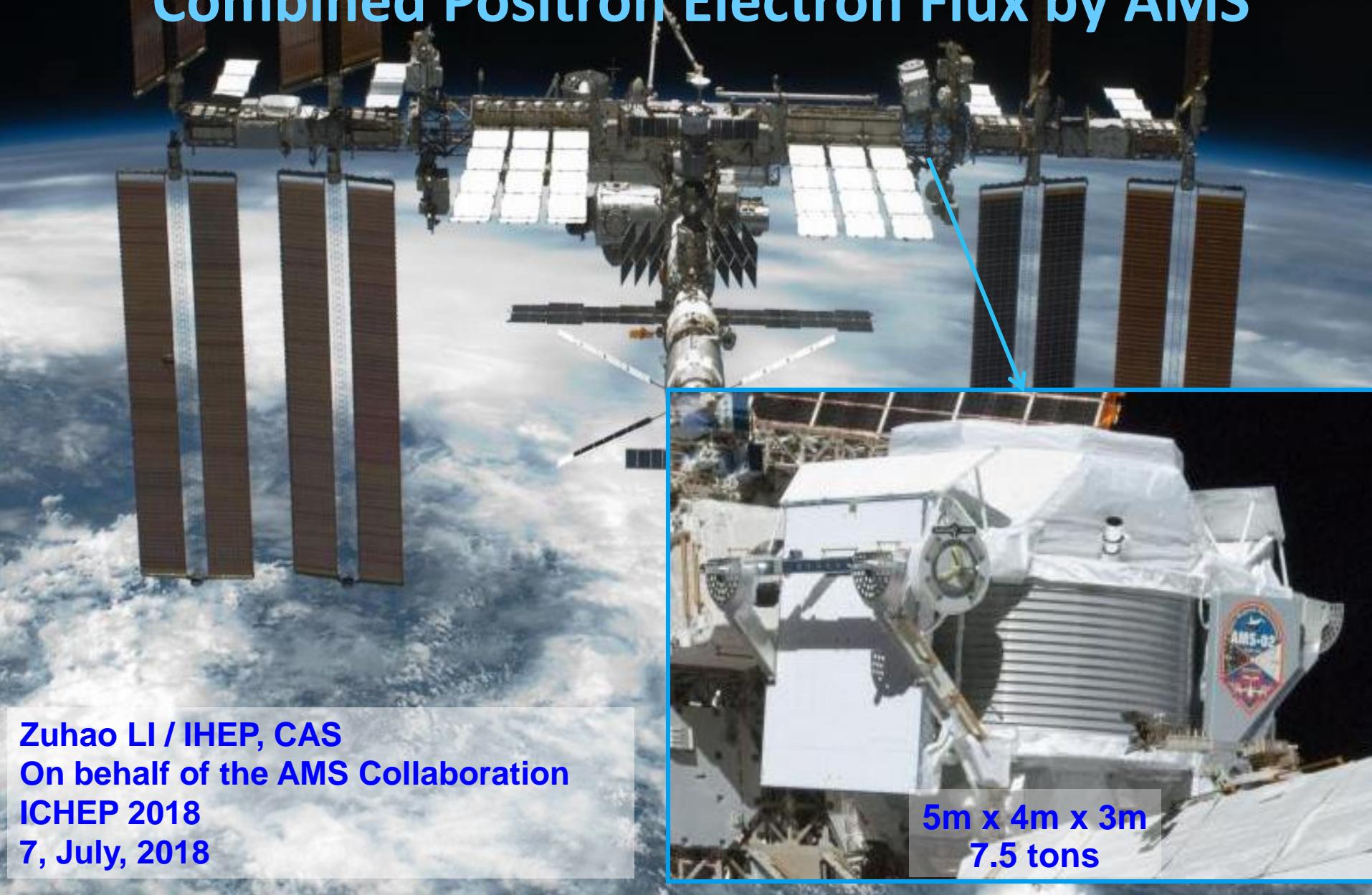
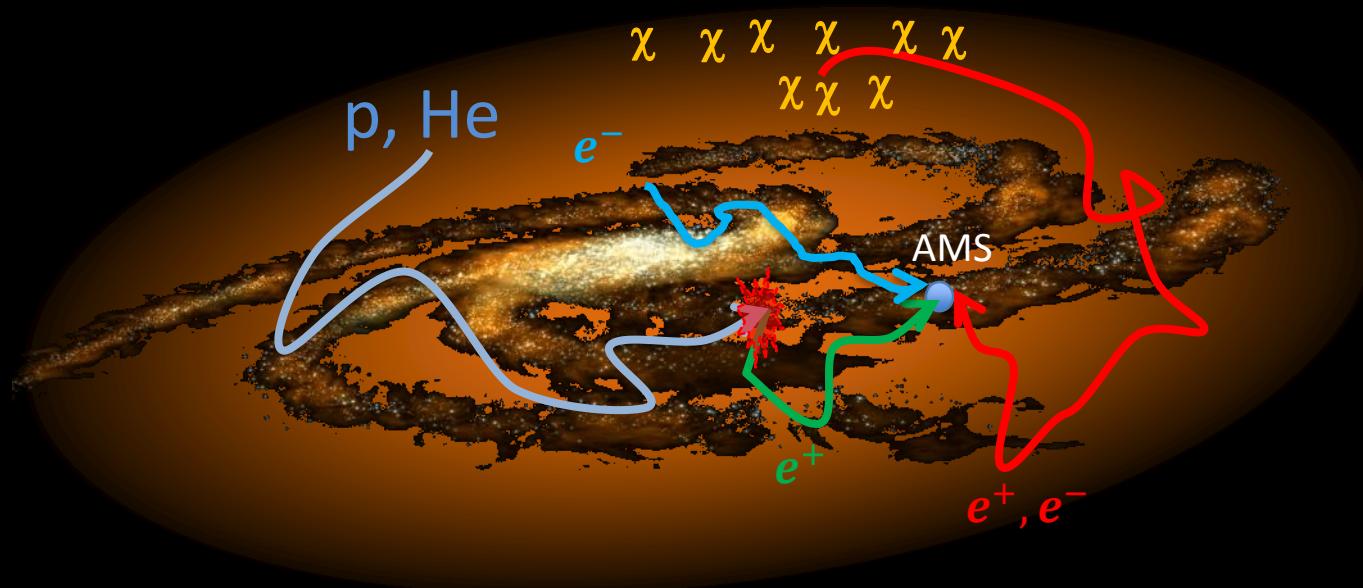


Precision Measurement of Positron Fraction and Combined Positron Electron Flux by AMS



Dark Matter search in space

- There are particles (protons, electrons) and antiparticles (positrons, antiprotons, anti-deuterons) in the cosmos.
- Particles are produced in many astrophysical sources.
- Antiparticles are much less abundant from astrophysical processes.
- Both particles and antiparticles can be produced by new physics sources, like **Dark Matter**.



Measuring antiparticles are more sensitive to Dark Matter, because the astrophysical background is much smaller.

AMS: A unique TeV precision, multipurpose, magnetic spectrometer

Transition Radiation Detector (TRD)

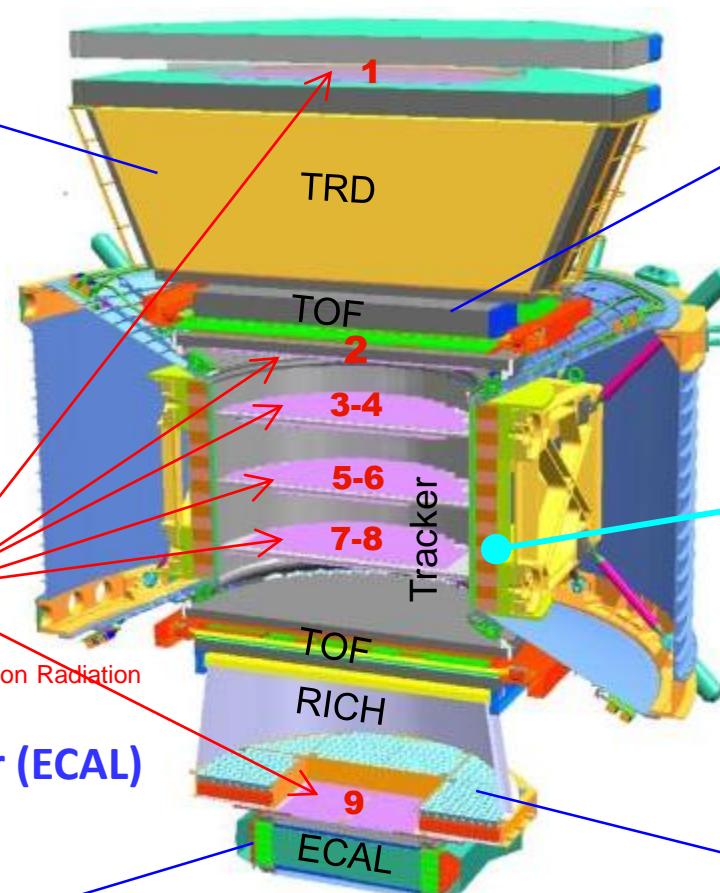
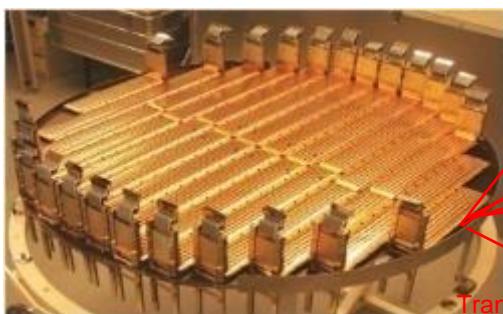
Identify e^+ , e^-



Time of Flight (TOF)
 Z, E



Silicon Tracker
 Z, P or $R=P/Z$



Magnet
 $\pm Z$



Ring Imaging Cherenkov (RICH)
 Z, E



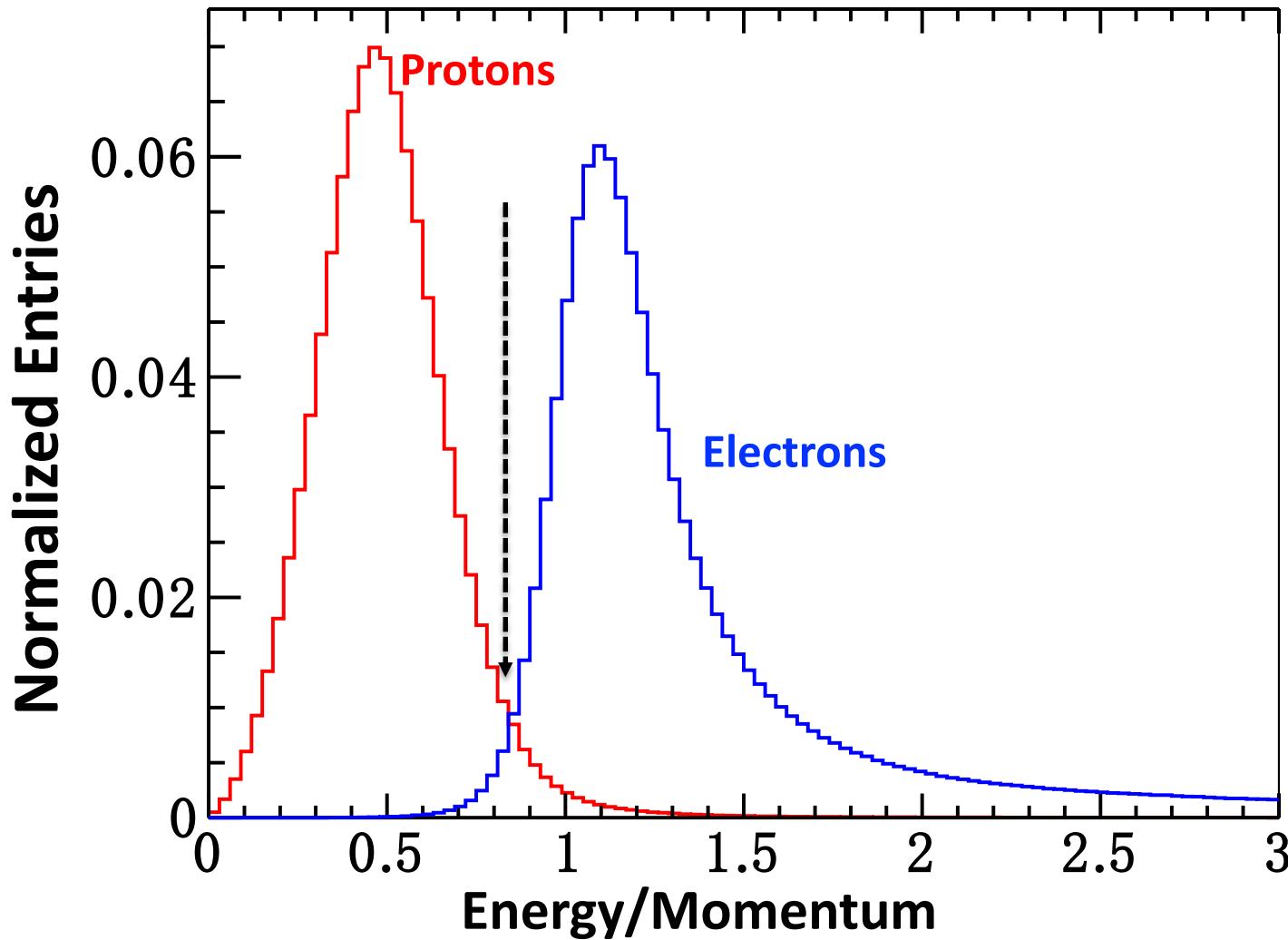
Electromagnetic Calorimeter (ECAL)
 E of e^+, e^-



Z and P, E or R are
measured independently by Tracker,
ECAL, TOF and RICH

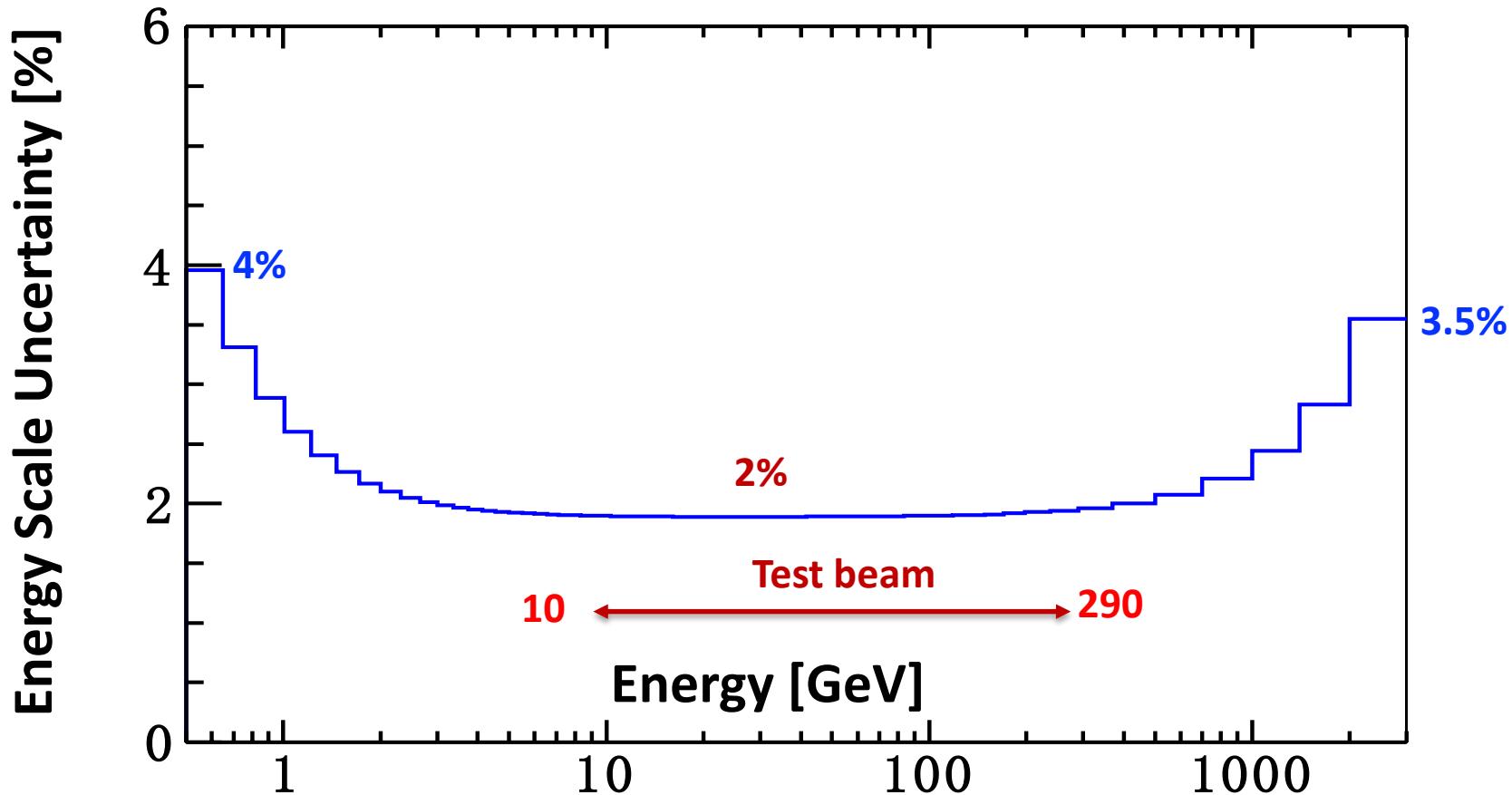
Unique feature of AMS

- The synergy of the Energy from ECAL and the Momentum from tracker can be used for proton separation .
- The protons deposit less energy in the calorimeter



Unique feature of AMS

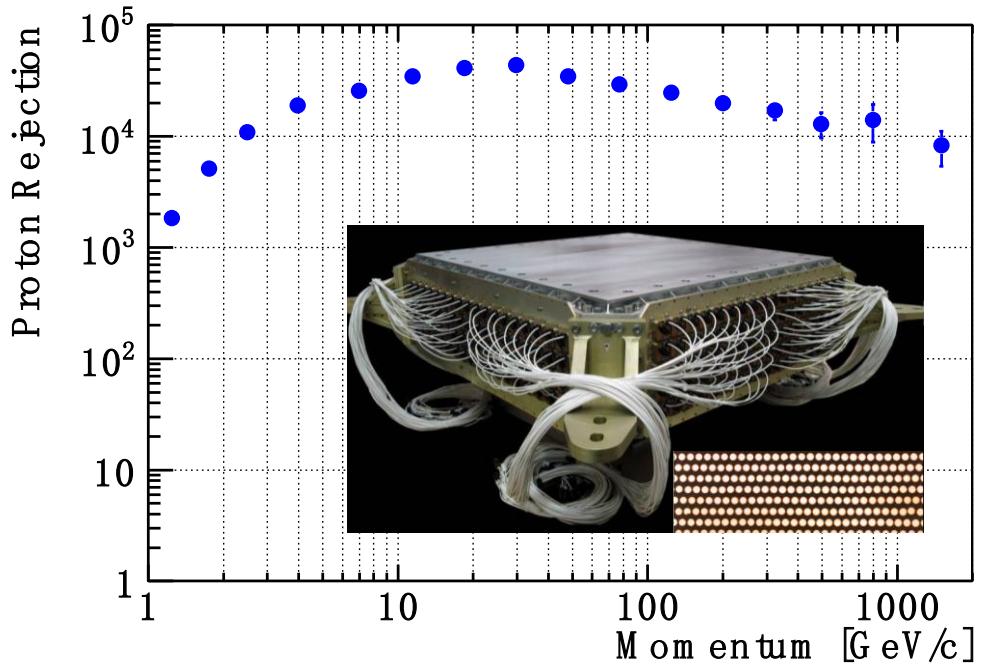
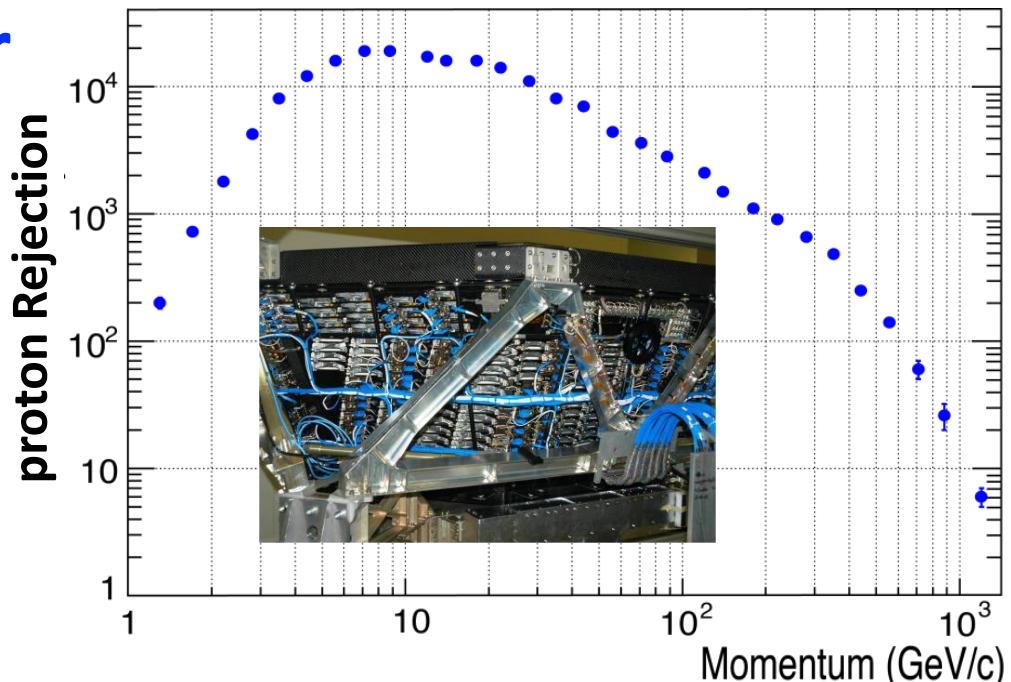
- The energy scale is the most important source of systematic errors for non-magnetic cosmic ray experiments.
- AMS determines the energy scale by using the tracker and magnet



By comparing the ISS data with beam data and MC simulation, the energy scale uncertainty is estimated to be 2% from 10-290GeV, 3% at 2 TeV

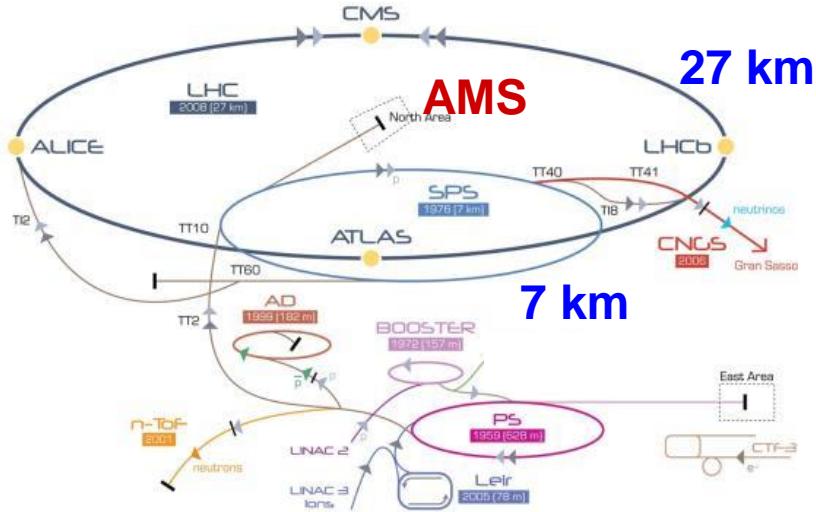
Proton rejection power

- Proton rejection 10^3 to 10^4 with TRD
- Proton rejection is above 10^4 with ECAL and tracker
- TRD and ECAL is separated by the magnet, and have independent proton rejection power.
- The proton rejection power is better than 10^6



Calibration of the AMS Detector

Test beam at CERN SPS:
 p, e^\pm, π^\pm , 10–400 GeV



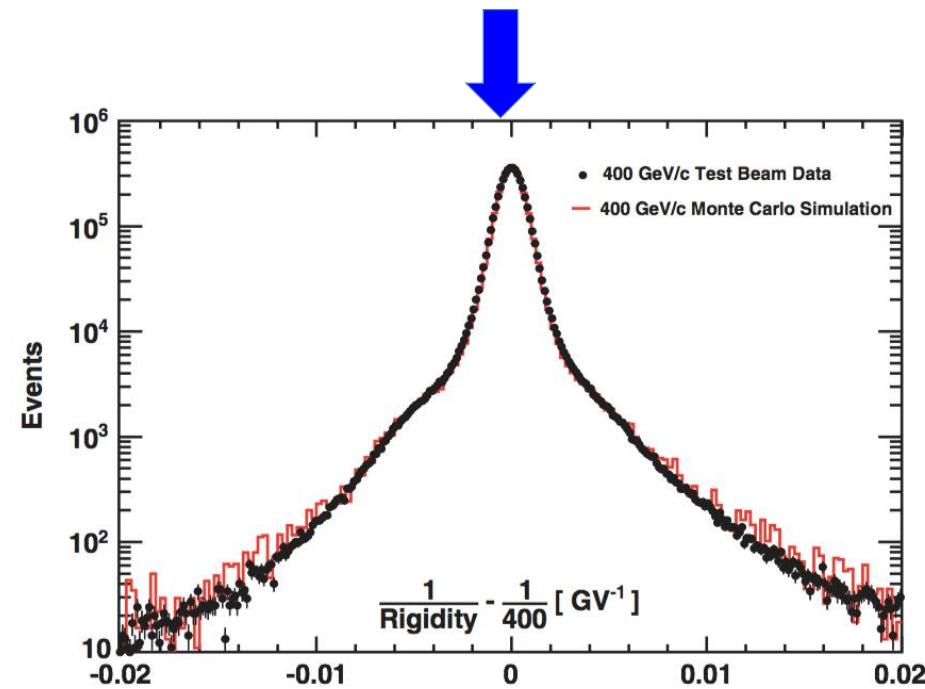
2000 positions



12,000 CPU cores at CERN



Computer simulation:
Interactions, Materials, Electronics



In 7 years on ISS,
AMS has collected over 120 billion cosmic rays.

Search for Dark Matter is one of the main physics topic of AMS .



The measurement of electrons and positrons in AMS

Primary cosmic ray particle:

- $E > 1.2 \cdot \text{max cutoff}$

TOF:

- Down-going particle $\beta > 0.8$
- Charge $|Z| = 1$ particle

TRD:

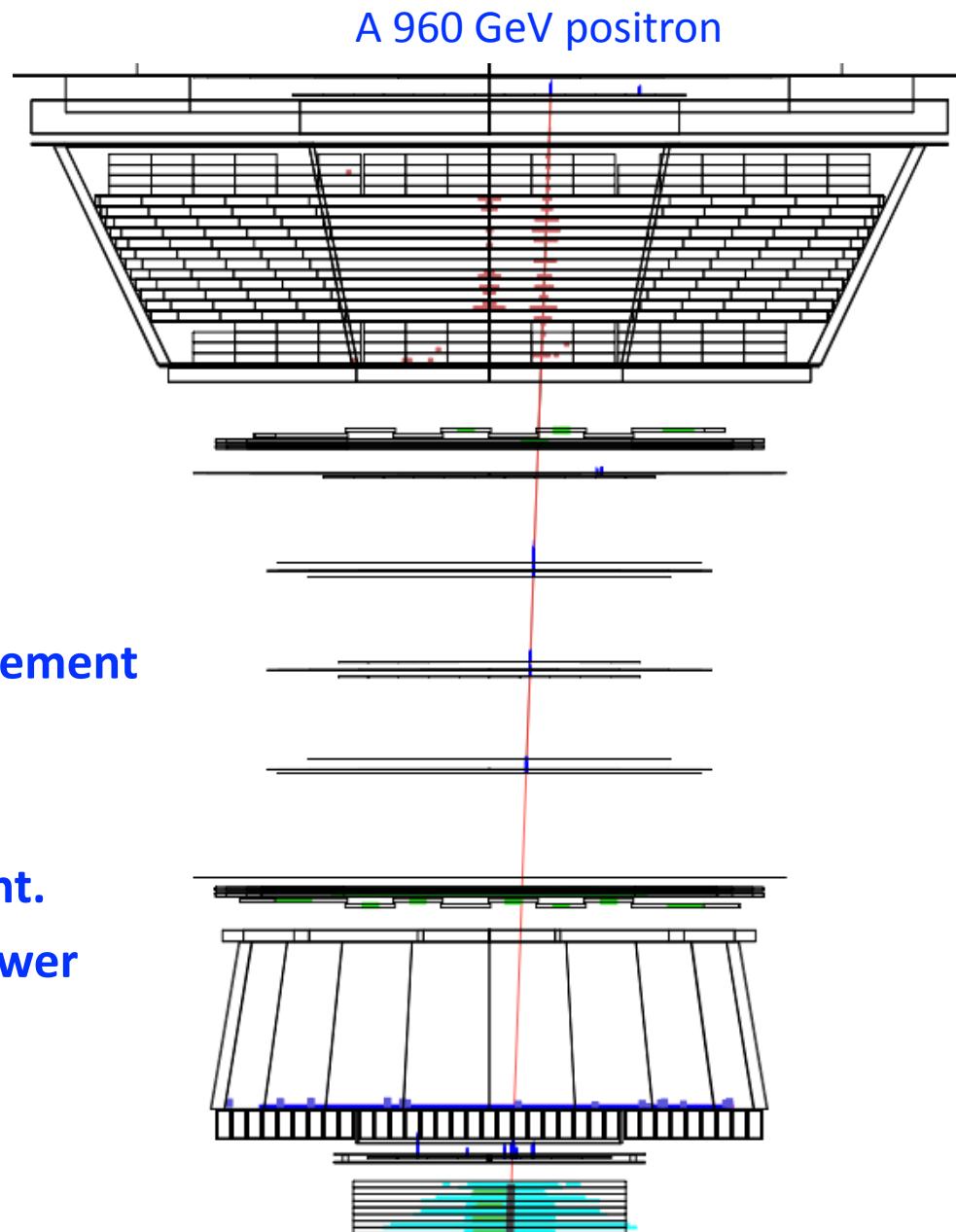
- Provide proton rejection

tracker and magnet:

- Provide accurate momentum measurement
- Charge $|Z| = 1$ particle

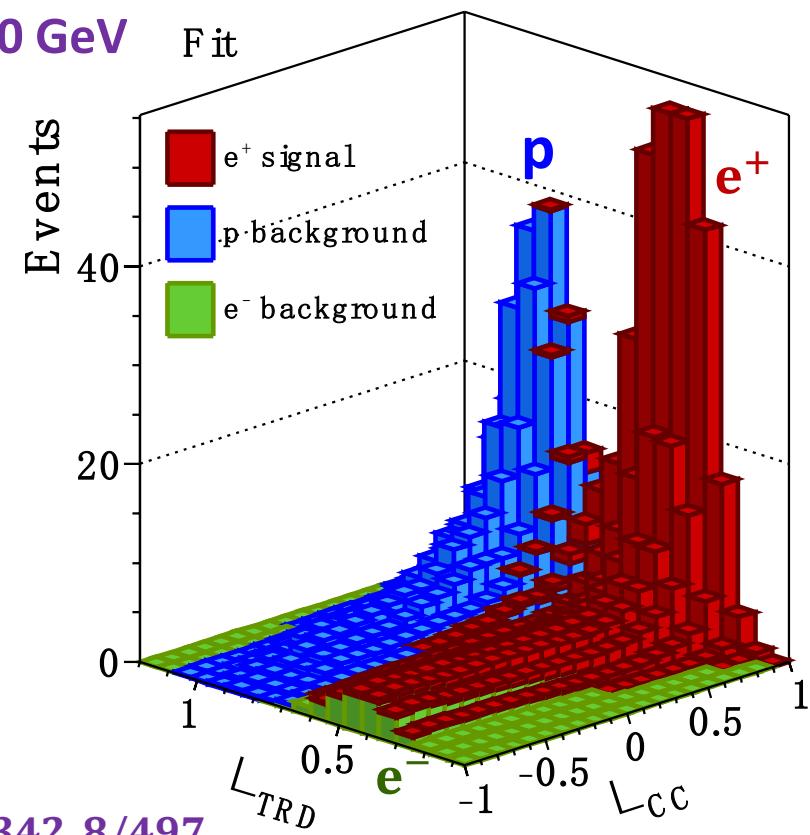
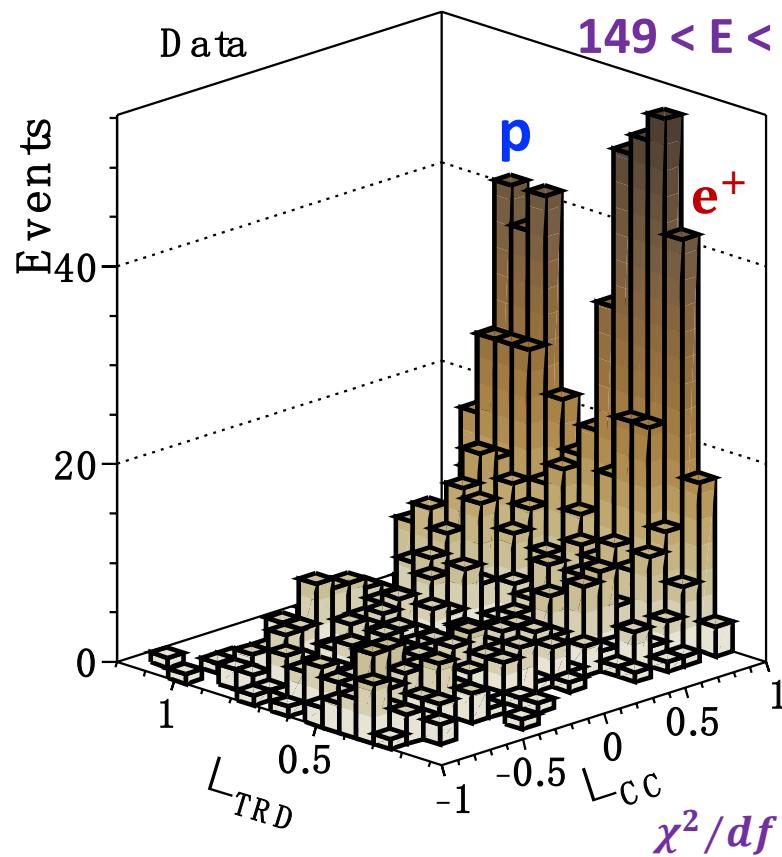
ECAL:

- Provide accurate energy measurement.
- Provide proton rejection with 3D shower shape



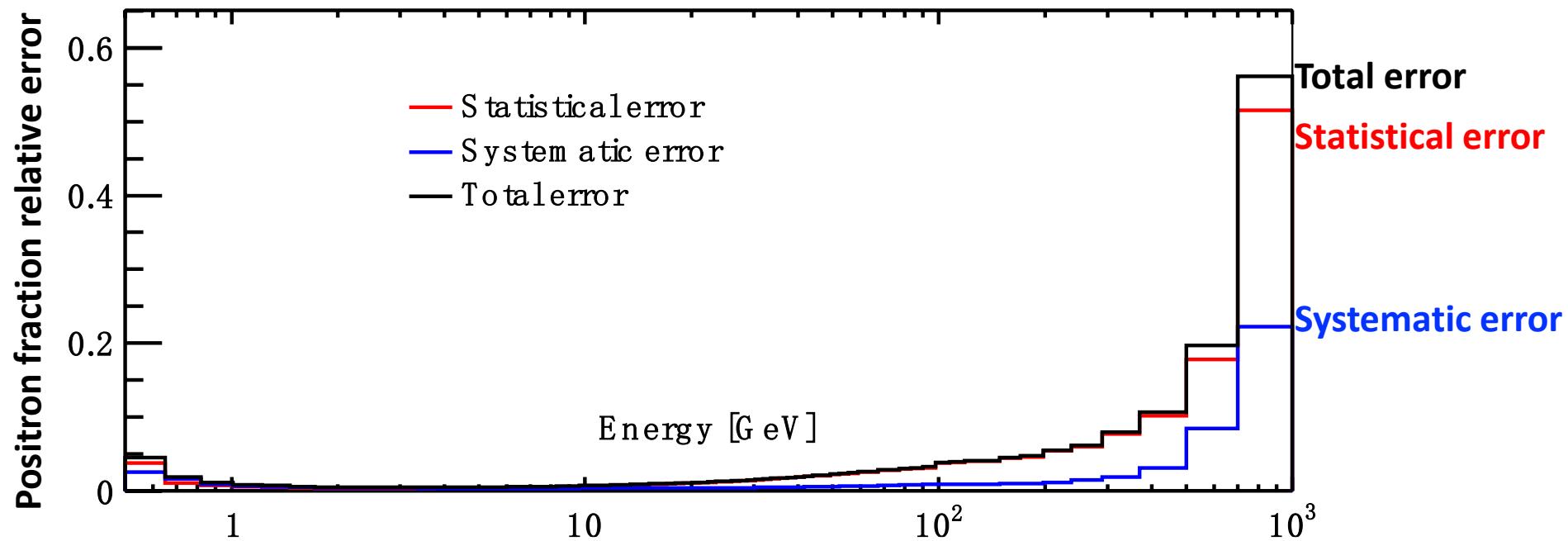
Analysis method to determine the number of e^+

- ECAL selection to remove bulk of the proton background.
- For each bin, fit templates to positive data sample in $(\Lambda_{TRD} - \Lambda_{CC})$ plane
- Positron signal template from data using electrons
- Proton background template from proton data
- Charge confusion electron template from electron MC



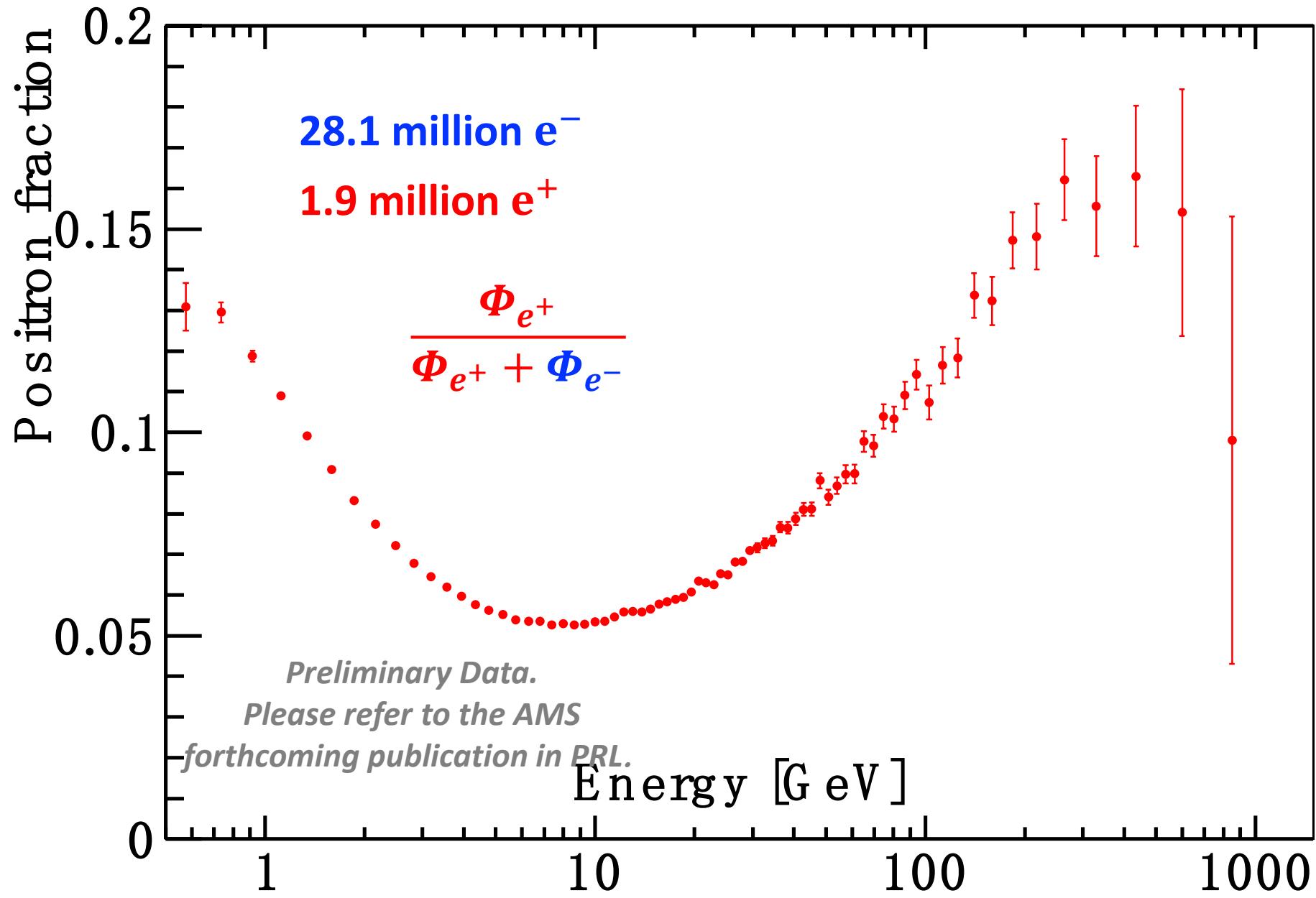
With 28.1 million electrons and 1.9 million positrons,
the study of systematic errors is crucial

1. Charge confusion
2. Template selection
3. Template statistical fluctuation

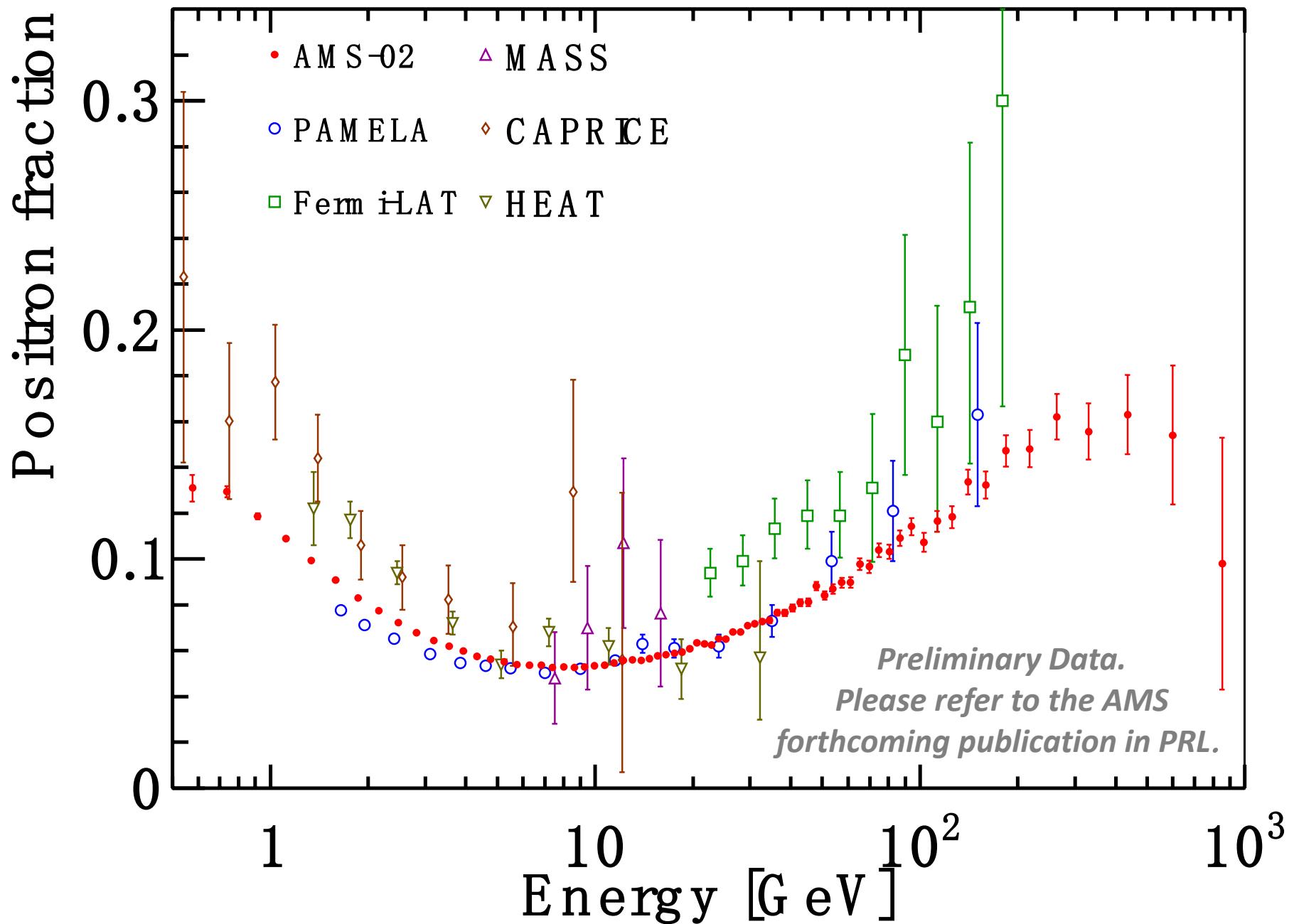


Statistical errors dominates above 30 GeV for positron flux

AMS Positron fraction



AMS Positron fraction together with earlier experiments



A sample of papers on AMS data from more than 2300 publications

- 1) J. Kopp, Phys. Rev. D 88, 076013 (2013);
- 2) L. Feng, R.Z. Yang, H.N. He, T.K. Dong, Y.Z. Fan and J. Chang Phys.Lett. B728 (2014) 250
- 3) M. Cirelli, M. Kadastik, M. Raidal and A. Strumia ,Nucl.Phys. B873 (2013) 530
- 4) M. Ibe, S. Iwamoto, T. Moroi and N. Yokozaki, JHEP 1308 (2013) 029
- 5) Y. Kajiyama and H. Okada, Eur.Phys.J. C74 (2014) 2722
- 6) K.R. Dienes and J. Kumar, Phys.Rev. D88 (2013) 10, 103509
- 7) L. Bergstrom, T. Bringmann, I. Cholis, D. Hooper and C. Weniger, PRL 111 (2013) 171101
- 8) K. Kohri and N. Sahu, Phys.Rev. D88 (2013) 10, 103001
- 9) A. Ibarra, A.S. Lamperstorfer and J. Silk, Phys.Rev. D89 (2014) 063539
- 10) Y. Zhao and K.M. Zurek, JHEP 1407 (2014) 017
- 11) C. H. Chen, C. W. Chiang, and T. Nomura, Phys. Lett. B 747, 495 (2015)
- 12) H. B. Jin, Y. L. Wu, and Y.-F. Zhou, Phys.Rev. D92, 055027 (2015)
- 13) A. Reinert and M. W. Winkler JCAP 01 (2018) 055
and many other excellent papers ...

Dark Matter explaining
the AMS e+ data

- 1) R.Cowsik, B.Burch, and T.Madziwa-Nussinov, Ap.J. 786 (2014) 124
- 2) K. Blum, B. Katz and E. Waxman, Phys.Rev.Lett. 111 (2013) 211101
- 3) R. Kappl and M. W. Winkler, J. Cosmol. Astropart. Phys. 09 (2014) 051
- 4) G.Giesen, M.Boudaud, Y.Gènolini, V.Poulin, M.Cirelli, P.Salati and P.D.Serpico, JCAP09 (2015) 023;
- 5) C.Evoli, D.Gaggero and D.Grasso, JCAP 12 (2015) 039.
- 6) R.Kappl, A.Reinert, and M.W.Winkler, arXiv:1506.04145 (2015)
and many other excellent papers ...

New Propagation Models
explaining the AMS e+ data

- 1) T. Linden and S. Profumo, Astrophys.J. 772 (2013) 18
- 2) P. Mertsch and S. Sarkar, Phys.Rev. D 90 (2014) 061301
- 3) I. Cholis and D. Hooper, Phys.Rev. D88 (2013) 023013
- 4) A. Erlykin and A.W. Wolfendale, Astropart.Phys. 49 (2013) 23
- 5) P.F. Yin, Z.H. Yu, Q. Yuan and X.J. Bi, Phys.Rev. D88 (2013) 2, 023001
- 6) A.D. Erlykin and A.W. Wolfendale, Astropart.Phys. 50-52 (2013) 47
- 7) E. Amato, Int.J.Mod.Phys.Conf.Ser. 28 (2014) 1460160
- 8) P. Blasi, Braz.J.Phys. 44 (2014) 426
- 9) D. Gaggero, D. Grasso, L. Maccione, G. DiBernardo and C Evoli, Phys.Rev. D89 (2014) 083007
- 10) M. DiMauro, F. Donato, N. Fornengo, R. Lineros and A. Vittino, JCAP 1404 (2014) 006
- 11) K. Kohri, K. Ioka, Y. Fujita, and R. Yamazaki, Prog. Theor. Exp. Phys. 2016, 021E01 (2016)
and many other excellent papers ...

New Astrophysical Sources
explaining the AMS e+ data

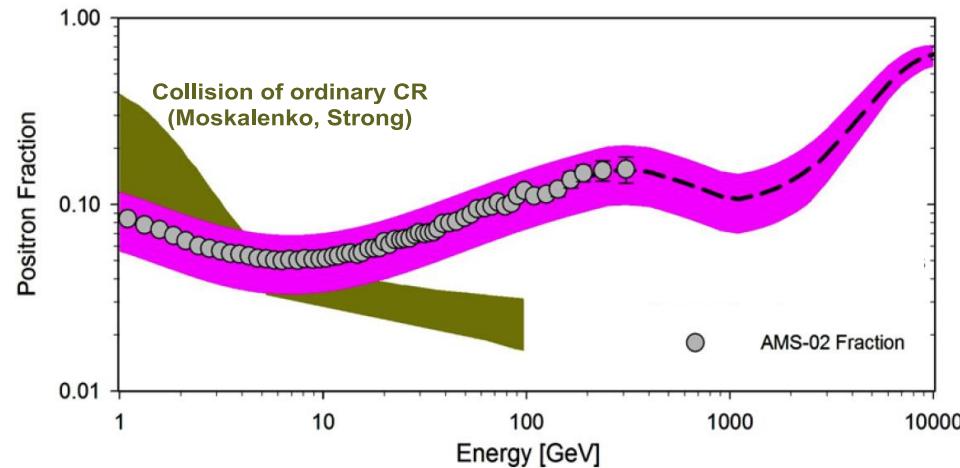
Models to explain the AMS Positron Fraction Measurements

Some models are constrained by other measurements by AMS.

Examples 1: Modified propagation of cosmic rays

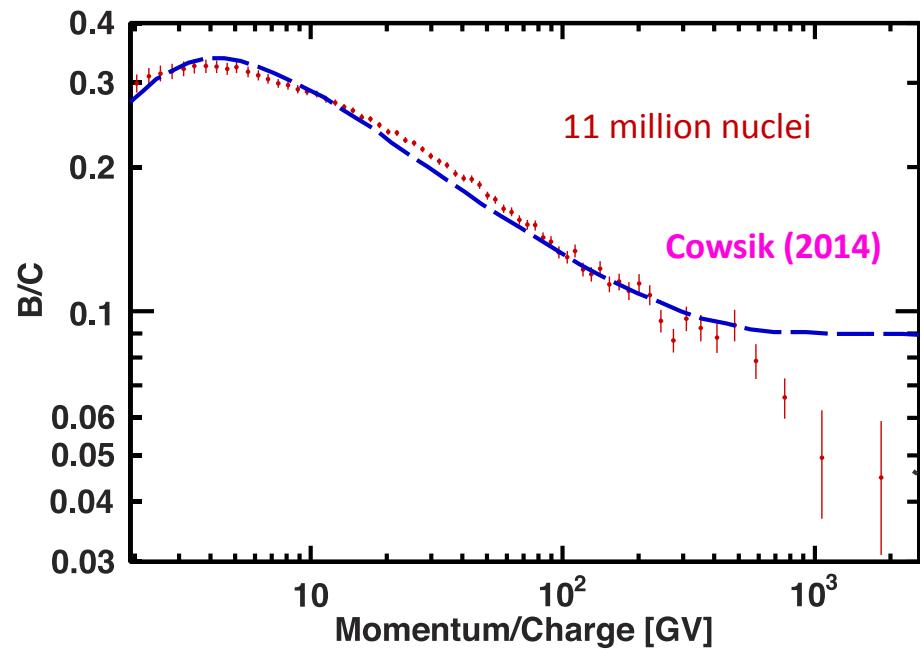
R. Cowsik *et al.*, Ap. J. 786 (2014) 124,
(pink band) explaining that the AMS
positron fraction (gray circles) above 10 GV
is due to propagation effects.

However, this requires a specific energy
dependence of the B/C ratio



The AMS Boron-to-Carbon (B/C) flux ratio

PRL 117, 231102 (2016)



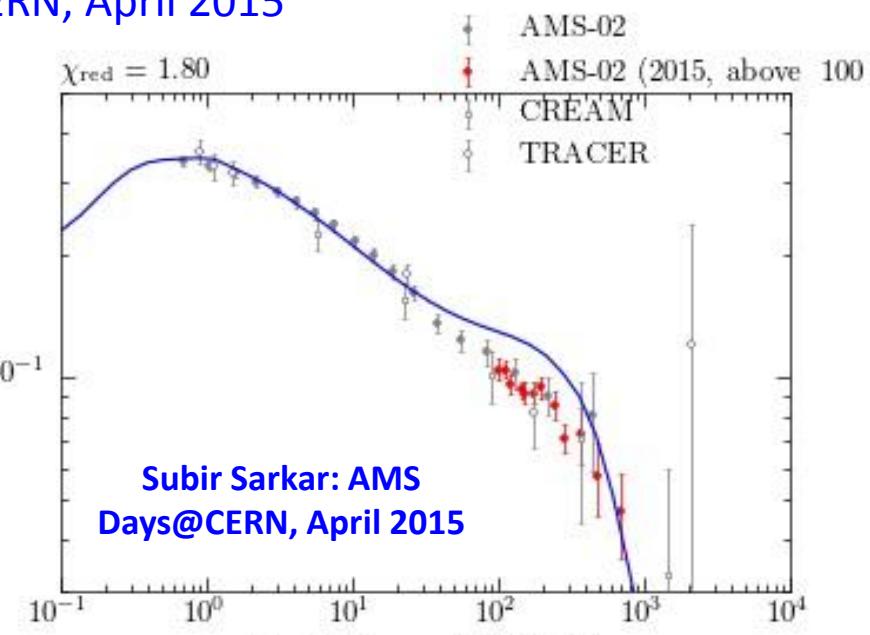
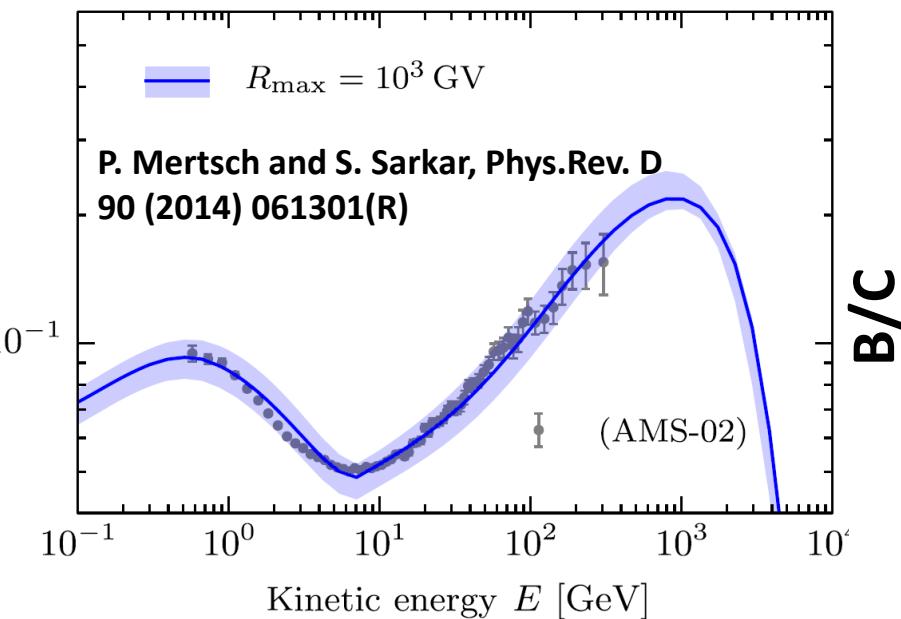
Models explain the AMS Positron Fraction Measurements

Some models are constrained by other measurements by AMS.

Examples 2: Supernova Remnants

Subir Sarkar: AMS days@CERN, April 2015

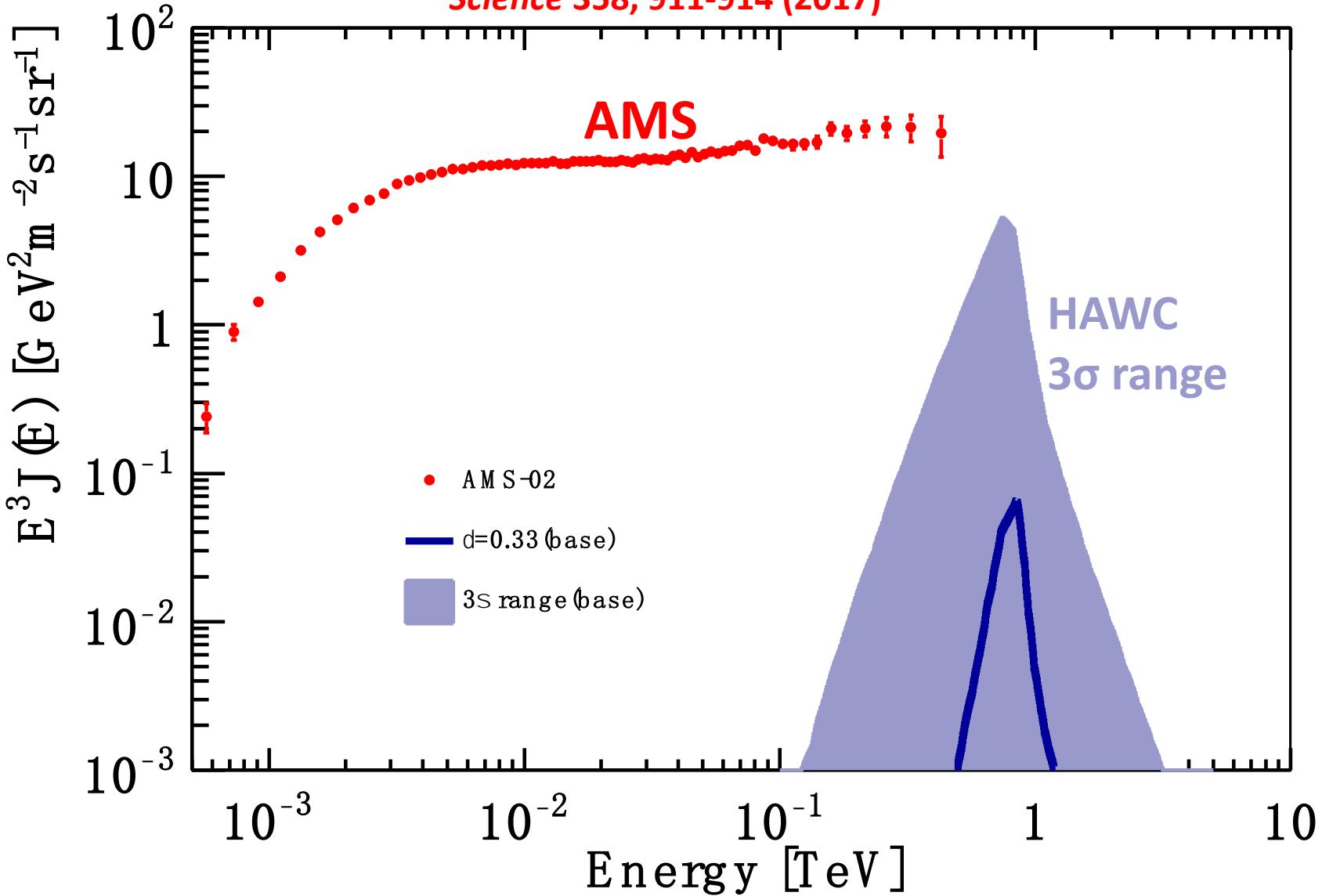
positron fraction



Not able to fit simultaneously the positron and B/C.

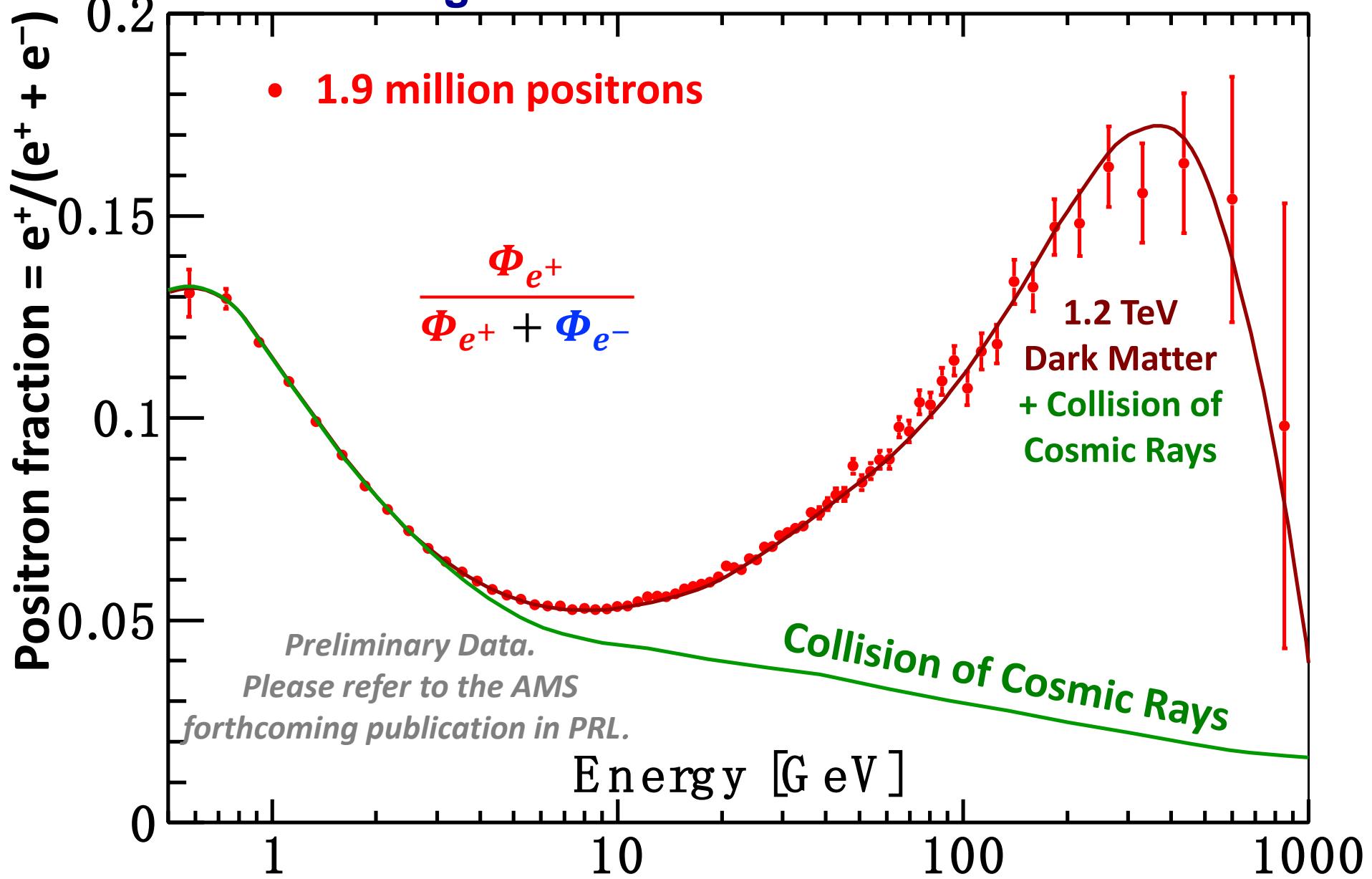
HAWC rules out that the positron excess is from nearby pulsars

Science 358, 911-914 (2017)

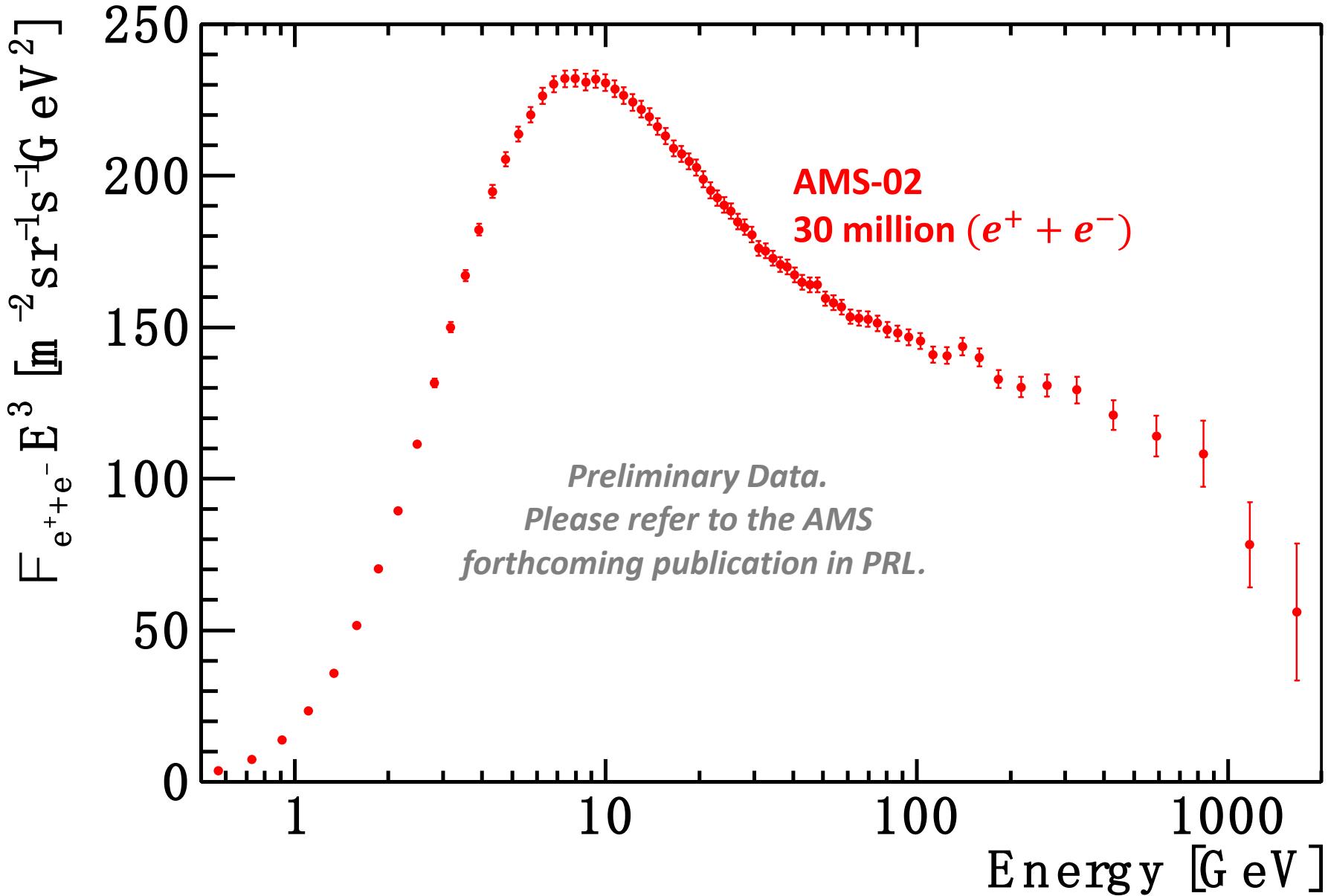


AMS measurement of positron anisotropy (presentation by Jorge Casaus)
constrains the pulsar origin of positrons

Latest AMS Positron fraction results appears to be in excellent agreement with Dark Matter model

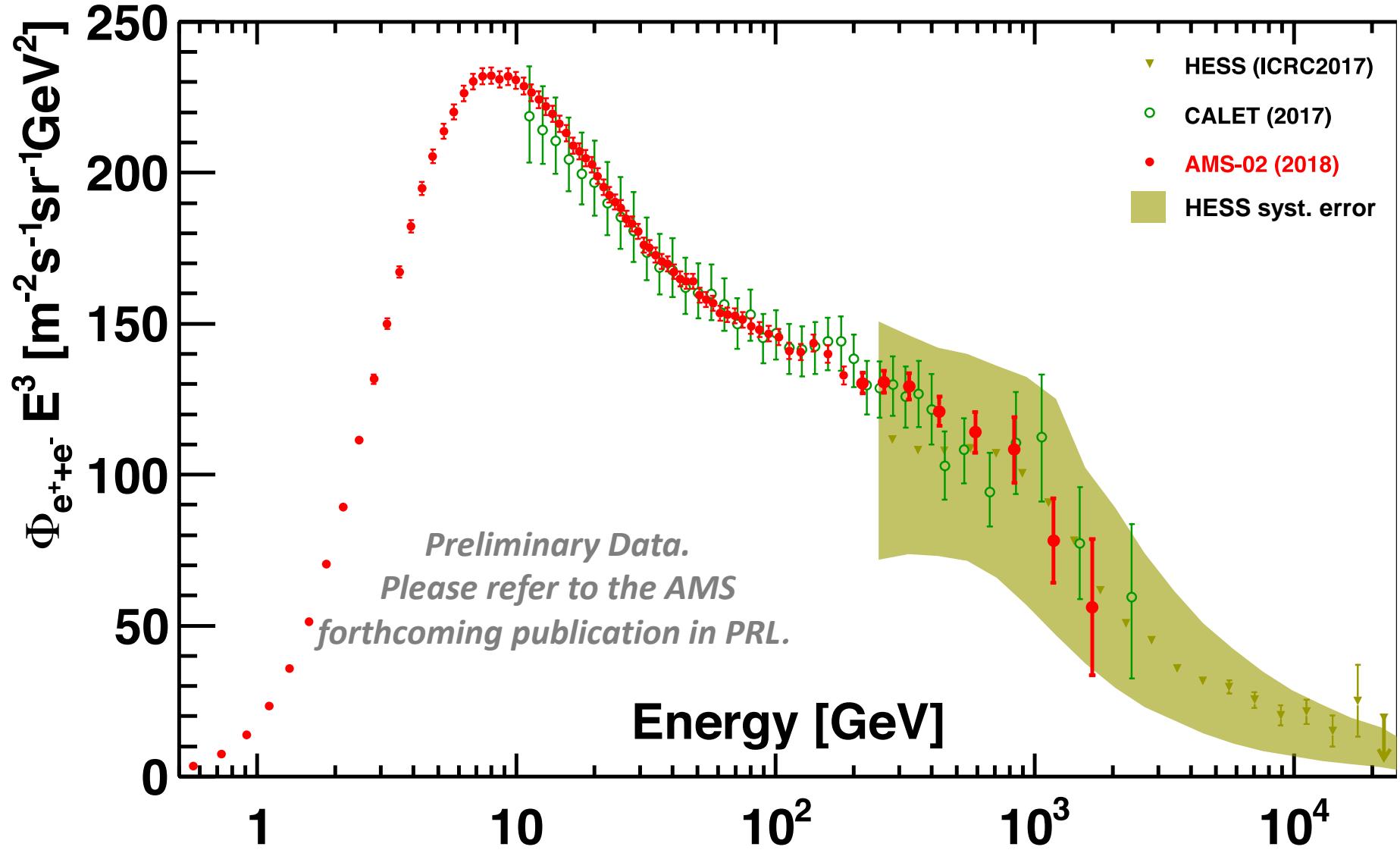


The combined ($e^+ + e^-$) flux

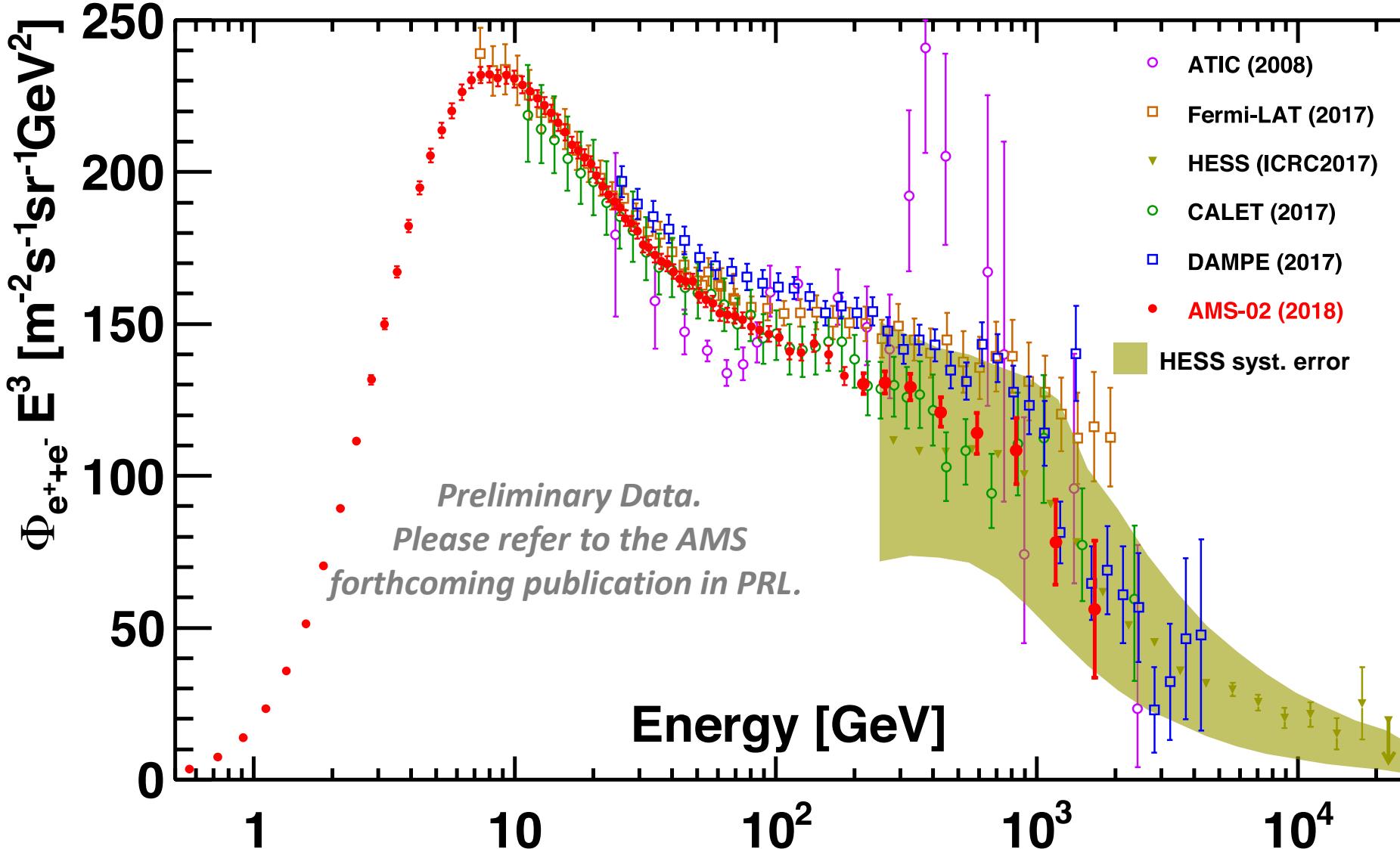


The spectrum is smooth, no sharp structure is observed

AMS ($e^+ + e^-$) data with a few non-magnetic detectors



$(e^+ + e^-)$ data with AMS and with non-magnetic detectors



HESS, DAMPE and AMS all observed a spectral break at ~ 1 TeV

Measuring e^+ is the most sensitive way to identify χ via $\chi + \chi \rightarrow e^+, e^-$, ...

Measuring $(e^+ + e^-)$ is much less sensitive to χ due to the large e^- background

**With 1.9 million positrons and 28.1 million electrons,
AMS extends the positron fraction measurement to 1 TeV,
and the combined (positron + electron) flux to 2 TeV.**

**AMS positron fraction by far exceeds the prediction from
collisions of cosmic rays and appears to be in excellent
agreement with a Dark Matter model.**

**By 2024 AMS will collect 4 million positrons, and will be able to
determine the origin of the positron excess.**