AMS Highlights

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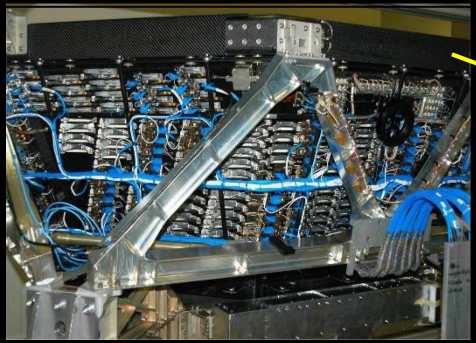
On behalf of the AMS Collaboration

ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

AMS-02: A TeV precision magnetic spectrometer in space

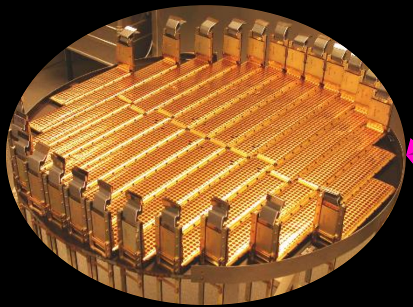
Transition Radiation Detector

Identifies e^+, e^-



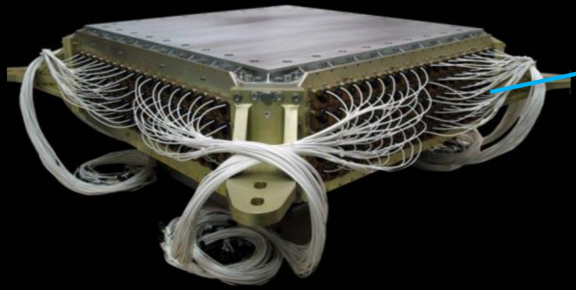
Silicon Detector

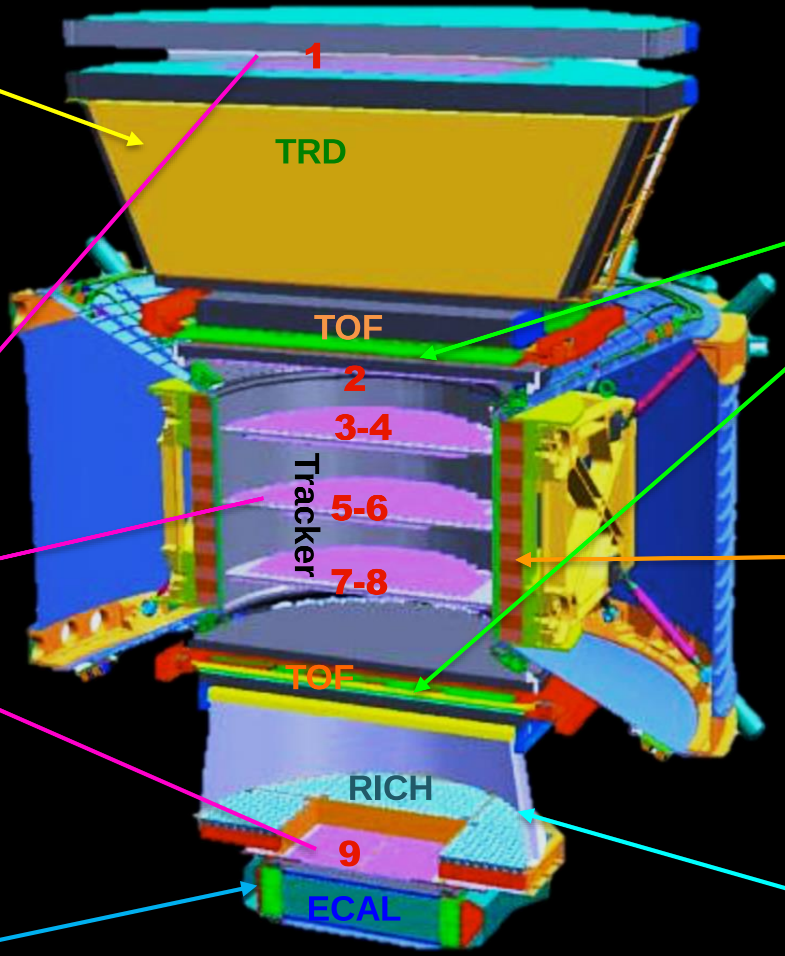
Rigidity=p/Ze, ±Z



Electromagnetic Calorimeter

Energy of e^+, e^-



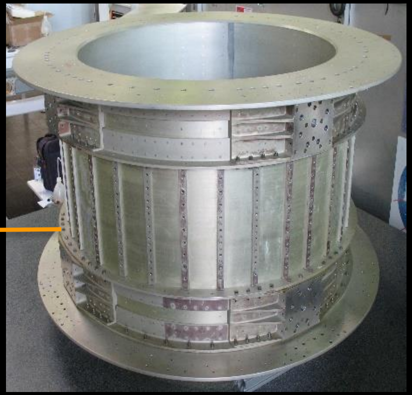


Time Of Flight

β, Z

Magnet

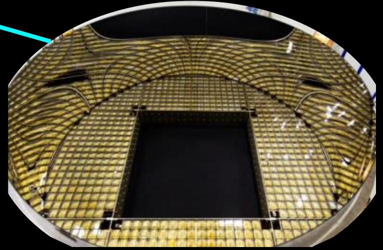
B = .15 T



Ring Imaging Cherenkov

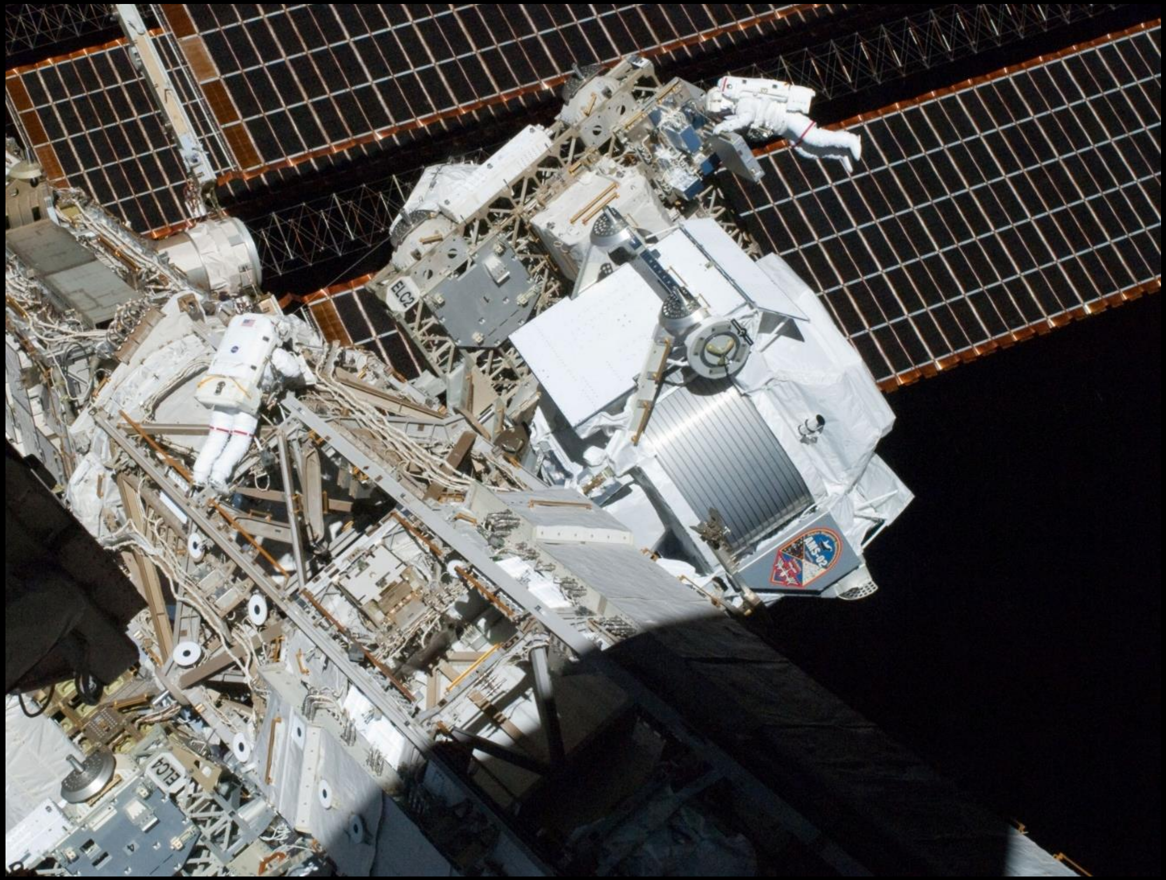
β, Z

Isotopic composition



Redundant measurements
of Charge and Energy

Space Shuttle *Endeavour* lift off
May 16, 2011, 08:56:28 EDT



AMS installed on the ISS
on May 19, 2011


AMS-02 time on ISS since May 19th, 5:46 a.m. EDT:
3696 DAYS
6 HOURS
10 MINUTES
3 SECONDS


AMS has collected
181,981,725,292
cosmic ray events
Last update: July 1, 2021, 3:12 PM

Cosmic rays measurements with AMS

First and only instrument providing simultaneous measurements of particles/anti-particles, chemical composition up to Fe in an extended energy range and over a solar cycle

Physical Review Letters

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)*
16. *Properties of Cosmic Helium Isotopes Measured by the Alpha Magnetic Spectrometer (2019)*
17. *Properties of Neon, Magnesium, and Silicon Primary Cosmic Rays Results from the Alpha Magnetic Spectrometer (2020)*
18. *Properties of Iron Primary Cosmic Rays: Results from the Alpha Magnetic Spectrometer (2021)*
19. *Properties of Heavy Secondary Fluorine Cosmic Rays: Results from the Alpha Magnetic Spectrometer (2021)*

Ediitors'Suggestion

… Properties of a New Group of Cosmic Nuclei: Results from the Alpha Magnetic Spectrometer on Sodium, Aluminum, and Nitrogen (In Press)
… Periodicities in the Daily Proton Fluxes: Results from the Alpha Magnetic Spectrometer (Submitted)
… Periodicities in the Daily Helium Fluxes: Results from the Alpha Magnetic Spectrometer (in preparation)
… Periodicities in the Daily Electrons and Positrons Fluxes: Results from the Alpha Magnetic Spectrometer (in preparation)

Physics Reports

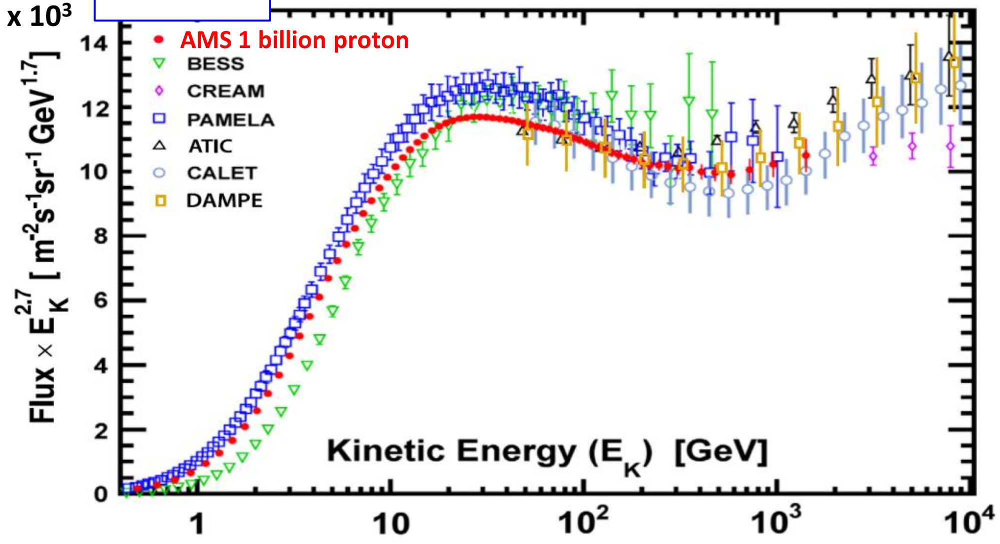
The Alpha Magnetic Spectrometer (AMS) on the International Space Station: Part II - Results from the First Seven Years (2021)

Elementary Particles in Cosmic Rays

Phys. Rep. 894 (2021) 1-116

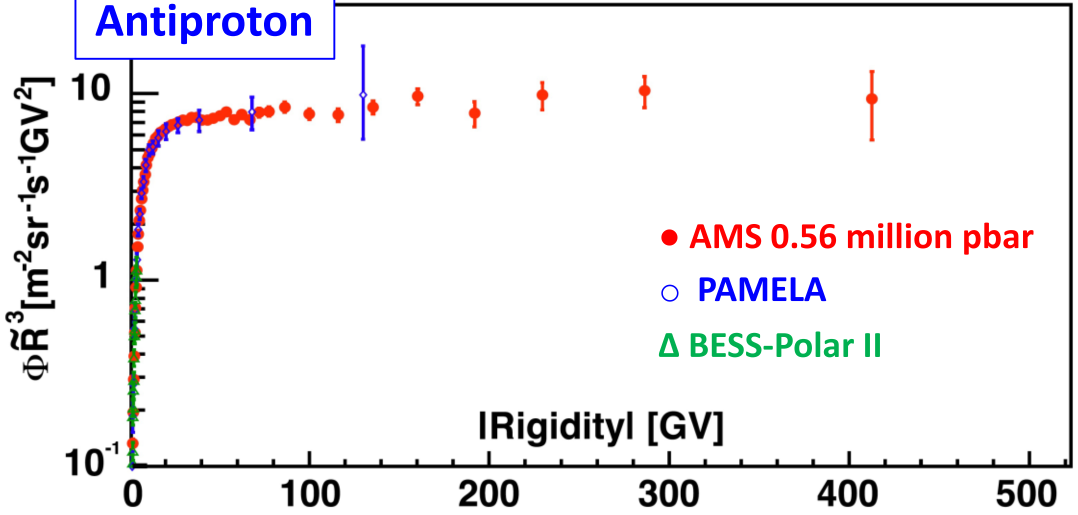
Proton

R: [0.4 GeV – 1.8 TeV]



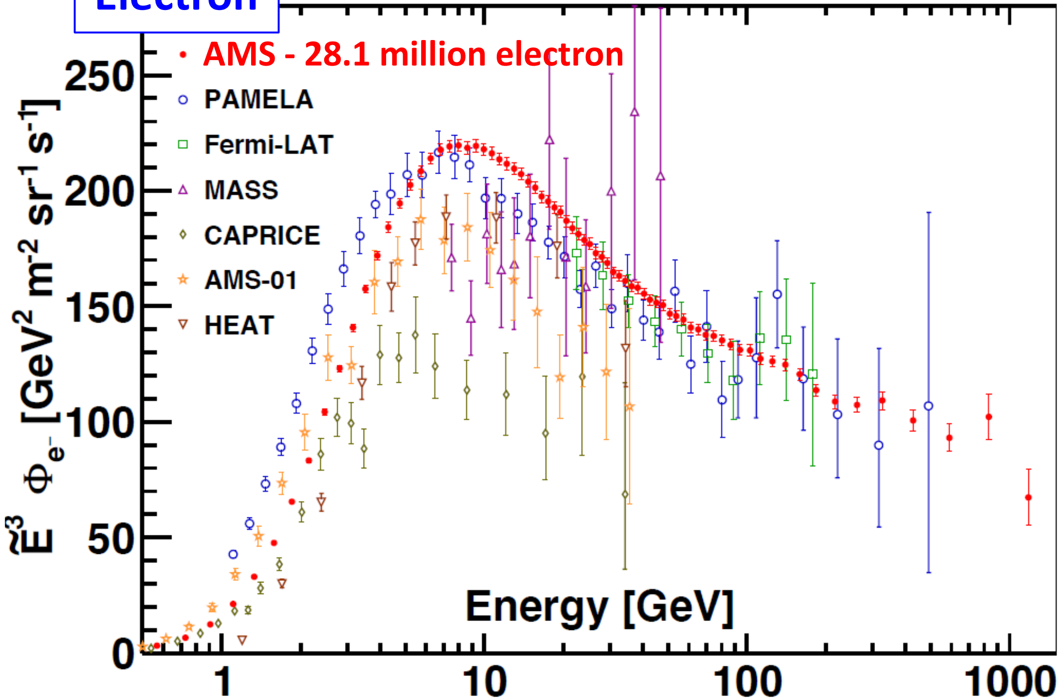
Antiproton

|R|: [1.GV – 525 GV]



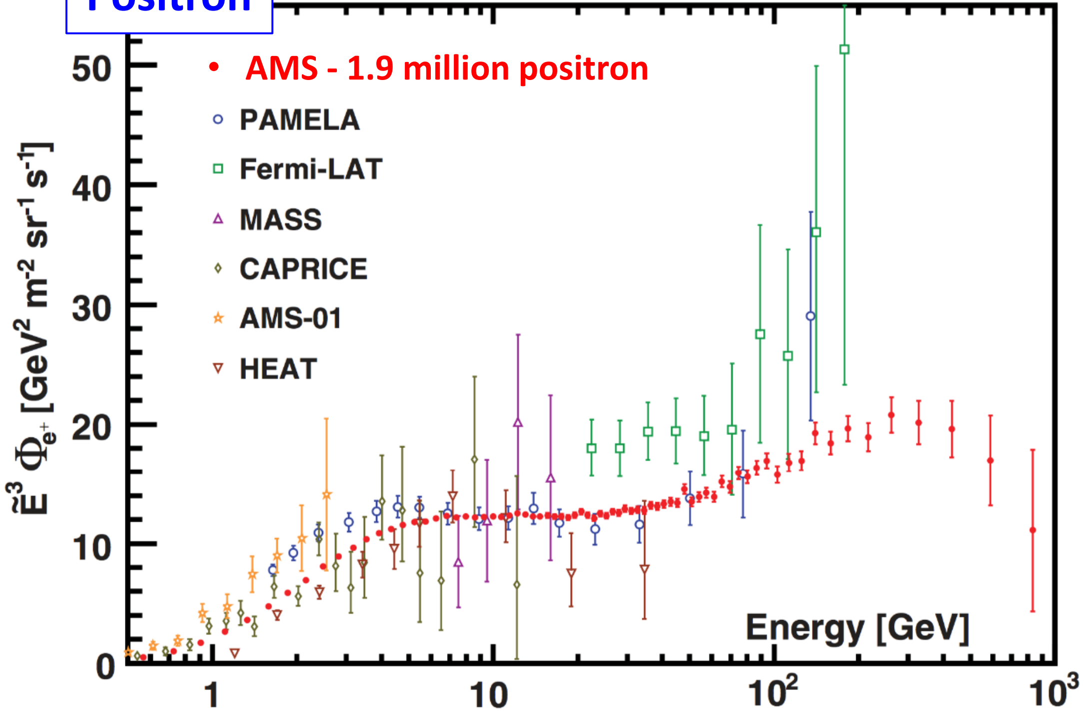
Electron

E: [0.5 GeV – 1.4 TeV]



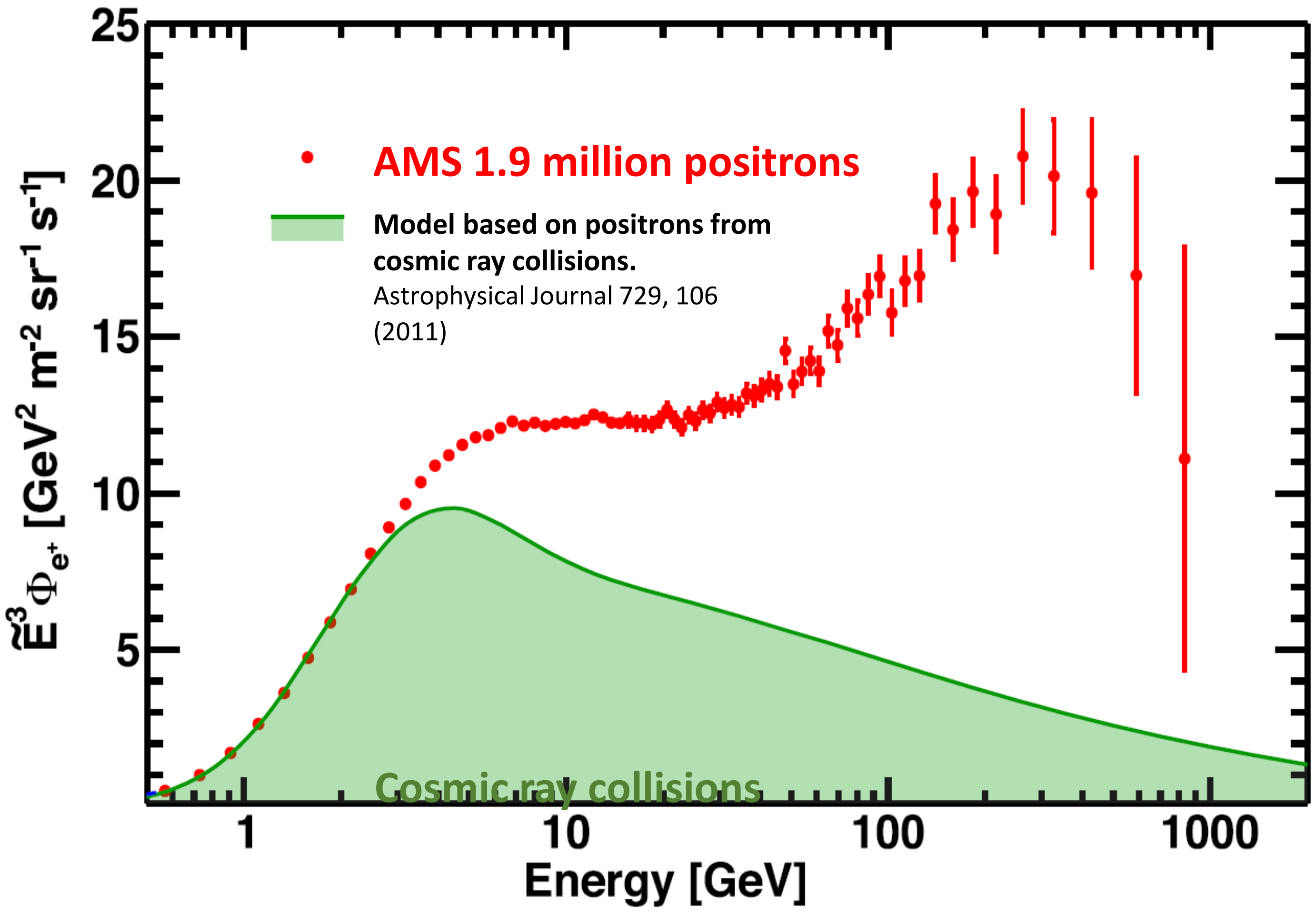
Positron

E: [0.5 GeV – 1.0 TeV]



Positron flux

Positron flux shows an excess above 10 GeV that is not consistent with only the secondary production of positrons.



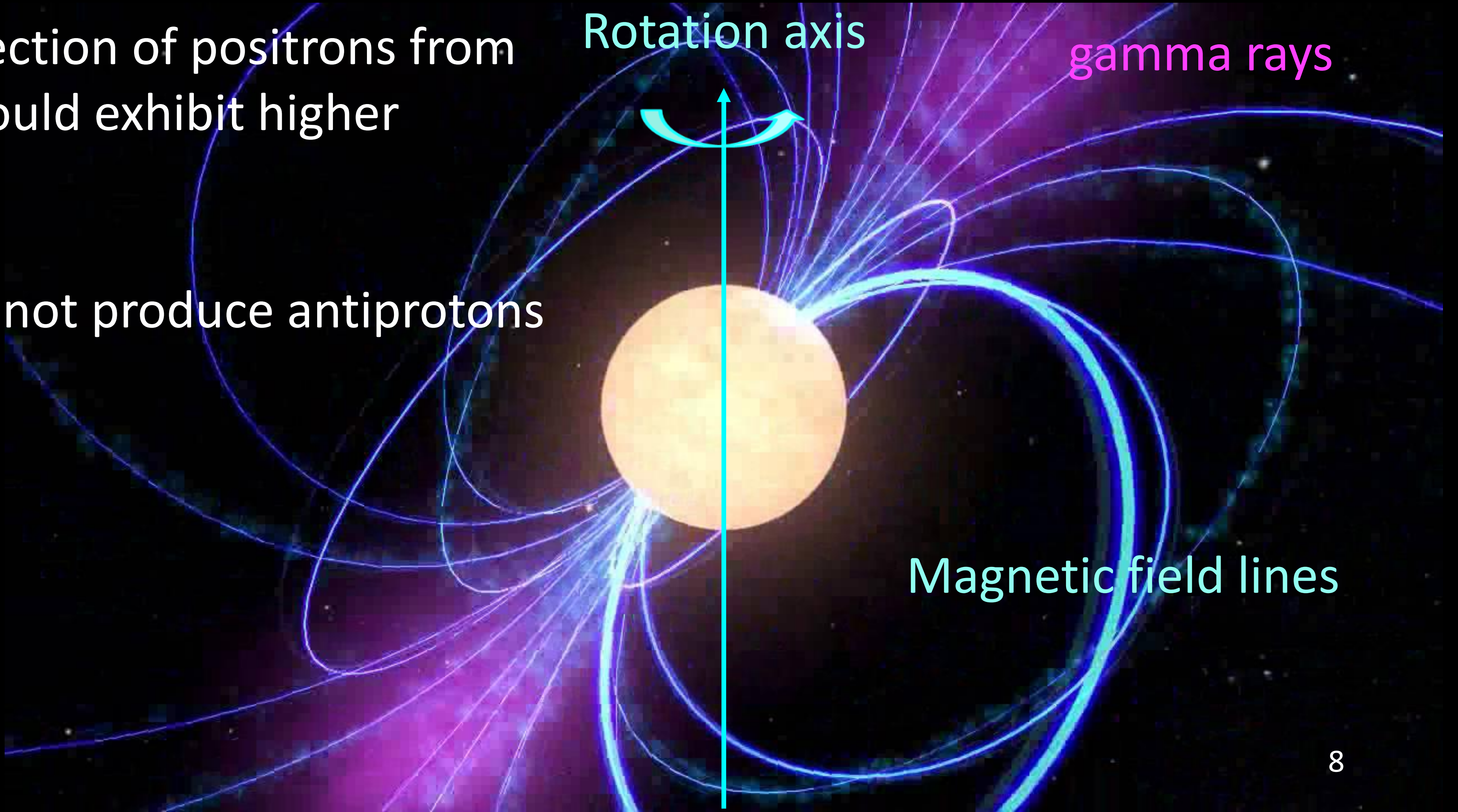
The observation requires the inclusion of primary sources whether from a particle physics or an astrophysical origin.

Positrons from Pulsars

Pulsars produce and accelerate positrons at high energy.

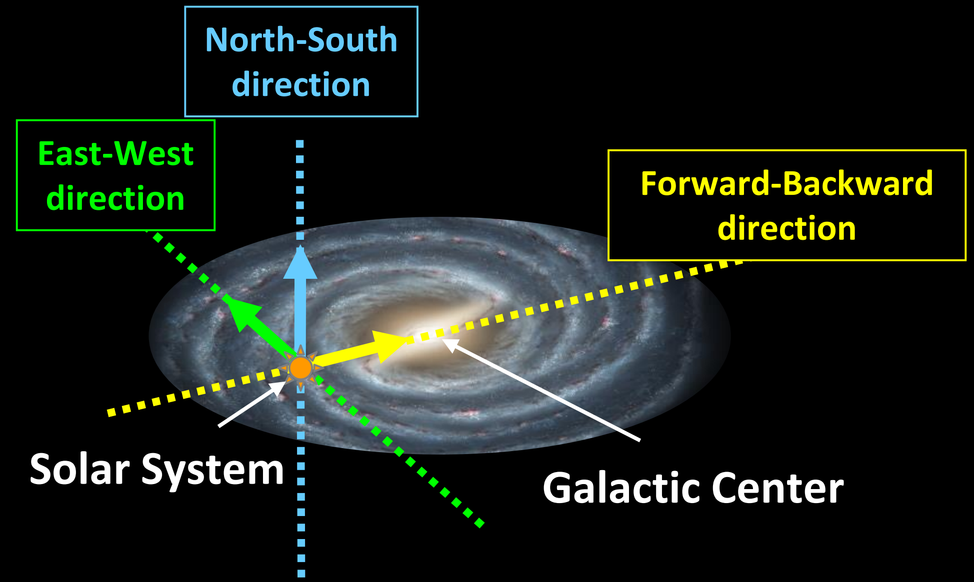
1. Arrival direction of positrons from Pulsars should exhibit higher anisotropy

2. Pulsars do not produce antiprotons

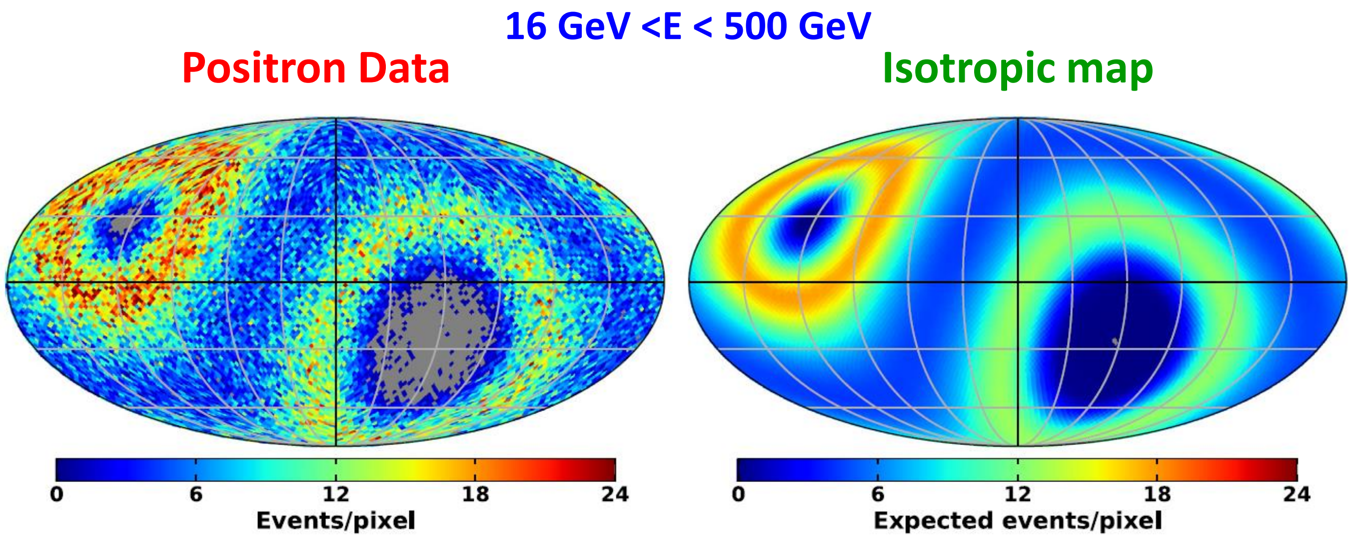


Positron absolute anisotropy

Galactic Coordinates



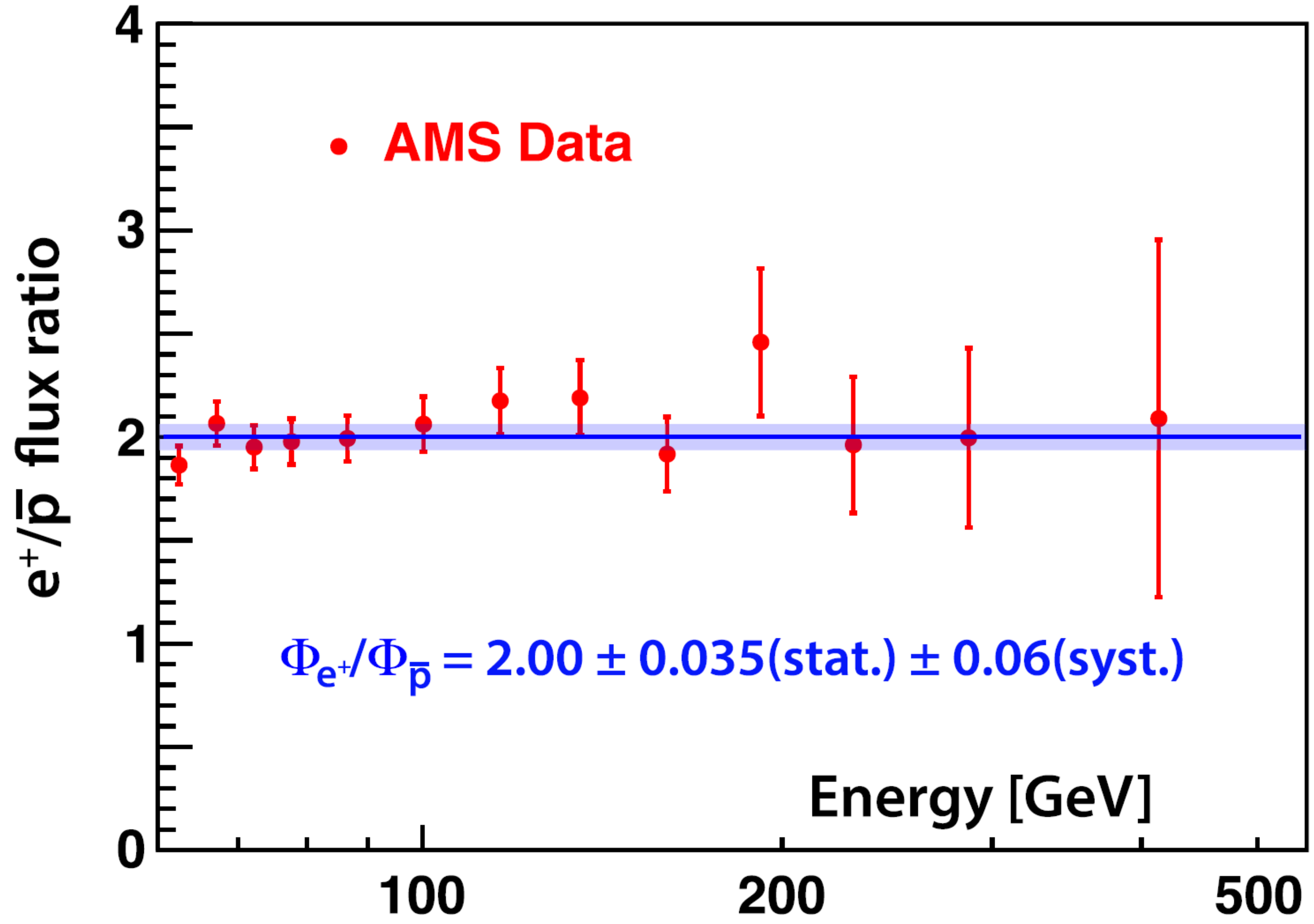
The arrival directions of positron events are compared to the expected map for an isotropic flux in galactic coordinates



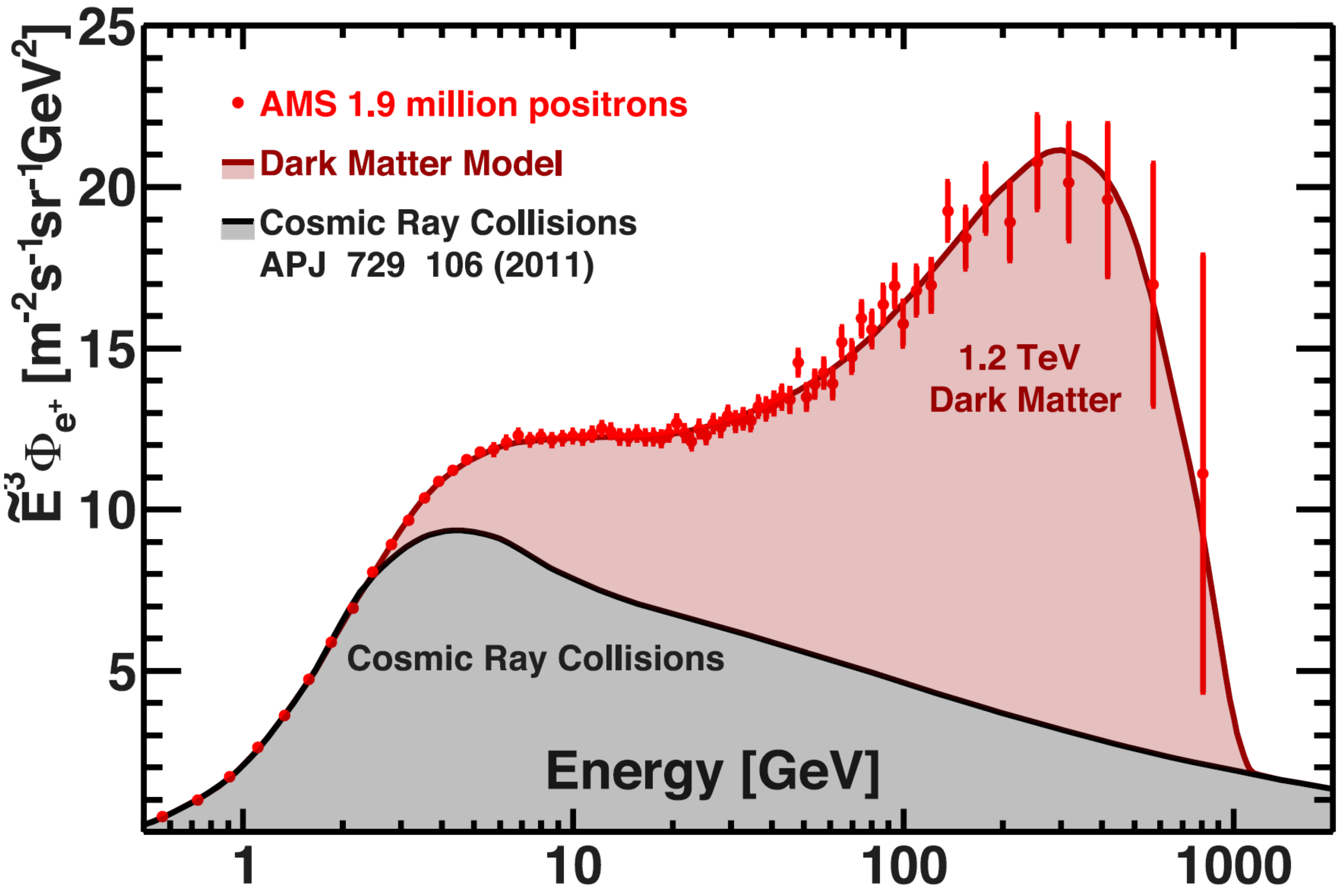
Results are consistent with isotropy

Positron to Antiproton ratio

Antiproton data show a similar trend as positrons

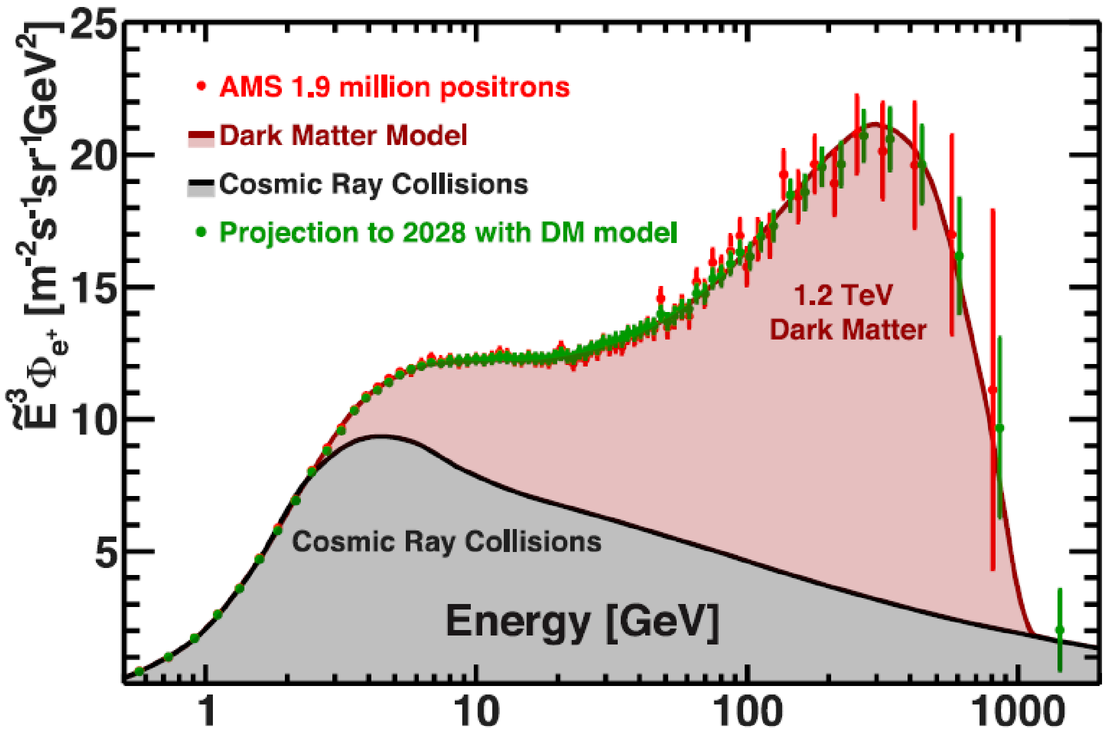


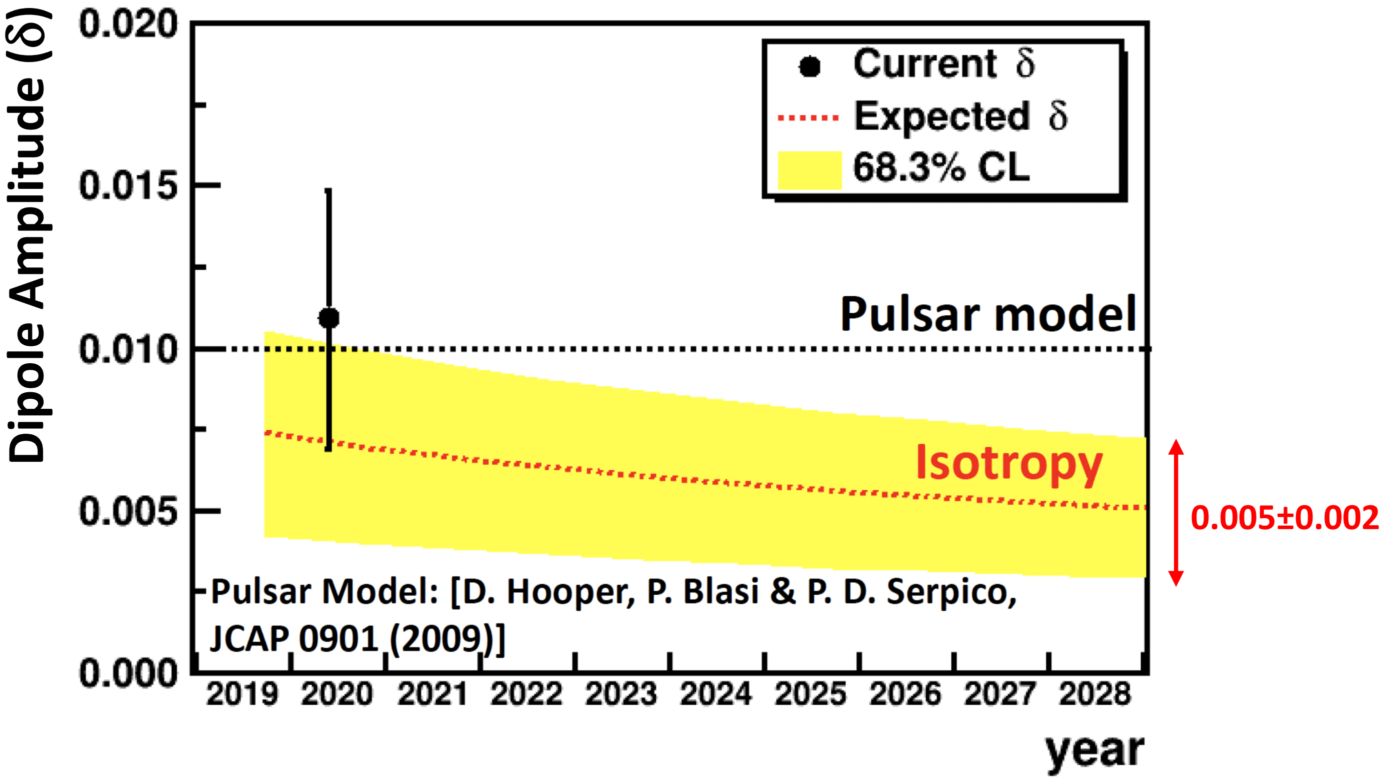
Dark Matter Model



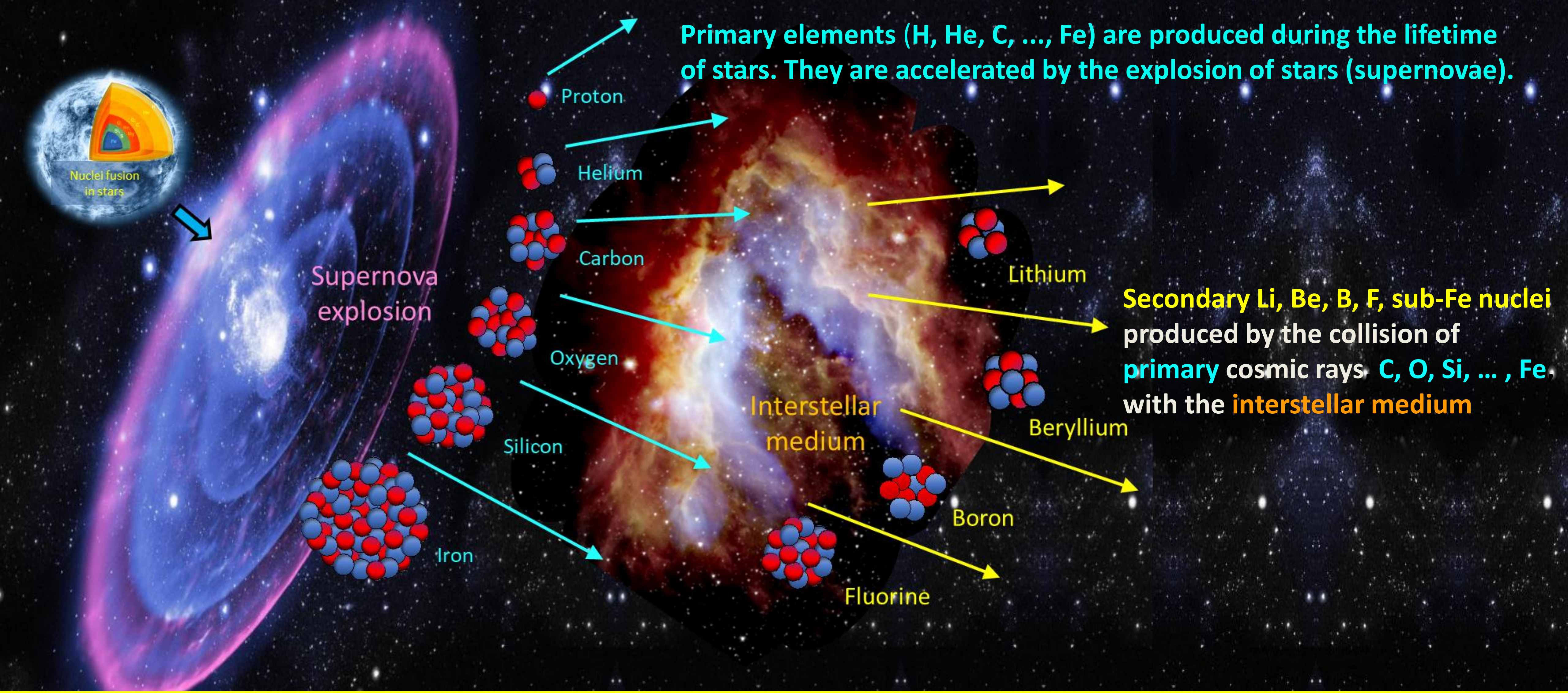
The Origin of Positrons

By continuing AMS operation through the live time of the Space Station, we will extend the measurement to higher energies.



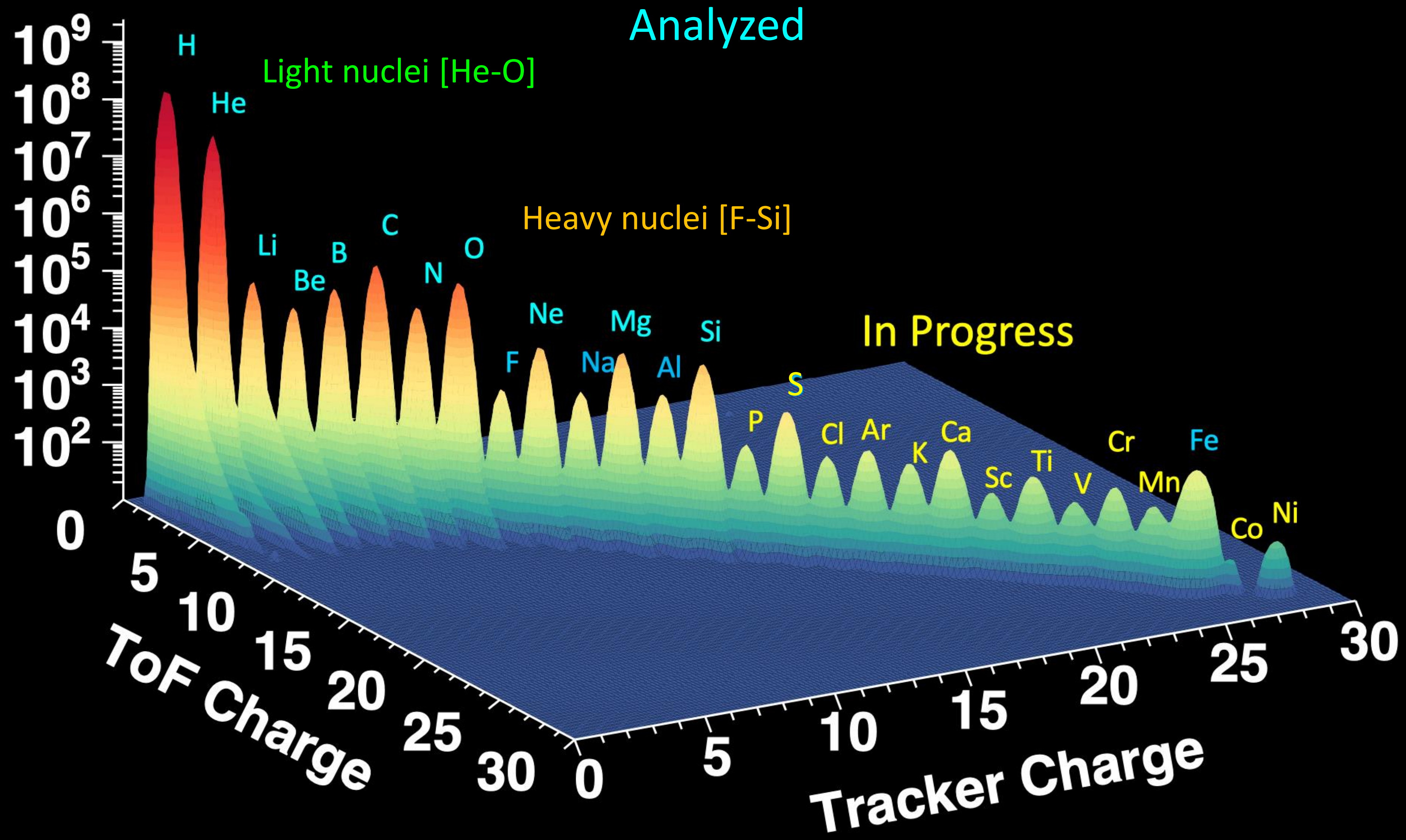


Nuclei Cosmic Rays



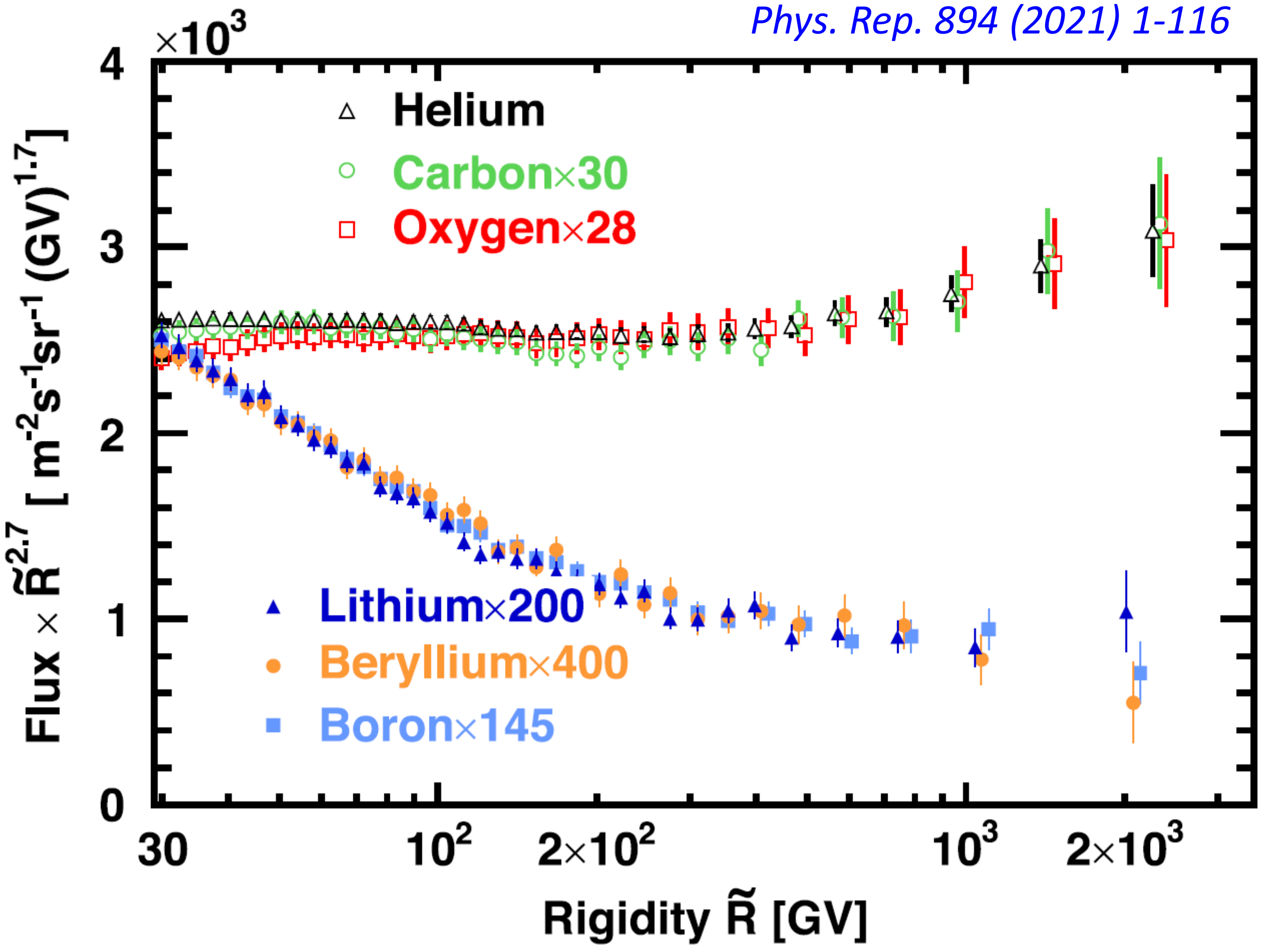
Precise measurements of primary and secondary rigidity dependences provide key information on propagation and source processes

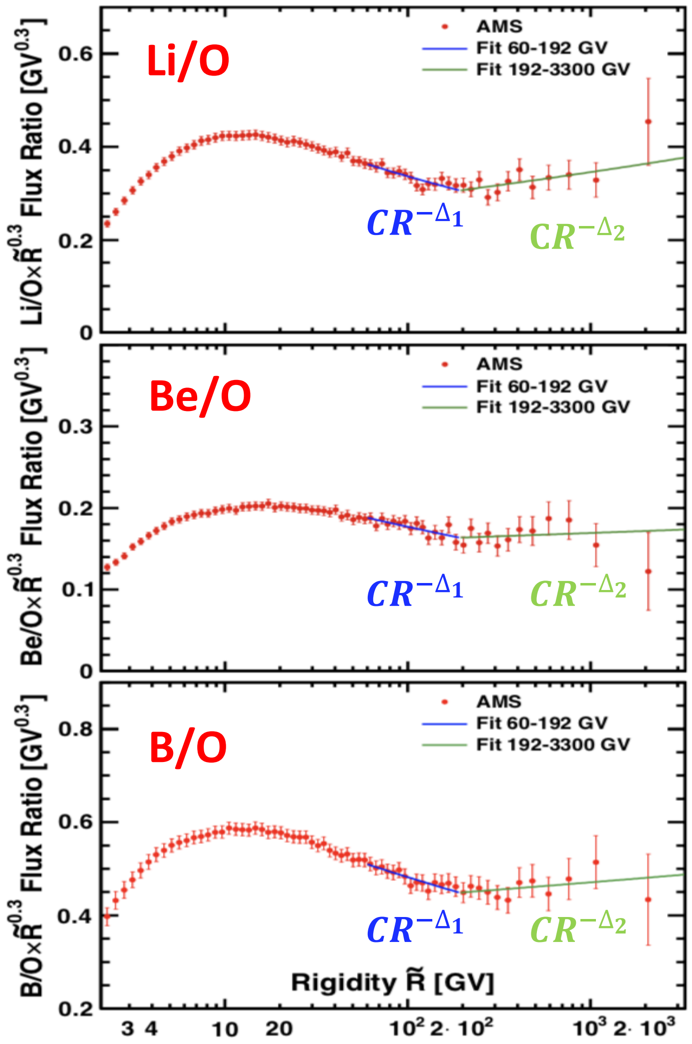
Nuclei cosmic rays detected by AMS



Latest AMS Measurements of Light Nuclei in Cosmic Rays

Above 200 GV, primary and secondary cosmic ray deviate from a single power law





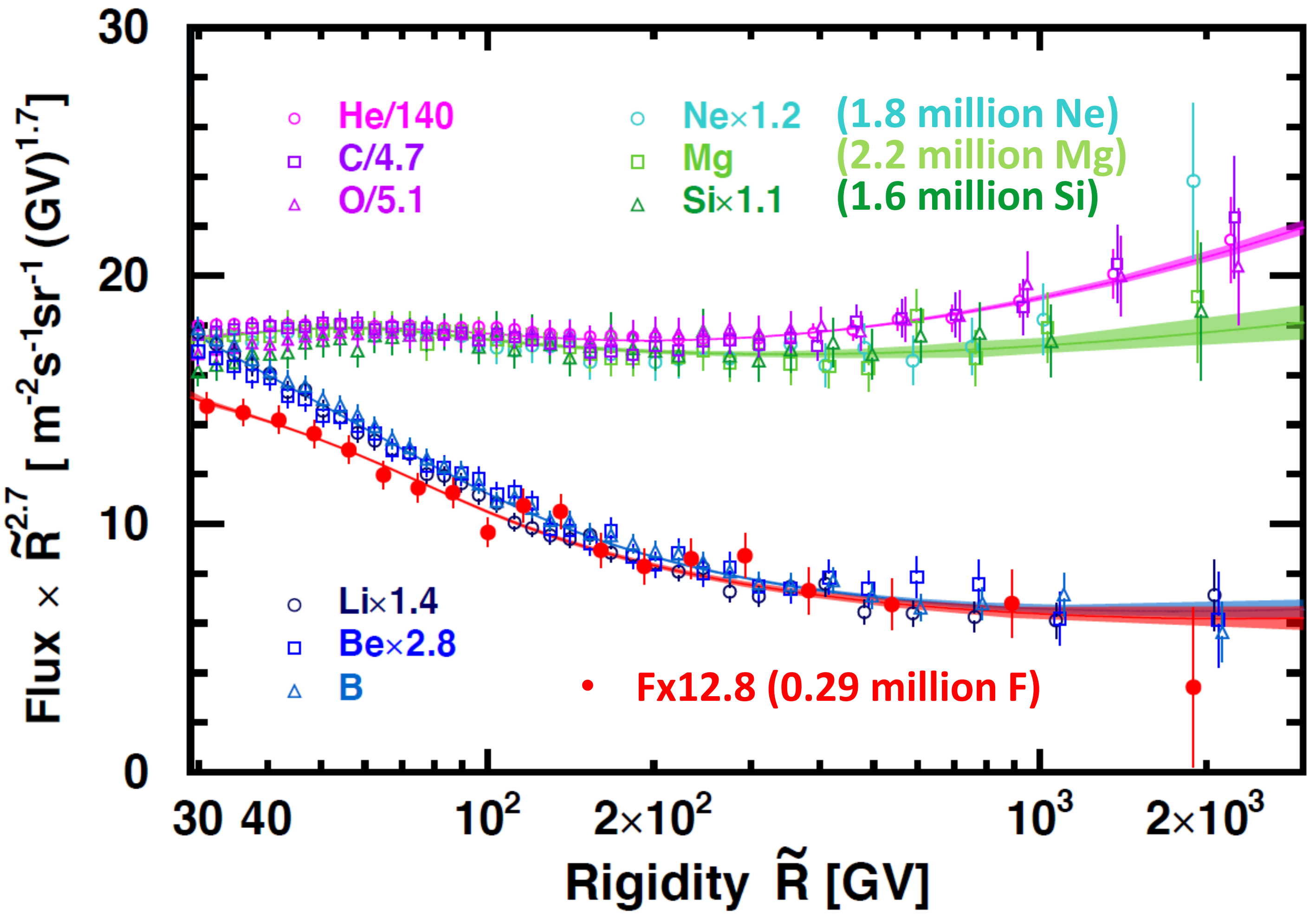
Secondary cosmic ray harden more than primary

Average hardening $\Delta = \Delta_2 - \Delta_1$ = 0.140 ± 0.025 (significance 5.6 σ)

Heavy Cosmic Rays

Above 200 GV, primary and secondary cosmic ray deviate from a single power law

PRL 124, 211102 (2020)   PRL 126, 081102 (2021)



Ne, Mg, Si have distinctly different rigidity behavior from He, C, O

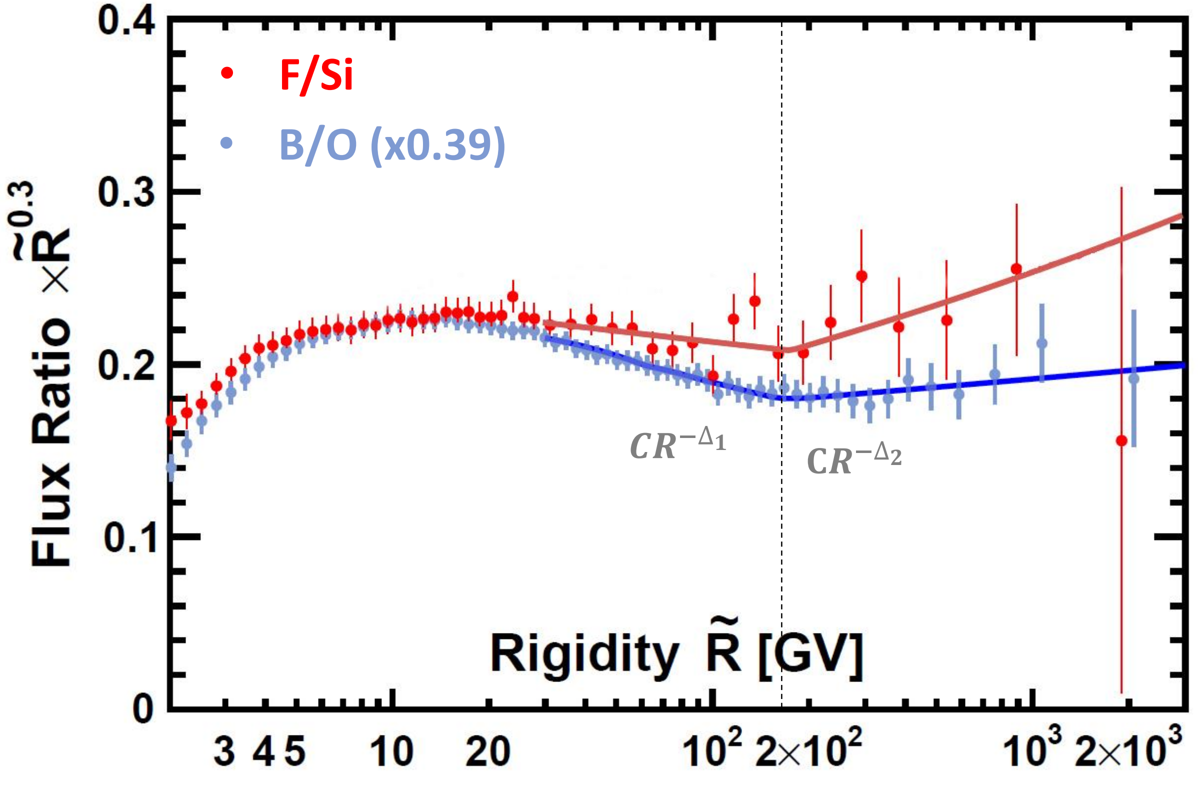
F also has distinctly different rigidity dependence from Li, Be, B

Heavier secondary-to-primary flux ratios (F/Si)

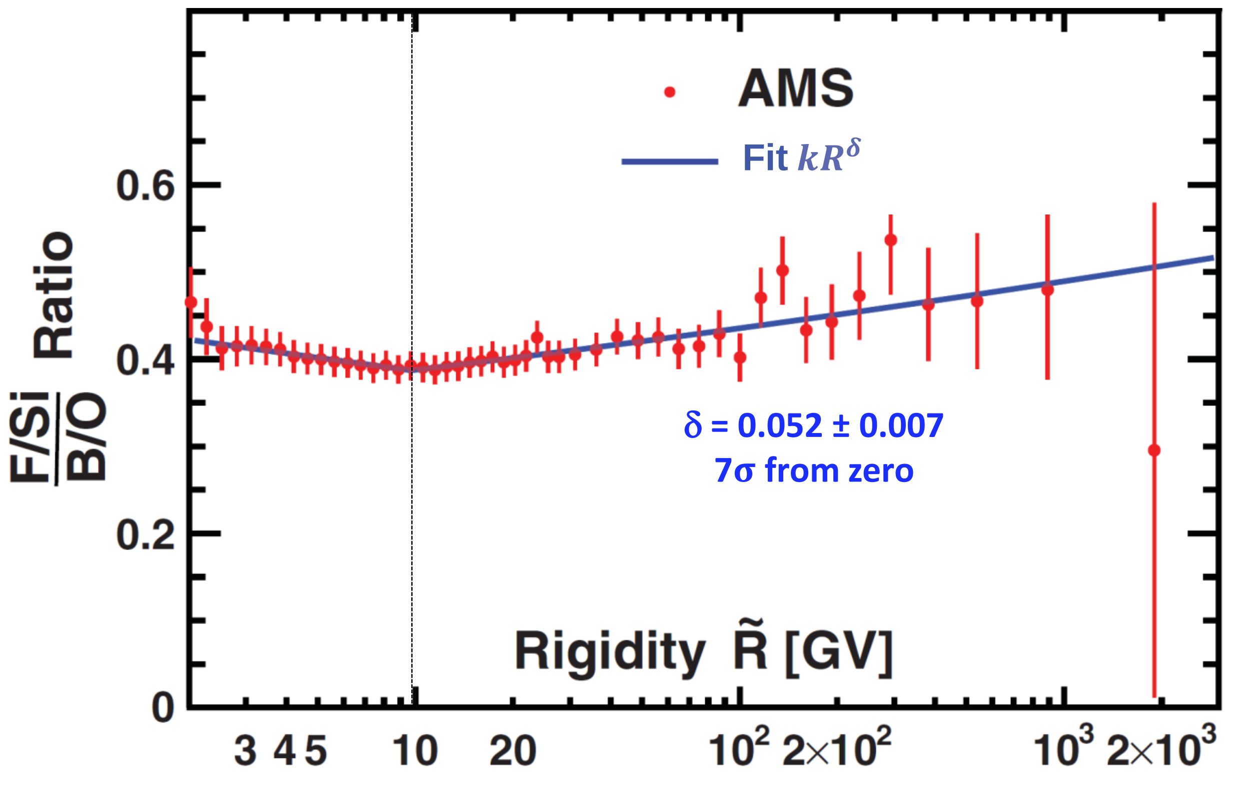
Traditionally the light secondary-to-primary ratio B/O (or B/C) is used to describe the propagation properties of all cosmic rays.

F/Si flux ratio hardens above 175 GV

Average hardening $\Delta = \Delta_2 - \Delta_1 = 0.15 \pm 0.07$

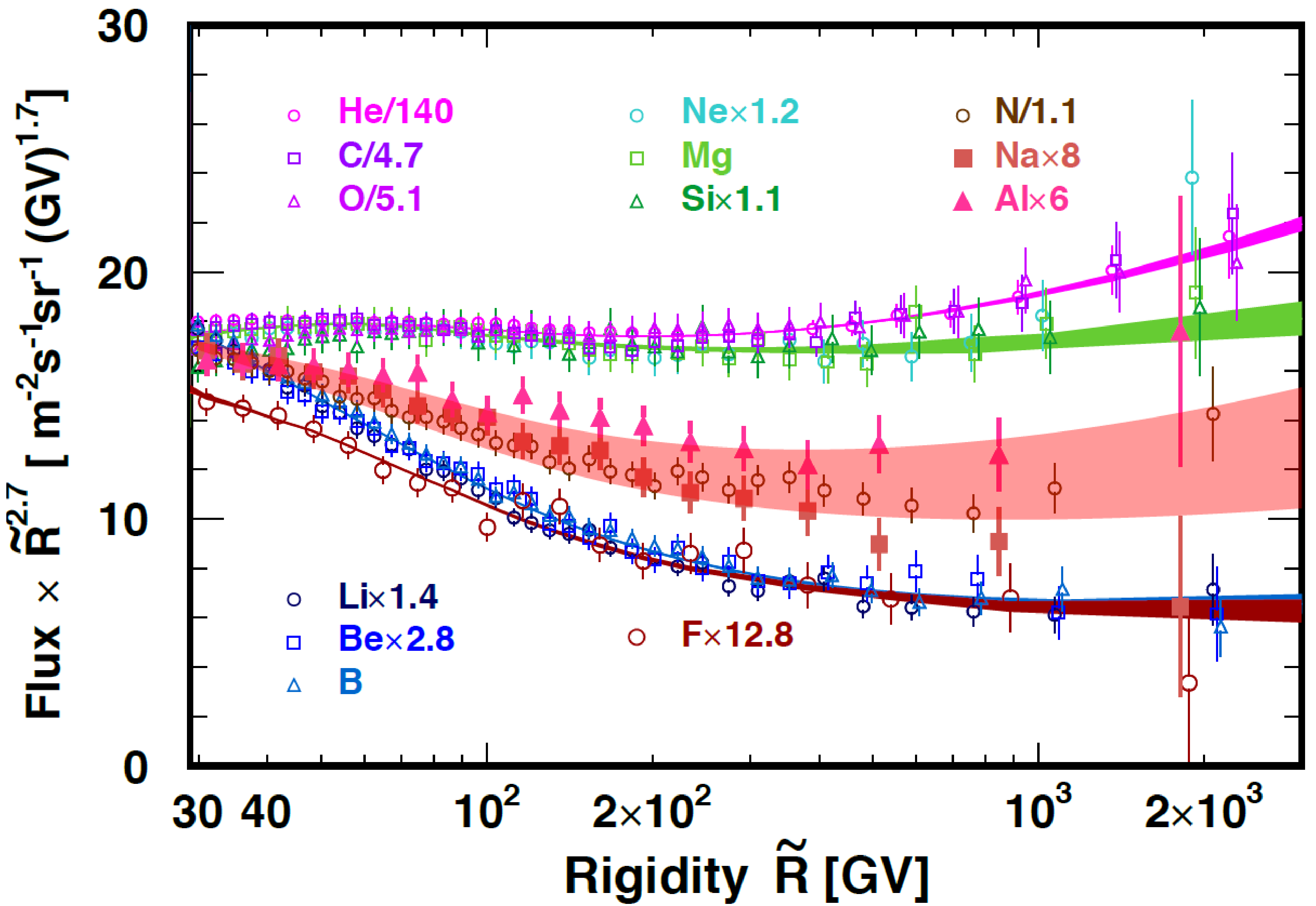


Above 10 GV, the (F/Si)/(B/O) ratio can be described by a single power law with δ=0.052±0.007



The propagation properties of heavy cosmic rays are different from those of light CRs.

AMS Nuclei Cosmic Rays fluxes



Cosmic Nuclei with both, Primary and Secondary components (N, Na, Al)

3.9×10^6 Nitrogen
0.46×10^6 Sodium
0.51×10^6 Aluminum

N, Na and Al fluxes expressed as sum of primary and secondary

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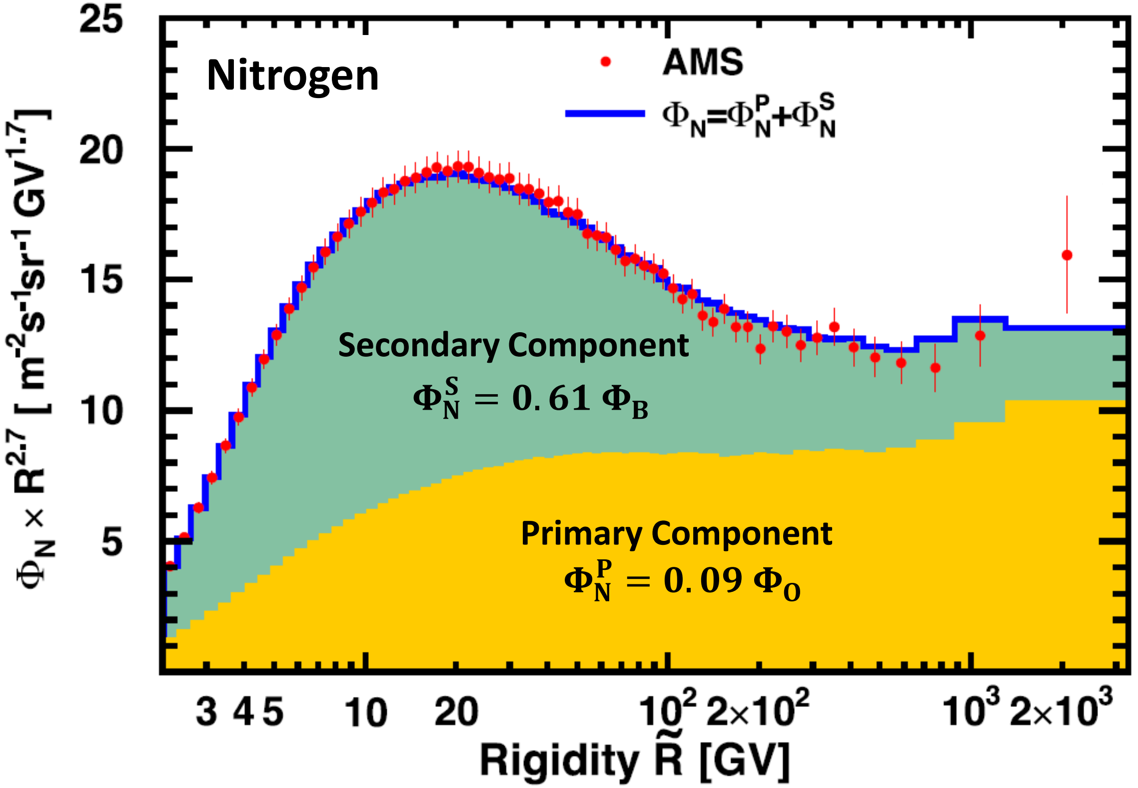
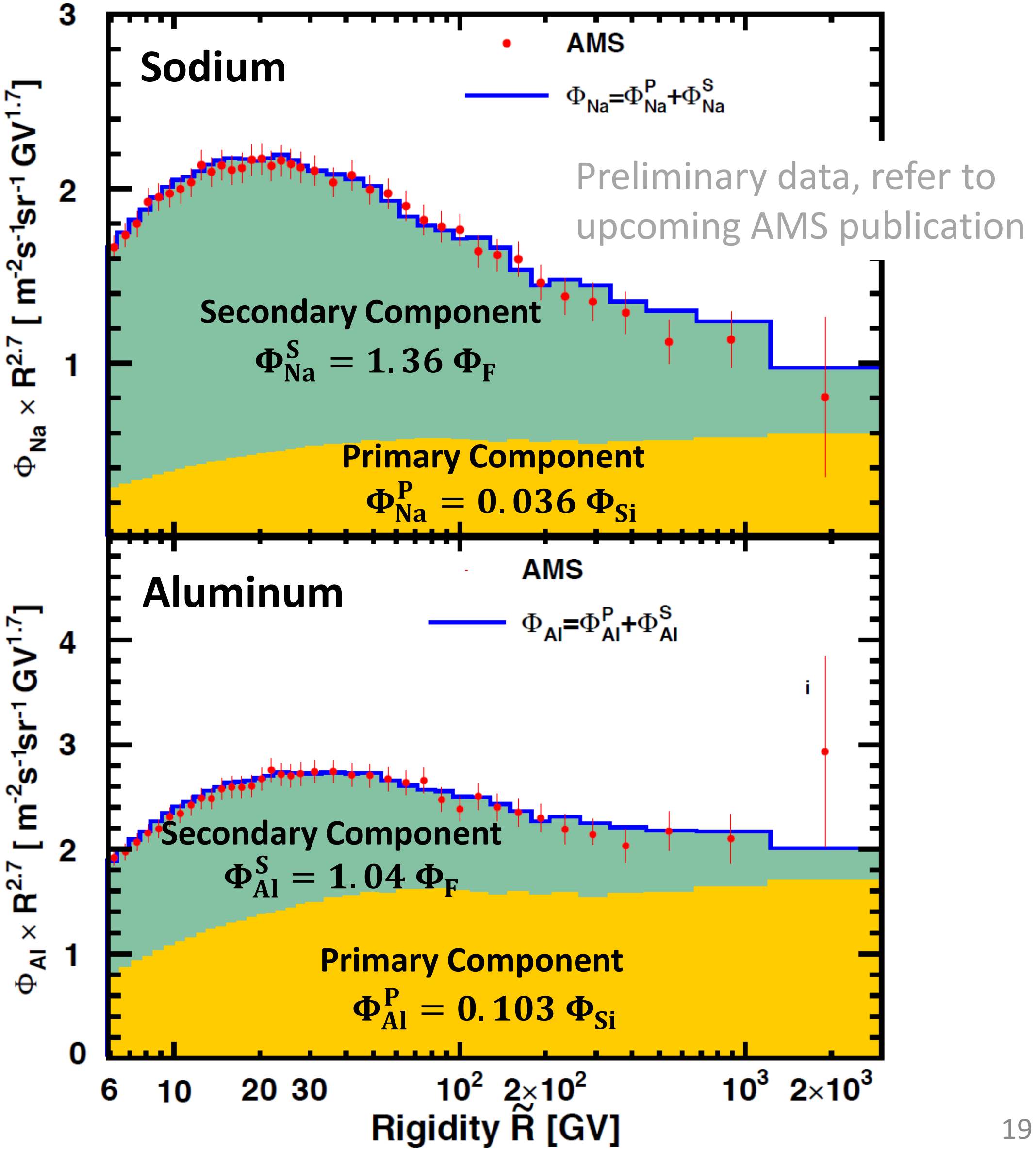


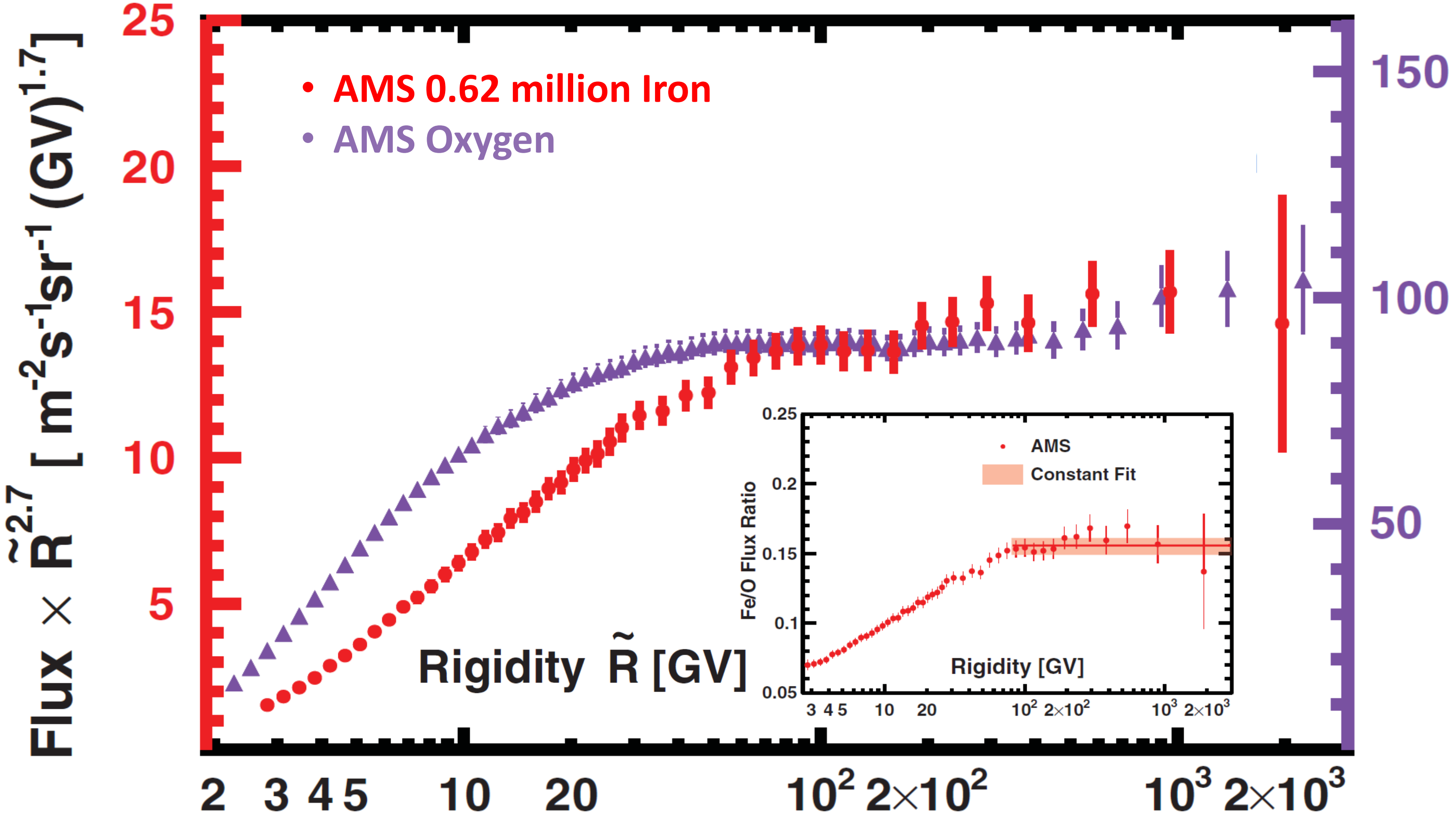


ϕ_N / ϕ_O, ϕ_{Na} / ϕ_{Si}, and ϕ_{Al} / ϕ_{Si} abundance ratios at the source are determined without the need to consider the Galactic propagation of cosmic rays.

Iron nuclei flux

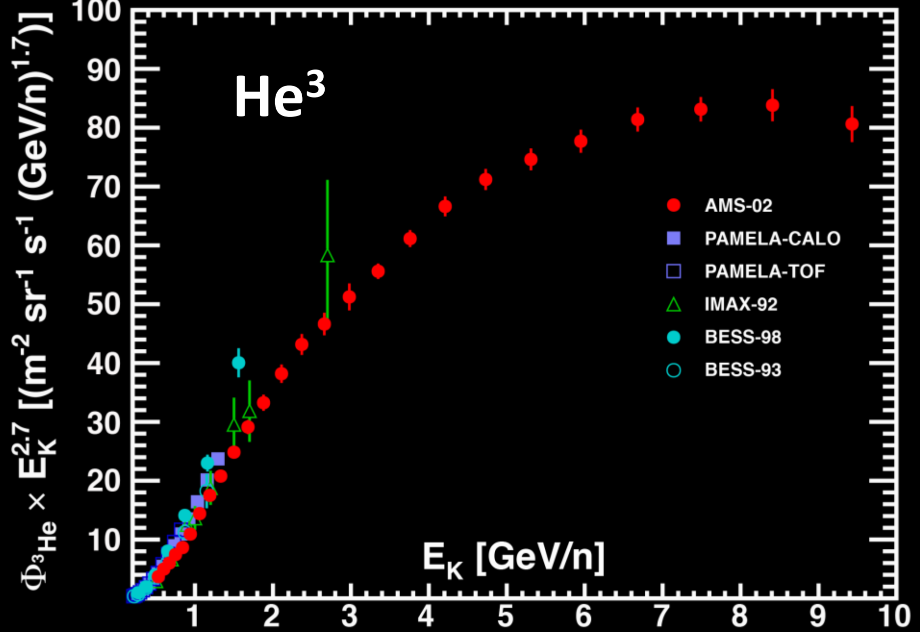
Above 200 GV, Iron flux deviates from a single power law

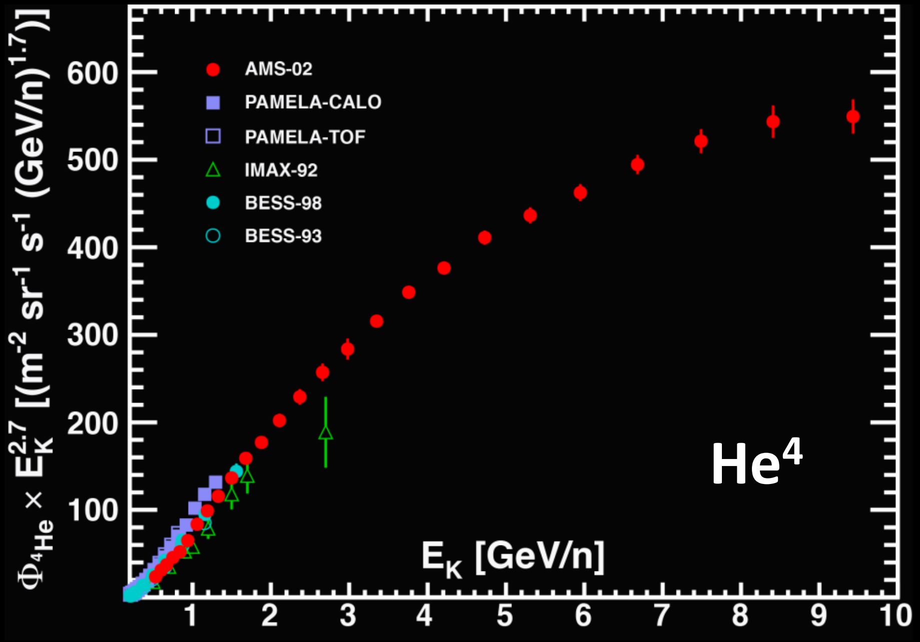
PRL 126, 041104 (2021)

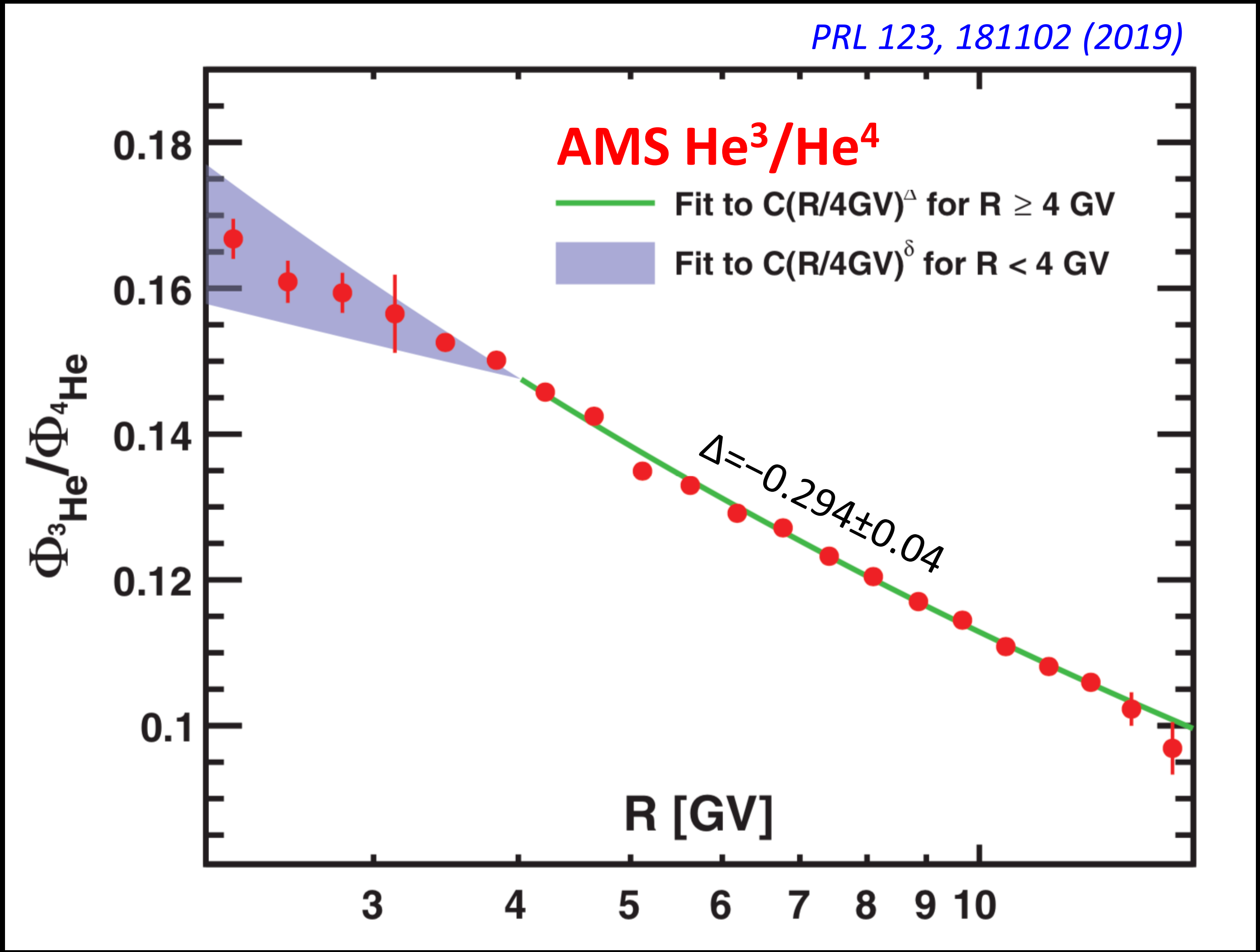


Iron and Oxygen have identical rigidity dependence above 80.5 GV

Measurement of Isotopes with AMS 02

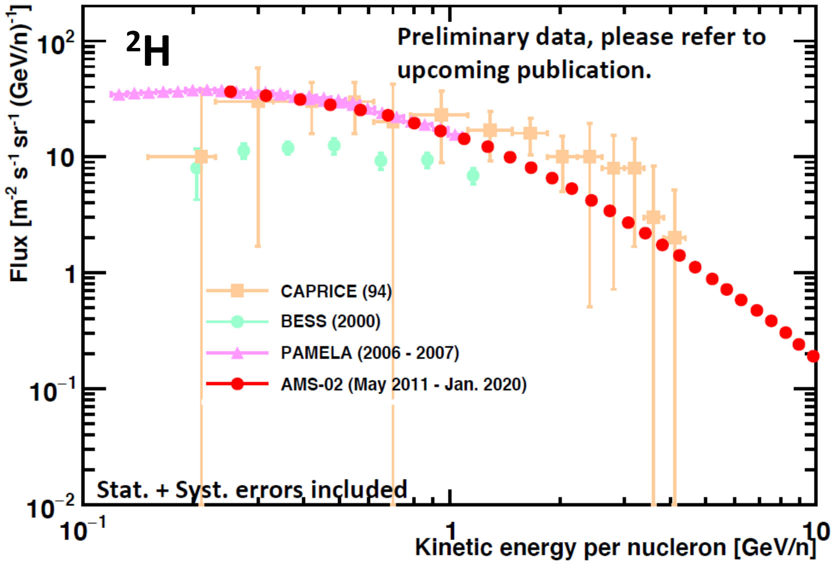


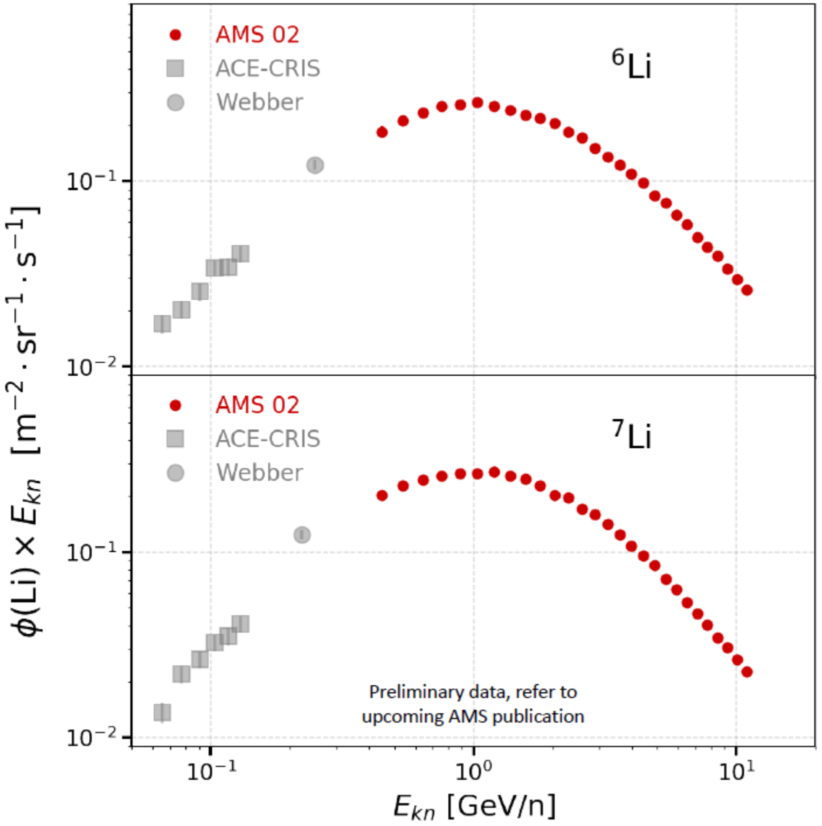


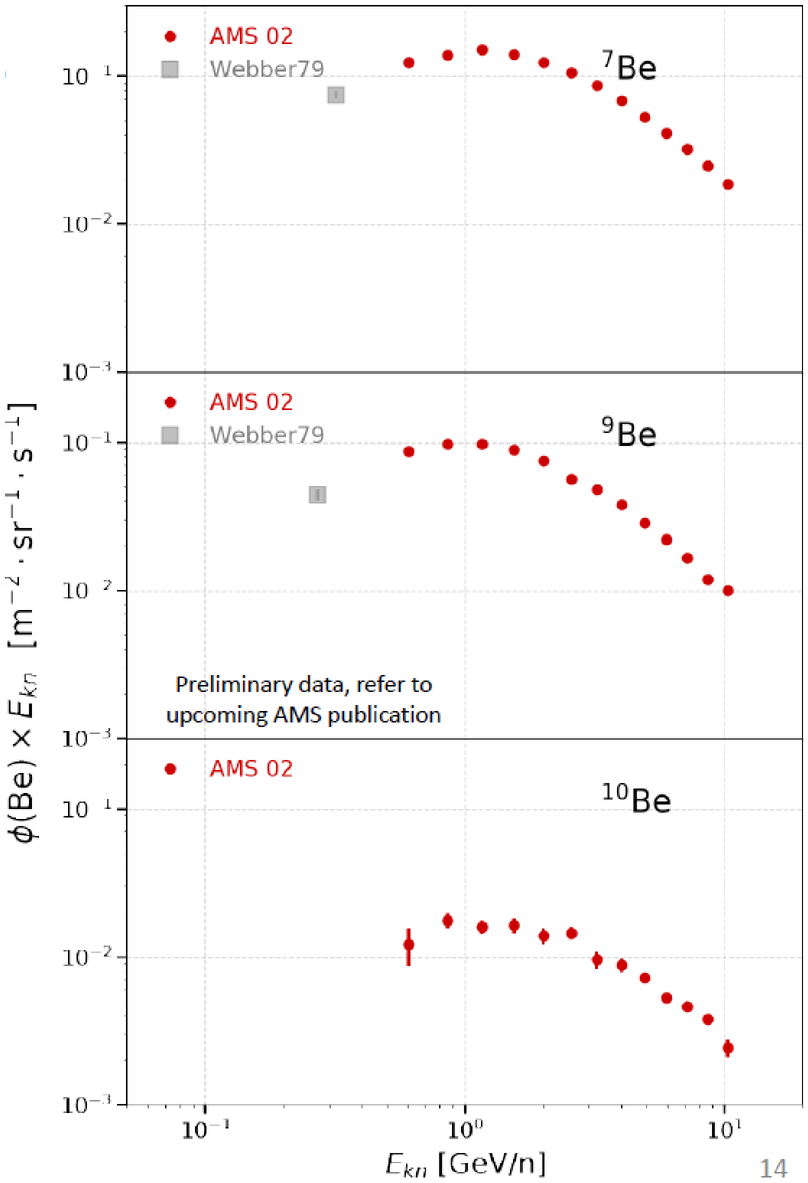


Measurement of Isotopes with AMS 02

Extend the measurement up to 10 GeV/n

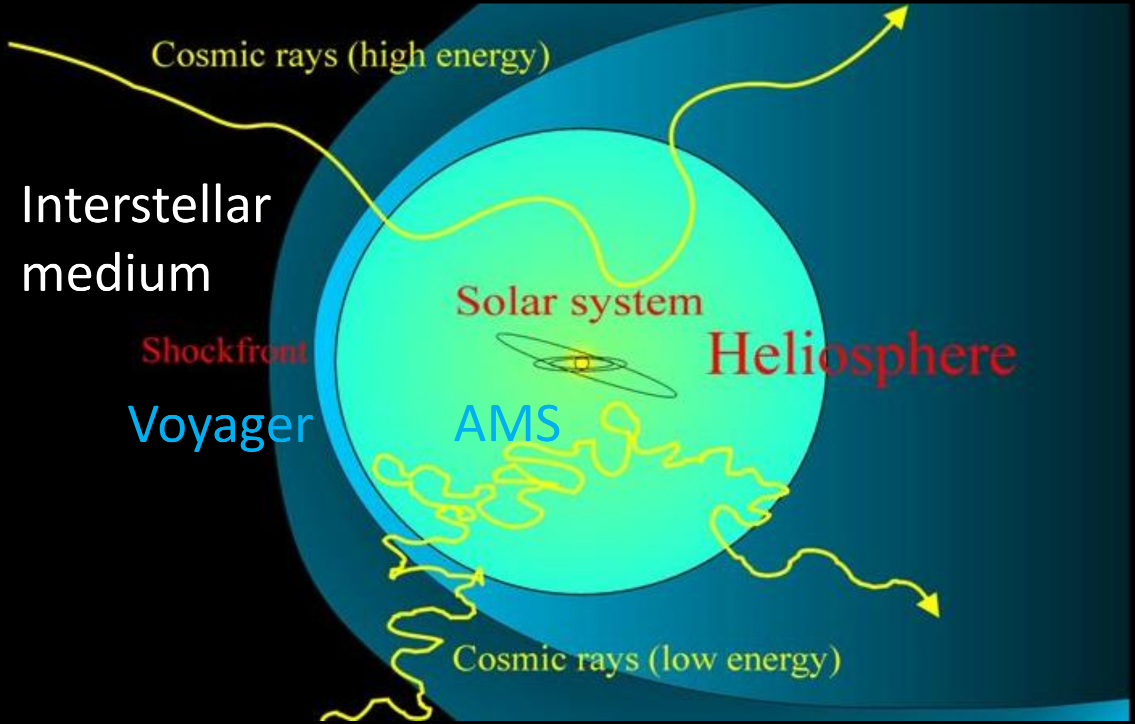


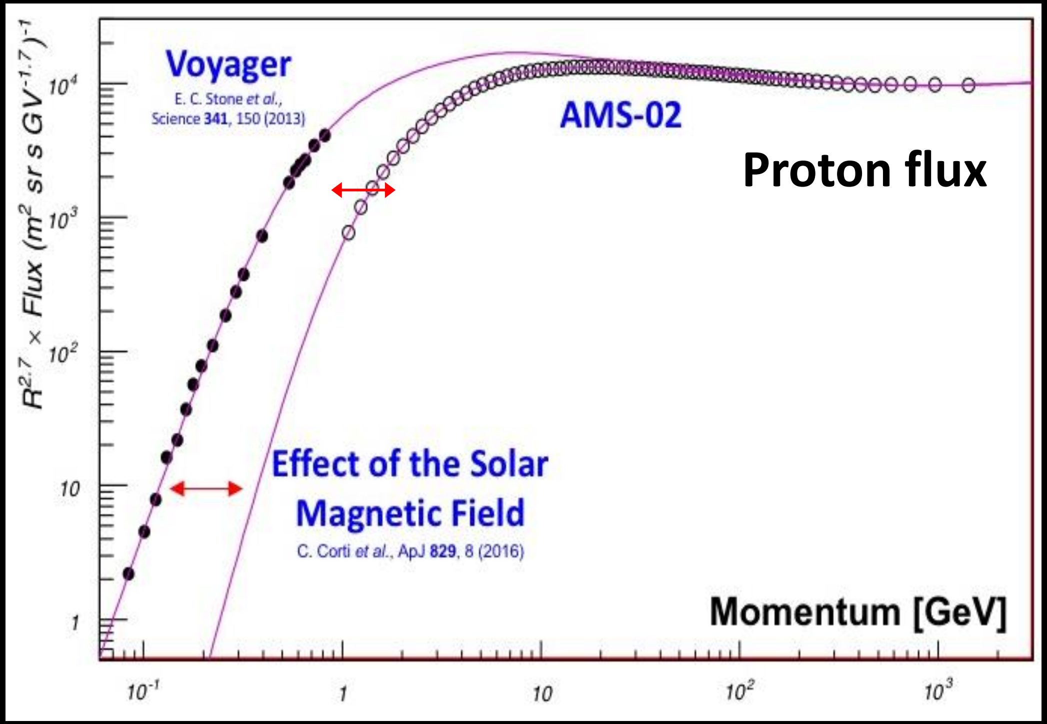




Cosmic ray spectra and Solar Physics

Cosmic rays from the interstellar medium are "screened" by the heliosphere
This is particularly visible at low energies





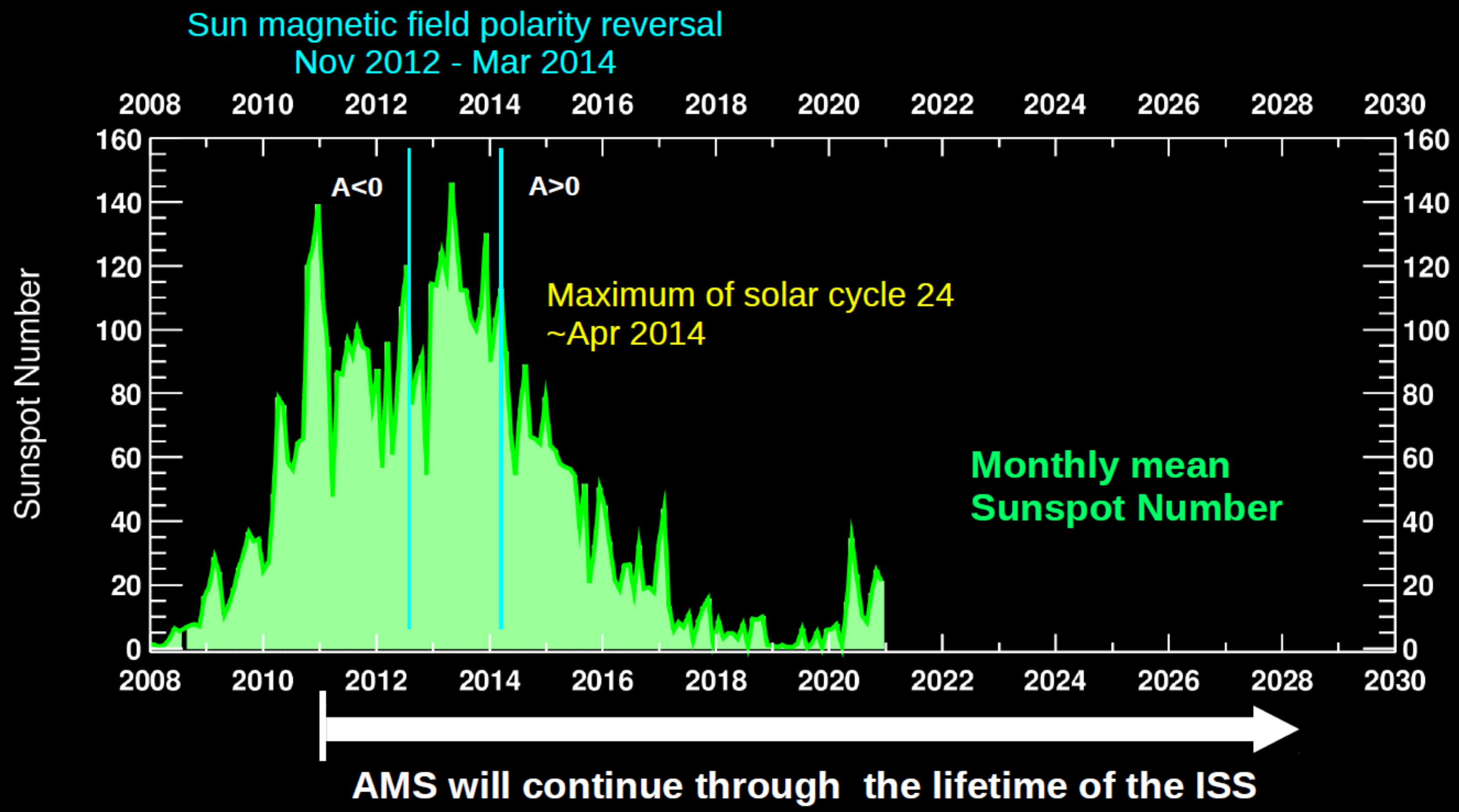
The temporal evolution of the interplanetary space environment causes disturbances in the cosmic-ray fluxes that correlate with solar activity

Measurements of time evolution of cosmic ray fluxes of different particles over an extended period of time is very valuable input

AMS period of observation

Cosmic ray flux variations correlate with solar activity at different time scales

The most significant long-term scale variation is the 11-year solar cycle
during which the number of sunspots changes from minimum to maximum and then back to a minimum



Previously, AMS has reported the time evolution of the monthly (Bartels rotation) proton, helium, electrons and positrons fluxes measured during the first 7 years of data taking.

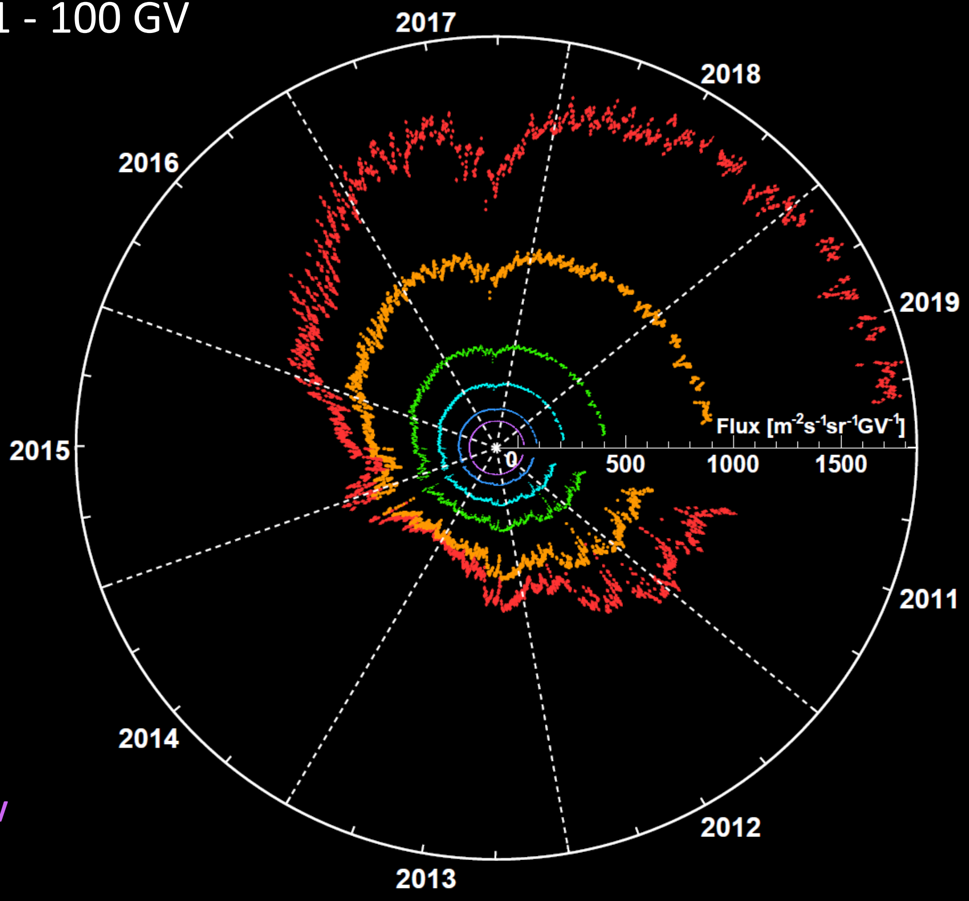
AMS Daily Proton and Helium Fluxes

Preliminary data, refer to upcoming AMS publication

Data collected from May 20, 2011 to October 29, 2019 (2824 days or 114 Bartels rotations)

5.5 billion protons
Rigidity: 1 - 100 GV

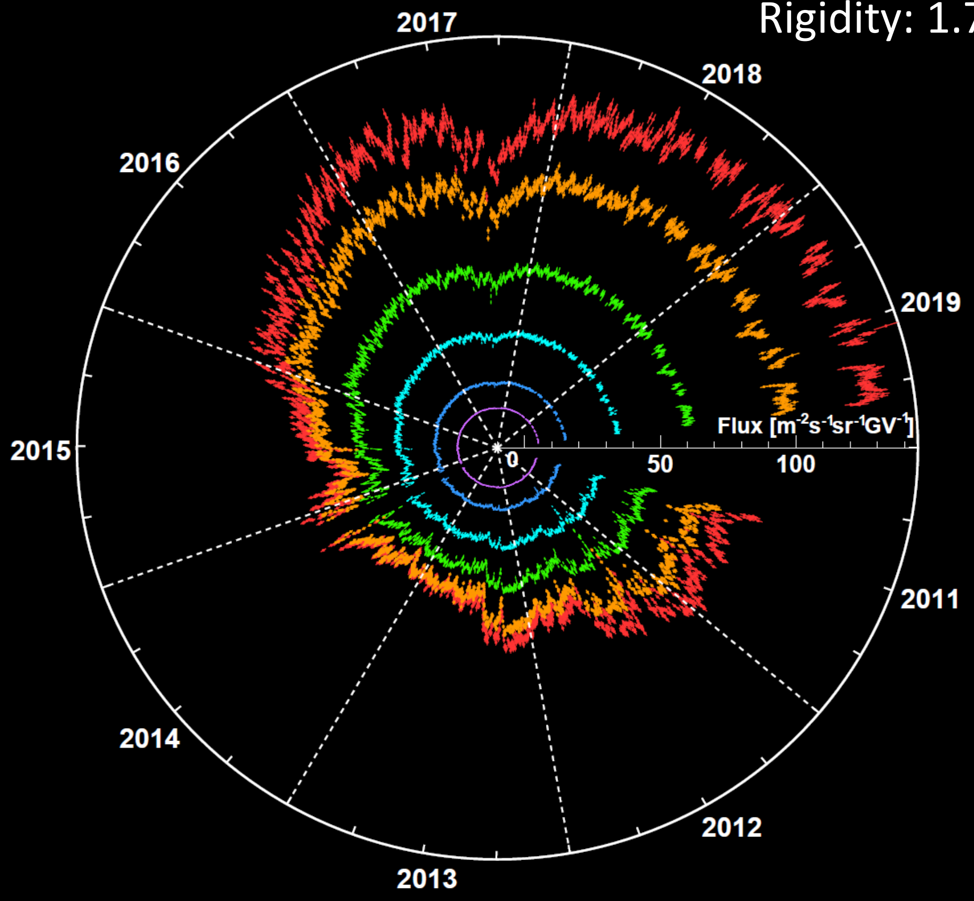
Daily proton flux



[1.00-1.16] GV
[1.92-2.15] GV
[2.97-3.29] GV
[4.02-4.43] GV
[5.90-6.47] GV
[9.26-10.10] GV

Daily helium flux

0.76 billion helium
Rigidity: 1.71 - 100 GV



[1.71-1.92] GV
[2.15-2.40] GV
[2.97-3.29] GV
[4.02-4.43] GV
[5.90-6.47] GV
[9.26-10.10] GV

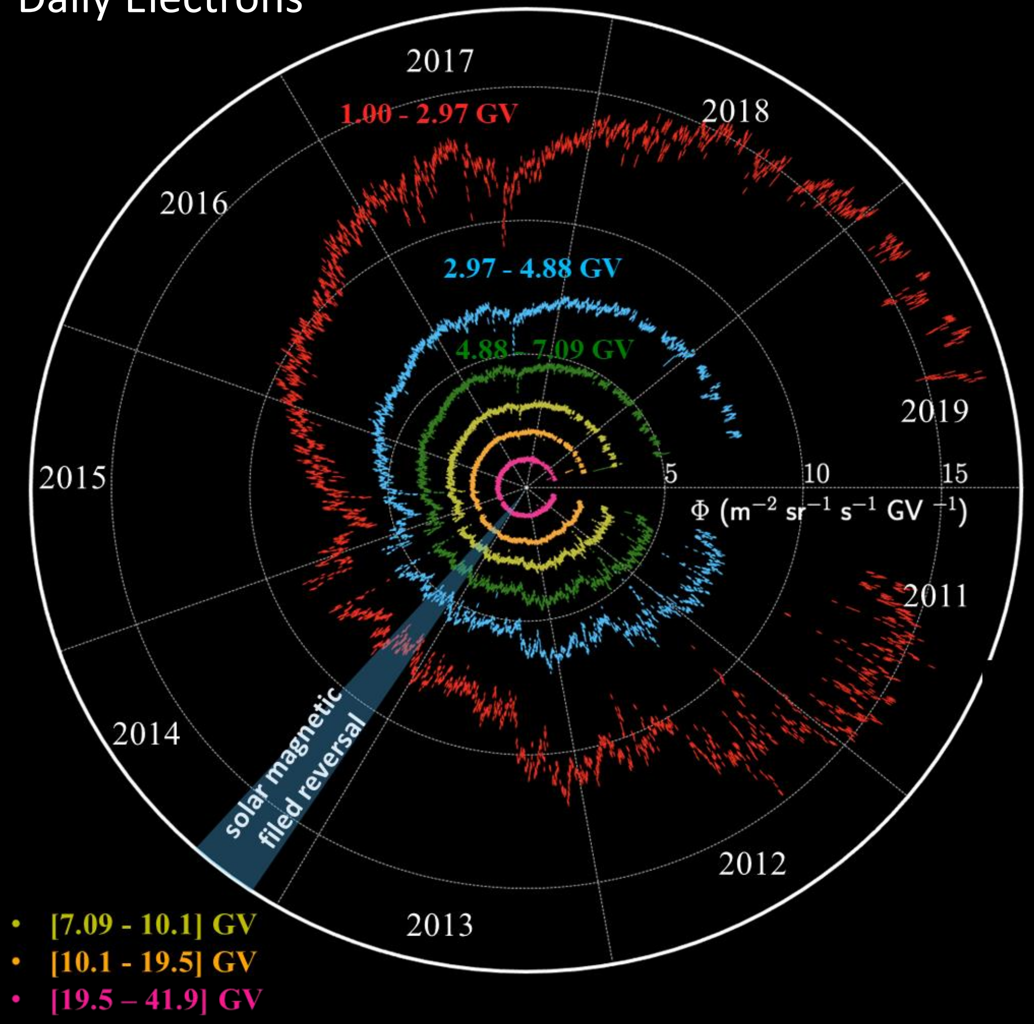
Both fluxes exhibit variations on different time scales, from days to years
The relative magnitude of these variations decreases with increasing rigidity.

AMS Daily Electron and Positron Fluxes

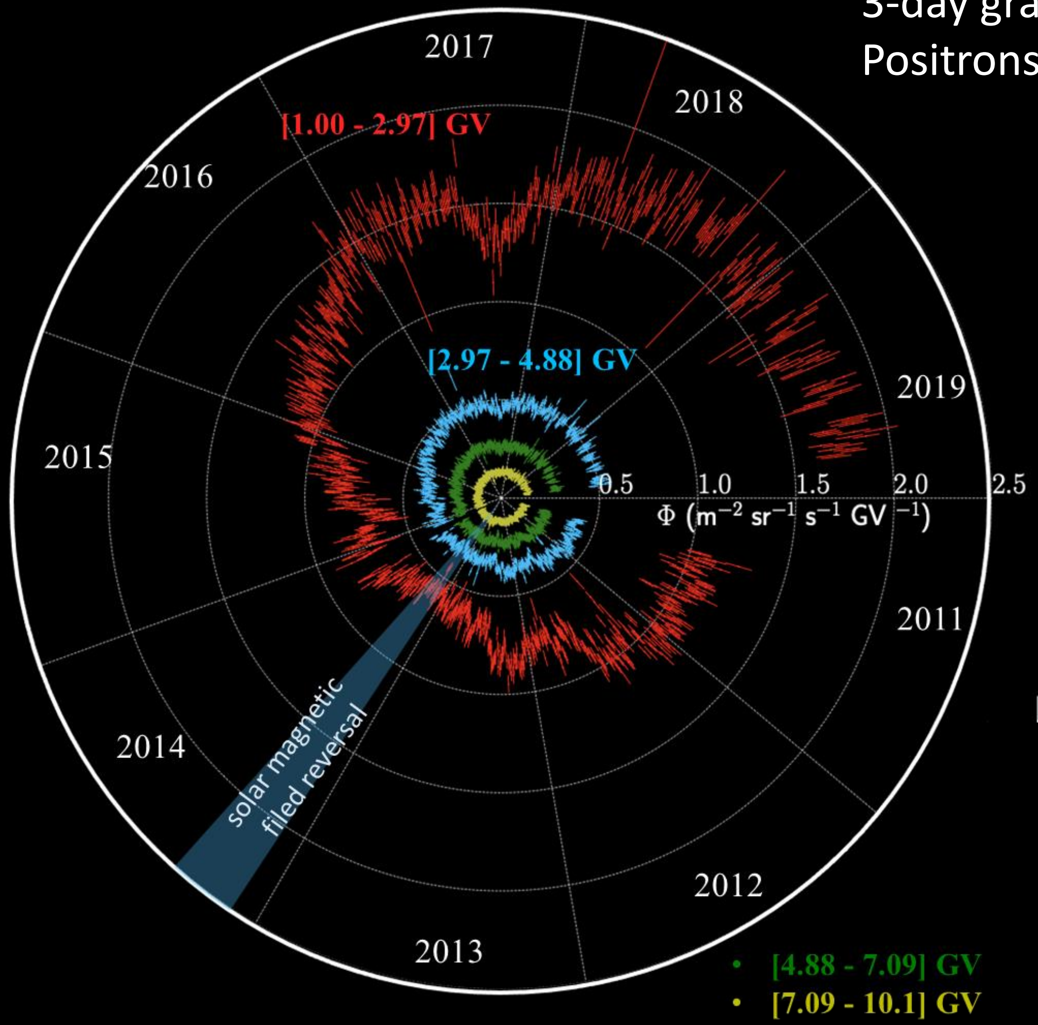
Preliminary data, refer to upcoming AMS publication

Simultaneous measurements of particle and anti-particle over a complete solar activity cycle represent a unique input to study charge-sign dependent heliosphere effects

Daily Electrons



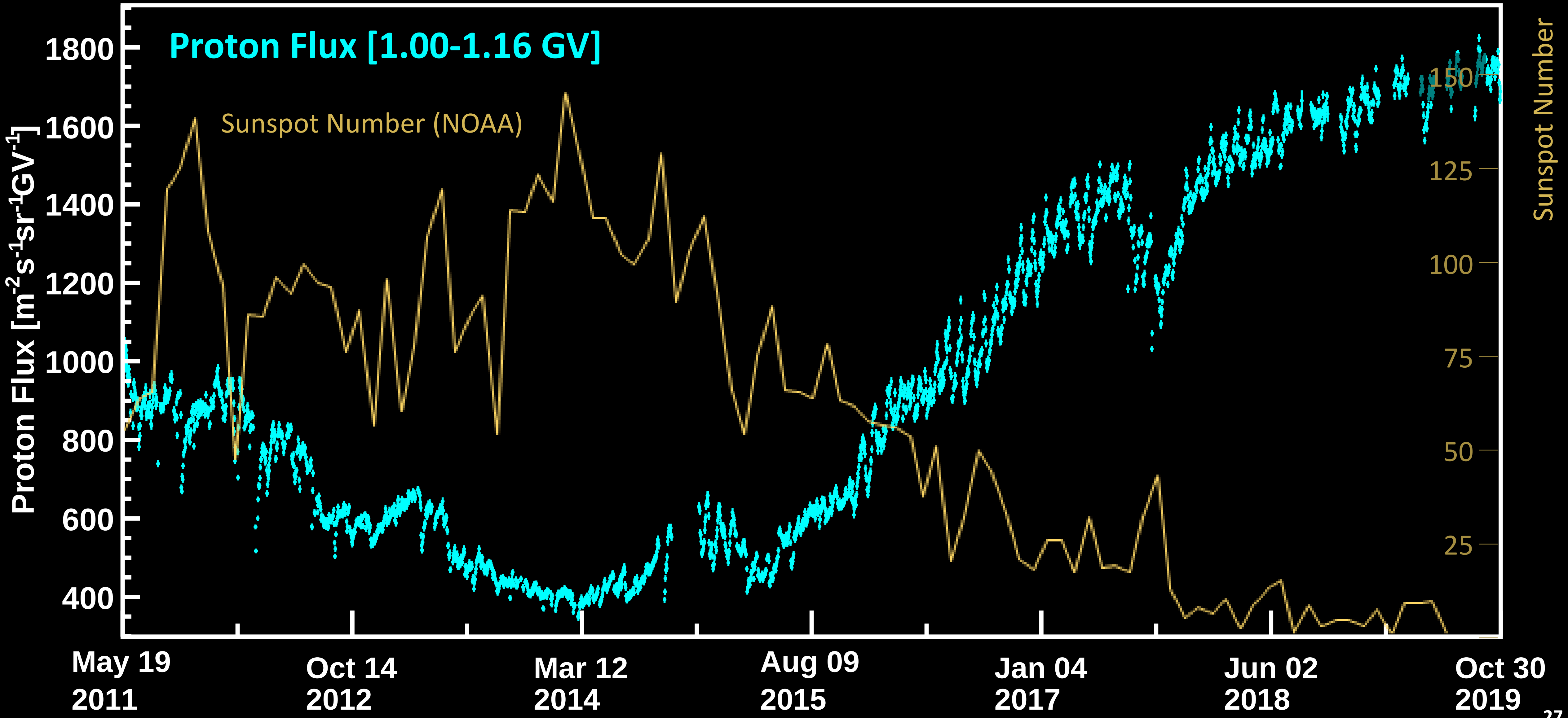
3-day granularity Positrons



AMS Daily Proton Flux

Preliminary data, refer to upcoming AMS publication

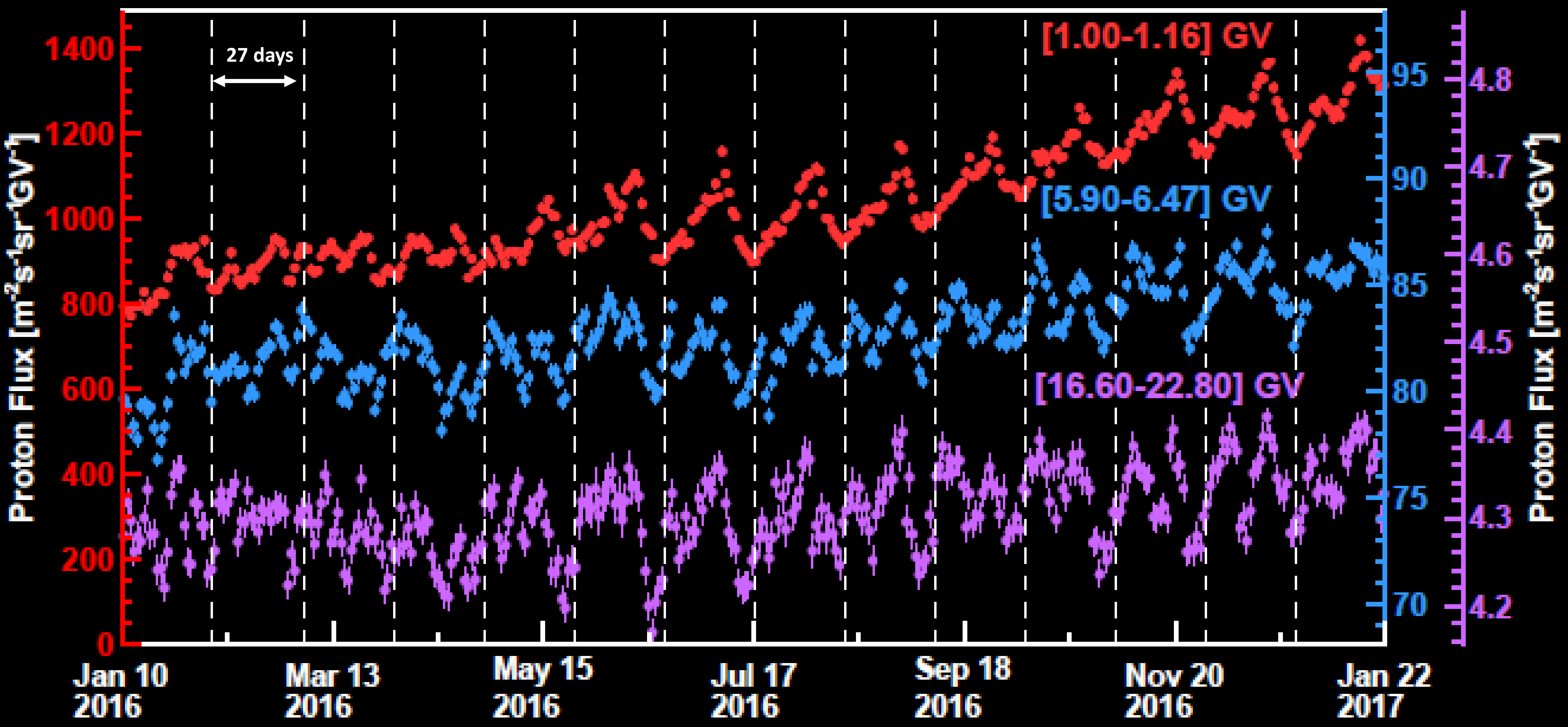
Long-term variation related to the 11-year solar cycle



Periodicities in the Daily Proton Fluxes

From 2014 to 2018, we observed recurrent flux variations with a period of 27 days.

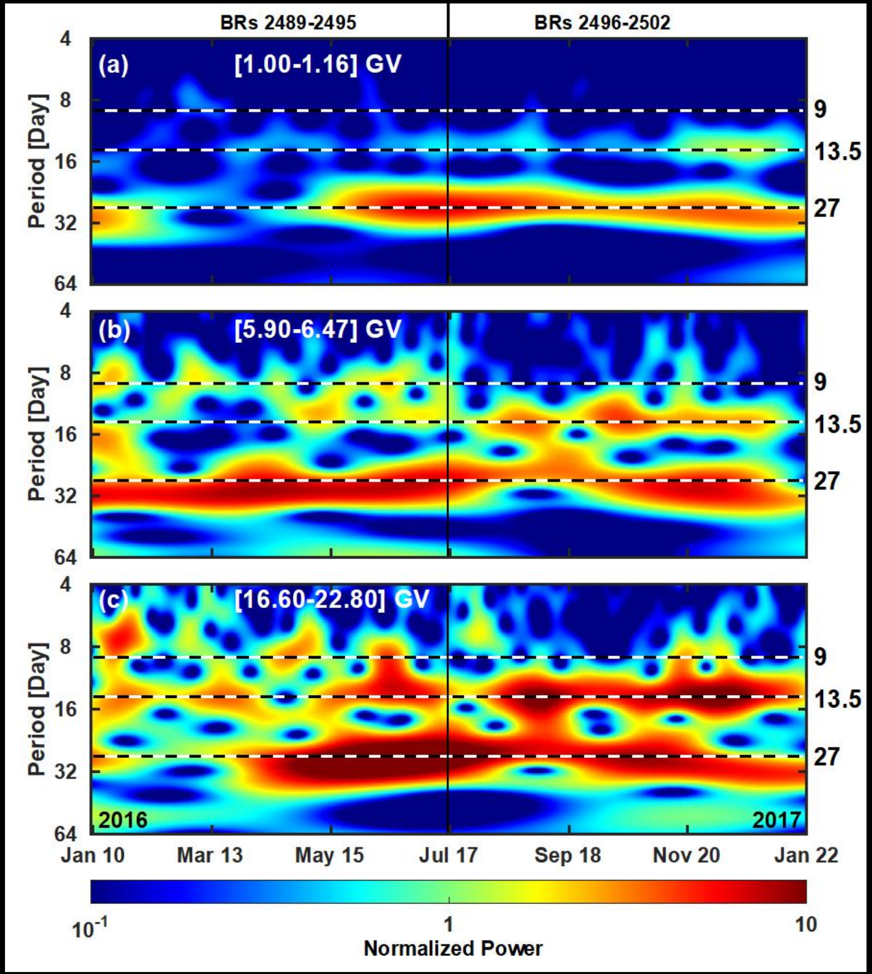
Shorter periods of 9 days and 13.5 days are observed in 2016



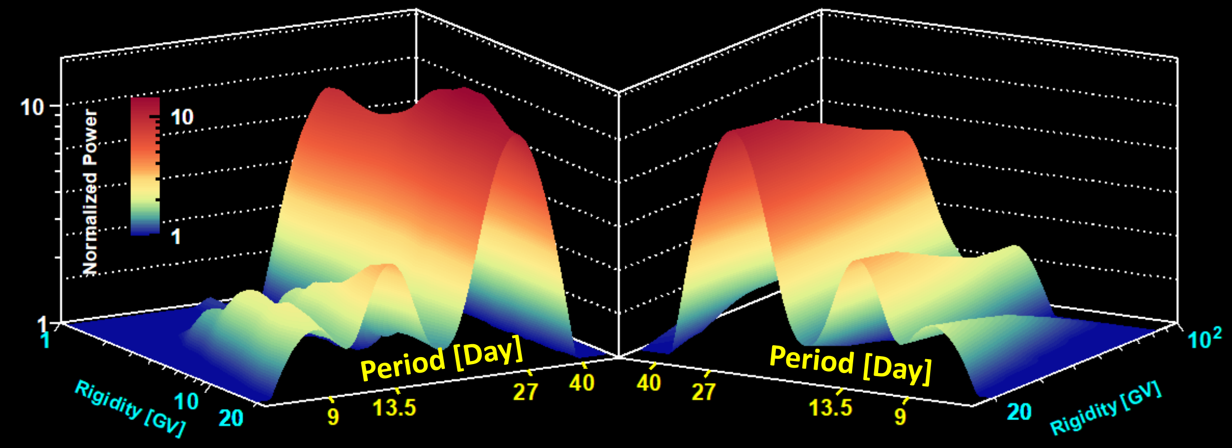
Periodicities in the Daily Proton Fluxes

Wavelet time-frequency analysis to identify when periodic structures are significant

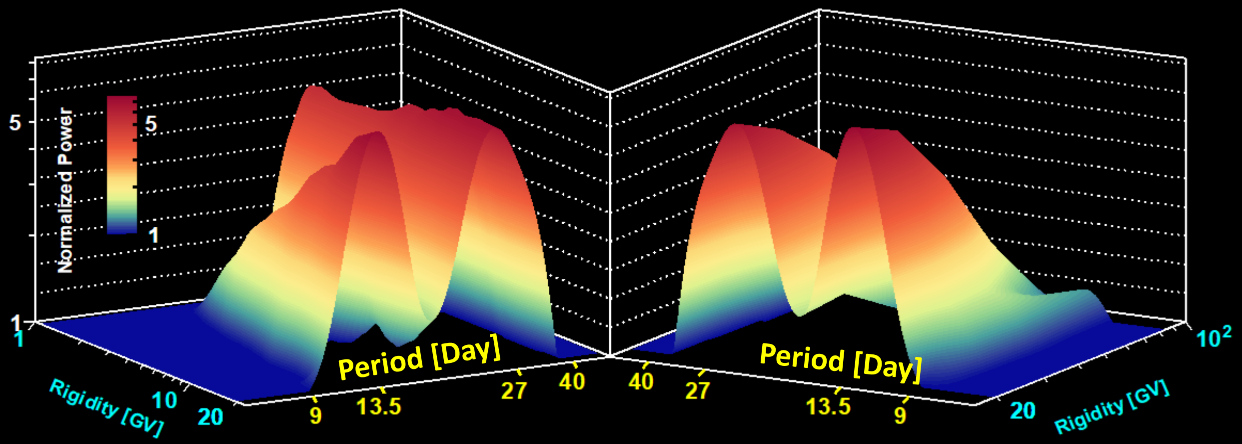
2016



First half of 2016 (Jan 10-Jul 16)



Second half of 2016 (Jul 17-Jan 21, 2017)



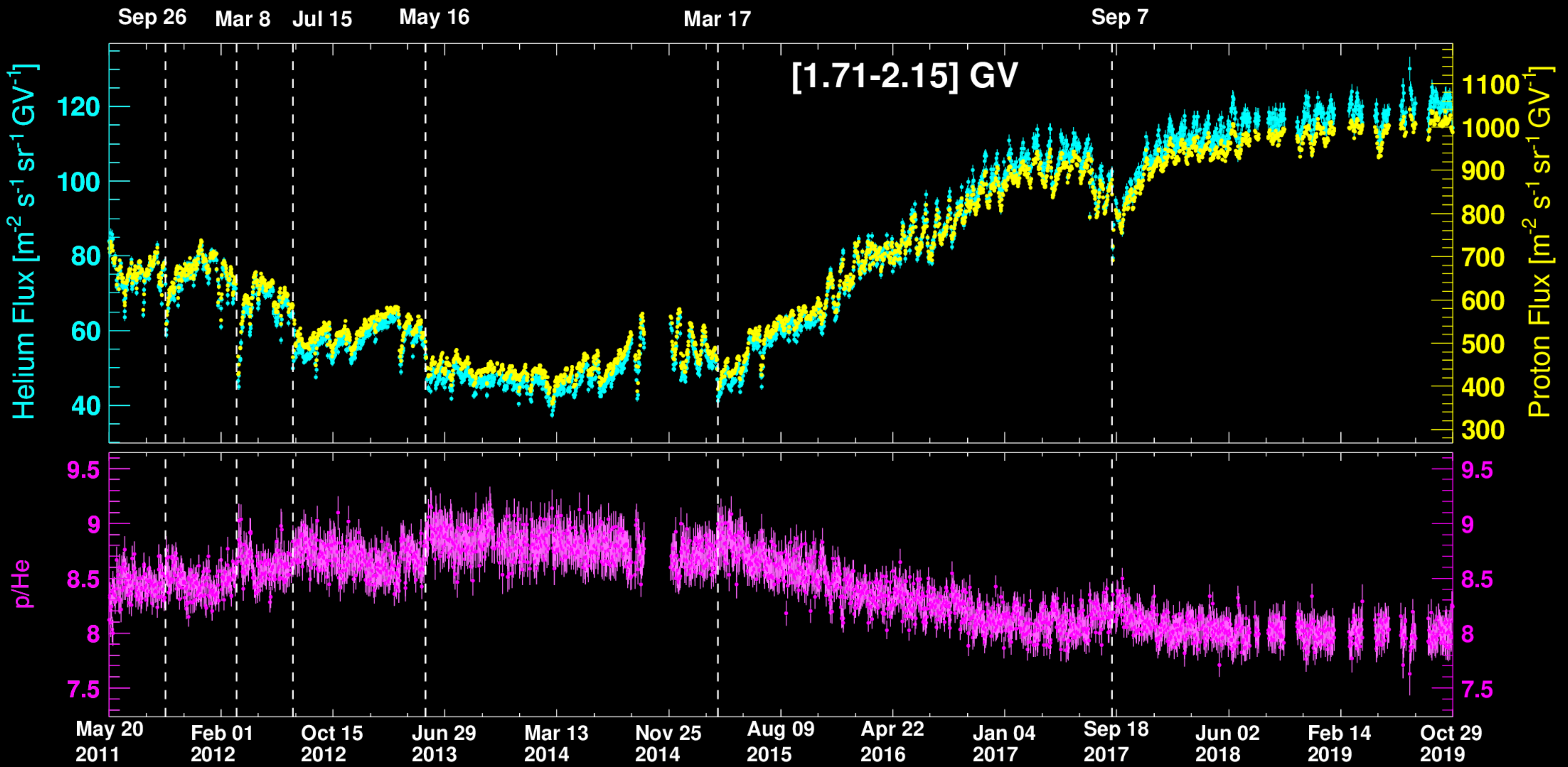
Power is normalized by the variance of flux in the corresponding time interval to show the strength of the periodicities.

Daily p/He Flux Ratio

Preliminary data, refer to upcoming AMS publication

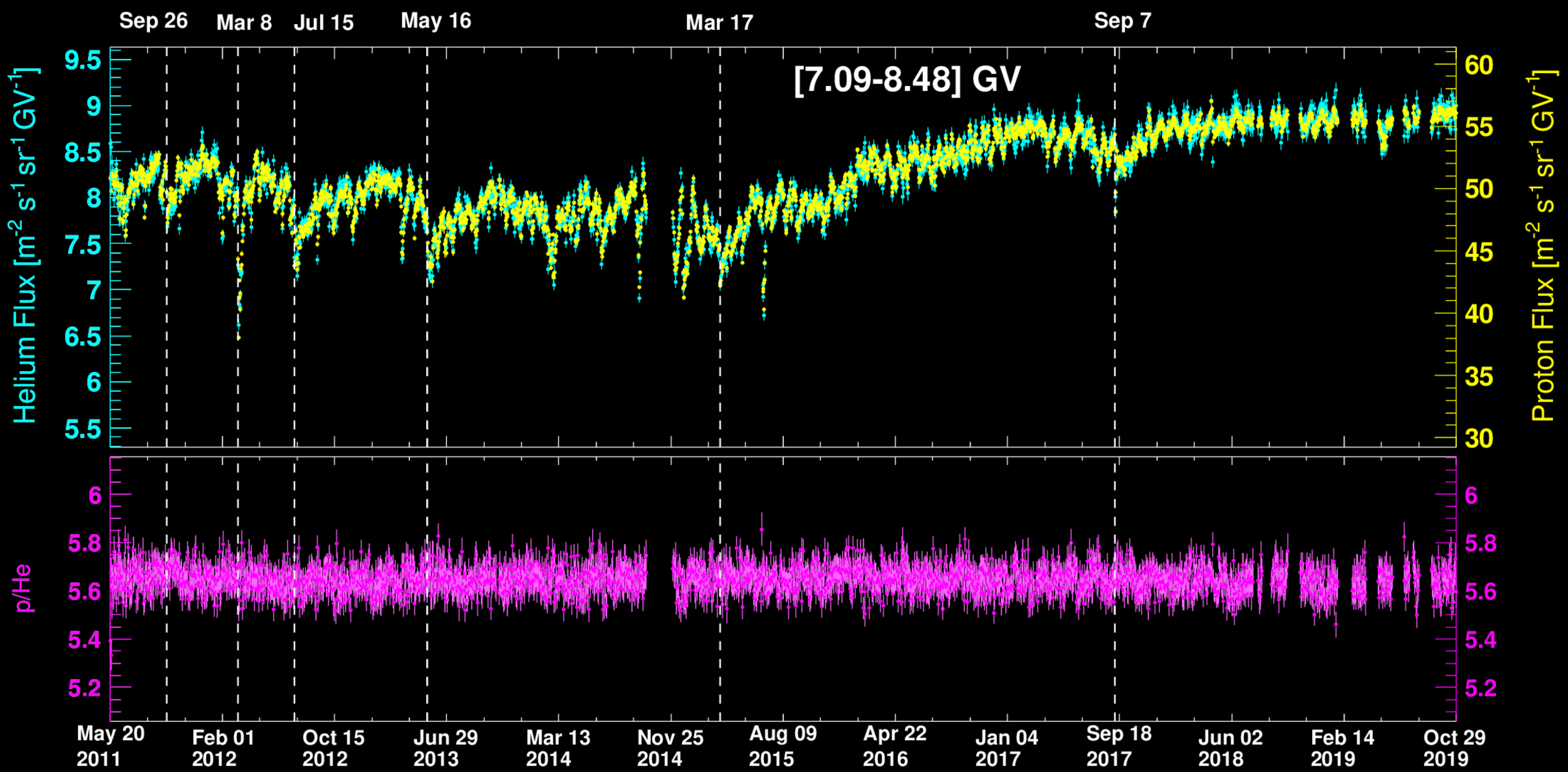
p/He flux ratio exhibits a long-term variation in 8.5 years

The daily p/He ratio shows sub-structures in the short-term variation in coincidence with periods where the p and He fluxes has strong flux suppression.



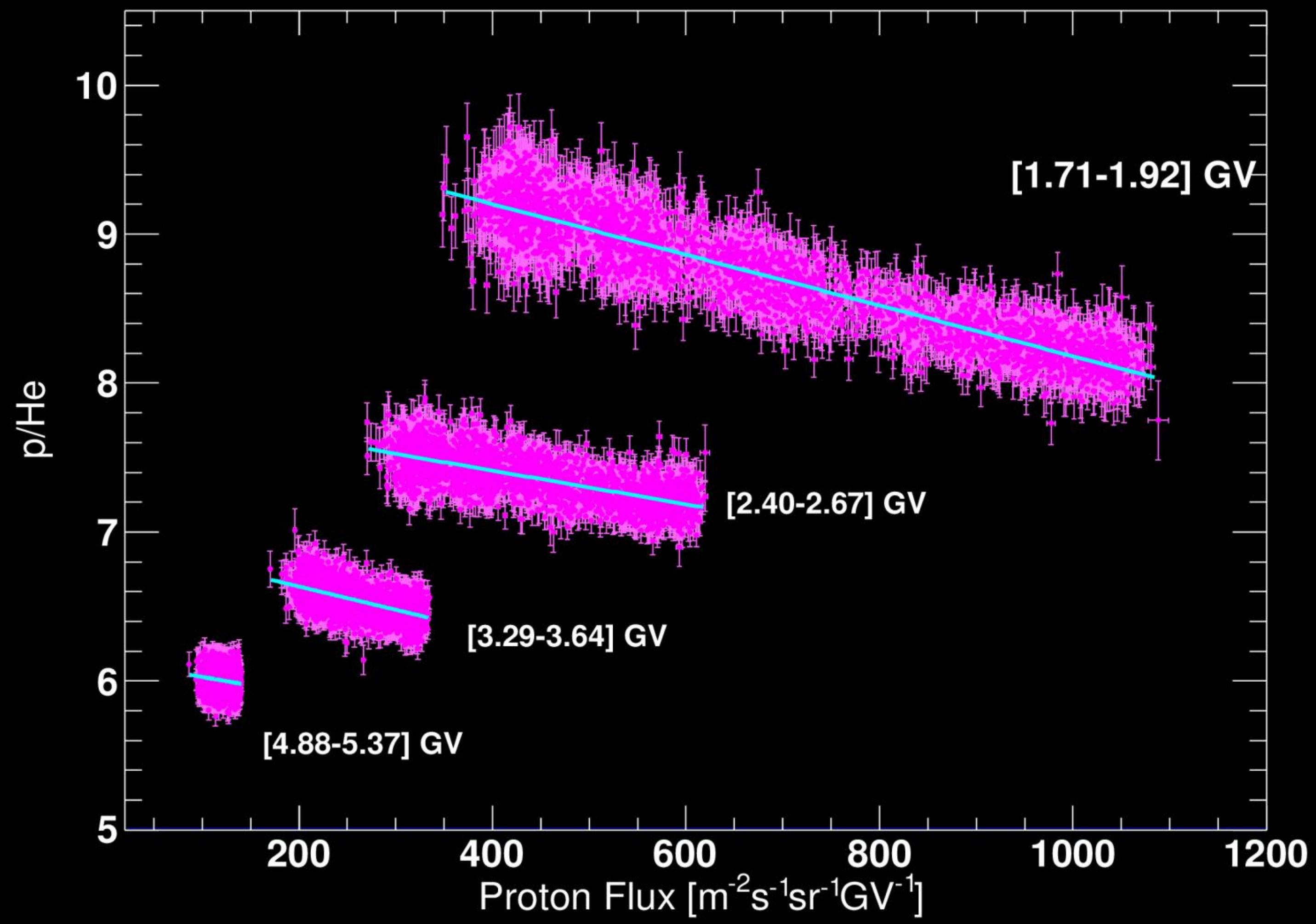
Daily p/He Flux Ratio

p/He flux ratio long-term variation is not observable above 8 GV



Daily p/He Flux Ratio

A strong anti-correlation is observed between the p/He flux ratio and the p flux at low rigidities.

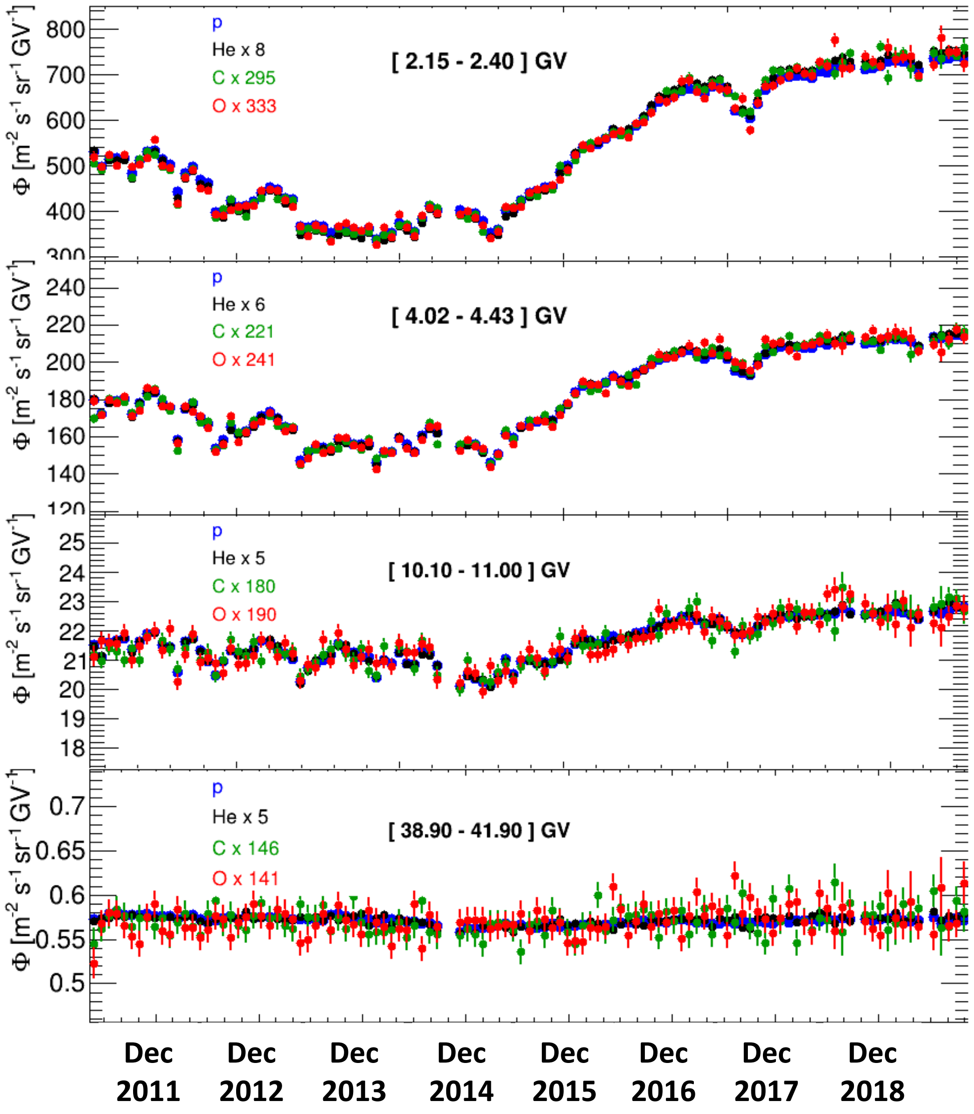


Preliminary data, refer to upcoming AMS publication

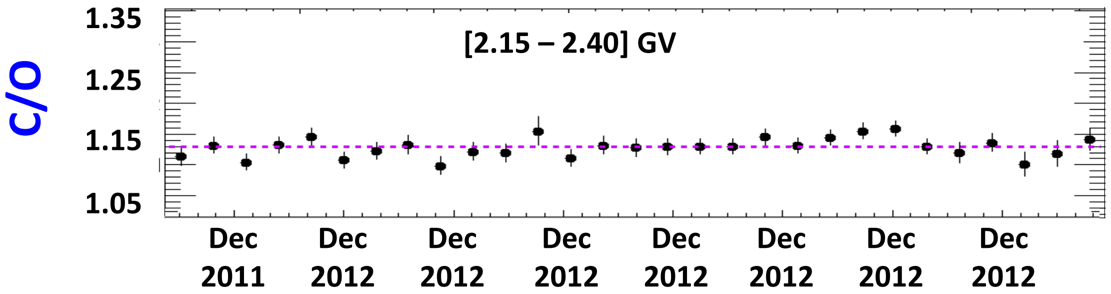
Preliminary data, refer to upcoming AMS publication

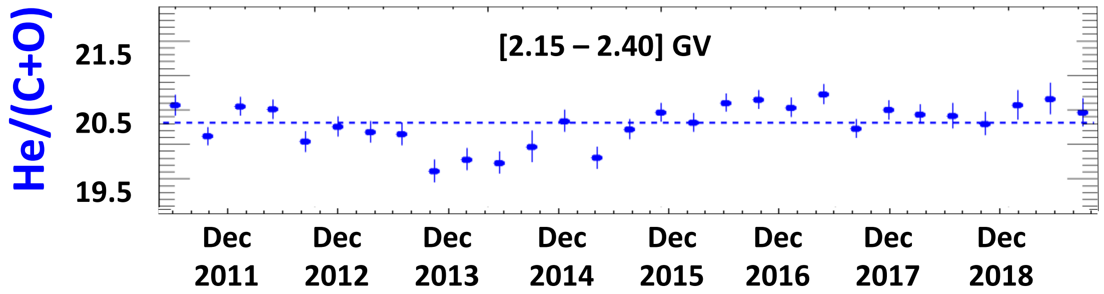
Time evolution of C and O fluxes

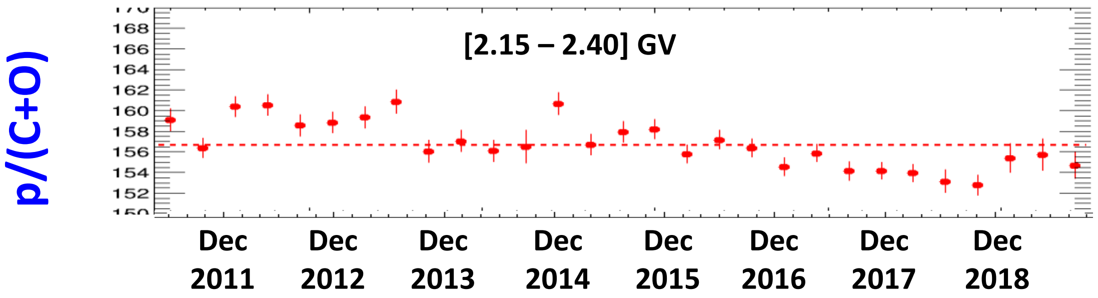
from May 2011 to Oct. 2019, in 27 days time interval Bartels rotations



4 Bartels rotations time interval







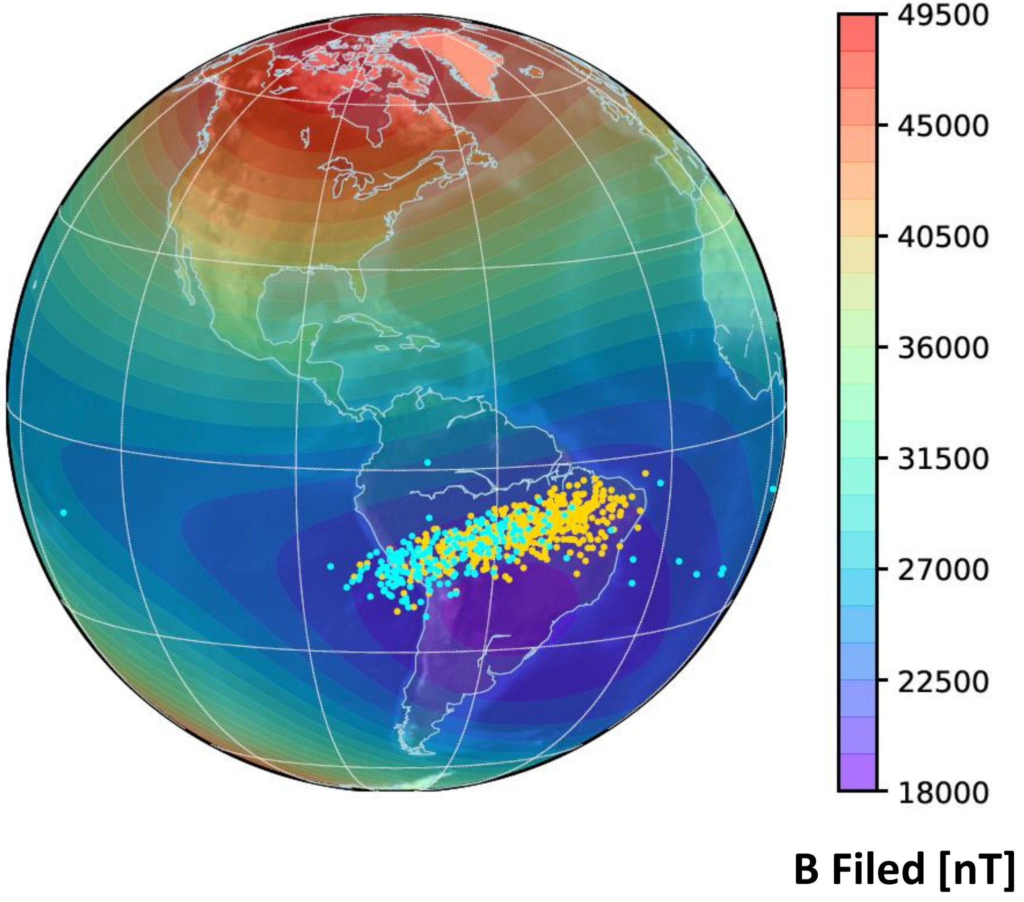
This data provides unique input to understand the contribution of the LIS and the velocity dependence of cosmic rays propagation in the heliosphere

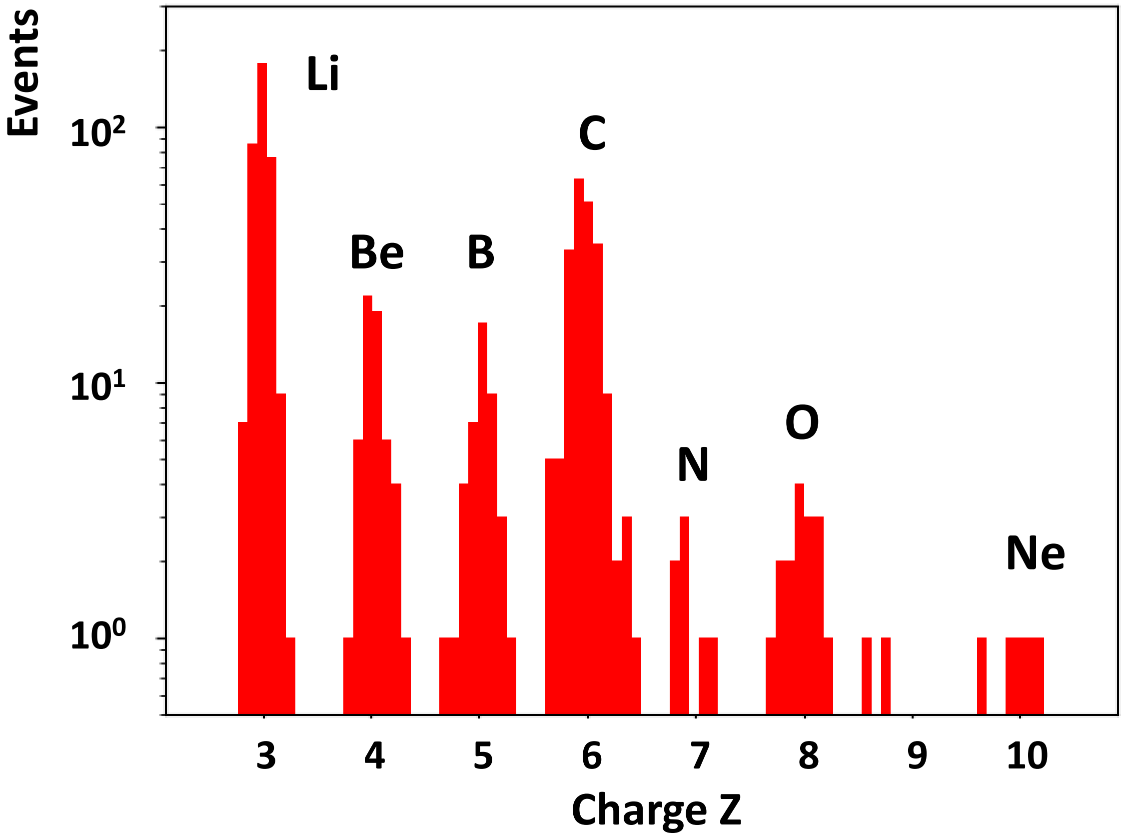
Observation by AMS of Z>2 trapped nuclei

A population of trapped nuclei has been identified near the equator inside SAA

Includes events traversing AMS from both down-going and up-going directions.

The relative abundances of the trapped particles are distinctly different from the galactic cosmic rays.





Conclusions

In ten years on the ISS, AMS has recorded more than 180 billion cosmic rays.

AMS is the first and only instrument providing simultaneous measurements of particles/anti-particles, chemical composition up to Fe in an extended energy range and over a solar cycle

The new features measured by AMS on high and low energy cosmic rays are new phenomena.

AMS will continue to collect and analyze data for the lifetime of the Space Station

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37th International
Cosmic Ray Conference
12–23 July 2021

AMS-02 Contributions

July, 14	#763-CRD	*Properties of Neon, Magnesium, and Silicon Primary Cosmic Rays Results from the Alpha Magnetic Spectrometer.*	Alberto Oliva
	#743-CRD	*Properties of Cosmic Sodium : Results from the Alpha Magnetic Spectrometer.*	Cheng Zhang
	#803-CRD	*Properties of Cosmic Aluminum Nuclei: Results from the Alpha Magnetic Spectrometer.*	Zhen Liu
	#1145-CRD	*Properties of Iron Primary Cosmic Rays: Results from the Alpha Magnetic Spectrometer.*	Yao Chen
	#749-SH	*Precision Measurement of Periodicities in the Daily Proton Fluxes with the Alpha Magnetic Spectrometer.*	Yi Jia
July, 15	#1024-CRD	*Towards Understanding the Origin of Cosmic-Ray Positrons.*	Zhili Weng
	#805-CDR	*Towards Understanding the Origin of Cosmic-Ray Electrons.*	Dimitri Krasnopevtsev
	#958-CDR	*Antiproton Flux and Properties of Elementary Particles in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS.*	Hsin-Yi Chou
	#995-CRD	*Anisotropy of Positron and Electron Fluxes Measured with the Alpha Magnetic Spectrometer on the ISS.*	Miguel Molero
	#770-CRD	*Anisotropy of Protons and Light Primary Nuclei in Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS.*	Miguel Angel Velasco
	#1003-SH	*Solar Energetic Particles measured by the Alpha Magnetic Spectrometer during solar cycle 24.*	Light Christopher
July, 16	#1139-SH	*Precision Measurement of Daily Helium Fluxes by the Alpha Magnetic Spectrometer.*	Cristina Consolandi
	#1211-SH	*Precision measurement of daily electrons fluxes by AMS.*	Weiwei Xu
	#1133-SH	*Precision Measurement of low energy positron fluxes by AMS.*	Maura Graziani
	#1009-SH	*Precision Measurement of the Monthly Proton, Helum, Carbon and Oxygen Fluxes in Cosmic Rays with AMS on the ISS.*	Matteo Palermo
	#760-SH	*Observation of Z>2 trapped nuclei by AMS on ISS.*	Martha Valencia
July, 19	#1008-CRD	*Properties of Light Primary and Secondary Cosmic Rays He-C-O and Li-Be-B Measured with the AMS on the ISS.*	Henning Gast
	#707-CRD	*Properties of Heavy Secondary Fluorine Cosmic Rays Results from the Alpha Magnetic Spectrometer.*	Qi Yan
	#887-CRD	*Precision Measurement of Cosmic Ray Deuterons with Alpha Magnetic Spectrometer.*	Eduardo Ferronato Bueno
	#320-CRD	*Properties of Cosmic Helium Isotopes Measured by the Alpha Magnetic Spectrometer.*	Francesca Giovacchini
	#992-CRD	*Cosmic-Ray Isotopes with the Alpha Magnetic Spectrometer.*	Laurent Derome