

Alpha Magnetic Spectrometer on the ISS

Andrei Kounine / MIT

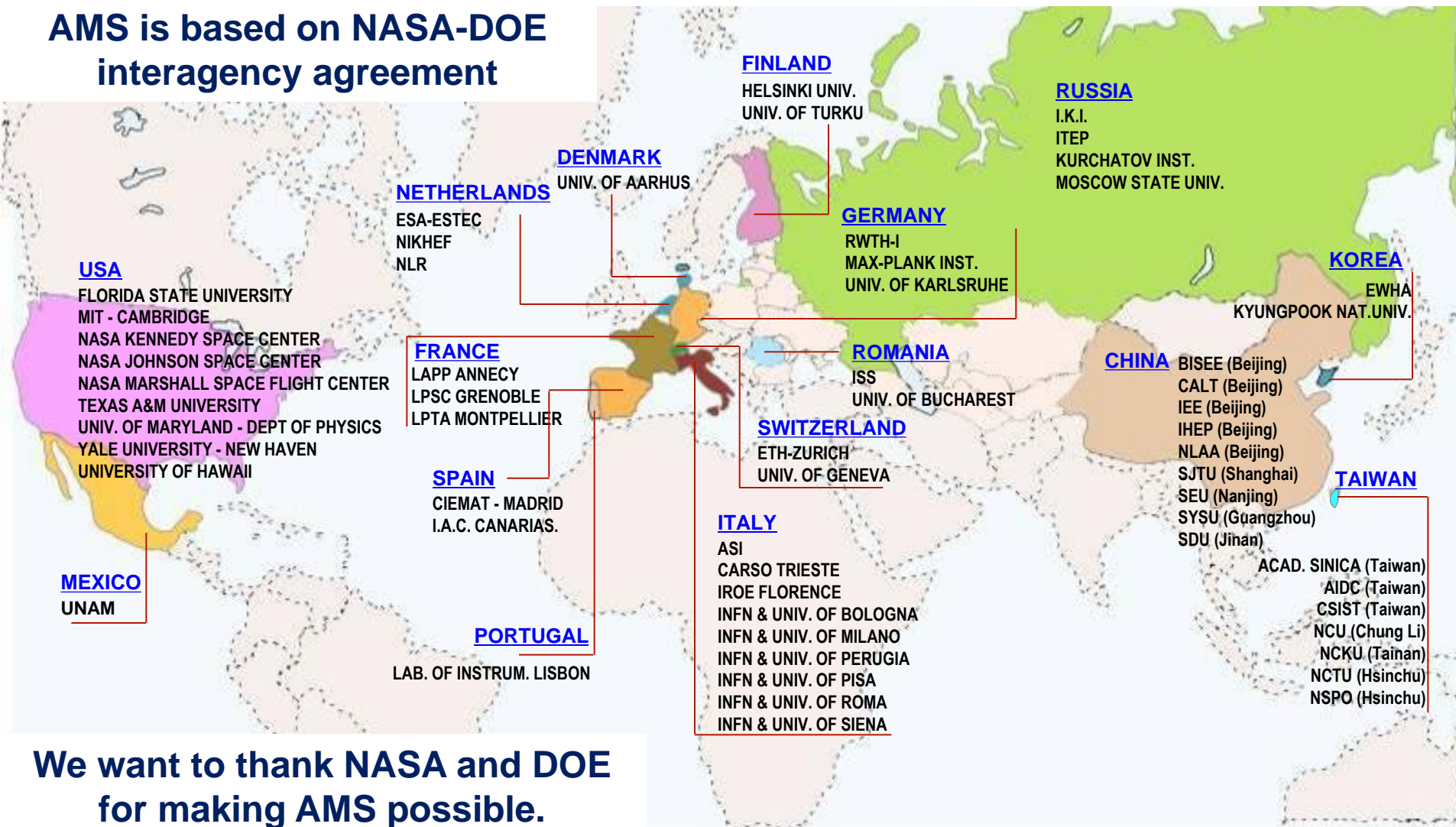


Aspen, 31 January 2013

AMS – International Collaboration

16 Countries, 60 Institutes and 600 Physicists

AMS is based on NASA-DOE interagency agreement



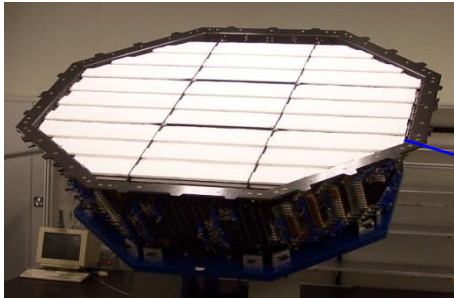
We want to thank NASA and DOE for making AMS possible.

The detectors were built all over the world and assembled at CERN, near Geneva, Switzerland

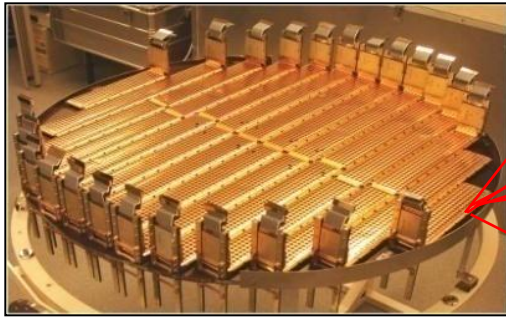
AMS: A TeV precision, multipurpose particle physics spectrometer in space.

TRD

Identify e^+ , e^-



Silicon Tracker
 Z, P

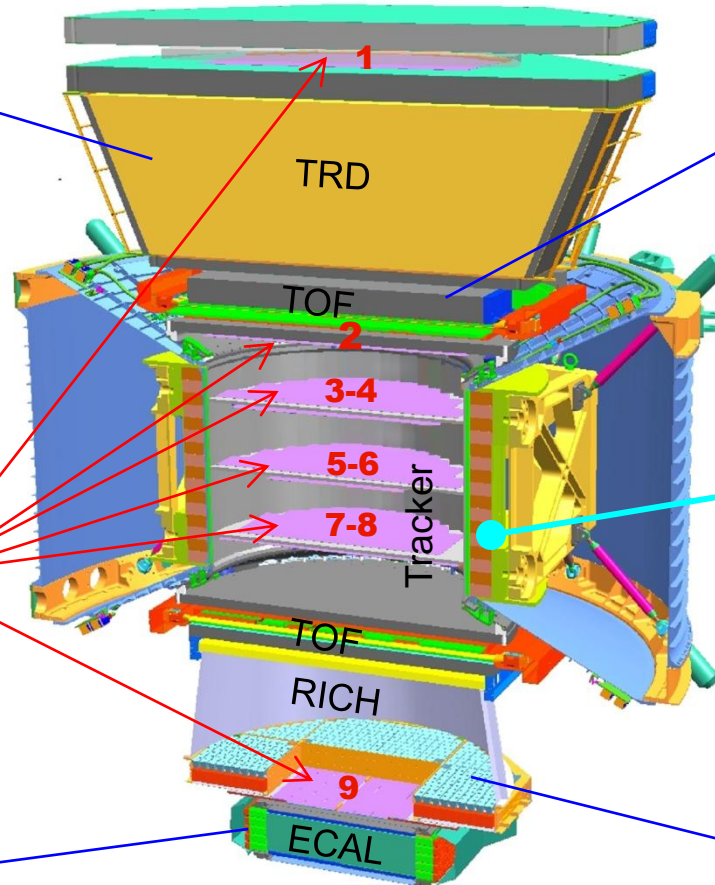


ECAL

E of e^+ , e^- , γ



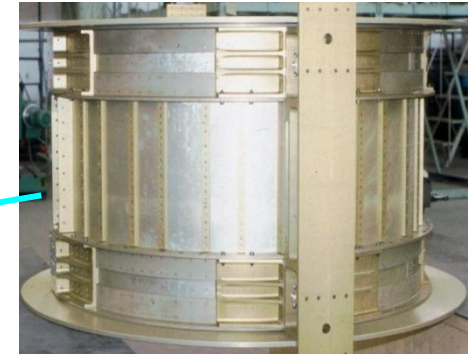
Particles and nuclei are identified by their charge (Z) and energy ($E \sim P$)



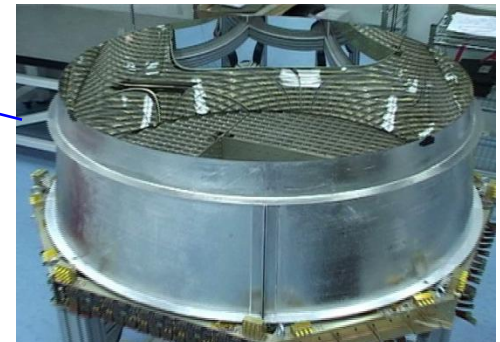
TOF
 Z, E



Magnet
 $\pm Z$



RICH
 Z, E



5m x 4m x 3m

7.5 tons

Z, P are measured independently from Tracker, RICH, TOF and ECAL

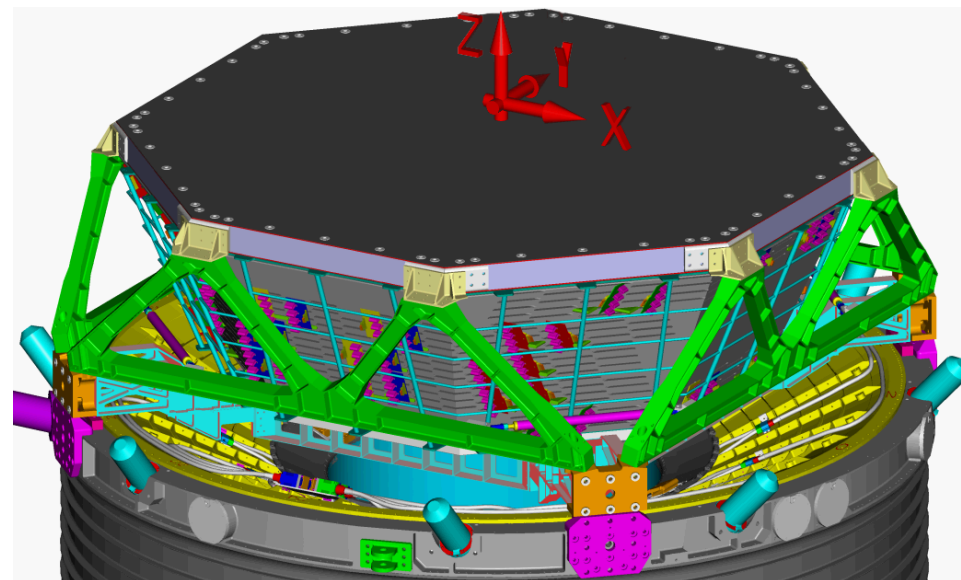
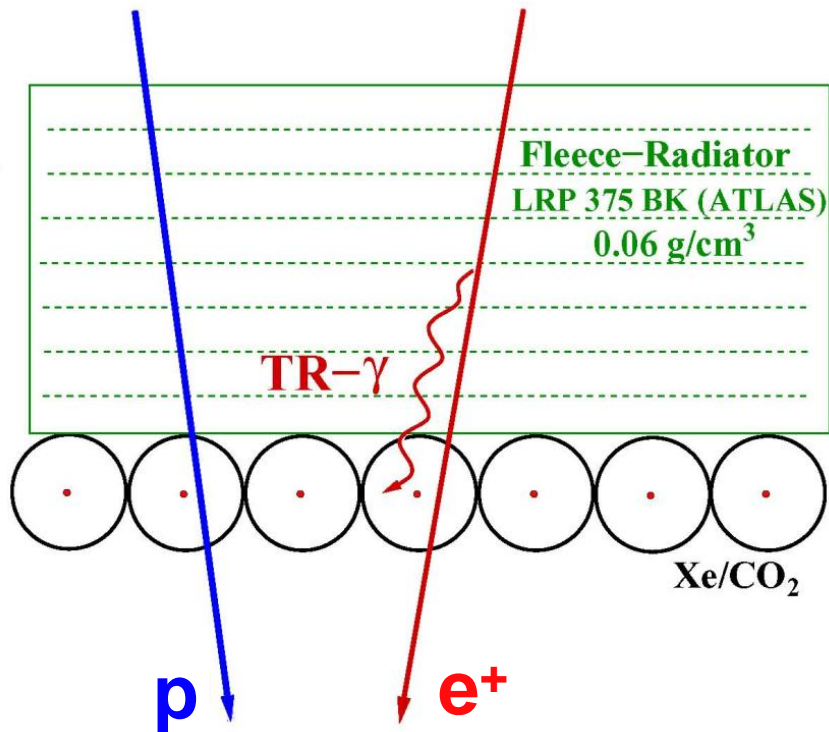
Transition Radiation Detector:

TRD

Identify e^+ , reject P

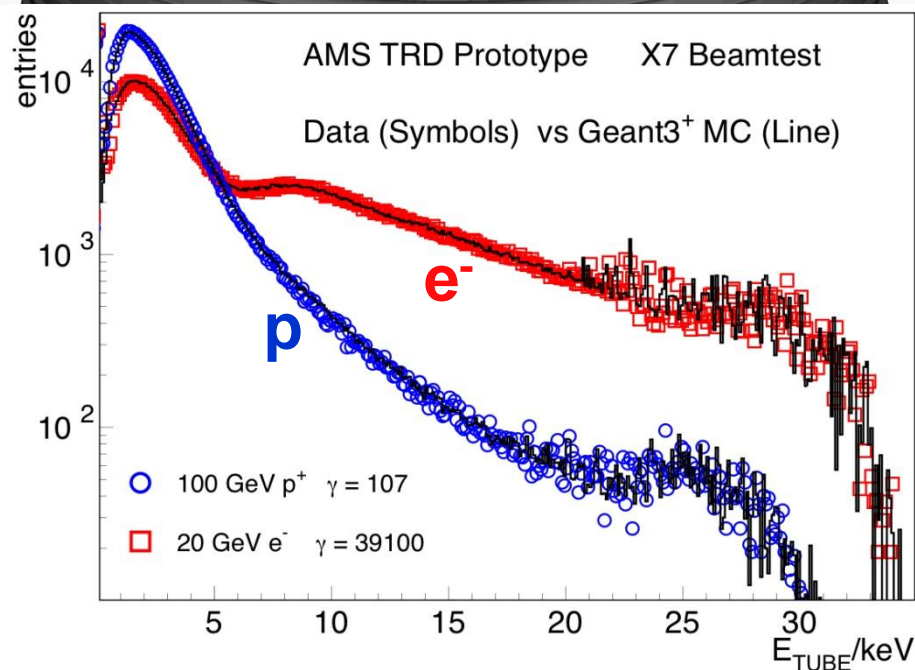


One of 20 Layers

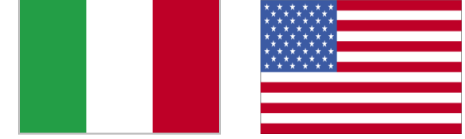


Leak rate: $\text{CO}_2 \approx 5 \mu\text{g/s}$

Storage: 5 kg, >20 years lifetime



Time of Flight (TOF)

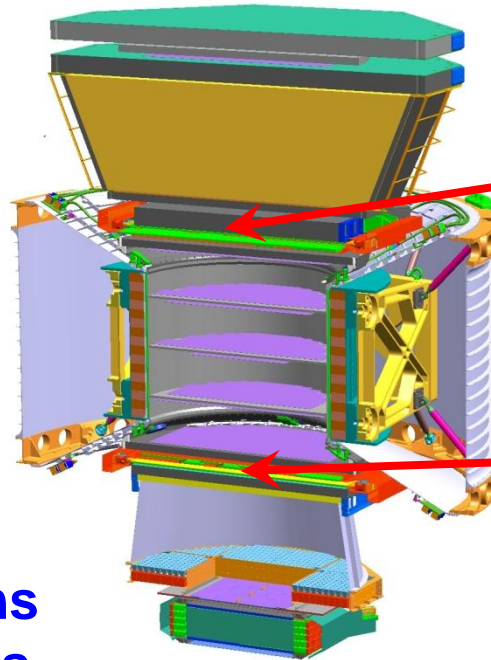


4 scintillator planes

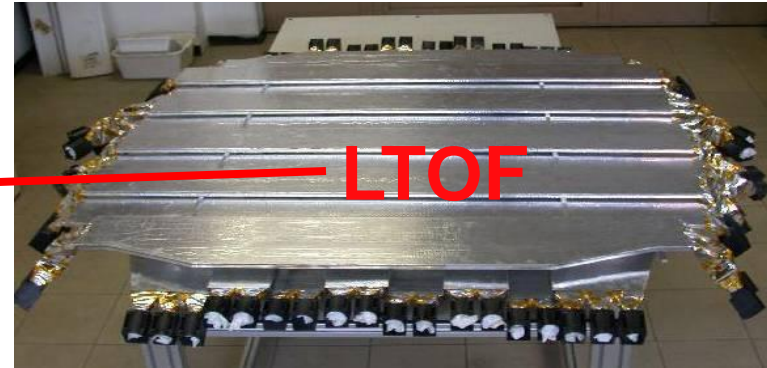
Provides trigger for charged particles

Trigger time is synchronized to UTC time to $1\mu\text{s}$

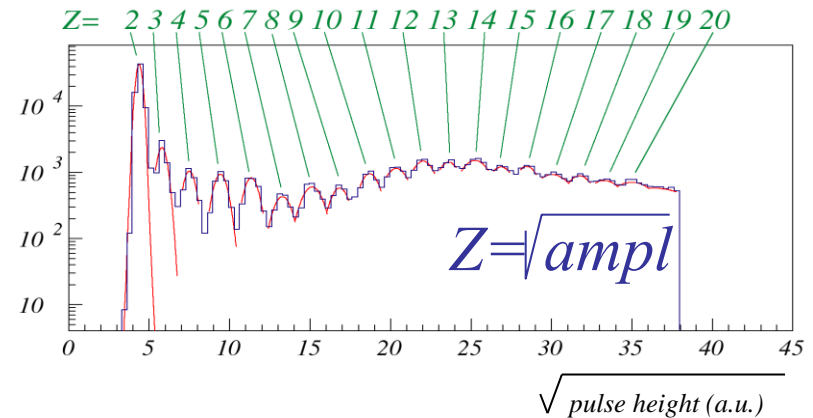
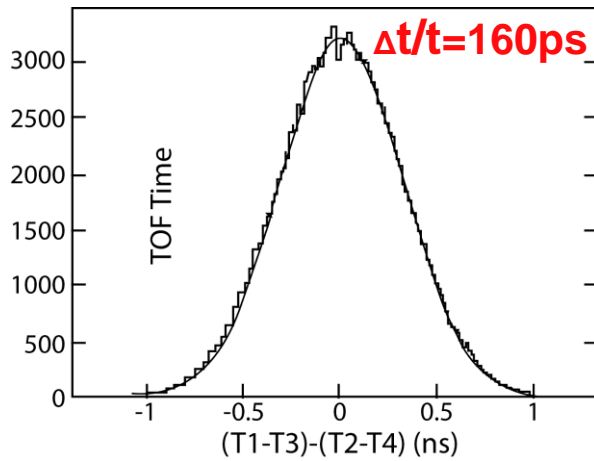
Measures the time of relativistic protons to 160 picoseconds



UTOF

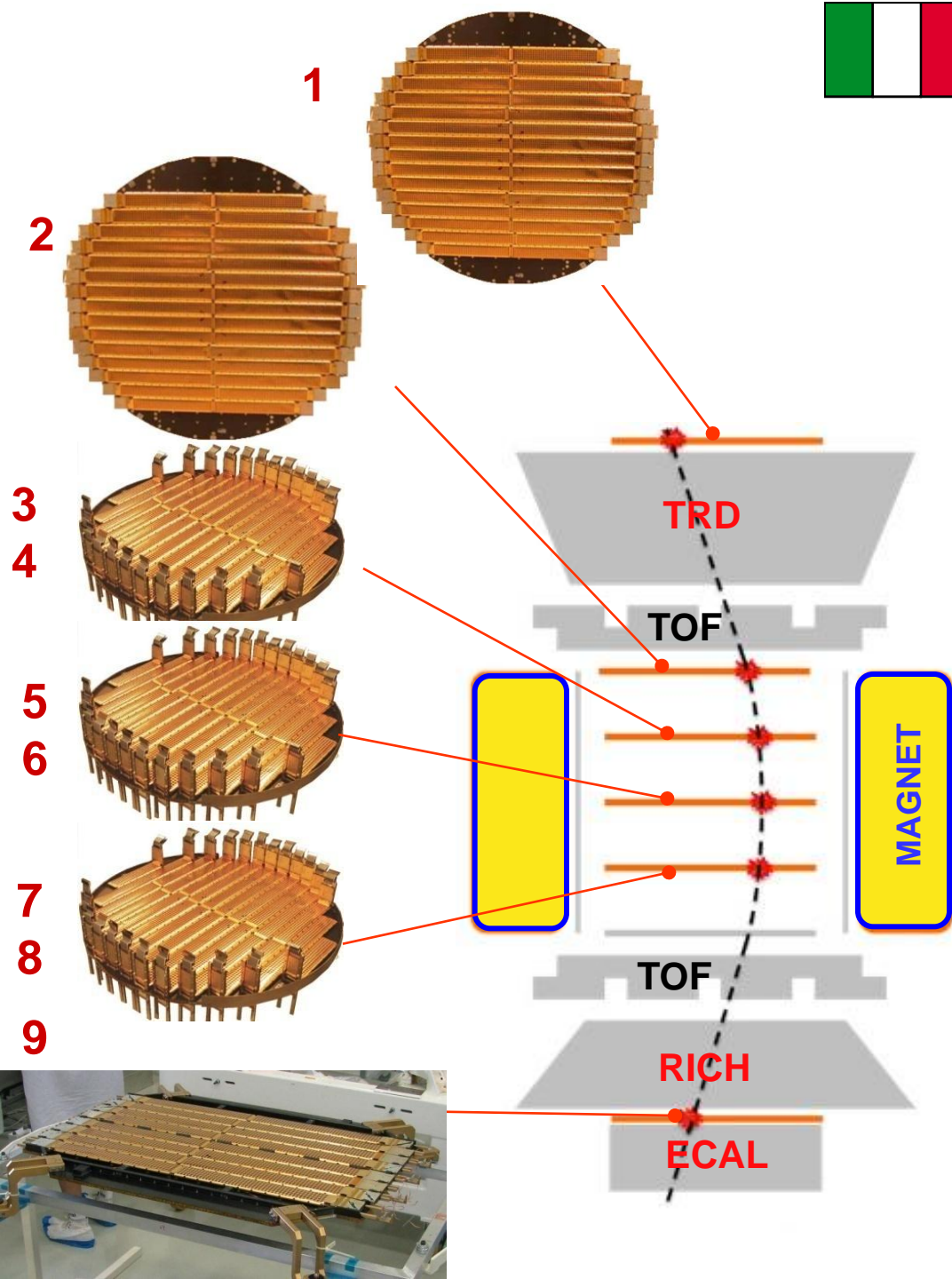
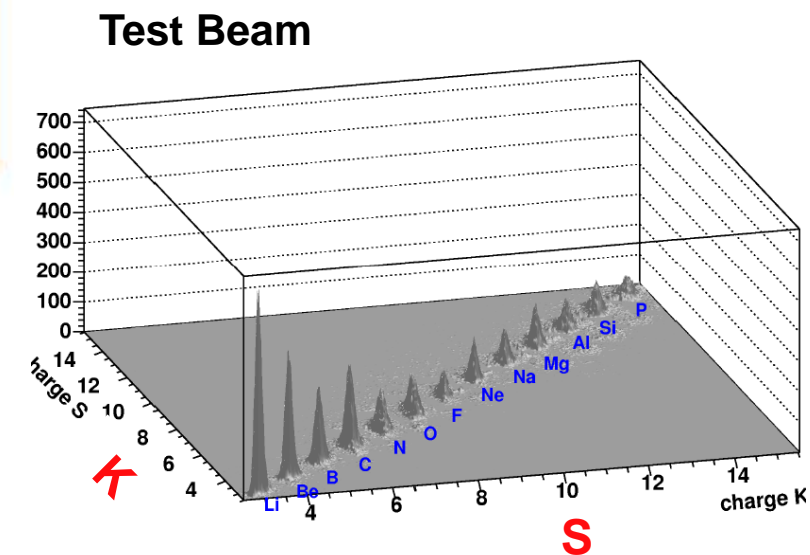
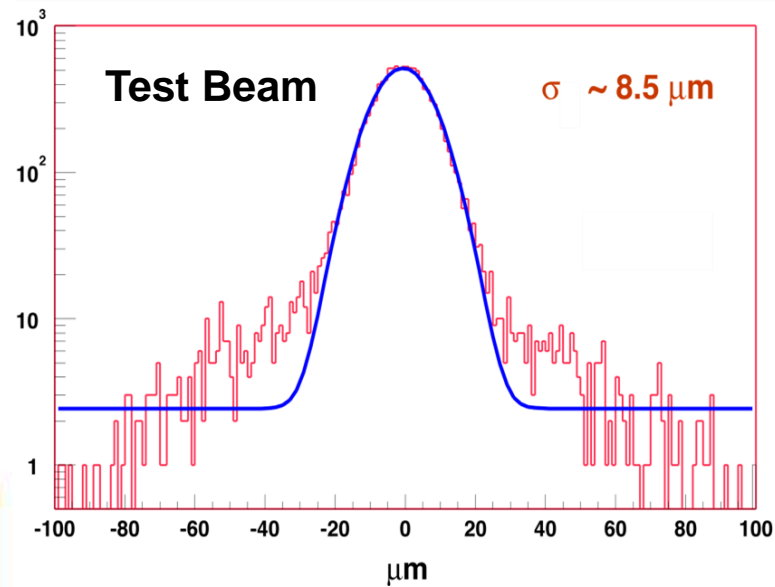


LTOF

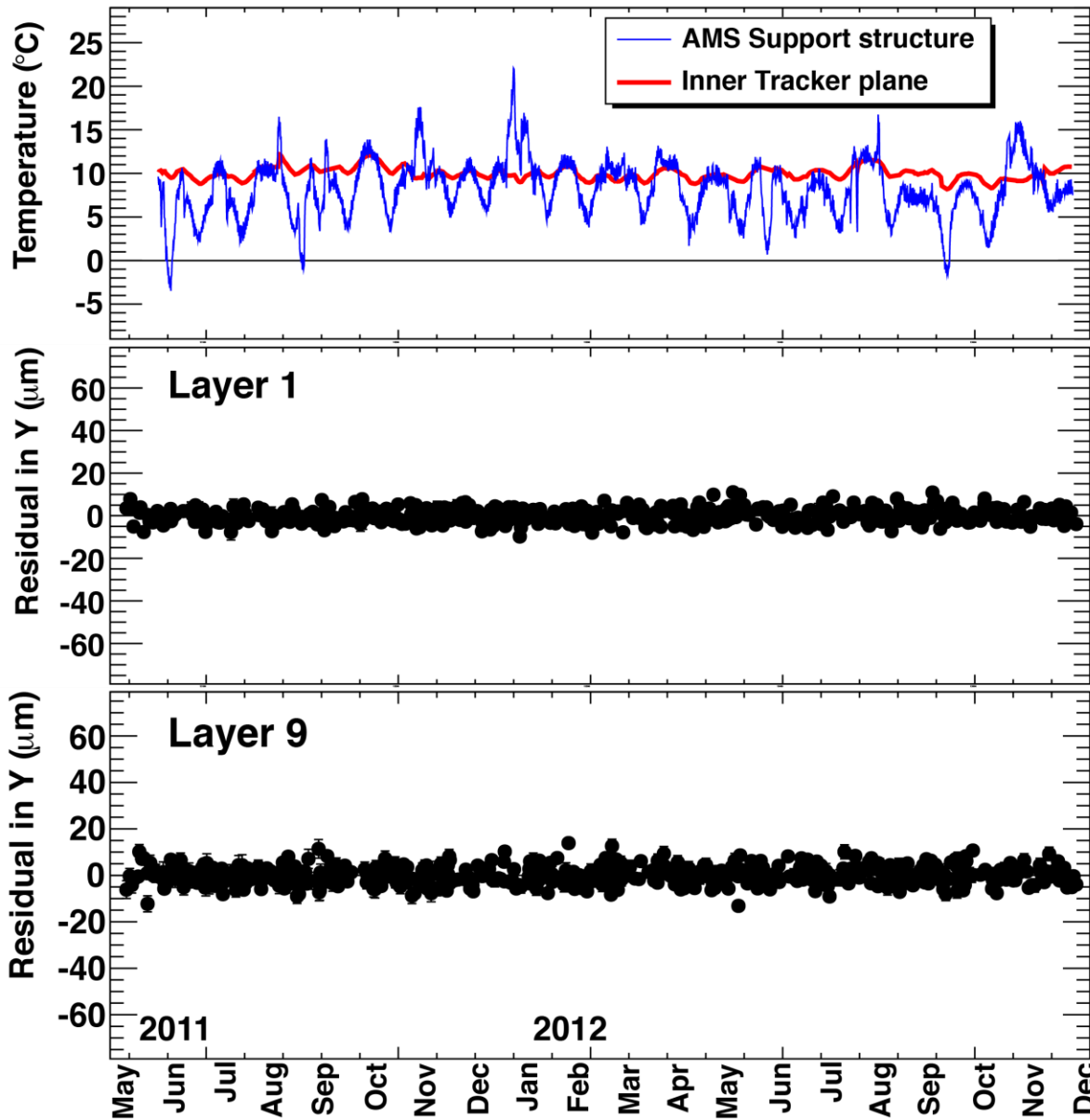




$MDR_p = 2.14 \text{ TV}$
 $MDR_{He} = 3.75 \text{ TV}$



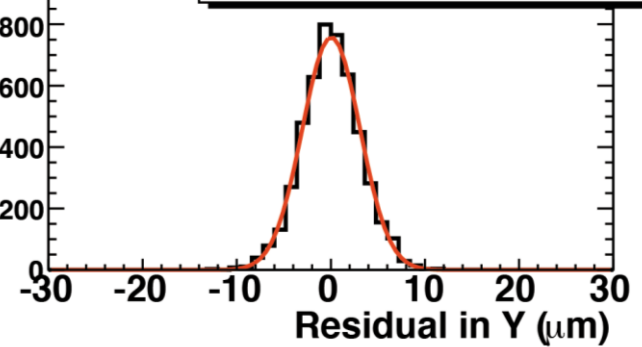
Stability of the alignment on Tracker plane 1 & 9



Layer 1

Entries
1000
800
600
400
200
0

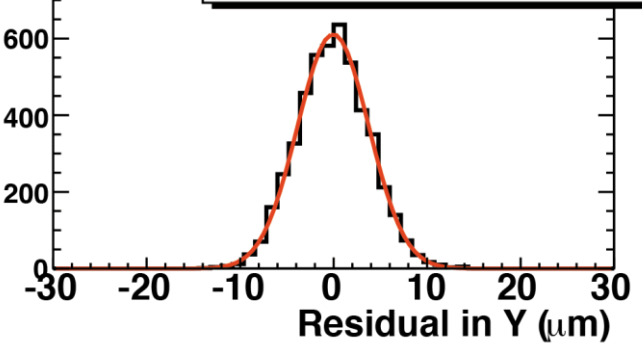
Entries	4890
Constant	758.04 ± 13.89
Mean	0.04 ± 0.04
Sigma	3.07 ± 0.04



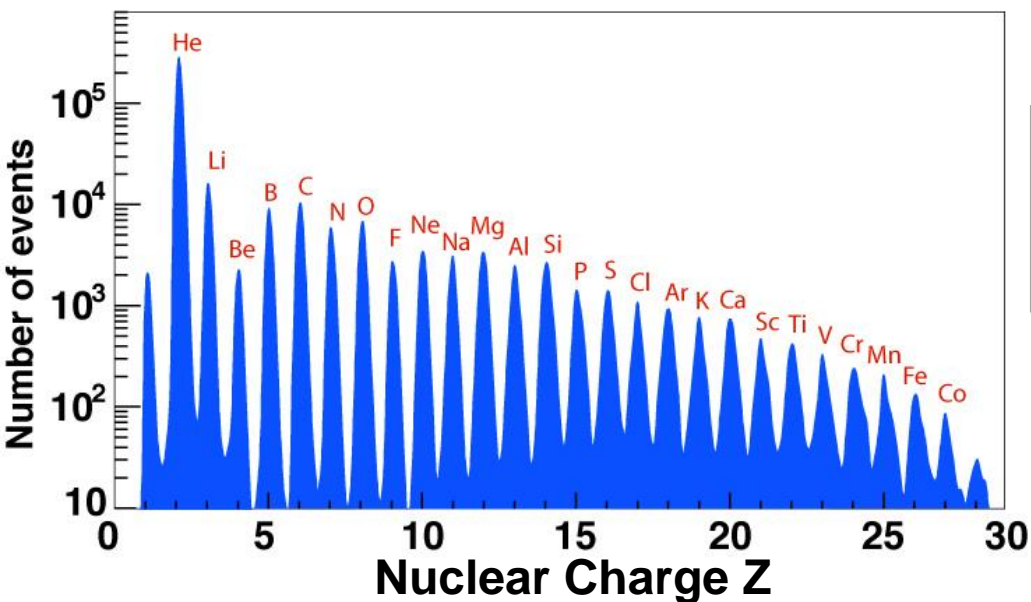
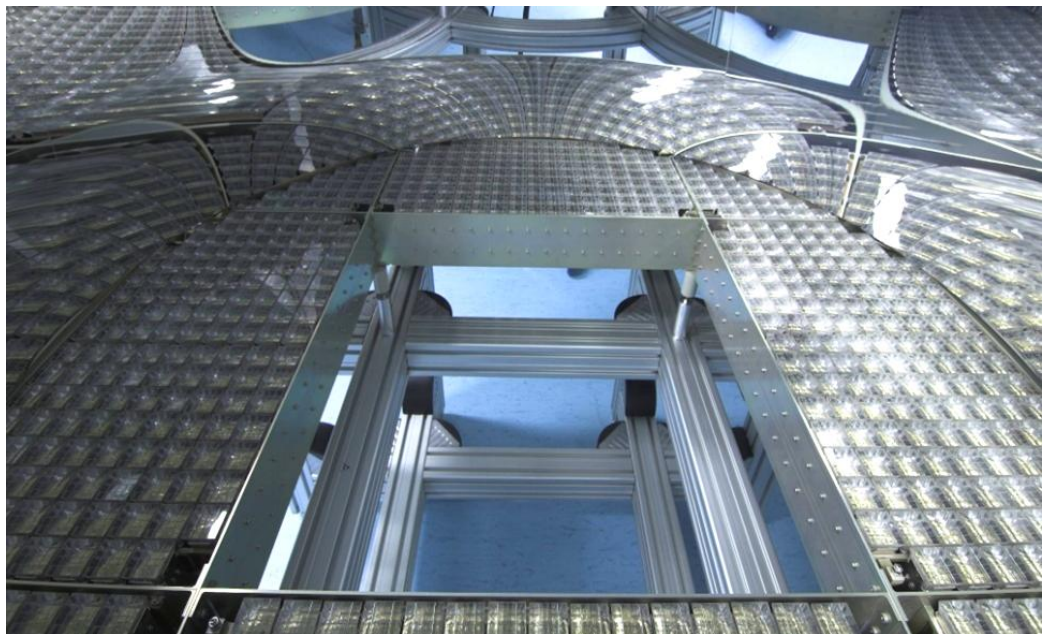
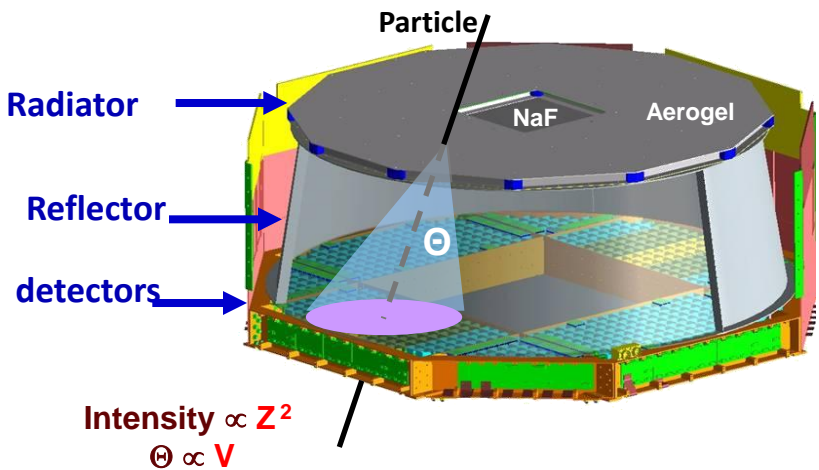
Layer 9

Entries
800
600
400
200
0

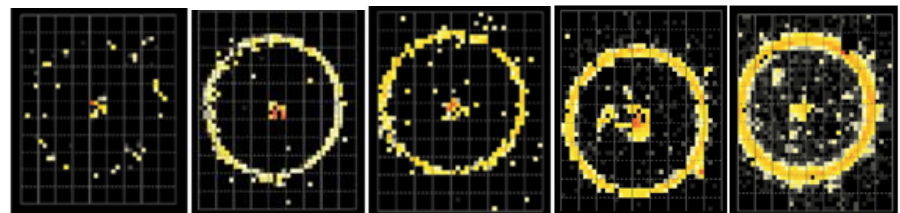
Entries	4890
Constant	611.13 ± 10.75
Mean	-0.05 ± 0.05
Sigma	3.82 ± 0.04



Ring Imaging Cherenkov Detector (RICH)



10,880 photosensors



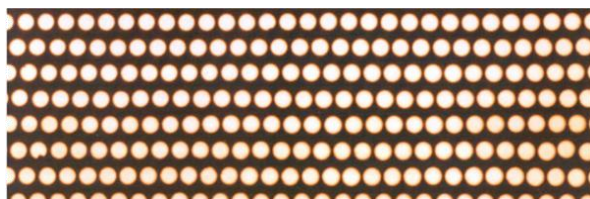
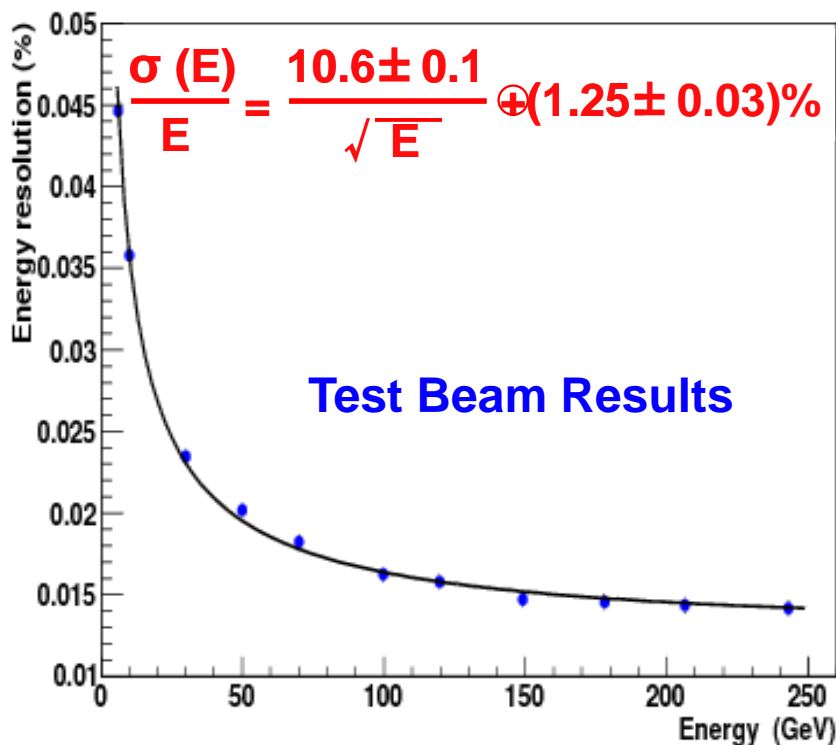
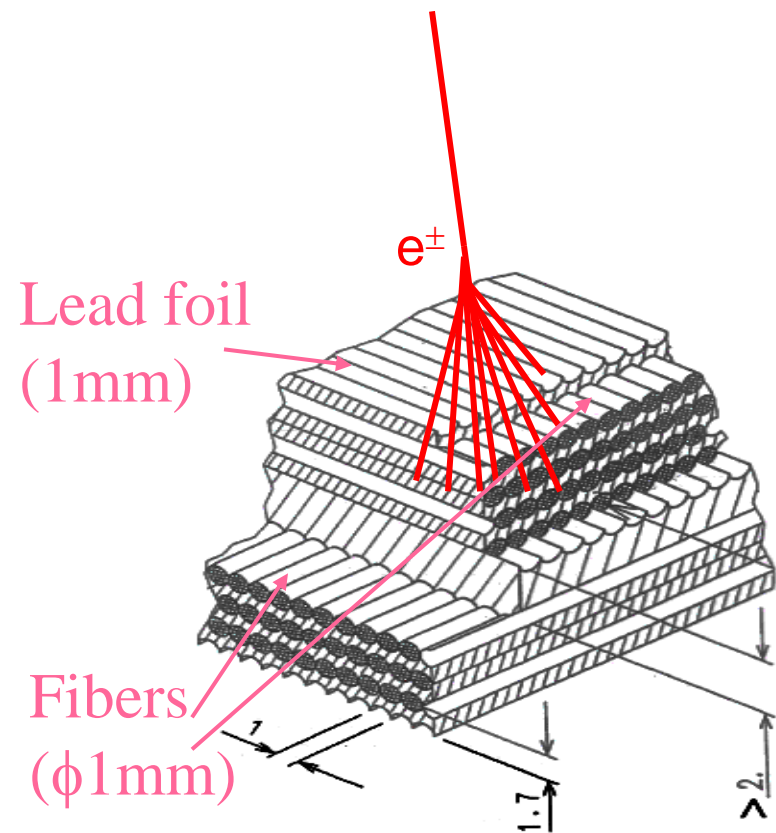
Single Event Displays

RICH test beam E=158 GeV/n



Calorimeter (ECAL)

A precision, $17 X_0$, TeV, 3-dimensional measurement of the directions and energies of light rays and electrons

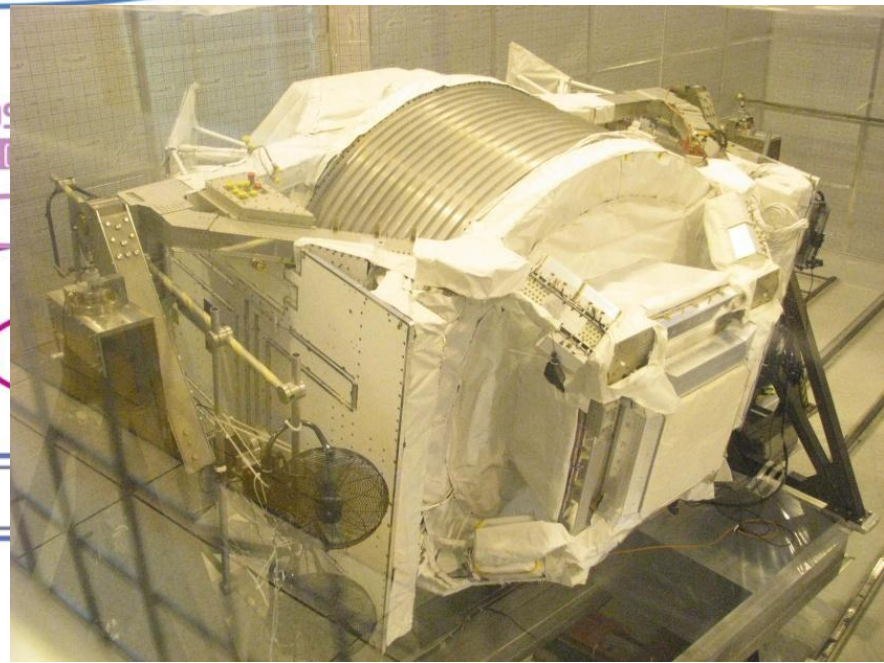
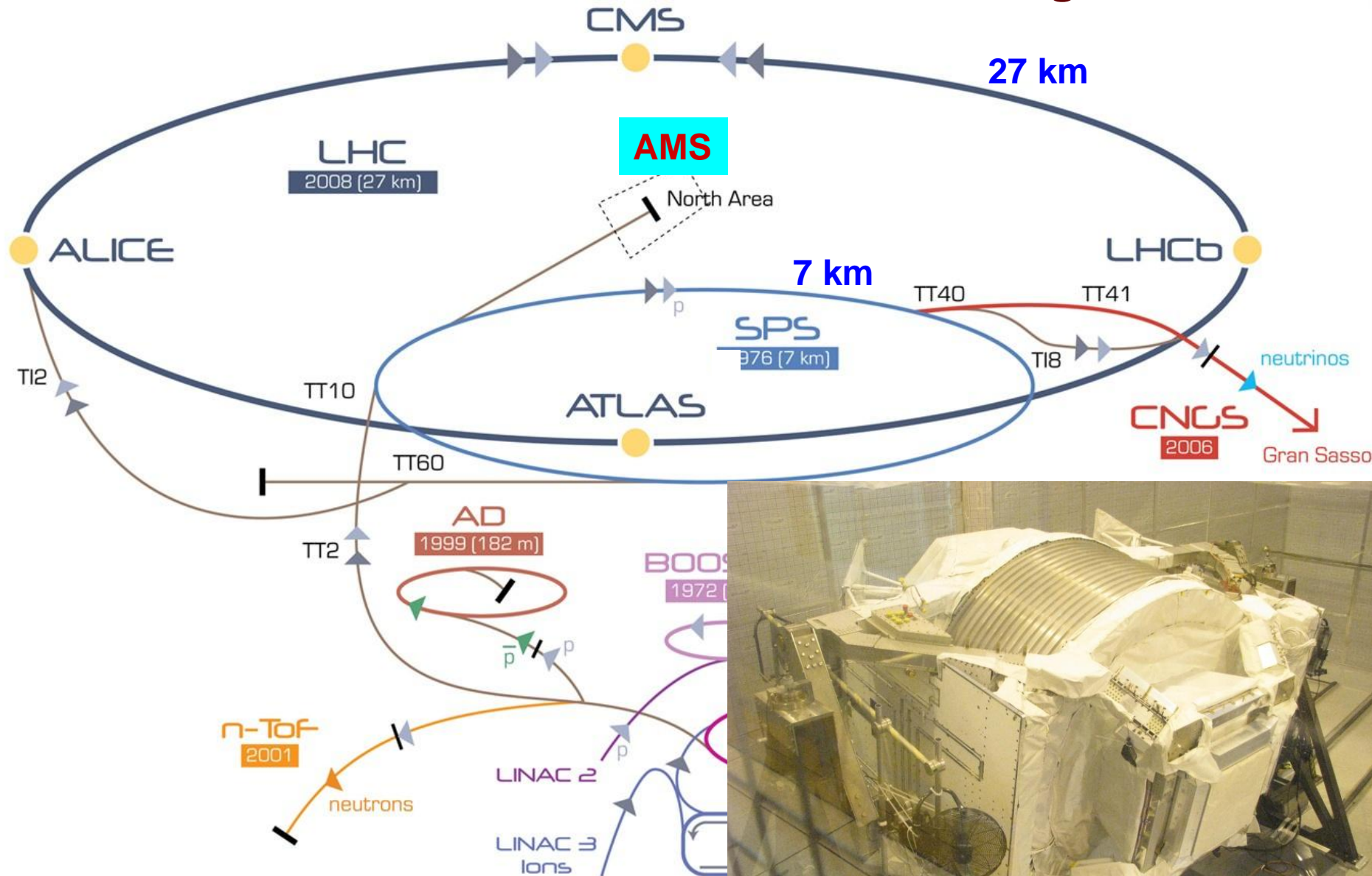


50 000 fibers, $\phi = 1\text{ mm}$
distributed uniformly
Inside 1,200 lb of lead

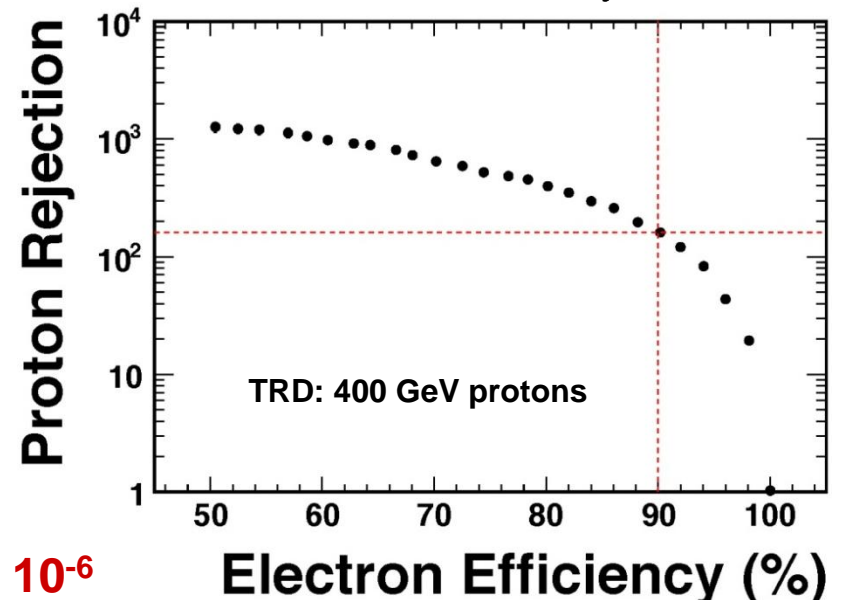
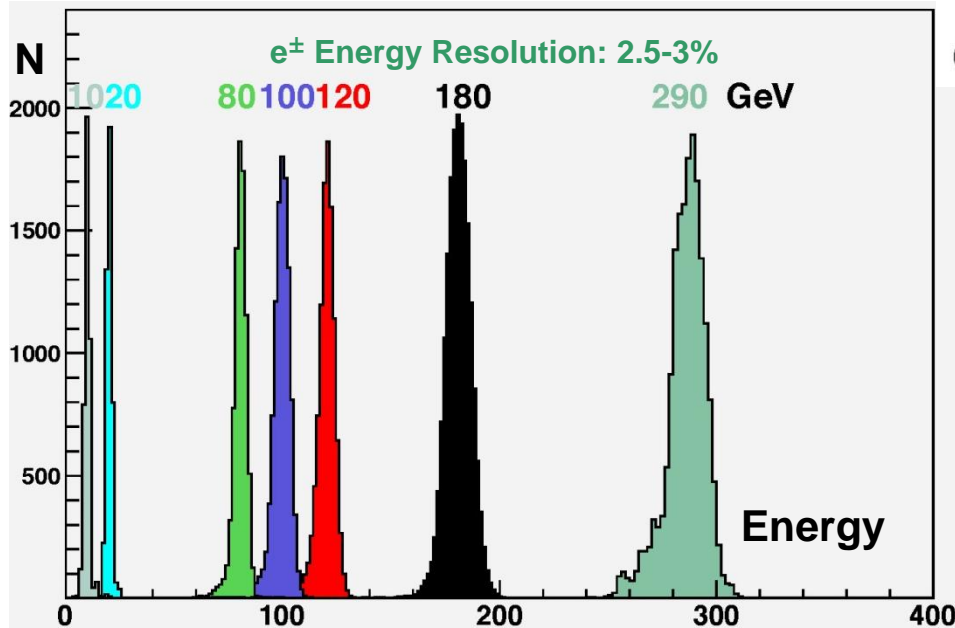
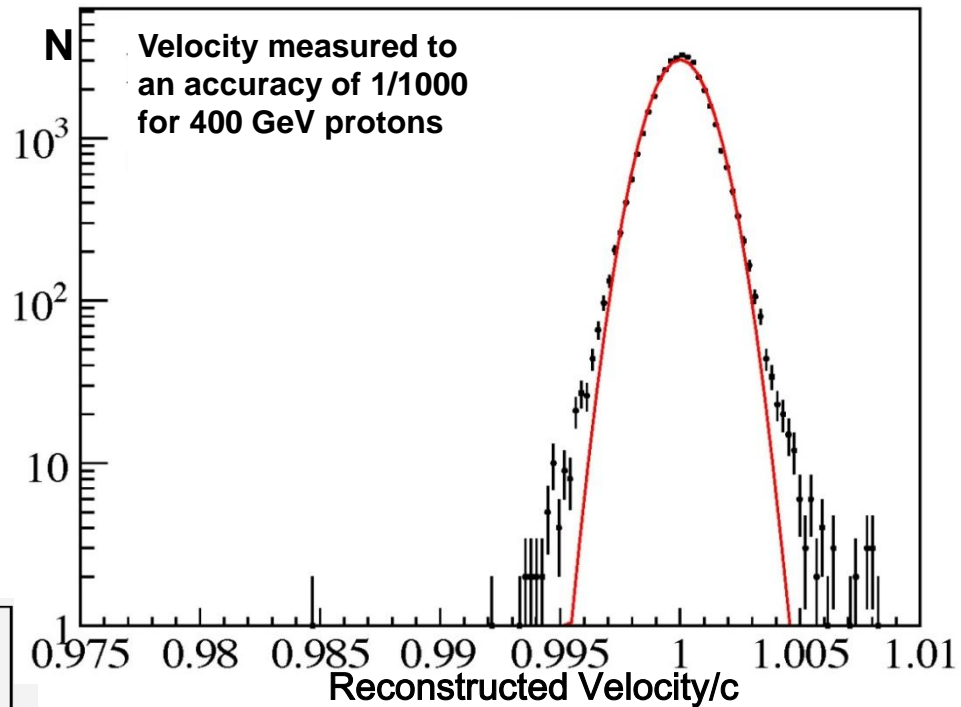
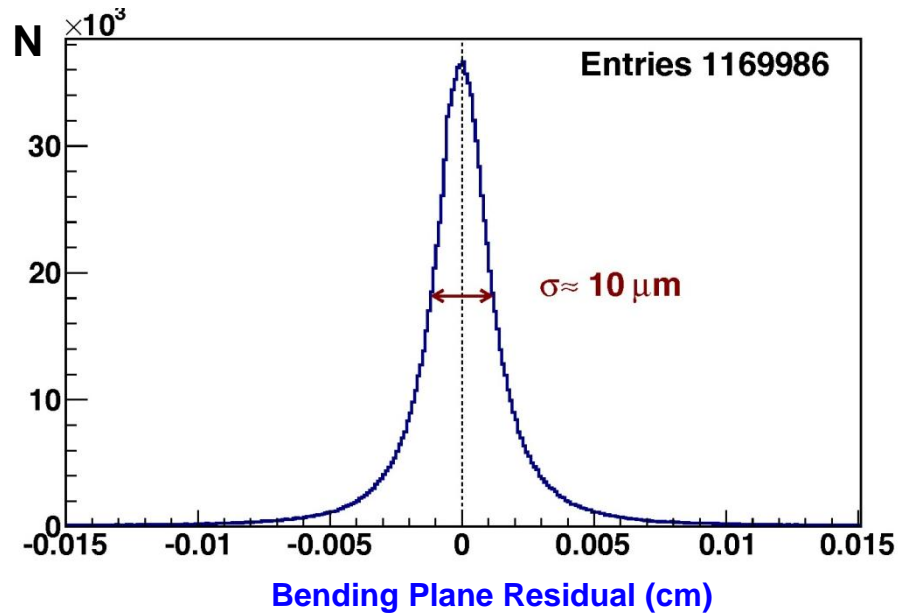


Tests at CERN

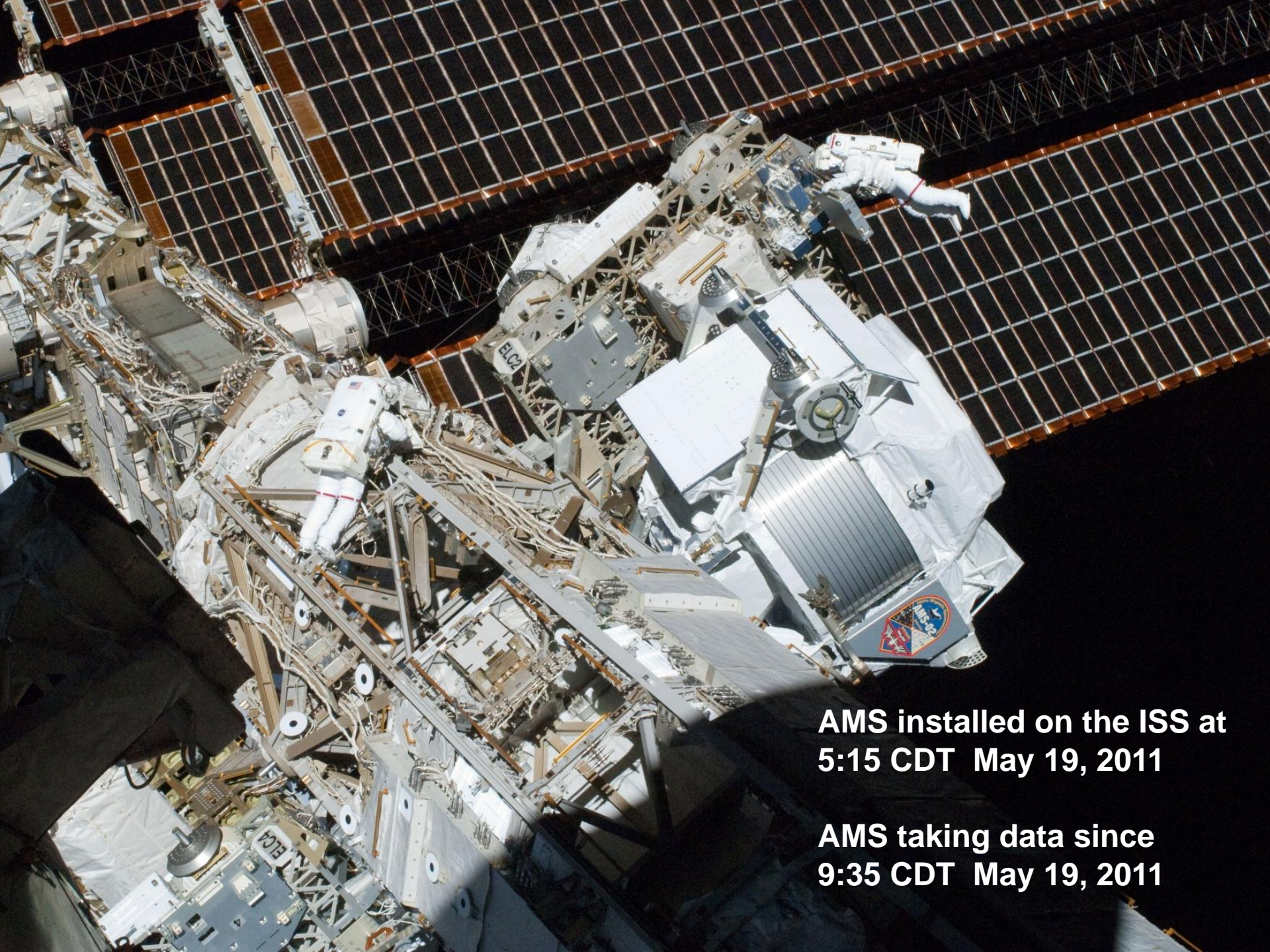
AMS in accelerator test beams Feb 4-8 and Aug 8-20, 2010



Test Beam Results – 8-20 Aug 2010, CERN



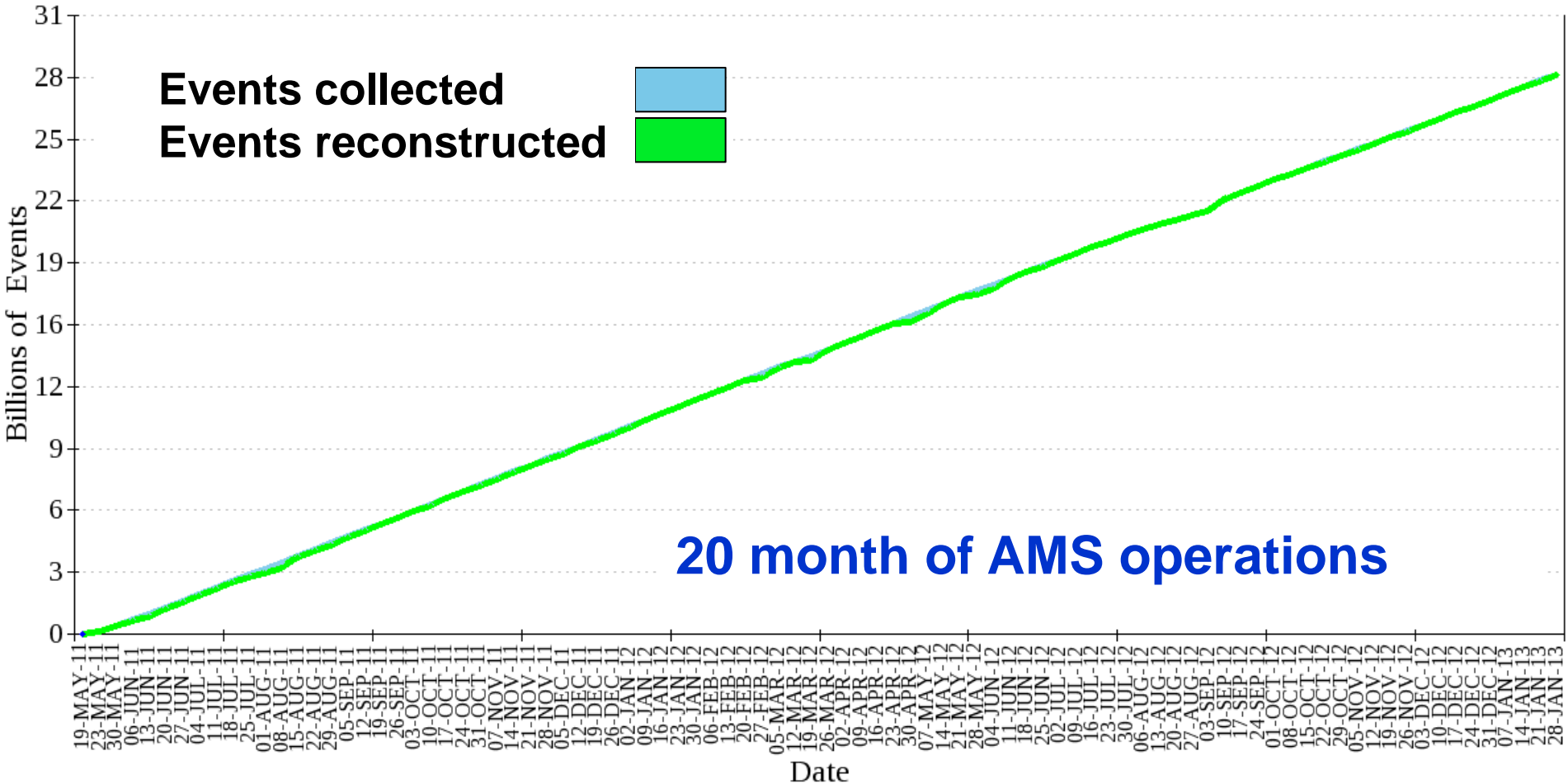
Measured combined rejection power at 400 GeV: $e^+/p = 10^{-6}$



**AMS installed on the ISS at
5:15 CDT May 19, 2011**

**AMS taking data since
9:35 CDT May 19, 2011**

To date AMS collected over 28 billion events

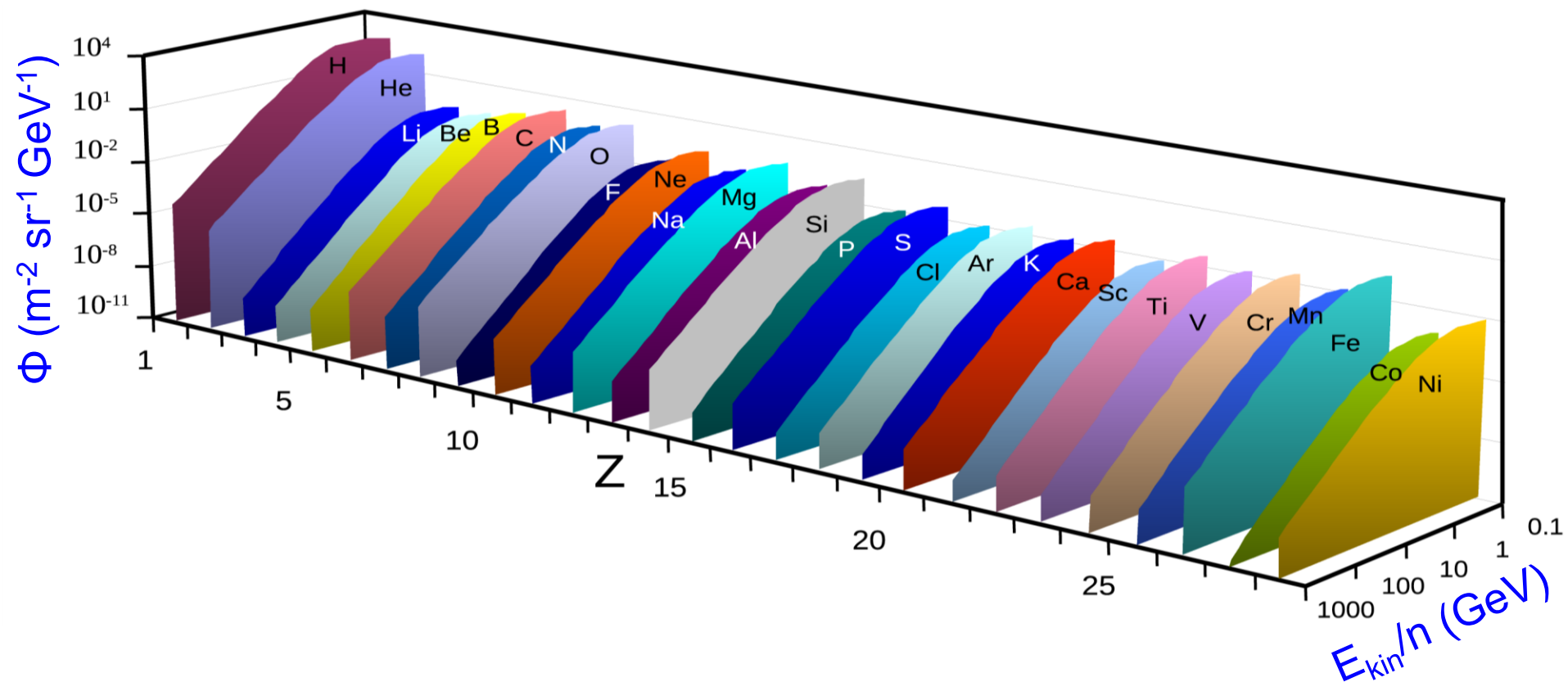


AMS Physics Potential

- **Searches for primordial antimatter:**
 - Anti-nuclei: $\bar{\text{He}}$, ...
- **Dark Matter searches:**
 - e^+ , e^\pm , \bar{p} , ...
 - simultaneous observation of several signal channels.
- **Searches for new forms of matter:**
 - strangelets, ...
- **Measuring CR spectra – refining propagation models;**
- **Understanding of local sources:**
 - SNR, Pulsars, PBH, ...
- **Study effects of solar modulation on CR spectra over 11 year solar cycle**
- ...

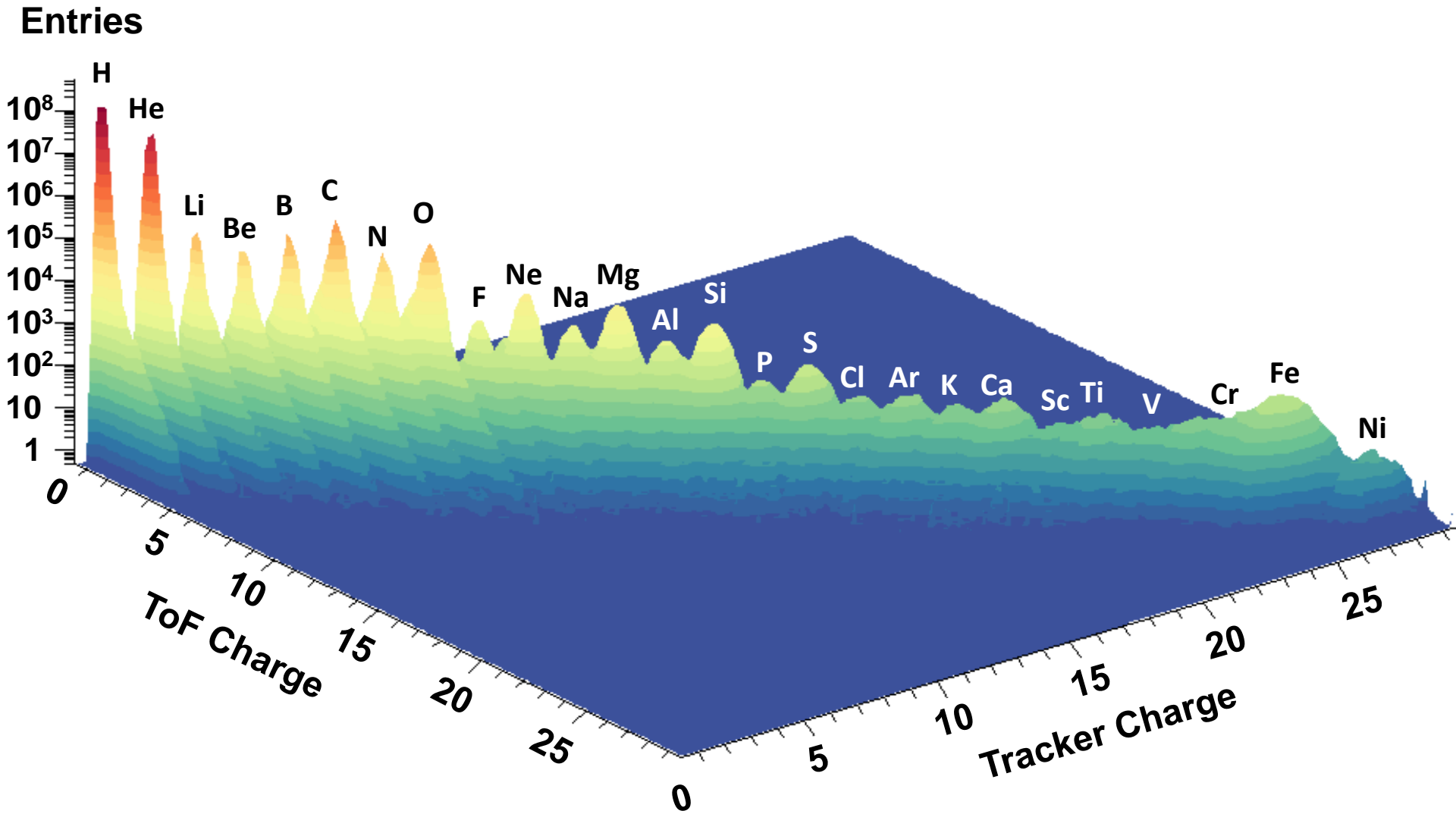
Physics of AMS: Nuclear Abundances Measurements

For energies from 100 MeV to 1 TeV
with 1% accuracy over the 11-year solar cycle.



These spectra will provide experimental data that go into calculating the background in the Search for Dark Matter, i.e., $p + C \rightarrow e^+, \dots$

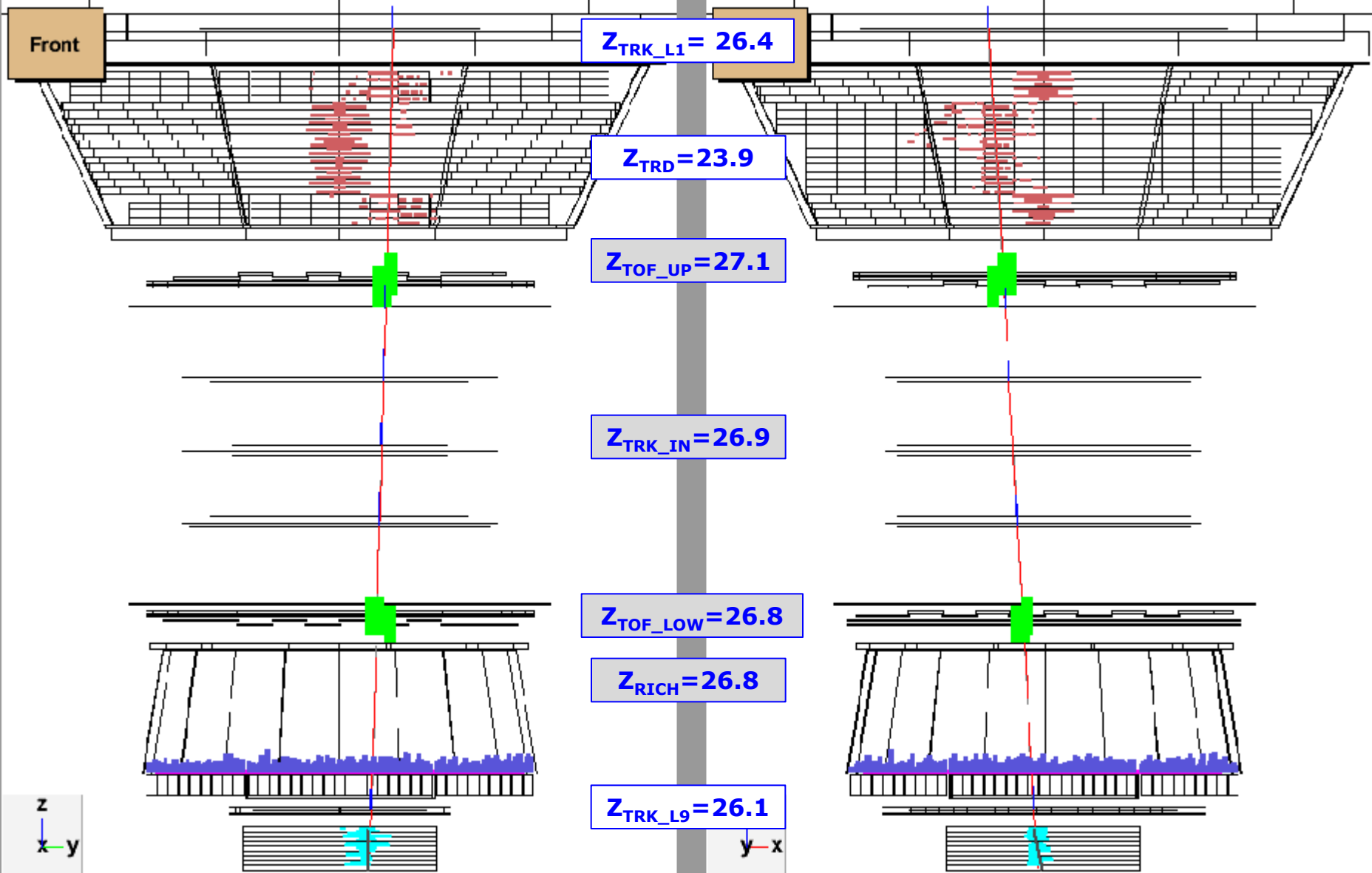
AMS Nuclei Measurement on ISS



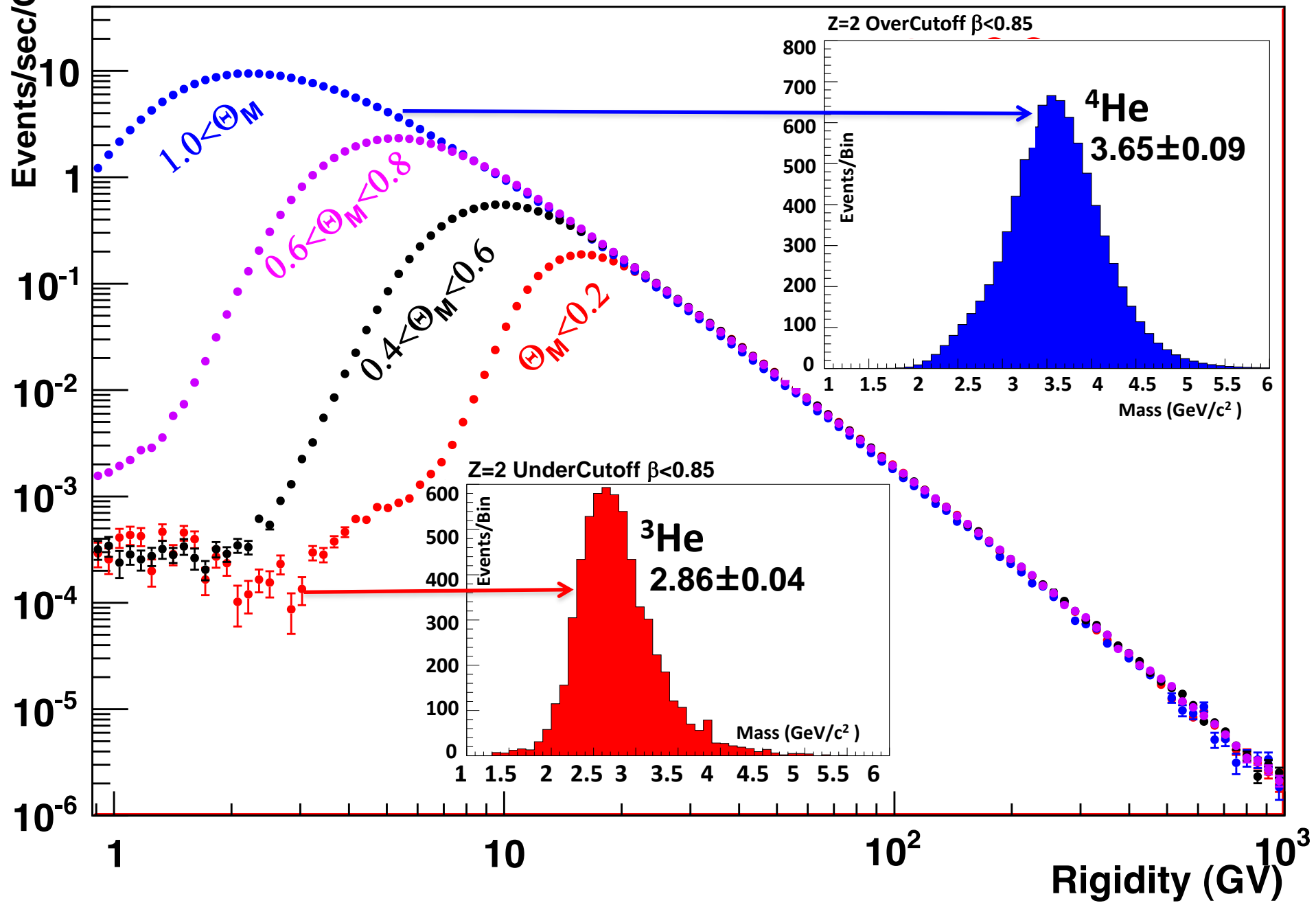
Data from ISS

AMS Event Display

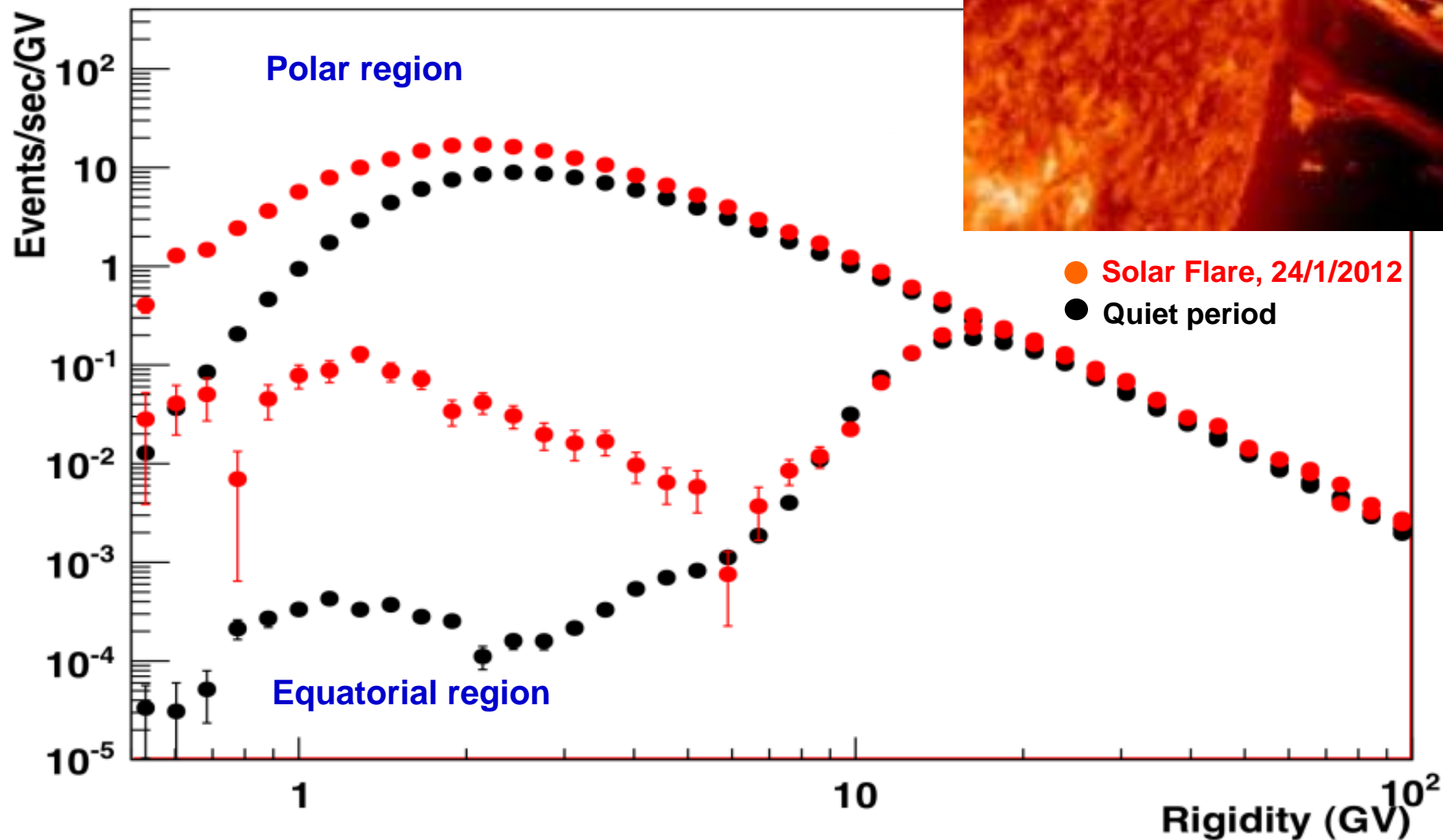
Run/Event 1331498136 / 219985 GMT Time 2012-071.20:50:42



He Rates



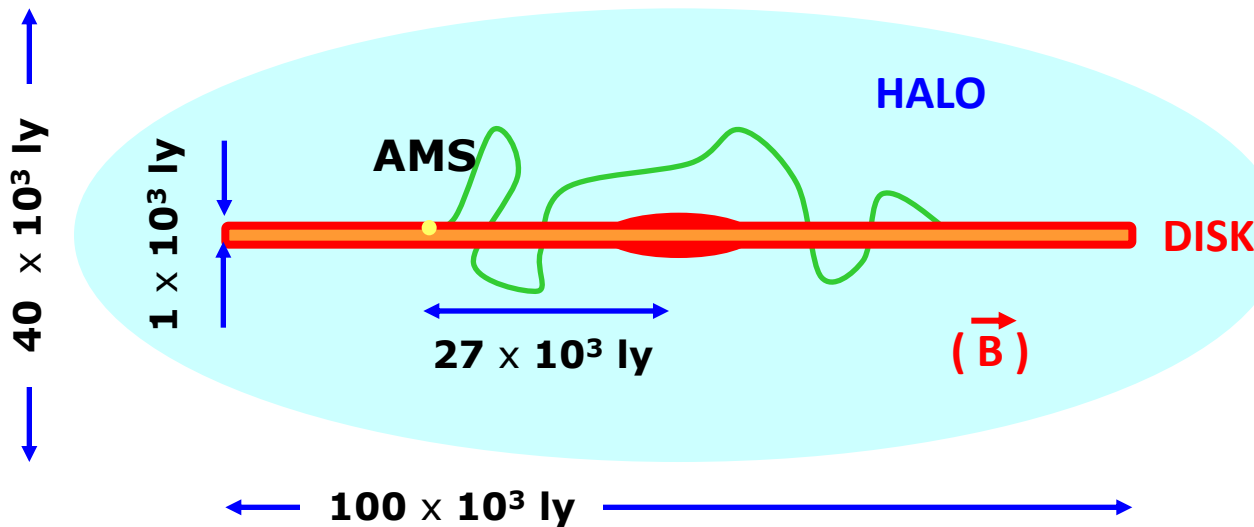
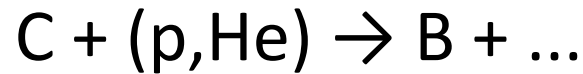
AMS data: He rate and Solar Flare



B/C ratio up to TeV

Precise measurement of the energy spectra of B/C provides information on Cosmic Ray Interactions and Propagation

Interactions with the Interstellar Medium:

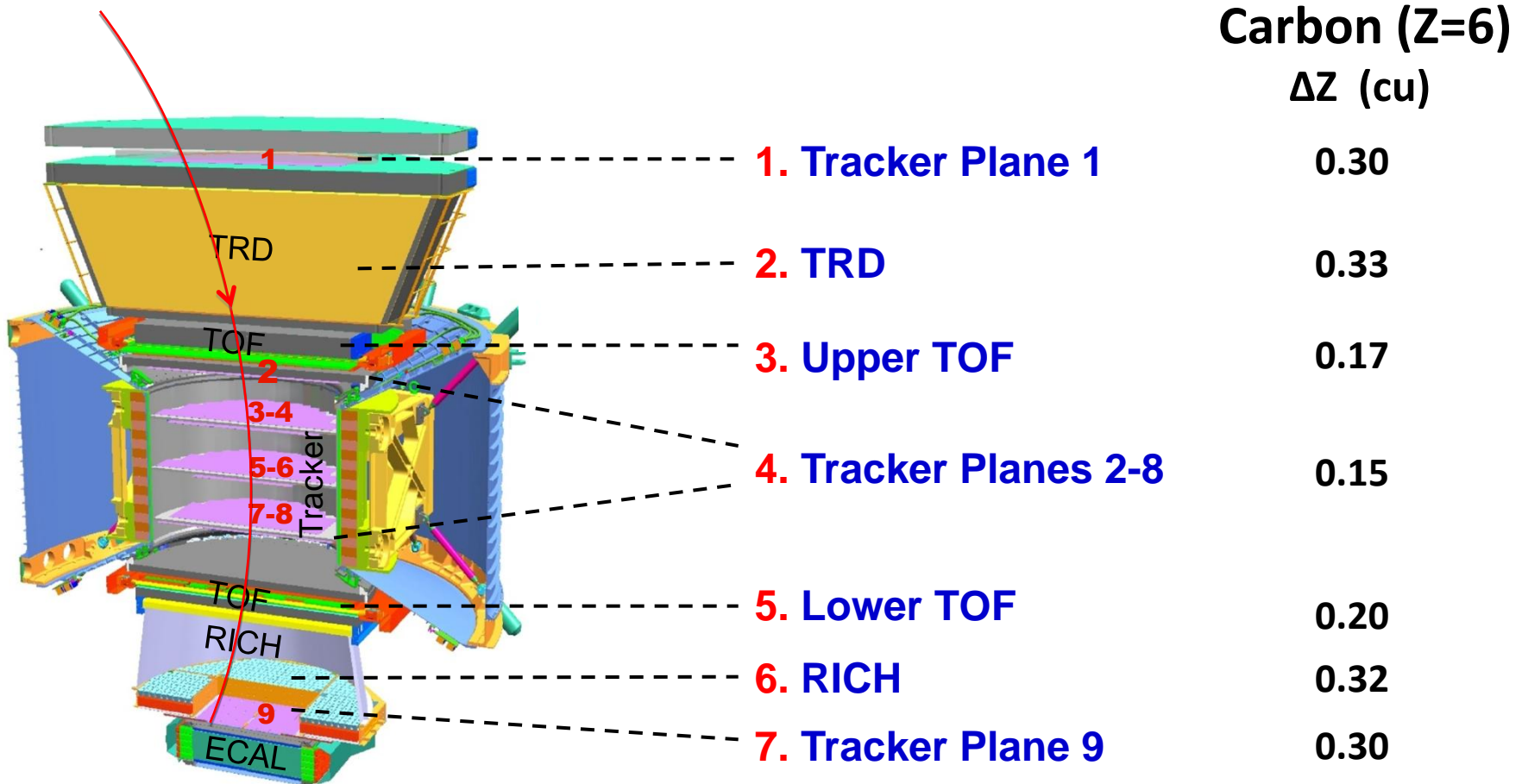


Diffusion
Convection
Reacceleration

Interactions with the Interstellar Medium (ISM):

- Fragmentation
- Secondaries
- Energy loss

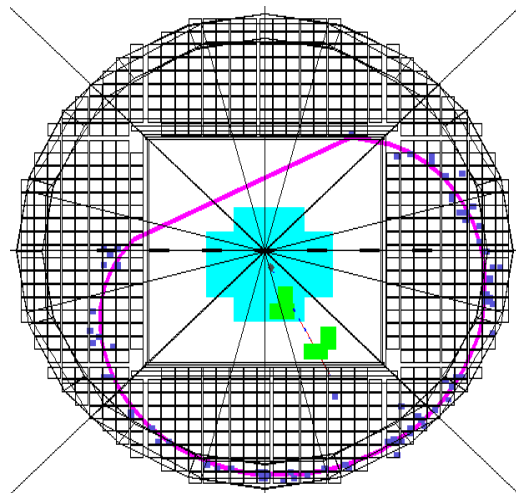
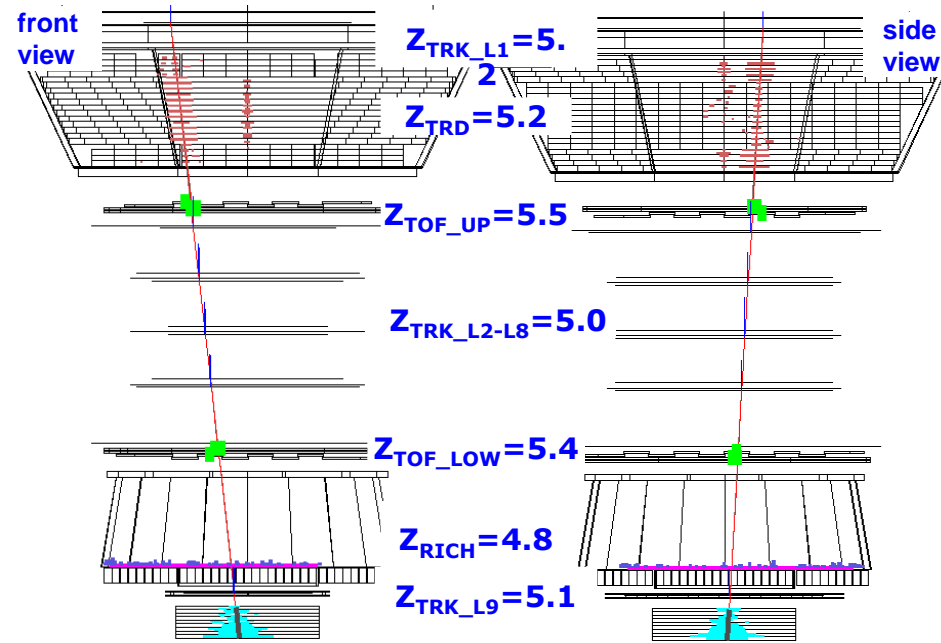
Multiple Independent Measurements of the Charge ($|Z|$)



Rigidity ~ 700 GV

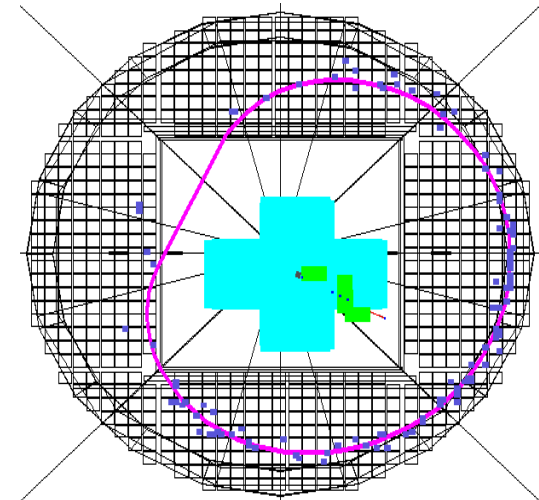
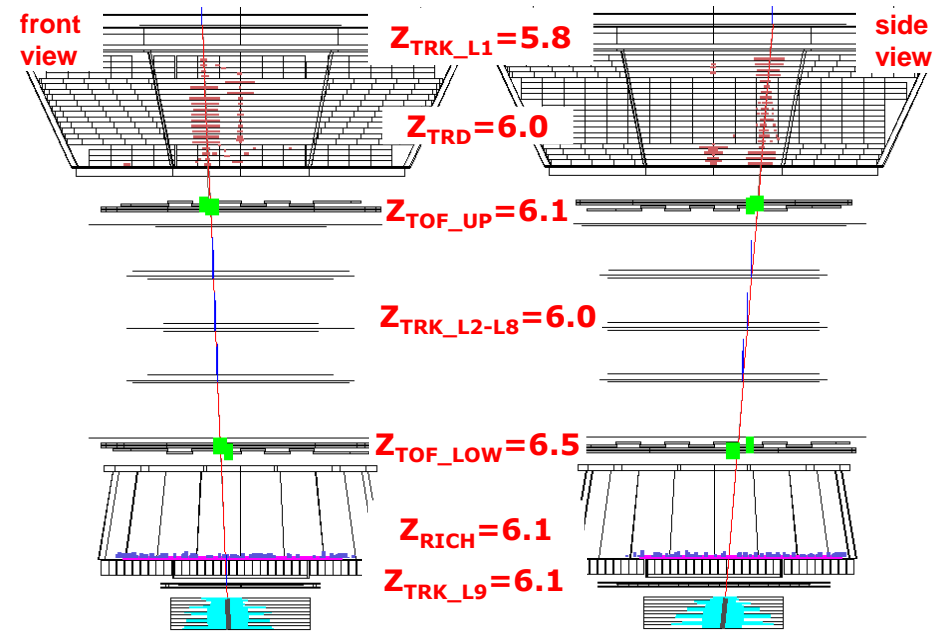
Boron
Rigidity=680 GV

Run/Event 1319990213/ 235892



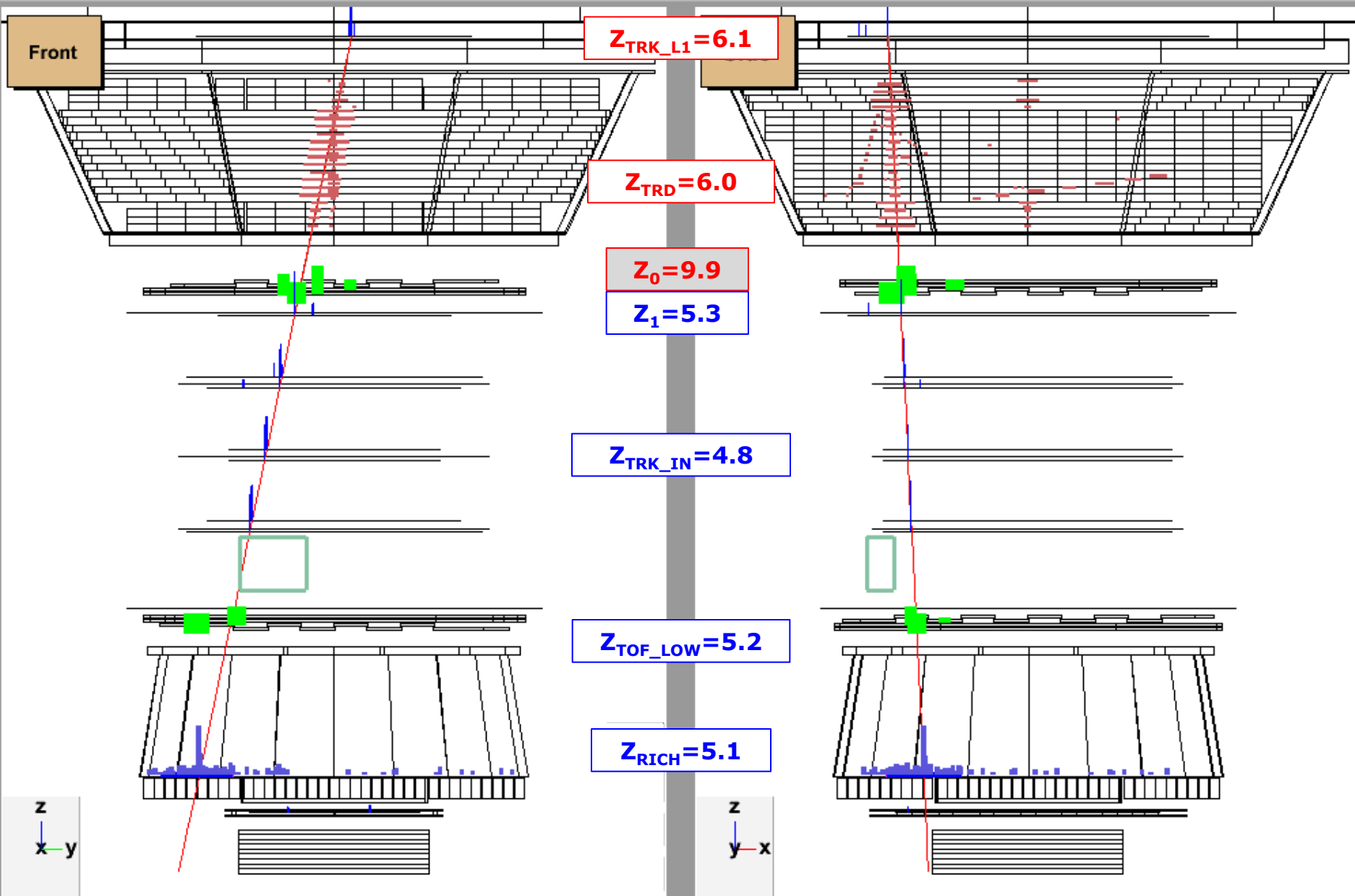
Carbon
Rigidity=666 GV

Run/Event 1327184805/ 266043

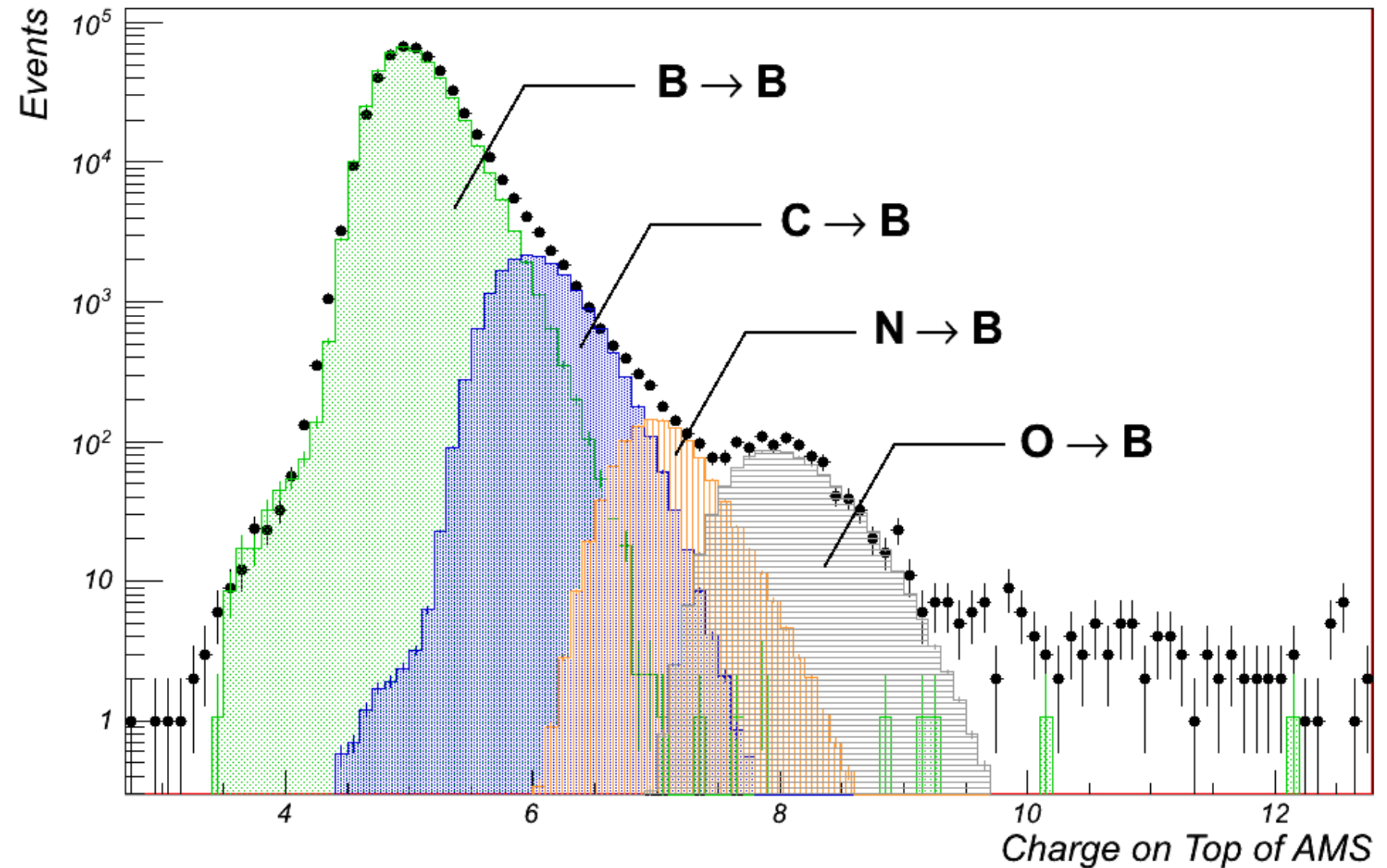


Carbon Fragmentation to Boron in Upper TOF

Rigidity 10.6 GV

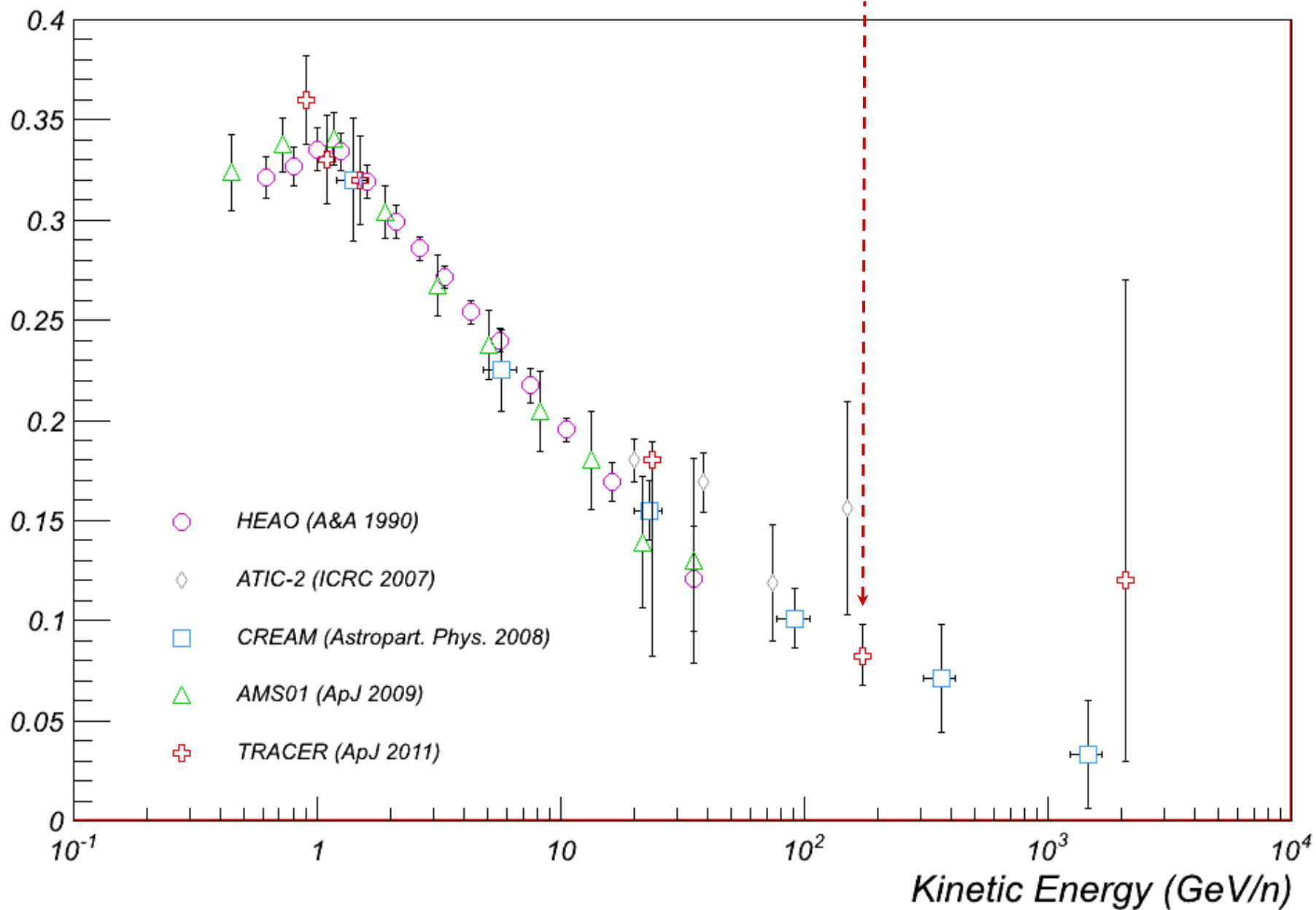


Boron measured by AMS

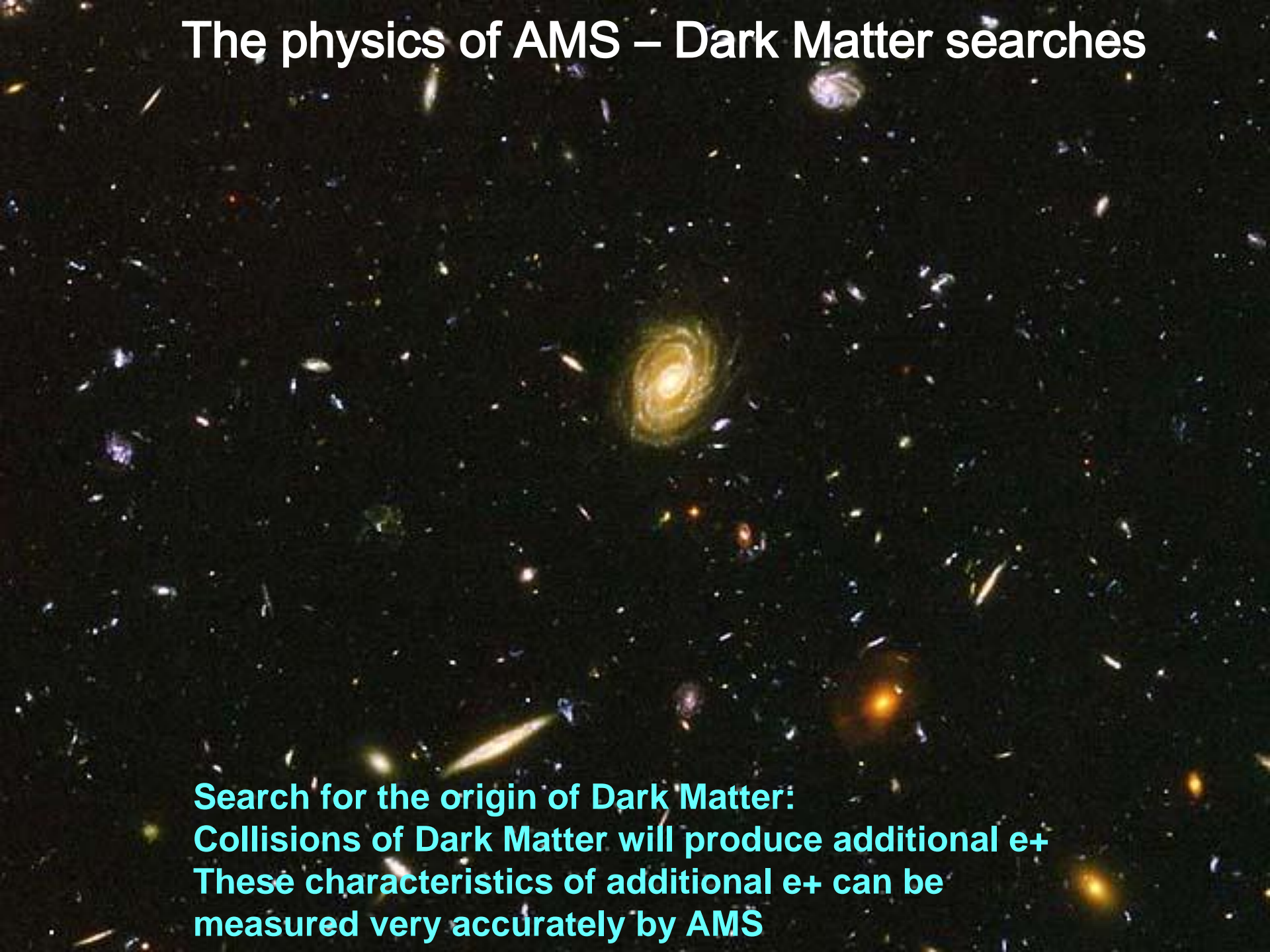


Example of AMS-02 data point

Boron-to-Carbon Ratio

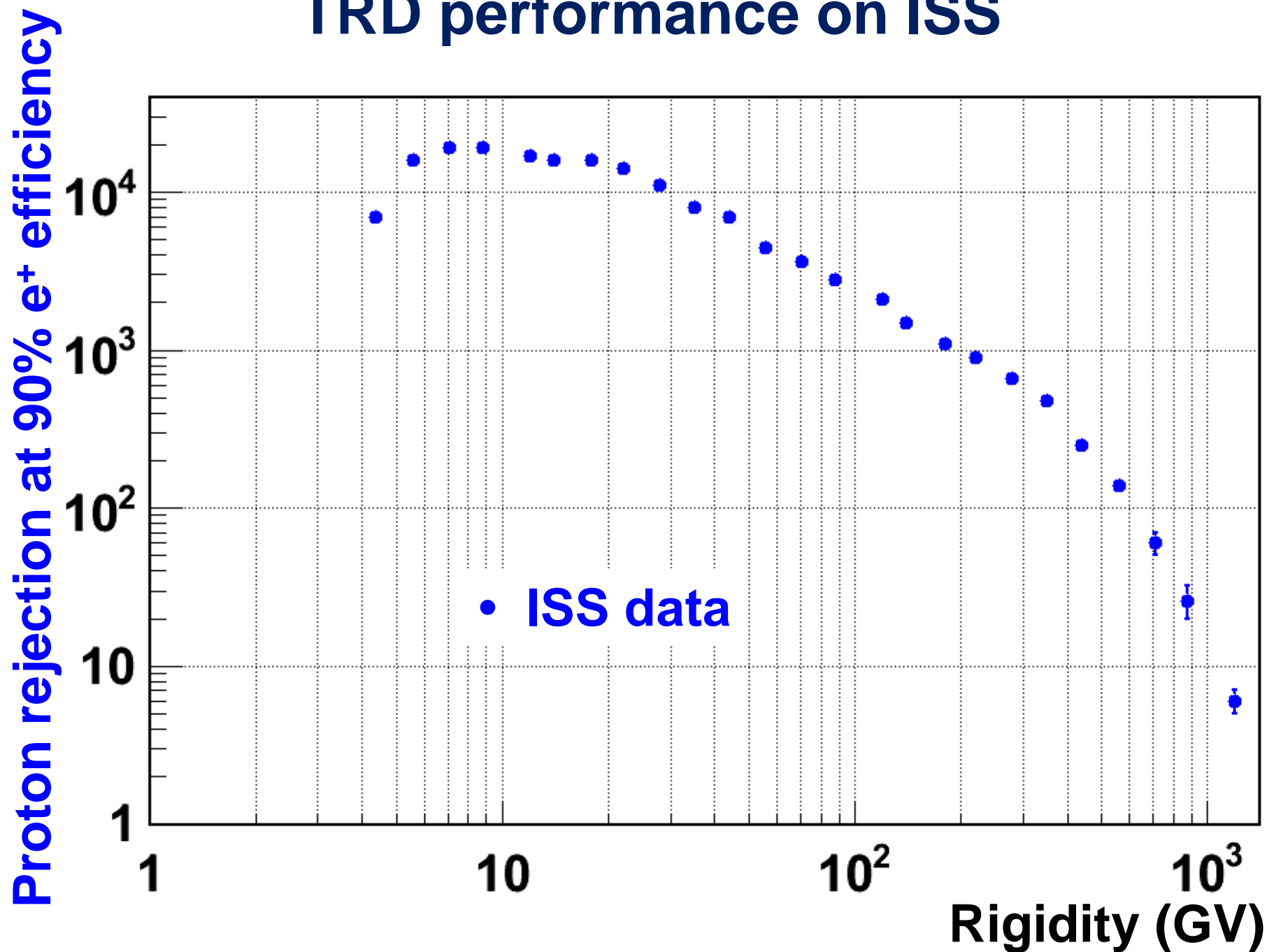


The physics of AMS – Dark Matter searches

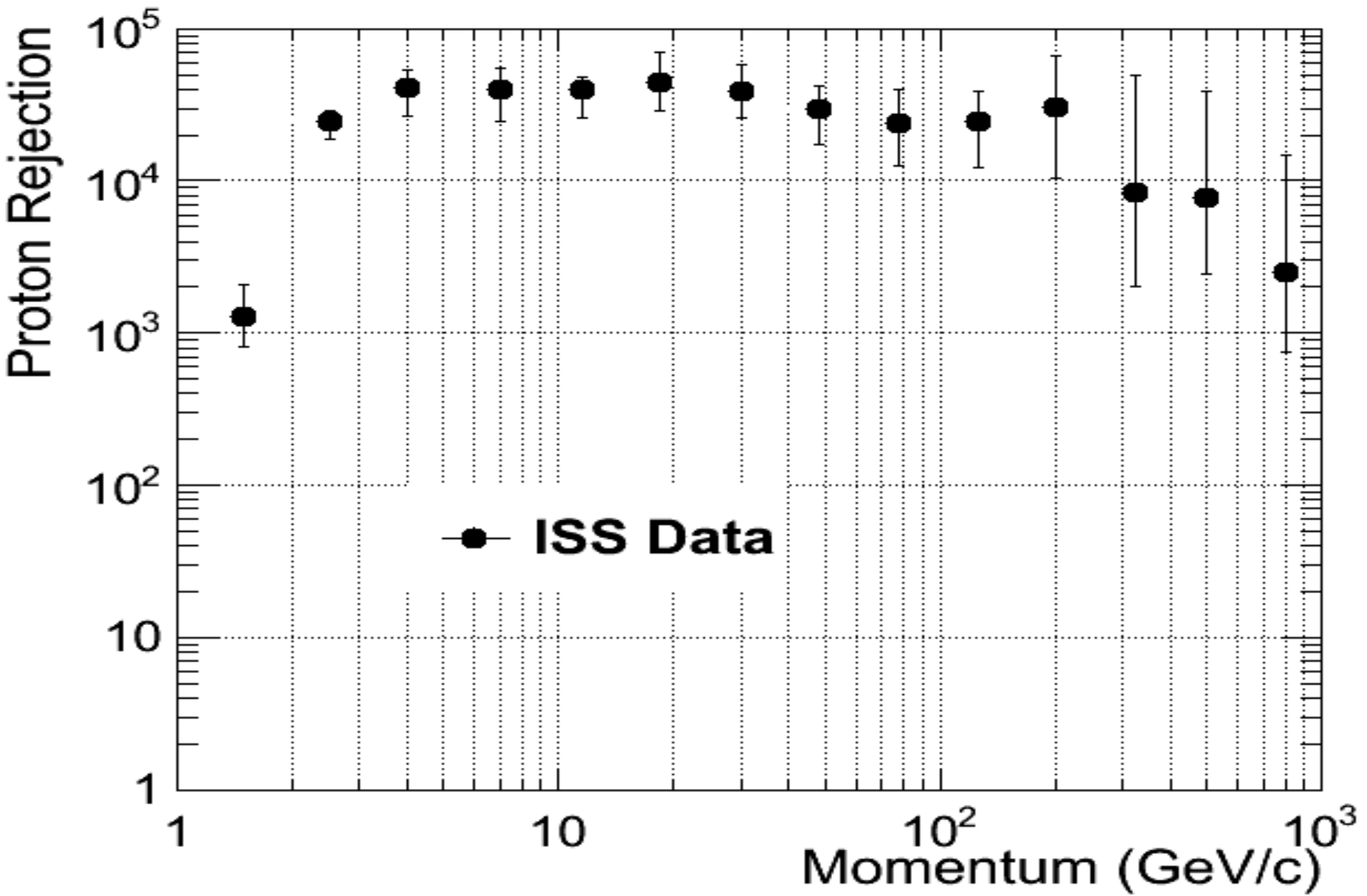


**Search for the origin of Dark Matter:
Collisions of Dark Matter will produce additional e^+
These characteristics of additional e^+ can be
measured very accurately by AMS**

TRD performance on ISS

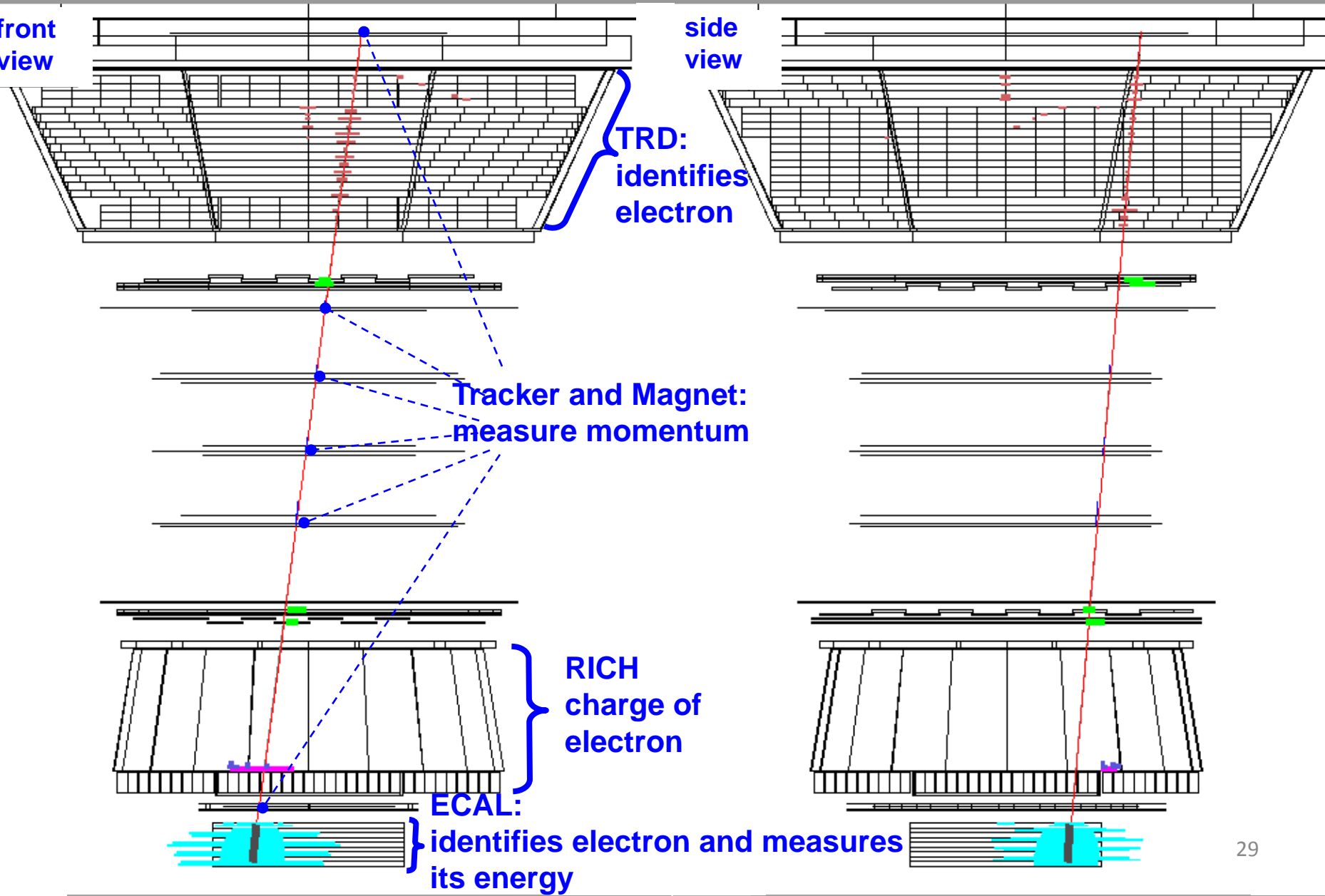


ECAL performance on ISS



front view

side view

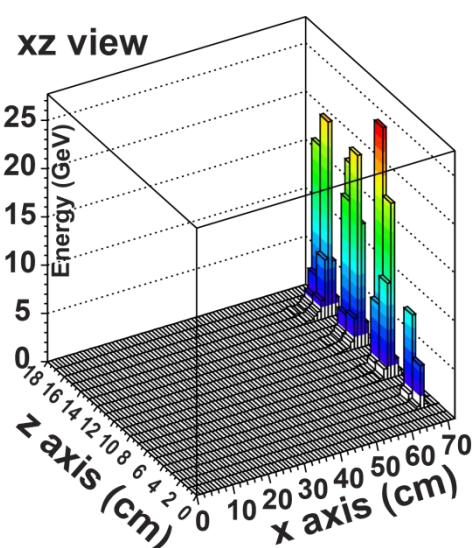
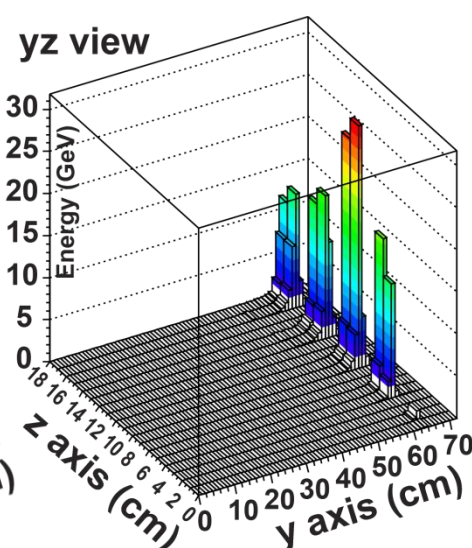
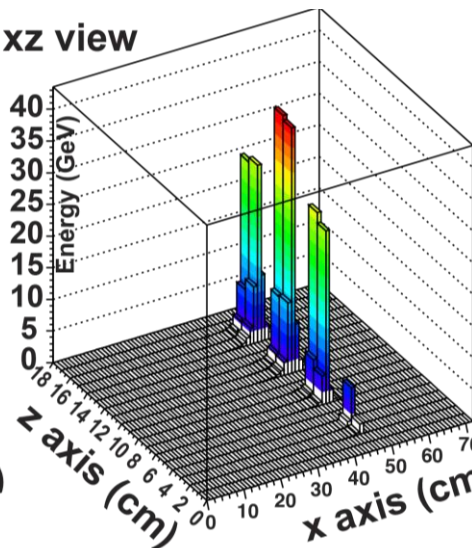
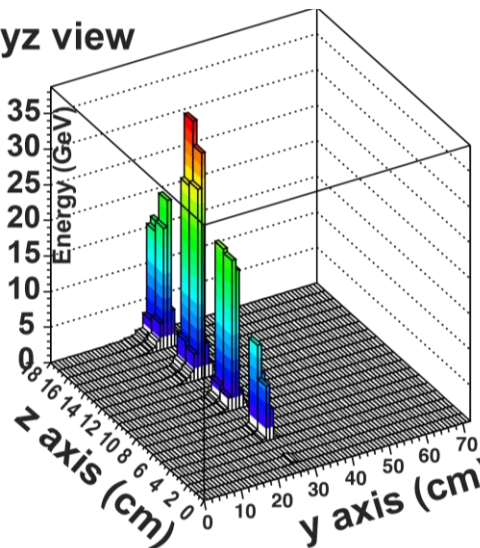
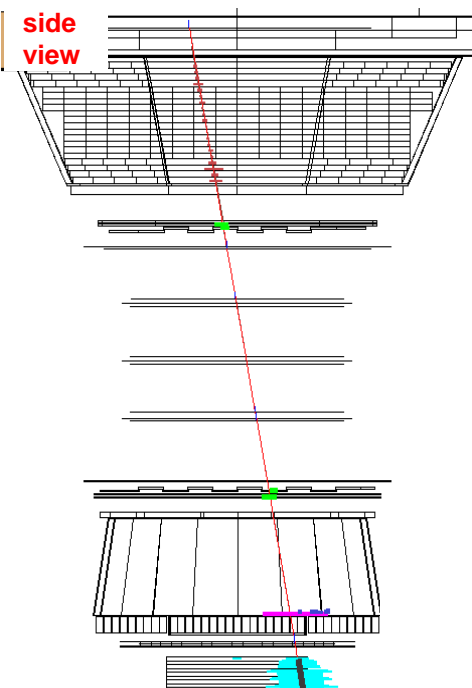
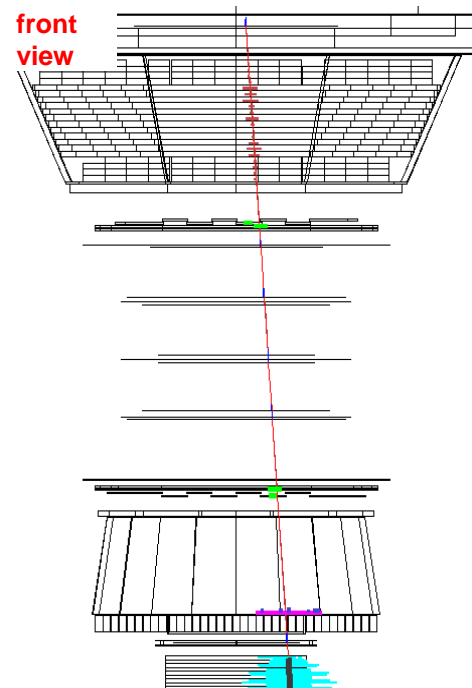
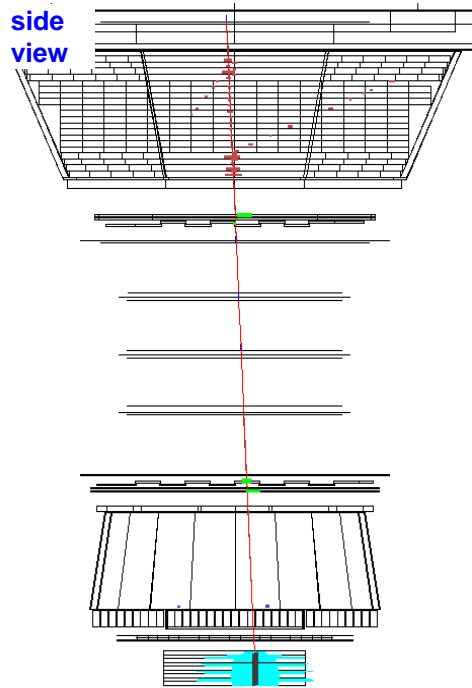
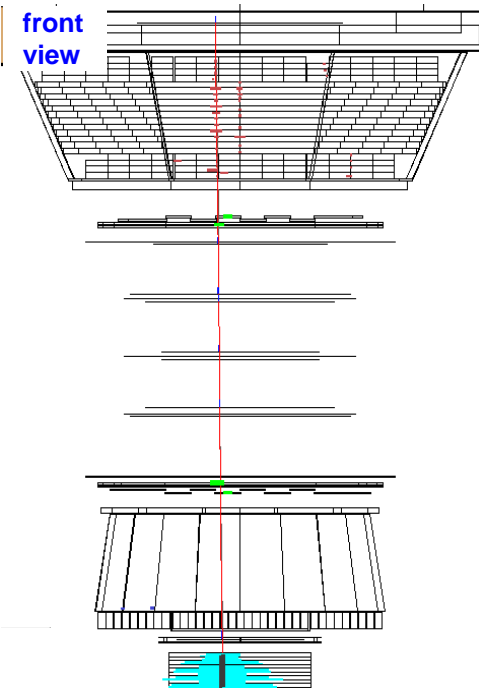


Electron E=982 GeV

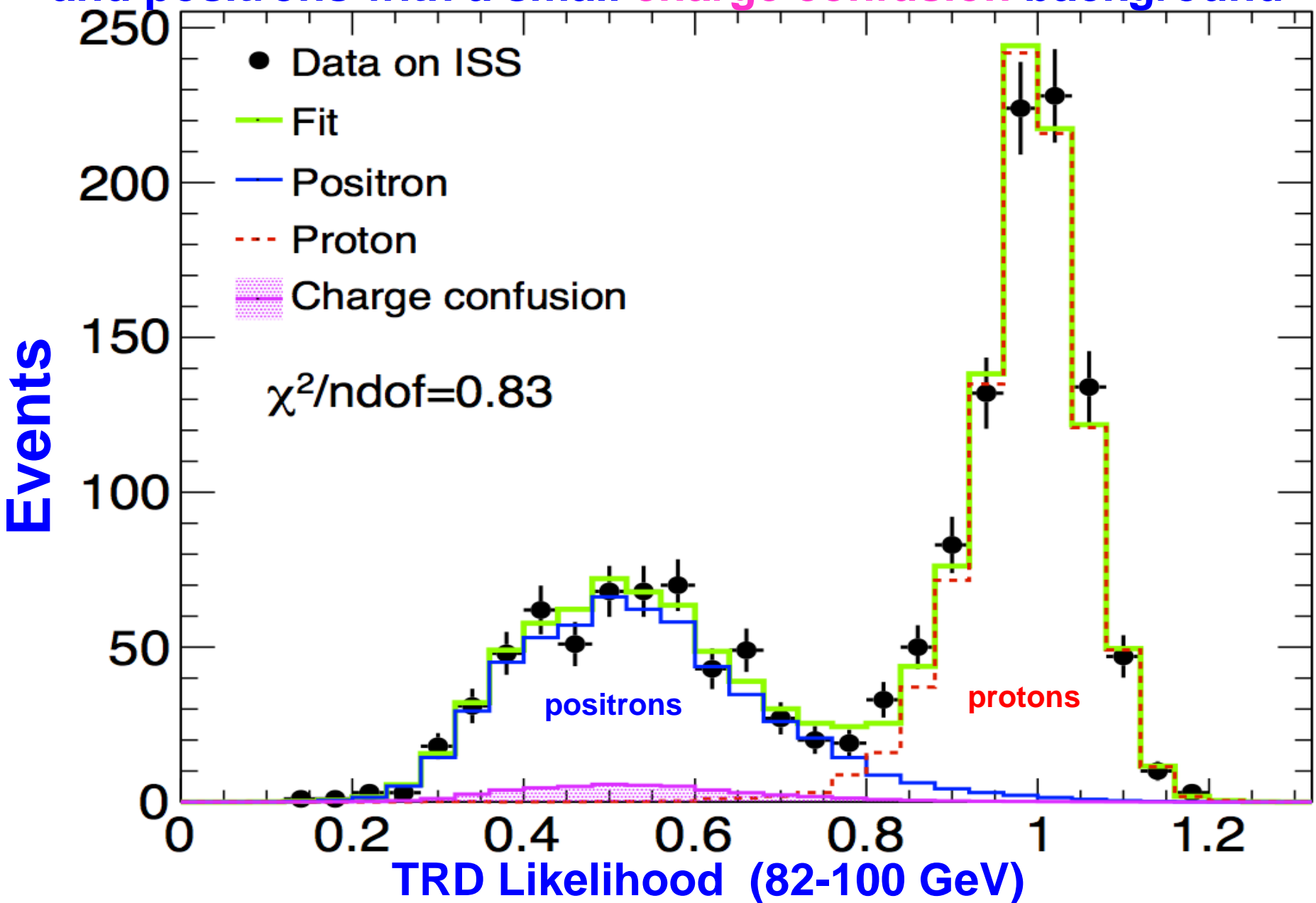
Run/Event 1329775818/ 60709

Positron E=636 GeV

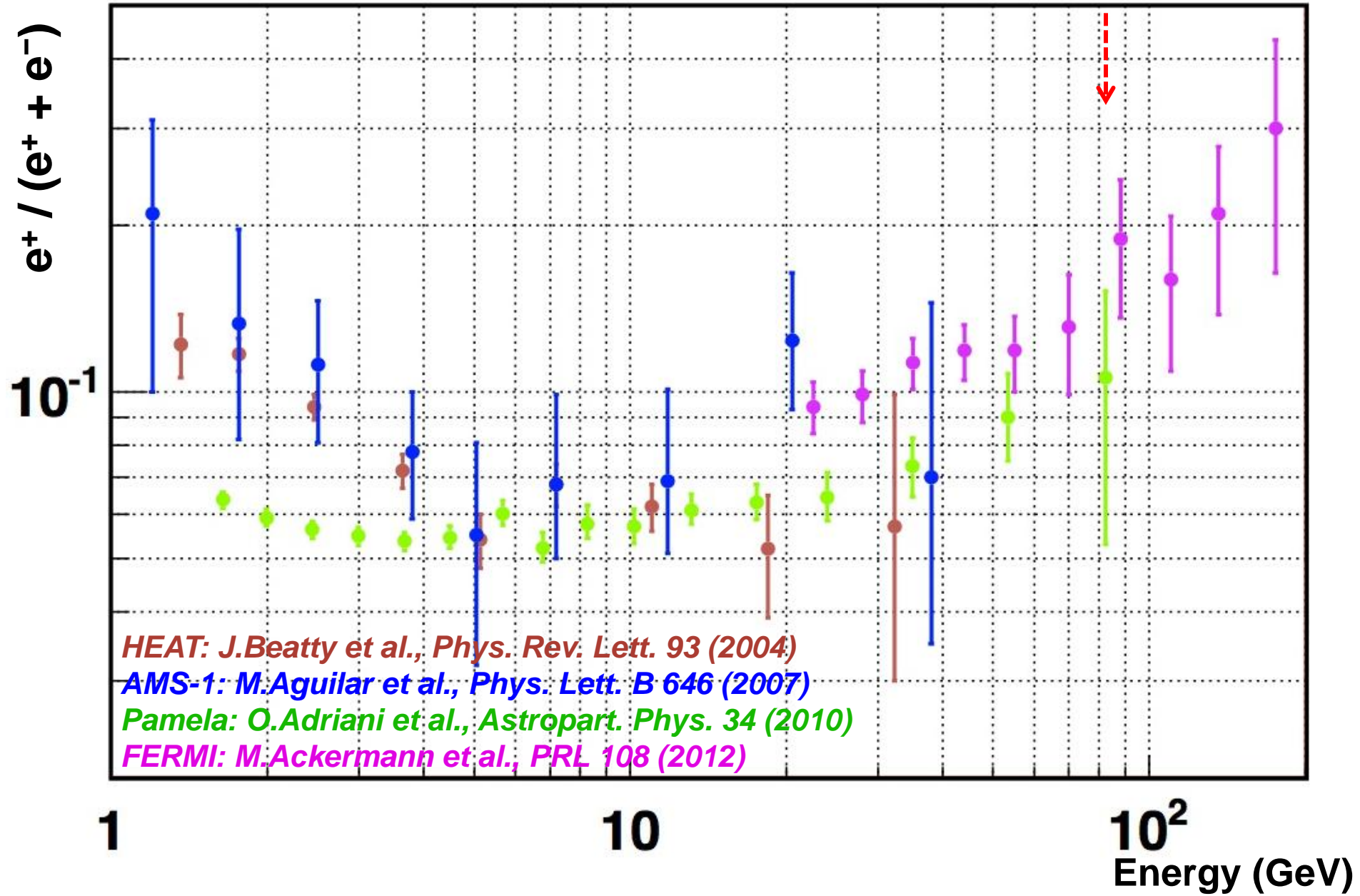
Run/Event 133119-743/ 56950



The TRD Likelihood shows clear separation between **protons** and **positrons** with a small **charge confusion** background

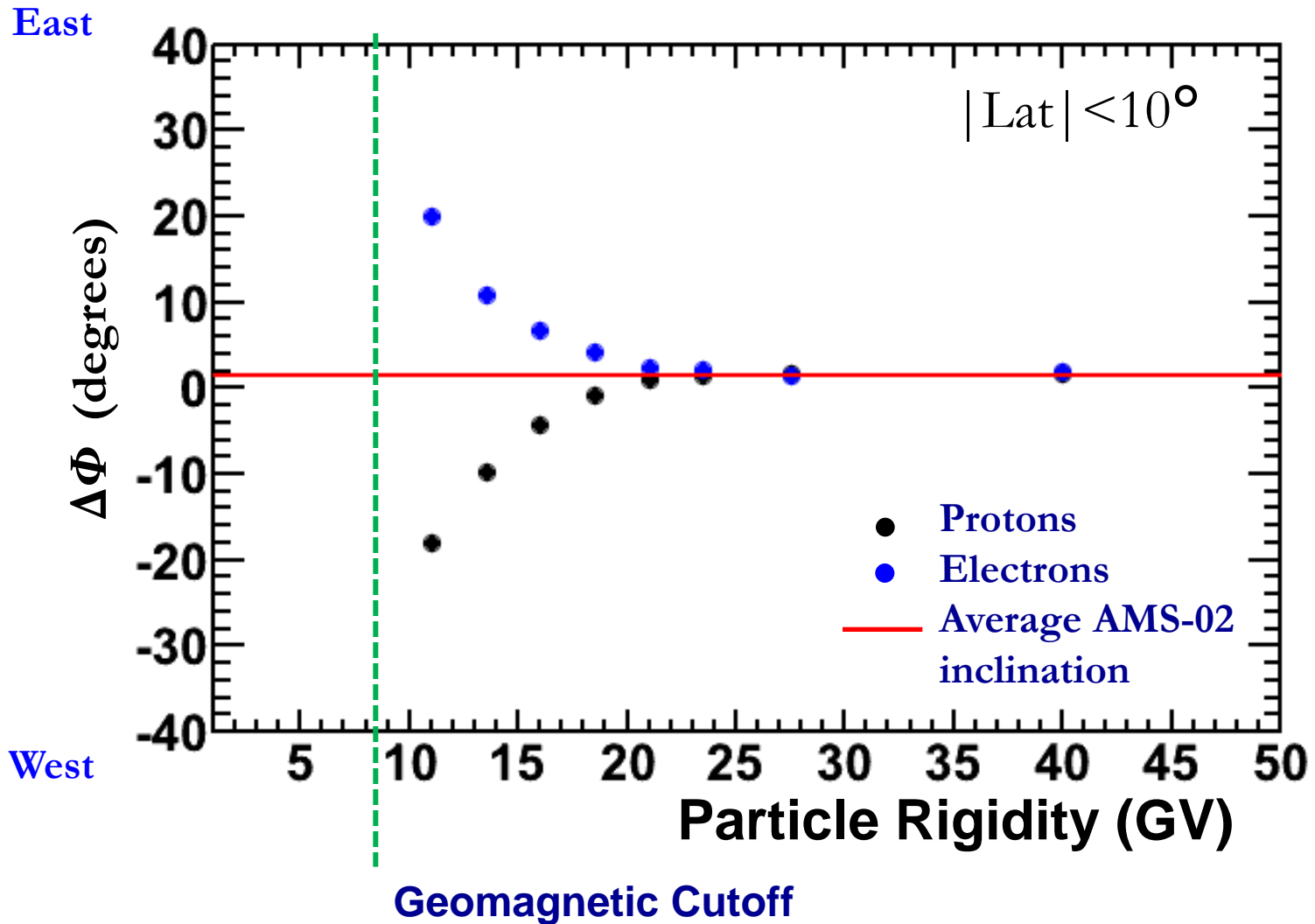


AMS
1600 e+ events (65-100 GeV)
Error size \ddagger



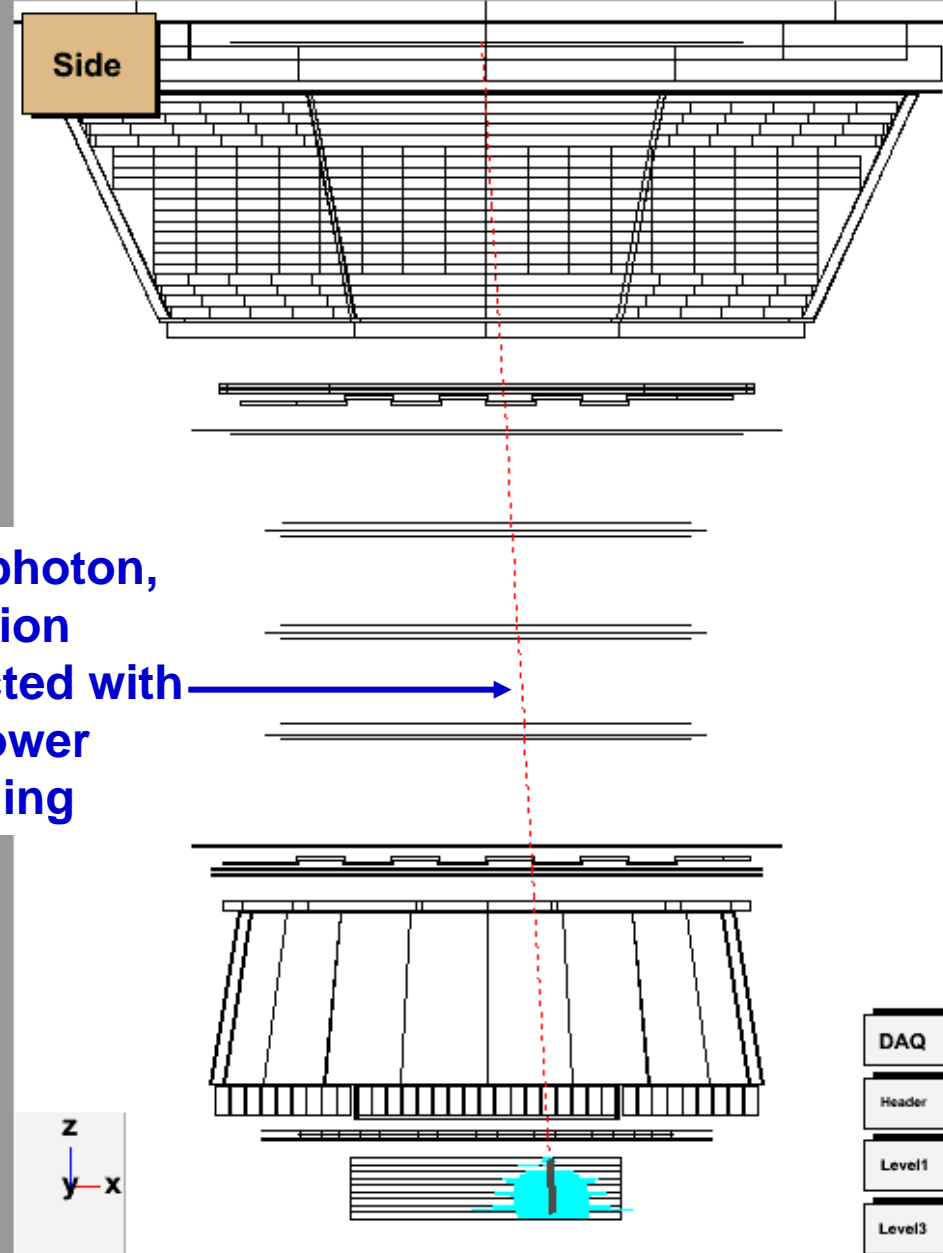
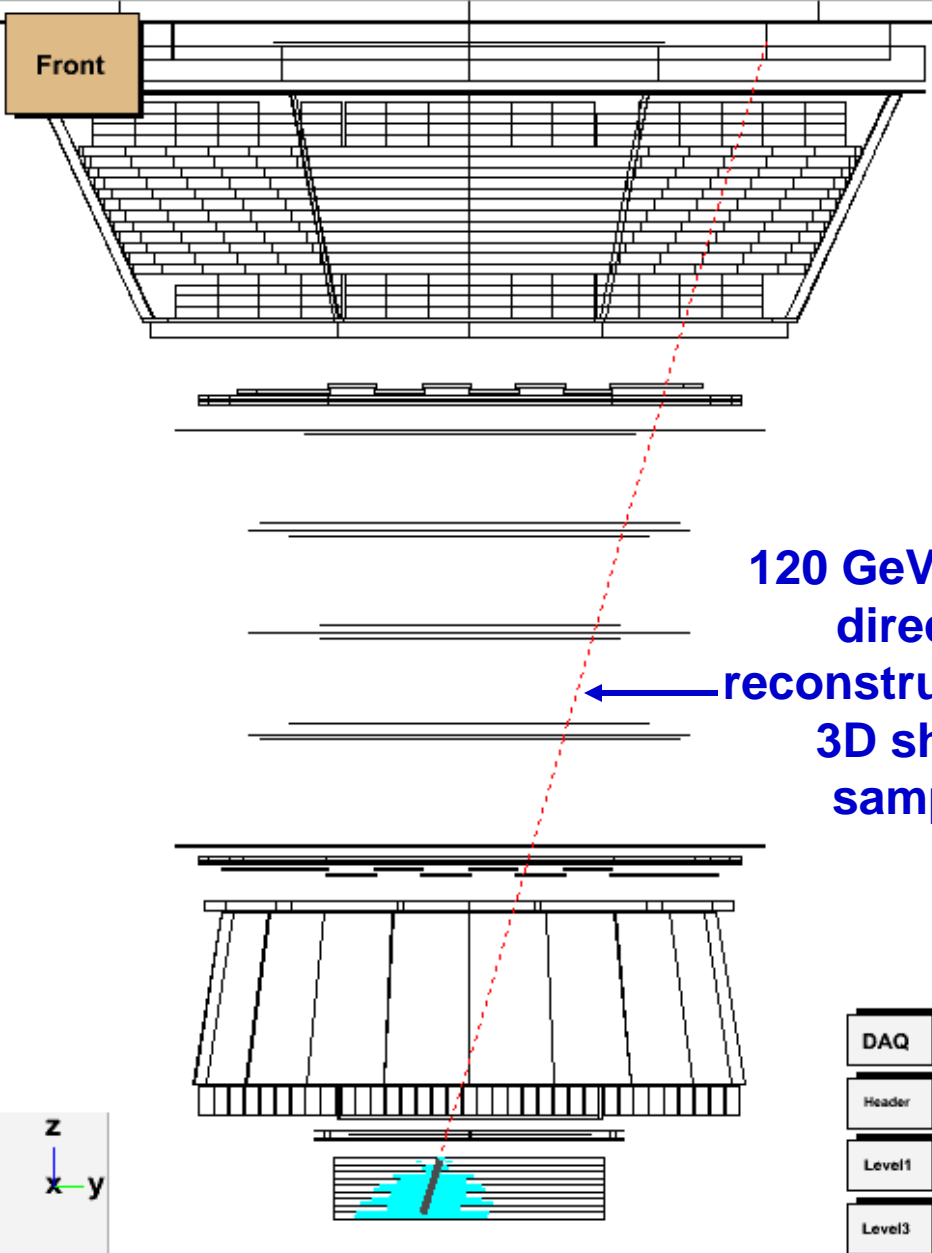
Anisotropies at different scales – the Earth scale

Average Incidence angle



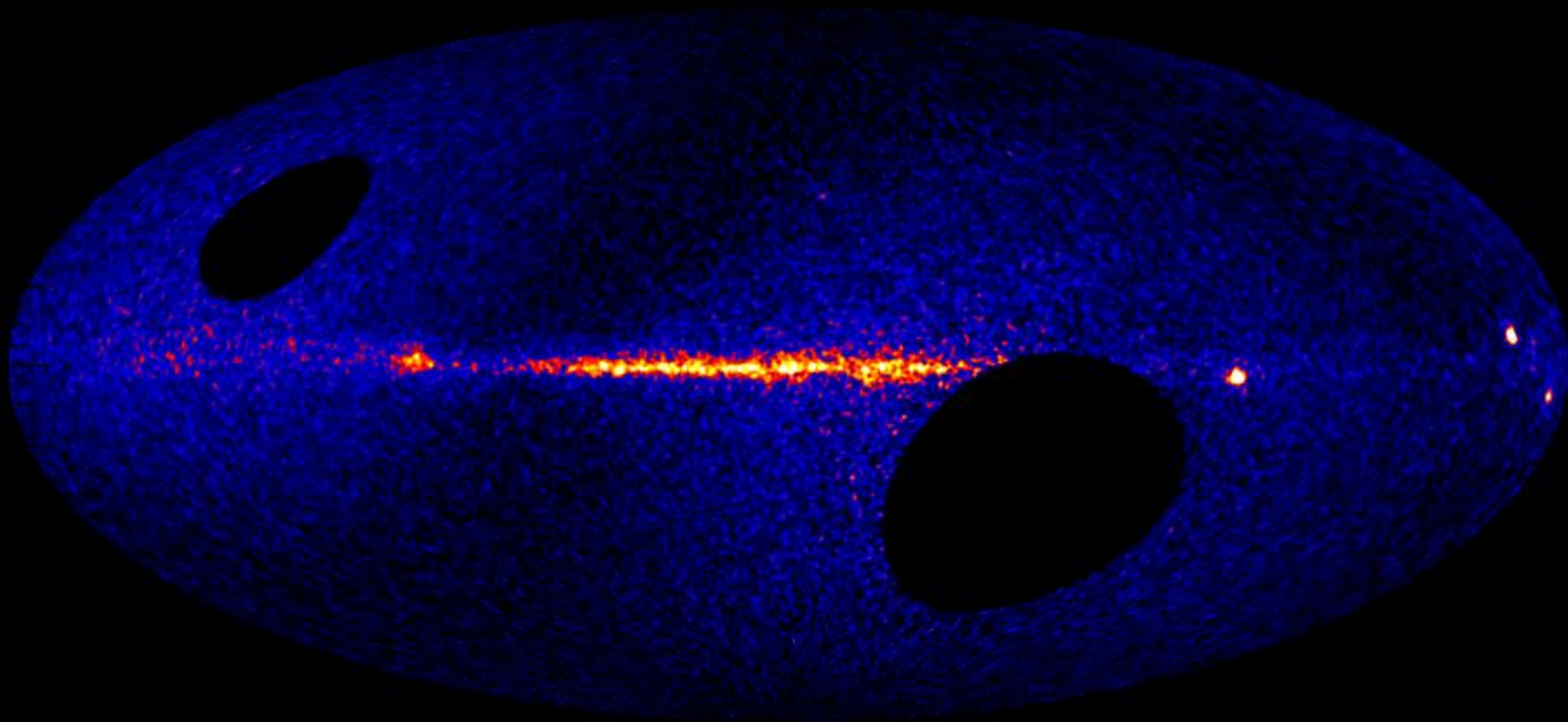
Photons in AMS: 120 GeV photon

Unique Features: $17 X_0$, 3D ECAL, measure γ to 1 TeV, time resolution of $1\mu\text{sec}$

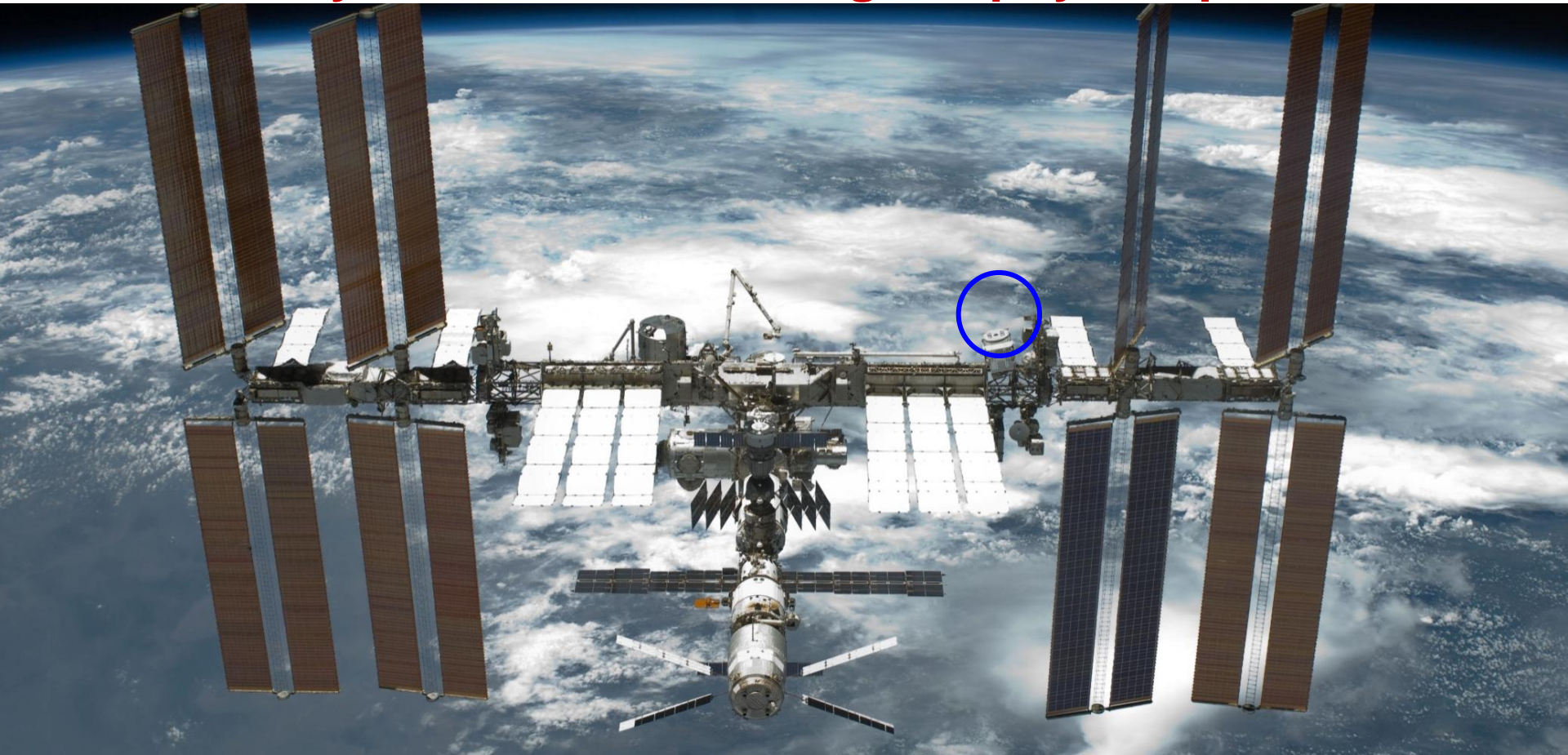


AMS-02 Gamma-ray sky

17 months



AMS is taking data since May 19, 2011
All sub-systems are fully operational.
10+ years onboard ISS – great physics potential



Data analysis is in progress:

- **Positron fraction**
- **He flux & B/C ratio**
- **...**