

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



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AMS on the International Space Station



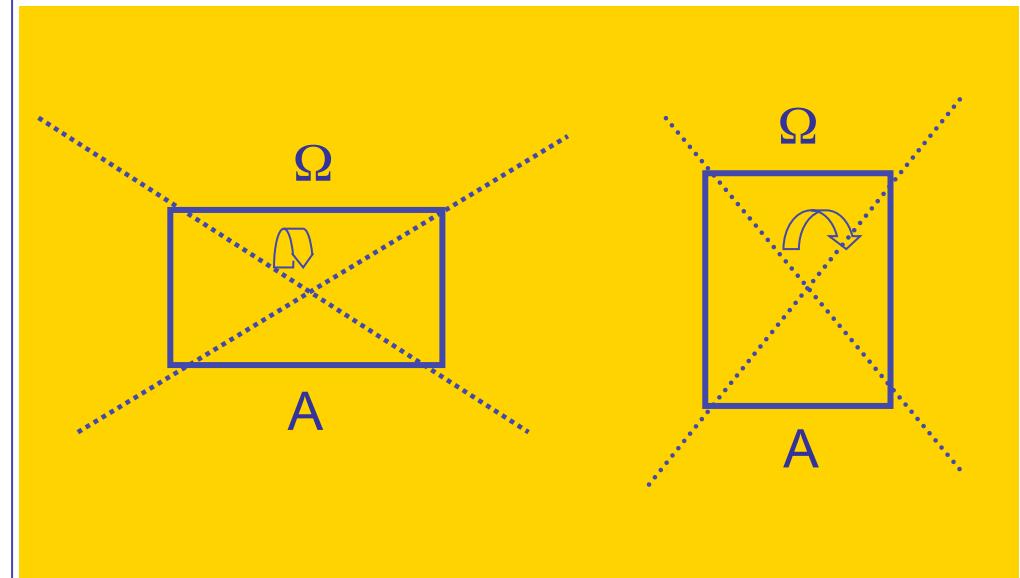
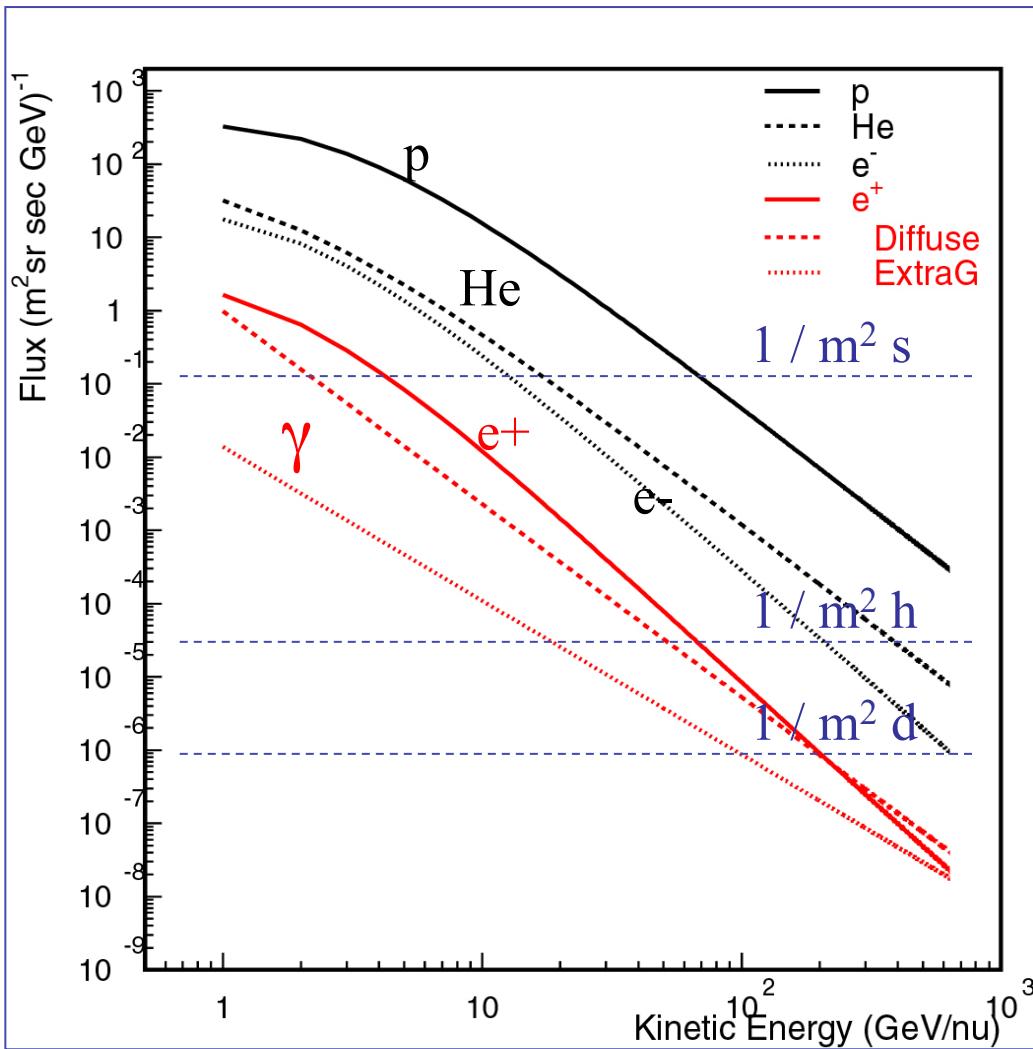
- Cosmic Antimatter search with 10^{-9} sensitivity
- Indirect Dark Matter search (e^+ , \bar{p} , γ)
- Relative abundance of nuclei and isotopes in primary cosmic rays
- γ ray astrophysics



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

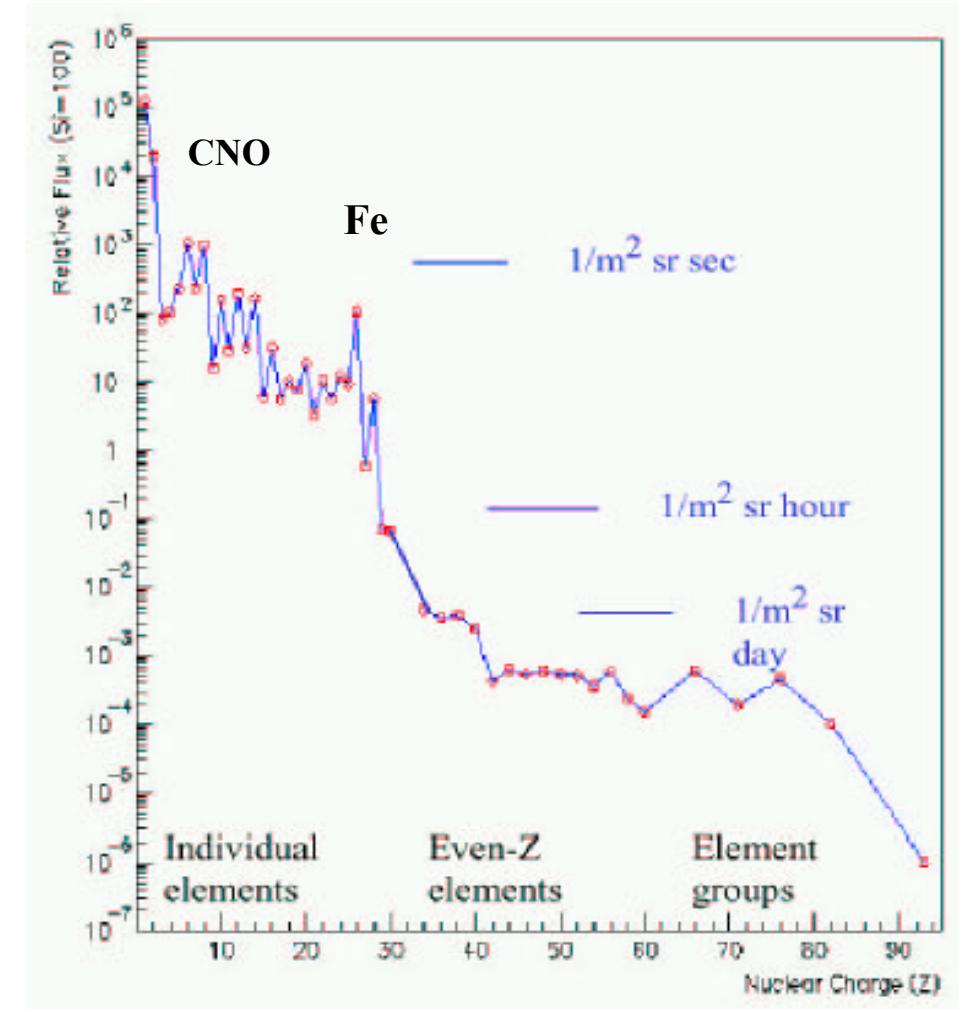
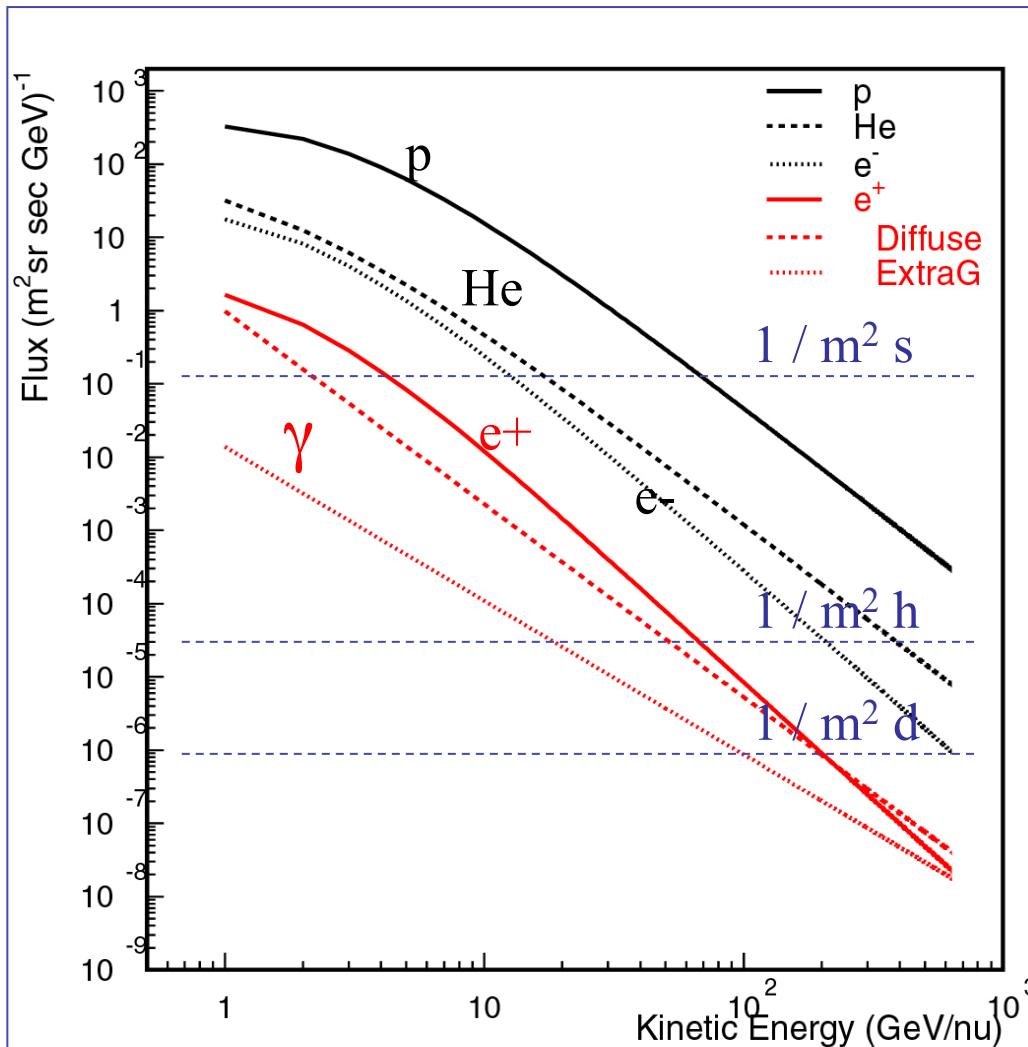


High Energy CR flux and composition





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}



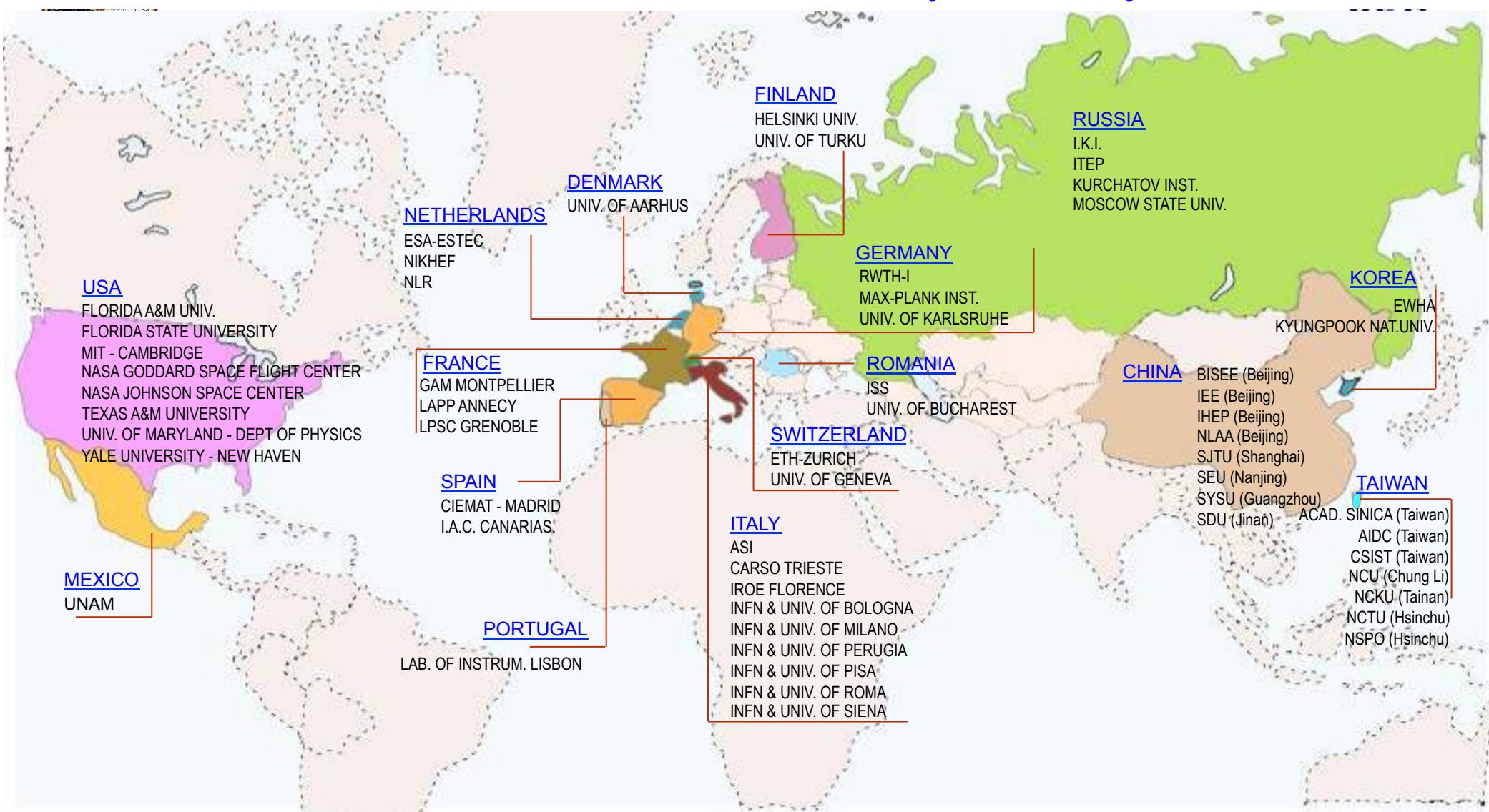


The instrument we need has ...

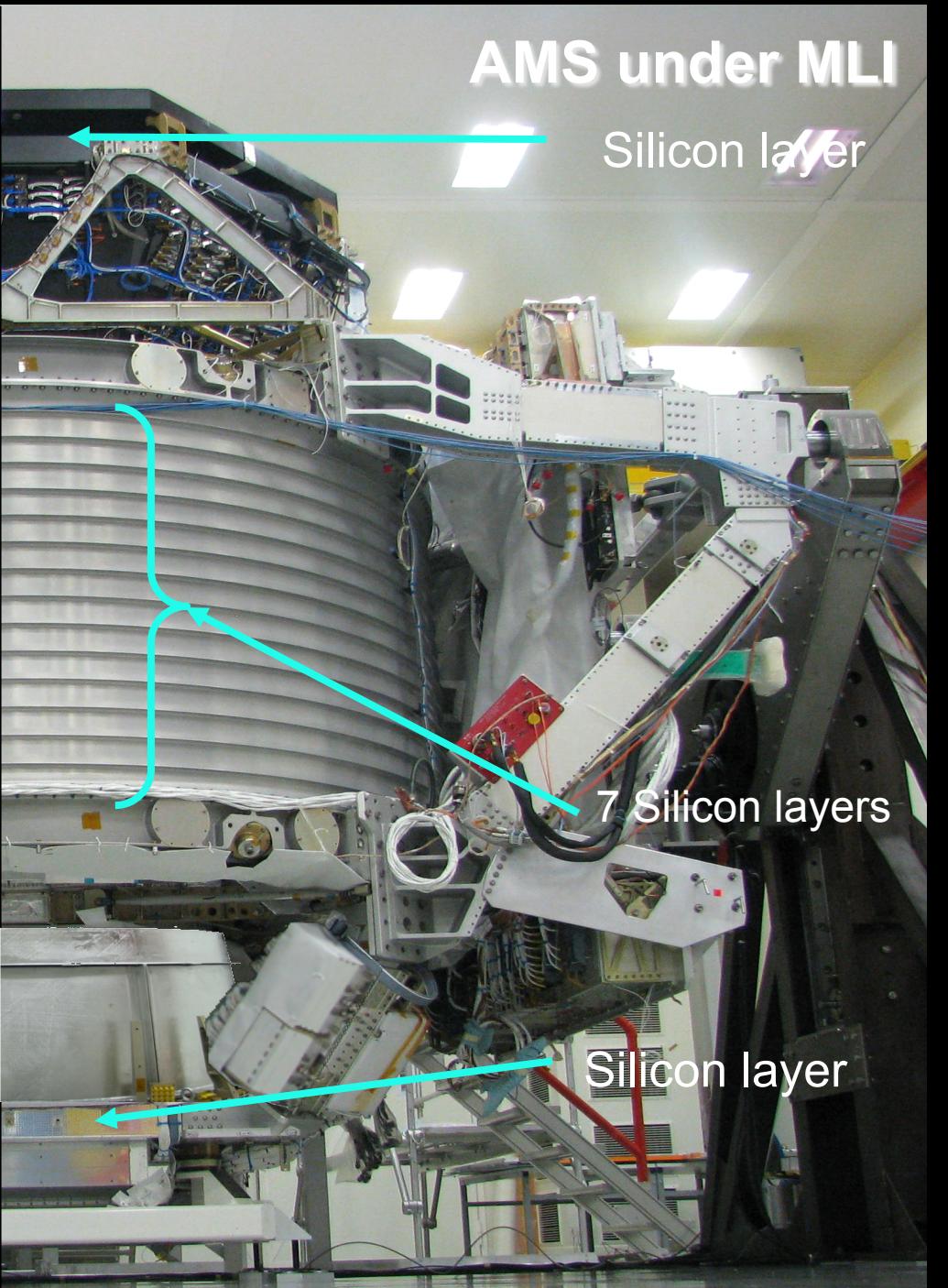
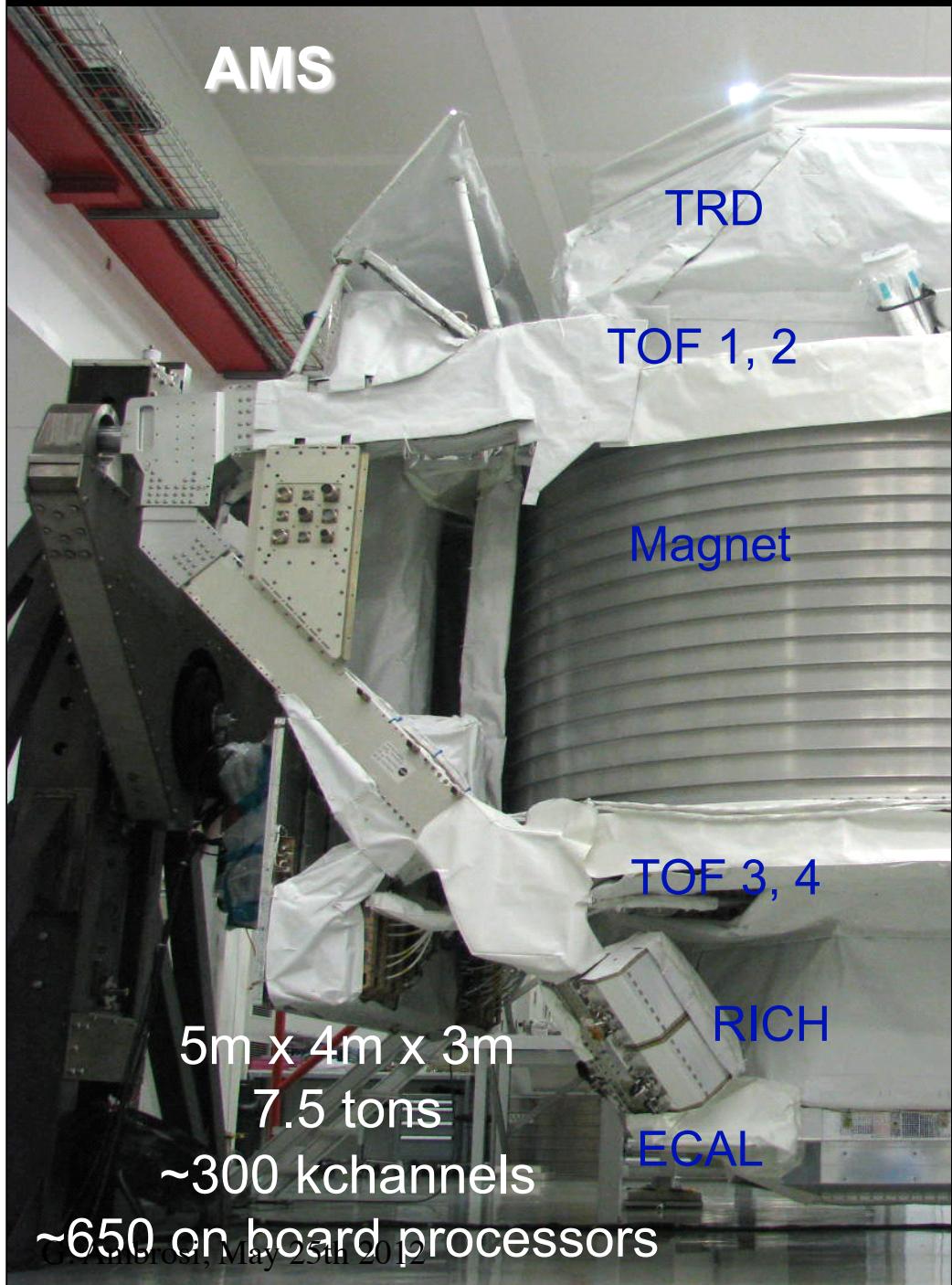
- performance a la 'particle physics':
 - high resolution measurements of momentum, velocity, charge and energy
- characteristics to properly work in the space environment:
 - Vibration (6.8 G rms) and acceleration (17 G)
 - Temperature variation (day/night $\Delta T = 100^\circ\text{C}$)
 - Vacuum (10^{-10}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



Tracker

TRD

TOF

MAGNET

ACC

Tracker

ACC

MAGNET

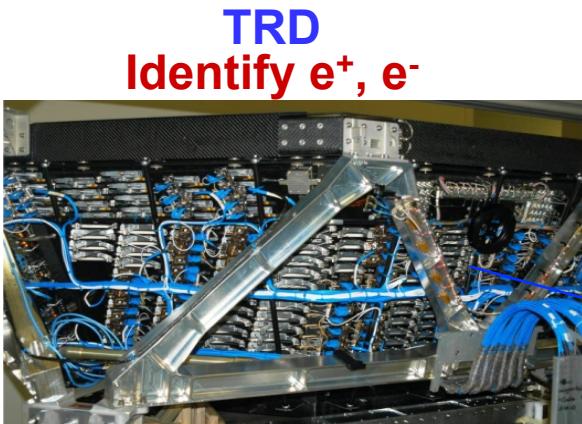
TOF

RICH

Tracker

ECAL

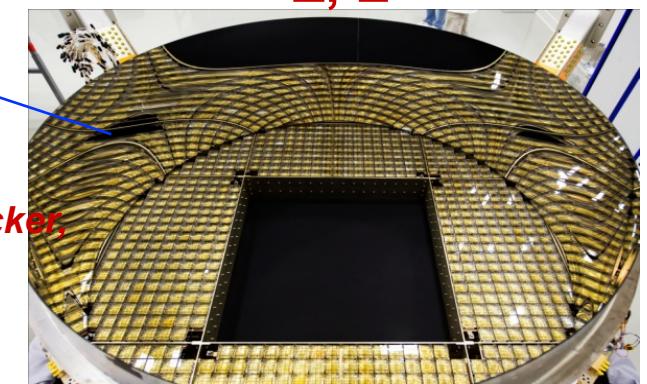
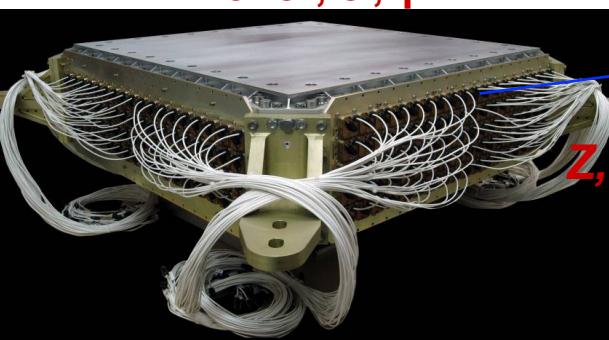
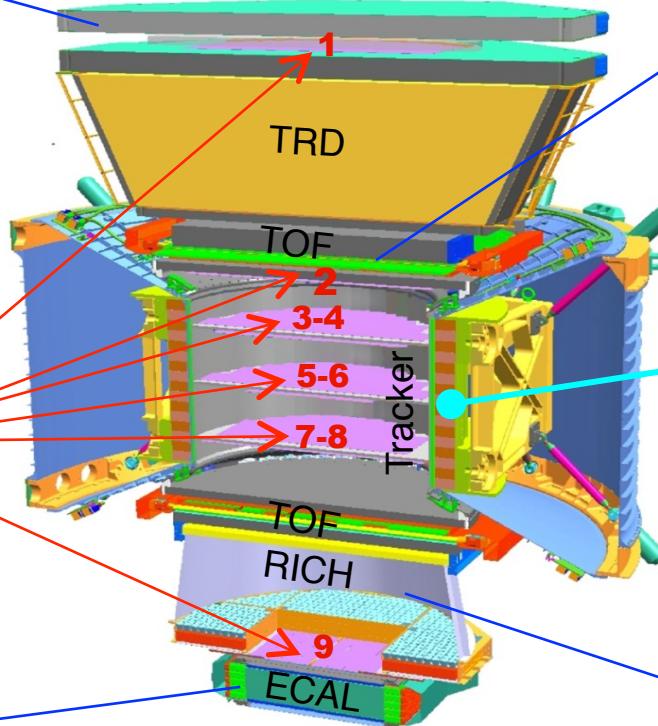
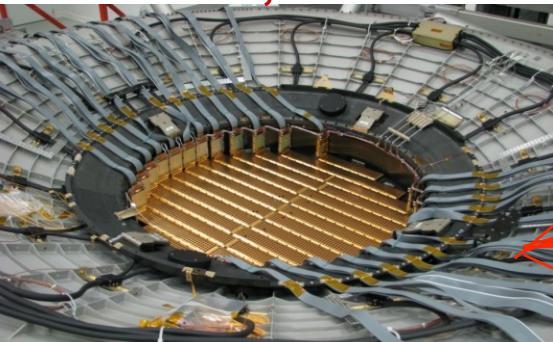
AMS: A TeV precision, multipurpose spectrometer



Particles and nuclei are defined by their charge (Z) and energy ($E \sim P$)



Silicon Tracker
 Z, P



TRD

Identify e^+ , e^-

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

Silicon Tracker Z, P

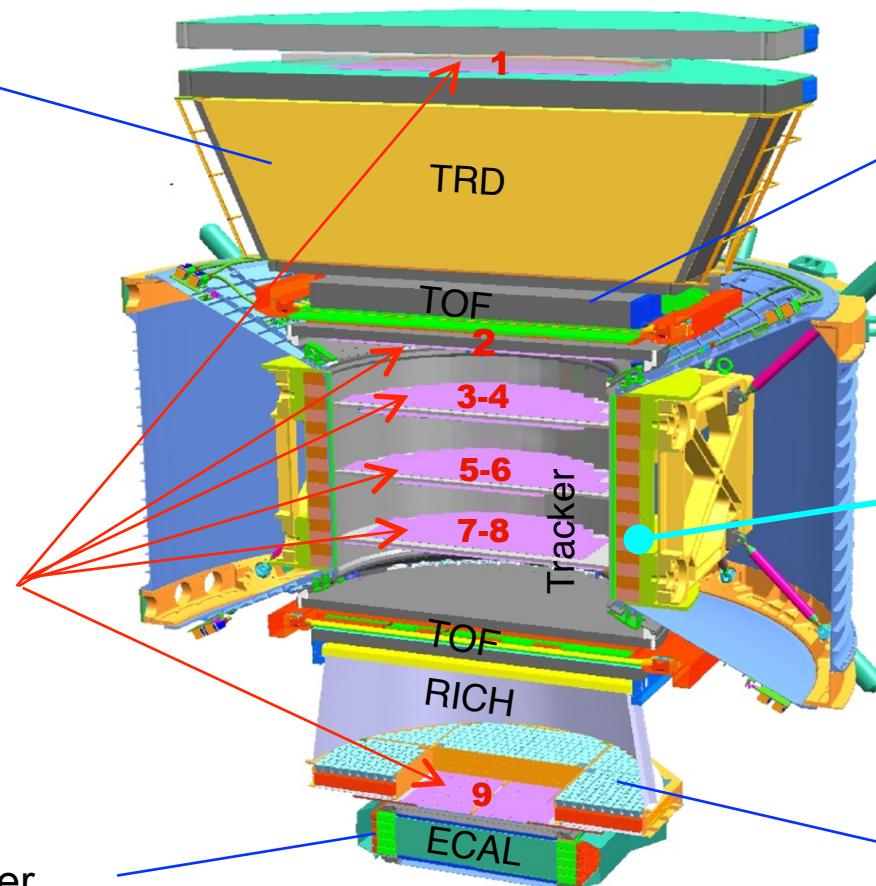
- 9 layer double sided detector
- 192000 high dyn. range readout channel
- low material budget
- D. Rapin poster

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 ($E \sim P$)



TOF Z, E

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

Magnet $\pm Z$

- $B \sim 0.14$ 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

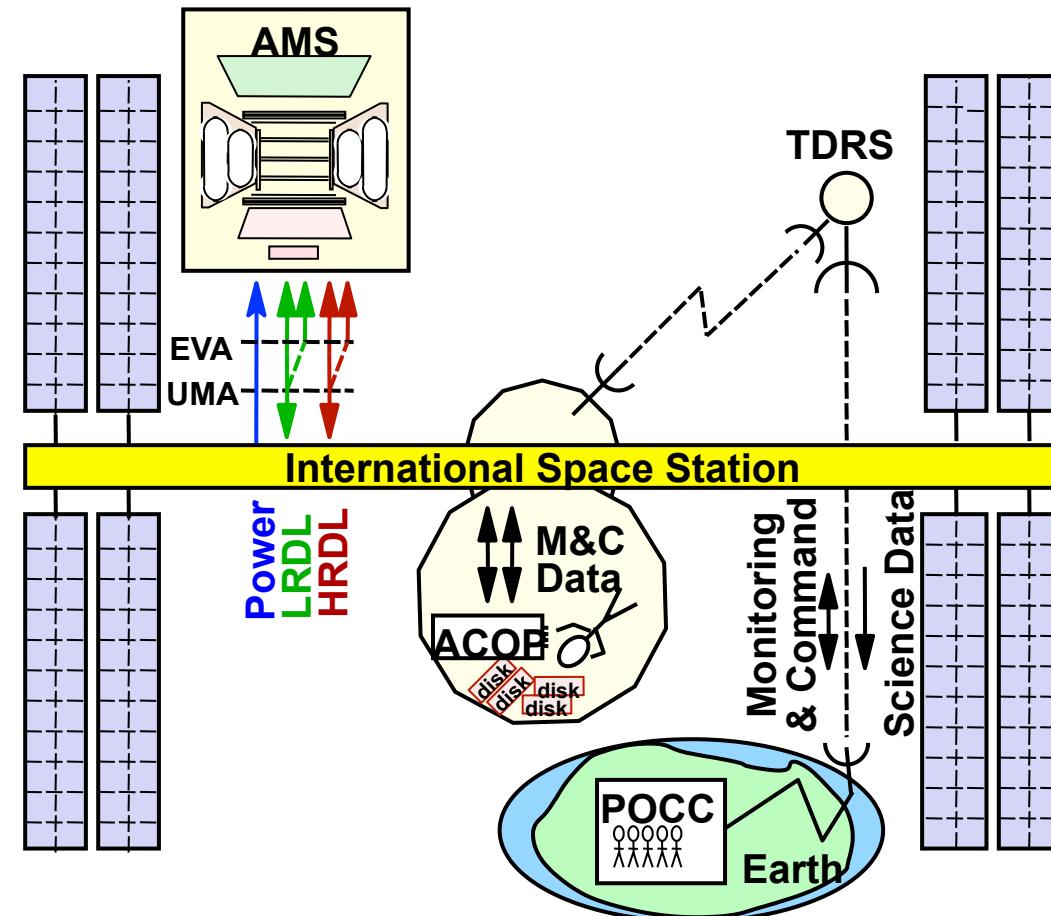
LRDL

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

HRDL

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

xRDL: Duty cycle ~50-70%

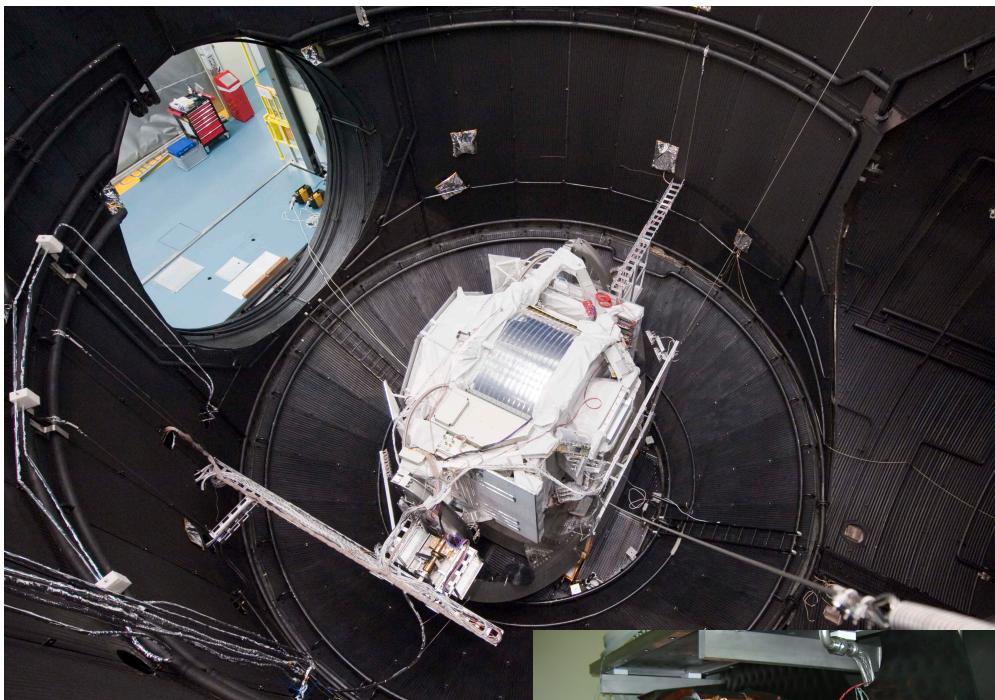




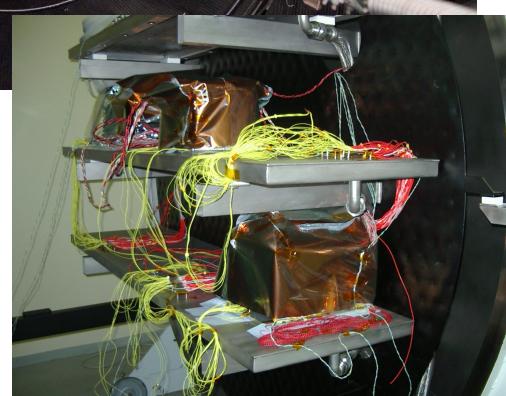
AMS in ESTEC (ESA test facility)



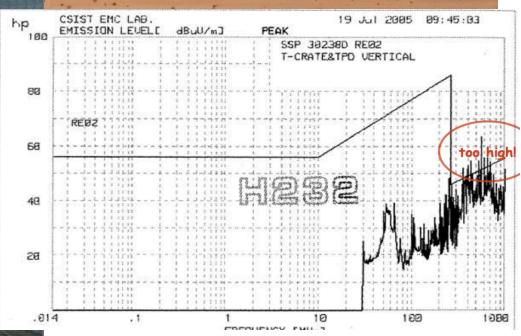
vacuum test (~400 h, P<10⁻⁶ mbar, T -90°C +40°C



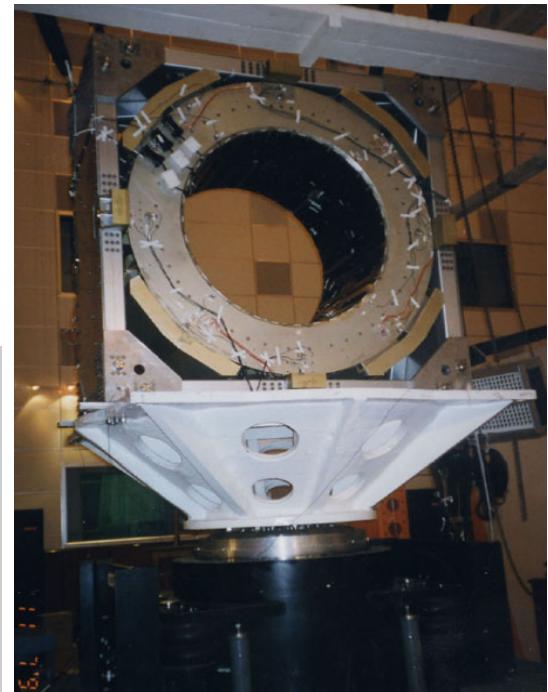
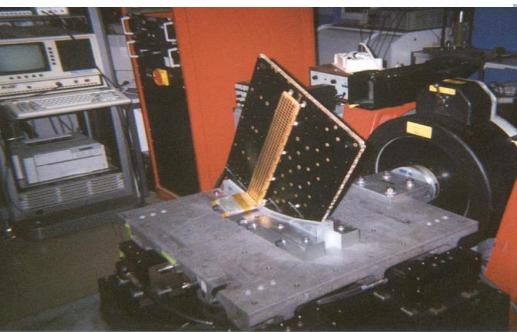
9000 hours of subsystem test



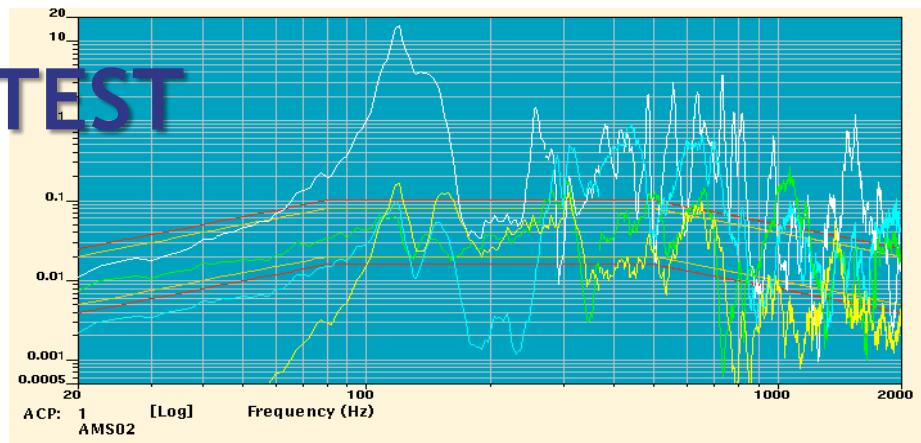
EMI/EMC test



G. Ambrosi, May 25th 2012

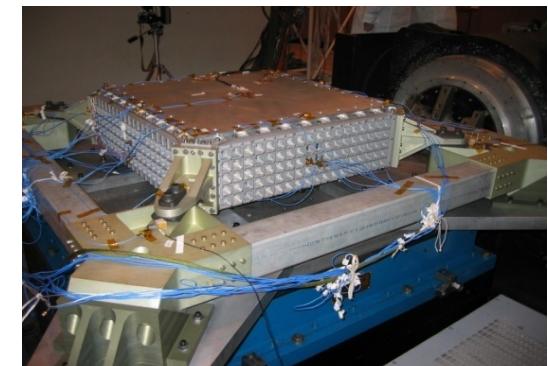


STRUCTURAL TEST

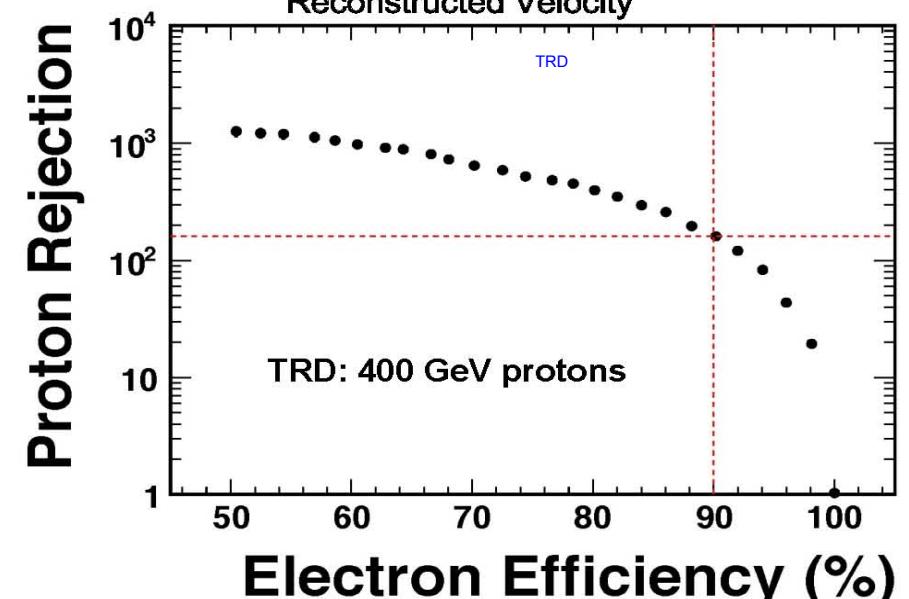
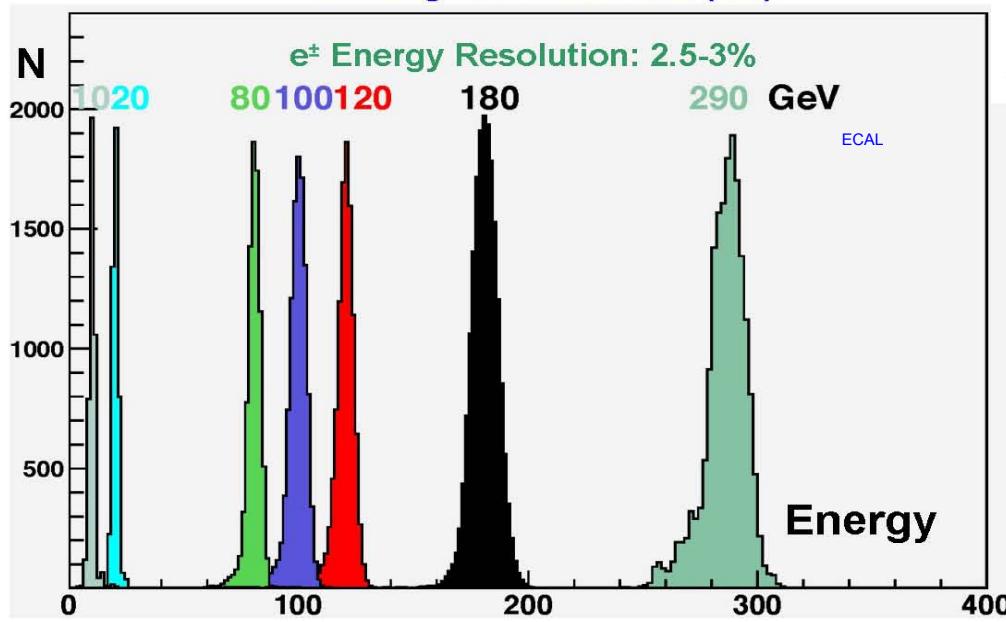
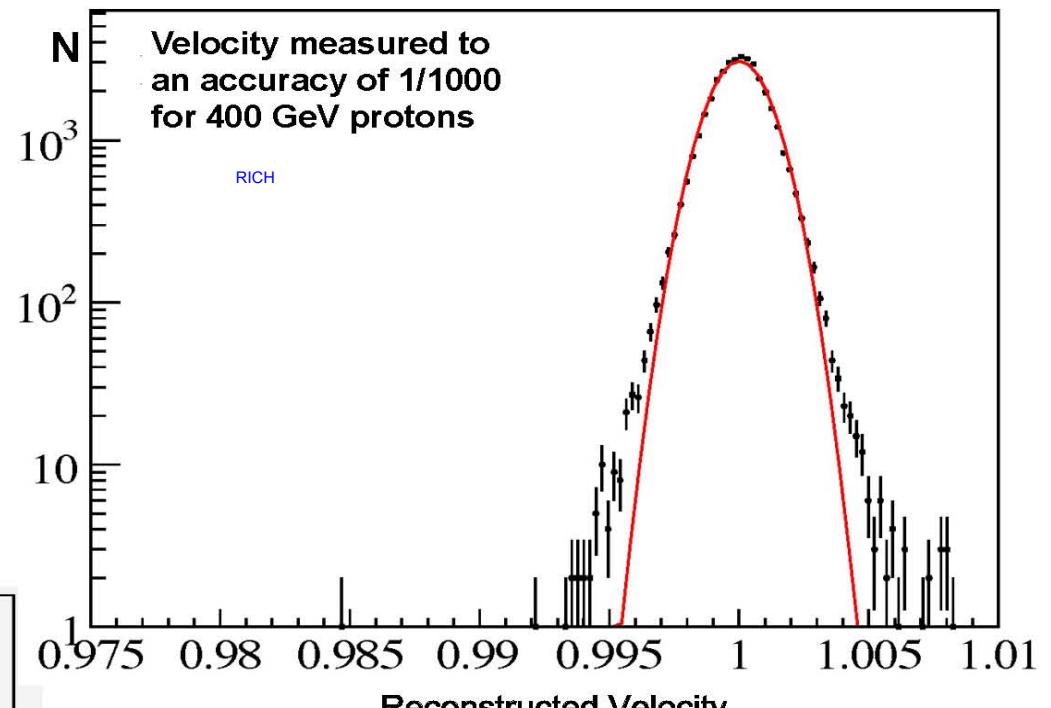
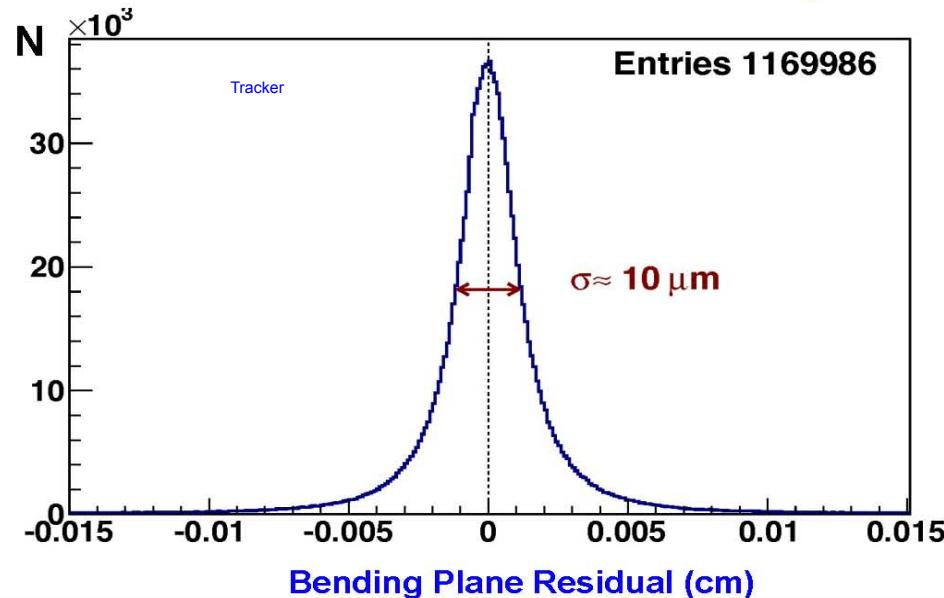


Test
at components level
and at system level

on EM, QM, FM

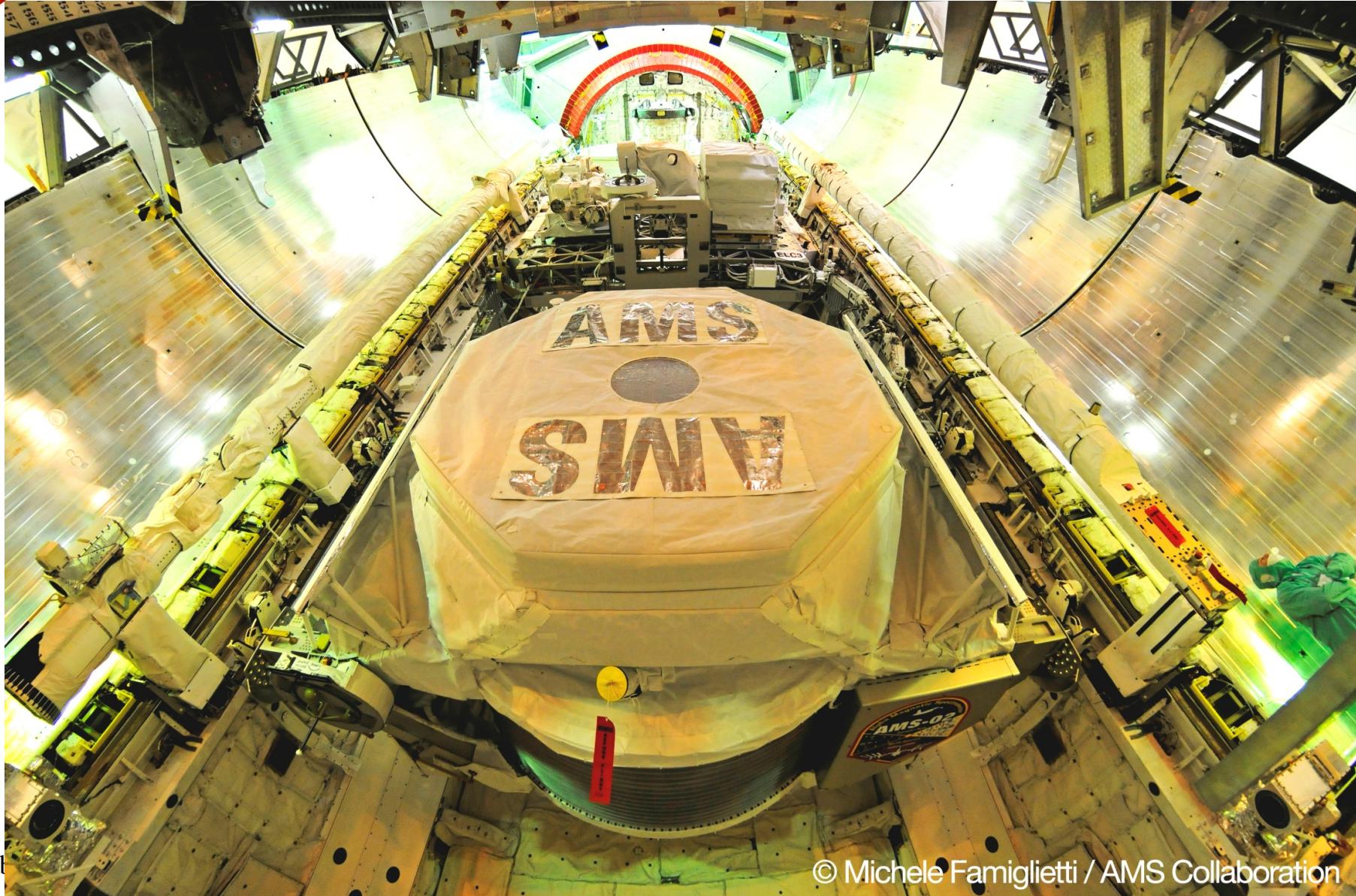


Test Beam Results with permanent magnet – 8-20 Aug 2010





AMS in the Shuttle cargo bay



G. Am

© Michele Famiglietti / AMS Collaboration



Bookmarks Tools Help

AMS Monitoring Interface - Mozilla Firefox

http://pcposj0.local:8081/welcome/show/GTSN/0x28/3_hours

Global Site

AMS Monitoring Interface

Every 180 secs.)

GTSN

JPD-A

JPD-B

CHECK

CHECK	Value
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

Until now or 16:35 16/05/2011

Everything OK

2.5 h after the launch

SAMSUNG

FROM SHUTTLE TO ISS



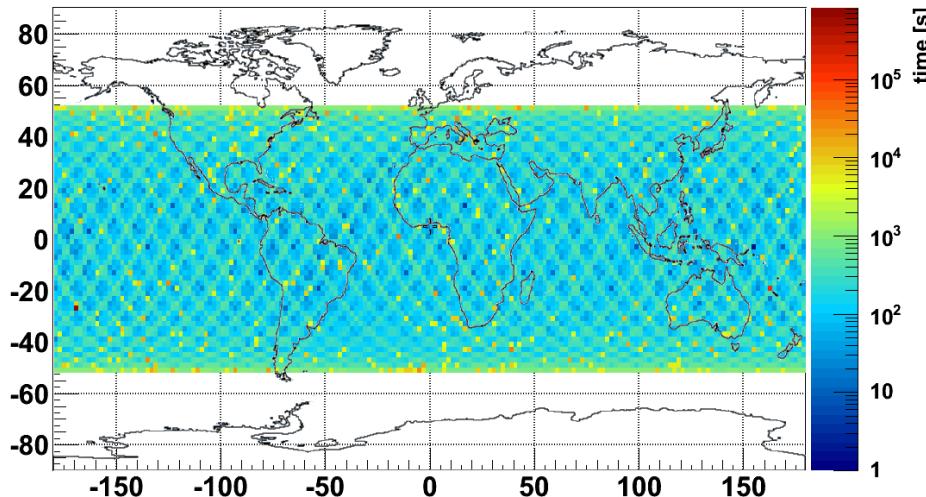
ON ISS



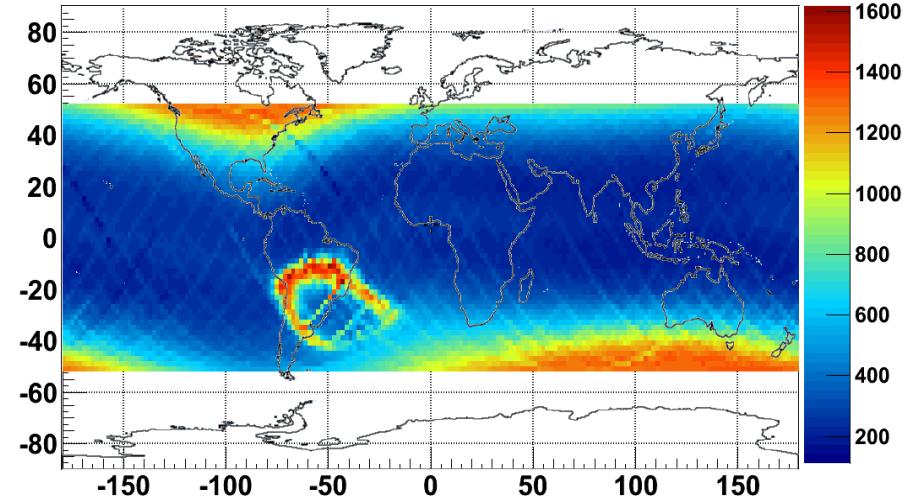


Orbital DAQ parameters

Time at location [s]



Acquisition rate [Hz]

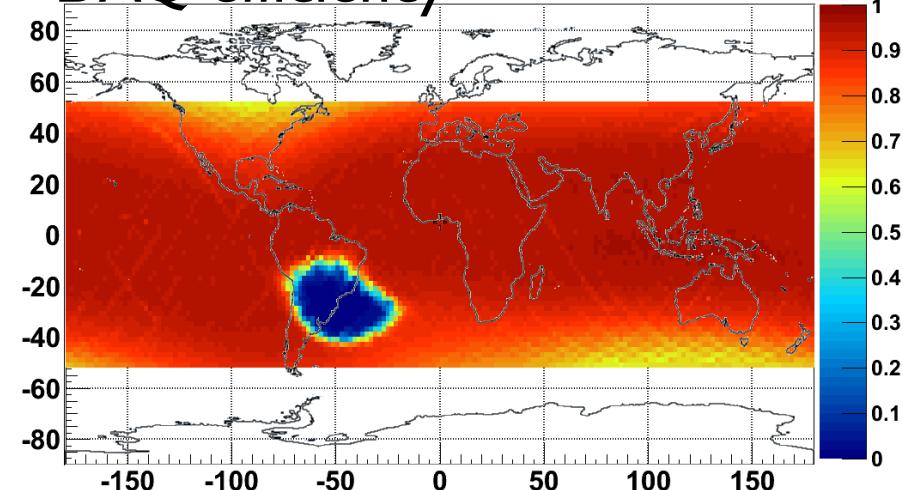


Particle rates: 200 to 2000 Hz per orbit

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

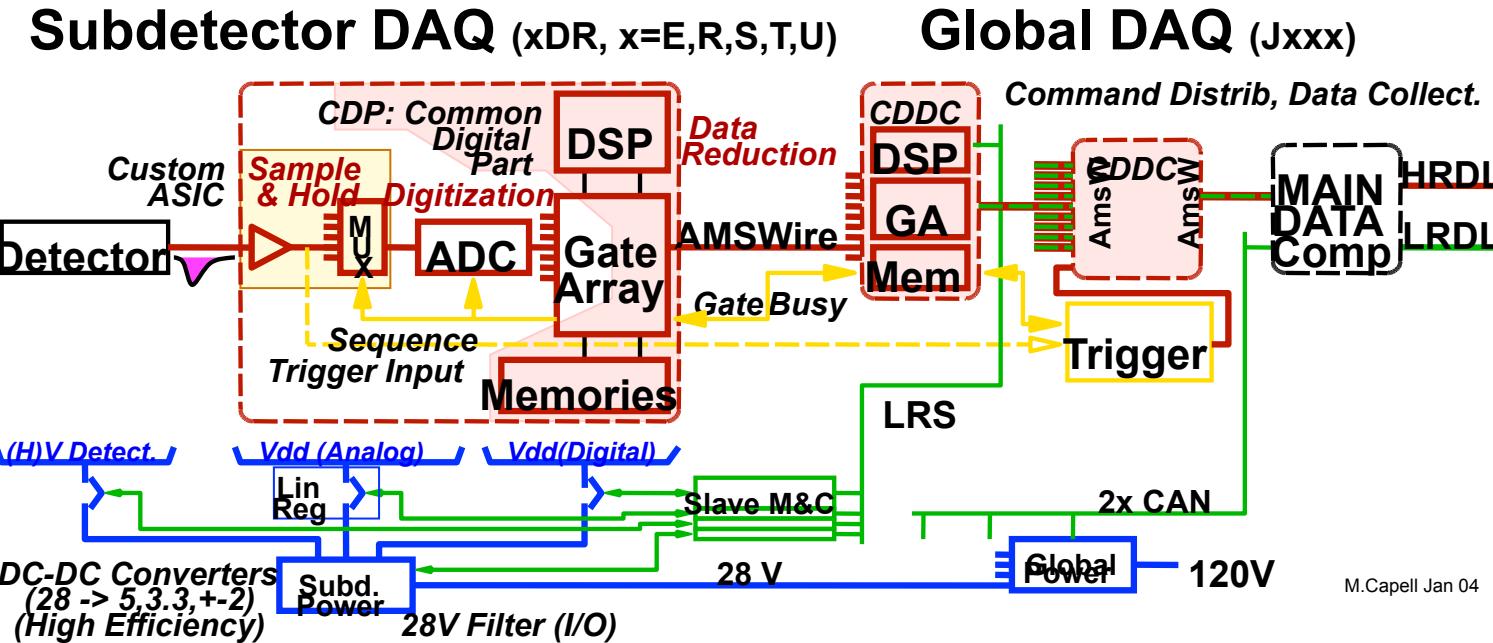
1 year of data: $1.6 \cdot 10^{10}$ events
35 TB raw events

DAQ efficiency

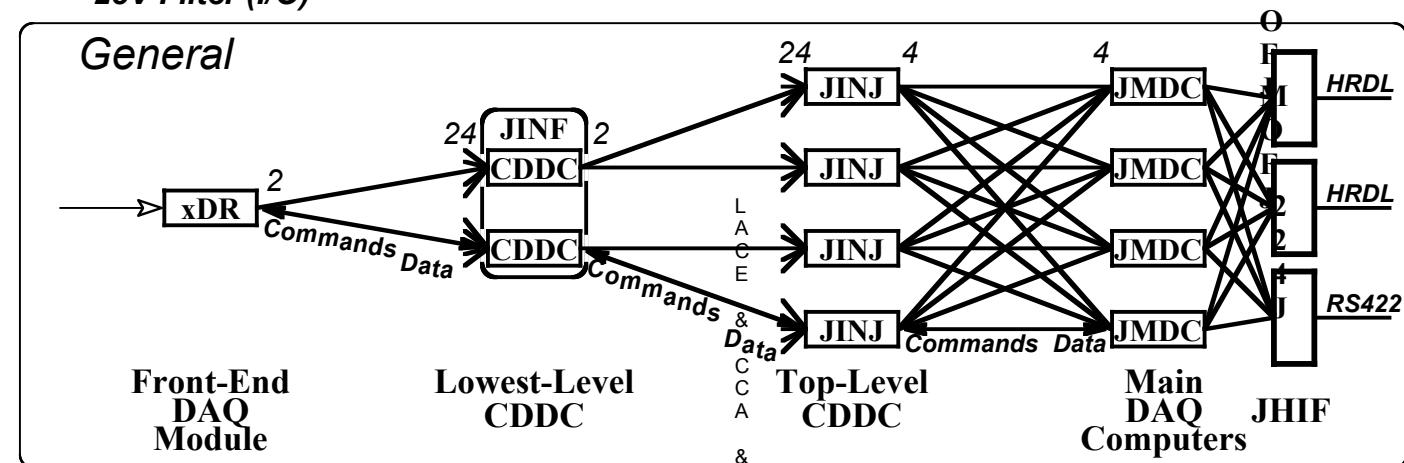




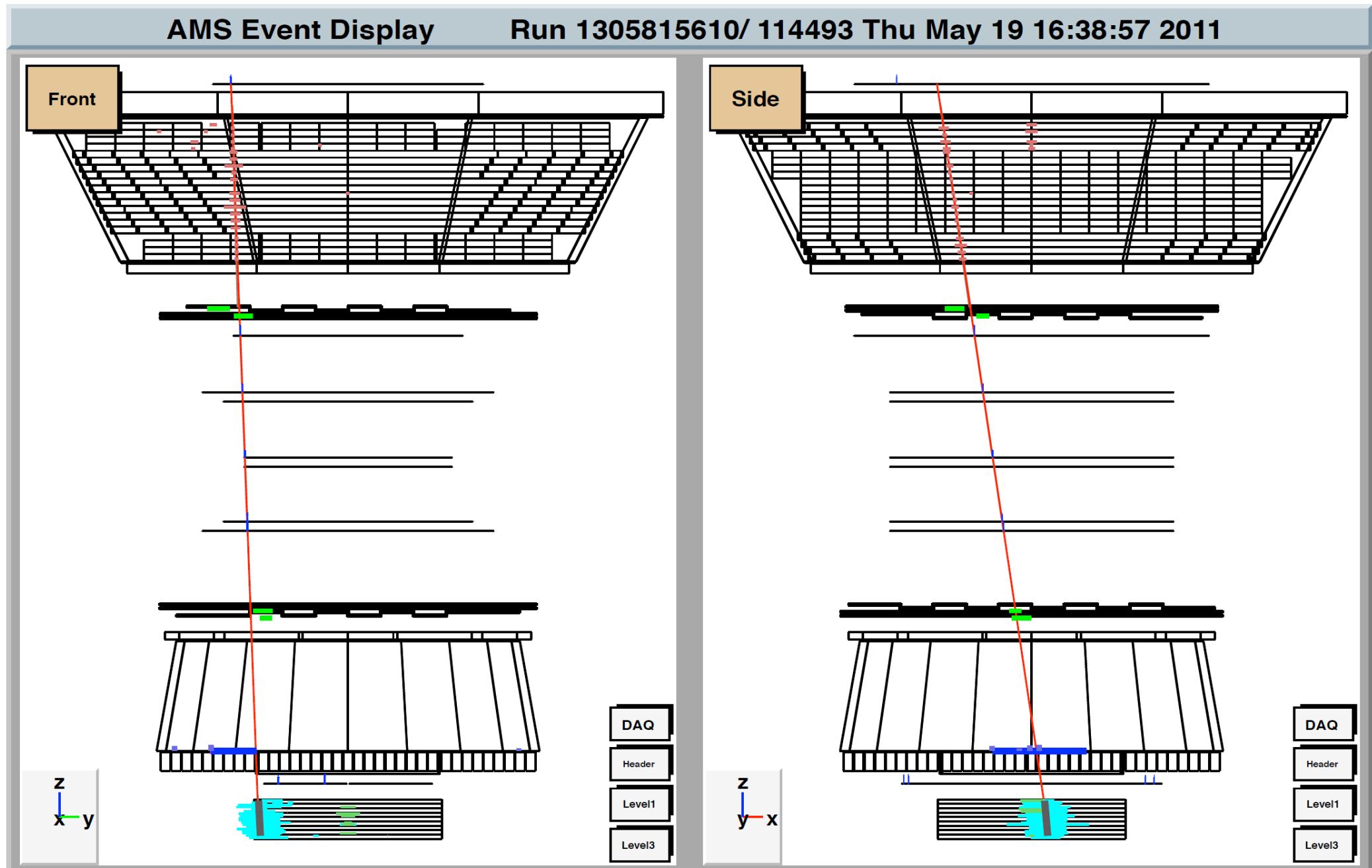
AMS-02 Custom/Common Readout Unit



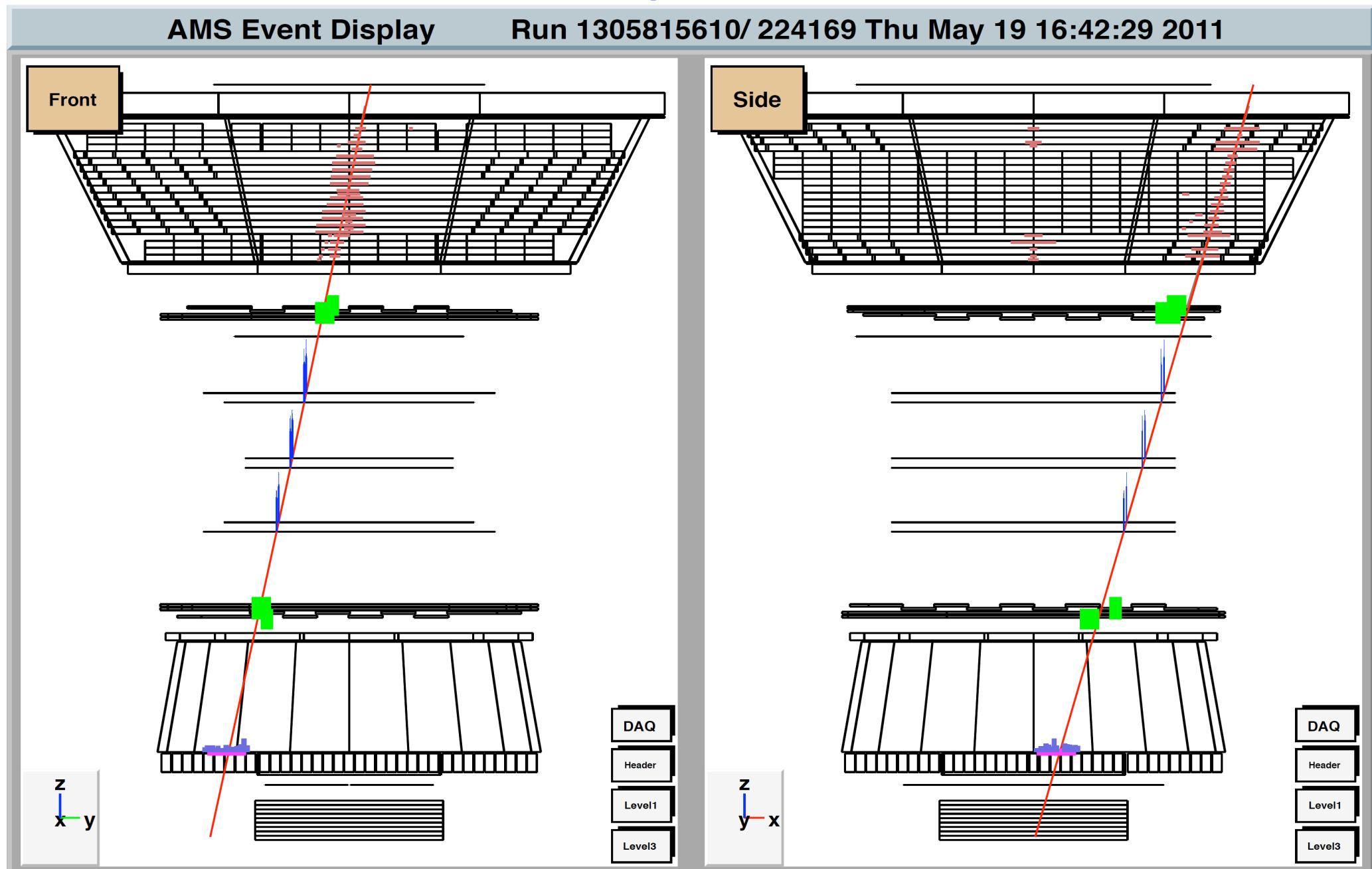
Raw event: 3674 Kbit
Compr. event: 2500 bit



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

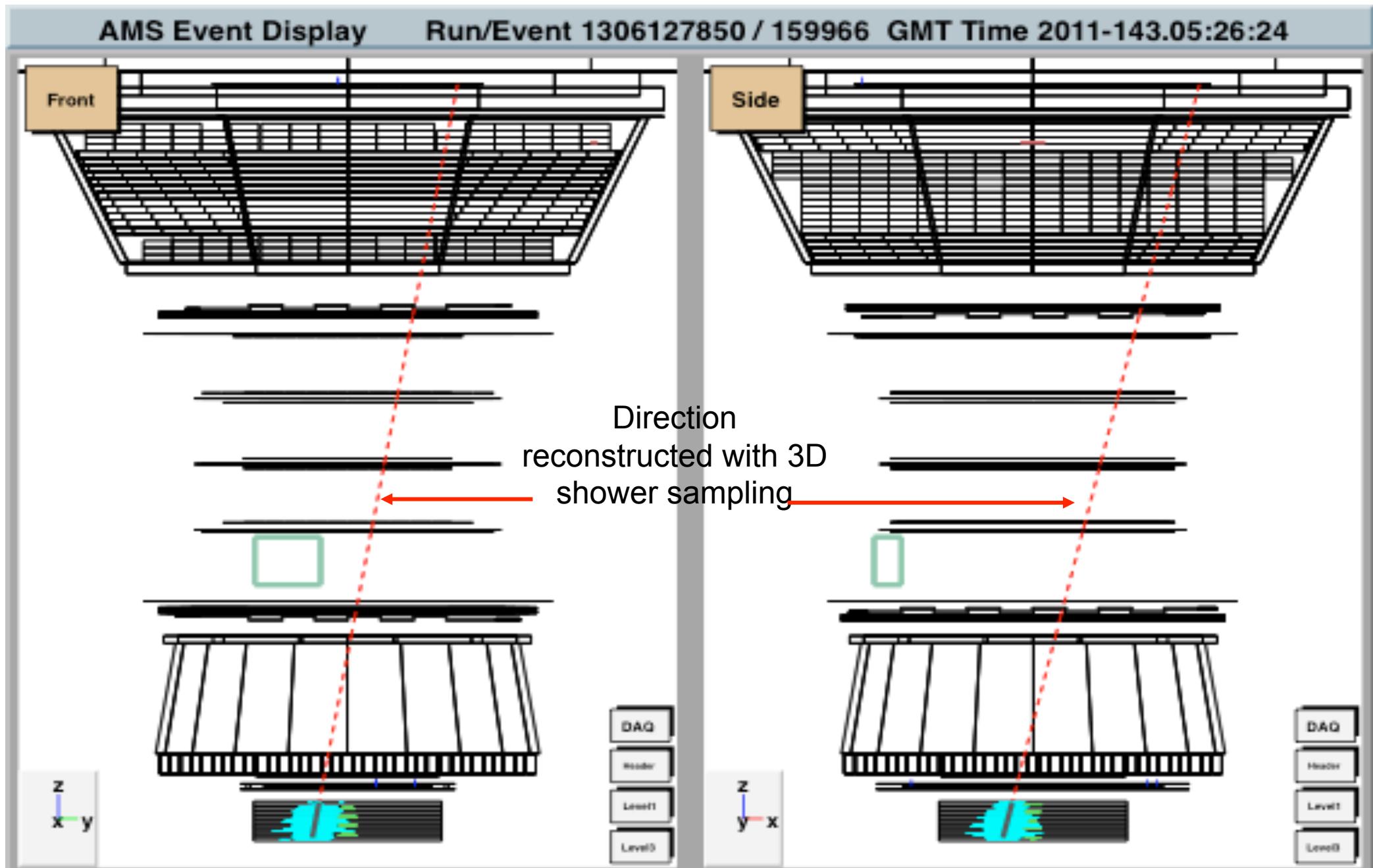


Data from the 1st few minutes – 42 GeV/c Carbon, 19 May 2011



AMS data on ISS

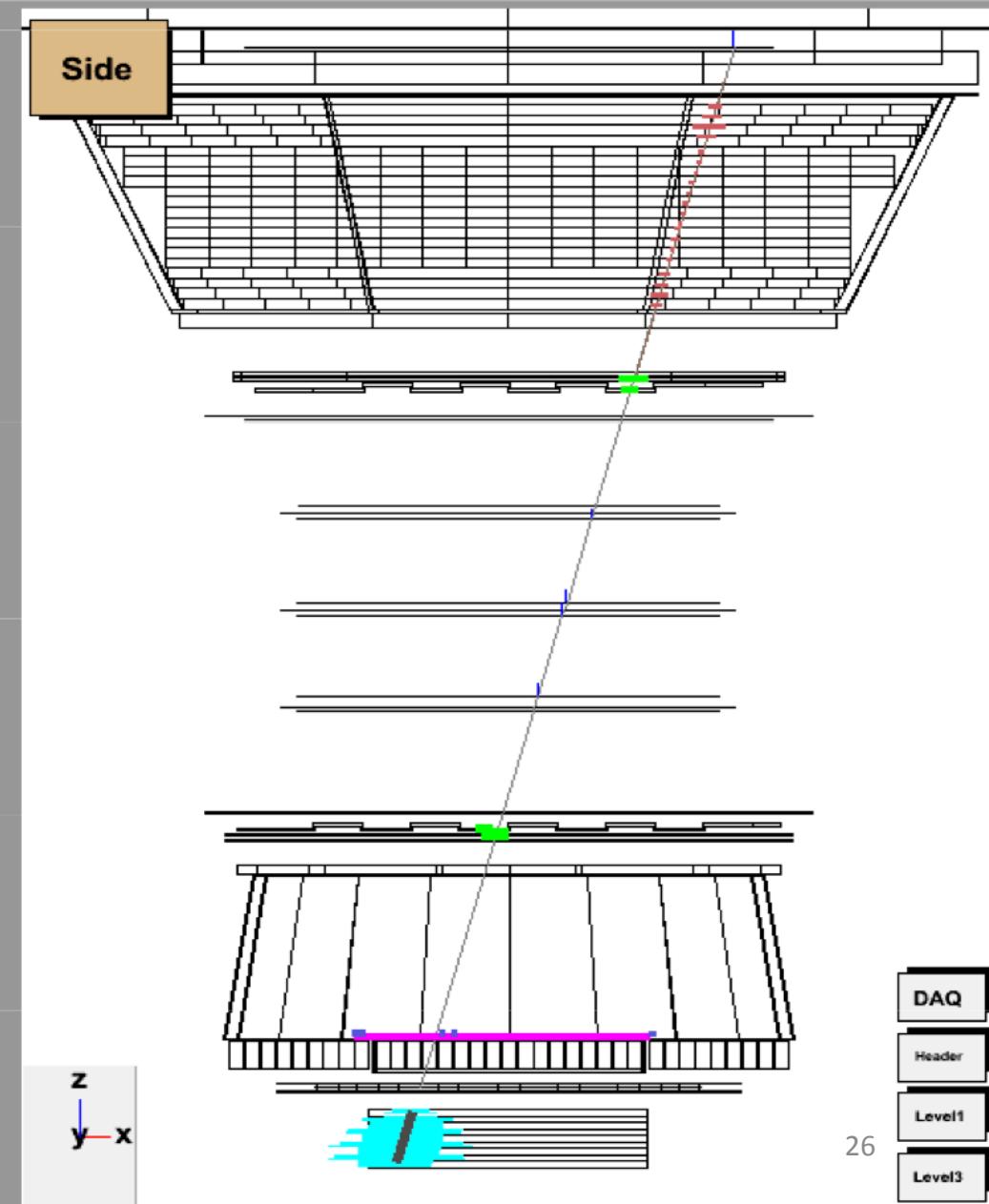
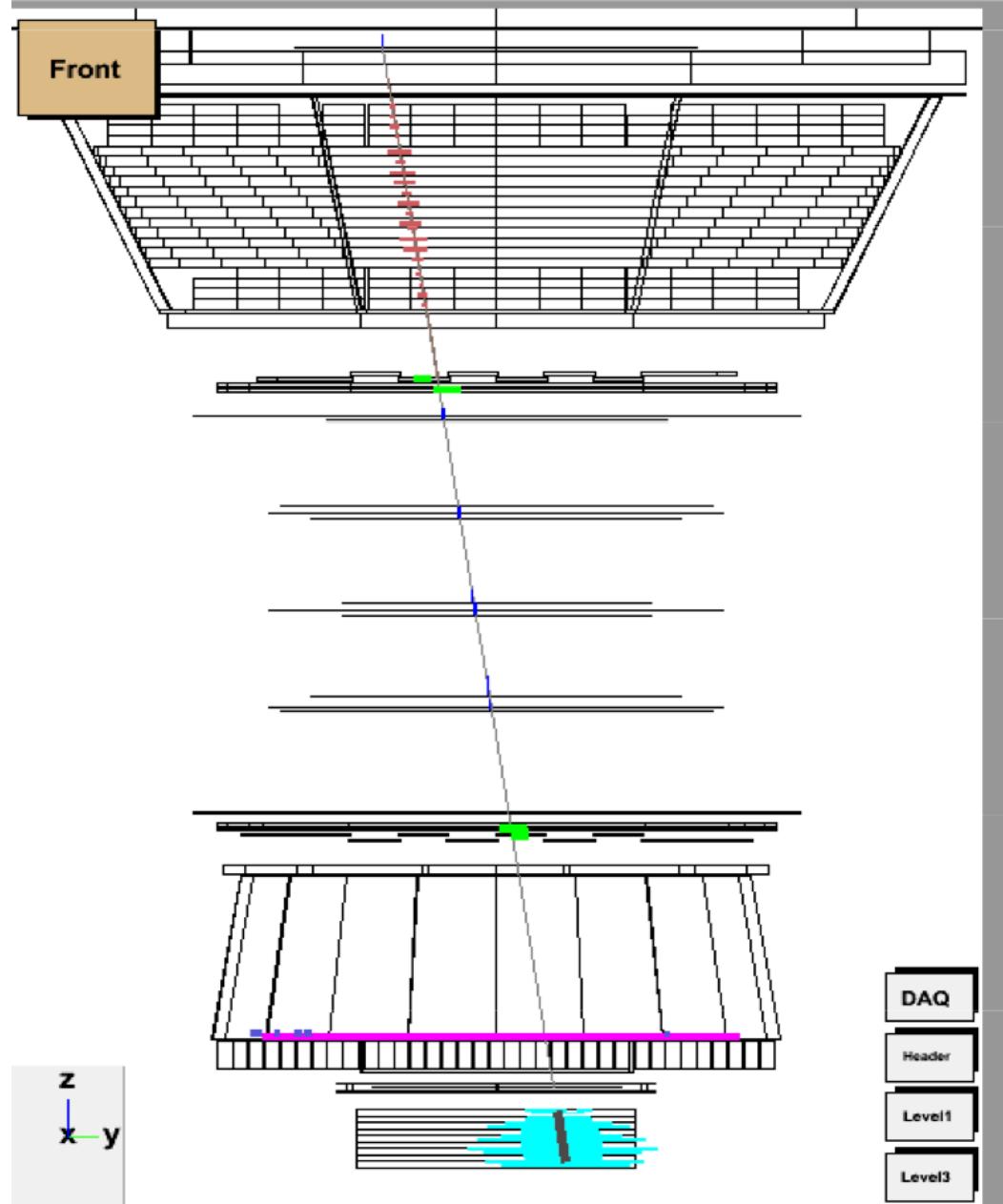
Photon 40 GeV, 23 May



205 GeV positron

AMS Event Display

Run/Event 1311119461 / 175264 GMT Time 2011-201.00:04:26

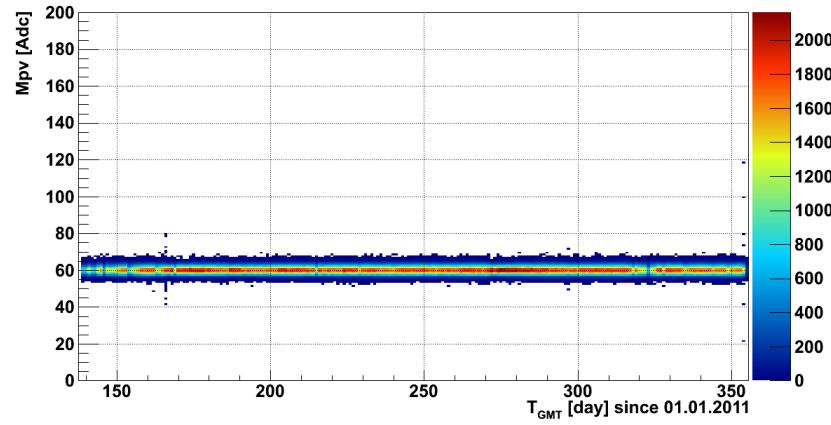
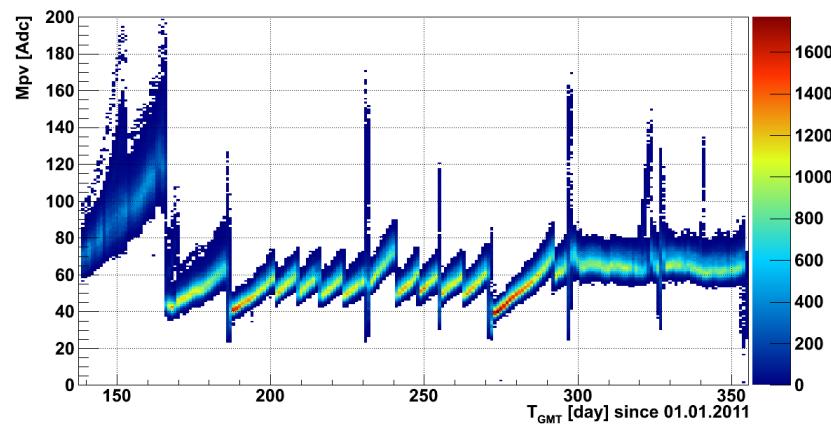




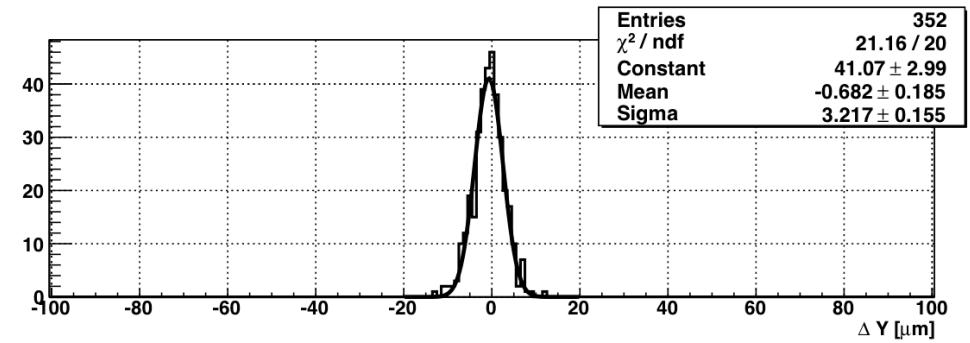
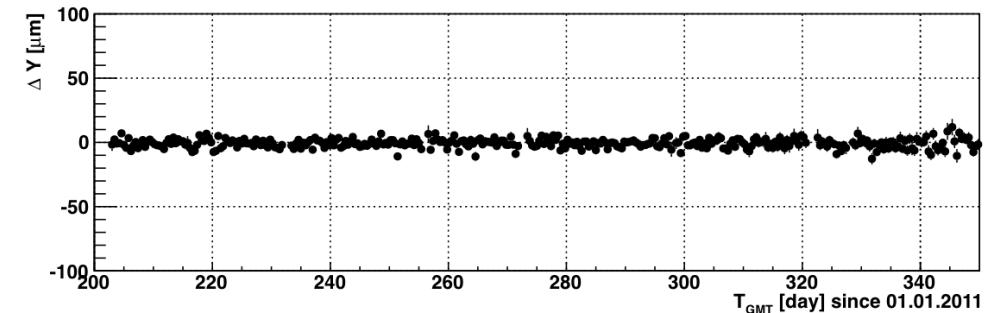
on orbit performance



TRD gain calibration

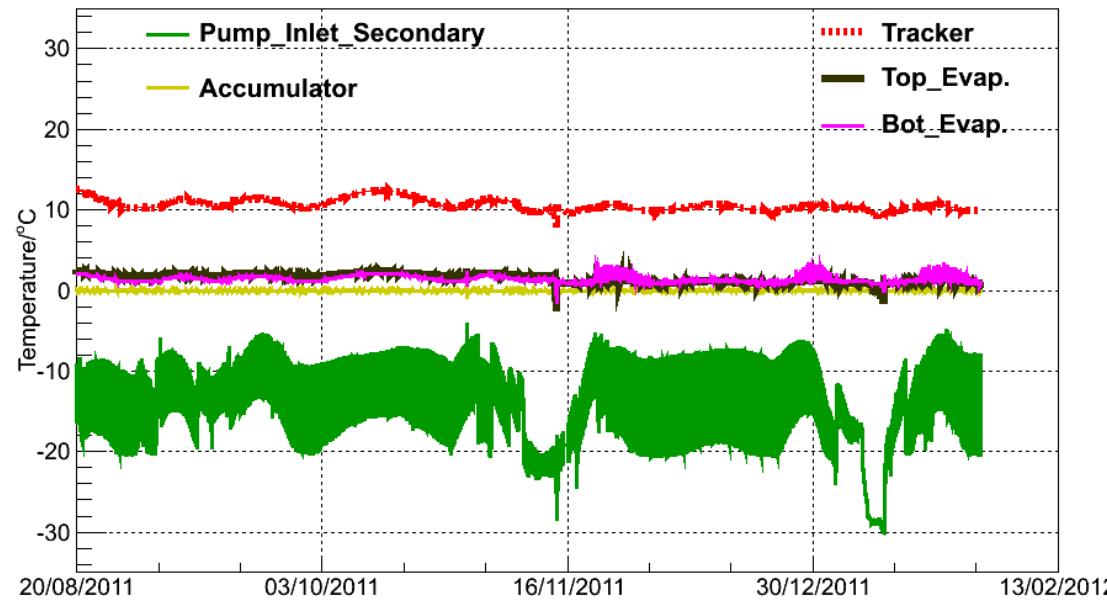


Alignment stability

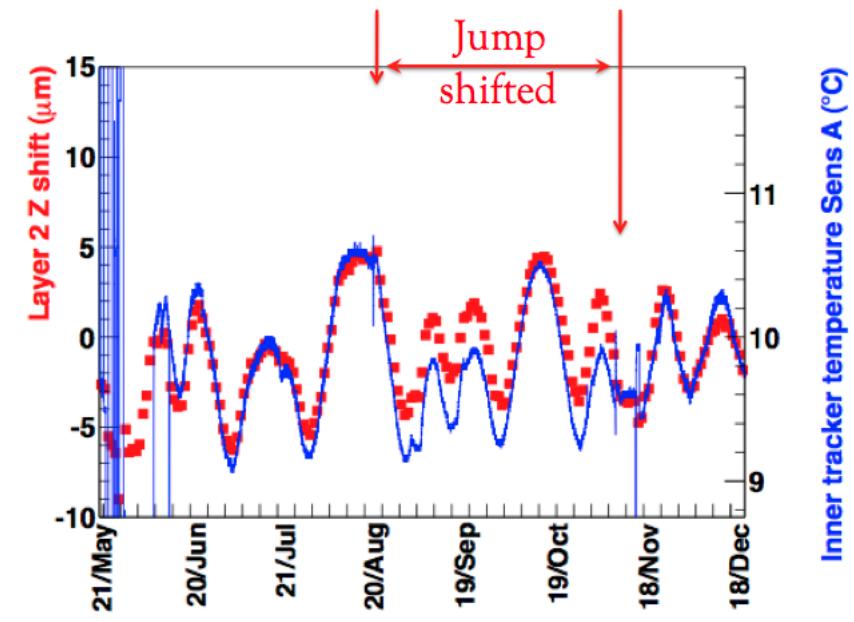
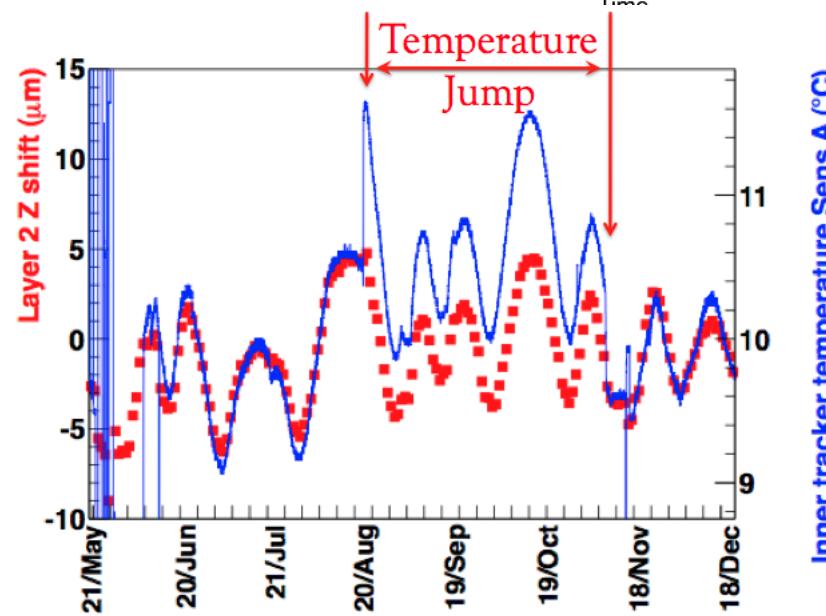




on orbit performance



Temperature effects



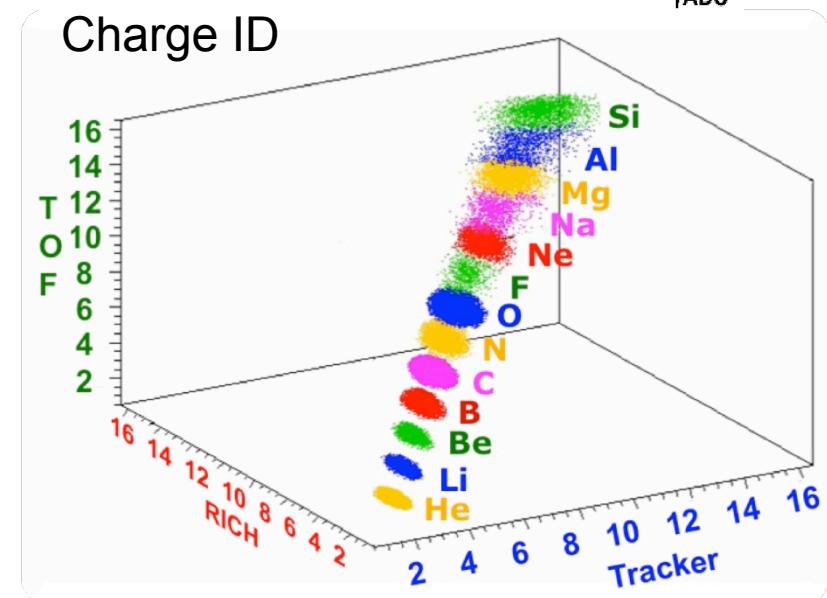
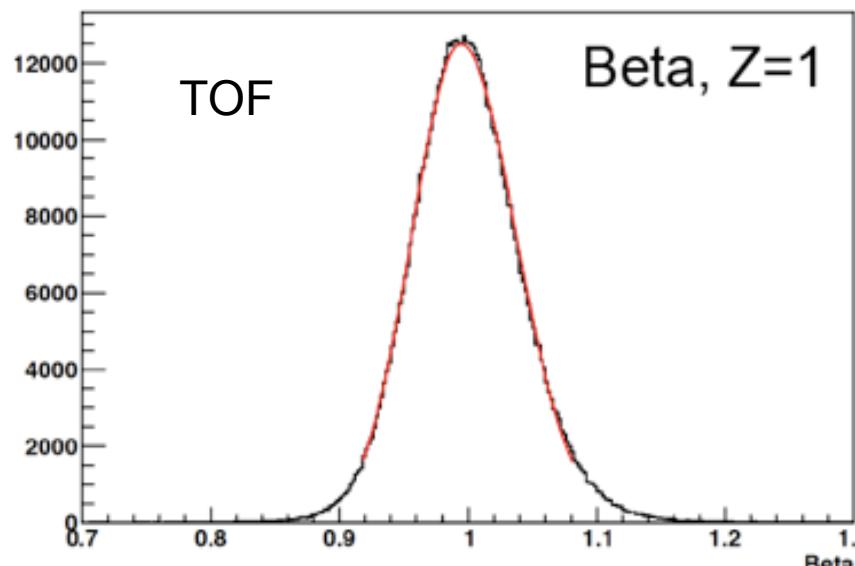
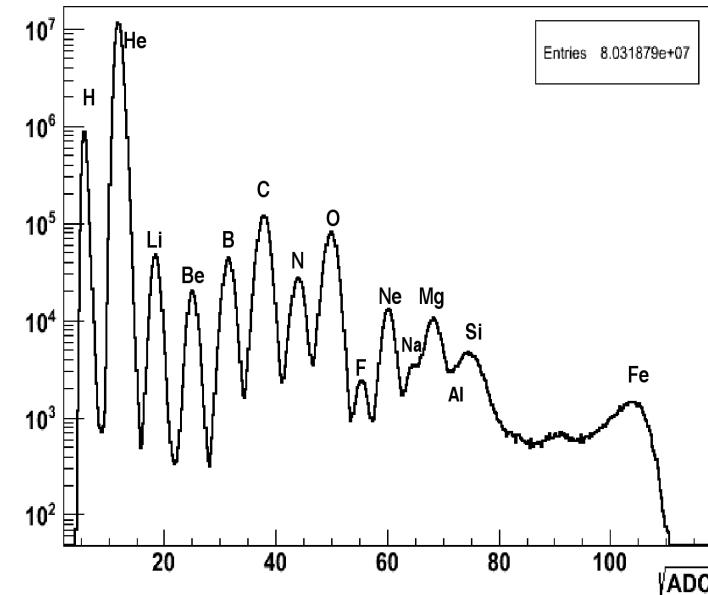
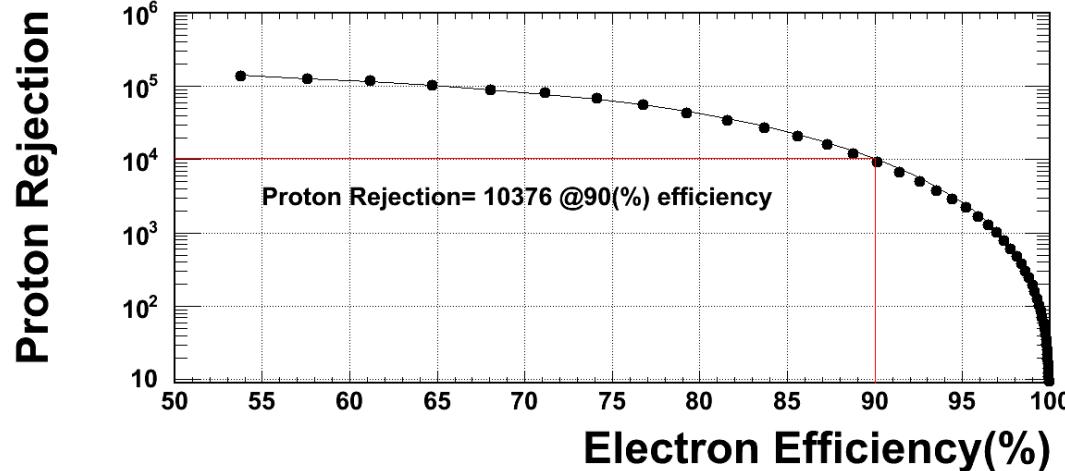
Inner tracker temperature Sens A ($^{\circ}\text{C}$)



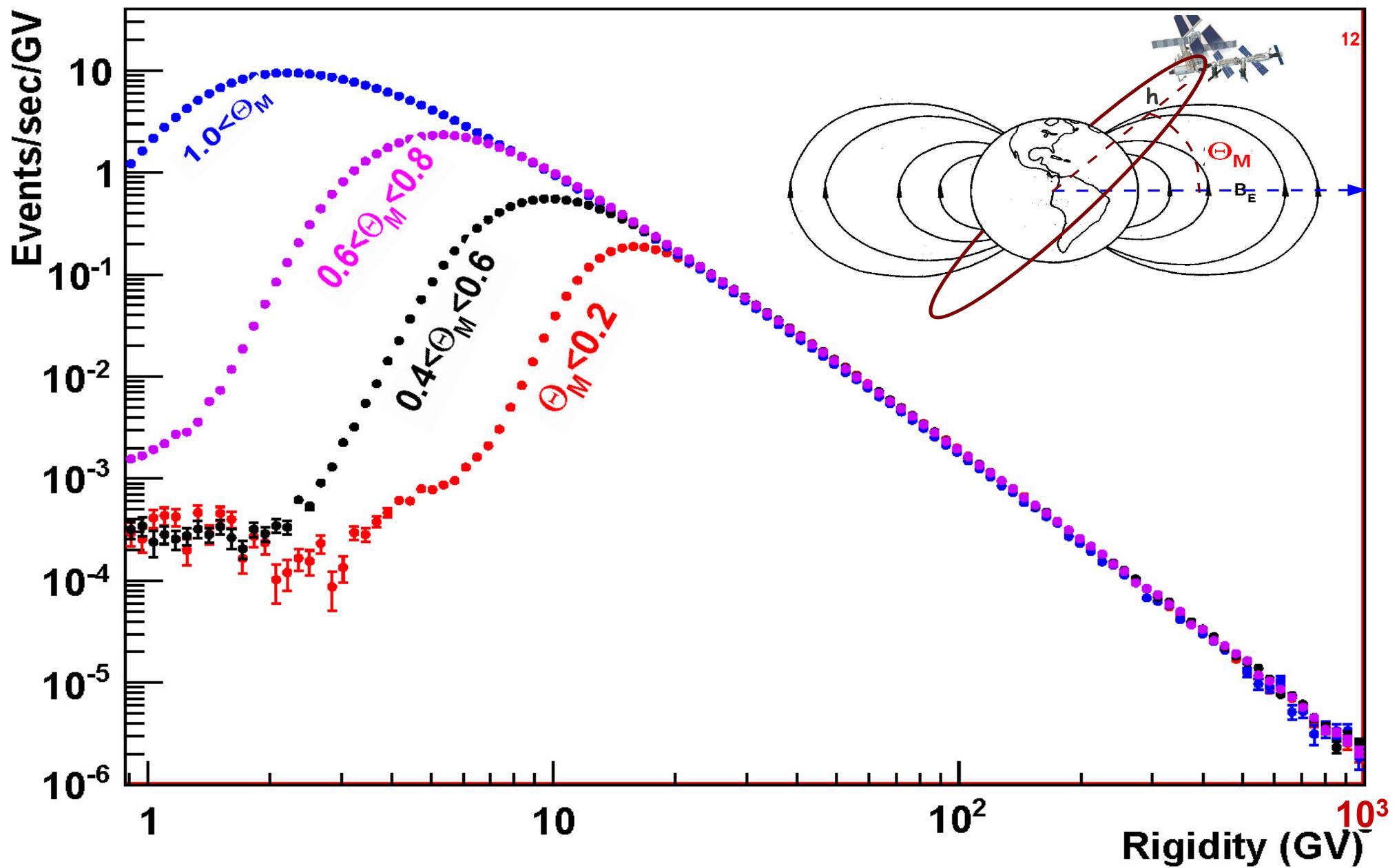
on orbit performance



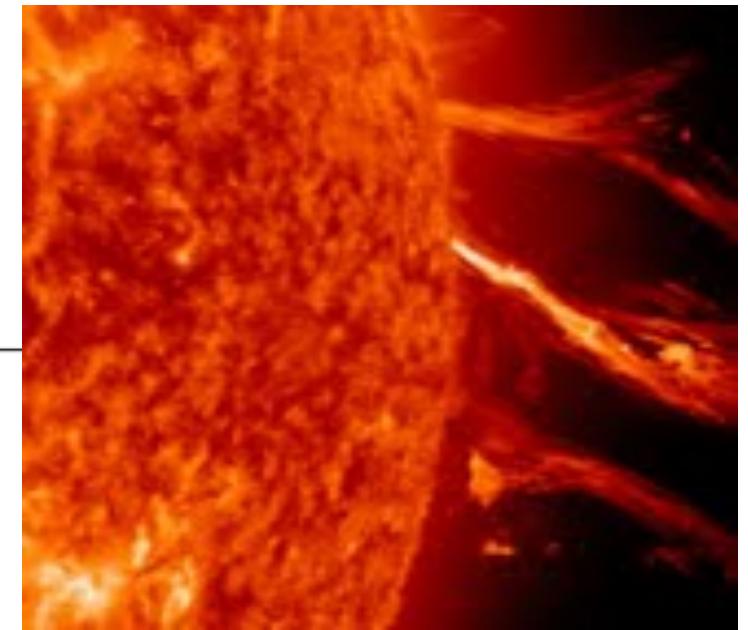
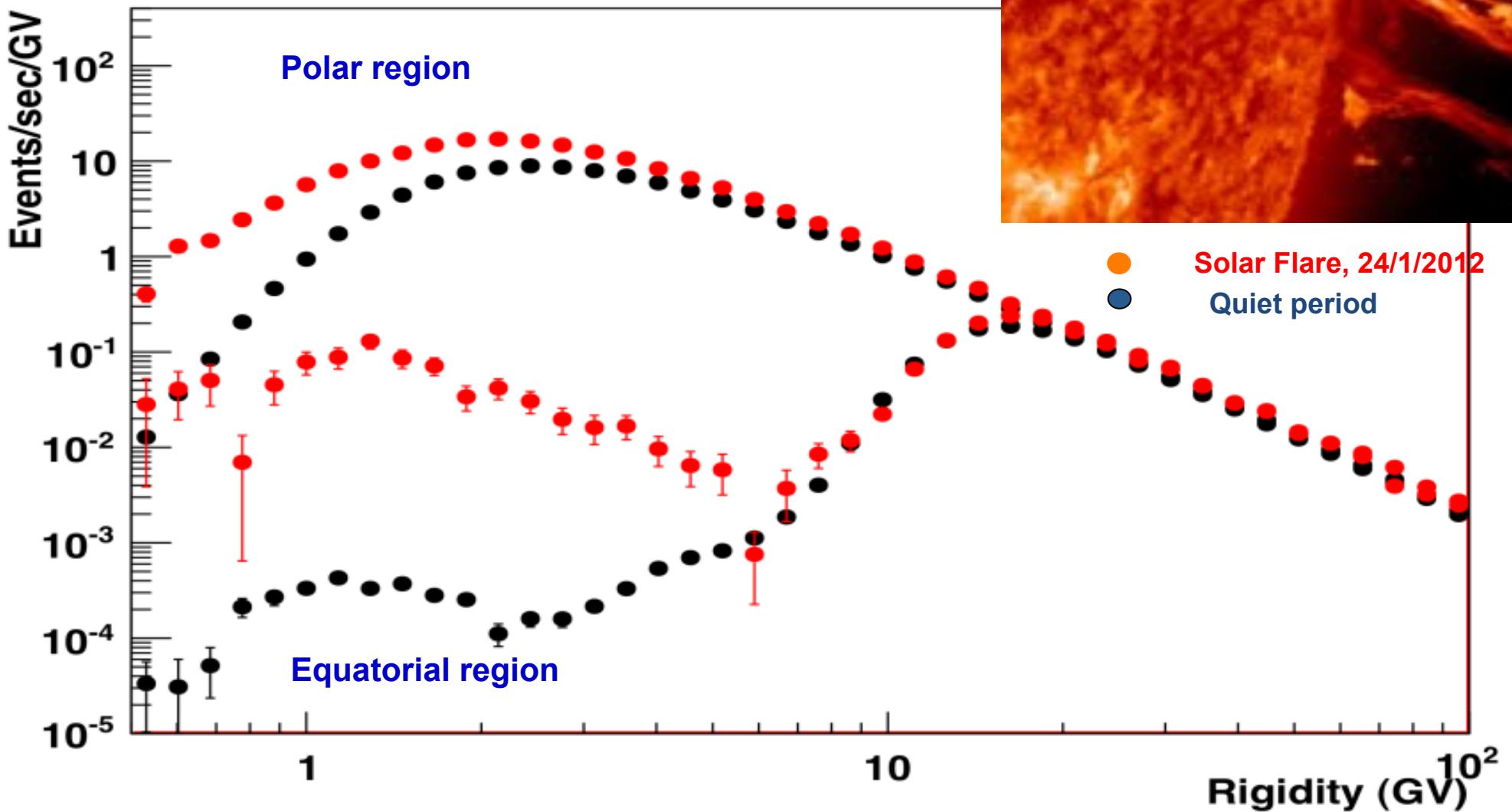
TRD gain calibration



AMS data on ISS: He rate



AMS data: He rate and Solar Flare

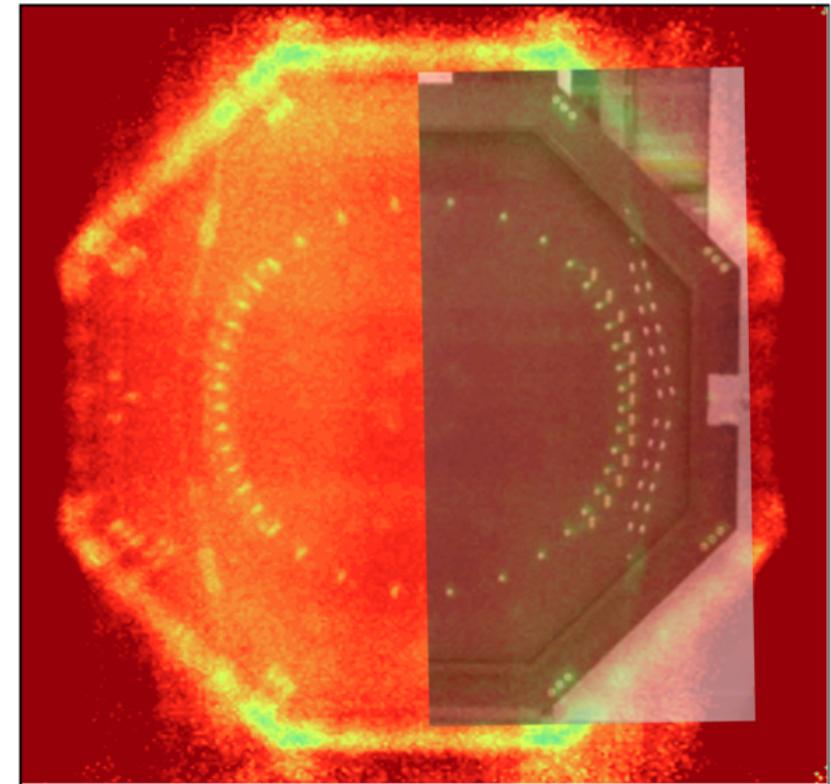
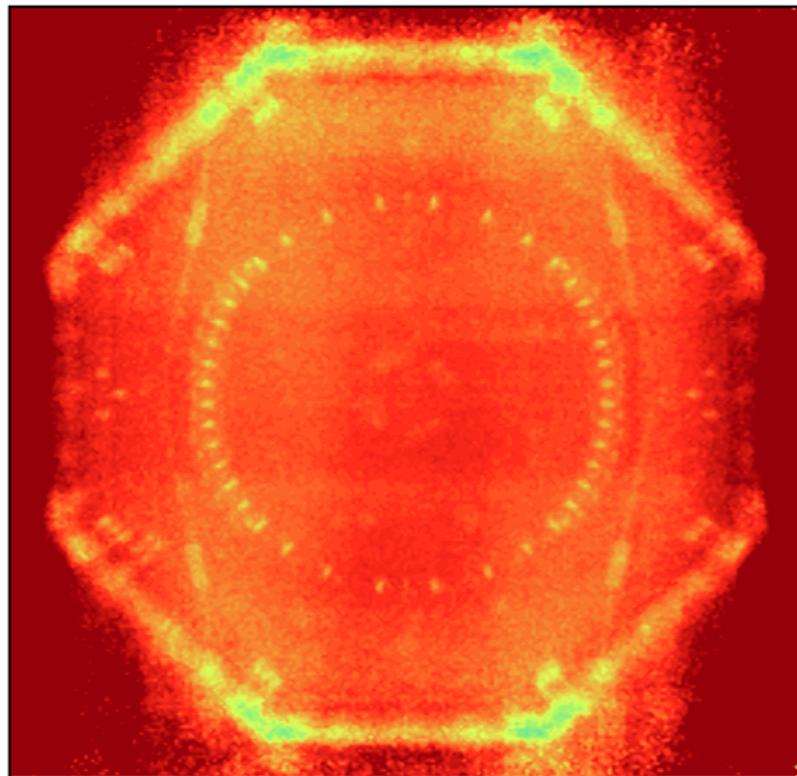




tomography of support plane



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

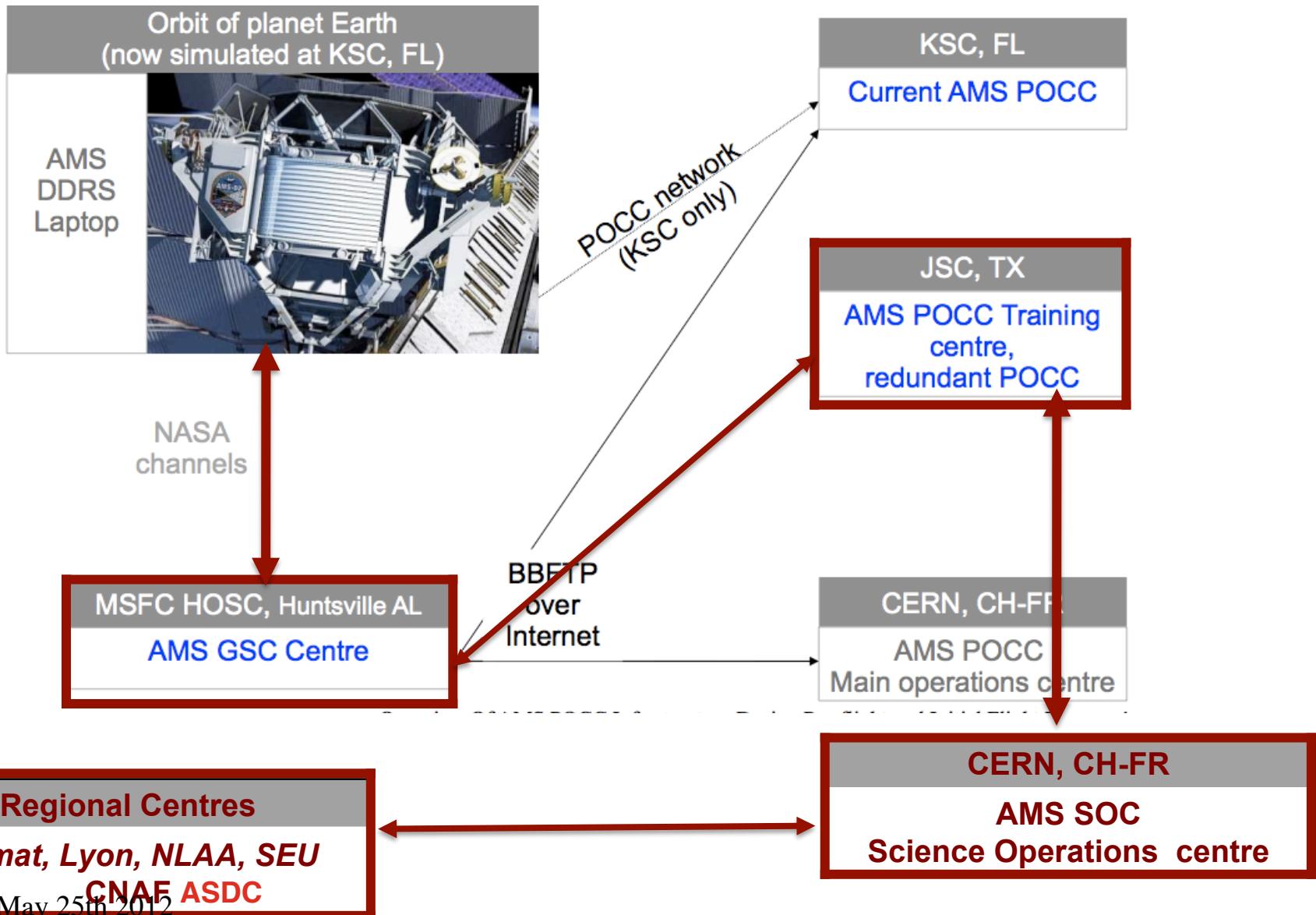




Science will come soon!

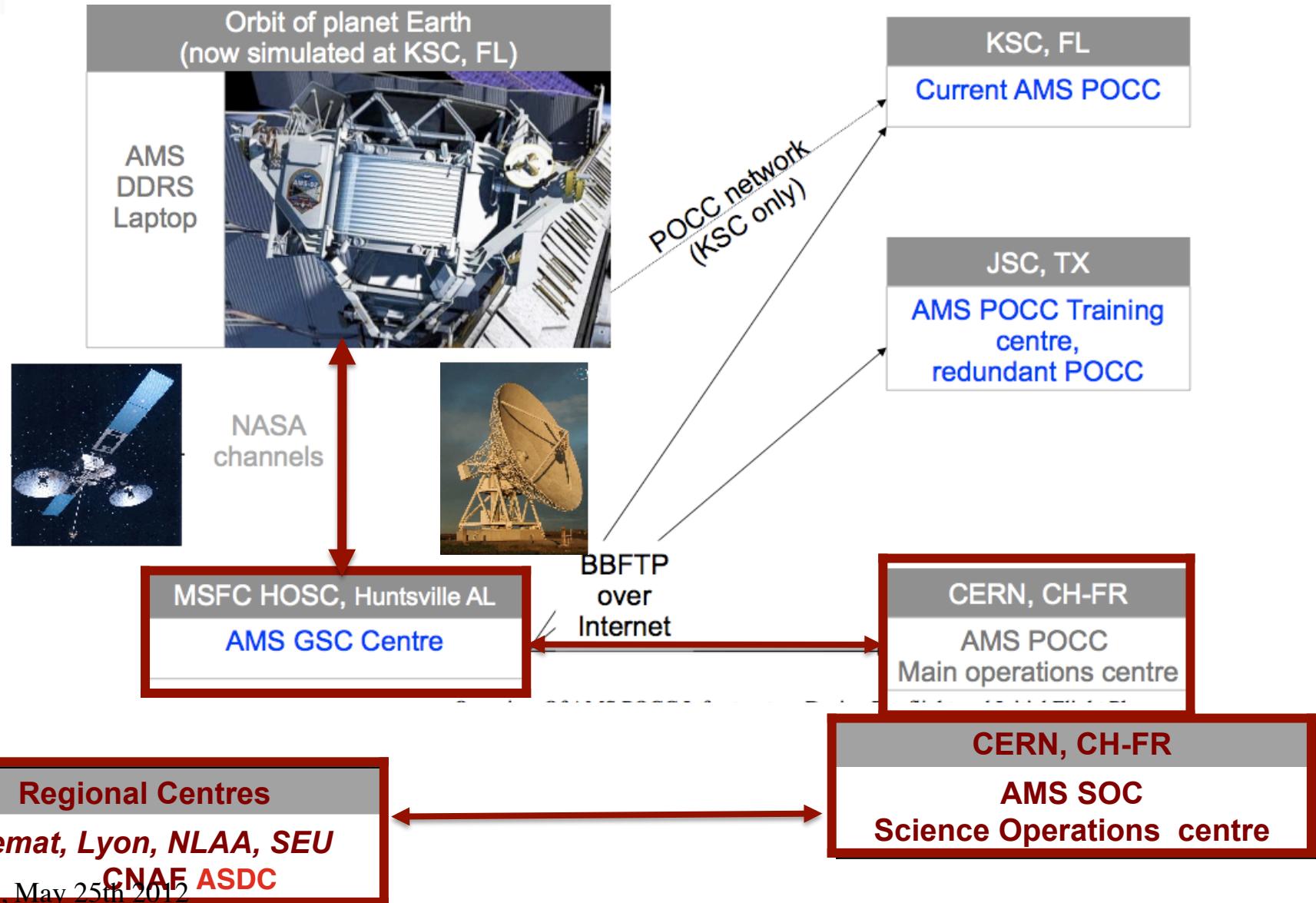


AMS Data Flow: POCC@JSC configuration



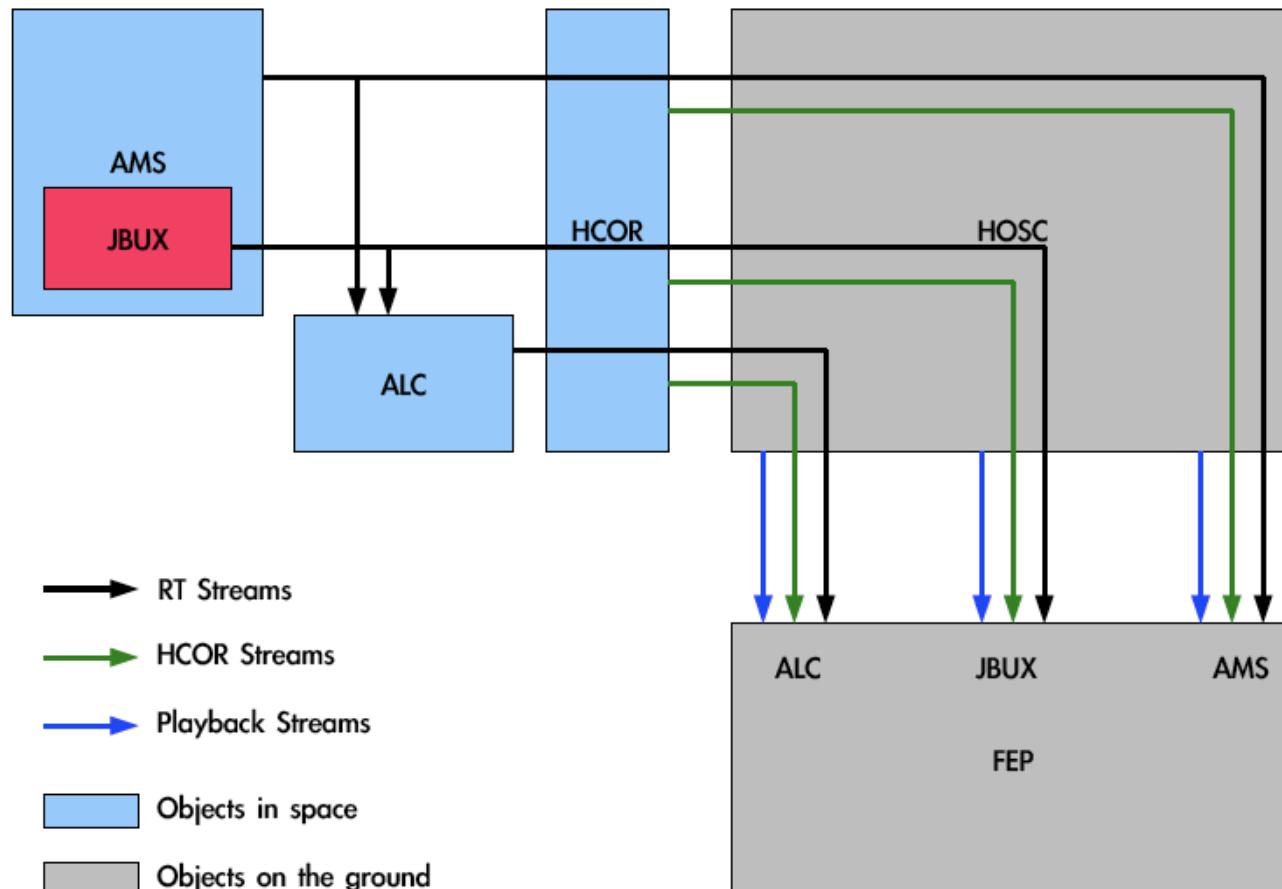


AMS Data Flow: POCC@CERN configuration





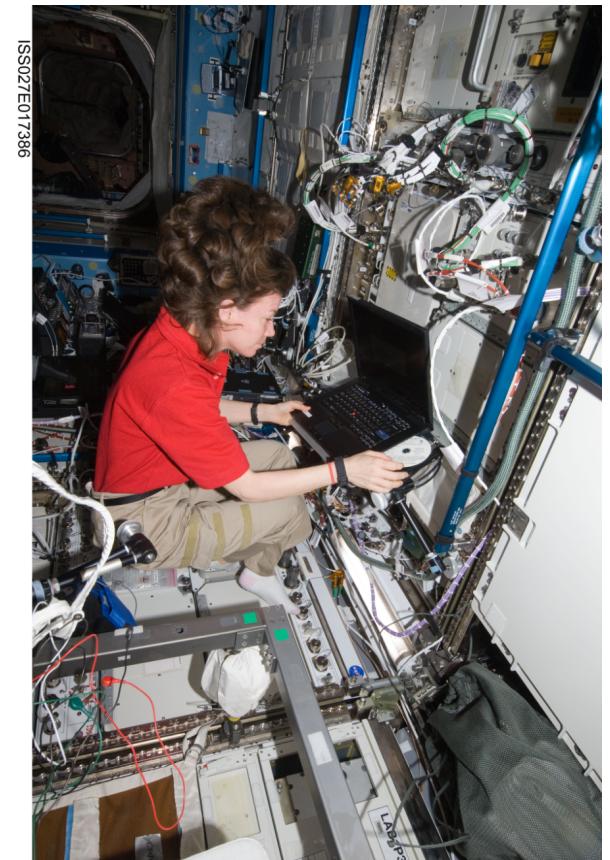
AMS data streams



2

Gabriele Alberti

AMS laptop on ISS





Data path

Reg. CENTERS:
CHINA-EU-USA

ISS
position



CNAF-IT



CERN



SOCC -CERN
AMS-MIB



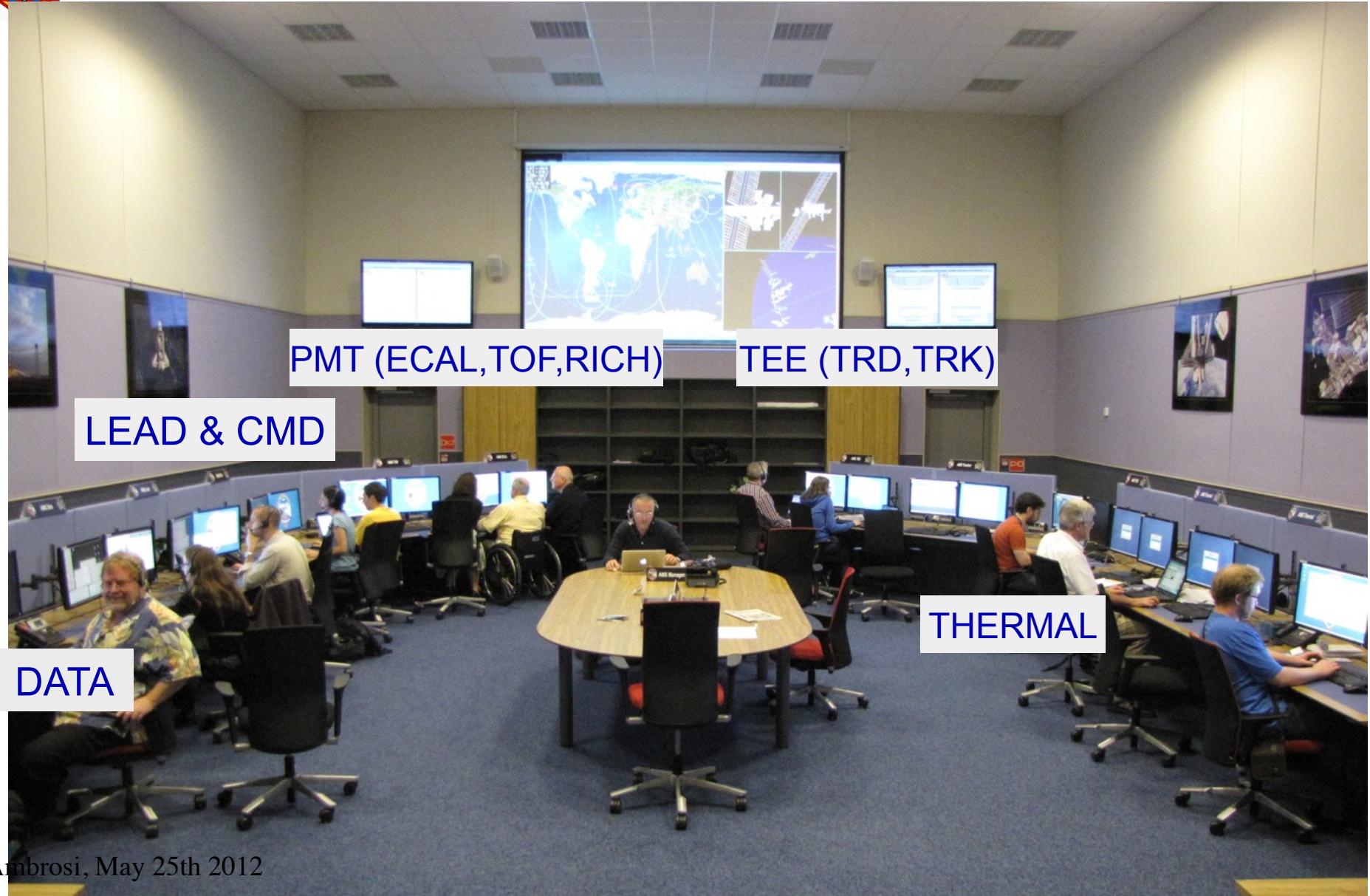
White Sands - NM



Marshall Space Flight Center

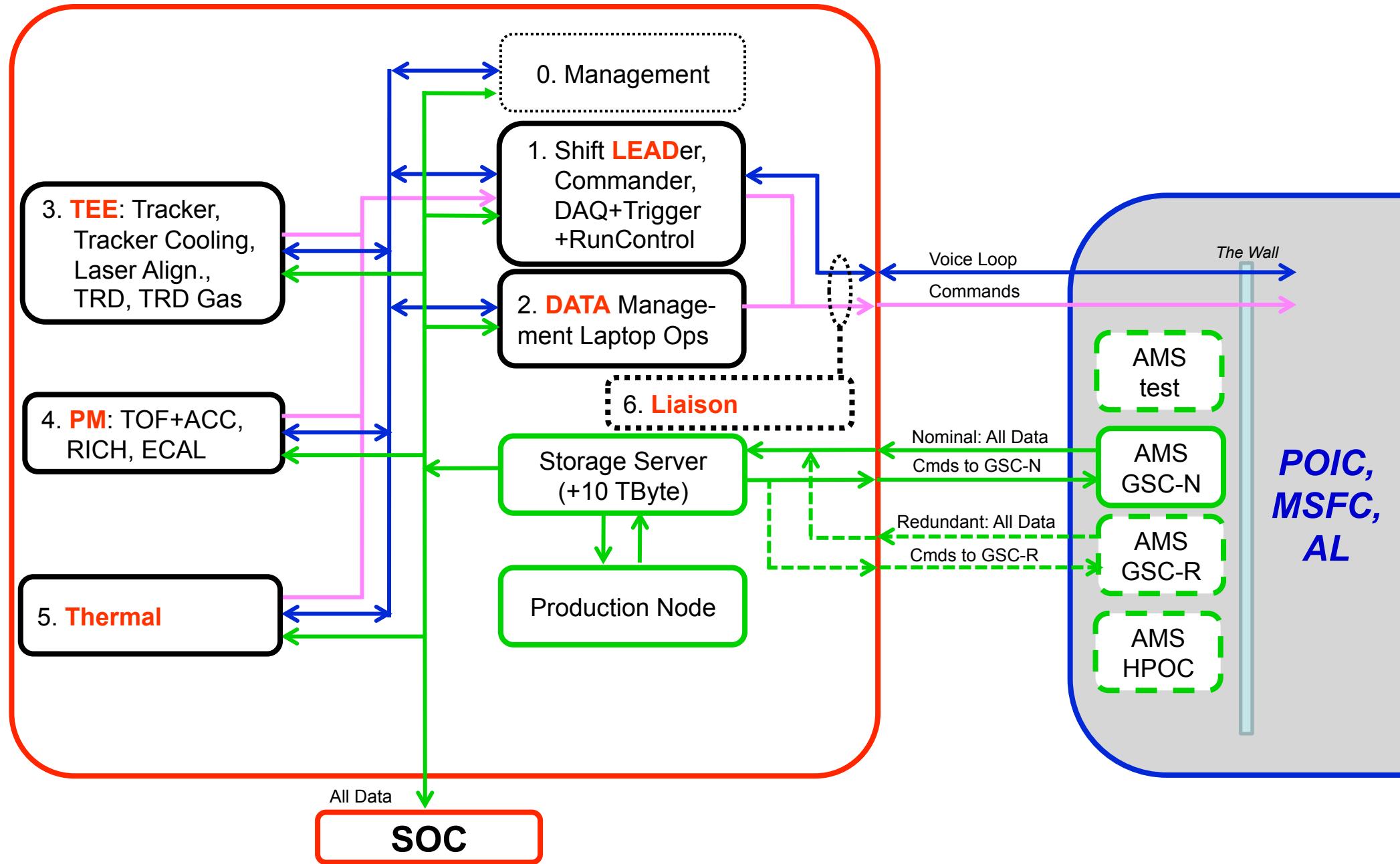


POCC at CERN (Switzerland)



G. Ambrosi, May 25th 2012

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





Onboard Short Term Planner Viewer

POIC: ISS Ops - External User - Windows Internet Explorer
https://roci1.dn2.hosc.msfc.nasa.gov/

File Edit View Favorites Tools Help

Favorites | HOSC Portal | OSTPV

POIC: ISS Ops - External User

IPV OSTPV Onboard Short Term Plan Viewer ISS

Last Modified: 347/06:58:06

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SAA

Altitude

ISS ORBIT NO 2884 2885 2886 2887 2888 2889 2890

Day/Night

CHECS-KU D/L-CMD JEM-VIDEO B-DOWNLINK MDCA-FLEX-TEST CMD

FPMU-DATA-DOWNLINK HRDL-LEHX-3M

KU-BD CHECS-KU D/L-CMD PACE2-OPS-TST CMD

OCA-MAIL-SYNC

COMMS-FSL HRD-DL

ONT RS-CONT RS-CONTG-TLM RS-CONTG-TLM CCS-T VS PRO-C FDS-SD A

S-BD

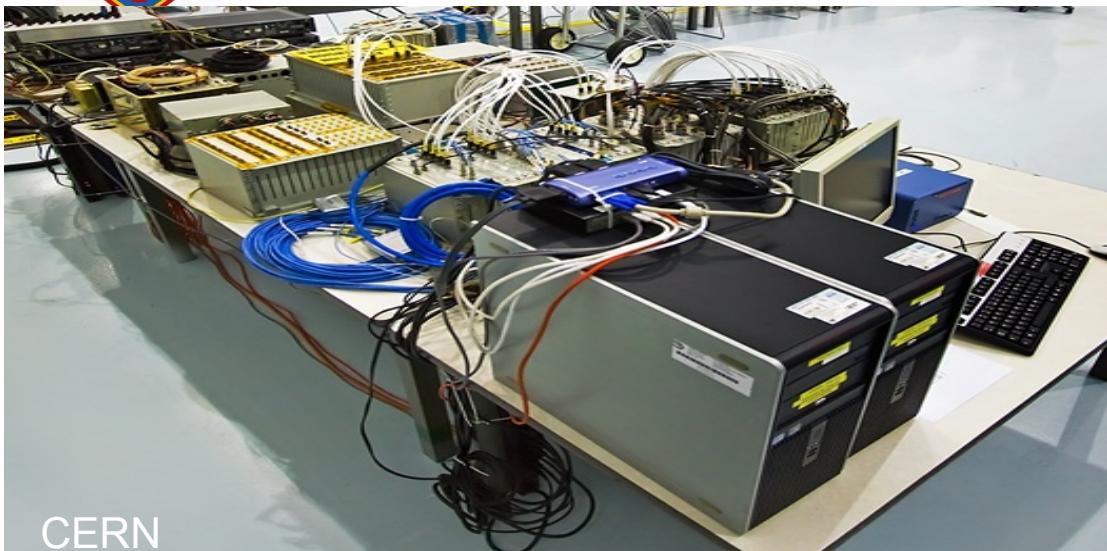
NASA EXT AMS-PL OPS-CMD ELC1-RESOURCE-TRK ELC2-RESOURCE-TRK ELC3-RESOURCE-TRK ELC4-RESOURCE-TRK HREP-PL-OPS HREP-SCENE-DNLK MISSE8-PL-OPS RRM-H/W PWR-ELC4 HREP-SCENE-DNLK STHPH3-PL-OPS ALTEA-SHIELD-OPS LADTOP OPS

G. Ambrosi, May 25th 2012

Trusted sites | Protected Mode: Off 100% 100%



Software Development and Test Facilities



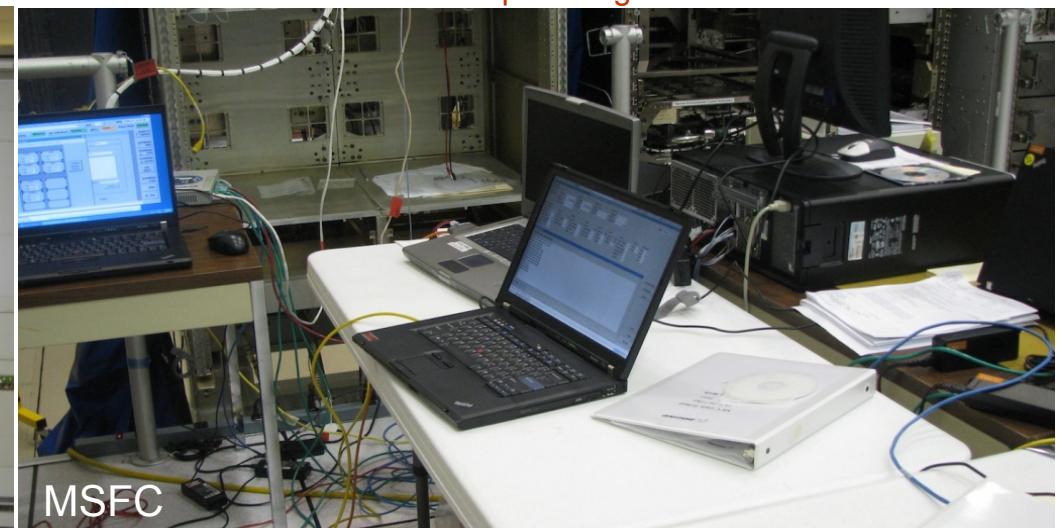
(A) AMS Simulator Laboratory at CERN

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

