# Antiproton Flux and Properties of Cosmic Rays Elementary Particles with AMS

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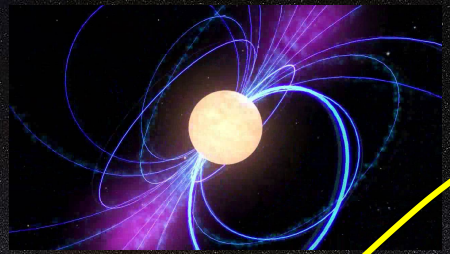
# Elementary Particles in Cosmic Rays

$e^-, e^+, p, \bar{p}$

New Astrophysical Sources: Pulsars, …



Supernovae

Protons, Helium, e⁻…

Interstellar Medium

e± from Pulsars

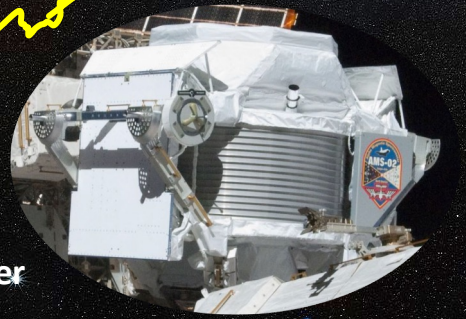
antiprotons, e⁺, …

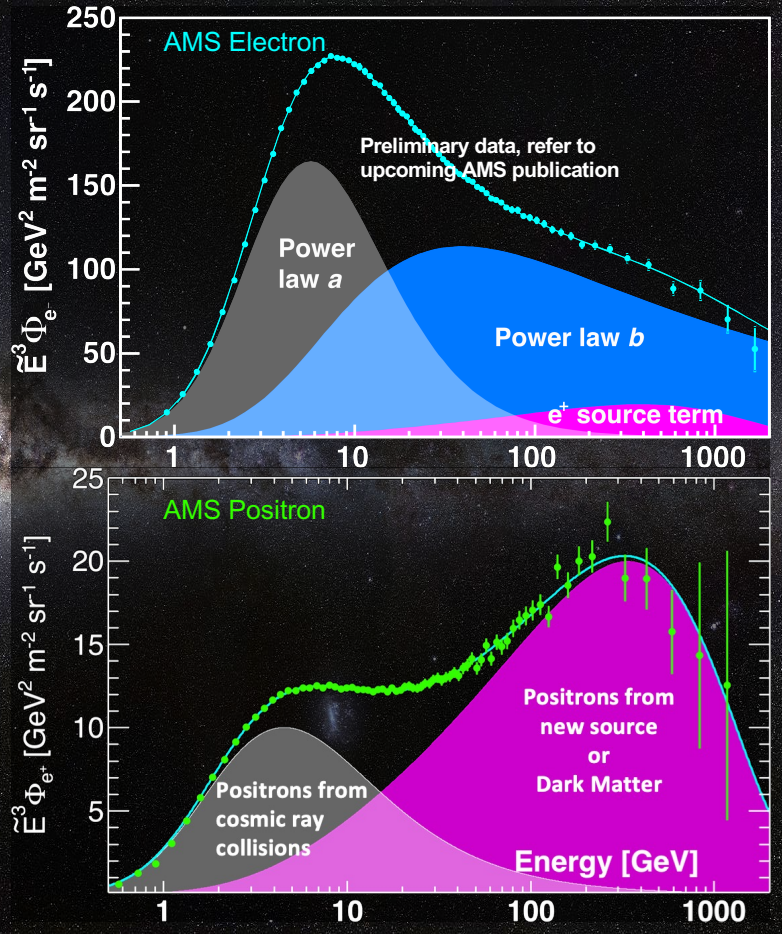
antiprotons, e⁺, …

Dark Matter

p, e⁻

Dark Matter






Refer to C. Zhang and S. Li's presentation

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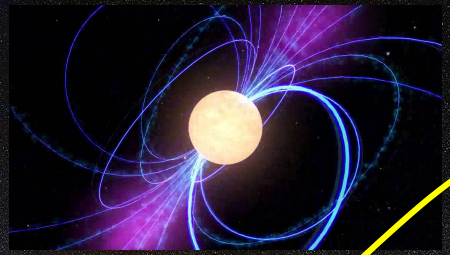

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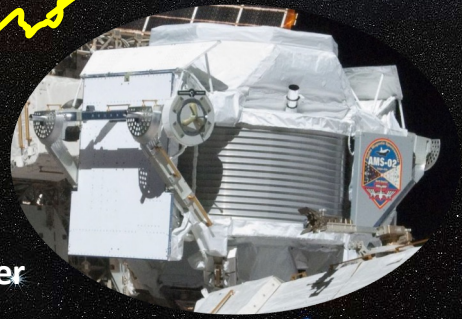
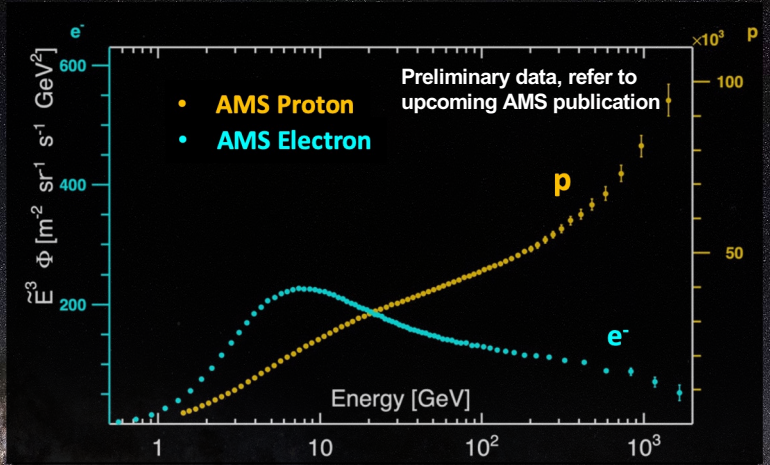
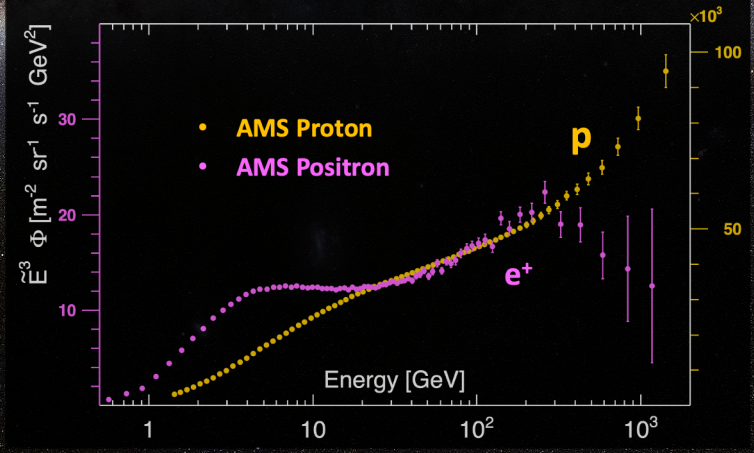




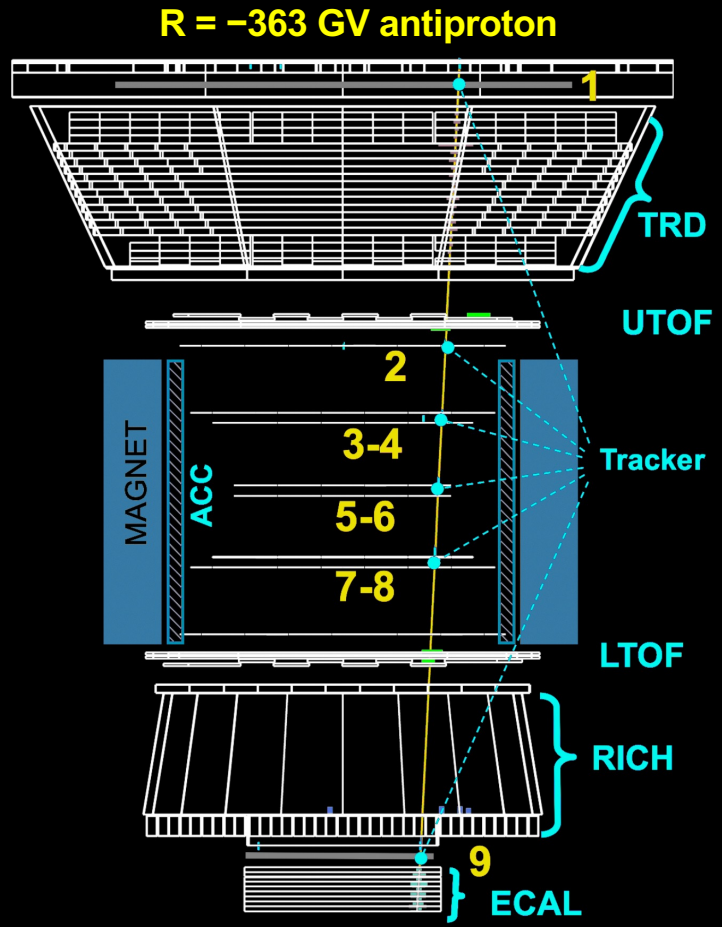



# Antiproton Measurements with AMS

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

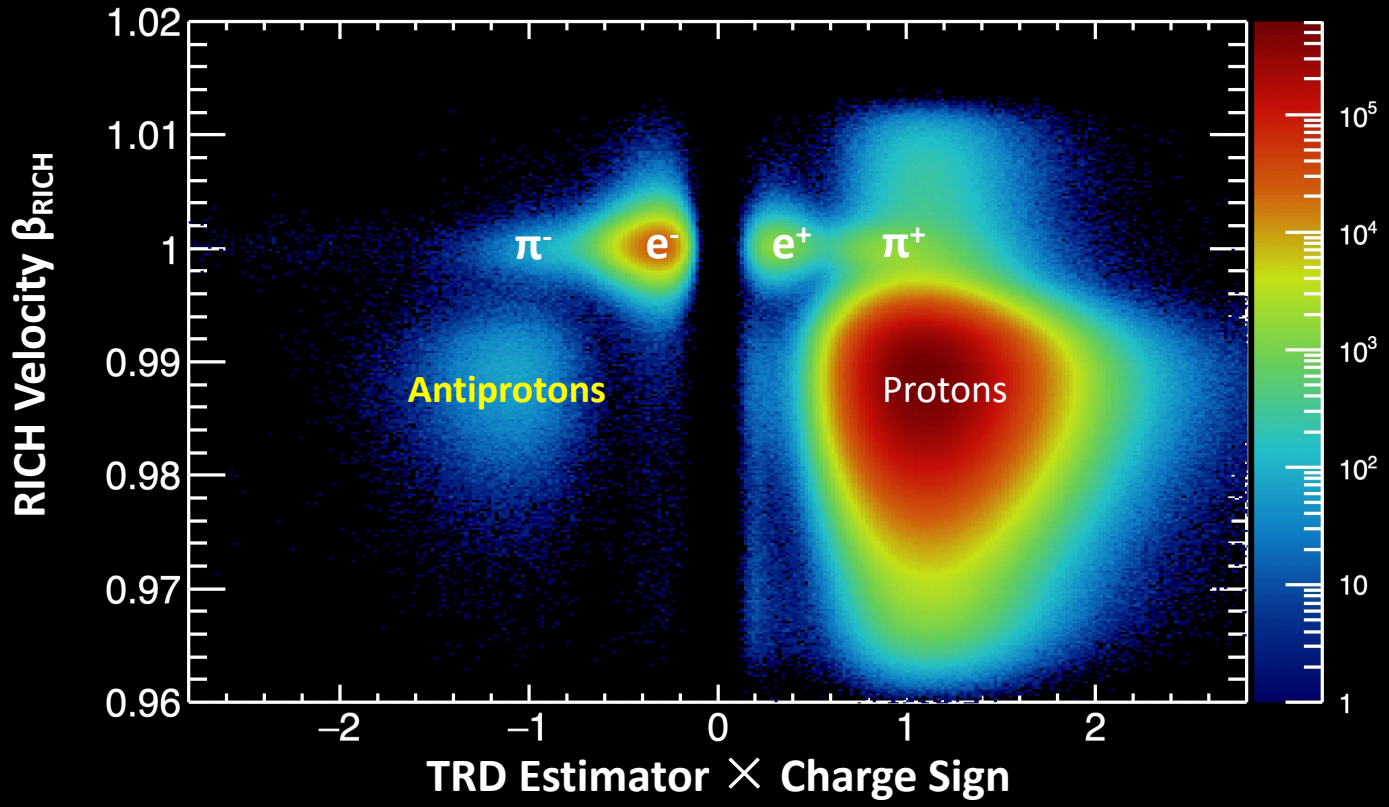
**A percent precision experiment requires background rejection close to 1 in a million**

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



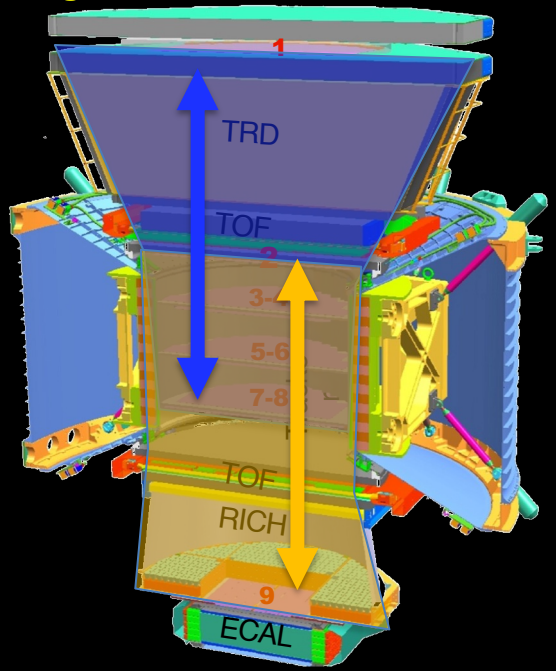
# Antiproton Analysis Overview

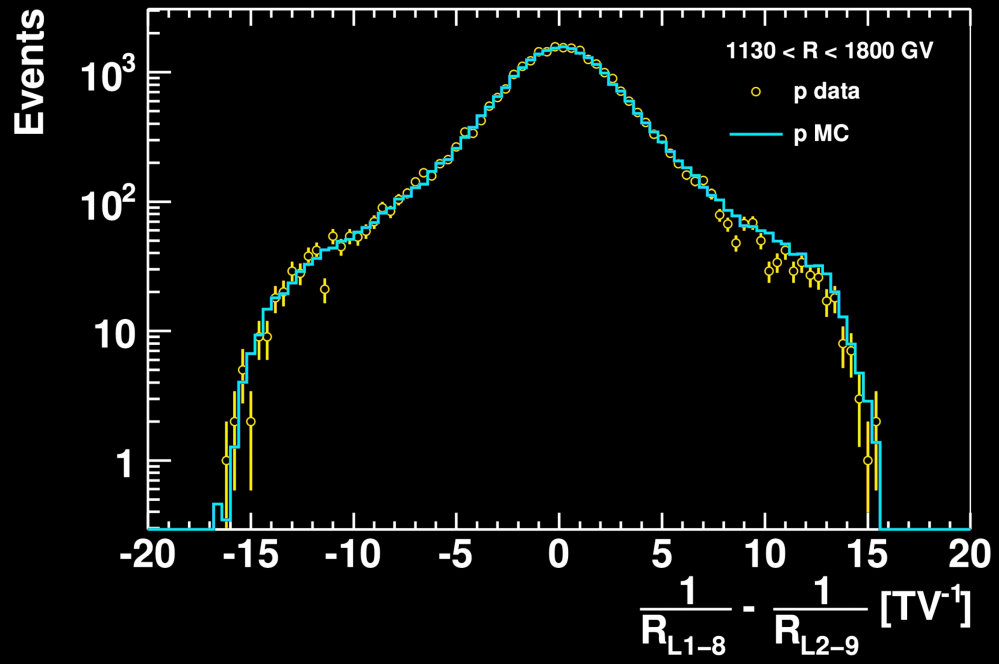
Example: Data Sample composition in |Rigidity|=6 GV



# 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.**



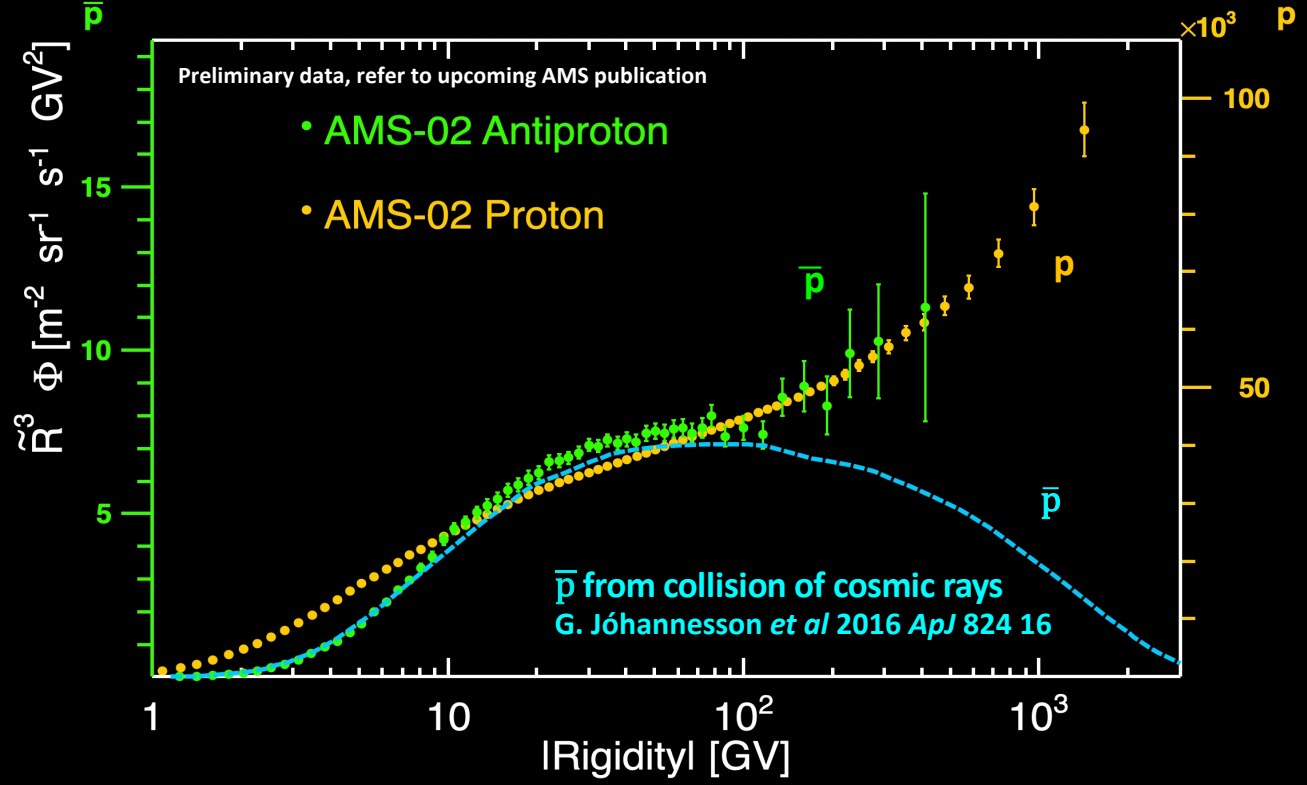



# Precision study of the properties of antiproton flux

**To date, AMS has identified over 1.1 million antiprotons from 1 to 525 GV**

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

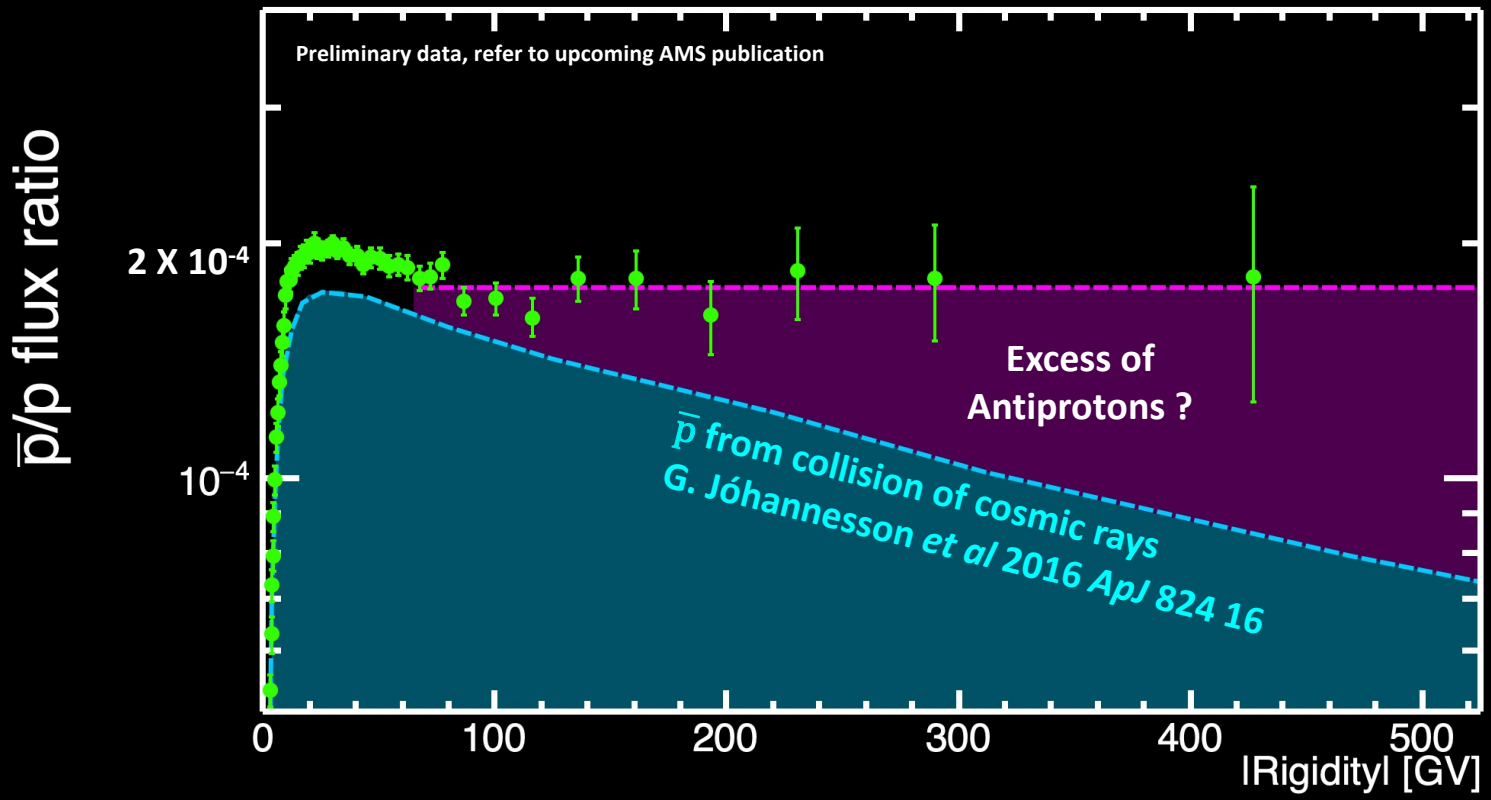
**Contradict with traditional cosmic ray model with only secondary $\bar{p}$ produced from collision of cosmic rays**



# 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

I. Cholis *et al.*, **JCAP,10 (2022) 051**

P. De La Torre Luque, JCAP11(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**

……

**Antiproton production and propagation**

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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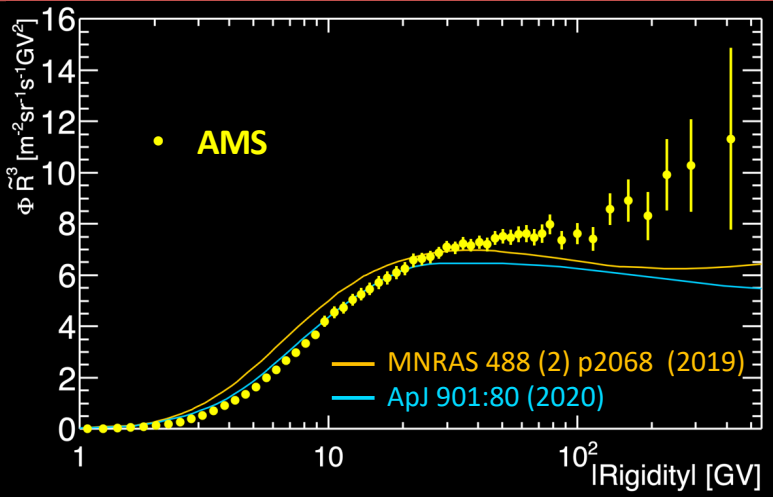
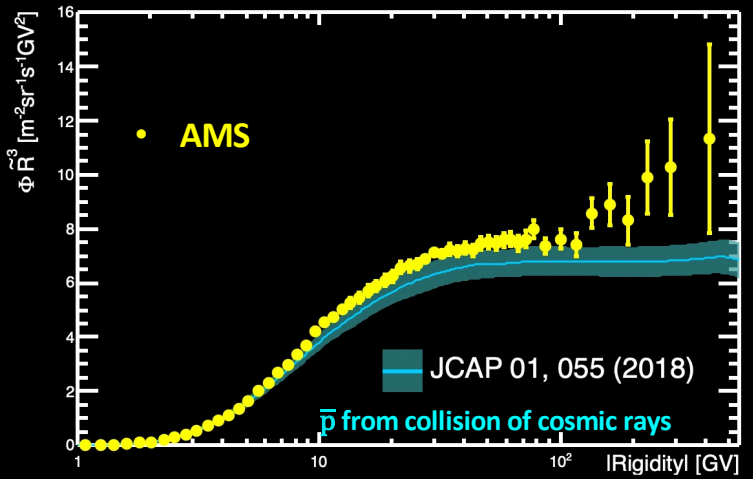
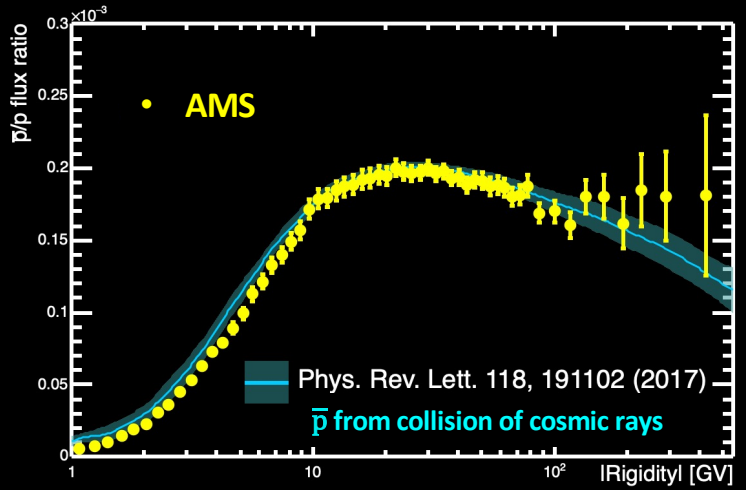
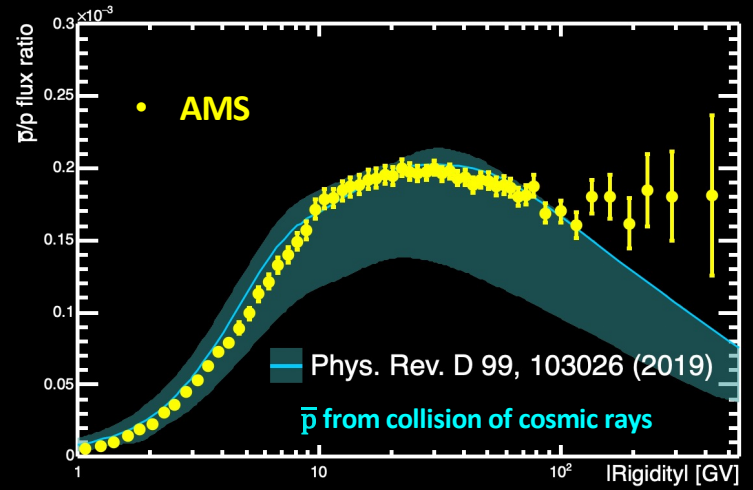
**Antiprotons from Dark Matter**

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

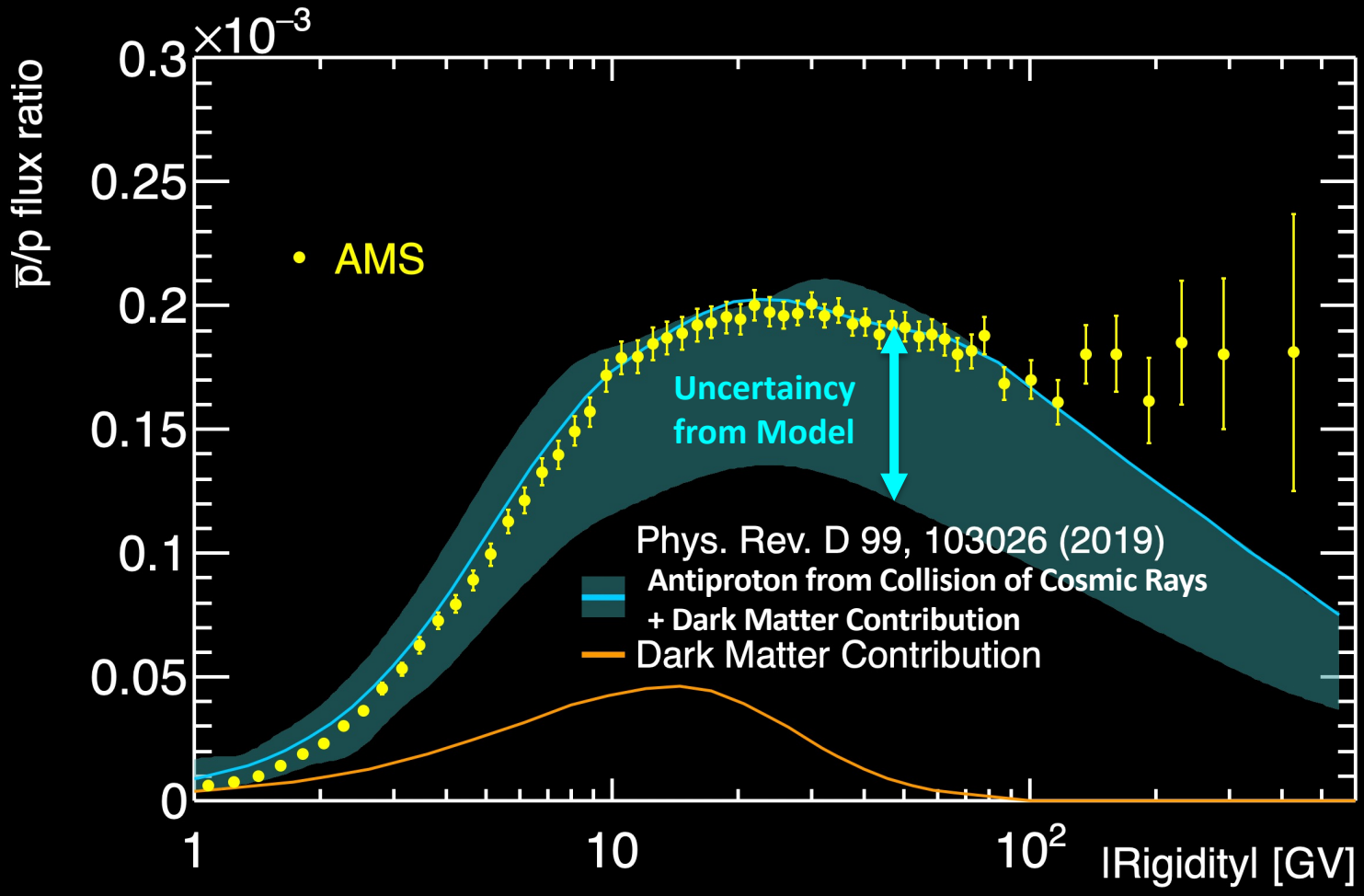


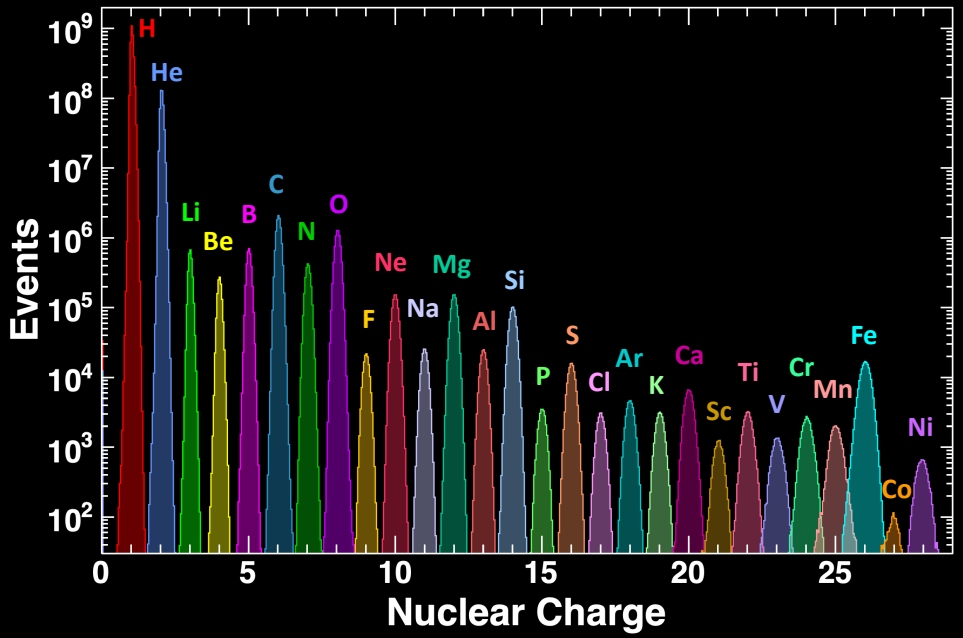



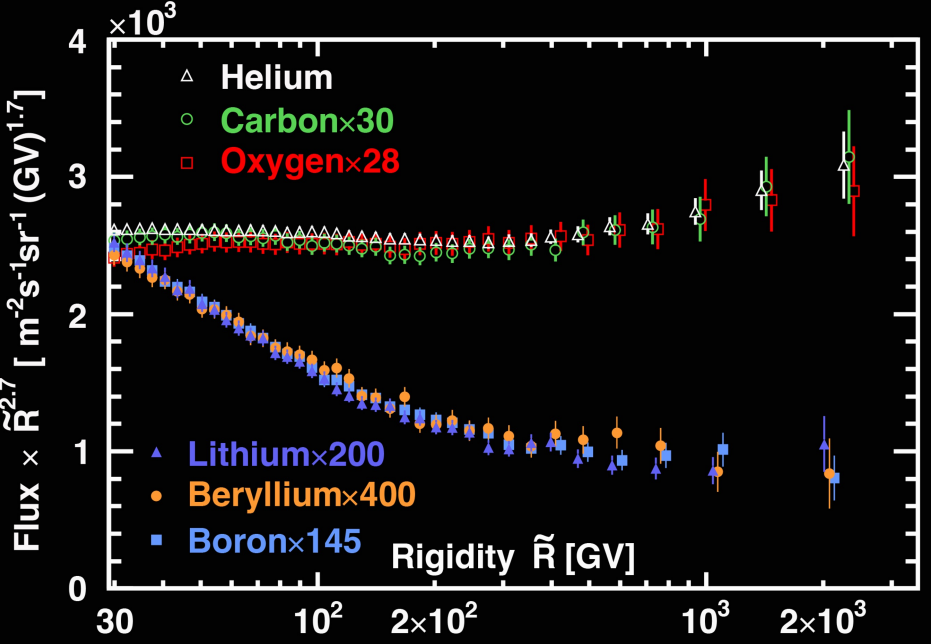
# Example: AMS Antiproton Results Compared with Low Mass Dark Matter Model



# 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.**

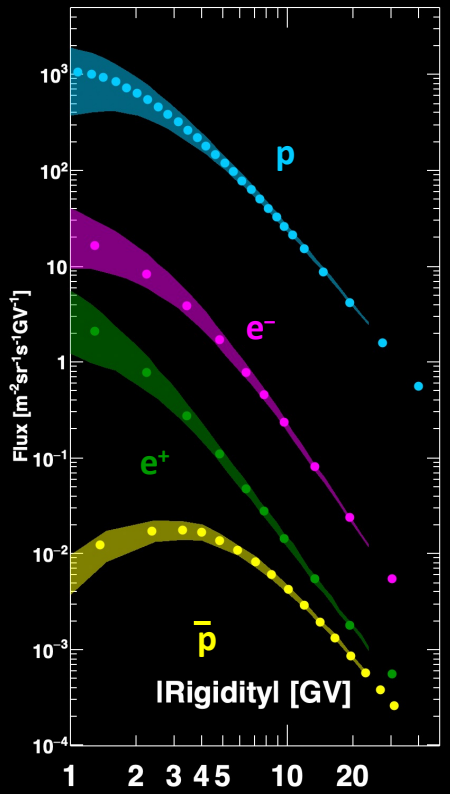


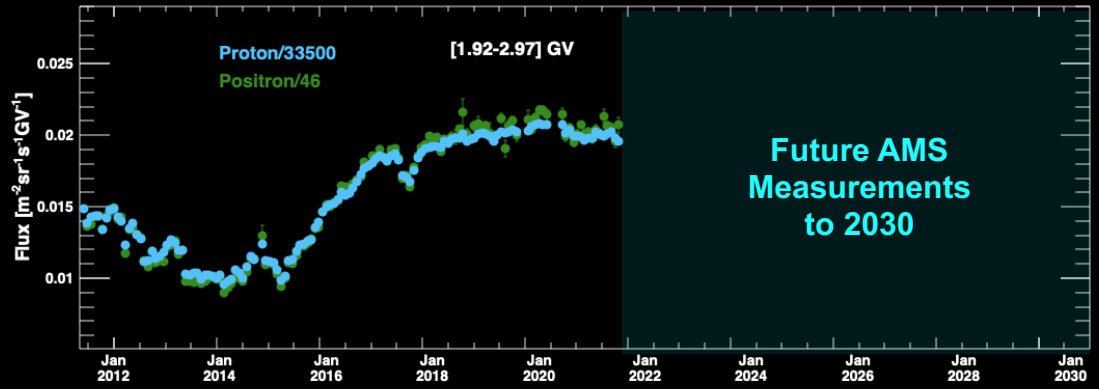



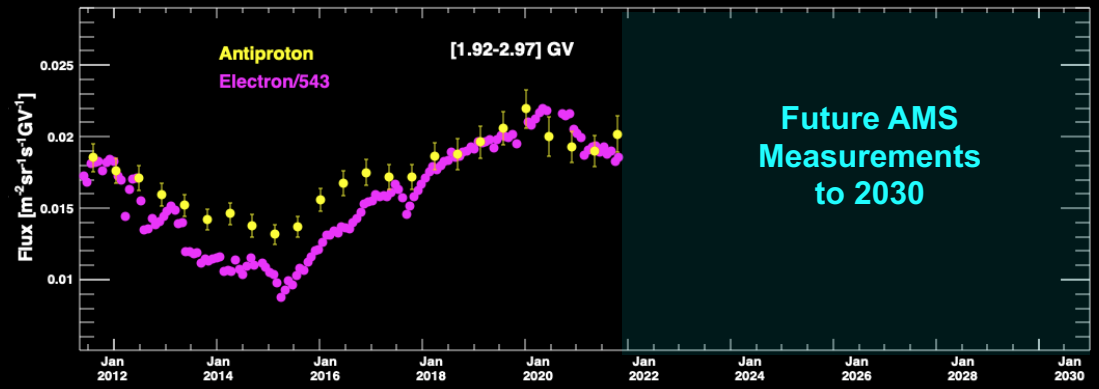

Refer to W. Xu, Y. Chen, Z. Wang's presentation

# 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**



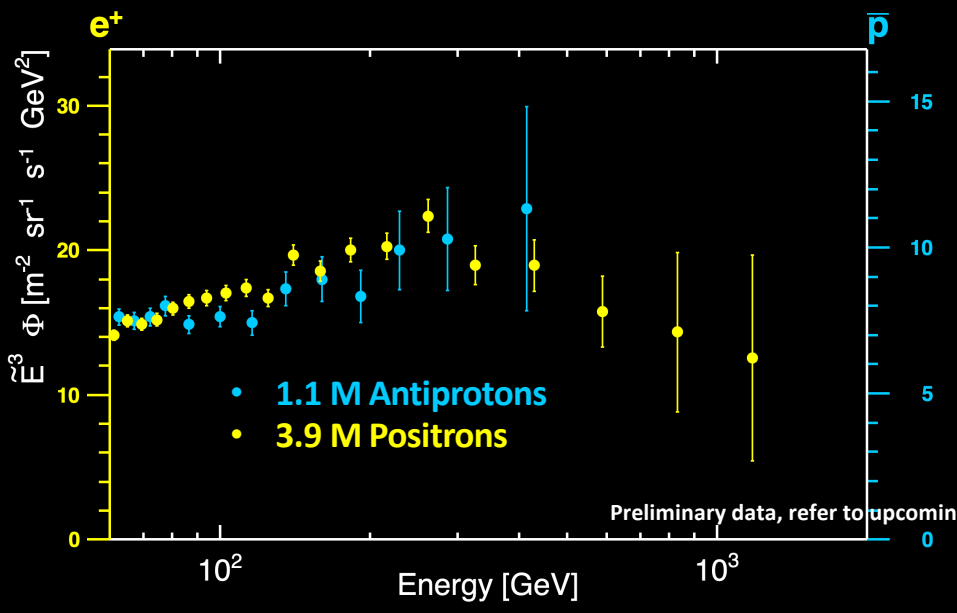



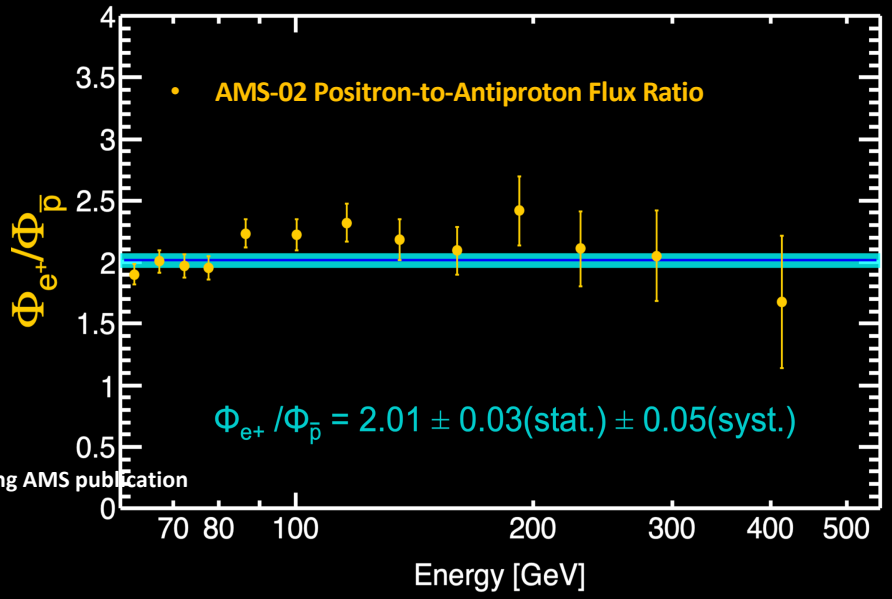

Refer to F. Zhang, T. Su, Z. Sun's presentation

# Unique Observation from AMS:

**Positron and Antiproton have nearly identical energy dependence**

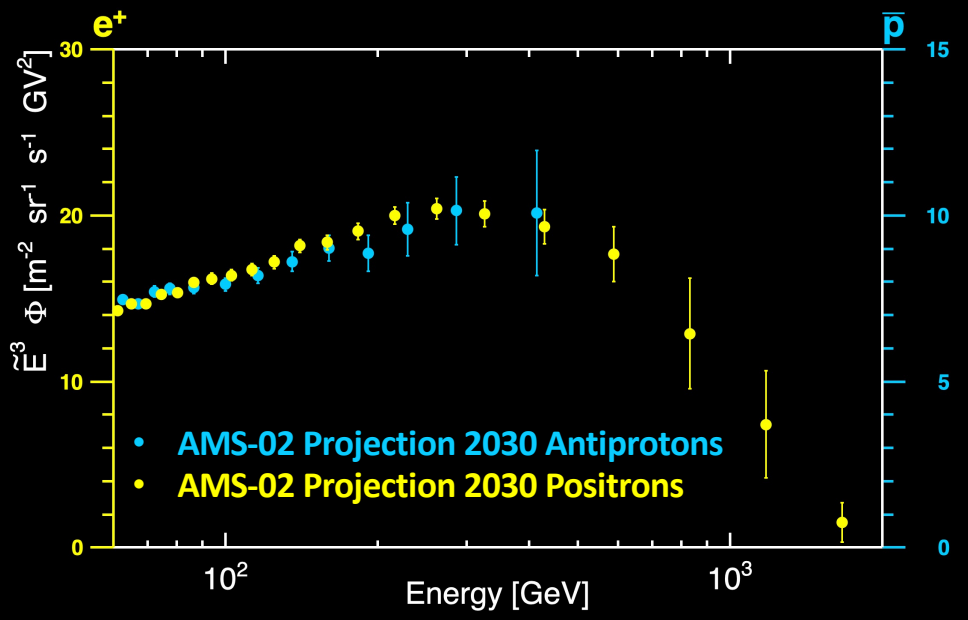
**The positron-to-antiproton flux ratio is independent of energy.**

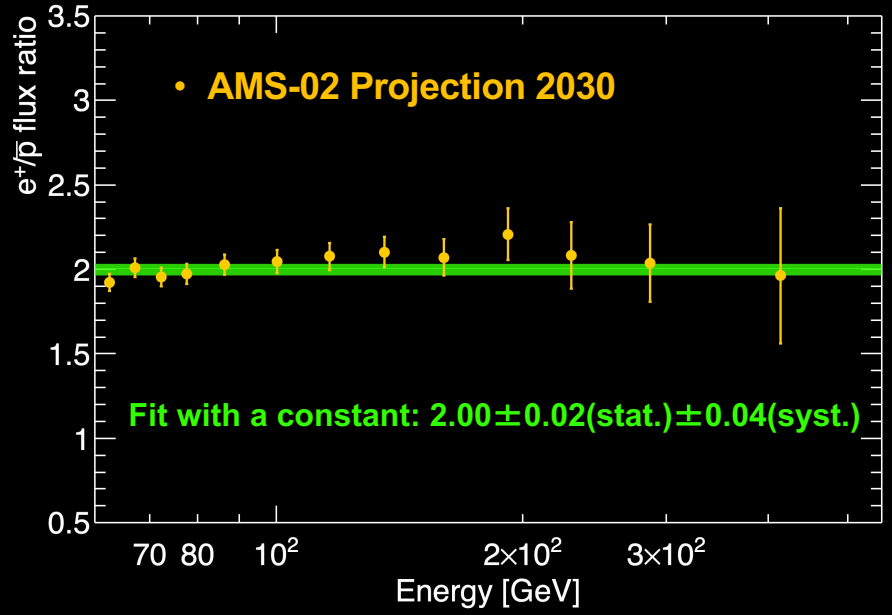



**Antiprotons cannot come from pulsars**

# Future Measurement of Antiproton and Positrons with AMS Upgrade




**AMS will greatly improve the accuracy of the measurement. The identical behaviour of high energy positrons and antiprotons could shed light on their origin**

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

**AMS will provide unique dataset for understanding of the origin of antiparticles in cosmic rays**