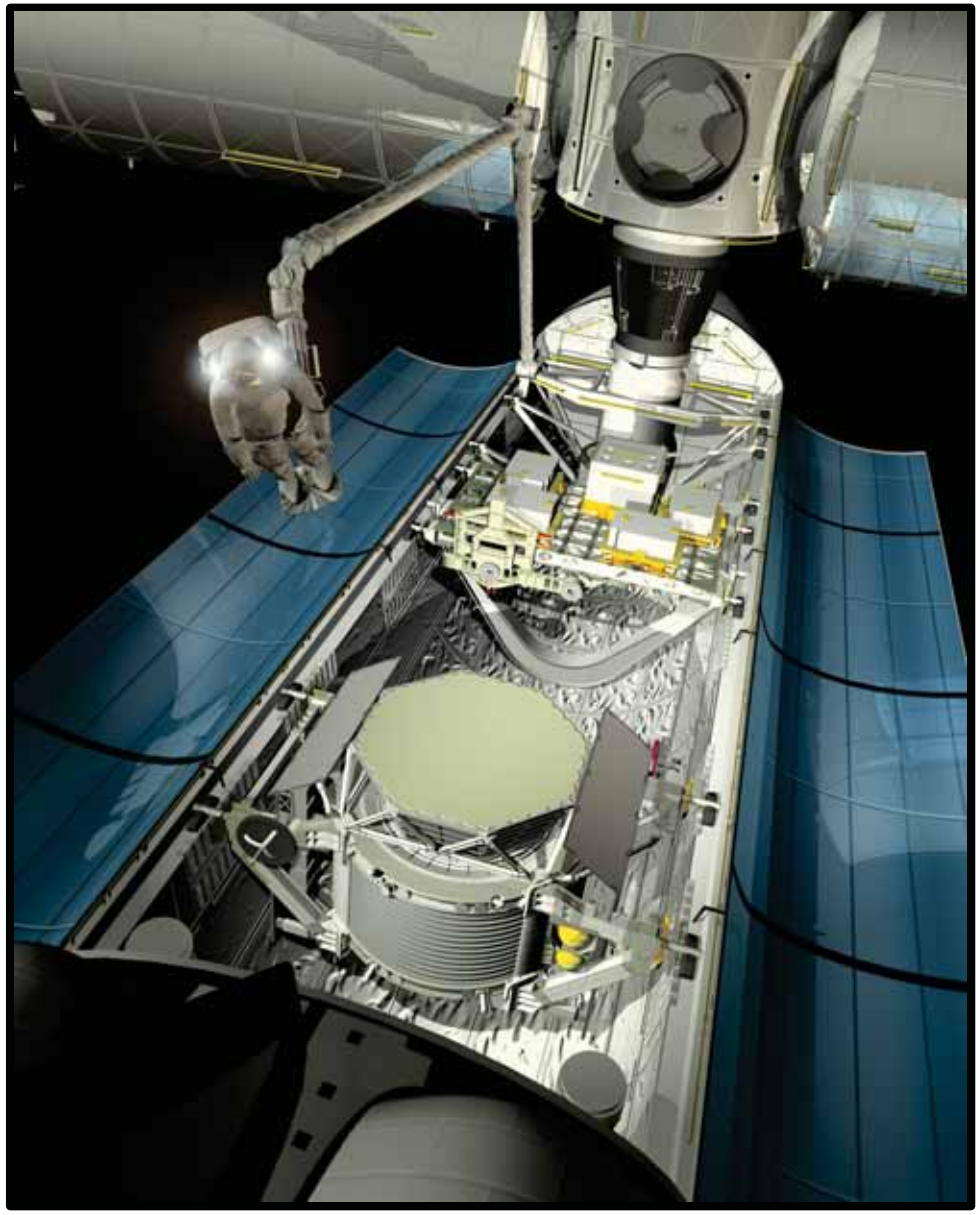
XCIV Congresso Nazionale Società Italiana di Fisica
Genova, 22-27 Settembre 2008

AMS-02: uno spettrometro per la ricerca di antimateria nello spazio è ora una realtà

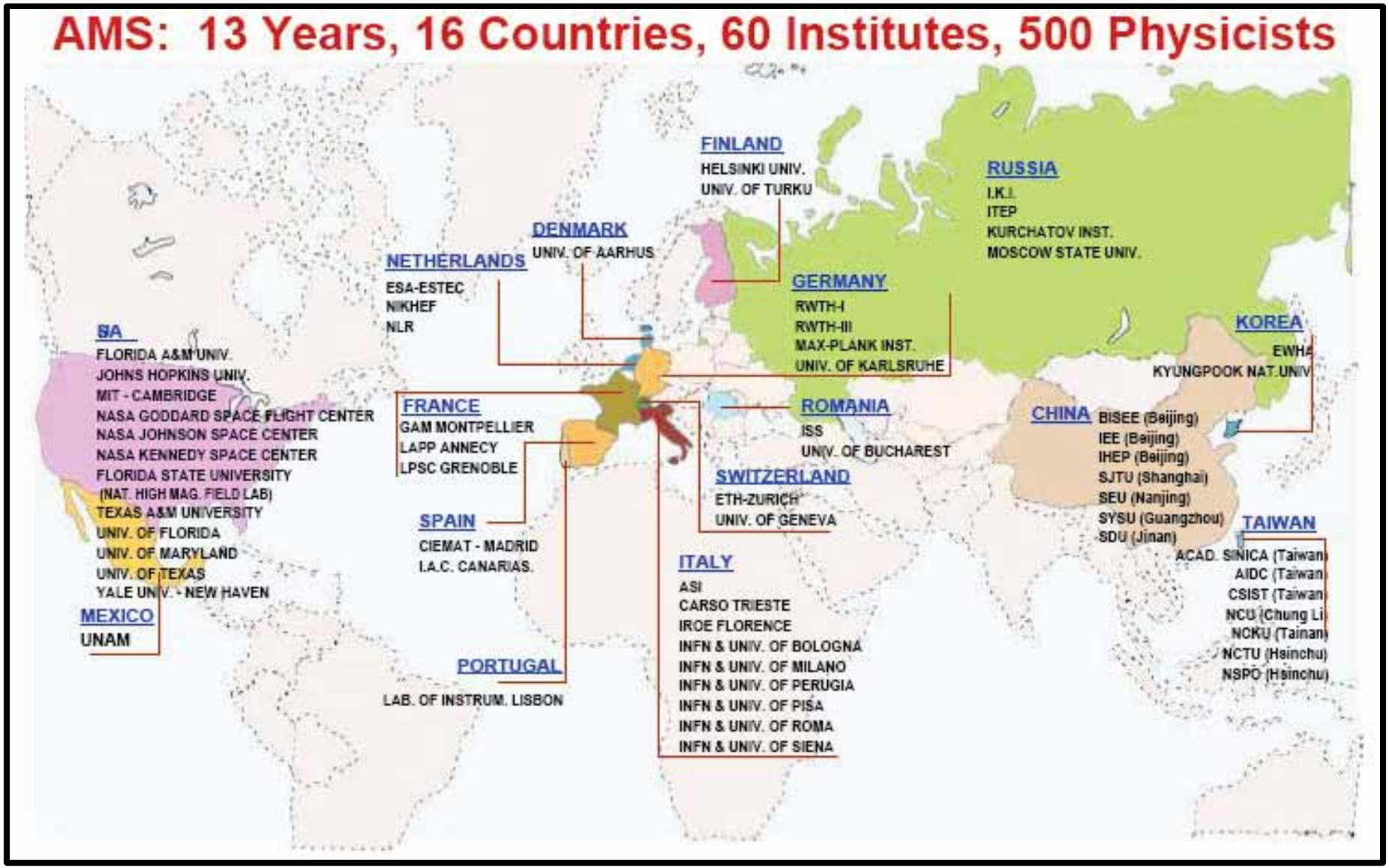
***Veronica Bindi*, Bologna University and INFN**

Outline

- AMS-02 experiment
- Objectives
- Status of the detector
- Performances
- Space qualification Tests
- Perspectives

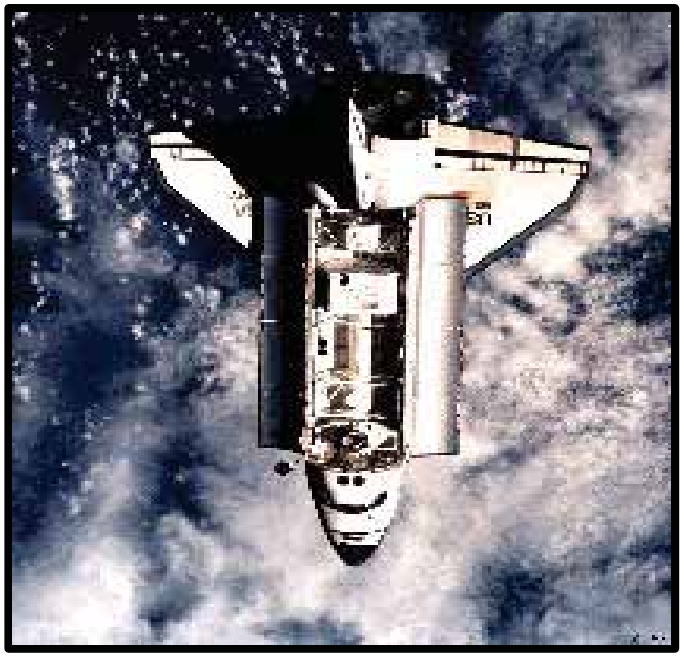


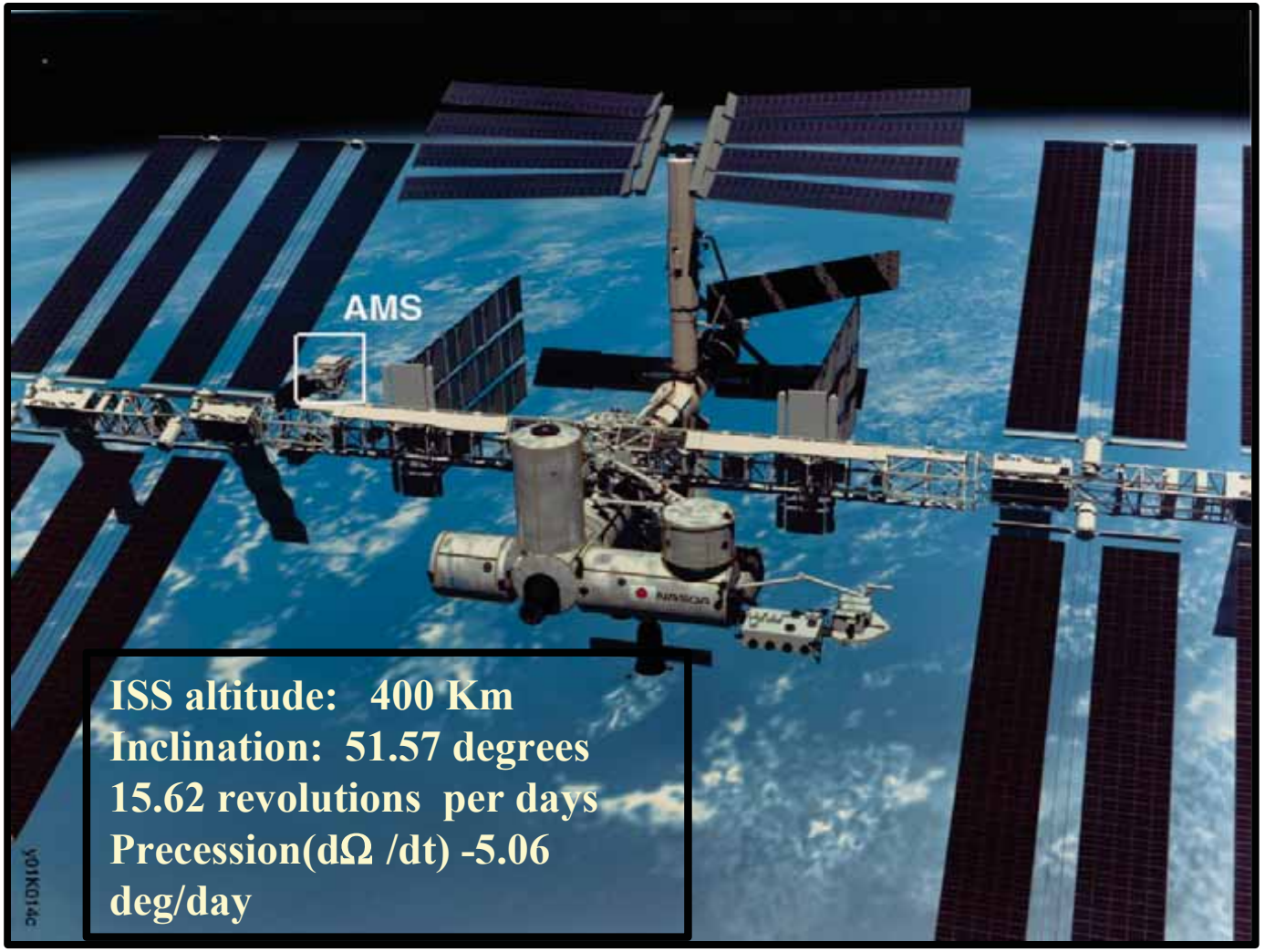
AMS Collaboration



AMS-02

AMS-01: 10 days in 1998 on board of Space Shuttle





Improved acceptance, Magnetic field, redundancy, particle ID.

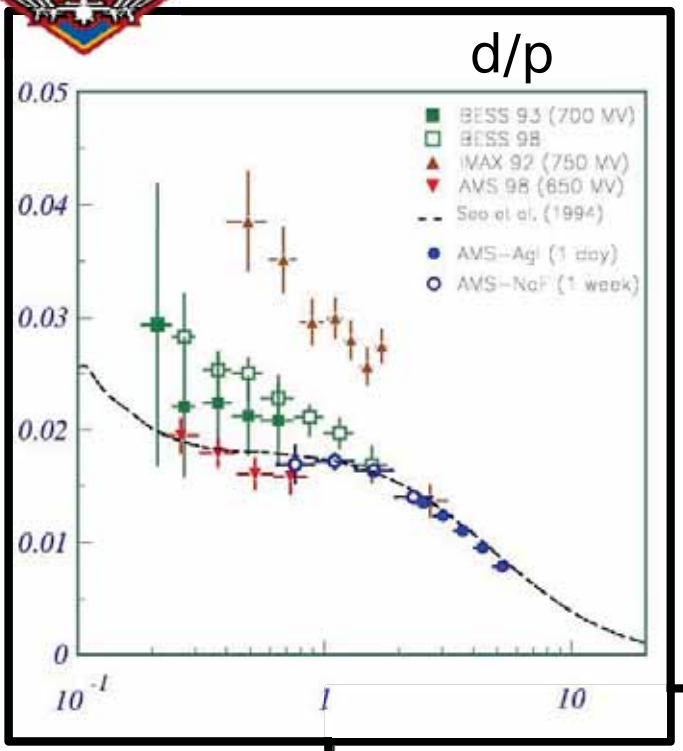
AMS-02 objectives

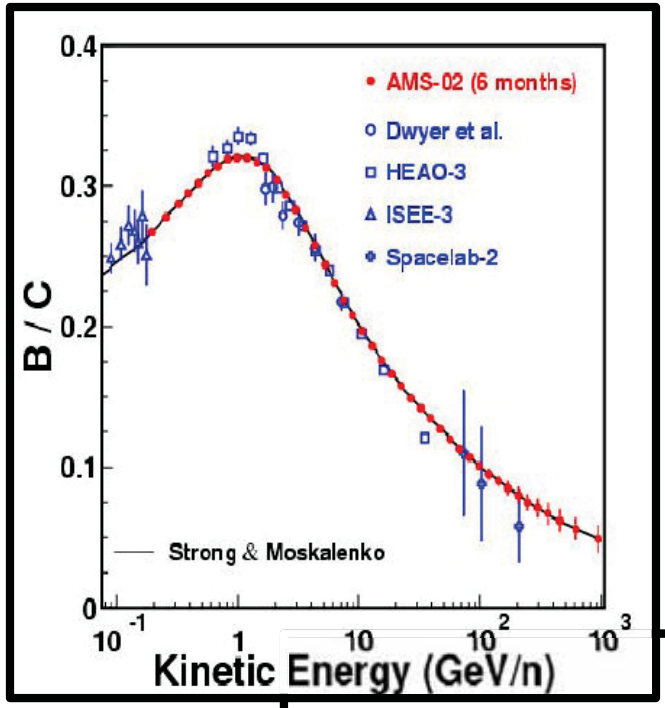
- High statistic measurement of cosmic rays in GeV- TeV energy range till Z< 25
- Indirect search for Dark Matter signals
- Gamma ray astrophysics till 300 GeV energies
- Cosmic anti-matter

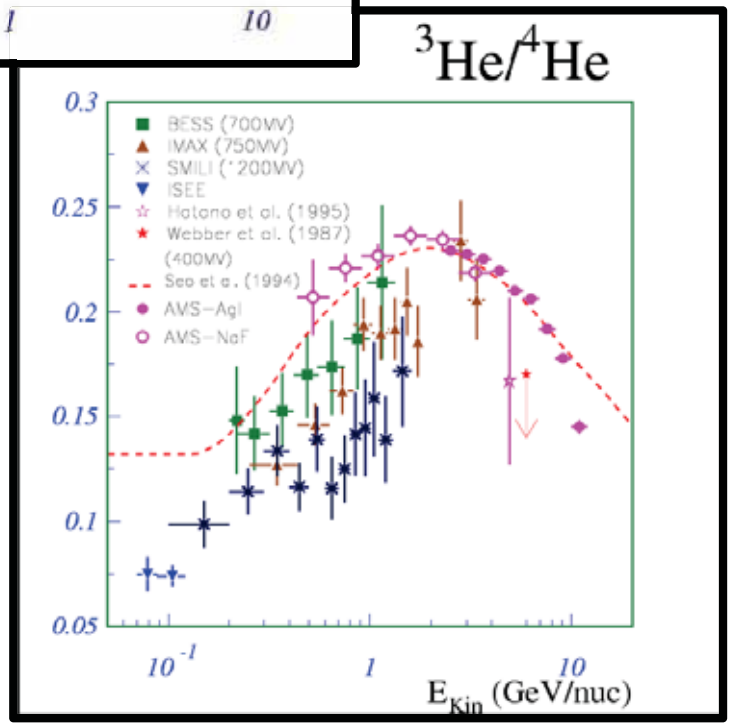
Expected data statistics for AMS on ISS

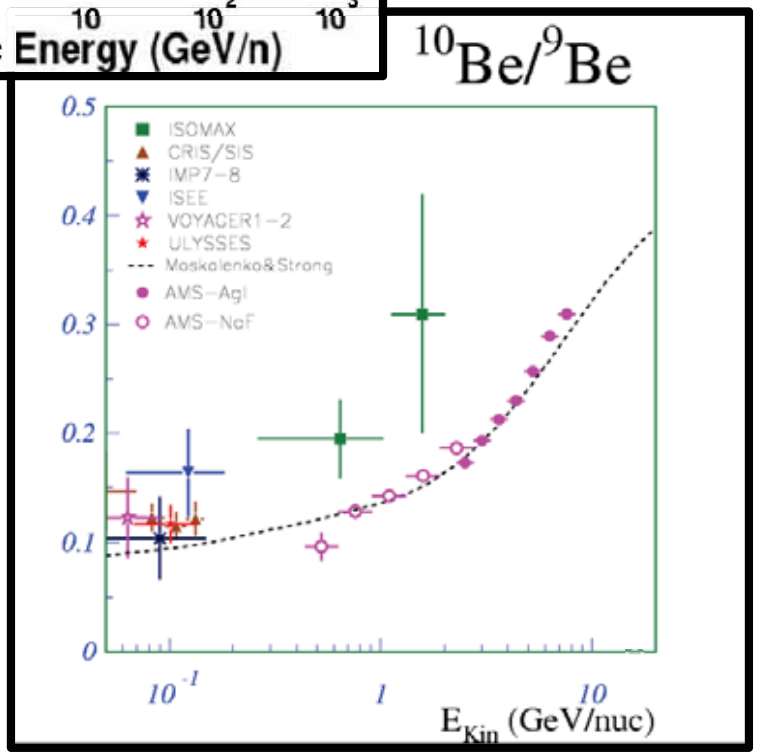
Above	> 1 GeV/c	>5 GeV/c	>10 GeV/c	>100 GeV	> 1 TeV
Protons			6.1×10^9	1.5×10^8	2.5×10^6
Electrons	1.4×10^8	7.3×10^7	6.8×10^6	7.2×10^4	5.4×10^2
Positrons	9×10^6	3.8×10^6	3×10^5	1.6×10^3	6
Antiprotons	1.5×10^6	1.1×10^6	1.4×10^4	3.2×10^3	5.8×10^2
Helium	6.4×10^8	4.3×10^8	2.1×10^8	7.3×10^6	1.7×10^5

AMS-02 isotopic ratios

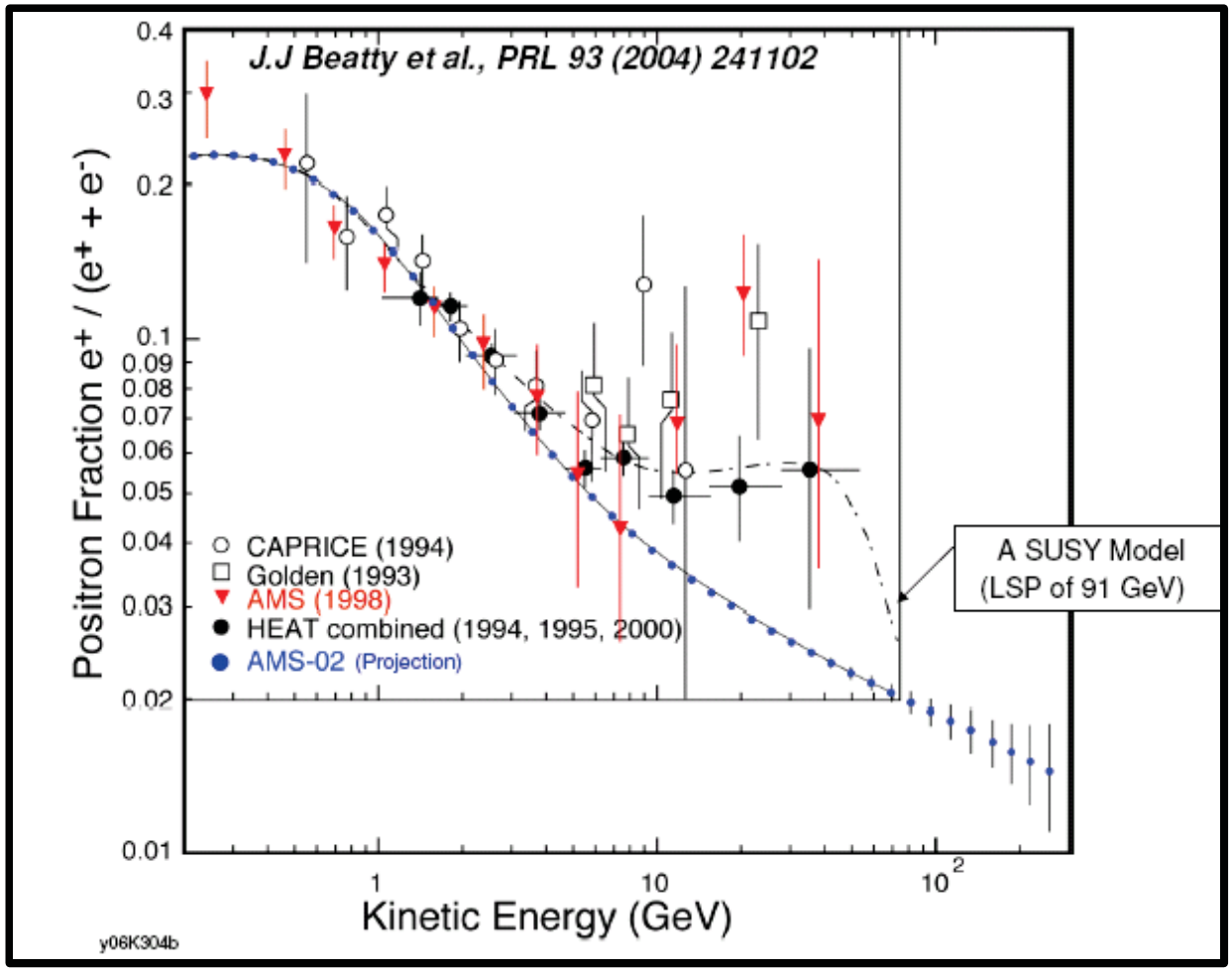








Indirect DM Detection: Positrons Fractions



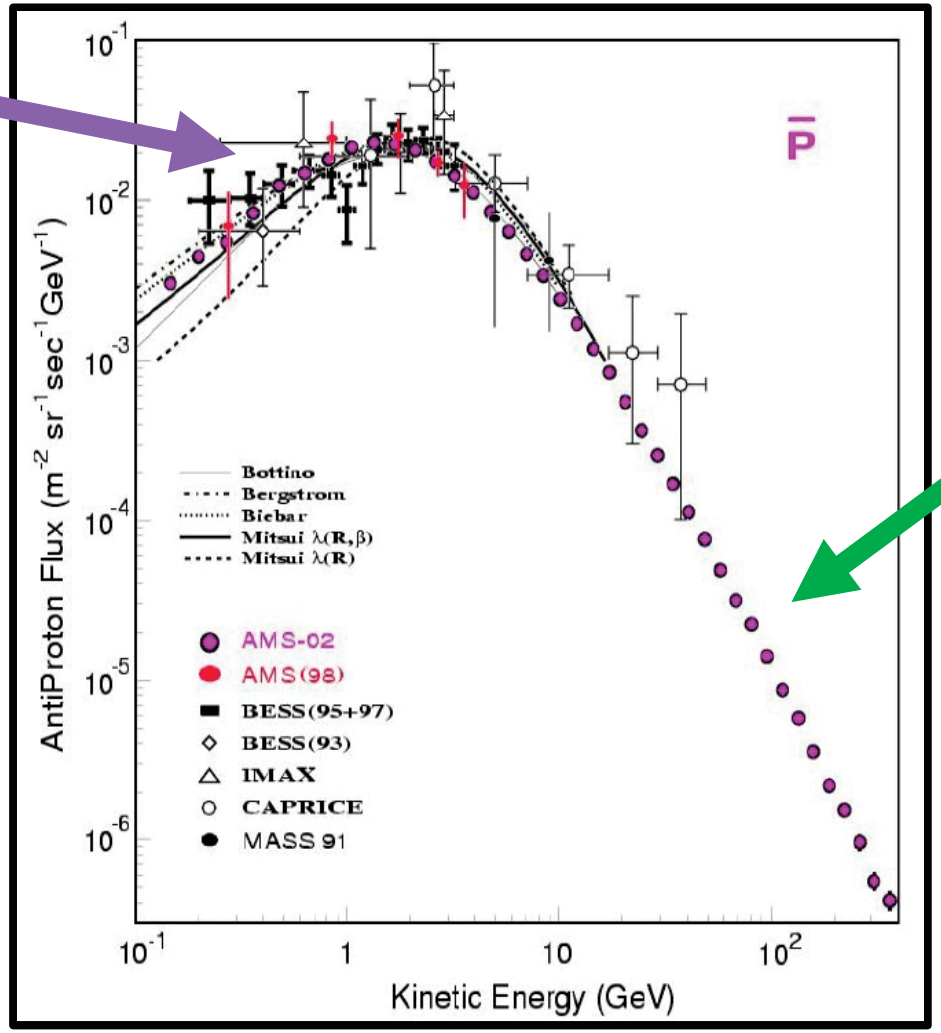
Instrumentation focus: TRD, ECAL

XX annihilation would give bump around ~ 10-100 GeV

Will measure positron spectrum precisely to ~300 GeV/c

Indirect DM Detection: Anti-protons spectra

SUSY DM signal most likely at low energy, mostly below geo-magnetic cutoff, low energies may have less background (few to ~10 GeV)



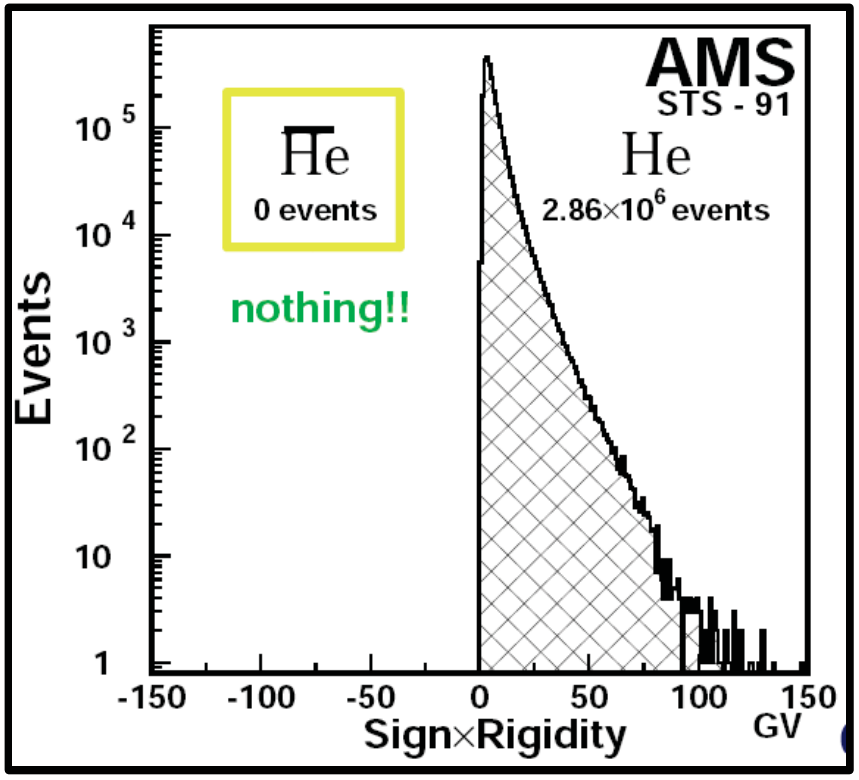
Possibly some distortion ... but at the least, will better understa nd CR bg models

Anti-protons DM signal in ~< 1 GeV range

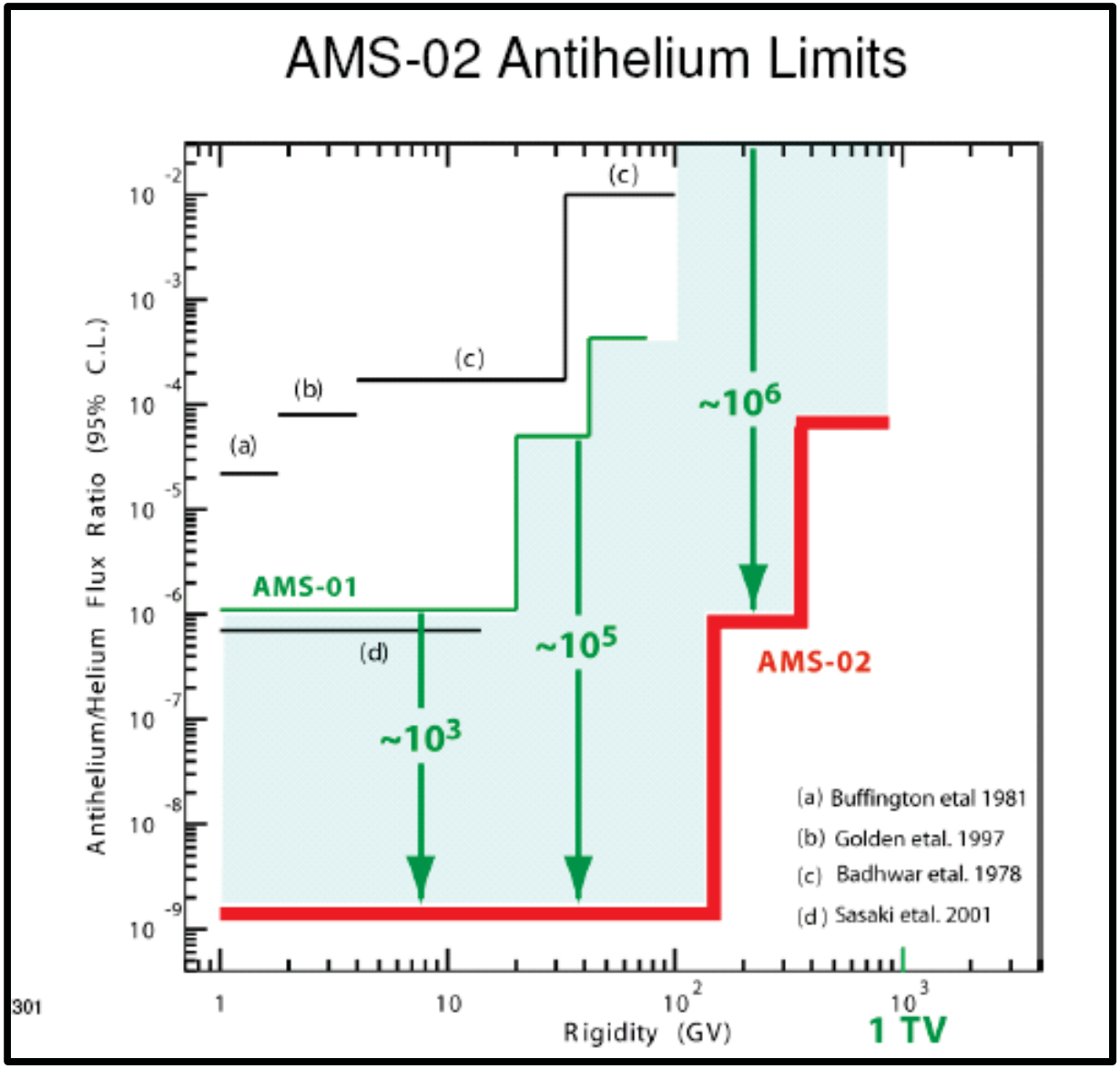
Search for Anti-matter

AMS-01

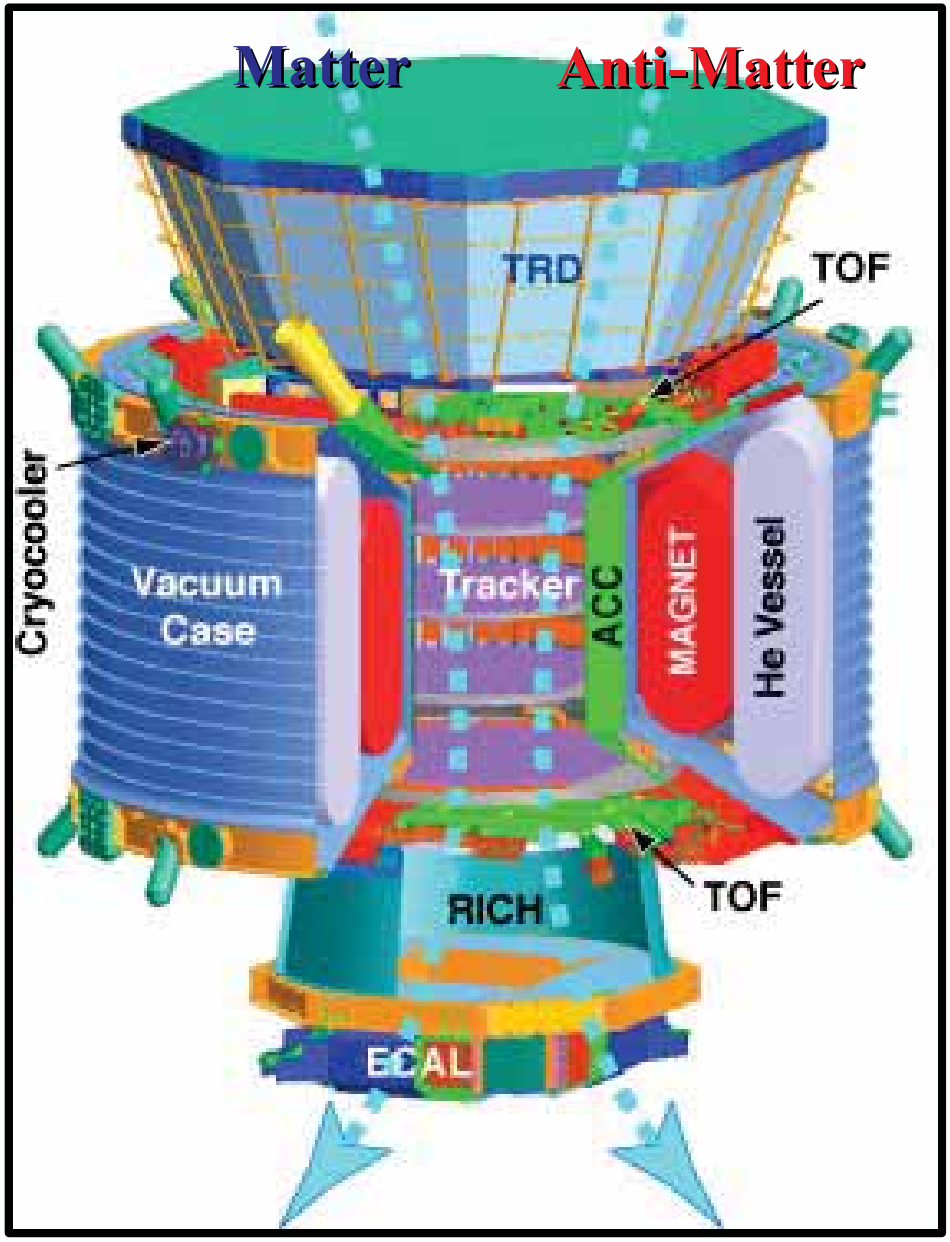
Permanent magnet, 0.15 T
Si tracker, TOF, Cherenkov



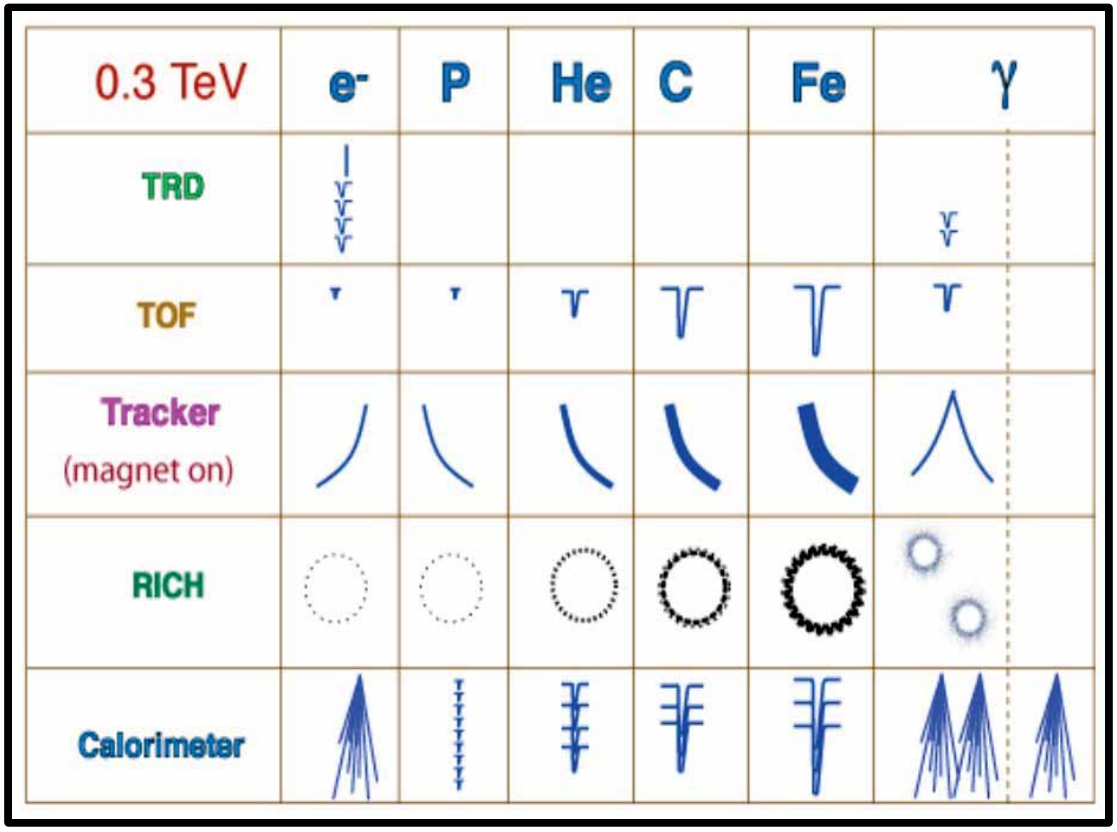
June 2-12, 1998 on Discovery, STS-91
51.7 degree orbit 320-390 km;
~100 hours of data 100 million particles



AMS-02



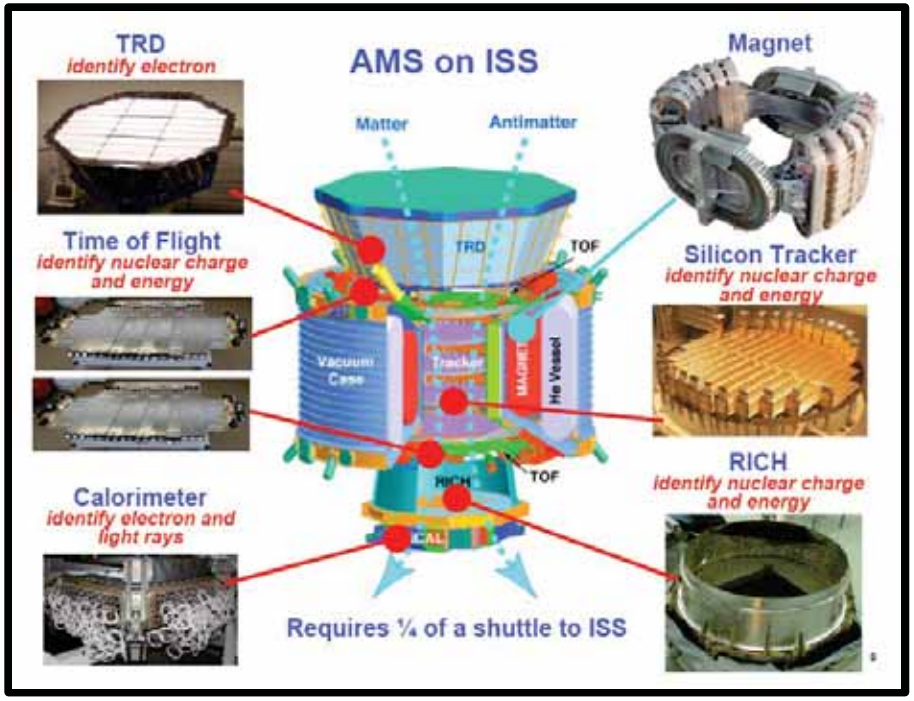
Dimension = 3.0m× 3.0m× 3.0m, 7 t
Acceptance = 0.5 m^2sr, 3 yrs Operation
Nuclear Charge Separation up to Z=26
Data rate ~ 2 Mbyte/s

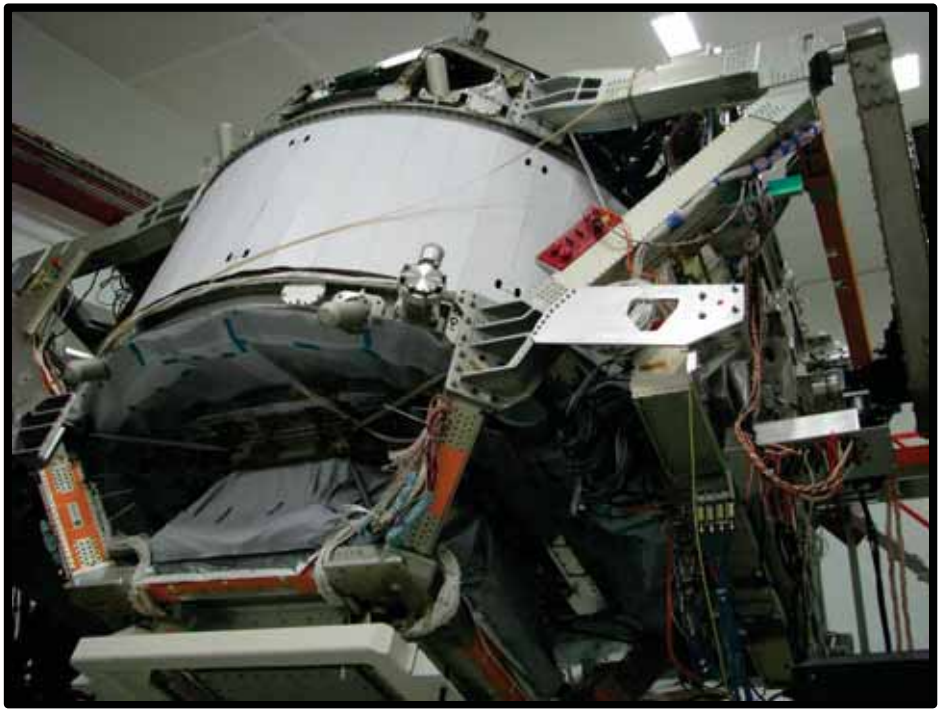


Pre-integration

Dec 2007-June 2008

- Verification of the mechanical integration of the whole apparatus
- Integration of the flight electronics from the front-end boards to the complete data acquisition chain
- Testing of the functionalities of the sub-detectors and tuning of the setting parameters
- 2 months of cosmic ray acquisition with all detectors to prove capabilities (more than 2000 runs):- TOF results (L. Quadrani)
  - Tracker results (P. Zuccon, A. Oliva)





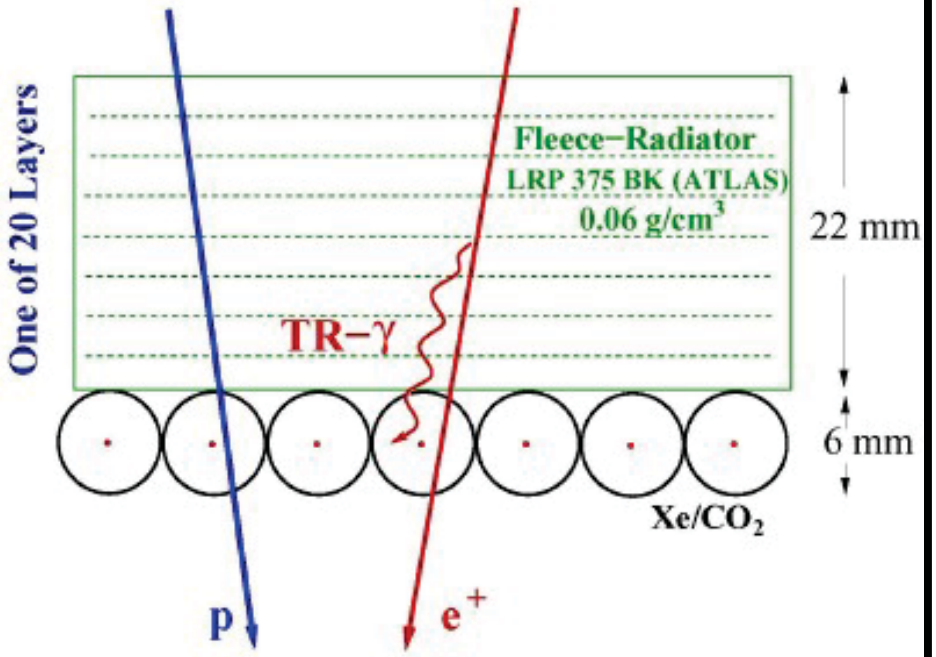
Transition Radiation Detector

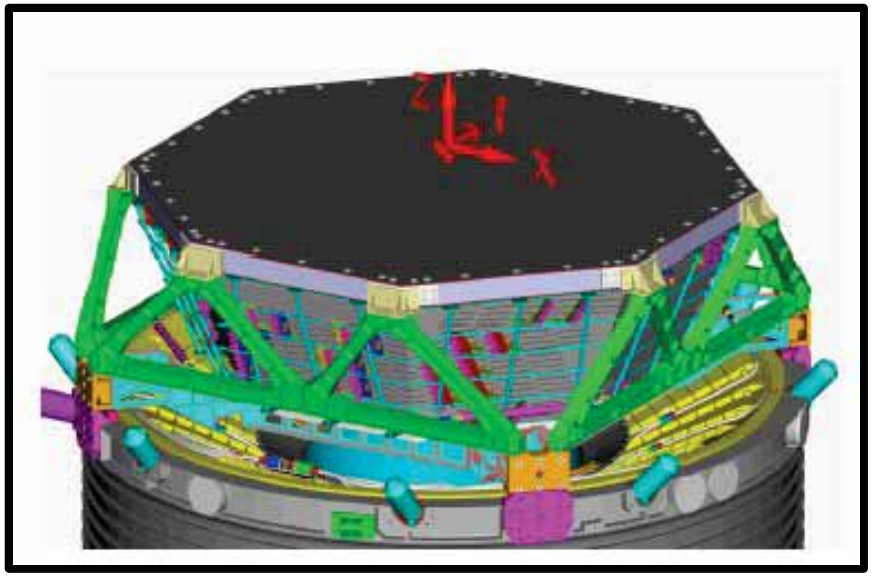
p^+ rejection $>10^2$ 1-300 GeV
acceptance: 0.45m^2sr

Choosen configuration for 60 cm height:

20 Layers each existing of:

- **22 mm fibre fleece**
- **Ø 6 mm straw tubes filled with Xe/CO_2 80%/20%**





TRD integration on AMS-02

November 2007

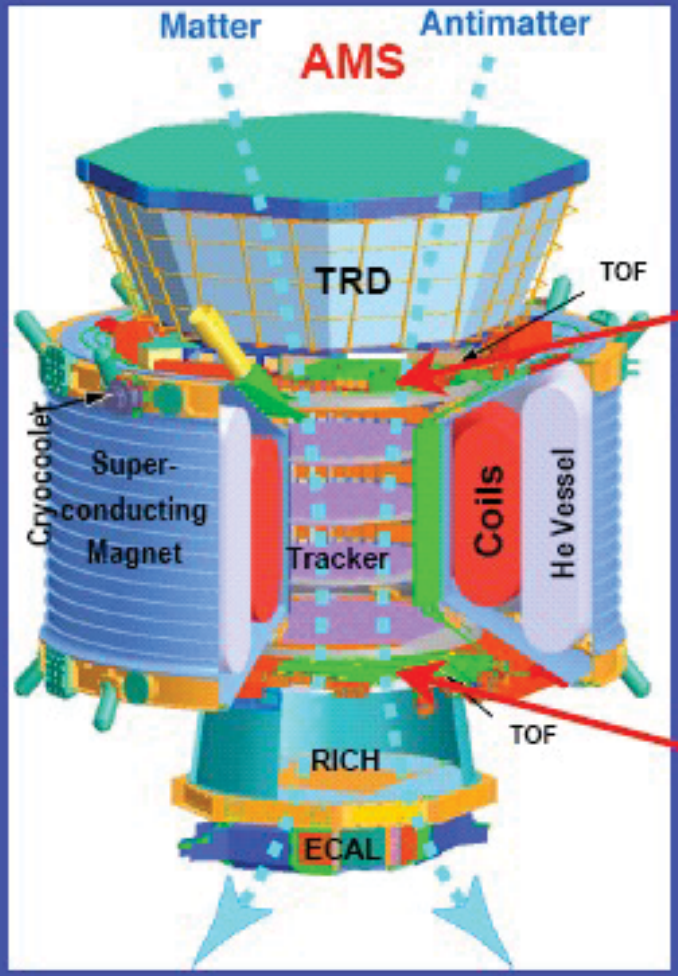
AMS-02 TRD

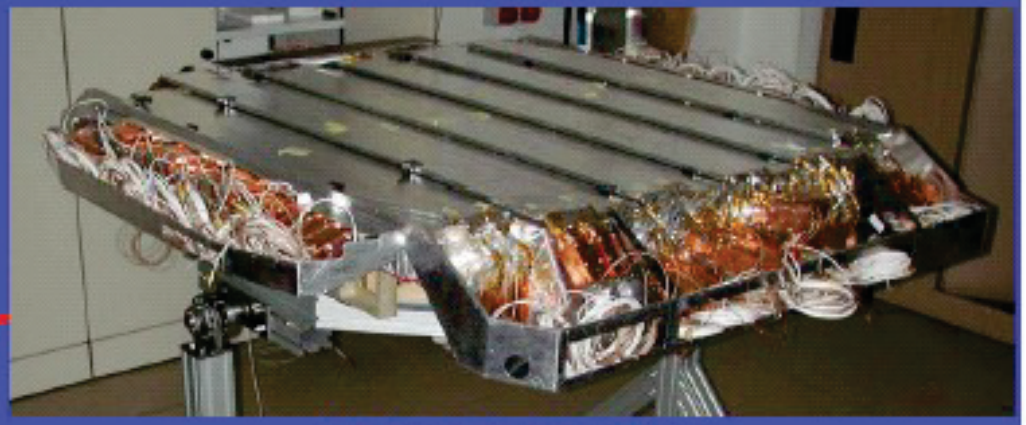

The AMS TRD was tested 1 month in Aachen
with cosmics before it was delivered to CERN
All 5248 channels are working !

The Time of Flight

Time of Flight (TOF)

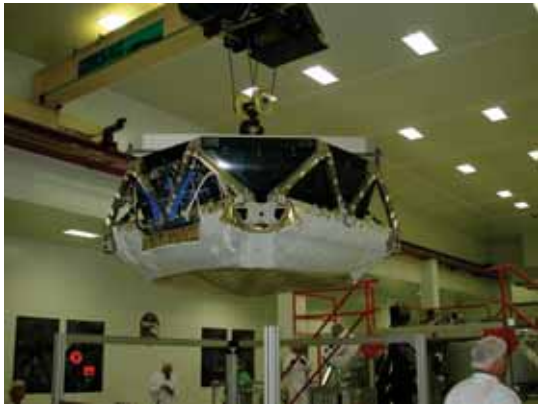
Measures the Time of relativistic particles to 150 ps

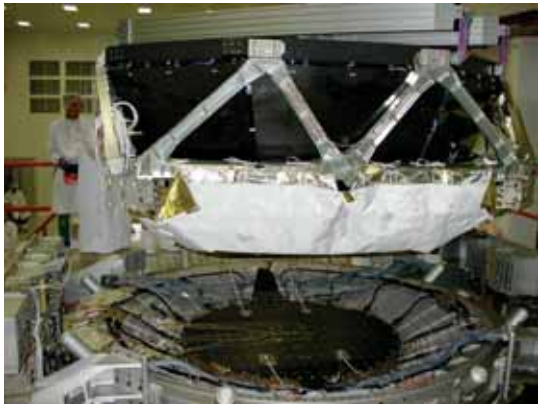


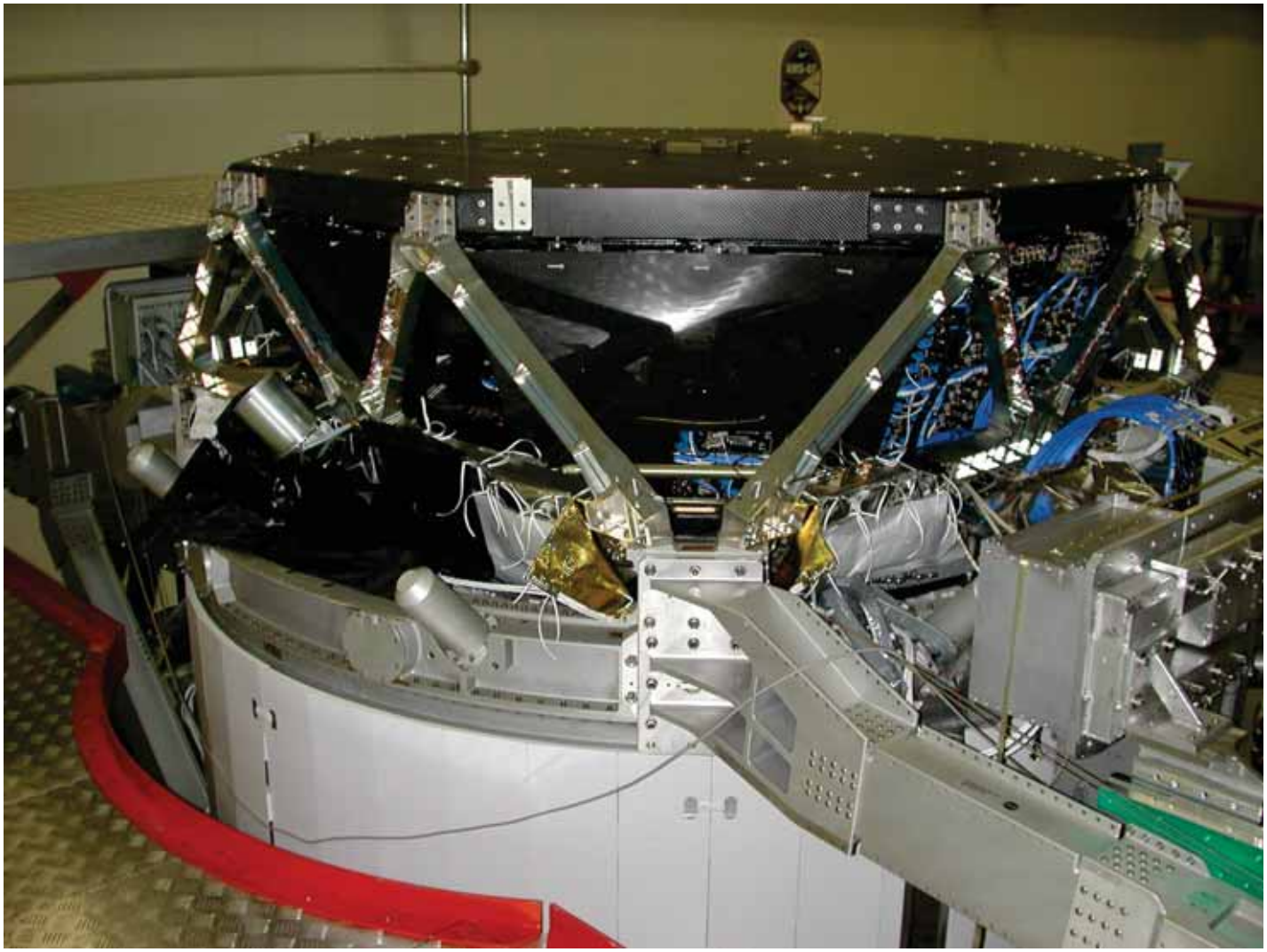


Very precise space borne Time of Flight

Upper TOF on AMS-02







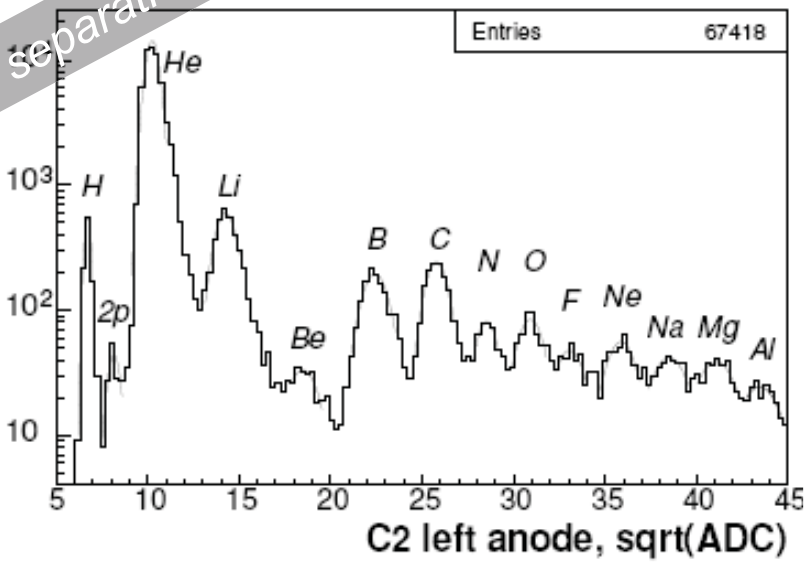
Since December 2007 Upper TOF was integrated on AMS-02

Lower TOF on AMS-02

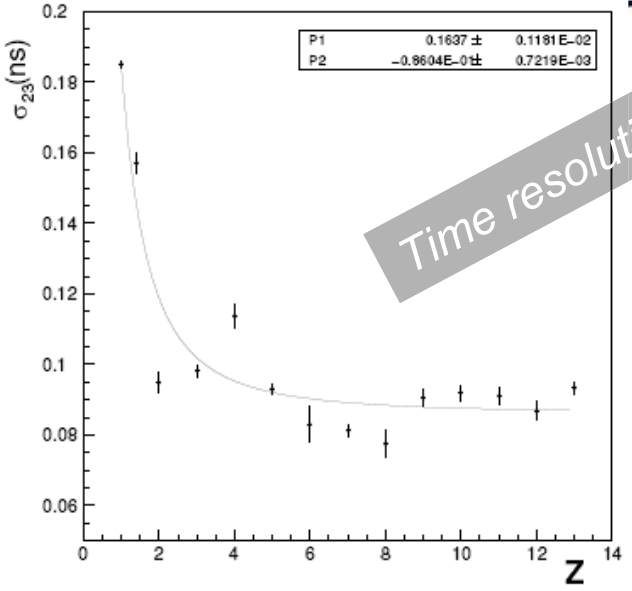
March 2007

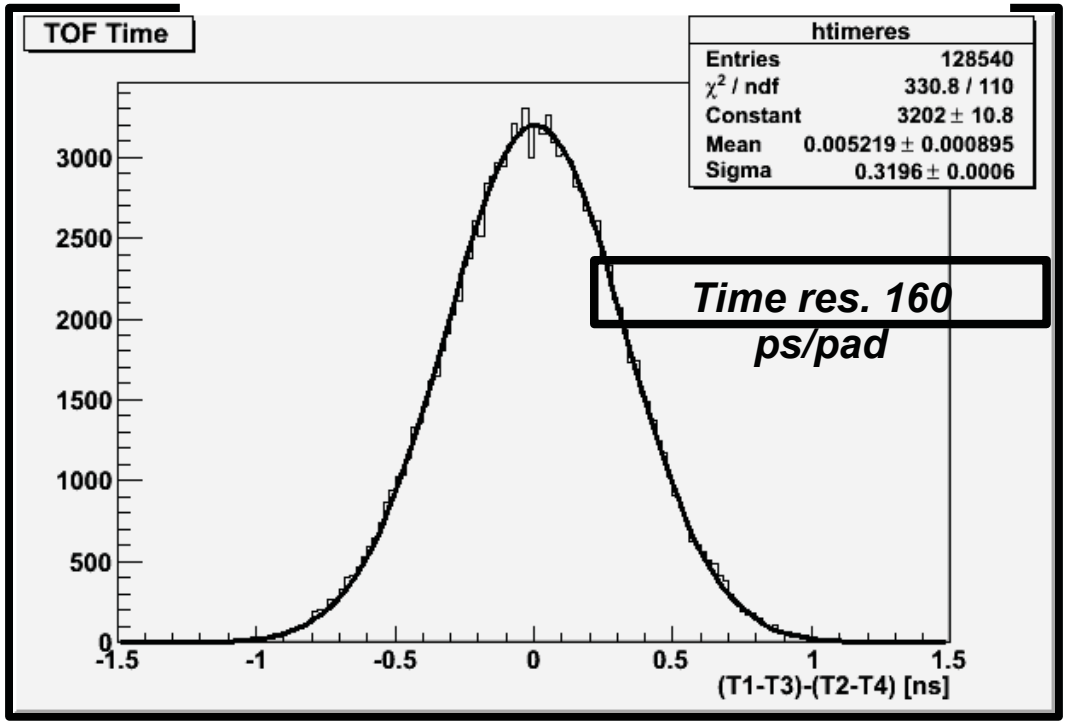
TOF resolutions

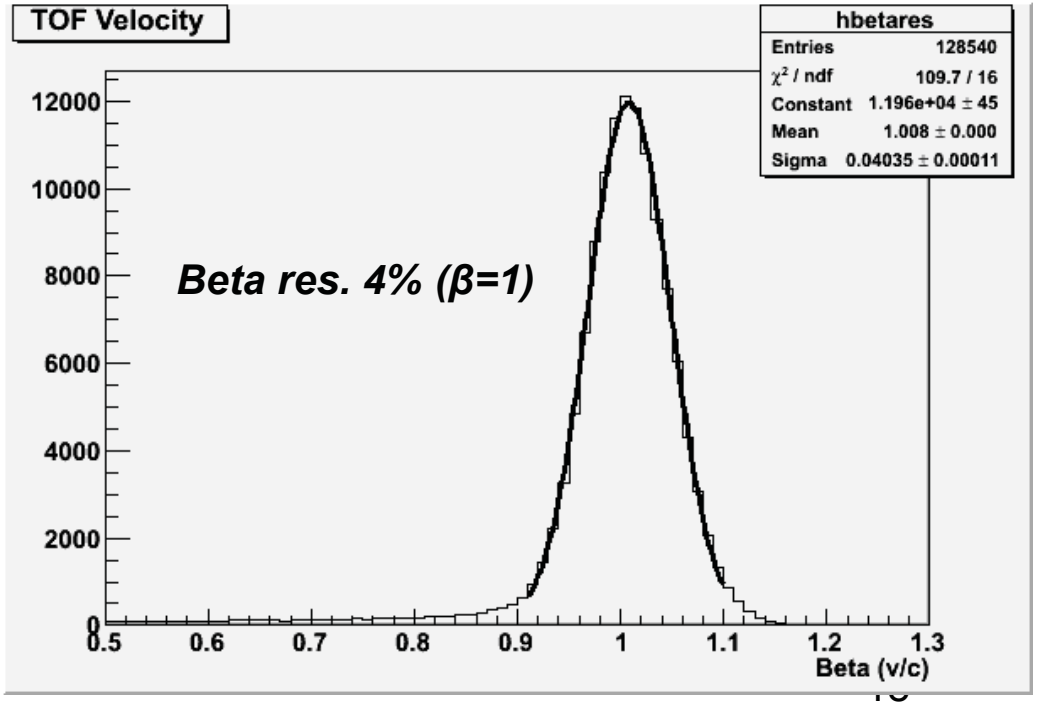
charge separation



Time resolution



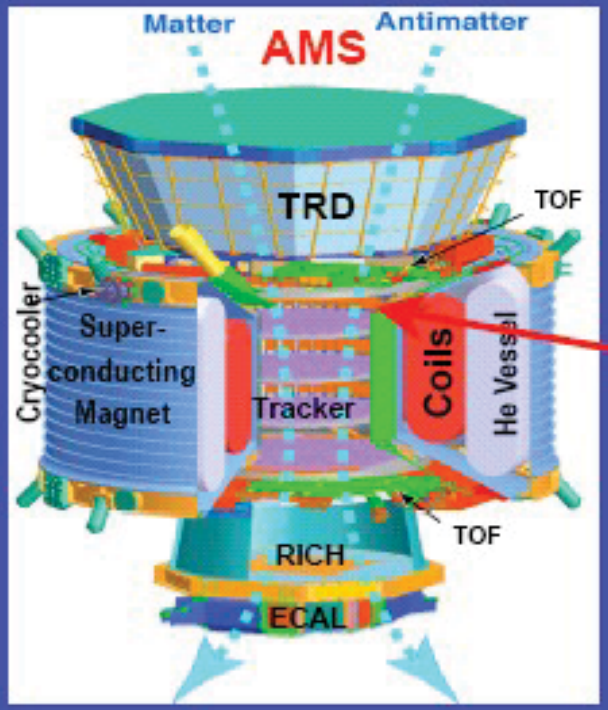




The silicon Tracker

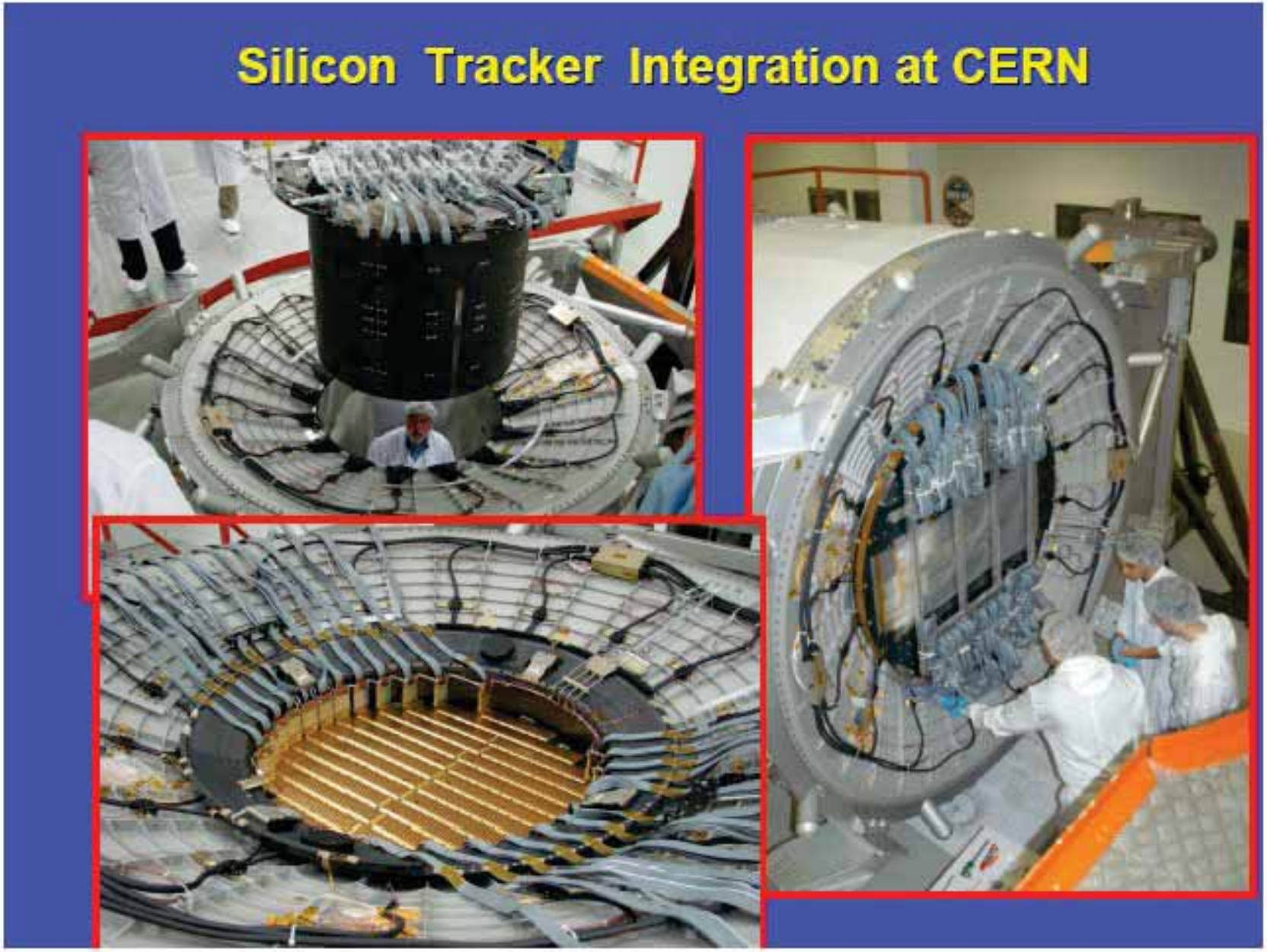
THE AMS SILICON TRACKER ans TTCS

To use the bending power of the magnet, we have built a state of the art Tracking Detector based on 8 thin layers of Silicon Detectors, with a spatial accuracy better than 10 micron

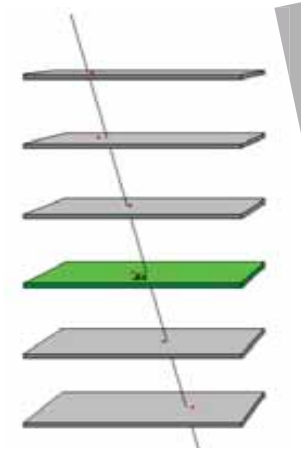


Tracker on AMS-02

October 2007

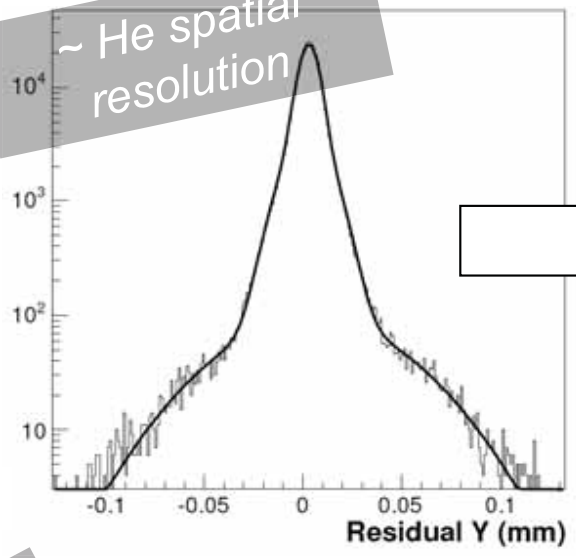


The silicon Tracker

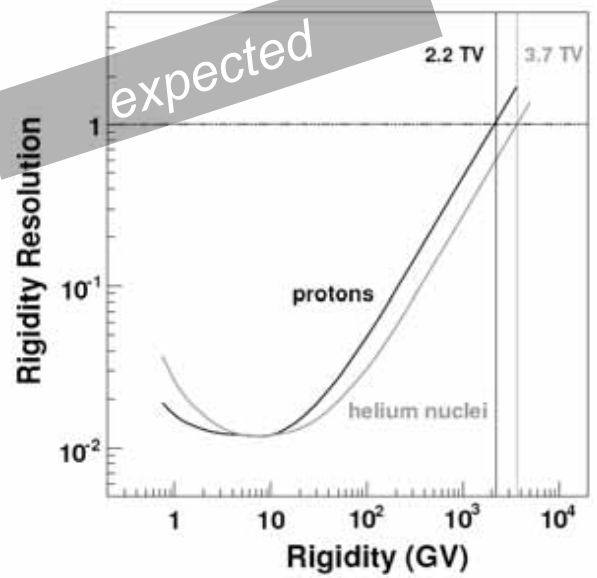


Residual = $X_{meas} - X_{xfit}$

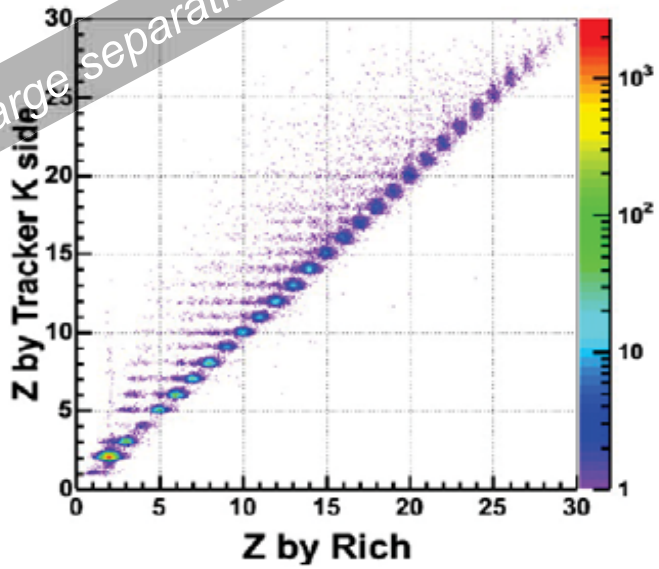
~ He spatial resolution



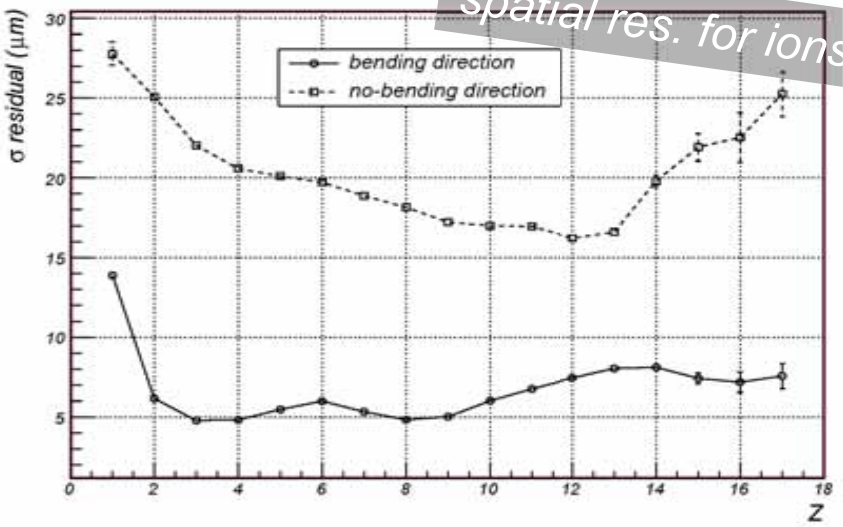
expected



charge separation



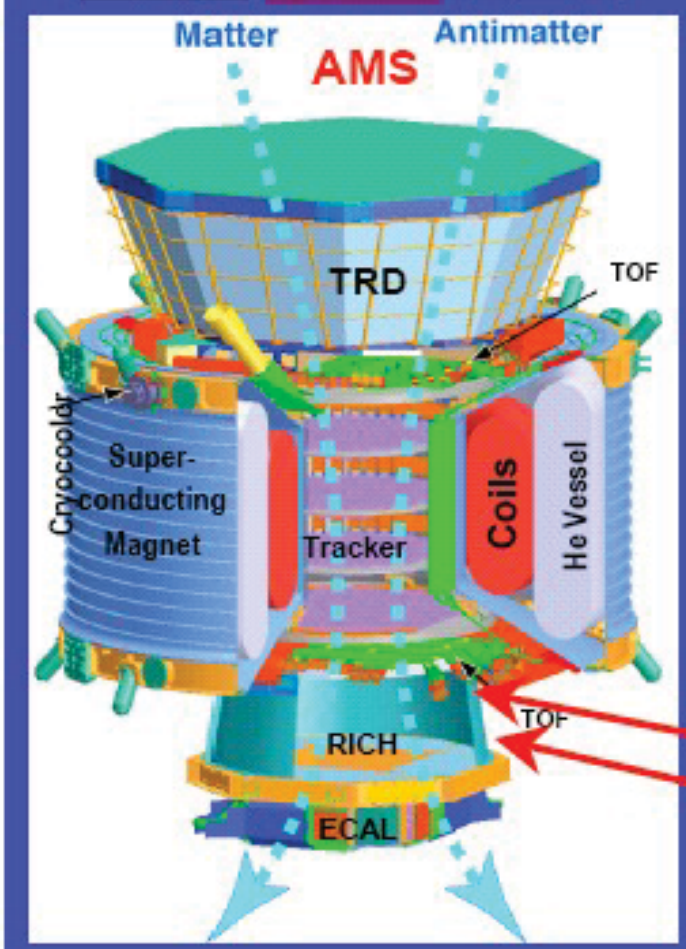
spatial res. for ions



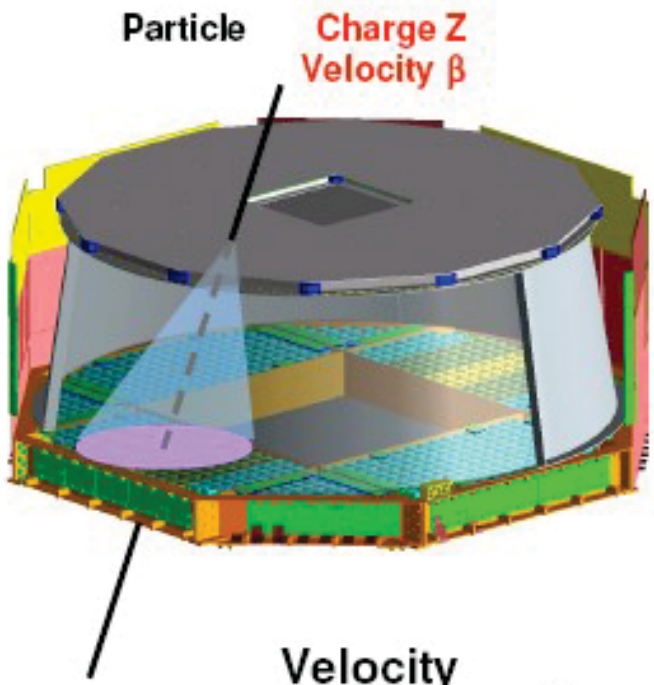
(from A. Oliva)

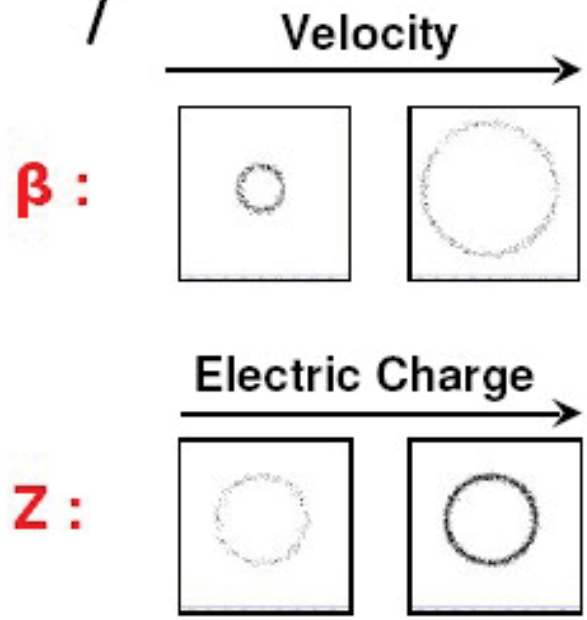
AMS-02 RICH

Ring Imaging Cerenkov Radiator (RICH)

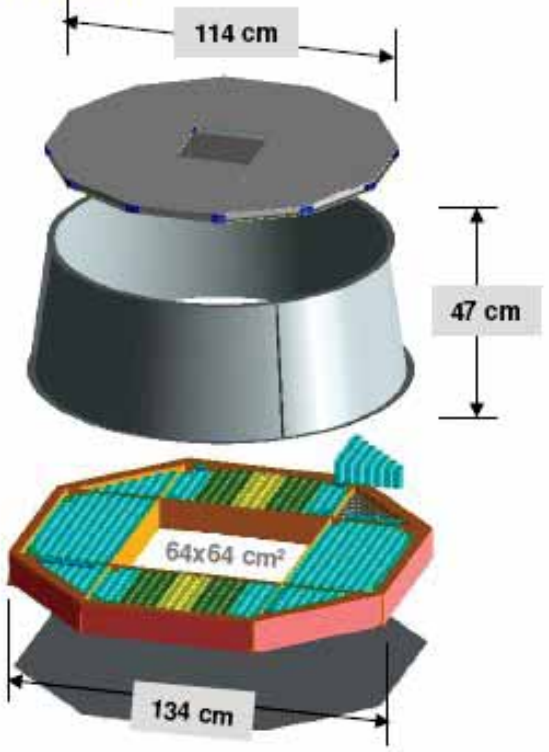


The RICH detector





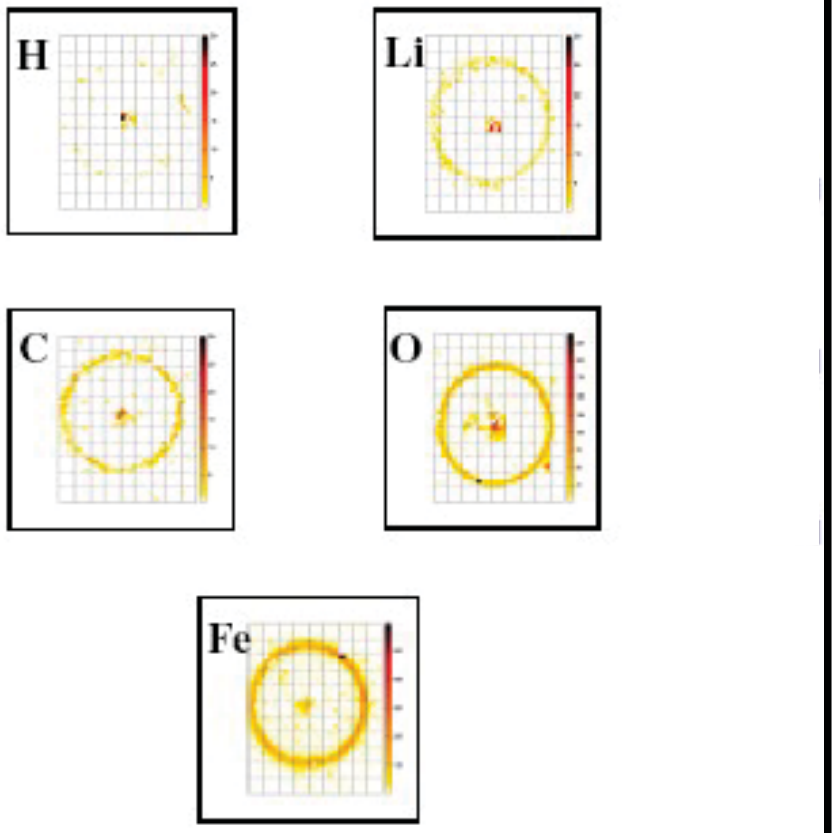
- **Dual solid radiator configuration**
  - Low index aerogel (n=1.05)
  - Sodium fluoride (n=1.33)
- **Photomultiplier matrix**
  - 10880 pixels
  - Spatial granularity: 8.5 x 8.5 mm²
- **Conical reflector**

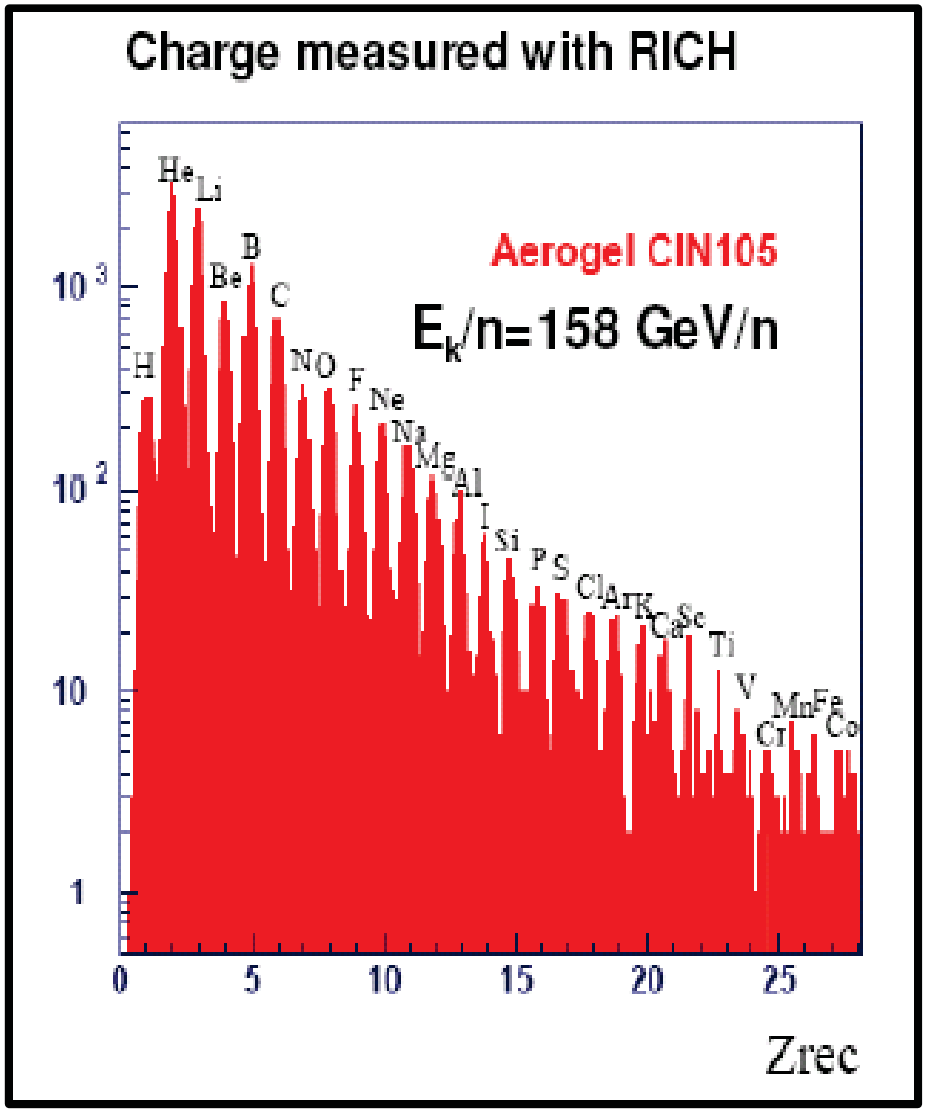


Test beam with Rich prototype

2002: 20 GeV/n Pb on Be target

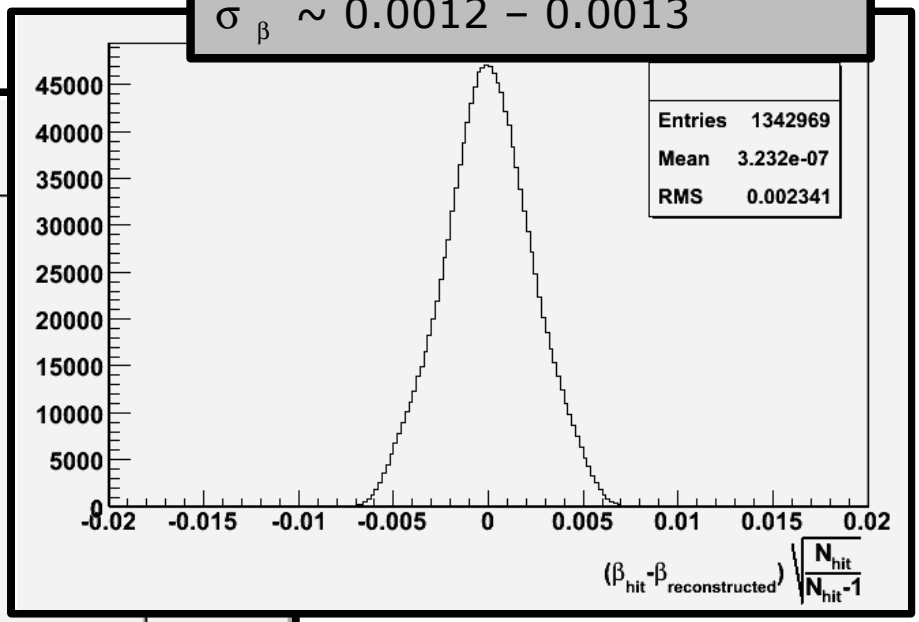
2003: 158 GeV/n In on Pb target

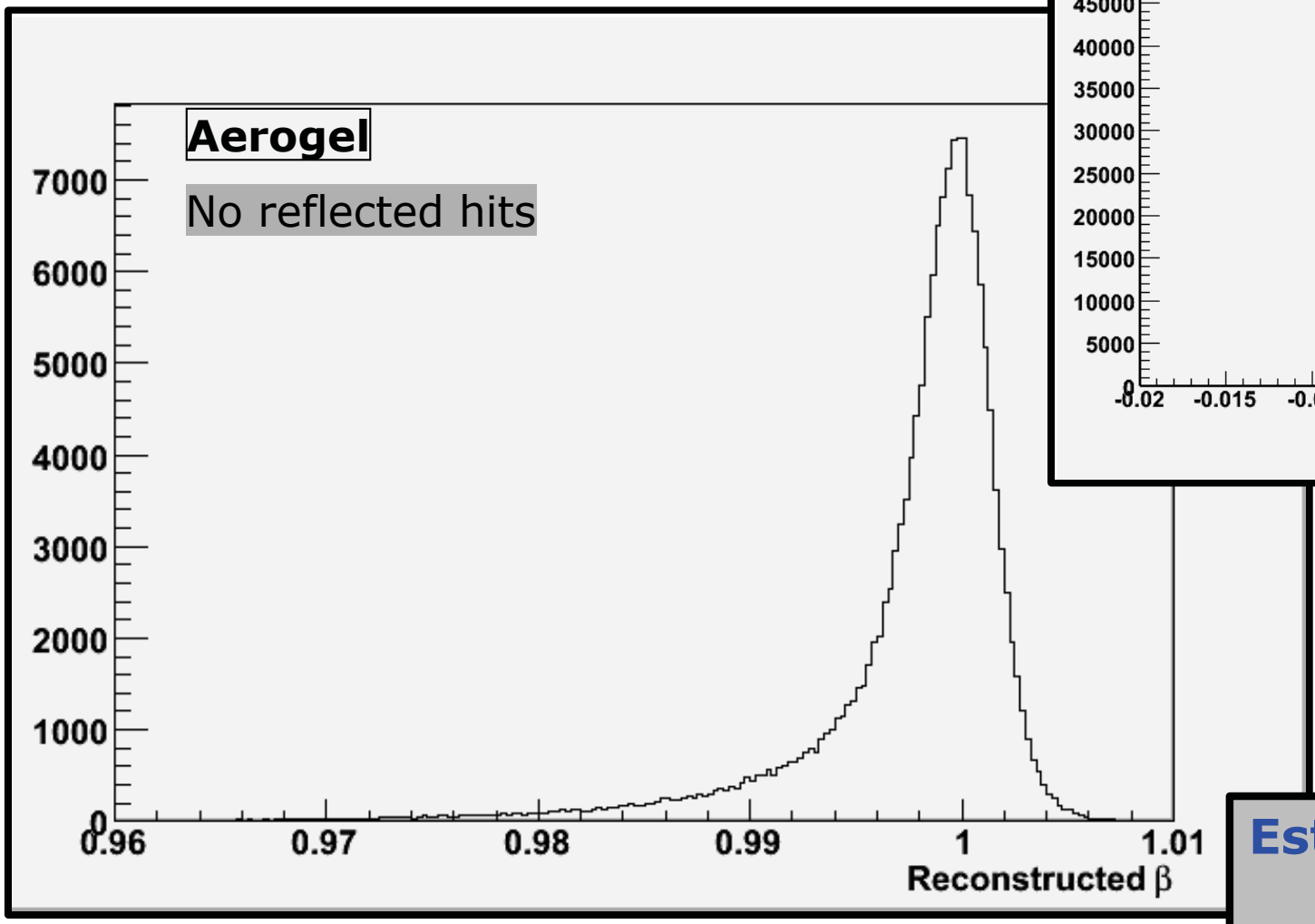




RICH ß resolution

Residues still compatible with
σ_β ~ 0.0012 – 0.0013



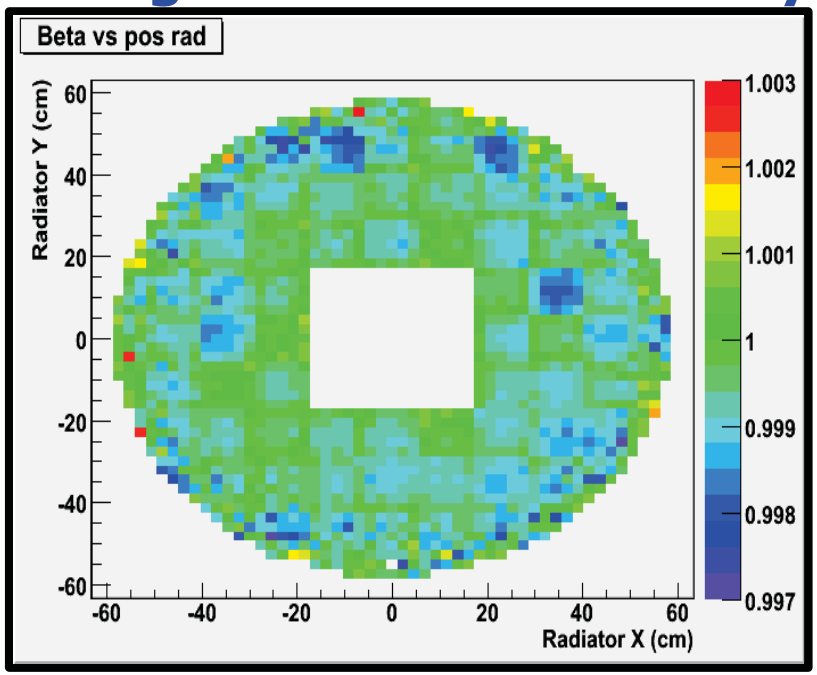


Estimated resolution

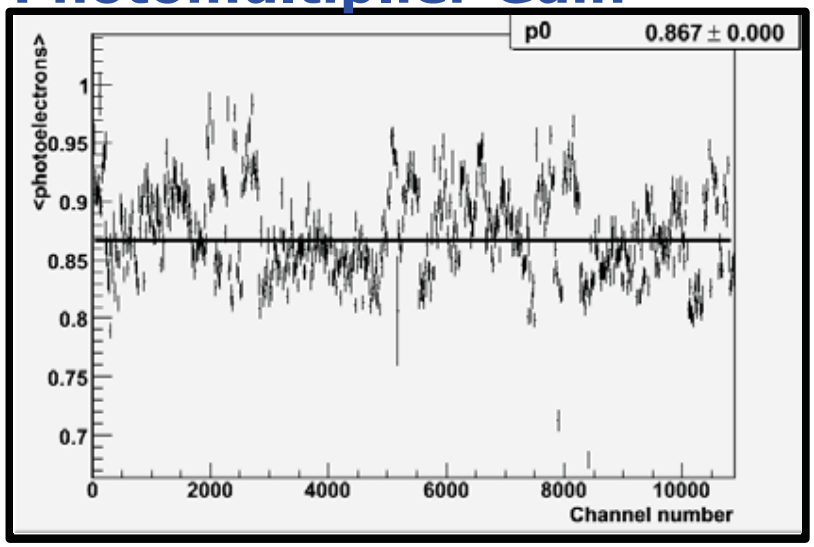
σ_β ~ 0.0014 -0.0015

Additional correction

Aerogel sub-tile uniformity



Photomultiplier Gain



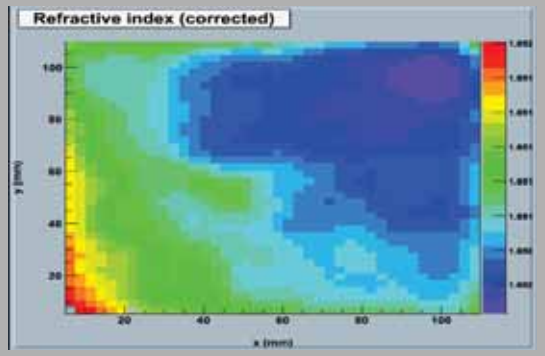
Additional correction (2)

Update the gains and relative efficiencies per channel

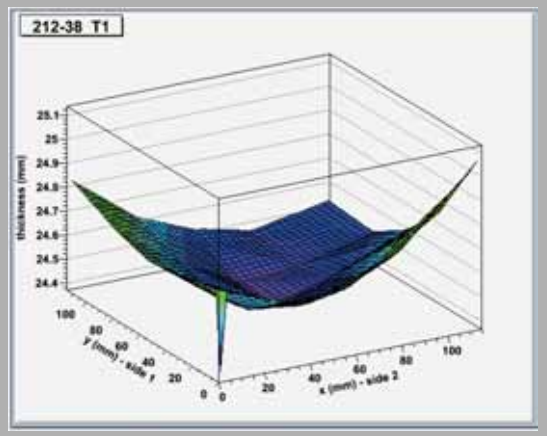
Additional correction (1)

The measured refractive index maps per tile must be included in the reconstruction software

Reflective index



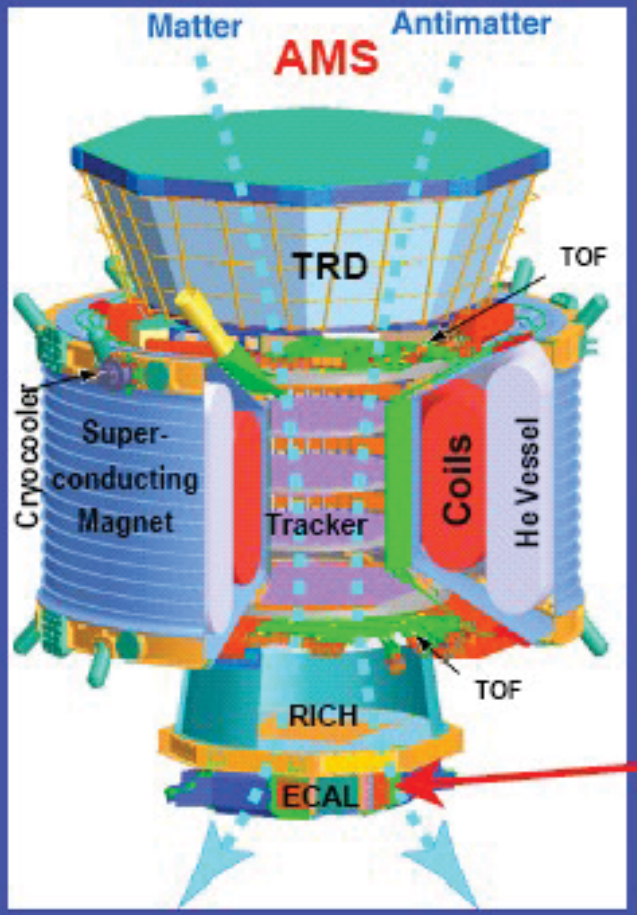
Thickness



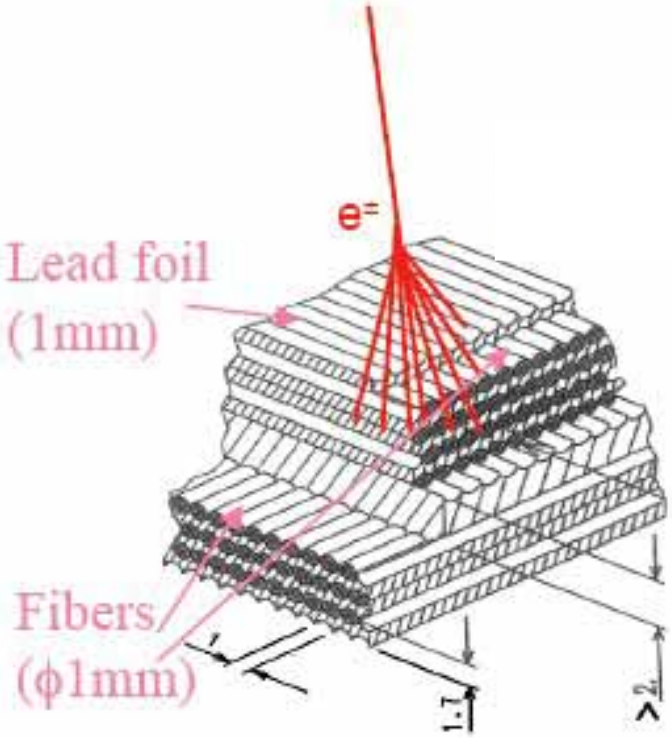
The Electromagnetic Calorimeter

Electromagnetic Calorimeter (ECAL)

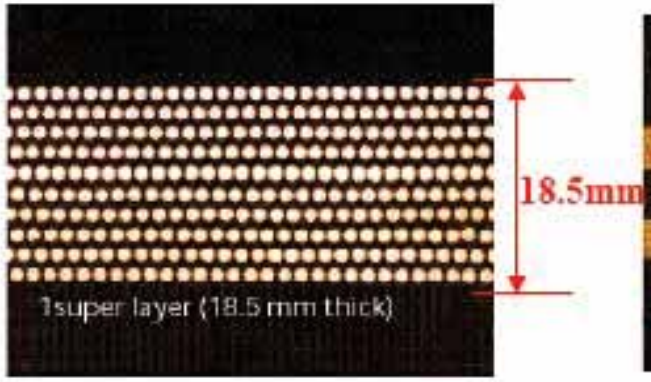
A precision 3-dimensional measurement of the directions and energies of light rays and electrons

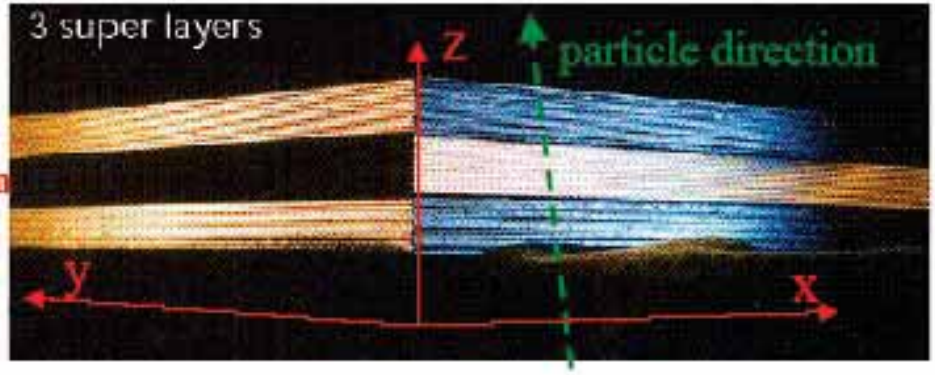


The ECAL detector



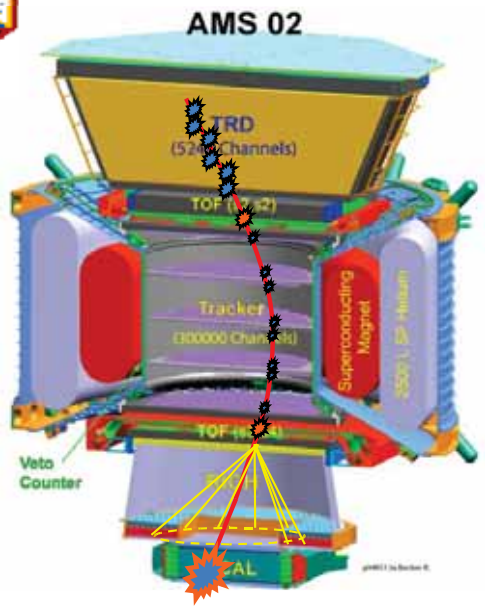
- Sampling calorimeter with lead foils and scintillating fibers
- Stack 9 superlayers with fibers which run

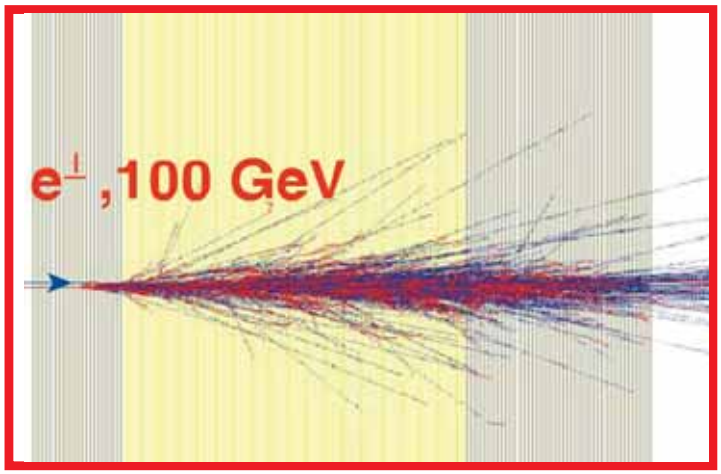




ECAL signal

Positron



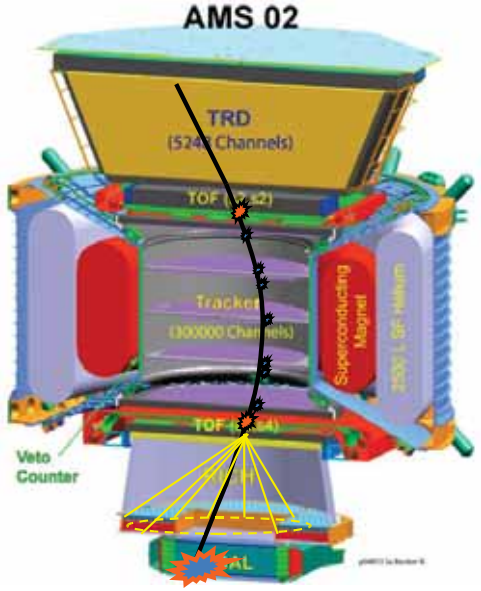


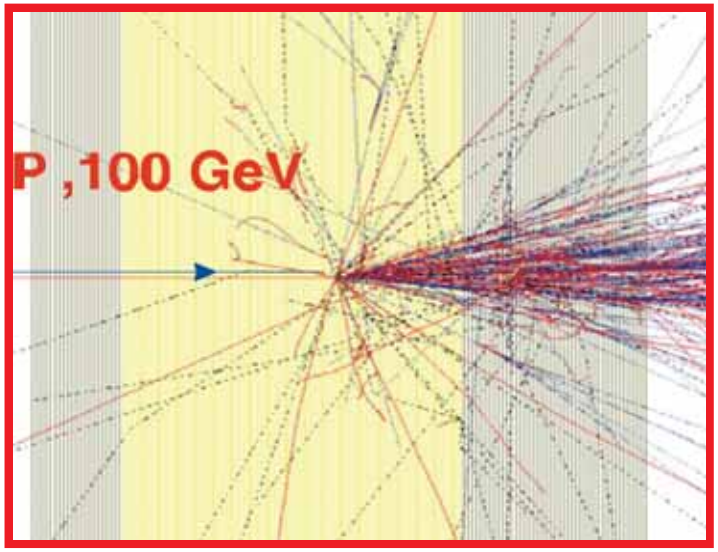
~16X_0

Electromagnetic shower:

- prompt
- known longitudinal profile
- recoverable leakage
- narrow
- strongly collimated

Proton





~1λ_I

Hadronic shower:

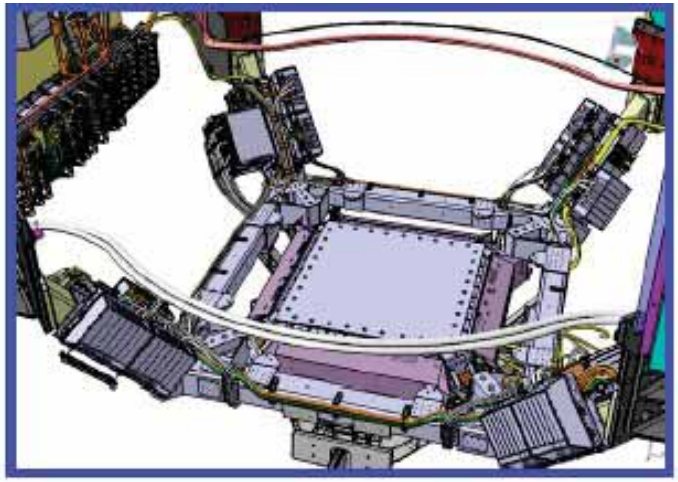
- not prompt
- wrong longitudinal profile
- unrecoverable leakage
- wide
- weakly collimated

Rejection factor ~10^3

Acceptance for e^+: ~0.045 sr m^2 from 3 to 300 GeV

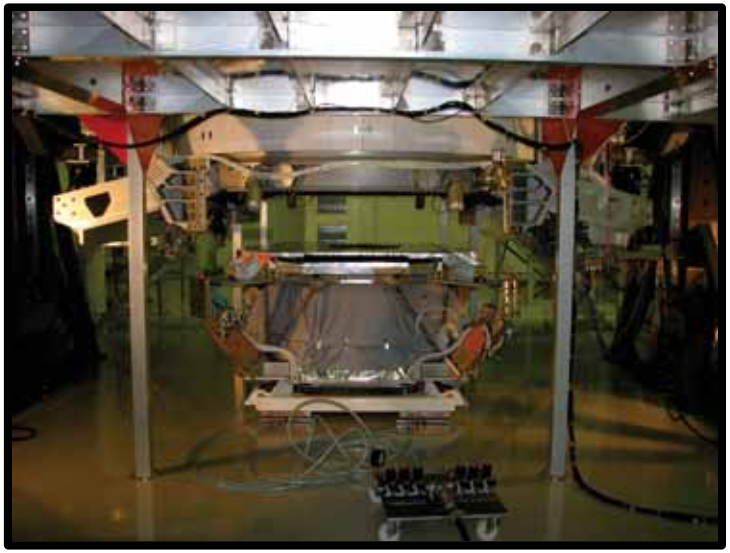
ECAL assembly & integration

ECAL INTEGRATION ON UNIVERSAL SUPPORT STRUCTURE (LUSS)

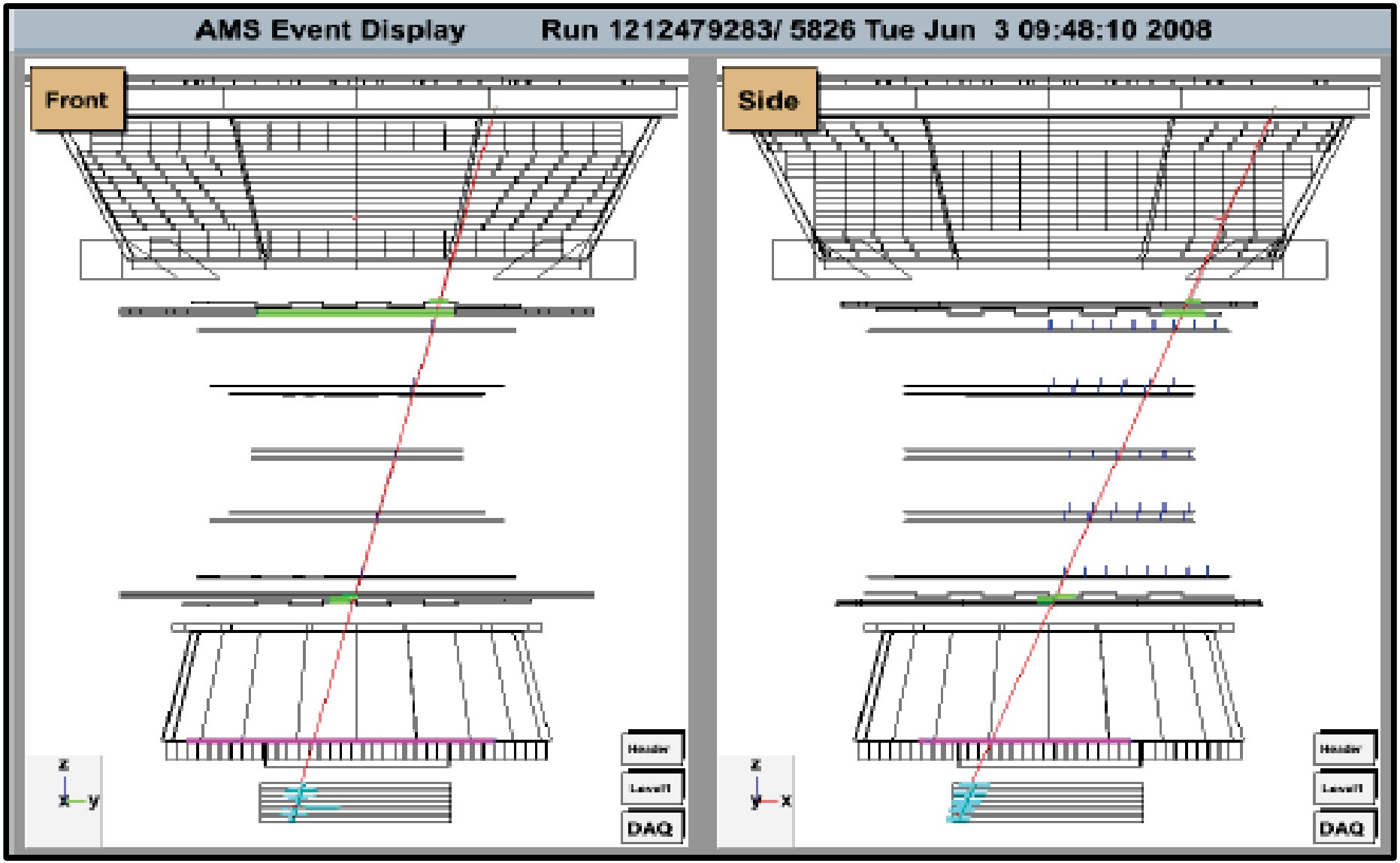


STUDIES OF CABLING AND INTEGRATION ON USSII

Lower USS integration

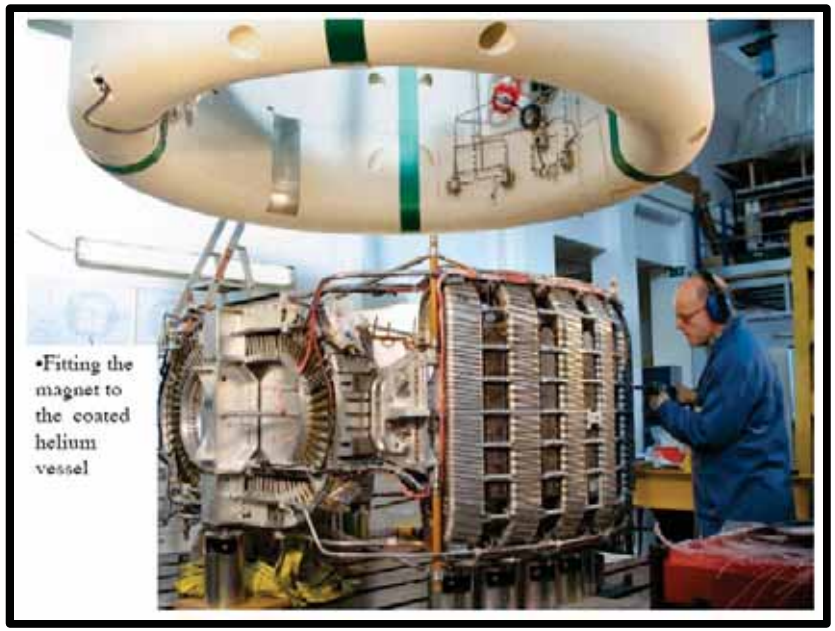


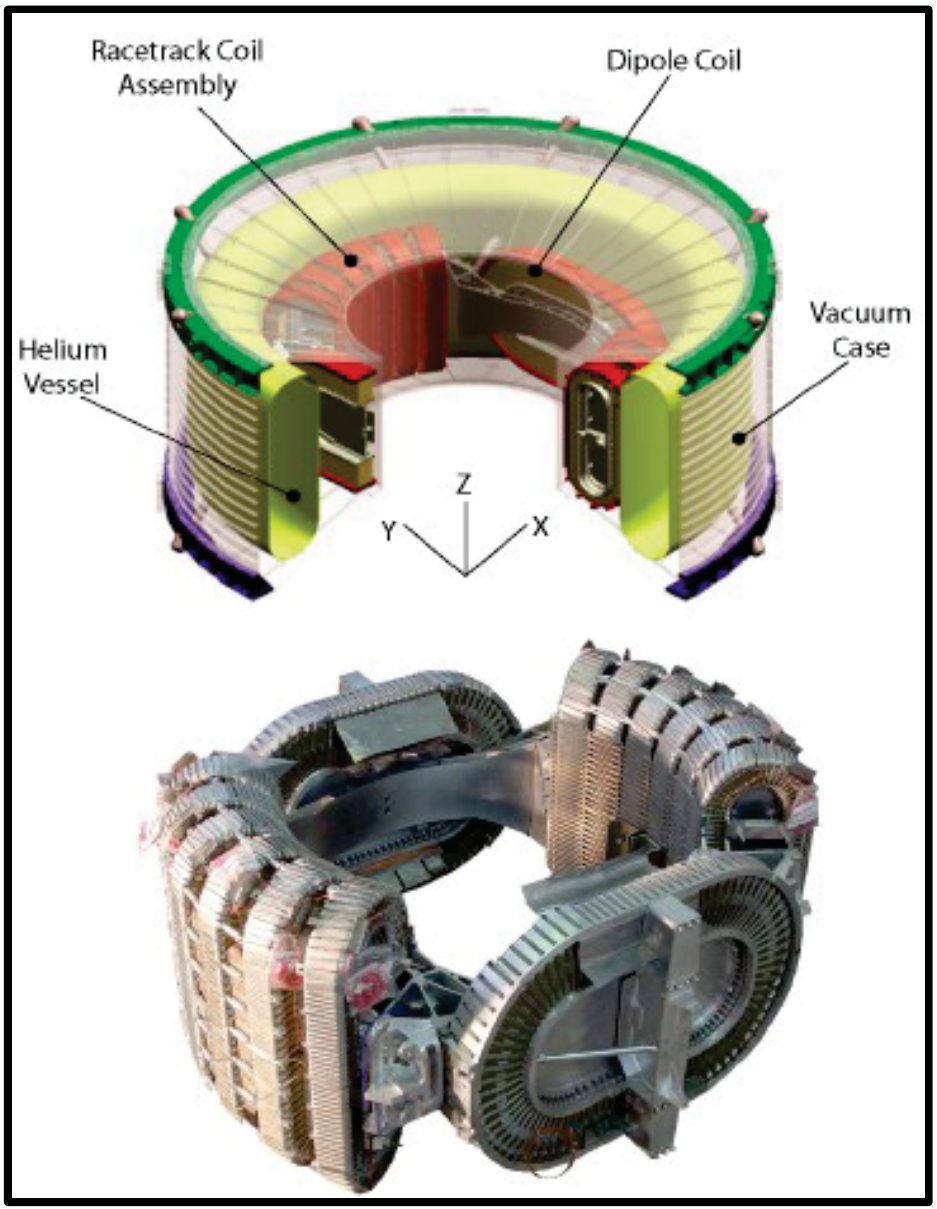
A muon track on AMS



The super conducting magnet

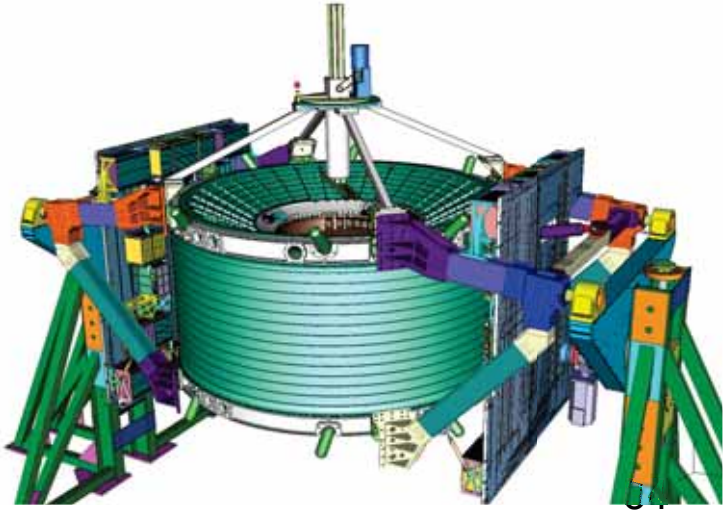
- 2 ‘dipole’ coil, 12 ‘racetrack’ coil
- B~0.8 T, 1.1 m inner diameter, 2360 Kg weight
- 55 Km of superconducting wire (NbTi/Cu embedded in pure aluminum)
- Indirect cooling with super-fluid helium (1.8 K)
- 2500 liters helium vessel plus cry-coolers for 3 years operation



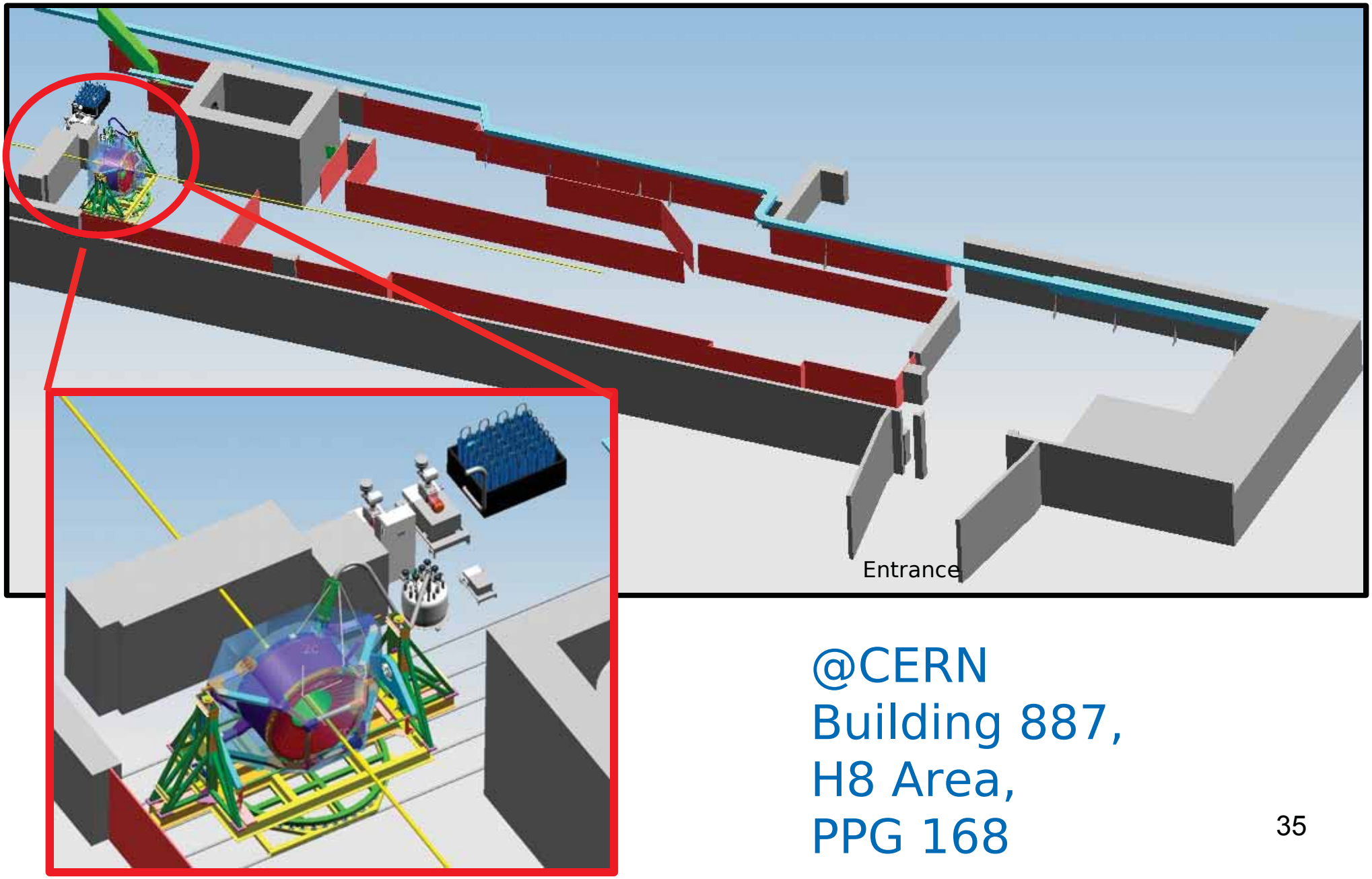


Flight integration schedule

- October 2008: delivery AMS Magnet at CERN
- AMS Magnetic field mapping
- Flight integration of the detectors till April 2009
- Test beam at CERN
- TVT and EMI at ESA/ESTEC
- Transport at KSC



AMS-02 Test beam



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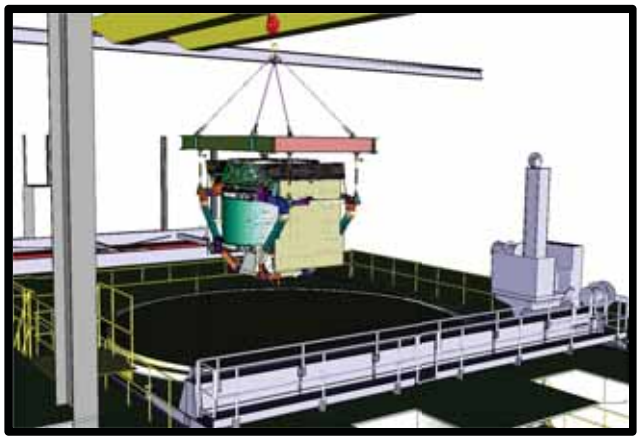
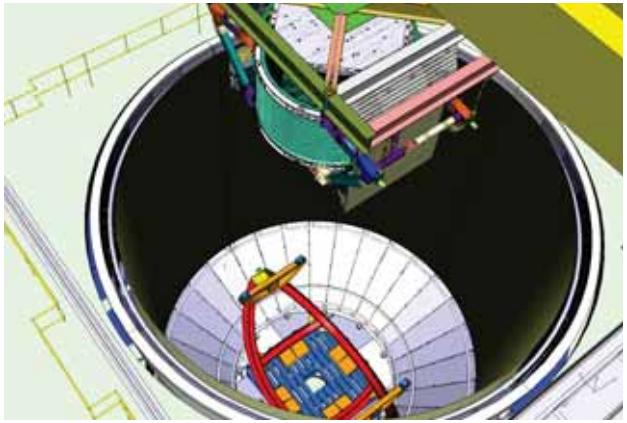
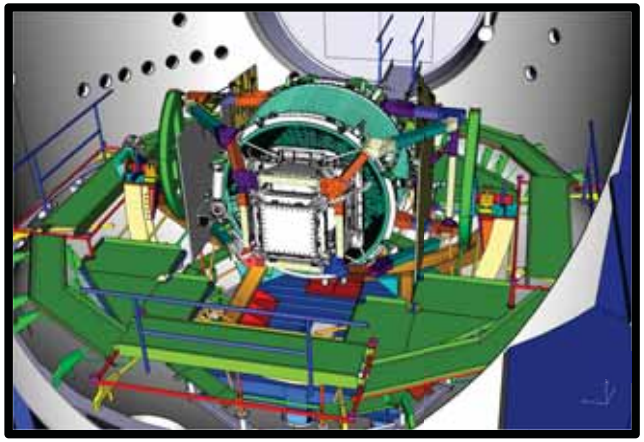
Building 887,
H8 Area,
PPG 168

AMS-02 Thermal Vacuum test

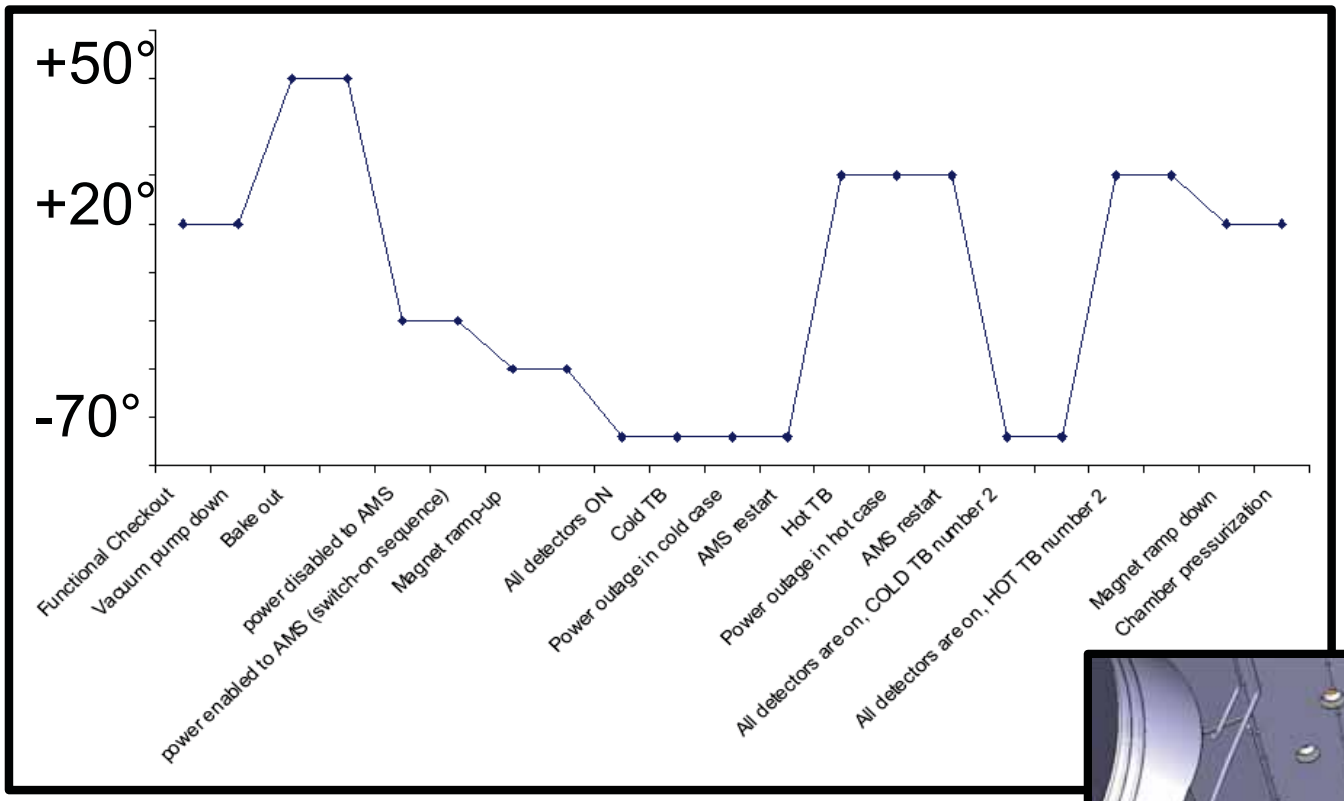
- For each detector, a cold and a hot environment will be provided for performance evaluation in vacuum
- Transition between hot and cold
- Model correlation





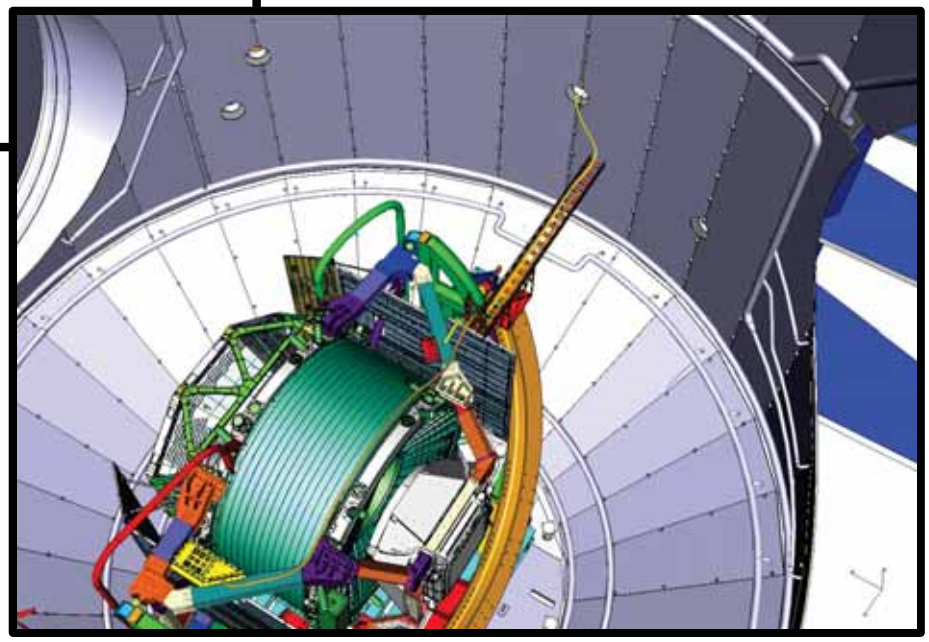


Thermal Test sequence_



The working pressure during the test shall be less than 1x10-5 Torr.

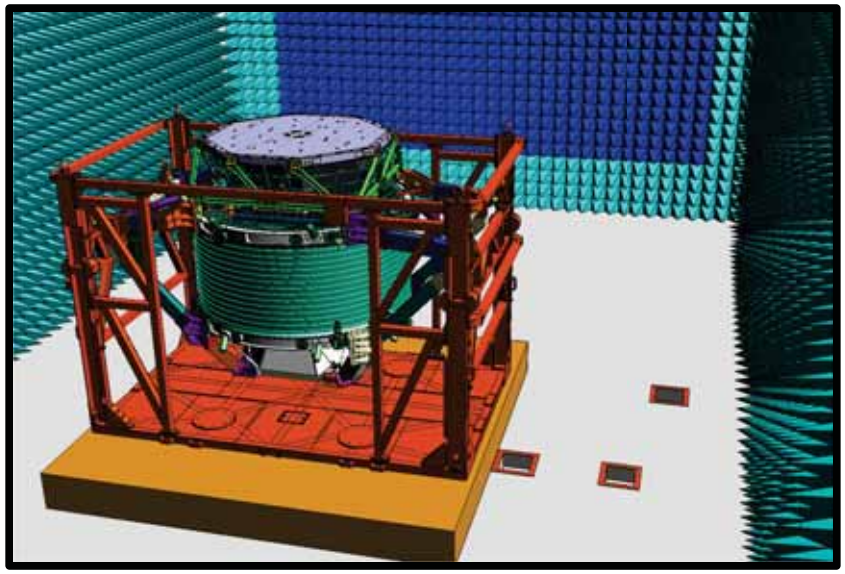
30 days + 12 days contingency are foreseen as actual test duration.

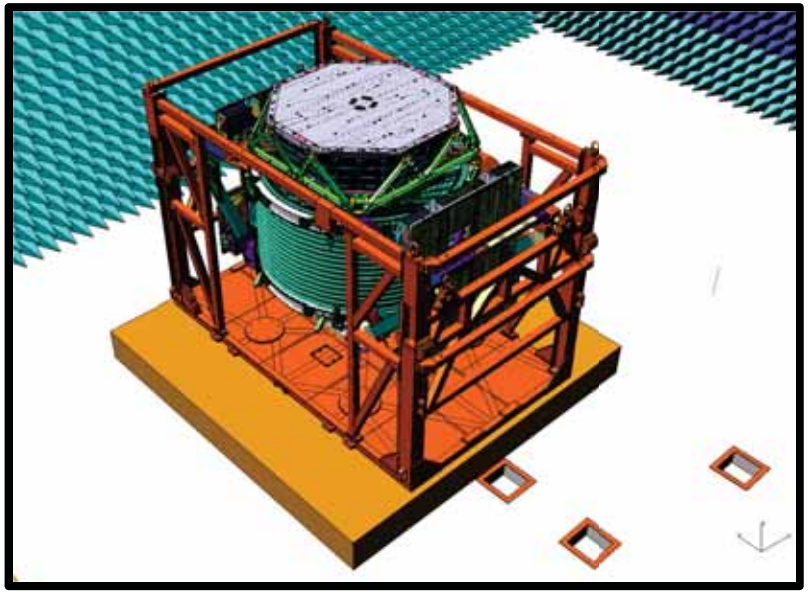


EMI Test at Estec_

EMI Testing of AMS-02 is required to ensure Electromagnetic Compatibility (EMC) with:

- Shuttle Transportation System (STS) Orbiter
- International Space Station (ISS)





Test Plan Objective

- AMS-02 performance is not adversely affected by the expected EMI environment of ISS.
- AMS-02 will not generate EMI that will adversely affect ISS systems.
- AMS-02 will perform as intended during exposure to all applicable EMI environments.

Shuttle missions to the ISS

Mission #	NET Date
✓ STS-114	Jul 2005
✓ ULF 1.1/STS-121	Jul 2006
✓ 12A/STS-115	Sep 2006
✓ 12A.1/STS-116	Dec 2006
✓ 13A/STS-117	Jun 2007
✓ 13A.1/STS-118	Aug 2007
✓ 10A/ STS-120	Oct 2007
✓ 1E/ STS-122	Feb 2008
✓ 1J/A/ STS-123	Mar 2008
✓ 1J/ STS-124	May 2008
HST-SM4/STS-125	Oct 2008
ULF2/STS-126	Nov 2008
15A/ STS-119	Feb 2008

Mission #	NET Date
2J/A/ STS-127	May 2009
17A/ STS-128	Jul 2009
Six person Crew	
ULF3/ STS-129	Oct 2009
19A/ STS-130	Dec 2009
ULF4/ STS-131	Feb 2010
20A/ STS-132	Apr 2010
ULF 5/ STS-133	May 2010

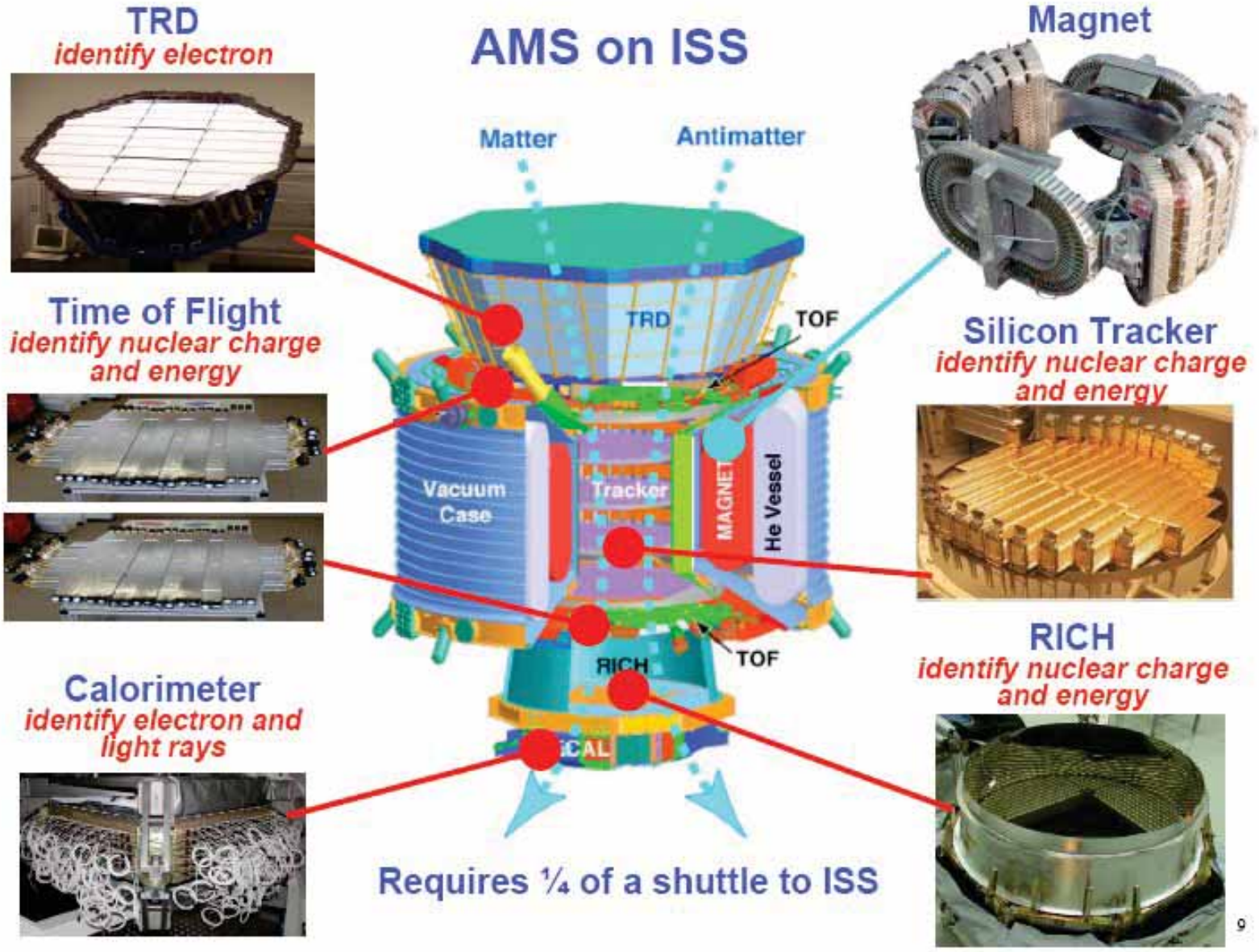
*NOTE:
Dates for missions after STS-126 are currently being reviewed.

Congress is considering a plan for one additional flight in the first half of 2010, a mission to carry the AMS experiment to the space station.

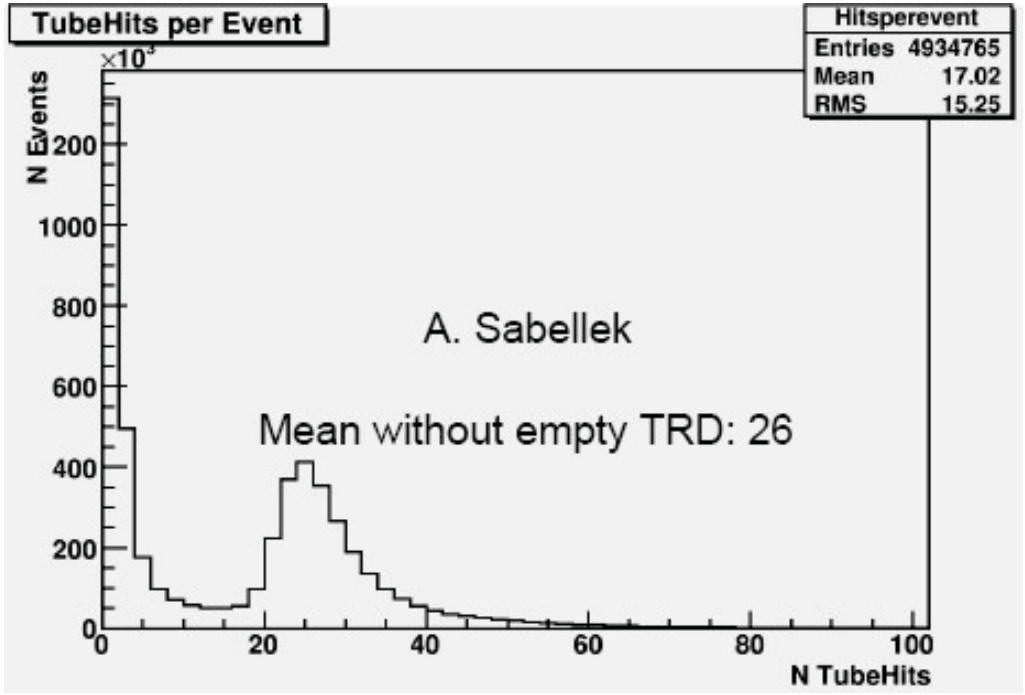
Outlook & Conclusions

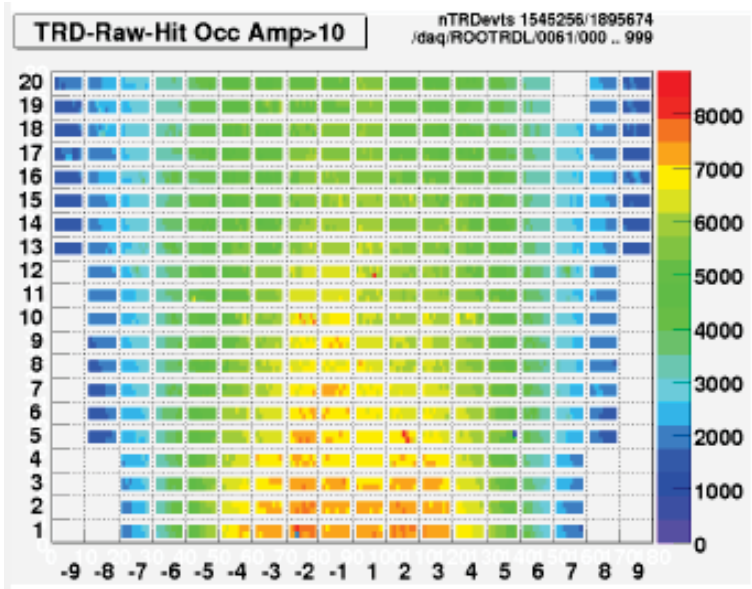
- AMS has been successfully pre-integrate;
- All the detectors are working as expected;
- In October 2008 after magnet arrival, flight integration will start;
- Space qualification tests will be in 2009;
- NASA shuttle program is ‘back on track’, possibly an additional flight for AMS;
- PAMELA will give important inputs to AMS-02;
- AMS-02 will provide CR measurements of excellent precision starting from 2010.

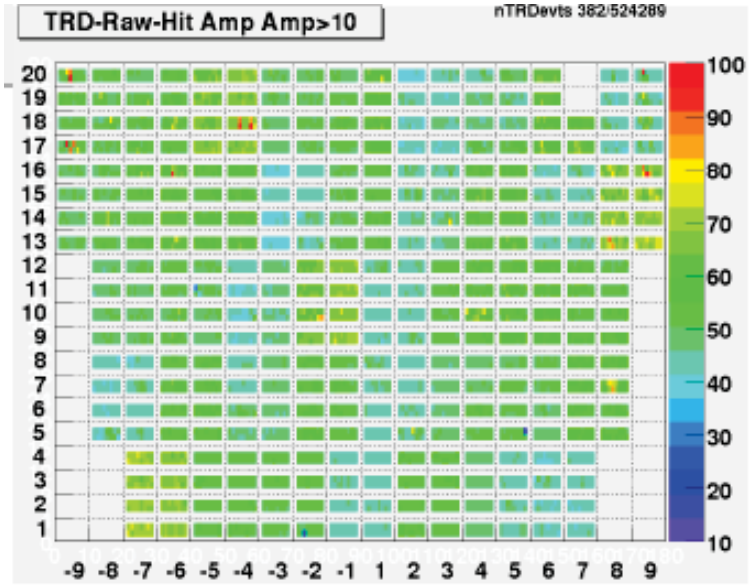
AMS-02


TRD
identify electron
AMS on ISS
Matter
Antimatter
Magnet
Time of Flight
identify nuclear charge
and energy
TRD
TOF
Silicon Tracker
identify nuclear charge
and energy
Vacuum
Case
Tracker
MAGNET
He Vessel
RICH
identify nuclear charge
and energy
TOF
RICH
Calorimeter
identify electron and
light rays
CAL
Requires ¼ of a shuttle to ISS

AMS-02 TRD


TubeHits per Event
Hitsperevent
Entries 4934765
Mean 17.02
RMS 15.25
×10³
N Events
A. Sabellek
Mean without empty TRD: 26
N TubeHits


TRD-Raw-Hit Occ Amp>10
nTRDevts 1545256/1895674
/daq/ROOTRDL/0061/000 .. 999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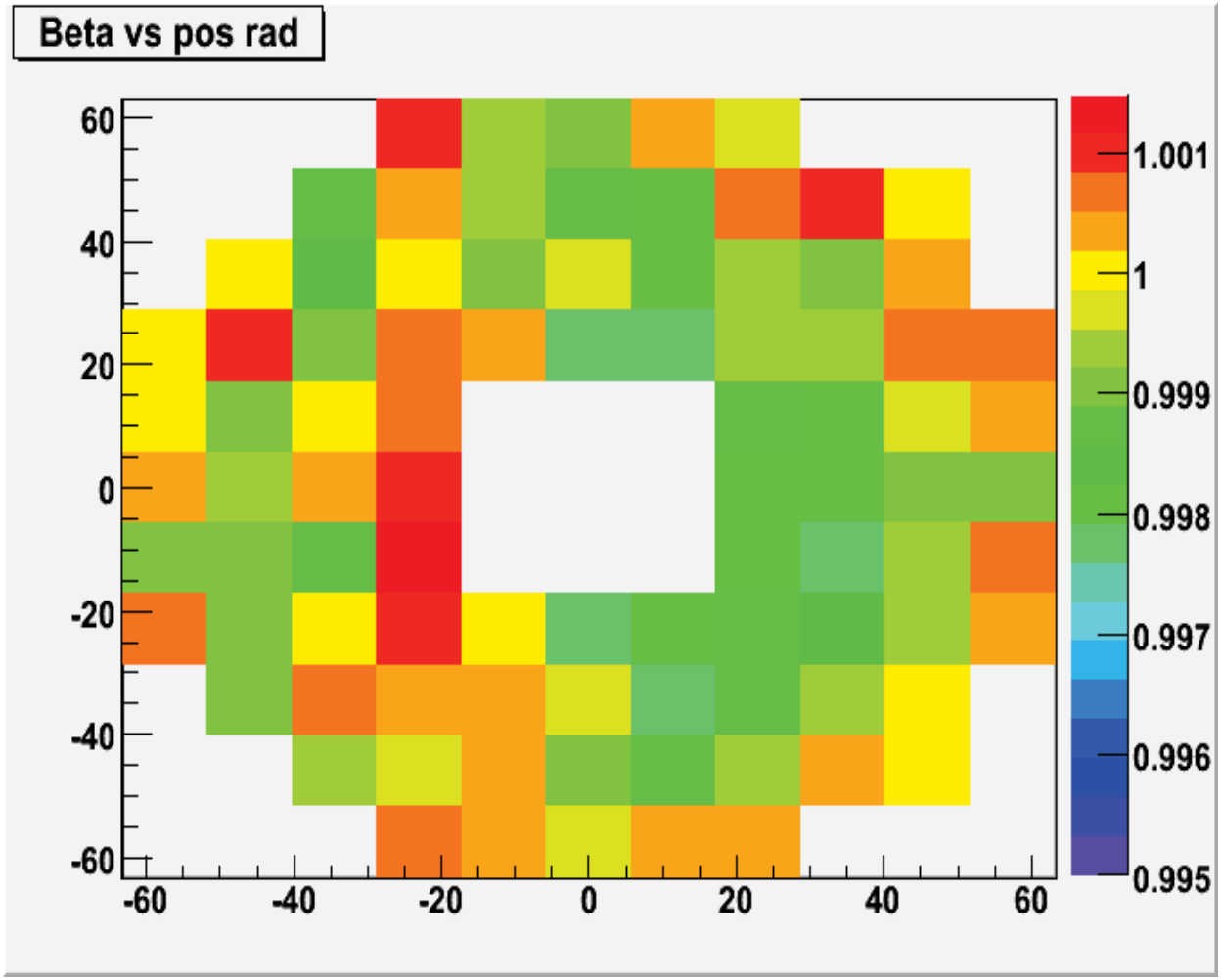
nTRDevts 382/524289

First correction

Independent refractive index per tile on the radiator



AMS-02 Test beam

H8 beam characteristics

- Proton energy-up to 300 GeV
- Pion energy-up to 350 Gev
- Electron energy-up to 150 GeV and can be as low as 1 GeV.