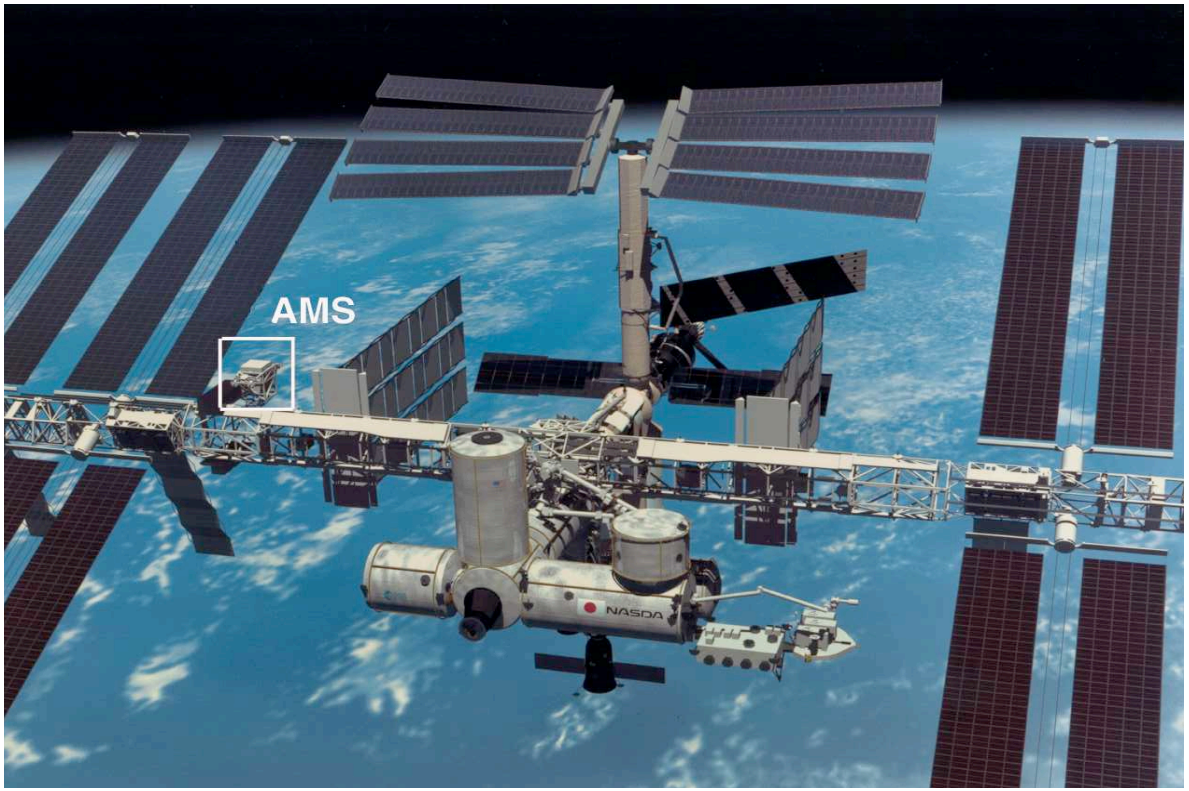
The AMS02 Silicon Tracker: status and performance

G. Ambrosi

Firenze, October 2nd 2009

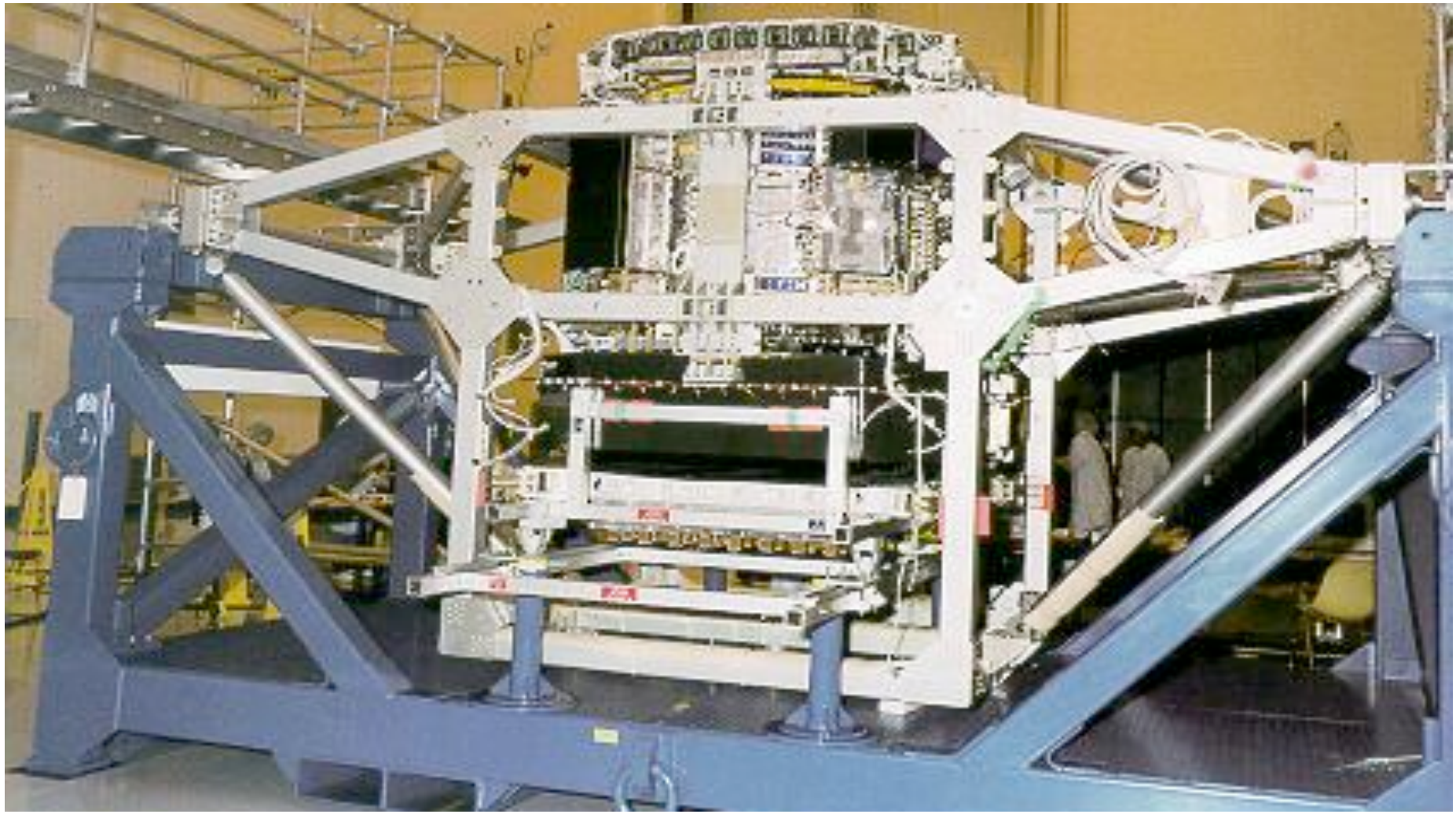
AMS on the International Space Station

- 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 purpose of the AMS experiment is to perform accurate, high statistics, long measurements of charged cosmic rays (0.5 GV - 1 TV) and γ rays (E>1GeV)

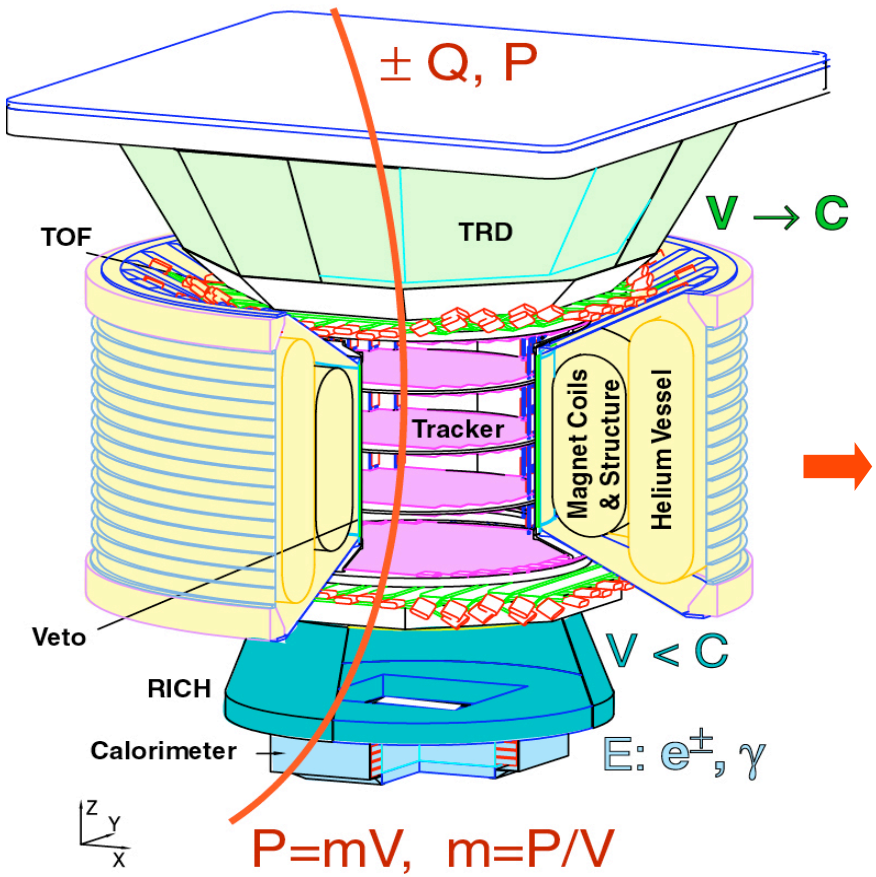
AMS01 at KSC (Florida) in 1998



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

The AMS-02 detector

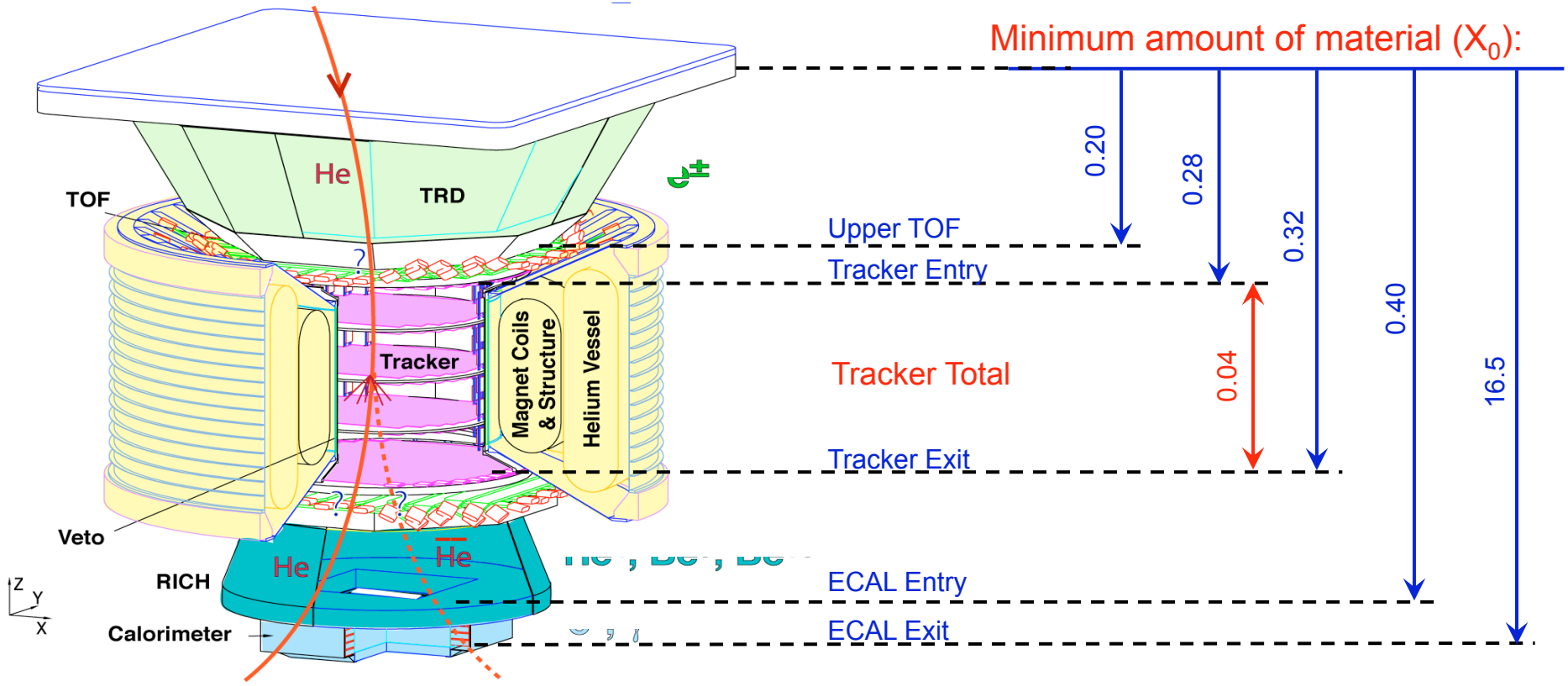


Acceptance ~ 0.5 m^2 sr
B field ~ 0.7 T

- TRD: e/h separation up tp 300 GeV
- TOF: β, dE/dx, direction
- Tracker: rigidity (p/Ze), Z
- RICH: β, dE/dx
- ECAL: e/h separation, E

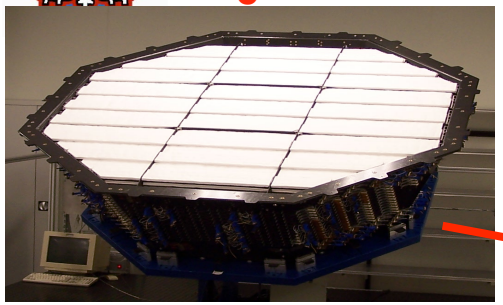
- Orbital parameters
  - ~92 minutes period
  - ~400 Km altitude
  - 51.6° inclination

transparent detector

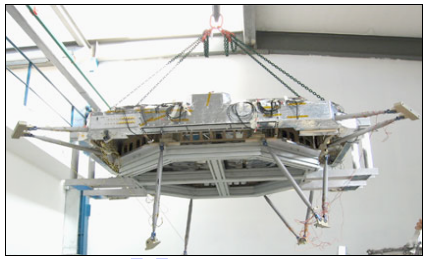


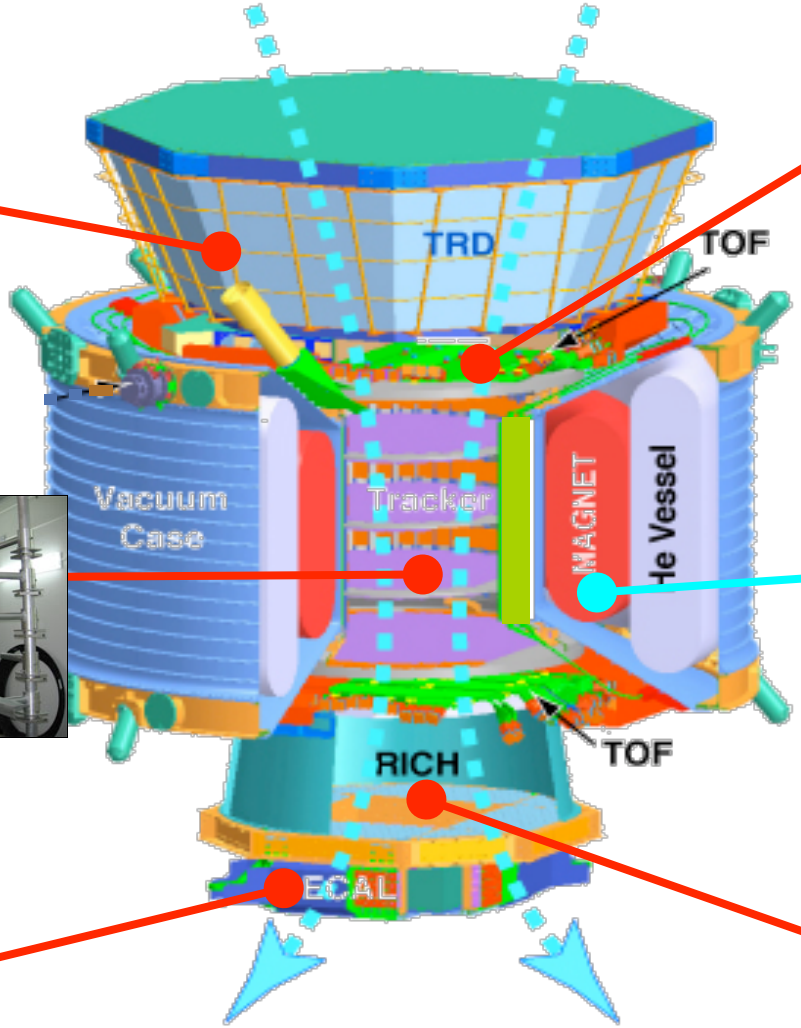
construction complete

TRD
e

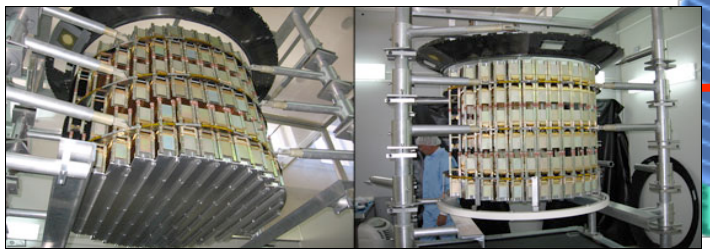


Time of Flight
v, Z

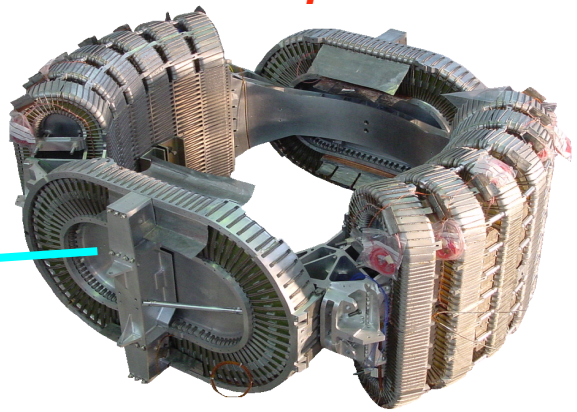




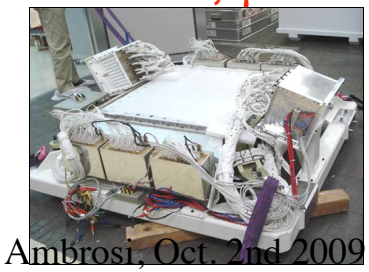
Silicon Tracker
Z, P



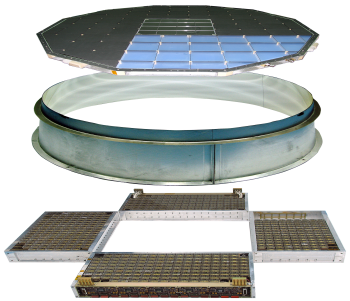
Magnet
P



Calorimeter
e, γ



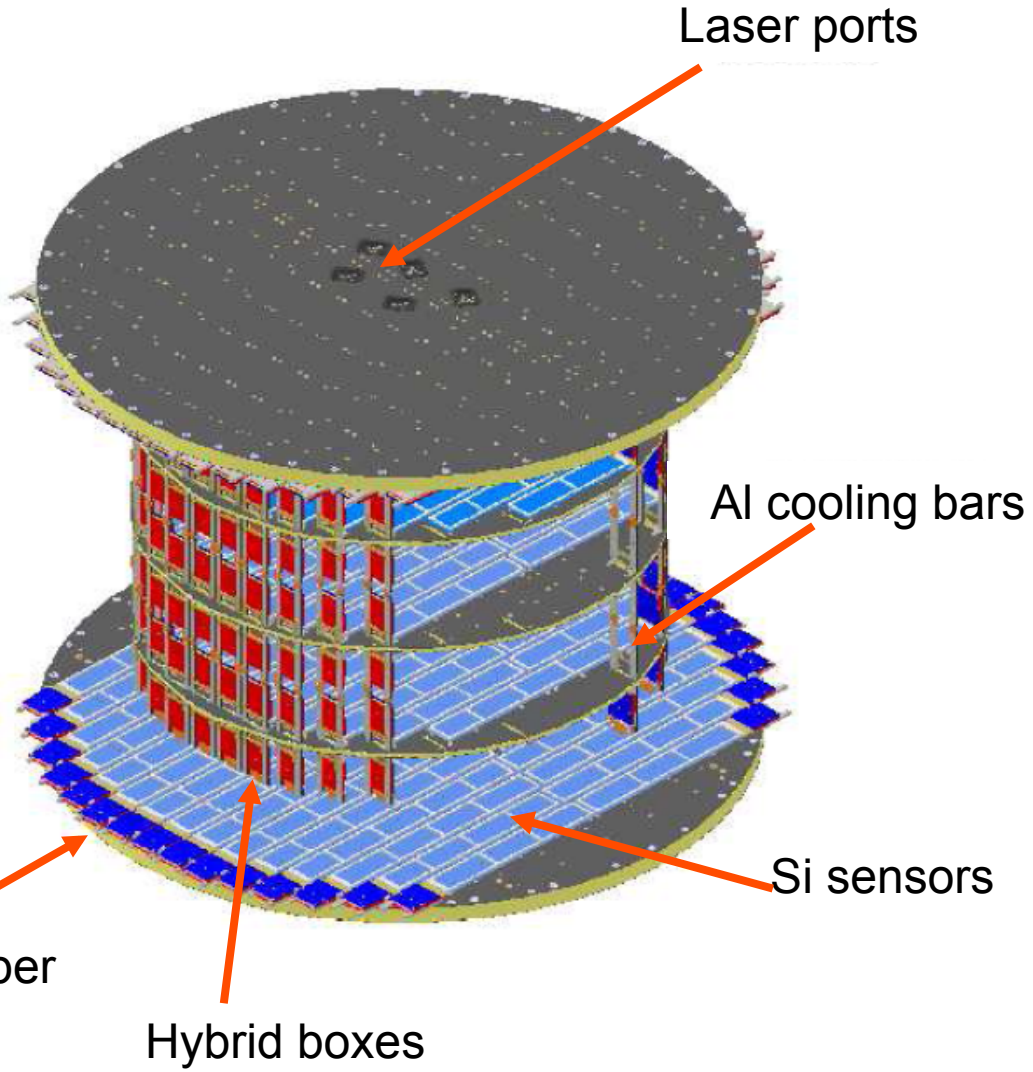
RICH
v, Z



Size: 3m x 3m x 3m
Weight: 7 tons

Silicon Tracker

- 8 layers of double sided silicon detectors arranged in 192 ladders
- 5 honeycomb carbon fiber plane
- detector material ~ 0.04 Xo
- total of 200 kchannels for 192 watt dissipated inside the magnet volume
- 10 μm (30 μm) spatial resolution in bending (non bending) plane
- momentum resol 1.5% at 10 GeV
- high dynamic range front end for charge measurement
- wide temperature range (-20/+40 survival, -10/+25 oper.)



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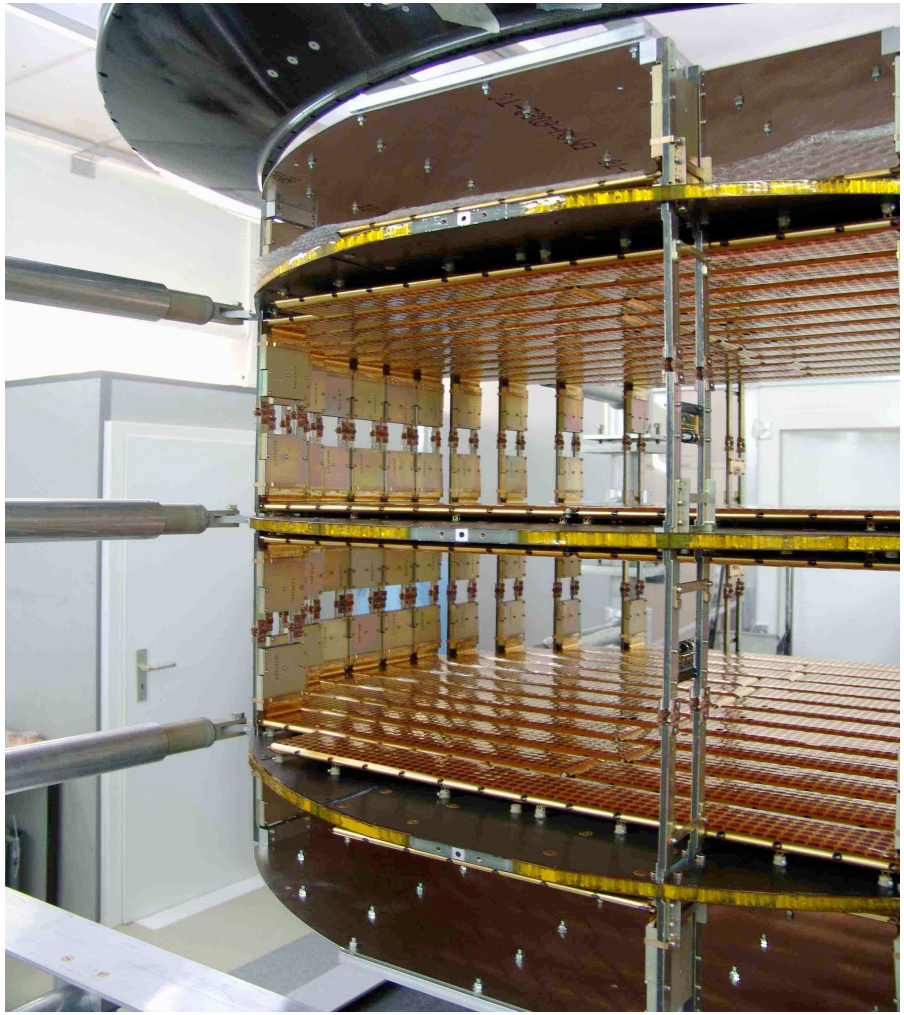

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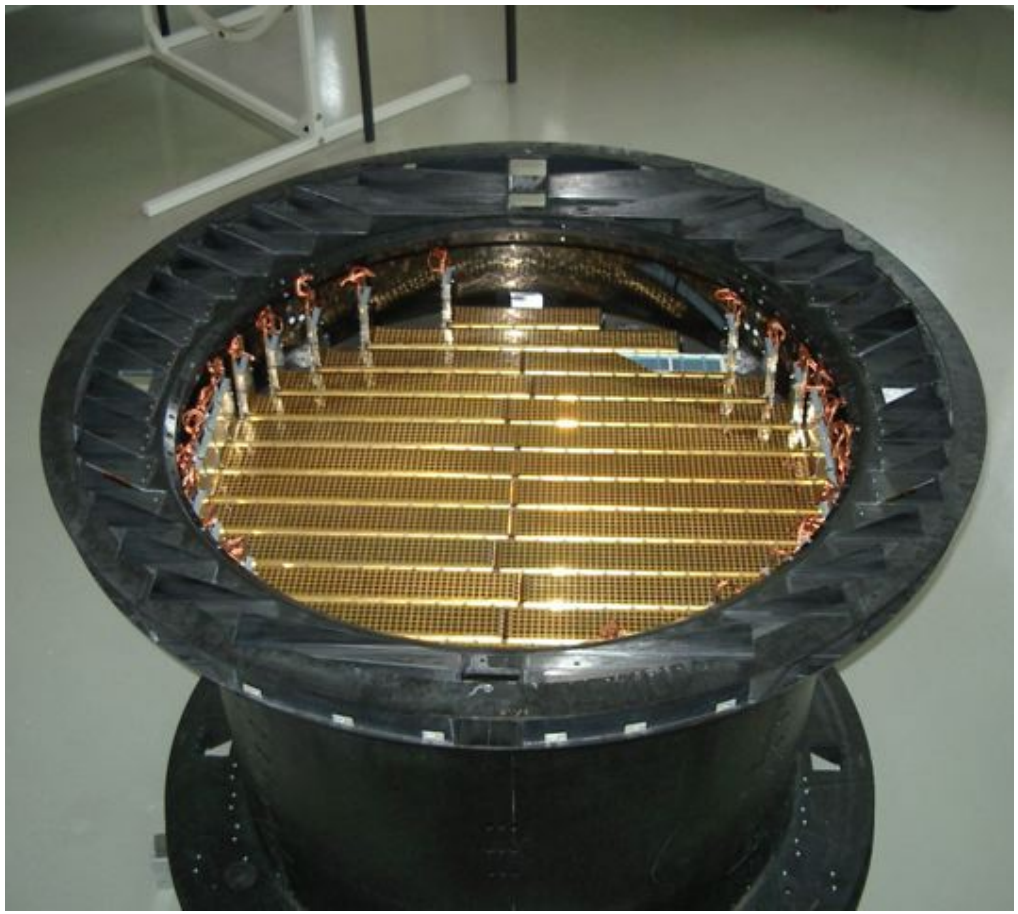
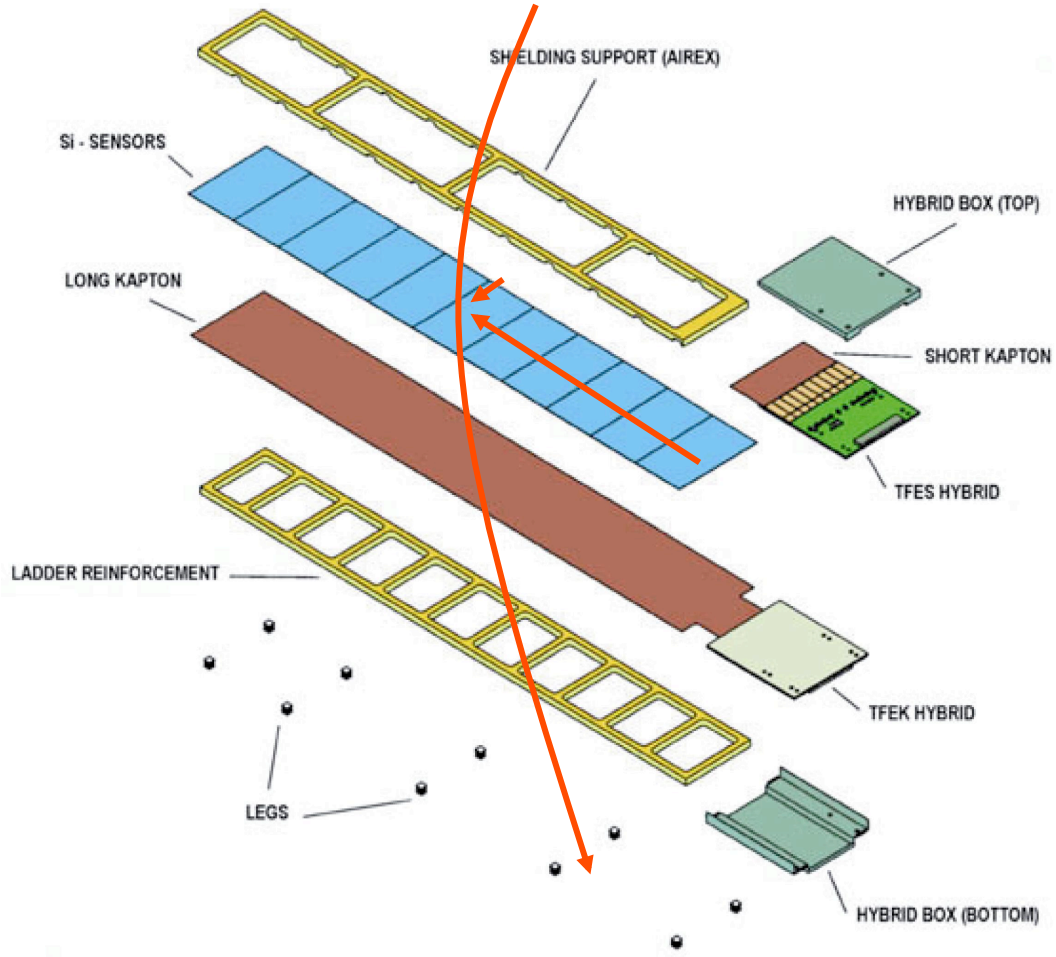


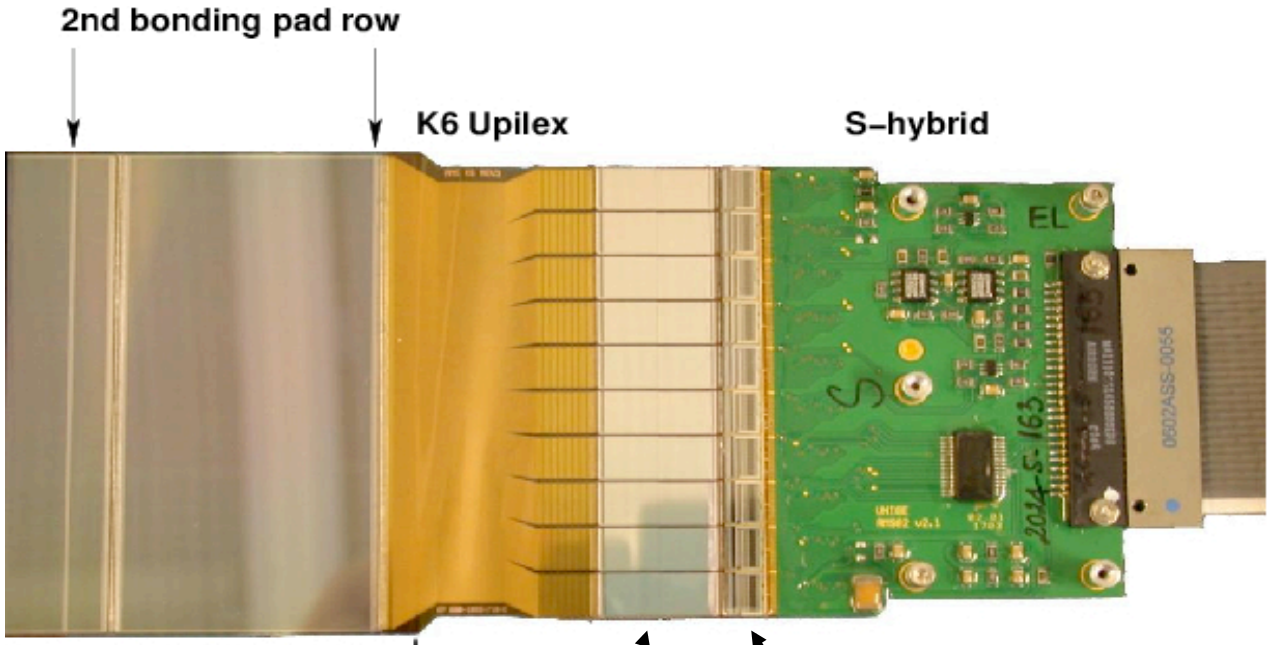
AMS silicon ladders



- 1024 high dynamic range, AC coupled readout channels:
  - 640 on junction (S) side
  - 384 on ohmic (K) side
- Impl/readout pitch:
  - 27.5/110 μm (S side)
  - 104/208 μm (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)

Ladder components (p side)

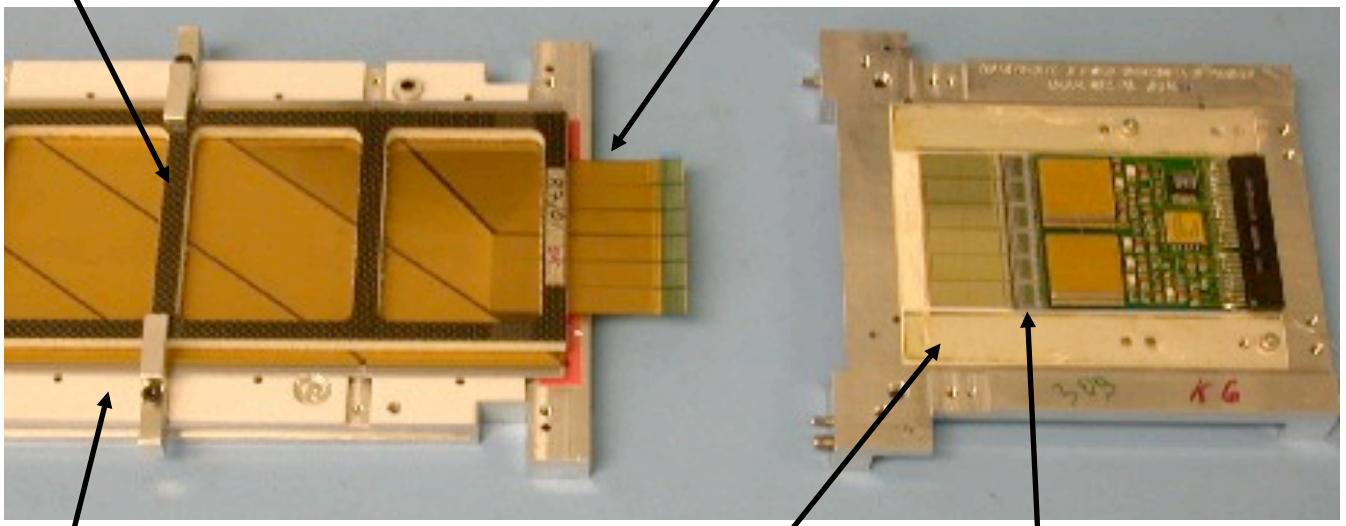


double sided, DC coupled
300 μm thickness
7 - 15 sensors in a ladder
produced at:
- Colybris (CH)
- IRST (IT)

700 pF coupling capa

10 VA_hdr64a (IDEas, NO)
640 channels, 0.7 mW power each
CR-RC shaper and S&H
4 μs shaping time
100 MIP dynamic range

Ladder components (n side)

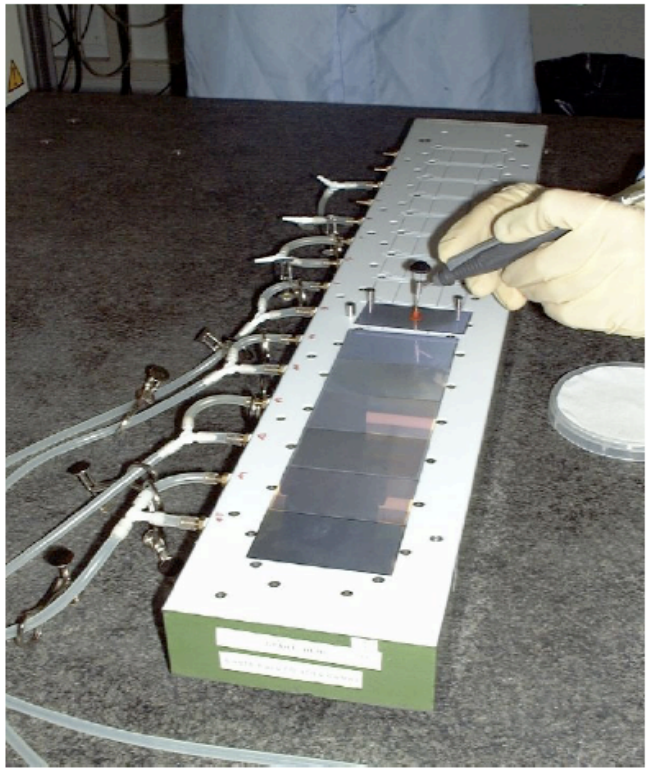


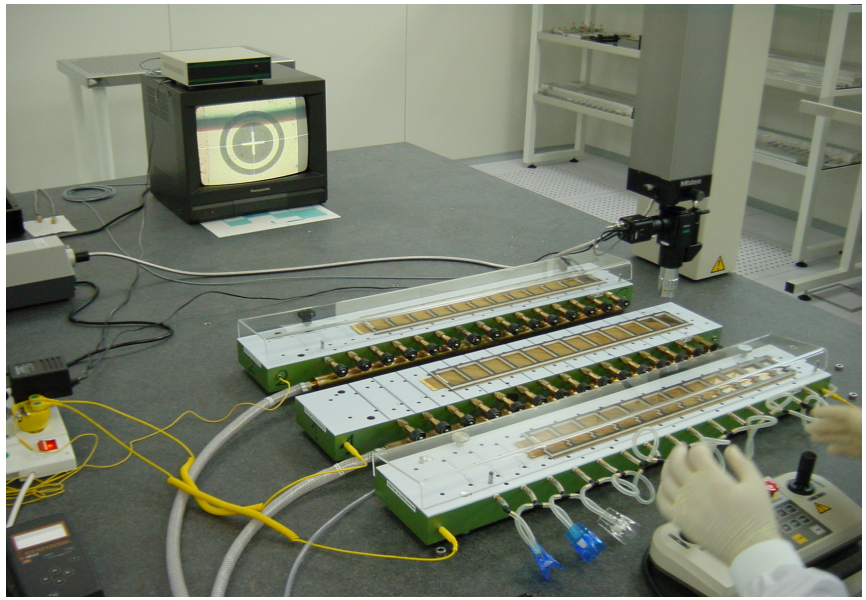
double sided, DC coupled
300 μm thickness
7 - 15 sensors in a ladder
produced at:
- Colybris (CH)
- IRST (IT)

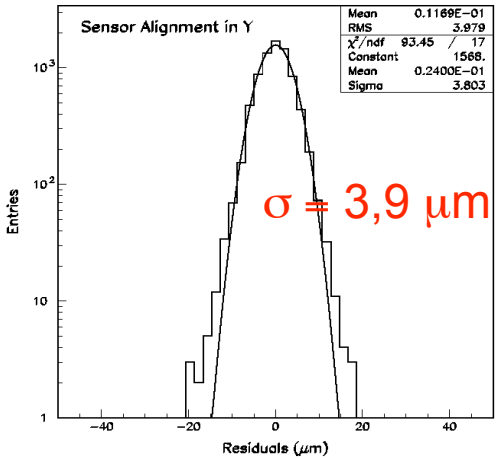
700 pF coupling capa

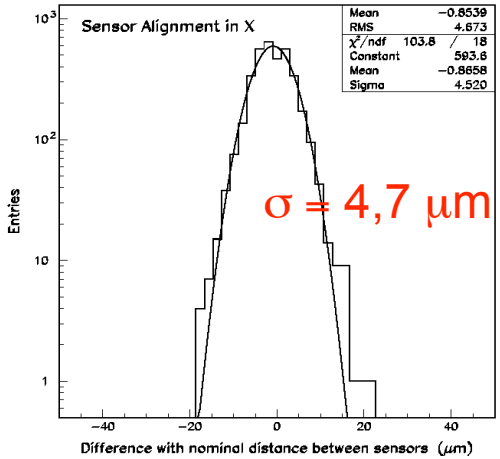
6 VA_hdr64a (IDEas, NO)
384 channels, 0.7 mW power each
CR-RC shaper and S&H
4 μs shaping time
100 MIP dynamic range

Silicon positioning and metrology



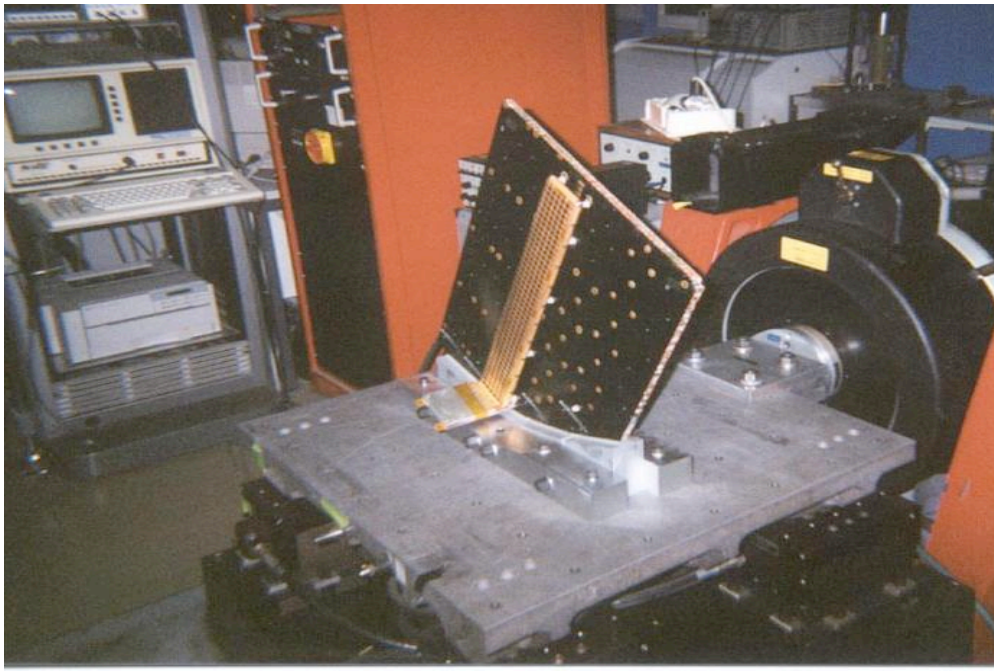






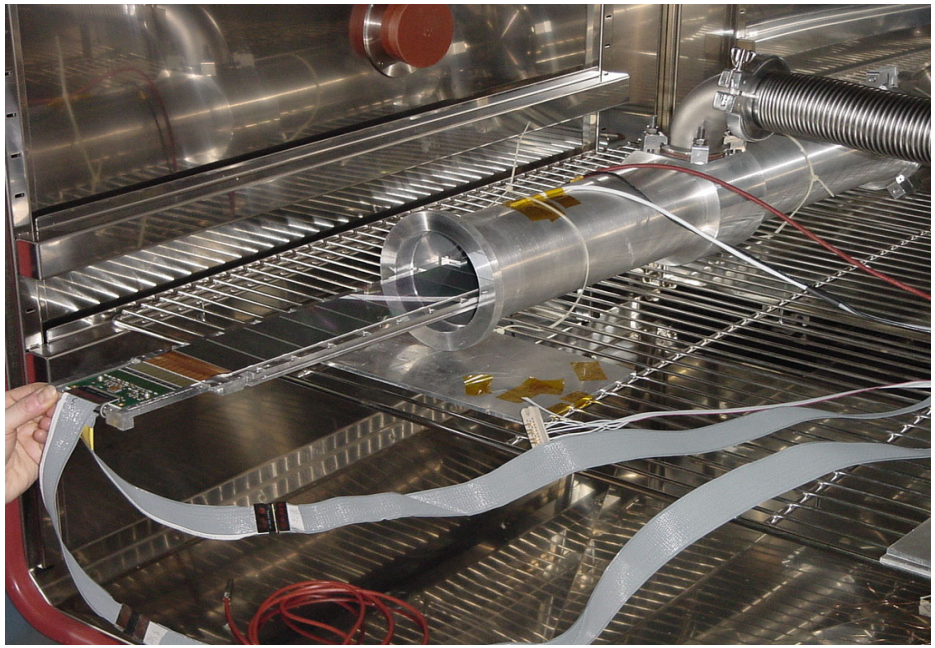
Space qualification tests

ladder on plane



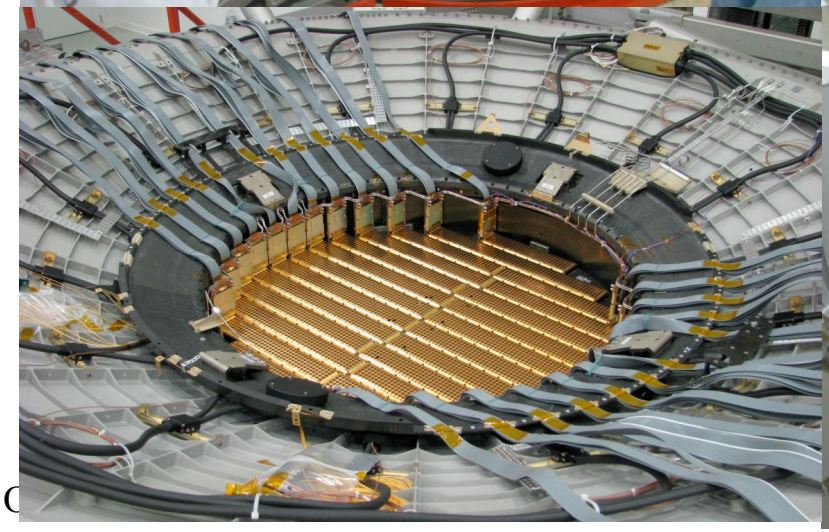
no missing bonds after ladder
and test structure vibration

ladder in vacuum

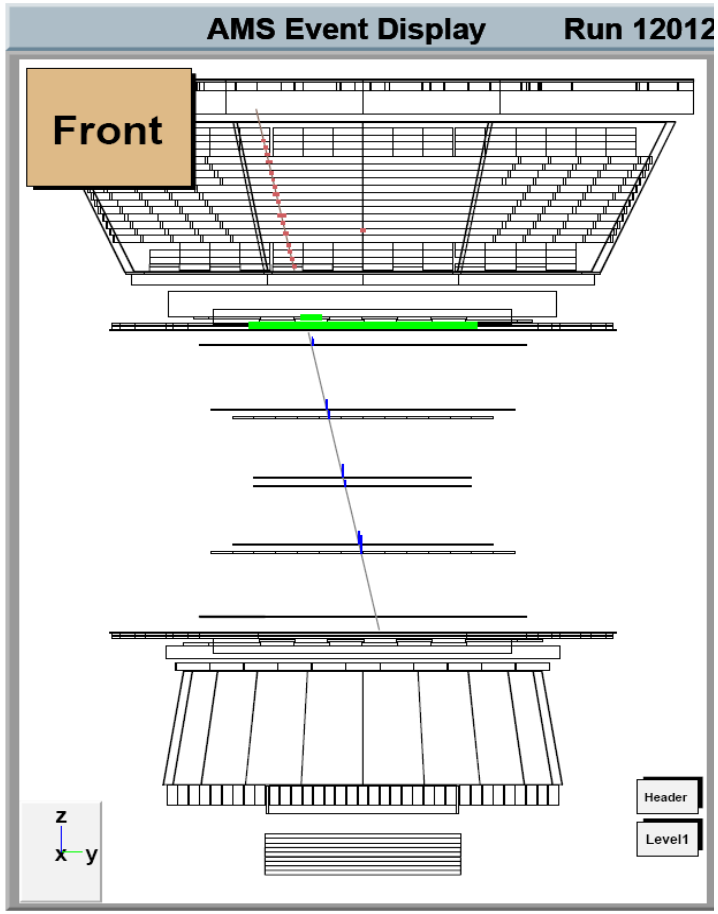


still functioning after -30° +60° C
temperature cycles

Tracker pre-integration (spring 2008)

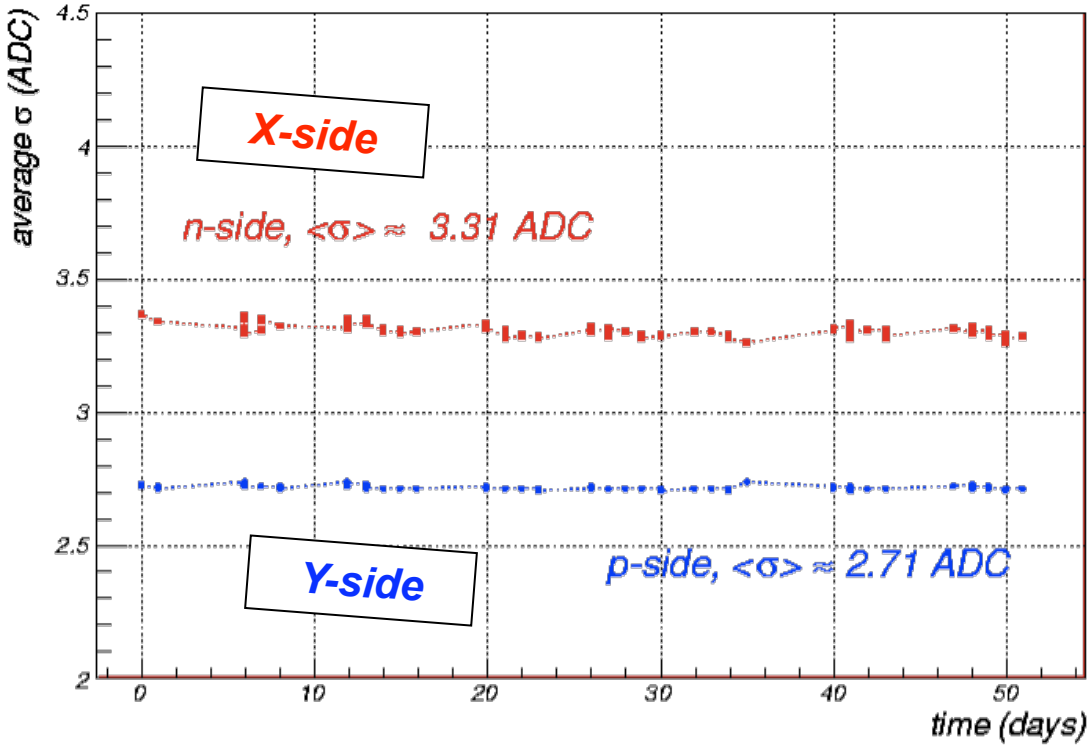


the full AMS-02 detector



no magnetic field

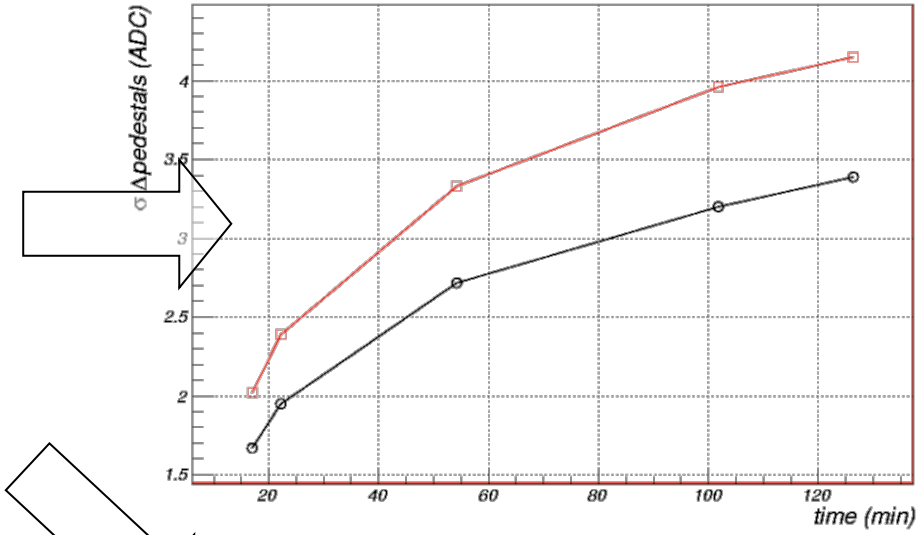
Tracker calibration stability



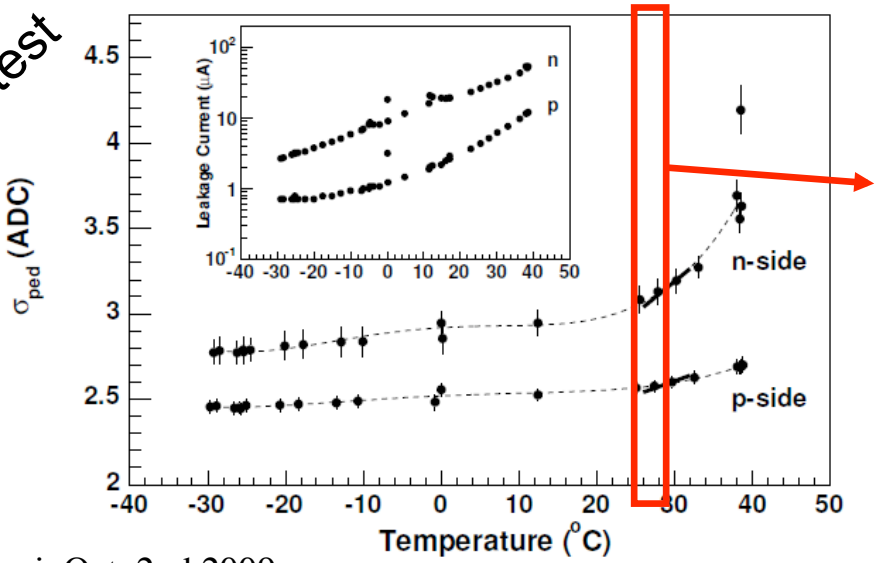
- dead channels fraction = 0.04 (0.26) % for Y (X)
- noisy channel fraction = 2.11 (3.36) % for Y (X)
- mean noise (<σ>) = 2.71 (3.31) for Y (X)
- The 98% of bad channels are bad in the 90% of the calibrations
- The 96.6 % is always good!!!

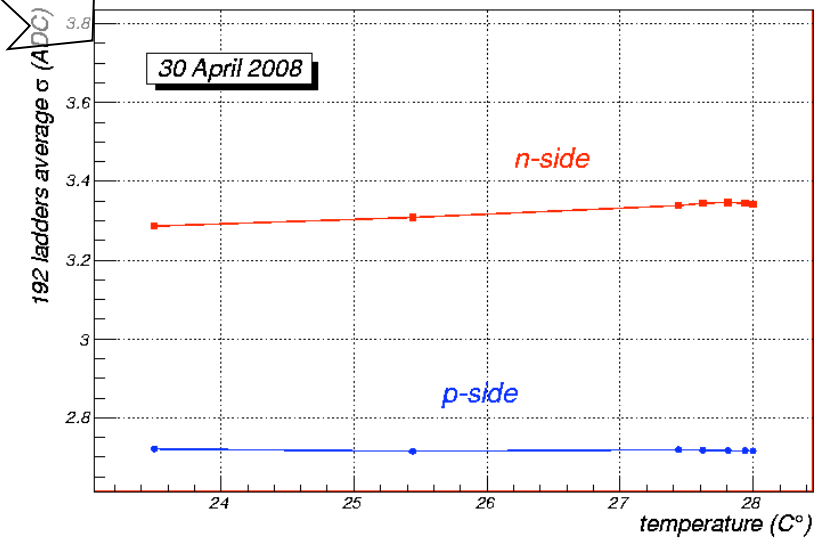
Temperature dependencies

- Pedestals: the drift depend from temperature (electronics)
  → corrected by calibration procedure
- Noise Level: grows with temperature (silicon)
  → a small effect



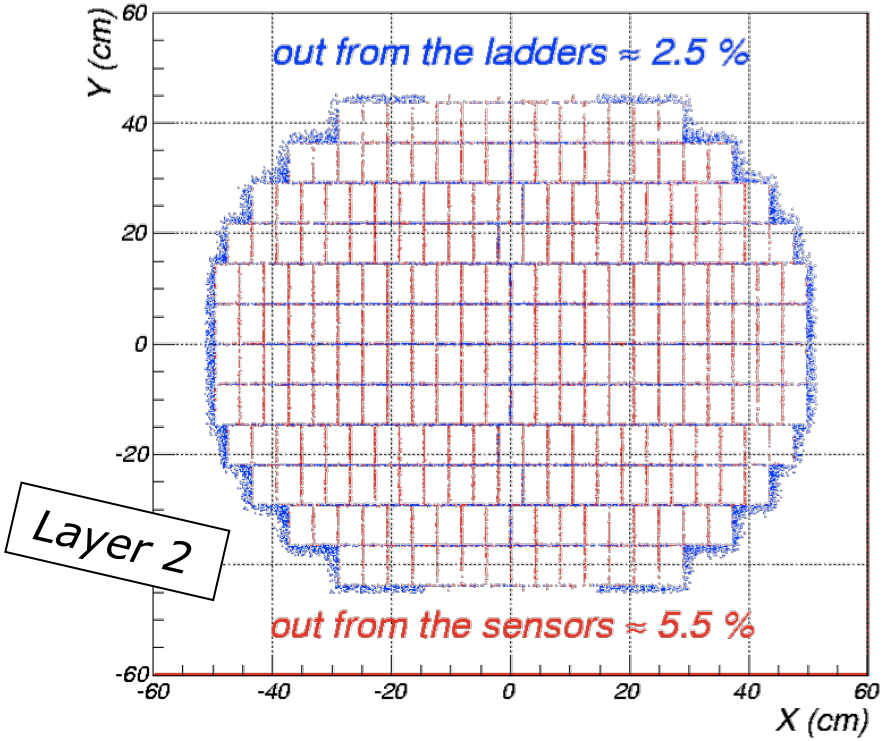
TV test



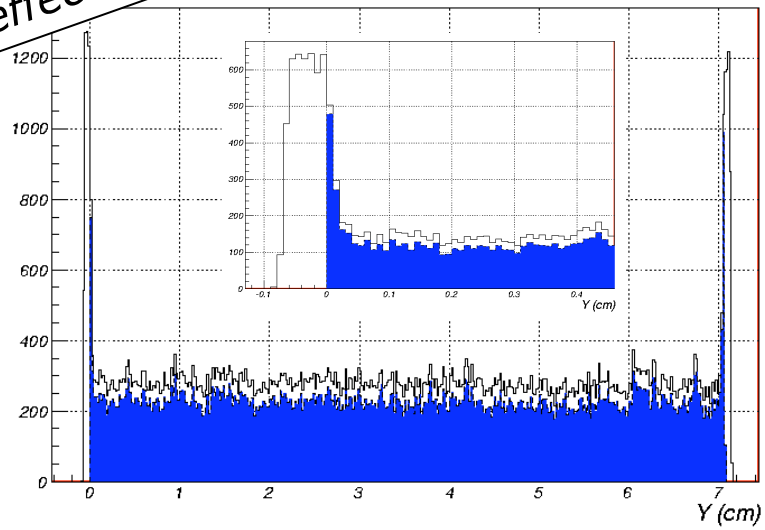


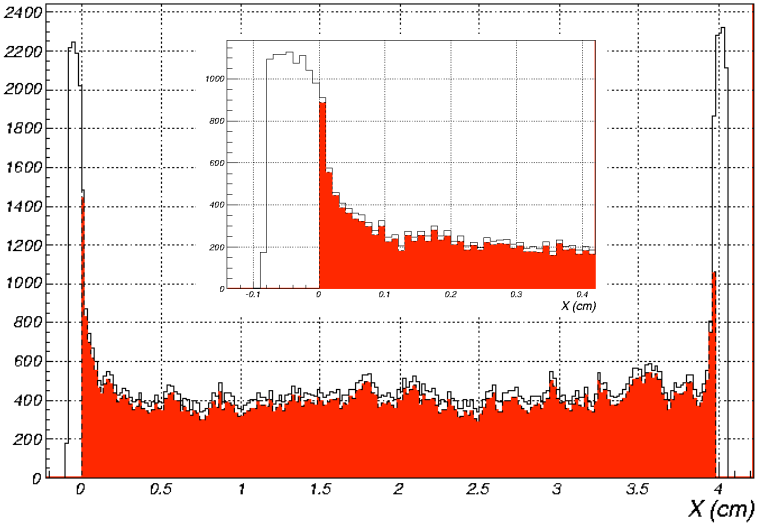
Geometric inefficiencies

edge effects

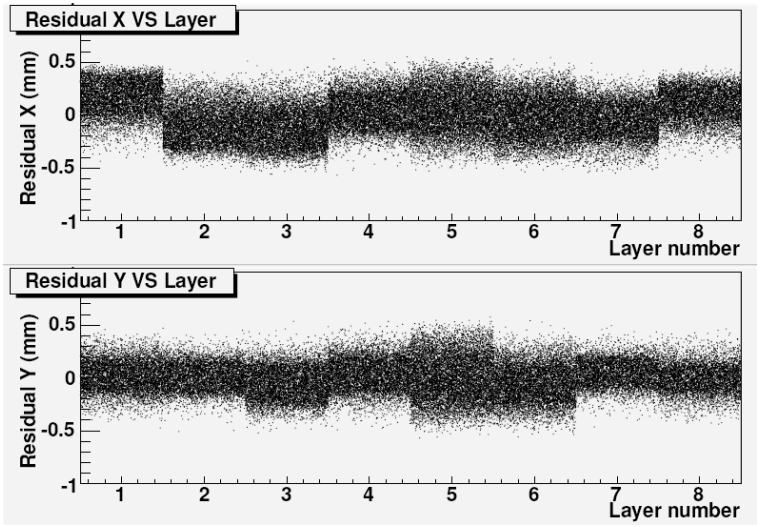


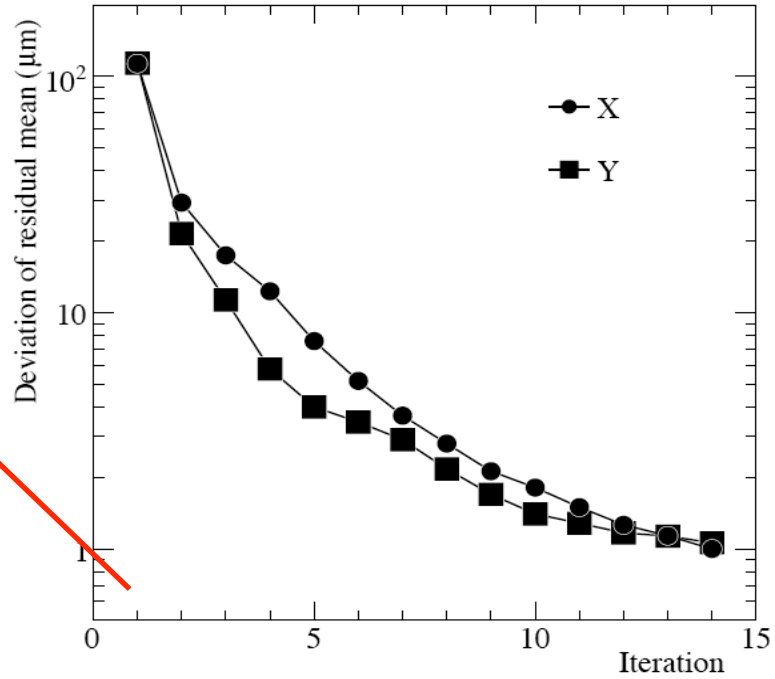
Layer 2

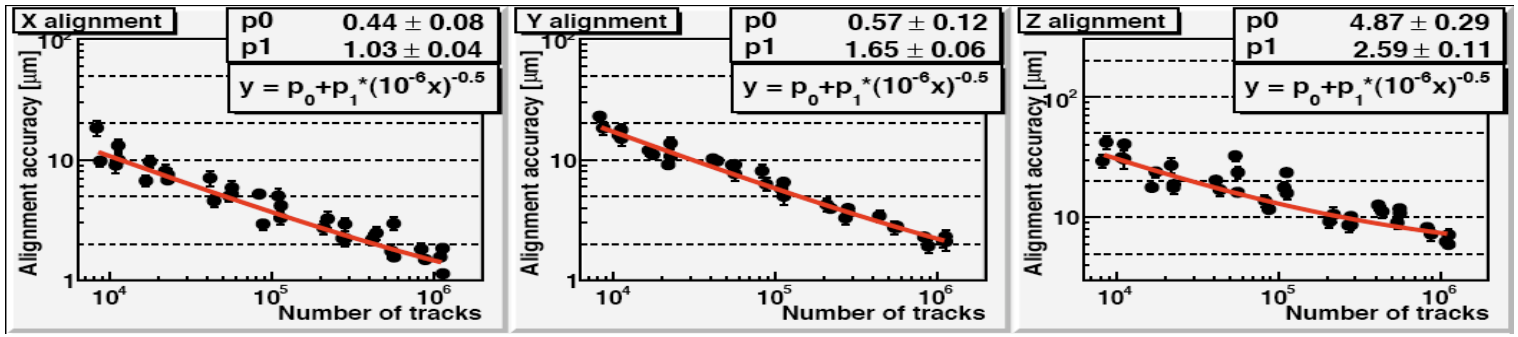




Alignment results







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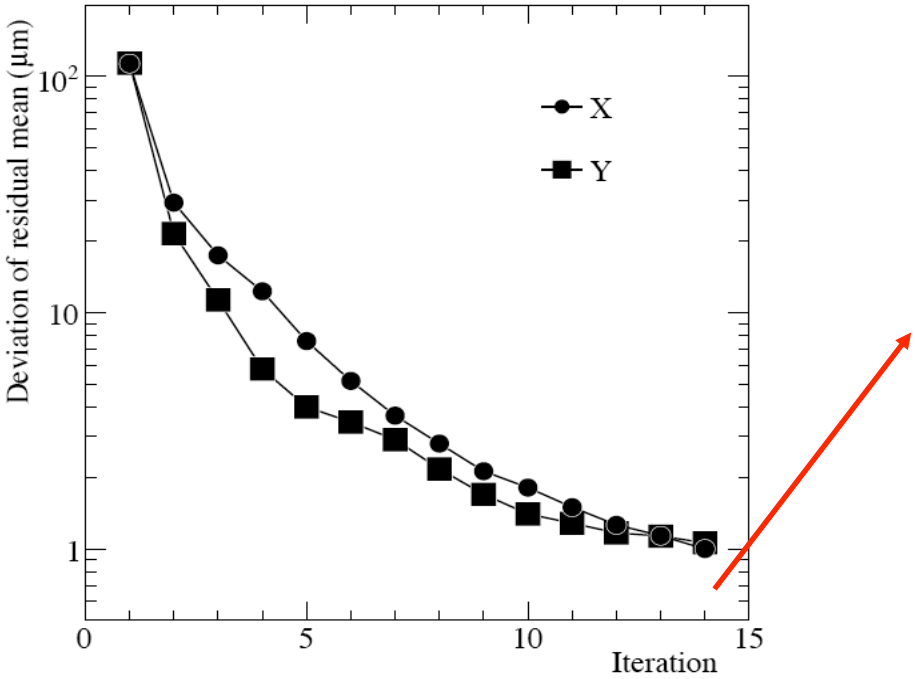
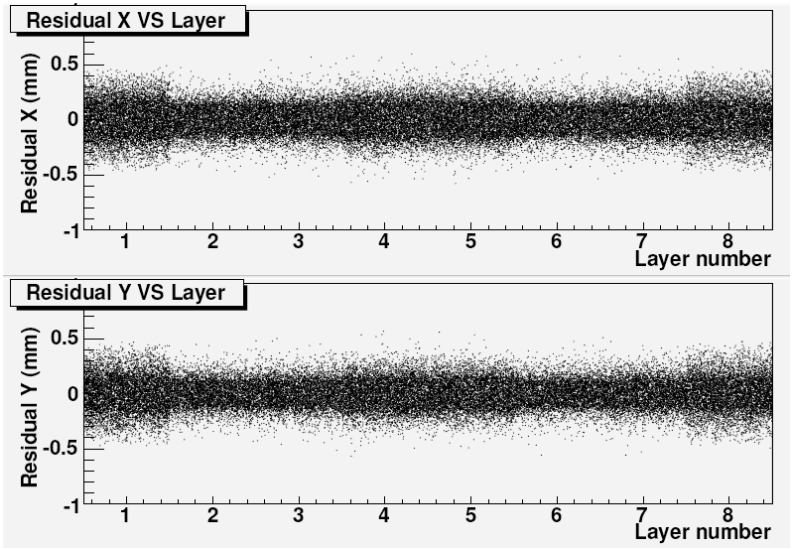
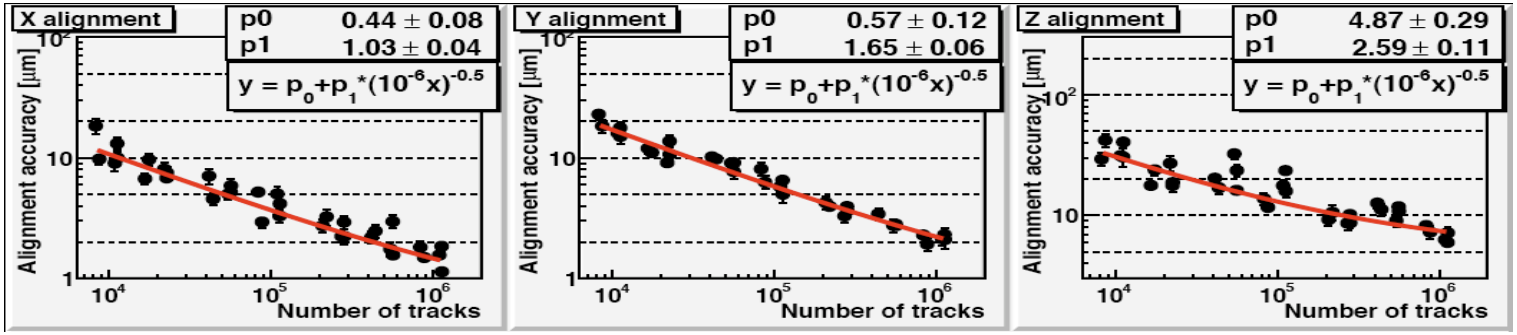
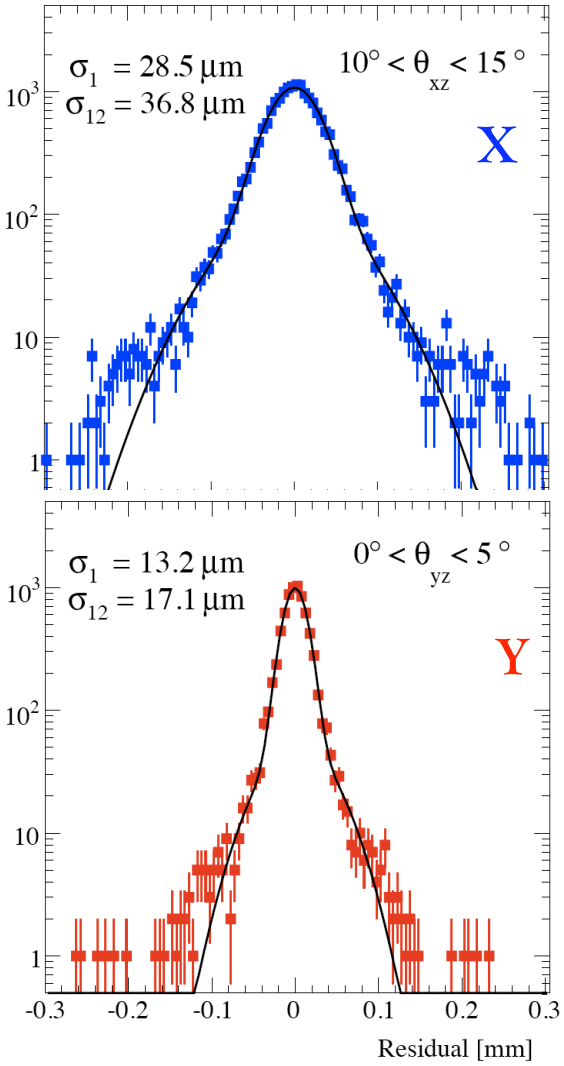


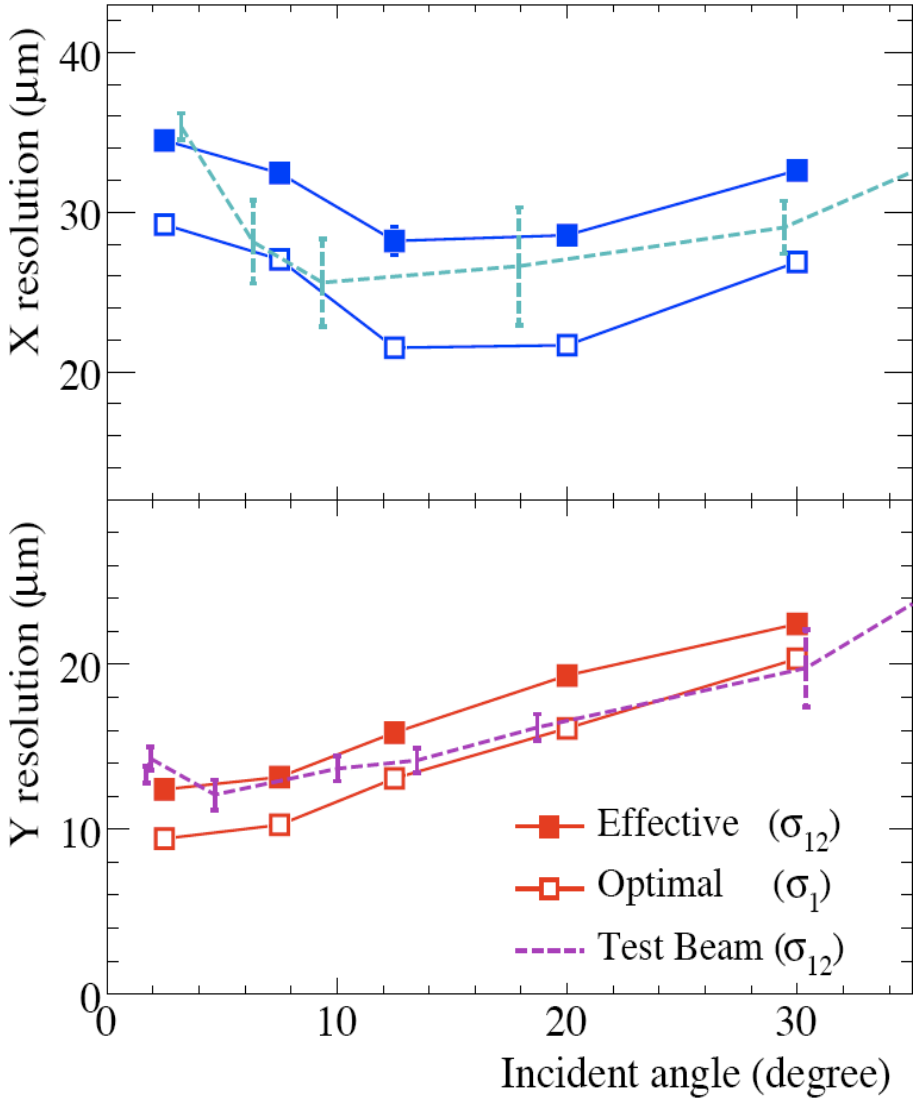




Residual and resolution

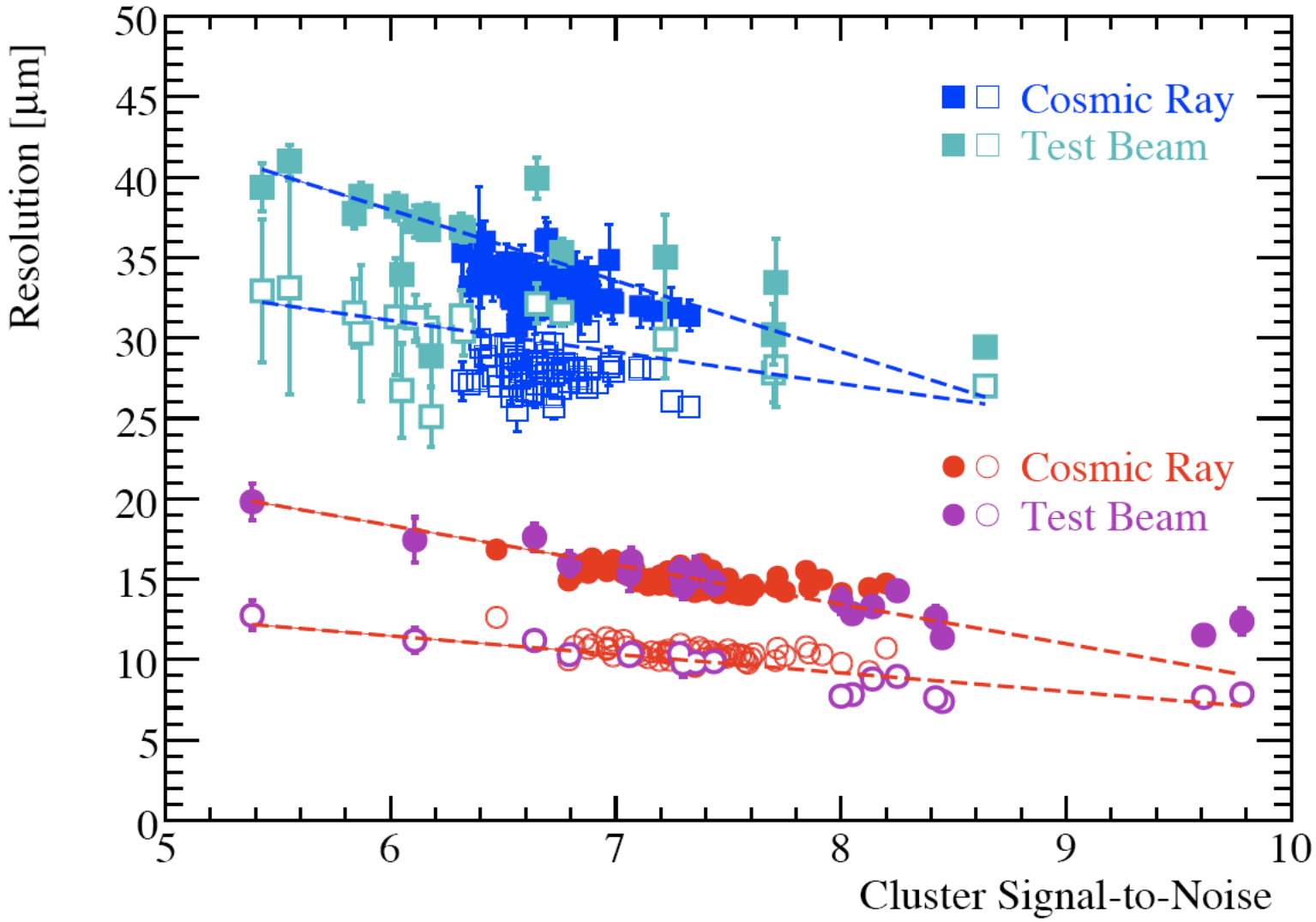
test beam data



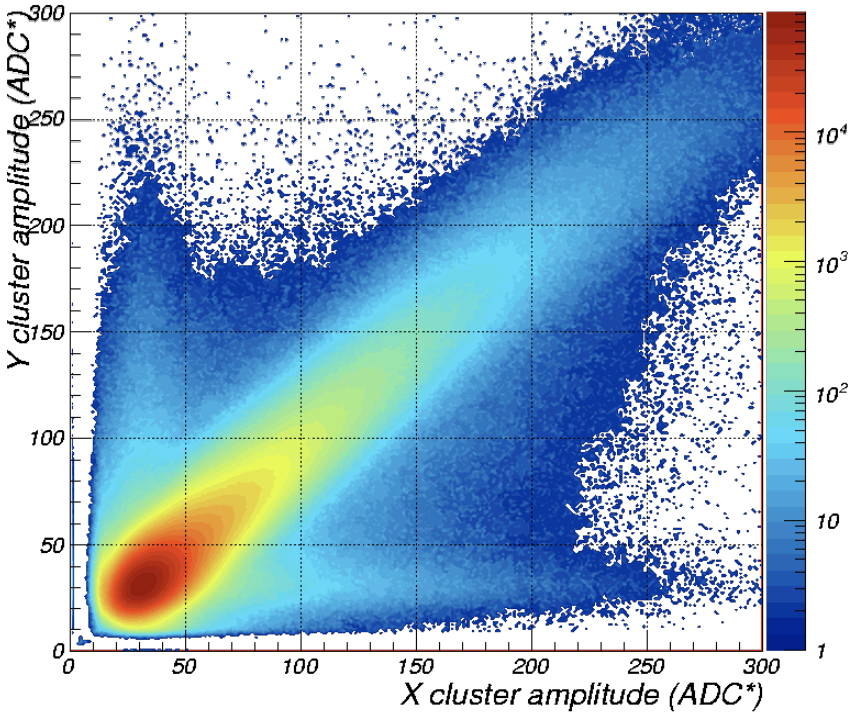


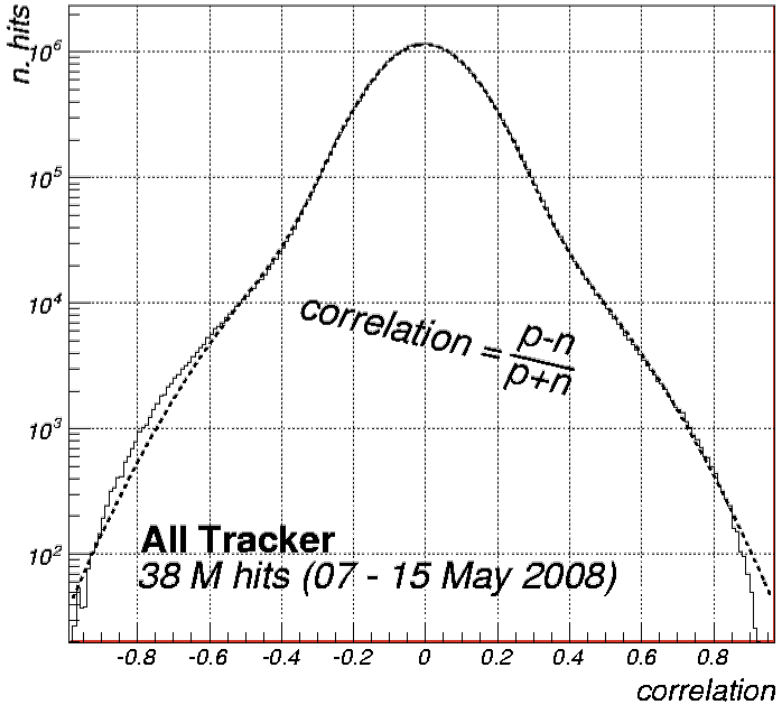
pre integration data

Signal/Noise and resolution



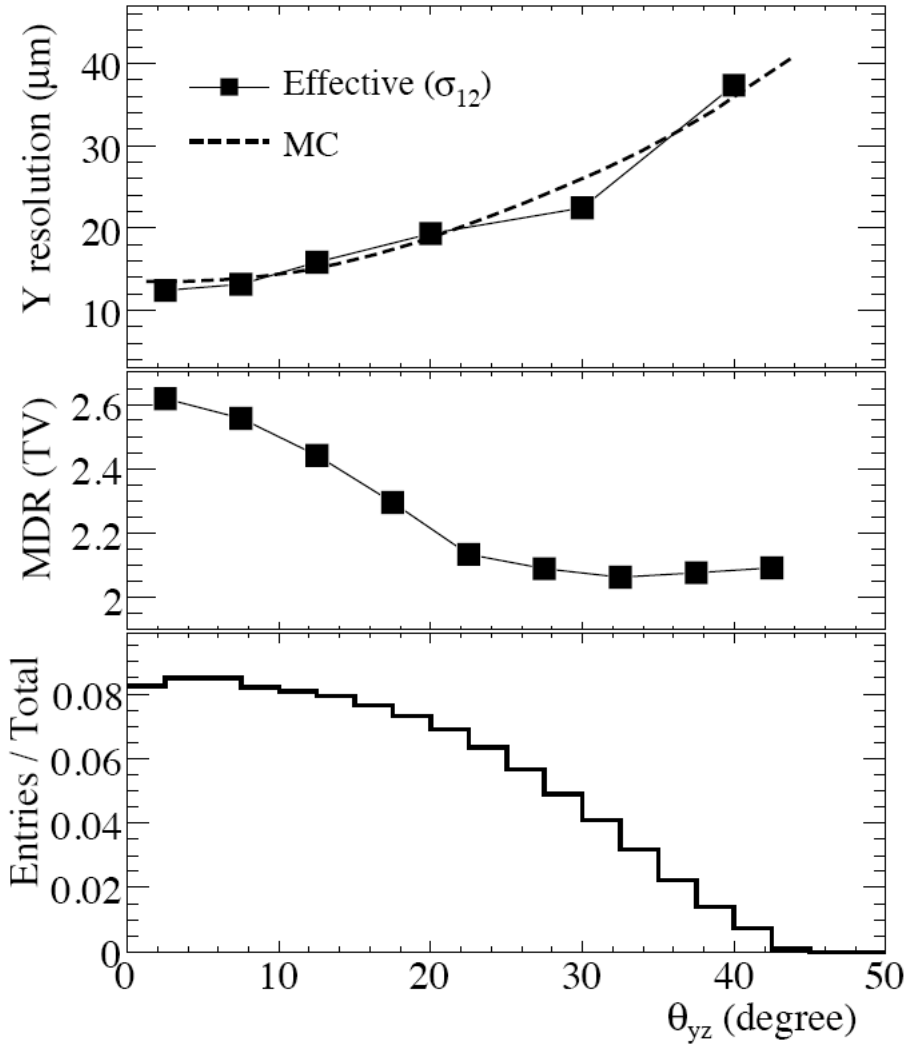
junction and ohmic side charge correlation

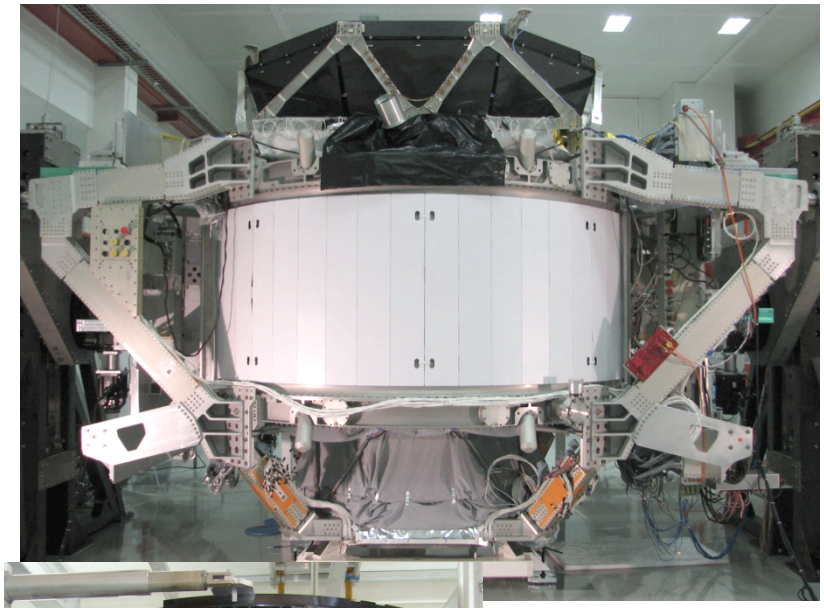


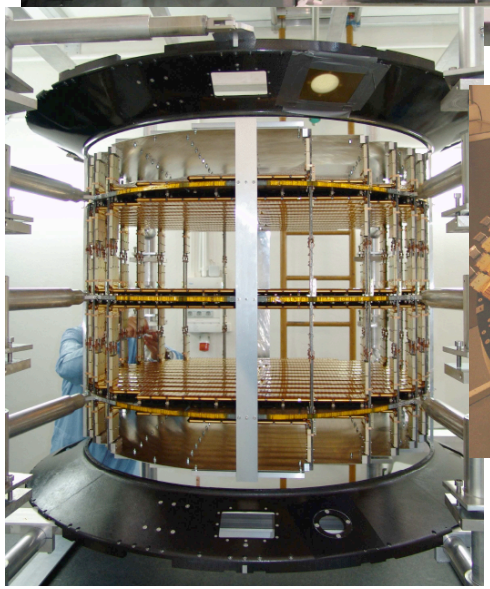


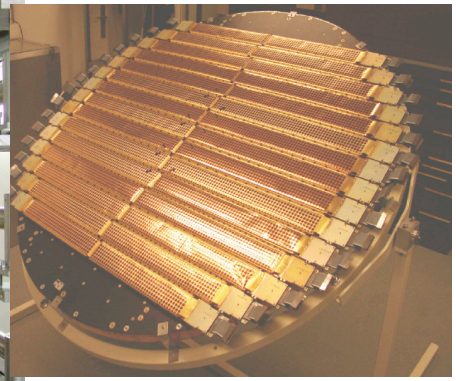
all correction applied (track angle, impact point, gain)

Tracker performance





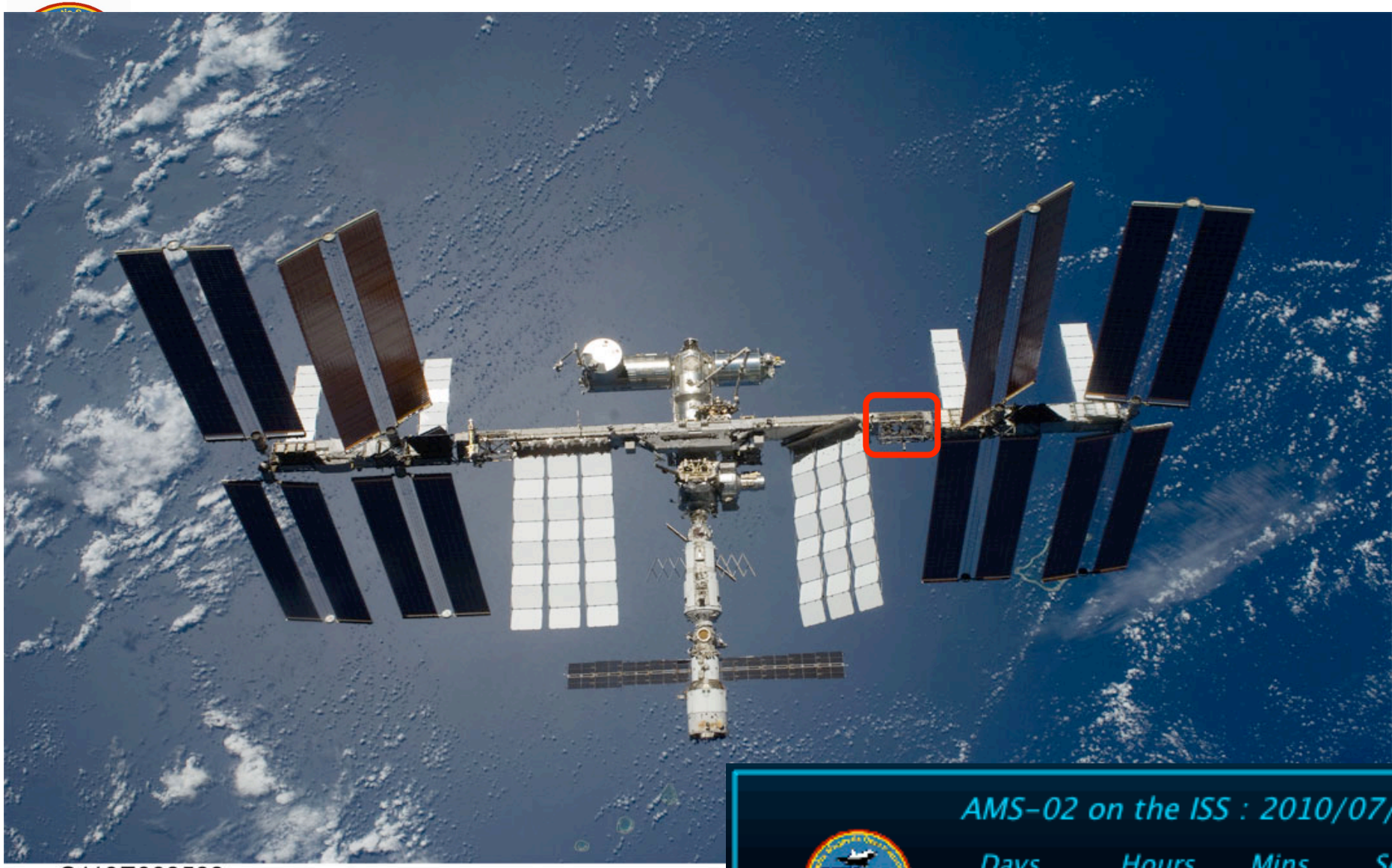




Conclusions

- Tracker performance estimated by CR muons:
  - Stable and uniform signal and noise level
  - Alignment accuracy estimated as 2μm
  - Designe value of the position resolution has been achieved :σ_y = 10 μm at $\theta \sim 0$
  - Spillover limit estimated from measured resolution ~1 TeV for e^+/e^- separation

- Full system integration and test by the end of 2009
- AMS-02 will be ready for launch and operation on board the ISS in spring 2010



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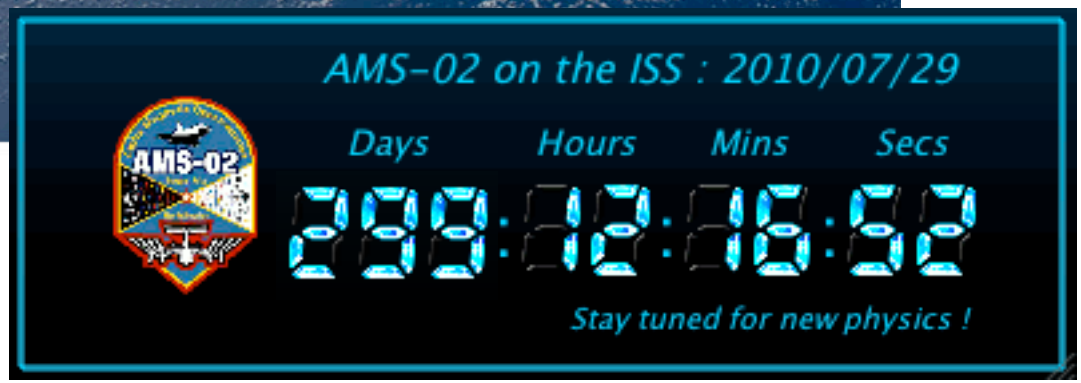

G. Ambrosi, Oct. 2nd 2009