Recent results from the AMS-02 Experiment

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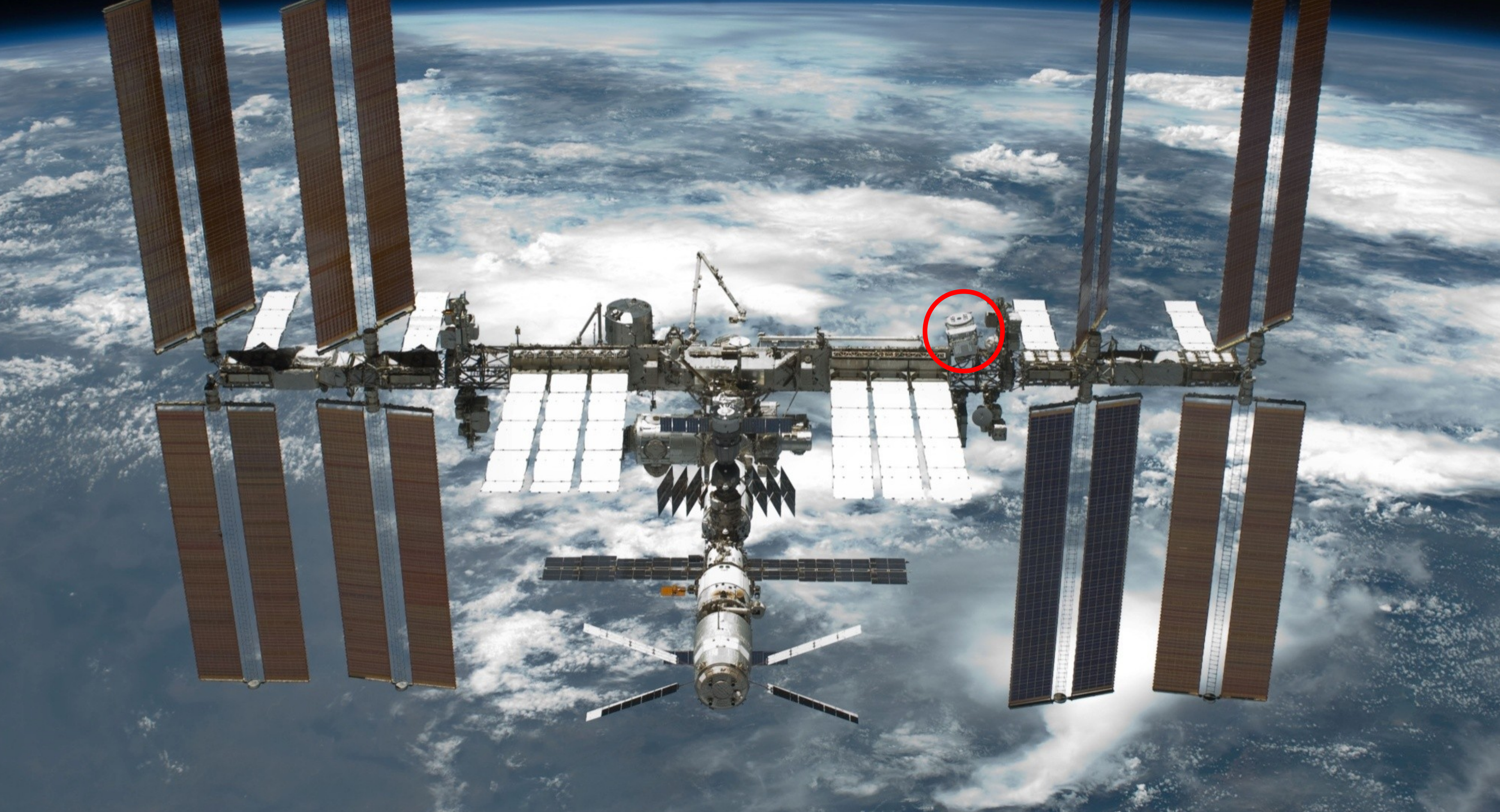
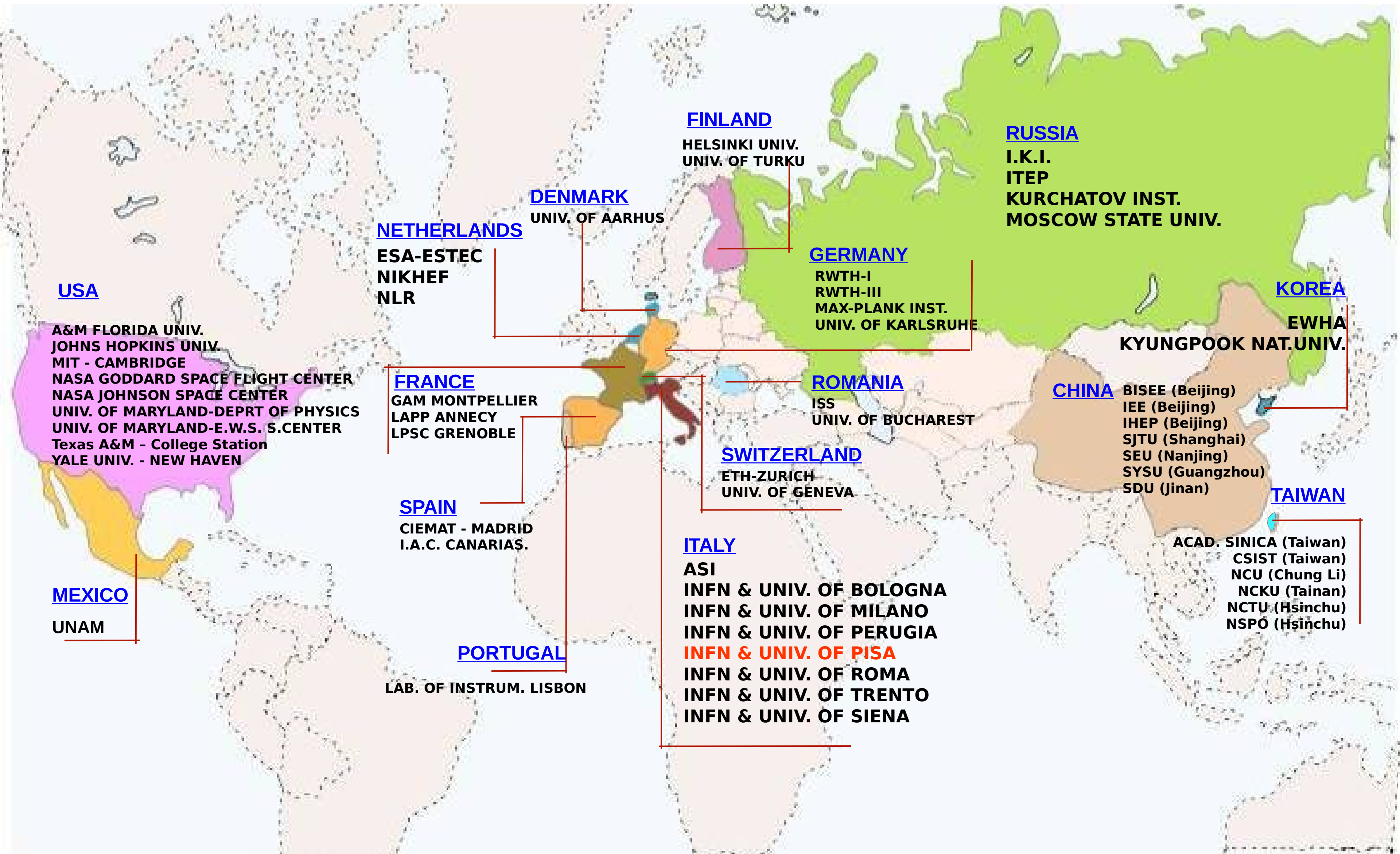


Outline

- The AMS experiment
- AMS Physics opportunities
- Previous results from Pamela
- Positron fraction and electron and positron fluxes
- Proton, Helium and Lithium flux
- Antiproton/proton ratio
- B/C ratio
- Future experiments: CALET, DAMPE, HERD

The AMS-02 international collaboration



16 countries, 56 Institutions, 500 Phycisist

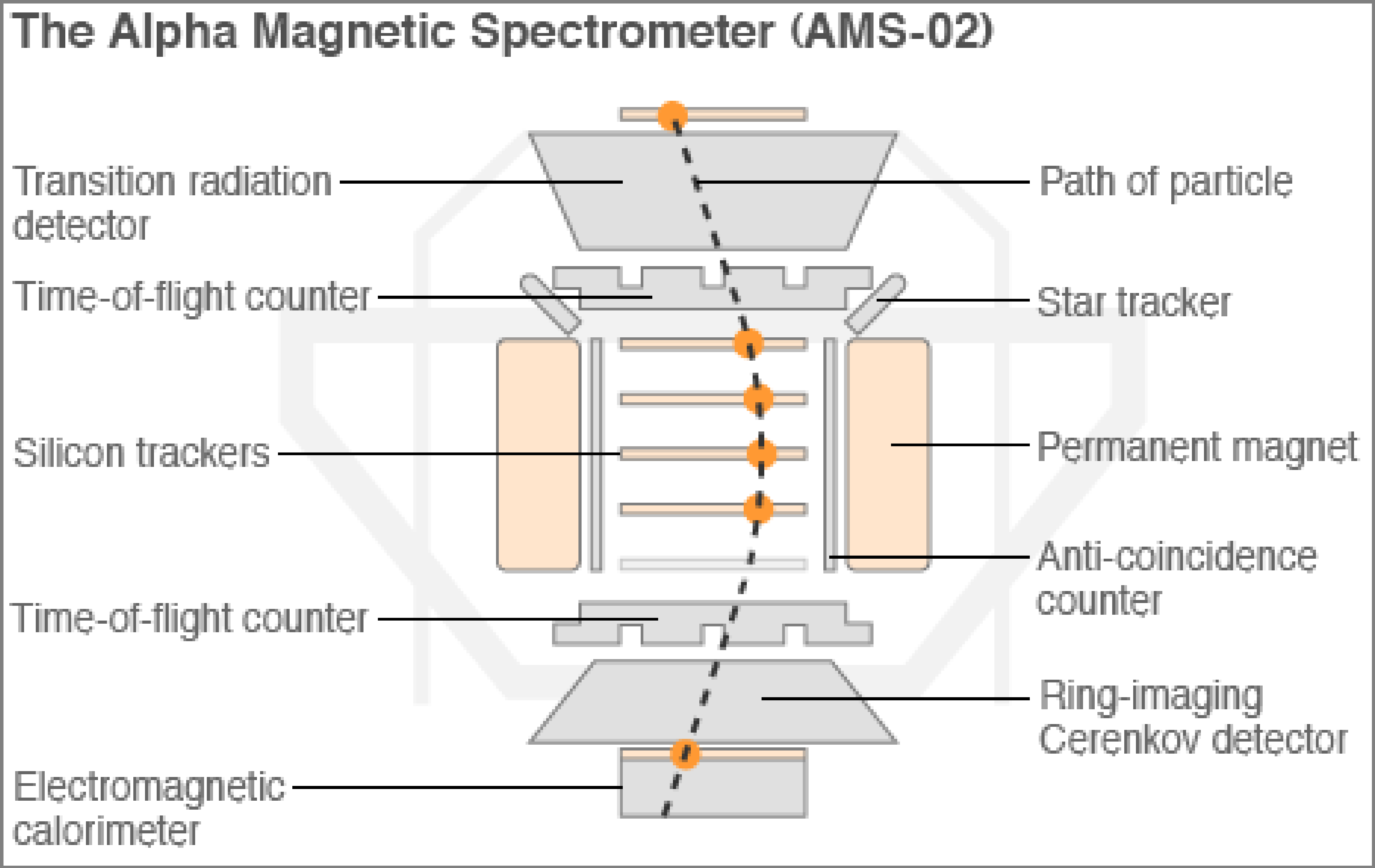
AMS: a particle physics experiment in Space

Weight   7500 kg
Volume   64 cubic meters
 (5m x 4m x 3m)
Power   2500 watts
Data flow 2 Mbps (average)

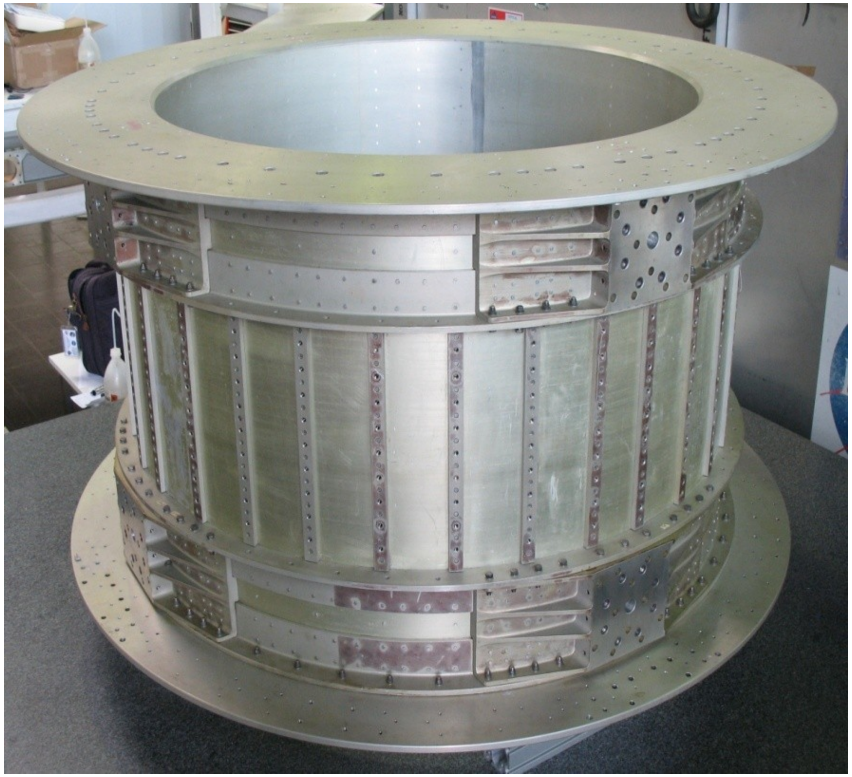
Launch 16th May 2011, 08:56 am
Mission duration through the lifetime of the ISS, until 2028

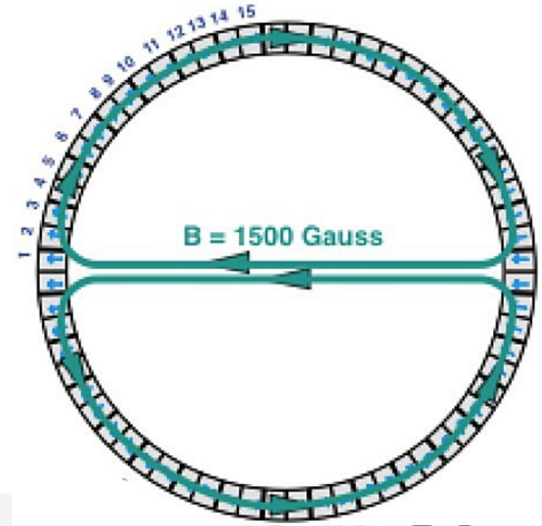
Construction 1999-2010
Cost $1.5 billion (estimated)

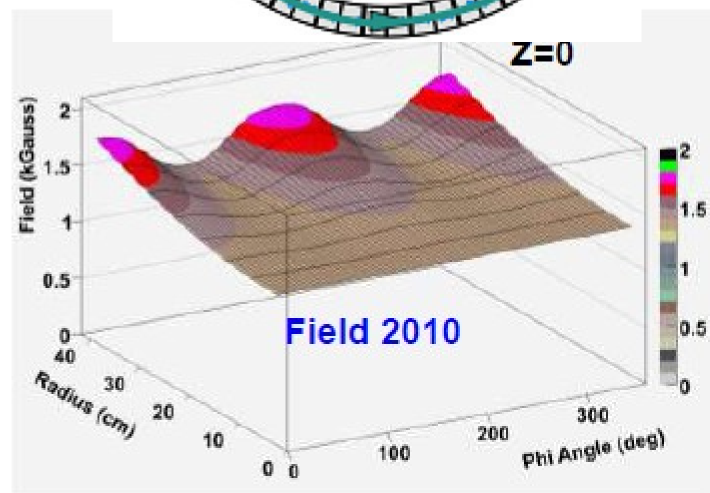
15 Subsystems among particle detectors and supporting subsystems


The Alpha Magnetic Spectrometer (AMS-02)
Transition radiation detector
Path of particle
Time-of-flight counter
Star tracker
Silicon trackers
Permanent magnet
Anti-coincidence counter
Time-of-flight counter
Ring-imaging Cerenkov detector
Electromagnetic calorimeter

The Magnet



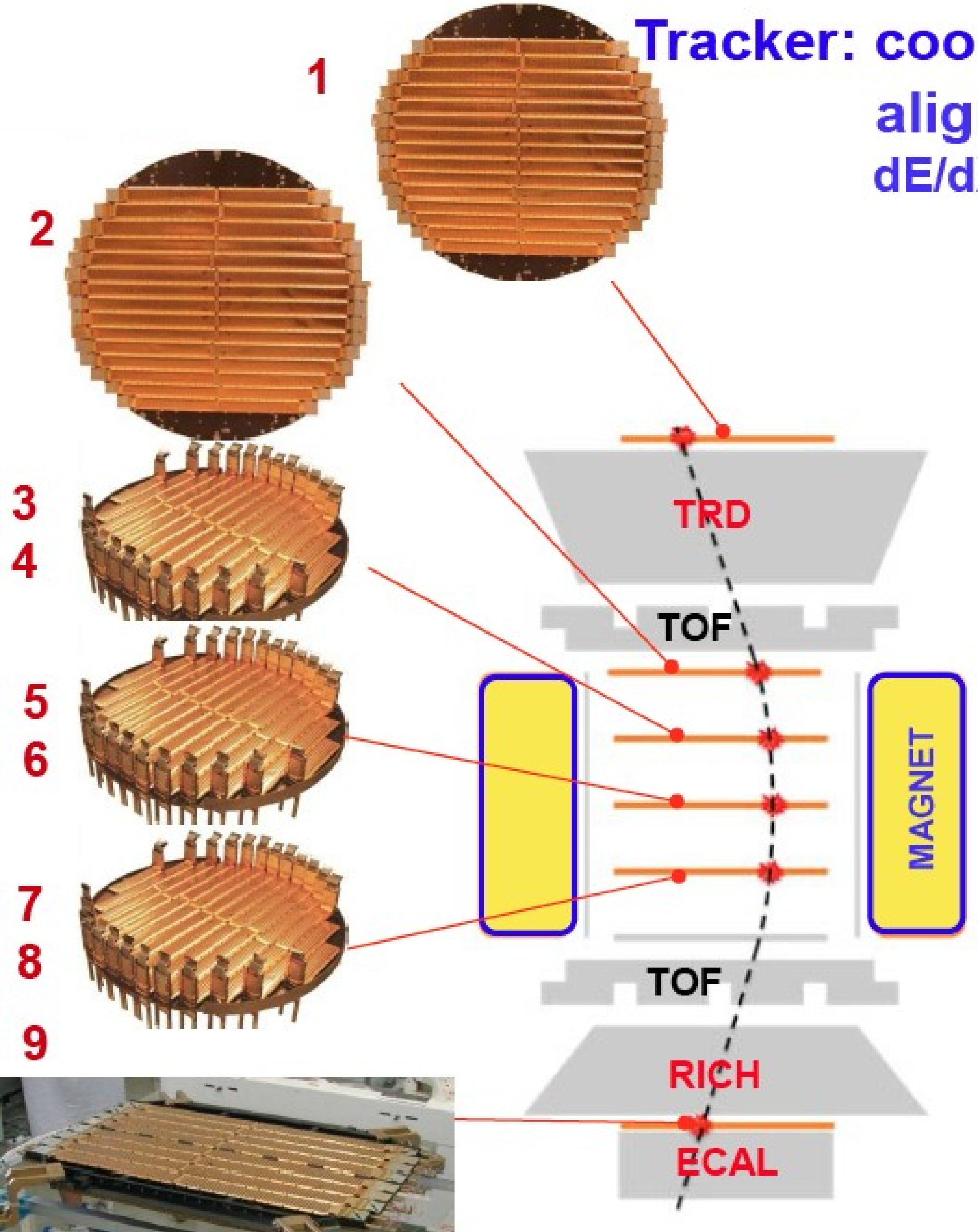


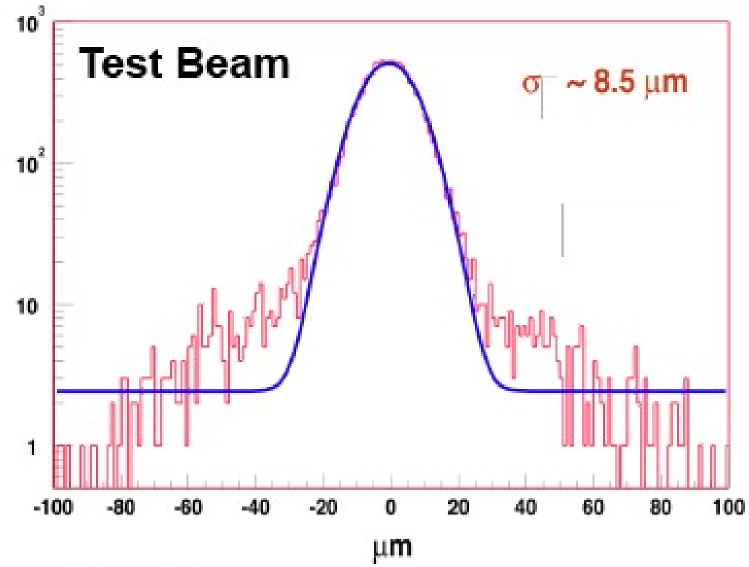


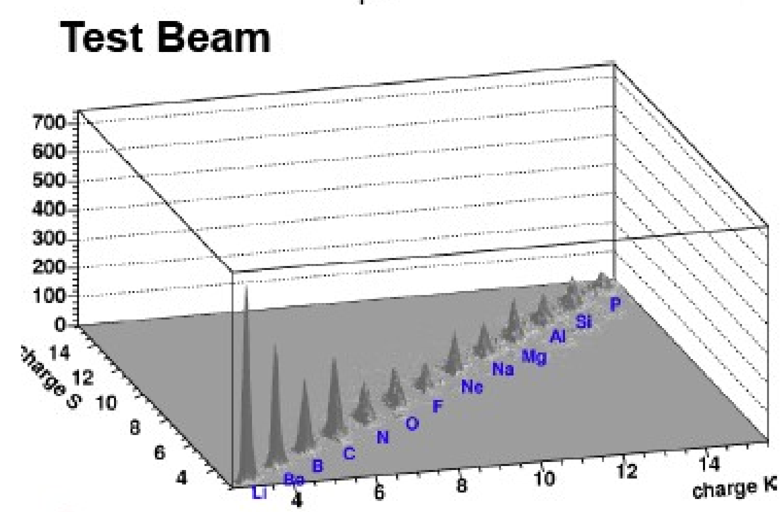
1. Stable: no variation
2. Safety : no field leak out of the magnet
3 . Low weight (1200 kg): Neodymium alloy (no iron)

The detailed 3D field map (120k locations) was measured in May 2010: It was found that the deviation from the 1997 measurement had remained the same to <1%

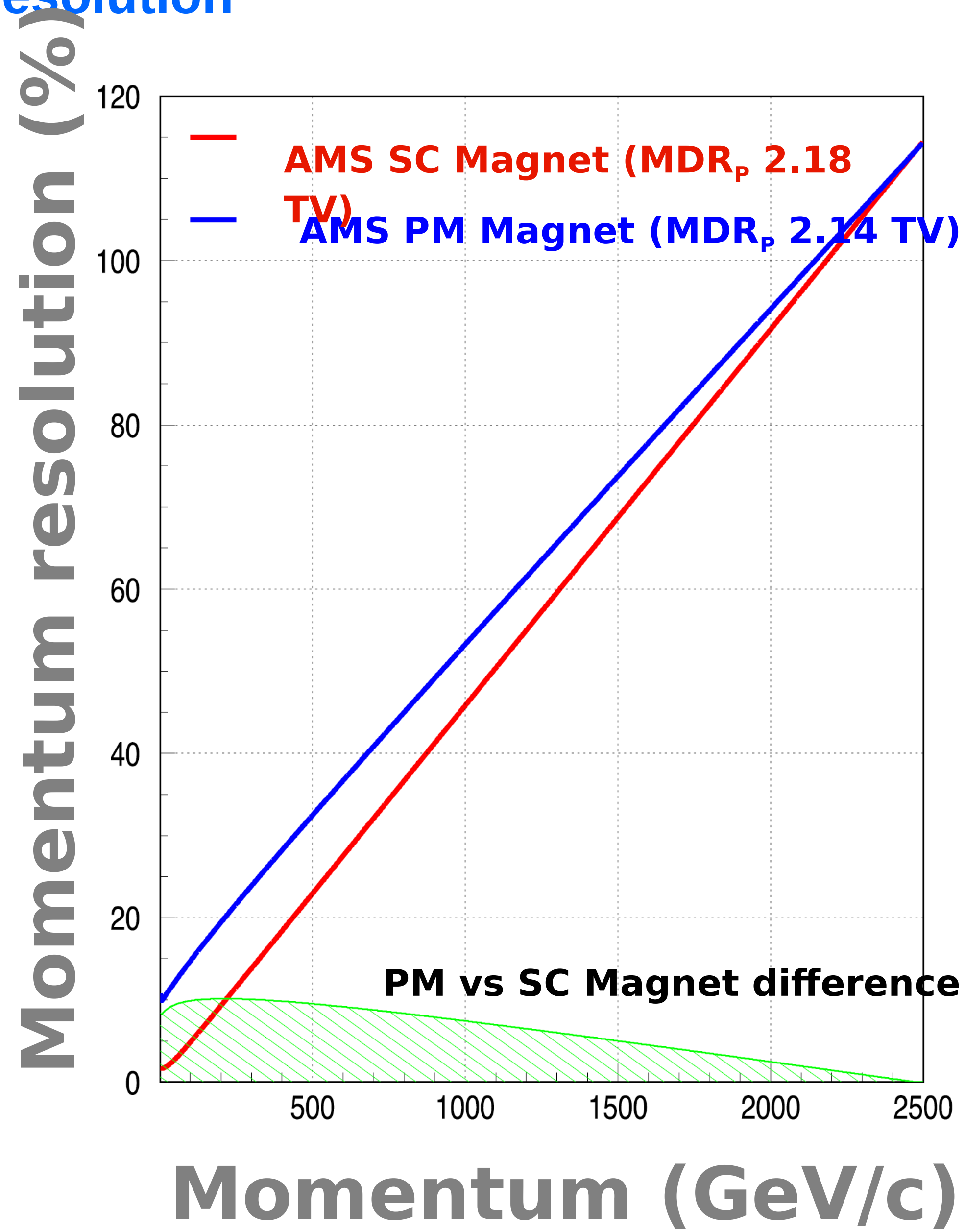
Tracker: coordinate resolution 10 μ
alignment: 3 μ with 20 UV lasers
dE/dX: identify nuclei



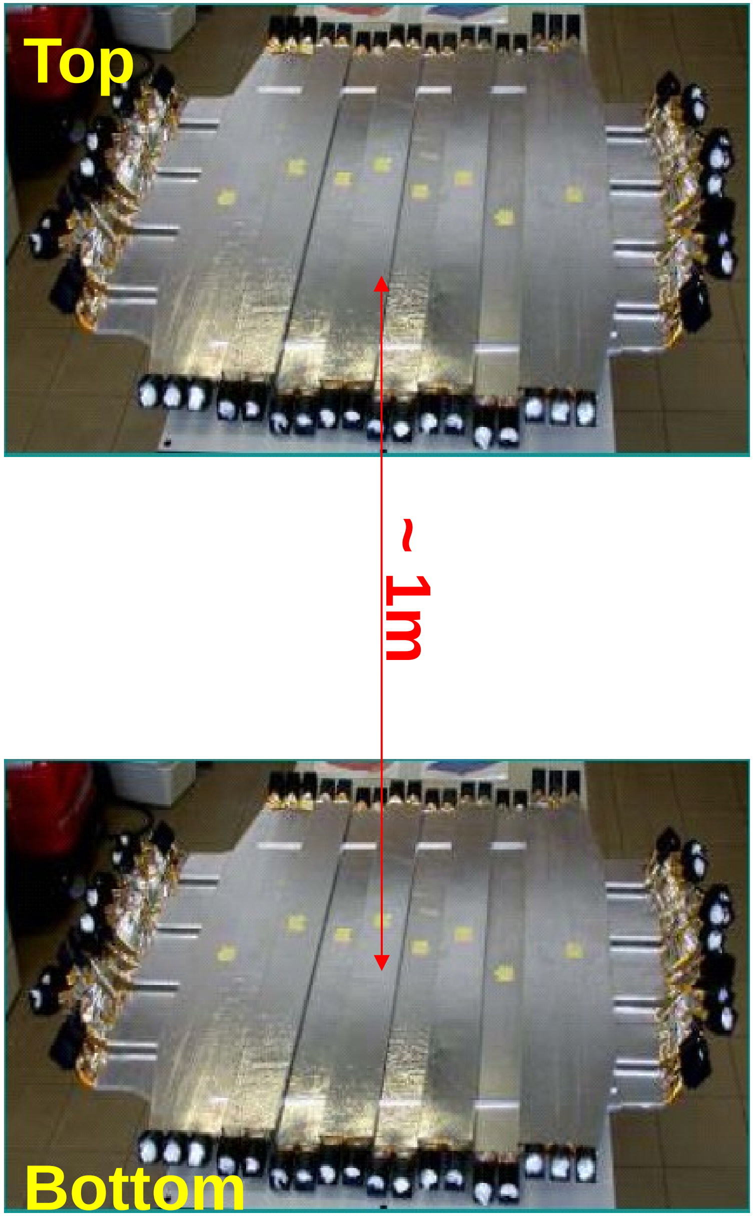




Momentum Resolution



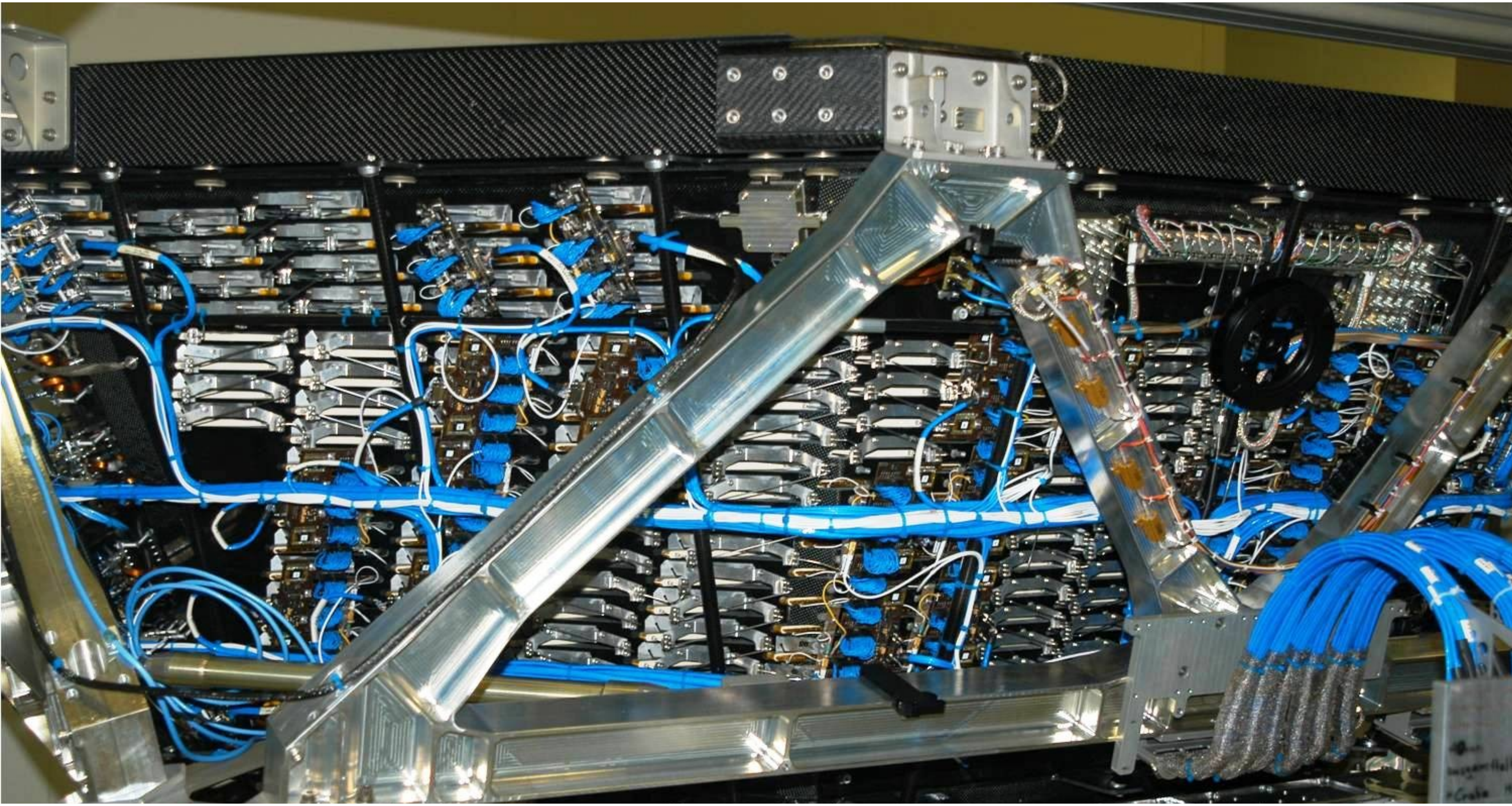
Time Of Flight



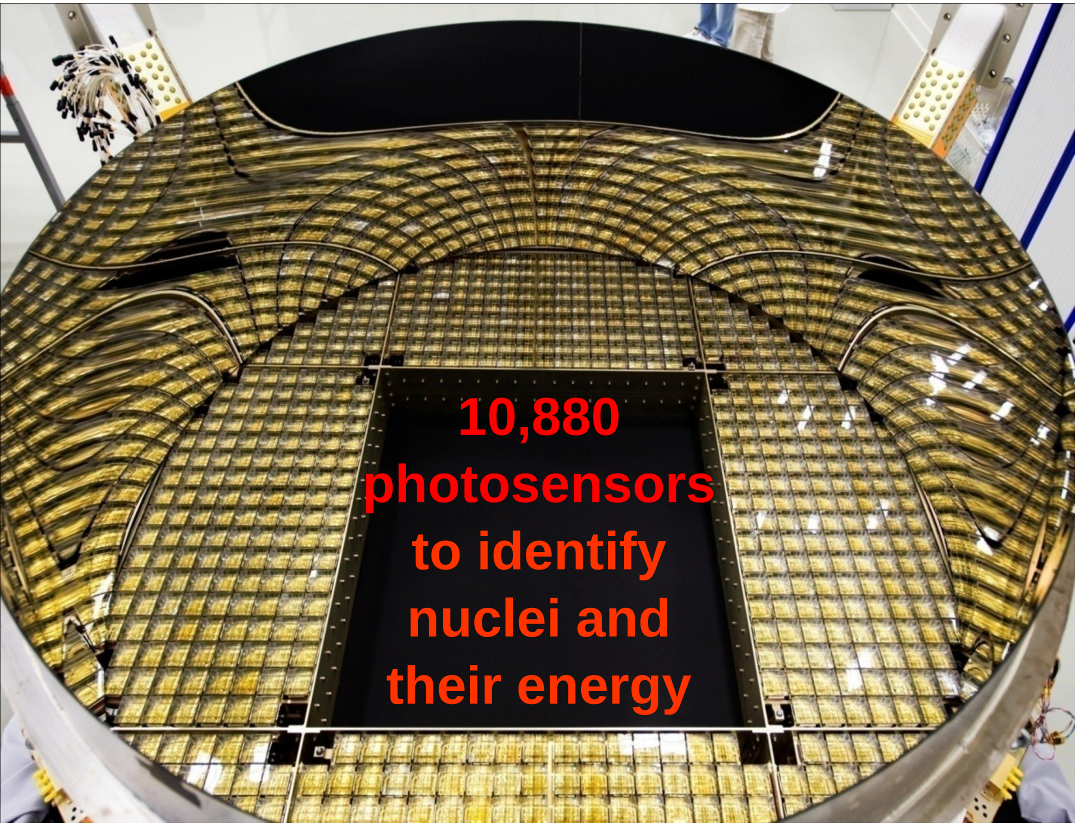
2x2 layers of scintillation counters

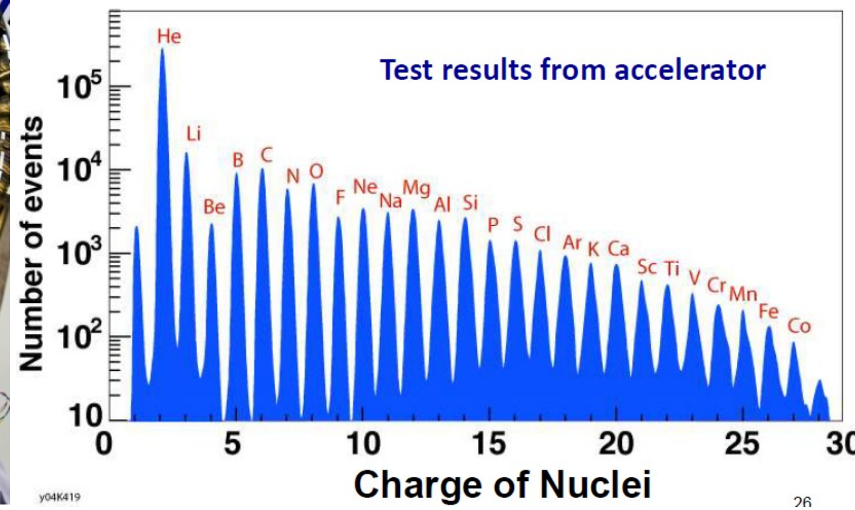
- ✓ Time resolution: 60 ps
- ✓ Particle direction
- ✓ β
- ✓ Charge Z (dE/dx)

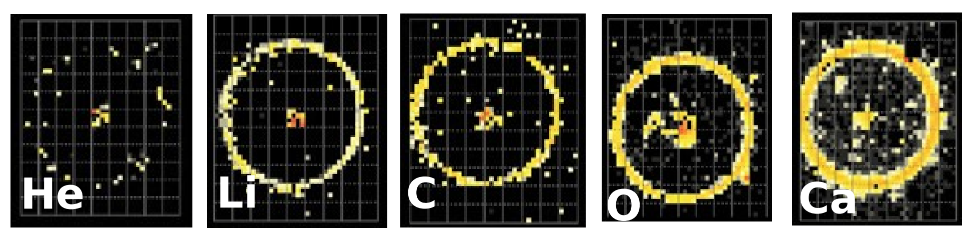
Transition Radiation Detector (TRD)



Ring Imaging CHerenkov (RICH)

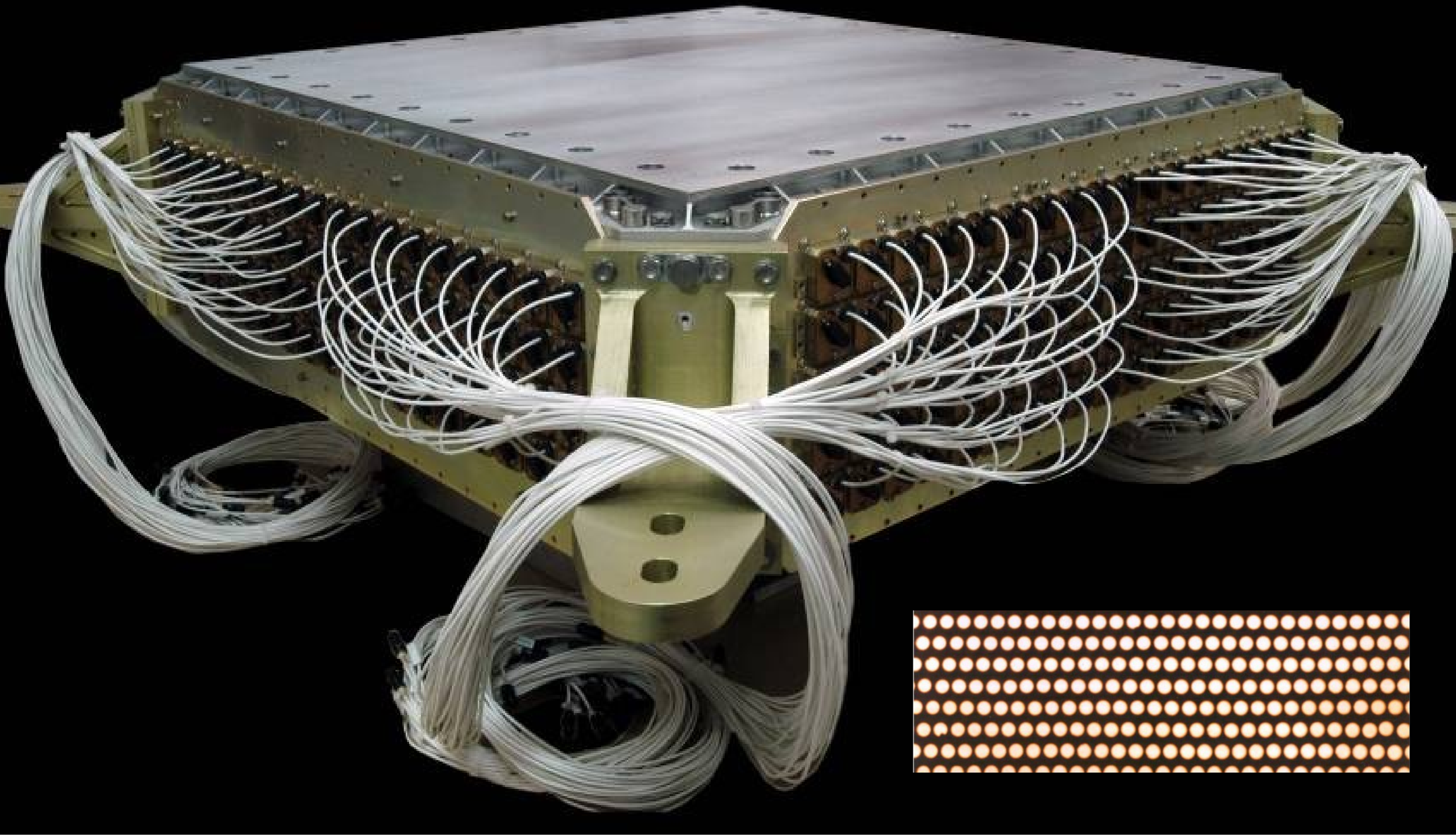






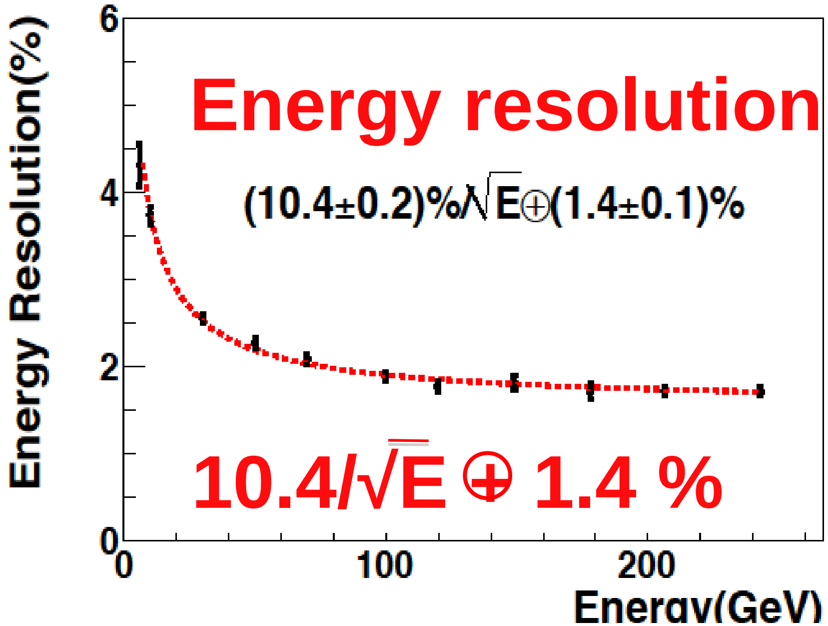
- β resolution: 0.1%
- Nuclei identification

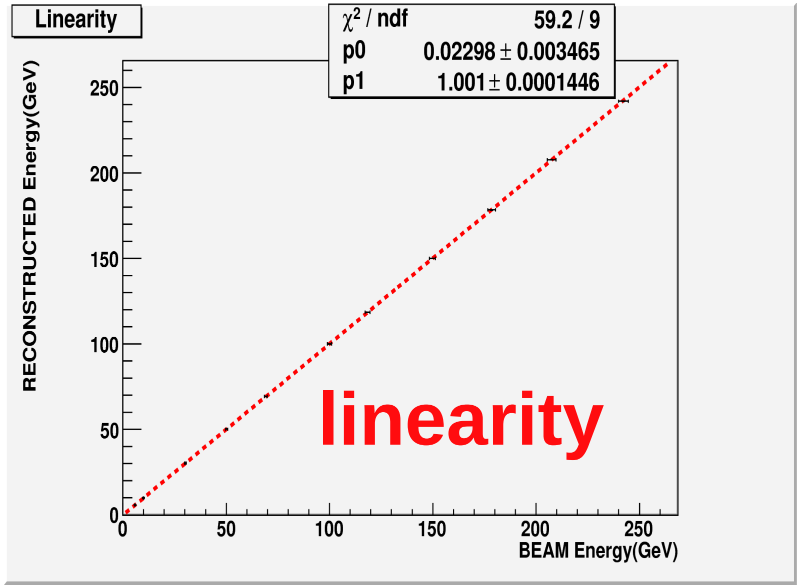
Electromagnetic Calorimeter (ECAL)

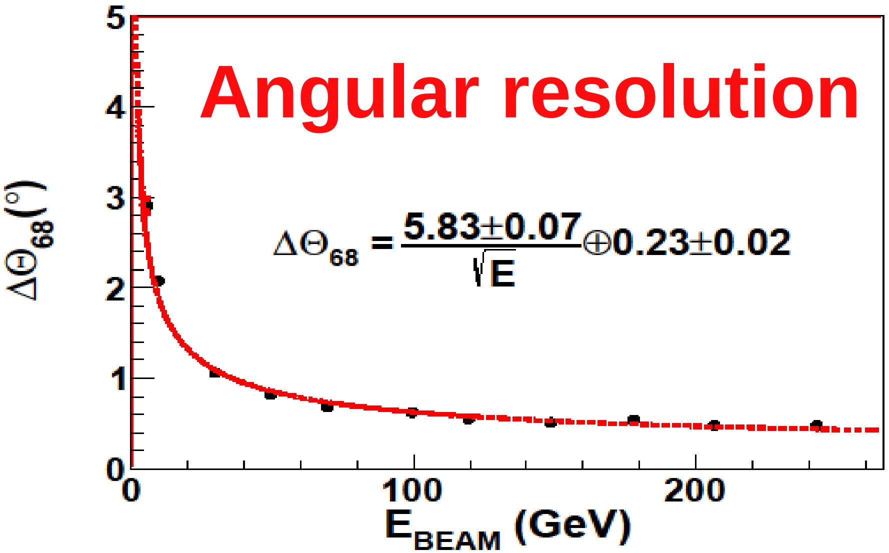


50,000 optical fibers,diameter=1 mm, distributed uniformly inside 600 kg of lead to measure energy (~2% resolution) of electrons and gamma rays up to 1 TeV

ECAL performances measured at test beam





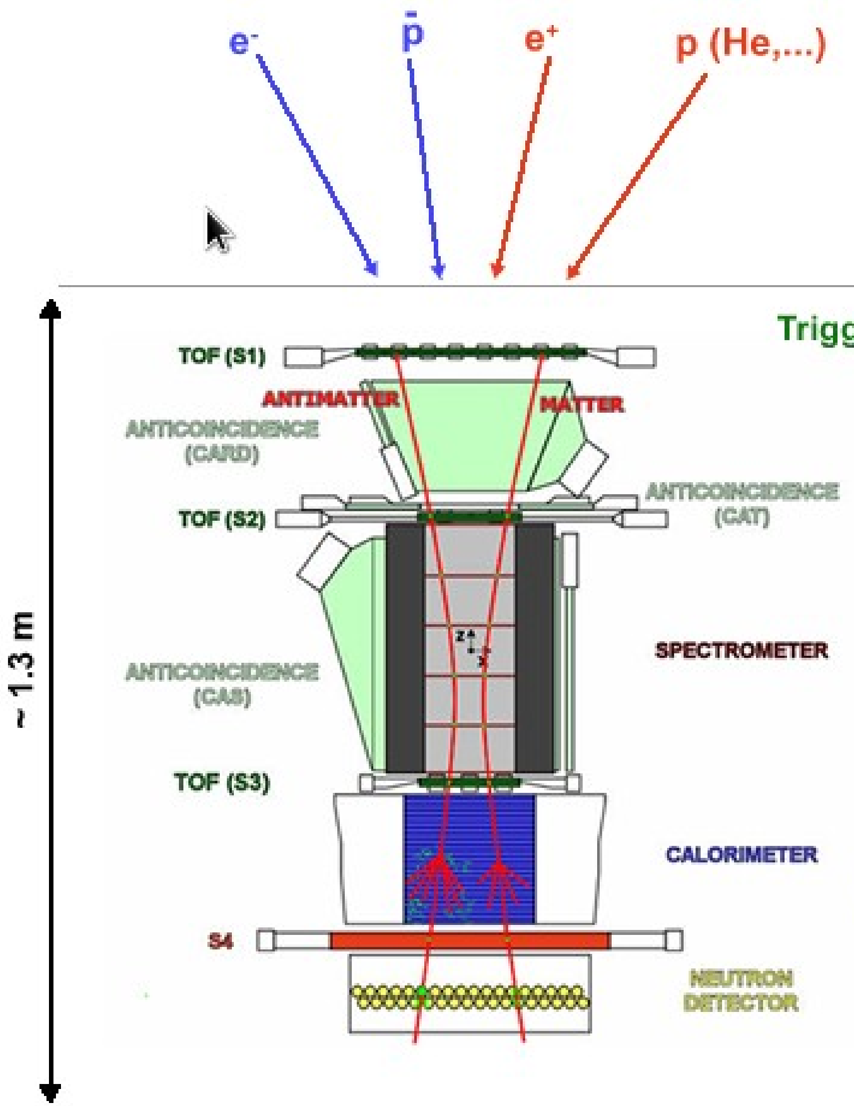


2010 Test Beam results

AMS Physics goals

	e^-	p	He,Li,Be,..Fe	γ	e^+	$\bar{p}$, $\bar{d}$	$\bar{He}$, $\bar{C}$
TRD							
TOF							
Tracker							
RICH							
ECAL							
Field of study	CR Spectroscopy				Dark Matter		Antimatter

The Pamela experiment



~470 Kg / ~360 W

Trigger, ToF, dE/dx

- S1, S2, S3; double layers, x-y
- plastic scintillator (8mm)
- ToF resolution ~300 ps (S1-3 ToF >3 ns)
- lepton-hadron separation < 1 GeV/c
- S1.S2.S3 (low rate) / S2.S3 (high rate)

Sign of charge, rigidity, dE/dx

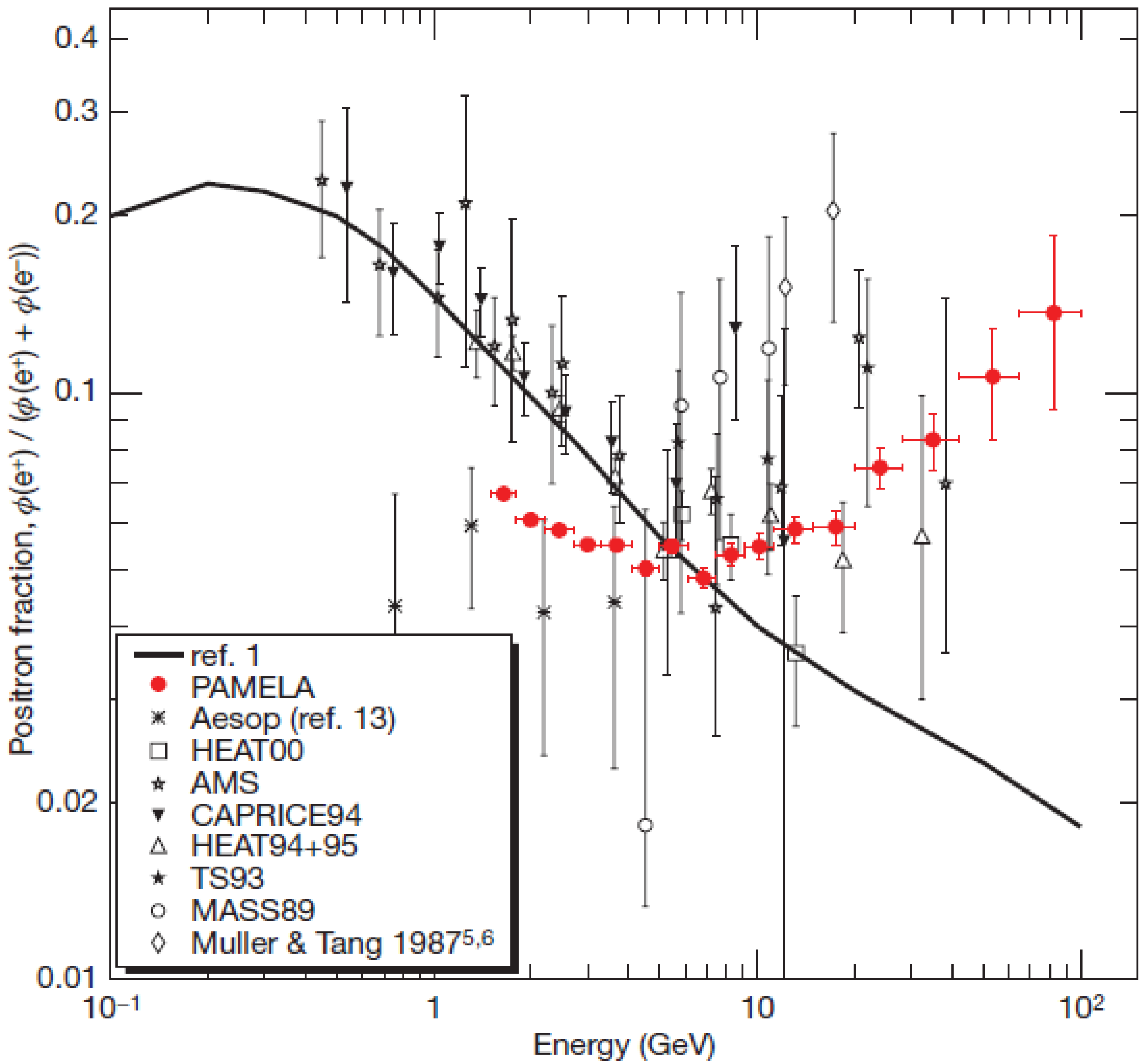
- Permanent magnet, 0.43 T
- 21.5 cm^2 sr
- 6 planes double-sided silicon strip detectors (300 μm)
- 3 μm resolution in bending view → MDR ~800 GV (6 plane) ~500 GV (5 plane)

Electron energy, dE/dx, lepton-hadron separation

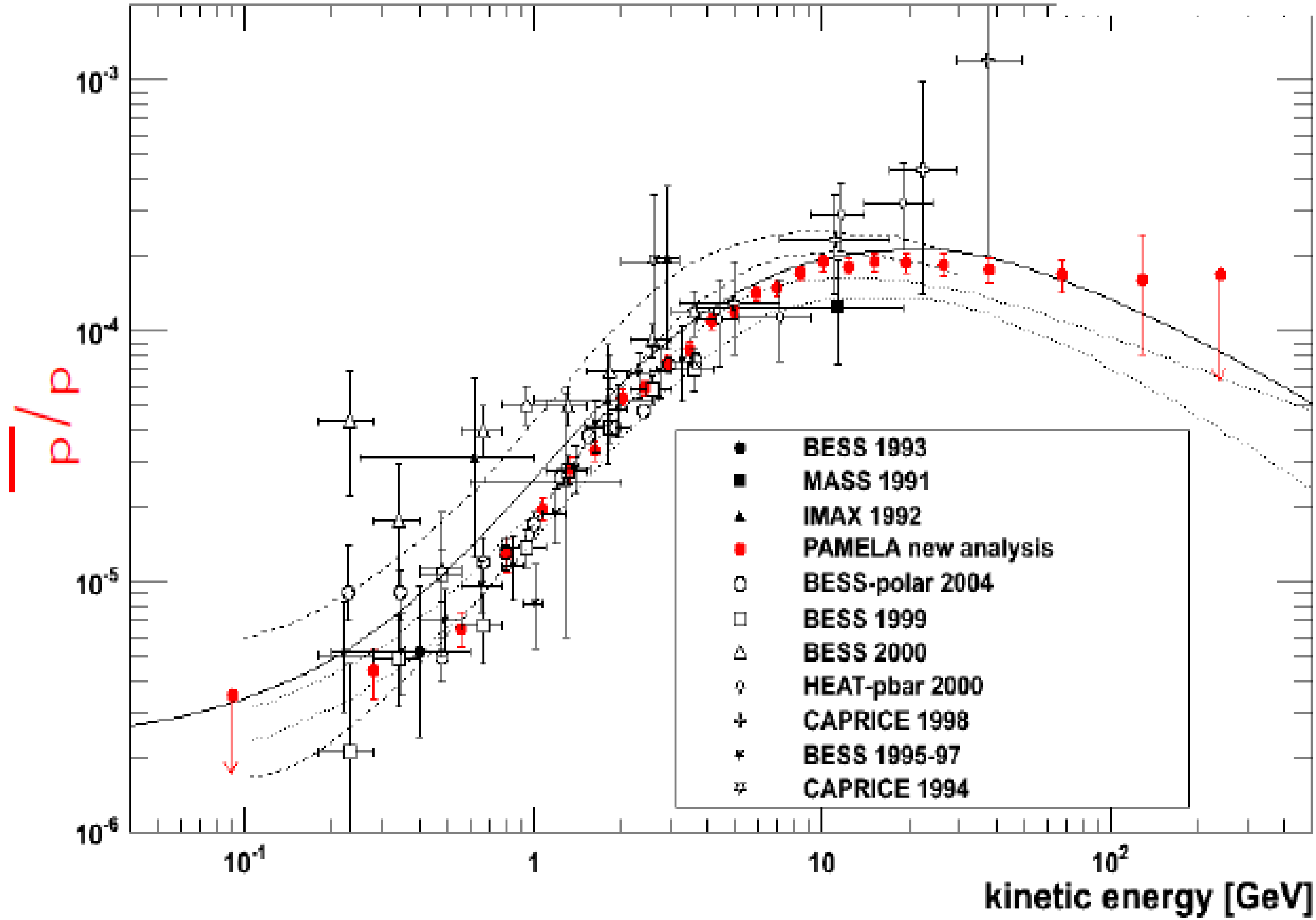
- 44 Si-x / W / Si-y planes (380)
- 16.3 X0 / 0.6 L
- dE/E ~5.5 % (10 - 300 GeV)
- Self trigger > 300 GeV / 600 cm^2 sr

- 36 ^{3}He counters
- ^{3}He(n,p)T; E_p = 780 keV
- 1 cm thick poly + Cd moderator
- 200 μs collection

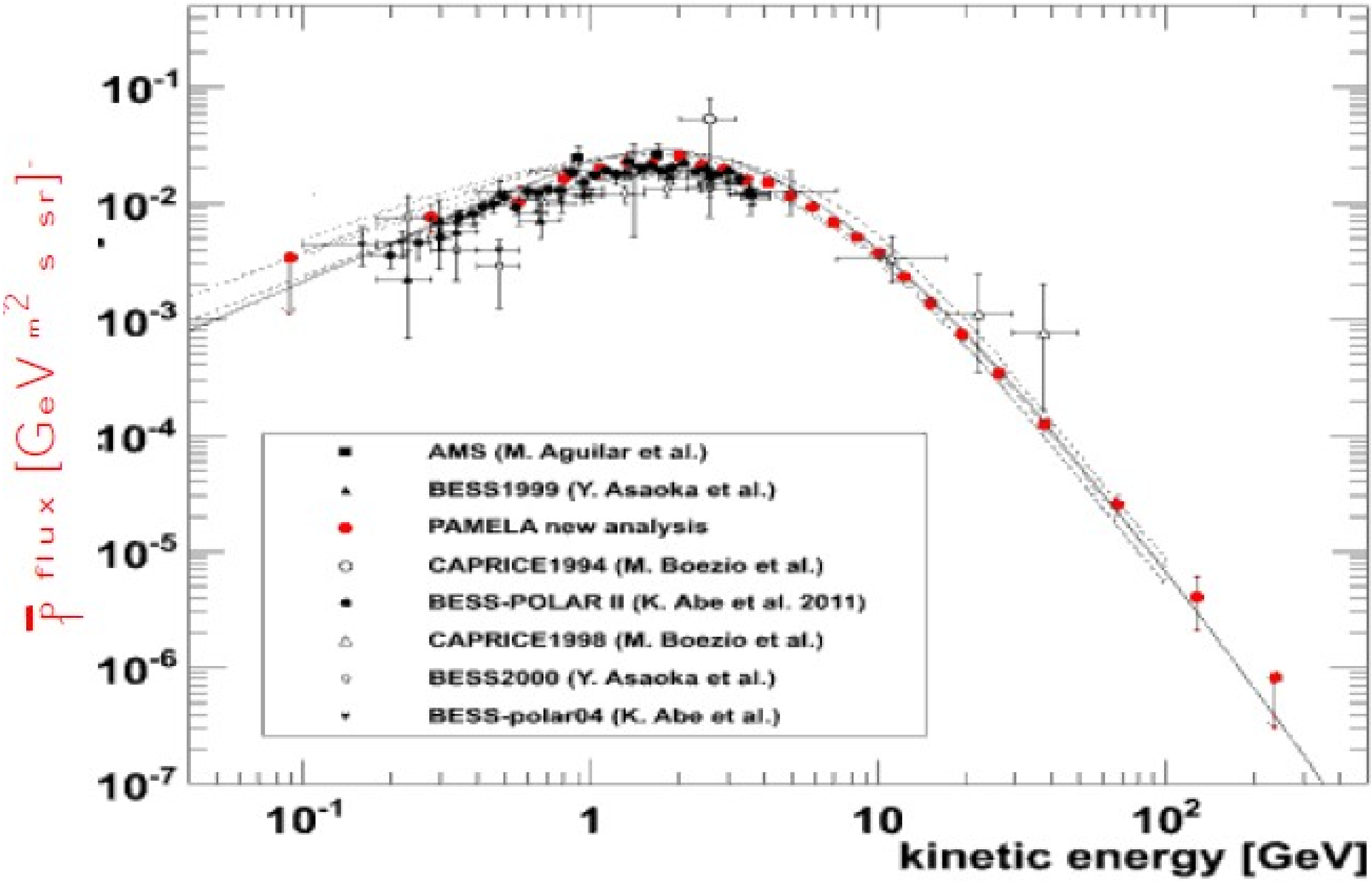
Pamela discovery (2009): a raise in positron fraction



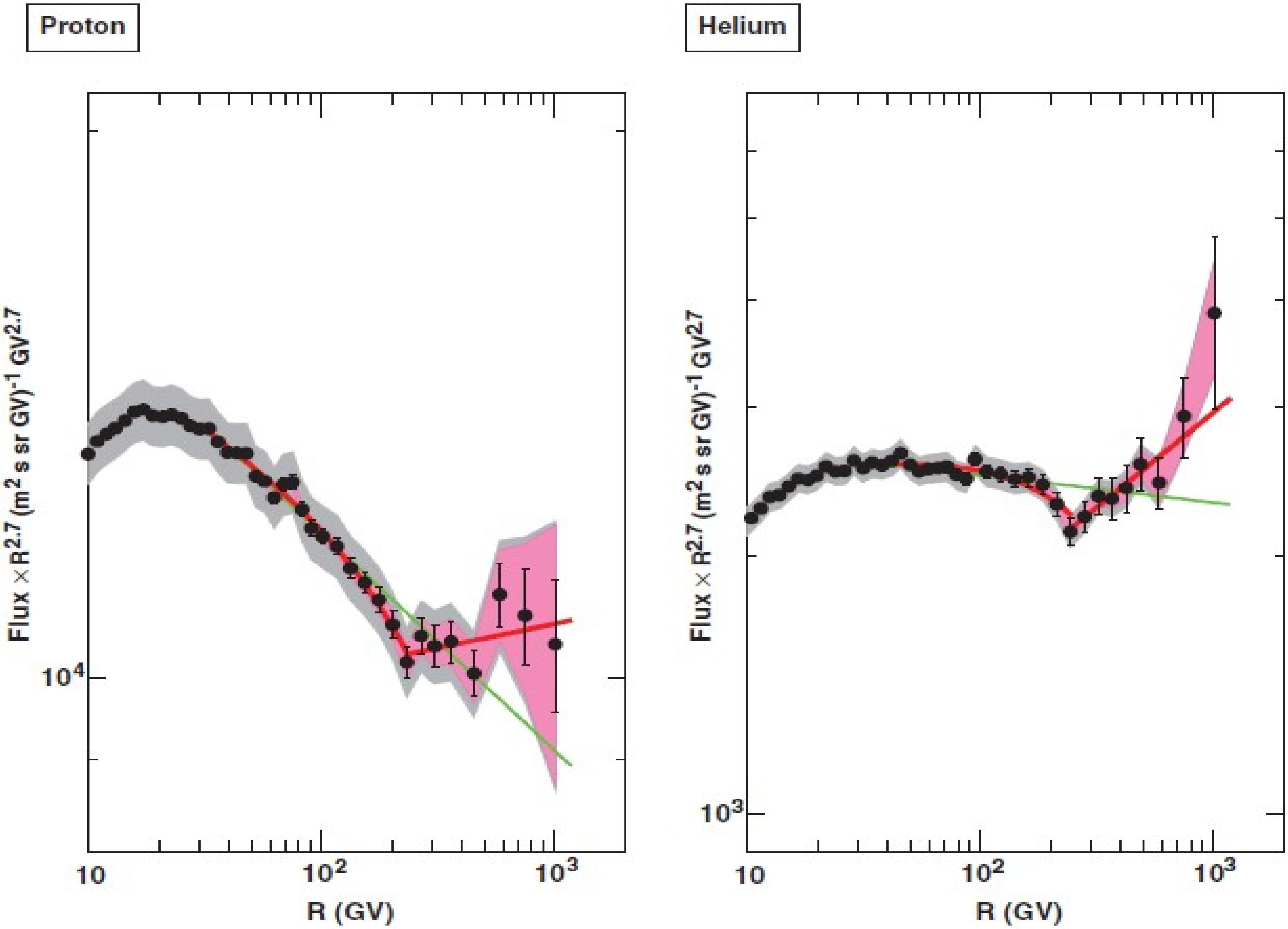
Pamela antiproton fraction (2009)



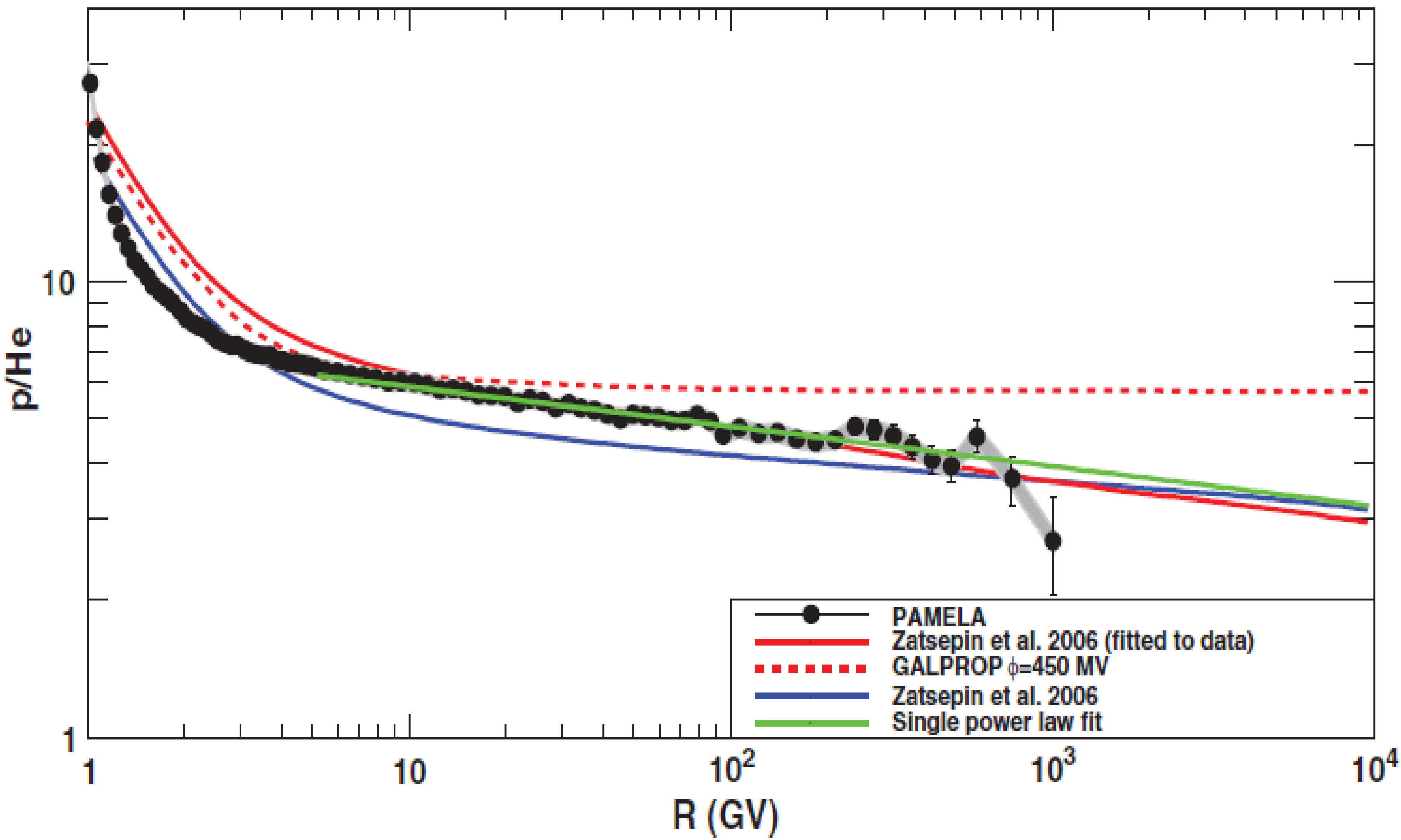
Pamela antiproton flux (2010)



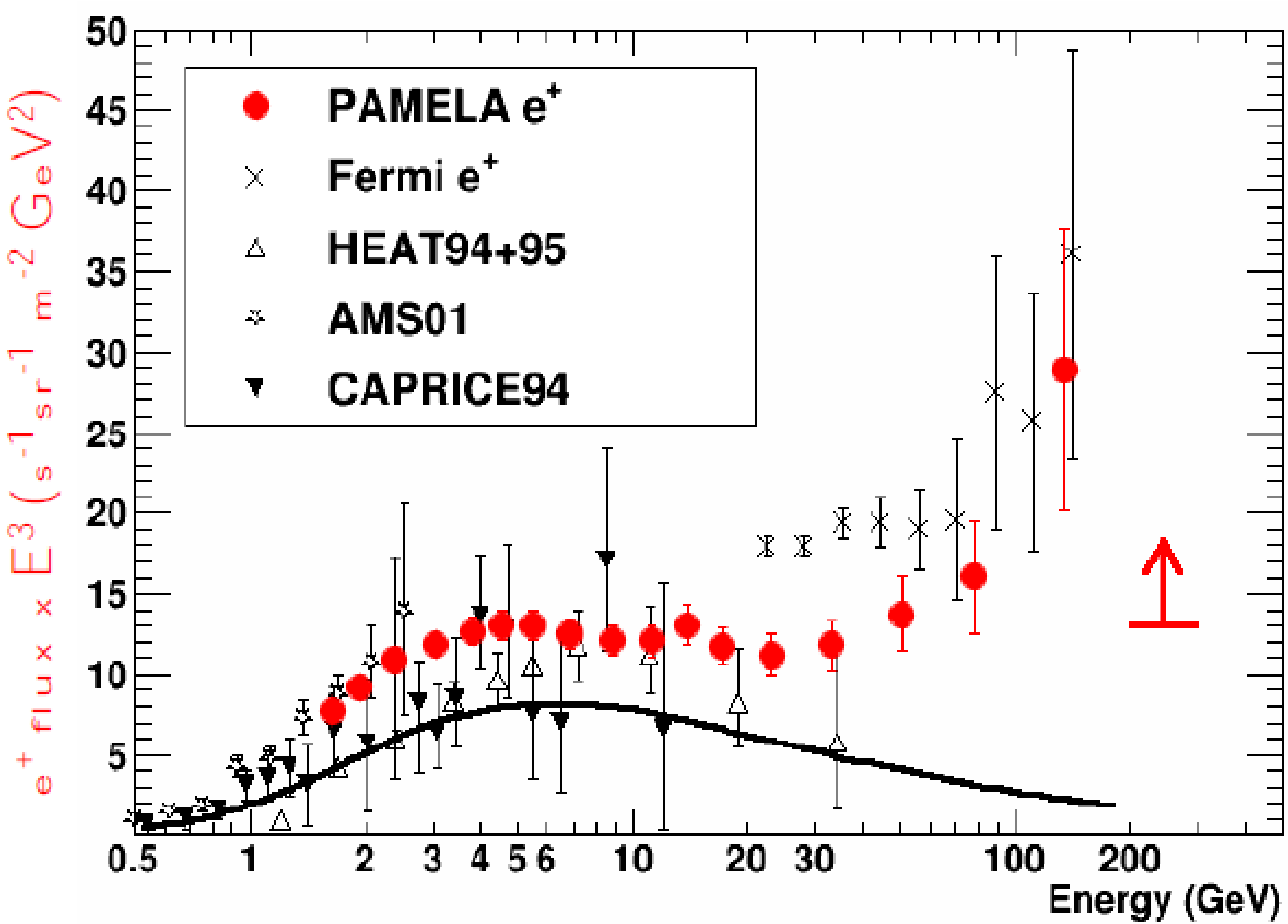
Pamela discovery (2011): a break in proton and Helium spectrum



Pamela proton/Helium ratio (2011)

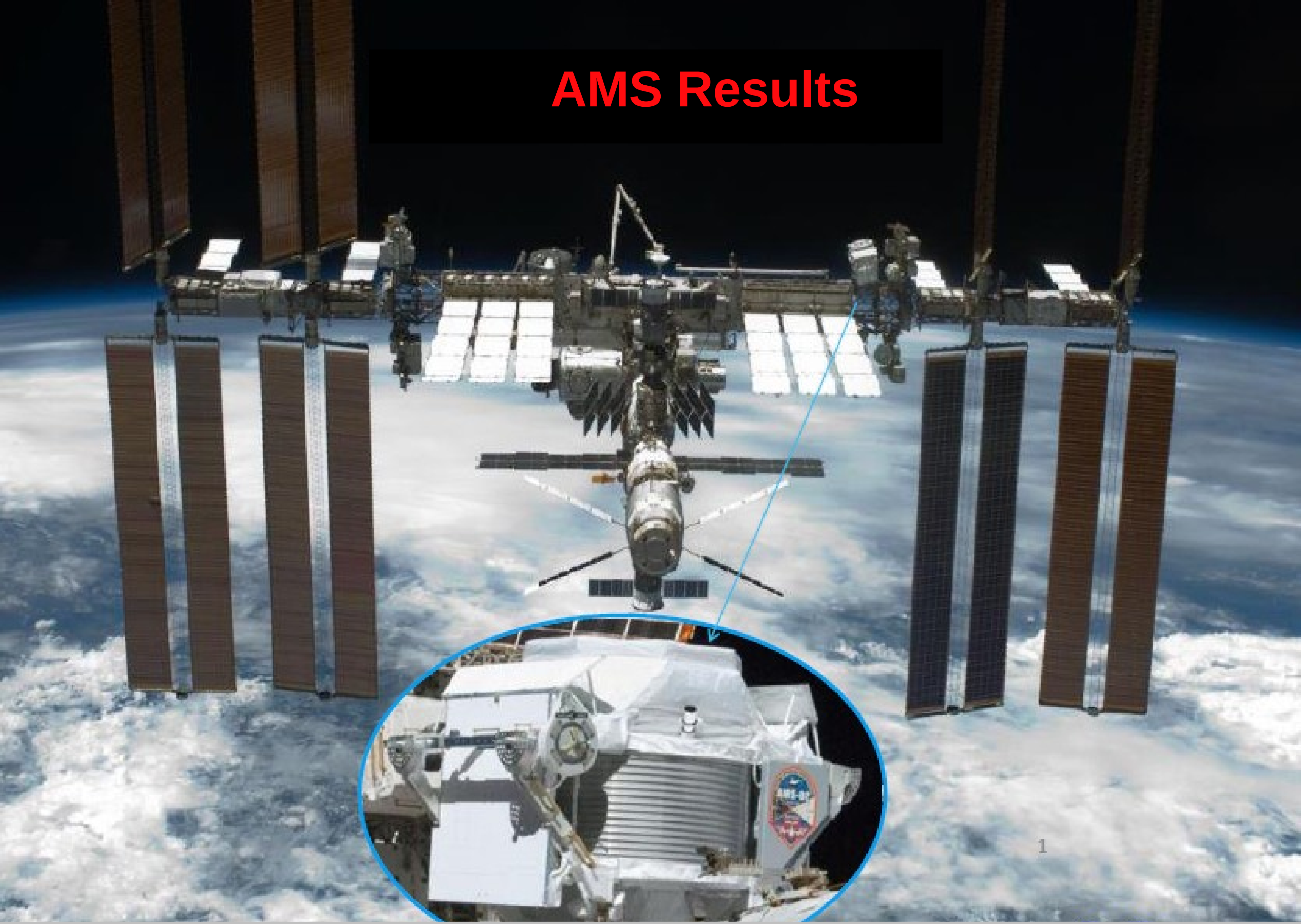


Pamela positron flux (2013)



May 16, 2011

AMS Results

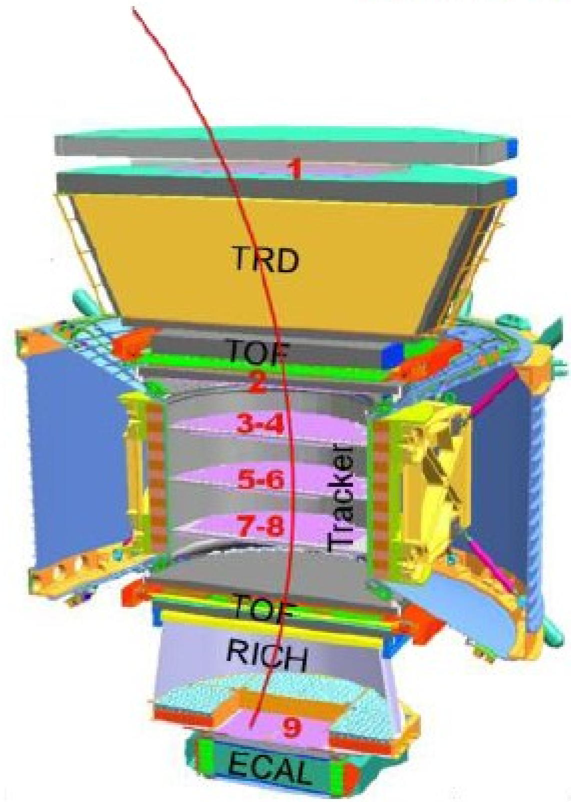


Recently published or presented at AMS days at Cern in April 2015

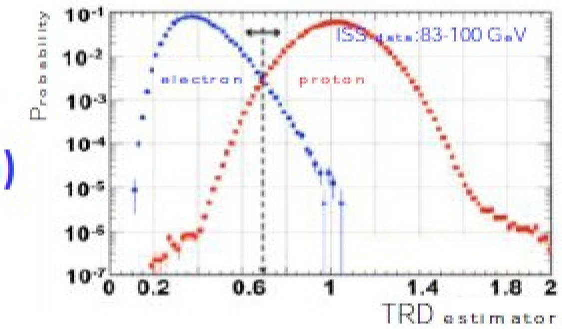
The positron fraction: event selection

Physics of 11 million e^+, e^- events

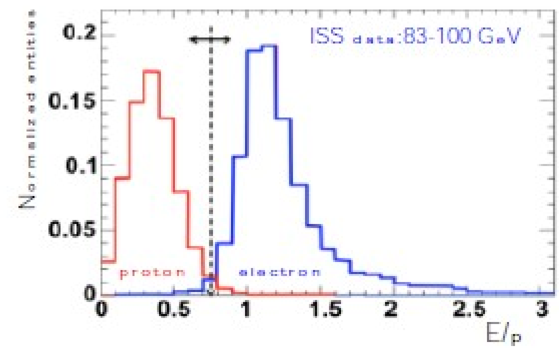
Measuring electrons and positrons



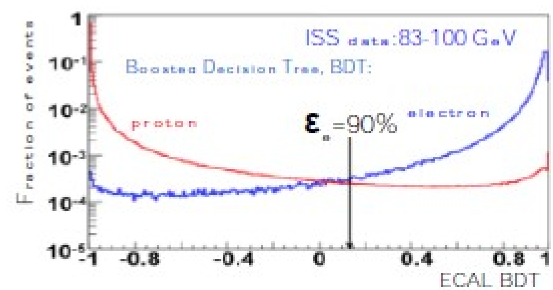
TRD
(transition radiation)
to identify $e^\pm$



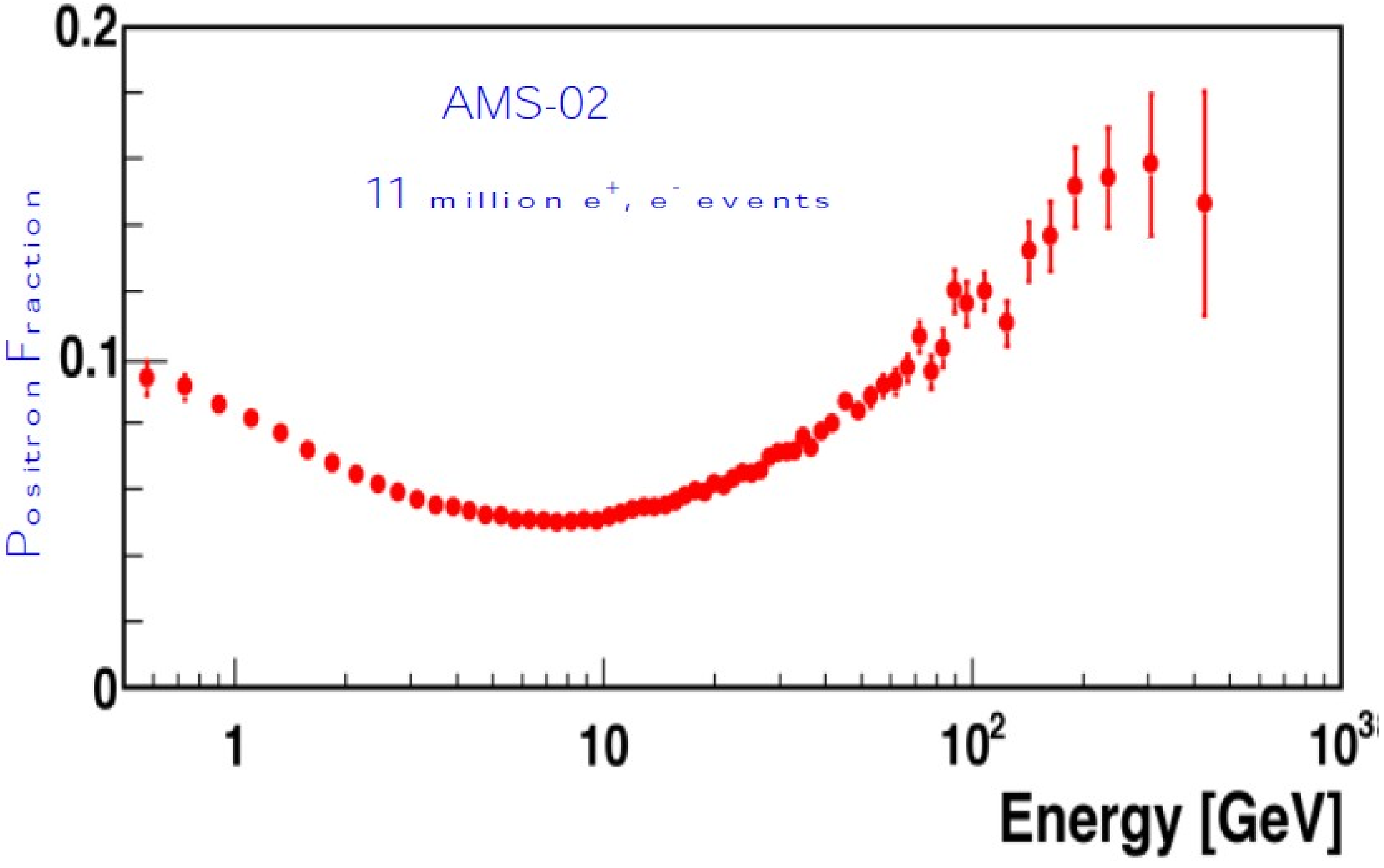
ECAL measures E
Tracker measures p
$e^\pm$: E=p
proton: E<p



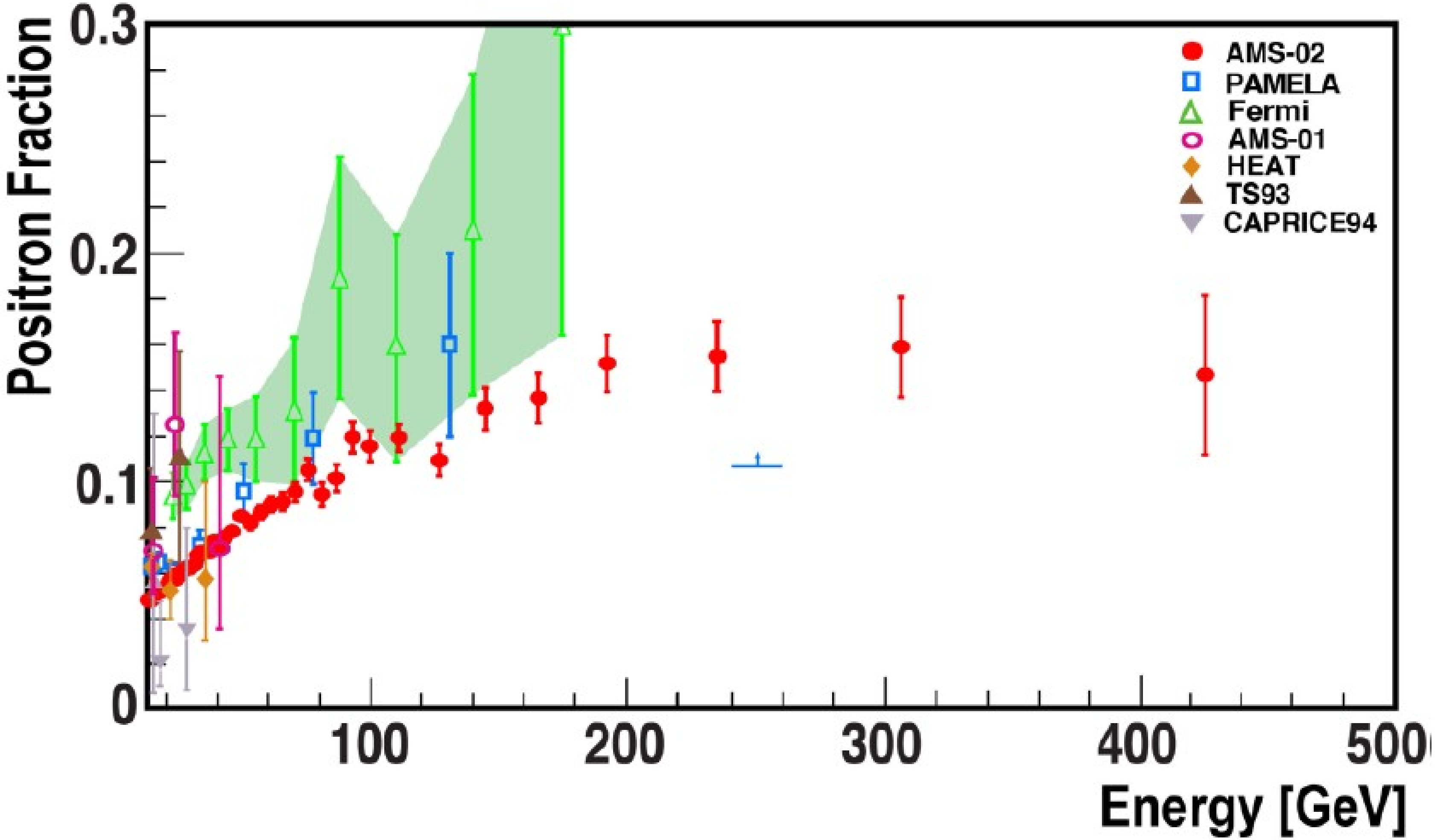
ECAL
(shower shape)
to separate $e^\pm$
from protons



AMS positron fraction (2014)

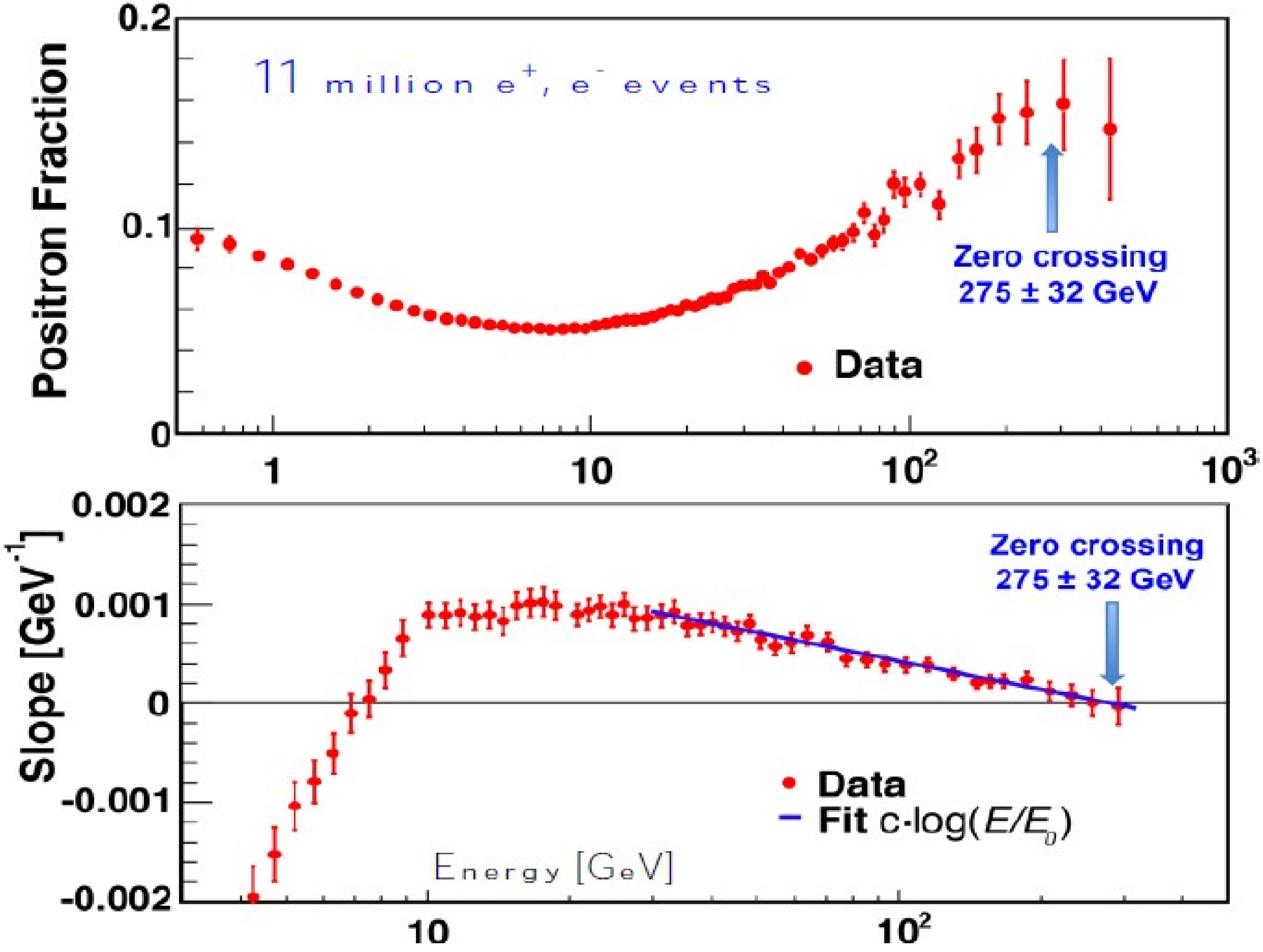


AMS positron fraction (2014)

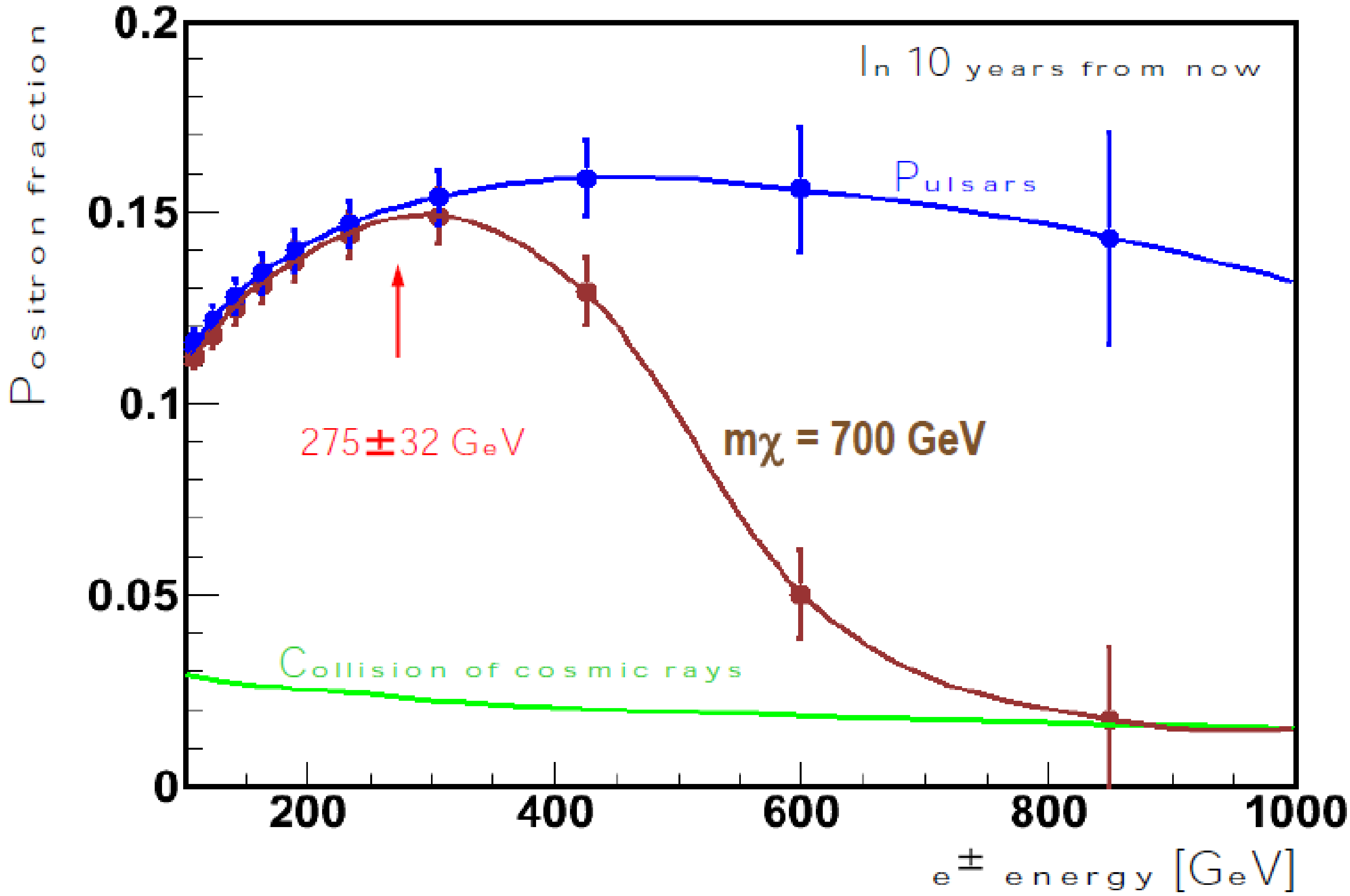


Latest bin: 72 e^+ between 350 and 500 GeV

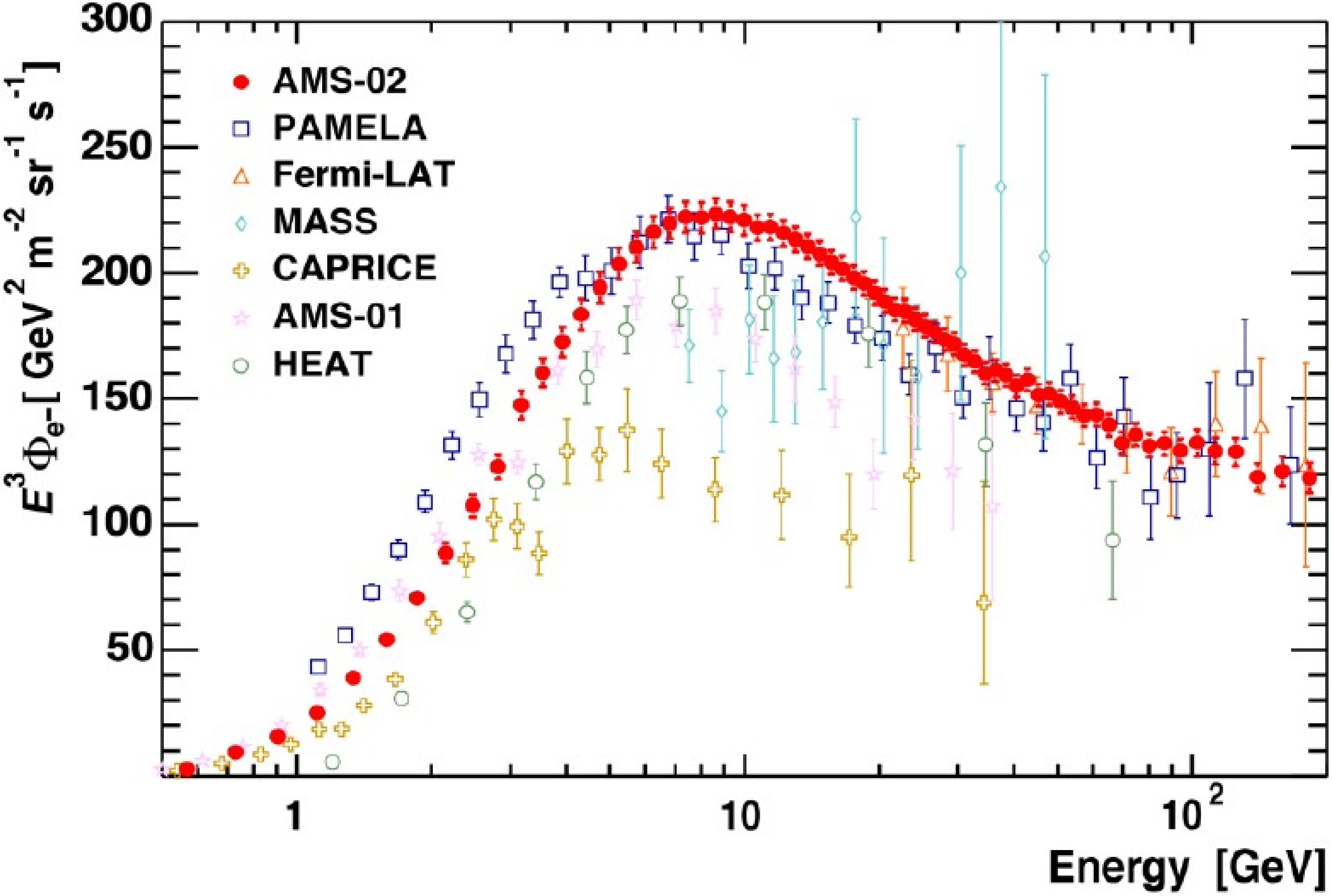
AMS result (2014): positron fraction flattens at ~300 GeV



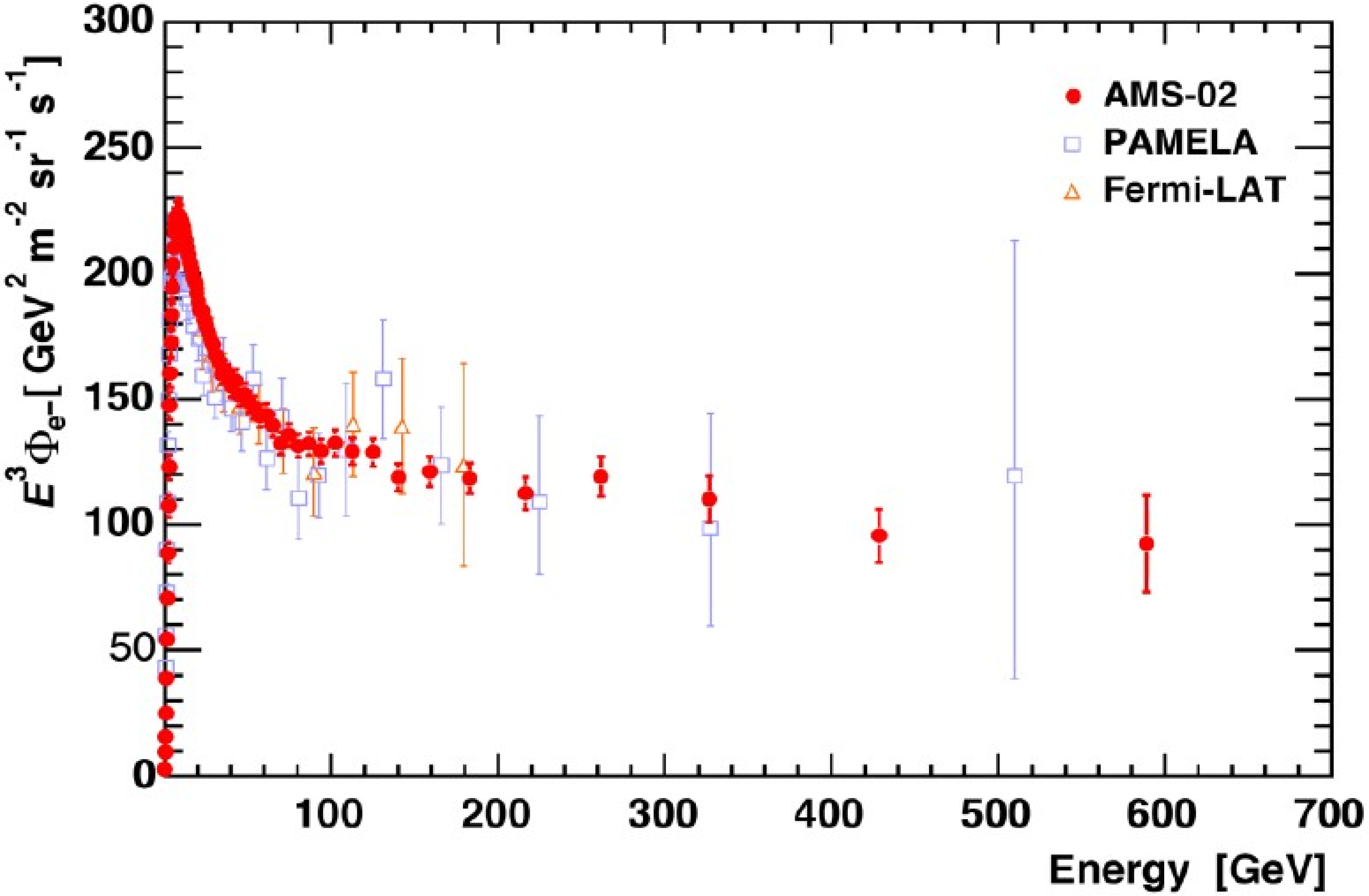
Expected AMS sensitivity on positron fraction in 10 years from now



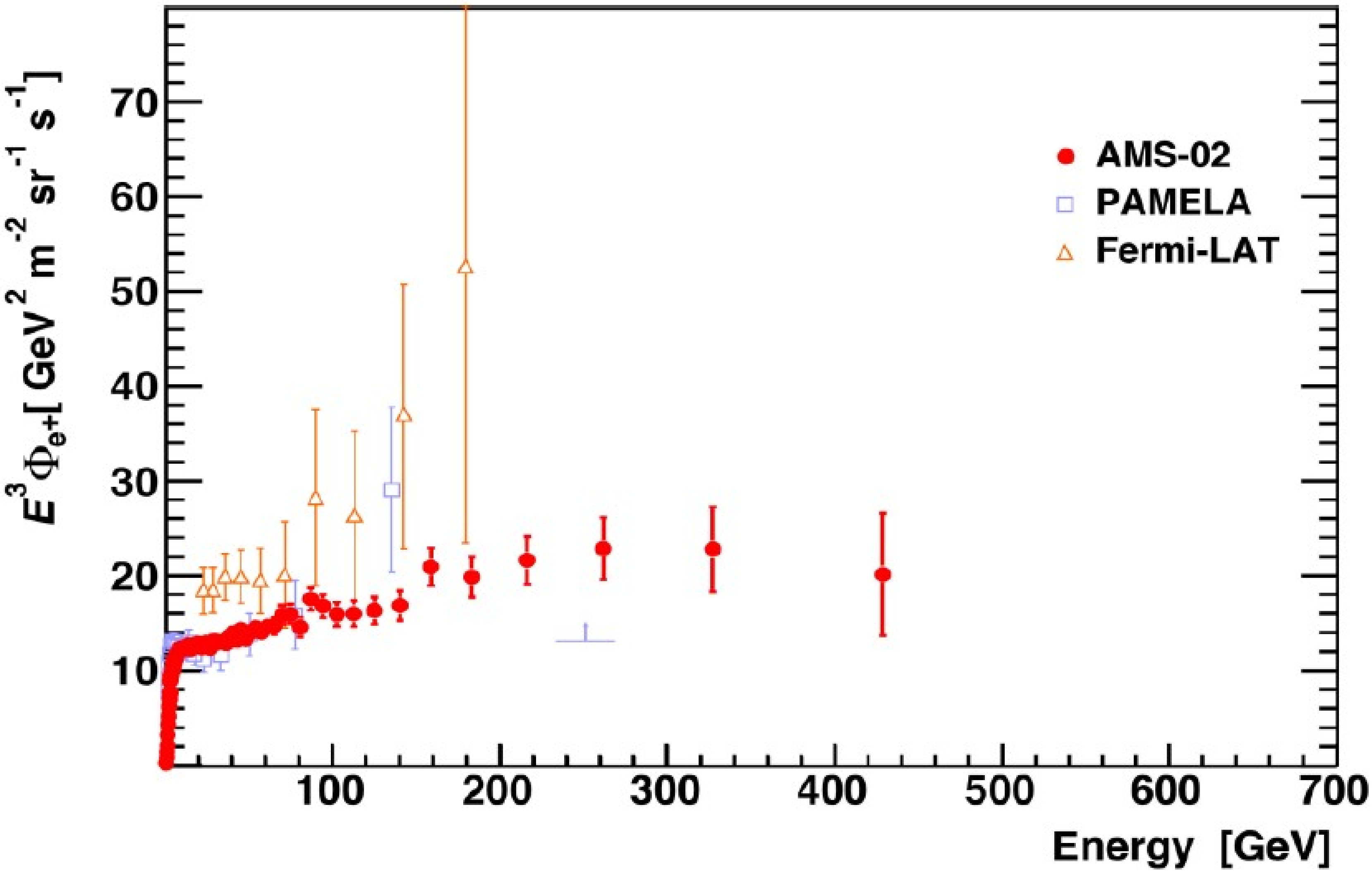
AMS electron flux (2014)



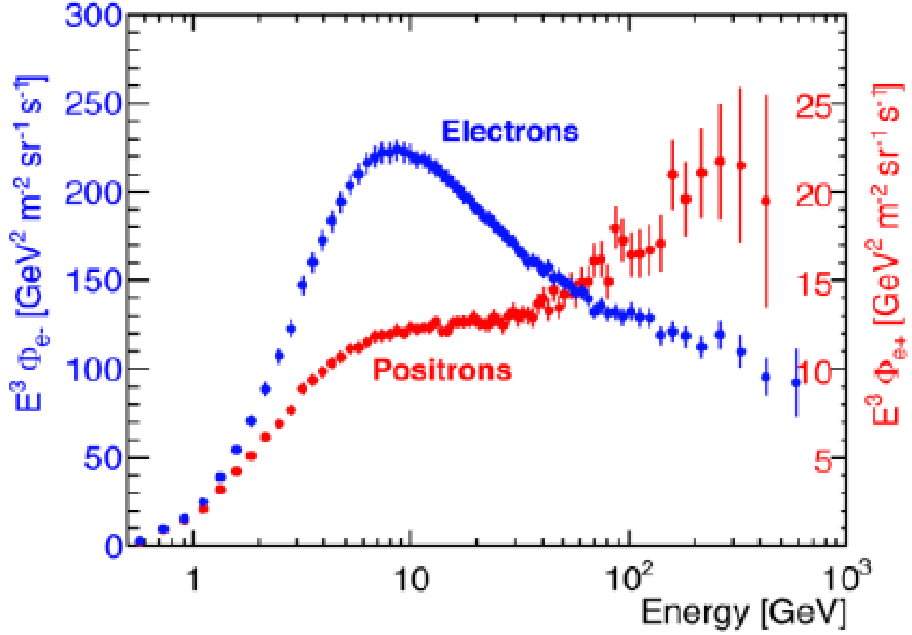
AMS electron flux (2014)

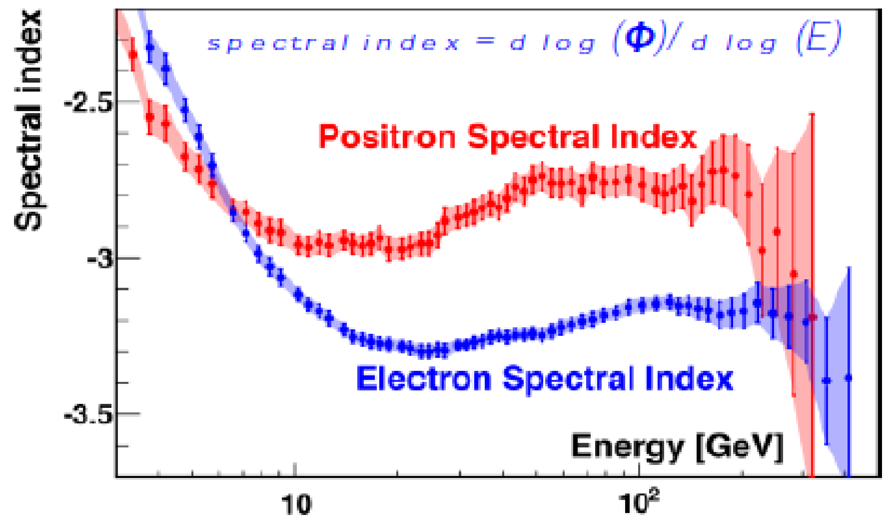


AMS positron flux (2014)



AMS result (2014): positron and electron spectral indexes

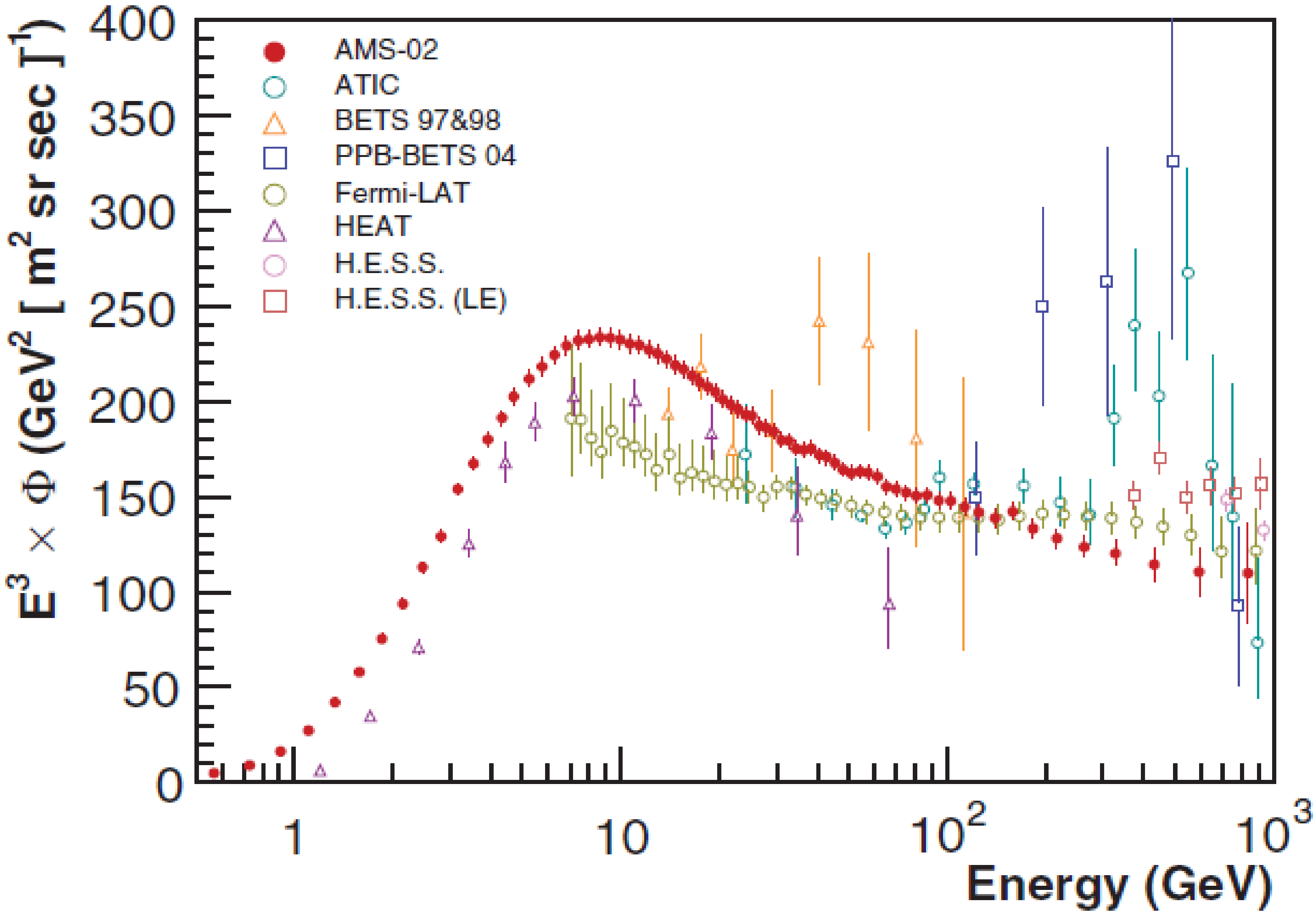




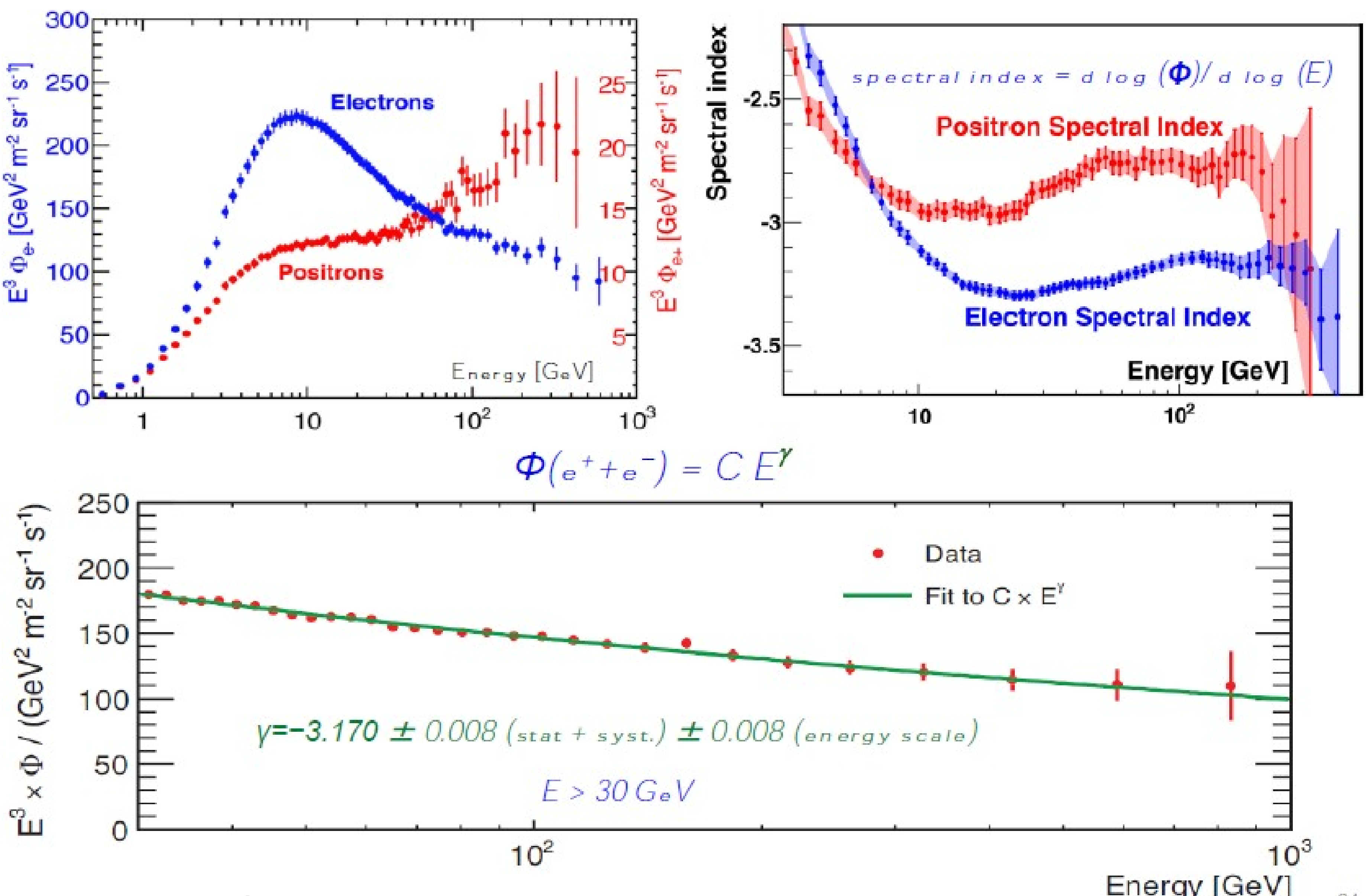
Observations:

1. The electron flux and the positron flux are different in their magnitude and energy dependence.
2. Both spectra cannot be described by single power laws.
3. The spectral indices of electrons and positrons are different.
4. Both change their behavior at ~30GeV.
5. The rise in the positron fraction from 20 GeV is due to an excess of positrons, not the loss of electrons (the positron flux is harder).

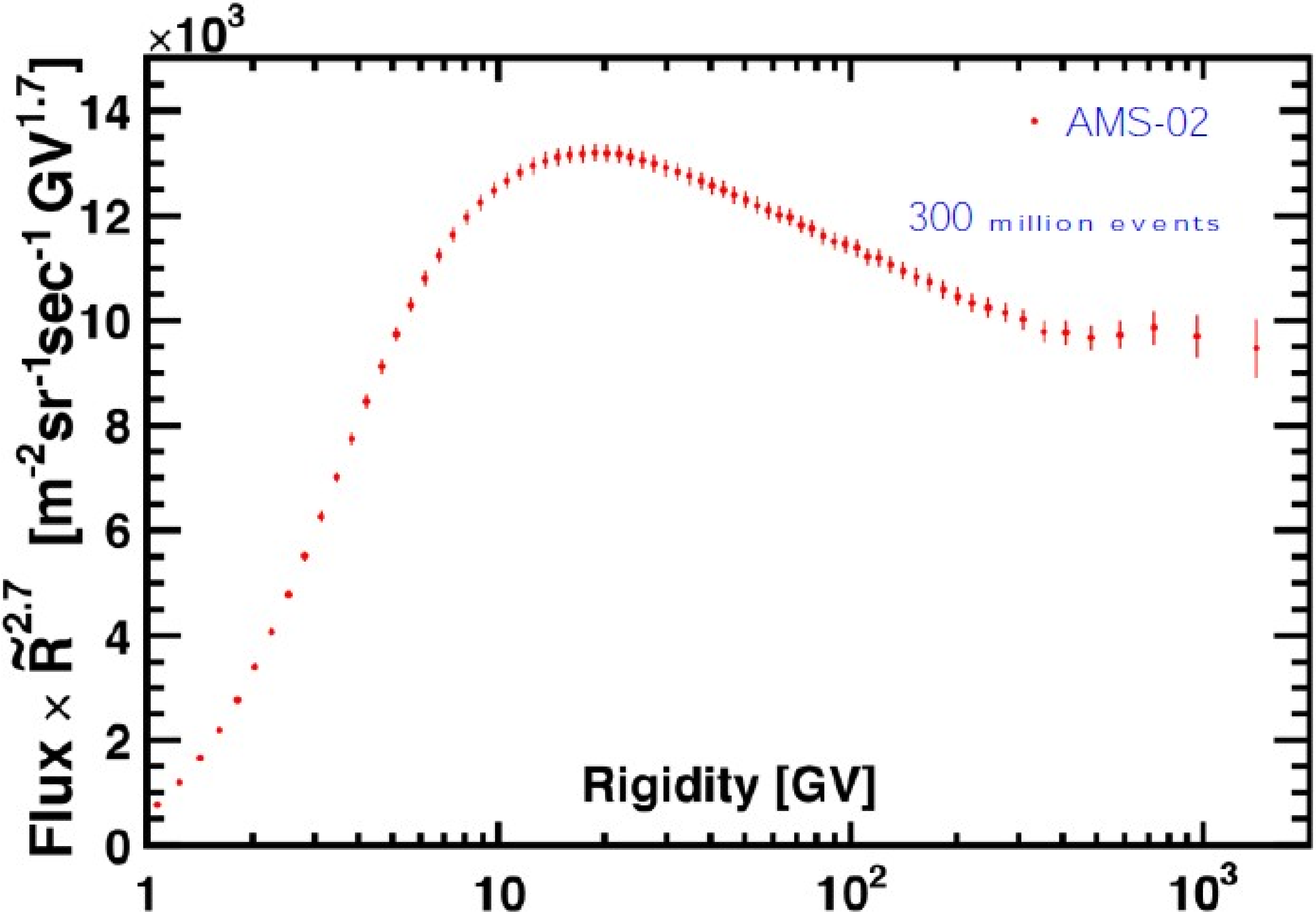
AMS $e^+ + e^-$ flux (2014)



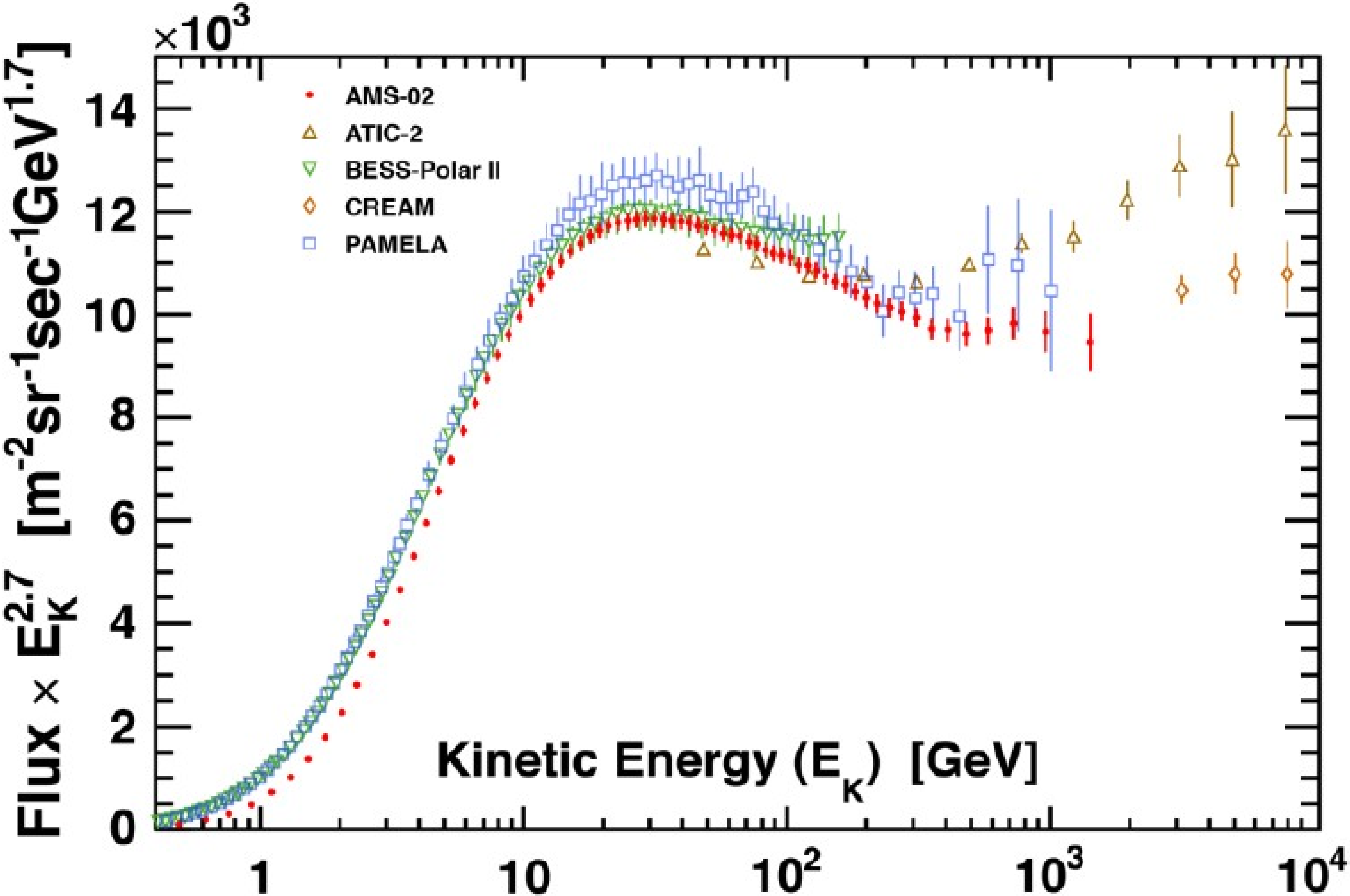
AMS result (2014): $e^+ + e^-$ spectral index is constant above 30 GeV



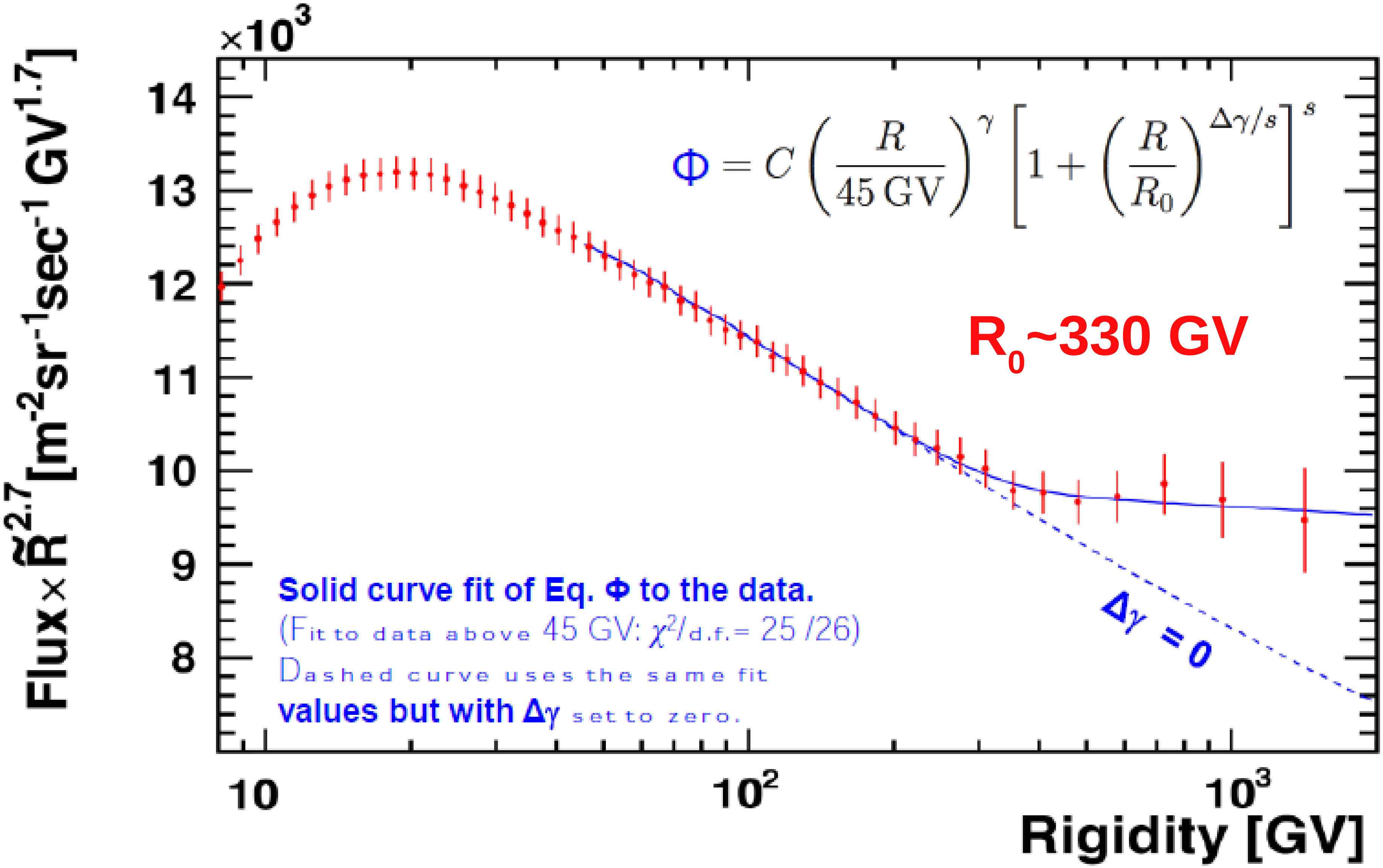
AMS proton flux (2015)



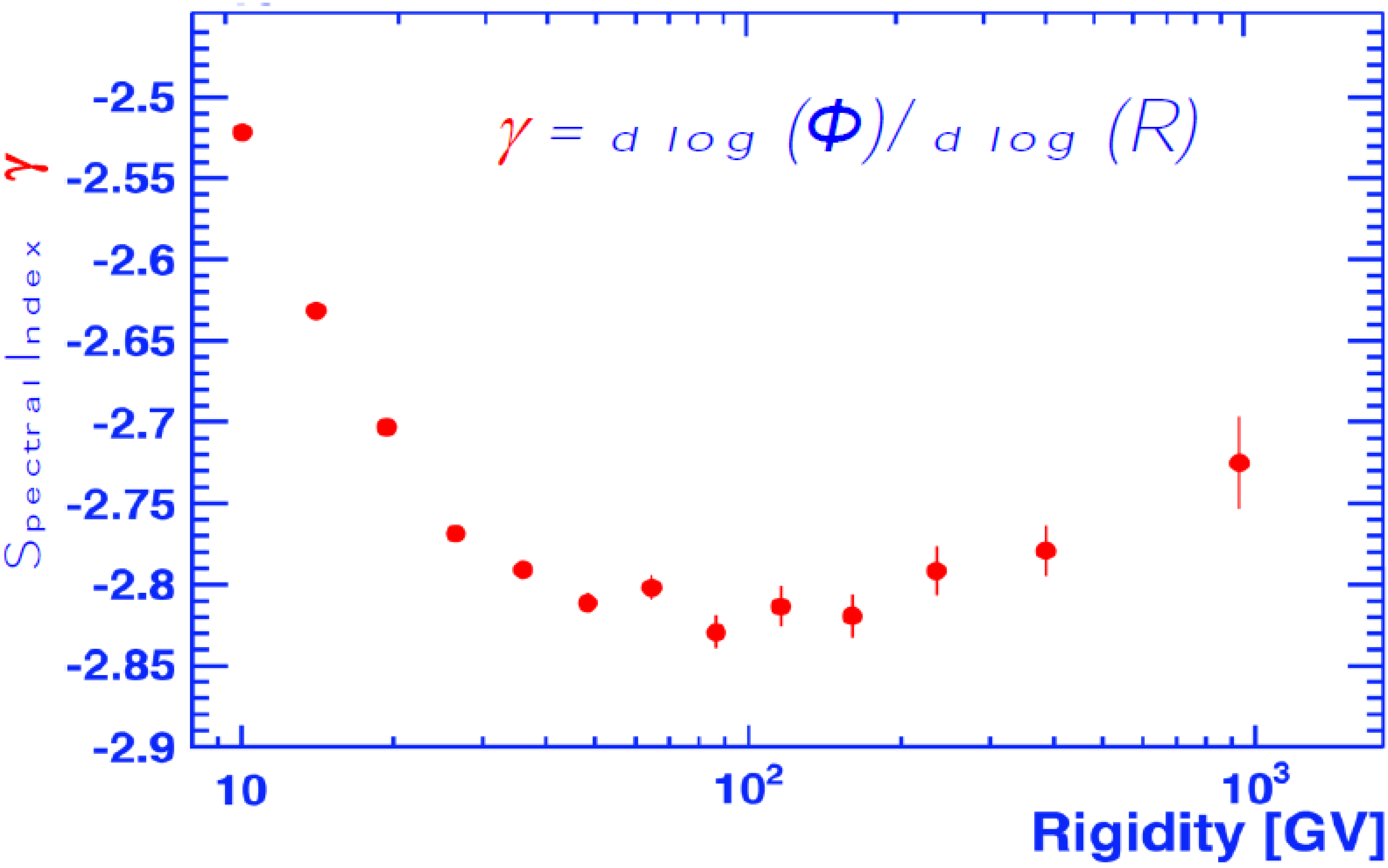
AMS proton flux (2015)



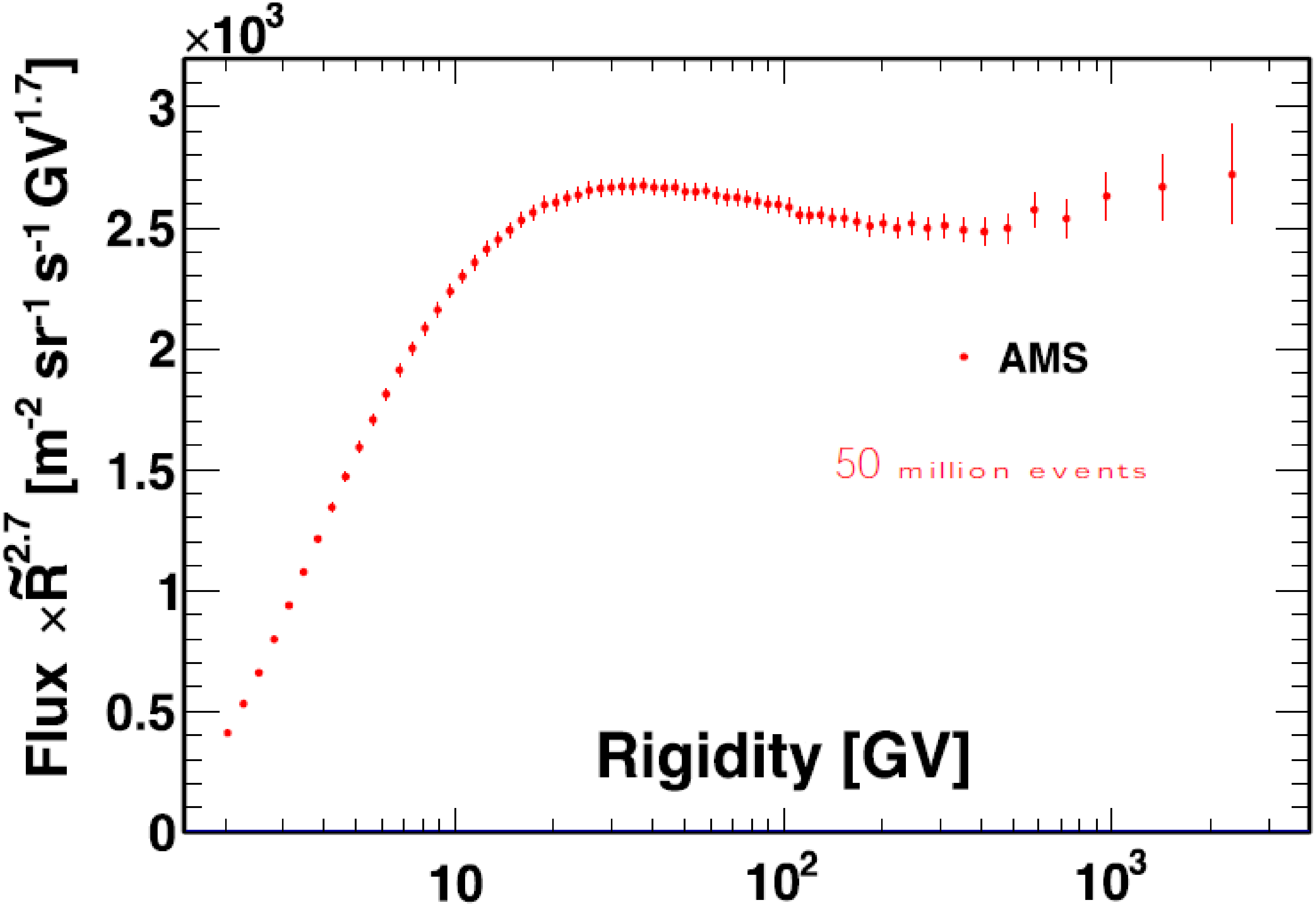
AMS result (2015): break in proton flux



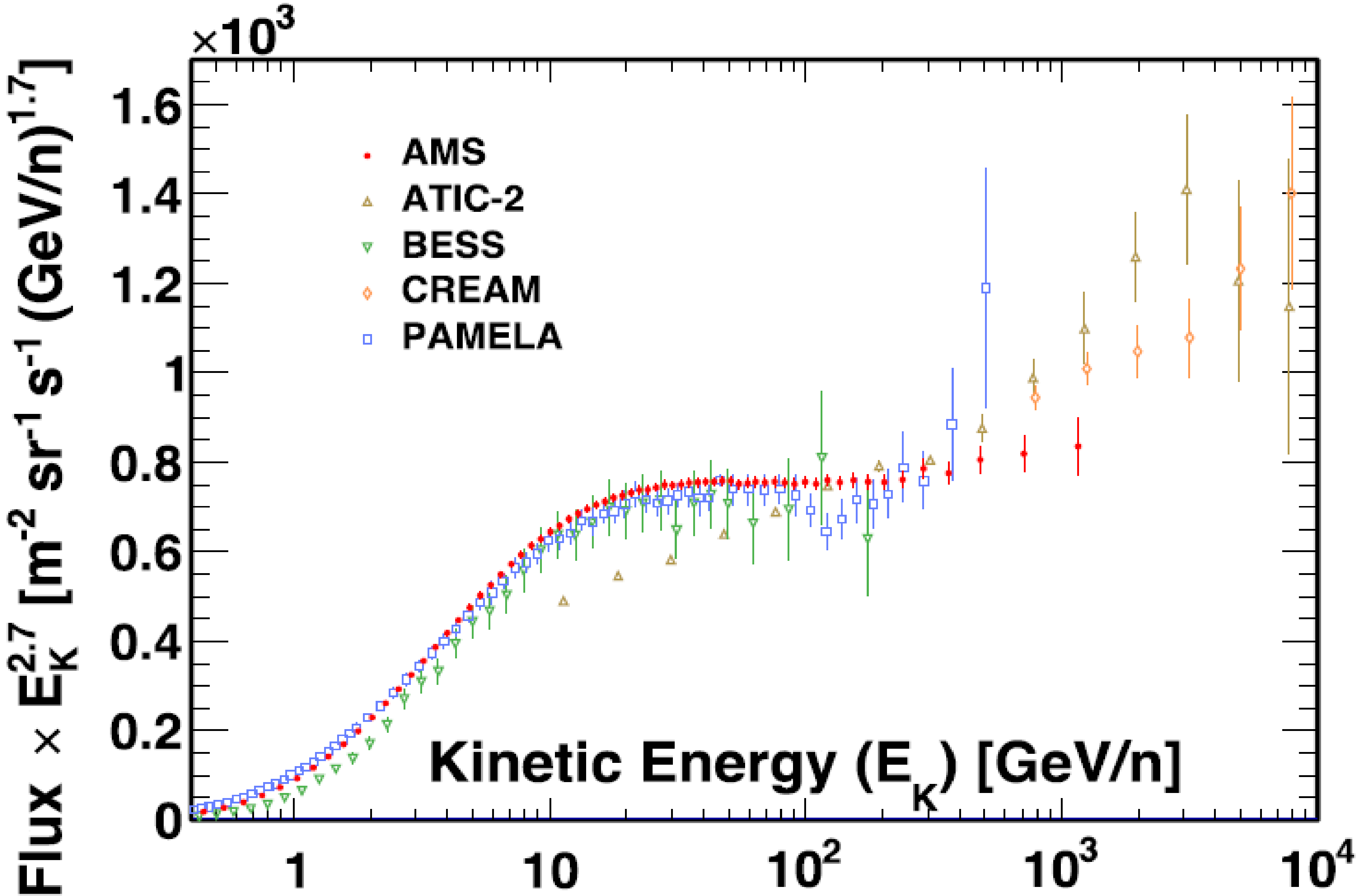
AMS result(2015): proton spectral index



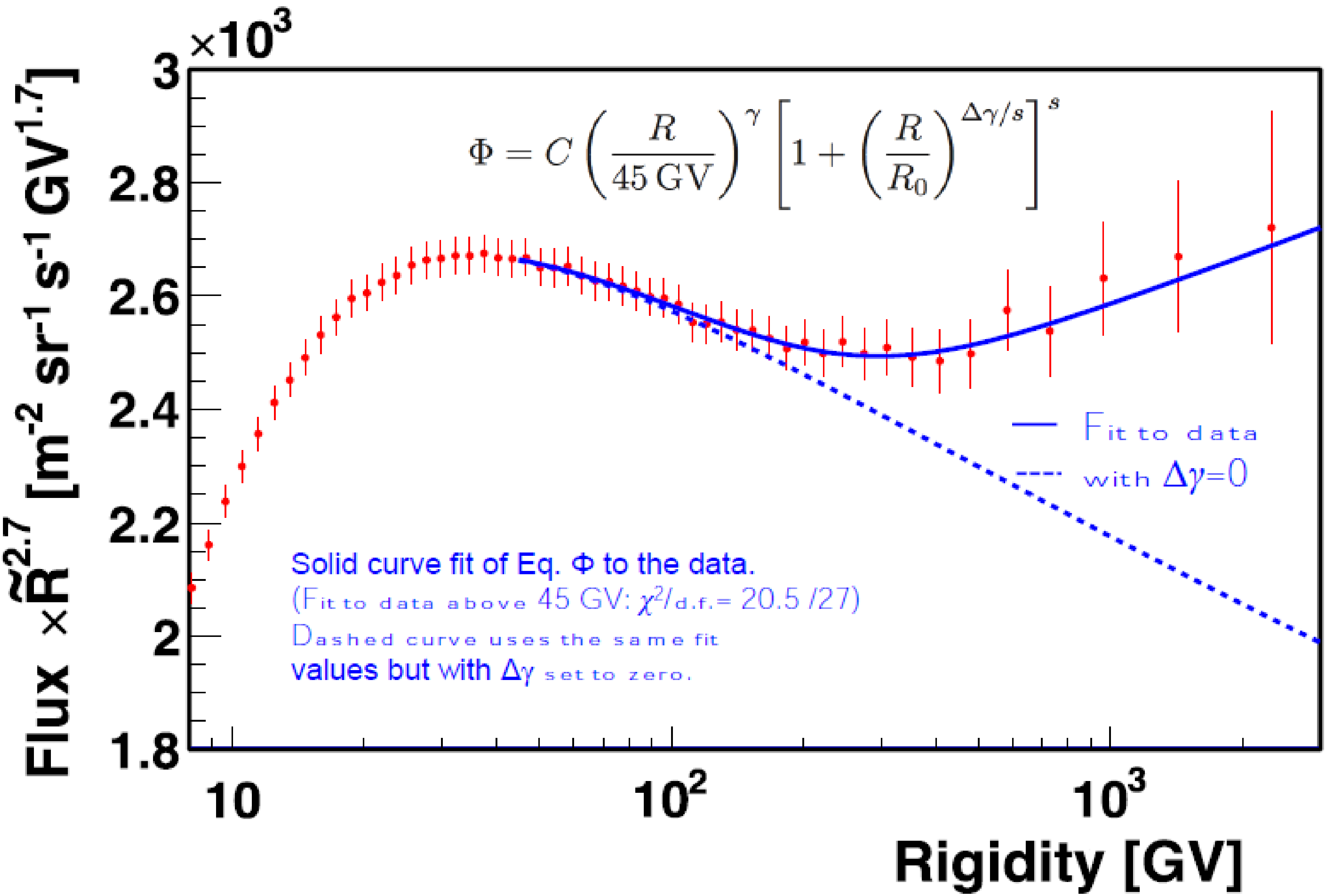
AMS helium flux



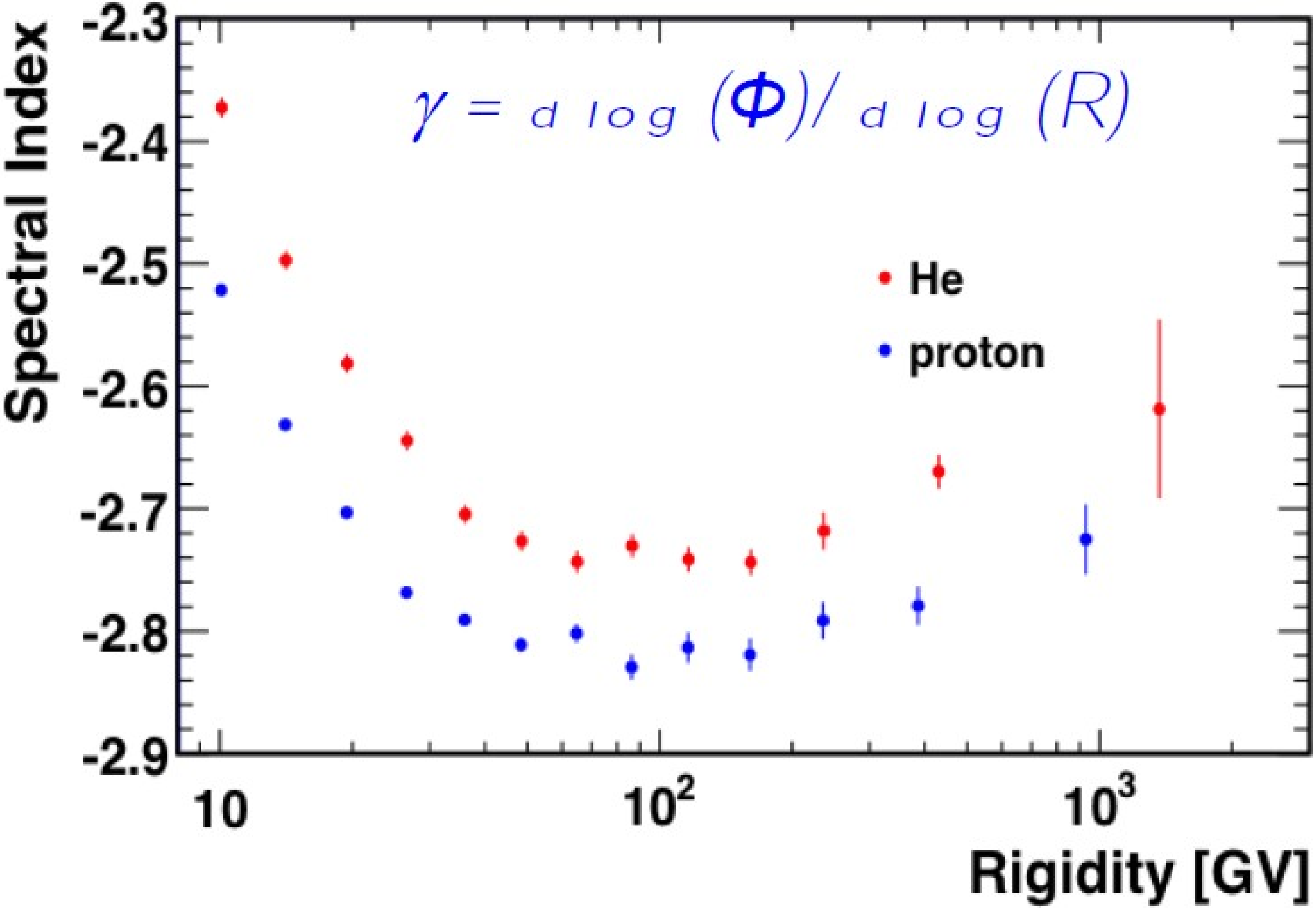
AMS helium flux



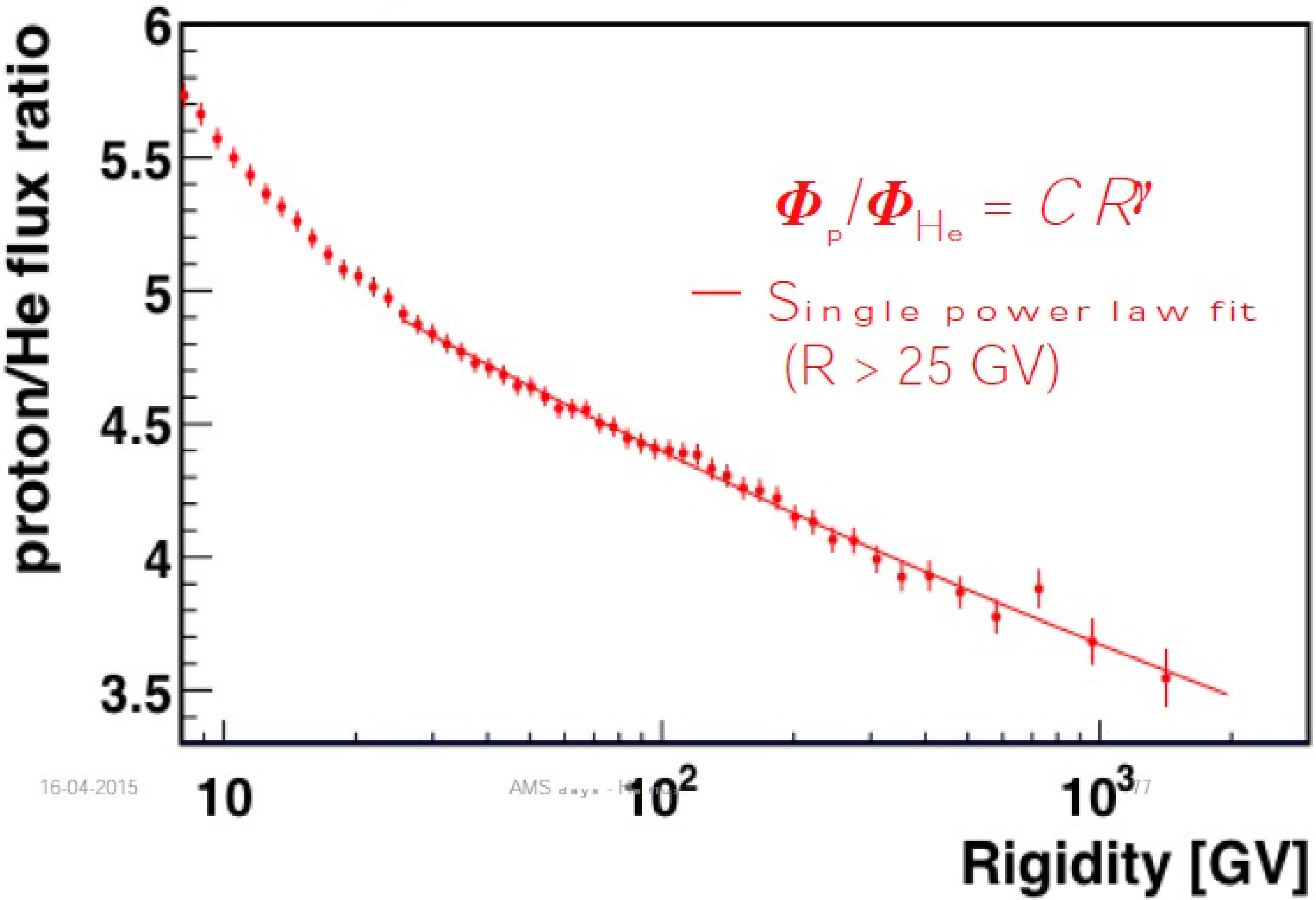
AMS preliminary result: break in helium flux



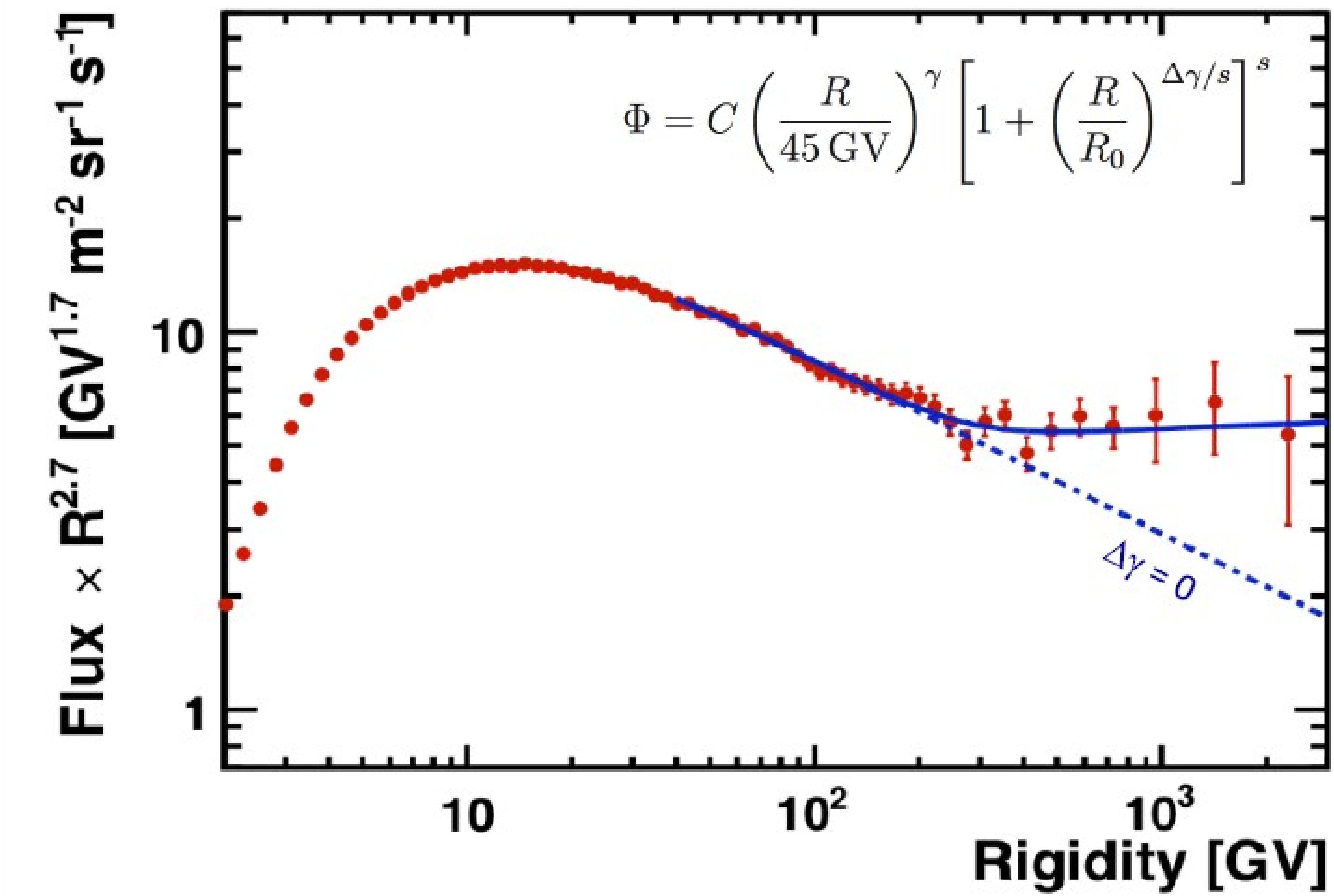
AMS helium and proton spectral indexes



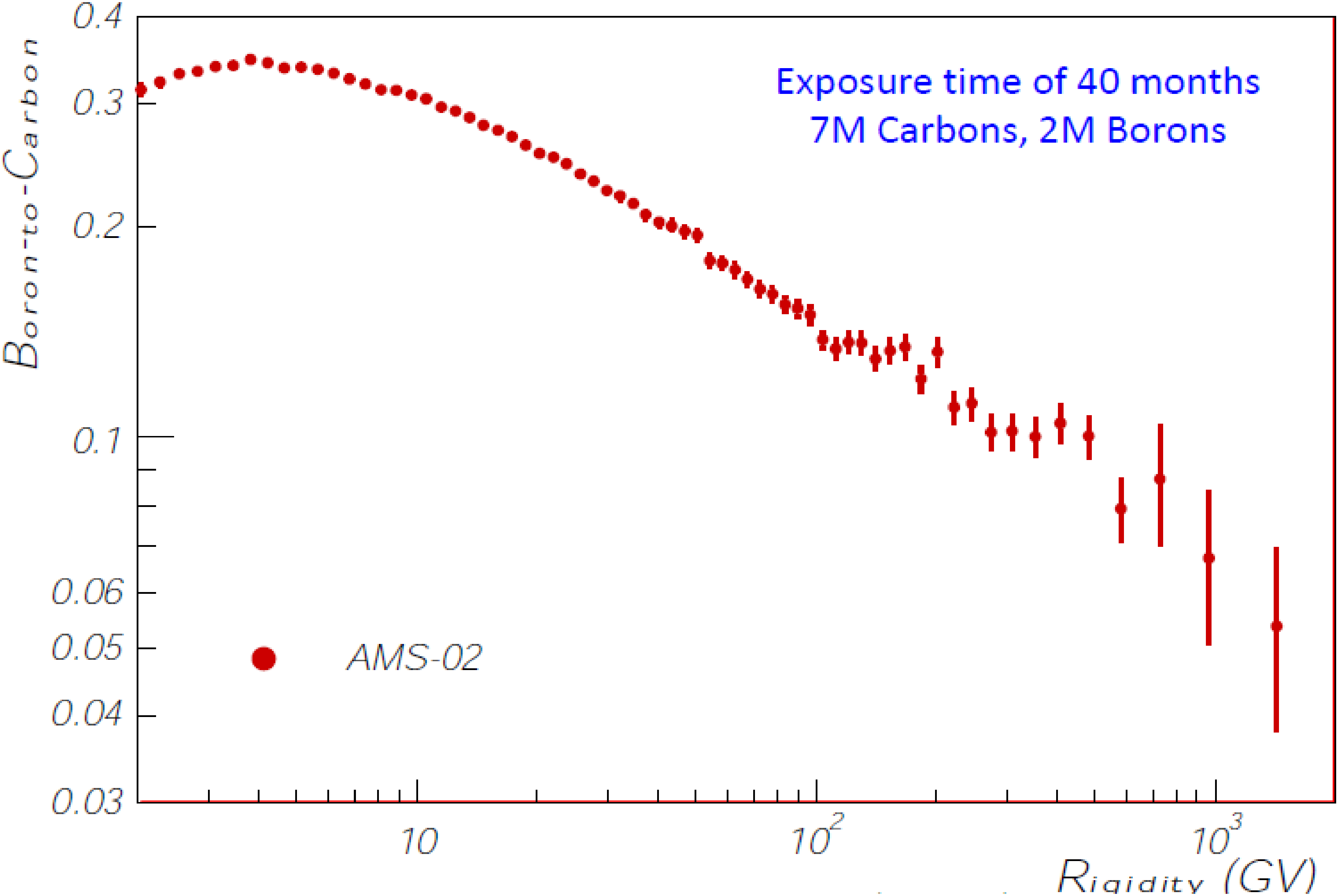
AMS result (preliminary): no break in proton/Helium ratio



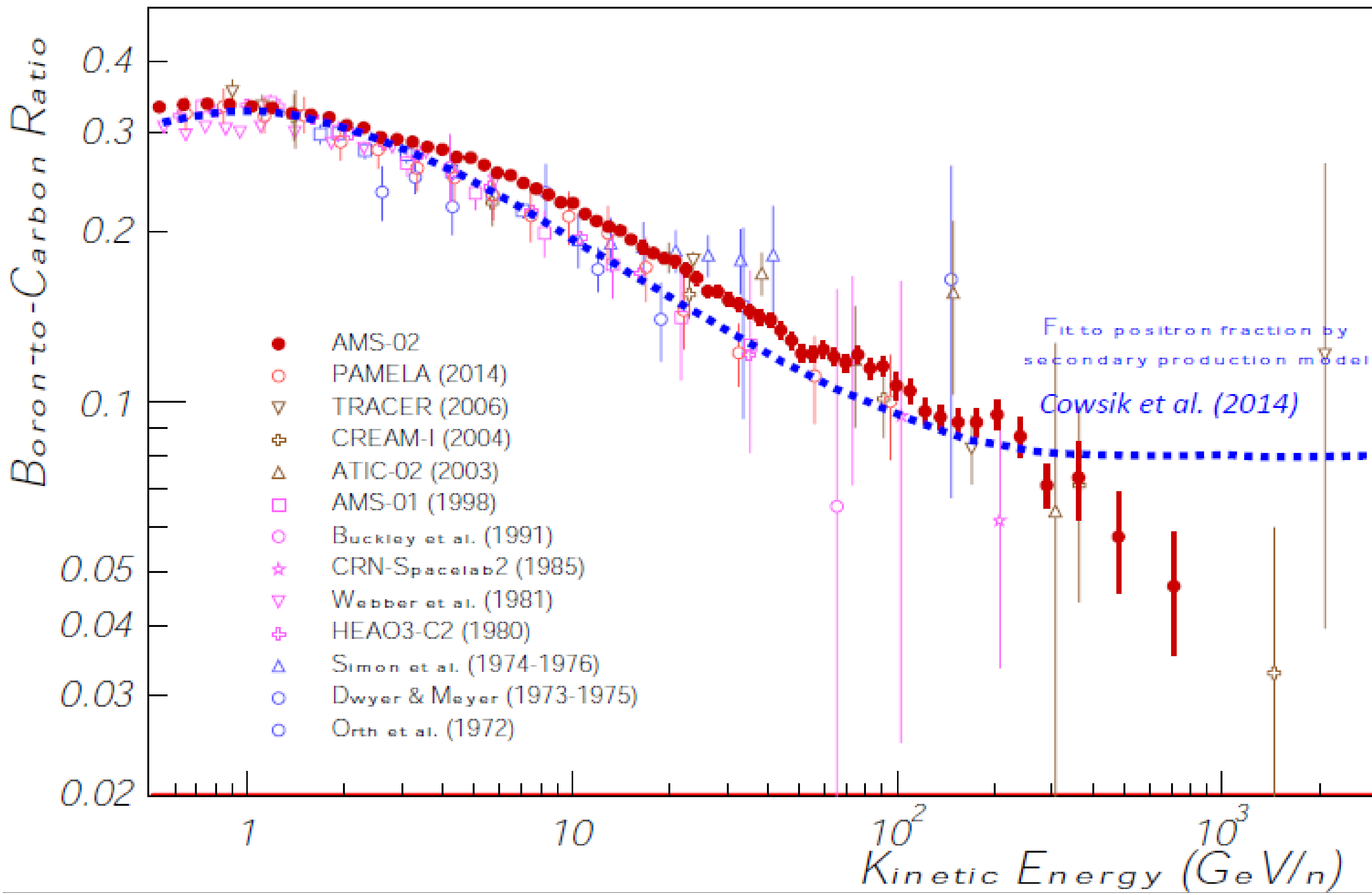
AMS preliminary result: break in Lithium flux



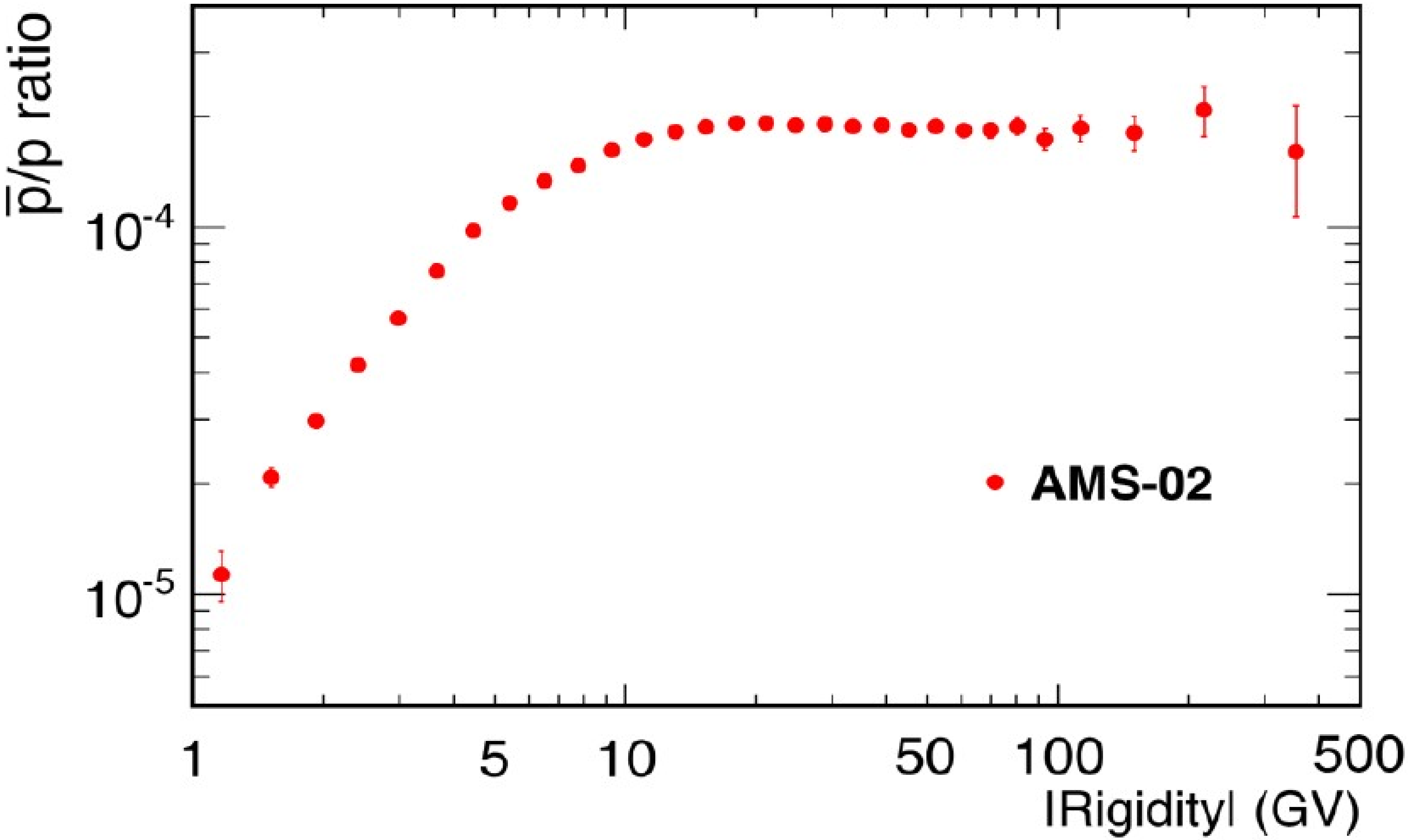
AMS preliminary result: B/C ratio



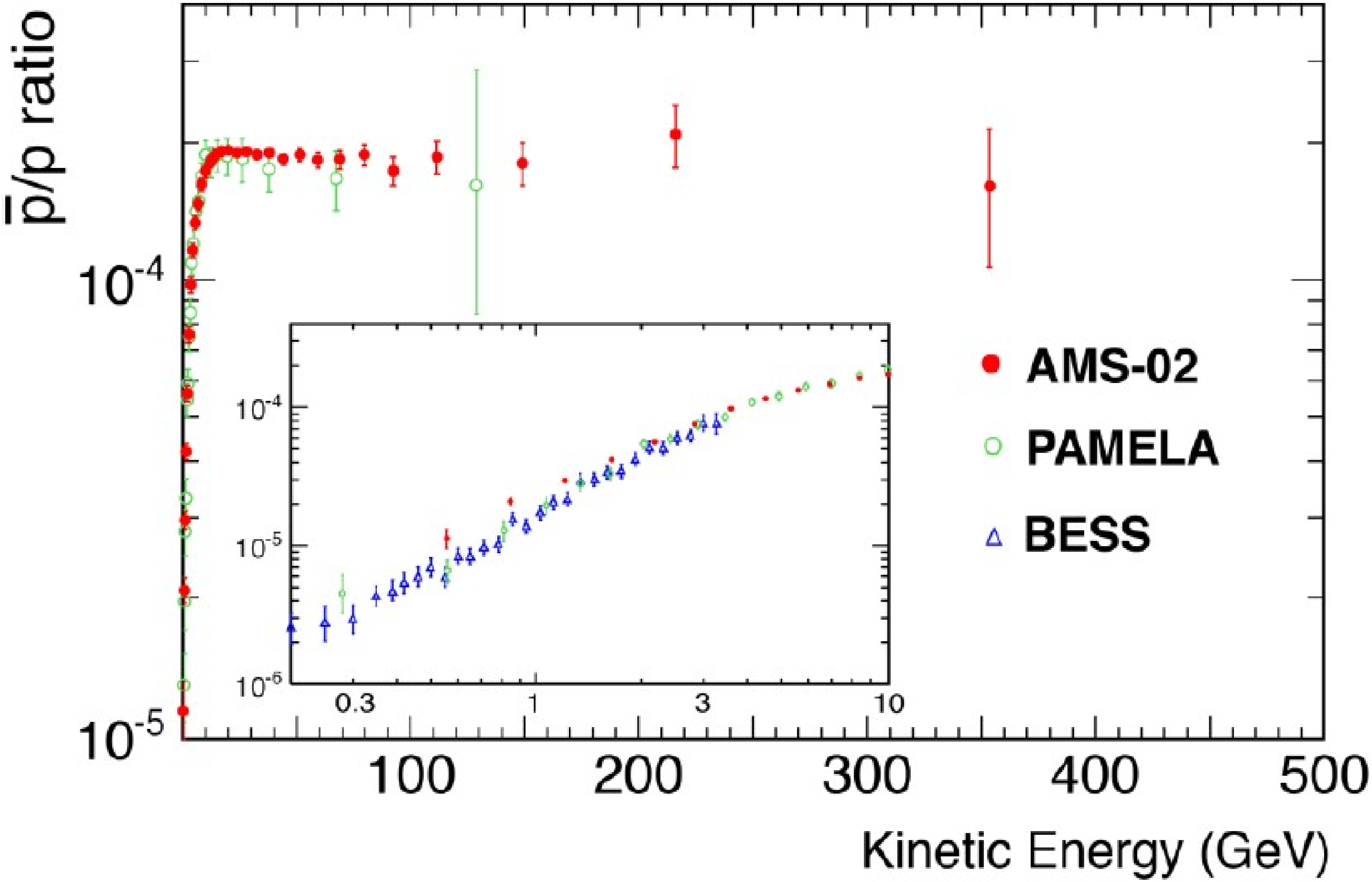
AMS preliminary result: B/C ratio



AMS preliminary result: antiproton/proton ratio



AMS preliminary result: antiproton/proton ratio



Next and future experiments

There's no plan to launch any spectrometer in space in the next years

Next high acceptance experiments (without magnetic field):

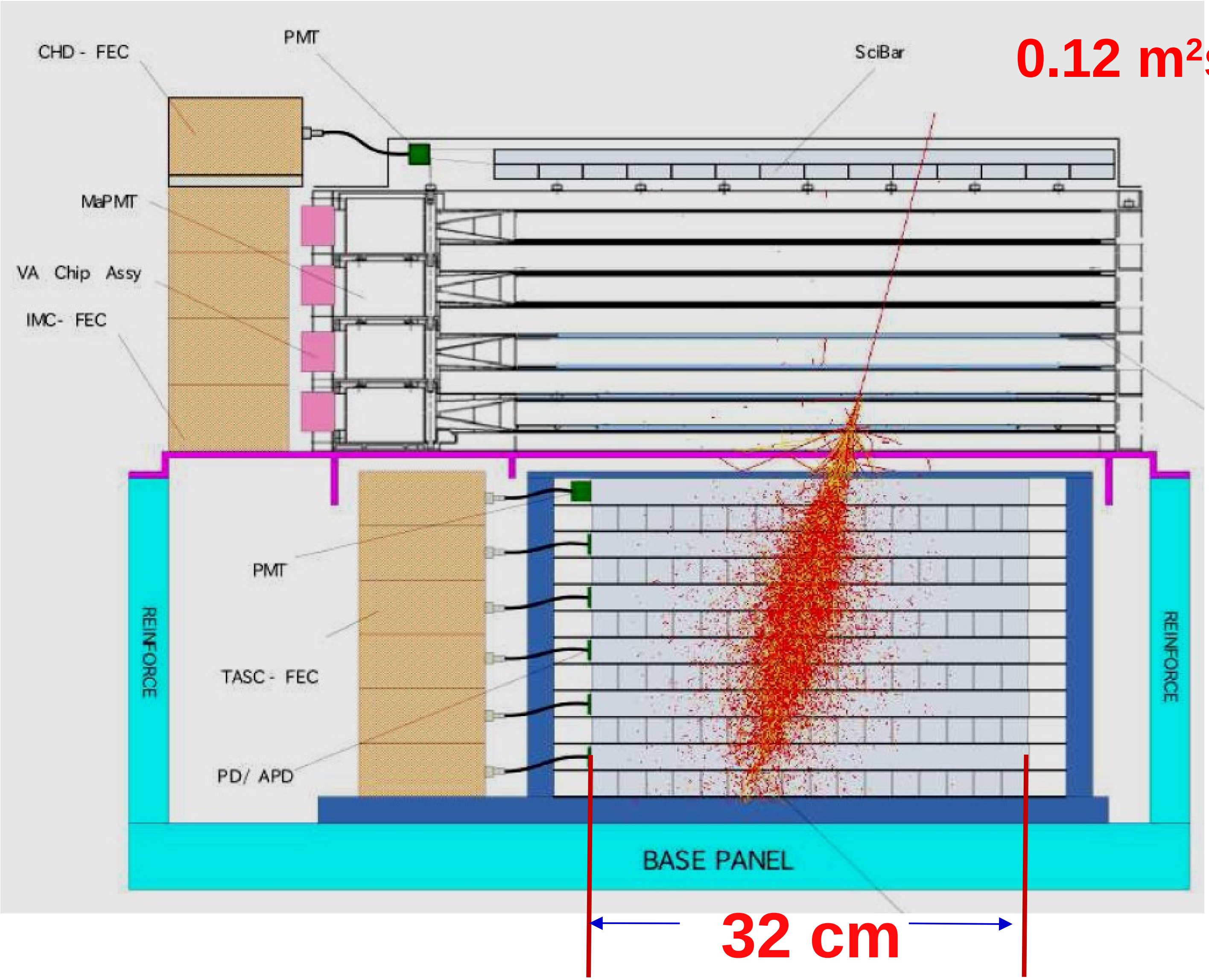
CALET: installed on ISS in august 2015

DAMPE: satellite expected launch: fall 2015

GAMMA 400: satellite (see Marco Tavani's talk)

HERD: on Chinese space station (>= 2020)

CALET



0.12 m²sr@100TeV

Charge Detector

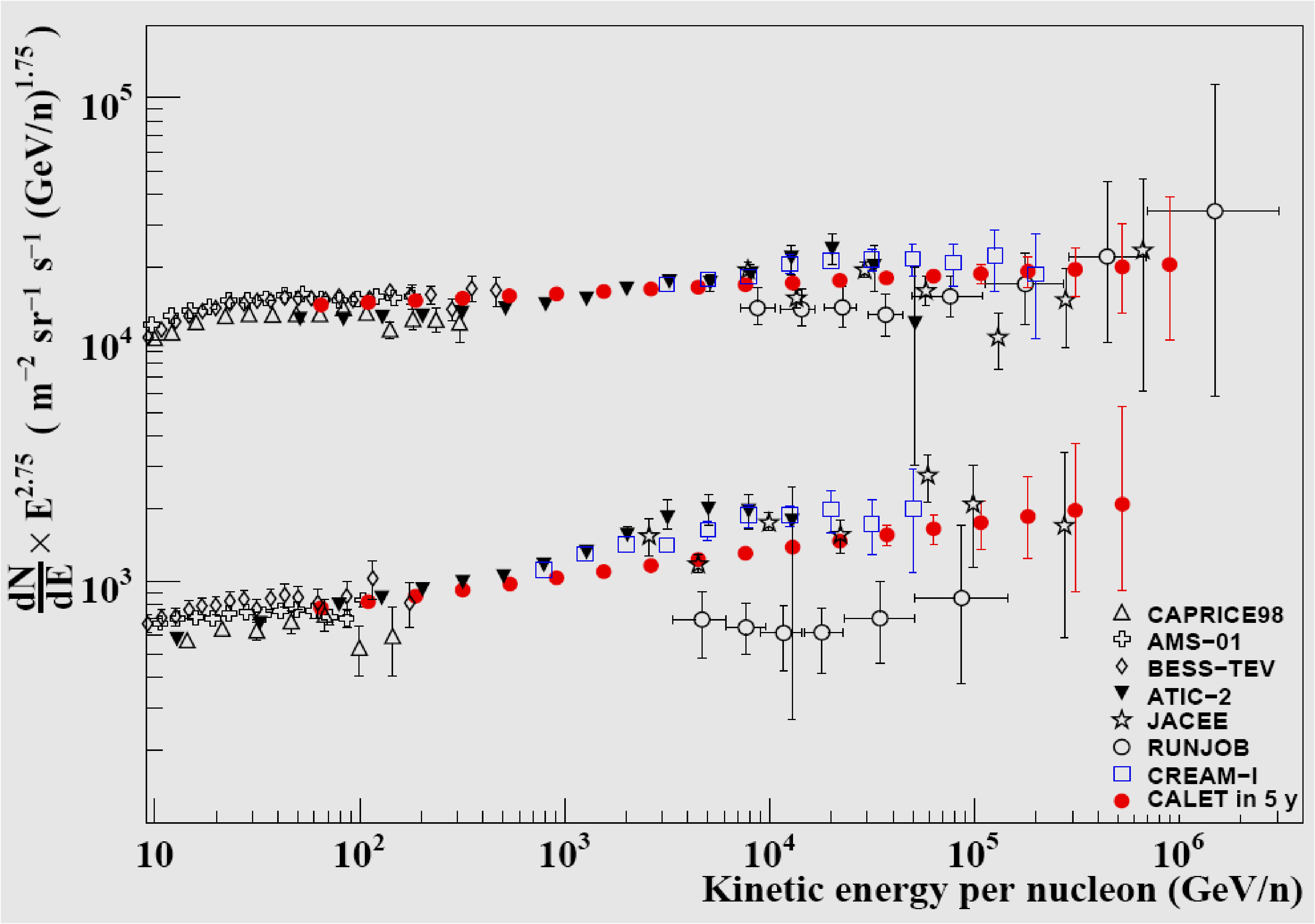
Imaging Calorimeter

Total Absorption Calorimeter

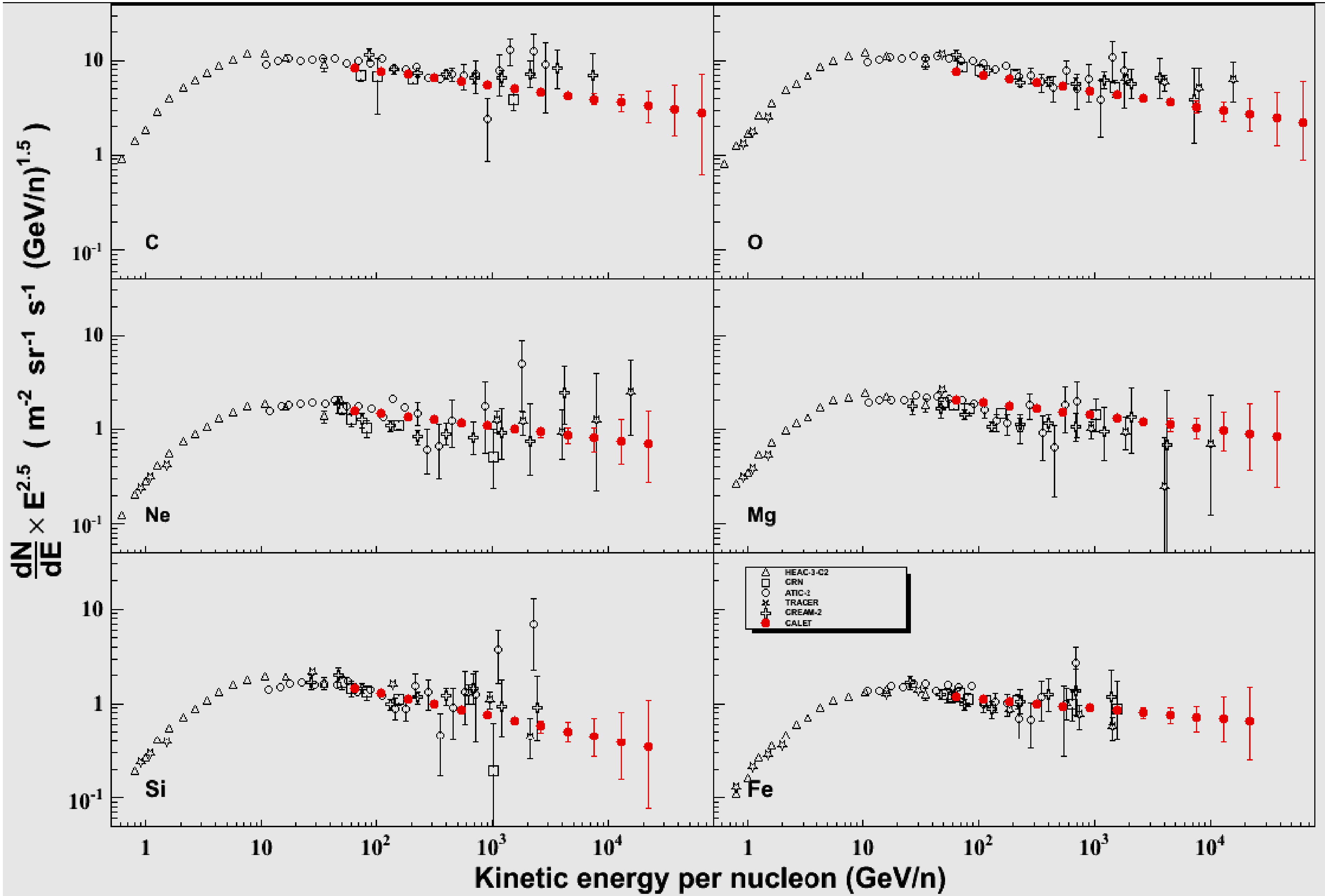
32 cm

CALET on ISS (may 2015)

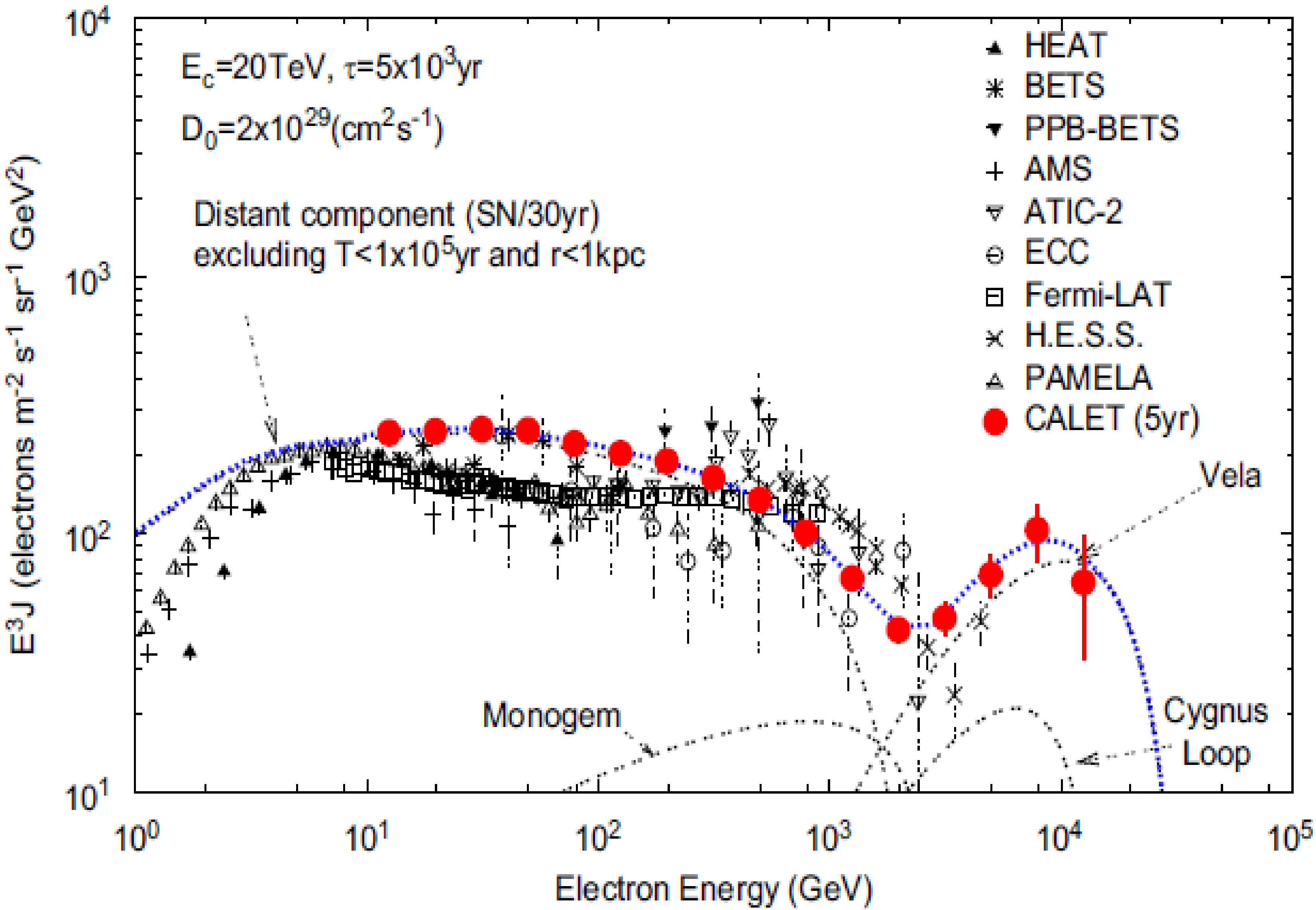
CALET expected proton and Helium spectrum



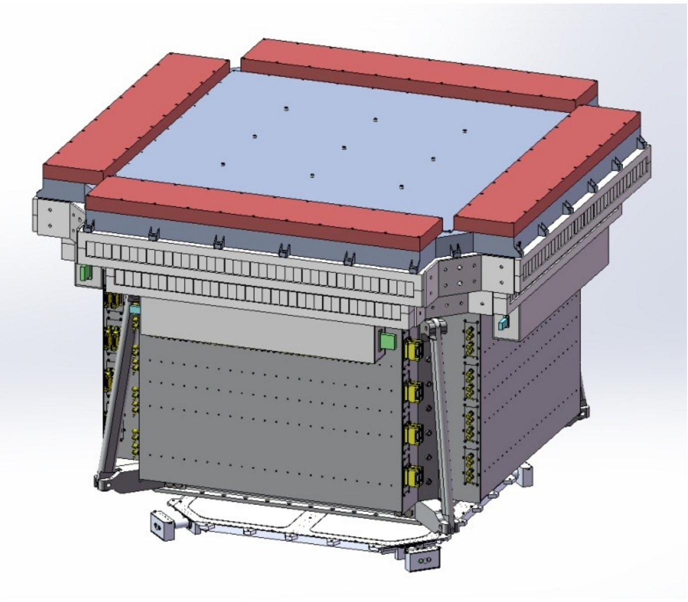
CALET expected heavy nuclei spectra



CALET expected all electron spectrum after 5 years



DAMPE



The detector is consisted of 4 parts:
Top scintillators
Si tracker (5 layers)
BGO calorimeter
Neutron detector

e: 0.3m²sr@200GeV

p: 0.12 m²sr@100TeV

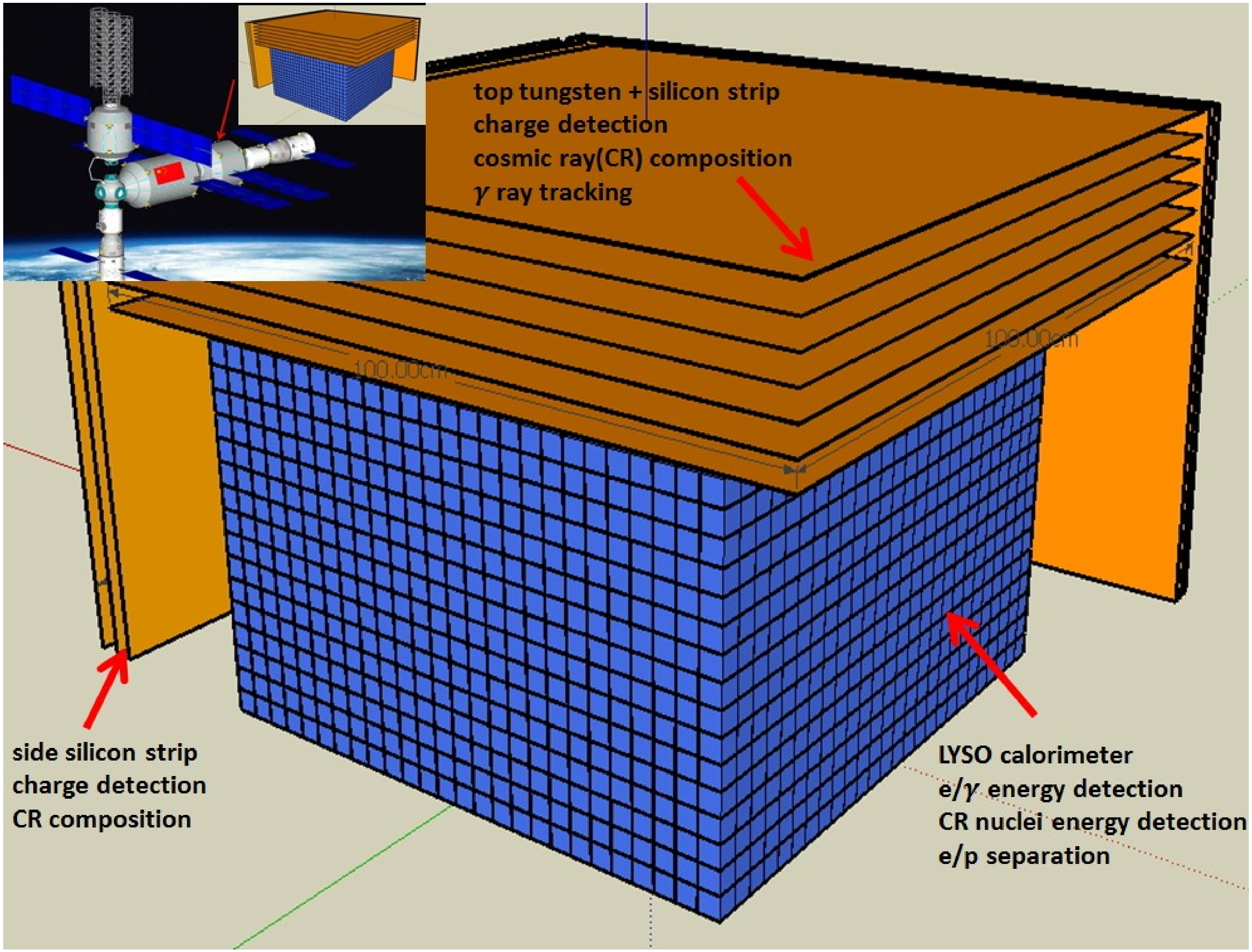
DAMPE expected performance

	DAMPE	AMS-02	Fermi LAT
e/γ Energy range (GeV)	5 - 10^4	0.1 - 10^3	0.02 - 300
e/γ Energy res.@100 GeV (%)	1.5	3	10
e/γ Angular res.@100 GeV (°)	0.1	0.3	0.1
e/p discrimination	10^5	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	31	17	8.6
Geometrical accep. (m^2sr)	0.29	0.09	1

Geometrical acceptance with BGO alone: 0.36 m^2sr

- BGO+STK+PSD: 0.29 m^2sr
- First 10 layers of BGO (22 X_0) +STK+PSD: 0.36 m^2sr

HERD


top tungsten + silicon strip
charge detection
cosmic ray(CR) composition
γ ray tracking
100.00cm
100.00cm
side silicon strip
charge detection
CR composition
LYSO calorimeter
e/γ energy detection
CR nuclei energy detection
e/p separation

HERD expected performance

γ (electron) energy range	tens of GeV-10TeV
nucleon energy range	up to PeV
γ angular resol. (silicon)	0.1^{o}
nucleon charge resol. (silicon)	0.1-0.15 c.u
γ (electron) energy resolution	1%@200GeV
proton energy resolution	20%
e/p separation power	10^{-6}
electron geometrical factor	3.1 m^2sr@200 GeV
proton geometrical factor	2.3 m^2sr@100 TeV

Conclusions

AMS-02 has measured with unprecedented precision the positron fraction, the antiproton fraction, the spectral indexes of proton, Helium, lithium, electron and positron spectra and the B/C ratio.

This measurements allow an improvement of theoretical and fenomenological models describing cosmic ray production, acceleration and propagation, helping to identify possible signals of dark matter in the universe.

The next generation of high acceptance experiment can improve the statistical error on proton, electron and nuclei spectra extending them to several TeV.