Latest Results from the AMS experiment

Washington DC 04/25/2017

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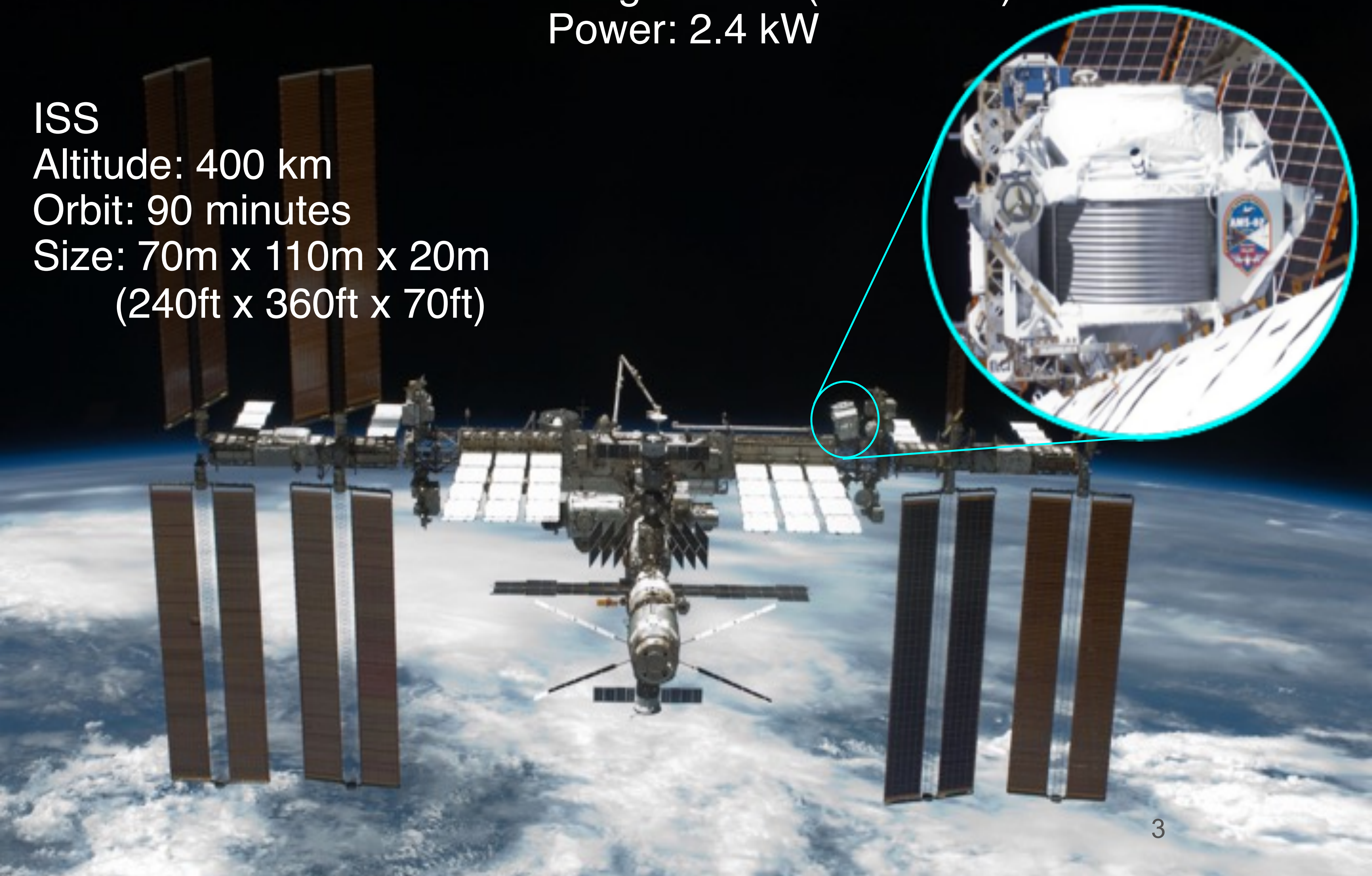
The travel of AMS to the ISS

May 16, 2011: AMS Flight, Space Shuttle Endeavor

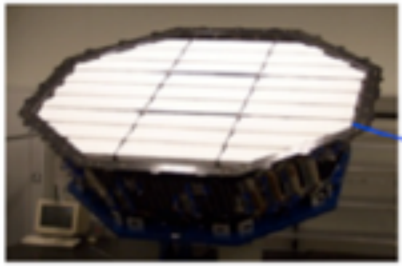


AMS-02 **Installed on the ISS May 19, 2011**
Size: 5m x 4m x 3m (16ft x 13ft x 10ft)
Weight: 7 ton (15000 lbs)
Power: 2.4 kW

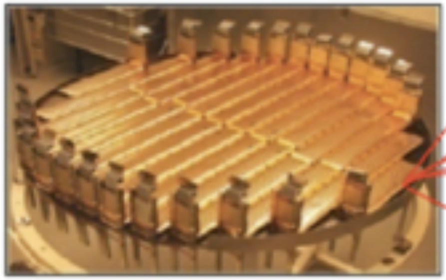
ISS
Altitude: 400 km
Orbit: 90 minutes
Size: 70m x 110m x 20m
(240ft x 360ft x 70ft)

The AMS Experiment

TRD
Identify e+, e-

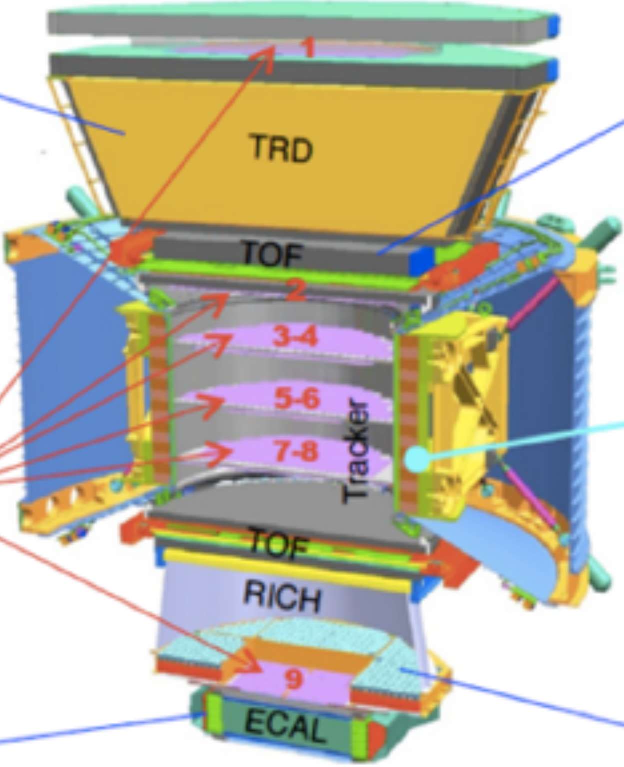


Silicon Tracker
Z, P



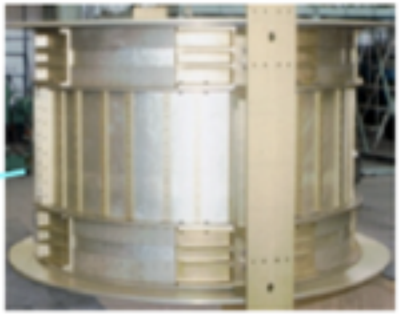
ECAL
E of e+, e-, γ

Particles and nuclei are defined by their charge (Z) and energy (E ~ P)

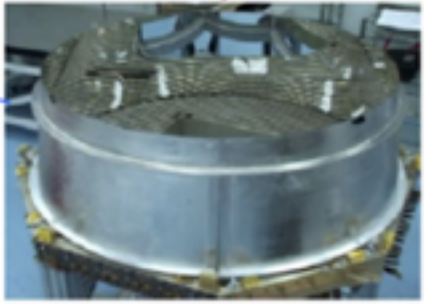


TOF
Z, V

Magnet
±Z



RICH
Z, V



Accuracy and Redundancy

Acceptance 0.4 m^2sr
Rigidity range 0.5 GV to a few TV

Challenges in Space

Thermal environment

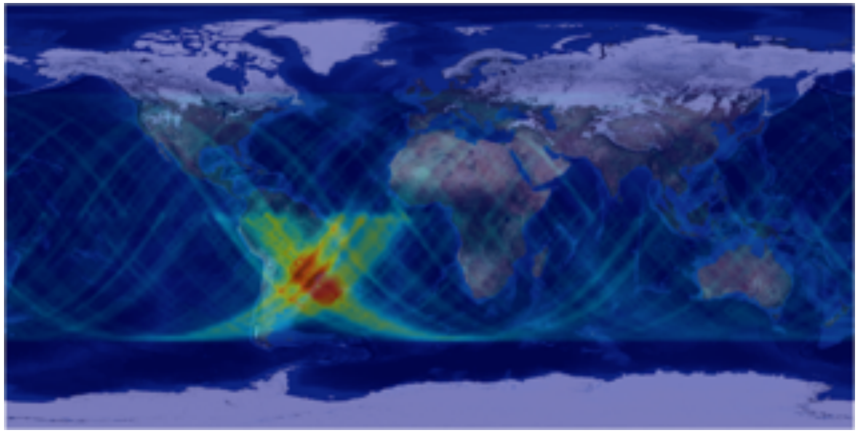
1) The thermal environment constantly changes (90 min orbit)
2) No control of the ISS

- Monitor the temperature sensors
- Improve the thermal models and develop safety procedures

Radiation Dose

Passing heavy nuclei can induce errors or damages in the electronic components

- Periodic checks and automatic procedure to restore nominal conditions (average of 2 bit flip errors per day)
- Redundancy in the electronics



Data Transfer

AMS collects 7 Gbit/s of scientific data

- Online processing reduces the data to 6 Mbit/s

Flight and Ground Operations

ISS Astronaut with AMS Laptop

Ku-band High Rate (down):
Events <10Mbit/s>
Monitoring: 30 Kbit/s

S-band Low Rate:
Commanding: 1 Kbit/s (up)
No Ku: 10 bits/s (down)

Payload Operations Control Centers (POCC) at CERN

AMS Computers at MSFC, AL

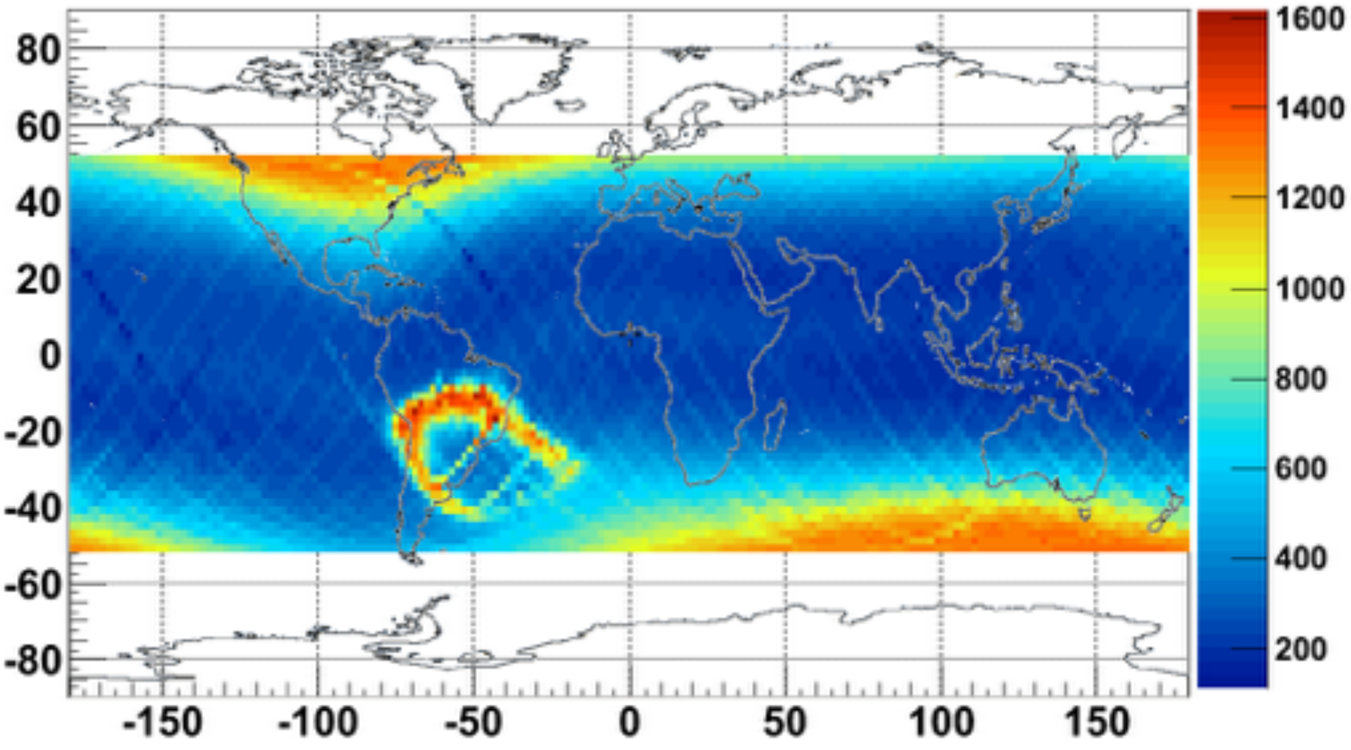
White Sands Ground Terminal, NM

AMS Data

In 5 years of operation AMS has collected over 90 billion events

The ISS orbits the Earth at 400 km altitude and 51.6° to the Equator.

Acquisition rate [Hz]

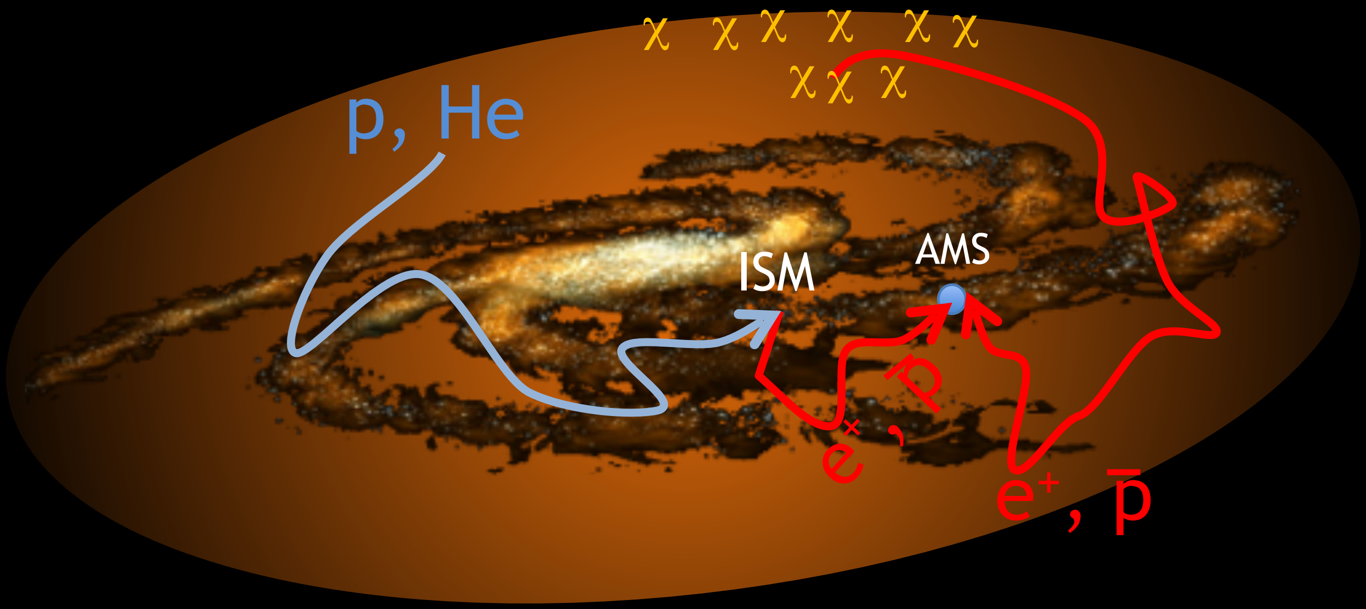


Particle rates vary from 200 to 2000 Hz per orbit

1) Dark Matter: χ

Collision of Cosmic Rays with the Interstellar Medium will produce e^+, $\bar{p}$…

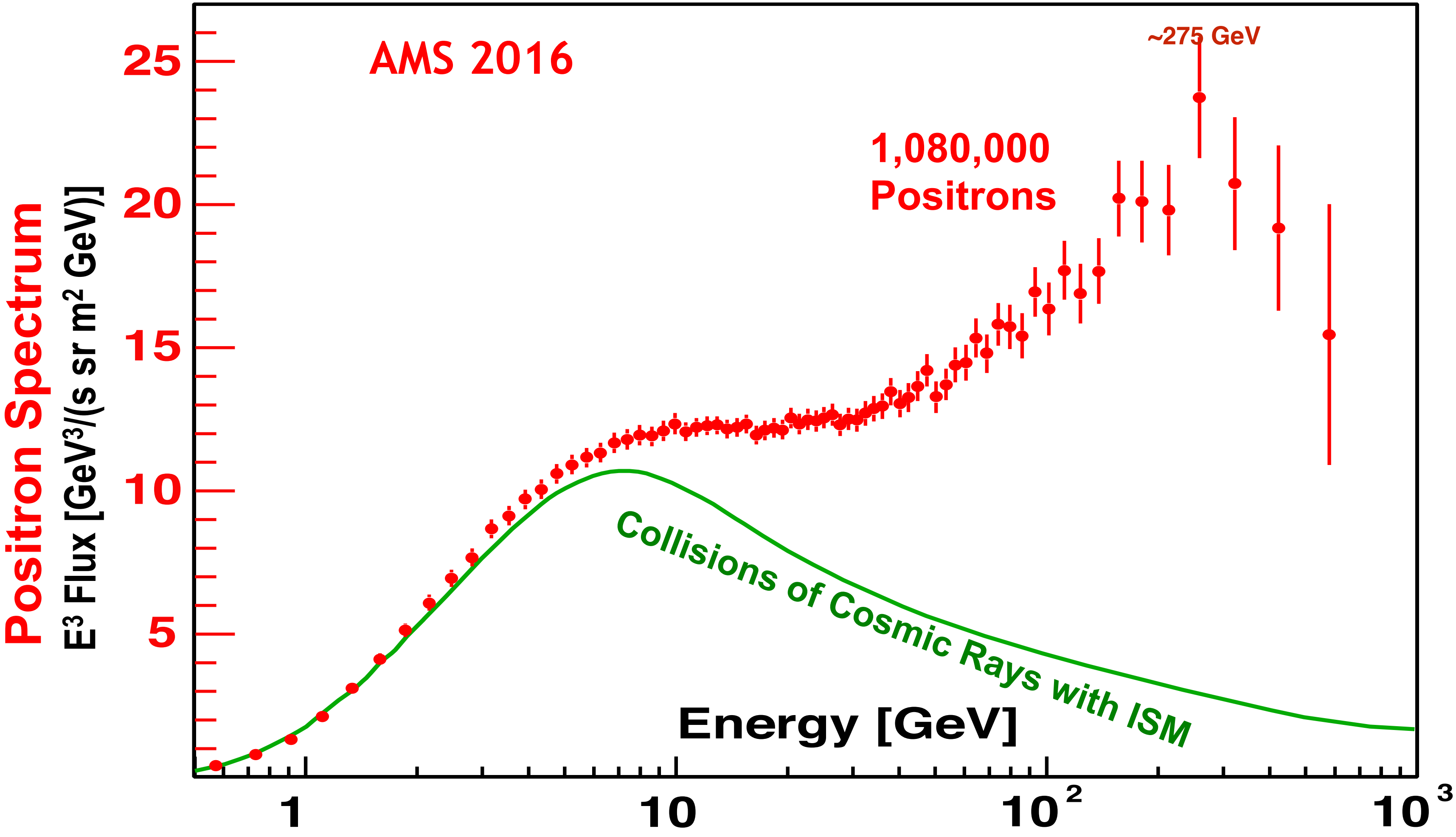
p, He + ISM → e^+, $\bar{p}$ + ...



Dark Matter (χ) annihilations $\chi + \chi \rightarrow e^+, \bar{p} + \ldots$

The excess of e^+, $\bar{p}$ from Dark Matter (χ) annihilations
can be measured by AMS

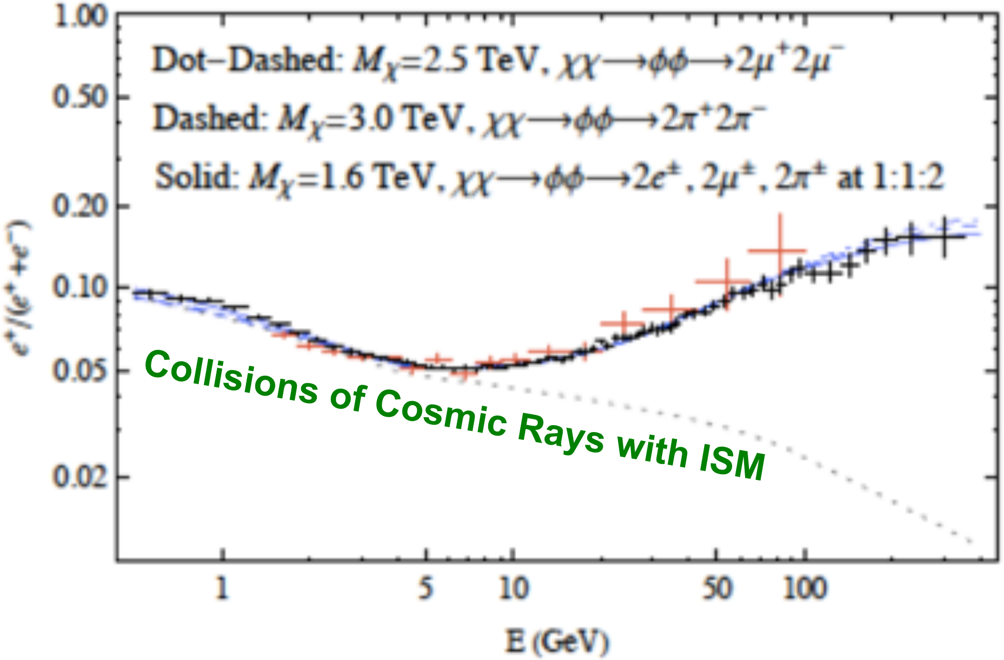
Positrons in the Galaxy



Starting from ~8 GeV, the AMS e+ data show an excess above ordinary Cosmic Ray collisions.

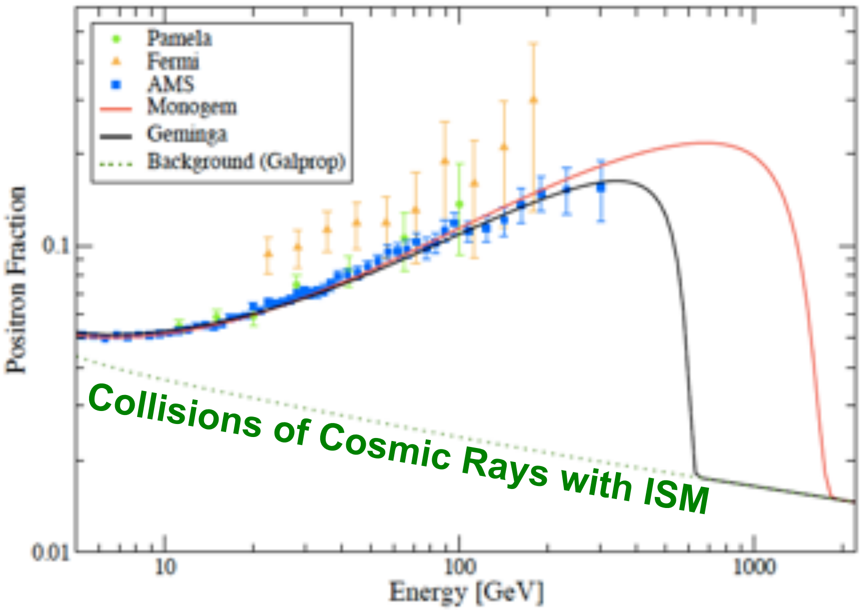
On the positron excess

Positron excess can be explained by **dark matter annihilation**, a contribution from a **nearby pulsar**, **supernova remnants** reaccelerating at the source or **modified propagation** of cosmic rays.



Choolis & Hooper, 1304.1840

Dark matter annihilation in light intermediate states.

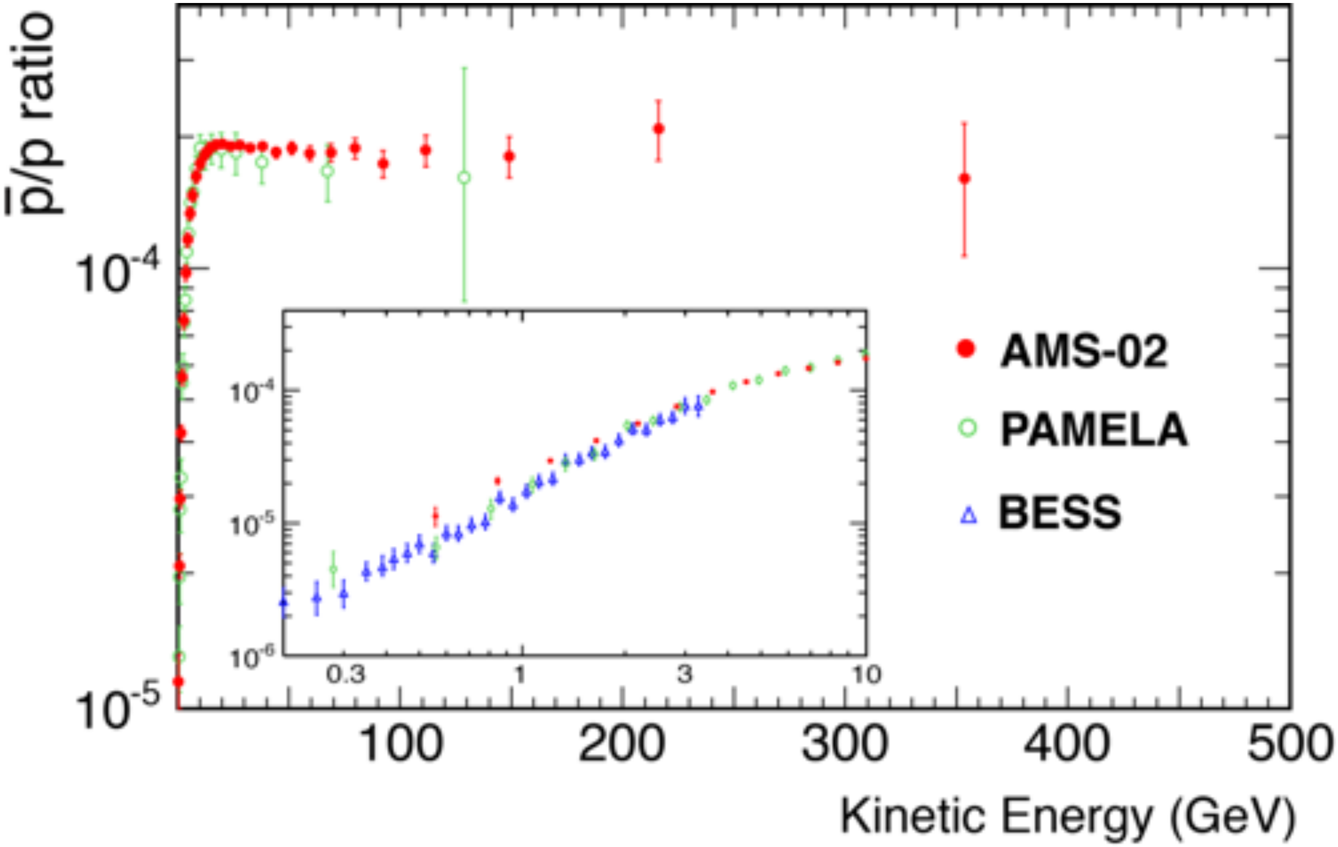


Linden and Profumo, 1304.1791

Contribution from nearby young pulsars.

Dark Matter search:
Antiproton/Proton Ratio

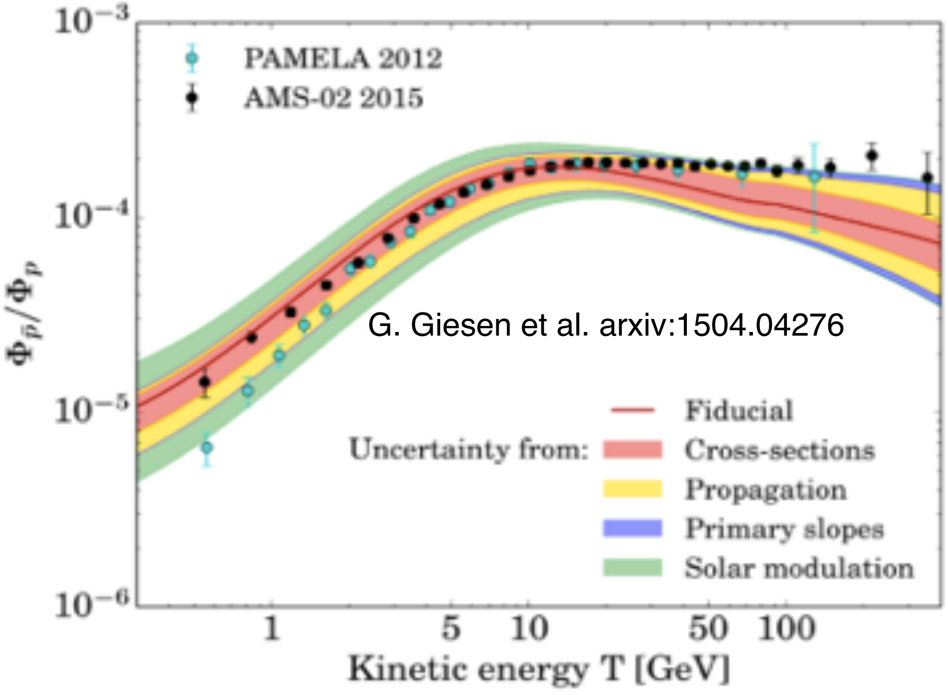
Antiprotons are secondary in origin and are generated by spallation of GCR in the interstellar medium.



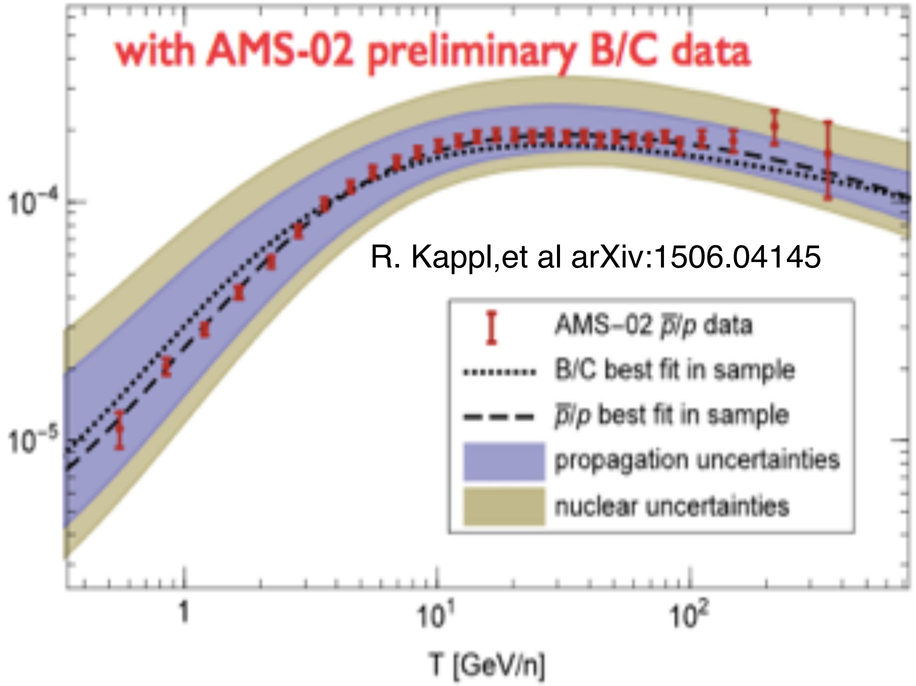
An excess of antiprotons cannot come from pulsars and it would be a Dark Matter signature.

Antiproton/Proton Interpretation

Theoretical uncertainties are still too big and AMS data are compatible with the background.



G. Giesen et al. arxiv:1504.04276

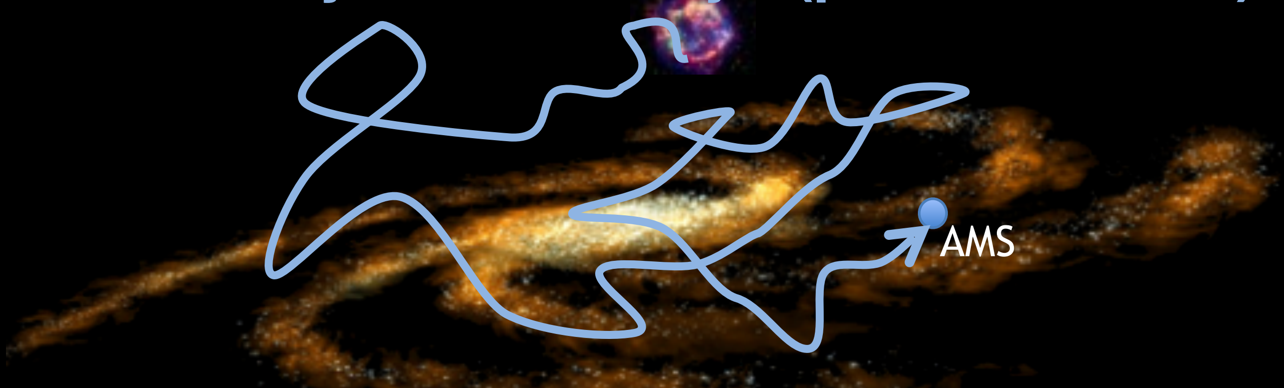


R. Kappl,et al arXiv:1506.04145

AMS measurements are opening new scenarios in the physics of cosmic rays

2) CR acceleration and propagation

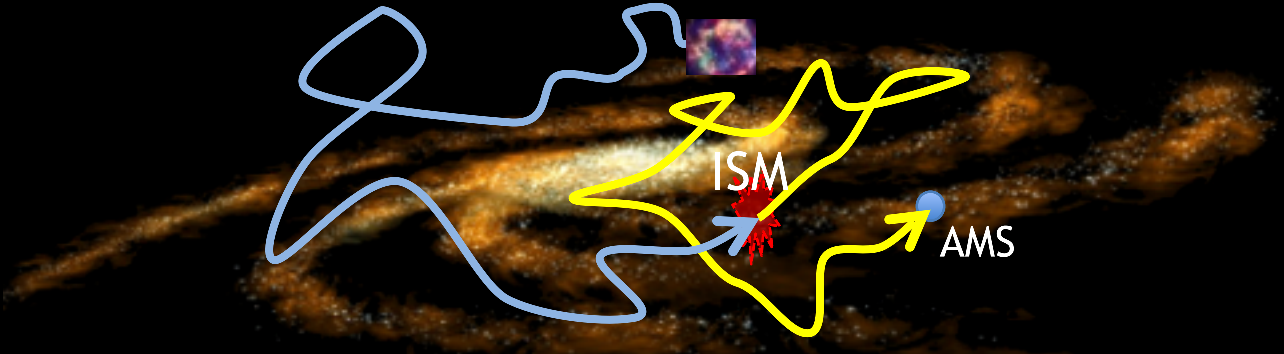
Primary Cosmic Rays (p, He, C, O, …)



Primary cosmic rays carry information about their original spectra and propagation.

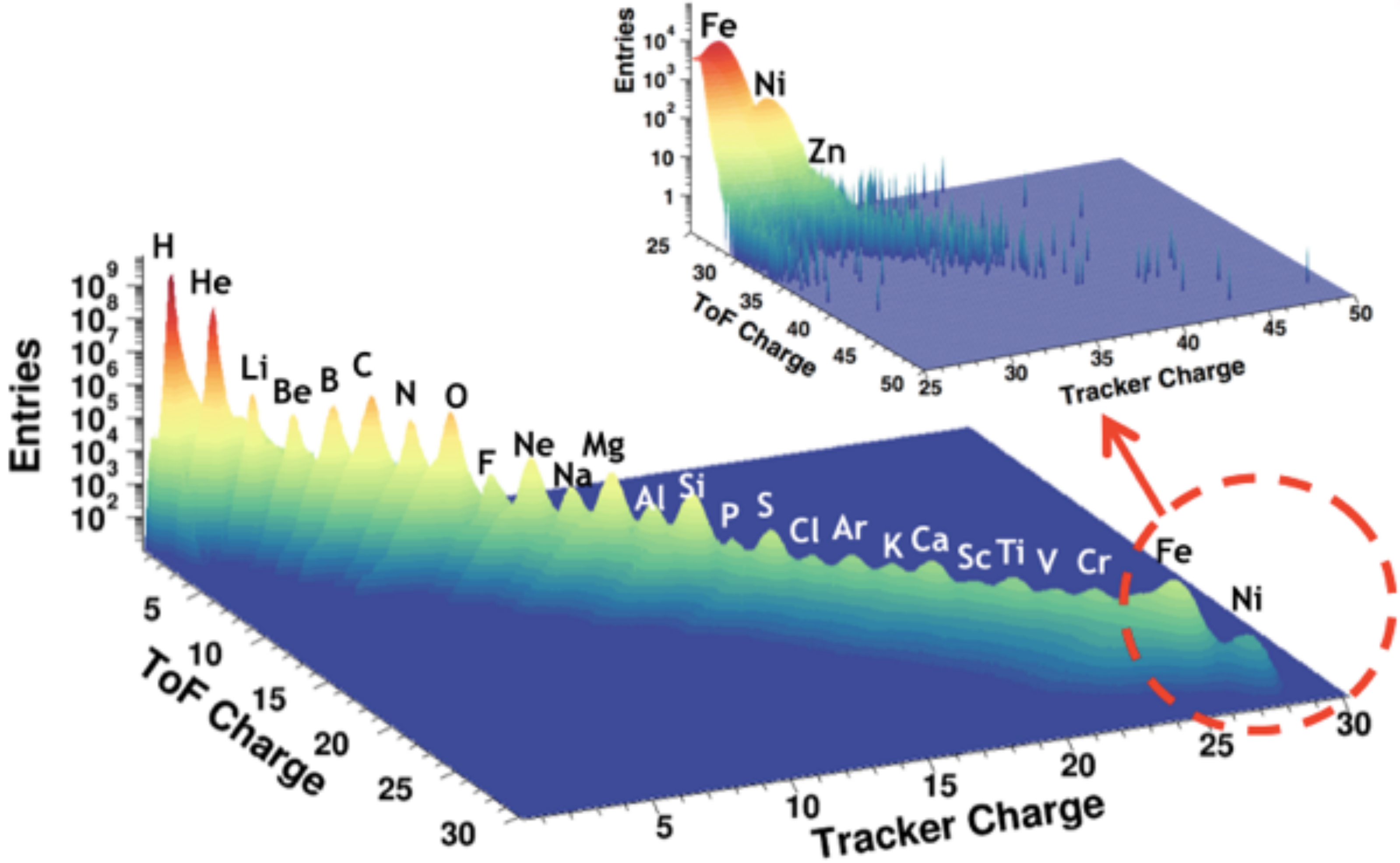
Secondary Cosmic Rays (Li, Be, B, …)

C, O, …, Fe + ISM → Li, Be, B + X



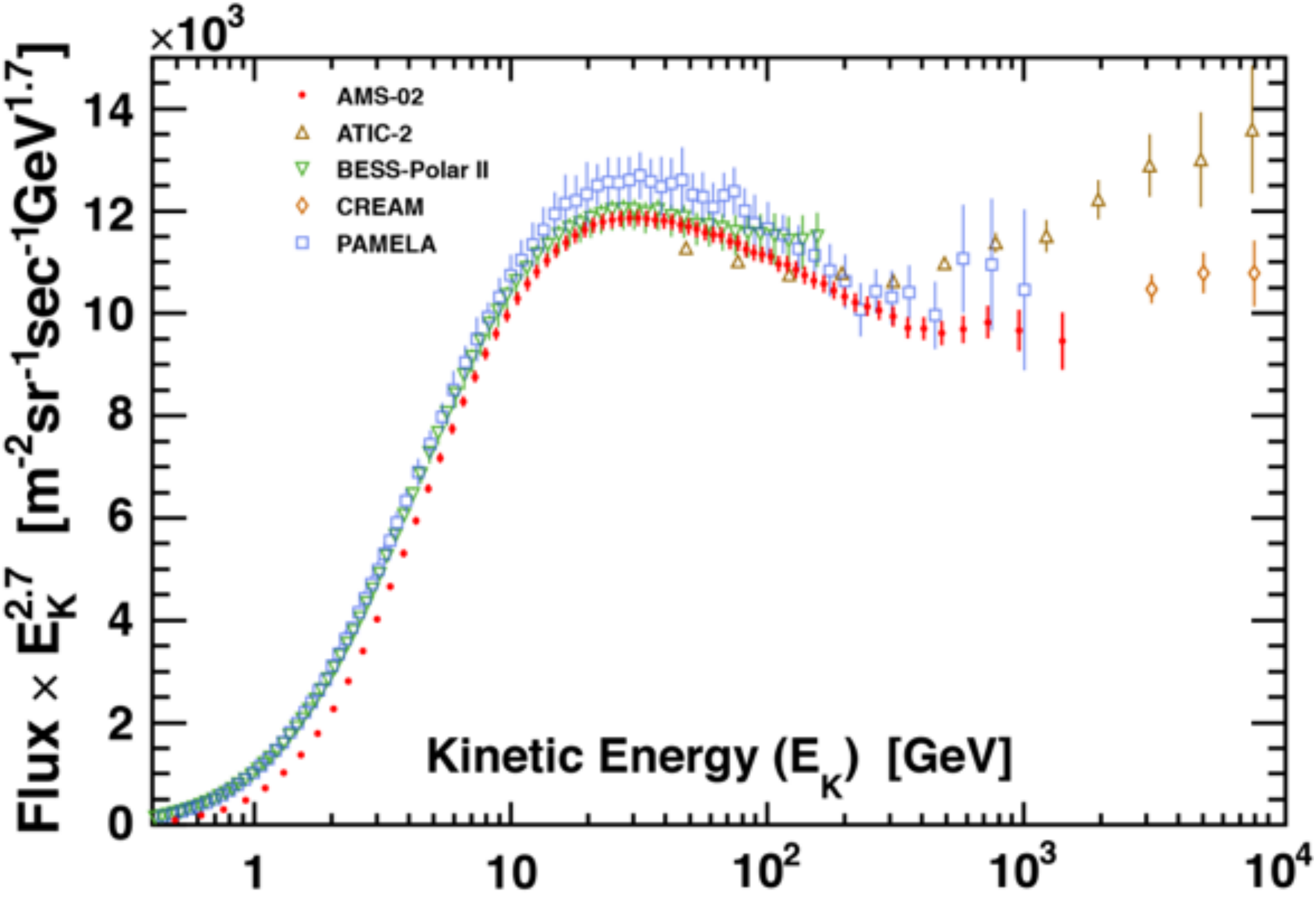
Secondary cosmic rays carry information about propagation of primaries, secondaries and the ISM.

Cosmic-Rays Composition with AMS

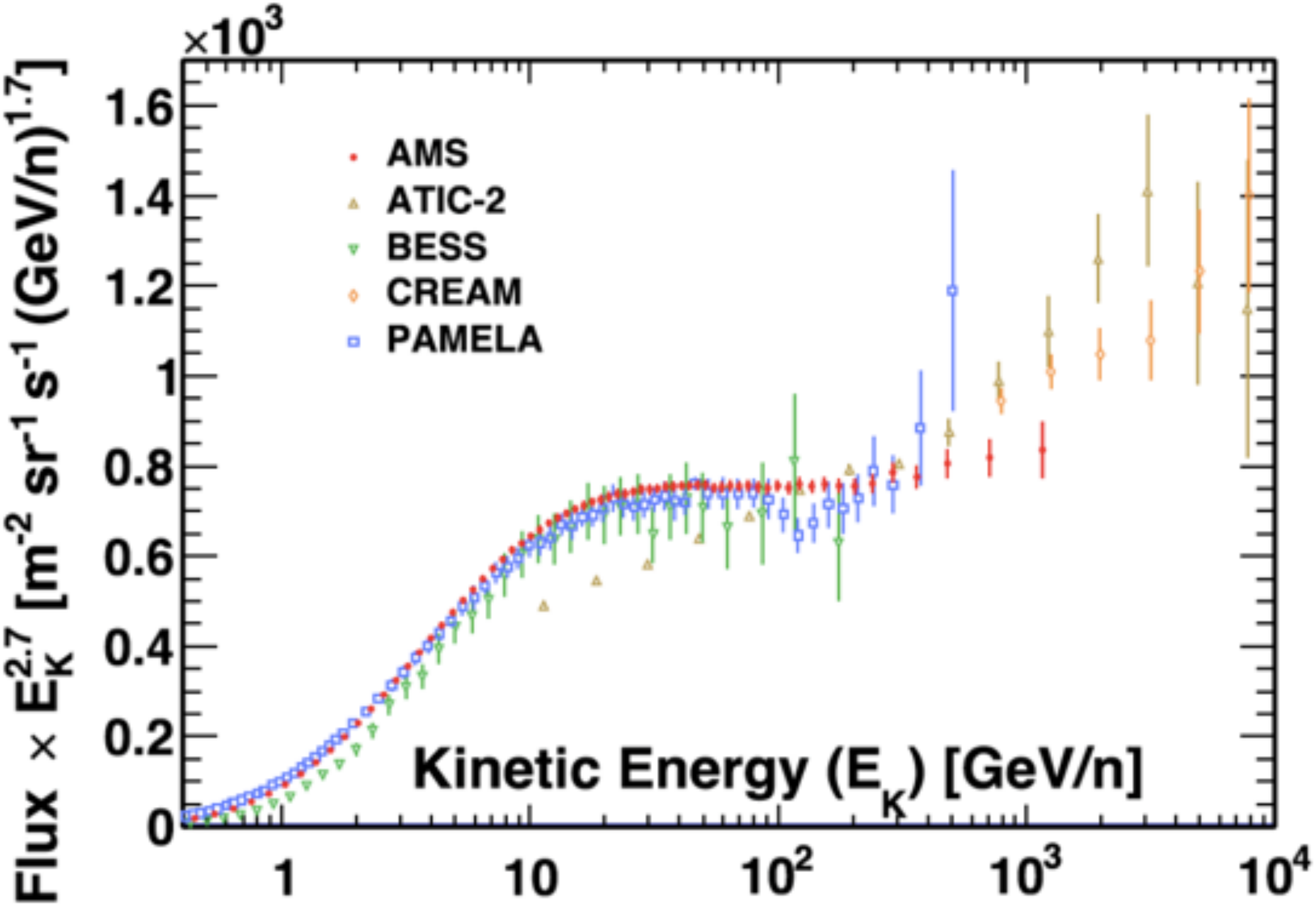


AMS is capable of measuring all the species of cosmic rays at the percentage level up to the iron and above.

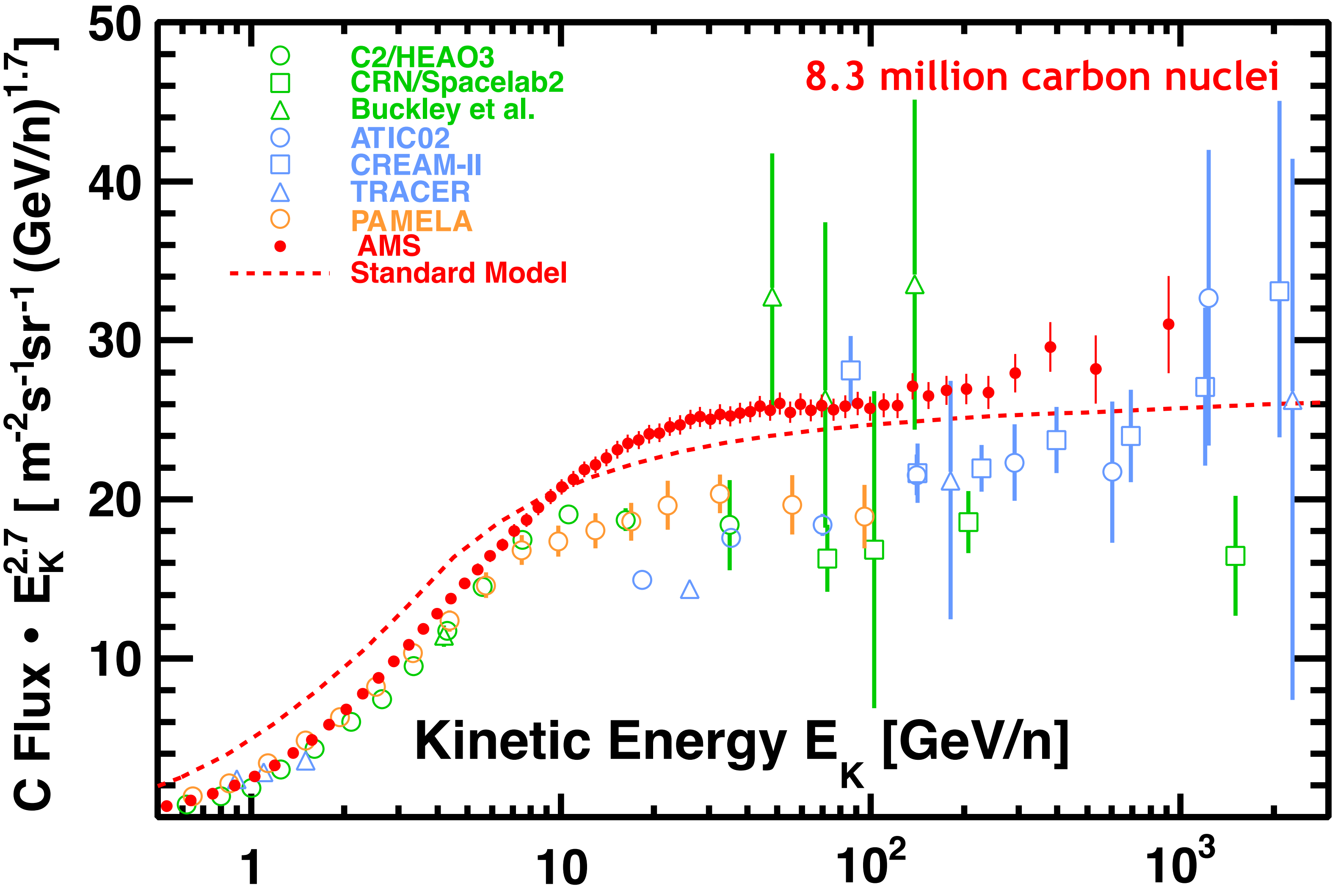
Primary Cosmic Ray Proton



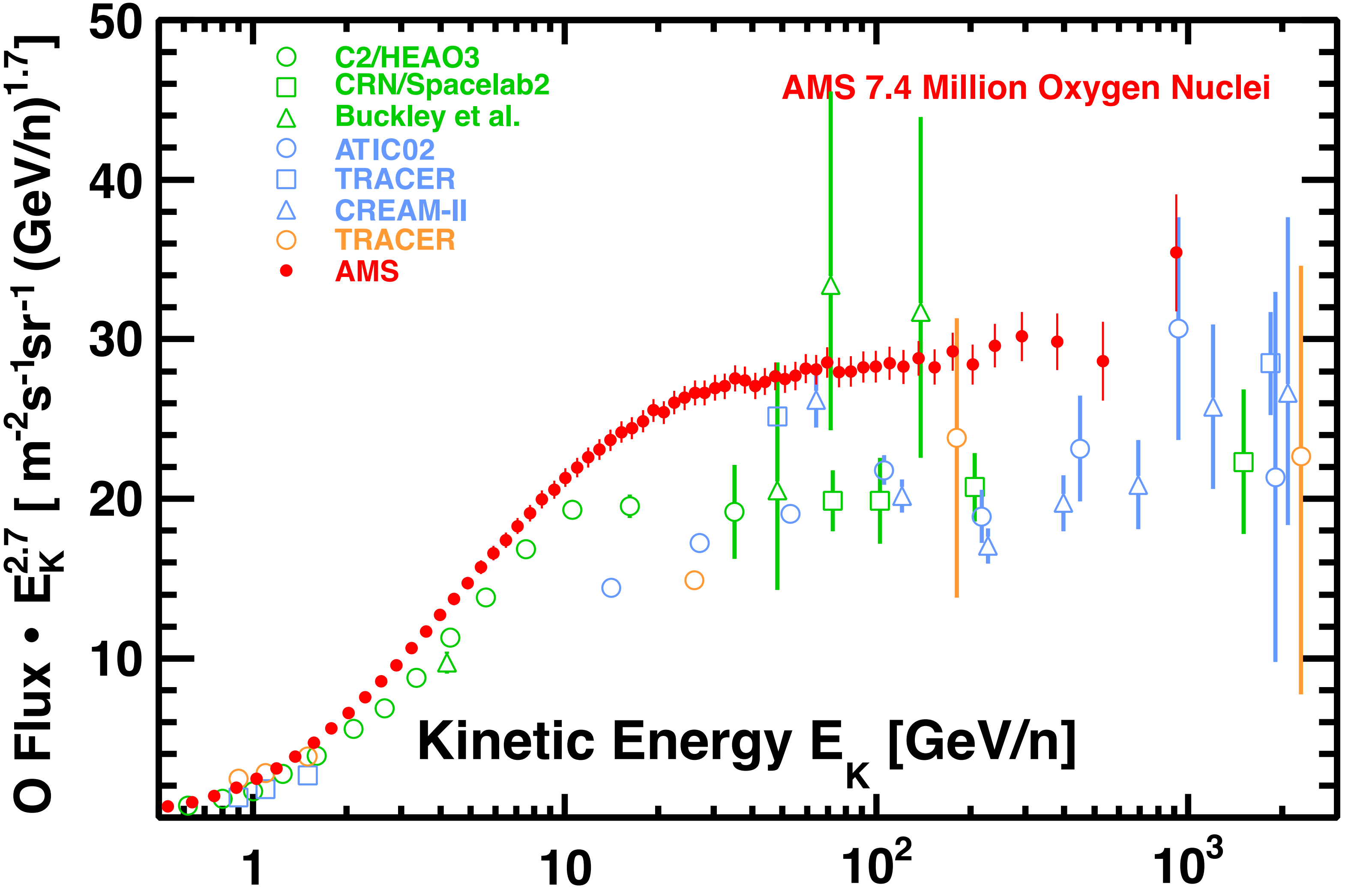
Primary Cosmic Ray Helium



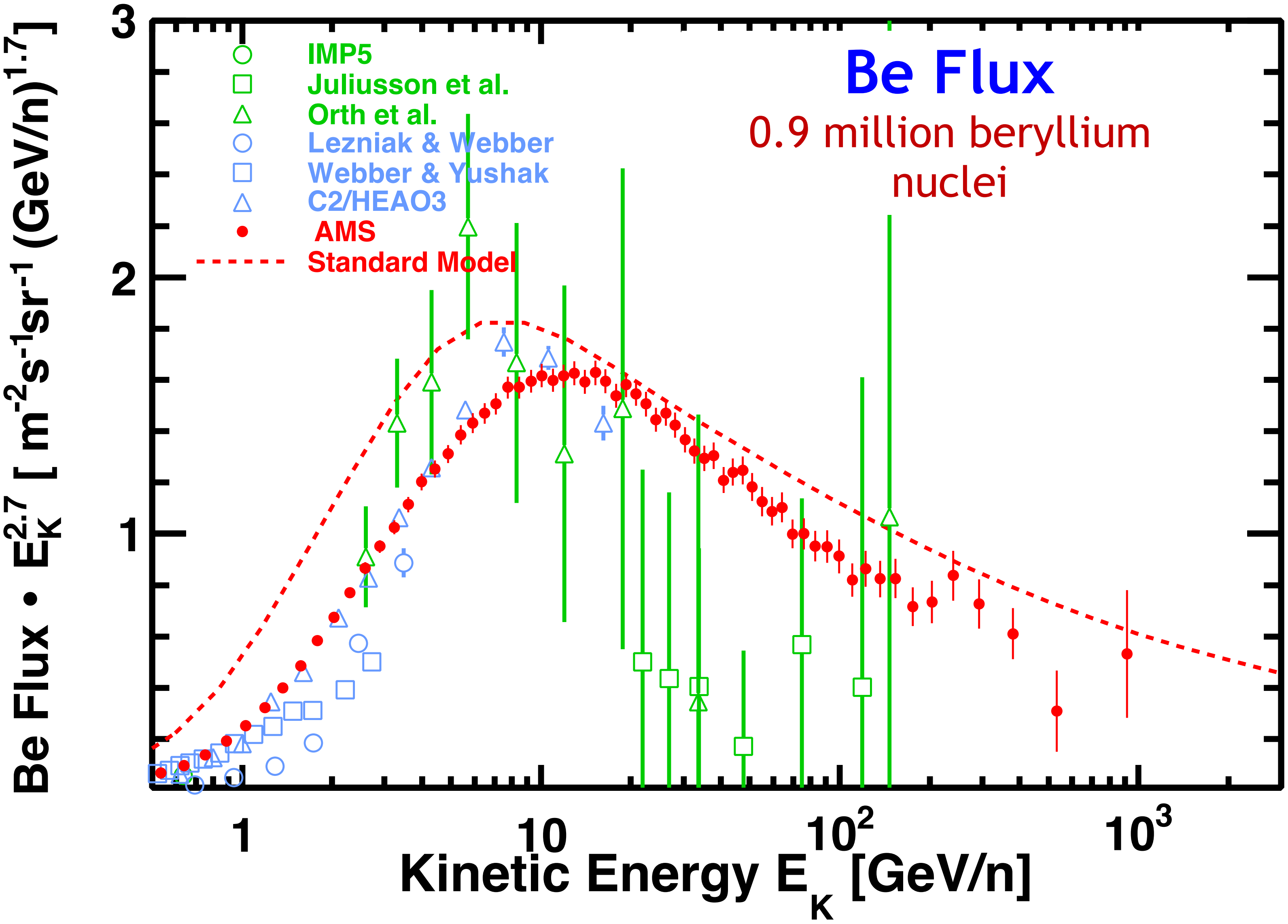
Primary Cosmic Ray Carbon



Primary Cosmic Ray Oxygen



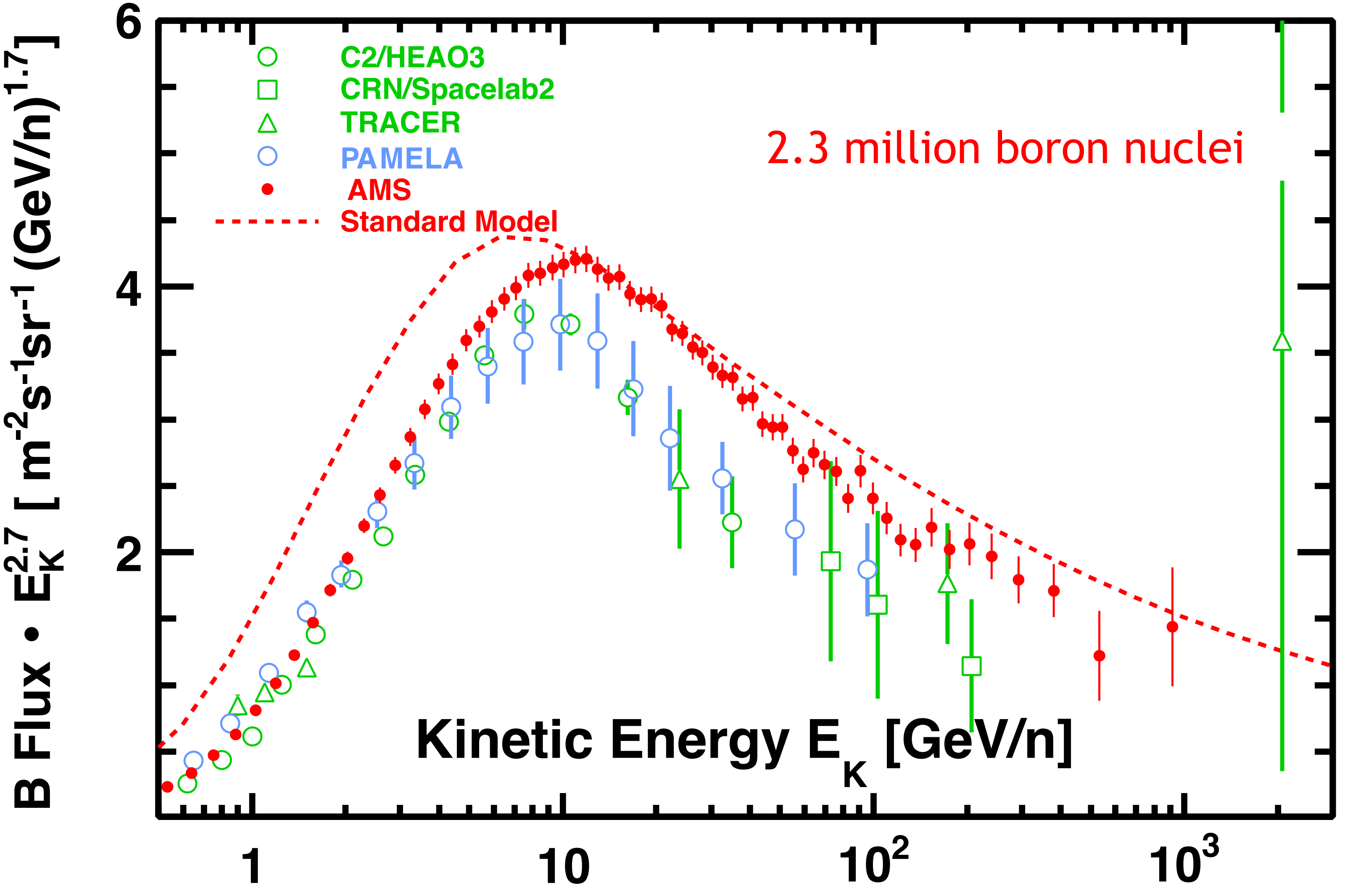
Secondary Cosmic Ray Beryllium



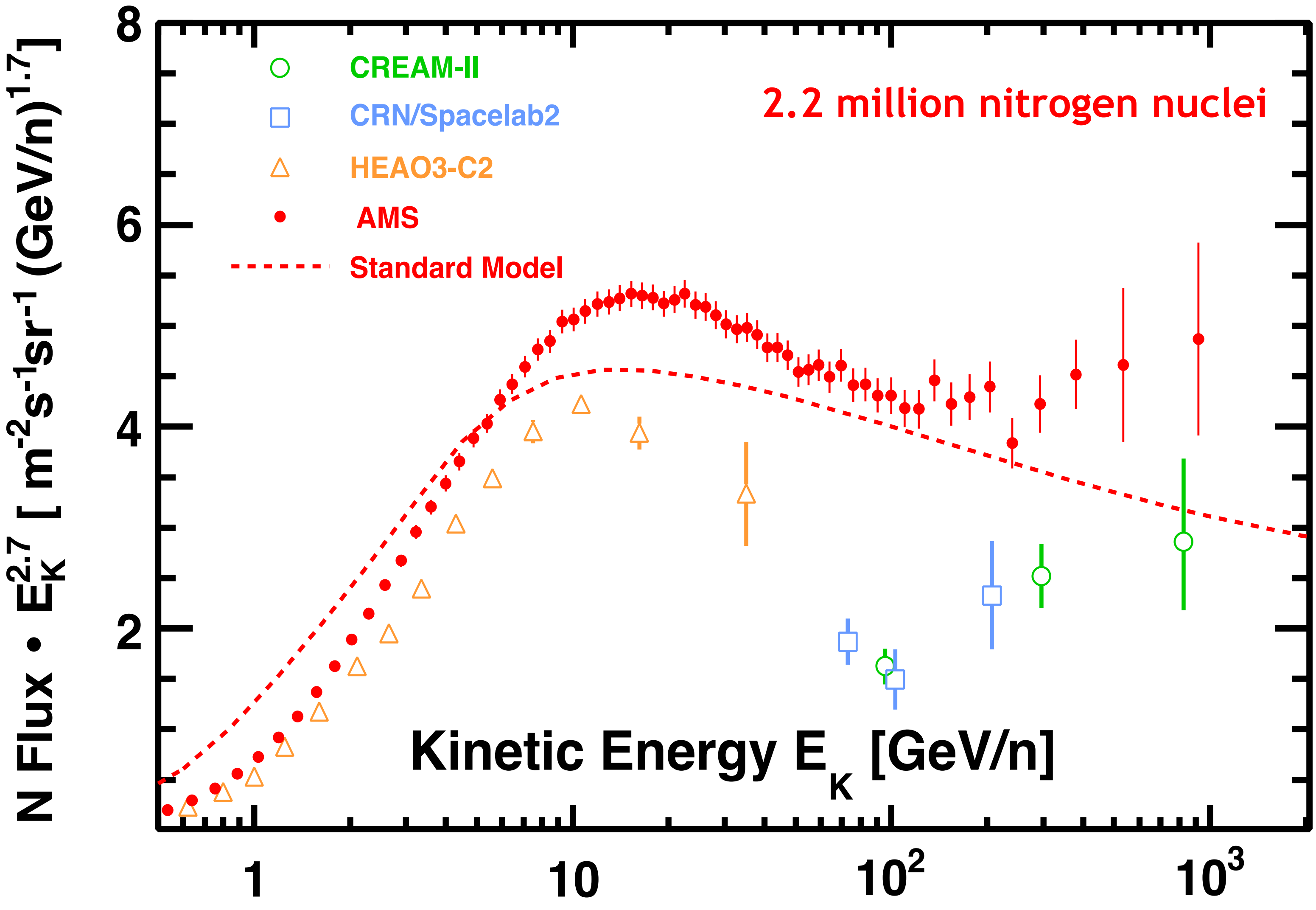
Be Flux

0.9 million beryllium nuclei

Secondary Cosmic Ray Boron

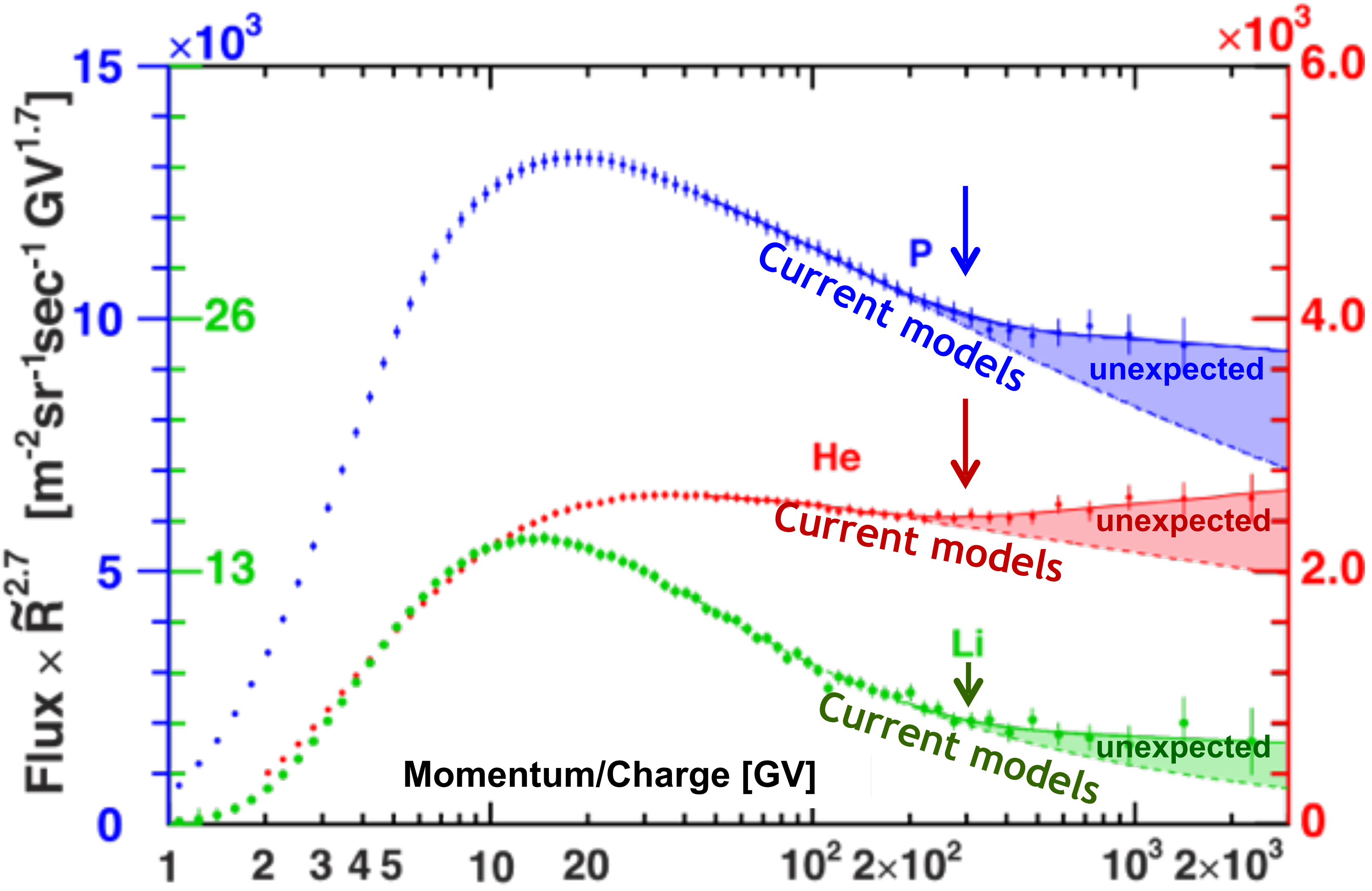


Secondary Cosmic Ray Nitrogen



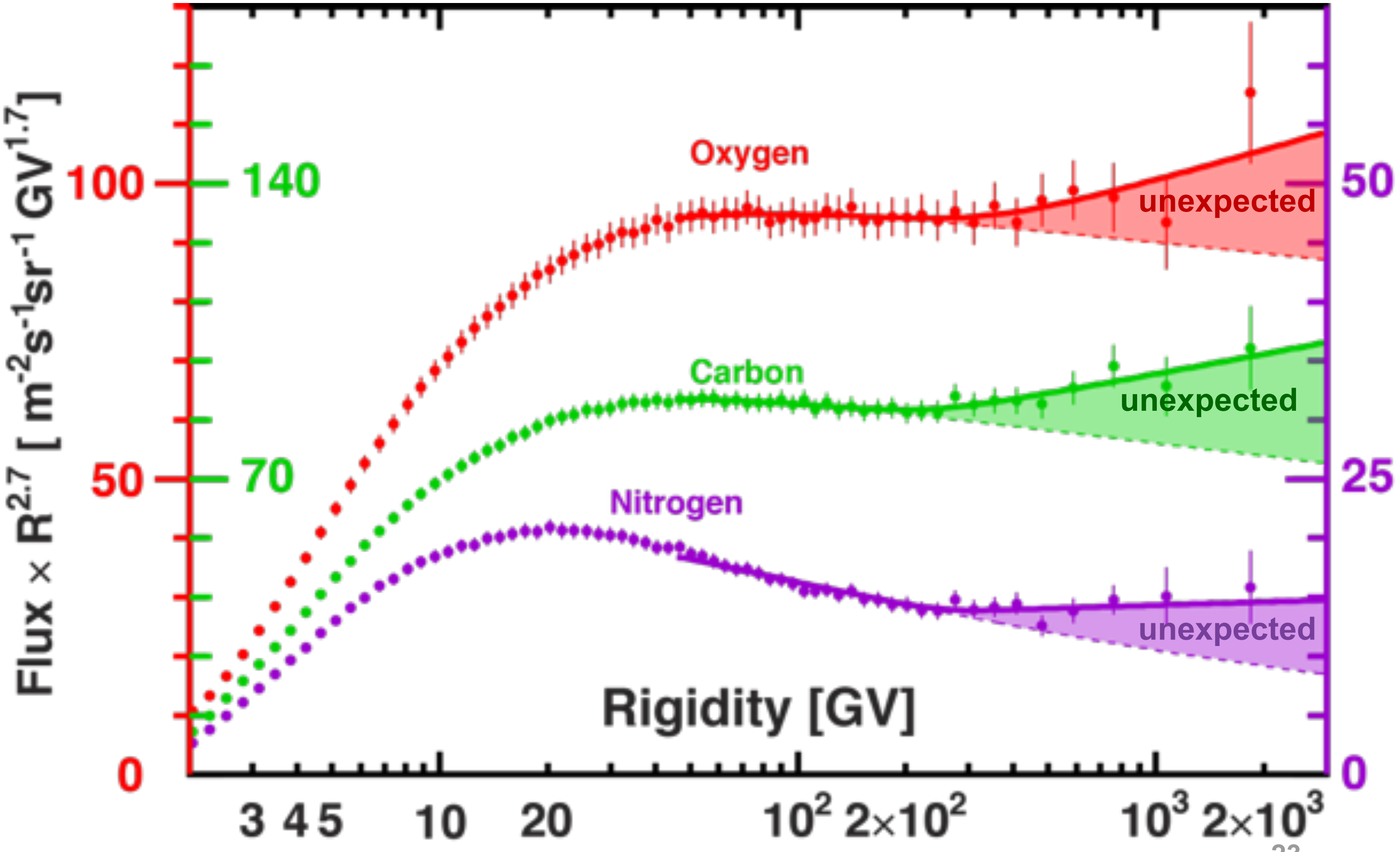
AMS results

Protons, helium and lithium do not follow the traditional single power law. They all change their behavior at the same energy.



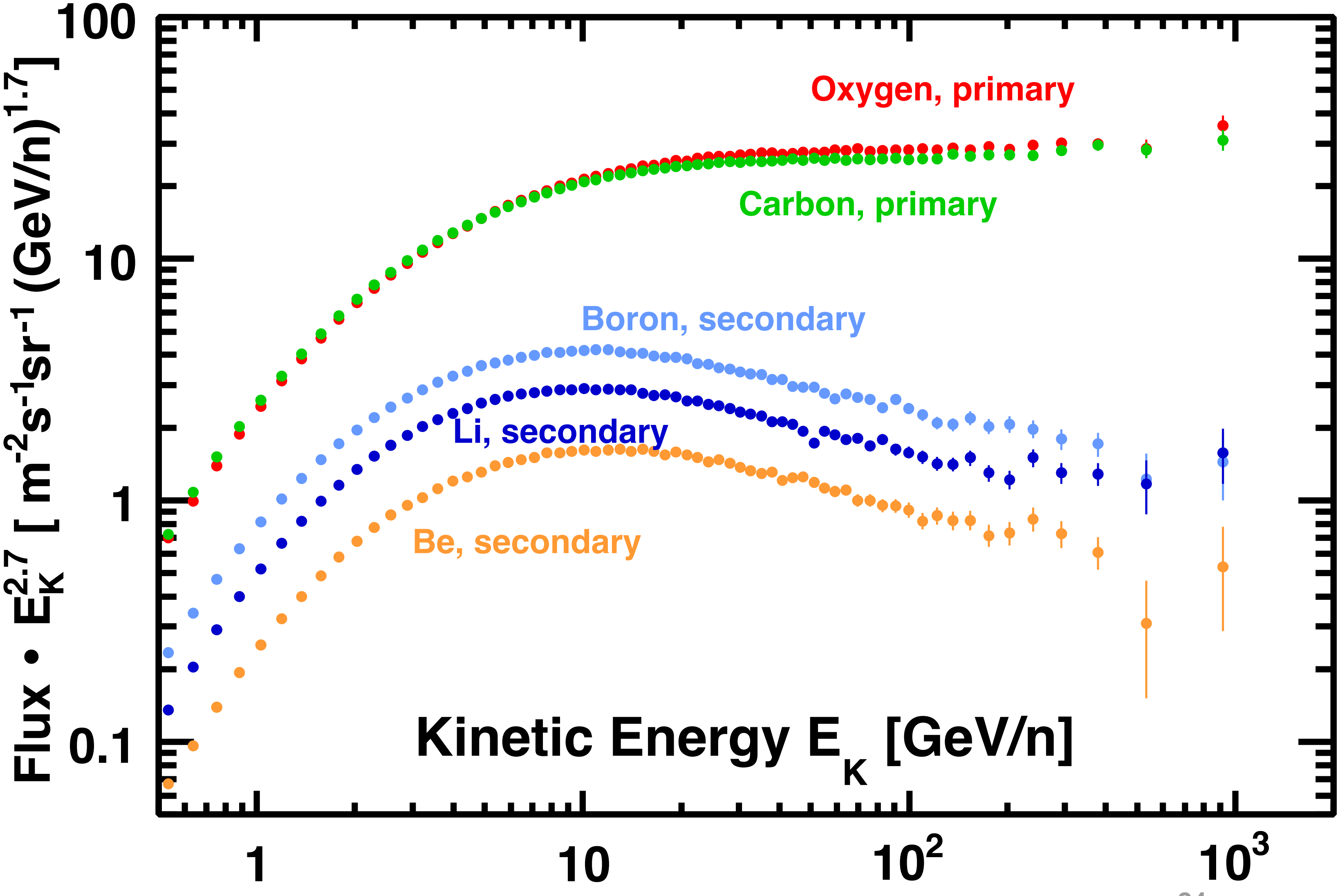
AMS results

The spectra of primary oxygen, carbon and nitrogen do not follow the traditional single power law.
They all change their behavior at the same energy.
Carbon and Oxygen have identical momentum dependence.



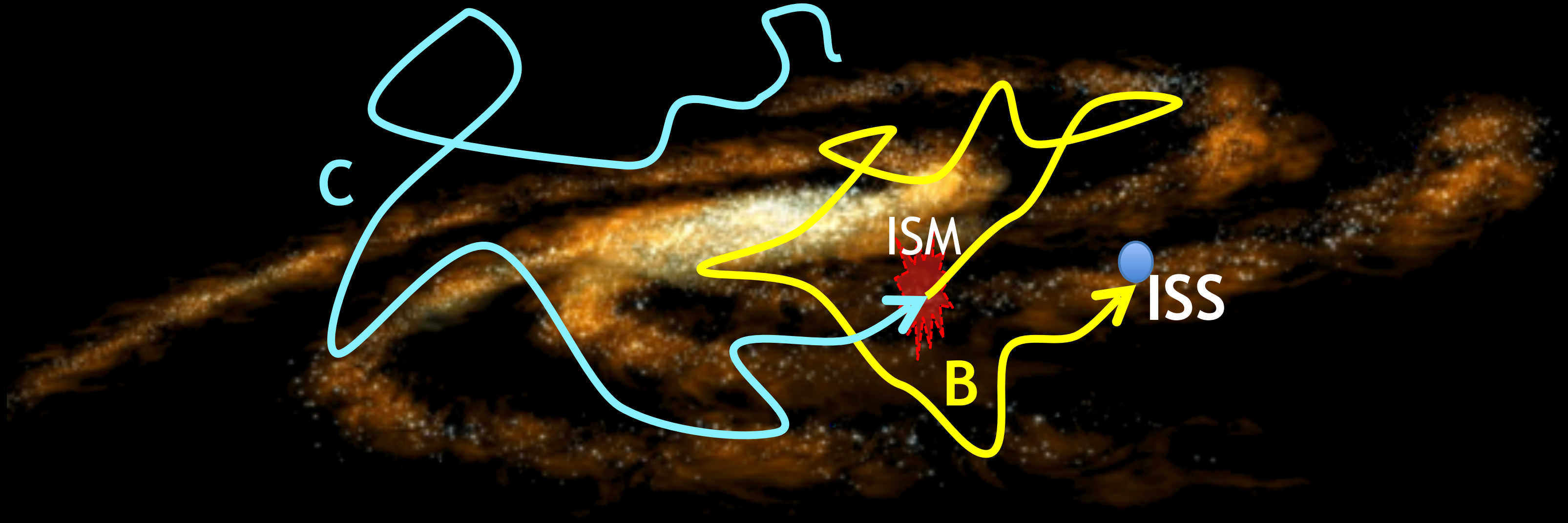
AMS results

Primary and secondary Cosmic Rays have very different energy dependence.



3) GCR propagation

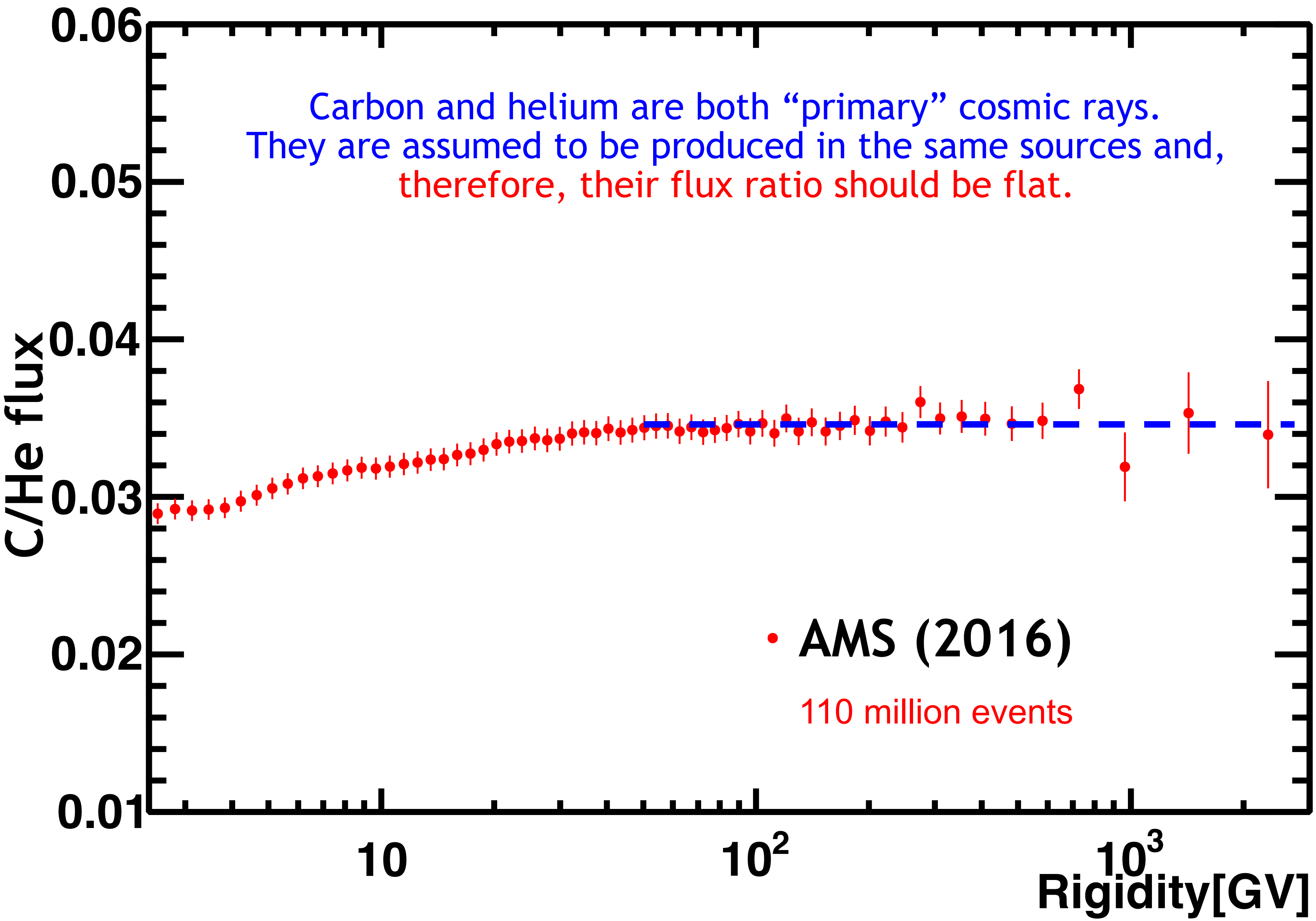
The flux ratio between primaries (C) and secondaries (B) provides information on propagation and the ISM



Cosmic ray propagation is commonly modeled as a fast moving gas diffusing through a magnetized plasma.

At high rigidities, models of the magnetized plasma predict different behavior for $B/C = kR^{\delta}$.

The AMS carbon/helium flux ratio

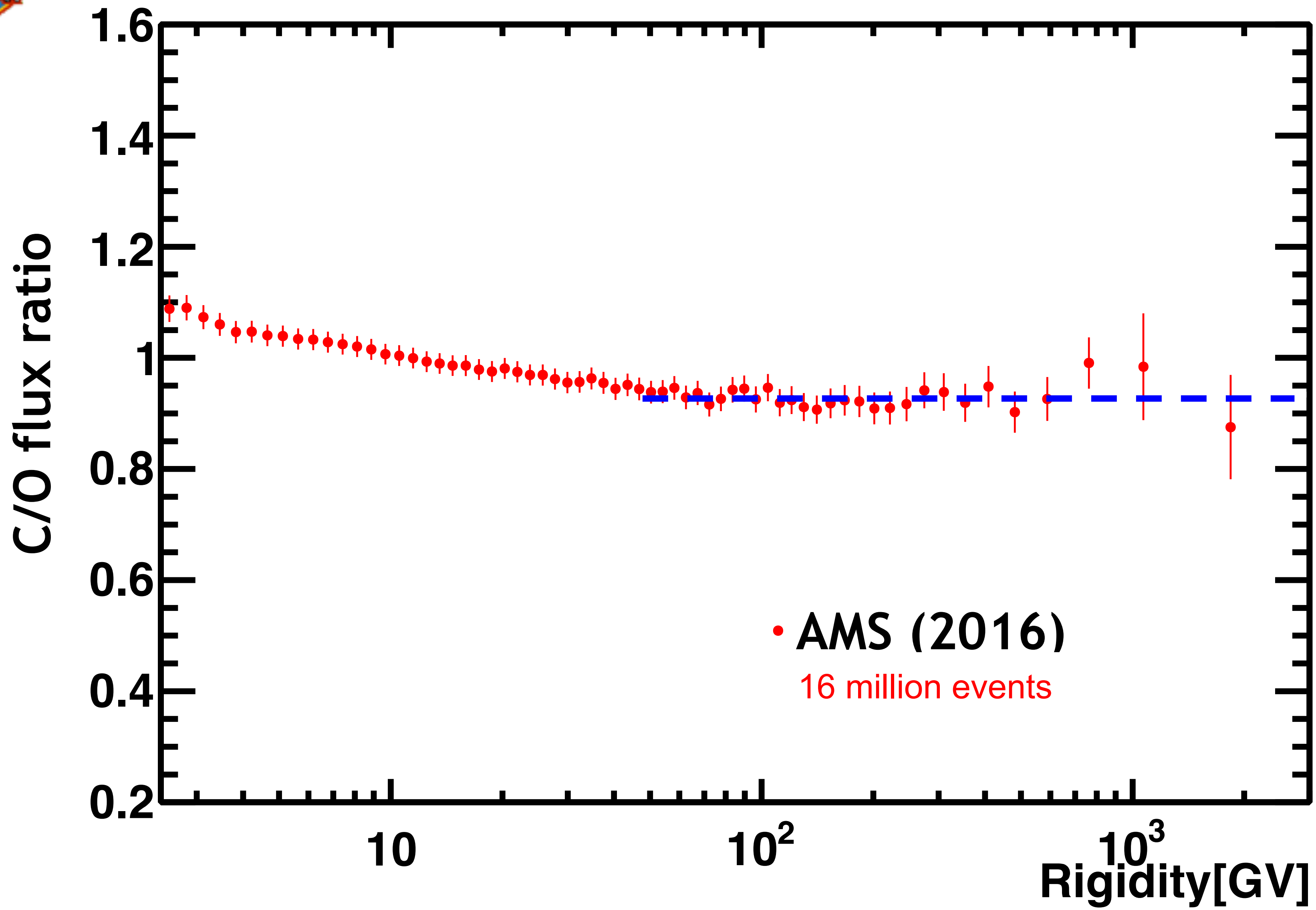


Carbon and helium are both “primary” cosmic rays.
They are assumed to be produced in the same sources and,
therefore, their flux ratio should be flat.

110 million events

AMS result: the flux ratio is flat.

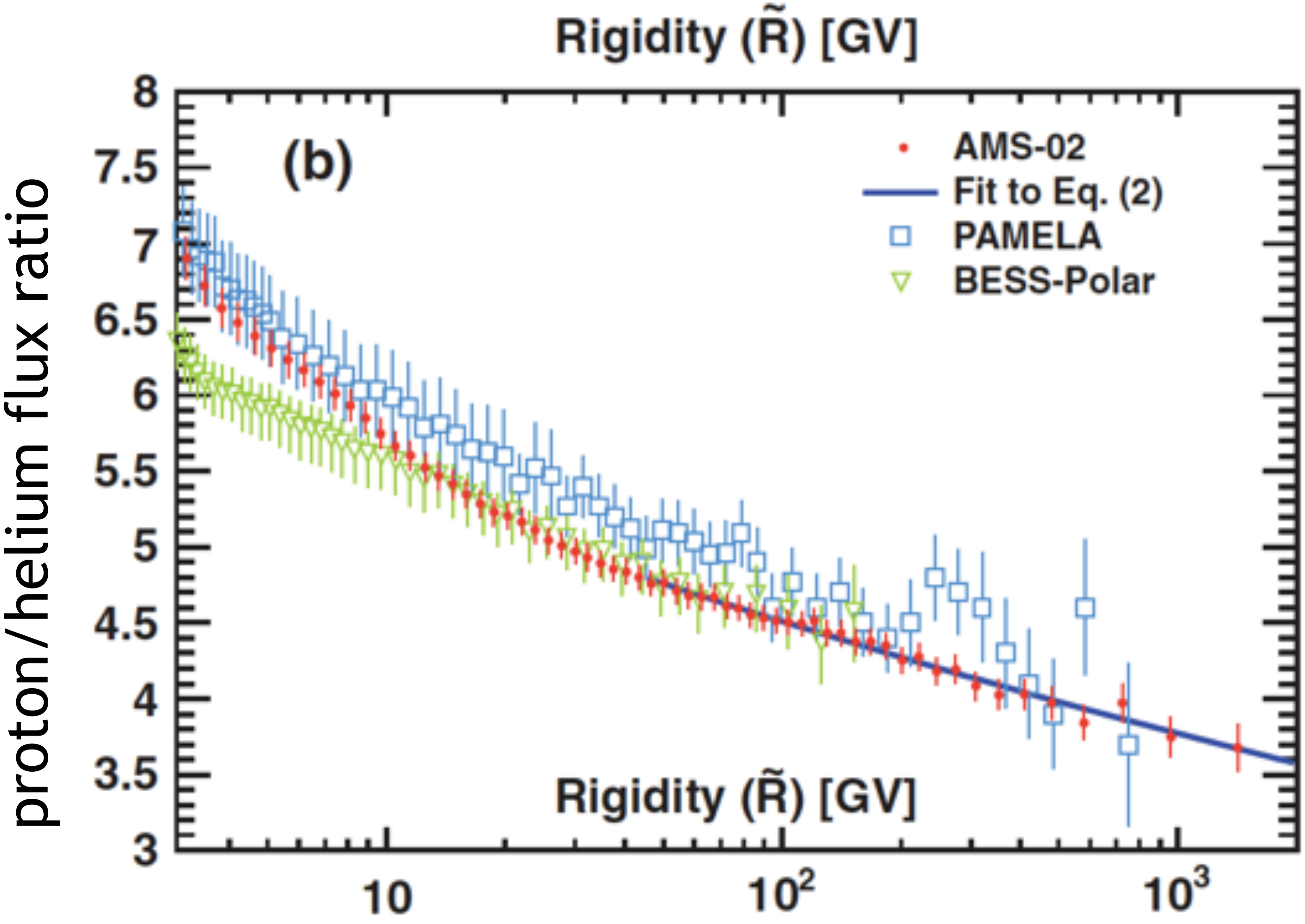
The AMS carbon/oxygen flux ratio



AMS result: the flux ratio is flat.

The AMS proton/helium flux ratio

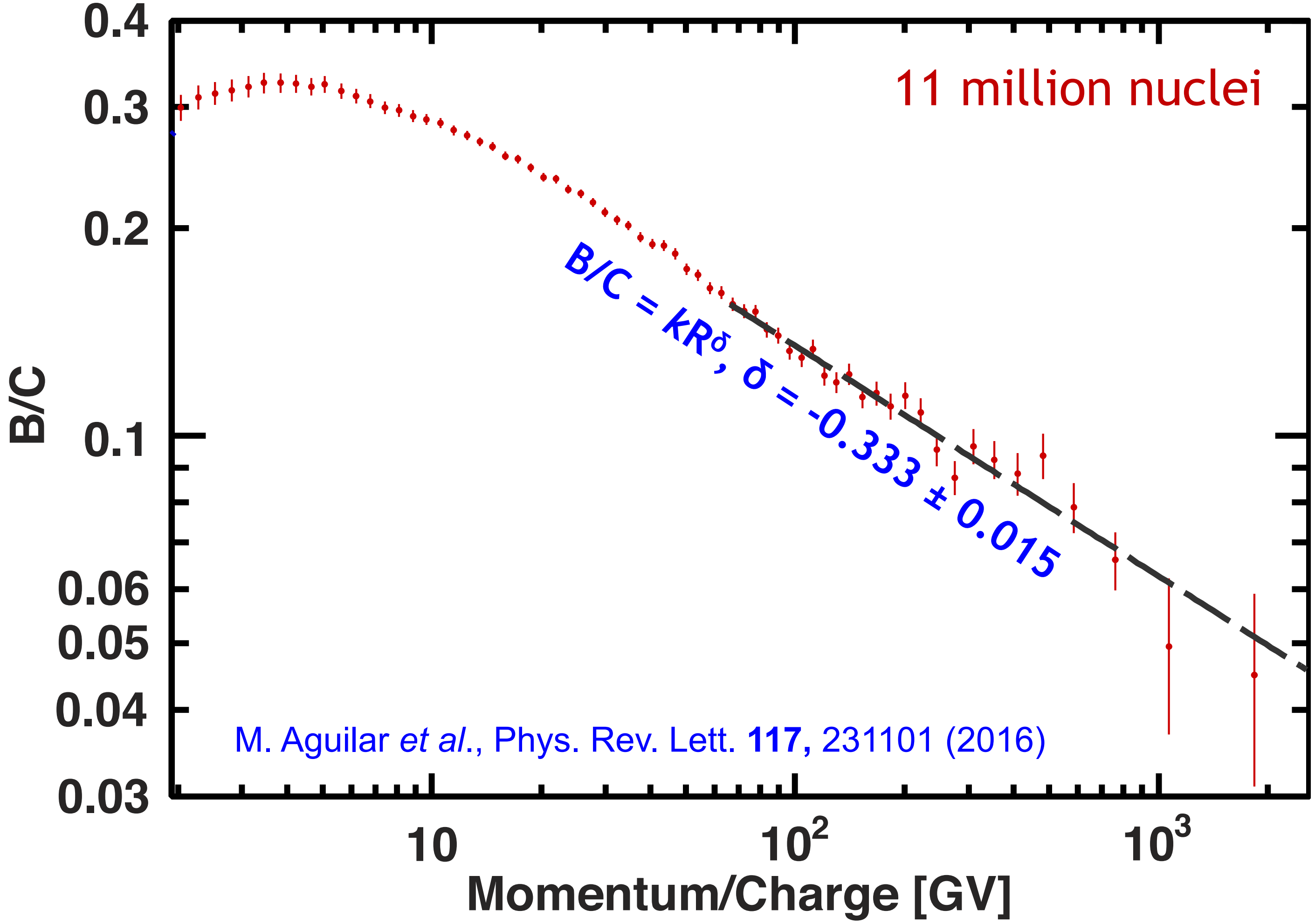
Protons and helium are both “primary” cosmic rays therefore, their flux ratio should be flat.



AMS result: the flux ratio is NOT flat.

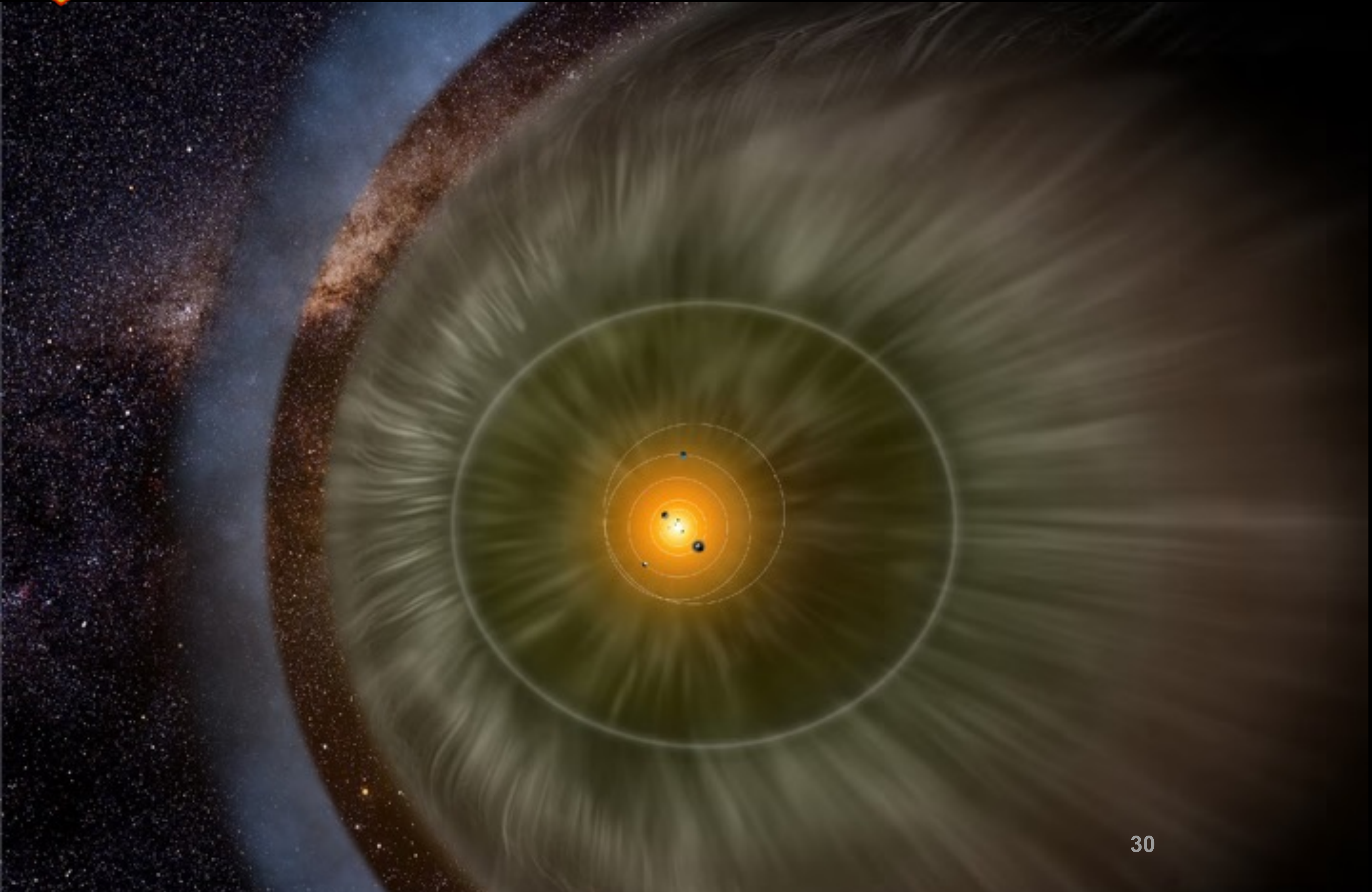
The Boron-to-Carbon (B/C) flux ratio

The B/C ratio (secondary/primary ratio) does not show any significant structures in contrast to many cosmic ray models

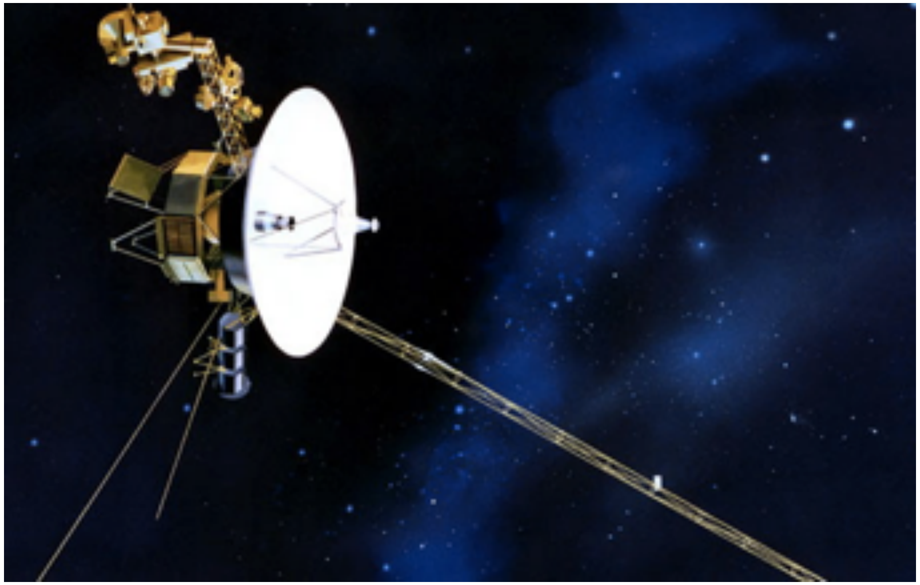


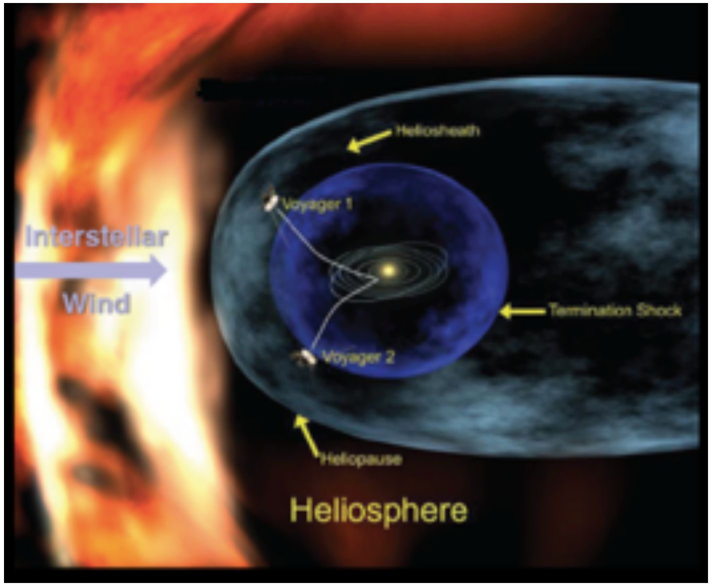
In agreement with the Kolmogorov turbulence model of magnetized plasma (**$\delta = -1/3$** asymptotically).

4) Propagation of GCRs in the heliosphere and short term solar activity



Local interstellar spectrum from Voyager 1

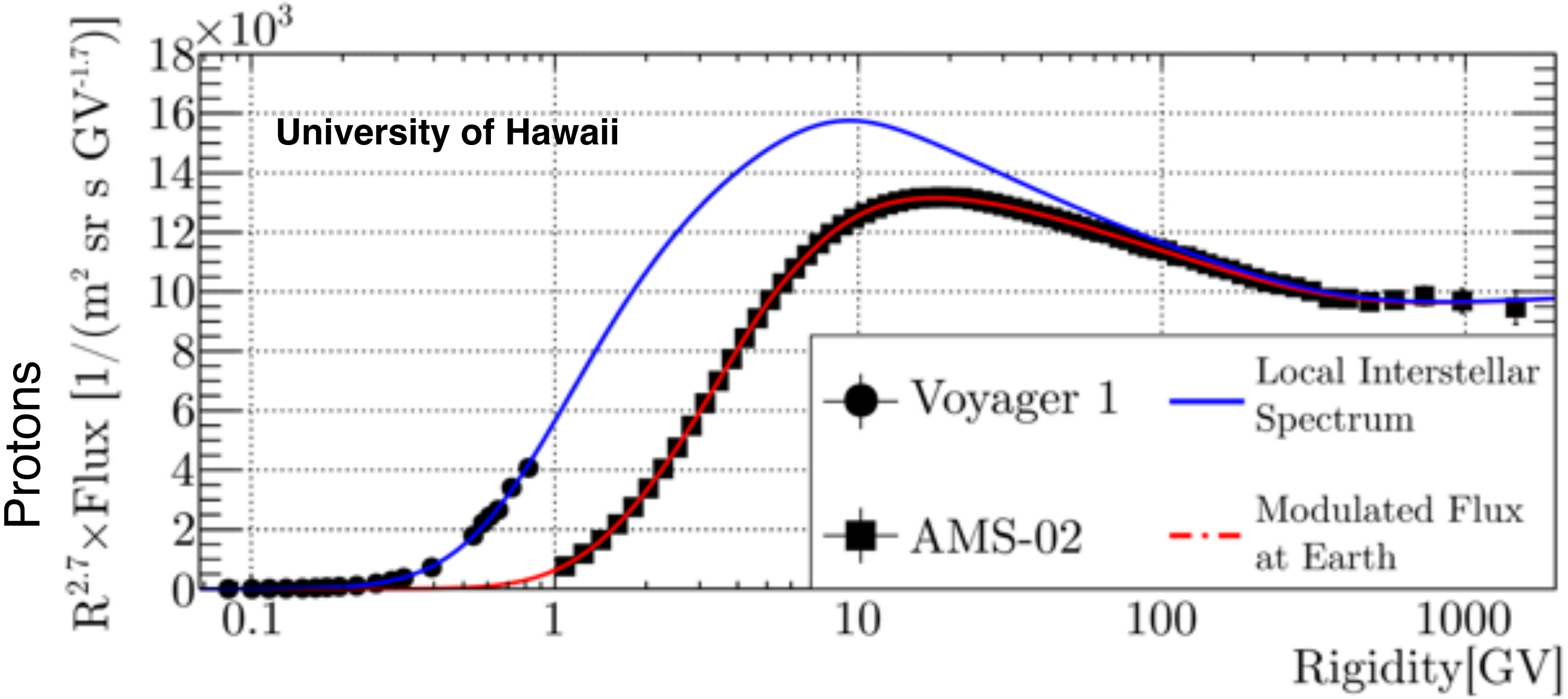




- Voyager 1: launched in 1977 is Earth's Farthest Spacecraft has recently left the Solar System

- First measurement at low energy of the Local Interstellar Spectrum.

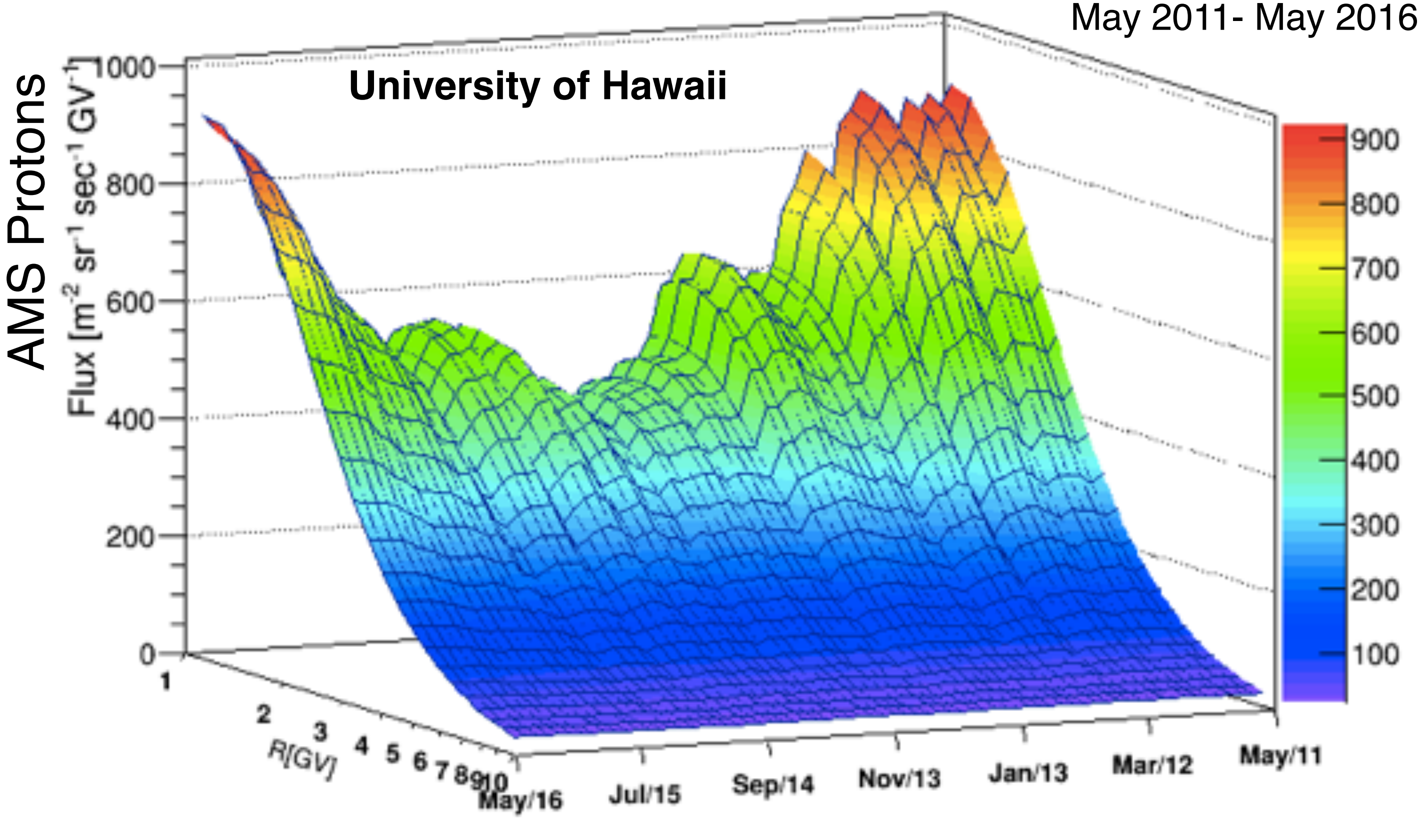
Local interstellar spectrum and propagation of GCR inside the heliosphere



- New parametrization of the proton and helium LIS derived from Voyager 1 and AMS-02. *Details: Corti, Bindi, Consolandi, Whitman, 2016, ApJ, 892, 8*
- Models describing propagation of GCR into the heliosphere to be able to extract the flux of GCRs on Mars or other locations in the solar system.

Details in Claudio Corti's talk

Study of the long term solar modulation with AMS



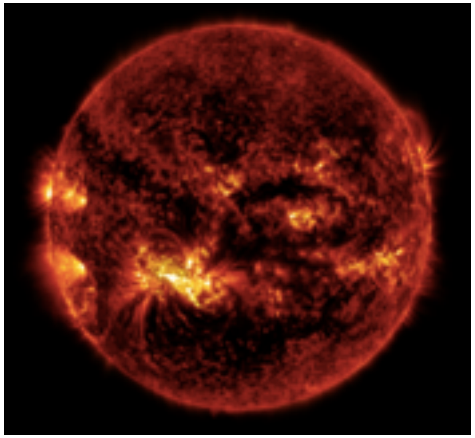
May 2011- May 2016

- The overall reduction of the proton flux at low energies due to increasing solar activity at unprecedented accuracy.
- Detailed studies of the solar modulation are ongoing for different species of GCRs.

Details in Cristina Consolandi's talk

Study of the Short term Solar activity with AMS

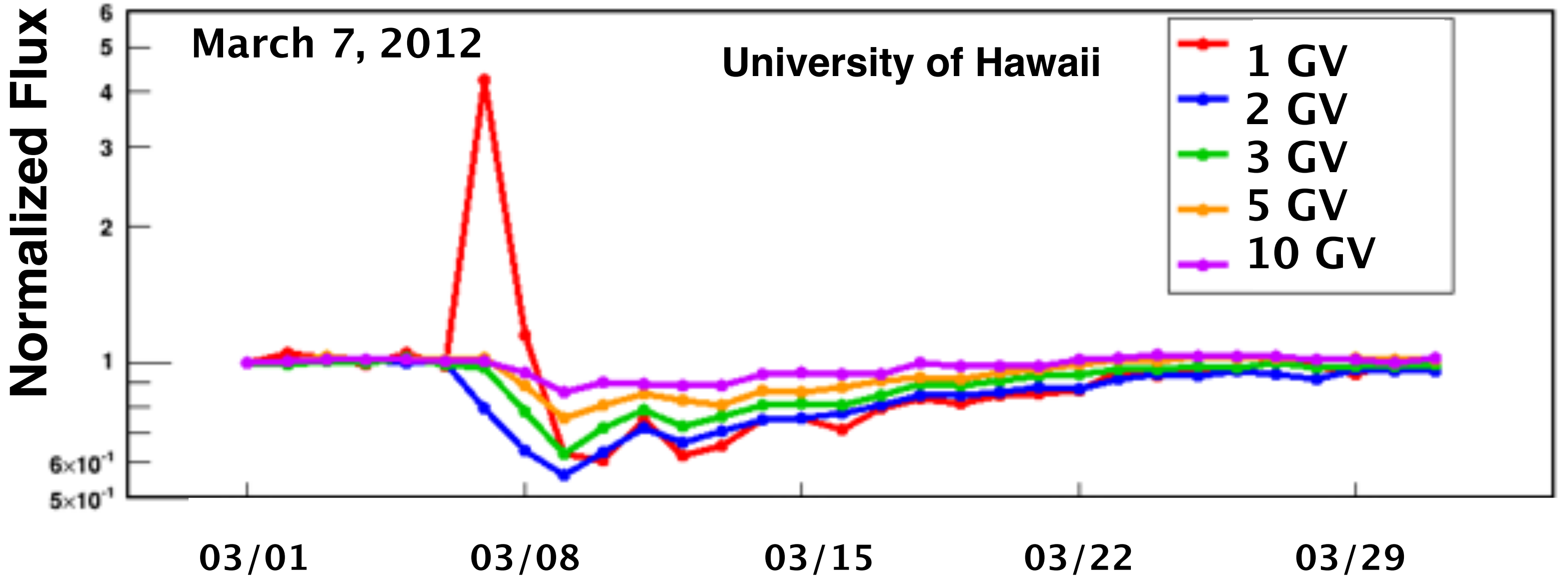
SEP - Temporary increase in particle flux < 1 – 2 GV related to solar flares and high speed CME.



Forbush Decrease - Temporary decrease in the galactic cosmic ray flux caused by turbulent structures in the solar wind.

March 7, 2012 event:

two Solar Flares of class X 5.4, X1.3 and two CMEs (linear speed 2684-1825 km/s)

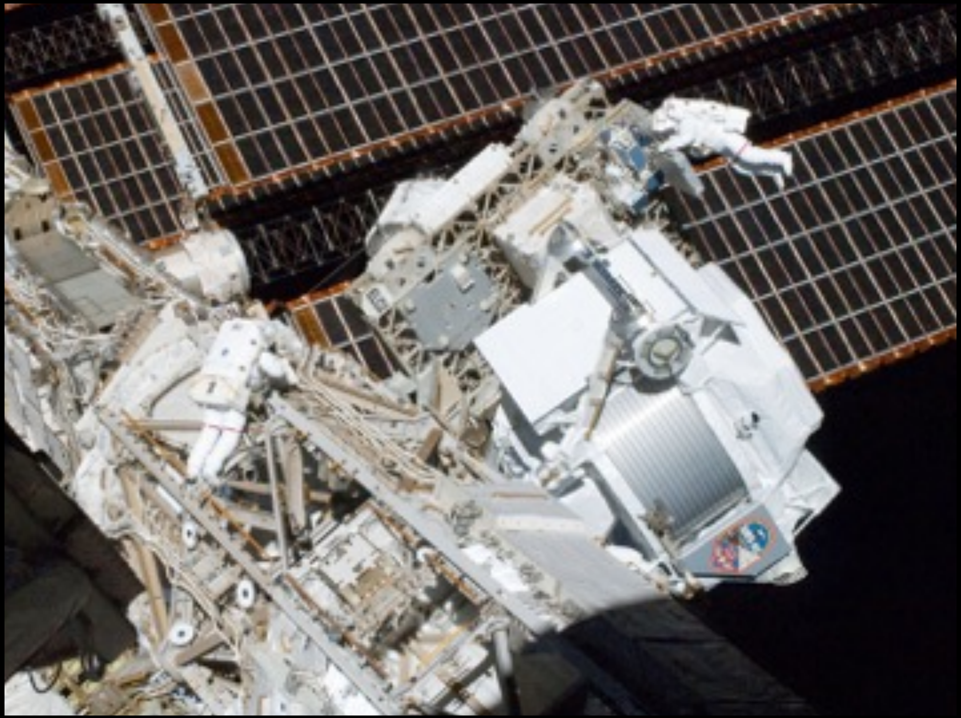


Details in Katie Whitman's talk

5) Space Radiation

Space radiation represents one of the major challenges for human space exploration.

- AMS is able to distinguish particles from protons to Iron, for a proper estimation of space radiation.
- This new and crucial information will allow the NASA Advanced Exploration Systems group to develop radiation models and to support the design of effective space radiation shielding and storm shelters for space exploration missions.



Conclusions

- The results from AMS to date are unexpected and are going to deeply improve our understanding of galactic cosmic ray origin, acceleration and propagation in the galaxy and in the heliosphere.

- By collecting data through 2024, we should be able to determine the origin of many of these unexpected phenomena.

- The solar modulation effect on GCRs are being systematically and continuously studied for all particle species measured by AMS.

- AMS identified 33 major Forbush decreases and measured 27 SEP events allowing the study of their time evolution at different rigidities and their composition.

- The Hawaii group is working on parametrization and models that describe particle transport in the heliosphere to define the flux of GCRs in different locations, like on Mars.

- The Hawaii group is working with the NASA Advanced Exploration Systems group to improve their predictions of space radiation doses.