Antiproton Flux and Antiproton-to-Proton Flux Ratio in Primary Cosmic Rays measured with AMS on ISS

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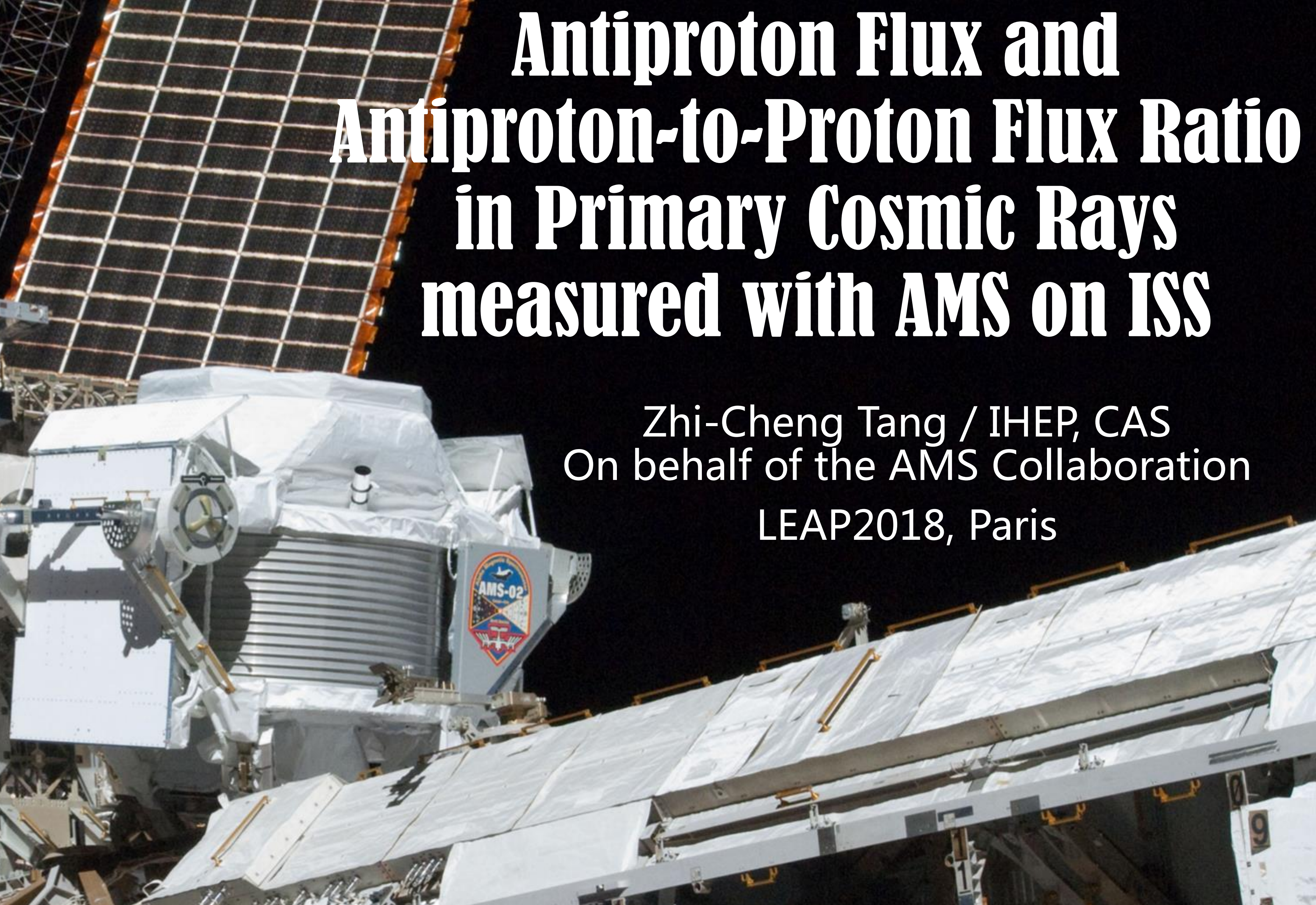
On behalf of the AMS Collaboration

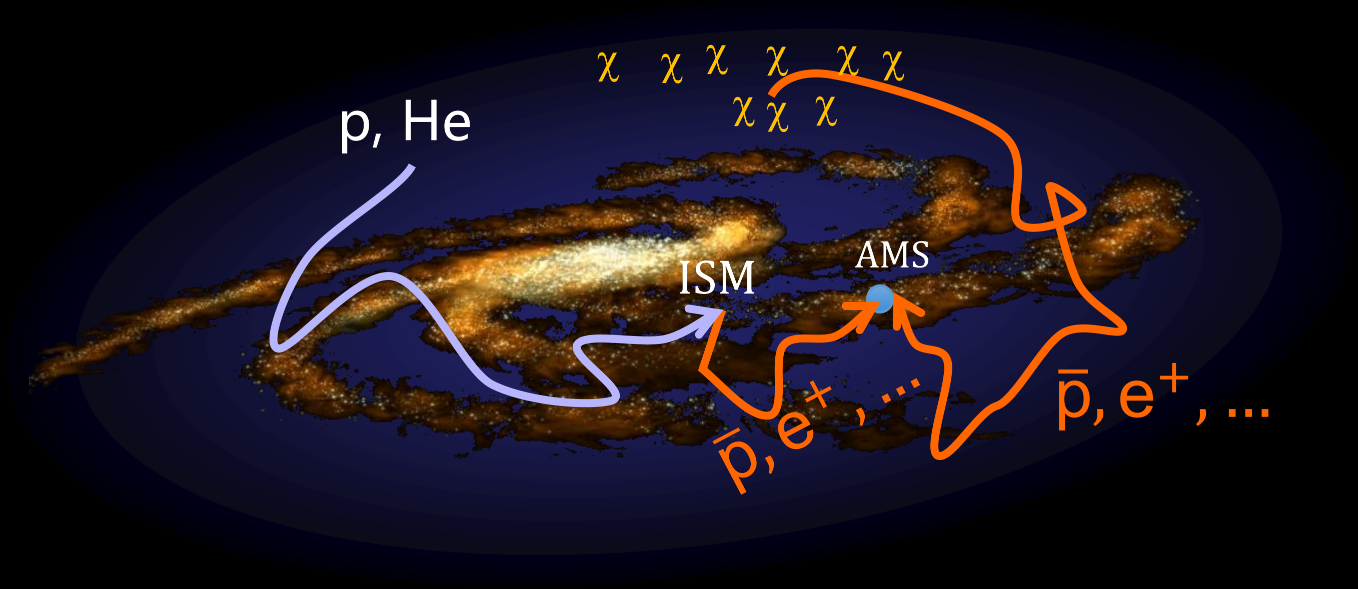
LEAP2018, Paris



Dark Matter Searches at AMS

The collision of cosmic rays with interstellar medium(ISM) will produce $\bar{p}$

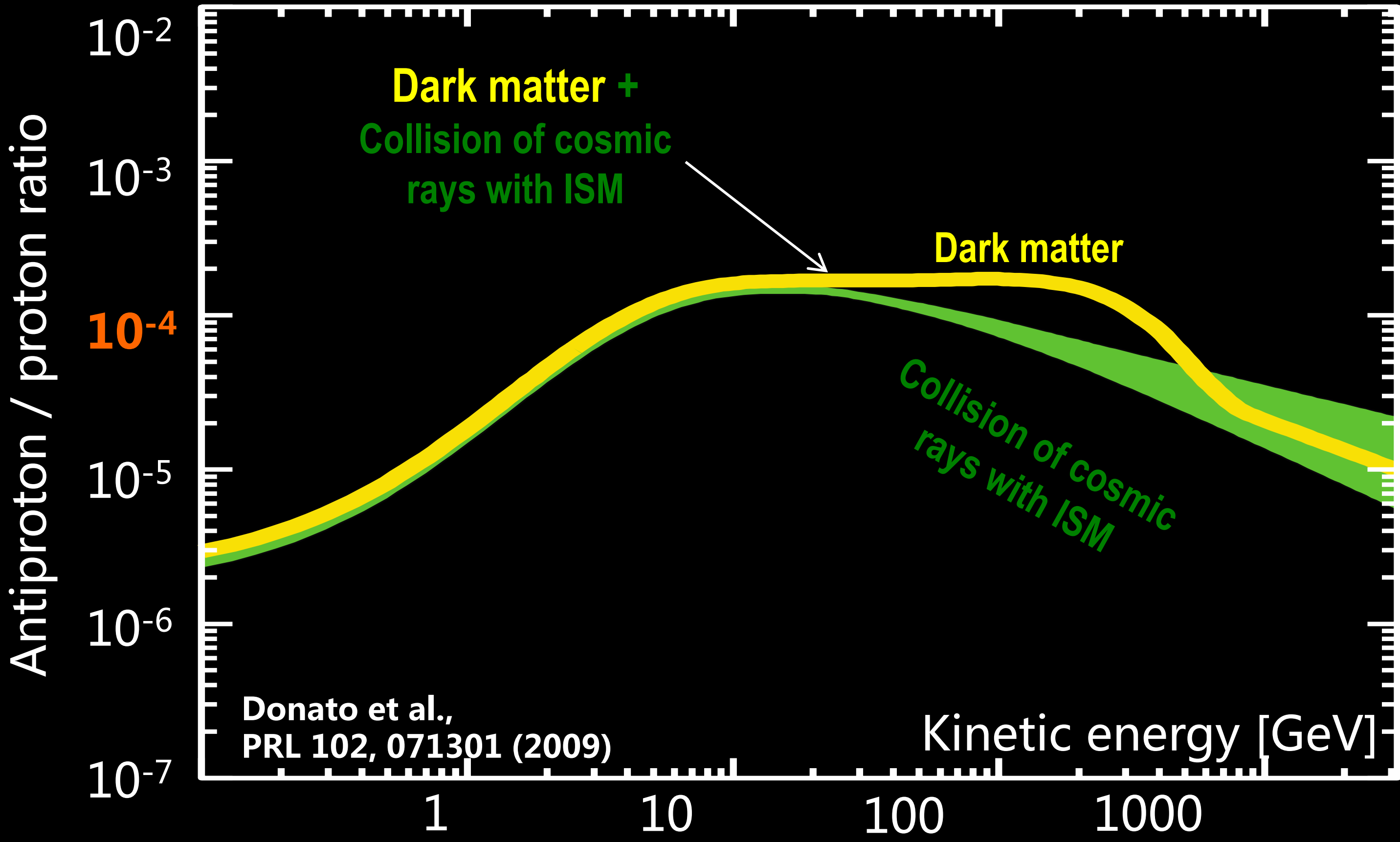
$p, He + ISM \rightarrow \bar{p} + \ldots$



$\chi + \chi \rightarrow \bar{p} + \ldots$

The collision of dark matter particles will produce additional $\bar{p}$

Antiprotons in the Cosmos



The excess of $\bar{p}$ can be accurately measured by AMS

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

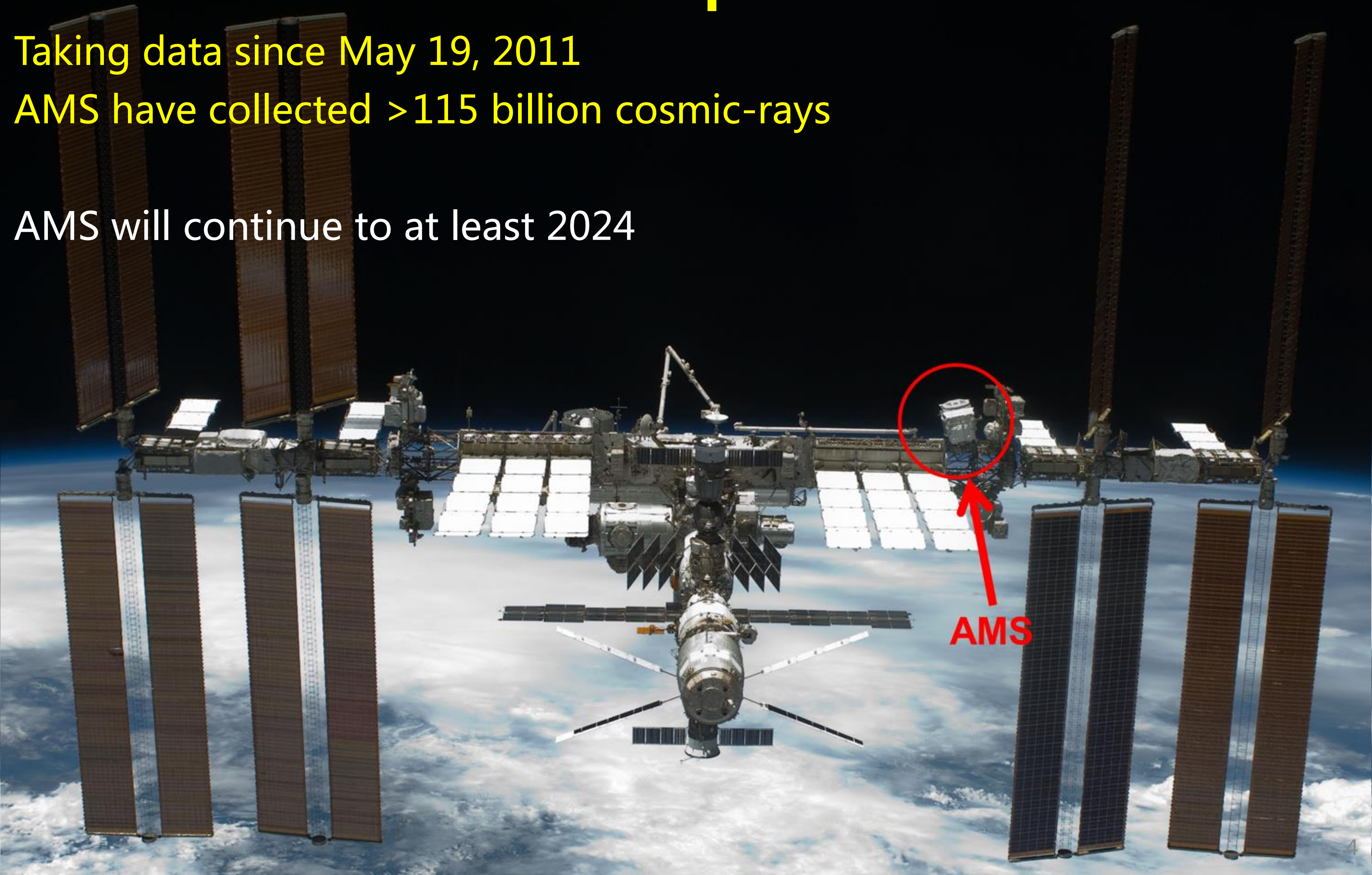
A percentage precision experiment requires background rejection close to 1 in a million

AMS on the Space Station

Taking data since May 19, 2011

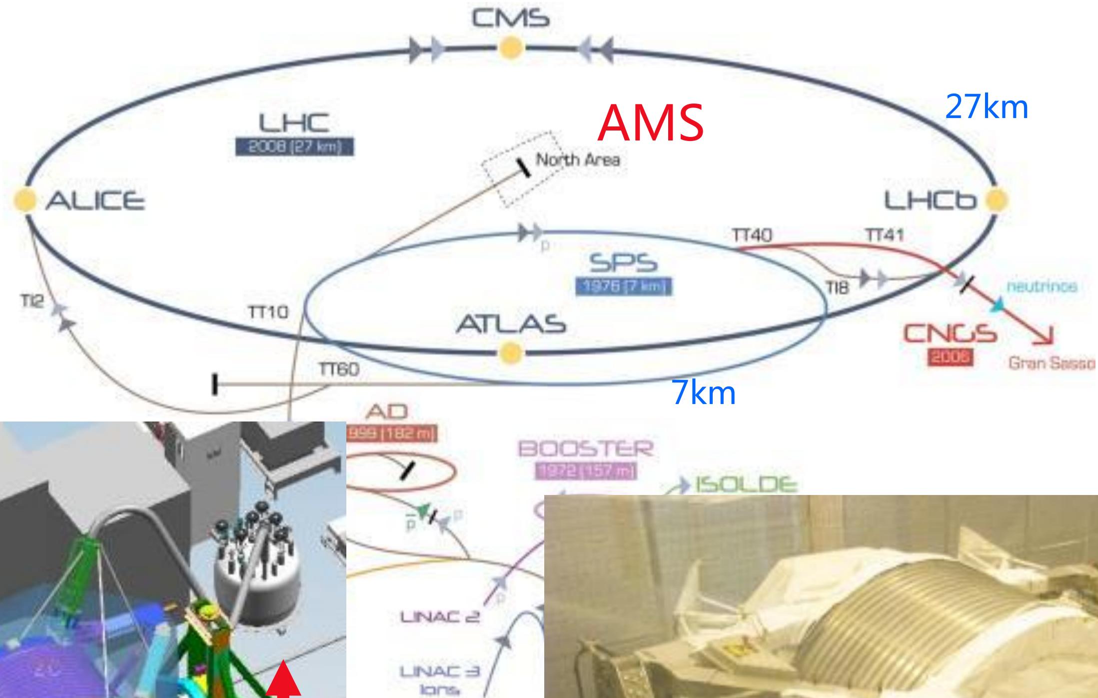
AMS have collected >115 billion cosmic-rays

AMS will continue to at least 2024

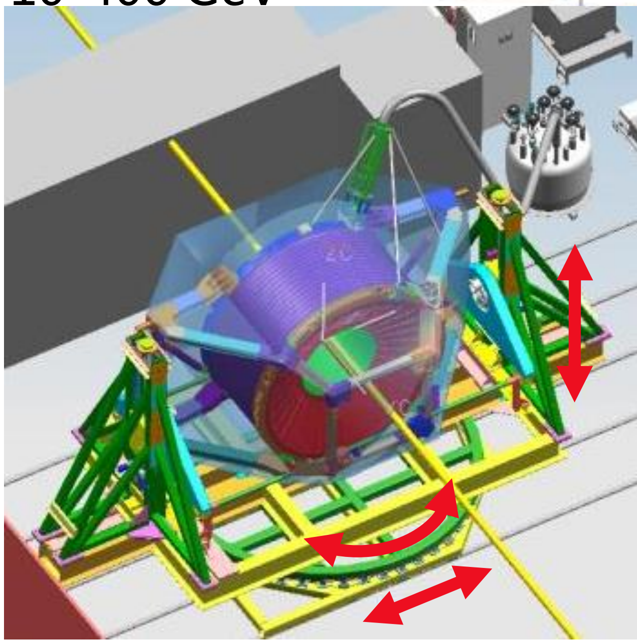


AMS detector calibration at CERN

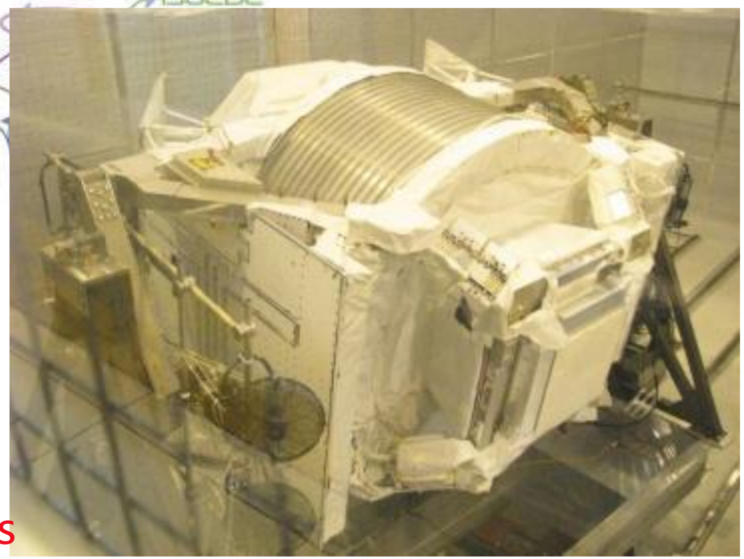
In accelerator test beams Feb 4-8 and Aug 8-20, 2010



p, e+, e-, π
10-400 GeV

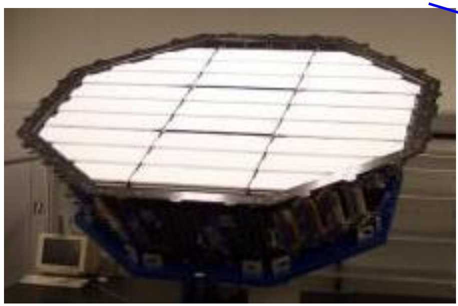


2000
positions

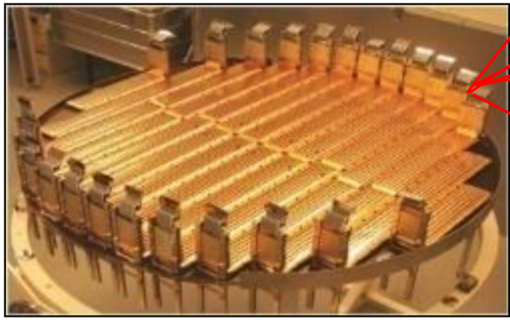


Alpha Magnetic Spectrometer

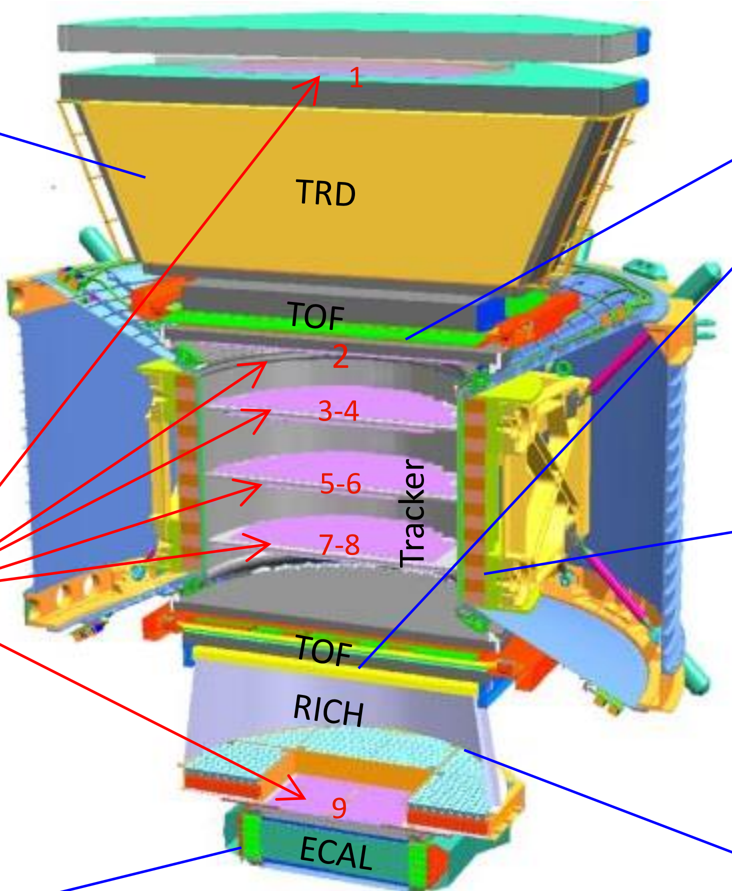
Transition Radiation Detector
p,$\bar{p}$ / $e^{\pm}$



Silicon Tracker
Z, P, Rigidity(=P/Z)

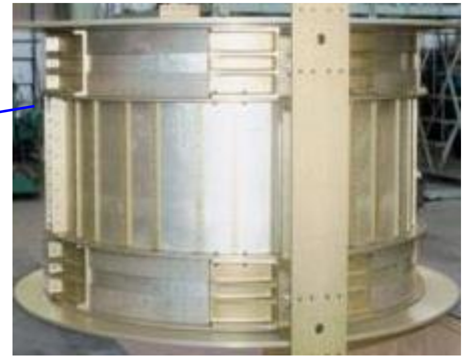


Electromagnetic Calorimeter
E of $e^{\pm}$; p,$\bar{p}$ / $e^{\pm}$



Time of Flight
Z, E

Magnet
$\pm$Z, $\bar{p}$/p

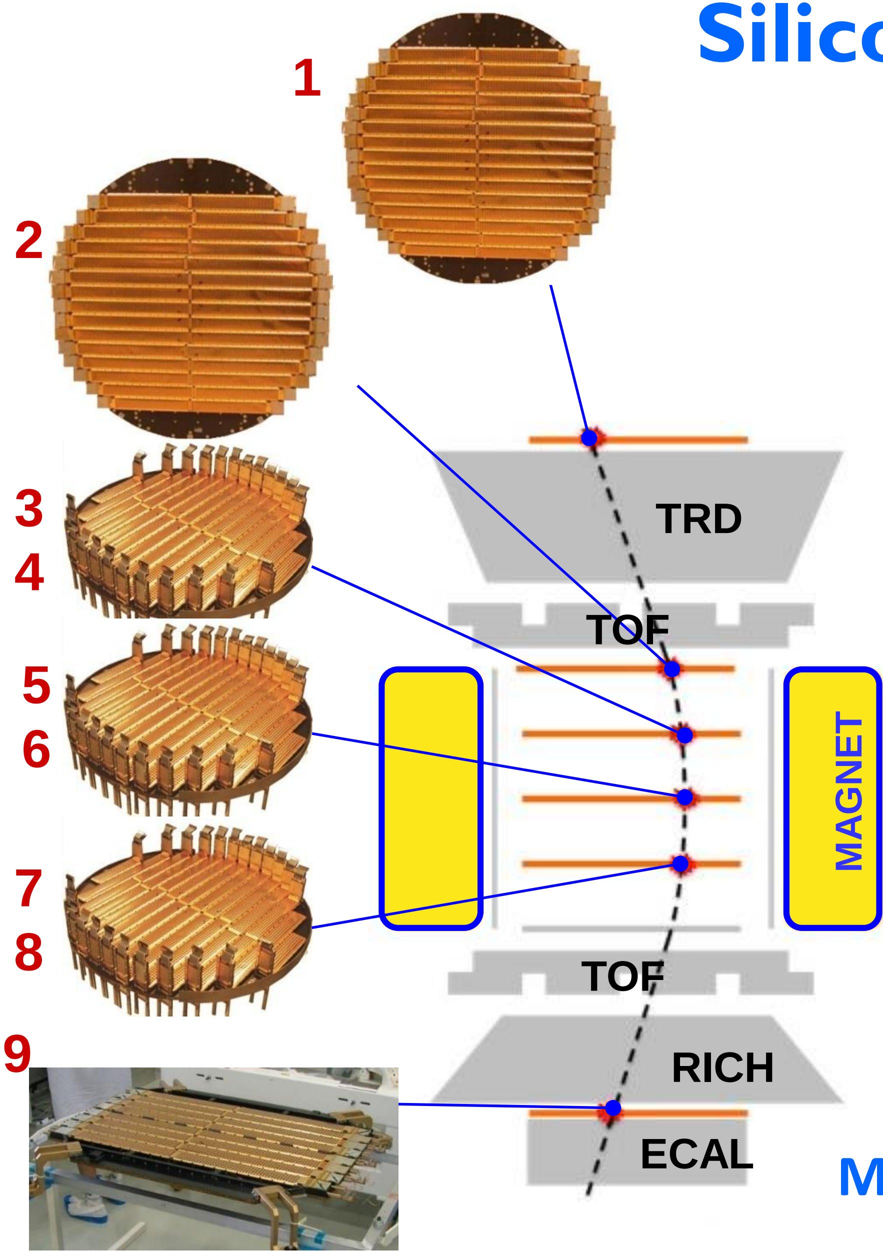


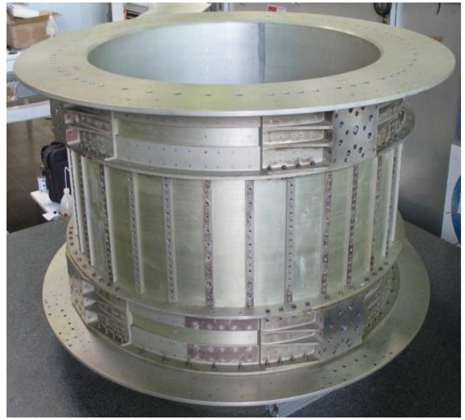
Ring Imaging Cherenkov
Z, E

The Charge(Z), Energy(E) or Rigidity(R=P/Z) are measured independently by several detectors

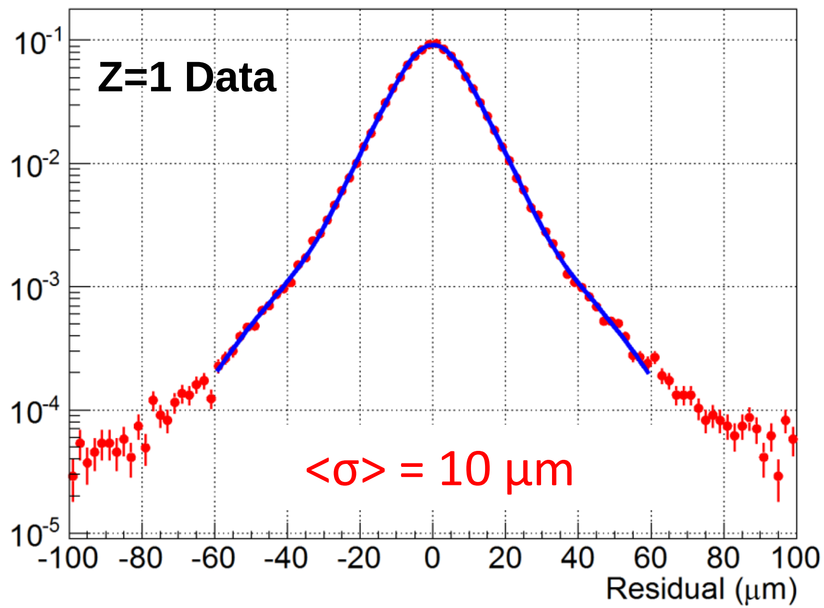
Precise identification of particle and nuclei species

Silicon Tracker and Magnet



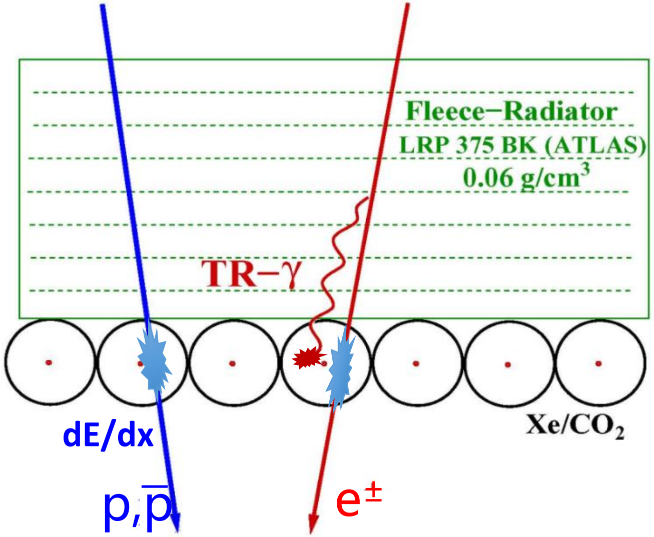


1.4 kG

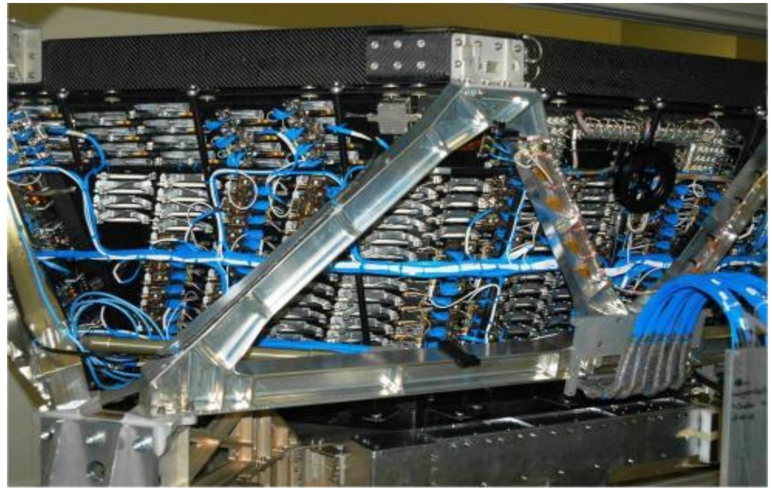


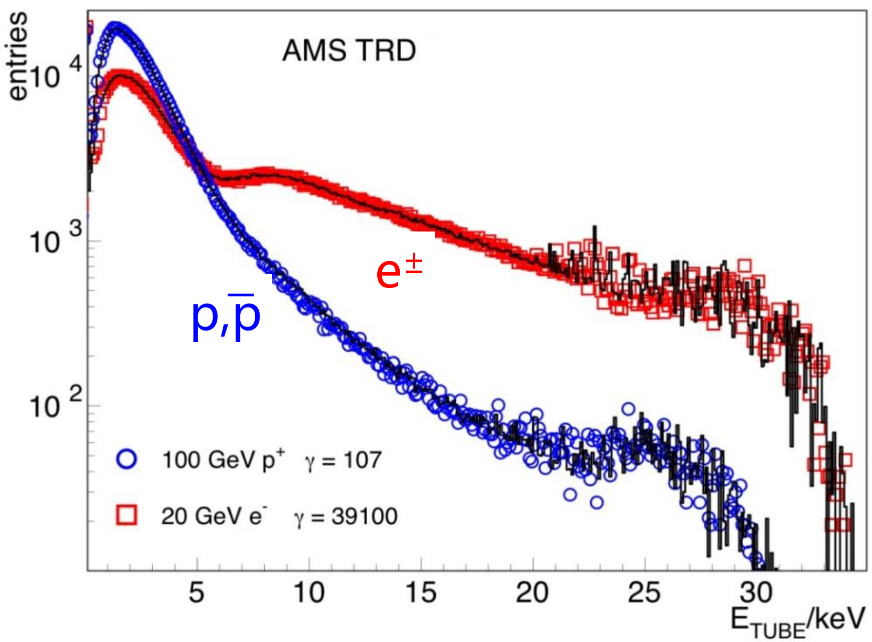
Maximum Detectable Rigidity(MDR) 2 TV for Z=1 particles

Transition Radiation Detector (TRD)

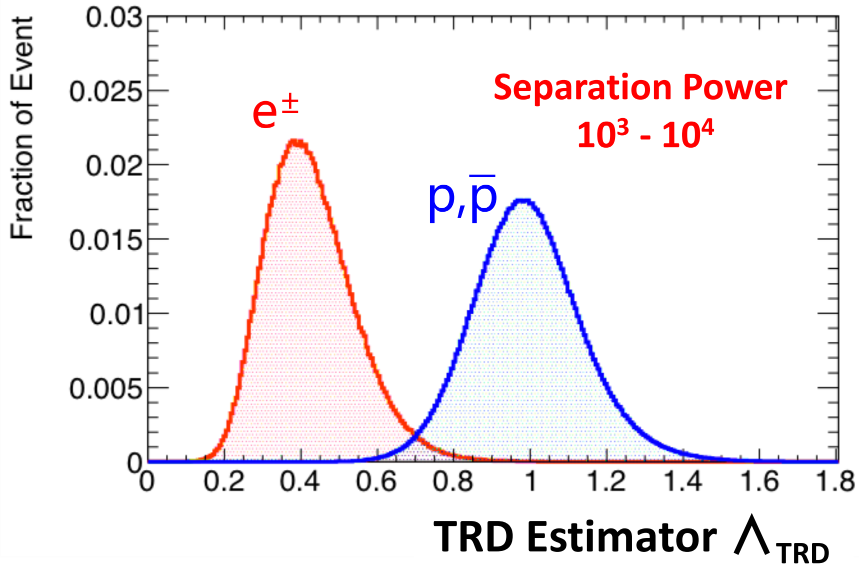


One of 20 layers

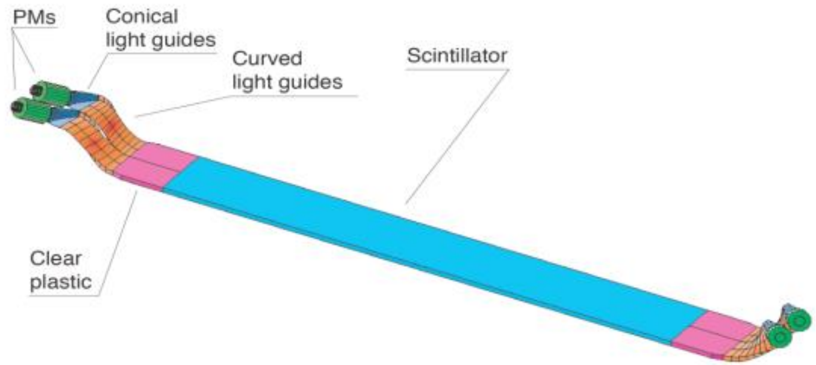




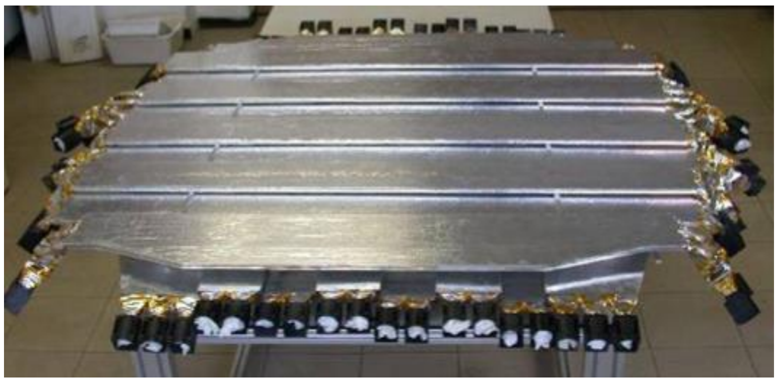
TRD estimator = -ln(P_e/(P_e+P_p))



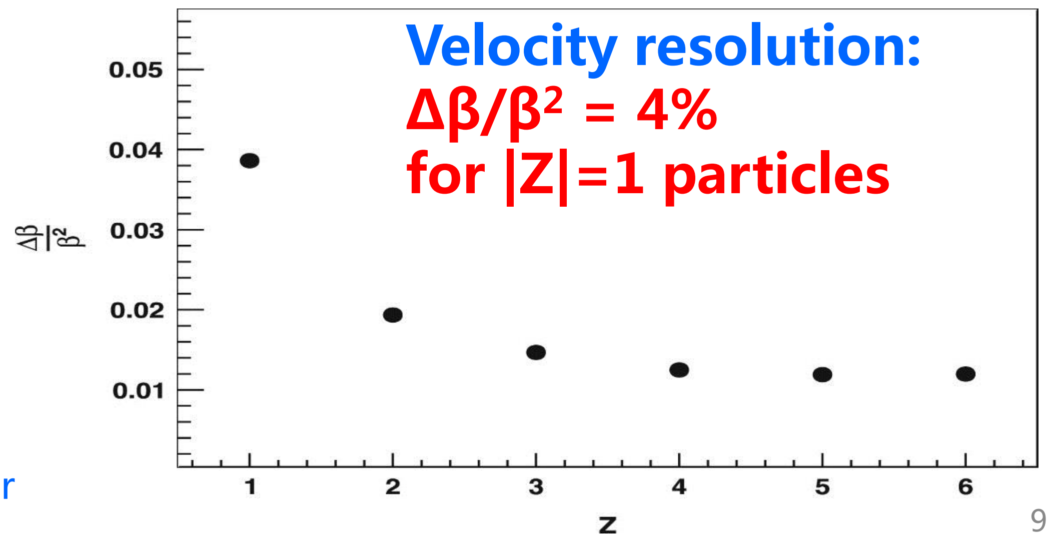
Time of Flight (TOF)



Time resolution: 160ps for |Z|=1

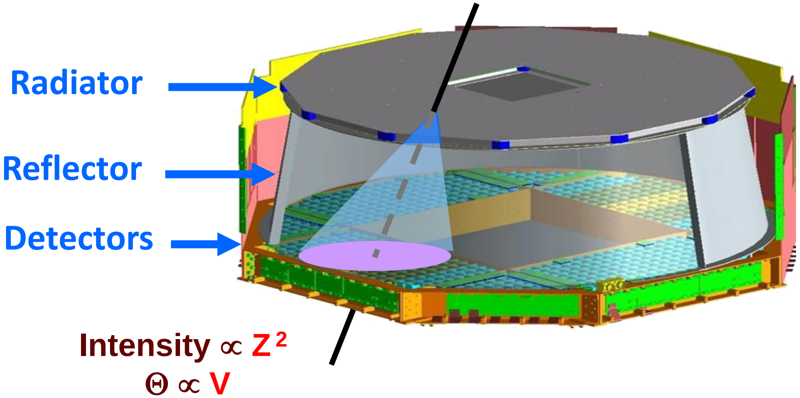


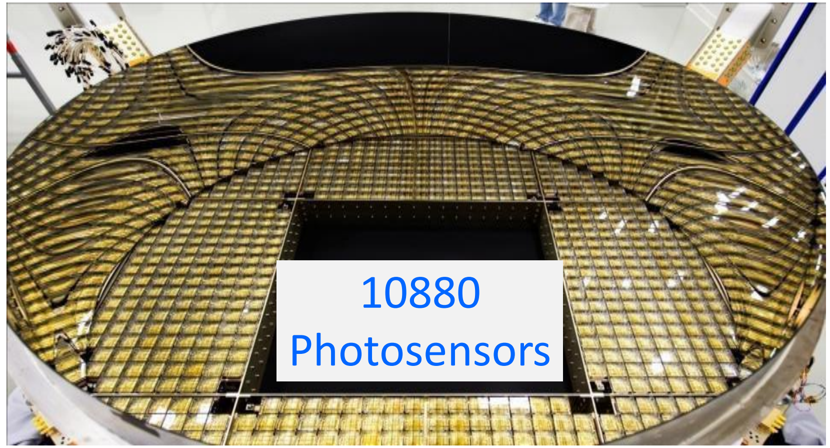
Particle mass from TOF and tracker

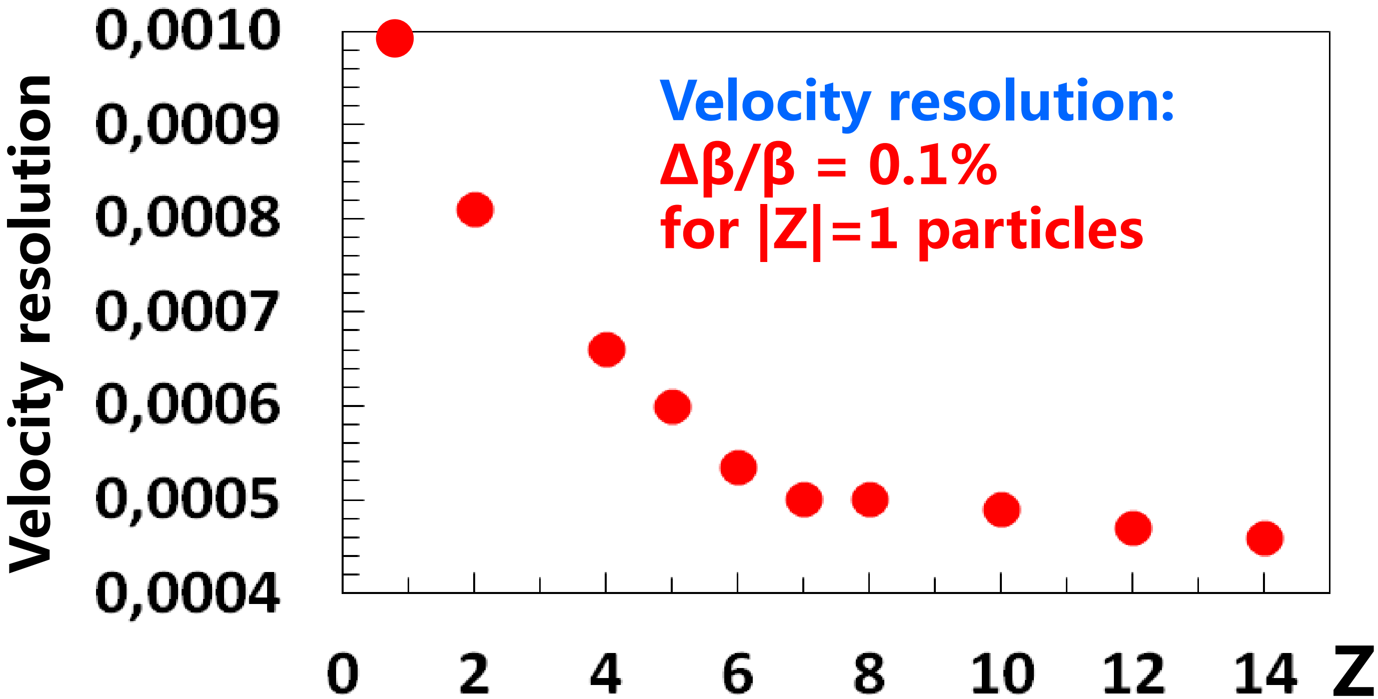


Velocity resolution:
$\Delta\beta/\beta^2$ = 4%
for |Z|=1 particles

Ring Imaging Cherenkov detector (RICH)

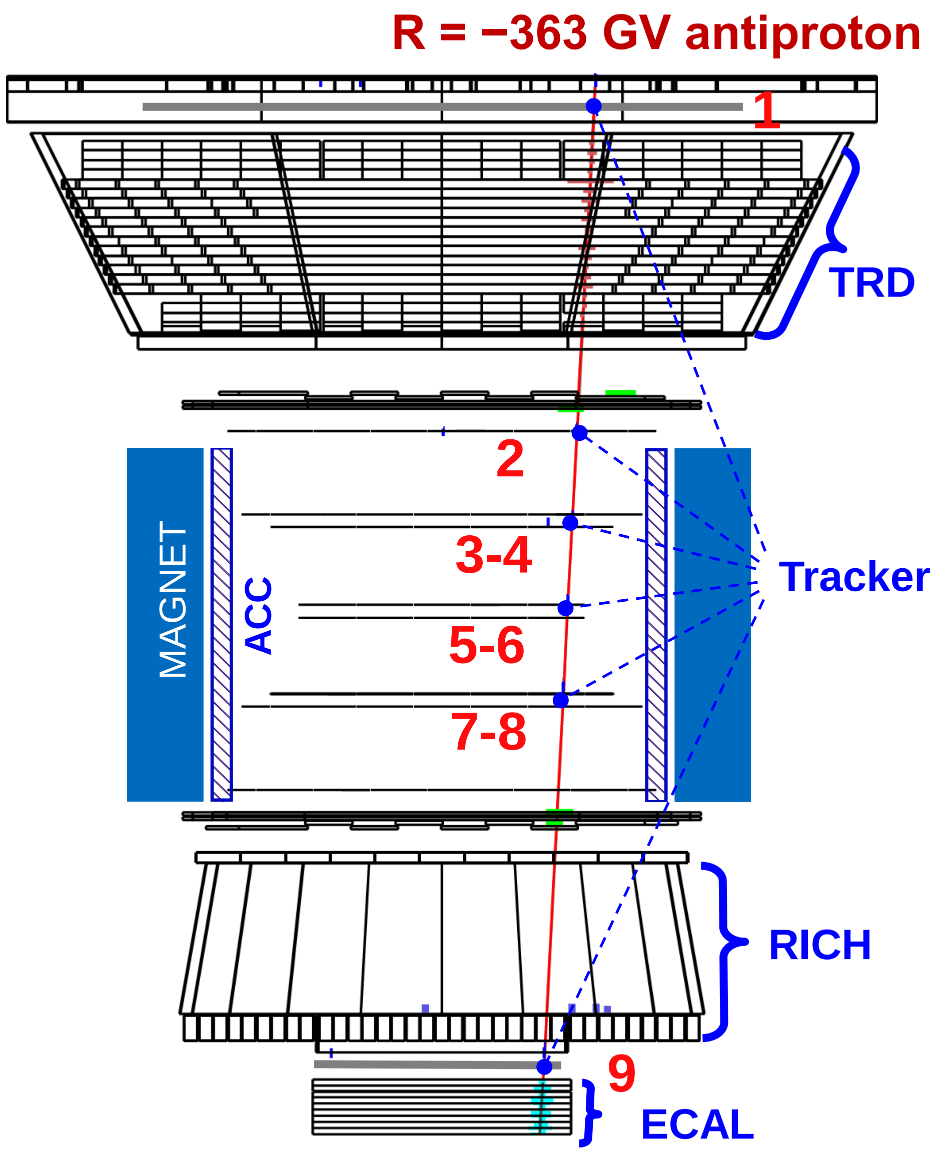






Event selection for the $\bar{p}$ analysis

- **Primary cosmic ray particle:**
  - **|R| > 1.2·max cutoff**
- **TOF:**
  - **Down-going particle**
  - **β>0.3**
- **TRD:**
  - **at least 12 hits**
- **TRACKER:**
  - **Track quality**
  - **0.8 < |Q| < 1.2**
- **ECAL:**
  - **Hadron shower shape**



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

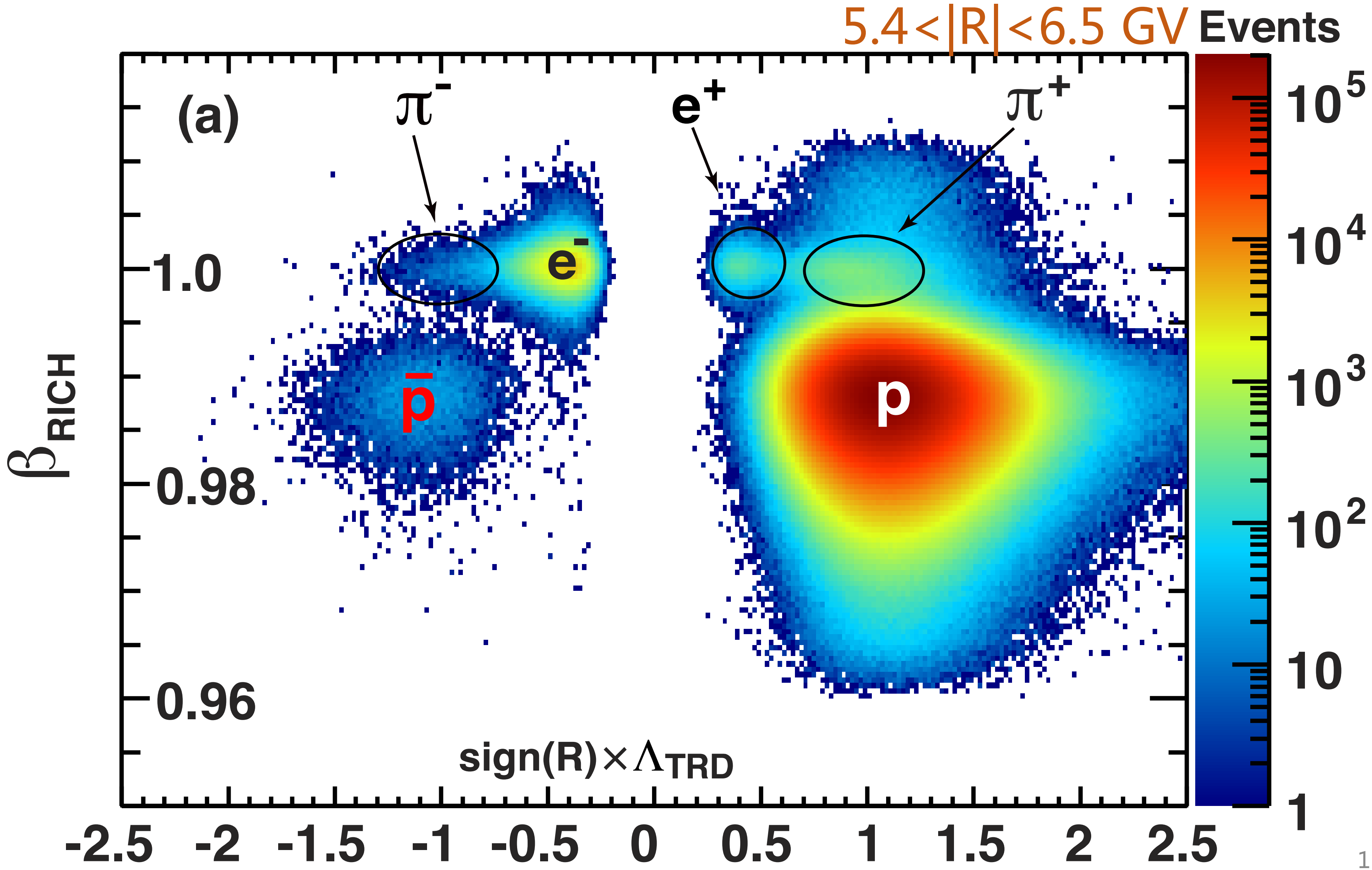
   3.67-18.0 GV **RICH and The TRD estimator**

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

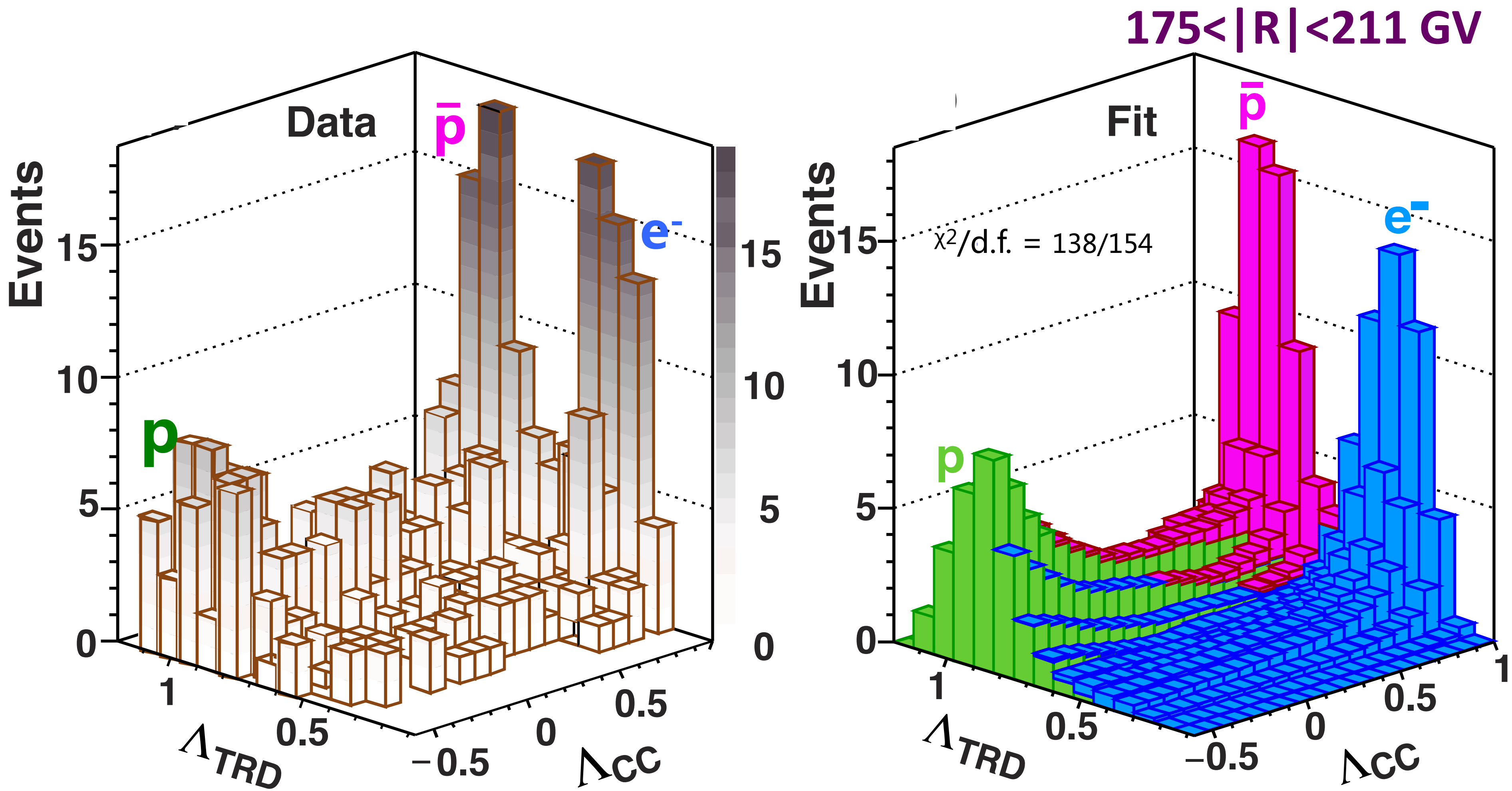
   16.6-450 GV **2D template in (Λ_{TRD} - Λ_{CC}) plane**

In 4 years, 3.49×10^5 antiprotons and 2.42×10^9 protons are selected in the rigidity range $1<|R|<450$ GV

Antiproton identification at intermediate rigidity



Antiproton identification at high rigidity



In 4 years, >2200 antiprotons above 100 GV

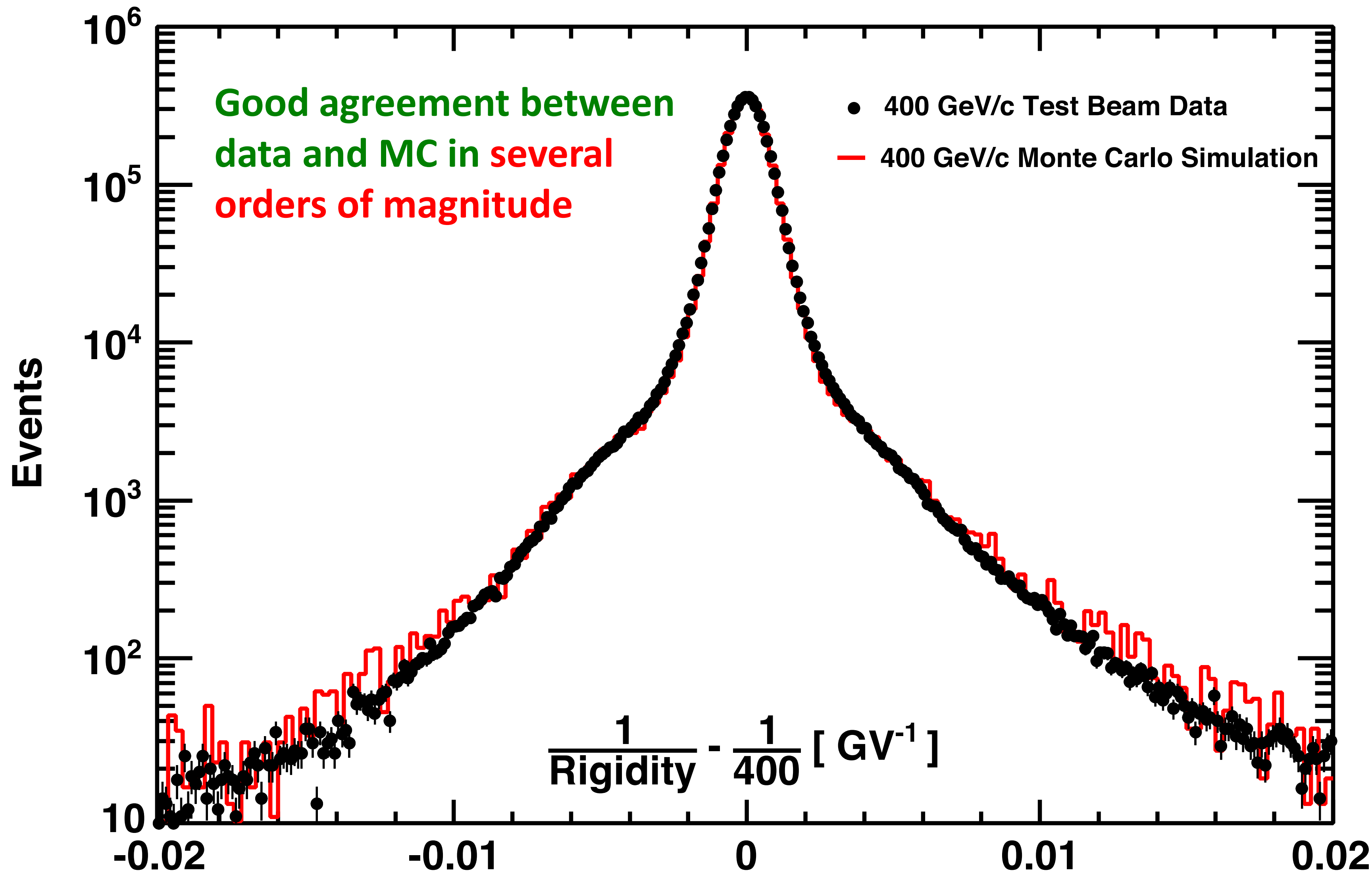
In first 4 years, 3.49×10^5 antiprotons and 2.42×10^9 protons are selected in the rigidity range $1<|R|<450$ GV

More than 2200 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

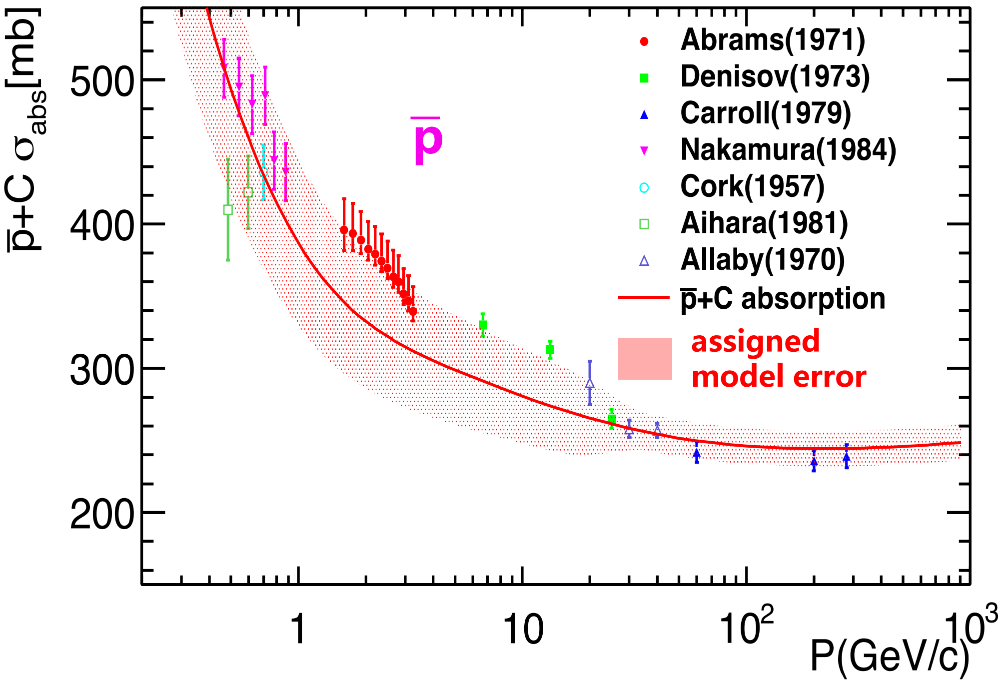
Systematic error from charge confusion templates

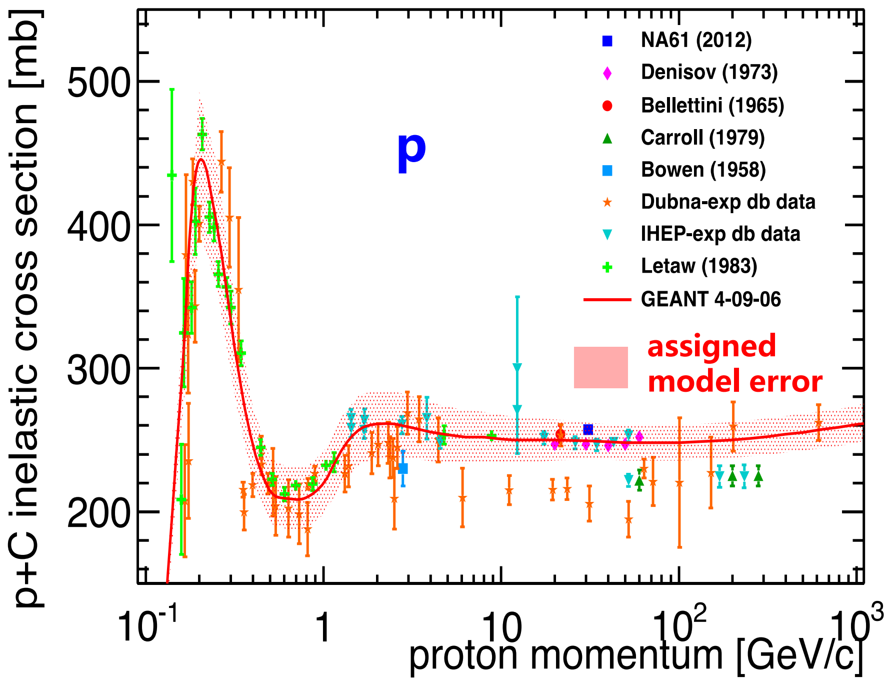


The minor difference between MC simulation and data is taken as the associated error.

Systematic error from cross section uncertainty

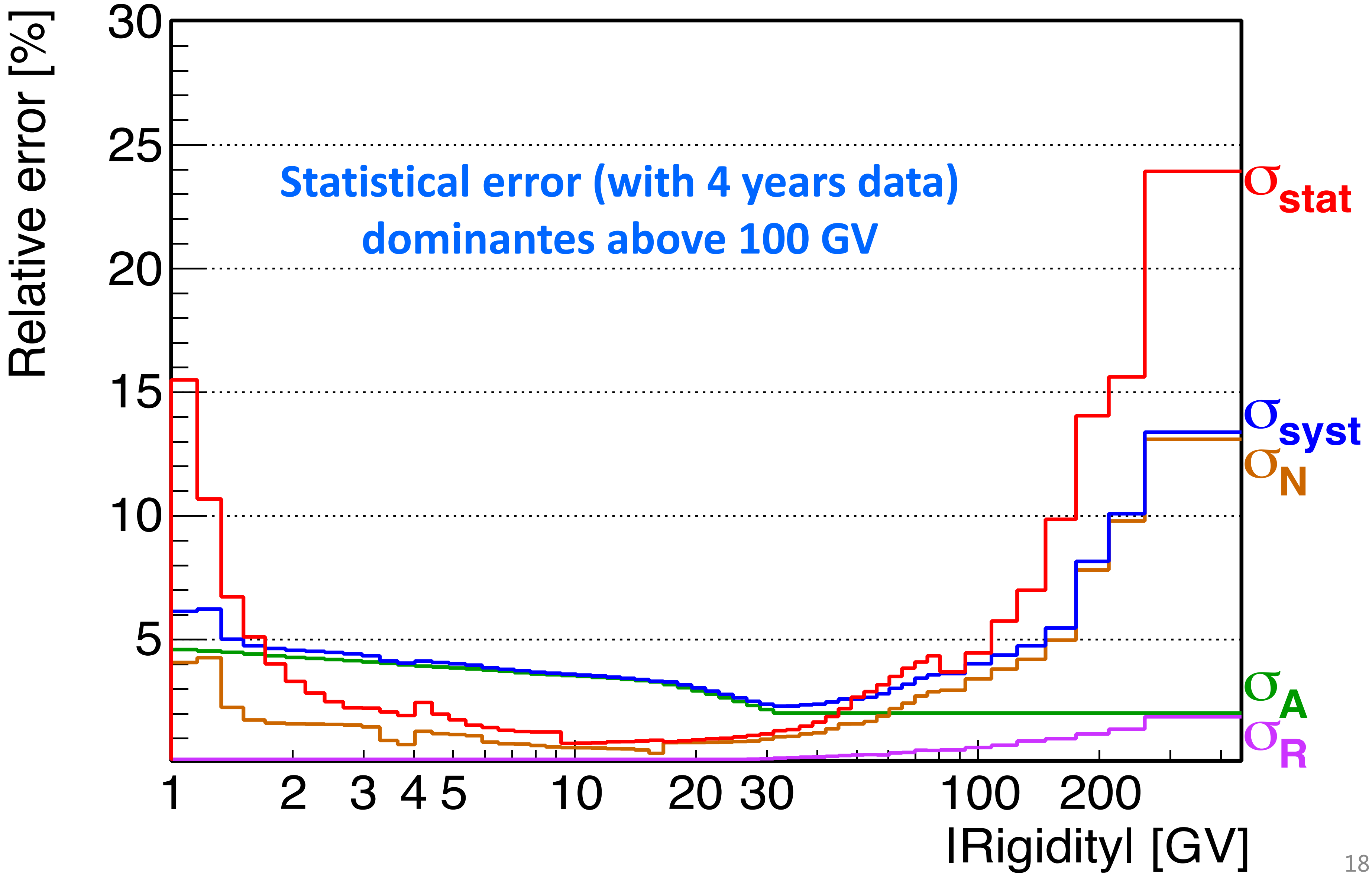
The inelastic cross sections are used in MC simulation to calculate the effective acceptance





The inelastic cross sections are varied within **the error band** to obtain the systematic error on the effective acceptance of antiprotons and protons

Error breakdown

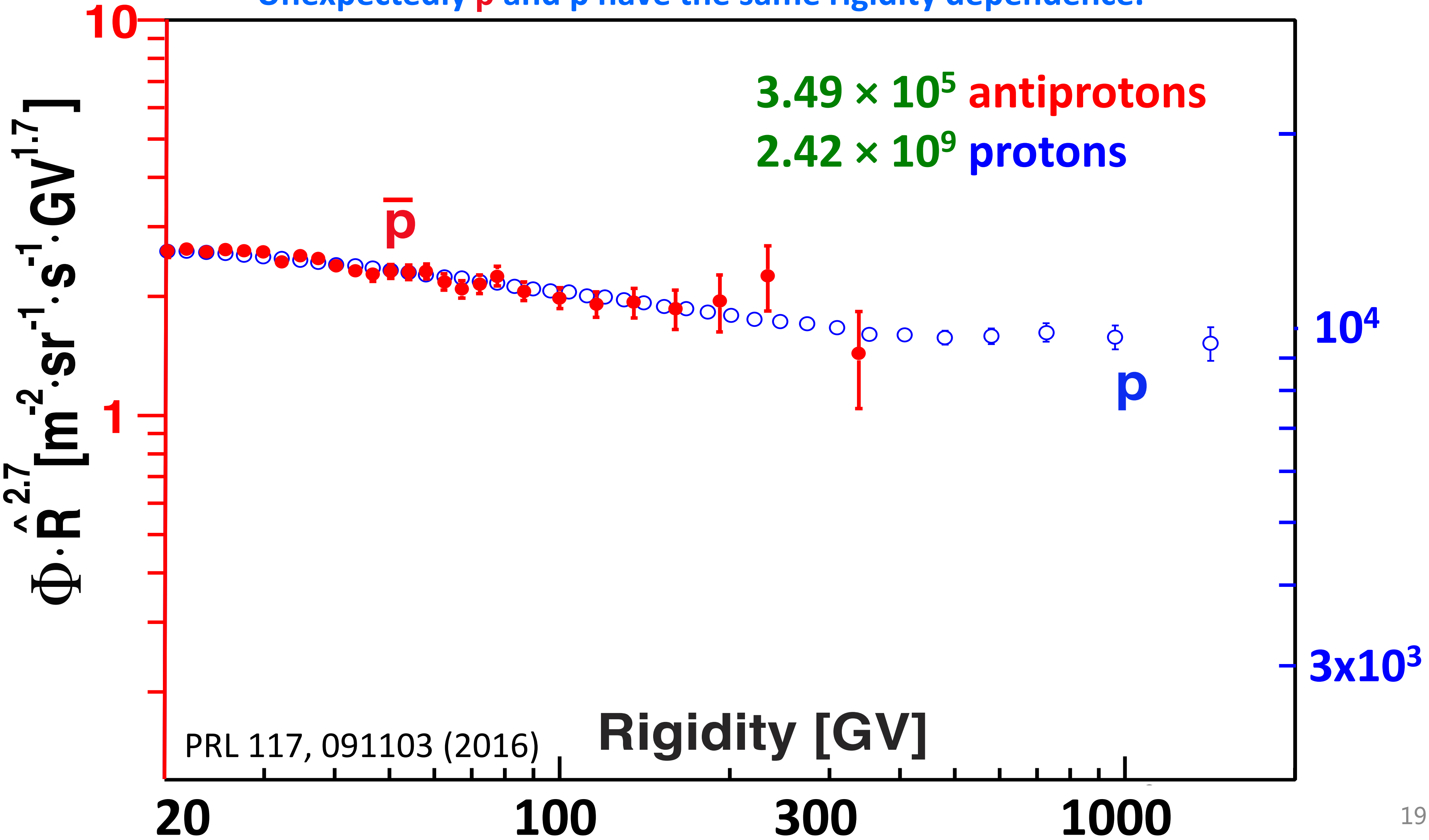


Unexpected: The Spectra of Protons and Antiprotons:

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

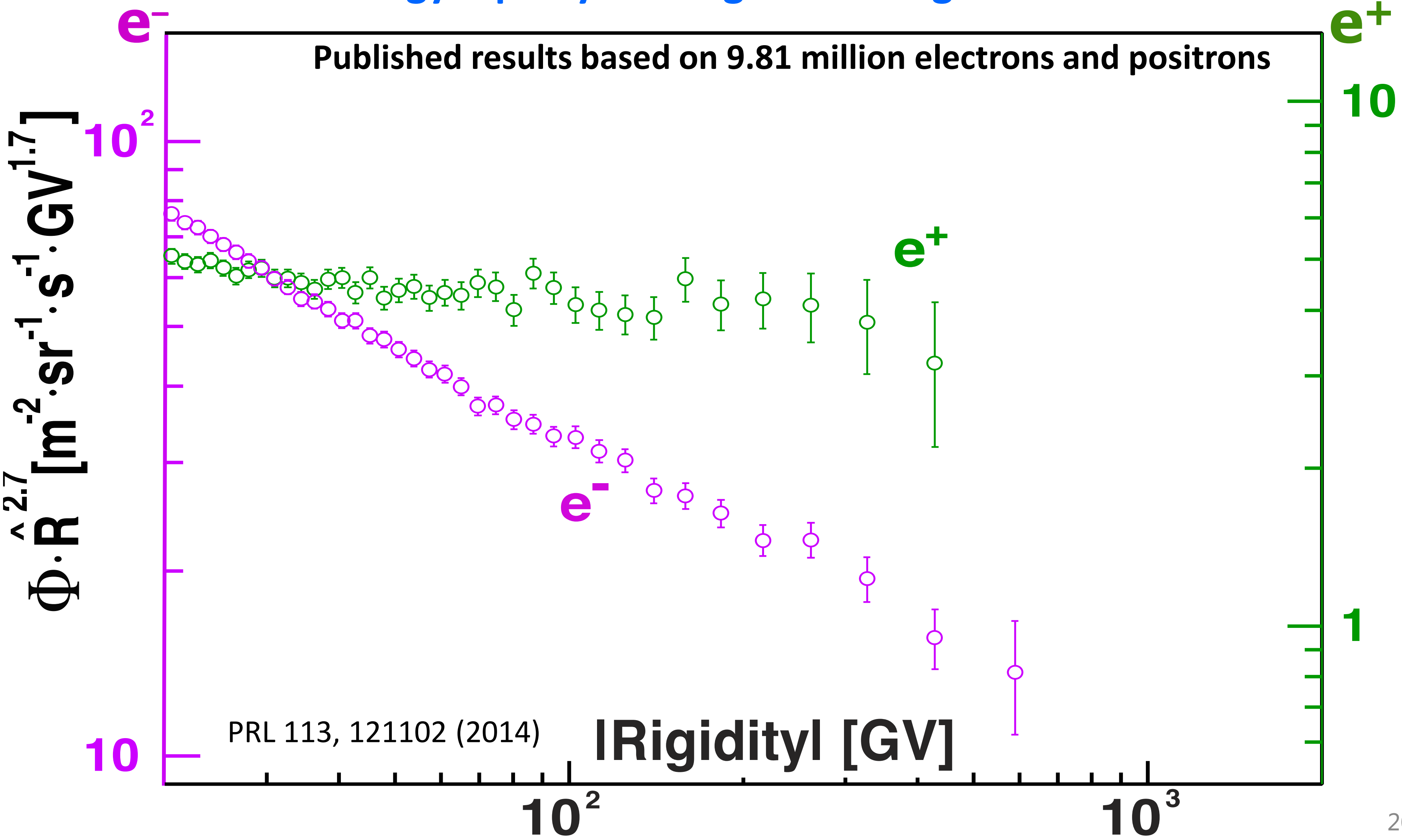
$p + ISM \rightarrow \bar{p} + \ldots$

Unexpectedly $\bar{p}$ and p have the same rigidity dependence.



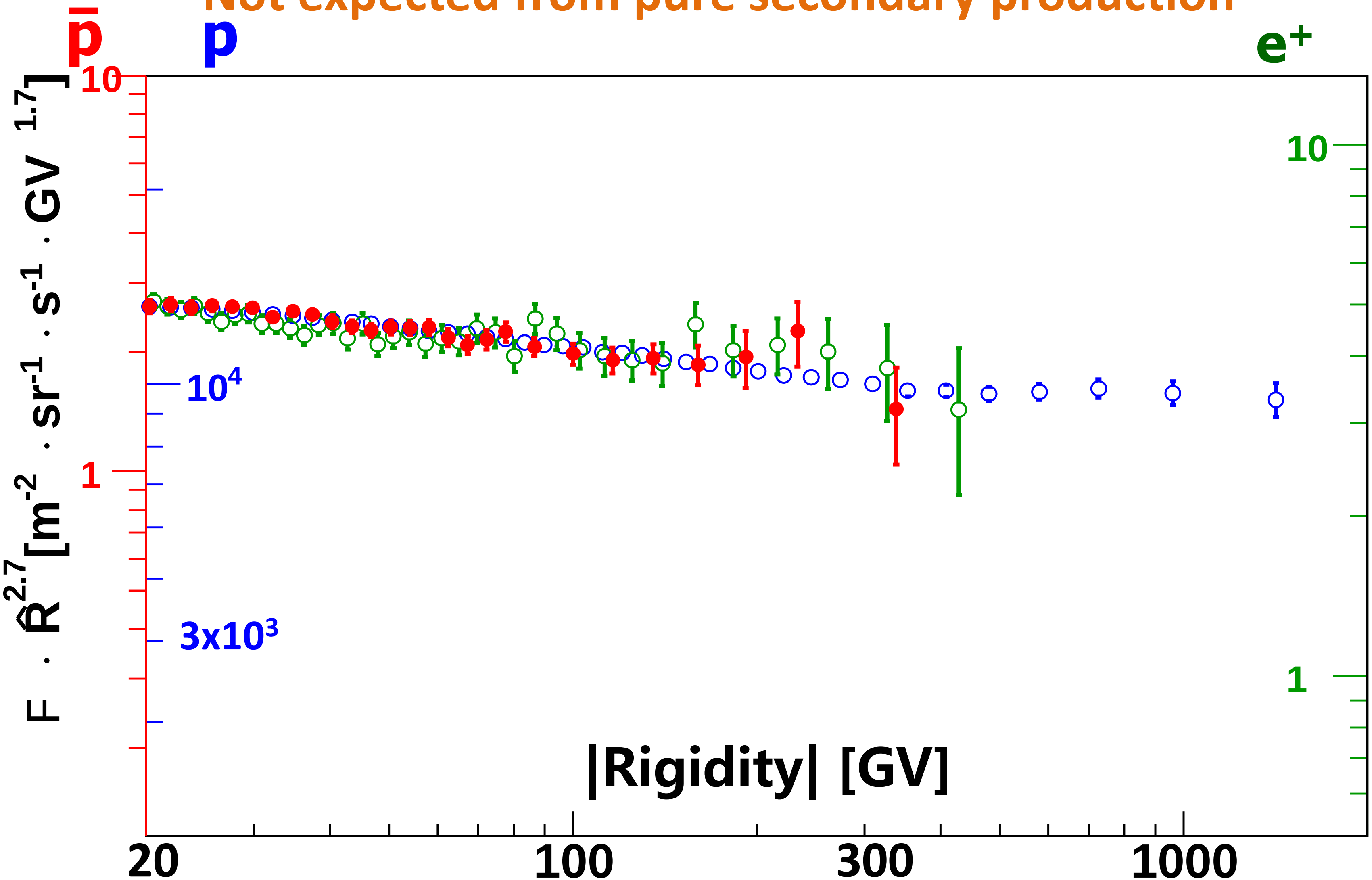
Unexpected: The Spectra of Electrons and Positrons:

e^- and e^+ have very different rigidity dependence despite the fact that they lose energy equally in the galactic magnetic field.



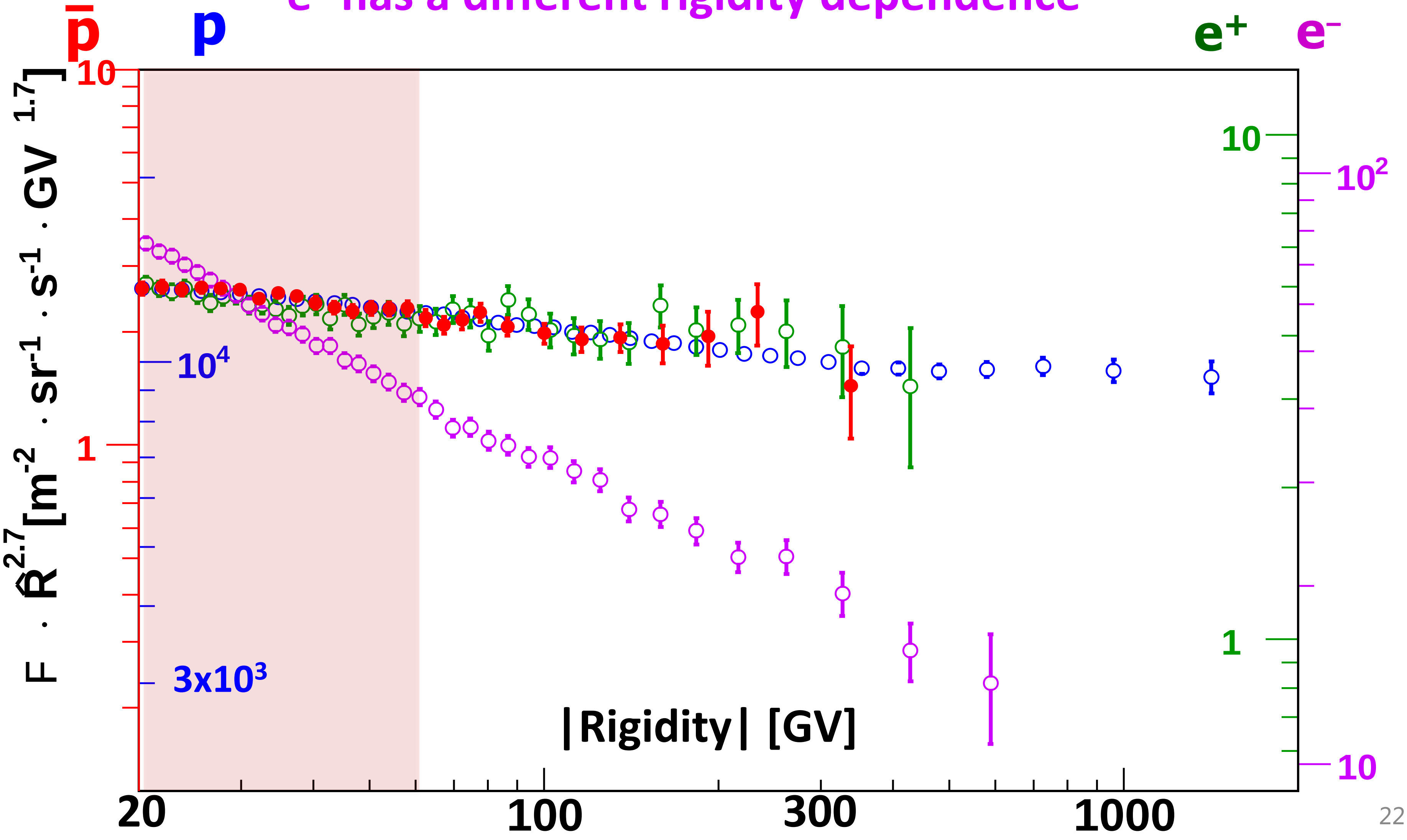
Unexpected results: the rigidity dependence of e^+, $\bar{p}$, p are identical from ~60 to ~500 GV

Not expected from pure secondary production

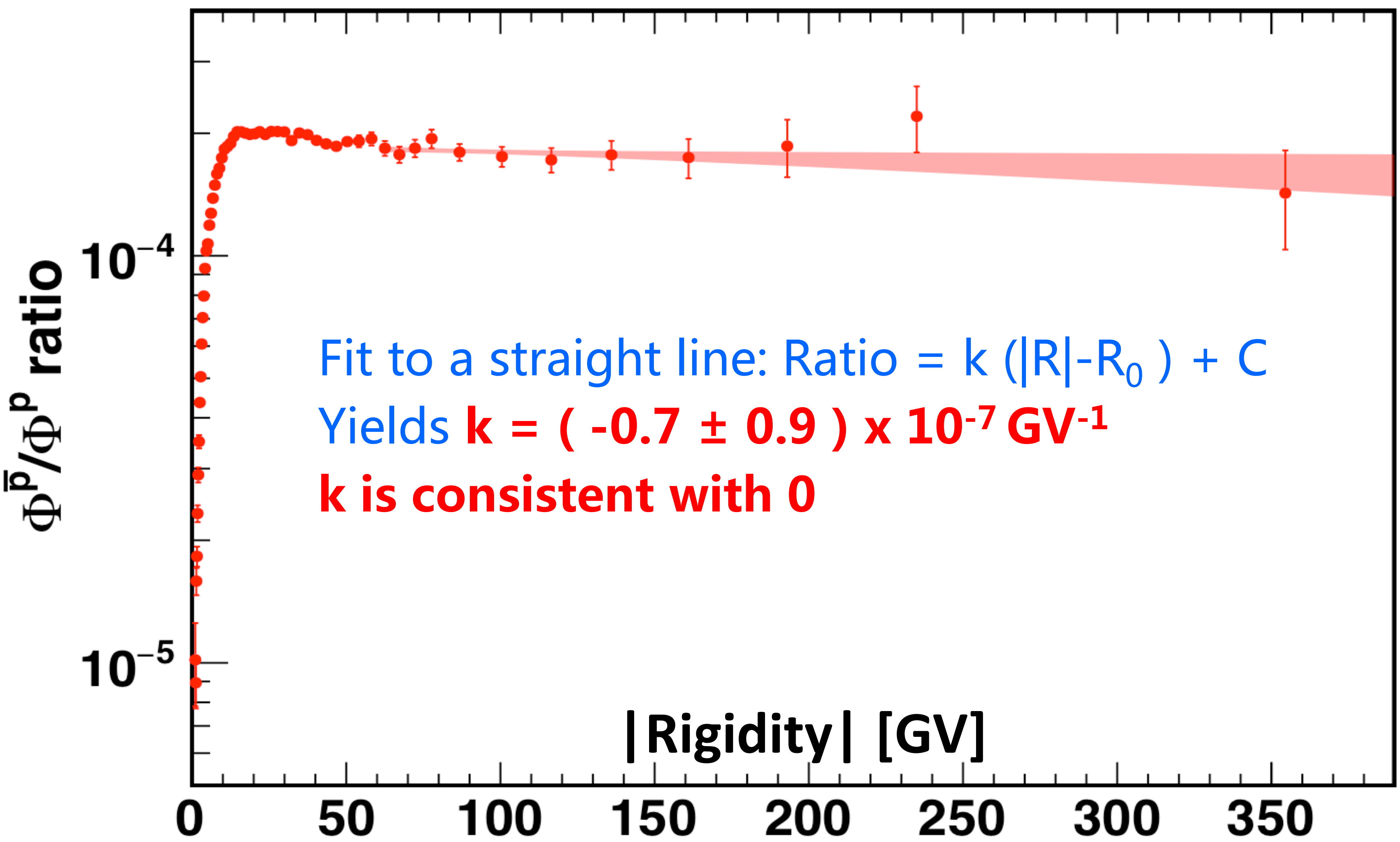


Unexpected results: the rigidity dependence of e^+, $\bar{p}$, p are identical from ~60 to ~500 GV

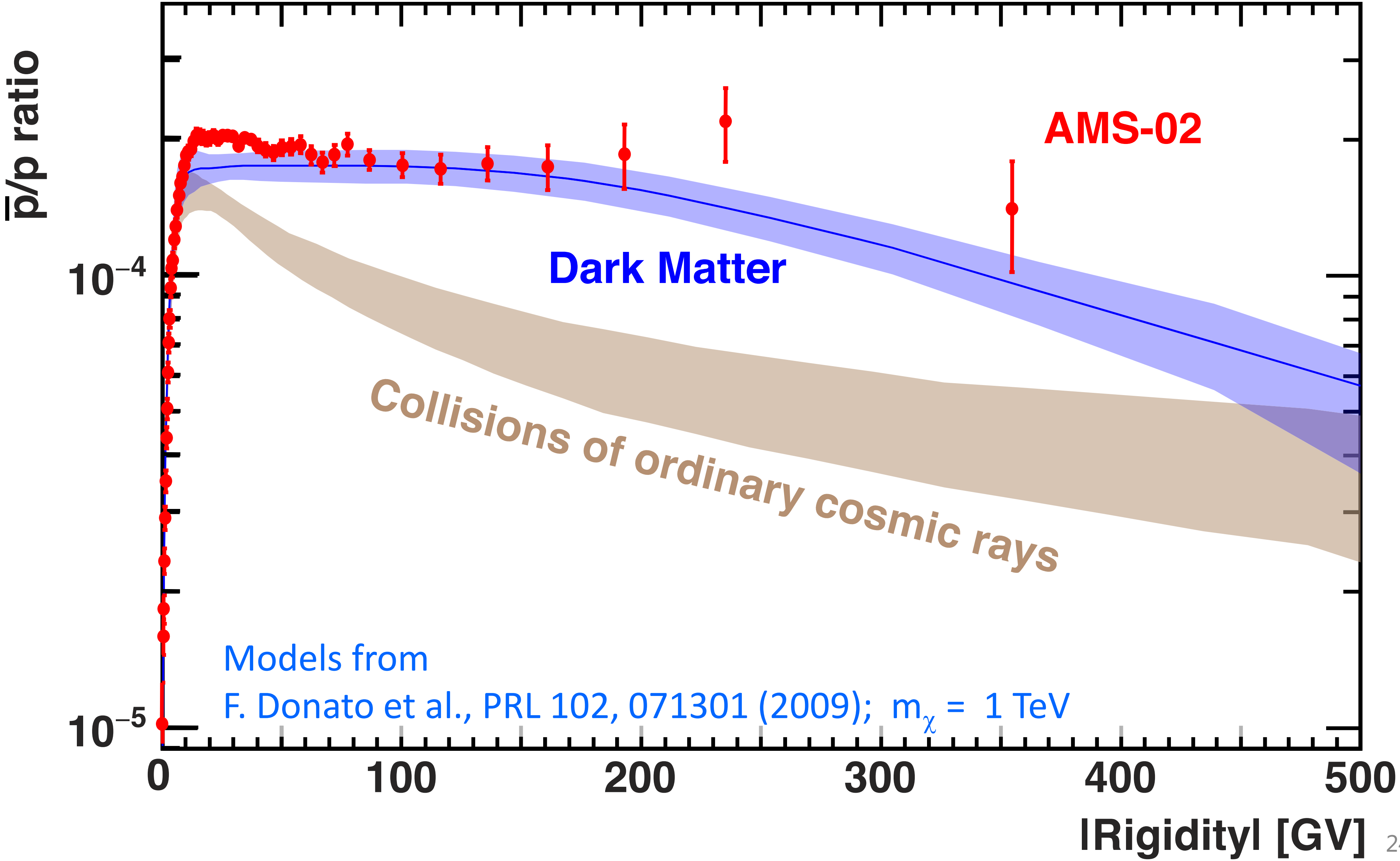
e^- has a different rigidity dependence



Antiproton-to-Proton Flux Ratio
Show no rigidity dependence above 60GV



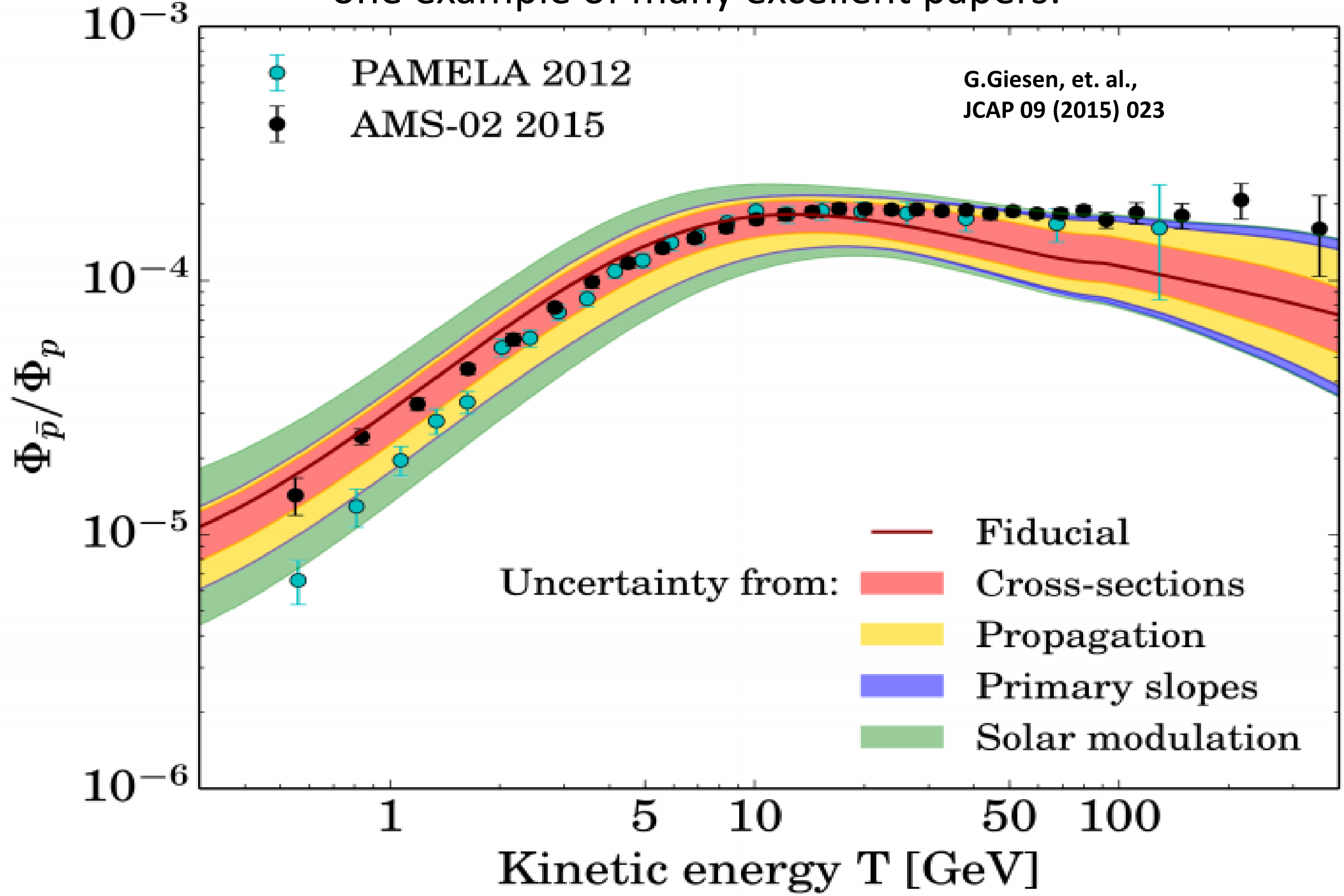
AMS antiproton results and modeling



Recent models of antiproton production

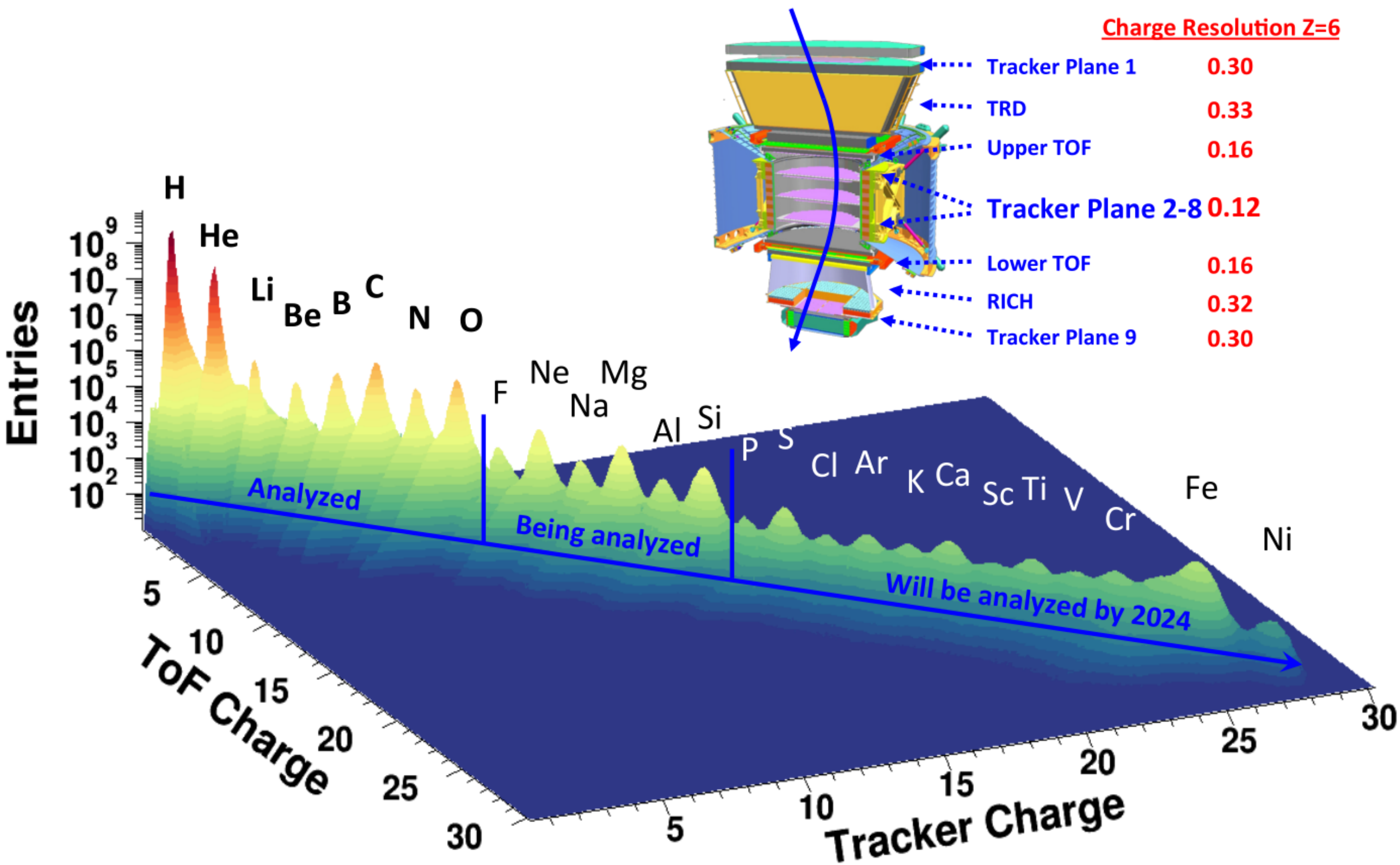
From collision of cosmic rays with interstellar medium

one example of many excellent papers:

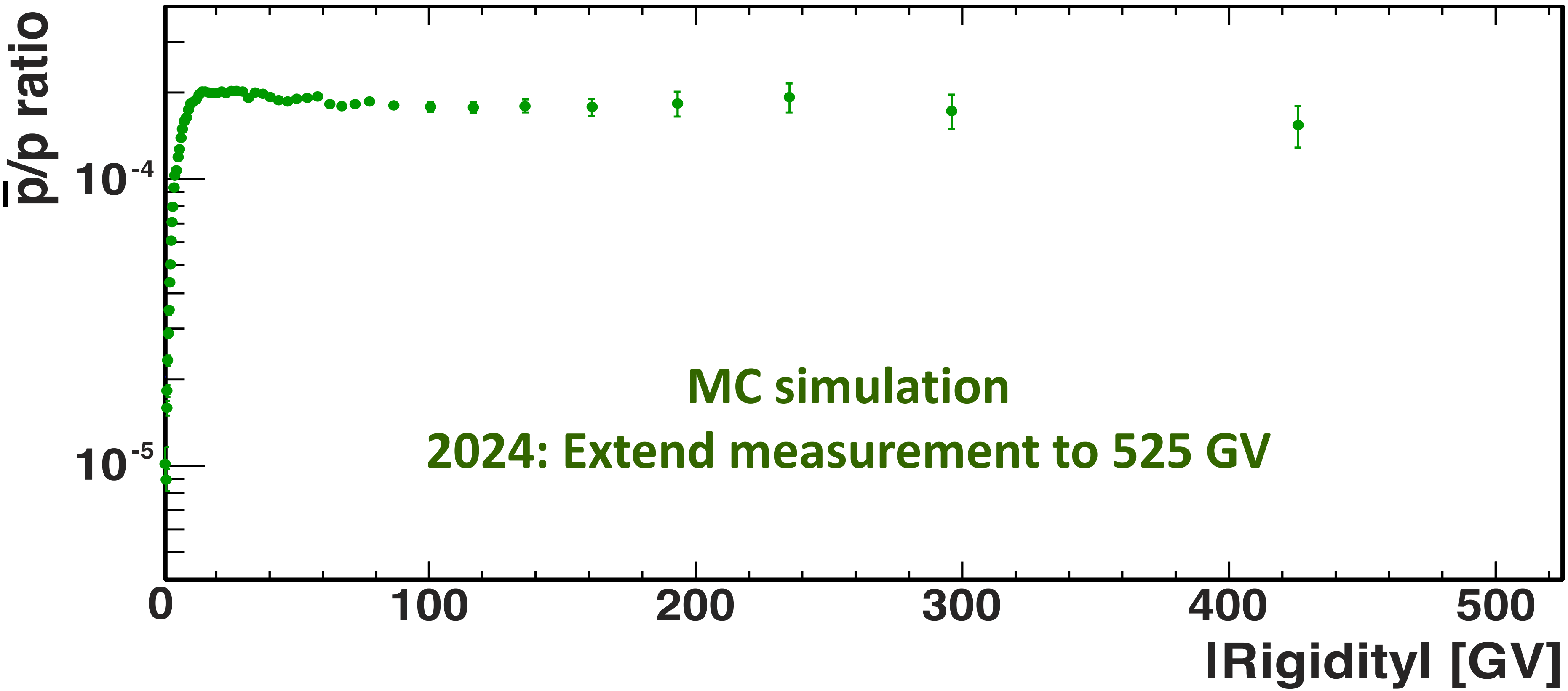


The precision and comprehensive data from AMS allows for the exploration of new phenomena

AMS nuclei identification



Measuring antiproton through the life time of the space station



By collecting more data,
AMS will explore to higher rigidity with better accuracy

Summary

- With the first 4 years AMS data, 3.49×10^5 antiprotons and 2.42×10^9 protons has been analyzed from 1 GV to 450 GV

- The antiproton, proton and positron flux show identical rigidity dependence in 60-500 GV

- We will collect more data through the life time of the Space Station, to increase the precision and further explore the high rigidity region