

# The AMS02 Spectrometer: first data and detector performance



G. Ambrosi

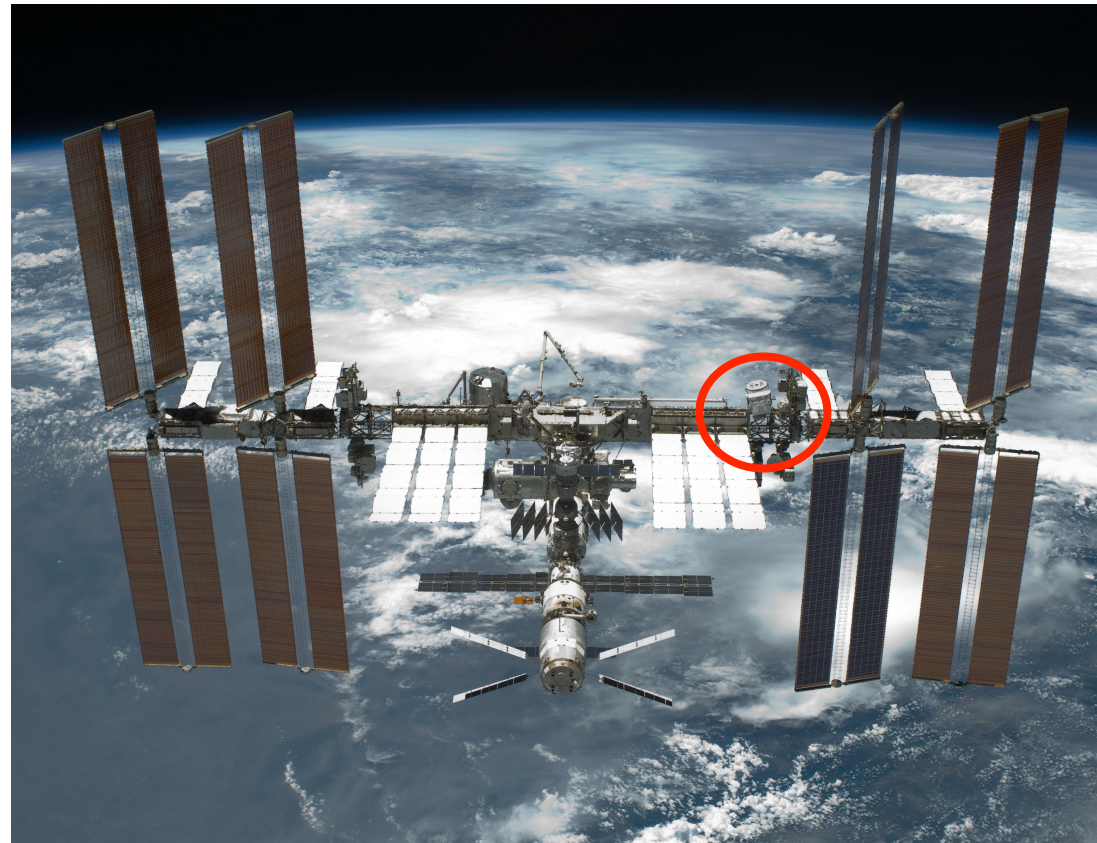
on behalf of the Tracker group

(Perugia INFN and University, Geneva University)



# AMS on the International Space Station

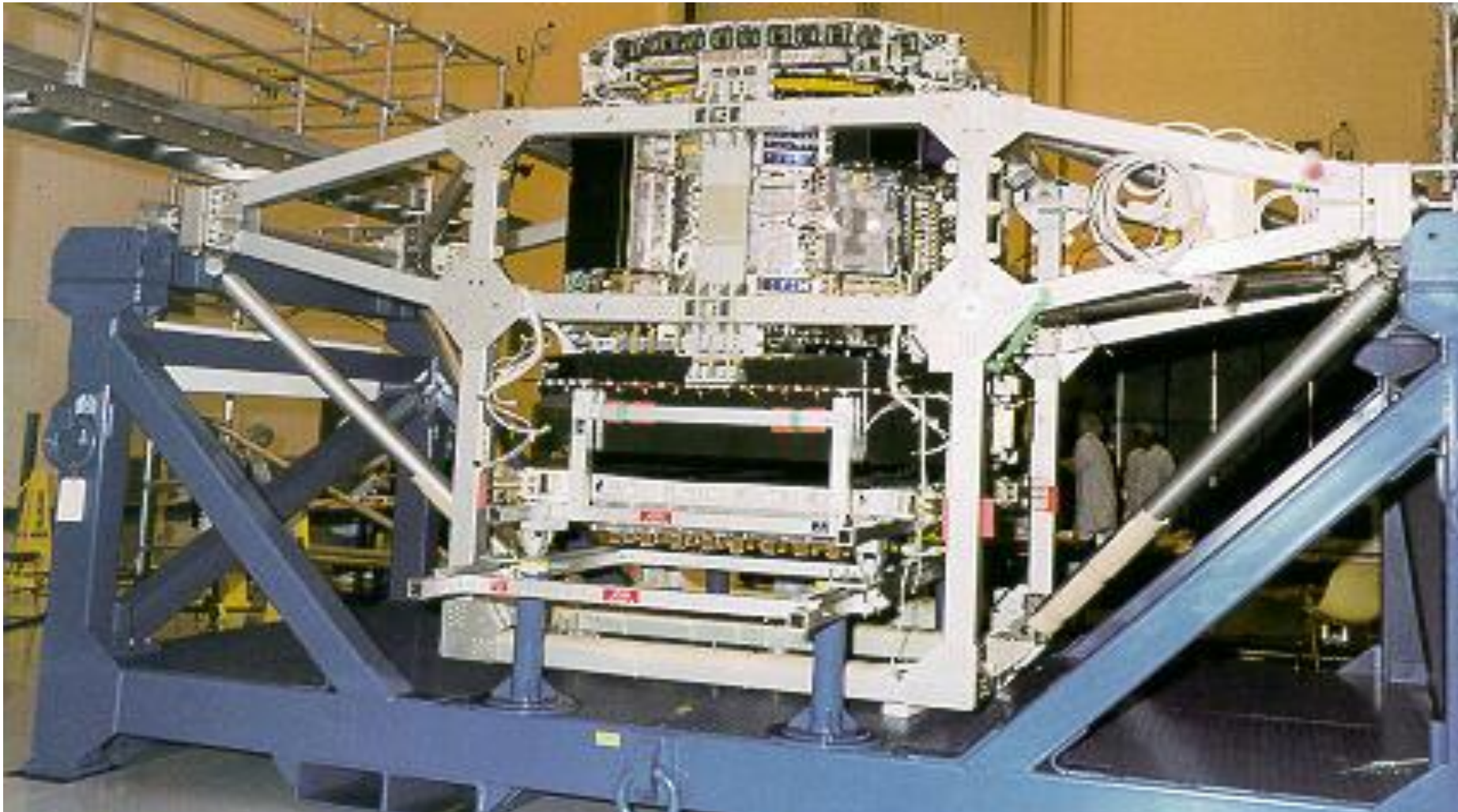
- Cosmic Antimatter search with  $10^{-9}$  sensitivity
- Indirect Dark Matter search ( $e^+$ ,  $\bar{p}$ ,  $\gamma$ )
- Relative abundance of nuclei and isotopes in primary cosmic rays
- $\gamma$  ray astrophysics



The purpose of the AMS experiment is to perform accurate, high statistics, long measurements of charged cosmic rays (0.5 GV - 1 TV) and  $\gamma$  rays ( $E > 1 \text{ GeV}$ )



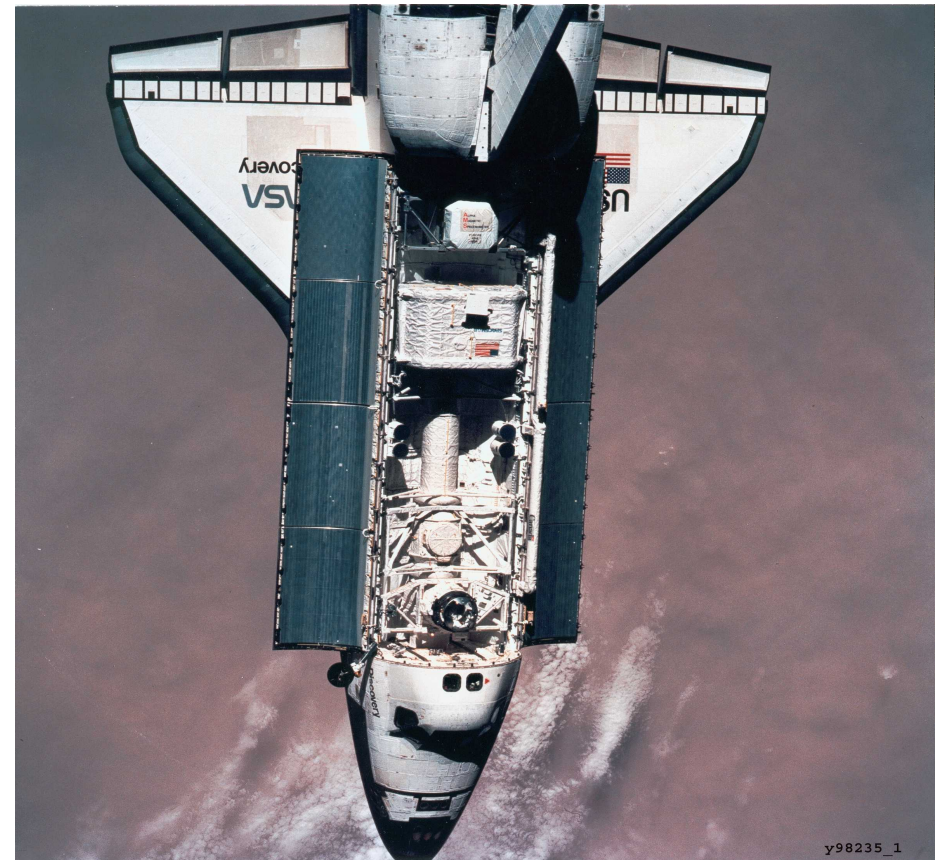
# AMS01 at KSC (Florida) in 1998





# AMS-01 pilot experiment: STS91, June 2<sup>nd</sup> - 12<sup>th</sup> 1998

- 10 days of data taking in orbit:
  - 400 Km altitude
  - latitudes  $+51.7^\circ$
  - 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  $10^{-6}$



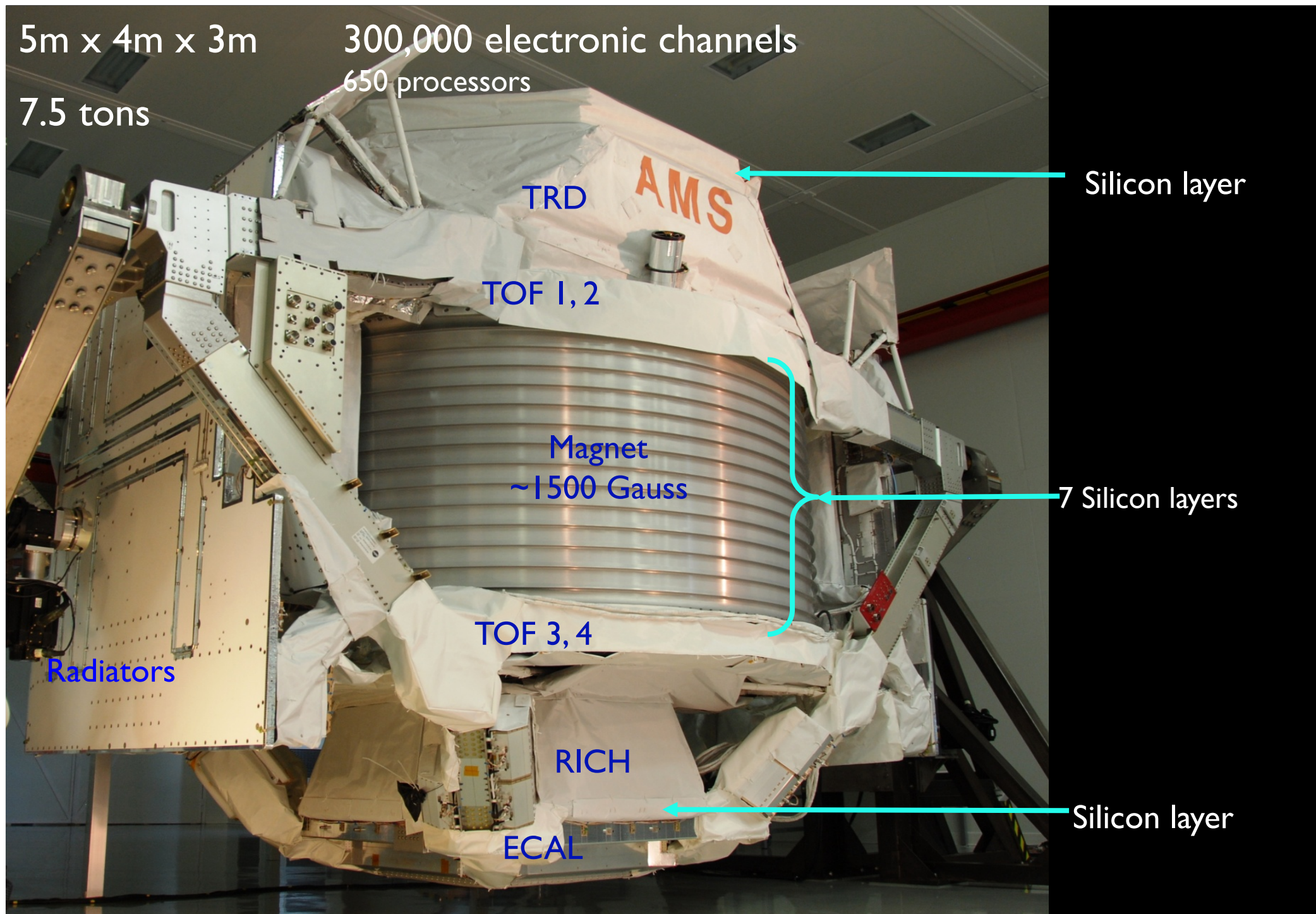


## The instrument we need has ...

- 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

5m x 4m x 3m  
7.5 tons

300,000 electronic channels  
650 processors



Silicon layer

7 Silicon layers

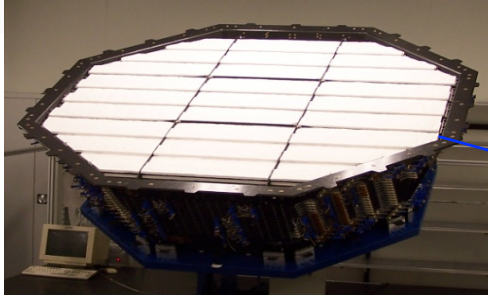
Silicon layer

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

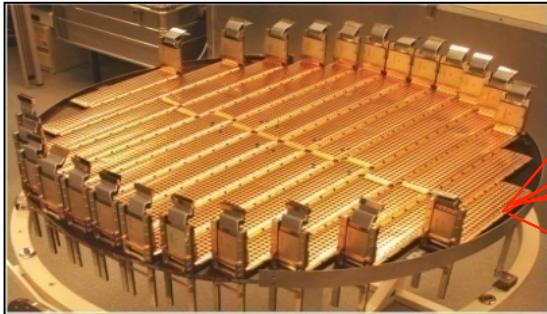


TRD

Identify  $e^+$ ,  $e^-$



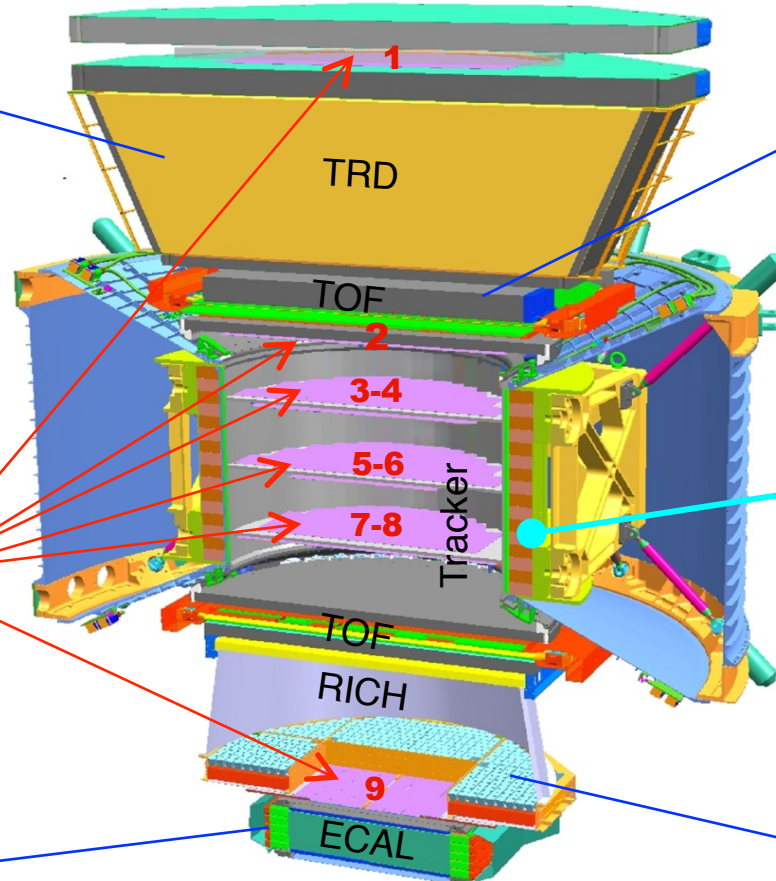
Silicon Tracker  
 $Z, P$



ECAL  
 $E$  of  $e^+$ ,  $e^-$ ,  $\gamma$



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



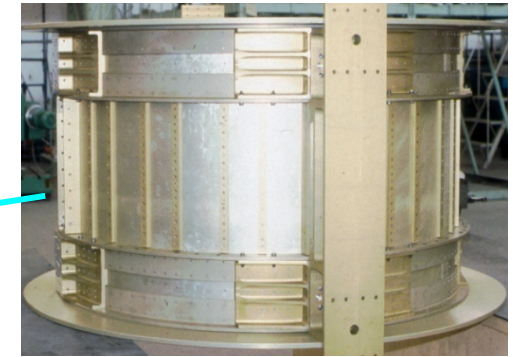
$Z, P$  are measured independently by the Tracker, RICH, TOF and ECAL



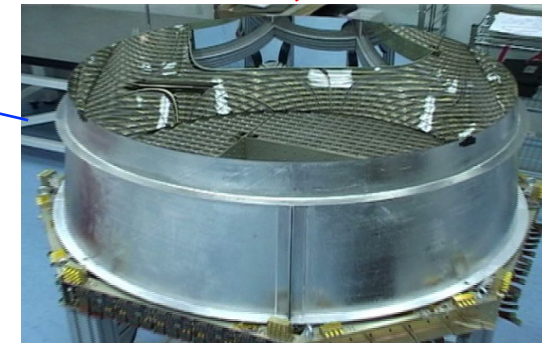
TOF  
 $Z, E$



Magnet  
 $\pm Z$

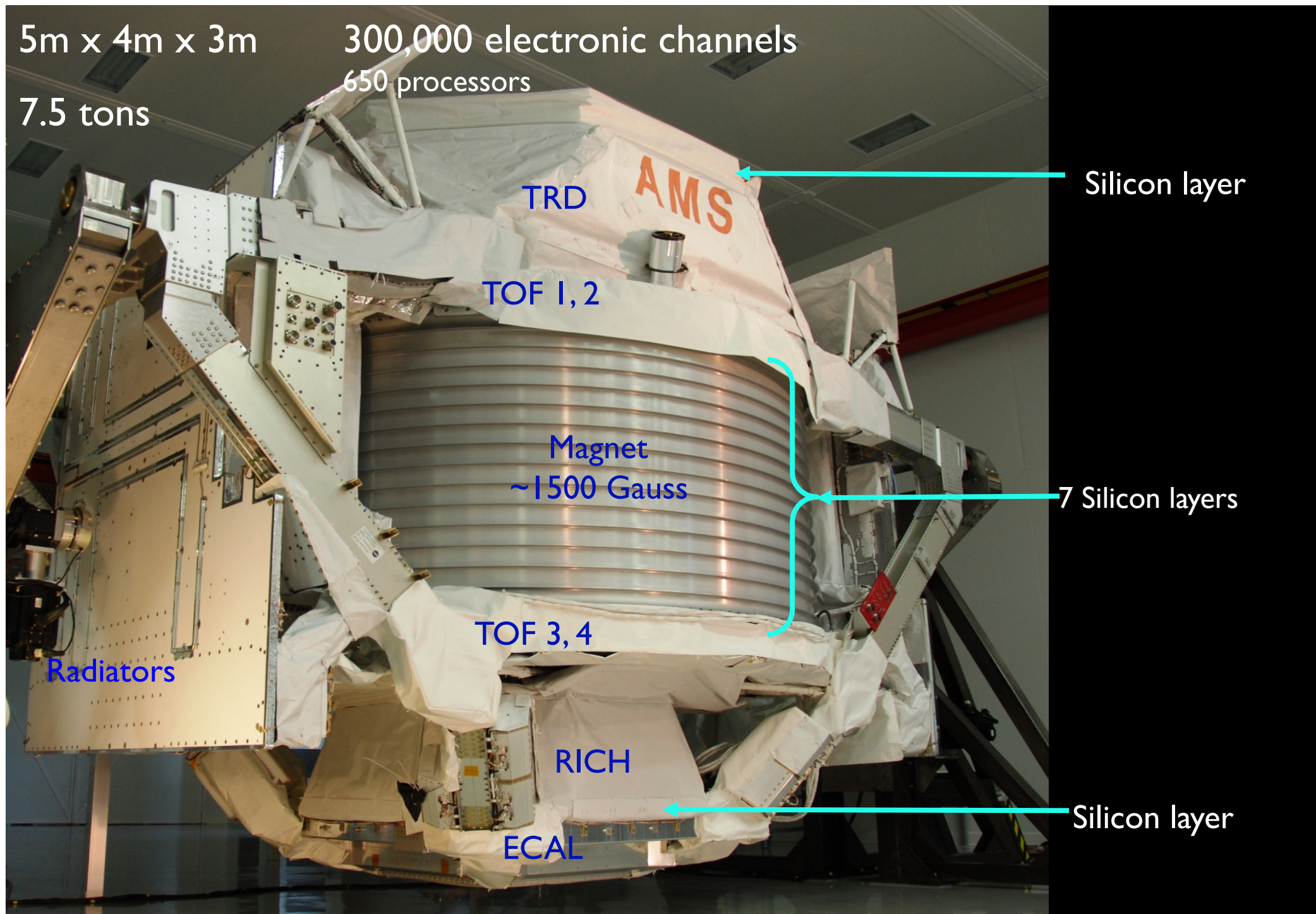


RICH  
 $Z, E$



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Silicon layer





	$e^-$	P	He, Li, Be, .. Fe	$\gamma$	$e^+$	$\bar{P}, \bar{D}$	$\bar{He}, \bar{C}$
<b>TRD</b>							
<b>TOF</b>							
<b>Tracker</b>							
<b>RICH</b>							
<b>ECAL</b>							
<b>Physics example</b>	<b>Cosmic Ray Physics</b>				<b>Dark matter</b>	<b>Antimatter</b>	



## recent AMS02 history in short



- fall 2009: integration at CERN
- February 2010: test beam at CERN
- spring 2010: EMI and TV test at ESTEC (ESA)
- late spring 2010: magnet replacement at CERN
- August 2010: test beam at CERN
- fall/winter/spring 2010-2011 integration at KSC (Florida)
- May 16<sup>th</sup> 2011: launch!
- May 19<sup>th</sup> 2011: first activation in space: everything is working!!



## recent AMS02 history in short

- fall 2009: integrat
- February 2010: t
- spring 2010: EM
- late spring 2010:
- August 2010: tes
- fall/winter/spring  
(Florida)
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- May 19<sup>th</sup> 2011: f  
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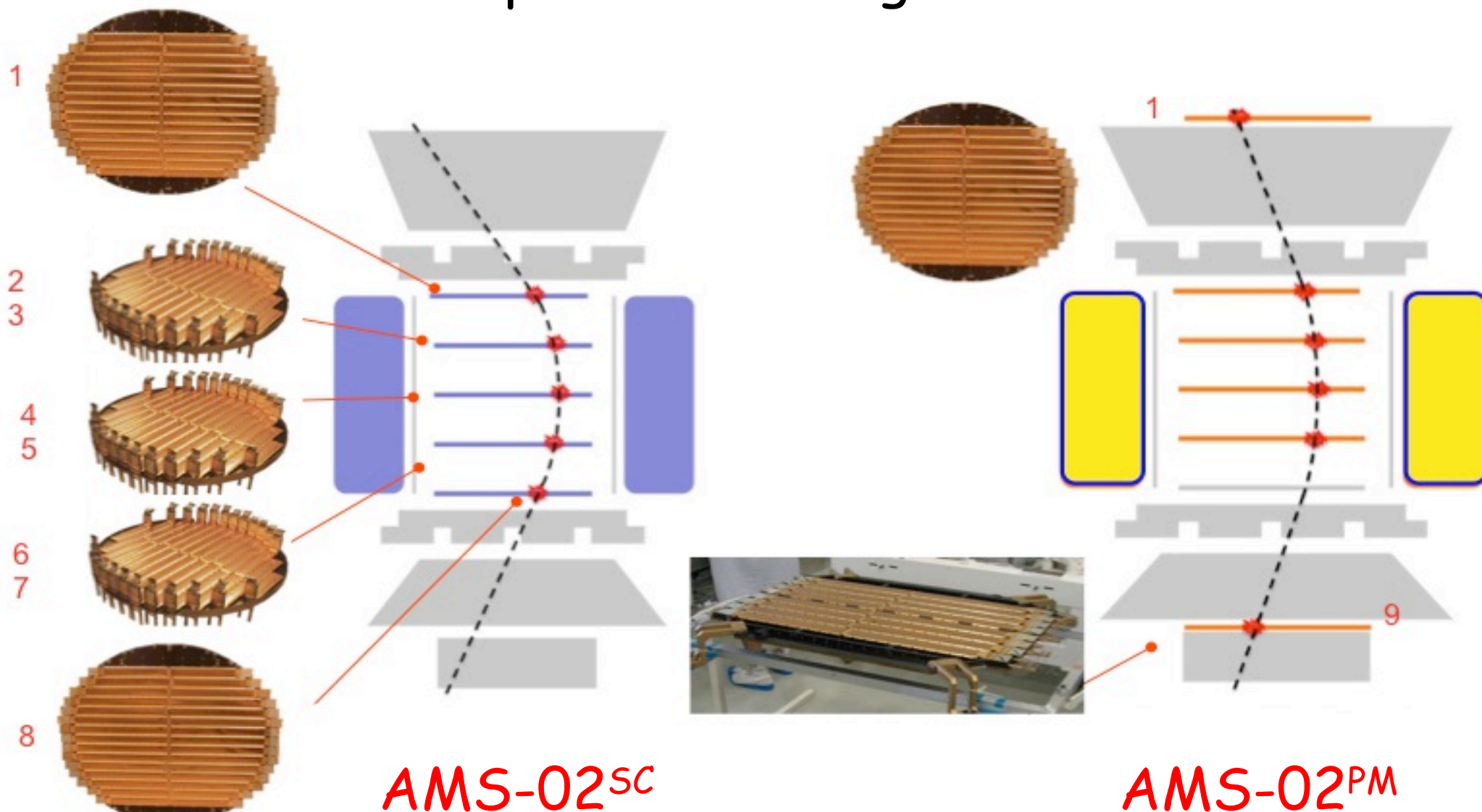


(ESA)  
at CERN

n at KSC



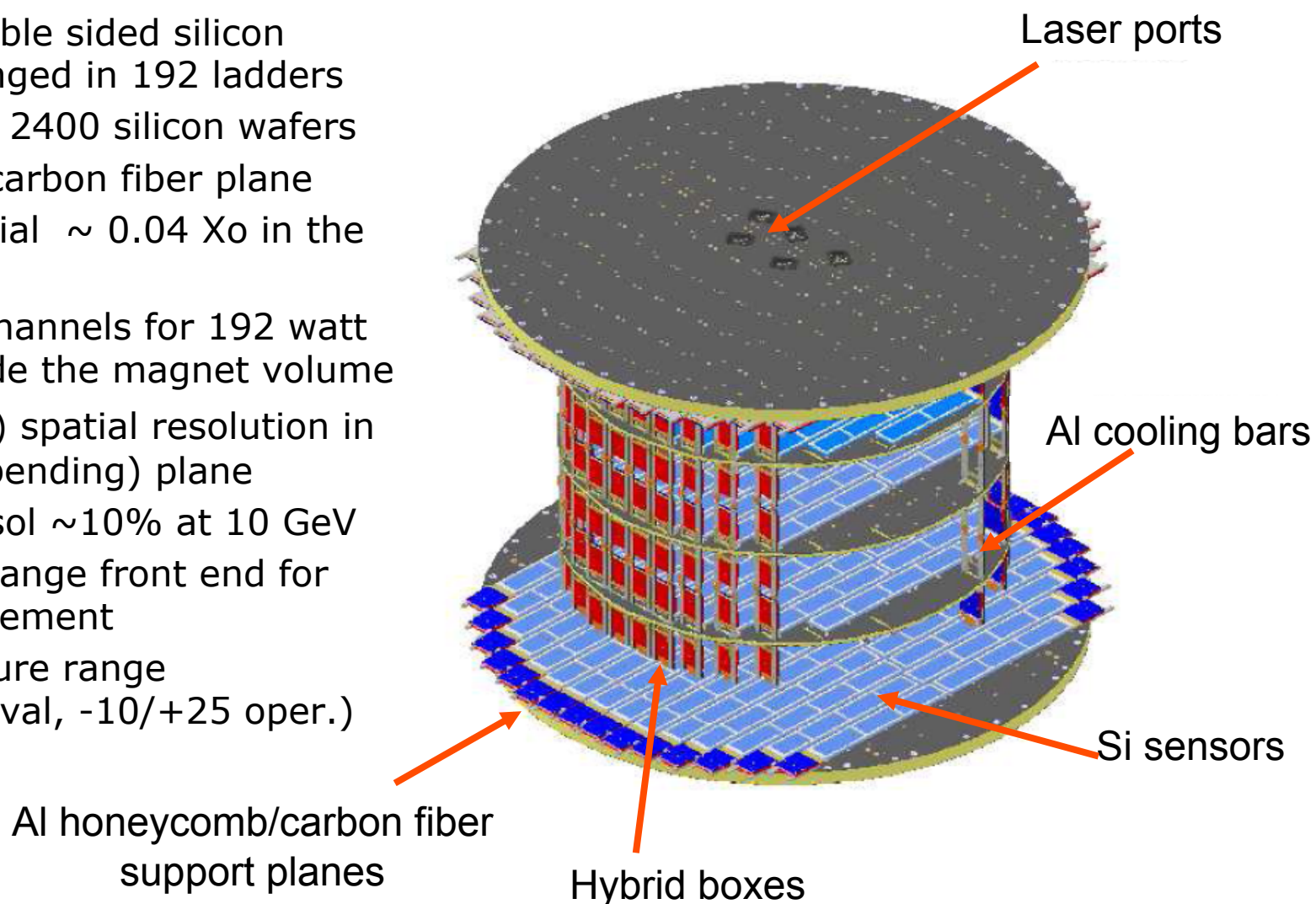
# Layout modification to use the permanent magnet





# Silicon Tracker

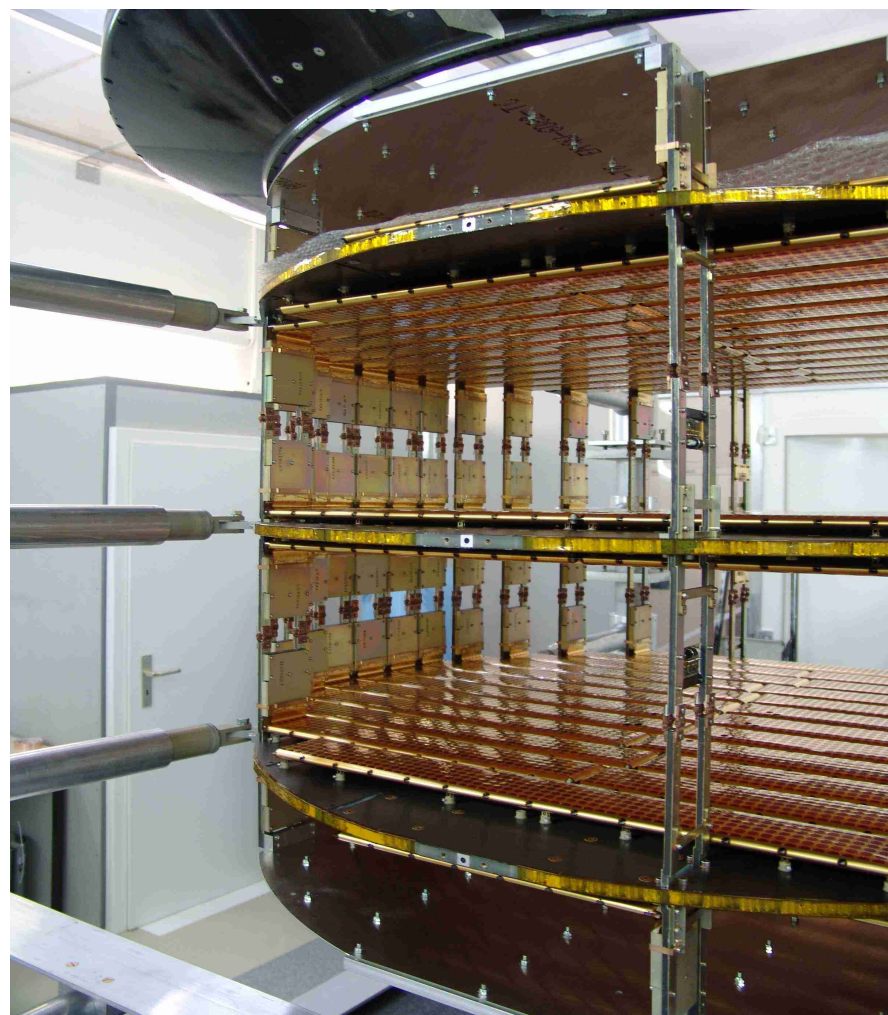
- 9 layers of double sided silicon detectors arranged in 192 ladders for a total of  $\sim 2400$  silicon wafers
- 6 honeycomb carbon fiber plane
- detector material  $\sim 0.04 X_0$  in the inner tracker
- total of 200 kchannels for 192 watt dissipated inside the magnet volume
- $10 \mu\text{m}$  ( $30 \mu\text{m}$ ) spatial resolution in bending (non bending) plane
- momentum resol  $\sim 10\%$  at 10 GeV
- high dynamic range front end for charge measurement
- wide temperature range (-20/+40 survival, -10/+25 oper.)





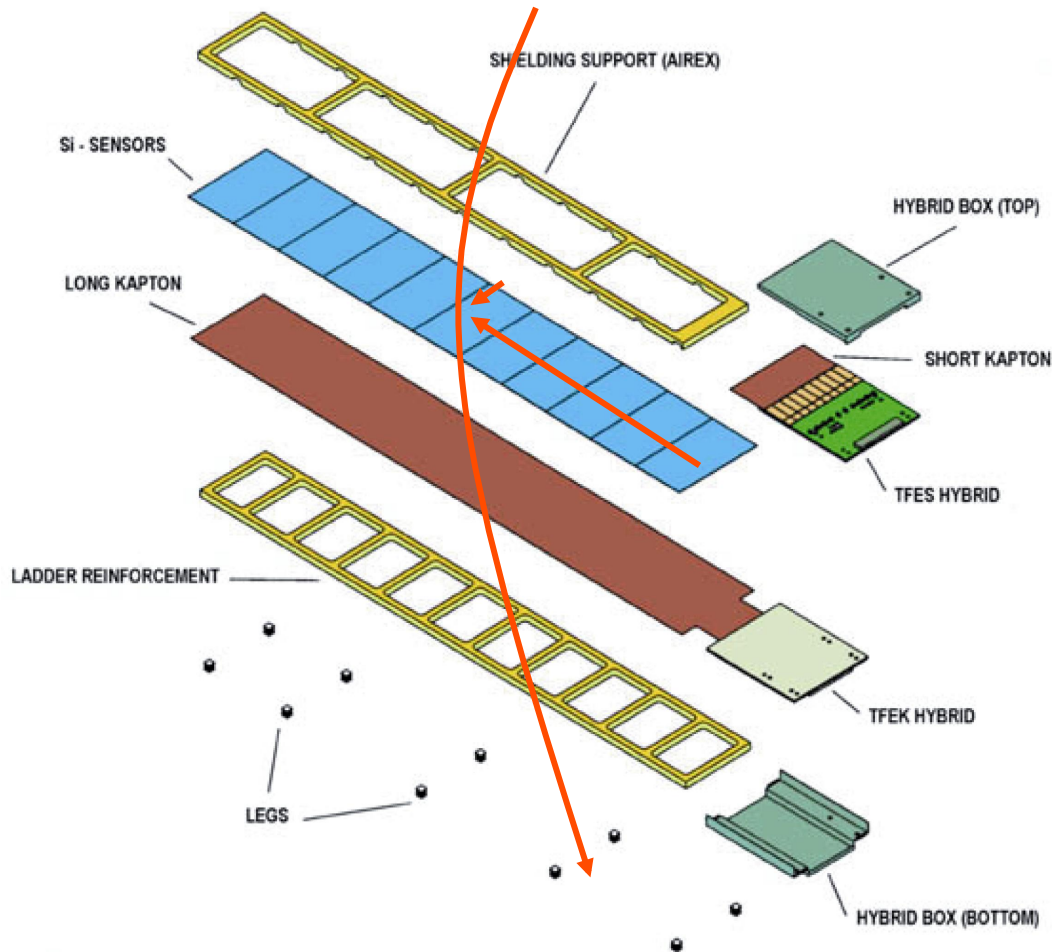
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# AMS silicon ladders

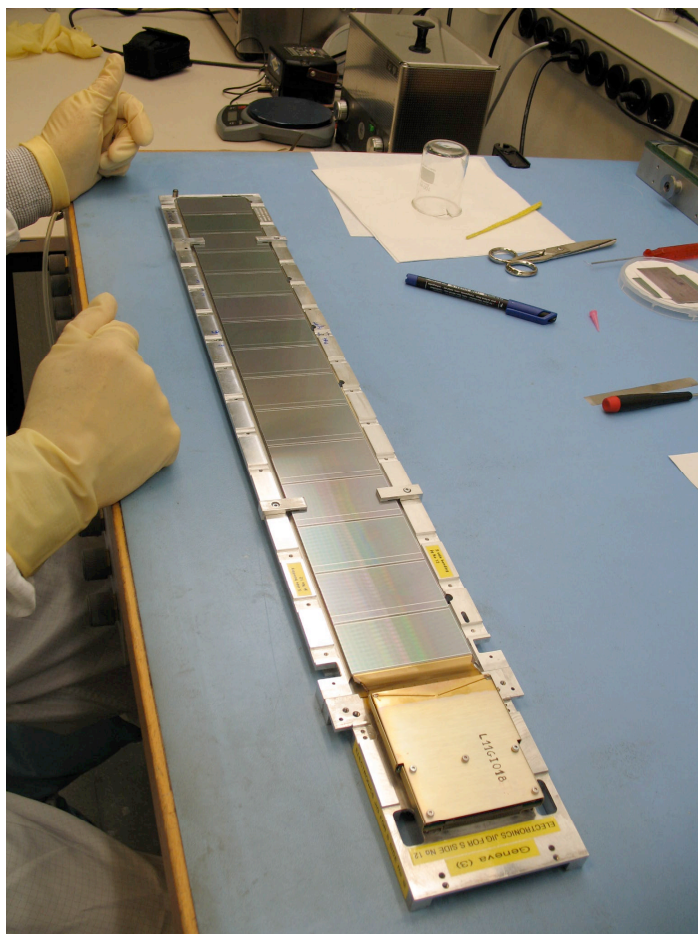


- 1024 high dynamic range, AC coupled readout channels:
  - 640 on junction (S) side
  - 384 on ohmic (K) side
- Impl/readout pitch:
  - 27.5/110  $\mu\text{m}$  (S side)
  - 104/208  $\mu\text{m}$  (K side)
- 7 - 15 wafers (28 - 60 cm)

192 flight units, 210 assembled in 3 lines:  
Perugia (I), Geneva-ETHZ (CH), G&A (Carsoli, I)



# AMS silicon ladders

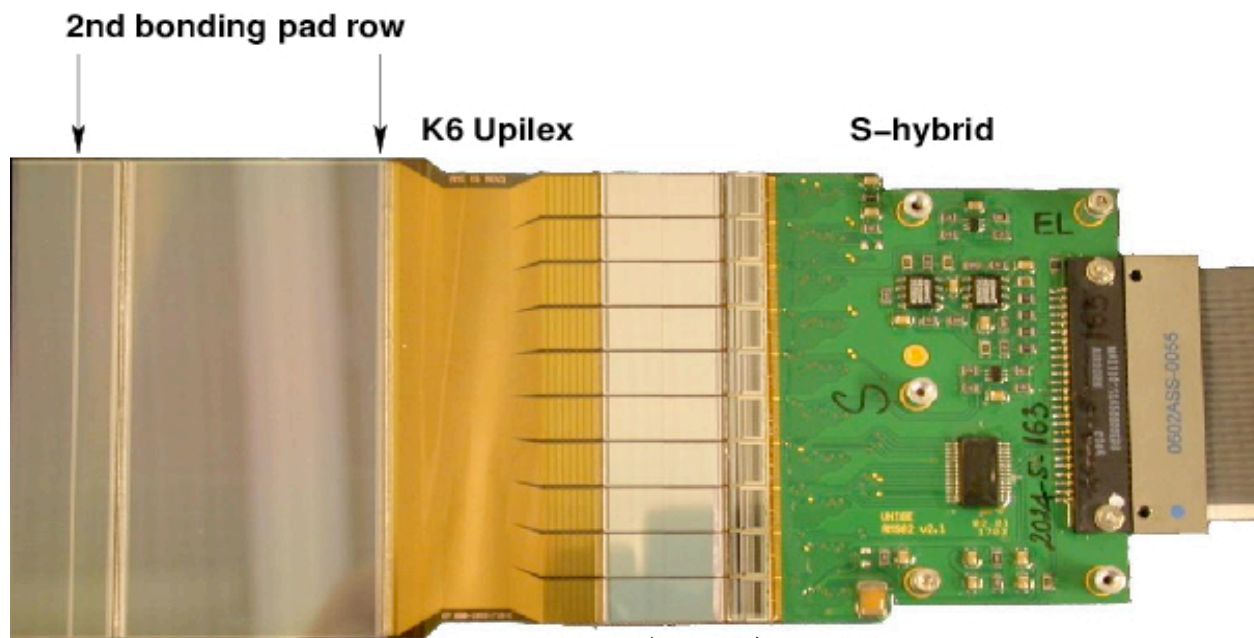


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192 flight units, 210 assembled in 3 lines:  
Perugia (I), Geneva-ETHZ (CH), G&A (Carsoli, I)



# Ladder components (p side)



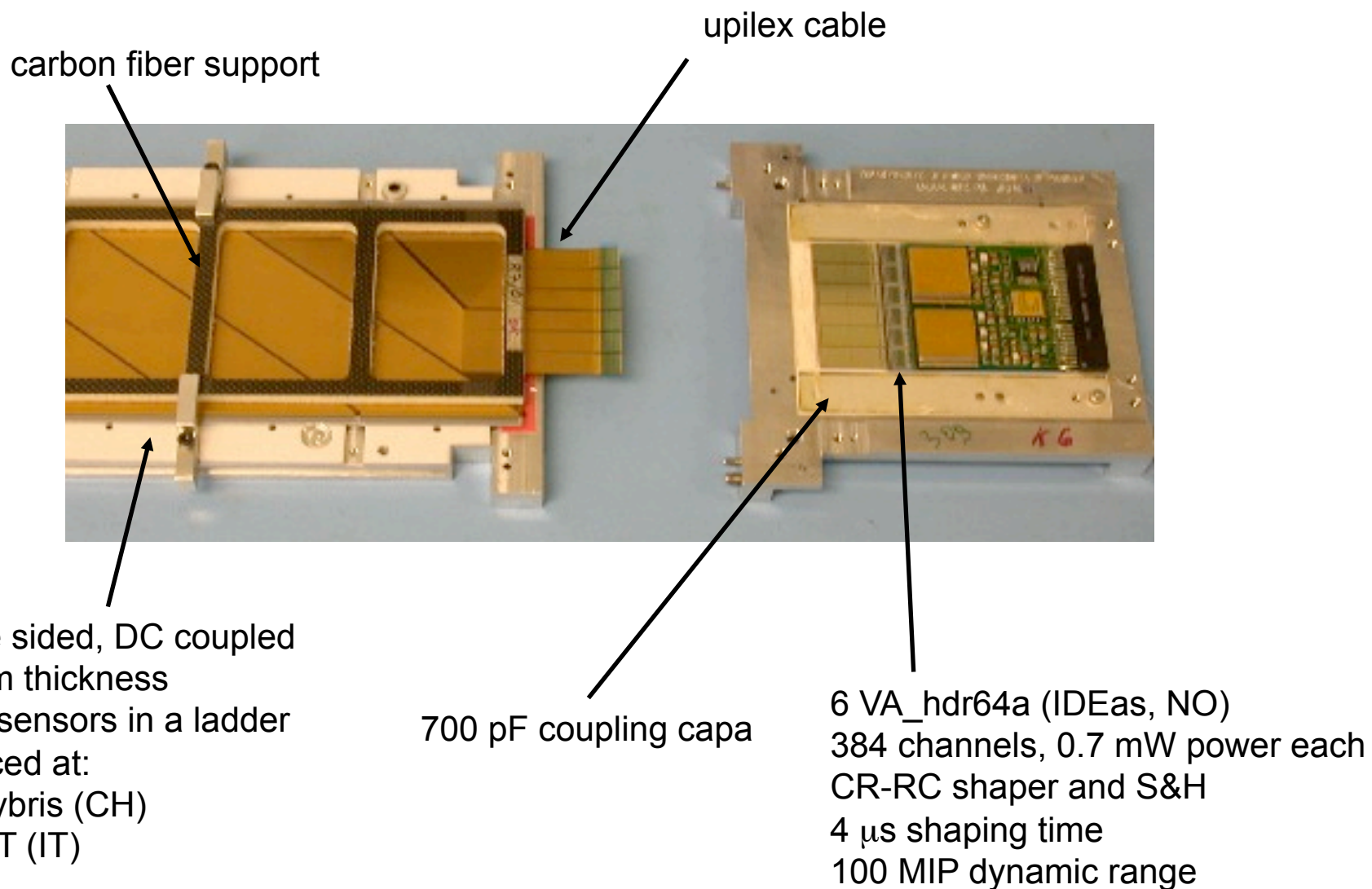
double sided, DC coupled  
 300  $\mu\text{m}$  thickness  
 7 - 15 sensors in a ladder  
 produced at:  
 - Colybris (CH)  
 - IRST (IT)

1st sensor edge  
 700 pF coupling capa

10 VA\_hdr64a (IDEas, NO)  
 640 channels, 0.7 mW power each  
 CR-RC shaper and S&H  
 4  $\mu\text{s}$  shaping time  
 100 MIP dynamic range



# Ladder components (n side)





# Radiation 'hard' electronics

The problem are the SEE (Single Event Effect)

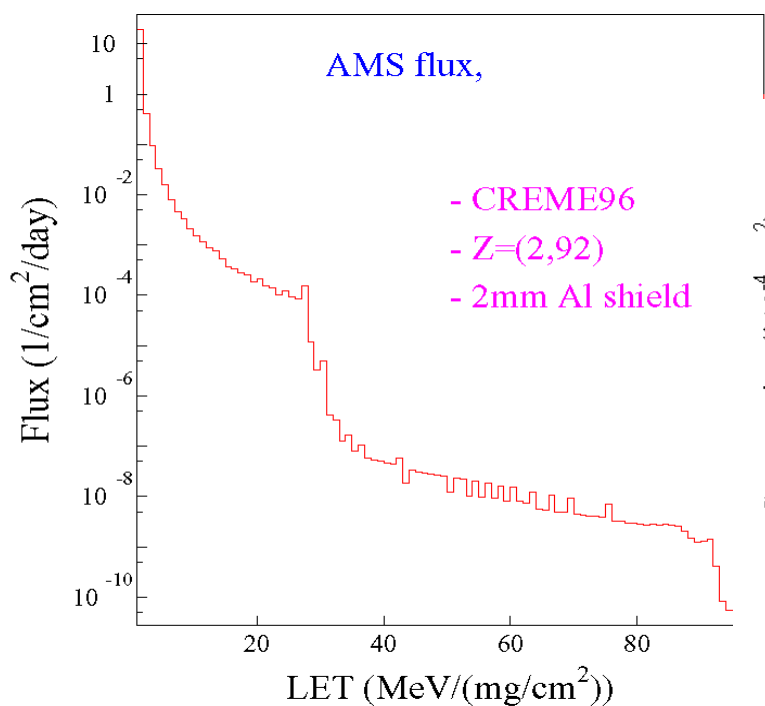


Figure 5: Expected fluxes on ISS in 2003.

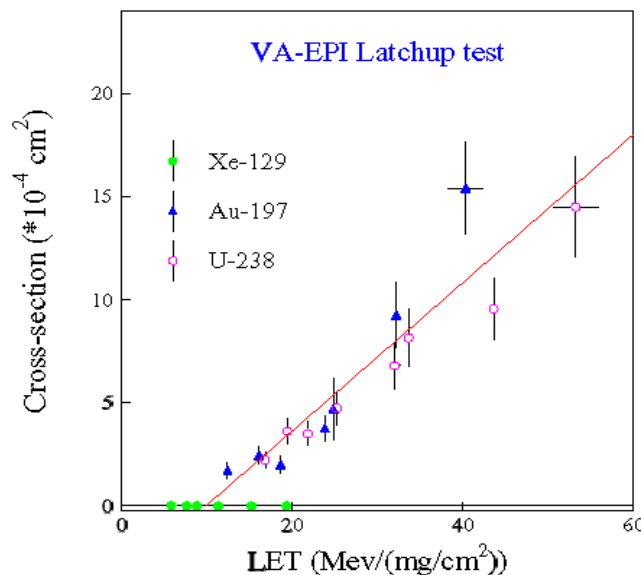
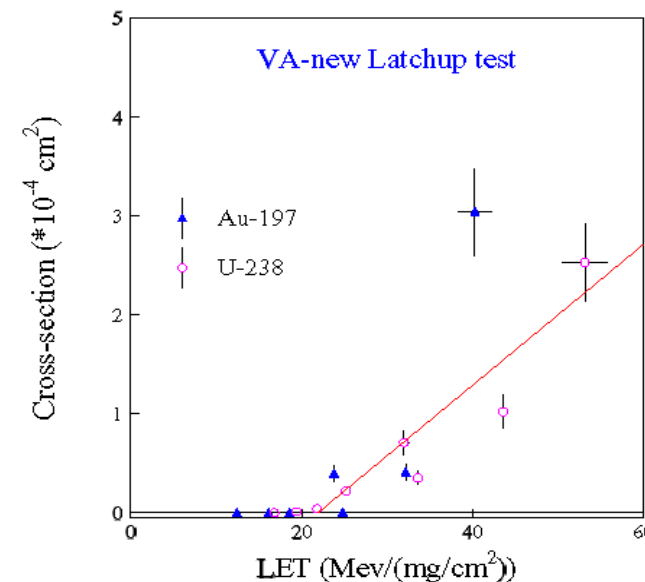


Figure 12: The new VA – SEL rates as measured in GSI



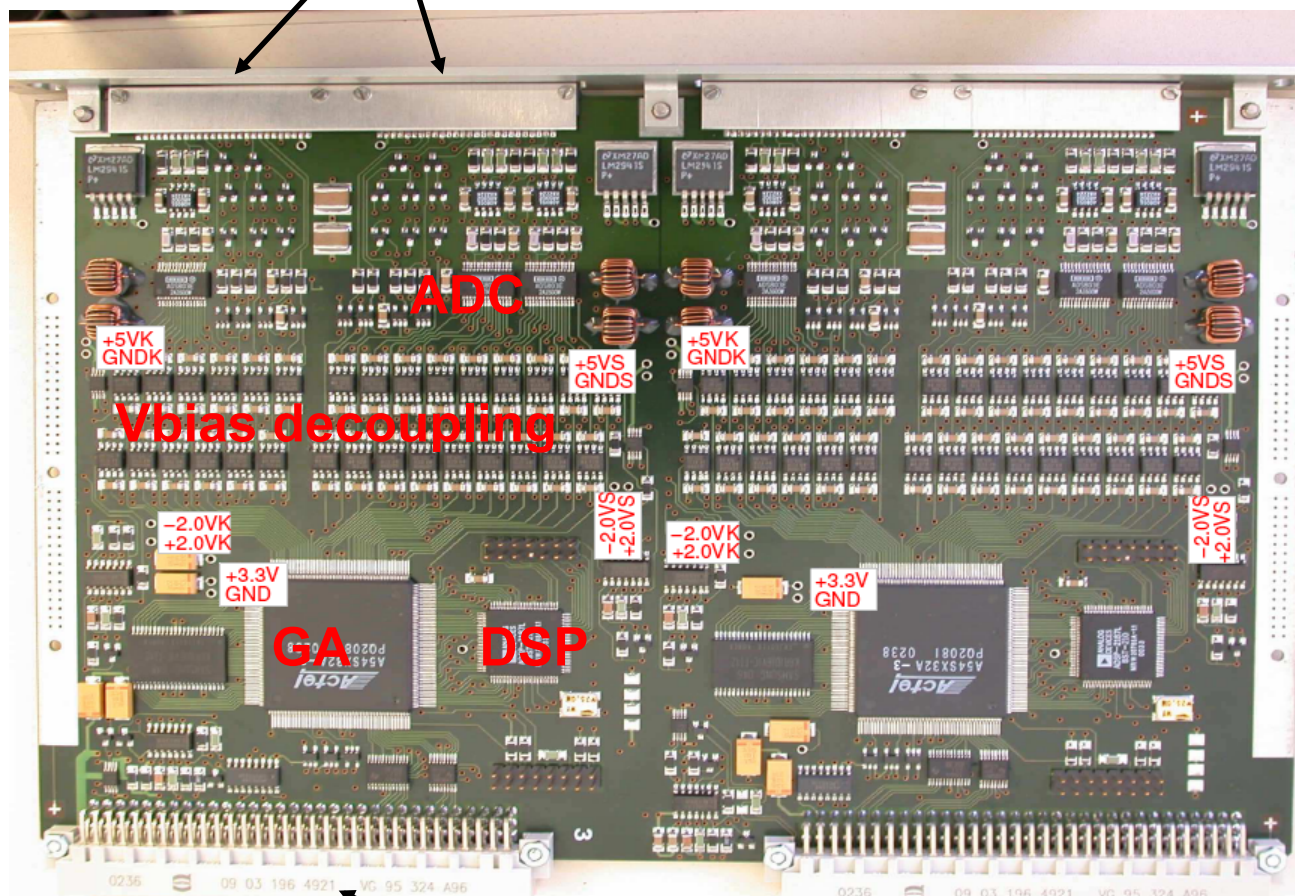
current limit protection is present for all active components



# Data Reduction Board (TDR2)



analog signal in



compressed digital out

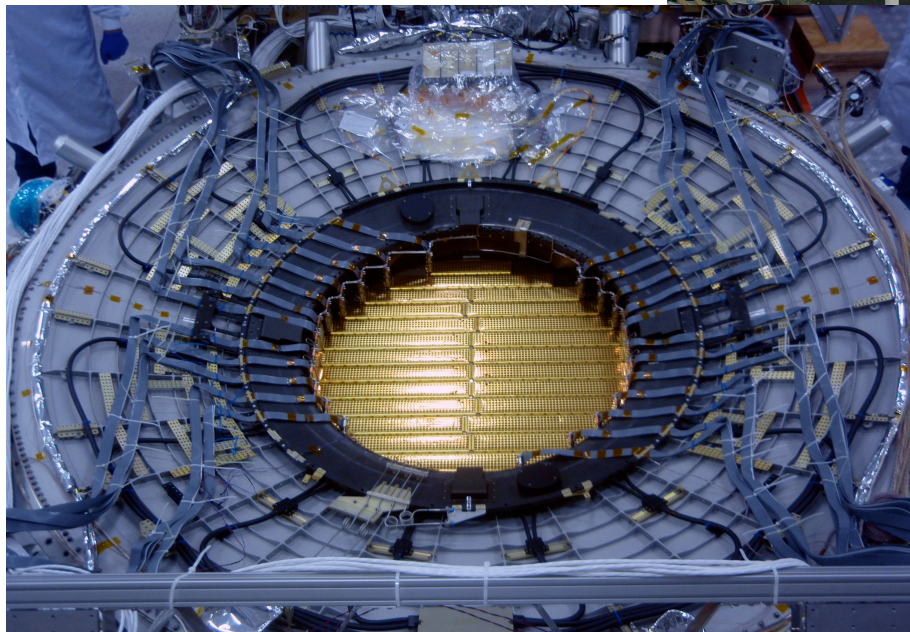
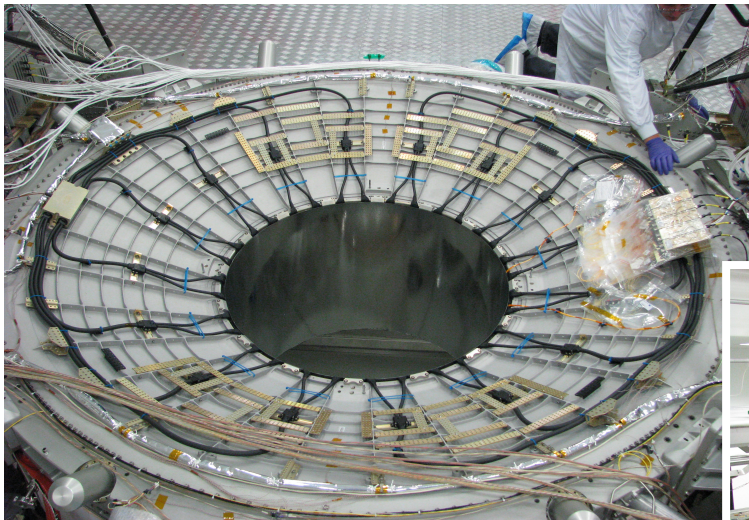
Collect analog data and digitize it (100  $\mu$ s irred. dead time)

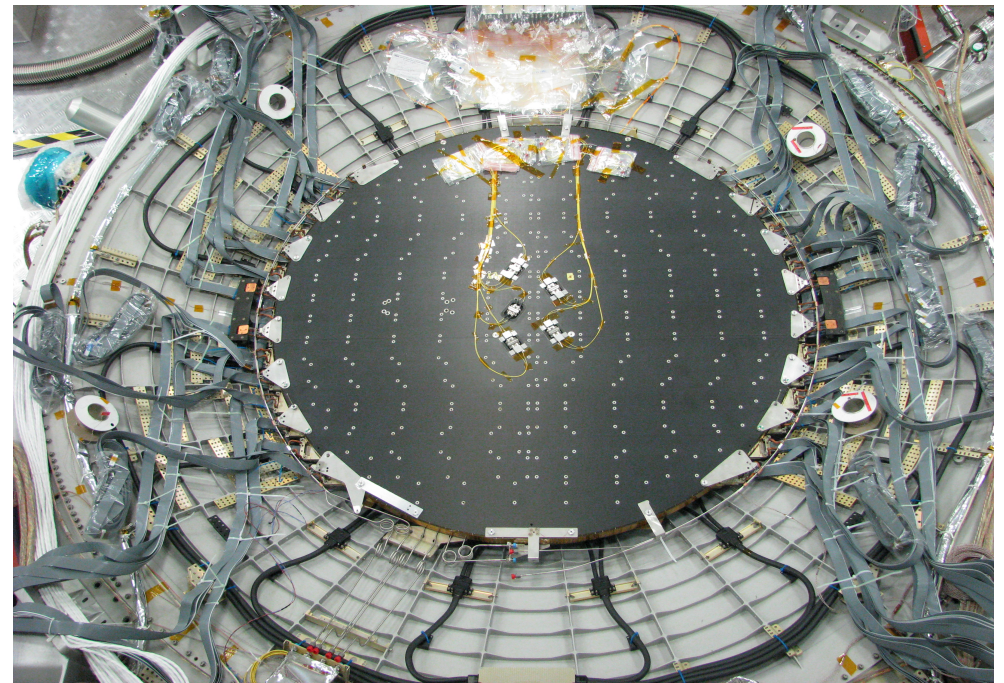
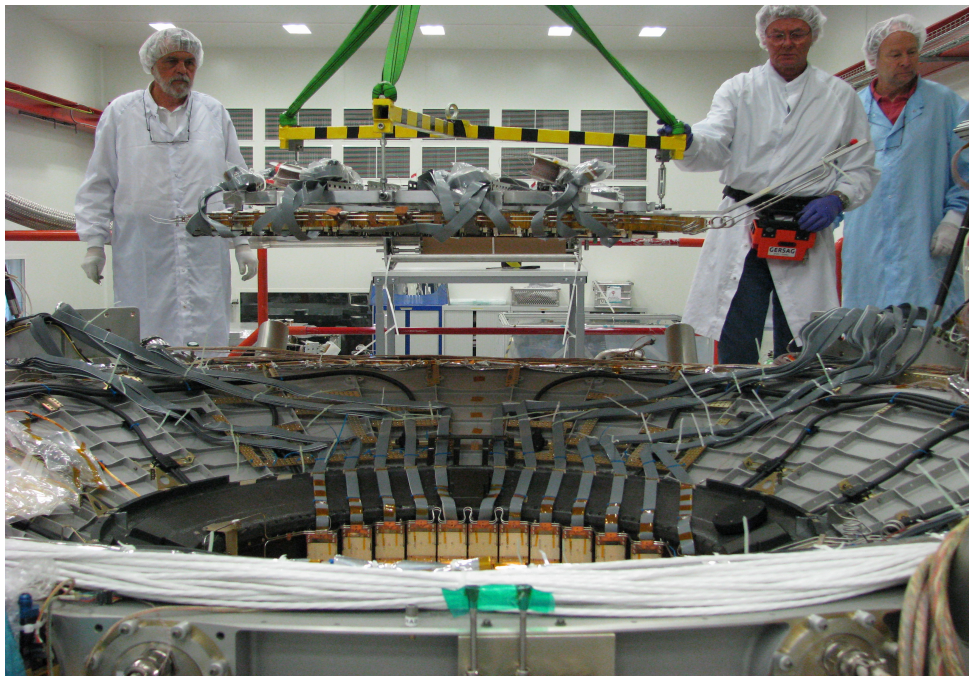
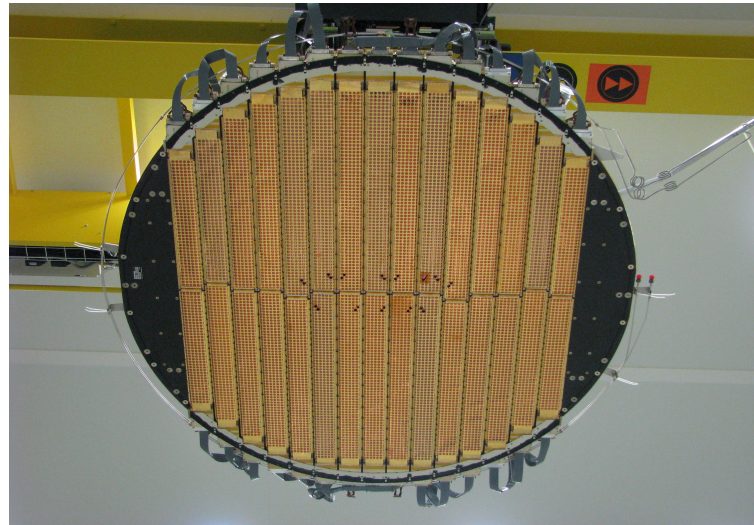
Perform online data compression

- Remove Pedestals
- Calculate and Remove Common Noise
- Search Clusters

Up to 5 KHz trigger rate in compressed mode

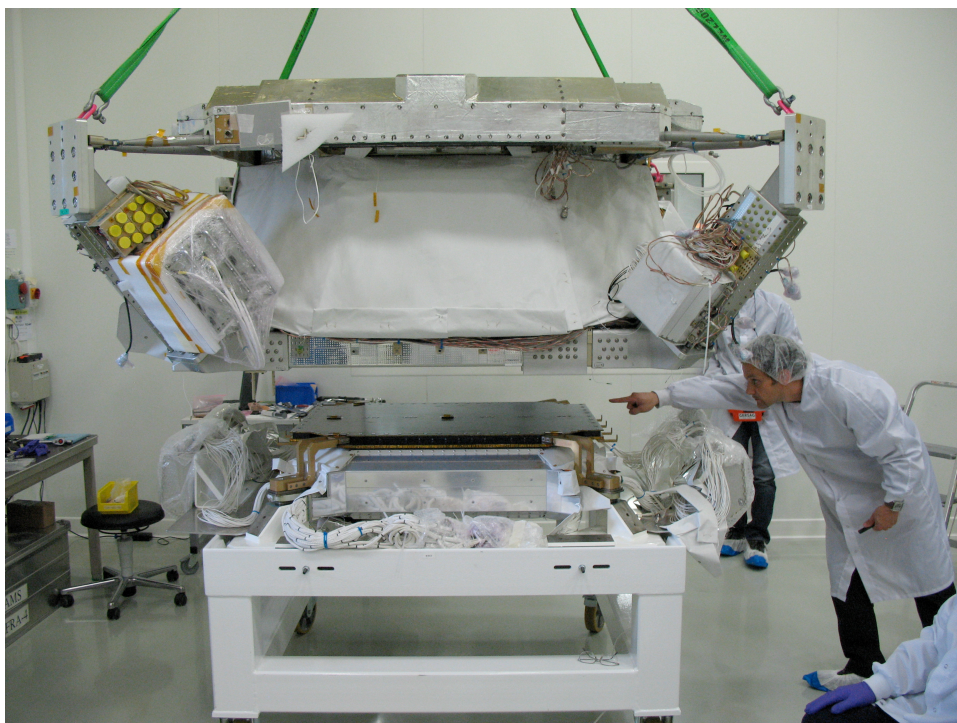
# inner Tracker integration





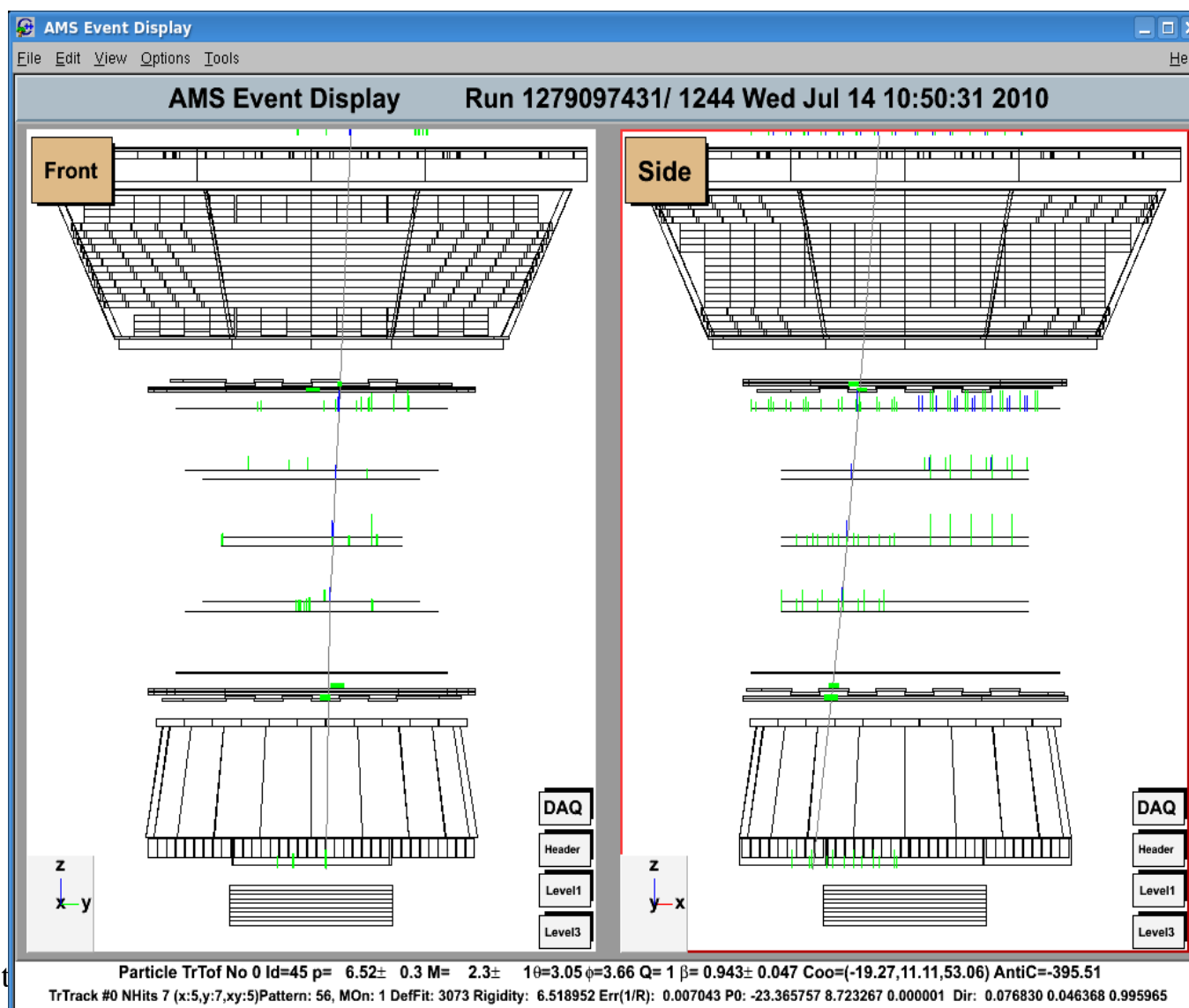


# Tracker integration (2)





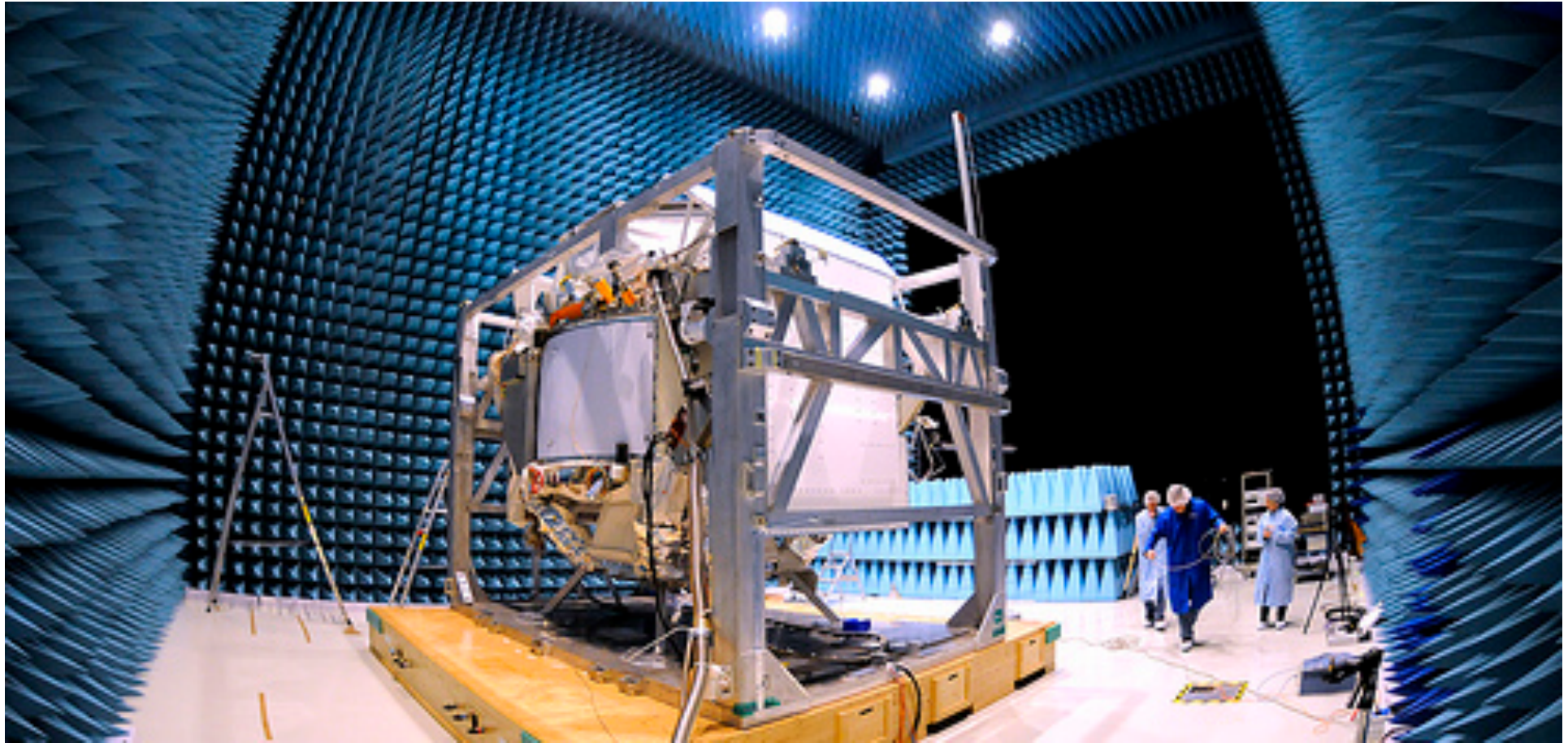
# the first muon with the new Tracker





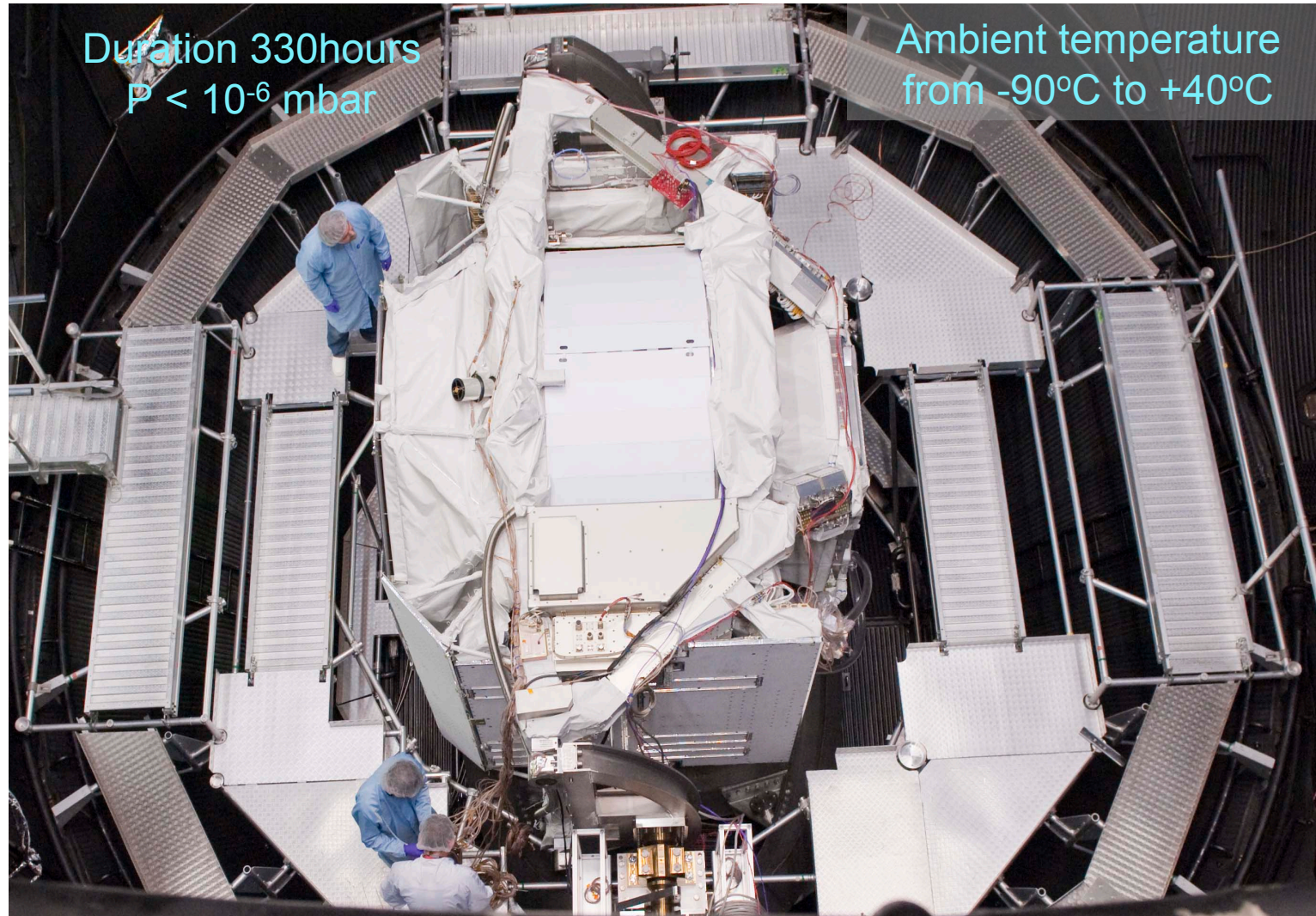


# AMS in the ESA EMI Chamber, March 2010, ESTEC, Noordwijk, Netherlands



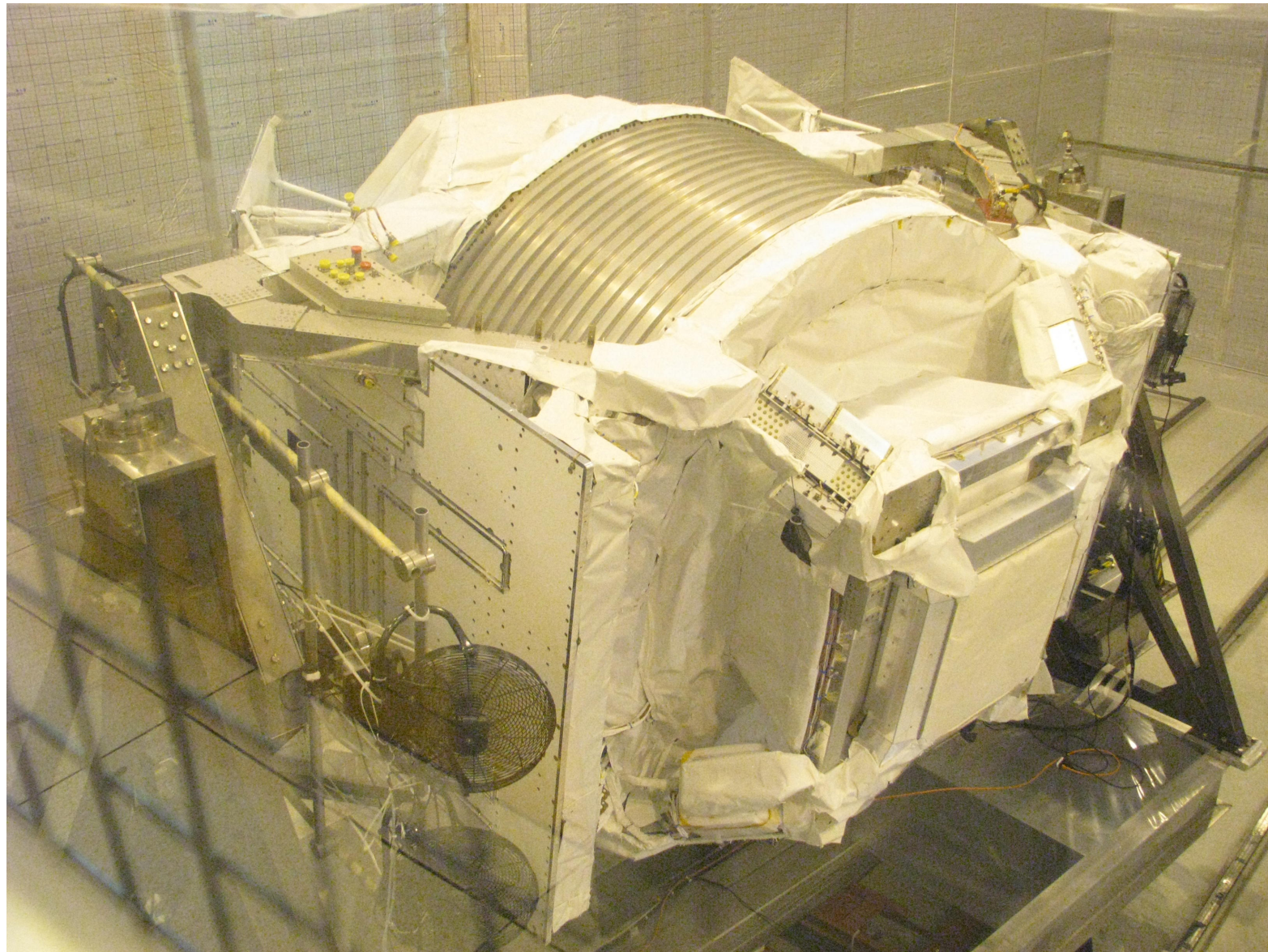


# AMS in the ESA TVT Chamber, April 2010, ESTEC



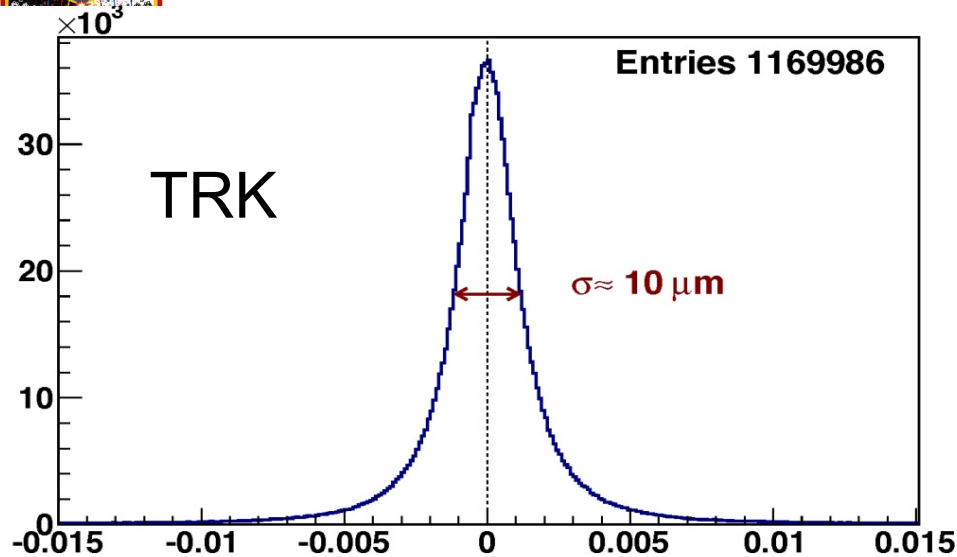


# AMS in Test Beam - 8-20 Aug 2010, CERN

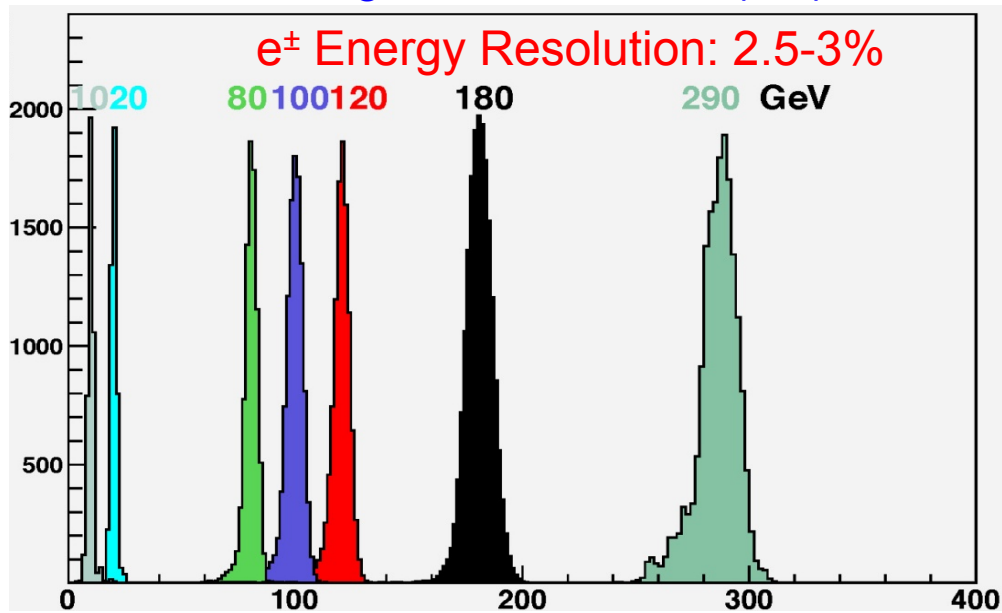
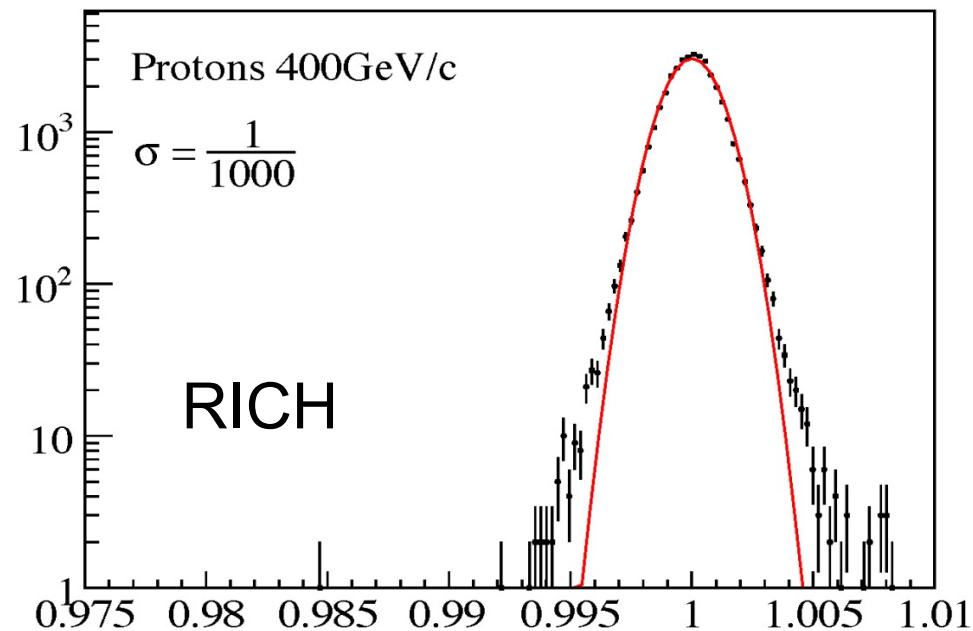




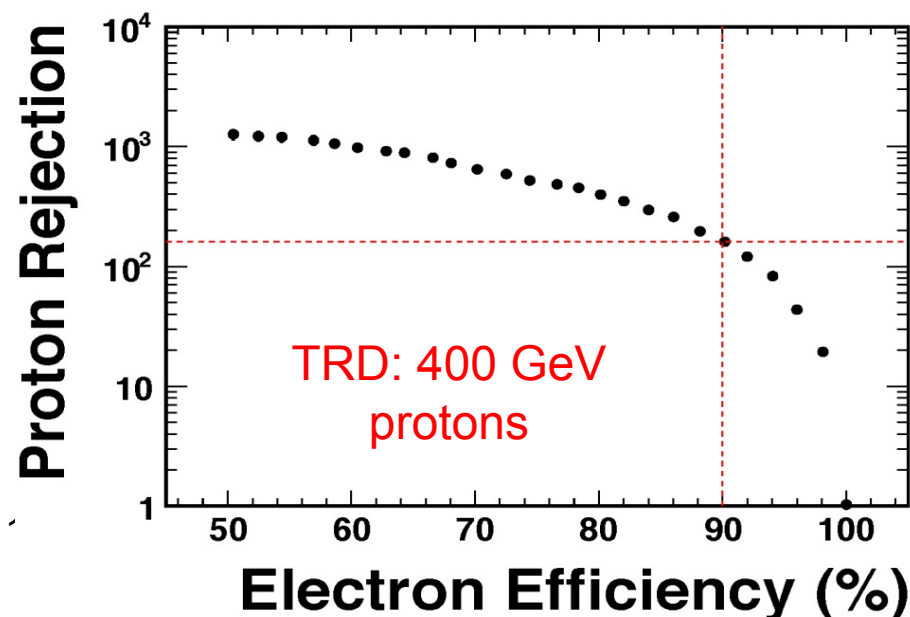
# Beam test calibration



Bending Plane Residual (cm)



SN2 -





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



# Monitoring Interface



Until now or

## GTSN

JPD-A  
JPD-B

### CHECK

Everything OK

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

2.5 h after the launch



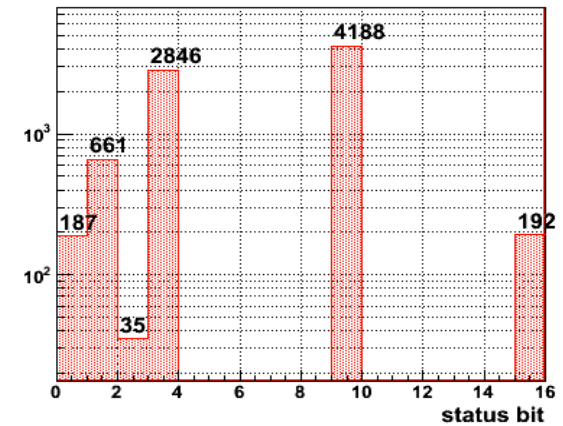
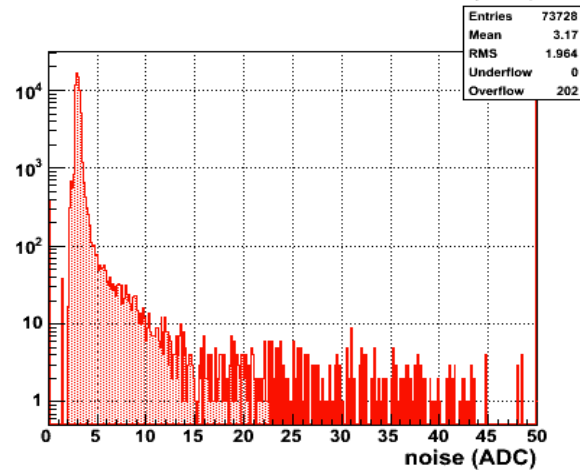
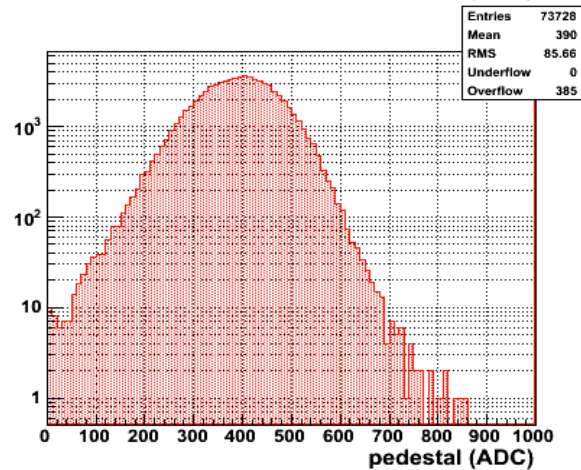
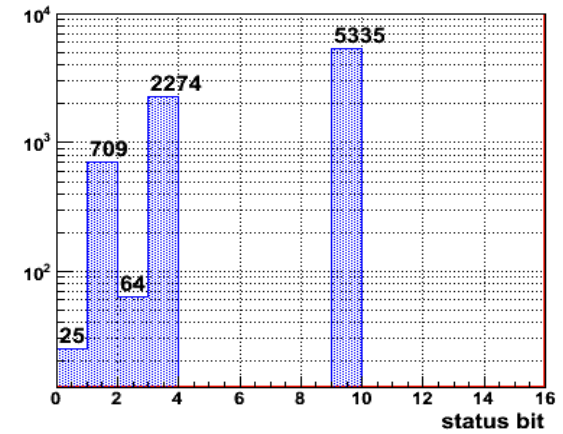
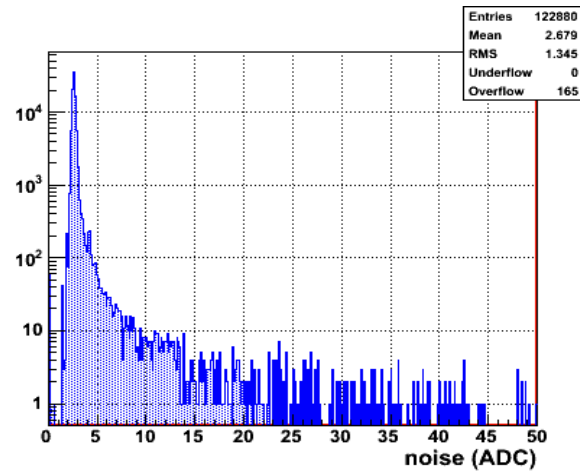
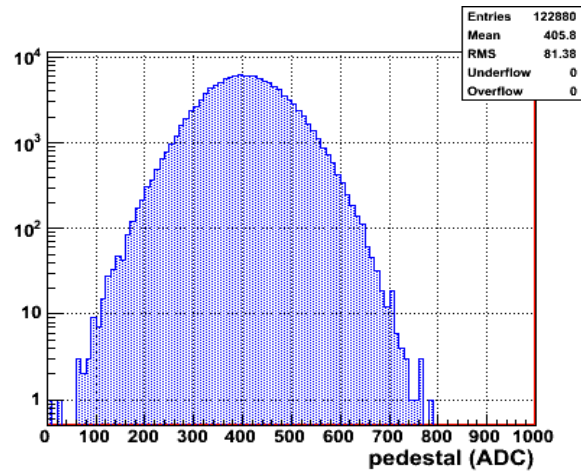
# AMS-02 : the Collaboration @ NASA-JSC







# First Tracker calibration in space



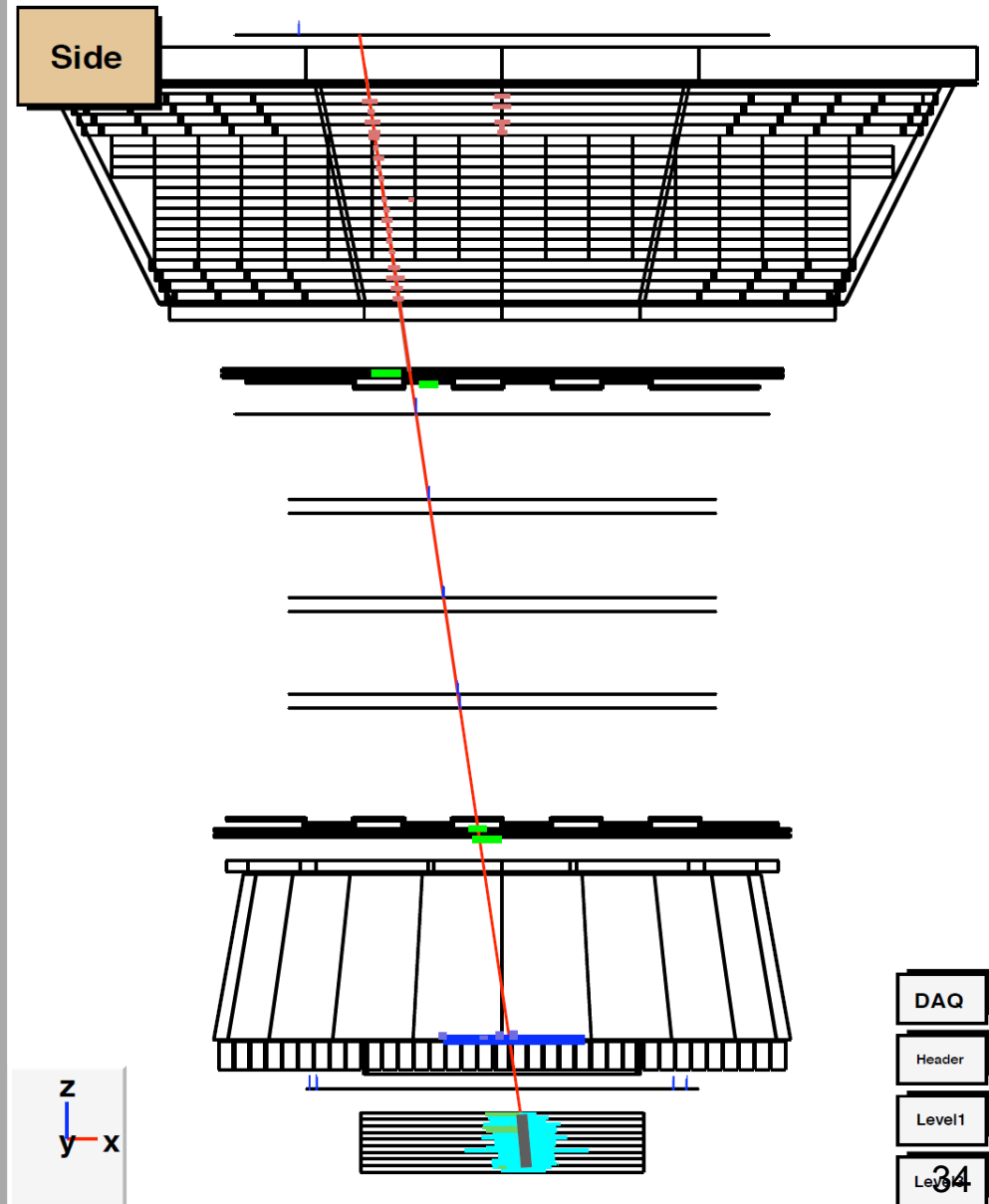
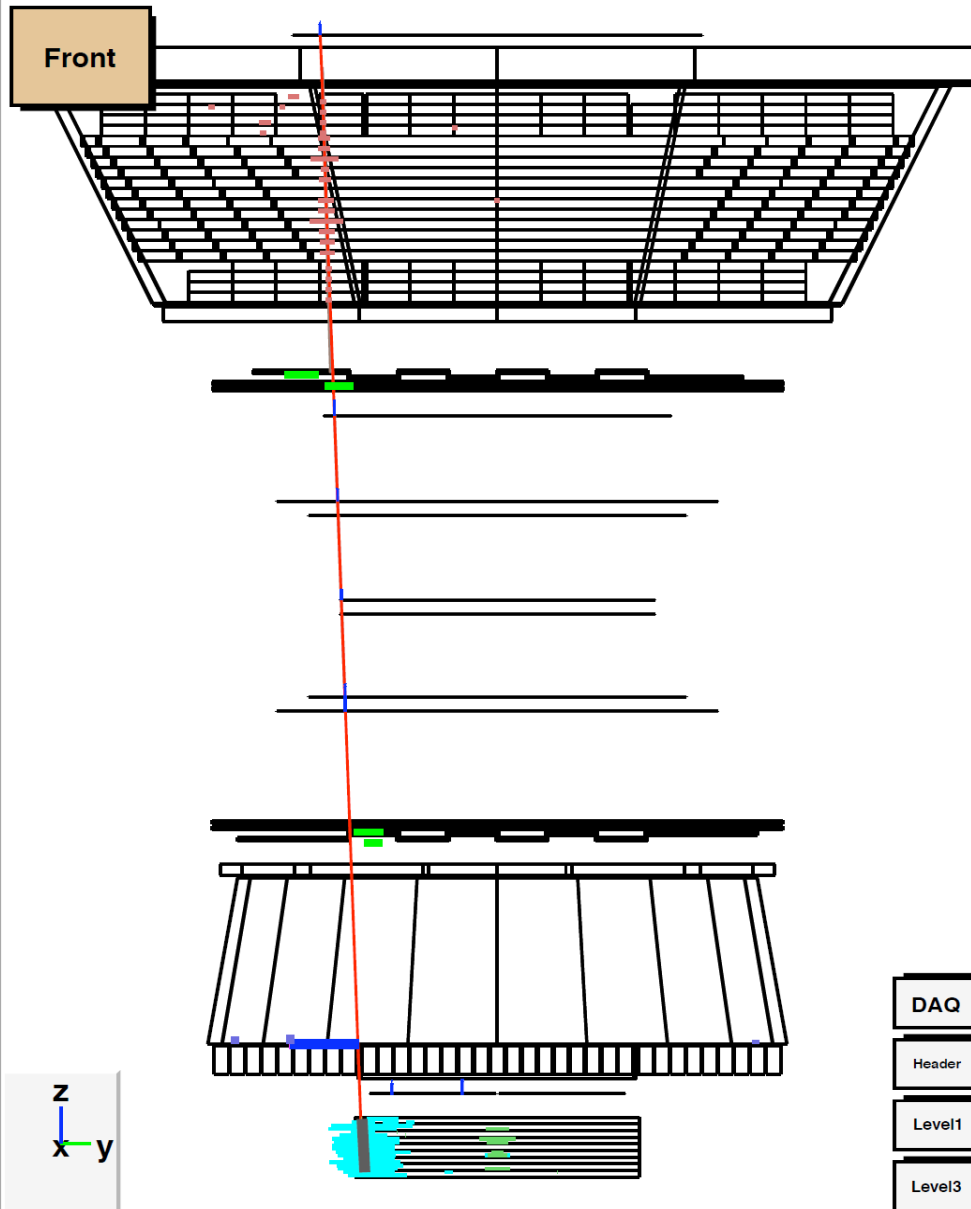
# Data from the 1<sup>st</sup> few minutes – 20 GeV Electron, 19 May 2011

AMS-02

AMS-02

AMS Event Display

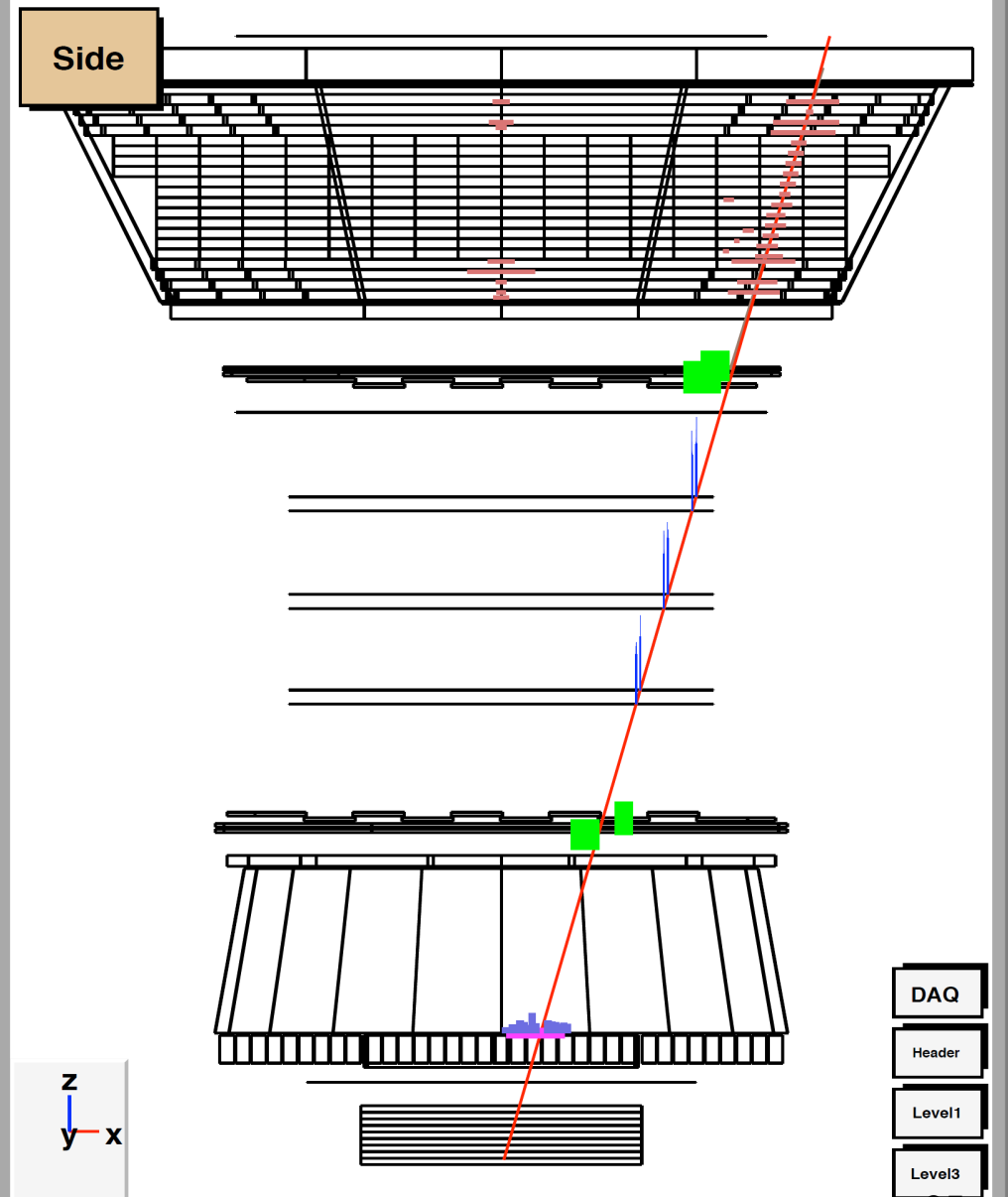
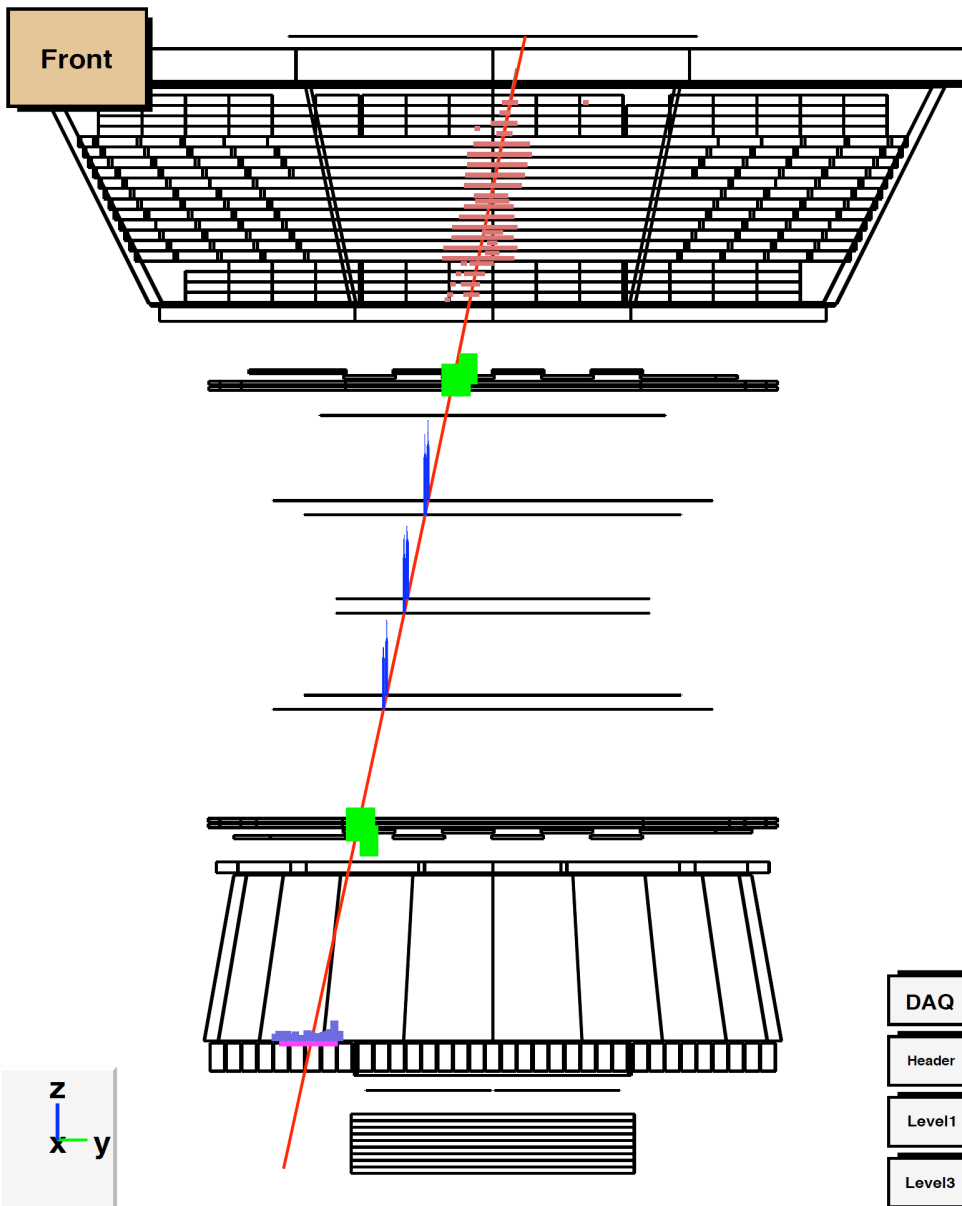
Run 1305815610/ 114493 Thu May 19 16:38:57 2011



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

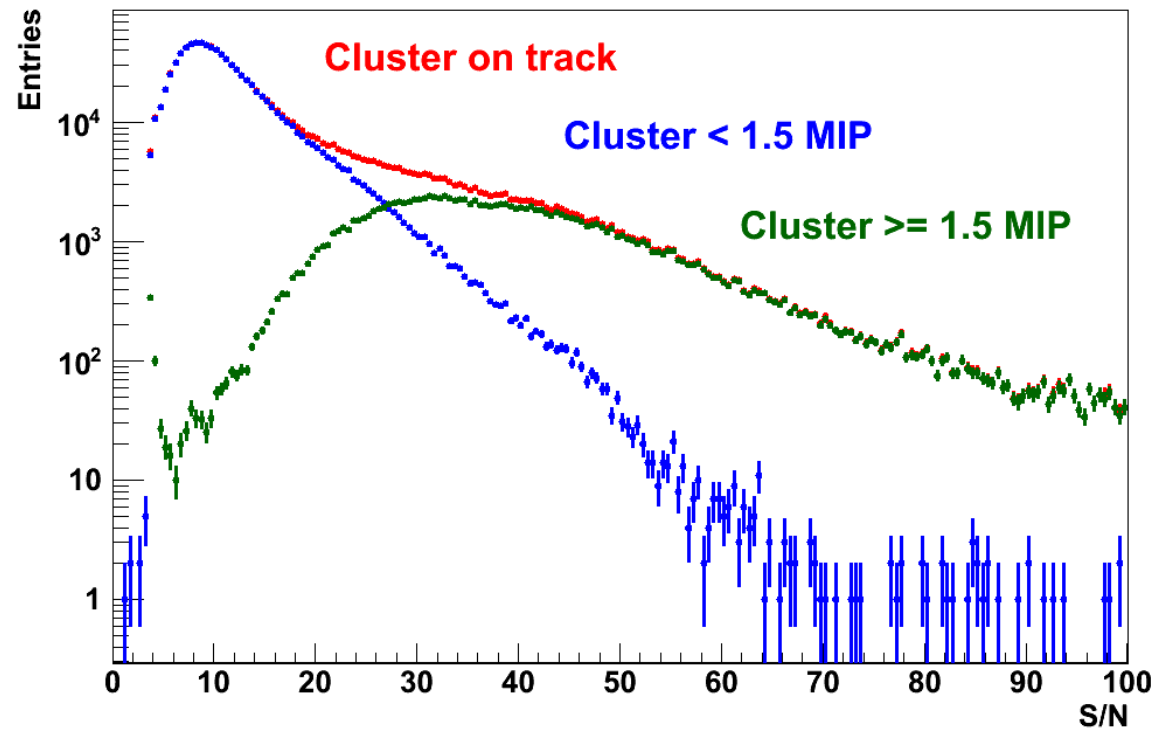
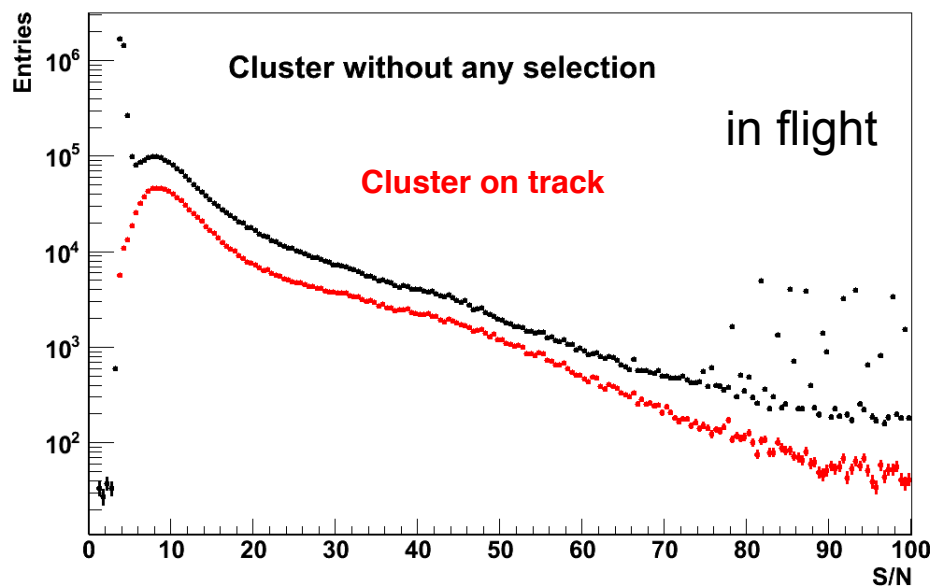
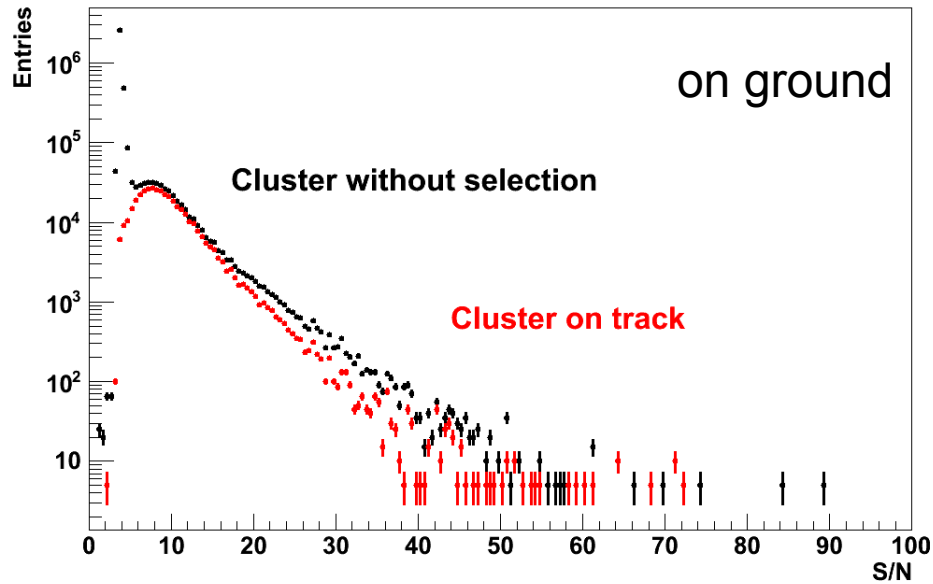
AMS Event Display

Run 1305815610/ 224169 Thu May 19 16:42:29 2011



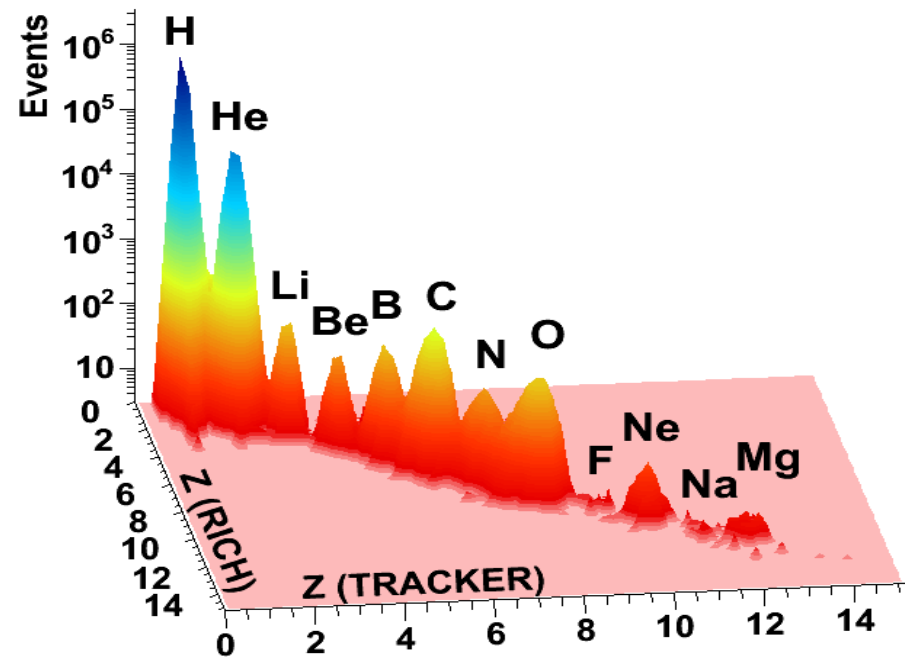
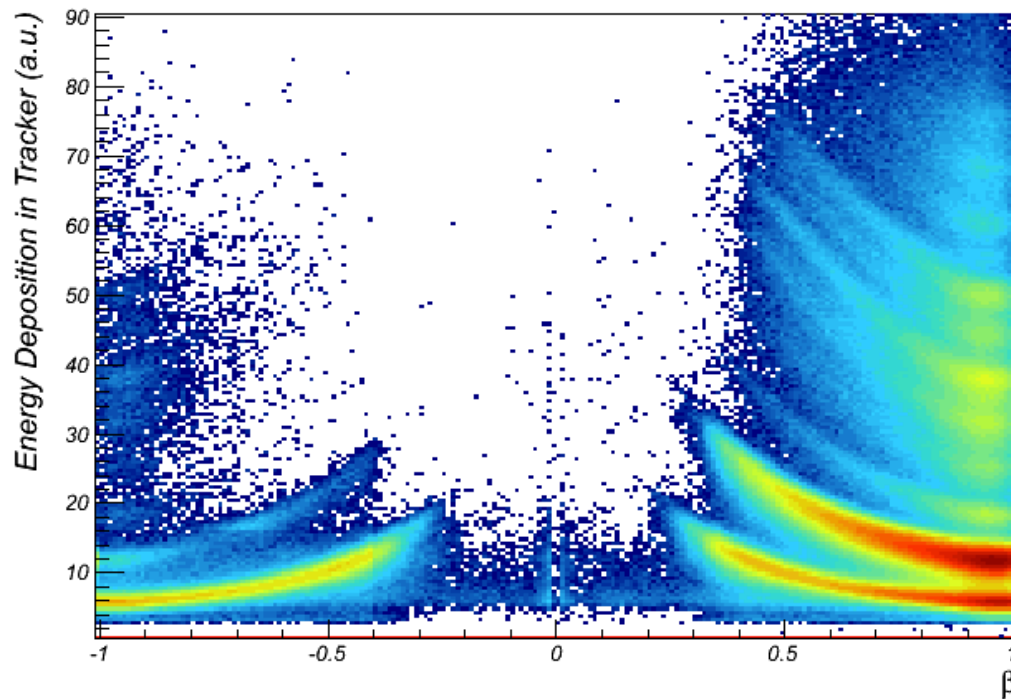


# the Tracker signals



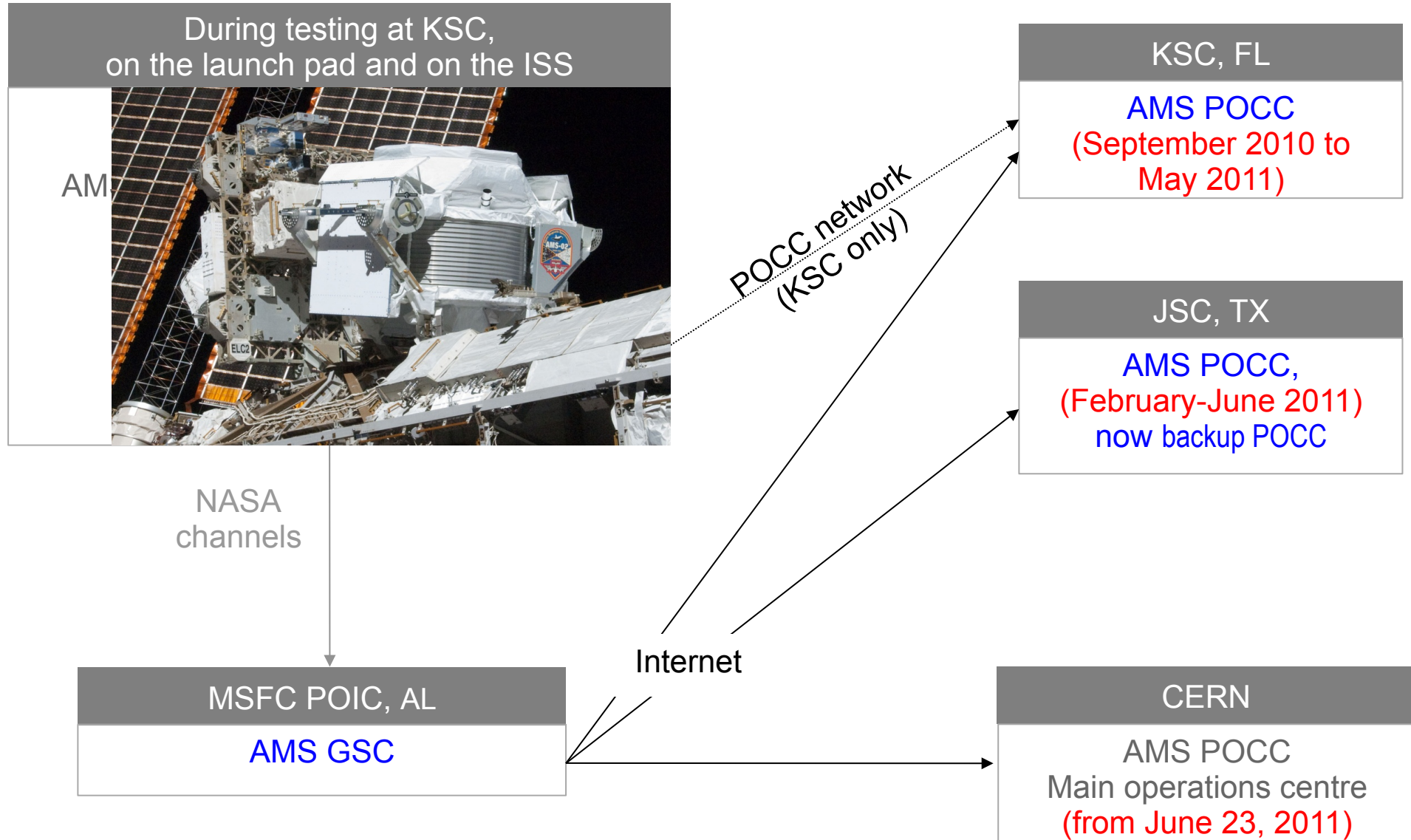


# the particles we see



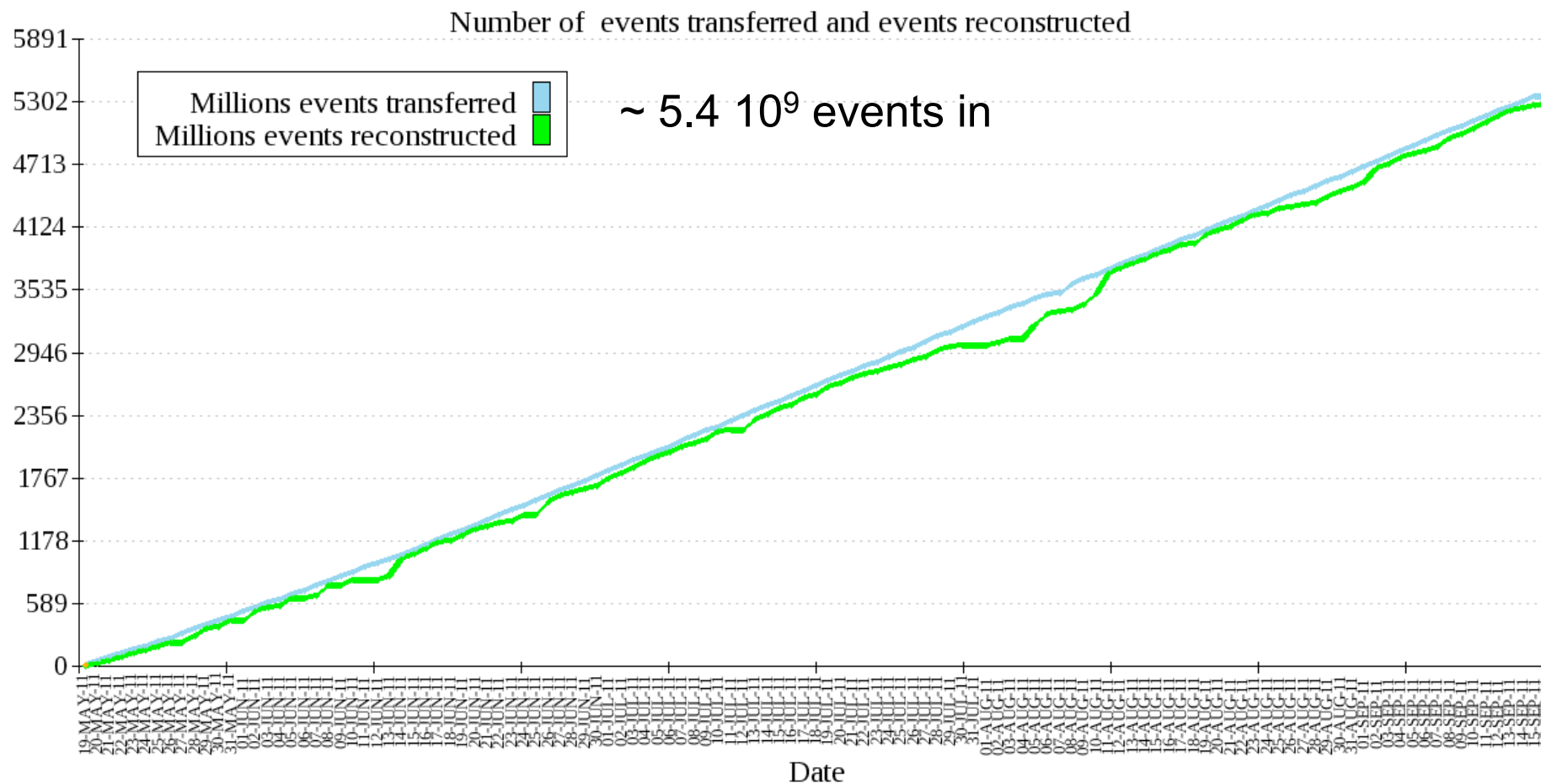


# AMS-02 : the flight experience





# DAQ and data processing: routine operations

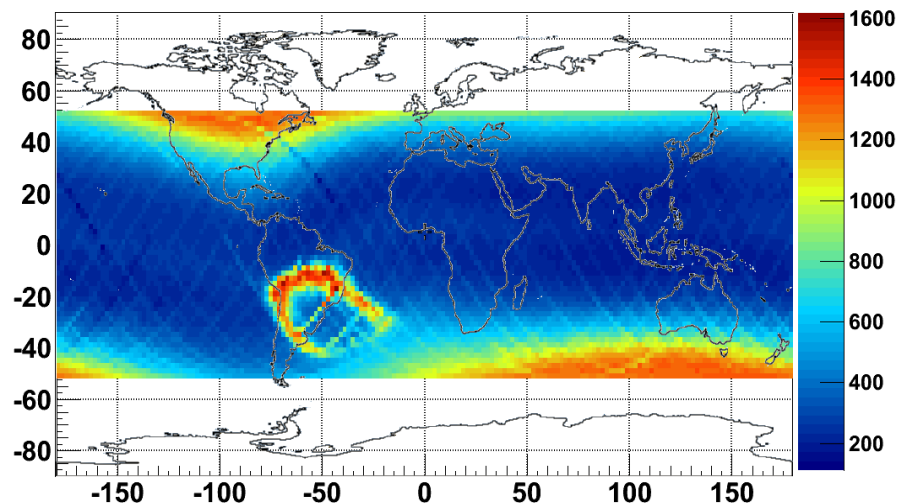




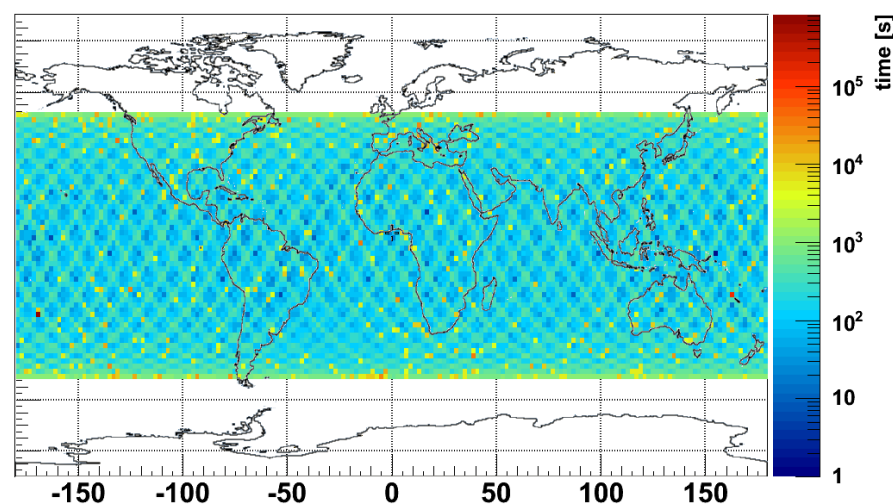
# DAQ orbital parameter



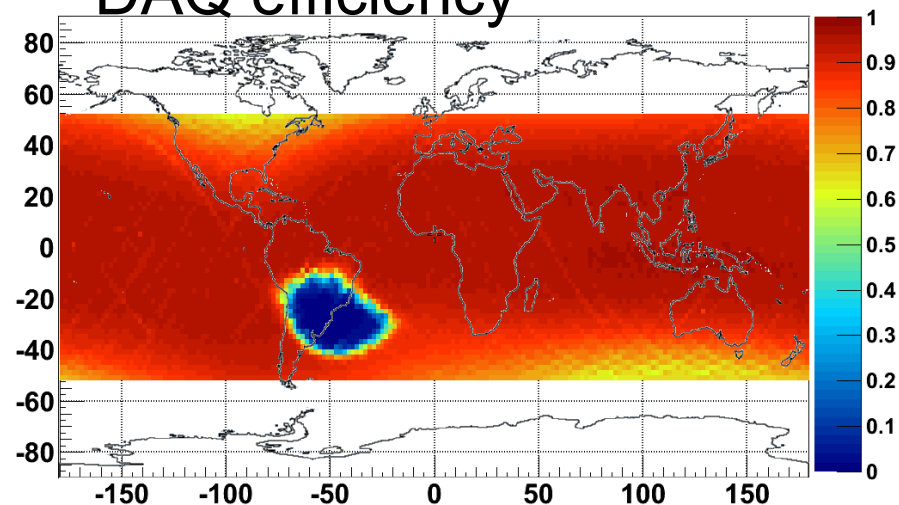
## Acquisition rate [Hz]



## Time at location [s]



## DAQ efficiency



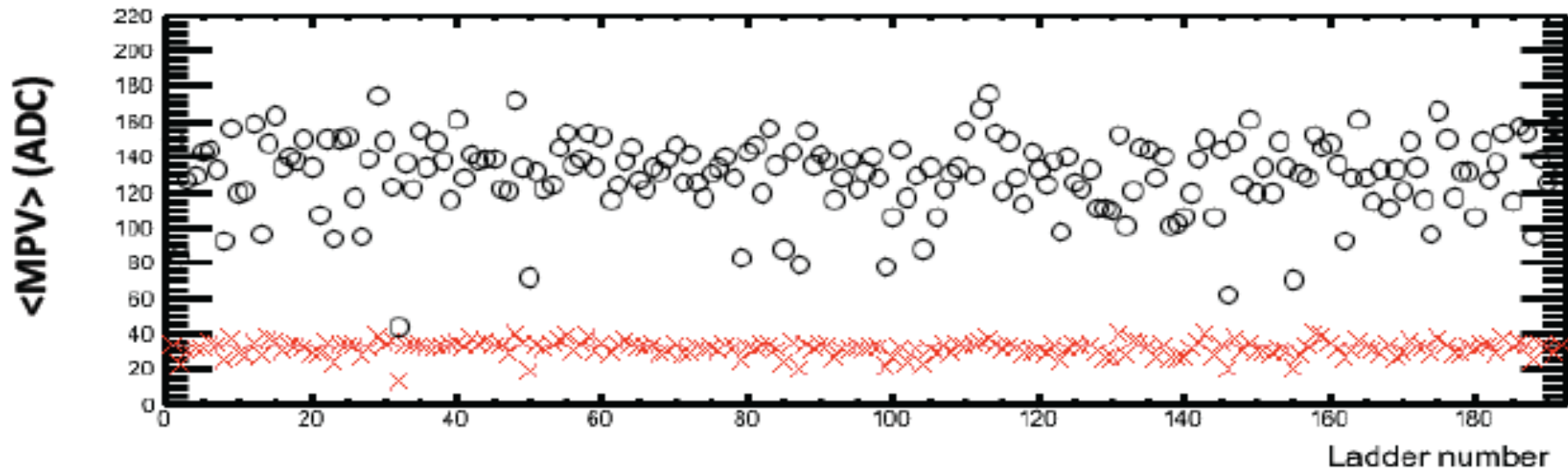
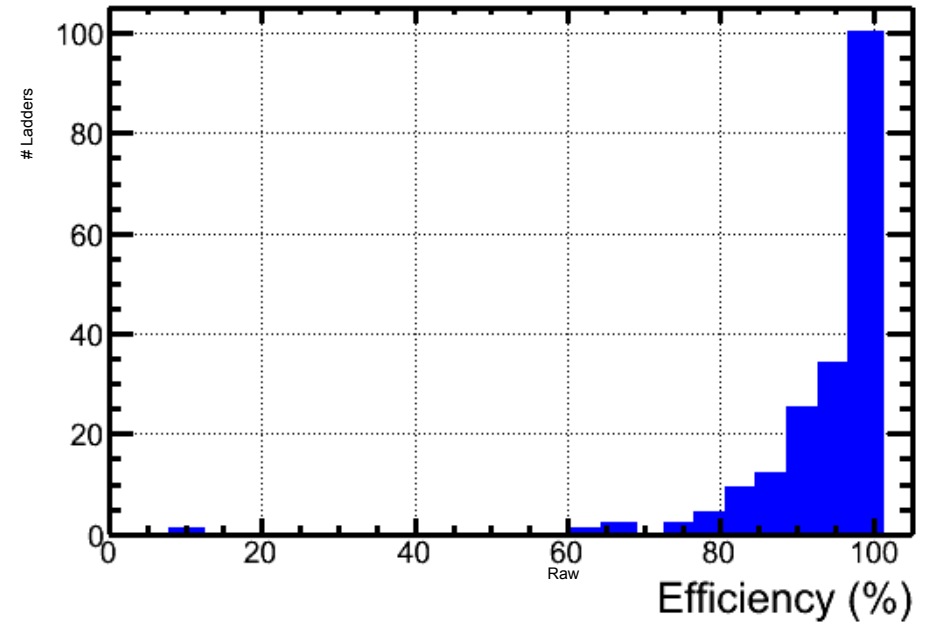
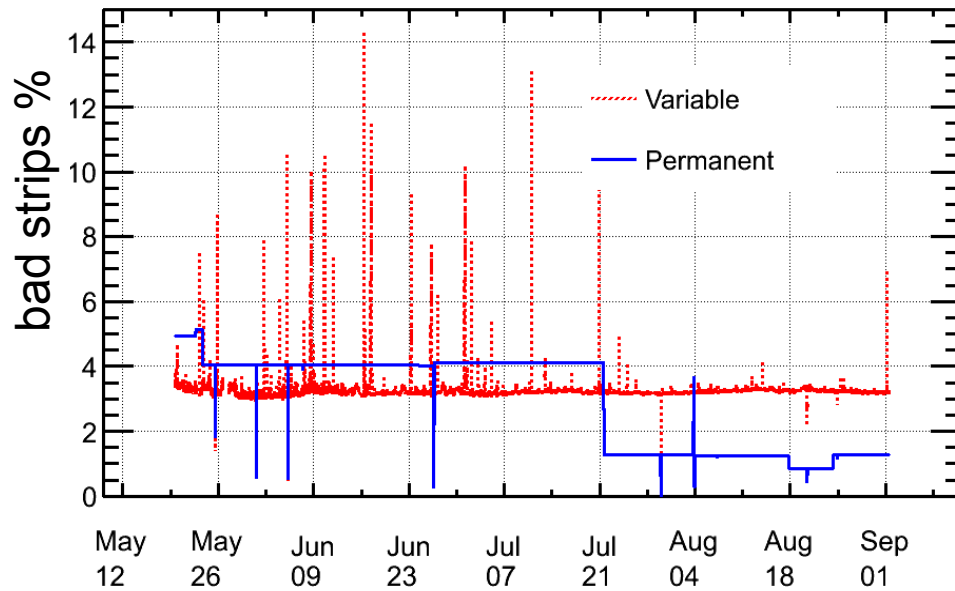
Particle rates vary from  
200 to 2000 Hz per orbit

On average:  
DAQ efficiency 85%  
DAQ rate ~700Hz



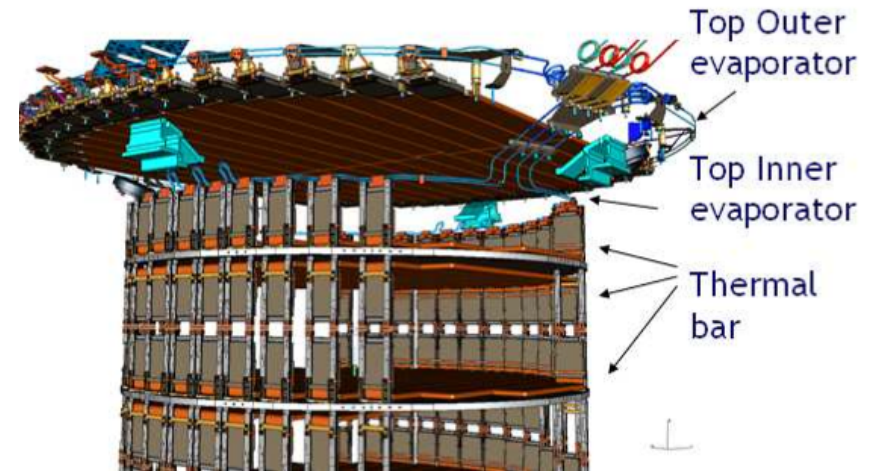
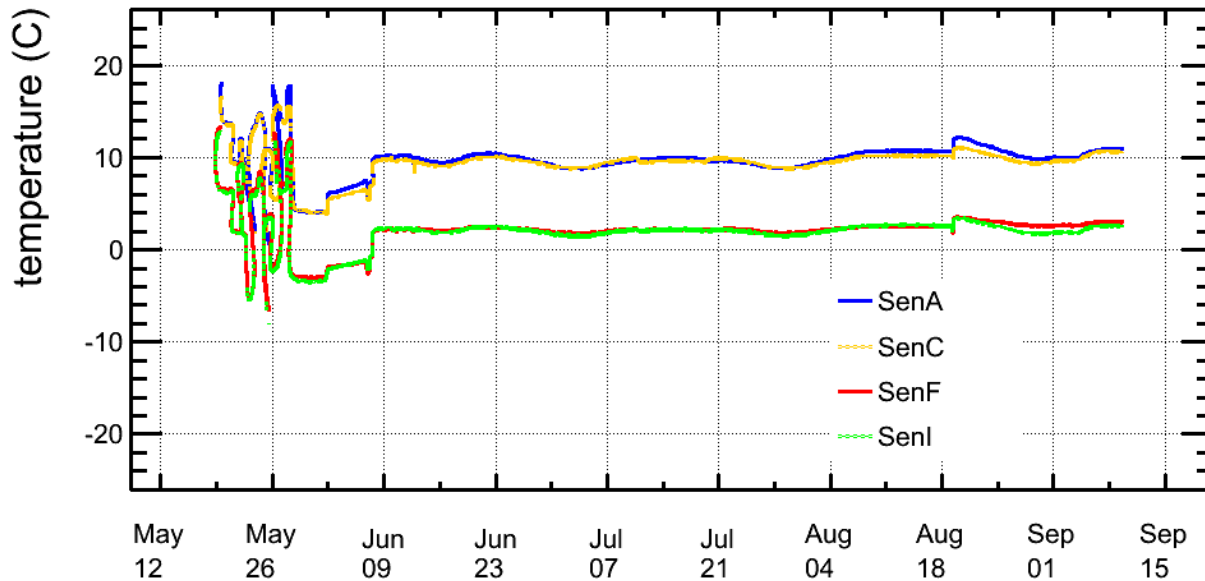
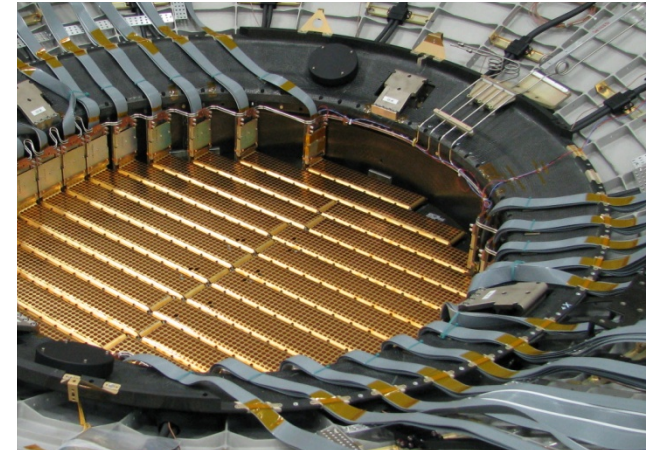
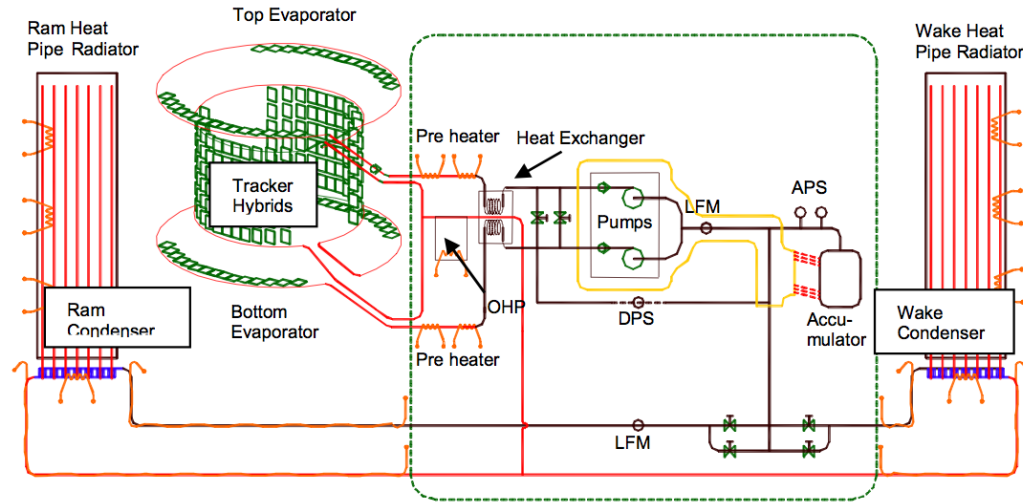


# AMS-02: Tracker in flight experience



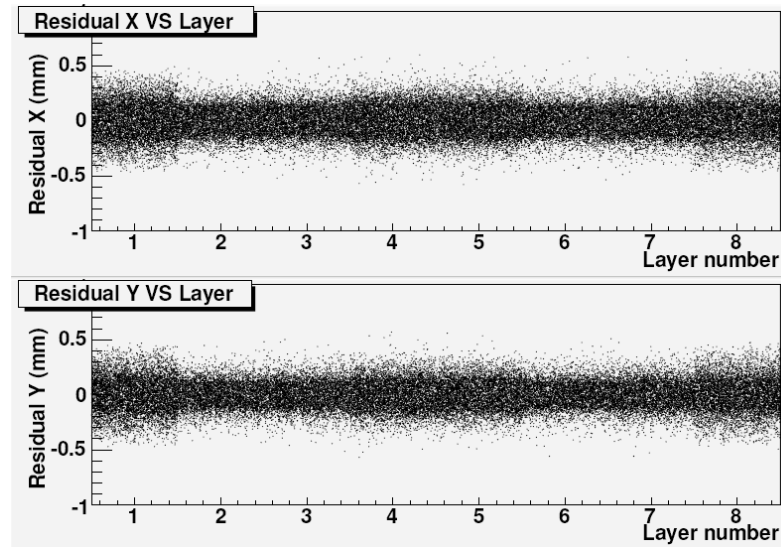
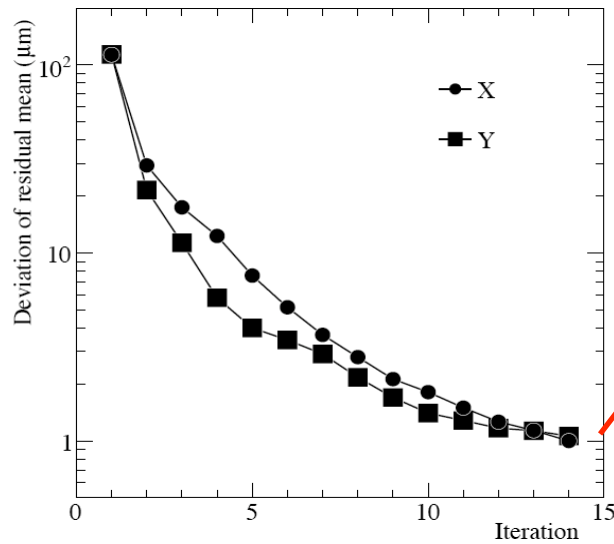


# Tracker cooling: 2 phases CO2 pumped loop

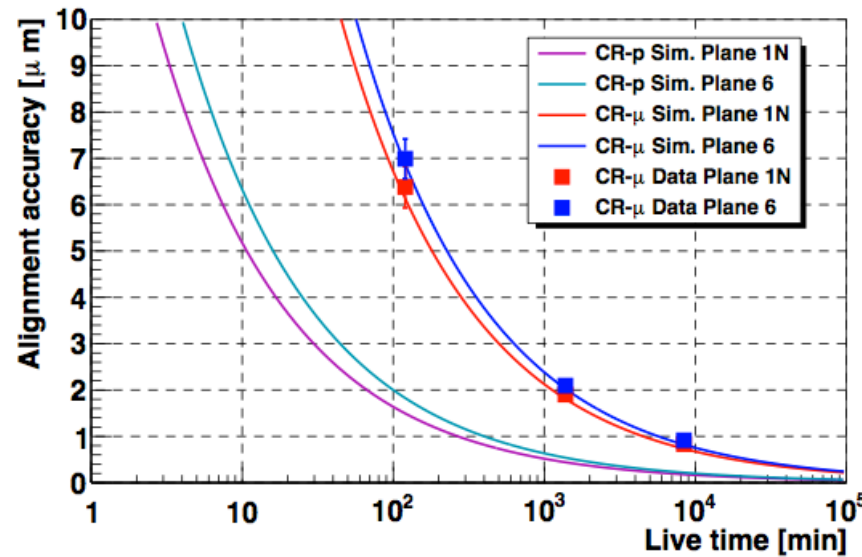
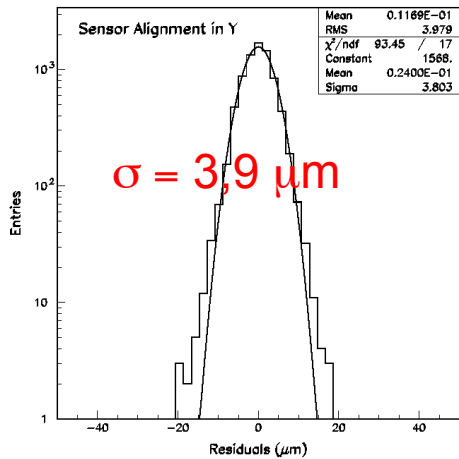




# experience to come: alignment



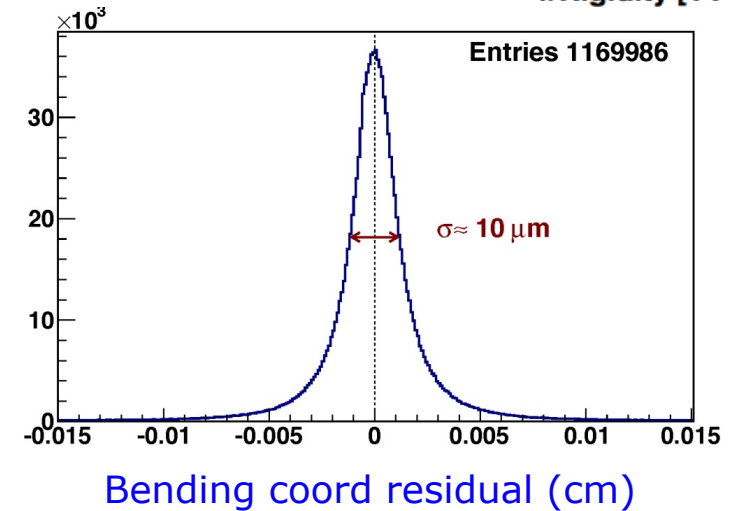
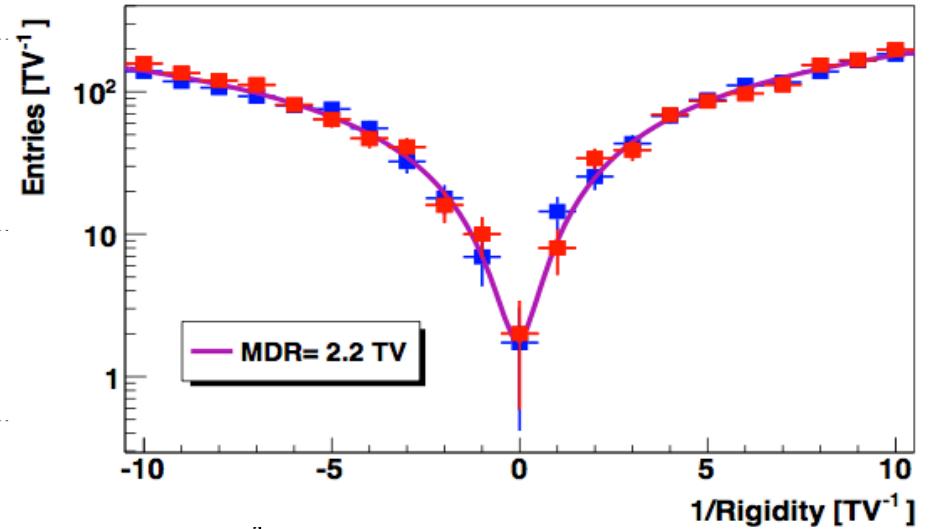
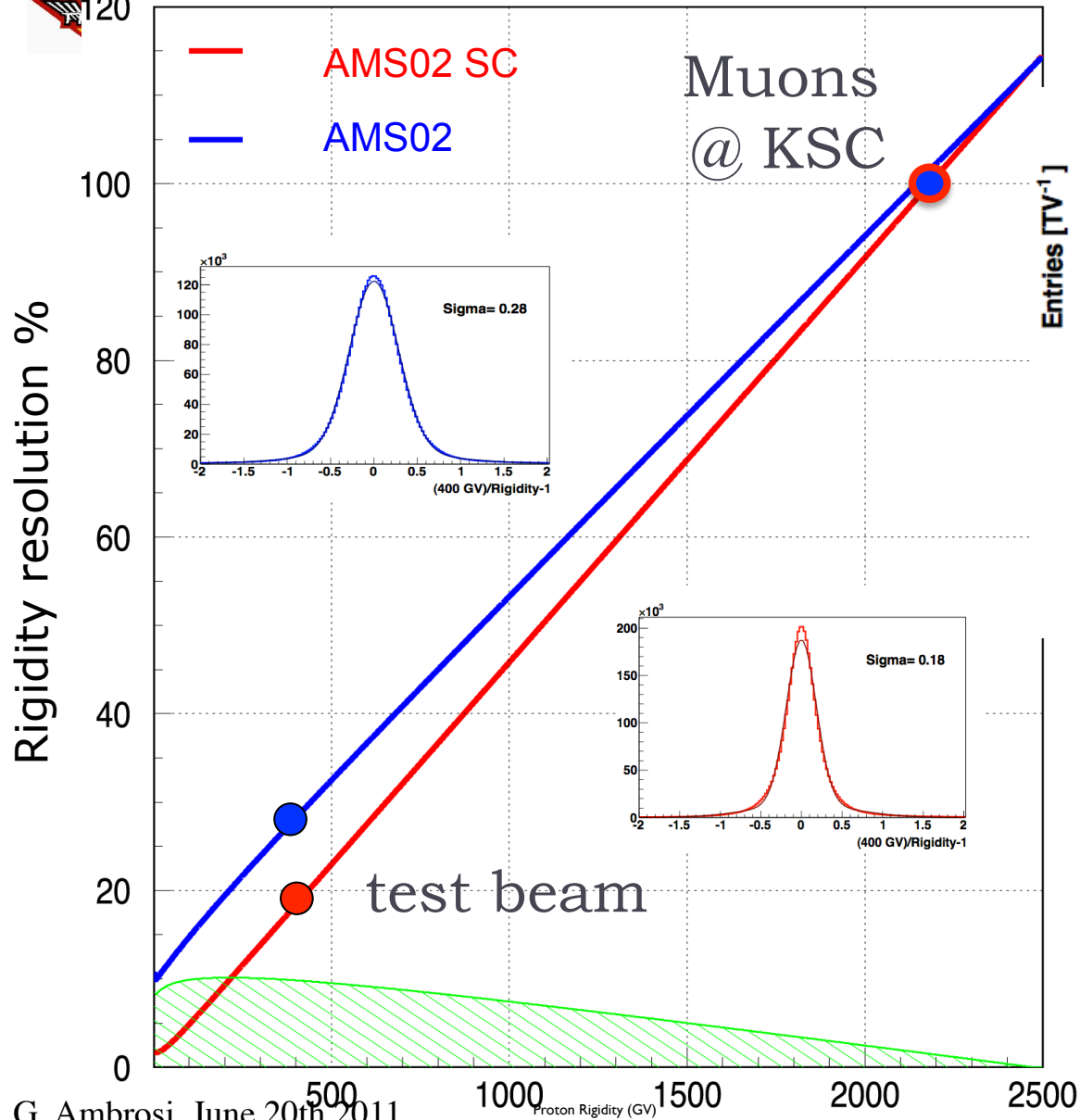
on ground results  
inner planes



external planes  
expected results



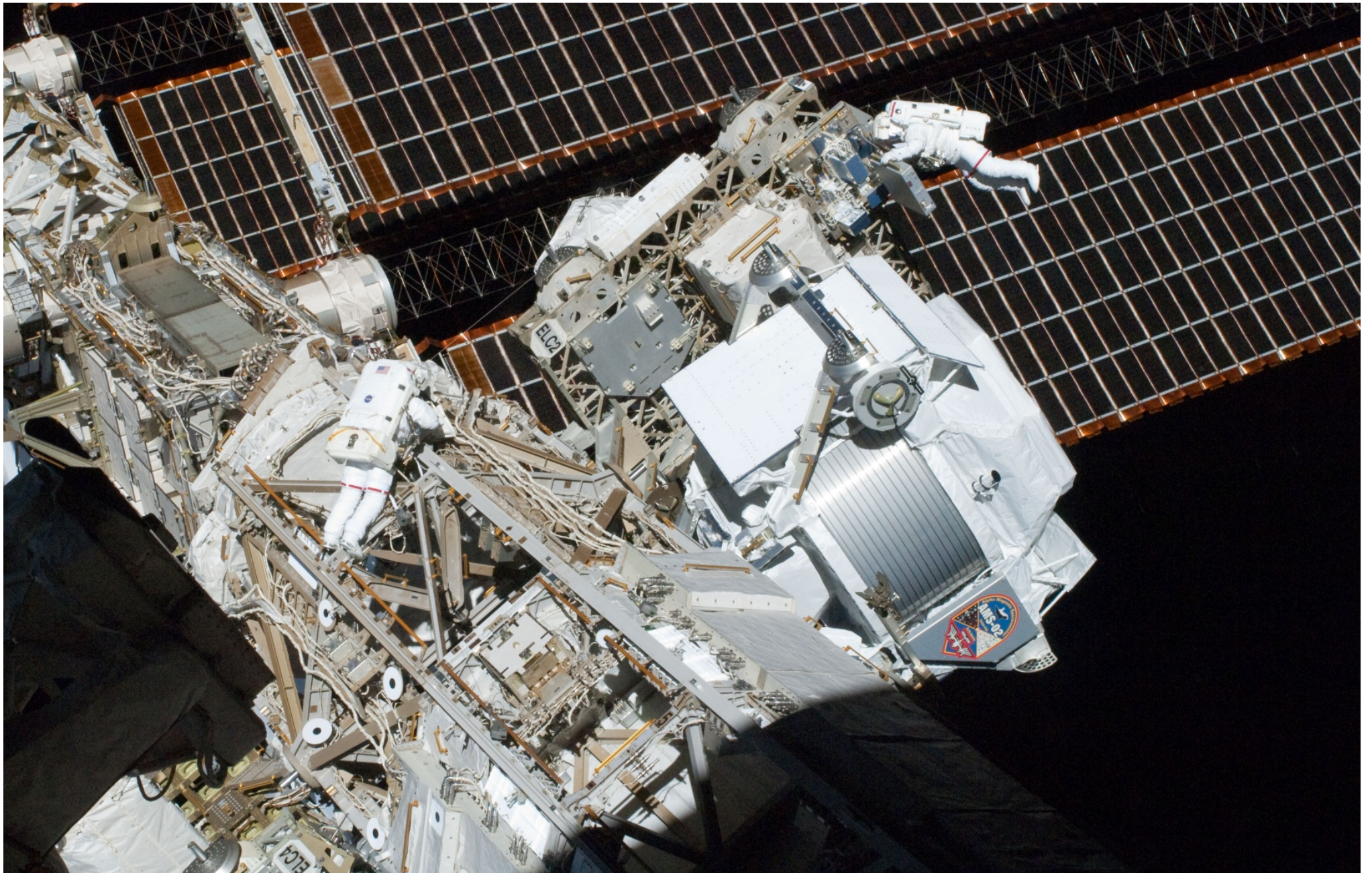
# the performance we do expect





# Conclusions

- AMS02 is in orbit since May 16<sup>th</sup> 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 19<sup>th</sup> 2011
- Tracker behavior is as expected in term of signal and noise levels
- 10+ years on board the ISS: great discovery potential, lot of work ongoing (alignment!)



**Science will come soon!**



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