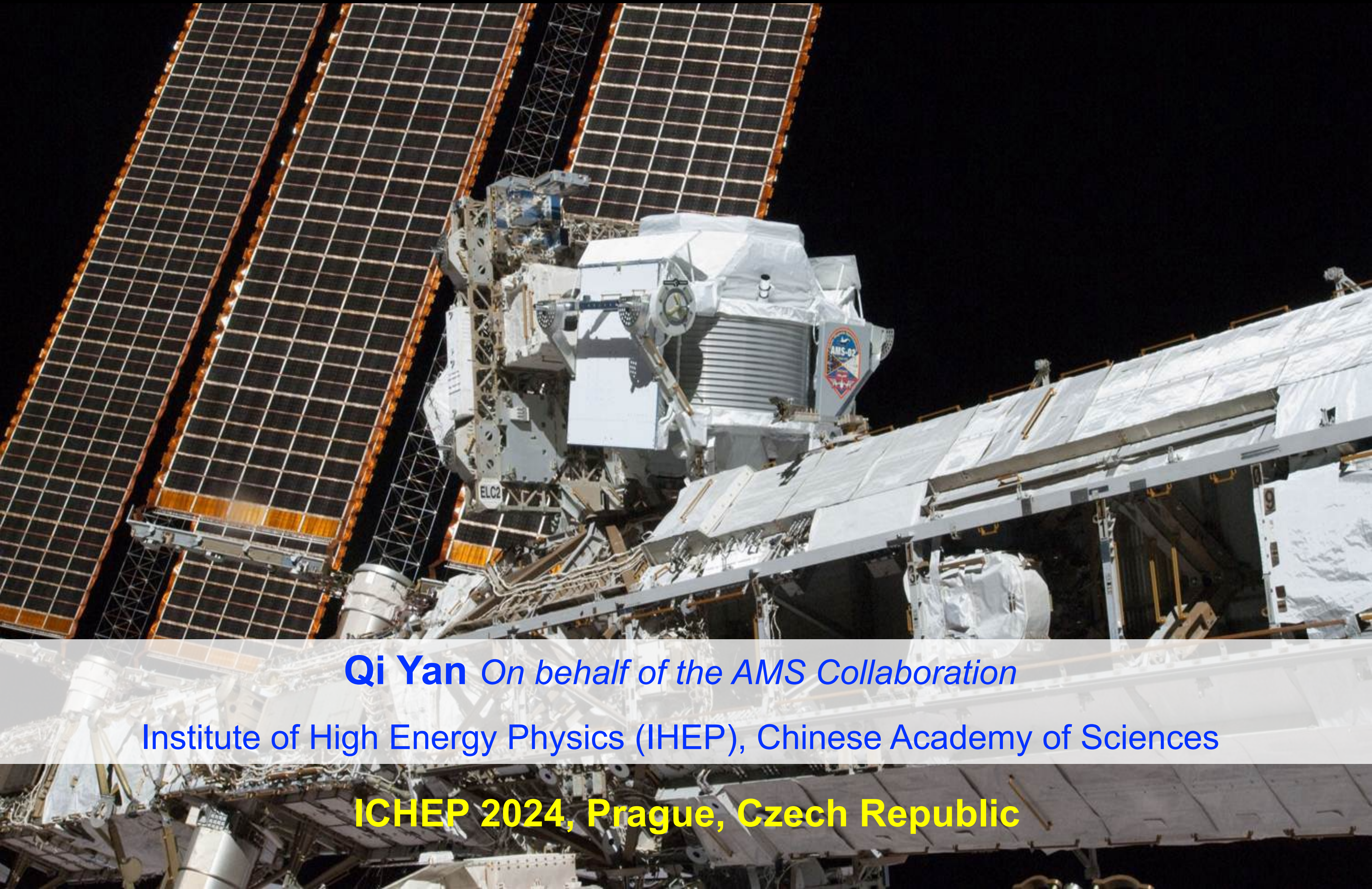
Unique Properties of Primary Cosmic Rays Measured by AMS



Qi Yan *On behalf of the AMS Collaboration*

Institute of High Energy Physics (IHEP), Chinese Academy of Sciences

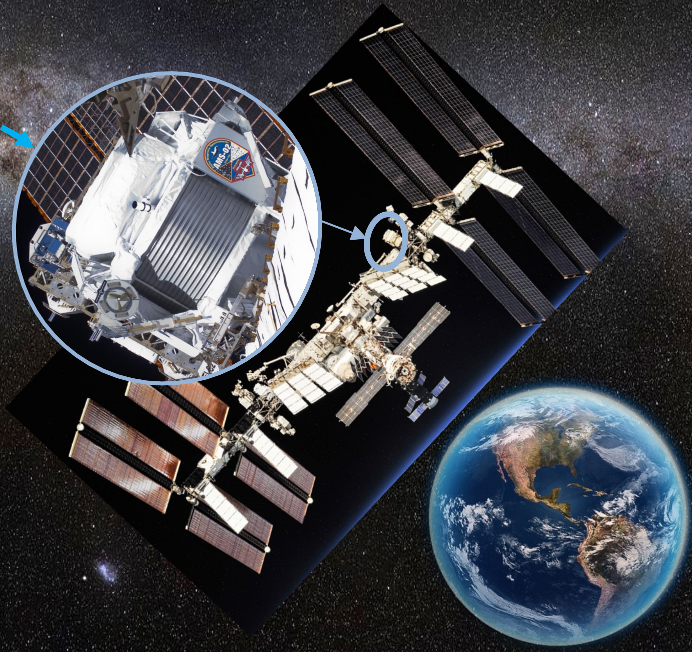
ICHEP 2024, Prague, Czech Republic

Primary Cosmic Rays

Primary cosmic ray p, He, C, O, …, Si, …, Fe, … are mostly produced during the lifetime of stars and accelerated in supernovae shocks.

Primary Cosmic Rays:
p, He, C, O, …, Si, …, Fe, …

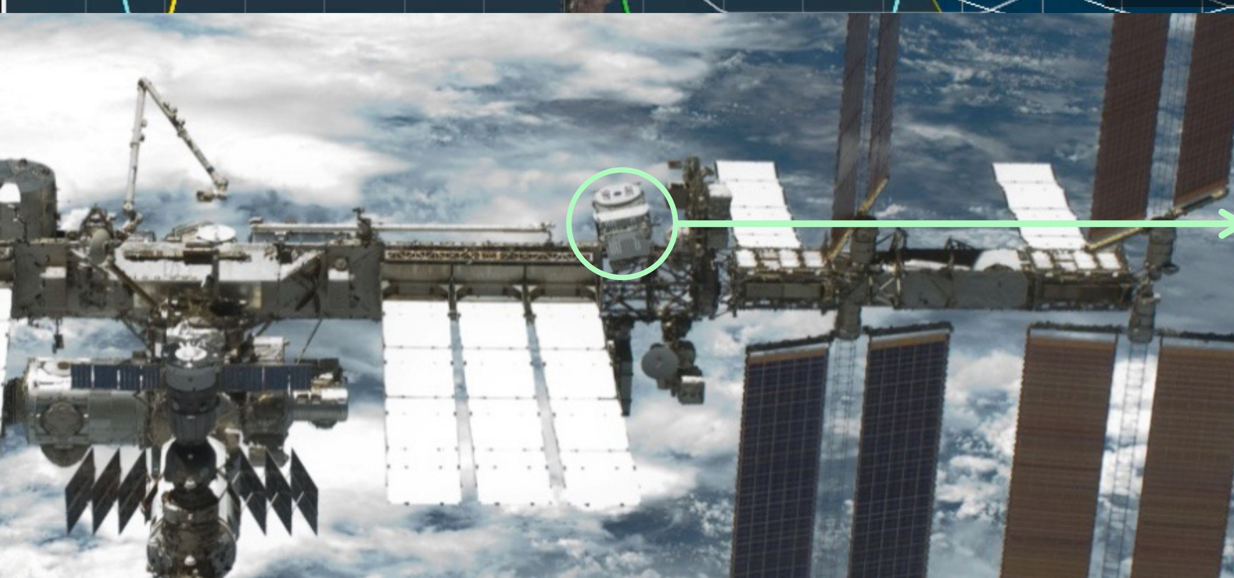
Interstellar Medium

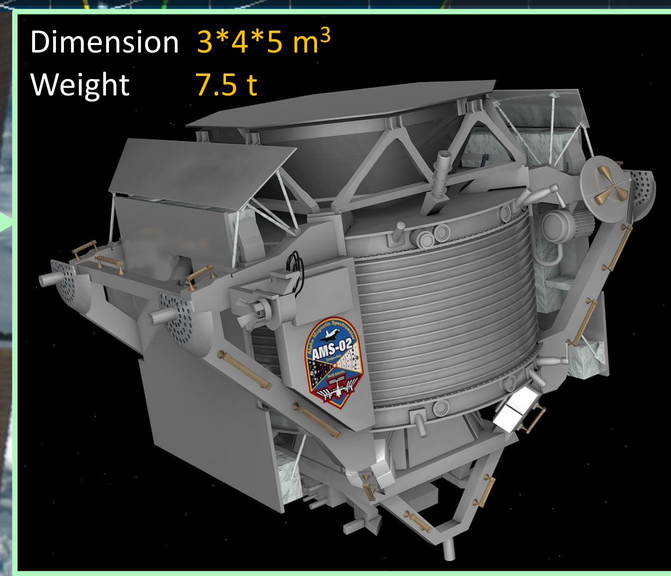


Measurements of the primary cosmic ray spectra carry information about the sources, acceleration, and propagation processes of cosmic rays in the Galaxy.

2011-2023: AMS is taking data without interruption

Over 12 years, AMS has collected more than 220 billion cosmic ray events : e^+, e^-, p, $\bar{p}$, nuclei, …



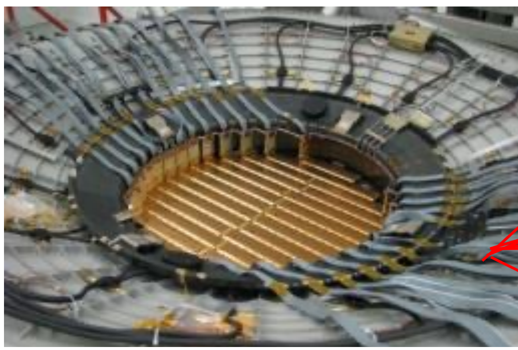


AMS: a unique TeV precision, accelerator-type spectrometer in space

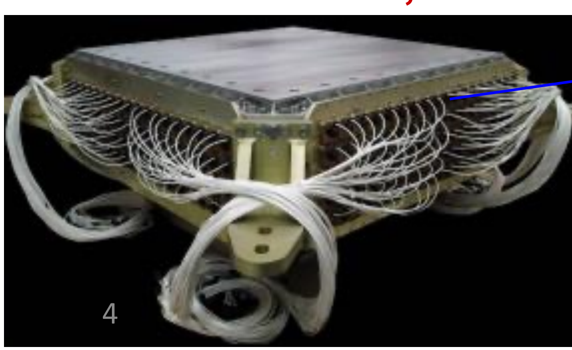
Particles and nuclei are defined
by their charge (Z)
and energy (E)
or momentum (P).
Rigidity R = P/Z

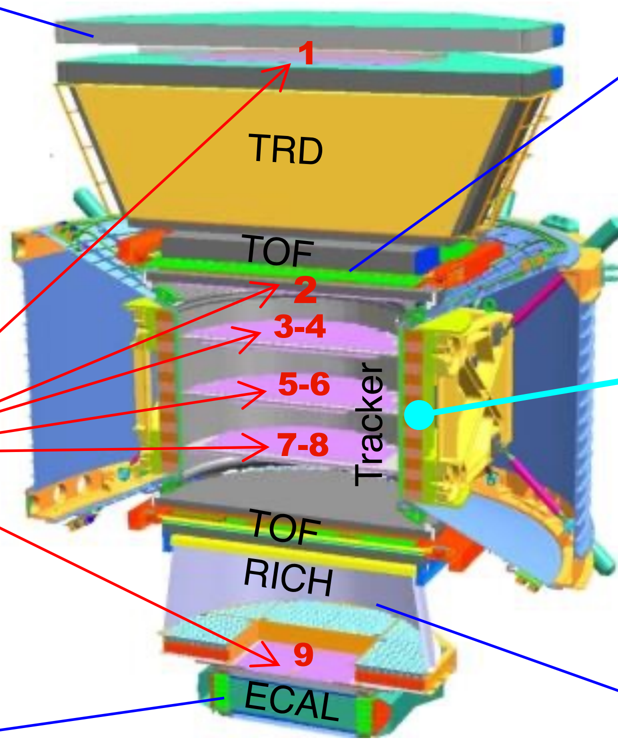
TRD: Identify e^+, e^-, Z

Silicon Tracker: Z, P



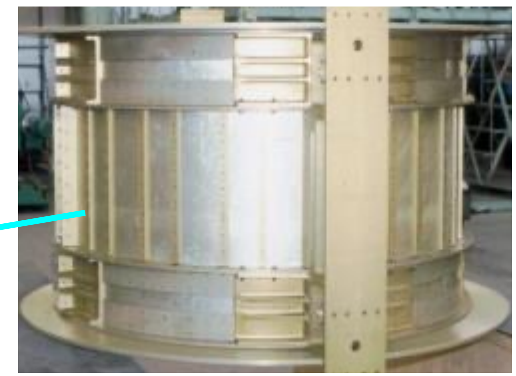
ECAL: E of e^+, e^-



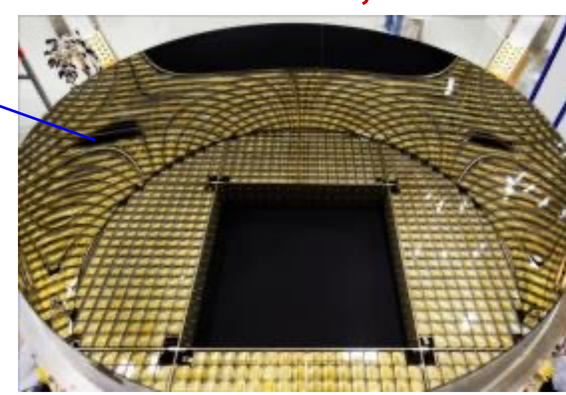


TOF: Z, E

Magnet: ±Z



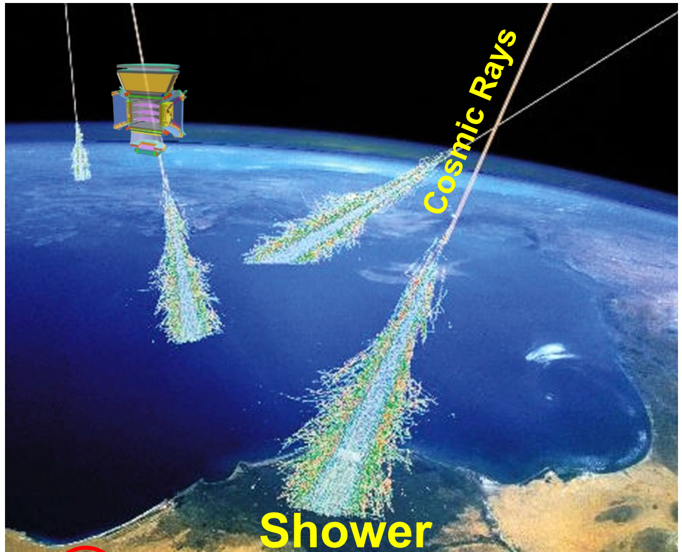
RICH: Z, E

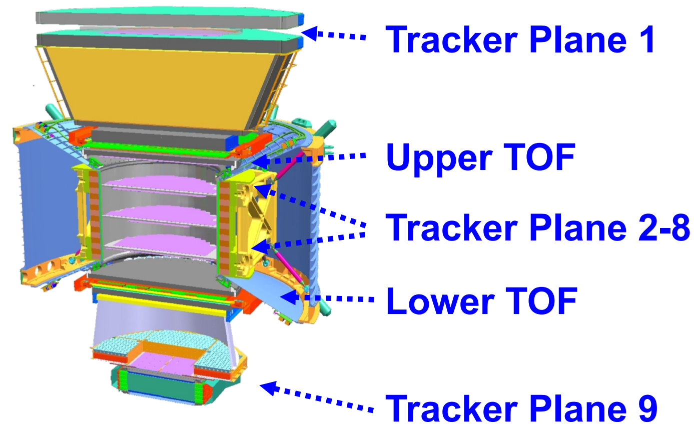


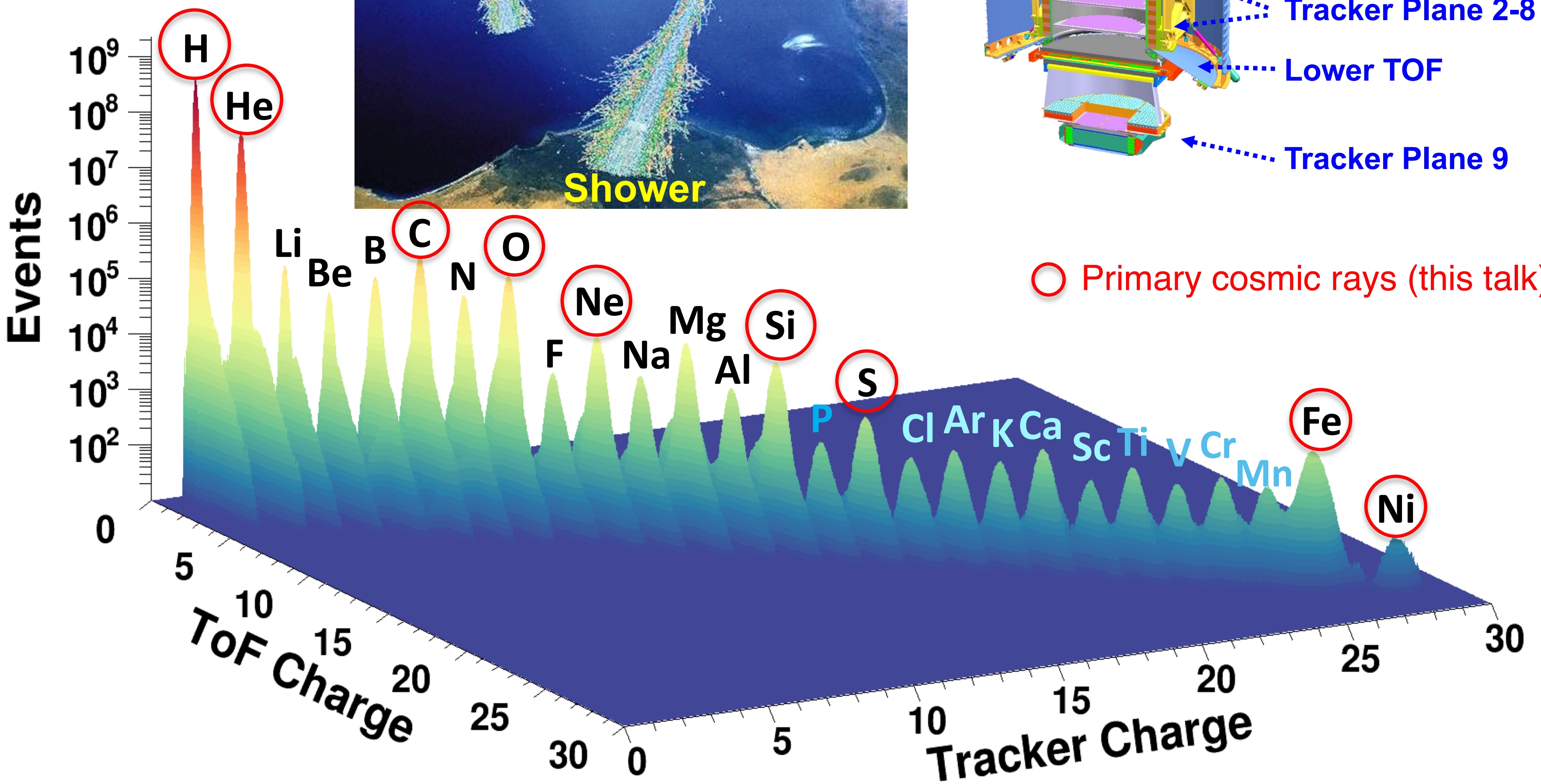
Z and P (or E)

are measured independently by the Tracker, RICH, TOF, and ECAL

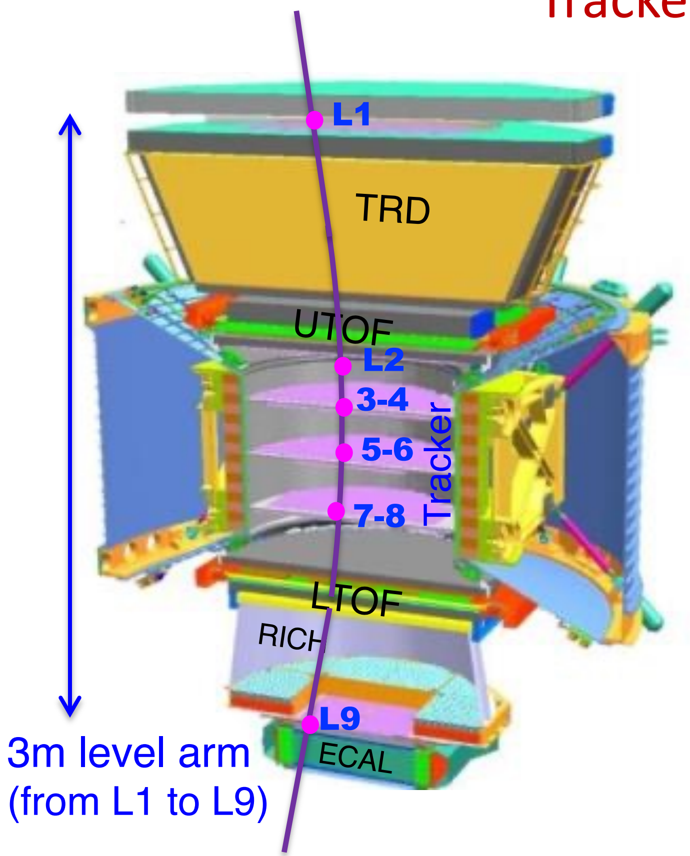
Chemical Composition in Cosmic Rays







AMS Cosmic Ray Nuclei Measurements



Tracker (9 Layers) + Magnet: Rigidity (Momentum/Charge)

	Coordinate Resolution	MDR
Z =1	10 μm	2 TV
2≤Z≤26	5-8 μm	3-3.7 TV

G. Ambrosi *et al.*, Nucl. Instrum. Methods Phys. Res. A **869**, 29 (2017).

TOF (4 Layers): Velocity and Direction

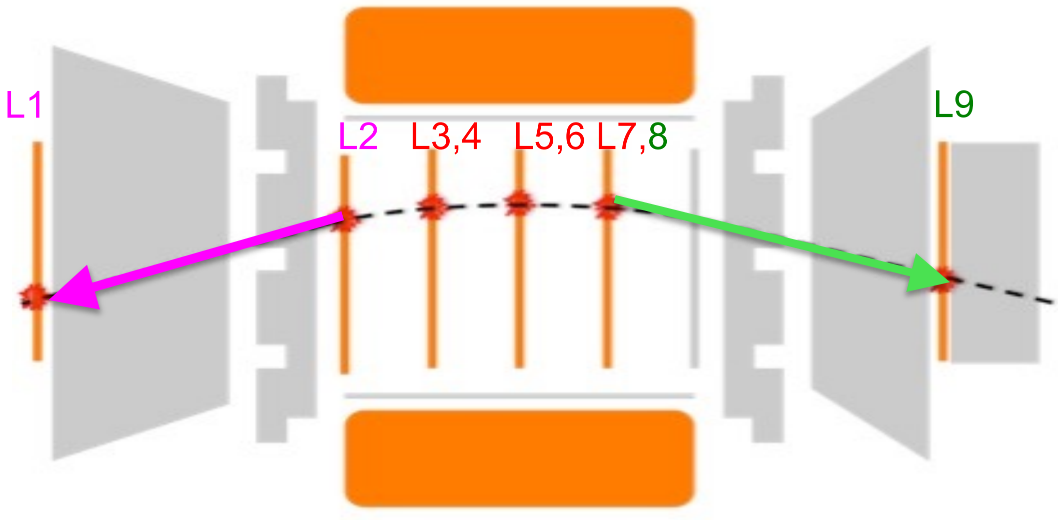
$\Delta(1/\beta) \approx 4\%$ (Z=1)

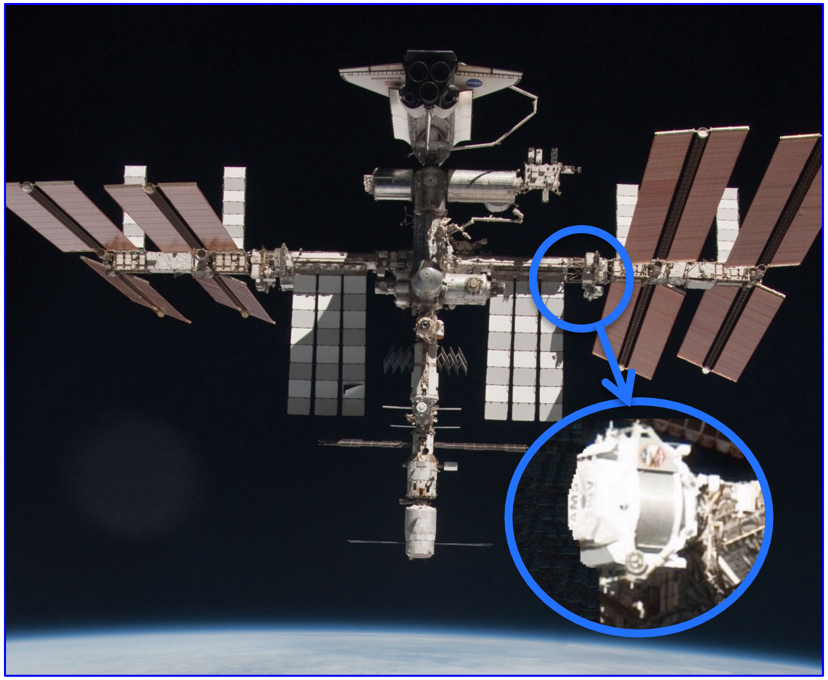
$\Delta(1/\beta) \approx 1\text{-}2\%$ (Z≥2)

V. Bindi *et al.*, Nucl. Instrum. Methods Phys. Res. A **743**, 22 (2014).

Nuclear Interaction Cross-Section Measurements with AMS

To accurately measure the fluxes of cosmic ray nuclei, the knowledge of nuclear interaction cross sections with the AMS material is important. The material of AMS is composed mostly of *C* and *Al*. The interaction cross sections of *Nu + C, Nu + Al* were not well known before AMS.

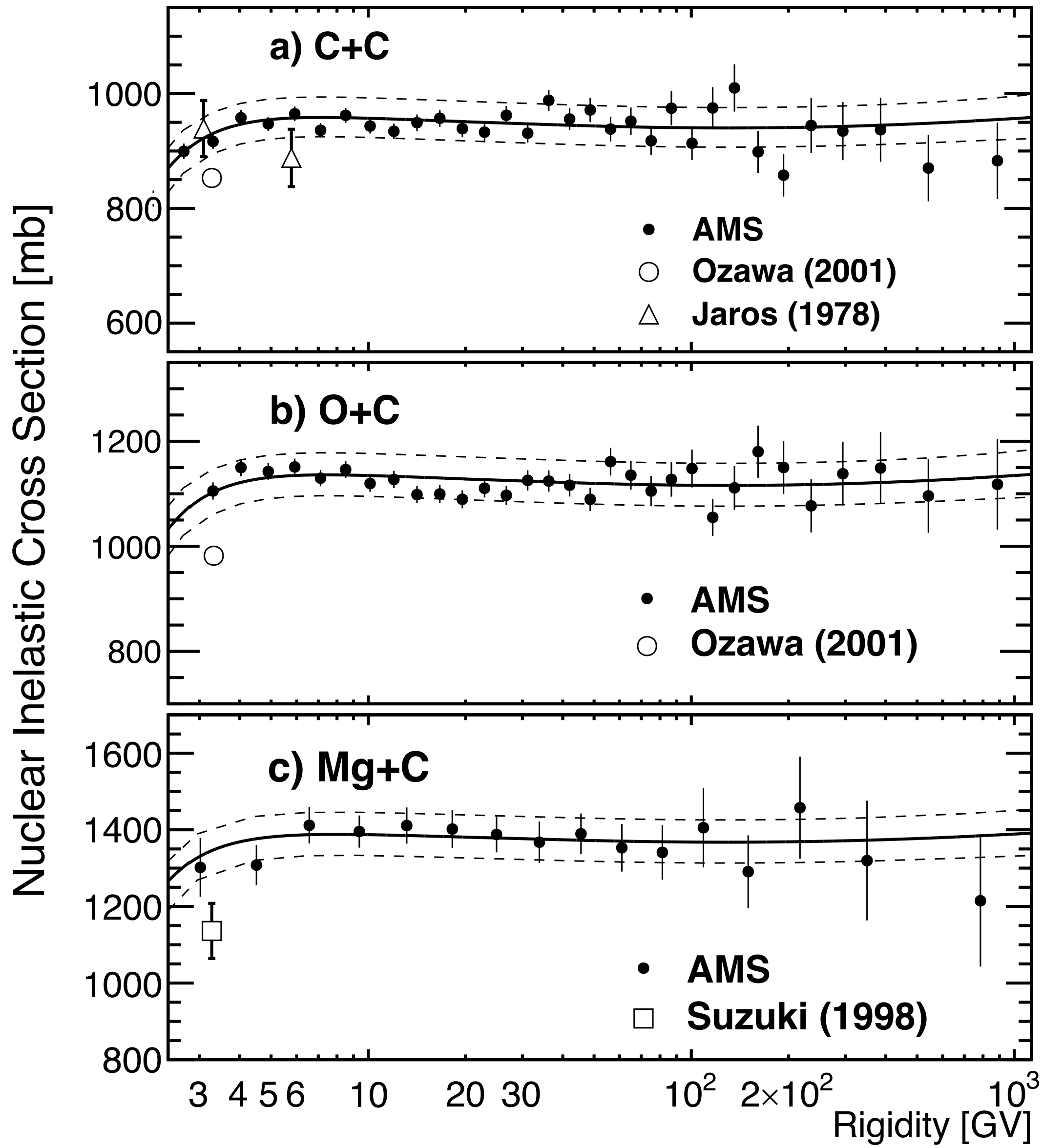




AMS data acquisition when the attitude of the International Space Station was rotated 90 degree, in which particles can enter AMS both right to the left and left to the right.

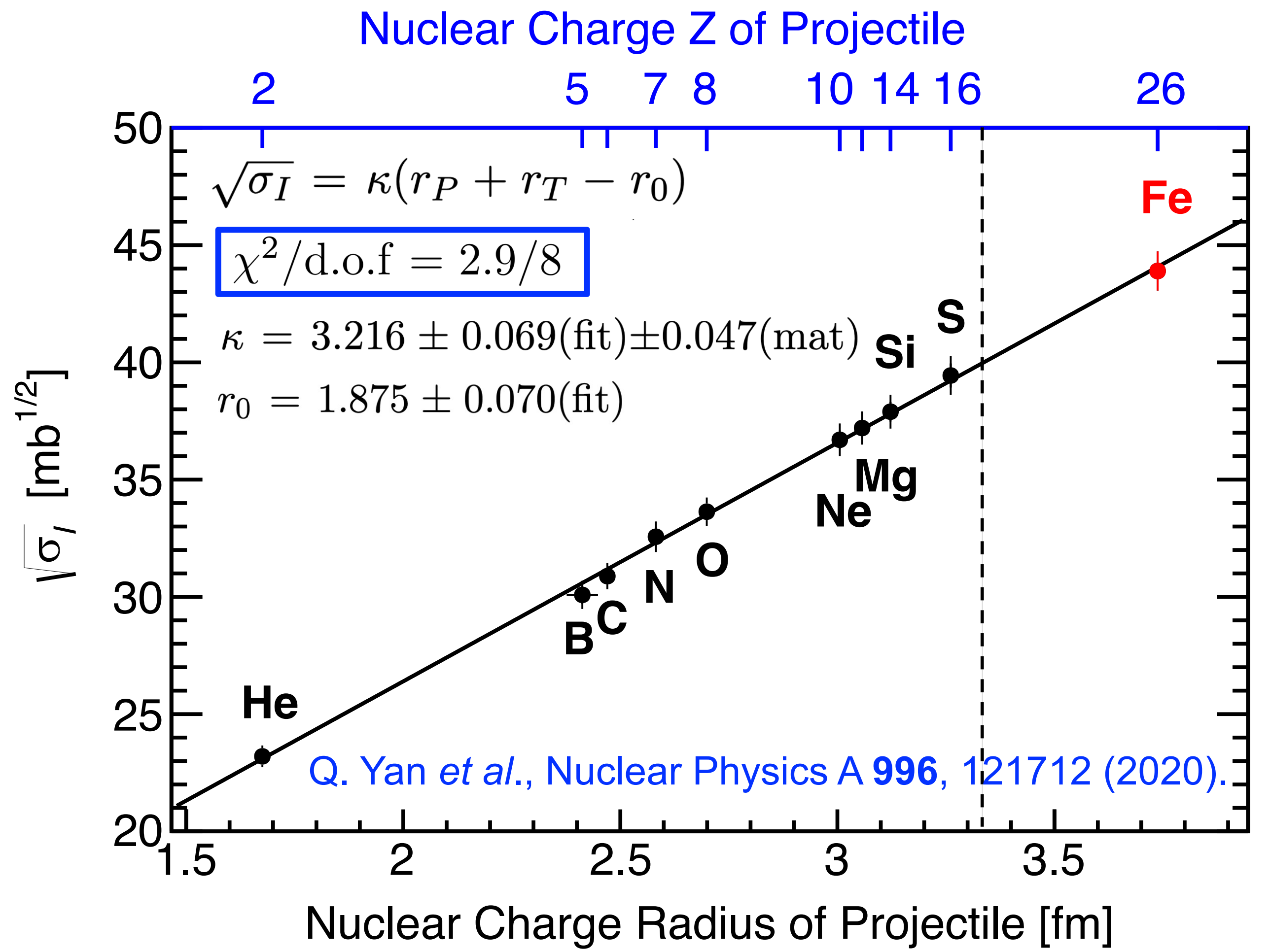
We have made nuclear Interaction cross-section measurements in a wide rigidity range from a few GV to TV using the AMS collected cosmic ray events.

AMS measured *Nu* + C Interaction Cross Section



Q. Yan *et al*., Nuclear Physics A **996**, 121712 (2020).

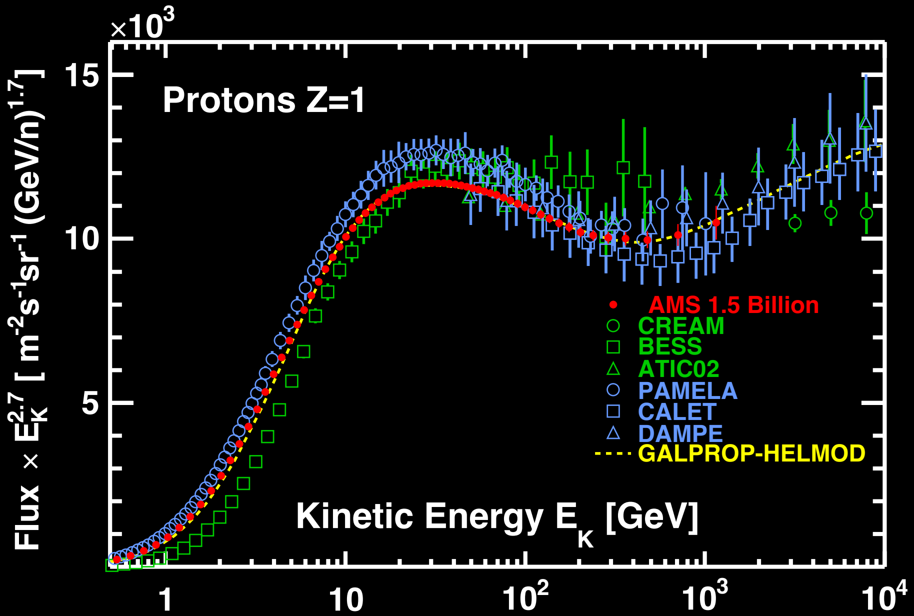
Nuclei+C Interaction Cross Sections Measured with AMS

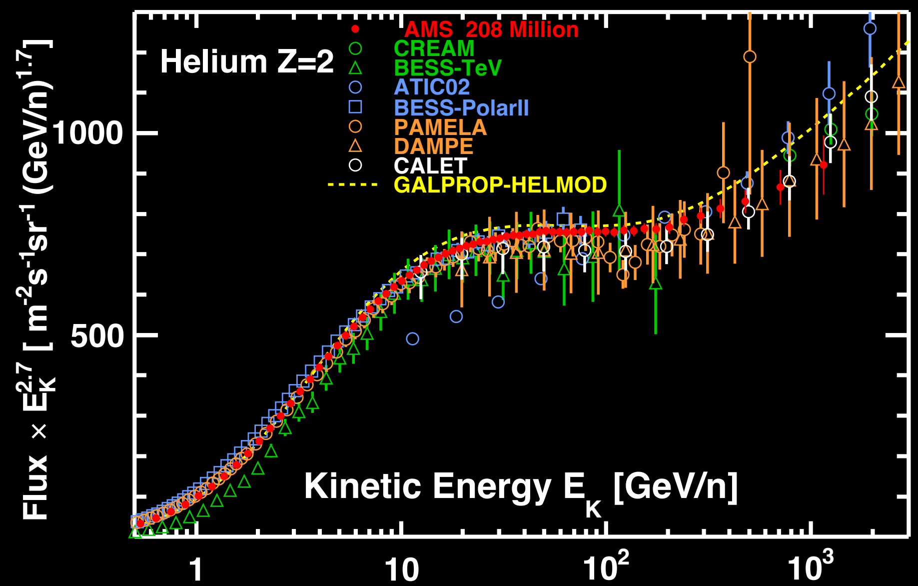


The square root of the interaction cross section on carbon target at rigidity 15 GV as a function of nuclear charge radius (r_P) for the projectile nuclei He, B, C, N, O, Ne, Mg, Si, S, and Fe measured with AMS. The nuclear charge radii are from "I. Angeli and K. P. Marinova, Atomic Data and Nuclear Data Tables 99 (2013) 69-95".

Through this study, the systematic error on nuclei fluxes measured by AMS due to uncertainties in the nuclear interactions is reduced at the percent level over the entire rigidity range.

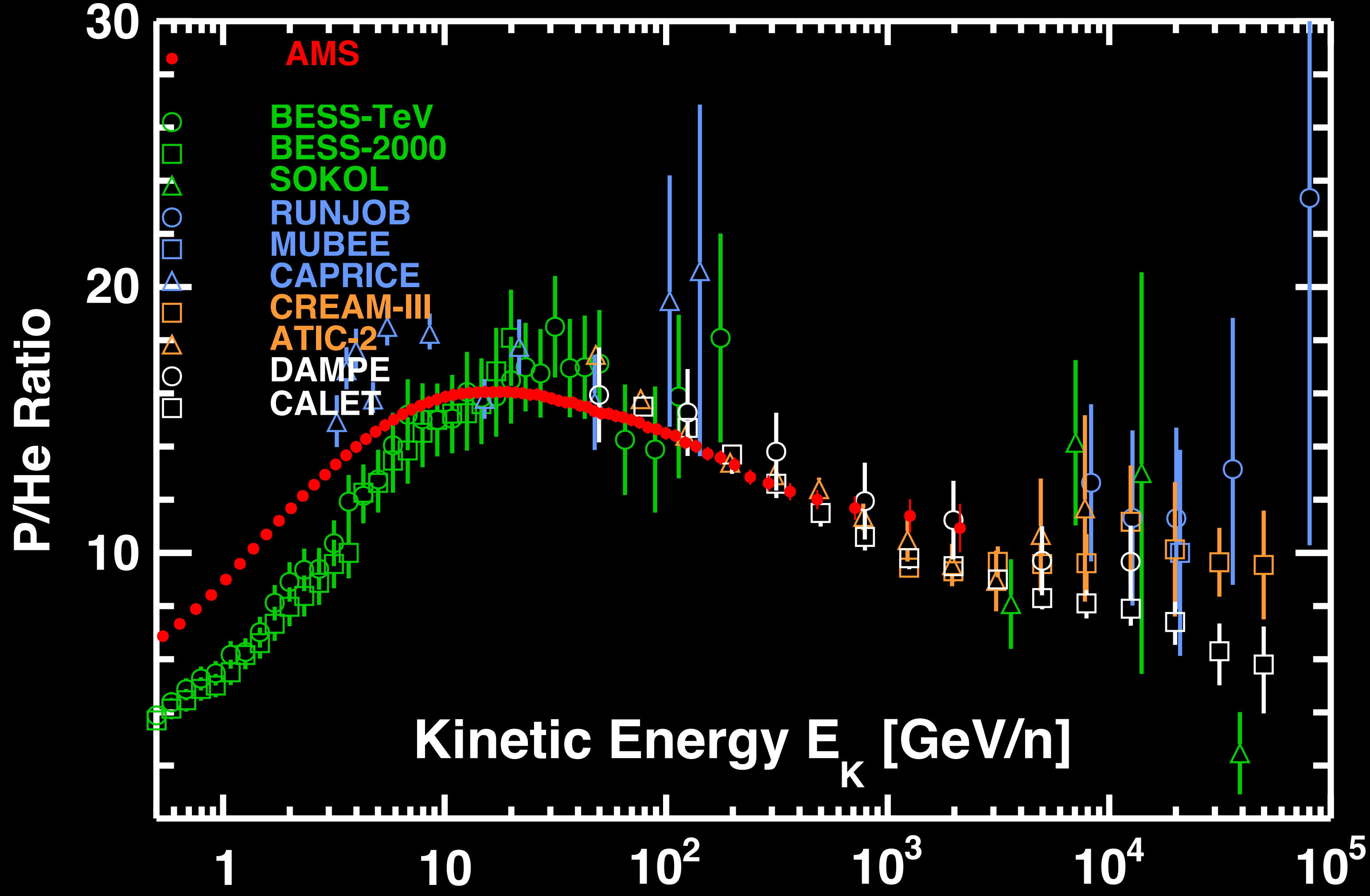
AMS Proton and Helium Fluxes together with Other Measurements



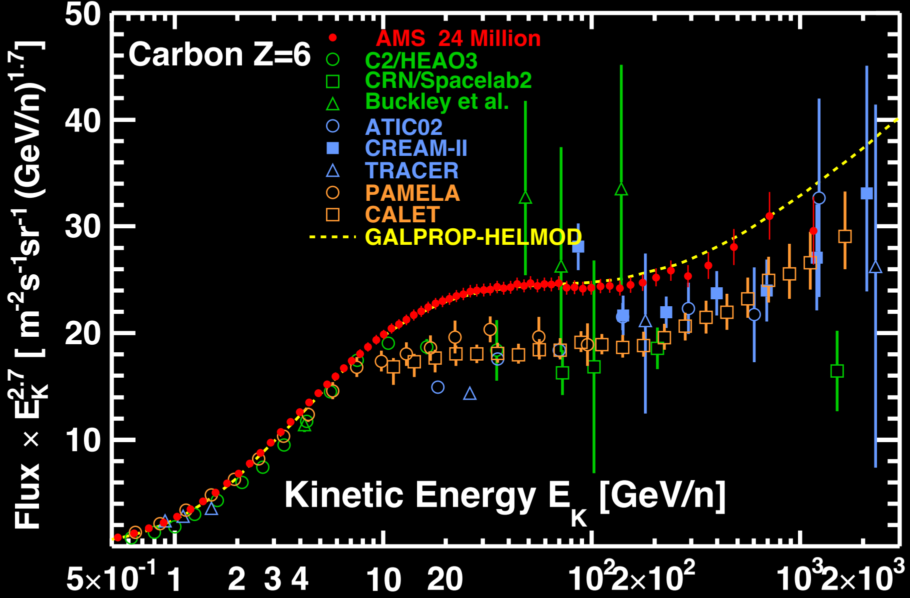


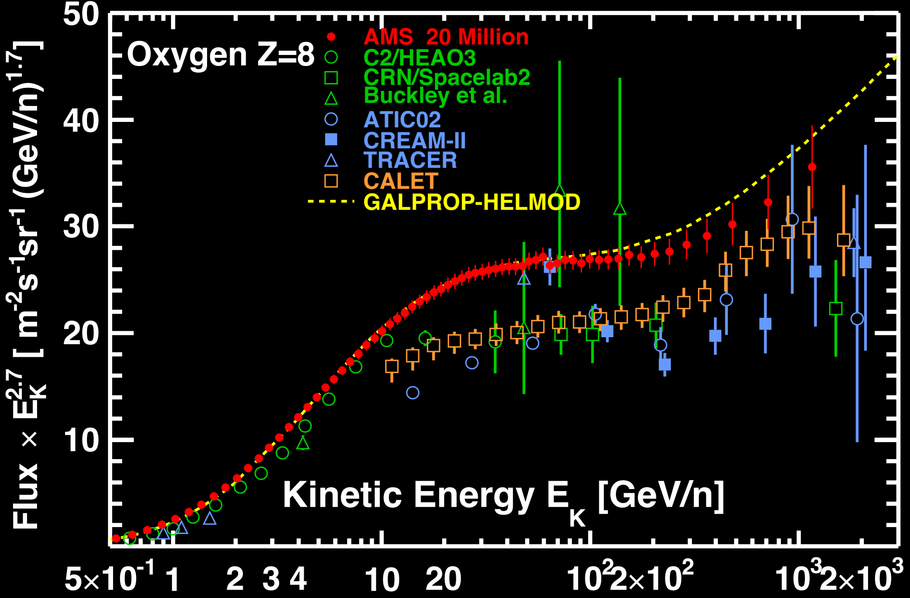
AMS measures proton and helium fluxes with unprecedented precision. Both spectra exhibit significant hardening at a rigidity of about 200 GV.

Proton-to-Helium Flux Ratio



AMS Carbon and Oxygen Fluxes together with Other Measurements

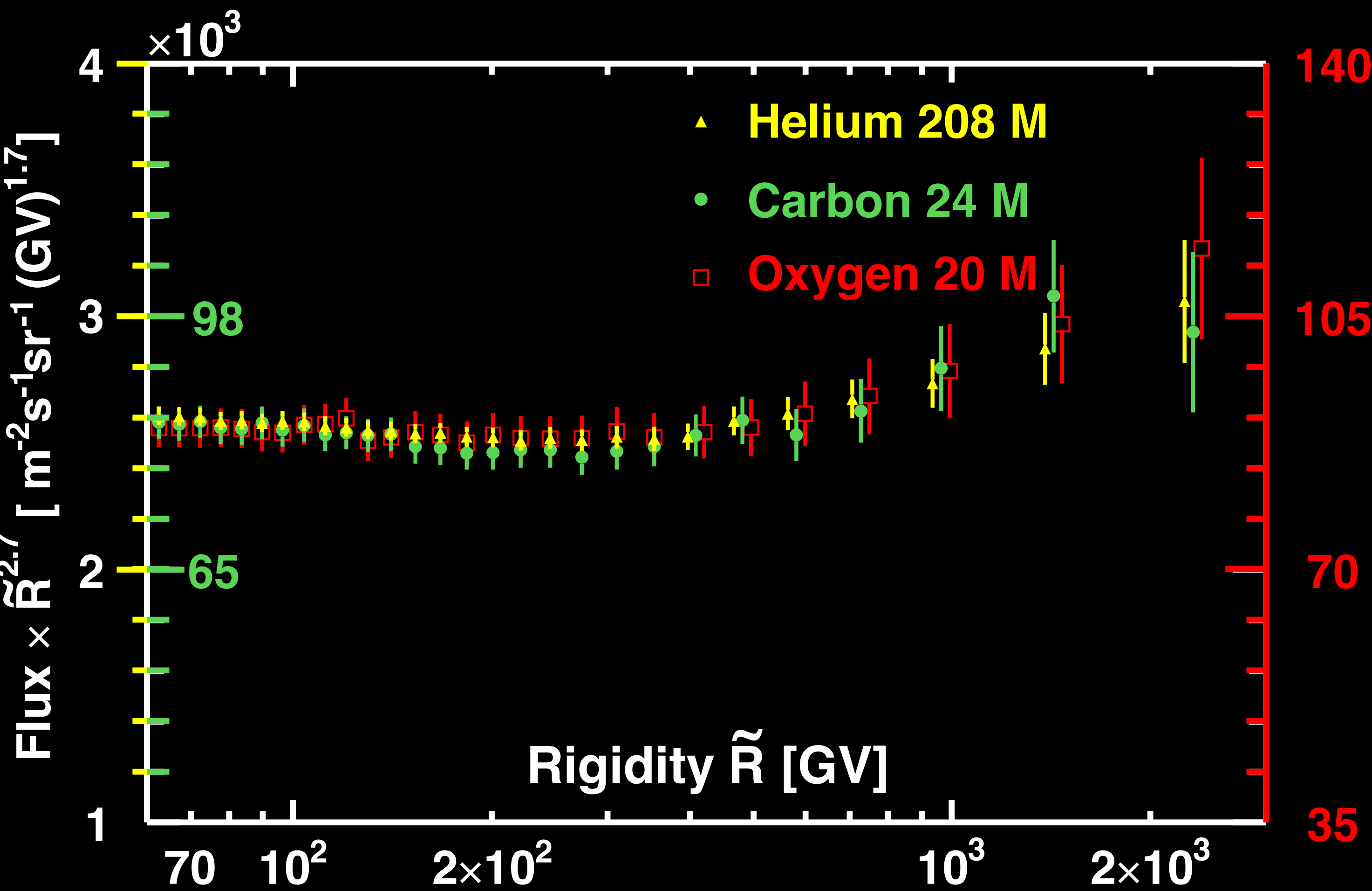




AMS results differ from other measurements.

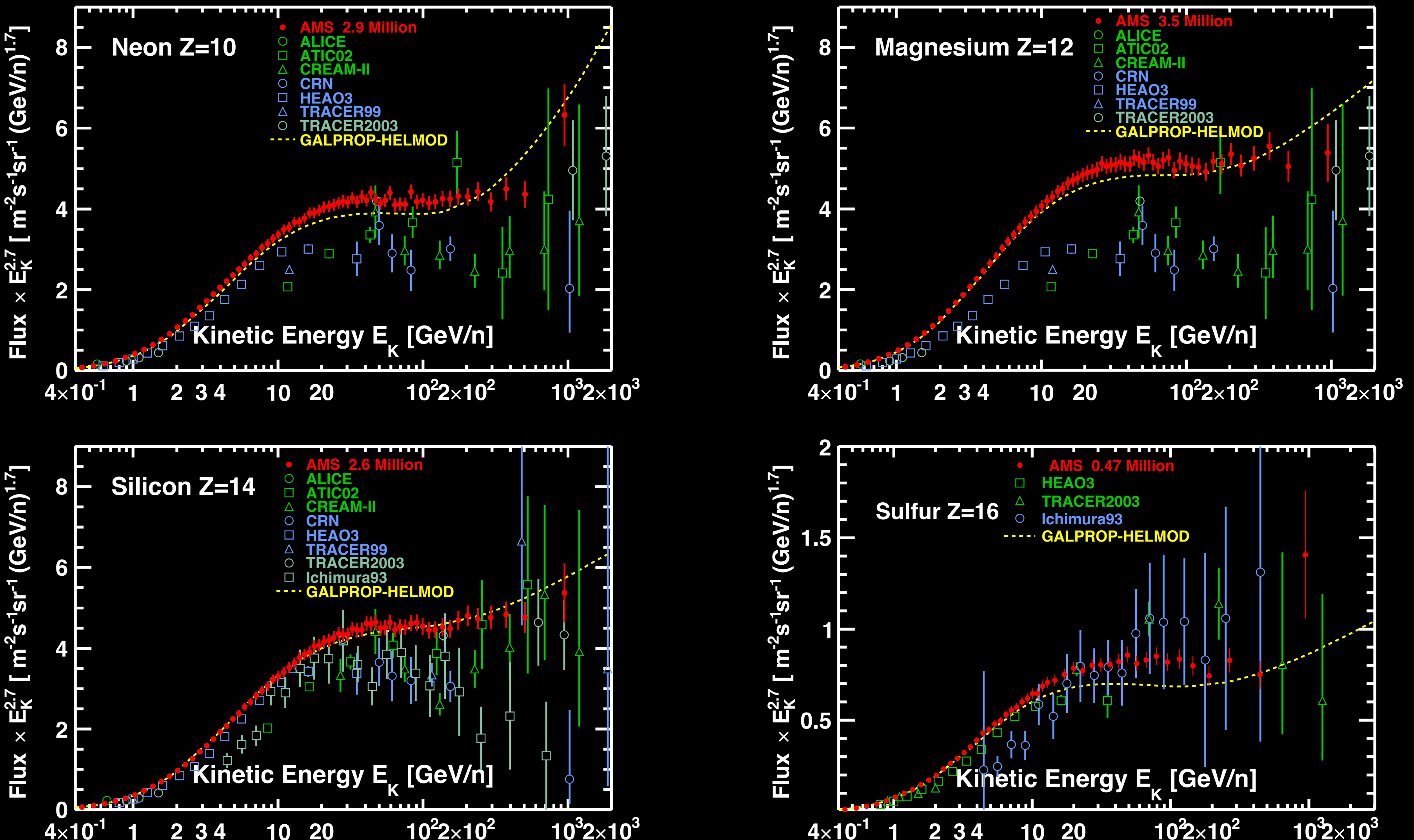
Carbon and Oxygen spectra also exhibit significant hardening at a rigidity of about 200 GV.

Properties of Light Primary Cosmic-Ray He, C, and O



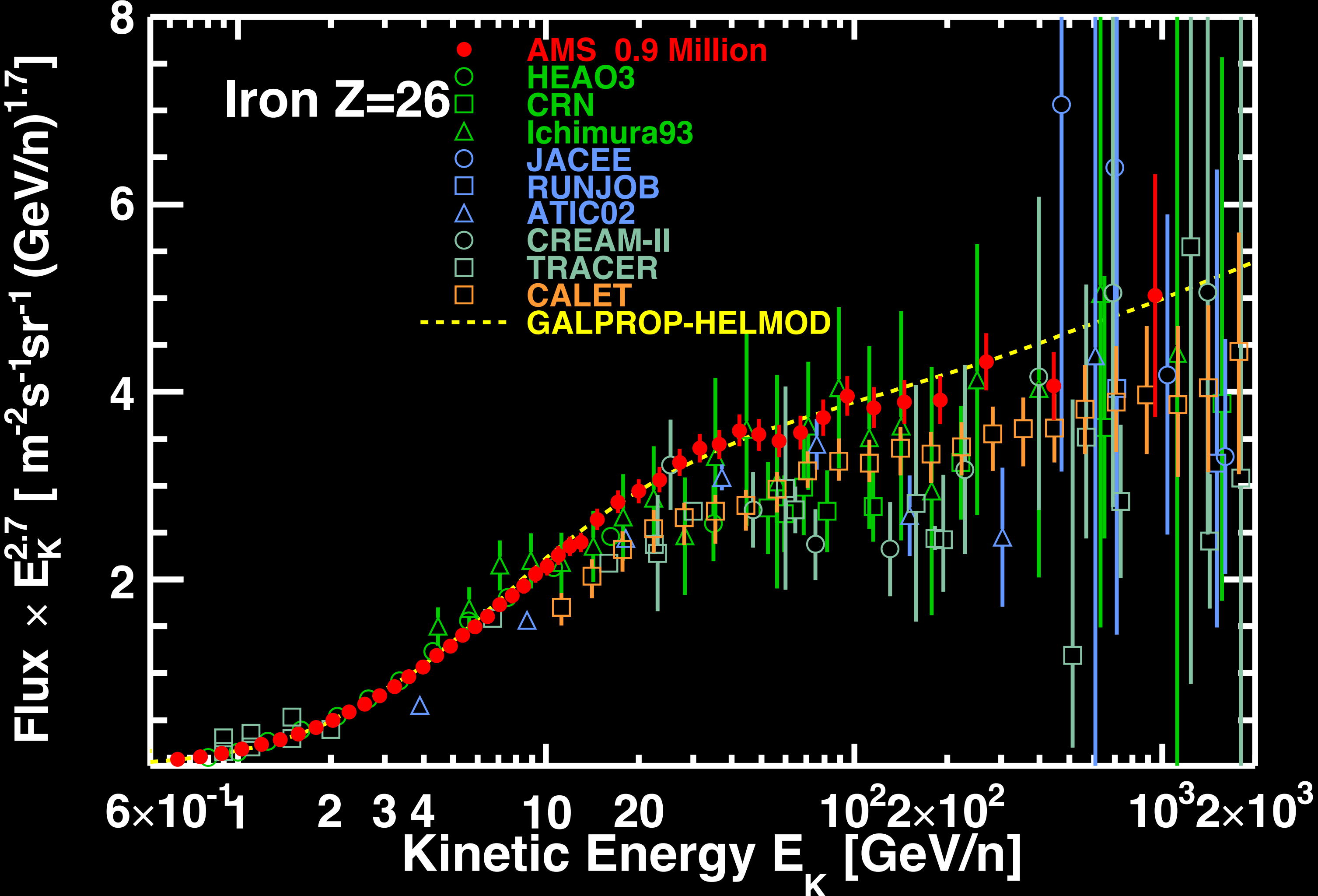
He, C and O spectra have an identical rigidity dependence above 60 GV. Above 200 GV, they all deviate from a single power law and harden in an identical way.

Neon, Magnesium, Silicon, and Sulfur Fluxes



AMS results differ from other measurements both in magnitude and precision.

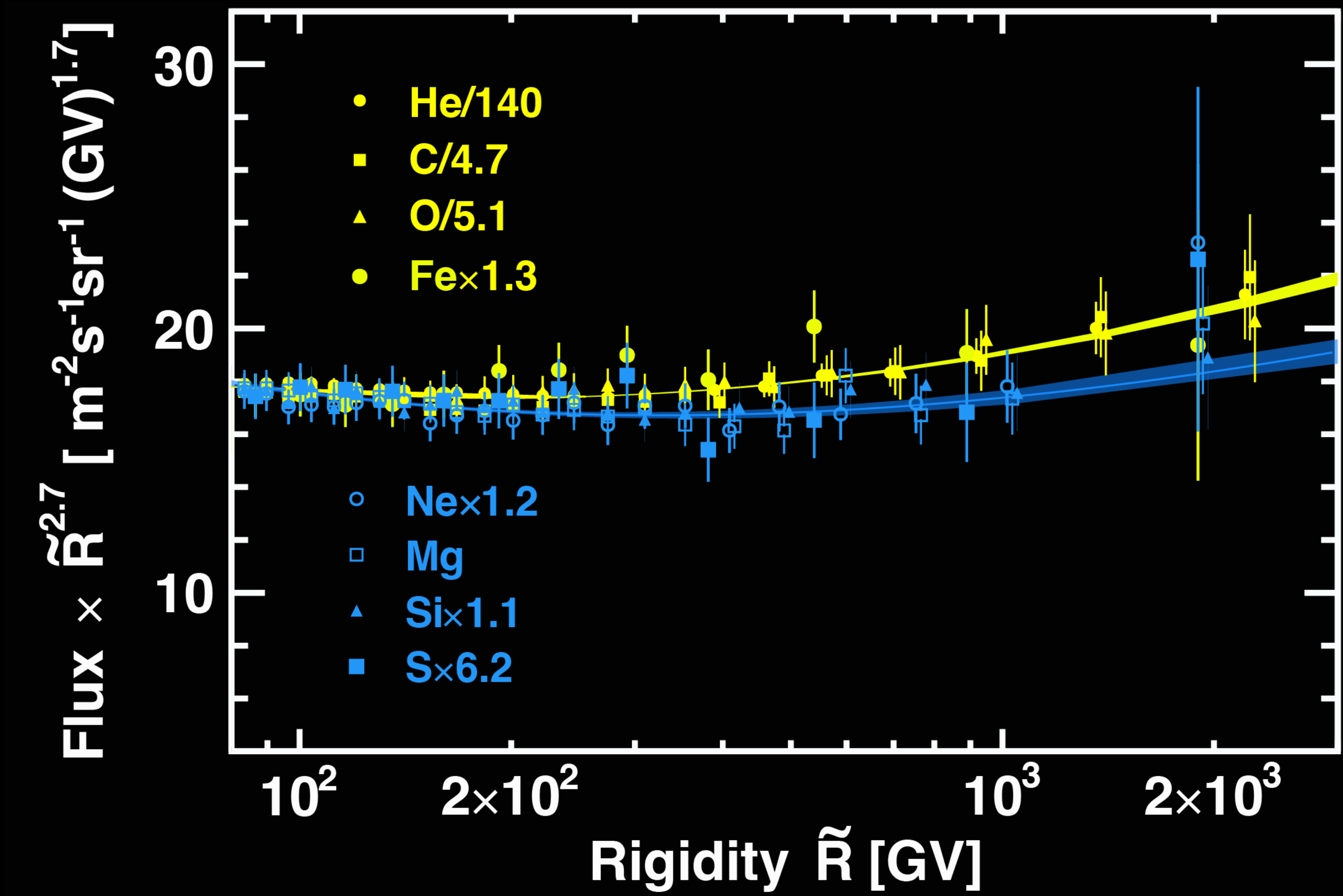
Iron Flux



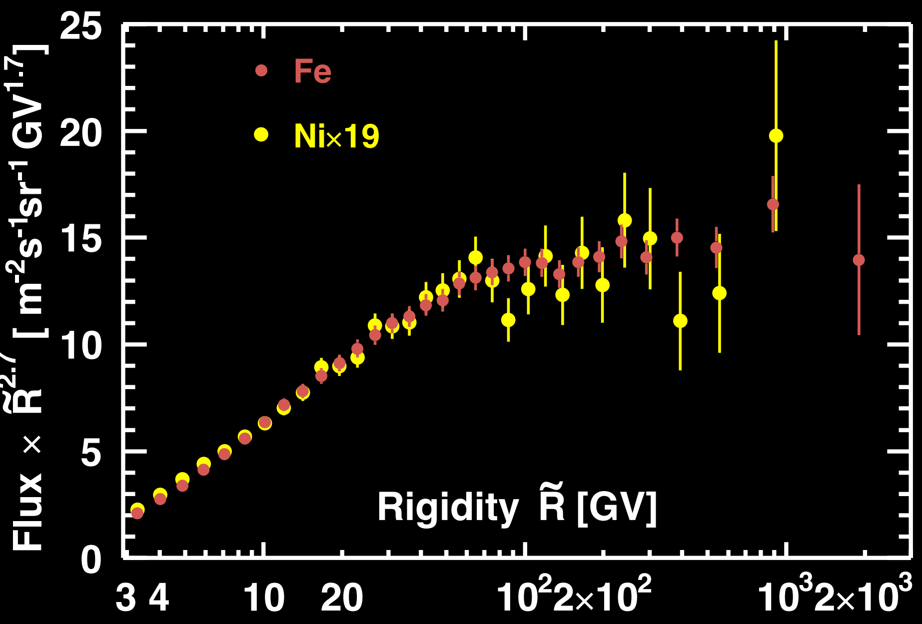
M. J. Boschini *et al.*, ApJS **213** (2021) 5 :
Model with AMS data including AMS Fe data

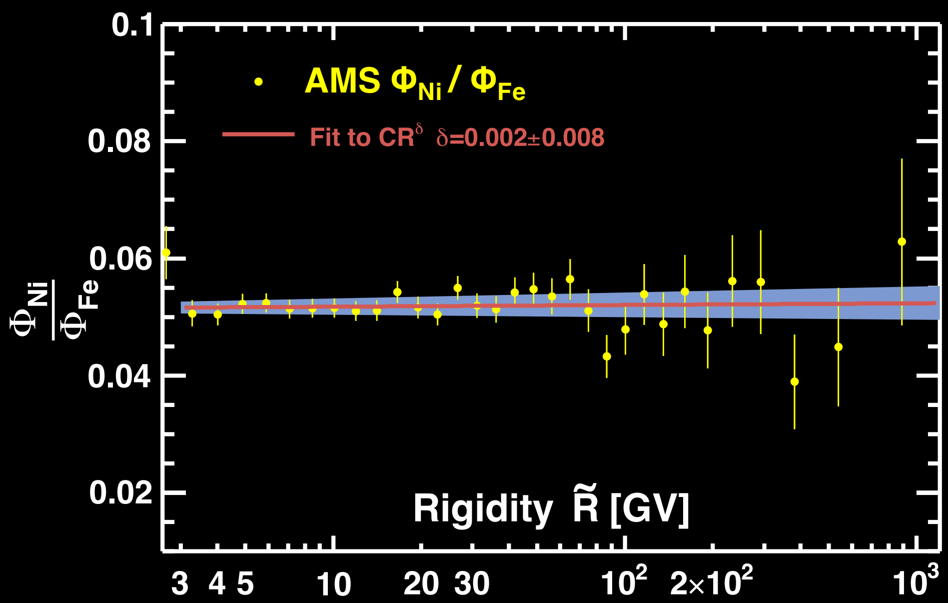
Properties of 8 Primary Cosmic-Ray Elements

They are in two classes



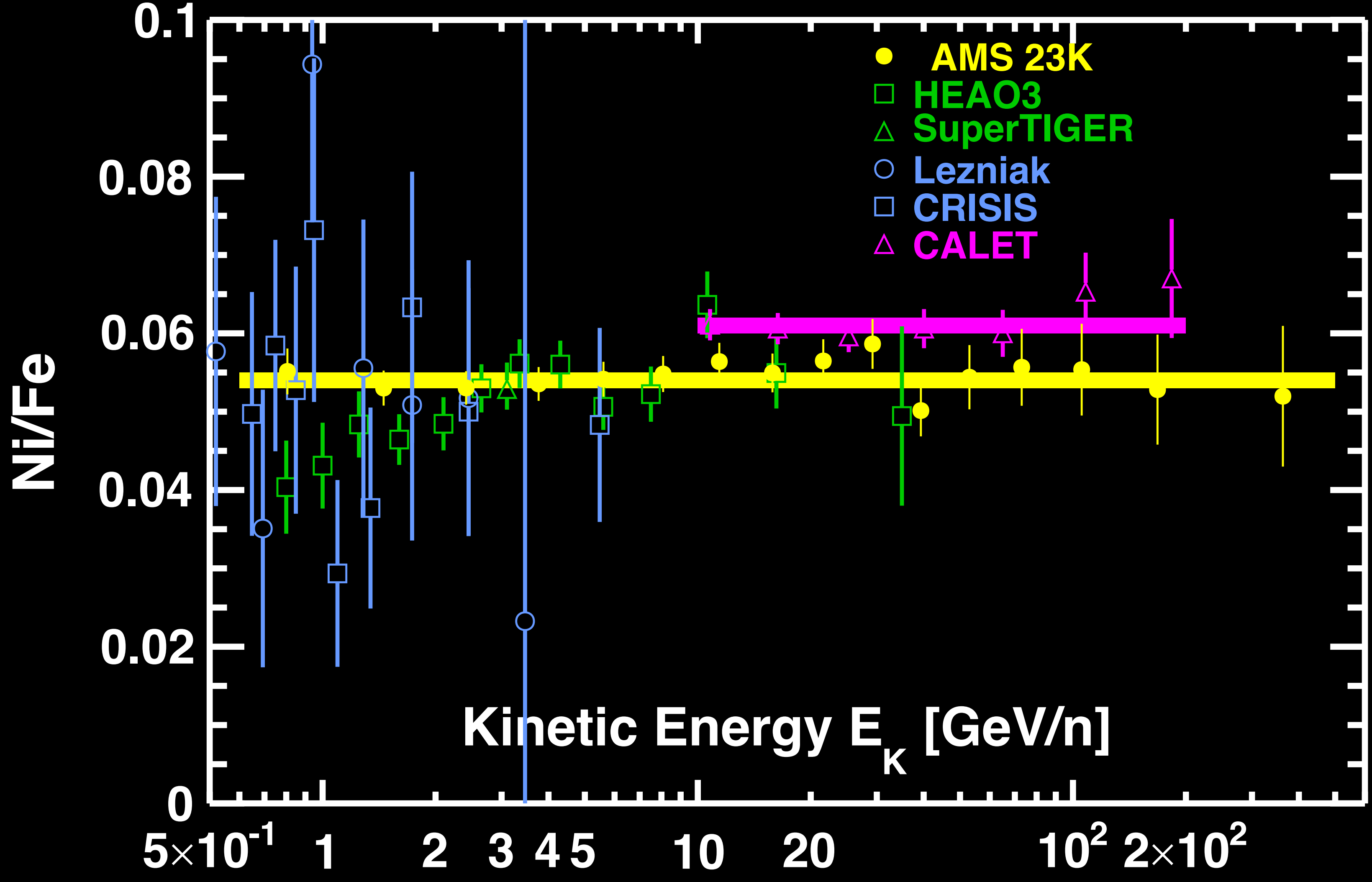
Nickel Flux: The Same Rigidity Dependence as Fe





Ni and Fe belong to the same class of primary cosmic rays.

AMS Ni/Fe Flux Ratio Compared with Other Measurements



Summary

- AMS has measured primary cosmic ray P, He, C, O, Ne, Mg, Si, S, Fe, and Ni from 1(2) GV to 3 TV with unprecedented precision, revealing new and unexpected properties of cosmic rays.

- Future high precision AMS measurements of all cosmic rays will continuously provide unique insight into understanding of the cosmic rays.