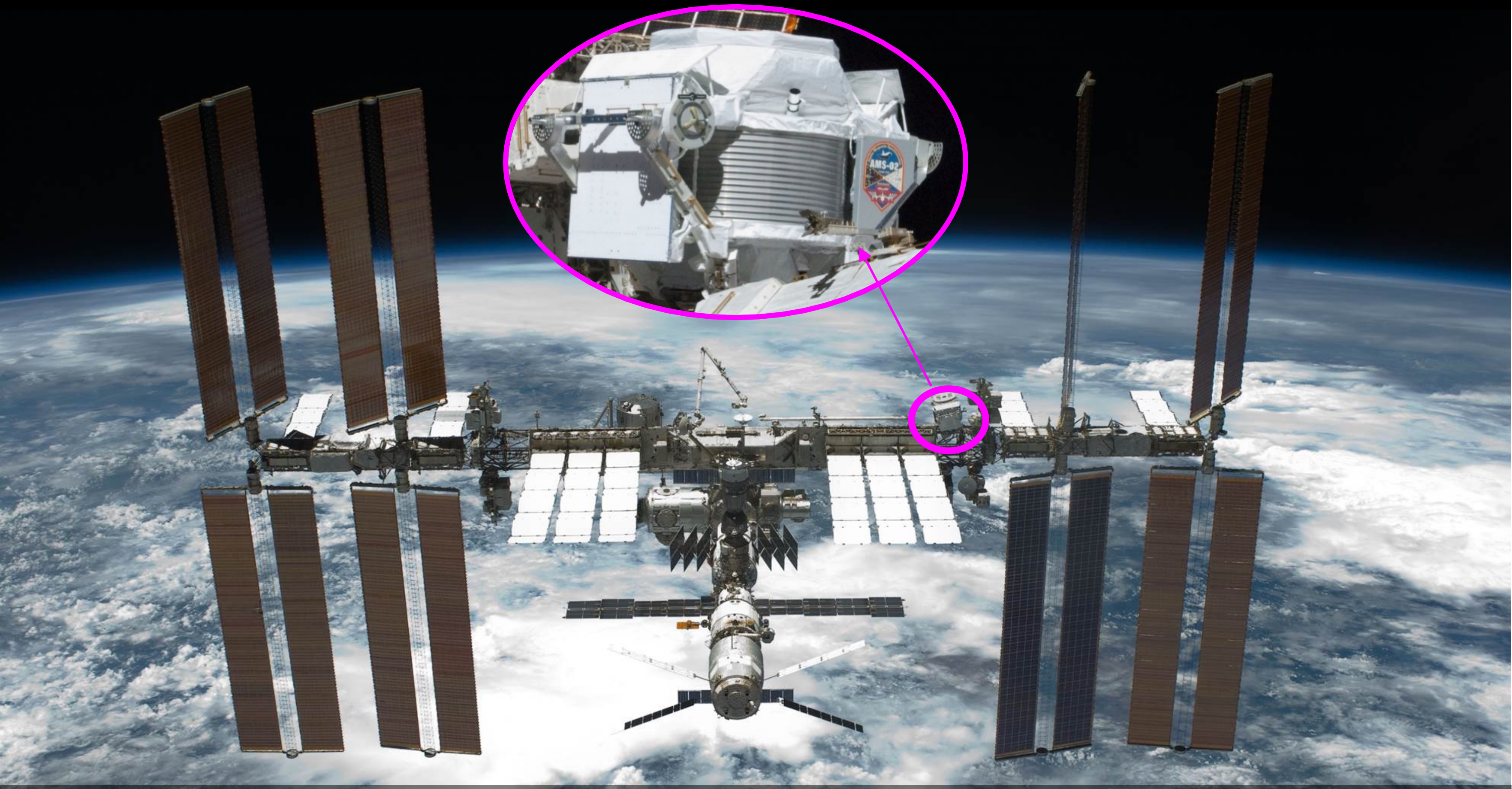
Antiproton Flux and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS



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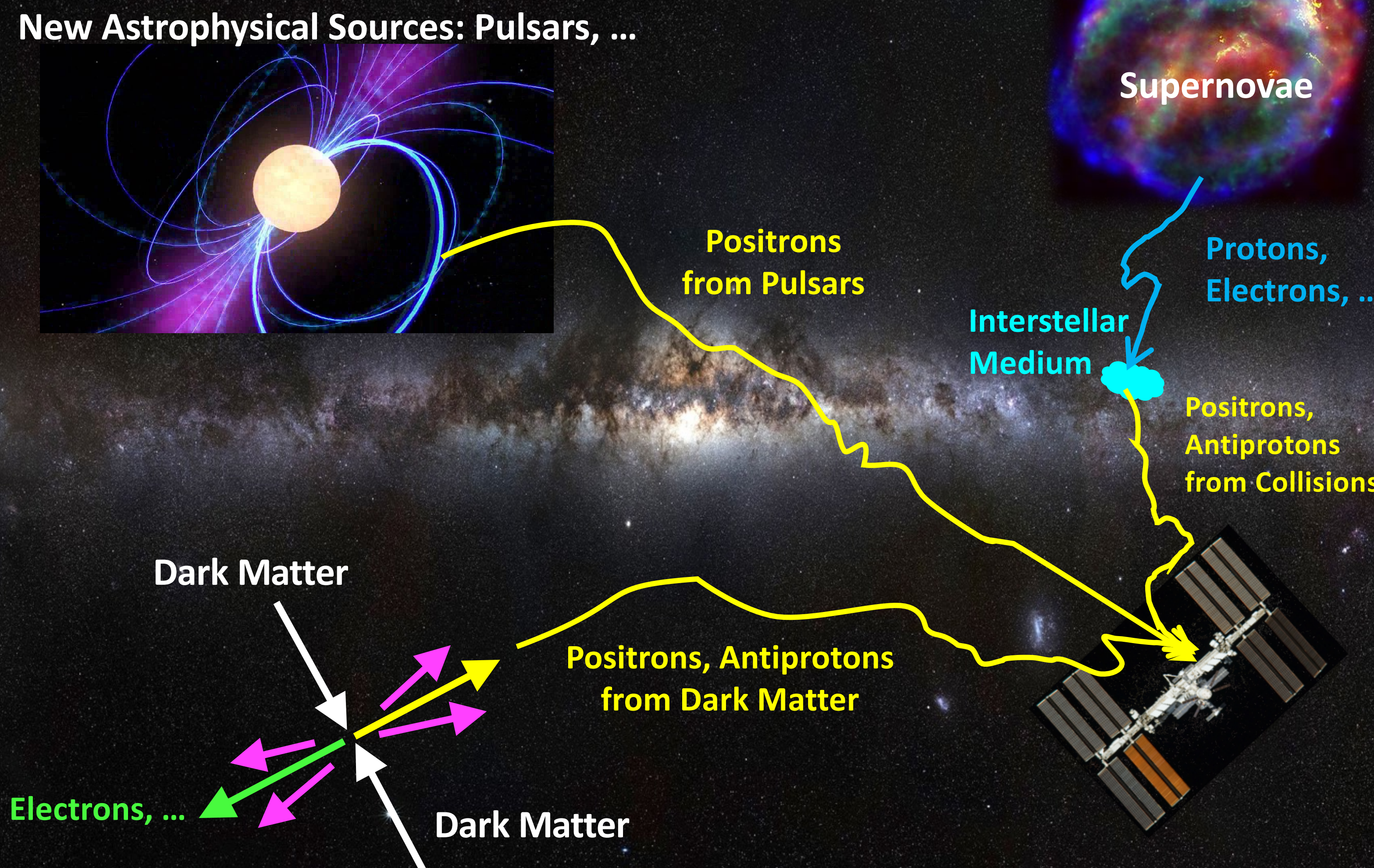
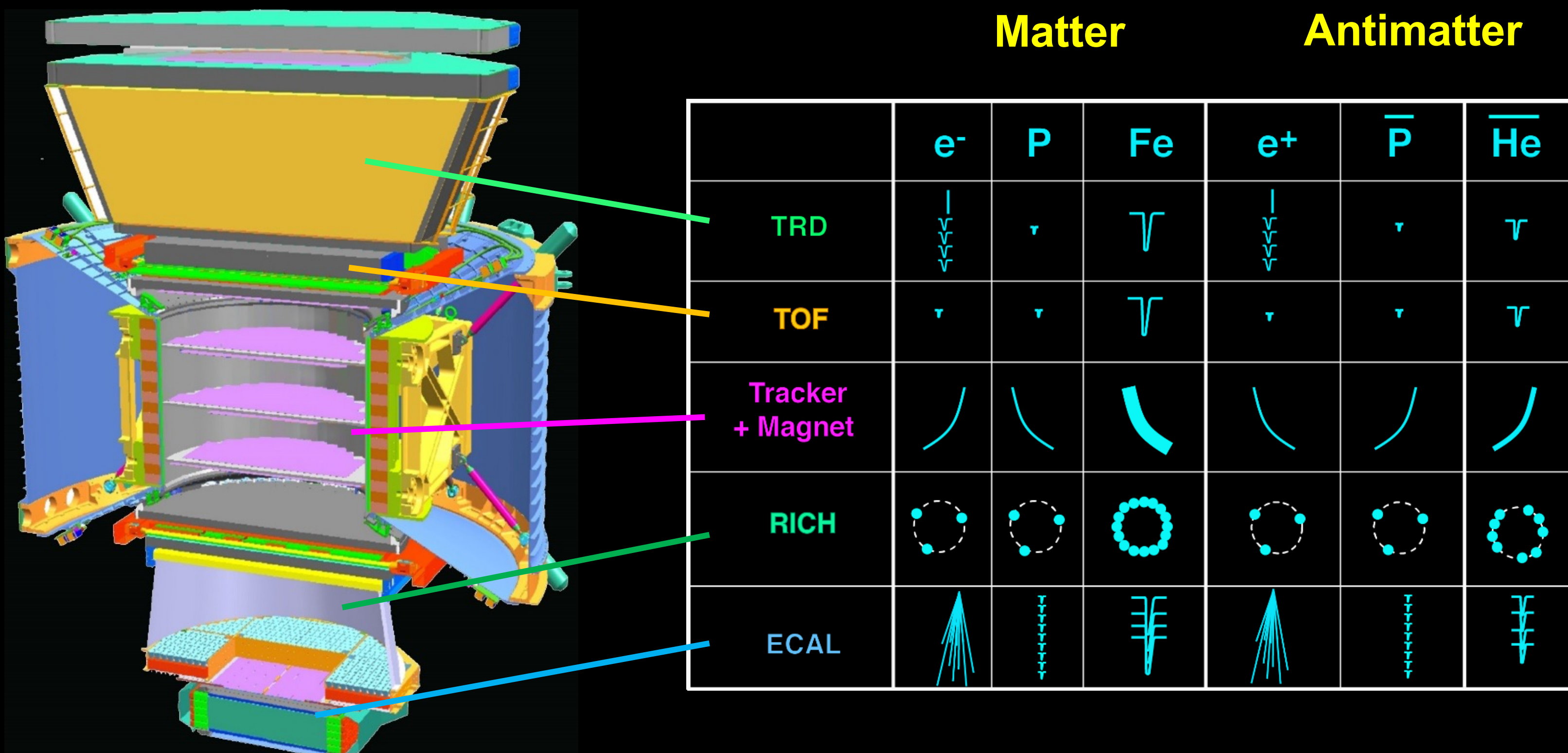
on behalf of the AMS Collaboration

On the Origins of Cosmic Rays



Measurement of these elementary particles ($p, \overline{p}, e^{-}, e^{+}$)
is a major tool to study new physics in space

AMS is a unique magnetic spectrometer in space



Cosmic rays are defined by:

- Energy (E in units of GeV)
- Charge (Z - location on the periodic table: H Z=1, He Z=2, …)
- Rigidity (R=P/Z in units of GV)

Antiproton Analysis

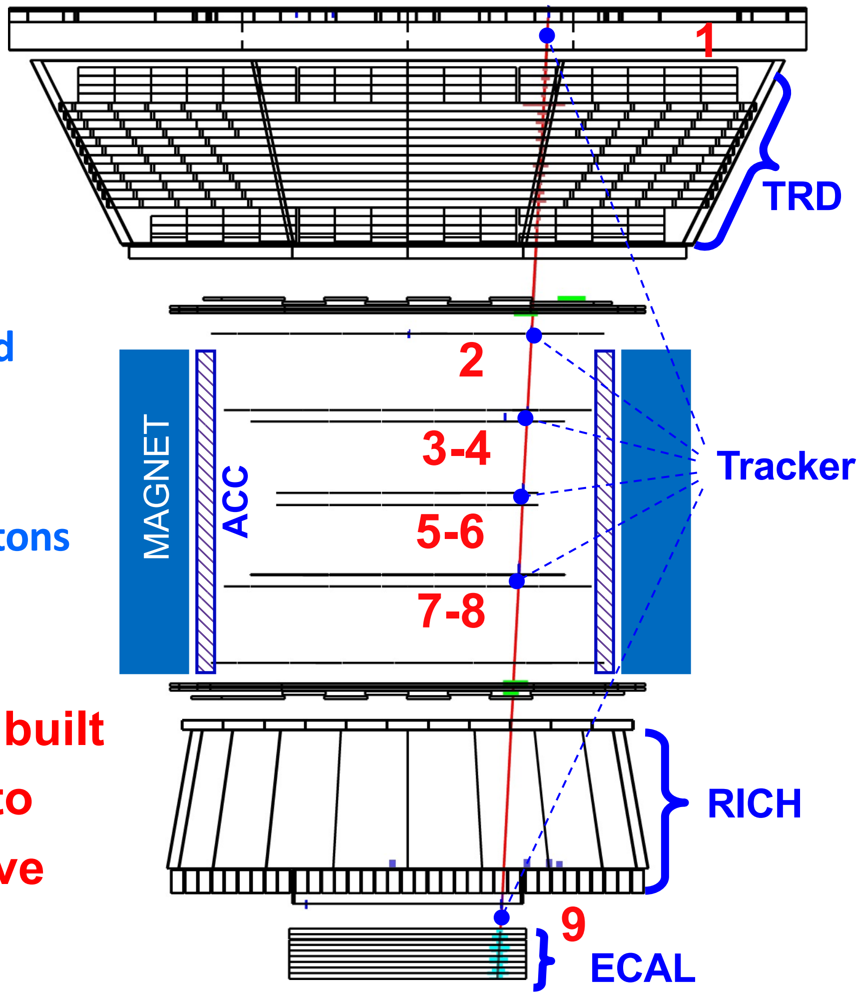
The Antiproton Flux is ~10^{-4} of the Proton Flux.

A percent precision experiment requires background rejection close to 1 in a million.

- **TOF & RICH:** select down going particles and measure velocity
- **TRD & ECAL:** reject electron background
- **Tracker:** Measure rigidity, separate antiprotons from charge confusion protons

- **A charge confusion estimator was built with Tracker and TOF information to reject protons measured as negative rigidity.**

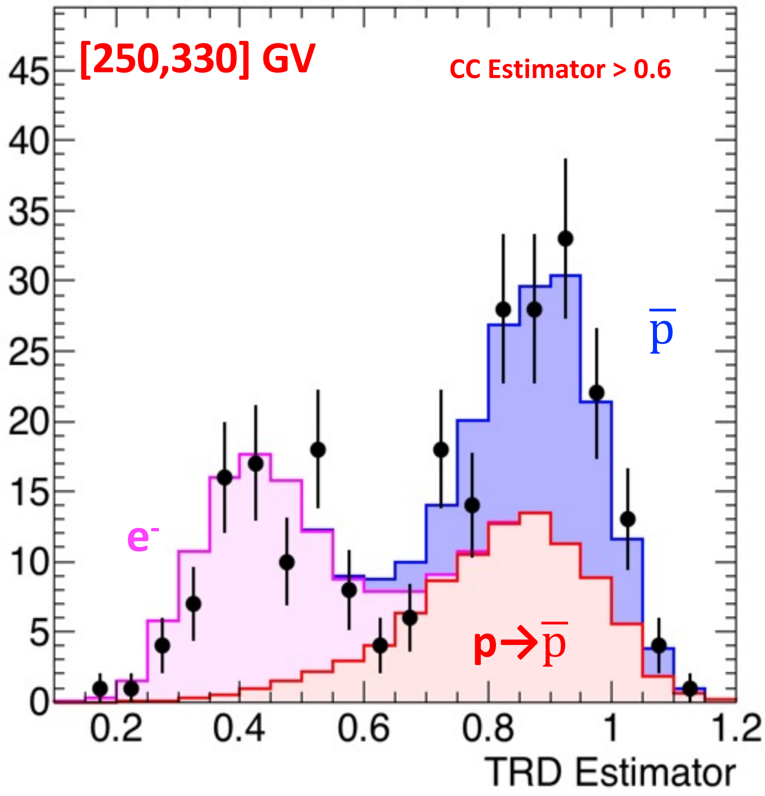
R = −363 GV antiproton



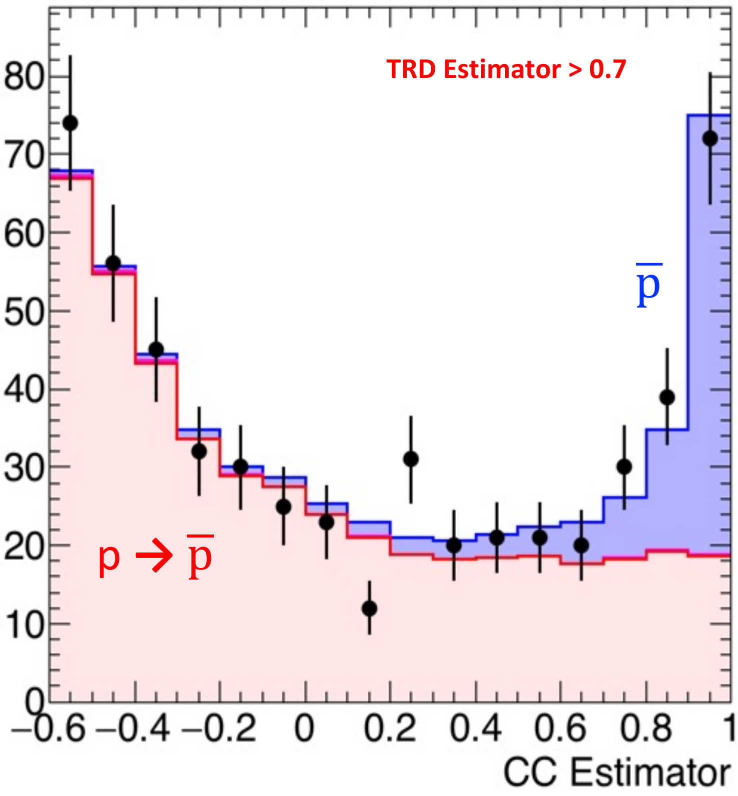
Antiproton identification at High Rigidity

- **Number of antiprotons are obtained by a fit to data sample in 2-D plane.**
  - **Electron : identified by TRD estimator**
  - **Charge Confusion Proton: identified by Charge Confusion estimator**

TRD Estimator Projection



Charge Confusion (CC) Estimator Projection

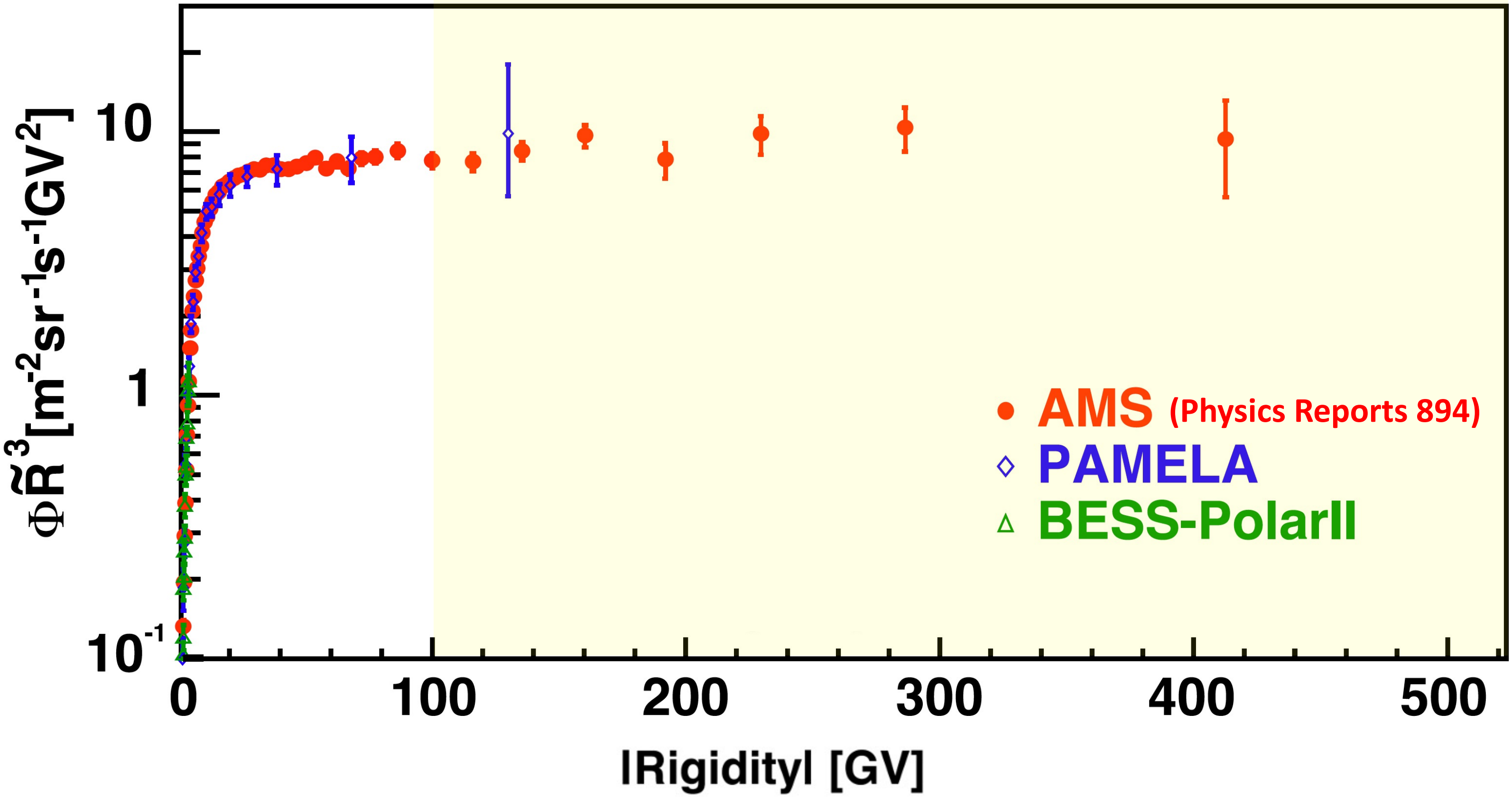


Antiproton Signal are clearly identified in the signal region.

AMS Measurement of Antiproton Flux

Latest result based on 5.6 x 10^5 Antiproton Events from 1 to 525 GV

Higher statistics and improved accuracy in the high rigidity range.



A sample of recent papers on AMS antiproton data

Antiproton production and propagation

Genolini Y, Boudaud M., Cirelli M., et.al. arXiv:2103.04108 (2021)

Philipp Mertsch, Andrea Vittino, Subir Sarkar, arXiv:2012.12853 (2020)

Bresci V., Amato E., Blasi P., Morlino G. Mon. Not. R. Astron. Soc., 488 (2019), p. 2068

Michael Korsmeier, Fiorenza Donato, Mattia Di Mauro Phys. Rev. D 97, 103019 (2018)

Lipari P. Phys. Rev. D, 95 (2017), Article 063009

Ilias Cholis, Dan Hooper, and Tim Linden, Phys. Rev. D 95(2017), 123007

M. Winkler, JCAP, vol. 2017(02), 048

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Antiprotons from Dark Matter

Heisig J., Modern Physics Letters A, (2021), 36, 05

Cholis I., Linden T., Hooper D. Phys. Rev. D, 99 (2019), p. 103026

Cuoco A., Heisig J., Klamt L., Korsmeier M., Krämer M. Phys. Rev. D, 99 (2019), Article 103014

Carena M., Osborne J., Shah N.R., Wagner E.M., C. Phys. Rev. D, 100 (2019), p. 055002

Reinert A., Winkler M.W. JCAP, 01 (2018), p. 055

Cuoco A., Krämer M., Korsmeier M. Phys. Rev. Lett., 118 (2017), Article 191102

Cui M.Y., Yuan Q., Tsai Y.L.S., Fan Y.Z. Phys. Rev. Lett., 118 (2017), Article 191101

Chen Y.-H., Cheung K., Tseng P.-Y. Phys. Rev. D, 93 (2016), p. 015015

Hamaguchi K., Moroi T., Nakayama K. Phys. Lett. B, 747 (2015), p. 523

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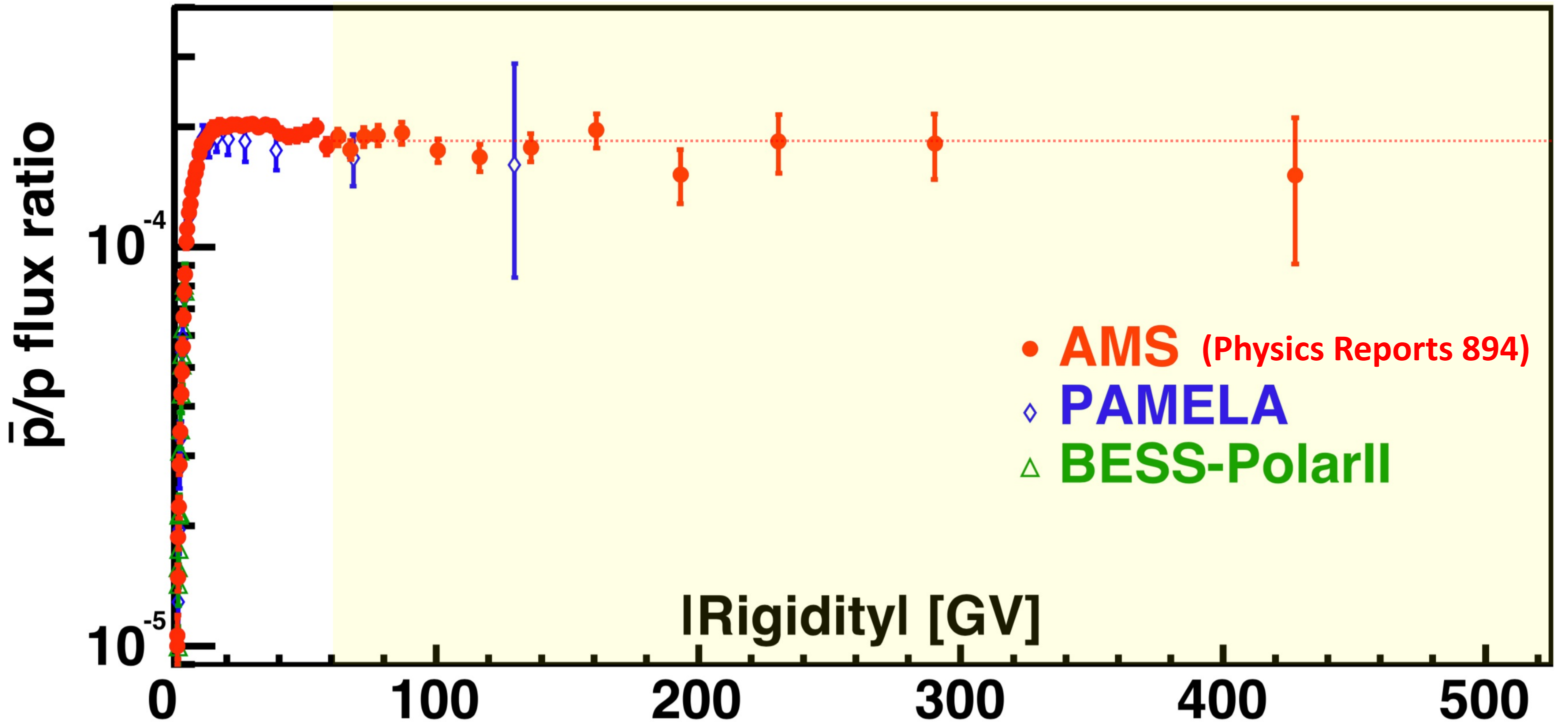
Antiproton-to-Proton flux ratio

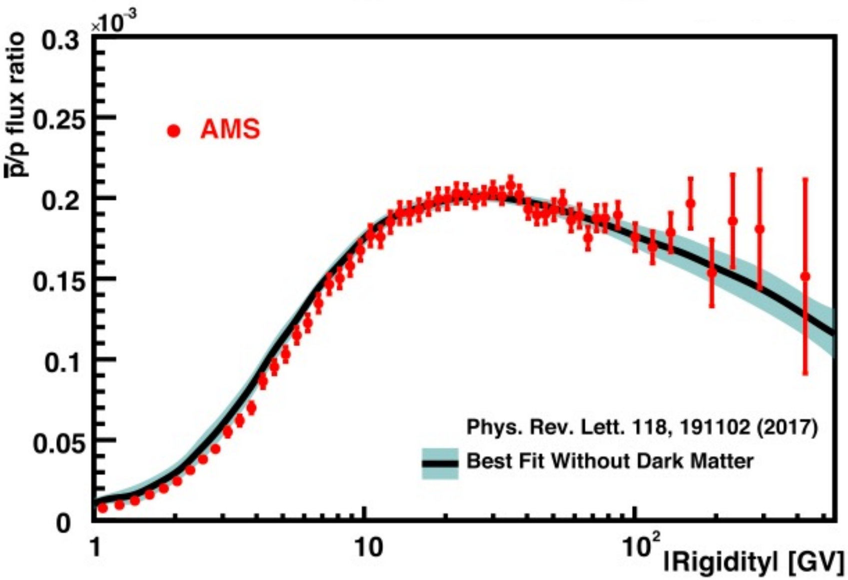
If $\bar{p}$ are secondaries produced in the interstellar medium, their rigidity dependence should be different than p

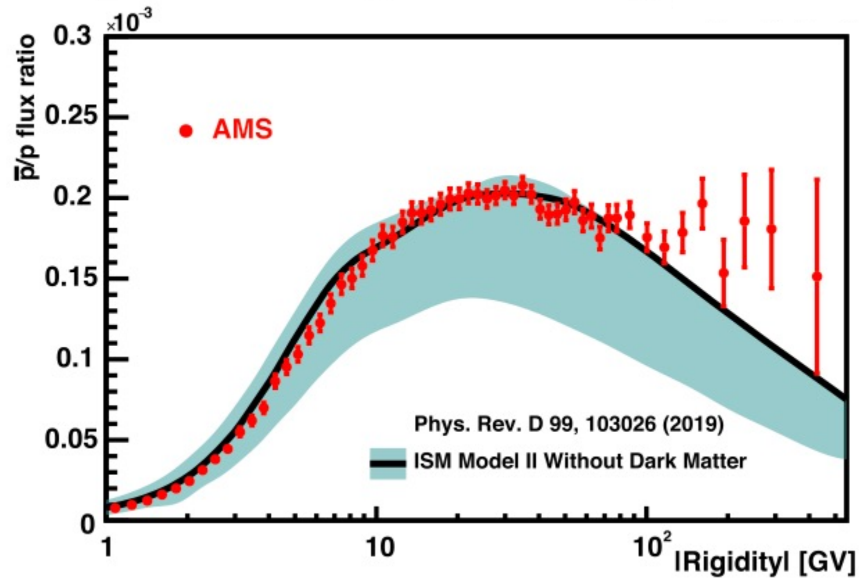


- **Starting from 60 GV, the flux ratio is a constant up to 525 GV.**
- **This result is not expected if antiprotons are produced only in collisions of cosmic rays with the interstellar medium.**

Example: AMS Antiproton Results compared with Models

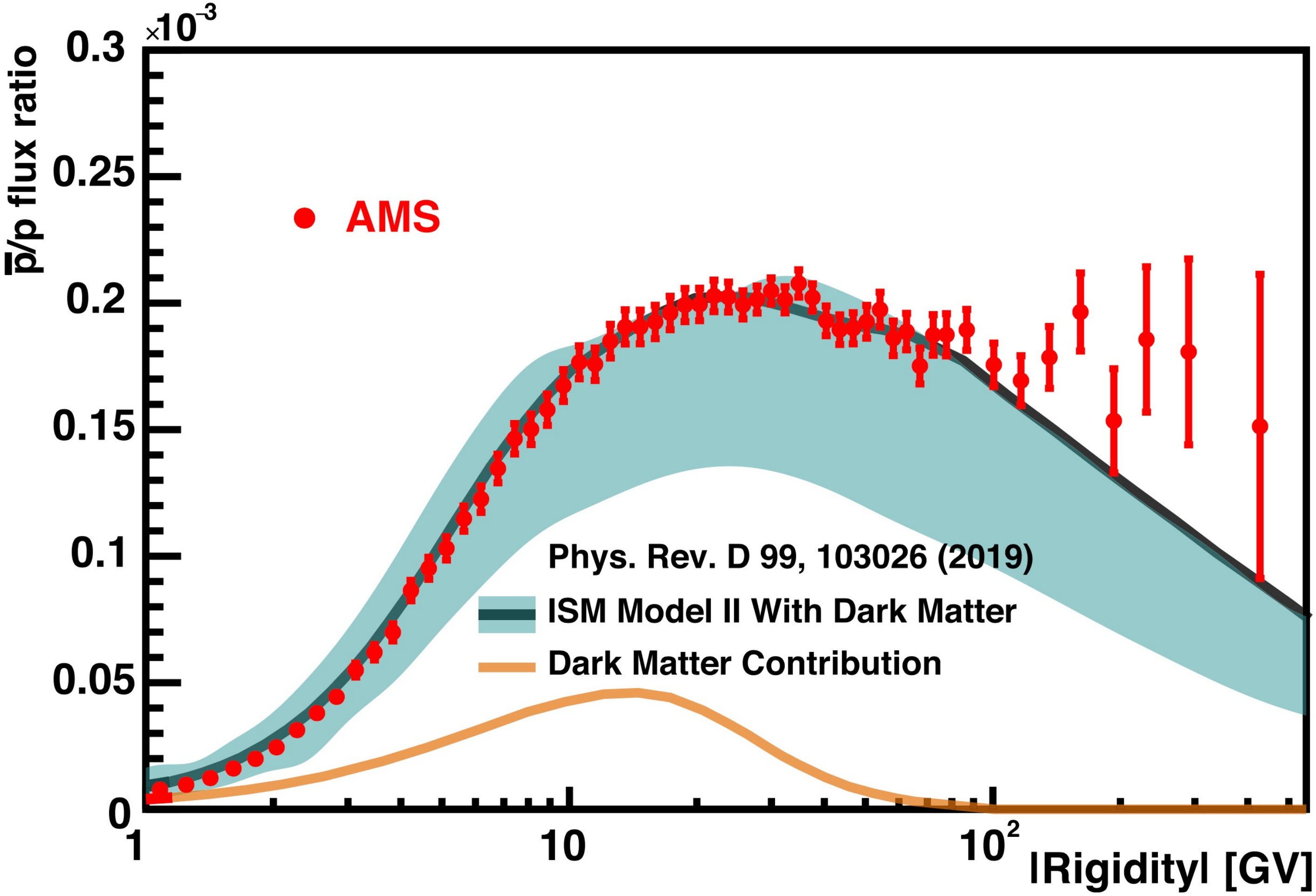
Predictions taking into account only cosmic-ray collisions



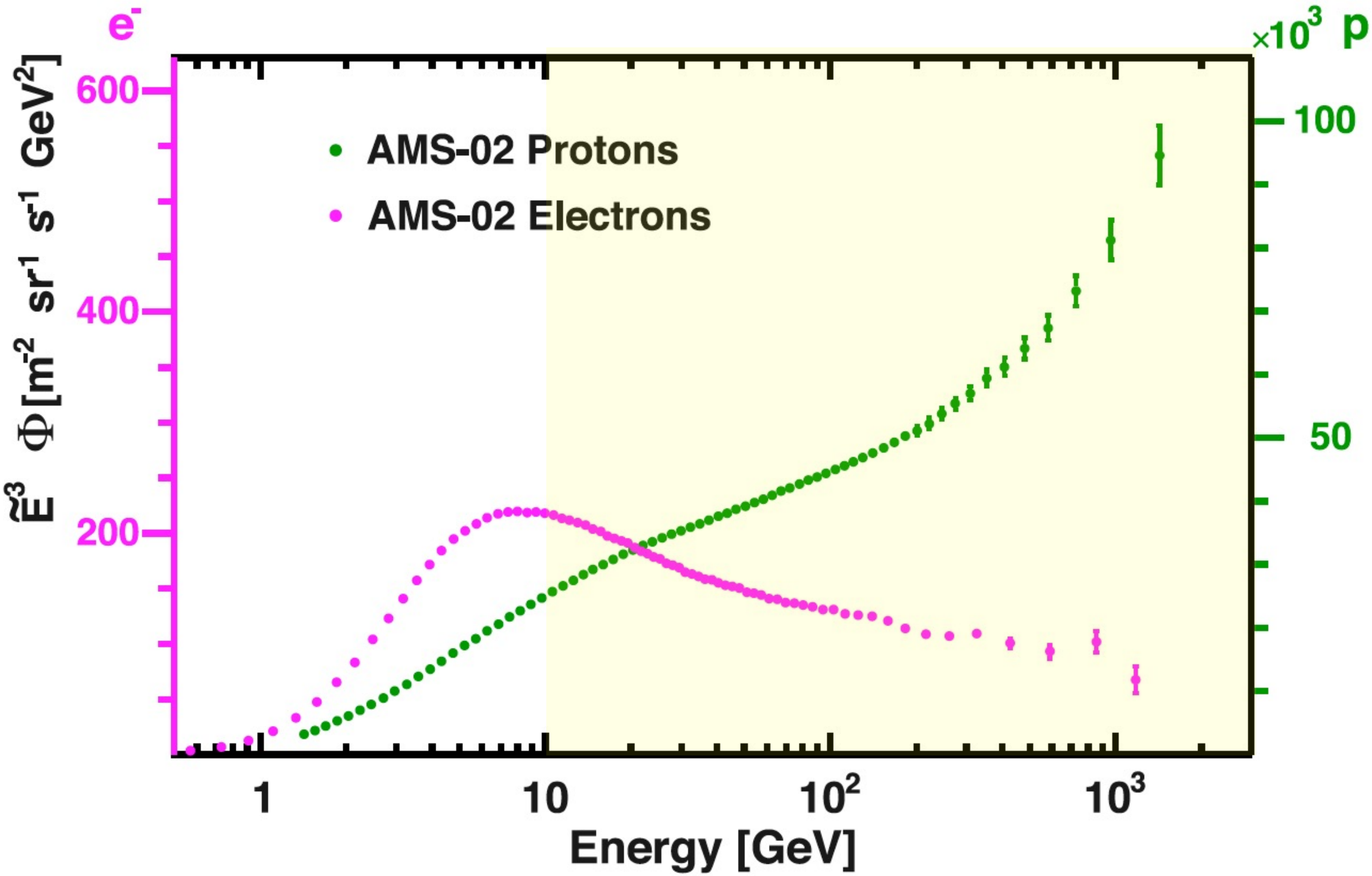


Example: AMS Antiproton Results compared with Model

Predictions taking into account dark matter annihilations and cosmic-ray collisions



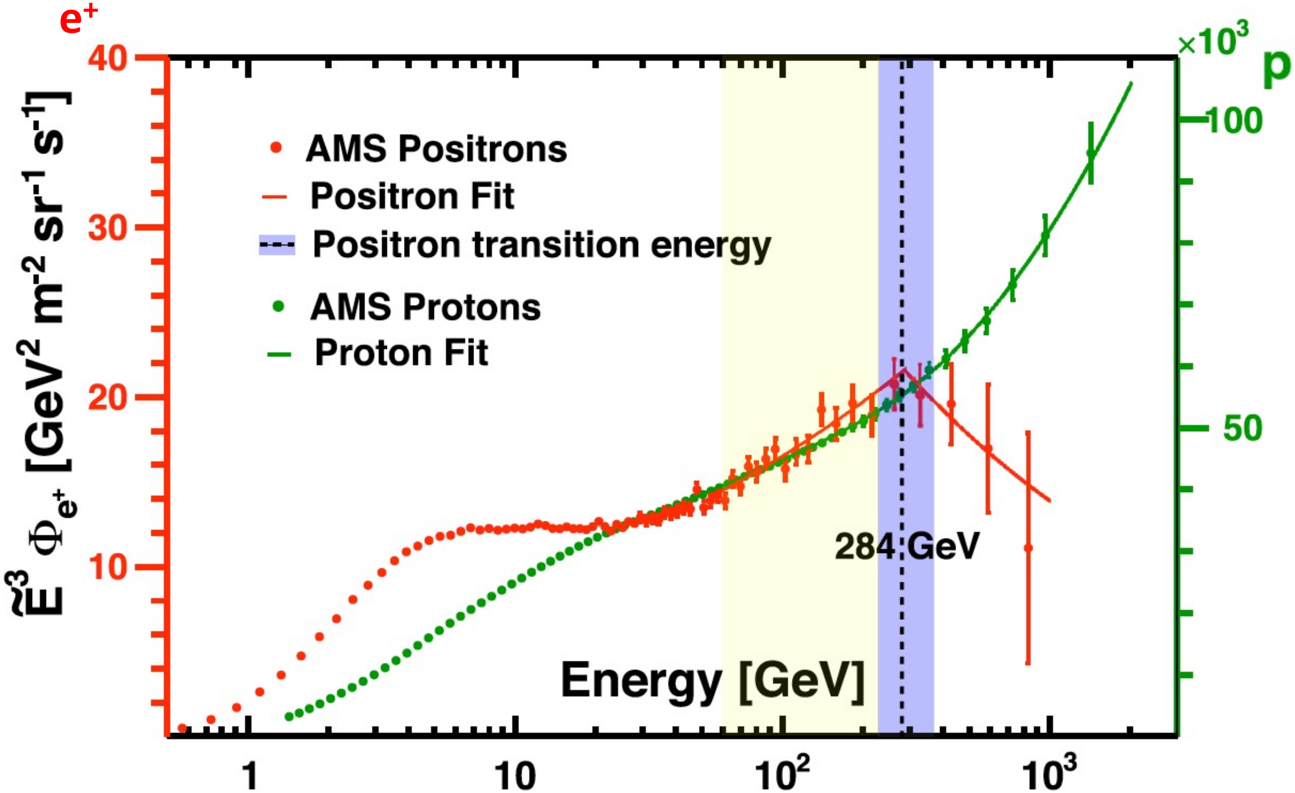
The Spectra of Electrons and Protons



- Starting from ~10 GeV, electrons spectrum is much softer compared to protons.
- Electrons lose energy much faster than proton during propagation

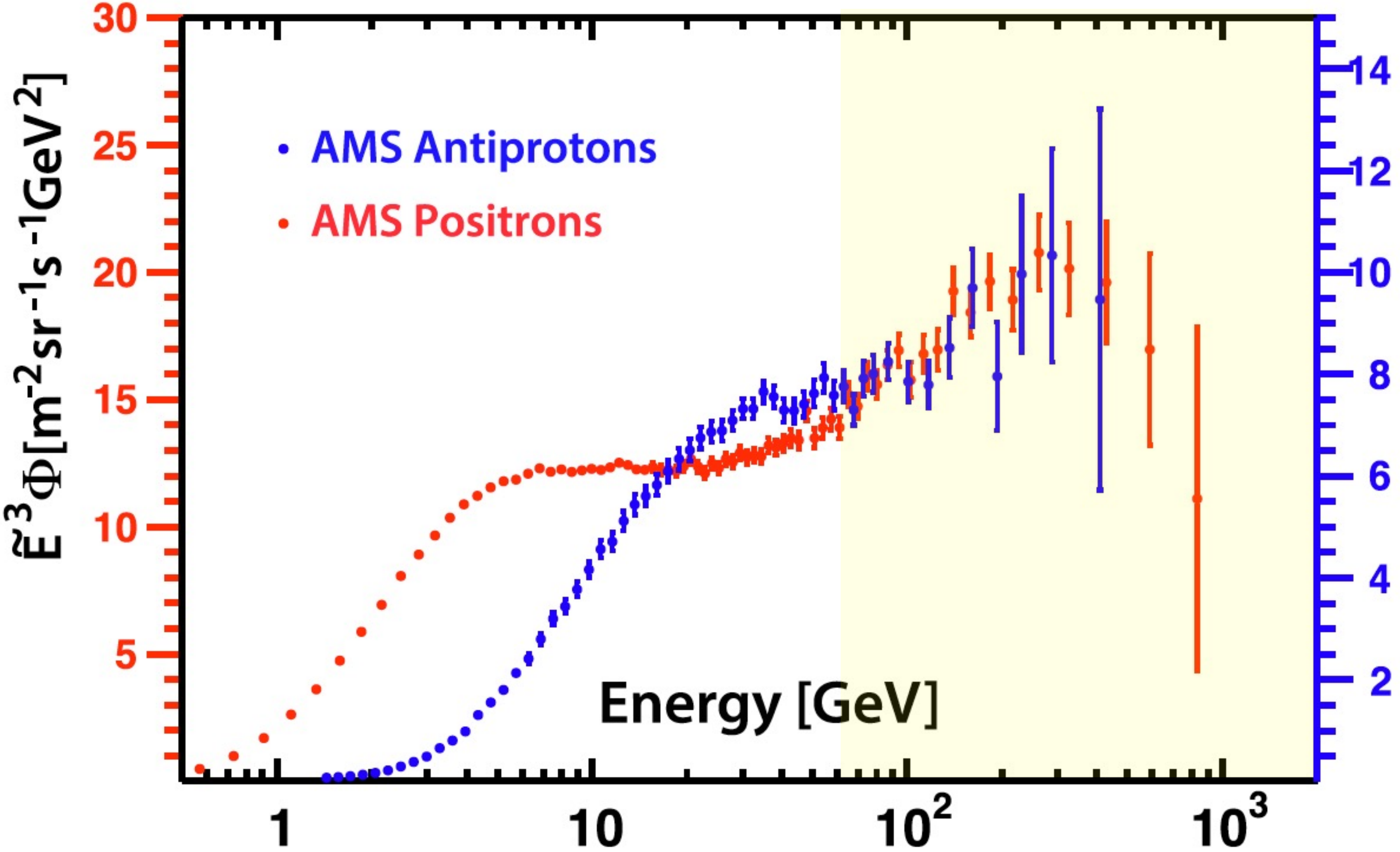
The Spectra of Positrons and Protons

- **Protons and positron have a very different origin and propagation history:**
  - Secondary positrons: softer than proton due to diffusion and energy loss



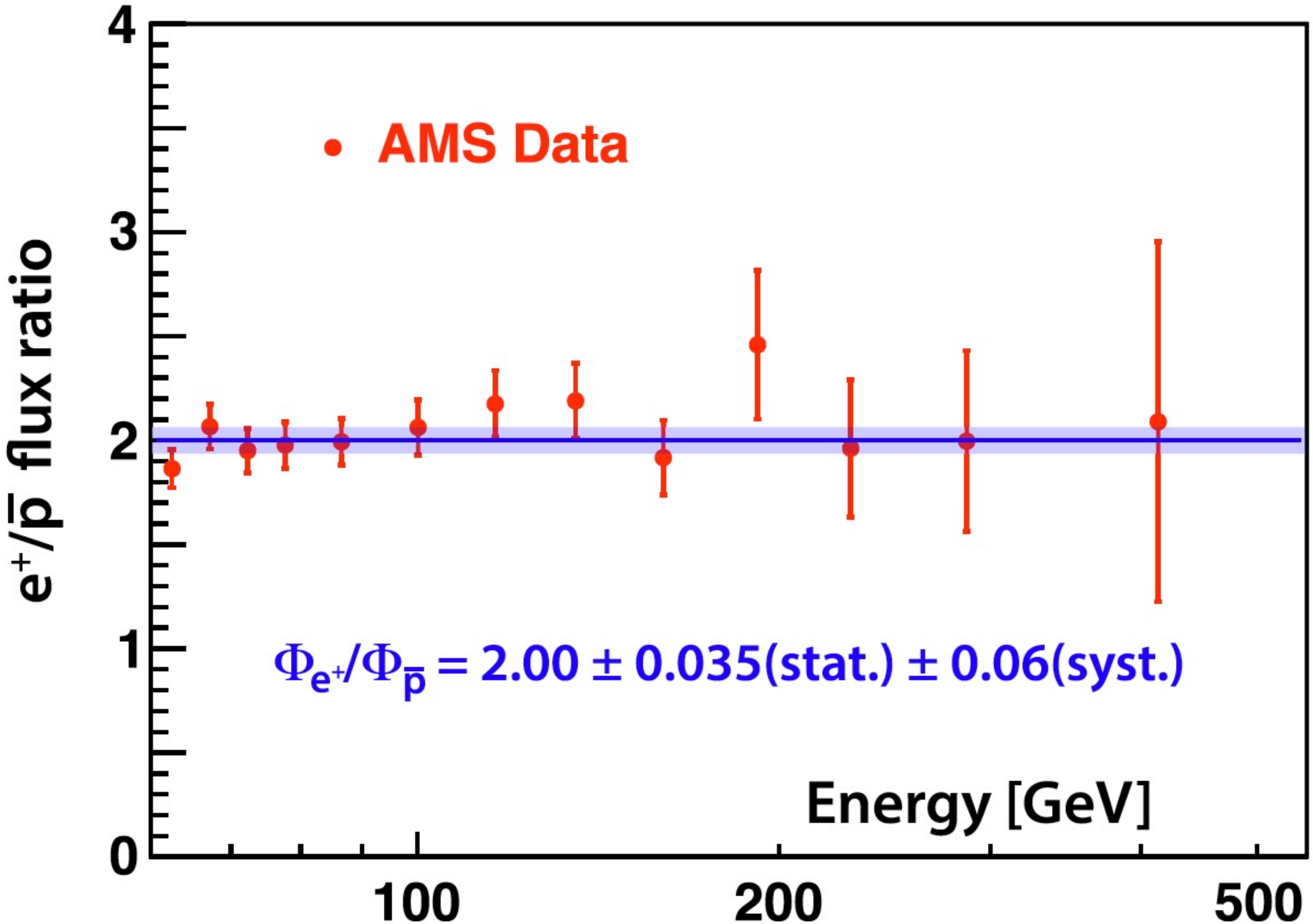
- **From ~60 GeV to 260 GeV, Positron spectrum is harder than Proton.**
- **Starting from ~280 GeV, Positron flux shows a drop-off, in contrast with the proton spectrum**

Antiproton flux shows a similar trend as Positrons



This suggests a possible common source of high energy positrons and antiprotons.

The positron-to-antiproton flux ratio is constant independent of energy.



High-energy antiprotons cannot come from pulsars if the common source is existence.

Conclusion

- AMS has measured the fluxes of all charged elementary particles $(p, \bar{p}, e^-, e^+)$. Detail comparisons of different fluxes are performed:
  - Antiproton/proton flux ratio is a constant up to 525GV.
  - Positron flux shows a drop-off at around 280GeV, and proton flux shows progressive hardening towards higher energy.
  - Positron and antiproton spectra have similar behavior above 60 GeV.

- The continuation of AMS data taking through the lifetime of ISS will provide an important confirmation of the origin of high-energy positrons and antiprotons.