The AMS-02 Detector: Design and Operation onboard the International Space Station

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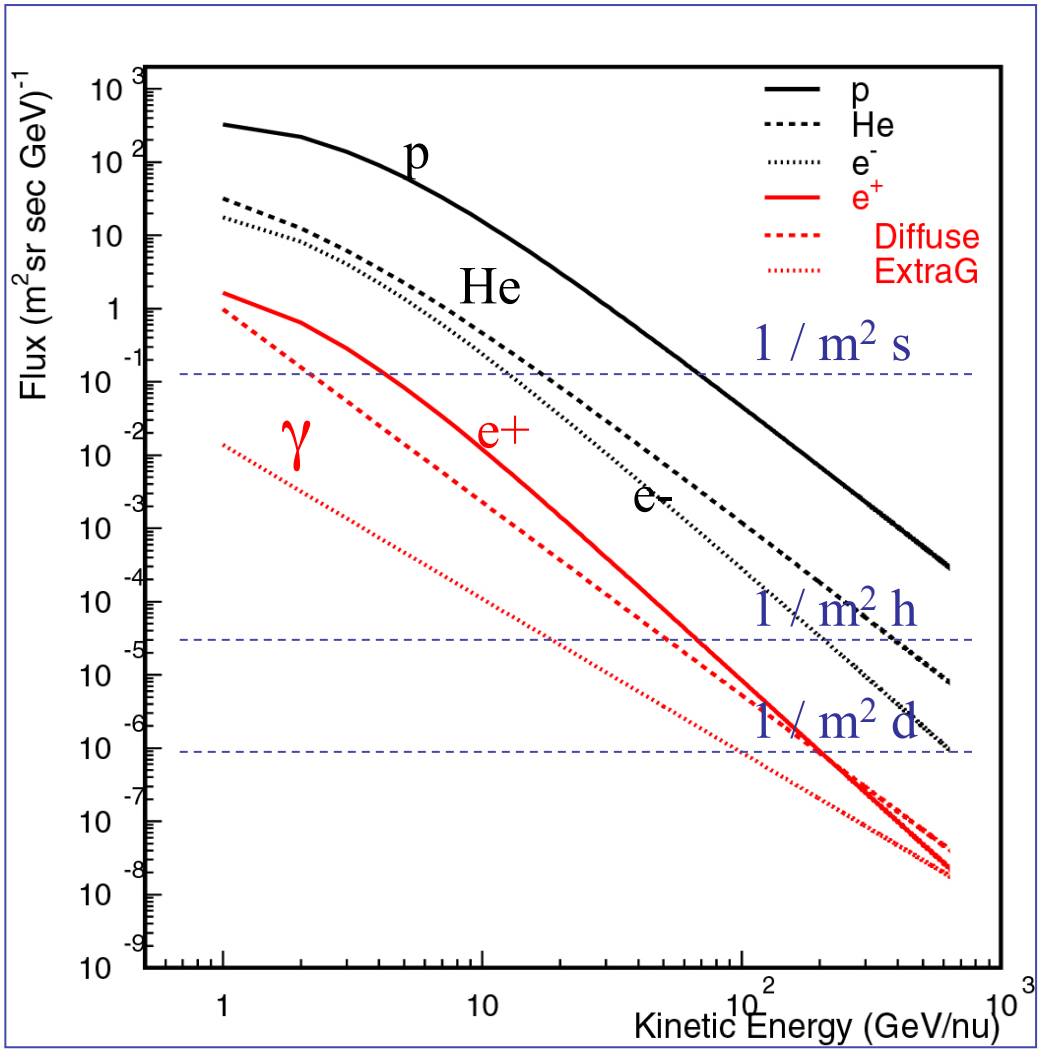
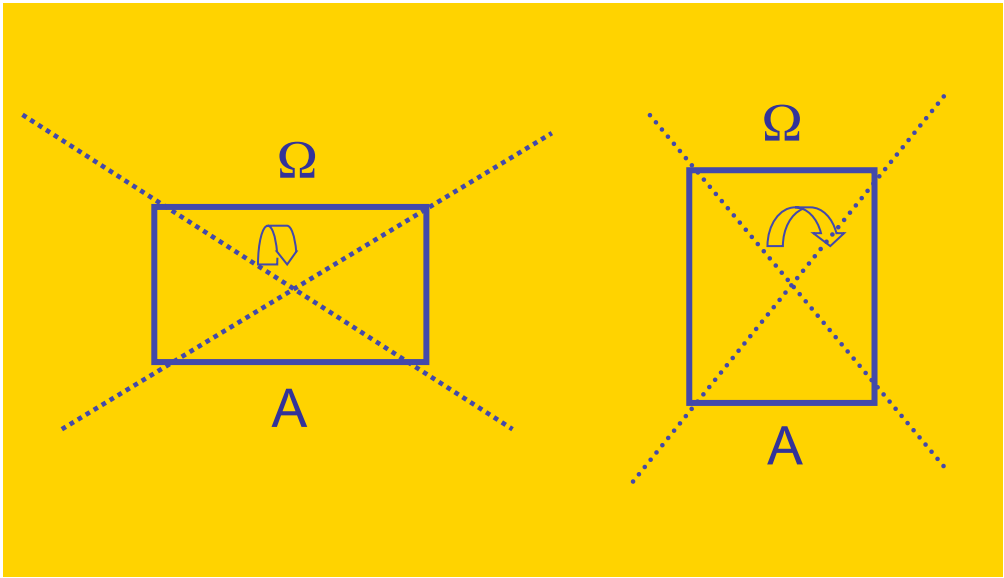
AMS on the International Space Station

- Cosmic Antimatter search with 10^{-9} sensitivity
- Indirect Dark Matter search ($e^+, \bar{p}, \gamma$)
- Relative abundance of nuclei and isotopes in primary cosmic rays
- γ ray astrophysics

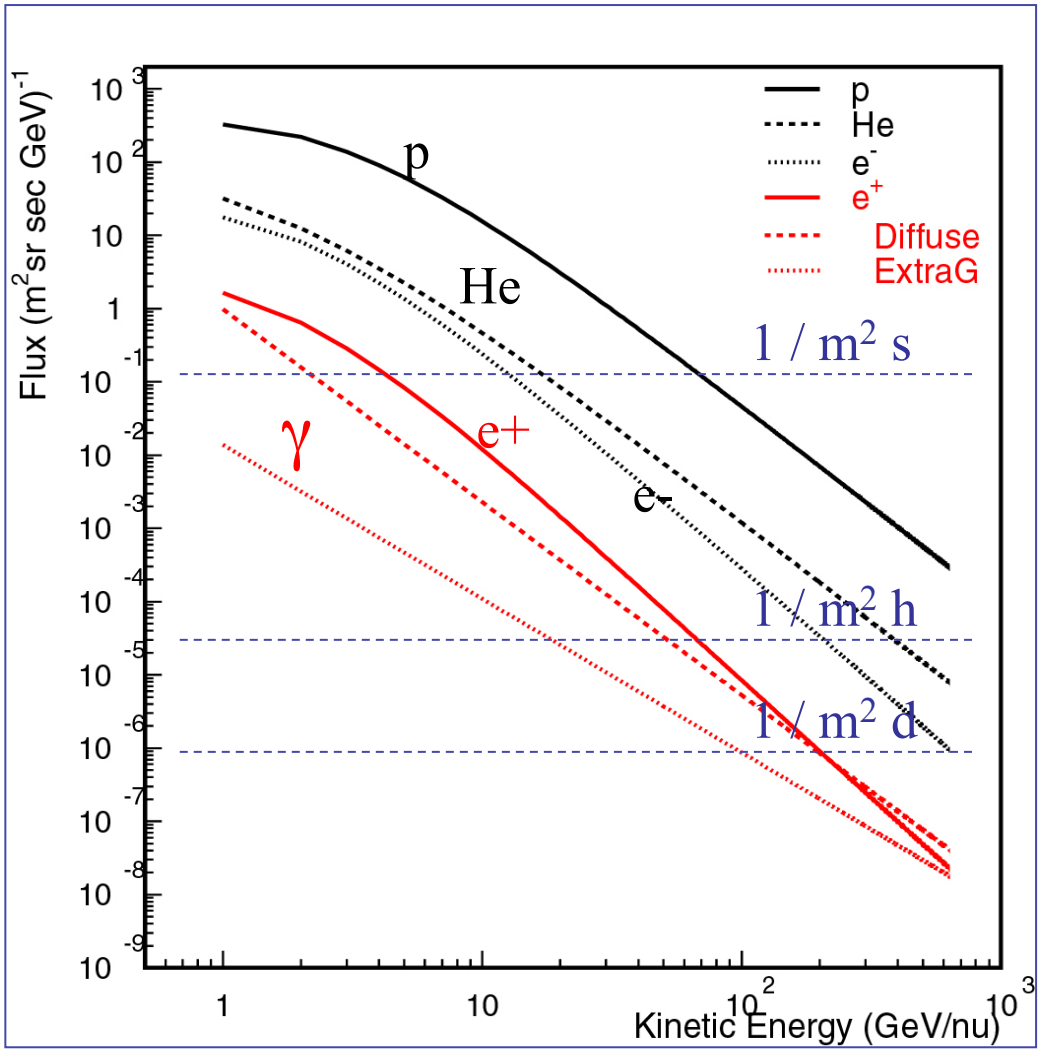
The experimental challenge: perform accurate, high statistics, long term measurements of charged cosmic rays (0.5 GV – O(TV)) and γ rays (E>1GeV)

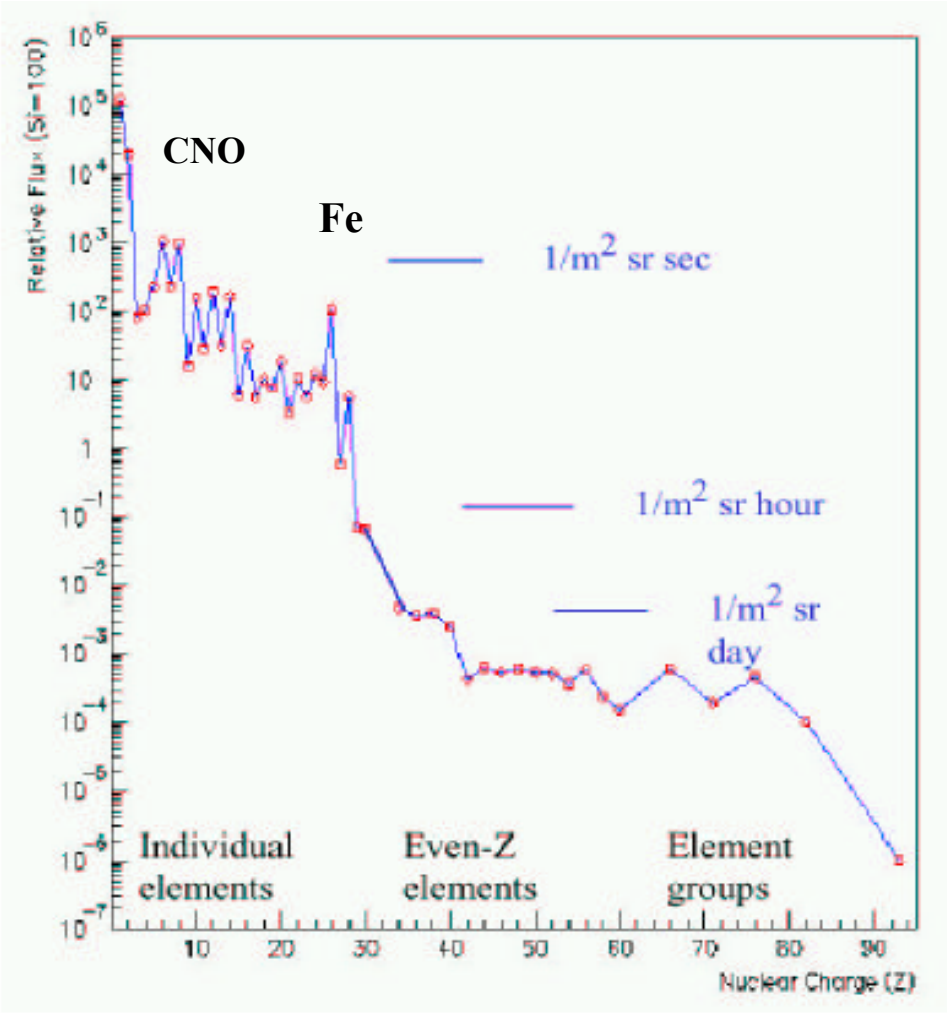
High Energy CR flux and composition





High Energy CR flux and composition





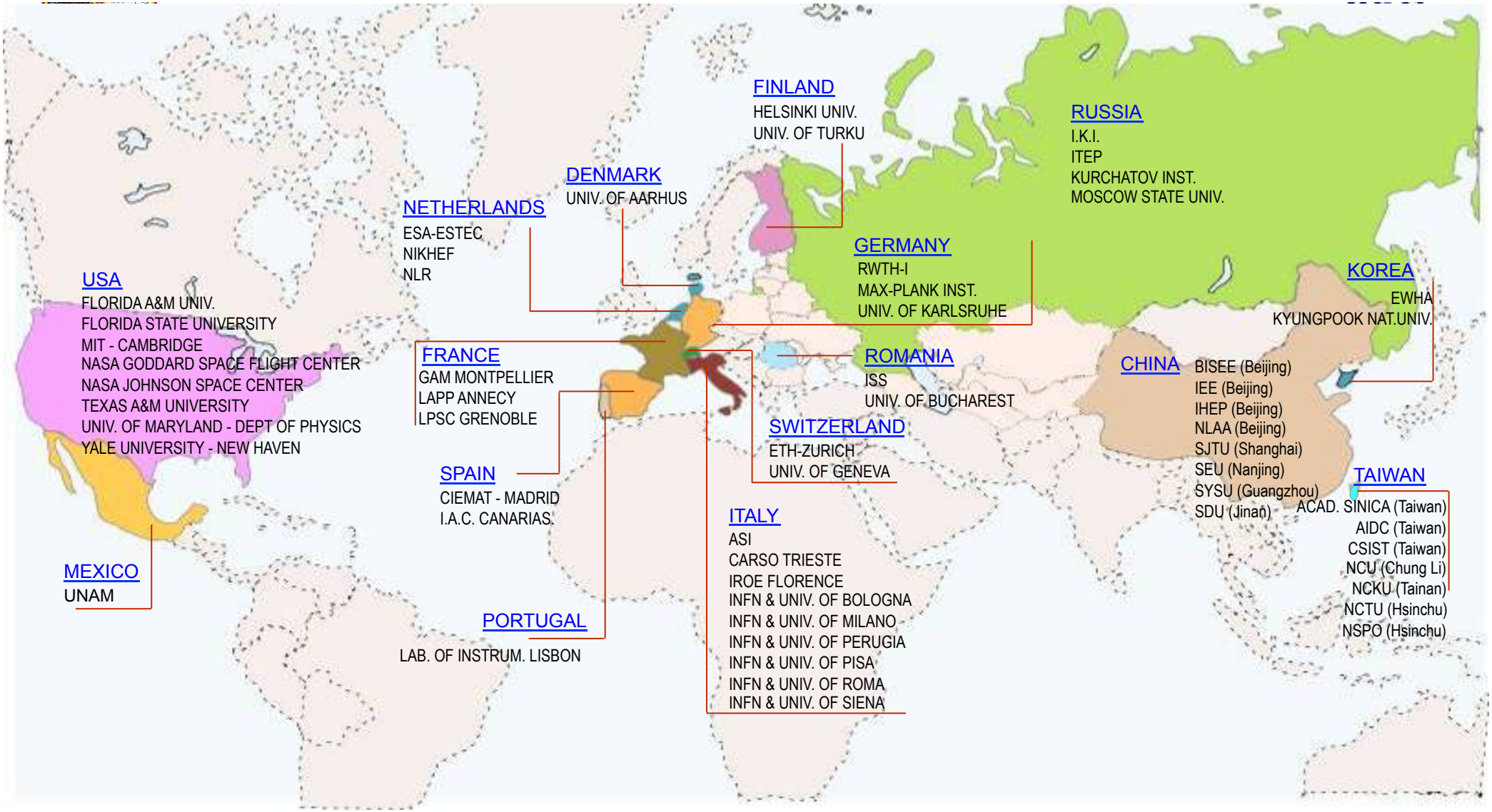
AMS-01 pilot experiment: STS91, June 2nd - 12th 1998

- 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}

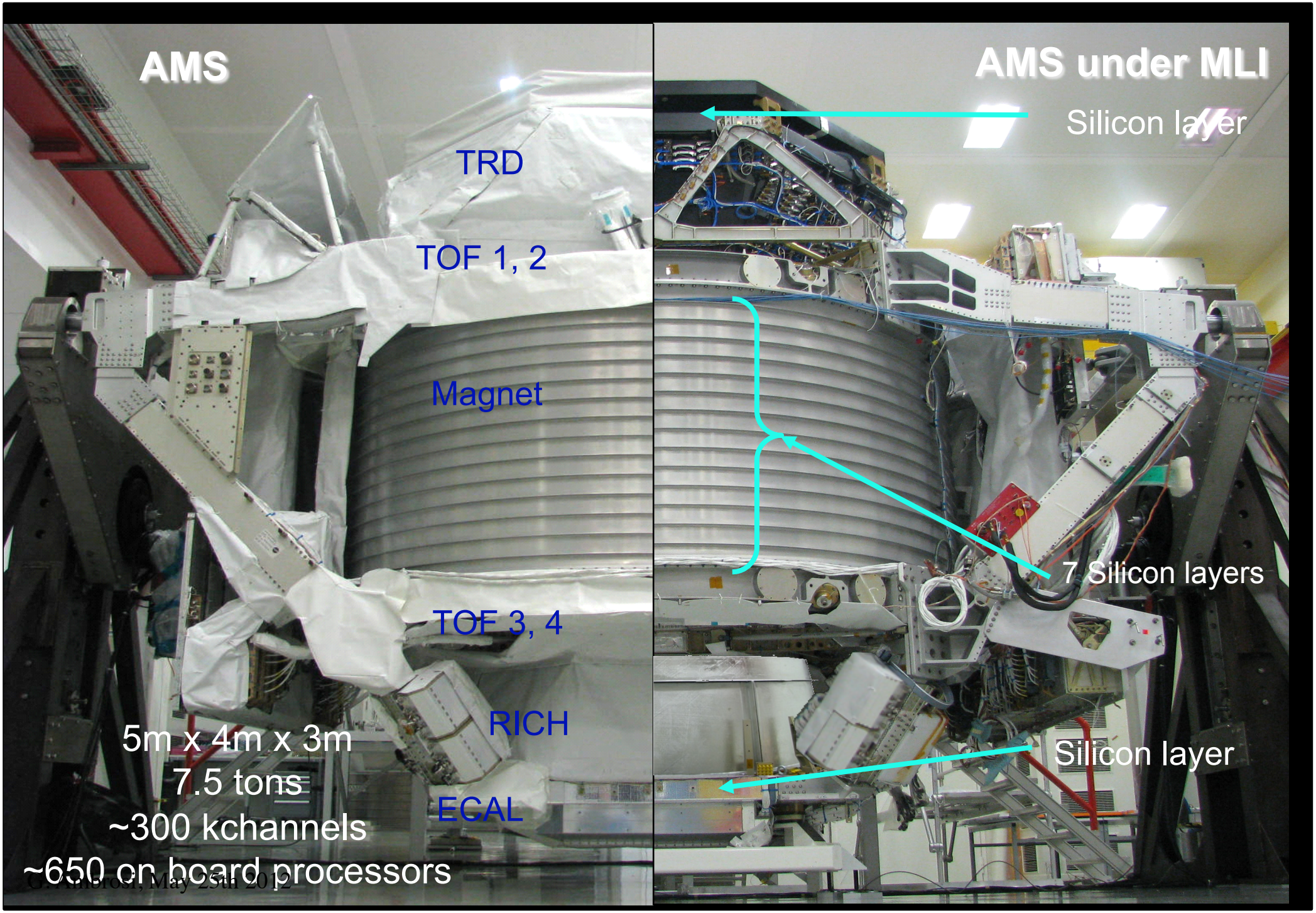
The instrument we need has …

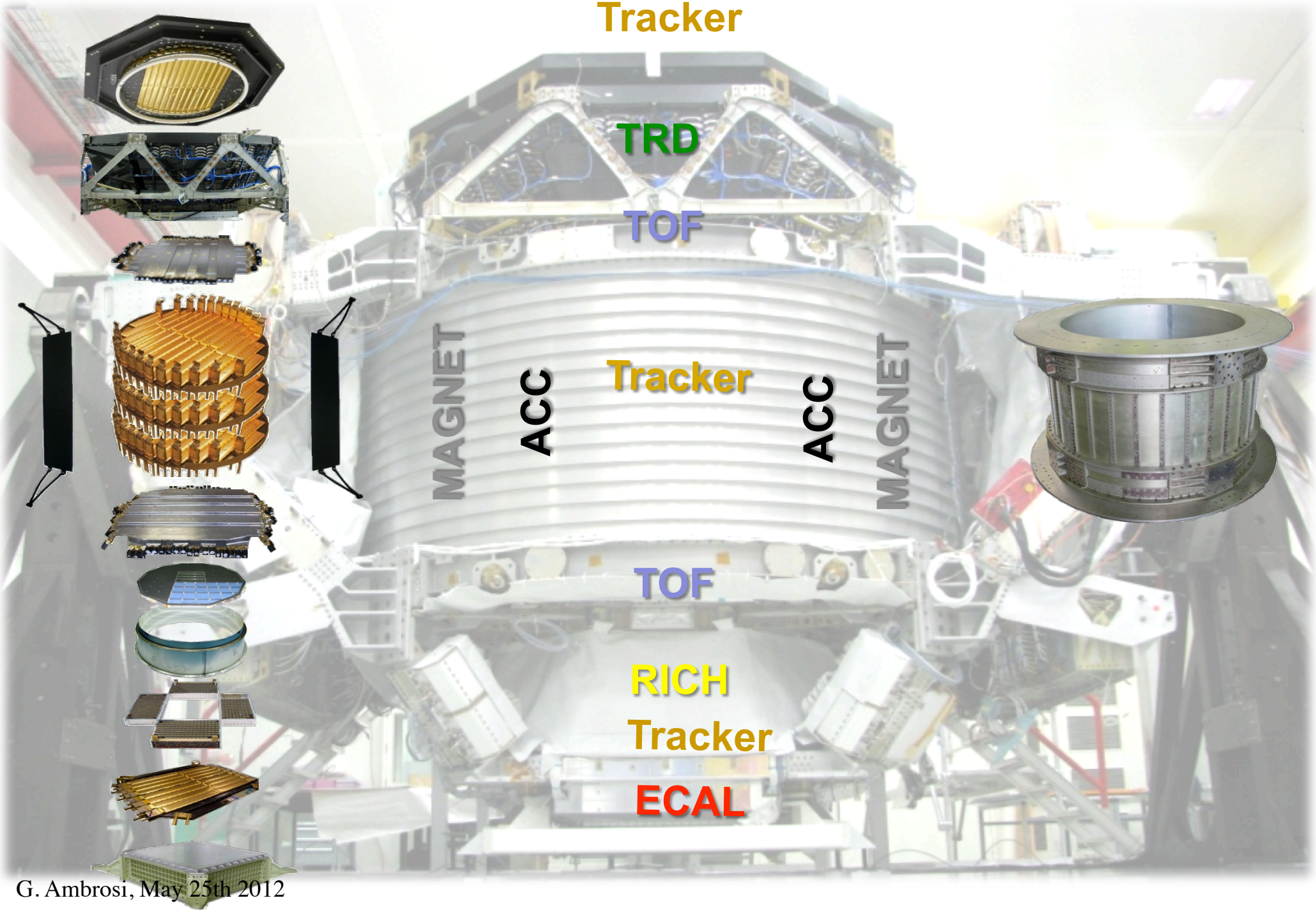
- performance a la 'particle physics':
  - high resolution measurements of momentum, velocity, charge and energy
- characteristics to properly work in the space environment:
  - Vibration (6.8 G rms) and acceleration (17 G)
  - Temperature variation (day/night $\Delta T = 100^{o}C$)
  - Vacuum (10^{-10} Torr)
  - Orbital debris and micrometeorites
  - Radiation (Single Event Effect)
- limitation in weight (15000 lb), power (~2KW), bandwidth and maintenance
- Compliant with Electromagnetic Interference and Electromagnetic Compatibility specs

AMS international collaboration
16 Countries, 60 Institutes and 600 Physicists, 17 years



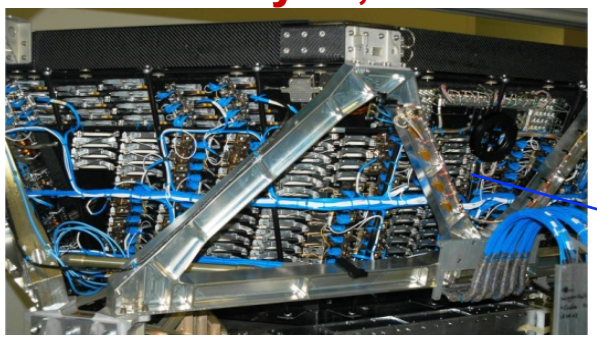
The detectors and electronics were built all over the world and assembled at CERN, Switzerland.


AMS
TRD
TOF 1, 2
Magnet
TOF 3, 4
RICH
ECAL
5m x 4m x 3m
7.5 tons
~300 kchannels
~650 on board processors
AMS under MLI
Silicon layer
7 Silicon layers
Silicon layer

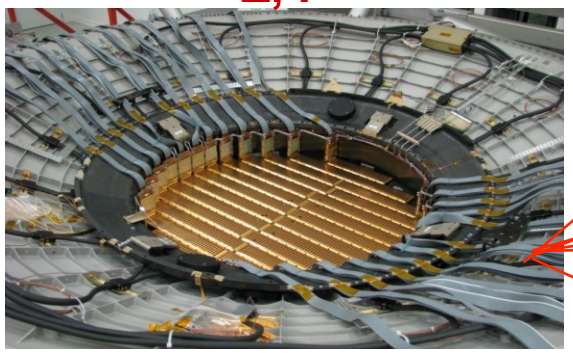

Tracker
TRD
TOF
MAGNET
ACC
Tracker
ACC
MAGNET
TOF
RICH
Tracker
ECAL

AMS: A TeV precision, multipurpose spectrometer

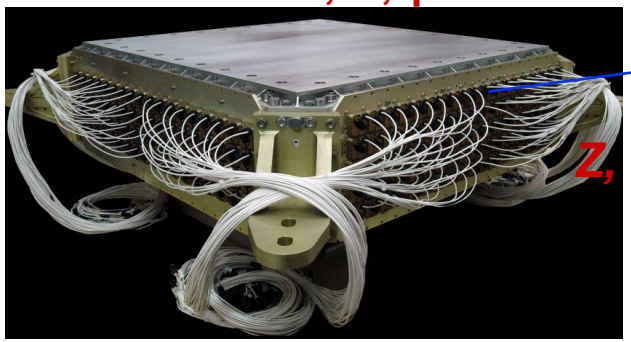
TRD
Identify e^+, e^-



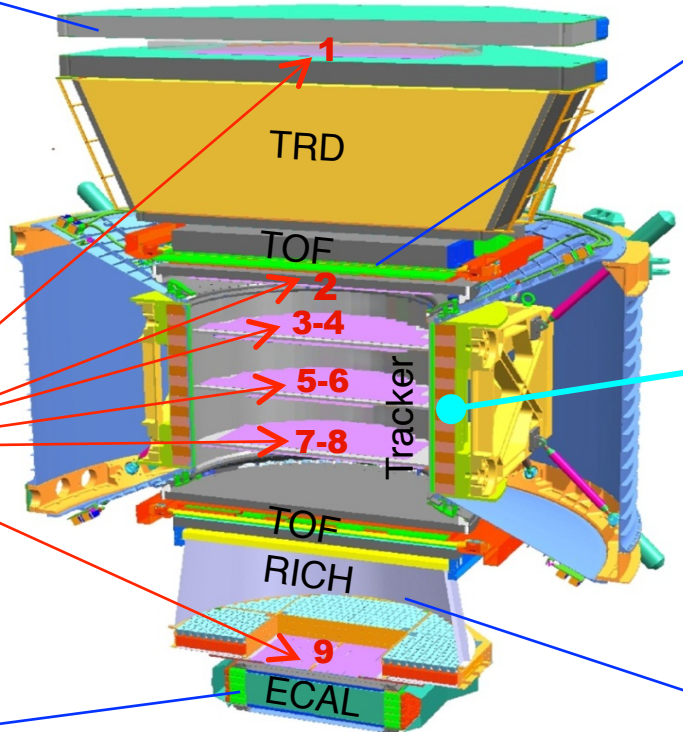
Silicon Tracker
Z, P



ECAL
E of e^+, e^-, γ

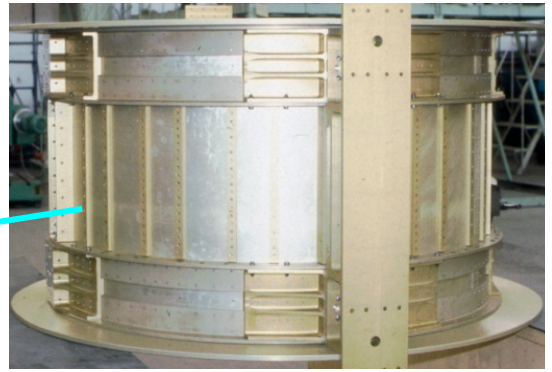


Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

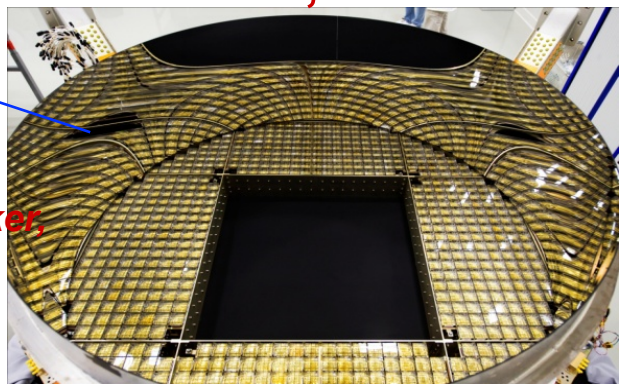


TOF
Z, E

Magnet
±Z



RICH
Z, E



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

TRD
Identify e+, e-

- 20 layer radiator/straw tubes
-Xe/CO_2 80%/20% gas
- 5284 channel
-F. Spada poster

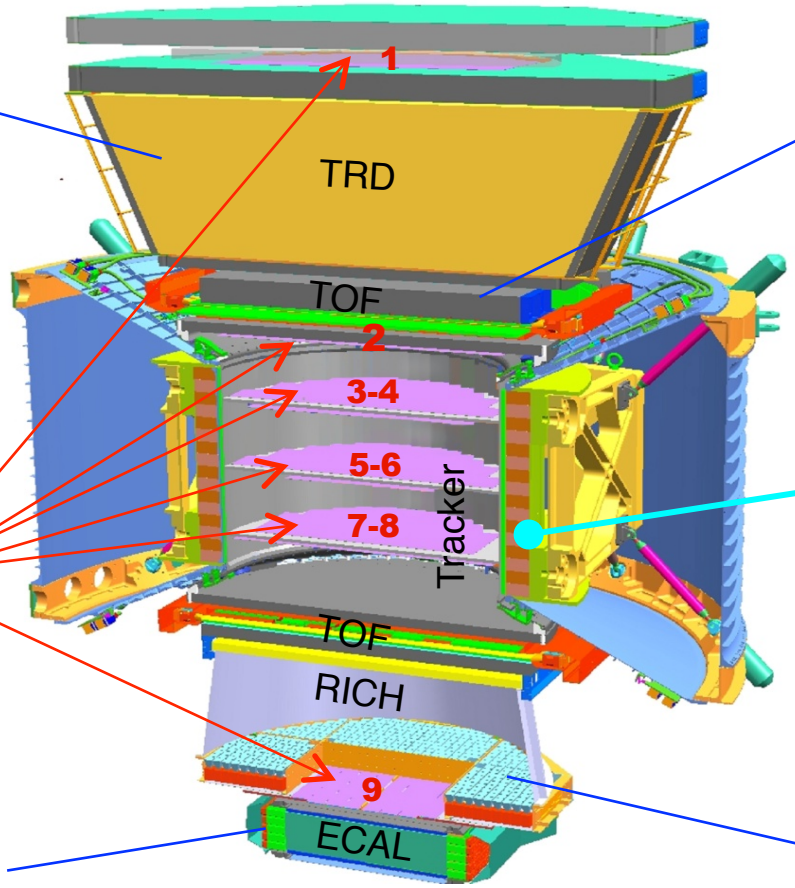
Silicon Tracker
Z, P

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

ECAL
E of e+, e-, γ

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

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

Magnet
±Z

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

RICH
Z, E

- Areogel and NaF radiator
- 680 MAPMT
- 21726 channels

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

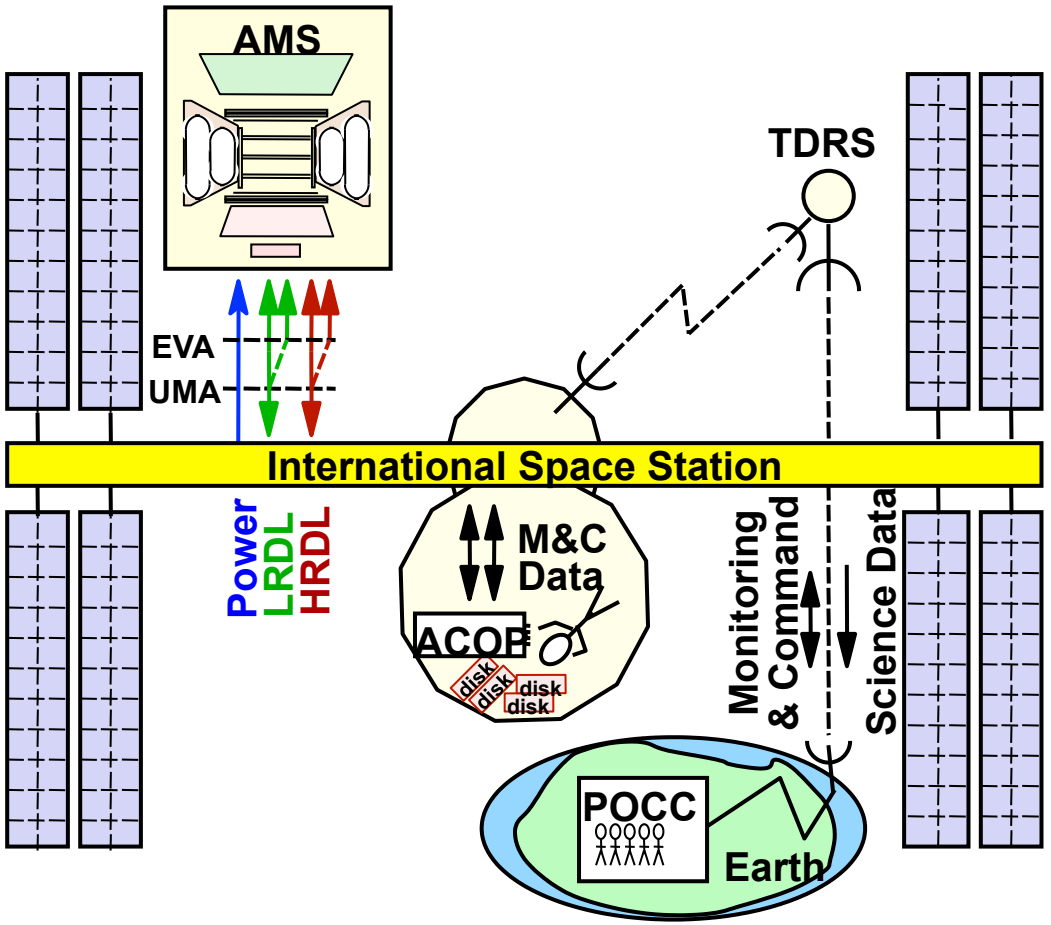
AMS Electrical Interfaces on ISS

Power:
- 109-124VDC
- ~2KW

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

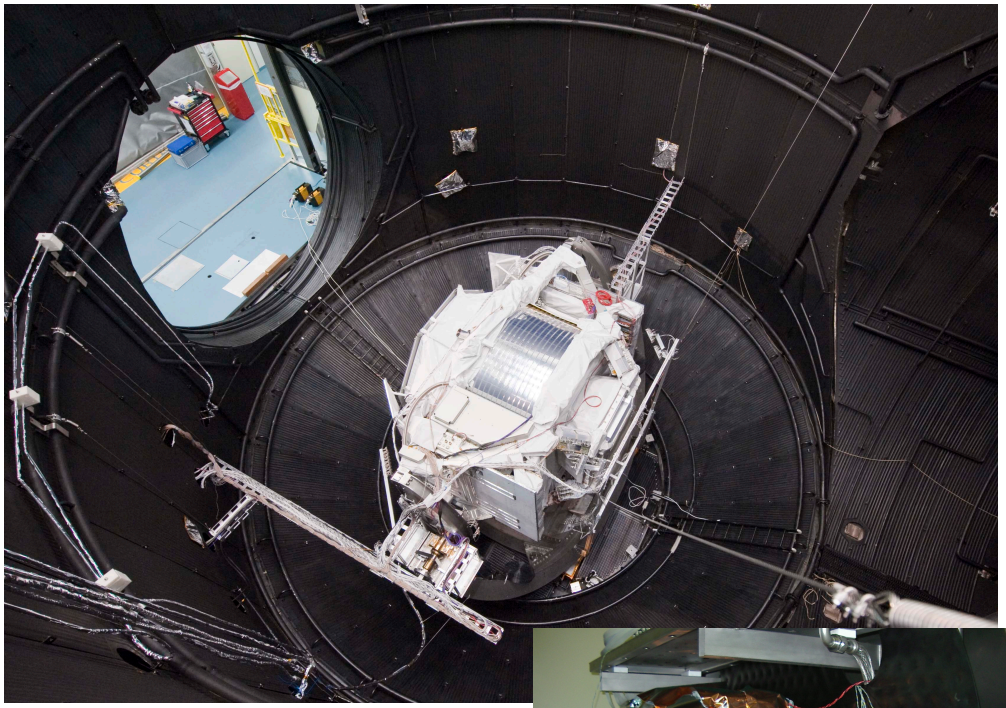
HRDL
- for Event Data
- Taxi F/O
- <13Mbit/s>$_{orbit}$

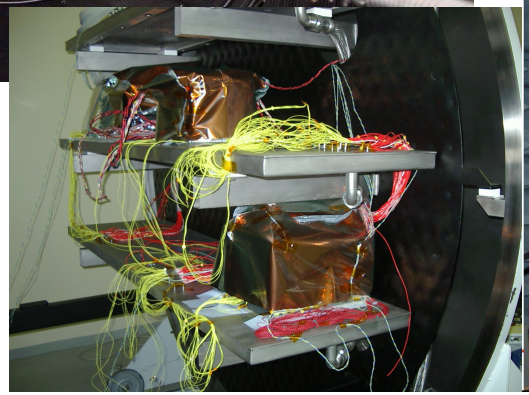
xRDL: Duty cycle ~50-70%



AMS in ESTEC (ESA test facility)

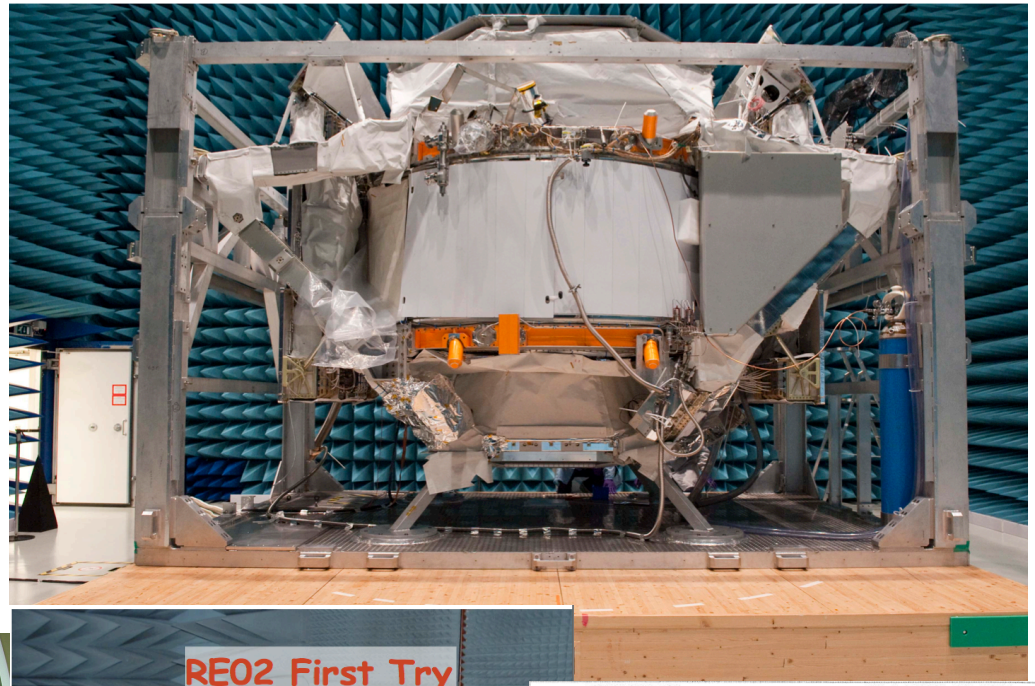
um test (~400 h, P<10^{-6} mbar, T -90°C +40°C

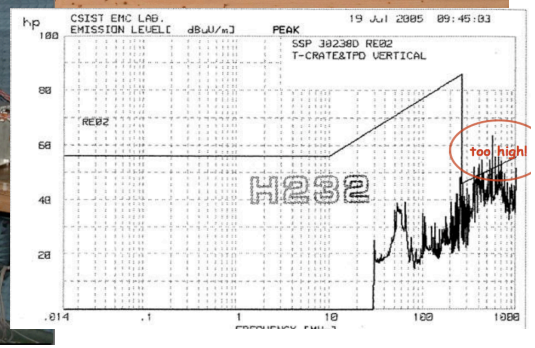




9000 hours of subsystem test

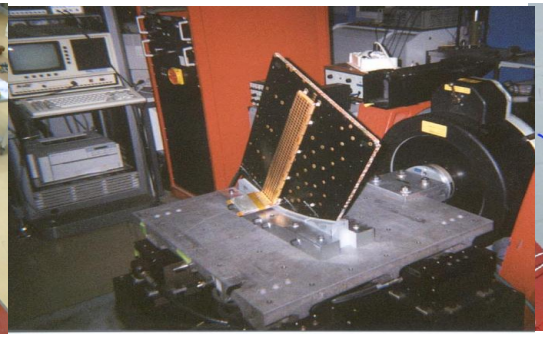
EMI/EMC test

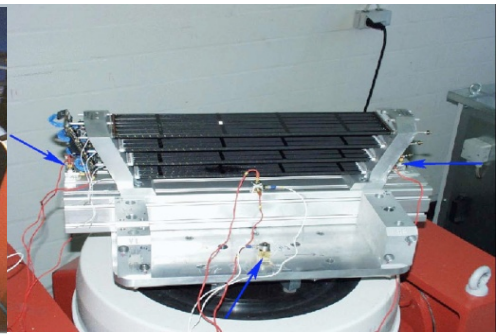


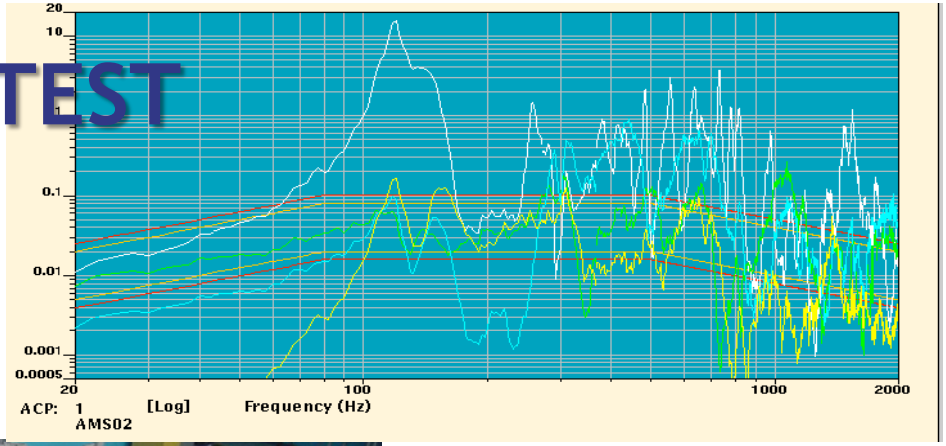


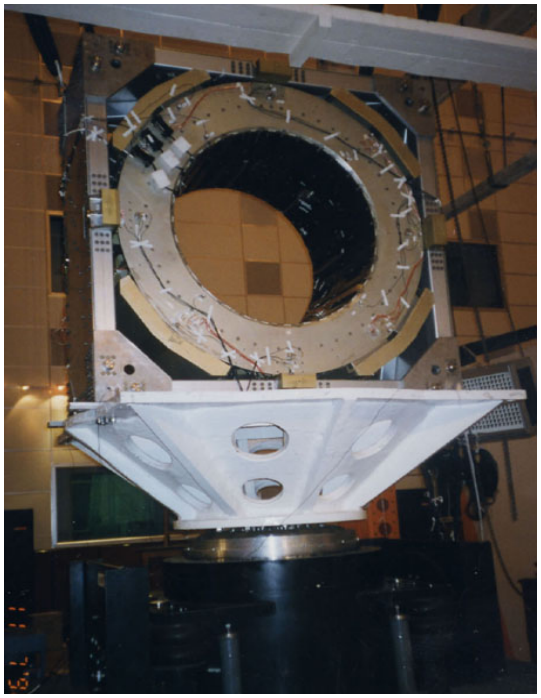
G. Ambrosi, May 25th 2012

STRUCTURAL TEST



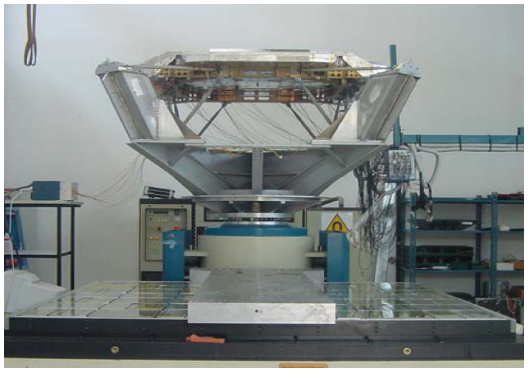


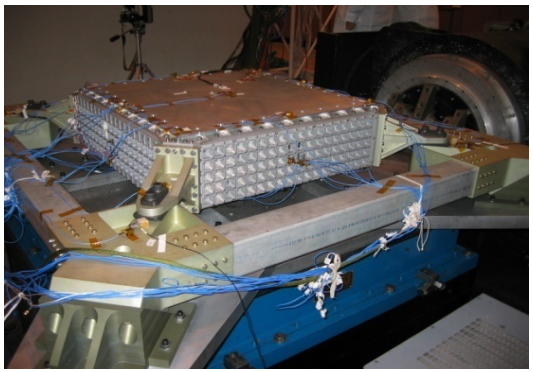




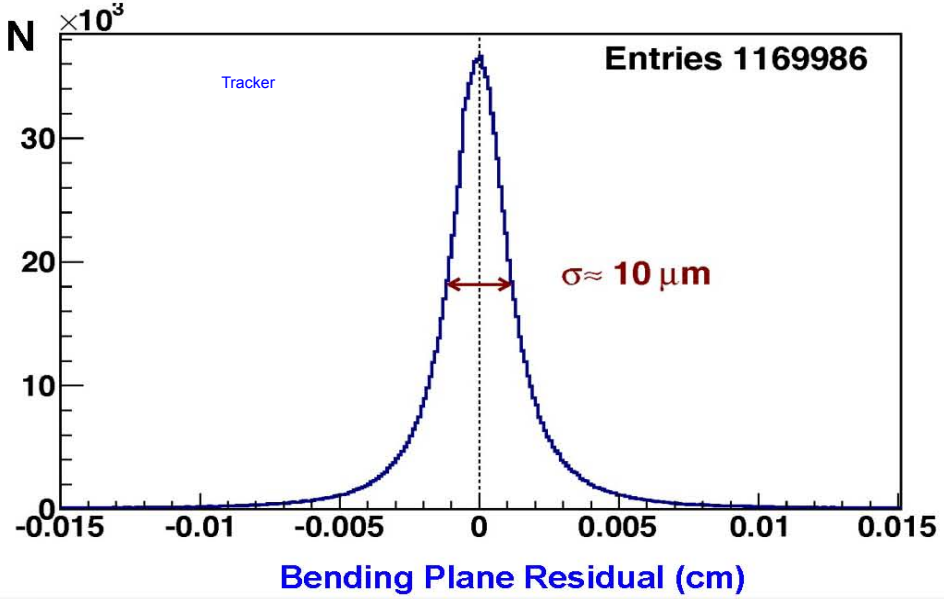
Test
at components level
and at system level

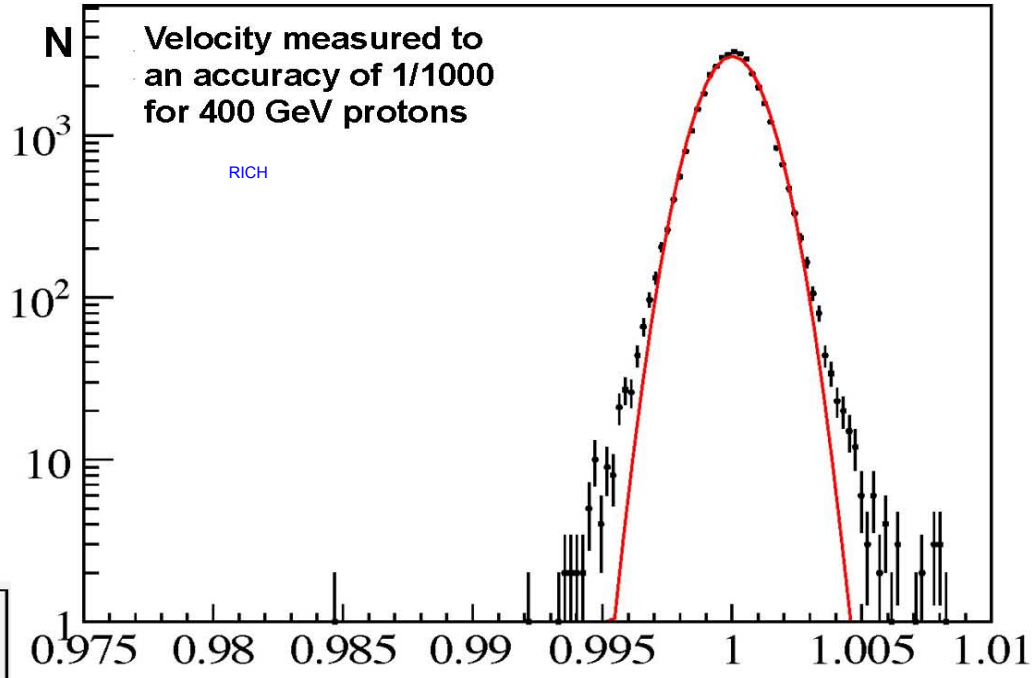
on EM, QM, FM

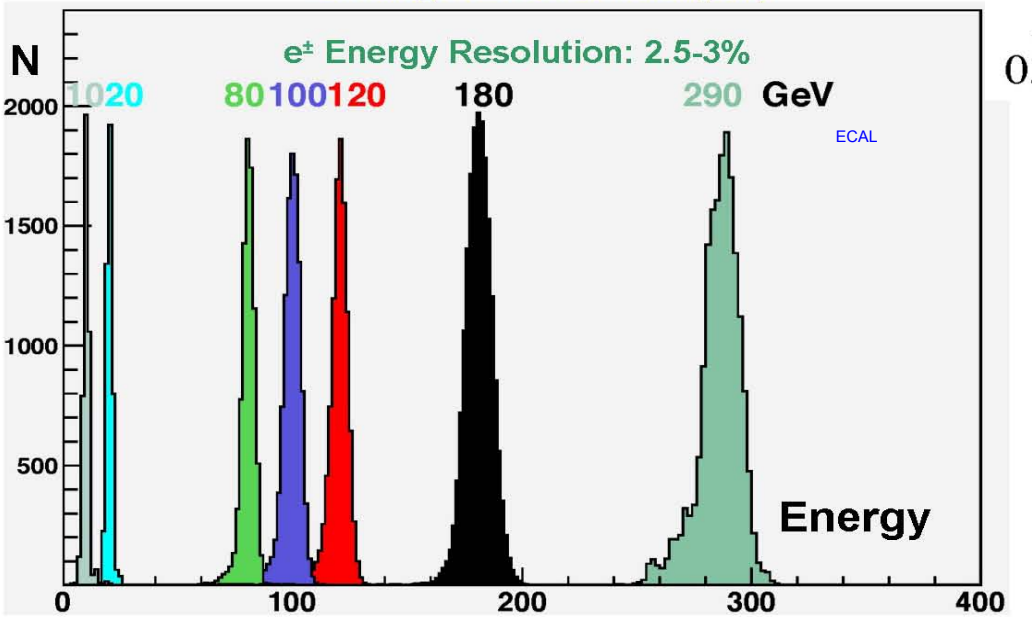


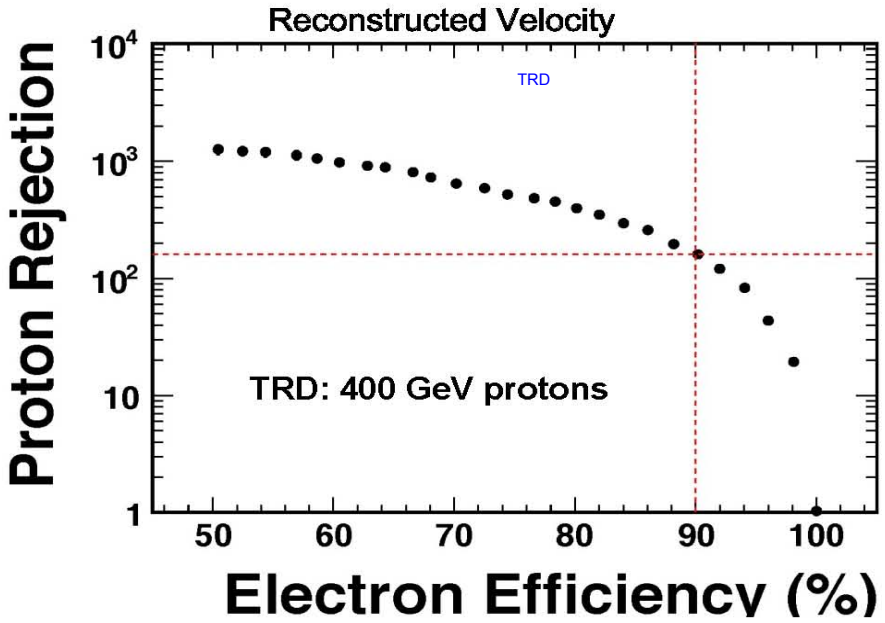


Test Beam Results with permanent magnet – 8-20 Aug 2010



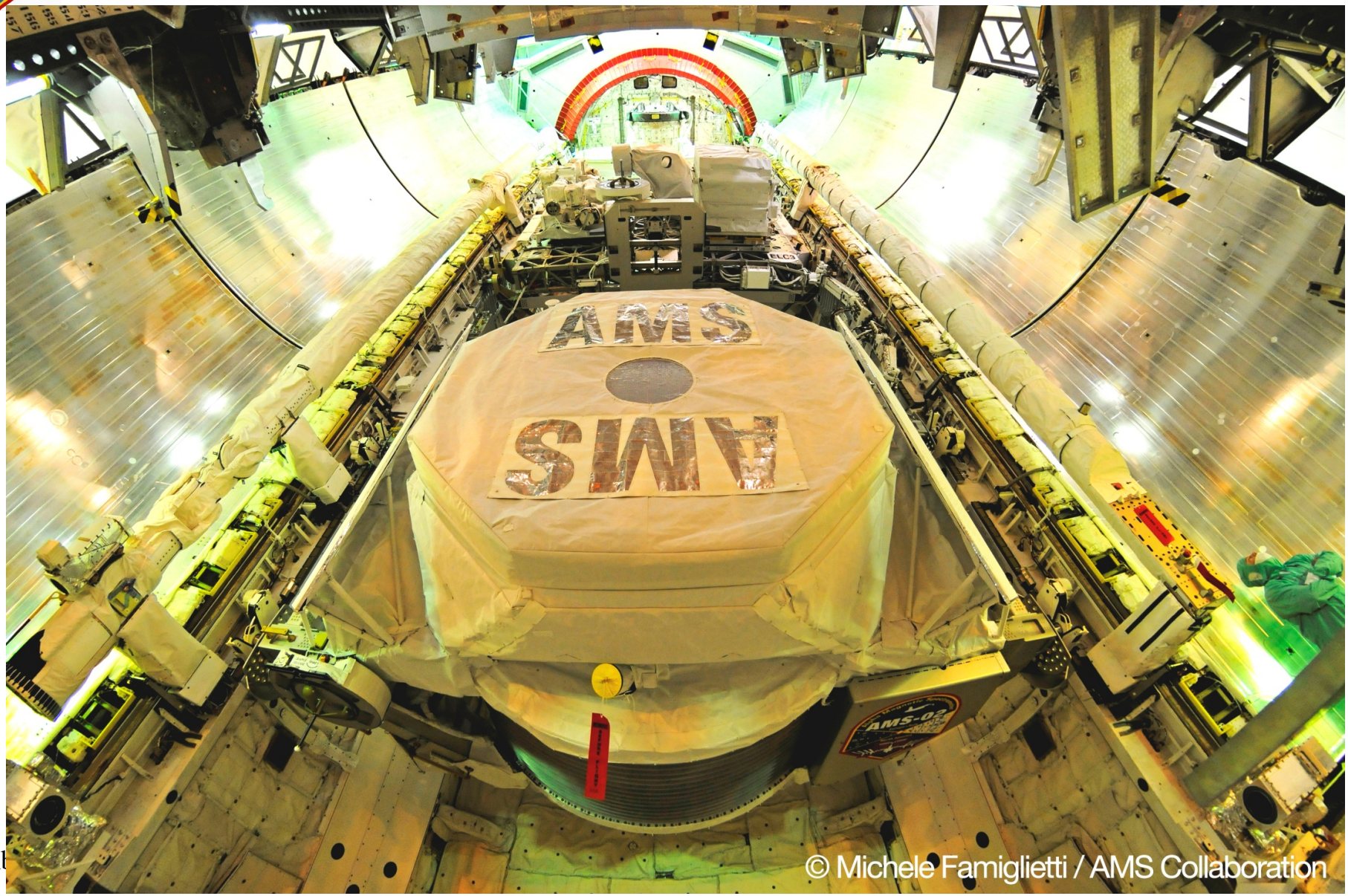




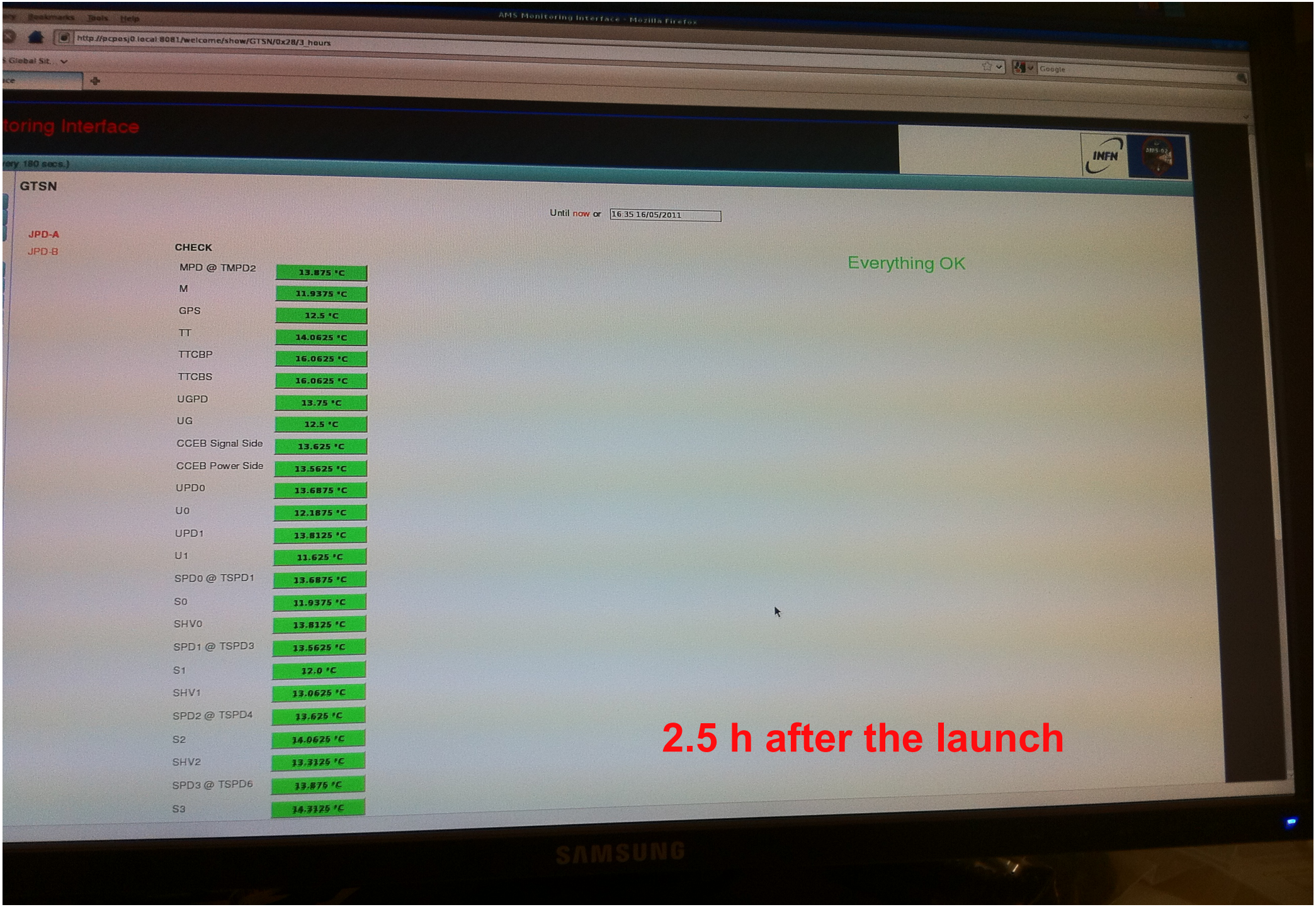


G. Ambrosi, May 25th 2012

AMS in the Shuttle cargo bay




May 16, 2011 @ 08:56 AM

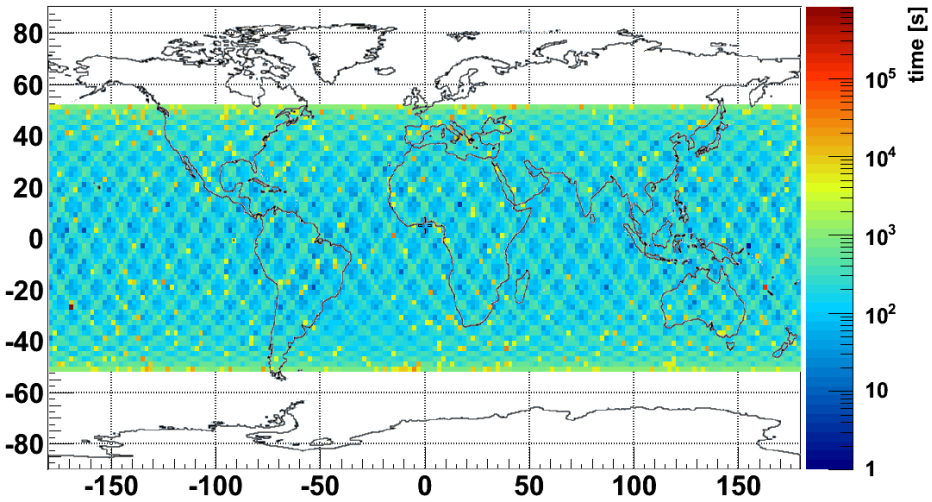

AMS Monitoring Interface - Mozilla Firefox
http://pcpasj0.local:8081/welcome/show/GTSN/0x28/3_hours
toring Interface
INFN
GTSN
Until now or 16:35 16/05/2011
JPD-A
JPD-B
CHECK
MPD @ TMPD2 13.875 °C
M 11.9375 °C
GPS 12.5 °C
TT 14.0625 °C
TTCBP 16.0625 °C
TTCBS 16.0625 °C
UGPD 13.75 °C
UG 12.5 °C
CCEB Signal Side 13.625 °C
CCEB Power Side 13.5625 °C
UPD0 13.6875 °C
U0 12.1875 °C
UPD1 13.8125 °C
U1 11.625 °C
SPD0 @ TSPD1 13.6875 °C
S0 11.9375 °C
SHV0 13.8125 °C
SPD1 @ TSPD3 13.5625 °C
S1 12.0 °C
SHV1 13.0625 °C
SPD2 @ TSPD4 13.625 °C
S2 14.0625 °C
SHV2 13.3125 °C
SPD3 @ TSPD6 13.875 °C
S3 14.3125 °C
Everything OK
2.5 h after the launch
SAMSUNG

FROM SHUTTLE TO ISS

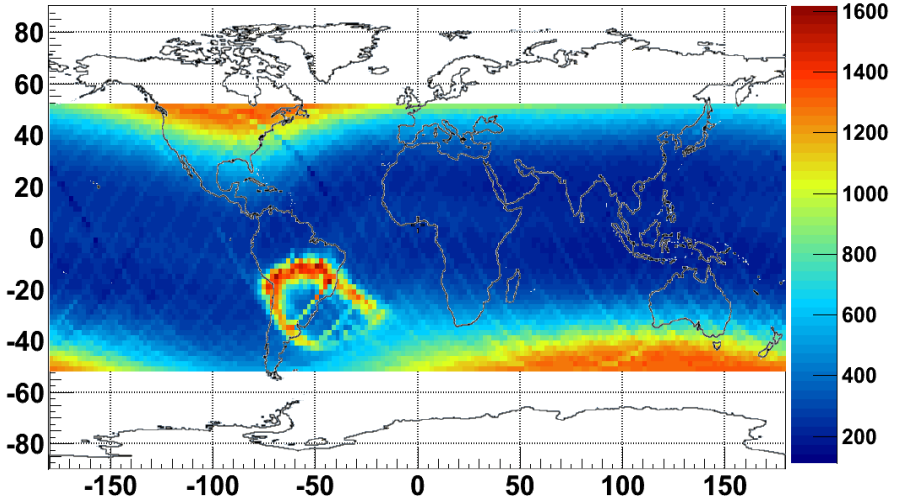
ON ISS

Orbital DAQ parameters

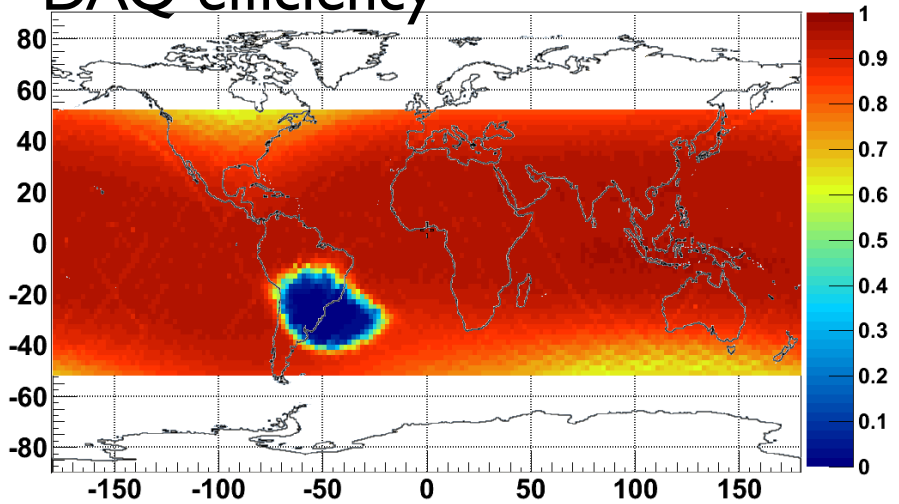
Time at location [s]



Acquisition rate [Hz]



DAQ efficiency

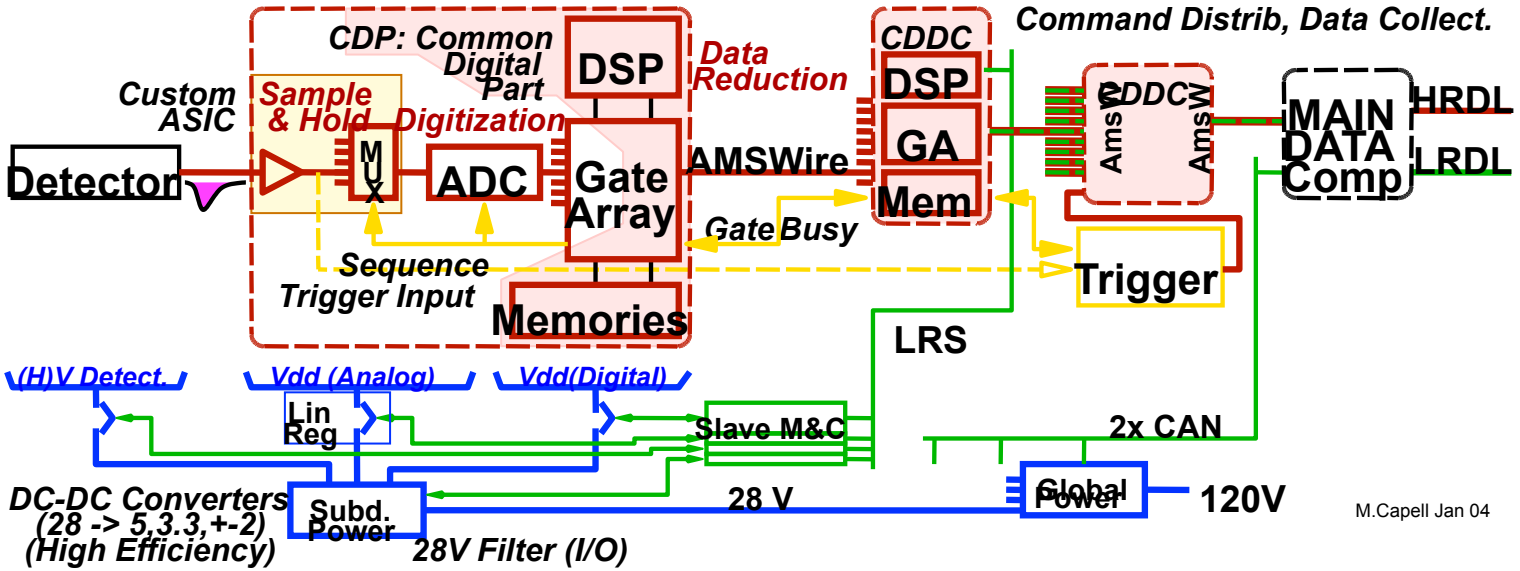


Particle rates: 200 to 2000 Hz per orbit

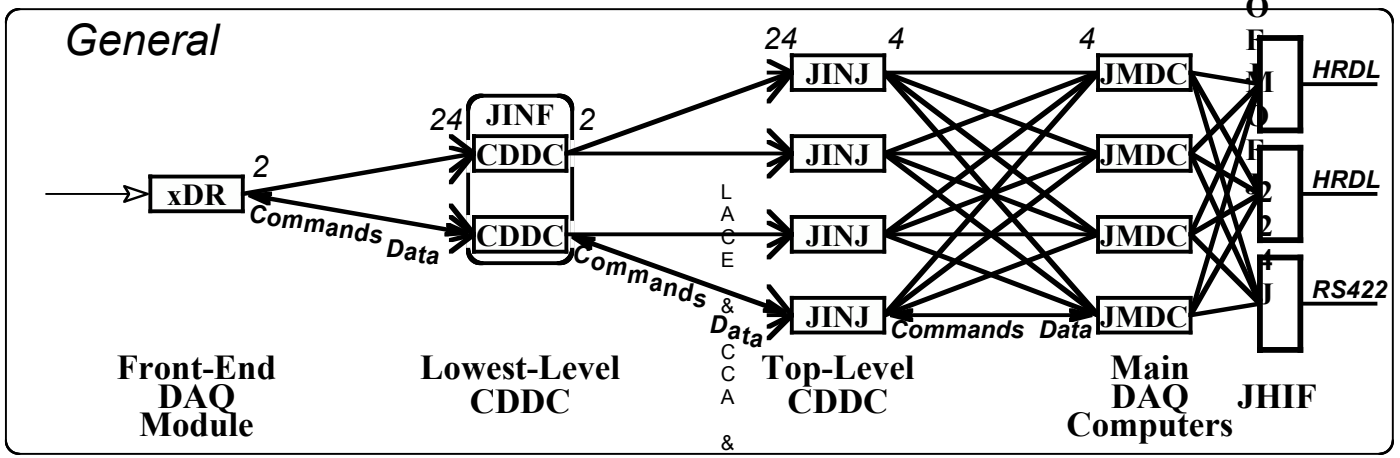
Orbit average: DAQ efficiency 85%
DAQ rate ~530Hz

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

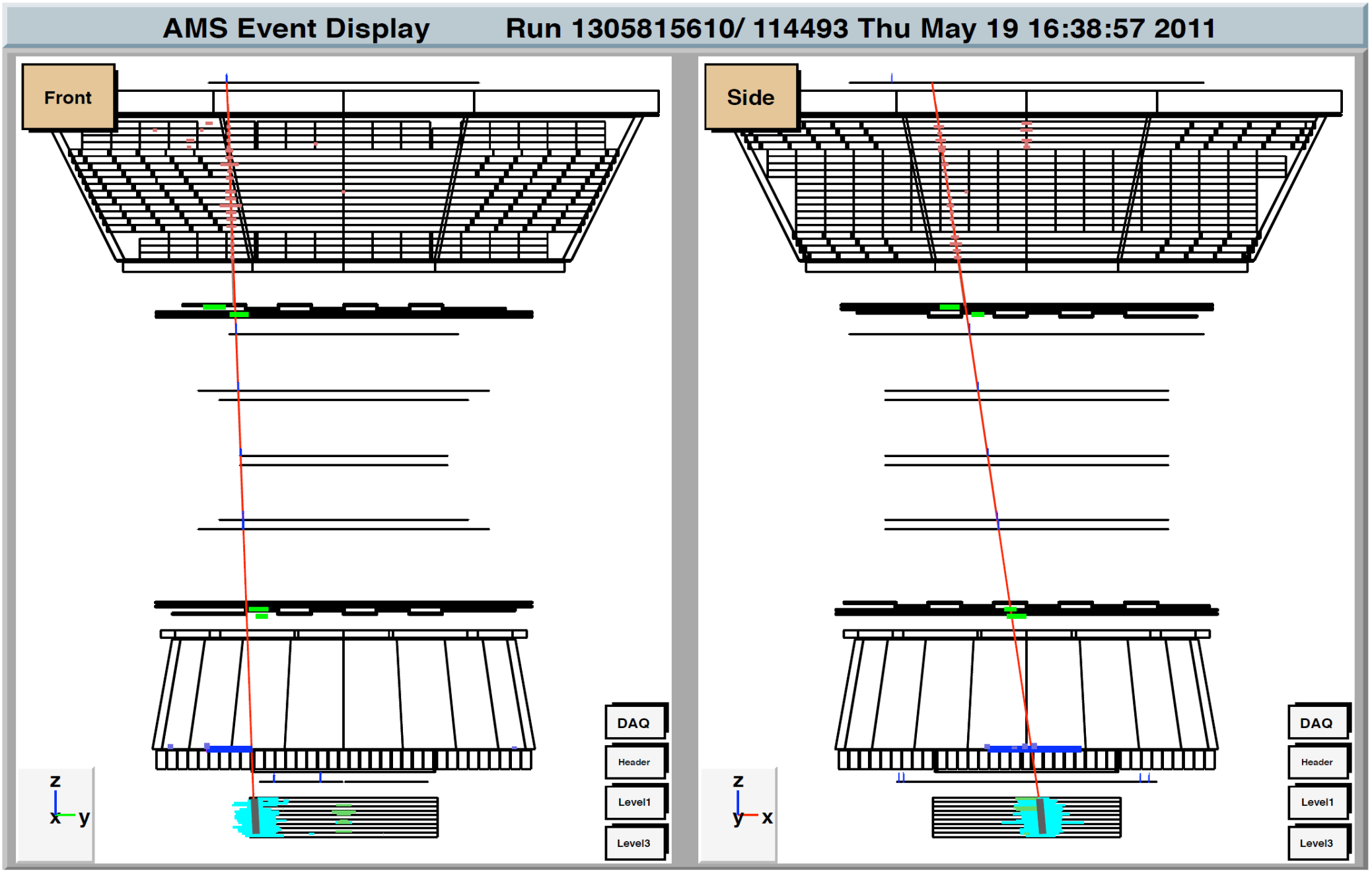
AMS-02 Custom/Common Readout Unit



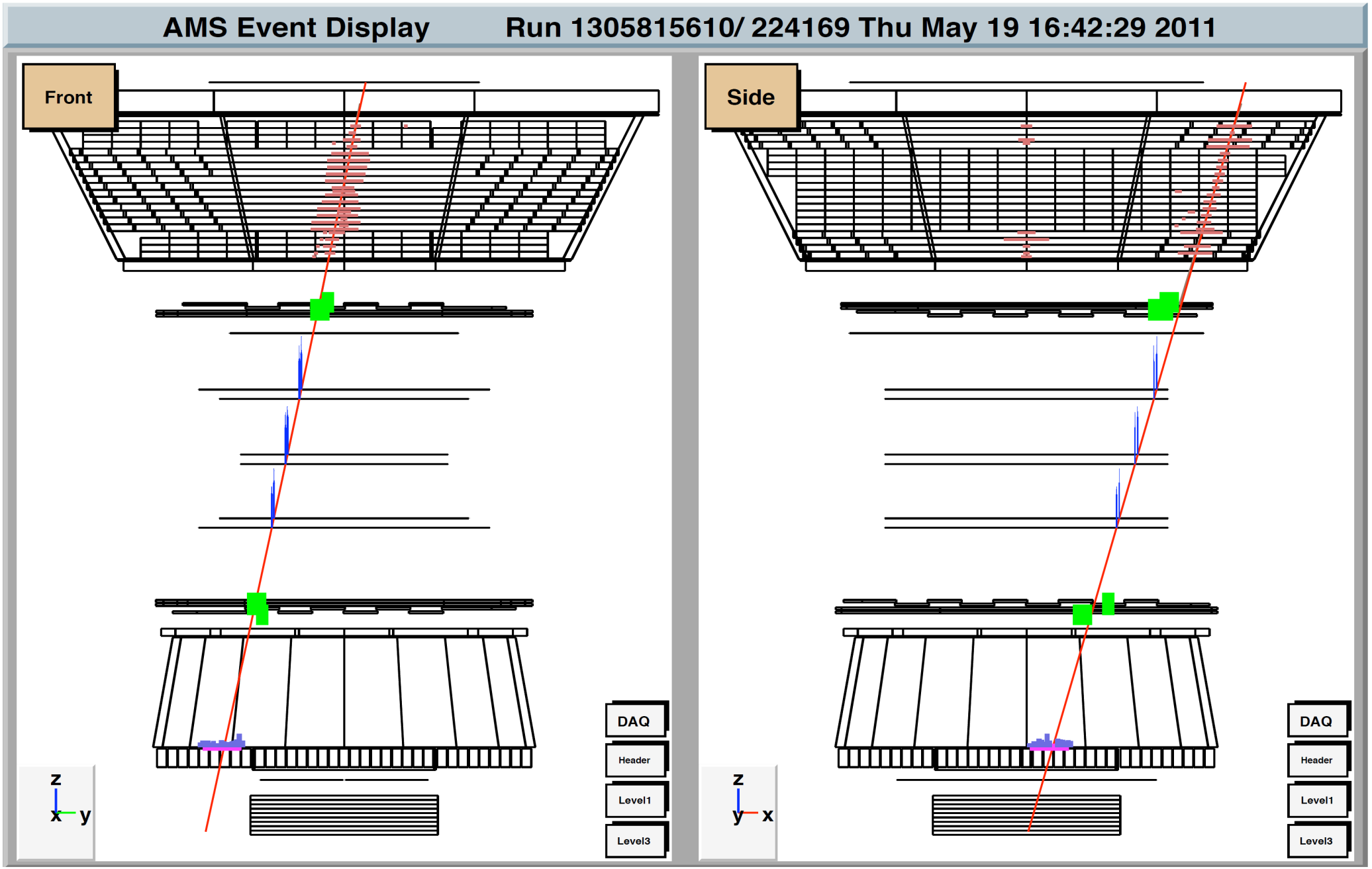
Raw event: 3674 Kbit
Compr. event: 2500 bit



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

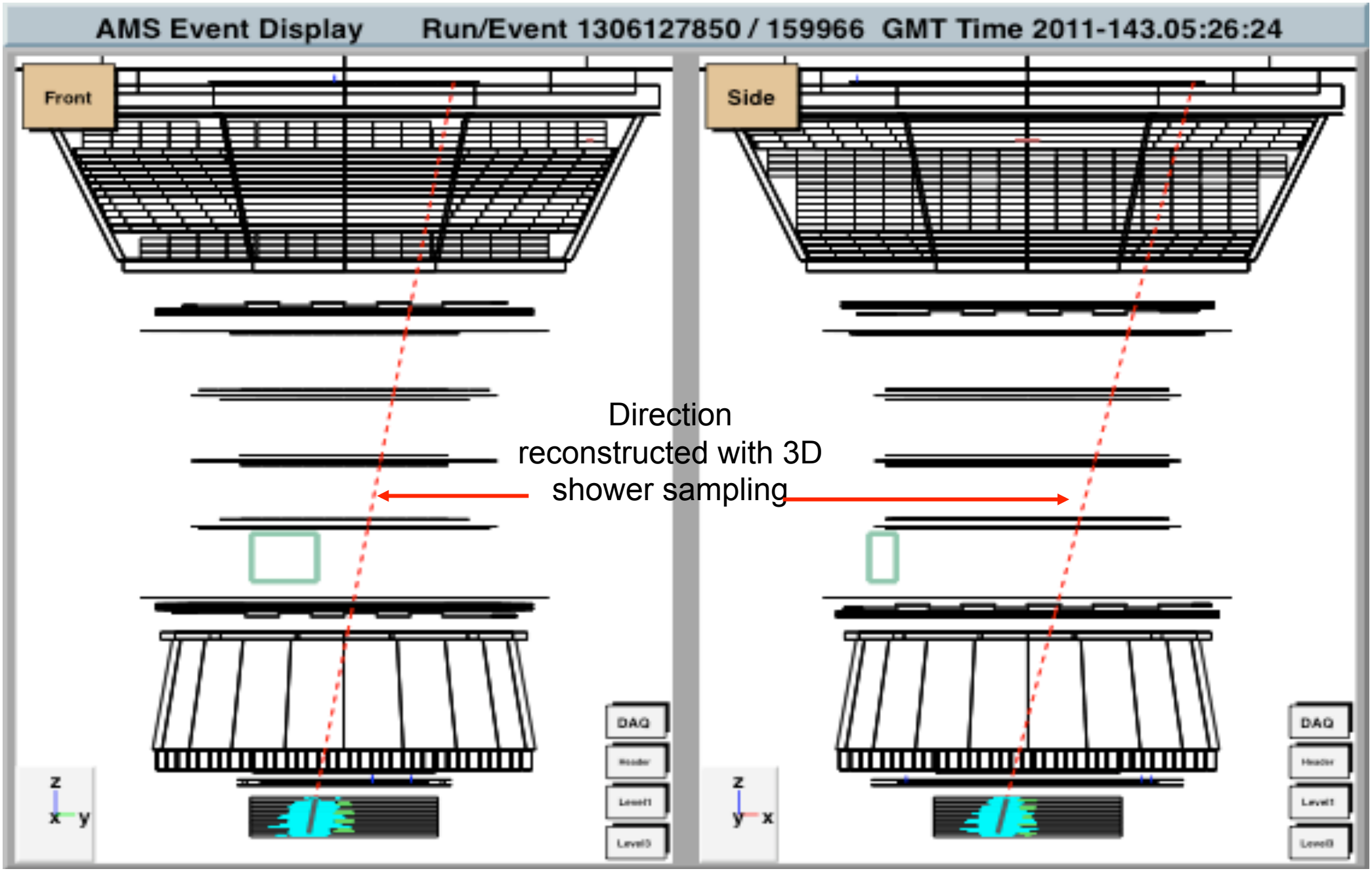


Data from the 1st few minutes – 42 GeV/c Carbon, 19 May 2011

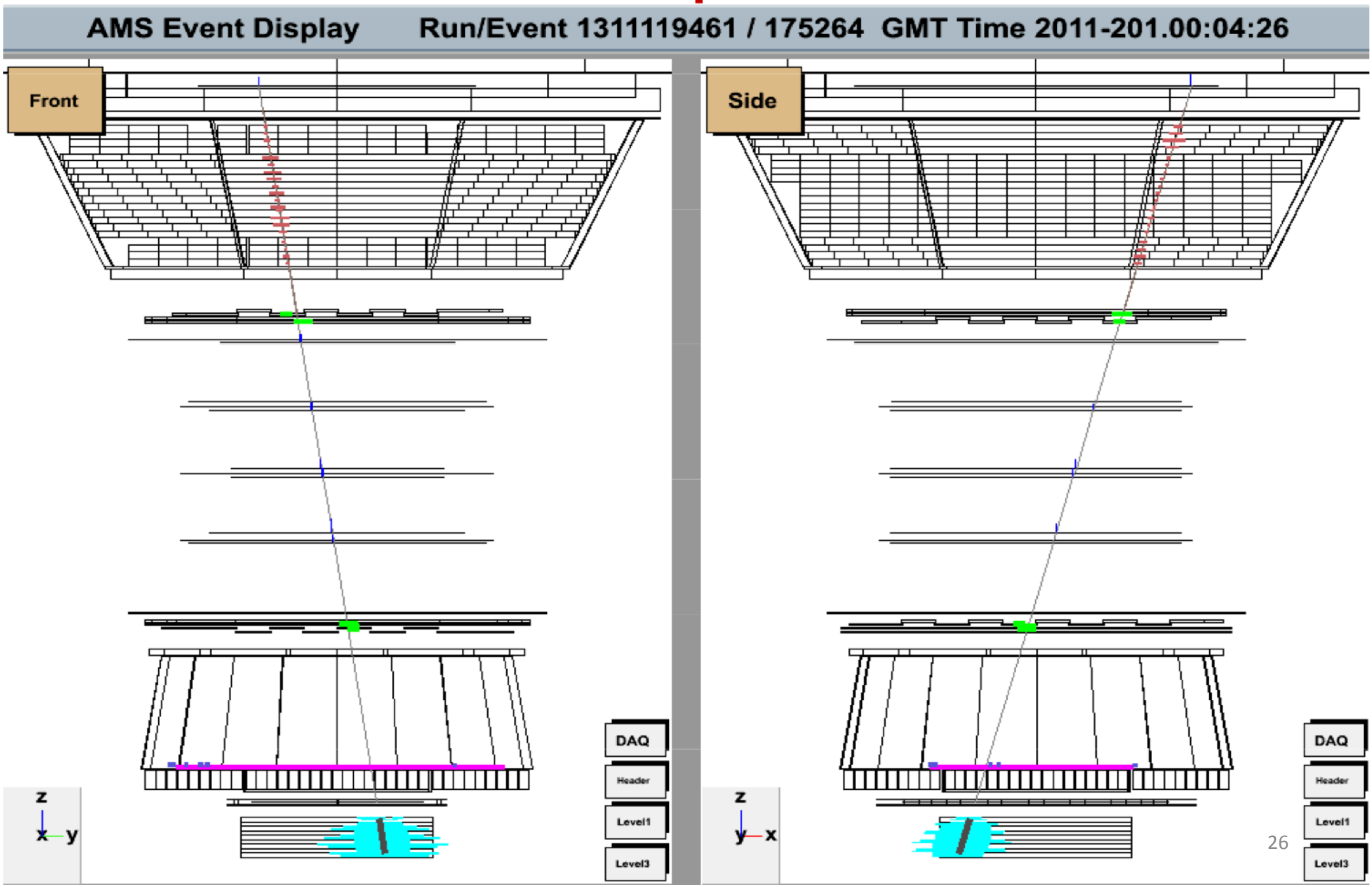


AMS data on ISS

Photon 40 GeV, 23 May

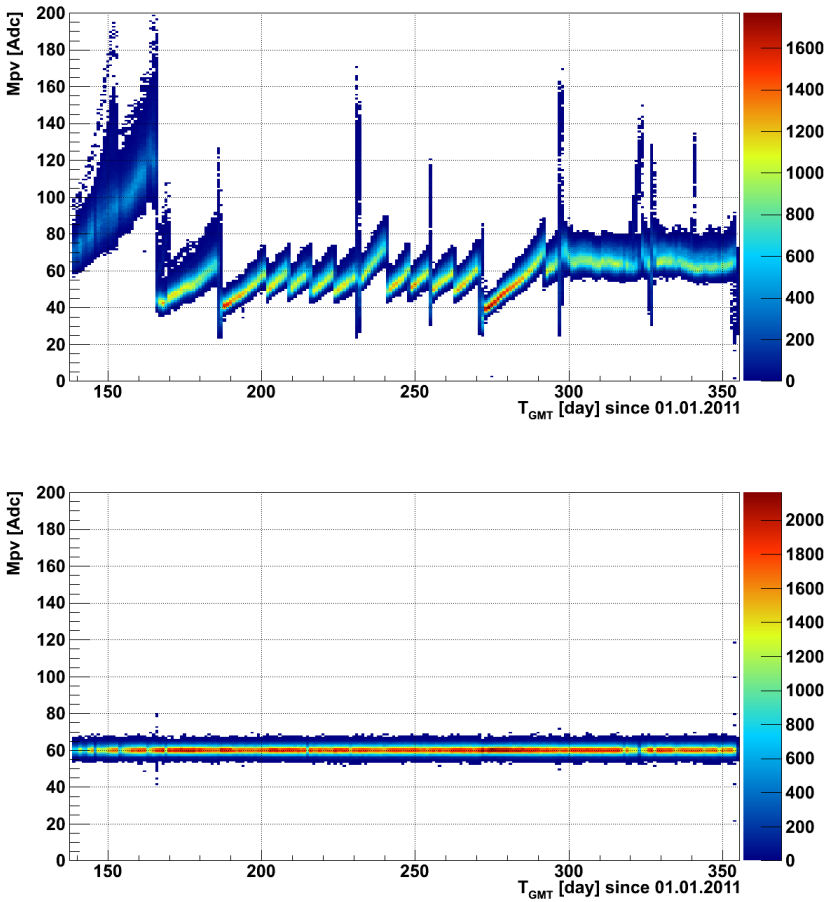


205 GeV positron

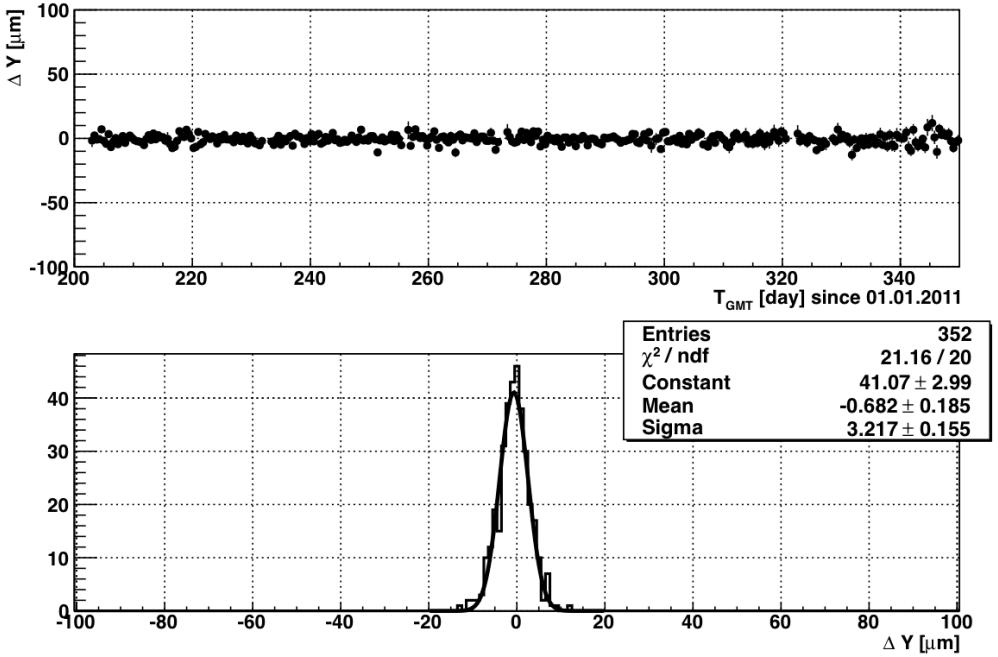


on orbit performance

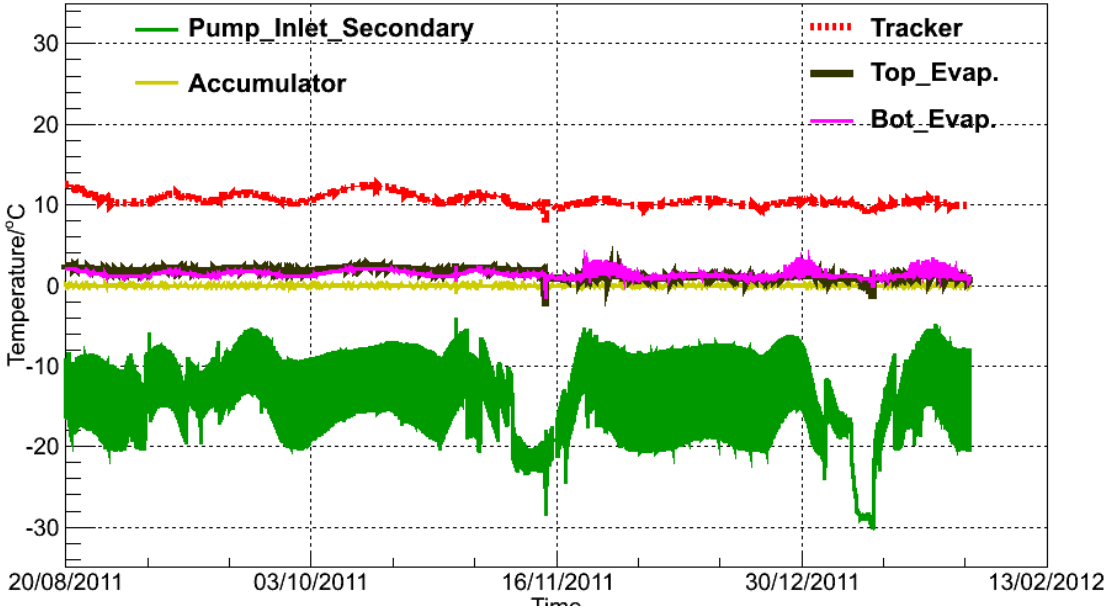
TRD gain calibration



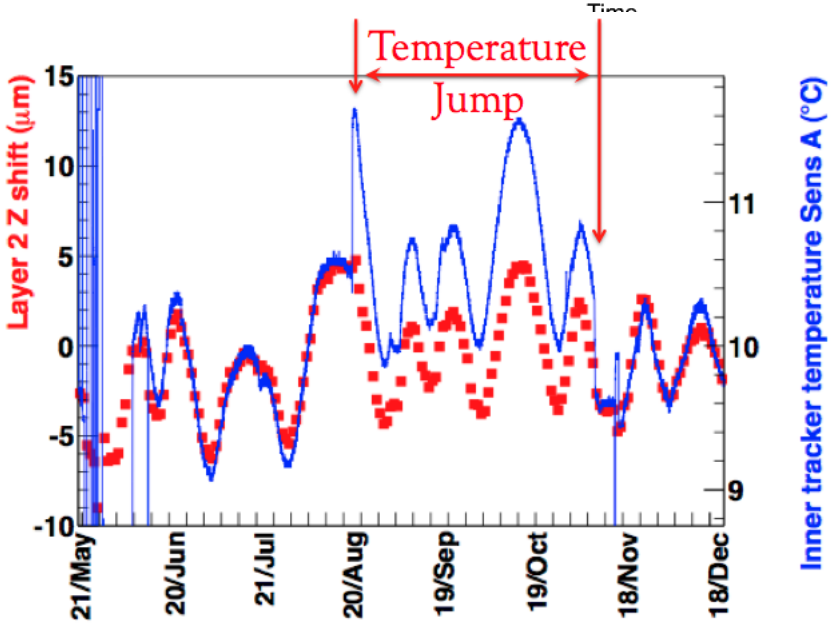
Alignment stability

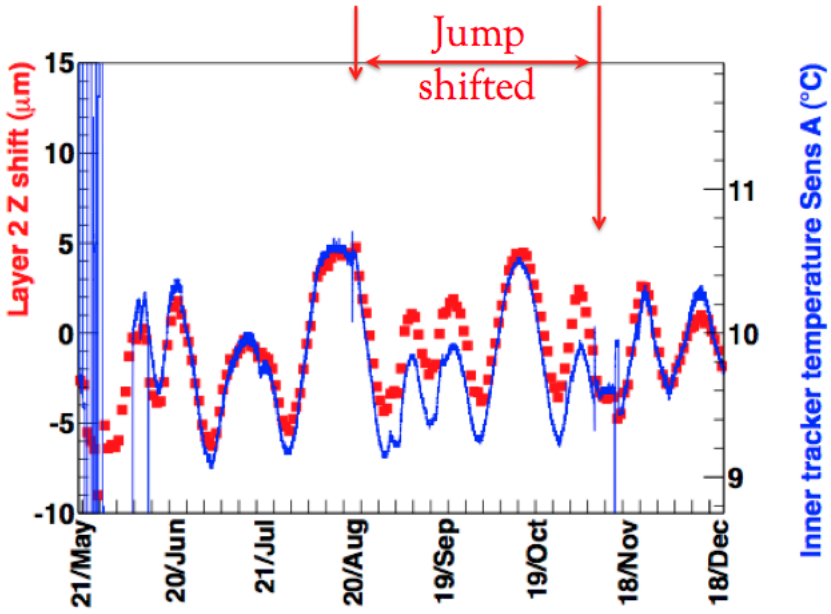


on orbit performance



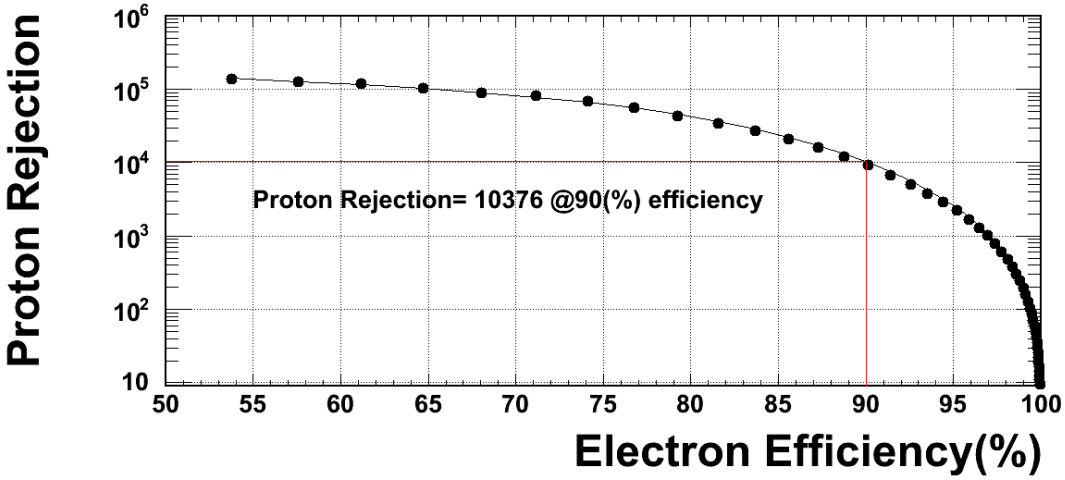
Temperature effects

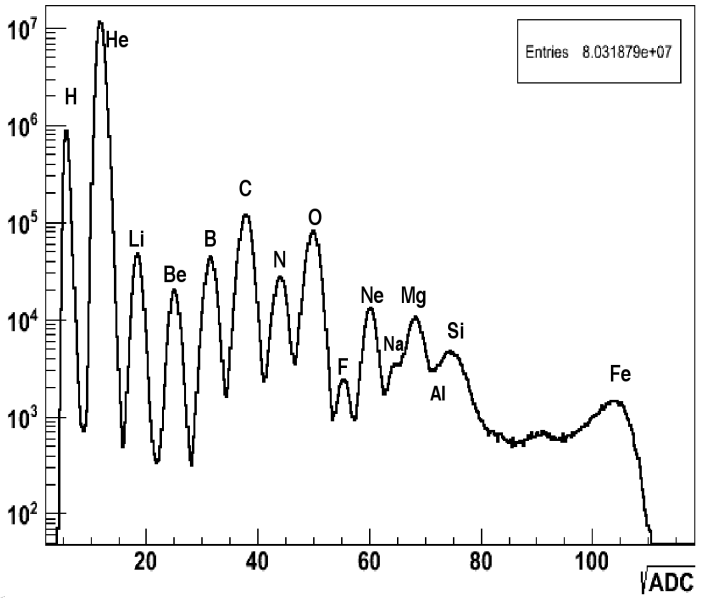


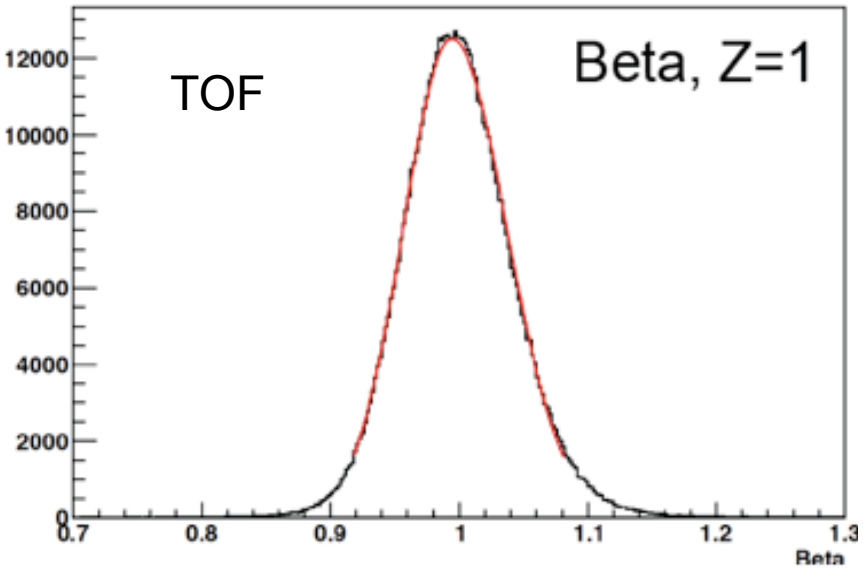


on orbit performance

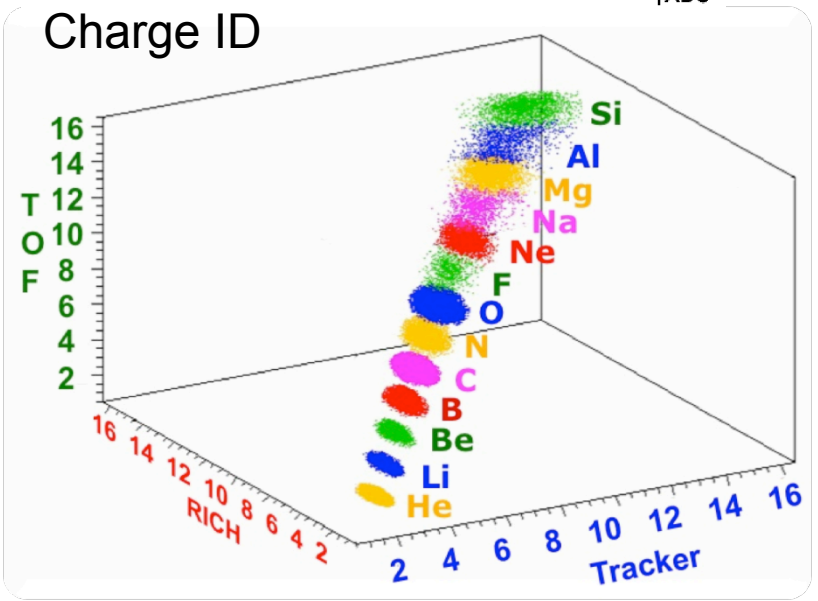
TRD gain calibration



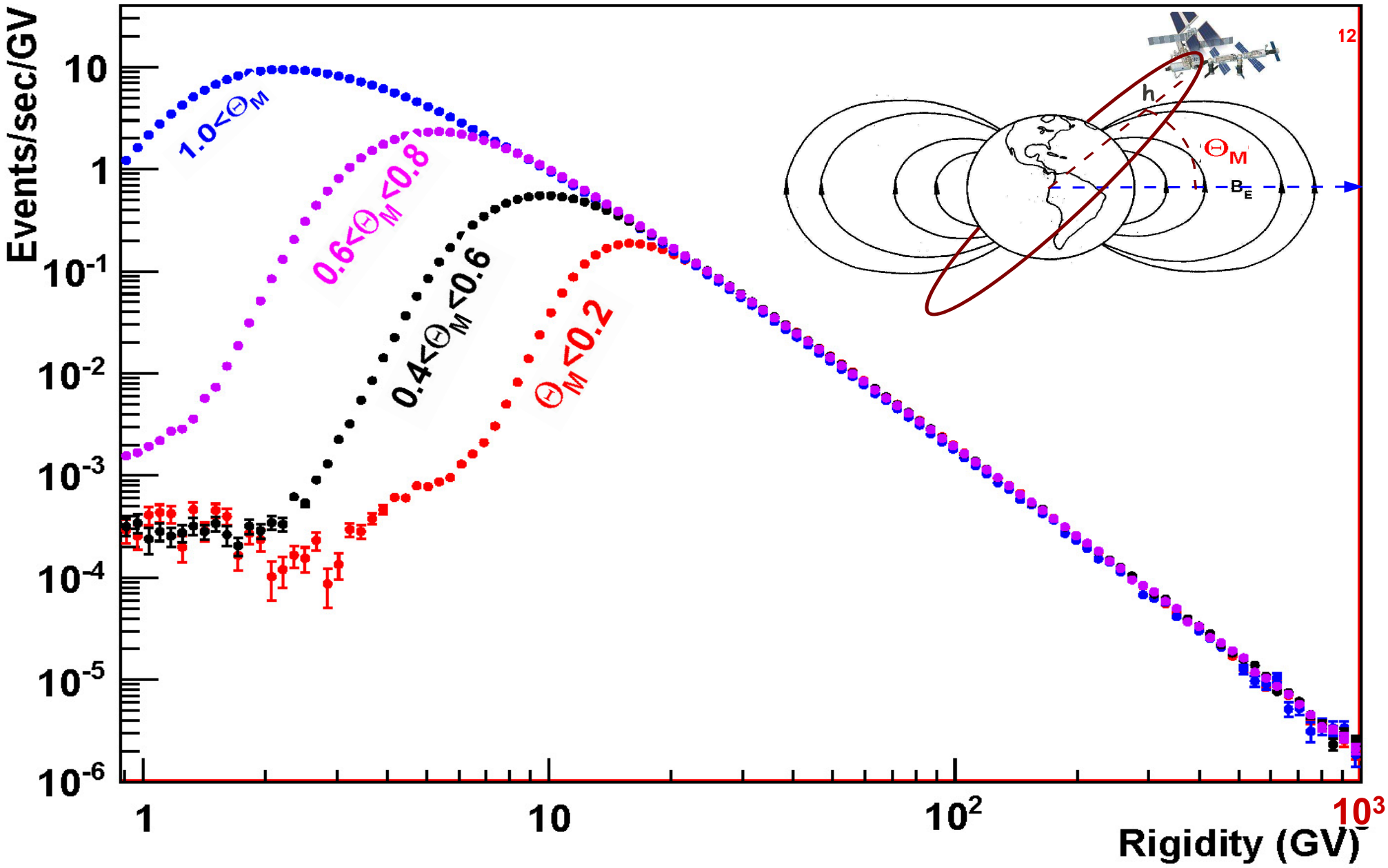




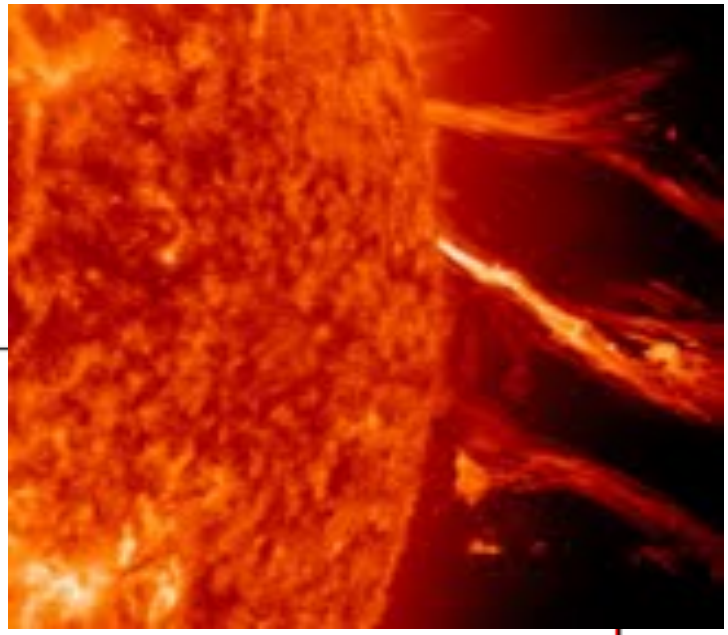
Charge ID

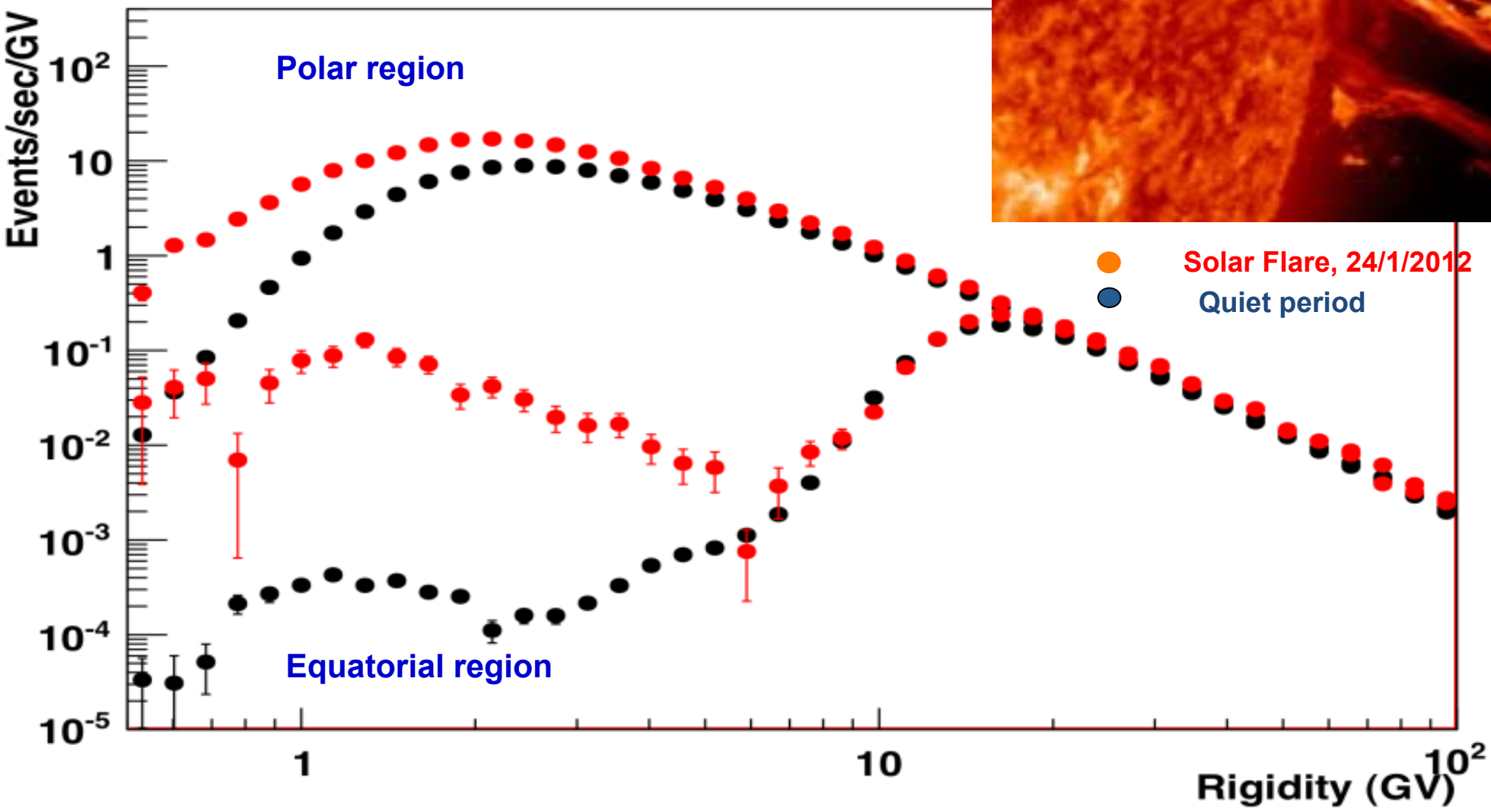


AMS data on ISS: He rate



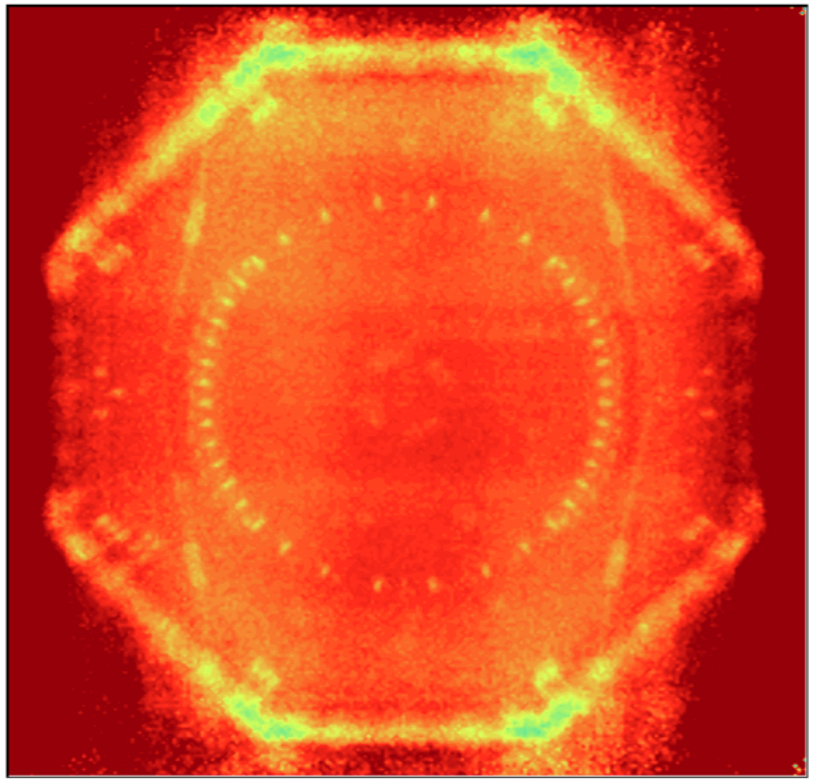
AMS data: He rate and Solar Flare

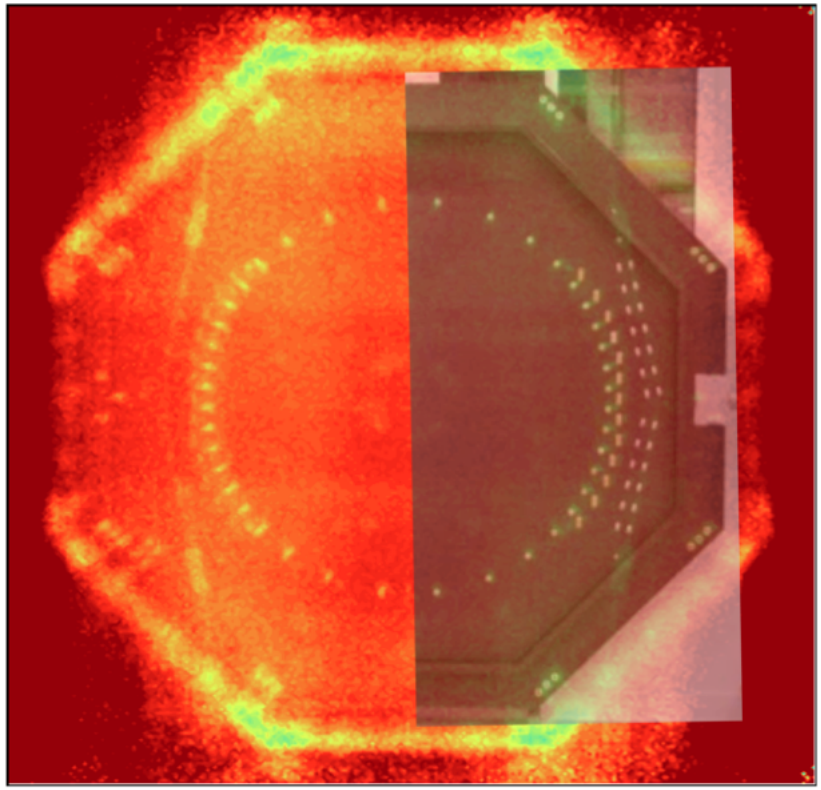




tomography of support plane

He missing particles extrapolated to the first mechanical Tracker support





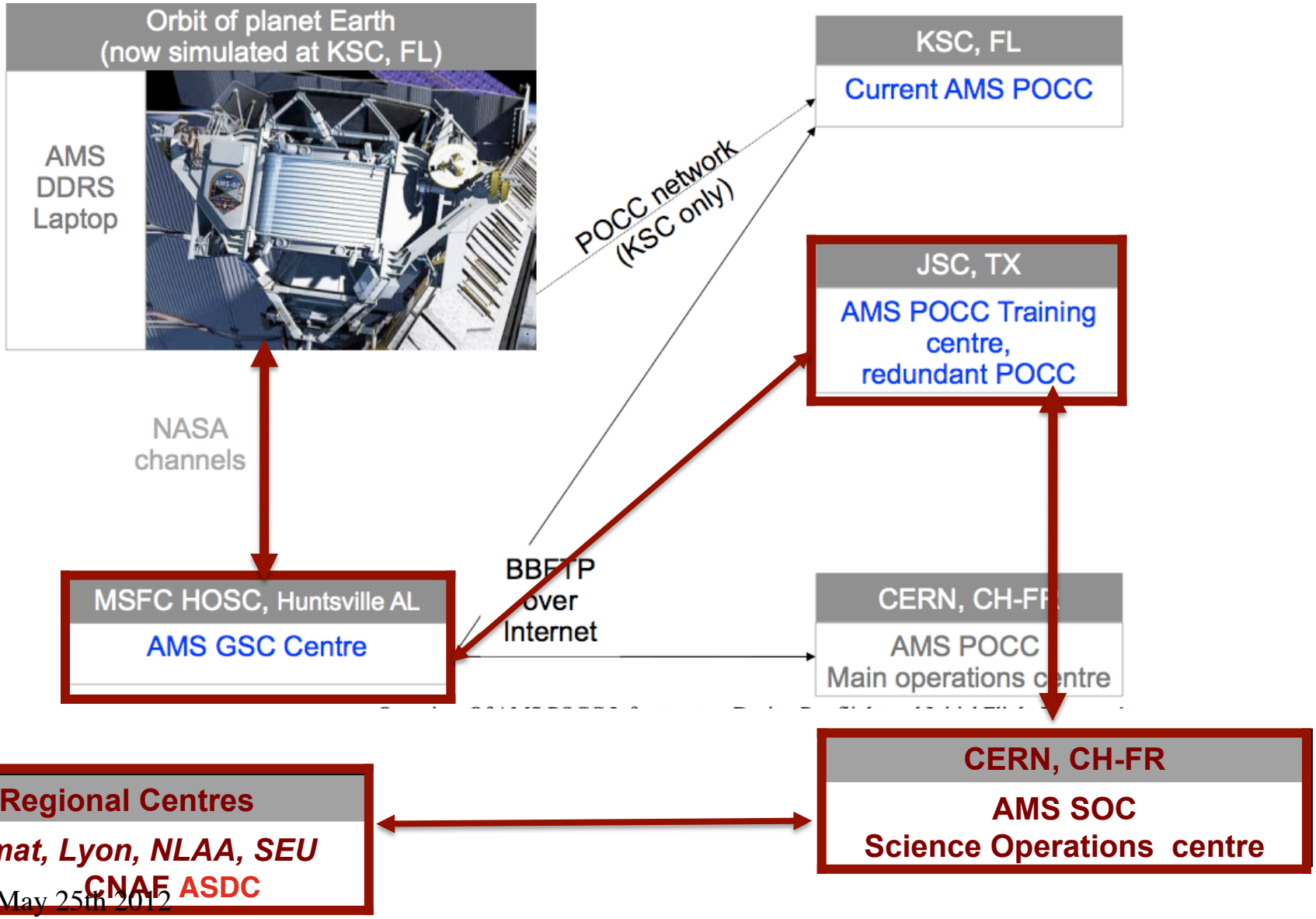
Conclusions

- AMS02 is in orbit since May 16th 2011
- No 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
- 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: great discovery potential


AMS-02
NASA
esa
JAXA
AMS Tracker
AMS Lead
STS-134
Chips Ahoy!

Science will come soon!

AMS Data Flow: POCC@JSC configuration

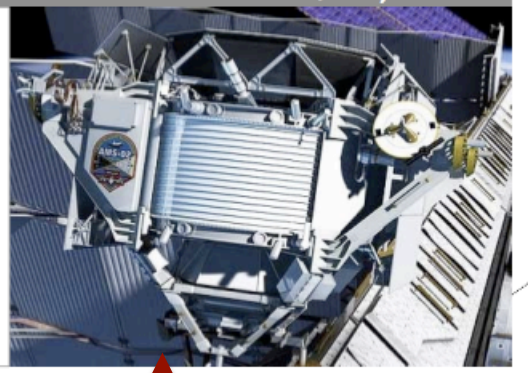


AMS Data Flow: POCC@CERN configuration

Perugia INFN Istituto Nazionale di Fisica Nucleare

Orbit of planet Earth
(now simulated at KSC, FL)

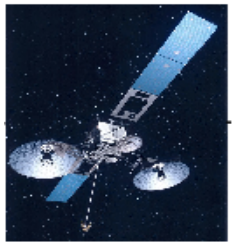
AMS
DDRS
Laptop



POCC network
(KSC only)

KSC, FL
Current AMS POCC

JSC, TX
AMS POCC Training centre, redundant POCC



NASA
channels

BBFTP
over
Internet

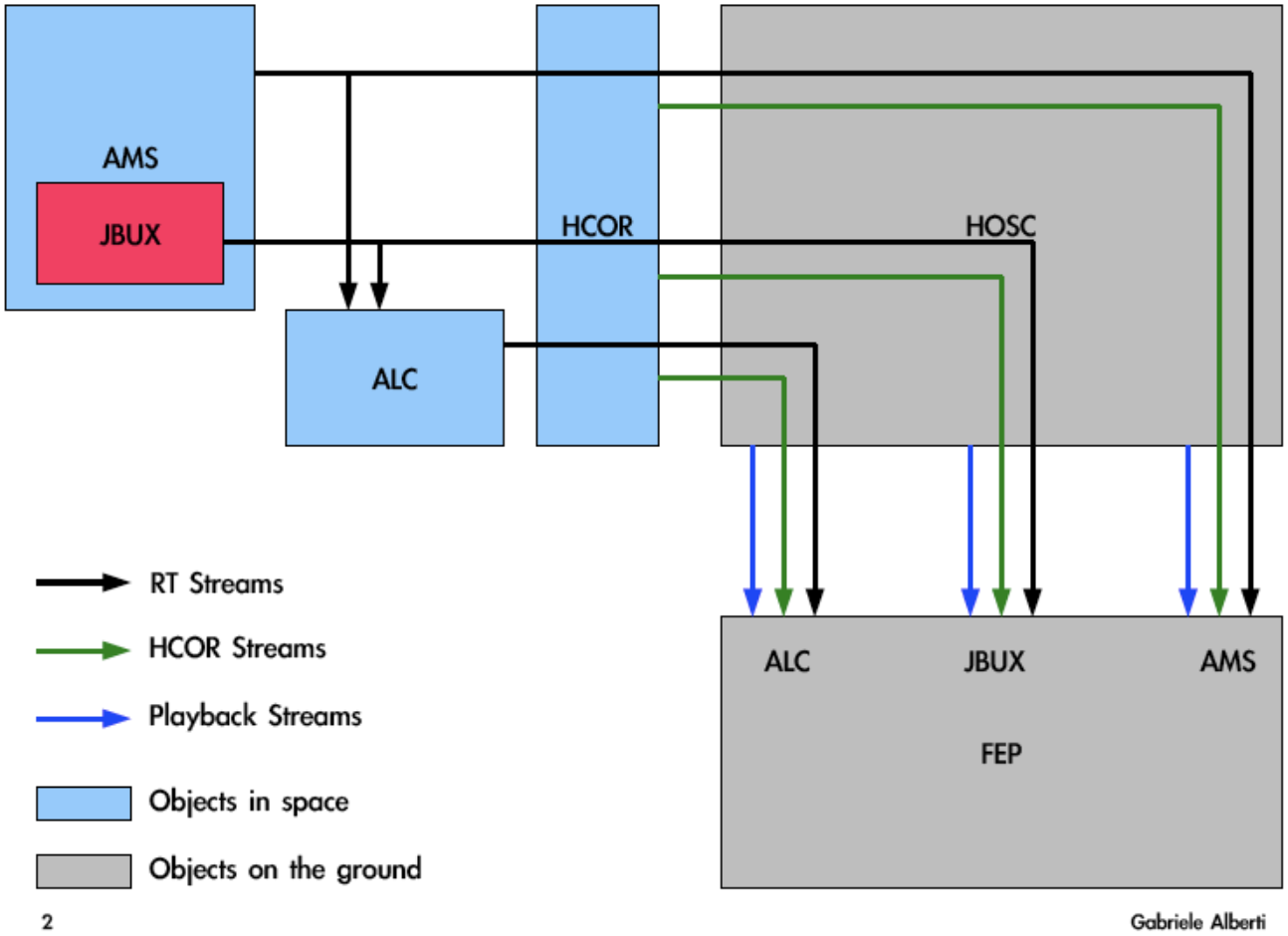
MSFC HOSC, Huntsville AL
AMS GSC Centre

CERN, CH-FR
AMS POCC
Main operations centre

CERN, CH-FR
AMS SOC
Science Operations centre

Regional Centres
Ciemat, Lyon, NLAA, SEU
CNAF ASDC

AMS data streams



AMS laptop on ISS

Data path

Reg. CENTERS:
CHINA-EU-USA

CNAF-IT

ISS
position

CERN

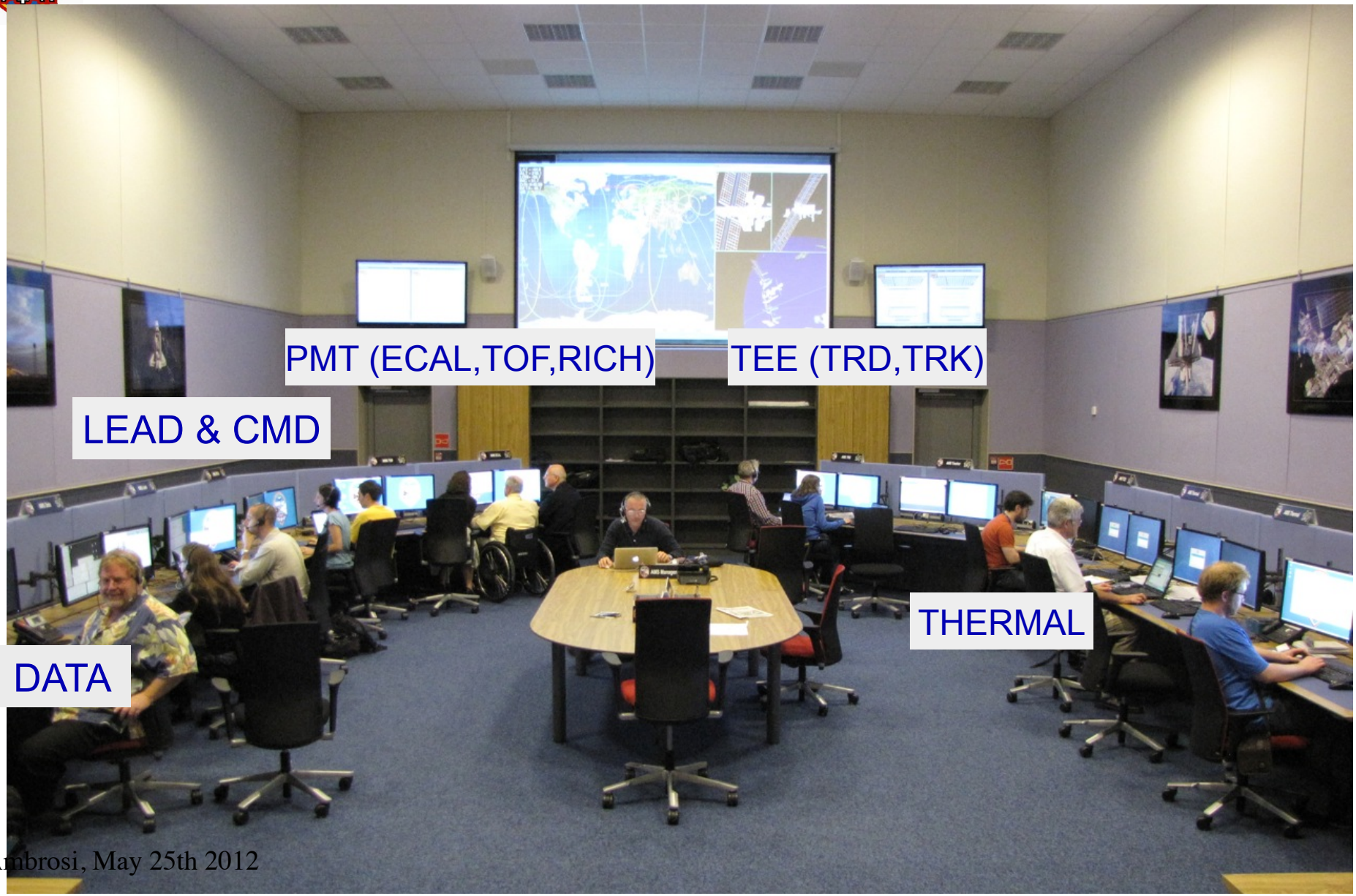
SOCC -CERN

AMS-MIB

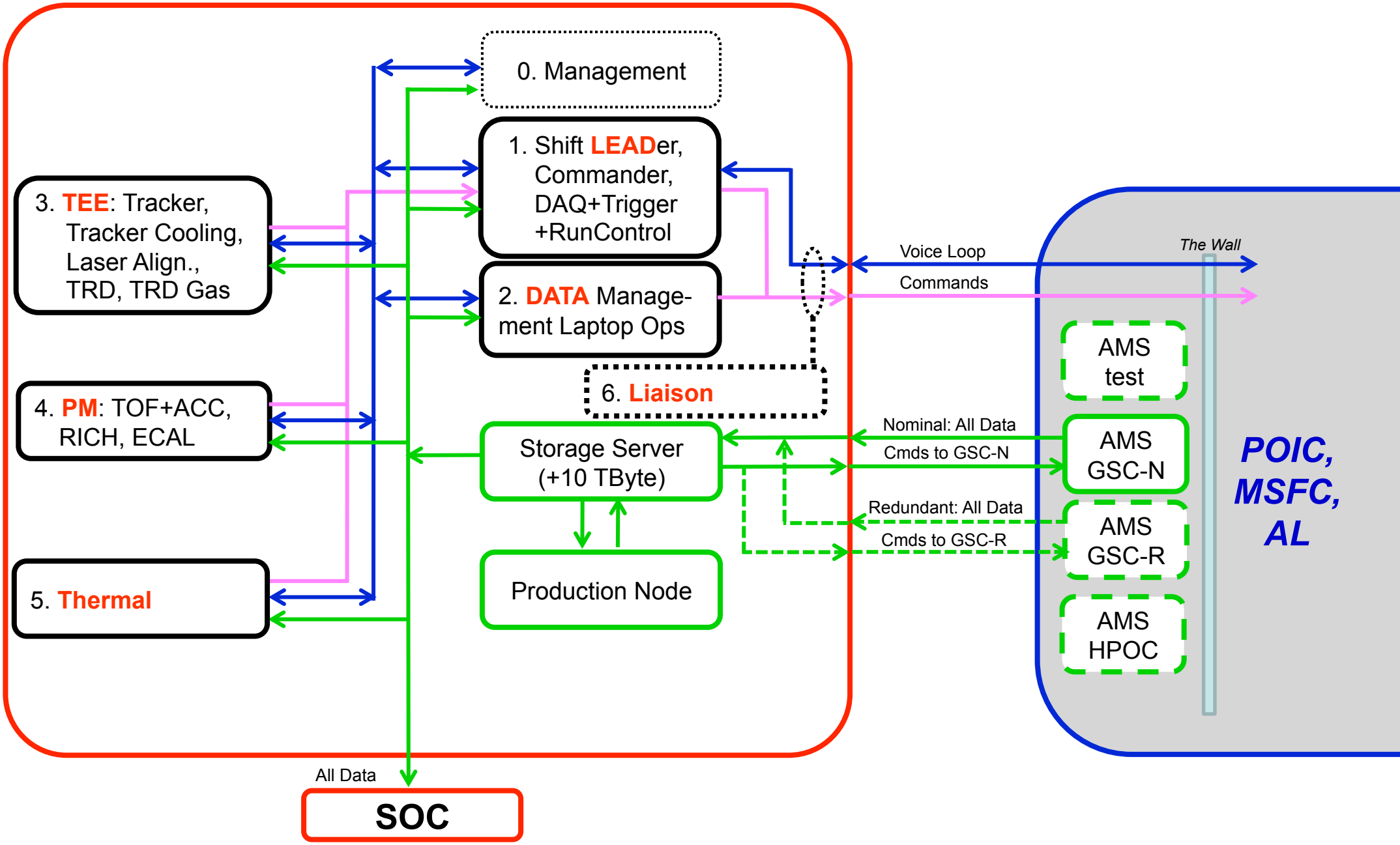
White Sands - NM

Marshall Space Flight Center

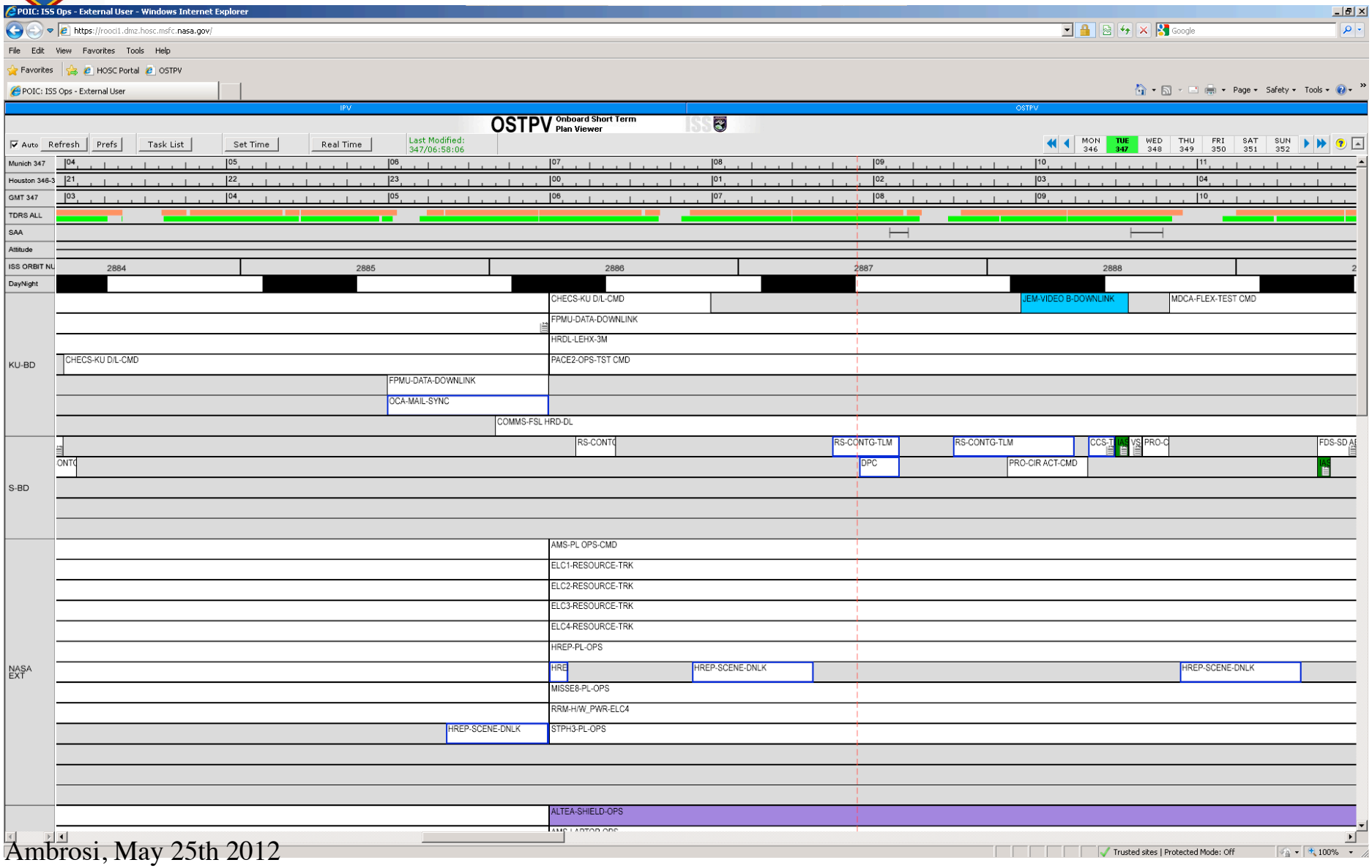
POCC at CERN (Switzerland)



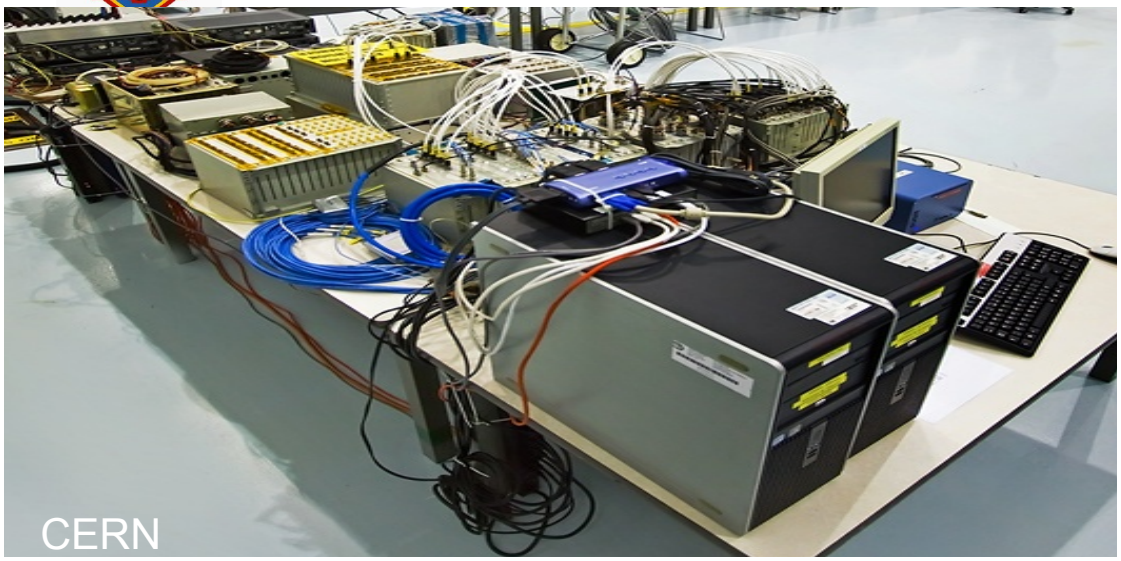
AMS POCC: 5 positions (24/7/365 for 20 years?)



Onboard Short Term Planner Viewer



Software Development and Test Facilities

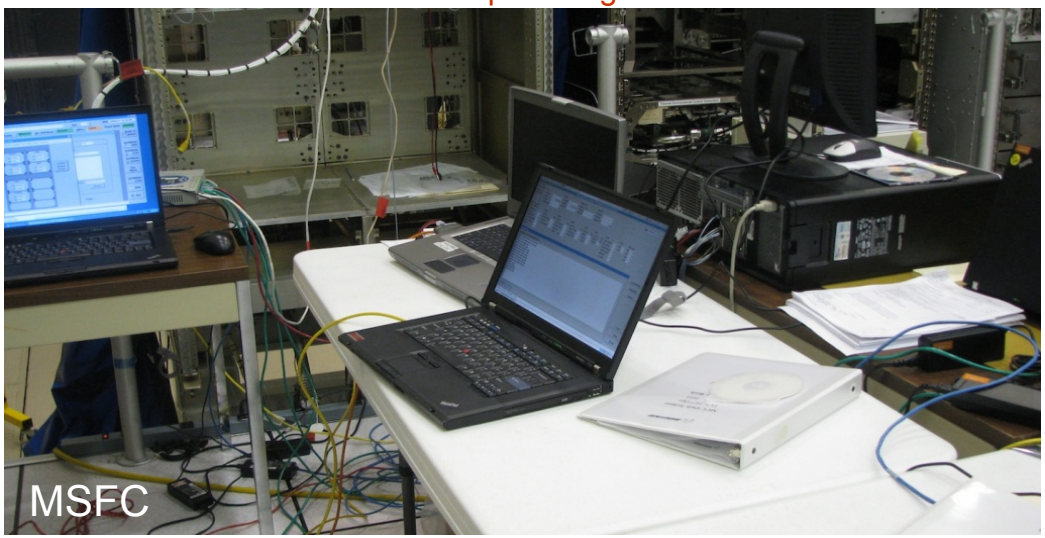


(A) AMS Simulator Laboratory at CERN

1. Flight Simulator
2. ISS Avionics Simulator
3. AMS Laptop Simulator
4. Development and Test Facilities

(B) AMS Flight Equivalent Unit
at JSC Software Development and Integration Lab (SDIL)

(C) AMS ISS Laptop and AMS Ground Software checkout
at Marshall Space Flight Center



Alignment of the Outer Tracker Planes

Comparison between TB and MC

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