Properties of Light Primary and Secondary Cosmic Rays He-C-O and Li-Be-B Measured with the AMS on the ISS

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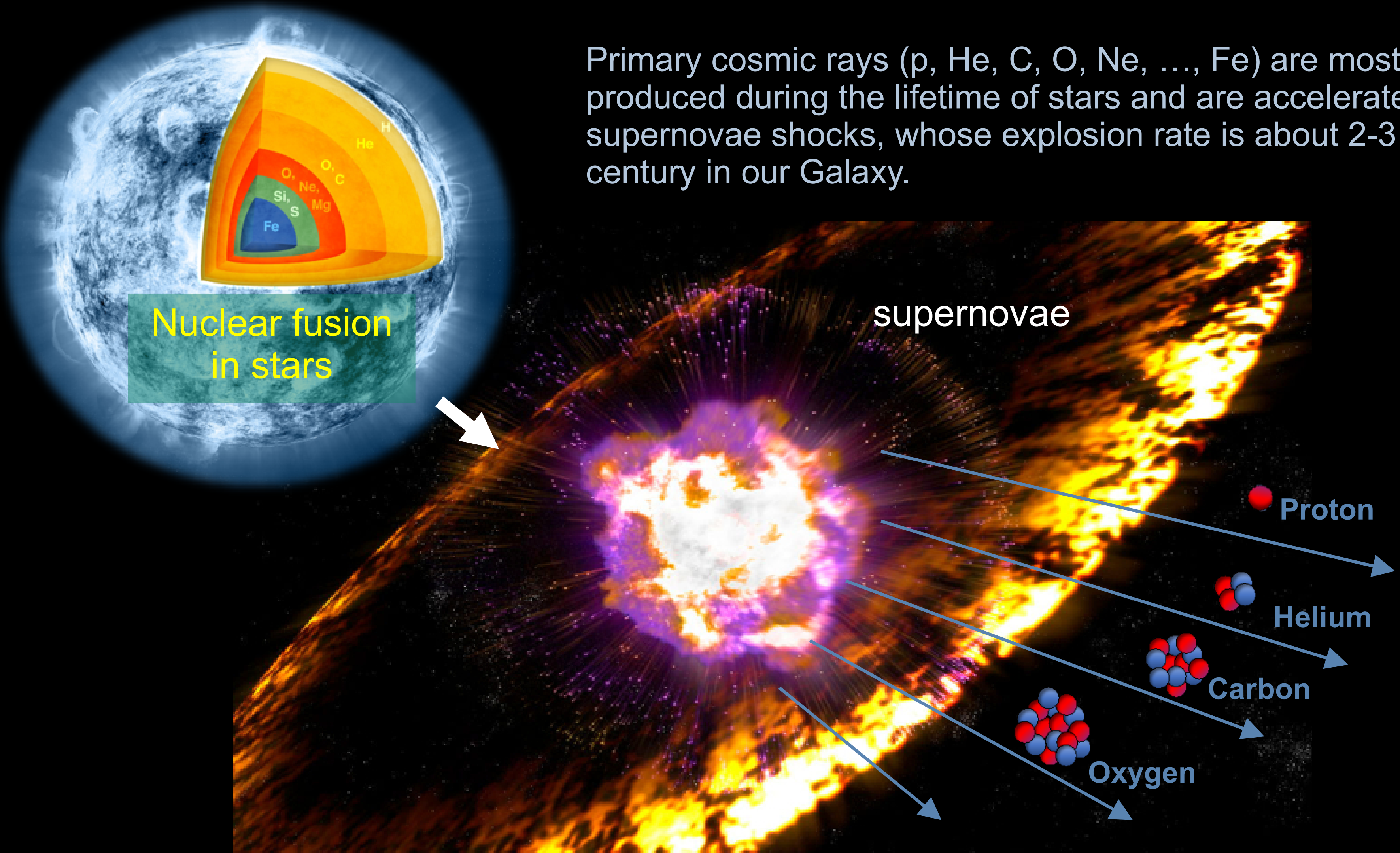
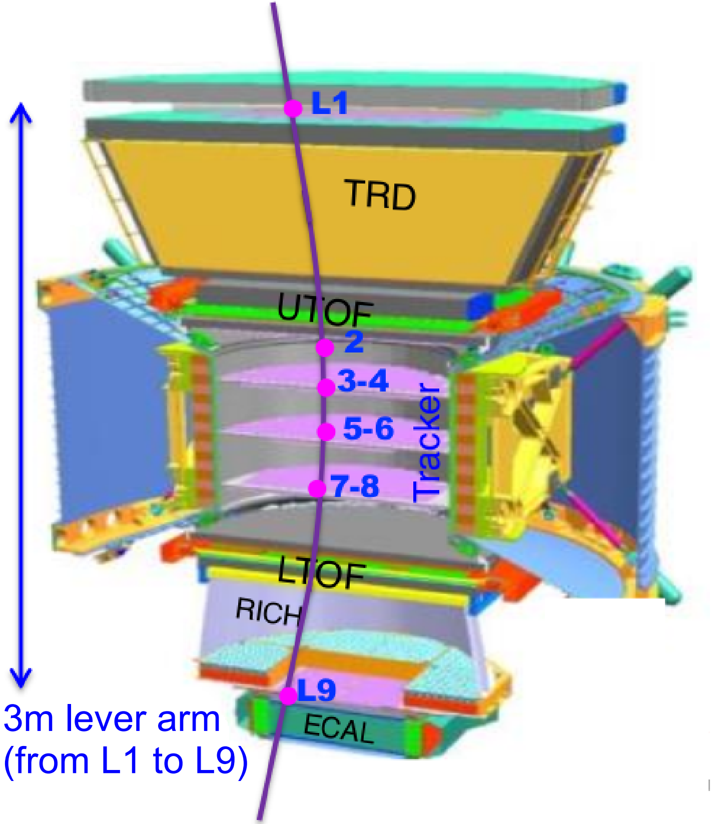
Primary cosmic rays

Primary cosmic rays (p, He, C, O, Ne, …, Fe) are mostly produced during the lifetime of stars and are accelerated in supernovae shocks, whose explosion rate is about 2-3 per century in our Galaxy.



Light nuclei measurements by AMS

AMS is a unique precision magnetic spectrometer on the International Space Station.

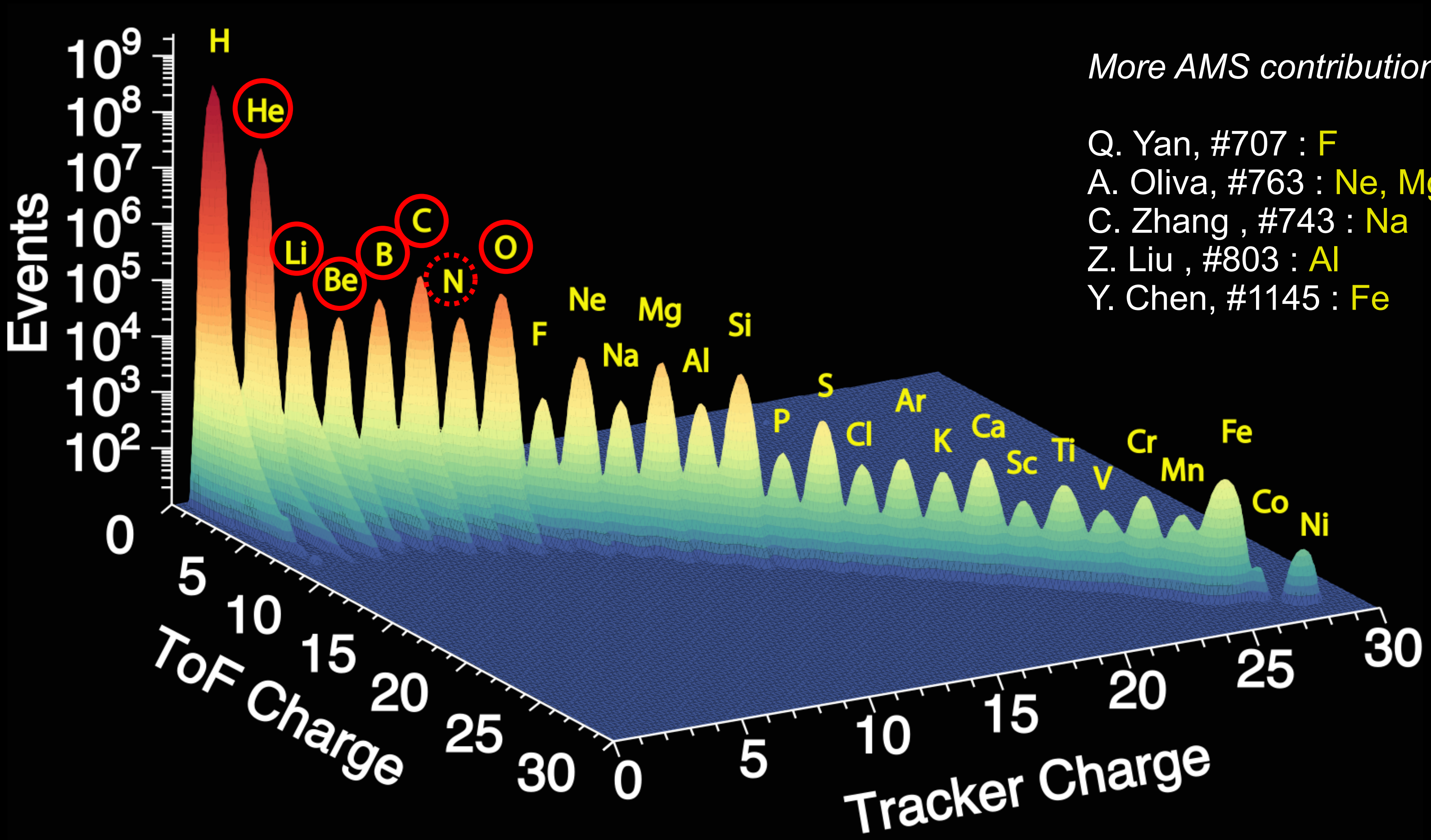


- Tracker (9 layers: L1 - L9) + magnet: Rigidity (=p/Z)
  Coordinate resolution: 5-7 μm (2 ≤ Z ≤ 8)
  MDR: 3.2 – 3.7 TV (2 ≤ Z ≤ 8)

- Time-of-Flight (TOF, 4 layers): Velocity and Direction
  $\Delta\beta/\beta^2 \approx$ 1-2% (2 ≤ Z ≤ 8)

- L1, UTOF, Inner Tracker (L2-L8), (LTOF and L9):
  Consistent Charge along particle trajectory.
  Inner Tracker resolution: $\Delta Z \approx 0.07 – 0.12$ (2 ≤ Z ≤ 8).

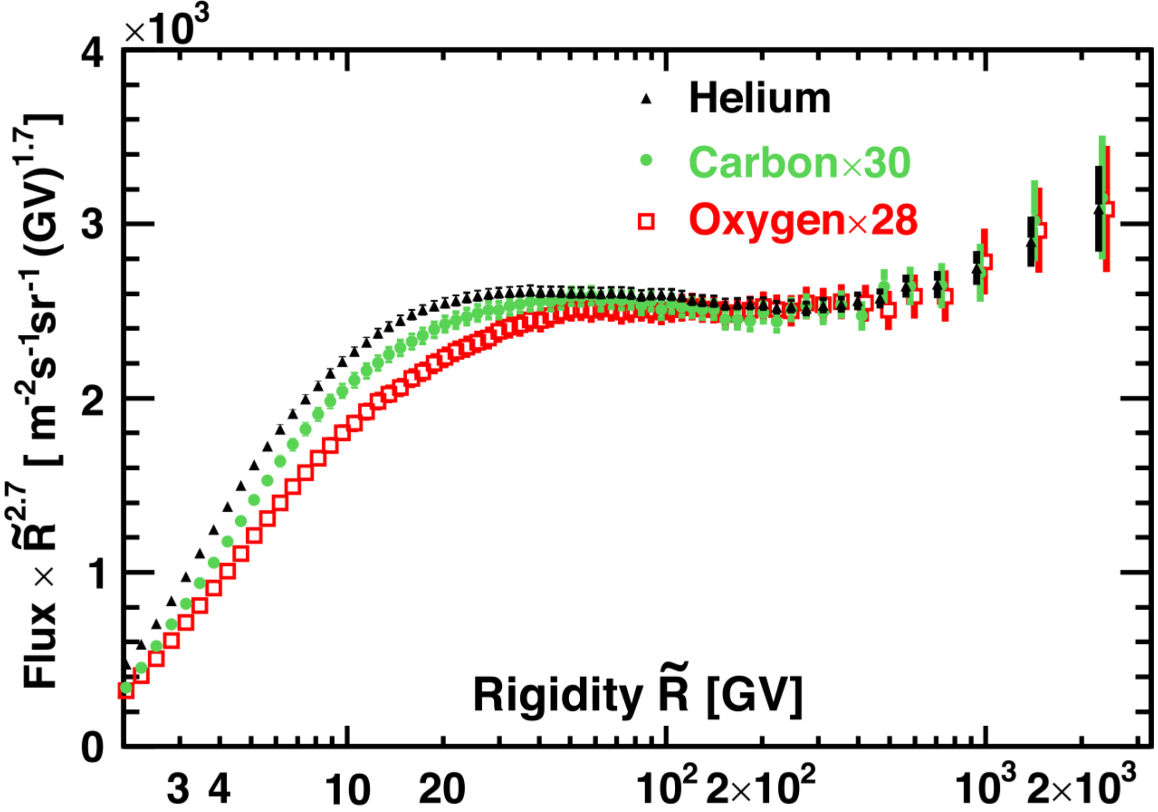
Nuclei charges measured redundantly by AMS



More AMS contributions on nuclei:

Q. Yan, #707 : F
A. Oliva, #763 : Ne, Mg, Si
C. Zhang , #743 : Na
Z. Liu , #803 : Al
Y. Chen, #1145 : Fe

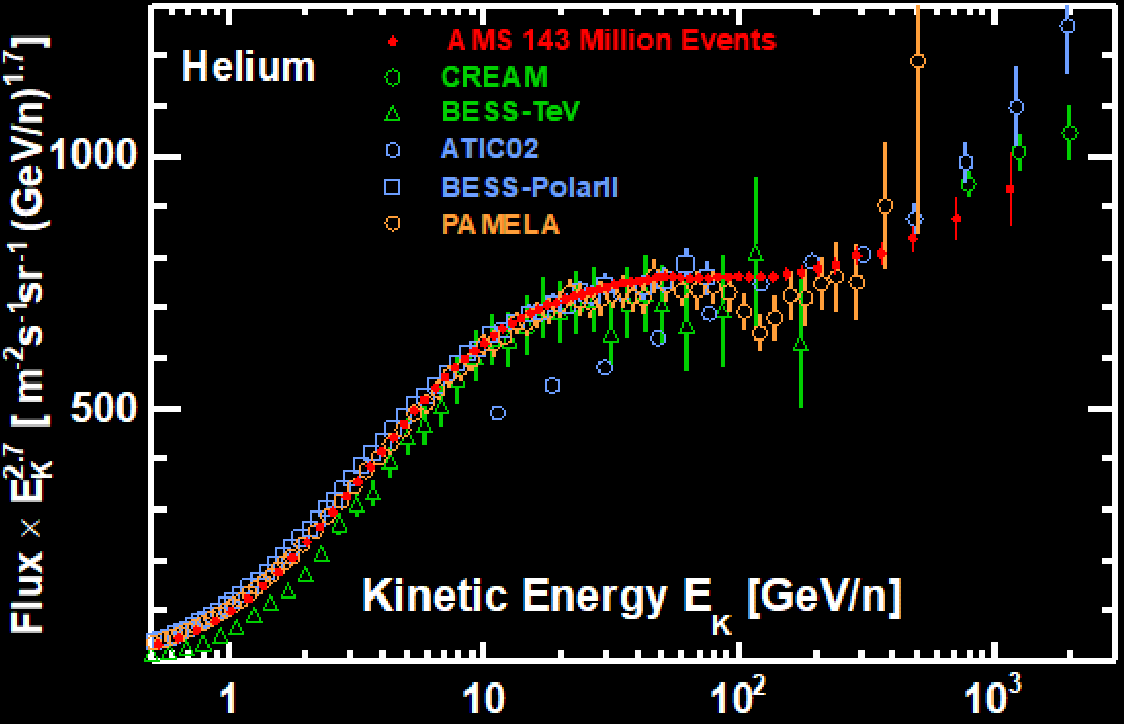
Fluxes of primary nuclei by AMS

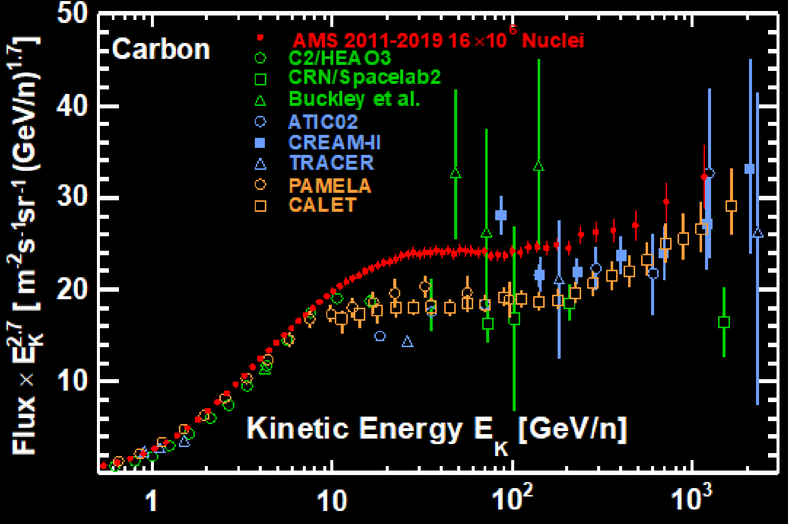


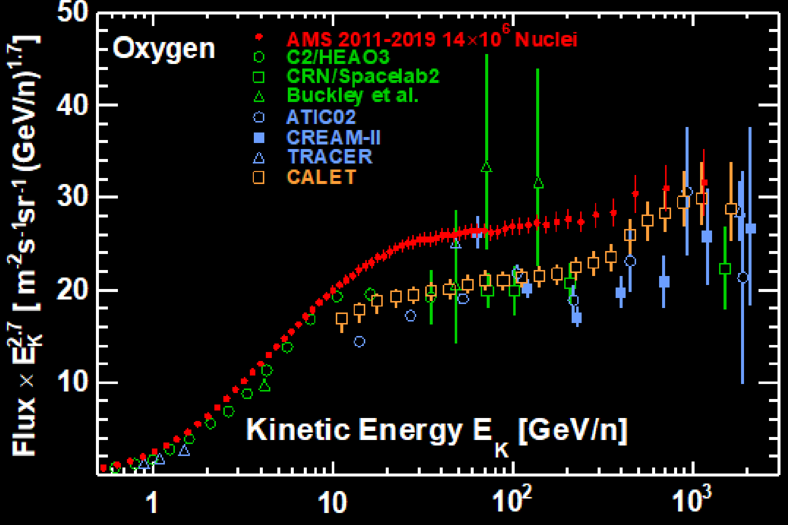
Above 60 GV, the He, C, and O spectra have identical rigidity dependence.

In particular, they all deviate from a single power law and harden progressively from ~200 GV.

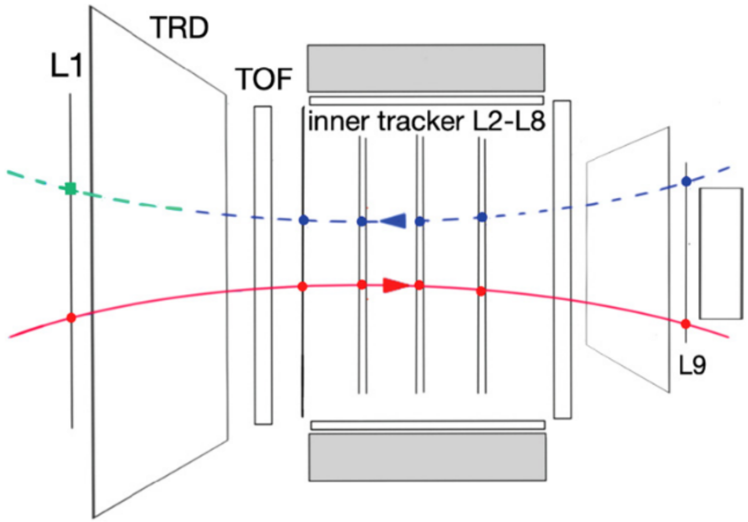
Comparison to earlier experiments



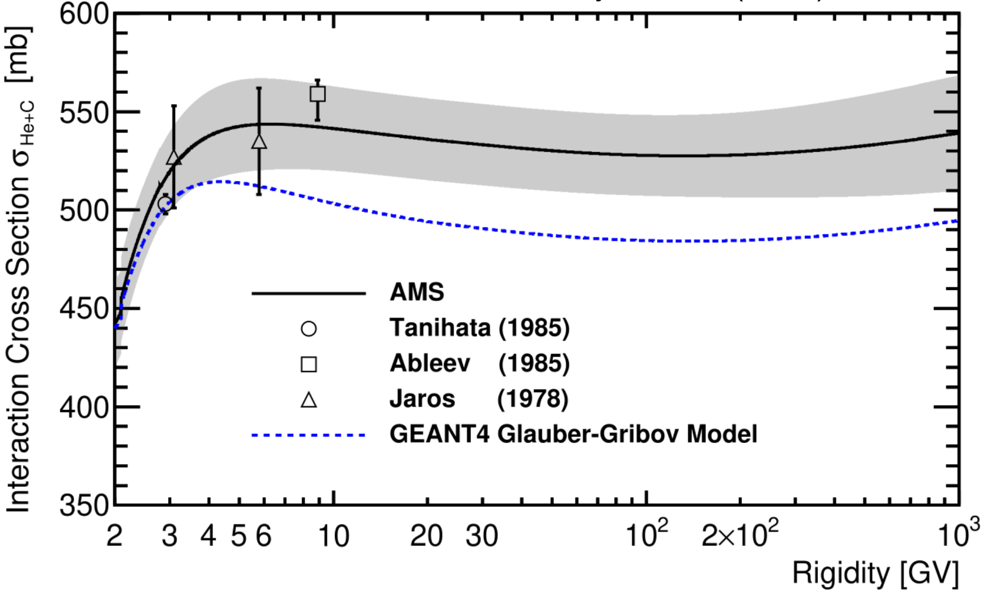




Measurement of nuclei cross sections by AMS



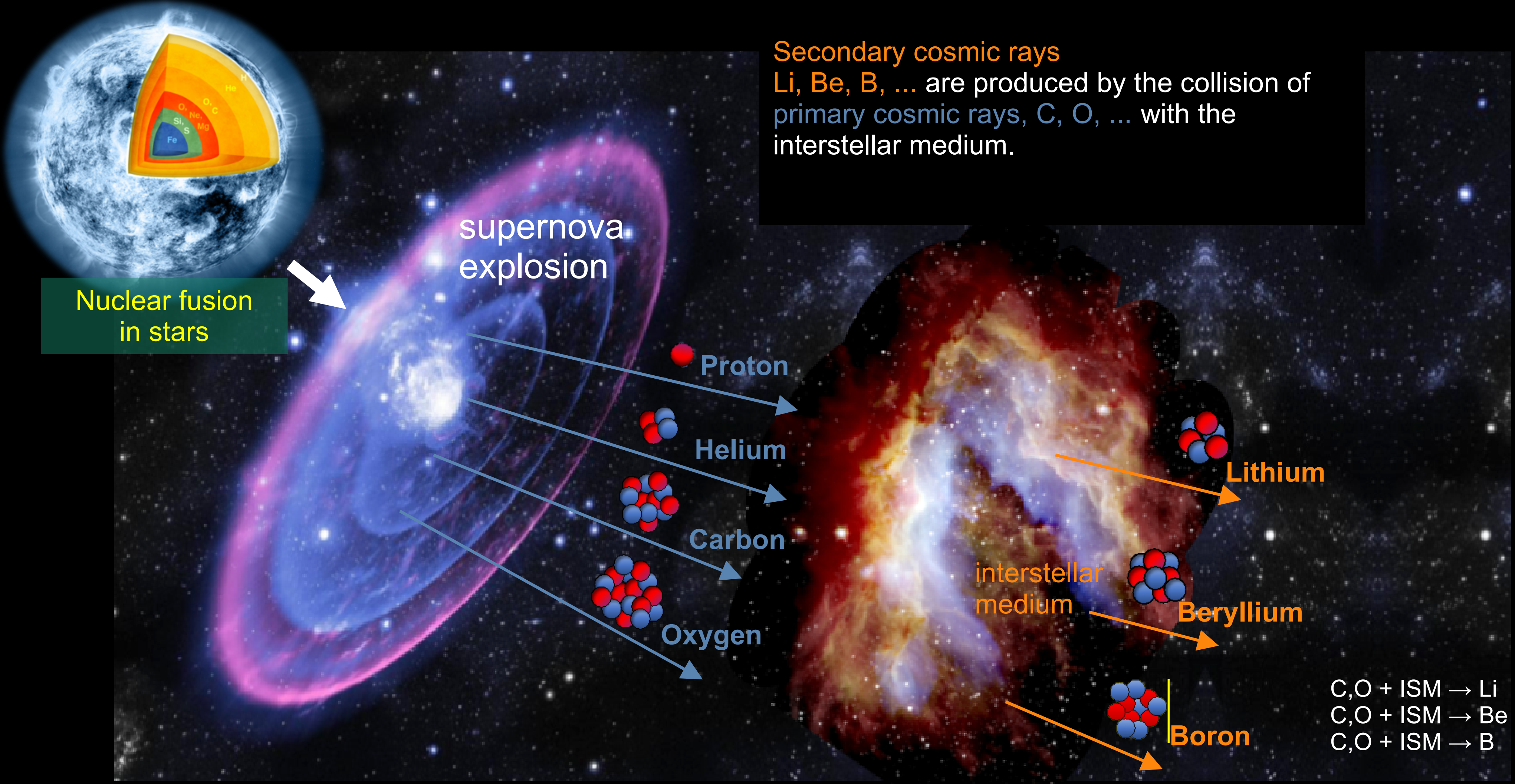
Q. Yan et al., Nucl. Phys. A 996 (2020) 121712



AMS measured the survival probabilities of nuclei during dedicated ”horizontal” runs (~10^5 sec exposure).

Precise knowledge of nuclear interactions with the detector materials is crucial for the accurate measurements of cosmic-ray nuclei fluxes.

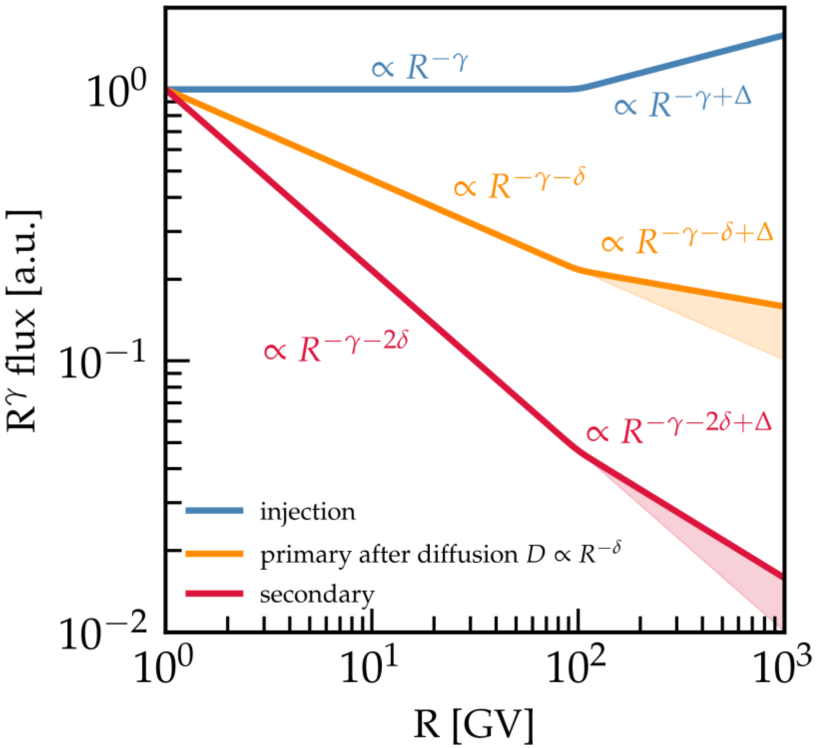
Secondary cosmic rays



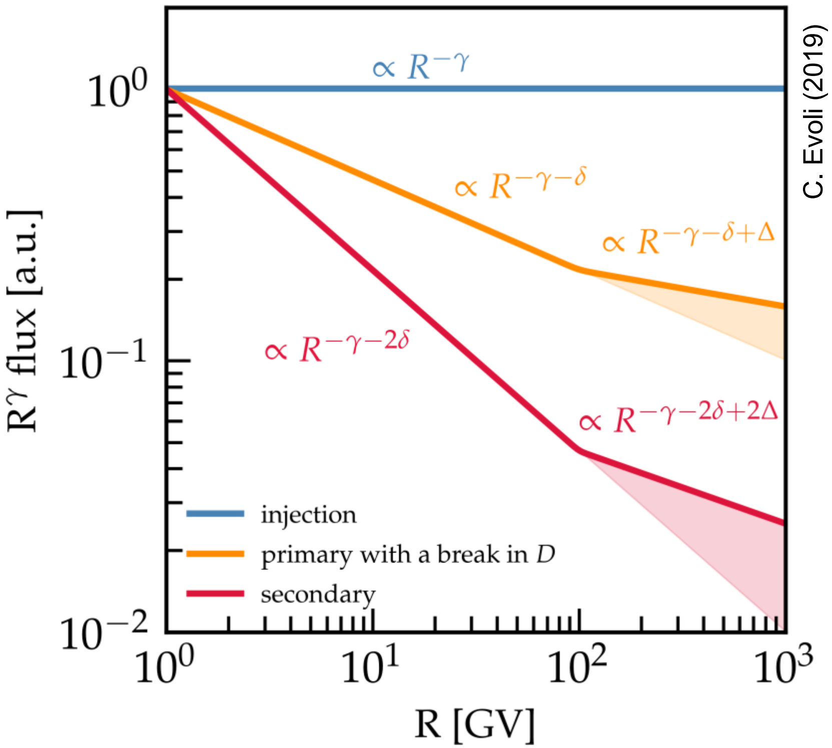
Secondary cosmic rays
Li, Be, B, ... are produced by the collision of primary cosmic rays, C, O, ... with the interstellar medium.

C,O + ISM → Li
C,O + ISM → Be
C,O + ISM → B

Spectral break: Source effect or propagation effect?



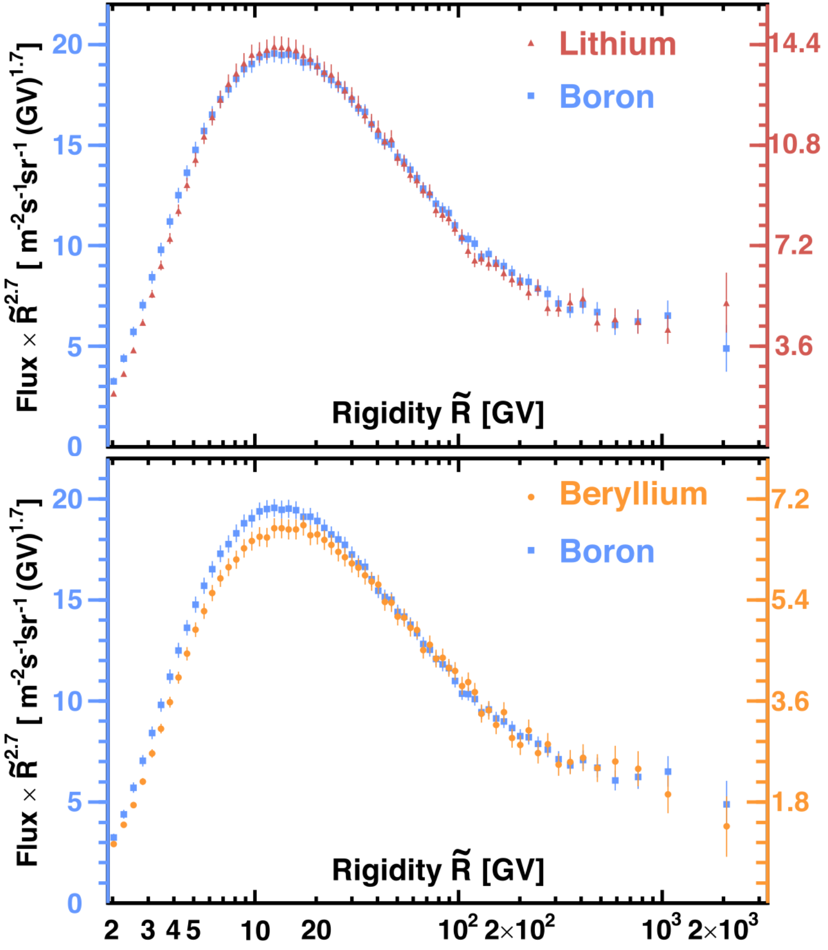
Break in source spectrum
→ no break in secondary/primary ratio.

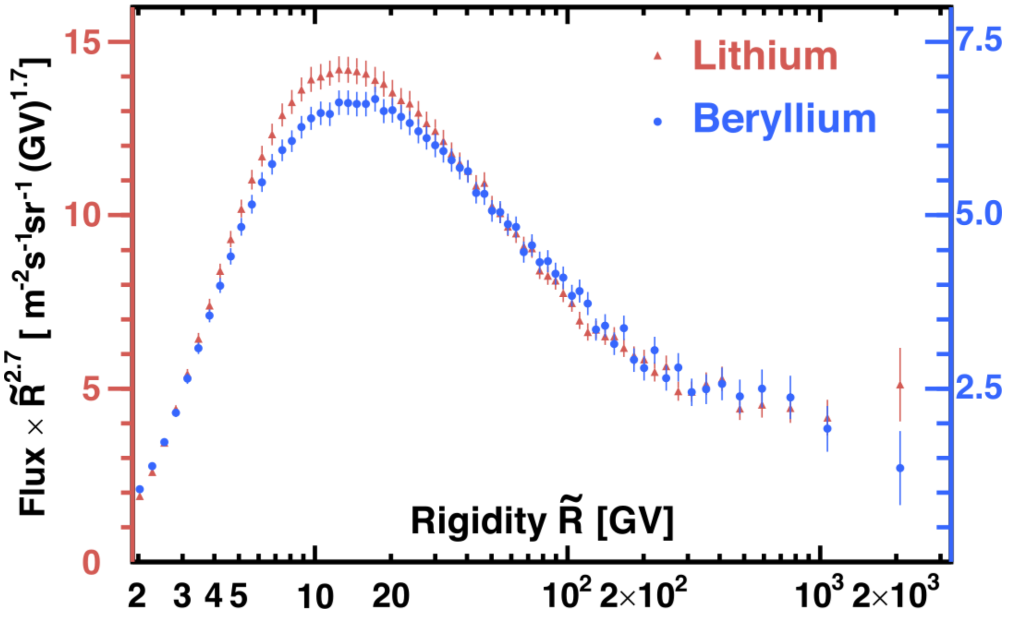


C. Evoli (2019)

Break in diffusion coefficient (propagation)
→ break in secondary/primary ratio.

Fluxes of secondary nuclei by AMS

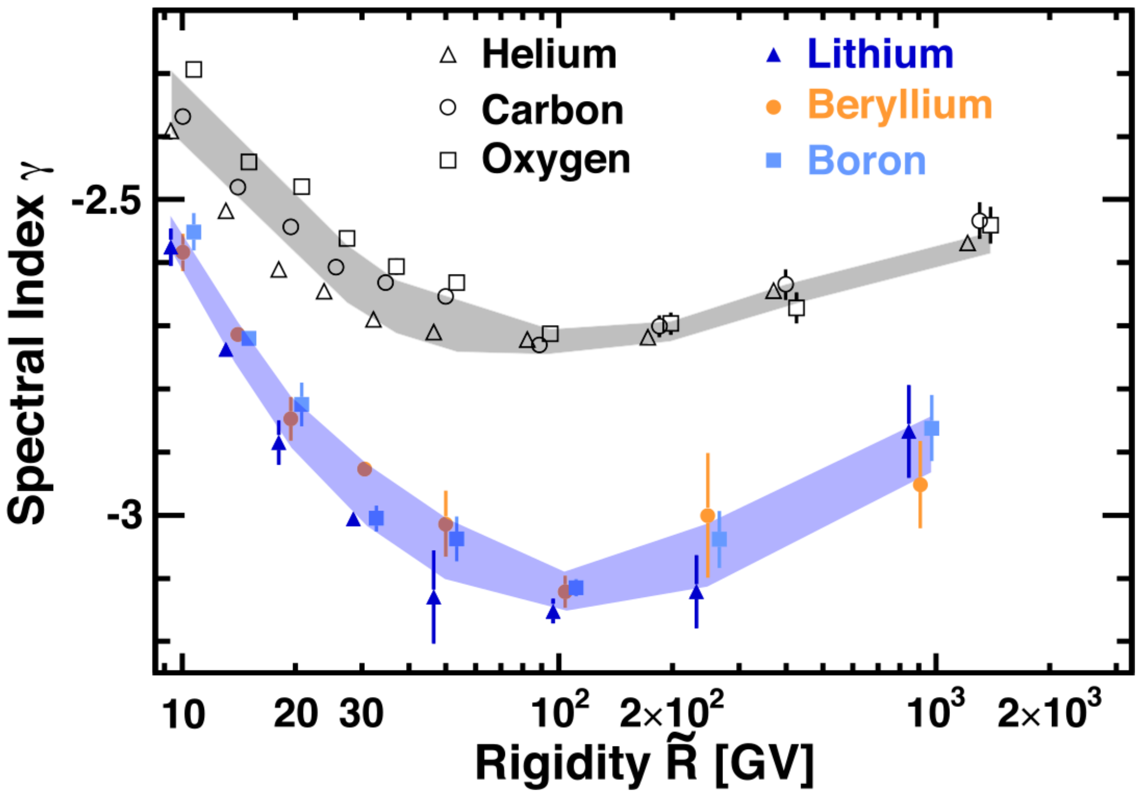




Lithium and boron fluxes have identical rigidity dependence above ~7 GV.

All three secondary fluxes have identical rigidity dependence above ~30 GV.

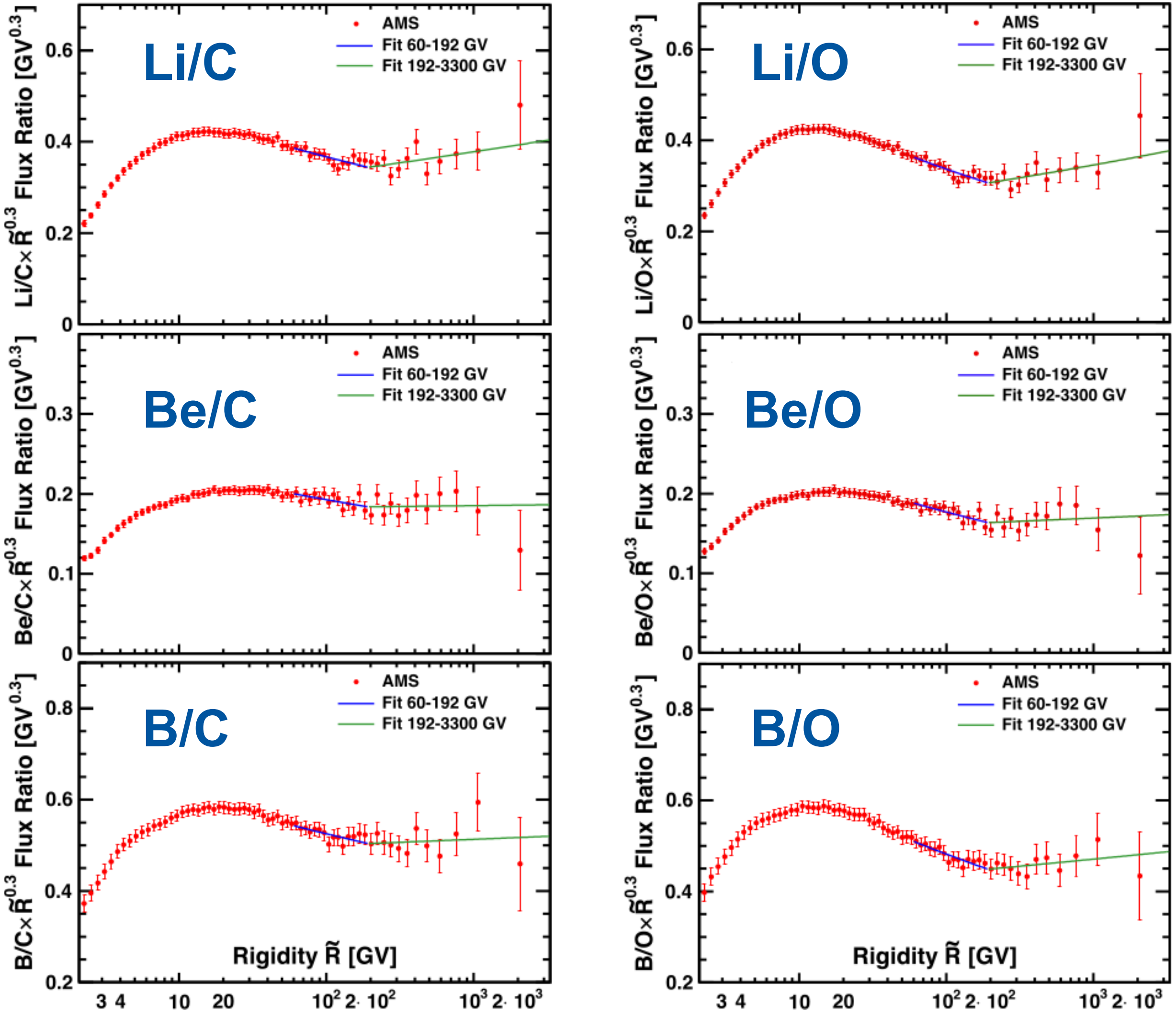
Comparison of spectral indices



The magnitude and rigidity dependence of the Li, Be, and B spectral indices are nearly identical. But they are distinctly different from He, C, and O.

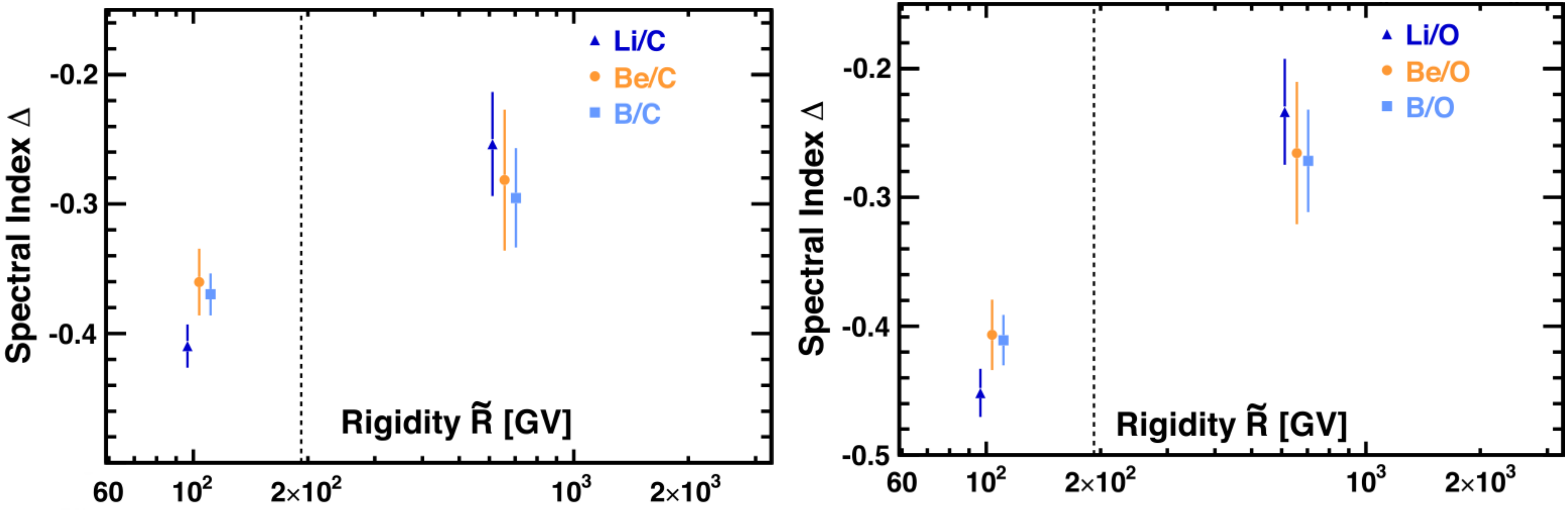
Above ~200 GV, the secondaries harden more than the primaries.

Secondary-to-primary ratios



Power-law fits to secondary-to-primary ratios in two non-overlapping rigidity regions.

Spectral hardening

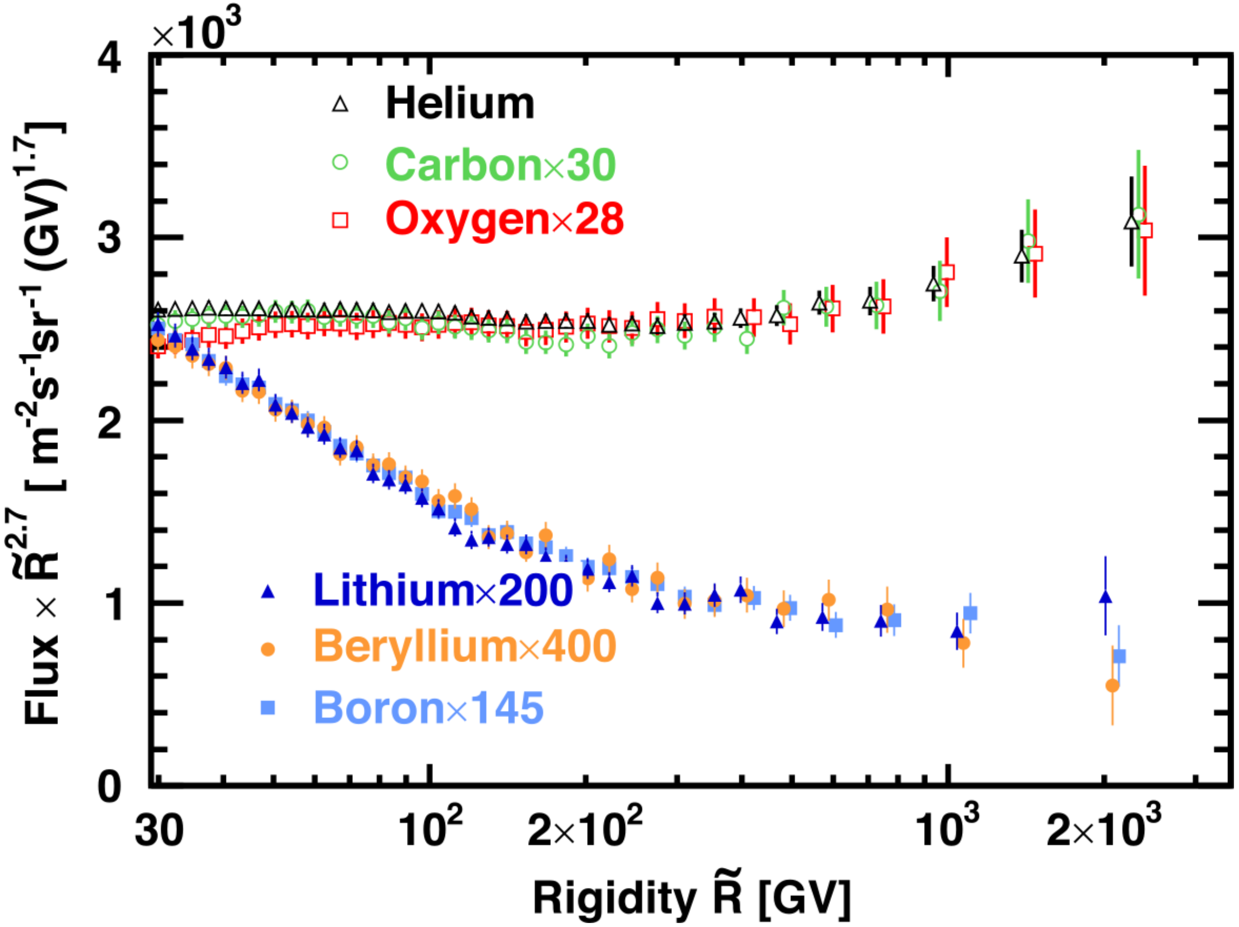


Average hardening: $\Delta_{[192-3300]\,\mathrm{GV}} - \Delta_{[60.3-192]\,\mathrm{GV}} = 0.140 \pm 0.025$

The significance of this hardening is found to exceed 5σ.

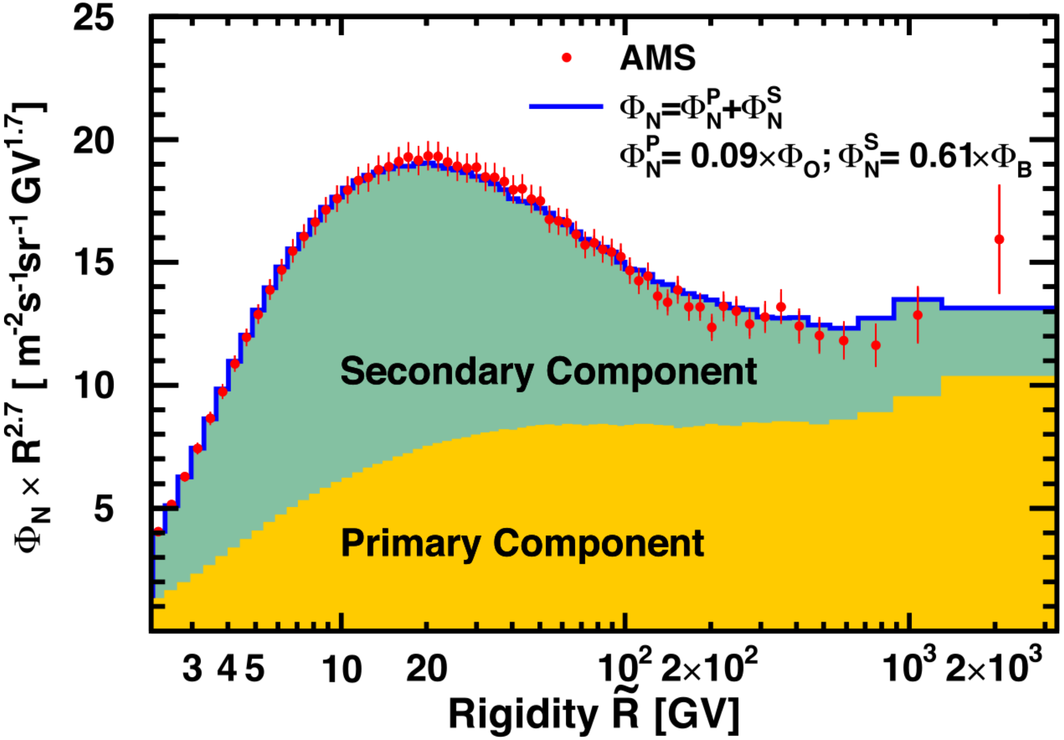
This is consistent with expectations when the hardening is due to propagation in the Galaxy.

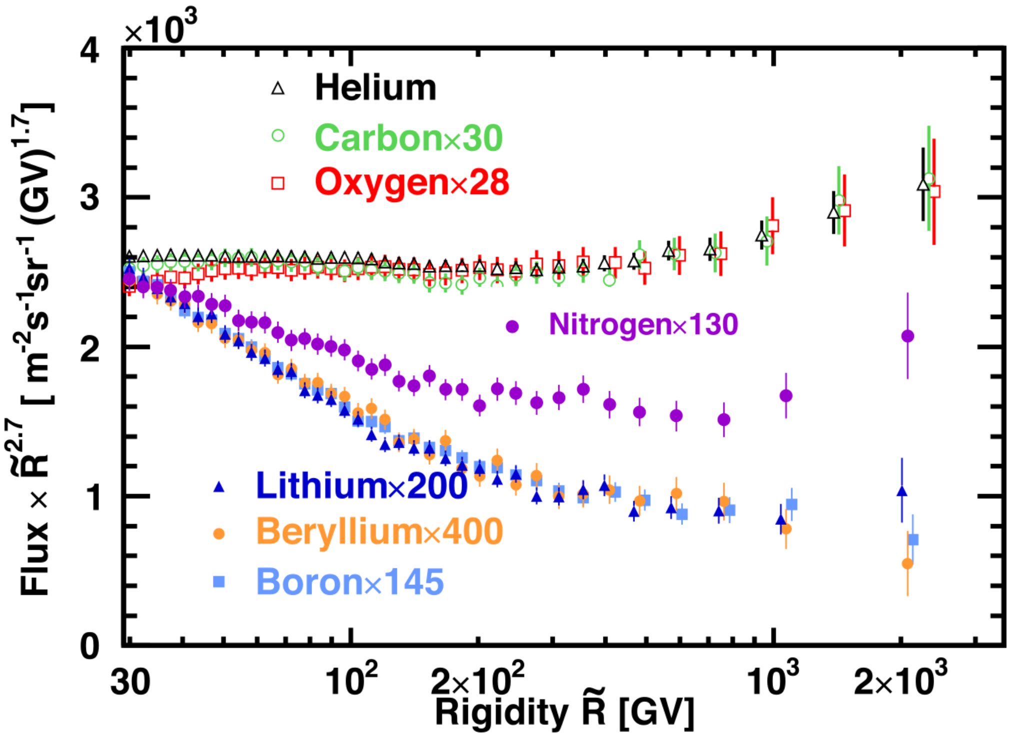
High-energy behavior of secondary and primary fluxes



Phys. Rep. 894 (2021) 1-116

Nitrogen





The nitrogen flux is well described by the sum of a primary component (9.2% of the oxygen flux) and a secondary component (61% of the boron flux).

Conclusions

- Above 60 GV, the He, C, and O spectra have identical rigidity dependence.
- The spectra all progressively harden above 200 GV.

- The Li, Be, and B fluxes have identical rigidity dependence above 30 GV and deviate from a single power law above 200 GV in an identical way.
- The rigidity dependence of the secondary fluxes is distinctly different from the primary fluxes. Above 200 GV, the spectral indices of the secondaries harden by an average of 0.140 ± 0.025 more than the primaries (>5σ effect).