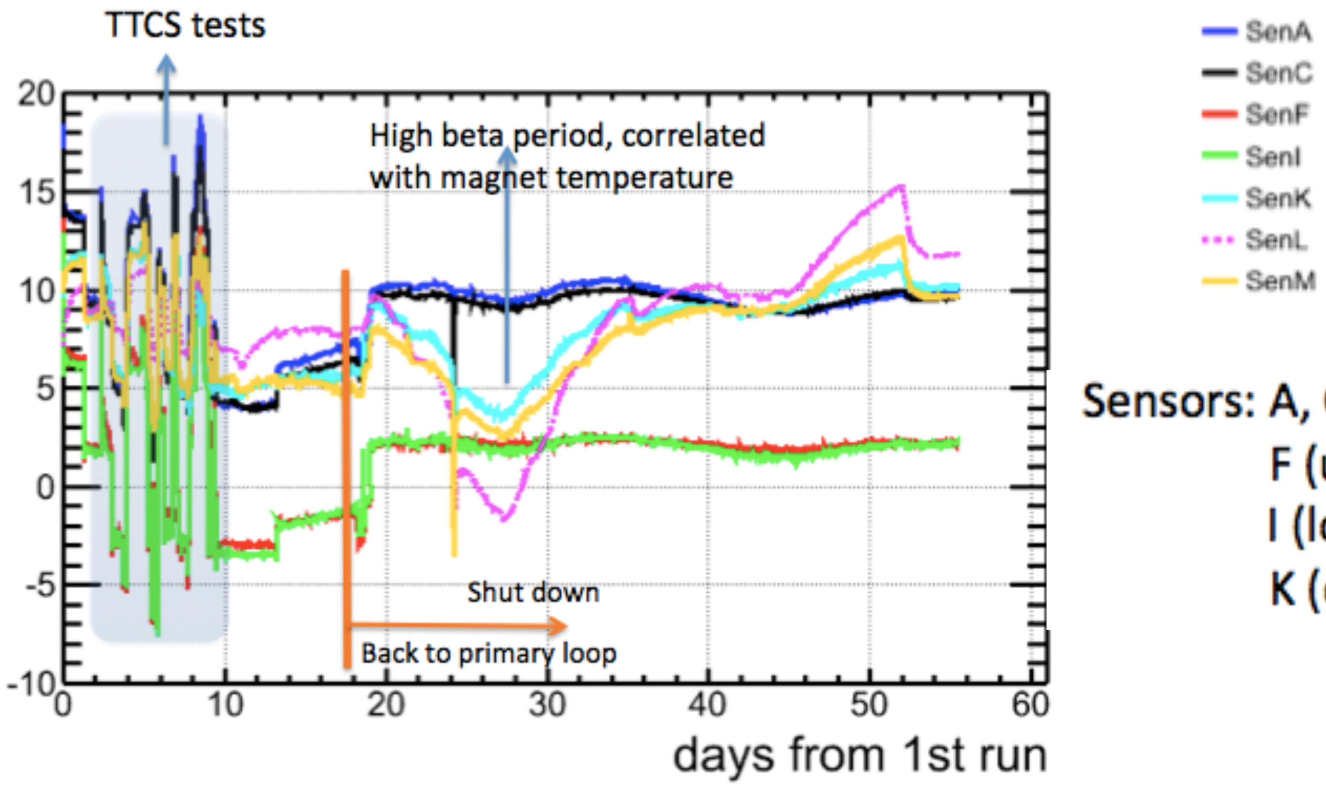


✓Tracker and TTCS temperatures

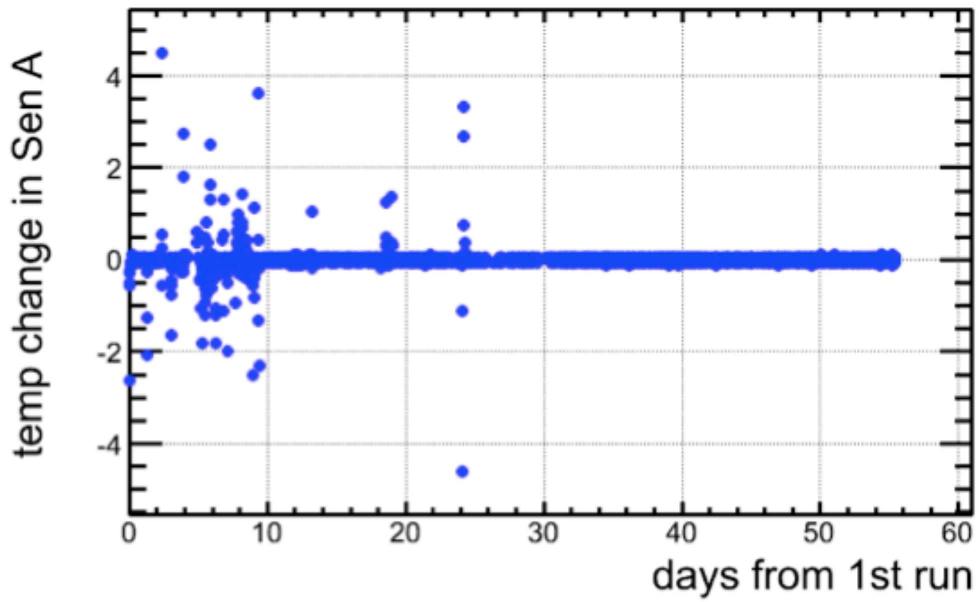
✓Crates and TDRs currents



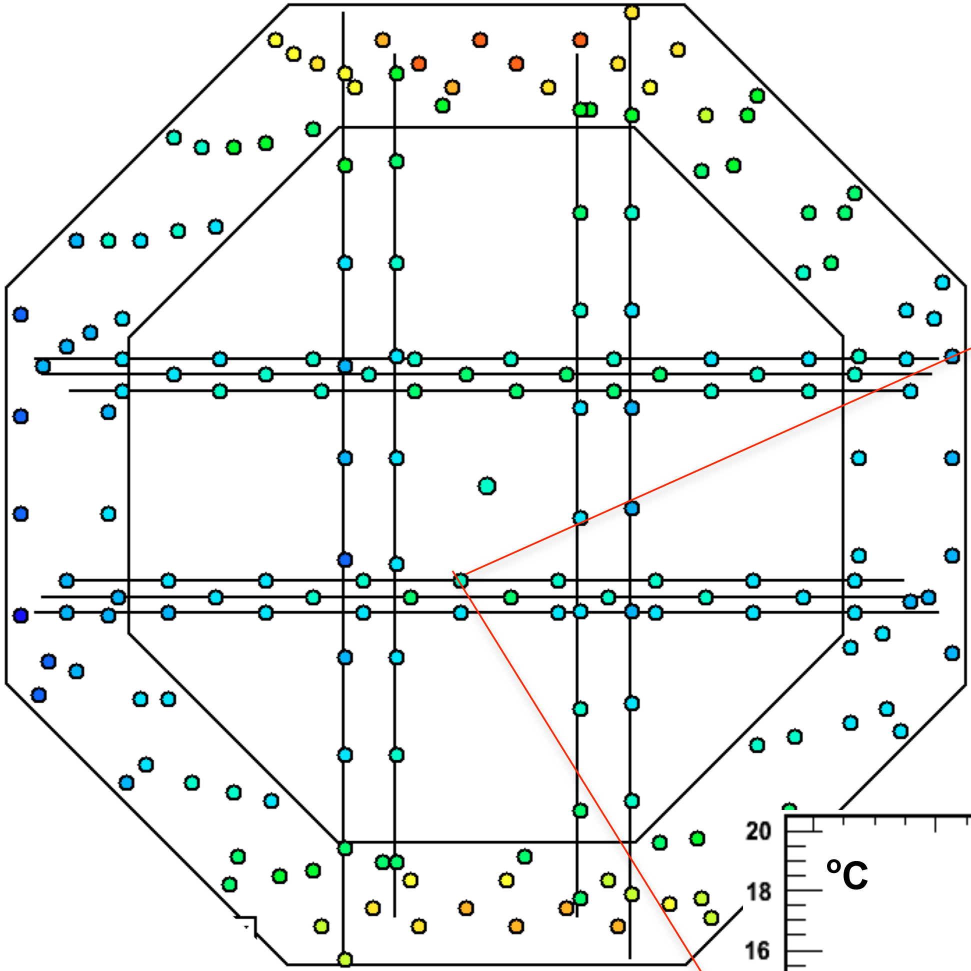
TRACKER THERMAL STABILITY : OK

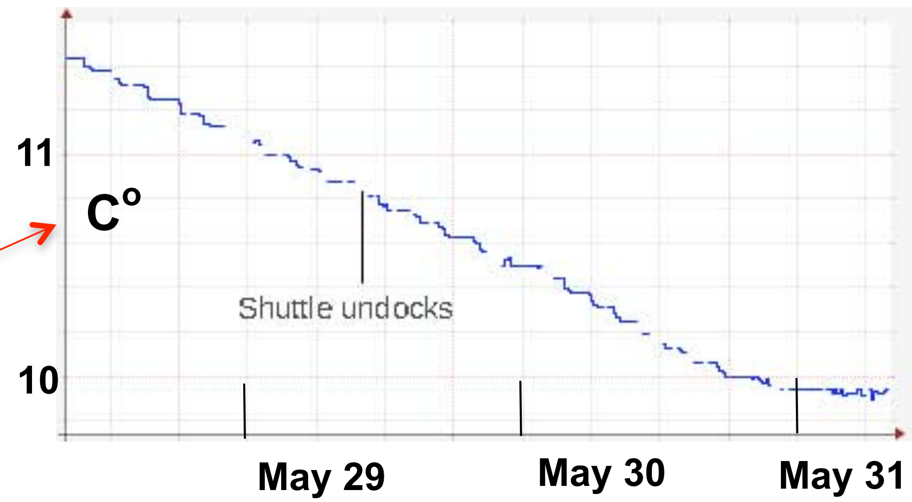


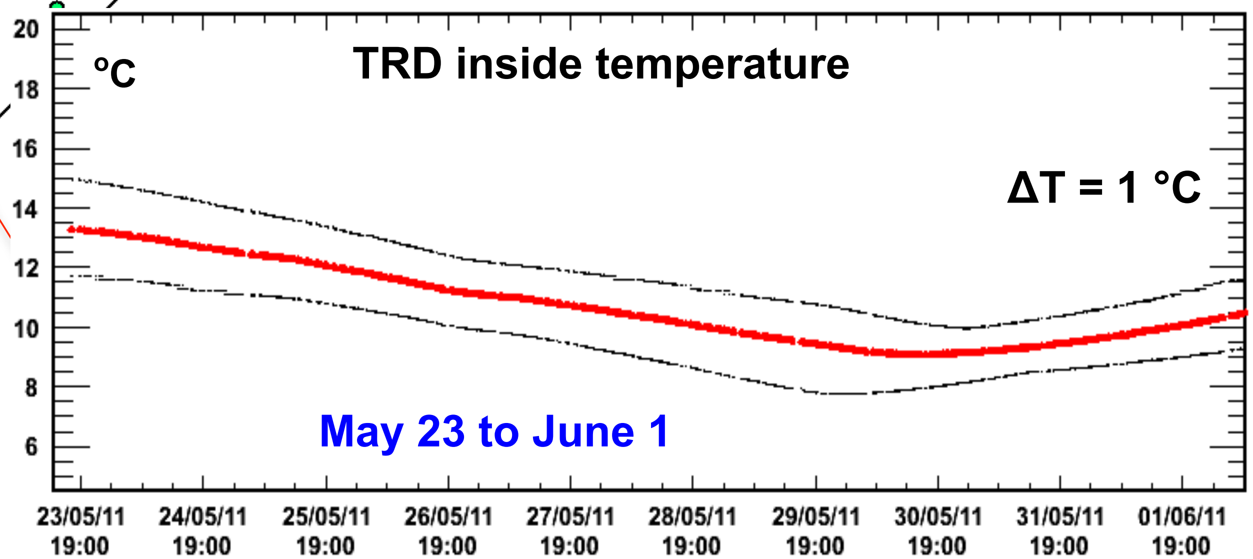
Sensors: A, C (inner tracker)
F (upper evaporator)
I (lower evaporator)
K (on thermal bars), M, L (layer 9)



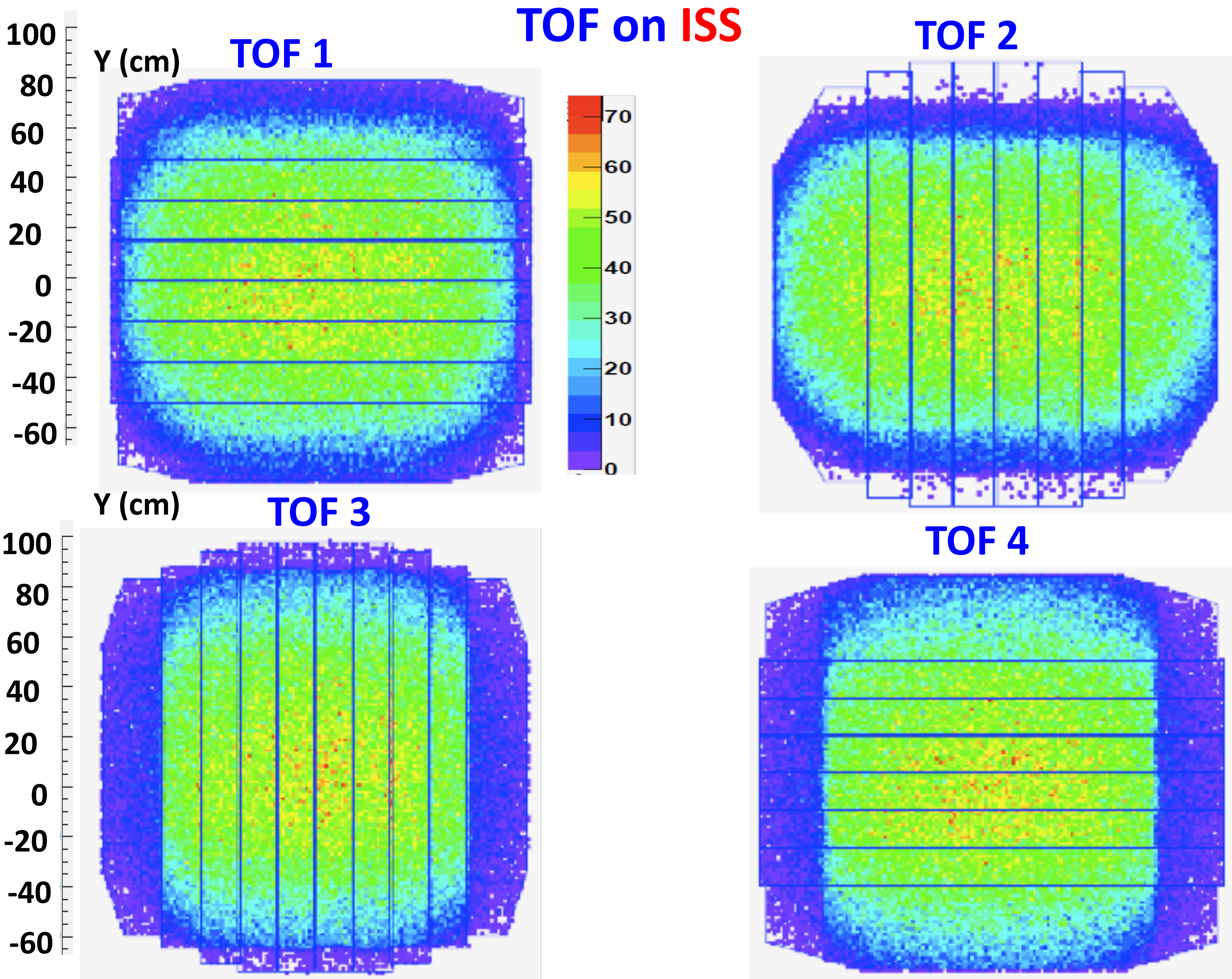
TRD Temperature Monitoring on ISS, to be within ±2C°





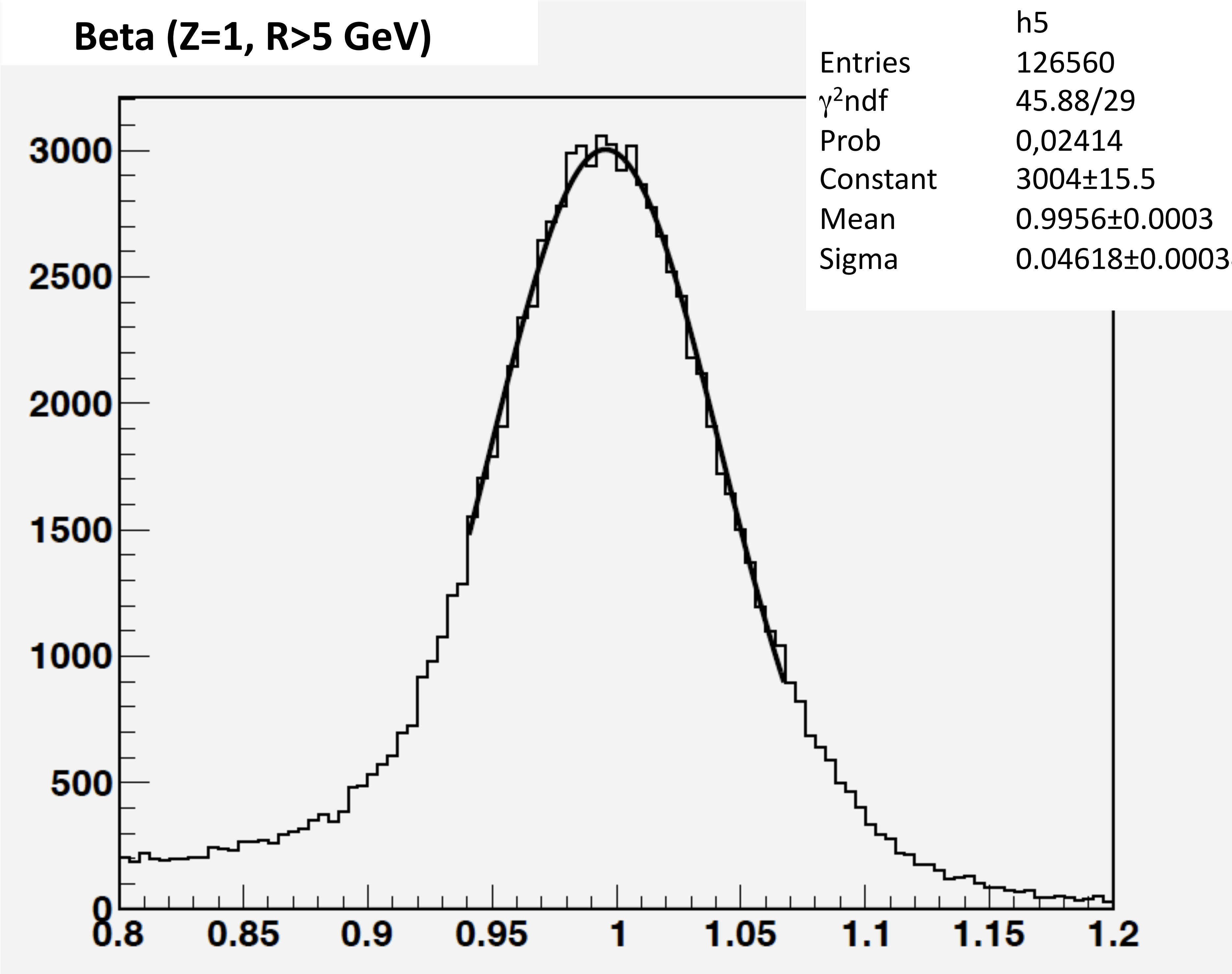


AMS data on ISS



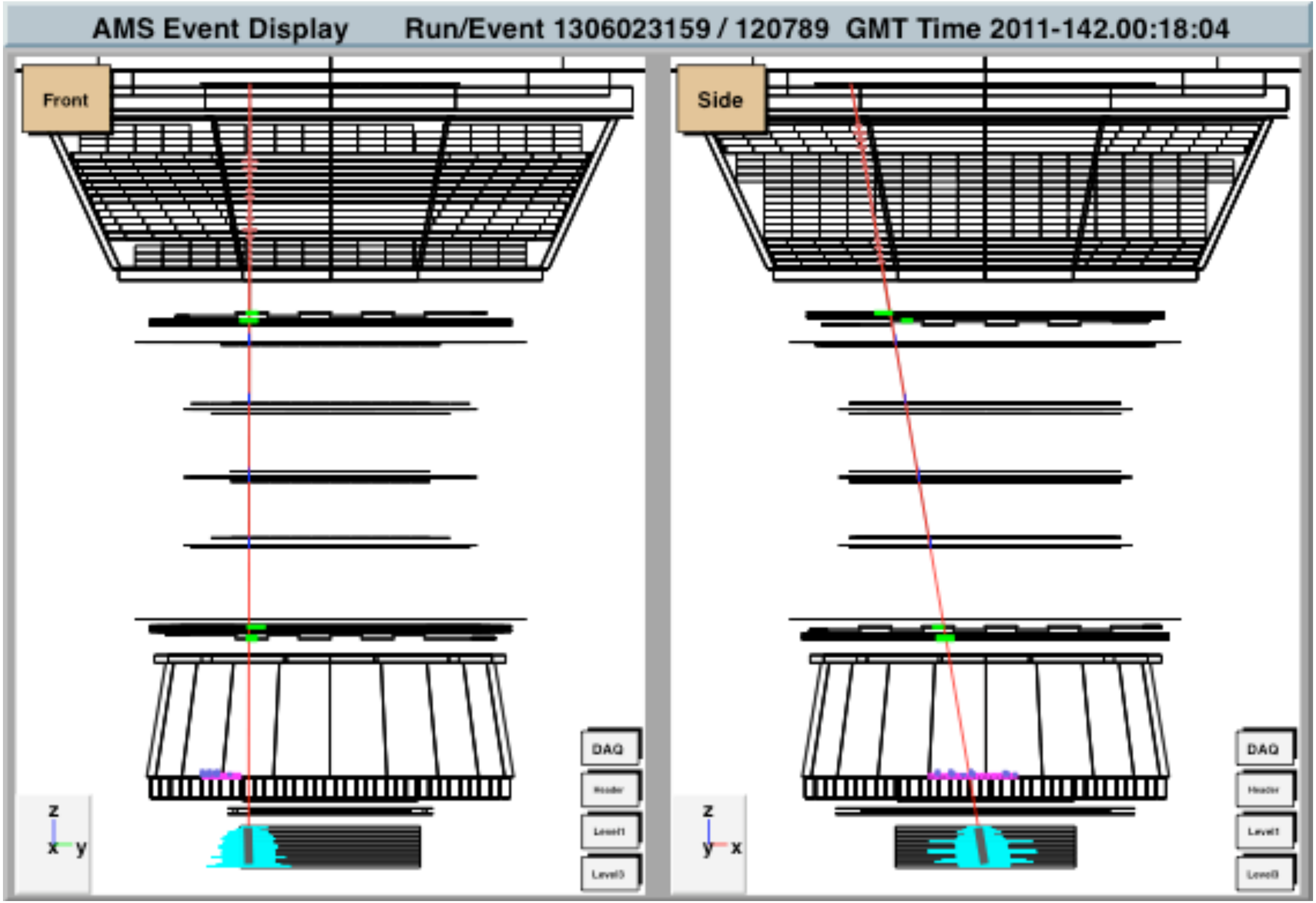
TOF on ISS
TOF 1
TOF 2
TOF 3
TOF 4
Y (cm)
Y (cm)
100
80
60
40
20
0
-20
-40
-60
70
60
50
40
30
20
10
0

Beta (Z=1, R>5 GeV)

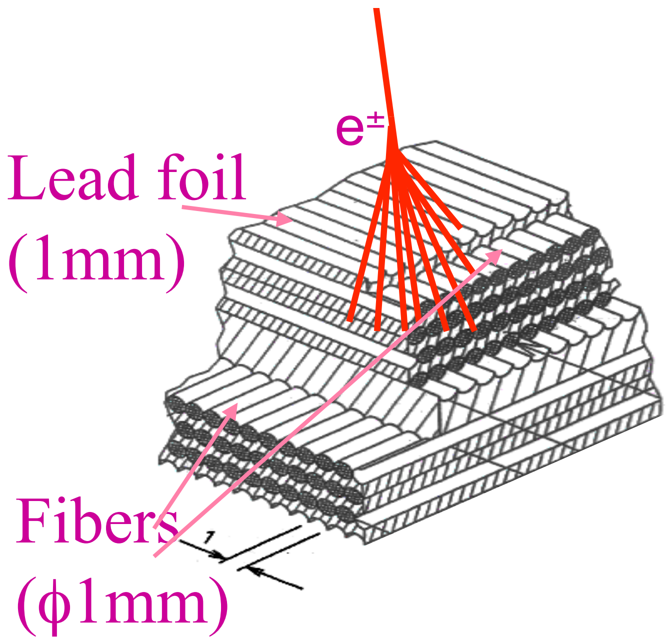


AMS data on ISS

Electron 240 GeV, 22 May

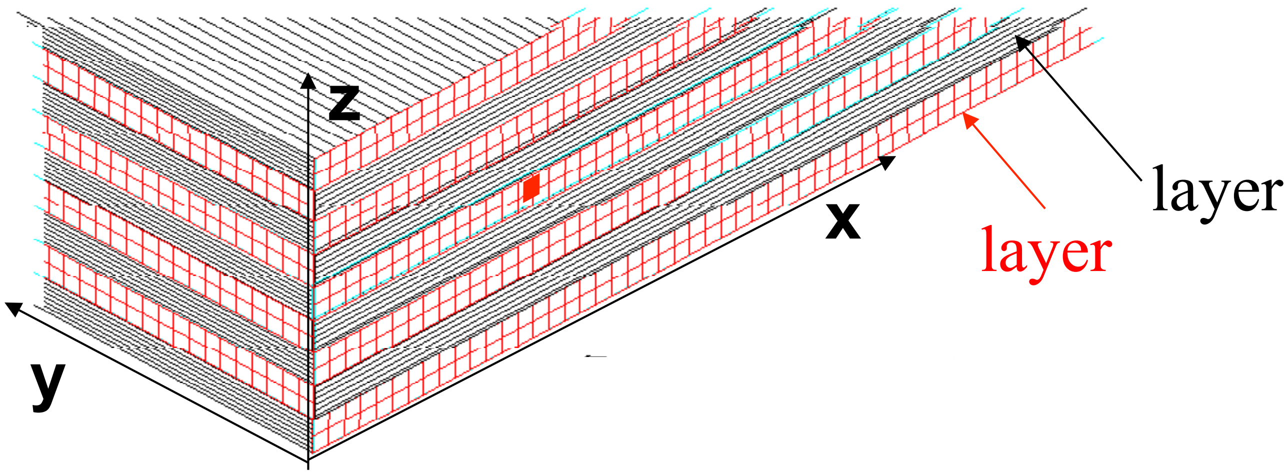


Calorimeter (ECAL) 3D Sampling of Showers

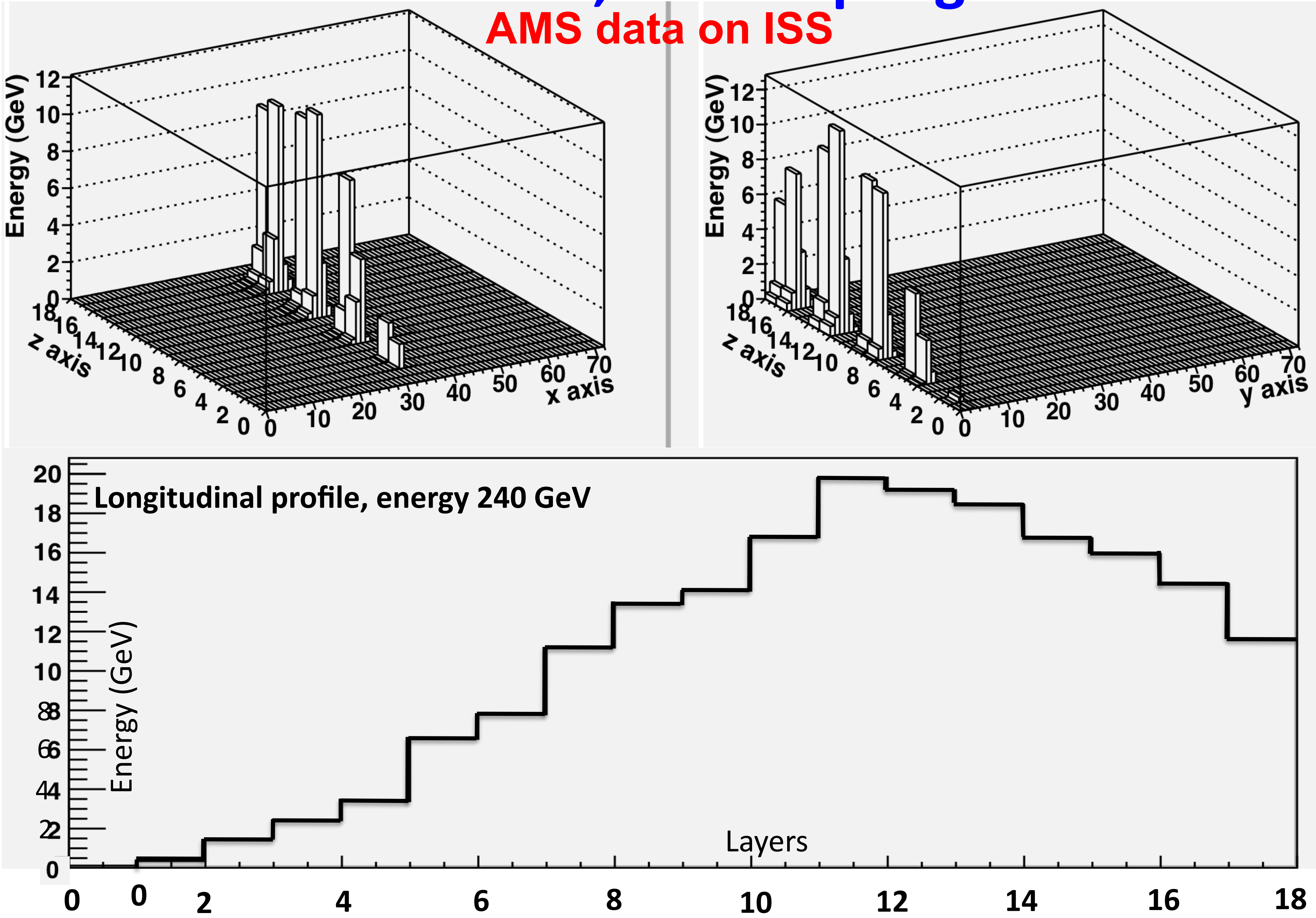


18 longitudinal samplings (9 groups of 2 layers)

Readout cell dimensions: Z (9 mm), X (9 mm), Y (9 mm)

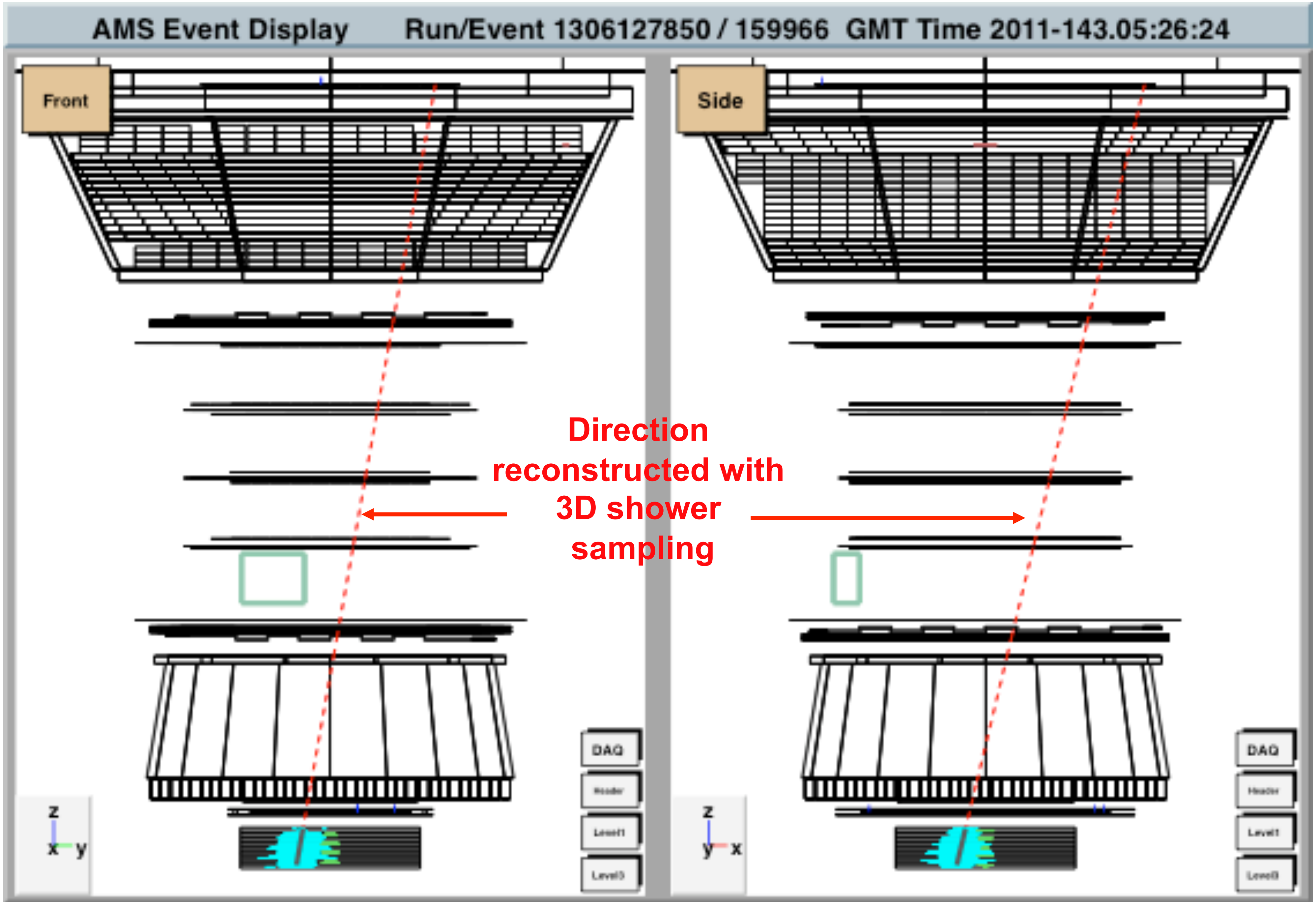


240 GeV Electron, 3D Sampling of Shower



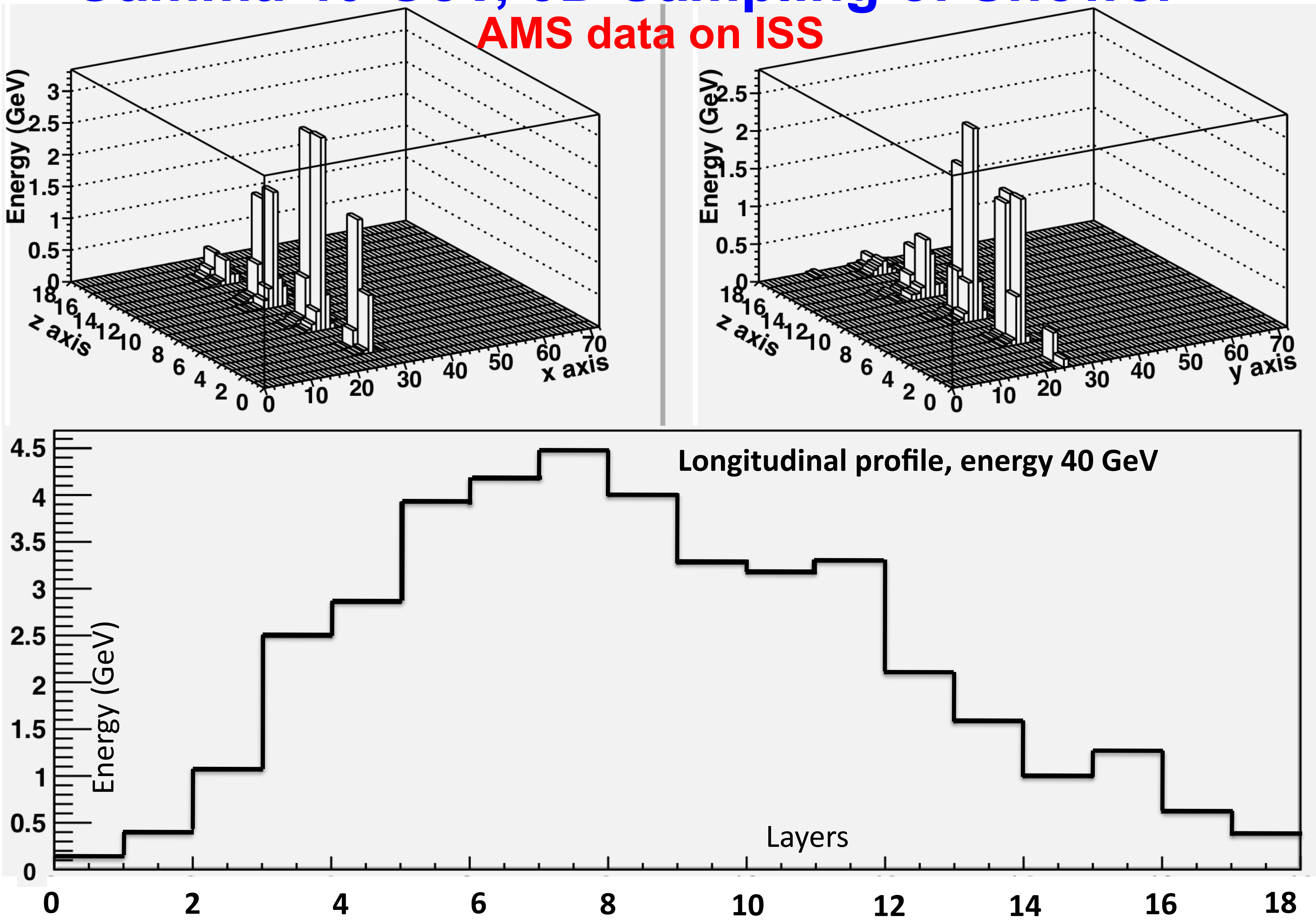
AMS data on ISS

Photon 40 GeV, 23 May



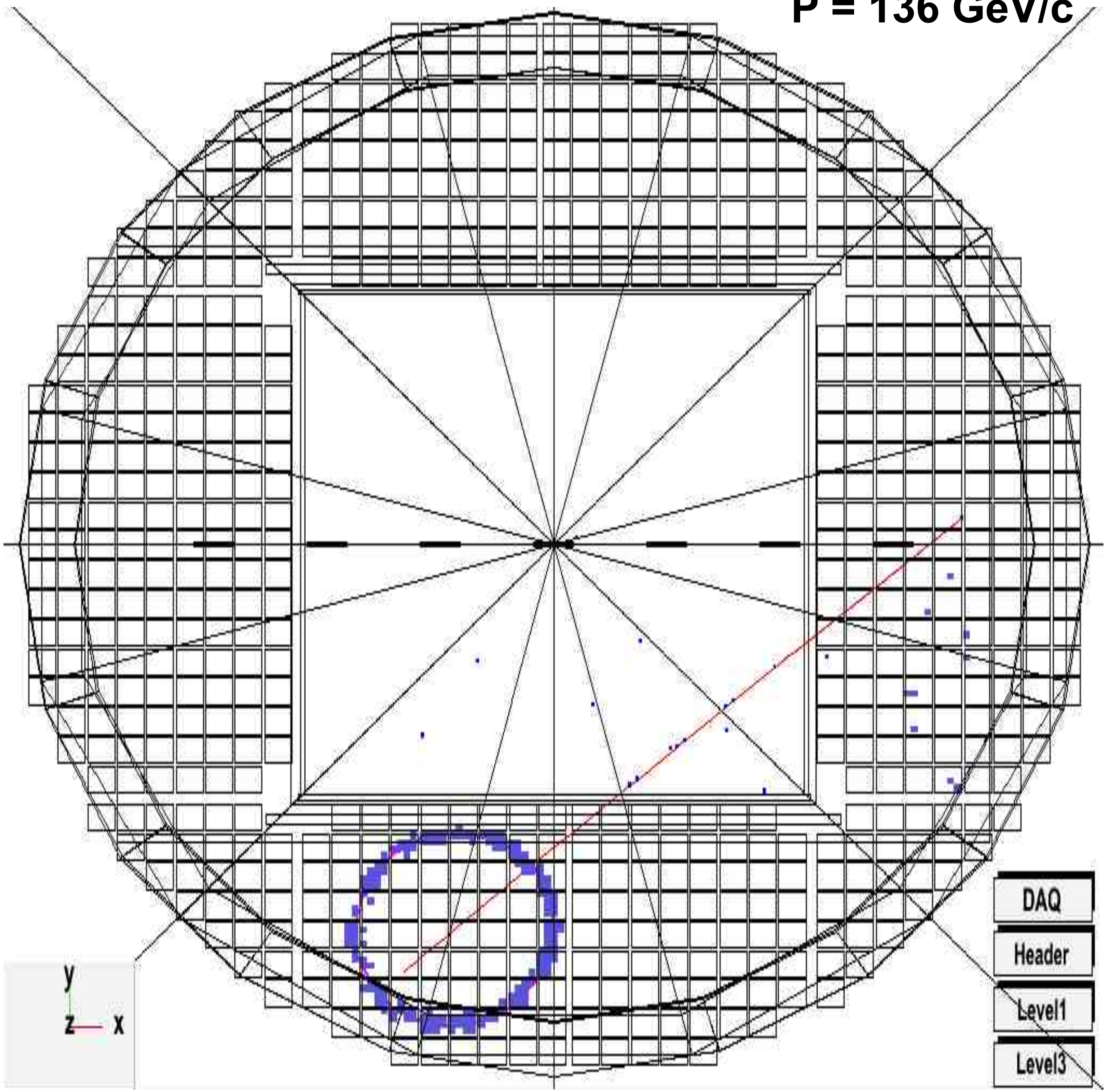
Gamma 40 GeV, 3D Sampling of Shower

AMS data on ISS



AMS data on ISS

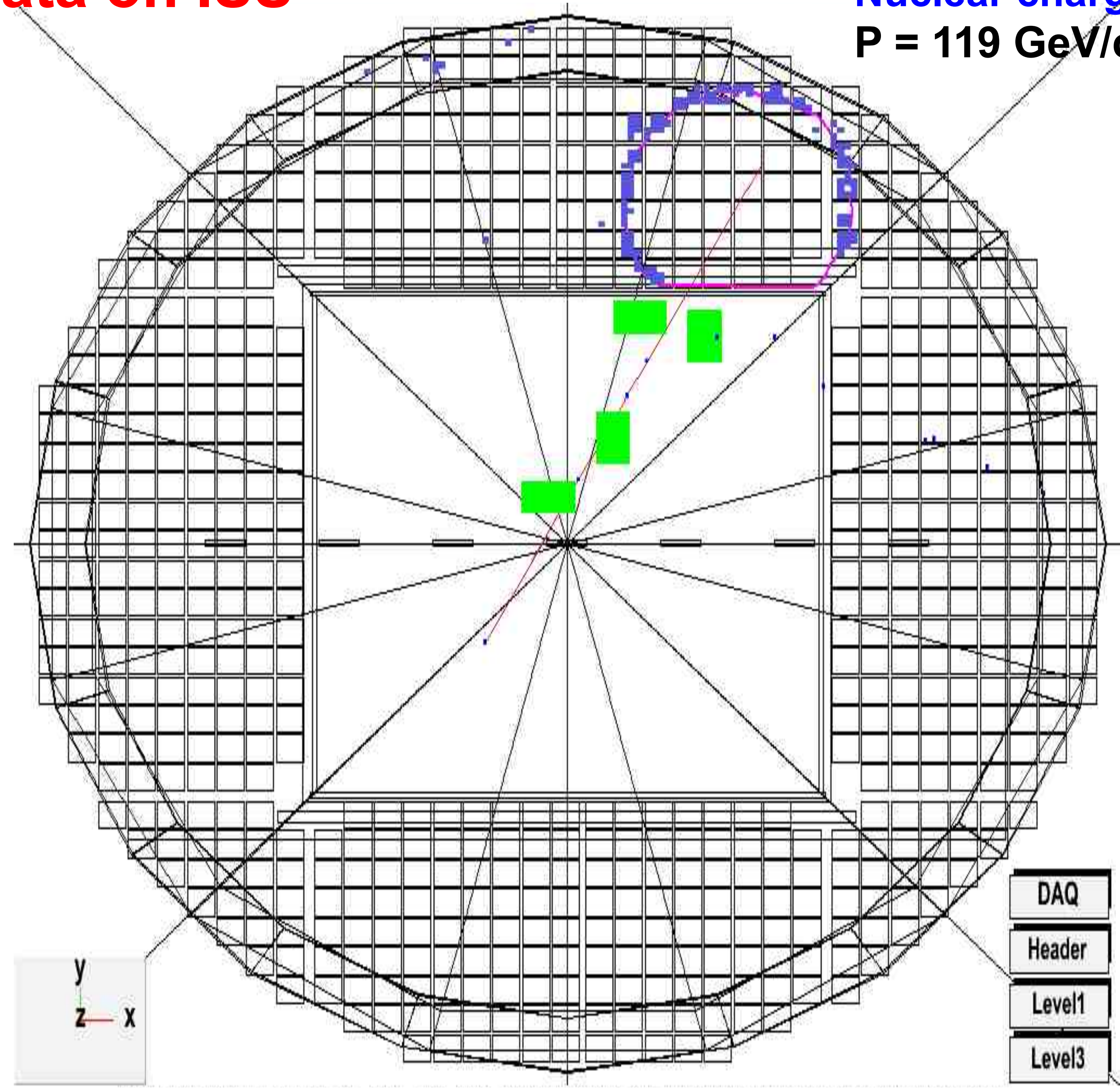
Nuclear charge Z=14, Si
P = 136 GeV/c

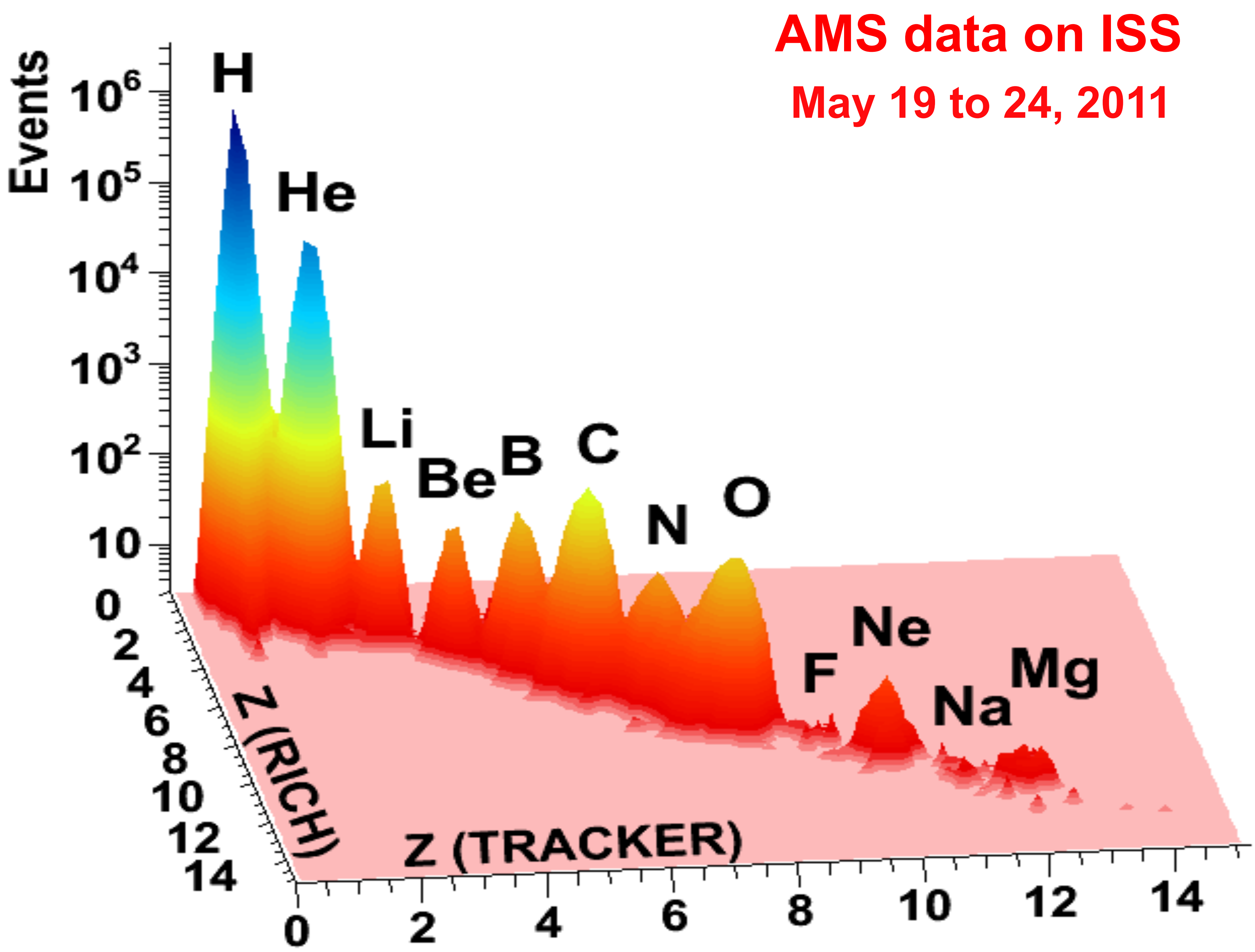


AMS data on ISS

Nuclear charge **Z=8, O**

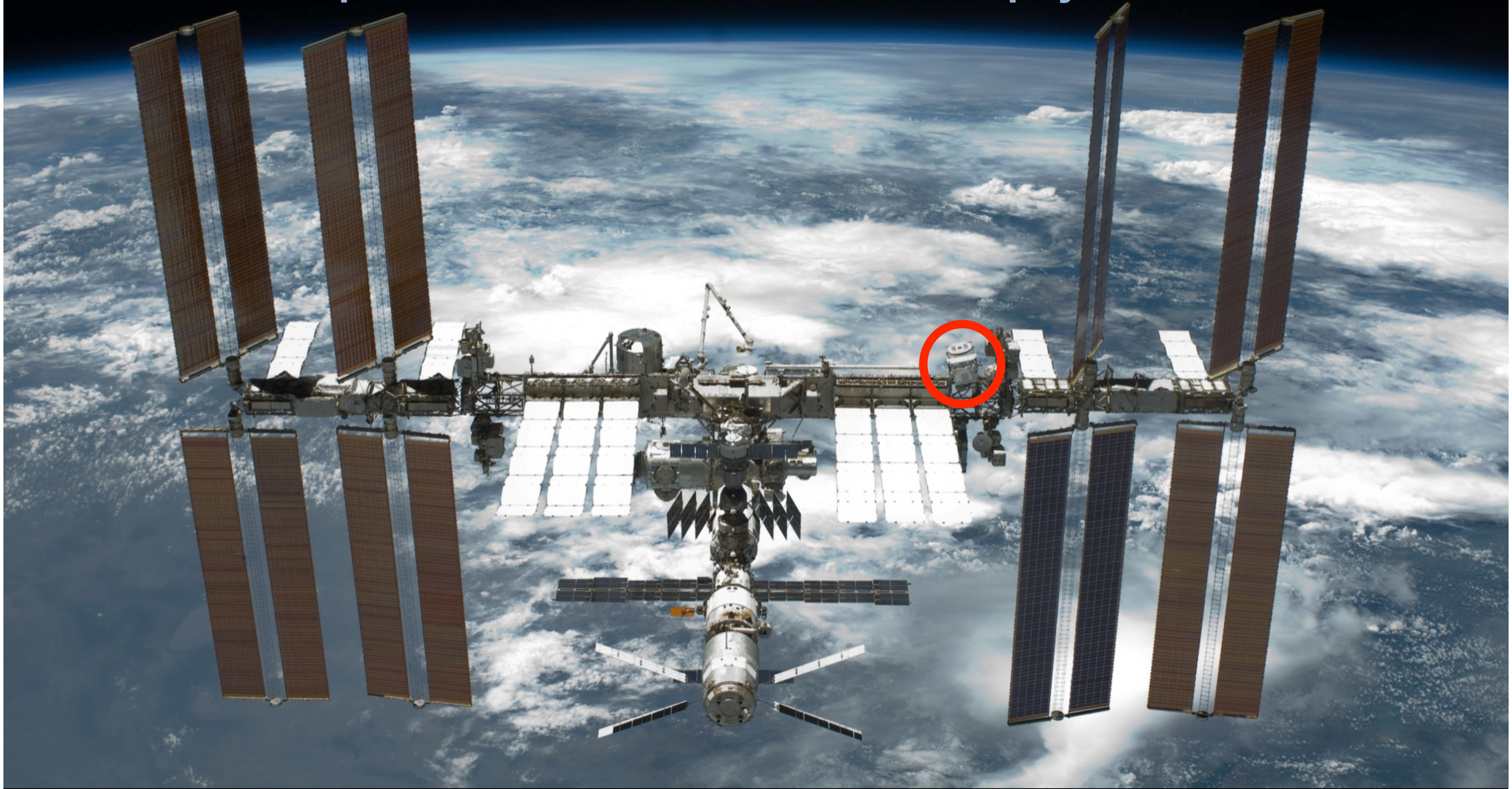
P = 119 GeV/c




AMS data on ISS
May 19 to 24, 2011
Events
10^6
10^5
10^4
10^3
10^2
10
0
H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Z (RICH)
Z (TRACKER)
0
2
4
6
8
10
12
14

The Cosmos is the Ultimate Laboratory.

The issues of antimatter in the universe and the origin of Dark Matter probe the foundations of modern physics.



AMS is the only large scientific experiment to study these issues in space.

Backup slides

SC → PM
Change in the tracker geometry