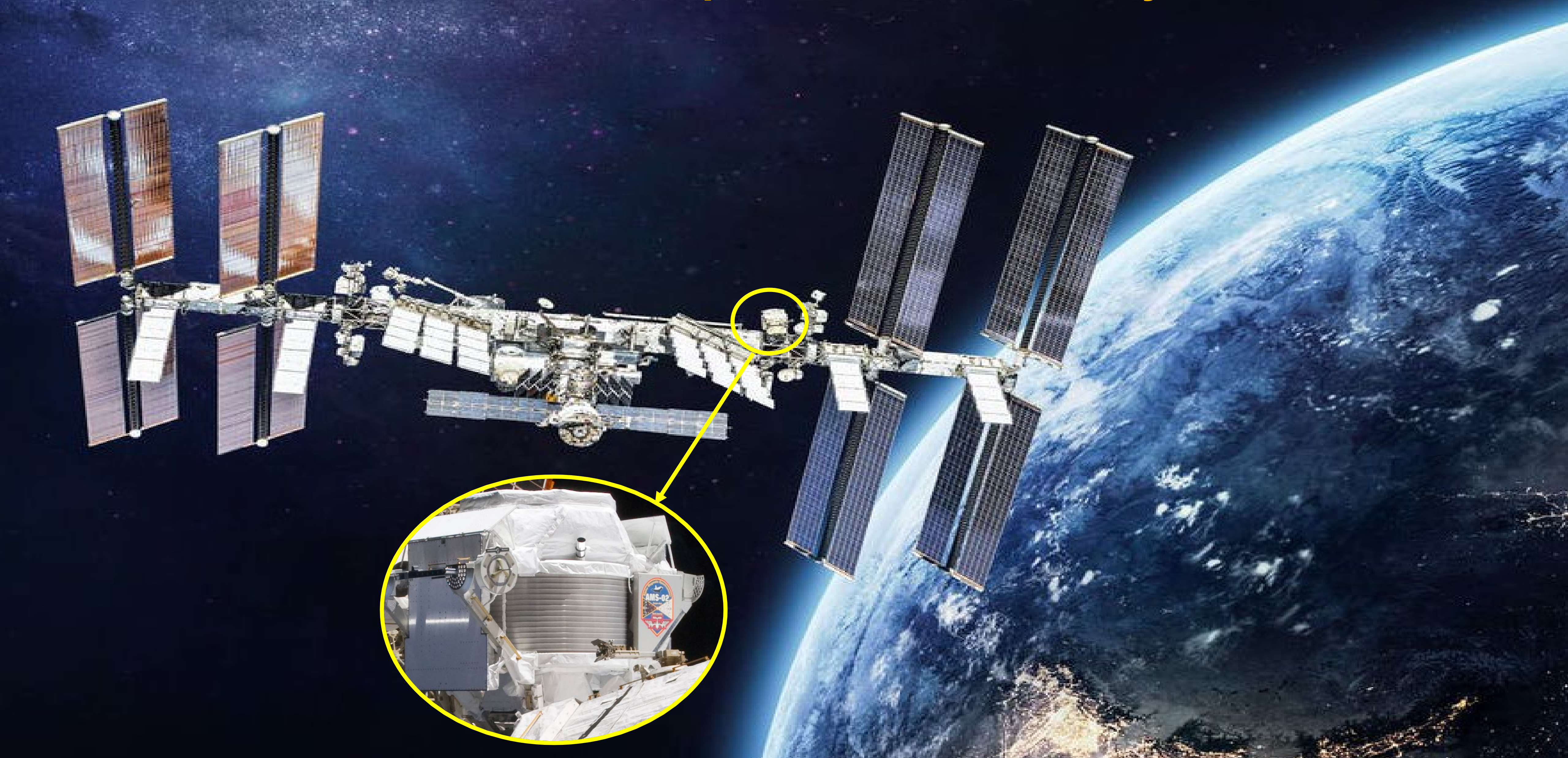
# Cosmic Anti-Protons and Properties of Elementary Particle Fluxes




ICHEP 2024 | PRAGUE

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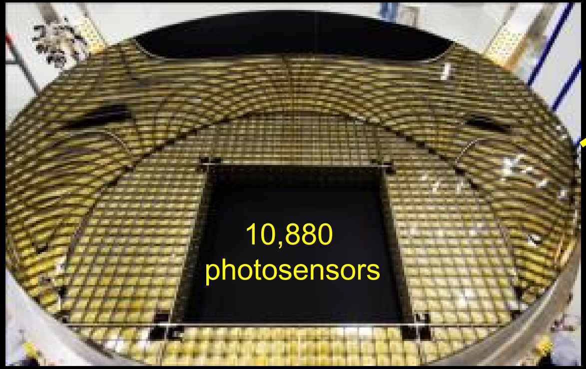
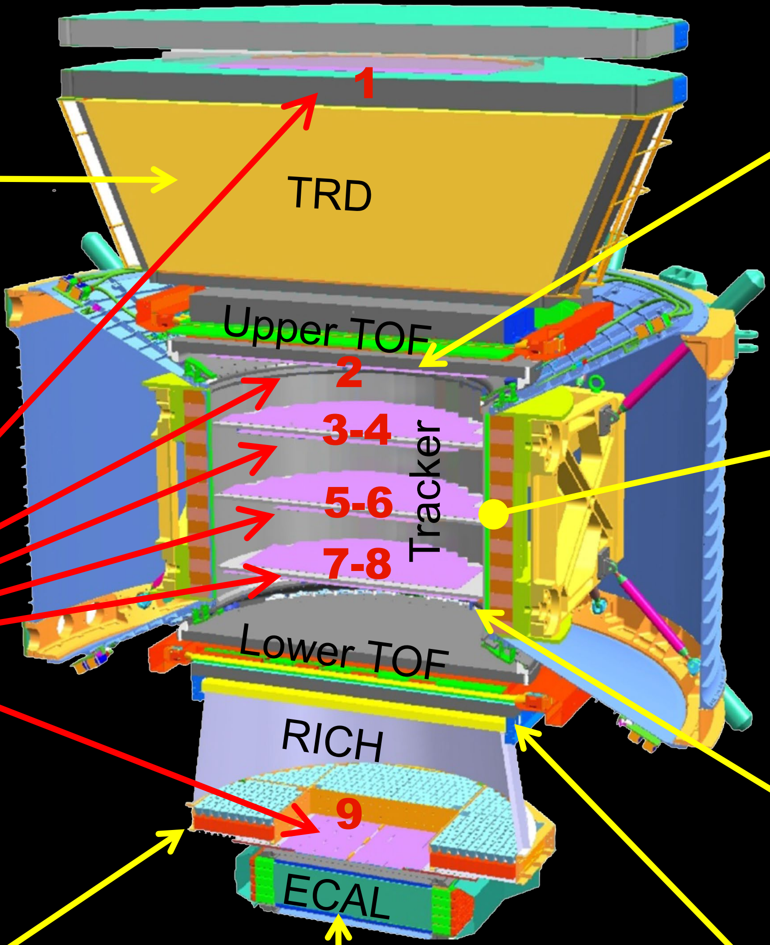
# AMS is a space version of a precision magnetic spectrometer

Transition Radiation Detector (TRD)
identify $e^+$, $e^-$

Silicon Tracker
measure Z, P

Ring Imaging Cerenkov (RICH)
measure Z, E




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

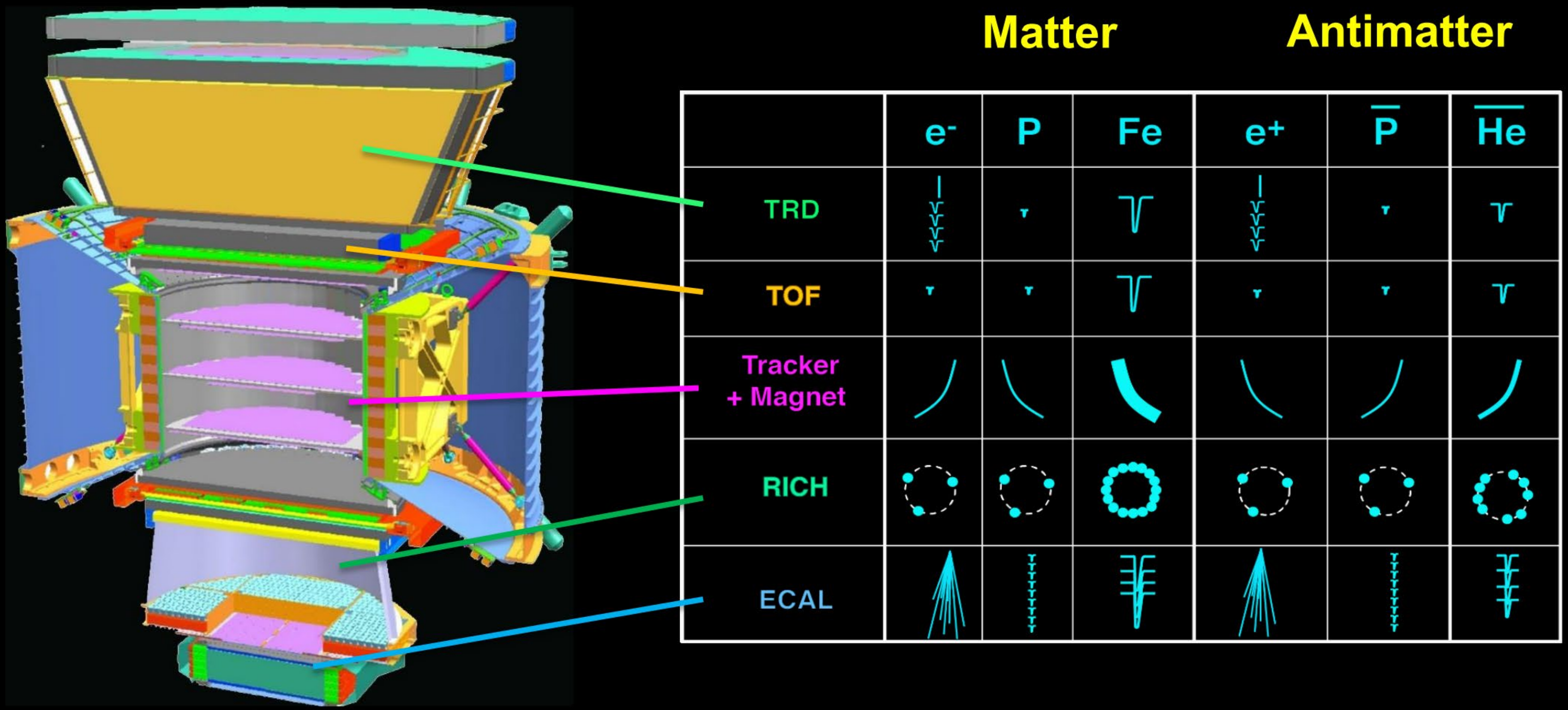
Upper TOF measure Z, E

Magnet identify ±Z, P

Anticoincidence Counters (ACC)
reject particles from the side

Lower TOF measure Z, E

# AMS is a unique magnetic spectrometer in space




**AMS is able to pick out 1 positron from 1,000,000 protons;**
**unambiguously separate positrons from electrons up to a trillion eV;**
**and accurately measure all cosmic rays to trillions of eV.**
**In 13 years, the detectors have performed flawlessly, collected more than 230 billion cosmic rays.**

# AMS on ISS

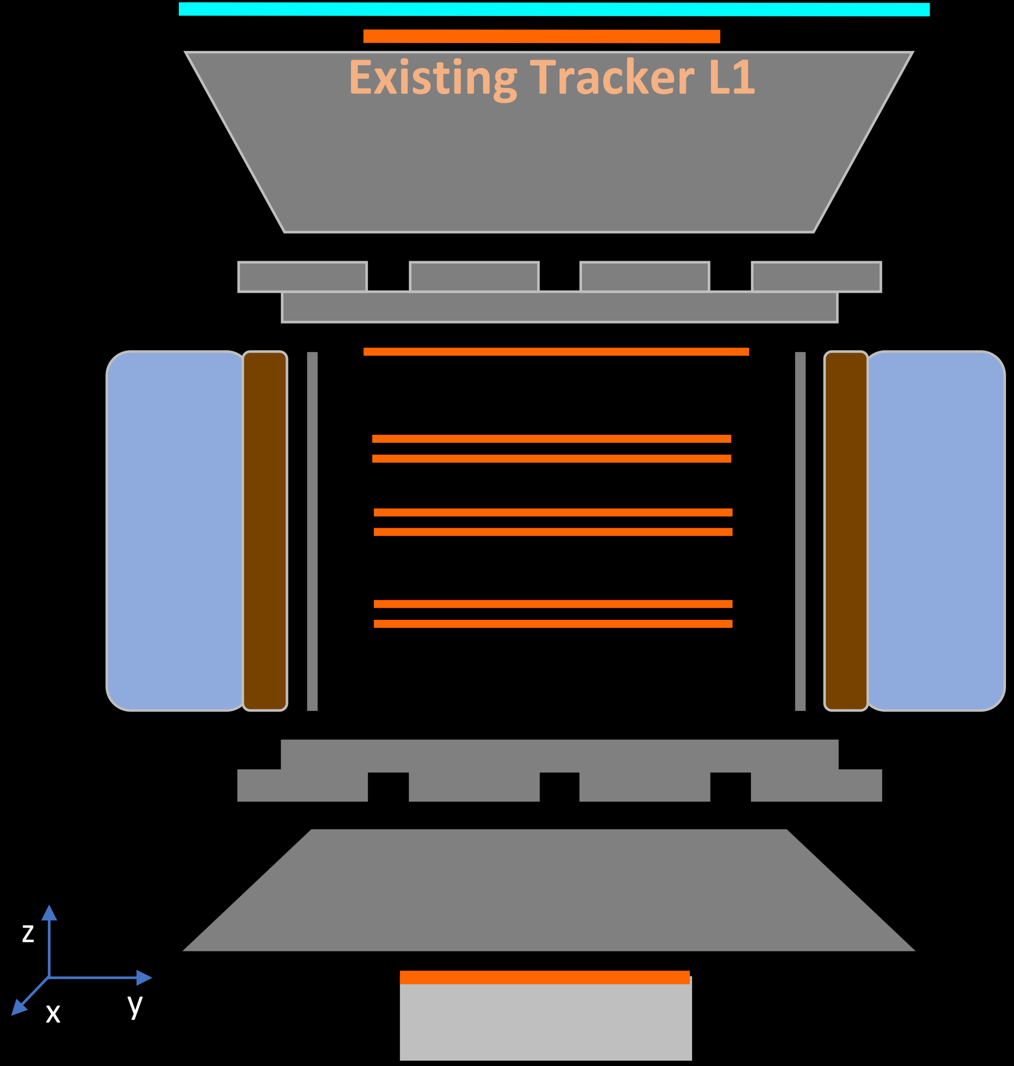
## AMS 2011-2025

Continuous data-taking


Latest Results: 2011-2024

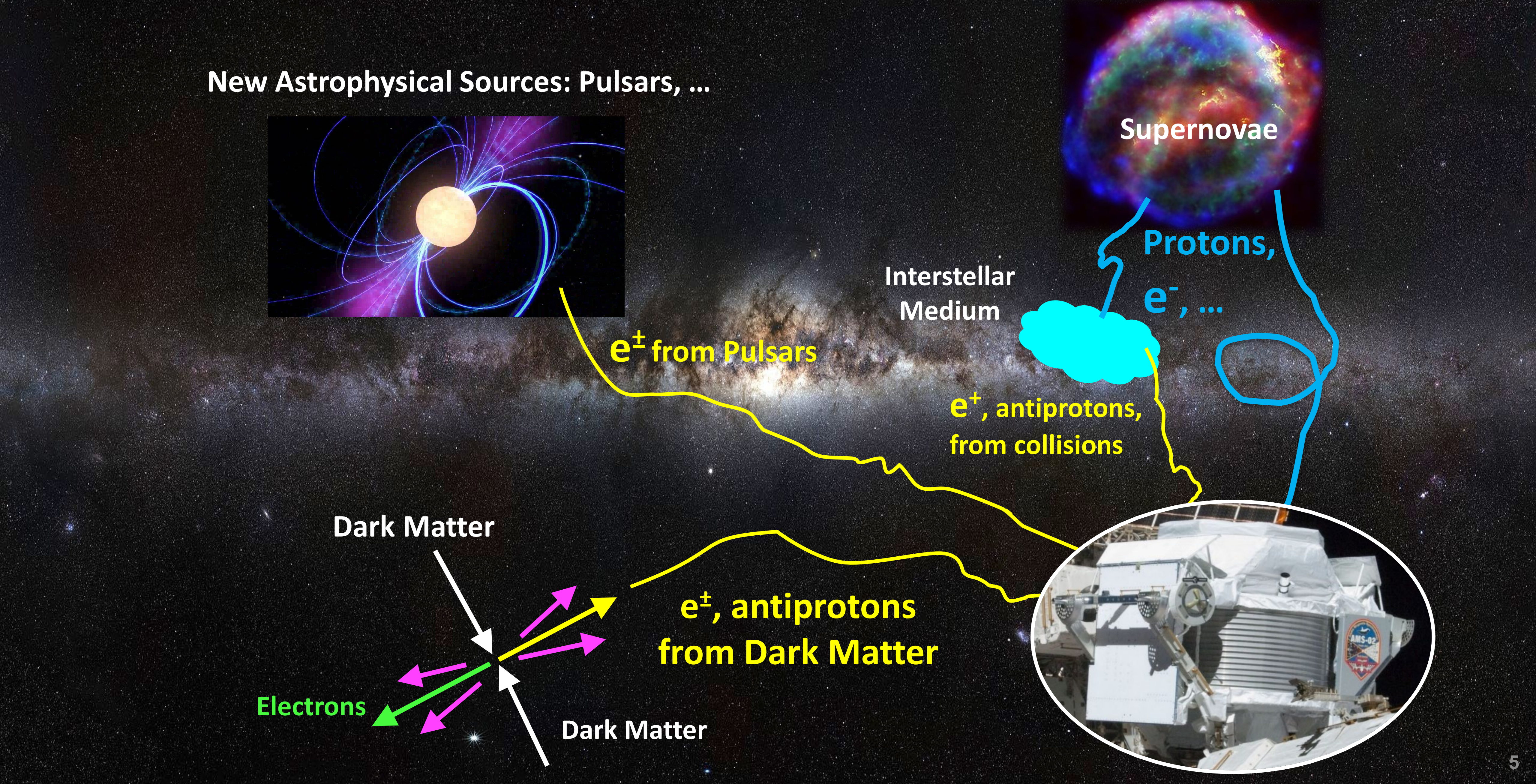
## AMS 2025-2030

New $8m^2$ Silicon Tracker Layer
Acceptance increased to 300%




and Projections to 2030

# Elementary Particles in Cosmic Rays



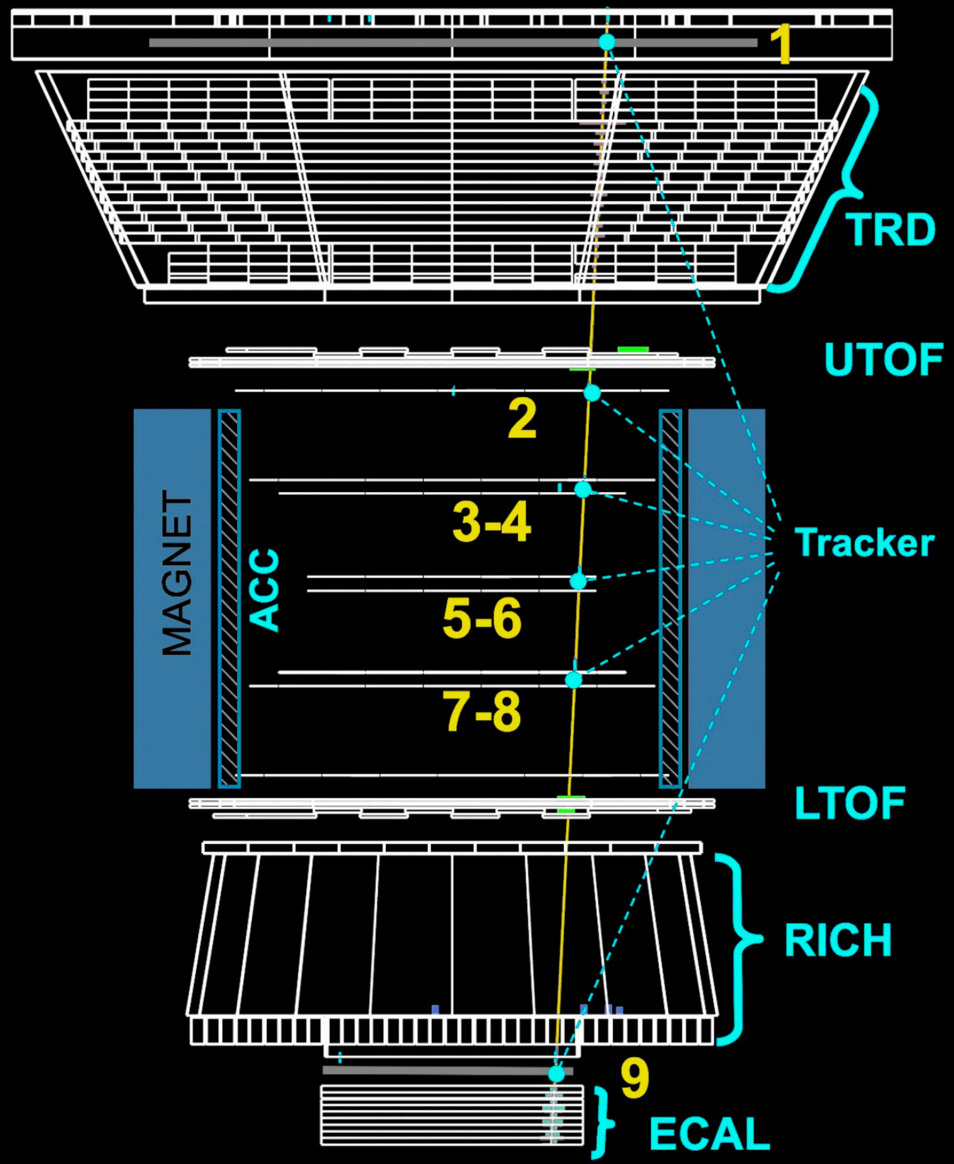
# Antiproton Measurements with AMS

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

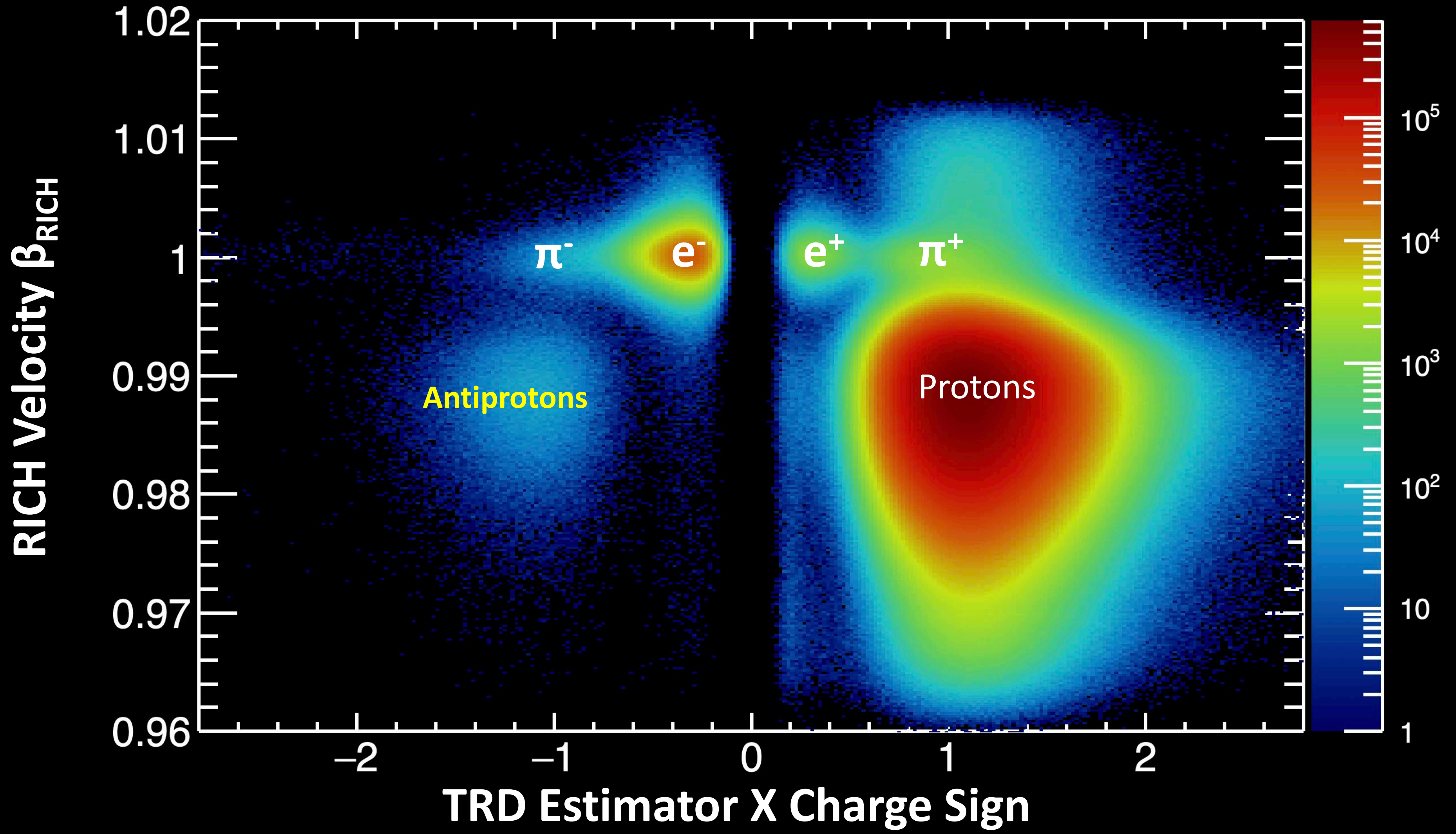
R = −363 GV antiproton



# Antiproton Analysis Overview

## Use TOF, RICH, and TRD identify antiproton from backgrounds

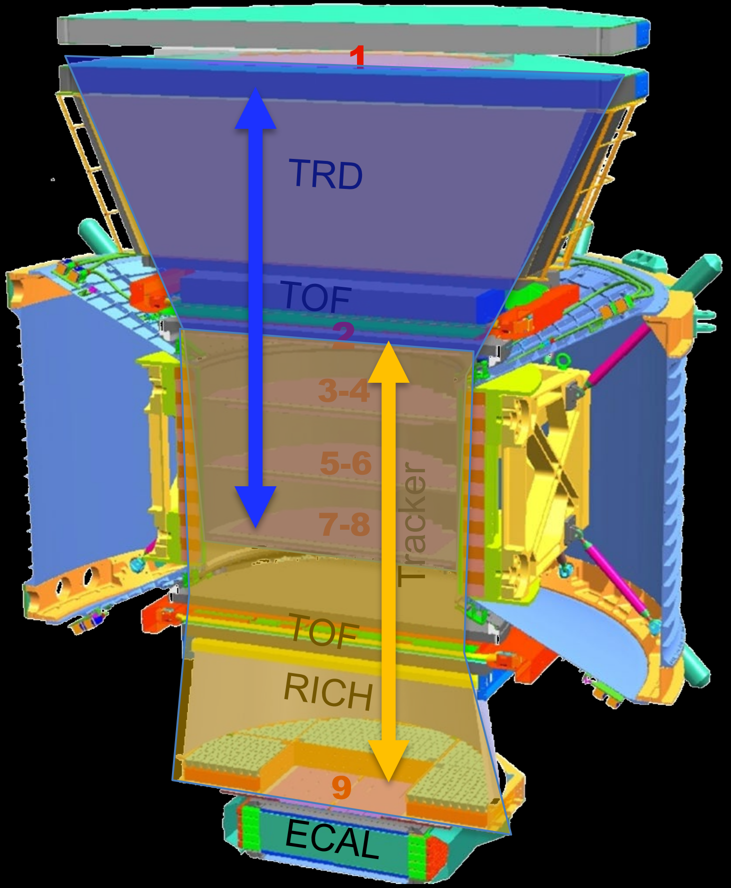
**Example: Data Sample composition in |Rigidity|=6 GV**

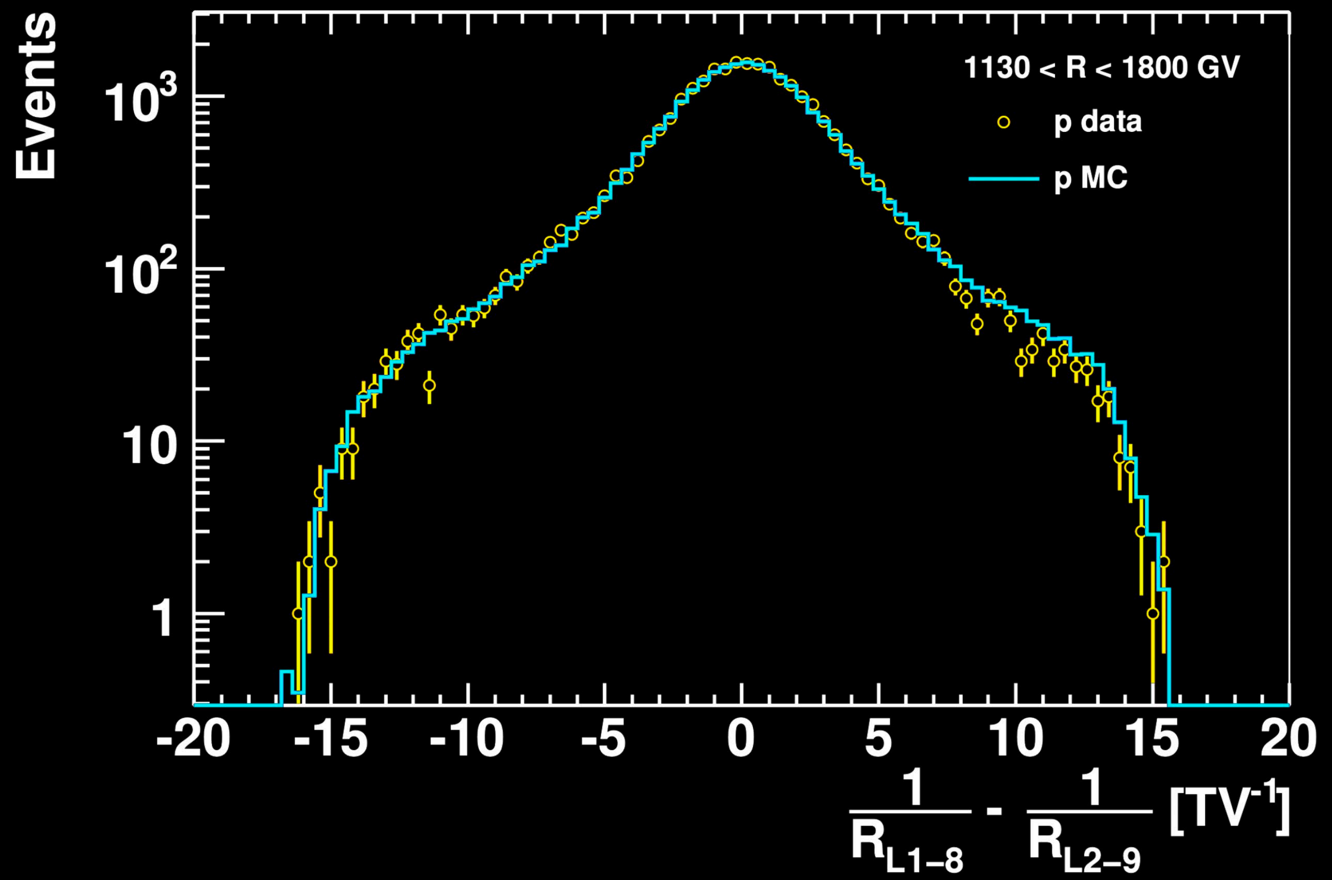


# Antiproton Analysis Overview

**Antiproton Measurement at 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.**

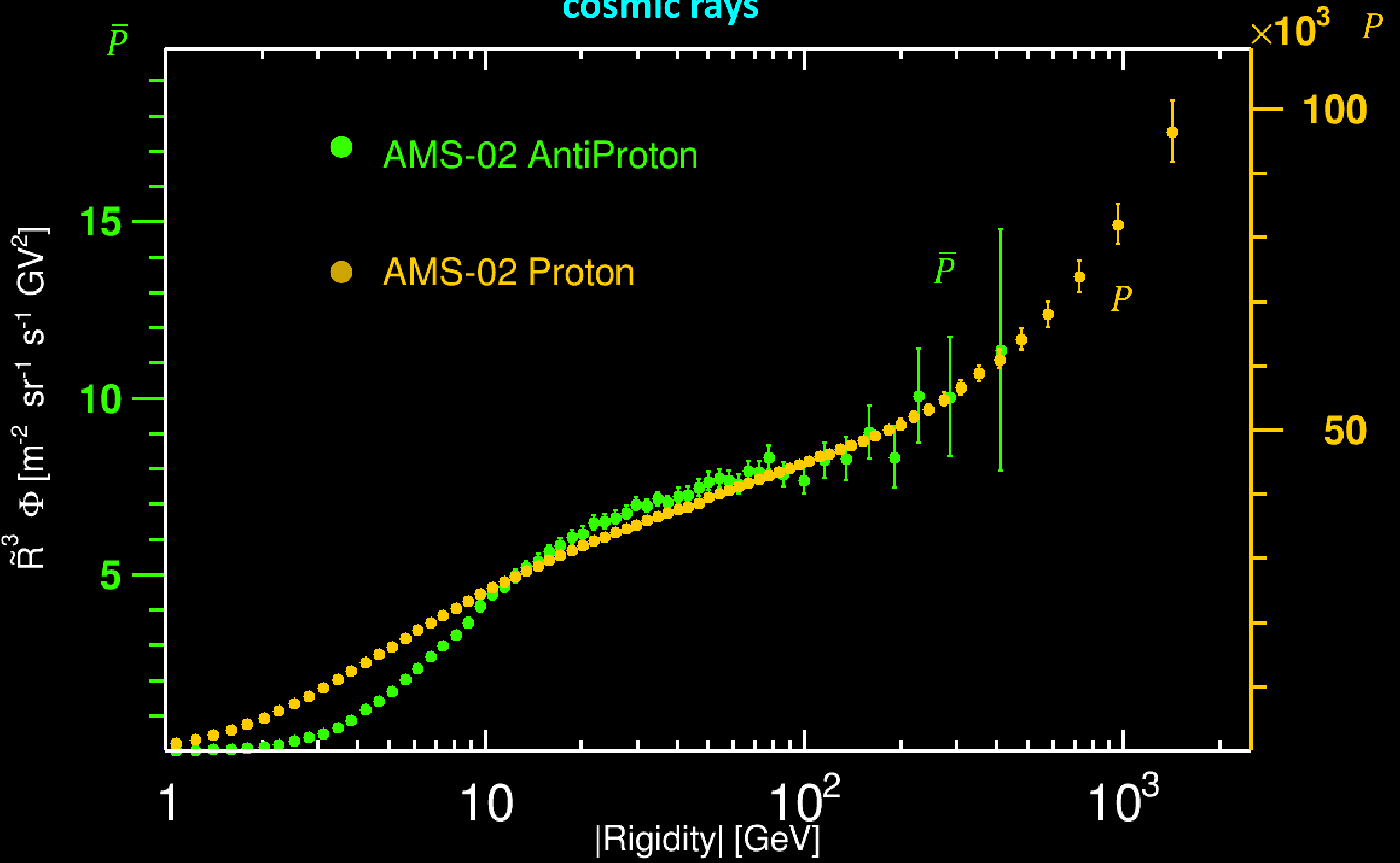


# Precision study of the properties of antiproton flux

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

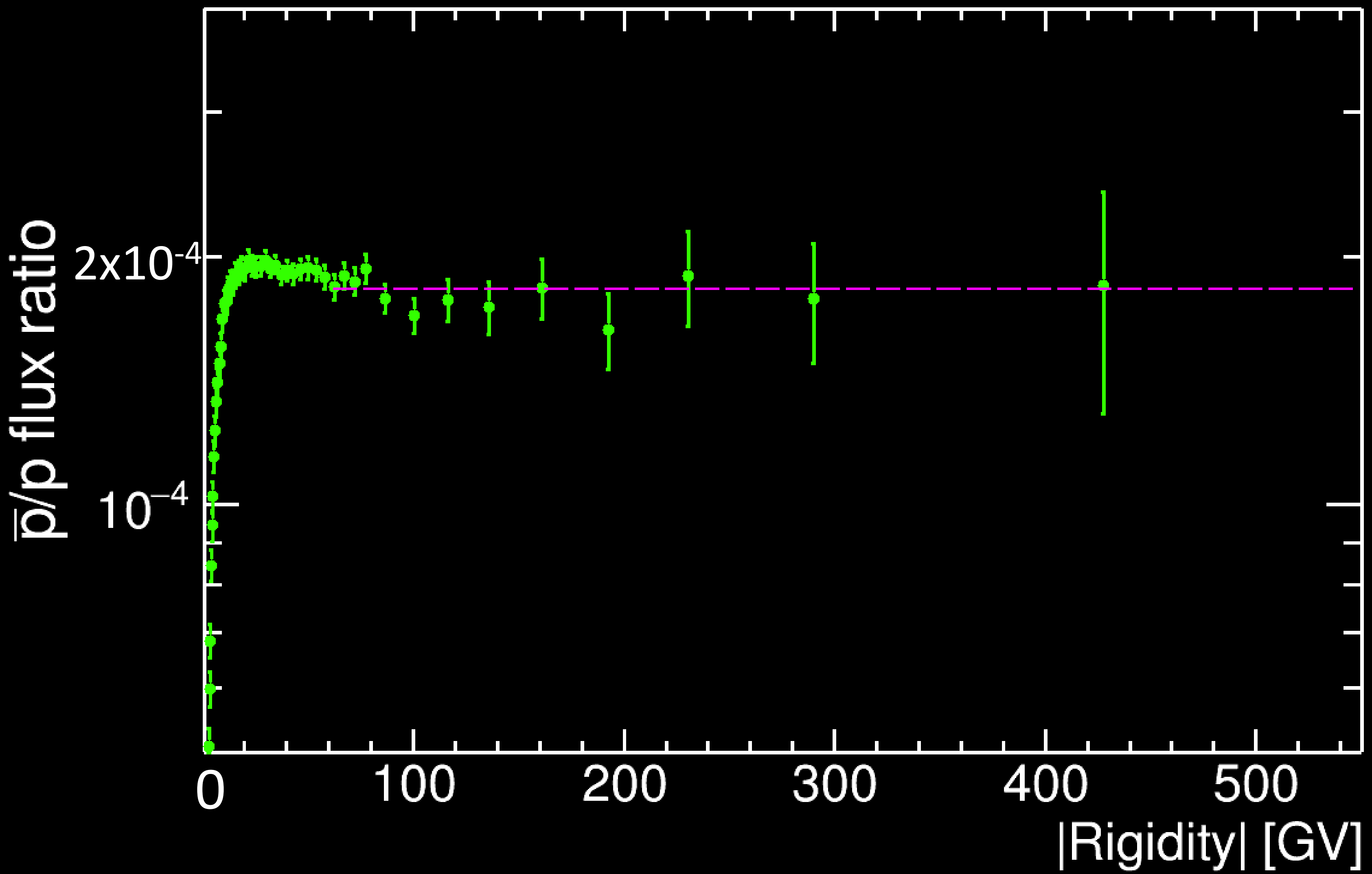
**Contradict with traditional cosmic ray model with only secondary $\bar{p}$ produced from collision of cosmic rays**



# 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

## Antiproton production and propagation

E. Silver *et al.*, ***ApJ***,*963:111 (2024)*

Y. Yao et al., **Phys. Rev. D 109 (2024) 063001**

**B. Qiao** *et al.*, **ApJ, 956(2):75, (2023)**

**P. Zhang** et al., **Phys. Rev. D 105 (2022) 023002**

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)**

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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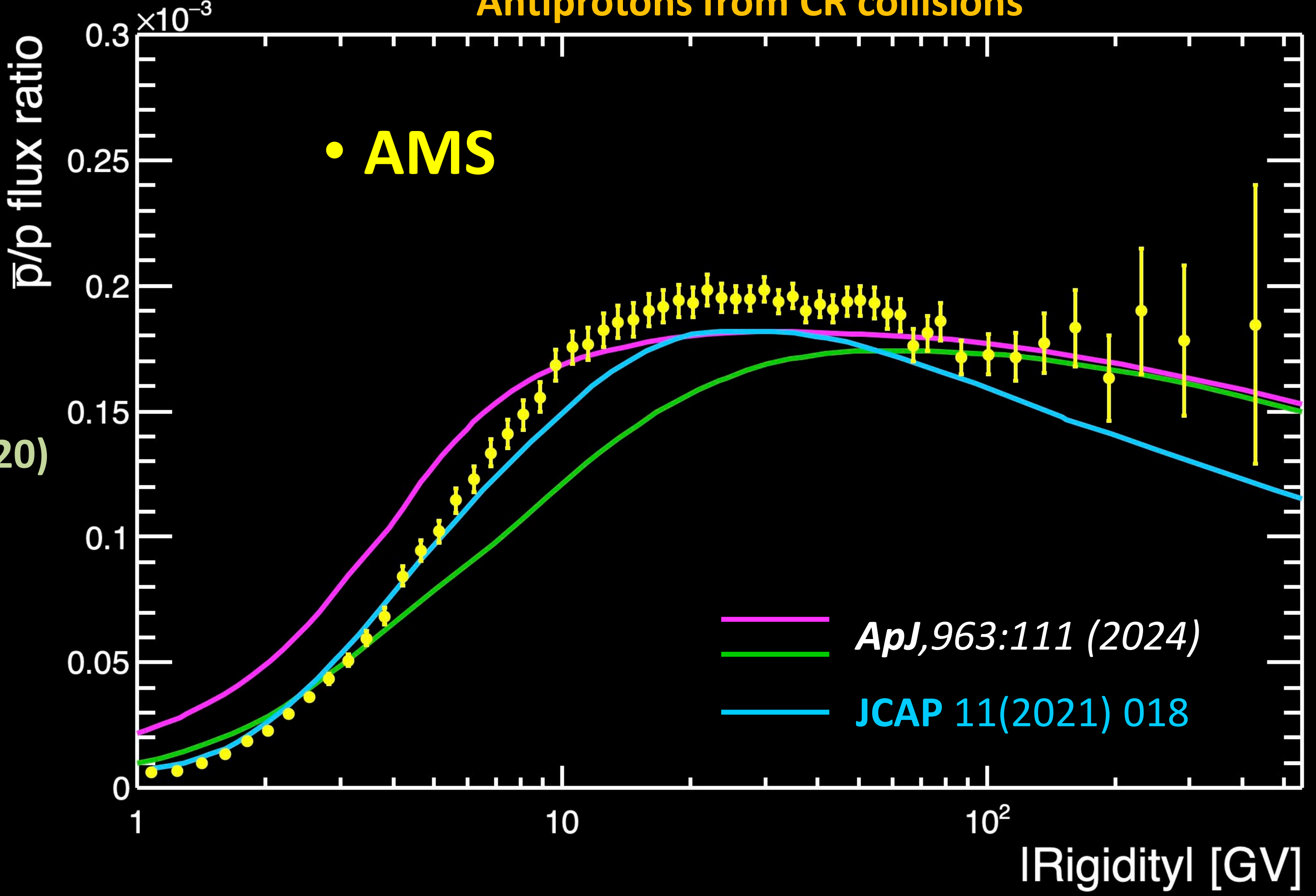
Antiprotons from CR collisions



# A sample of recent papers on AMS antiproton data

## Antiprotons and Dark Matter

P. De la Torre Luque, *et al.,* **JCAP** 05 (2024) 104

X. Qin *et al.,* **Phys. Rev. D., 107 (2023), 095026**

C. Zhu *et al.,* **Phys. Rev. Lett., 129 (2022), 231101**

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

Y. Genolini *et al.,* **Phys. Rev. D 104 (2021), 083005**

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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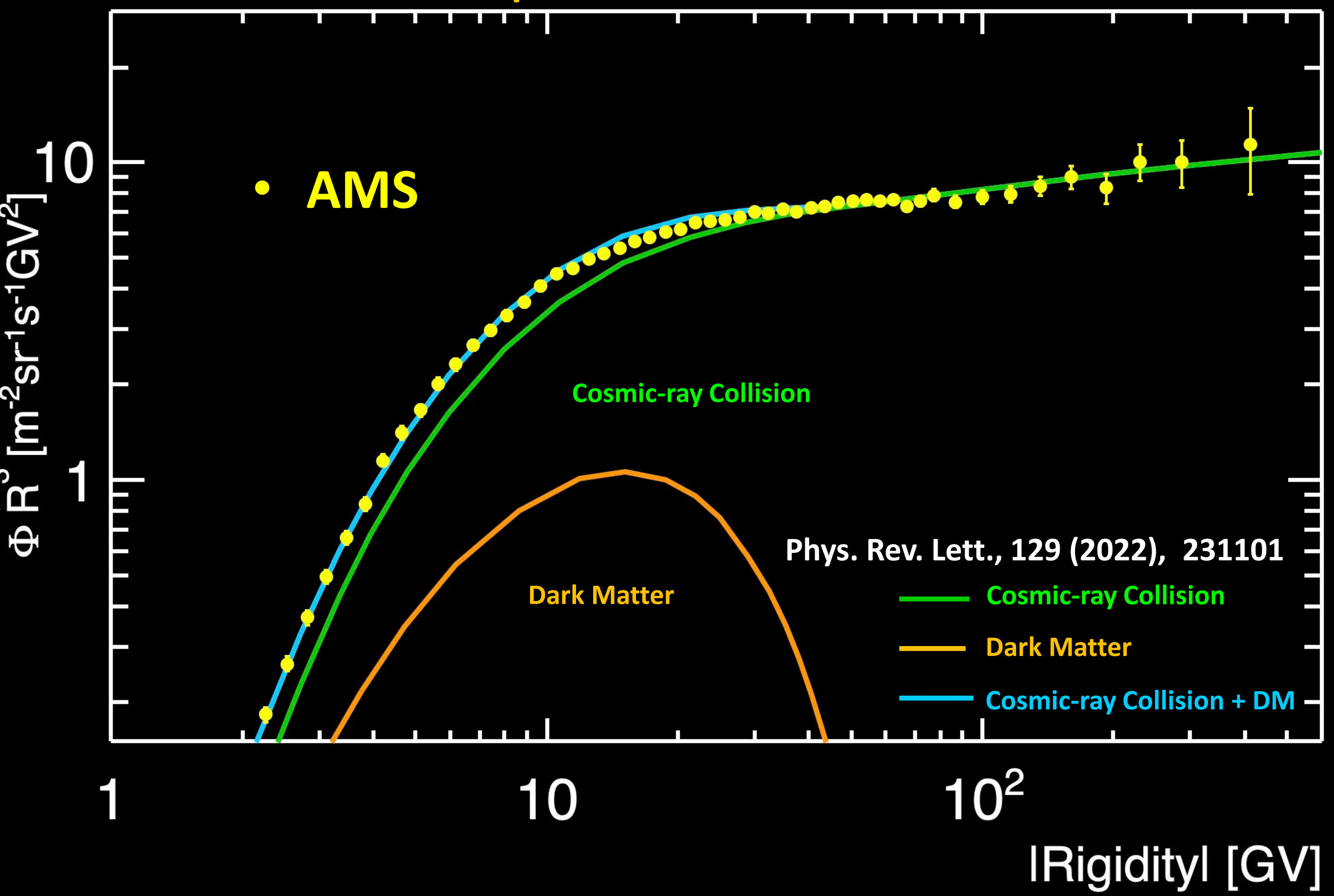
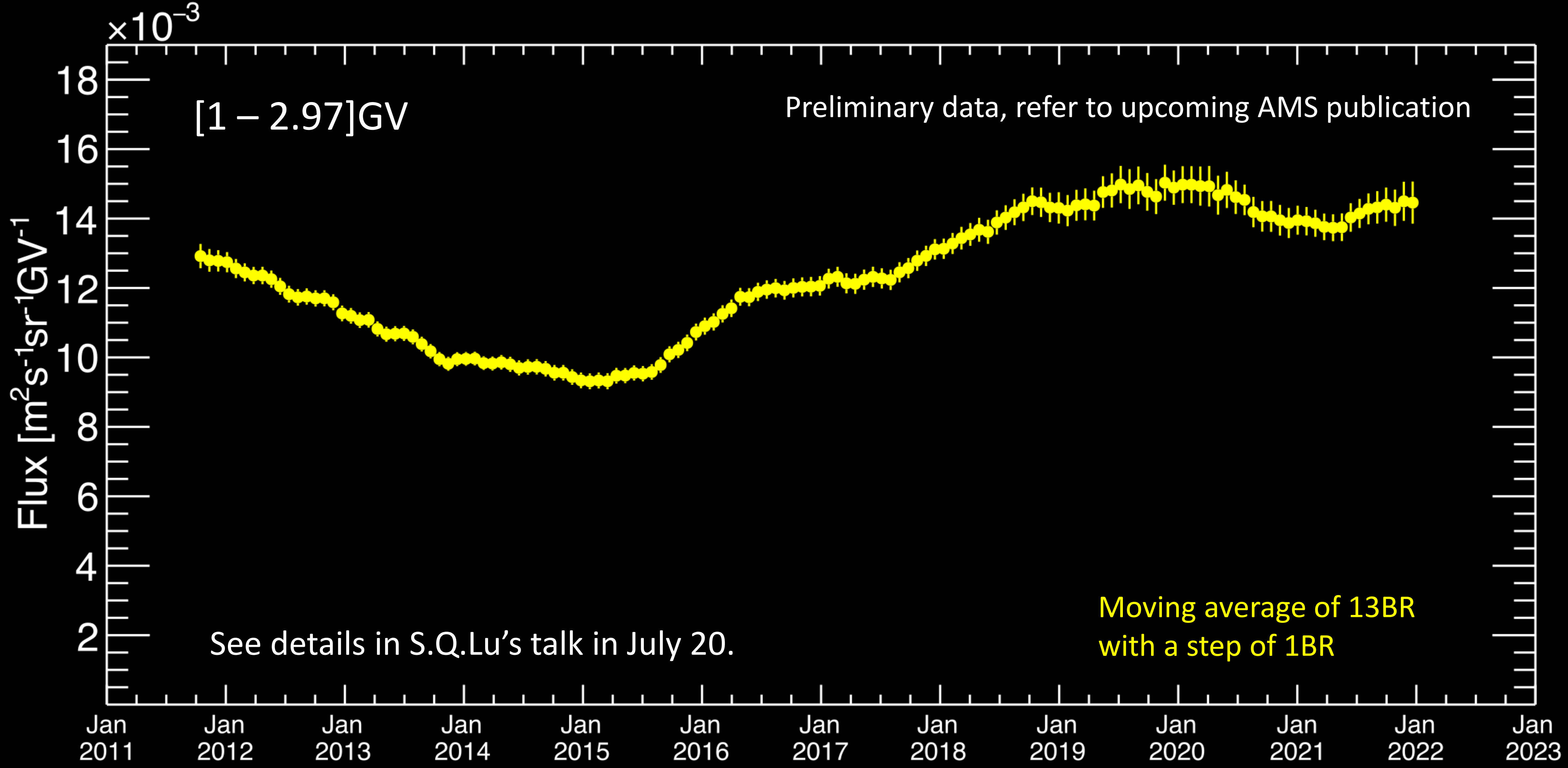
Antiprotons from CR collisions + DM



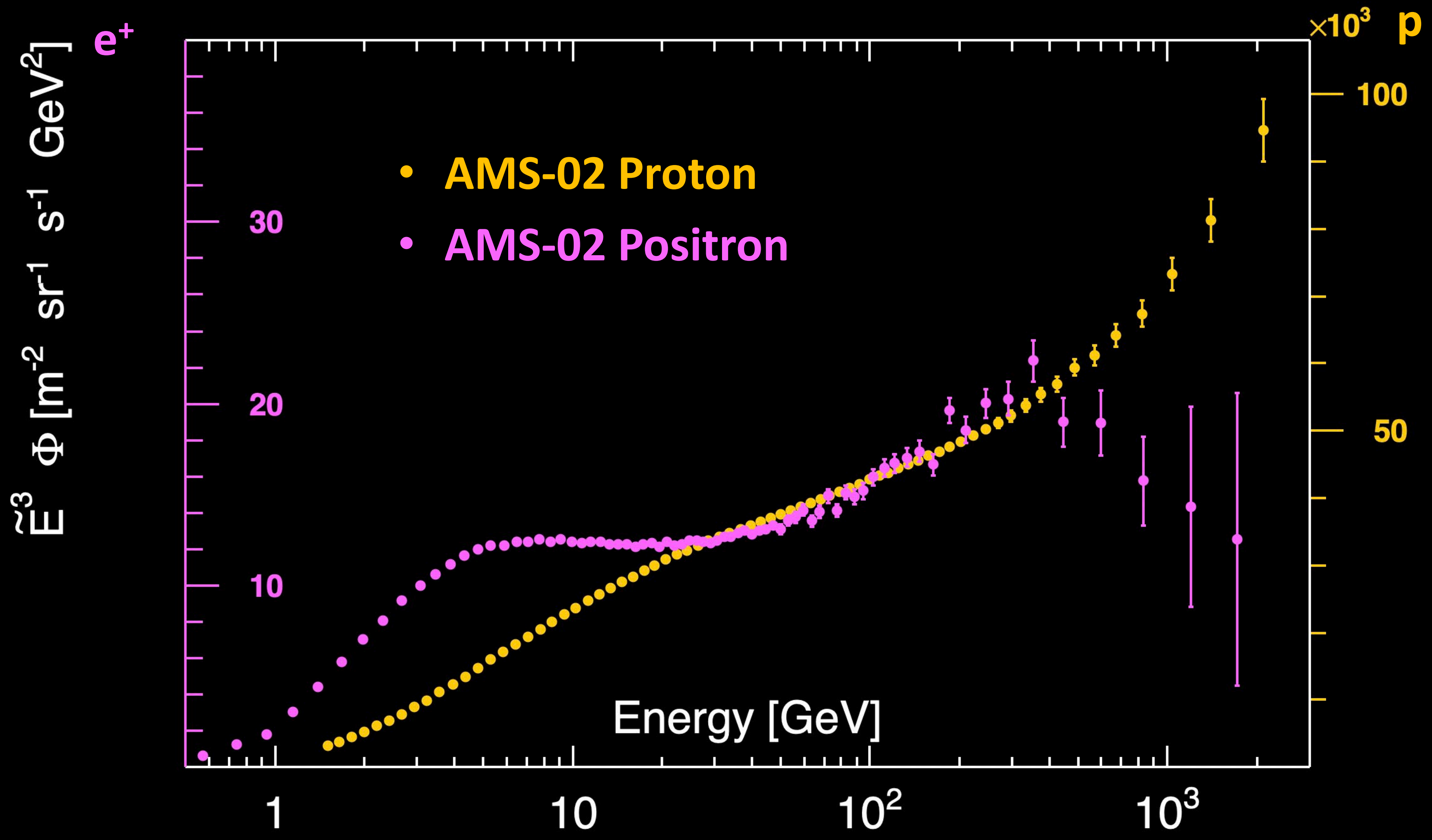
## Understanding Antiprotons with AMS Measurements

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



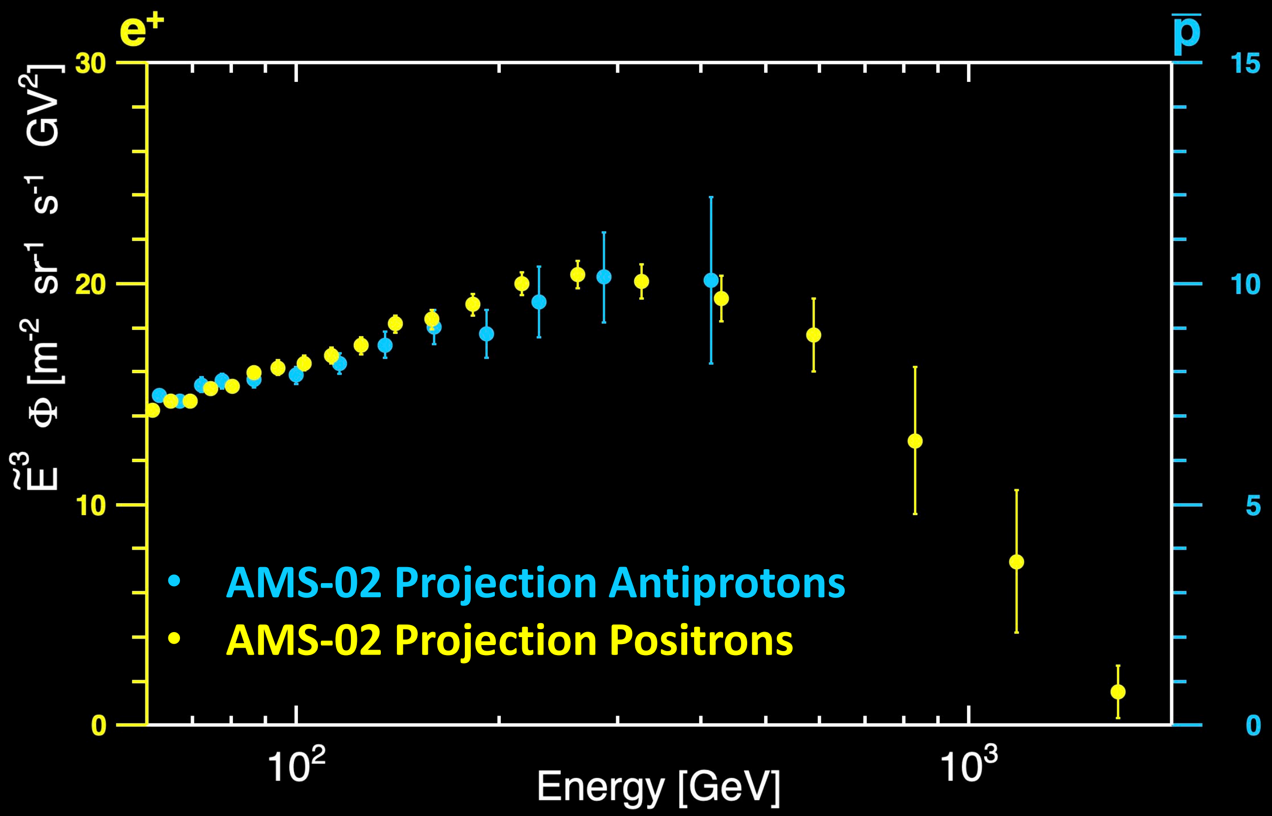
# The Spectra of Protons and Positrons

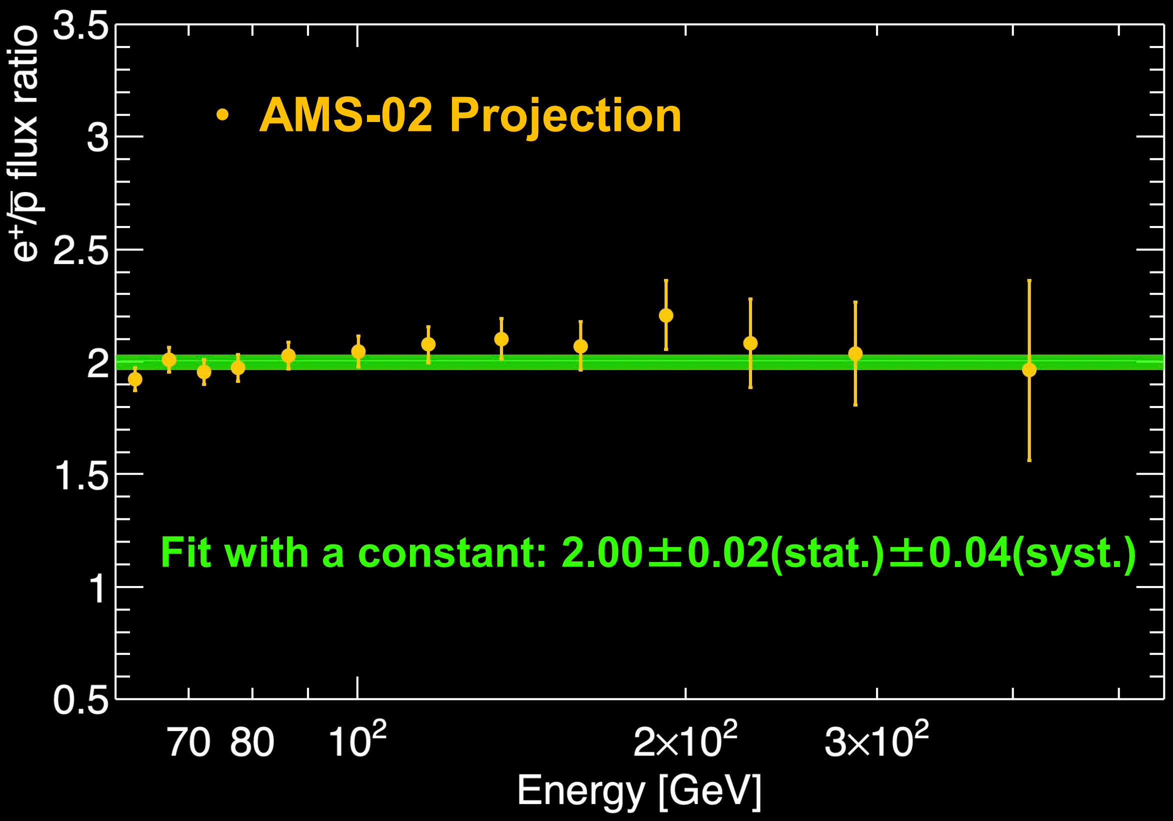
**Protons and positron have different origin and propagation history**




**AMS measurement shows new source of positrons with high energy cutoff**

# Future Measurement of Antiproton and Positrons with AMS Upgrade

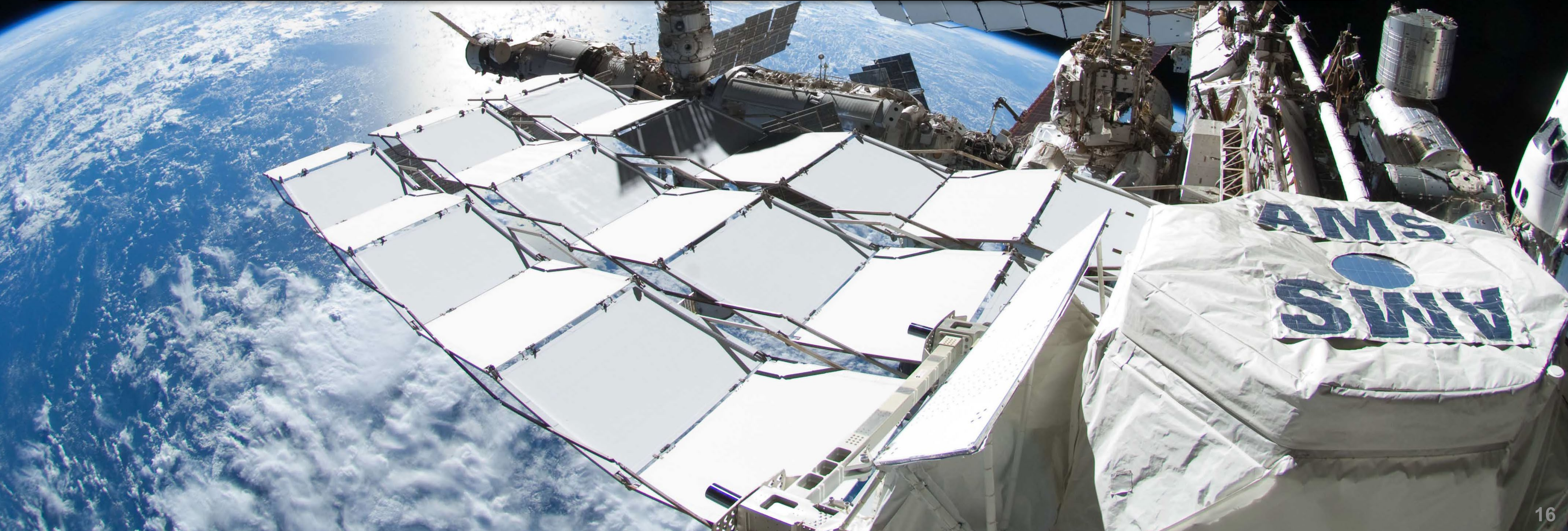



**The AMS upgrade will greatly improve the accuracy of the measurement of the positrons and antiprotons. The identical behaviour of positrons and antiprotons excludes the pulsar origin of positrons**

**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.**



# AMS Presentations in ICHEP

Jul 19

- Cosmic Anti-Protons and Properties of Elementary Particle Fluxes *C.Zhang*
- Origin of Cosmic Positrons and Electrons in the TeV Region *A.Kounine*
- Determination of Anisotropy of Elementary Particles *M.M.Gonzalez*
- Unique Properties of Twelve Years Positron and Electron Spectra measured by AMS *J.Casaus*

Jul 20

- Unique Properties of Primary Cosmic Rays measured by the Alpha Magnetic Spectrometer *Q.Yan*
- Properties of Cosmic Deuterons Measured by the Alpha Magnetic Spectrometer *C.D.Mendez*
- Properties of Secondary Cosmic Rays: Results from the Alpha Magnetic Spectrometer *J.O.Peleteiro*
- Unique Properties of Light Nuclei Time Variation up to 60 GV Measured by the Alpha Magnetic Spectrometer *V. Formato*
- Unique Features of Twelve Years Anti-Proton Spectrum measured by AMS *S.Q.Lu*