The AMS-02 detector on the ISS

Status and highlights after 13 years on orbit

Agenzia Spaziale Italiana

INFN

V. Vagelli (Italian Space Agency & INFN)
on behalf of the AMS collaboration

CRIS-MAC 2024

AMS-02 has collected

236,977,489,091

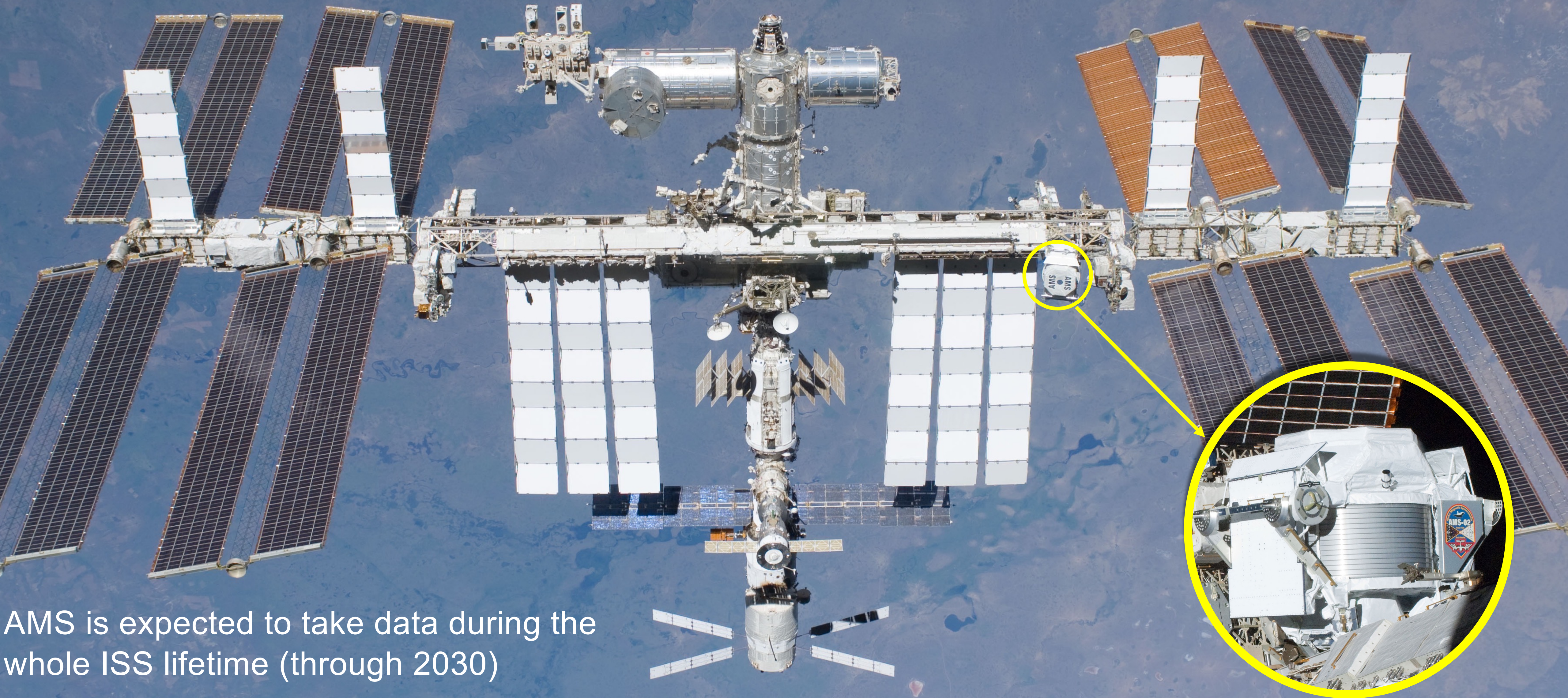
cosmic ray events

Last update: Jun 16, 2024, 15:00 CET

http://ams02.space/

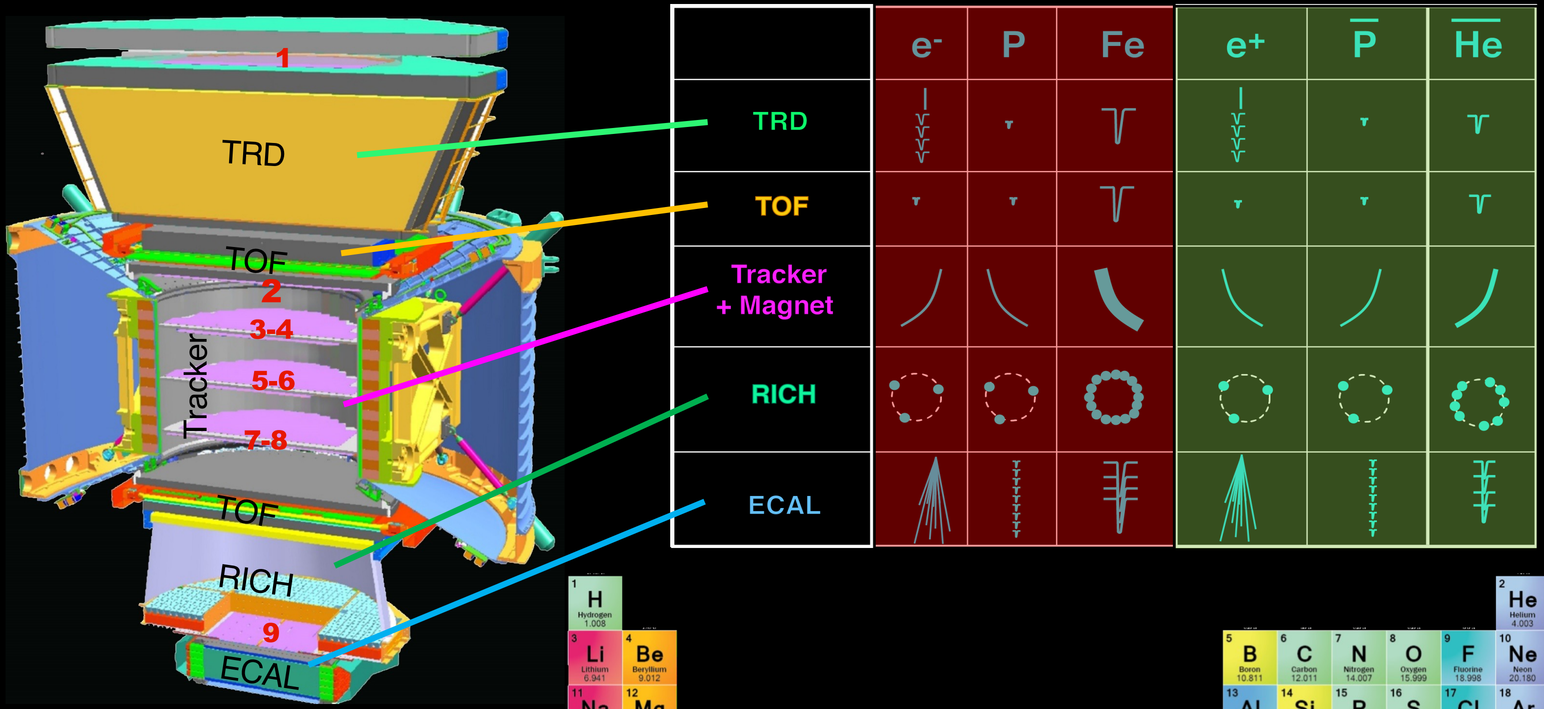
AMS-02 in orbit

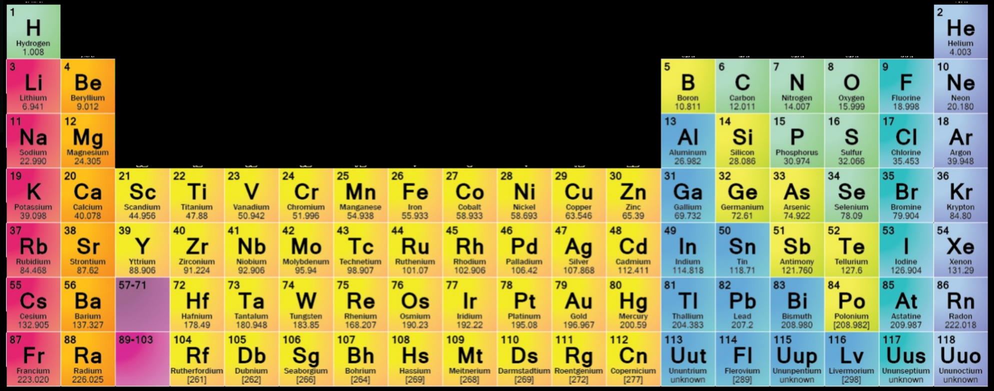
AMS-02 is a large-acceptance high-energy **magnetic spectrometer** capable of measuring accurately particles in the **GeV-TeV** energy range. Since **2011** May 19th AMS-02 has been operating on the International Space Station (ISS). AMS recorded **>230 billion CR triggers** in ~13 years of operation.



AMS is expected to take data during the whole ISS lifetime (through 2030)

Cosmic ray identification



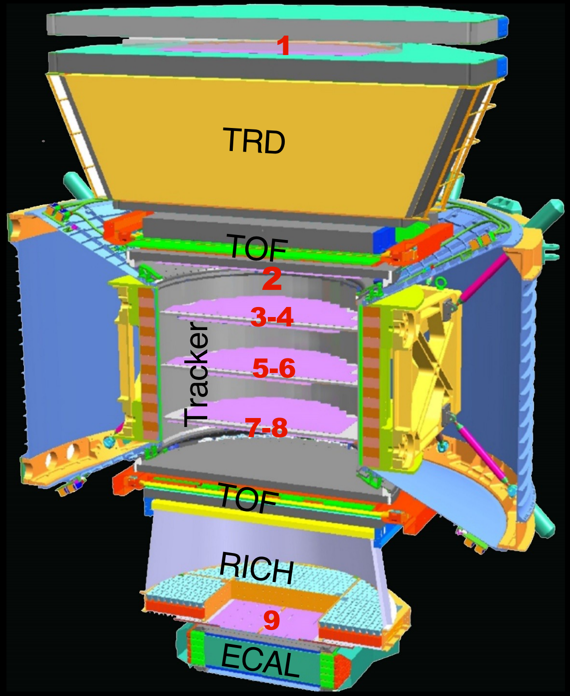


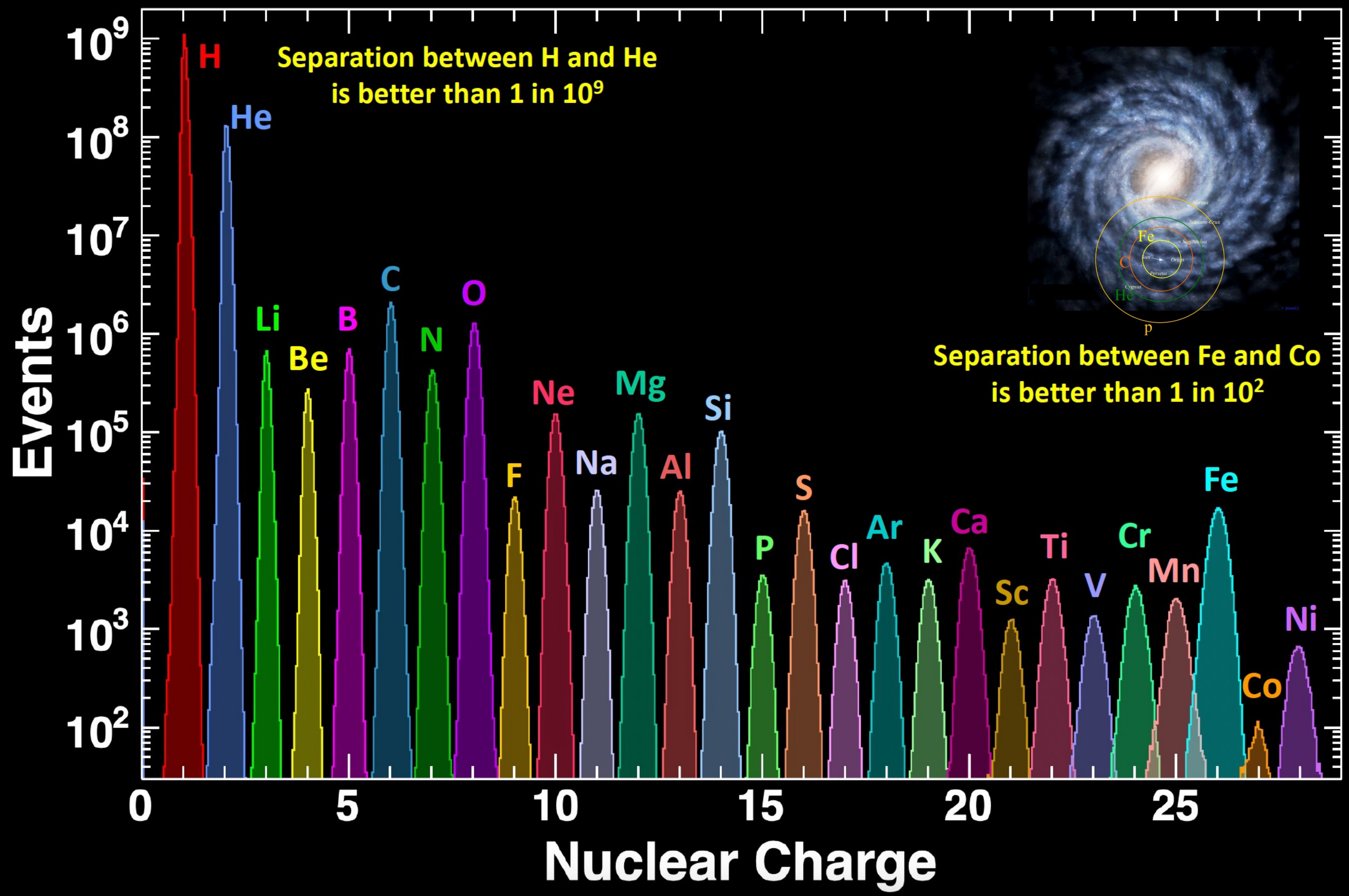
AMS measures :

- Momentum (P, GeV/c)
- Charge (Z)
- Rigidity (R=P/Z, GV)
- Energy (E, GeV/A)
- Flux (signals/(s sr m^2 GeV))

for matter and antimatter cosmic rays up to TeV energies

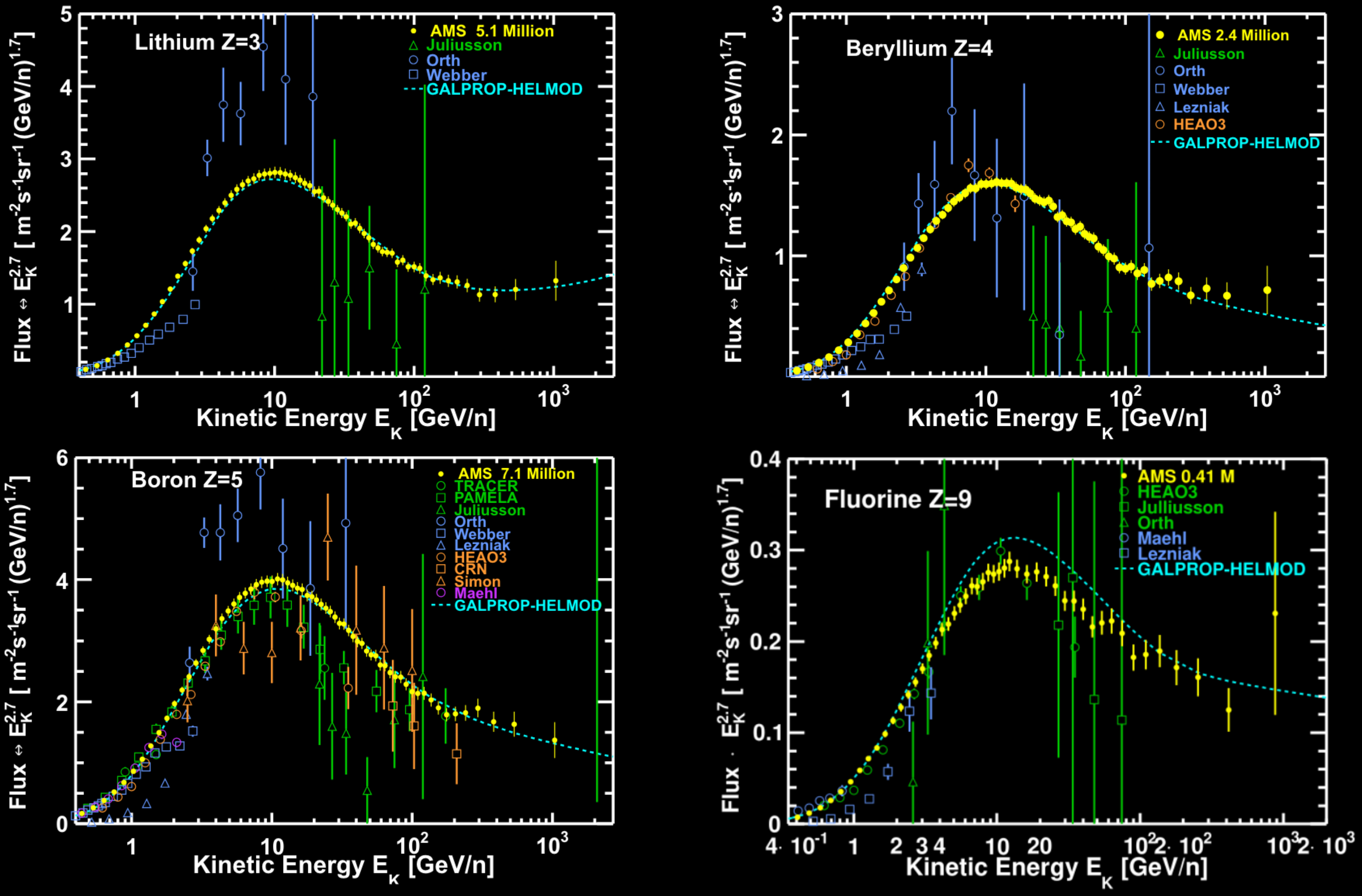
Measurement of cosmic ray nuclei



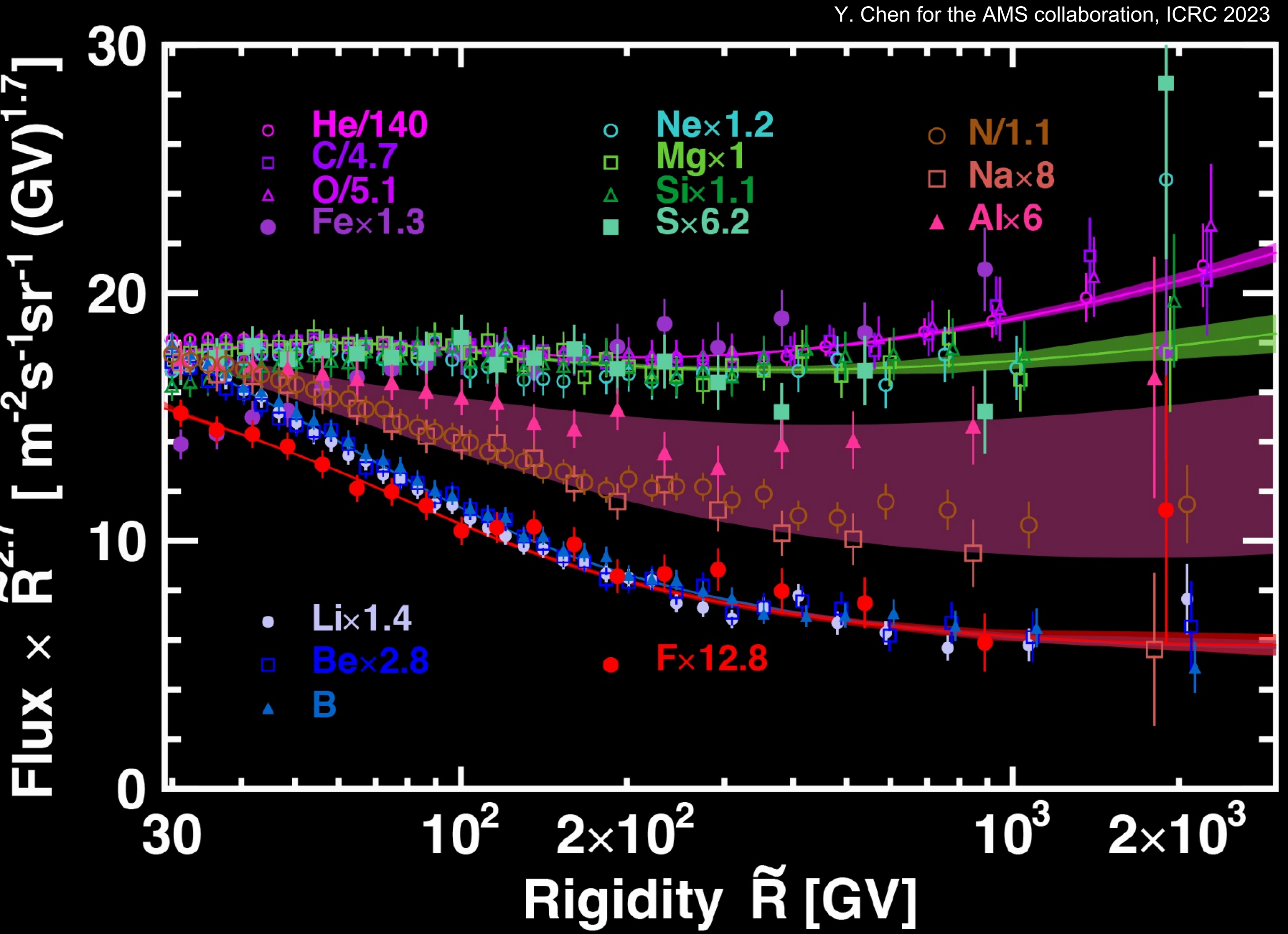


Measurement of cosmic ray nuclei

J. Peleteiro for the AMS collaboration, TeVPA 2023



Measurement of cosmic ray nuclei



Primary cosmic rays are produced during the lifetime of stars. They are accelerated by the explosion of stars (supernovae).
Two classes: He, C, O, Fe, Ni / Ne, Mg, S, Si

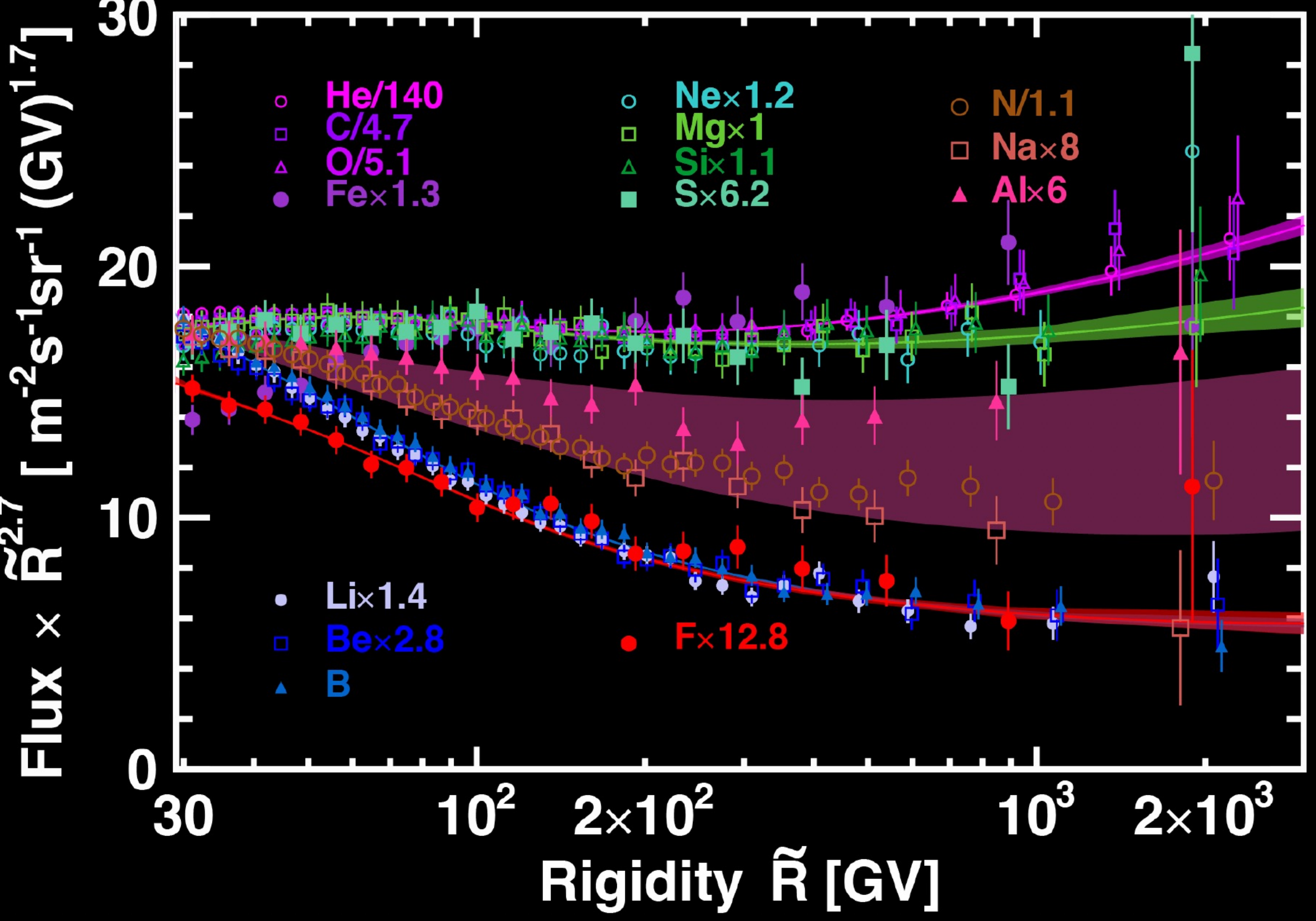
Iron and Nickel is in the He, C, O primary cosmic ray group instead of the expected Ne, Mg, Si group.

Secondary cosmic rays are produced by the collision of primary cosmic rays and interstellar medium. Two classes: Li, Be, B / F

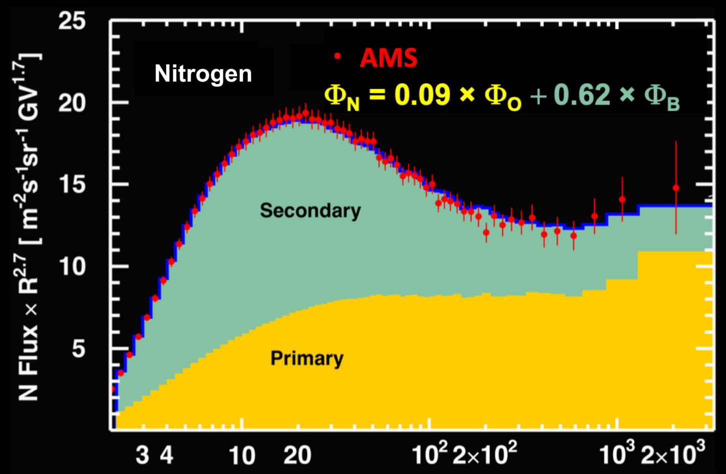
N, Na and Al nuclei are produced both in stars and by collisions of primary cosmic rays with the interstellar medium. They belong to a **third class of cosmic rays**, which is a combination of primary and secondary origin.

Measurement of cosmic ray nuclei

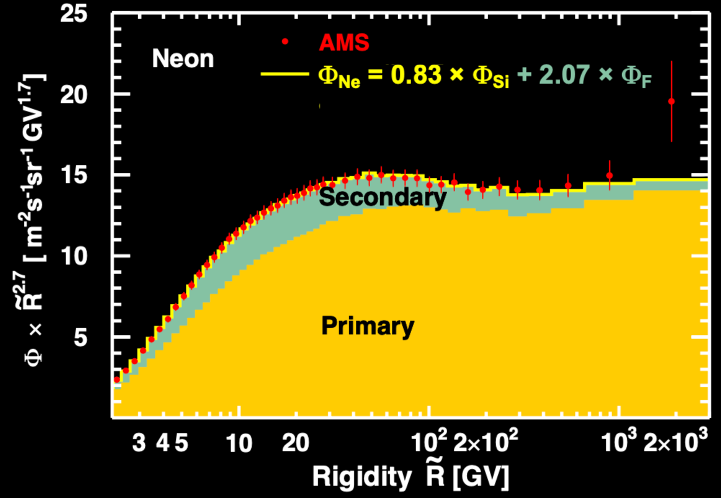
Y. Chen for the AMS collaboration, ICRC 2023



N, Na and Al fluxes Φ_X can be described by a weighted sum of a primary component $\Phi_X^P \propto \Phi_{O,Si}$ and a secondary component $\Phi_X^S \propto \Phi_{B,F}$



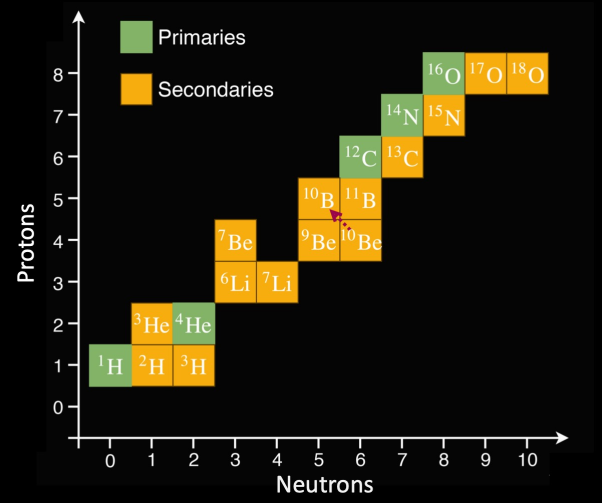
Also C, Ne, Mg and S require a small fraction (<5%) of a secondary component for their description.

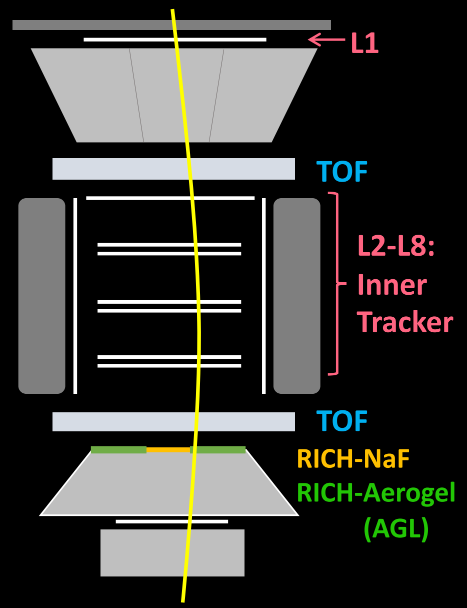


Measurement of cosmic ray isotopes

Isotope studies give unique information on **propagation** (D, ^{3}He), **production mechanisms** (^{6,7}Li, ^{7,9}Be) and measure the **galactic halo size** (^{9,10}Be).

- D and ^{3}He are mostly produced by the fragmentation of ^{4}He: simpler comparison with propagation models than heavier primary/seconday ratios
- Smaller cross-section of He: D/^{4}He and ^{3}He/^{4}He probe the properties of diffusion at larger distances
- ^{10}Be/^{9}Be provides more sensitive measurement of the age of cosmic rays than Be/B flux ratio
- ^{7}Li measurements may shed light on the origin of cosmic lithium



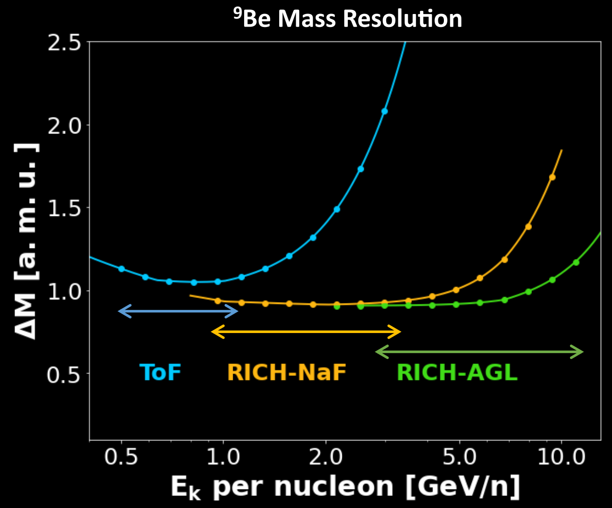


$$M = \frac{RZ}{\beta\gamma}$$

- R measurement :
  - Tracker, $\Delta R/R \sim 10\%$ at 10 GV
- β measurements:

	E_{kn} range (GeV/n)	$\Delta\beta/\beta$ (Z=1)	$\Delta\beta/\beta$ (Z=4)
TOF	(0.5, 1.2)	~3%	~1.5%
RICH-NaF (n=1.33)	(0.8, 4.0)	~0.3%	~0.15%
RICH-AGL (n=1.05)	(3.0, 12)	~0.1%	~0.05%

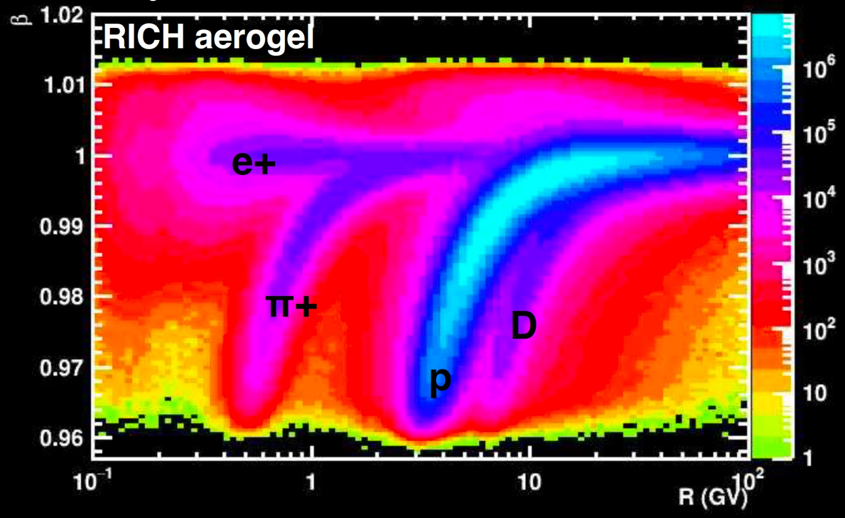
$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left(\gamma^2 \frac{\Delta\beta}{\beta}\right)^2}$$

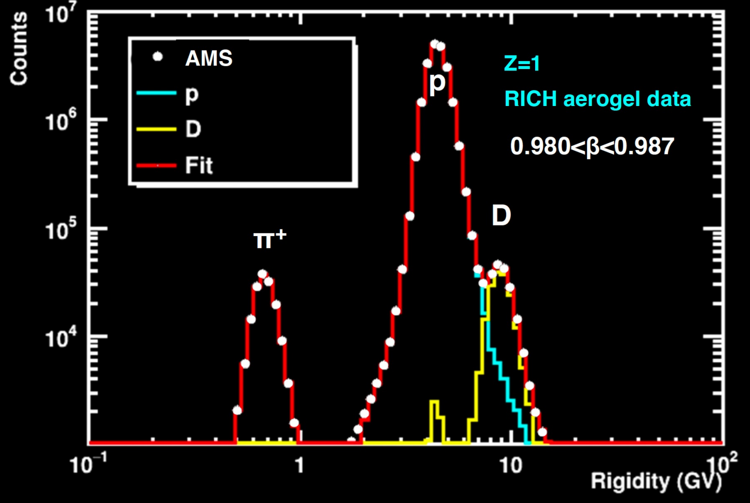


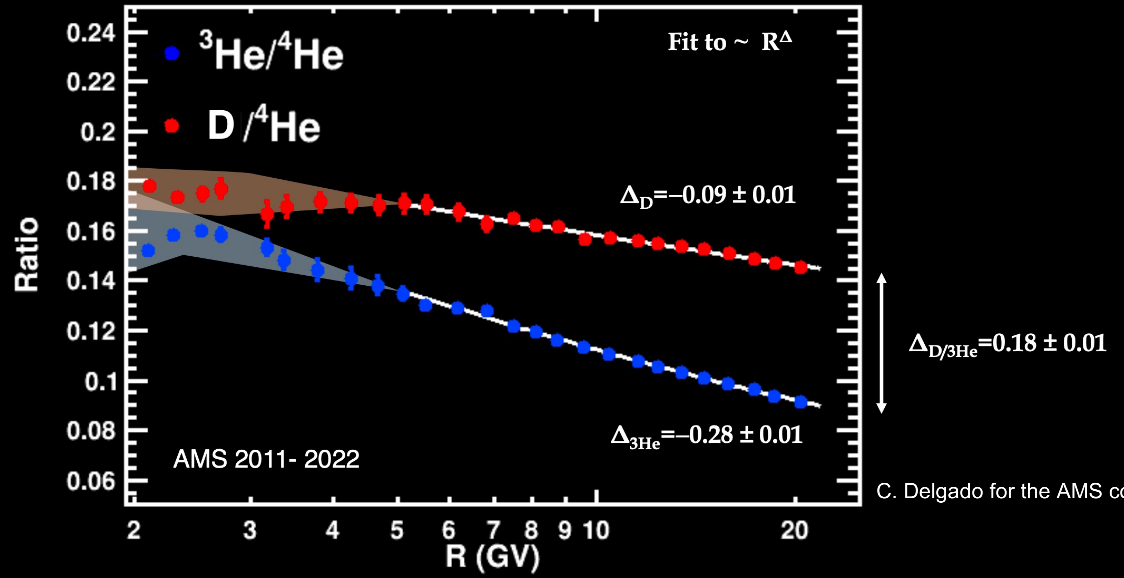
Measurement of cosmic ray H and He isotopes

Preliminary data. Please refer to upcoming AMS publications

C. Delgado for the AMS collaboration, ICRC 2023

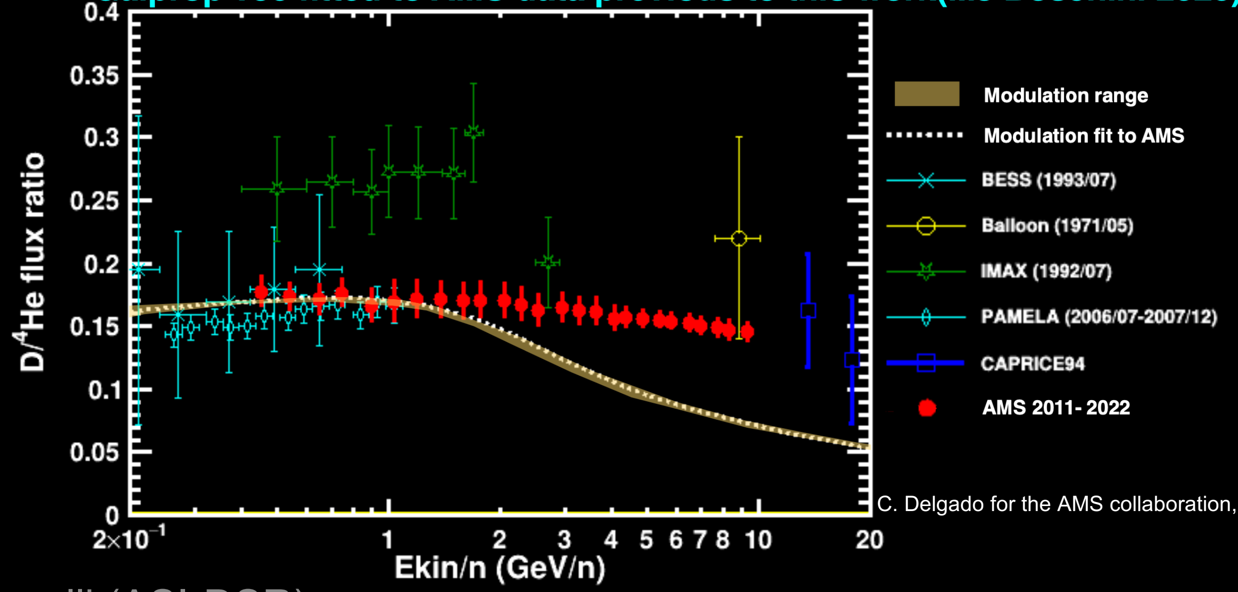






C. Delgado for the AMS collaboration, ICRC 2023

Galprop v56 fitted to AMS data previous to this work(MJ Boschini 2020)

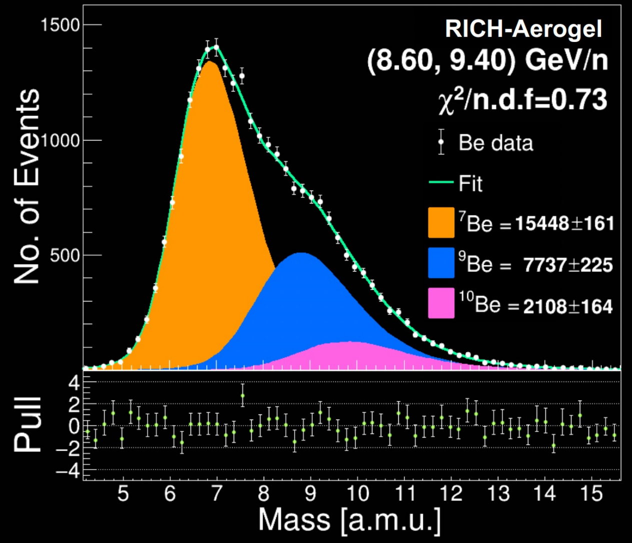


C. Delgado for the AMS collaboration, ICRC 2023

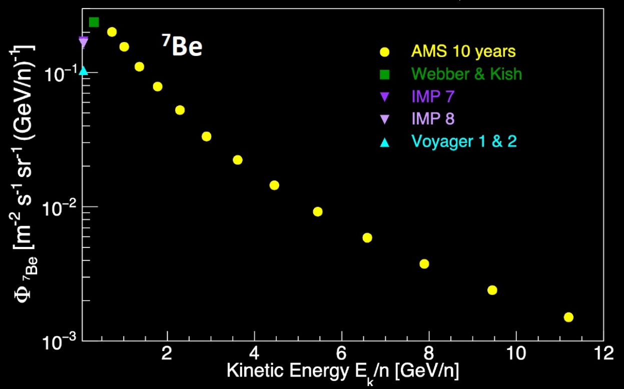
Measurement of cosmic ray Be isotopes

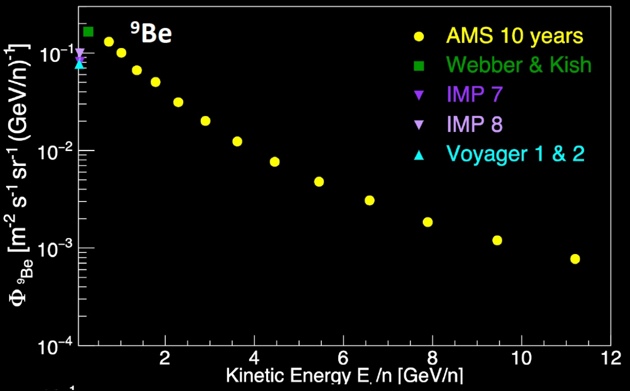
Preliminary data. Please refer to upcoming AMS publications

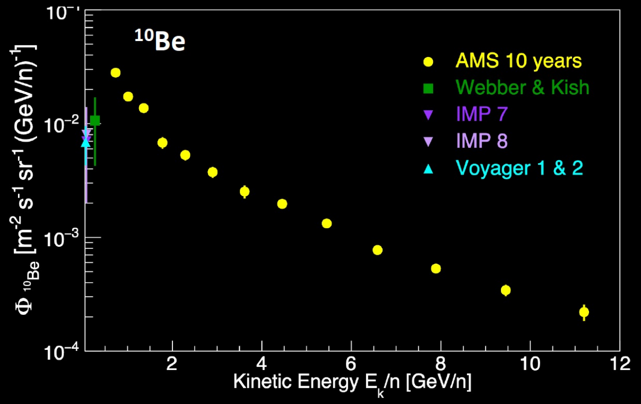
J. Wei for the AMS collaboration, ICRC 2023



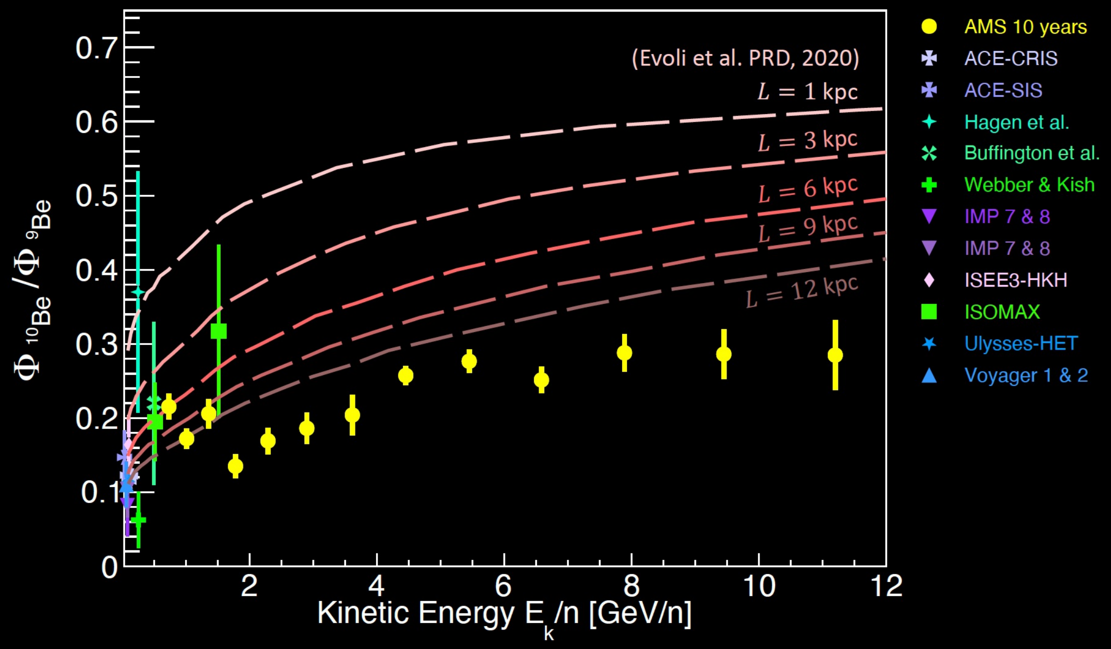
J. Wei for the AMS collaboration, ICRC 2023





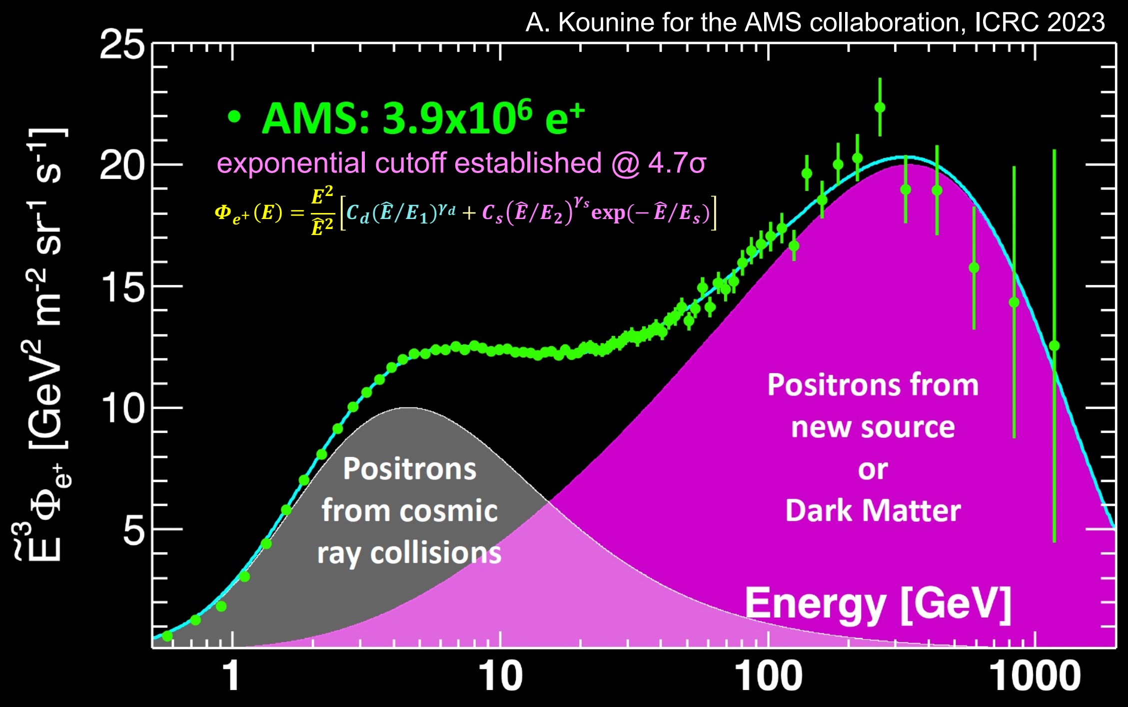


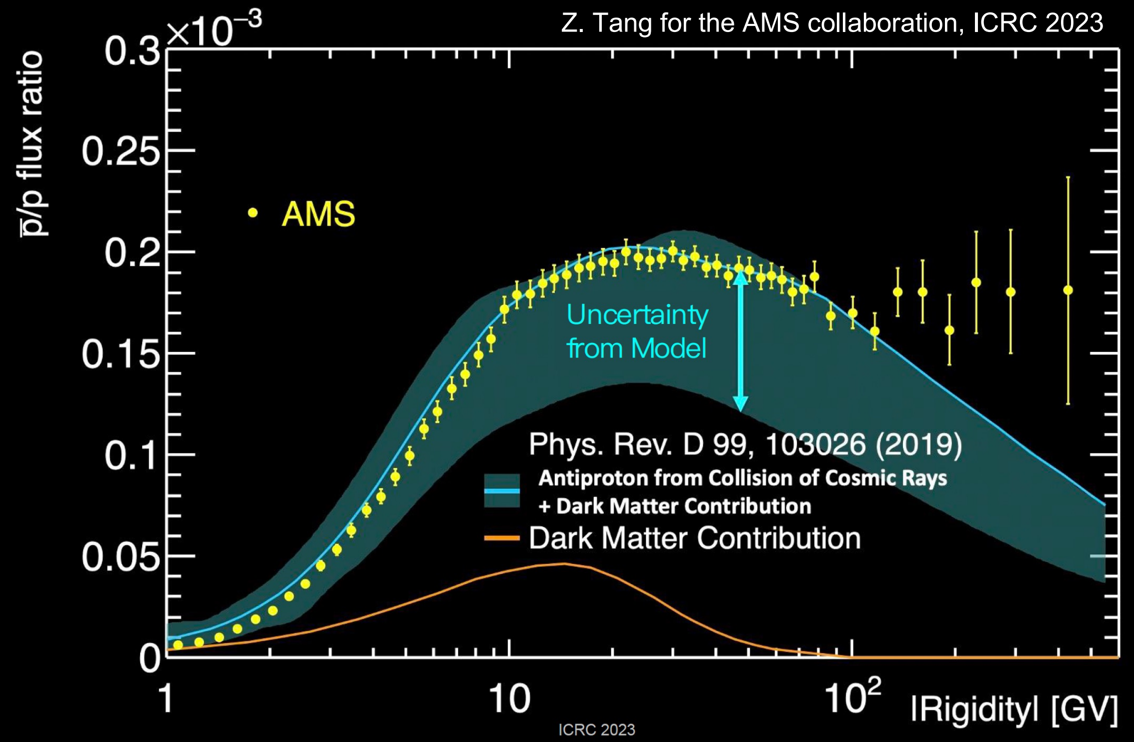
J. Wei for the AMS collaboration, ICRC 2023

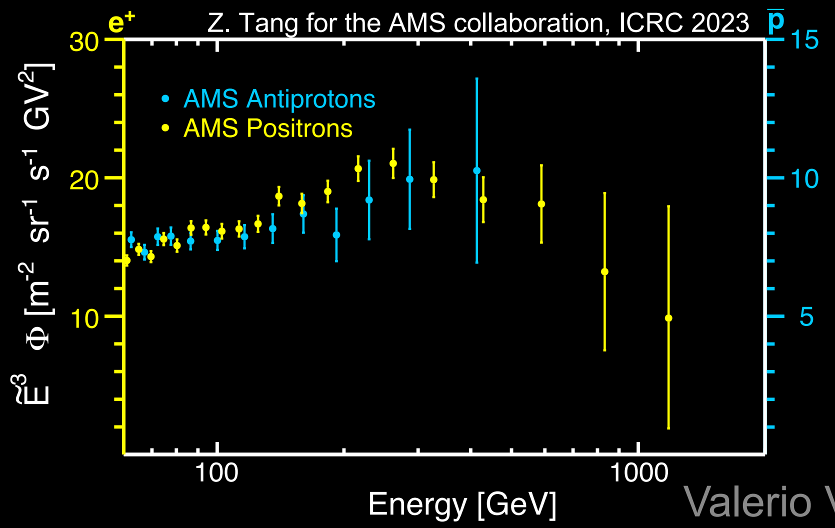


AMS-02 measurements based of Be events test an uncharted energy range probing production and propagation mechanisms

Be isotope measurements test the model predictions of the galactic halo size

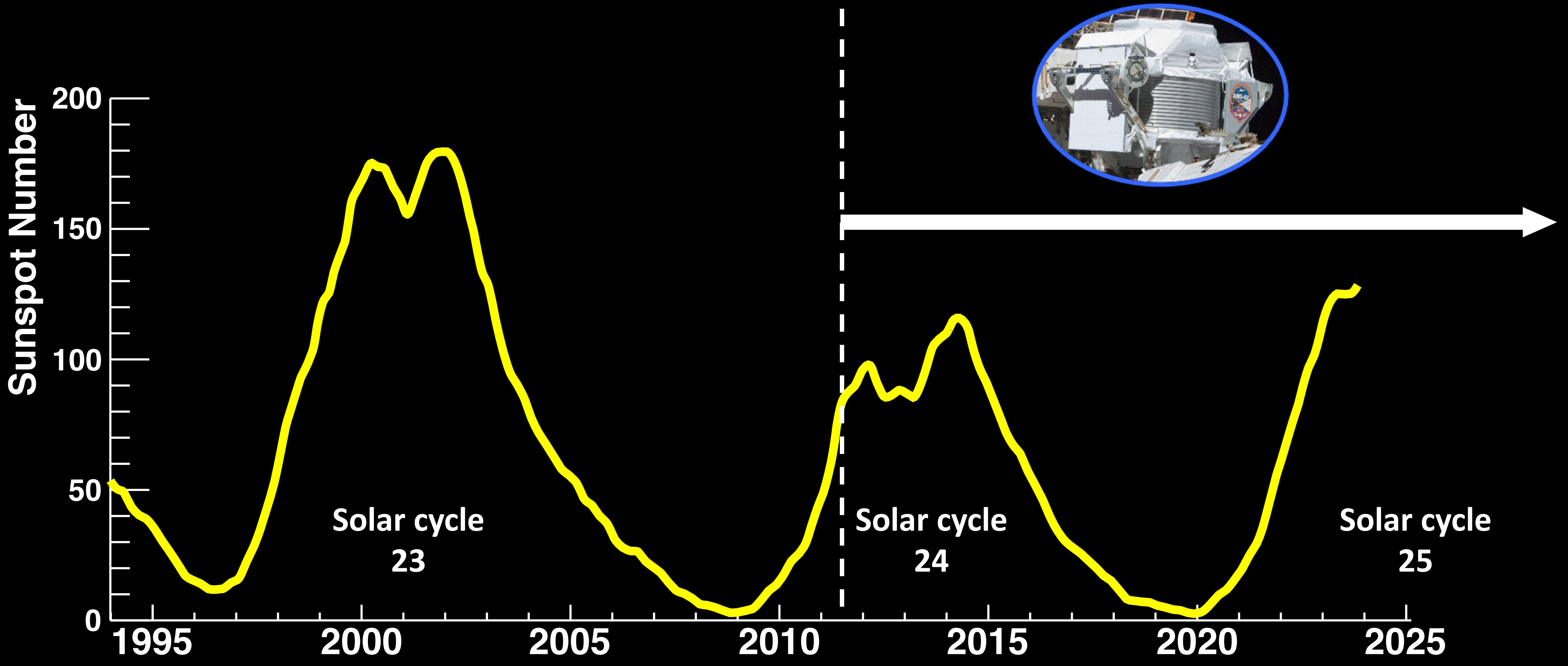






Positrons and antiprotons feature similar high-energy spectral dependence despite their different origins and propagation mechanisms

Long-term and short-term variations in cosmic rays



Cosmic ray long-term and short-term variations are unique probes of fundamental properties of solar system and provide information for safe human space exploration

AMS Daily Proton and Helium Fluxes

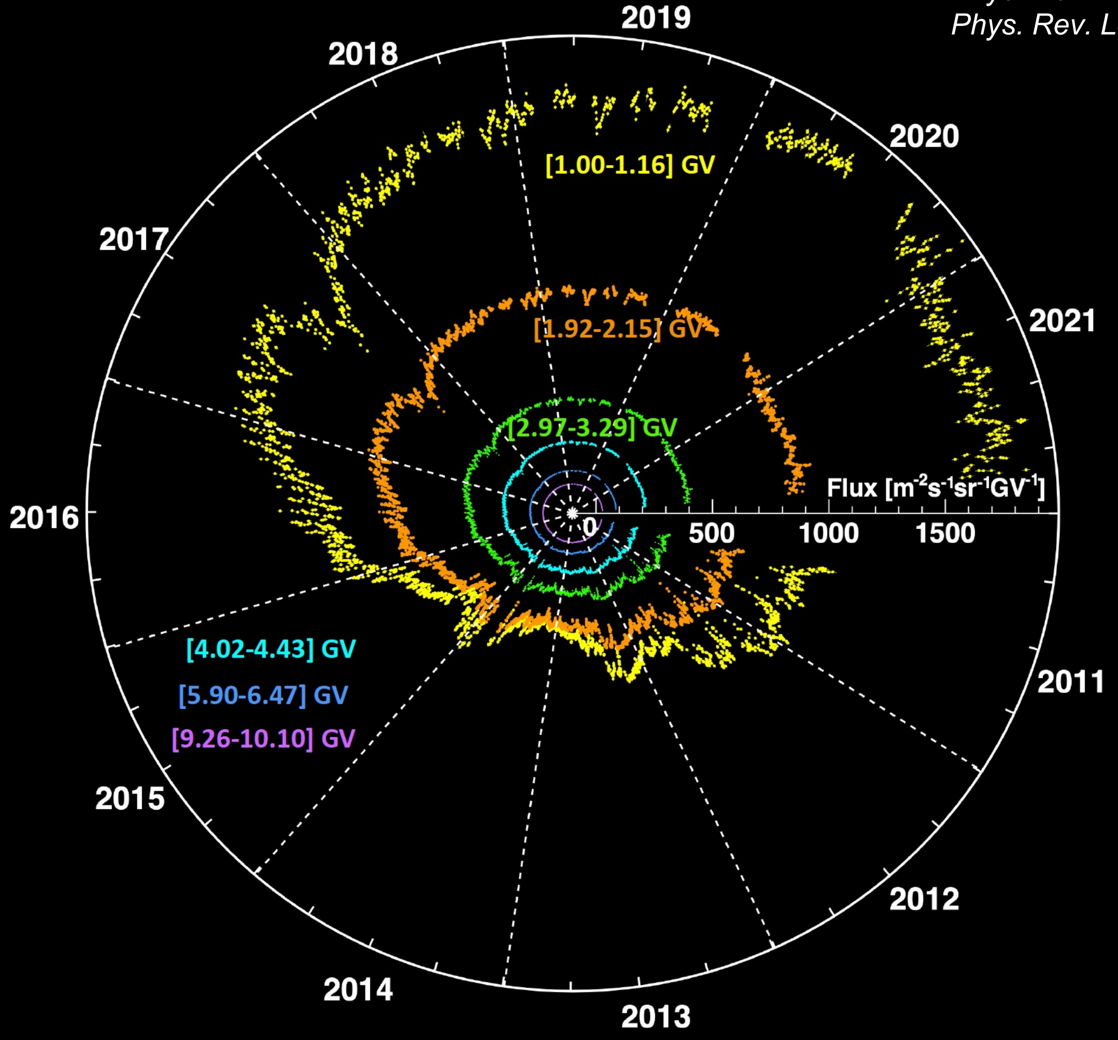
Y. Ja for the AMS collaboration, ICRC 2023

Daily flux measurements data from **May 2011** to **Nov 2021**

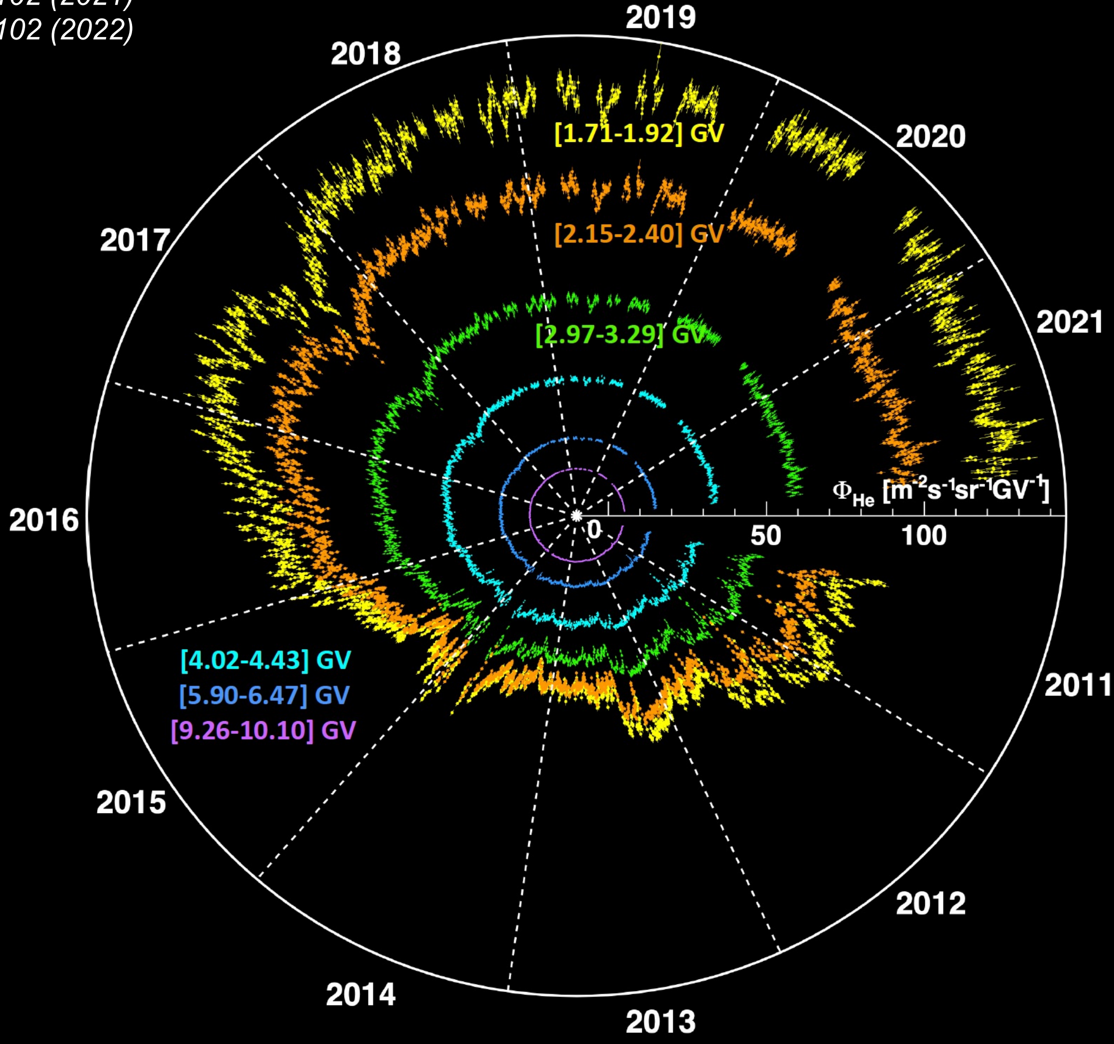
Y. Ja for the AMS collaboration, ICRC 2023

AMS 10 years update. Last ublications:
Phys. Rev. Lett. 127, 271102 (2021)
Phys. Rev. Lett. 128, 231102 (2022)

Daily Protons

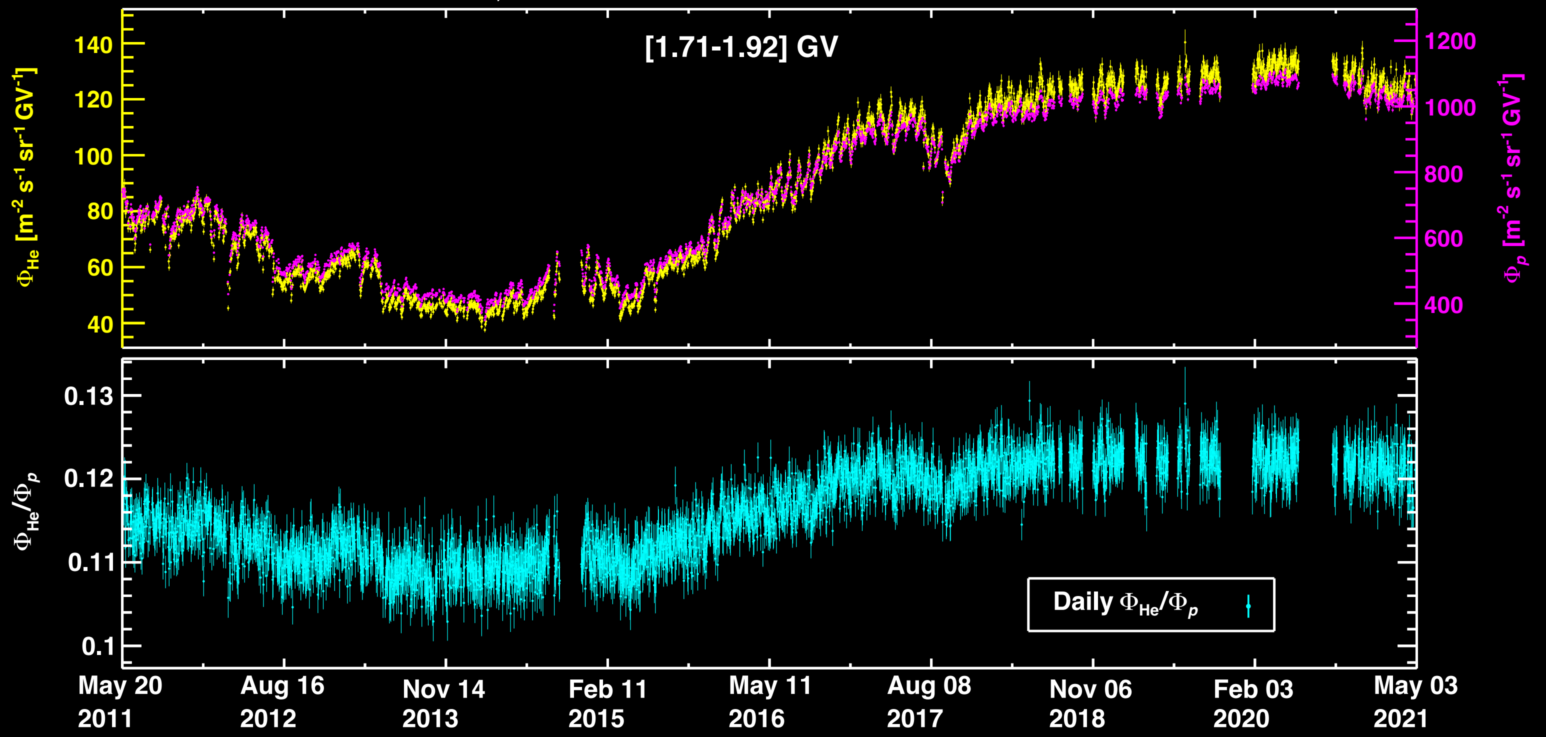


Daily Helium

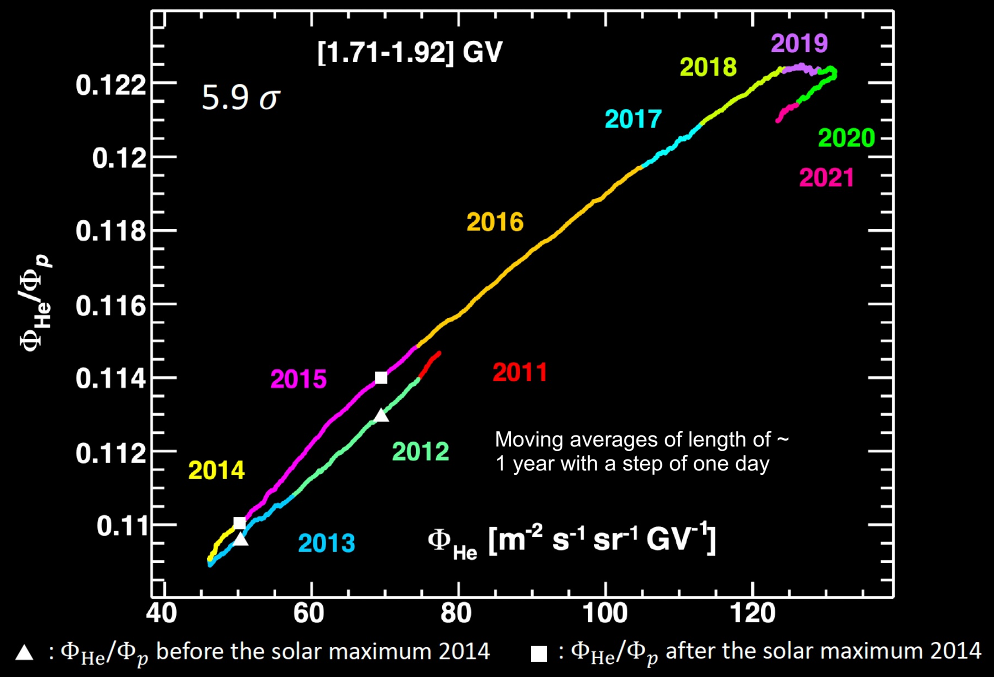


AMS Daily Proton and Helium Fluxes

Y. Ja for the AMS collaboration, ICRC 2023



Y. Ja for the AMS collaboration, ICRC 2023



Proton and Helium fluxes exhibit short-term and long-term variations that depend on time and on rigidity.

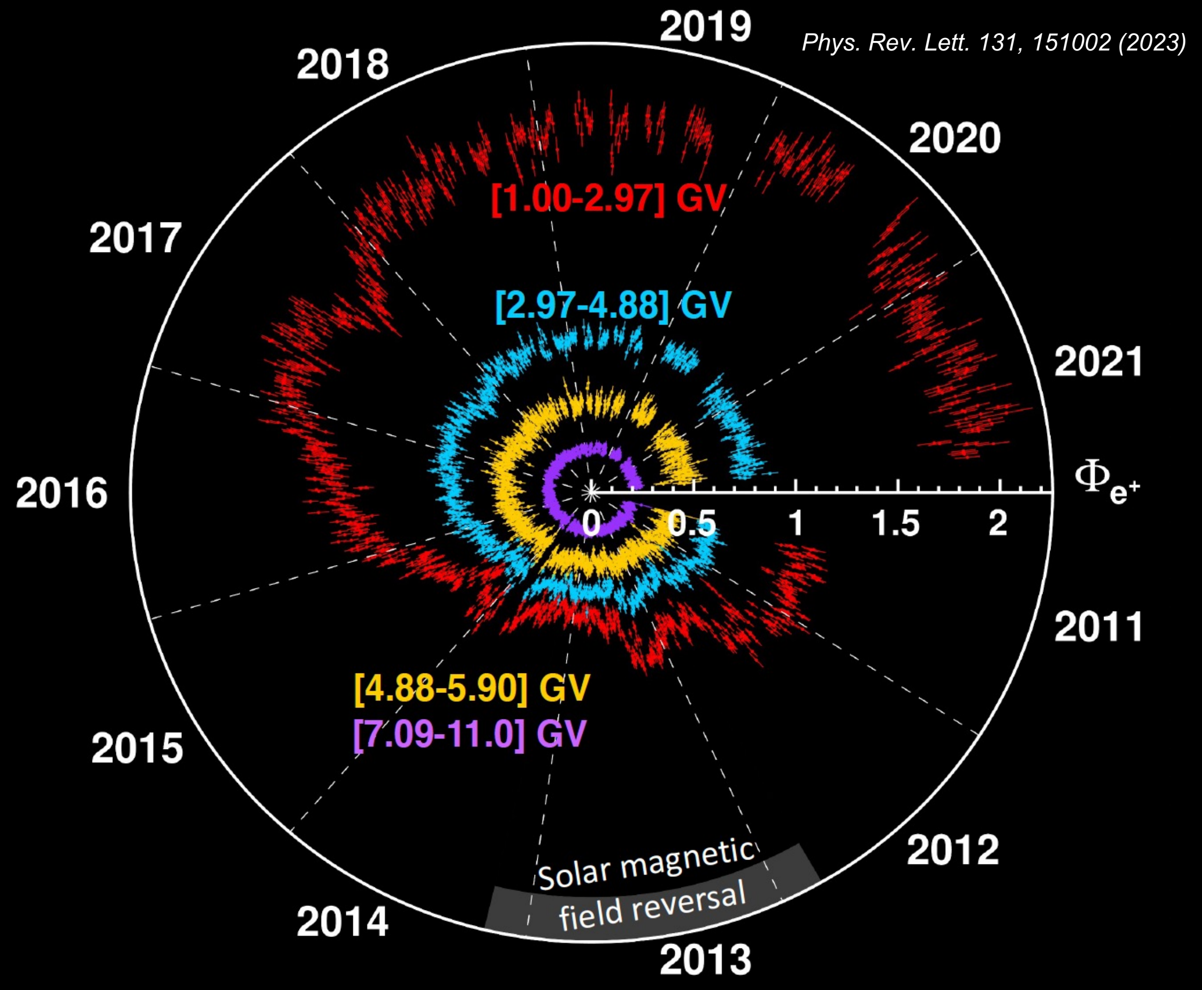
The helium flux exhibits larger time variations than the proton flux.

At low rigidity the modulation of the helium to proton flux ratio is different before and after the solar maximum in 2014.

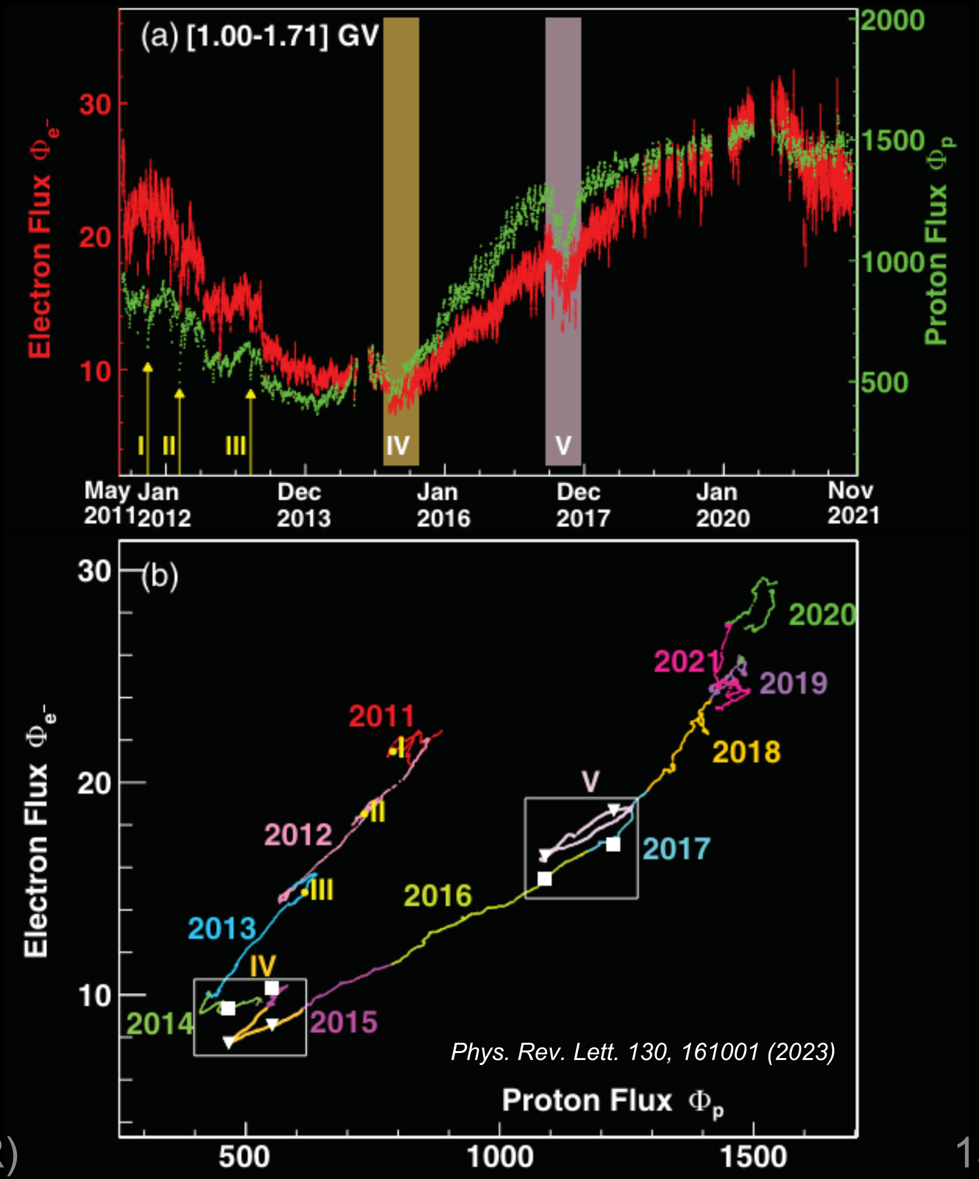
7σ effect observed in the He/p hystheris below 2.4 GV

AMS Daily Positron and Electron Fluxes

AMS daily **positron** measurements based on 3.4 million positrons
First daily positron dataset over an extended period of time

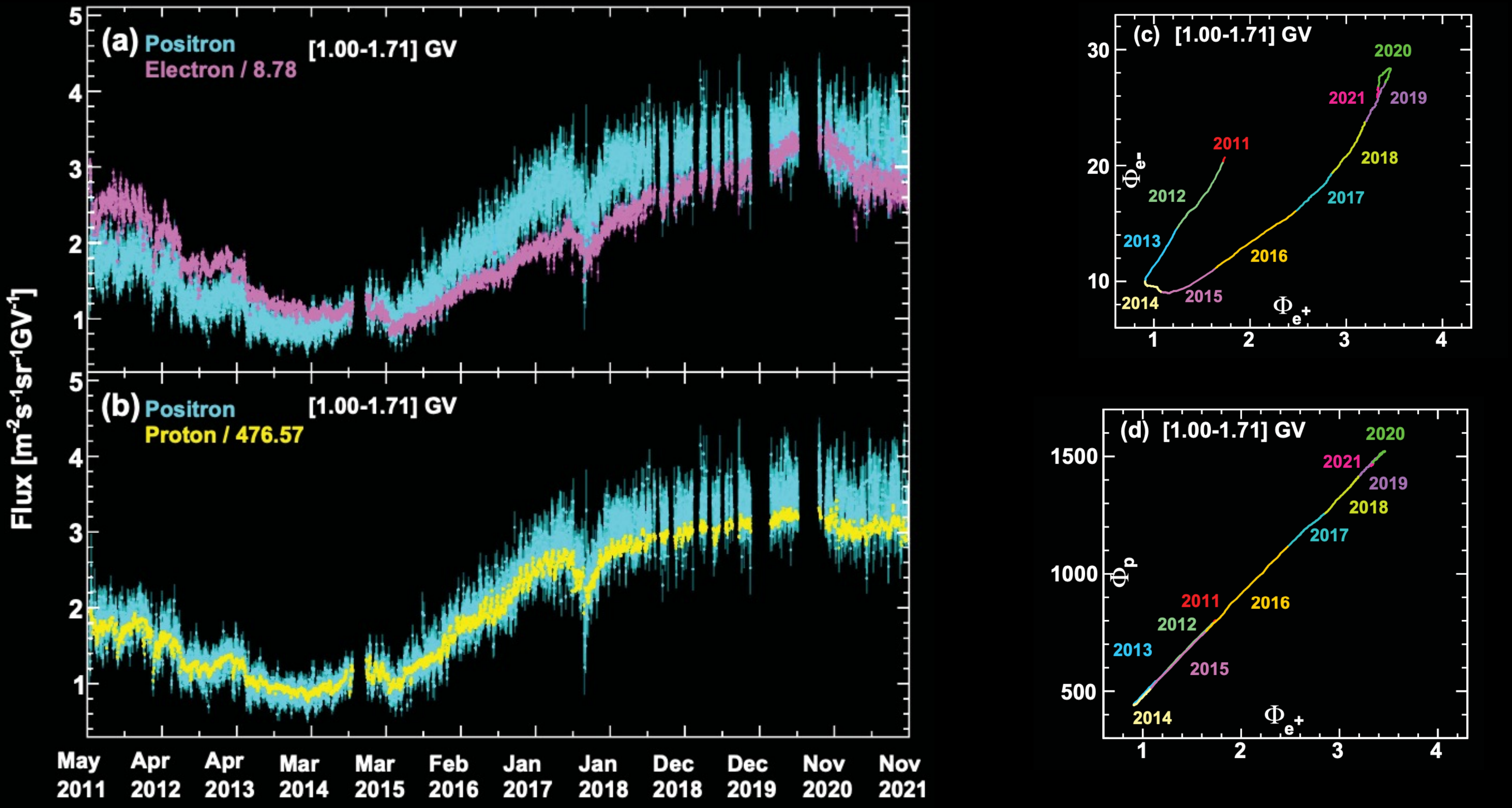


Structures in the **electron-proton** hysteresis based on 380 million electrons



AMS Daily Positron and Electron Fluxes

Phys. Rev. Lett. 131, 151002 (2023)

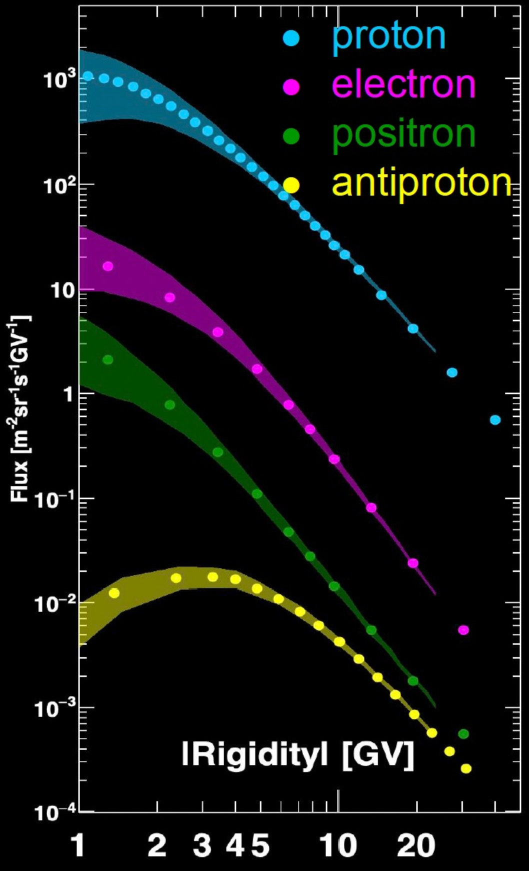


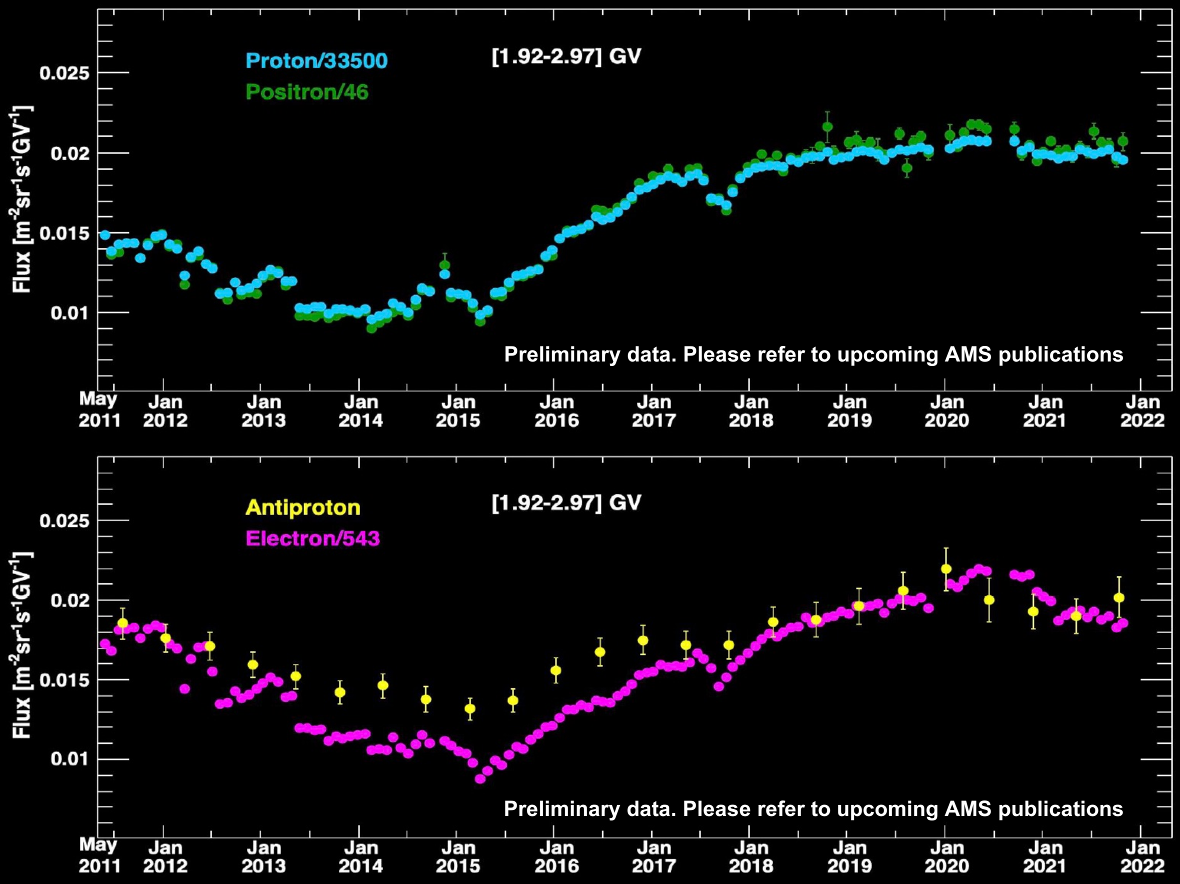
Time dependence of light cosmic particles

Preliminary data. Please refer to upcoming AMS publications

For the first time, solar modulation of p, p-bar, e^+, and e^- is being studied with the same experiment over an extended period of time

Z. Tang for the AMS collaboration, ICRC 2023





Unexpected observation:

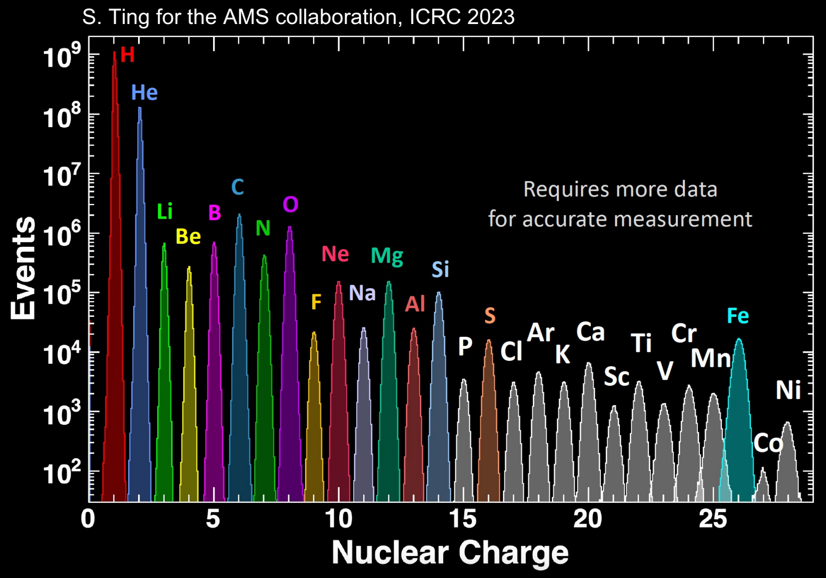
Positive charge
positrons and protons
have similar temporal structure

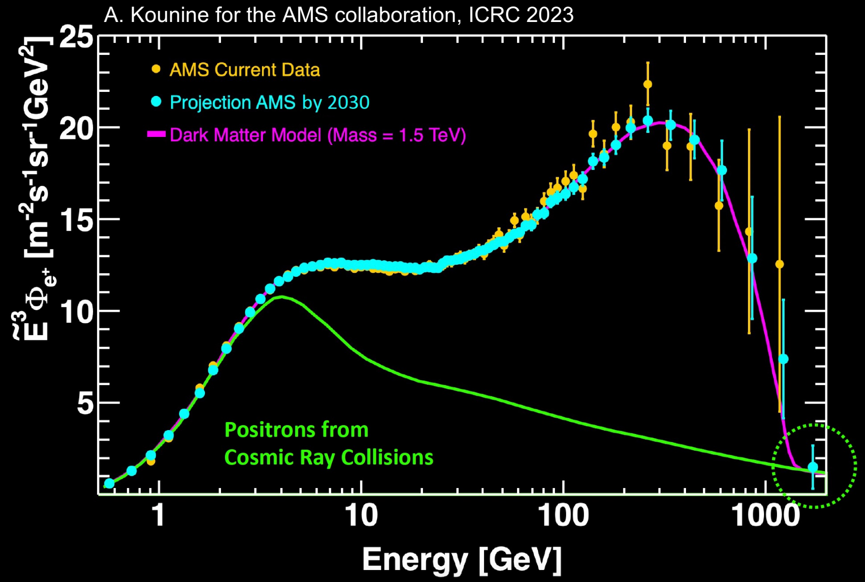
Negative charge
electrons and antiprotons
have different temporal structure

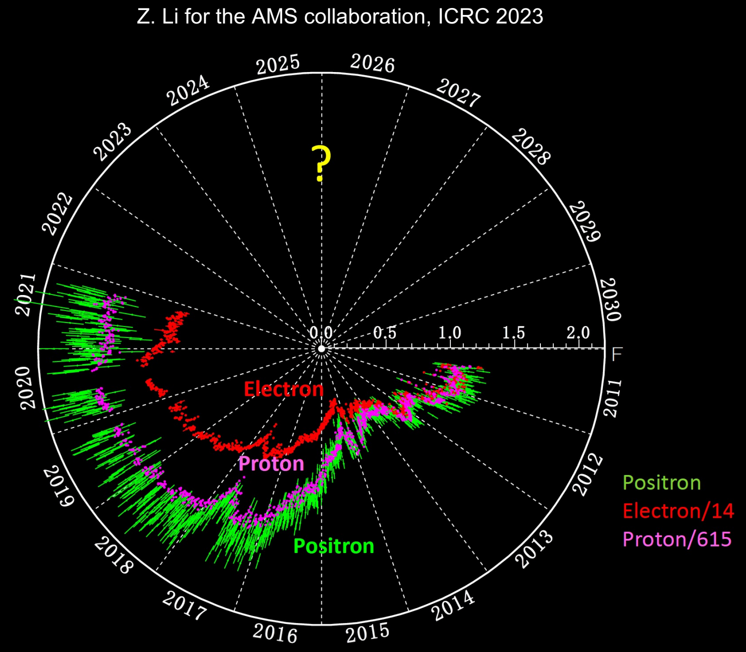
Measurement of antiproton flux time dependence:

- study of solar modulation mechanisms
- assessment of time dependent effects in low-energy antiproton DM searches

Many analyses ongoing

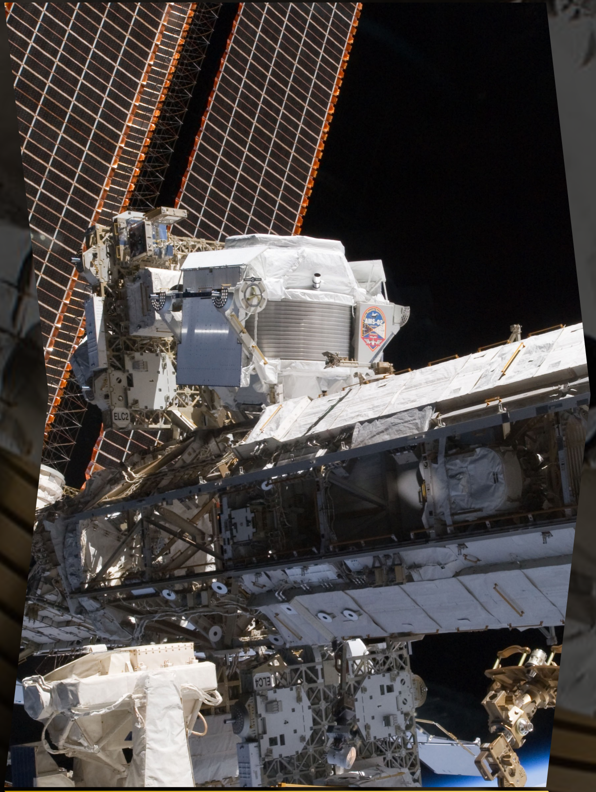






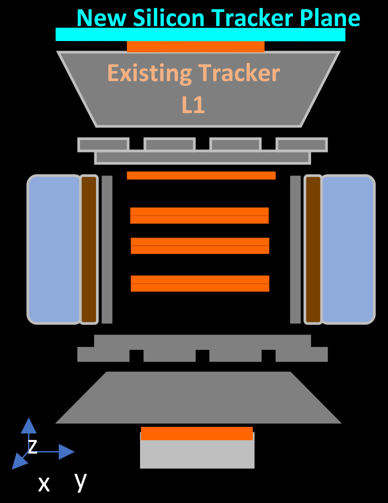
AMS operations to 2030 will complete and accurate spectra for the 29 nuclei elements, electrons and antimatter and provide the foundation for a comprehensive theory of cosmic rays

AMS operations to 2030 will provide the first detailed time, rigidity and charge resolved monitoring of heliospheric effects over an entire polarity cycle



Installation of additional Si-tracker layer

Layer 0 (L0)



2011 AMS-02
Installed On ISS

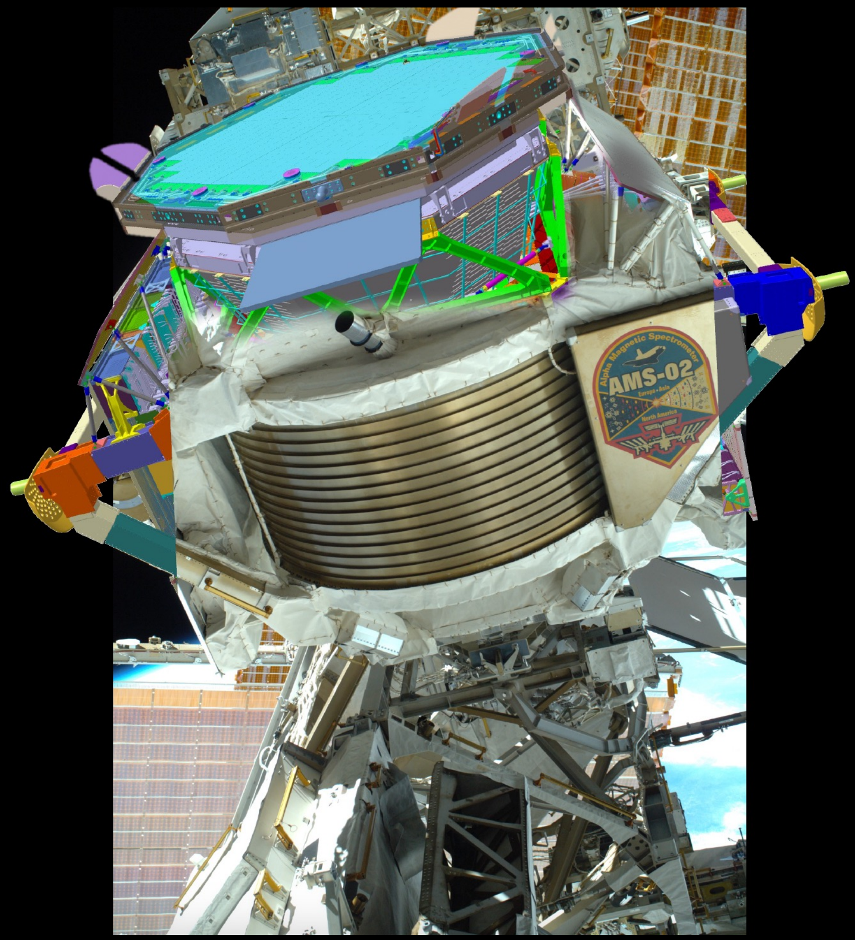
2020 AMS-02.01
Upgrade: UTTPS

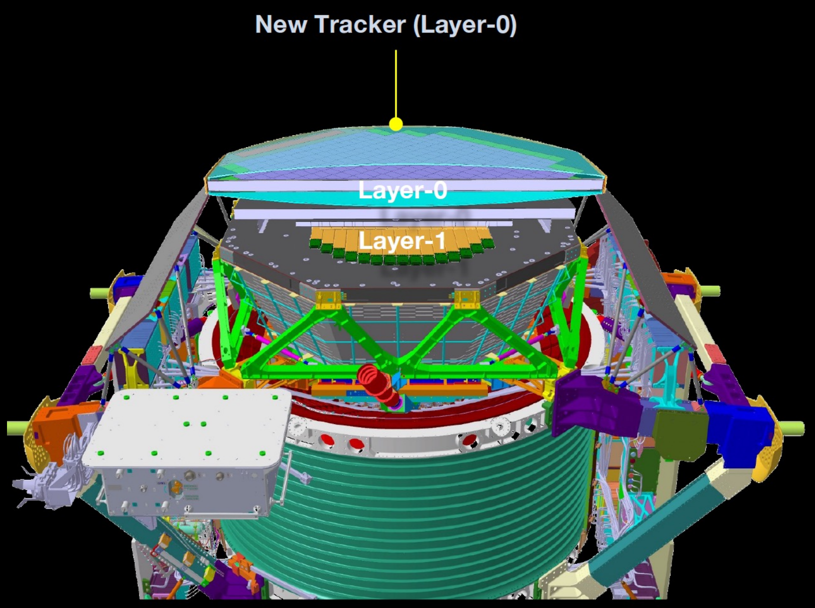
AMS-02.02
Upgrade: L0

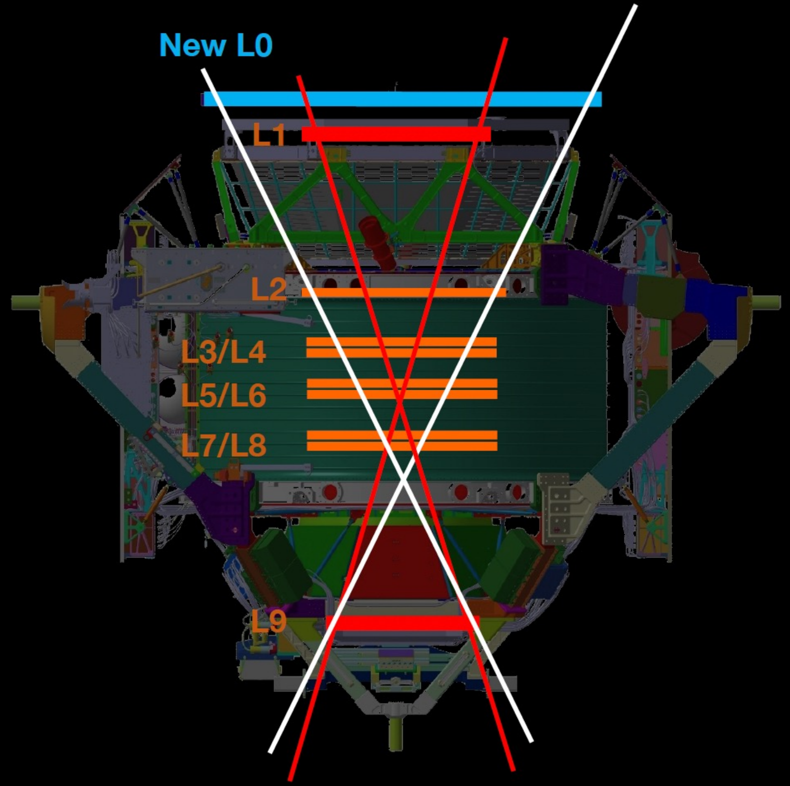
AMS Tracker Layer 0: acceptance increase by 300%

AMS-02 Layer-0 upgrade

AMS-02 Layer-0 upgrade







300% acceptance increase to allow maximum data collection in many analysis channels (e.g., nuclei, antimatter, ...) and extend solar modulation monitoring for beyond an entire solar cycle with improved accuracy

There is no other magnetic spectrometer in space in the foreseeable future.

By collecting data through the lifetime of ISS AMS will shed new light to the origin of the observed unexpected phenomena.

The AMS mission is supported by the Italian Space Agency under
ASI-INFN Agreement No. 2021-43-HH.0
ASI-INFN Agreement No. 2019-19-HH.0 and its amendments
ASI-University of Perugia Agreement No. 2019-2-HH.0

Agenzia Spaziale Italiana

AMS published data are available for access at Cosmic Ray Database hosted in ASI-SSDC
https://tools.ssdc.asi.it/CosmicRays/