Antiprotons and Elementary Particles over a Solar Cycle: Results from AMS

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on behalf of the AMS collaboration

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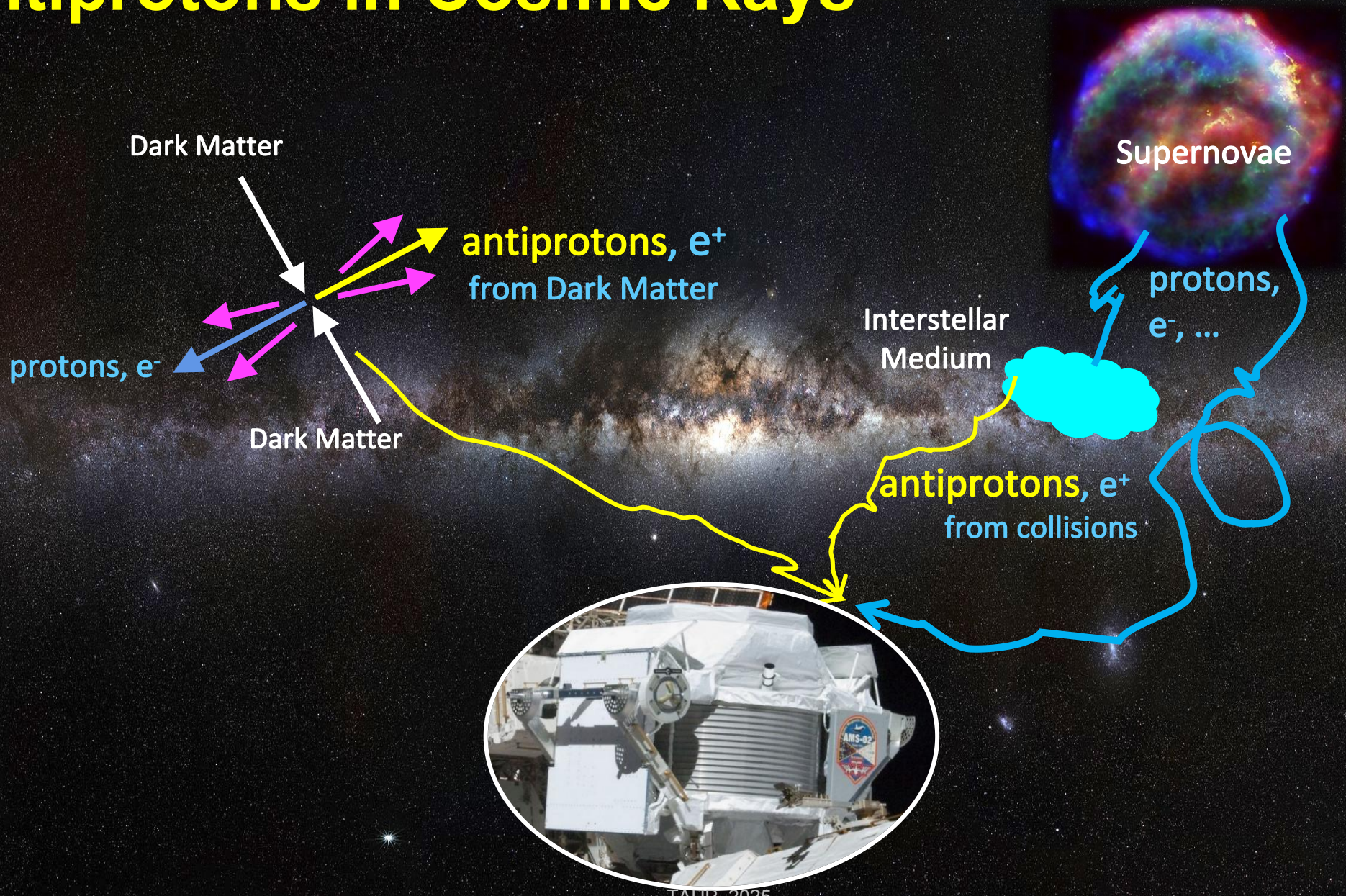
Antiprotons in Cosmic Rays

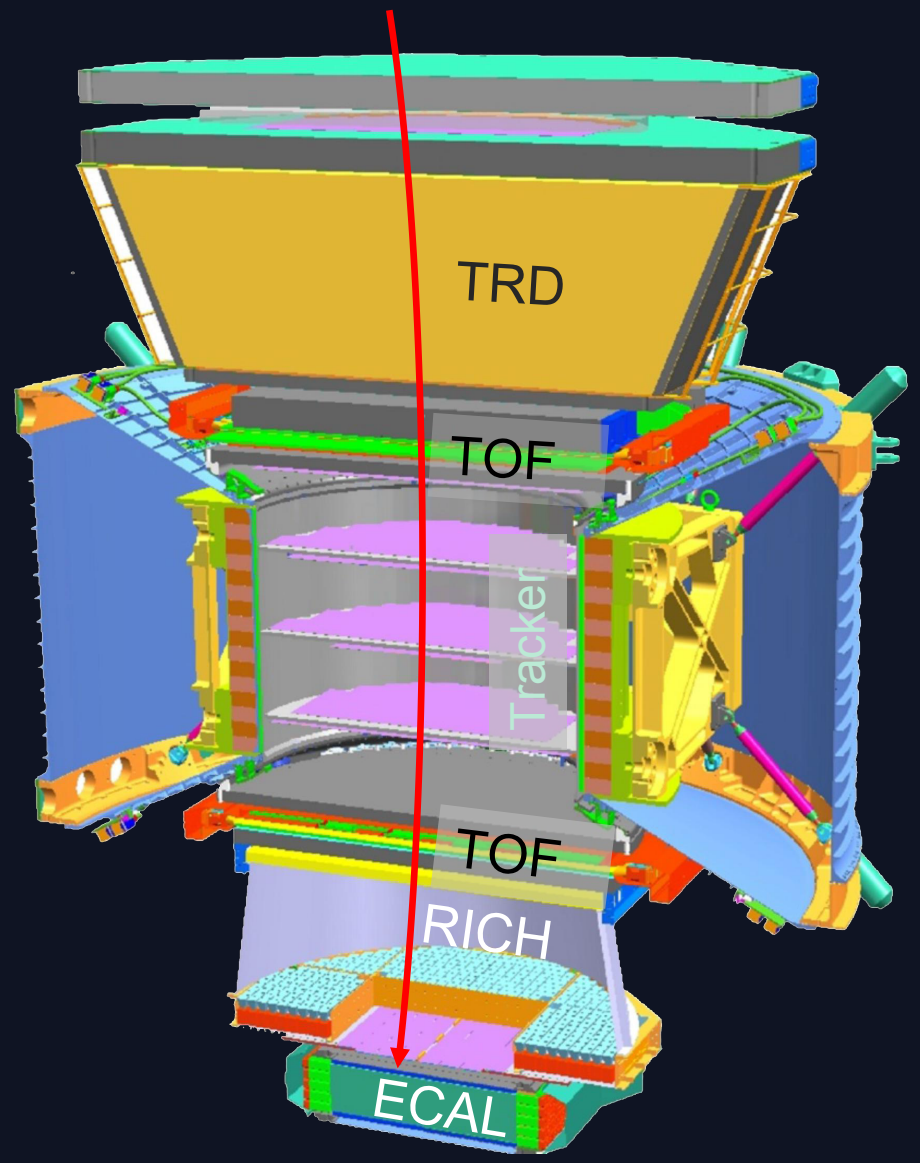


Measurement of Cosmic Antiprotons in AMS

The Antiproton flux is ~10^{-4} of the proton flux.

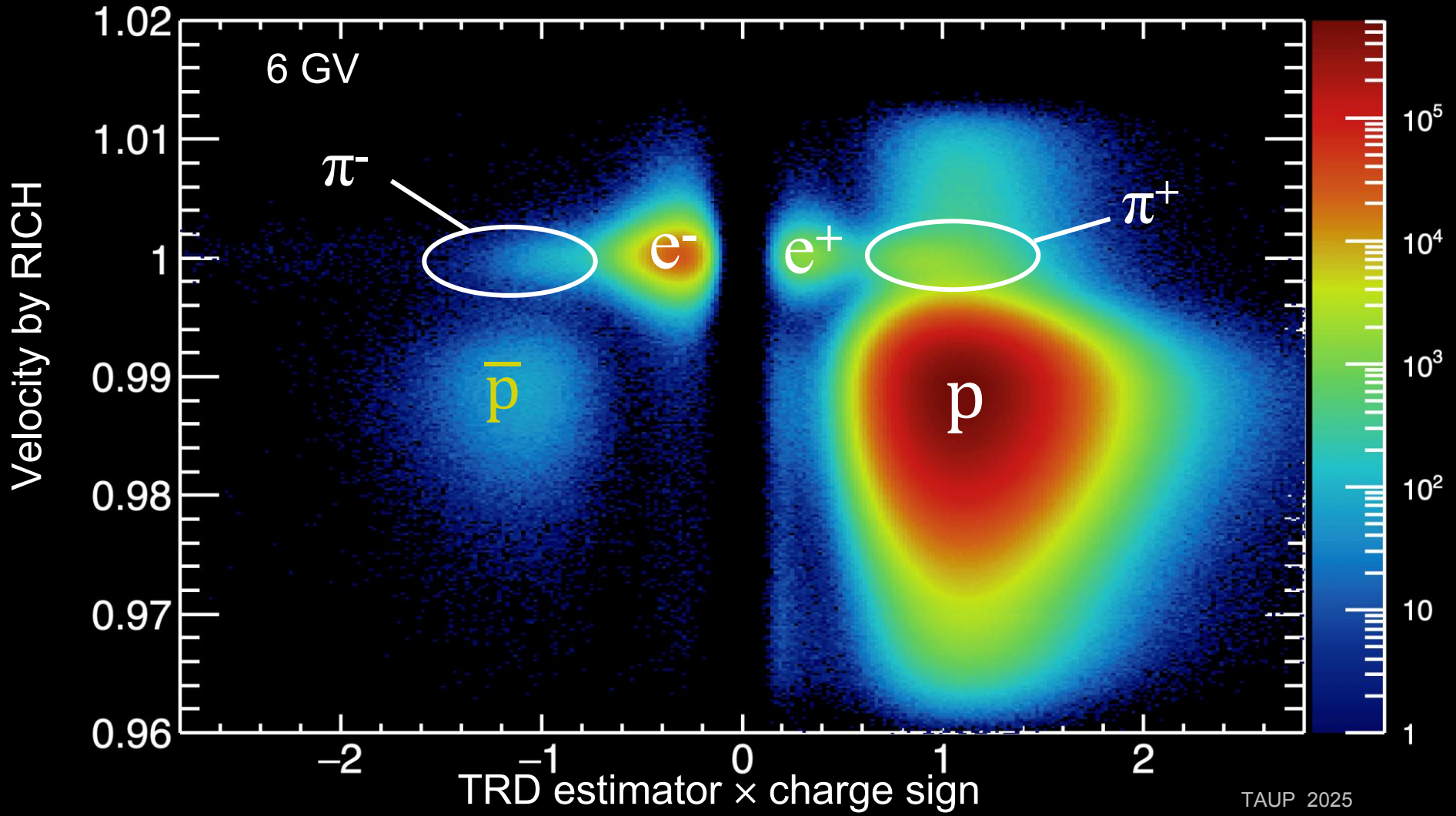
A percent level precision measurement requires background rejection close to 1 in a million

- TRD & ECAL:
  reject electron backgrounds
- Tracker & TOF:
  separate proton backgrounds
- RICH and tracker:
  identify antiprotons by mass



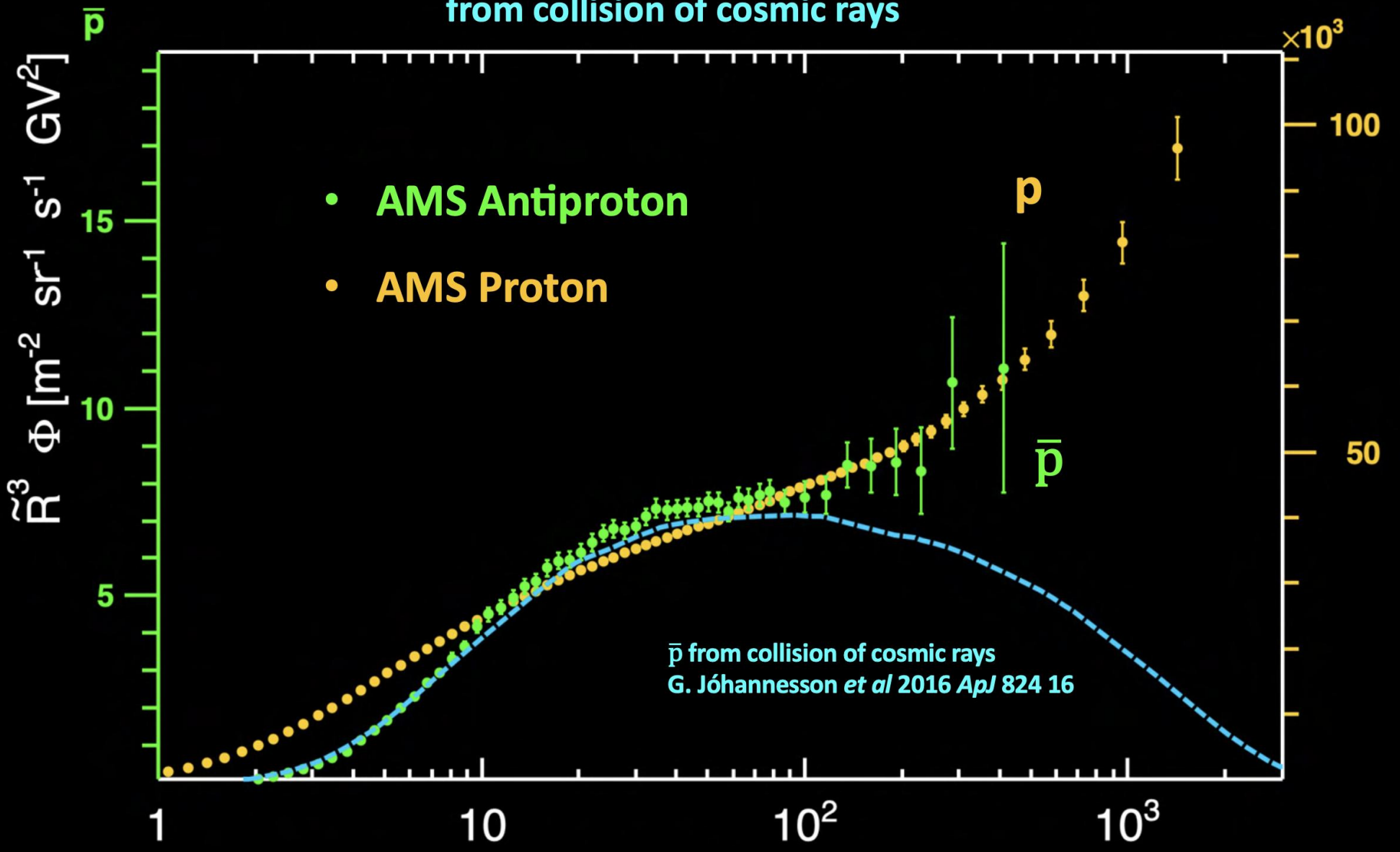
Antiproton Identification

Using Tracker, TOF, RICH and TRD to separate antiproton signals from backgrounds

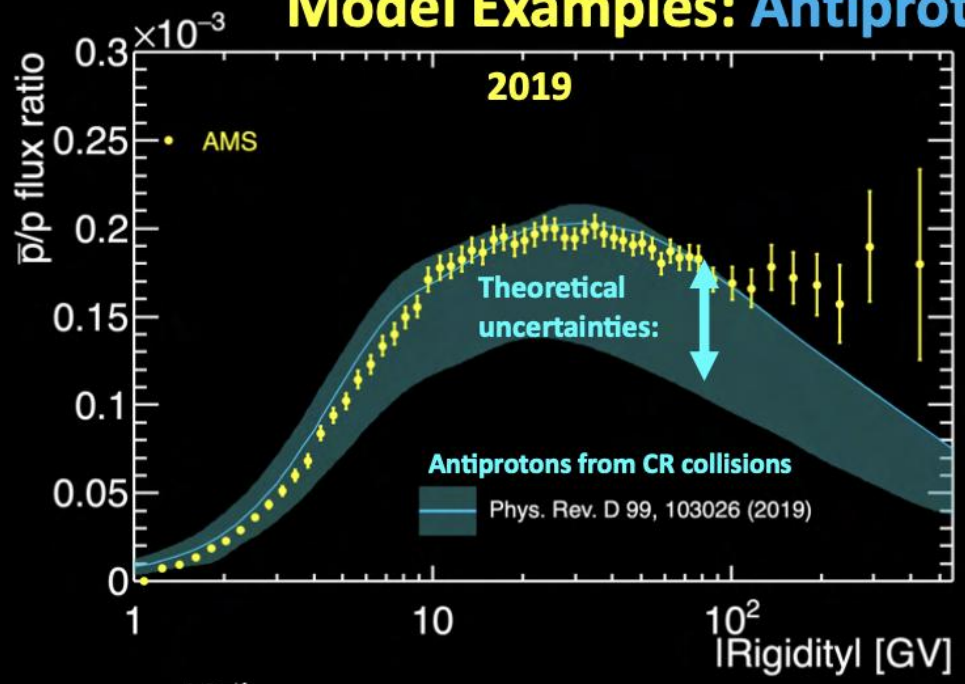


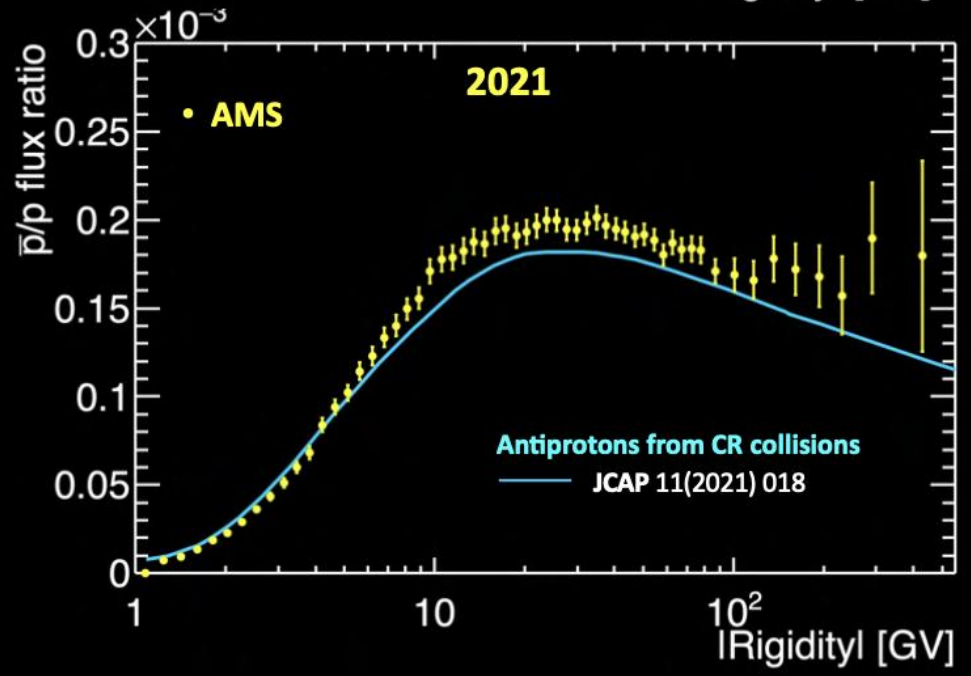
New Results on Cosmic Antiprotons

Does not agree with traditional cosmic ray model with only secondary $\bar{p}$ produced from collision of cosmic rays



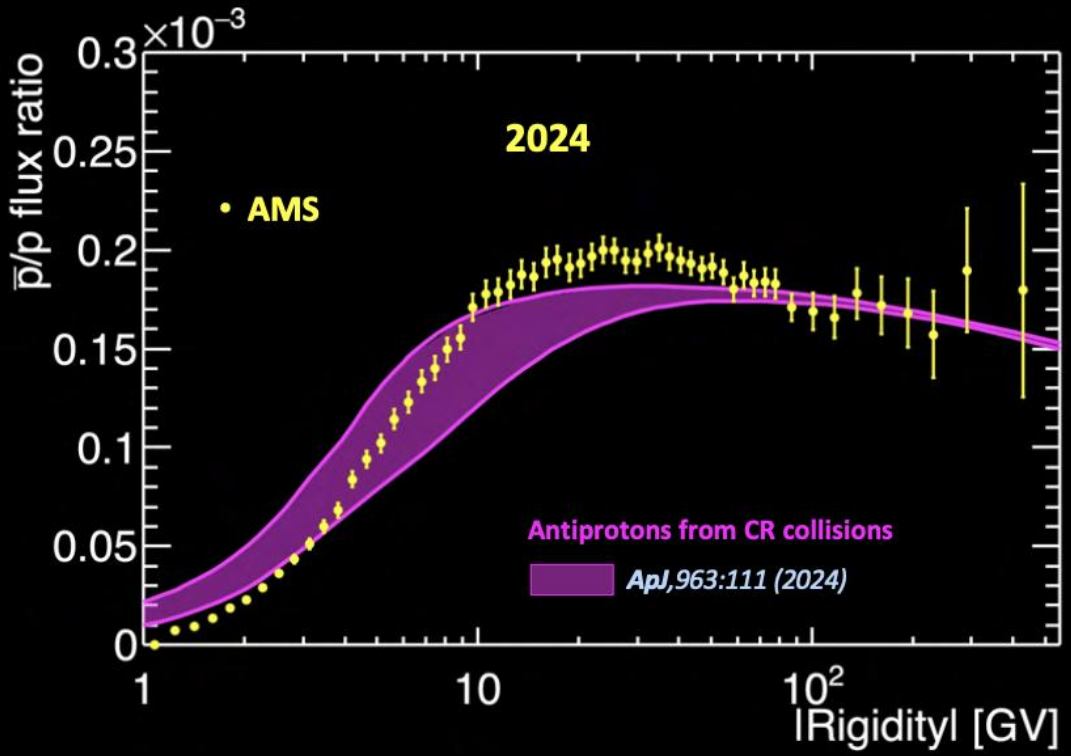
Model Examples: Antiprotons from Cosmic-Ray Collisions



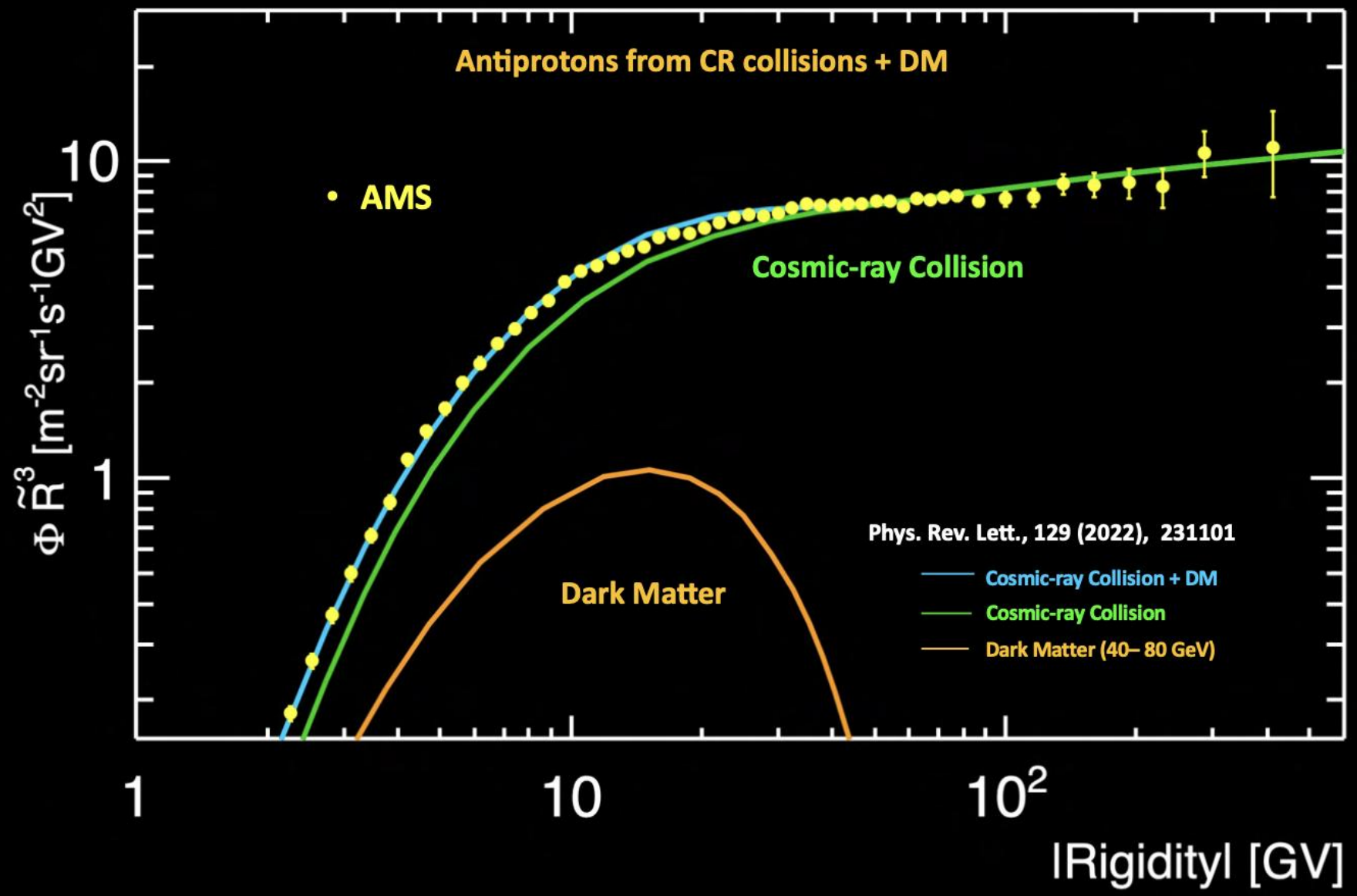


Theoretical uncertainties in Cosmic-Ray Collision Models:

- **Cosmic ray acceleration and propagation**
- **Particle transportation in the heliosphere**
- **Antiproton production cross-section**



Model Example: Antiprotons from Cosmic-Ray Collisions and Dark Matter



The accuracy of the models need to be improved with AMS Data

Time Variation of Antiprotons

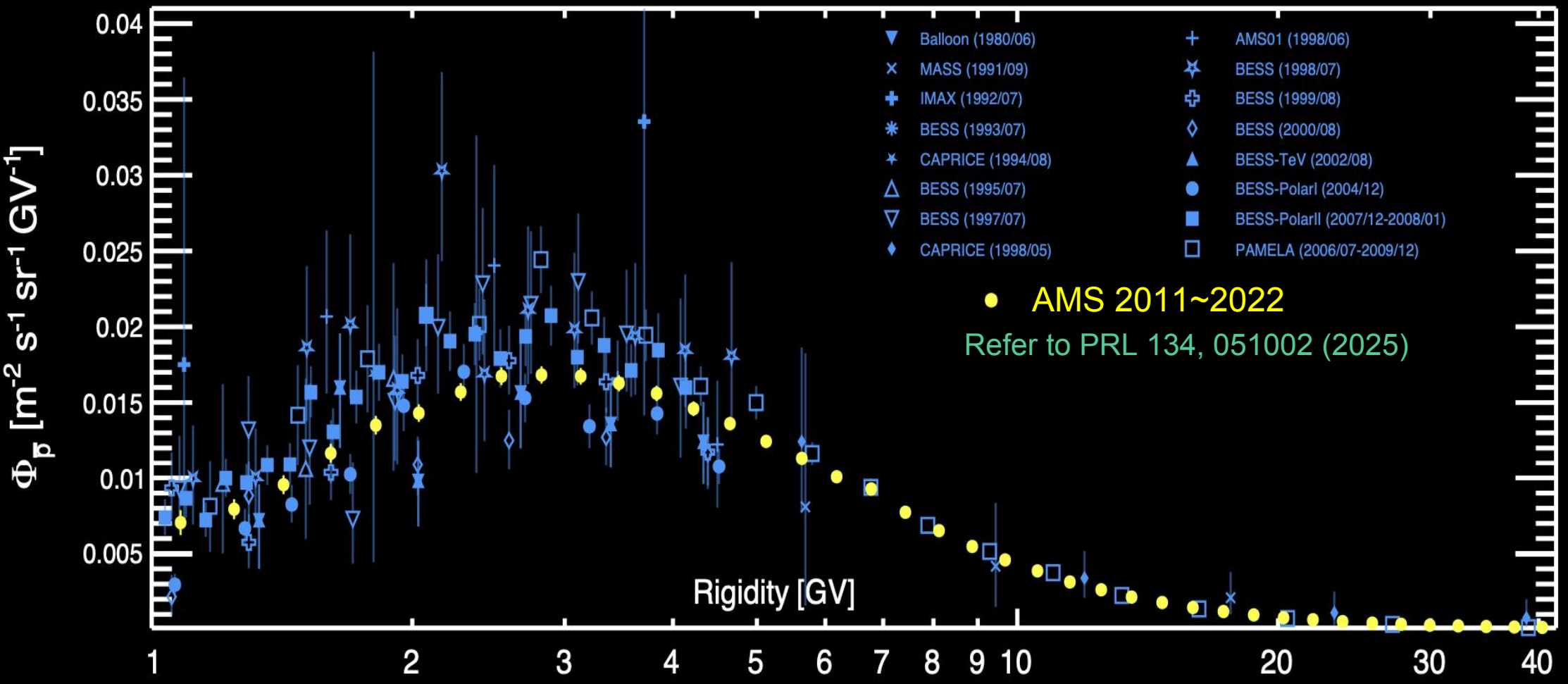
AMS is the only experiment which can measure precisely and continuously the time dependence of cosmic ray antiprotons.

Measurement of time dependence of antiprotons is important:

- To understand the background to search for new physics (e.g. dark matter) from the antiproton measurements.
- To study the solar modulation.

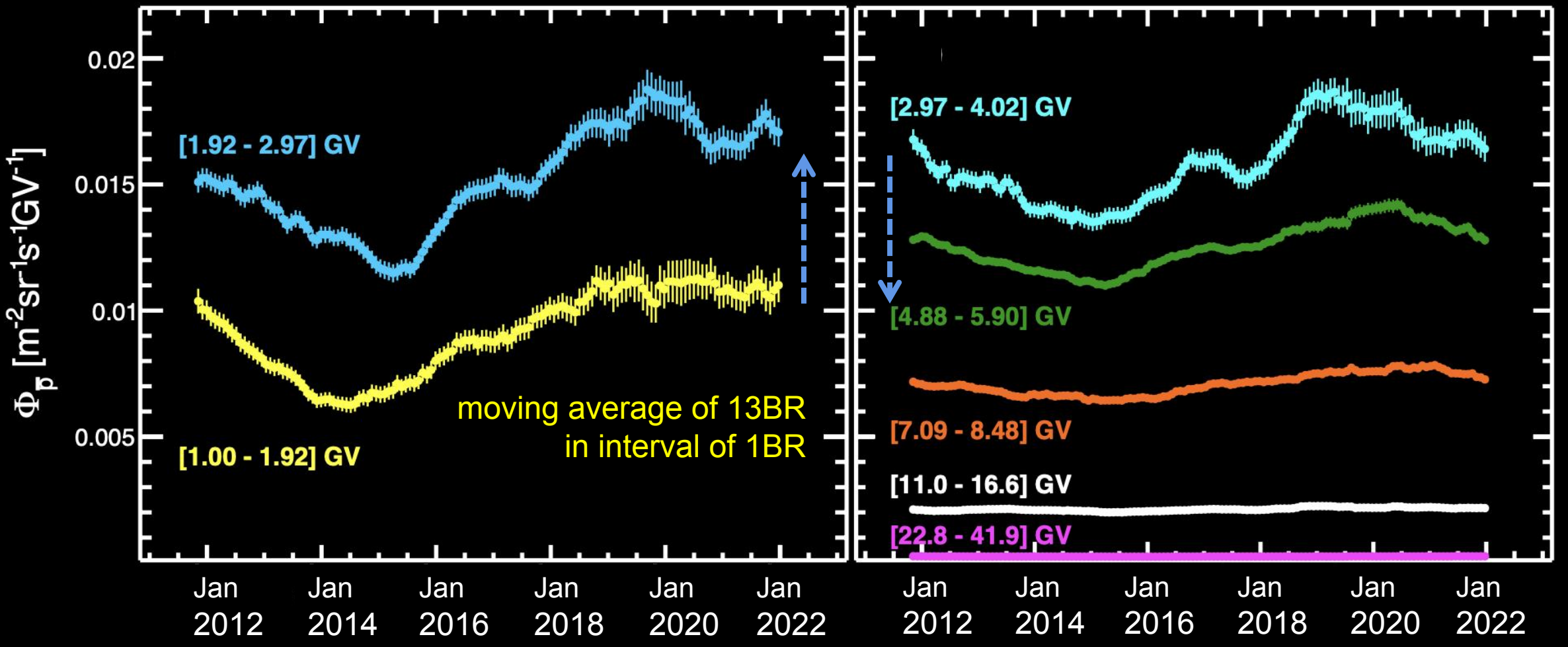
Together with AMS measured p, e^+, e^- fluxes, solar modulation can be studied with all four elementary charged particles in cosmic rays from the very same experiment.

Low Energy Antiproton Flux



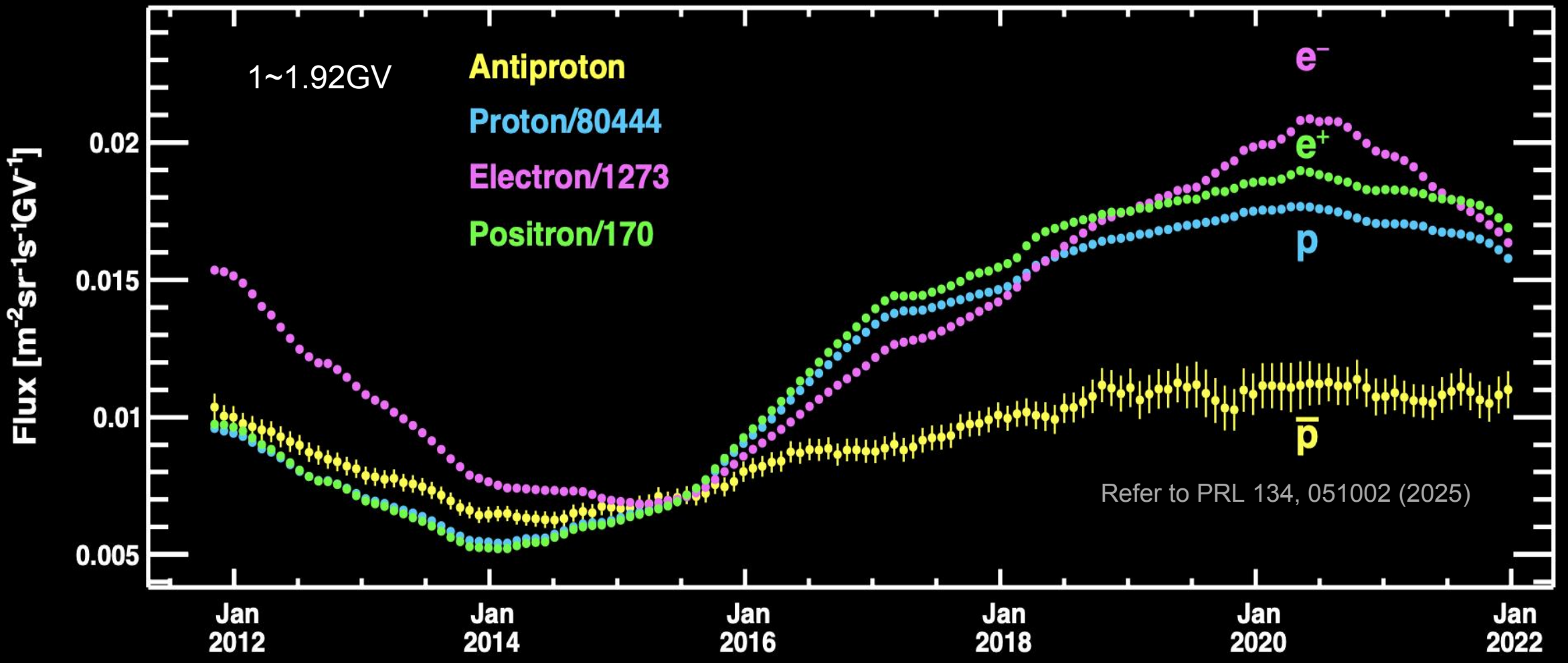
Time Dependent Antiproton Fluxes

Refer to PRL 134, 051002 (2025)



Elementary Particles Fluxes Time Dependence

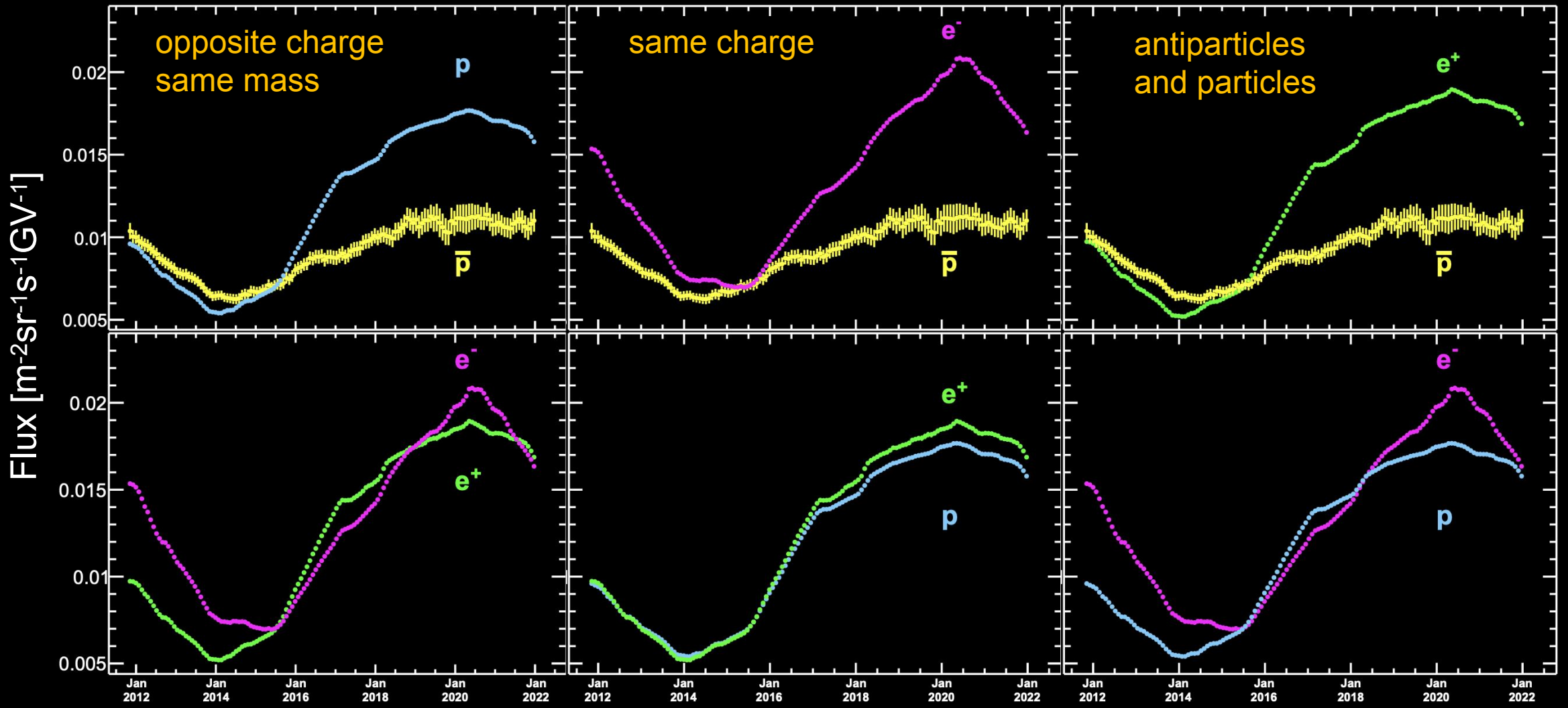
Antiproton flux is distinct to other particles



Refer to Z. Sun's presentation for more details

Elementary Particles Fluxes Time Dependence

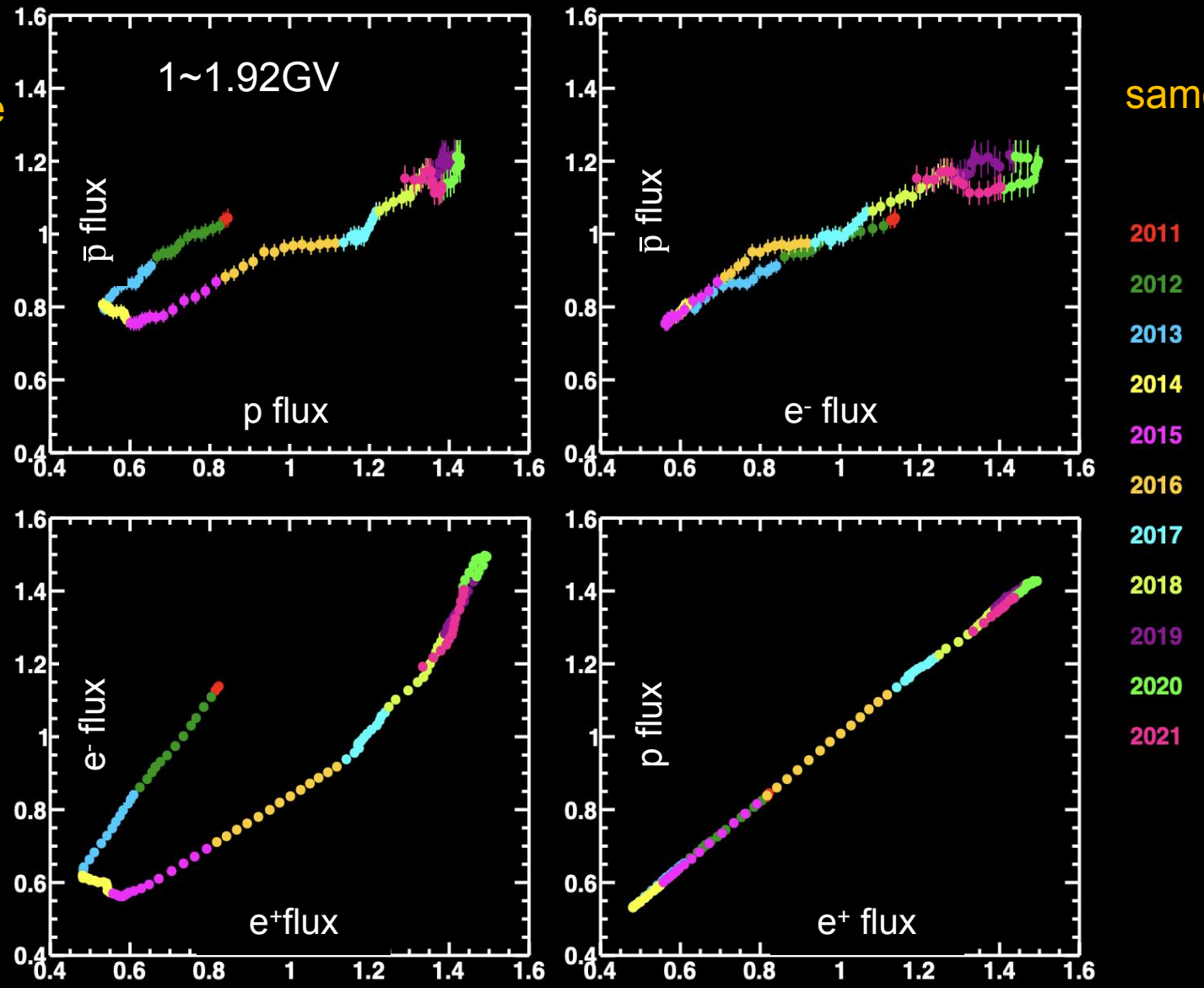
1~1.92GV



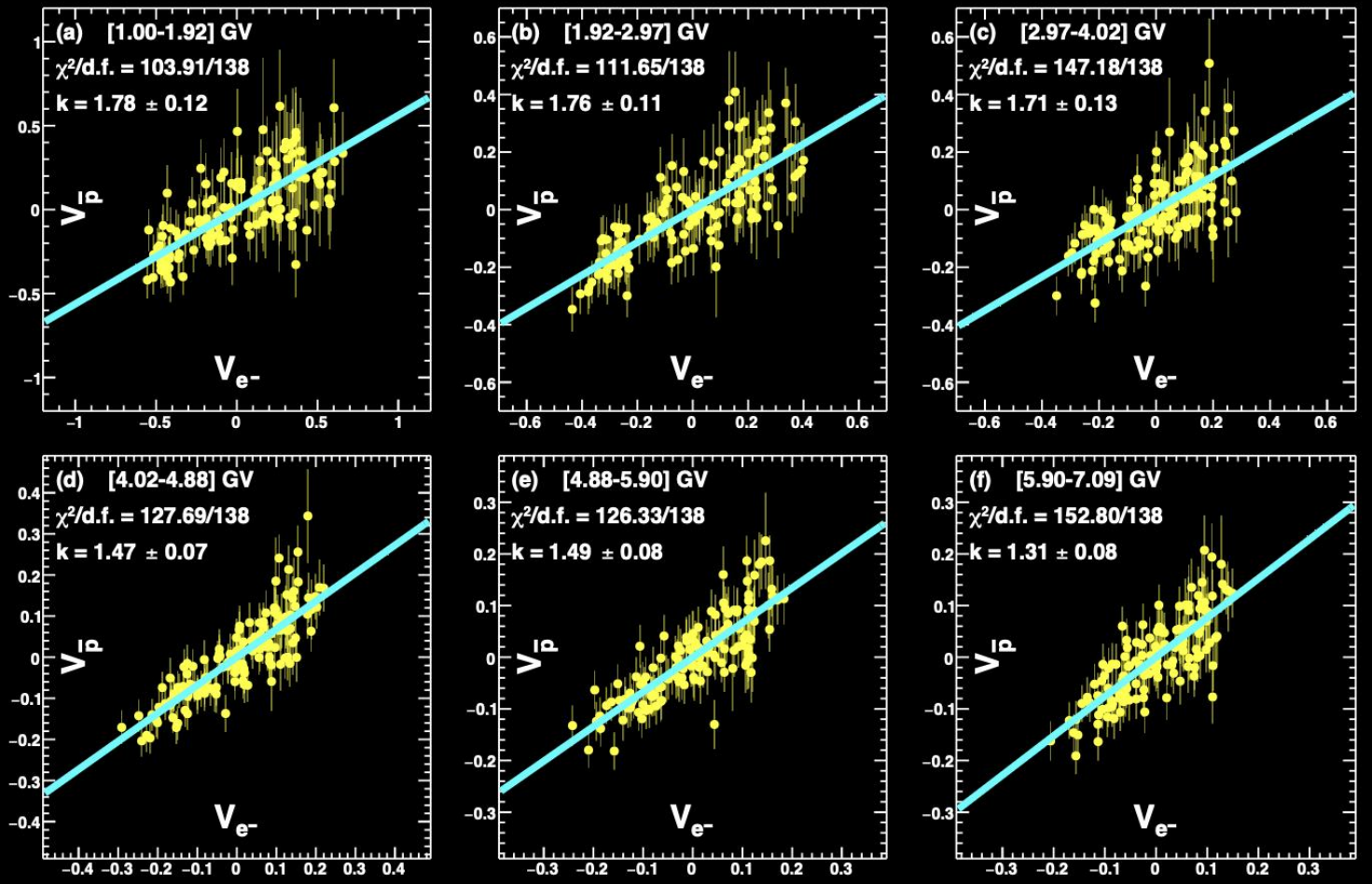
Correlations of Elementary Particle Fluxes

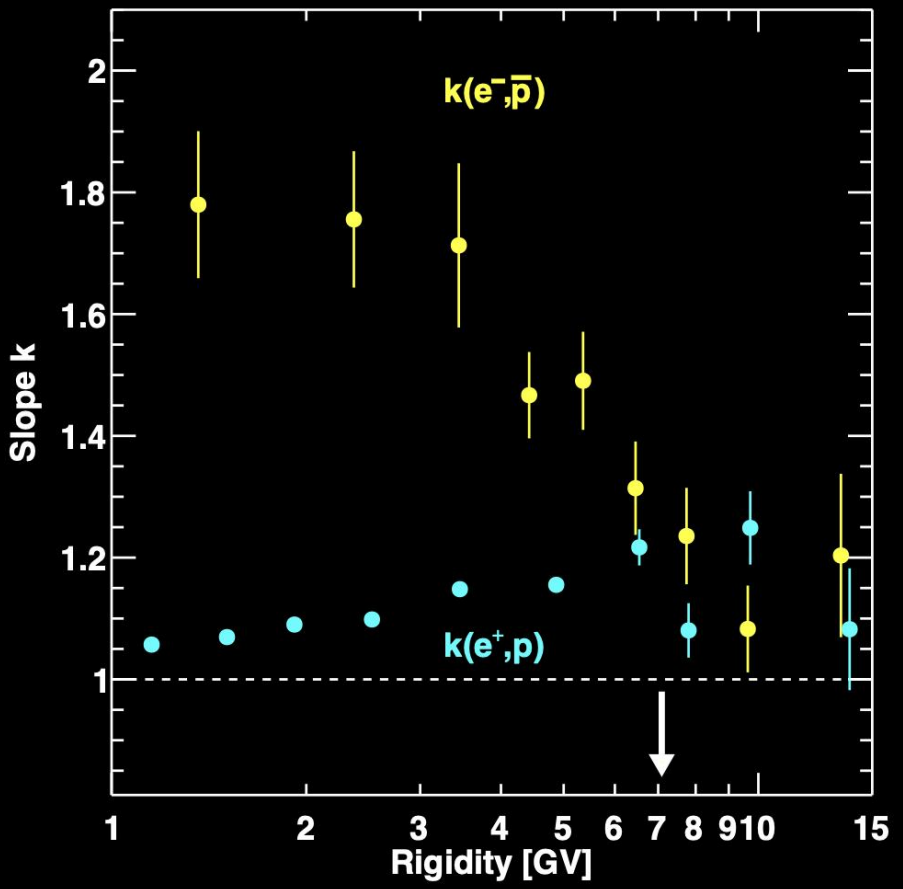
opposite charge

same charge

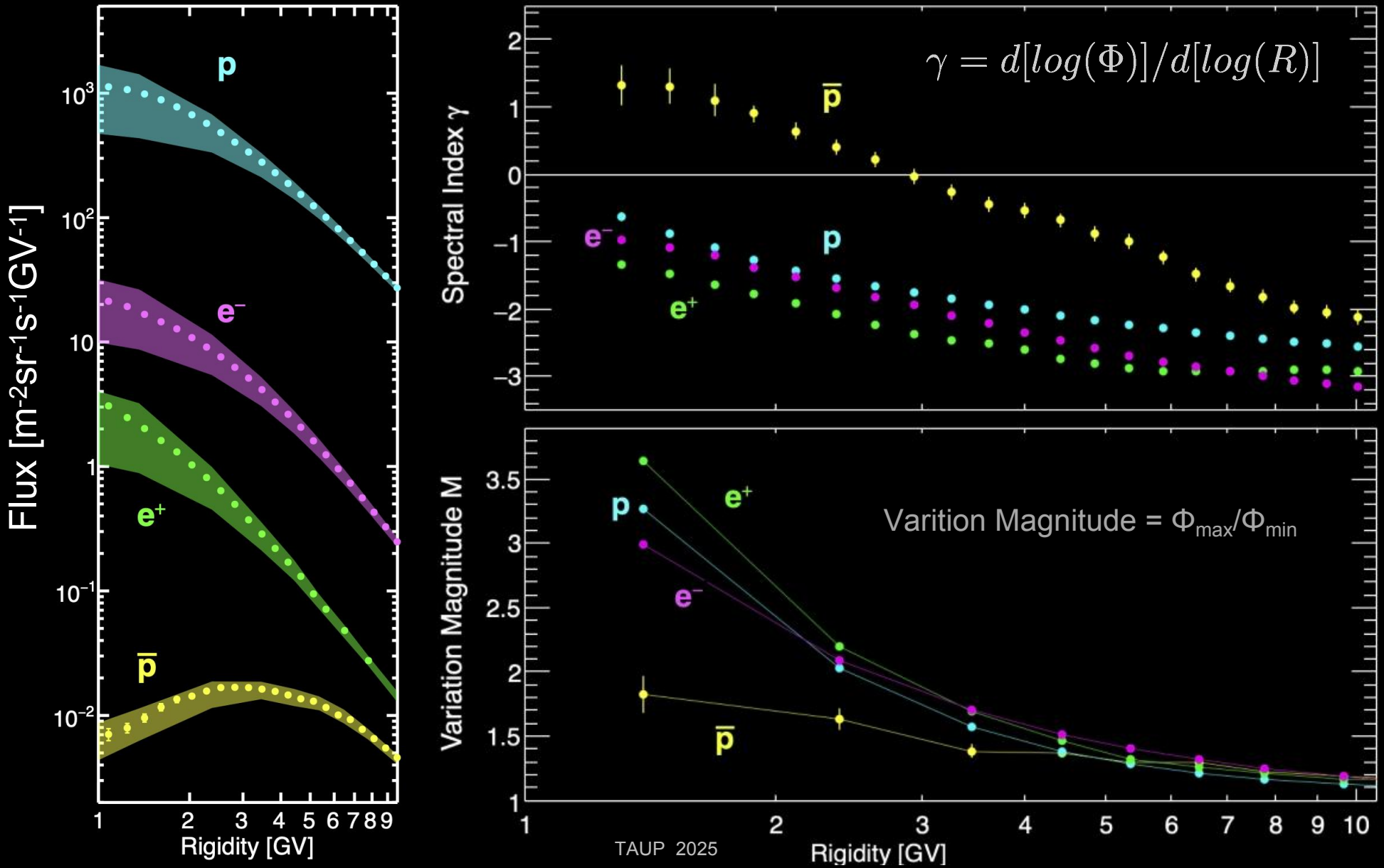


Linear Relation of Antiprotons and Electrons

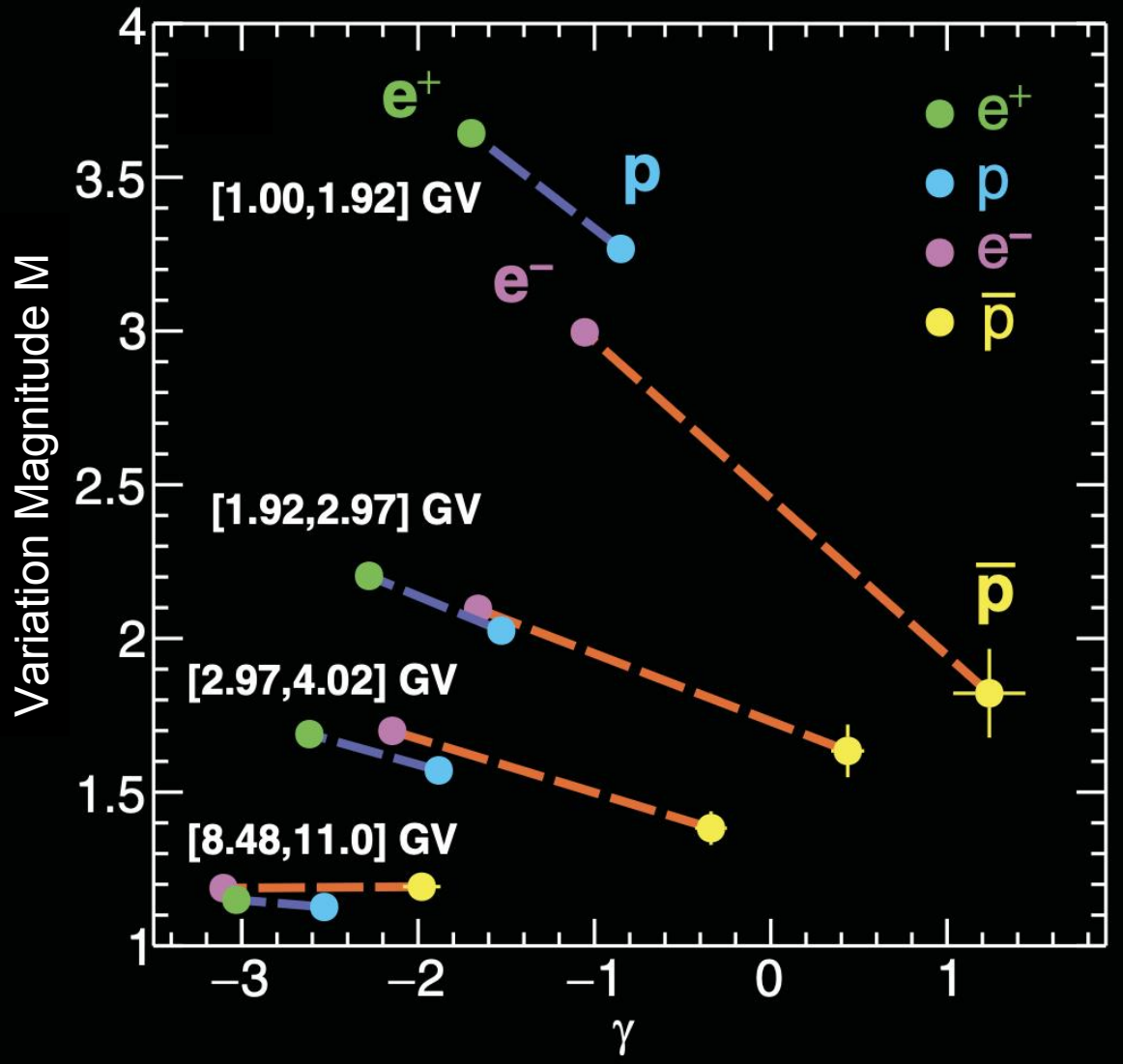




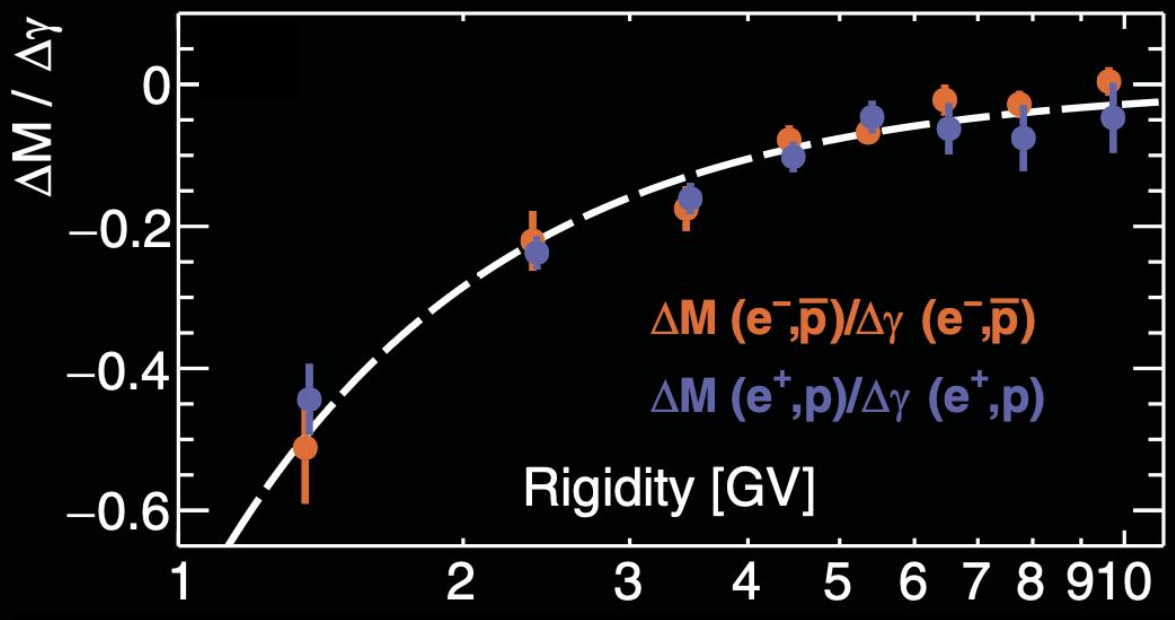
Variation Magnitudes and Flux Spectra



Variation Magnitudes and Spectrum Indexes



- Clear relationship between γ and M for both positive and negative particles in each rigidity bin
- The ratio approaches zero at high rigidity
- Most importantly the ratios for positive and negative particles are consistent



Summary

- Cosmic antiproton fluxes and time variation have been measured using the first 11 years AMS data
- Temporal variations of all four cosmic-ray elementary charged particles p, e^-, e^+, and $\bar{p}$ are studied simultaneously over an 11-year solar cycle
- A hysteresis between $\bar{p}$ fluxes and p fluxes is observed. In contrast, $\bar{p}$ and e^- fluxes show a linear correlation but $\bar{p}$ fluxes change significantly less than e^- fluxes.
- Remarkably, a clear correlation between the magnitude of flux temporal variation over an 11-year solar cycle and the shape of their rigidity spectra, universally for both positively charged and negatively charged particles are found.
- By continuously operating to 2030, AMS measurement will cover two 11-year solar cycles and provide unique contribution to the understanding of solar modulation.