# Properties of the Third Group of Cosmic Rays Measured by the Alpha Magnetic Spectrometer

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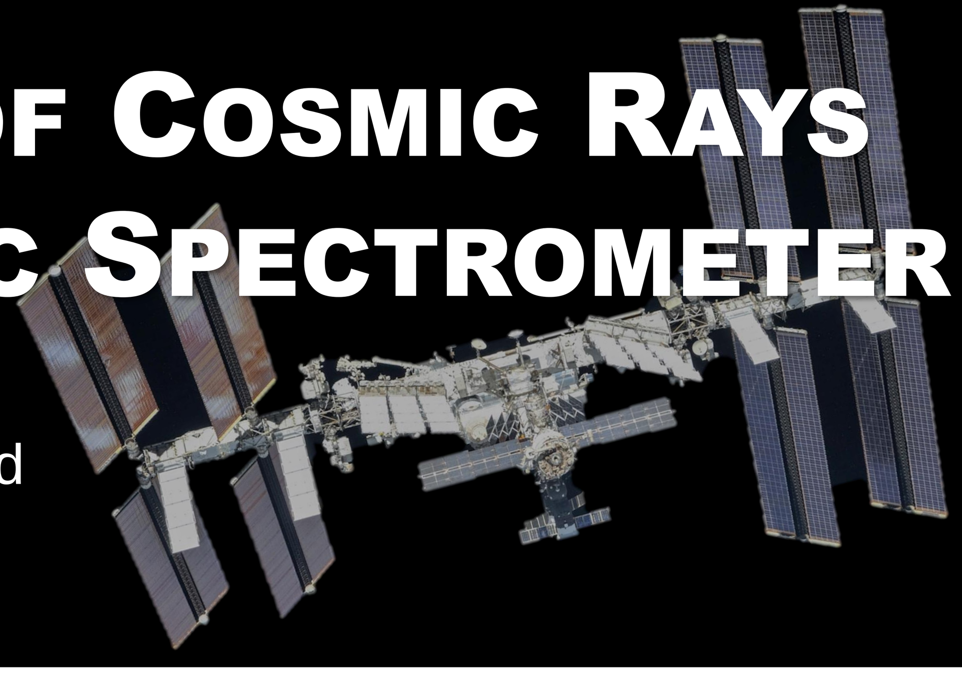
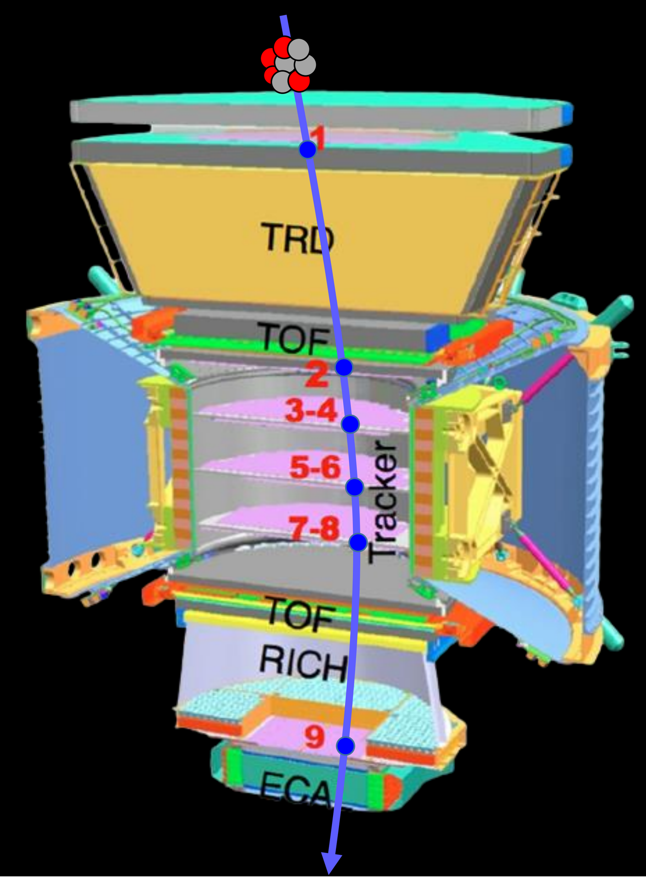


## AMS and the Fluxes of Cosmic Nuclei

### A Precision Spectrometer in Space




*AMS-02* is a multipurpose large-acceptance spectrometer capable of performing accurate measurements thanks to its redundant sub-detectors. It has been operating on-board the ISS since May 2011.

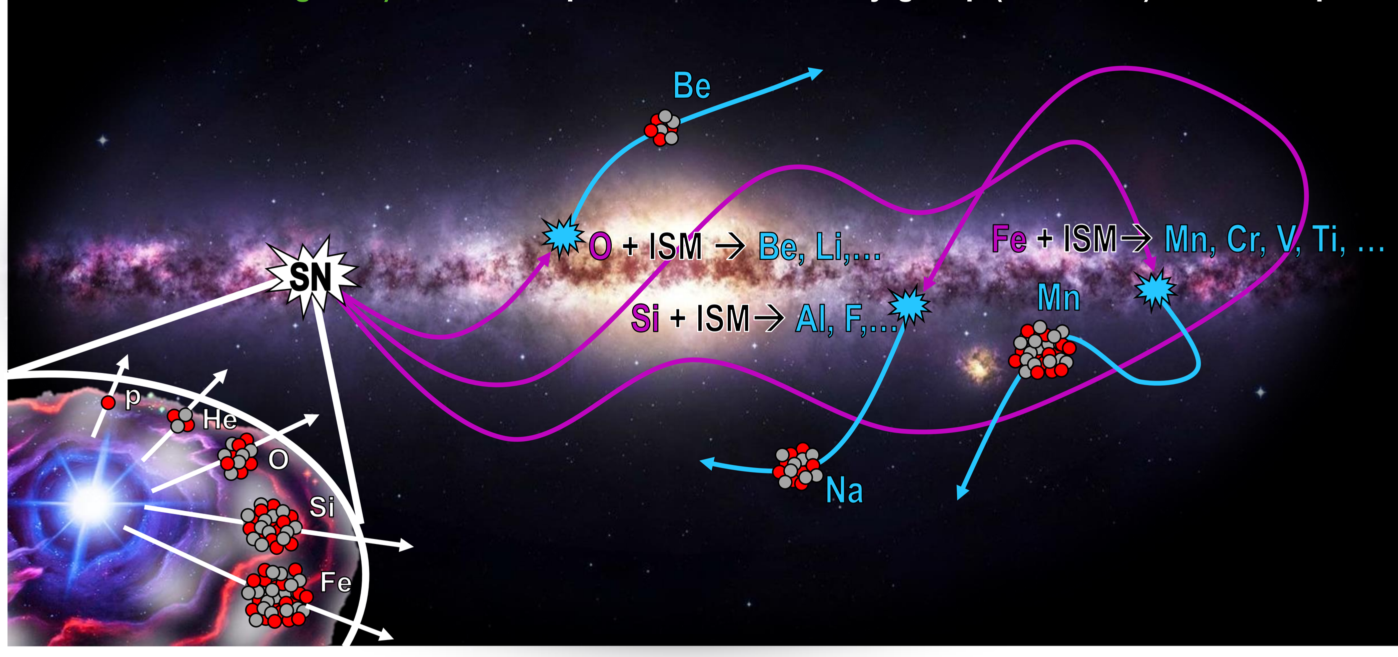
*RIGIDITY* (R=p/Z) is measured with the reconstruction of the particle trajectory through the 9 silicon tracker layers spanning a 3 m level-arm in a 0.15 T permanent magnet.

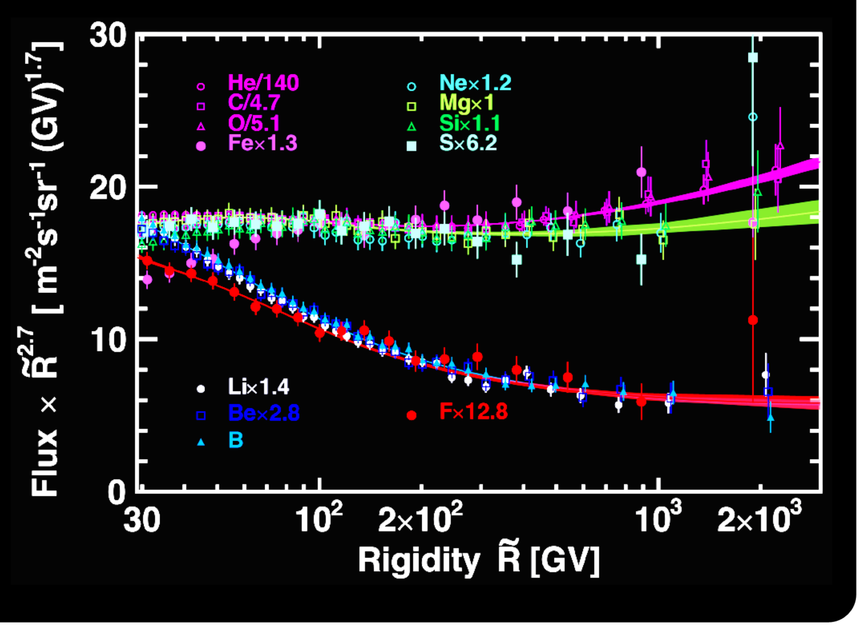
*NUCLEUS IDENTIFICATION* is performed with redundant charge measurements of the 9 silicon tracker layers and the 4 layers of plastic scintillators of time of flight.

### Primary and Secondary Nuclei

Primary nuclei are fused in stars through the α-process and injected into the galaxy in a supernova explosion.
Secondary nuclei are produced by the fragmentation of primary nuclei with the ISM (cold H and He).

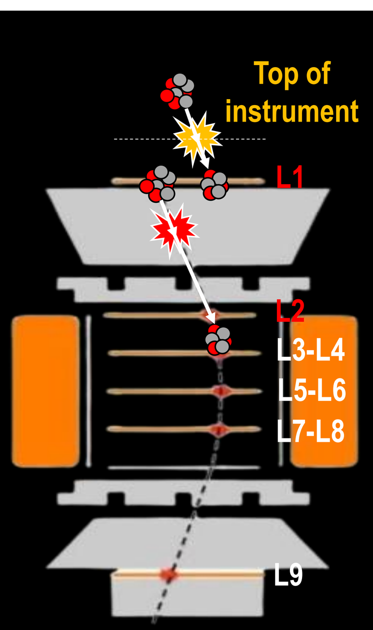
AMS measurements support the classification of nuclei into two groups according to the rigidity dependence of their fluxes: primary group (He-C-O-Fe and Ne-Mg-Si-S) with hard spectra and secondary group (Li-Be-B-F) with soft spectra.

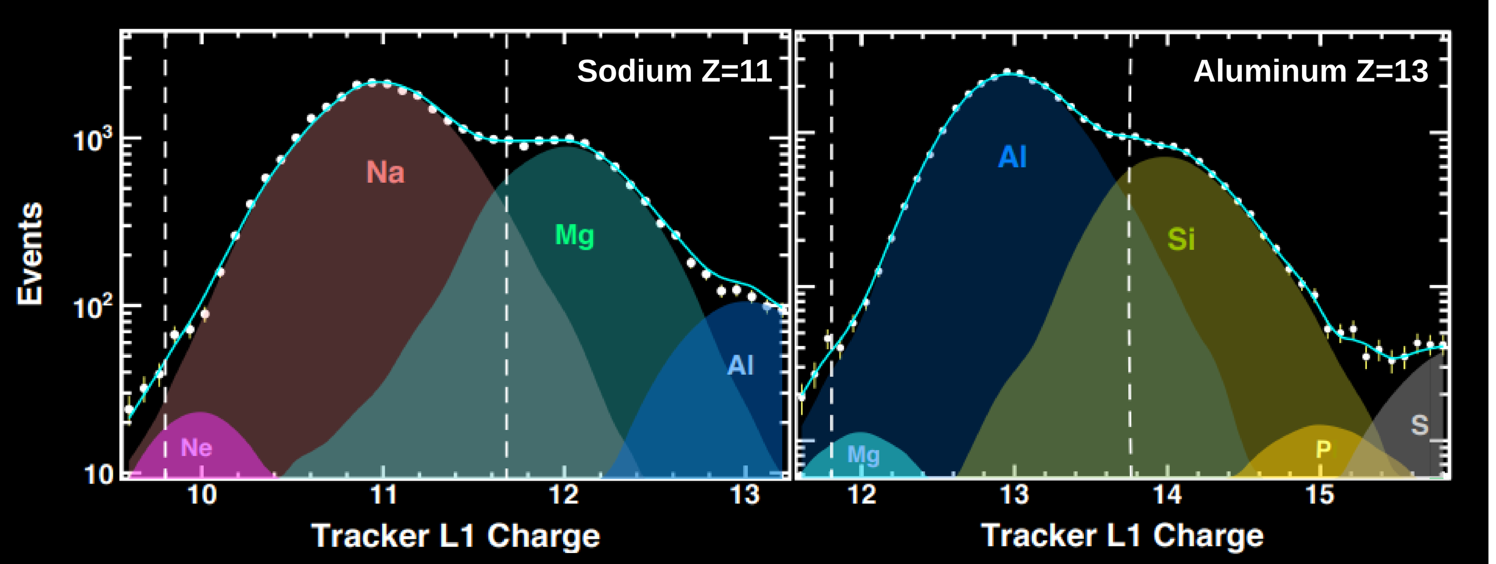



## Measurement of the Fluxes of Nitrogen, Sodium and Aluminum

### Background Subtraction



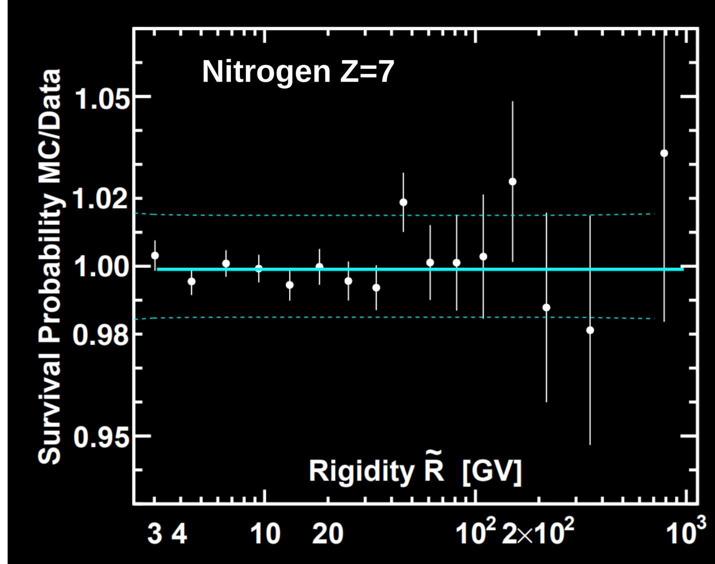



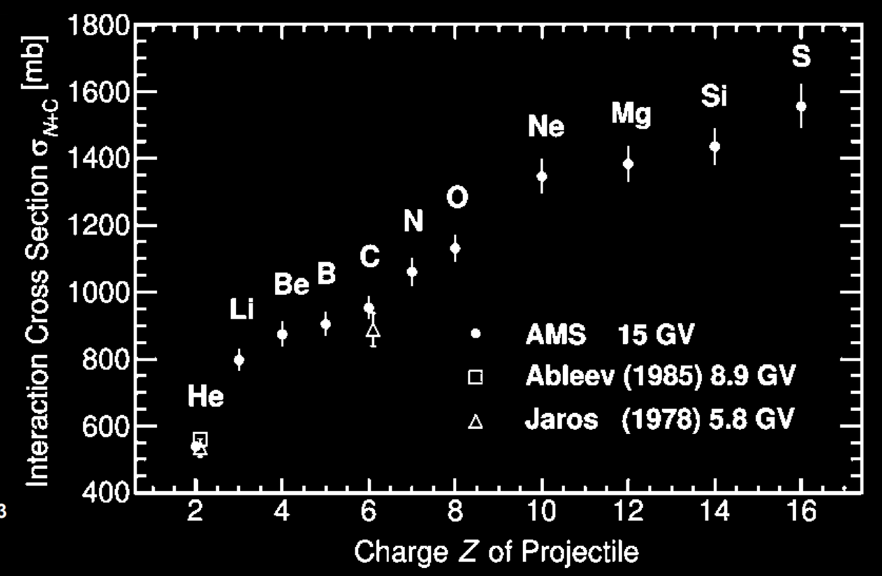

A residual background originates from inelastic interactions in the material between the L2 and the L1 of the tracker. The contamination in the nucleus selection is estimated and subtracted based on template fits of charge distributions.

The background from interactions on the little material at the top of instrument has been estimated from simulation using MC samples generated according to AMS flux measurements.

The error due to background subtractions typically amounts to few percent (<2% below 100 GV and <6% below 3 TV).

### Studies of Fragmentation of Nuclei

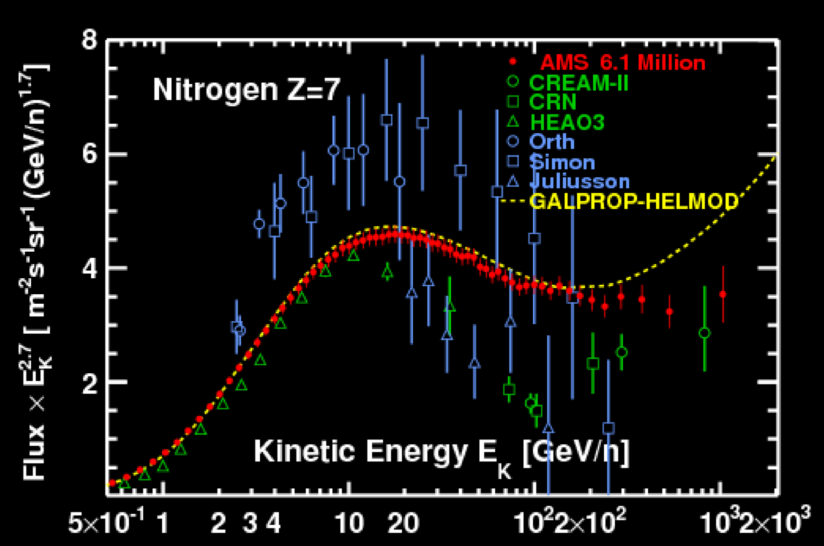


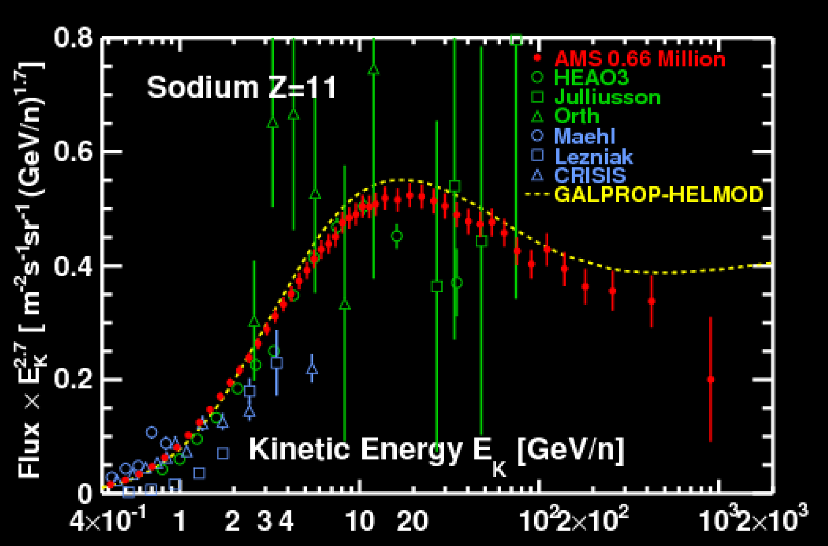



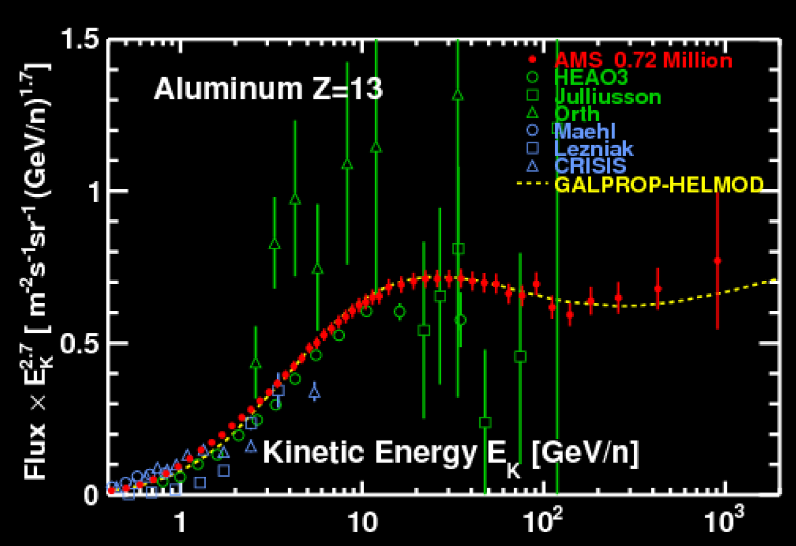

The absolute normalisation of the fluxes is largely dependent on the nuclear inelastic cross-section of cosmic rays with the material of AMS (carbon and aluminium). The survival probability of the signal inside the instrument has been found to be in agreement with MC.

The inelastic cross sections of nuclei with carbon target has been measured by determining the tracker L1-L2 and L8-L9 nuclei survival prob. [Q. Yan *et al.*, *Nuclear Physics A* 996, 121712 (2020)].

### Results




Previous measurements of the N, Na and Al fluxes were performed with calorimeter experiments.

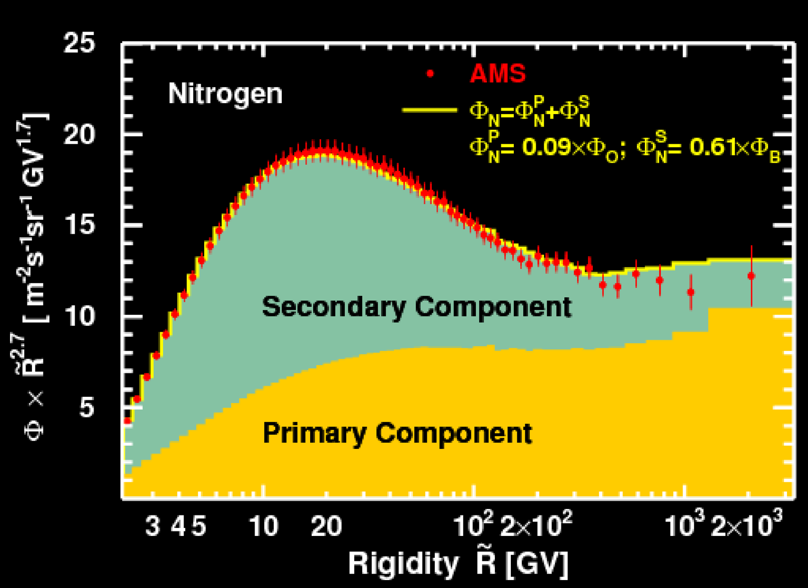
AMS has measured the fluxes of N, Na, and Al with unprecedented precision and accuracy from 2 GV to 3 TV. The total errors at ~50 GeV/n are <3.5%.

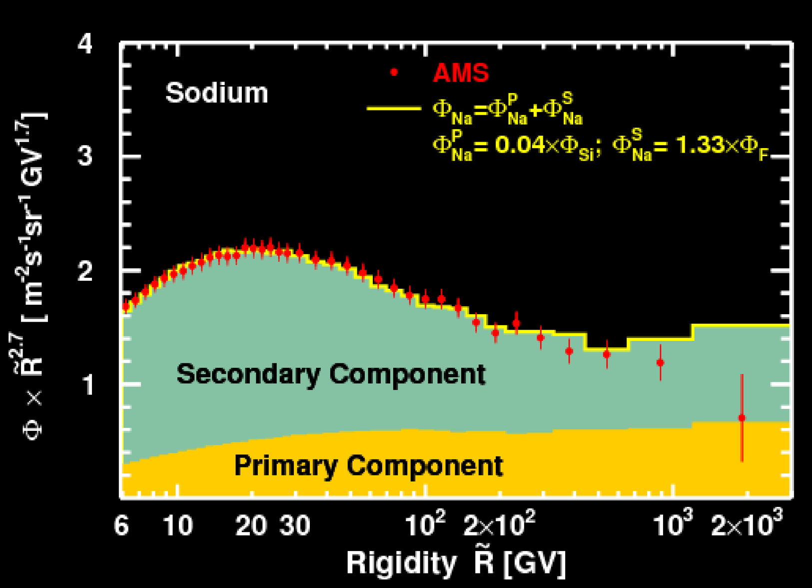
The sate-of-the-art GALPROP-HELMOD model prediction tuned to reproduce previous AMS data can describe the spectral shape of the N, Na and Al fluxes.

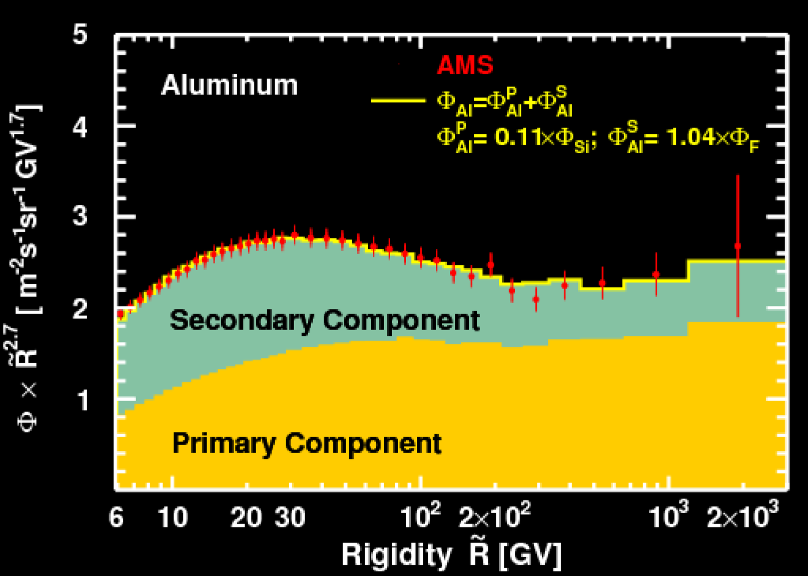
The results span 11 years of AMS operation [original papers: PRL 121, 051103 (2018); PRL 127, 021101 (2021)].

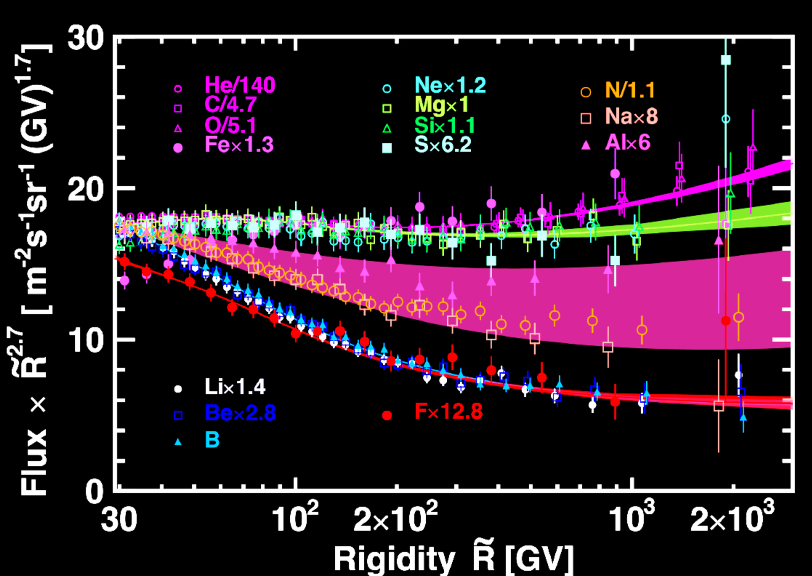
## Determination of the Composition of Cosmic-Ray Fluxes

### A Third Group of Cosmic Nuclei



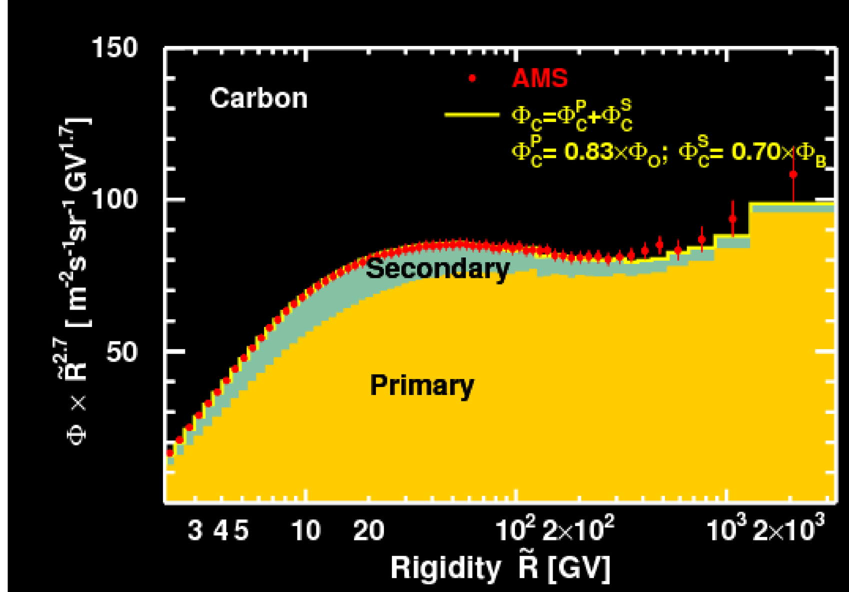



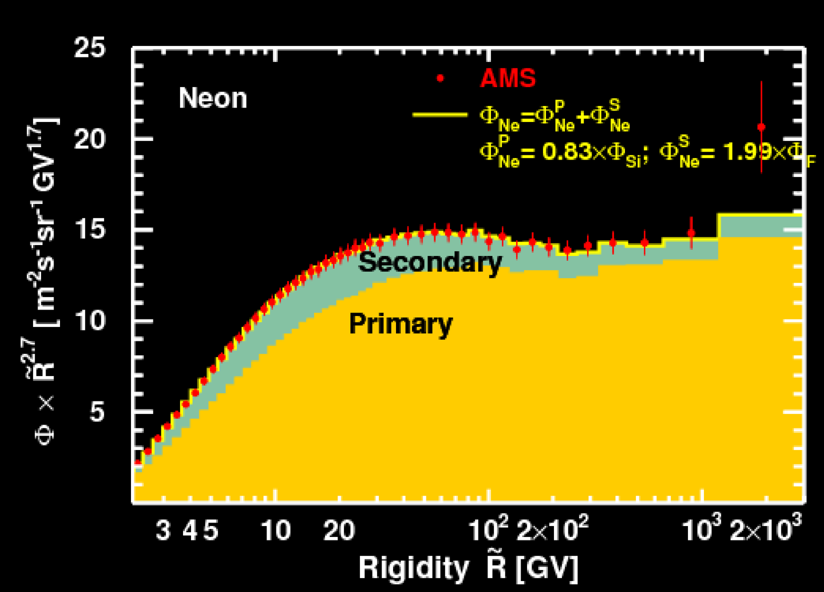



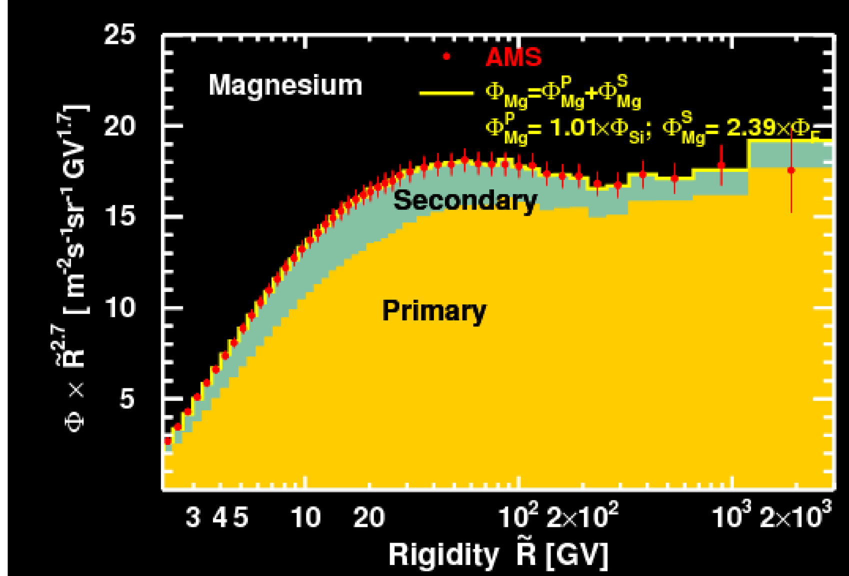

The fluxes of N, Na and Al can be described in a large rigidity range (6 GV to 3 TV) with a linear combination of a primary flux (O or Si) and a secondary flux (B or F). The secondary component gets larger at lower rigidities.

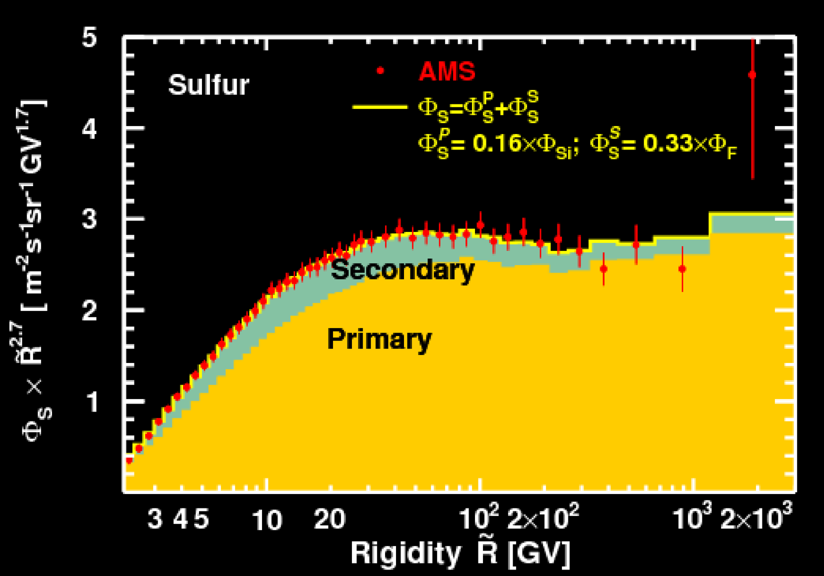
N, Na and Al belong to a third group of cosmic rays with a harder spectrum than secondary nuclei but softer than secondary nuclei. These fluxes have sizable primary and secondary components.

### EXTRA: Primary and Secondary Fractions in Even-Z Nuclei




Moreover, the fluxes of C, Ne, Mg and S can be described by a linear combination of primary and secondary fluxes, where the primary component largely dominates.

The abundance ratio at the source of C, Ne, Na, Mg, Al and S can be determined independently of cosmic-ray propagation from the fitted fraction of the primary component [see PRL 130, 211002 (2023)].