Antiproton Flux and Antiproton-to-Proton Flux Ratio in Primary Cosmic Rays Measured with AMS on the Space Station

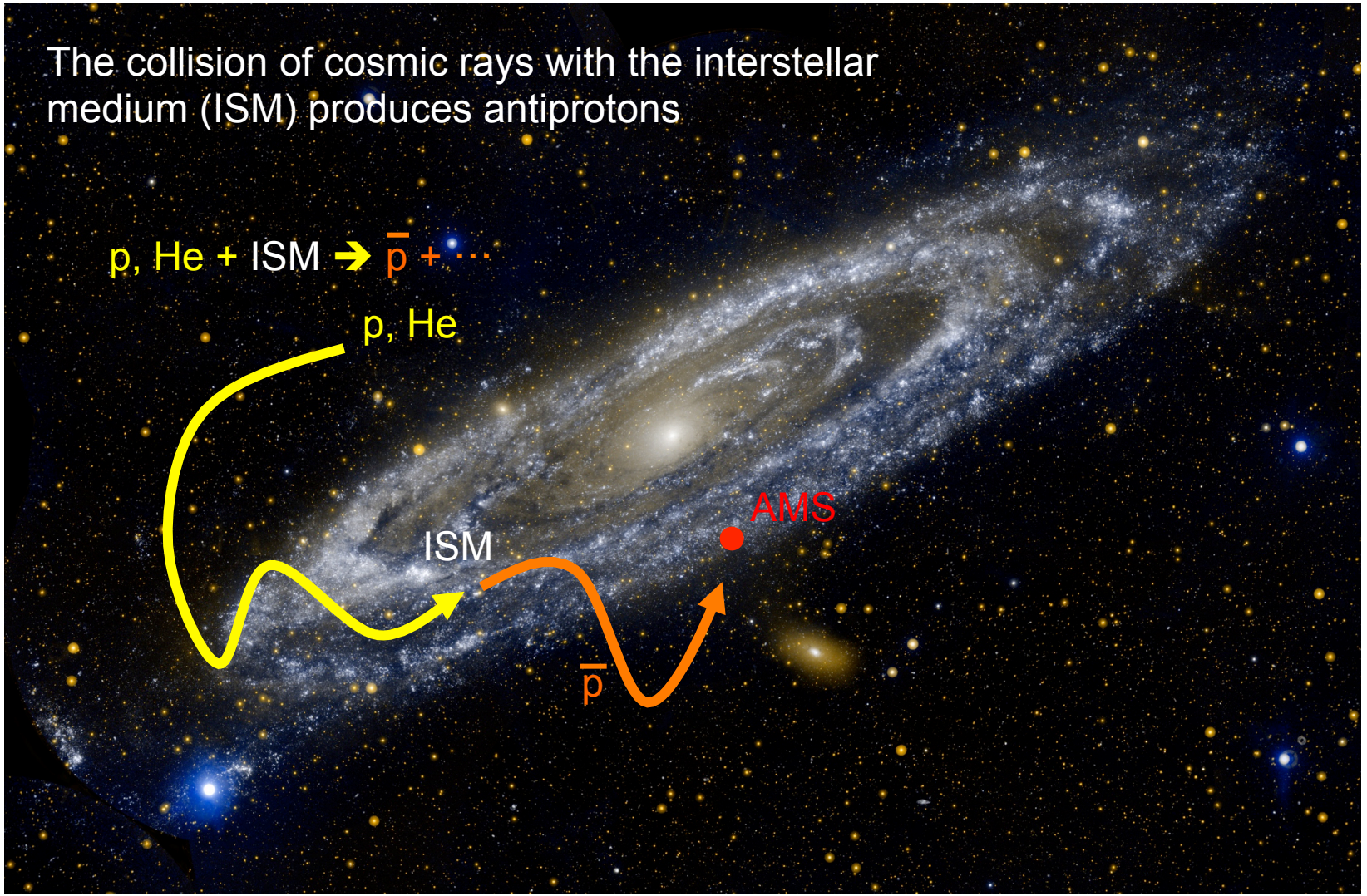
Andreas Bachlechner on behalf of the AMS collaboration

07.08.2017 | TeVPA 2017, Columbus

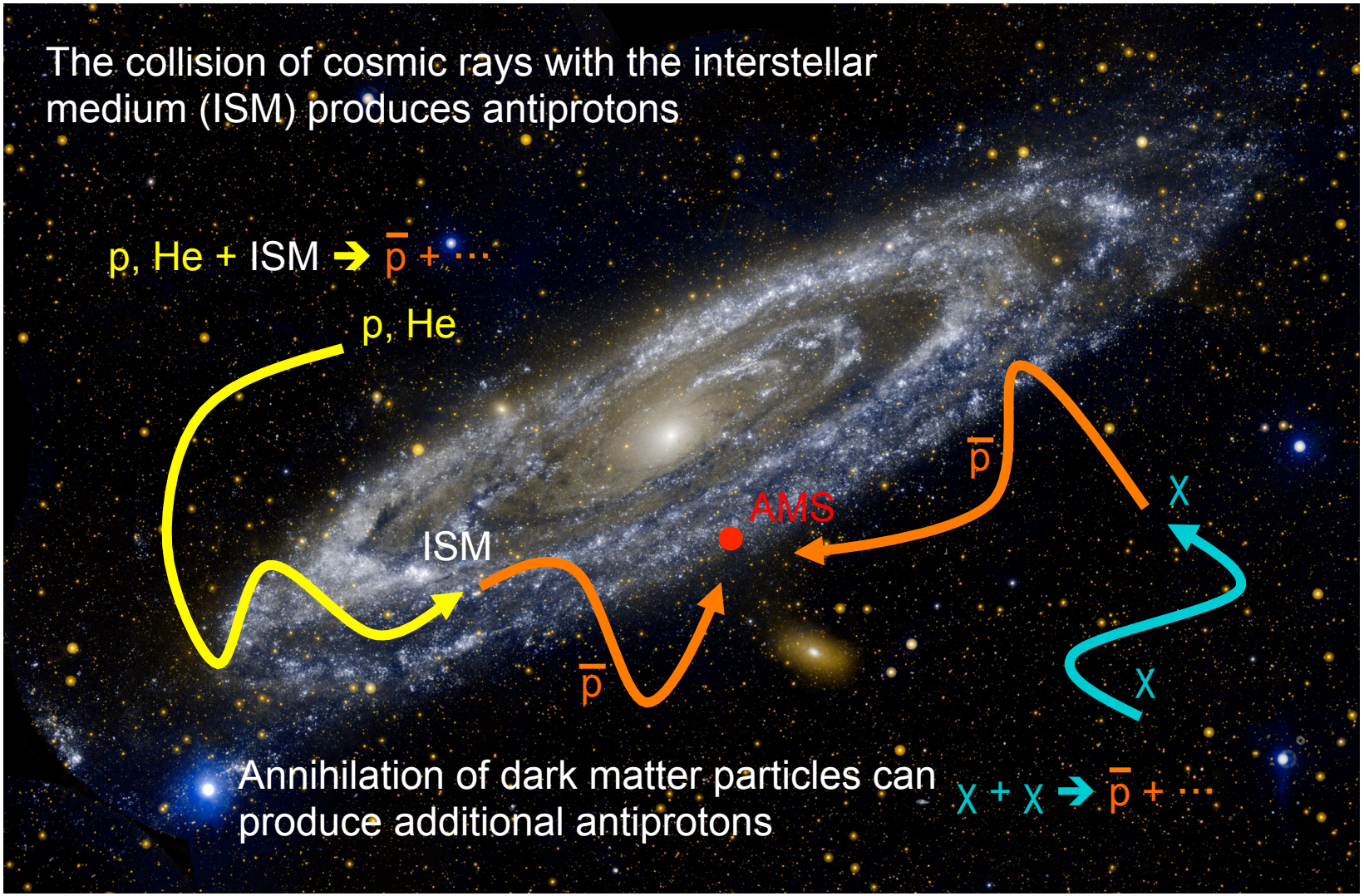
AMS-02

RWTH AACHEN UNIVERSITY

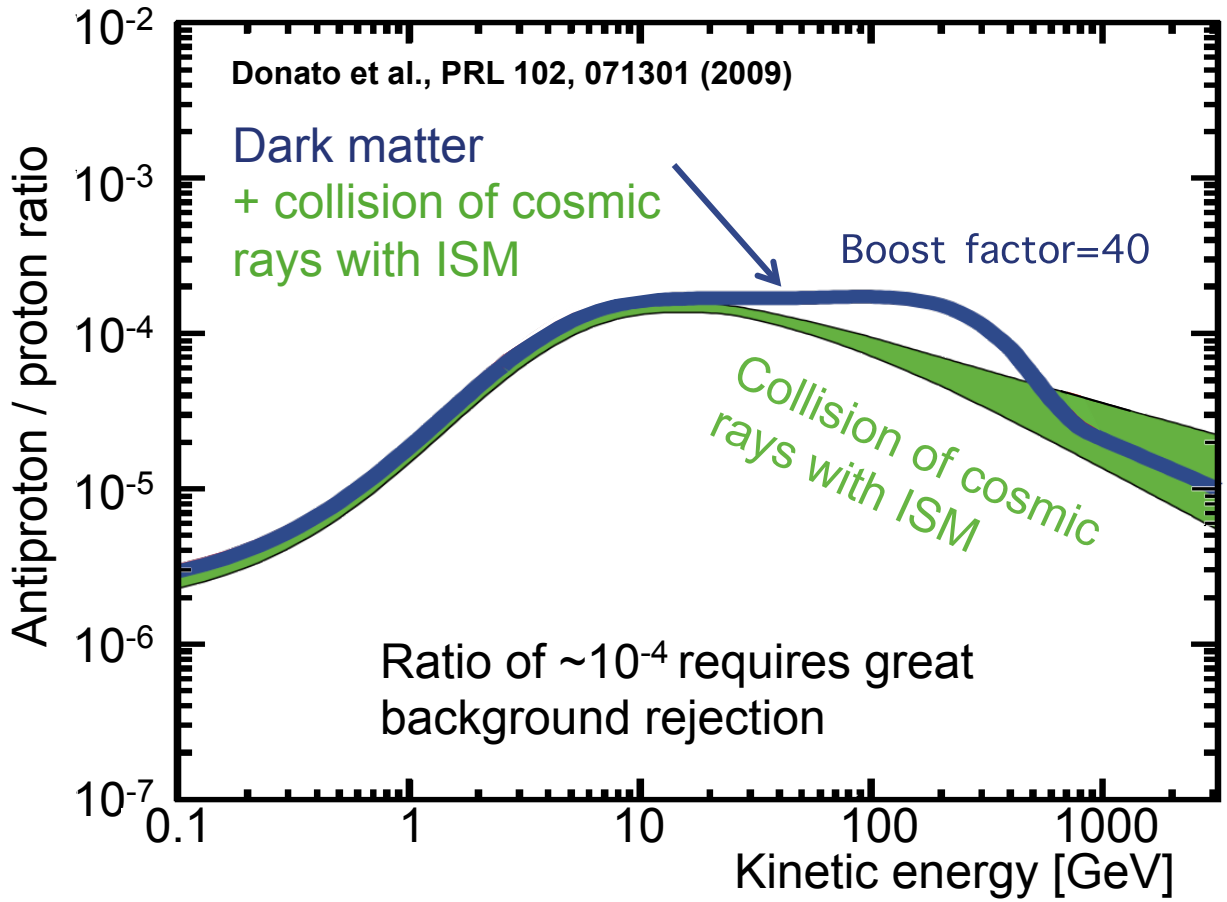
Antiprotons in cosmic rays



~85% of the matter in the Universe is dark



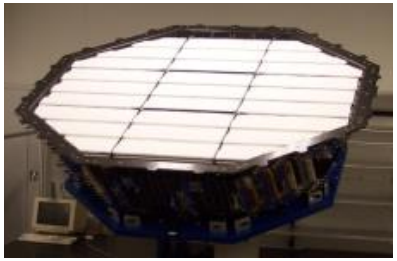
Antiproton to proton ratio in the cosmic rays



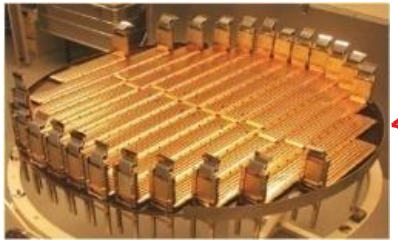
- Antiproton excess can be measured by AMS

AMS: A TeV precision, multipurpose spectrometer

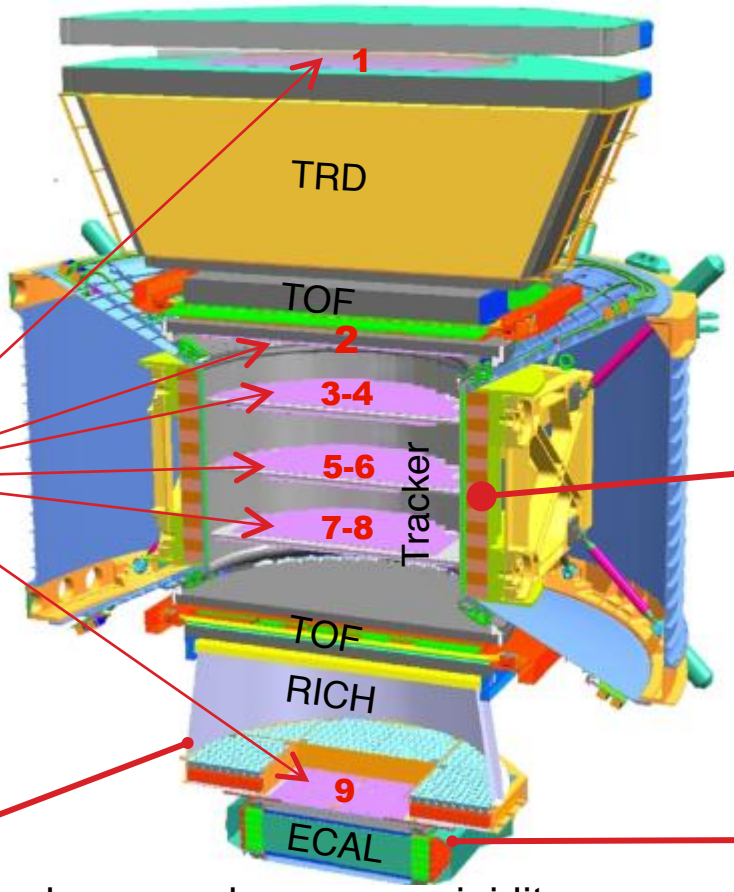
Transition Radiation Detector
Separate p,$\bar{p}$ from $e^{\pm}$



Silicon Tracker
Z, R

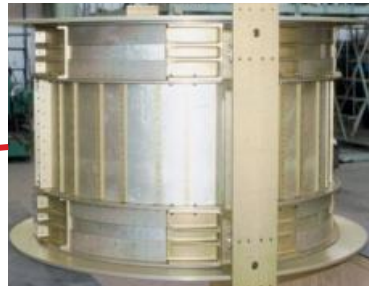


Ring Imaging Cherenkov
Z, β



Time of Flight
Z, β

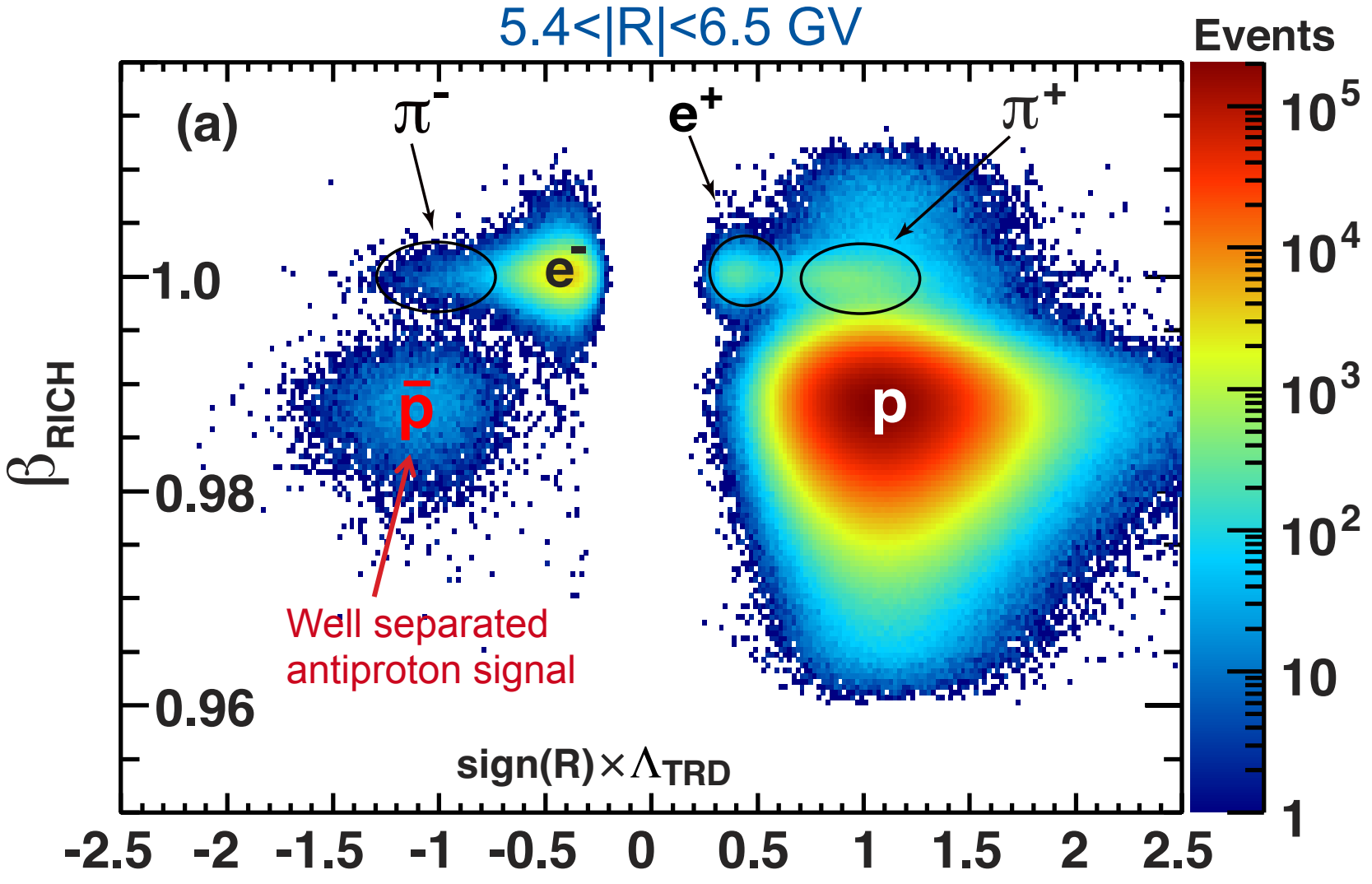
Magnet
± Z



Electromagnetic Calorimeter
Separate p,$\bar{p}$ from $e^{\pm}$

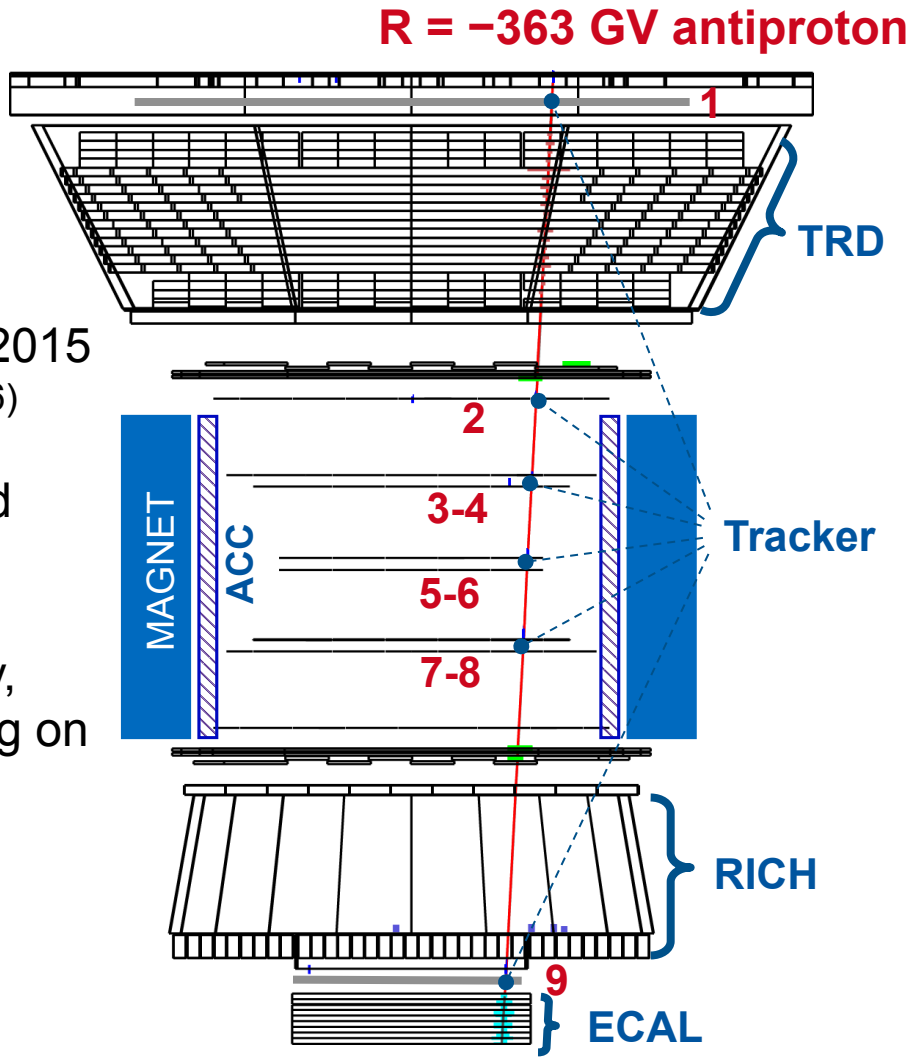
The charge and energy or rigidity are measured independently by several sub-detectors

Antiproton signal

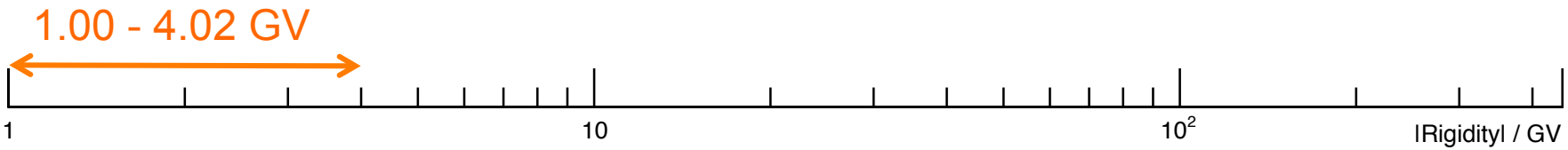


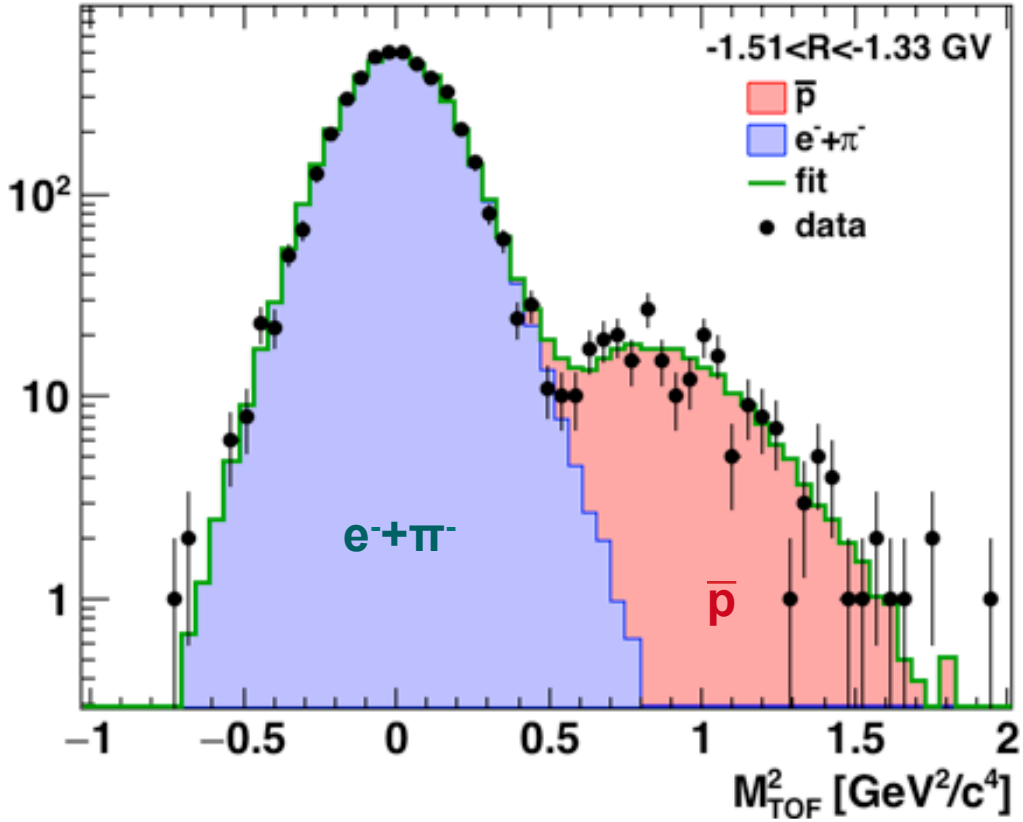
Event selection for the $\bar{p}/p$ analysis

- ISS data from May 19, 2011 to May 26, 2015
  M. Aguilar *et al.*, Phys. Rev. Lett. **117**, 091103 (2016)
- The number of antiprotons is determined from template fits.
- To maximize the measurement accuracy, different approaches are used depending on the backgrounds to challenge.



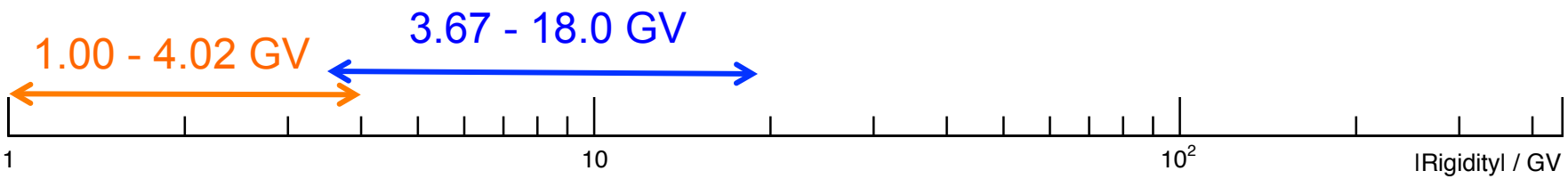
Antiproton identification (low rigidity region)

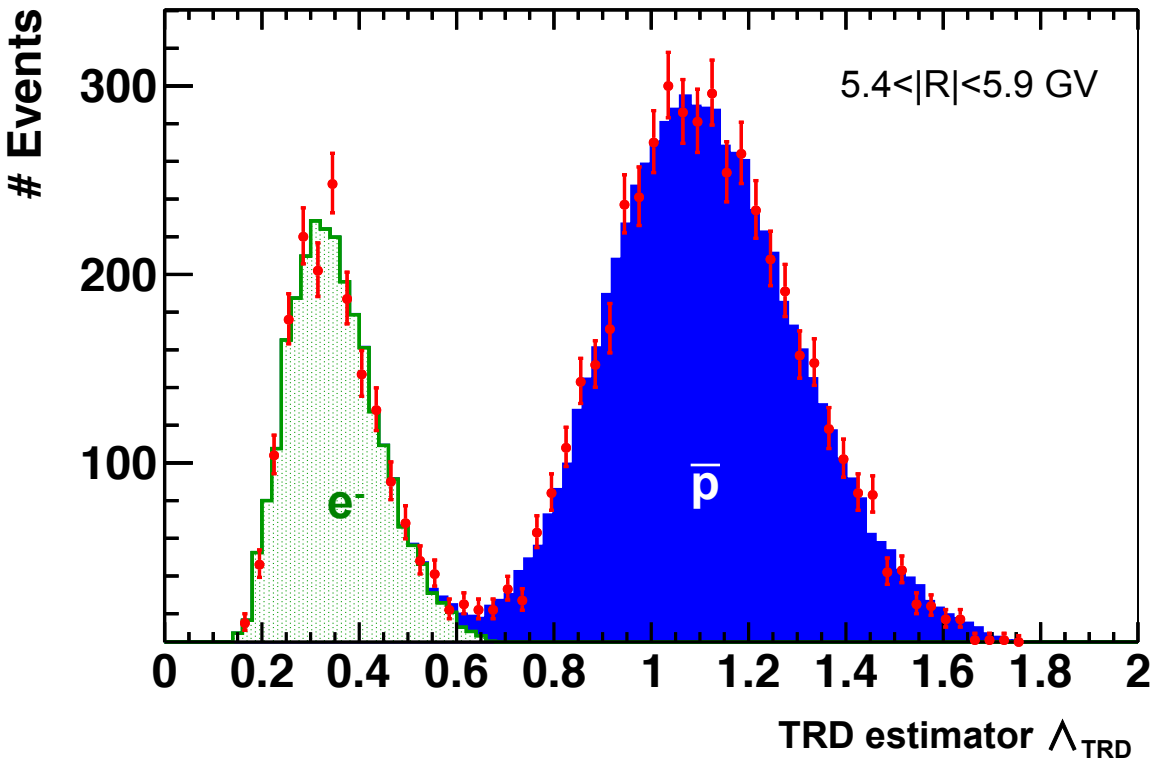




- Electron, pion background
- Mass calculated from TOF β and Tracker rigidity
- Cut on TRD estimator to suppress electrons
- Template events selected from ISS data via the RICH

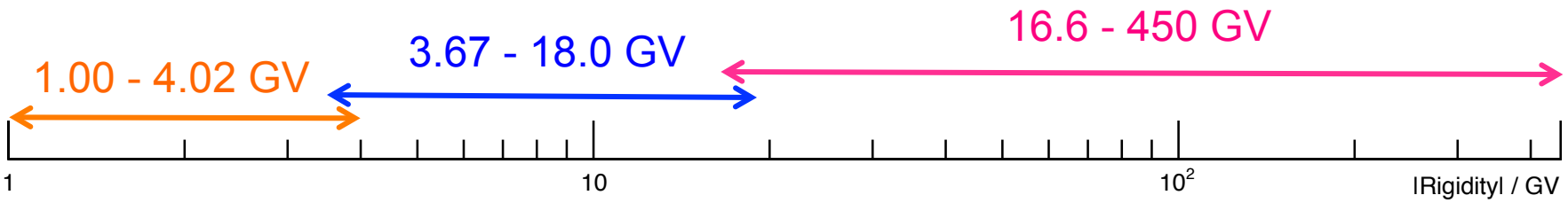
Antiproton identification (intermediate rigidity region)



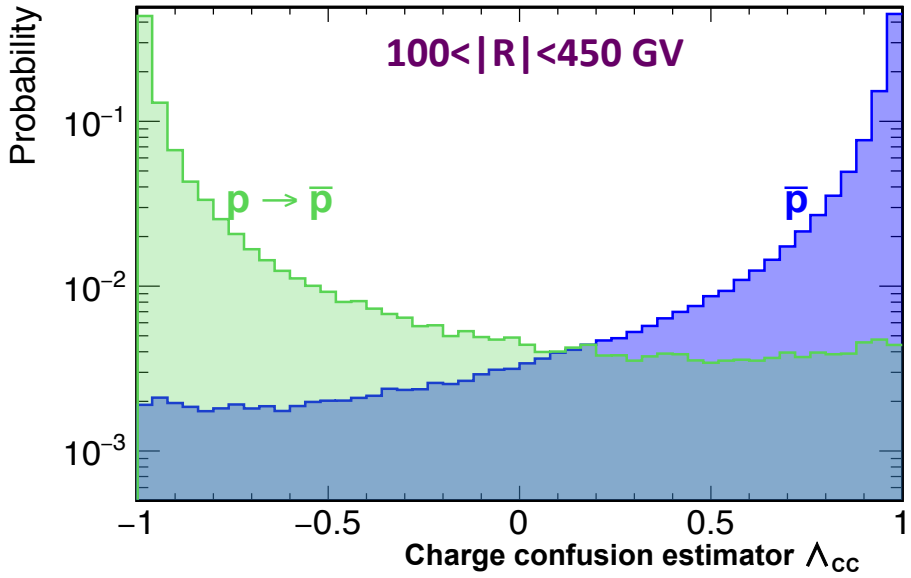


- Electron and small amount of pion background
- Utilize RICH information to remove residual Pion contamination
- Templates from ISS data

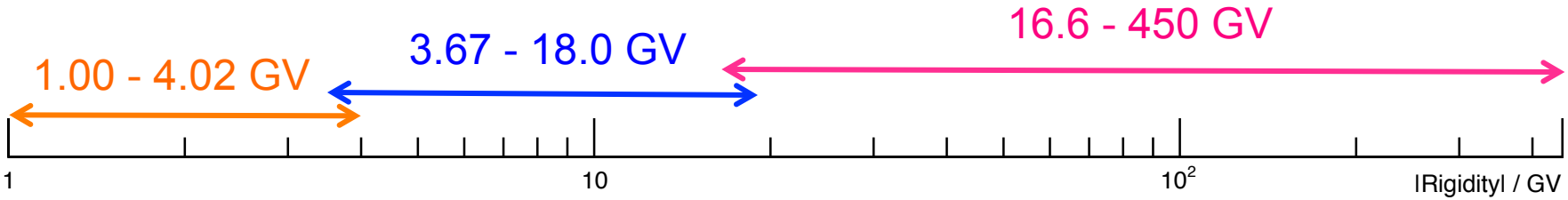
Antiproton identification at high rigidities

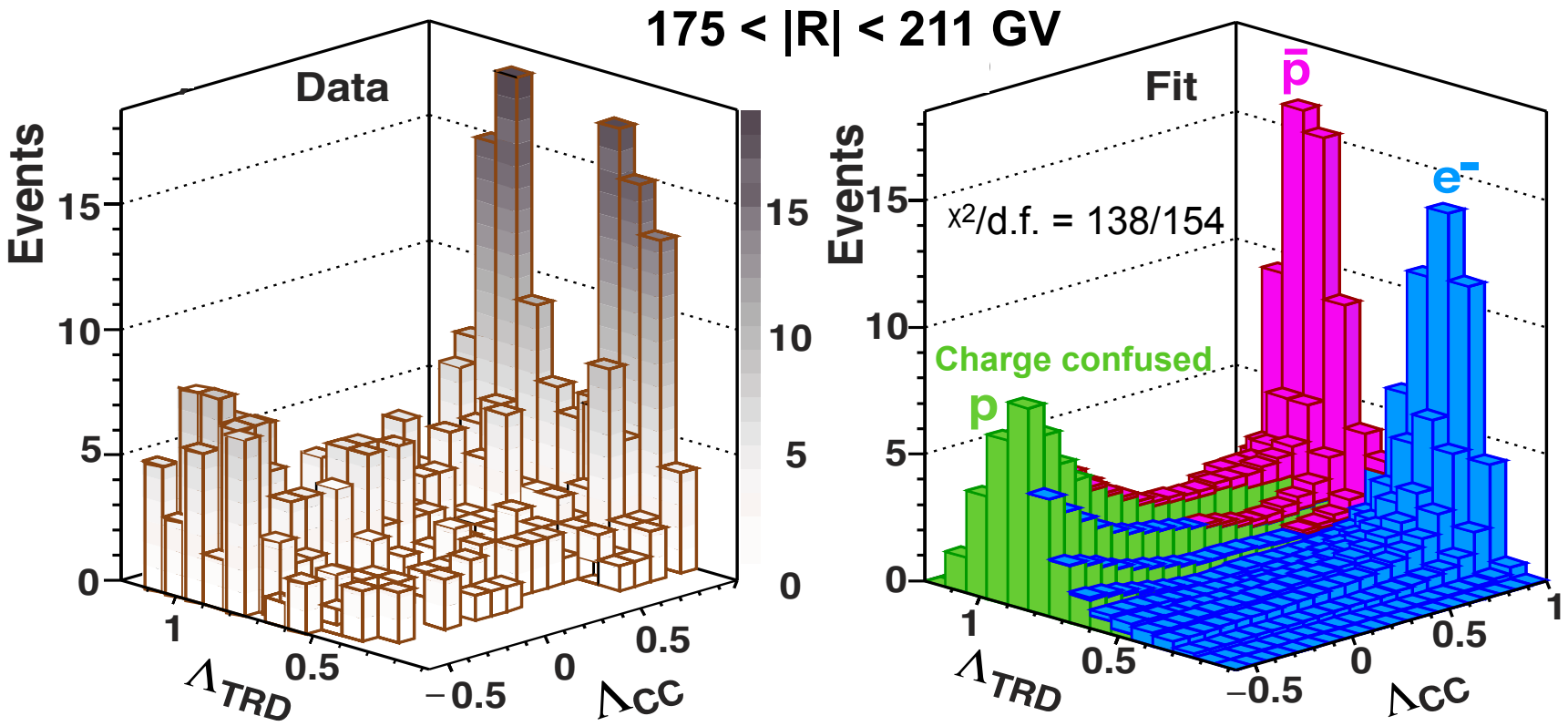


- Events may be reconstructed with wrong charge sign, due to:
  - Finite tracker resolution
  - Particle interactions with detector material
  - Leads to charge confused events
- Electron and charge confused proton background
- Charge confusion estimator Λ_{CC}:
  - MVA BDT 10 variables based on e.g.:
    - Track fit quality
    - Rigidity algorithms and track pattern
    - Charge measurements

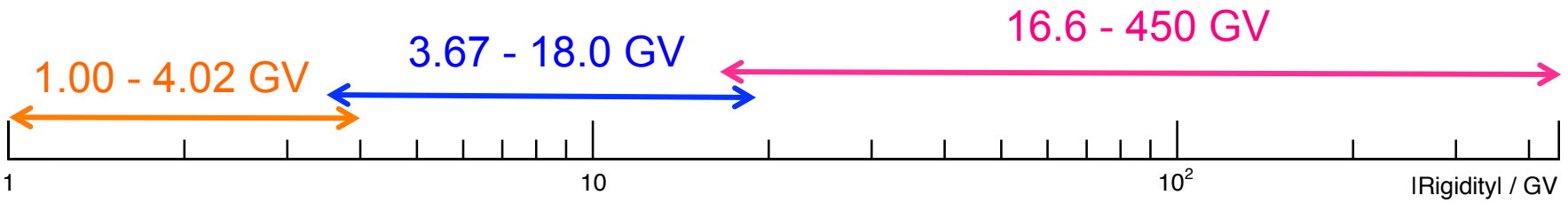


Antiproton identification at high rigidities





Antiproton identification



1. Low rigidity region: Electron, pion background
   1.00 - 4.02 GV The mass calculated from TOF and Tracker

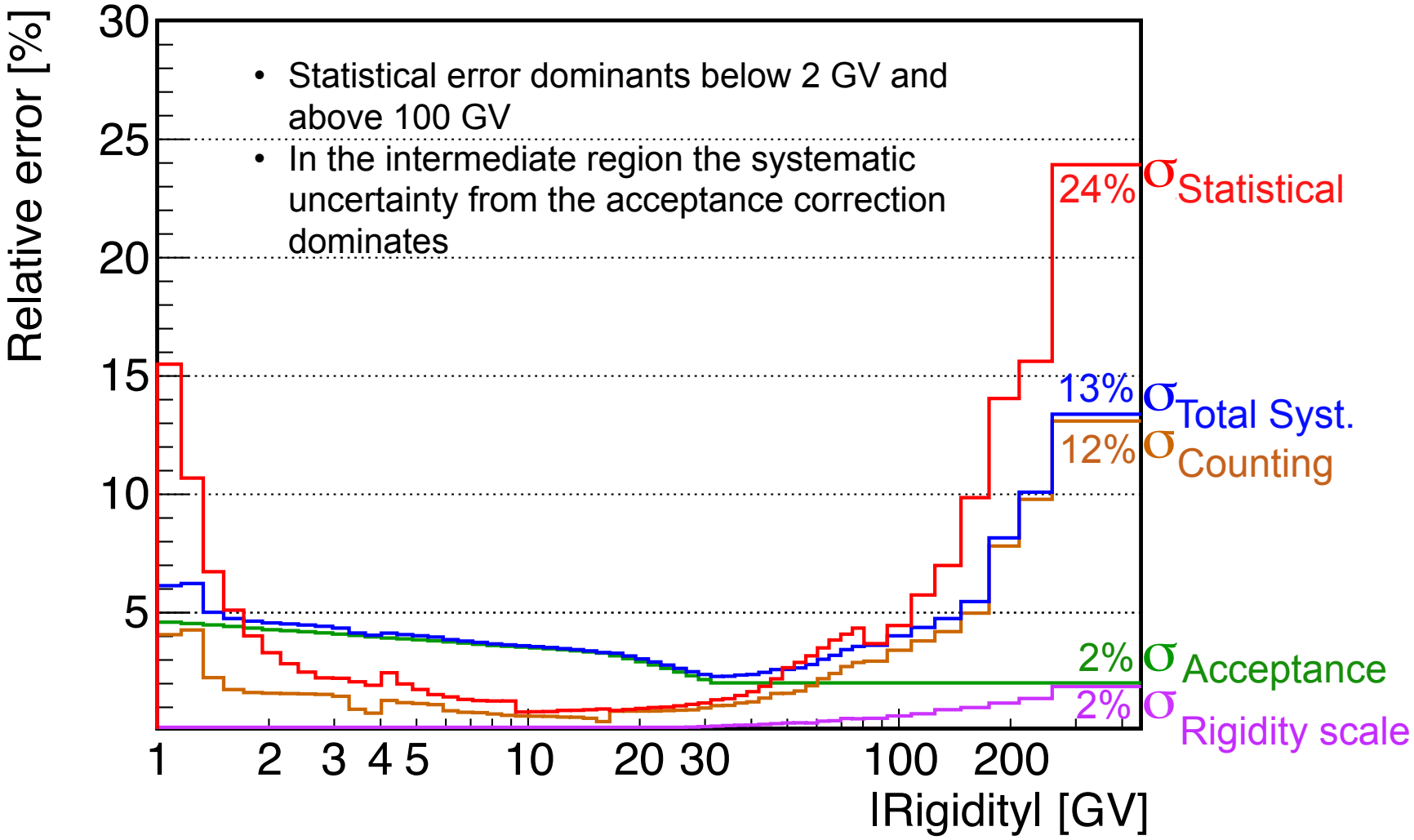
2. Intermediate region: Electron and small amount of pion background
   3.67 - 18.0 GV RICH and TRD estimator

3. High rigidity region: Electron and charge confusion proton background
   16.6 - 450 GV 2D template in (Λ_{TRD} - Λ_{CC}) plane

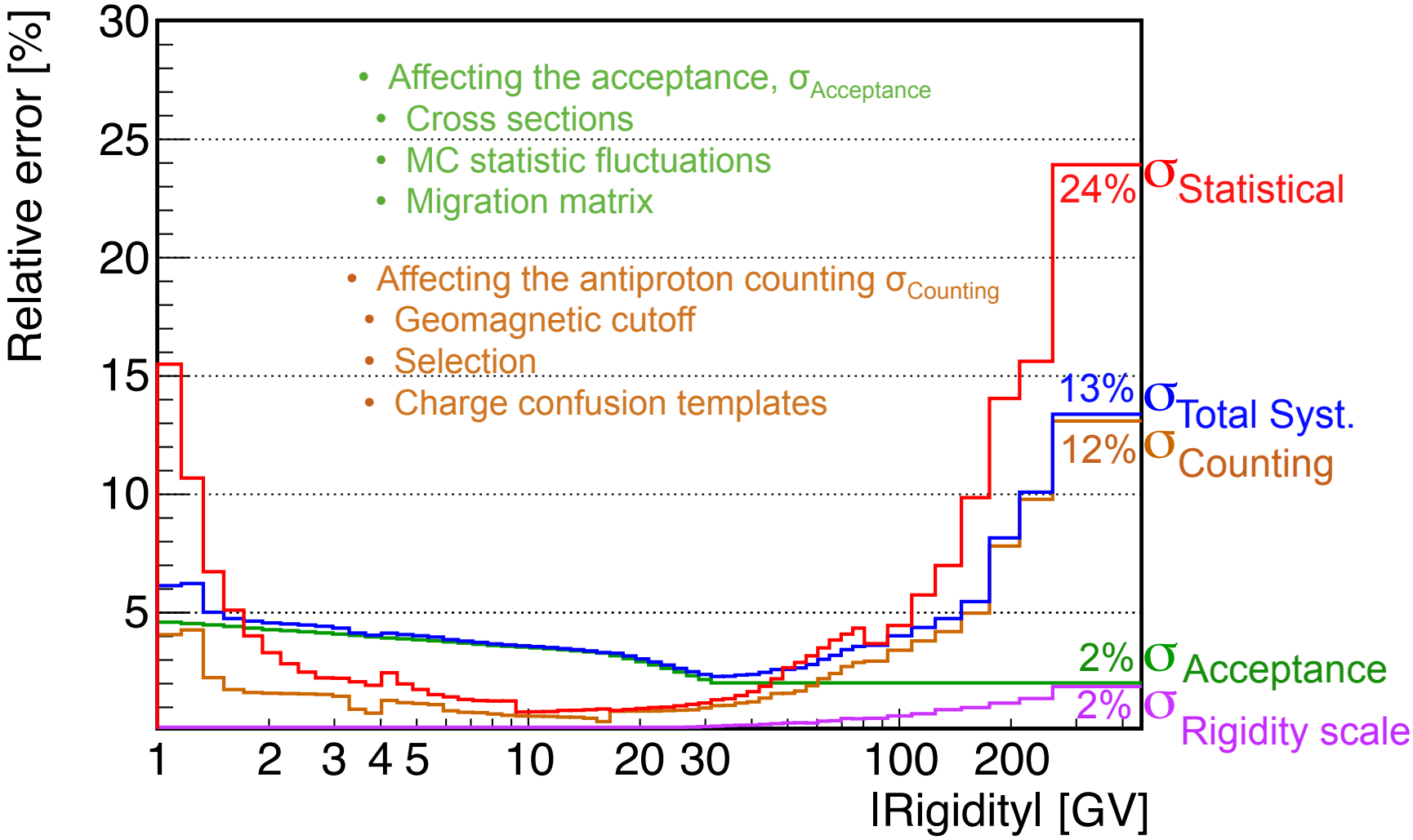
- The regions overlap, the analysis with the smallest error is taken

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

Antiproton uncertainties



Antiproton uncertainties



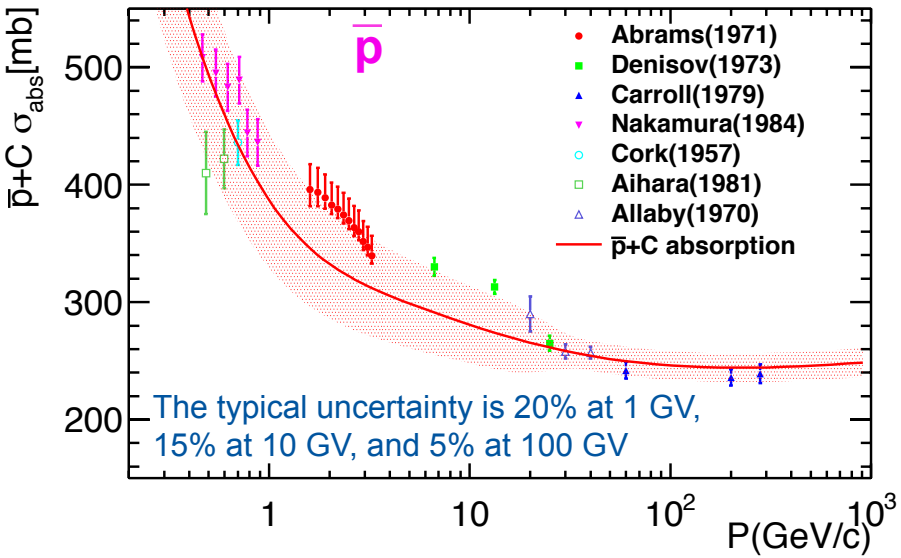
Systematic uncertainty from cross section uncertainty

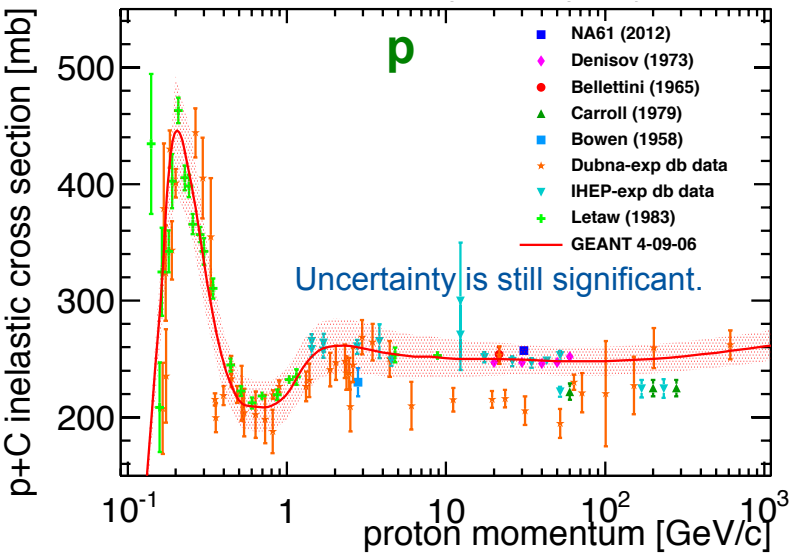
The antiproton-to-proton flux ratio is defined as

$$\left(\frac{\bar{p}}{p}\right)_i \equiv \frac{\Phi_i^{\bar{p}}}{\Phi_i^{p}} = \frac{\tilde{N}_i^{\bar{p}}}{\tilde{N}_i^{p}} \cdot \frac{\tilde{A}_i^{p}}{\tilde{A}_i^{\bar{p}}}$$

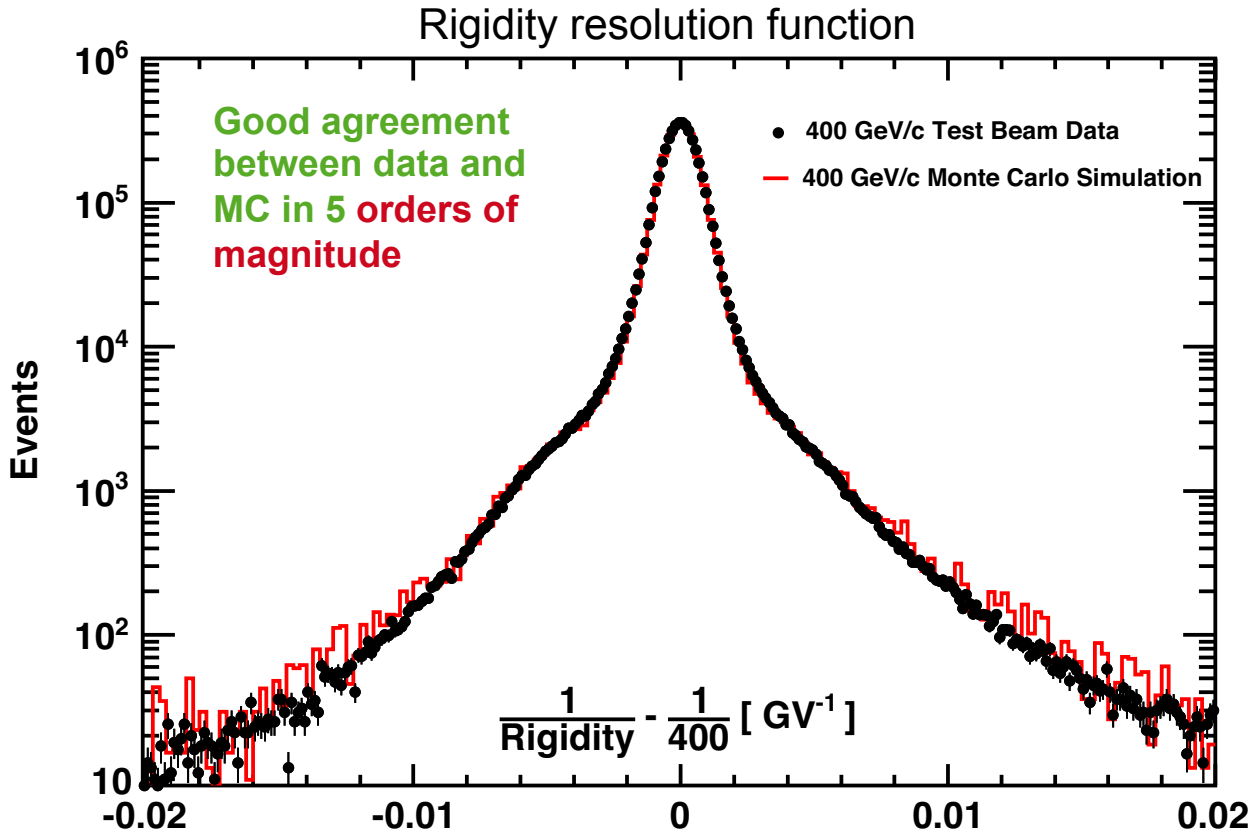
Number of observed antiprotons and protons

Acceptance ratio of protons to antiprotons



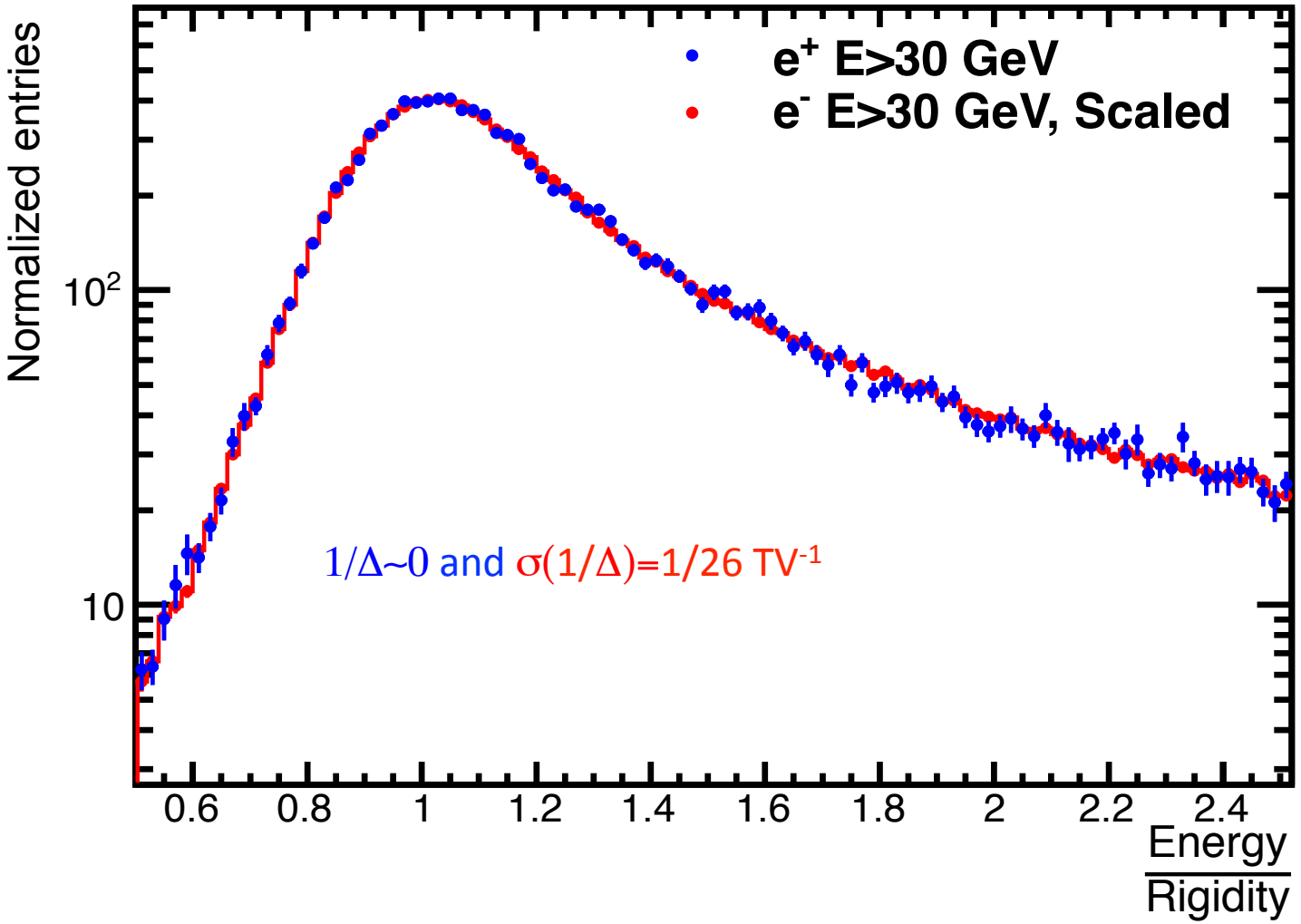


Systematic error from charge confusion templates

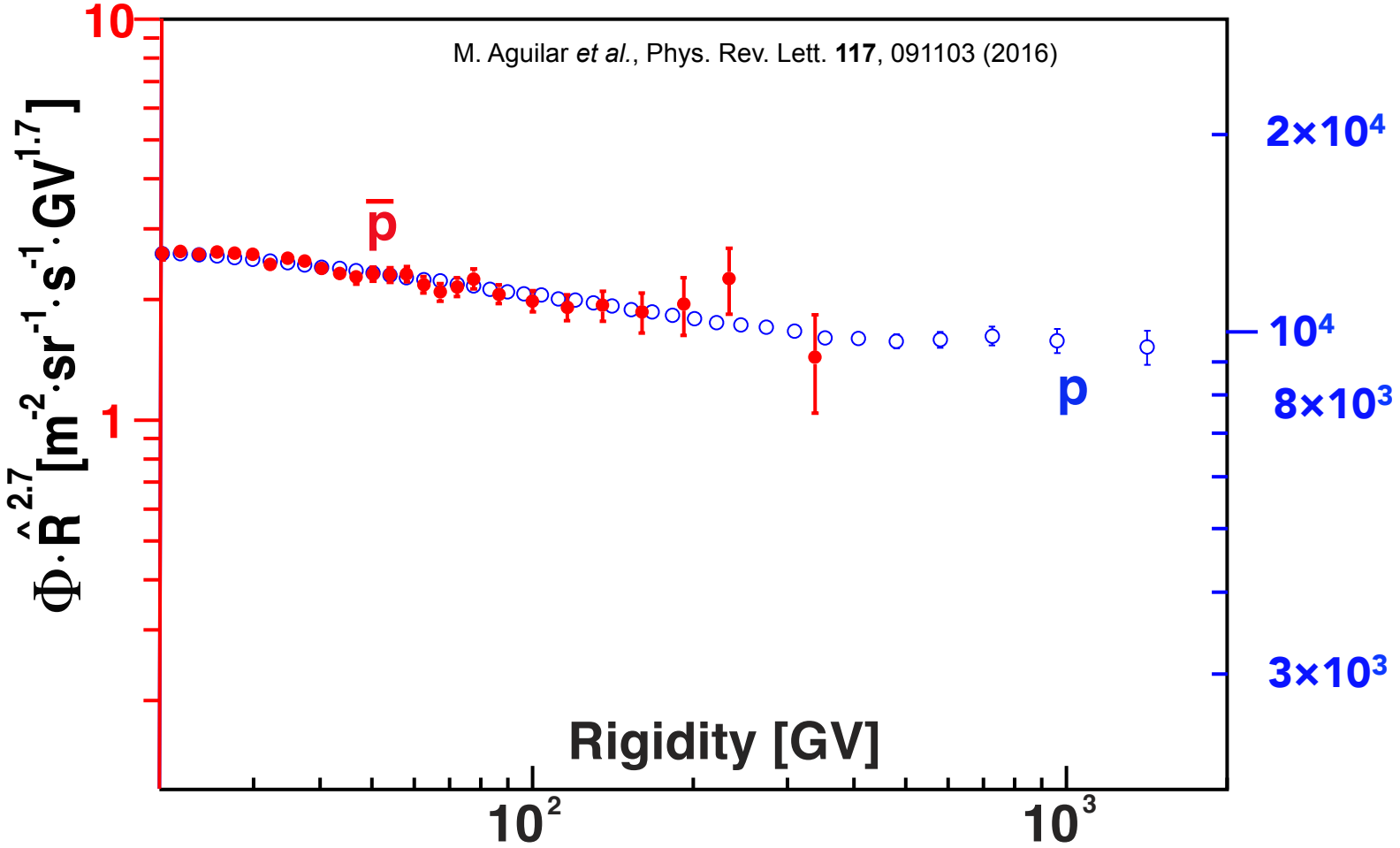


- The minor difference in charge confusion between MC simulation and data is taken as associated error

Systematic error from the rigidity scale uncertainty



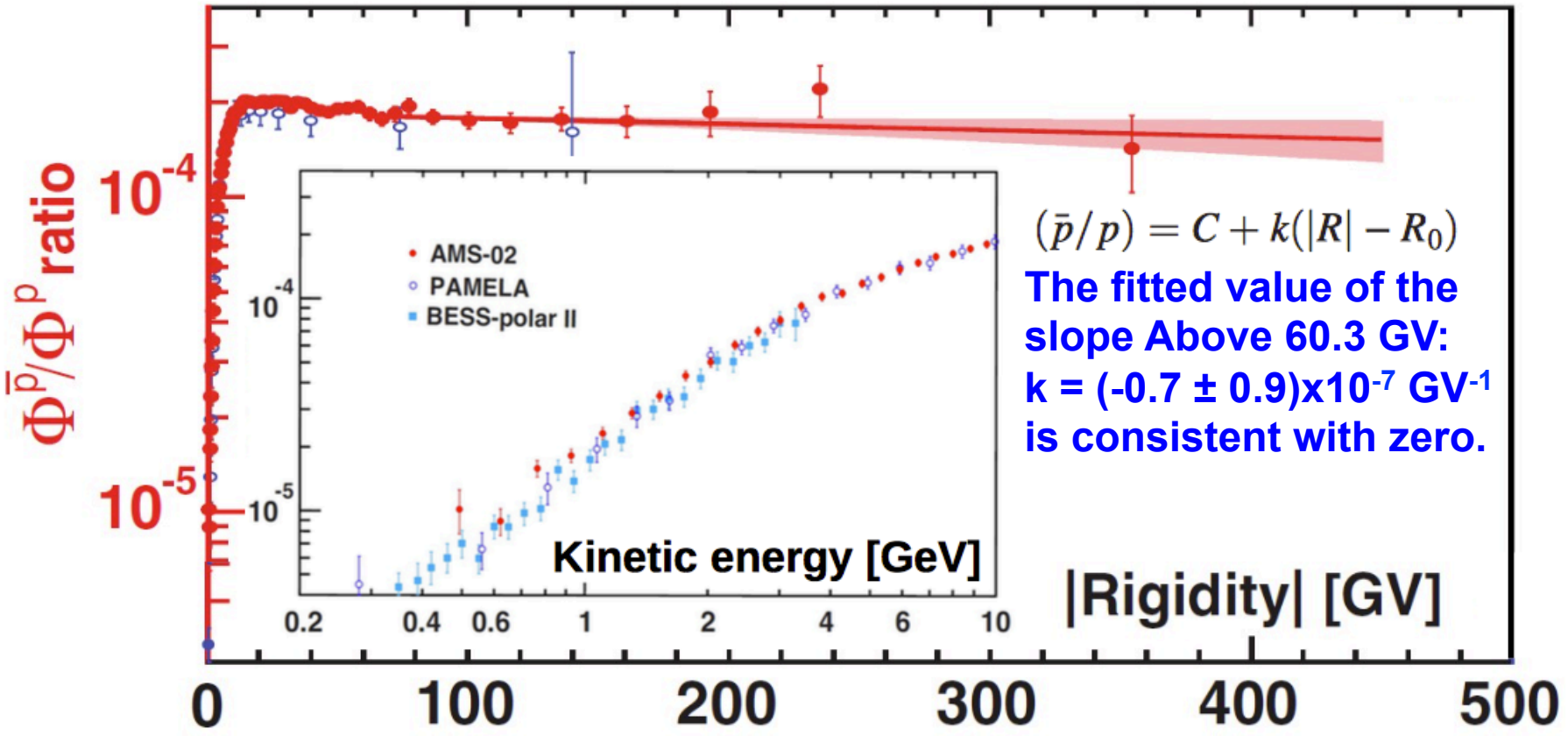
The Spectra of Protons and Antiprotons



- If $\bar{p}$ are secondaries, their spectrum should be different than p.
- Unexpectedly $\bar{p}$ and p have identical spectra.

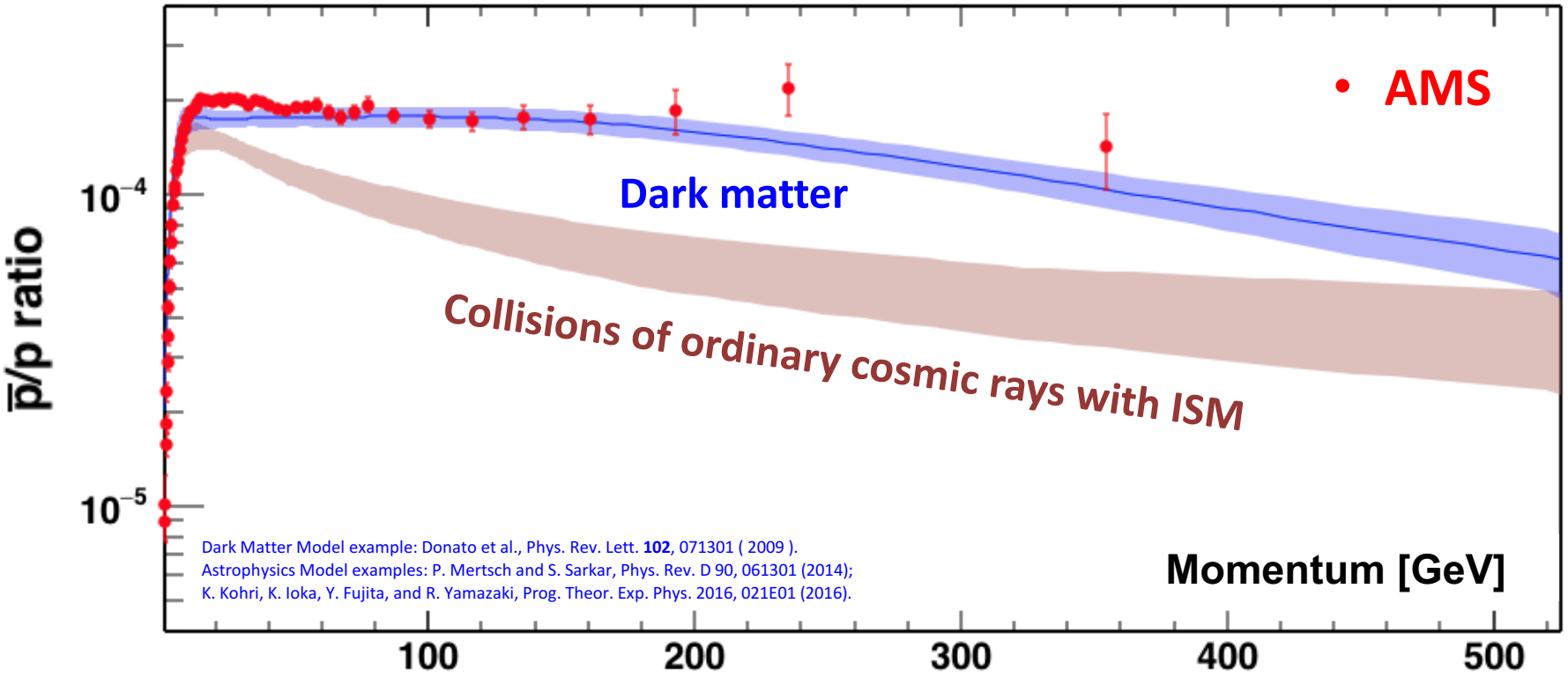
Antiproton-to-Proton Flux Ratio

M. Aguilar et al., Phys. Rev. Lett. 117 (2016) 091103.



- The antiproton-to-proton flux ratio reaches its maximum at 20 GV
- The antiproton-to-proton flux ratio shows no rigidity dependence above 60 GV

Antiproton-to-Proton Flux Ratio



- Different then the positron fraction excess the antiproton excess cannot be explained by Pulsars but could be explained by Dark Matter collisions or by new astrophysics phenomena

Conclusions

- Antiproton measurement up to 450 GV measured based on 3.49×10^5 antiprotons and 2.42×10^9 protons extending existing measurements with high precision

- The antiproton-to-proton flux ratio shows no rigidity dependence above 60 GV
  - Hint for dark matter or new astrophysical phenomena

- To test these signals a very precise theoretical prediction for the ISM background is needed

- AMS will continue to collect more data till the end of the ISS lifetime to further explore the high rigidity region, increase the precision and investigate the time dependent effects