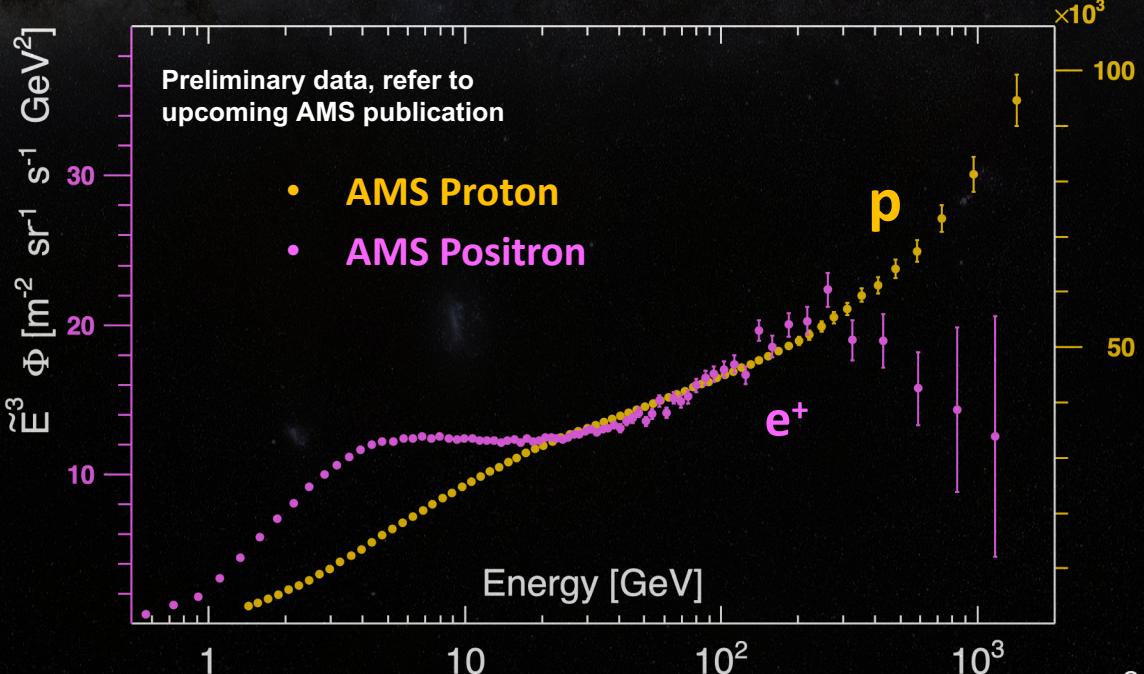
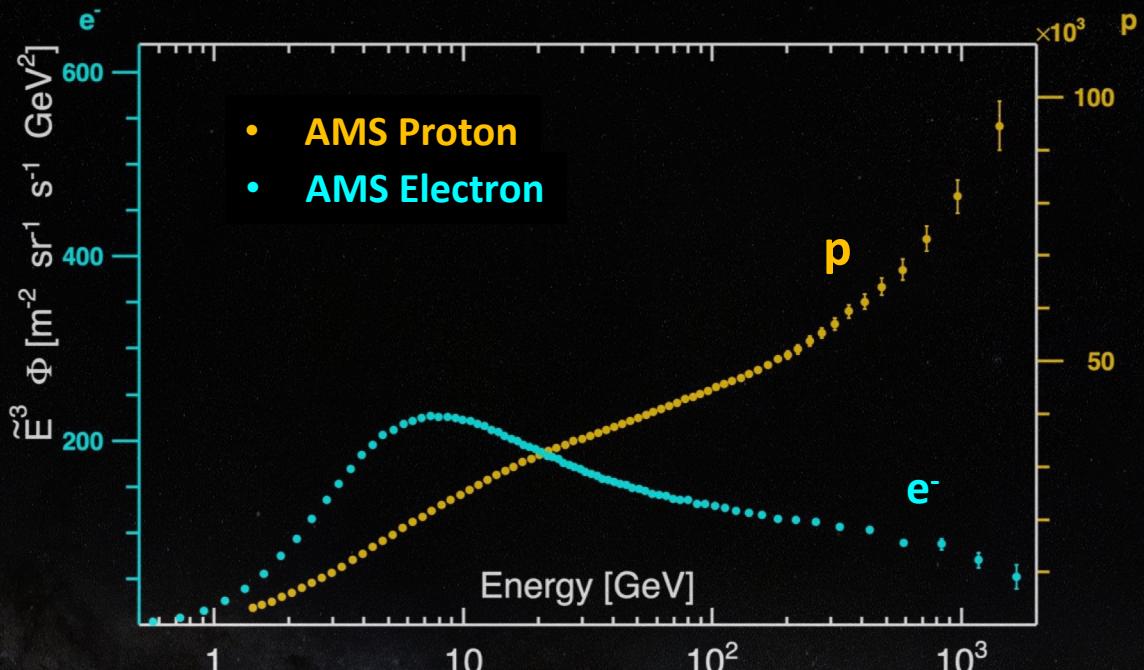
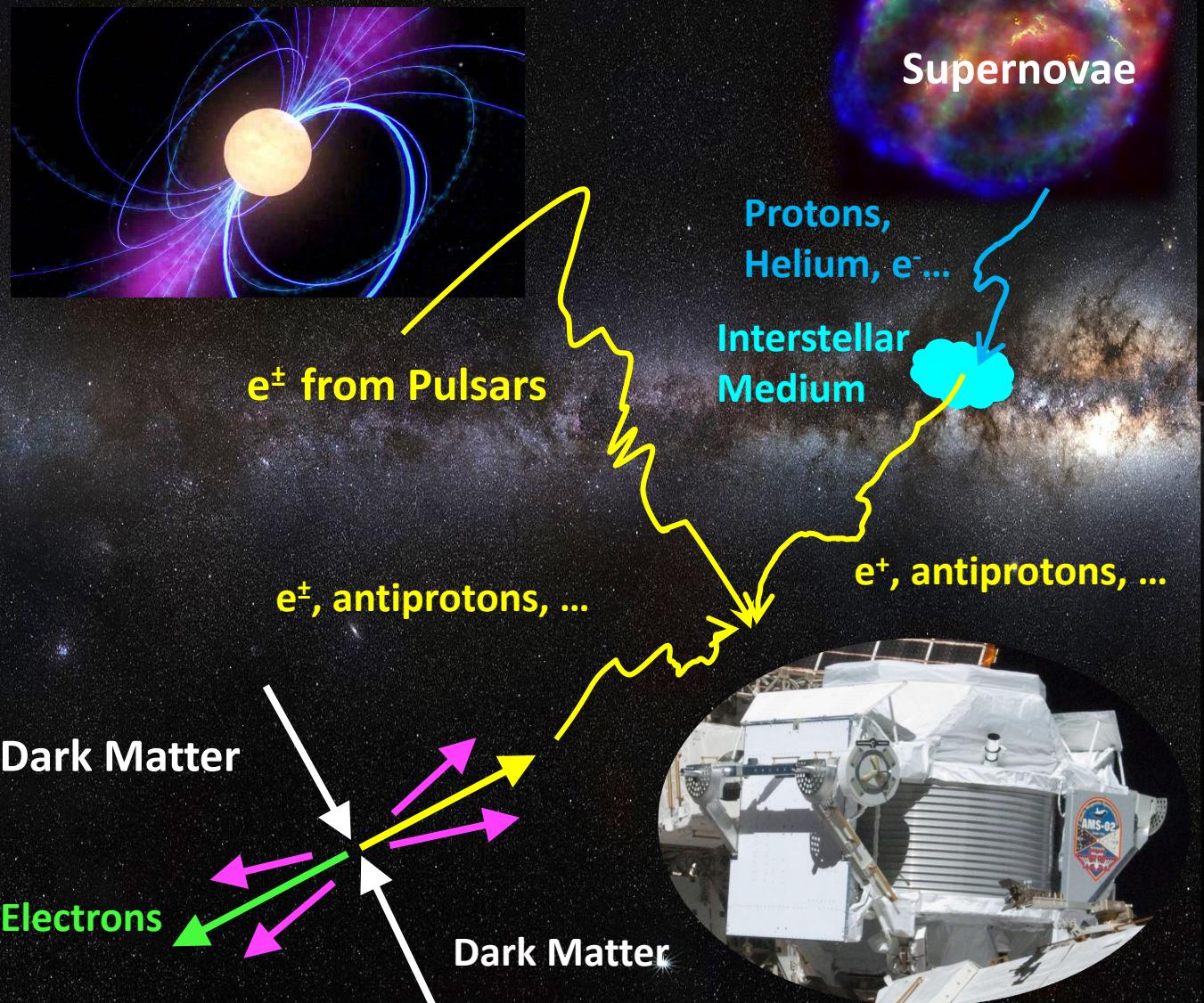


# Antiproton Flux and Properties of Elementary Particle Fluxes Measured with AMS



# Elementary Particles in Cosmic Rays

New Astrophysical Sources: Pulsars, ...

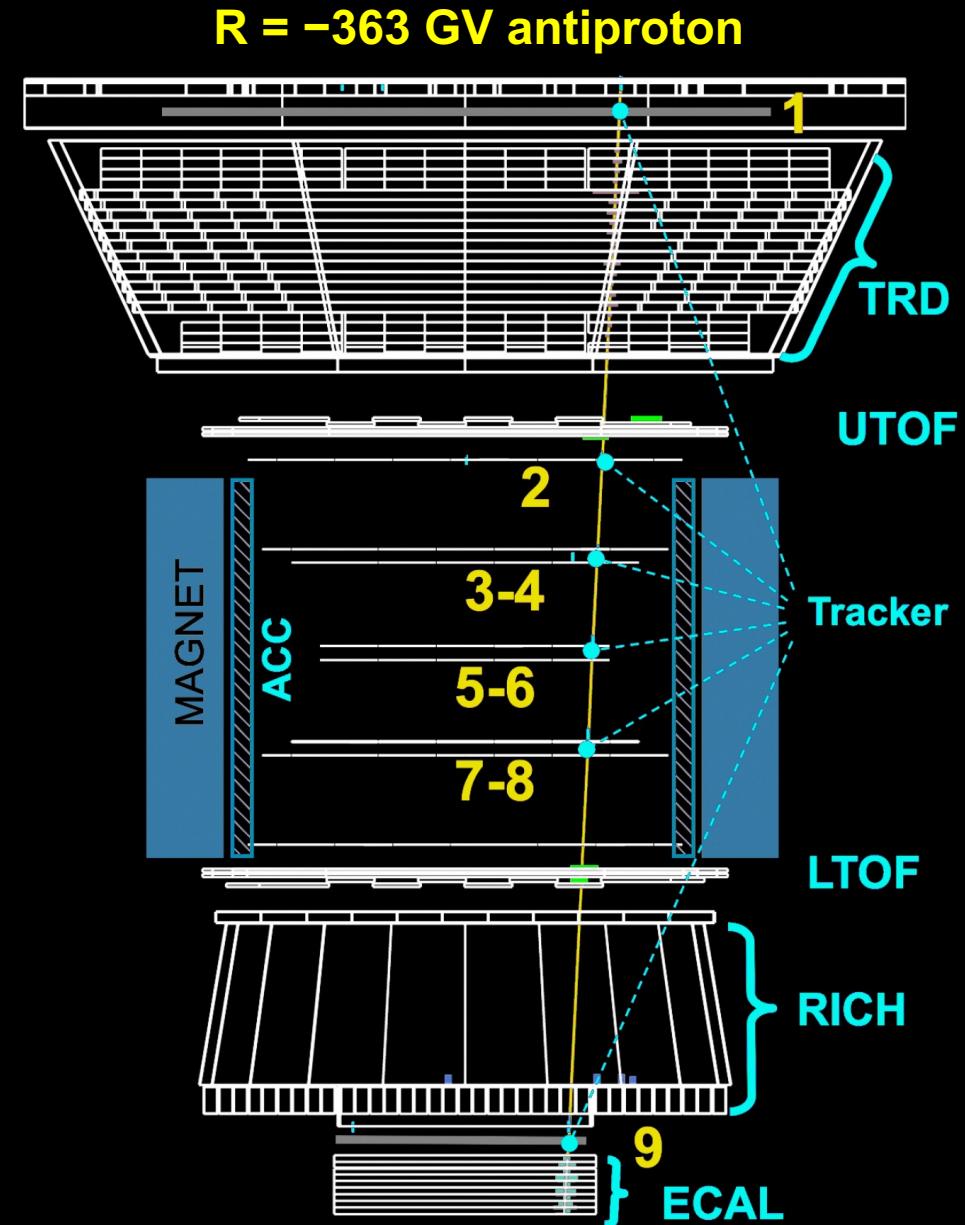


# Antiproton Measurements with AMS

The Antiproton Flux is  $\sim 10^{-4}$  of the Proton Flux.

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

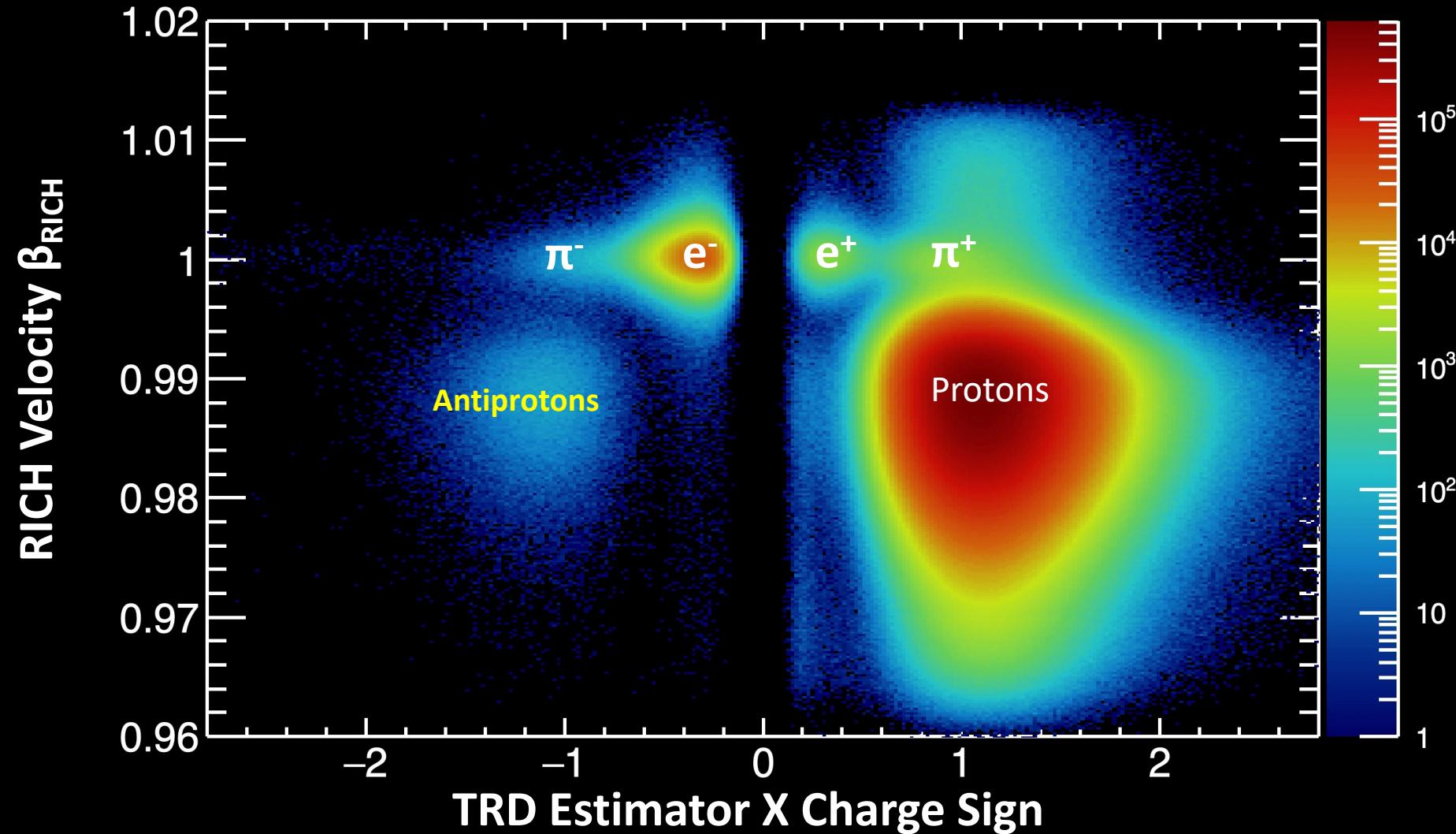
- Tracker & Magnet: measure rigidity, separate antiprotons from protons
- TRD & ECAL: reject electron background
- TOF & RICH: select down going particle and measure velocity



# Antiproton Analysis Overview

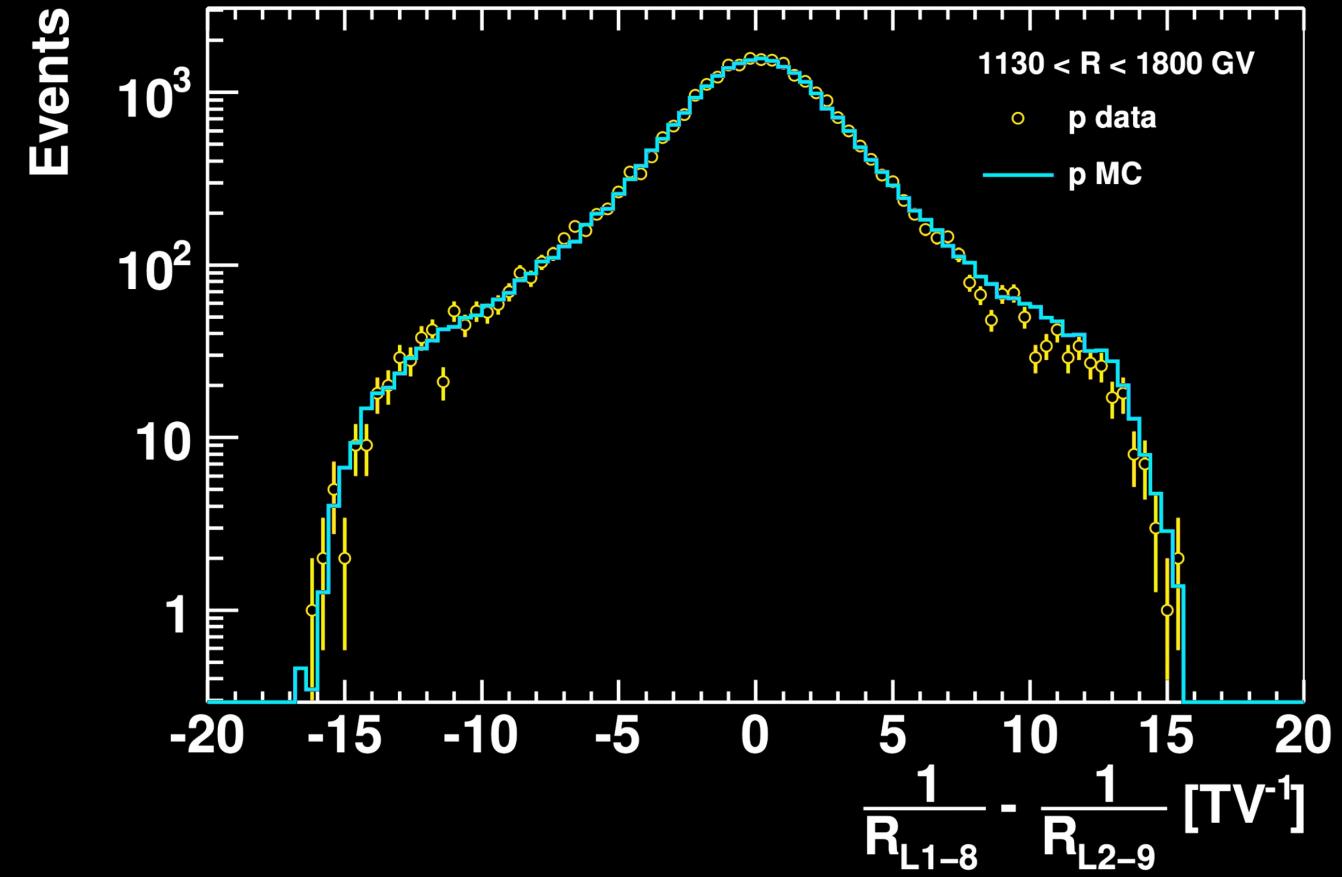
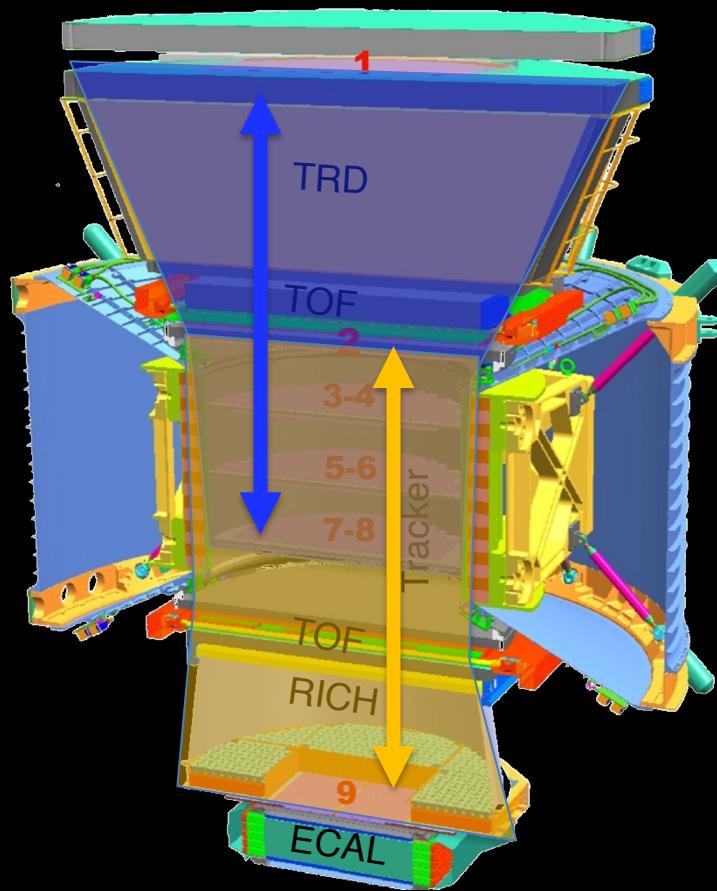
Use TOF, RICH, and TRD identify antiproton from backgrounds

Example: Data Sample composition in  $|{\text{Rigidity}}|=6 \text{ GV}$



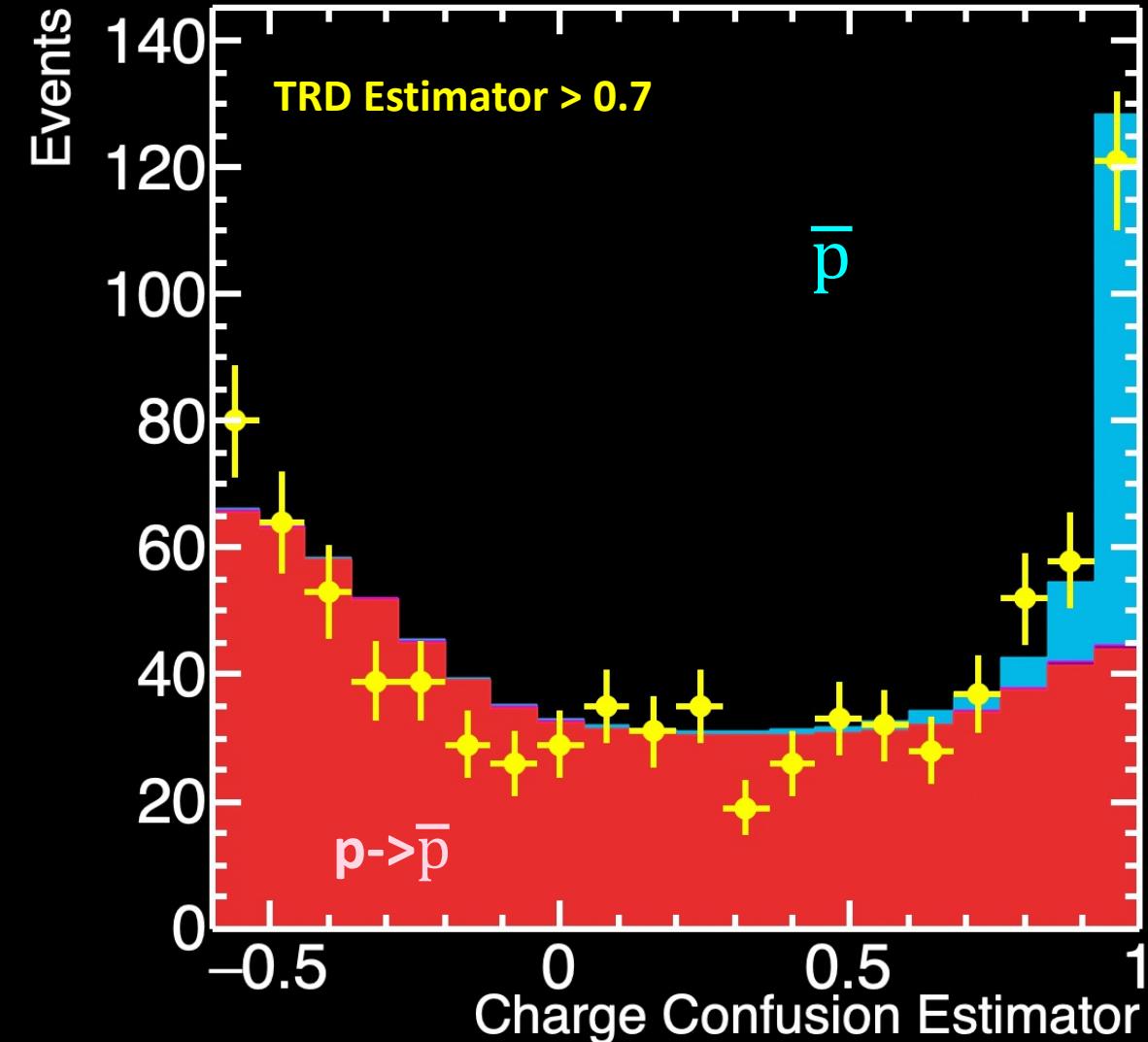
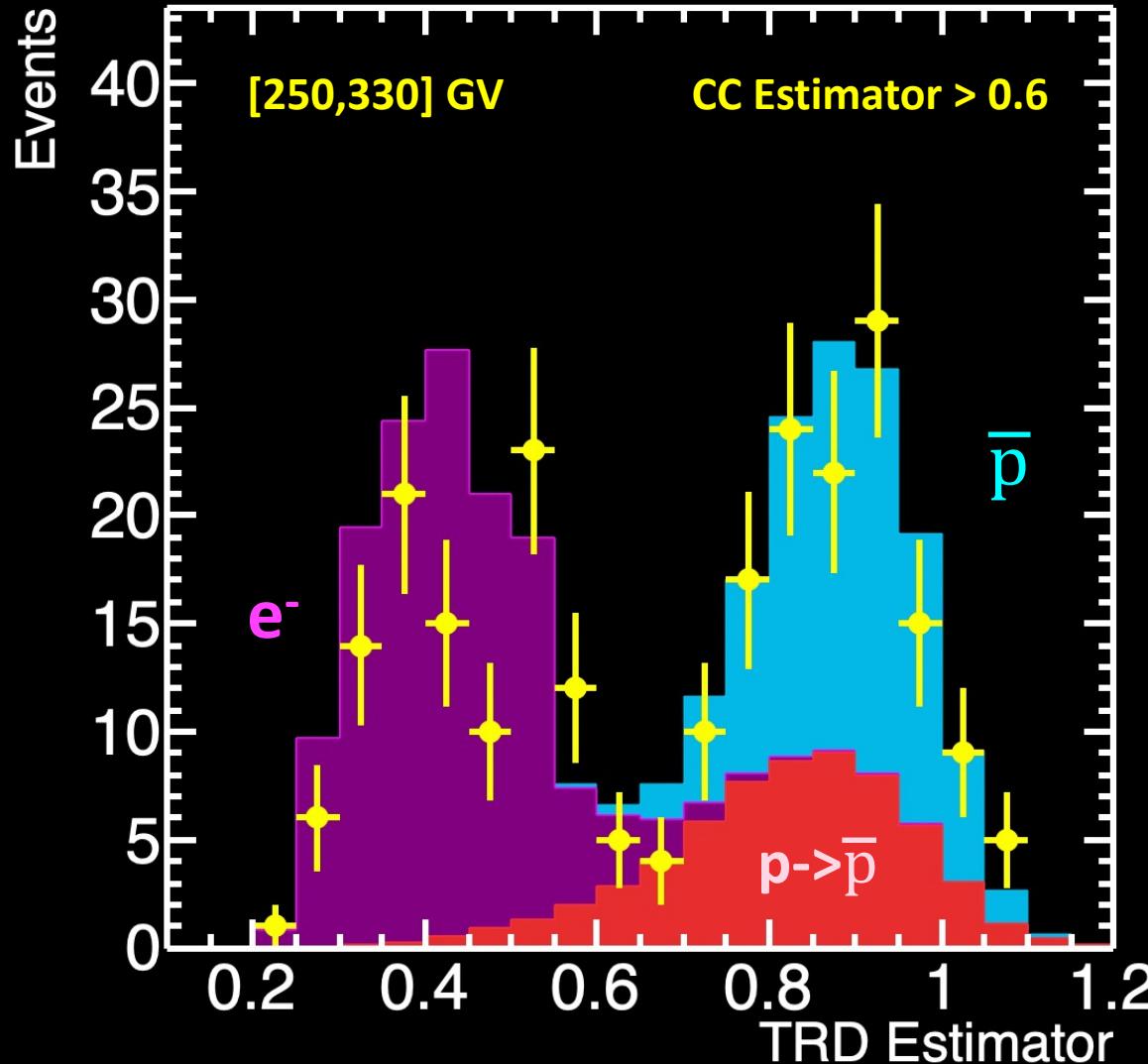
# Antiproton Analysis Overview

- **High Rigidity [16, 525] GV**
  - Background from electron and proton charge confusion.
  - Use TRD and ECAL to identify electrons.
  - **Proton charge confusion is the most important background.**
  - **Unique Feature of AMS: Use cosmic ray to verify detector performance beyond test beam energies.**



# 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

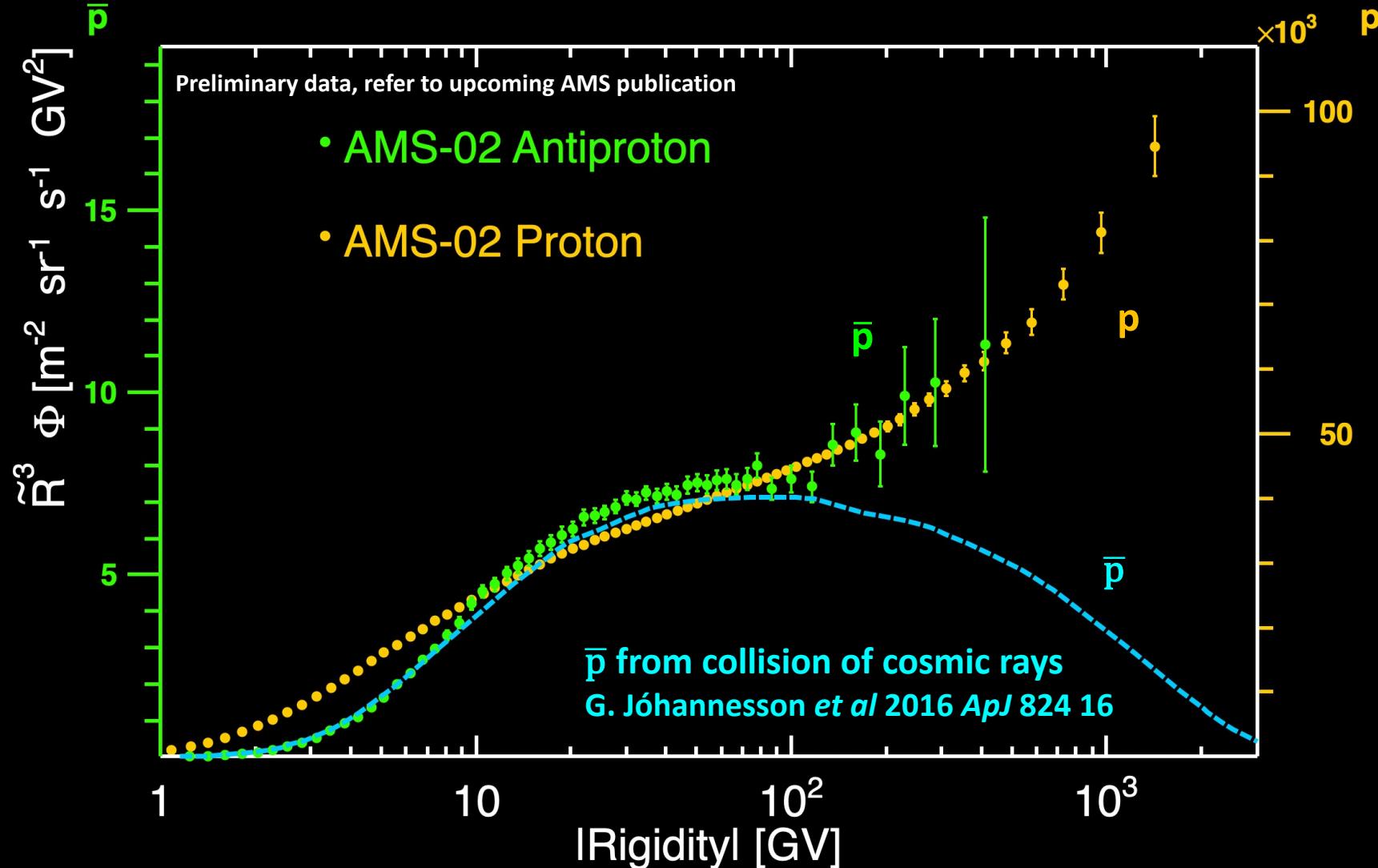


In 12 years, AMS has identified over 1.1 million antiprotons from 1 to 525 GV

# Precision study of the properties of antiproton flux

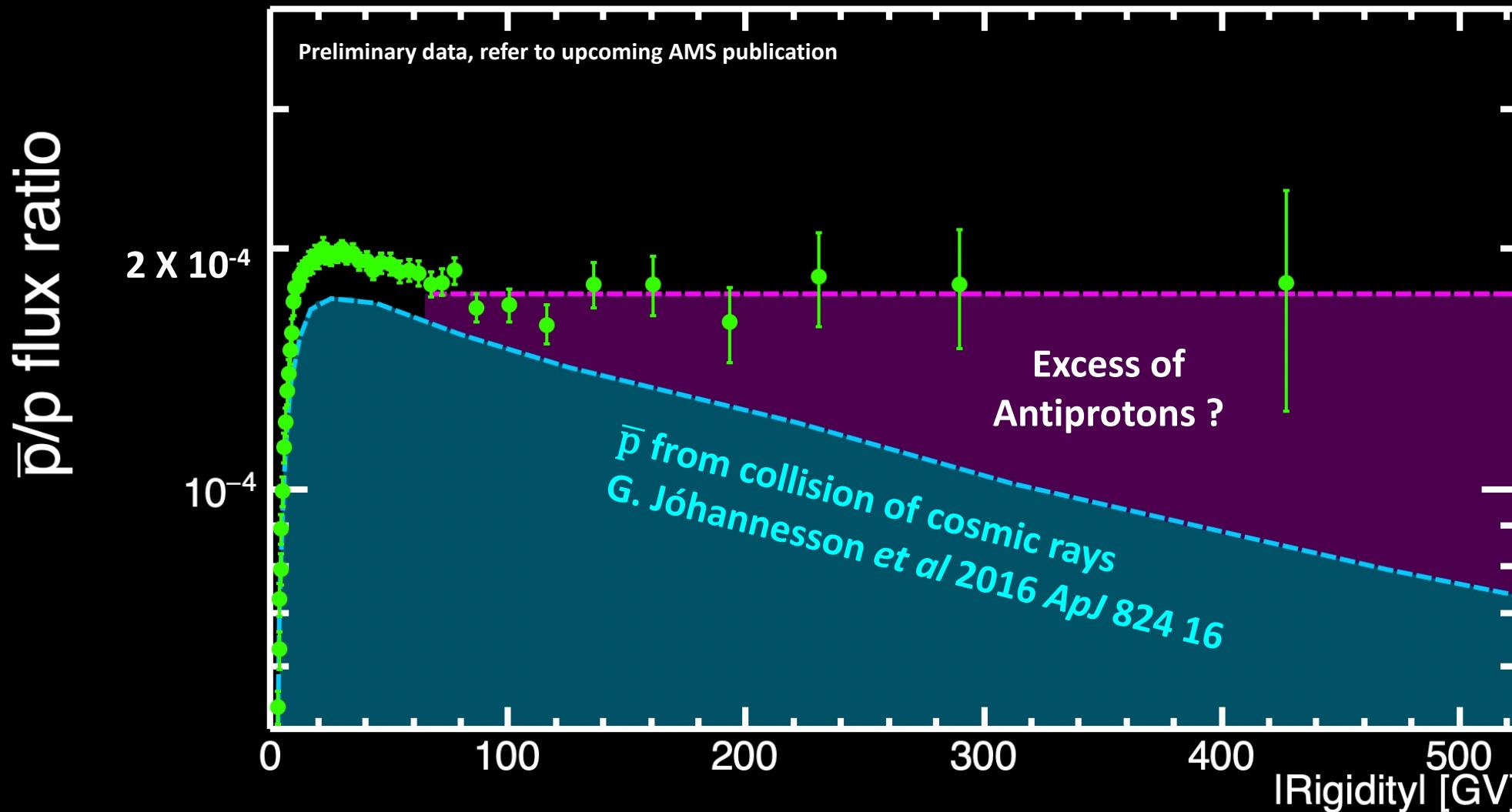
AMS measurements show that  $p$  and  $\bar{p}$  have identical rigidity dependence

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

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- I. Cholis *et al.*, **JCAP**, 10 (2022) 051
- P. De La Torre Luque, **JCAP**11(2021) 018
- 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

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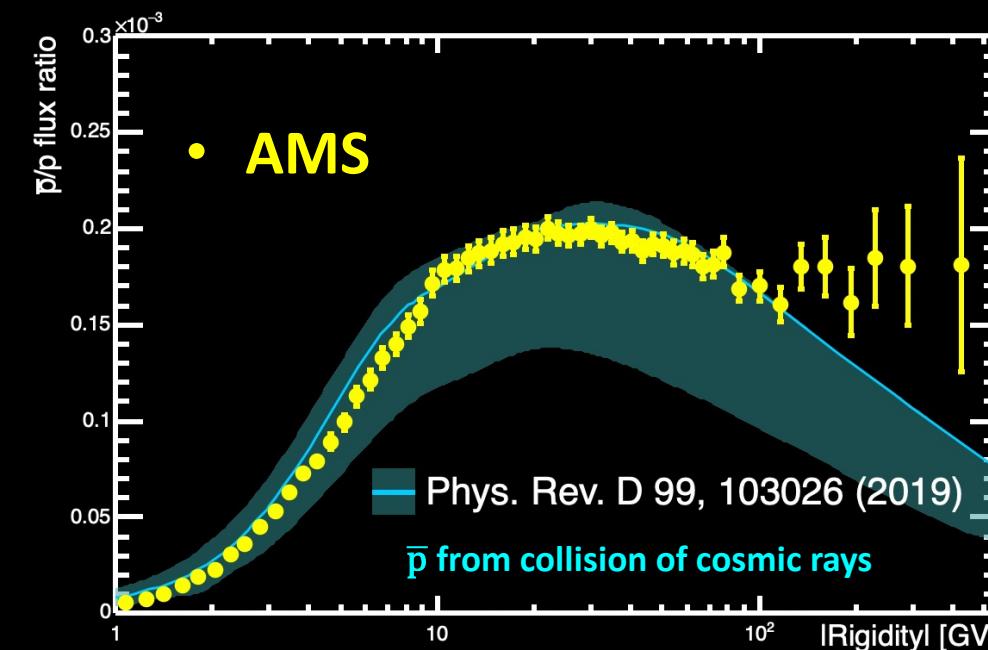
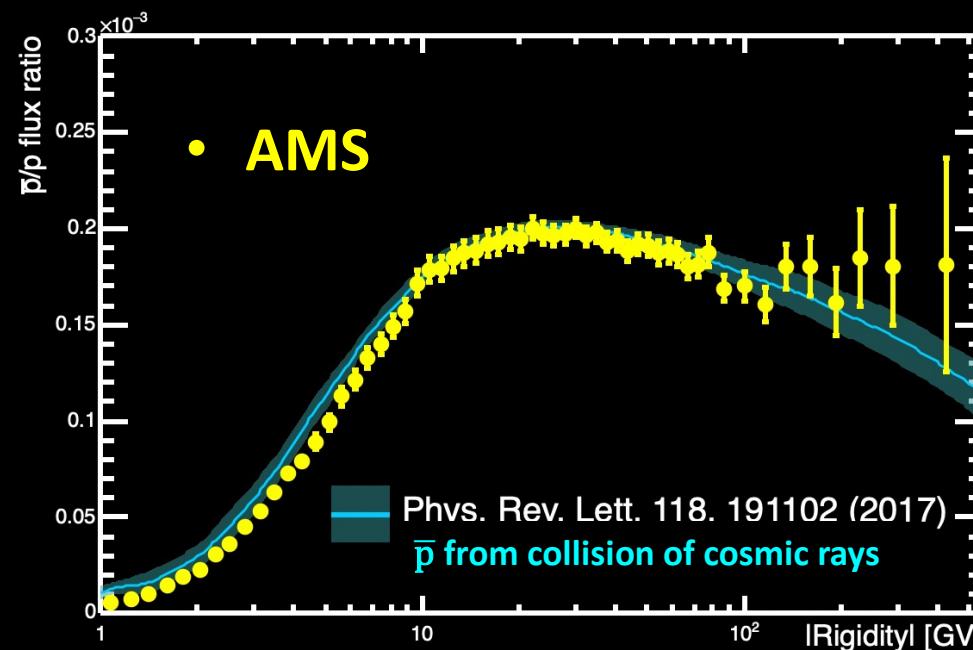
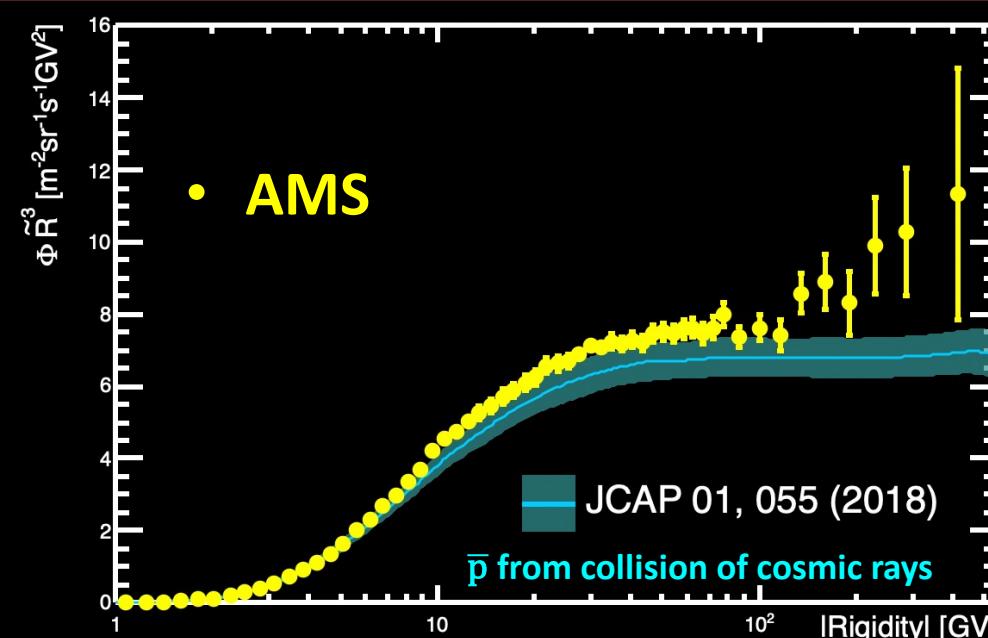
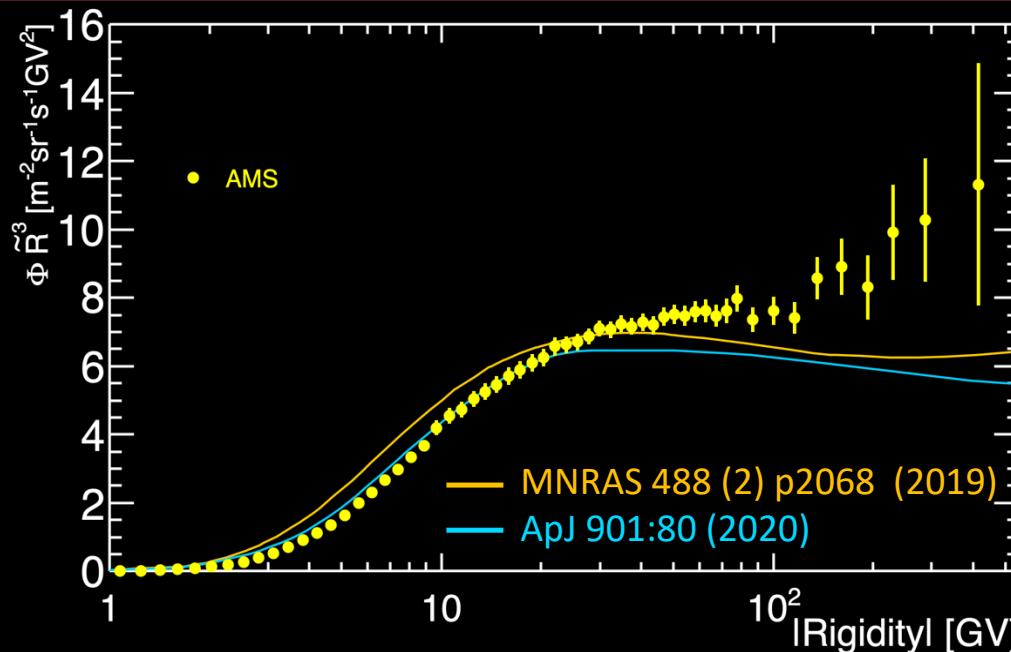
- X. Qin, **Phys. Rev. D.**, 107 (2023), 095026
- C. Zhu, **Phys. Rev. Lett.**, 129 (2022), 231101
- J. Heisig, **Modern Physics Letters A**, (2021), 36, 05
- Y. Genolini *et al.*, **arXiv:2103.04108** (2021)
- I. Cholis *et al.*, **Phys. Rev. D**, 99 (2019), 103026
- A. Cuoco *et al.*, **Phys. Rev. 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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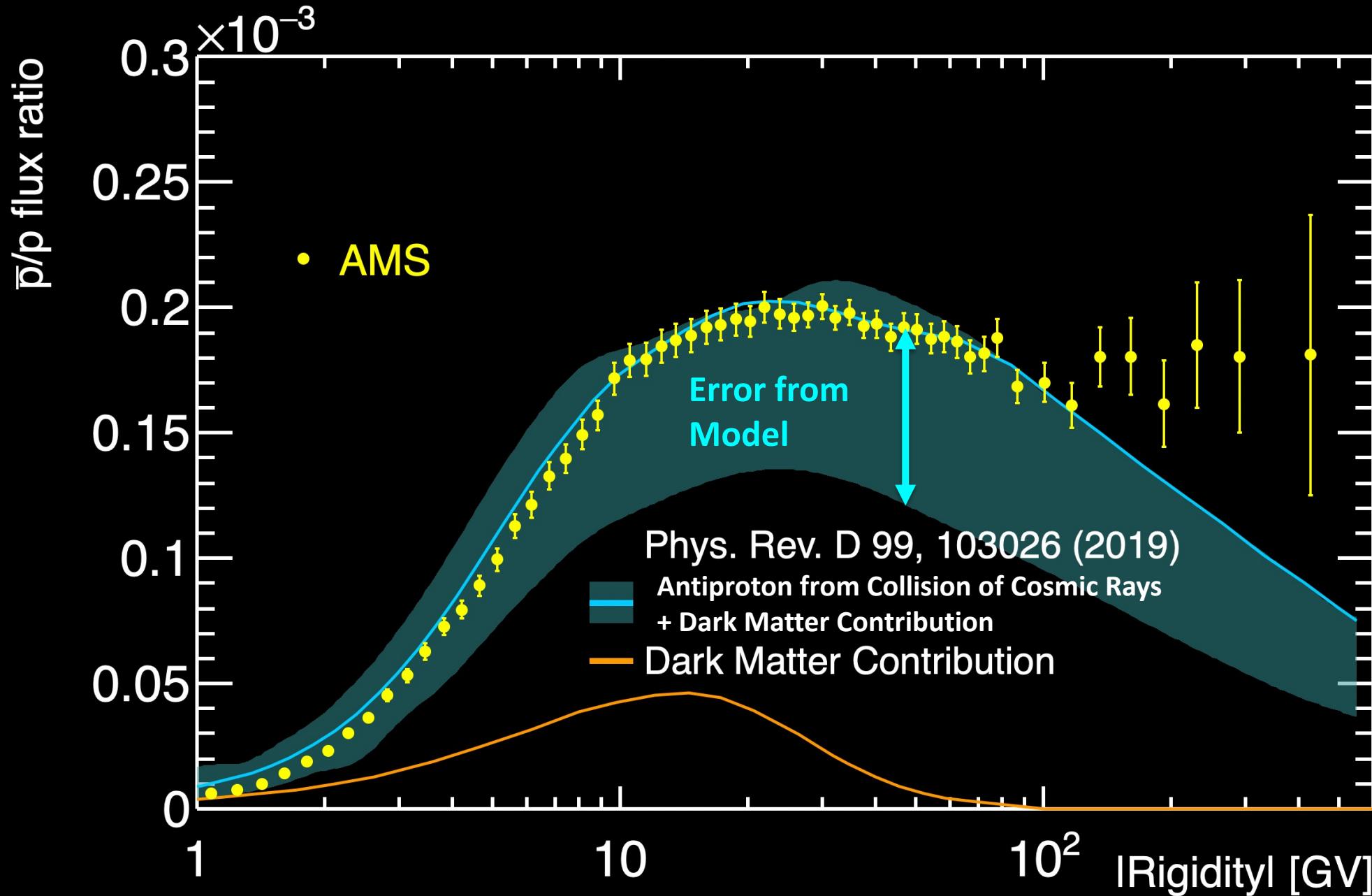
**Antiproton  
production  
and  
propagation**

**Antiprotons  
from  
Dark Matter**

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

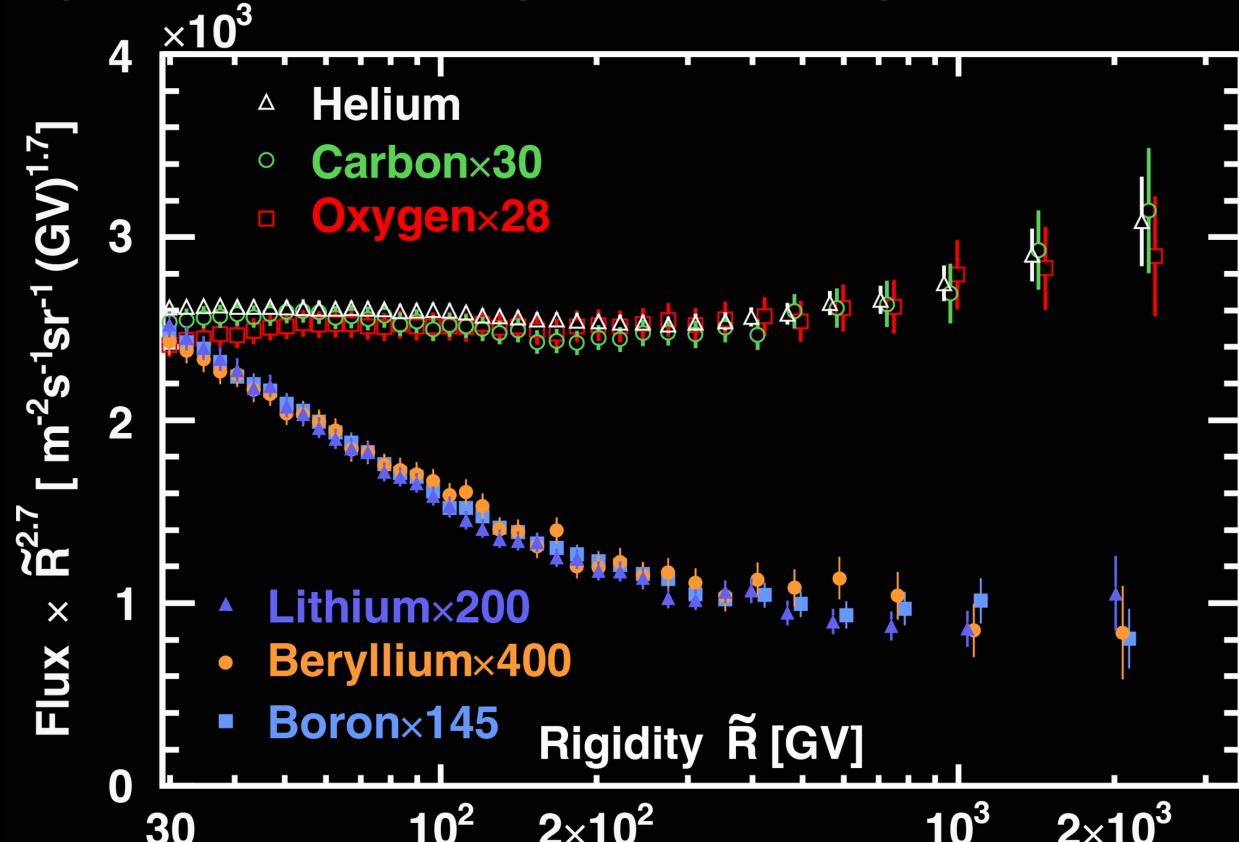
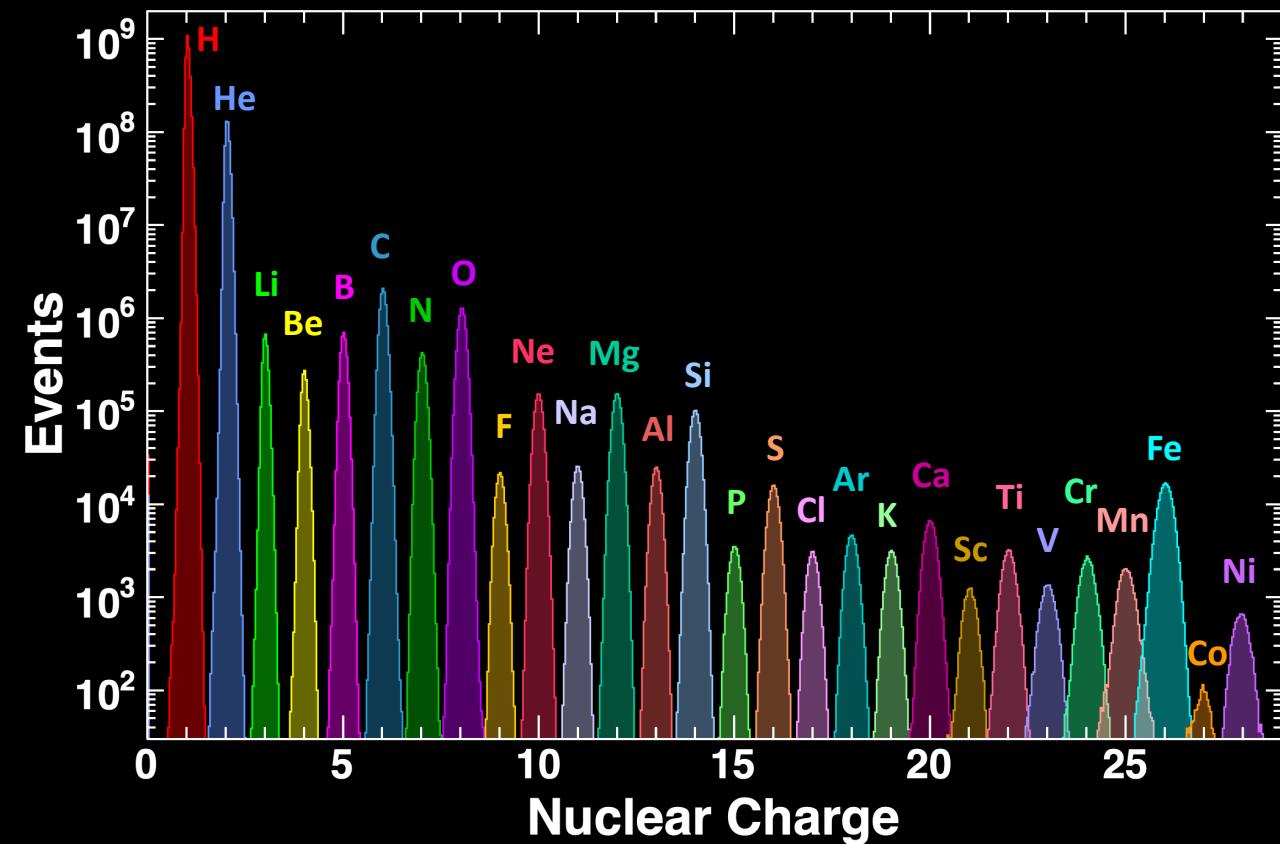


## Example: AMS Antiproton Results Compared with Low Mass Dark Matter Model



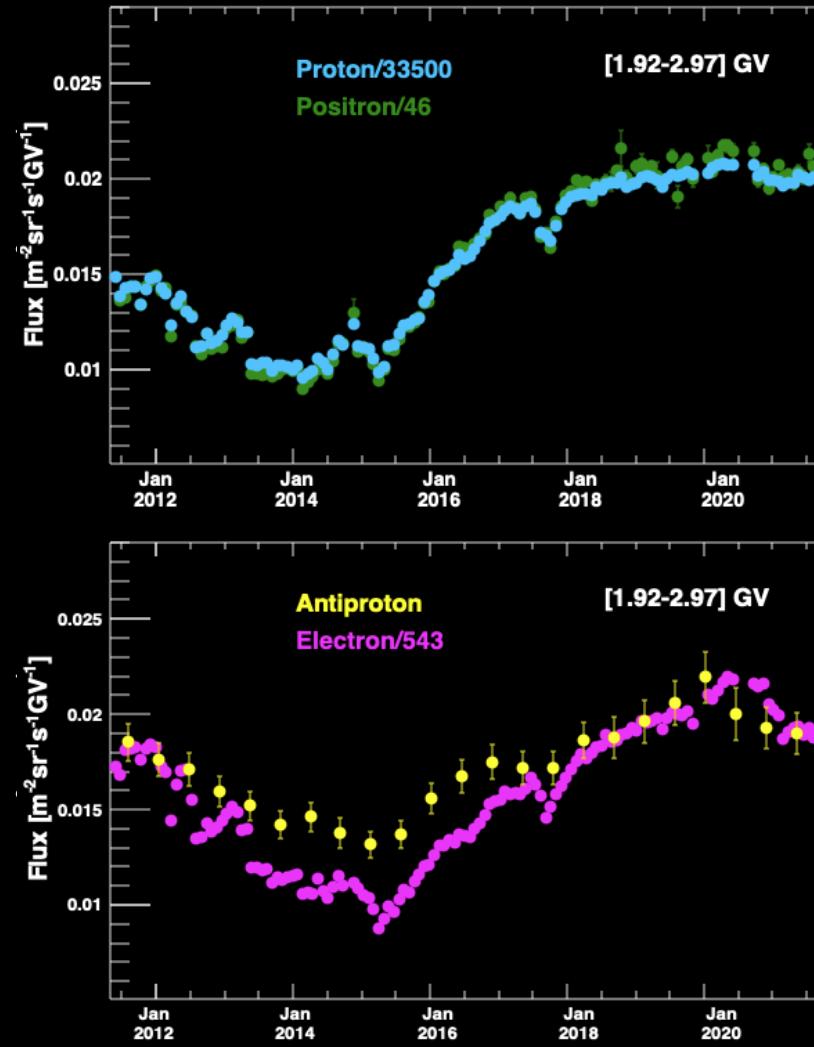
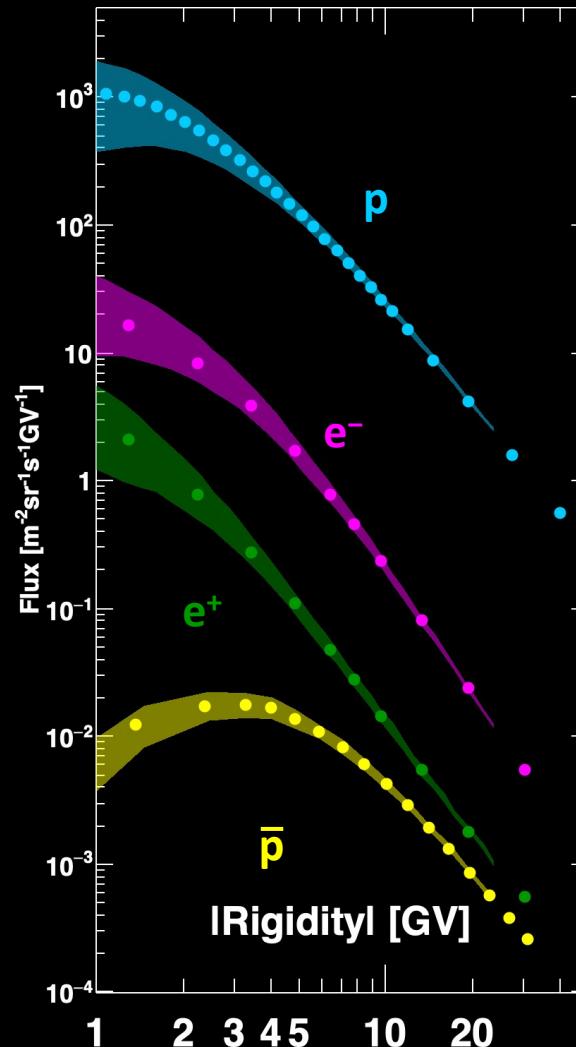
# Understanding Antiprotons with AMS Measurements

Precision AMS measurement continues to provide a complete and accurate spectrum for the all cosmic ray nuclei and provide the foundation for a comprehensive theory of cosmic rays.

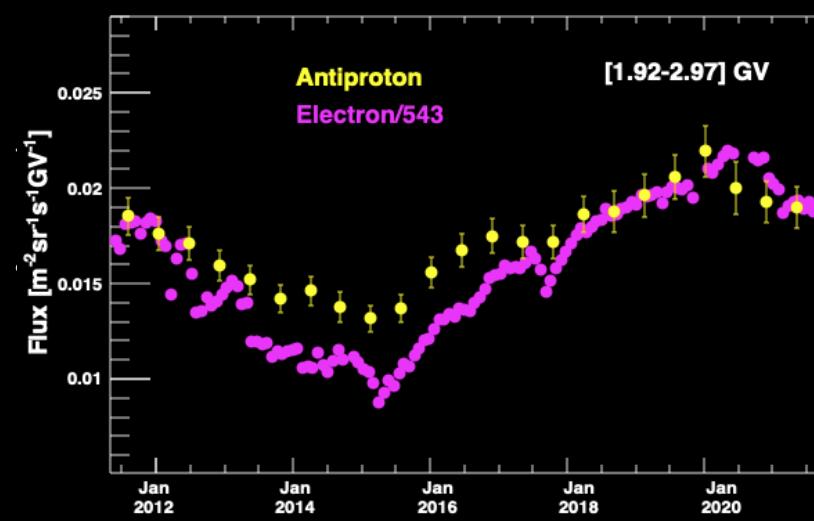


# Understanding Antiprotons with AMS Measurements

For the first time, the time dependence of 4 elementary ( $e^+$ ,  $e^-$ ,  $p$ ,  $\bar{p}$ , ...) are studied in detailed with the same experiment in a long duration



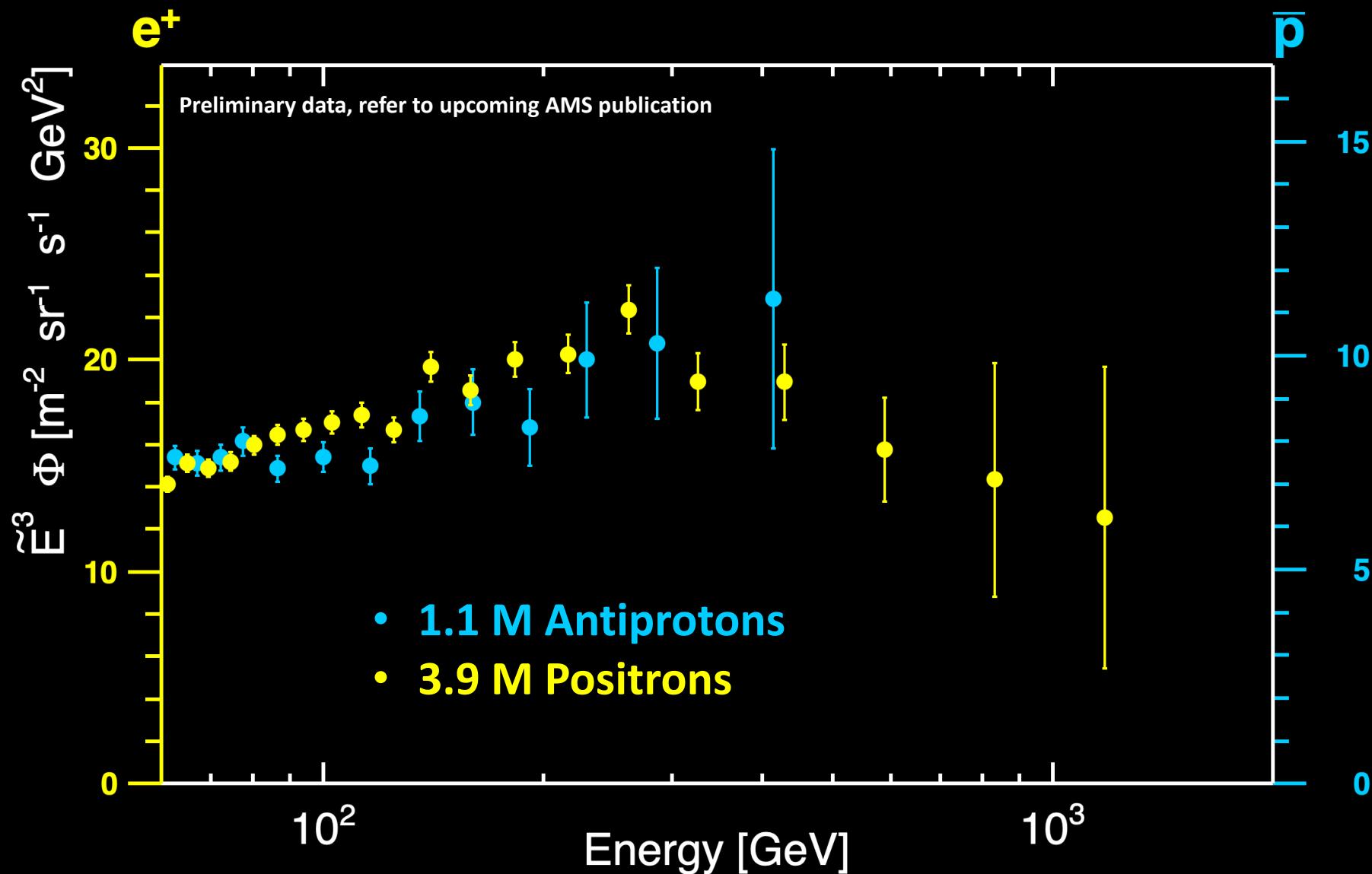
Future AMS Measurements to 2030



Future AMS Measurements to 2030

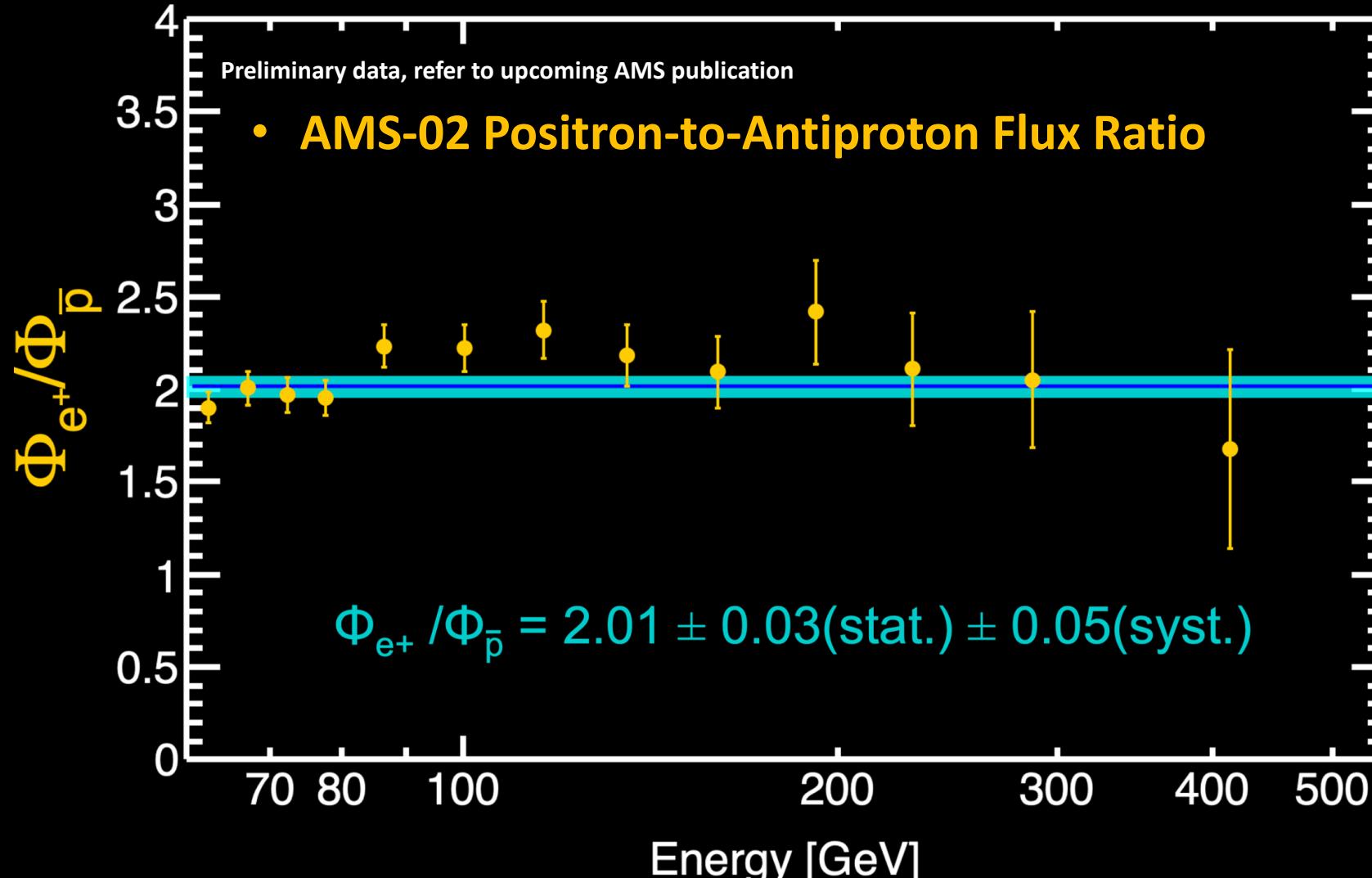
# Unique Observation from AMS:

Positron and Antiproton have nearly identical energy dependence.



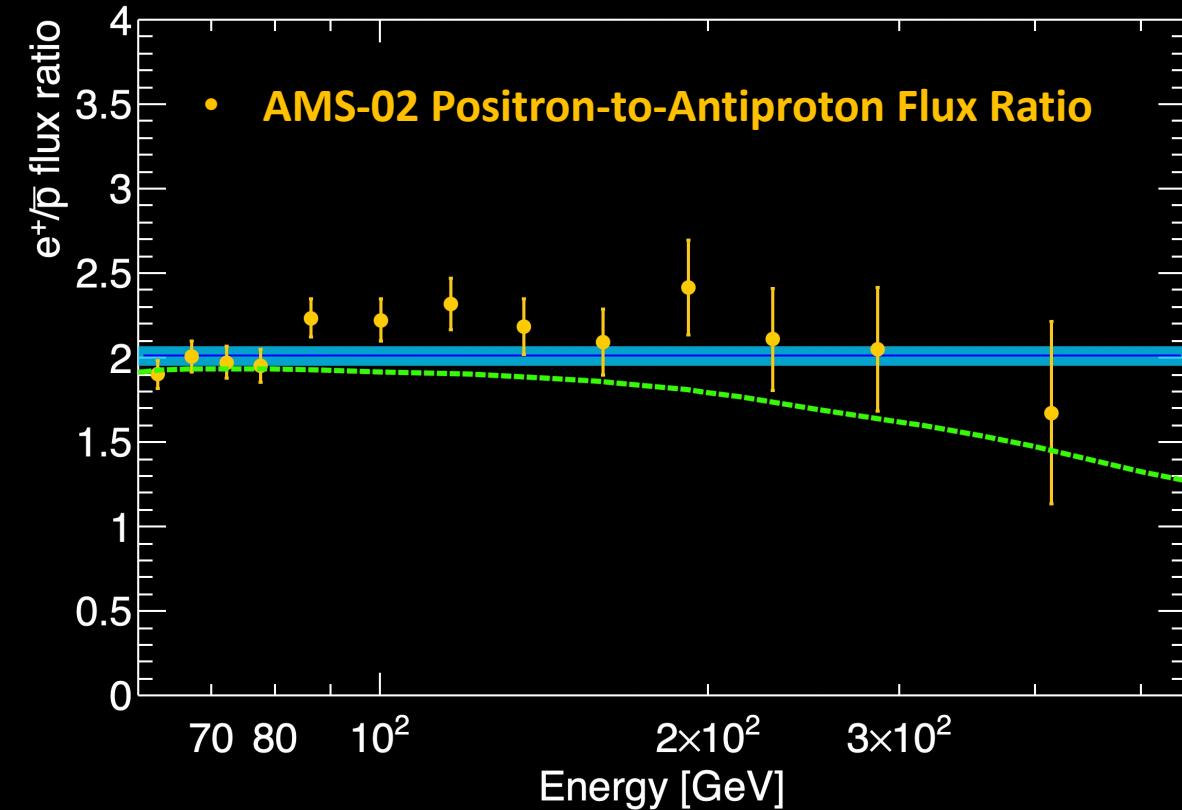
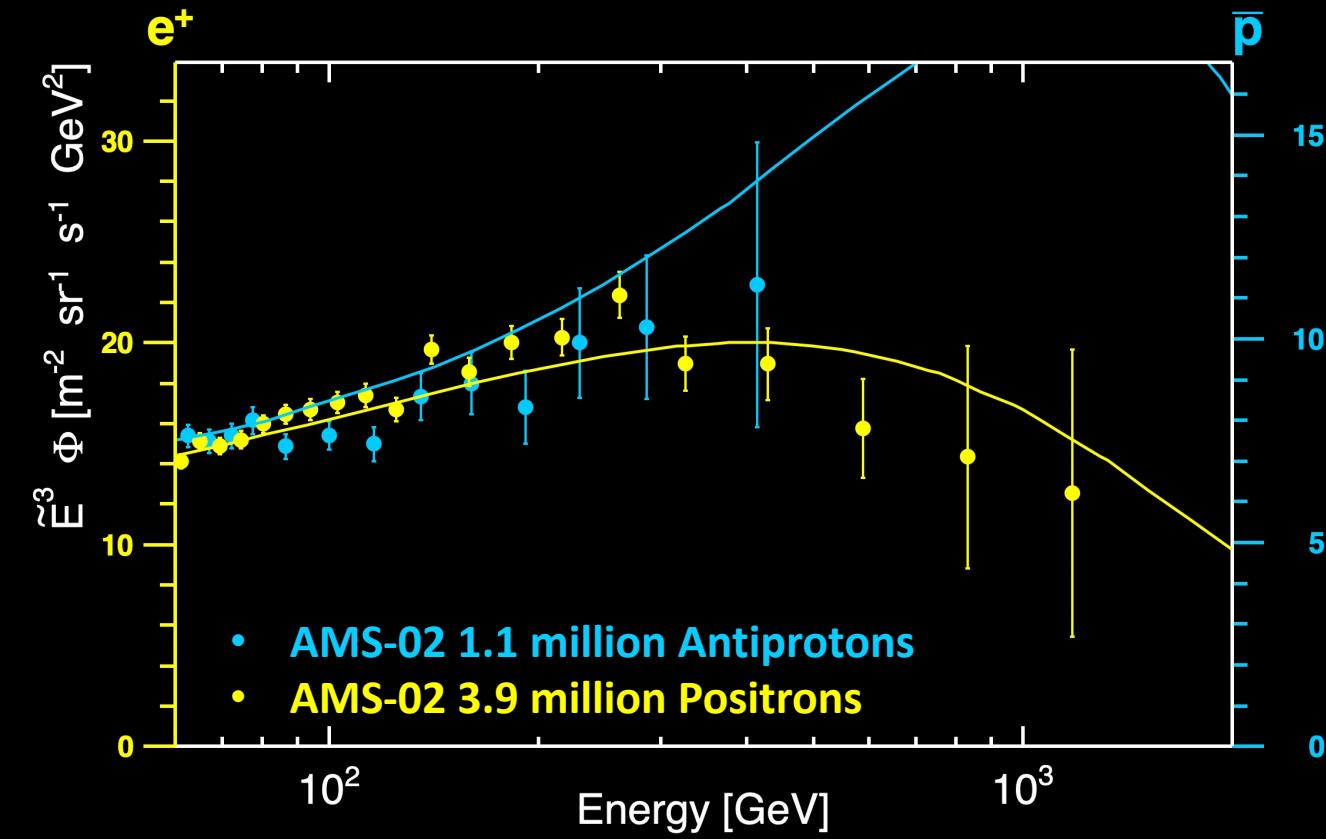
## Unique Observation from AMS:

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



Antiprotons cannot come from pulsars.

# Example: Positron and Antiproton spectra compared with recent model

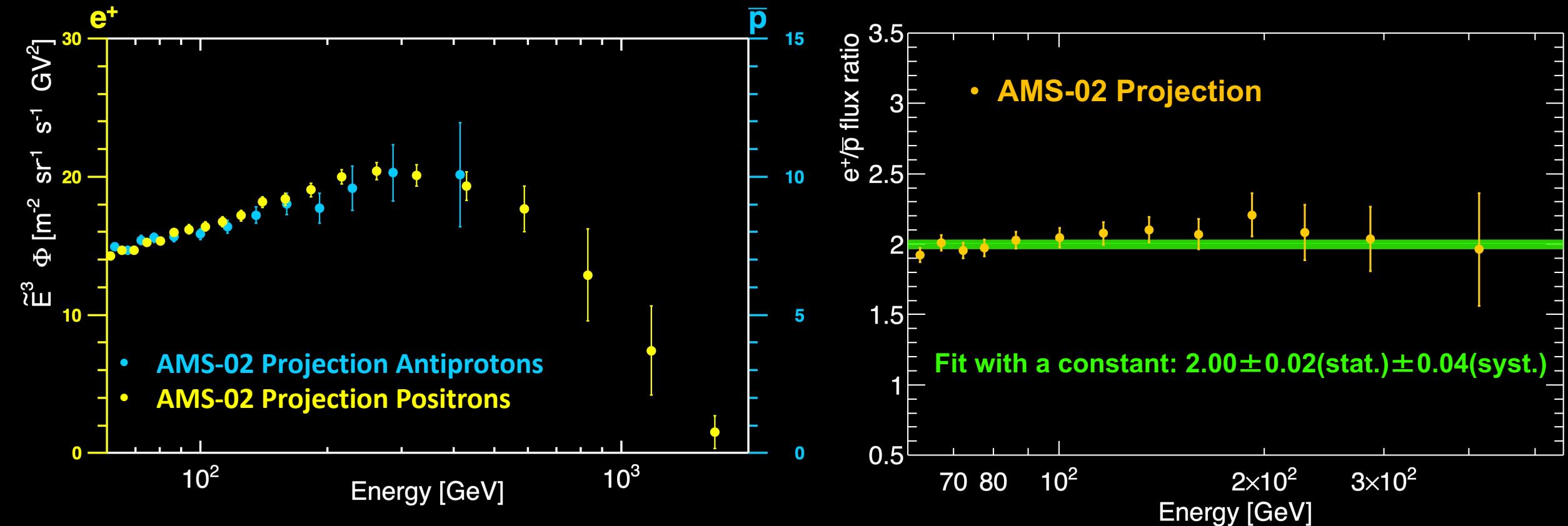


Model Example:

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, positrons,  
and antiprotons through the lifetime of the space station,**

**AMS will provide the definitive dataset to resolve the mystery of the  
origin of antimatter in cosmic rays.**

