

Unique Properties of Secondary Cosmic Rays measured by the Alpha Magnetic Spectrometer



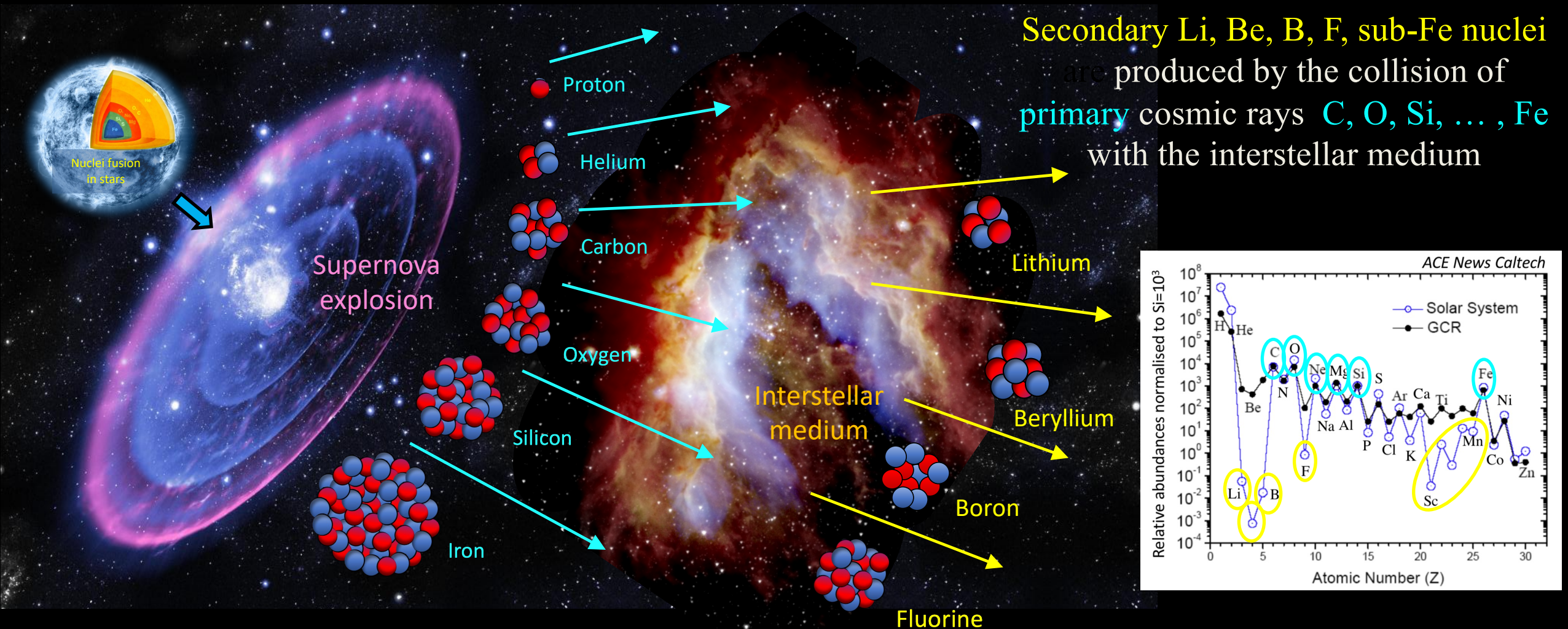
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on behalf of the AMS collaboration



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2nd kind of Cosmic Ray Nuclei: Secondary Cosmic Rays

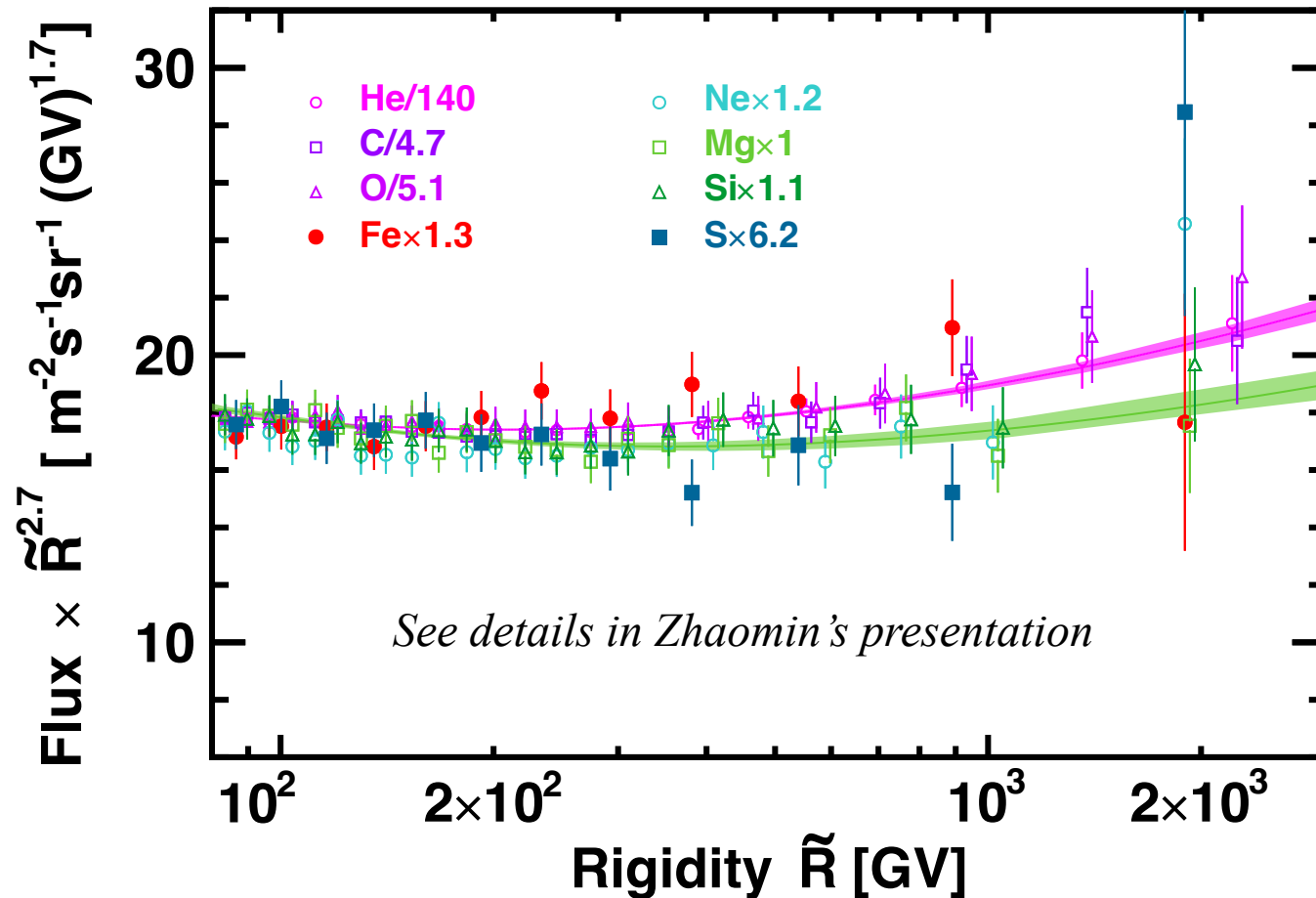


Precise knowledge of the secondary cosmic ray fluxes and the secondary-to-primary flux ratios is essential to study the propagation of cosmic rays in the Galaxy.

Properties of Primary Cosmic Ray Nuclei Fluxes by AMS

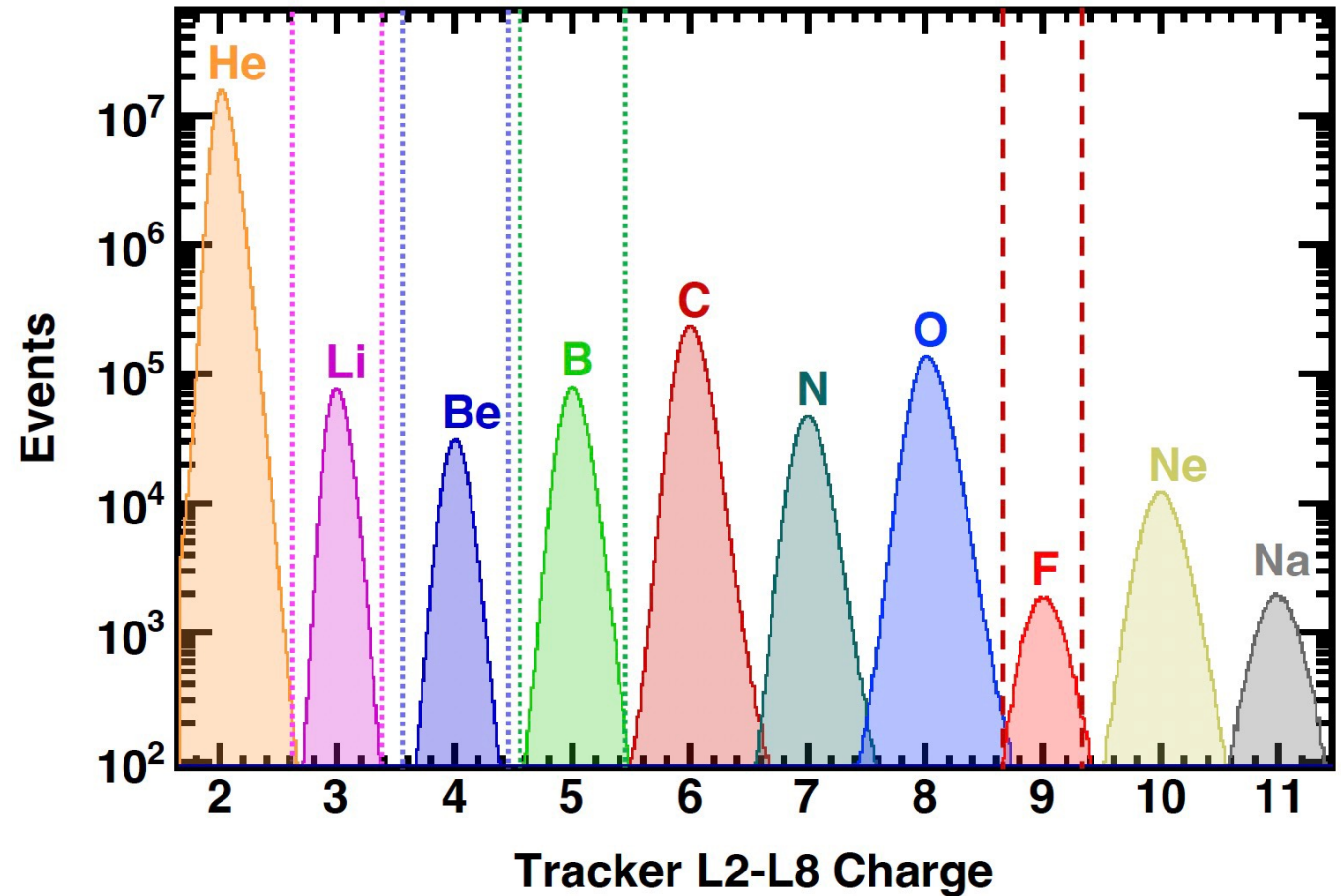
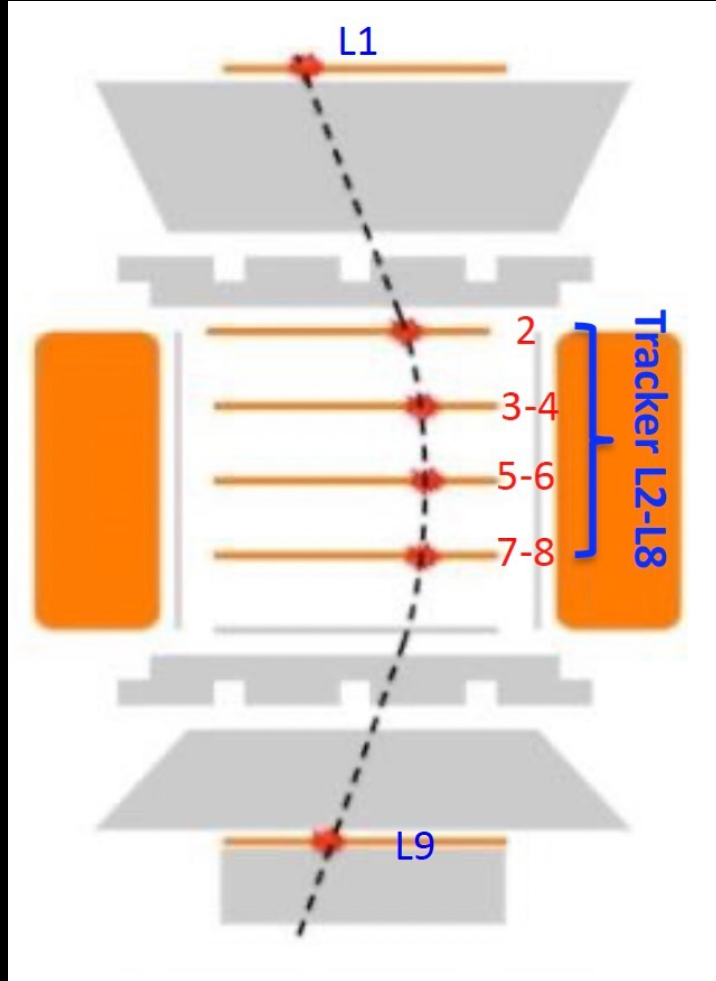
1) The observed spectral hardening at ~ 200 GV is presented in all primary cosmic rays: He (Z=2), C (Z=6), O (Z=8), Ne (Z=10), Mg (Z=12), Si (Z=14), S (Z=16), and Fe (Z=26).

2) Primary cosmic rays have at least two distinct classes: He-C-O-Fe class, and Ne-Mg-Si-S class.



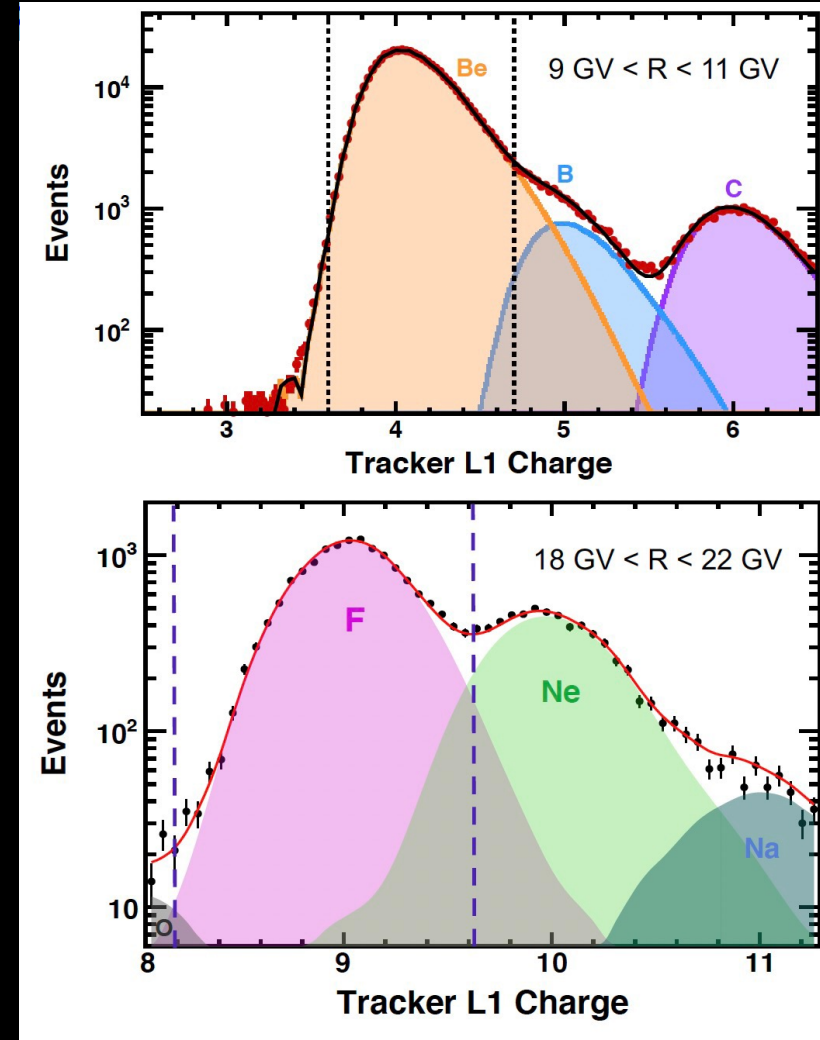
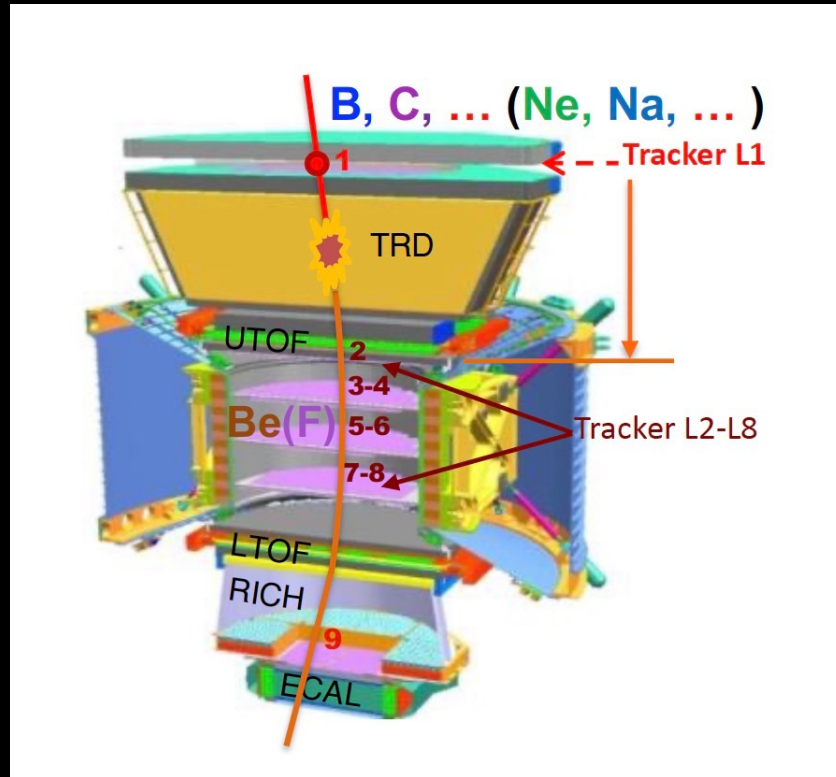
Nuclear Charge Identification for Li, Be, B, and F

AMS has a good charge measurement capability. The charge resolution for $2 \leq Z \leq 14$, when using the inner tracker detector only, ranges from 0.05 to 0.17 c.u. The background due to finite charge resolution is negligible for Li, Be, B, and F, $< 0.5\%$ over the entire rigidity range.

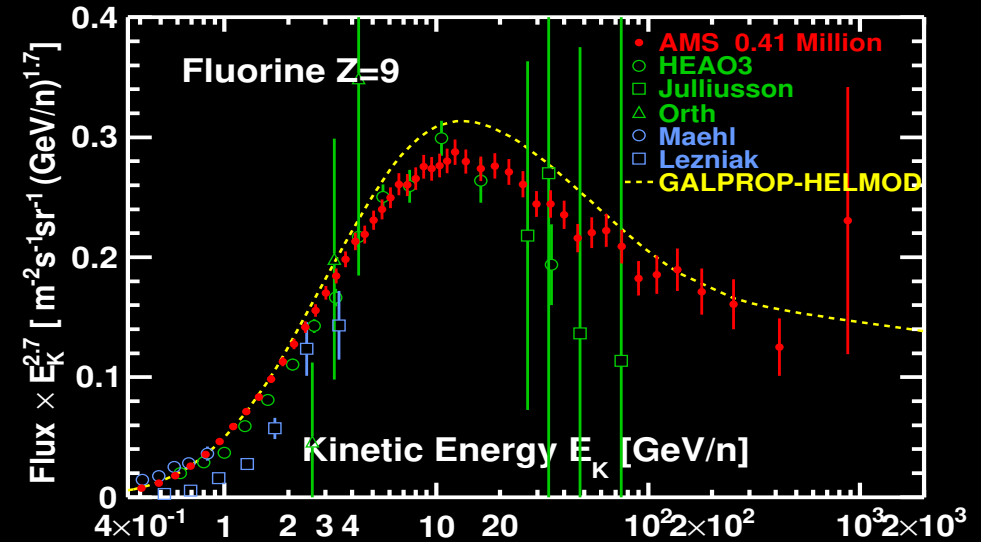
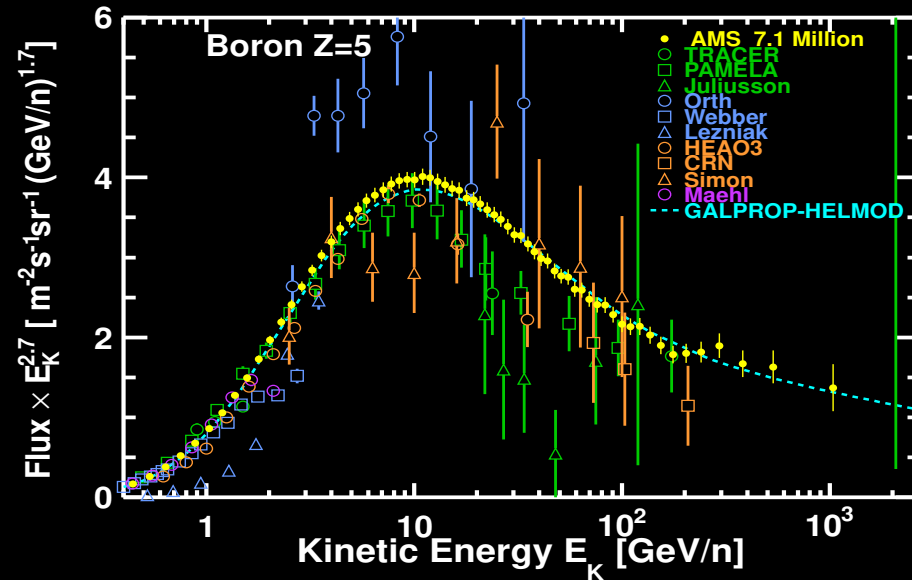
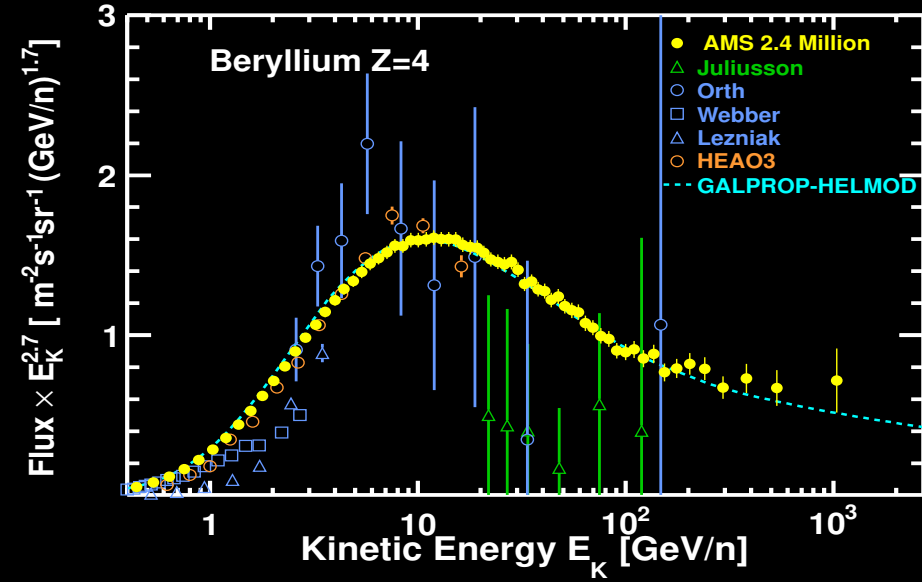
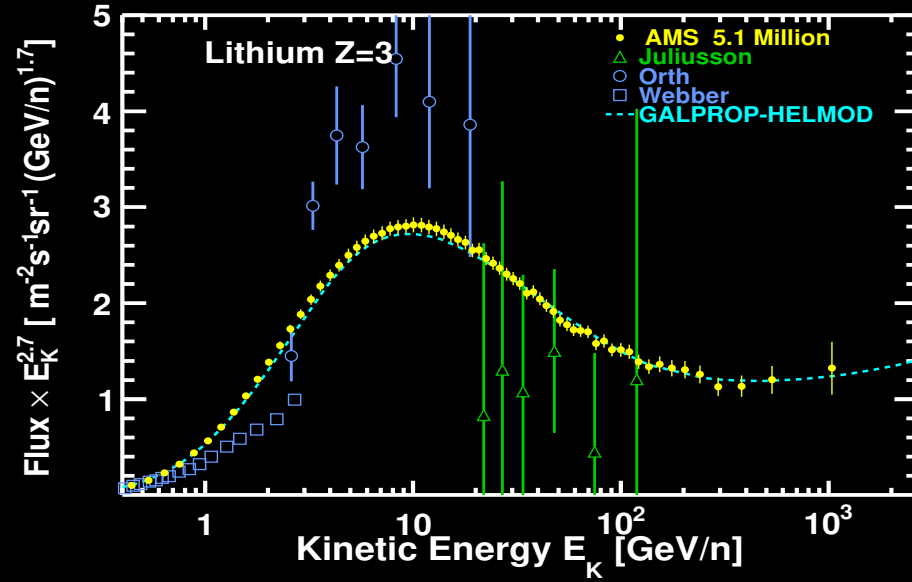


Background from Nuclei Interactions

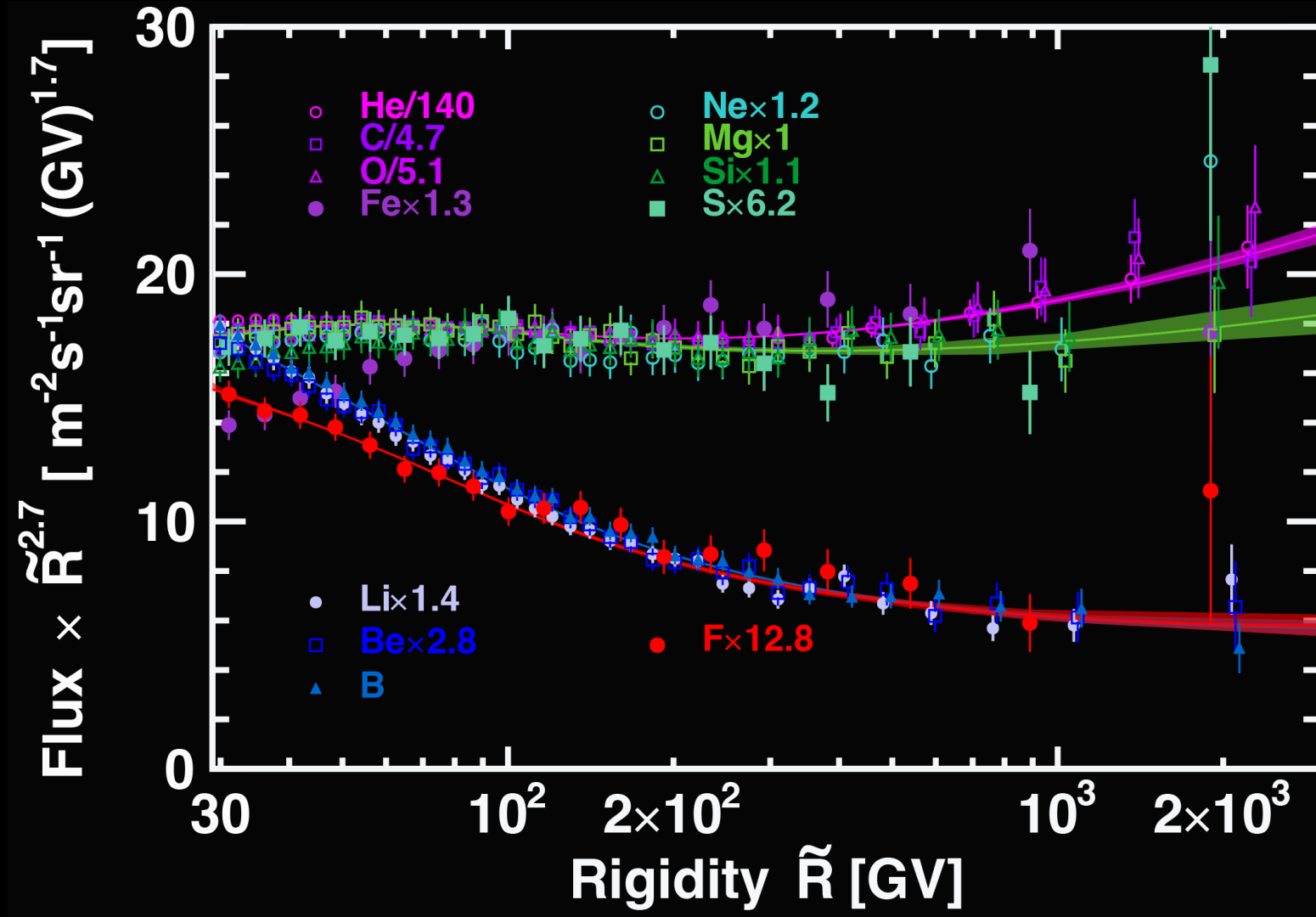
The background in the measurement, resulting from interaction of heavier nuclei in the AMS materials of TRD and UTOF (such as B, C, ... $\rightarrow$ Be or Ne, Na, ... $\rightarrow$ F) was accurately subtracted using the measured charge from AMS tracker L1, with a typical error of a few percent.



Li, Be, B and F Flues by AMS

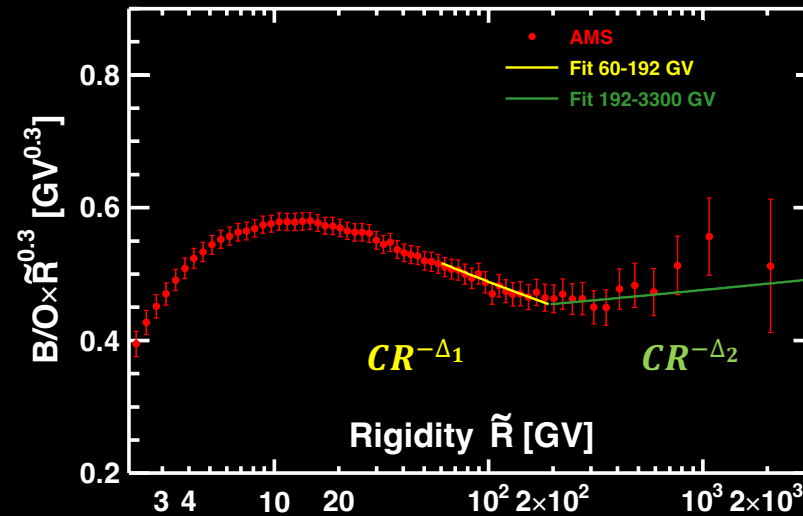
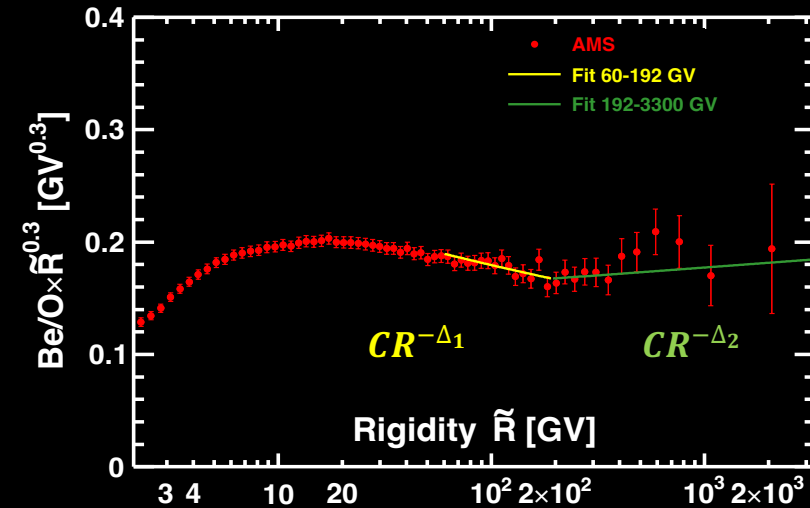
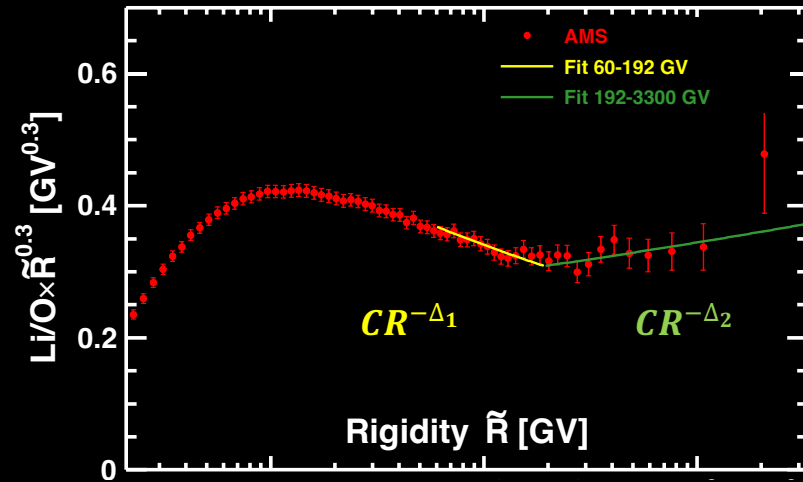


Primary and Secondary Cosmic Rays



As seen, the Li, Be and B fluxes exhibit an identical rigidity dependence above 30 GV. However, the fluorine flux displays a distinct rigidity dependence compared to Li-Be-B.

Secondary-to-Primary Flux Ratios: Li/O, Be/O and B/O

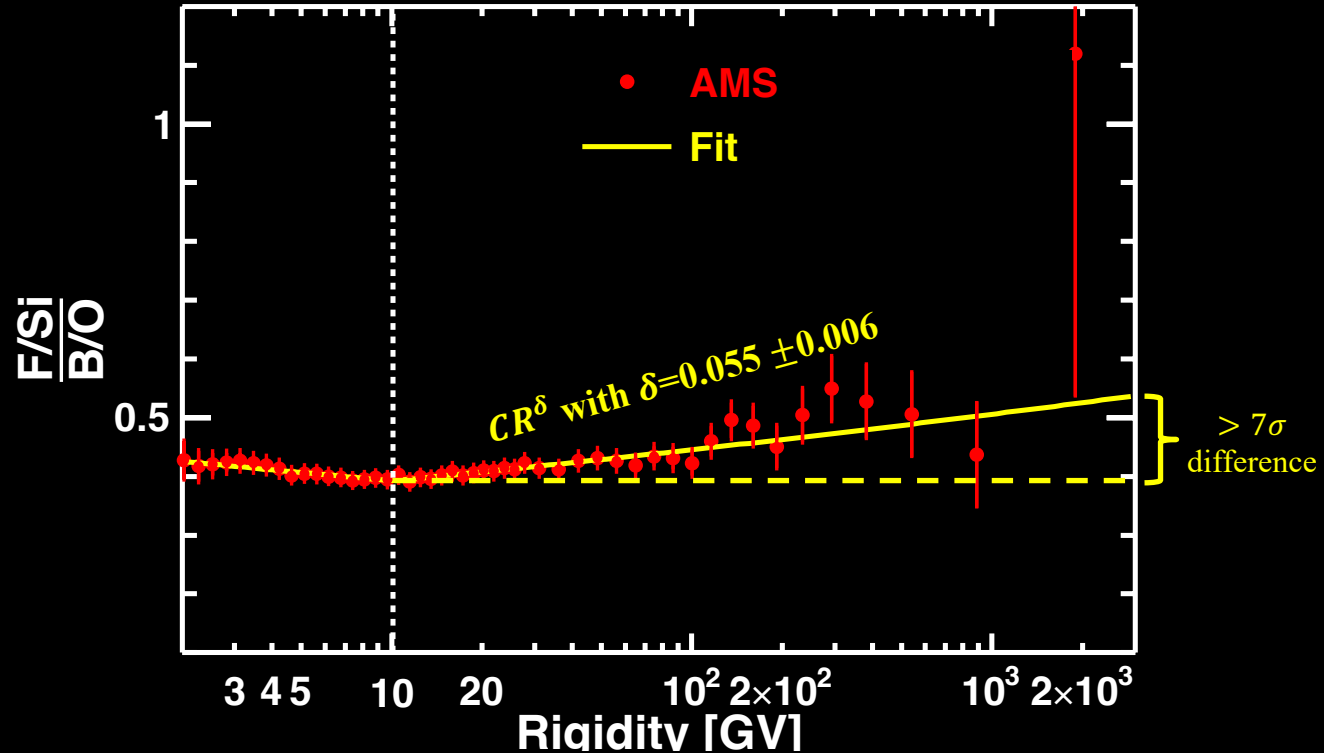
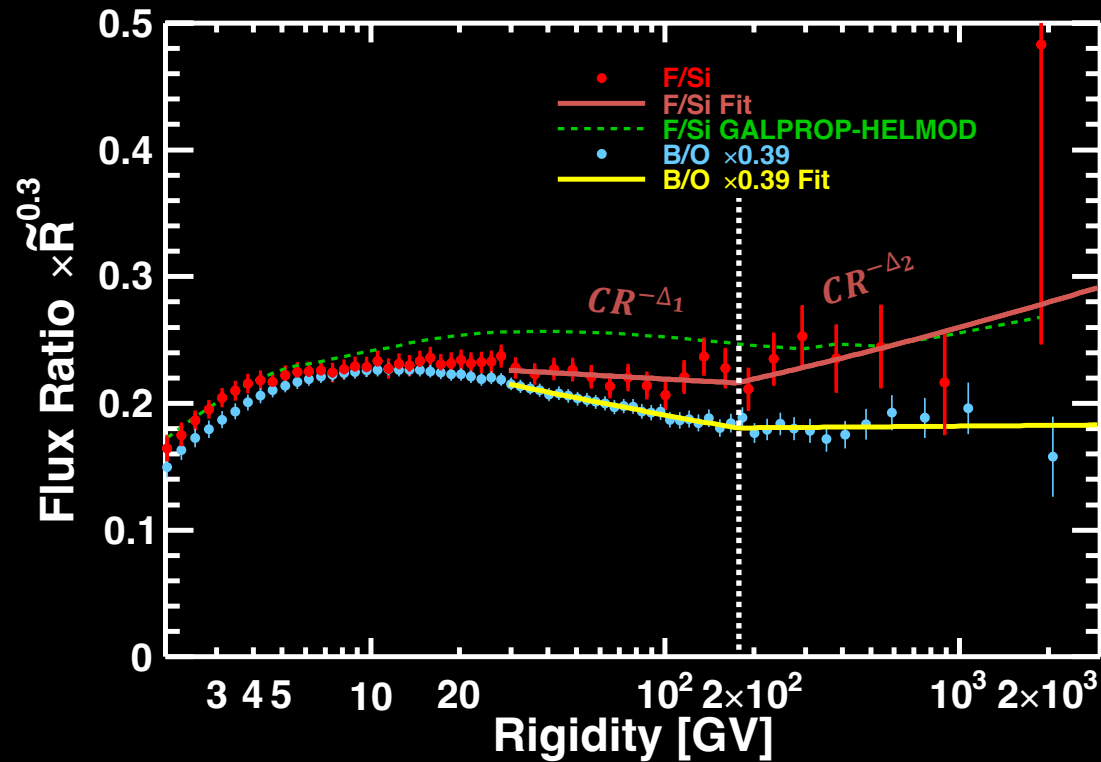


Above 192 GV, the secondary-to-primary flux ratios exhibit an additional hardening:
Secondary cosmic rays **hardens more** than primary.

This additional hardening favors the **propagation origin** of the spectral hardening.

Propagation Properties of Heavy Nuclei: Light vs Heavy secondary-to-primary

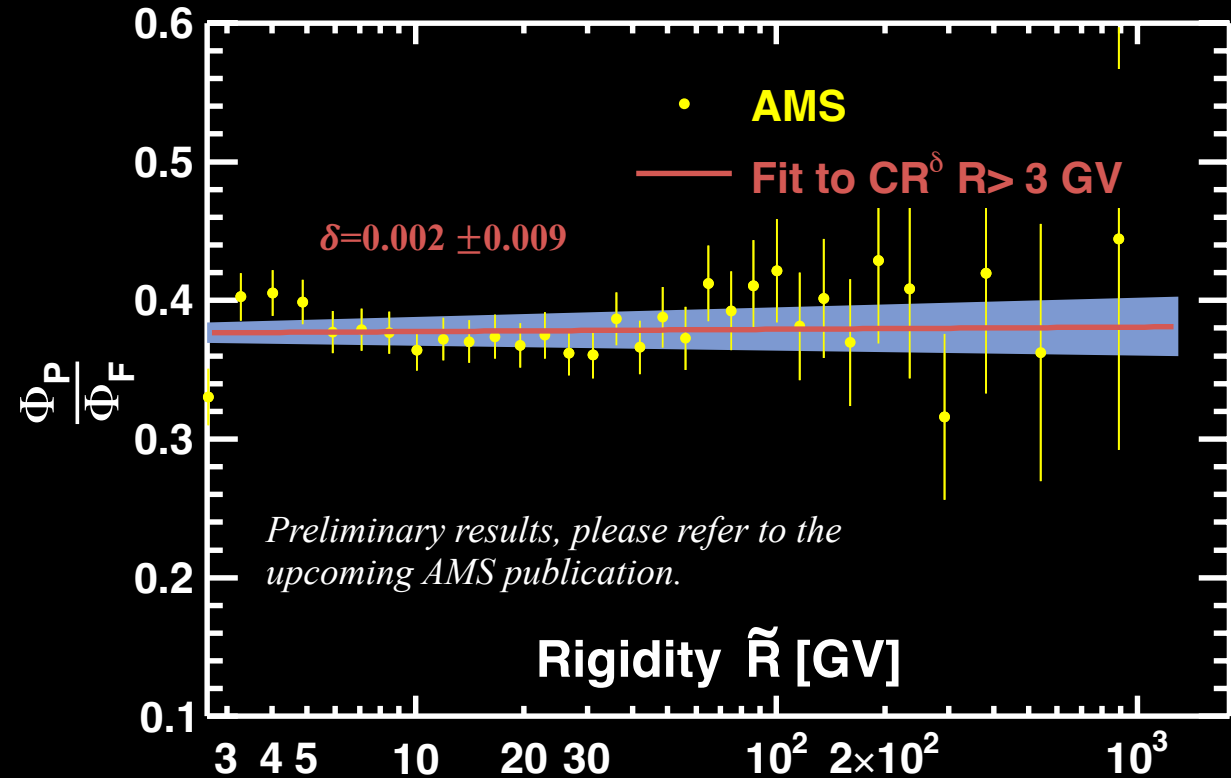
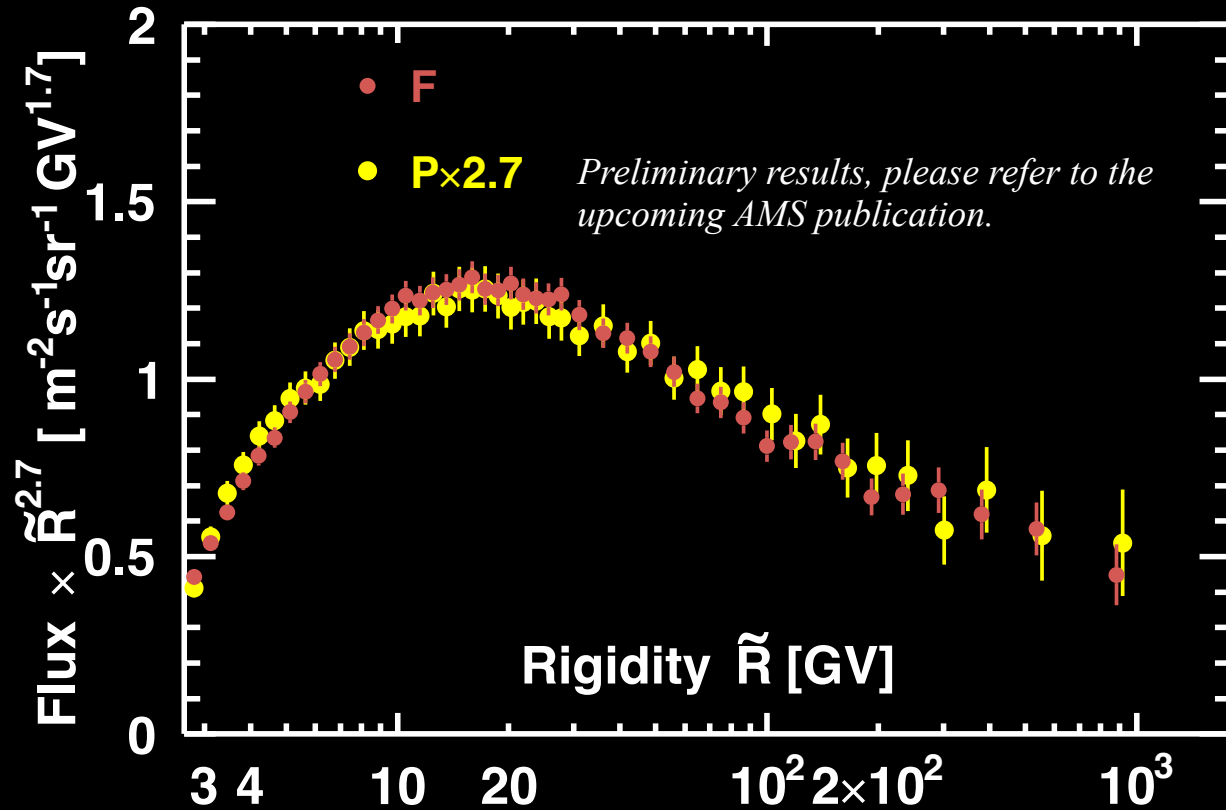
Traditionally, the light secondary-to-primary ratio B/O (or B/C) is used to describe the propagation properties of all cosmic rays.



Above 175 GV, the heavier secondary-to-primary ratio F/Si exhibits a hardening similar to lighter ones, but its rigidity dependence is different from B/O by a single power law. It reveals that the propagation properties of heavy cosmic rays, from F to Si, are different from those of light cosmic rays, from He to O.

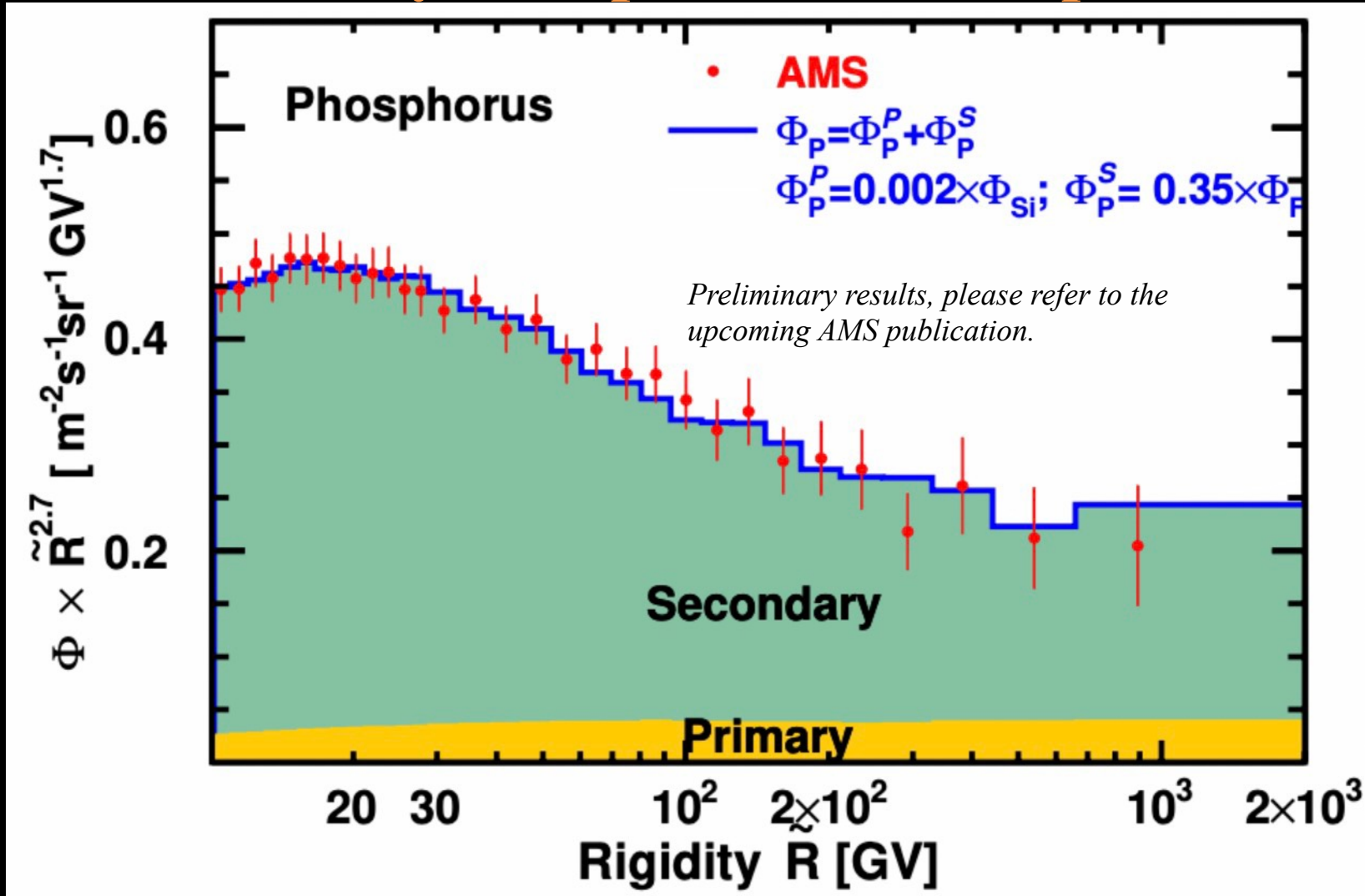
Phosphorus (P) Cosmic ray

Phosphorus is expected to be nearly pure secondary cosmic rays.



Phosphorus has similar rigidity dependence as heavy secondary cosmic ray Fluorine

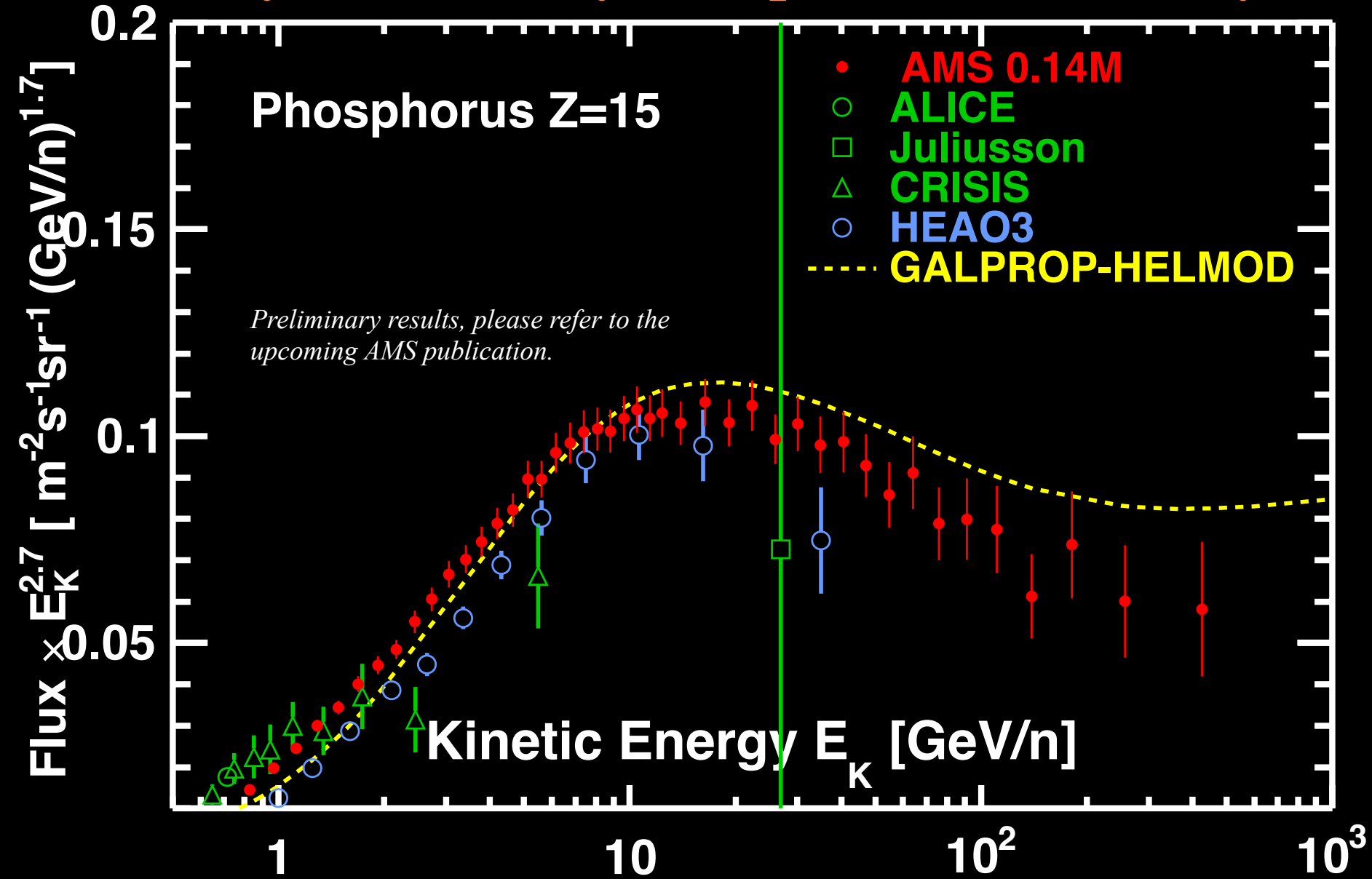
Primary Component of Phosphors



The small difference between P and F fluxes is due to the present of a tiny amount of primary components in P flux:

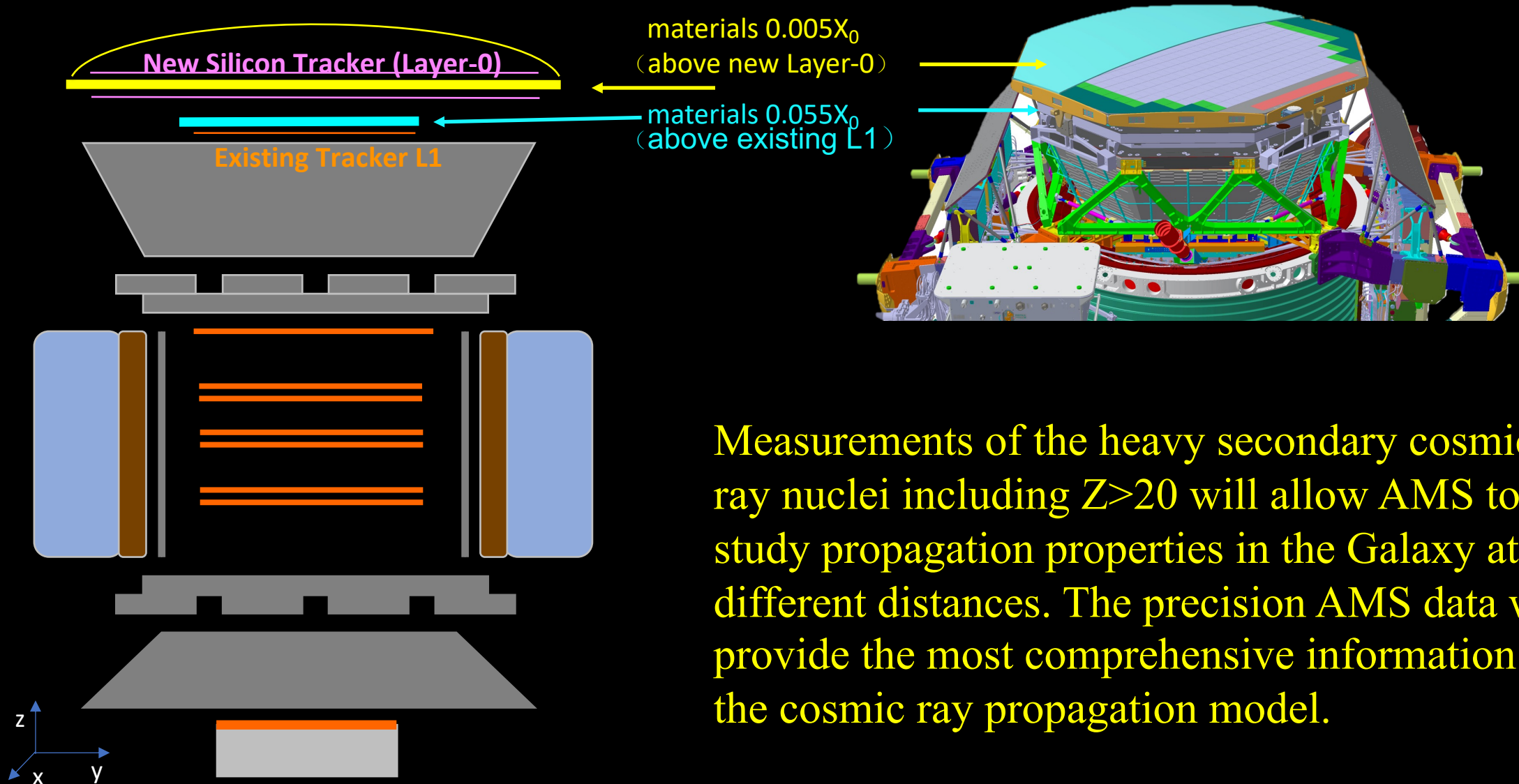
P and F fluxes belong to the same class of secondary cosmic rays.

Secondary Cosmic Ray Phosphorus (P) Flux by AMS



AMS Upgrade (2026)

With completion of the AMS Upgrade, acceptance will be increased by 300% **with minimal materials above**



Measurements of the heavy secondary cosmic ray nuclei including $Z > 20$ will allow AMS to study propagation properties in the Galaxy at different distances. The precision AMS data will provide the most comprehensive information on the cosmic ray propagation model.

Summary

- AMS found that there are at least two classes of secondary cosmic rays: Li-Be-B class, and F class. The propagation properties of heavy cosmic rays, from F to Si, are different from those of light cosmic rays, from He to O.
- Precision measurement of the heavy cosmic ray Phosphorus (P) flux from 2.65 GV to 1 TV by AMS is presented.
- P belongs to the same class of secondary cosmic ray as F. A tiny amount of primary component is found in P flux.
- AMS will continue to analysis heavier secondary cosmic ray fluxes, including sub-Fe, providing information of cosmic ray propagation effects in different distance.