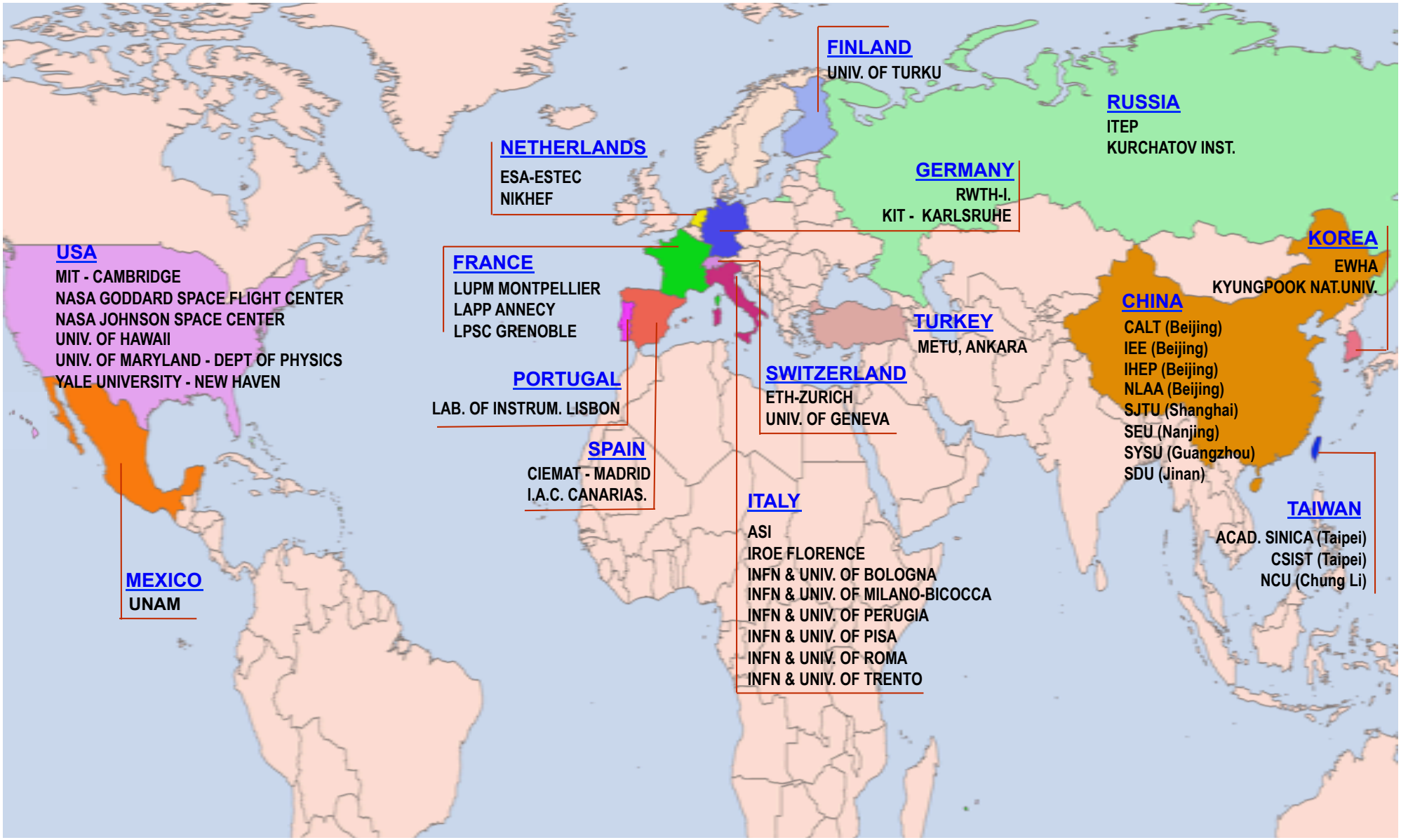
Latest Results from the Alpha Magnetic Spectrometer on the International Space Station

Martin Pohl
Université de Genève

IPA London
21.08.2014

AMS collaboration
16 Countries, 60 Institutes and 600 Physicists

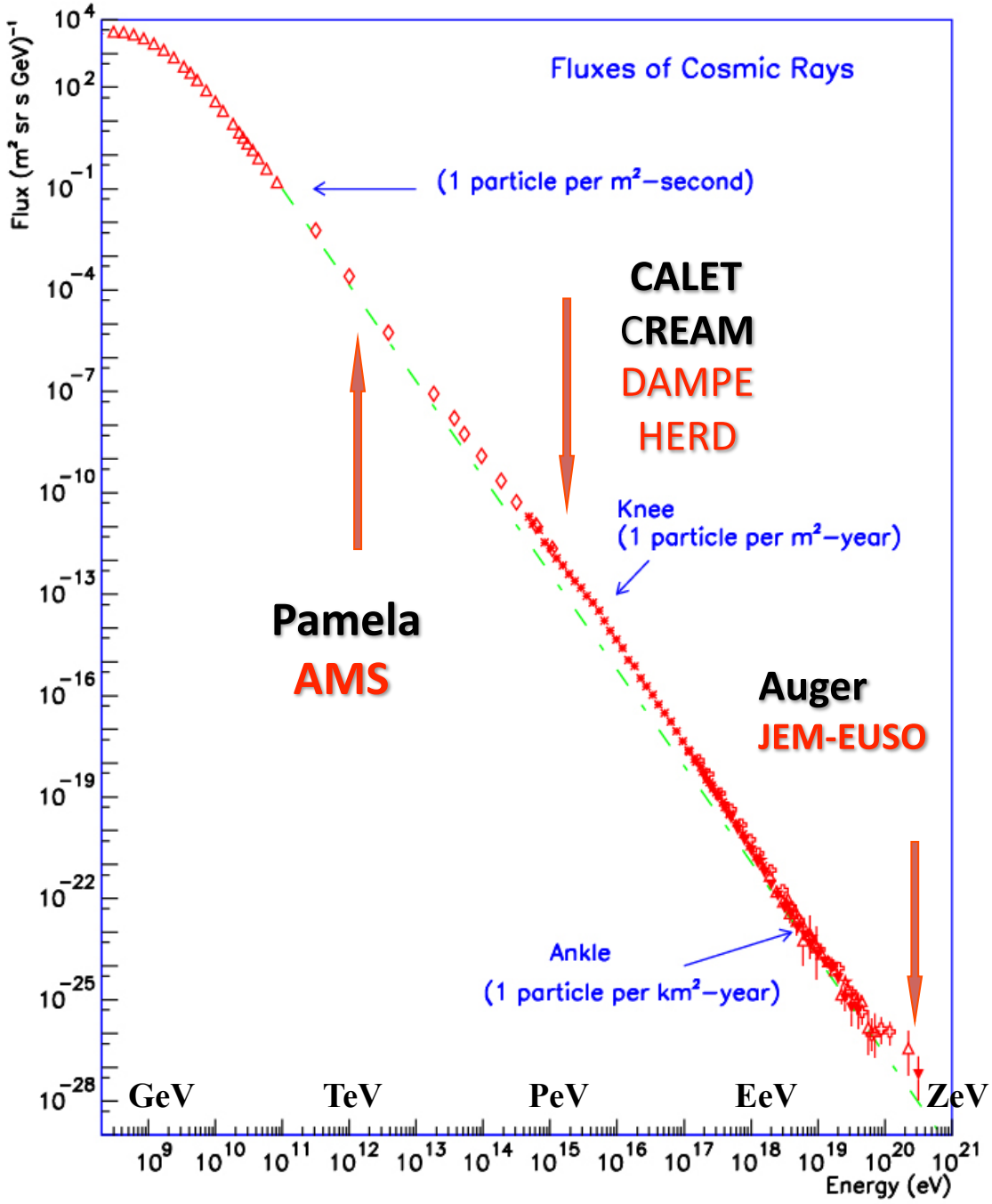


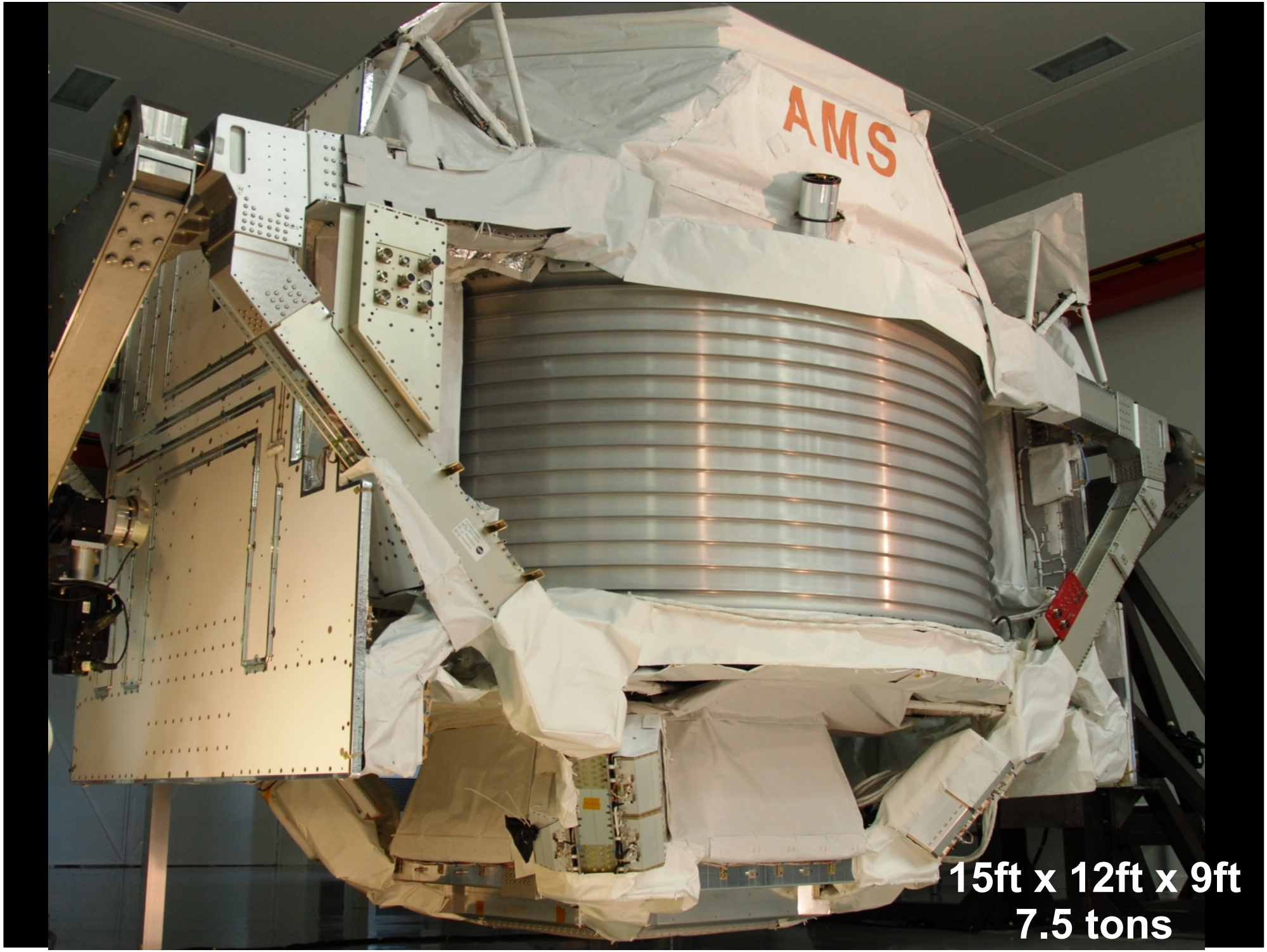
Cosmic Ray Measurements

Standard origin:
- spectrum
- chemical and isotopic composition
- sources and acceleration mechanism

Non-standard origin:
- dark matter
- residual antimatter

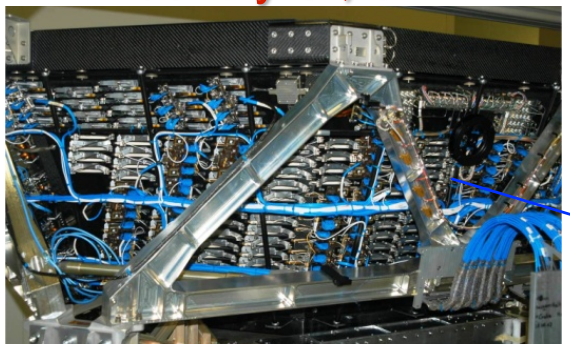
Acceptance × exposure determines energy reach!



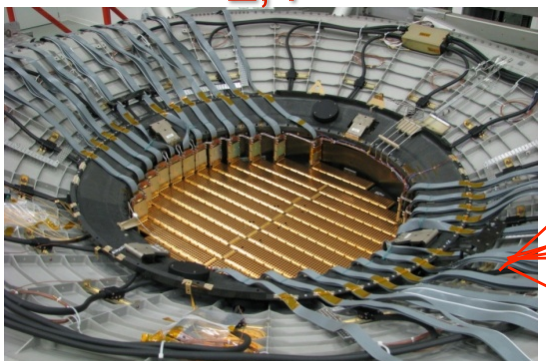

AMS
15ft x 12ft x 9ft
7.5 tons

AMS: GeV to TeV precision multipurpose spectrometer

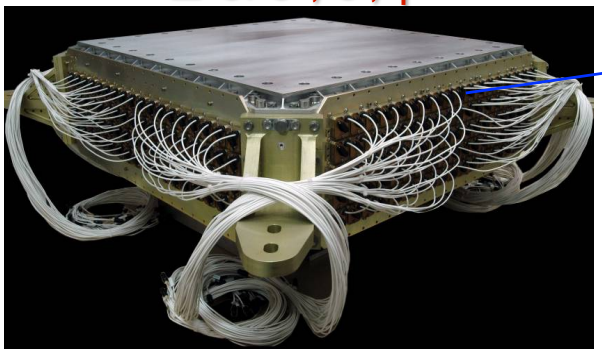
TRD
Identify e^+, e^-

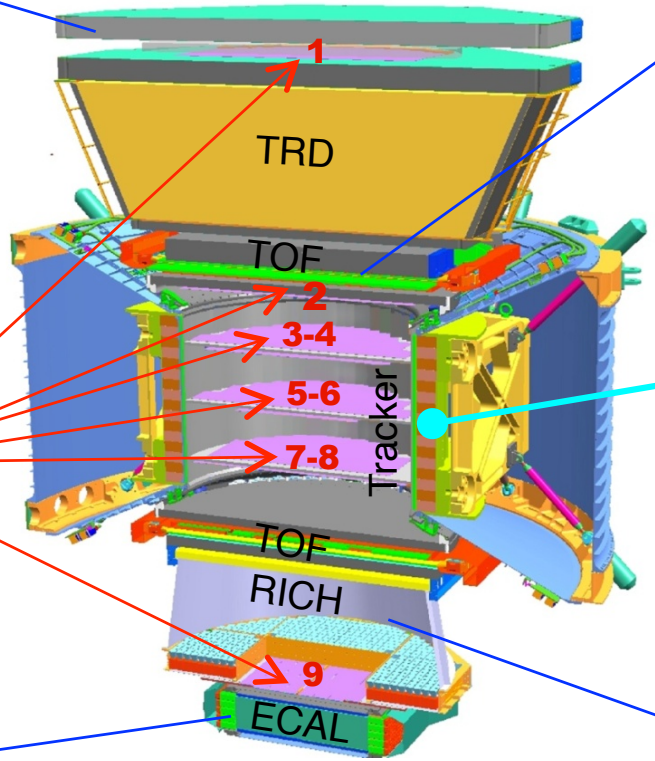


Silicon Tracker
Z, P



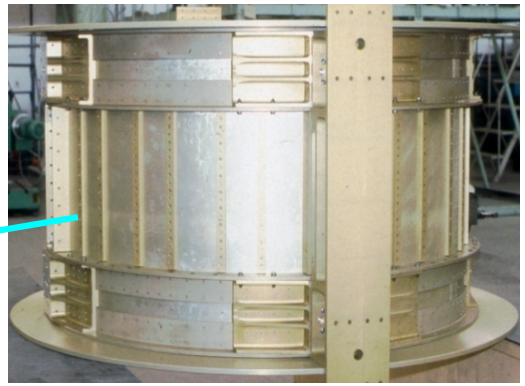
ECAL
E of e^+, e^-, γ



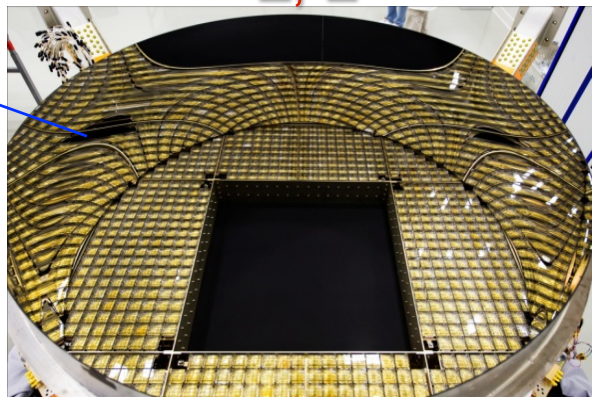


TOF
Z, E

Magnet
±Z



RICH
Z, E



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

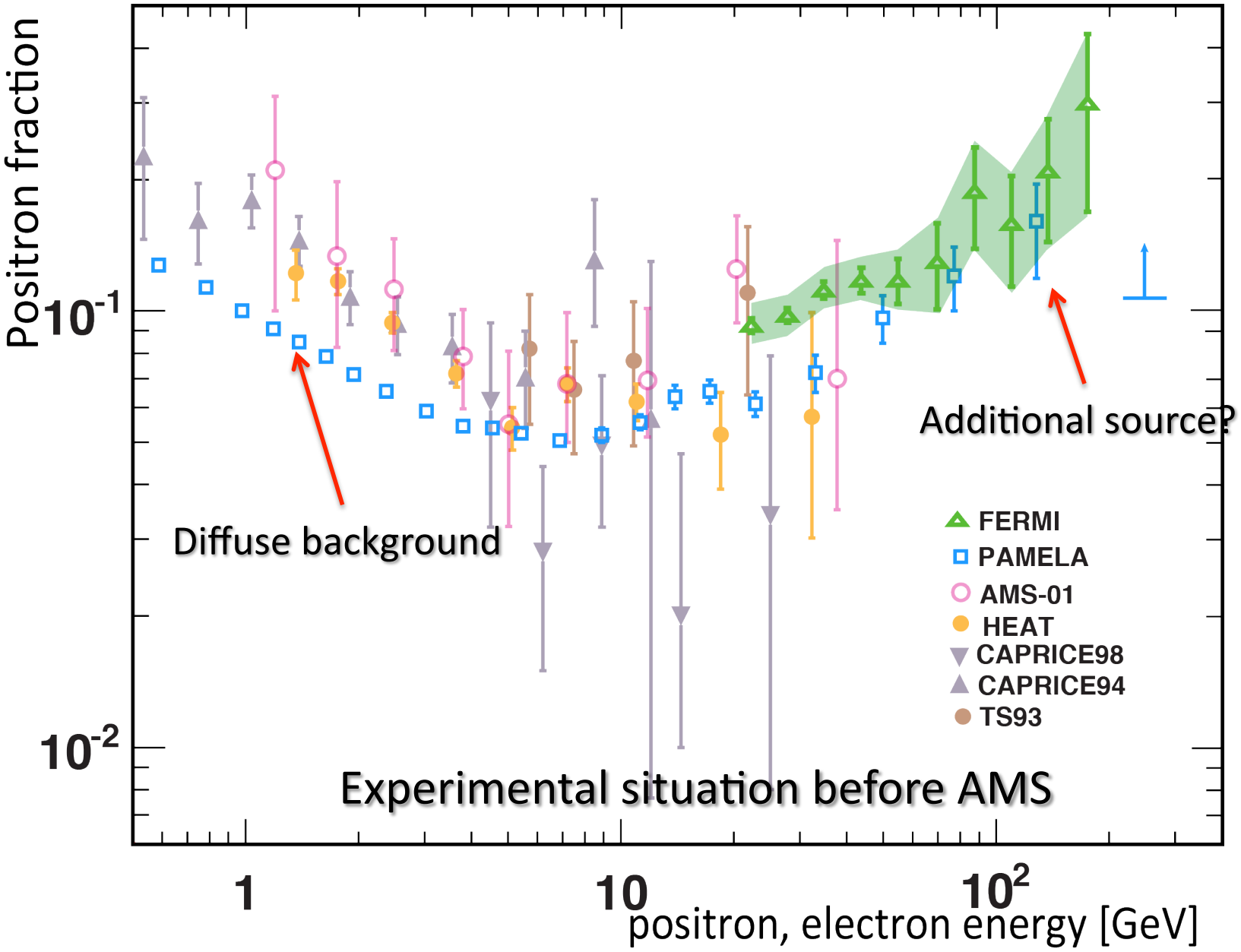
AMS-02 Launch

After 12 years of construction, integration, test…

STS-134 Endeavour:

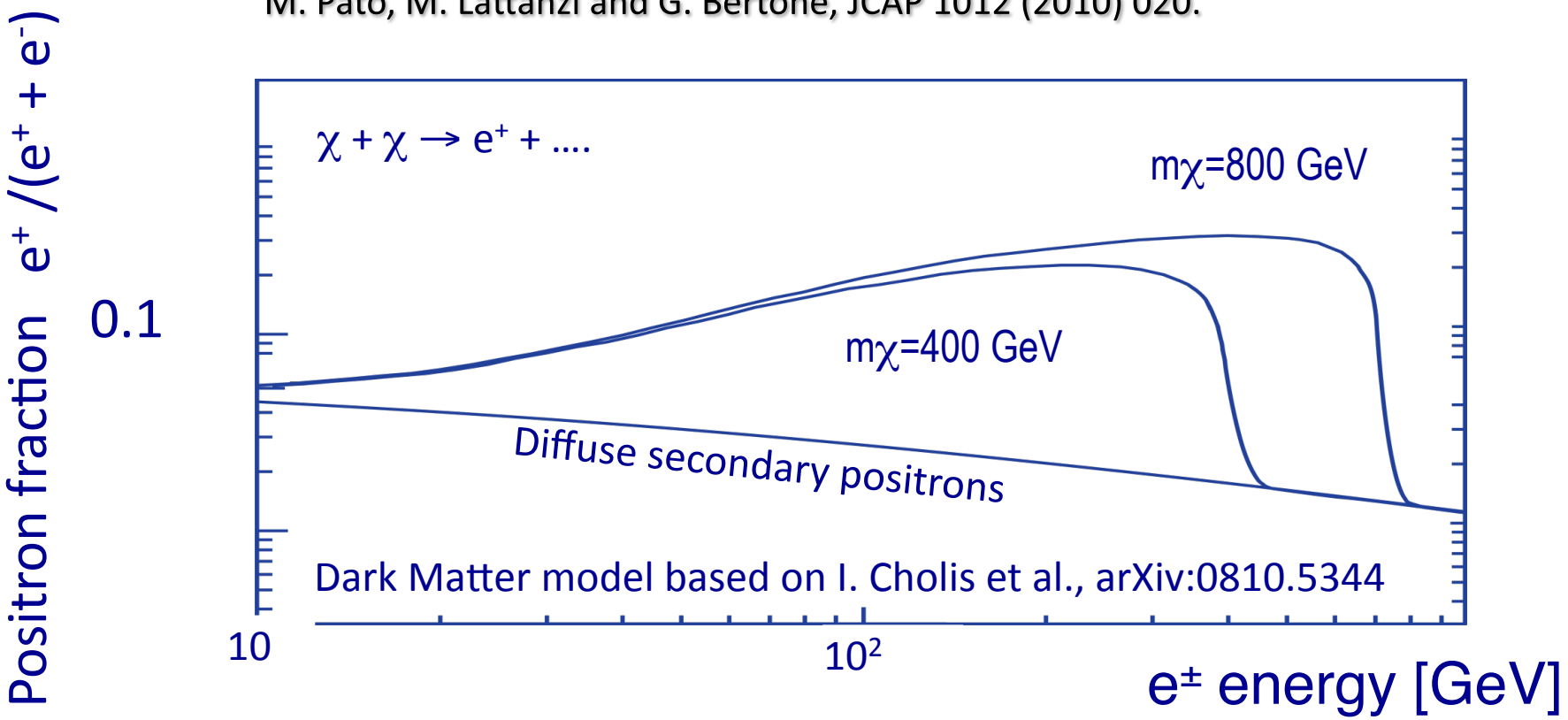
- Successful launch: May 16, 2011, 14:56
- Docking with ISS: May 17, 17:59
- AMS installation complete: May 19, 11:46
- AMS up and running: May 19, 16:38
- First He nucleus: May 19, 16:42

Positron Fraction = $\Phi(e^+) / [\Phi(e^+) + \Phi(e^-)]$



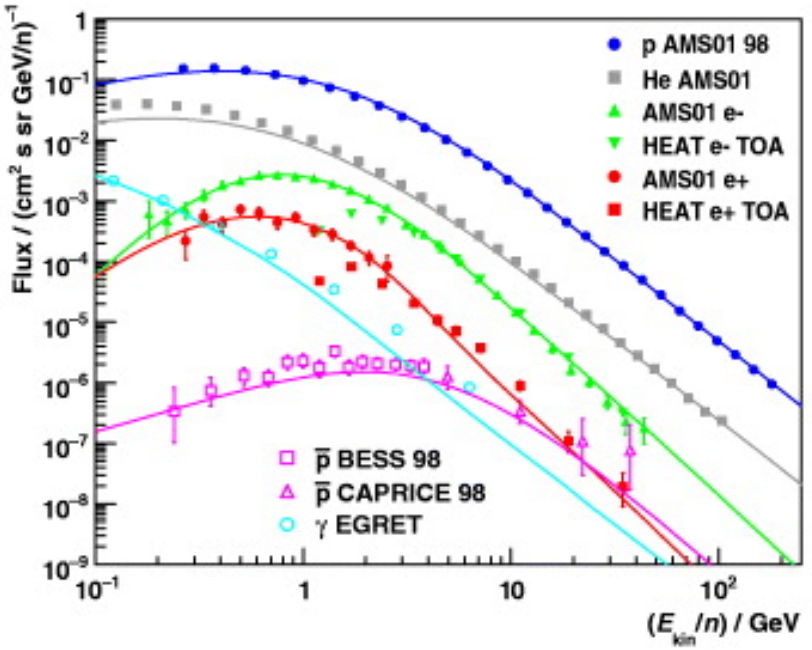
Physics of Positron Fraction

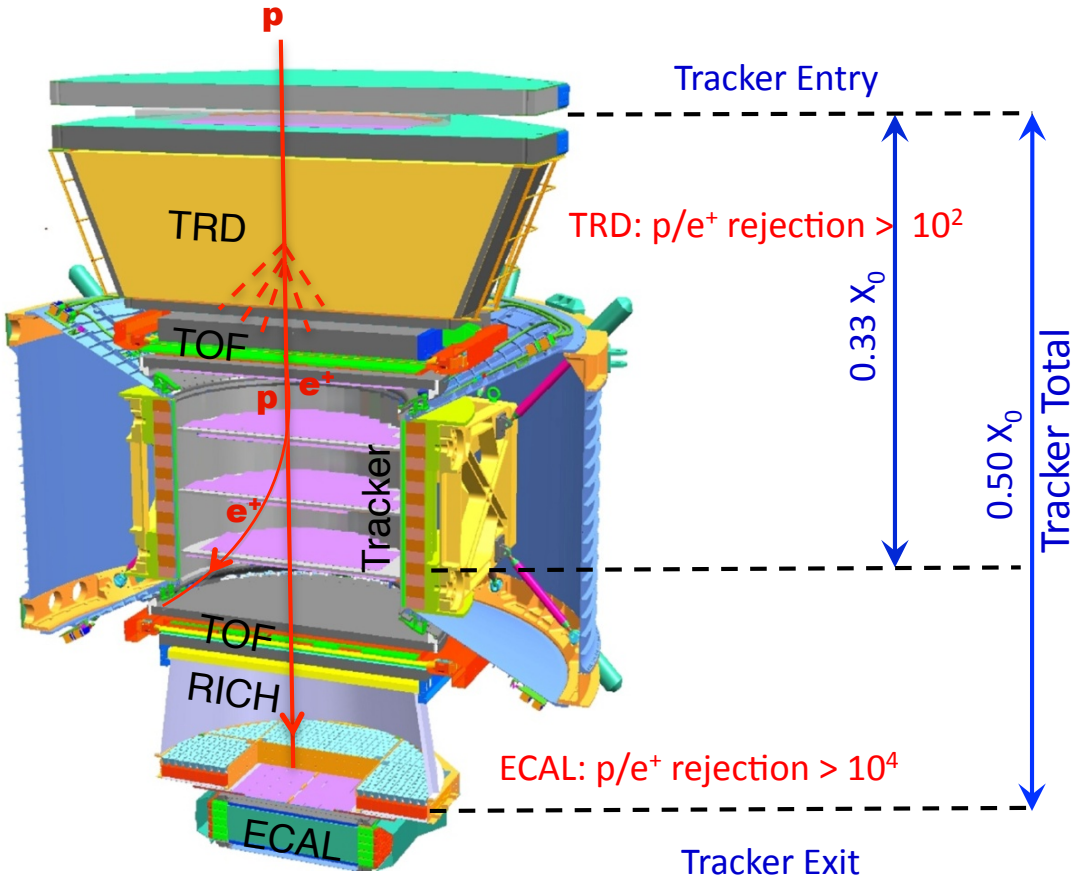
M. Turner and F. Wilczek, Phys. Rev. D42 (1990) 1001;
J. Ellis, 26th ICRC Salt Lake City (1999) astro-ph/9911440;
H. Cheng, J. Feng and K. Matchev, Phys. Rev. Lett. 89 (2002) 211301;
S. Profumo and P. Ullio, J. Cosmology Astroparticle Phys. JCAP07 (2004) 006;
D. Hooper and J. Silk, Phys. Rev. D 71 (2005) 083503;
E. Ponton and L. Randall, JHEP 0904 (2009) 080;
G. Kane, R. Lu and S. Watson, Phys. Lett. B681 (2009) 151;
D. Hooper, P. Blasi and P. D. Serpico, JCAP 0901 025 (2009) 0810.1527; B2
Y–Z. Fan et al., Int. J. Mod. Phys. D19 (2010) 2011;
M. Pato, M. Lattanzi and G. Bertone, JCAP 1012 (2010) 020.



Separation Power for $p/e^+ > 10^6$

Beischer et al., NJP 11 (2009) 105021



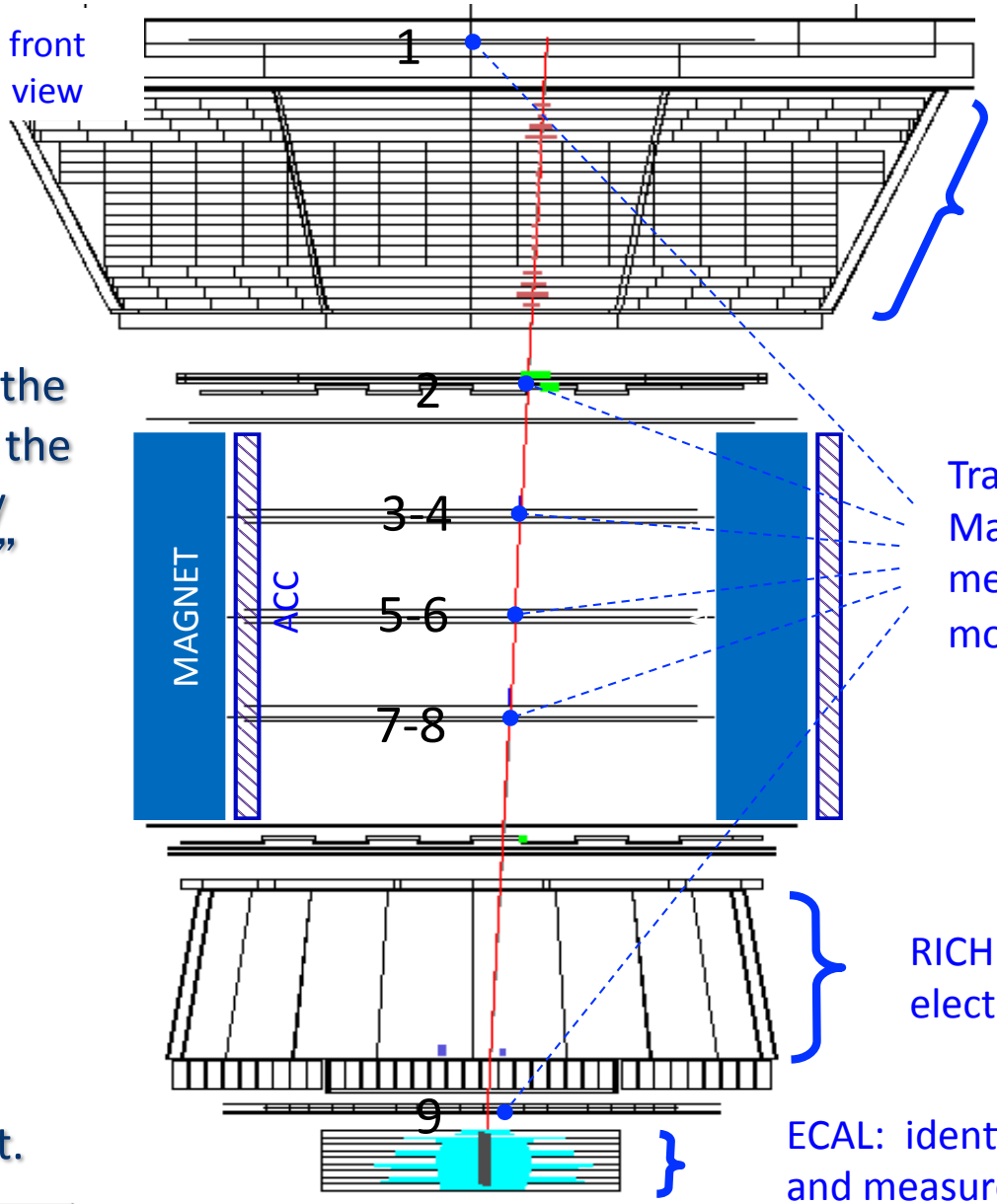


a) Minimal material in the TRD and TOF
So that the detector does not become a source of e^+.

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 data on ISS: 424 GeV positron



"First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV"

Selected for a
Viewpoint in Physics and
an Editors' Suggestion

Aguilar,M. et al (AMS Collaboration) Phys. Rev. Lett. 110, 141102 (2013)

From: Matteo Rini [mrini@aps.org]
Sent: 02 January 2014 19:09
To: Samuel Ting
Subject: your AMS paper as a 2013 Physics Highlights

Dear Sam,

this is just to let you know that your article the first AMS data has been selected in our 2013 APS Physics Highlights (http://physics.aps.org/articles/v6/139).

Congratulation on this work, which has generated a lot attention among our readers, the press and the scientific community.

Best regards,

Matteo

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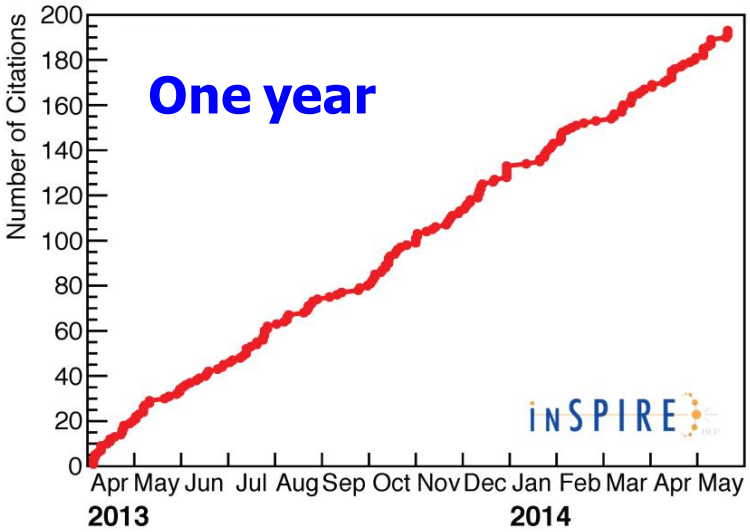
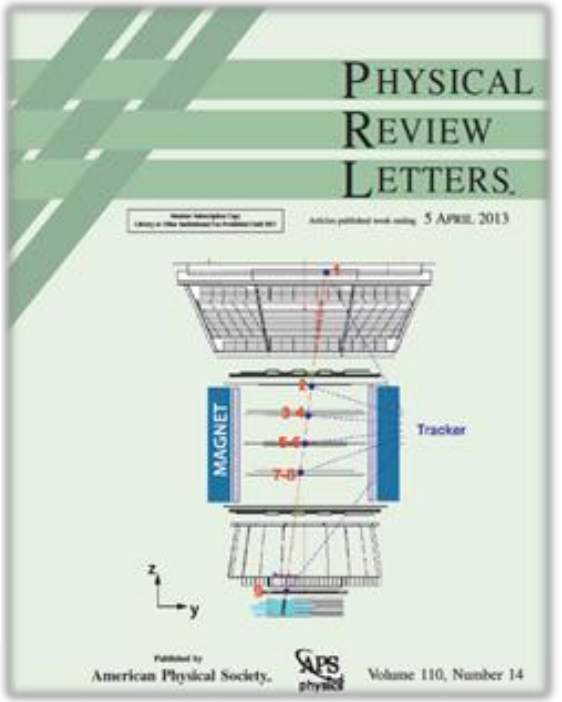
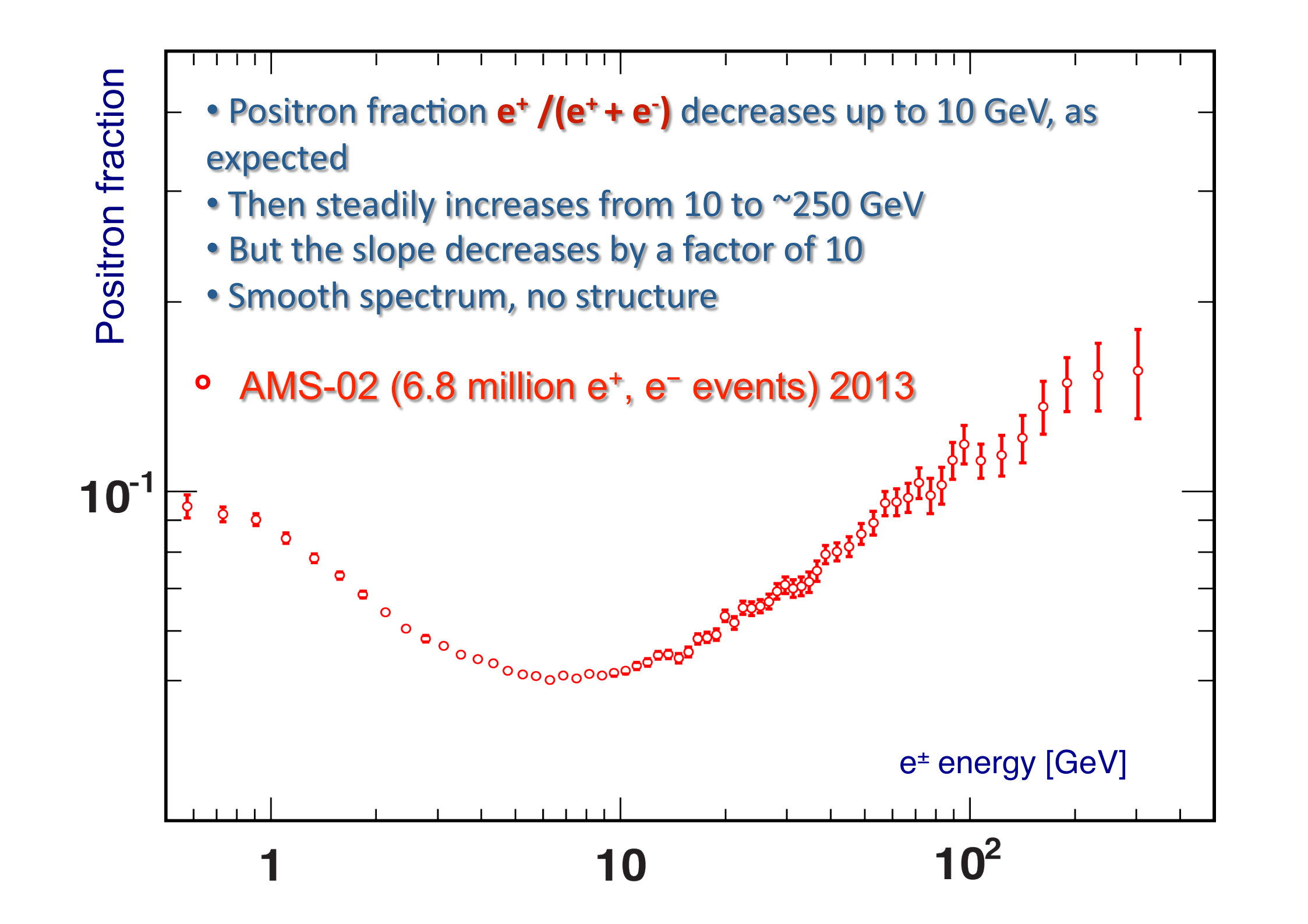
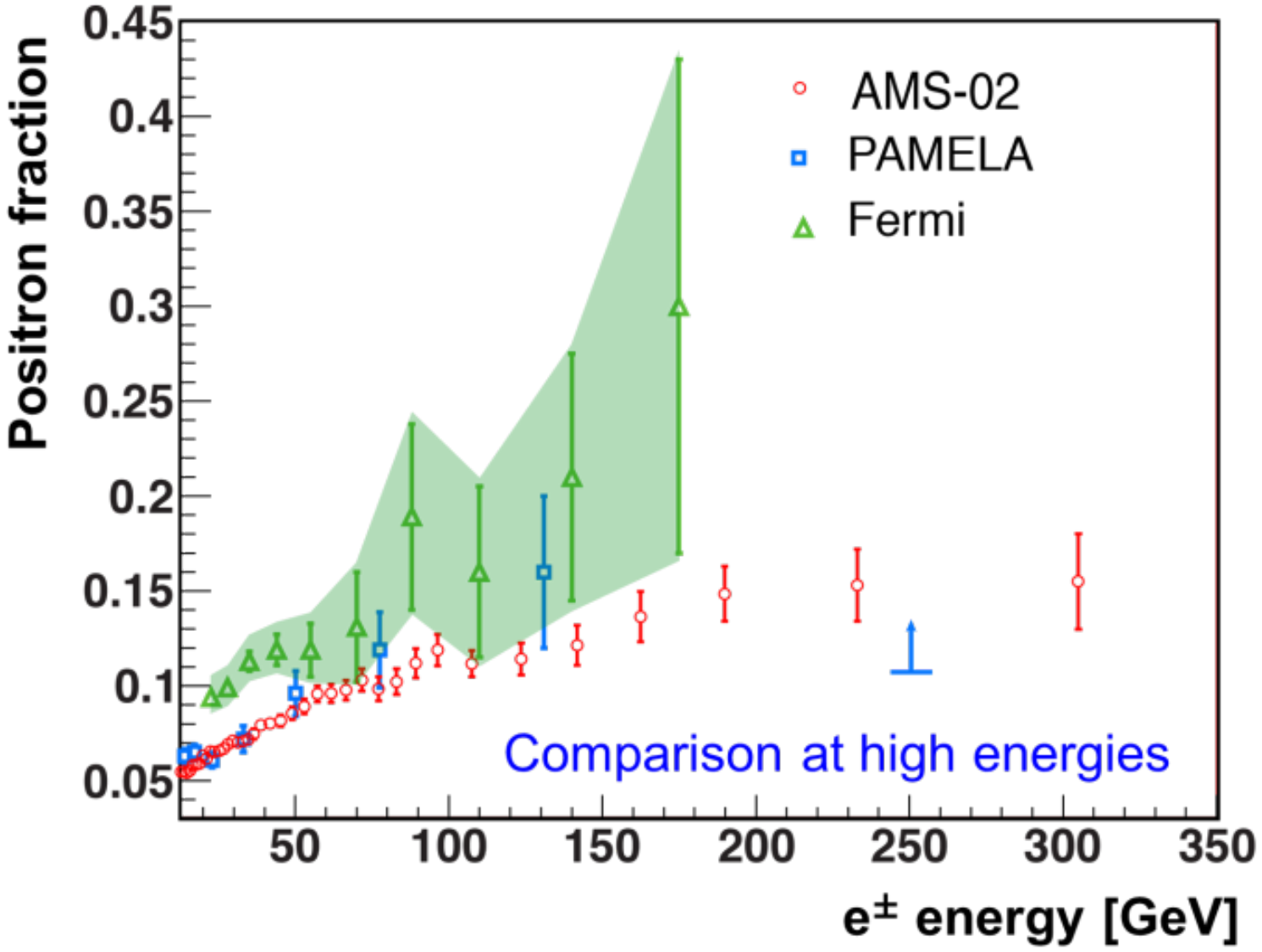
Matteo Rini, PhD
Deputy Editor, Physics
mrini@aps.org
http://physics.aps.org






• Positron fraction $e^+/(e^+ + e^-)$ decreases up to 10 GeV, as expected
• Then steadily increases from 10 to ~250 GeV
• But the slope decreases by a factor of 10
• Smooth spectrum, no structure
AMS-02 (6.8 million e^+, e^- events) 2013
Positron fraction
10^{-1}
1
10
10^2
$e^\pm$ energy [GeV]

AMS Positron Fraction 2013

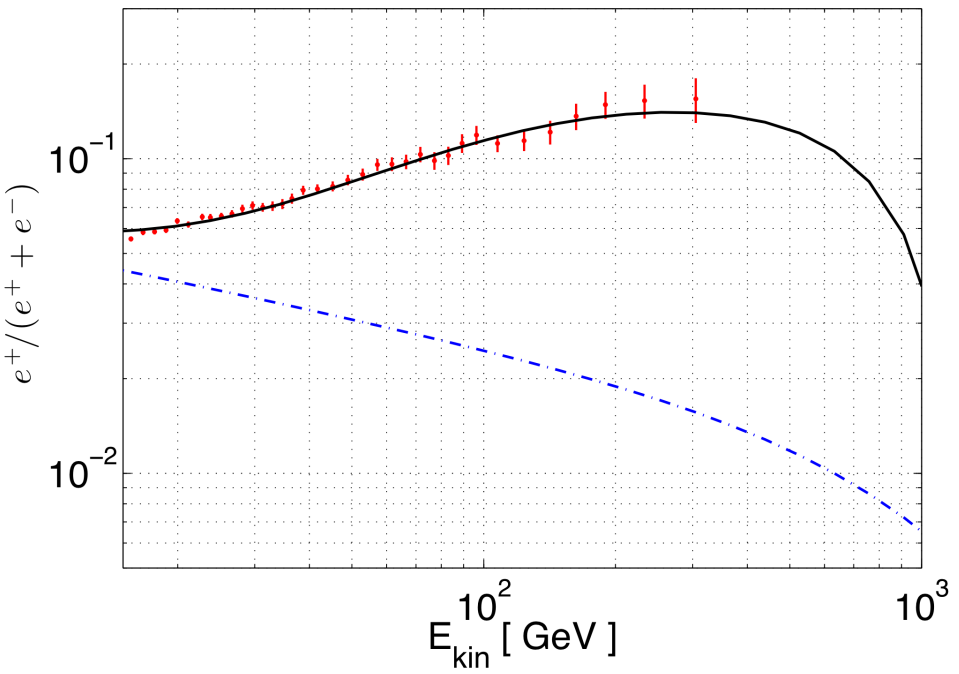


Low energy measurements include HEAT, CAPRICE, TS93 …

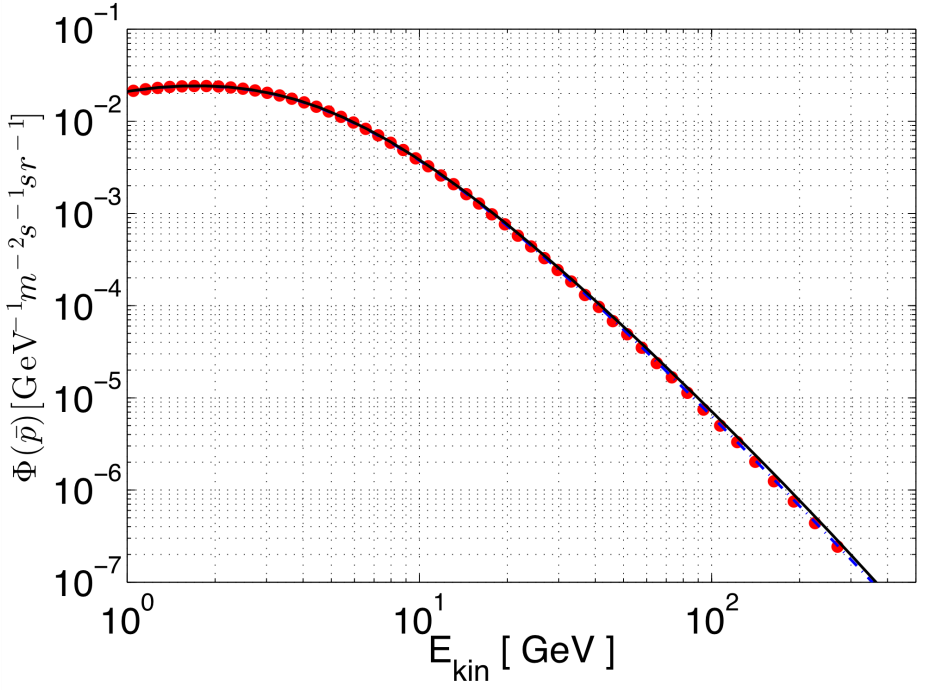
Interpretation example: DM DM → $\tau^+\tau^-$

Andrea De Simone, Antonio Riotto, Wei Xuec
CERN-PH-TH/2013-054 (April 3, 2013)

m_{DM} = 900 GeV
$\sigma v = 5 \times 10^{-23}$ cm^{3}s^{-1}



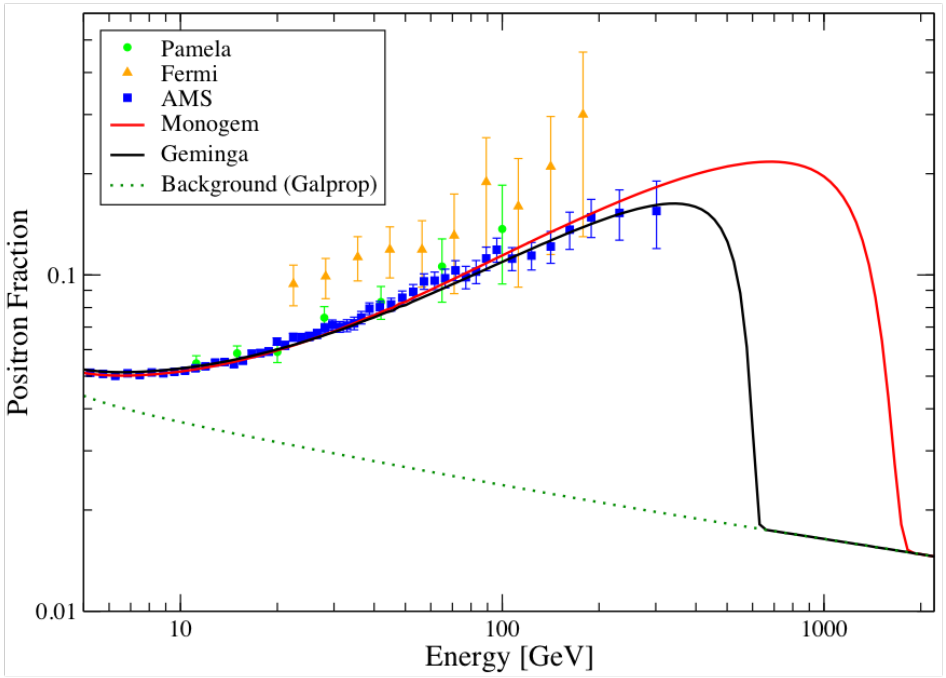
AMS Data: e^+ fraction

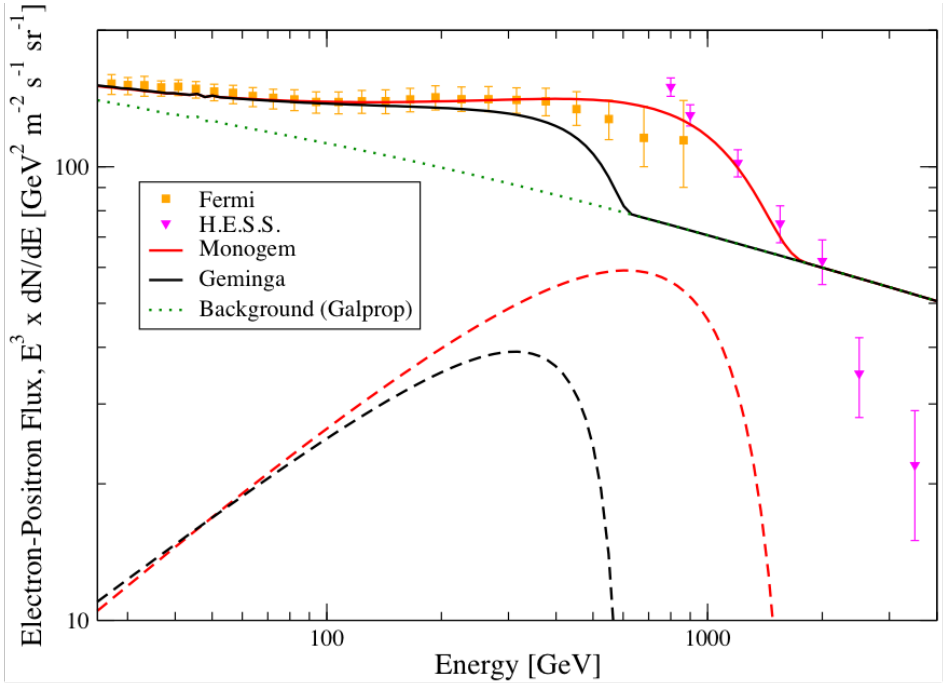


AMS expectation: $\Phi(\bar{p})$

Interpretation Example: Single Pulsar

Tim Linden and Stefano Profumo
arXiv:1304.1791v1 [astro-ph.HE] 5 Apr 2013





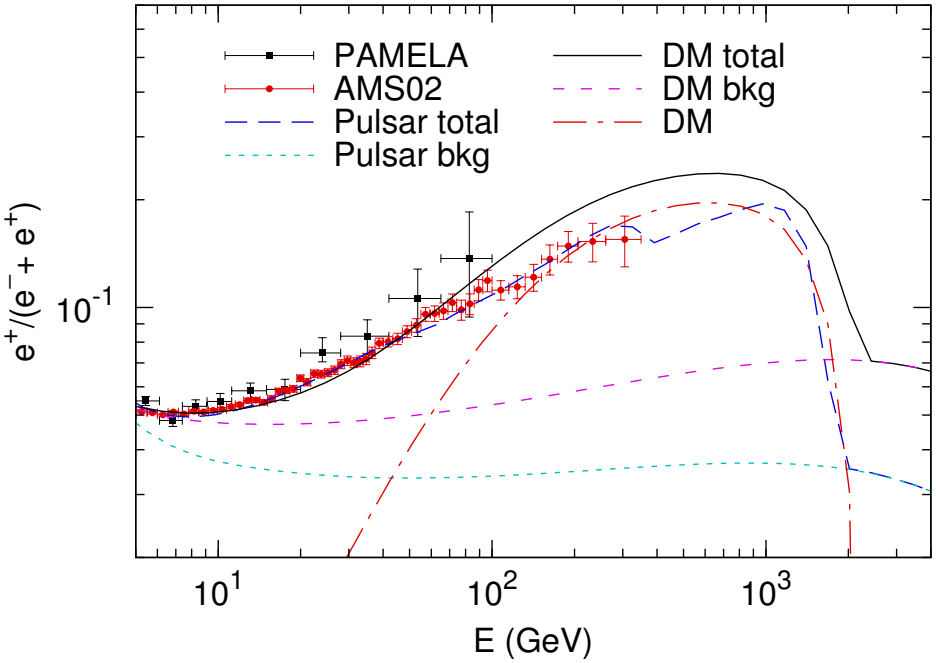
AMS Data: e^+ fraction

Fermi/HESS: e^-+e^+

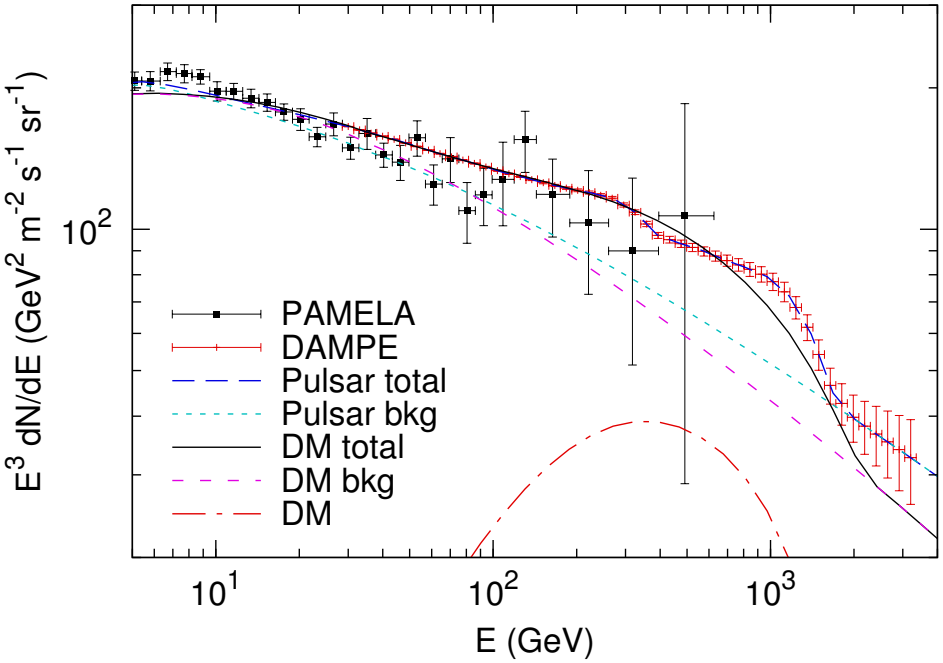
See also: Cholis and Hooper, arXiv:1304.840v1 [astro-ph.HE] 6 Apr 2013

Interpretation Example: Pulsars (+ DM?)

Peng-Fei Yin, Zhao-Huan Yu, Qiang Yuan and Xiao-Jun Bi
arXiv:1304.4128v1 [astro-ph.HE] 15 Apr 2013



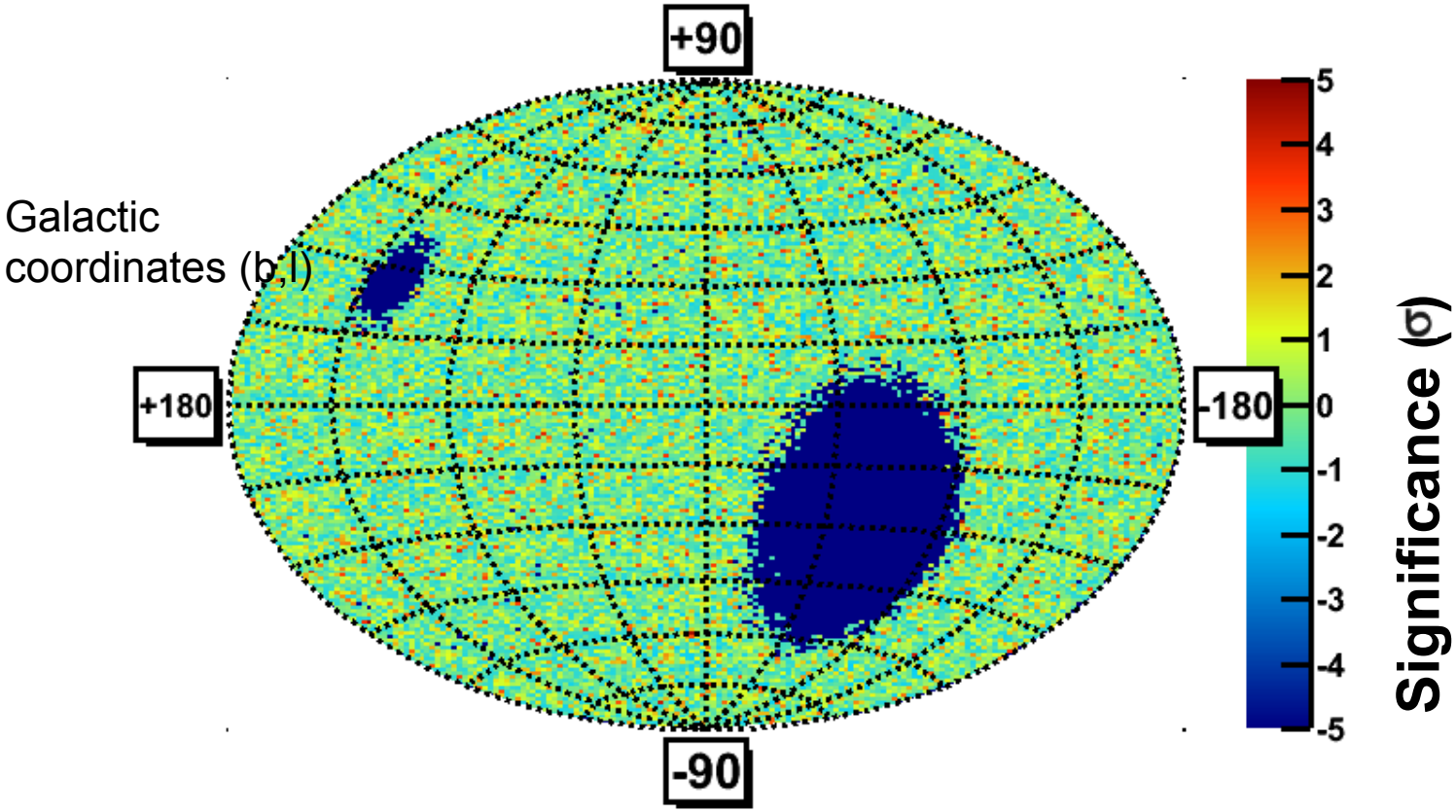
AMS data: e^+ fraction



Pamela data
DAMPE expectation: e^- flux

Accurate data on shape of cut-off are badly needed

More Information: Anisotropy



The fluctuations of the positron ratio e^+/e^- are isotropic.

The anisotropy in galactic coordinates:
$\delta \leq 0.030$ at the 95% confidence level

Dark Matter Searches

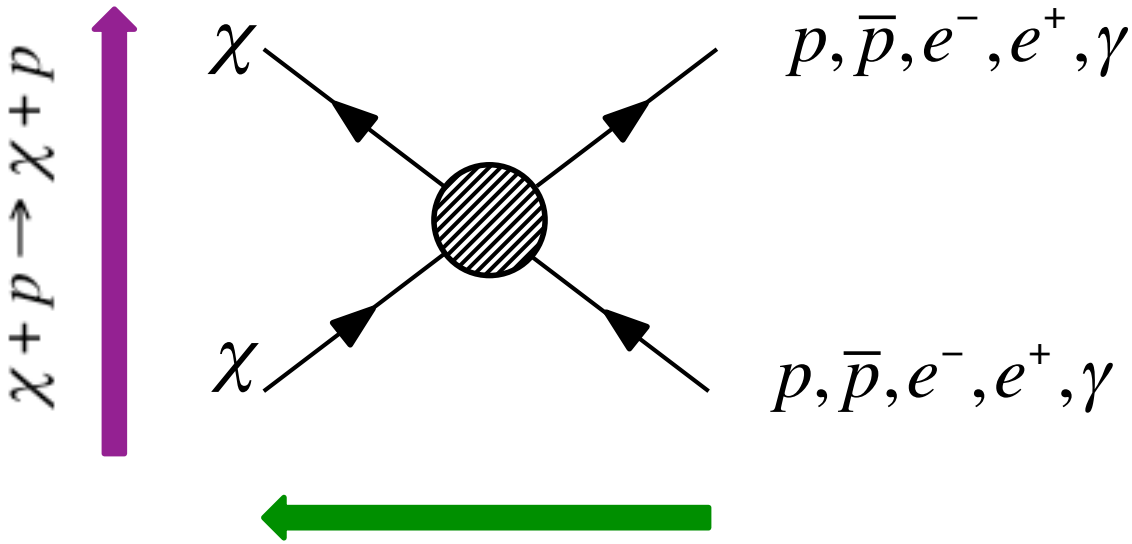
Annihilation (in Space)

$$\chi + \chi \rightarrow e^+, \bar{p}, \gamma, \ldots$$

AMS

Scattering (Underground Experiments World Wide):

LUX
DARKSIDE
XENON 100
CDMS II
…

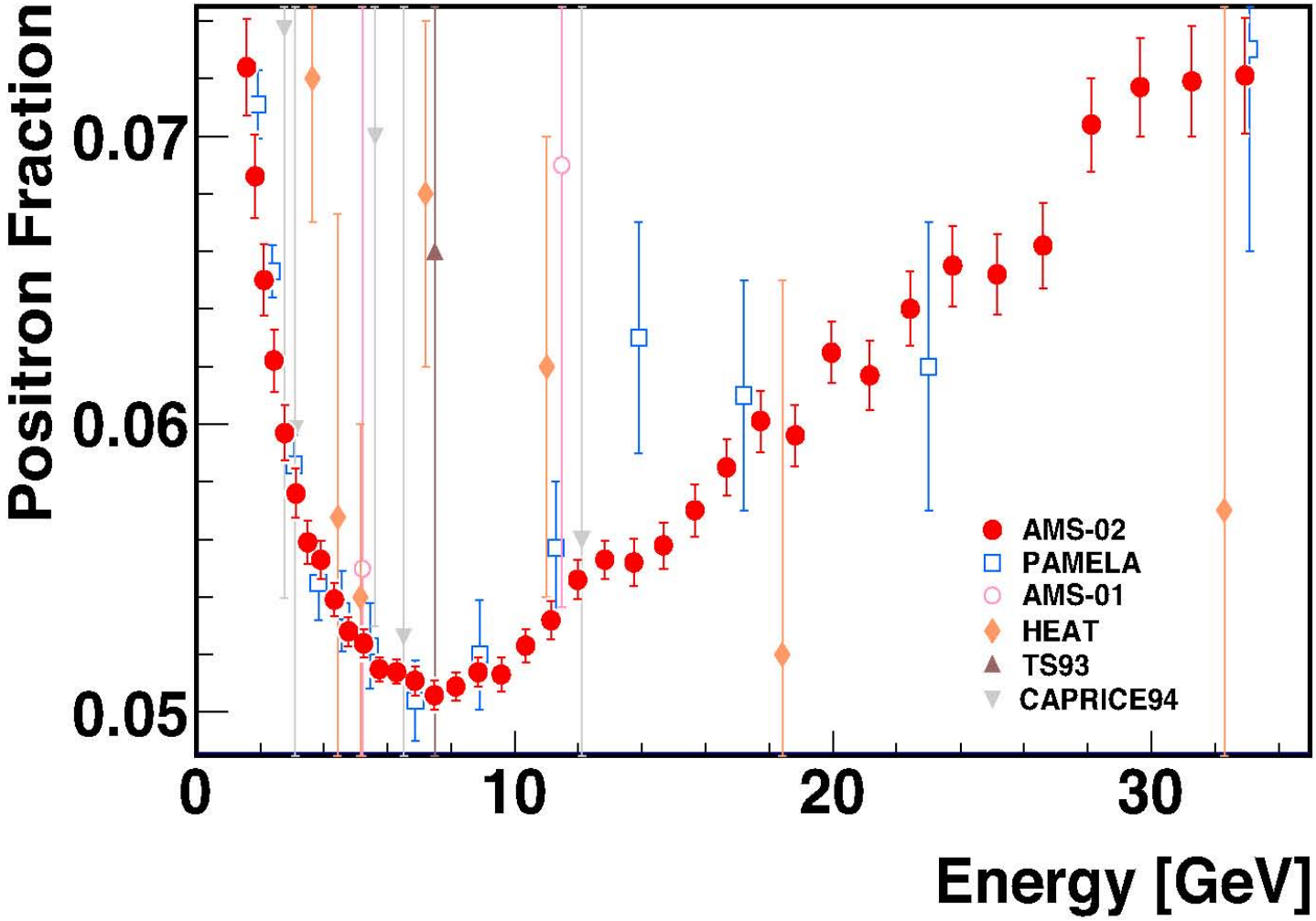


LHC

$$\chi + \chi \leftarrow p + p$$

Production (at Accelerators)

AMS Positron Fraction 2014 @ Low Energies



11 million electrons and positrons

AMS Positron Fraction 2014 @ High Energies

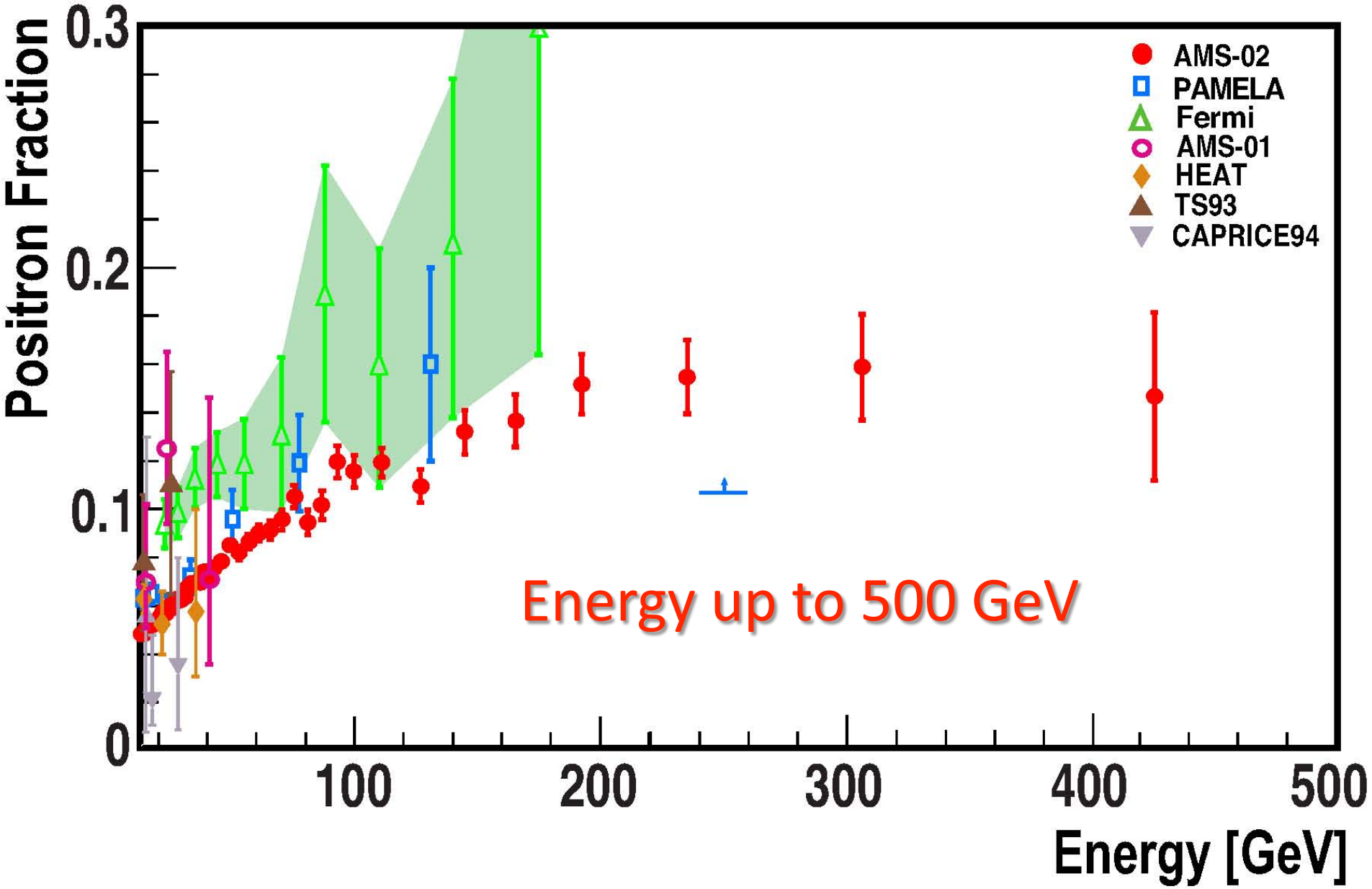


FIG. 3. The positron fraction above 10 GeV, where it begins to increase. The present measurement extends the energy range to 500 GeV

AMS Positron Fraction 2014 vs Minimal Model

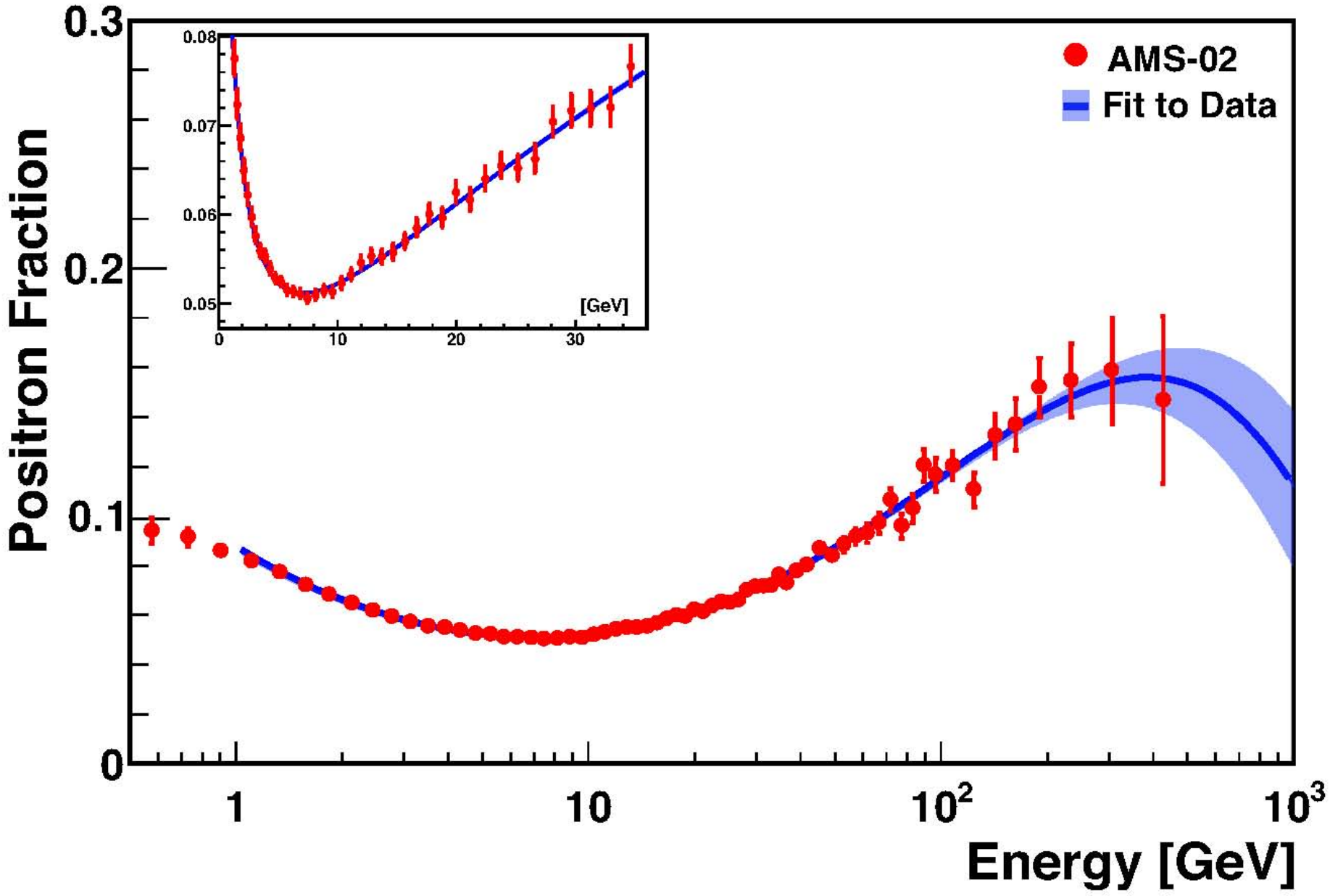
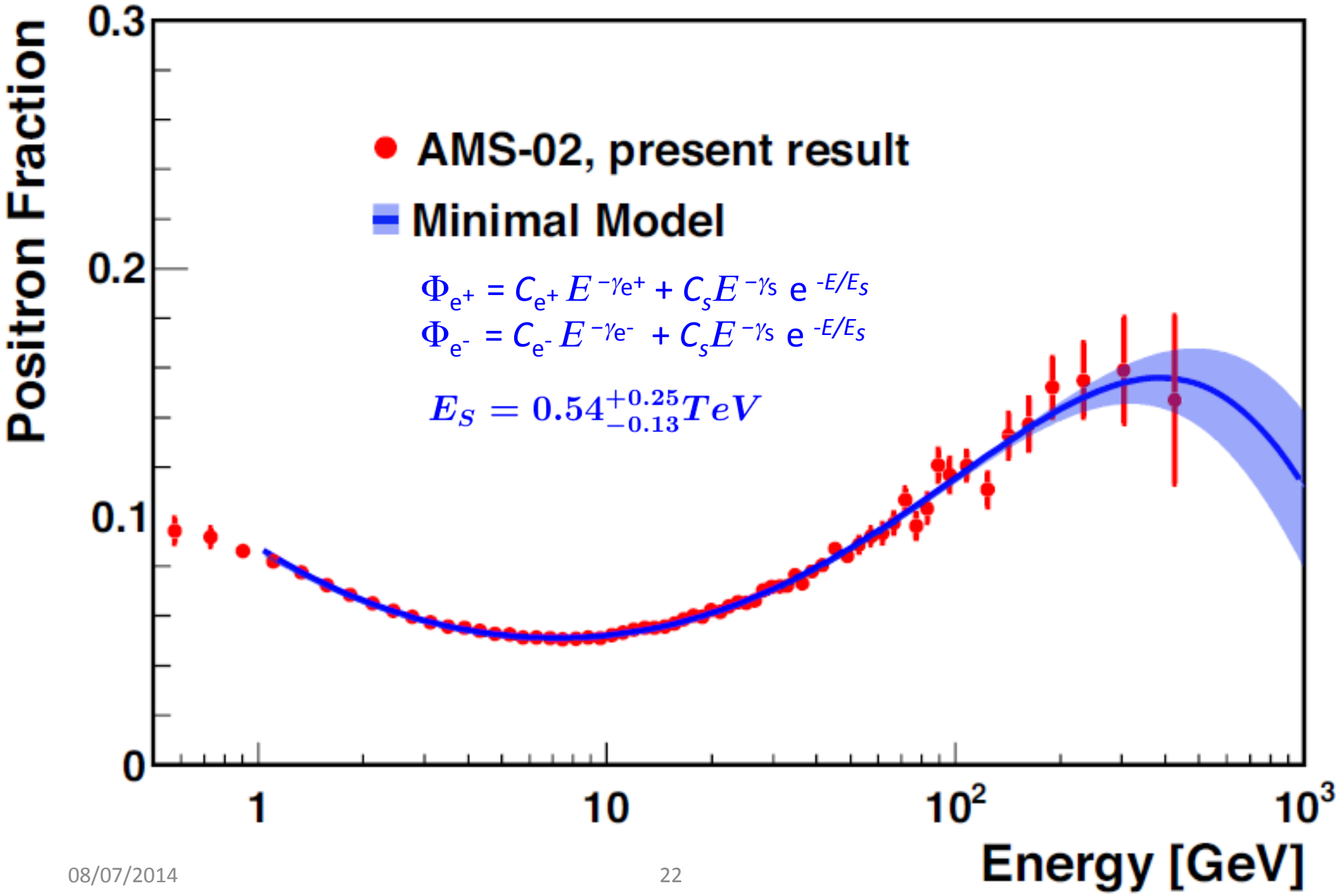
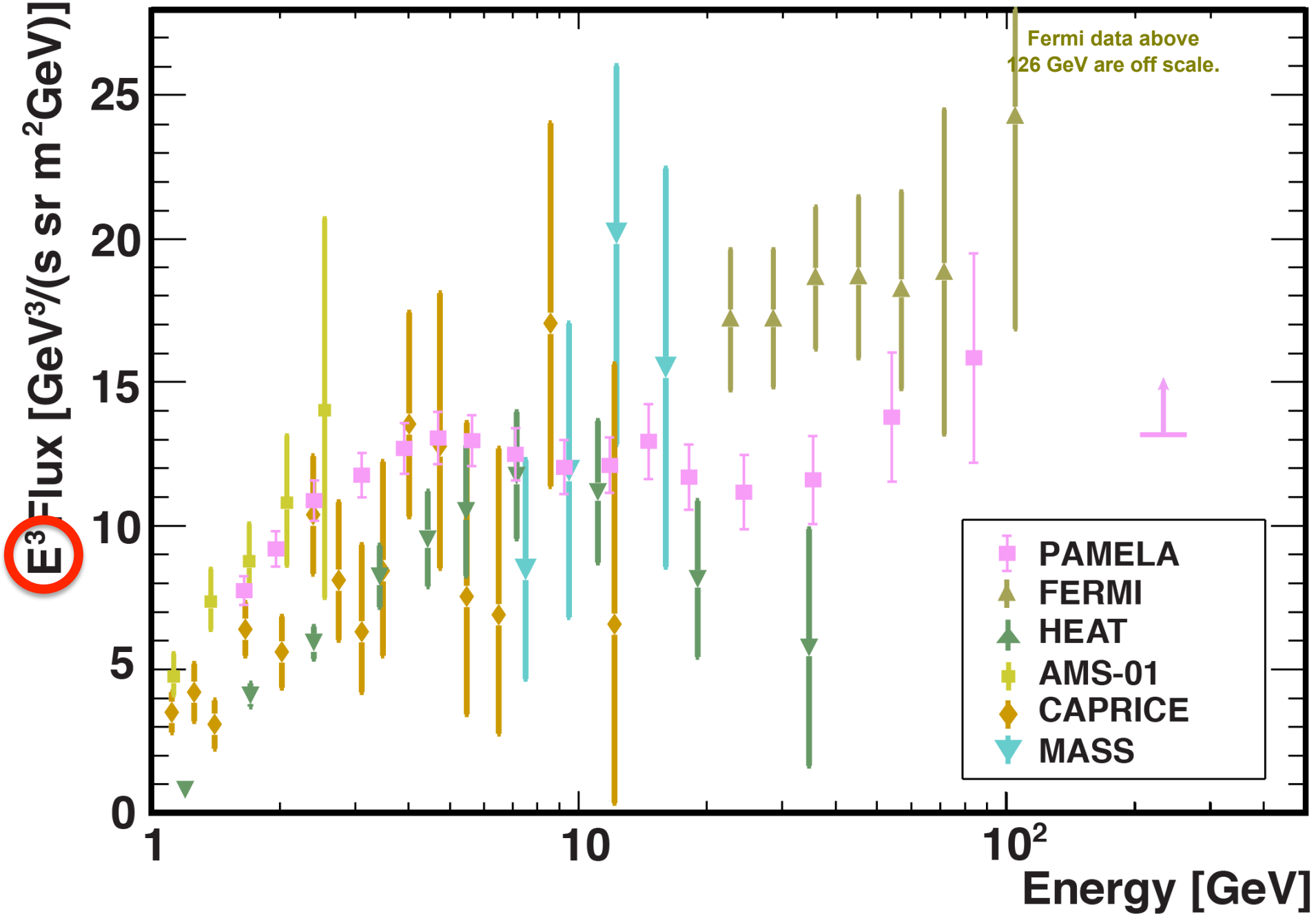


FIG. 4. The positron fraction measured by AMS and the fit of a minimal model (solid curve, see text) and the 68% C.L. range of the fit

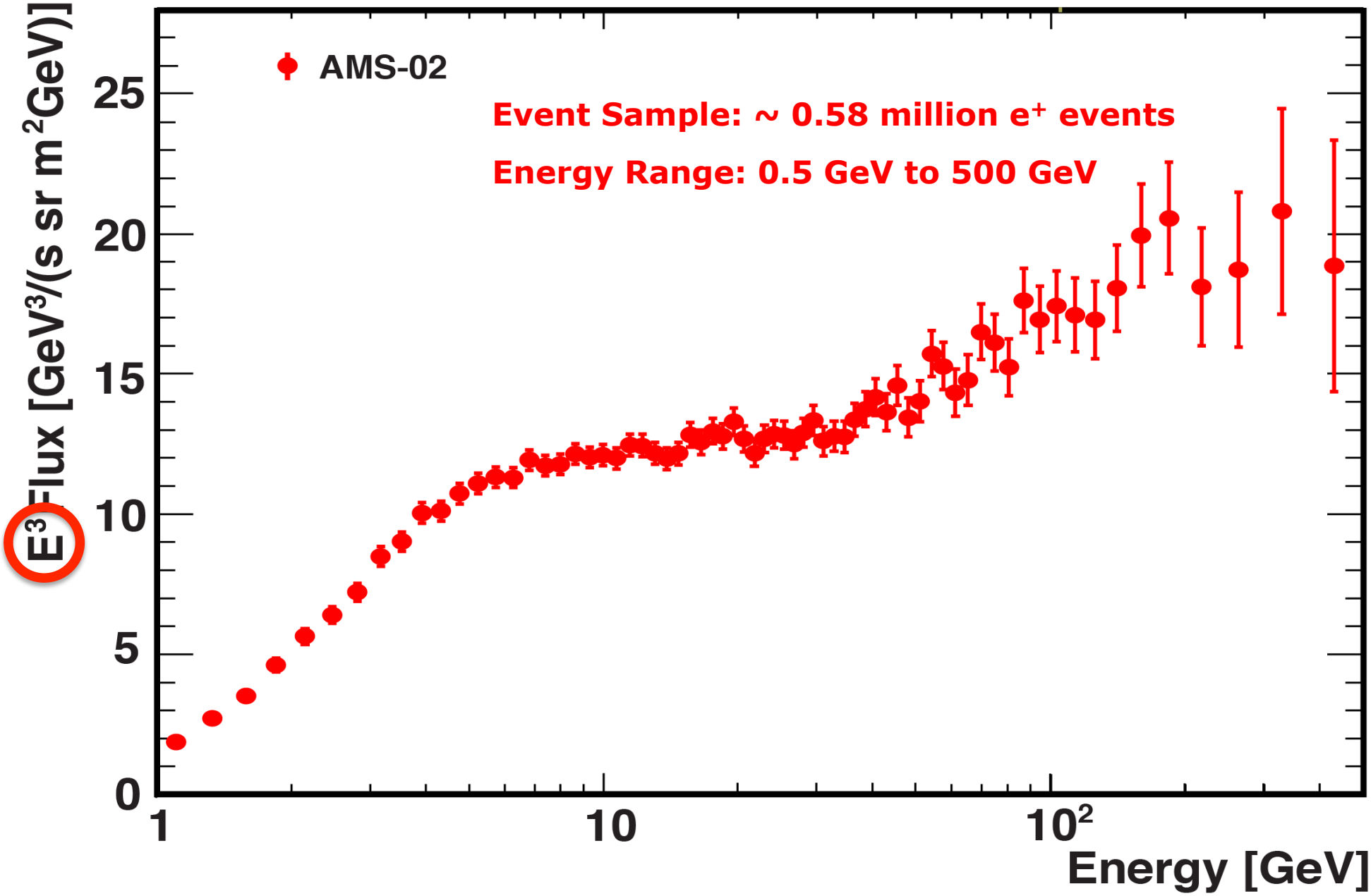
AMS Positron Fraction 2014 vs Minimal Model



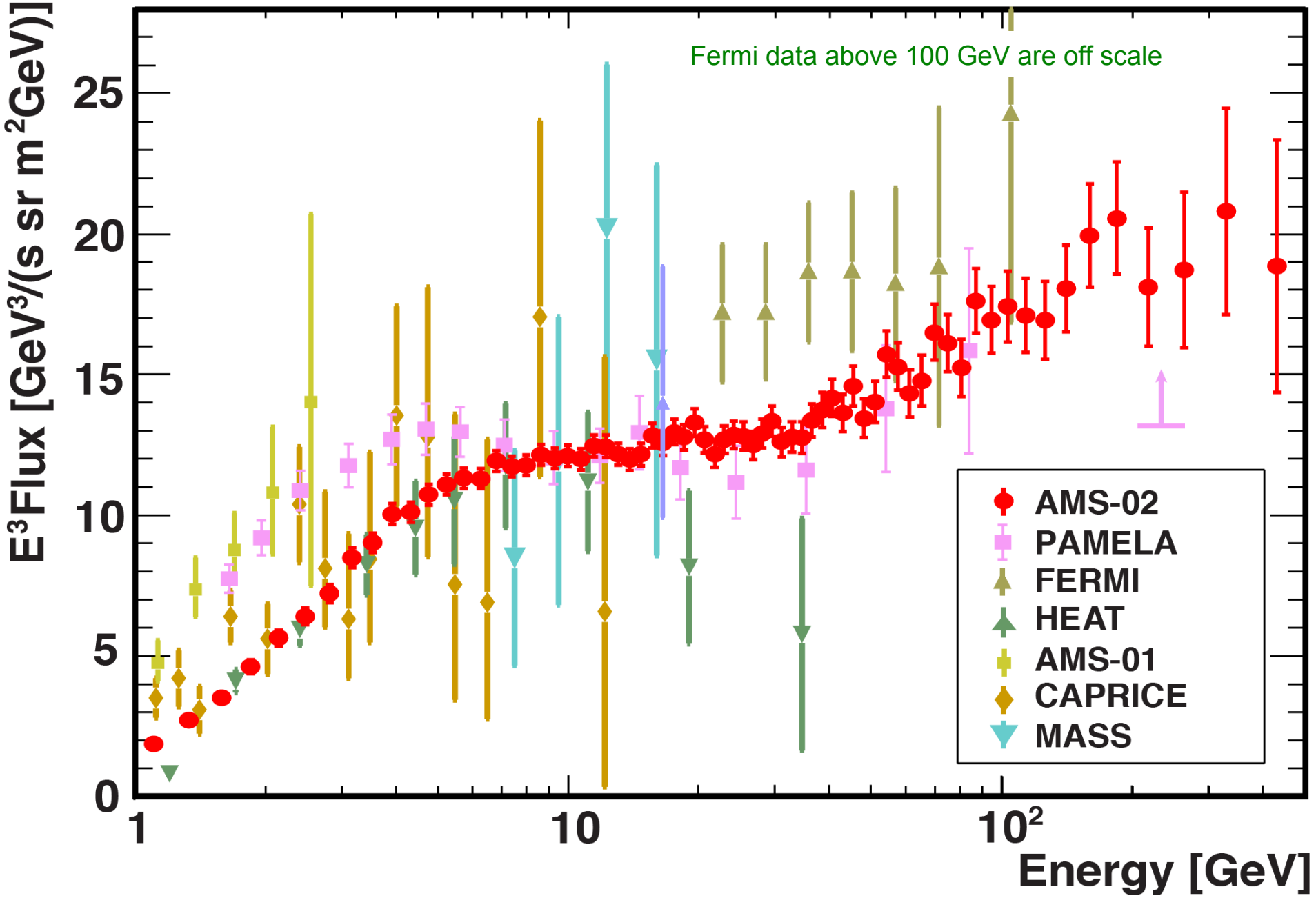
Positron Flux Scaled by E^3 Prior to AMS



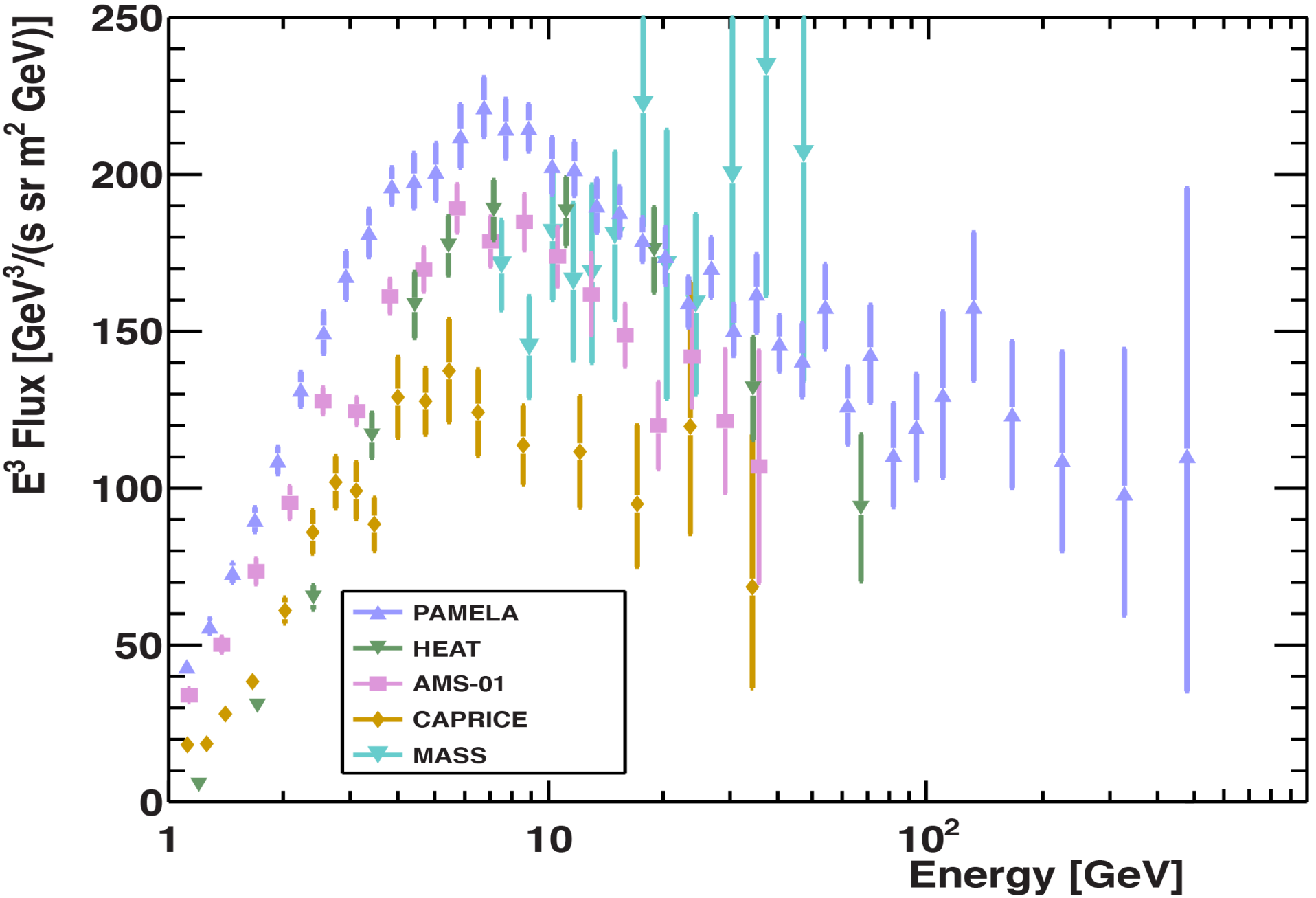
Positron Flux Scaled by E^3 AMS 2014



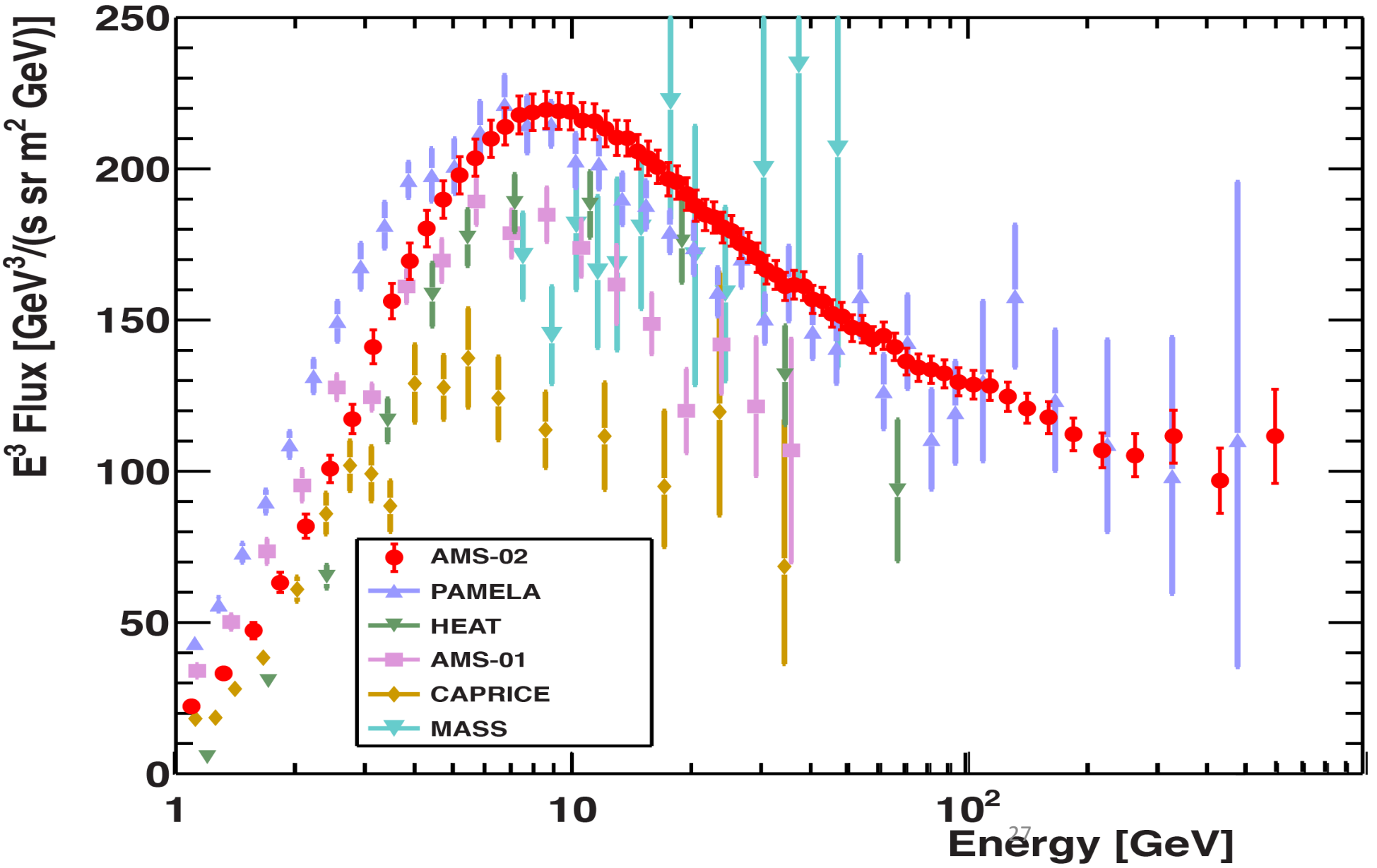
Positron Flux Scaled by E^3 AMS 2014



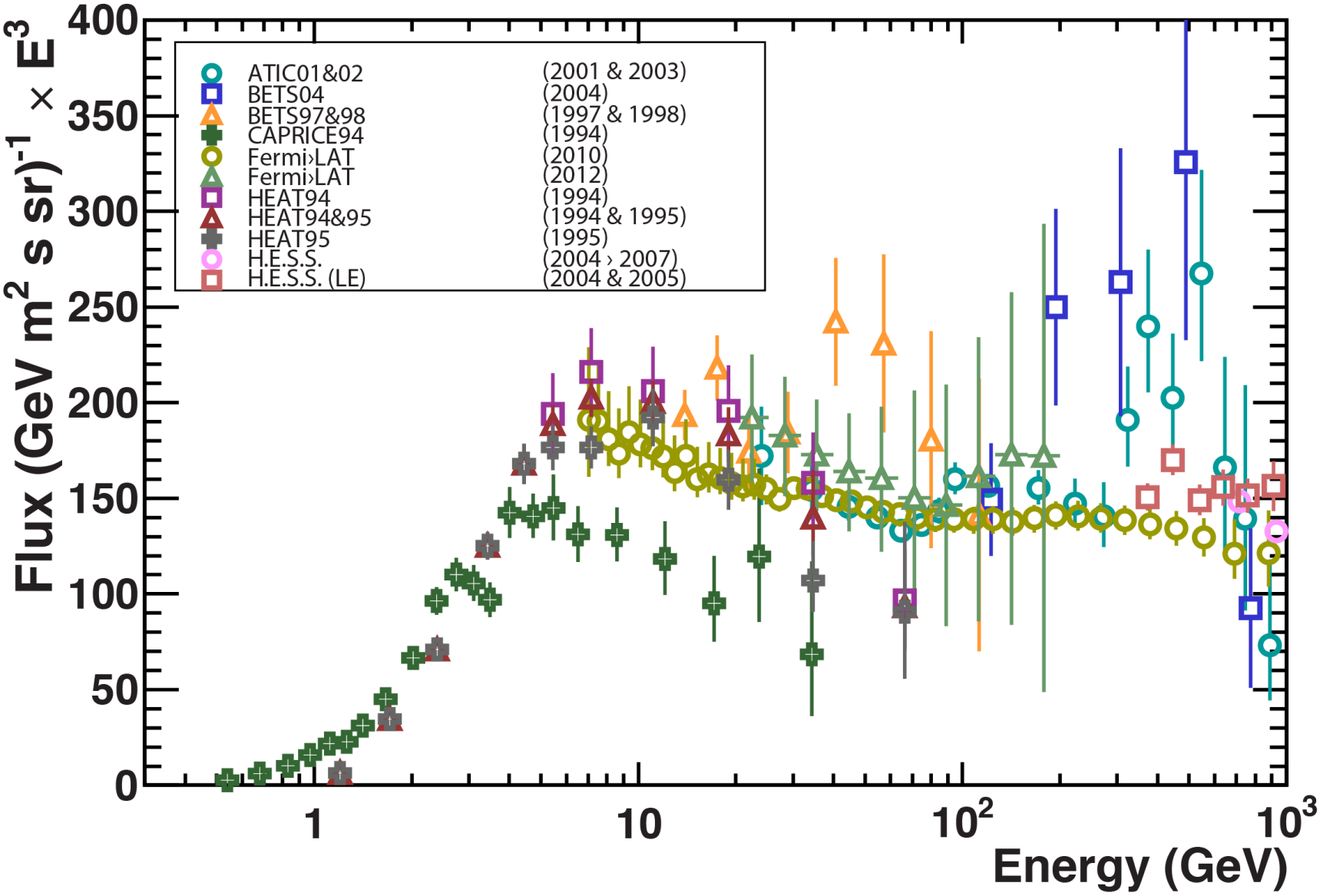
Electron Flux Scaled by E^3 Prior to AMS



Electron Flux Scaled by E^3 AMS 2014



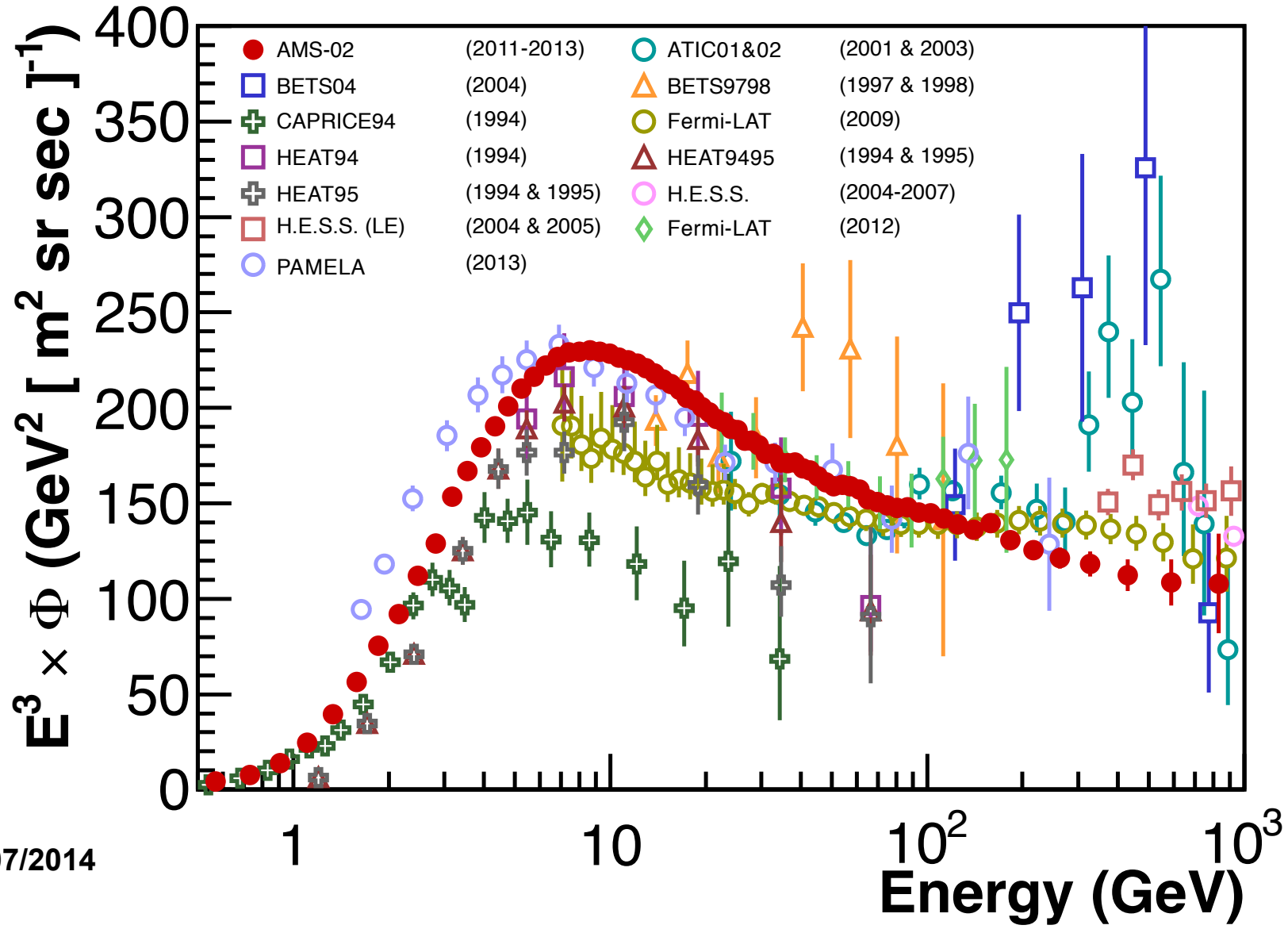
Electron+Positron Flux Scaled by E^3 Prior to AMS



Electron+Positron Flux Scaled by E^3 AMS 2014

Event Sample: ~ 10.5 million $e^{\pm}$ events

Energy Range: 0.5 GeV to 1 TeV

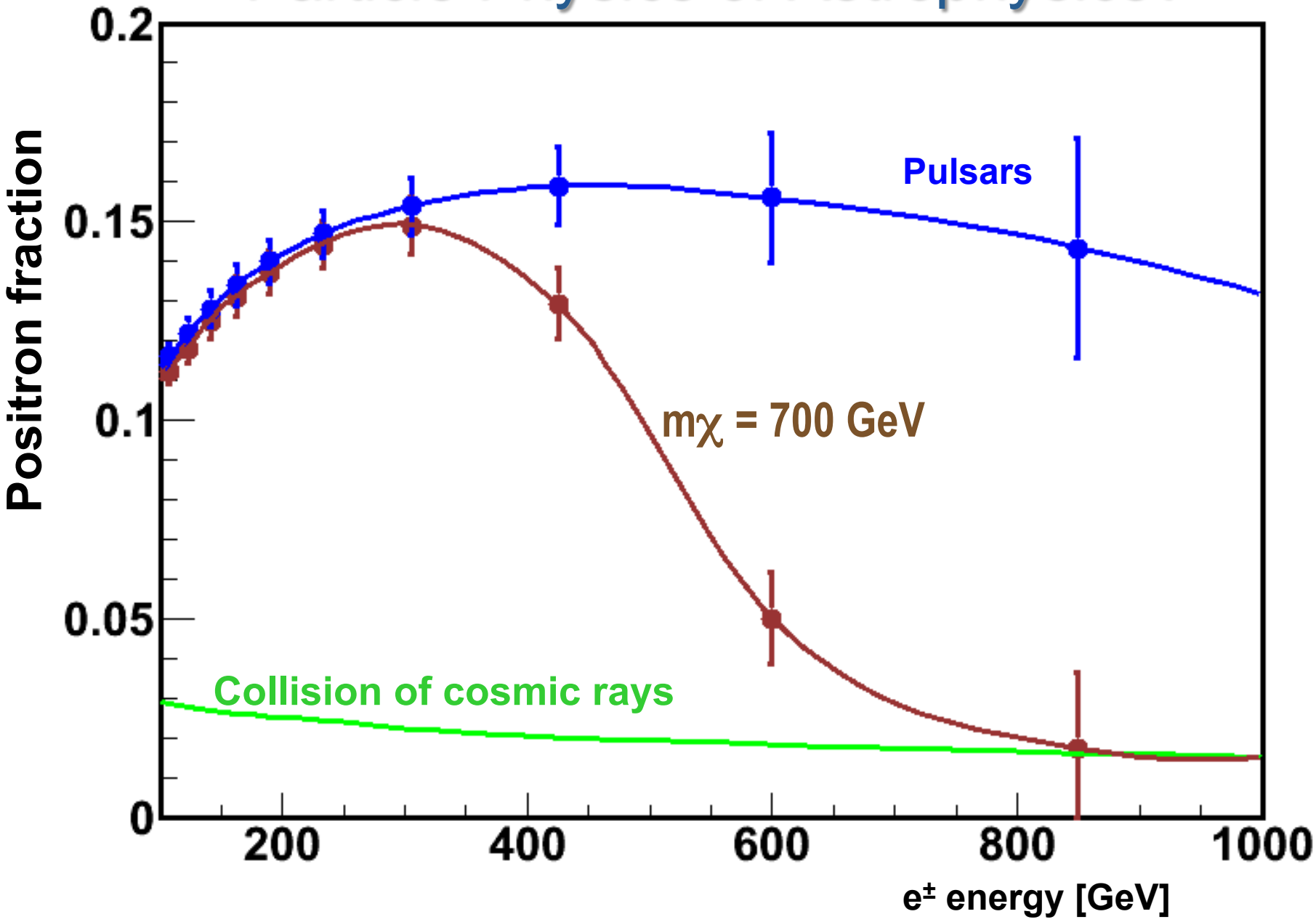


08/07/2014

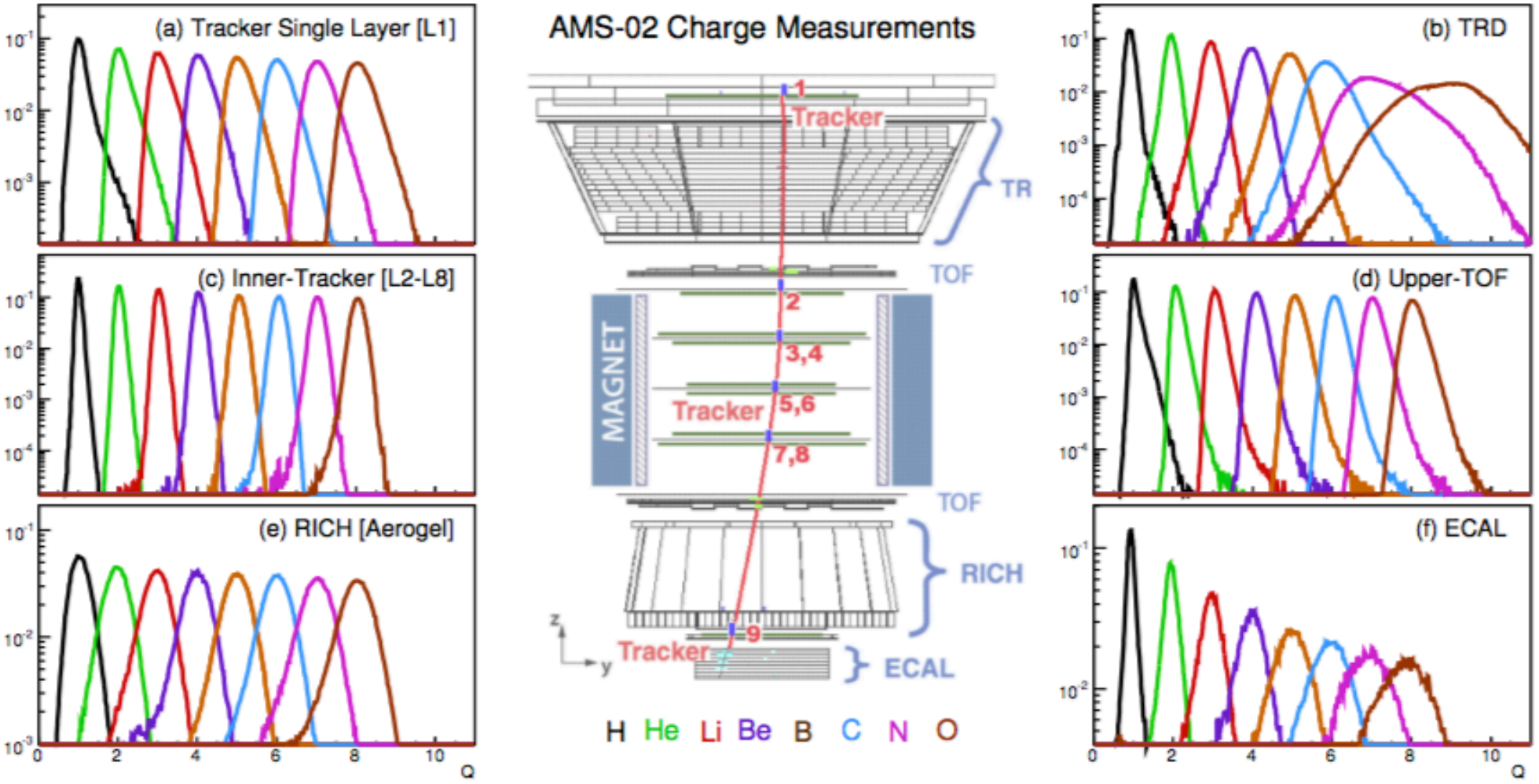
During lifetime of ISS, AMS expects to collect 300 billion Cosmic Rays

Examples of Future Plans

Origin of Positron Fraction: Particle Physics or Astrophysics?

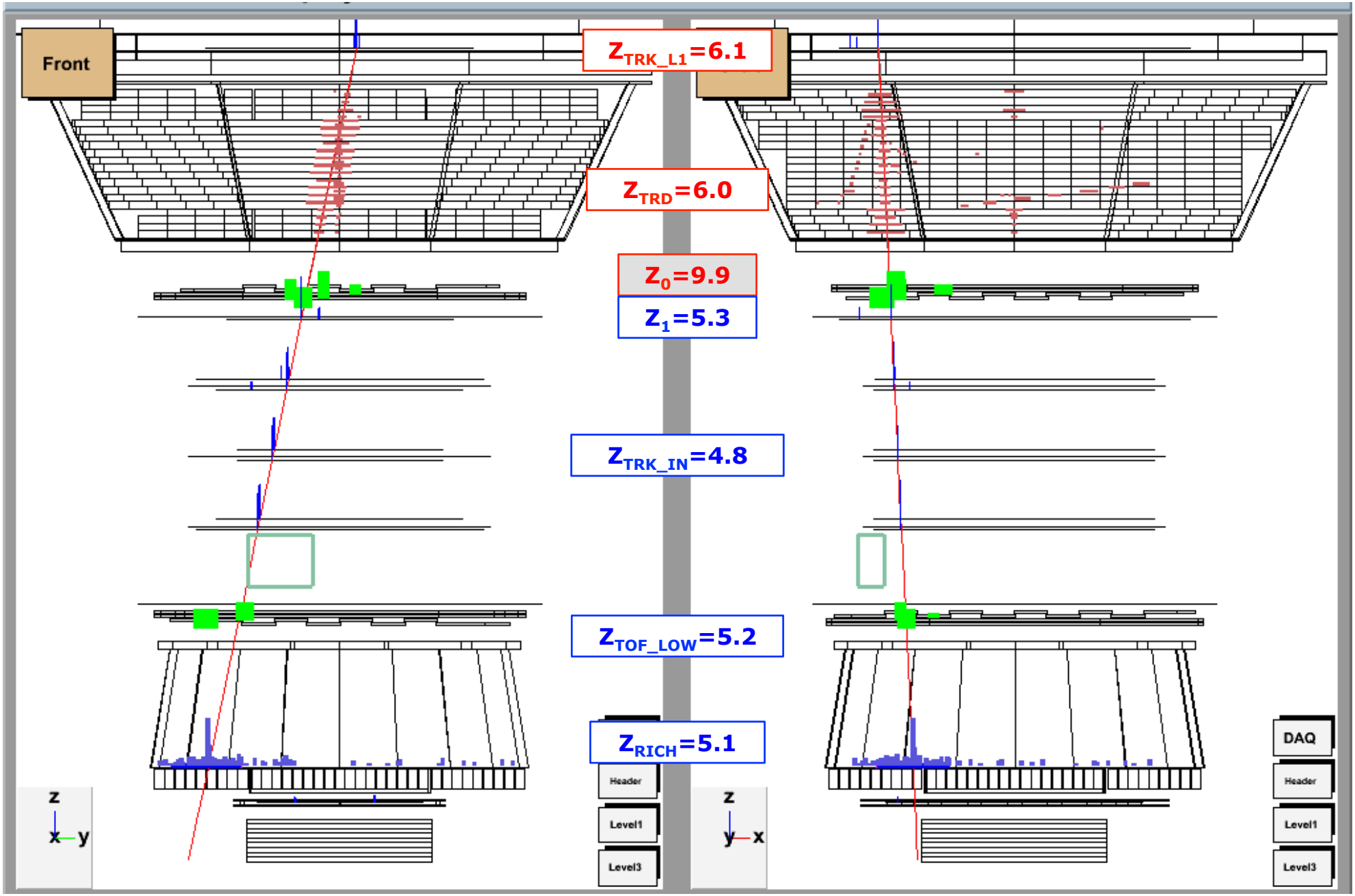


Flux of Nuclei: Redundant Charge Measurements



Low systematics, control of nuclear fragmentation

Flux of Nuclei: Control of Nuclear Fragmentation



Latest AMS Results and Future Plans:

Cosmic rays

Proton spectrum

Helium spectrum

Electron Spectrum

Boron Spectrum

Carbon Spectrum

Boron/Carbon ratio

Oxygen

Dark Matter

Positron Fraction

Anisotropy

Positron Spectrum

Antiproton Ratio

Future Plans

Positron Fraction

Anisotropy

Antiproton Ratio

Photons

Antimatter Search

Strangelet Search