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

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on behalf of the AMS Collaboration

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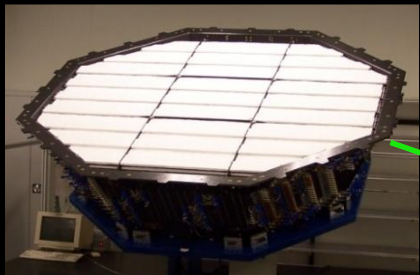
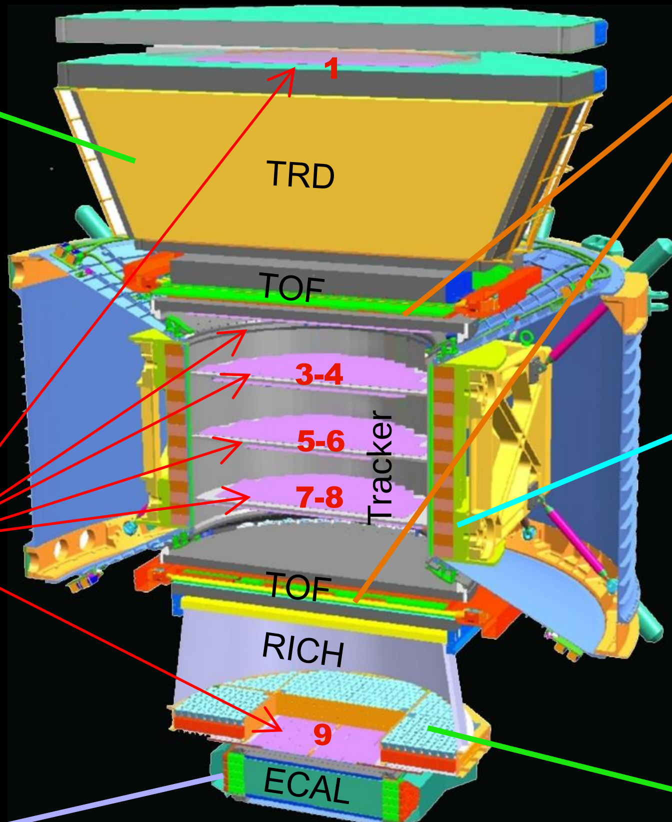
AMS is a space version of a precision detector used in accelerators

Transition Radiation Detector (TRD)



Particles and nuclei are defined by their charge (Z) and energy (E or P)

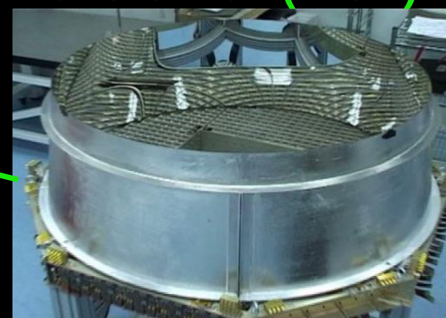
Time of Flight Detector (TOF)



Silicon Tracker

Magnet

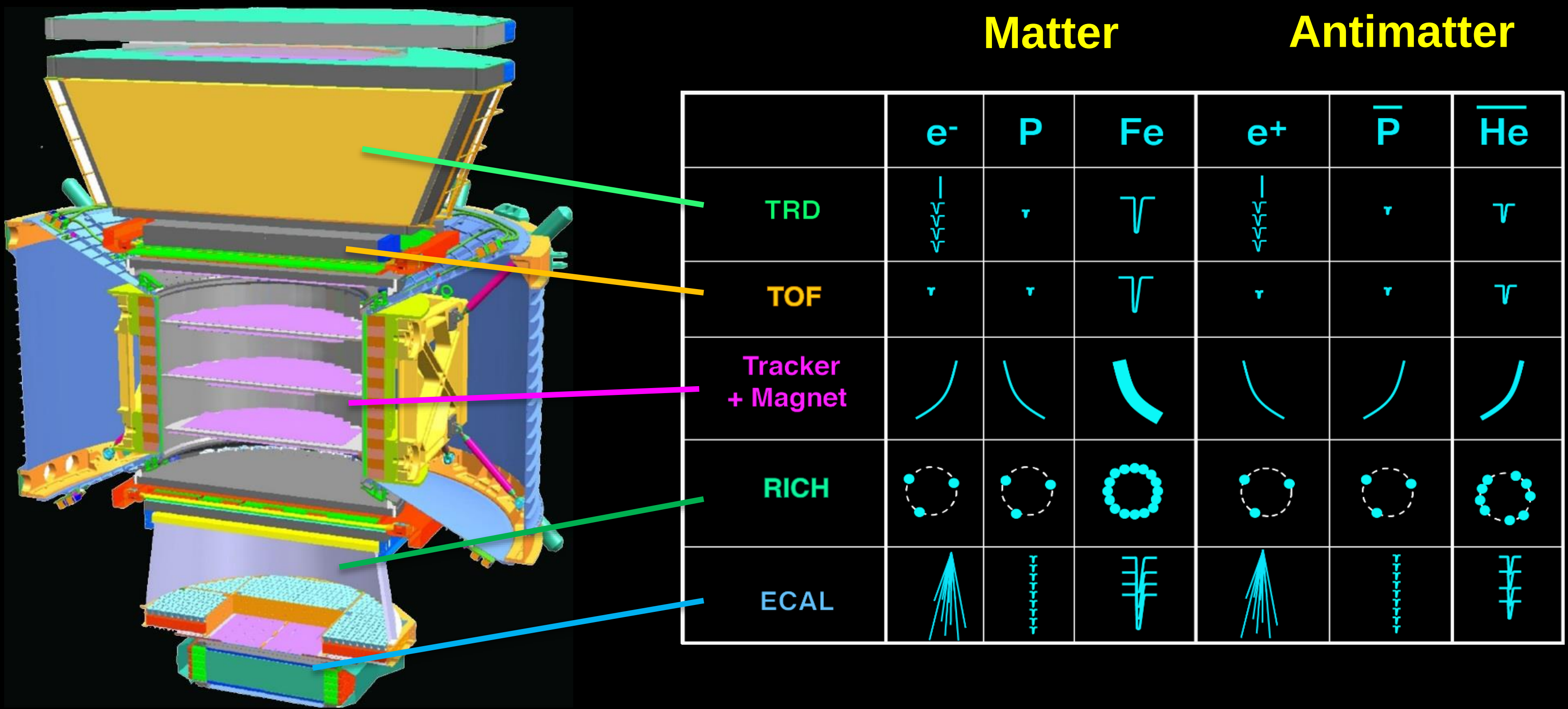
Ring Imaging Cherenkov (RICH)



Electromagnetic Calorimeter (ECAL)

Z and P are measured independently by the Tracker, RICH, TOF and ECAL

AMS is a unique magnetic spectrometer in space



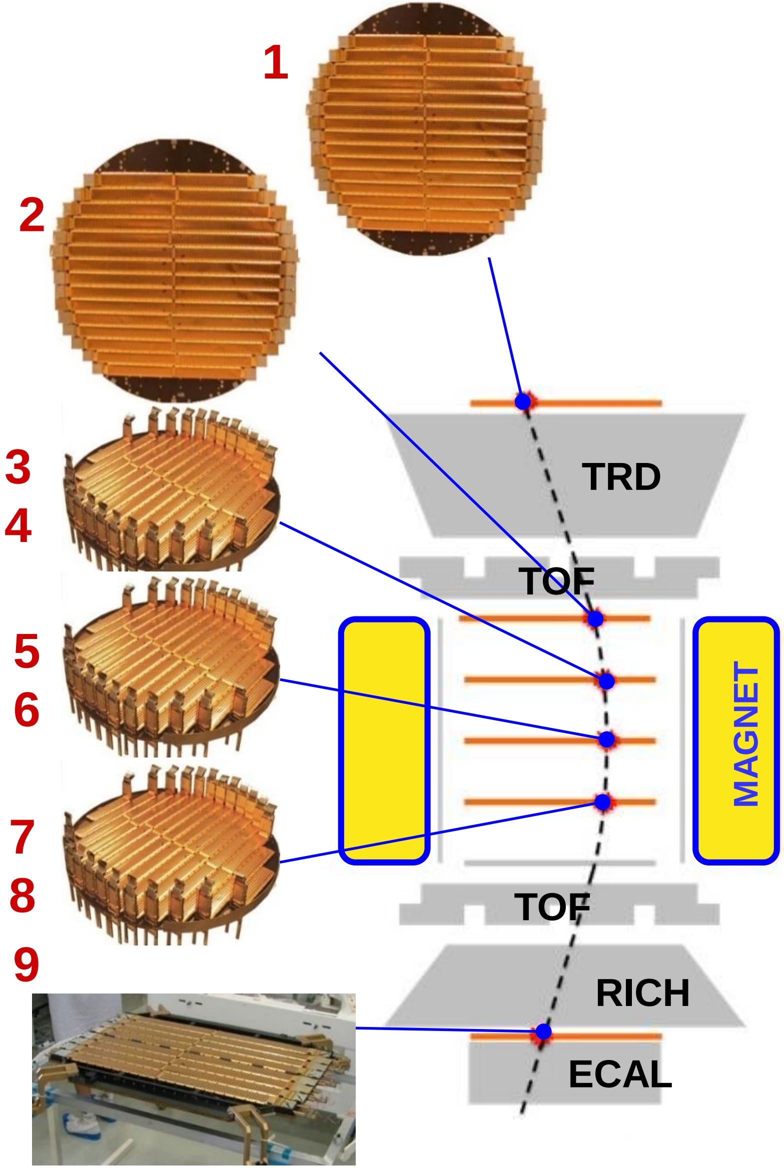
AMS is able to pick out 1 positron from 1,000,000 protons;

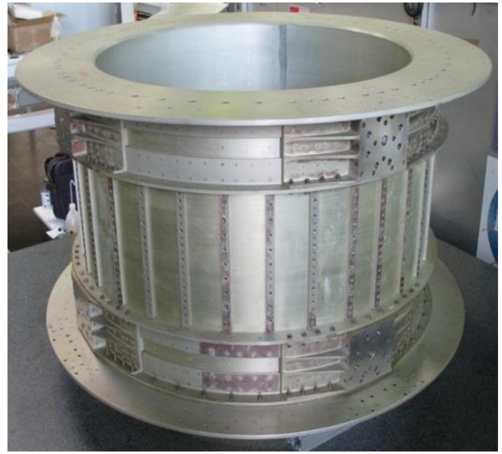
unambiguously separate positrons from electrons up to a trillion eV;

and accurately measure all cosmic rays to trillions of eV.

In 8 years, the detectors have performed flawlessly, collected more than 140 billion cosmic rays.

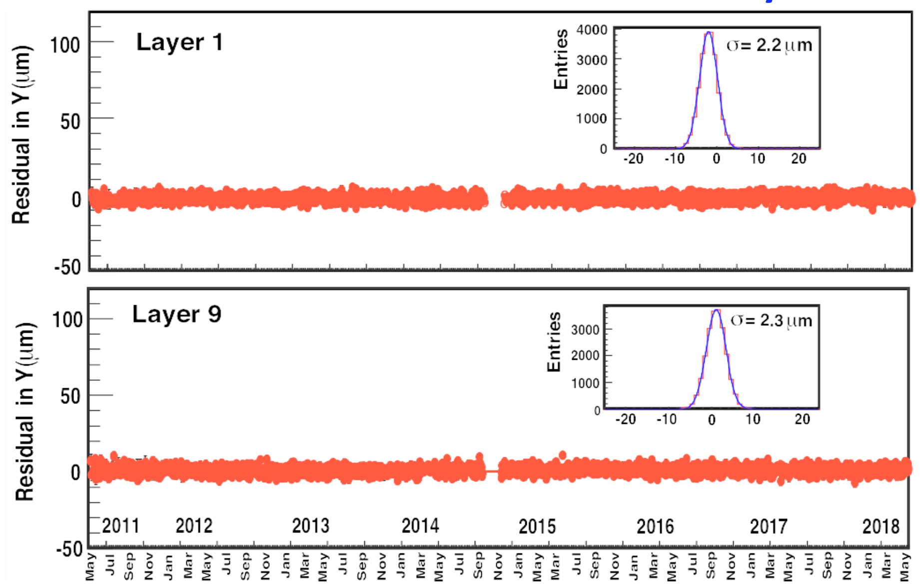
Silicon Tracker and Magnet





1.4 kG

Continuously monitor and calibrate the position of Tracker with 2 micron accuracy.

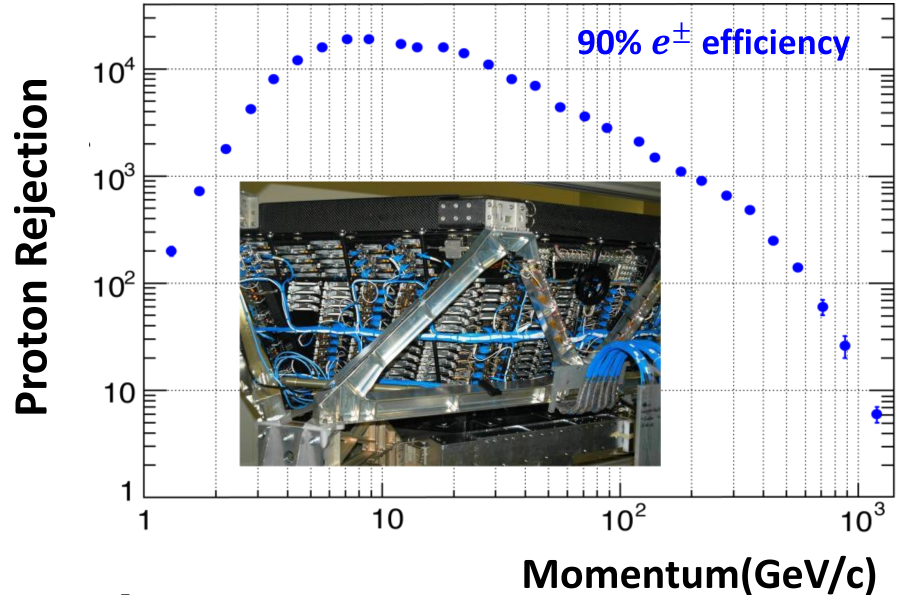


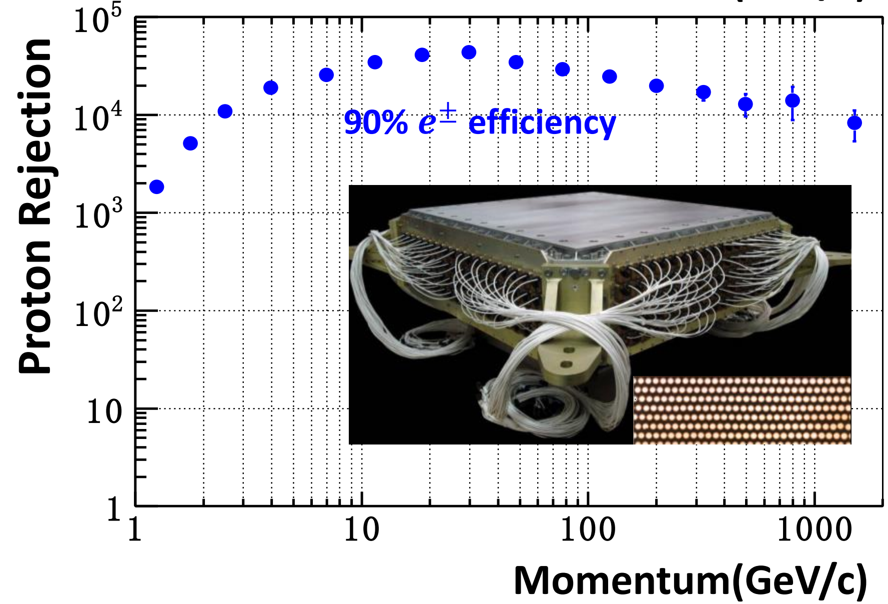
L1 to L9: 3 m level arm;

single point resolution: 10micron MDR: 2TV

$e^{\pm}$ and $p, \overline{p}$ seperation in AMS

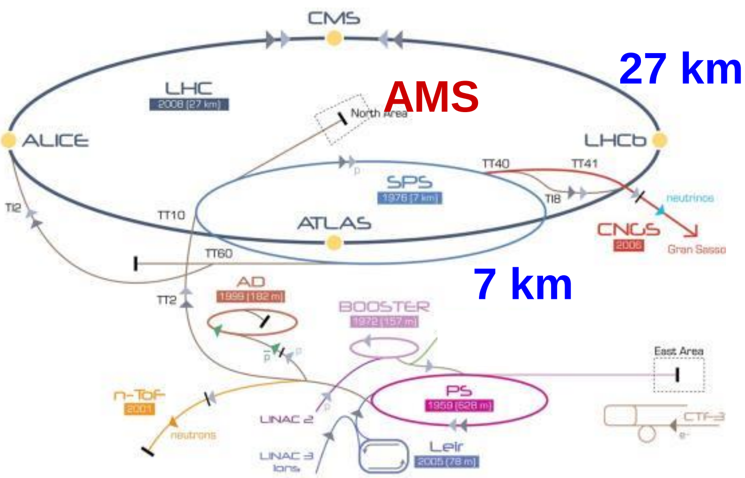
- Separation power is 10^3 to 10^4 with TRD
- Separation power is above 10^4 with ECAL and tracker
- TRD and ECAL is separated by magnet, they have independent particle separation





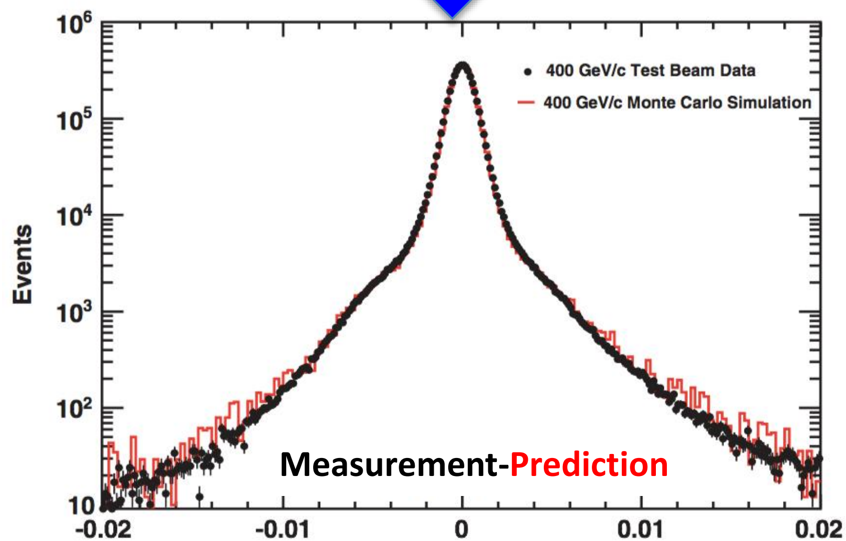
Calibration of the AMS Detector

Test beam at CERN SPS:
p, $e^{\pm}$, $\pi^{\pm}$, 10–400 GeV



2000 positions

Computer simulation:
Interactions, Materials, Electronics



Elementary Particles in Cosmic Rays

There are only four elementary particles which are long lived particles and could travel through the galaxy

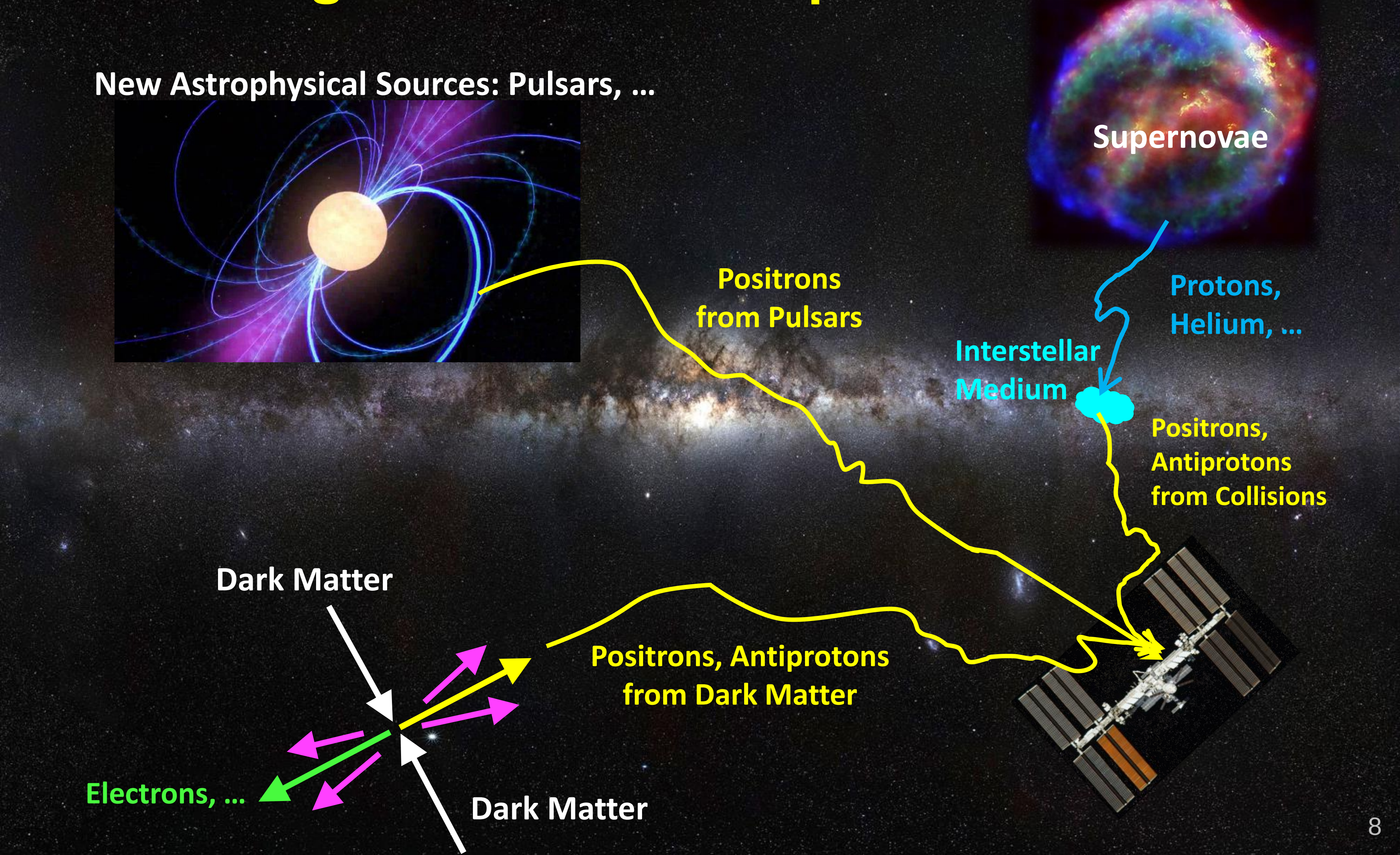
Protons	Antiprotons
Positrons	Electrons

They carry information of the origin and propagation history of cosmic rays.

Especially, antiprotons and positrons are anti-particles, it is particular interesting to find new phenomena because of the low backgrounds

The latest AMS measurement of these elementary particles will be presented. These results are in agreement with previous AMS publications, and extend to higher energy with better accuracy

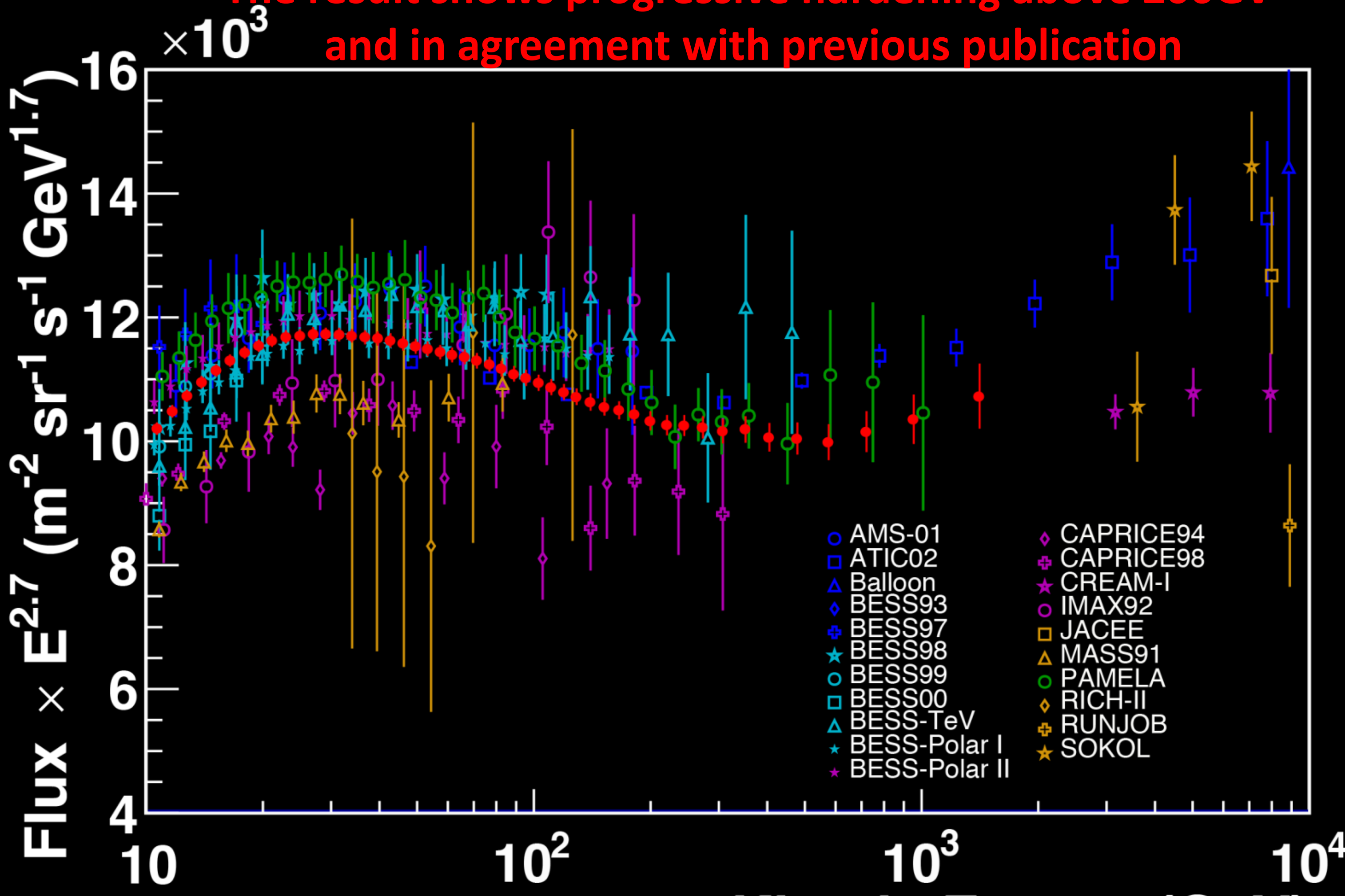
On the Origins of Cosmic Antiprotons and Positrons



AMS Measurement of the Proton Flux

Latest results – 1 billion protons

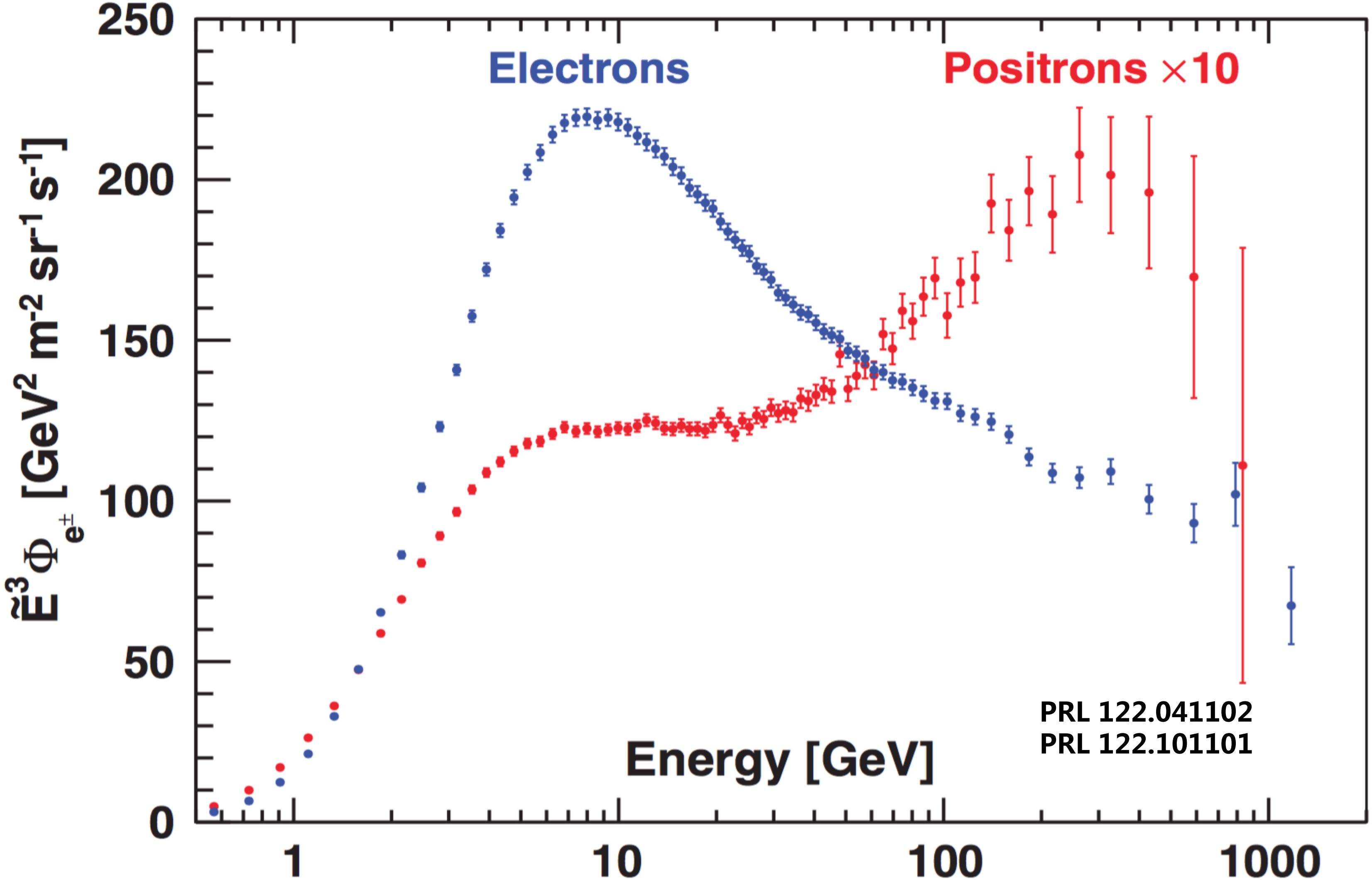
The result shows progressive hardening above 200GV and in agreement with previous publication



See Q.Yan's talk for details (CRD7a)

AMS Measurement of Electron and Positron Flux

Latest results – 28.1M electrons and 1.9 M positrons



PRL 122.041102
PRL 122.101101

See W.Xu's and Z.Weng's talk for details (CRD2b & CRD2h)

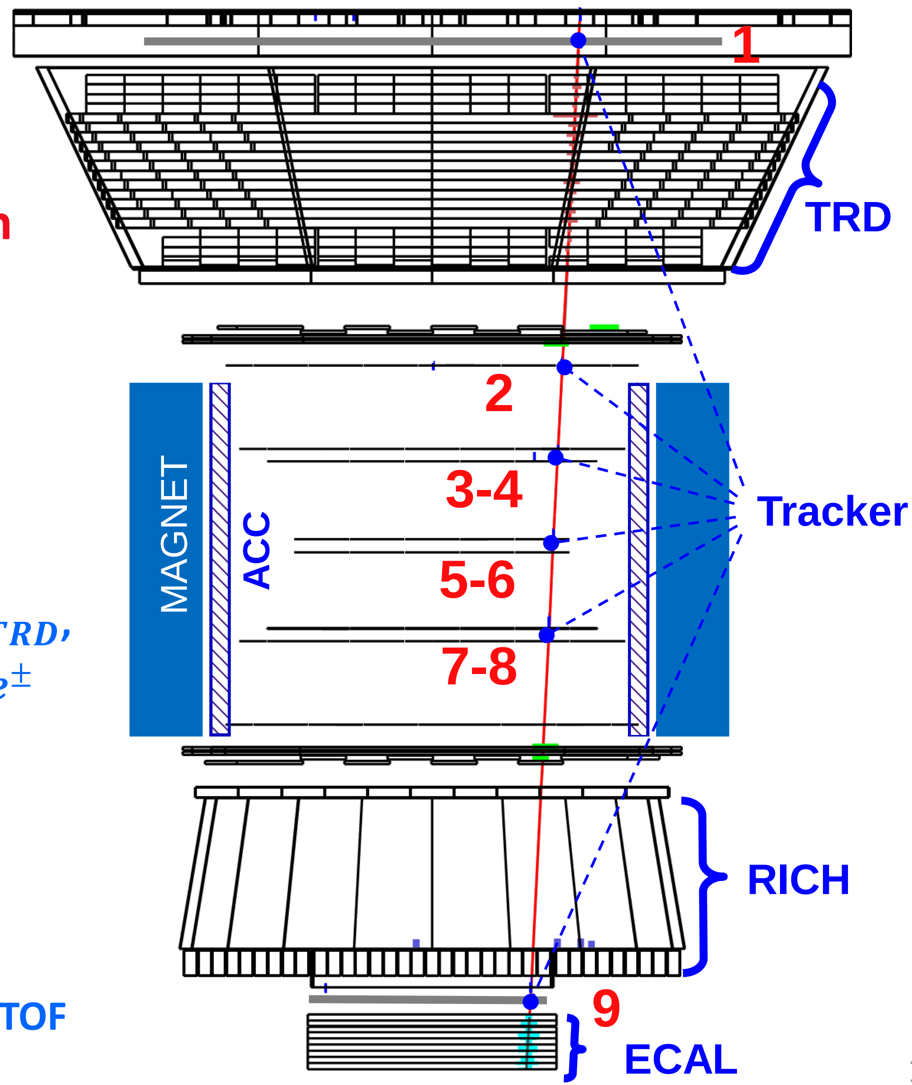
Antiproton Analysis

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

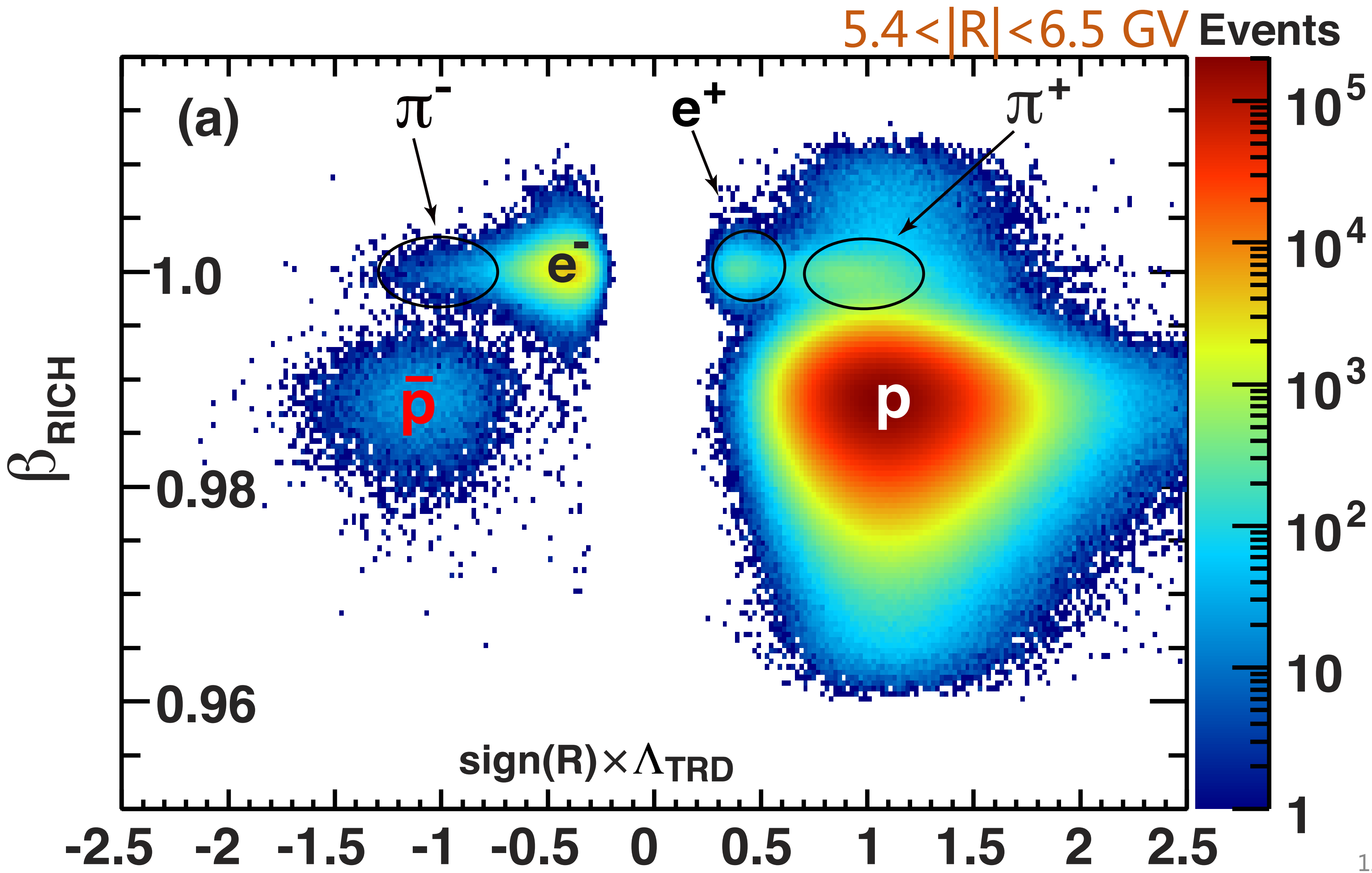
A percent precision experiment requires background rejection close to 1 in a million

- **TOF & RICH:** select down going particle and measure velocity
- **ECAL:** reject electron background
- **TRD:** provide proton/electron separation Λ_{TRD}, The ratio of the log-likelihood probability of the $e^{\pm}$ hypothesis to that of $p,\bar{p}$ hypothesis
- **Tracker:** Measure rigidity and reject misidentified proton with charge confusion estimator Λ_{cc}, the boosted decision tree value combines multiple information from tracker and TOF

R = −363 GV antiproton

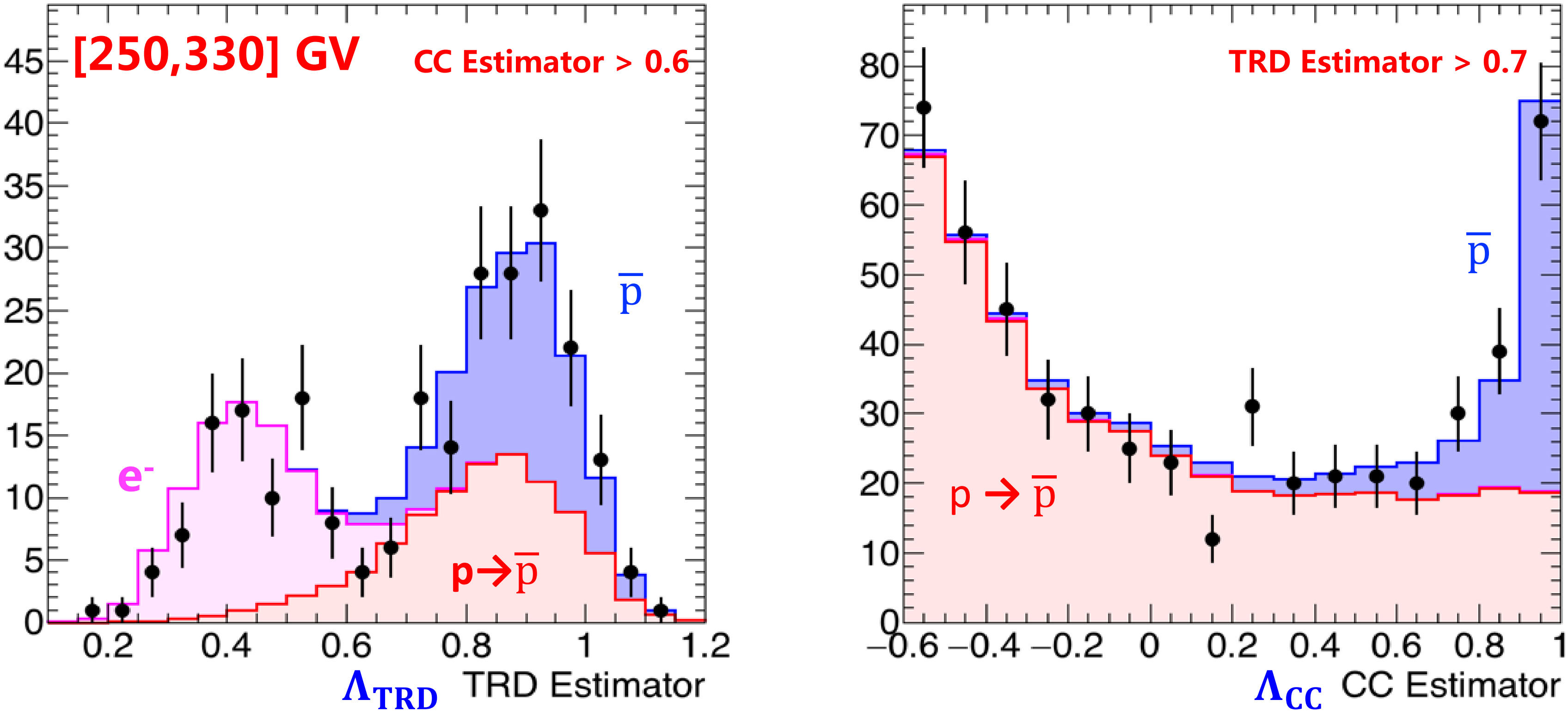


Antiproton identification at intermediate rigidity



Antiproton identification at High Energy

- Number of antiprotons are obtained by a fit to data sample in $(\Lambda_{TRD} - \Lambda_{CC})$ plane
- Precision determination of Signal and Background from Data:
  - Antiproton Signal are clearly identified in the signal region
  - Electron : identified by TRD estimator Λ_{TRD}
  - Proton Charge Confusion: identified by Charge Confusion estimator



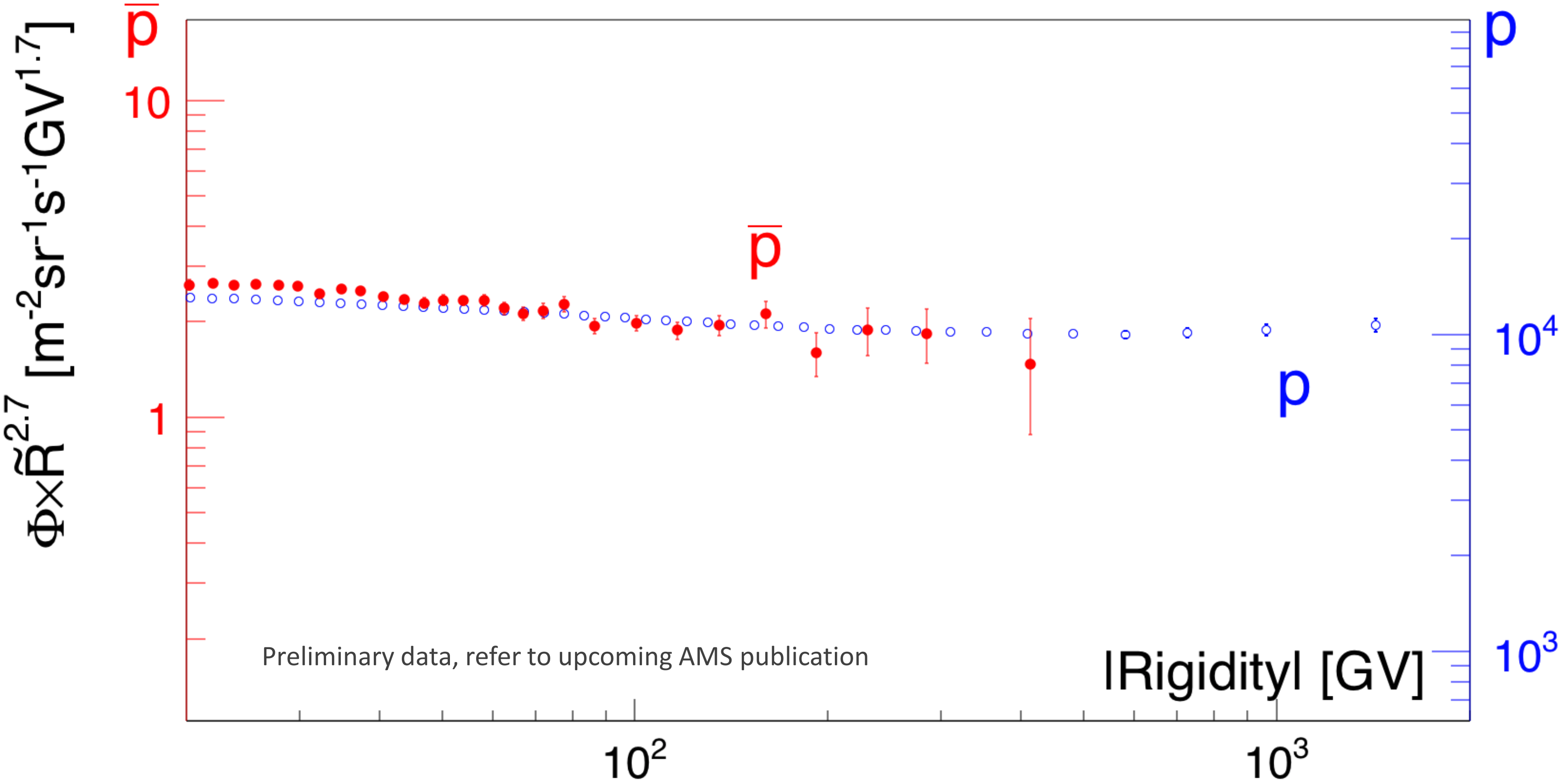
In first 6.5 years, ~0.56M antiprotons are analyzed in the rigidity range 1<|R|<525GV.

More than 3500 antiprotons above 100GV.

The Spectra of Protons and Antiprotons

If $\bar{p}$ are secondaries produced in ISM, their rigidity dependence should be different than p:

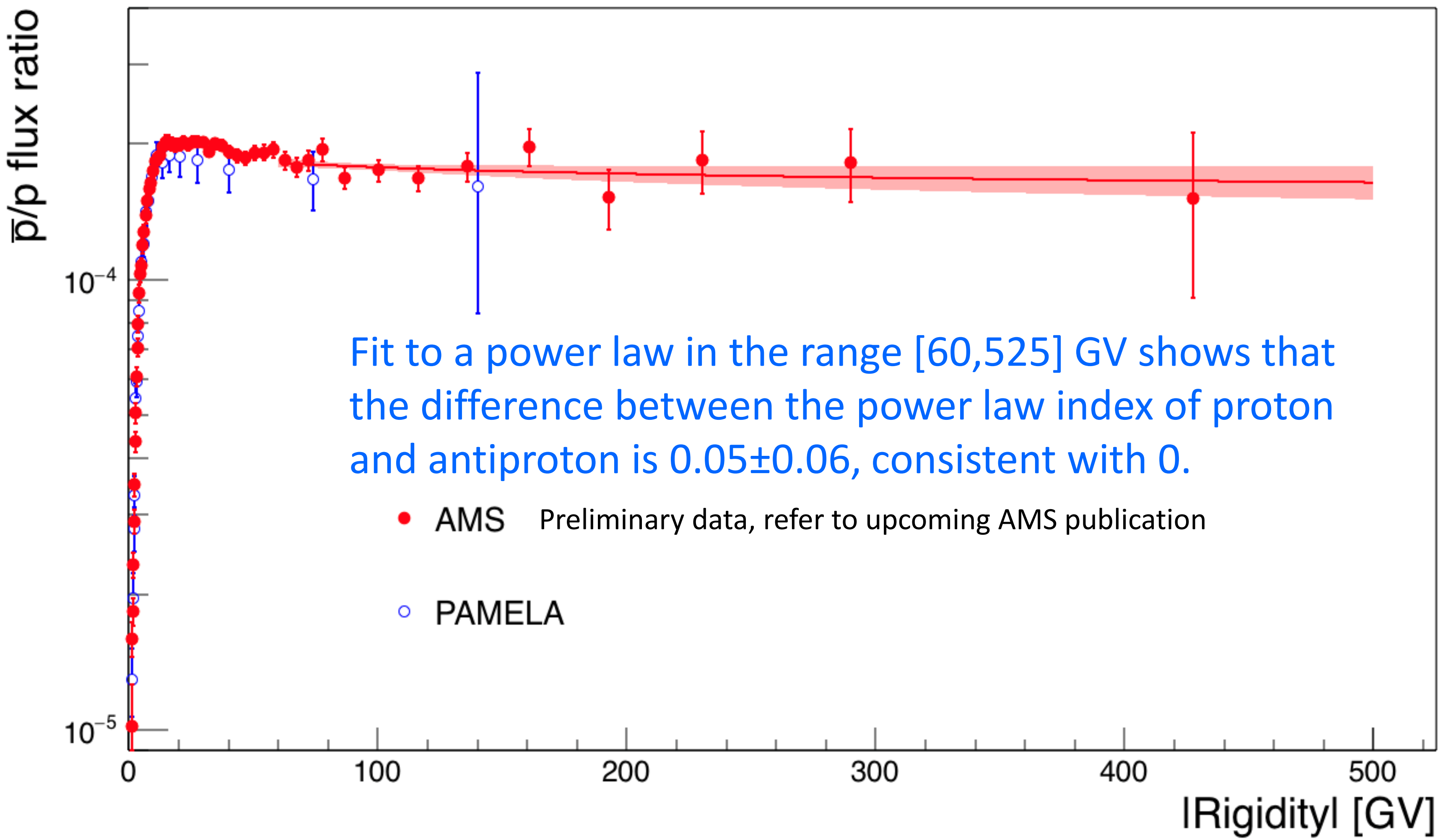
$$p + \text{ISM} \rightarrow \bar{p} + \ldots$$



AMS observed for the first time that above 60 GeV, p and $\bar{p}$ have identical behavior

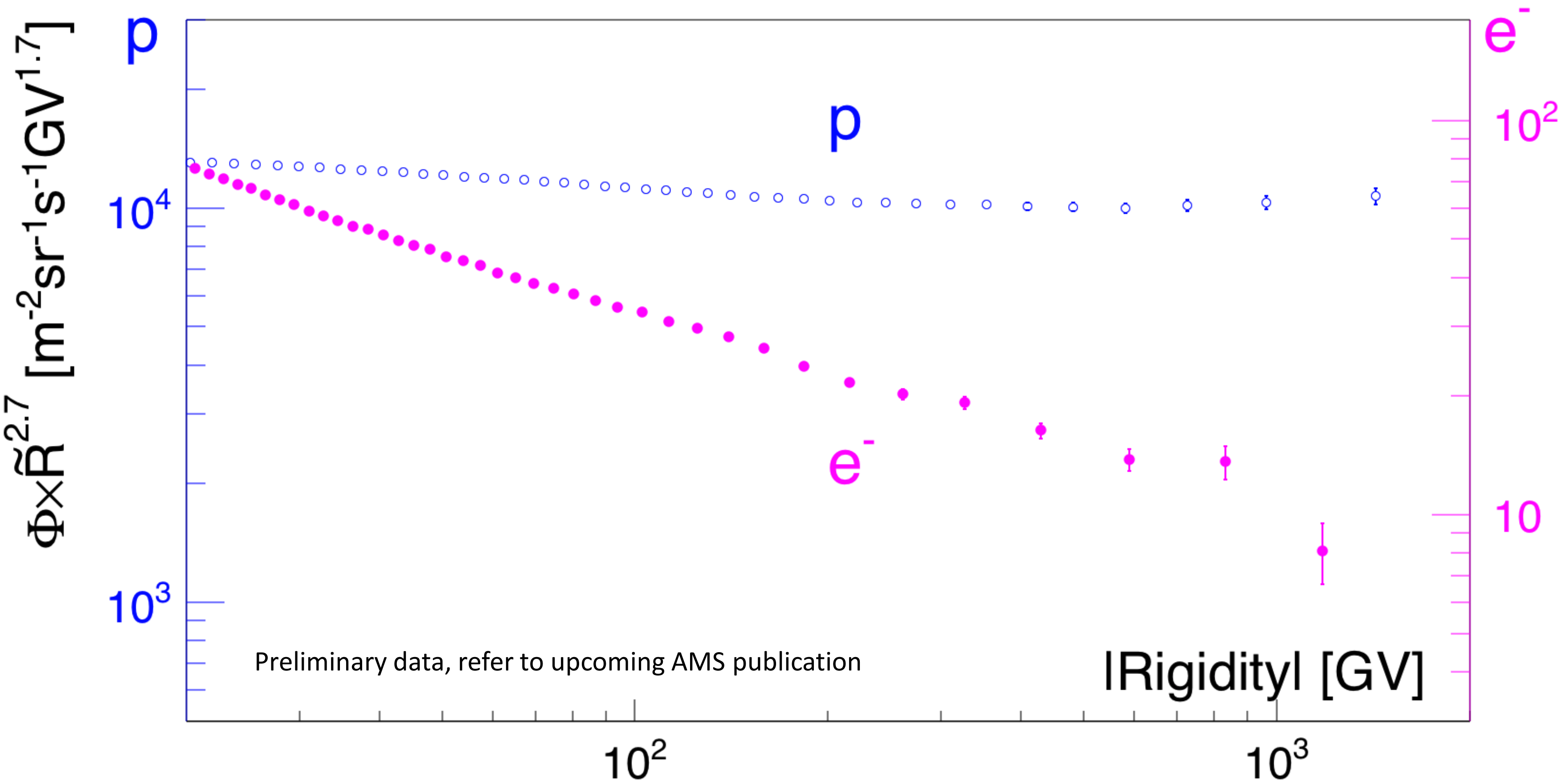
Antiproton-to-Proton Flux Ratio

Show no rigidity dependence above 60GV



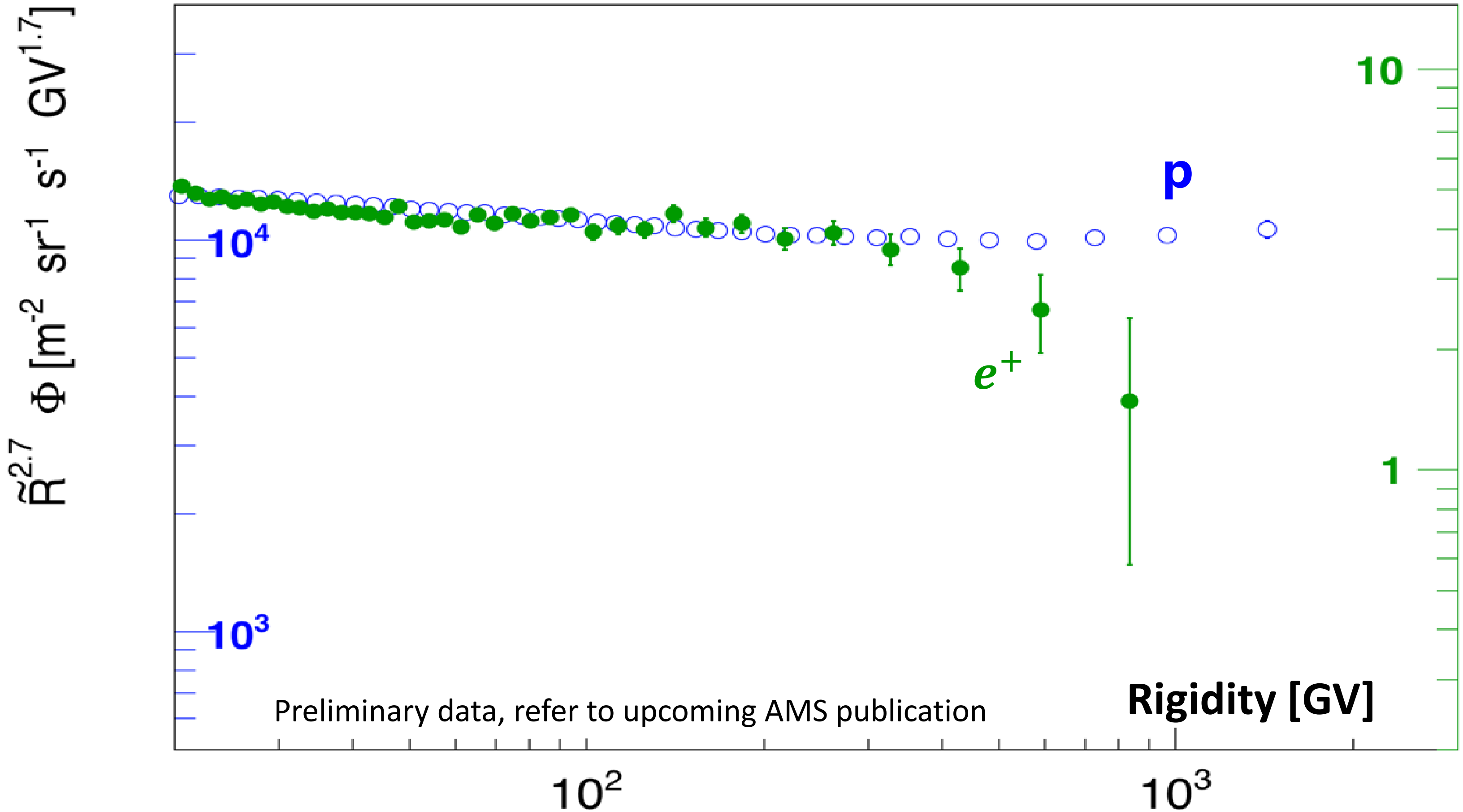
The Spectra of Protons and Electrons

Electron flux decrease with energy much faster than proton



The Spectra of Protons and Positrons

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

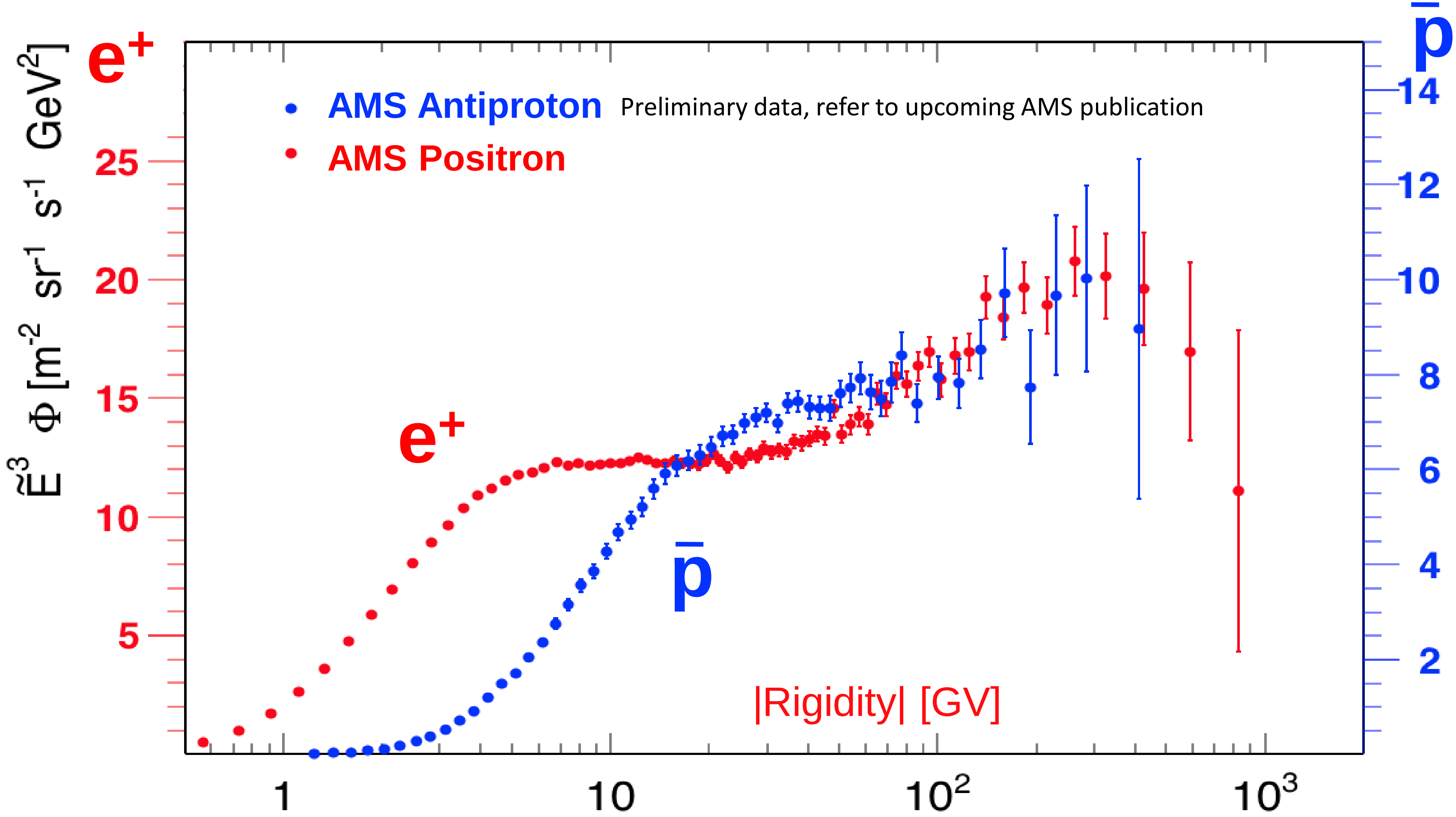


- **From ~60 GV , Positron and Proton have very similar rigidity dependence**
- **Starting from ~280GV, positron flux shows drop-off**
- **New source of high energy positron with energy cut-off.**

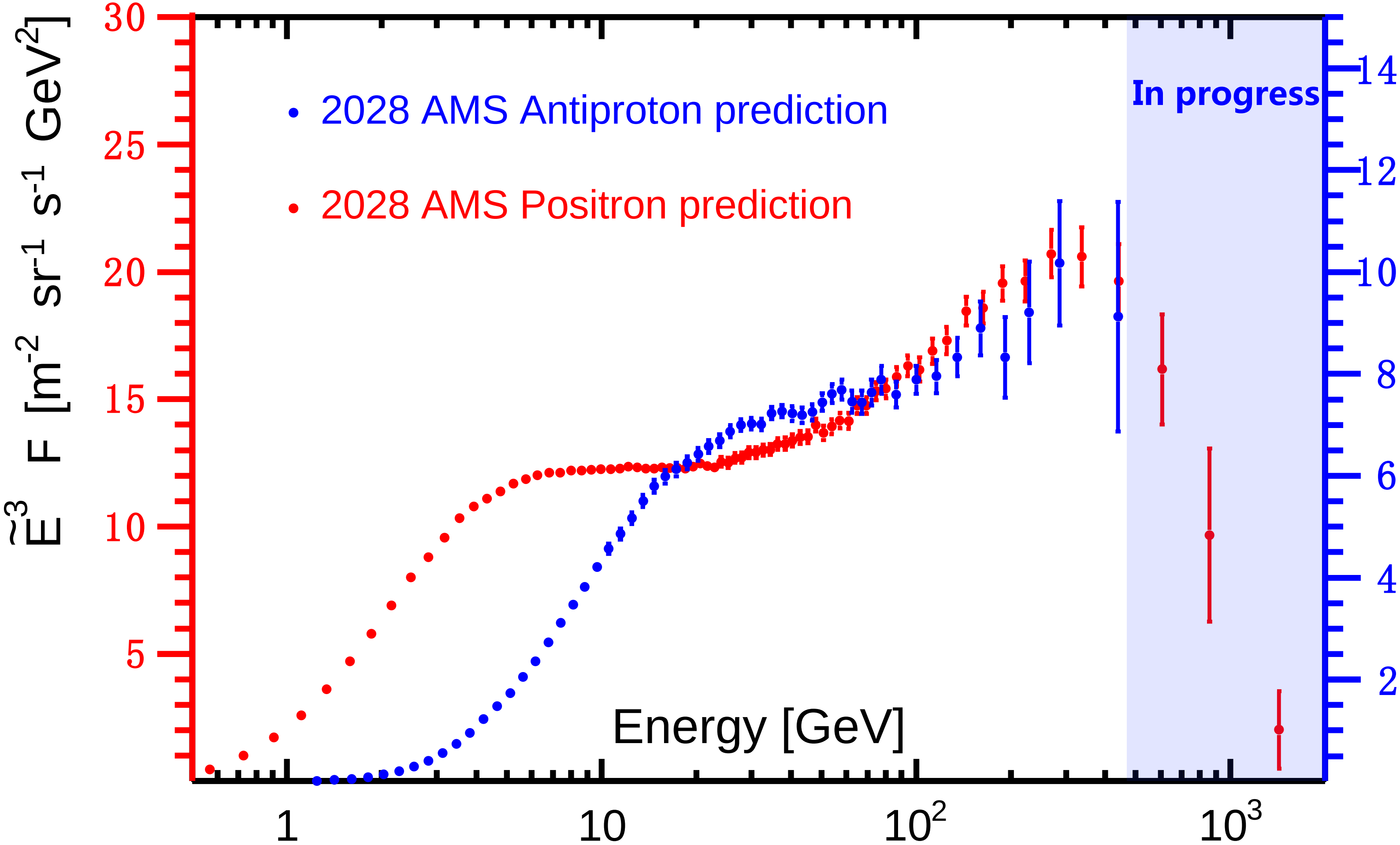
The spectra of antiproton and positron

At high energy Antiprotons have very similar trends with Positron

Antiprotons can not come from pulsar



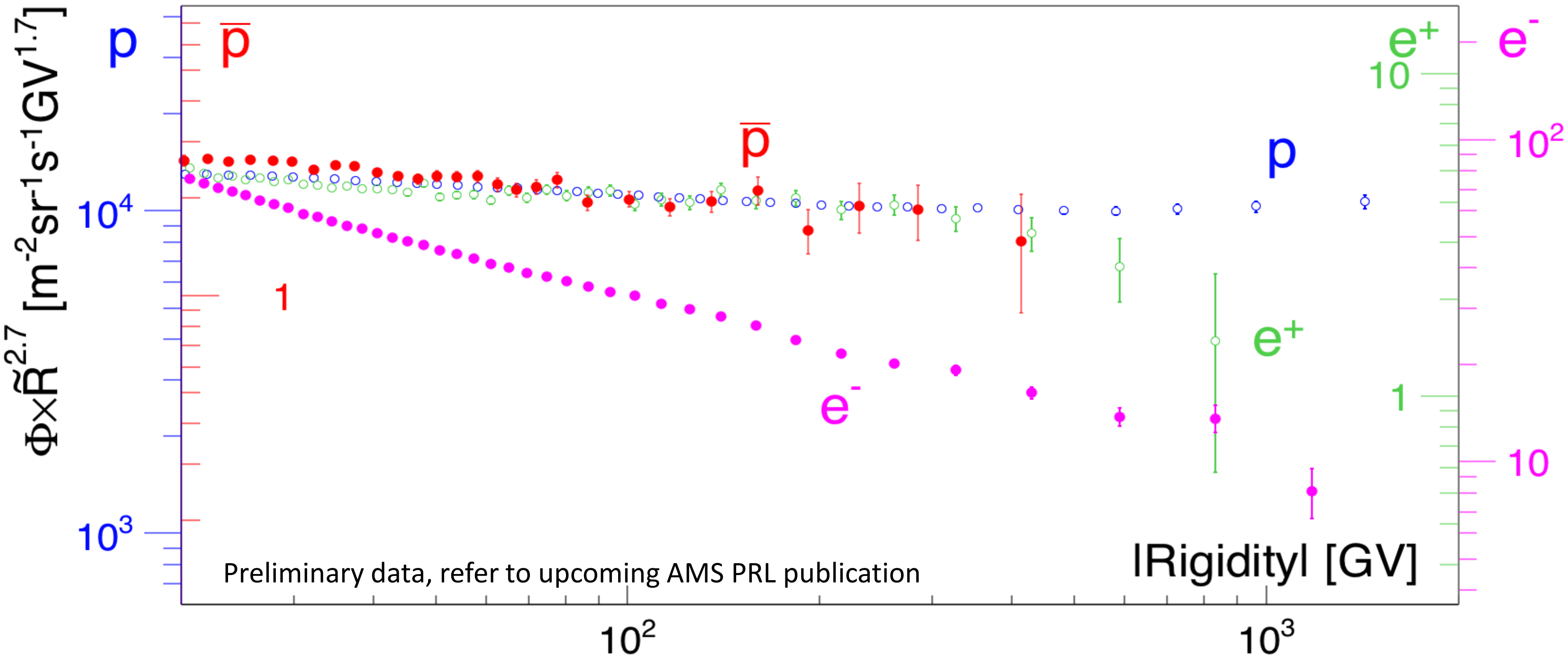
Antiprotons and Positrons to 2028



By continue taking data, AMS will improve the accuracy of these measurements and extend to higher energies.

Conclusion

Properties of elementary particle fluxes



1. The latest AMS measurement of elementary particles are presented.
2. The spectra of positrons, antiprotons, and protons are nearly identical in a large energy range and positron show drop-off at ~280GV.
3. Electron spectrum decrease faster than other three species.
4. By collecting data through the lifetime of ISS, AMS will greatly improve the accuracy of these measurements and reach to higher energy.

AMS Publications in PRL

In yellow: editors' suggestion

1. *First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV (2013)*
2. *Electron and Positron Fluxes in Primary Cosmic Rays Measured with the AMS on the ISS (2014)*
3. *High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–500 GeV with the AMS on the ISS (2014)*
4. *Precision Measurement of the $e^+ + e^-$ Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the AMS on the ISS (2014)*
5. *Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the AMS on the ISS (2015)*
6. *Precision Measurement of the He Flux in Primary Cosmic Rays of Rigidities 1.9 GVto 3 TV with the AMS on the ISS (2015)*
7. *Antiproton Flux, Antiproton-to-Proton Flux Ratio, and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the AMS on the ISS (2016)*
8. *Precision Measurement of the B to C Flux Ratio in Cosmic Rays from 1.9 GV to 2.6 TV with the AMS on the ISS (2016)*
9. *Observation of the Identical Rigidity Dependence of He, C, and O Cosmic Rays at High Rigidities by the AMS on the ISS (2017)*
10. *Observation of New Properties of Secondary Cosmic Rays Lithium, Beryllium, and Boron by the AMS on the ISS (2018)*
11. *Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes with AMS on the ISS (2018)*
12. *Observation of complex time structures in the cosmic-ray electron and positron fluxes with the AMS on the ISS (2018)*
13. *Precision measurement of cosmic-ray nitrogen and its primary and secondary components with AMS on the ISS (2018)*
14. *Towards Understanding the Origin of Cosmic-Ray Positrons (2019)*
15. *Towards Understanding the Origin of Cosmic-Ray Electrons (2019)*

… "Helium Isotopes in the Cosmos "

… "Rigidity Dependence of Ne, Mg, and Si Cosmic Rays"

…

AMS Presentations in ICRC

Jul 25-26

- CRD1a: Antiproton Flux and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS *C.Zhang*
- CRD2a: Observation of Complex Time Structures in the Cosmic-Ray Electron and Positron Fluxes by the Alpha Magnetic Spectrometer on the ISS *M.Duranti*
- CRD2b: Towards Understanding the Origin of Cosmic-Ray Electrons *W.Xu*
- CRD2h: Towards Understanding the Origin of Cosmic-Ray Positrons *Z.Weng*
- CRD4a: Anisotropy of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS, *I.Gebauer*

Jul 28-29

- SH5f: Solar Energetic Particles measured by the Alpha Magnetic Spectrometer on the International Space Station during solar cycle 24 *C.Light*
- CRD6b: Properties of Secondary Cosmic Rays Lithium, Beryllium and Boron Measured by the Alpha Magnetic Spectrometer on the International Space Station *A. Oliva*
- CRD6c: Cosmic-Ray Helium Isotopes with the Alpha Magnetic Spectrometer *C. Delgado*
- CRD6d: Cosmic-Ray Lithium Isotopes with the Alpha Magnetic Spectrometer *L. Derome*

Jul 30

- CRD7a: Properties of Primary Cosmic Rays Neon, Magnesium and Silicon Measured with the Alpha Magnetic Spectrometer on the ISS, *Q. Yan*
- CRD8a: Precision Measurement of the Monthly Carbon and Oxygen Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station, *F. Donnini*
- CRD8b: Properties of Primary Protons, Helium, Carbon and Oxygen Nuclei Measured with the Alpha Magnetic Spectrometer on the ISS *Q.Yan*
- CRD8c: Precision Measurement of the Daily Proton and Helium Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station *C. Consolandi*
- CRD8d: Precision Measurement of the Monthly Proton and Helium Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station, *N. Tomassetti*

Antiproton identification

- The number of antiprotons is determined from template fit.
- To maximize the measurement accuracy, different templates are used in three rigidity region

1. **Low rigidity region:** Electron, pion background

   1.00-4.02 GV **The mass calculated from TOF and Tracker**

2. **Intermediate region:** Electron and small amount of pion background

   3.67-18.0 GV **RICH and The TRD estimator**

3. **High rigidity region:** Electron and charge confusion proton background

   16.6-525 GV **2D template in (Λ_{TRD} - Λ_{CC}) plane**

In 6.5 years, >5.6×10^5 antiprotons are selected in the rigidity range 1<|R|<525 GV

In 6.5 years, $>5.6\times10^5$ antiprotons are selected

in the rigidity range $1<|R|<525$ GV

More than 3500 antiprotons above 100 GV

Systematic Errors Study

- **Affect the antiproton counting** σ_N
    - Geomagnetic cutoff
    - Event selection
    - **Charge confusion templates**
- **Affect the acceptance,** σ_A
    - **Inelastic cross sections**
    - Limited MC statistics
    - Migration matrix
- **Rigidity scale,** σ_R