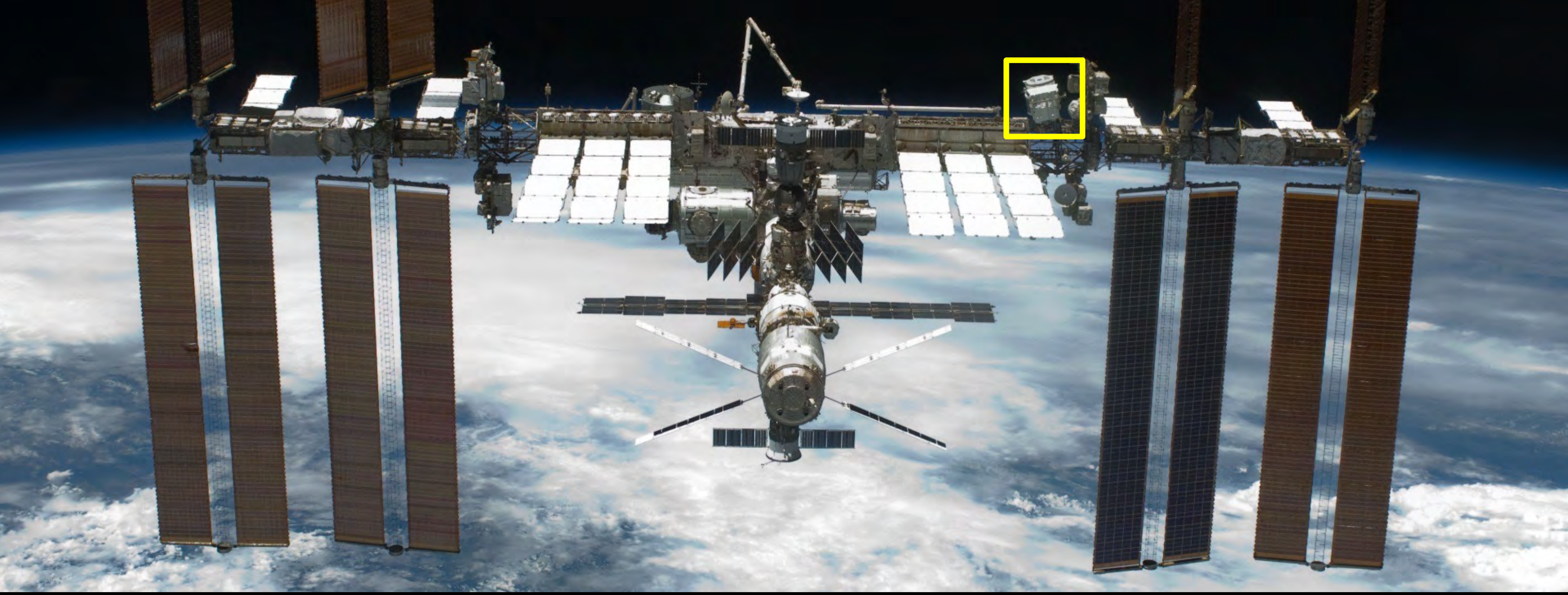
16th Marcel Grossmann Meeting

10 years of AMS-02 on the ISS

Paolo Zuccon
Trento University and INFN-TIFPA

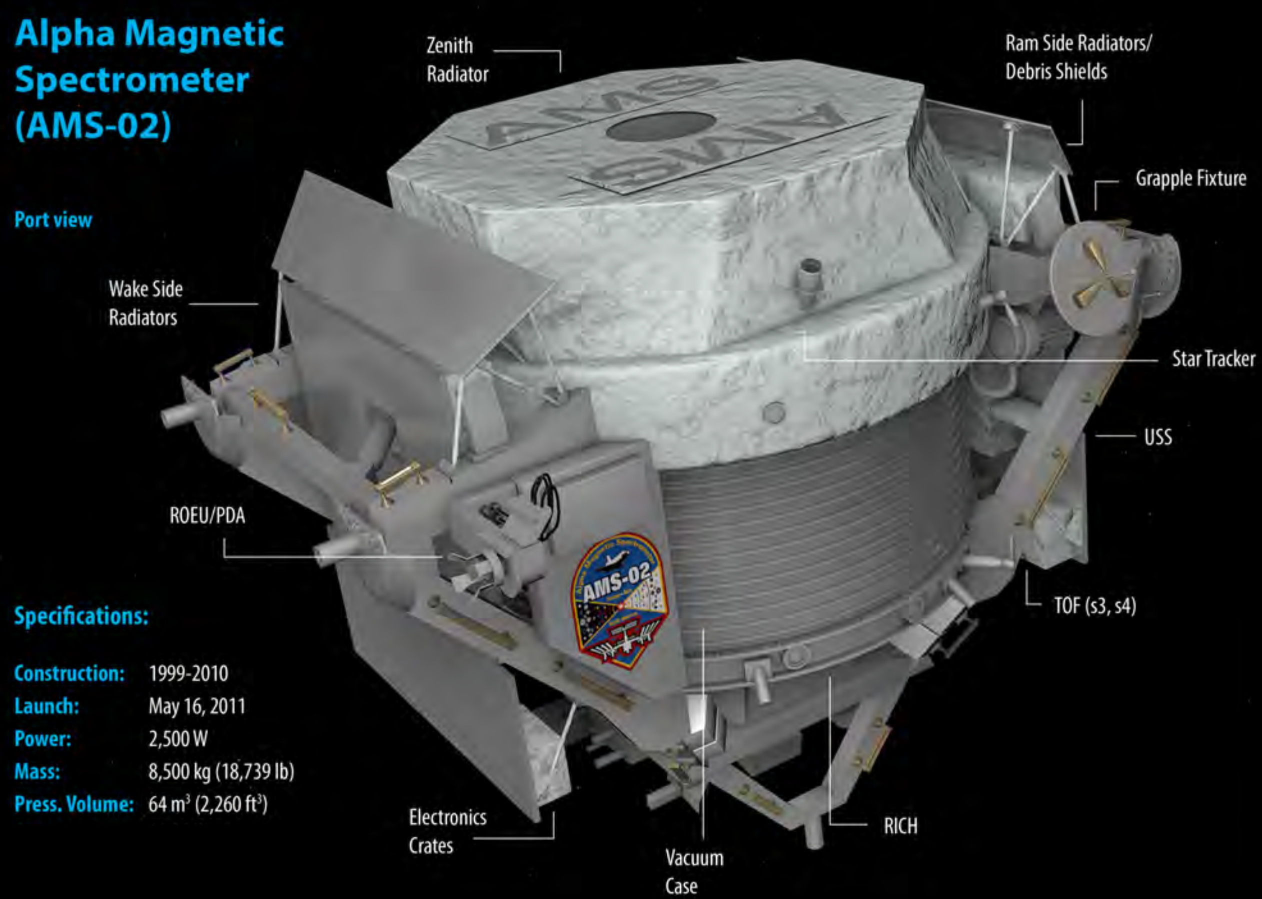


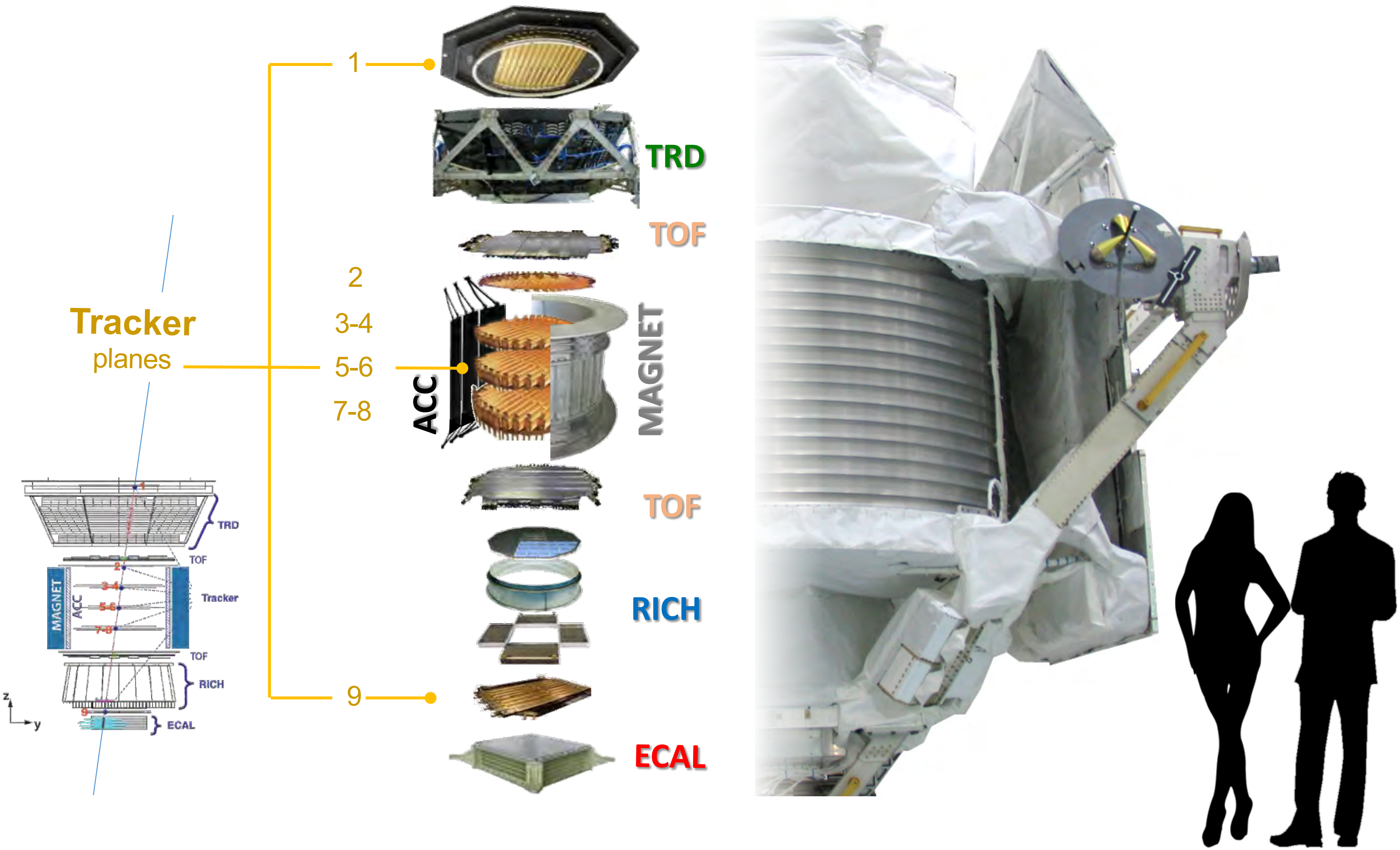
In 10 years, over 170 billion charged cosmic rays with energies up to multi-trillion eV have been studied by AMS

Istituto Nazionale di Fisica Nucleare · Agenzia Spaziale Italiana · NASA

AMS-02: Alpha Magnetic Spectrometer

Launch 16/5/2011 (Endevour)
Construction 1999-2010
Dimensions $3 \times 4 \times 5$ m^3
Wheight 8.5 t
Power 2500 W




Tracker
planes
1
2
3-4
5-6
7-8
9
TRD
TOF
ACC
MAGNET
TOF
RICH
ECAL
TRD
TOF
Tracker
MAGNET
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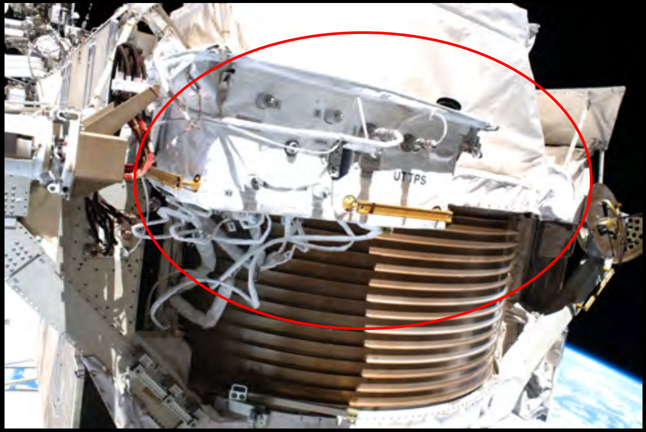
z
y

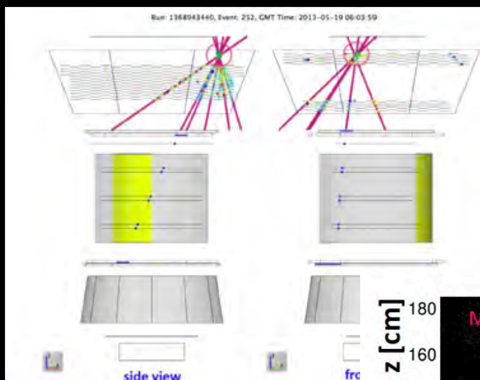

STS-134 launch May 16, 2011 @ 08:56 AM

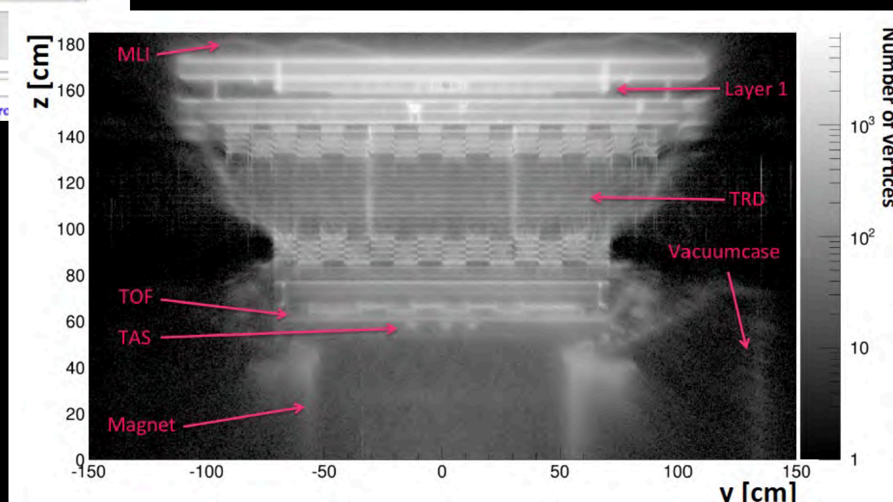
Fix of the Cooling system 2019/20

4 EVAs by
- **Luca Parmitano**
- **Andrew Morgan**

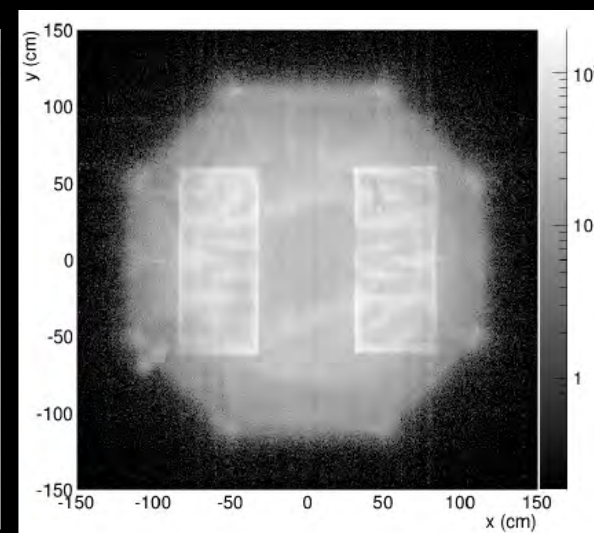


AMS “tomography” using rare nuclear interaction events



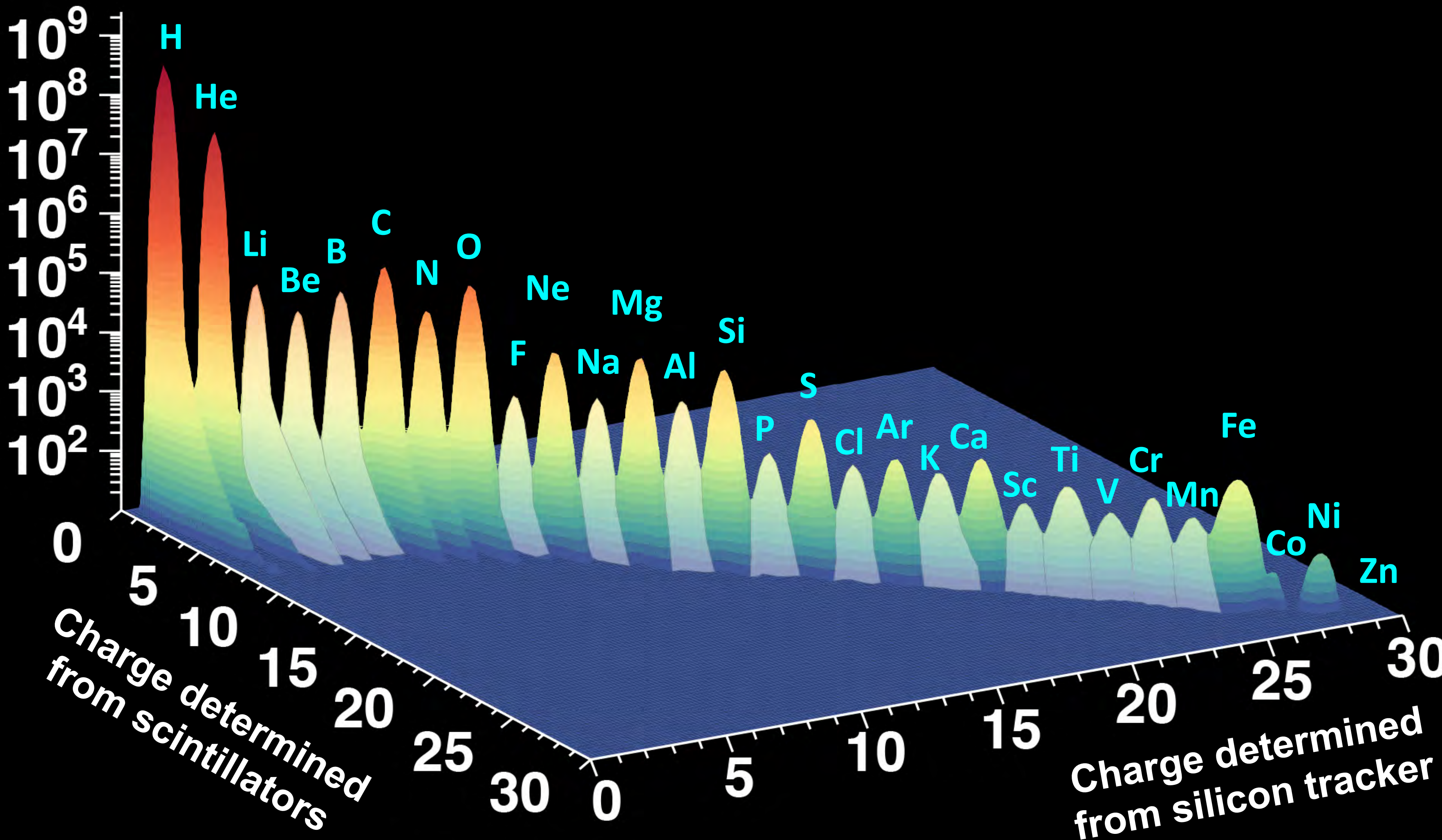


Z=178.5 cm

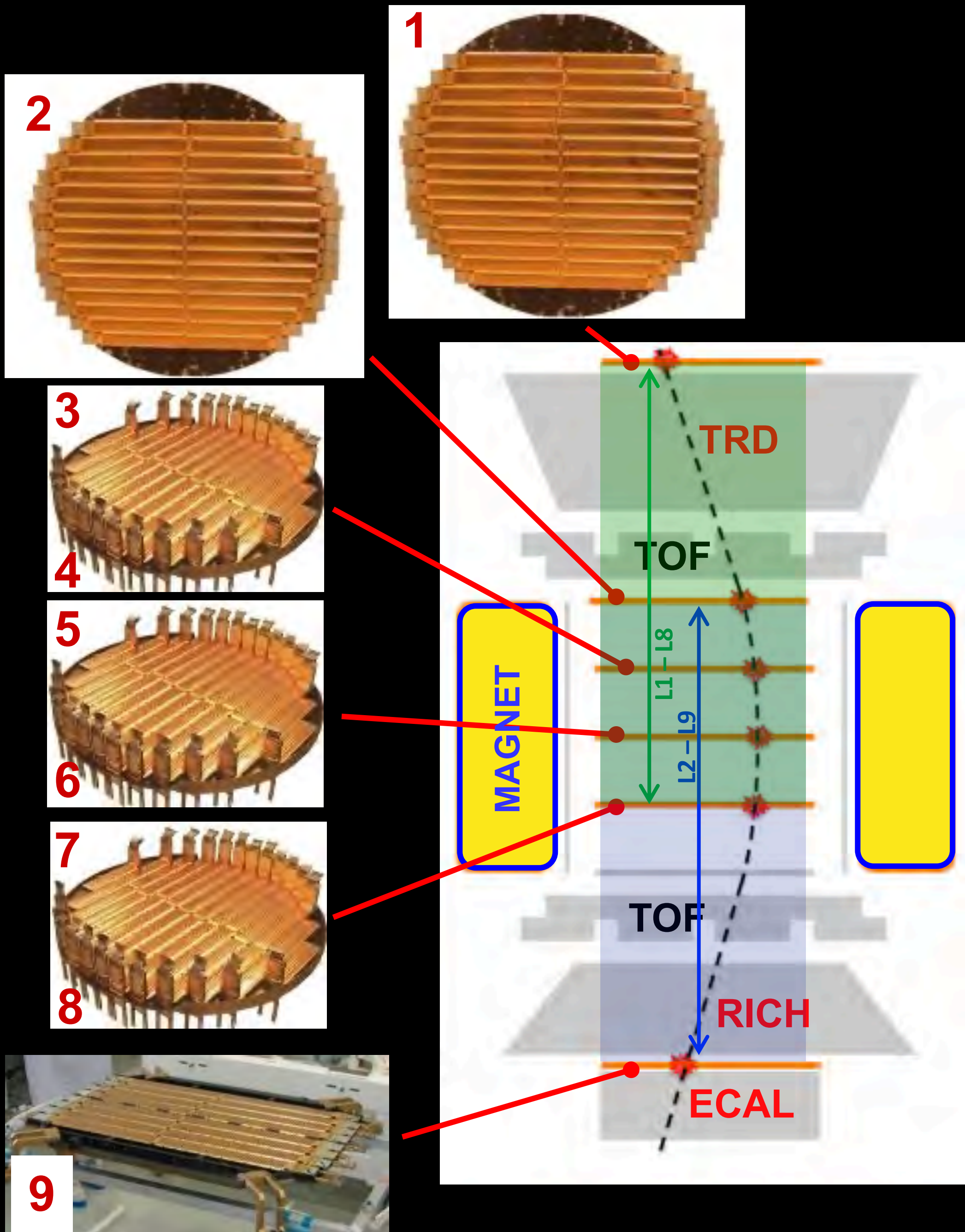


The gray scale is proportional the the number of found vertices

Precision Measurement of Cosmic Nuclei



Continuous Calibration at TeV (above CERN 0.4 TeV test beam)

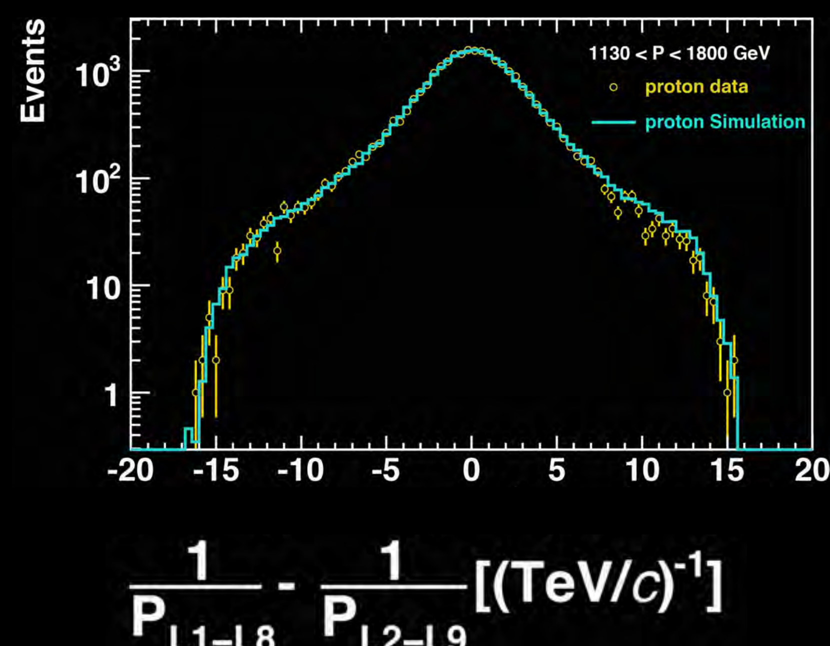


By comparing proton data and simulation from

the upper spectrometer (L1 to L8)

and

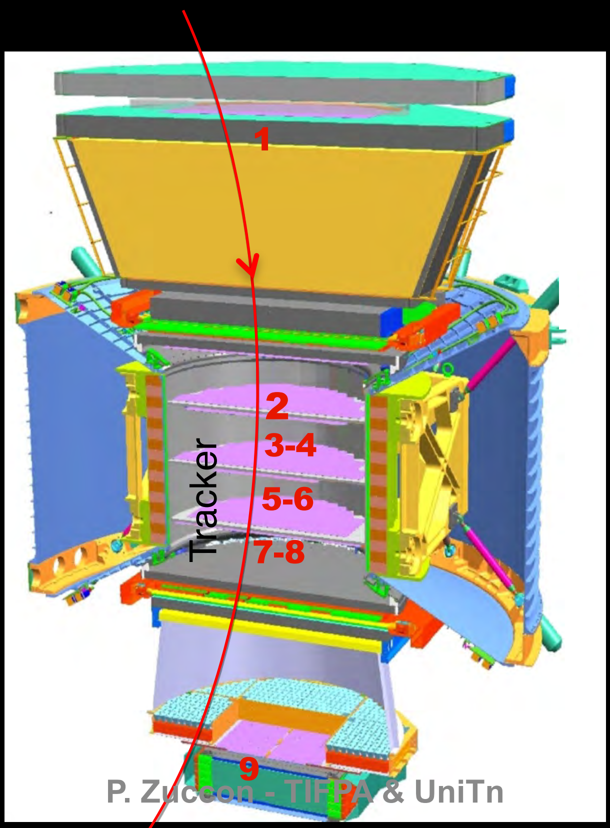
the lower spectrometer (L2 to L9)



Absolute Momentum Scale

In AMS, the largest systematic error in the determination of the fluxes at the highest energies is due to the uncertainty in the absolute momentum scale.

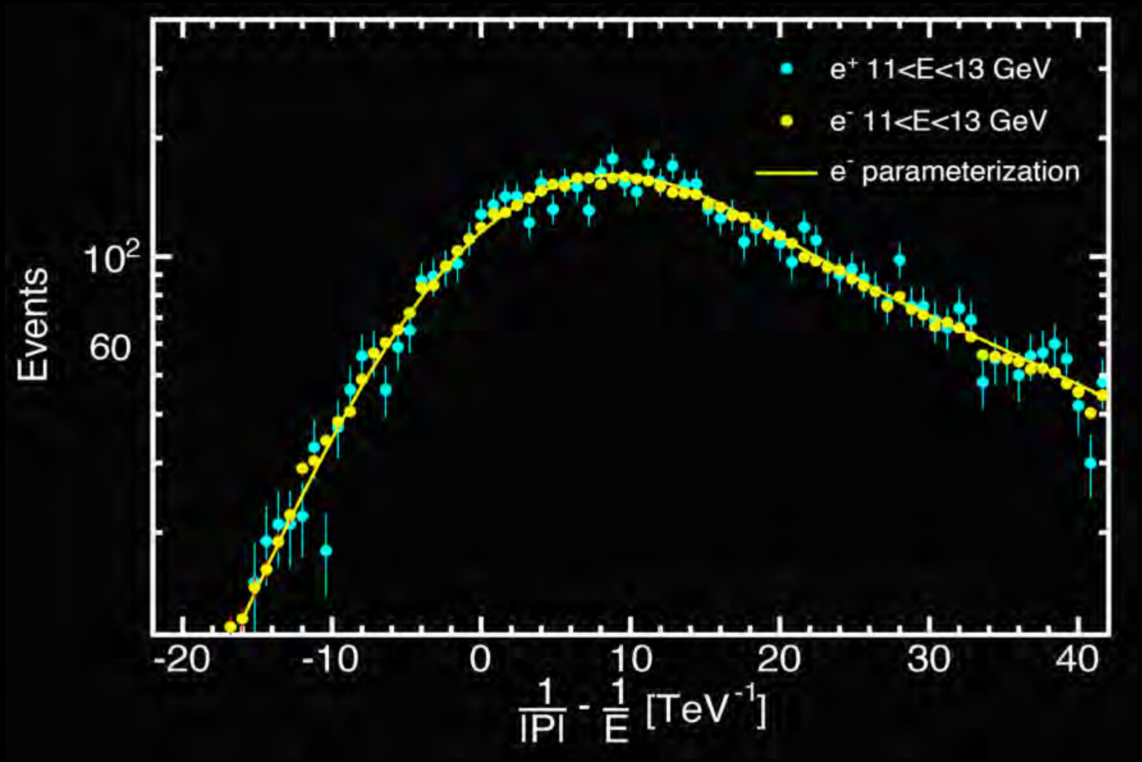
In space continuous outgassing of the carbon fiber supporting structure can affect the position of the tracker sensors at the sub-micron level.



A shift in the central tracker planes of 0.5 microns is sufficient to create a momentum shift of 10% at 1 TeV and bias flux measurements.

Momentum Scale Verification

By matching the momentum determined by the tracker and magnet with the energy measured in the ECAL for both e^+ and e^-



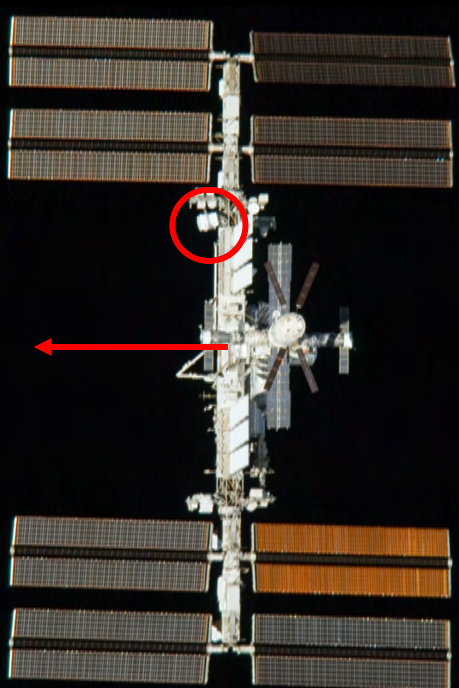
The accuracy of the momentum is determined to be 1/(30,000 GeV);

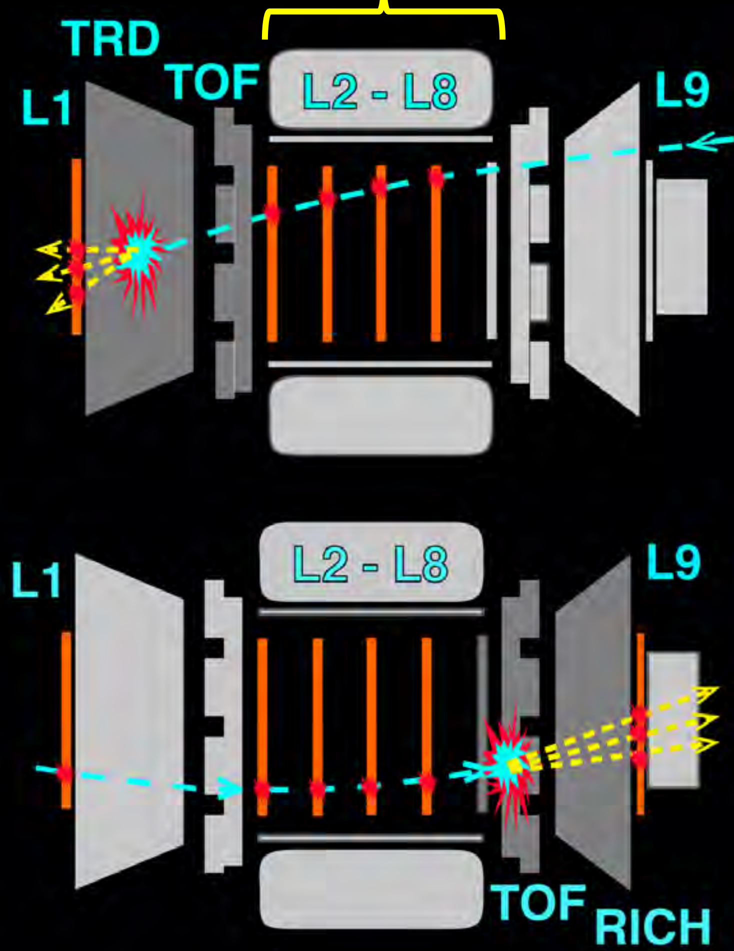
i.e., at 1 TeV the uncertainty is 3%

Precision measurement of cosmic-ray spectra requires an determination of nuclear interactions in the detector material

Define (P, Z) of nuclei with the central spectrometer

ISS horizontal



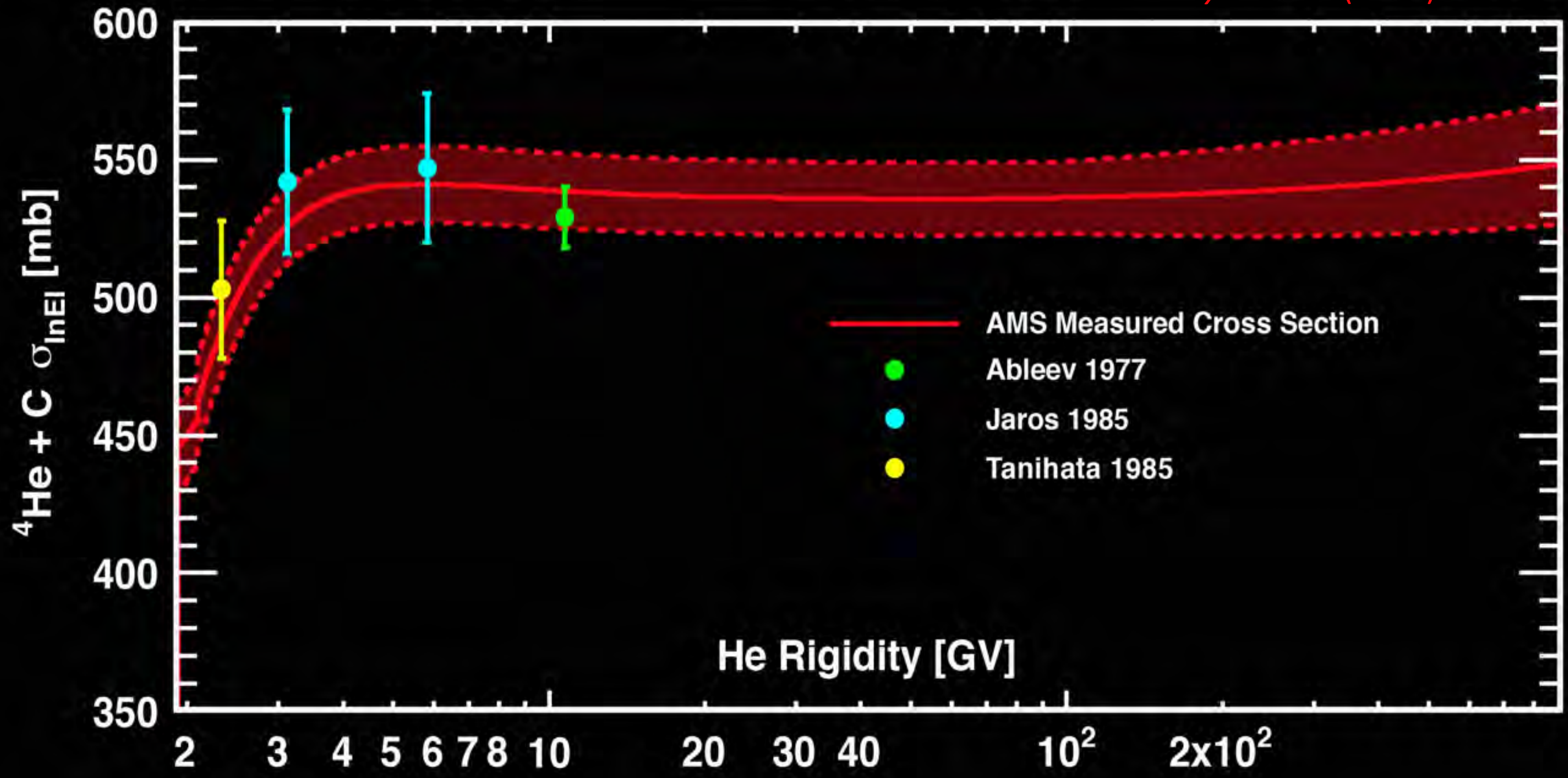


Use right-to-left nuclei to measure nuclear interactions in the TRD+TOF

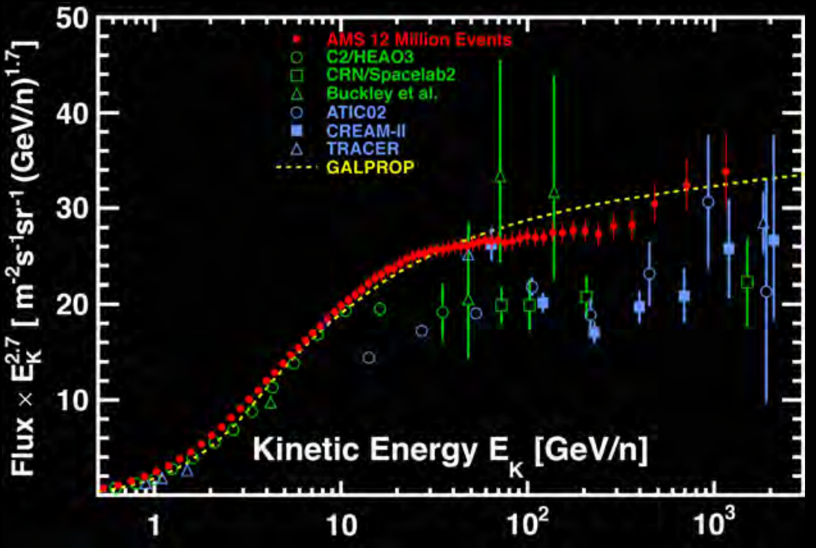
Use left-to-right nuclei to measure the nuclear interactions in the TOF+RICH

AMS Measurement of He-C Interaction Cross Section
as a function of rigidity

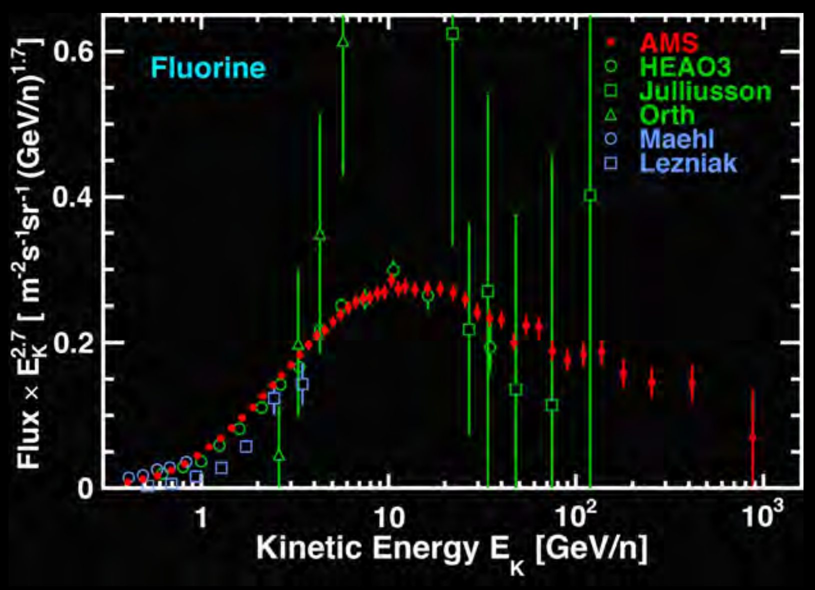
Nucl.Phys. A 996 (2020) 121712



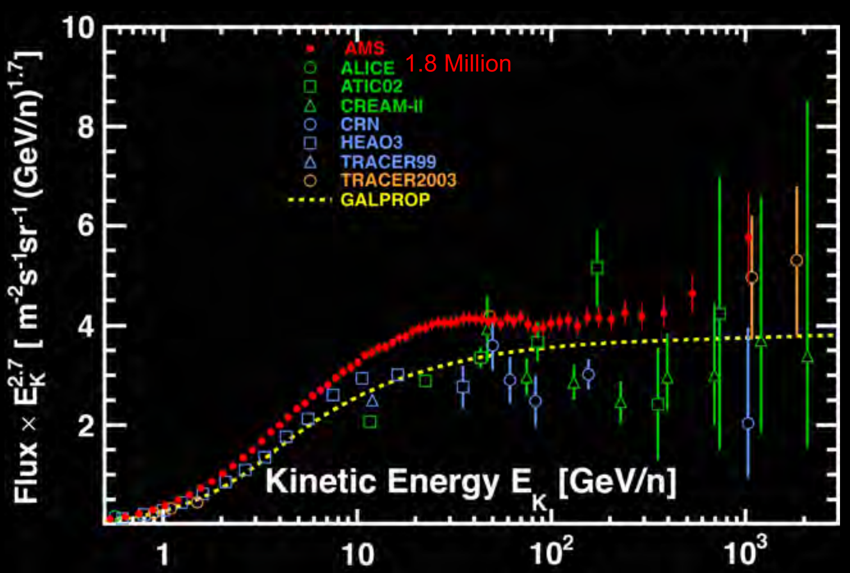
Oxygen (Z = +8)



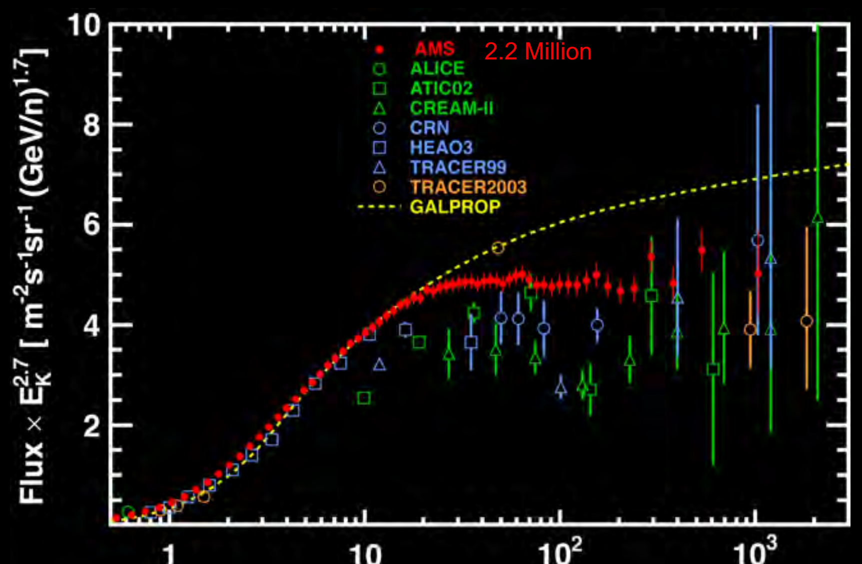
Fluorine (Z = +9)



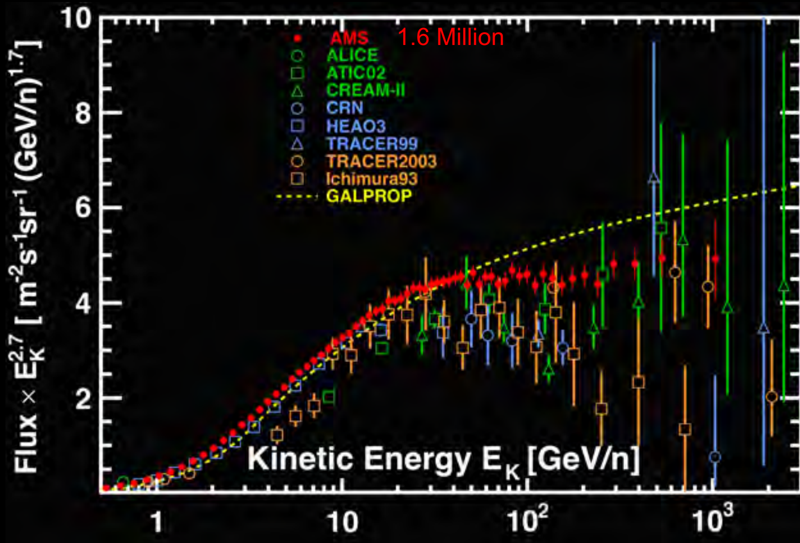
Neon (Z = +10)



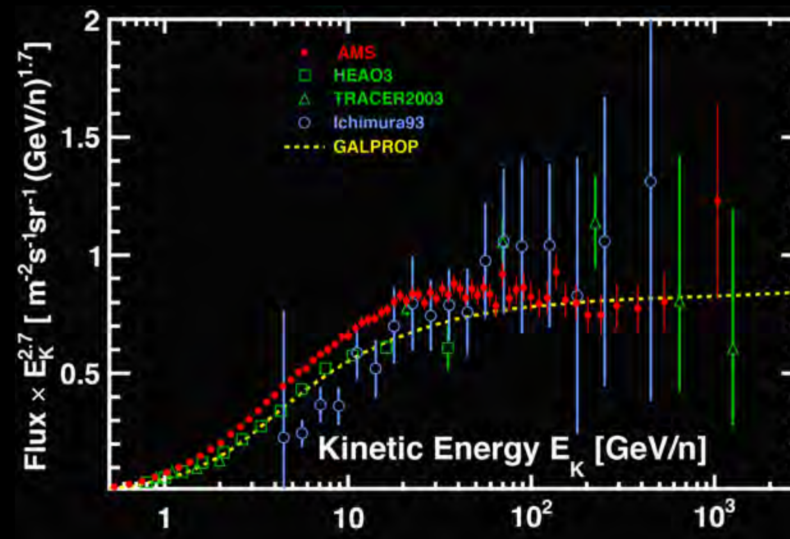
Magnesium (Z = +12)



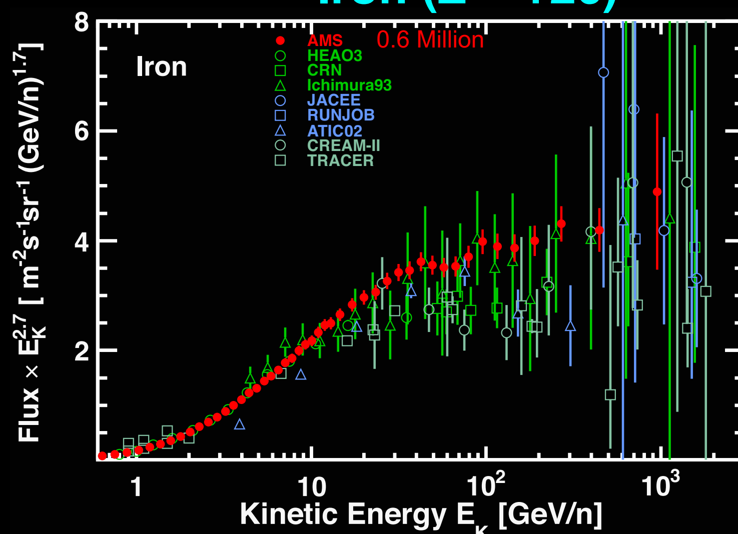
Silicon (Z = +14)



Sulfur (Z = +16)



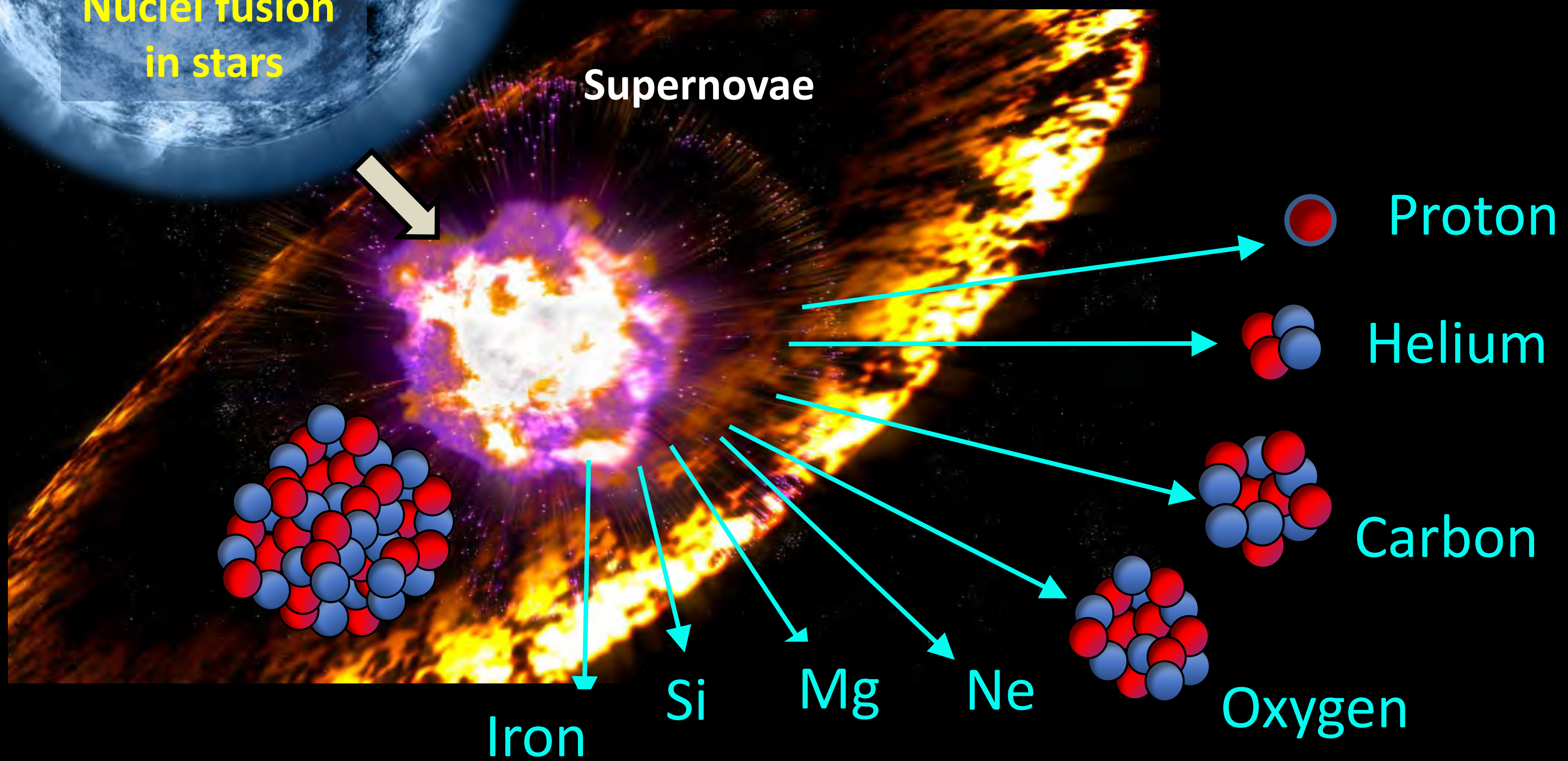
Iron (Z = +26)



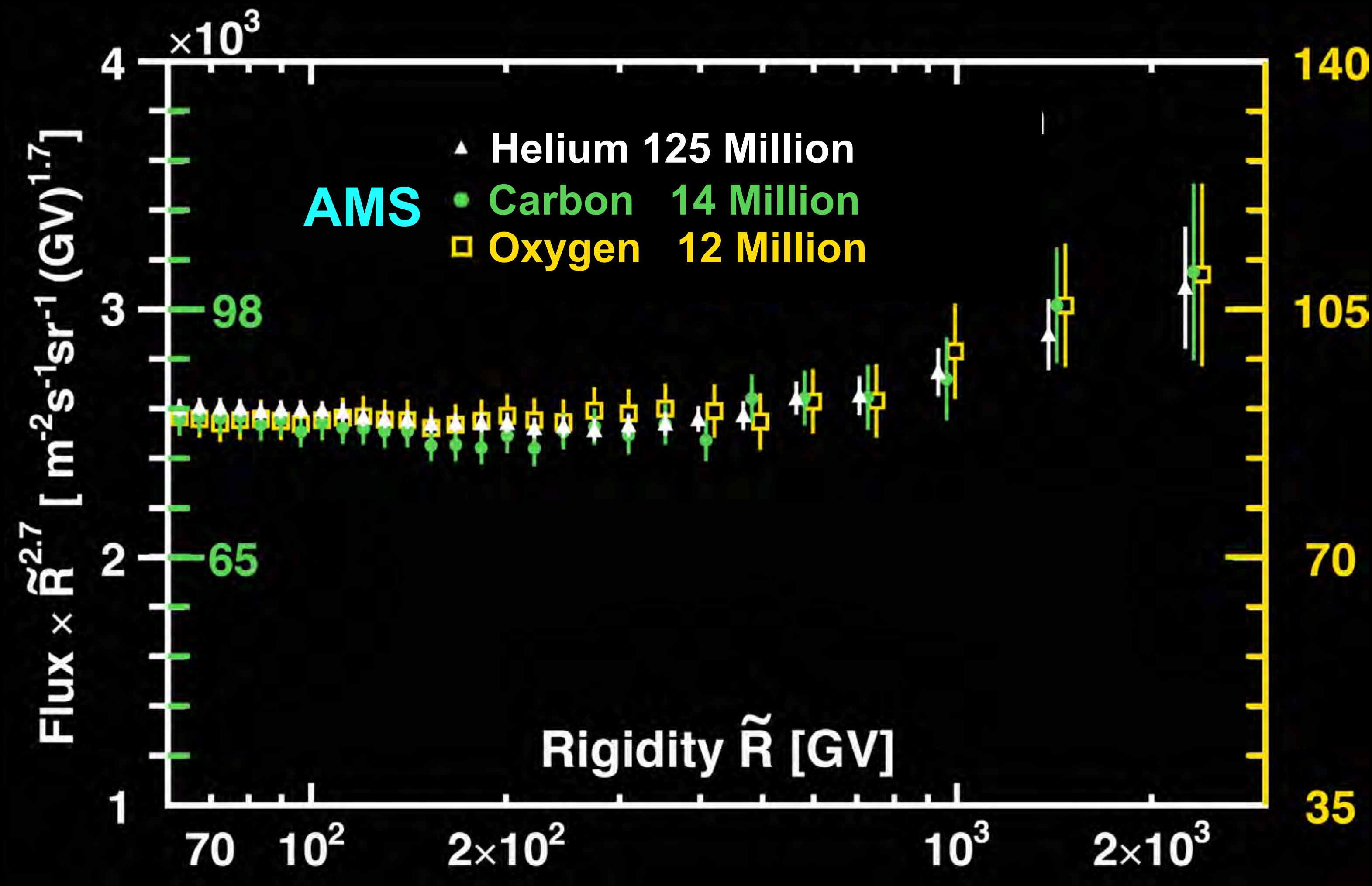
Properties of Primary Cosmic Rays

Primary elements (H, He, C, ..., Fe) are produced during the lifetime of stars.

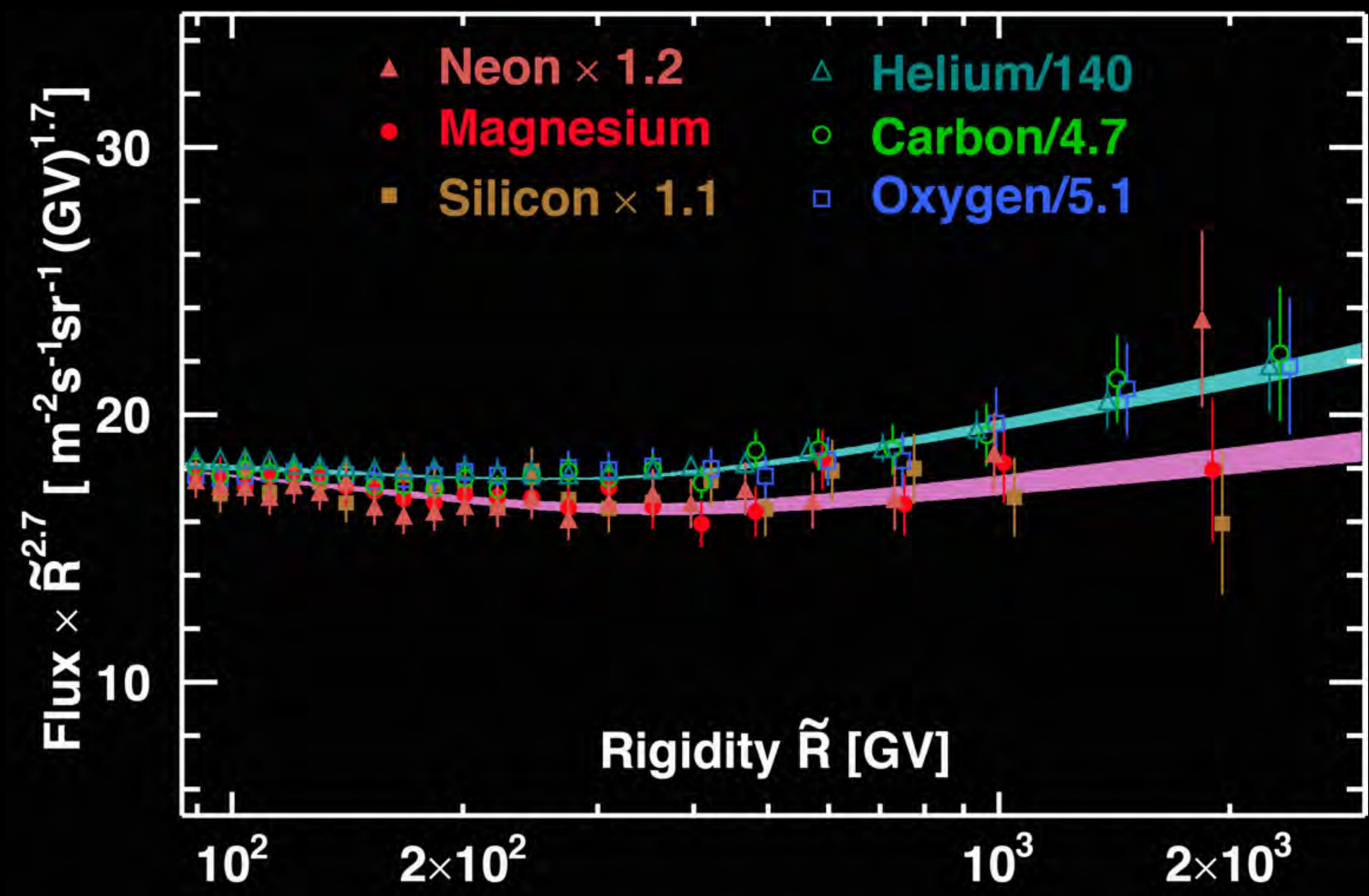
They are accelerated by the explosion of stars (supernovae).



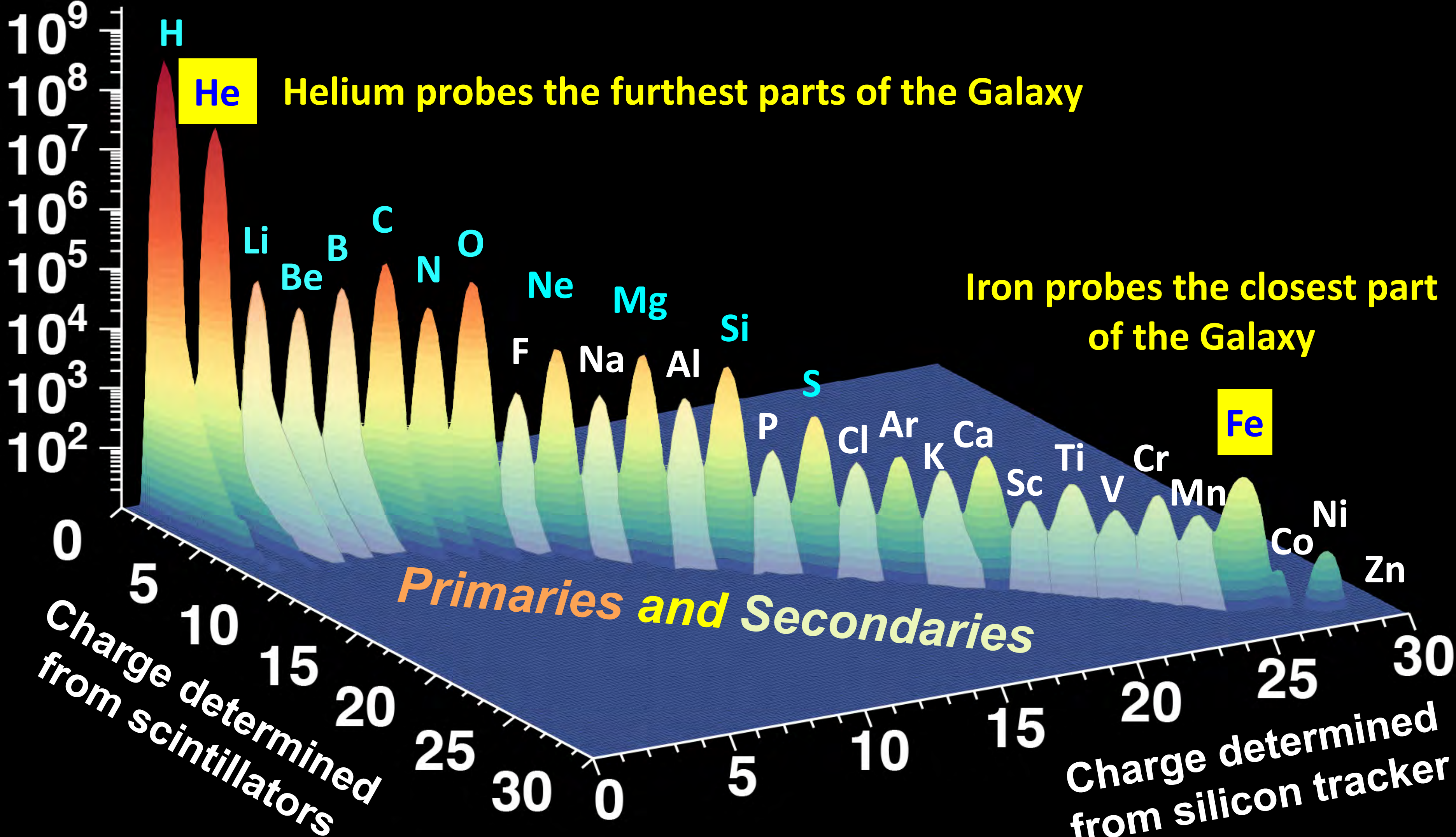
Surprisingly, above 60 GV, the primary cosmic rays have identical rigidity (P/Z) dependence.



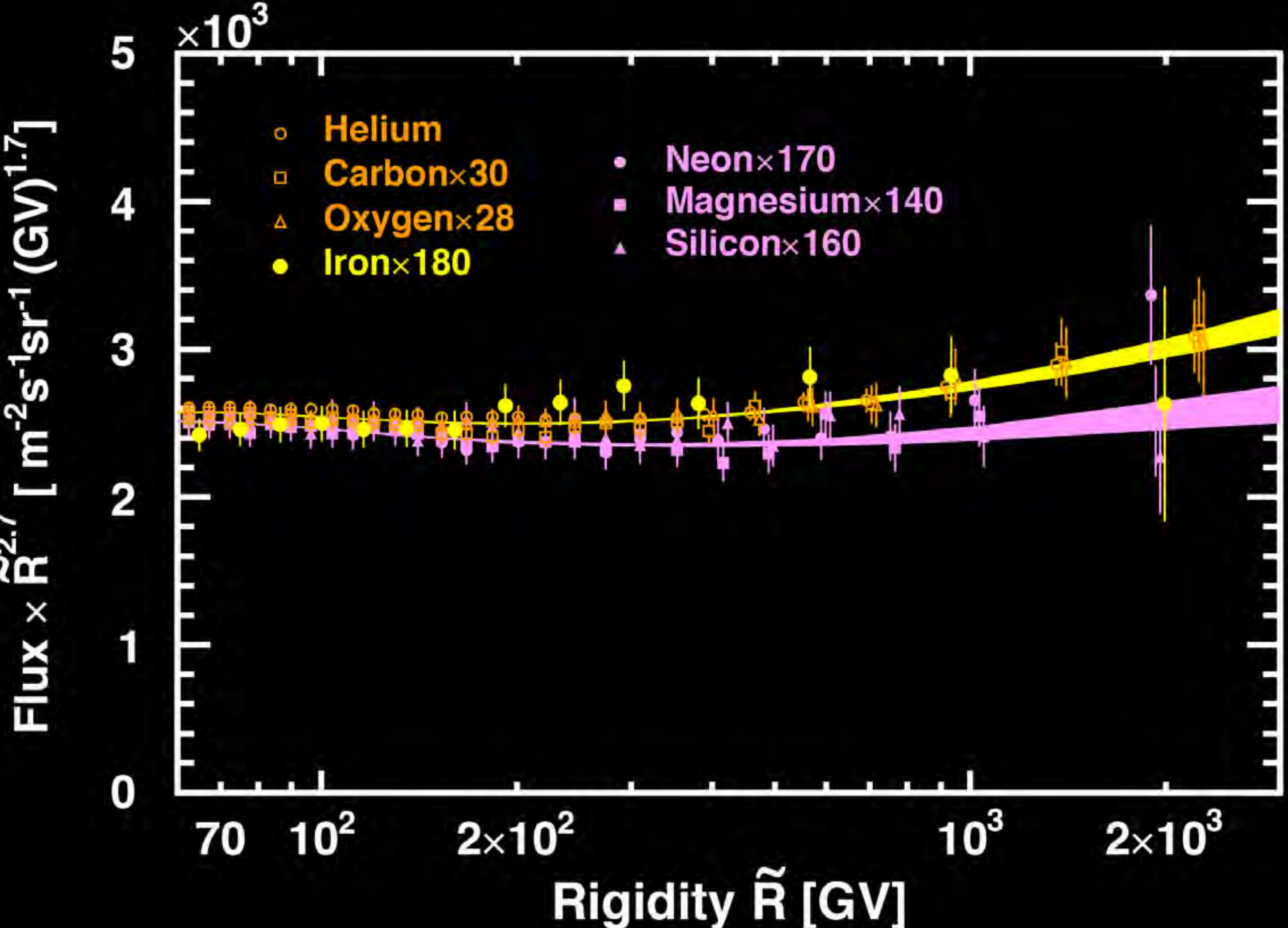
Heavier primary cosmic rays Ne, Mg, Si:
have their own identical rigidity behavior but different from He, C, O.
Primary cosmic rays have at least two classes.



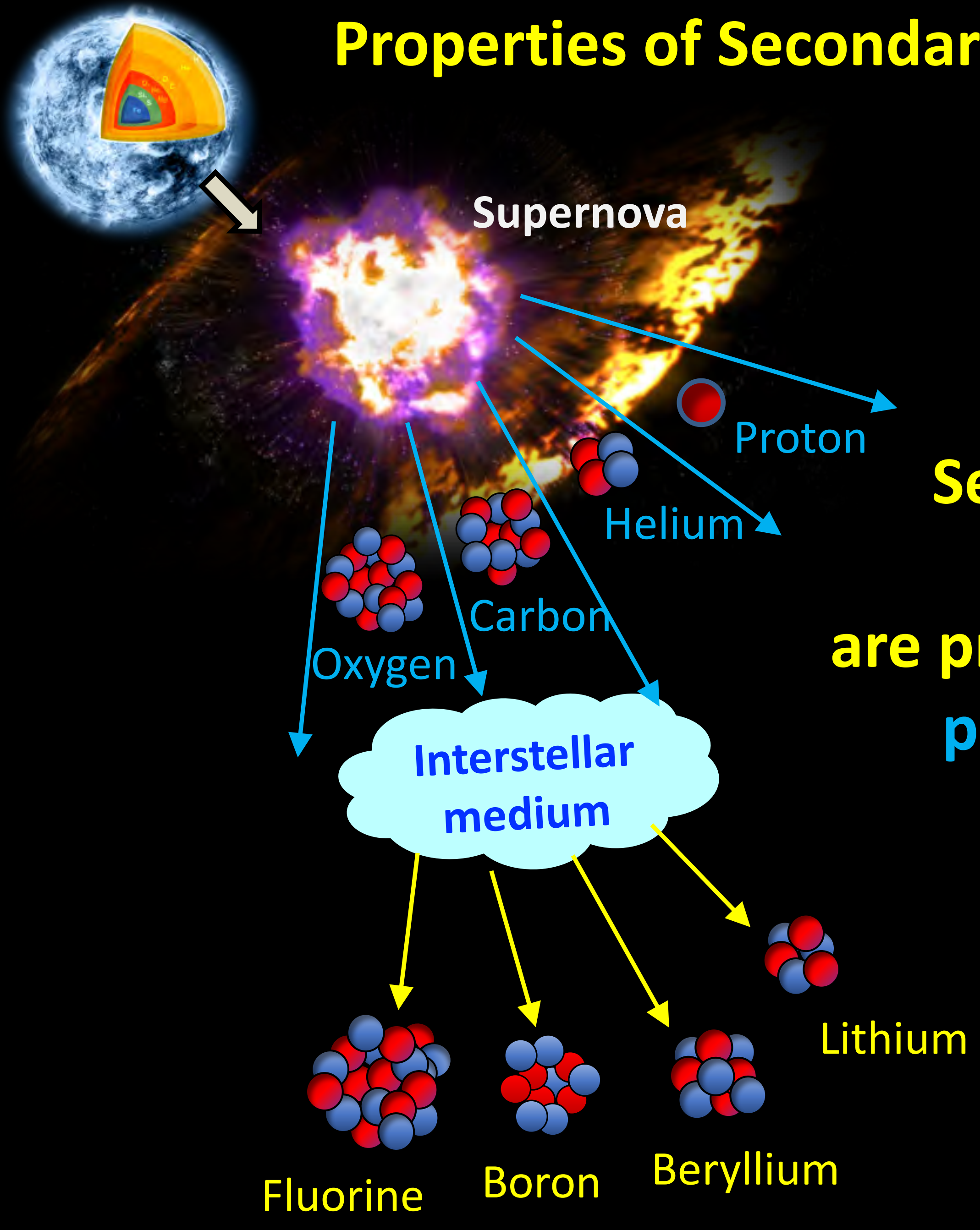
Iron is a very important element in cosmic ray theories because it is the heaviest element produced during stellar evolution. Iron has a large interaction cross section with the interstellar medium whereas helium has the smallest cross section.



Iron is in the He, C, O primary cosmic ray group

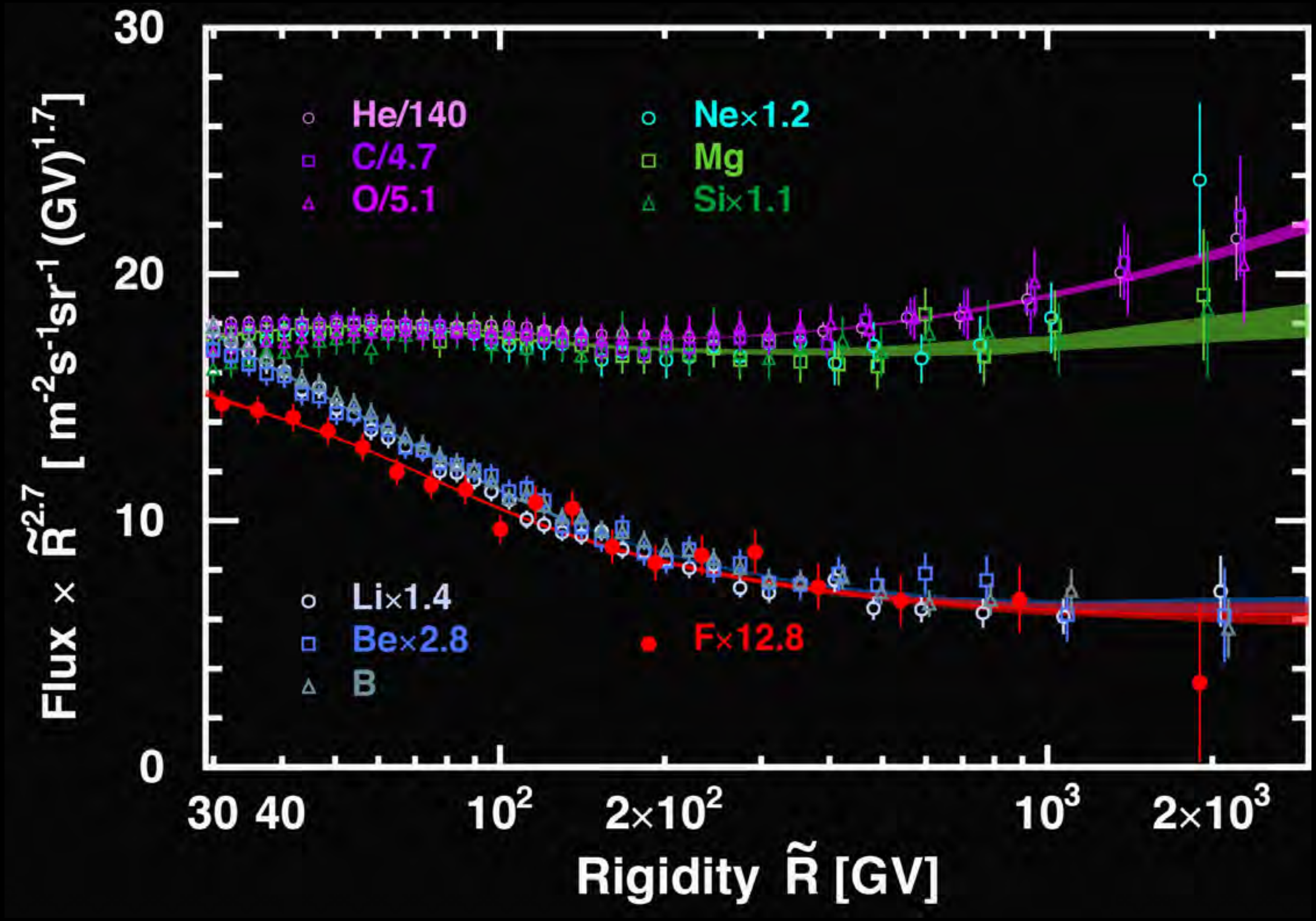


Properties of Secondary Cosmic Rays



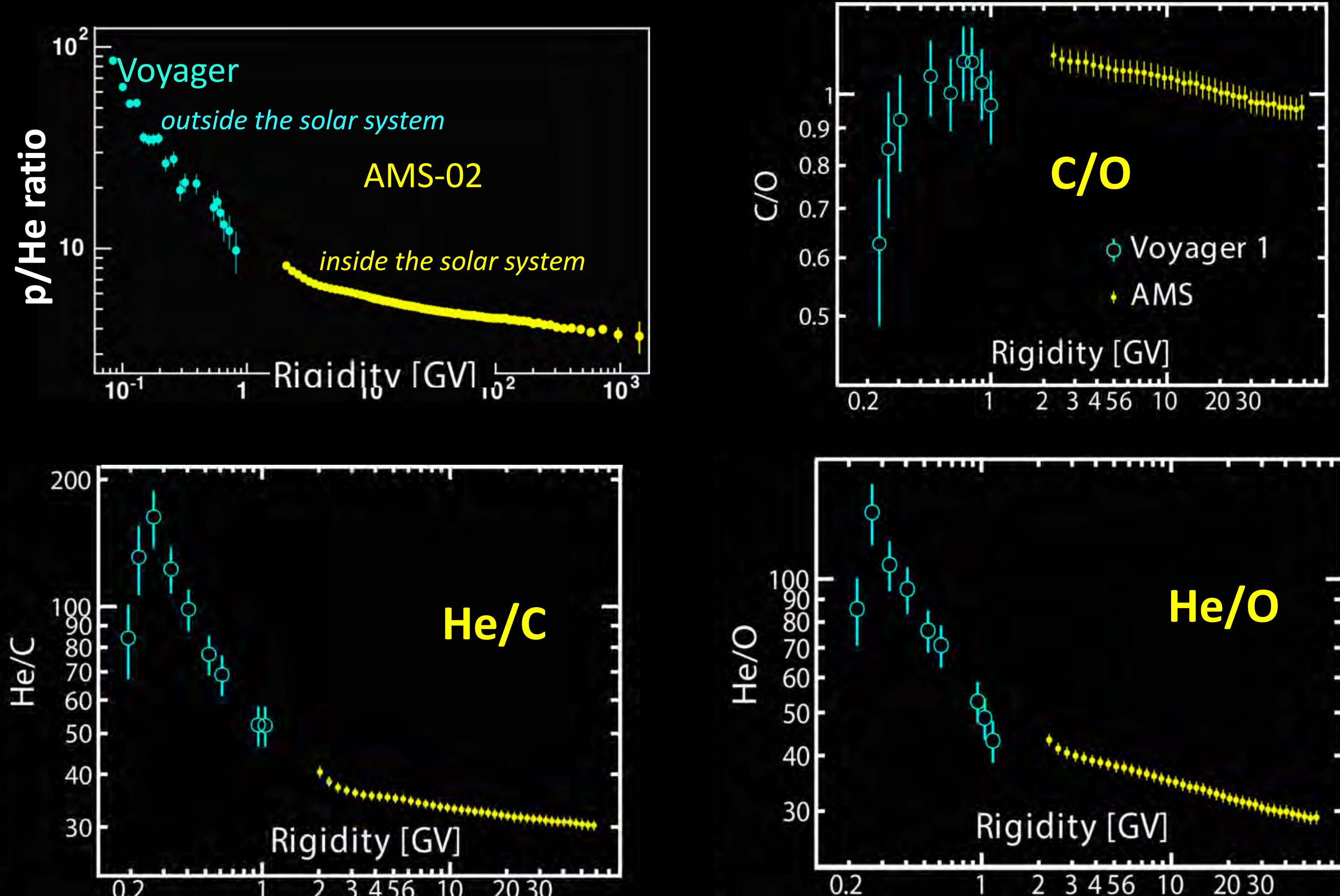
Secondary cosmic nuclei (Li, Be, B, …) are produced by the collision of primary cosmic rays and interstellar medium

Secondary Cosmic Rays also have two classes above 30 GV

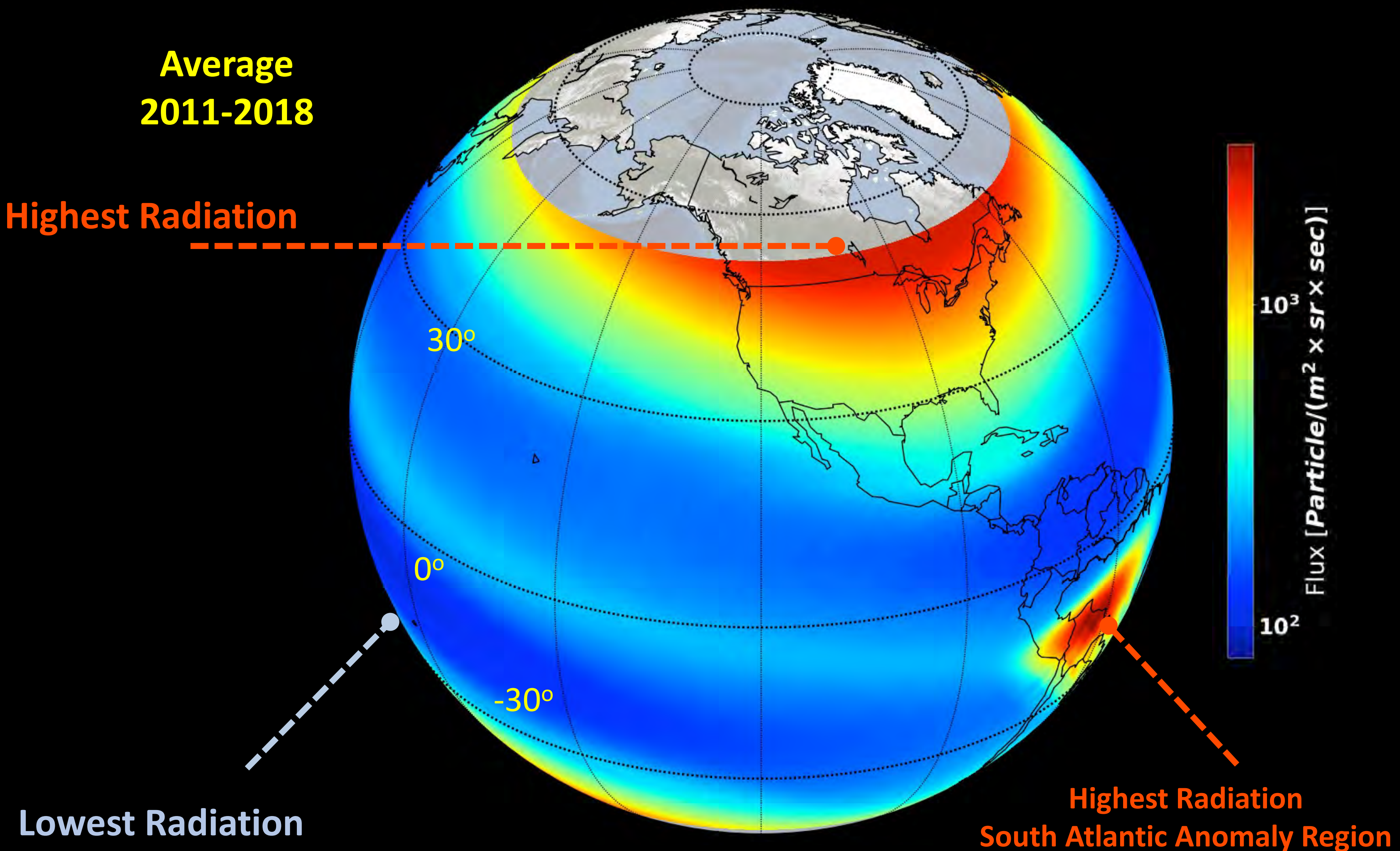


AMS Light nuclei comparison with Voyager-1

The ratios are independent of solar activity



Flux of Protons above 100 MeV

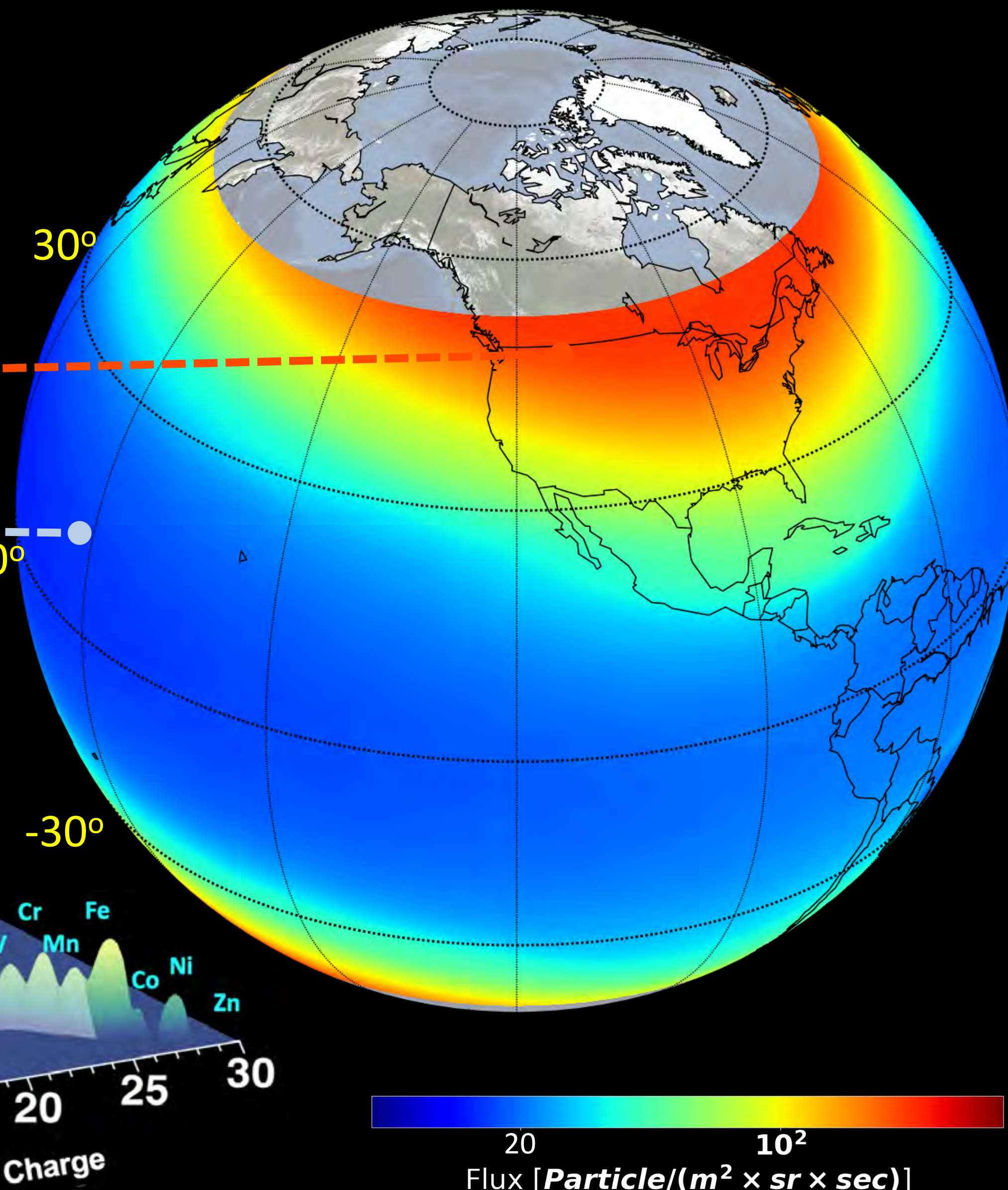


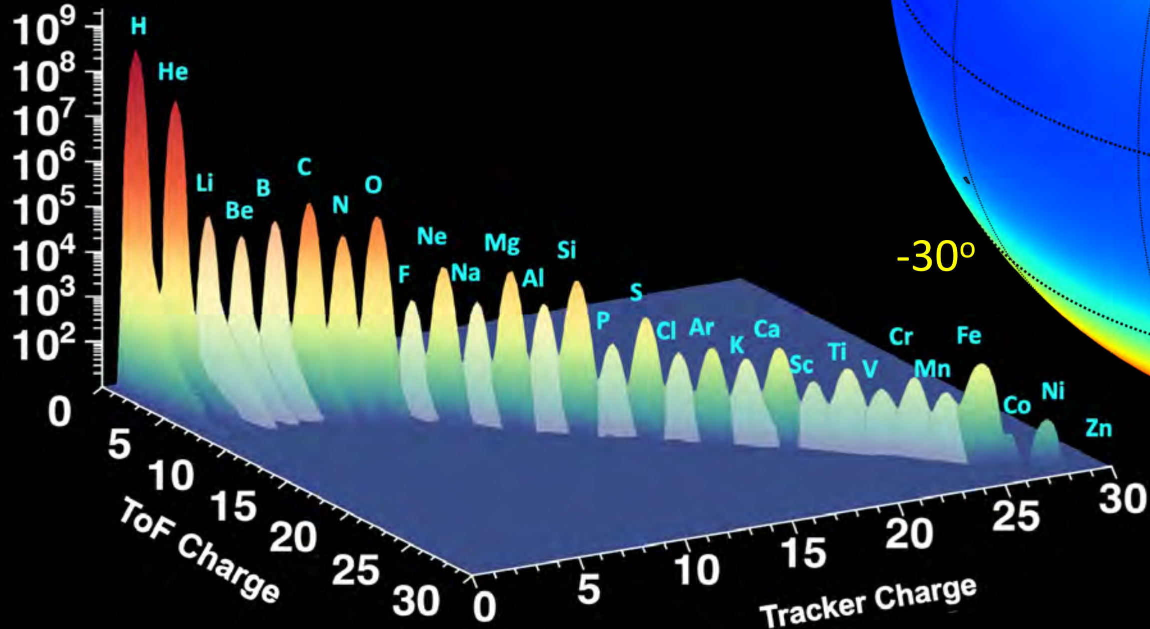
AMS Radiation Flux of Heavy Nuclei He(Z=2) to Zinc(Z=30)

Average 2011-2018

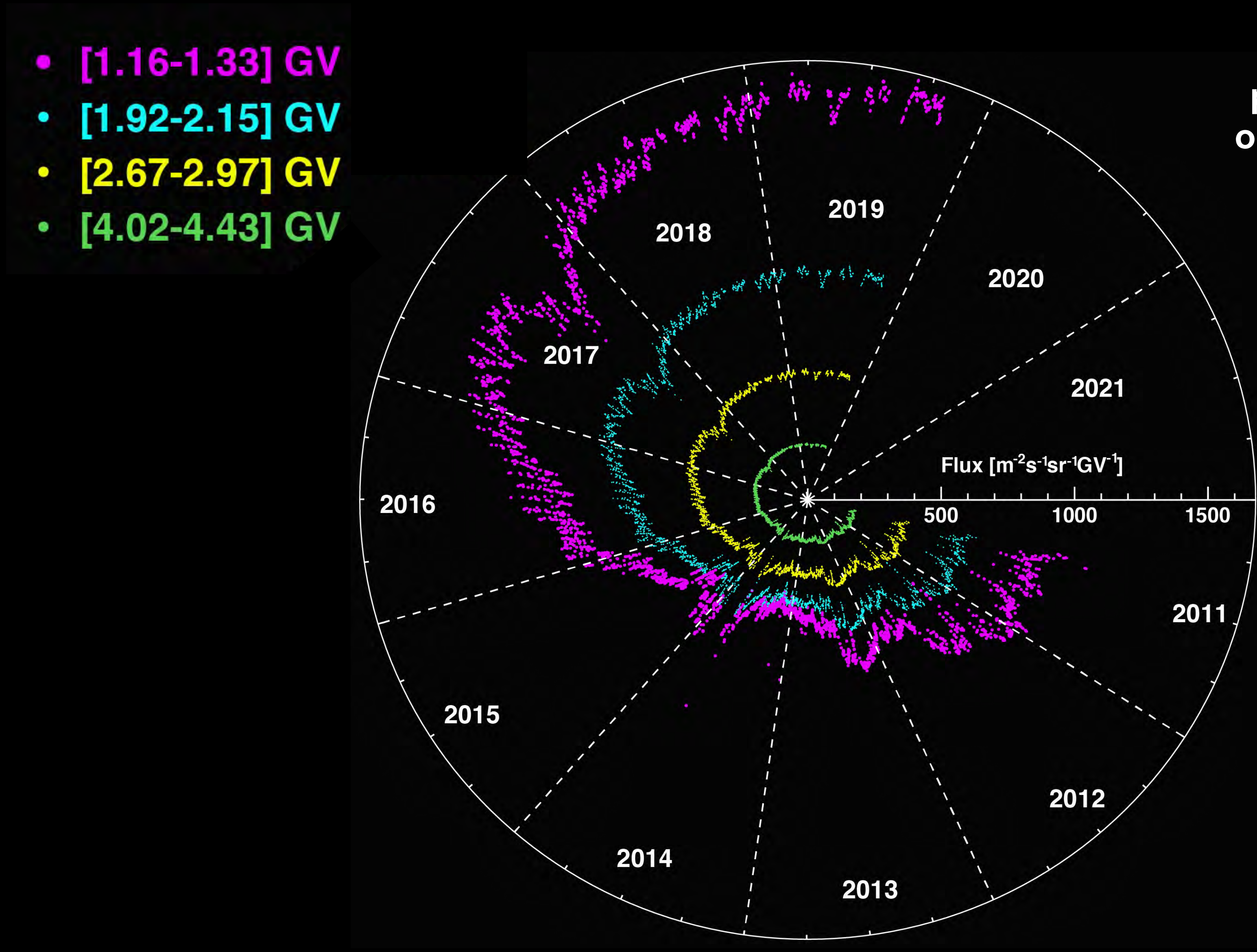
Highest Radiation

Lowest Radiation



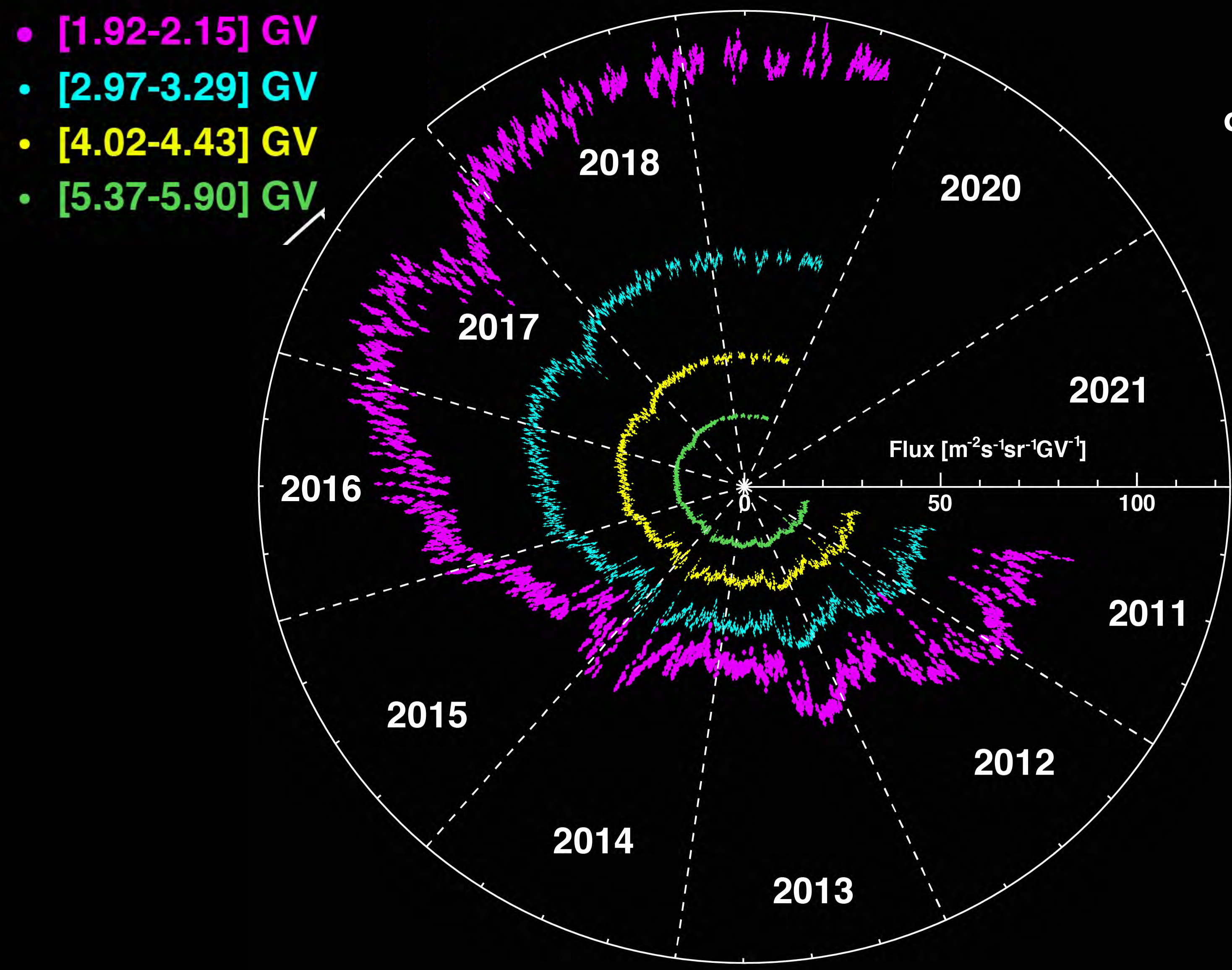


Daily Variations in the Proton Flux



Preliminary
please refer to our forthcoming publication in PRL

Daily Variations in the Helium Flux



Preliminary
please refer to our forthcoming publication in PRL

Conclusions

- AMS-02 is measuring with high accuracy the nuclei spectra up to Iron (and possibly just above)
- The AMS-02 measurements reveal new features
- AMS-02 can also study CR flux time dependence and its correlation with sun activity

AMS-02 Beyond 2021

- Positrons and anti-protons as probes for exotic signals
- Complete the CR spectra measurement
- Complete the CR fluxes study over a full solar cycle
- Search for heavy antimatter (few candidates observed) and anti-deuterons