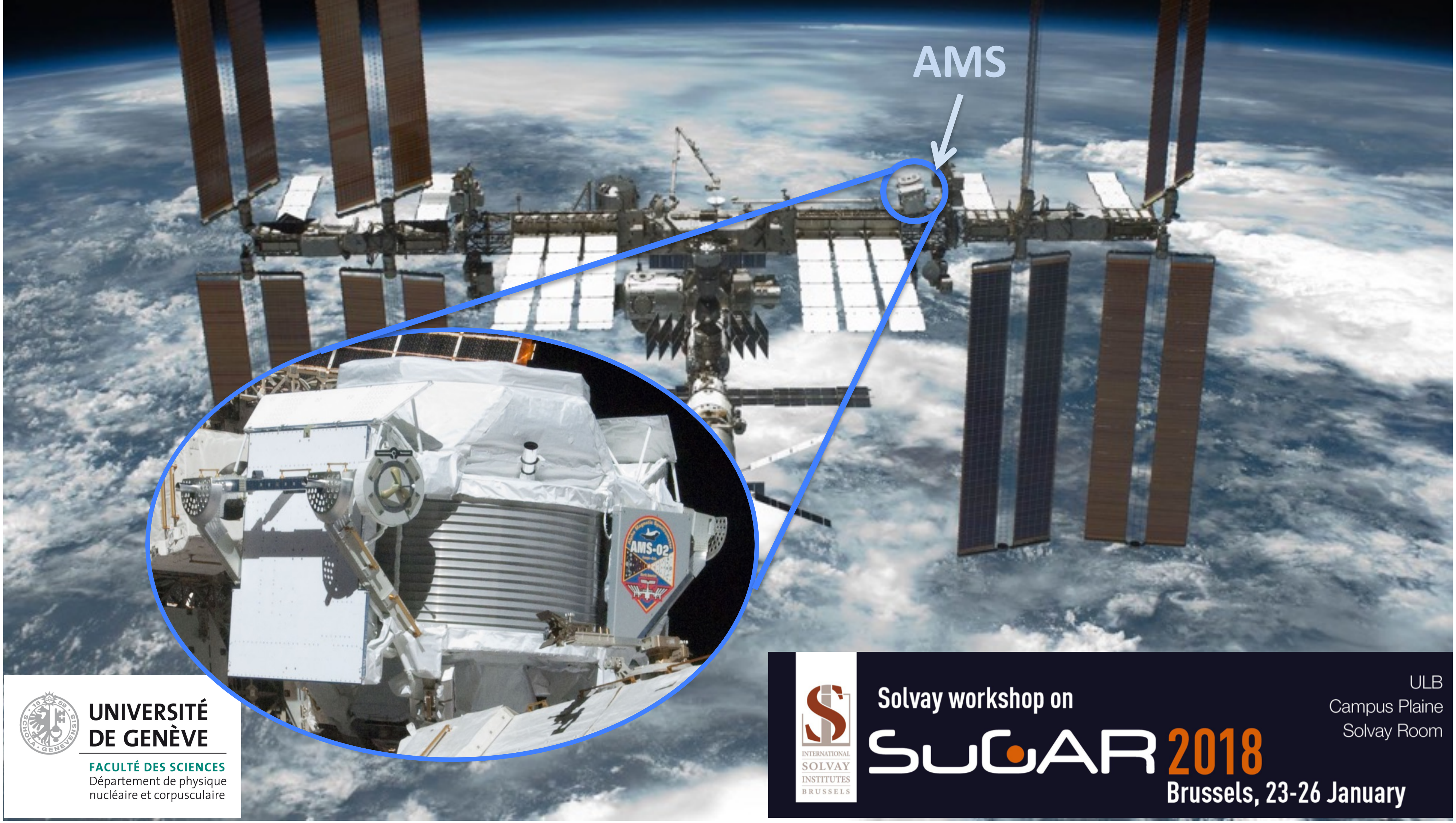
Latest Results from AMS on the International Space Station

Mercedes Paniccia, University of Geneva (Switzerland)
AMS Collaboration



UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique nucléaire et corpusculaire

Solvay workshop on SUGAR 2018
Brussels, 23-26 January
ULB
Campus Plaine
Solvay Room

The AMS Experiment

Magnetic Spectrometer:
- Rigidities from GV to TV
- Charged particles from Z=1 to 28

Installed on ISS since May 2011

Near Earth Orbit:
- altitude 400 Km
- inclination 52°
- period 92 min

Cosmic Ray data taking rate:
- 18 billion events per year

Mission duration:
- up to 2024

Physics goals:
- Cosmic Ray properties
- Dark Matter
- Antimatter

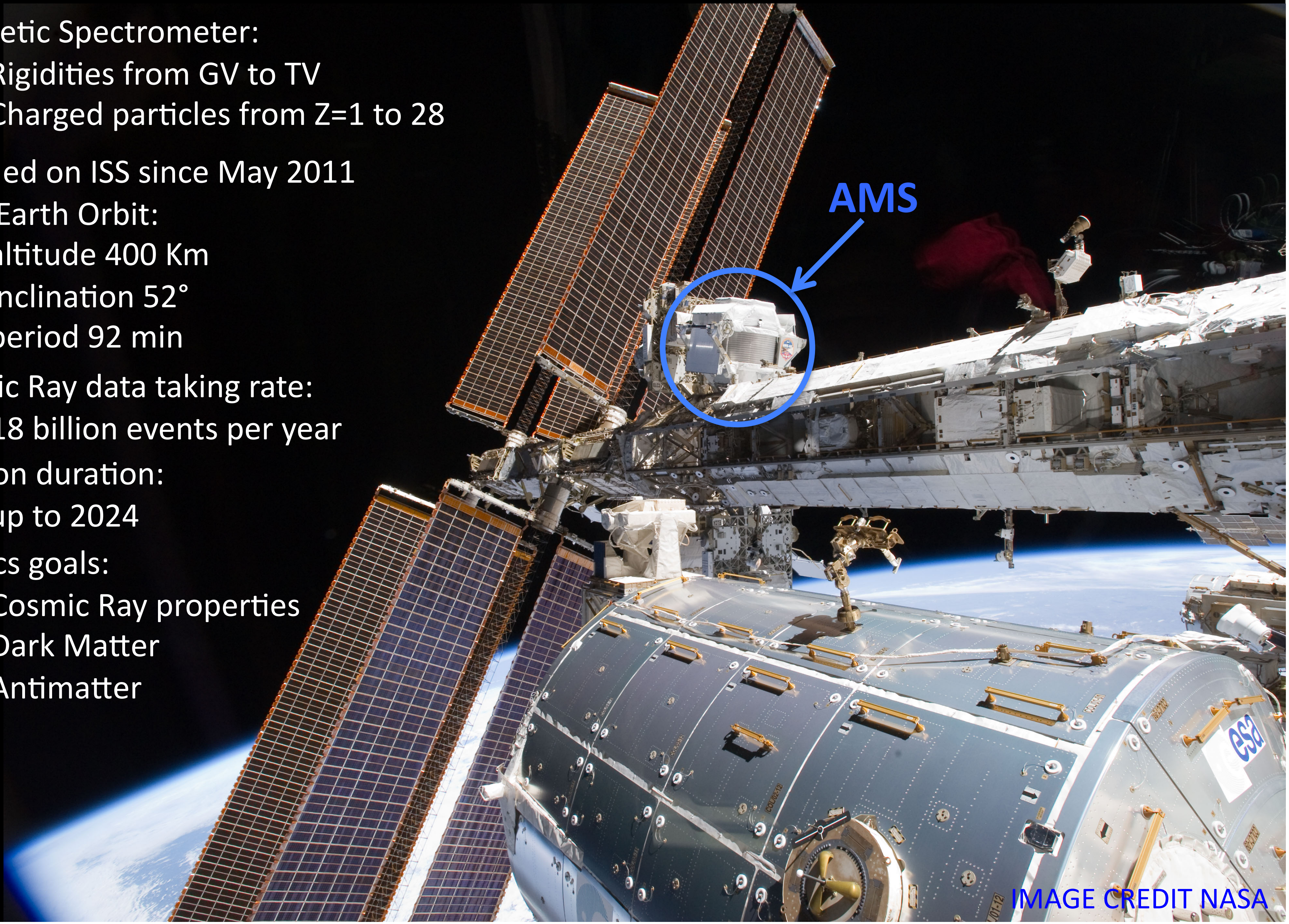
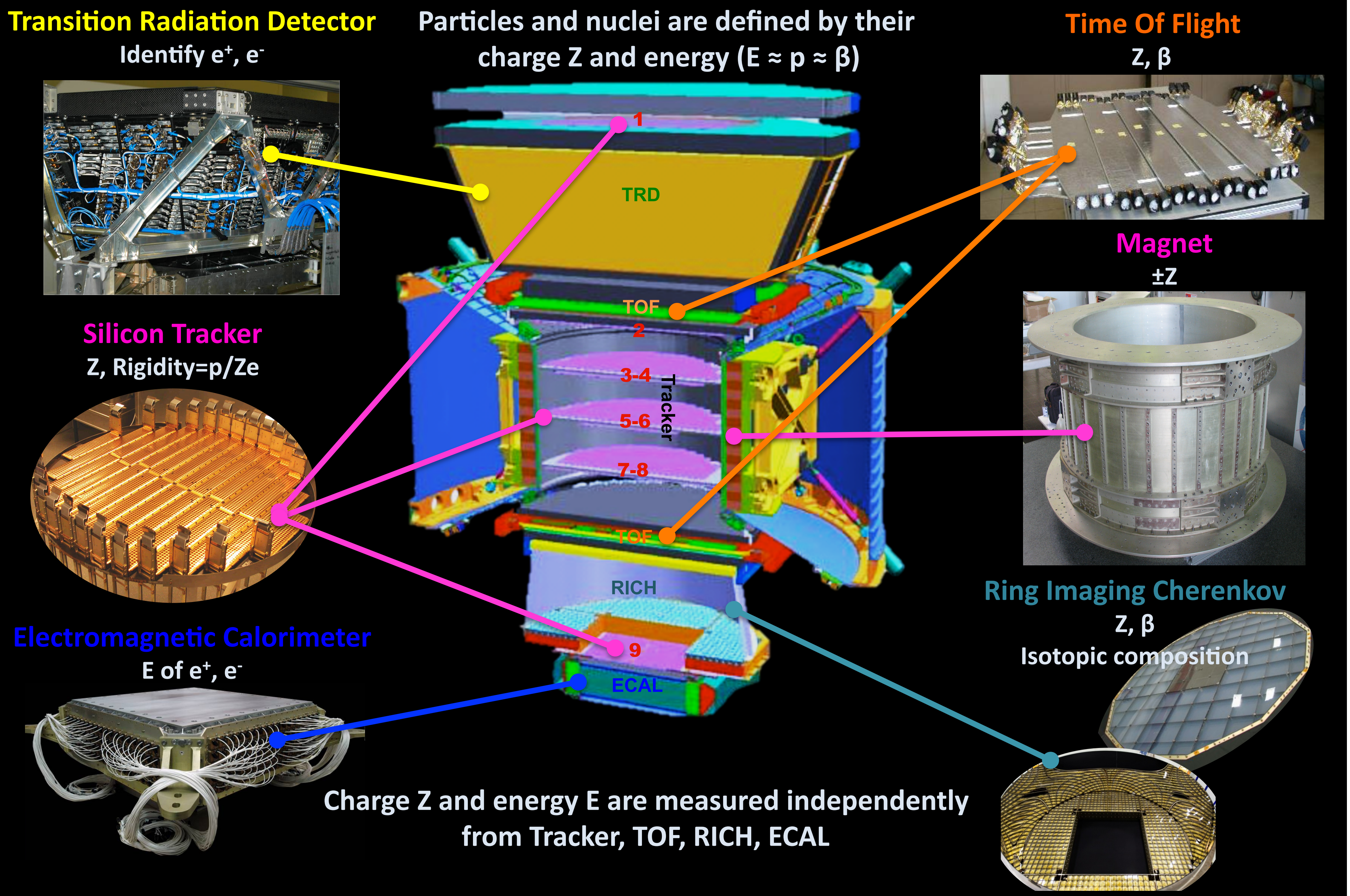
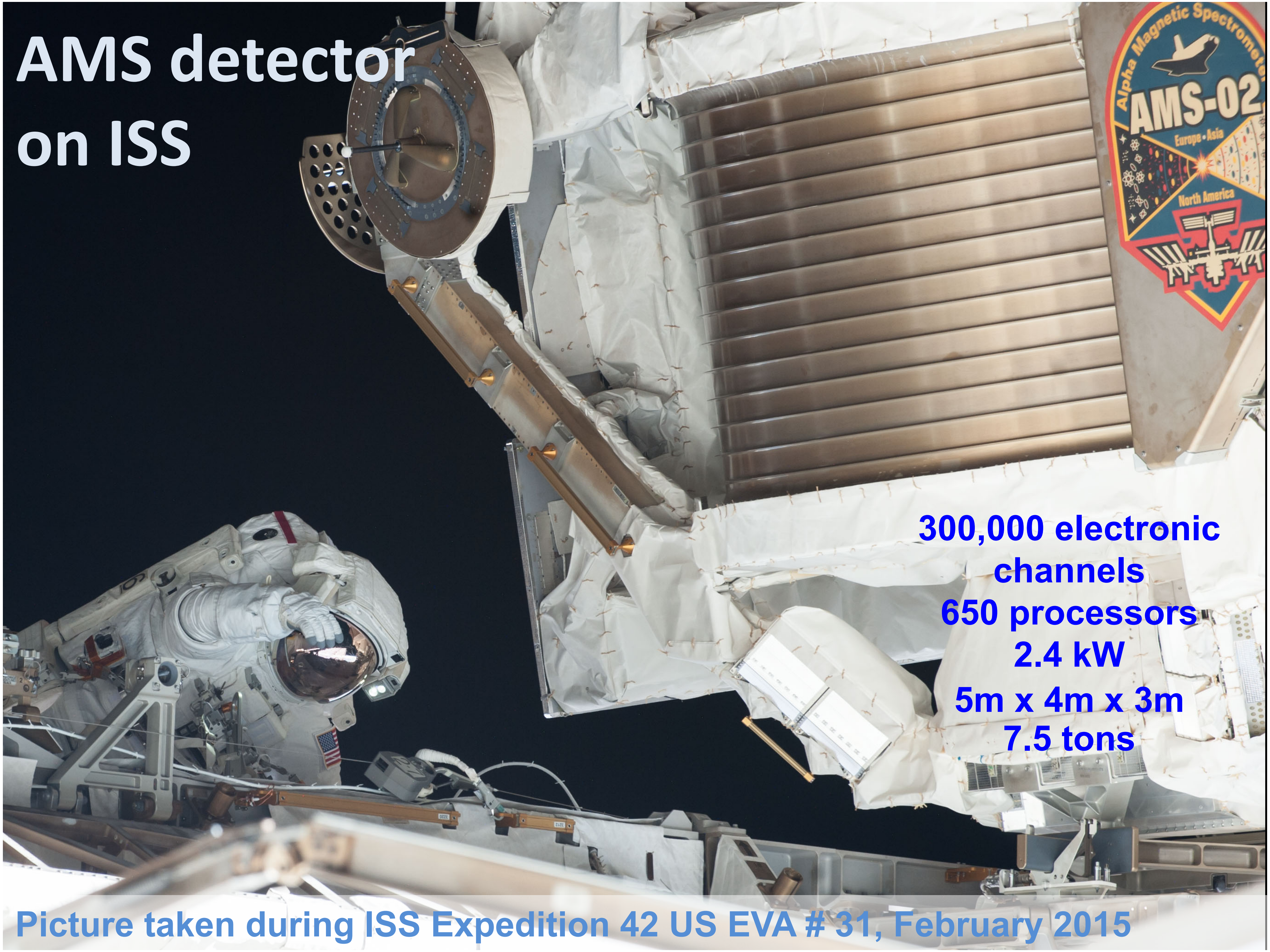


IMAGE CREDIT NASA

AMS: A TeV precision, multipurpose spectrometer



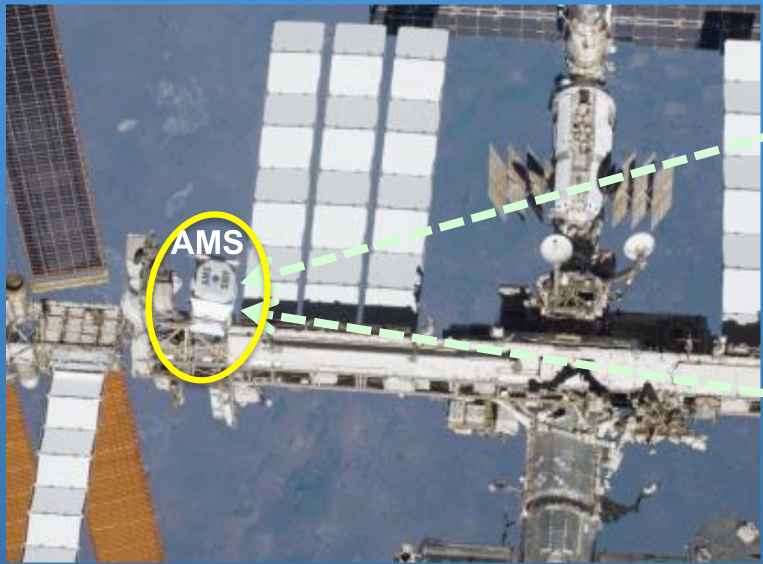
AMS detector on ISS



300,000 electronic channels
650 processors
2.4 kW
5m x 4m x 3m
7.5 tons

Picture taken during ISS Expedition 42 US EVA # 31, February 2015

AMS operations



ISS Astronaut with AMS Laptop

Cosmic rays measured as of 14 Oct. 2017 12:50 CEDT

Selection of AMS Physics Results and Prospects

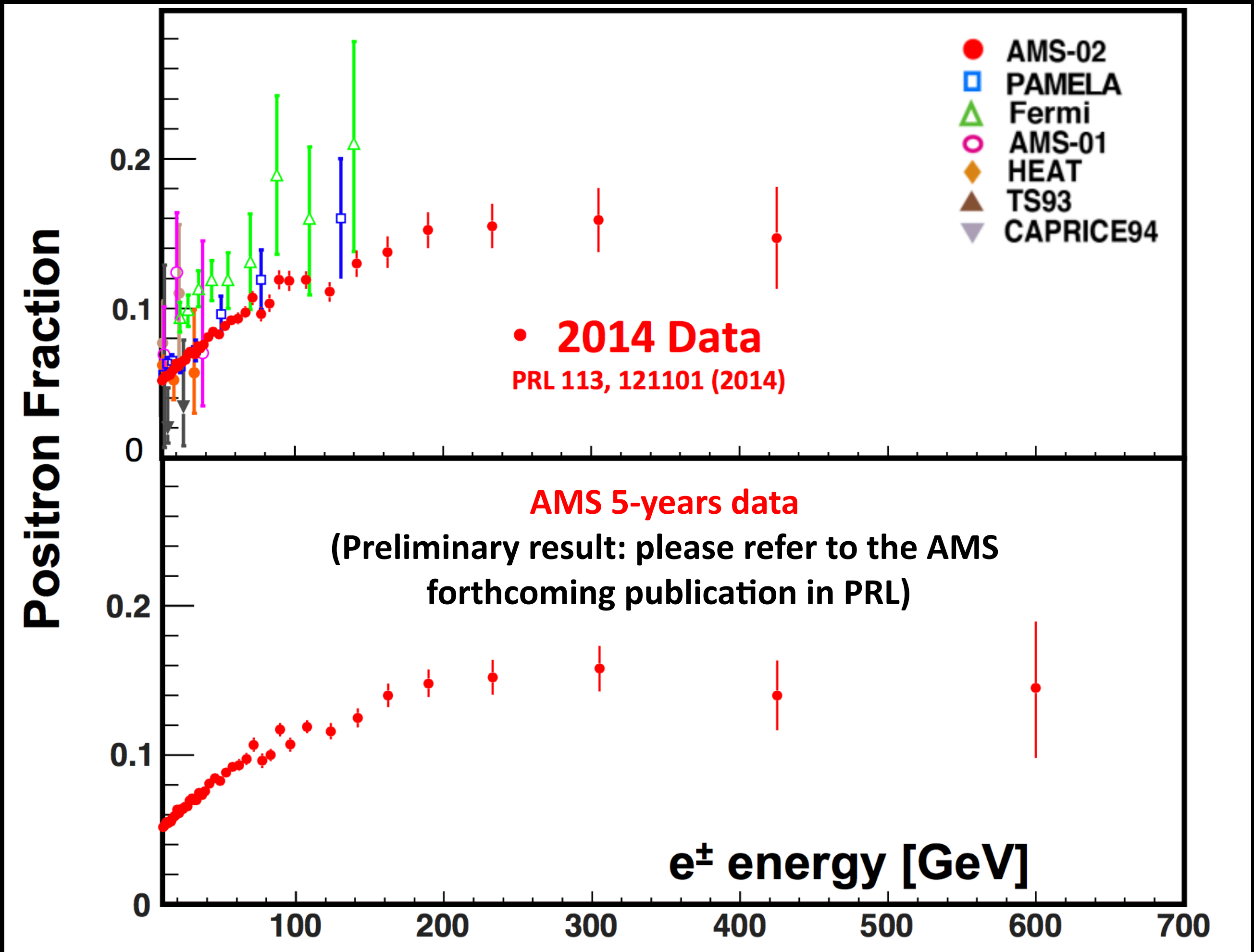
To date, we have collected more than 113 billion cosmic rays up to multi-TeV
This is much more than all cosmic rays over the last 100 years

Search For Dark Matter:
- Positron flux vs electron flux
- Antiproton flux and antiproton/proton ratio
- Prospects for anti-deuterons

Cosmic-Ray Properties:
- Primary Cosmic-ray: individual fluxes of Proton, Helium, Carbon and Oxygen
- Secondary Cosmic-Ray: individual fluxes of Lithium, Beryllium and Boron

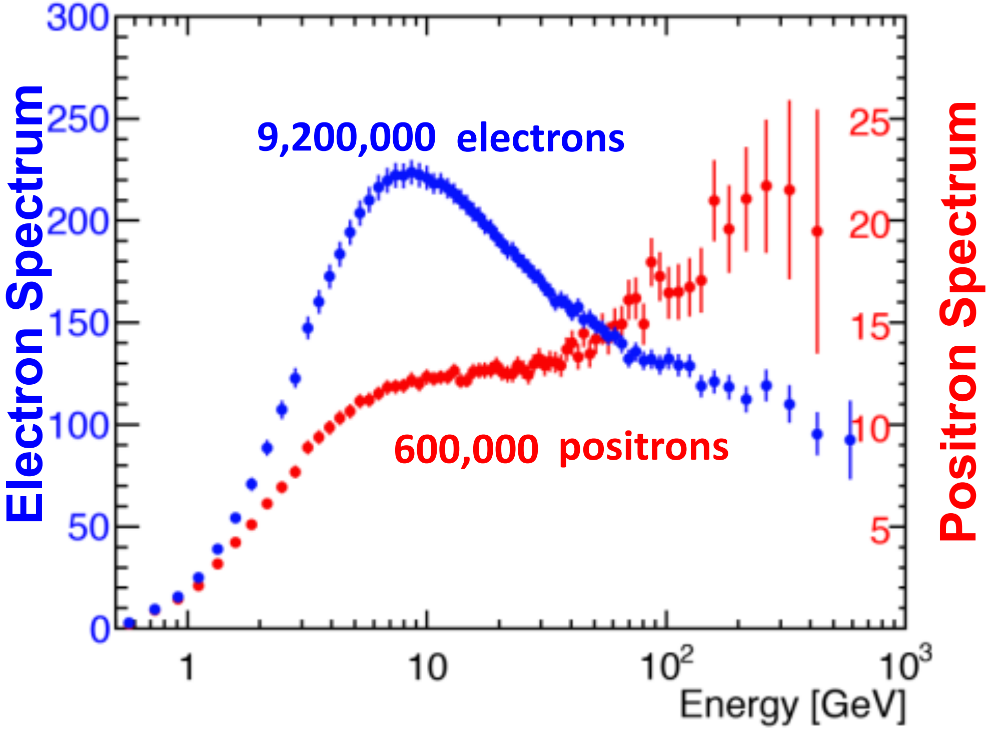
Updated Positron fraction measurement:

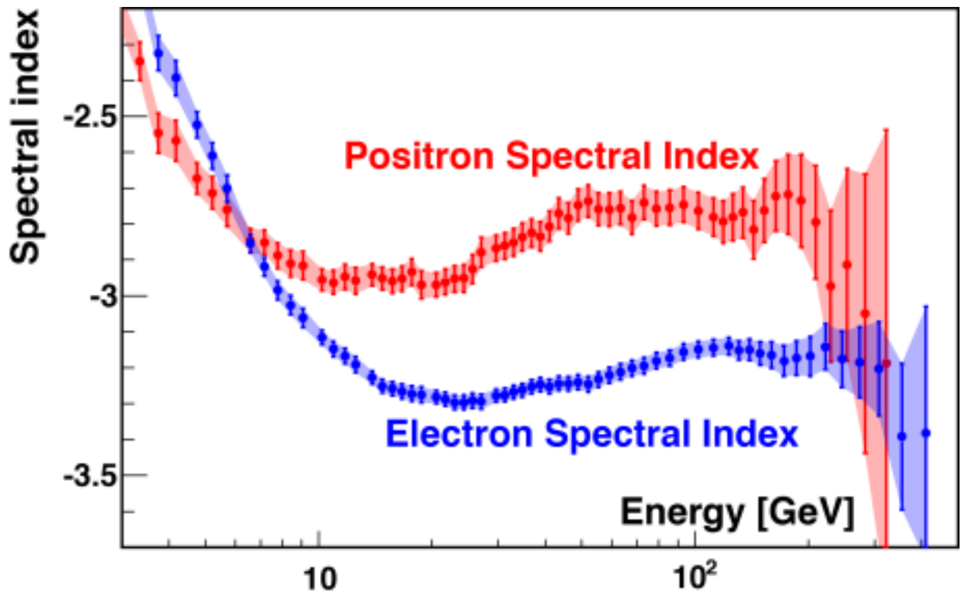
PRL 110, 141102 (2013) : energy range 0.5 to 350 GeV , 6.8 million $e^{\pm}$ events
PRL 113, 121101 (2014) : energy range increased to 500 GeV , 11 million $e^{\pm}$ events
Latest result (2016): energy range increased to 700 GeV, 20 million $e^{\pm}$ events



Evidence of additional source: individual positron and electron fluxes

AMS Measurement of Electron and Positron fluxes (PRL 113, 121102 (2014))
AMS 30 months of data

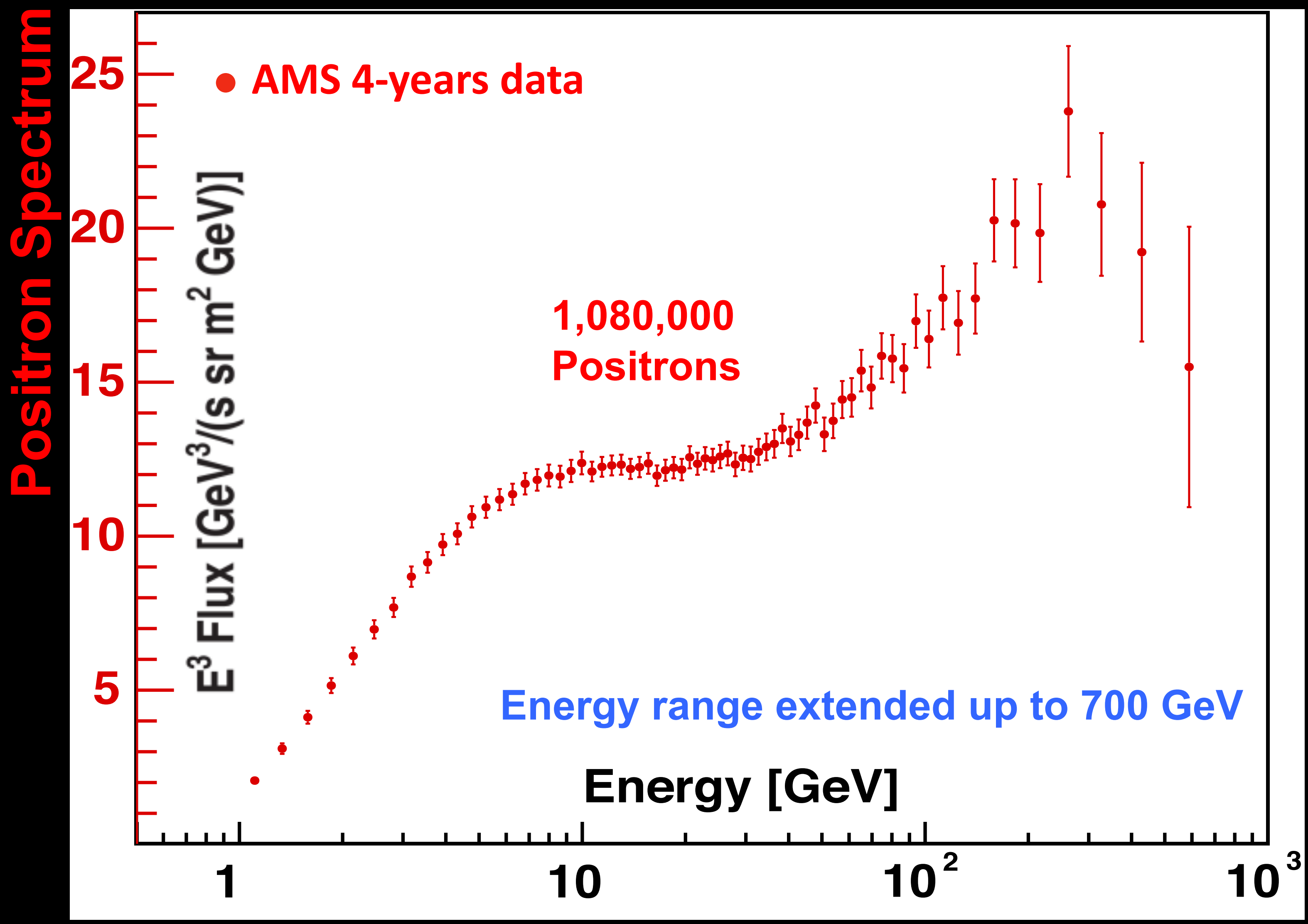




Both spectra harden above 30 GeV , so cannot de described by single power law
Different behavior of the spectral indices indicate high-energy e^+ have a different origins from e^-

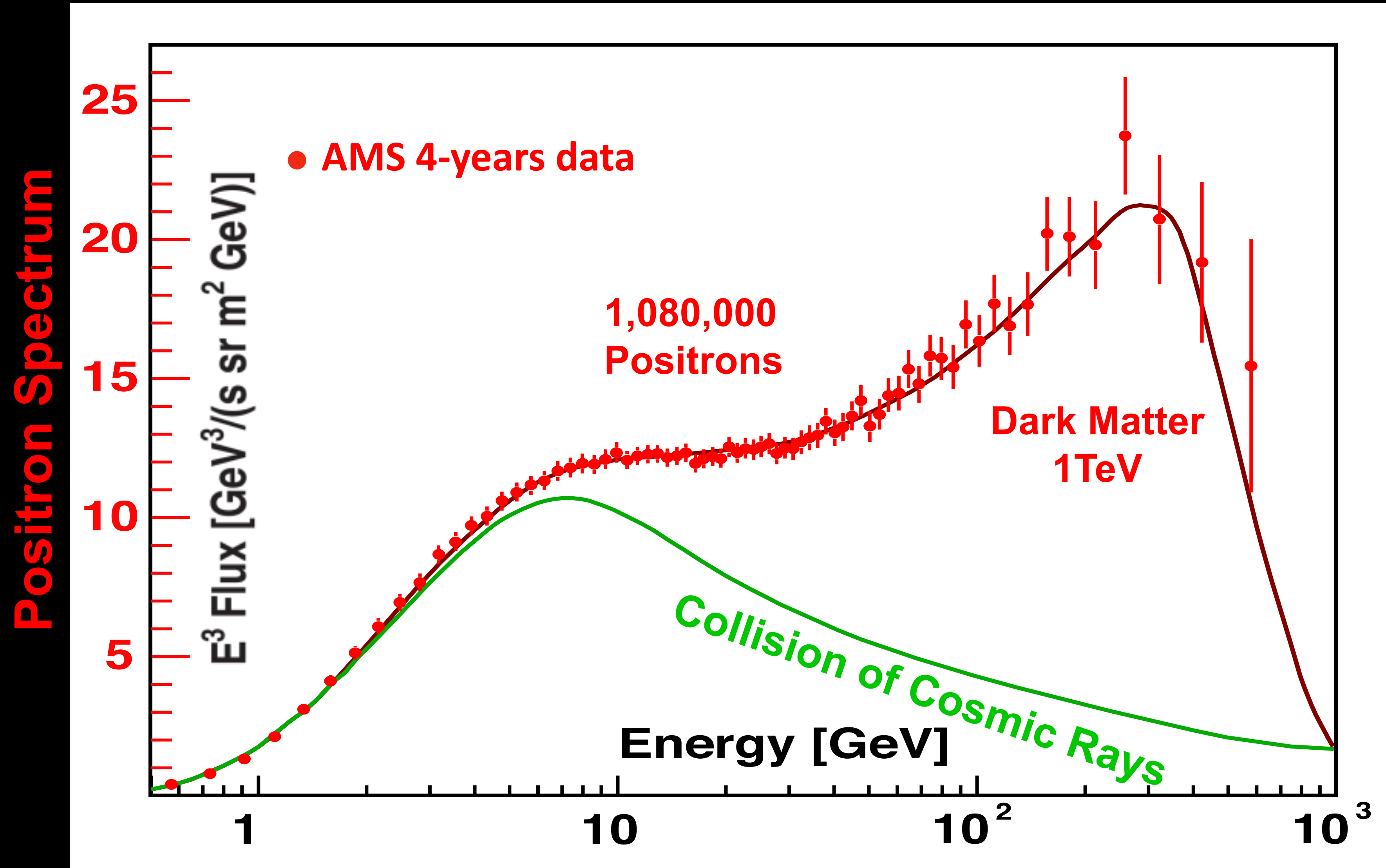
Positron flux

Latest results based on 1.08 million e^+ events

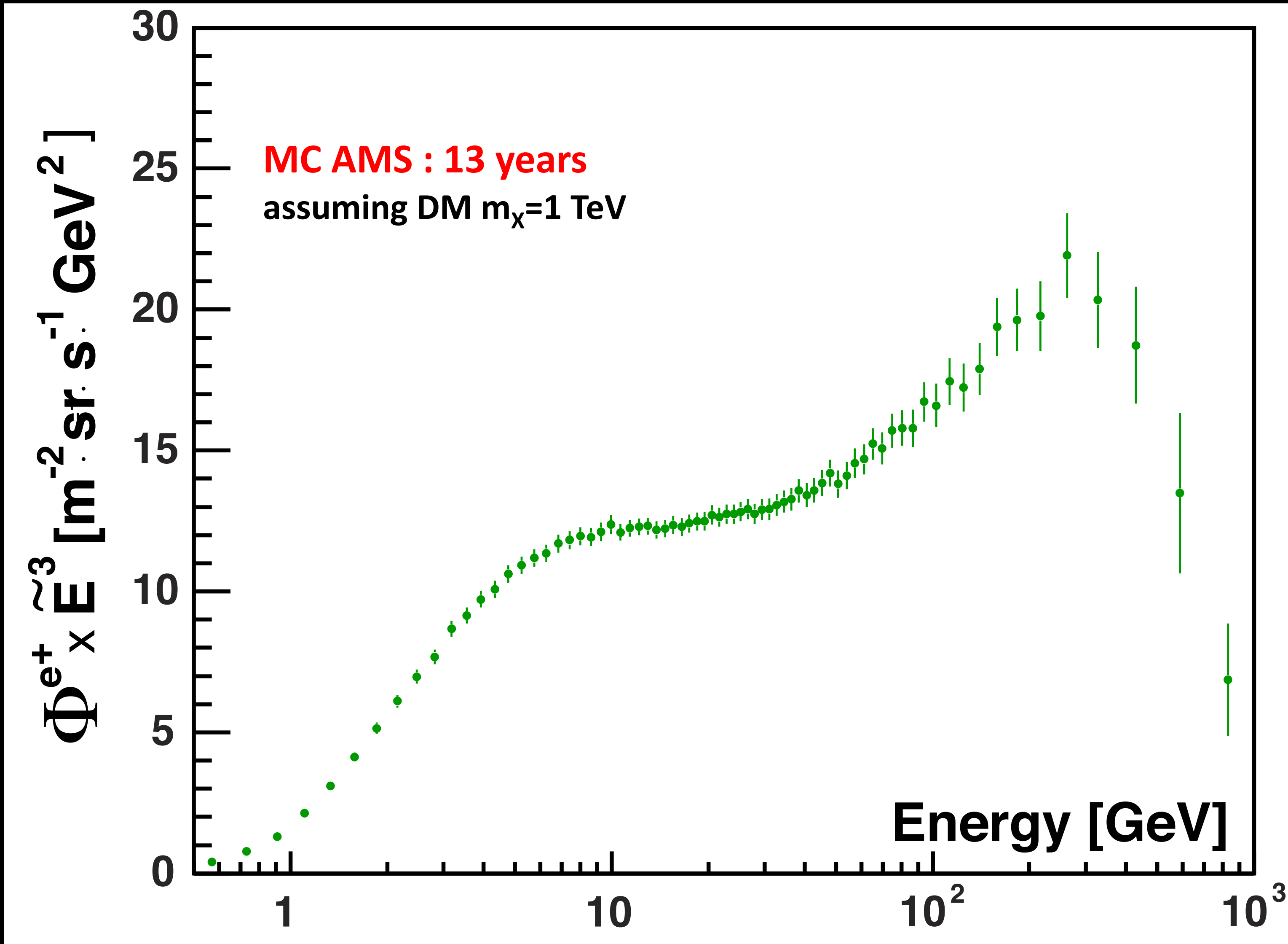


Indirect search for Dark Matter

Possible enhancement of rare secondary CR spectra from $\chi + \chi \rightarrow e^+$, anti-p, anti-d, ...



Positron flux
2024 prospect

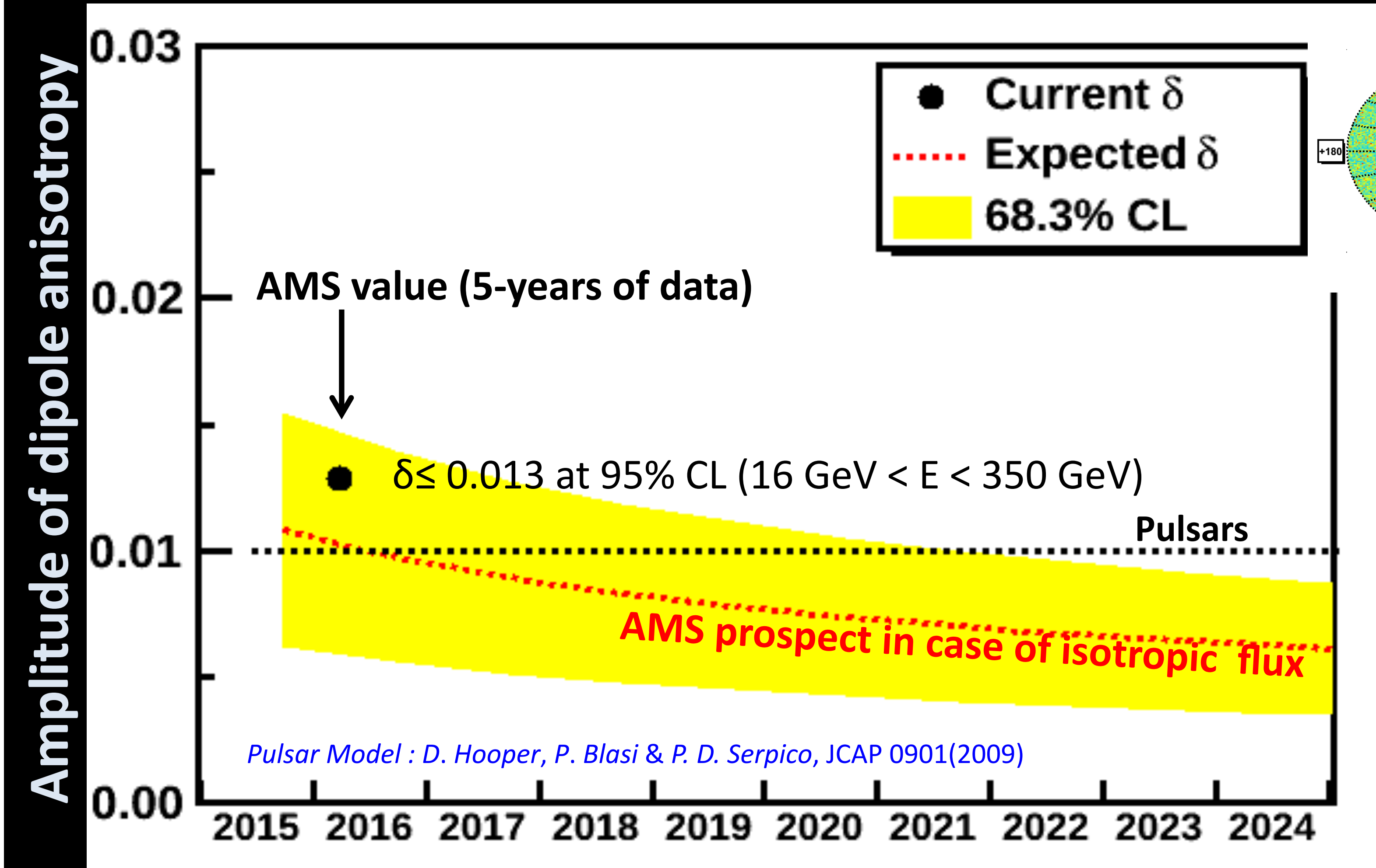


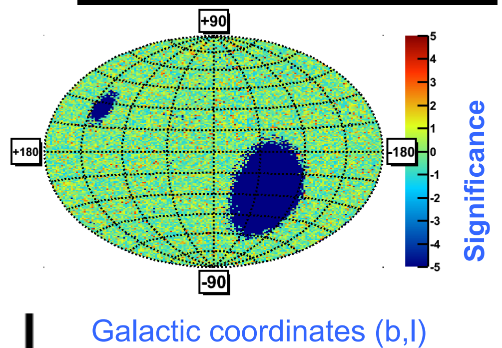
However DM is not the only possible interpretation of the observed positron excess

Pulsars vs DM

Higher level of anisotropy in the arrival direction of e^+ and e^- is expected from Pulsars wrt DM

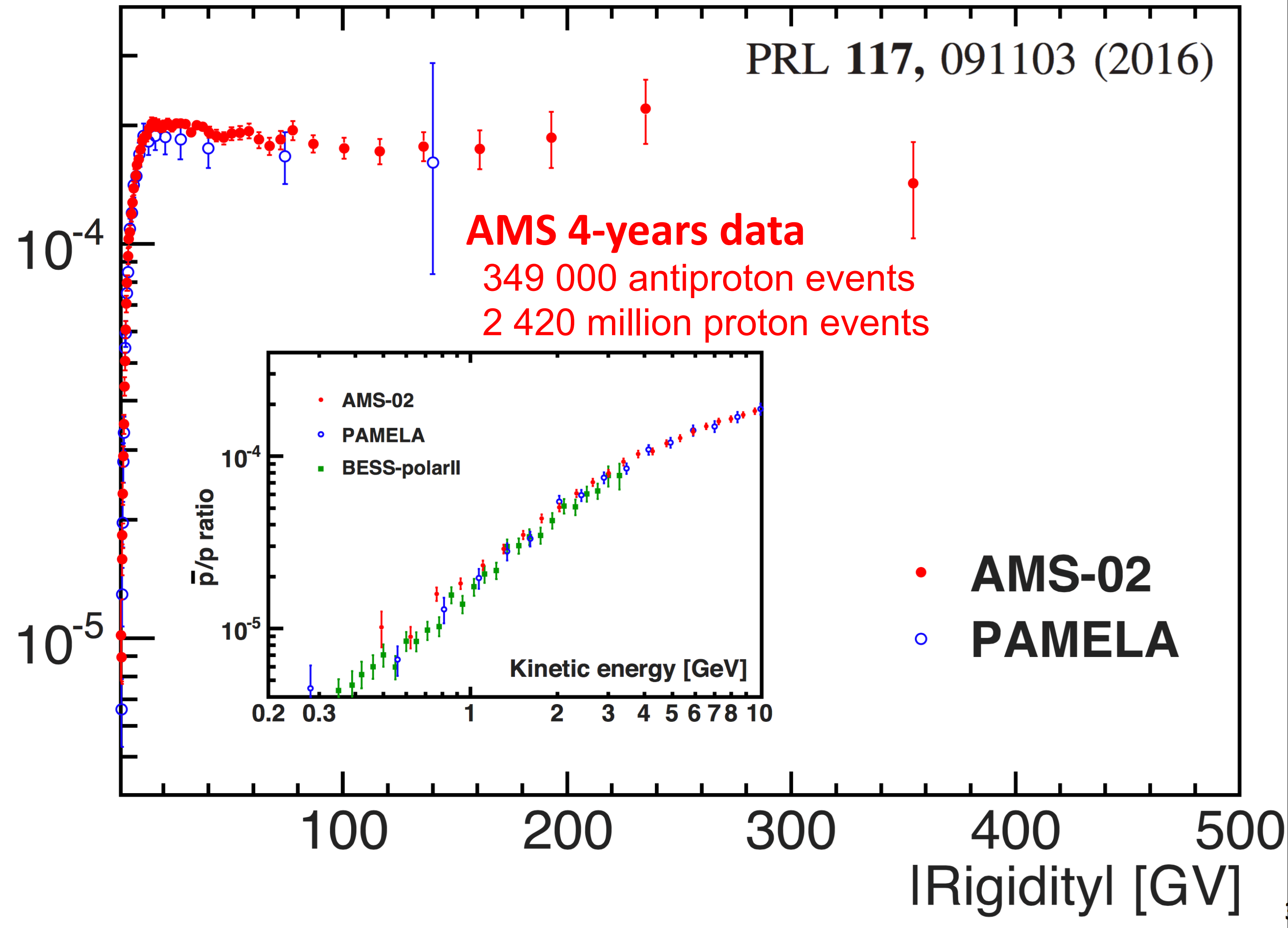
With the current data fluctuations of the positron ratio e^+/e^- are isotropic.





Data taking to 2024, will allow to explore anisotropies of 1%

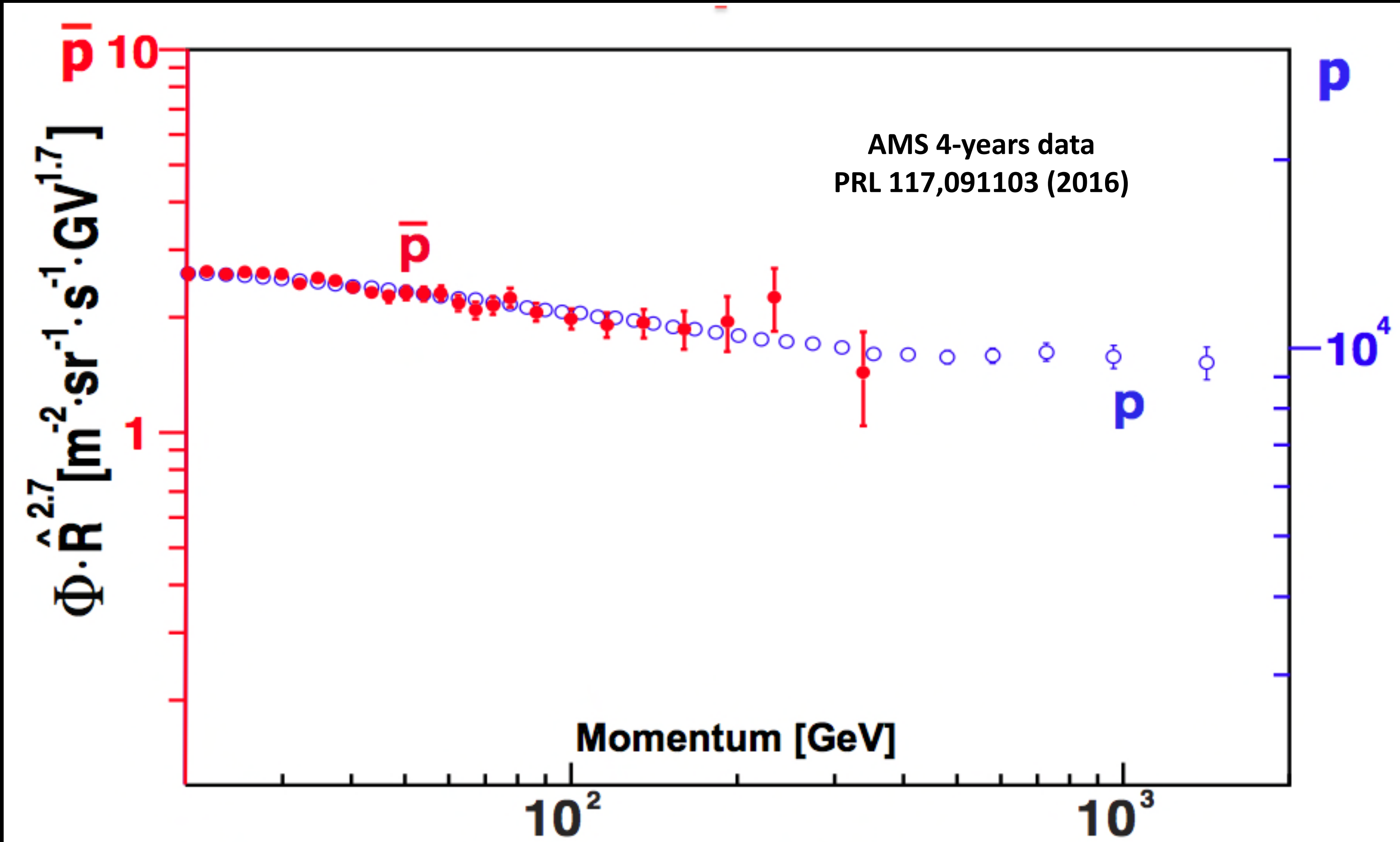
AMS result on antiproton-to-proton ratio



Antiproton to proton ratio is energy independent above 60 GV

The AMS measurement of the antiproton flux

Above 20 GV the proton and anti-proton spectra are identical

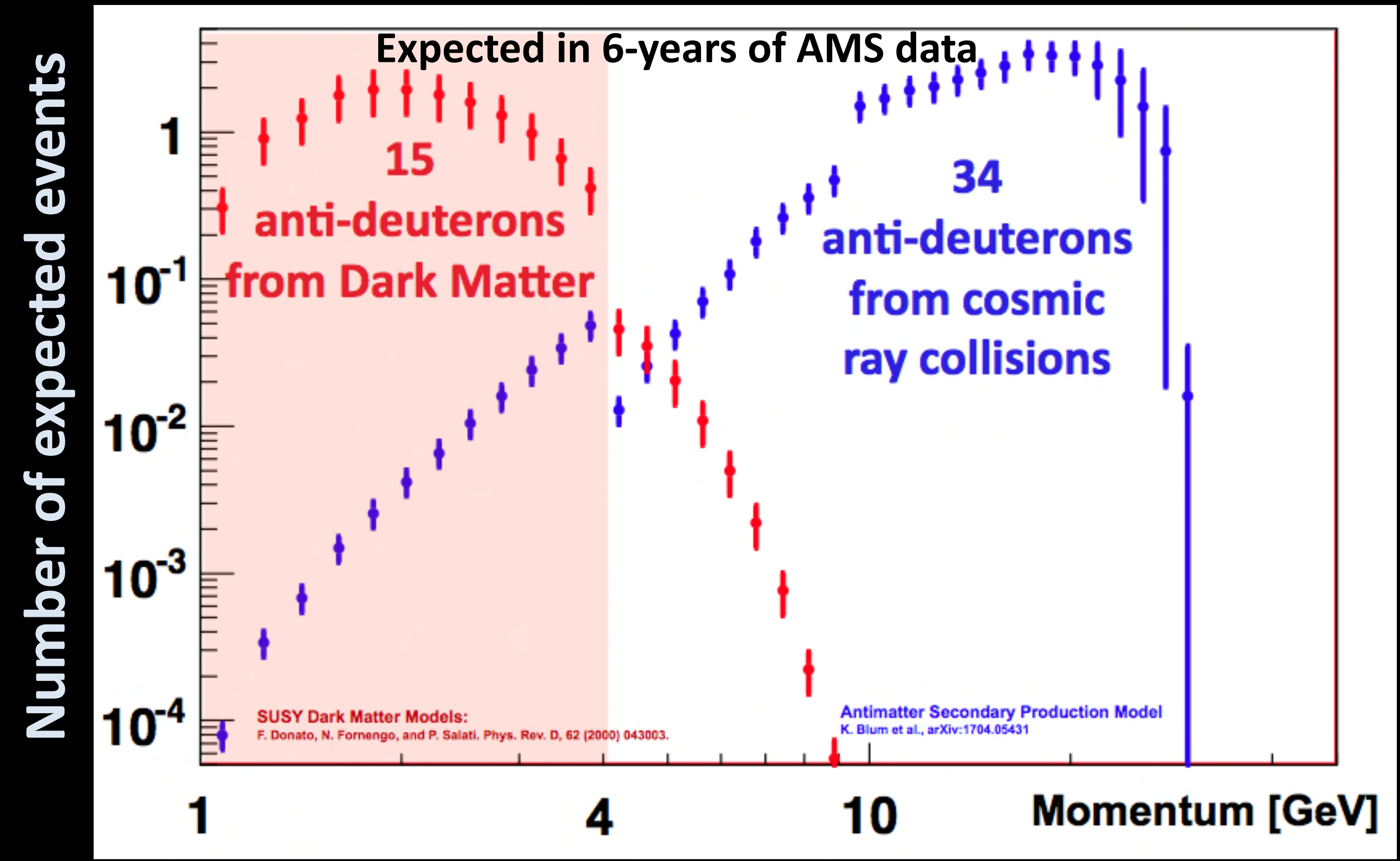


Antiprotons may hold Dark Matter Signal

See https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.118.191102

Searching for DM in cosmic anti-deuterons

In six years we have collected 10 billion protons and ~100 million deuterons. This provides a unique opportunity to measure cosmic anti-deuterons.



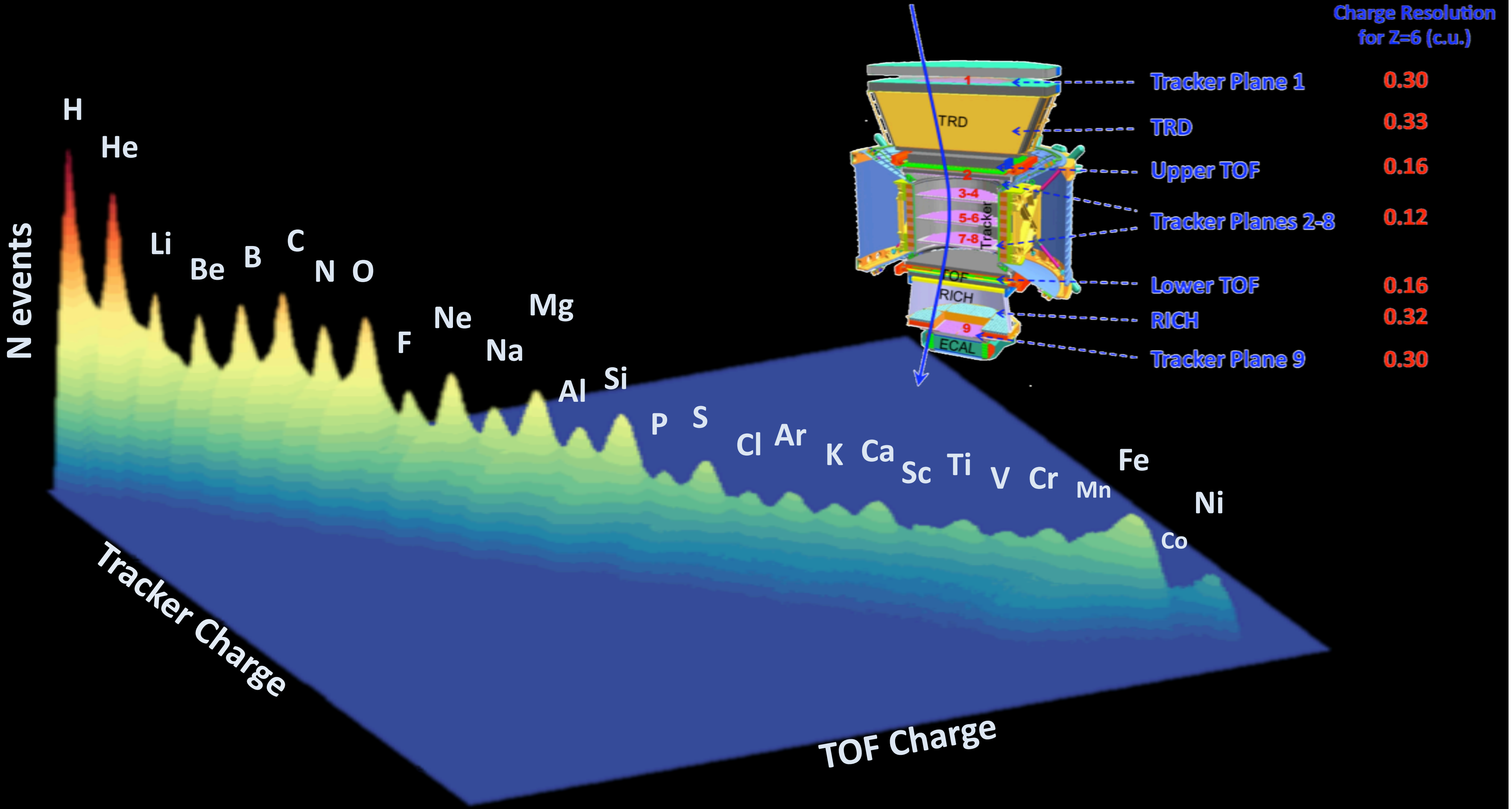
Data analysis effort currently ongoing

AMS Measurements of Cosmic-Ray Properties

Simultaneous measurements of cosmic-ray electron, positron, proton, antiproton, anti-d and nuclei (up to Nickel) individual fluxes

Crucial to understand CR origin, acceleration and propagation mechanisms

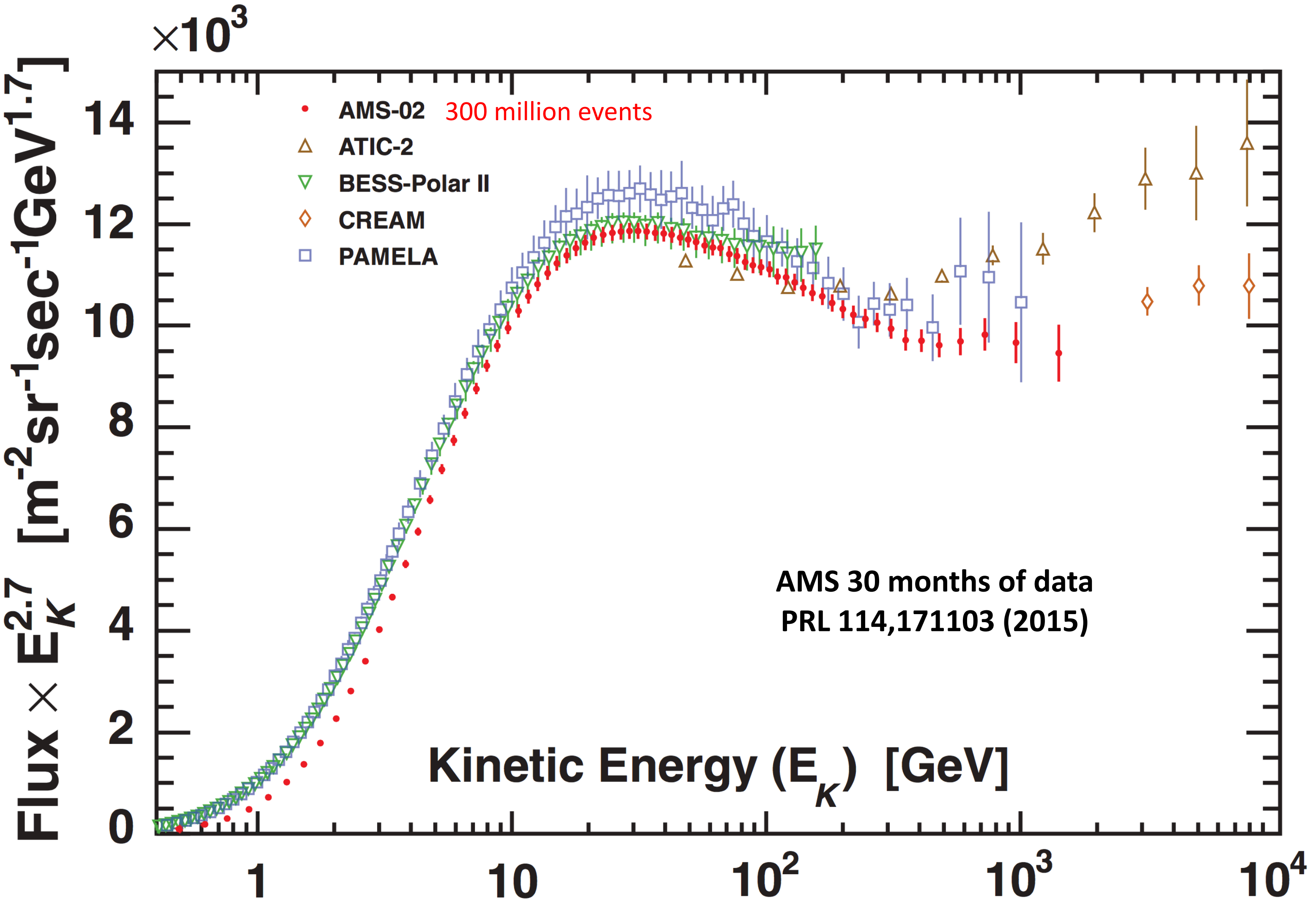
Key ingredient to assess background from collision of CR for DM searches



AMS Precision Measurement of the proton flux

PRL 114, 171103 (2015)

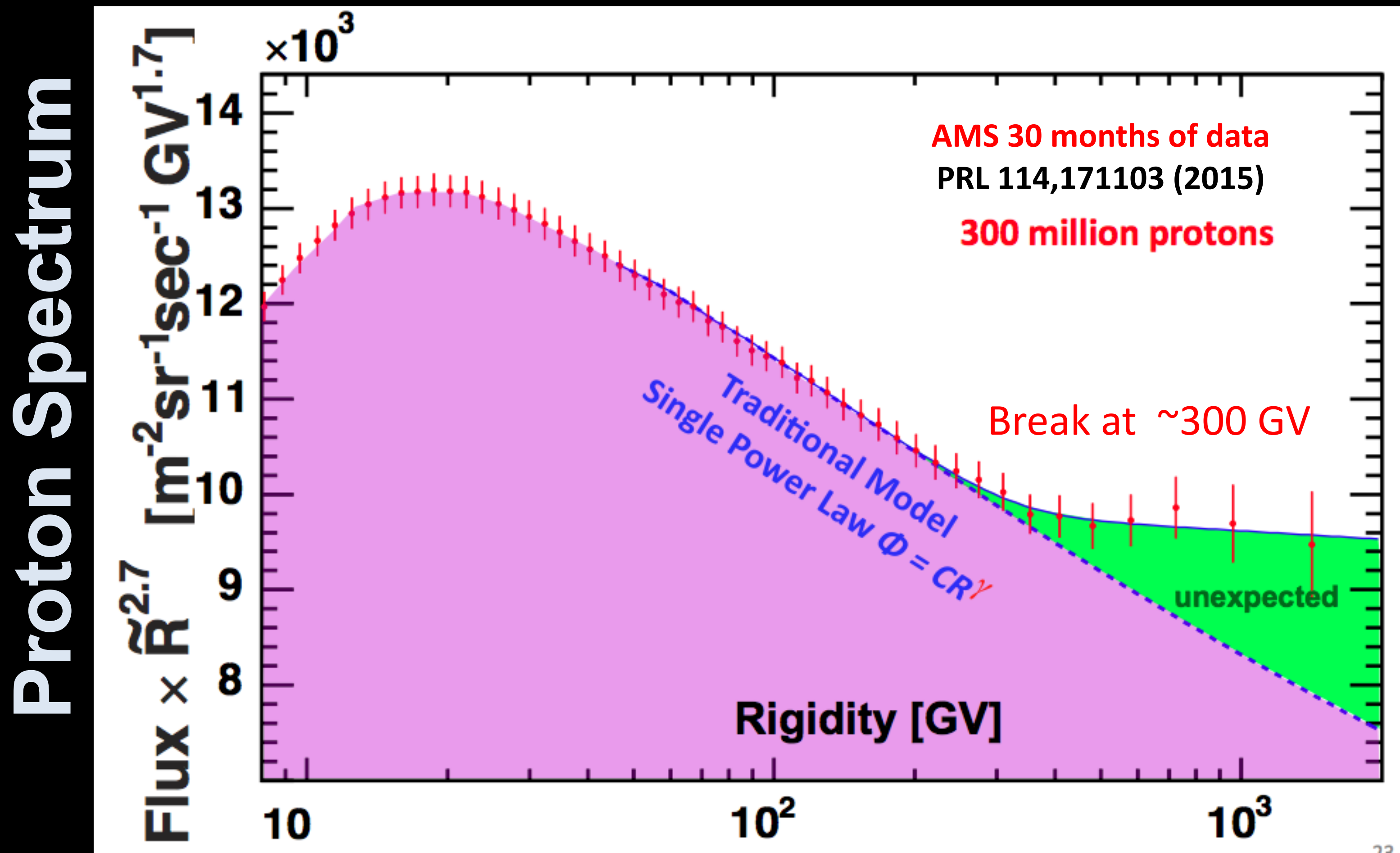
Proton Spectrum



AMS Precision Measurement of the proton flux

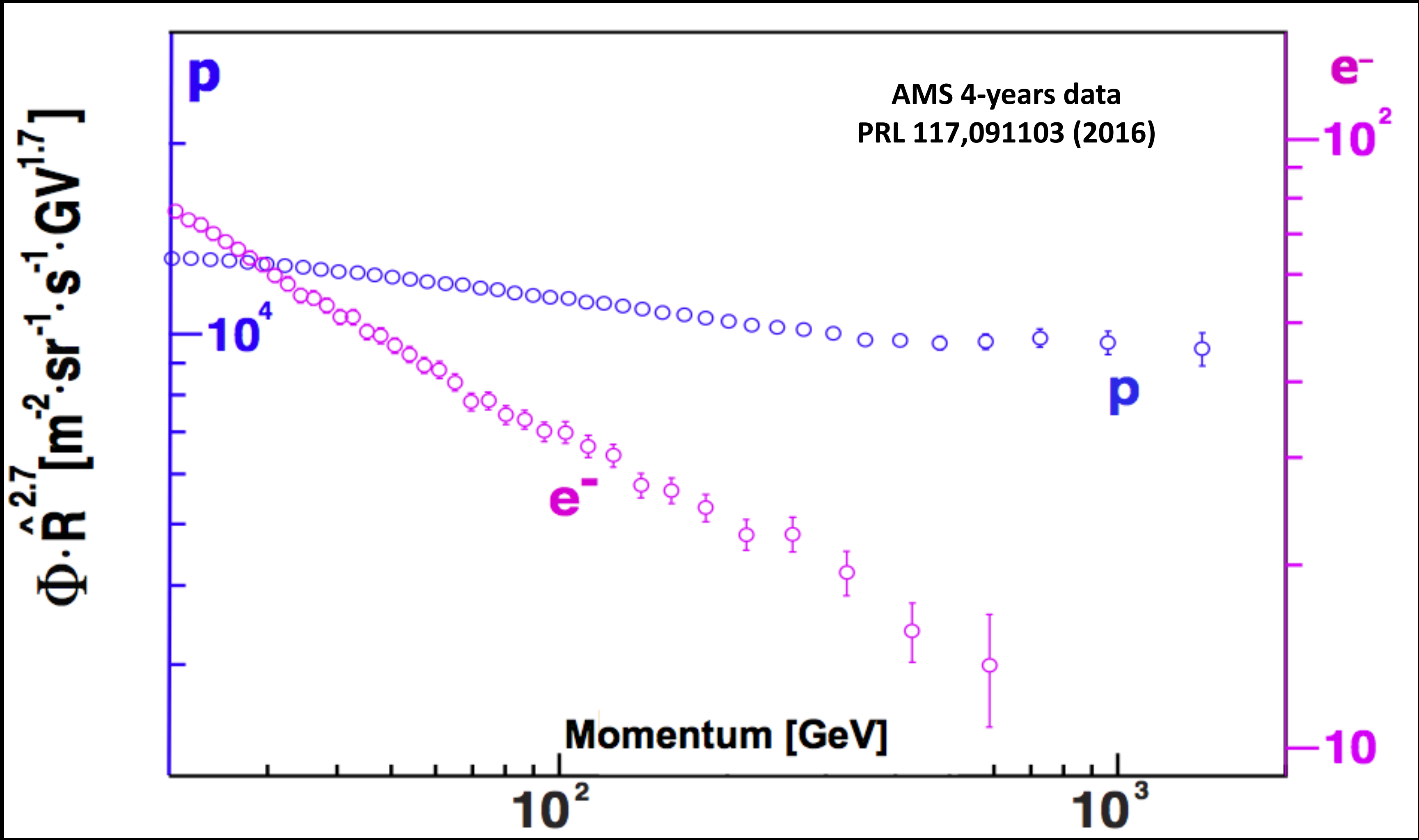
PRL 114, 171103 (2015)

The spectrum cannot be described by a single power law



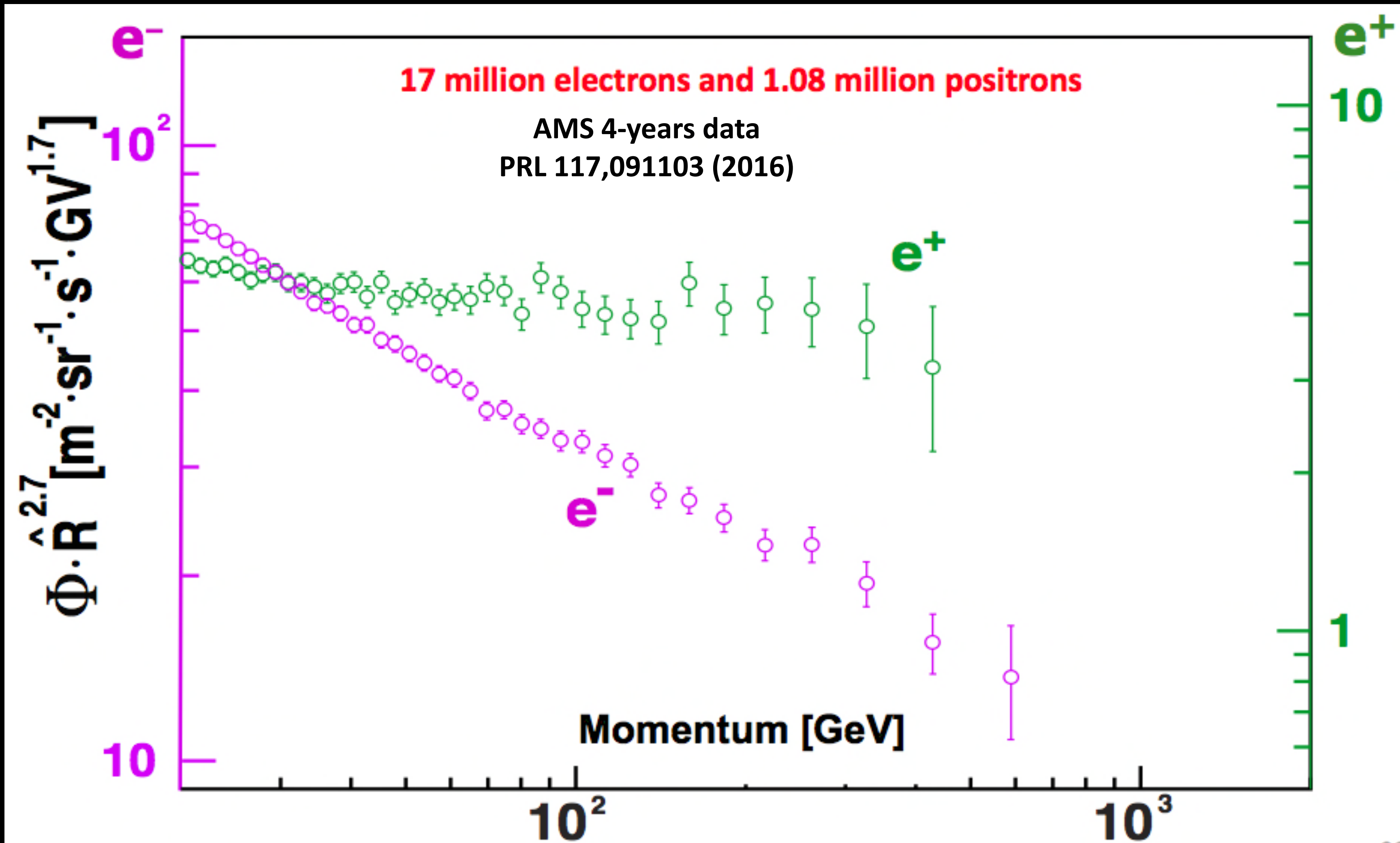
The proton flux and properties of elementary particle fluxes

As expected electrons undergo higher energy losses that proton

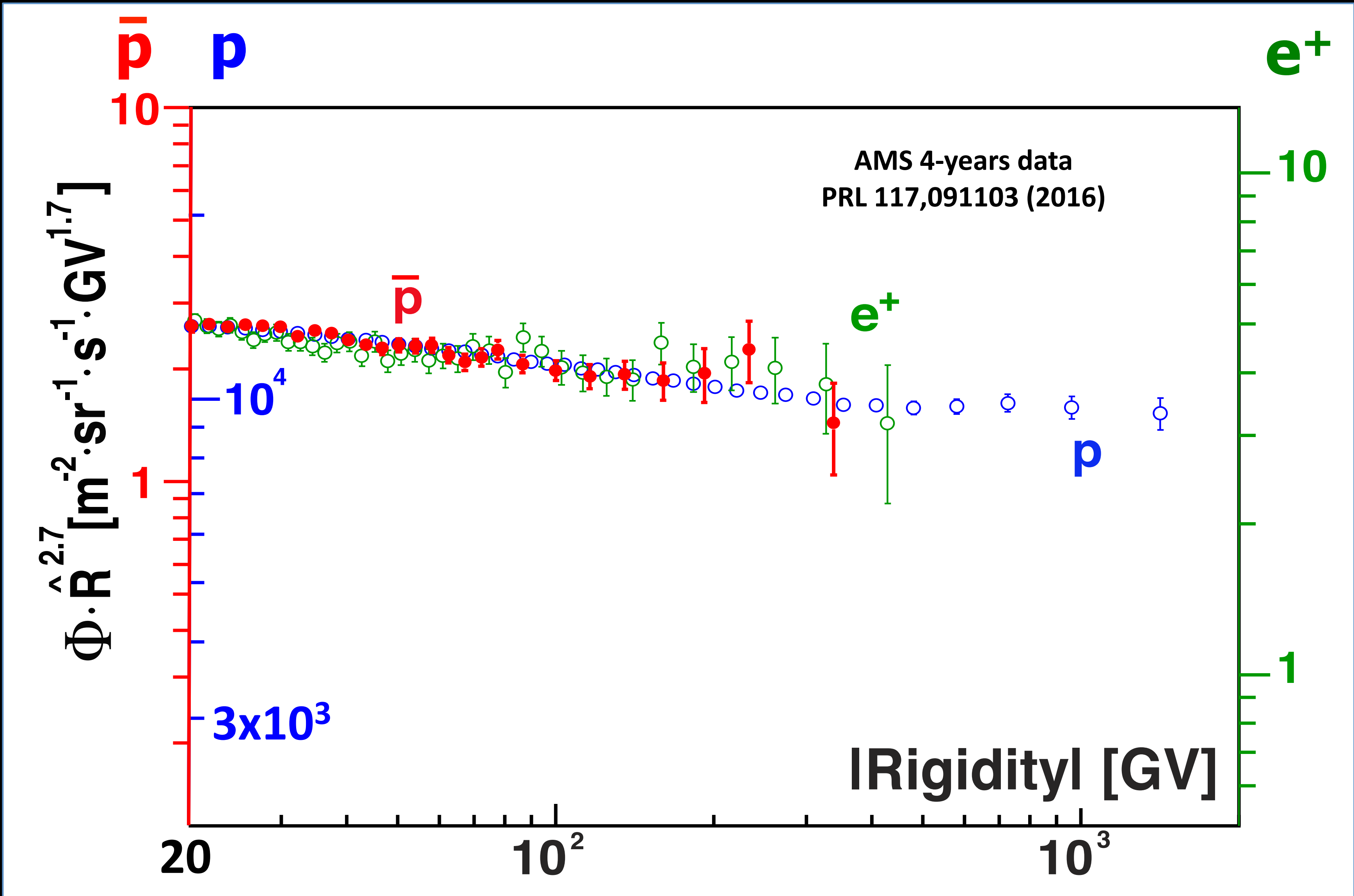


Properties of elementary particle fluxes

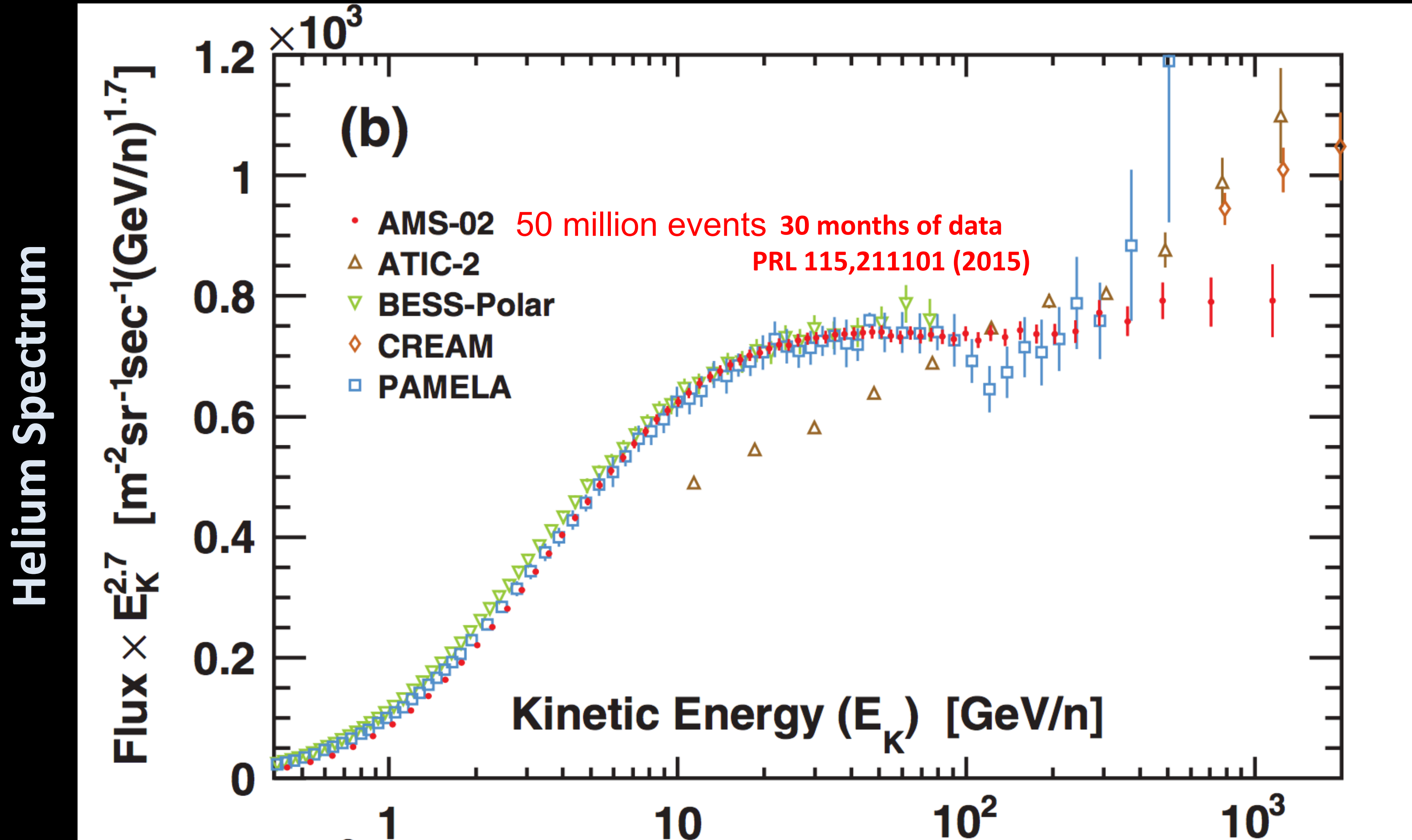
Unexpectedly positrons behaves differently from electrons



Unexpected Result:
the spectra of proton, antiproton and positrons have identical energy dependence

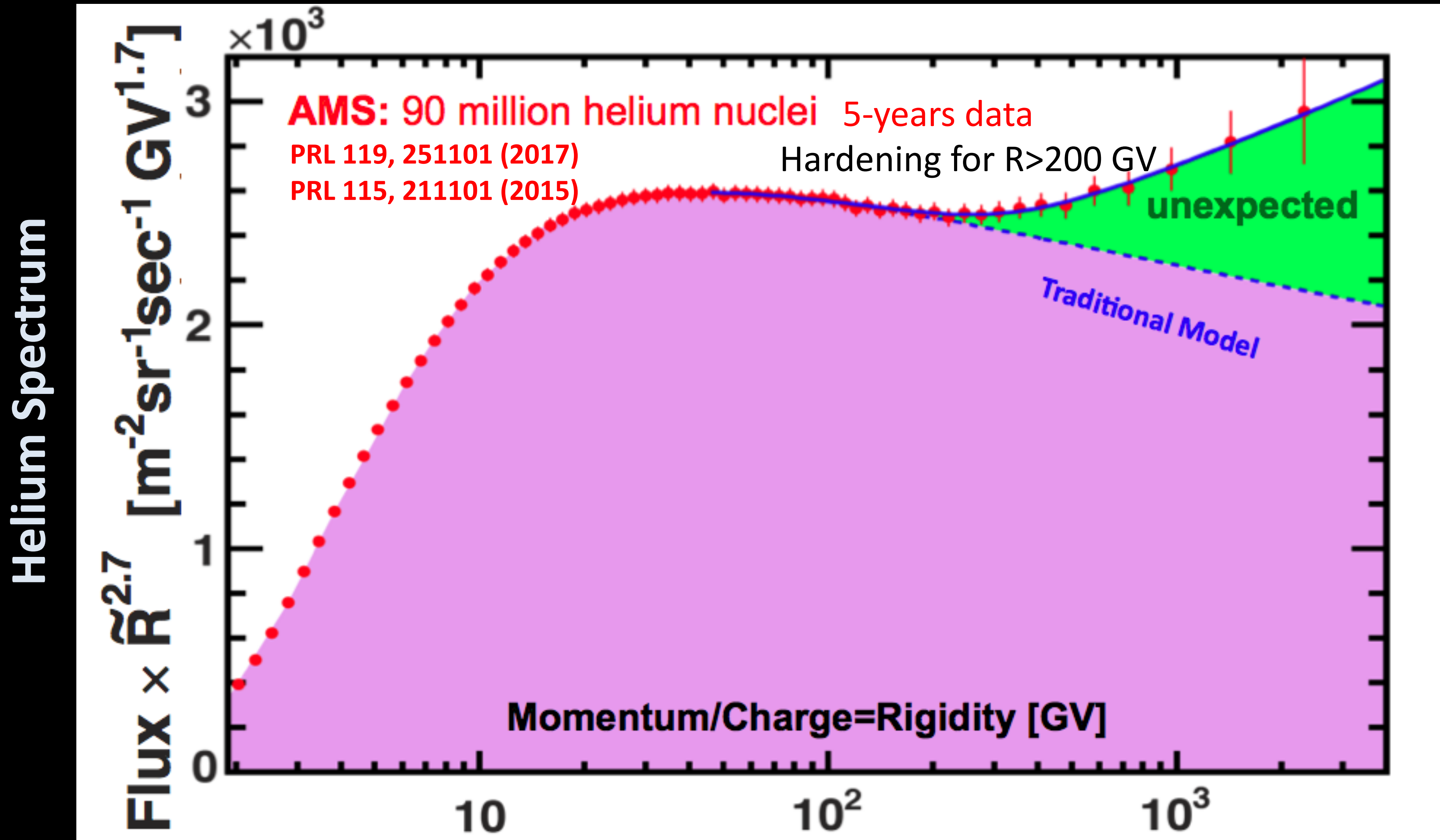


AMS Precision measurement of the Helium flux



AMS Precision measurement of the Helium flux

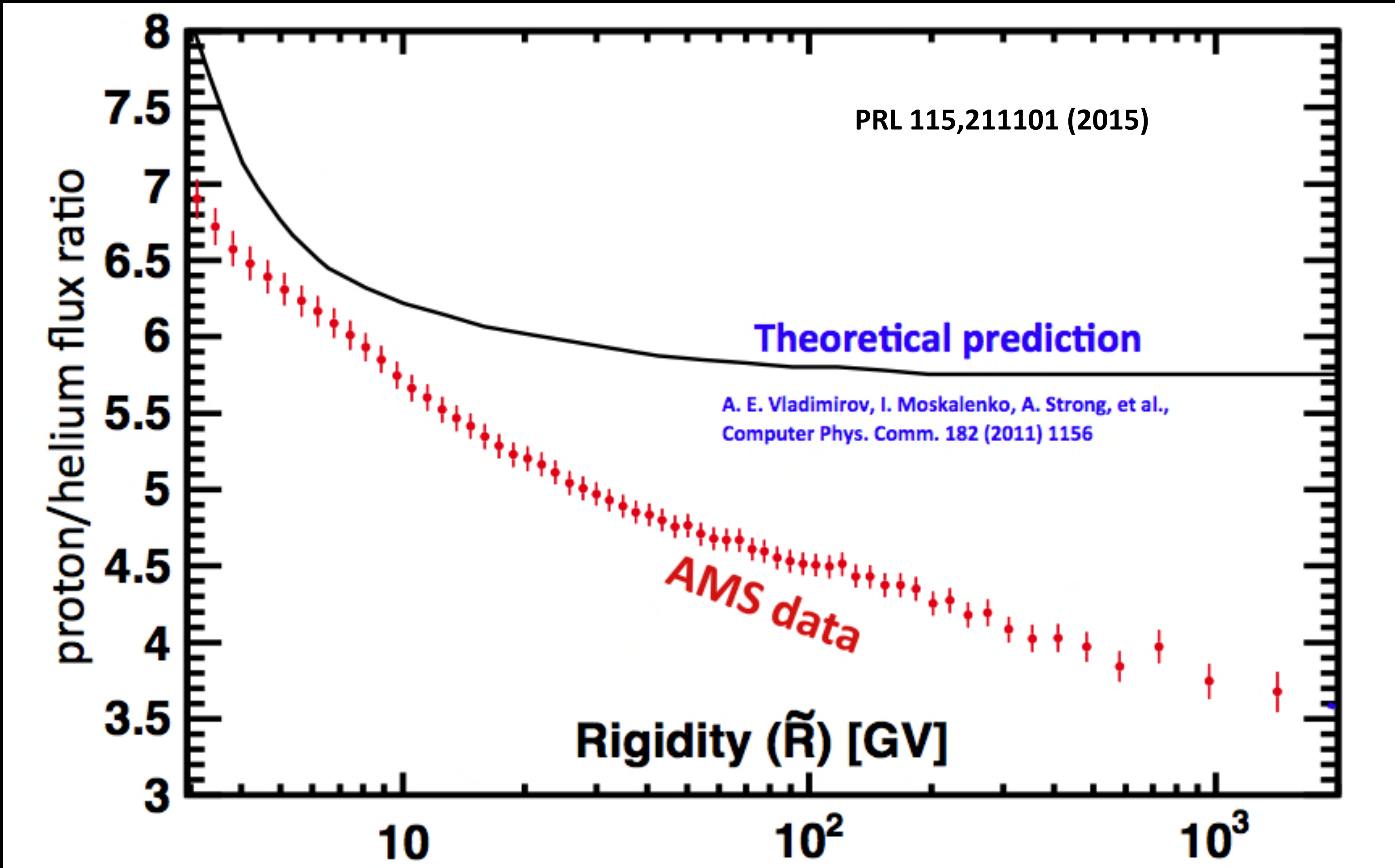
Doubled statistics wrt PRL 115, 211101 (2015)



AMS Proton to Helium flux ratio

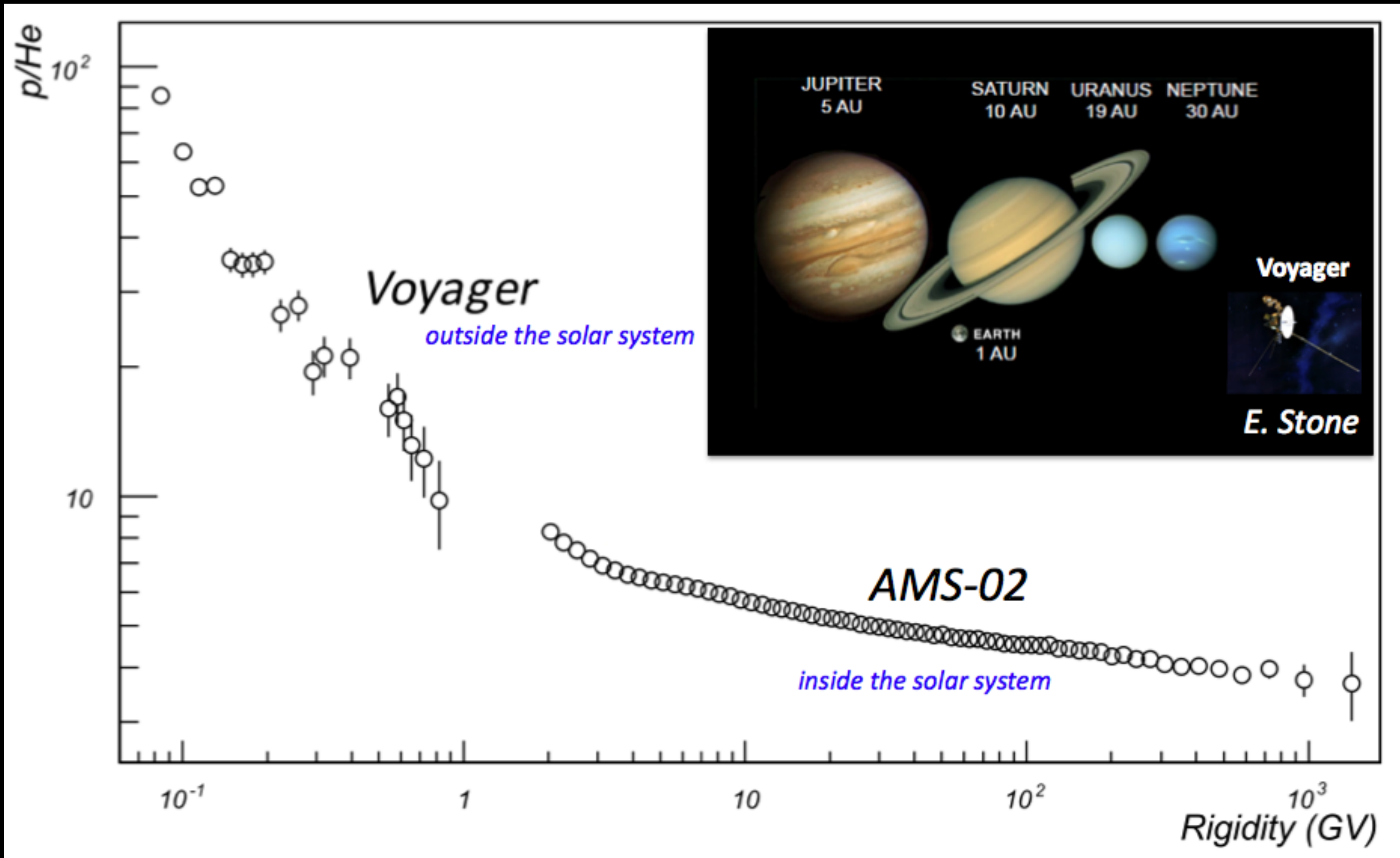
Protons and helium are both “primary” cosmic rays.
Their rigidity ratio has traditionally been assumed to be flat.

AMS p/He ratio is not flat: He spectra harder than p.

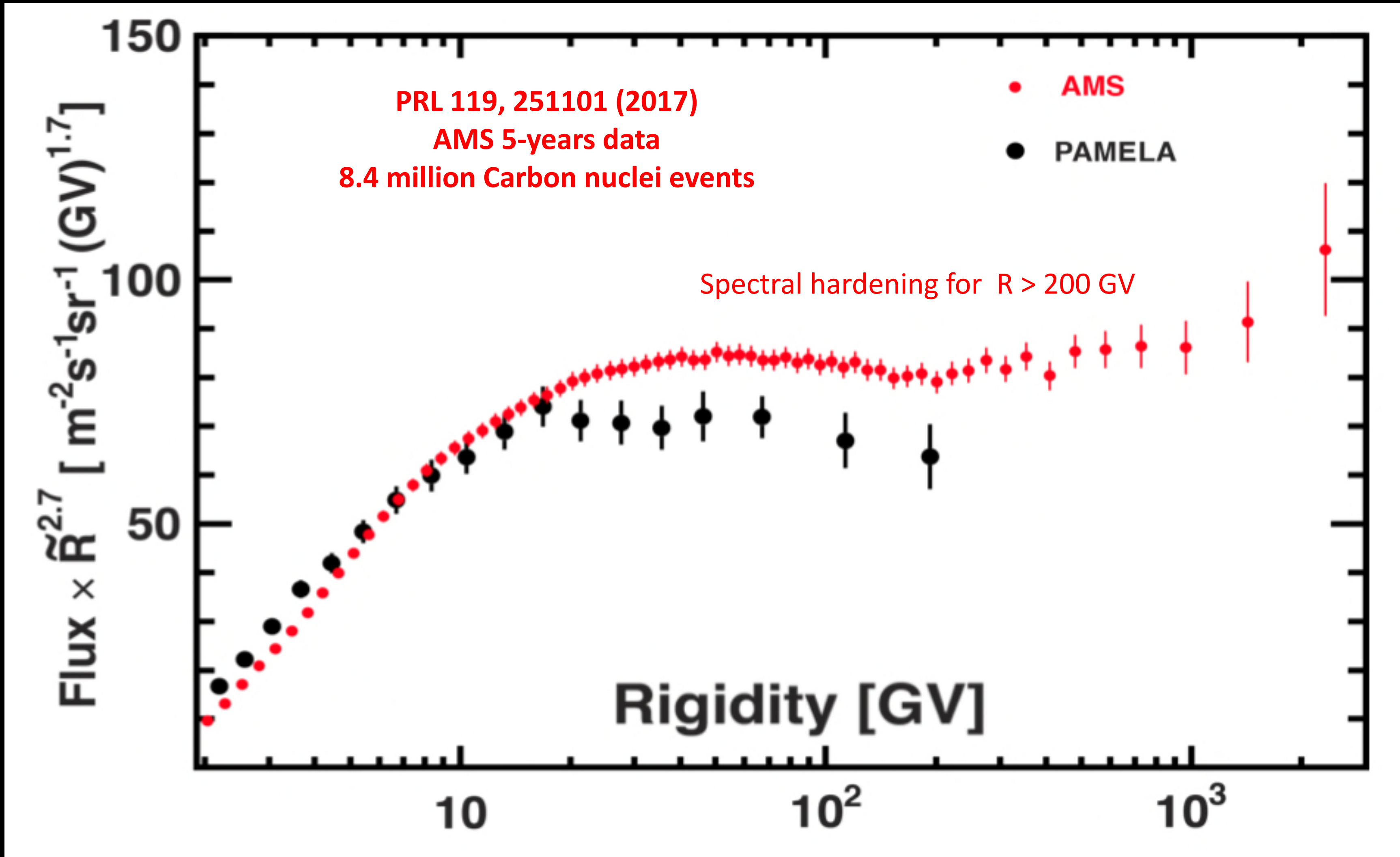


AMS vs Voyager Proton to Helium flux ratio

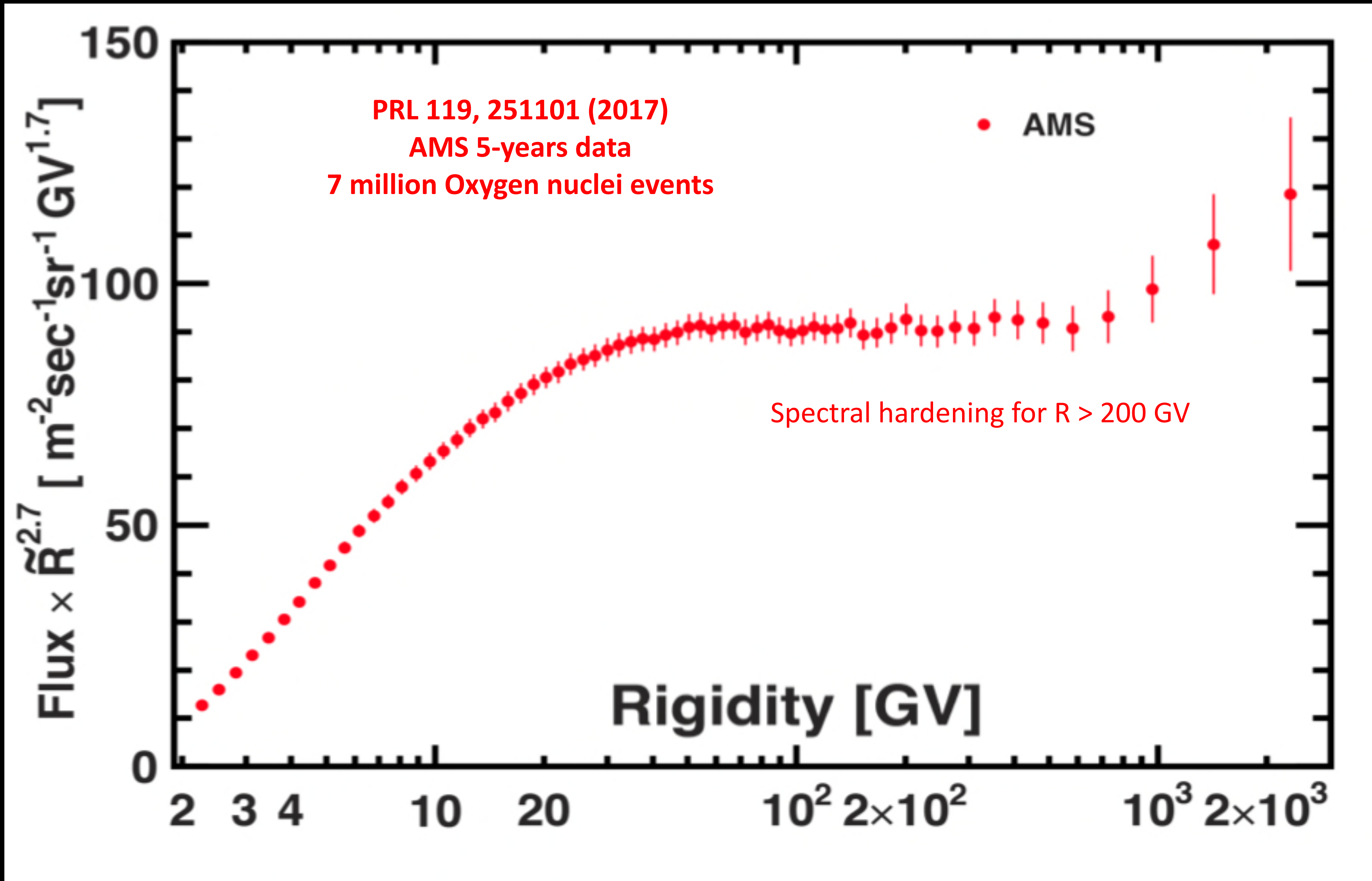
Interstellar Space p/He ratio measured by Voyager I smoothly connects to inside-Solar Sytem p/He measured by AMS02



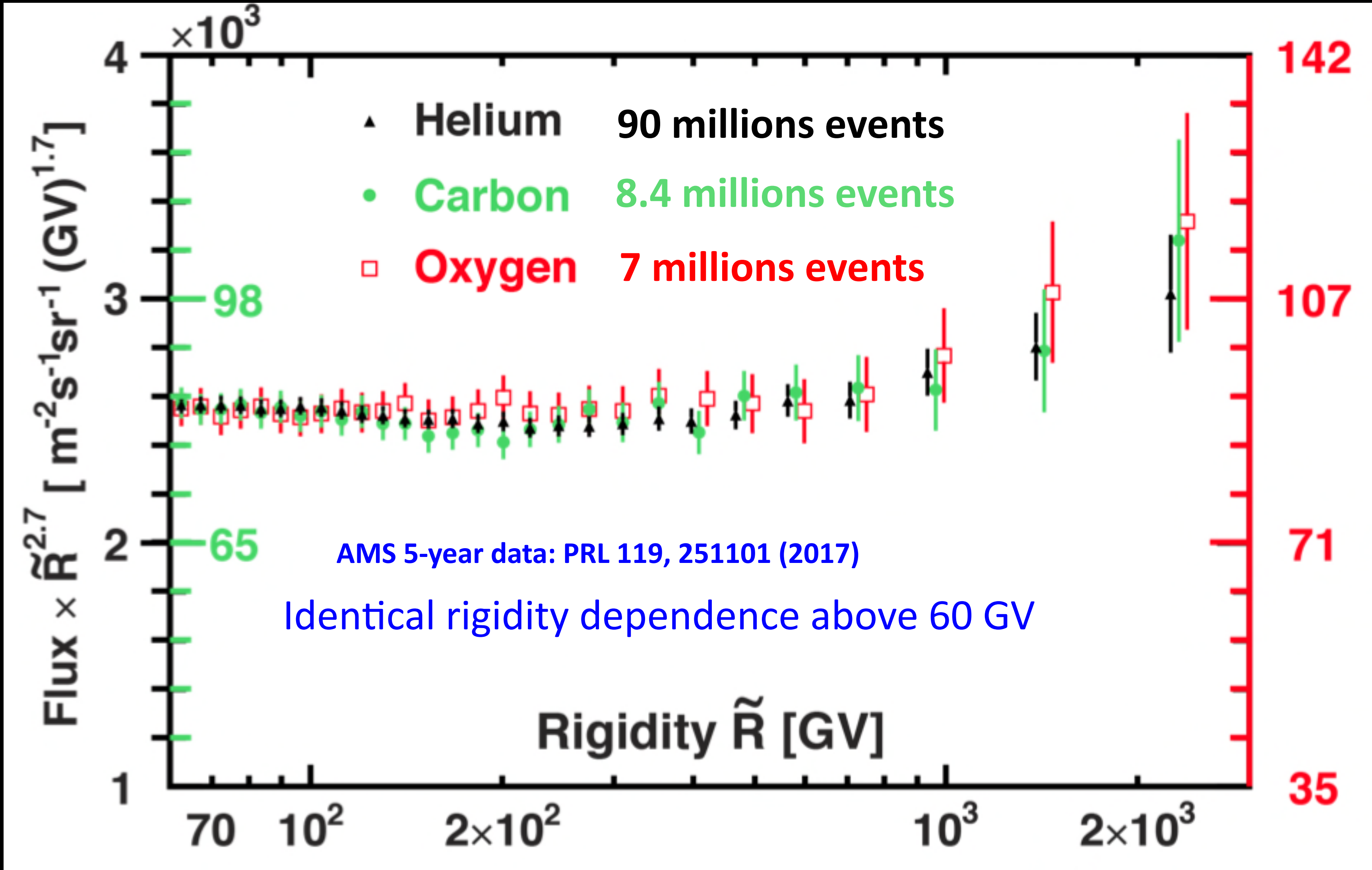
Measurement of other primary cosmic-ray nuclei: Carbon flux



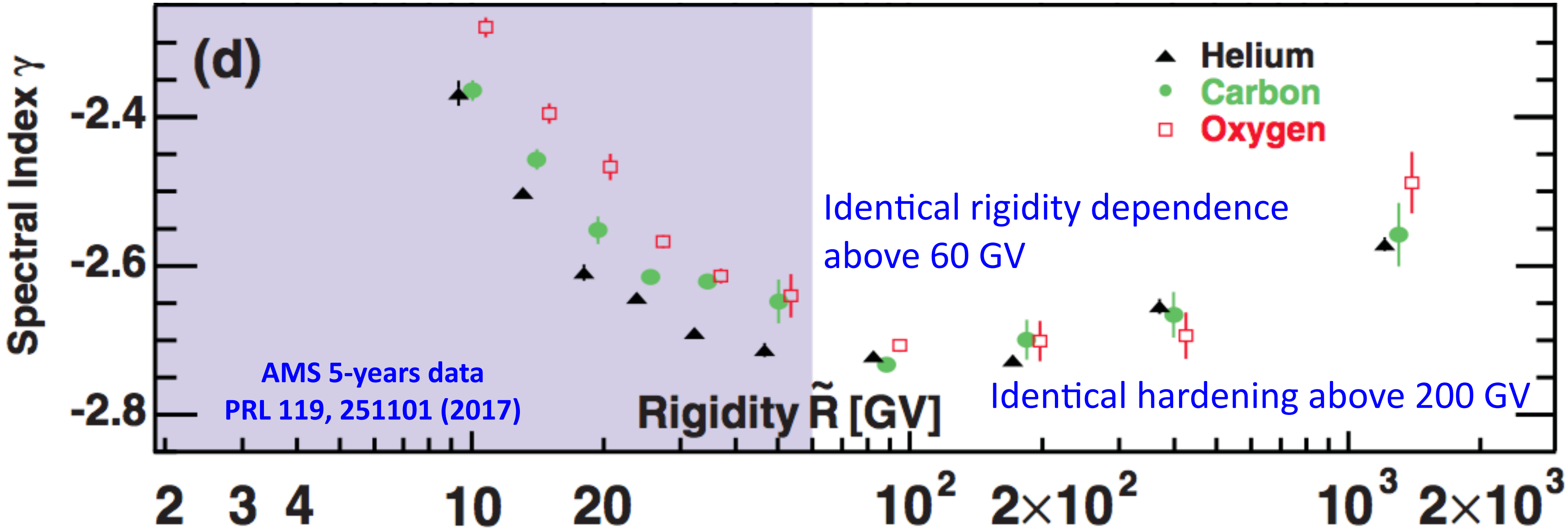
Measurement of other primary cosmic-ray nuclei: Oxygen flux



Comparison of primary cosmic-ray nuclei fluxes: Helium, Carbon and Oxygen

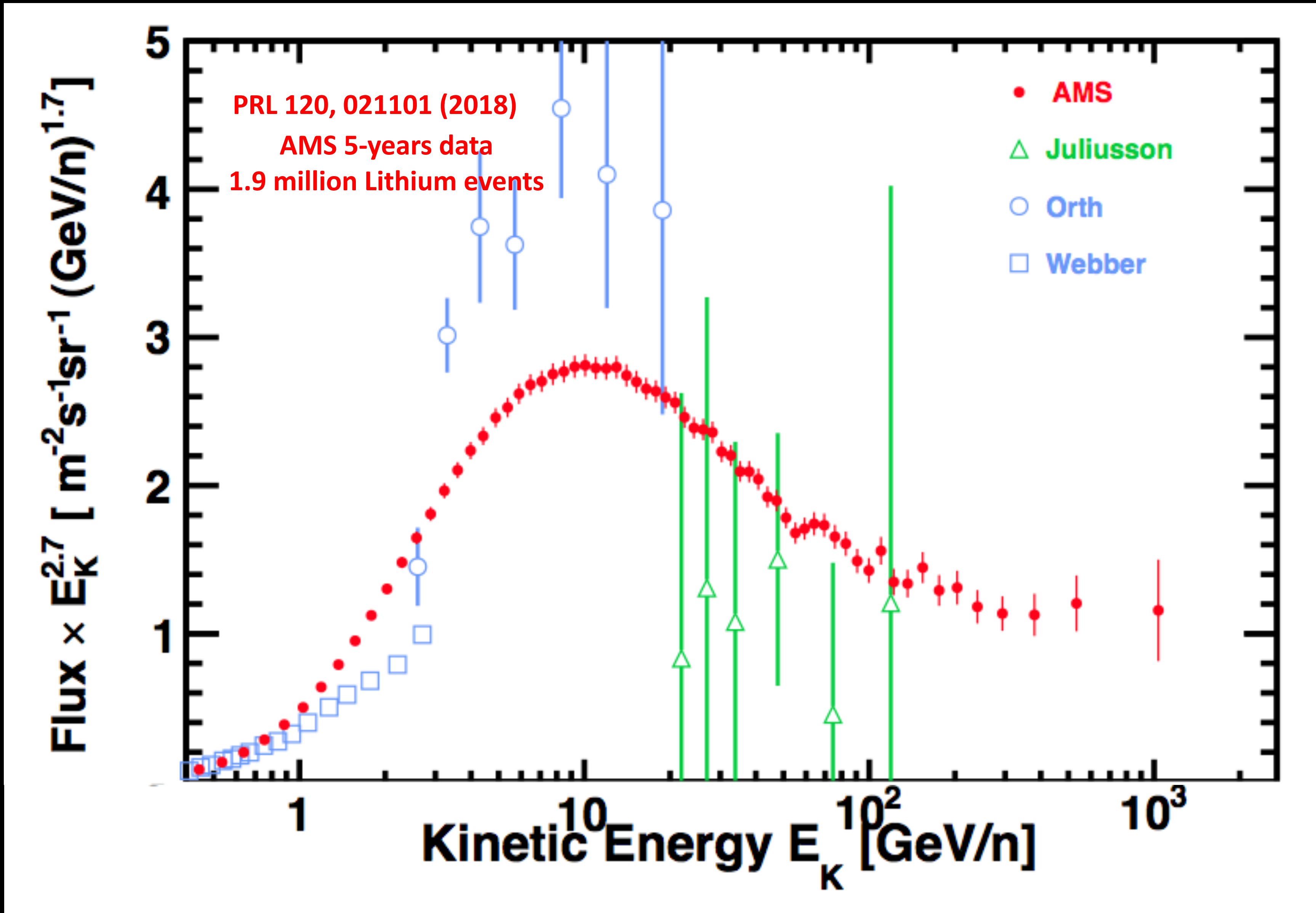


Spectral indices of primary cosmic-ray nuclei: Helium, Carbon and Oxygen

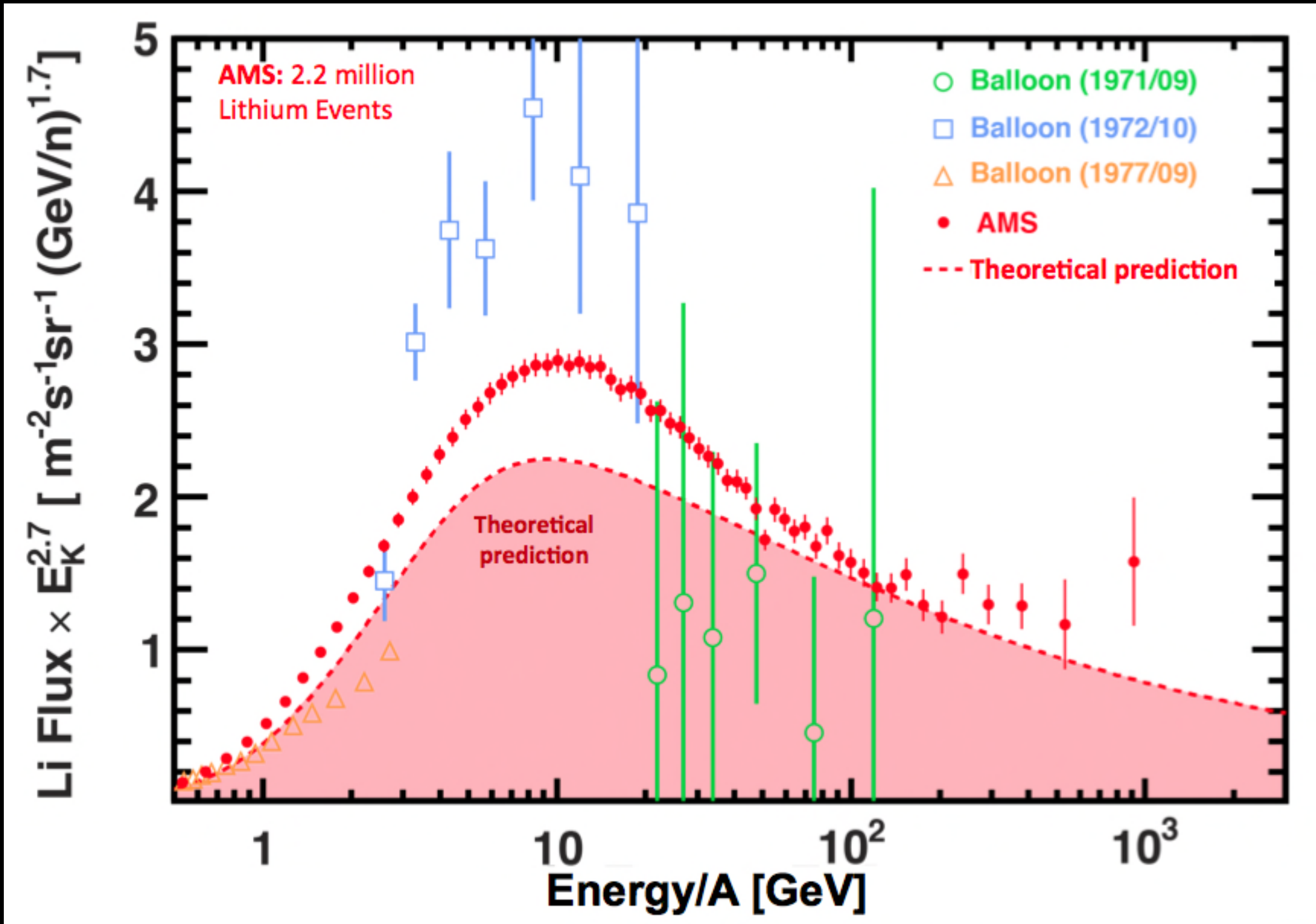


Above 60 GV the three spectral indices are identical
Above 200 GV Helium, Carbon and Oxygen spectra deviate from a single power law and harden in an identical way

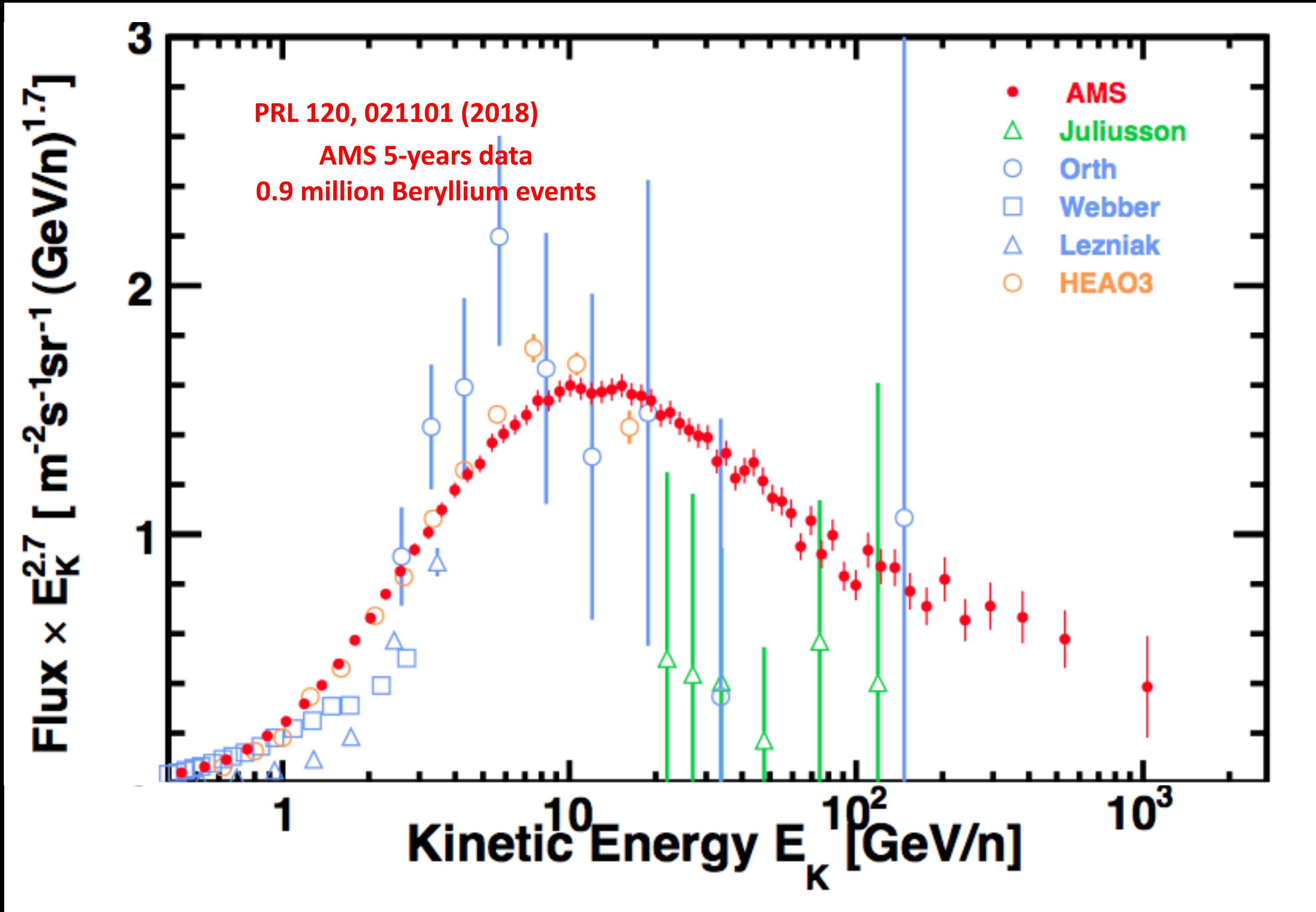
AMS measurement of secondary cosmic-ray nuclei: Lithium flux (5-years of data)



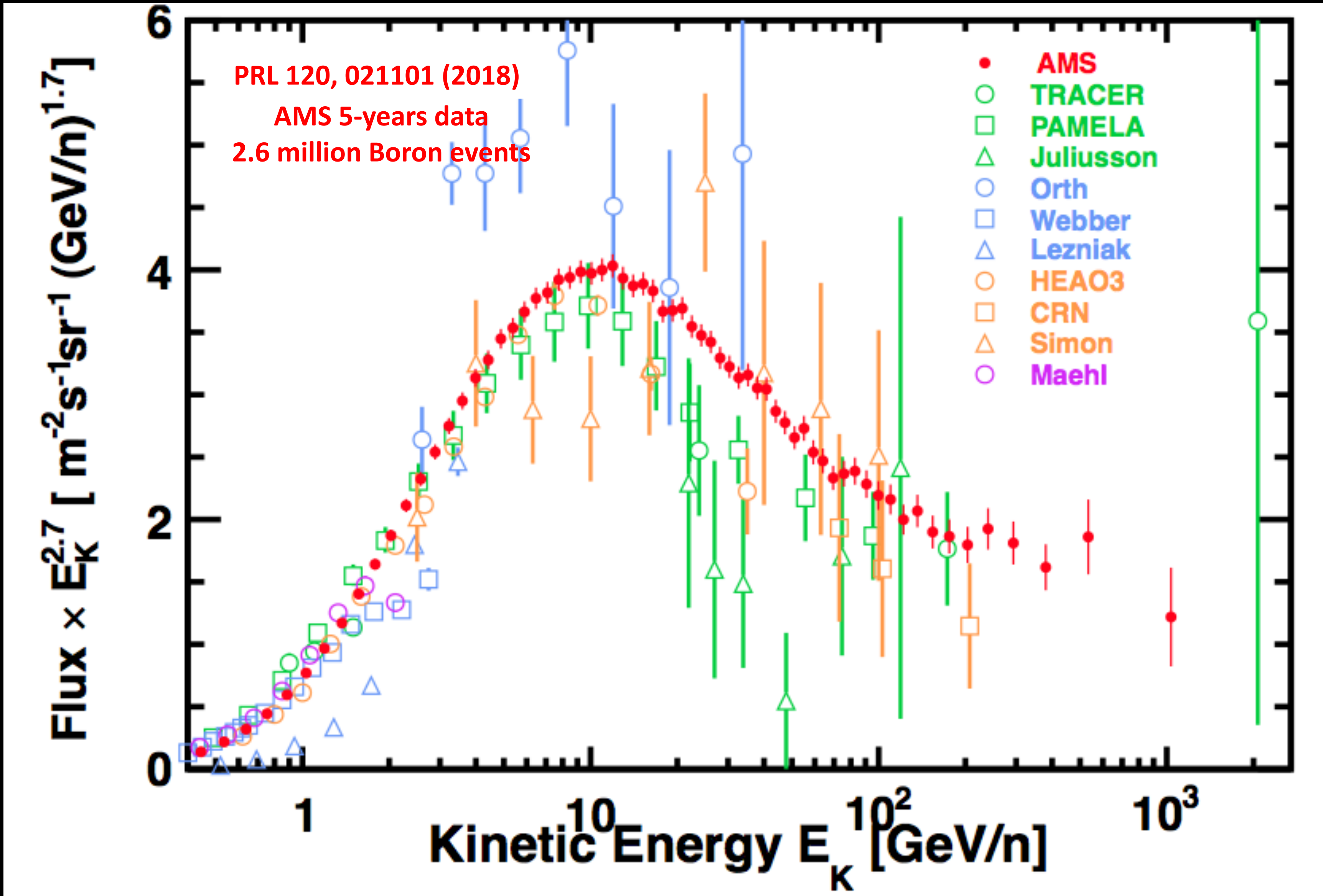
AMS measurement of secondary cosmic-ray nuclei: Lithium flux (6-years of data)



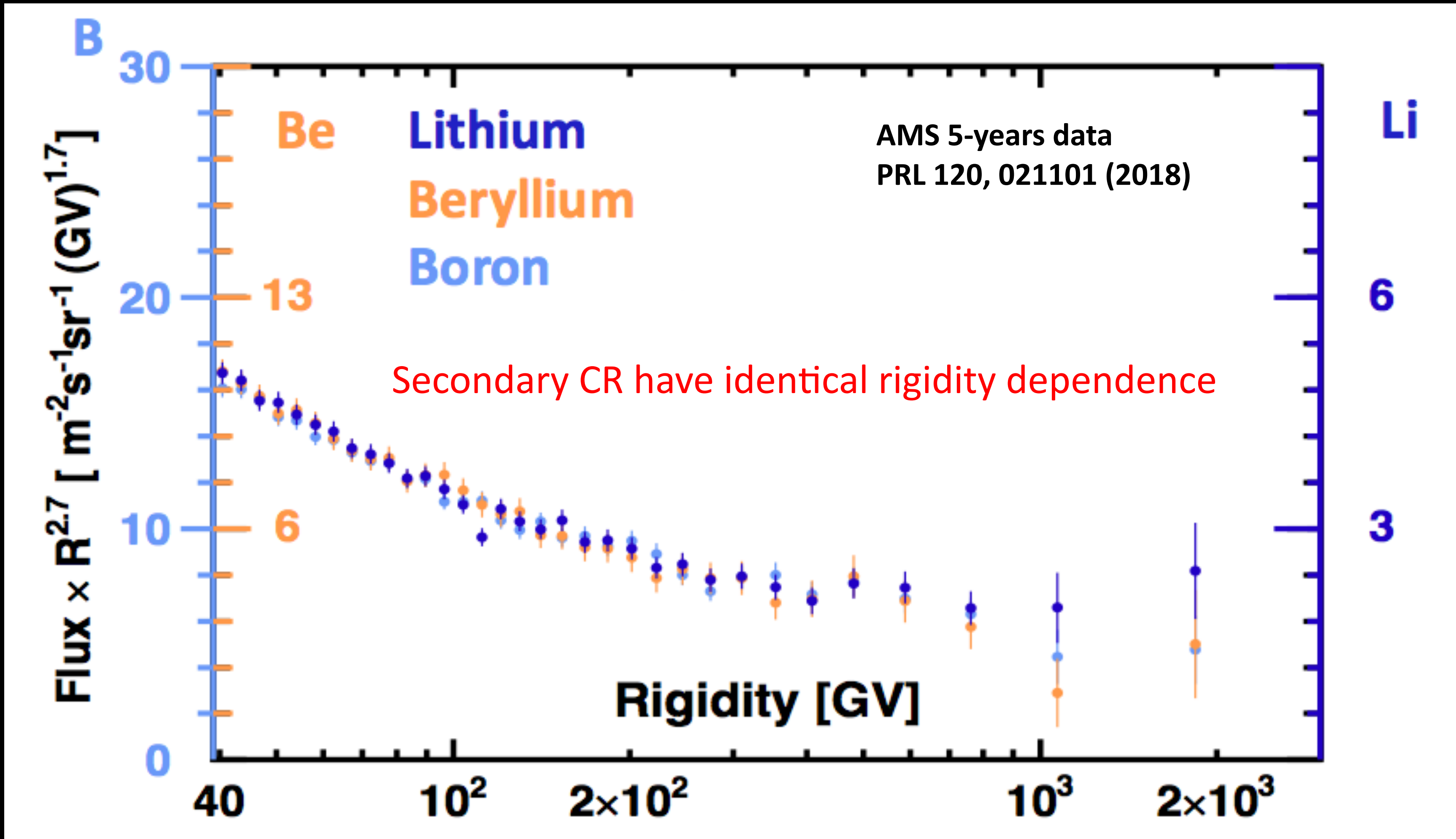
AMS measurement of secondary cosmic-ray nuclei: Beryllium flux



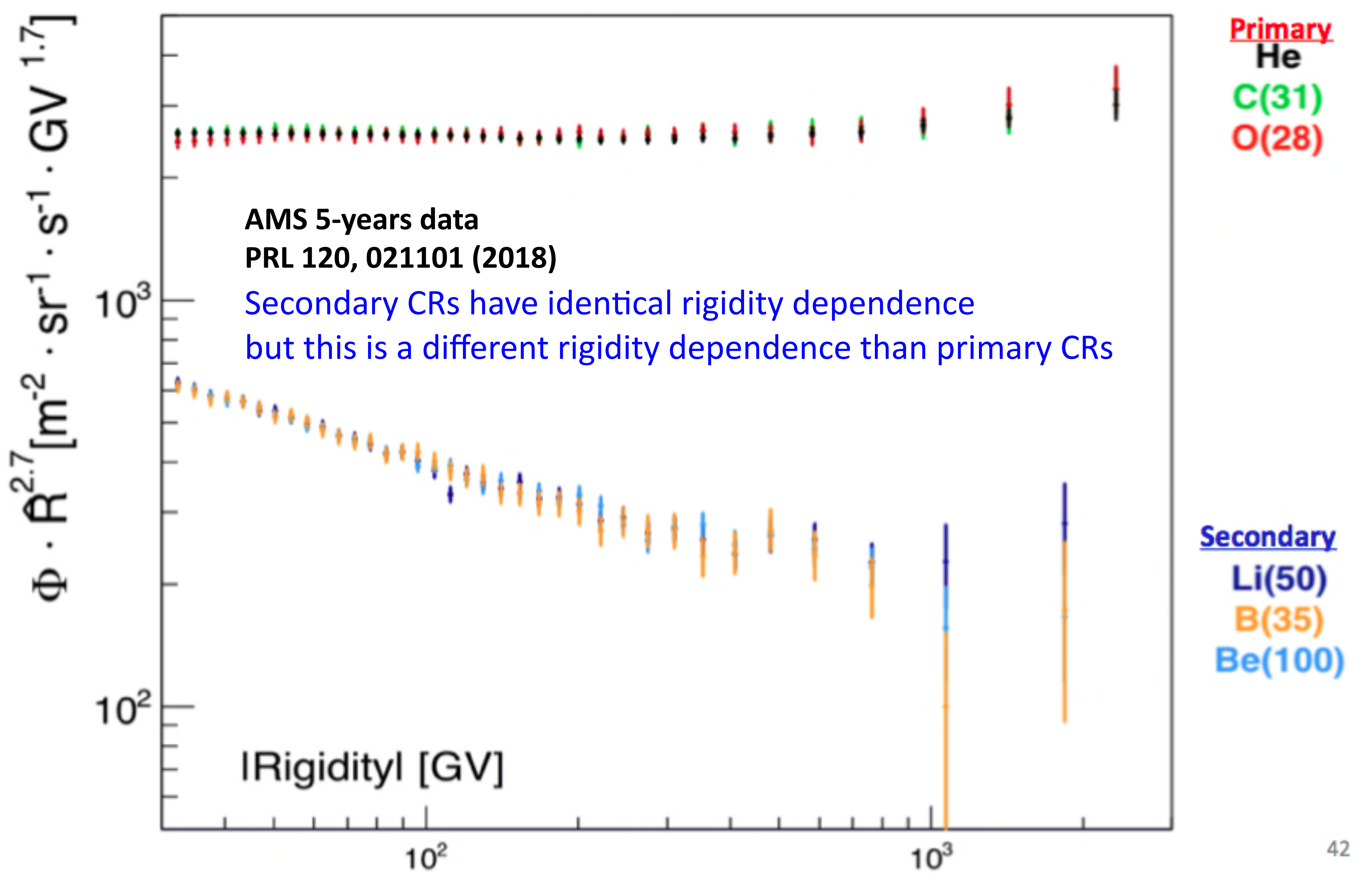
AMS measurement of secondary cosmic-ray nuclei: Boron flux



Comparison of secondary cosmic-ray nuclei fluxes: Lithium, Beryllium and Boron

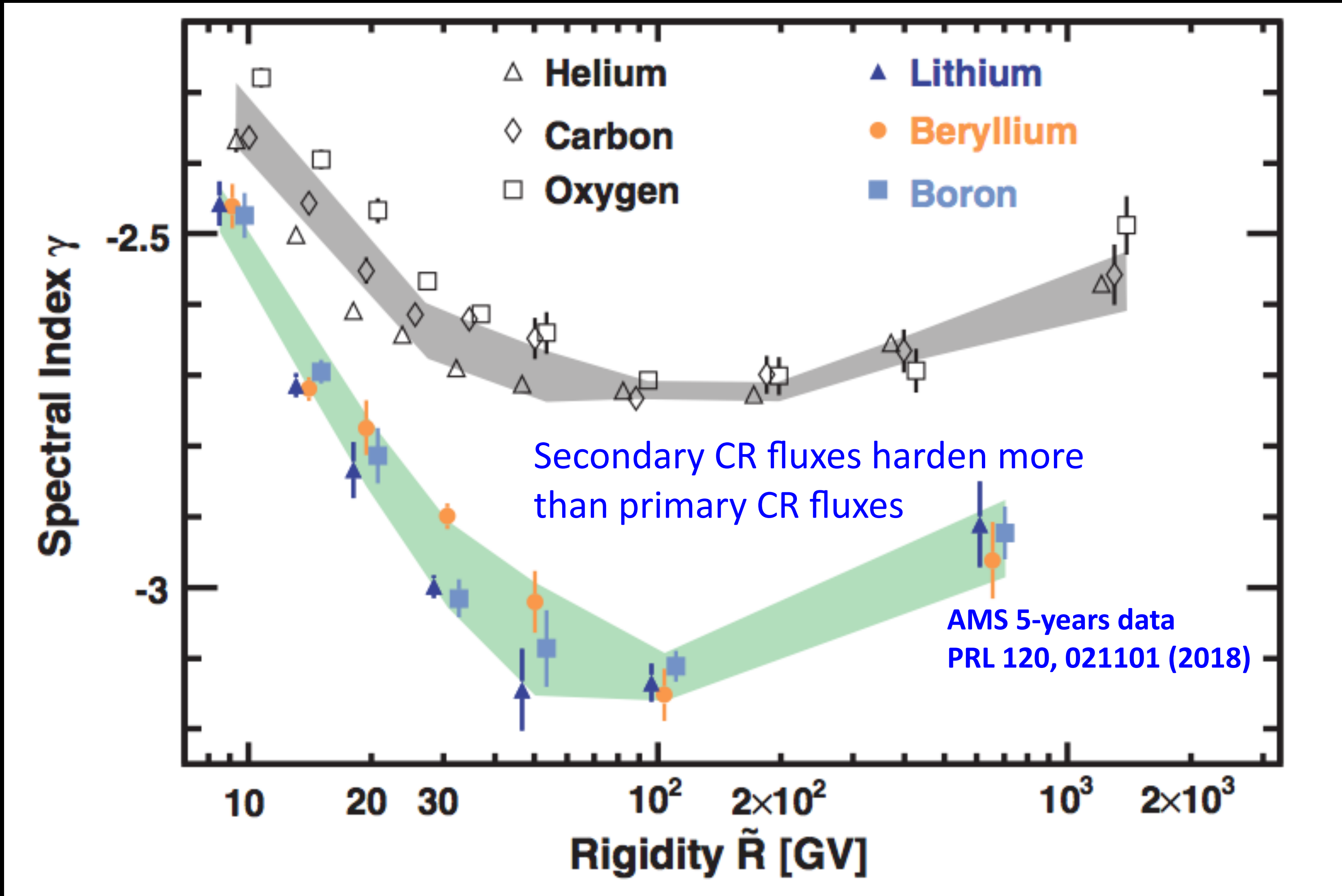


Primary vs secondary cosmic-ray nuclei spectra: He - C - O vs Li - Be - B

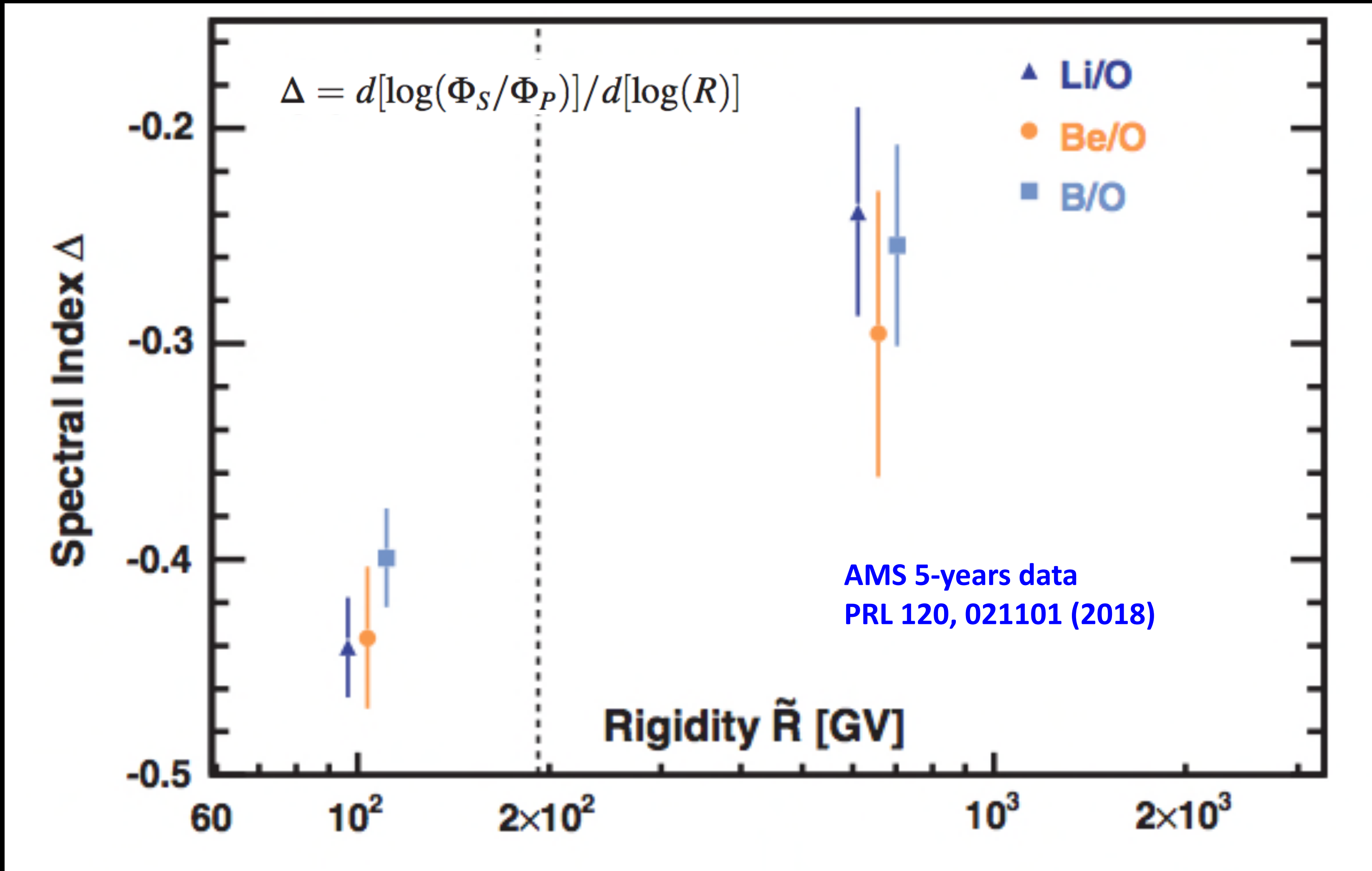


Spectral indices of secondary vs primary CR nuclei

Above 200 GV Lithium, Beryllium and Boron spectra deviate from a single power law and harden in an identical way (as observed for He, C and O)
But they harden more than Primary CR

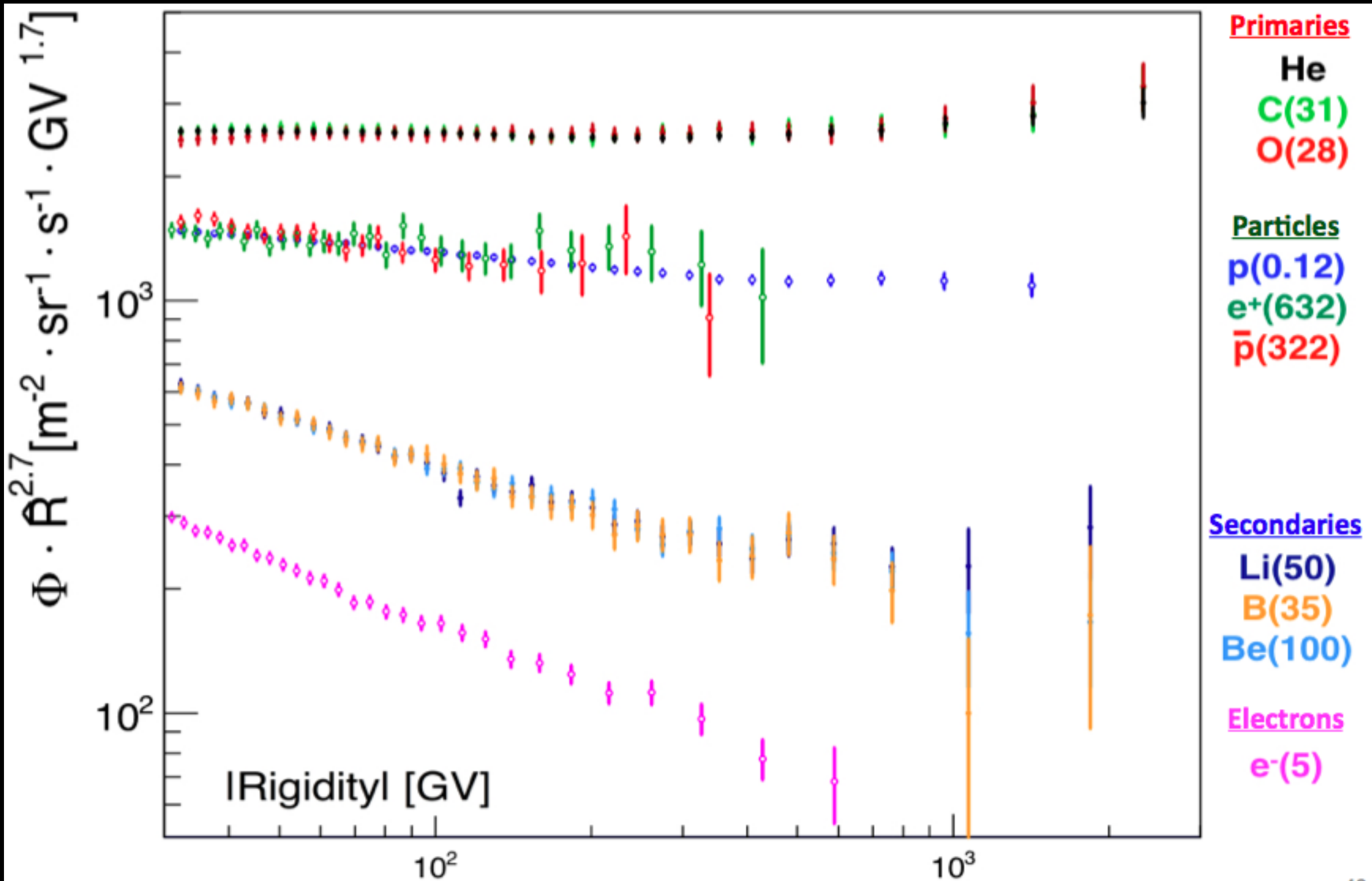


Spectral indices of secondary/primary ratios



Observed Secondary/Primary flux ratios average hardening of 0.13 ±0.03

Summary of latest AMS results



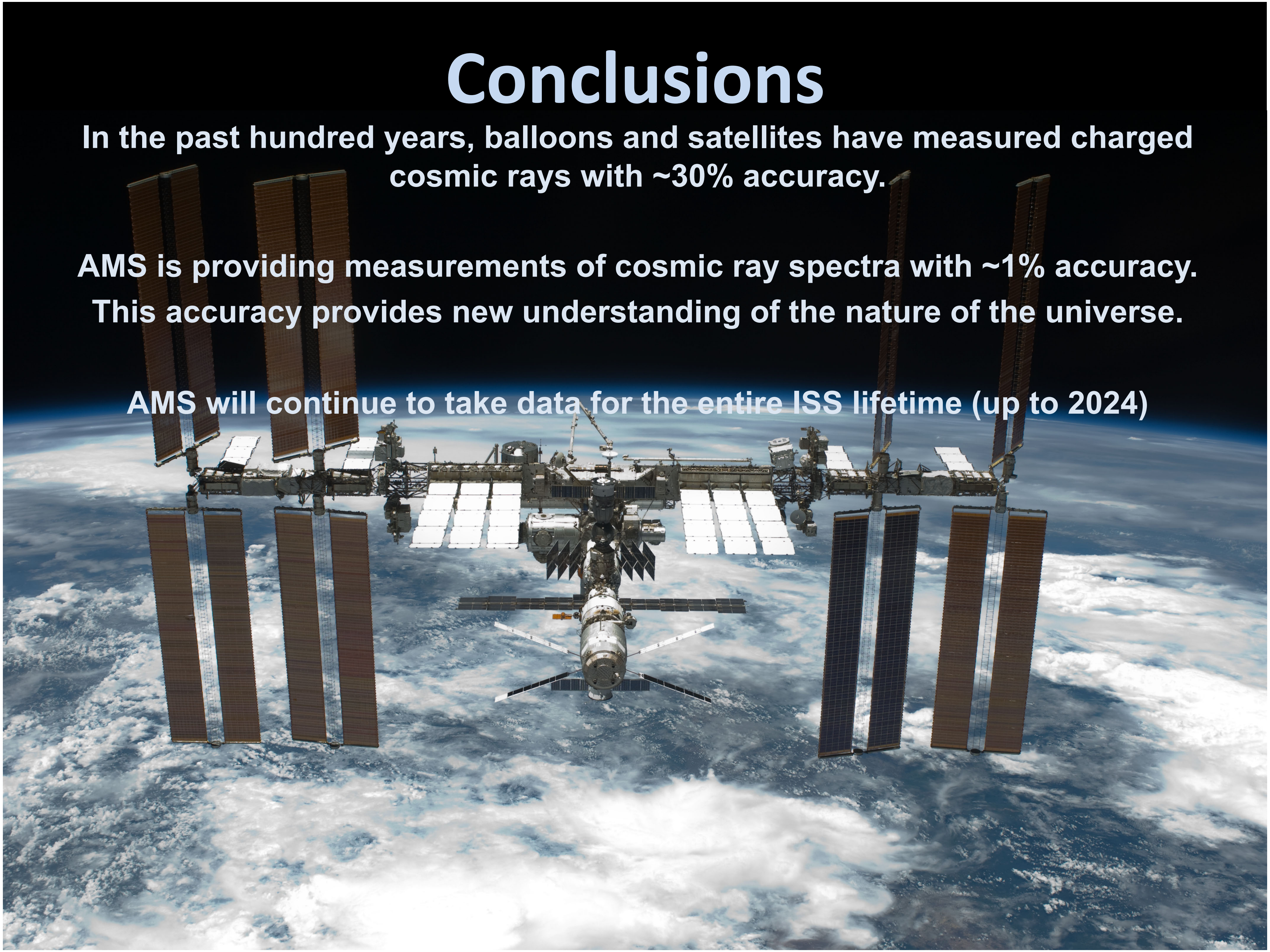
Simultaneous precision measurements of CR individual spectra in the GV-TV range are providing new insight in CR properties

Conclusions

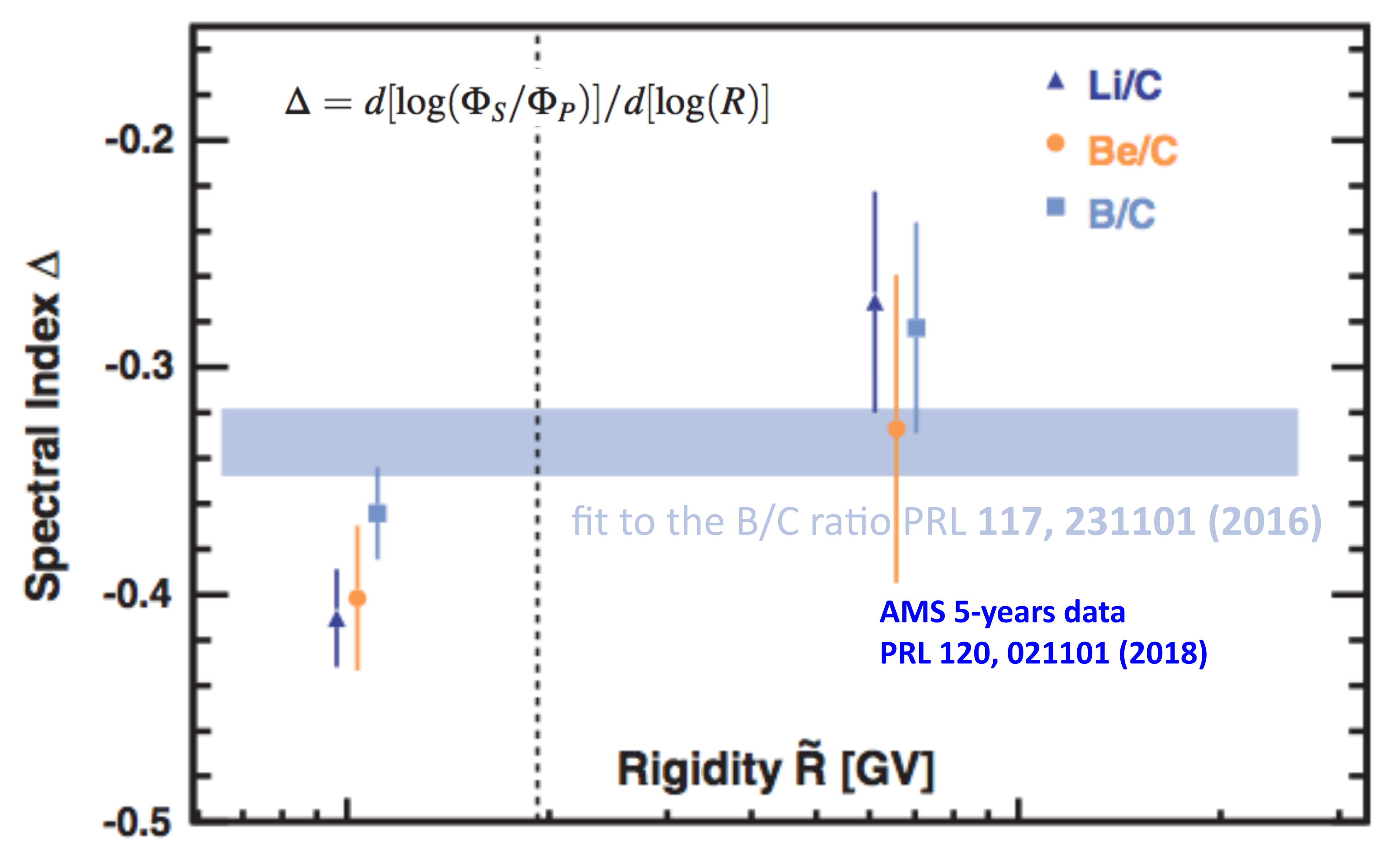
In the past hundred years, balloons and satellites have measured charged cosmic rays with ~30% accuracy.

AMS is providing measurements of cosmic ray spectra with ~1% accuracy. This accuracy provides new understanding of the nature of the universe.

AMS will continue to take data for the entire ISS lifetime (up to 2024)

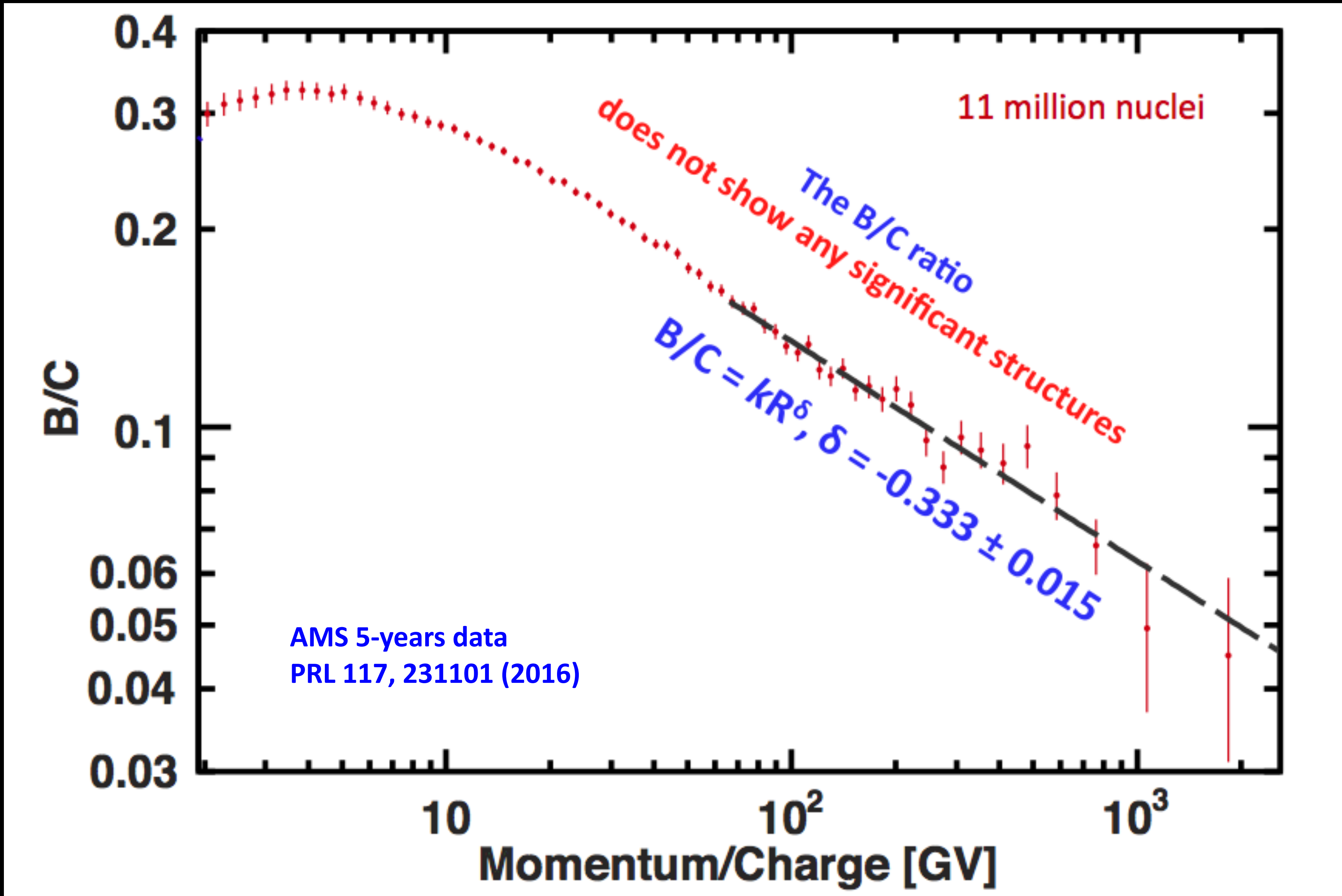


Spectral indices of secondary/primary flux ratios: Lithium, Beryllium and Boron to Carbon



Secondary/Primary flux ratios average hardening of 0.13 ±0.03

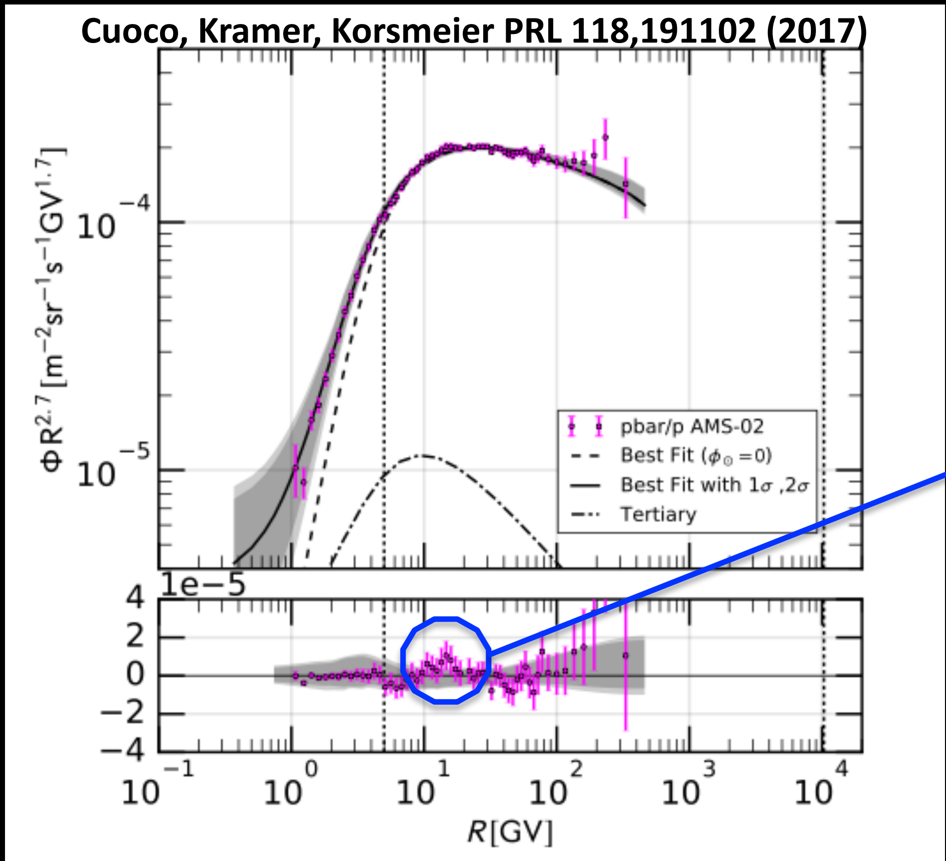
Boron to Carbon flux ratio

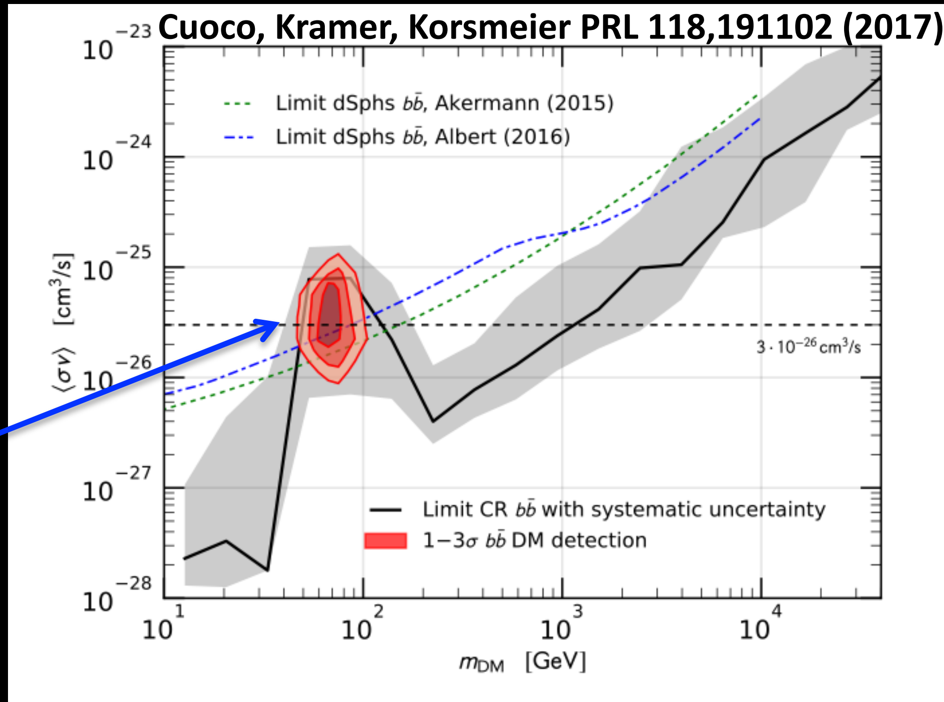


"Antiprotons may hold Dark Matter Signal"

https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.118.191102

https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.118.191101

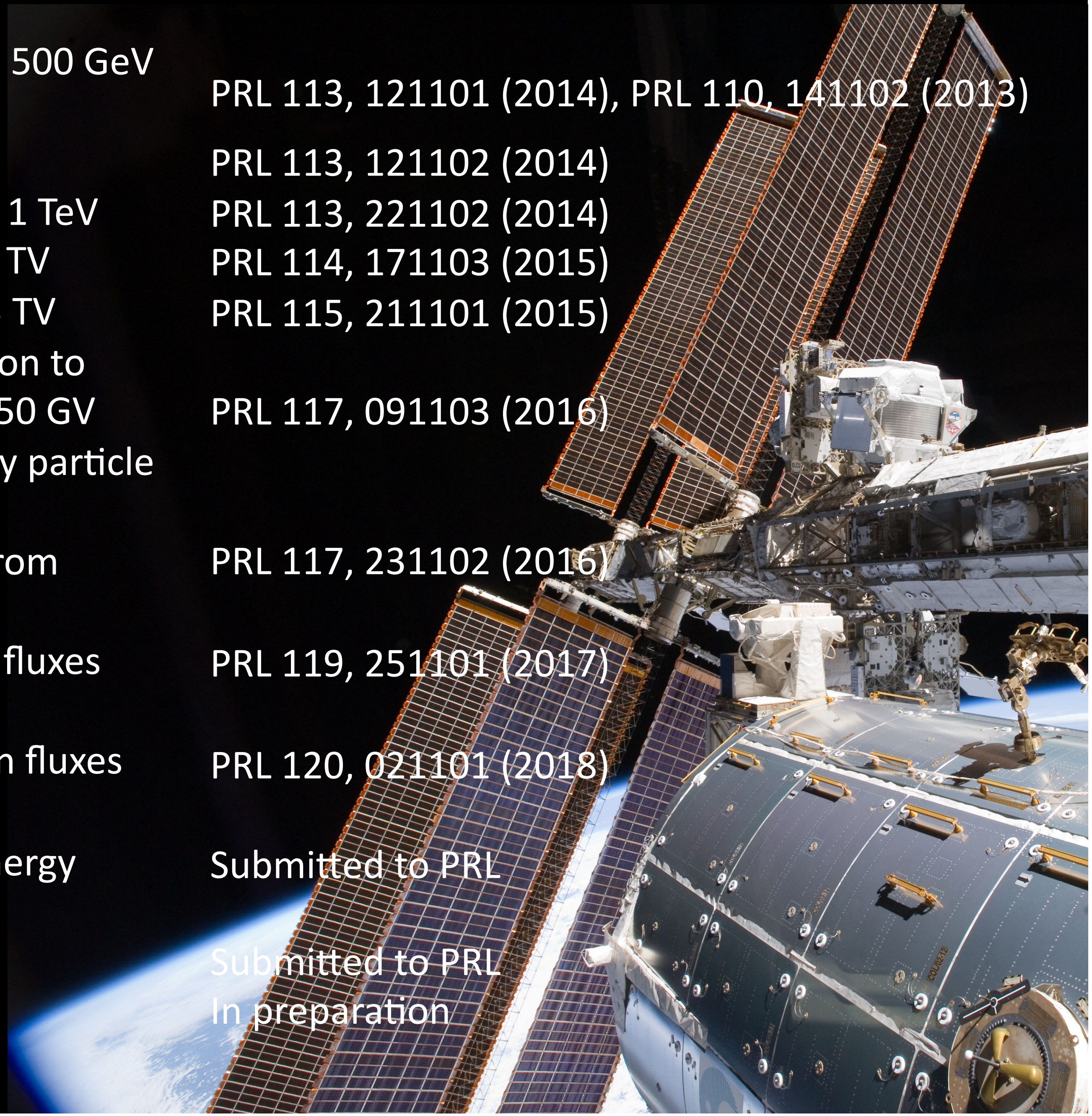




See also Cui, Yuan, Tsai, Fan PRL 118,191101 (2017)

The AMS-02 anti-proton excess is well fit by a ~80 GeV DM particle in good agreement with the Galactic Center gamma ray GeV excess

AMS Results (so far)



1. Positron fraction from 0.5 to 500 GeV 2. Anisotropy of e^+/e^-	PRL 113, 121101 (2014), PRL 110, 141102 (2013)
3. Electron and positron fluxes	PRL 113, 121102 (2014)
4. $(e^+ + e^-)$ flux from 0.5 GeV to 1 TeV	PRL 113, 221102 (2014)
5. Proton flux from 1 GV to 1.8 TV	PRL 114, 171103 (2015)
6. Helium flux from 1.9 GV to 3 TV	PRL 115, 211101 (2015)
7. Antiproton flux and antiproton to proton flux ratio from 1 to 450 GV and properties of elementary particle fluxes in CR	PRL 117, 091103 (2016)
8. Boron-to-Carbon flux ratio from 1.9 GV to 2.6 TV	PRL 117, 231102 (2016)
9. Helium, Carbon and Oxygen fluxes from 2 GV to 3 TV	PRL 119, 251101 (2017)
10. Lithium, Beryllium and Boron fluxes from 1.9 GV to 3.3 TV	PRL 120, 021101 (2018)
11. Time-dependence of Low Energy Proton and Helium	Submitted to PRL
12. Solar Modulation of e+, e-	Submitted to PRL
13. Nitrogen flux	In preparation