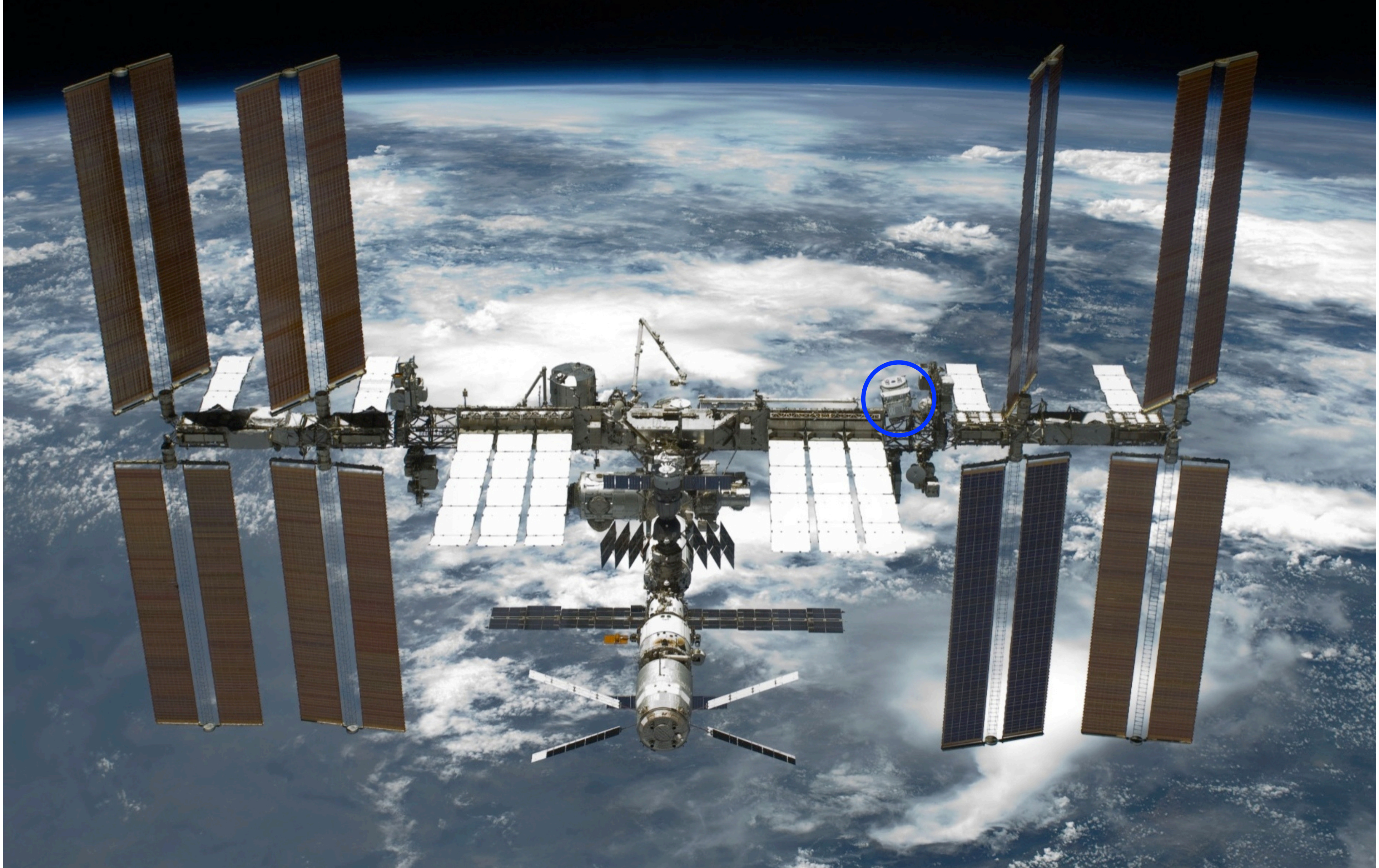
The Alpha Magnetic Spectrometer (AMS) Experiment

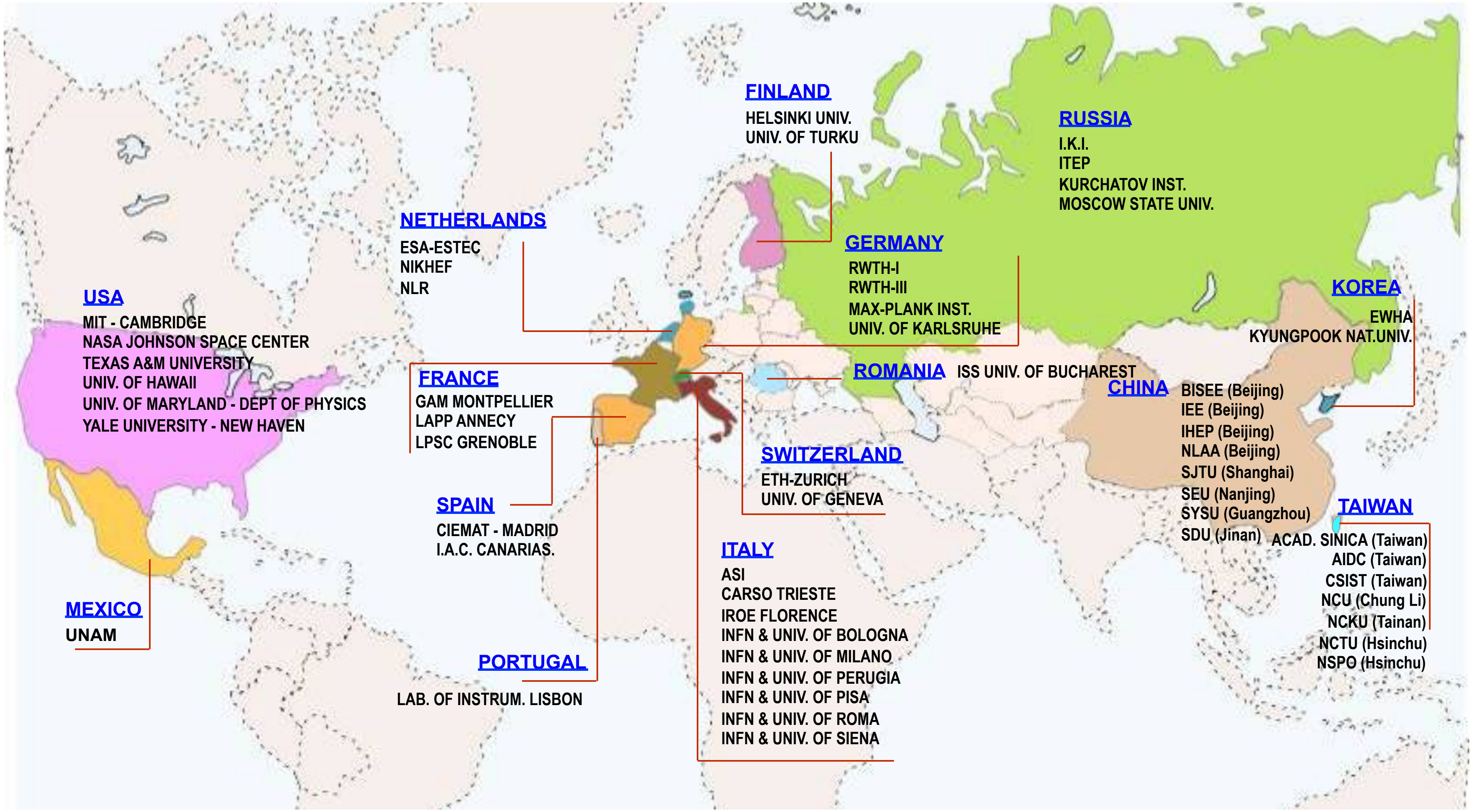


A. Contin on behalf of the AMS Collaboration

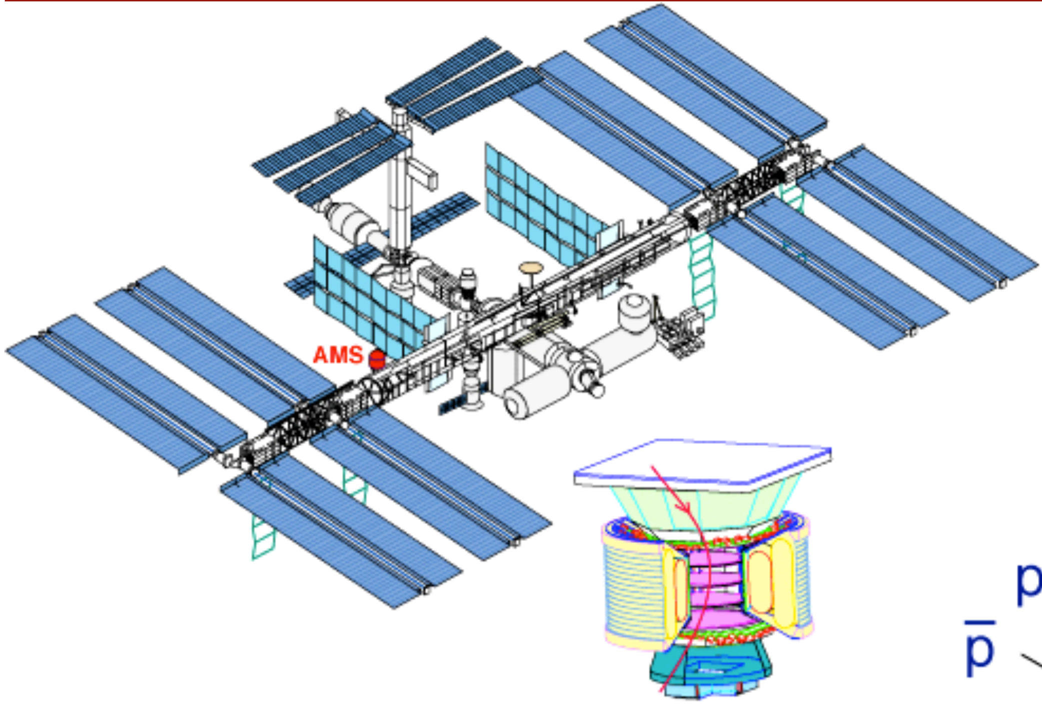
ICTP, 28/6/2013

The Collaboration

16 Countries, 60 Institutes and 600 Physicists



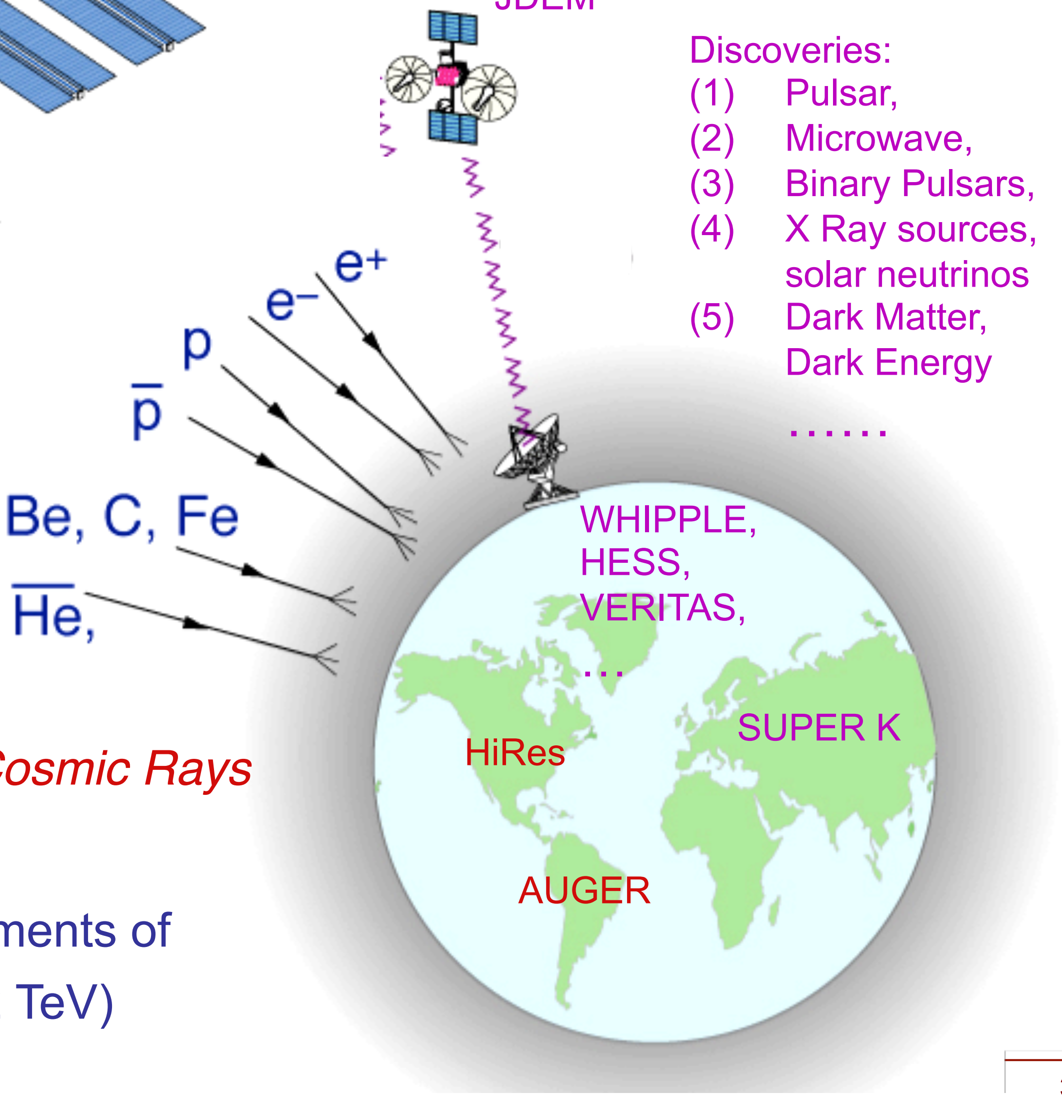
Why on space?



1- Neutral component: γ,ν

Hubble, Chandra, GLAST, JWST, JDEM

Discoveries:
(1) Pulsar,
(2) Microwave,
(3) Binary Pulsars,
(4) X Ray sources, solar neutrinos
(5) Dark Matter, Dark Energy
……



2- Charged component: He, Be, C, Fe

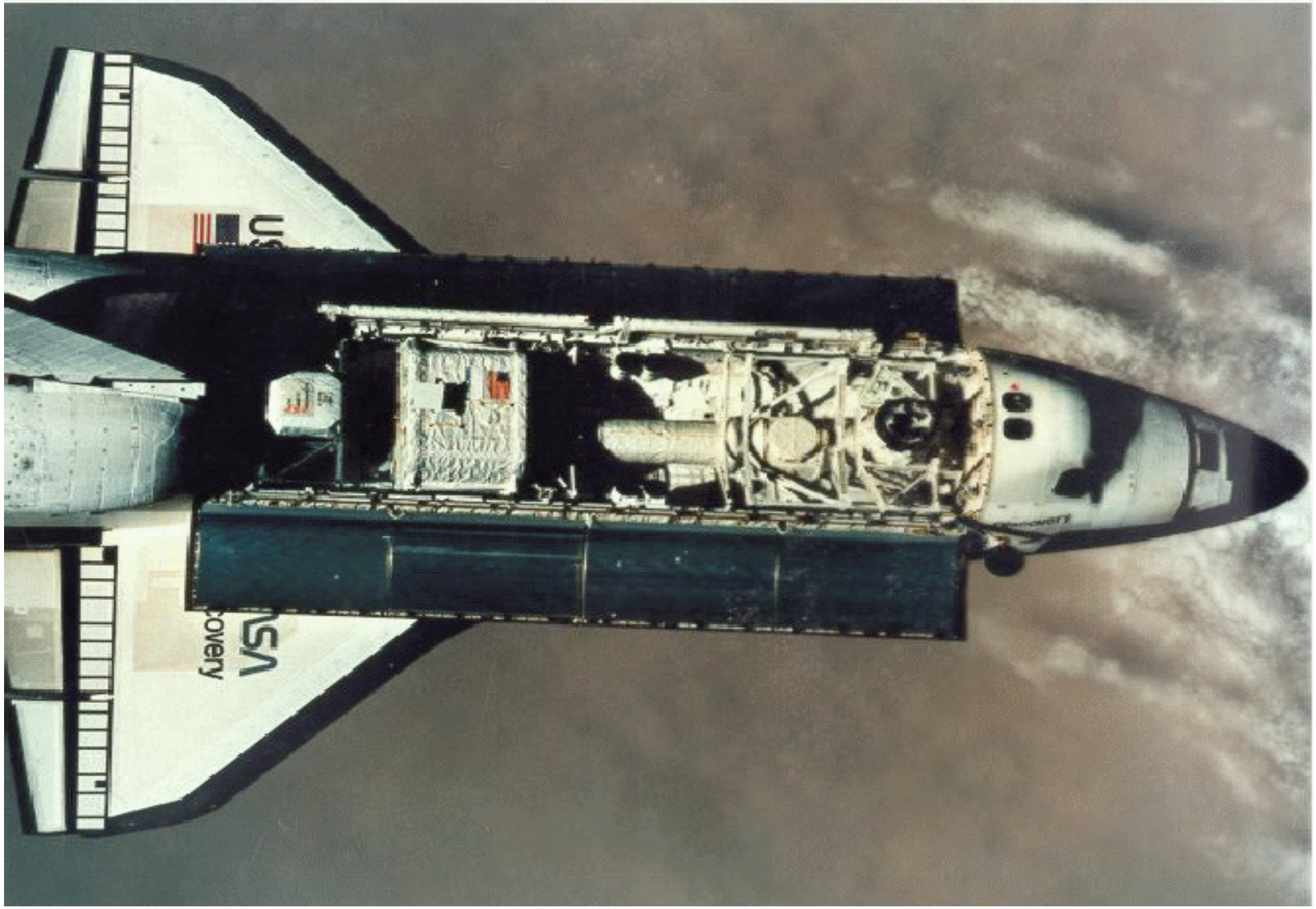
The highest energy particles are in Cosmic Rays

AMS will perform accurate measurements of energetic cosmic rays (0.3 GeV to 2 TeV)

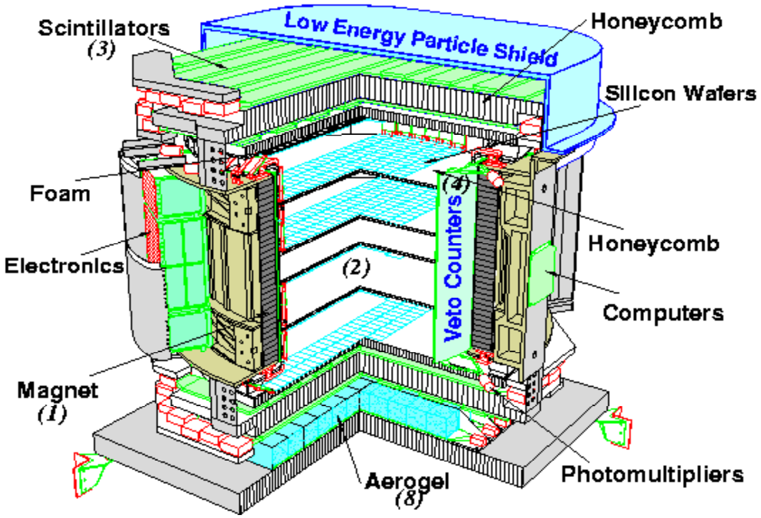
AMS Physics

- To search for Antimatter ($\overline{He}$,$\overline{C}$) in space with a sensitivity of 10^3 to 10^4 better than current limits.
- To search for dark matter
  - High statistics precision measurements of $e^{\pm}$, γ and $\overline{p}$ spectrum.
- To study Astrophysics.
  - High statistics precision measurements of D, ^{3}He, ^{4}He, B, C, ^{9}Be, ^{10}Be spectra
  - B/C: to understand CR propagation in the Galaxy (parameters of galactic wind).
    - ^{10}Be/^{9}Be: to determine CR confinement time in the Galaxy.

AMS-01 on Discovery during STS-91 Flight (June 1998)



AMS-01: STS-91 Flight Results



G.F.: ≈ 3000 cm^2.sr
MDR: ≈ 400 GV
Energy Range:
100 MeV/n<E_k< 300 GeV/n
Electronics channels: ≈ 70000
Power: ≈ 1 kW

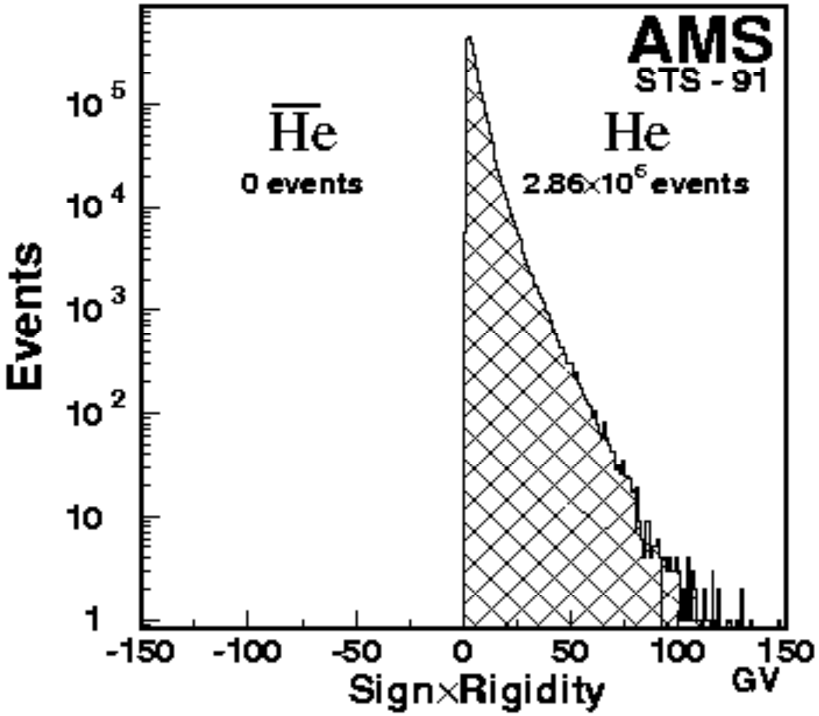
- ≈30 hours before and ≈105 hours after rendezvous with MIR (total of ≈135 hours including ≈11 hours of albedo measurements)
- Shuttle altitude ranged from 320 to 390 km
- Latitudes ±51.7°, All longitudes (except S.A.A.)
- A total of 100 million events recorded with event rates ranging from 100 Hz to 700 Hz (corresponding to 95%÷40% DAQ livetime)

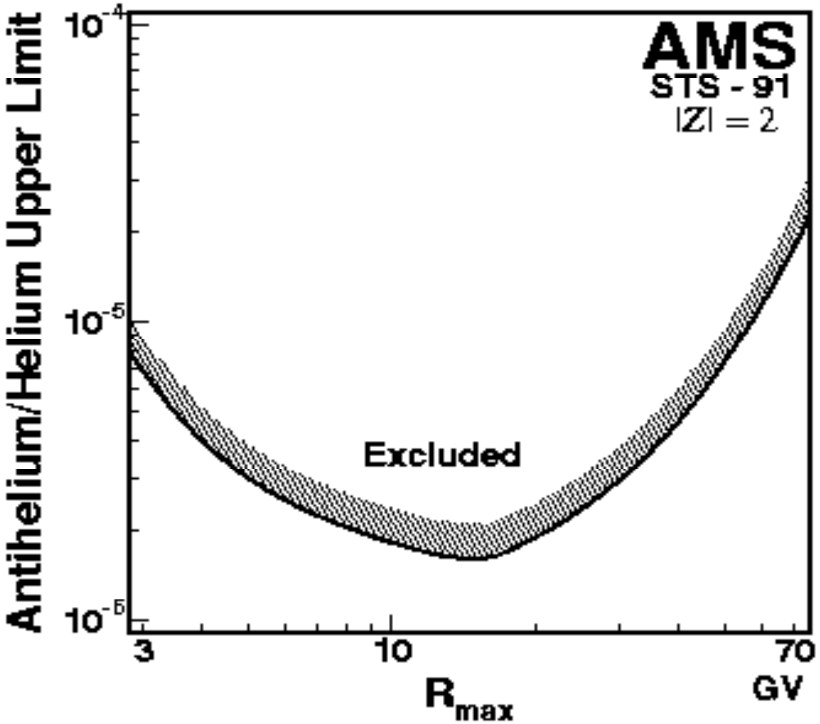
AMS-01: STS-91 Flight Results (2)

It was a successful flight !!

- Detector test in actual space conditions
  - Good performance of all subsystems
- Physics results:
  - Antimatter search
  - Charged cosmic ray spectra (p, $e^{\pm}$, D, He)
  - Geomagnetic effects on cosmic ray

AMS-01 STS-91 Flight Physics Results (1)





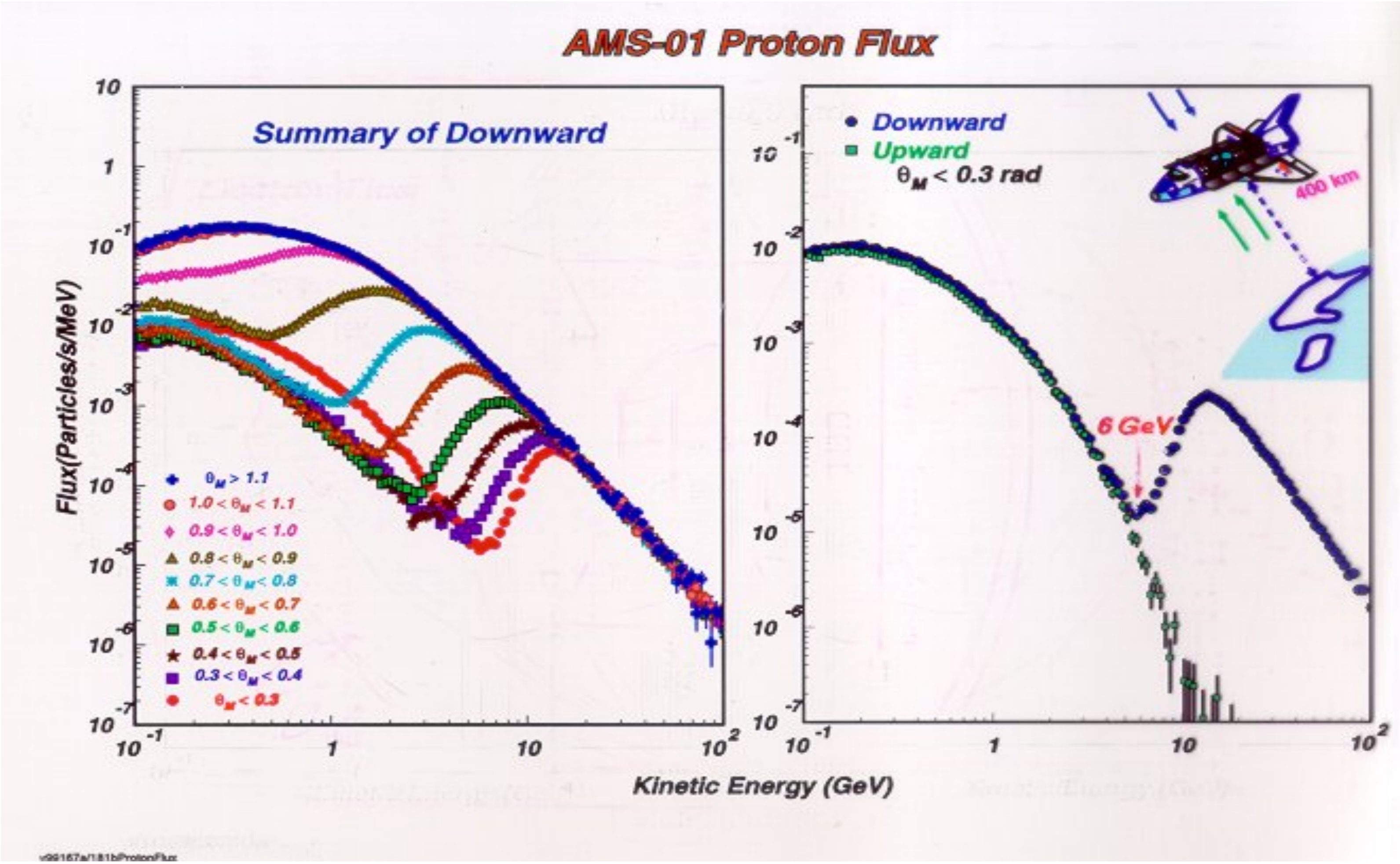
$N_{\overline{He}}/N_{He} = 1.1\mathrm{x}10^{-6}$

Same spectrum for He, $\overline{\mathrm{He}}$

(Ref. Phys. Lett. B461(1999)387-396)

Any Spectrum from $\overline{\mathrm{He}}$

AMS-01 STS-91 Flight Physics Results (2)



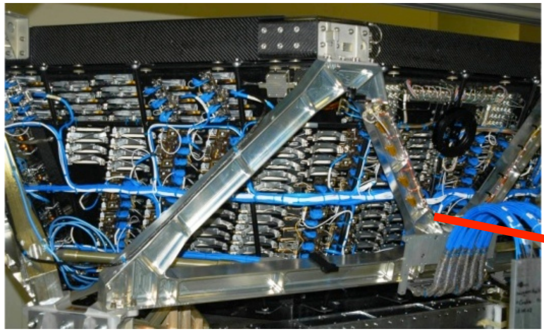
(Ref. Phys. Lett. B472(2000)215-226)

AMS-02 - Detector purpose

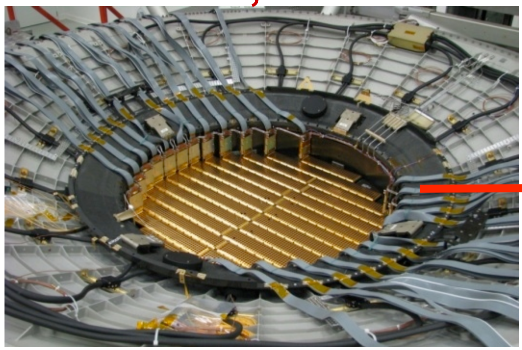
	e^-	p	He,Li,Be,..Fe	γ	e^+	$\bar{p}$, $\bar{D}$	$\overline{He}$, $\bar{C}$
TRD							
TOF							
Tracker							
RICH							
ECAL							
Physics example	Cosmic Ray Physics Strangelets				Dark matter		Antimatter

The first AMS-02

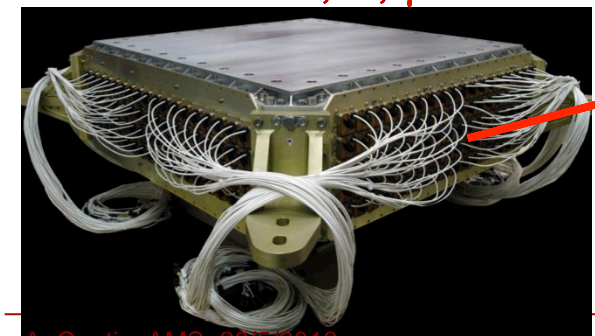
TRD
Identify e^+, e^-

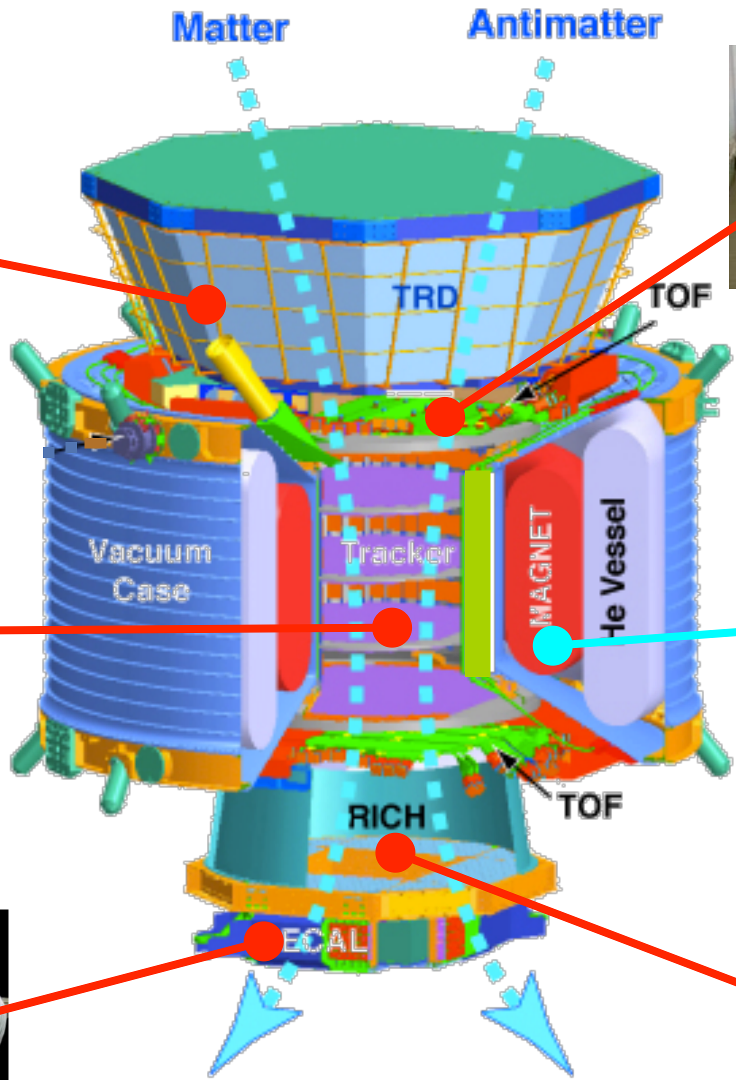


Silicon Tracker
Z, P



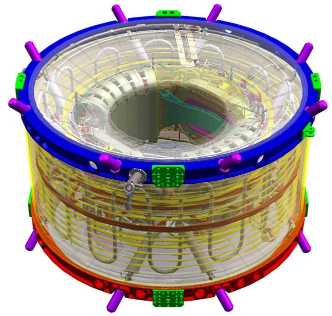
ECAL
E of e^+, e^-, γ



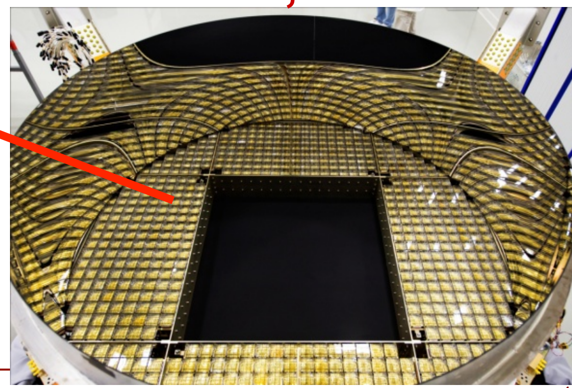


TOF
Z, E

Magnet
±Z

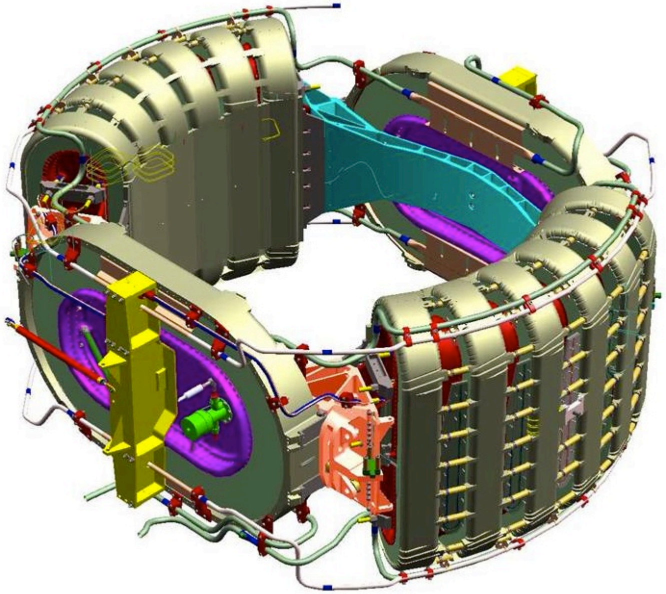


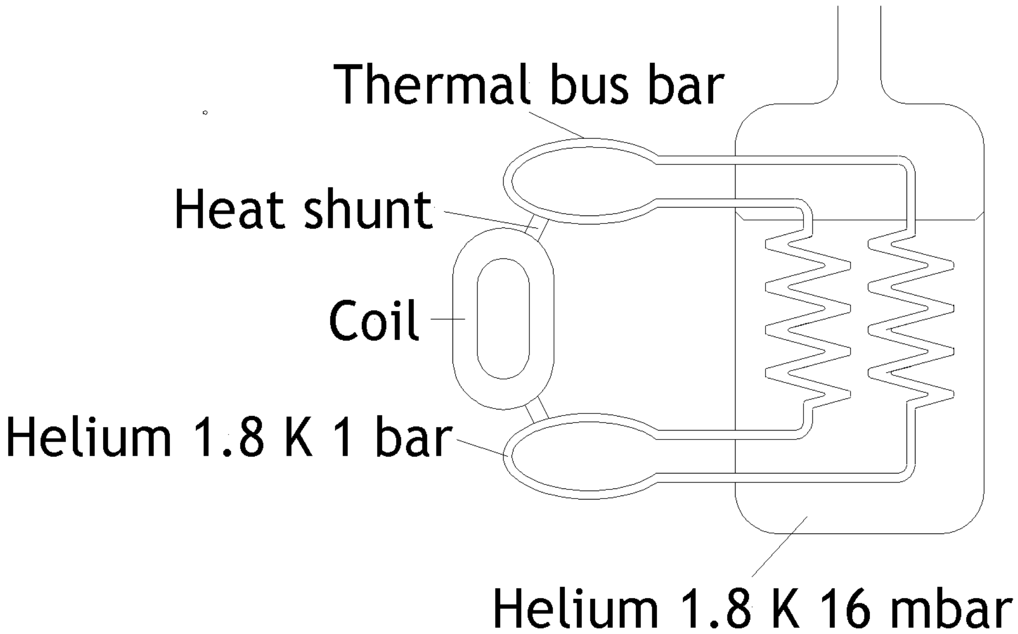
RICH
Z, E



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

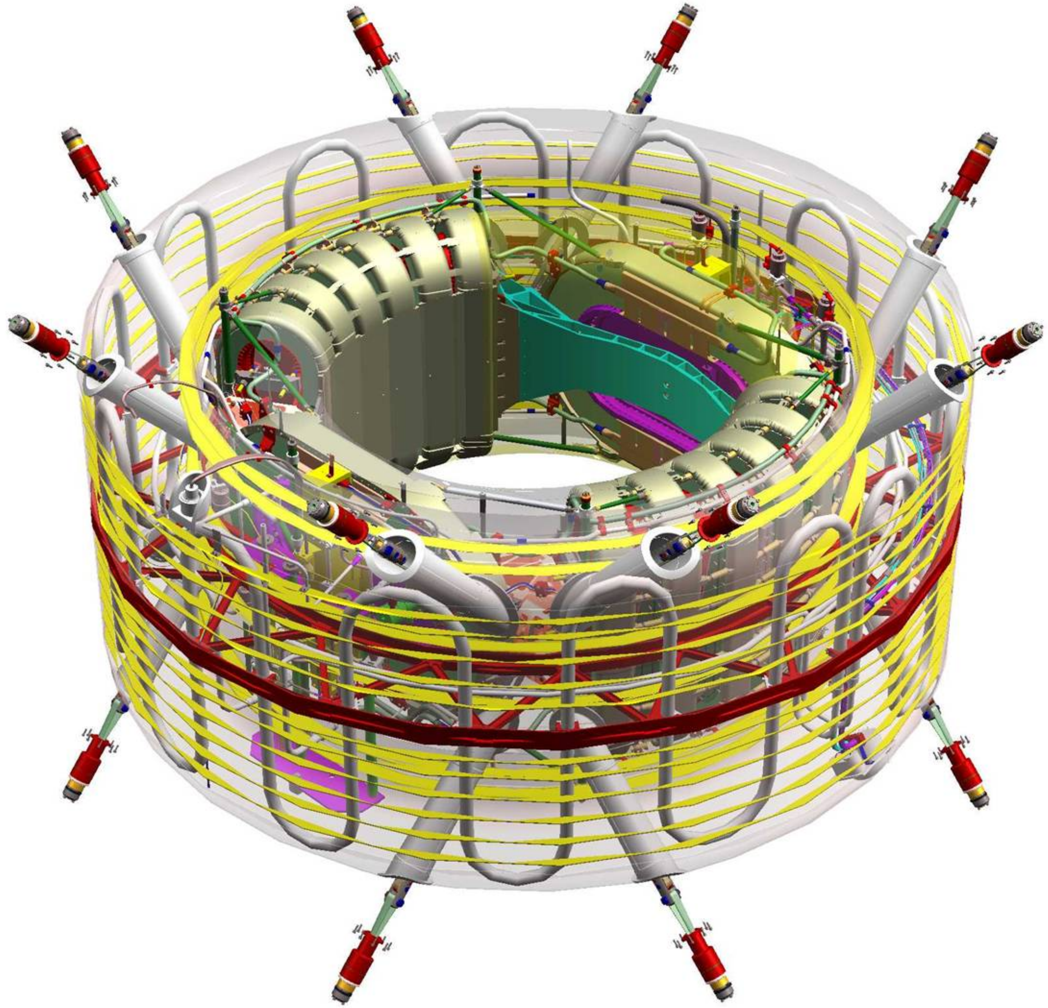
- The coils are cooled to a temperature of 1.8 K by a system of pipes…



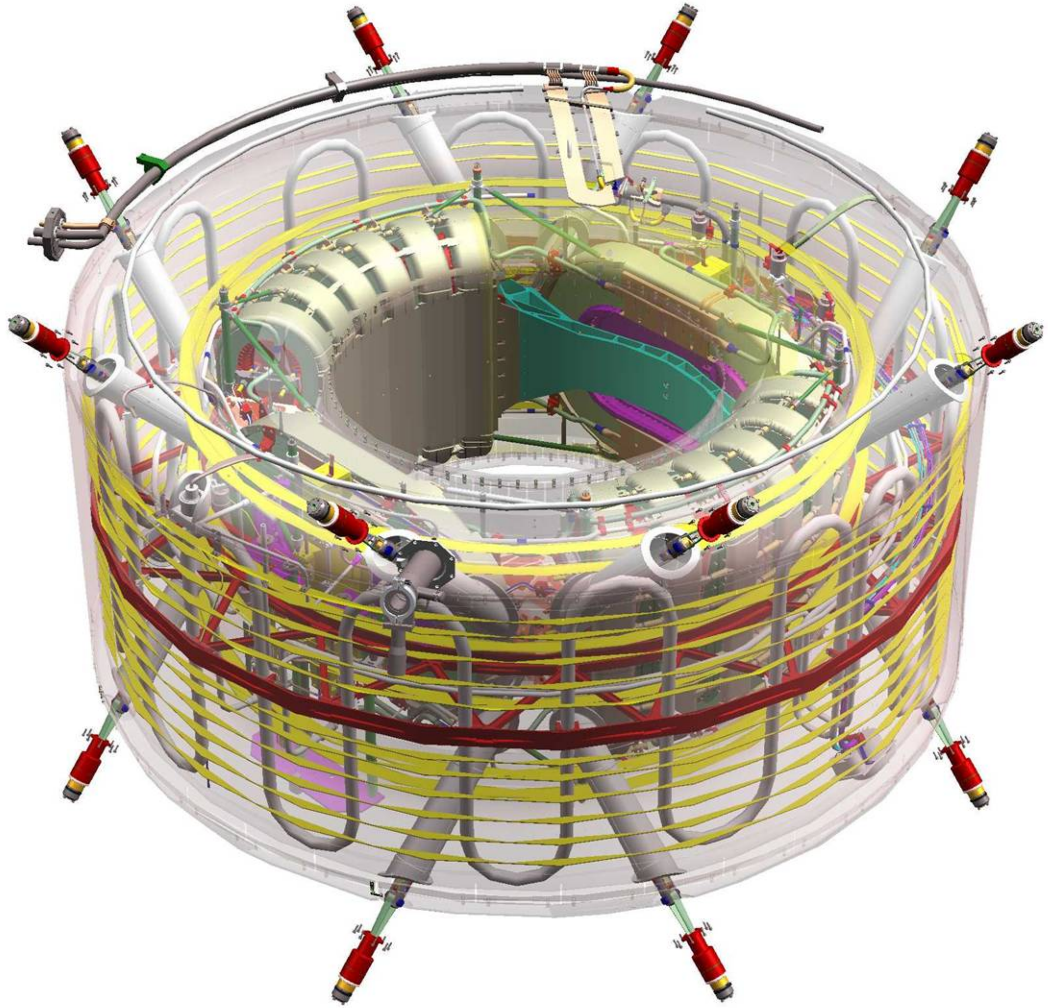


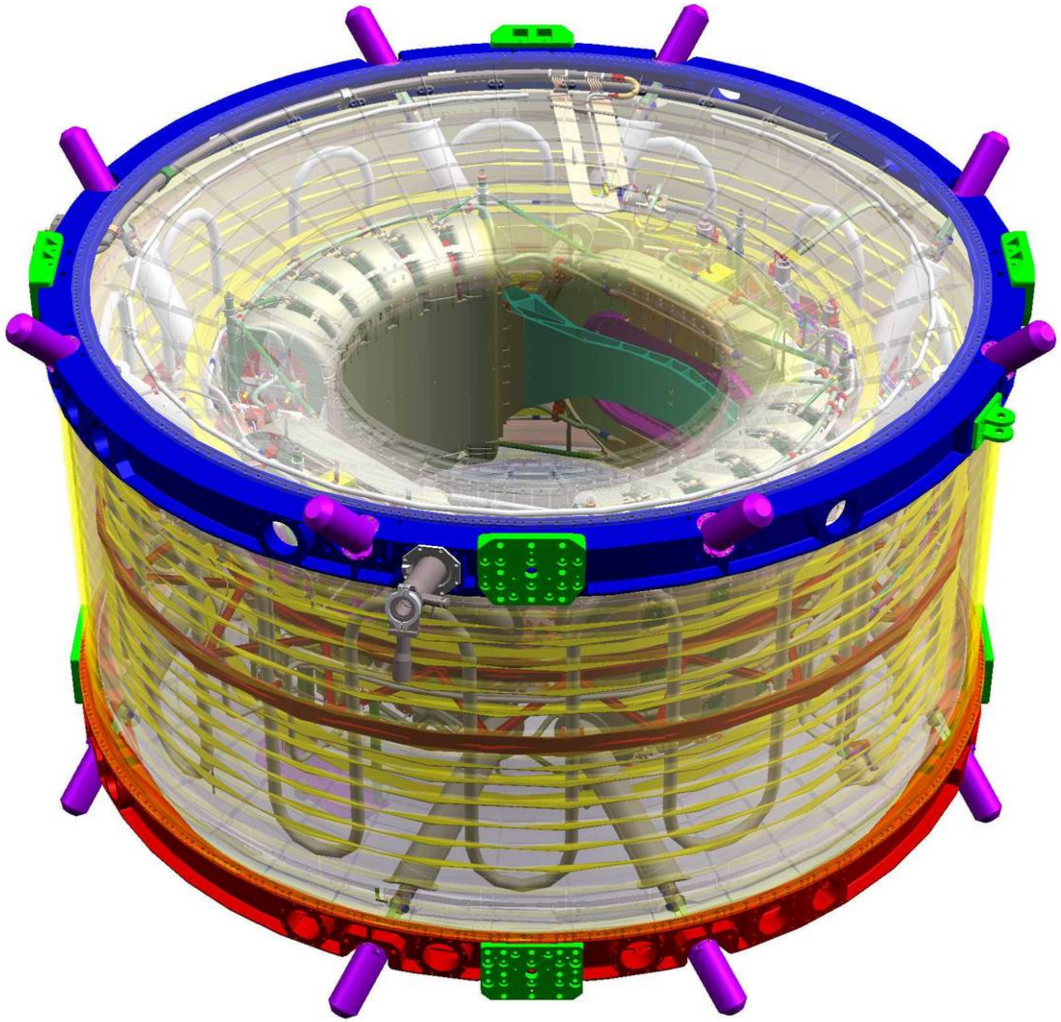
•…connected to a 2500 litre superfluid helium tank.

•The cold mass is suspended from a system of 16 composite straps.



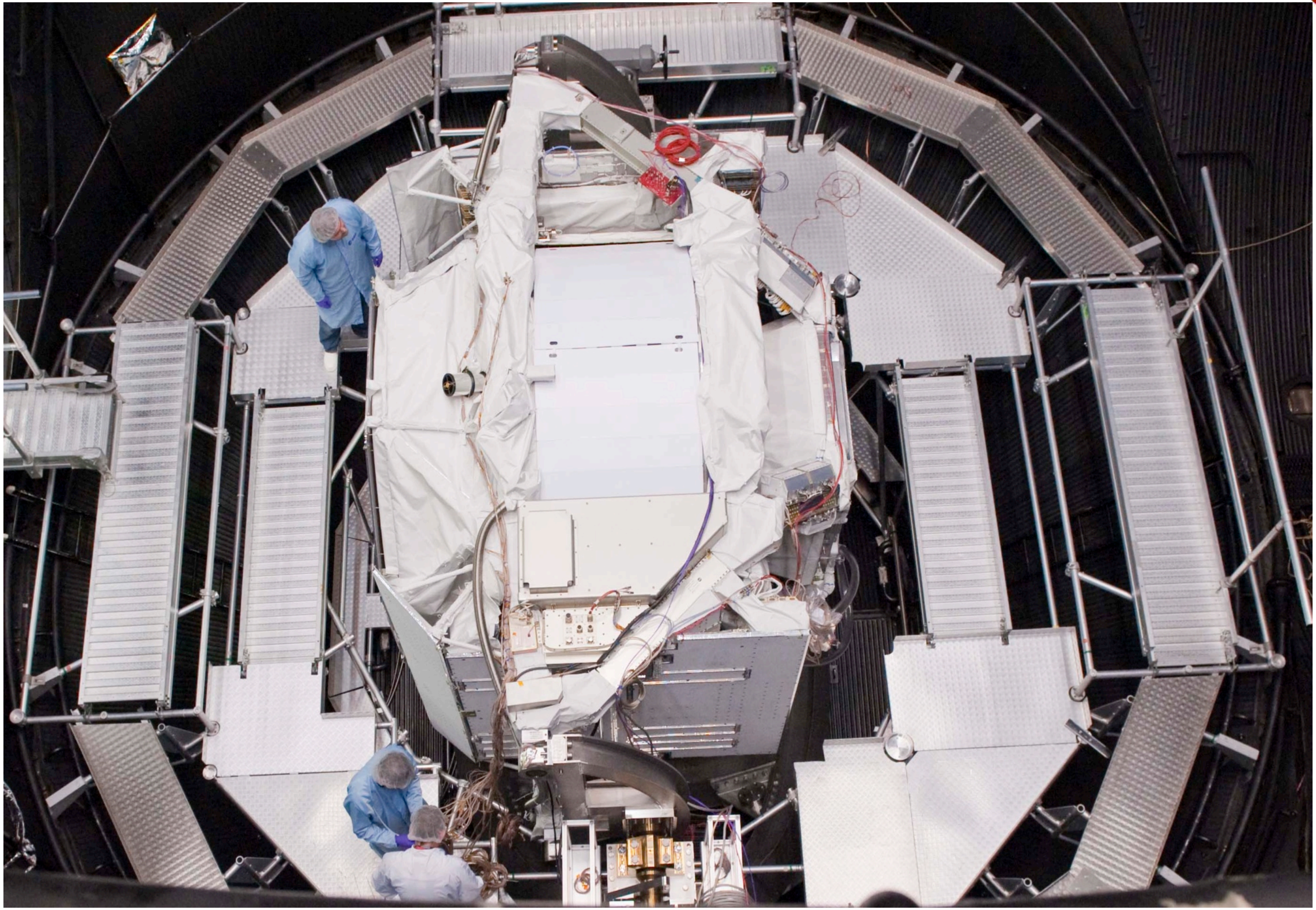
•The coils and helium vessel are enclosed in radiation shields and multi-layer superinsulation.





•All components are suspended within a vacuum tank.

AMS-02 in the ESA – ESTEC thermal vacuum chamber



Permanent magnet

April 2010:

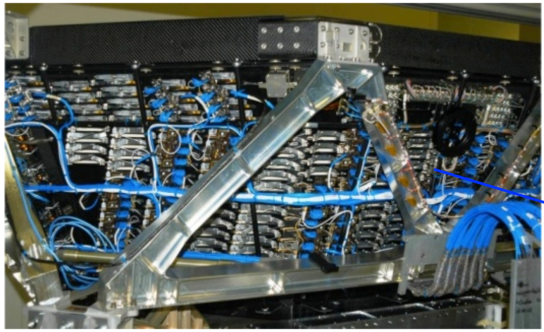
- Test results in ESTEC showed that the life of the Superconductiong Magnet was 20±4 months (with 2500 liters of superfluid He)

- NASA decided to increase the life of ISS up to 2028

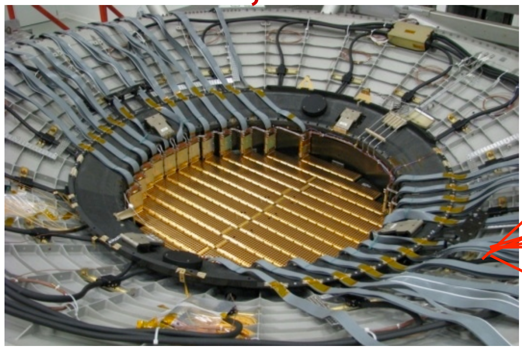
The permanent magnet was selected

The second AMS-02

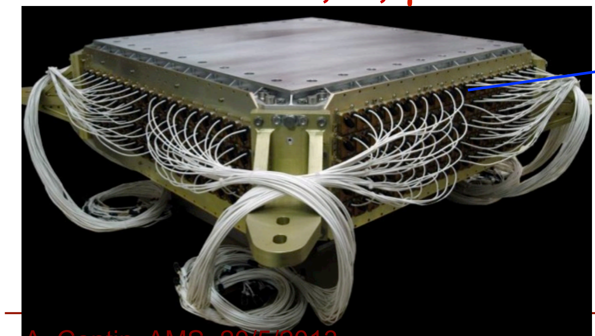
TRD
Identify e^+, e^-

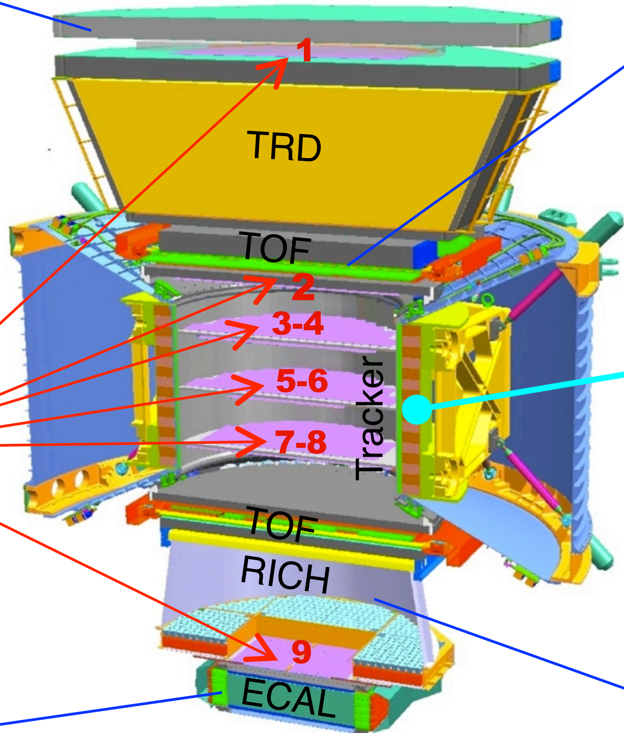


Silicon Tracker
Z, P



ECAL
E of e^+, e^-, γ

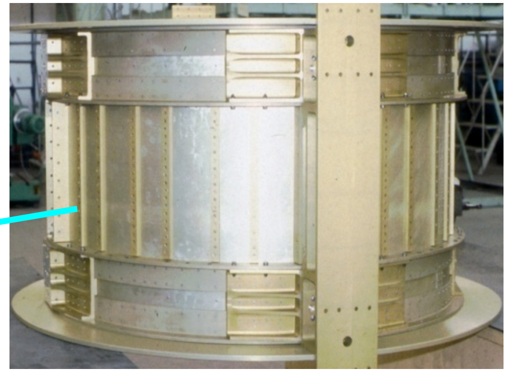




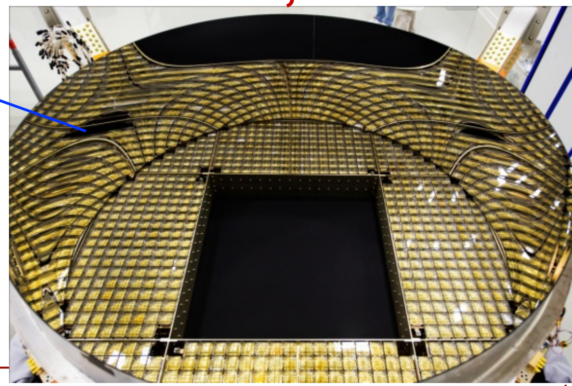
Z, P ***are measured independently by the Tracker, RICH, TOF and ECAL***

TOF
Z, E

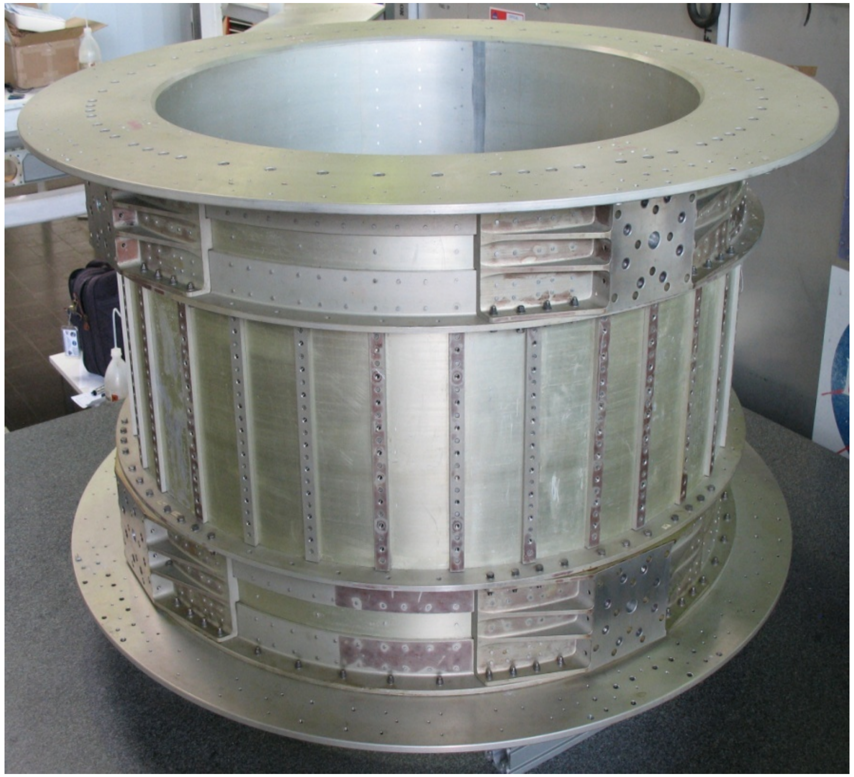
Magnet
±Z

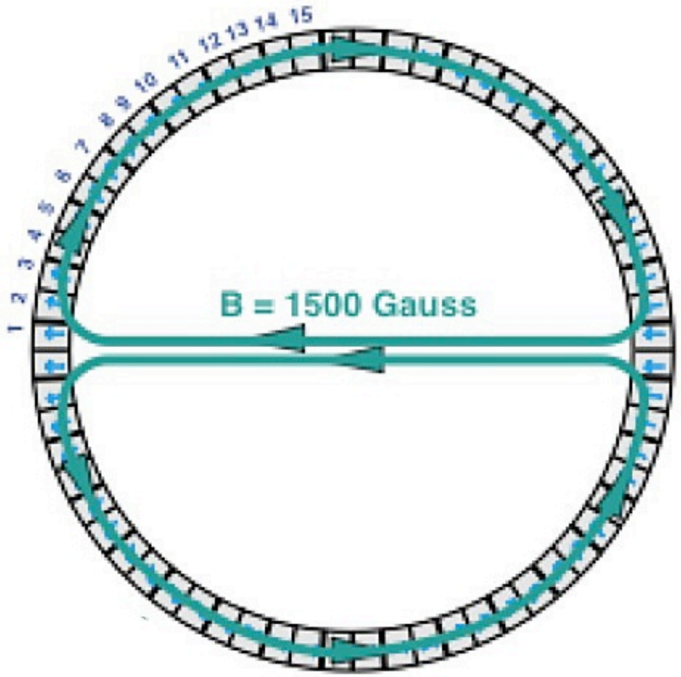


RICH
Z, E



The AMS-01 permanent magnet



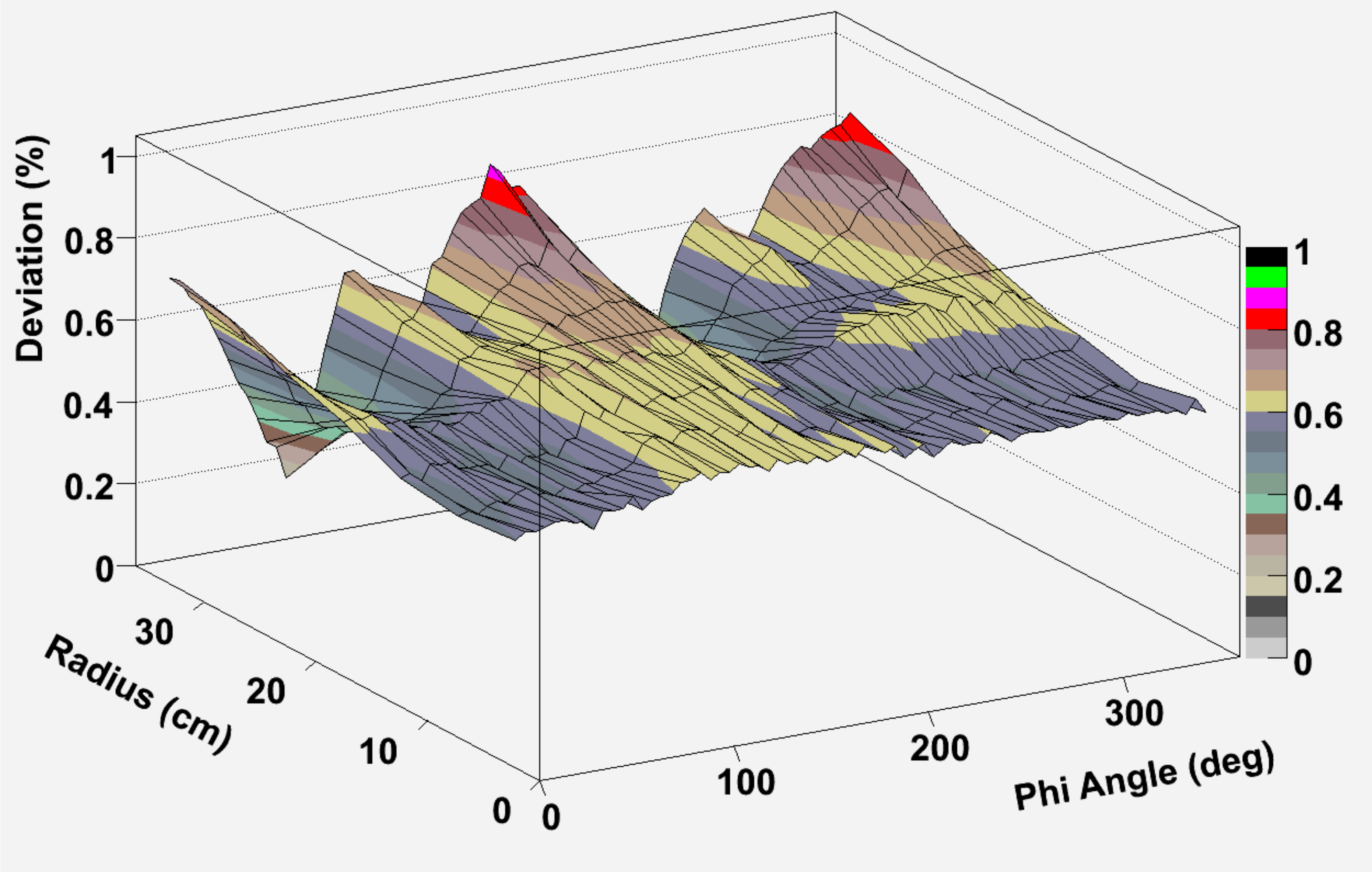


1. Stable: no torque
2. Safety : no field leak out of the magnet
3 . Low weight: no iron

The detailed 3D field map (120k locations) was measured in May 2010

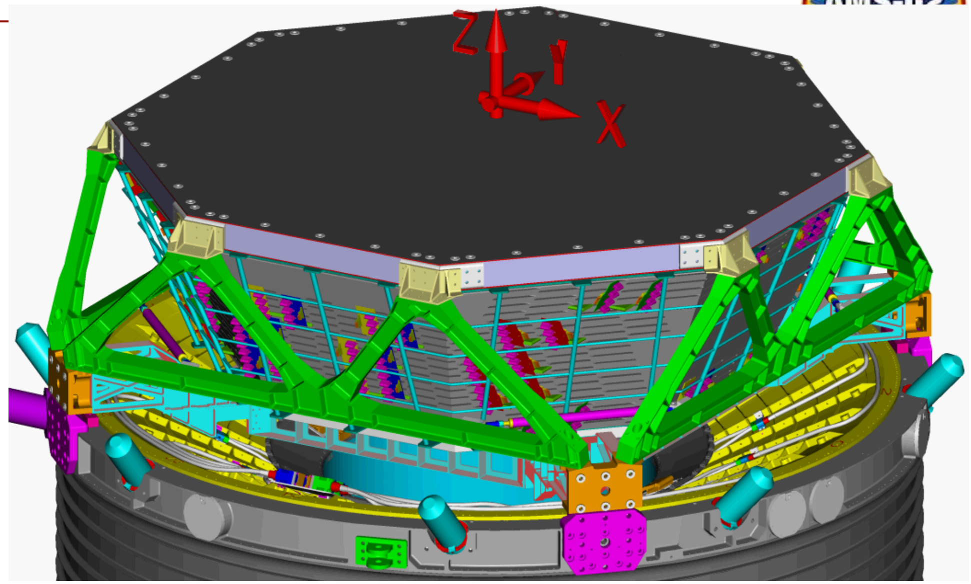
It was found that the deviation from the 1997 measurement are <1%

Deviation from 1997 measurements in R-Phi coordinates



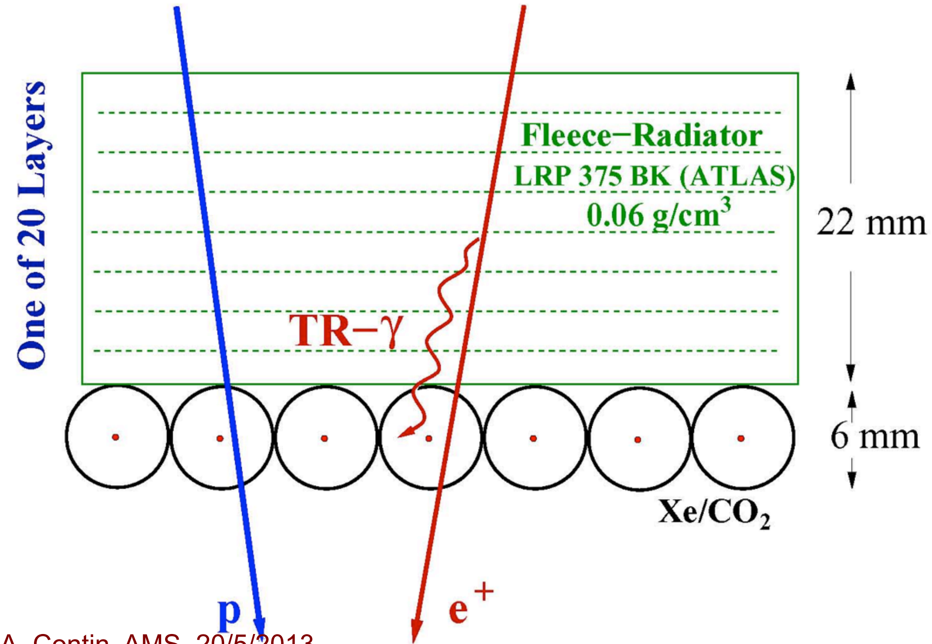
TRD principles

p^+ rejection $>10^2$ 1-300 GeV
acceptance: $0.5 m^2 sr$

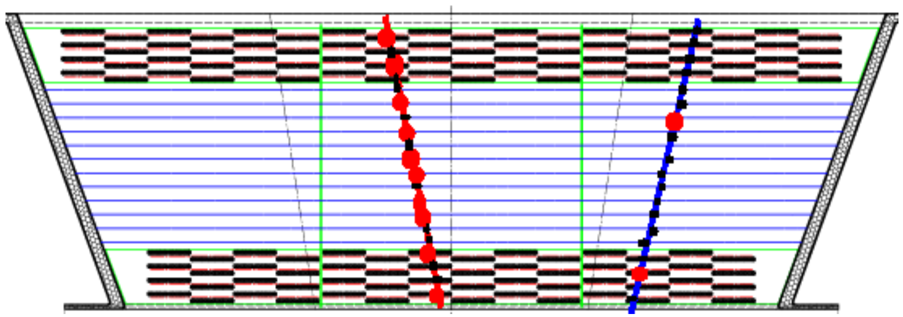


Choosen configuration for 60 cm height:
20 Layers each existing of:

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

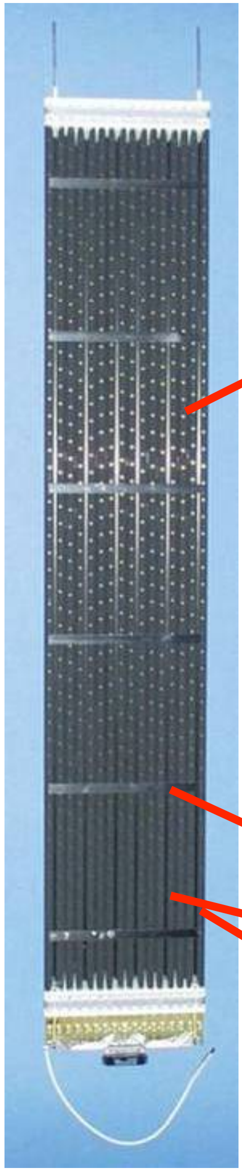


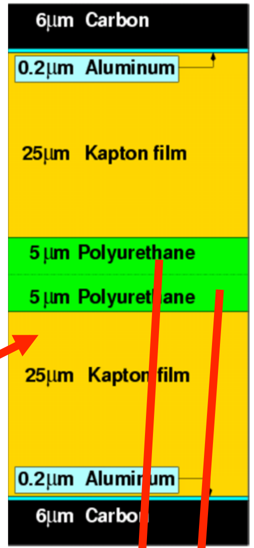
12 layers in the bending plane
2 x 4 layers in the non-bending plane

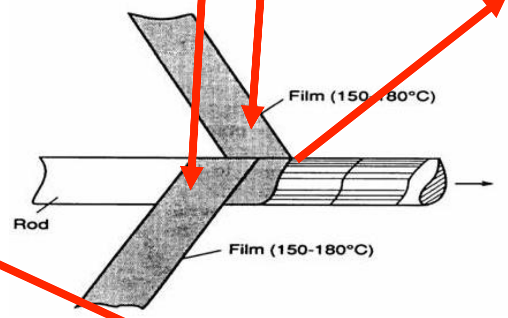


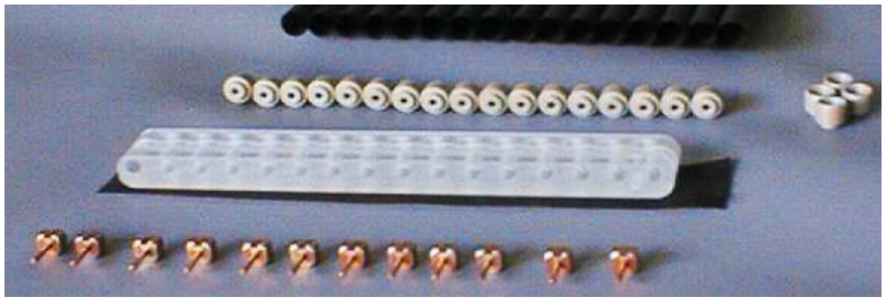
TRD straw tube proportional counter module

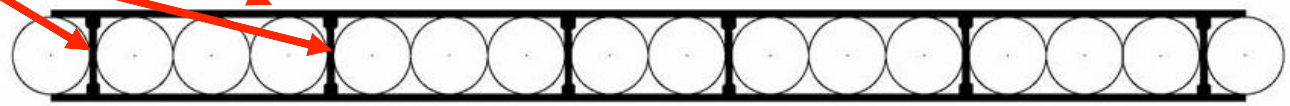
- Straw tubes: 72 μm multilayer aluminium kapton foil,
  Ø 6 mm , 0.8 ÷ 2.0 m length
- Wire: tungsten anode wire, 30 μm Ø, tension ≈ 100 g
- Gas mixture: Xe / CO_2 (80% / 20%)
- Operating HV ~ 1380 V → Gasgain of ~ 3000
- 1 Module → 16 Straws, 100 μm mechanical accuracy
- 328 Modules → 5248 Straws





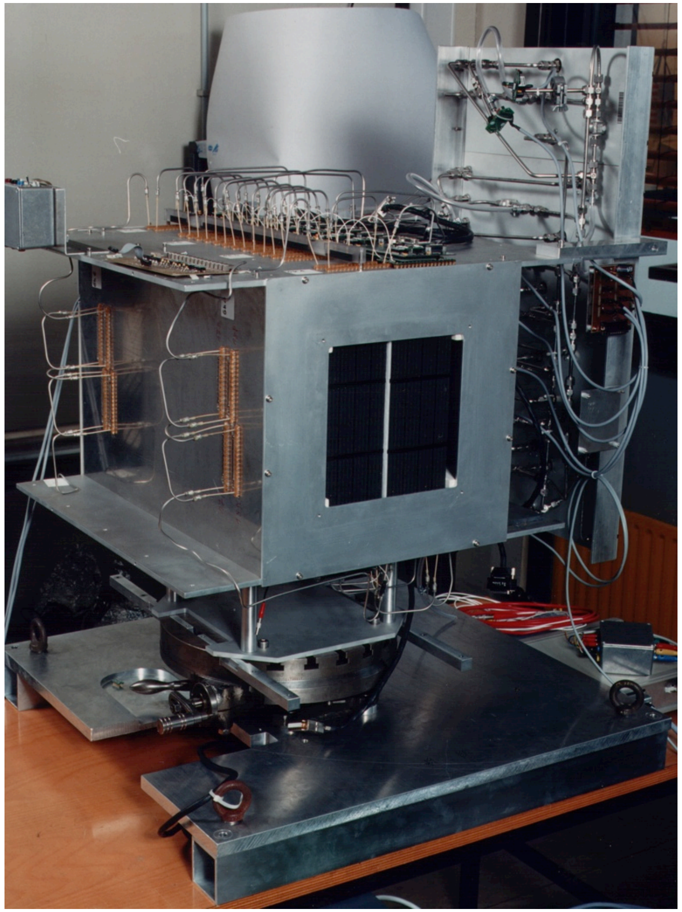


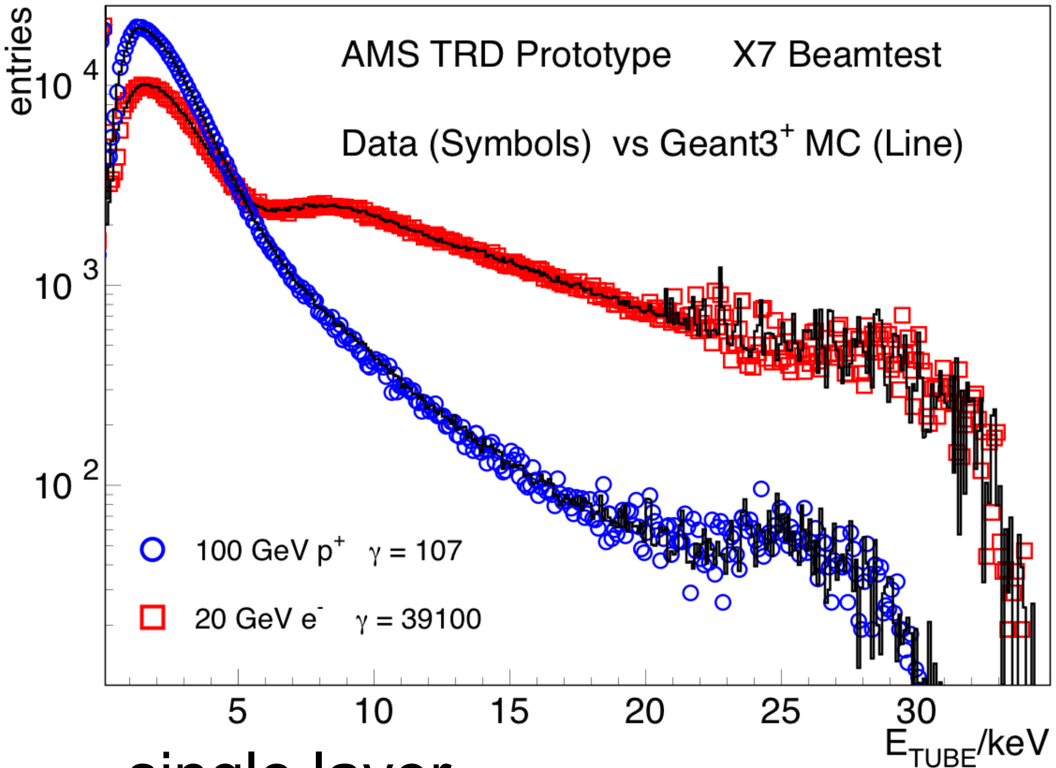




TRD Test beam

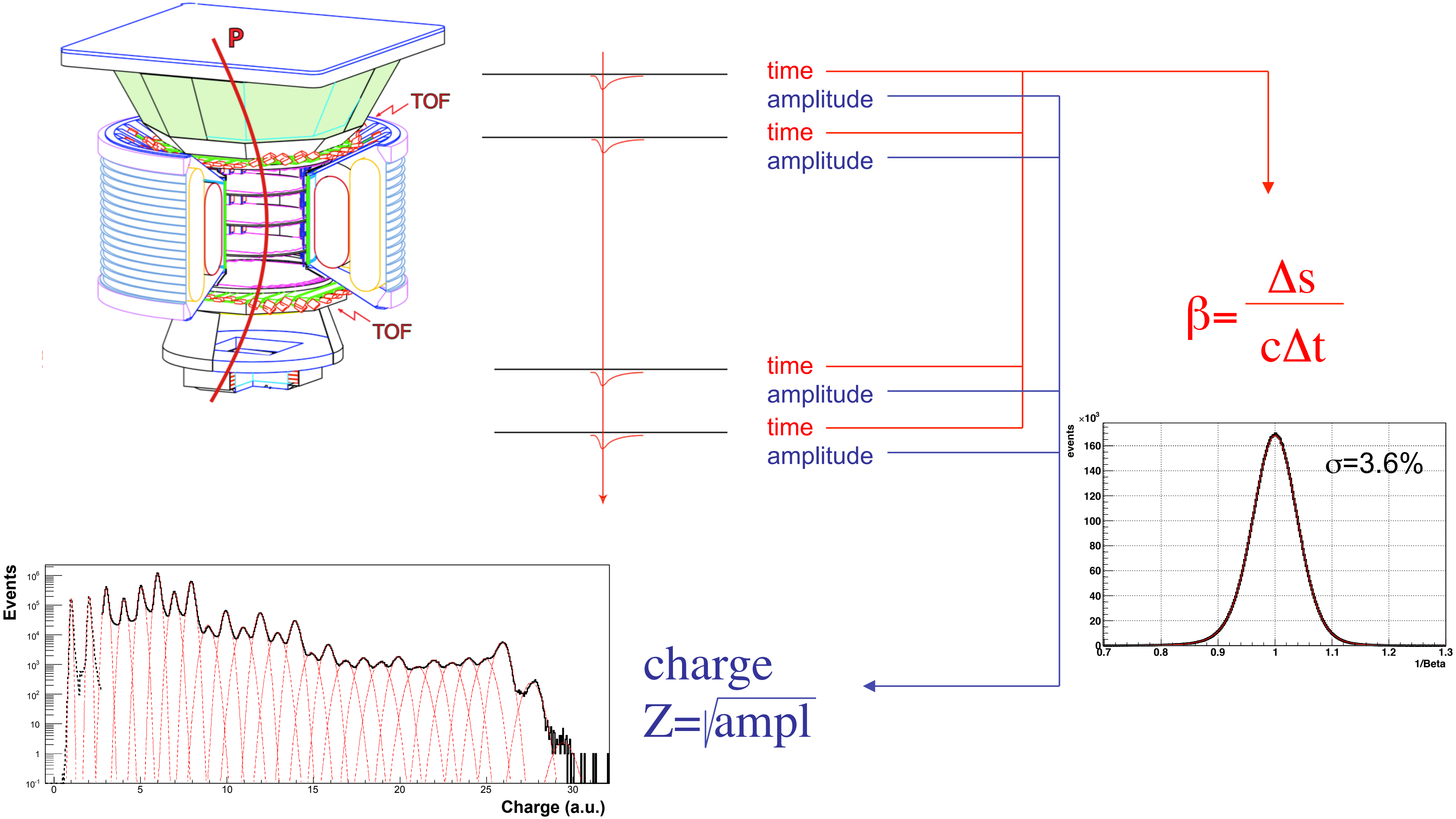
- **20 layer TRD detector in the test beam at CERN in 2000**
- **we have recorded 3 million events providing signals for protons, electrons, muons and pions at energies from 5-250 GeV**
- **Muon events have been used for an intercalibration of the individual straws to a relative accuracy of 2%.**





single layer

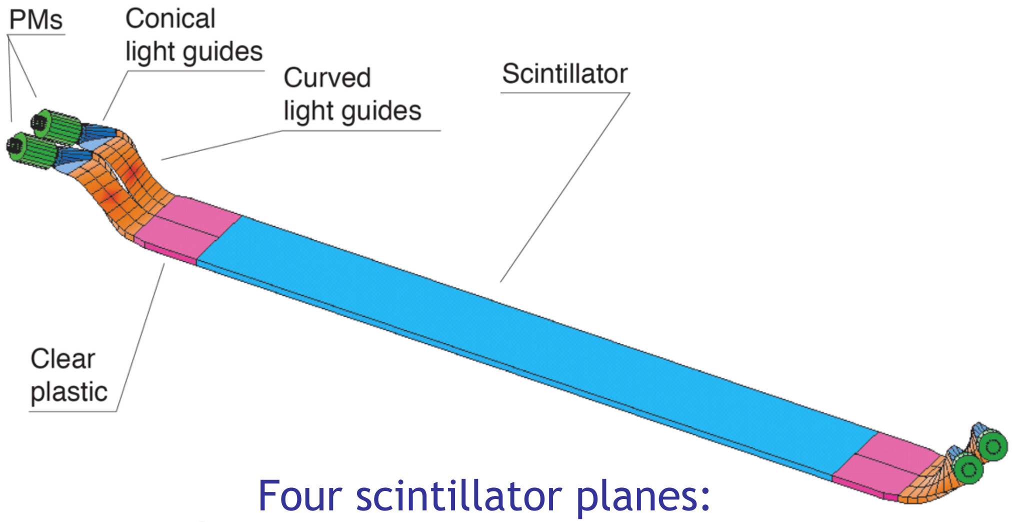
TOF principles

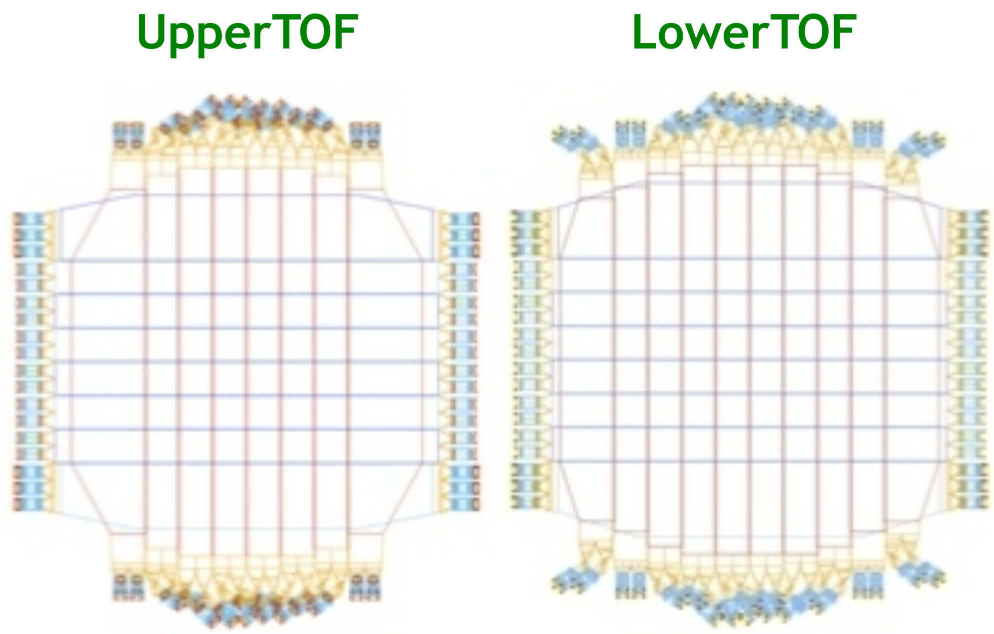


The TOF system

To cover the full solid angle of AMS-02, each TOF plane has a surface of about 1.4 m^2.

Each counter is 12 cm wide and overlaps by 0.5 cm with adjacent counters.





Four scintillator planes:

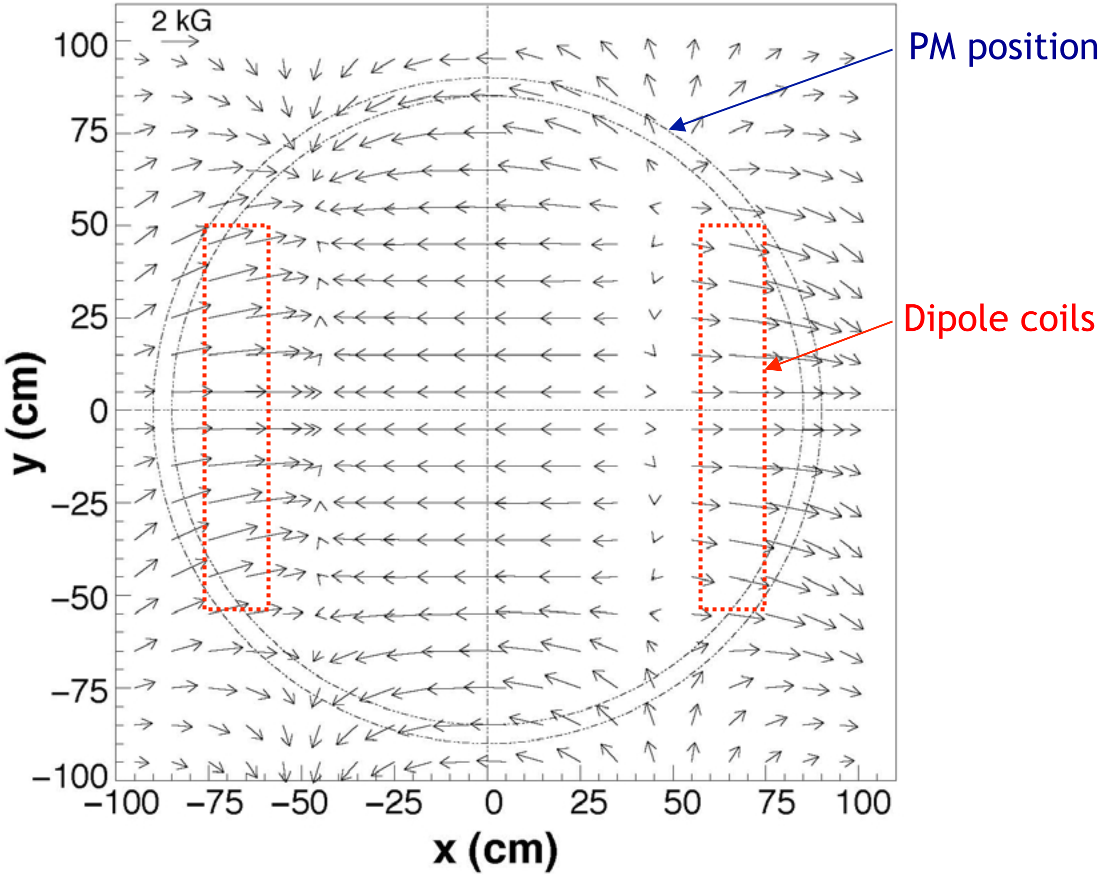
1) 8 counters, 36 PMTs
2) 8 counters, 32 PMTs
3) 10 counters, 40 PMTs
4) 8 counters, 36 PMTs

The system have been designed for maximum redundancy to ensure the fast trigger to AMS even in presence of HV, PMT or front-end electronics faults:

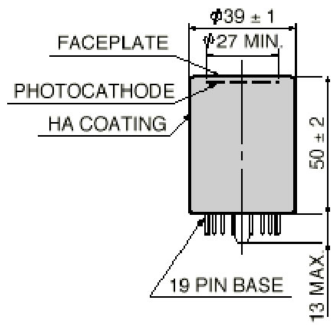
- Each counter is 4-fold redundant in PMTs
- Each HV power supply is doubly redundant
- Each coincidence signal for the fast trigger is doubly redundant

TOF in the magnetic field

The TOF has been designed to work with the SuperConducting Magnet initially foreseen to be used in AMS-02. The planes are placed just above and below the magnet (60 cm from the magnet center) therefore the magnetic field on the photomultipliers (PMs) was of the order of 1÷2kG.



Fine-mesh HAMAMATSU PM R5946



HV=2000 V
Gain=10^6 (4.3 x 10^5 at 0^o and 5kG)

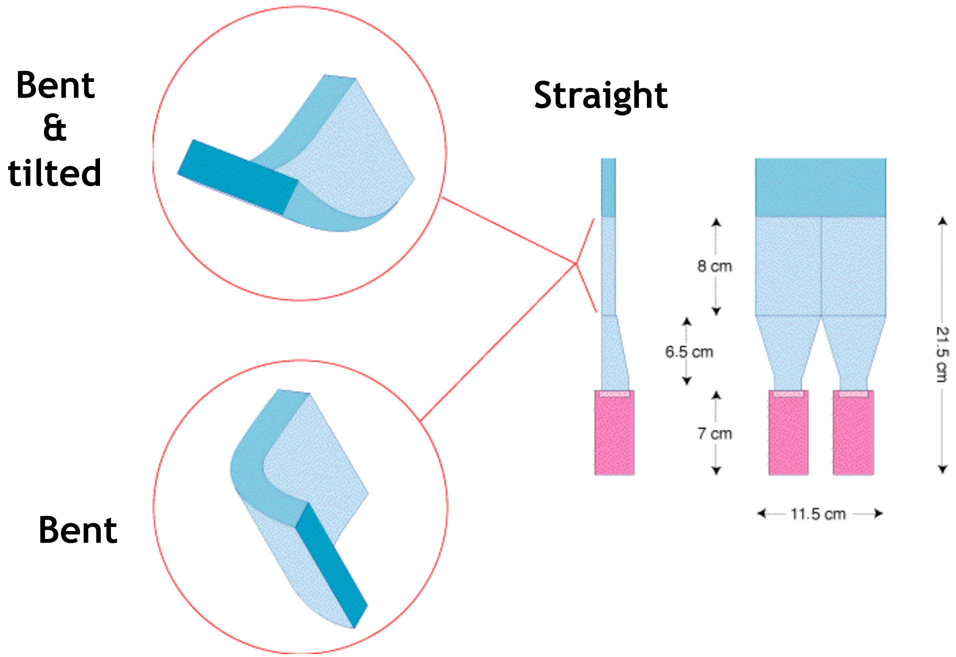
Insensitive up to 45^o w.r.t.magnetic field

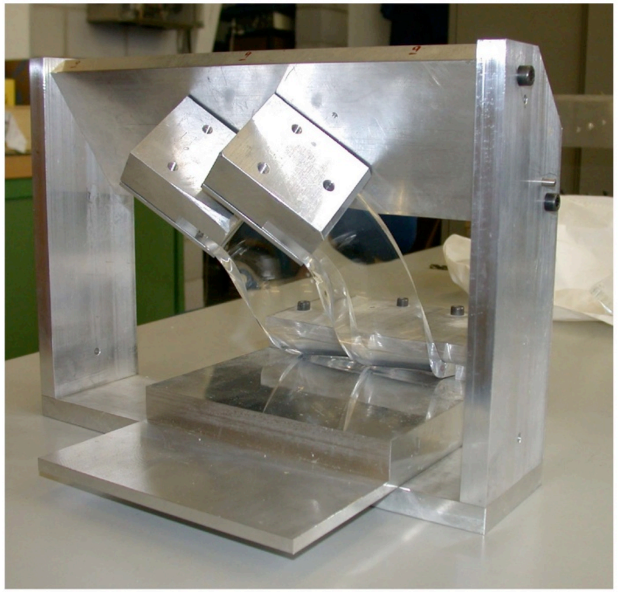
Note:
The same PMTs are used for the AntiCoincidence Counters (ACC)

TOF - light guides

To reduce the angle between the magnetic field and the PMT axis, the shape of each light guide has been determined according to the position of the PMT.

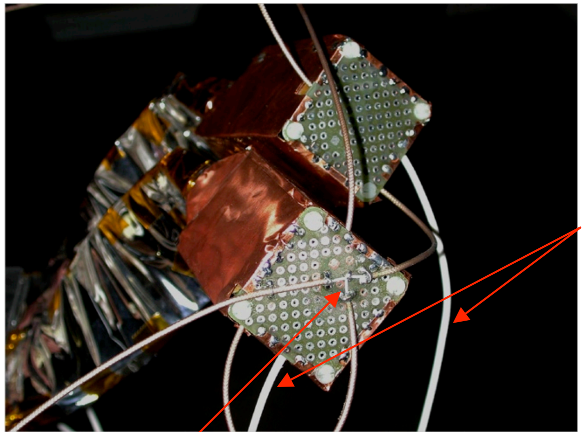
Therefore, straight, tilted, tilted and bent light guides have been built with special tools.





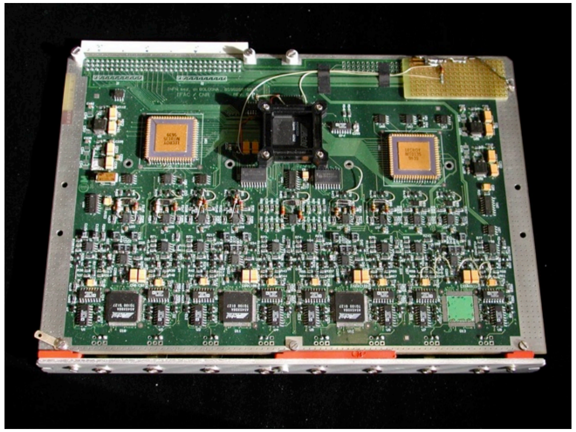
TOF – read-out electronics

Dynode signals

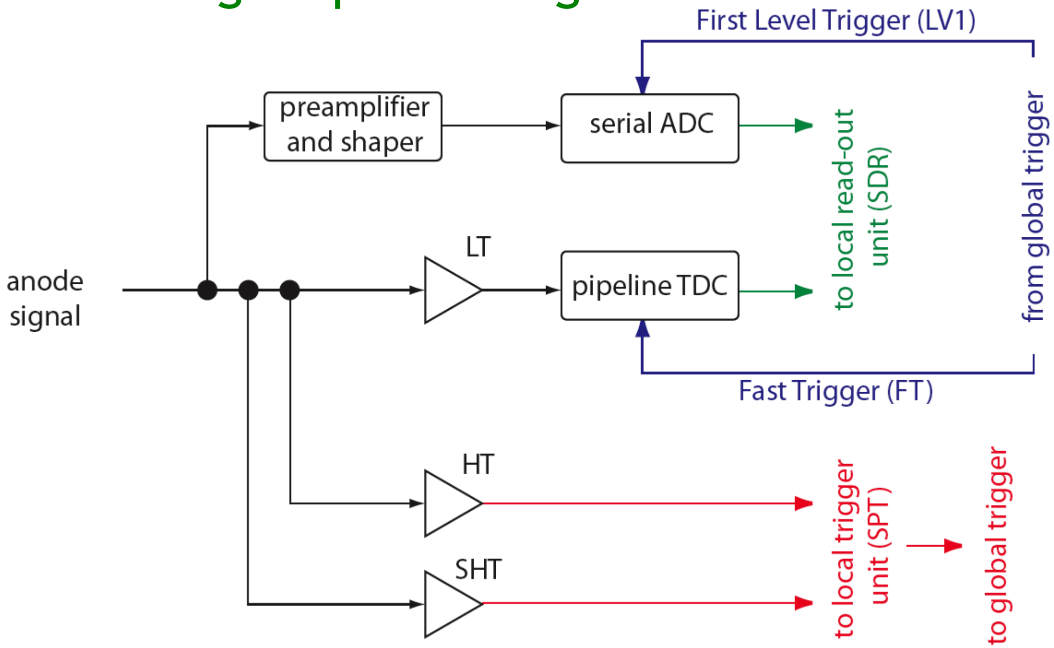


HV cables

Anode sum



Anode signal processing



Three thresholds are applied to the anode signal:
- Low (LT): time measurement
- High (HT): Z=1 selection
- SuperHigh (SHT): Z>1 selection

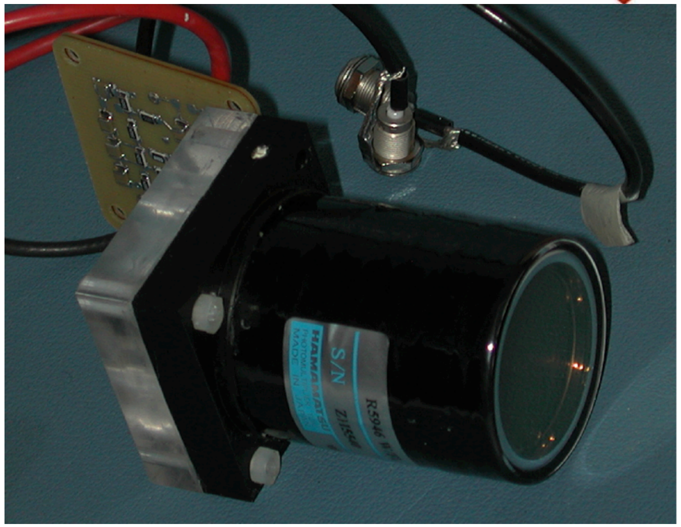
The amplitude of the anode signal is also measured with an ADC.

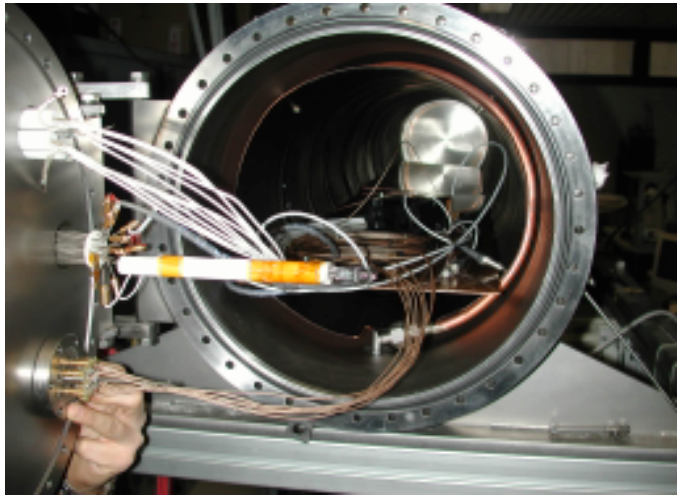
The amplitude of each dynode signal is read-out on a card mounted inside the detector.

TOF – operation in space

Requirements on the design and on the servicing electronics for the TOF system:

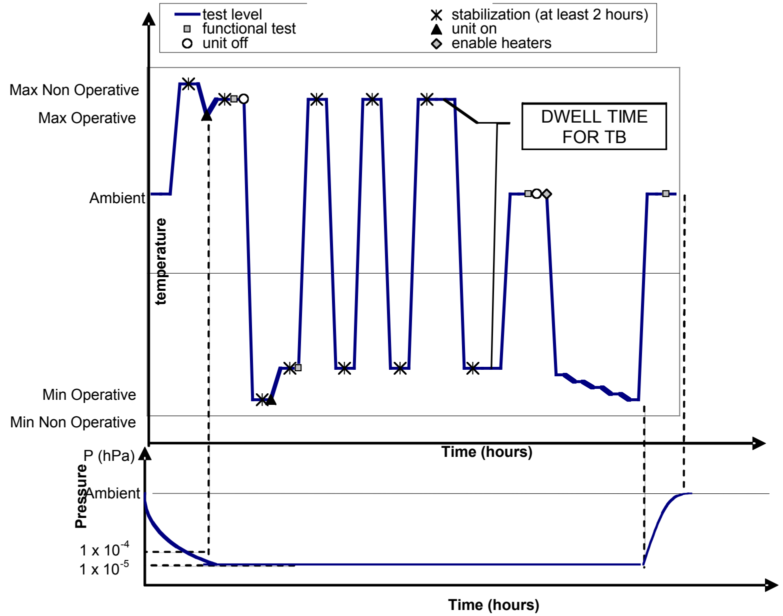
- Each plane is housed into a mechanically robust and light-tight cover with a system for fast depressurization
- The support structure conforms to the NASA specifications concerning resistance to load and vibrations
- The electronics is protected from the highly ionized low-orbit environment
- The system have been designed for maximum redundancy to ensure the fast trigger to AMS even in presence of HV, PMT or front-end electronics faults:
  - Each counter is 4-fold redundant in PMTs
  - Each HV power supply is doubly redundant
  - Each coincidence signal for the fast trigger is doubly redundant



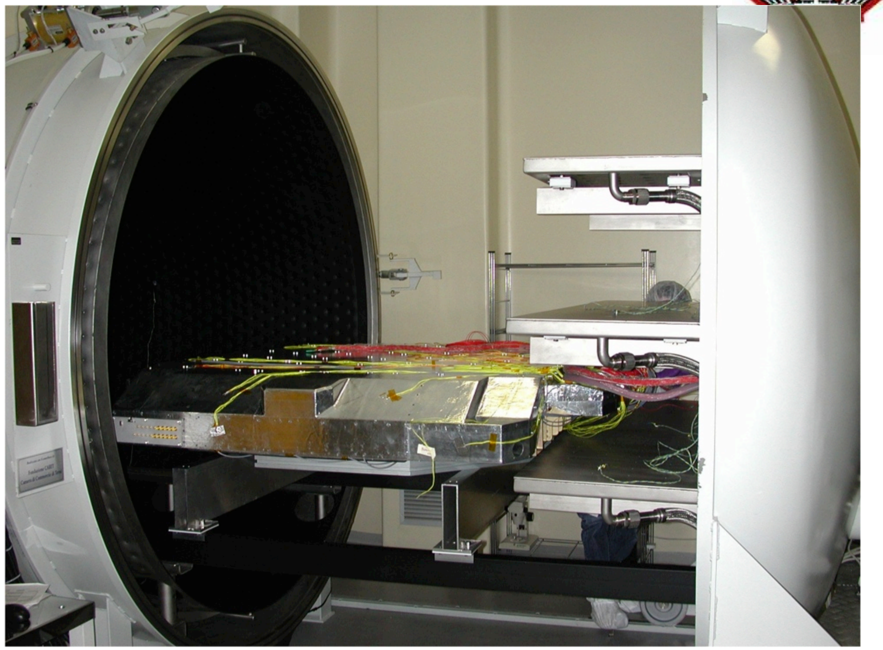


TOF – Thermal Vacuum Test and Vibration Test

Vacuum ≈ 10^{-5} mbar



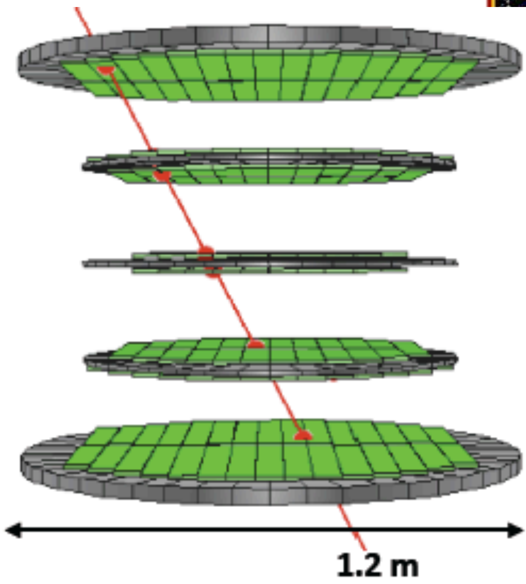
+50°
+45°
-30°
-30°

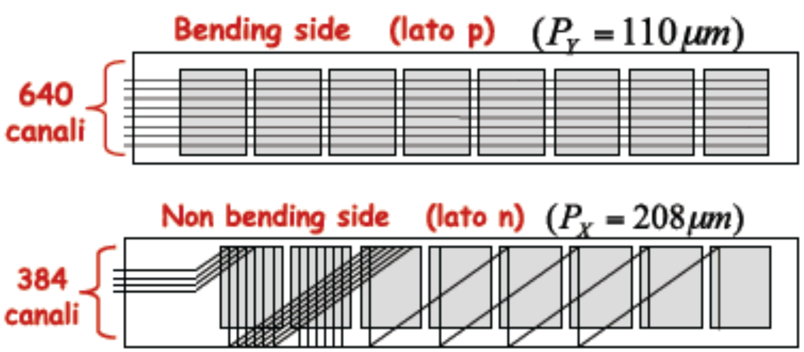


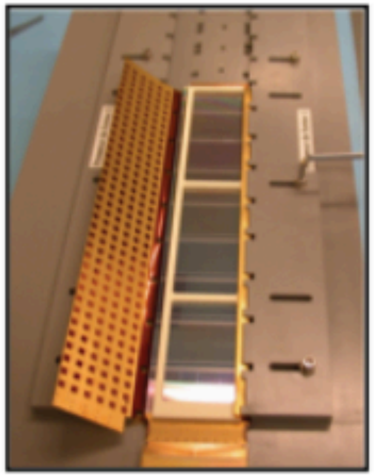
The vibration test has been performed along the three axes (X,Y,Z) with the Maximum Expected Flight Level specifications during shuttle launch.

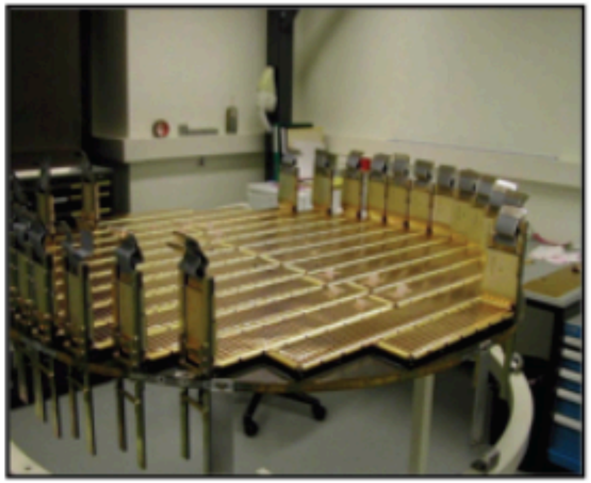
AMS-02 Silicon Tracker

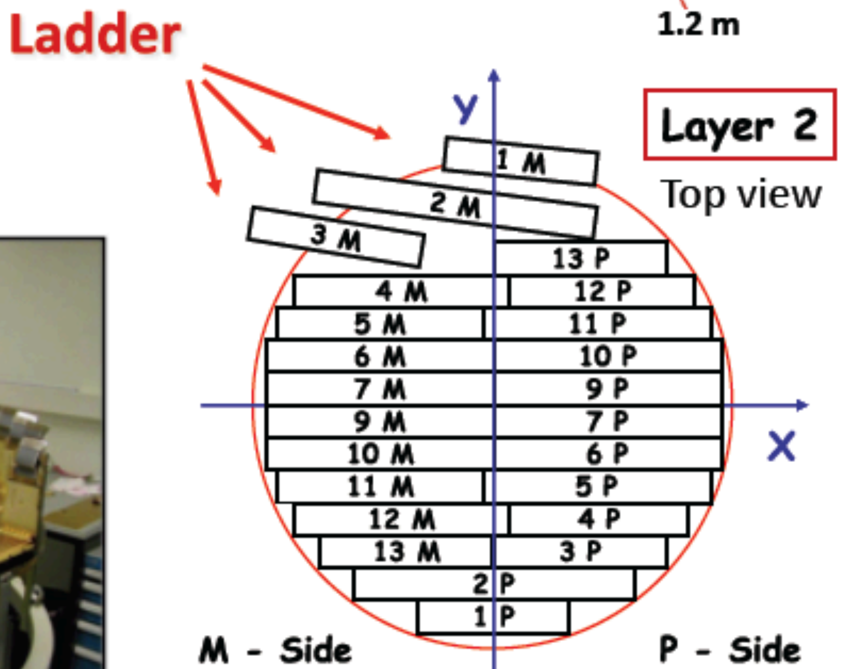
- Tracker : 192 ladders in 8 layers
- Ladder : 7~15 silicon sensors
- Sensor : Double-sided, 640(p)+384(n) ch





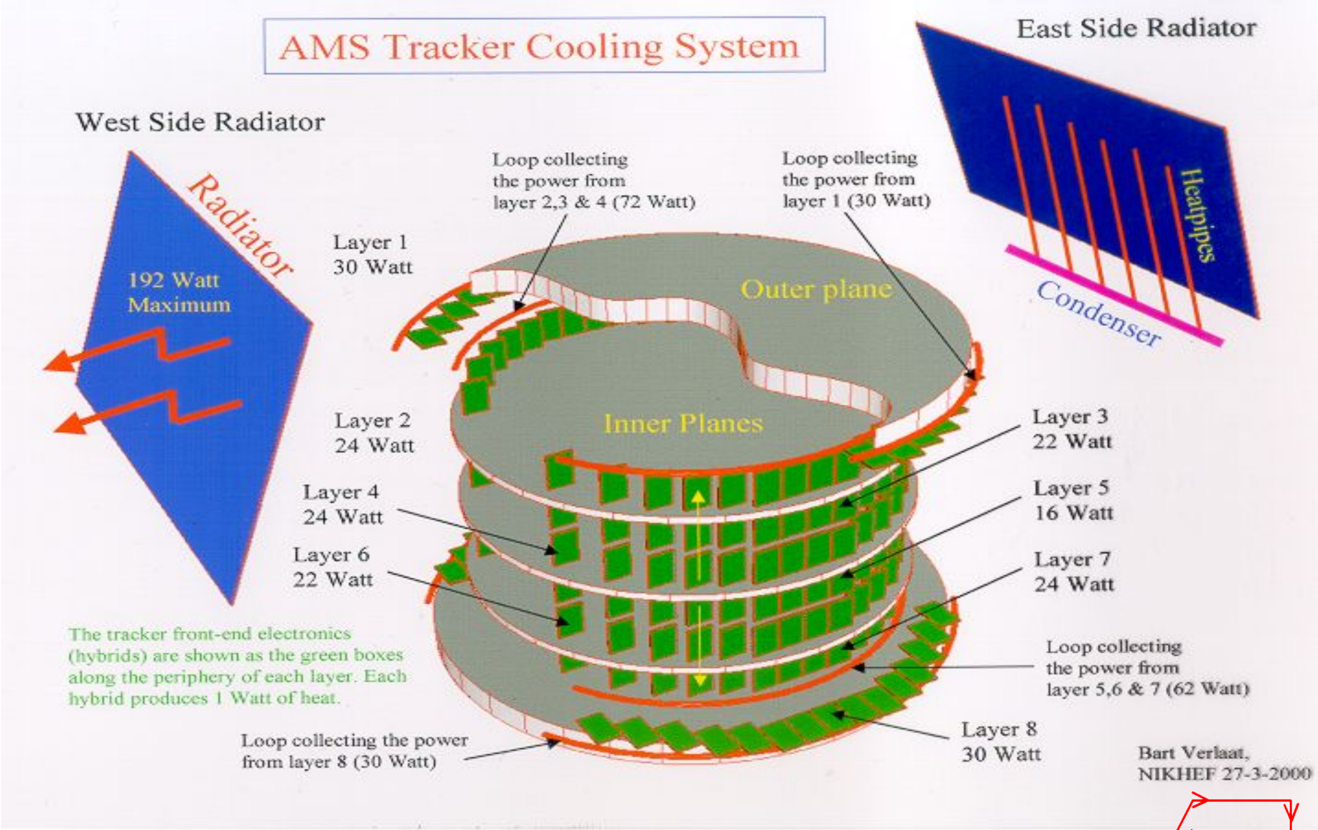


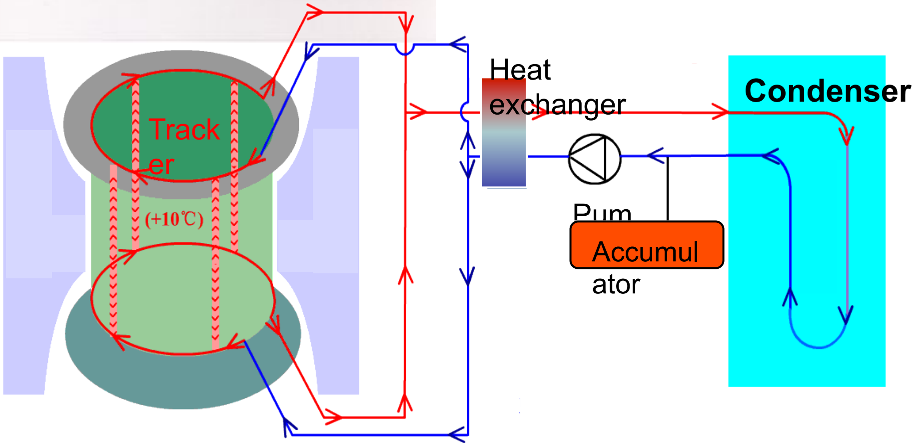




N. Tomassetti

Tracker – cooling system



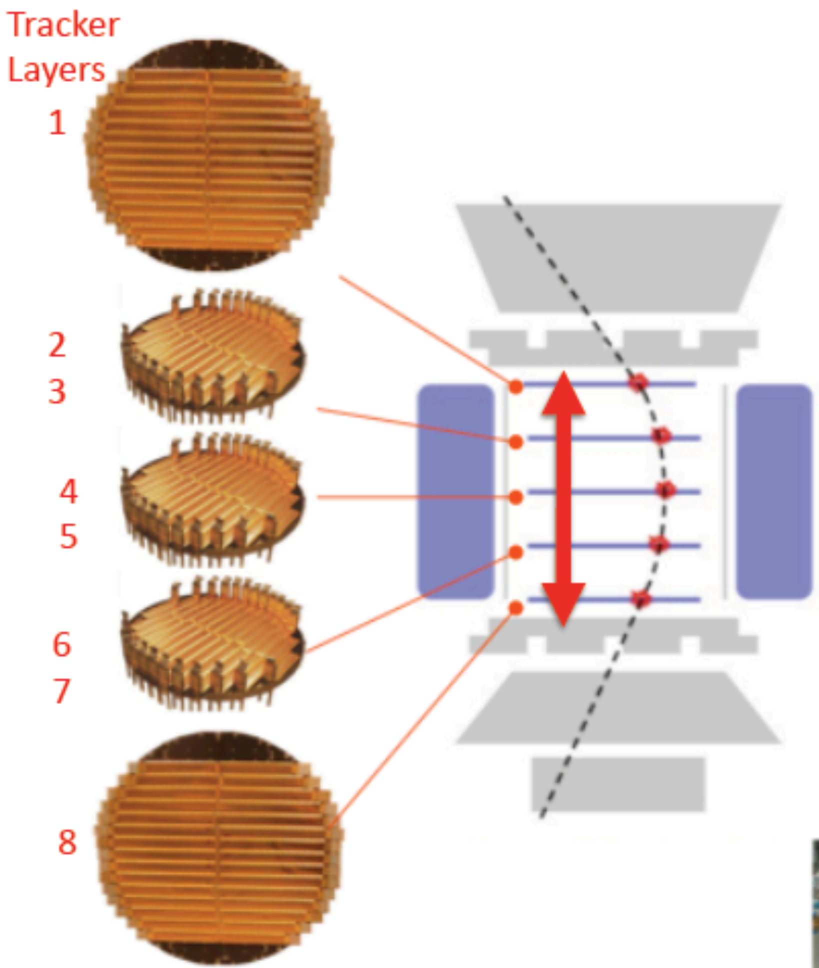


Red line: CO_2 gas/liquid two phase   Blue line: CO_2 liquid phase

Tracker – change to permanent magnet

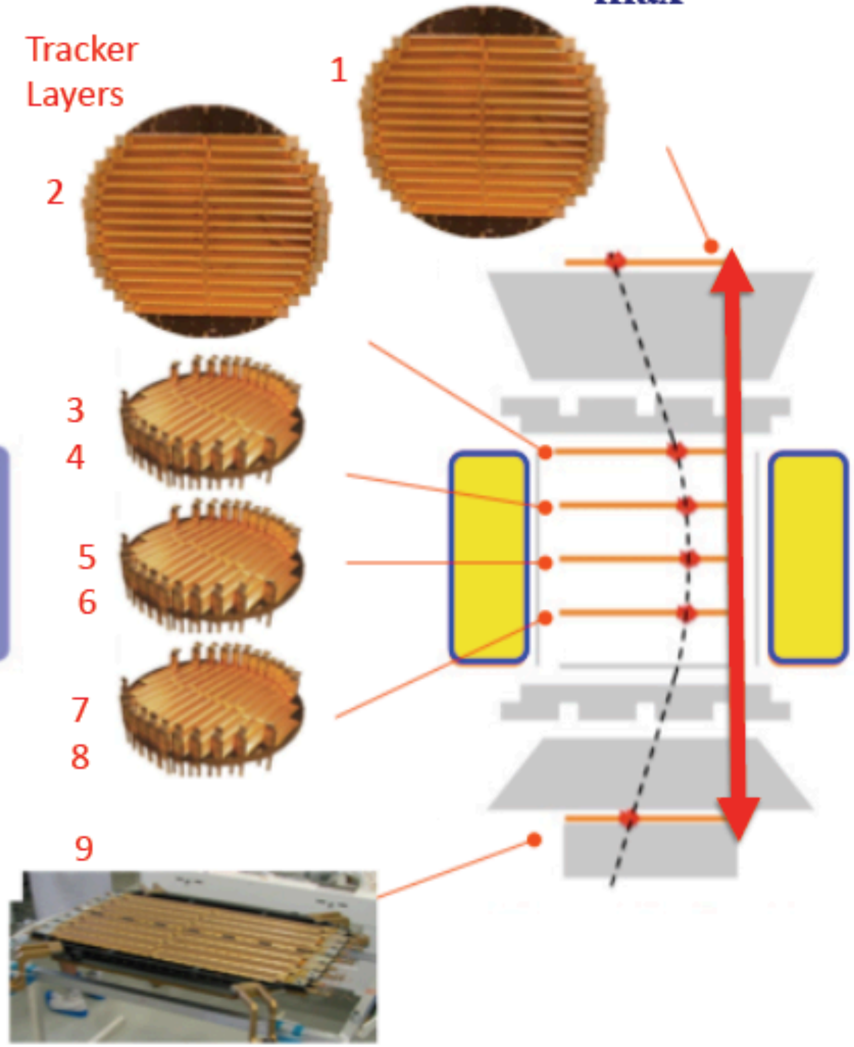
AMS-SC

$B = 0.8$ T, $L = 1$ m

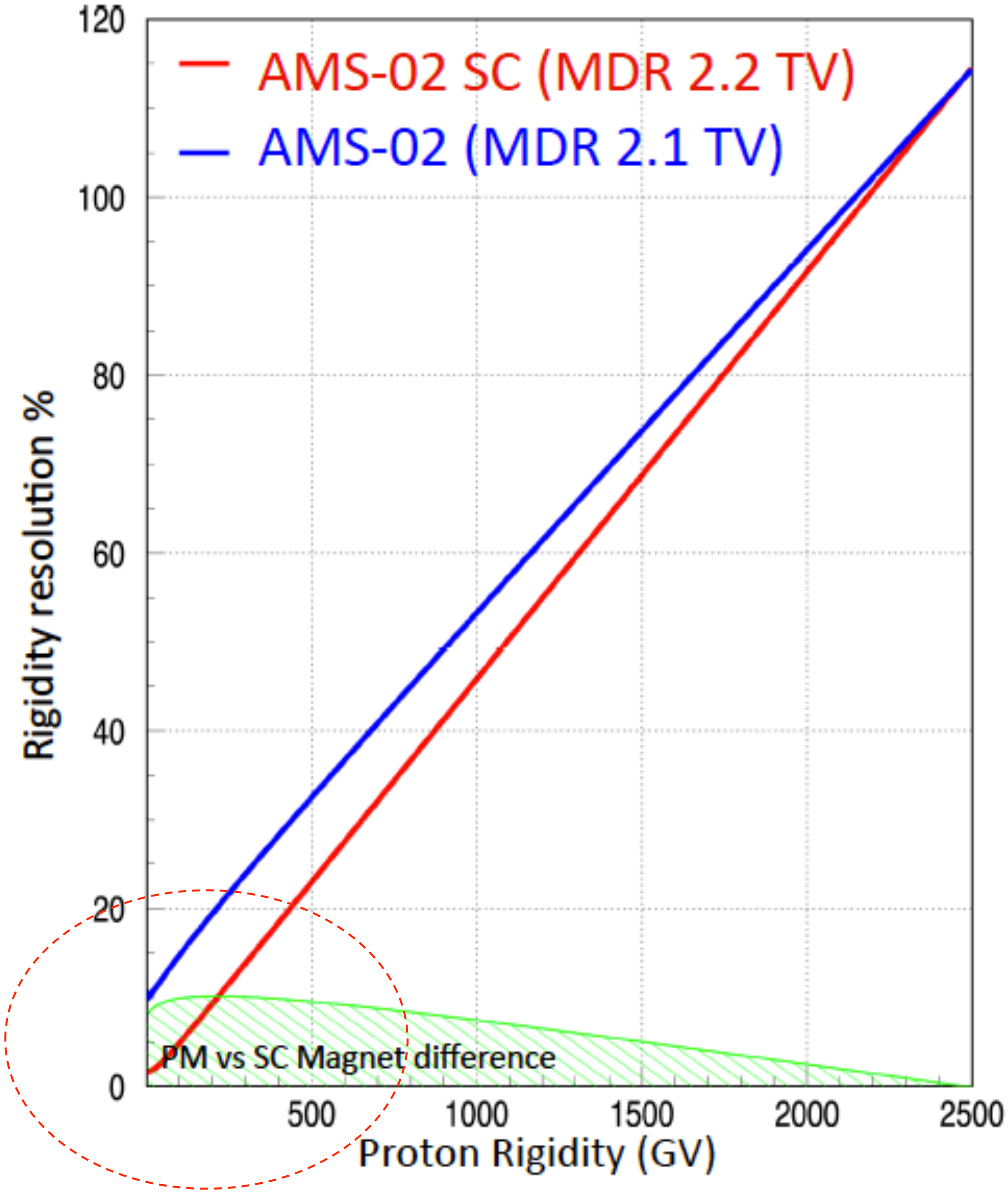


AMS-PM

$B = 0.15$ T, $L_{max} = 3$m

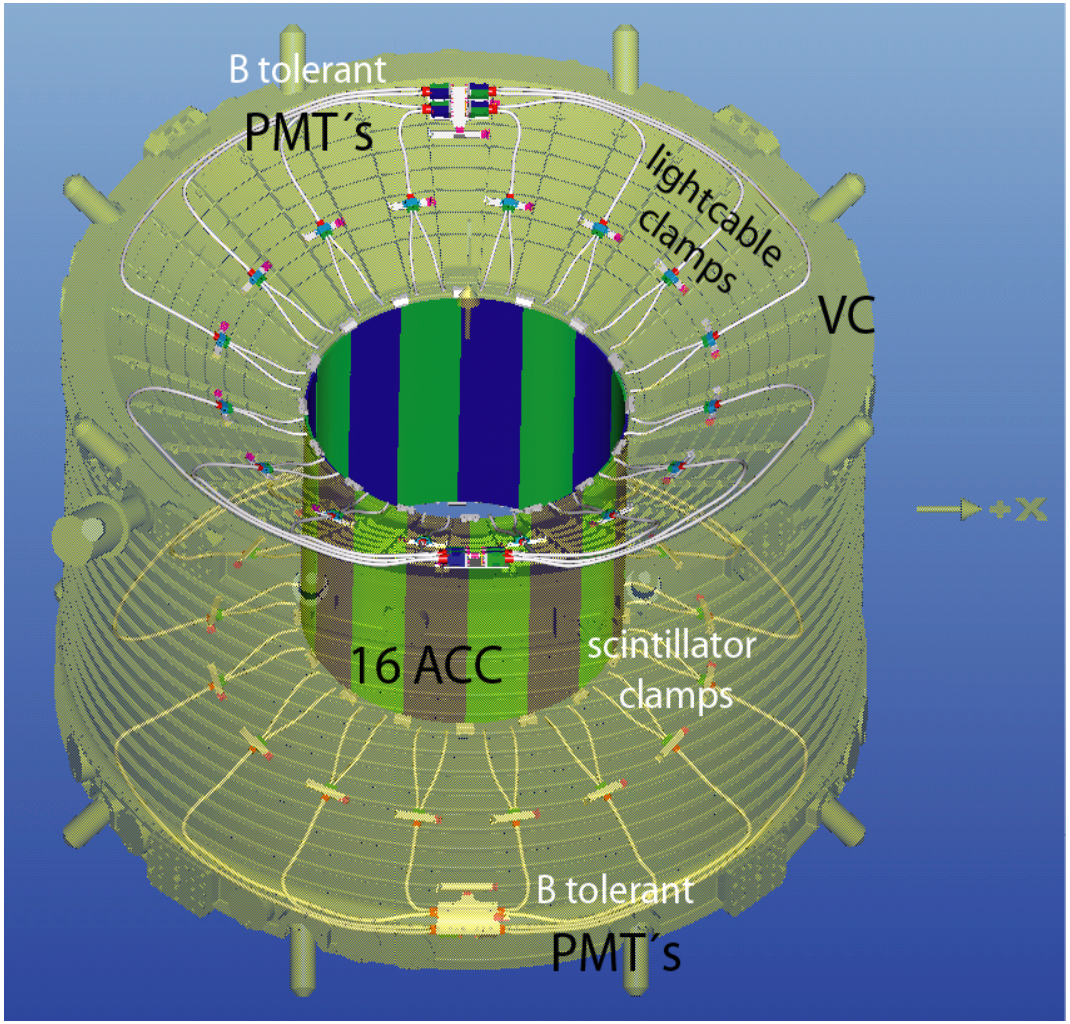


Tracker – momentum resolution

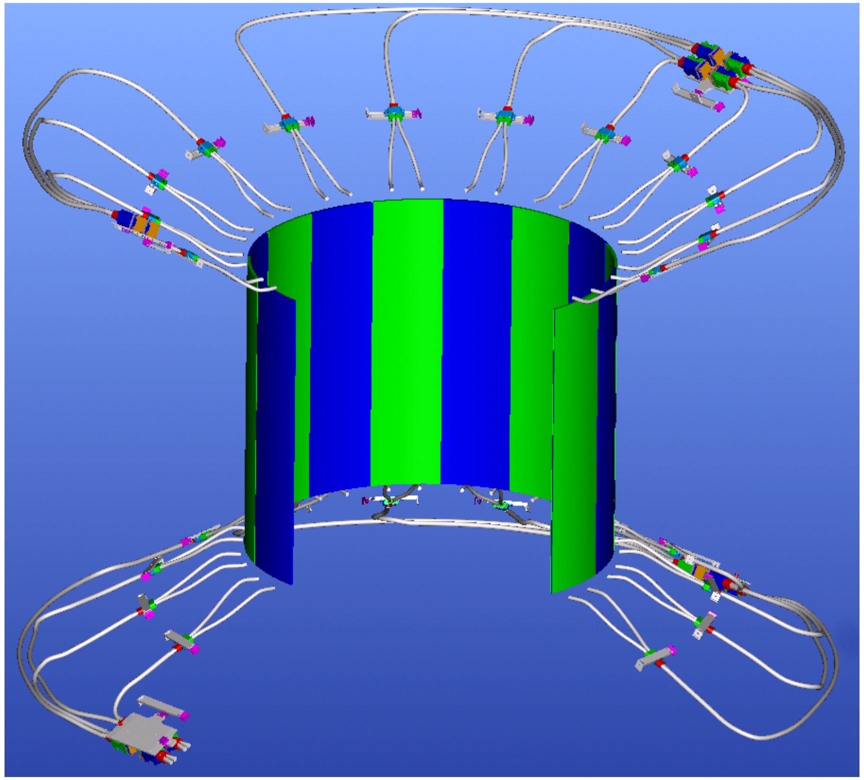


multiple scattering

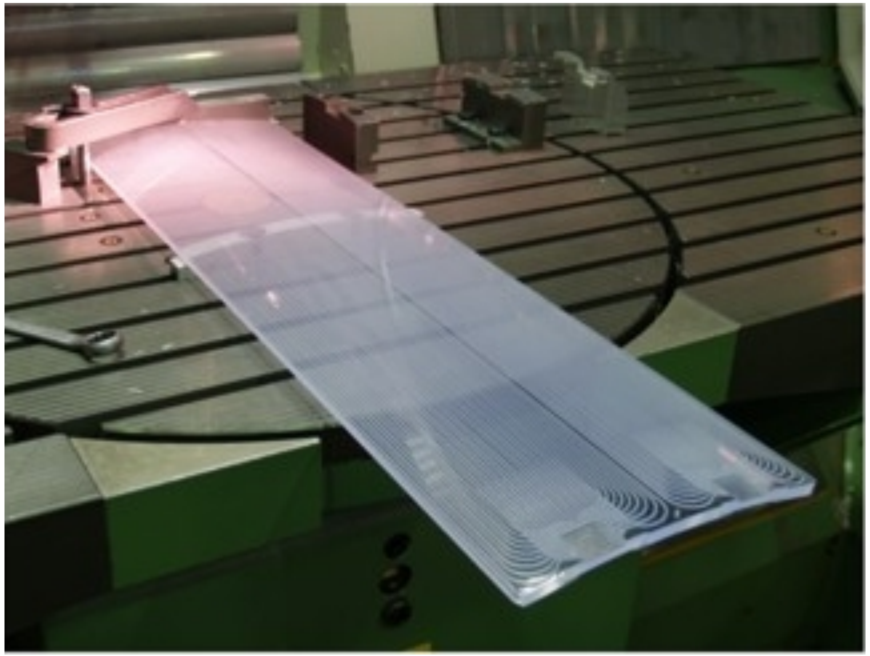
ACC (Anti-Coincidence Counters)



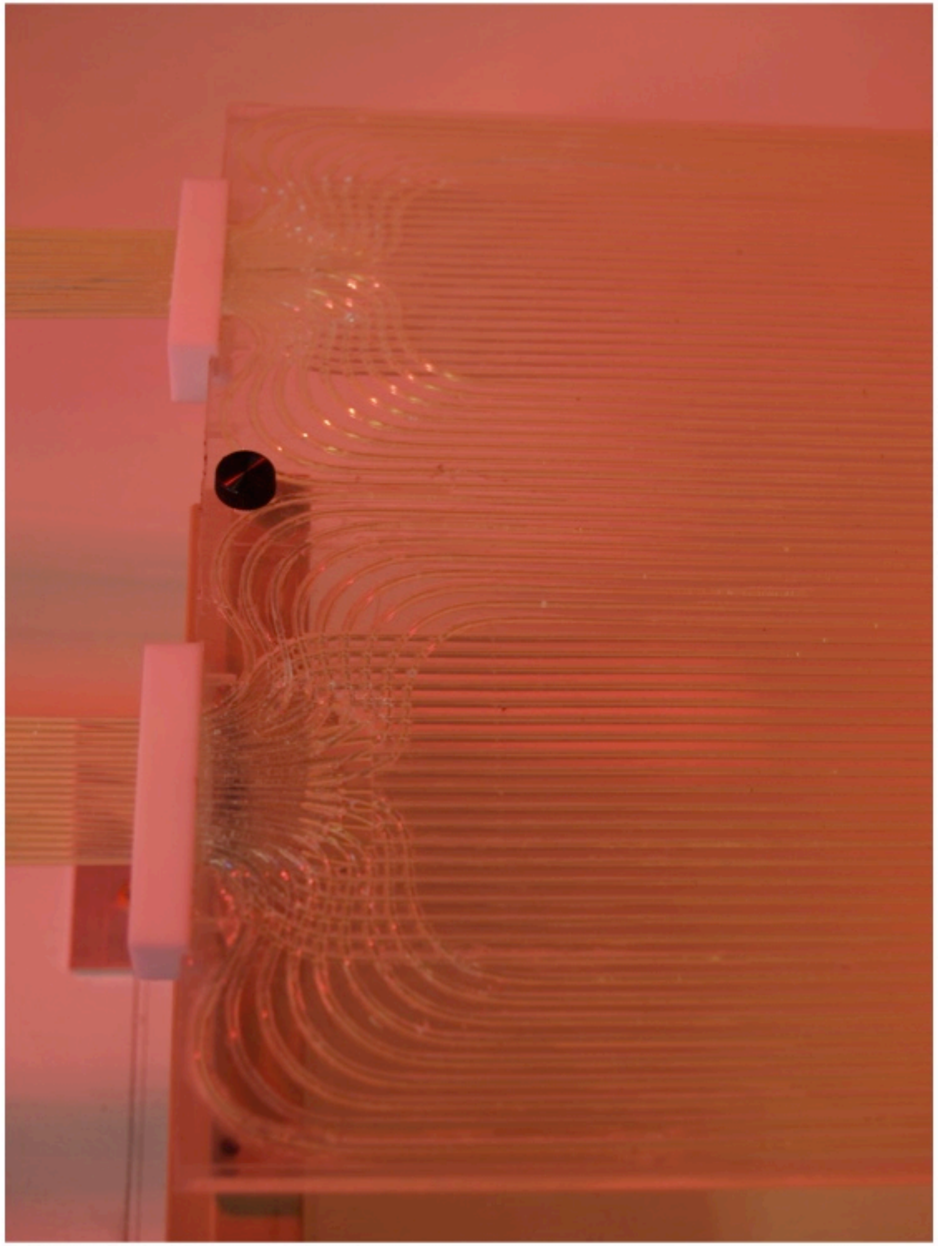
Panel: **Bicron BC414**
826.5mm x 230mm x 8mm
WLS: **Kuraray Y-11(200)M**
CLF: **Bicron BCF-98**
PMT's: **Hamamatsu R5946**



ACC - counters



Wavelength shifter fibers in the grooves



RICH - principles

- Velocity measurement comes from reconstructed Čerenkov angle:

$$\boxed{\beta = \frac{1}{n\cos\theta_c}} \qquad \boxed{\frac{\Delta\beta}{\beta} = \tan\theta_c \frac{\Delta\theta_c}{\sqrt{N_{pe}}}}$$

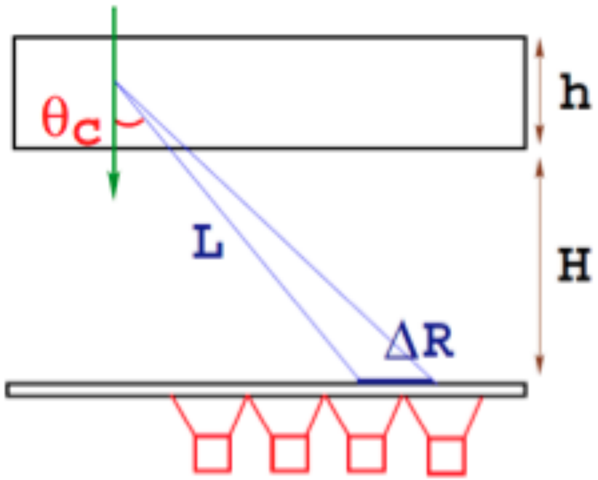
- Sources of uncertainty in θ_c measurement:
  - pixel size
  - radiator chromaticity: n = n(λ)
  - radiator thickness (ΔL = h tan θ_c, exact photon emission point unknown)

$$\boxed{\Delta\theta_c = (\Delta\theta_c)^{pixel} \oplus (\Delta\theta_c)^{thick} \oplus (\Delta\theta_c)^{chrom}}$$

- For an individual hit, i:

$$\boxed{\Delta\theta_c^{(i)} \approx \frac{\Delta R_i}{H}\cos^2\theta_c} \quad \text{(thickness)}$$

$$\boxed{\Delta\theta_c^{(i)} \approx \frac{1}{\tan\theta_c}\frac{\Delta n}{n}} \quad \text{(chromaticity)}$$



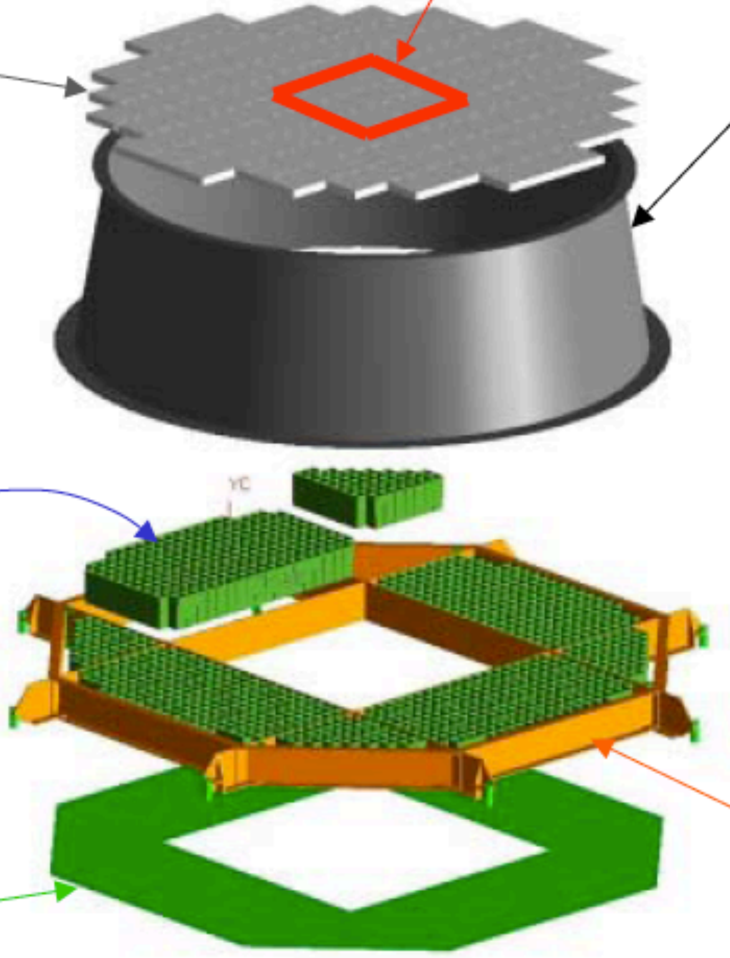
RICH - Construction

AEROGEL radiator plane.
Produced in Japan,
Characterized in Mexico
Support structure Madrid

NaF radiator

Mirror made in USA (~13kg)
Resp. Bologna

Photon drift space



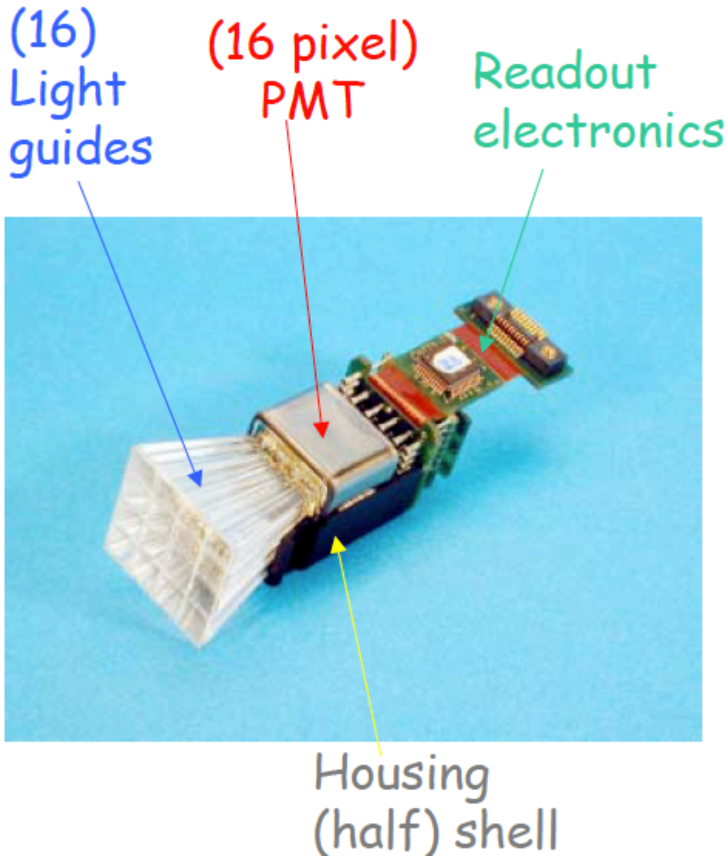
Photodetector plane
680 PMTs
~10^4 pixels of photosensors (Japan)

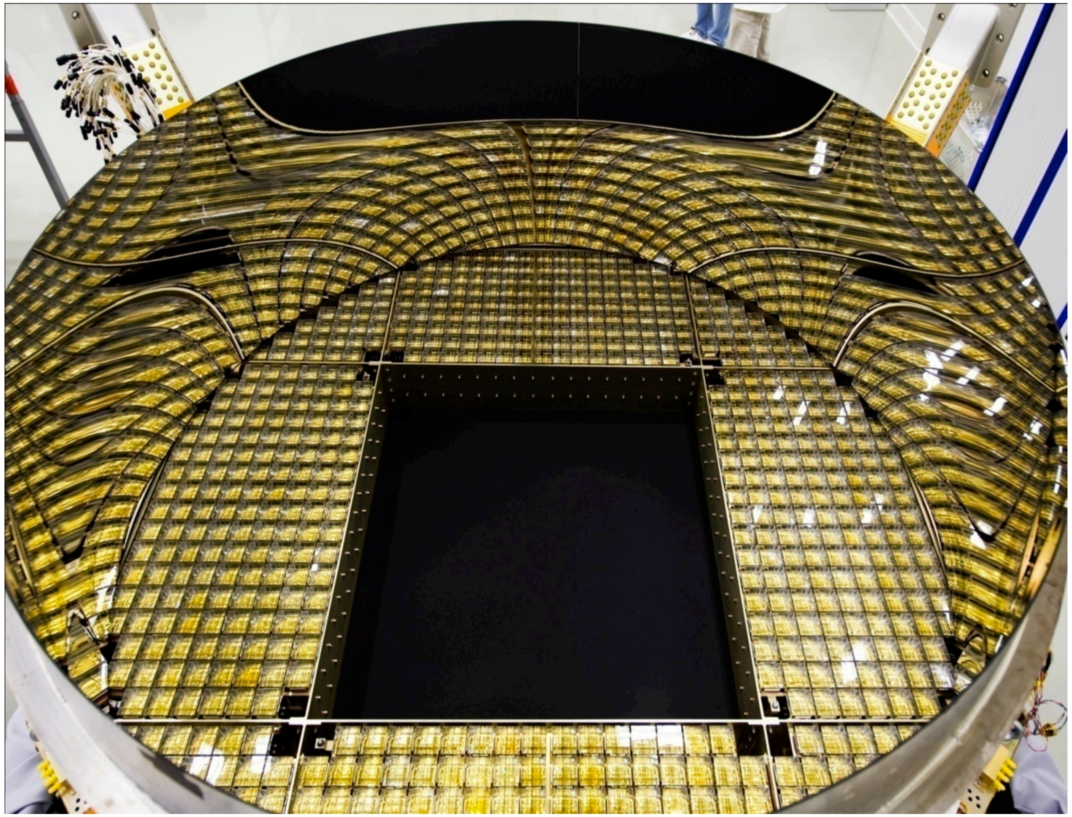
Mech Design from Gavazzi Co, Italy

LOWER PANEL

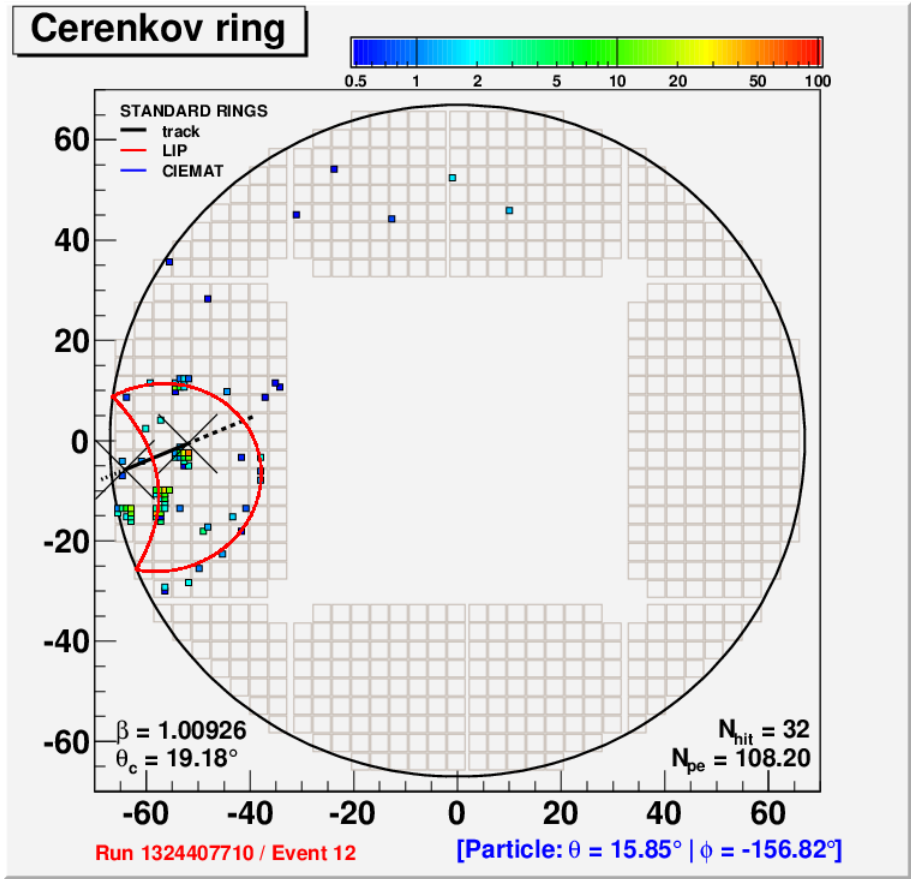
Structure Assembly (Bologna/Gavazzi)

RICH - PMTs

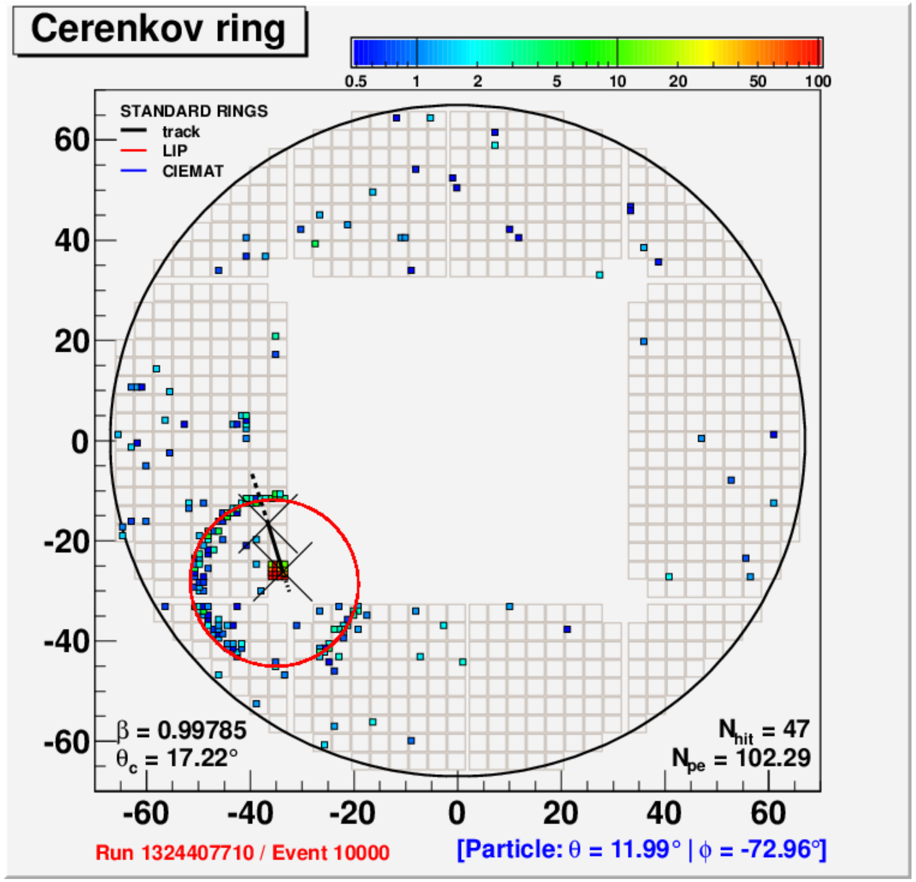

(16)
Light
guides
(16 pixel)
PMT
Readout
electronics
Housing
(half) shell



RICH - Images

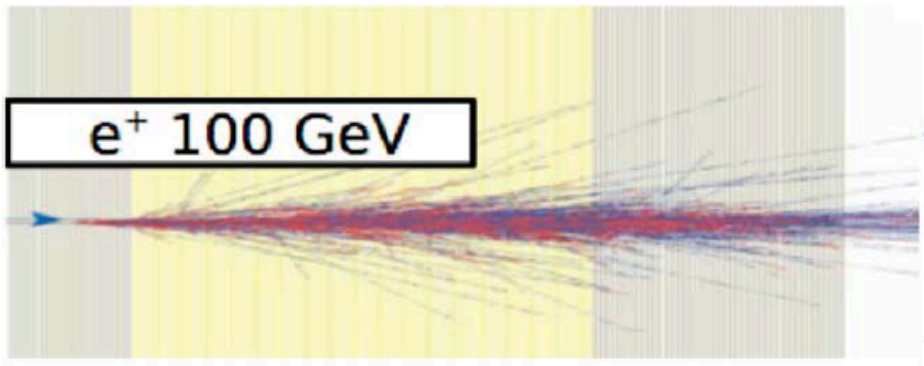


Cerenkov ring
STANDARD RINGS
track
LIP
CIEMAT
β = 1.00926
θc = 19.18°
Nhit = 32
Npe = 108.20
Run 1324407710 / Event 12
[Particle: θ = 15.85° | ϕ = -156.82°]



Cerenkov ring
STANDARD RINGS
track
LIP
CIEMAT
β = 0.99785
θc = 17.22°
Nhit = 47
Npe = 102.29
Run 1324407710 / Event 10000
[Particle: θ = 11.99° | ϕ = -72.96°]

ECAL - principles

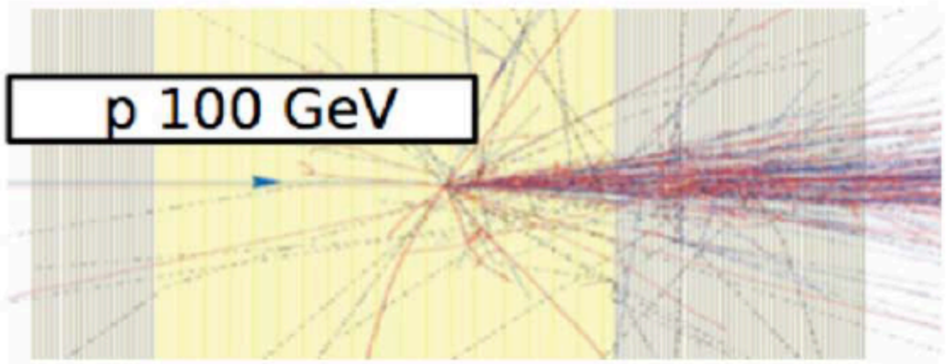


Positron 100 GeV

Longitudinally contained

Shower lateral size ~ $R_{\text{molière}}$(2cm)

$E_{ECAL} \sim P_{TRK}$

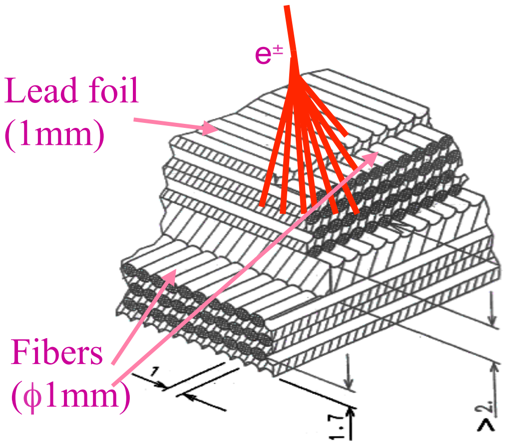


Proton 100 GeV

Longitudinal Leak

Shower lateral size >> $R_{\text{molière}}$

$E_{ECAL} \ll P_{TRK}$

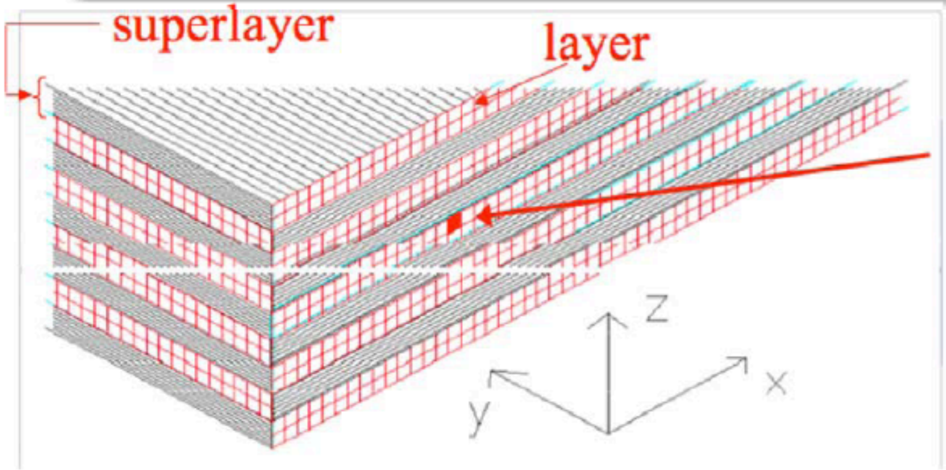


Proton rejection with ECAL:

- ✓ Energy fraction in each layer
- ✓ Shower lateral width in each layer
- ✓ Shower longitudinal profile
- ✓ Shower 3D profile

ECAL - design

A 3-D sampling calorimeter made out of lead and scintillating fibers



High granularity: ~ 0.9 x 0.9 cm

Readout cells: ~ 1 X_0(Z) × 0.5 $R_{\text{molière}}$(X,Y)

18 Longitudinal samplings

18 x 72 = 1296 cells ➔ 3D sampling

- Lead (58%), Scintillating fibers (33%), Optical glue (9%), Density ~ 6.8 g/cm^3
- Dimensions 648x648x167 mm

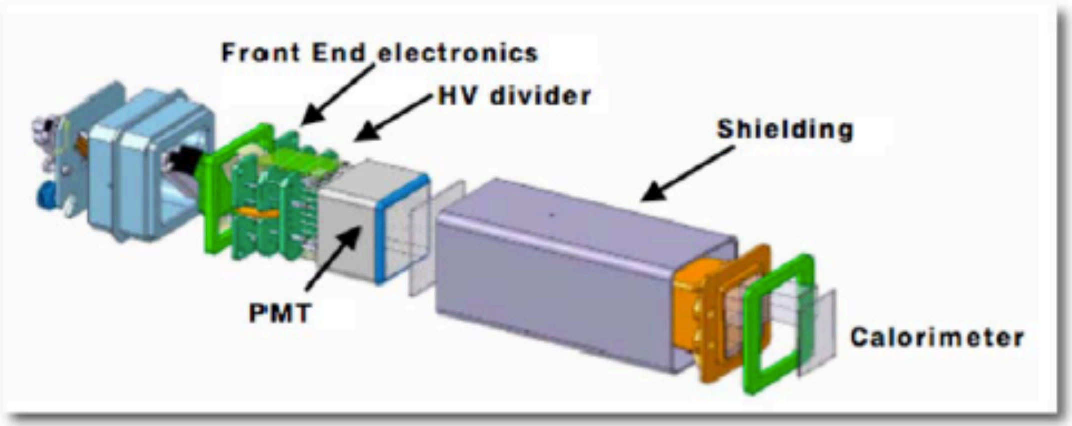
(17 X_0, λ_I / X_0~ 22)

ECAL - PMTs

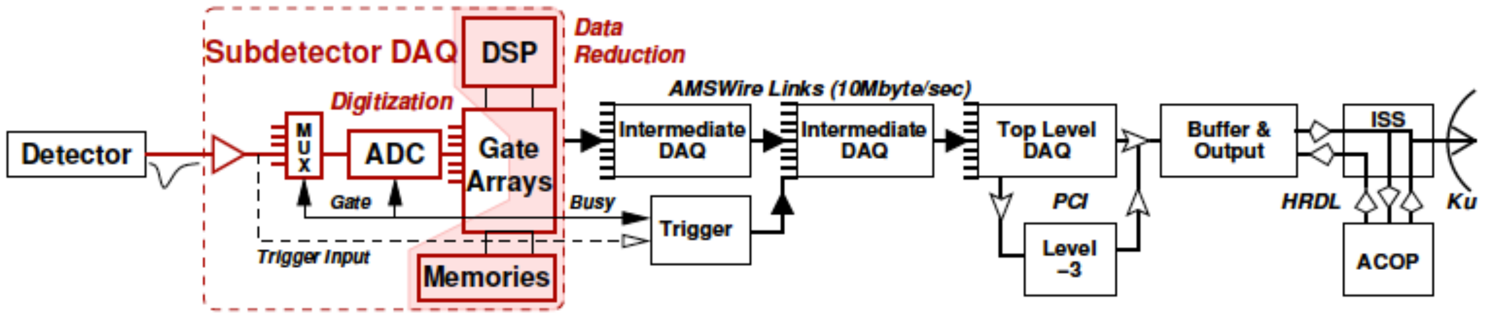
324 PMTs Hamamatzu R7600-00-M4 (4 anodes)

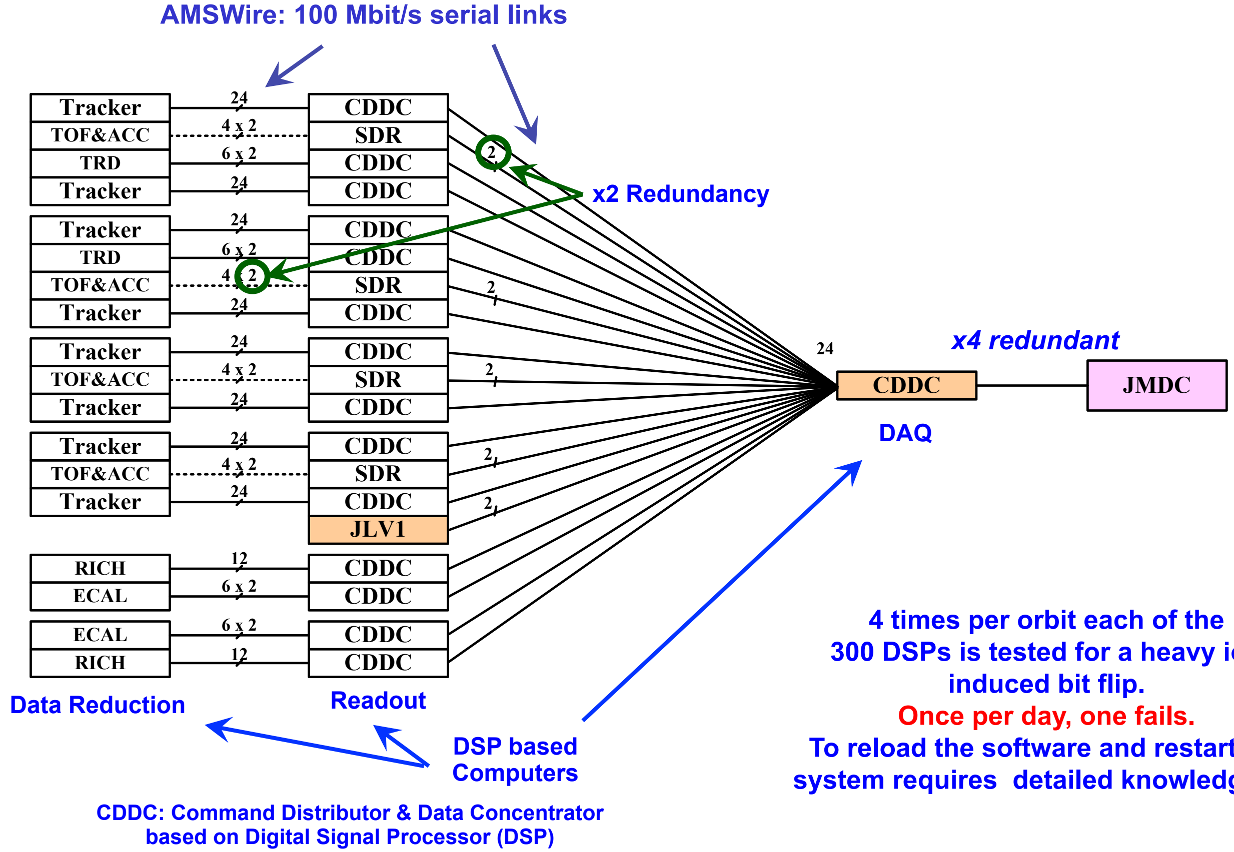
- 324 PMT, 4 pixels / PMT
- 2 dynamic ranges for each pixel (ADC 12 bits)
  - ✓ High Gain: 0.4 MeV - 1.6 GeV
  - ✓ Low Gain: 150 MeV - 55 GeV

1296 HG, 1296 LG, 324 dynodes



Electronics

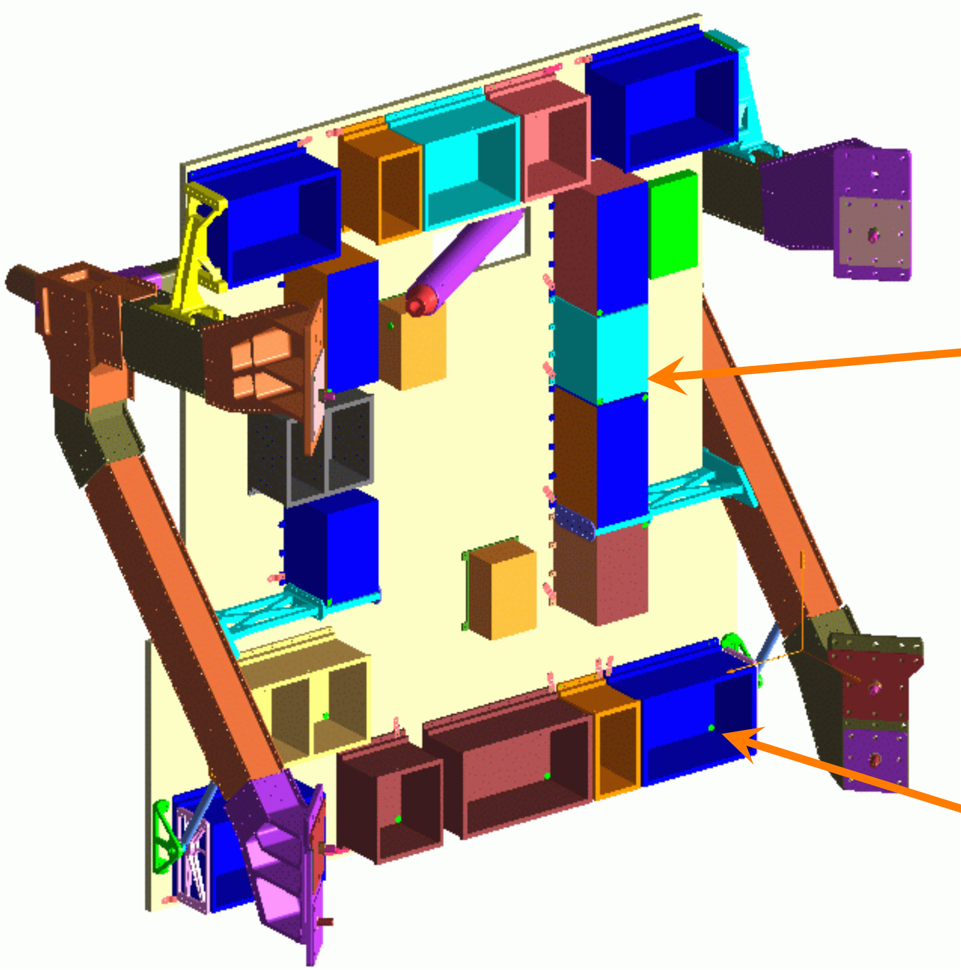




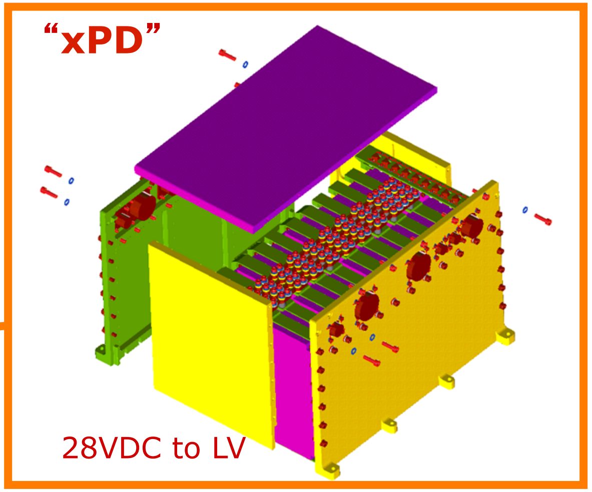
4 times per orbit each of the 300 DSPs is tested for a heavy ion induced bit flip.
Once per day, one fails.
To reload the software and restart the system requires detailed knowledge of:

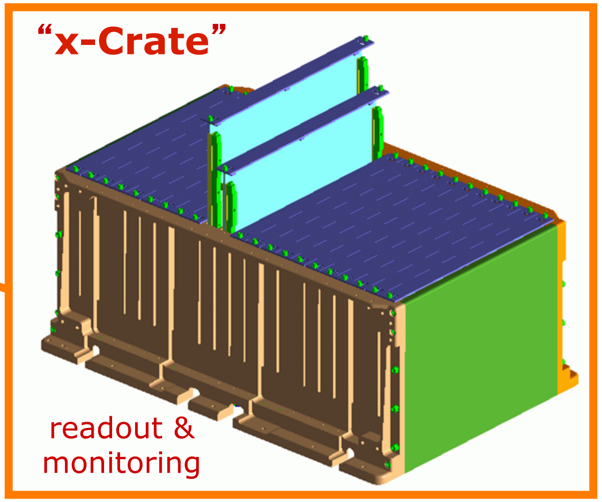
Electronics - mounting

Ram Radiator (~4m^2) Electronics ~ 750W

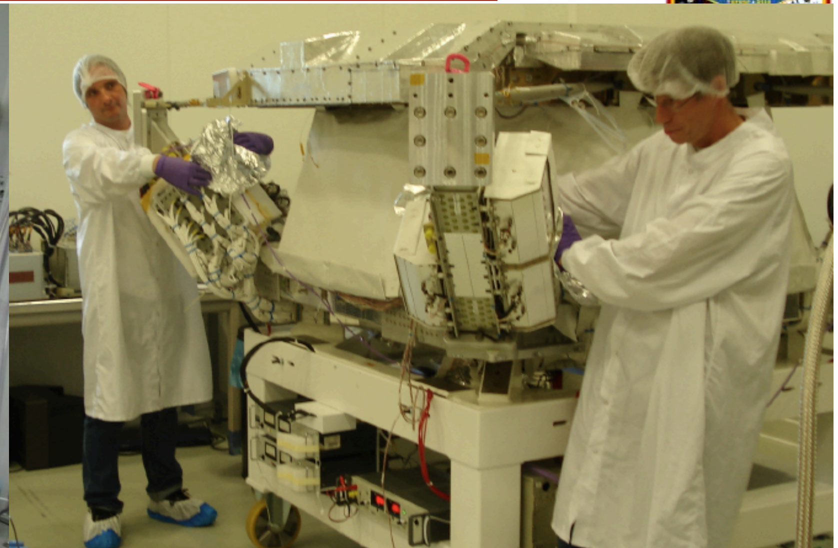


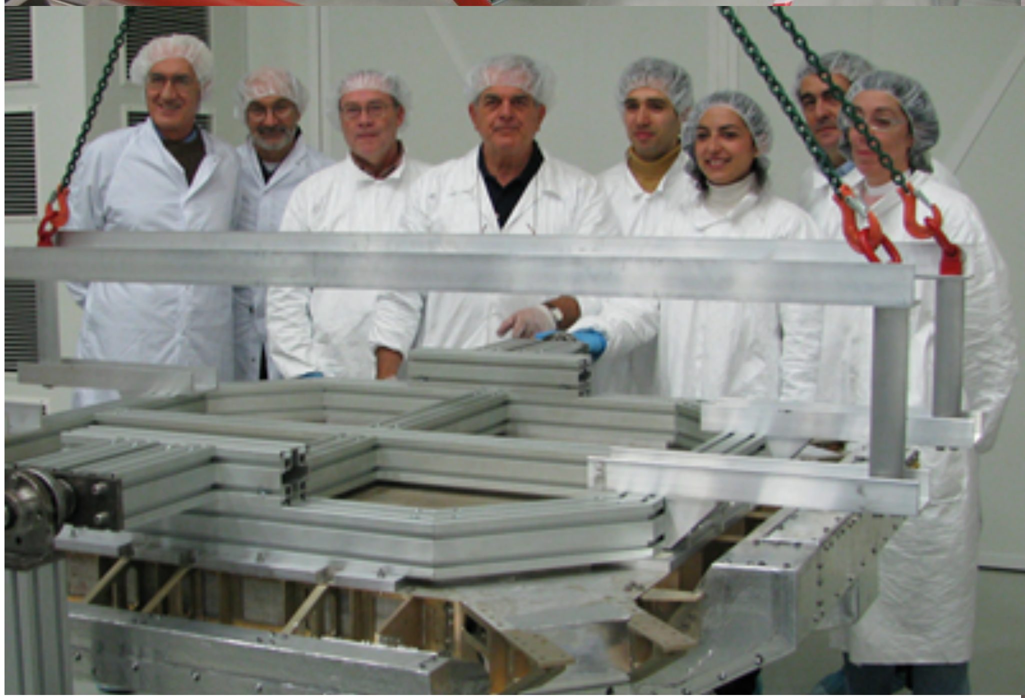
Each type of box optimized for weight vs. thermal performance

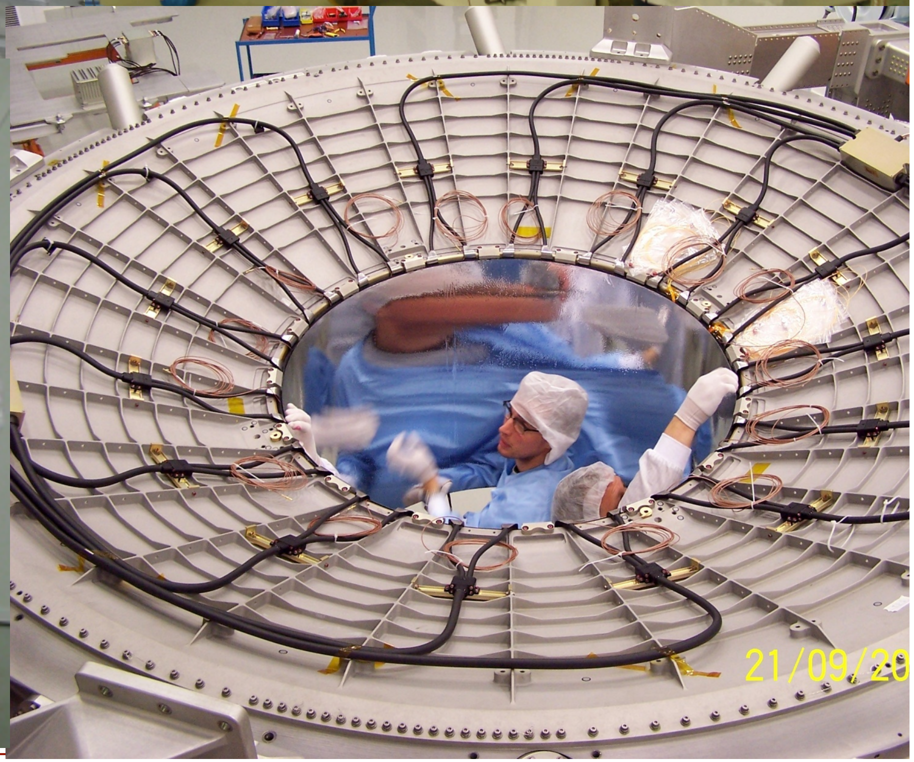




Detector integration

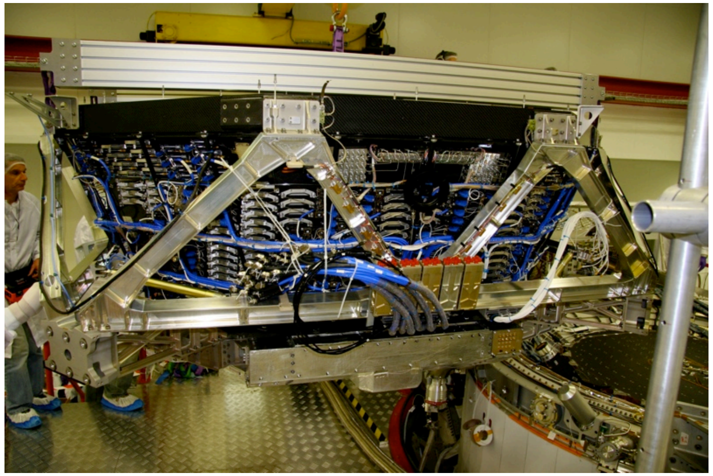






Detector integration

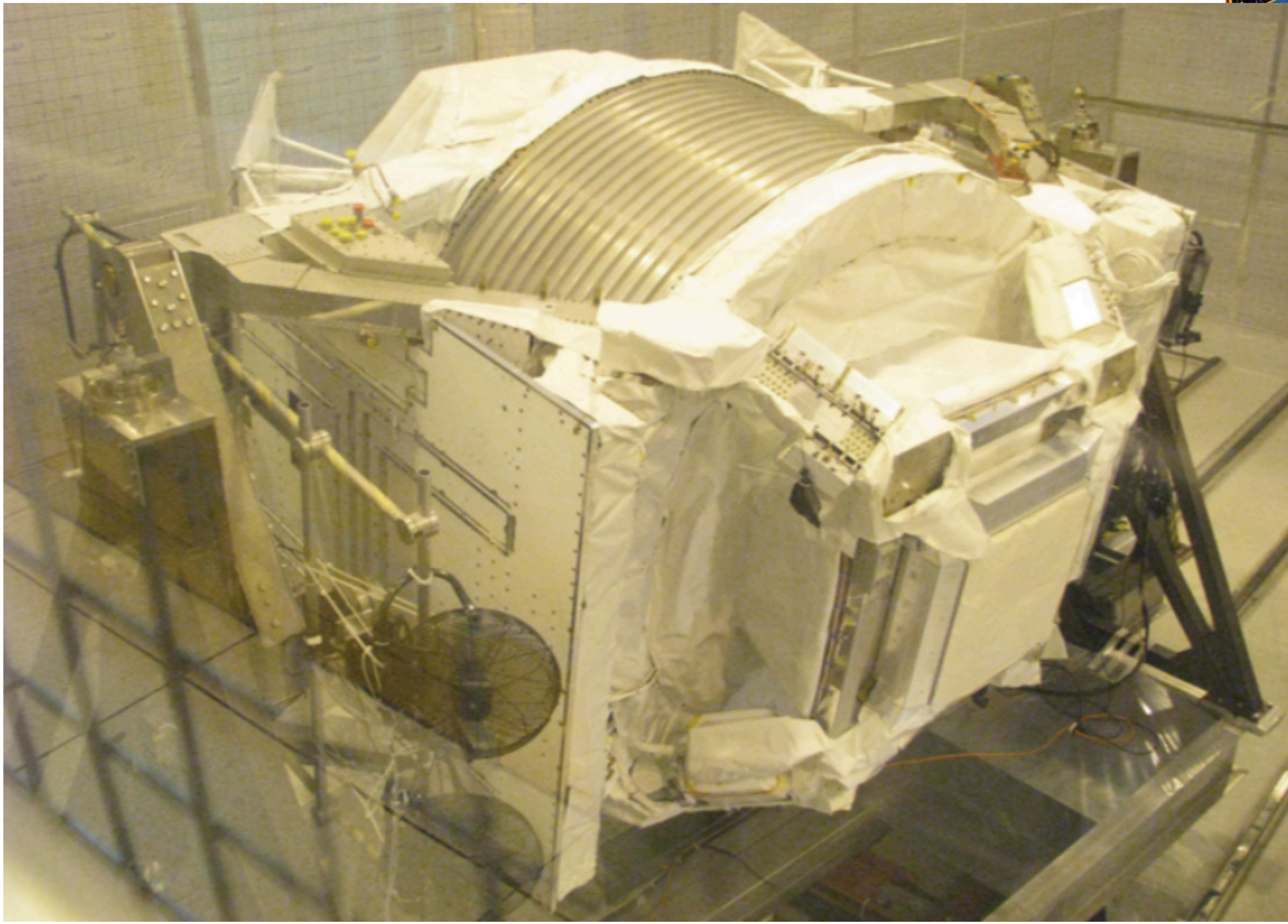
Detector integration



UTOF+TRD

LTOF+RICH+ECAL

AMS in the CERN test beam (8-20 Aug 2010)

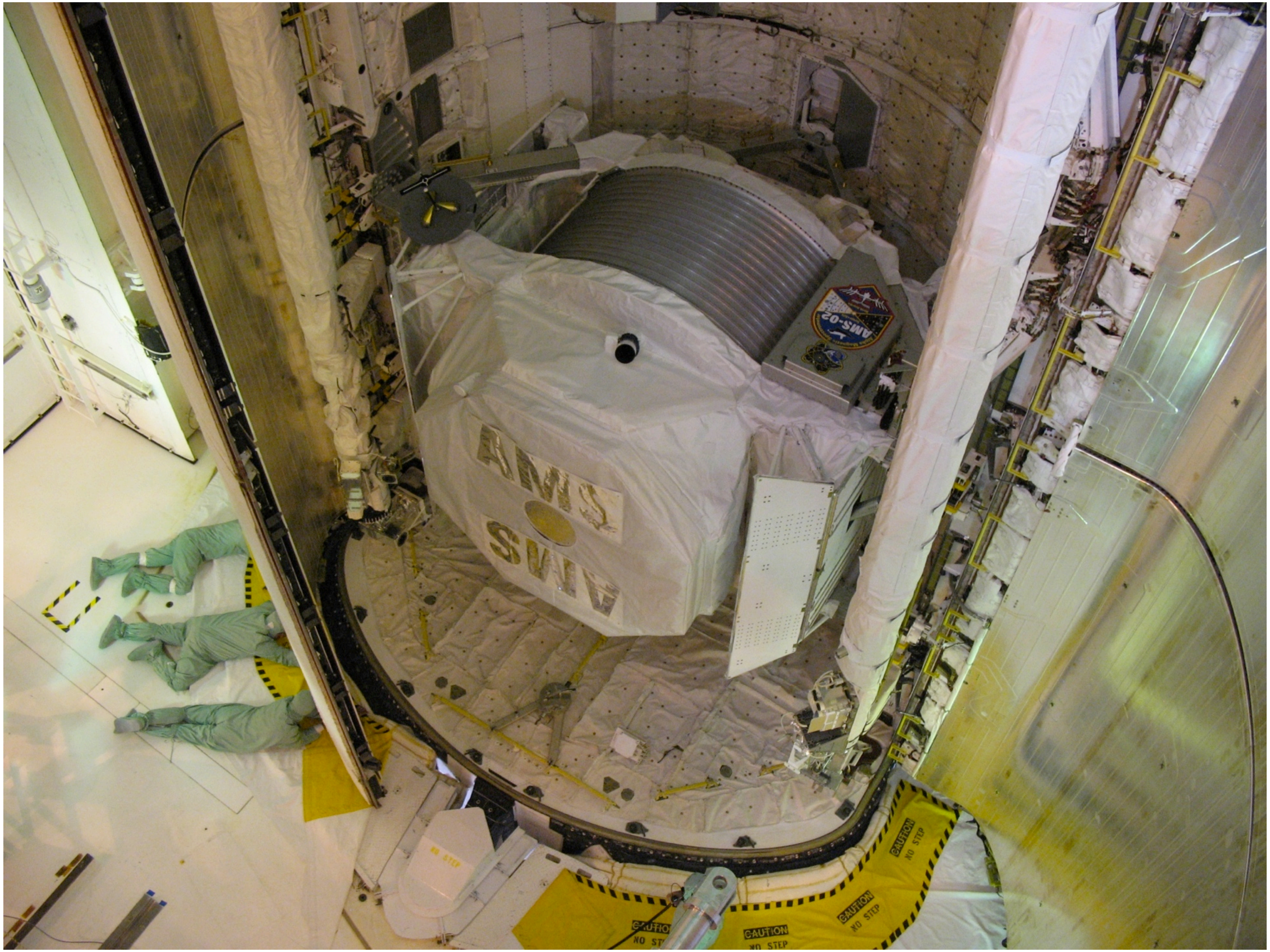


26 August - U.S. Air Force C-5 transported AMS to KSC

28 August - AMS powered and taking data at KSC

AMS in the Space Station Processing Facility (SSPF)

Closing Endeavour's Payload Bay Doors at the Launch Pad



STS-134 crew

The STS-134 crew leaves the Operations & Checkout building on their way to the Launch Pad

Counting down to the launch of STS-134

AMS POCC @ JSC

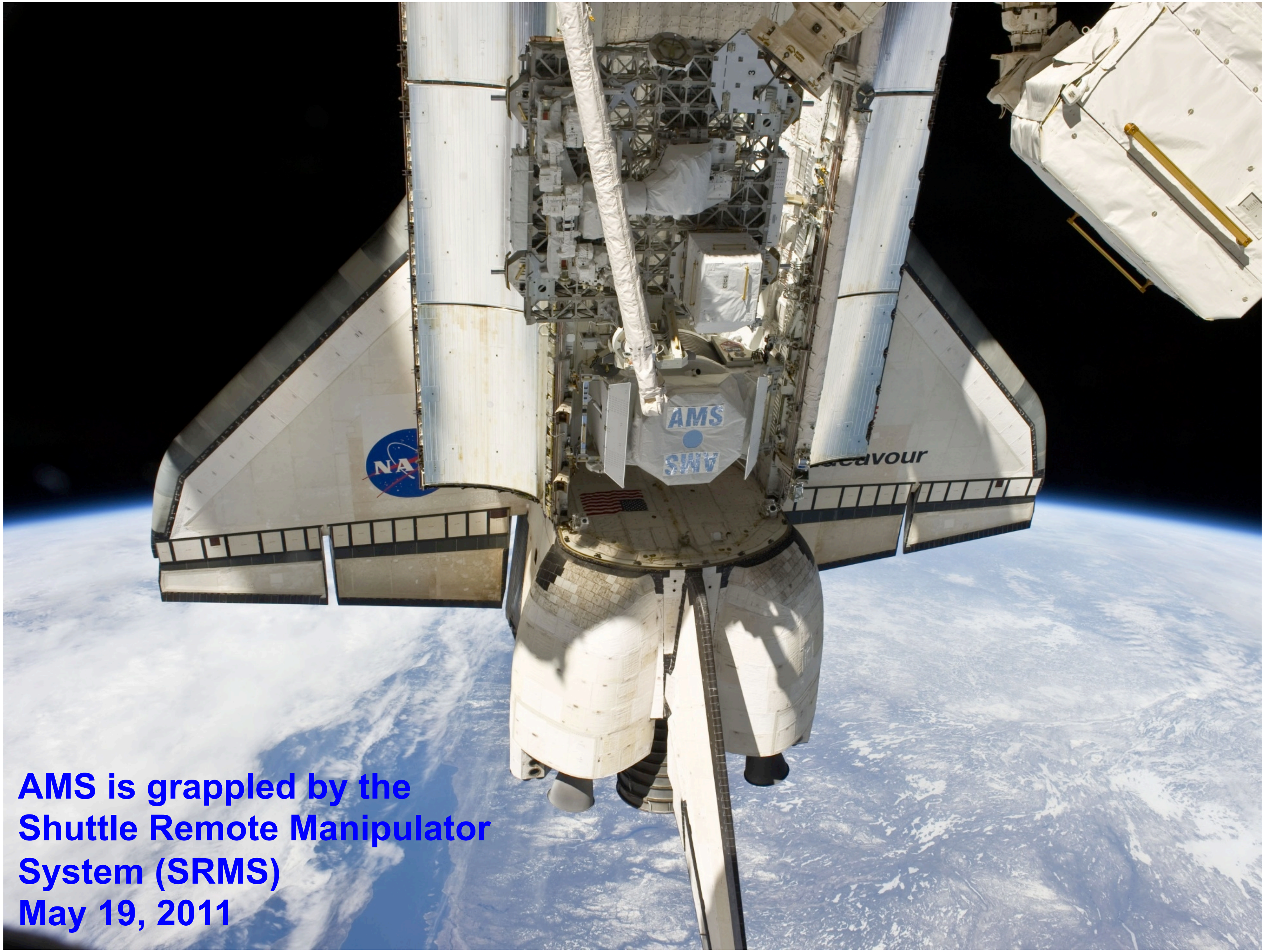
AMS POCC @ JSC waiting for launch

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

Seen from the AMS POCC @ JSC

Endeavour approaches the International Space Station

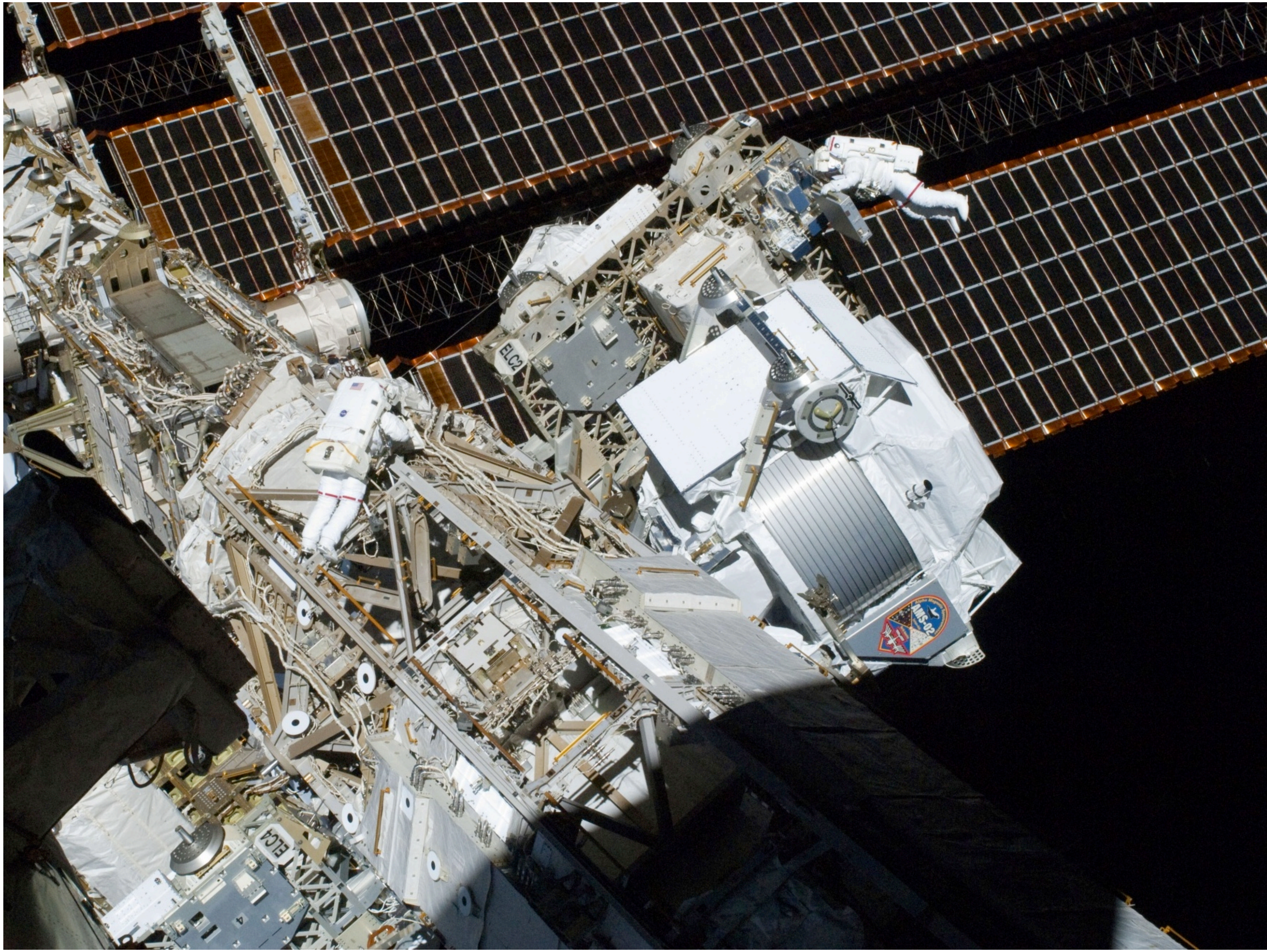
AMS transfer to the ISS



AMS is grappled by the Shuttle Remote Manipulator System (SRMS)
May 19, 2011

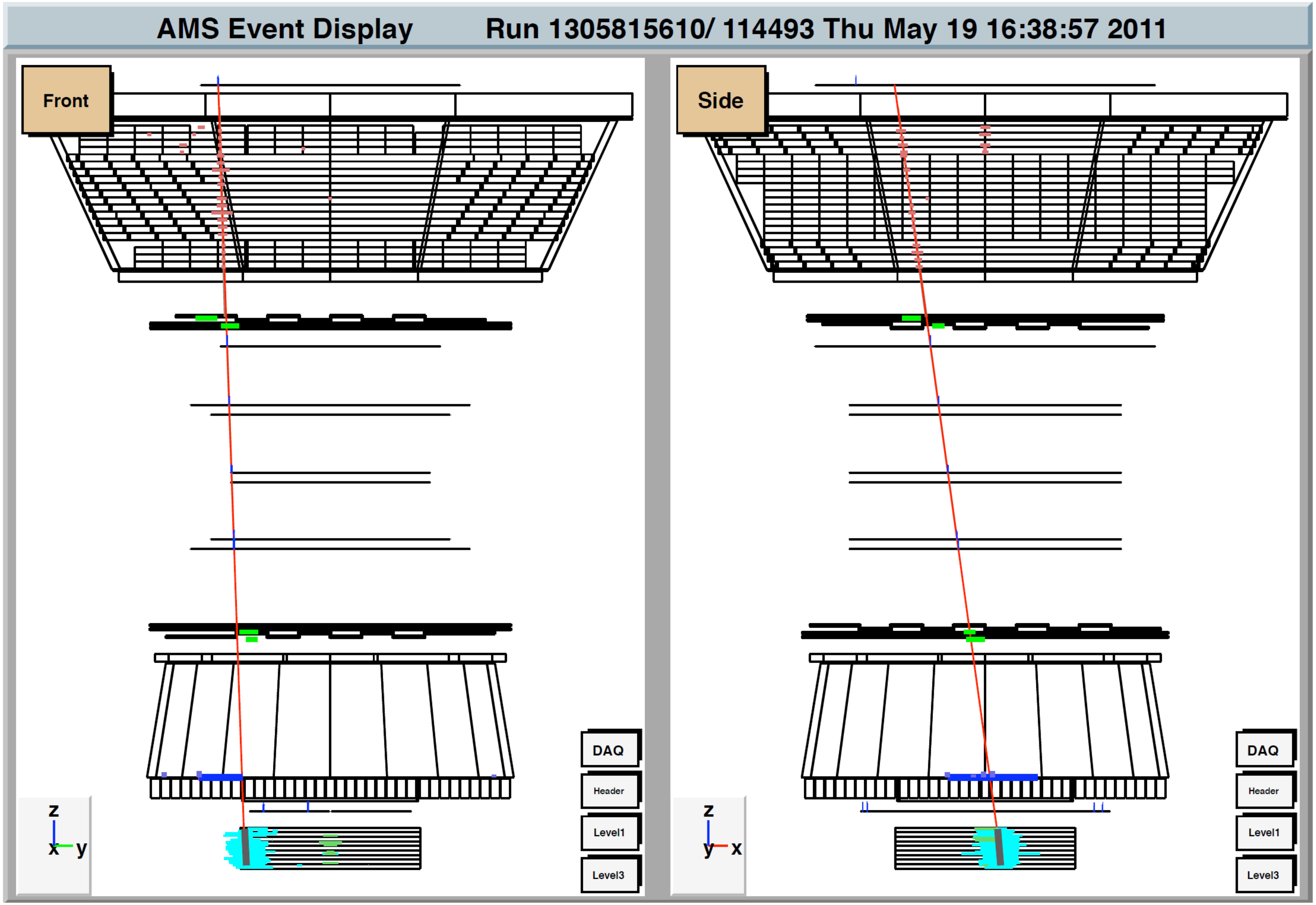
AMS installed on the ISS truss, May 19, 2011

Two astronauts working on the Space Station near AMS

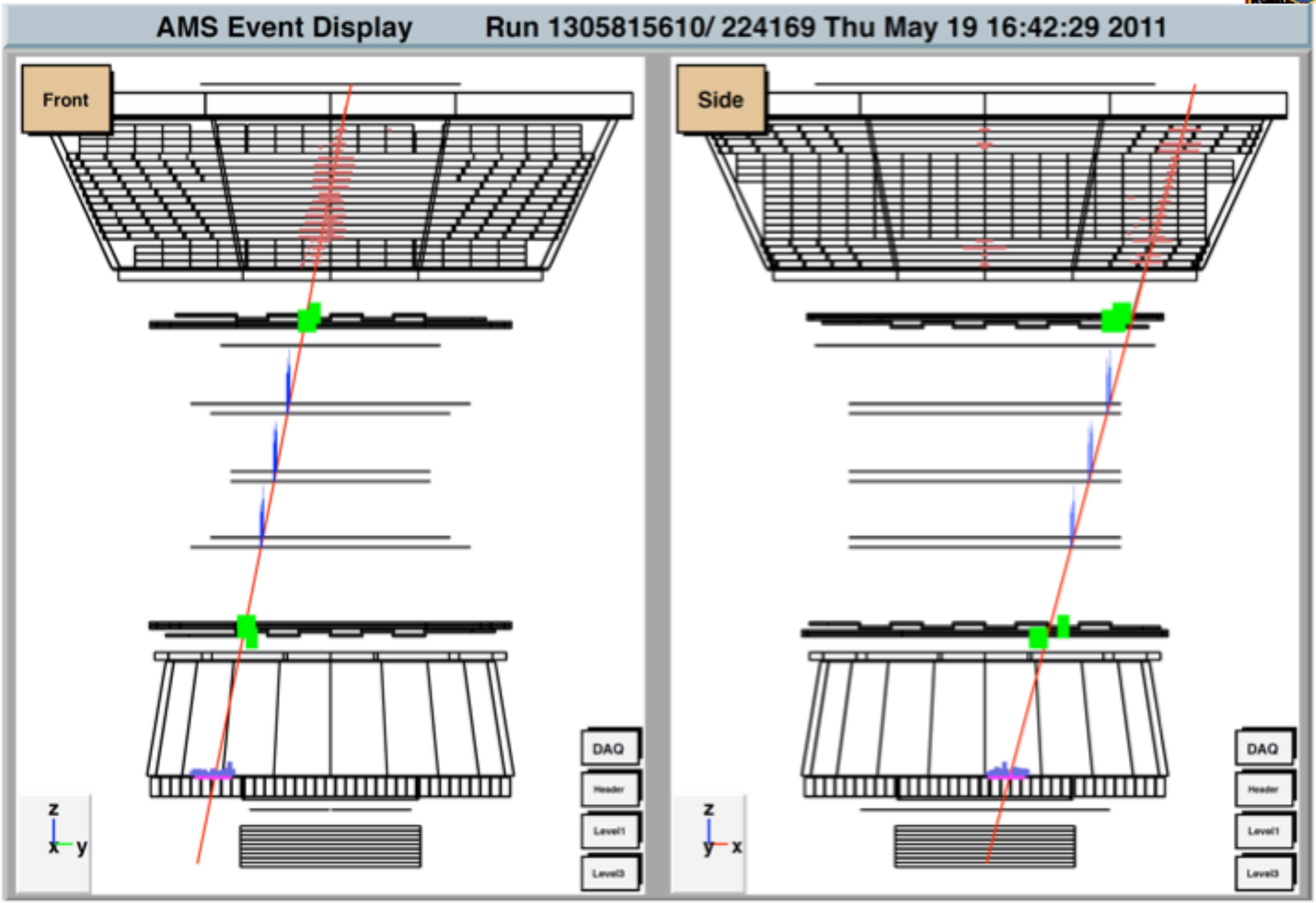


May 19: AMS installed on ISS 5:15 CDT, start taking data 9:35 CDT

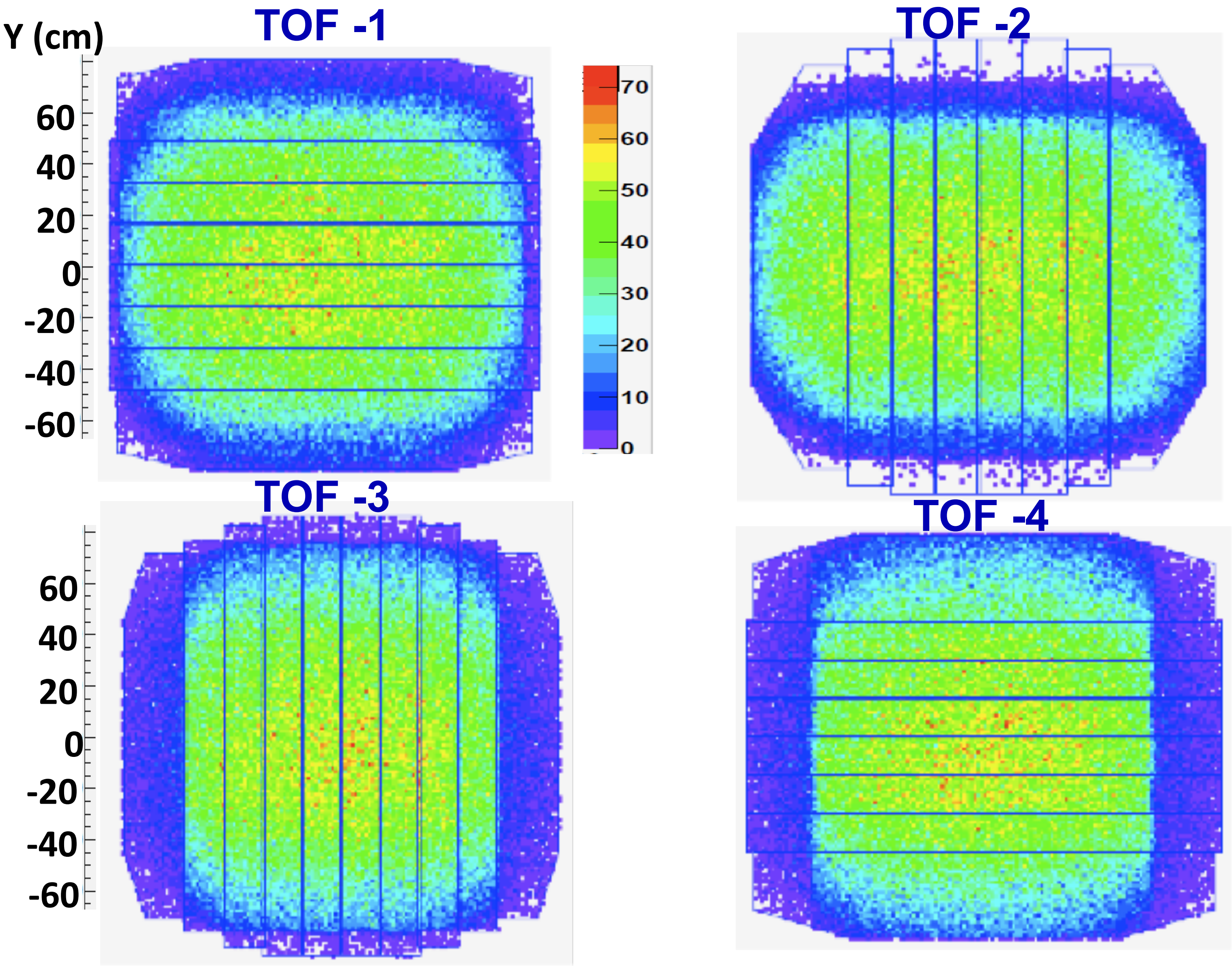
Data from the 1st few minutes – 20 GeV Electron, 19 May 211



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

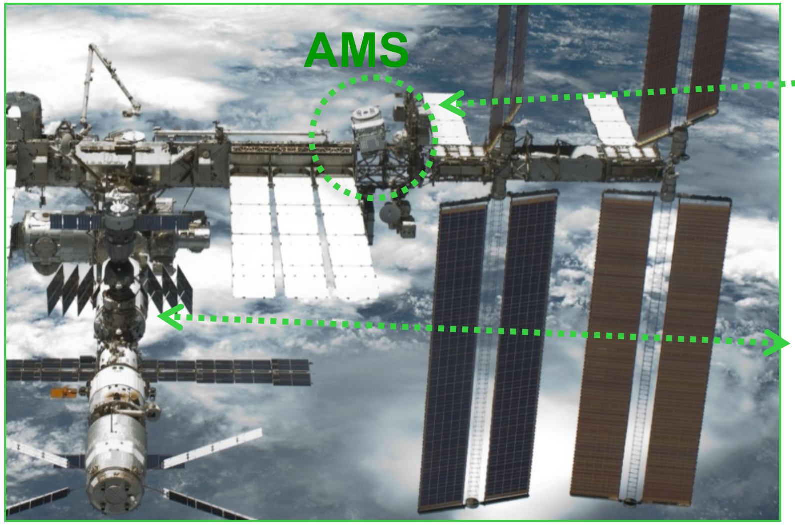


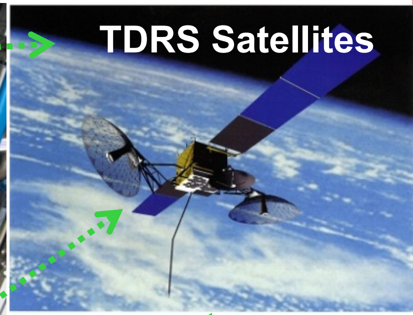
TOF - Trigger uniformity



The TOF particle distribution on the 4 layers.
The absence of holes indicates all the counters are functioning as expected.

Science Data Flow





Flight Operations

Ku-Band
High Rate (down):
Events <10Mbit/s>

Ground Operations

S-Band
Low Rate (up & down):
Commanding: 1 Kbit/s
Monitoring: 30 Kbit/s

AMS Payload Operations Control and Science Operations Centers (POCC, SOC) at CERN

AMS Computers at MSFC, AL

White Sands Ground Terminal, NM

CERN POCC fully operational

Visit by General Charlie Bolden, NASA Administrator, June 23, 2011

General Charlie Bolden, NASA Administrator, made a special trip to visit the AMS POCC on June 23, 2011.
Dr. Veronica Bindi and Dr. Lucio Quadrani explain the POCC details to General Bolden.

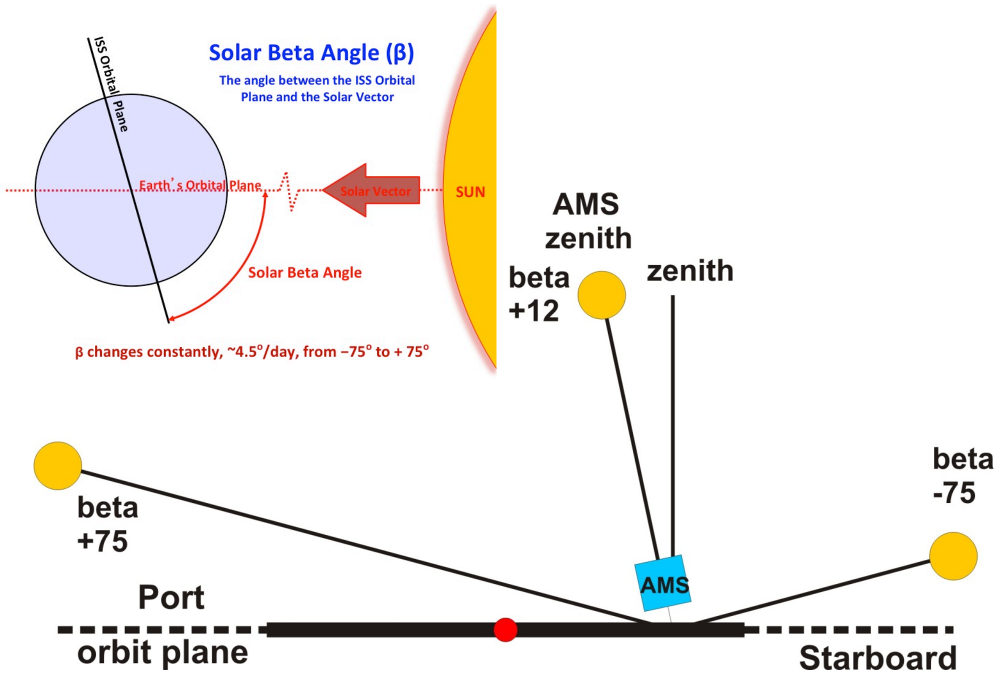
Thermal Control is one of the most challenging task in the operation of AMS

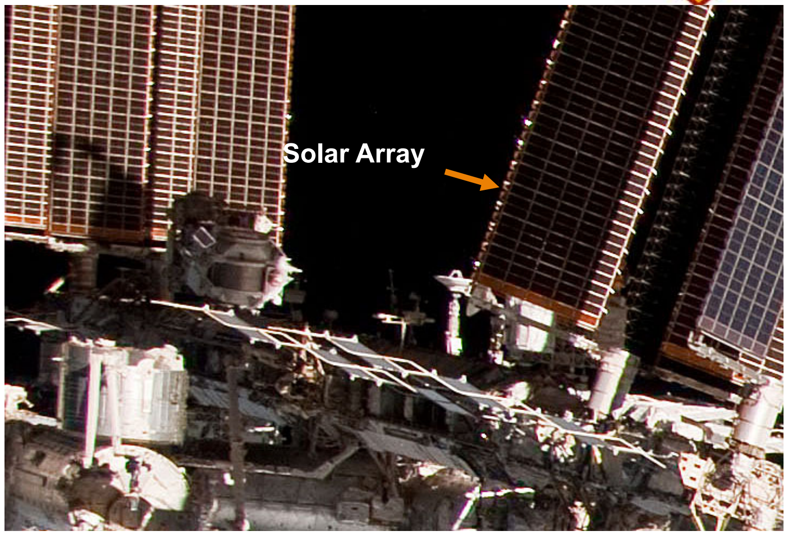
The thermal environment on ISS is constantly changing due to:

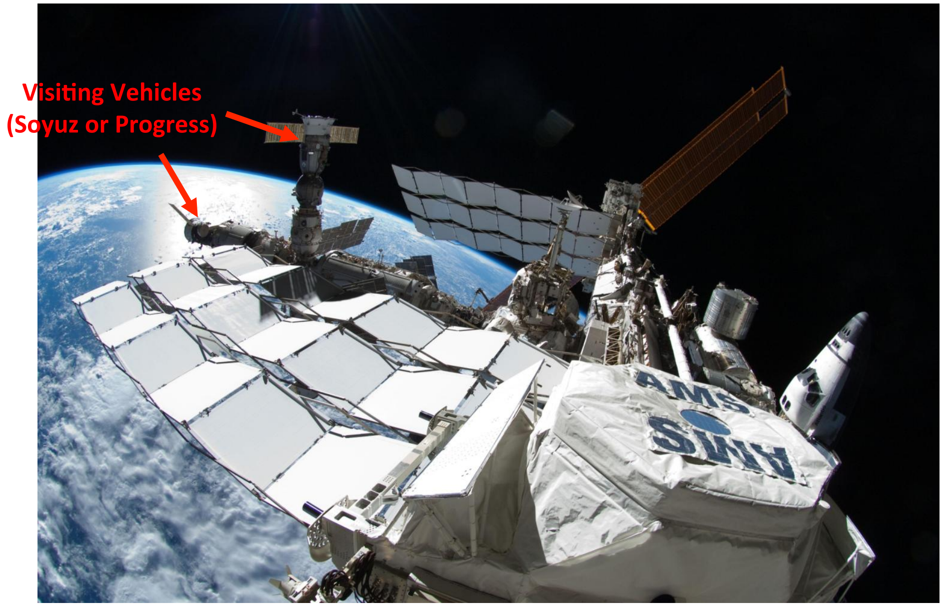
- **Solar Beta Angle (β)**
- **Position of the ISS Radiators and Solar Arrays**
- **ISS Attitude**

Over 1,100 temperature sensors and 298 heaters are monitored around the clock in the AMS POCC to assure components stay within thermal limits and avoid permanent damage.

Thermal control



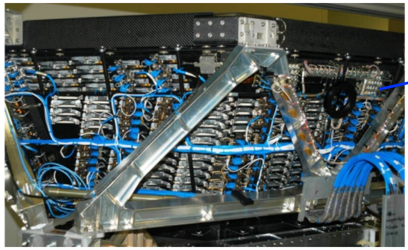


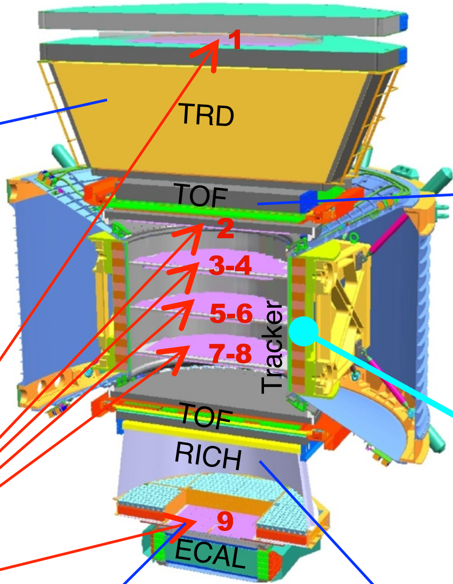


Thermal control

AMS Flight Electronics for Thermal Control

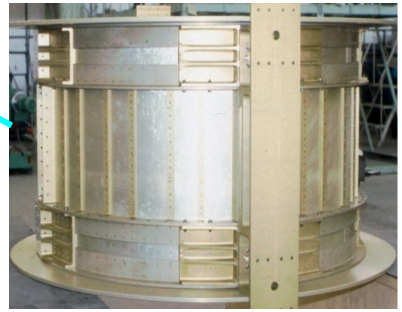
TRD
24 Heaters
8 Pressure Sensors
482 Temperature Sensors



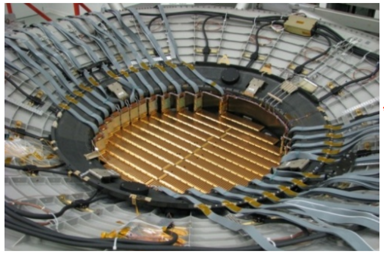


TOF & ACC
64 Temperature Sensors

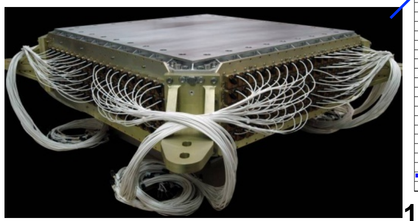
Magnet
68 Temperature Sensors

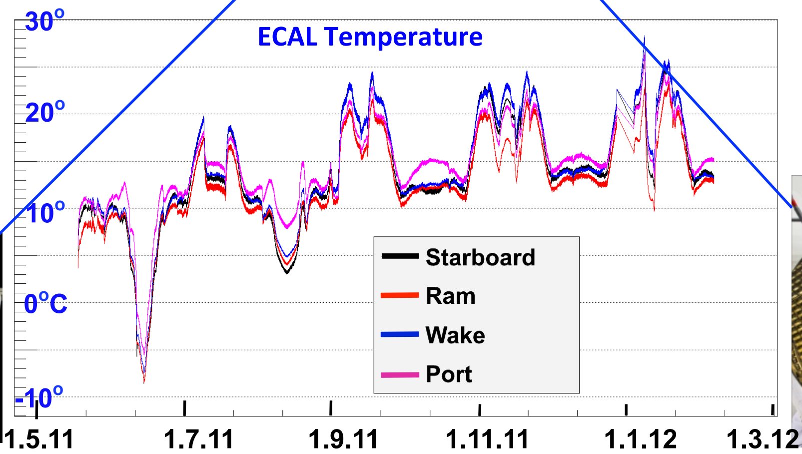


Silicon Tracker
4 -Pressure Sensors
32 Heaters
142 Temperature Sensors

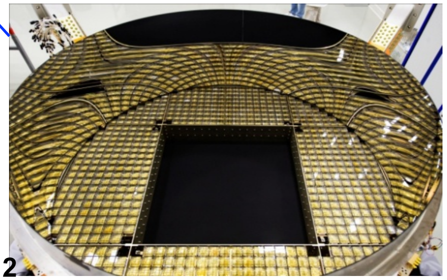


ECAL
80 Temperature Sensors

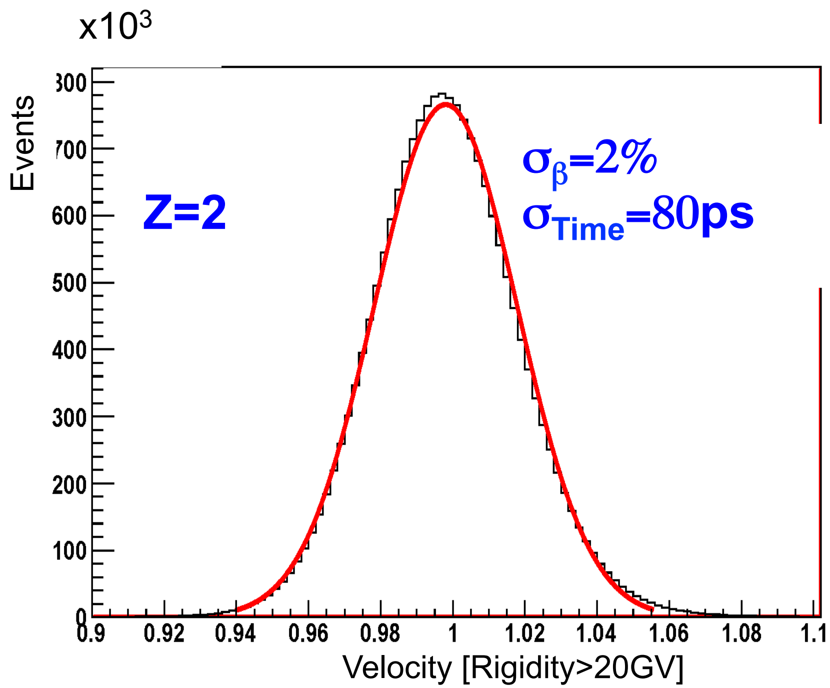


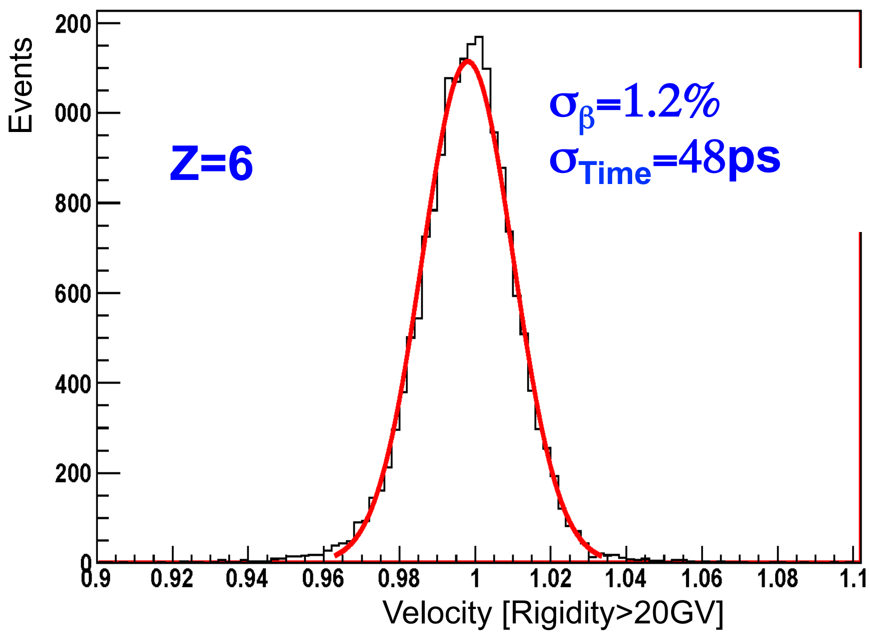


RICH
96 Temperature Sensors

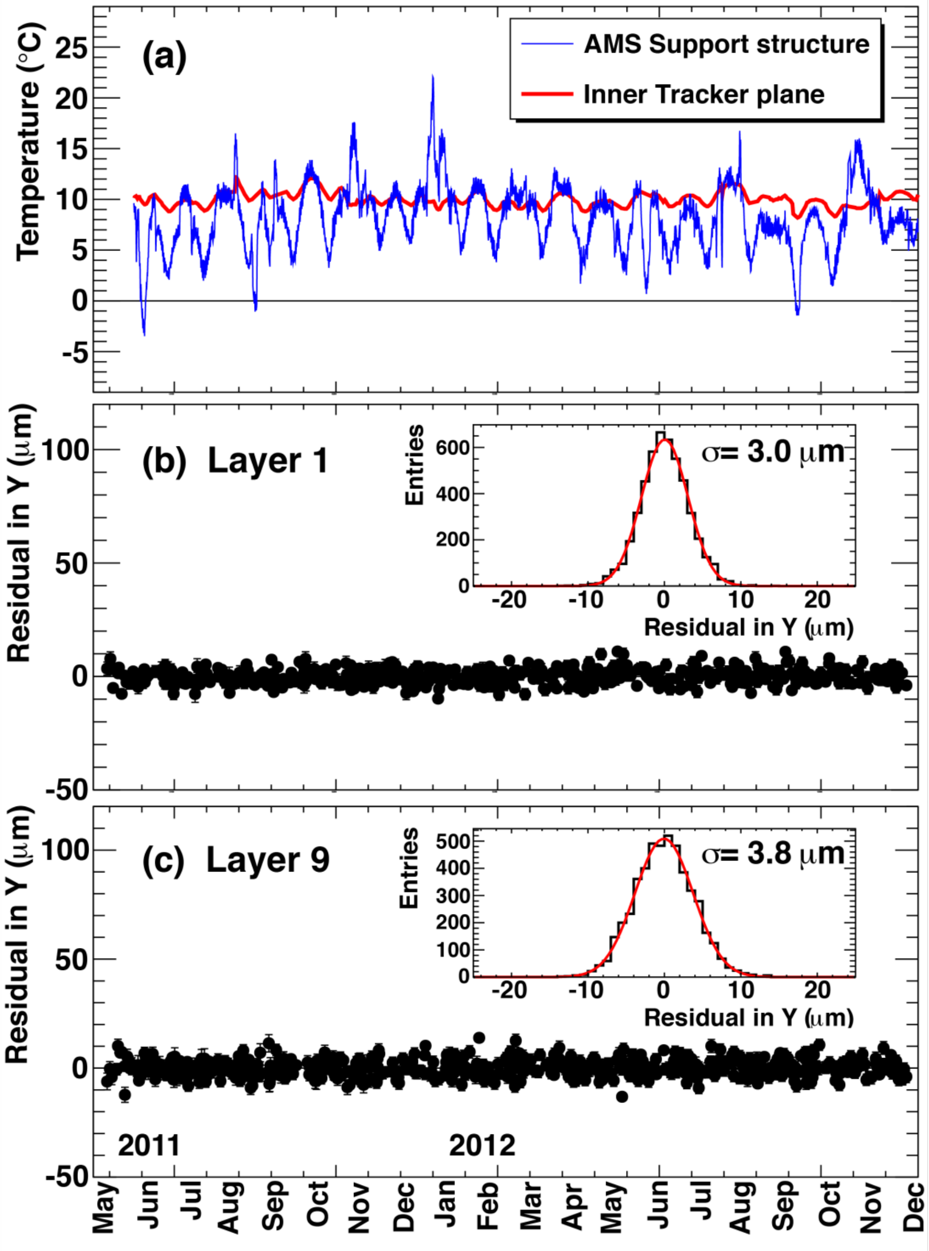


Performances in space – velocity measurement

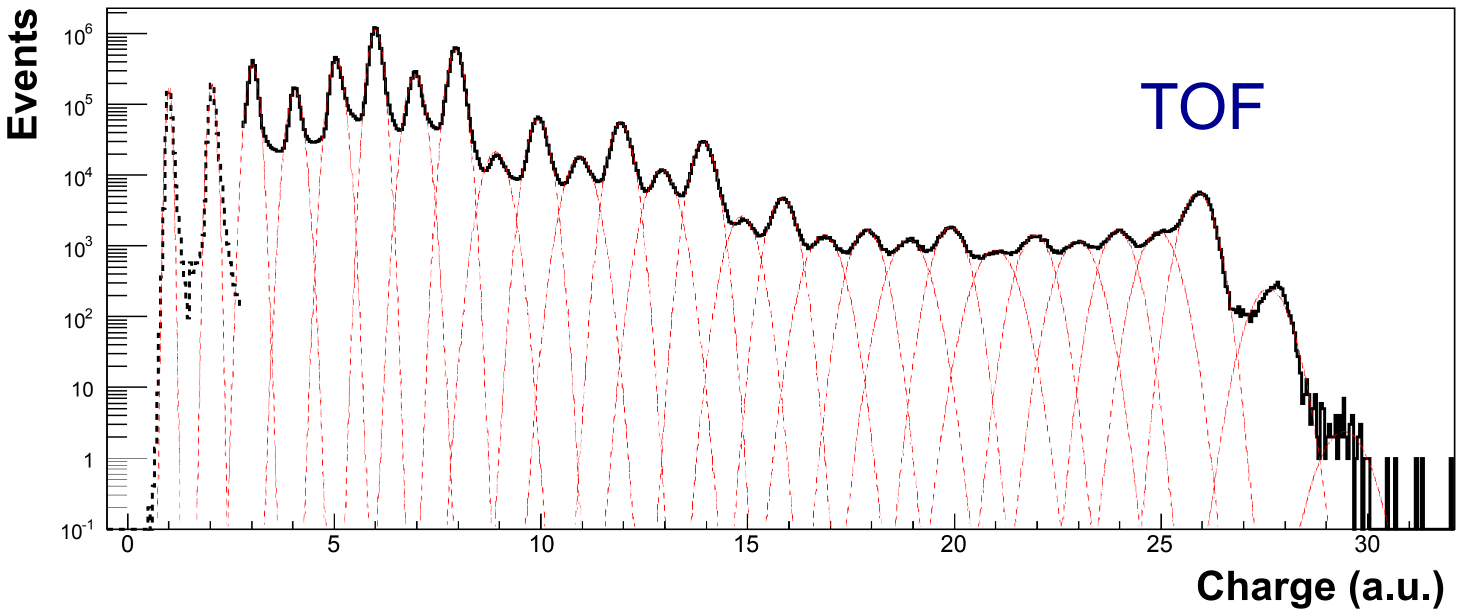


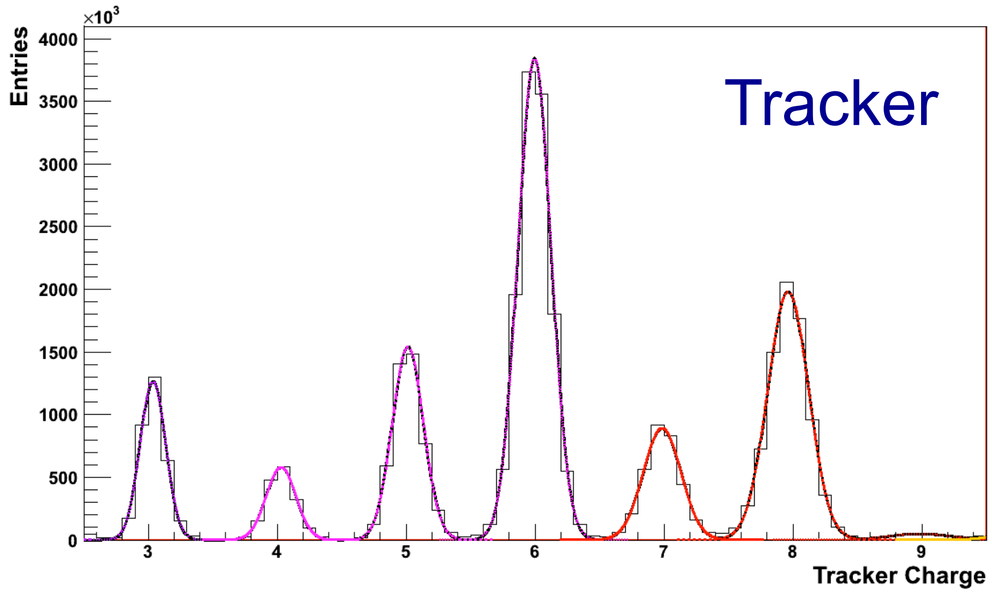


Performances in space – tracker stability

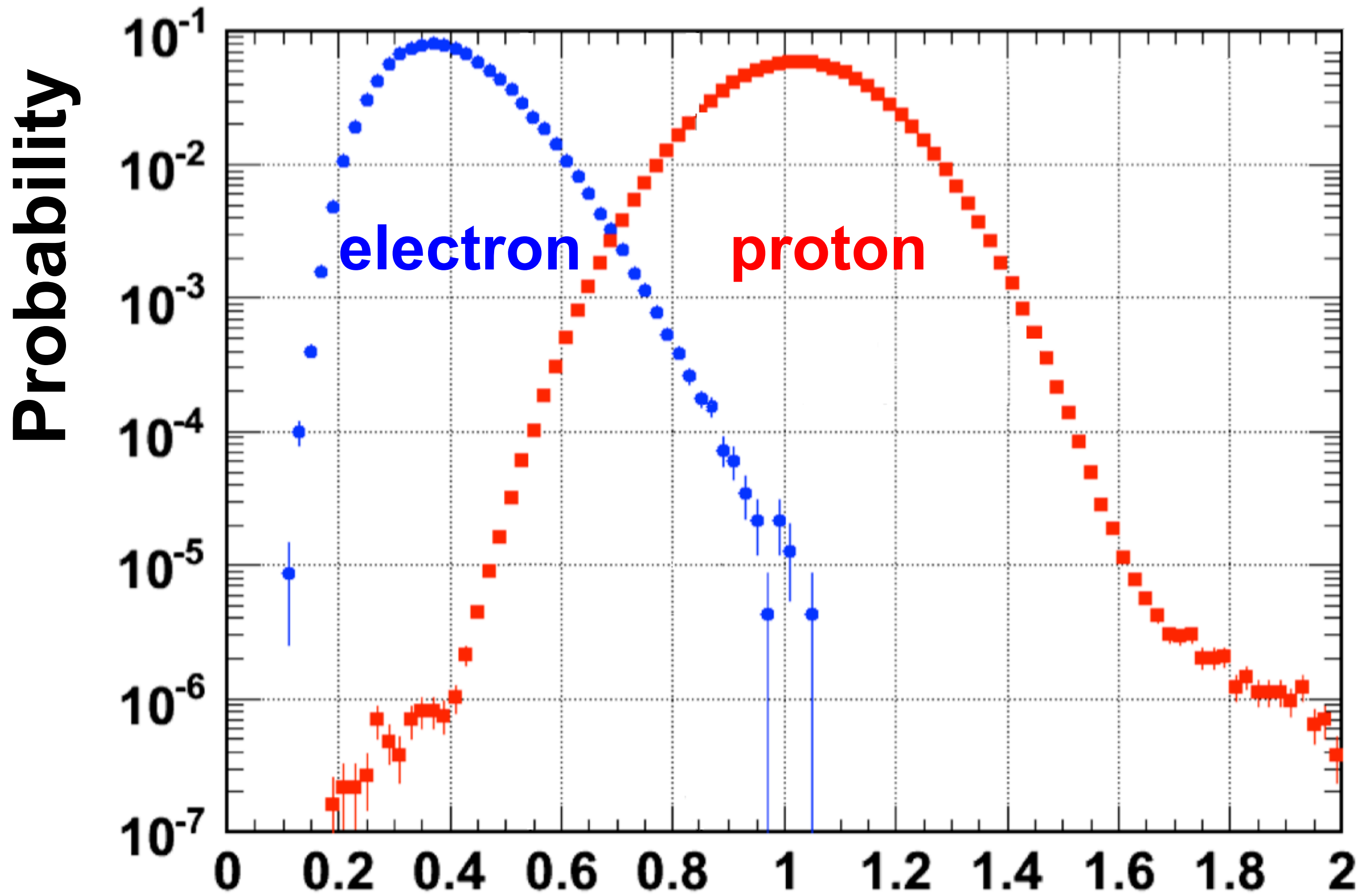


Performances in space – charge measurement





TRD estimator = $-\ln(P_e/(P_e+P_p))$

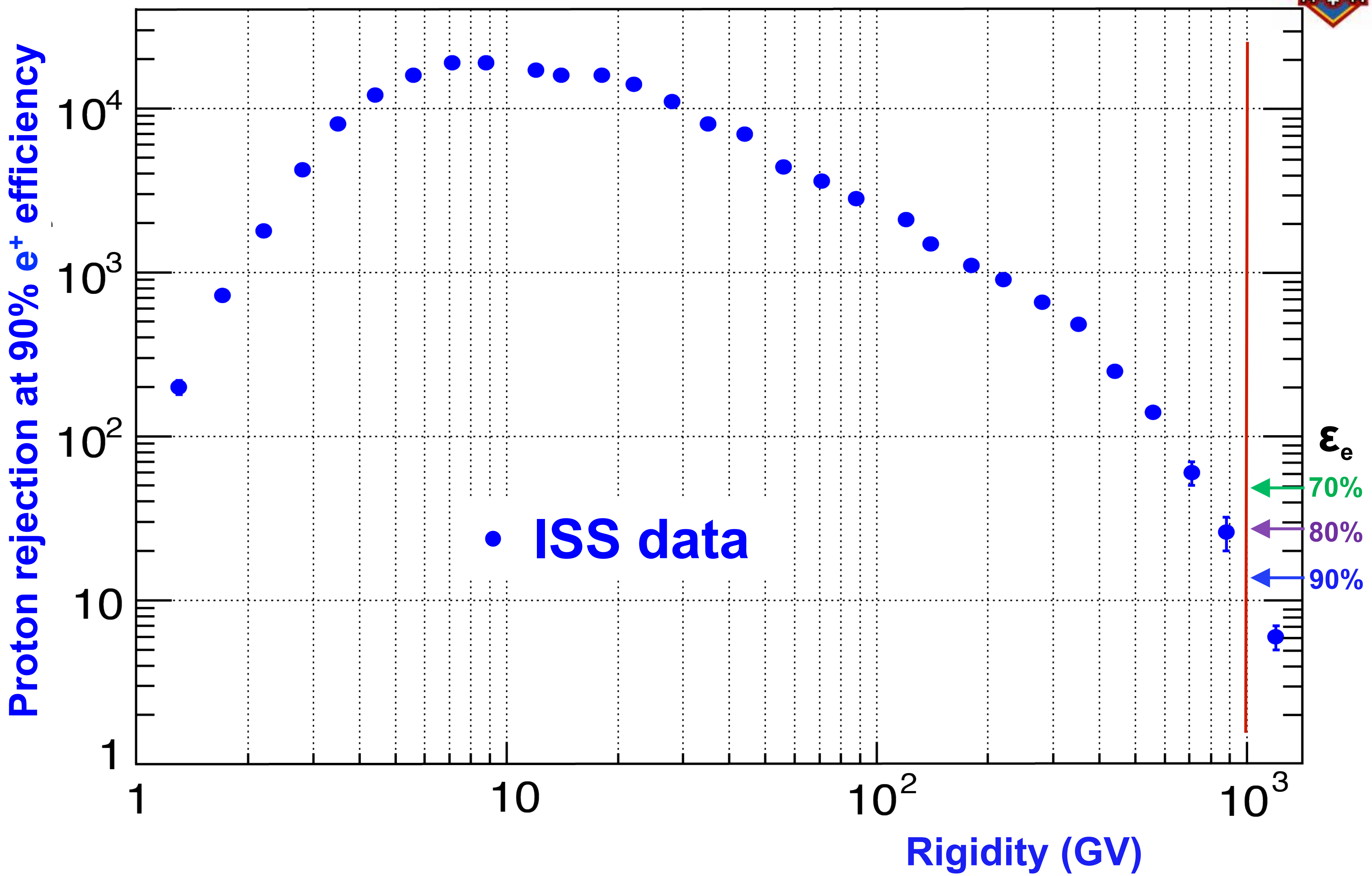


Normalized probabilities P_e and P_p

$$P_e = \sqrt[n]{\prod_i^n P_e^{(i)}(A)}$$

$$P_p = \sqrt[n]{\prod_i^n P_p^{(i)}(A)}$$

Performances in space – proton rejection using TRD



ECAL estimator = Boosted Decision Tree (BDT)

Shower Longitudinal Profile (25):
- Mean
- Sigma
- Skewness
- Kurtosis
- Energy deposit in first 2 layers
- Fraction of energy deposited in the first 2 layers
- Fraction of energy deposited in the last 2 layers

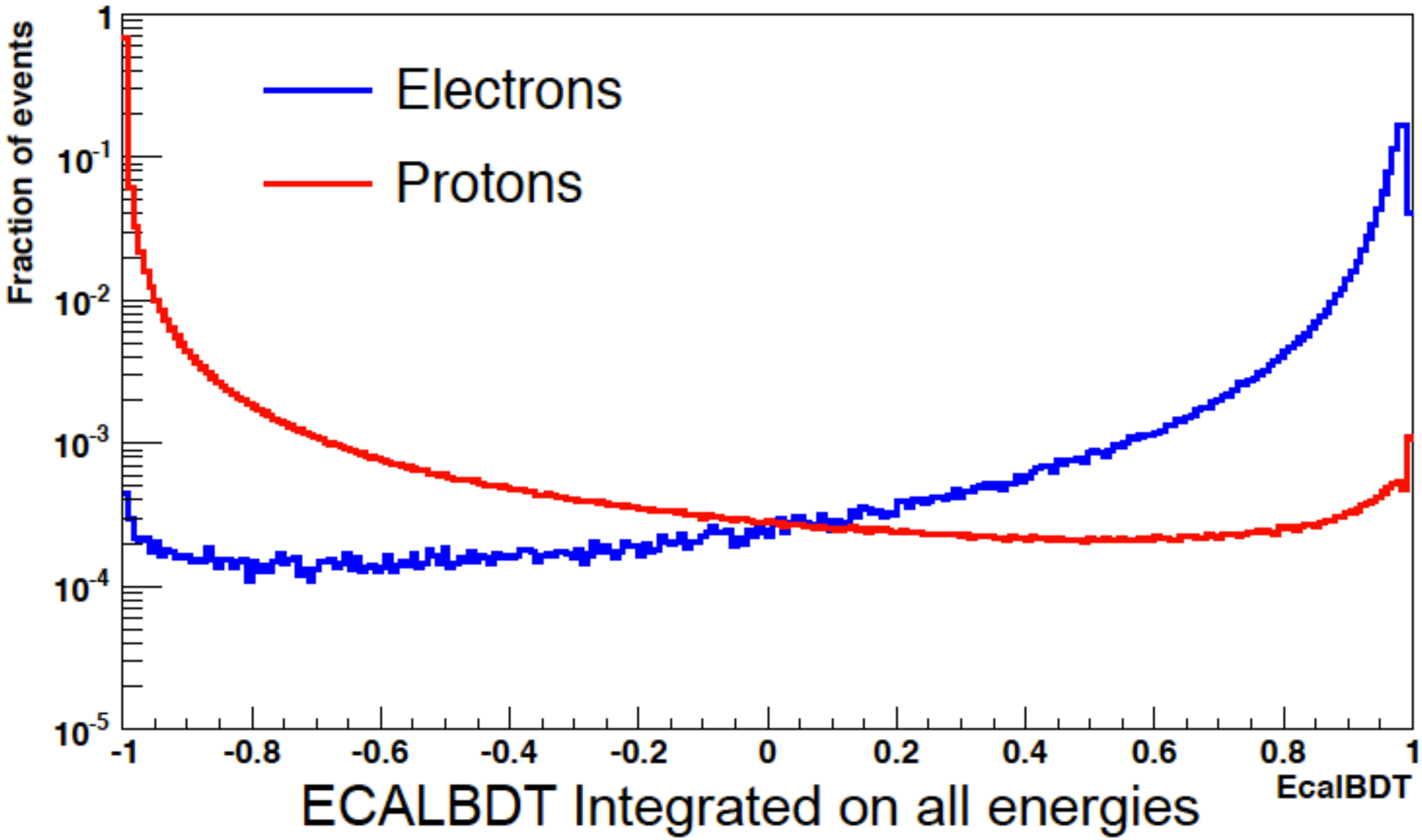
+
- Energy Fraction in the **18** layers

Shower Lateral Profile (25):
- Fraction of energy within 3 cm
- Fraction of energy within 5 cm
- Fraction of energy in 3 cells (X)
- Fraction of energy in 3 cells (Y)
- Fraction of energy in 5 cells (X)
- Fraction of energy in 5 cells (Y)
- Lateral sigma (X)
- Lateral sigma (Y)

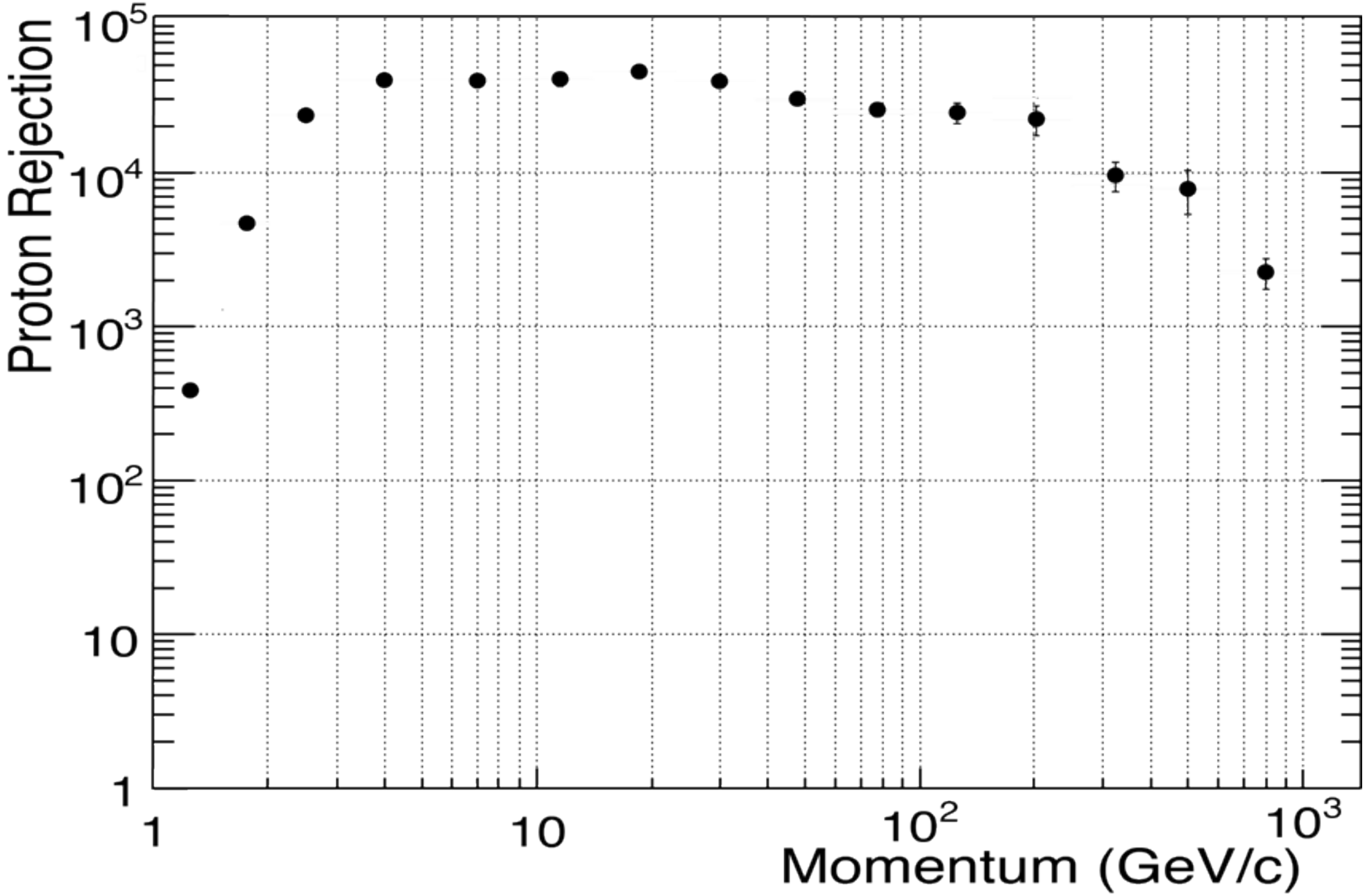
+
- Lateral sigma in the last **17** layers

Shower 3D Profile (4):
- Number of hits
- Footprint (X)
- Footprint (Y)
- X-Y asymmetry

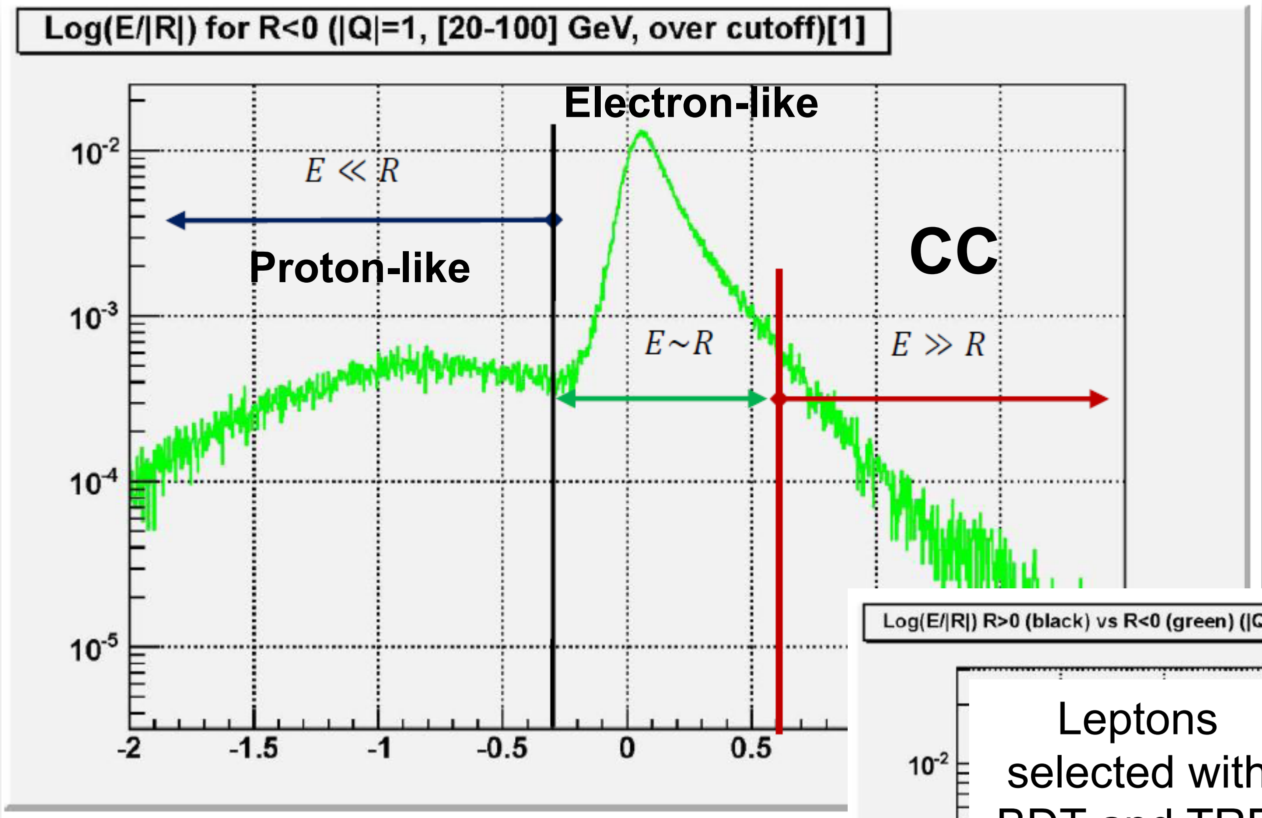
ECAL estimator = Boosted Decision Tree (BDT)

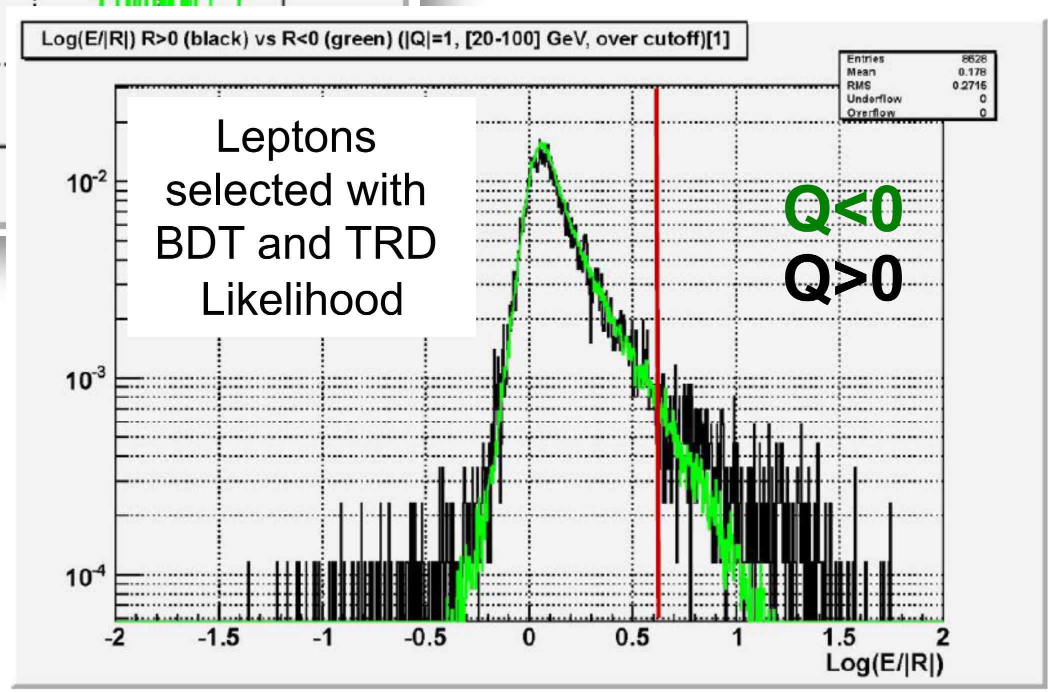


Data from ISS: Proton rejection using the ECAL

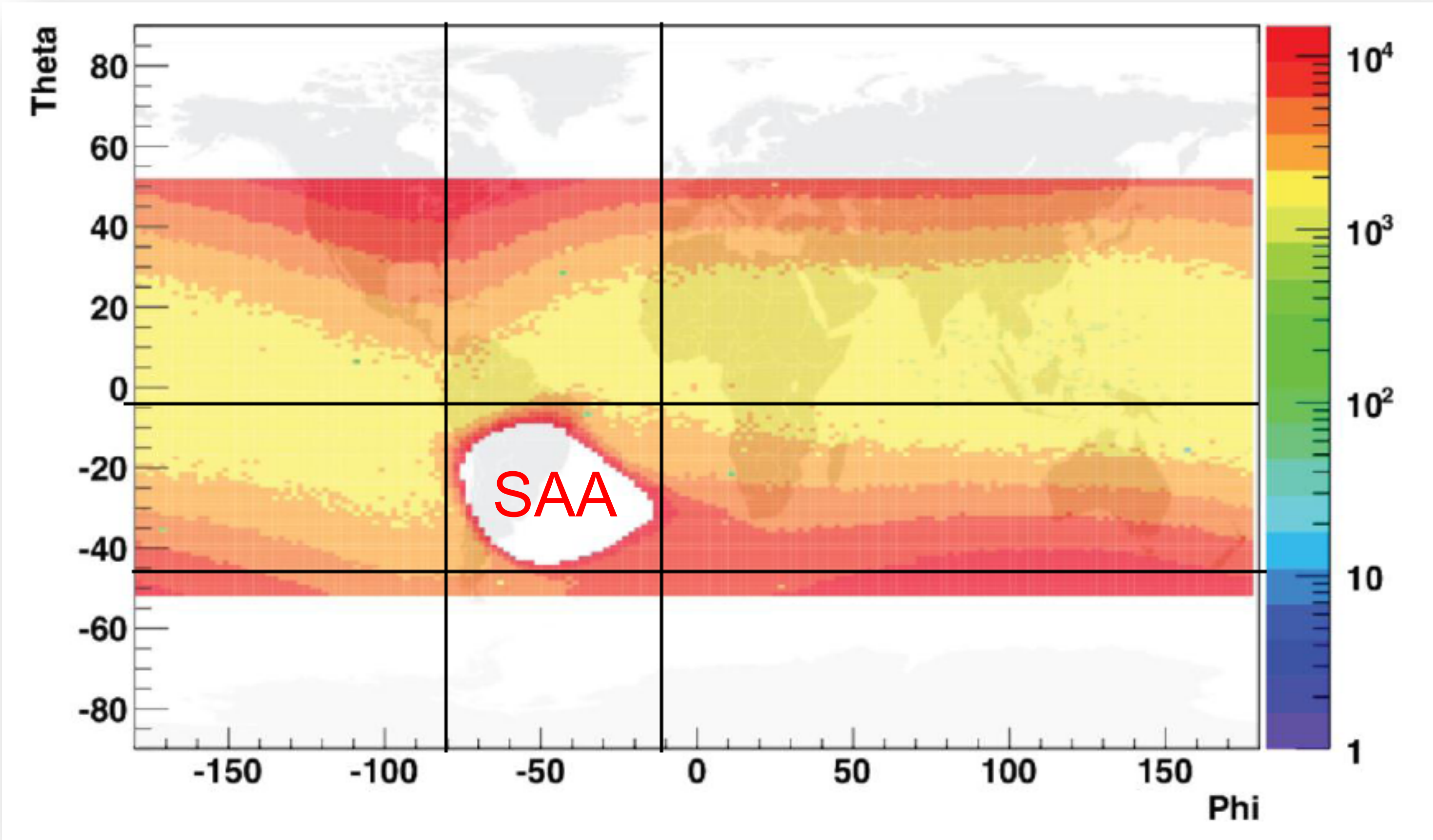


Performances in space – positron selection using ECAL&Tracker



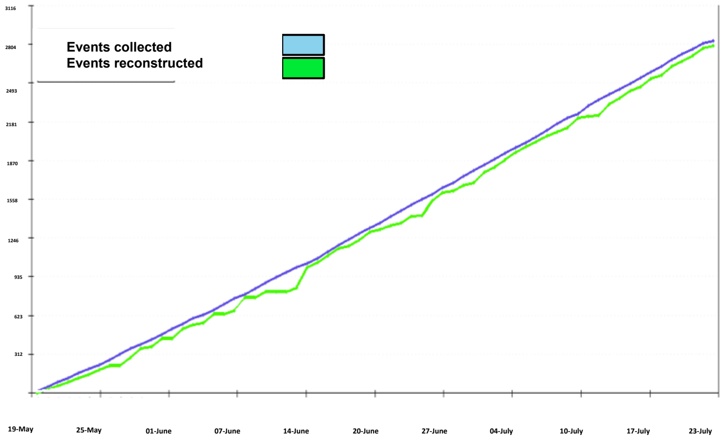


Data taking – Absolute rate on first TOF plane



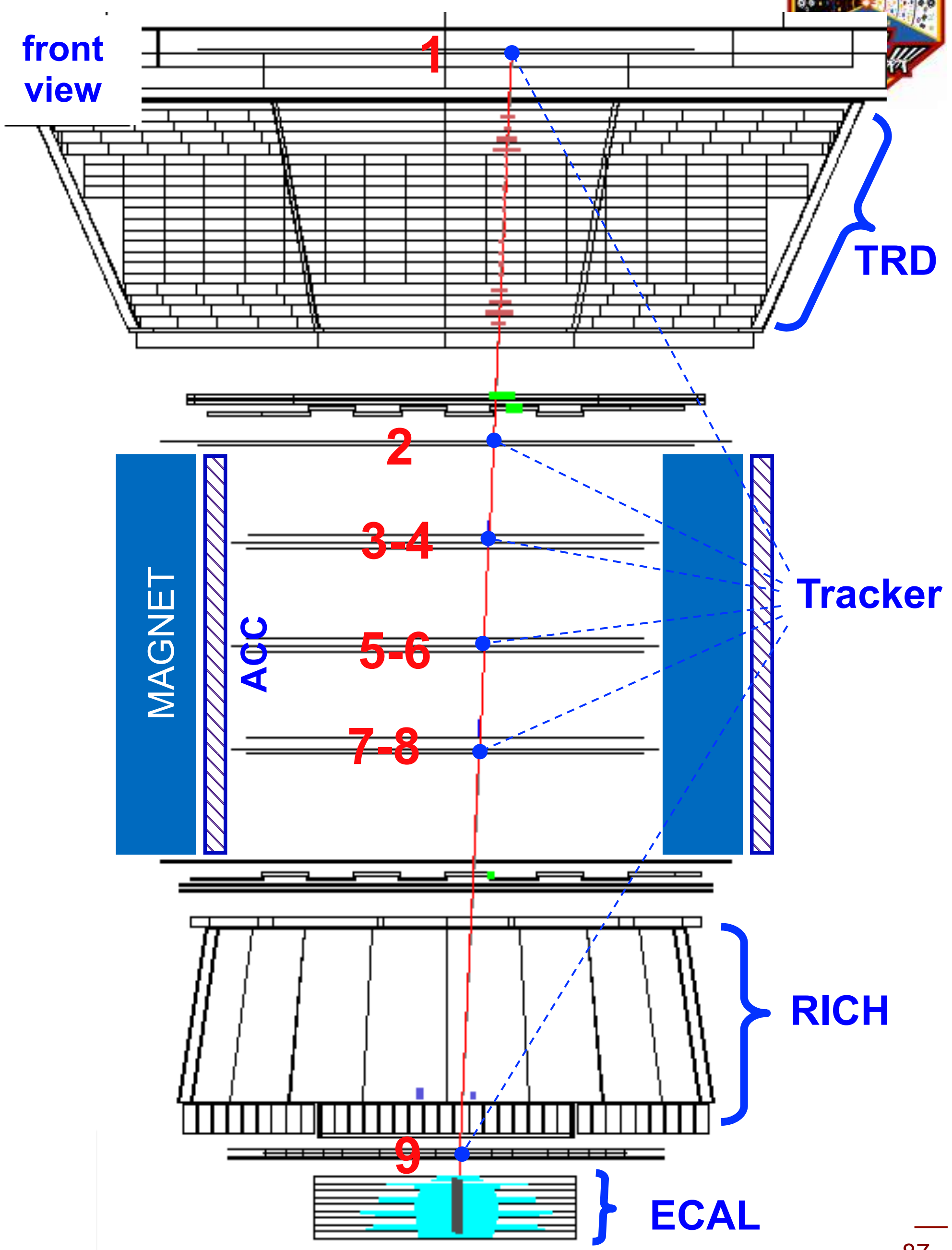
Data taken up to now

25 billion events
in 18 months



Event selection

Tracker
A track in the Tracker containing at least one hit in planes 1 or 2 or 9 and hits in planes (3 or 4), (5 or 6) and (7 or 8). In addition, the projected track must pass within 3 cm in x and 10 cm in y of the center of gravity of the ECAL shower.
The relative error on the curvature (inverse of the rigidity) value from the track fit is less than 50 %, which ensures that tracks have rigidities well below their Maximum Detectable Rigidity.
The detector livetime exceeded 50 %, which excludes, for example, the South Atlantic Anomaly.
TOF
The particle velocity measured by TOF $\beta > 0.8$.
The value of the absolute charge is required to be between 0.8 and 1.4.
TRD
At least 15 TRD hits on the Tracker track traced through the TRD.
ECAL
A shower axis within the ECAL fiducial volume.
The ECAL shower has electromagnetic shape

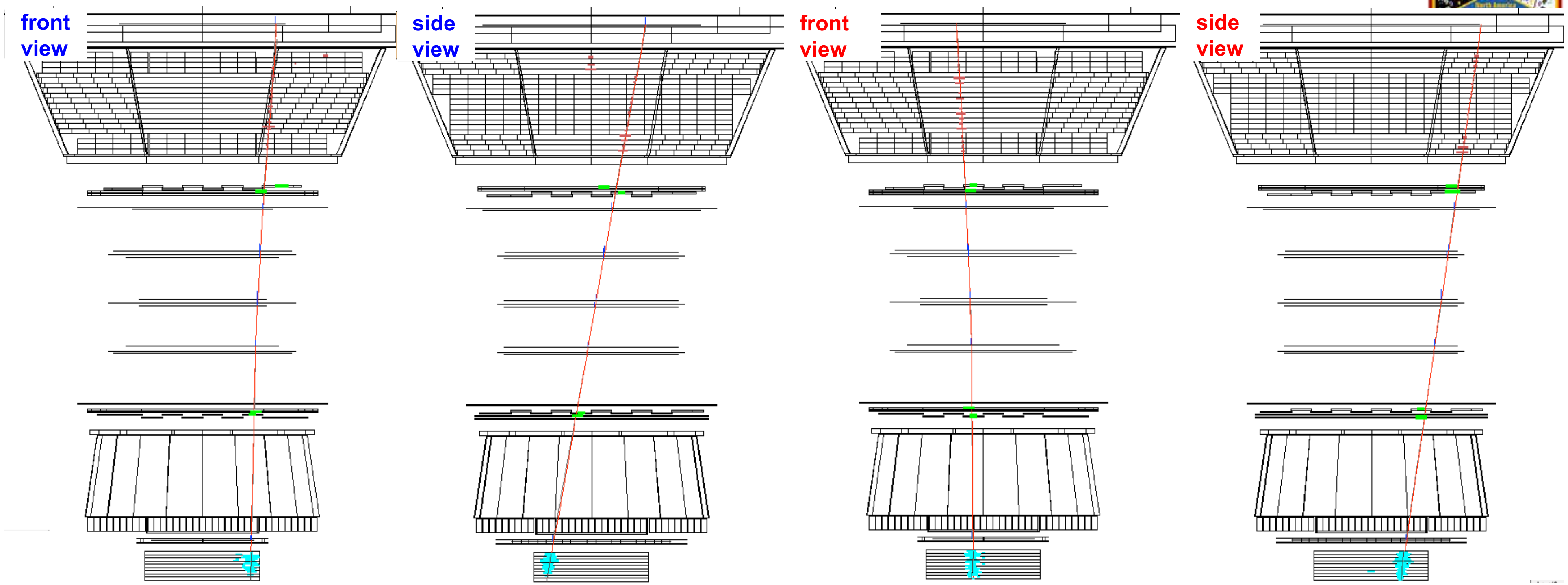


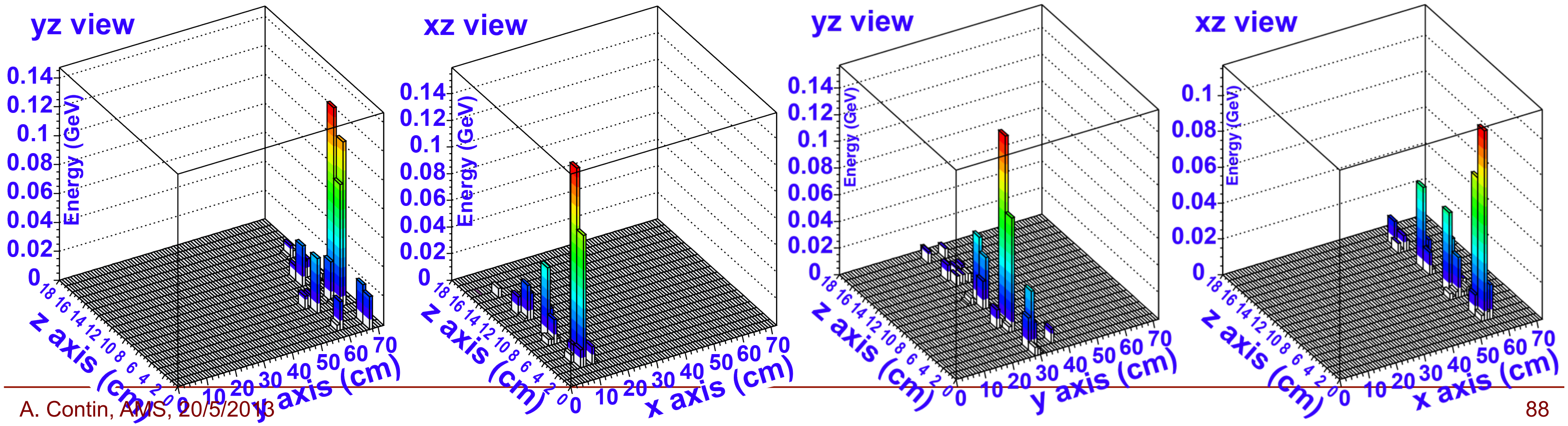
Electron E=1.1 GeV

Run/Event 1315150703/ 667540

Positron E=1.1 GeV

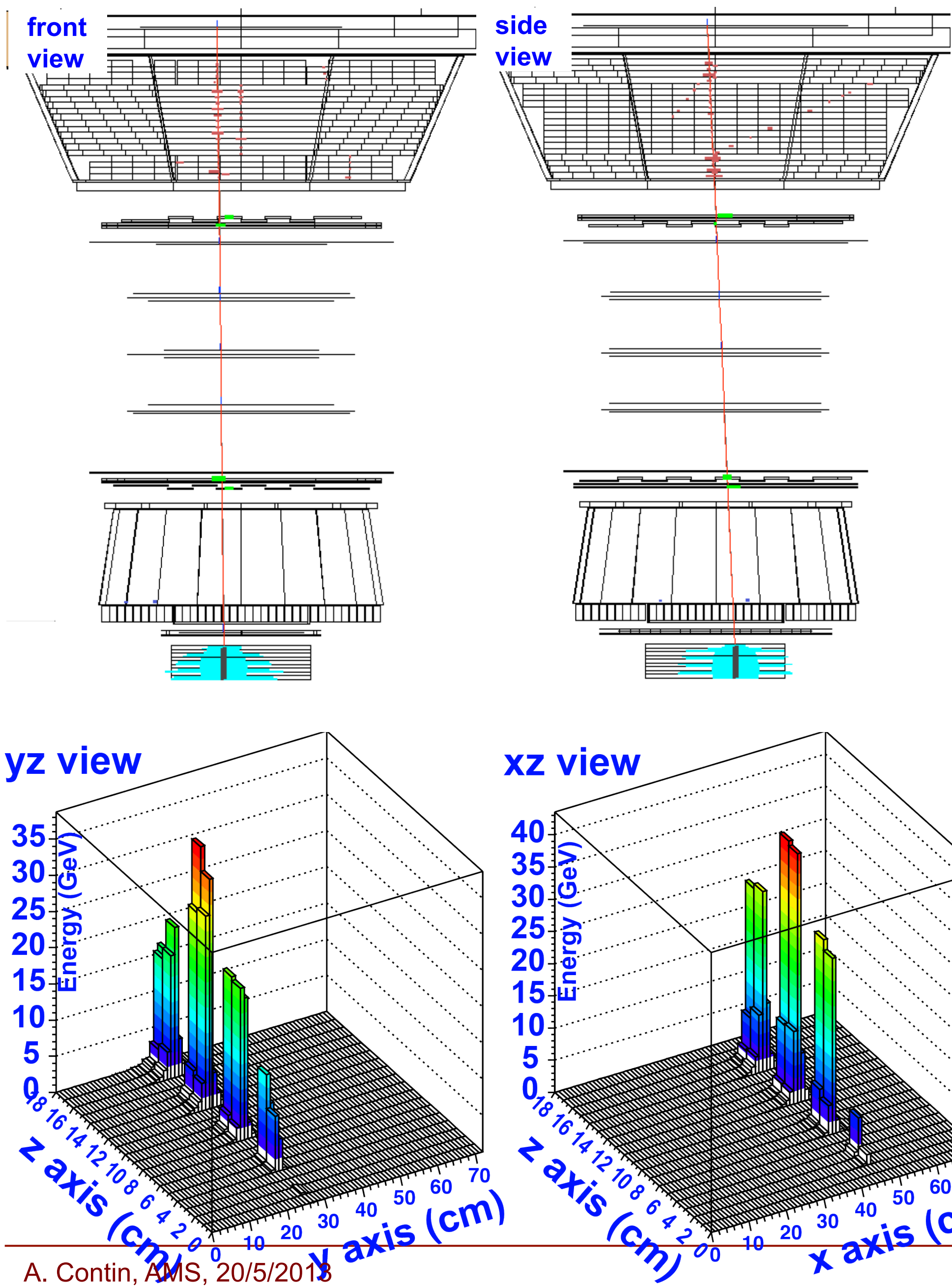
Run/Event 1316182344/ 919896





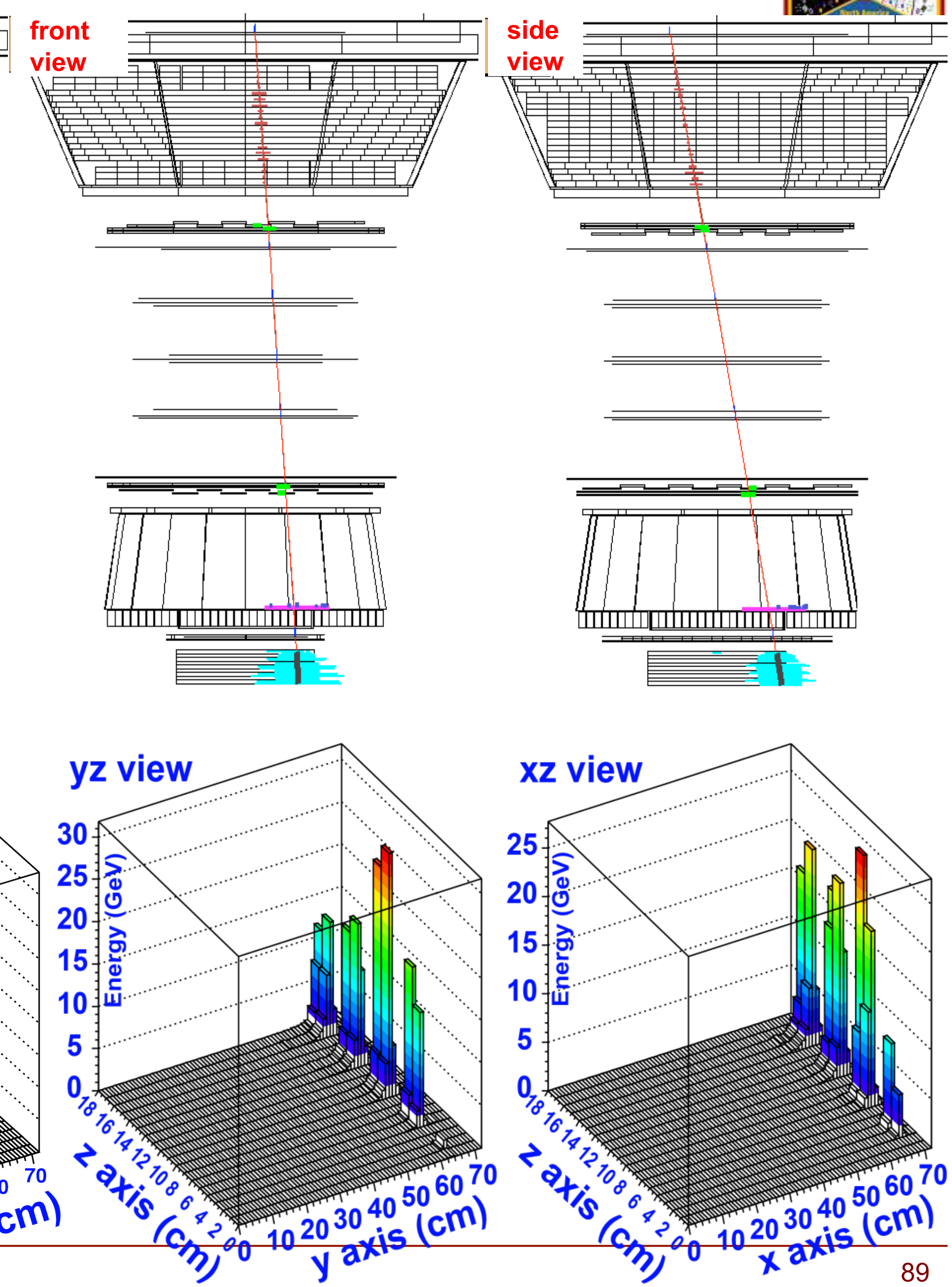
Electron E=982 GeV

Run/Event 1329775818/ 60709

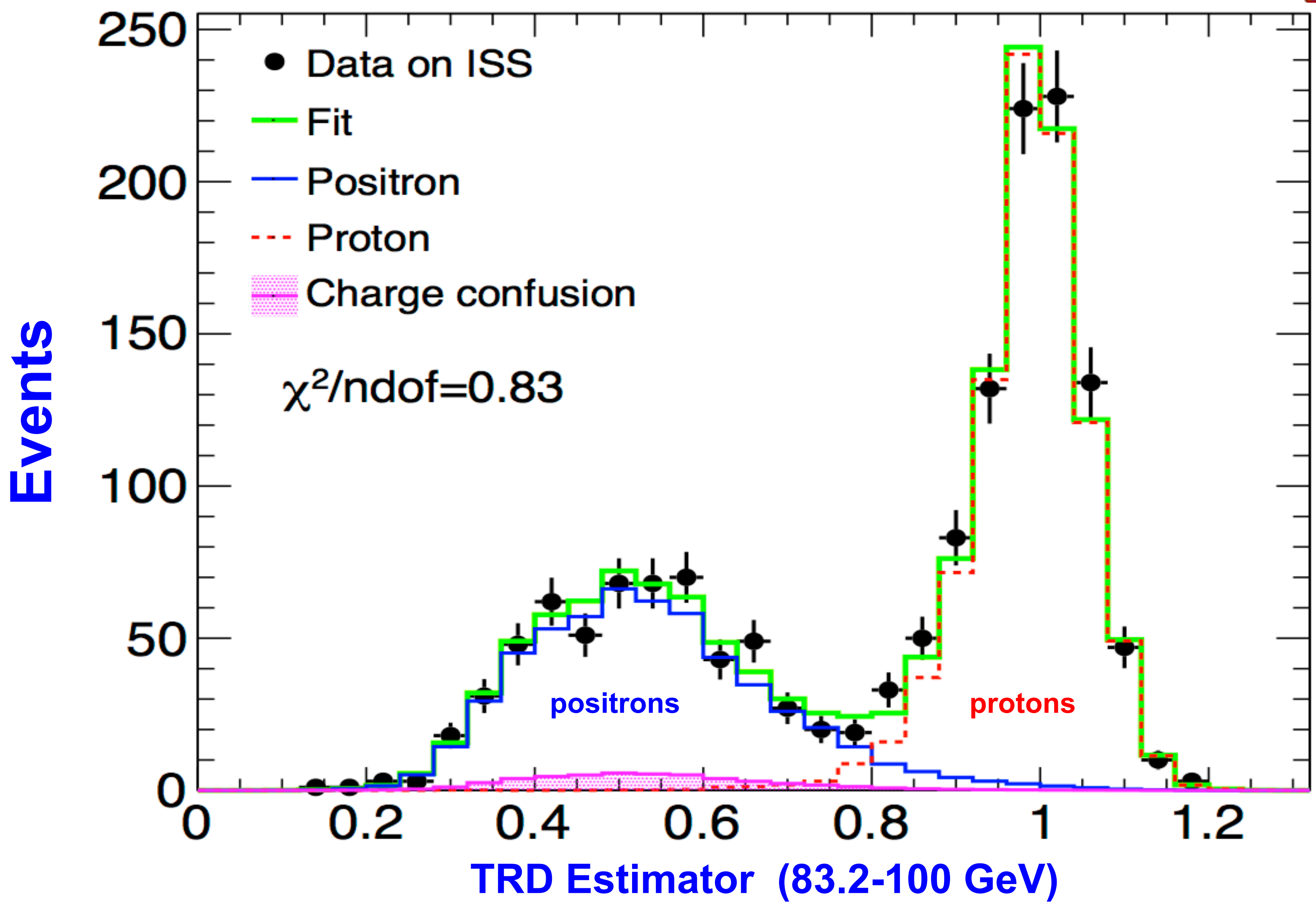


Positron E=636 GeV

Run/Event 133119-743/ 56950



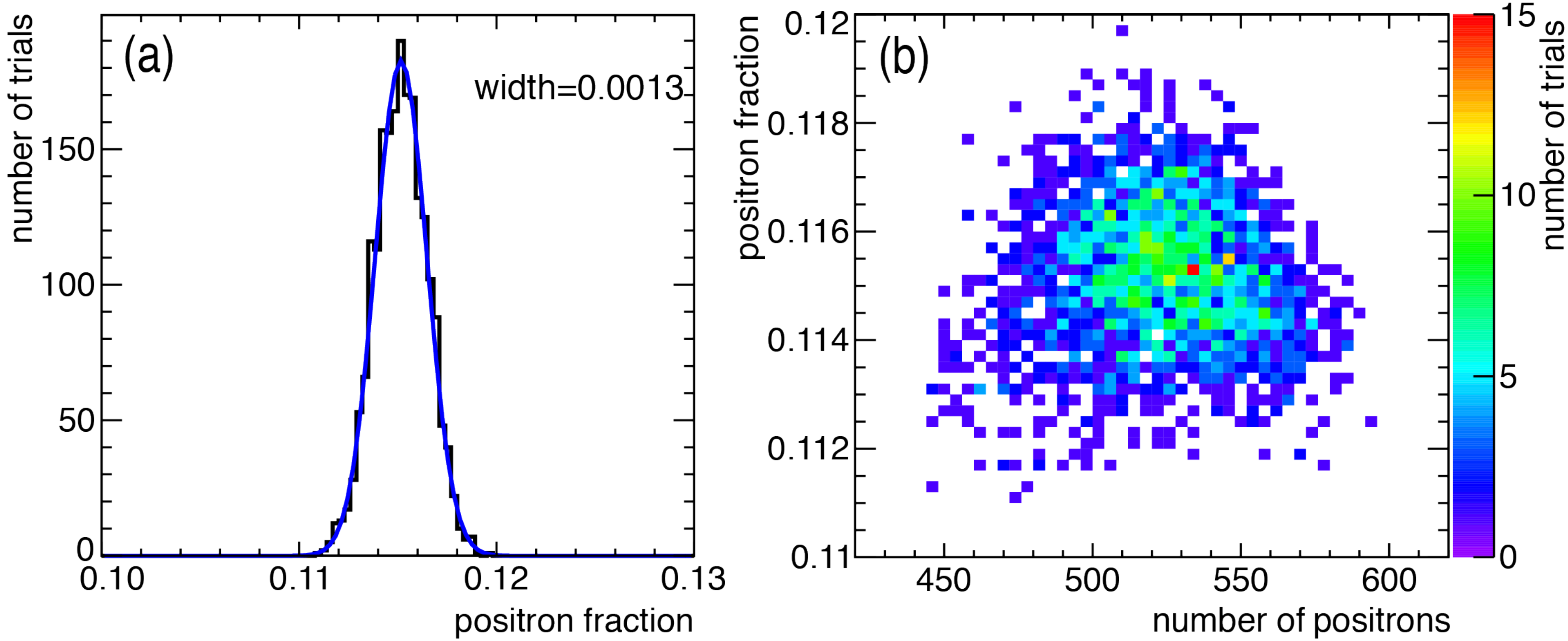
Example of event selection



Systematic errors

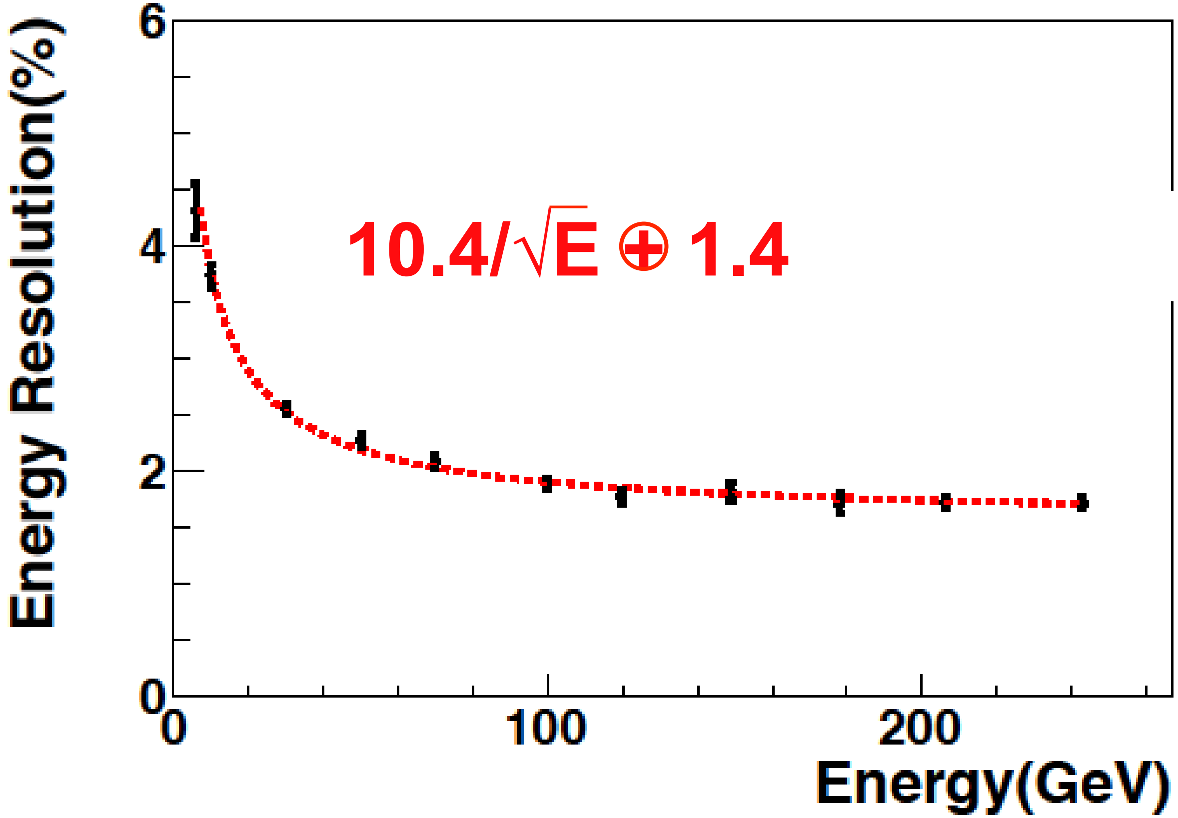
1. Acceptance asymmetry
   - Difference between positron and electron acceptance due to known minute tracker asymmetry
2. Selection dependence
   - Dependence of the result on the cut values
3. Migration bin-to bin
   - Migration of electron and positron events from the neighboring bins affects the measured fraction
4. Reference spectrum
   - Definition of the reference spectra is based on pure samples of electrons and protons of finite statistics
5. Charge confusion
   - Two sources: large angle scattering and production of secondary tracks along the path of the primary track. Both are well reproduced by MC. Systematic errors correspond to variations of these effects within their statistical limits.

Systematic error on the positron fraction: 2. Selection dependence



The measurement is stable over wide variations of the cuts in the TRD identification, ECAL Shower Shape, E (from ECAL) matched to |P| (from the Tracker), …
For each energy bin, over 1,000 sets of cuts were analyzed.

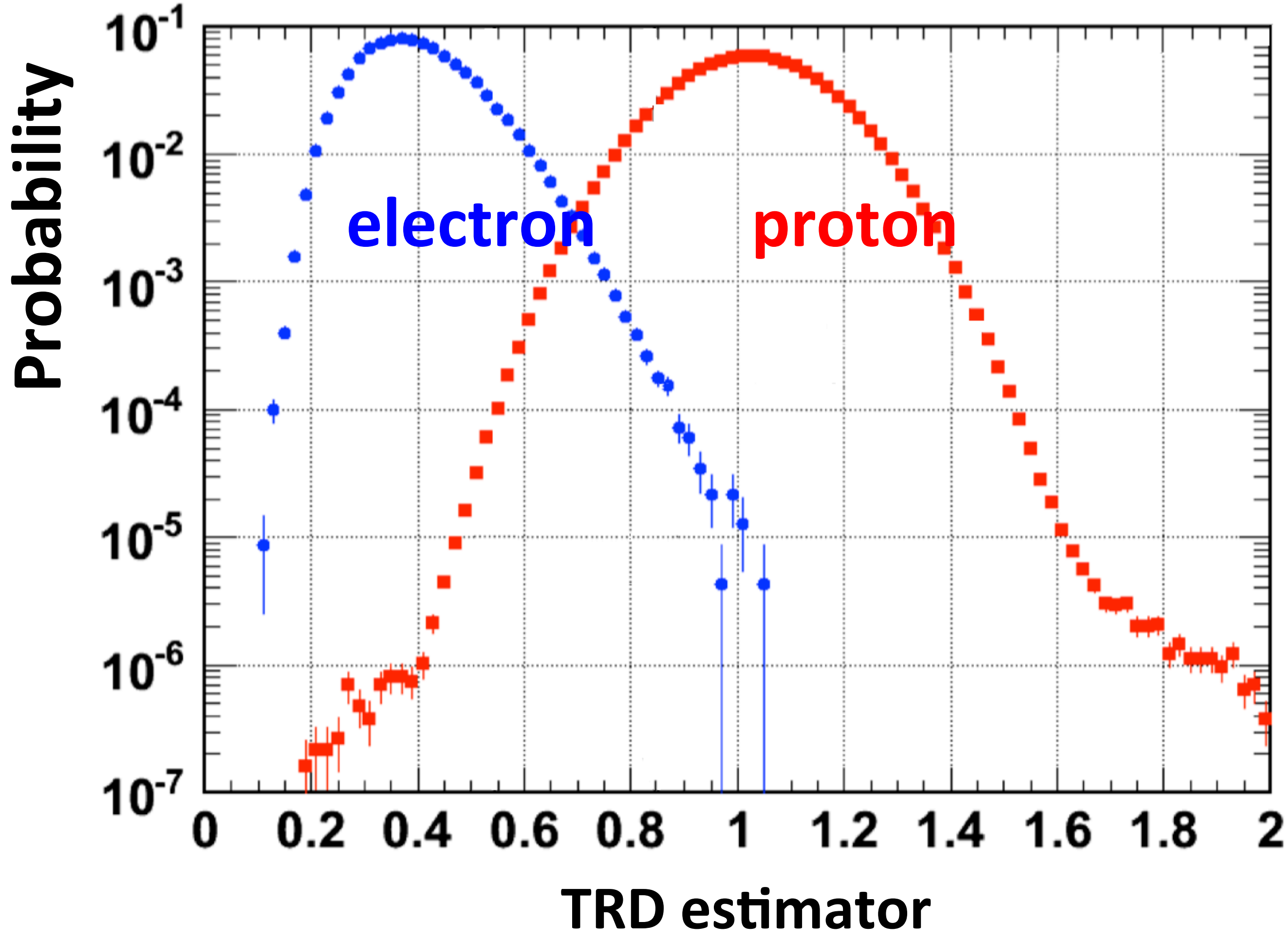
Systematic error on the positron fraction: 3. Bin-to-bin migration



Event migration effects are obtained by folding the measured spectra of positrons and electrons with the ECAL energy resolution.

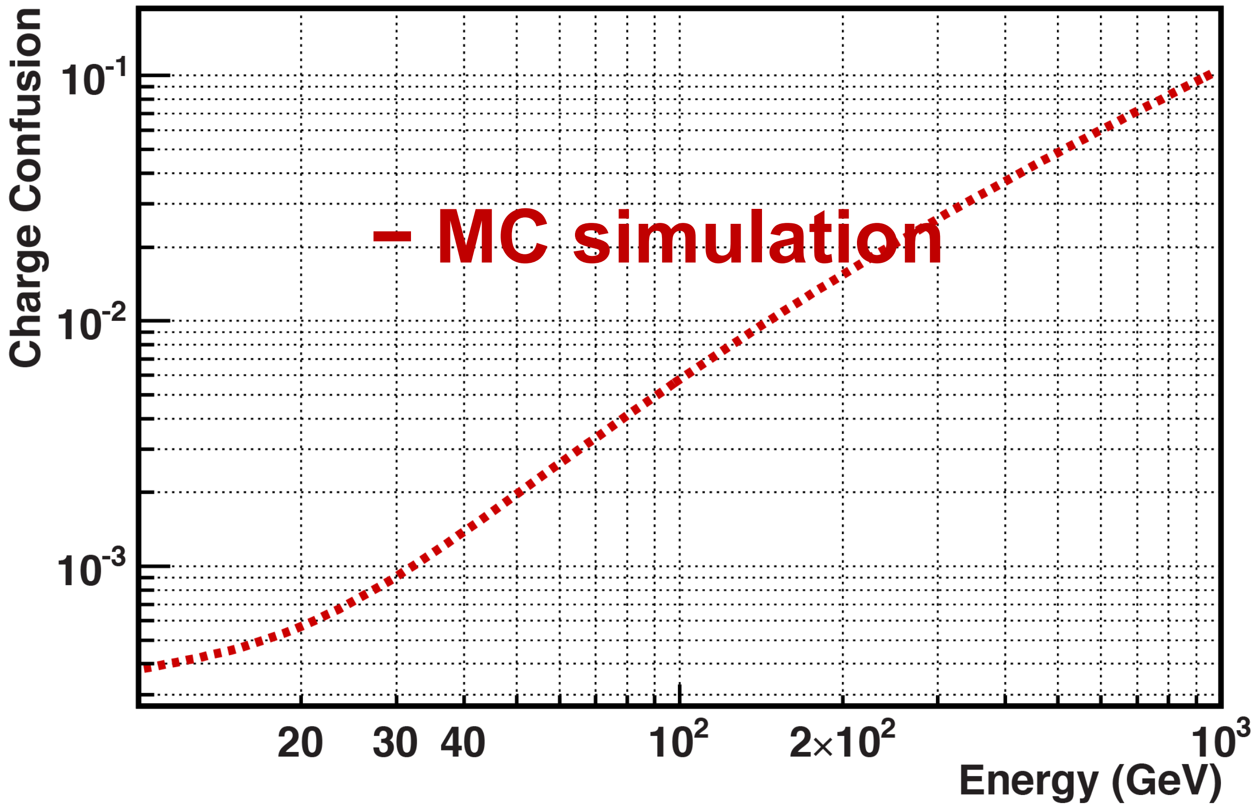
Bin width: 2σ at 5 GeV; 4σ at 50 GeV; 8σ at 100 GeV; 19σ at 300 GeV.

Systematic error on the positron fraction:
4. Reference spectra



Definition of the reference spectra is based on pure samples of electrons and protons of finite statistics.

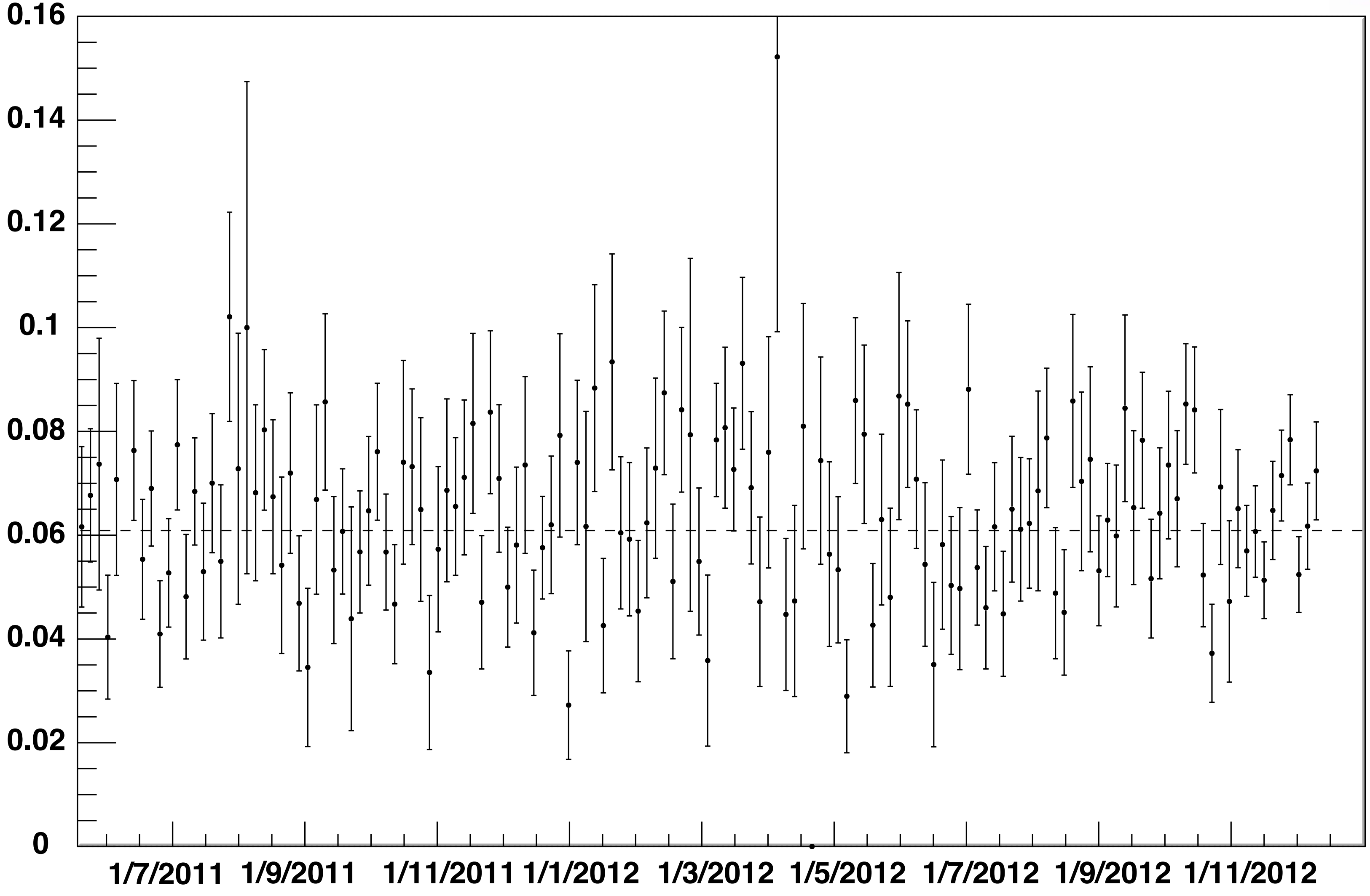
Systematic error on the positron fraction:
5. Charge confusion



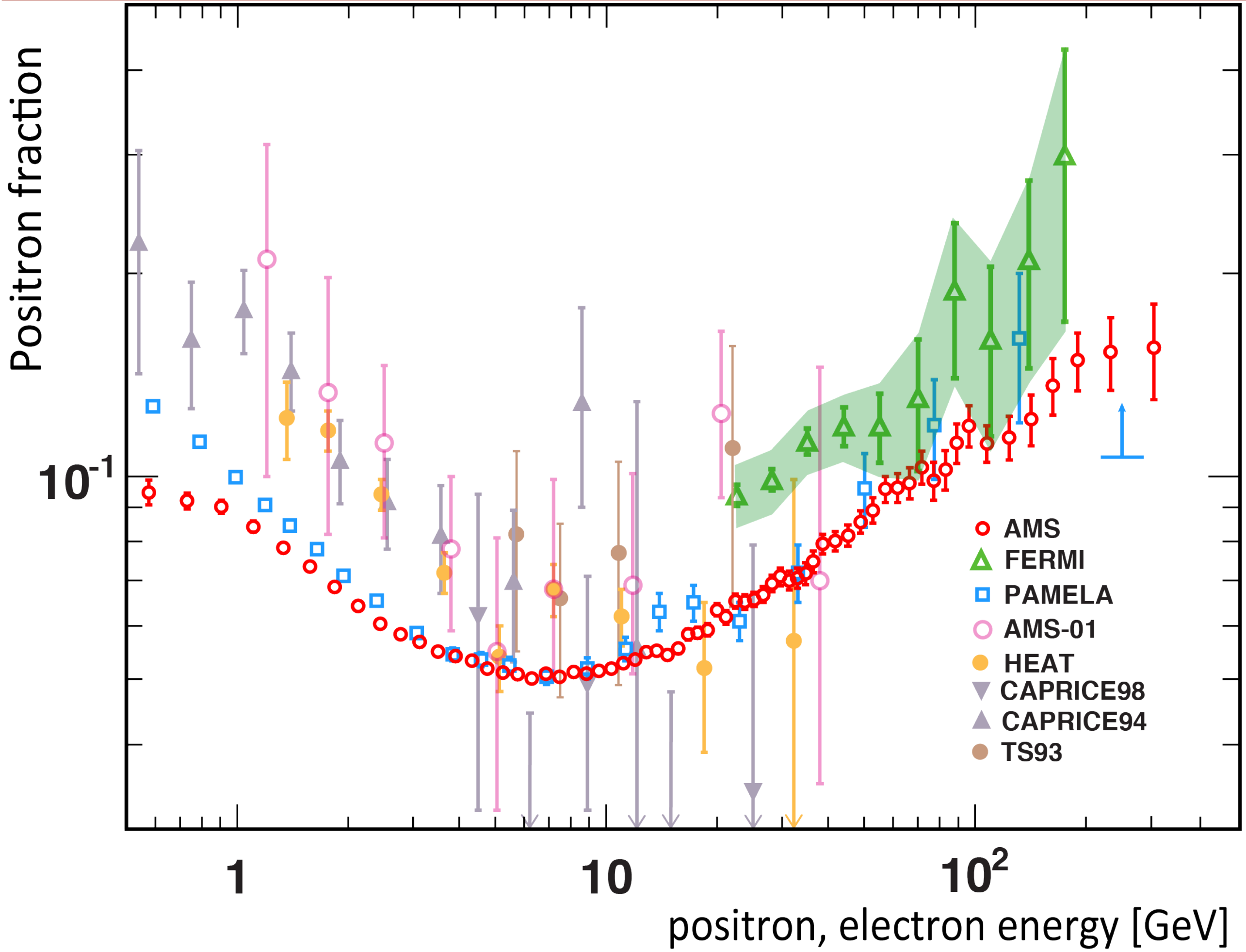
Two sources: large angle scattering and production of secondary tracks along the path of the primary track. Both are well reproduced by MC. Systematic errors correspond to variations of these effects within their statistical limits.

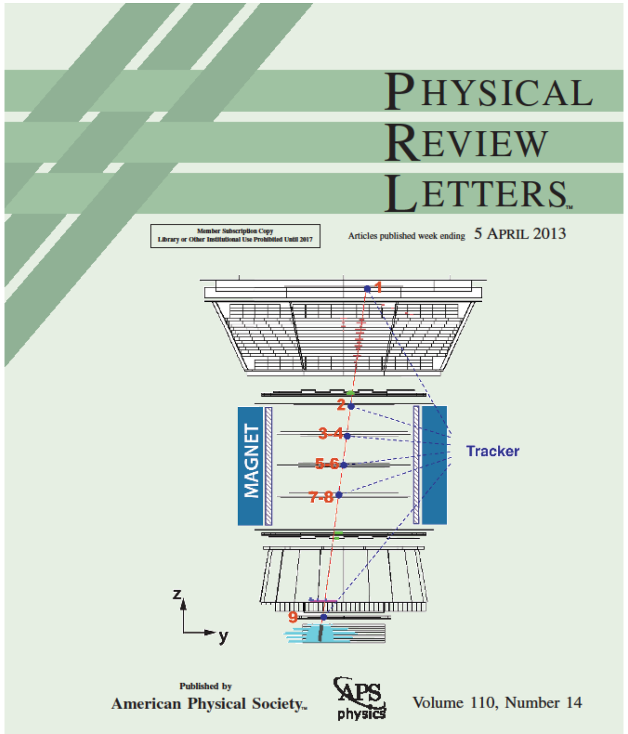
Time stability

Positron fraction E=20-100 GeV

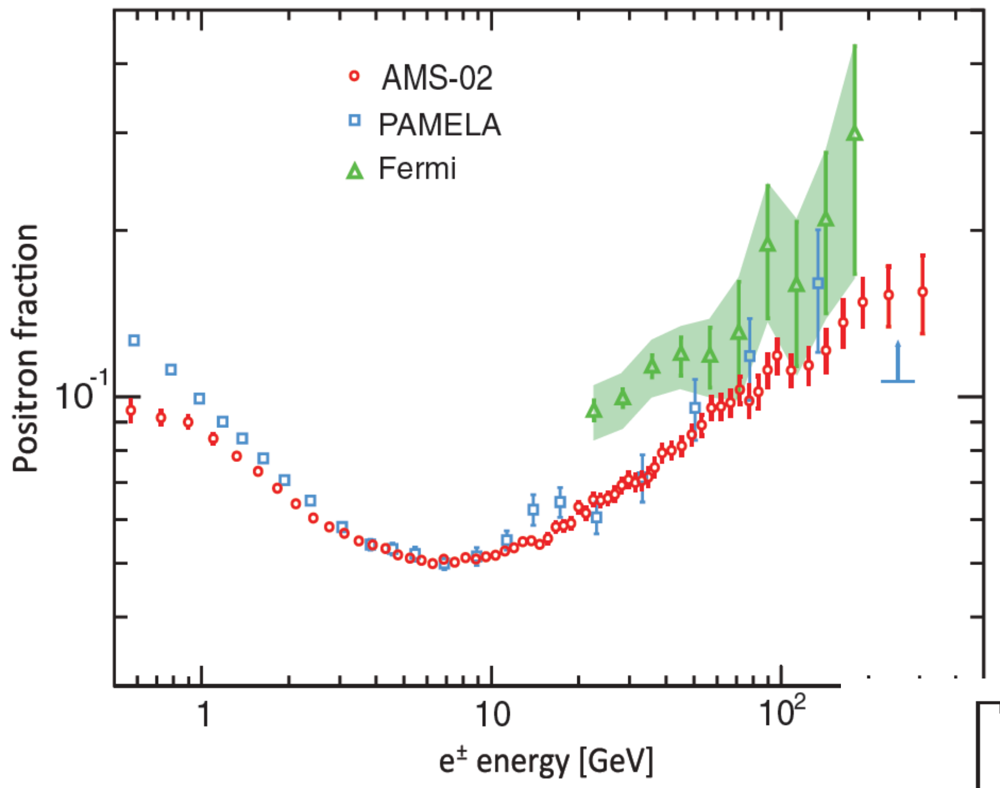


Results


Positron fraction
10^-1
1
10
10^2
positron, electron energy [GeV]
AMS
FERMI
PAMELA
AMS-01
HEAT
CAPRICE98
CAPRICE94
TS93


PHYSICAL
REVIEW
LETTERS
Articles published week ending 5 APRIL 2013
MAGNET
Tracker
Published by
American Physical Society
APS physics
Volume 110, Number 14

AMS-02 Results

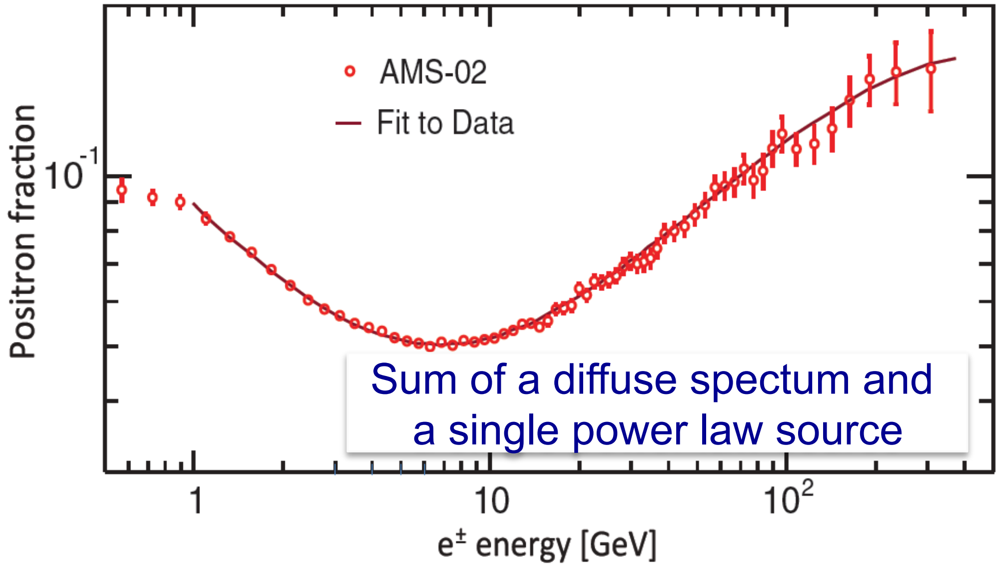


Anysotropy:

$$\delta = 3\sqrt{C_1/4\pi} \leq \mathbf{0.036}$$

$$\Phi_{e^+} = C_{e^+} E^{-\gamma_{e^+}} + C_s E^{-\gamma_s} e^{-E/E_s}$$

$$\Phi_{e^-} = C_{e^-} E^{-\gamma_{e^-}} + C_s E^{-\gamma_s} e^{-E/E_s}$$

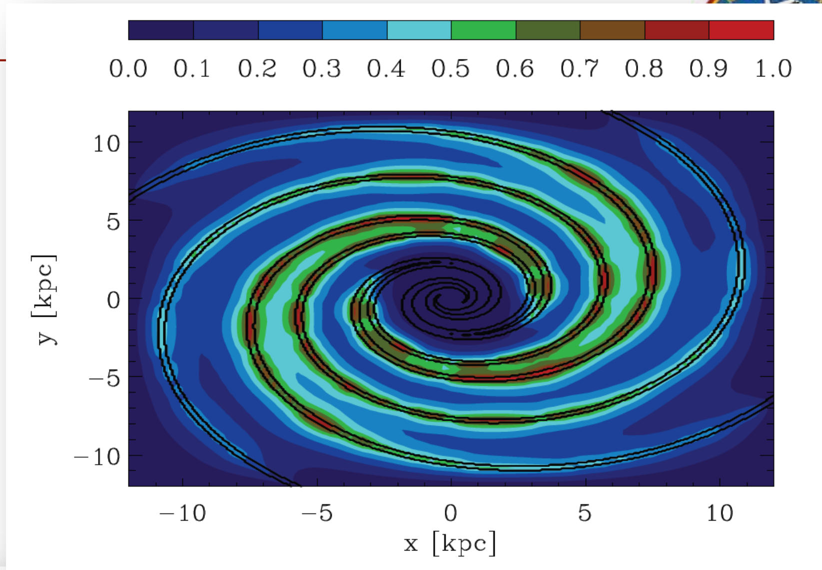


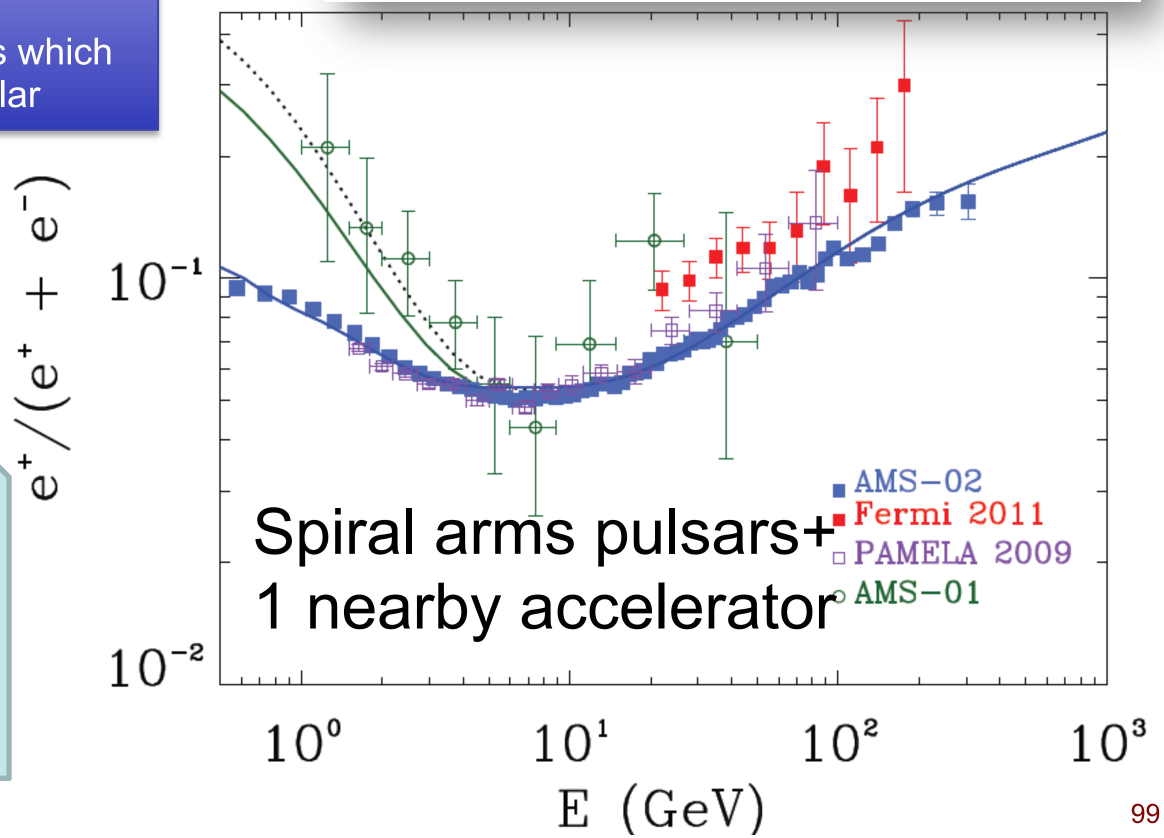
Sum of a diffuse spectum and a single power law source

Grasso et al.: arXiv:1304.6718v1

A novel propagation configuration: the leptons spectra are computed assuming the extra-component sources are located only in spiral arms.

In fact, although several SNRs and pulsars are observed in the nearby region (d < few hundred pc), only a few of these sources may significantly contribute to the observed e± flux, either because they are not powerful enough or because propagation may take place along streams which have a small probability to intersect the solar system

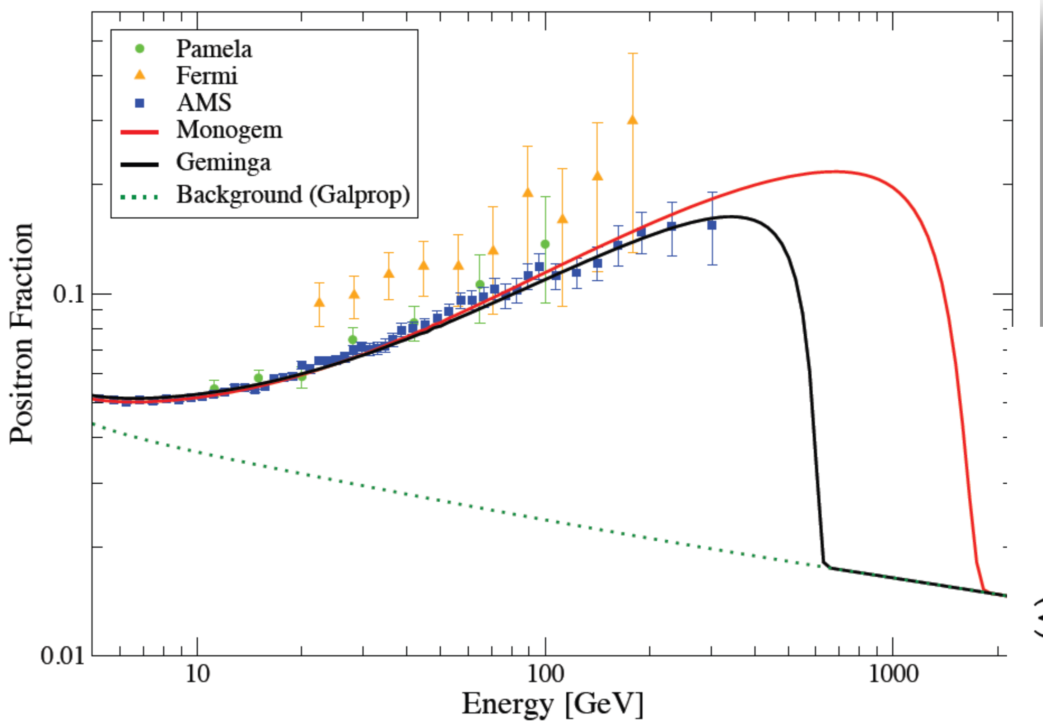




The contribution of single nearby pulsars becomes less and less significant at high energies (> 0.5 TeV), so that the anisotropy rapidly decreases

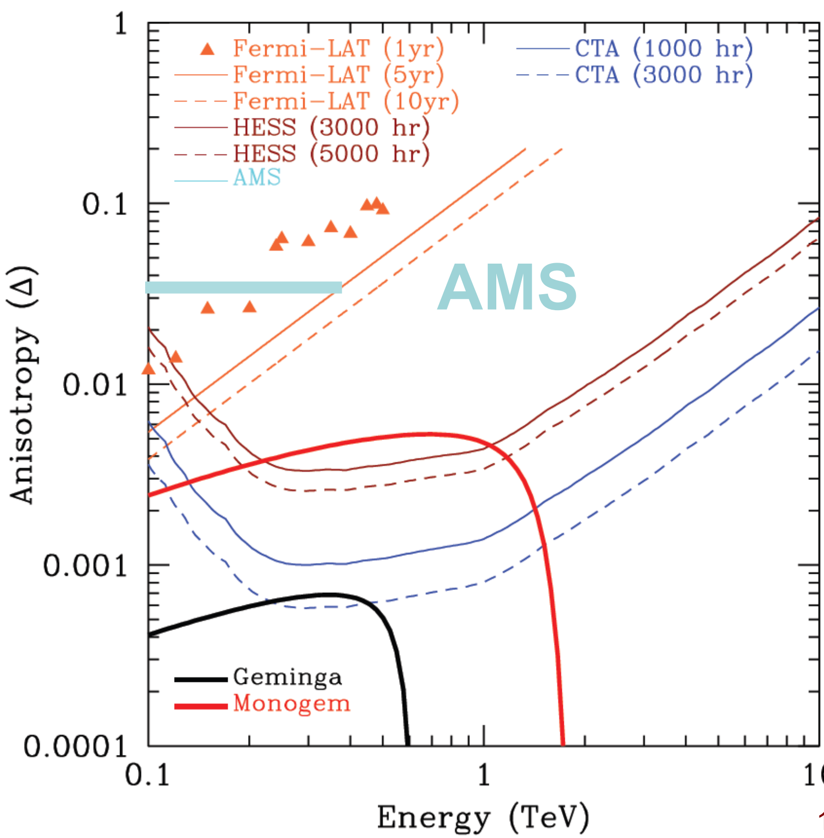
Profumo et al.: arXiv:1304.1791v1

Anyone of two well-known nearby pulsars, Geminga and Monogem, can satisfactorily provide enough positrons



Dipolar anisotropy:

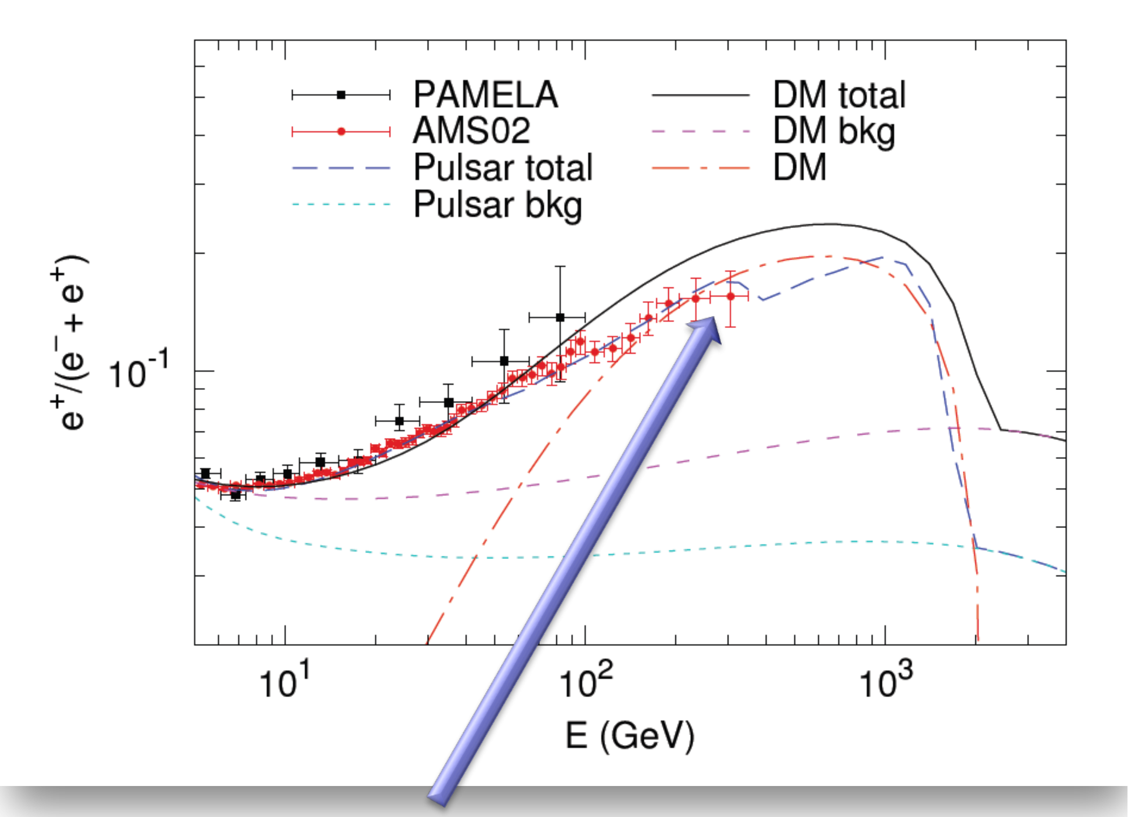
$$\Delta = \frac{N_f - N_b}{N_f + N_b}$$



A smoking-gun signature of this scenario is an anisotropy in the arrival direction of the cosmic-ray electrons and positrons. **The predicted anisotropy level is, at present, consistent with limits from Fermi-LAT and AMS-02**

Pulsar interpretation: arXiv:1304.4128v1

The contributions to the positron fraction of all the 178 pulsars in the ATNF catalogue
with d < 3 kpc fit AMS data very well



Both the pulsar (nearby or altogether) and the DM scenarios can fit the observations: it is a fundamental problem to distinguish these two scenarios. If the positron excess is from pulsars, it may have a characteristic spectrum with many structures, because the parameters of pulsars might differ from one to another. If such fine structures are not discovered, it would be a strong support to the DM interpretation.

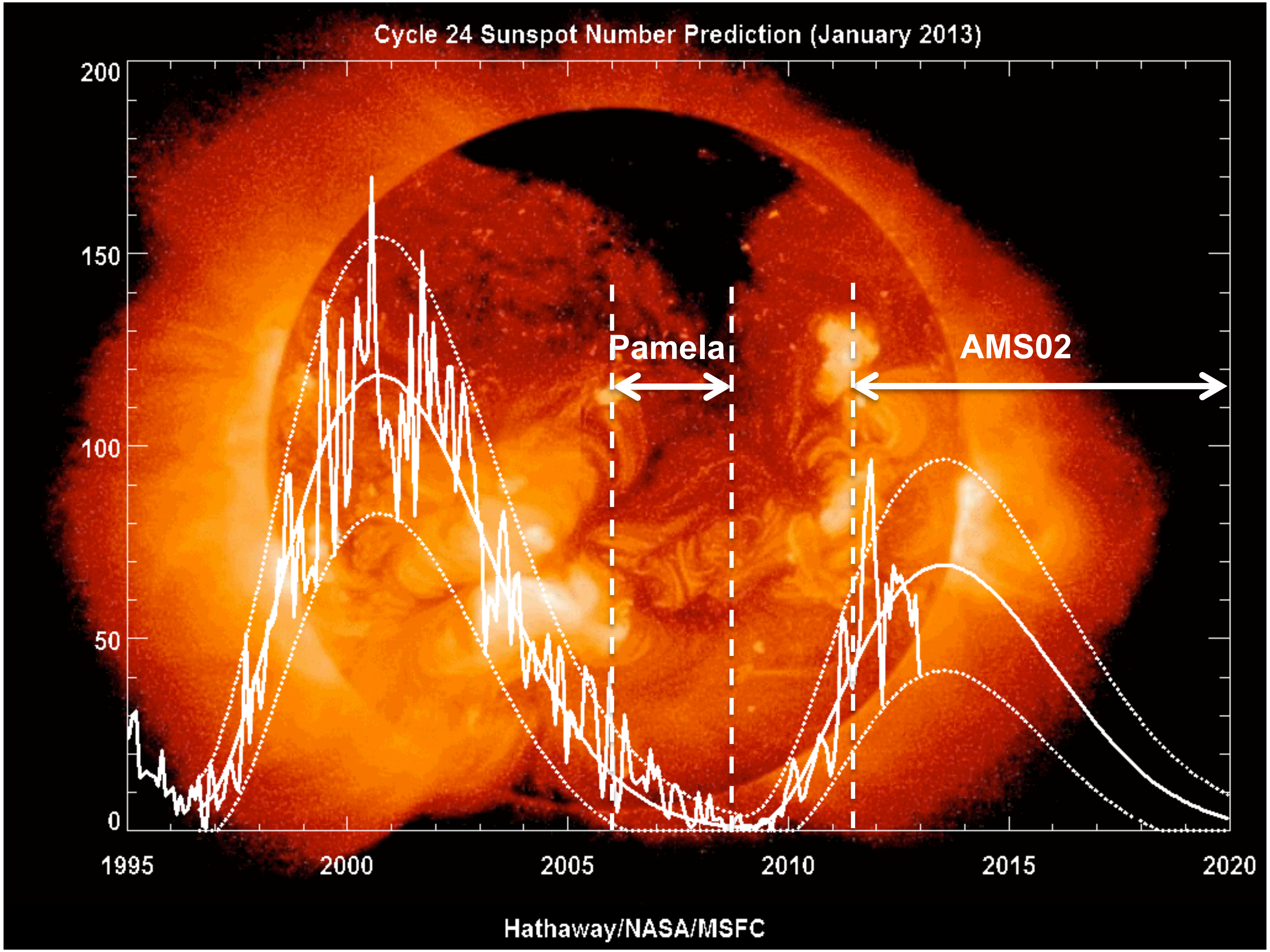
Conclusions

In conclusion, the first 6.8 million primary positron and electron events collected with AMS on the ISS show:

1. At energies < 10 GeV, a decrease in the positron fraction with increasing energy.
2. A steady increase in the positron fraction from 10 to ~250 GeV.
3. The determination of the behavior of the positron fraction from 250 to 350 GeV and beyond requires more statistics.
4. The slope of the positron fraction versus energy decreases by an order of magnitude from 20 to 250GeV and no fine structure is observed.
5. The positron fraction spectrum is consistent with $e^{\pm}$ fluxes each of which is the sum of its diffuse spectrum and a single common power law source.
6. The positron to electron ratio is consistent with isotropy; $\delta \leq 0.036$ at the 95% *C.L.*

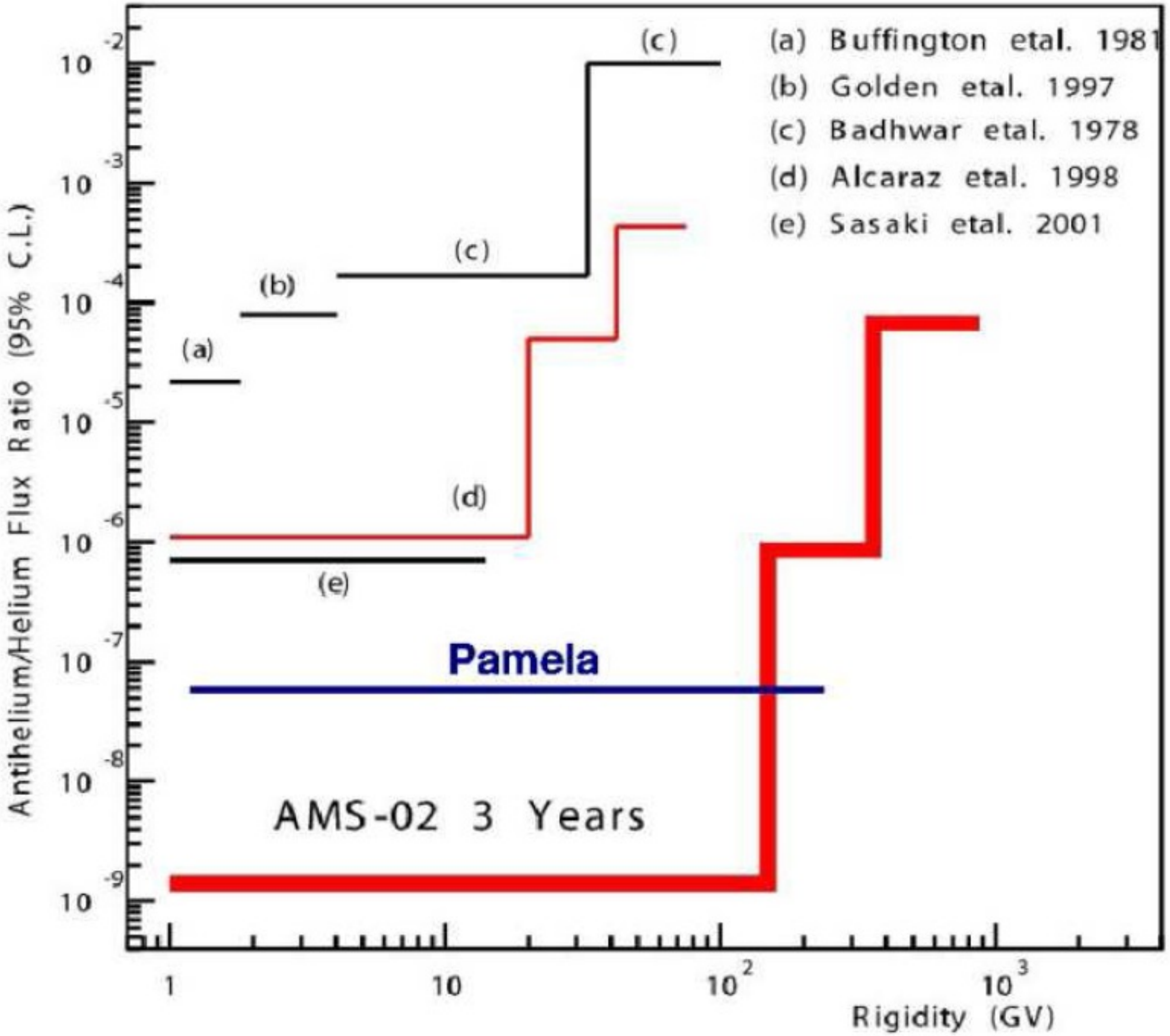
These observations show the existence of new physical phenomena, whether from a particle D3 physics or an astrophysical origin.

Future



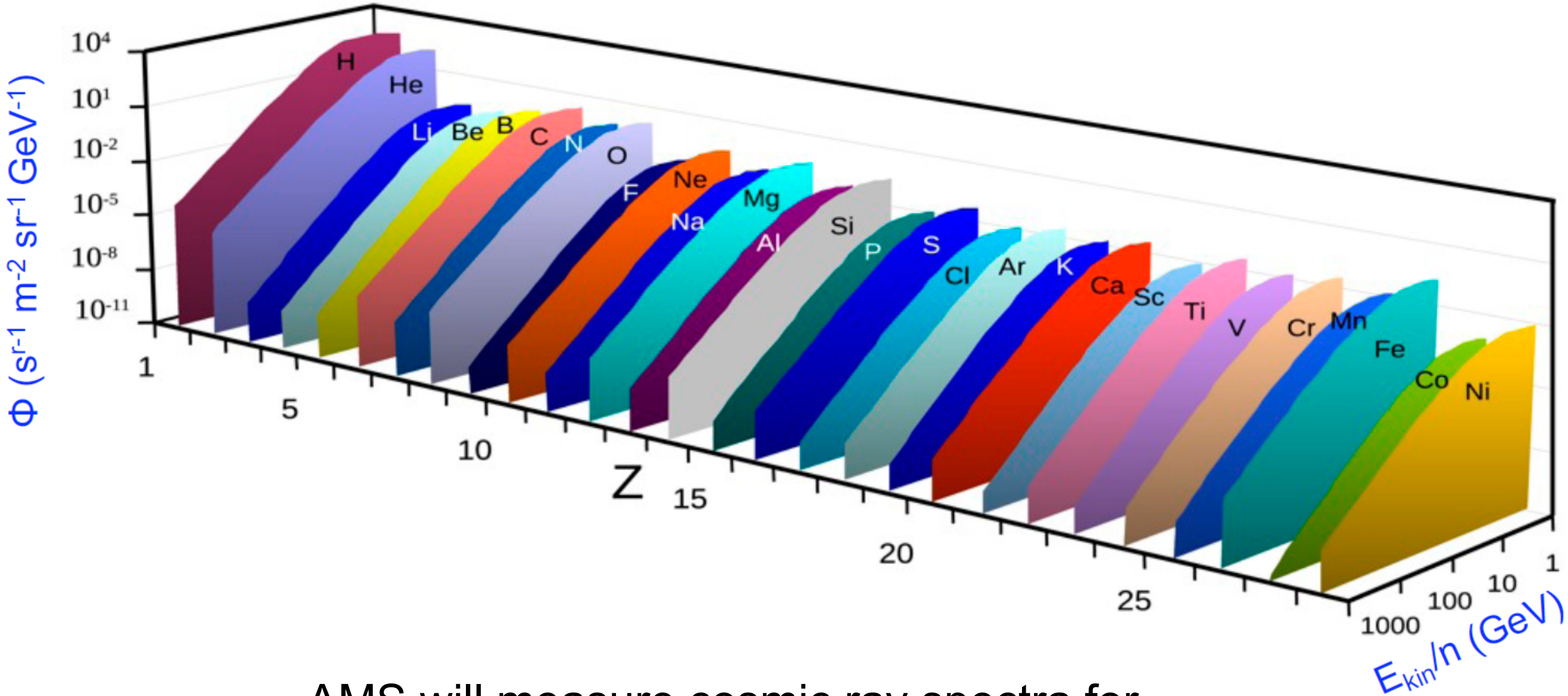
Cycle 24 Sunspot Number Prediction (January 2013)
200
150
100
50
0
1995
2000
2005
2010
2015
2020
Pamela
AMS02
Hathaway/NASA/MSFC

Future



Antihelium/Helium Flux Ratio (95% C.L.)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
(a) Buffington etal. 1981
(b) Golden etal. 1997
(c) Badhwar etal. 1978
(d) Alcaraz etal. 1998
(e) Sasaki etal. 2001
(a)
(b)
(c)
(c)
(d)
(e)
Pamela
AMS-02 3 Years
1
10
10^{2}
10^{3}
Rigidity (GV)

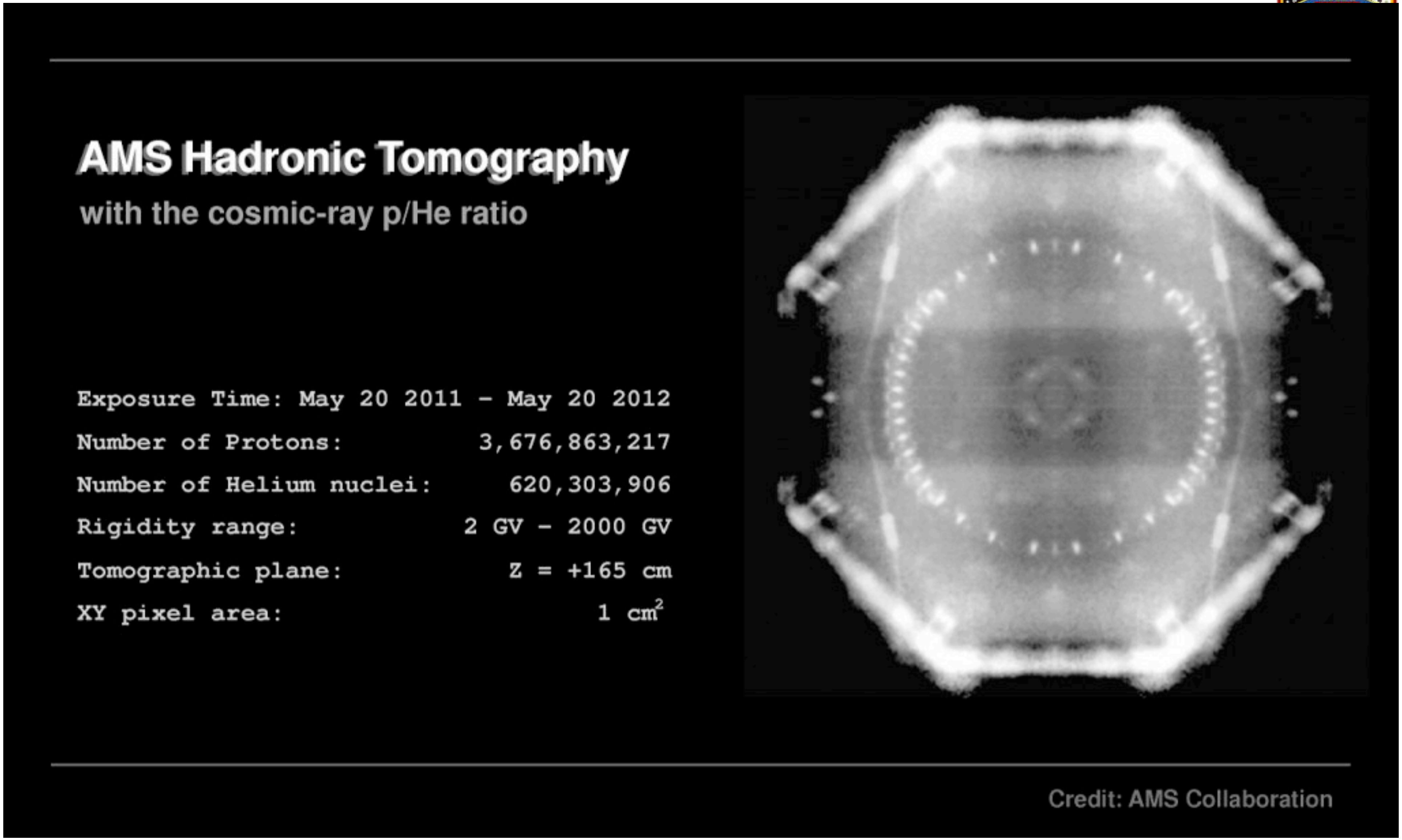
Future



AMS will measure cosmic ray spectra for energies from 100 MeV to 2 TeV with 1% accuracy continuously over the solar cycle

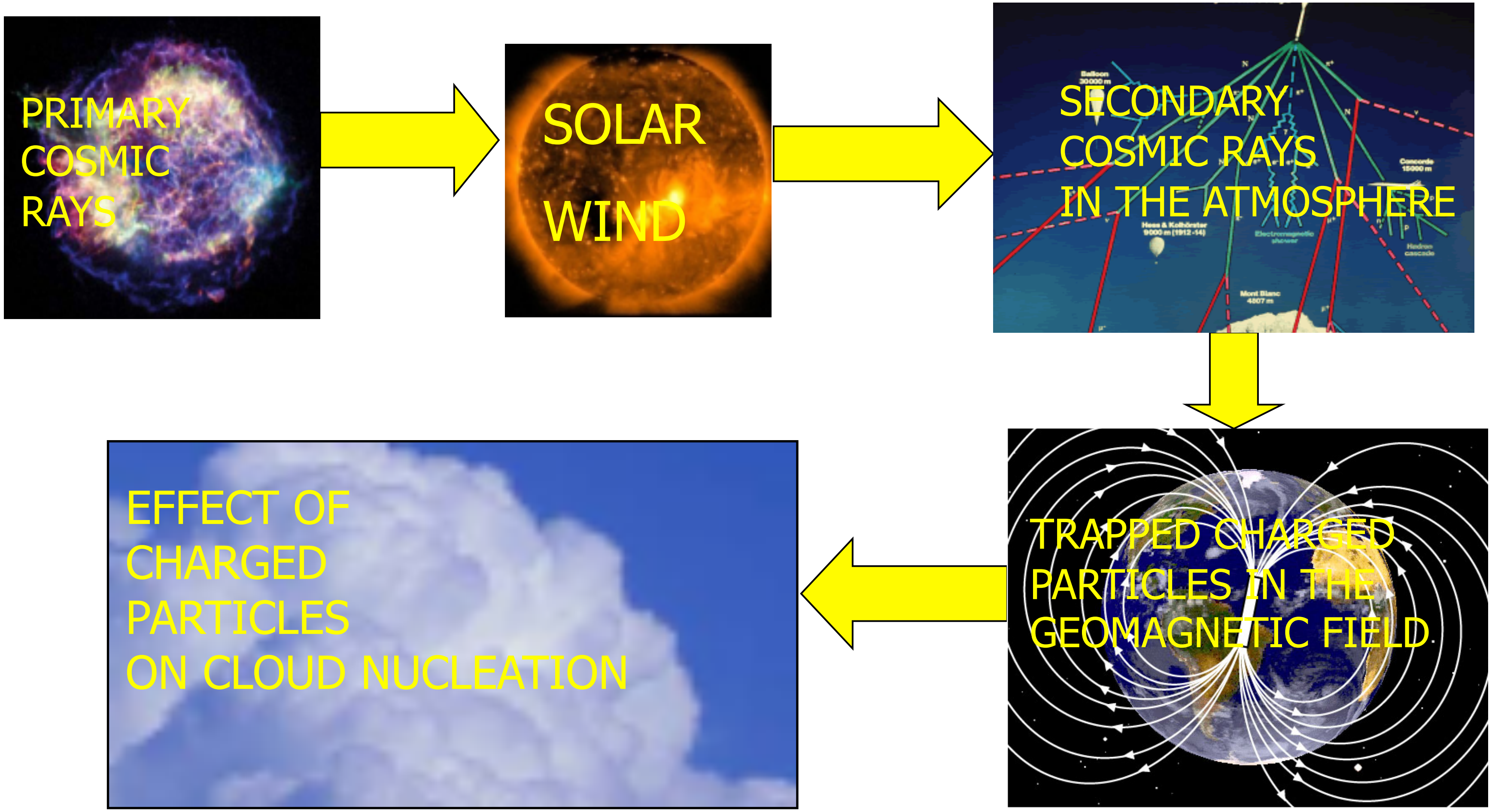
The isotopic composition of the CR is correlated with their propagation mechanisms

Ions



AMS Hadronic Tomography
with the cosmic-ray p/He ratio
Exposure Time: May 20 2011 - May 20 2012
Number of Protons: 3,676,863,217
Number of Helium nuclei: 620,303,906
Rigidity range: 2 GV - 2000 GV
Tomographic plane: Z = +165 cm
XY pixel area: 1 cm²
Credit: AMS Collaboration

Future


PRIMARY
COSMIC
RAYS
SOLAR
WIND
SECONDARY
COSMIC RAYS
IN THE ATMOSPHERE
TRAPPED CHARGED
PARTICLES IN THE
GEOMAGNETIC FIELD
EFFECT OF
CHARGED
PARTICLES
ON CLOUD NUCLEATION

Unknown

Facility		Original purpose, Expert Opinion	Discovery with Precision Instrument
P.S. CERN	(1960's)	π N interactions	Neutral Currents -> Z, W
Brookhaven	(1960's)	π N interactions	ν_e, ν_μ CP violation, J
FNAL	(1970's)	Neutrino physics	*b, t quarks*
SLAC Spear	(1970's)	ep, QED	Scaling, Ψ, τ
PETRA	(1980's)	t quark	*Gluon*
Super Kamiokande	(2000)	Proton decay	Neutrino oscillations
Hubble Space Telescope	(1990's)	Galactic survey	*Curvature of the universe, dark energy*
AMS on ISS		Dark Matter, Antimatter Strangelets,…	*?*

Exploring a new territory with a precision instrument is the key to discovery.