# GeV to Multi-TeV Cosmic Rays: AMS-02 Status and Future Prospects

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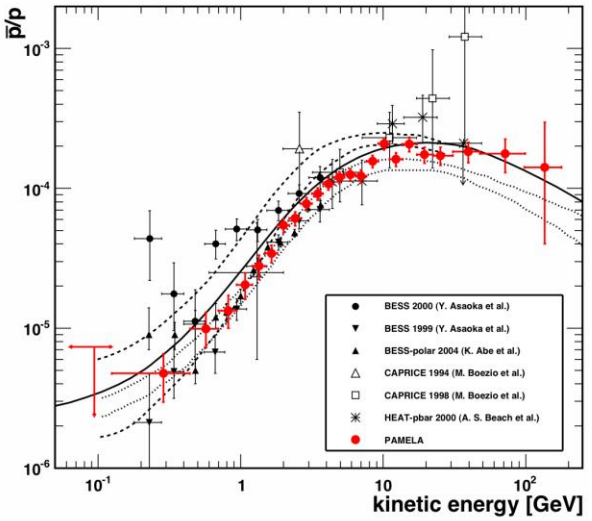
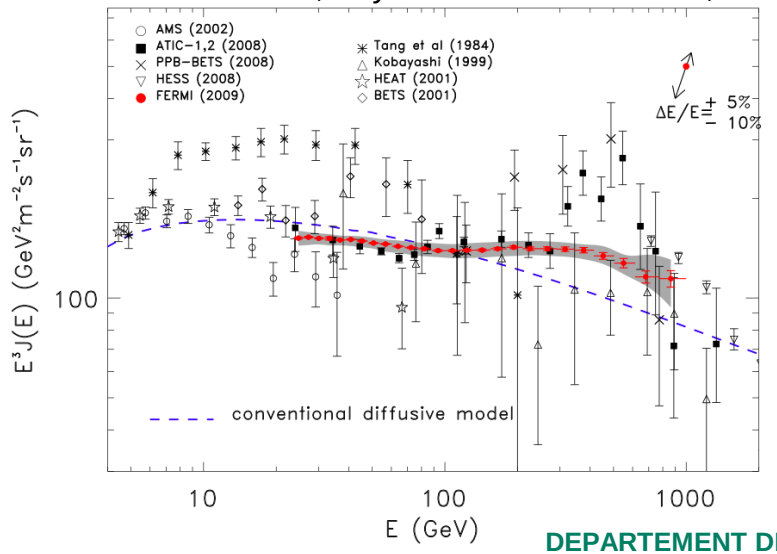
# Renewed Interest in Galactic CR

- Antiproton spectrum compatible with secondary production
- Positron and ($e^+$+$e^-$) spectra show unusual shape
- HEAT (2001), AMS-01 (2002), ATIC (2008), Pamela (2009), Fermi-LAT (2009), H.E.S.S. (2010)
- Astrophysical or DM source?

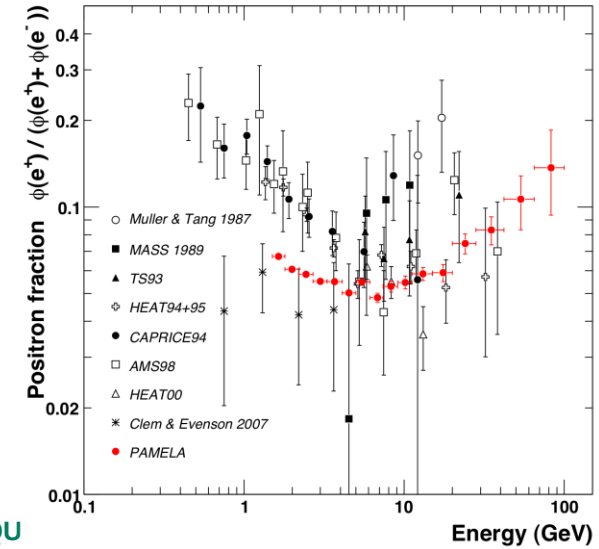
O. Adriani et al., arXiv:1007.0821 (2010)




A.A. Abdo et al., Phys.Rev.Lett.102:181101,2009.

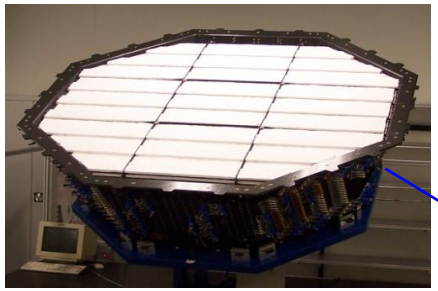



O Adriani *et al. Nature* **458**, 607-609 (2009)

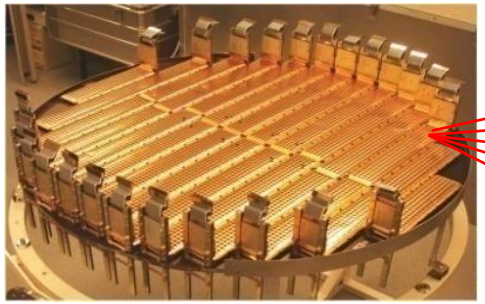


# AMS-02 with Superconducting Magnet

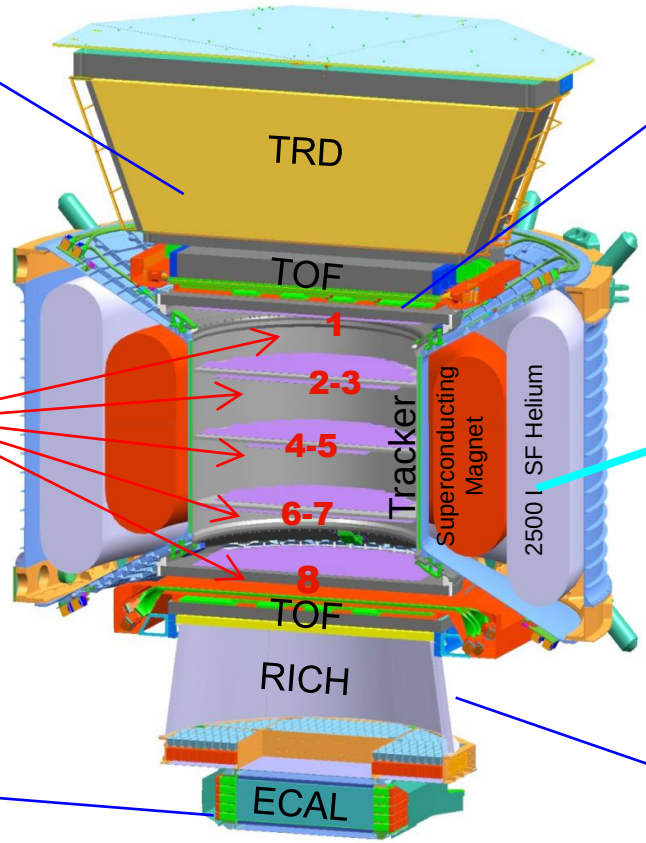
TRD
Identify e+, e-



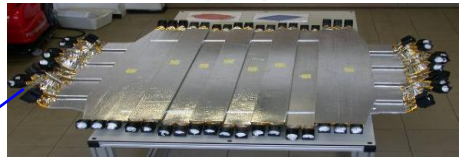
Silicon Tracker
m, Z, P



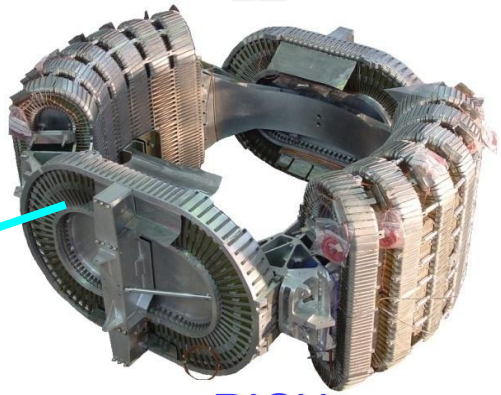
ECAL
E of e+, e-, γ



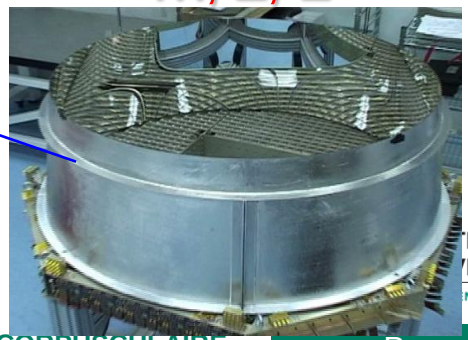

TOF
m, Z, E



Magnet
±Z

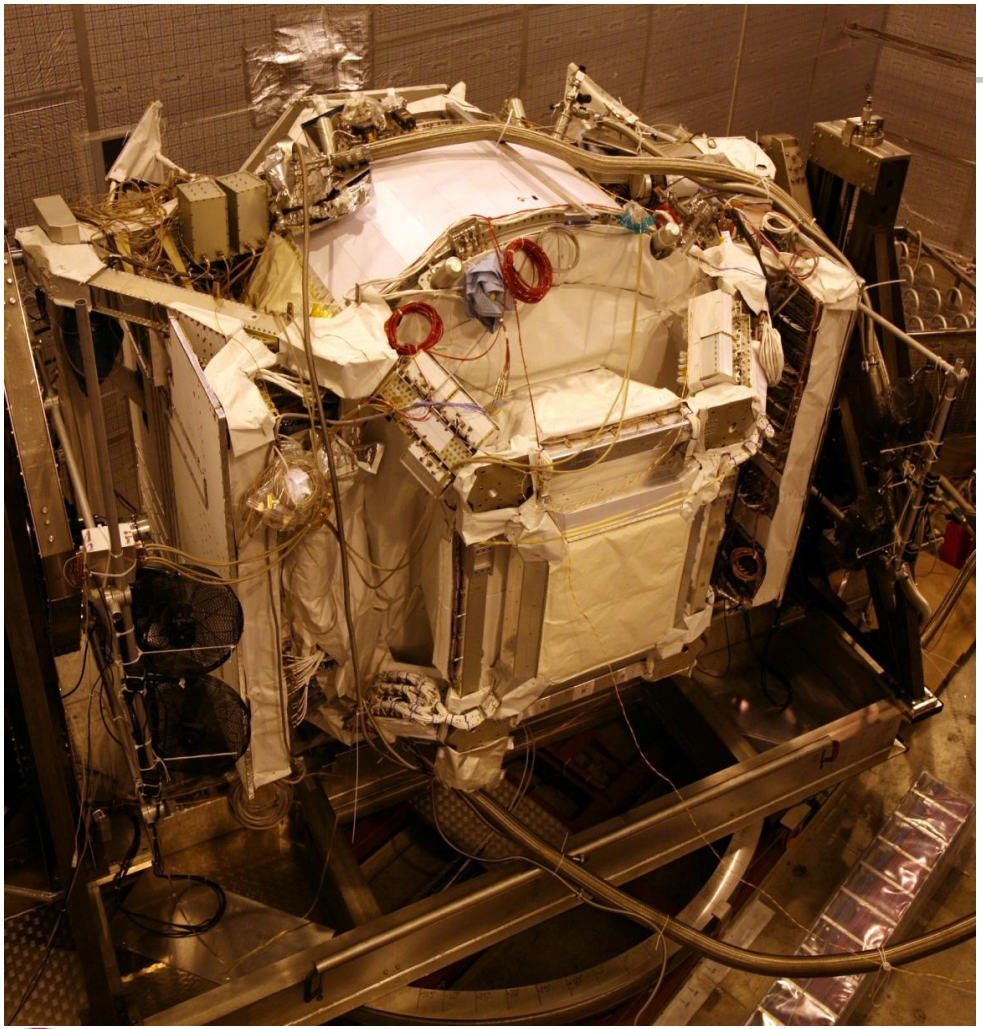


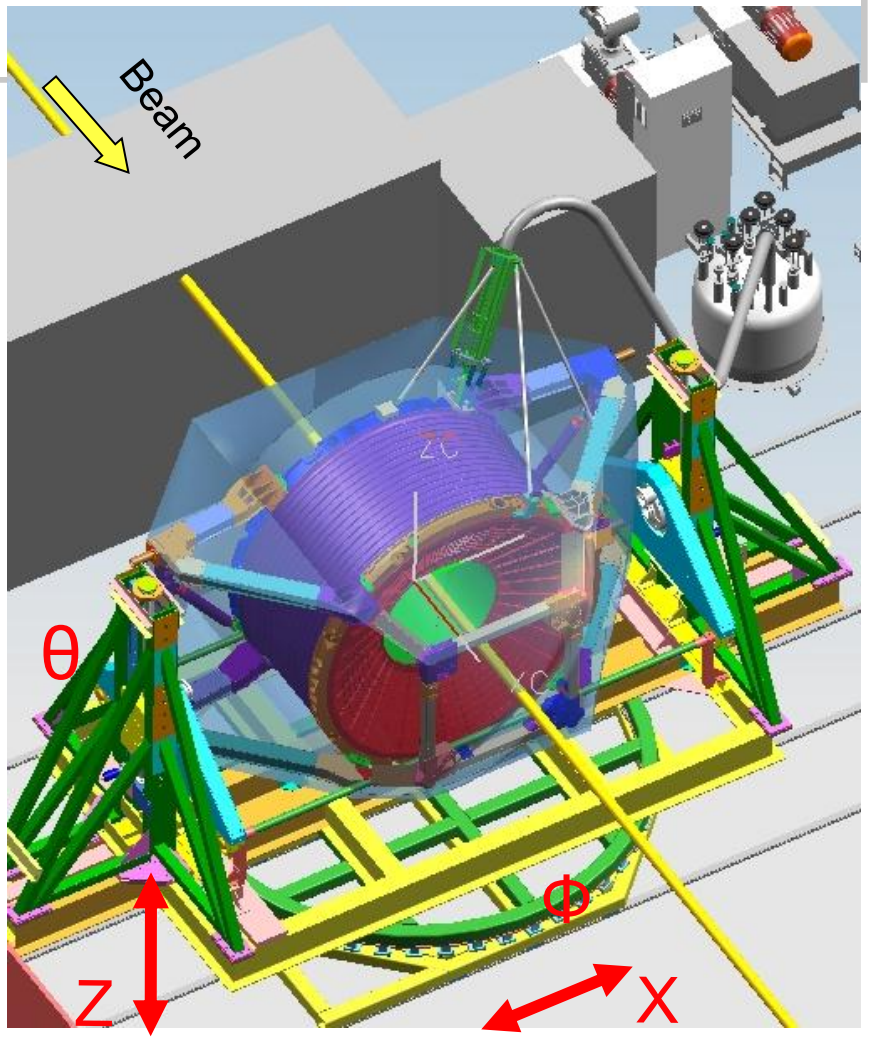
RICH
m, Z, E

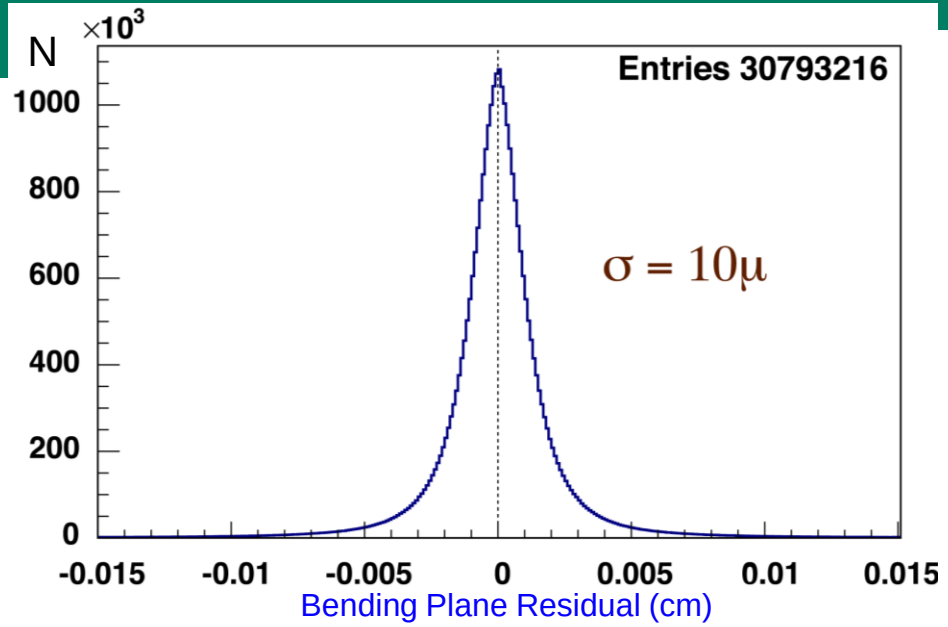


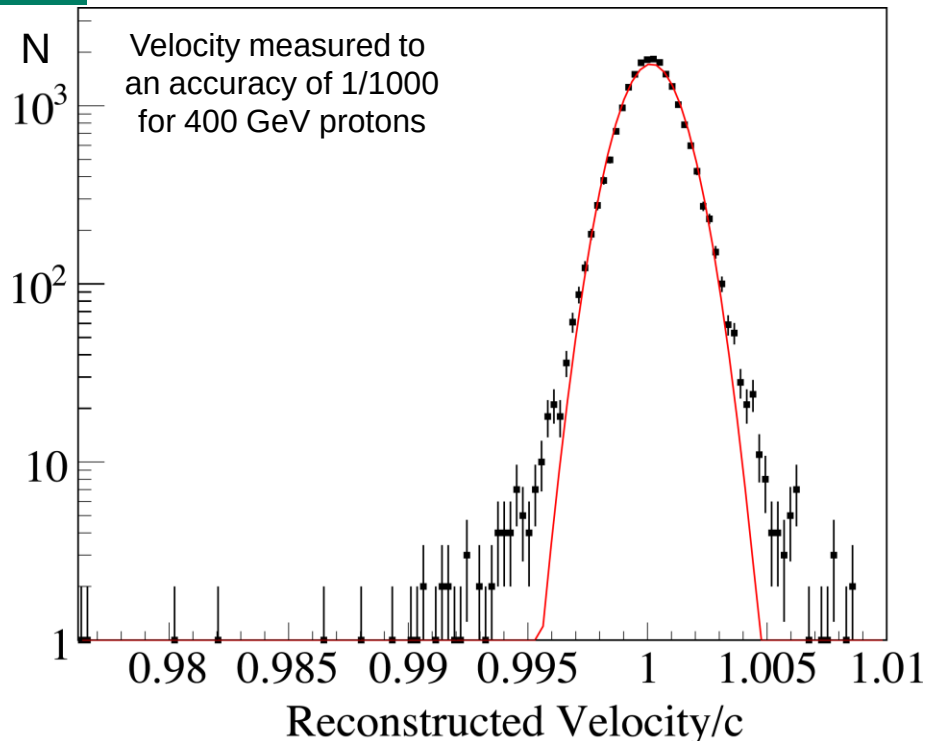
*m, Z, E are measured independently from Tracker, RICH, TOF and ECAL*

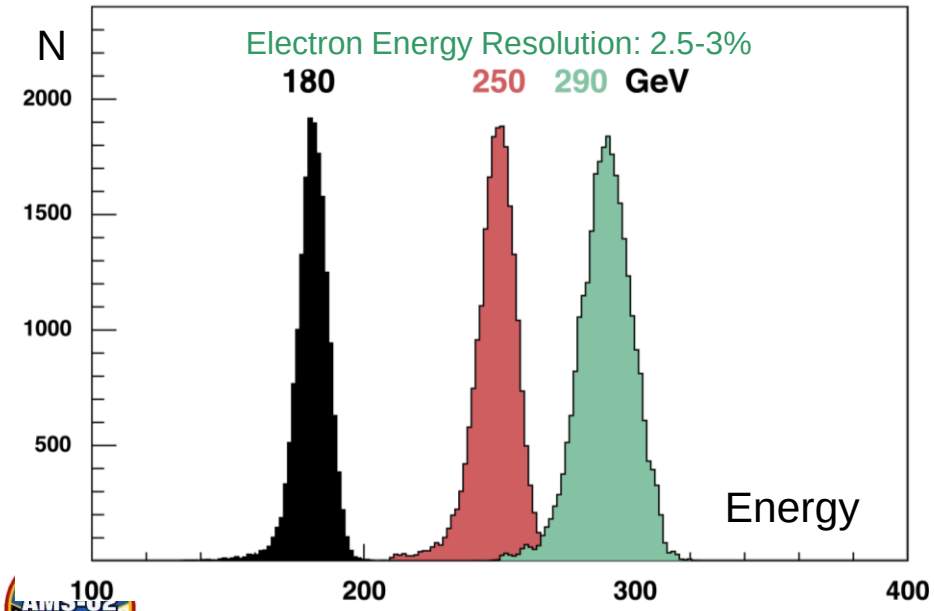
# AMS in CERN SPS Test Beam, Feb 4-8, 2010

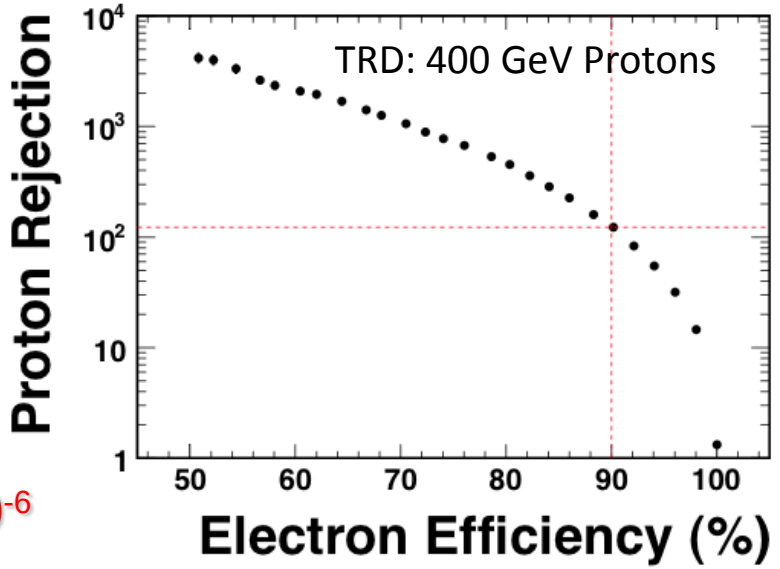






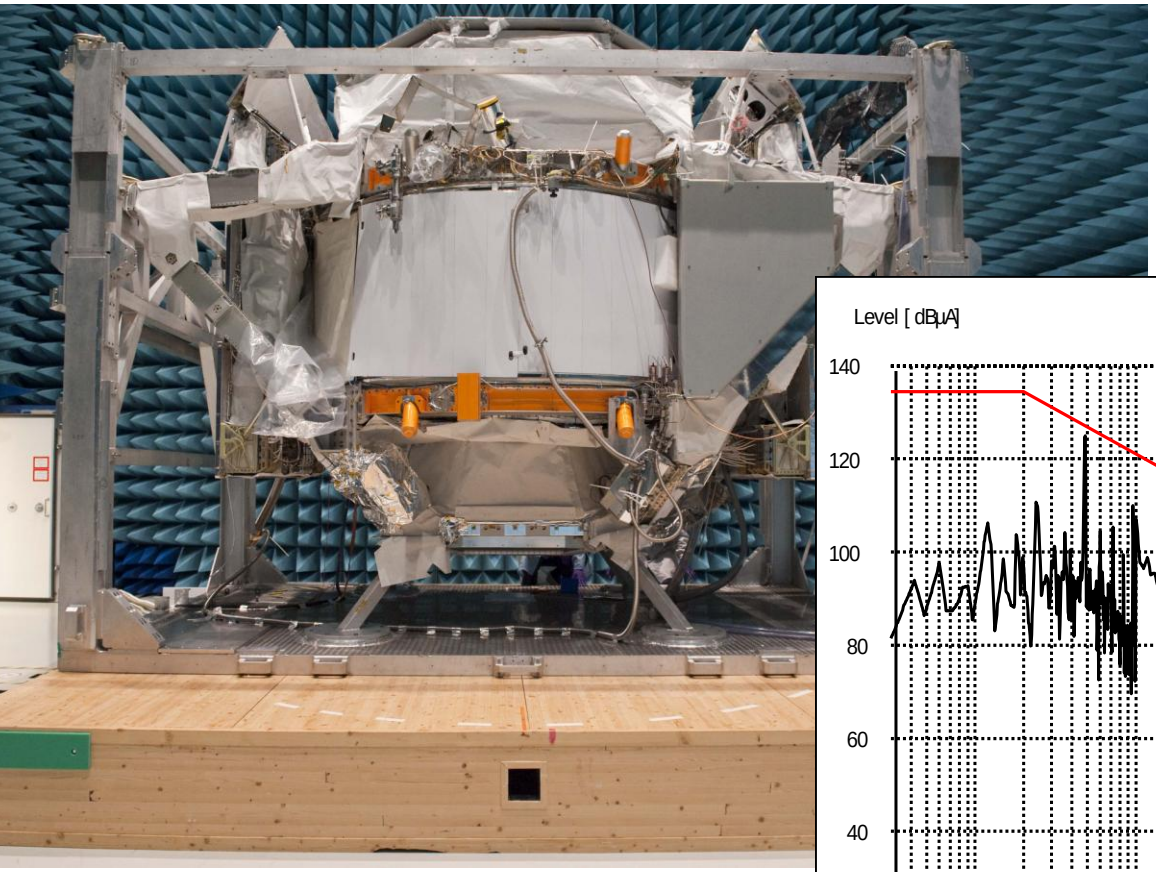



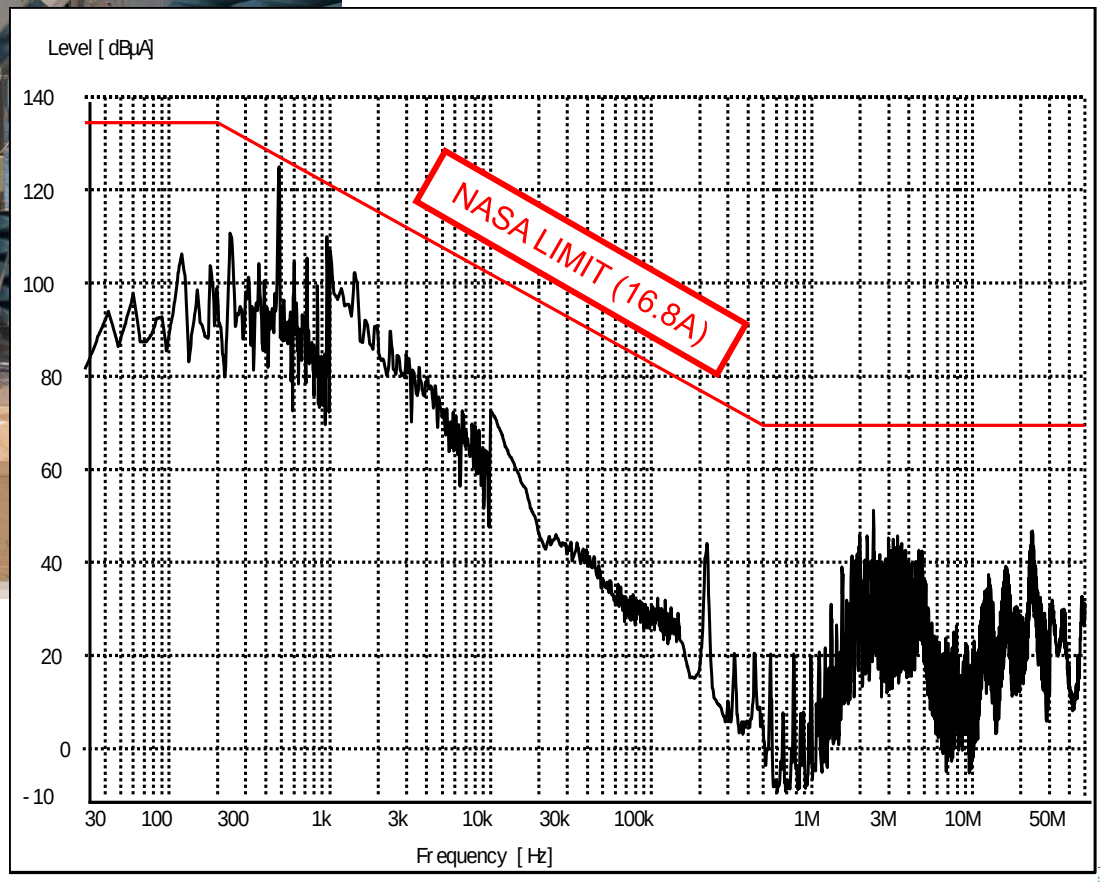



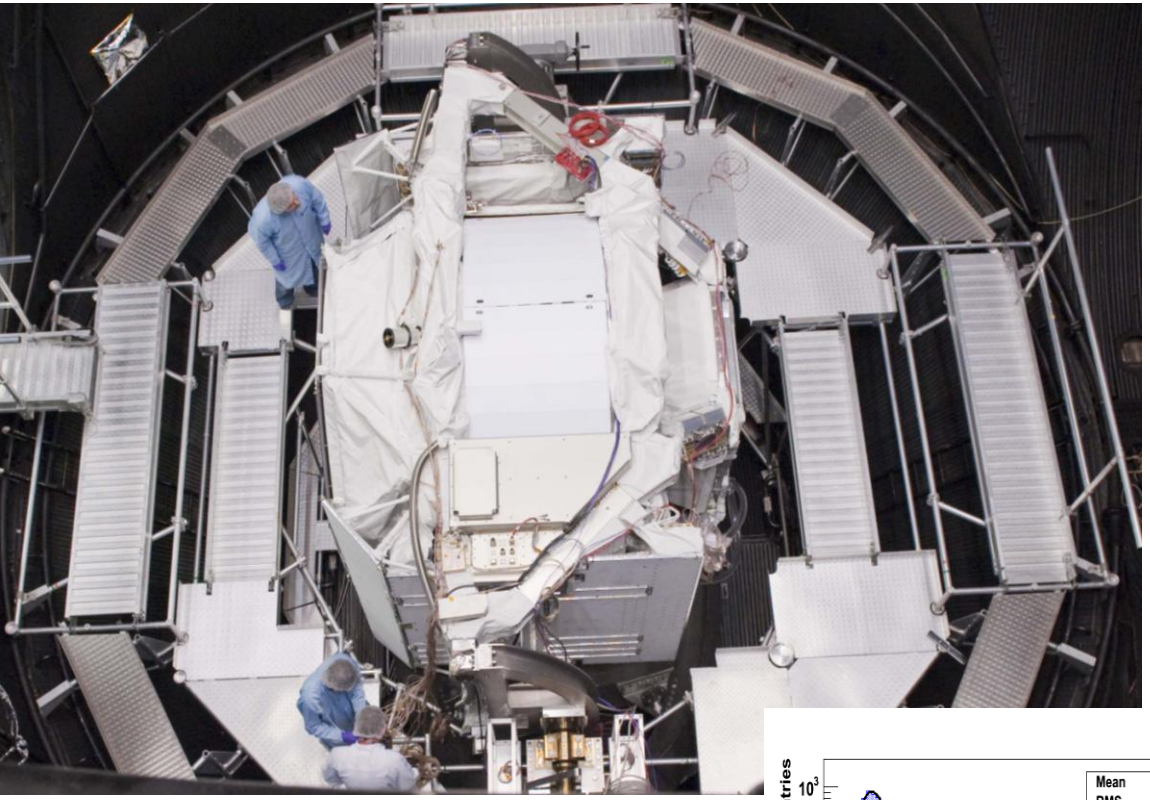

Combined rejection power at 400 GeV: $e^+/p = 10^{-6}$

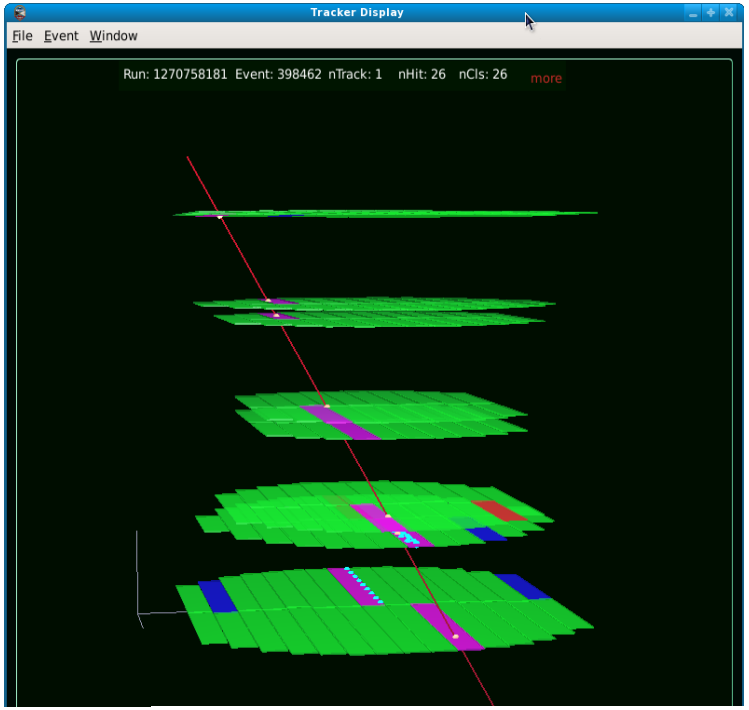
# AMS in the Maxwell EMI chamber at ESTEC



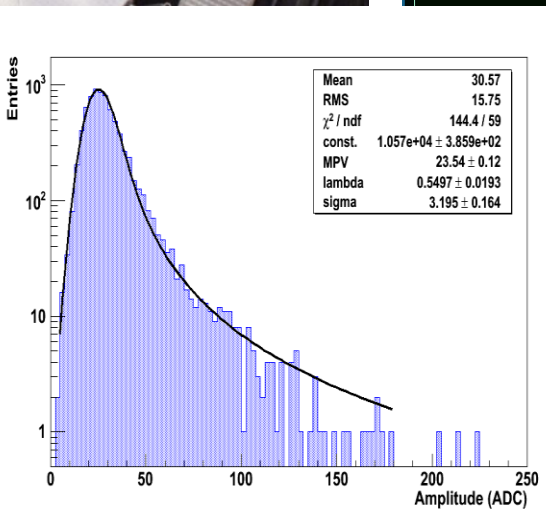


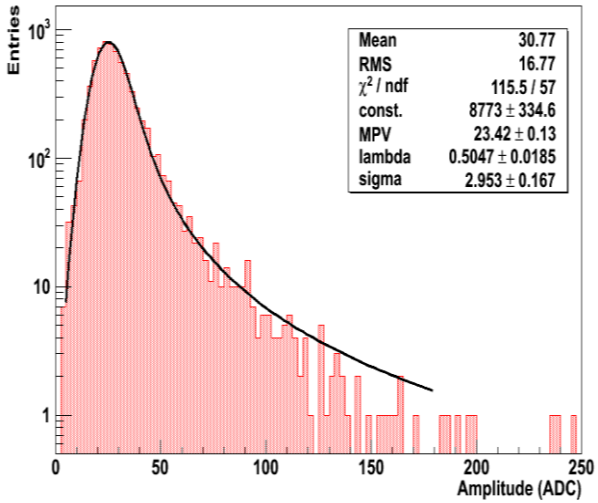
# AMS in the ESA TVT Chamber



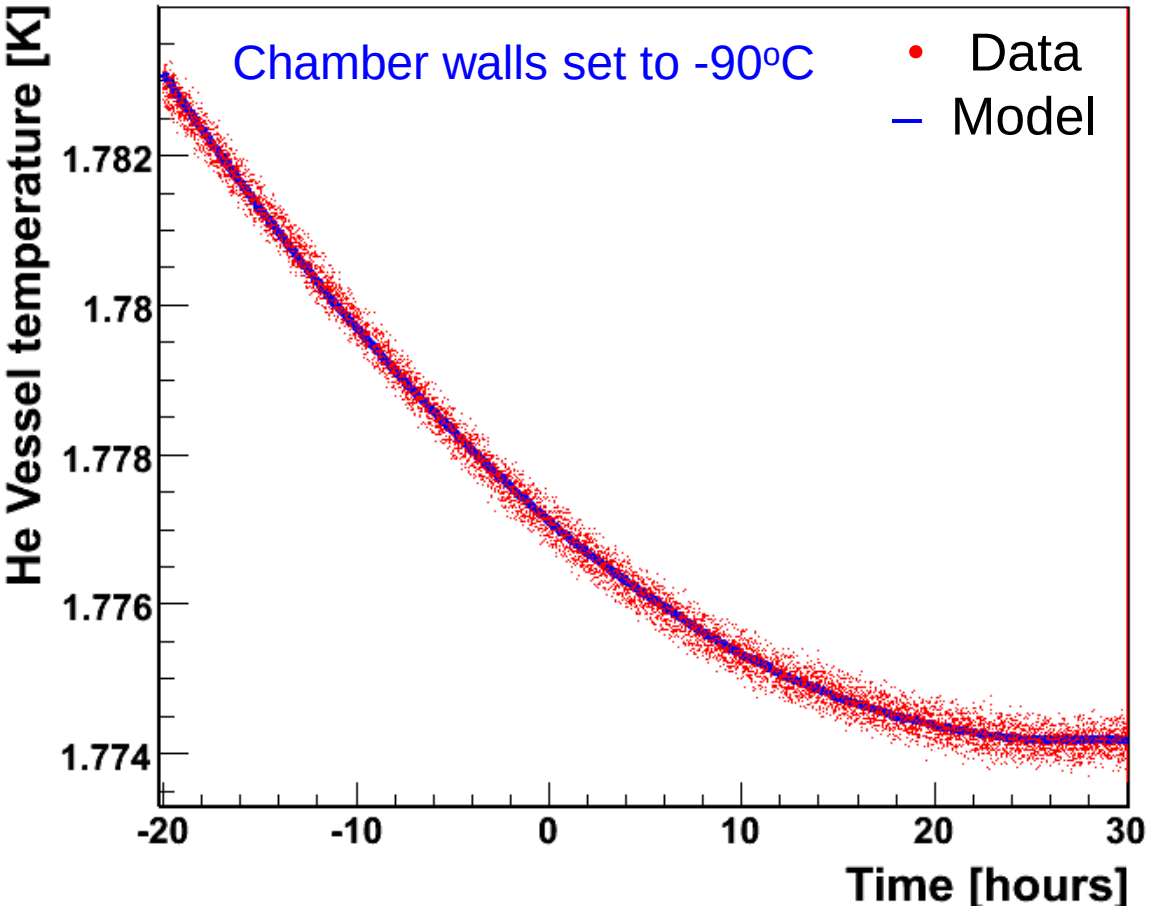



Tracker performance at −90°C:
muon track & mip signal



# Stabilization of the He Vessel




*Stability criteria:*
*dT/dt < 0.0001K/h*

Expected life time of the AMS Cryostat on ISS:

20±4 months with M87 cryocoolers (1999)

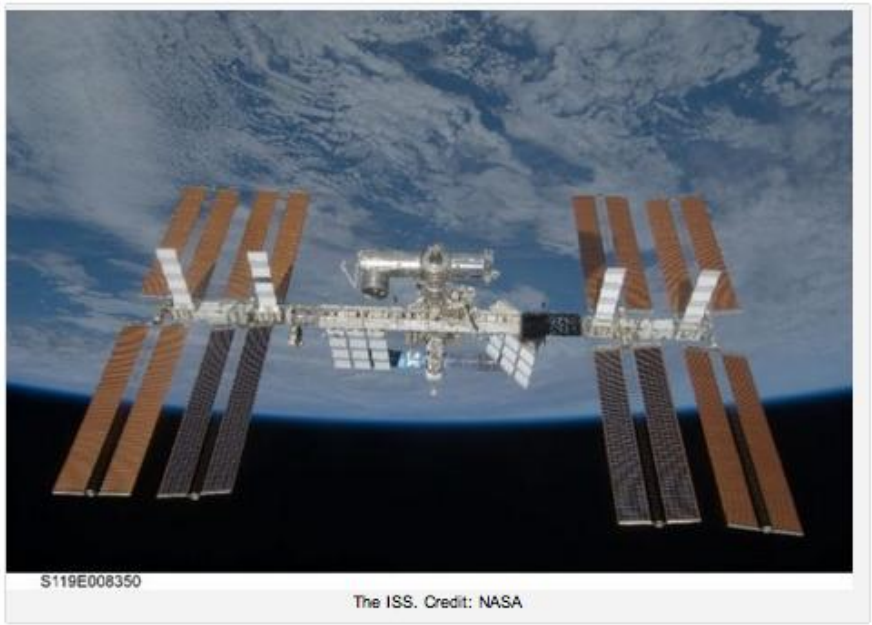
28±6 months with GT cryocoolers (2010)

# ISS Lifetime Extension

April 14th, 2009

Life of the ISS May be Extended

Written by Nancy Atkinson



S119E008350

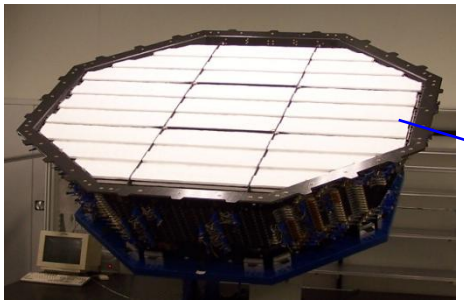
The ISS. Credit: NASA

Fifteen partnering nations have agreed in principle to extend the life of the International Space Station, and keep it operating through 2020, according to an article in the Wall Street Journal. That is at least five years beyond the current deadline. Until now, the major partners – NASA, ESA and the Russian Space Agency – hadn't committed to keeping the station operational past 2015, and questions loomed about the future of the ISS and its worthiness as a platform for scientific research. An extension could give new momentum to science, but may force NASA to siphon money away from other projects – like the new Constellation program – in order to pay for the additional years of operation.

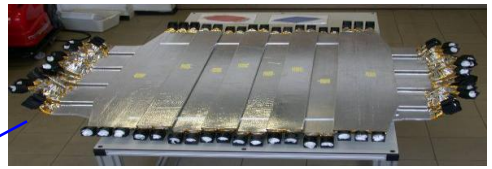
- The ISS lifetime has been extended from 2015 to 2020 (or even 2028).
- The Shuttle program will be definitely terminated, thus eliminating any possibility of returning and refilling AMS.
- A superconducting magnet was ideal for a three year stay on ISS as originally planned for AMS.
- With the extended ISS life, the super-conducting magnet is no longer the optimum choice.
- AMS-02 with the permanent magnet from AMS-01 will have 10-18 years time to collect data, providing much more sensitivity to search for new phenomena.

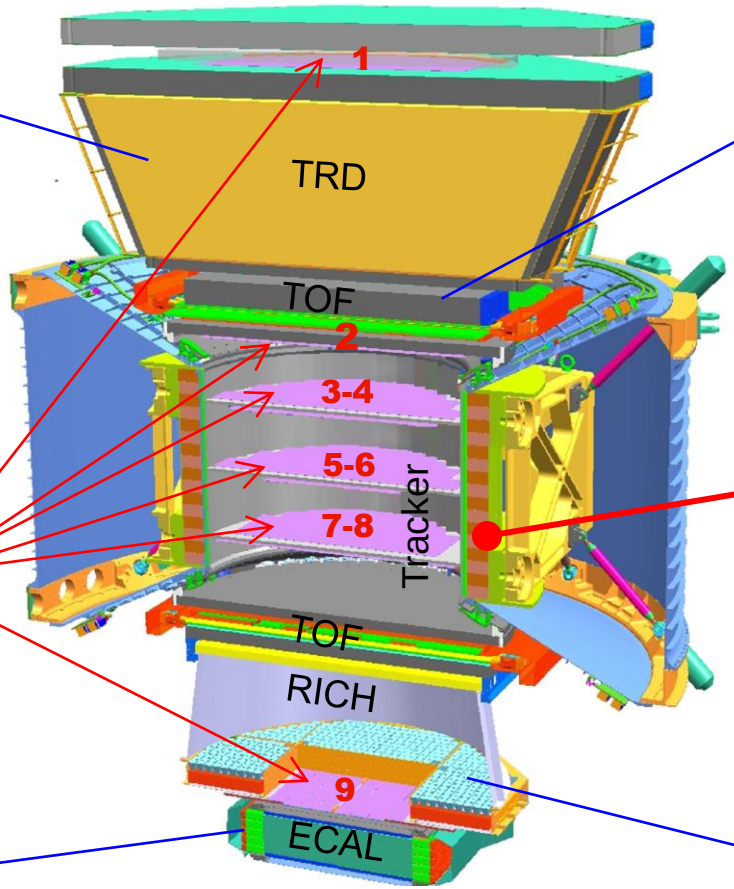
# AMS-02 with Permanent Magnet

TRD

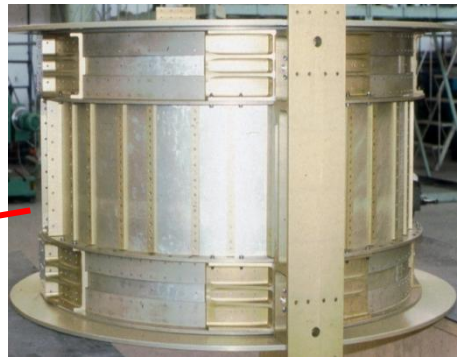


TOF





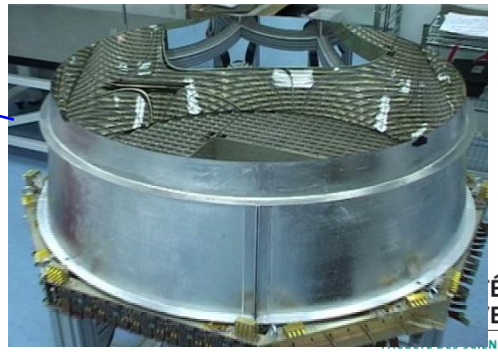

Permanent Magnet



Silicon Tracker

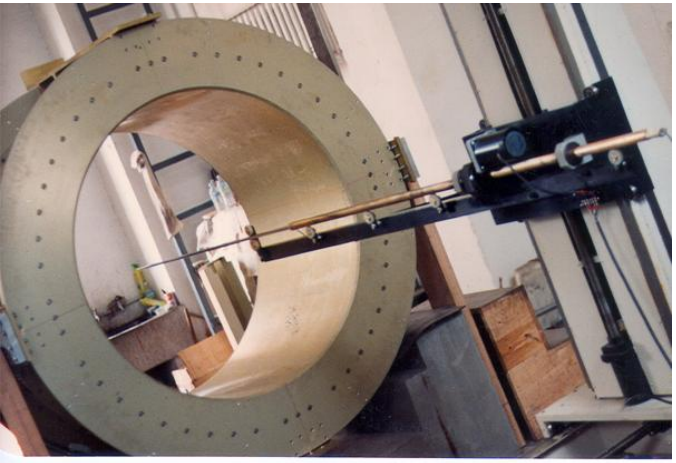
ECAL

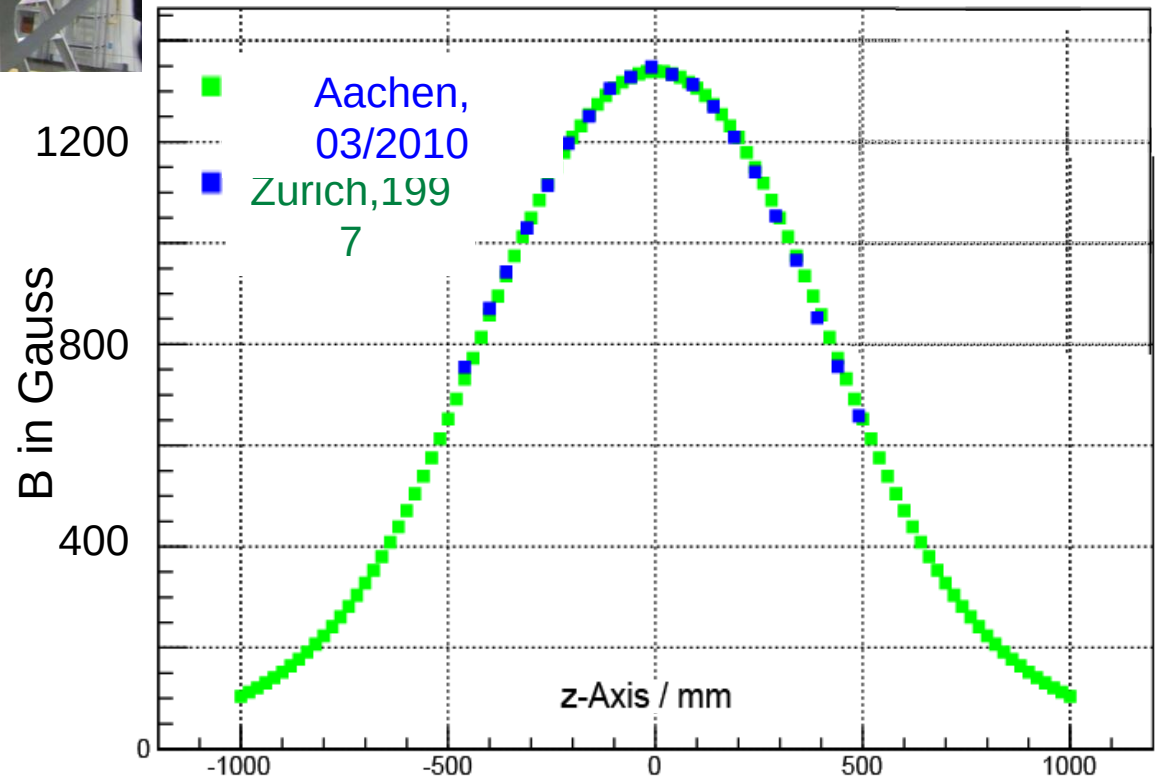
RICH



- One Tracker plane displaced to top
- One additional plane on bottom

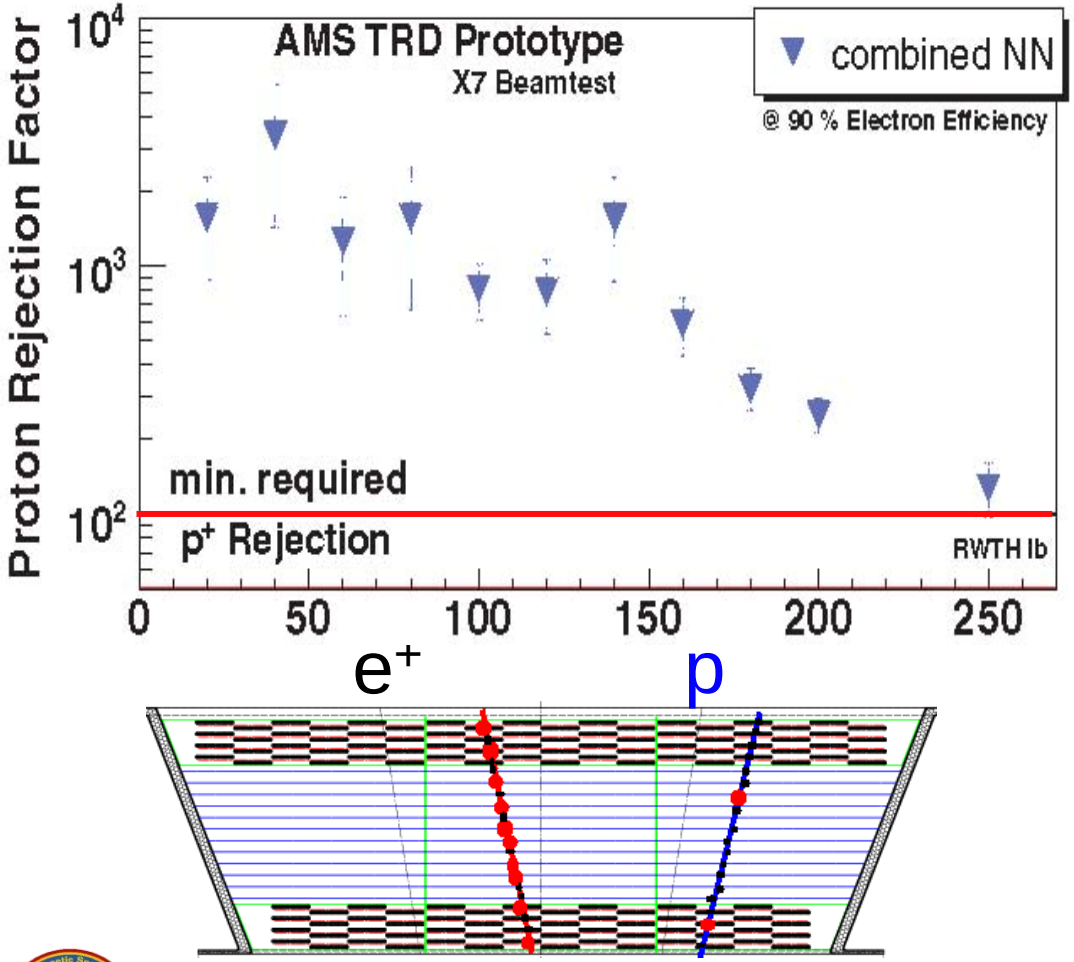
# AMS-01 Permanent Magnet in Aachen Germany, April/May 2010



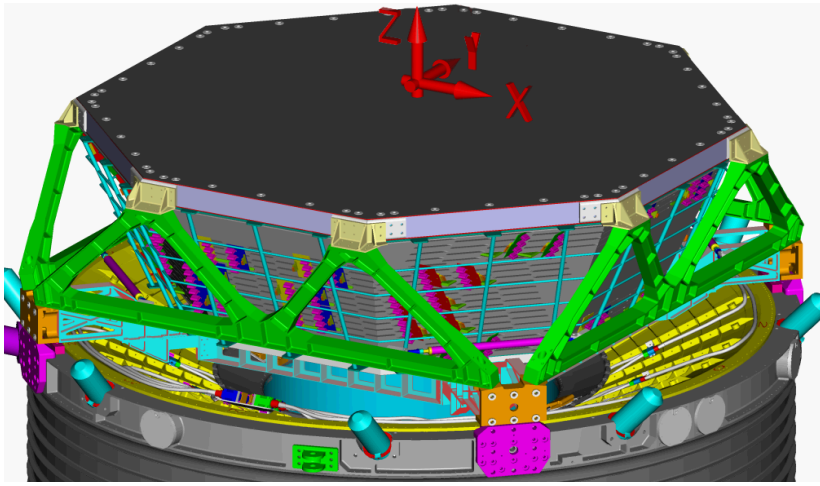



- SC: $B_{max}$ = 0.87T
- PM: $B_{max}$ = 0.14T

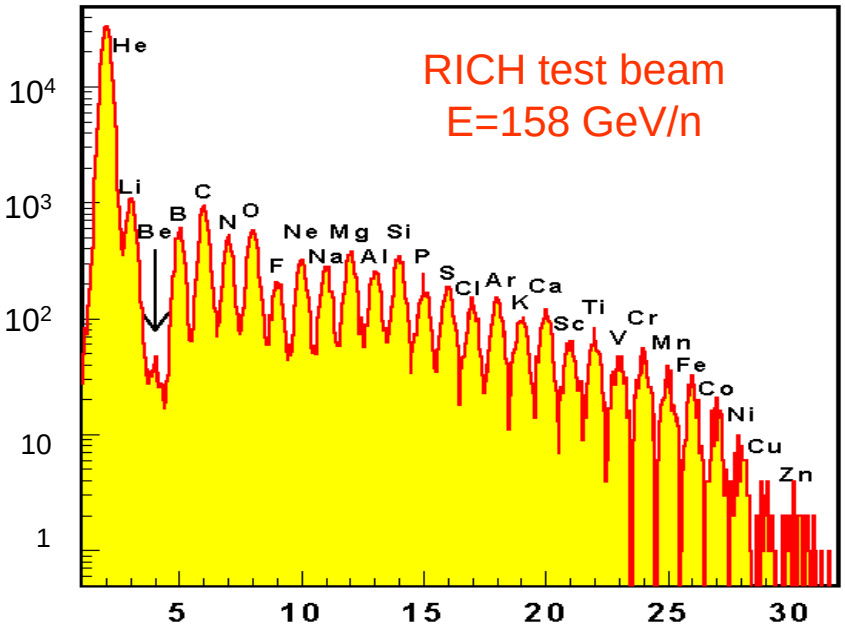
# Transition Radiation Detector (TRD)

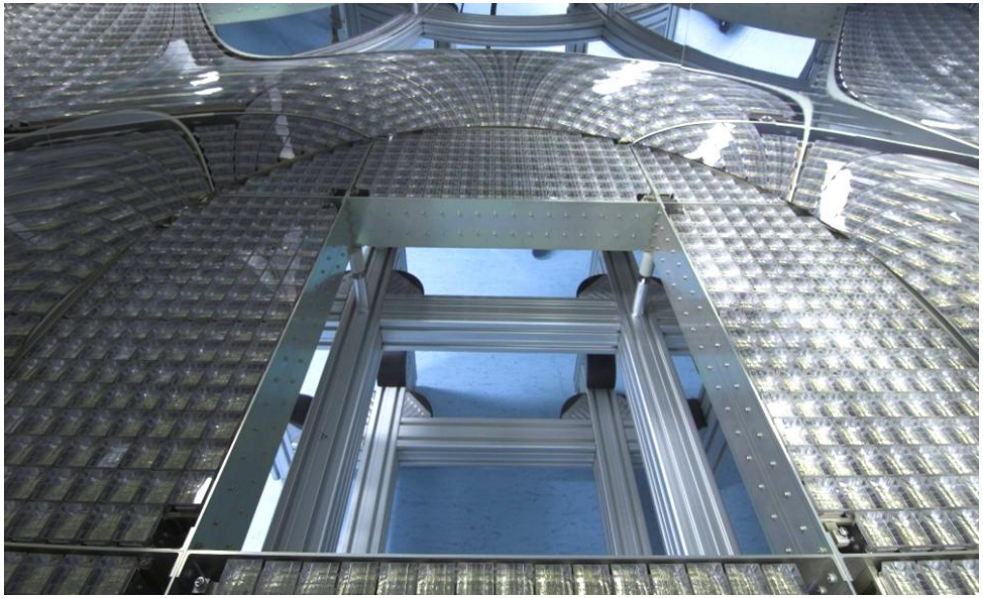



20 layers

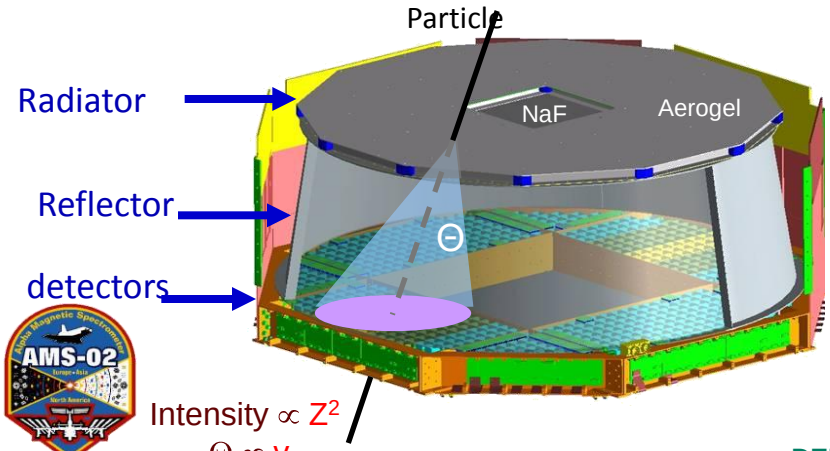


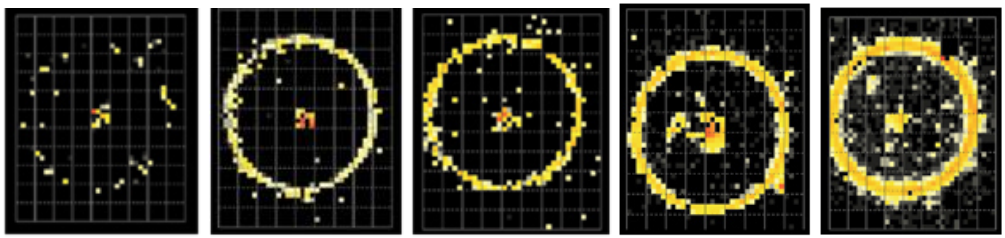

# Ring Imaging Cherenkov (RICH)



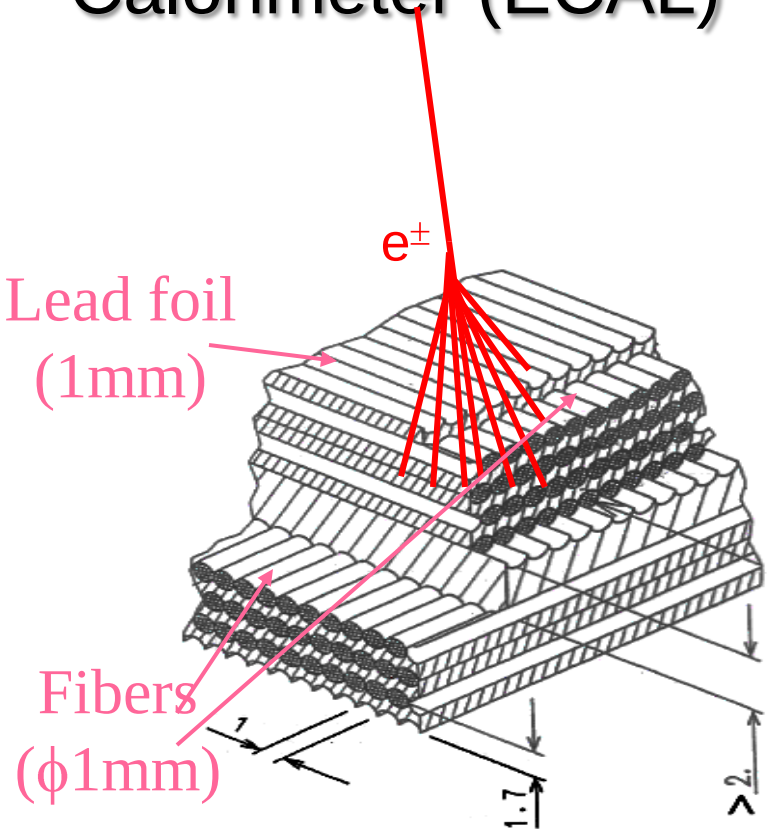
10,880 photosensors

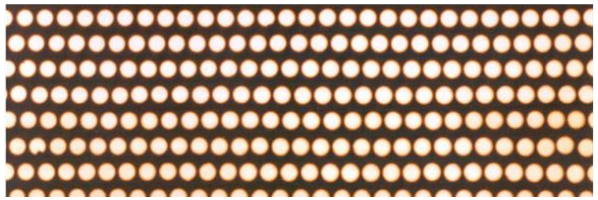


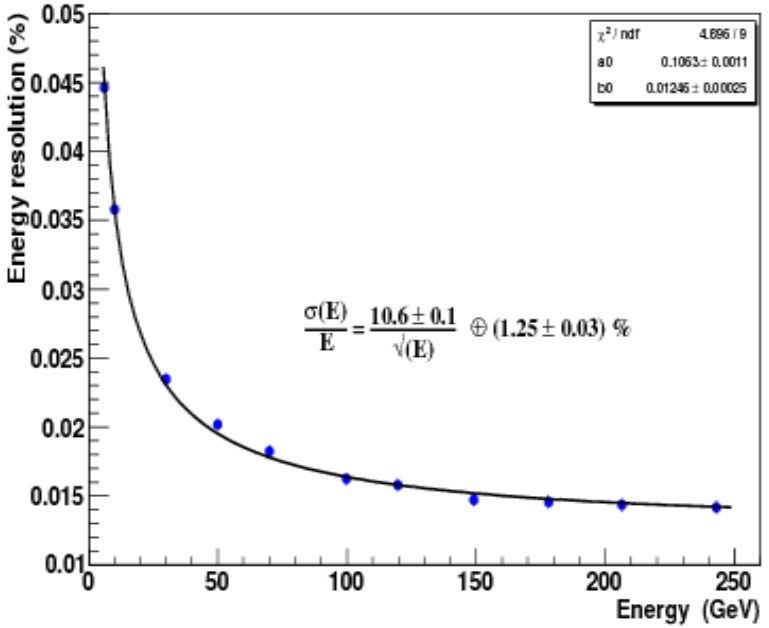

## Single Event Displays
## RICH test beam E=158 GeV/n

# Calorimeter (ECAL)

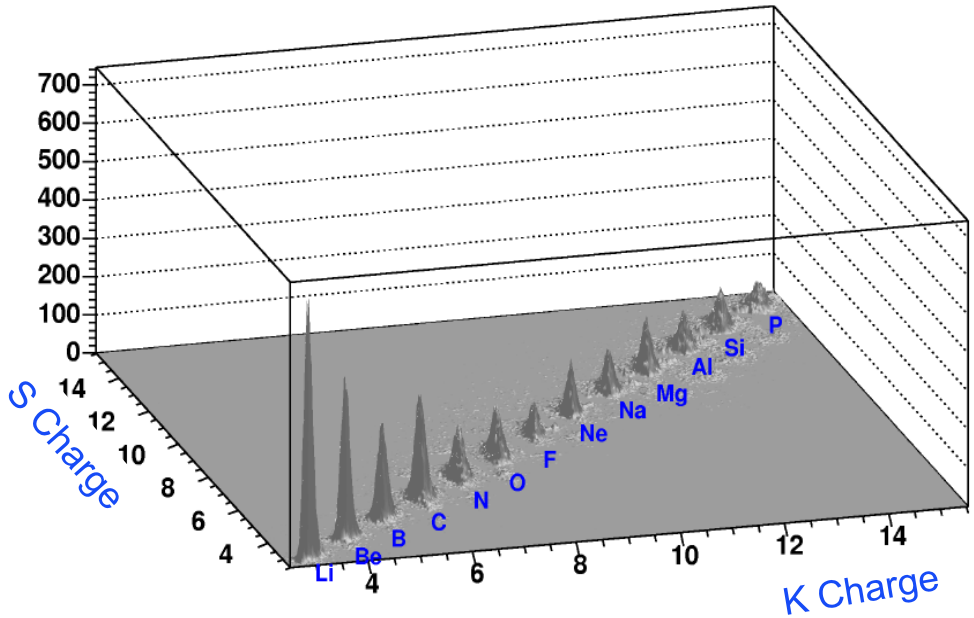


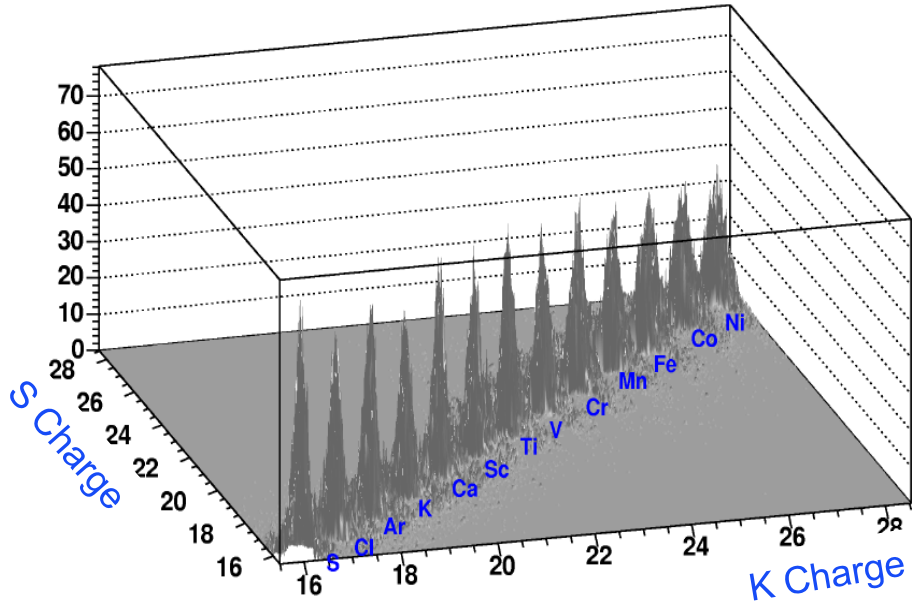



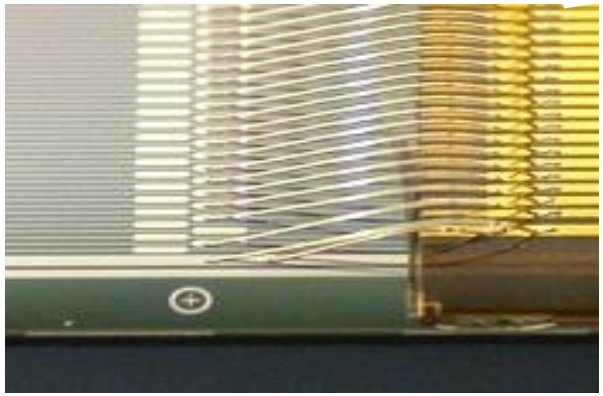
10 000 fibers, $\phi = 1$ mm
distributed uniformly
inside 1,200 lb of lead

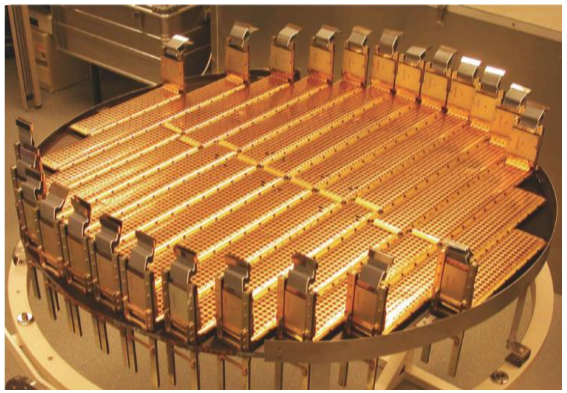


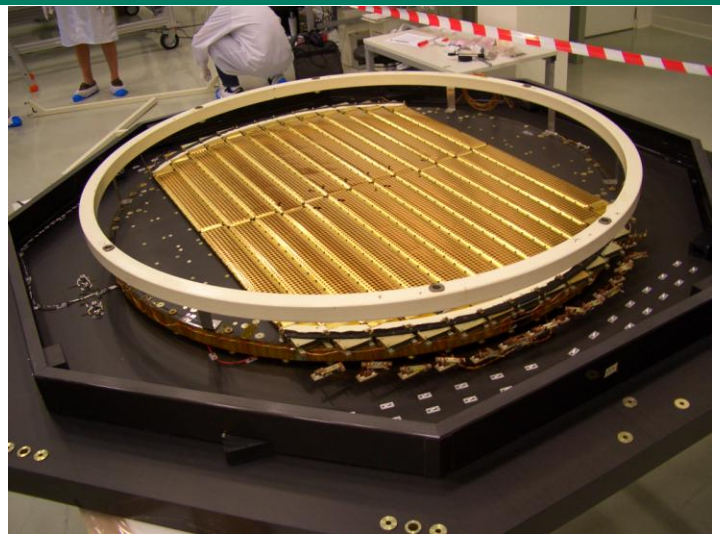
# Silicon Tracker: Rigidity and Charge



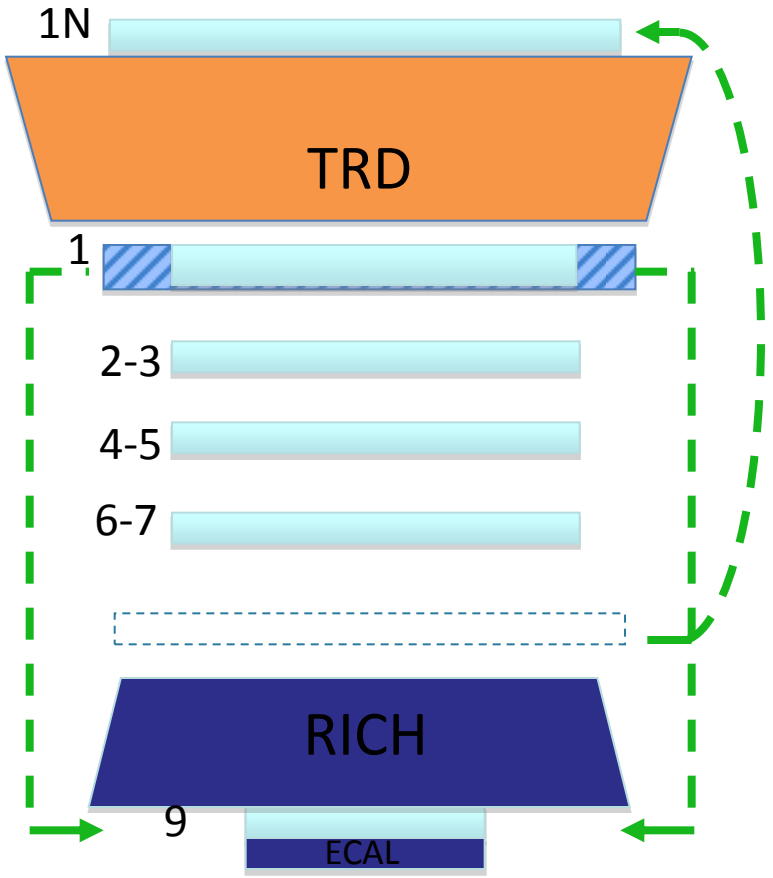



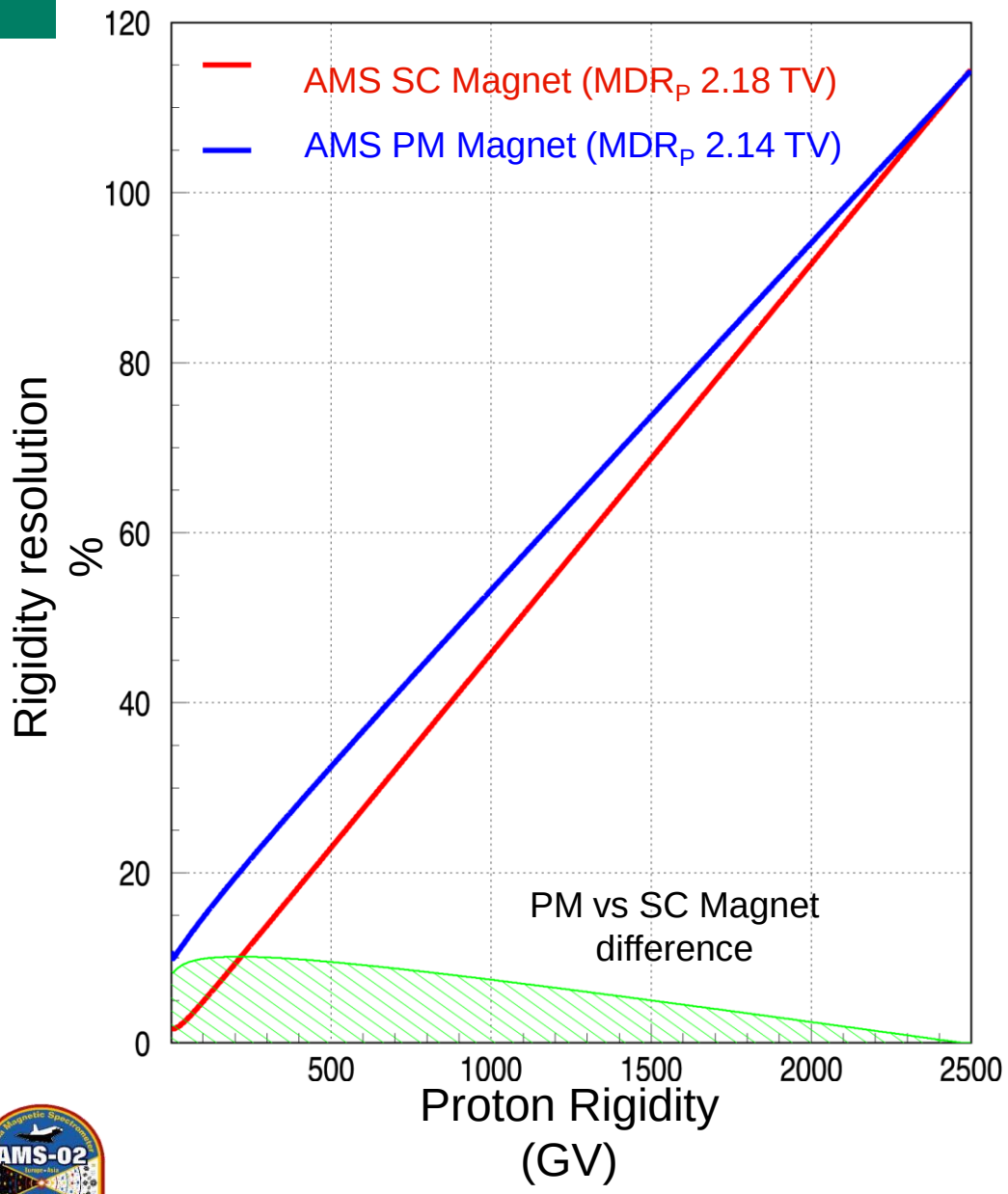




# AMS-02 Permanent Magnet Silicon Tracker Layers

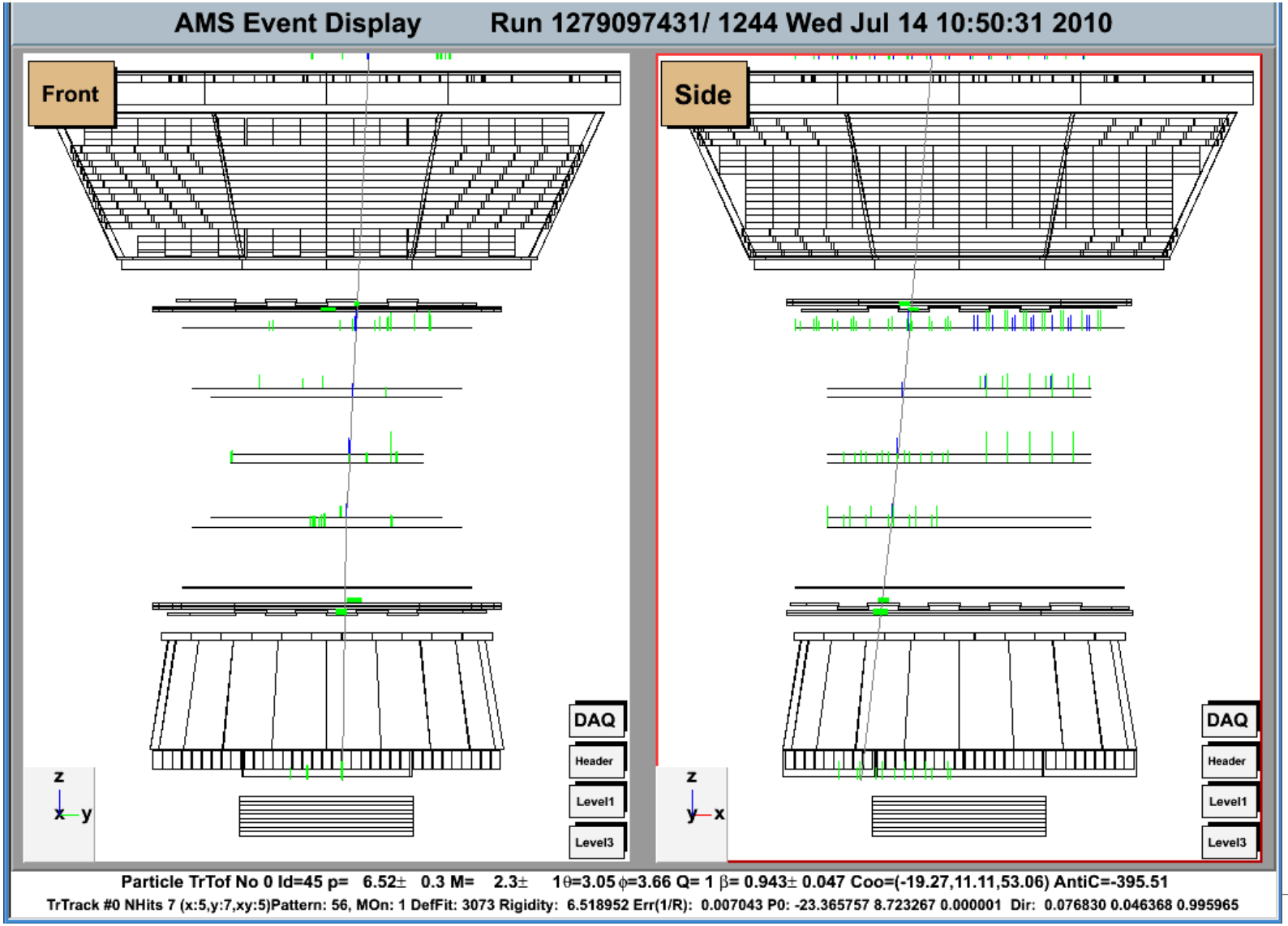



Layer 9 comes from moving the ladders at the edge of the acceptance from layer 1. Layer 8 is moved on top of the TRD to become 1N.

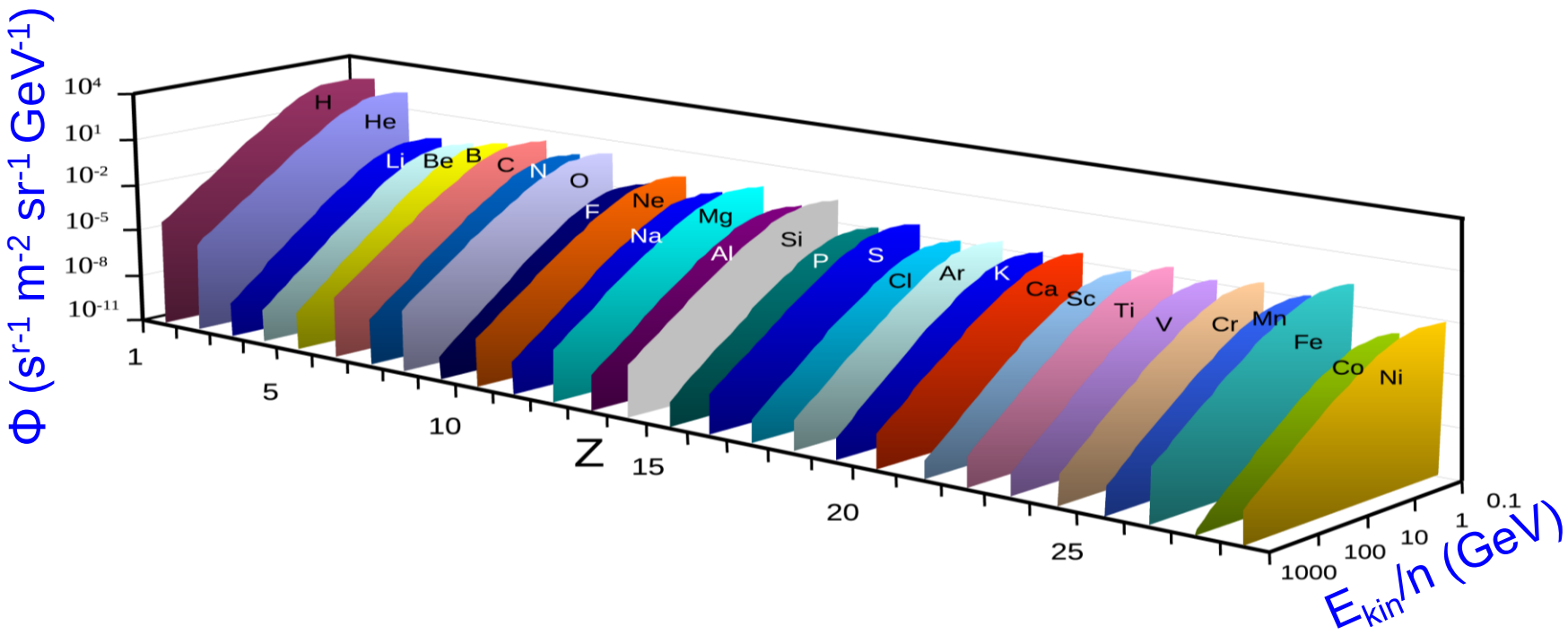



- With 9 tracker planes in the new configuration, the rigidity resolution of AMS with the permanent magnet is equal (within 10%) to that of the superconducting magnet.
- For helium nuclei, the MDR for the permanent magnet is 3.75 TV.
- Alignment will be done with 10'000 CR tracks per minute in orbit.

# Cosmic $\mu^-$, July 14, 2010

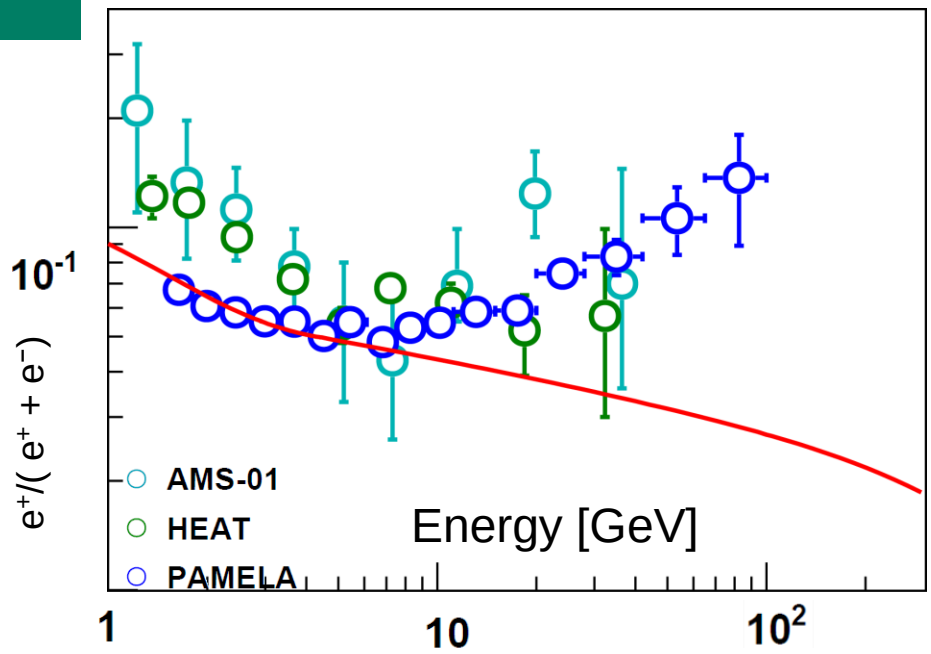


# Physics of AMS: Nuclear Abundances Measurements




AMS will measure of cosmic ray spectra for nuclei, for energies from 500 MeV to 2 TeV to 1% over the 11-year solar cycle.

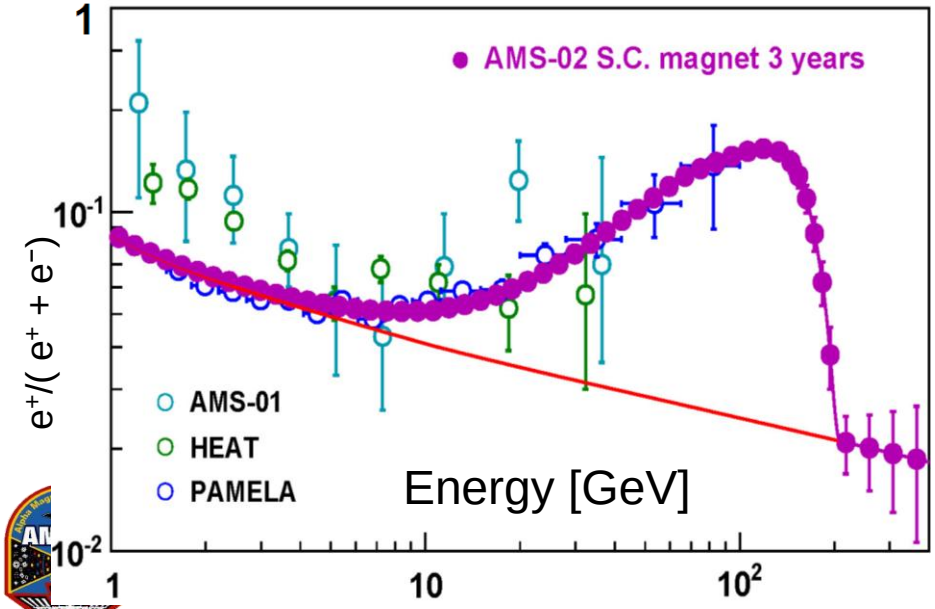
These spectra will provide experimental measurements of all the assumptions that go into calculating the background in searching for Dark Matter,
i.e., $p + C \rightarrow e^+, p, \ldots$

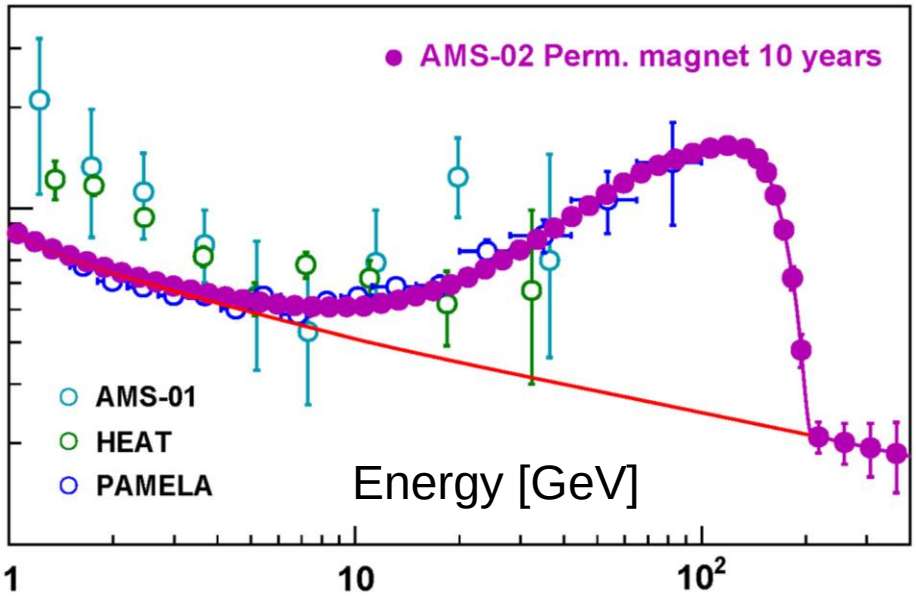


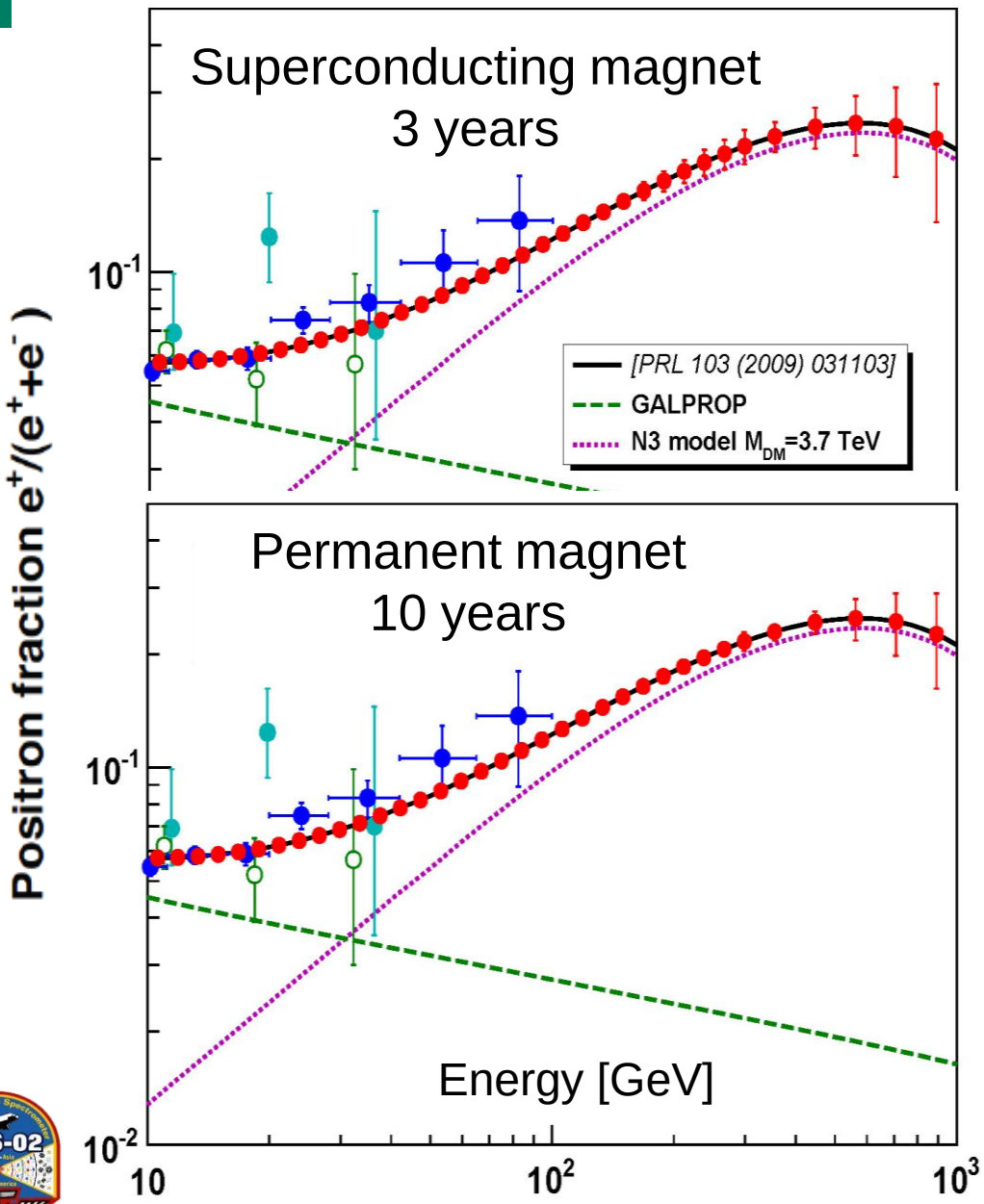

# Dark Matter Candidate $\chi^0$

$\chi^0 \rightarrow e^+e^-$

for $m\chi^0 = 200$ GeV





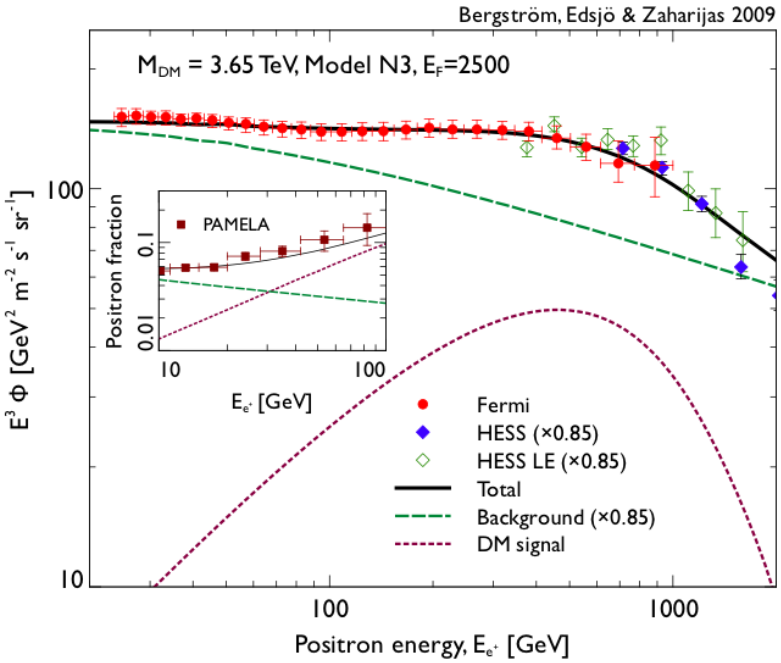

Bergström, Edsjö, Zaharias 2009

Fit to Pamela, Fermi-LAT, HESS

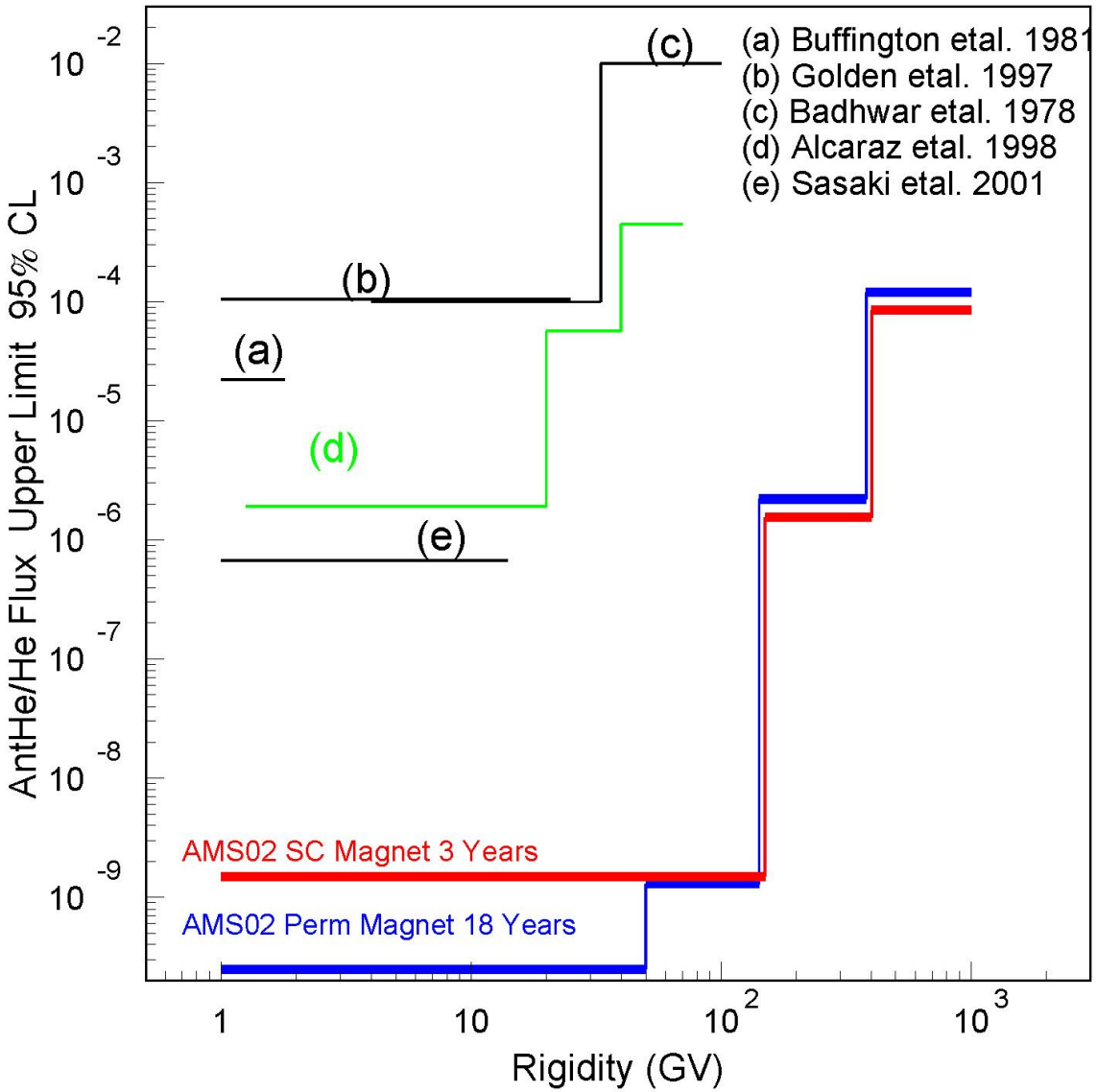
Nomura-Thaler model N3

$M_{DM}$ = 3.65 TeV

$E_F \approx 2500$

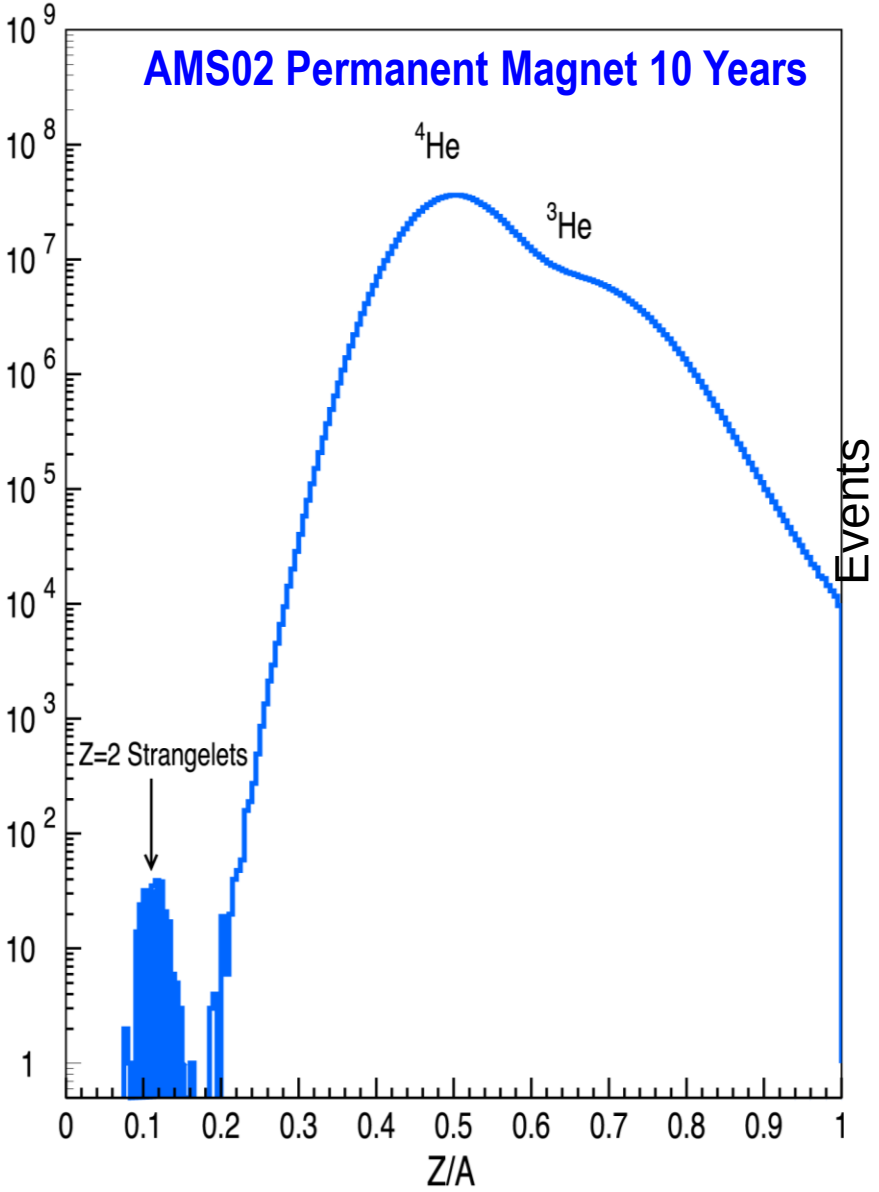


# Search for Residual Antimatter

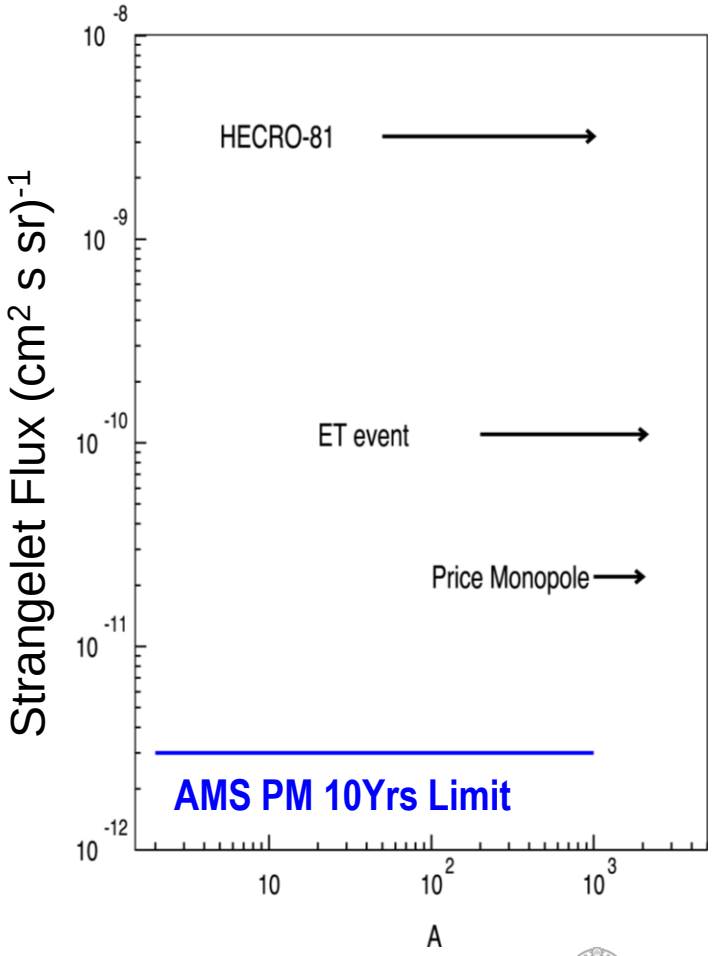


# Search for Strangelets

$\Phi_s = 5x10^{-10}(cm^2 s\ sr)^{-1}$




E. Witten, Phys. Rev. D,272-285 (1984)



# Conclusions

- AMS-02 has successfully been integrated with the long lifetime permanent magnet, to match the extended ISS lifecycle.
- The experiment performance at high energies is preserved.
- Schedule:
  - CERN test beam in final configuration from August 7 to 14, 2010.
  - US Air Force C5 will take us on August 26 to Kennedy Space Center, Florida.
  - On flight STS-134, scheduled for Feb. 26, 2011, space shuttle Endeavour will take us to the ISS.

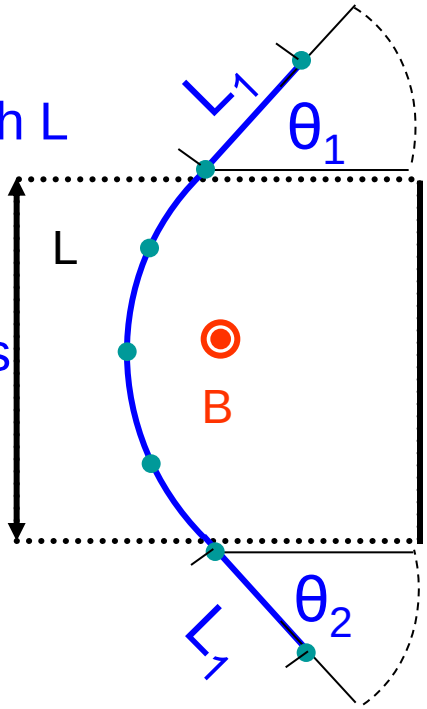
The momentum resolution (Δp/p) is the sum of two contributions:

1. Measurement inside the magnet with an effective length L

$$(Q/p)\cdot(\Delta p/p) \alpha 1/BL^2$$

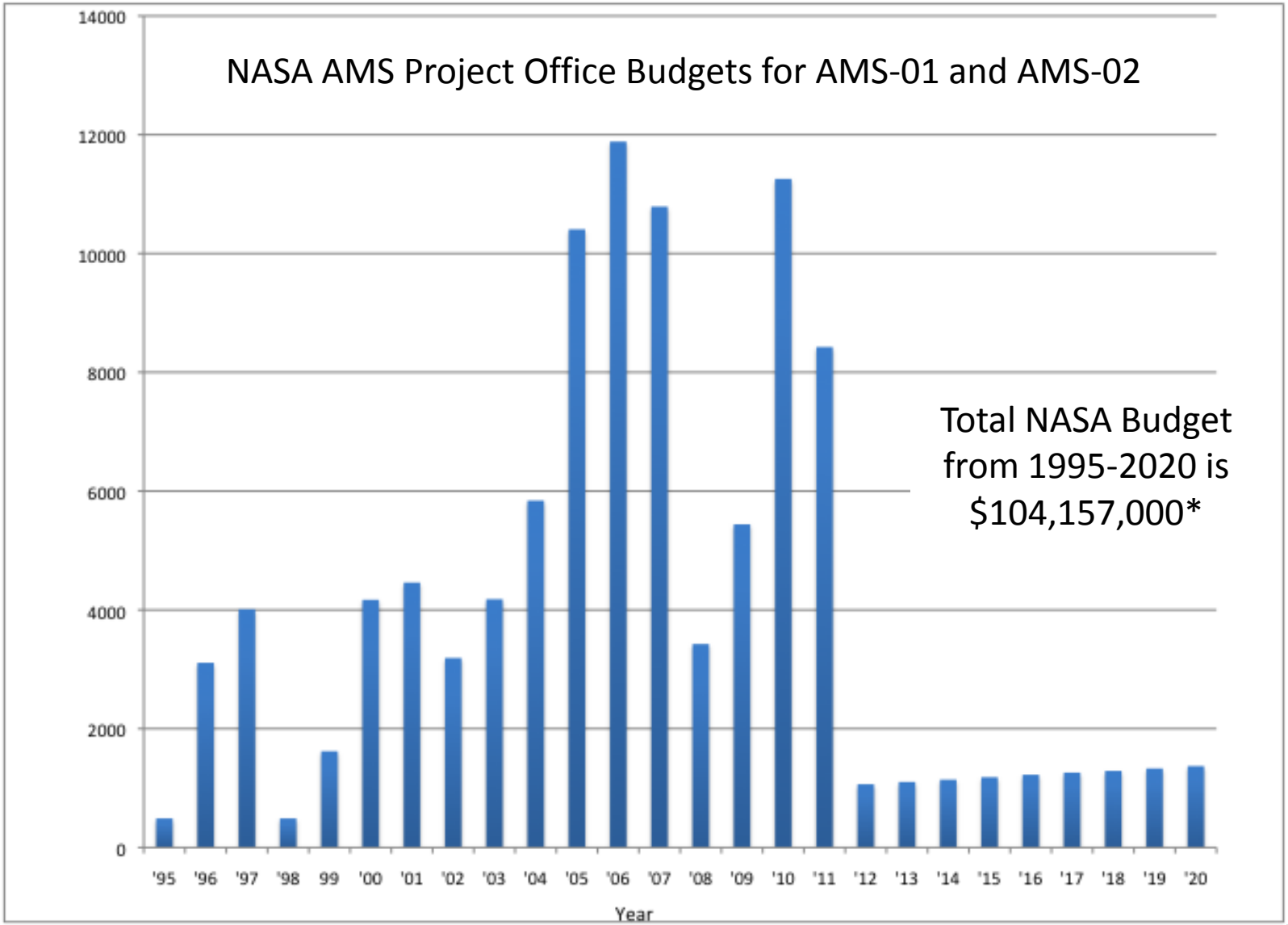
2. Measurement of the incident ($\theta_1$) and exit ($\theta_2$) angles which depend on the length $L_1$

$$(Q/p)\cdot(\Delta p/p) \alpha 1/BLL_1$$




For both magnets, L ~ 80 cm,
but in the permanent magnet B is 5 times smaller
to maintain the same Δp/p we increase L1 from ~15 cm (Superconducting Magnet) to ~125 cm (permanent magnet)

# Long term support from NASA already planned.




* Budget does not include launch costs

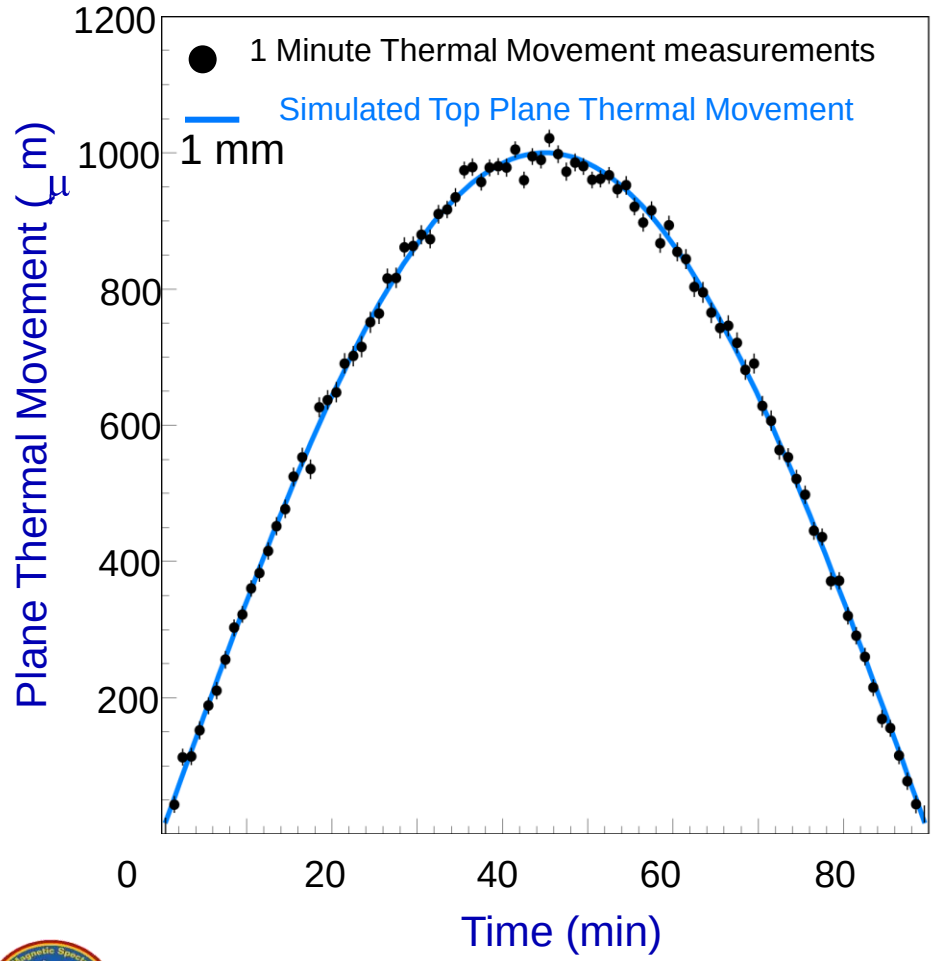
# AMS Vacuum Cases

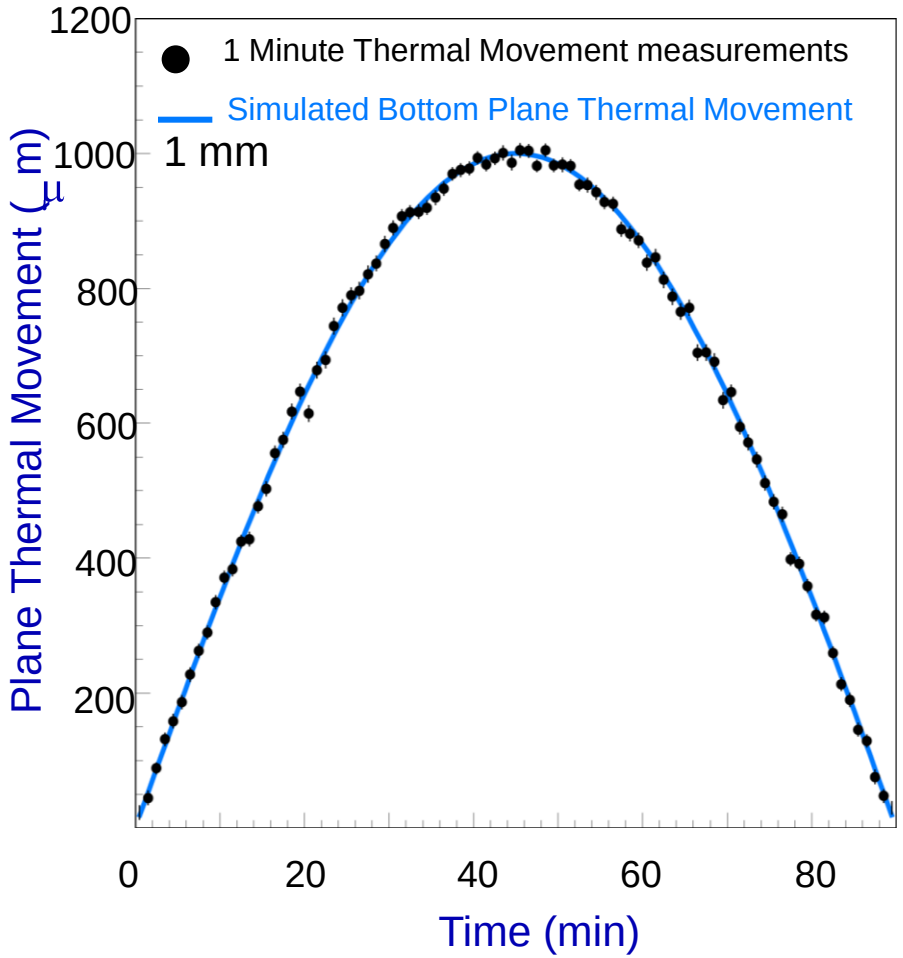
# Independent Alignment Systems of the AMS Tracker Planes

1. Alignment with CERN Test beam on 7-14 Aug 2010 using the highest energy protons (400 GeV).

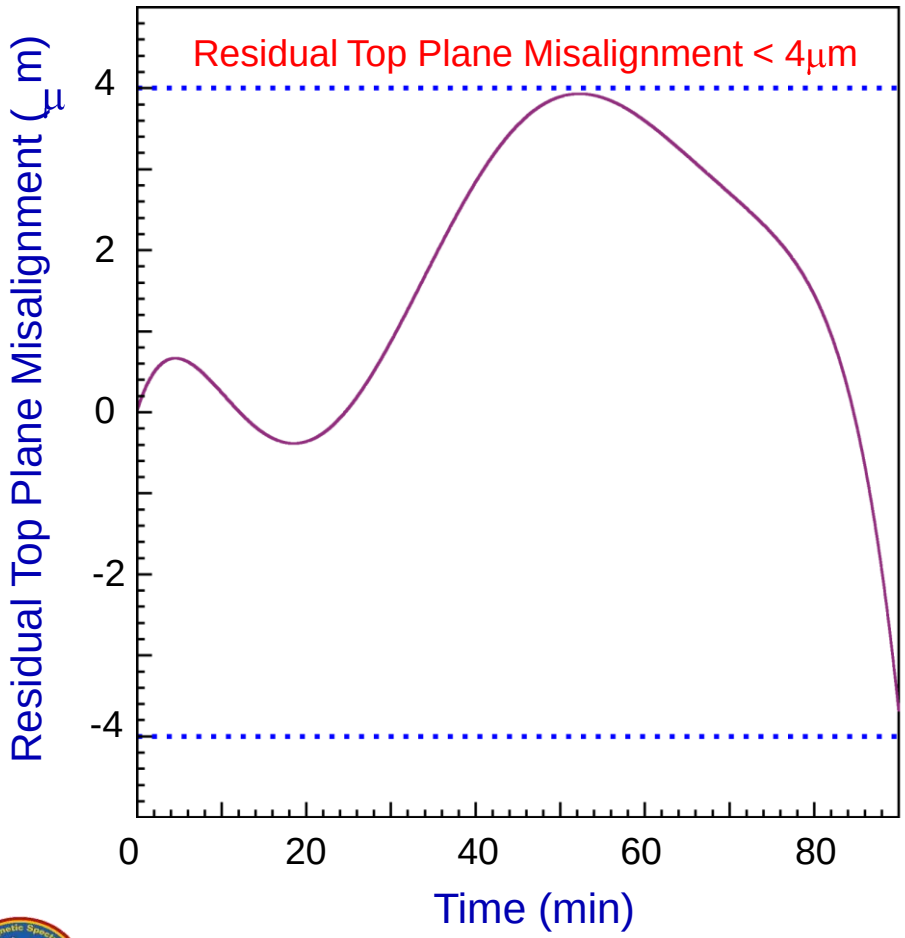
2. Alignment with 10,000 cosmic rays every minute in every orbit

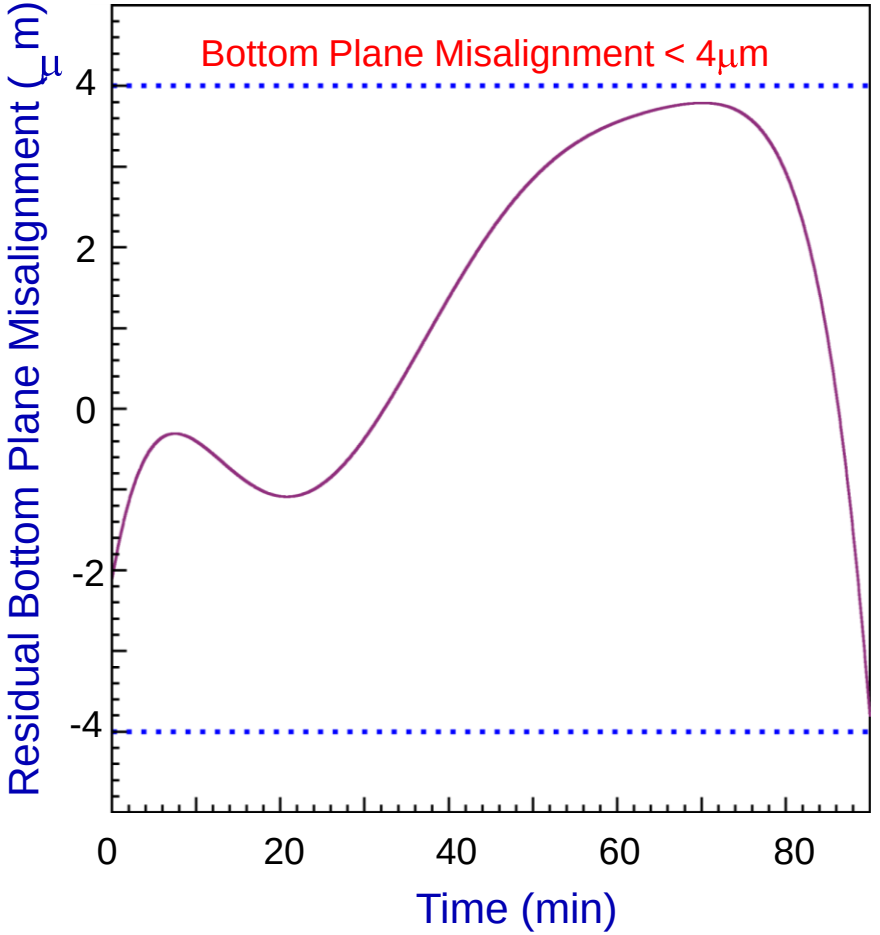
# External Plane Alignment with Cosmic Rays Minute by Minute



# External Planes Alignment Studies

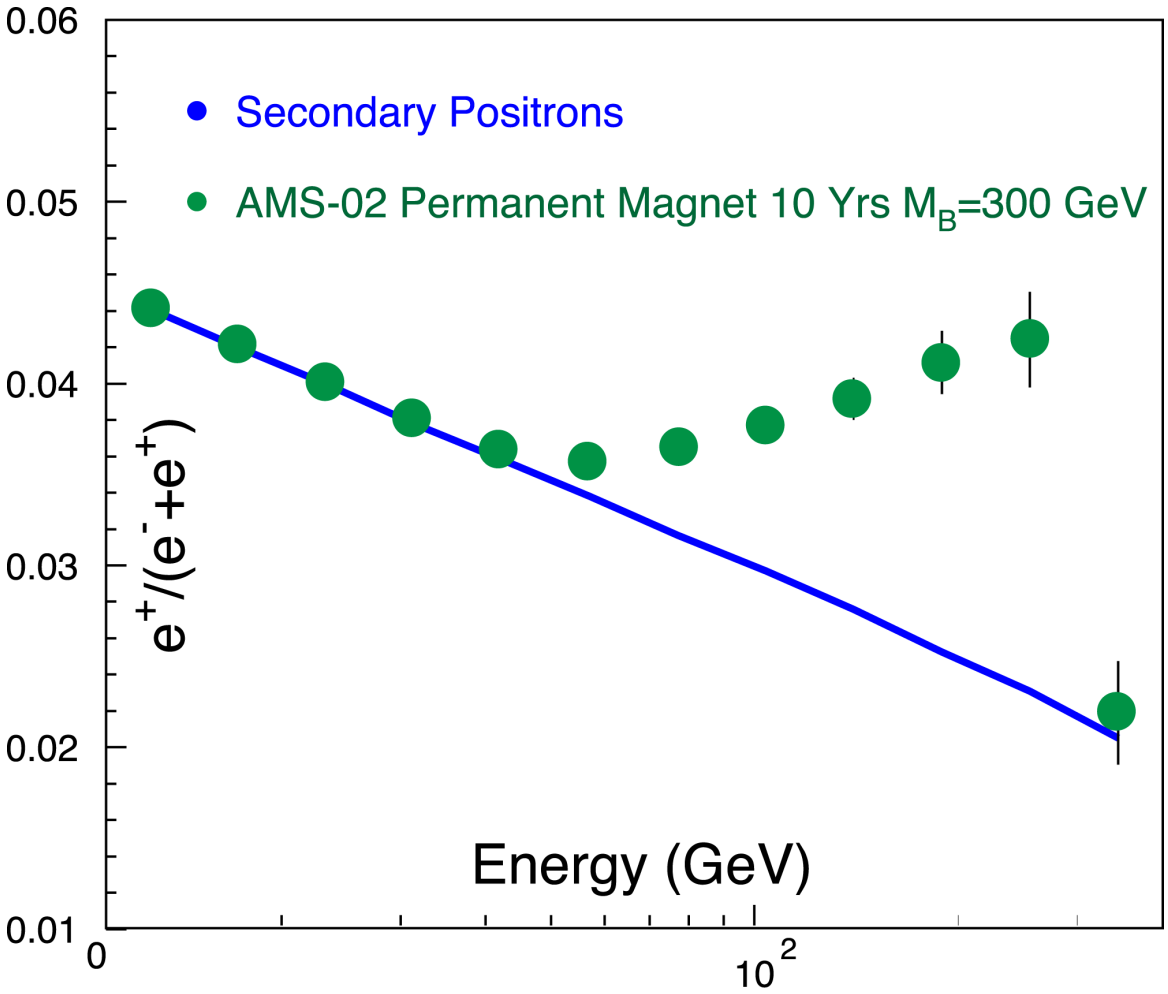


# Kaluza-Klein Bosons (*B*) are also Dark Matter candidates with a typical mass of 100 GeV to 1 TeV.

*A. L. Fitzpatrick, J. Kaplan, L. Randall, L-T Lian-Tao,, JHEP 0709 (2007) 013.*

## *BB* collisions produce structures in the $e^+$ and p spectra




*H.C.Cheng, J.L.Feng and K.T.Matchev, Phys.Rev.Lett 89, N21 (2002) 211301-1*