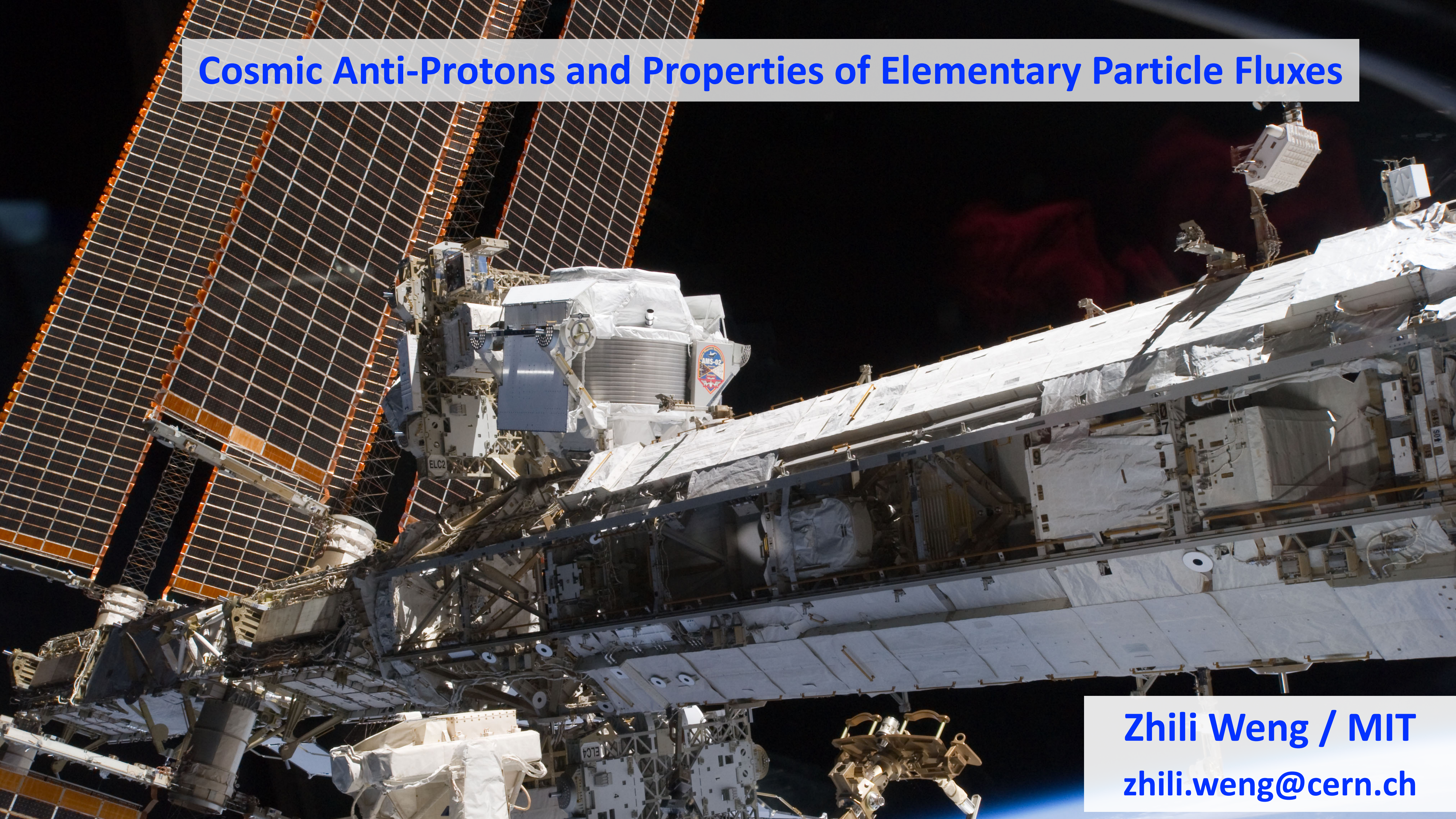
Cosmic Anti-Protons and Properties of Elementary Particle Fluxes



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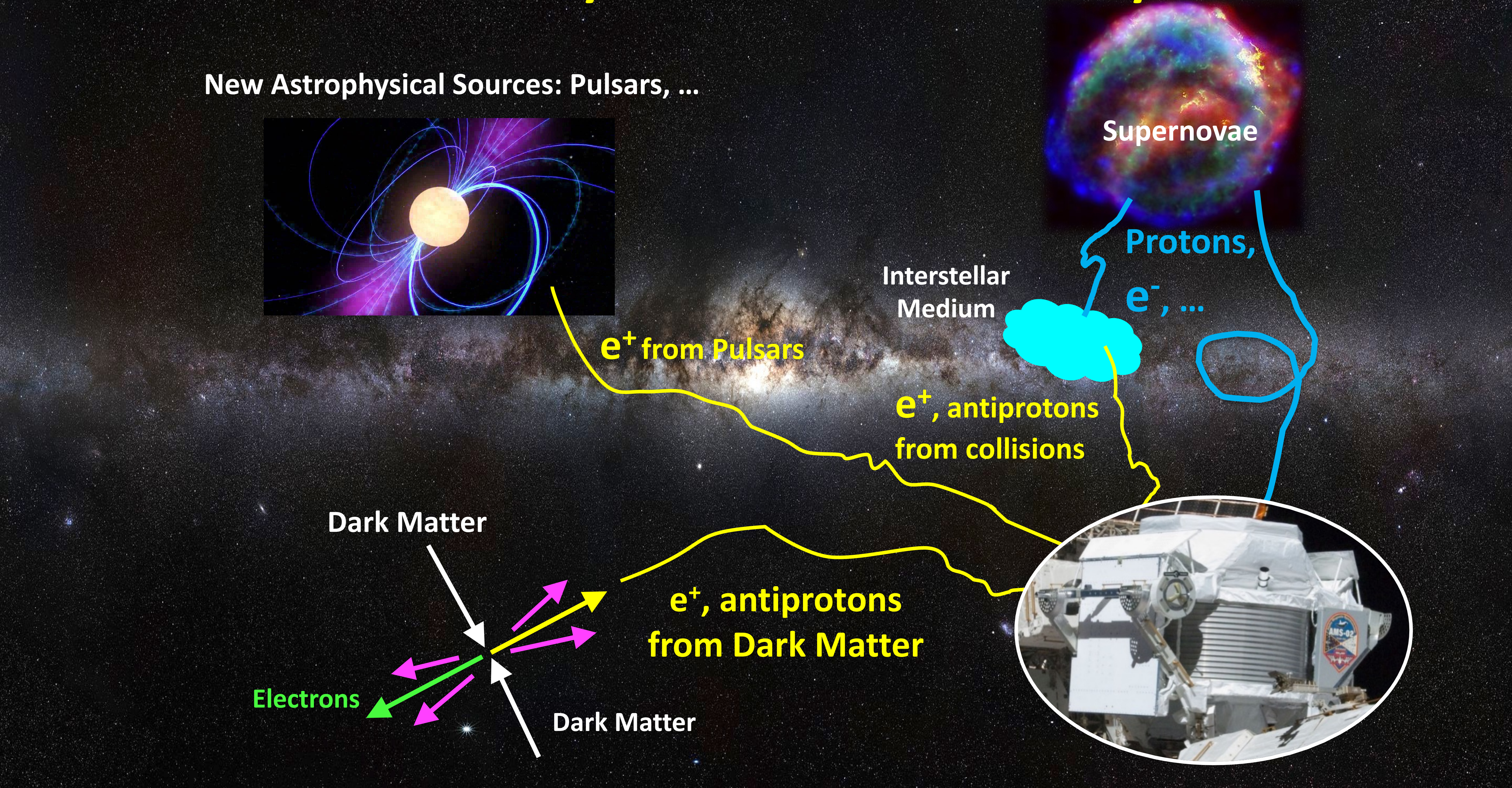
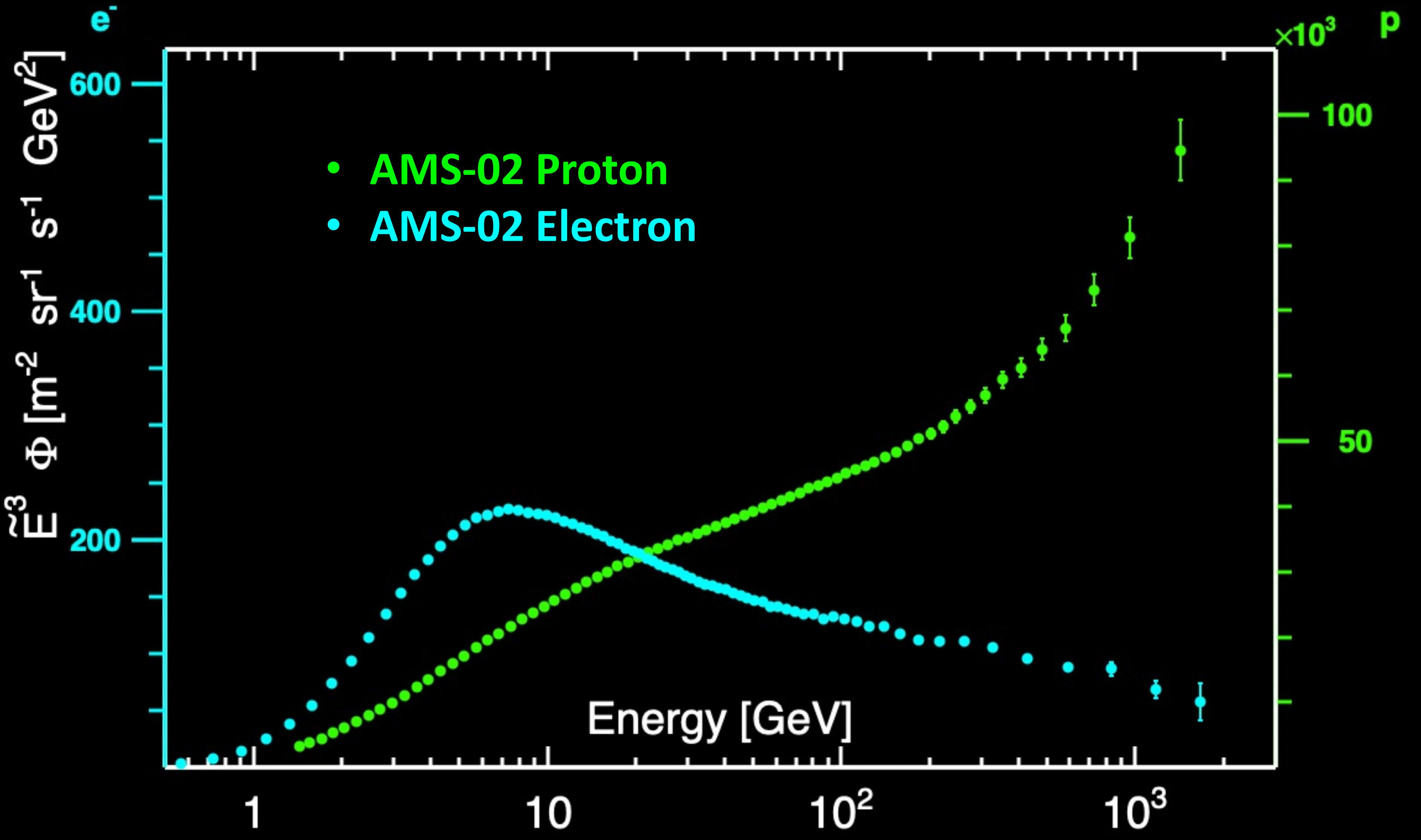
Elementary Particles in Cosmic Rays



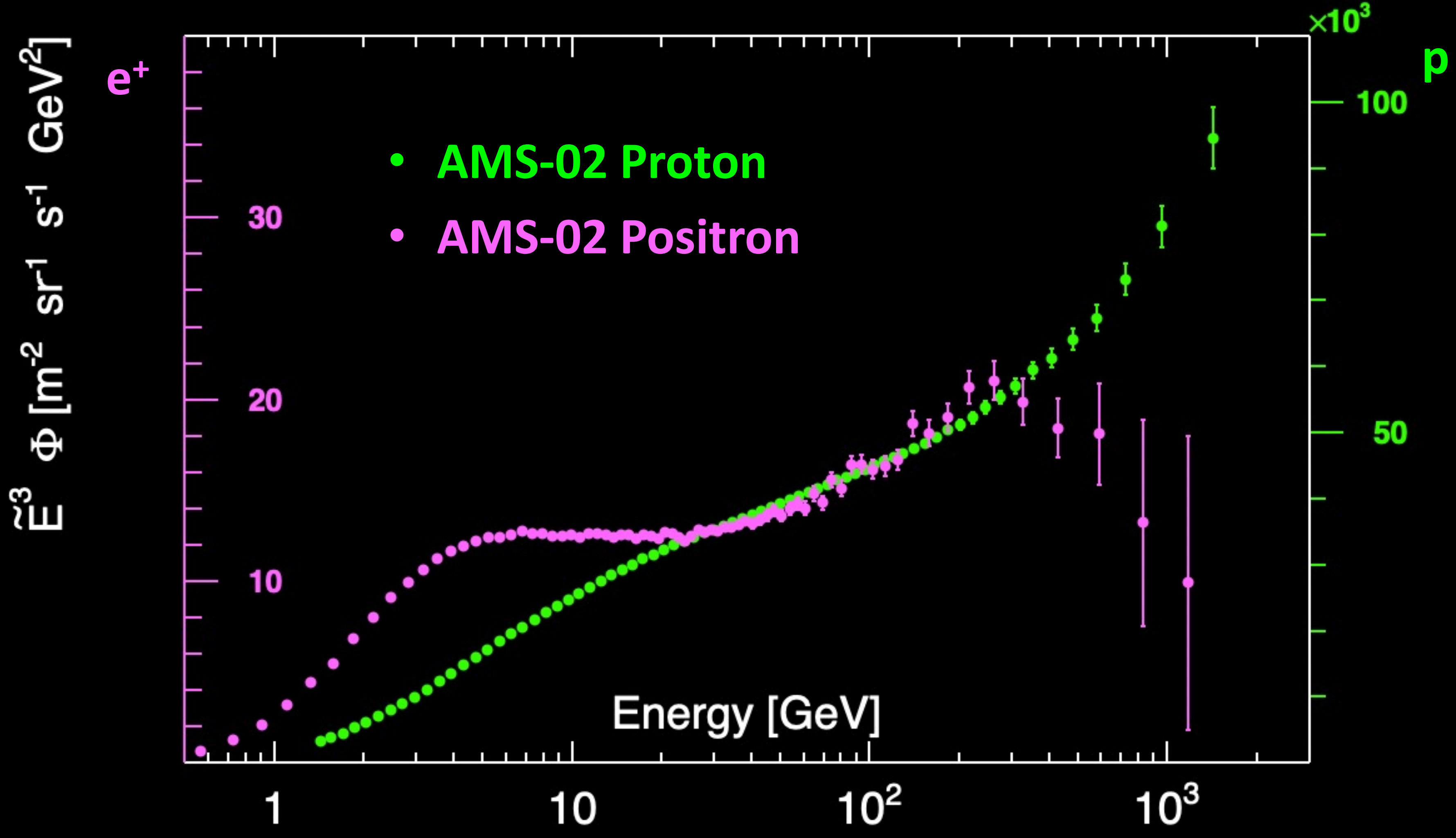
The Spectra of Electrons and Protons



Electron flux decrease faster than proton: Electron loss energy faster during propagation

The Spectra of Protons and Positrons

Protons and positron have different origin and propagation history



AMS measurement shows new source of positrons with high energy cutoff

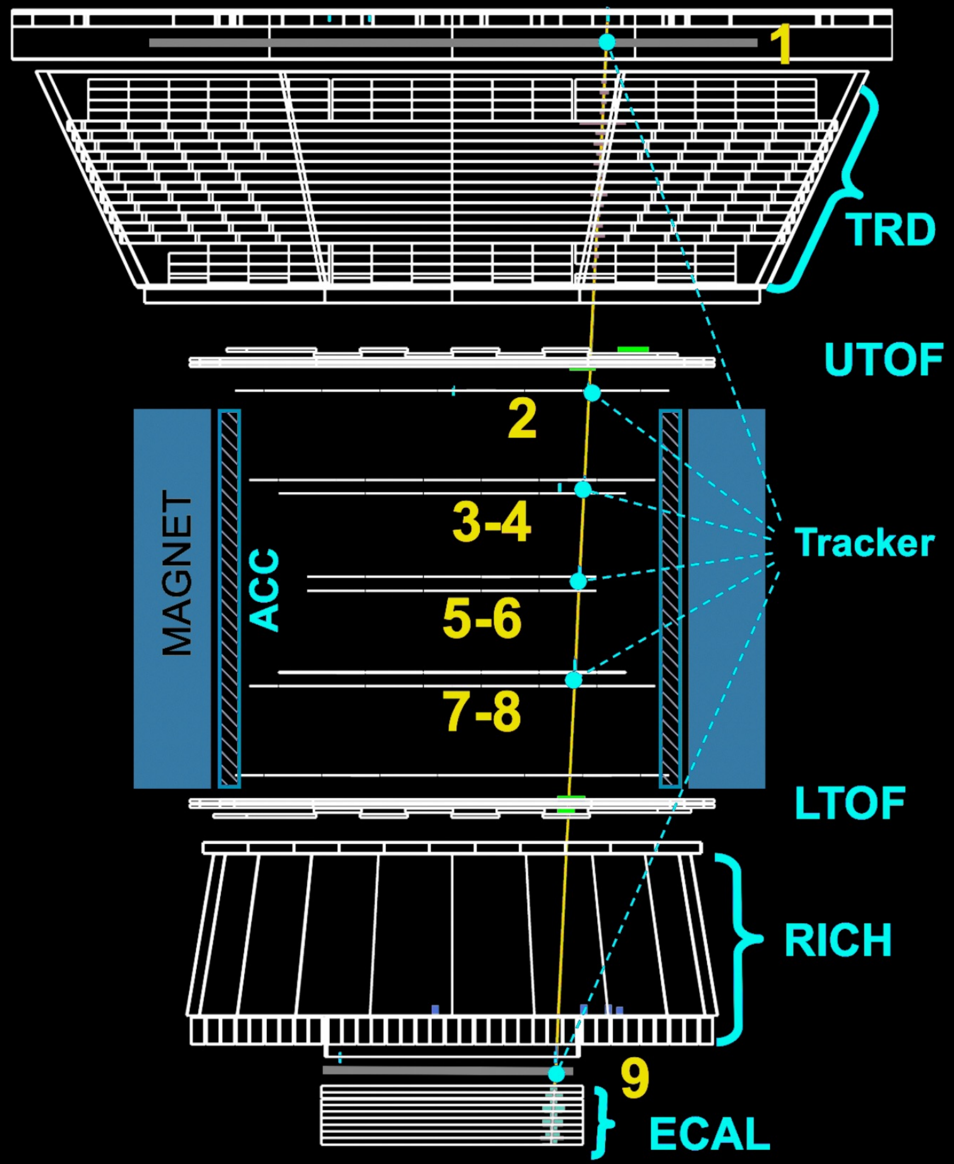
Antiproton Measurements with AMS

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

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

- Tracker & Magnet: measure rigidity, separate antiprotons from protons
- TRD & ECAL: reject electron background
- TOF & RICH: select down going particle and measure velocity

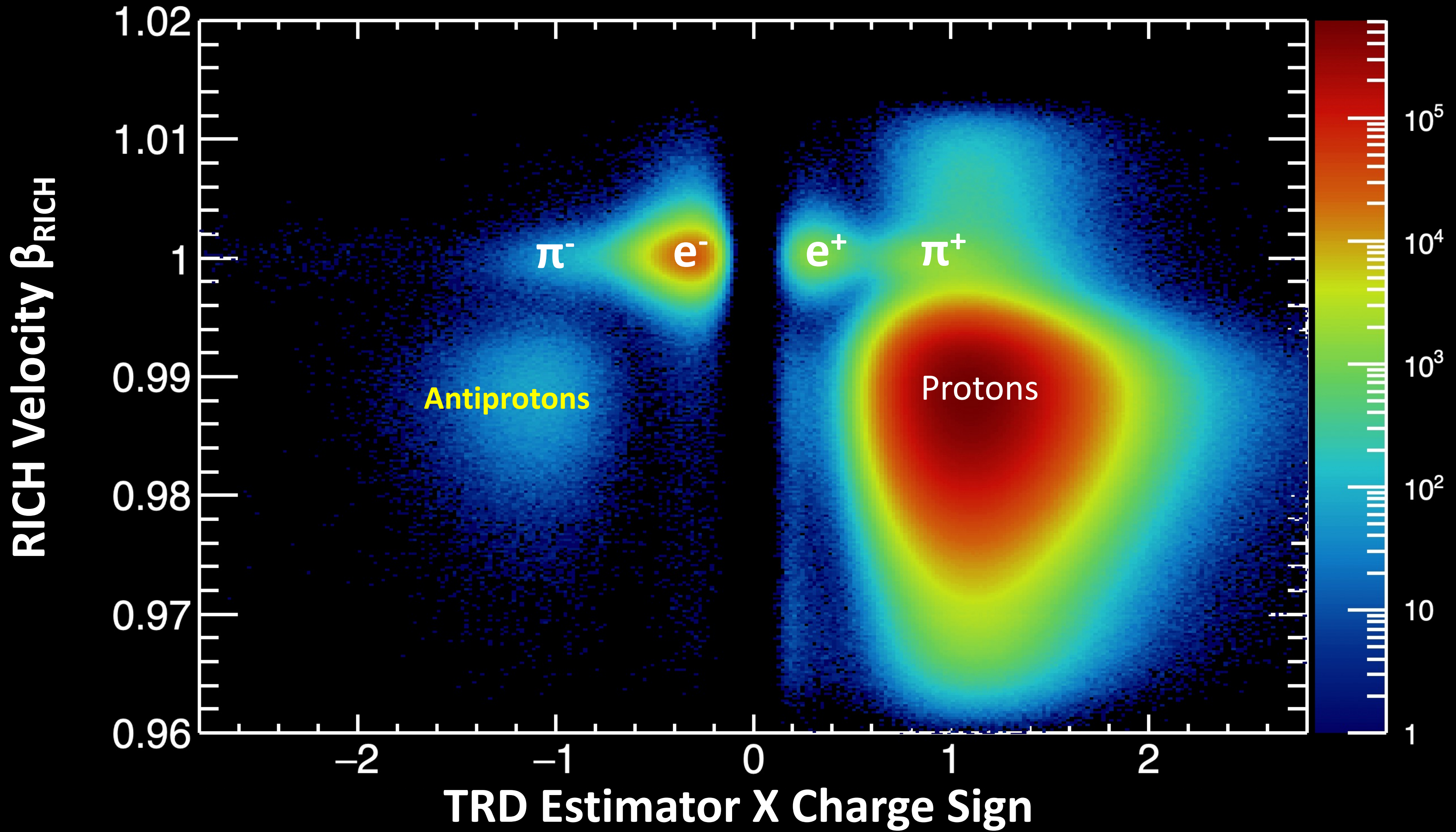
R = −363 GV antiproton



Antiproton Analysis Overview

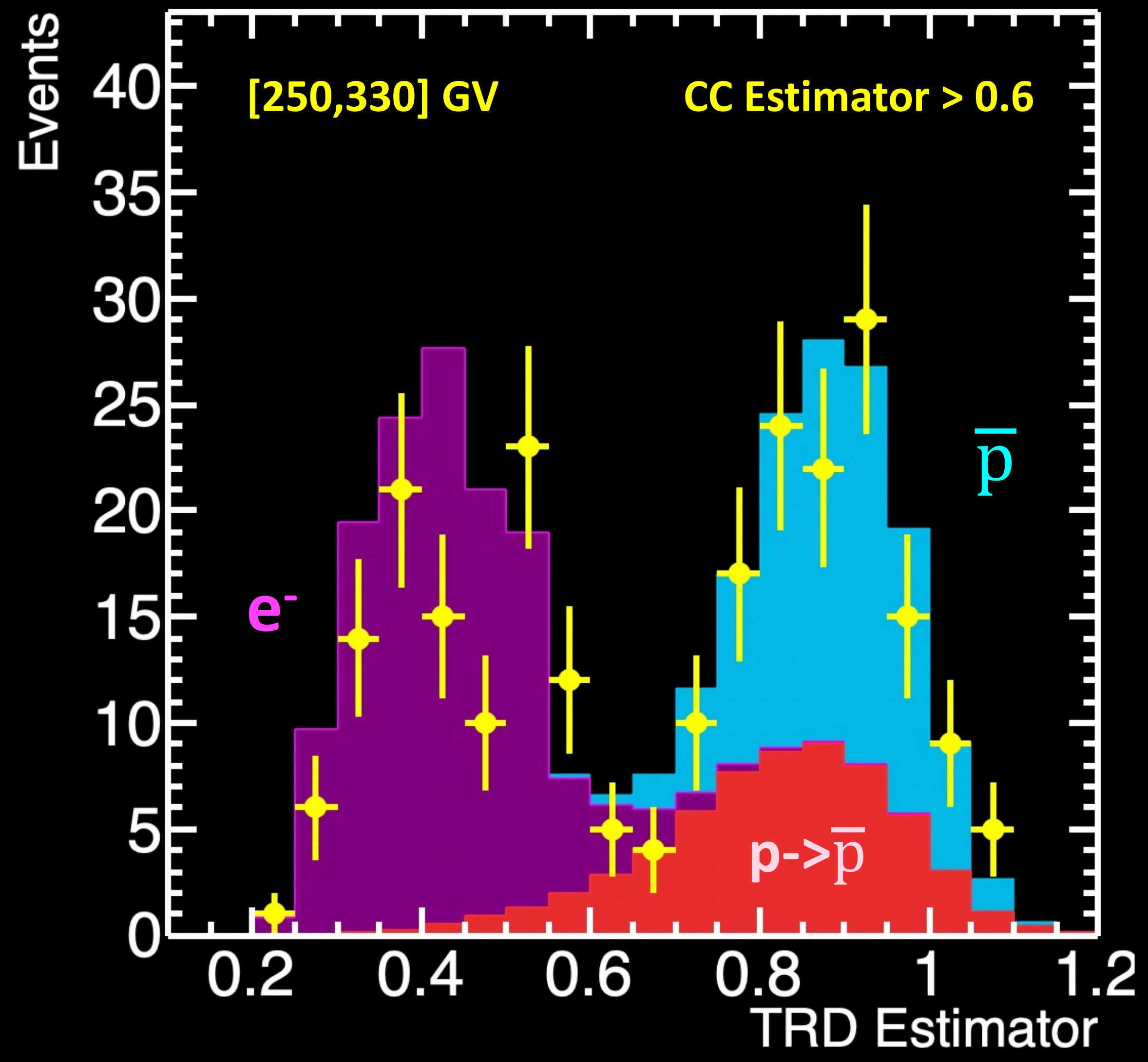
Use TOF, RICH, and TRD identify antiproton from backgrounds

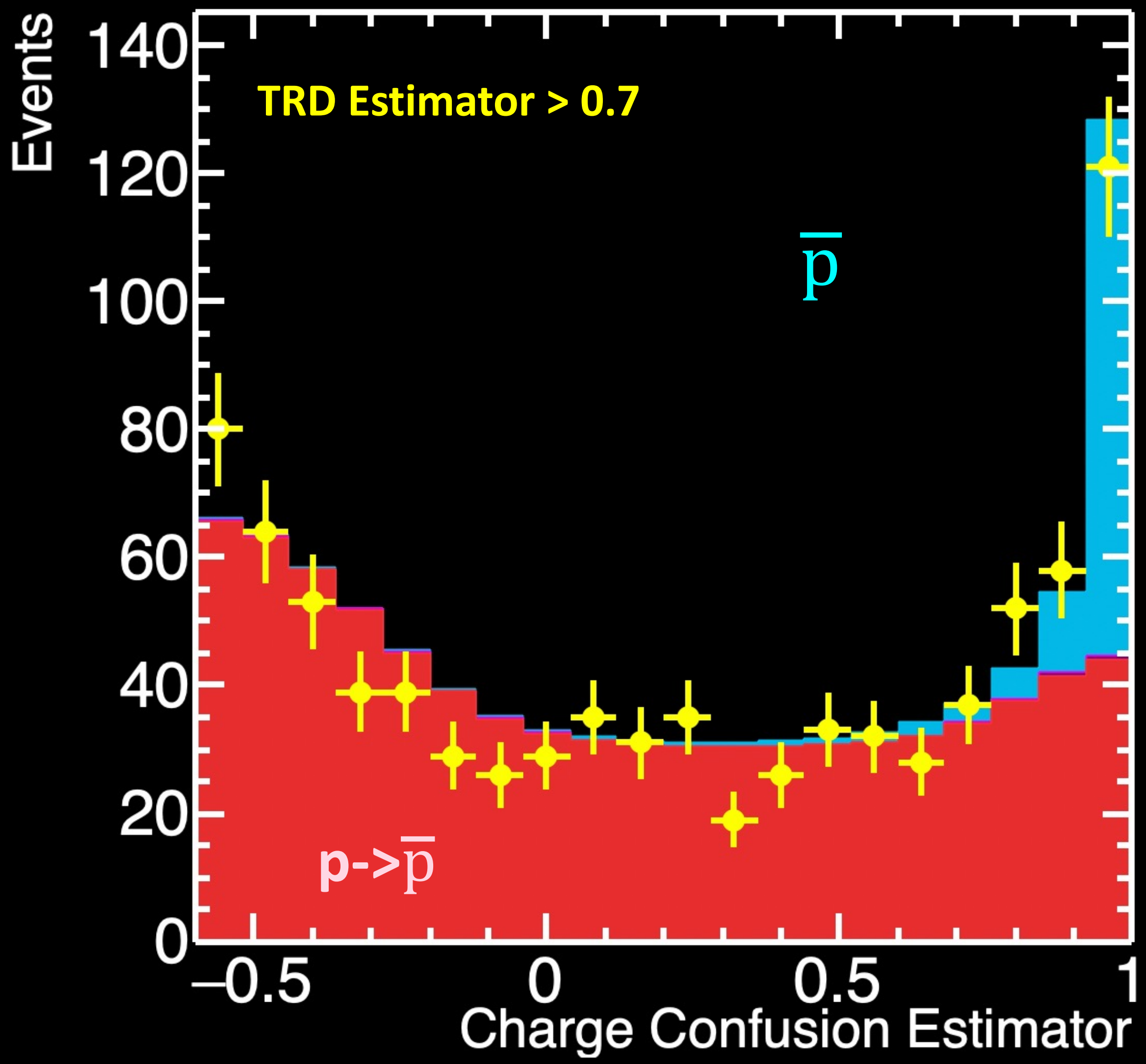
Example: Data Sample composition in |Rigidity|=6 GV



Antiproton Analysis Overview

- Identify Antiproton signal at high rigidity: Charge confusion estimator
- Number of antiprotons are obtained by a fit in (TRD Estimator – Charge Confusion Estimator) 2D plane



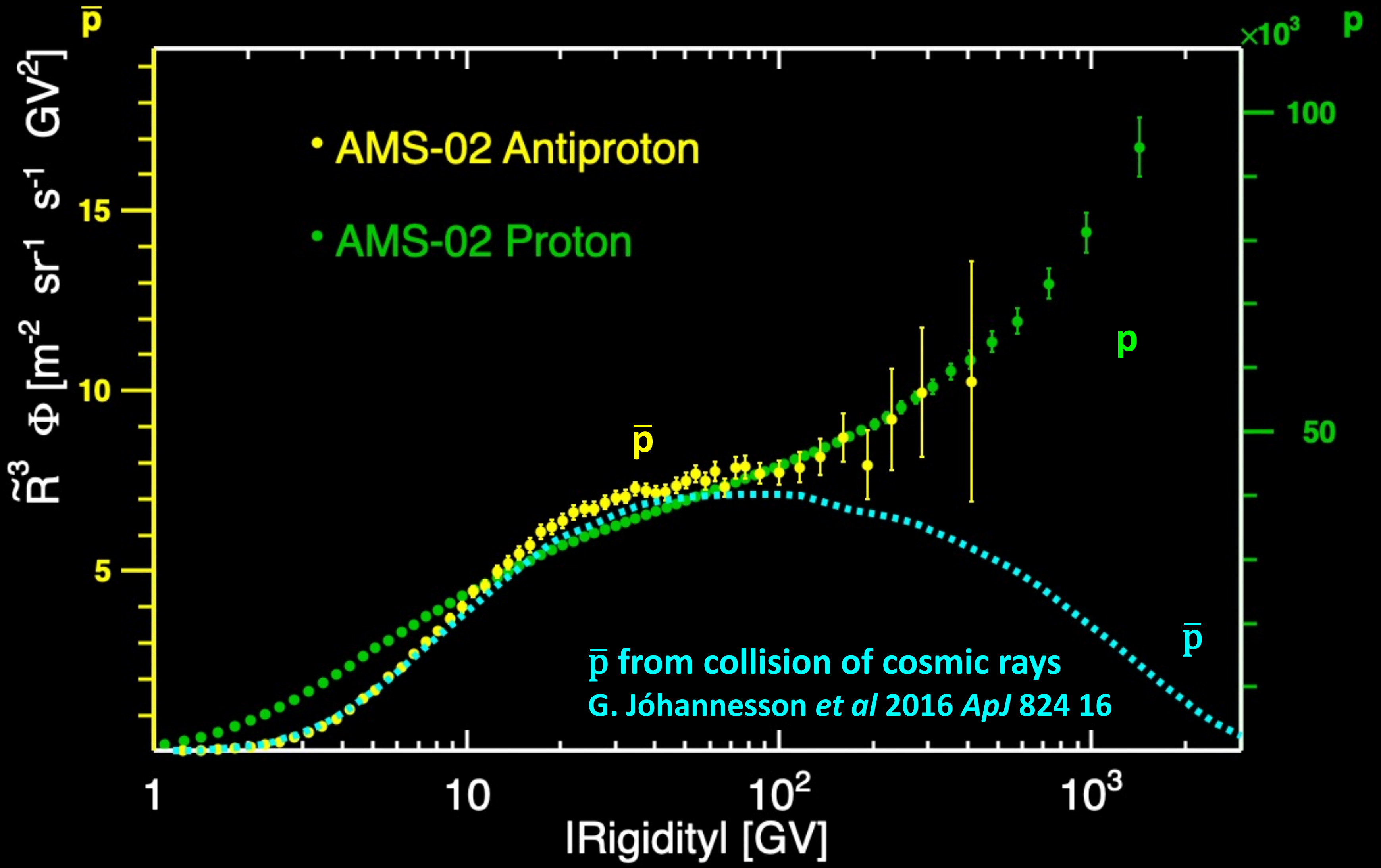


In 10 years, AMS has identified over 0.8 million antiprotons from 1 to 525 GV

Precision study of the properties of antiproton flux

AMS measurements show that p and $\bar{p}$ have identical rigidity dependence

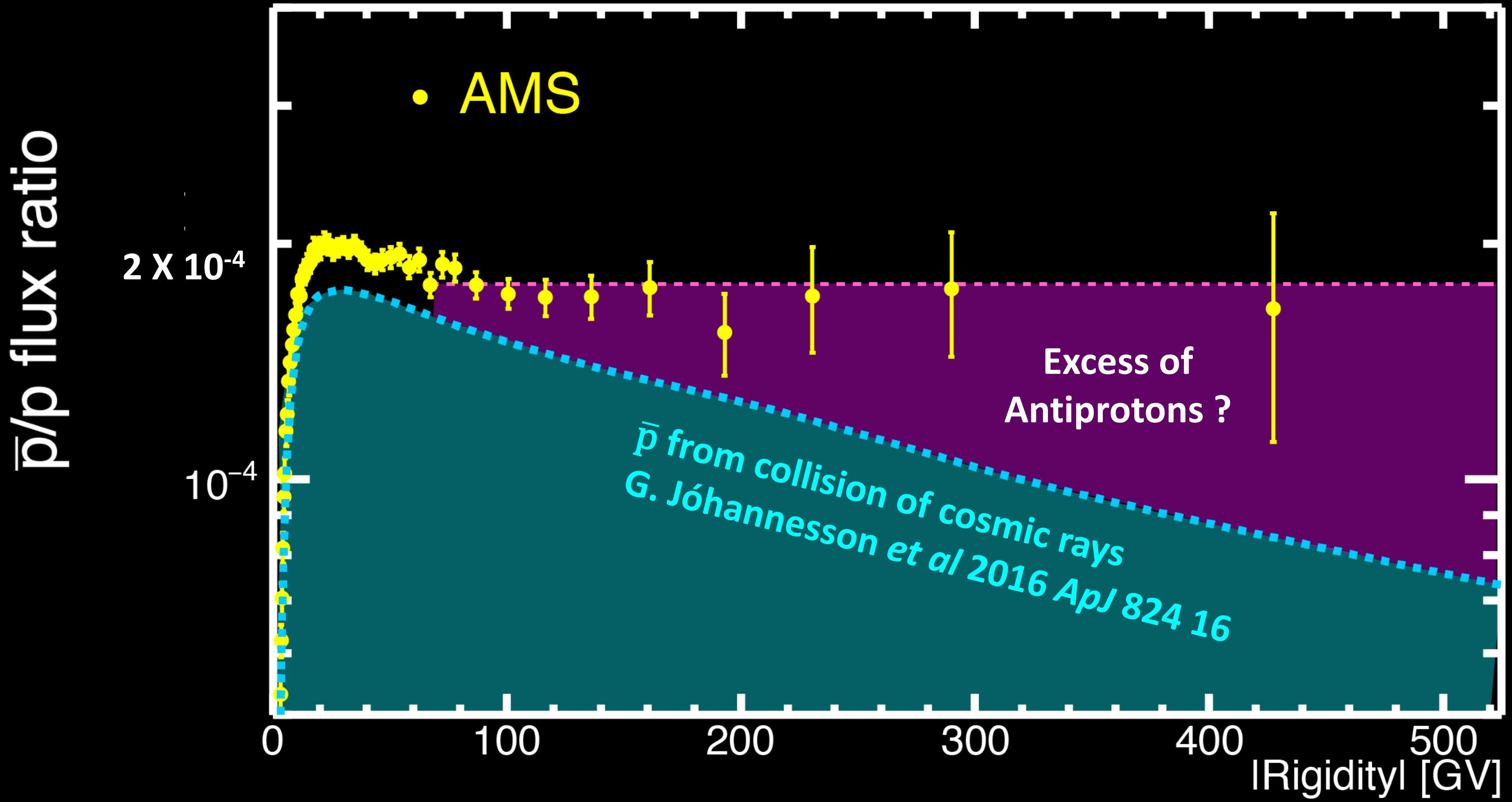
Contradict with traditional cosmic ray model with only secondary $\bar{p}$ produced from collision of cosmic rays



Antiproton-to-Proton flux ratio

The antiproton-to-proton flux ratio shows unexpected energy dependence

Distinctly different from antiprotons from collision of cosmic rays



A sample of recent papers on AMS antiproton data

P. Mertsch *et al.*, **Phys. Rev. D 104 (2021) 103029**

M. Boudaud et al., **Phys. Rev. Research 2, 023022 (2020)**

V. Bresci *et al.,* **Mon. Not. R. Astron. Soc., 488 (2019), p. 2068**

M. Korsmeier *et al.,* **Phys. Rev. D 97 (2018), 103019**

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

I. Cholis *et al.,* **Phys. Rev. D 95(2017), 123007**

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

……

Antiproton production and propagation

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

Y. Genolini *et al.,* **arXiv:2103.04108 (2021)**

I. Cholis *et al.,* **Phys. Rev. D, 99 (2019), 103026**

A. Cuoco *et al.,* **Phys. Rev. D, 99 (2019), 103014**

M. Carena *et al.,* **Phys. Rev. D, 100 (2019), 055002**

A. Reinert *et al.,* **JCAP, 01 (2018), p. 055**

A. Cuoco *et al.,* **Phys. Rev. Lett., 118 (2017), 191102**

M. Cui *et al.,* **Phys. Rev. Lett., 118 (2017), 191101**

Y. Chen *et al.,* **Phys. Rev. D, 93 (2016), p. 015015**

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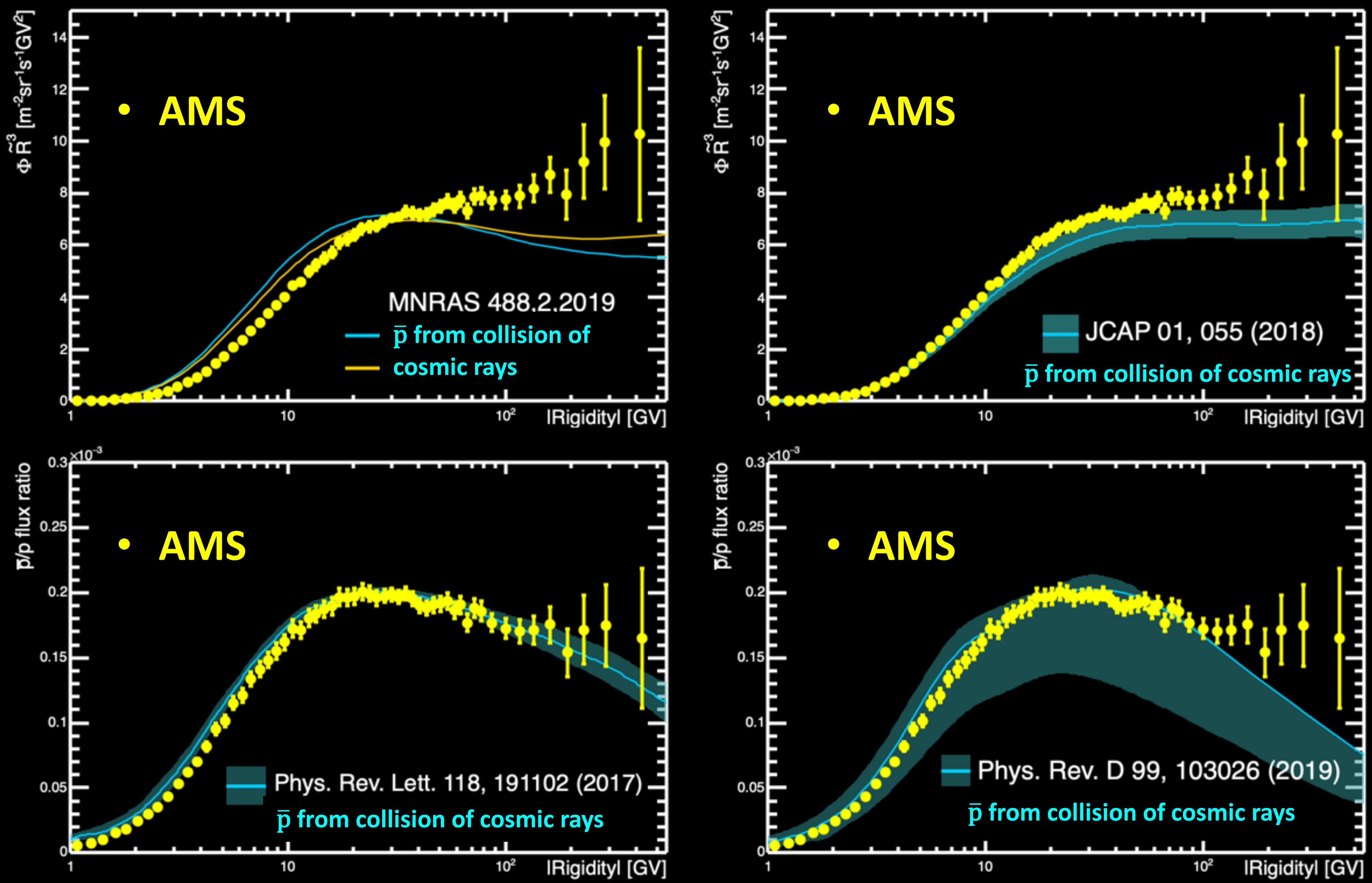
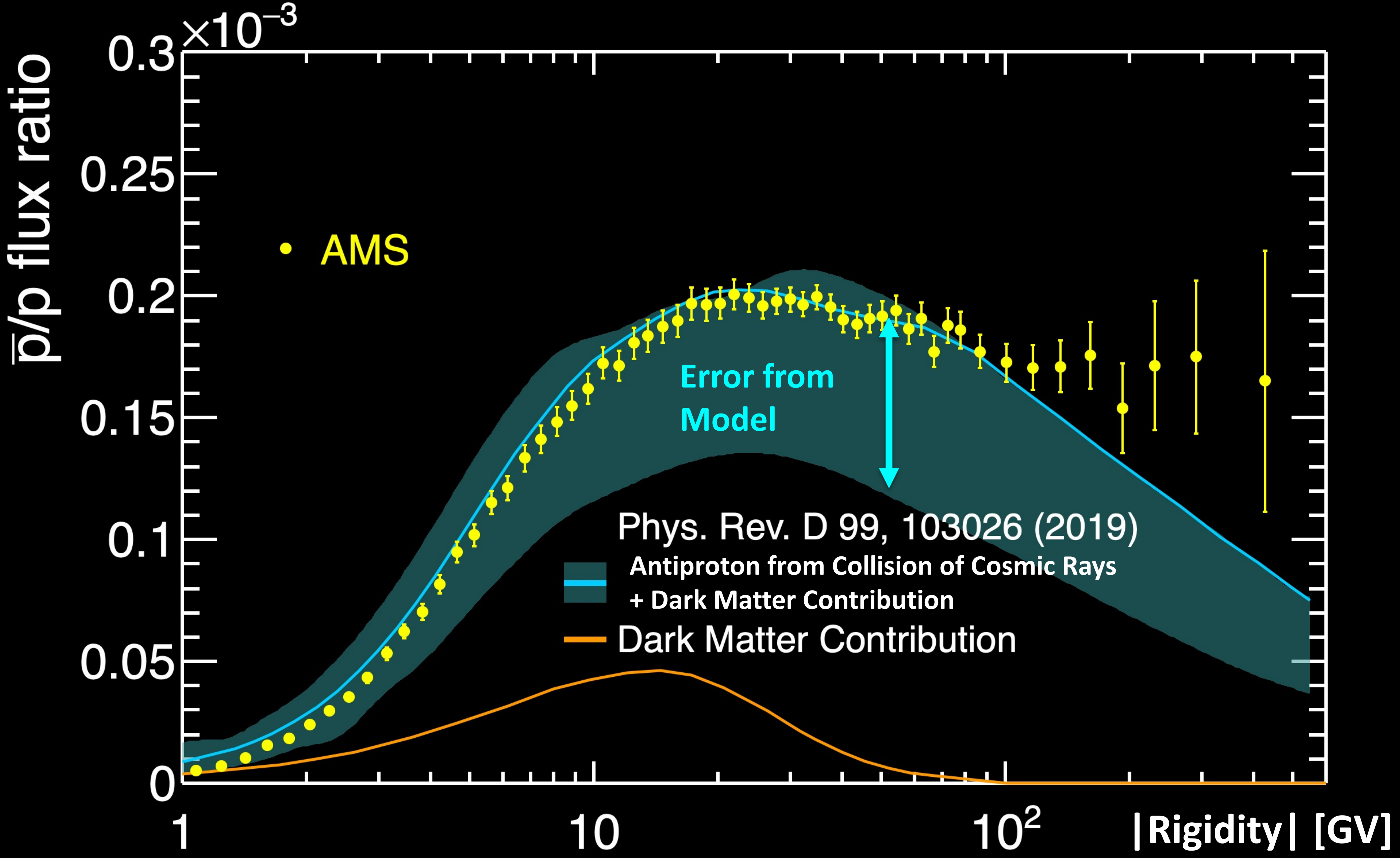
Antiprotons from Dark Matter

Example: AMS Antiproton Results compared with Cosmic Ray Models Based on AMS Data

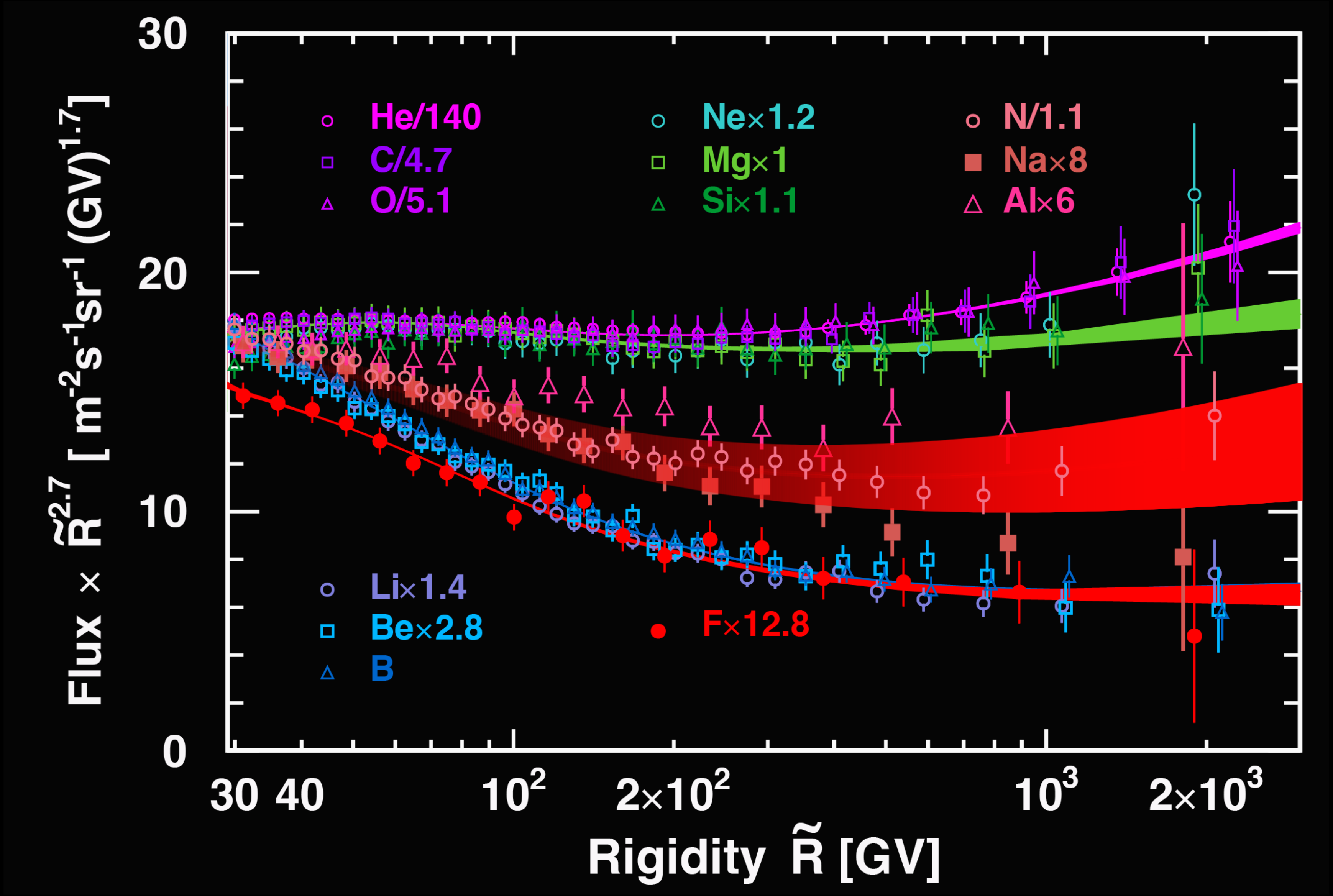


Example: AMS Antiproton Results Compared with Low Mass Dark Matter Model



Understanding Antiprotons with AMS Measurements

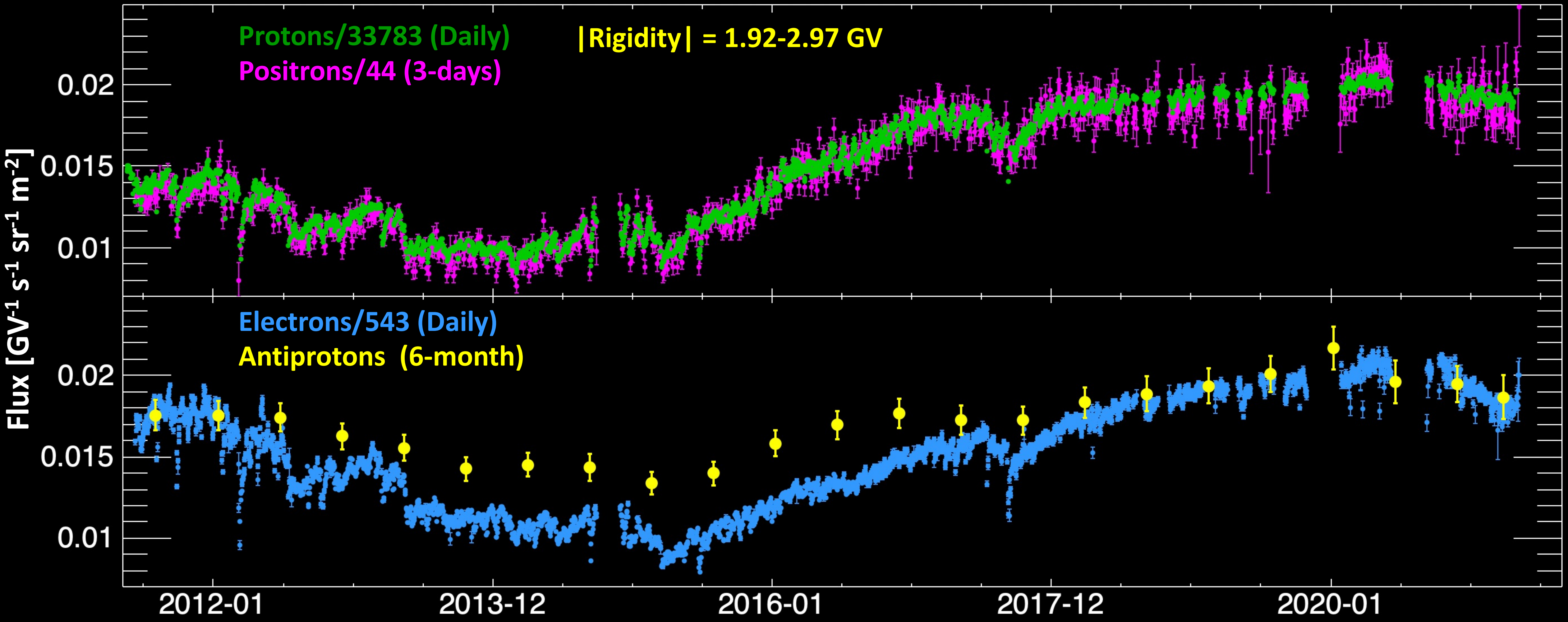
Precision AMS measurement significantly improves the understanding of cosmic ray propagation



See presentations of Drs. Y. Jia, V. Formato, and Y. Chen

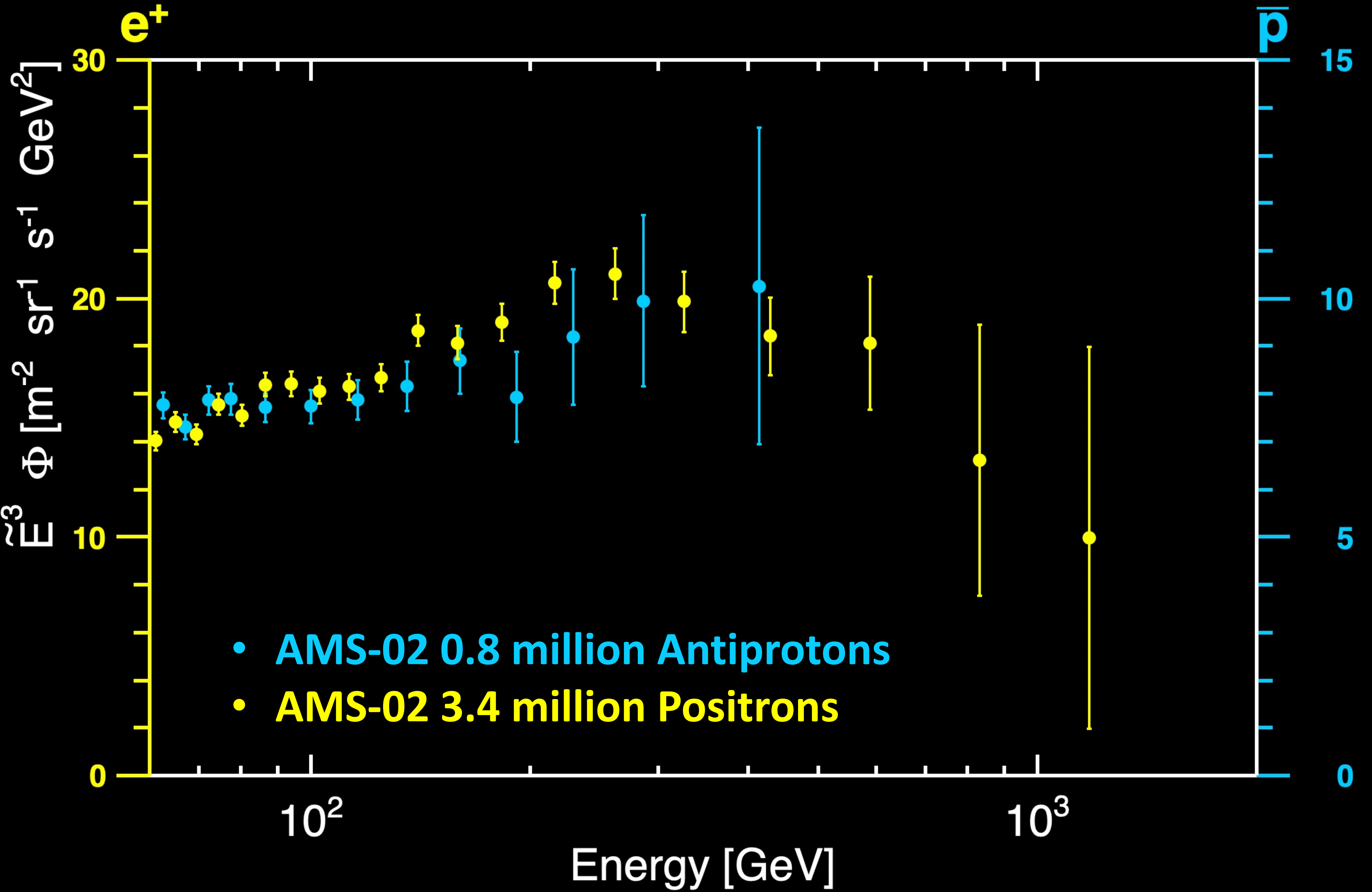
Understanding Antiprotons with AMS Measurements

AMS is the only instrument to measure positive charge and negative charge particles fluxes across entire solar cycle.



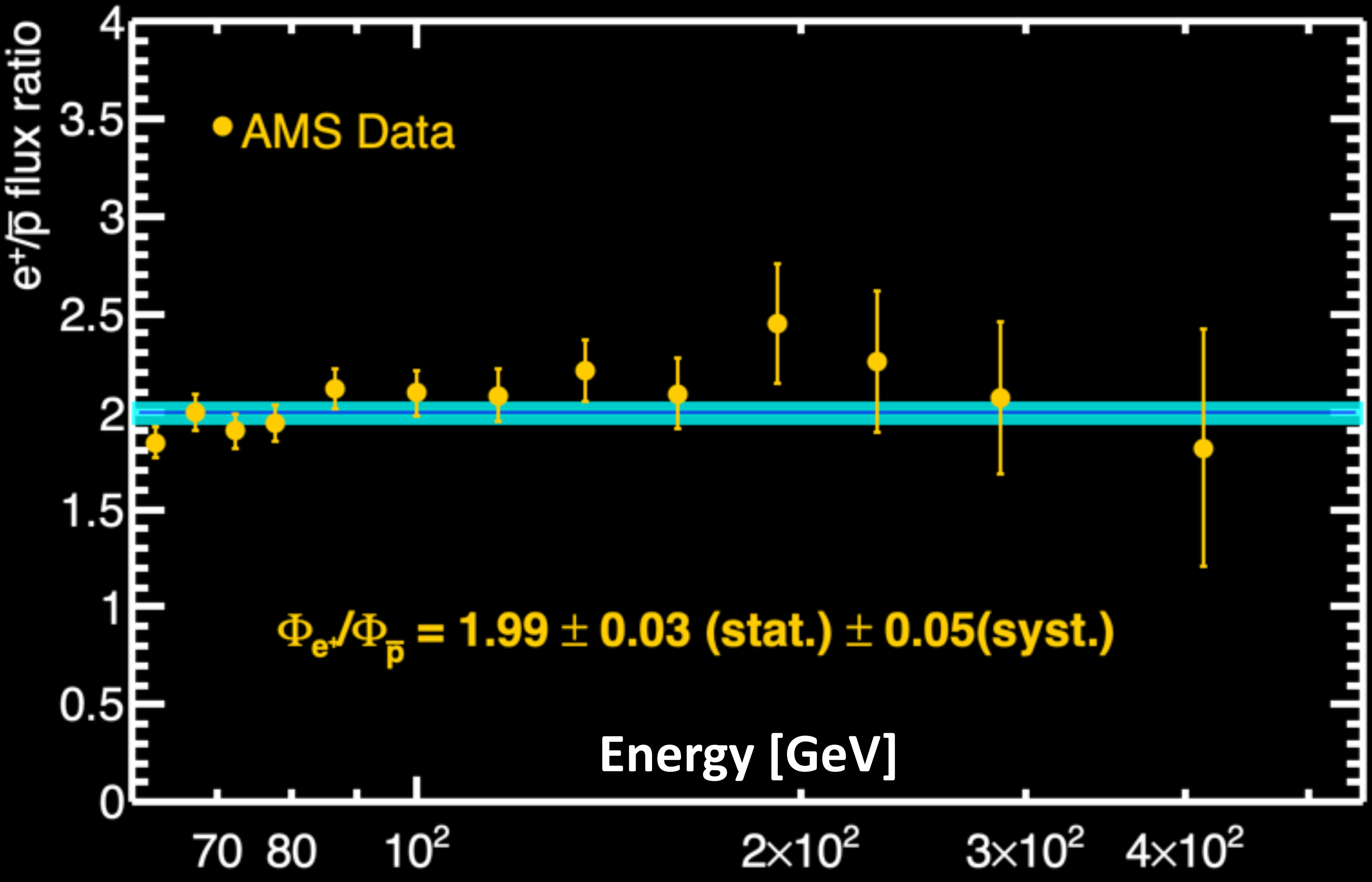
Unique Observation from AMS:

Positron and Antiproton have nearly identical energy dependence.



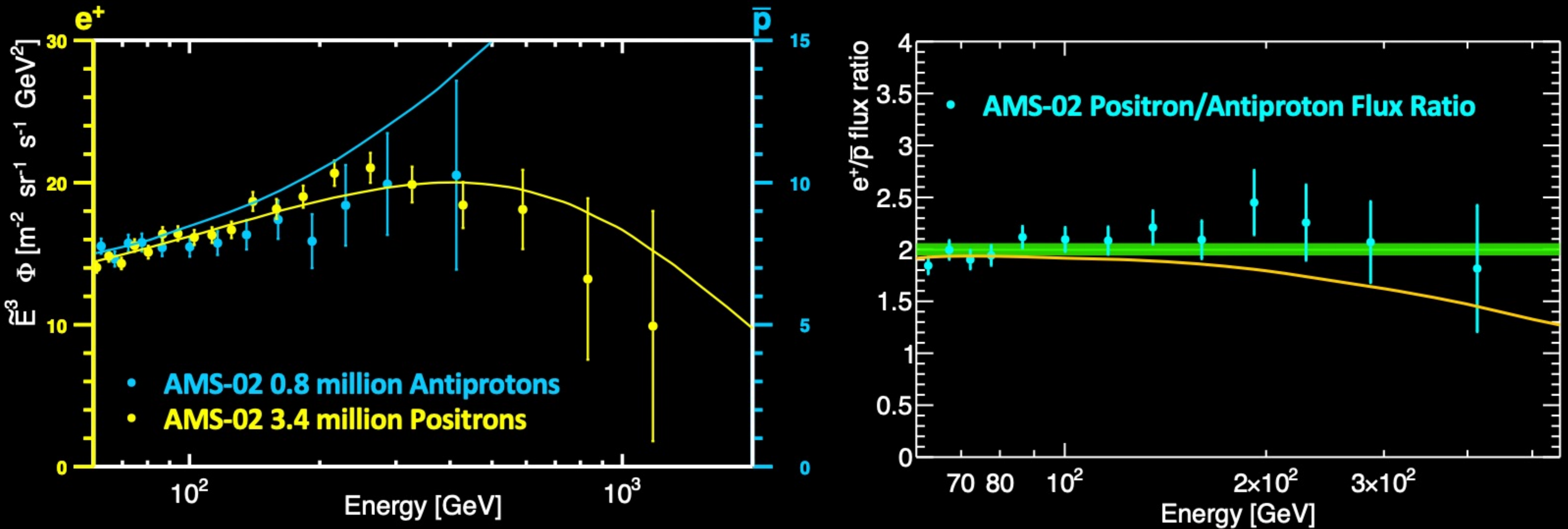
Unique Observation from AMS:

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



Antiprotons cannot come from pulsars.

Example: Positron and Antiproton spectra compared with recent model

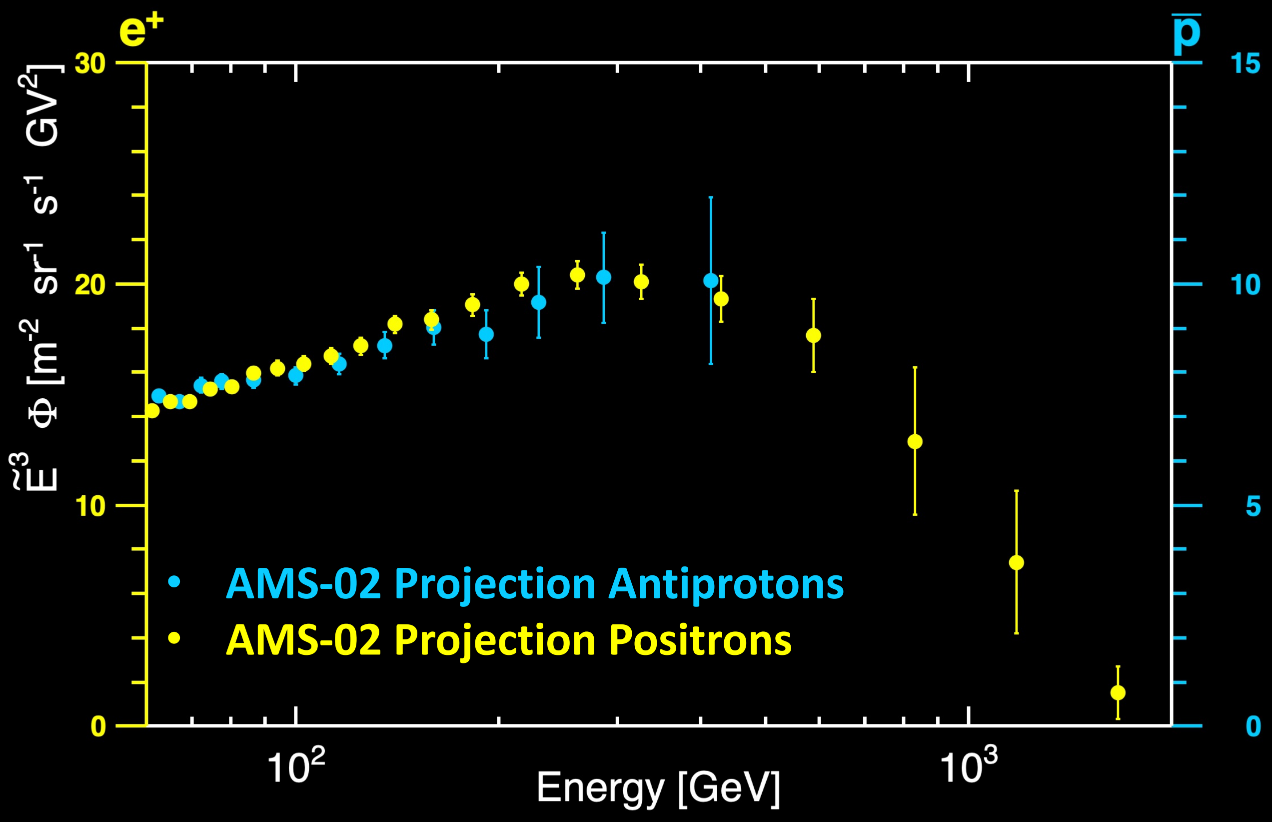


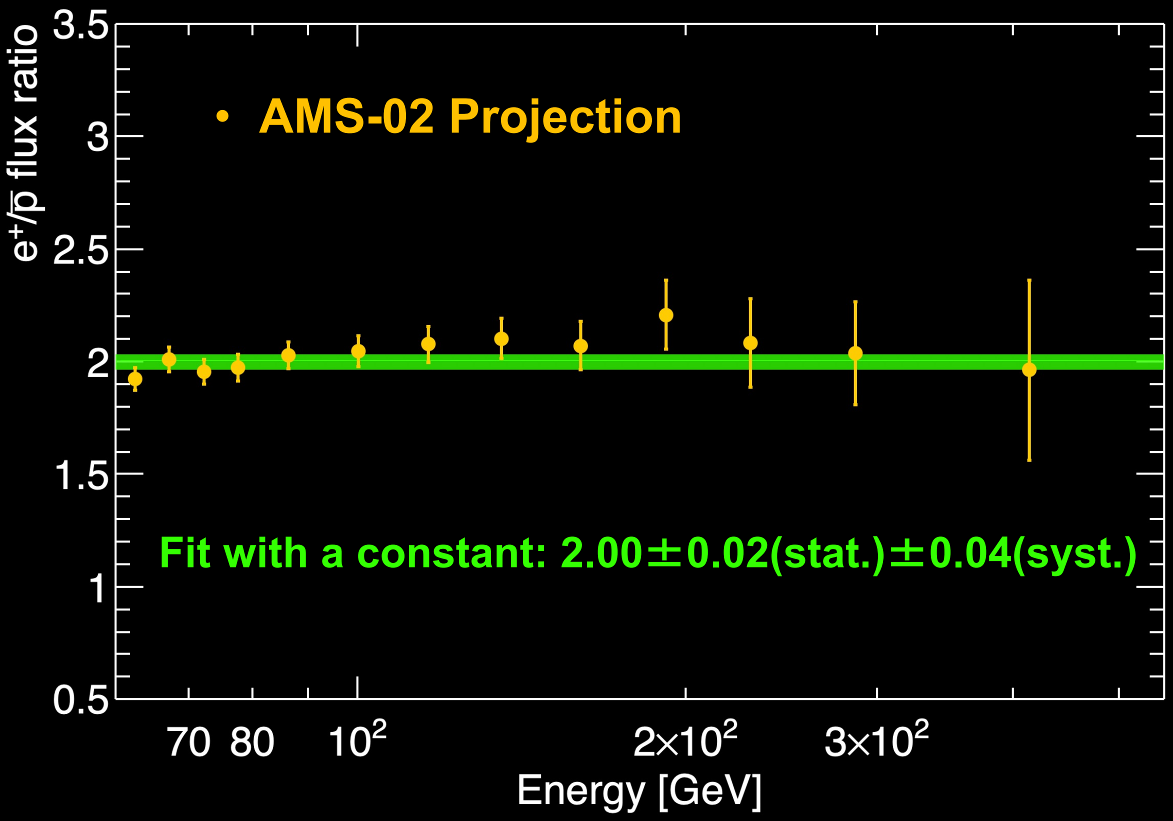
Model Example:

P. Mertsch, A. Vittino, S. Sarkar, PRD 104 (2021) 103029

"Explaining cosmic ray antimatter with secondaries from old supernova remnants"

Future Measurement of Antiproton and Positrons with AMS Upgrade





AMS will greatly improve the accuracy of the measurement of the positrons and antiprotons

The identical behaviour of positrons and antiprotons excludes the pulsar origin of positrons

By simultaneous measurement of cosmic protons, electrons, antiprotons, and positrons through the lifetime of the space station,

AMS will provide the definitive dataset to resolve the mystery of the origin of elementary particles in cosmic rays.