Astrofizyka cząstek

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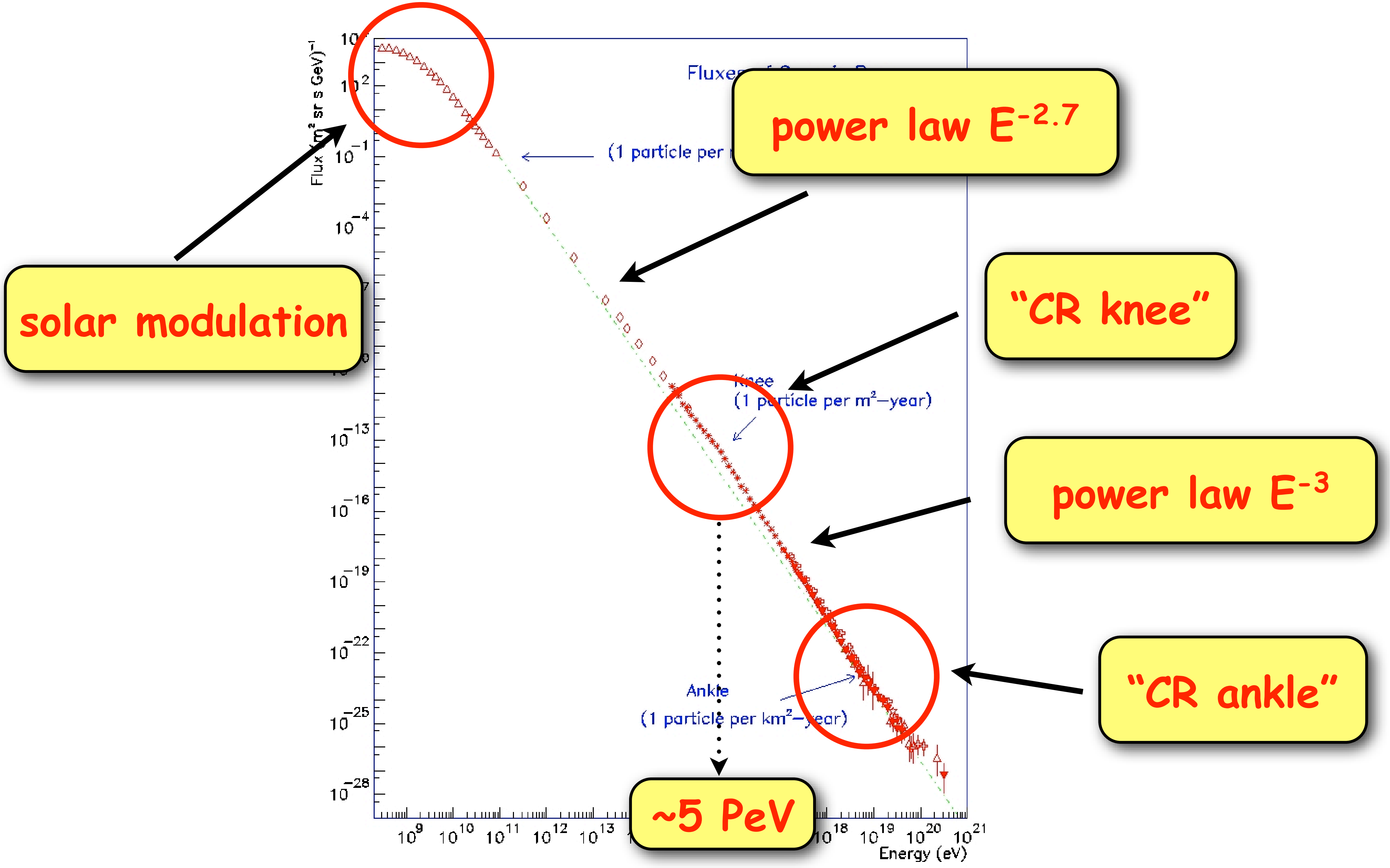
Zakład Cząstek i Oddziaływań Fundamentalnych IFD

Wykład VII

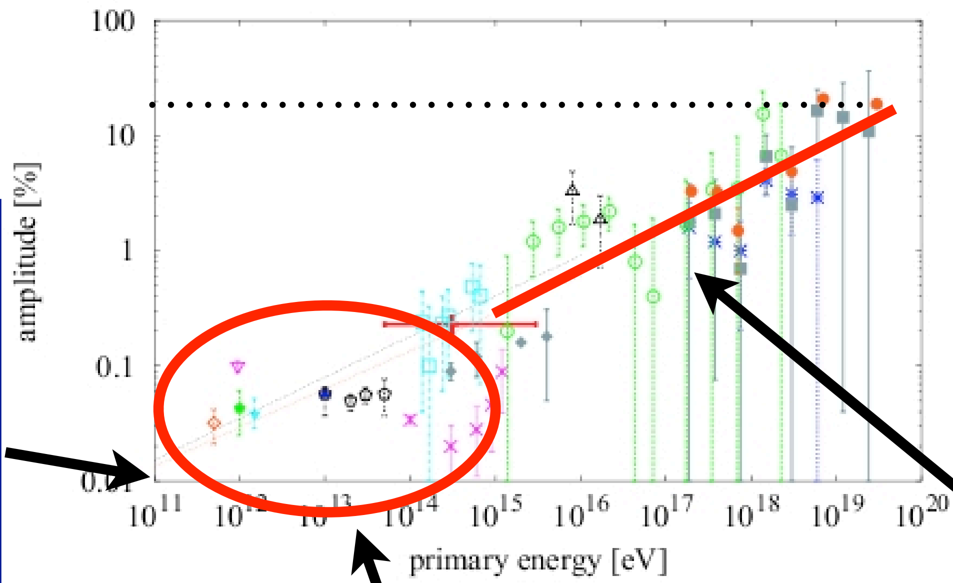
- promieniowanie kosmiczne: wprowadzenie
- eksperymenty satelitarne
- wybrane wyniki

The (local) Cosmic Ray spectrum



Cosmic Ray isotropy

Cosmic Ray anisotropy: $\delta = \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}}$ (I -> CR intensity)



CRs are very isotropic in the sky

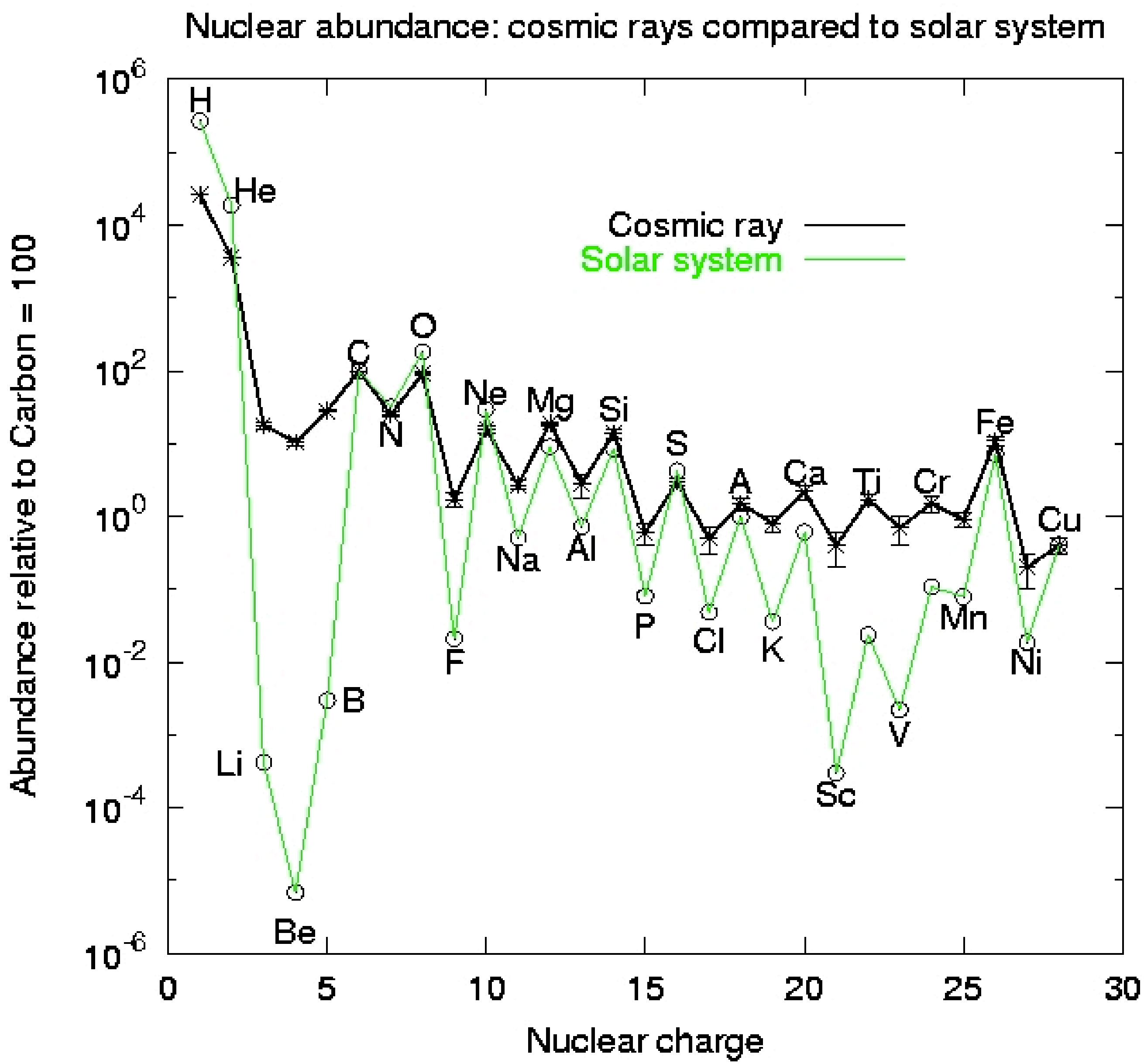
measures available only above ~500 GeV -> magnetic field of the solar system has no effect

the anisotropy increases with particle energy

$\delta \sim 10^{-3}$

figure from Iyono et al, 2005

Cosmic Ray composition



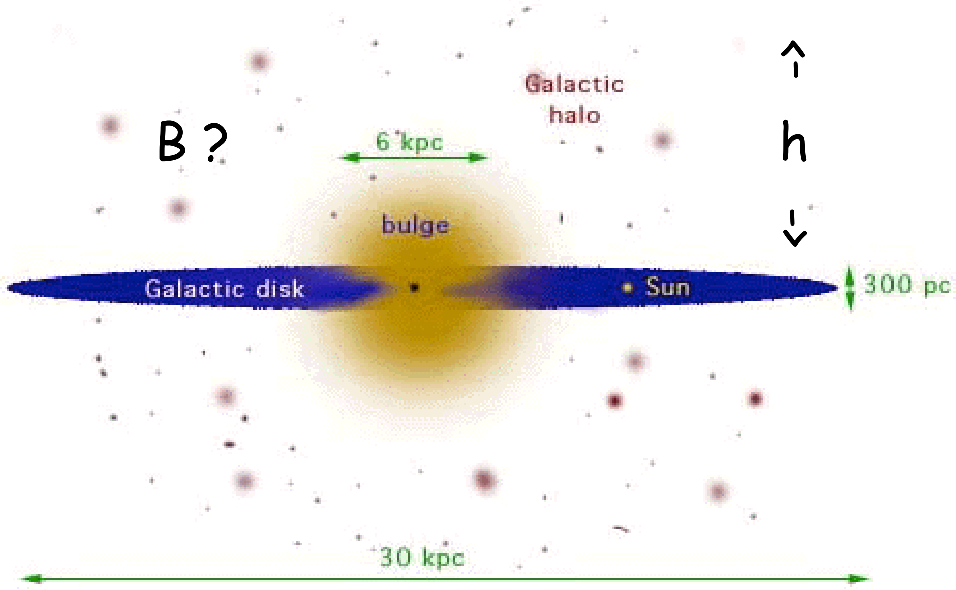
Gaisser & Stanev, 2005

What we have to explain about CRs:

- Energy density
- Energy spectrum
- Chemical composition
- Isotropy
- Stability in time
- Spatial homogeneity (?)

Galactic or extra-galactic?

Which CRs are confined in the Galaxy?



It depends on the values of the magnetic field and thickness of the halo (both poorly constrained...)

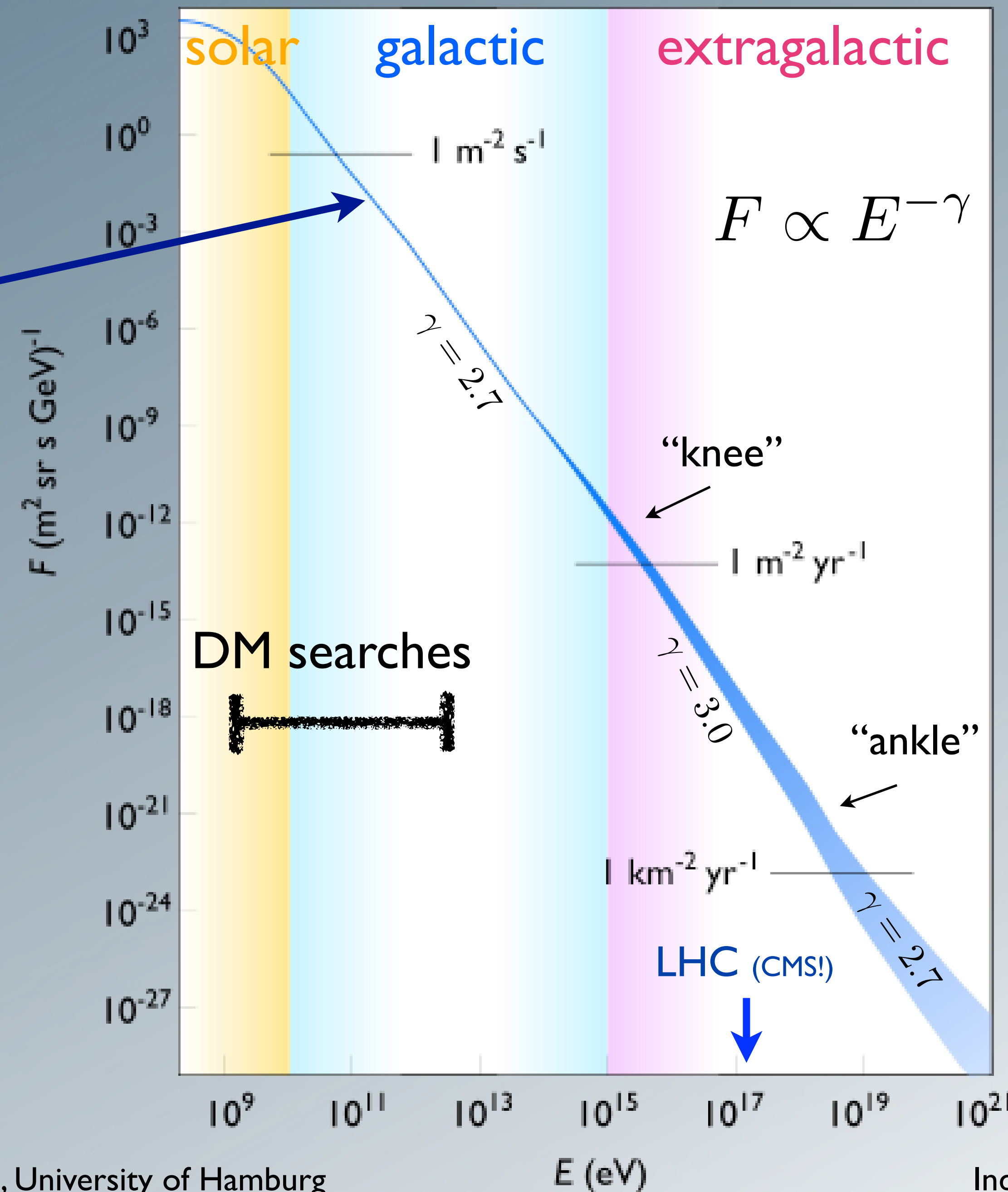
Confinement condition:

$$\frac{E(\mathrm{eV})}{300\ B(\mathrm{G})} = R_L < h \Rightarrow E < 10^{18}\left(\frac{h}{\mathrm{kpc}}\right)\left(\frac{B}{\mu\mathrm{G}}\right)\mathrm{eV} = 10^{17} \div 10^{20}\ \mathrm{eV}$$

(cm) Larmor radius halo size 1 - 10 0.1 - 10

Spectrum and origin of CRs

mostly protons!



A remarkable coincidence

Total CR power in the Galaxy ->

$$P_{CR} = 3 \times 10^{40} \text{ erg/s}$$

A SuperNova is the explosion of a massive star that releases ~10^{51} ergs in form of kinetic energy. In the Galaxy the observed supernova rate is of the order of 1/30 - 1/100 yr^{-1}.

Total SN power in the Galaxy ->

$$P_{SN} = 3 \times 10^{41} \text{ erg/s}$$

SuperNovae alone could maintain the CR population provided that about **10%** of their kinetic energy is **somehow converted into CRs**

TeV emission from SNRs: a test for CR origin

Detectability condition for HESS

$$W_{CR} > 5 \times 10^{47} \left(\frac{n_{gas}}{4 \text{ cm}^{-3}} \right)^{-1} d_{kpc}^2 \text{ erg}$$

above ~ 10 TeV

Assumptions...

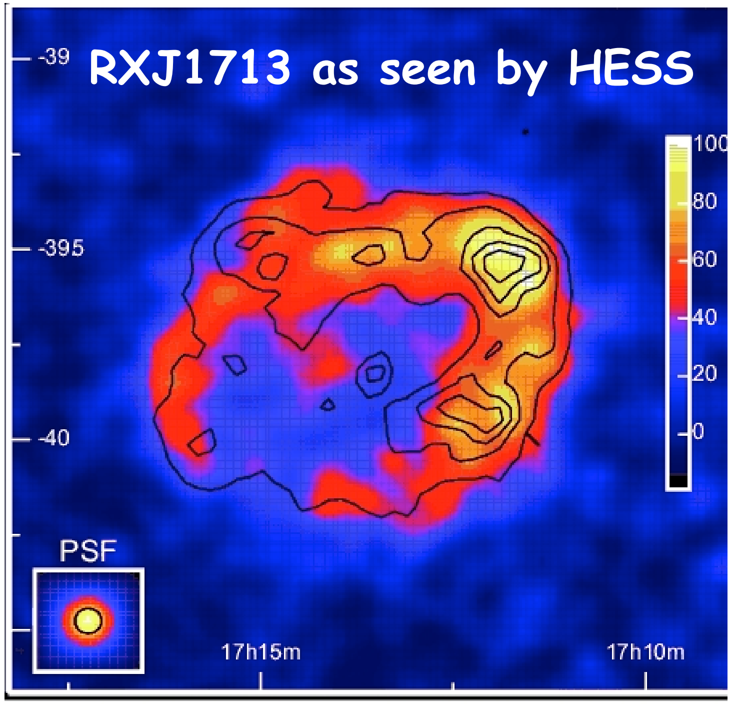
- 10% efficiency -> 10^{50} erg in CRs
- $E^{-2.1}$ spectrum
- up to the knee (5×10^{15} eV)

above ~ 10 TeV

$$W_{CR} \approx 3 \times 10^{49} \text{ erg}$$

If **SuperNova Remnants** indeed are the sources of galactic Cosmic Rays they MUST be visible in **TeV gamma rays**
(Drury, Aharonian, and Voelk, 1994)

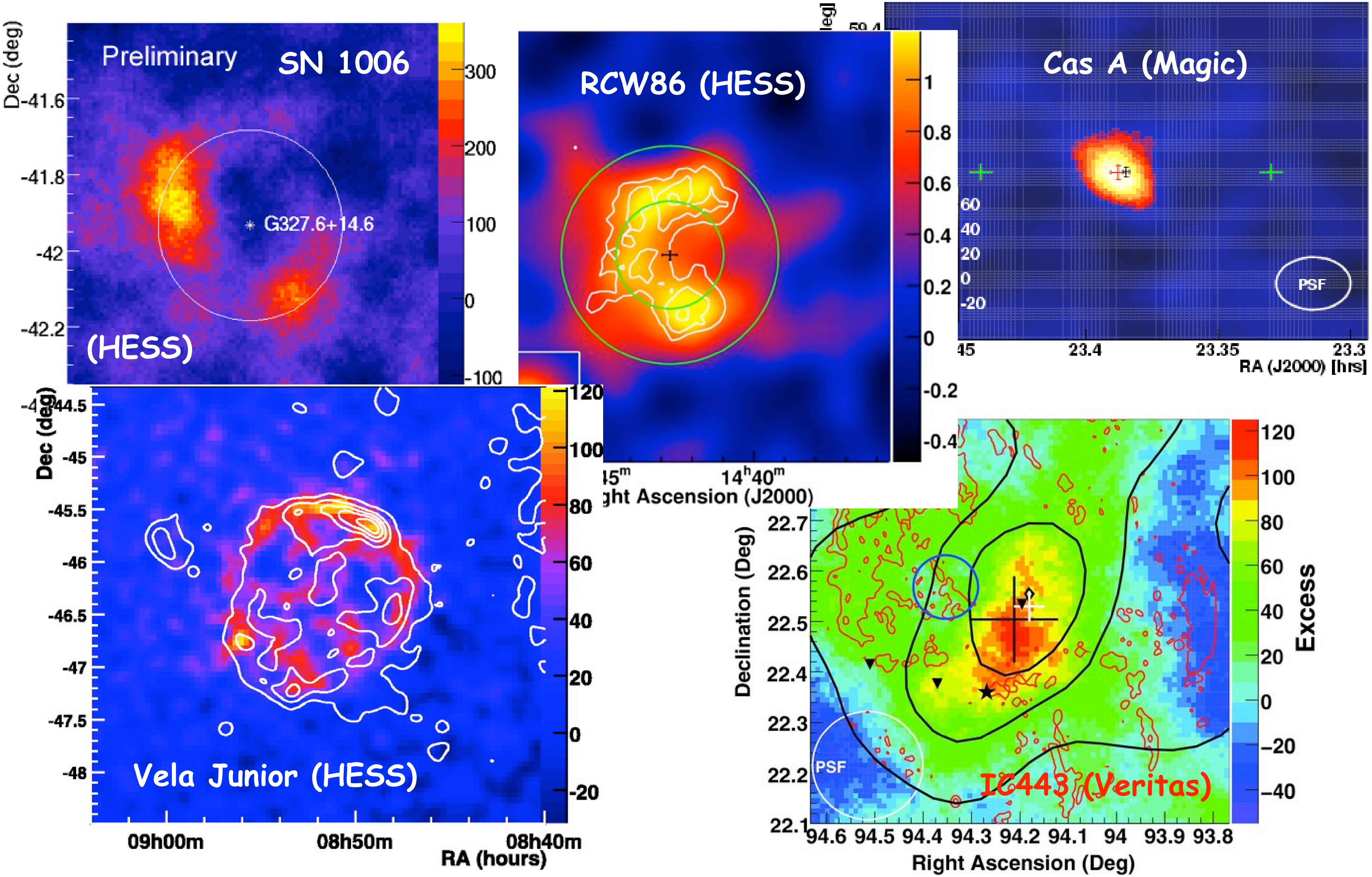
TeV emission from SNRs: a test for CR origin



Test passed!

This is still not a conclusive proof -> hadronic or leptonic emission?

SNRs in gamma rays



Shock waves

Supersonic motion + medium -> Shock Wave

(SuperNova ejecta) (InterStellar Medium)

velocity of SN ejecta up to $v_{ej} \approx 30000 \text{ km/s}$

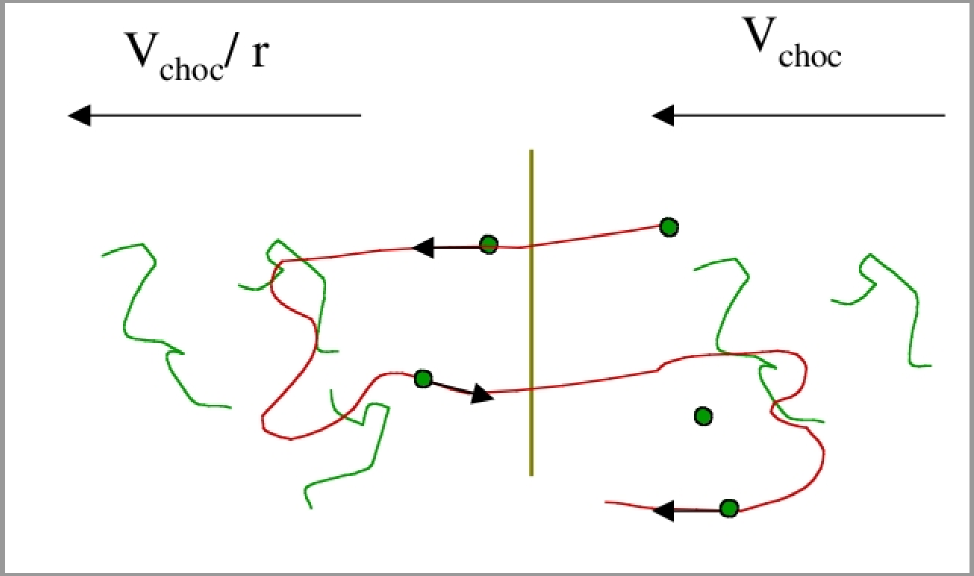
sound speed in the ISM $c_s = \sqrt{\gamma \frac{kT}{m}} \approx 10 \left(\frac{T}{10^4 K} \right)^{1/2} \text{ km/s}$

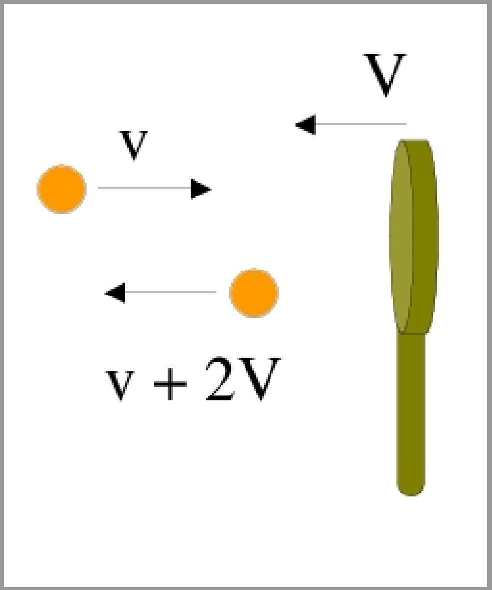
Mach number $\boxed{\mathcal{M} = \frac{v}{c_s} >> 1}$ strong shocks

Acceleration mechanism

Acceleration by change of referential : shock front referential

Shocked medium Interstellar medium





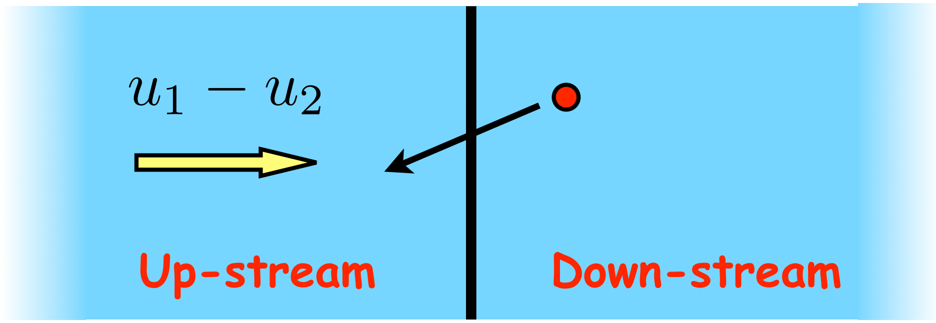
the main idea is : the probability of frontal hit is higher

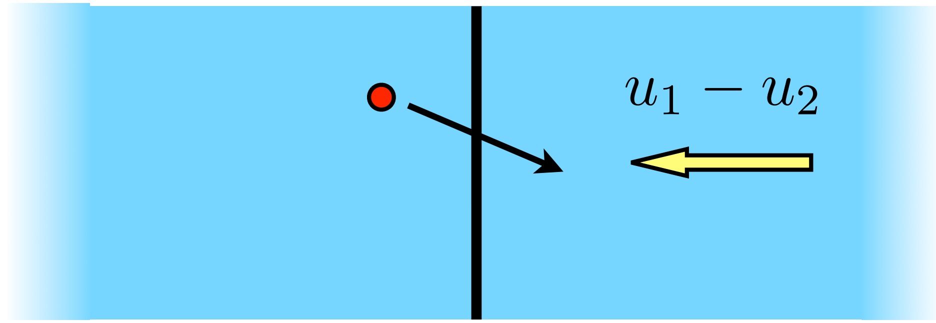
than the opposite → proportional to relative speed

→ **first-order Fermi acceleration mechanism**

Diffusive Shock Acceleration

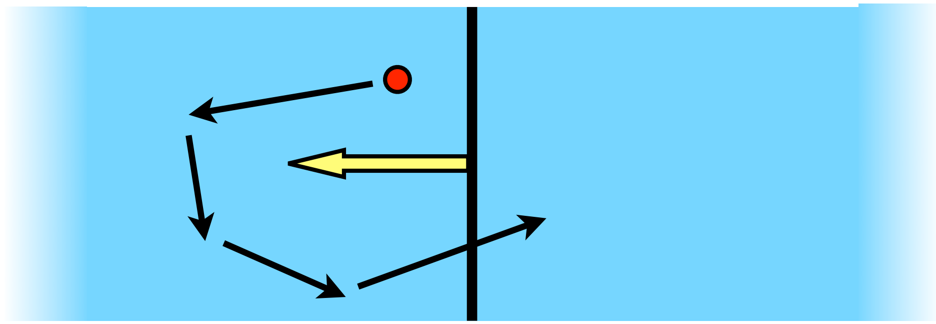
Symmetry

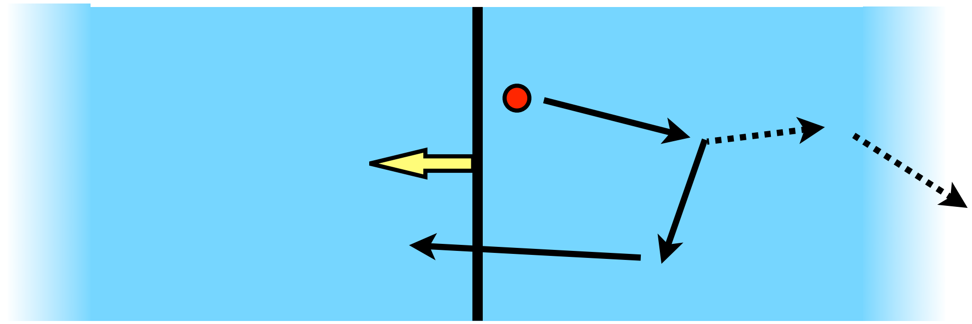




Every time the particle crosses the shock (up -> down or down -> up), it undergoes an head-on collision with a plasma moving with velocity u_1-u_2

Asymmetry





(Infinite and plane shock:) Upstream particles always return the shock, while downstream particles may be advected and never come back to the shock

Diffusive Shock Acceleration

What happens after n cycles?

$$\frac{E_{i+1} - E_i}{E_i} = \left< \frac{\Delta E}{E} \right> = \frac{4}{3} \left(\frac{v}{c} \right)$$

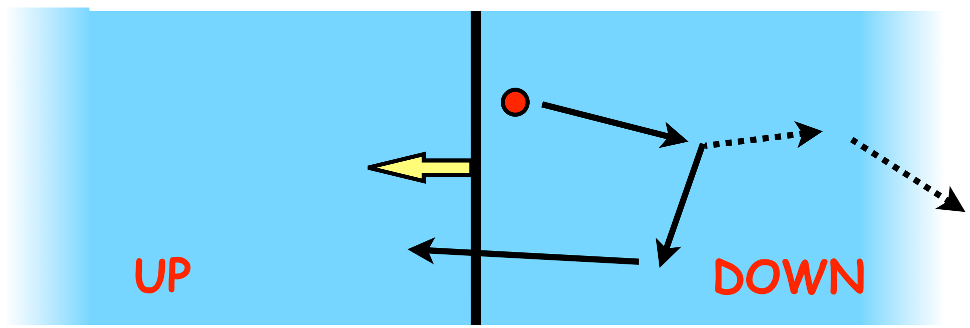
particle energy
at i-th cycle

$$E_{i+1} = \boxed{\left(1 + \frac{4}{3}\frac{v}{c}\right)} E_i$$

$$E_{i+1} = \beta \; E_i$$

Energy increases by a (small) factor beta after each cycle

Particles can escape downstream!



Diffusive Shock Acceleration

What happens after n cycles?

P -> probability that the particle remains within the accelerator after each cycle

after k cycles:

there are $N = N_0 P^k$ particles with energy above $E = E_0 \beta^k$

$$\log\left(\frac{N}{N_0}\right) = k \; \log P \qquad\qquad \log\left(\frac{E}{E_0}\right) = k \; \log \beta$$

$$\frac{\log(N/N_0)}{\log(E/E_0)} = \frac{\log P}{\log \beta}$$

$$\boxed{N(>E) = N_0 \left(\frac{E}{E_0}\right)^{\frac{\log P}{\log \beta}}}$$

Diffusive Shock Acceleration

$$\boxed{n(E) \;\propto\; E^{-1 + \frac{\log P}{\log \beta}}}$$

$$\log P \;=\; \log\left(1 - \frac{u_1}{c}\right) \;\sim\; -\frac{u_1}{c}$$

$$\log \beta \;=\; \log\left(1 + \frac{u_1}{c}\right) \;\sim\; \frac{u_1}{c}$$

UNIVERSAL SPECTRUM

$$\boxed{n(E) \propto E^{-2}}$$

Diffusive Shock Acceleration

Assumptions made:

- strong shock ☑ SNR shocks
- isotropy both up and down-stream ☑ turbulent B field
- test-particle (CR pressure negligible) ☐ efficient CR acceleration

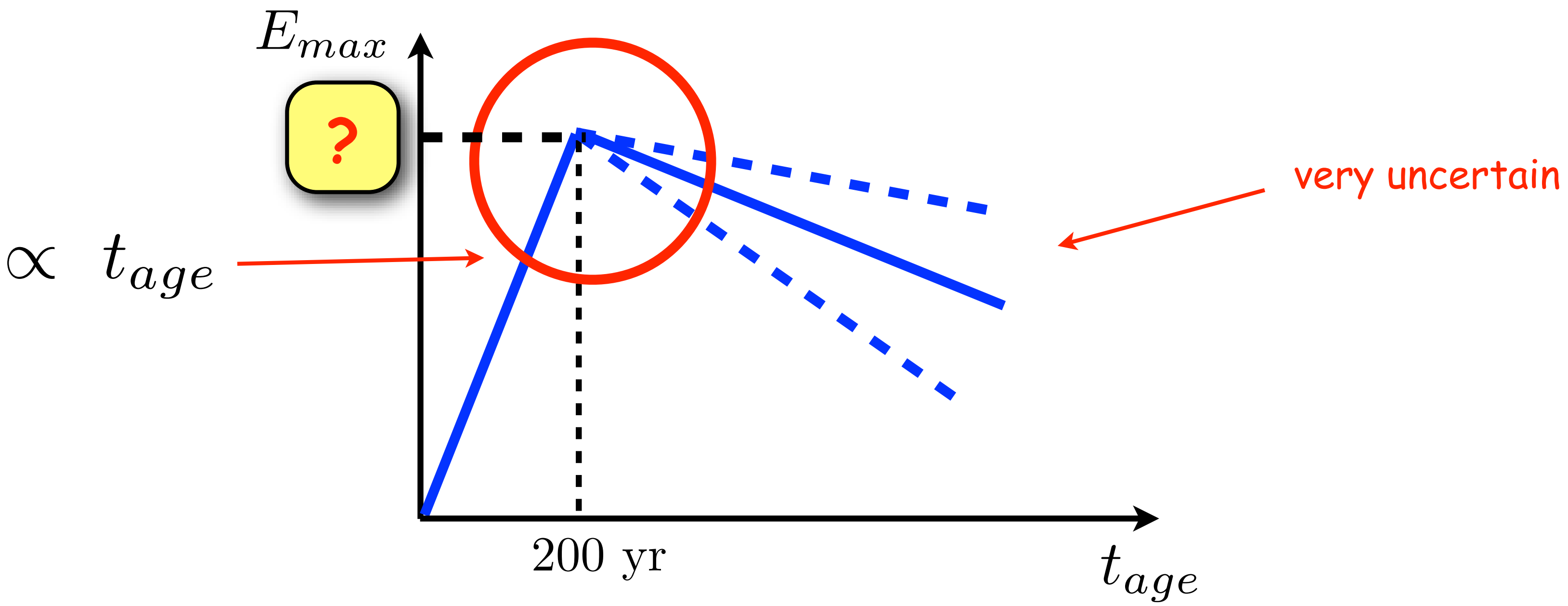
-> UNIVERSAL SPECTRUM

$$\boxed{n(E) \propto E^{-2}}$$

It doesn't depend on:

- shock velocity/Mach number
- gas density/pressure
- magnetic field intensity and/or structure
- diffusion coefficient ...

Can SNRs accelerate CRs up to the knee? YES!



$$\frac{D_B(E_{max})}{v_{FE}^2} = t_{Sedov}$$

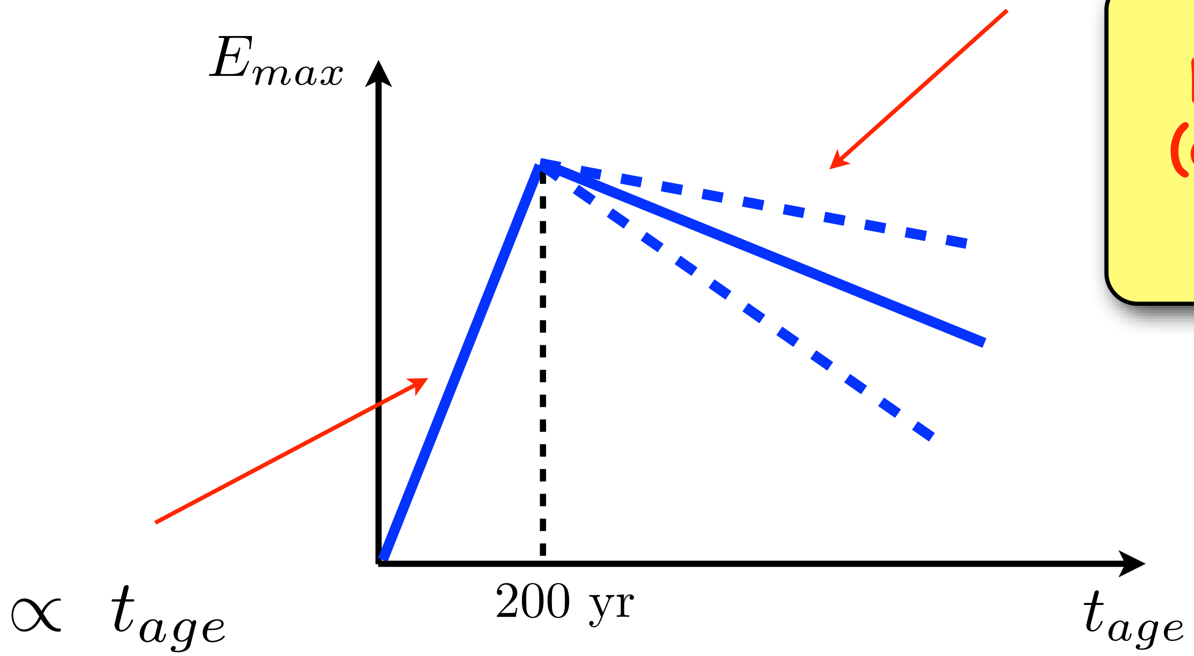
$$\Rightarrow \quad E_{max} \approx 20 \left(\frac{B}{100\ \mu\mathrm{G}} \right) \left(\frac{v_{FE}}{10^9\ cm/s} \right)^2 \left(\frac{t_{Sedov}}{200\ \mathrm{yr}} \right) PeV$$

Particle escape from SNRs

$$E_{max} \propto t_{age}^{-\delta}$$

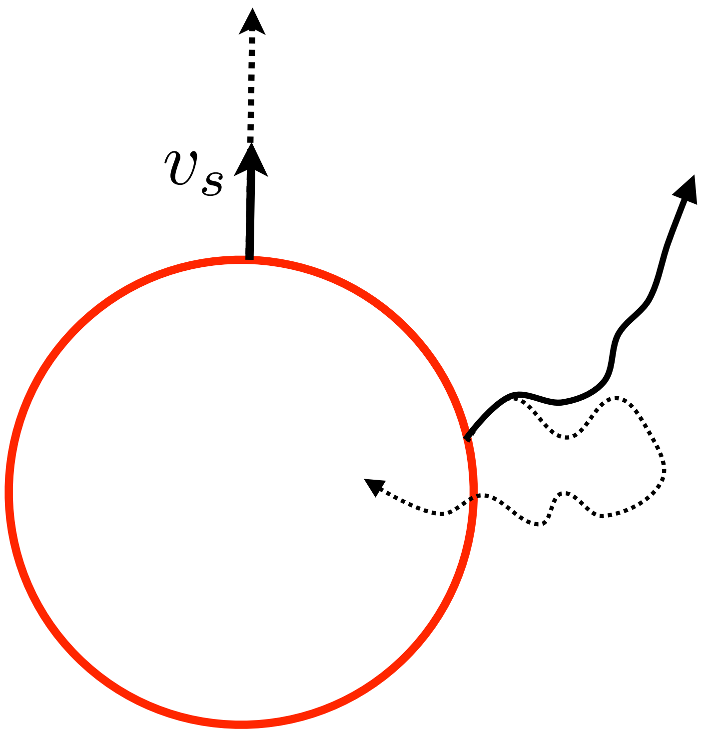
δ is basically unknown

particles with $E>E_{max}$
(accelerated at $t<t_{age}$)
escape the SNR



no particle escape

Particle escape from SNRs



This is a supernova remnant

- PeV particles are accelerated at the beginning of Sedov phase (~200yrs), when the shock speed is high!
- they quickly escape as the shock slows down
- Highest energy particles are released first, and particles with lower and lower energy are progressively released later
- a SNR is a PeVatron for a very short time
- still no evidence for the existence of escaping CRs

Summarizing:

SNRs are good candidate sources for CRs because:

- they can provide the right amount of energy in form of CRs (if **~10% efficiency**)
- they inject CRs in the ISM with (roughly) the spectrum needed to explain CR observations (**$\sim E^{-2.1 \ldots 2.4}$**)
- they can accelerate CRs (at least) up to the energy of the CR knee (**$\sim 5 \times 10^{15}$ eV**)

GCR composition

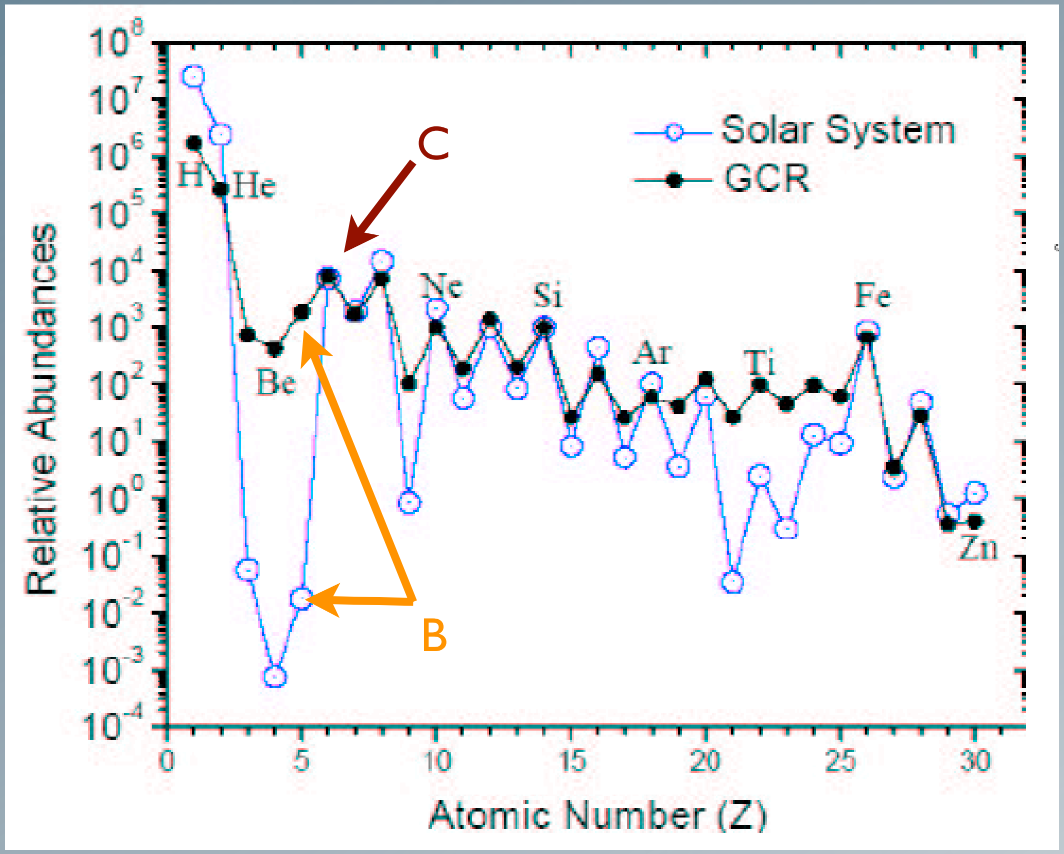


Fig. from D. Maurin

- Primary species
  - present in sources
  - element distribution following stellar nucleosynthesis
  - accelerated in supernova shockwaves
- Secondary species
  - much larger relative abundance than in stellar environments
  - produced by interaction of primary cosmic rays with interstellar medium

Cosmic ray propagation

- Little known about Galactic magnetic field distribution
- Magnetic fields confine CRs in galaxy for $E \lesssim 10^3\,\mathrm{TeV}$
- Random distribution of field inhomogeneities
  $\rightsquigarrow$ propagation well described by diffusion equation

$$\boxed{\frac{\partial\psi}{\partial t} - \nabla\cdot(D\nabla - v_c)\psi + \frac{\partial}{\partial p} b_{\mathrm{loss}}\psi - \frac{\partial}{\partial p} K \frac{\partial}{\partial p}\psi = q_{\mathrm{source}}}$$

often set to 0 (stationary config.)

Diffusion coefficient, often $D \propto \beta(E/q)^\delta$

convection

energy losses

diffusive reacceleration $K \propto v_a^2 p^2 / D$

Sources (primary & secondary)

CHARGED (GALACTIC) COSMIC RAYS

are charged particles (nuclei, isotopes, leptons, antiparticles) diffusing in the galactic magnetic field
Observed at Earth with E~ 10 MeV/n – 10^3 TeV/n

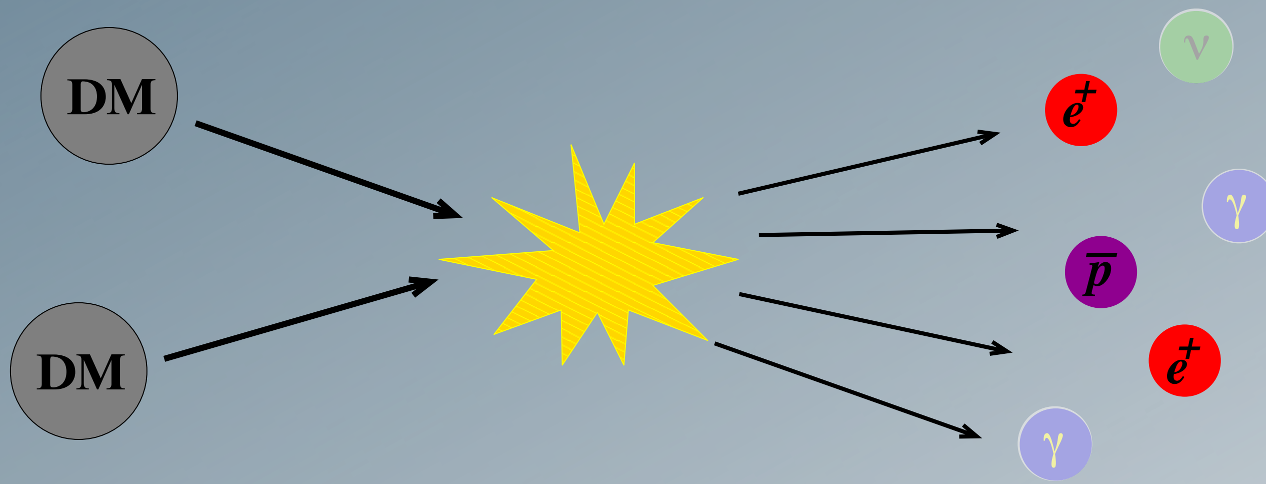
1. **SOURCES**
   PRIMARIES: directly produced in their sources
   SECONDARIES: produced by spallation reactions of primaries on the interstellar medium (ISM)

2. **ACCELERATION**
   SNR are considered the powerhouses for CRs. They can accelerate particles up to 10^2 TeV

3. **PROPAGATION**
   CRs are diffused in the Galaxy by the inhomogeneities of the galactic magnetic field.

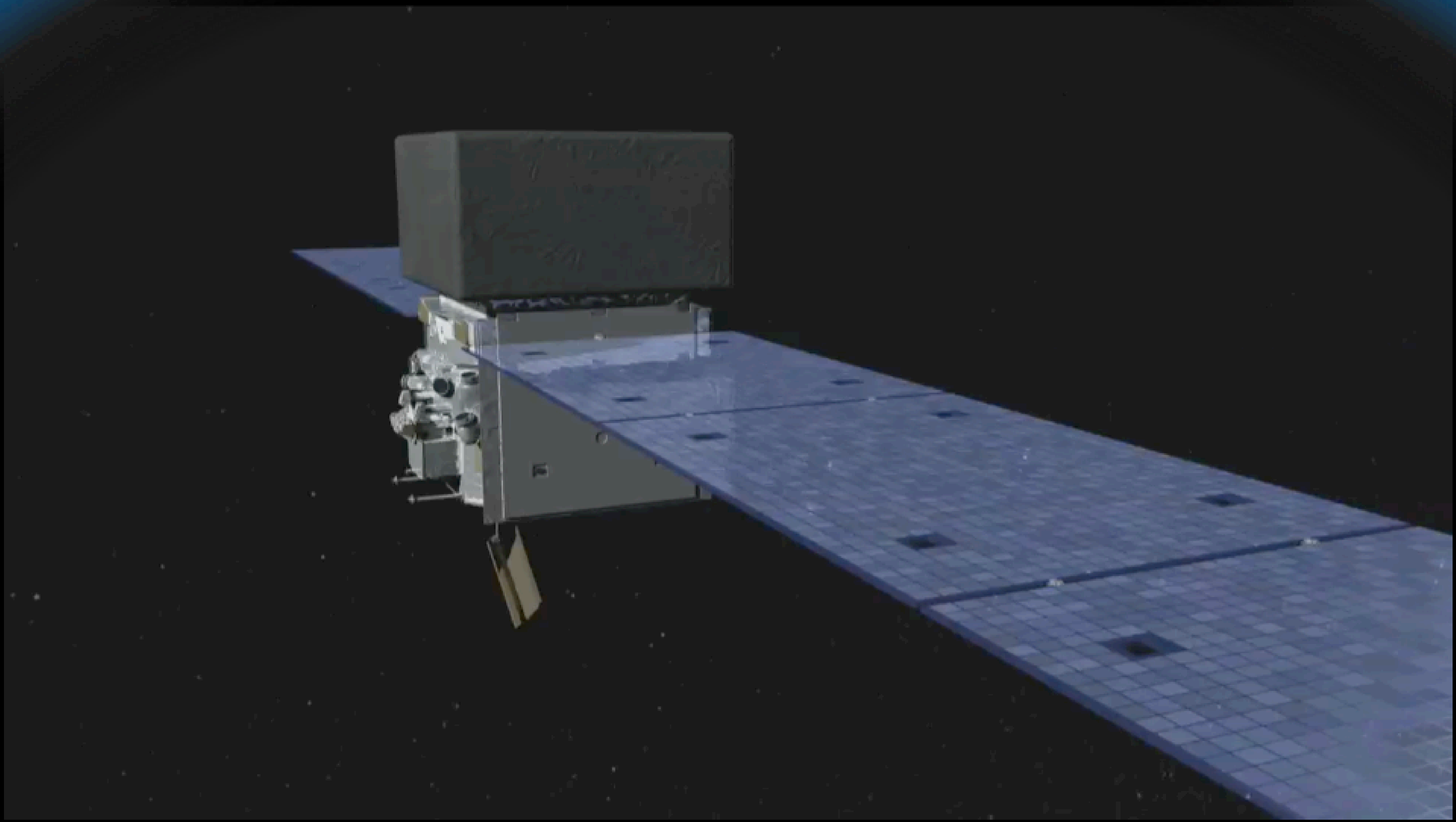
\+ loose/gain energy with different mechanisms

Charged cosmic rays

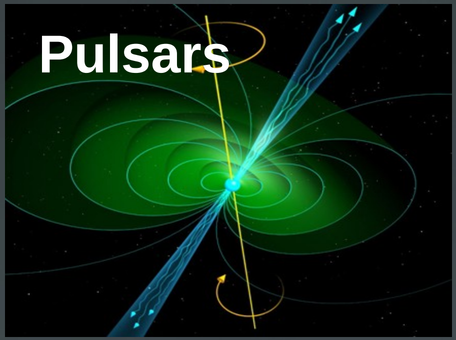


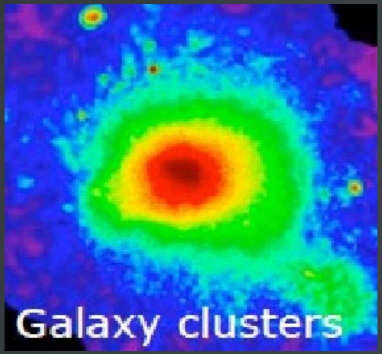
- GCRs are confined by galactic magnetic fields
- After propagation, no directional information is left
- Also the spectral information tends to get washed out
- Equal amounts of matter and antimatter
  ⇨ focus on antimatter (low backgrounds!)

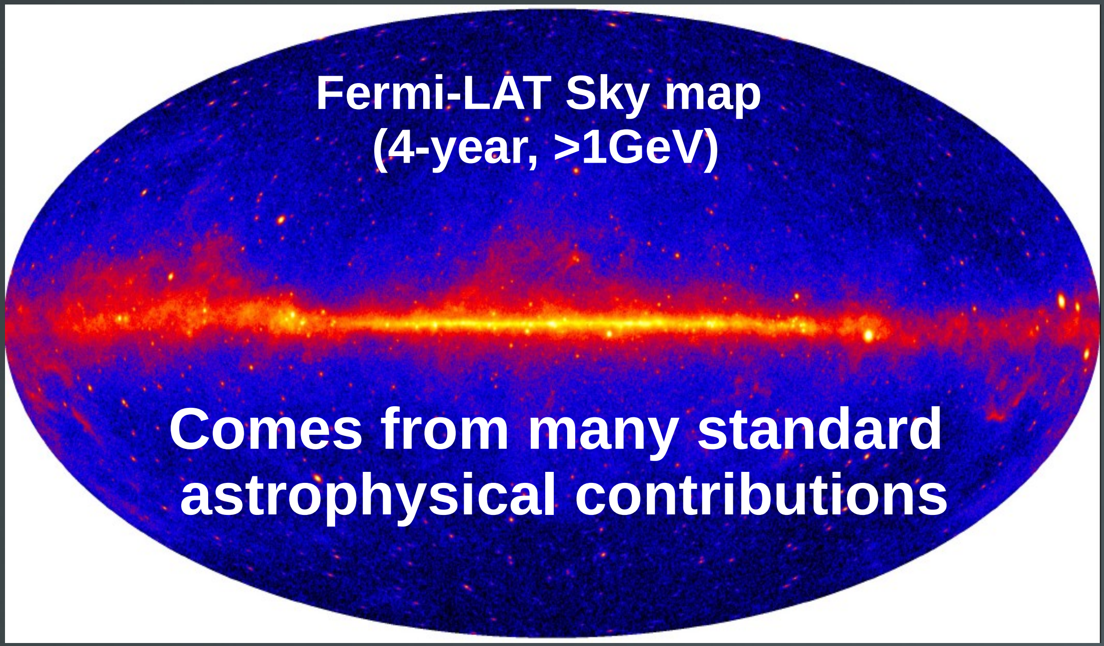
Modern Generation: Fermi GST



The GeV-TeV Gamma-ray Sky

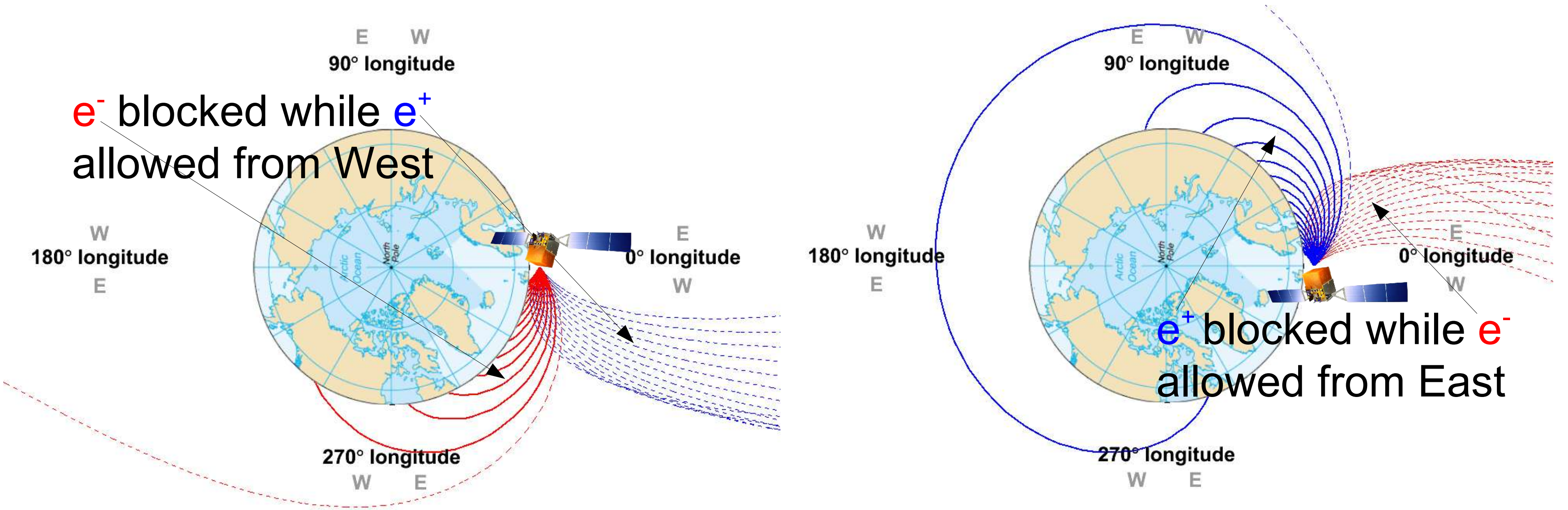






**Unidentified
??**

Principle: Use the Earth's Magnetic Field to Distinguish e^+ and e^-

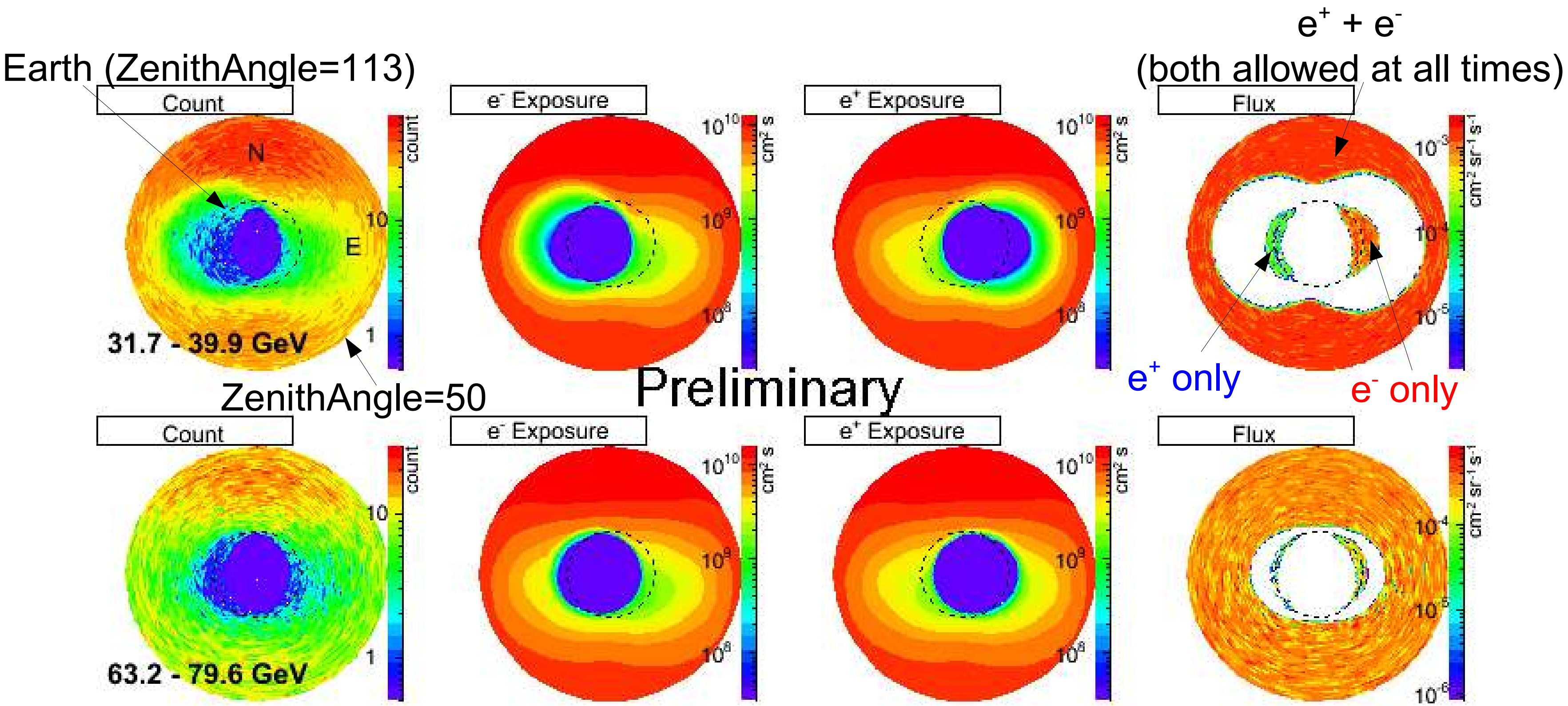


- **Pure e^+ region is in the west and same for e^- in the east**
- **The regions vary with particle energy and the LAT position**
- **To locate these regions, we use a code written by Smart, D. F. and Shea, M. A.* which numerically calculates a particle's trajectory in the geomagnetic field**

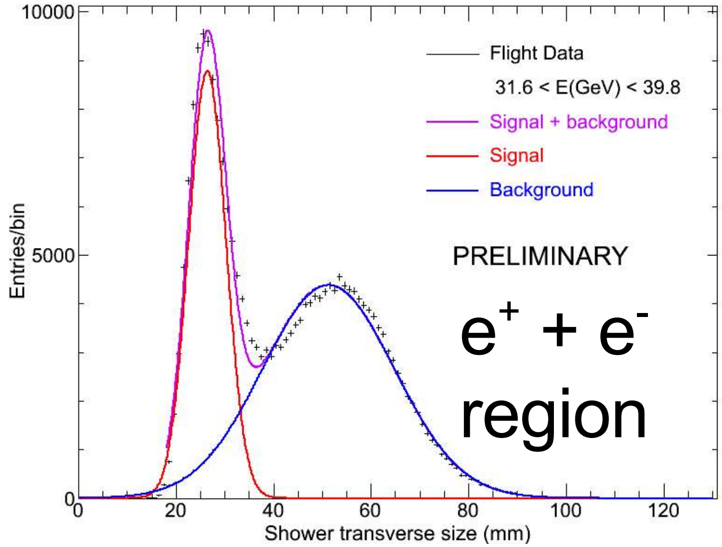
Center for Space Plasmas and Aeronomic Research, The University of Alabama in Huntsville

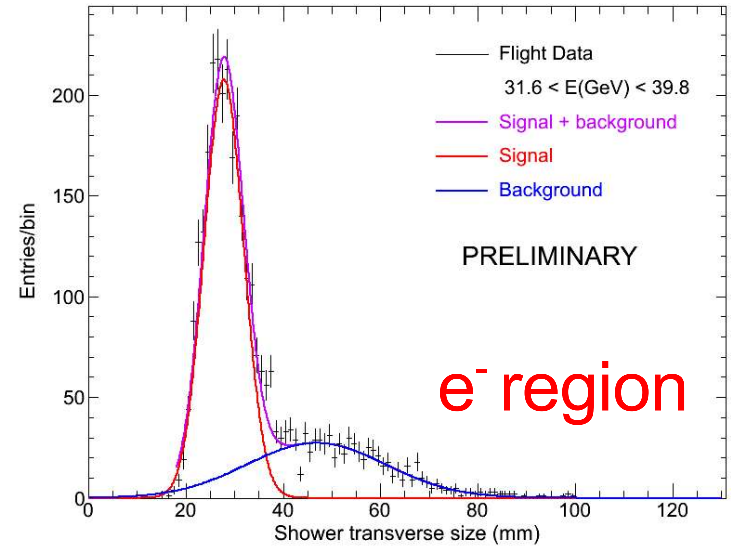
Data

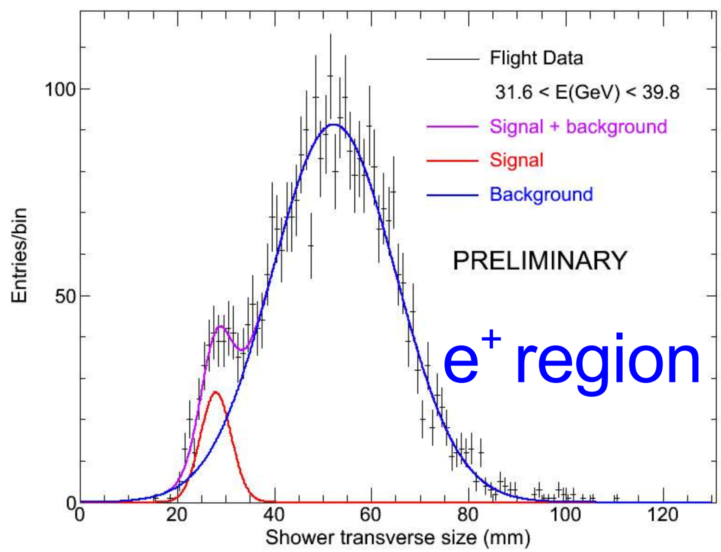
- **All data when the Earth limb is within 60 deg from the center of the LAT's field of view, up to April 15, 2011 (~41 days of livetime)**
- **Logarithmic energy binning, 10 bins per decade, starting from 20 GeV**



Background Subtraction: Fit-Based

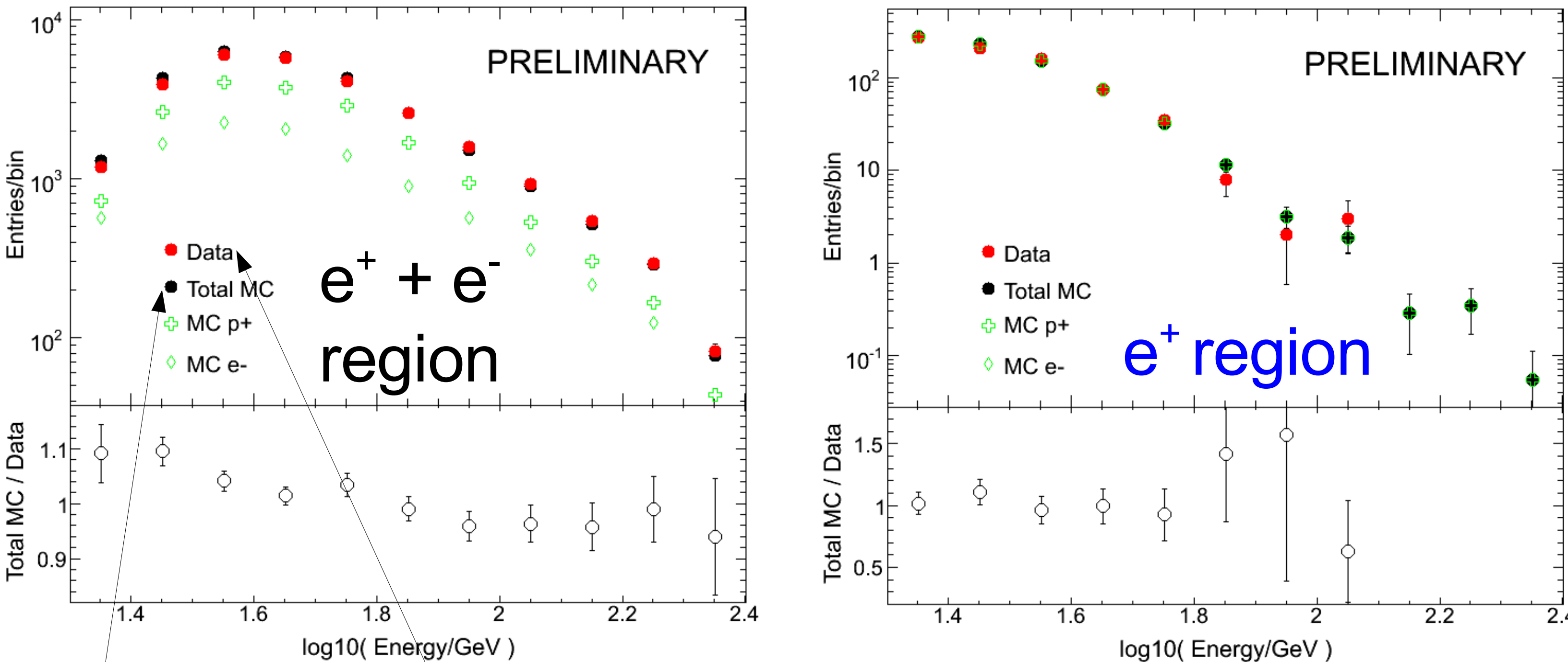






- **Two Gaussians fit well**
- **Fitting is stable for** $e^+ + e^-$ **and** e^-**, but is more challenging for** e^+ **because the statistics is lower**

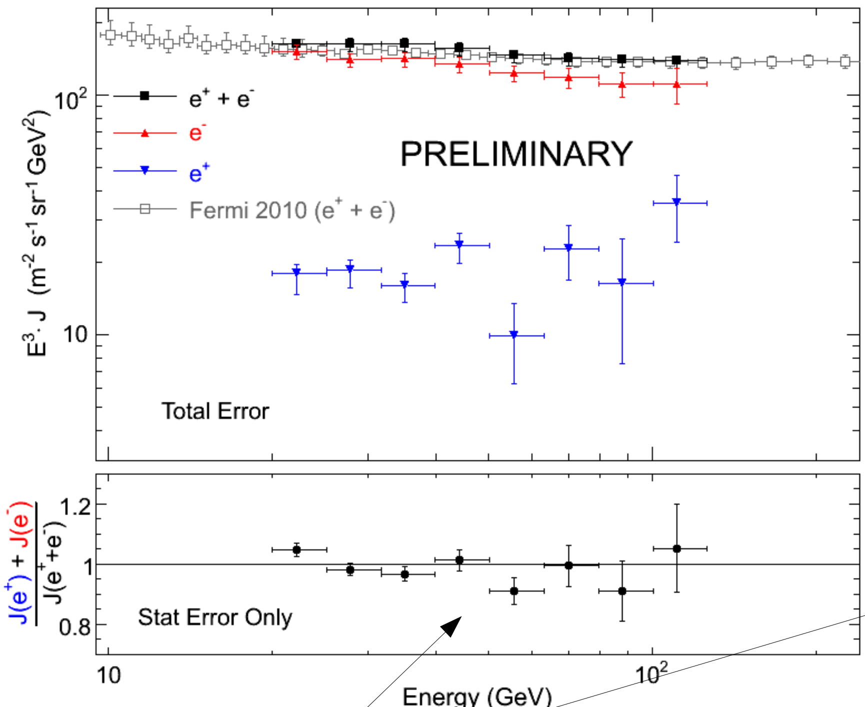
Background Subtraction: MC-Based



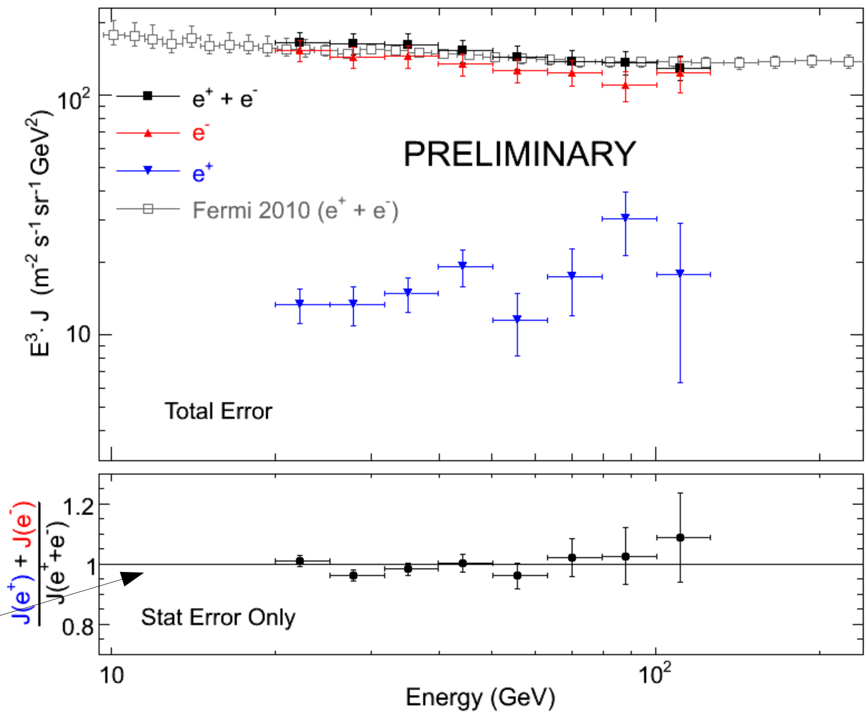
- **Simulations and data are shown at high-level event selection with an inverted criterion because we want to eliminate the signal and keep the background for comparison**
- **Simulations and data in** $e^+ + e^-$ region **and** e^+ region **agree within ~15%, sufficient for this analysis, which is dominated by statistical uncertainties**

e^+ and e^- Spectra

Fit-Based Result



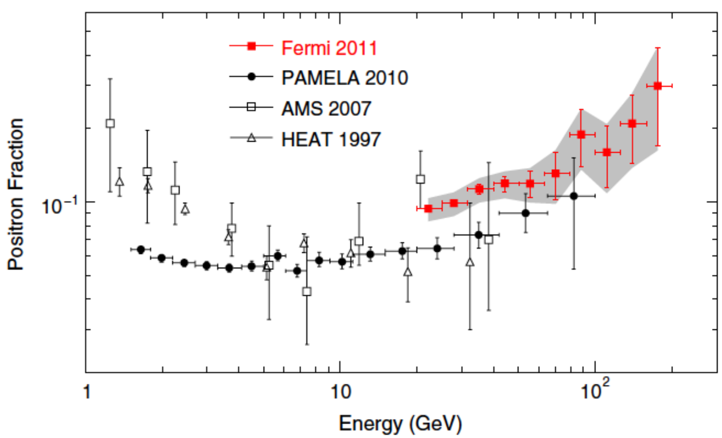
MC-Based Result

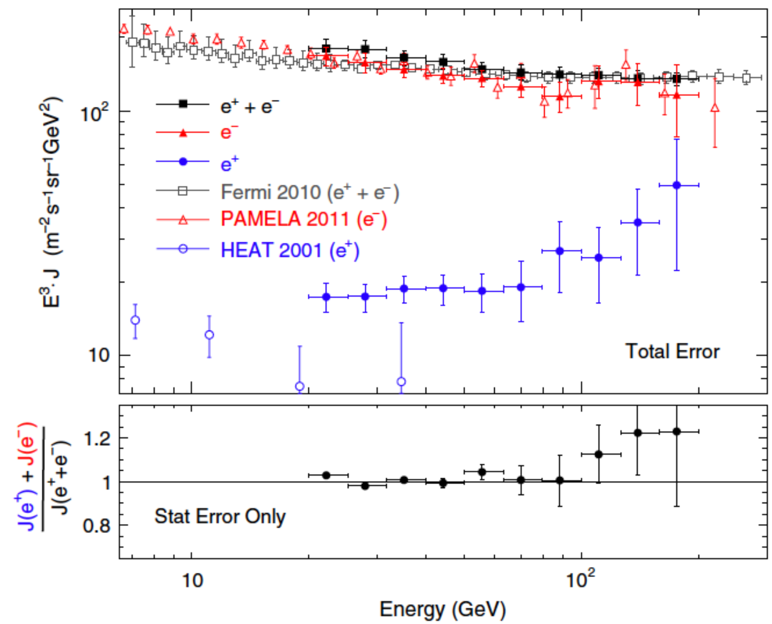


The ratio of the sum $J(e^+)+J(e^-)$ and the total flux $J(e^++e^-)$ being compatible with 1 shows that each method is self-consistent

Conclusion

- The Fermi-LAT has measured the cosmic-ray e^+ and e^- spectra separately, between 20 – 200 GeV, using the Earth's magnetic field as a charge discriminator
  - First measurement of absolute e^+ spectrum above 50 GeV
  - First published e^+ fraction above 100 GeV
- Two independent methods of background subtraction, Fit-Based and MC-Based, produce consistent results
- The observed e^+ fraction rises with energy, showing no sign of decreasing between 100-200 GeV



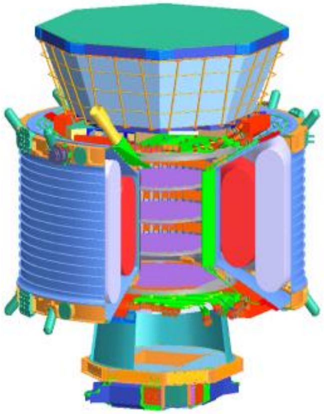


Antimatter Missions in “Space”

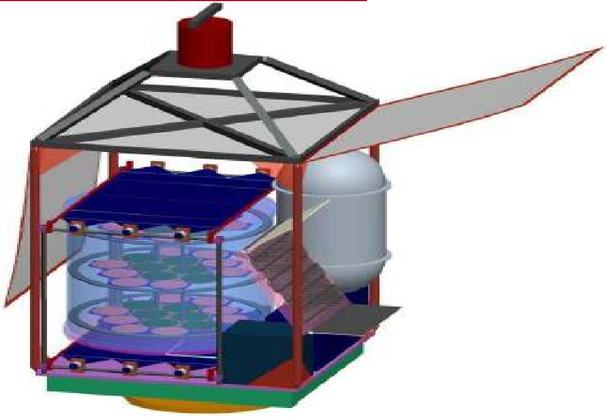
BESS LDBF
2004, 2007

PAMELA
2006-

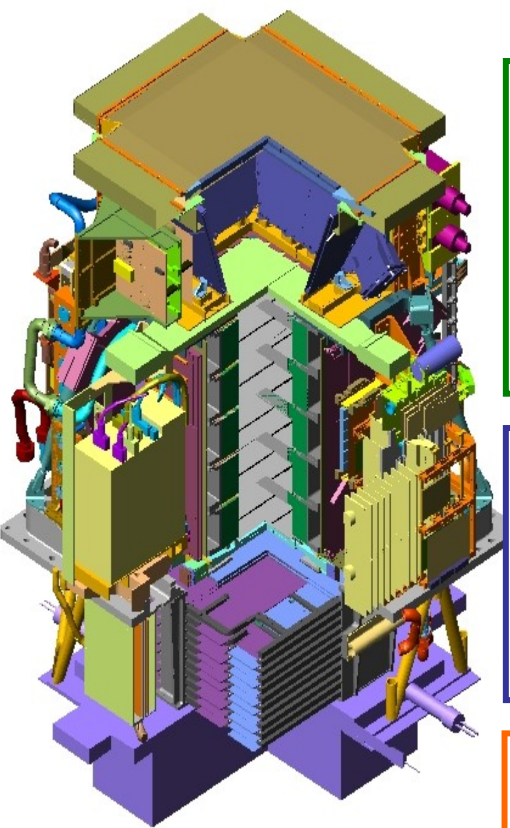
AMS-02
2011-



GAPS
2017?



PAMELA: high particle identification capabilities



Time-Of-Flight

plastic scintillators + PMT:

- Trigger
- Albedo rejection;
- Mass identification up to 1 GeV;
- Charge identification from dE/dX

Electromagnetic calorimeter

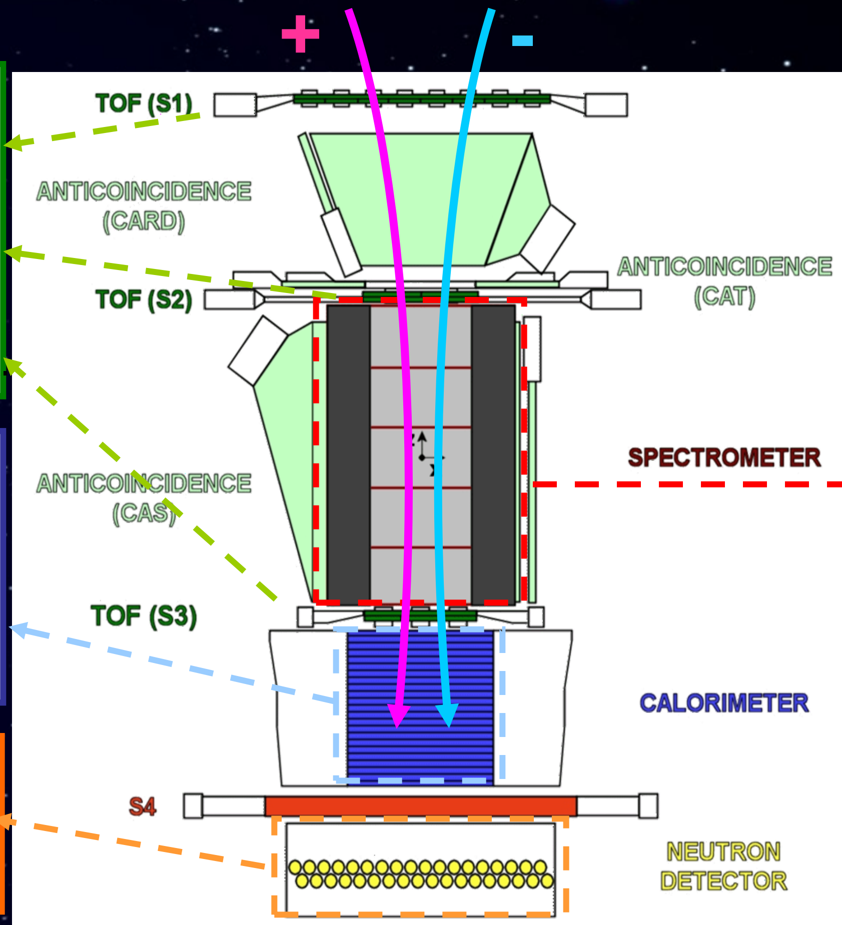
W/Si sampling (16.3 X_0, 0.6 λ_I)

- Discrimination e^+ / p, p-bar / e^- (shower topology)
- Direct E measurement for e^-

Neutron detector

^{3}He tubes + polyethylene moderator:

- High-energy e/h discrimination



GF: 21.5 cm^2 sr
Mass: 470 kg
Size: 130x70x70 cm^3
Power Budget: 360W
Today: 2529th day in orbit

Spectrometer

microstrip silicon tracking system + permanent magnet

It provides:

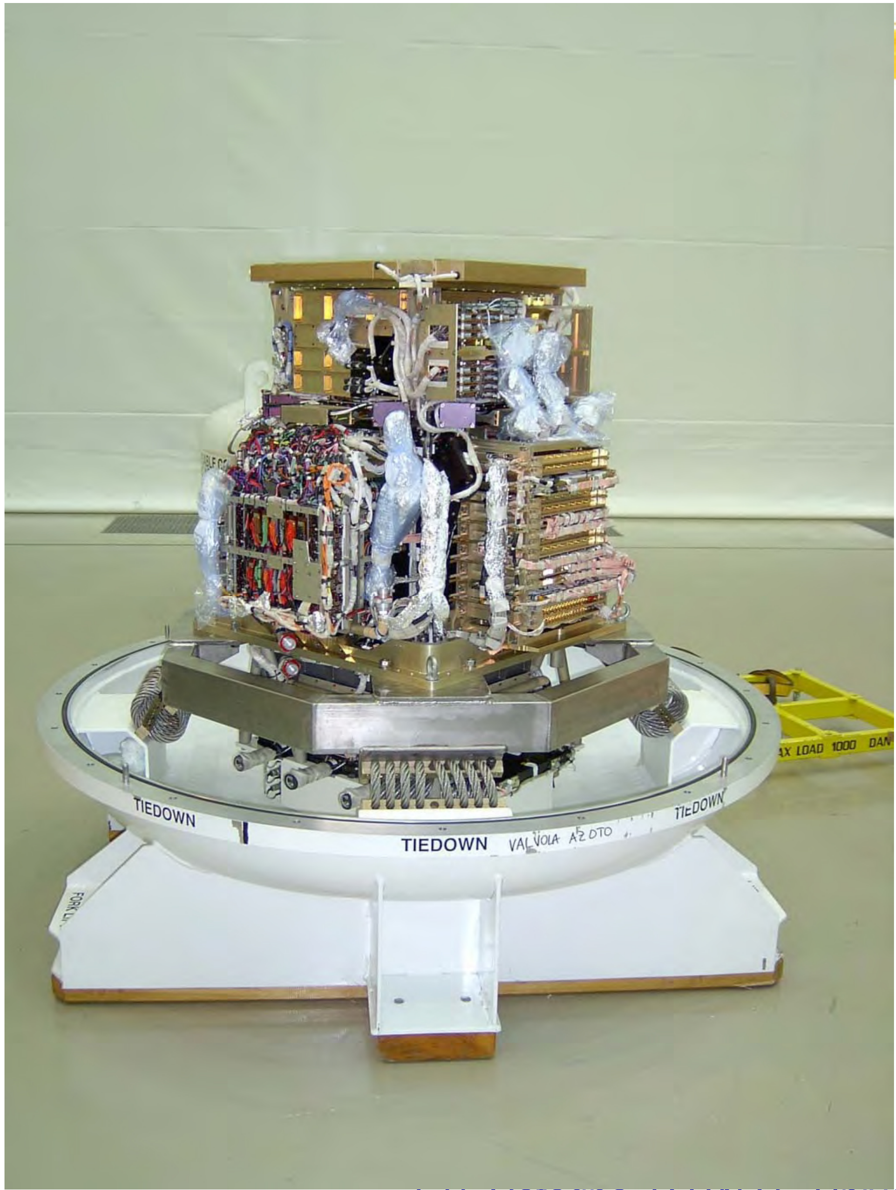
- Magnetic rigidity → R = pc/Ze
- Charge sign
- Charge value from dE/dx

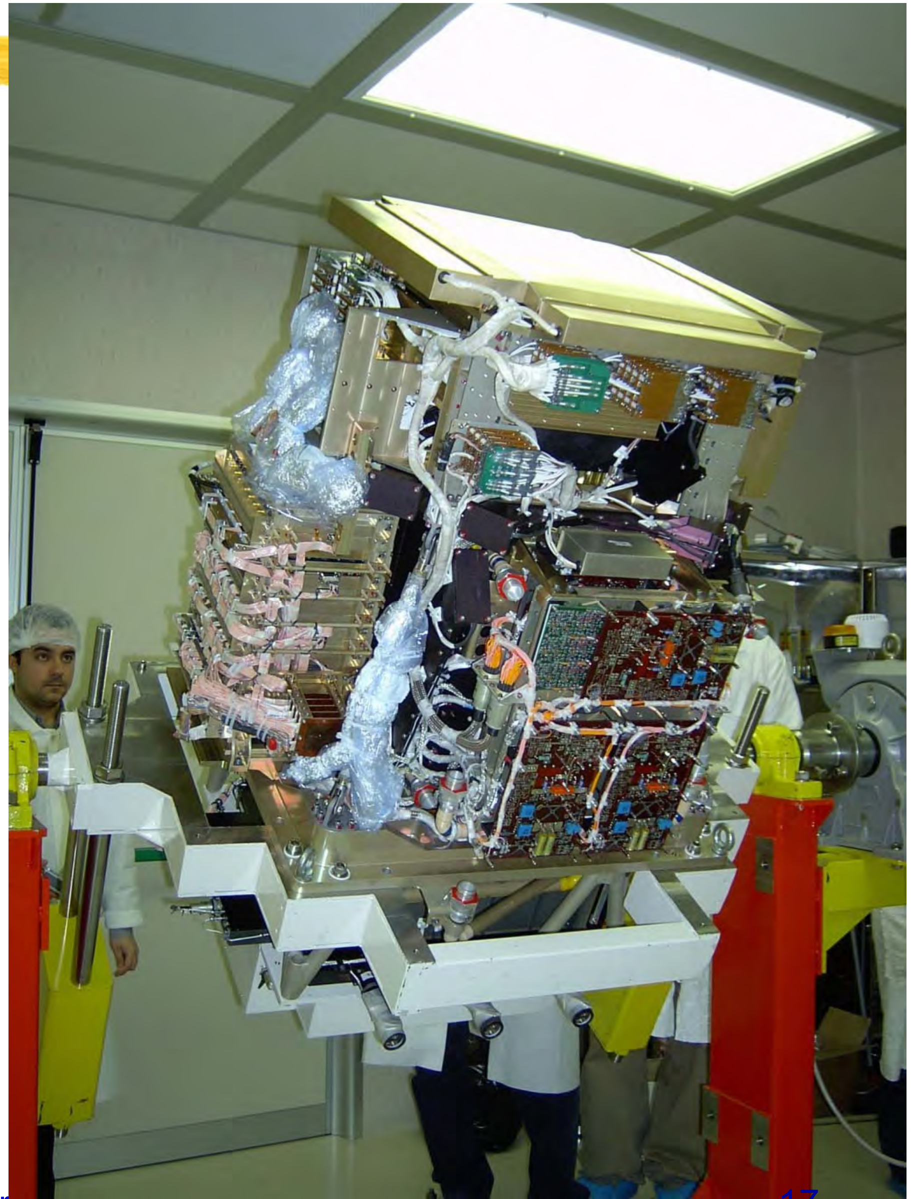
Design Performance

• Antiprotons	80 MeV - 150 GeV
• Positrons	50 MeV – 270 GeV
• Electrons	up to 400 GeV
• Protons	up to 700 GeV
• Electrons+positrons	up to 2 TeV (calorimeter alone)
• Light Nuclei (He/Be/C)	up to 200 GeV/n
• AntiNuclei search	sensitivity of 3×10^{-8} in $\overline{\mathrm{He}}/\mathrm{He}$

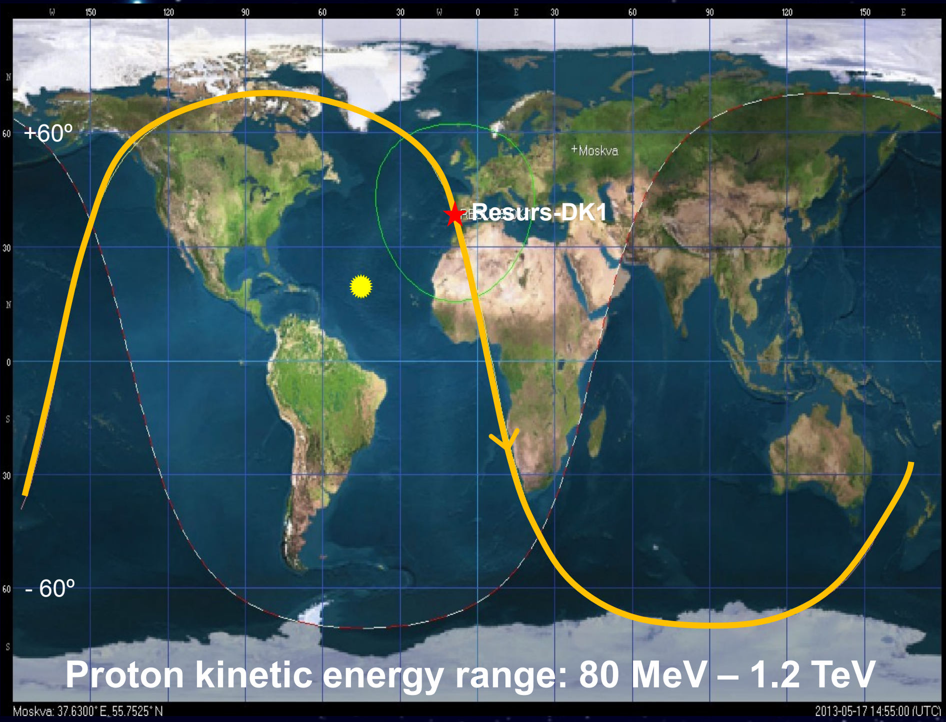
→ Simultaneous measurement of many cosmic-ray species
→ New energy range
→ Unprecedented statistics

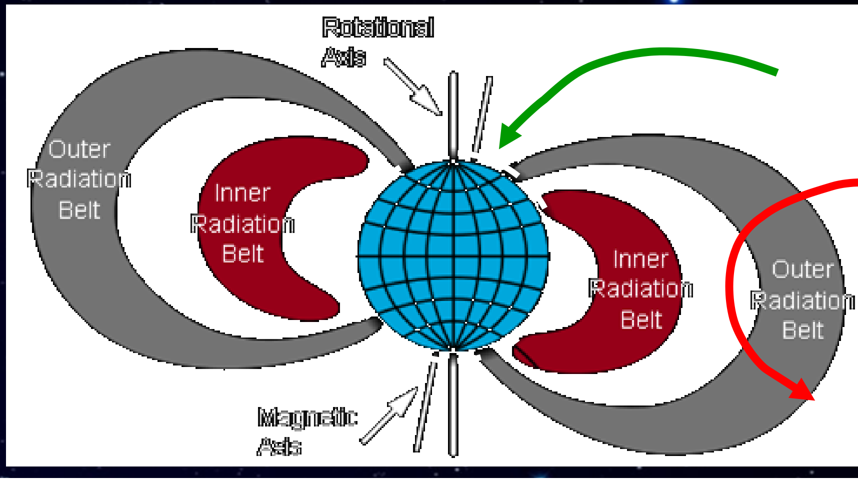
PAMELA: the integration



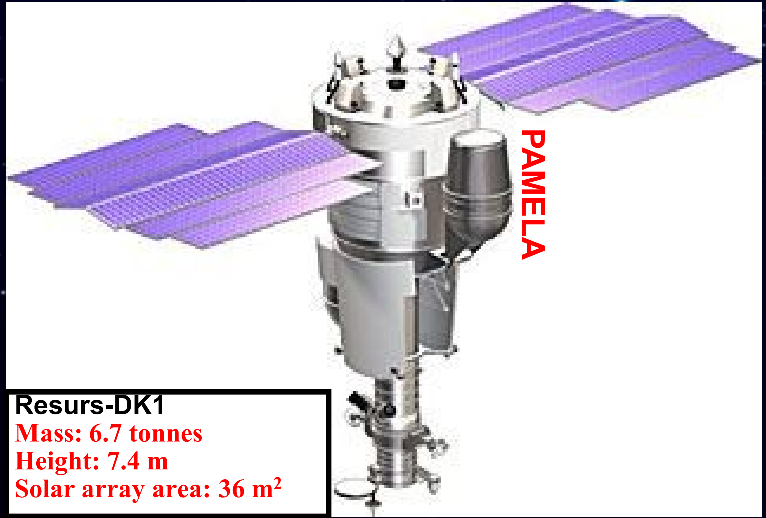


Resurs-DK1: low energy cutoff orbit

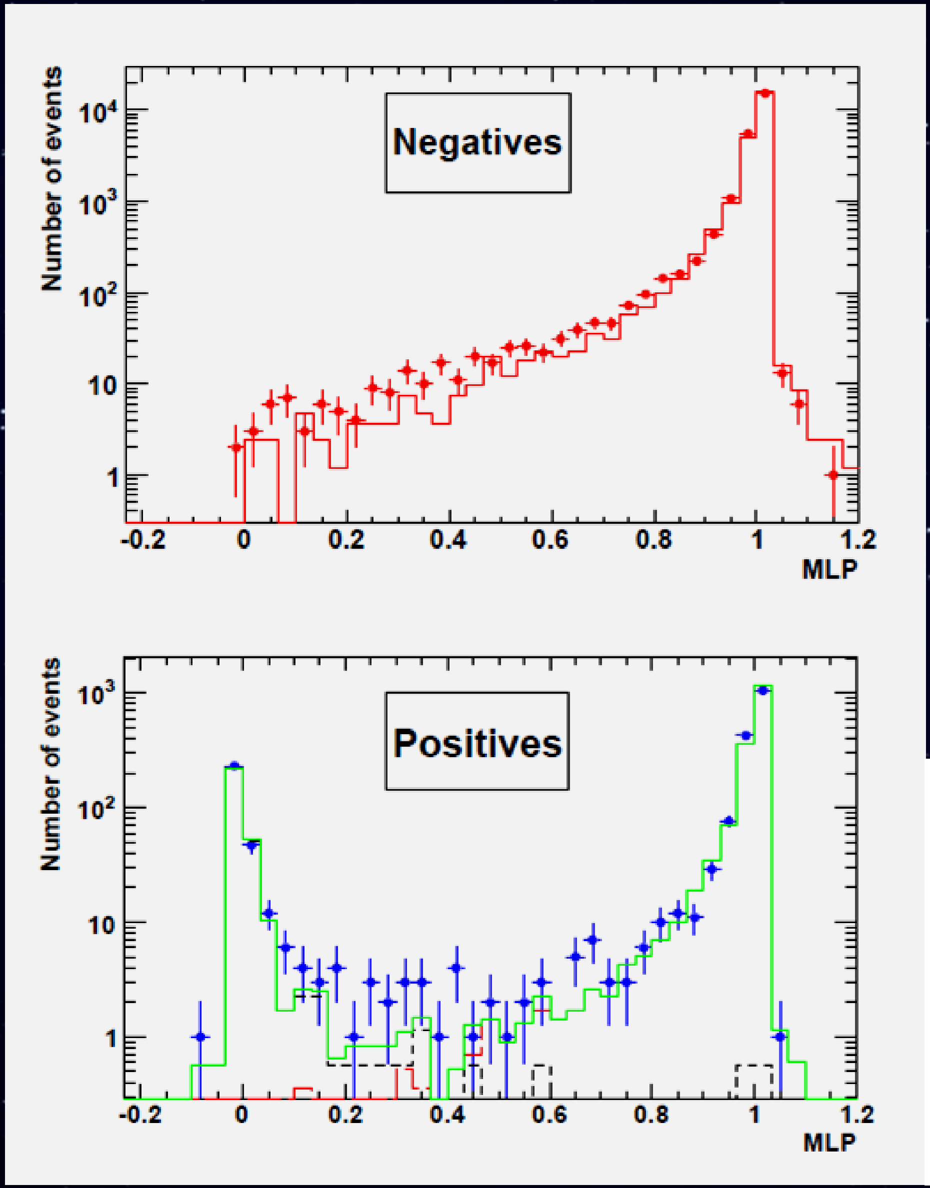




- Resurs-DK1 satellite: multi-spectral imaging of Earth's surface
- PAMELA mounted inside a pressurized container
- Launch 15/06/2006 - lifetime >3 years (assisted), extended till end of satellite operations
- Data transmitted to NTsOMZ, Moscow via high-speed radio downlink, ~16 GB / day
- Quasi-polar and elliptical orbit (70.0°, 350 km - 600 km) – from 2010 circular orbit (70.0°, 600 km)
- Traverses the South Atlantic Anomaly
- Crosses the outer radiation belts



Low energy region: many positrons



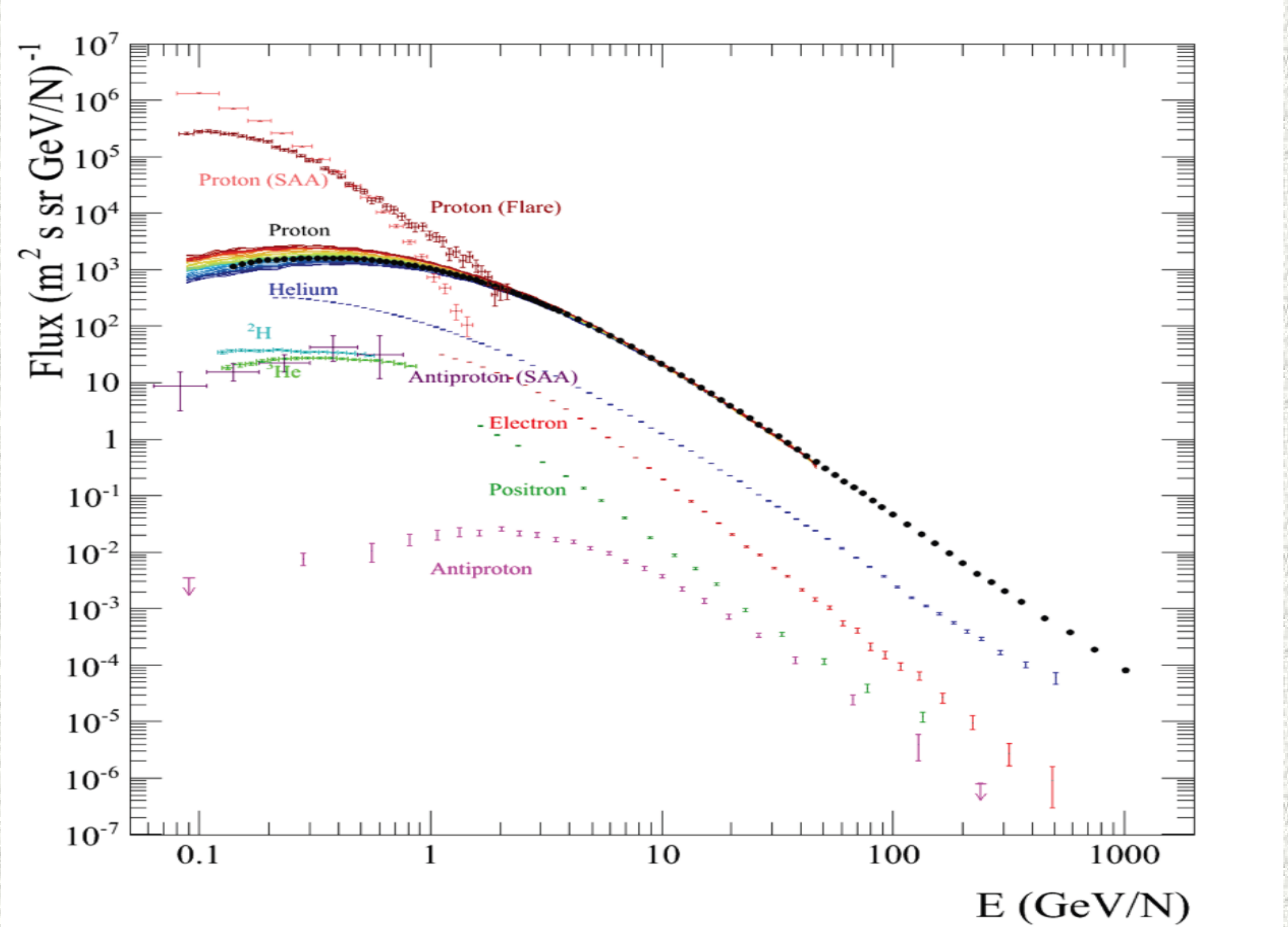
Spectral analysis using neural networks (MLP) in several cutoff and energy bins

0 – 0.75 GV cutoff bin
2.1 – 2.4 GV rigidity bin

points: real data

lines: fit with simulation MLP output shape (GEANT4)

All particle spectra (from Pamela experiment)

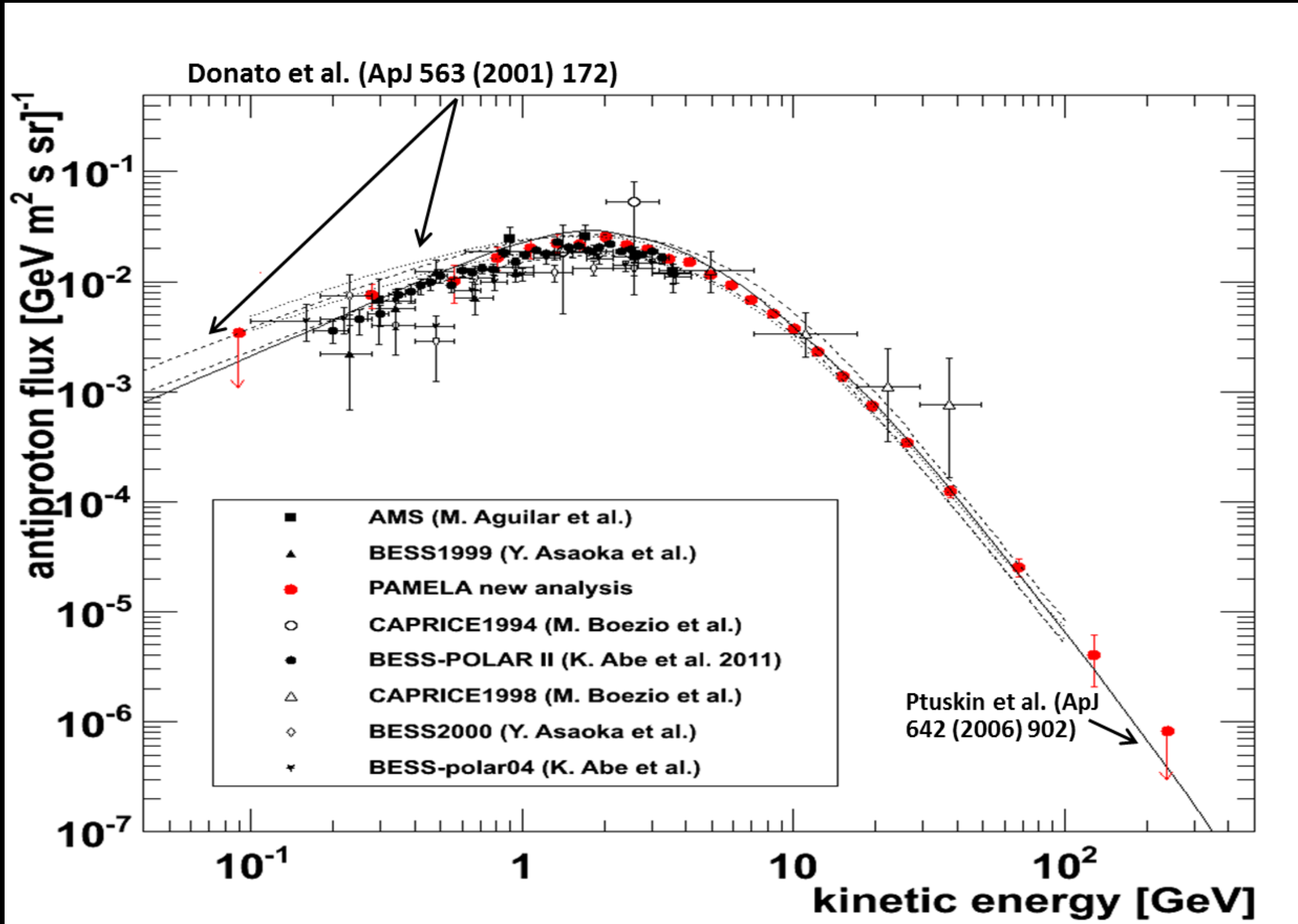


Credits: Valerio Formato & Mirko Boezio, Pamela Collaboration, 2013

Antiproton absolute flux

Apparently no extra sources

Rule out and strongly constrain many models of DM

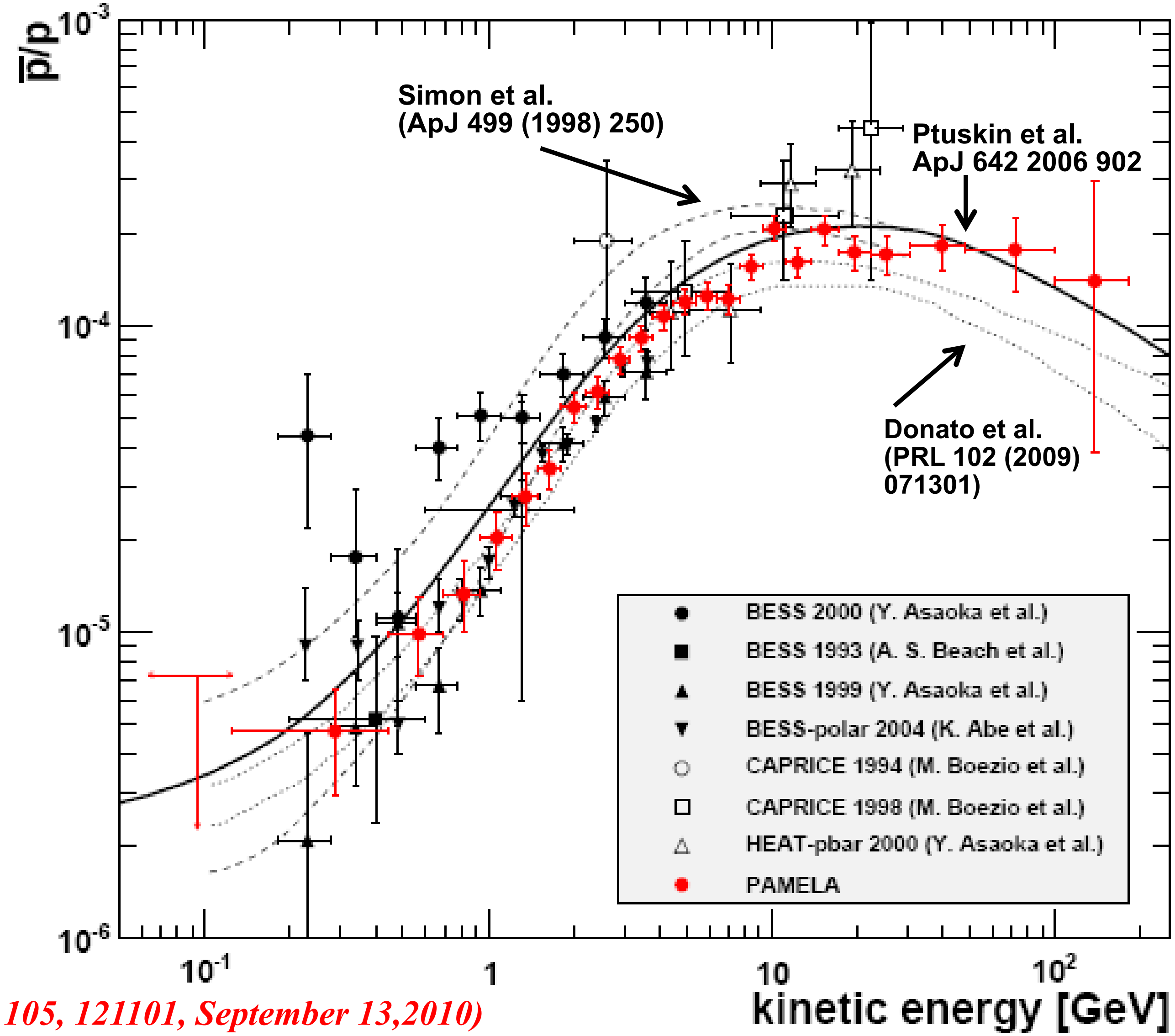


S M. Asano, et al, Phys. Lett. B 709 (2012) 128.
R. Kappl et al , PRD 85 (2012) 123522
M. Garnyet al, JCAP 1204 (2012) 033
D. G. Cerdeno, et al, Nucl. Phys. B 854

Antiproton/proton ratio

Low Energy →
Confirms charge dependent solar modulation

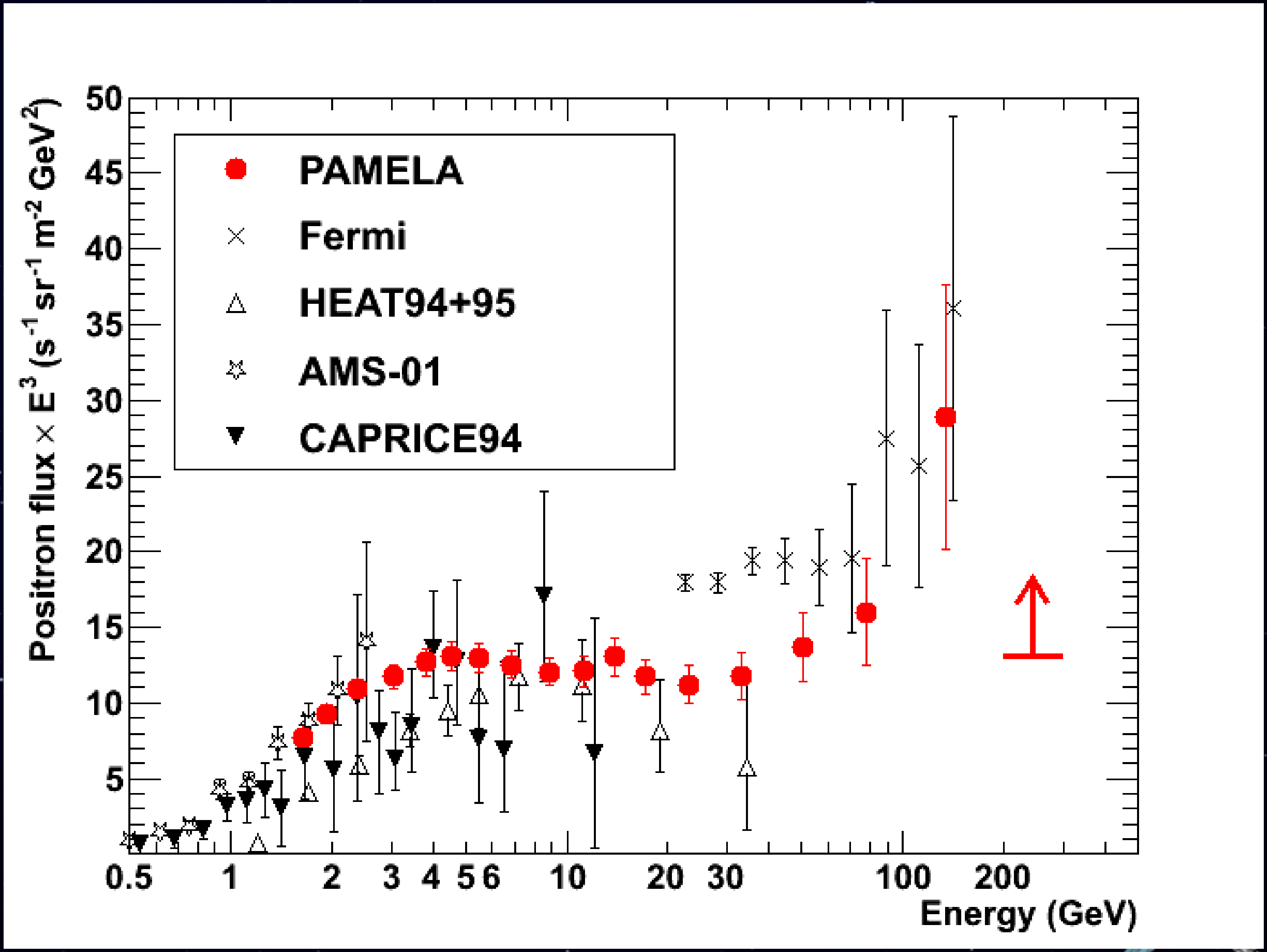
High Energy →
Consistent with models (Galprop, Donato…)



PRL. 105, 121101, September 13,2010)

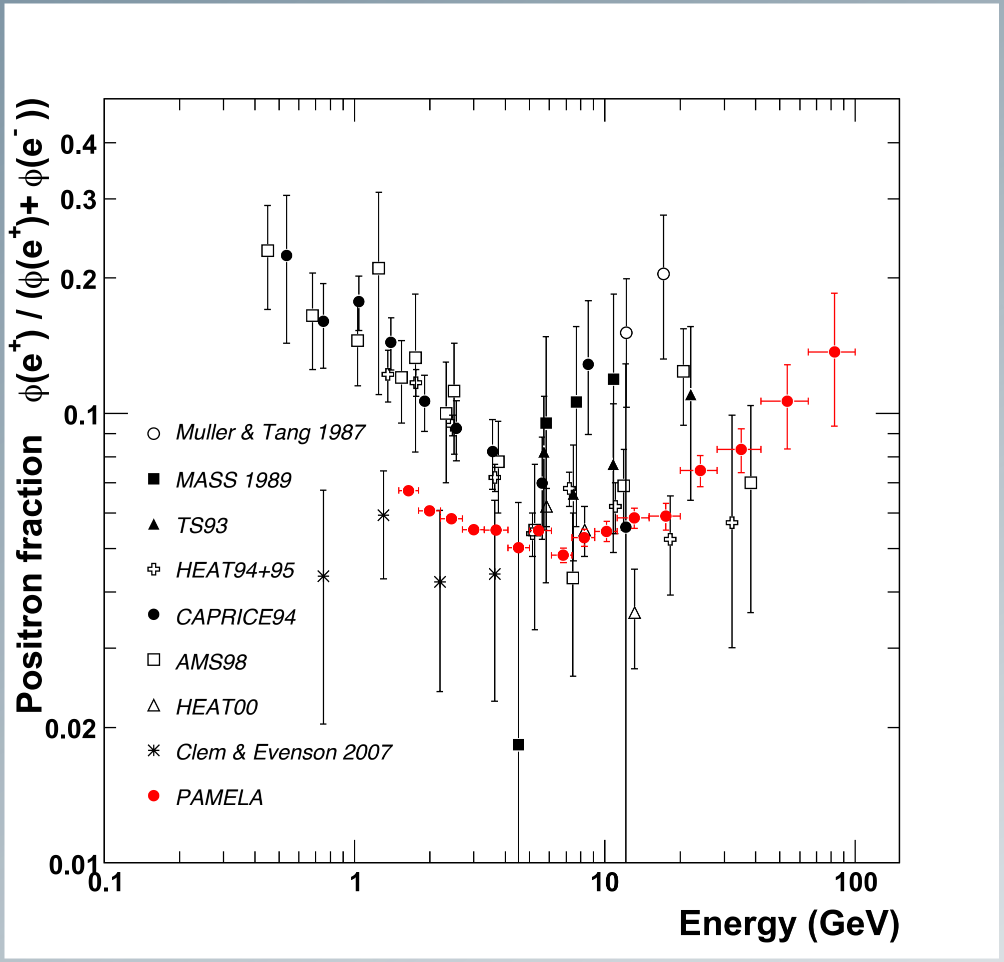
PRL 102:051101,2009

PAMELA positron flux increases above 20 GeV

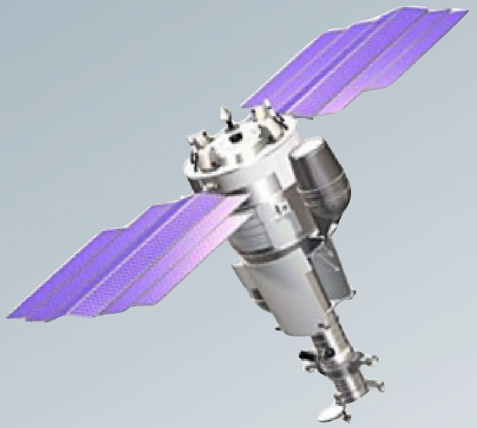


Positrons

Excess in cosmic ray positron data has triggered great excitement:

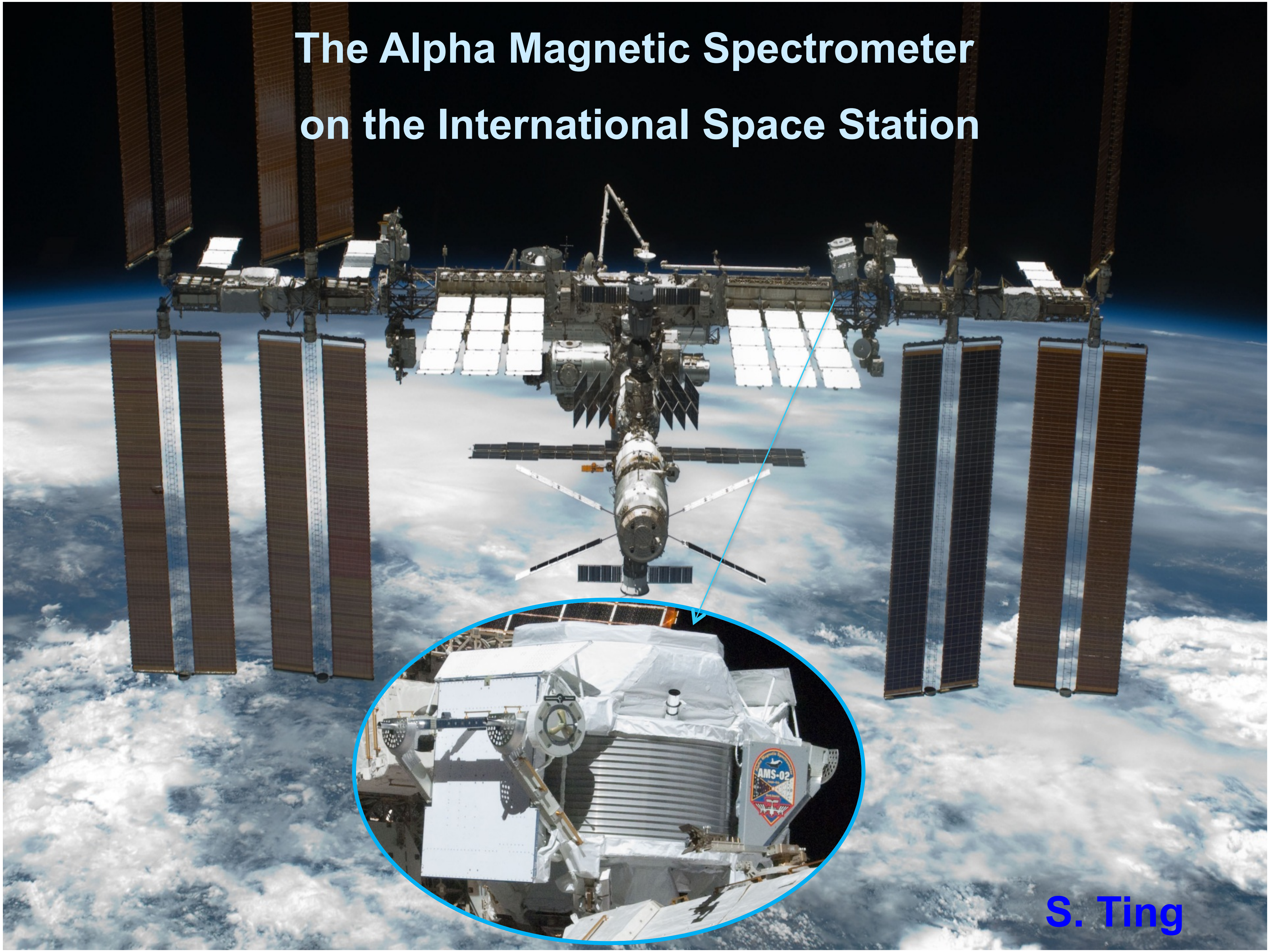


PAMELA



Adriani *et al.*, Nature '09

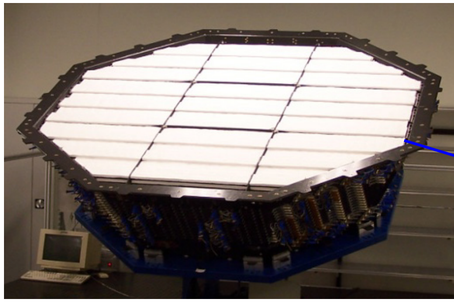
⇨ Are we seeing a DM signal ???


The Alpha Magnetic Spectrometer
on the International Space Station
AMS-02
S. Ting

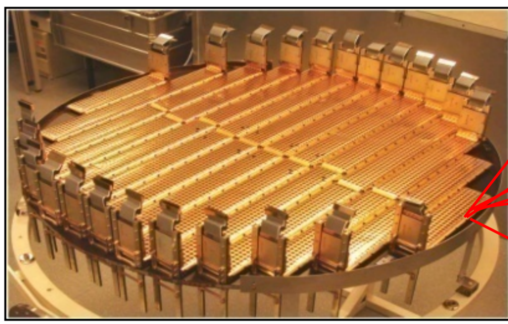
AMS: A TeV precision, multipurpose particle physics spectrometer in space.

Particles and nuclei are defined by their charge (Z) and energy (E ~ P)

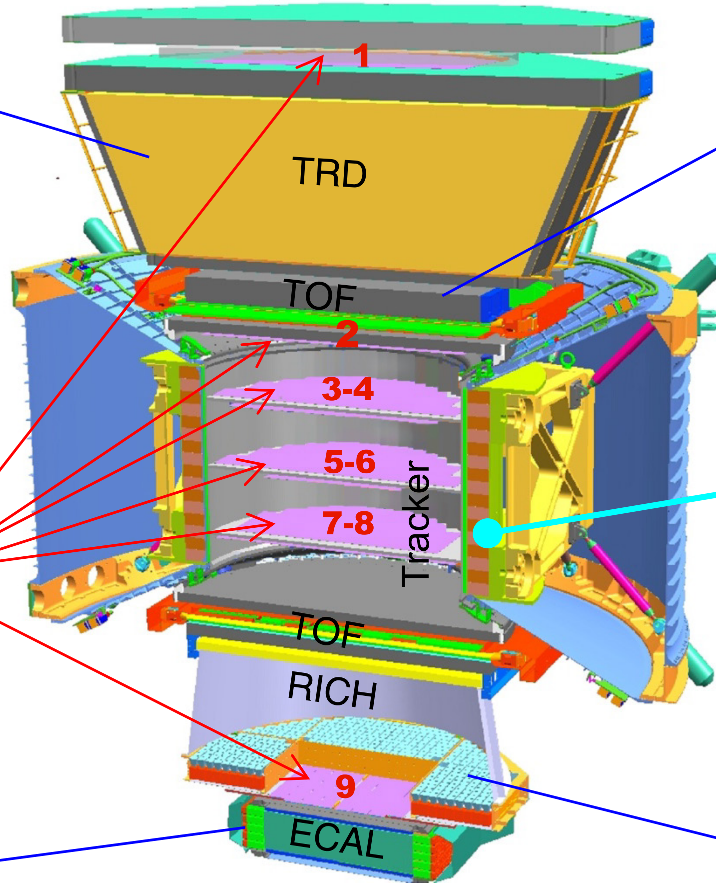
TRD
Identify e+, e-



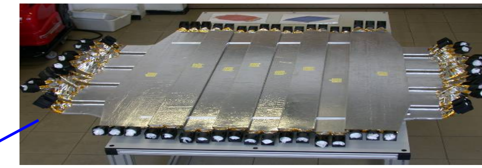
Silicon Tracker
Z, P



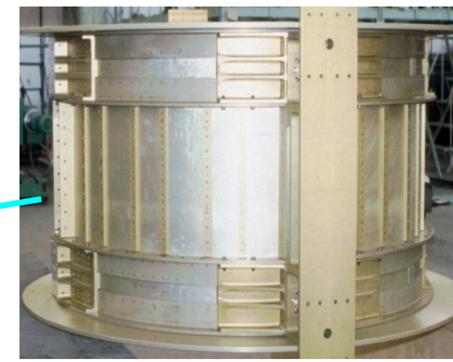
ECAL
E of e+, e-, γ



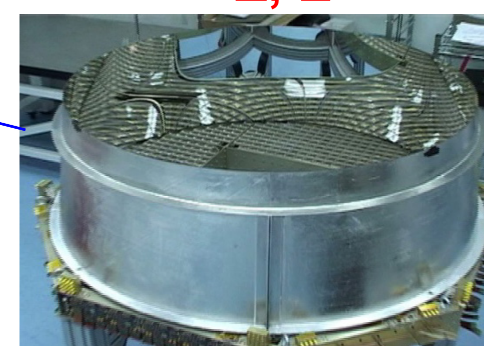
TOF
Z, E



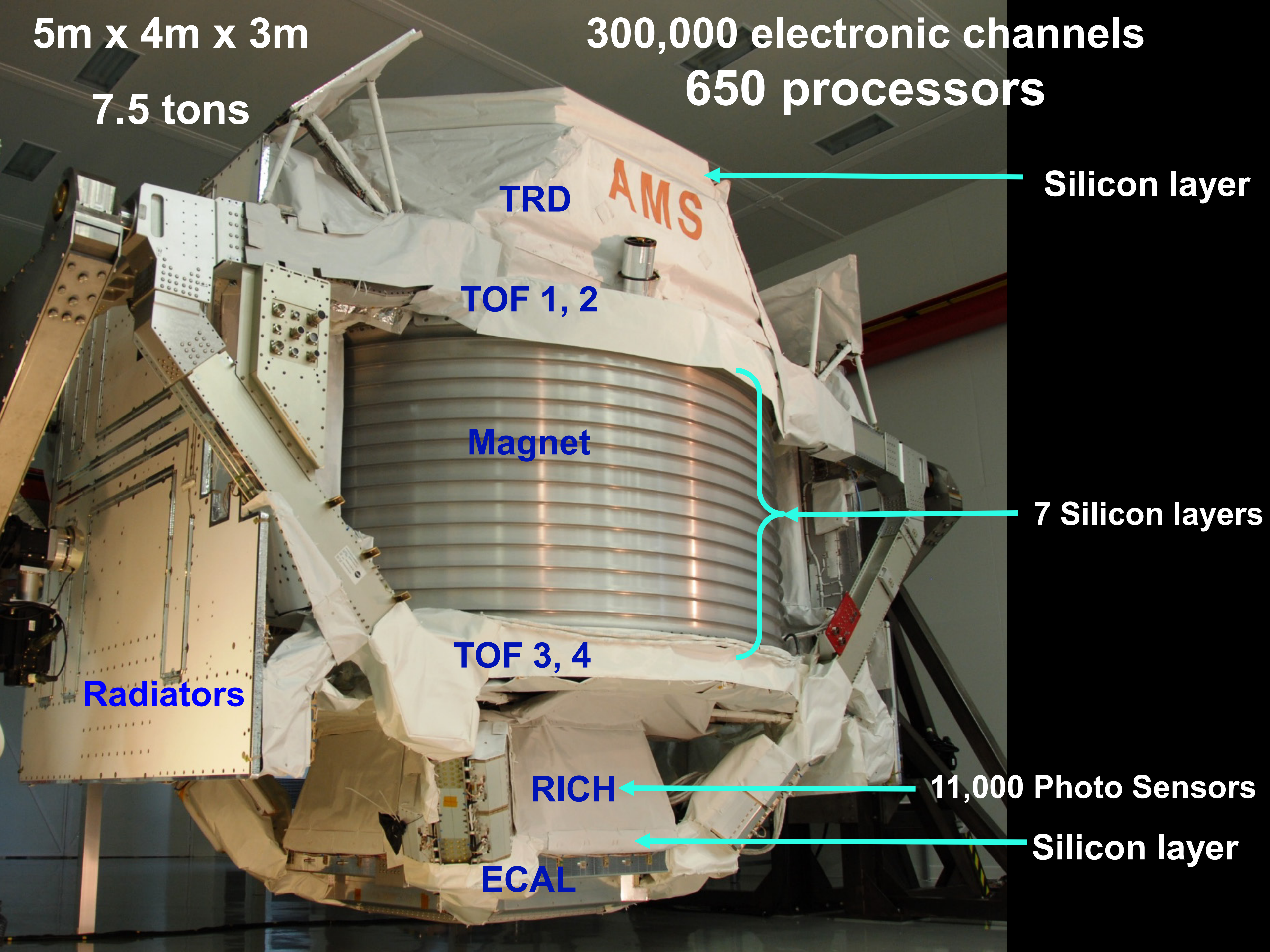
Magnet
±Z



RICH
Z, E

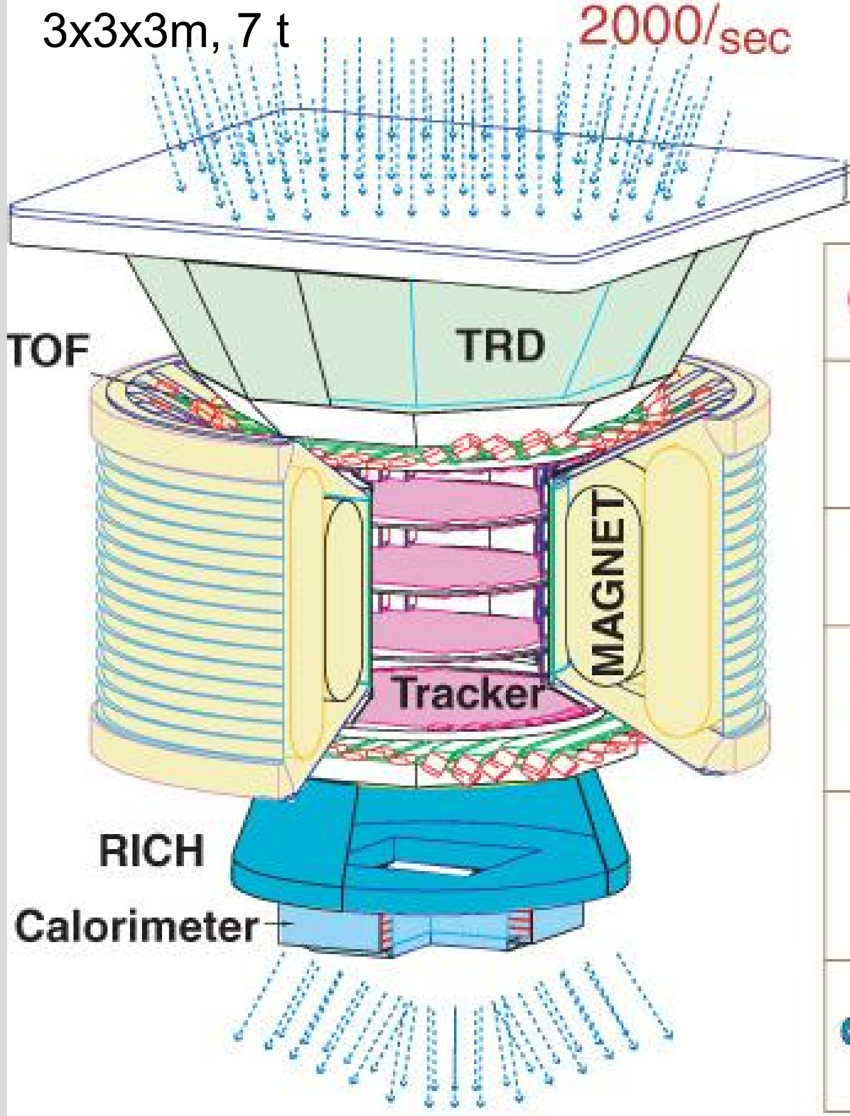


Z, P are measured independently by the Tracker, RICH, TOF and ECAL

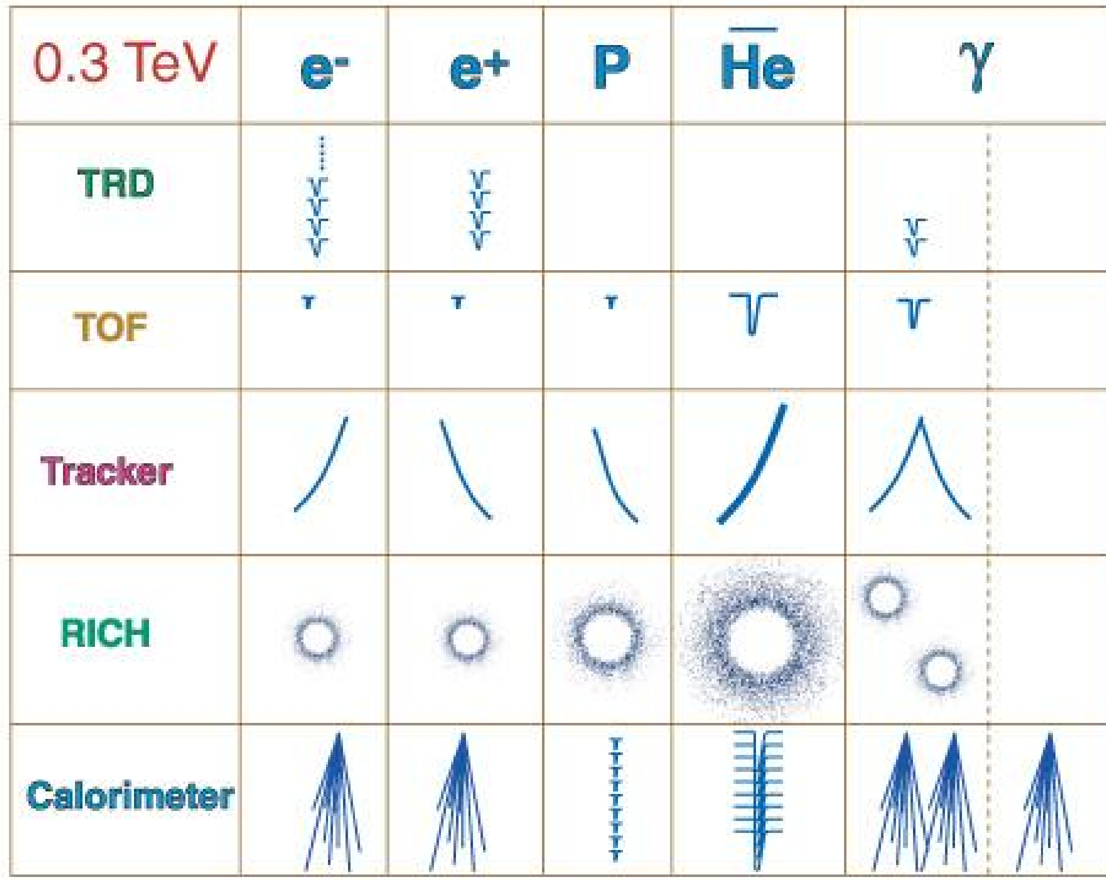

5m x 4m x 3m
7.5 tons
300,000 electronic channels
650 processors
TRD
AMS
Silicon layer
TOF 1, 2
Magnet
7 Silicon layers
TOF 3, 4
Radiators
RICH
11,000 Photo Sensors
Silicon layer
ECAL

AMS: A TeV Magnetic Spectrometer in Space

3x3x3m, 7 t



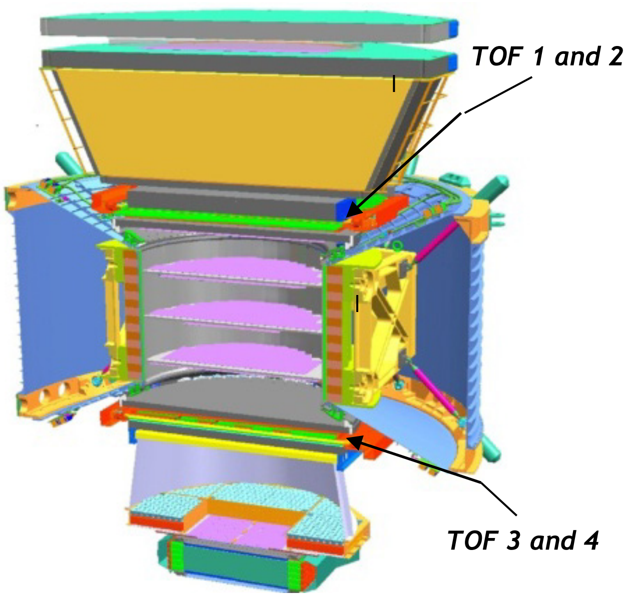
G.F. 4000 cm^2 sr
Exposure: 17 yrs

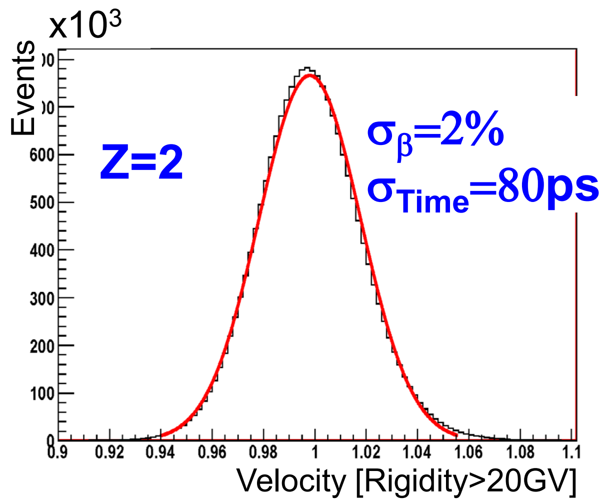


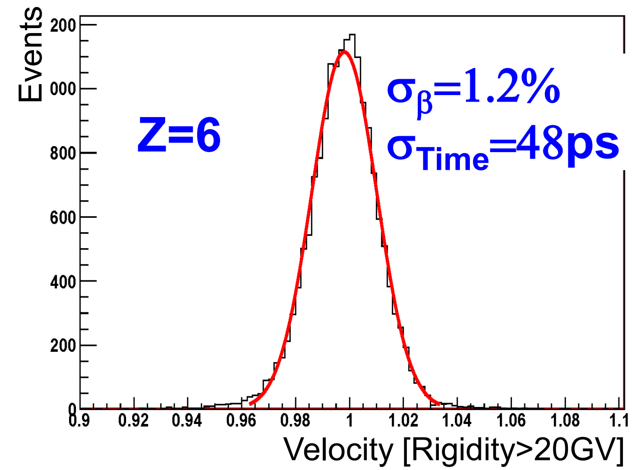
$dP/P^2 \sim 0.006 \rightarrow$ 1 TV, h/e = 10^{-6} (ECAL +TRD); Δx=10μm; Δt=100ps

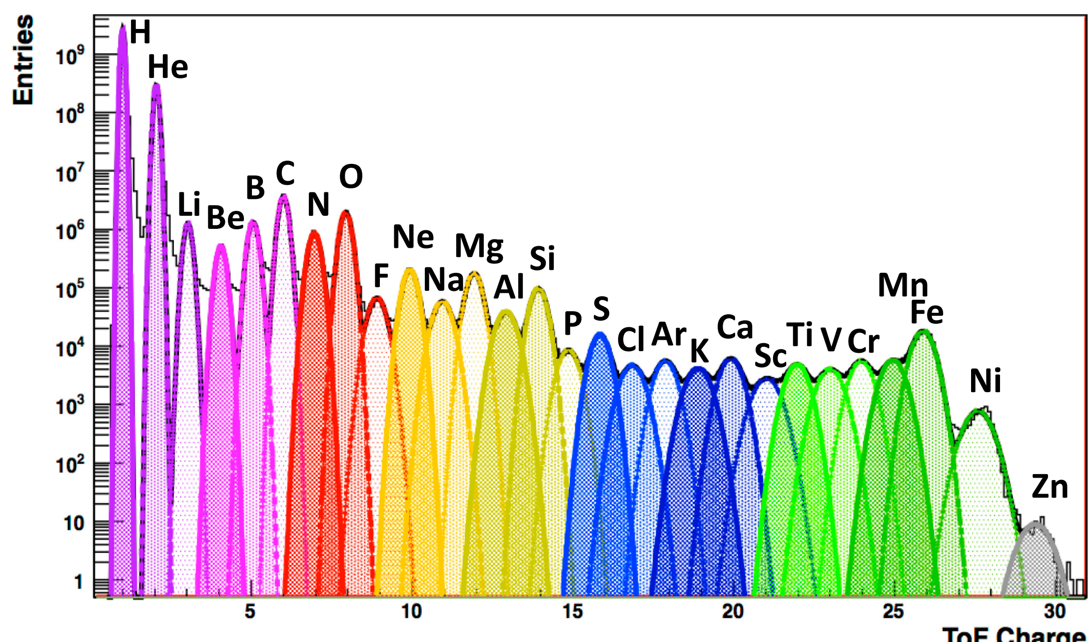
Data from ISS Time of Flight System

Measures Velocity and Charge of particles

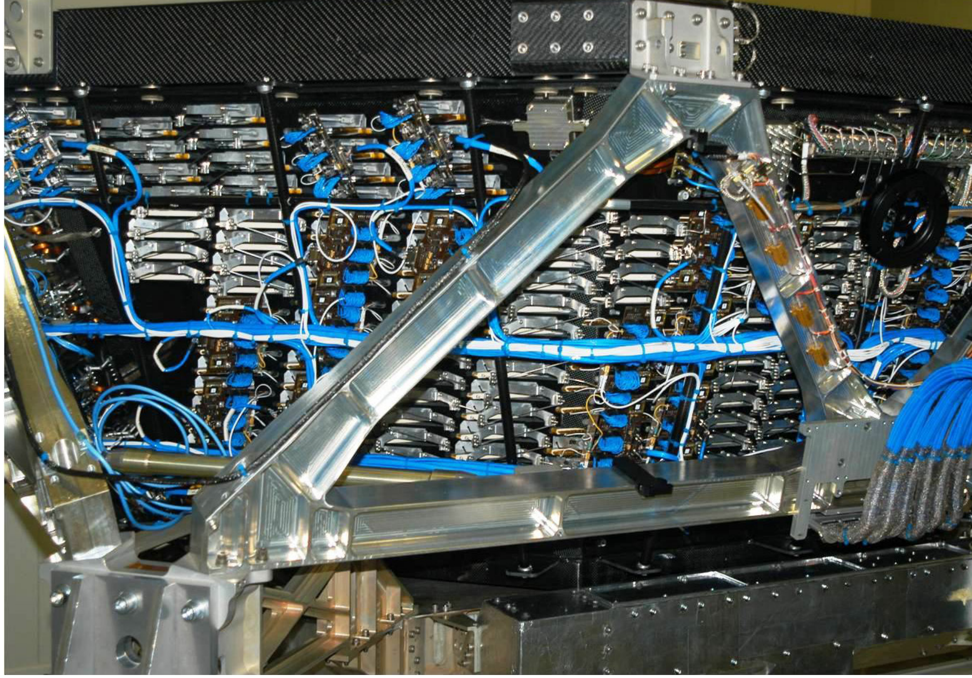






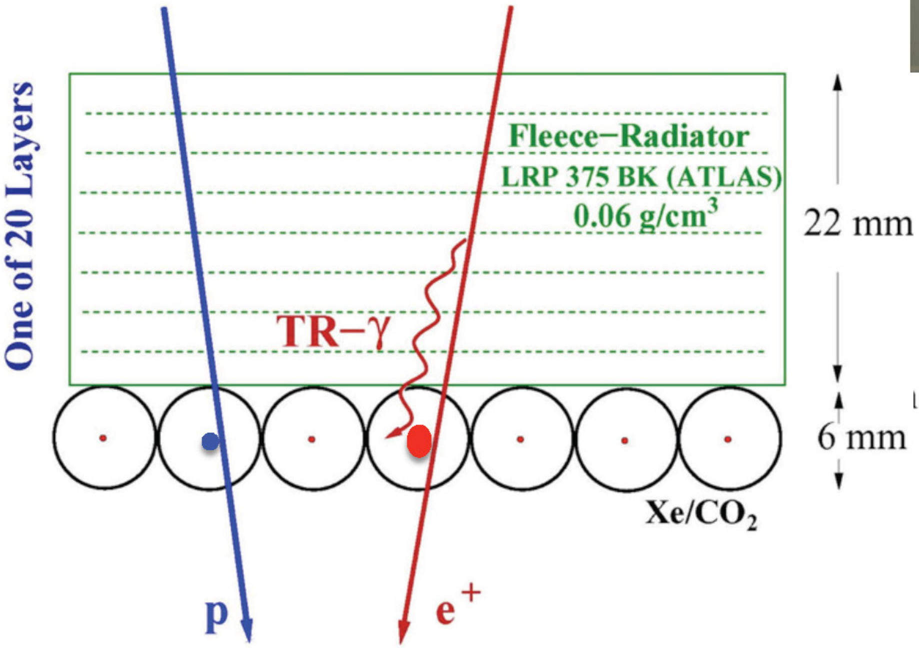


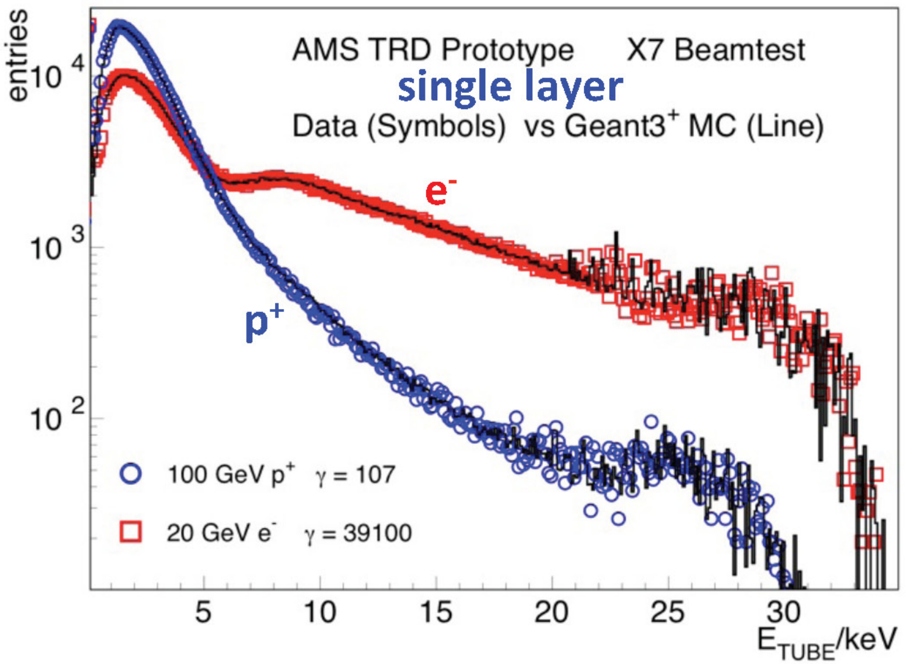
Transition Radiation Detector



20 Layers each consisting of:

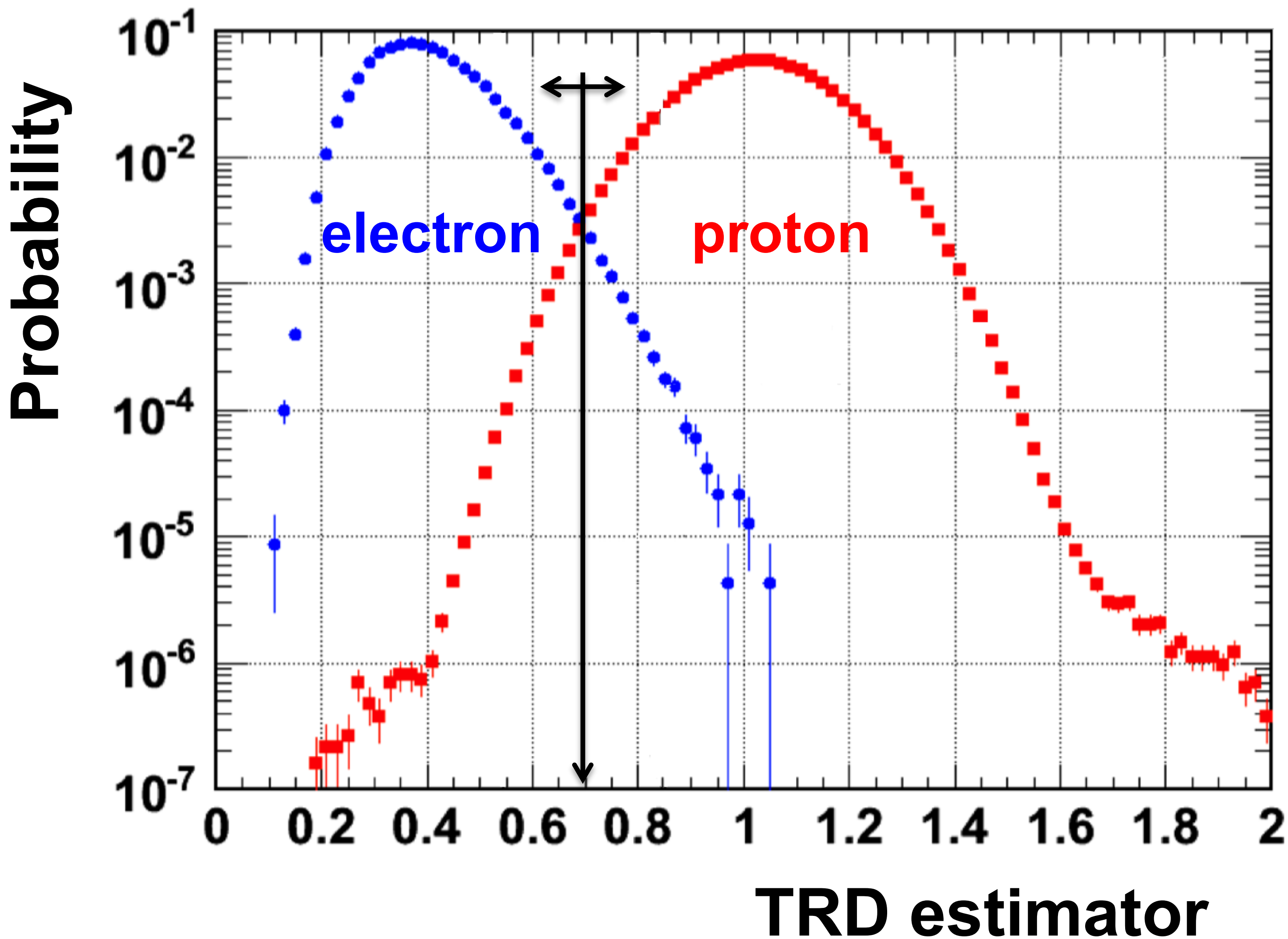
- 22 mm fibre fleece
- Ø 6 mm straw tubes
  filled with Xe/CO_2 80%/20%





TRD performance on ISS

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

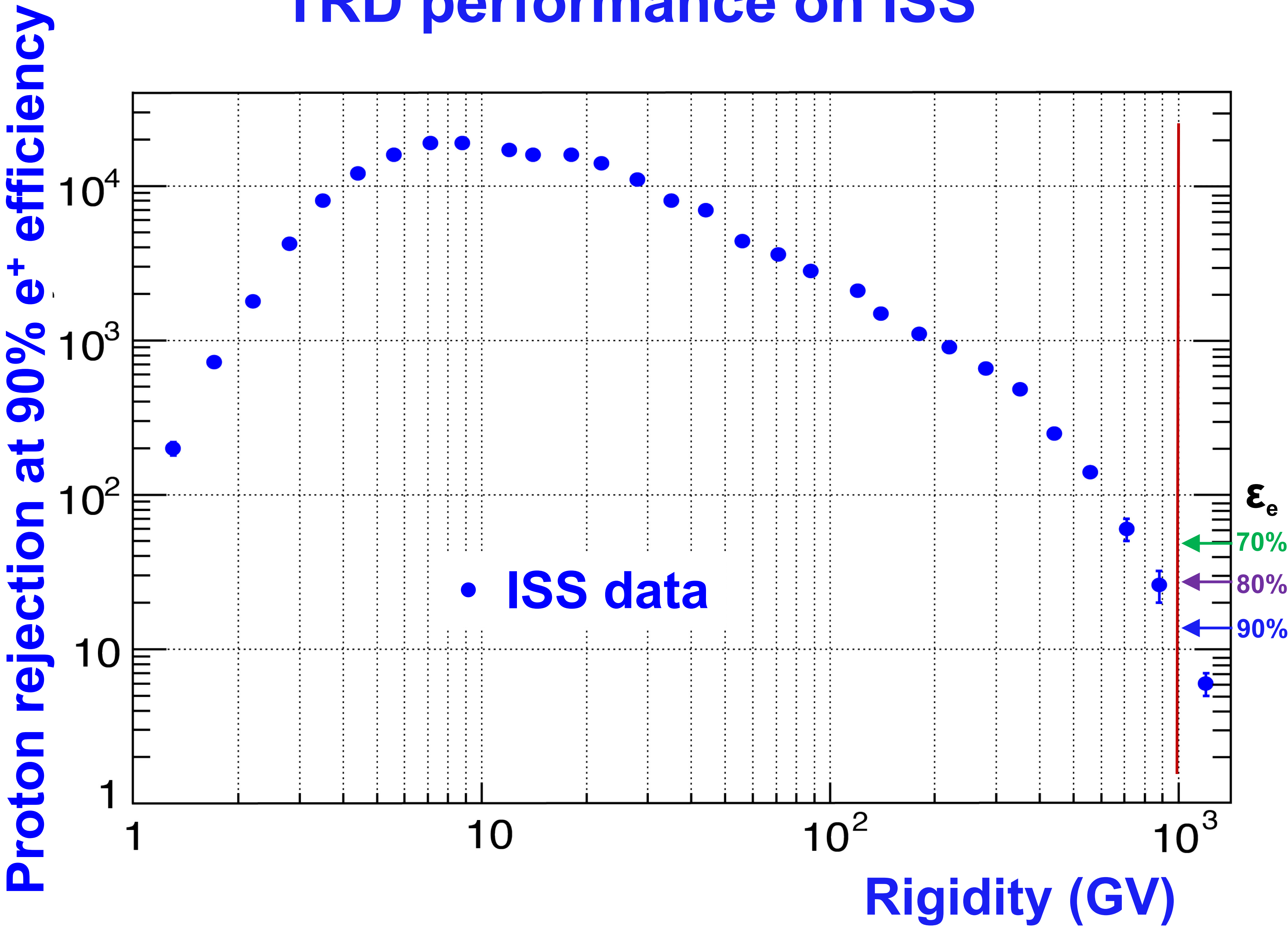


Normalized probabilities P_e and P_p

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

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

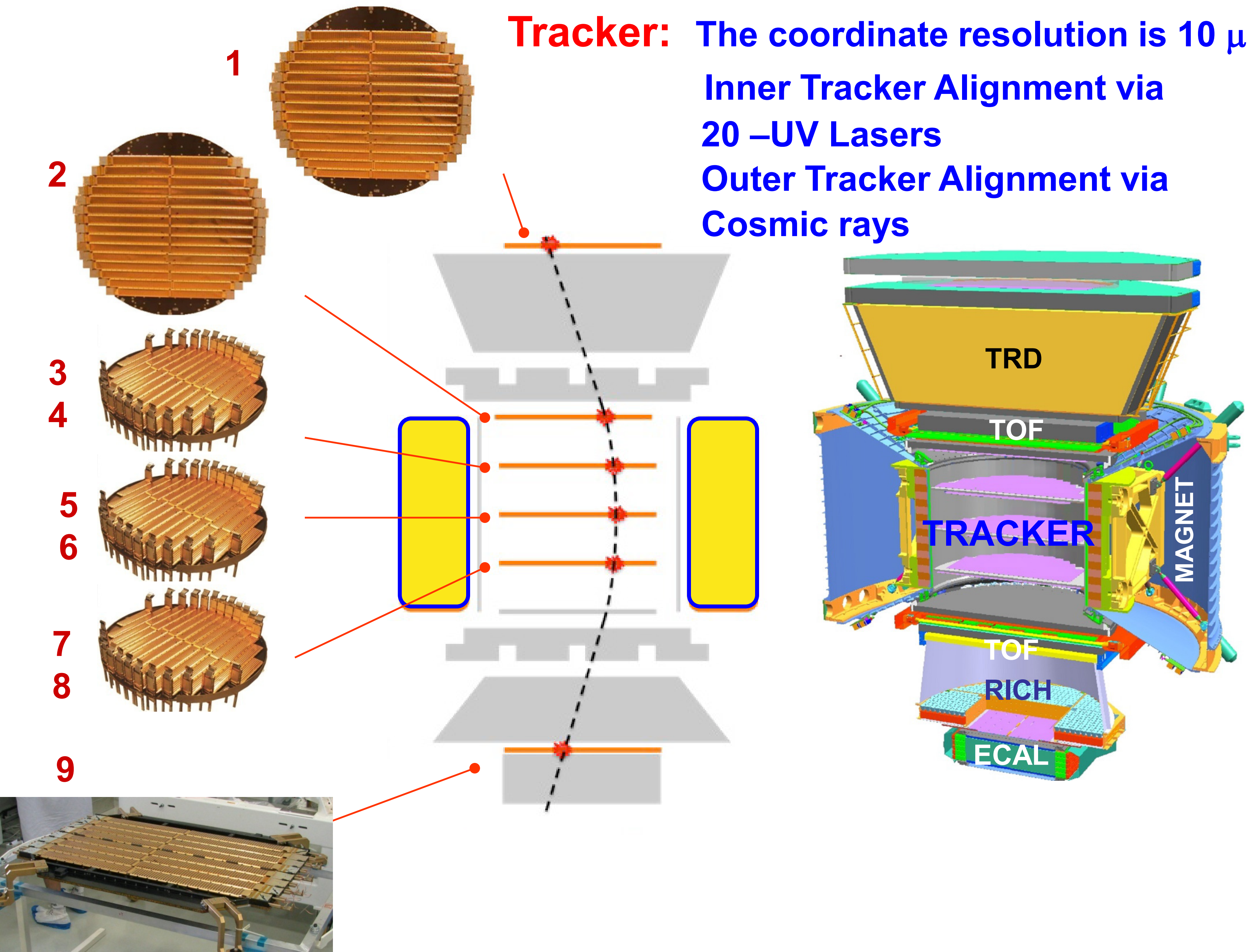
TRD performance on ISS



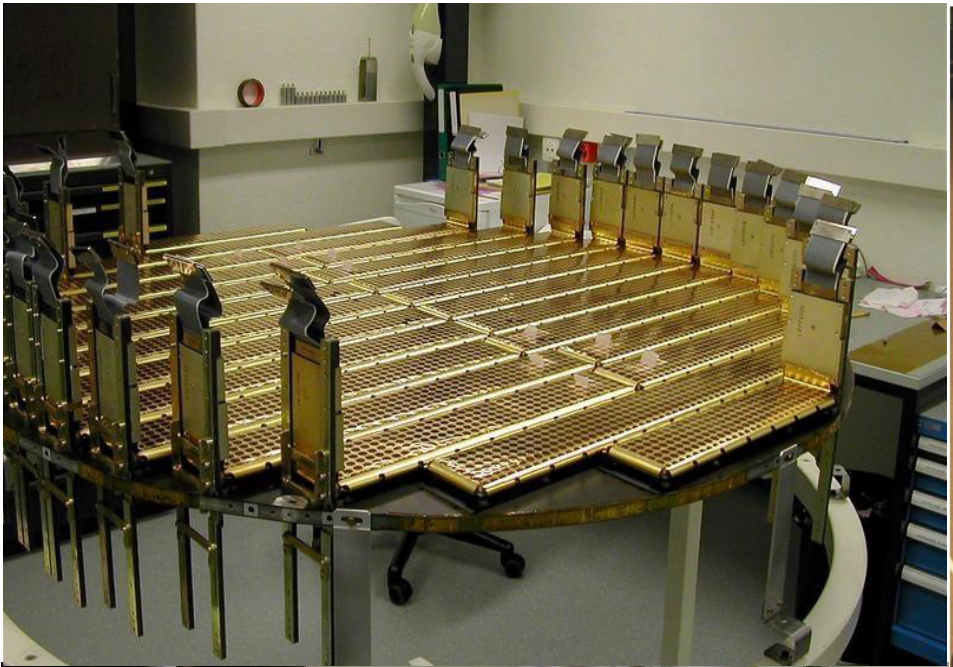
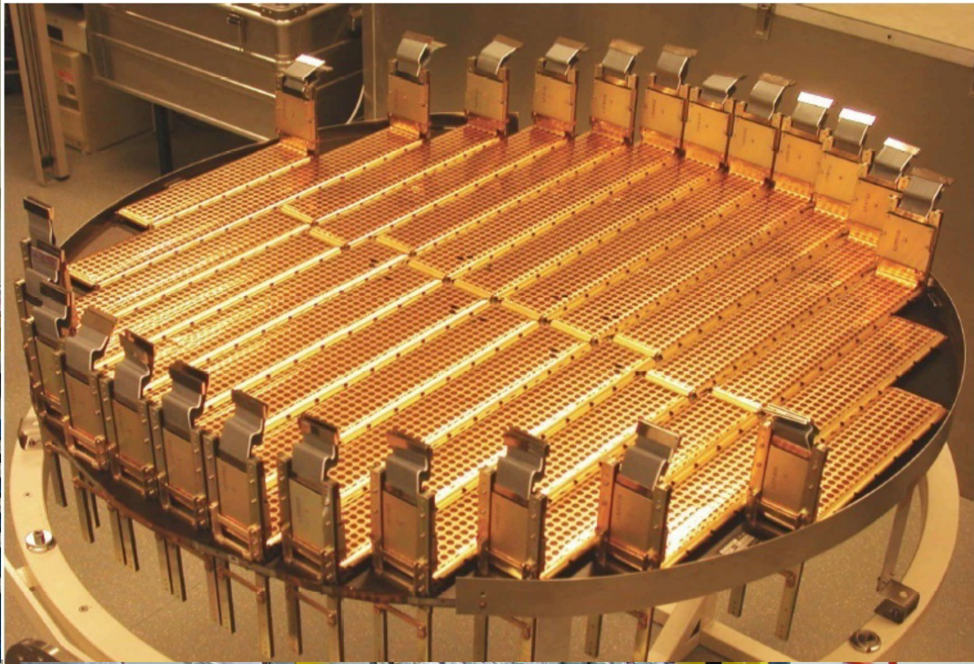
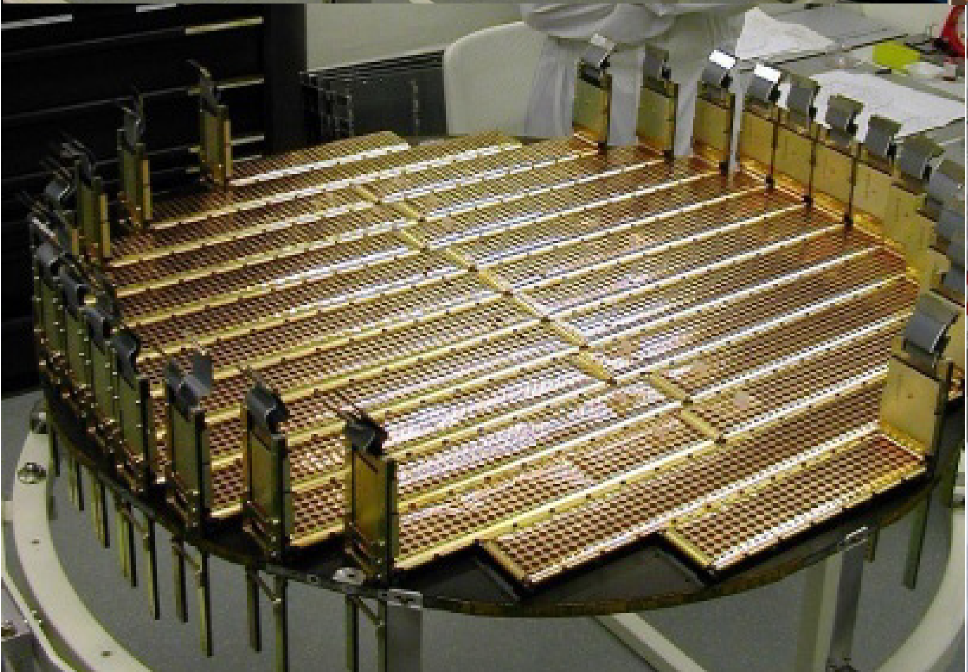
Tracker: The coordinate resolution is 10 μ

Inner Tracker Alignment via 20 –UV Lasers

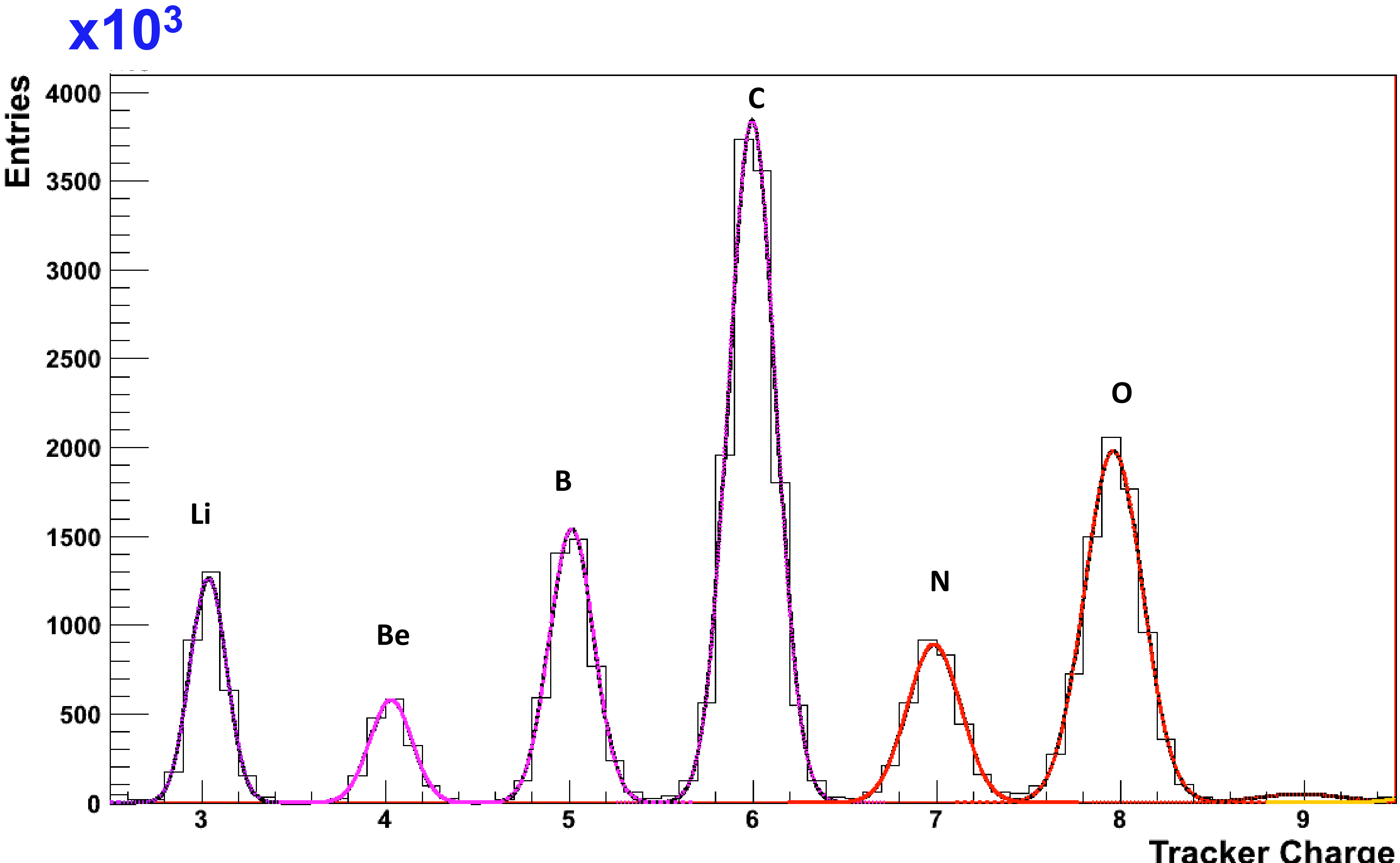
Outer Tracker Alignment via Cosmic rays



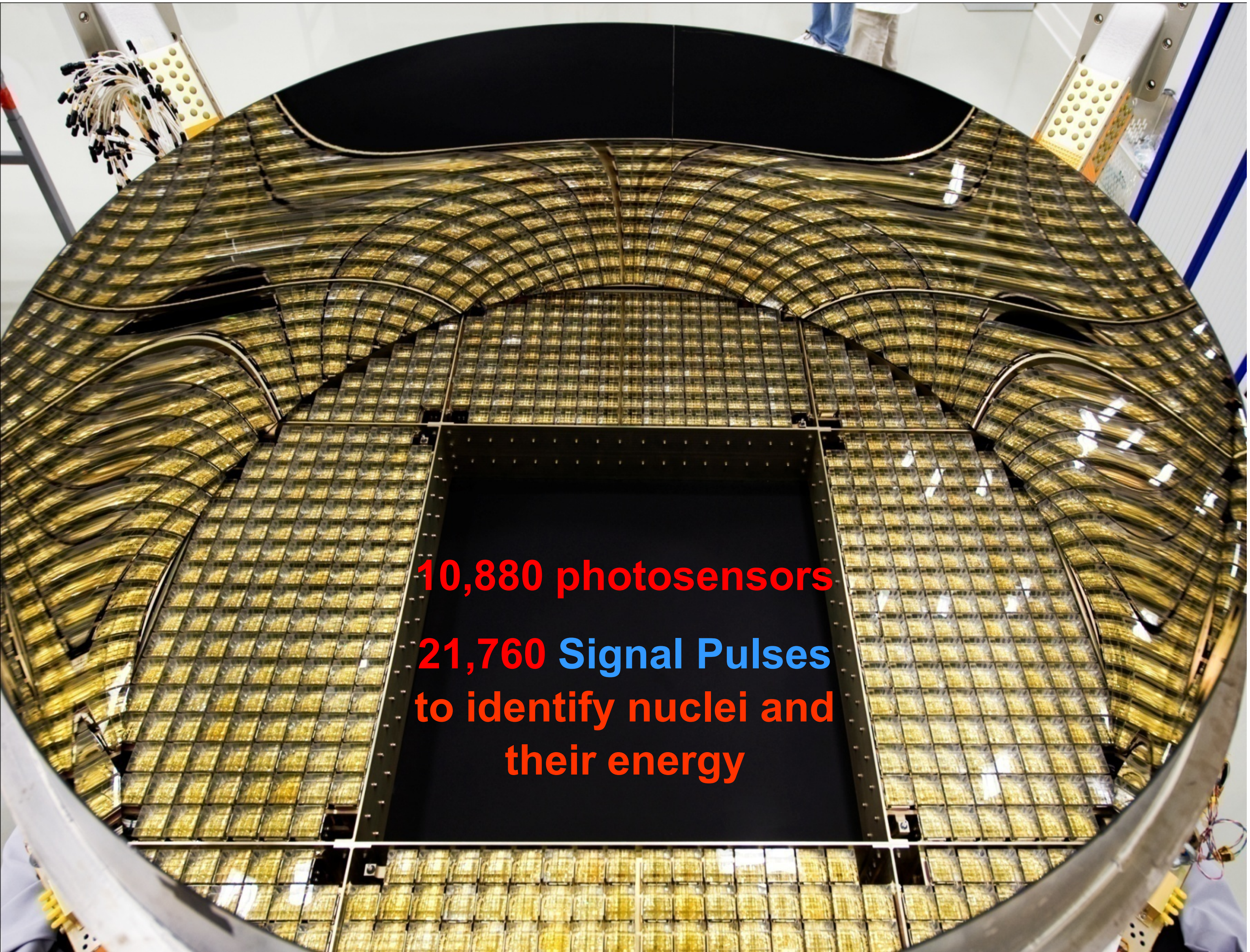
There are 9 planes with 200,000 channels aligned to 3 microns

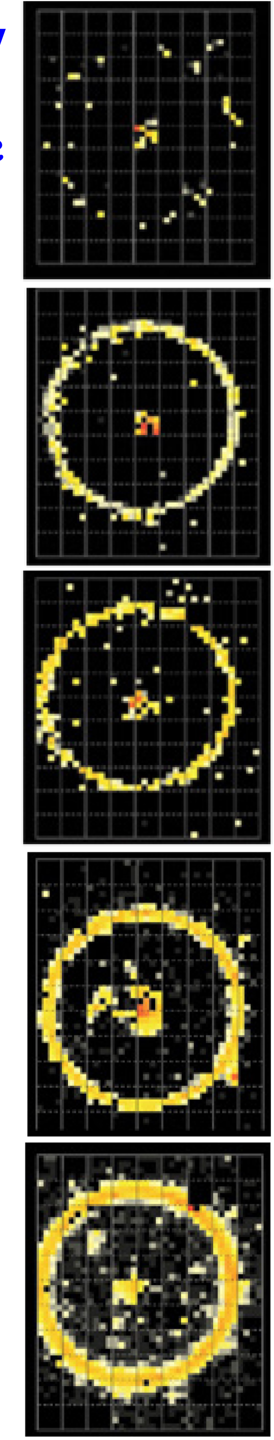





Tracker Charge

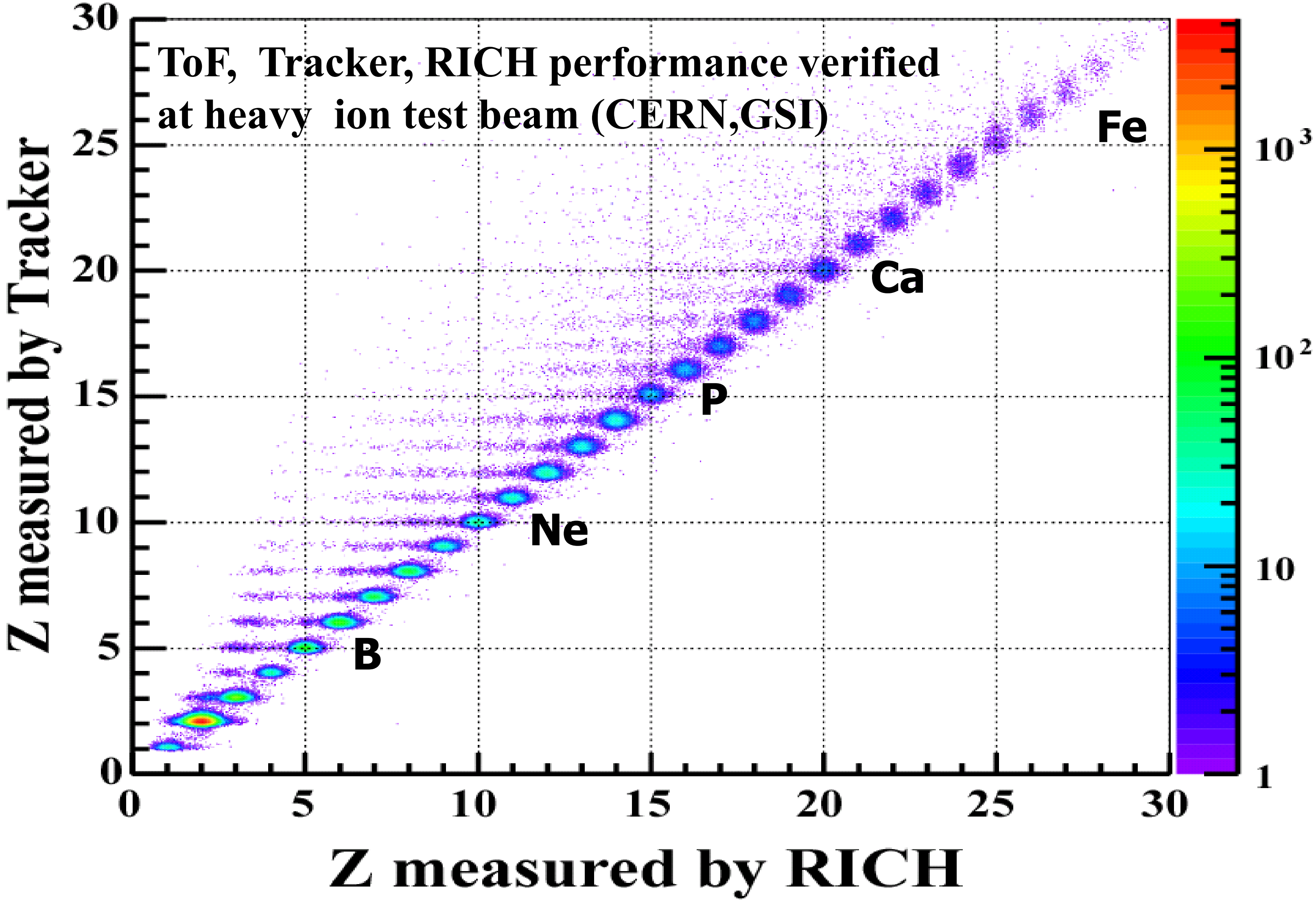


Ring Imaging CHerenkov (RICH)

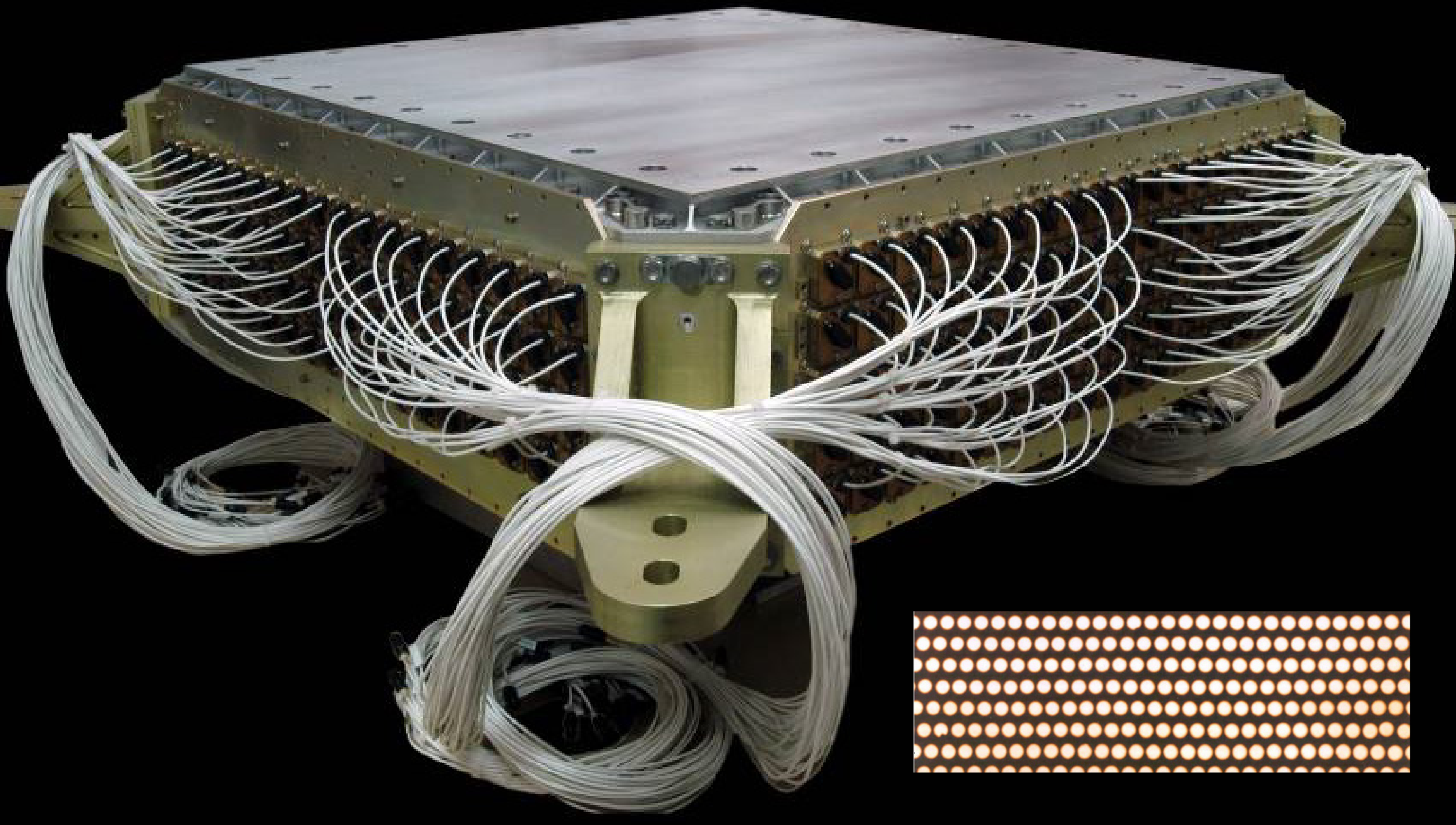




Z determination by Tracker and Rich



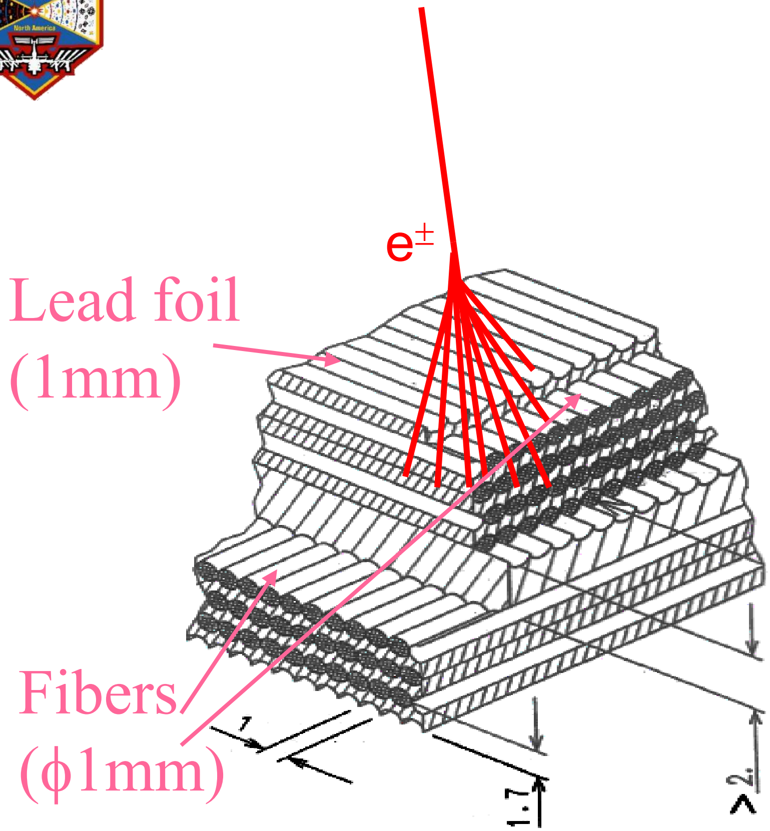
Calorimeter (ECAL)

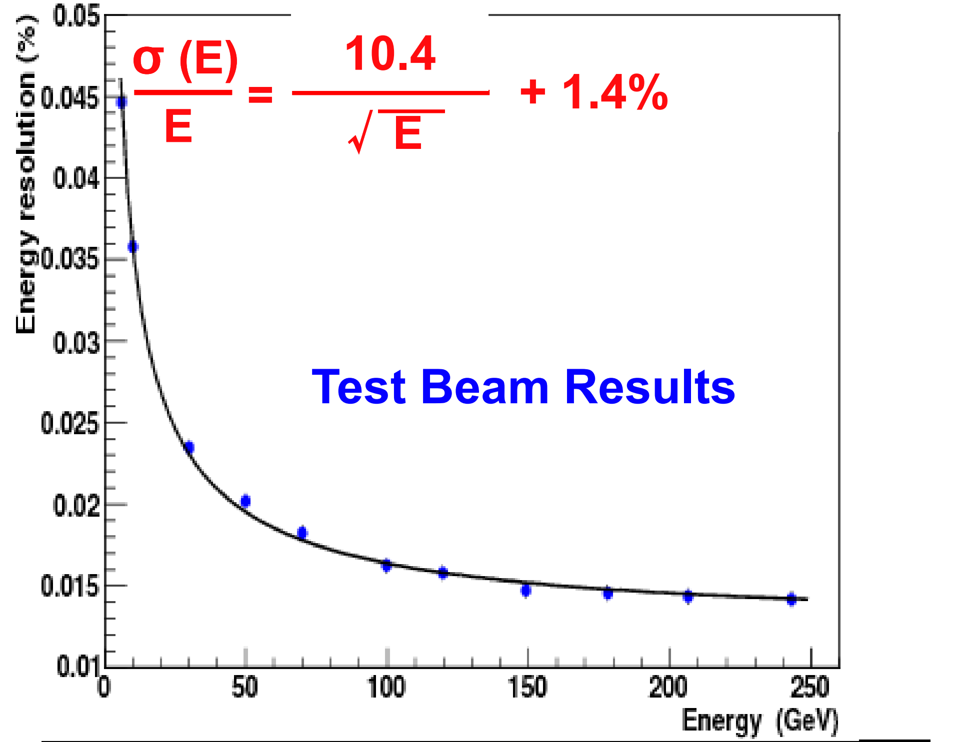


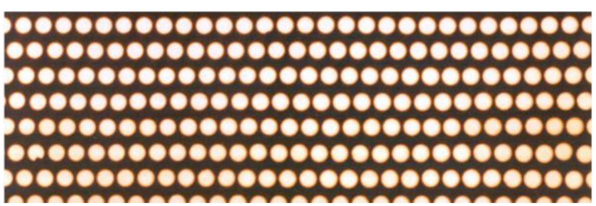
50,000 fibers, $\phi = 1$mm, distributed uniformly inside 1,200 lb of lead which provides a precision, 3-dimensional, $17X_0$ measurement of the directions and energies of light rays and electrons up to 1 TeV

Electromagnetic Calorimeter

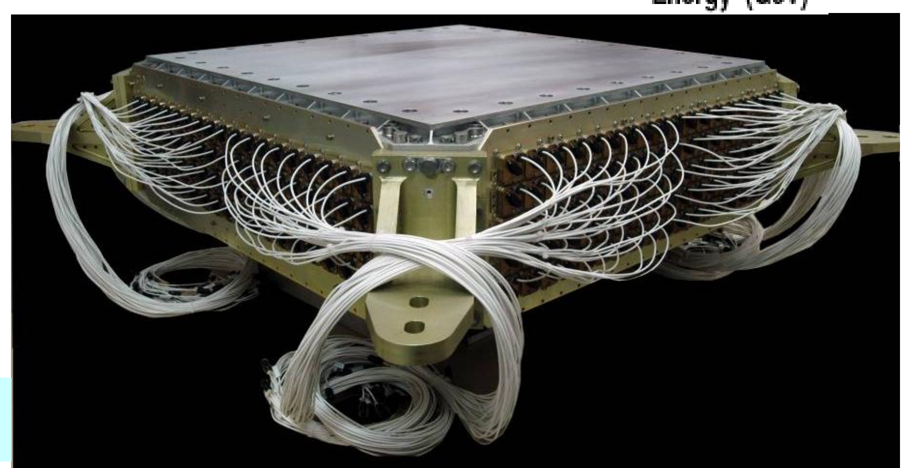
A precision, 17 X_0, TeV, 3D measurement of the directions and energies of light rays and electrons





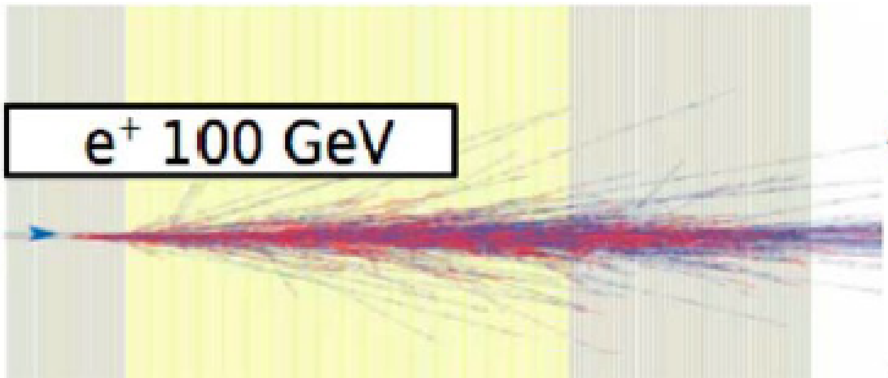


50 000 fibers, $\phi = 1$ mm distributed uniformly Inside 1,200 lb of lead



Reported by S. Di Falco, ICRC

Lepton hadron separation with ECAL



Positron 100 GeV

Longitudinally contained

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

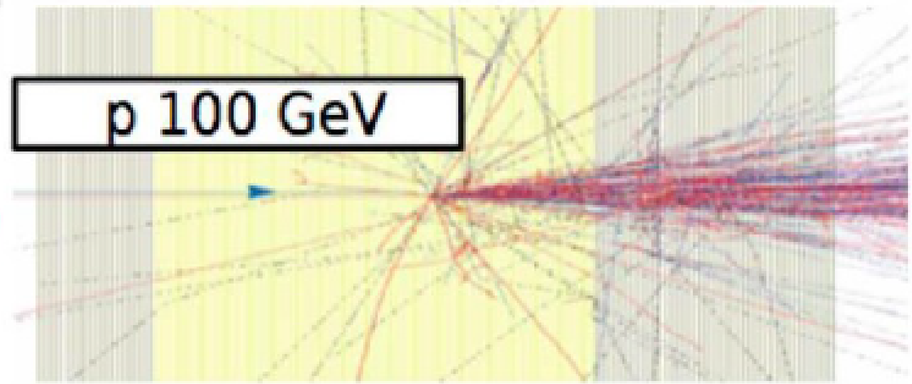
$E_{ECAL} \sim P_{TRK}$

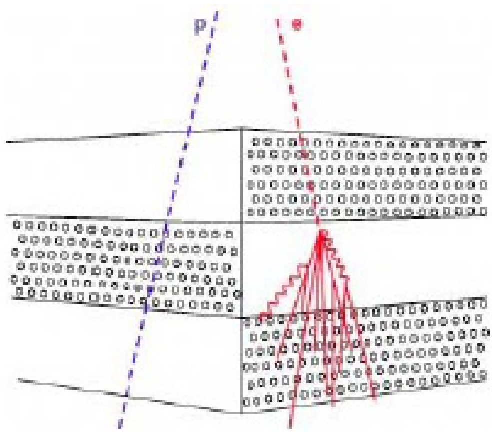
Proton 100 GeV

Longitudinal Leak

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

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

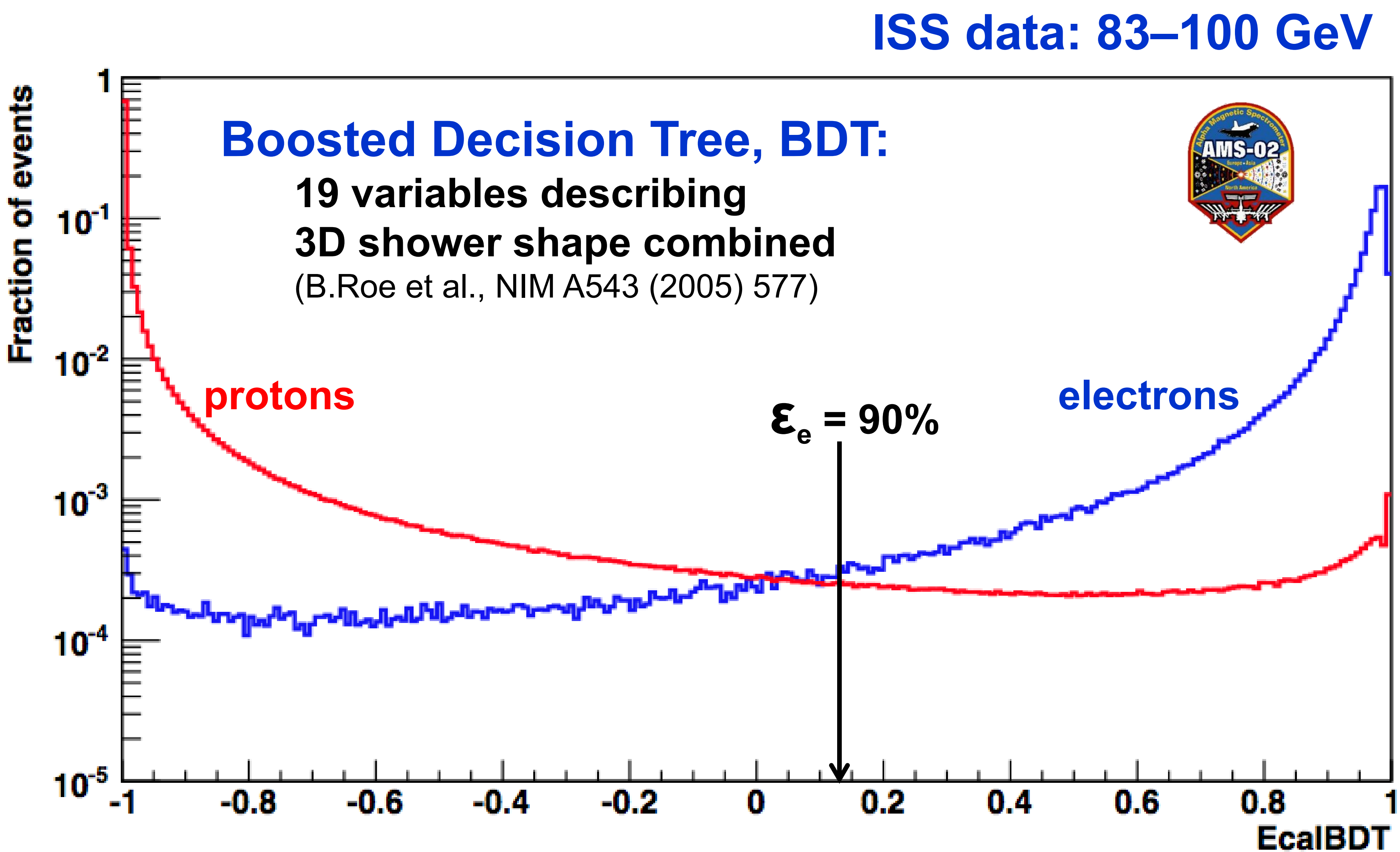




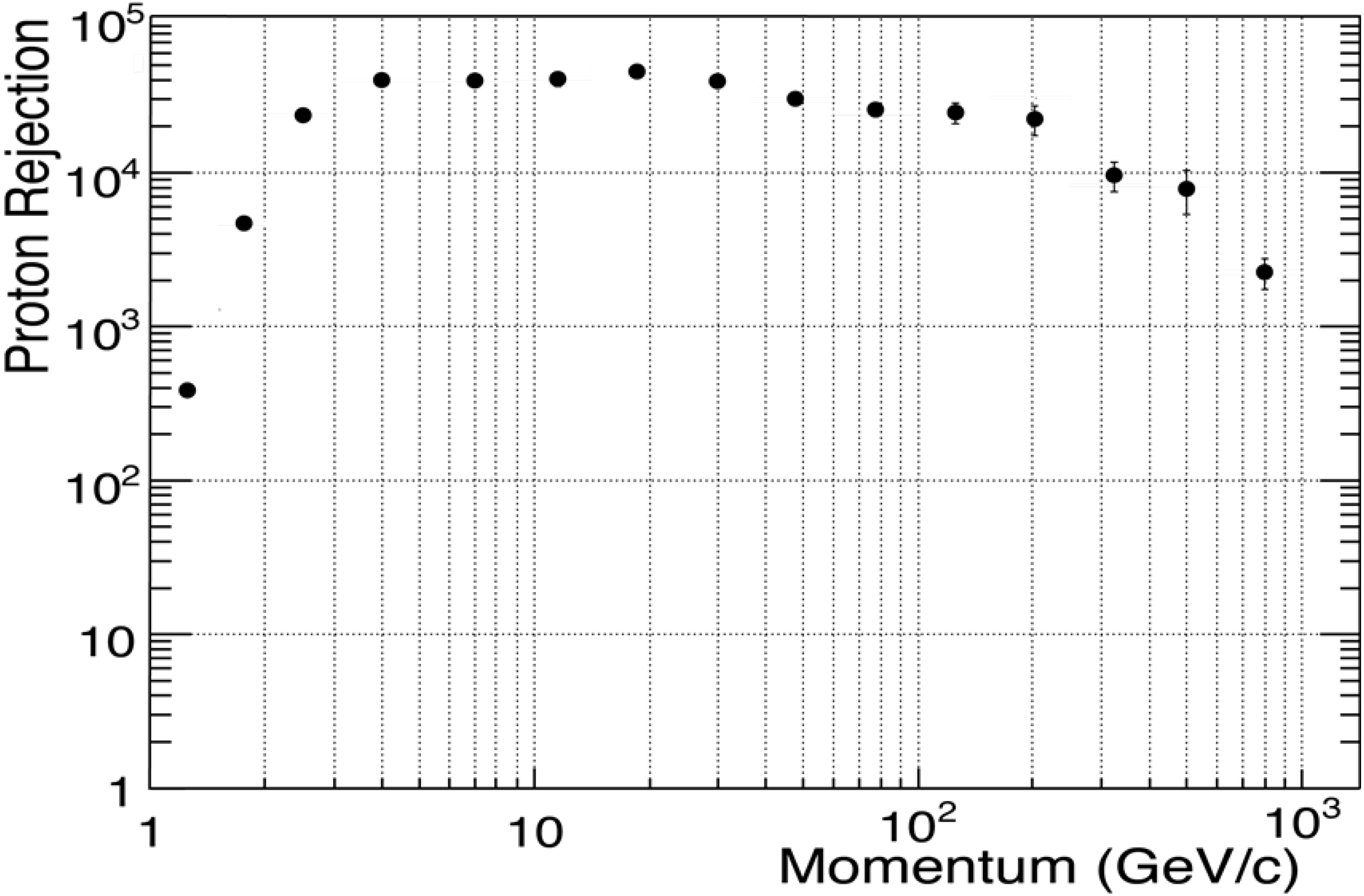
Proton rejection with ECAL:

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

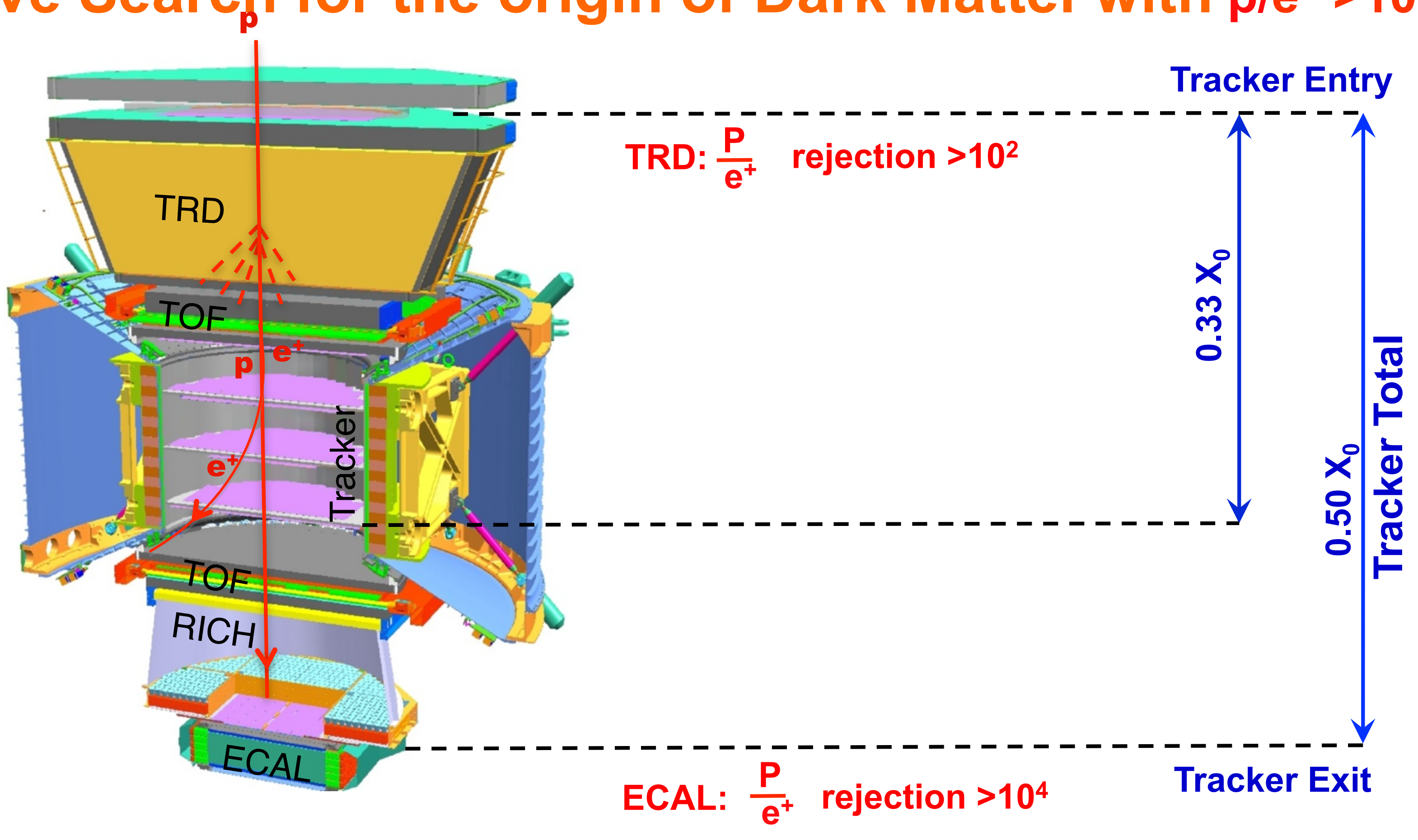
Separation of protons and electrons with ECAL



Data from ISS: Proton rejection using the ECAL



Sensitive Search for the origin of Dark Matter with $p/e^+ > 10^6$



a) Minimal material in the TRD and TOF
So that the detector does not become a source of e^+.

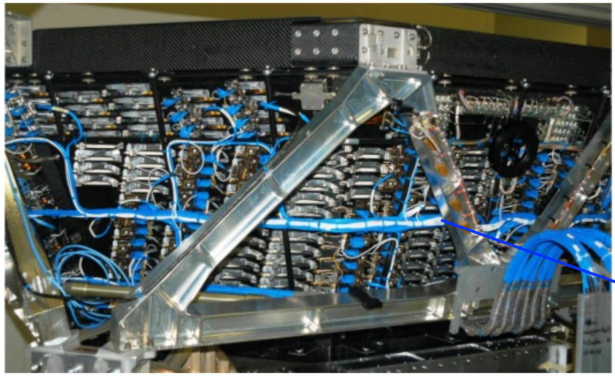
b) A magnet separates TRD and ECAL so that e^+ produced in TRD will be swept away and not enter ECAL
In this way the rejection power of TRD and ECAL are independent

c) Matching momentum of 9 tracker planes with ECAL energy measurements

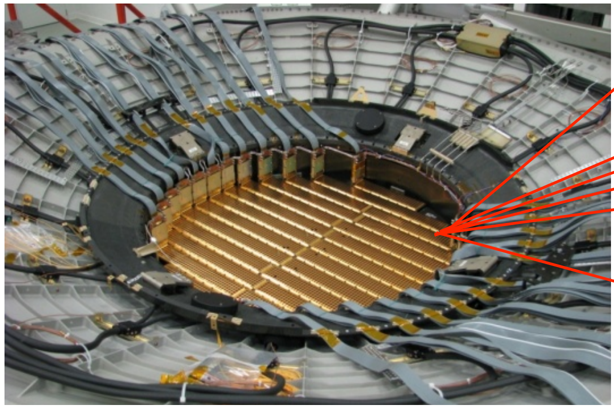
AMS Flight Electronics for Data Acquisition (DAQ)

300,000 channels at 2 KHz,
650 computers
designed and built by AMS

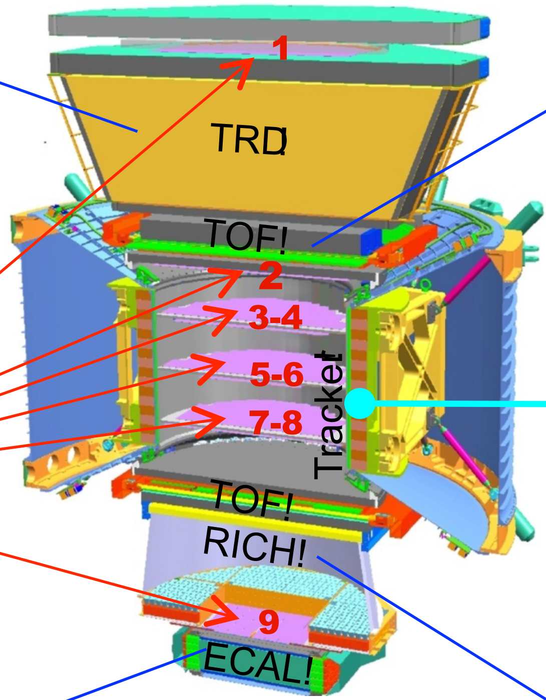
TRD: 5248 Signals



Silicon Tracker:
196,608 Signals

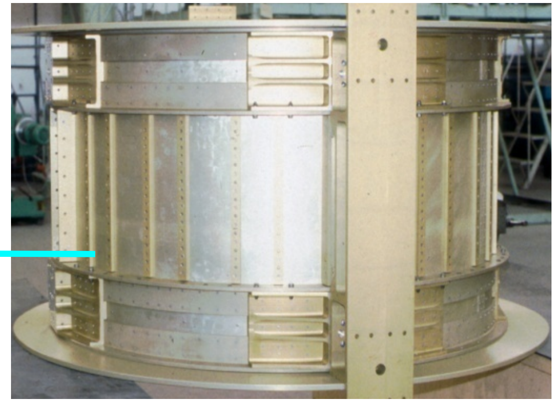


ECAL: 2,916 Signals

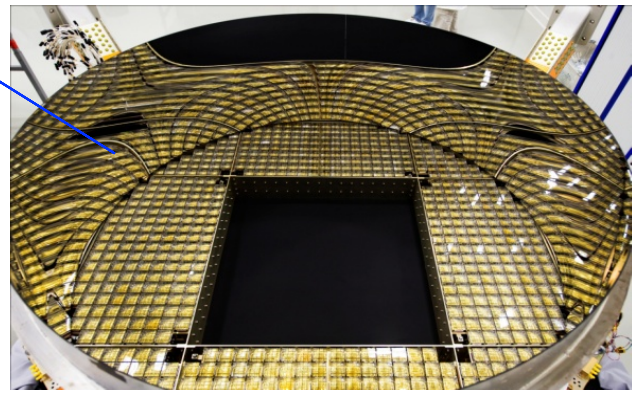


TOF & ACC: 88 Signals

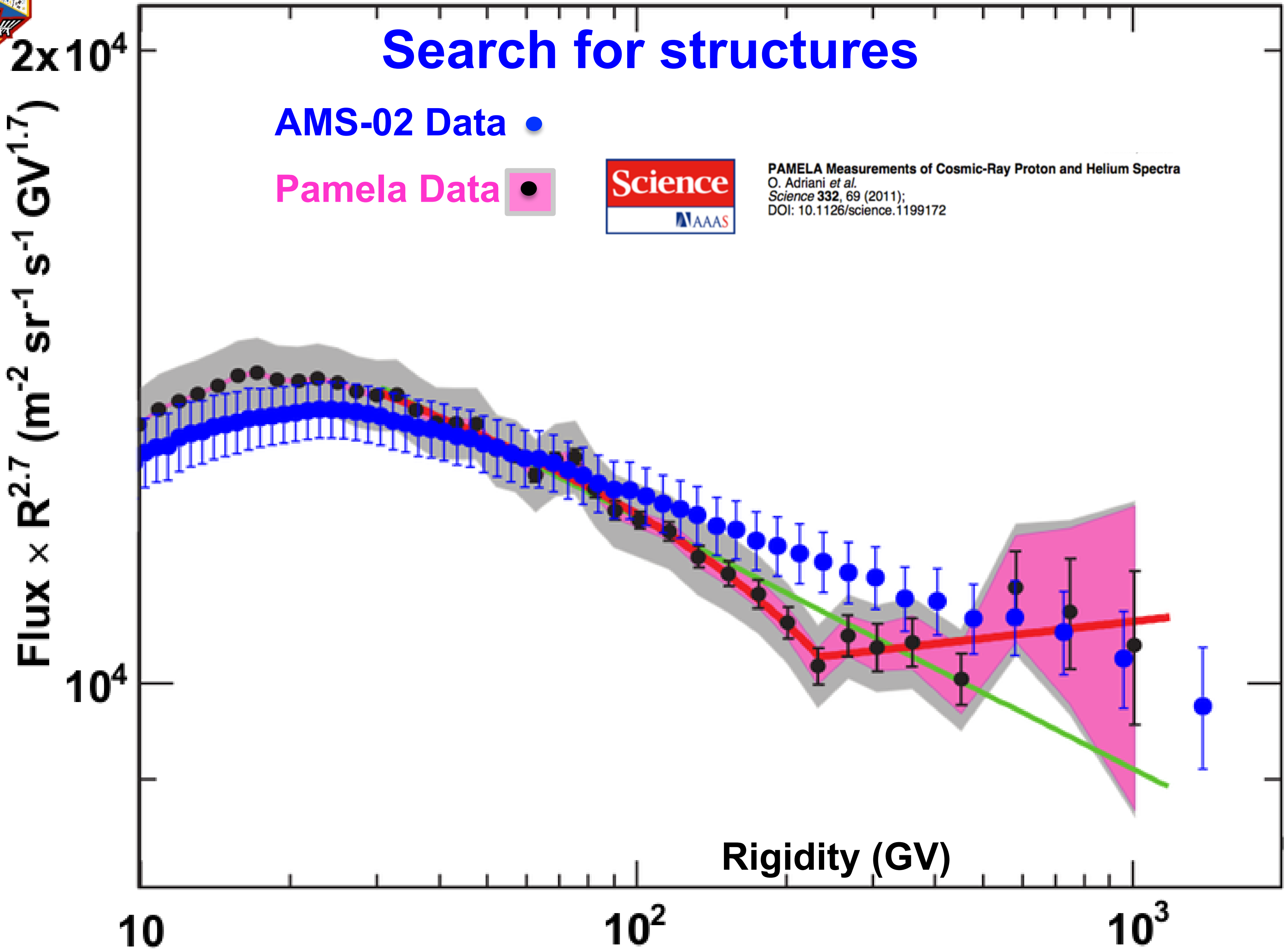
Magnet



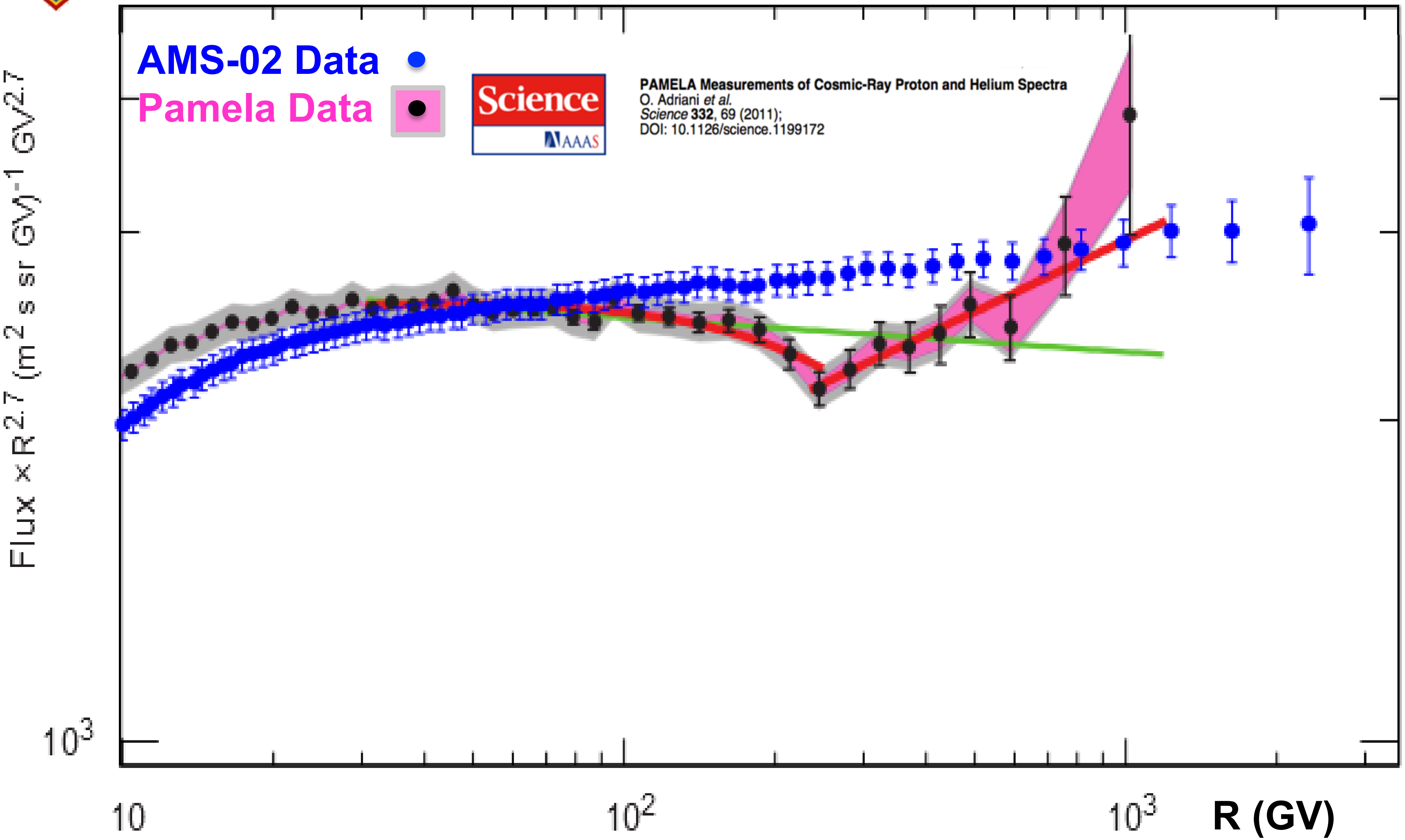
RICH: 10,800 * 2 Signals



Proton flux


Search for structures
AMS-02 Data
Pamela Data
Science
AAAS
PAMELA Measurements of Cosmic-Ray Proton and Helium Spectra
O. Adriani et al.
Science 332, 69 (2011);
DOI: 10.1126/science.1199172
2x10^4
10^4
Flux × R^2.7 (m^-2 sr^-1 s^-1 GV^1.7)
Rigidity (GV)
10
10^2
10^3

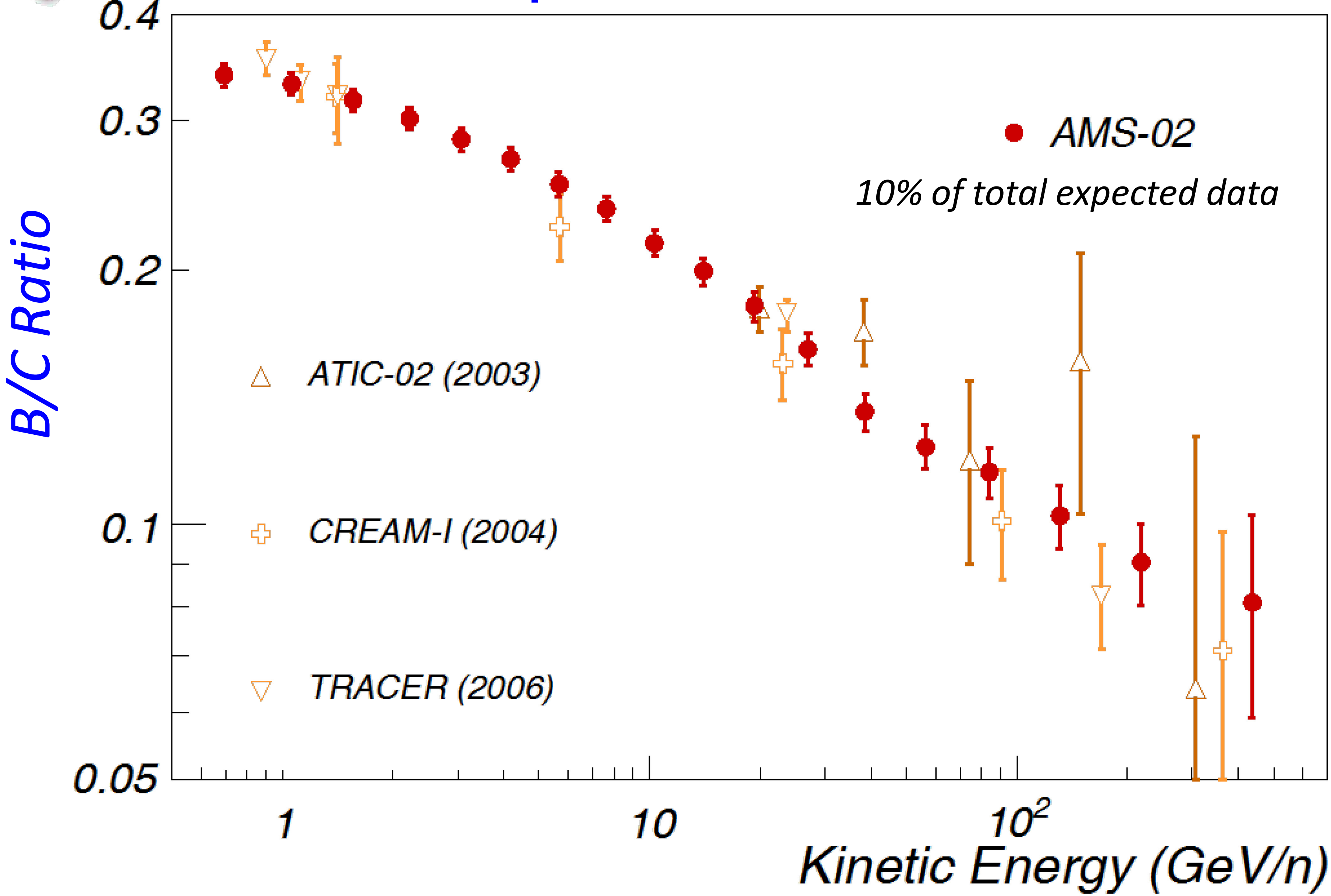
Helium flux
Search for structures



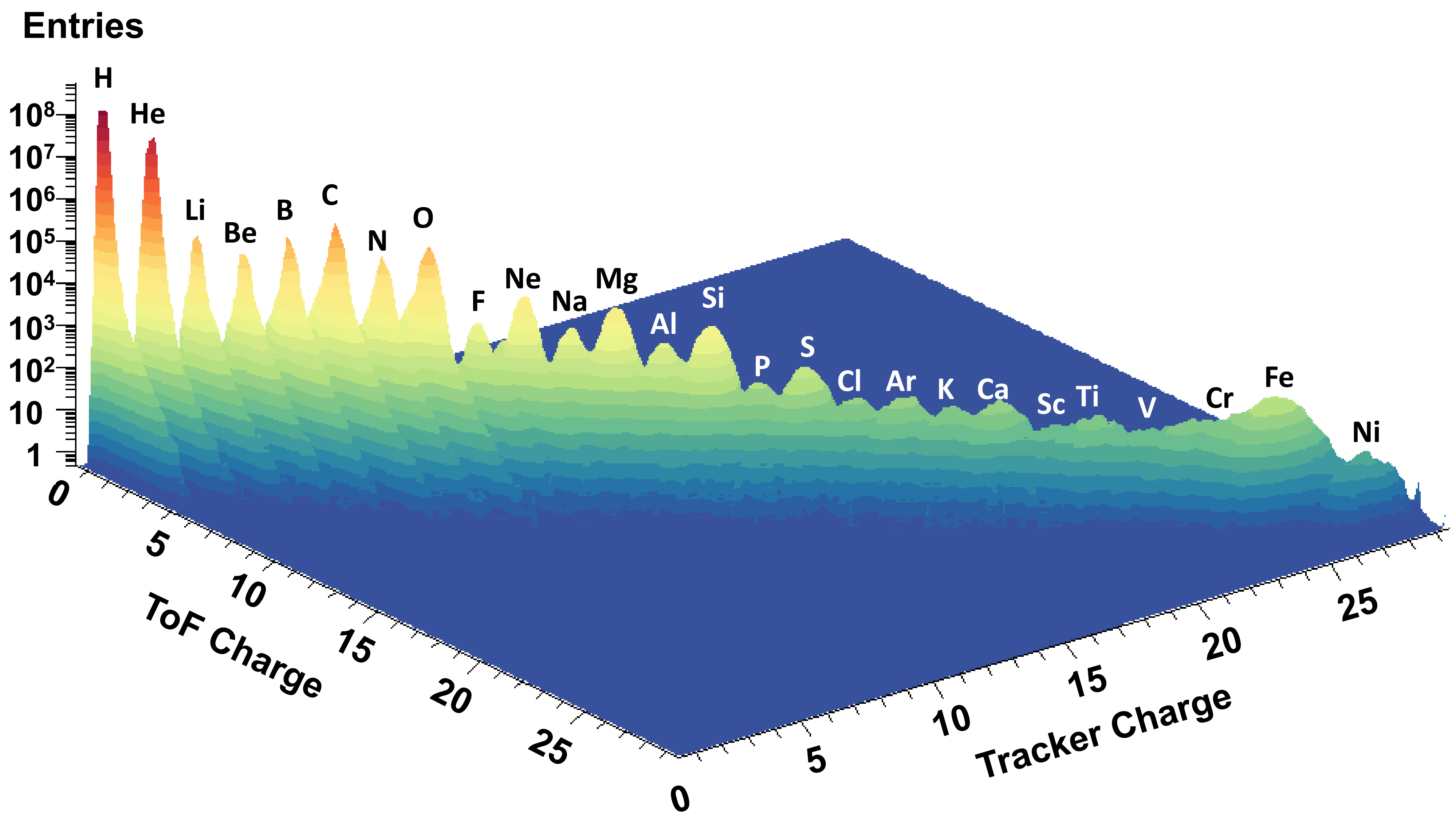
To be presented by V. Choutko (8 July, ICRC)

Boron-to-Carbon ratio

comparison with recent data

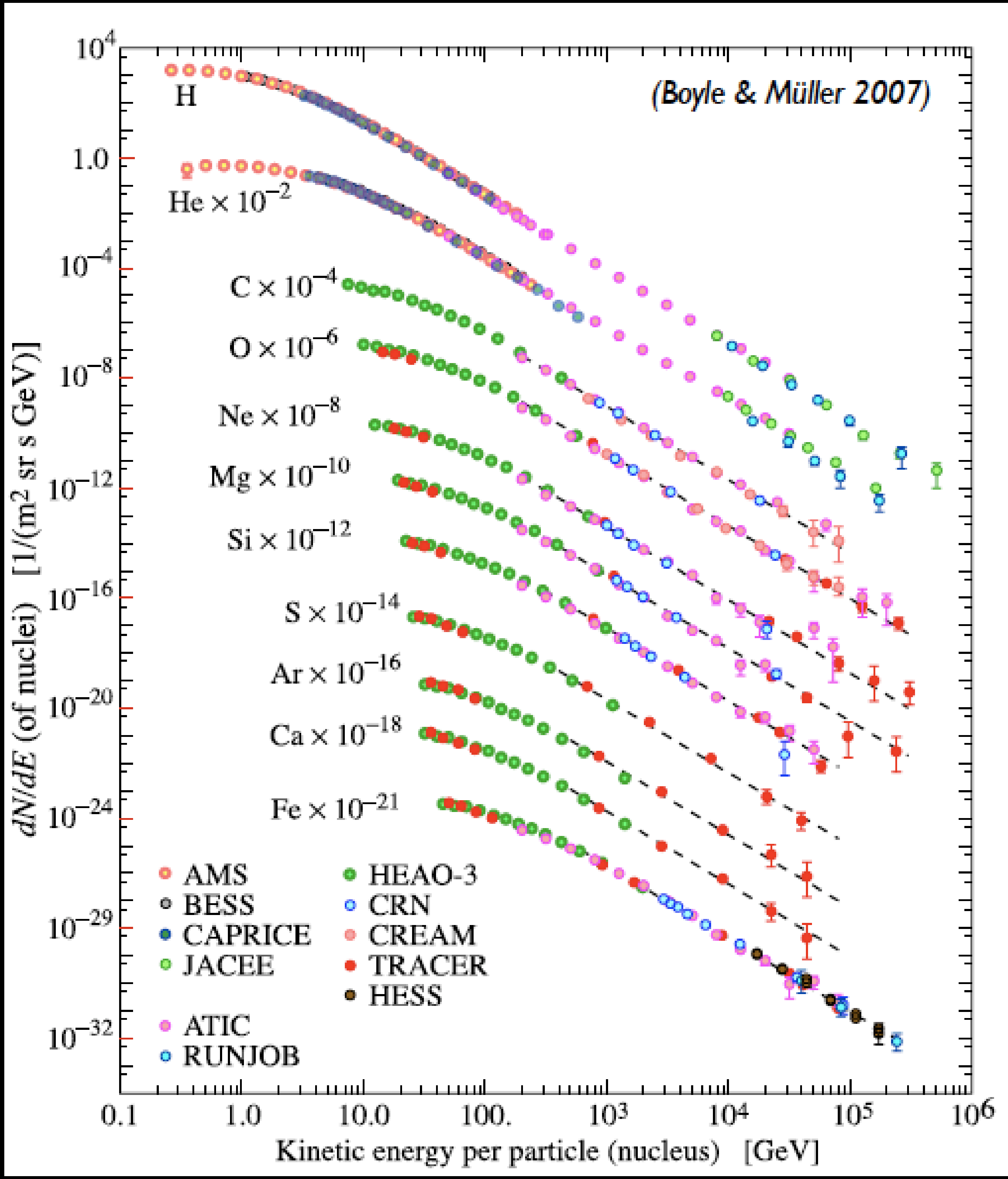


AMS Nuclei Measurement on ISS



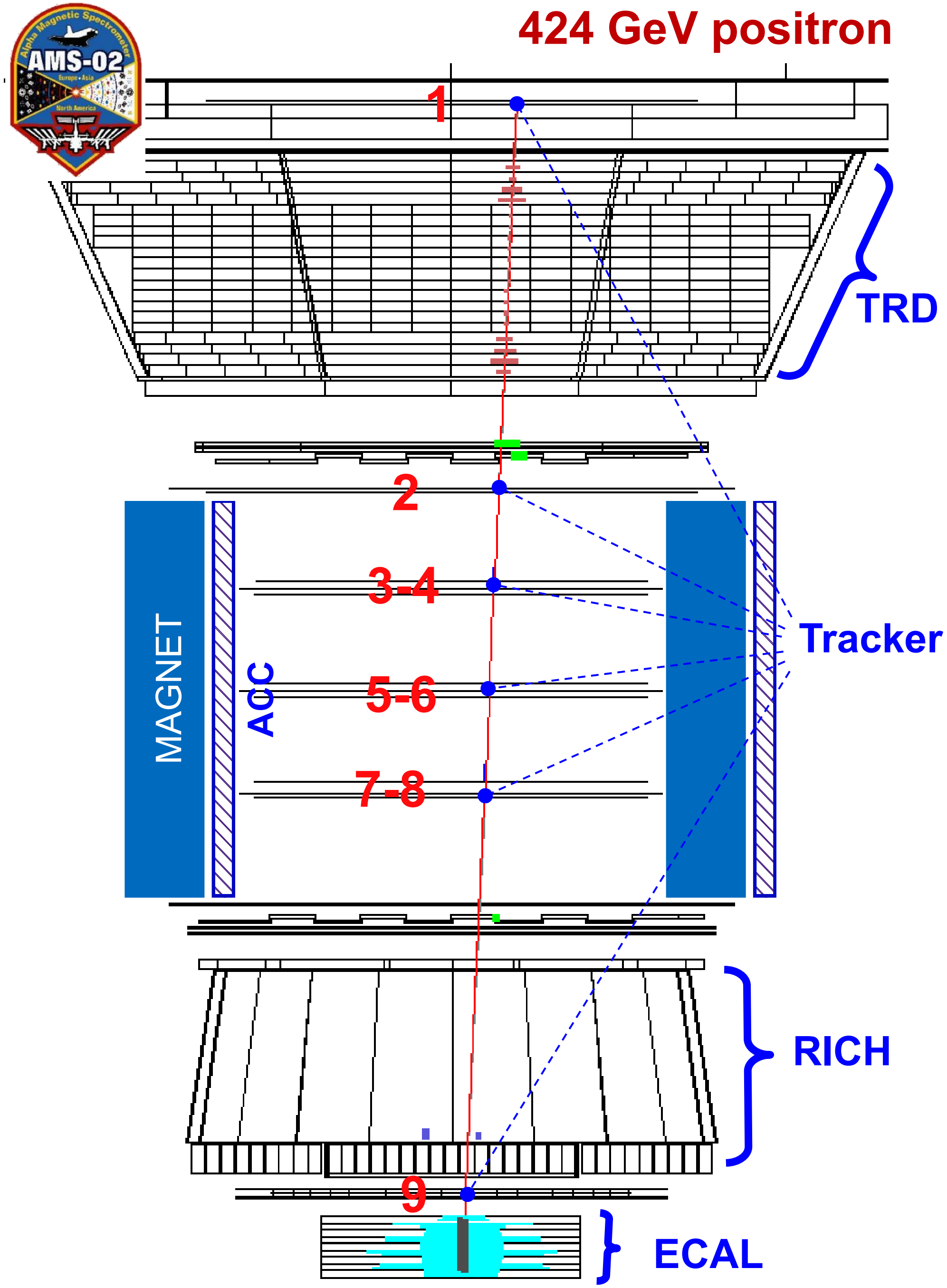
And to finish...

Grandeur of inferences: Fluxes of individual elements



Positron event selection.

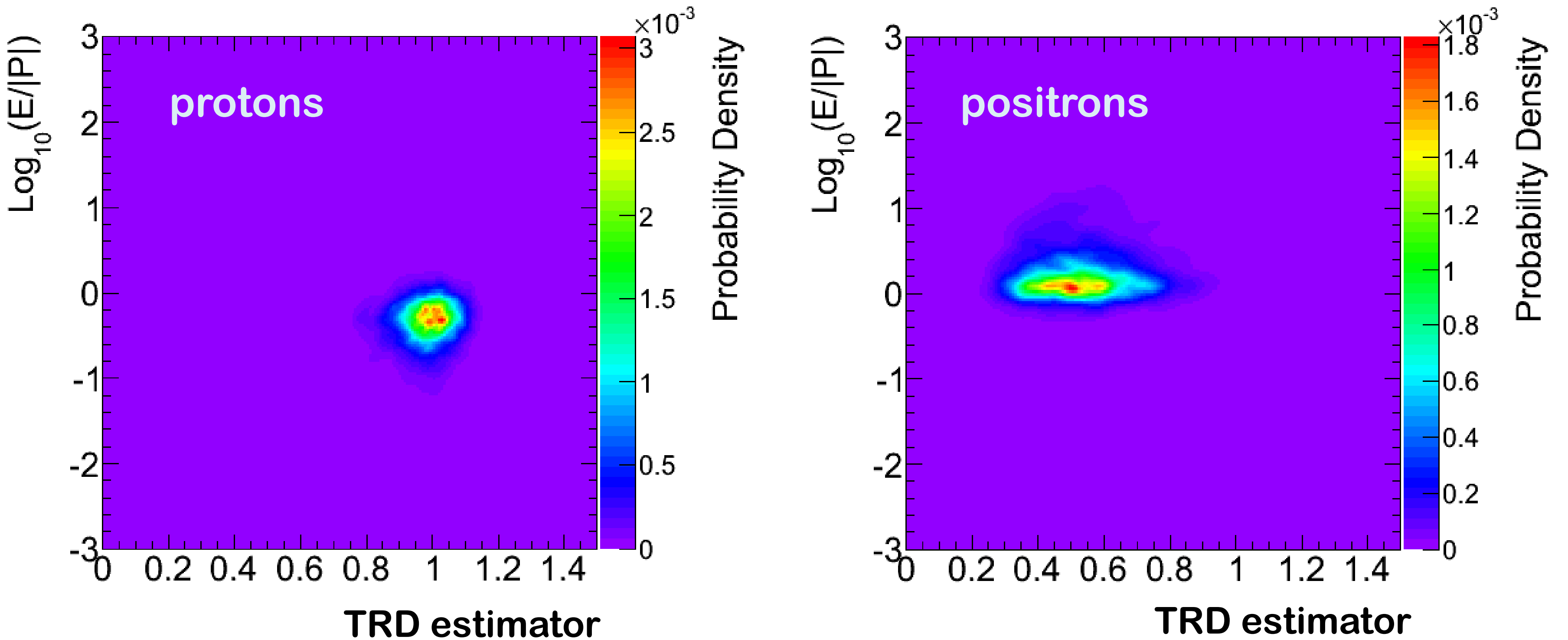
- **DAQ:** efficiency > 50% (no SAA)
- **Geomagnetic cutoff:** E>1.2·max cutoff
- **TRACKER:**
  - Track quality
  - geometrical match with ECAL shower
- **TRD:** at least 15 hits
- **TOF:** downgoing particle, $\beta>0.8$, $0.8<Z<1.4$
- **ECAL:**
  - shower axis within the fiducial ECAL volume
  - electromagnetic shape of the shower



Analysis: 2D fit to measure $Ne^{\pm}$ and Np

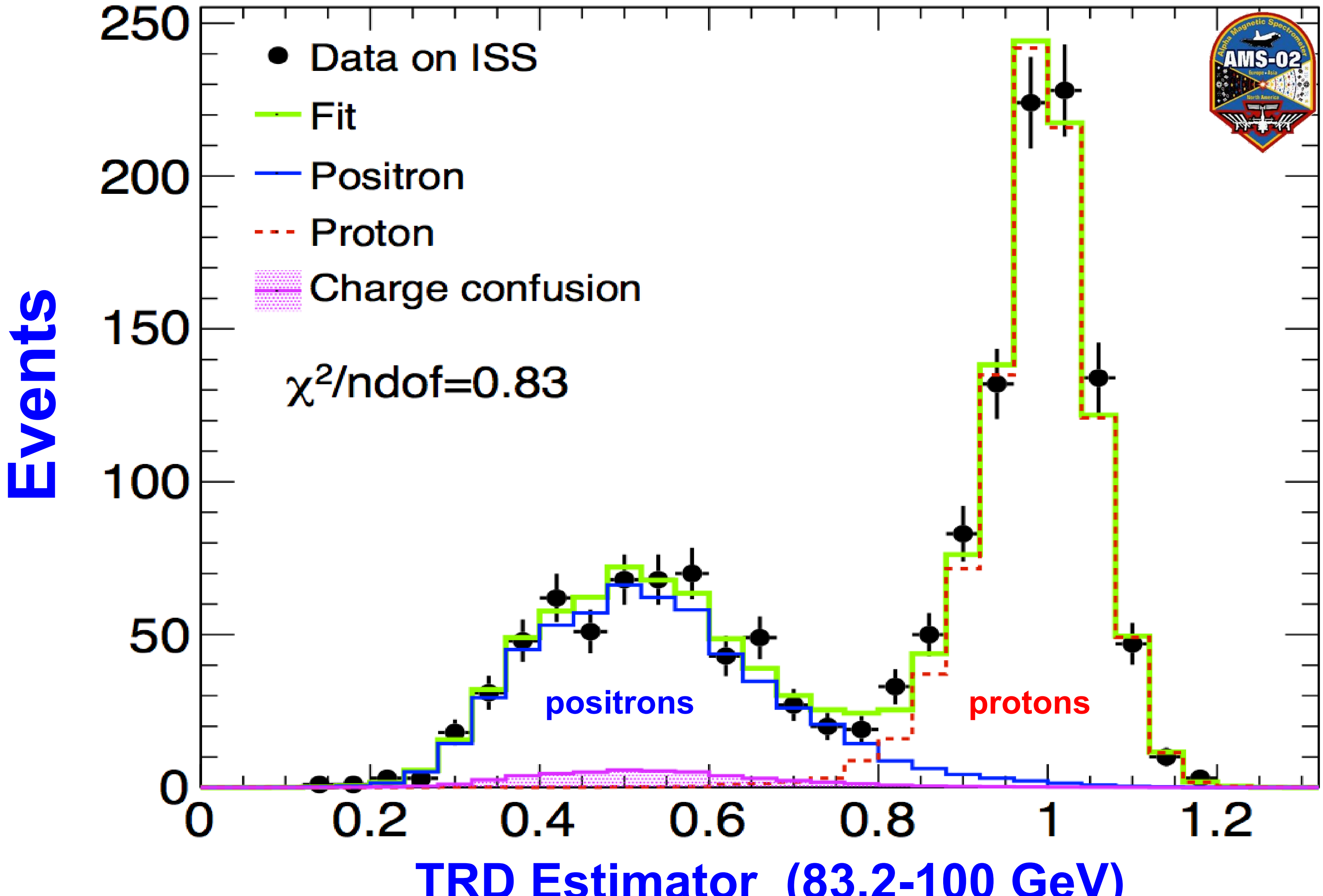
2D reference spectra for the signal and the background are fitted to data in the [TRD estimator- log(E/|P|)] plane.

The method combines redundant information from TRD, ECAL, and Tracker; and provides much better statistical accuracy compared to cut-based analysis.

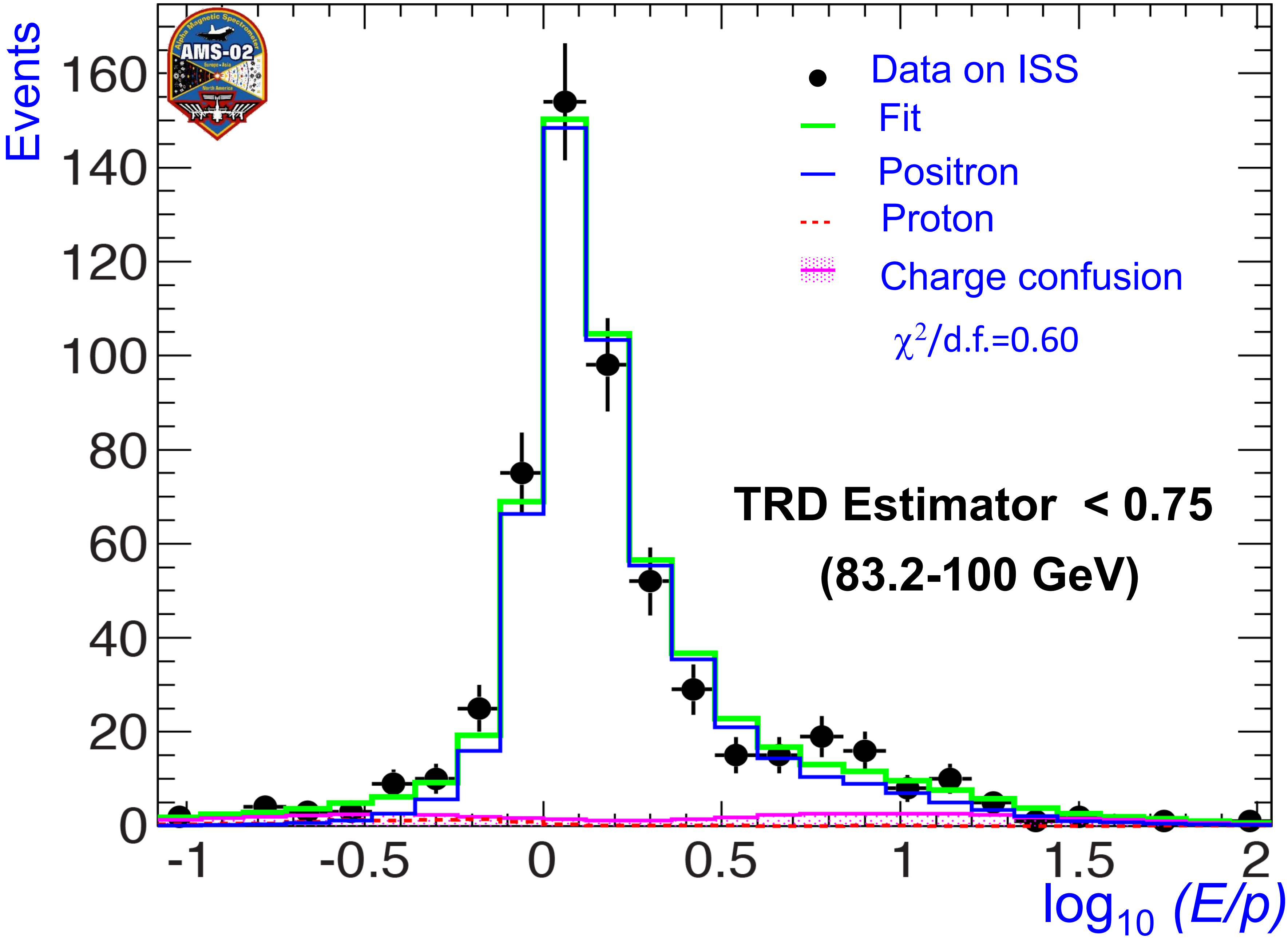


Results of the fit:

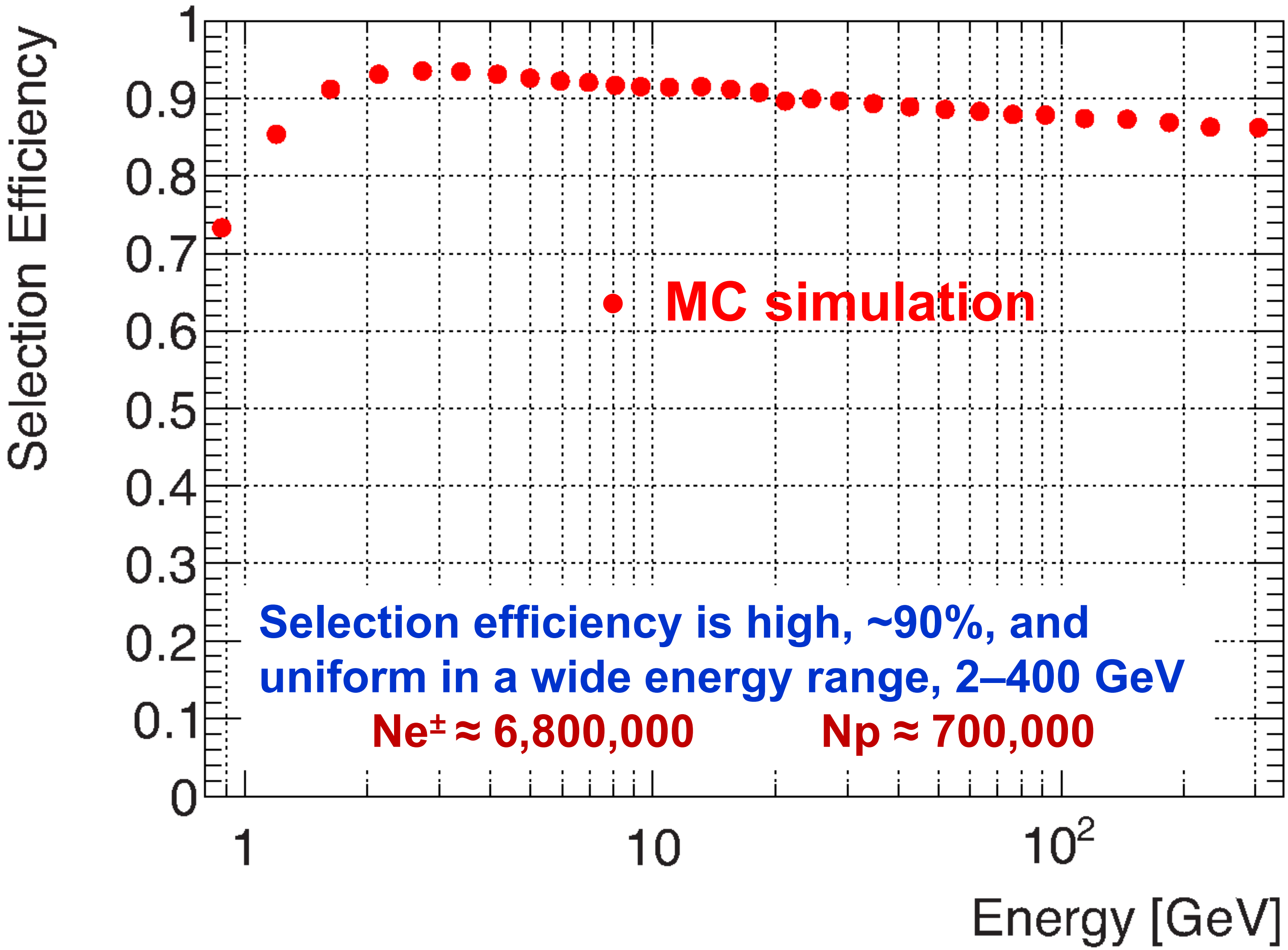
The TRD Estimator shows clear separation between protons and positrons with a small charge confusion background



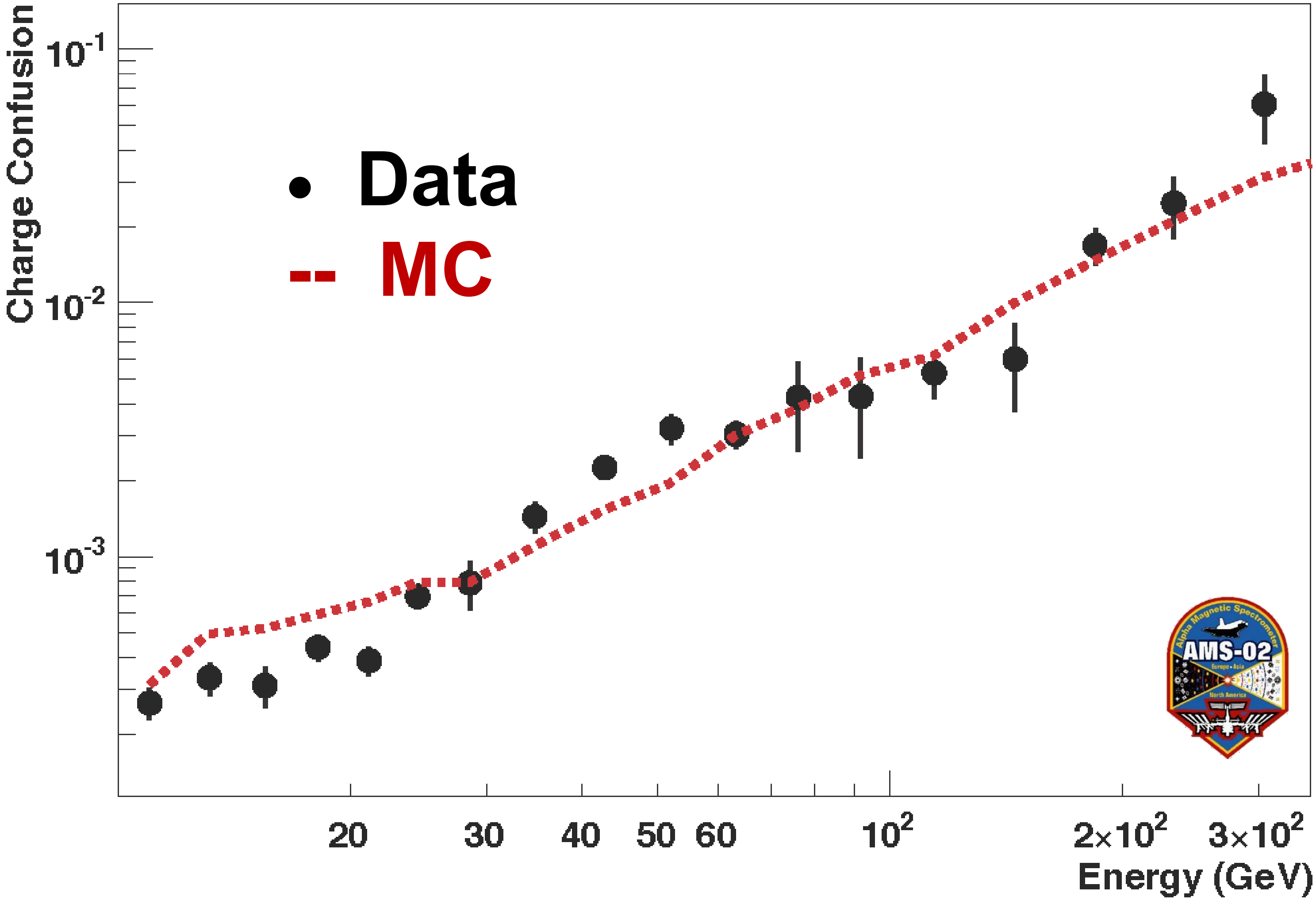
Results of the fit: in the signal region only 1 % of protons



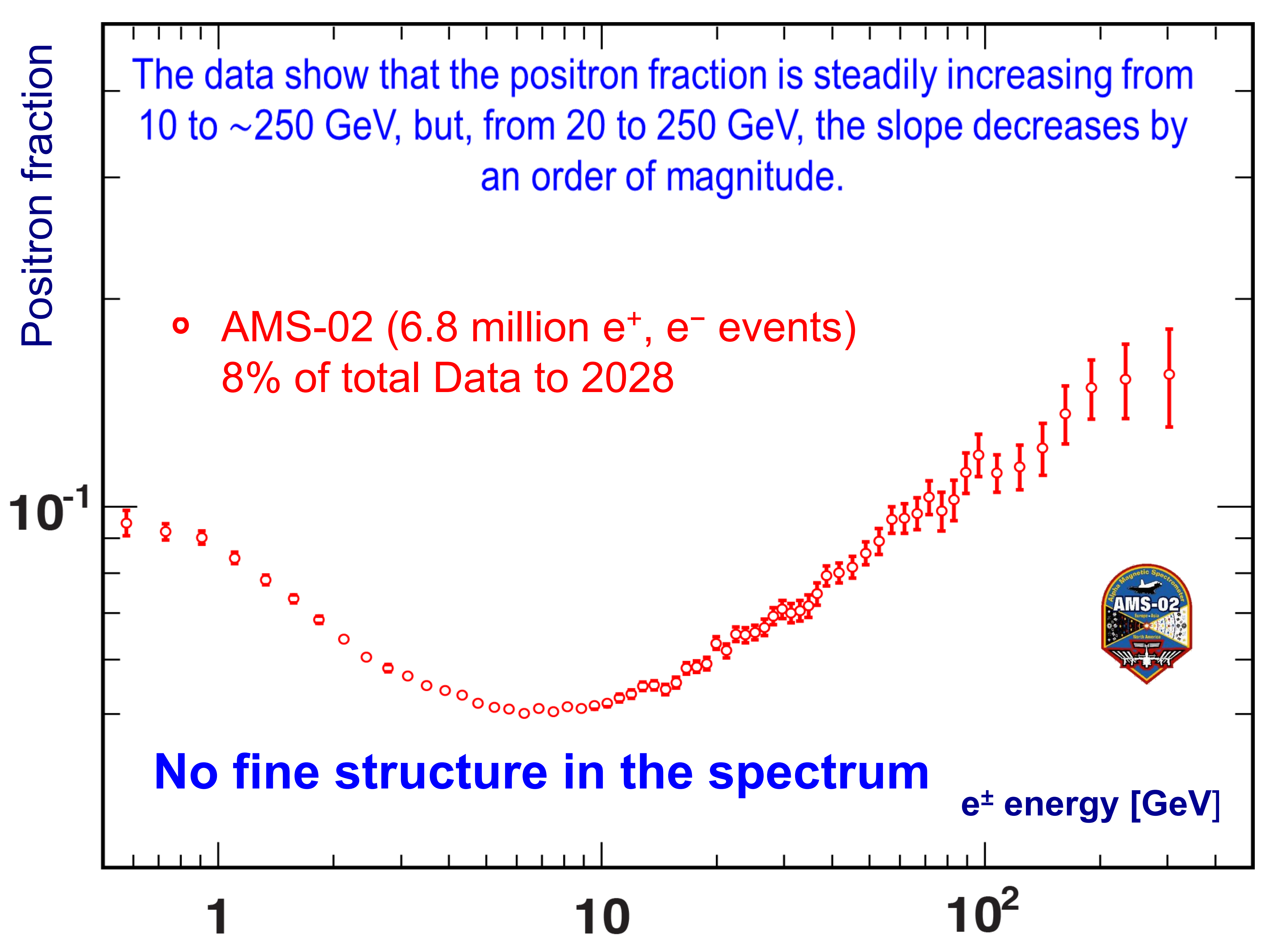
Selection efficiency



Systematic error on the positron fraction: 5. e+/- Charge confusion



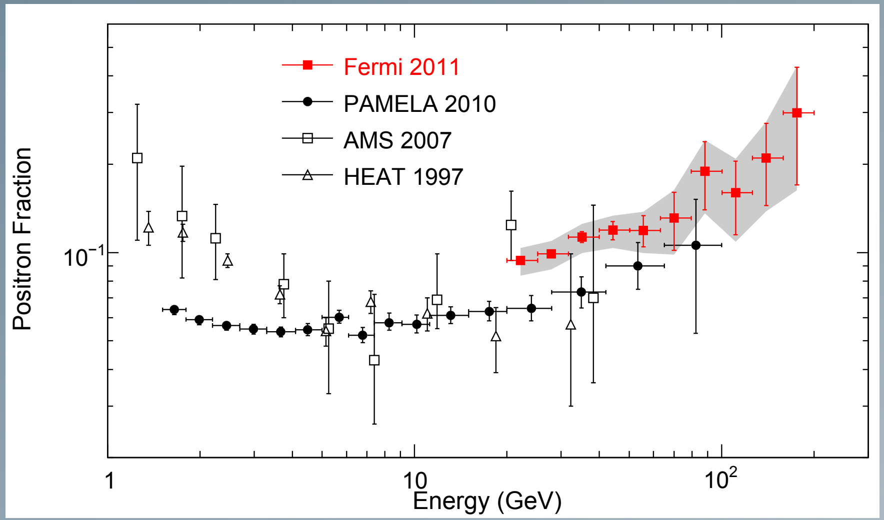
Two sources: large angle scattering and production of secondary tracks along the path of the primary track. Both are well reproduced by MC. Systematic errors correspond to variations of these effects within their statistical limits.



The data show that the positron fraction is steadily increasing from 10 to ~250 GeV, but, from 20 to 250 GeV, the slope decreases by an order of magnitude.
AMS-02 (6.8 million e+, e− events)
8% of total Data to 2028
No fine structure in the spectrum
Positron fraction
e± energy [GeV]
10-1
1
10
102
AMS-02

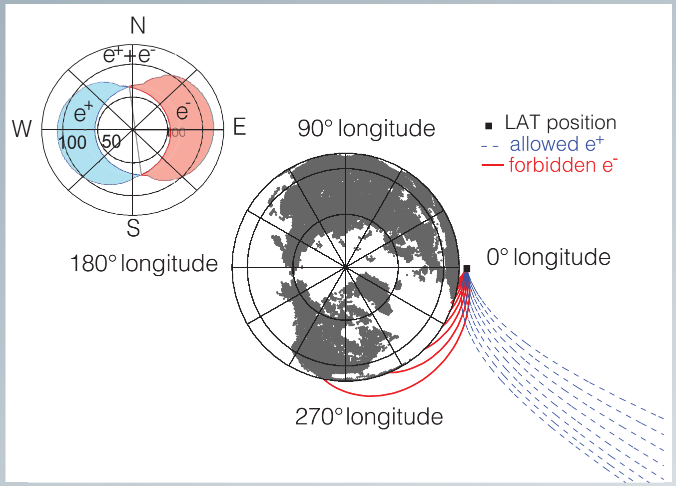
Independent confirmation

- By Fermi (!):

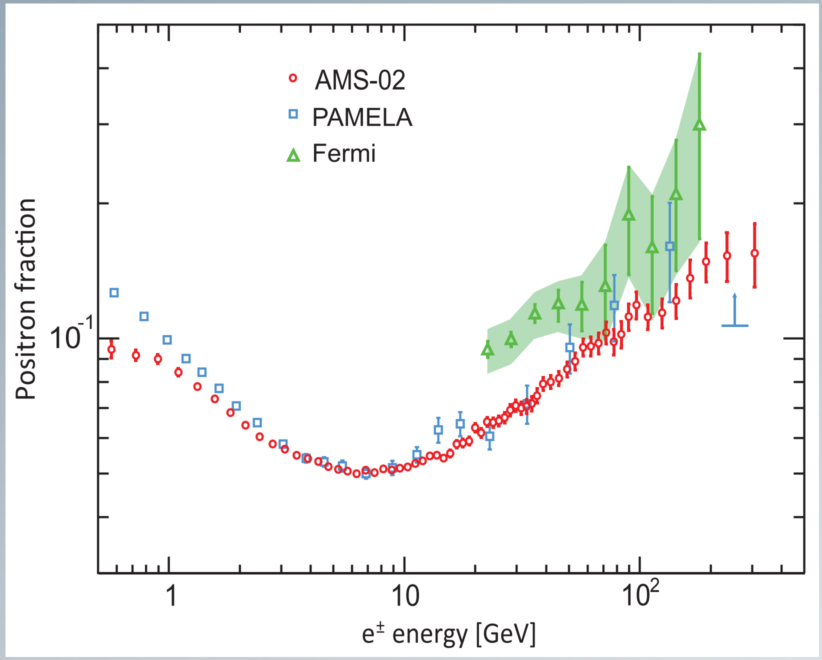


Ackermann *et al.*, PRL '12

NB: Fermi does not have a magnet on board, but uses the earth magnetic field!



- By AMS:



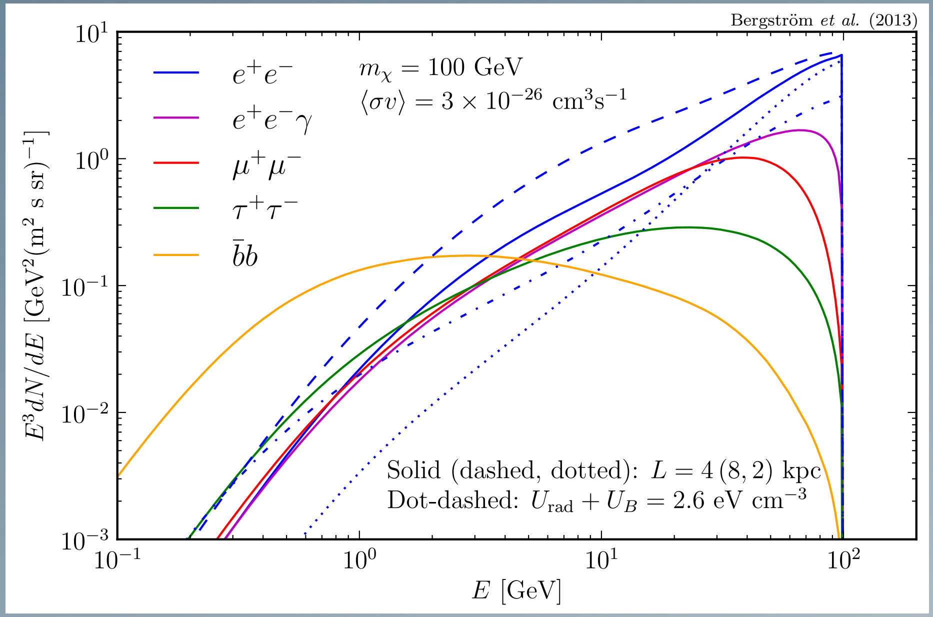
Aguilar *et al.*, PRL '13

S.Ting:

"Over the coming months, AMS will be able to tell us conclusively whether these positrons are a signal for dark matter, or whether they have some other origin"

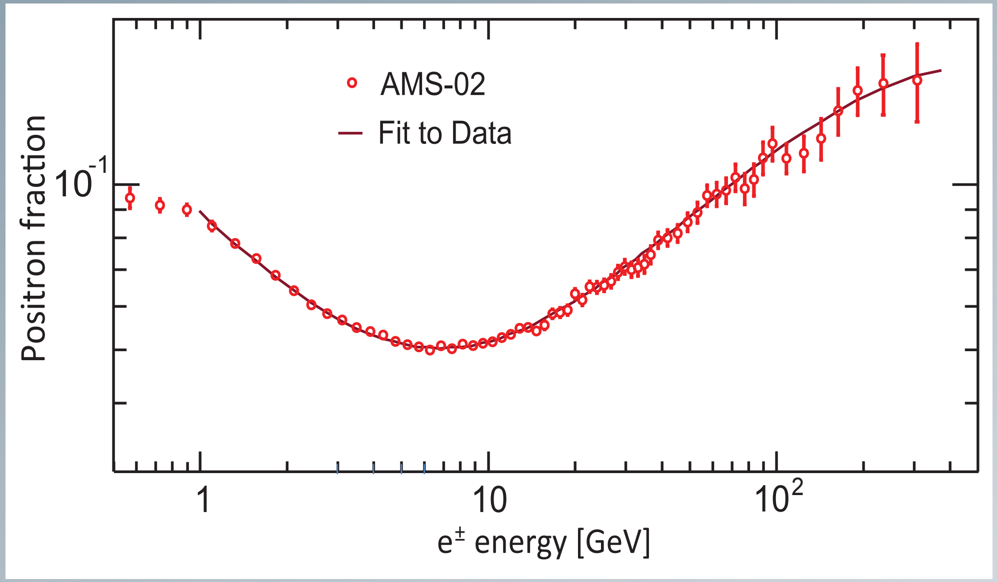
Re-assessing the e^+ channel

- Simple observation #1:



Sharp spectral features do exist, for leptonic channels, even after propagation!

- Simple observation #2:



AMS provides data
i) with extremely high statistics
ii) for which a simple (5 param) smooth BG model provides an excellent fit

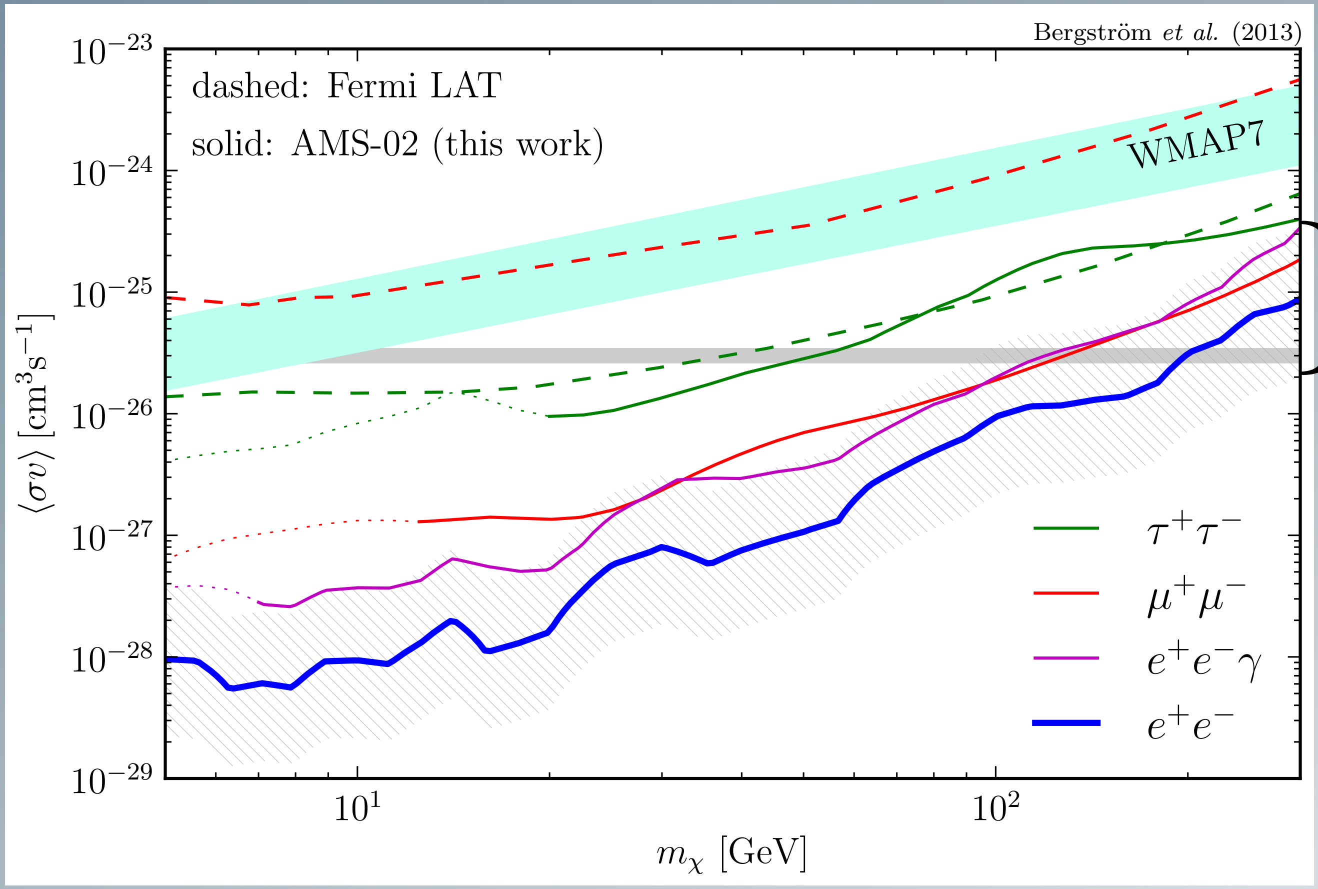
Let's try a spectral fit!

Spectral fit with positrons

Bergström, TB, Cholis, Hooper & Weniger, 1306.3983

- ~same procedure as for gamma rays...

[profile likelihood; *no* sliding energy window, 5 params for BG instead of 2]

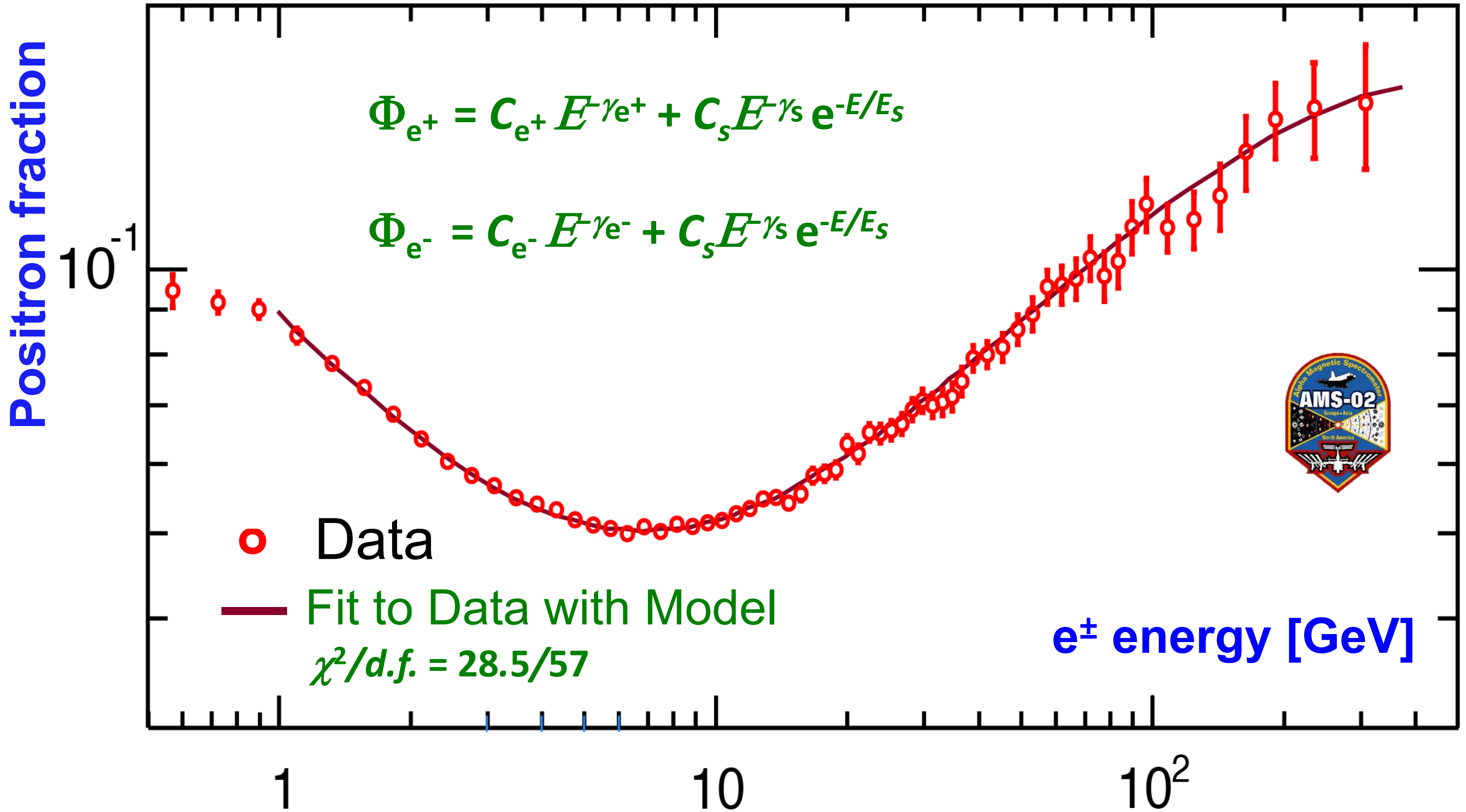


represents uncertainty in
i) local DM density
ii) local radiation density

NB: this method gives very robust limits – but only for spiky signals!

⇨ *Most stringent existing limits on (light) leptonic states!*

Physics Example: Comparing data with a minimal model.



The agreement between the data and the model shows that 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.

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

I. At energies < 10 GeV, a decrease in the positron fraction with increasing energy.

II. A steady increase in the positron fraction from 10 to ~250 GeV.

III. The determination of the behavior of the positron fraction from 250 to 350 GeV and beyond requires more statistics.

IV. The slope of the positron fraction versus energy decreases by an order of magnitude from 20 to 250GeV and no fine structure is observed. The agreement between the data and the model shows that 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.

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