Cosmic Beryllium Isotopes Measurement with the Alpha Magnetic Spectrometer

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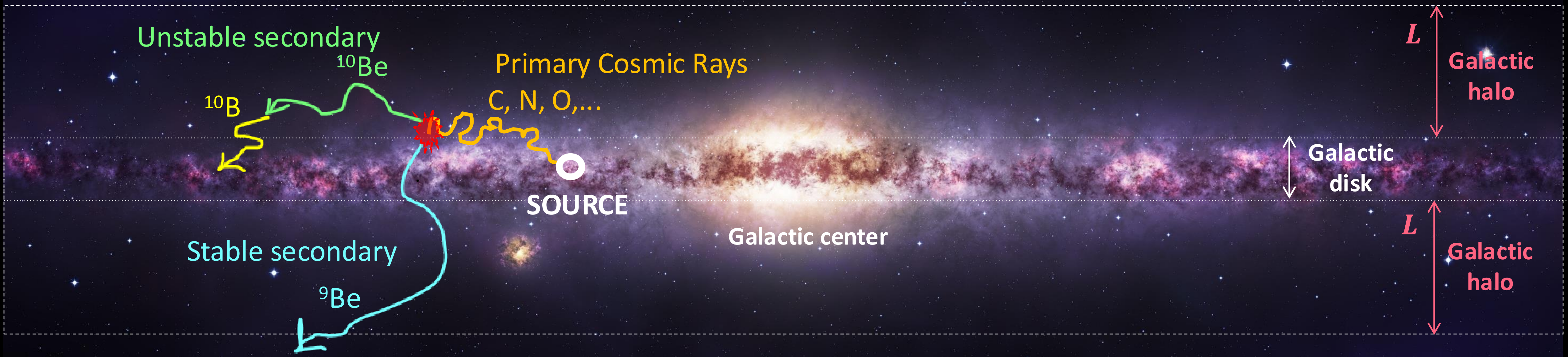
Cosmic-ray Beryllium isotopes

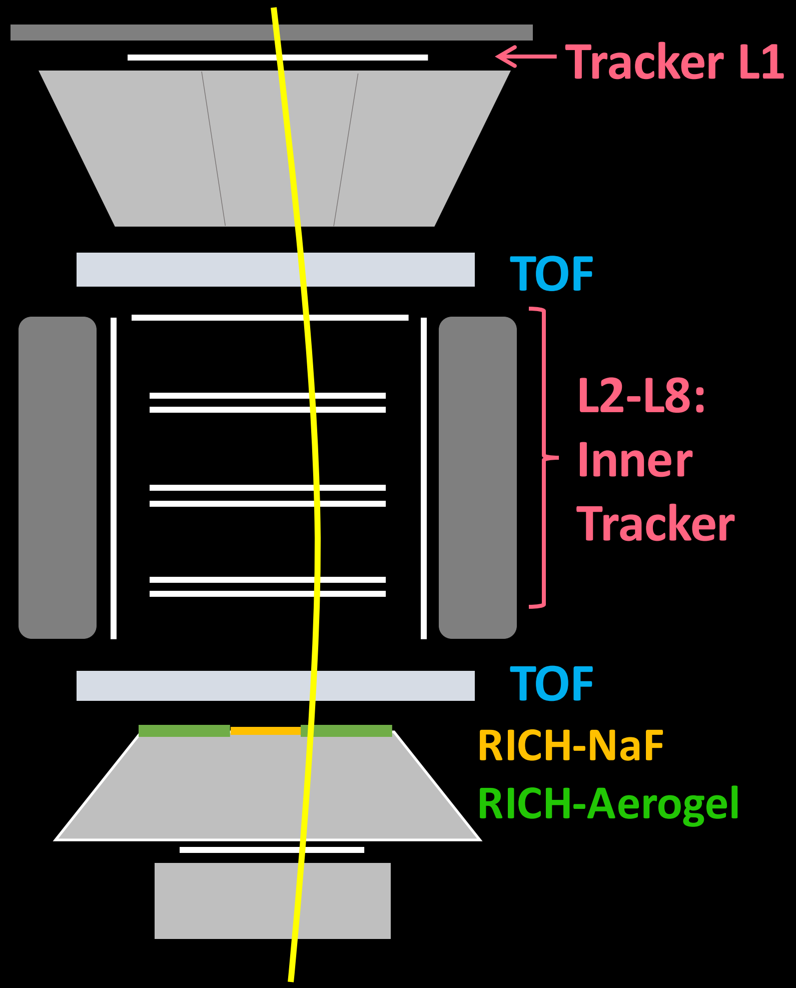
Beryllium nuclei are secondary cosmic rays.
They include three isotopes, ^{7}Be, ^{9}Be, and ^{10}Be.

Stable ^{9}Be propagate in the entire galactic halo,
while ^{10}Be decay to ^{10}B before reaching the boundary of the Galaxy.



The ratio of ^{10}Be/^{9}Be measures the Galactic halo size L.

Key detectors for measuring Isotopes with AMS-02



- AMS mass resolution depends on rigidity ($R = P/Z$) and velocity (β) resolutions:

$$M = \frac{RZ}{\beta\gamma}$$

$$\gamma = 1/\sqrt{1-\beta^2}$$

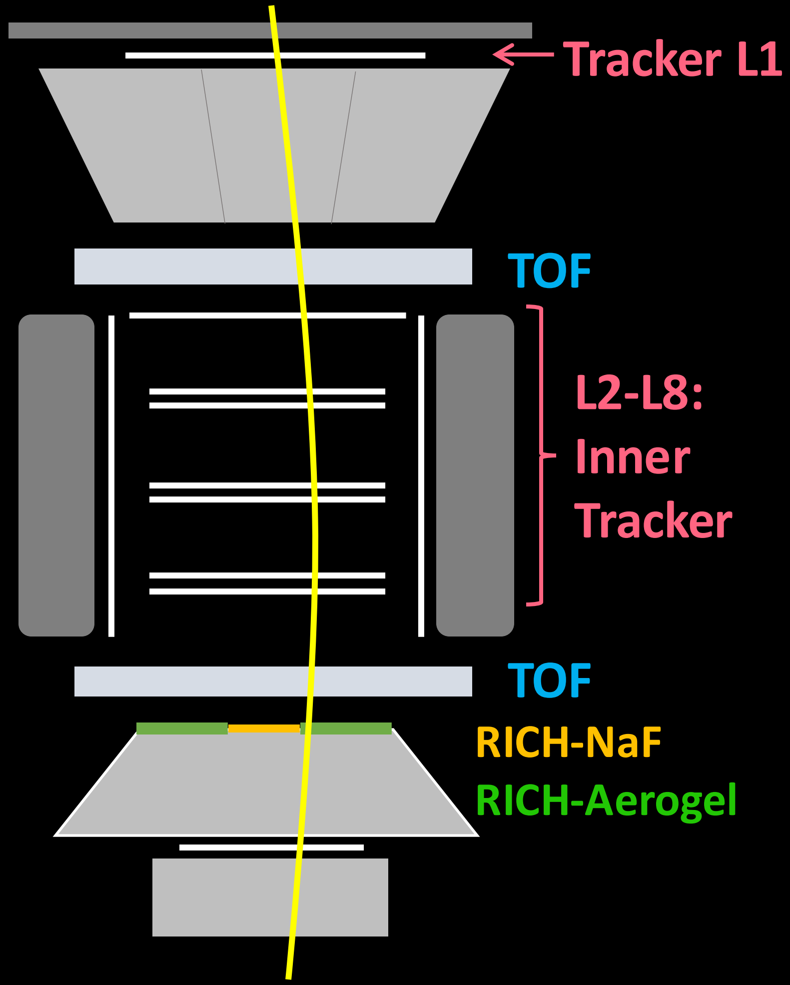
- R measured with Tracker:

  $\Delta R/R \sim 10\%$ below 30 GV

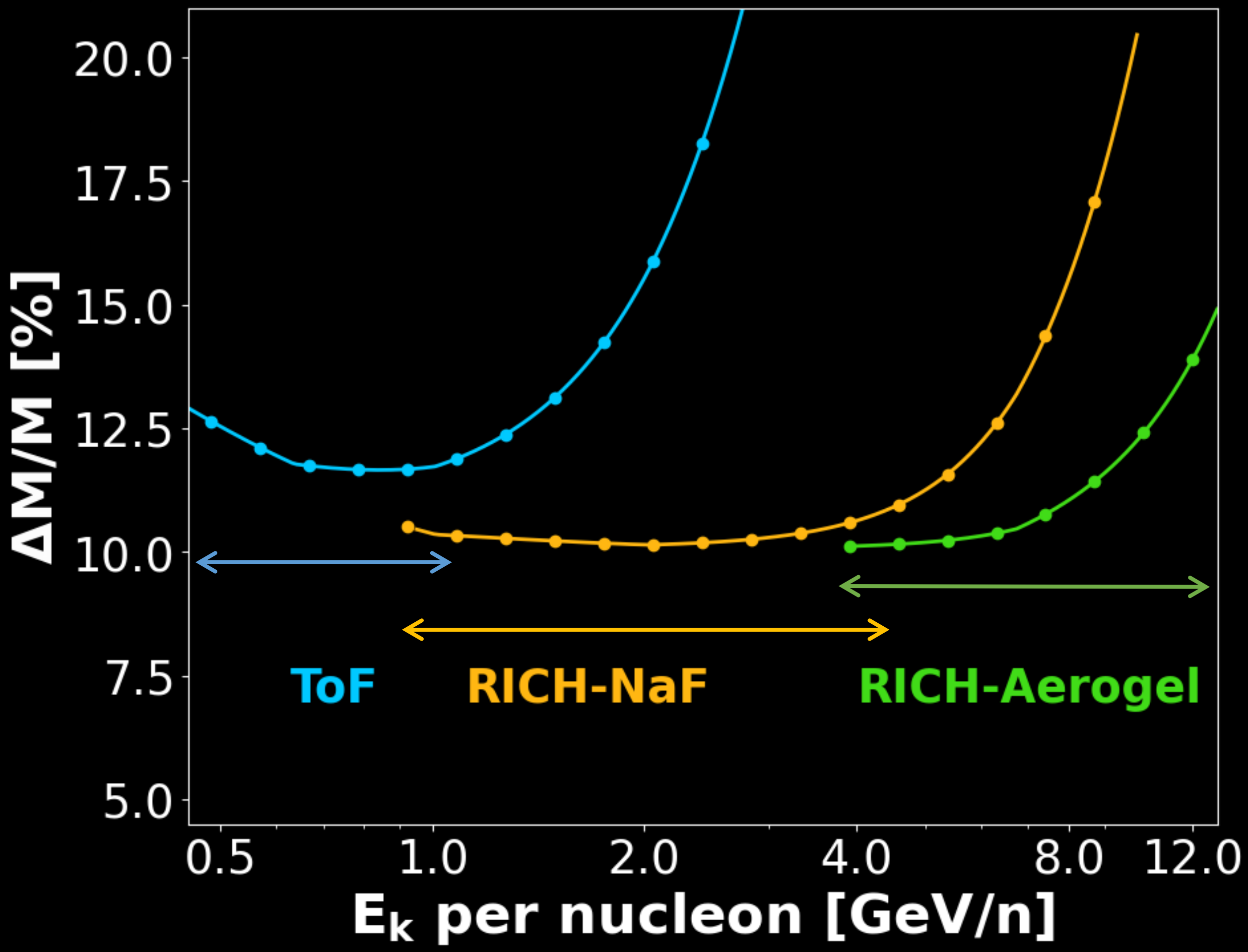
- β measured by three different detectors:

	E_k/n range (GeV/n)	$\Delta\beta/\beta$
TOF	(0.4, 1.2)	~1.5%
RICH-NaF	(0.8, 4.0)	~0.15%
RICH-Aerogel	(3.0, 12)	~0.05%

Measurement of Isotopes with AMS-02

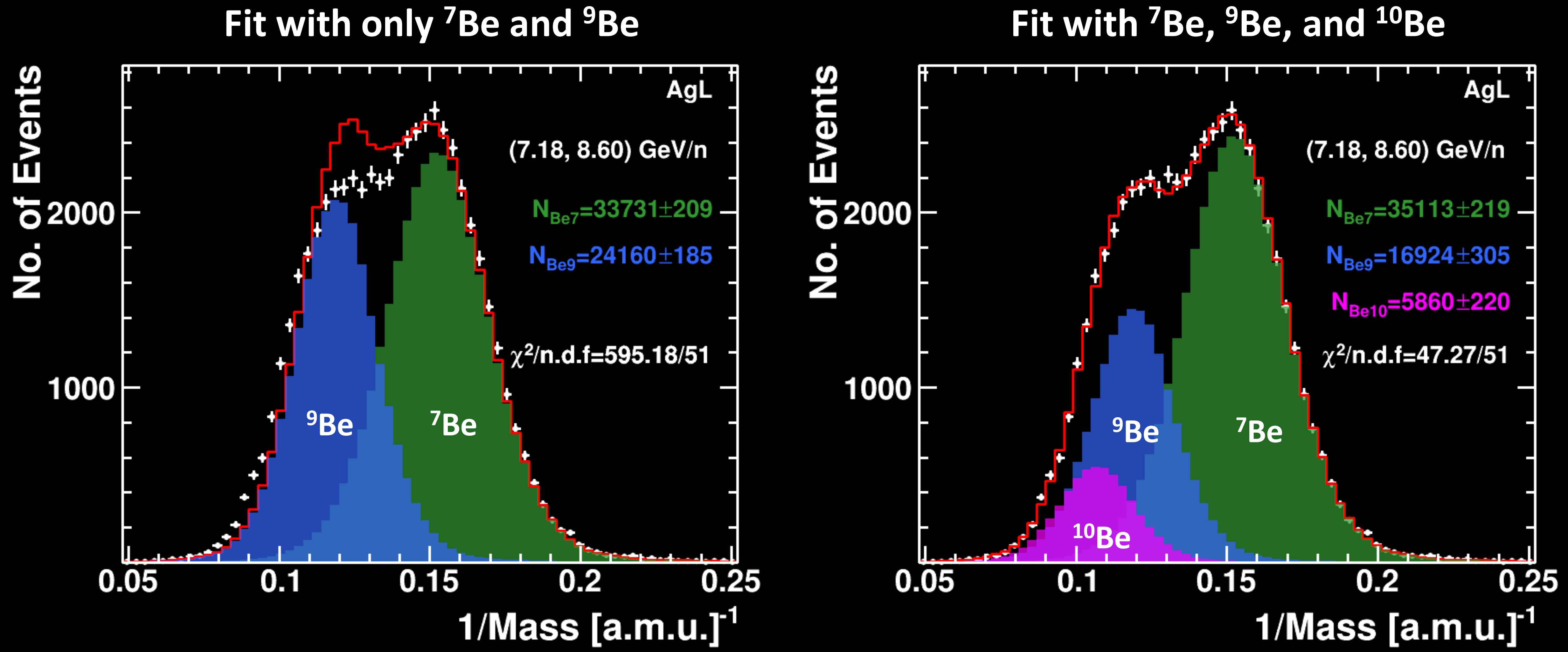


$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left(\frac{1}{1-\beta^2}\cdot\frac{\Delta\beta}{\beta}\right)^2}$$



Cross validation with TOF, RICH-NaF, and RICH-Aerogel

Examples of Mass Template Fit for Be Nuclei

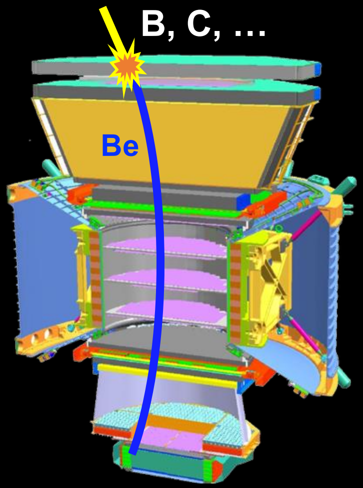


^{10}Be is needed to fit the data

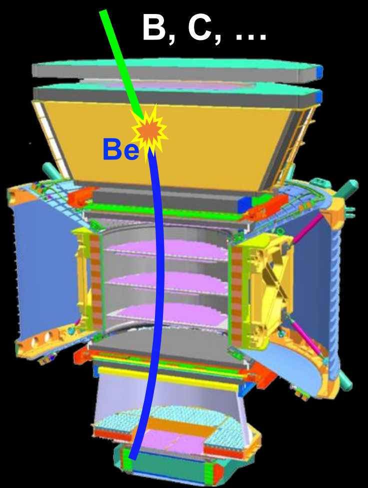
In total, we have analysed 0.7 million beryllium events.

Background from Heavier Nuclei Fragmentation

Above L1



Below L1



From heavier nuclei (Boron, Carbon……):

- **Below L1 background:** from the interactions with materials between Tracker L1 and L2.

Found to be <0.3%

- **Above L1 background:** from interactions with supporting structures above Tracker L1.

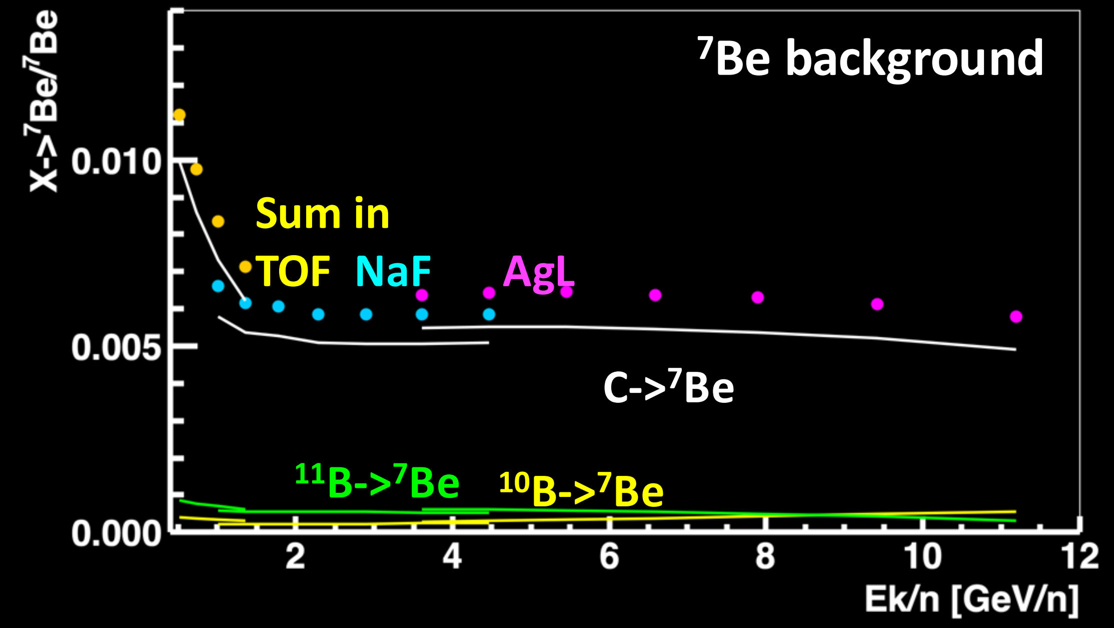
$$\frac{N^{X\rightarrow {}^{a}Be}}{N^{{}^{a}Be}} = \frac{\Phi^{X}}{\Phi^{{}^{a}Be}} \times \frac{A^{X\rightarrow {}^{a}Be}}{A^{{}^{a}Be}}$$

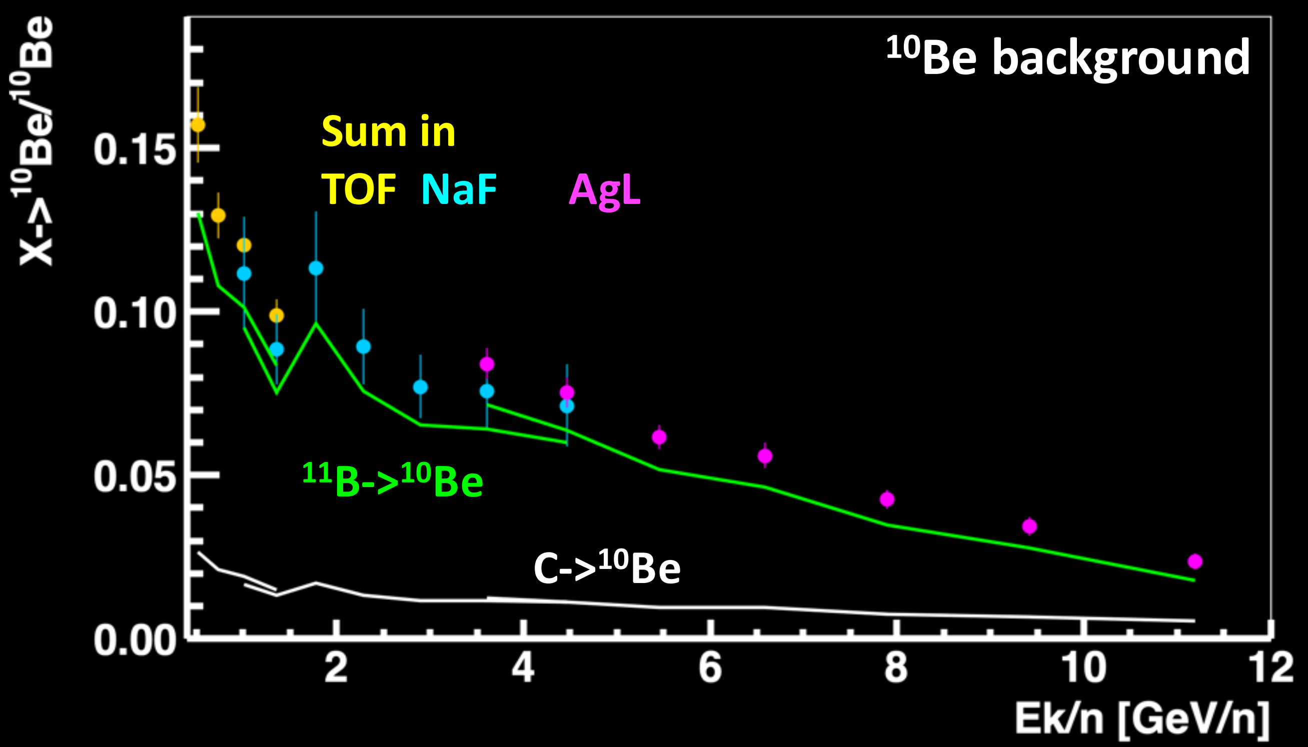
Background contamination | Flux ratio | Acceptance ratio with Be selection

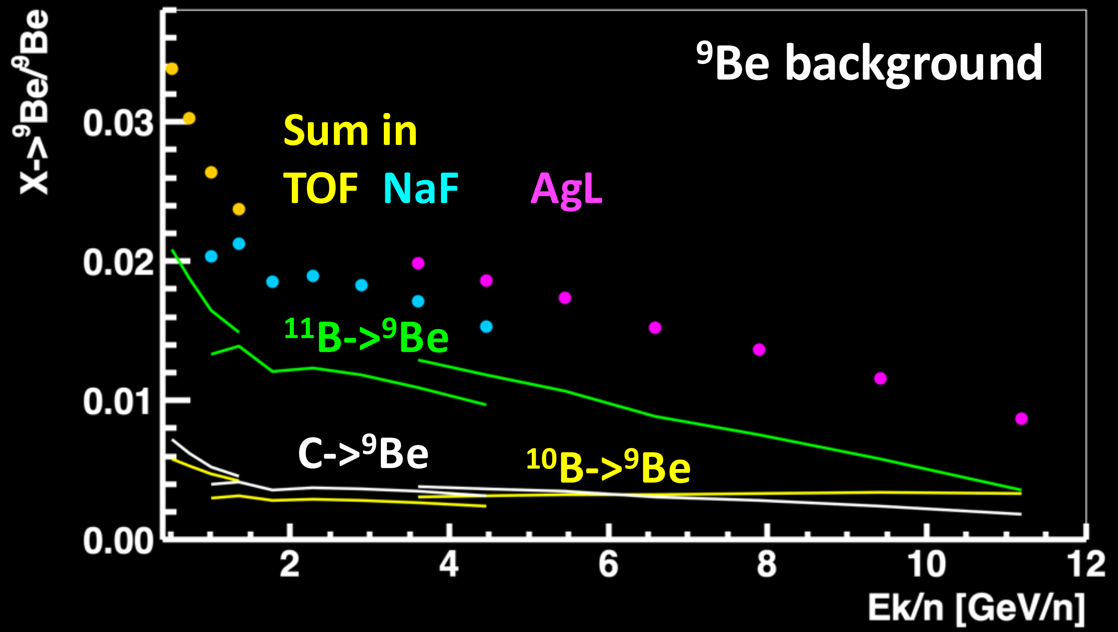
From Be isotope:

- Heavier Be isotope interact with detector materials produce lighter Be isotope: ${}^{10}\mathrm{Be} \rightarrow {}^{9}\mathrm{Be}$, ${}^{10}\mathrm{Be} \rightarrow {}^{7}\mathrm{Be}$ and ${}^{9}\mathrm{Be} \rightarrow {}^{7}\mathrm{Be}$.

Estimation of above-L1 background







The background mainly from B and C.

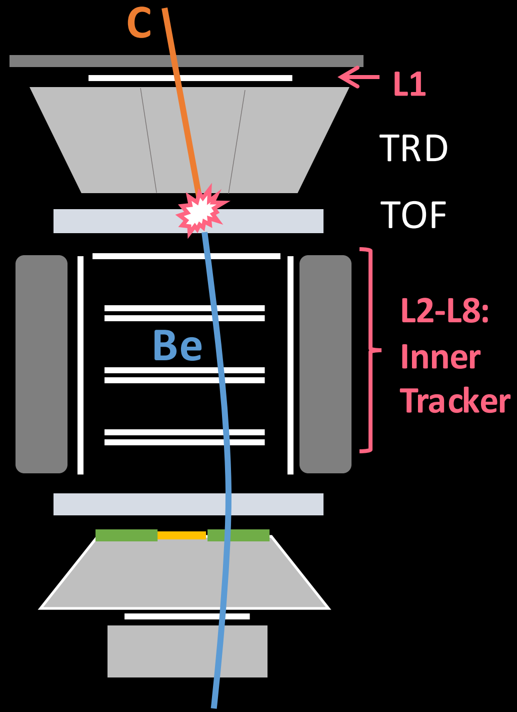
- ^{11}B is the dominate source for ^{10}Be and ^{9}Be.
- C is the dominate source for ^{7}Be

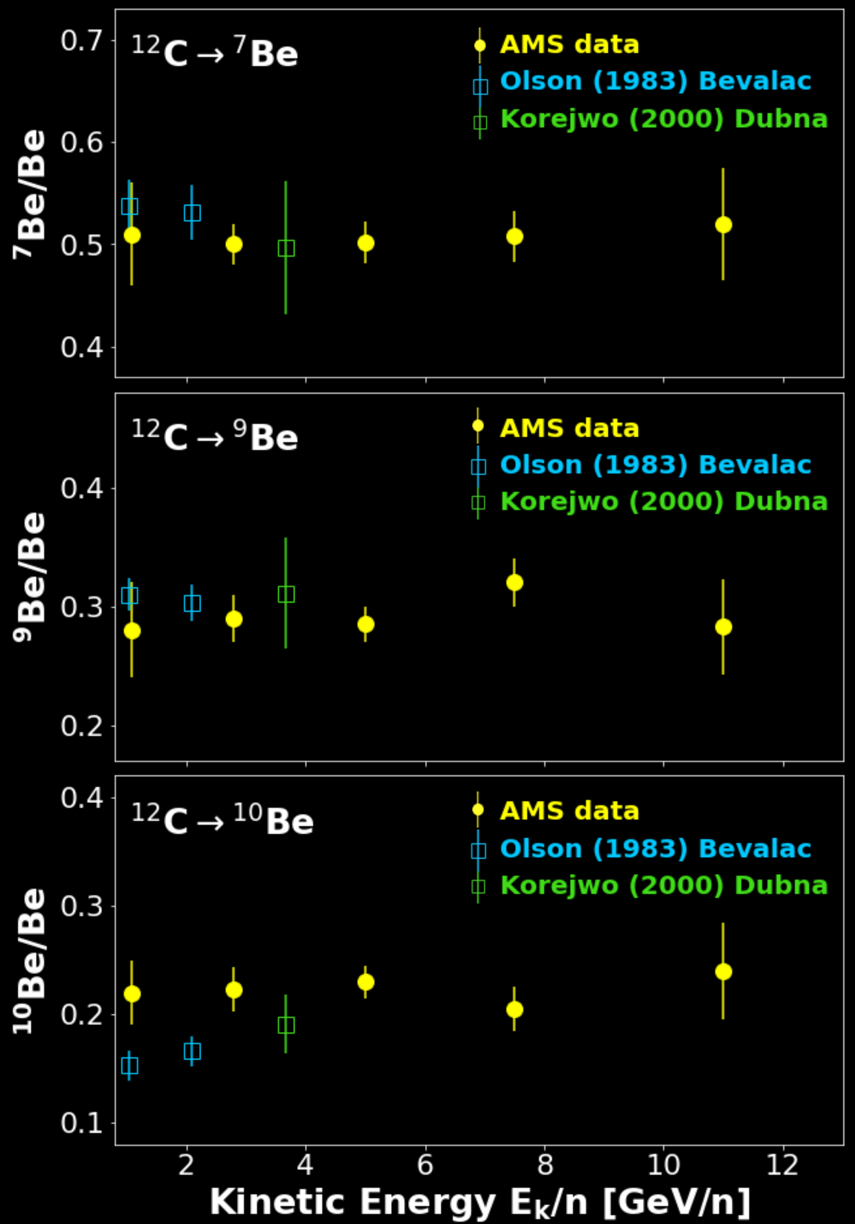
Validation of Fragmentation Cross Sections

Measurements of nuclei interaction cross sections were limited to few projectiles and low energy.

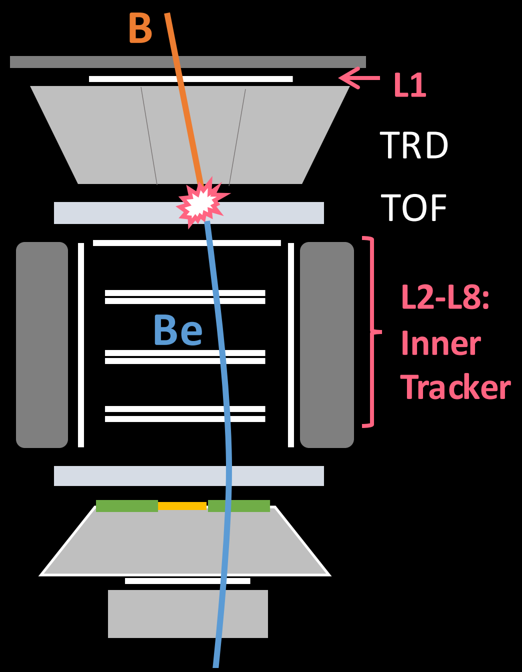
With cosmic ray data

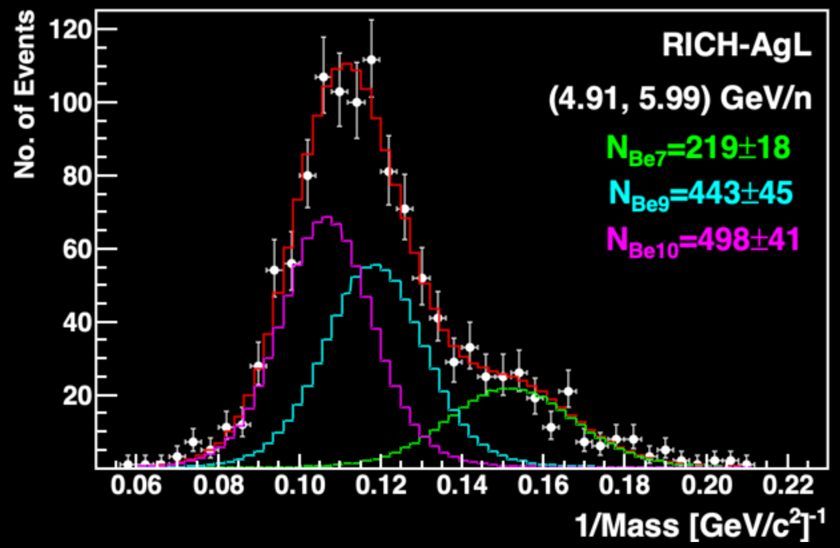
AMS measured the total and isotopic fragmentation cross sections and improved the MC simulation.

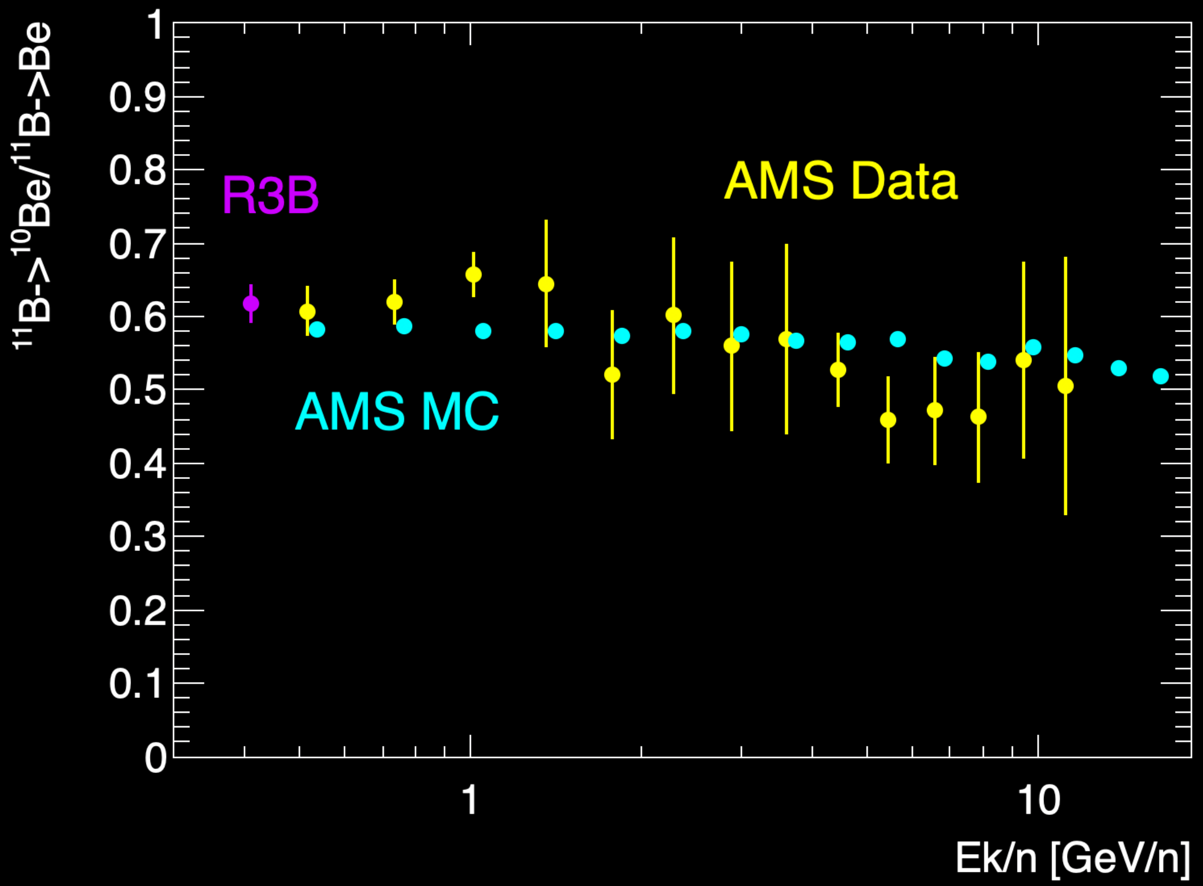




Measurement of $^{11}B \to ^{10}Be$ Fragmentation Cross Section



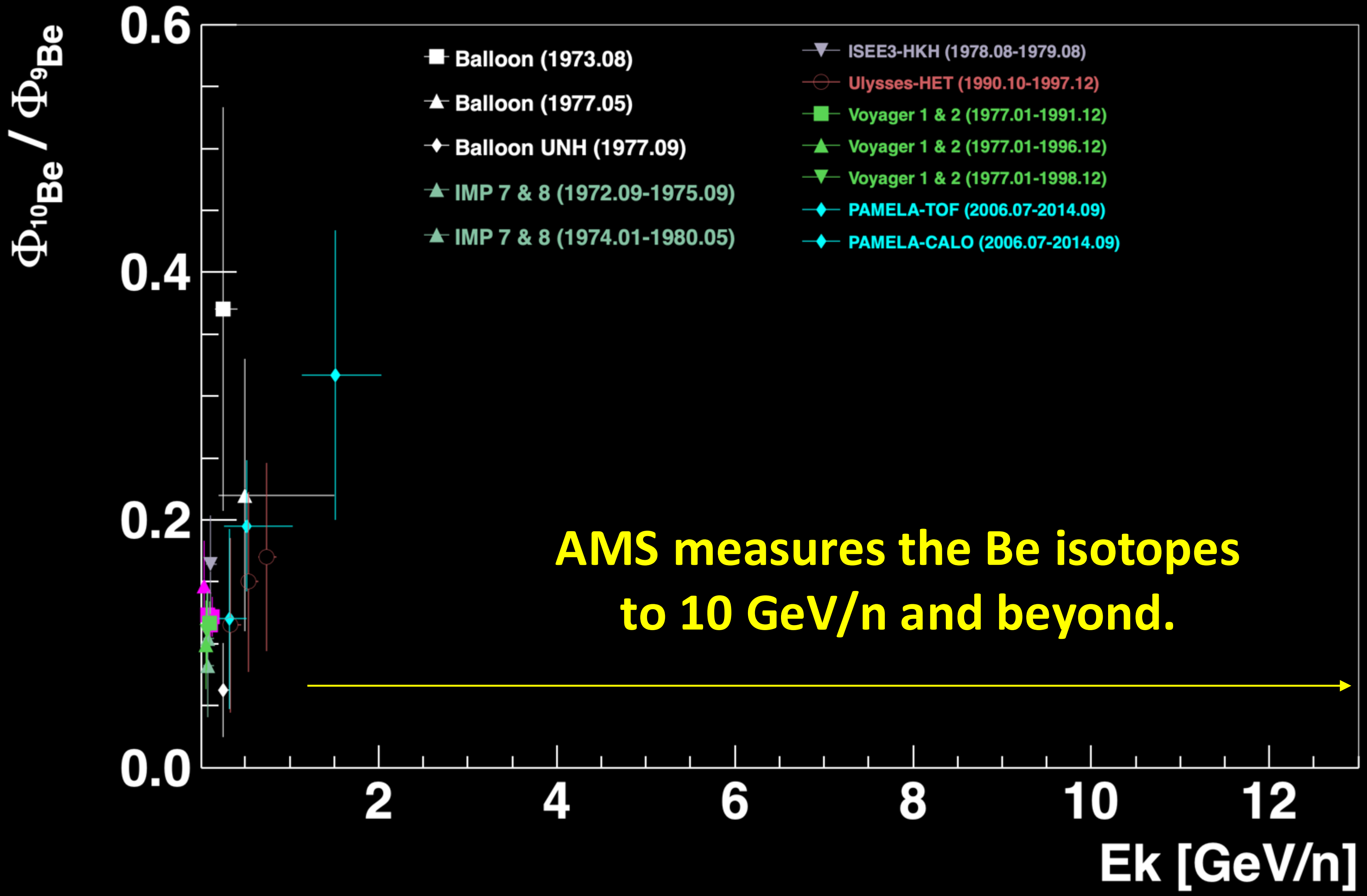




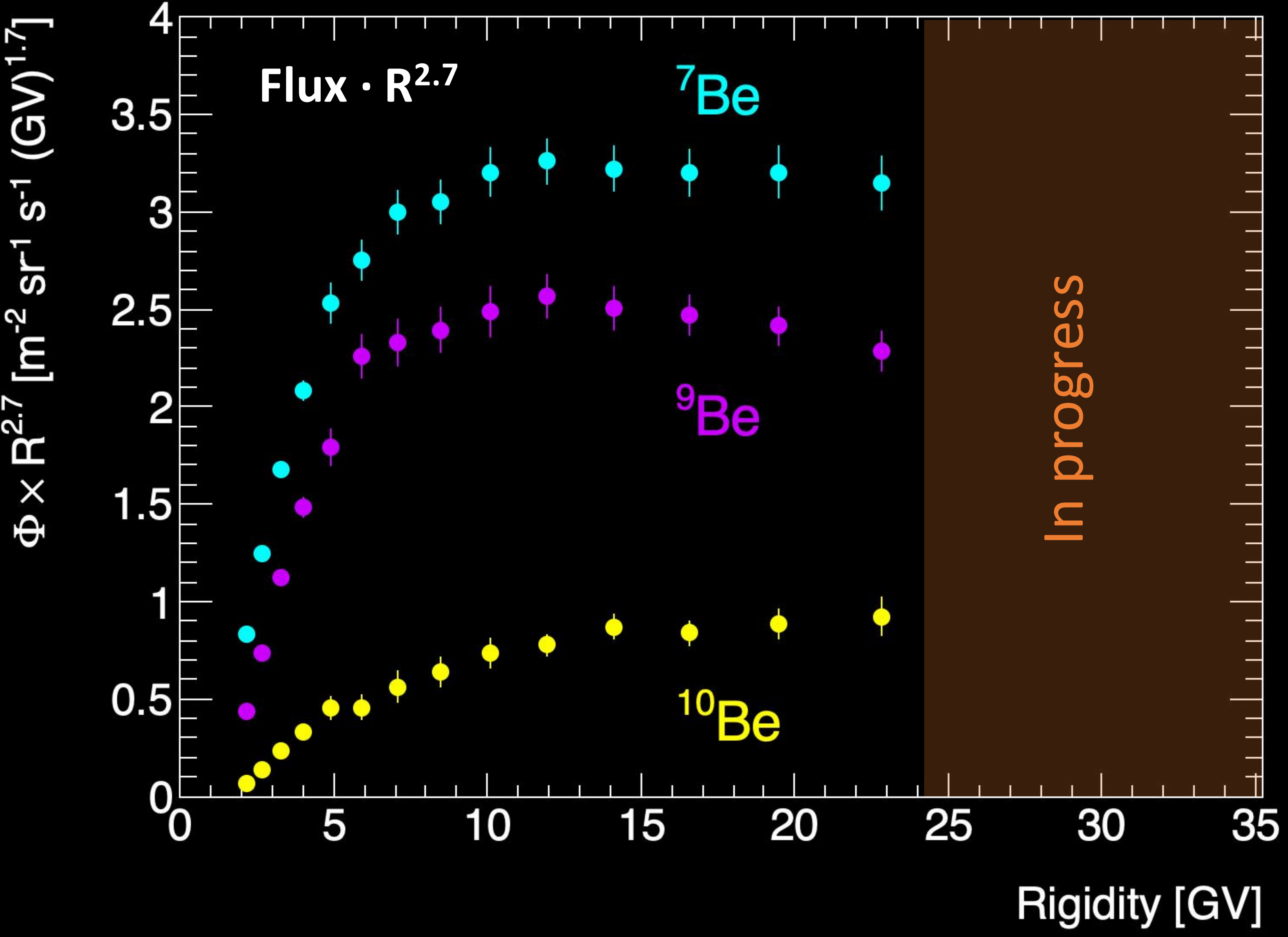
AMS results extrapolation to low energy agrees with R3B results.

AMS MC agrees with data in 15%

Cosmic $^{10}Be/^{9}Be$ Flux Ratio Before AMS-02

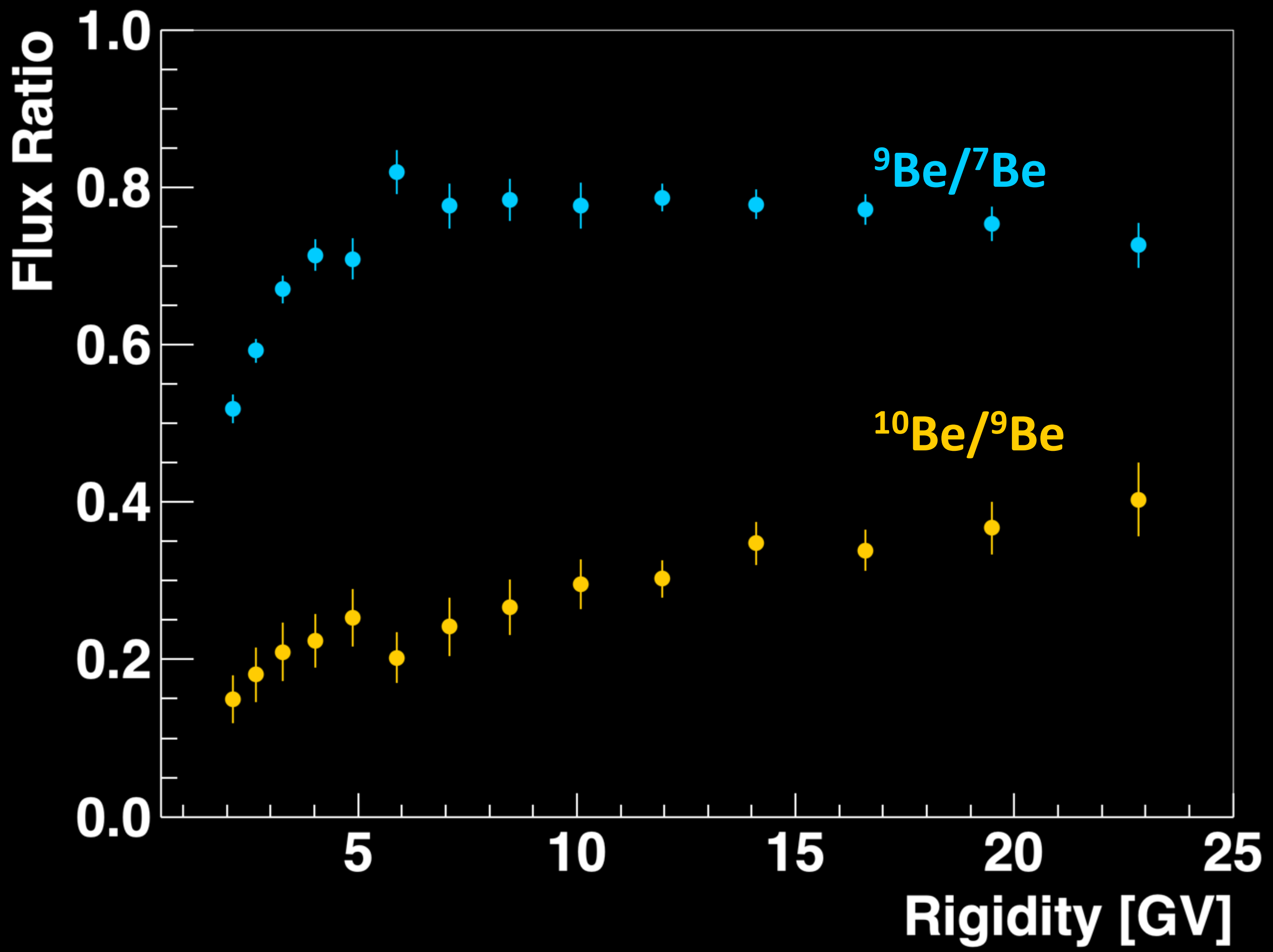


Beryllium Isotope Fluxes vs Rigidity



Preliminary data, refer to upcoming AMS publication

Beryllium Isotope Fluxes Ratios vs Rigidity



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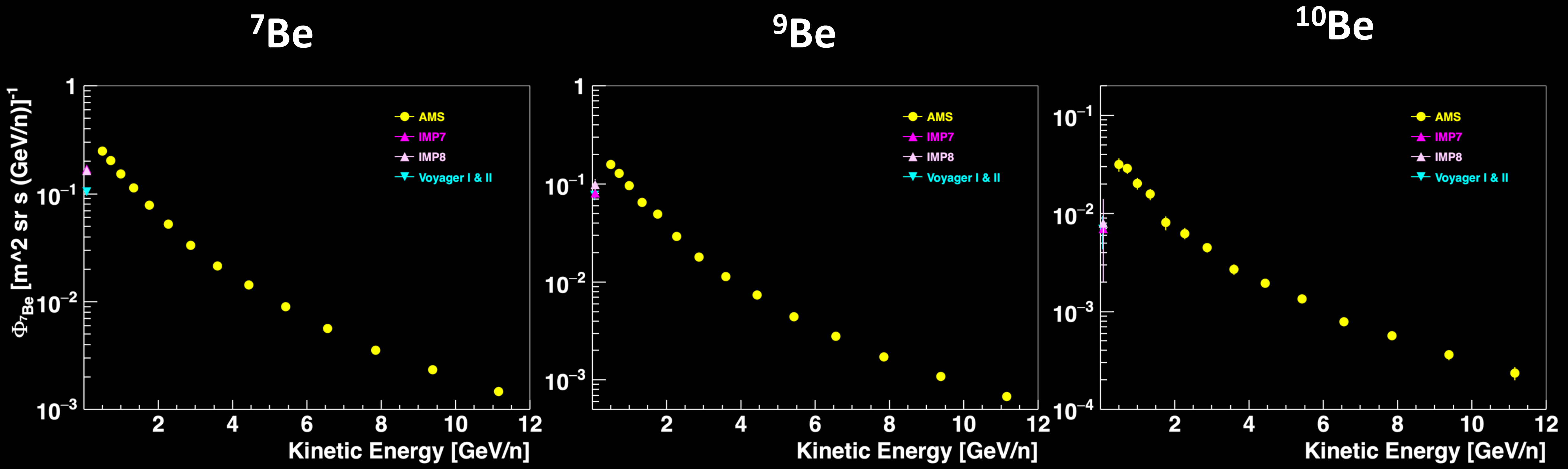
Beryllium Isotope Fluxes vs Kinetic Energy



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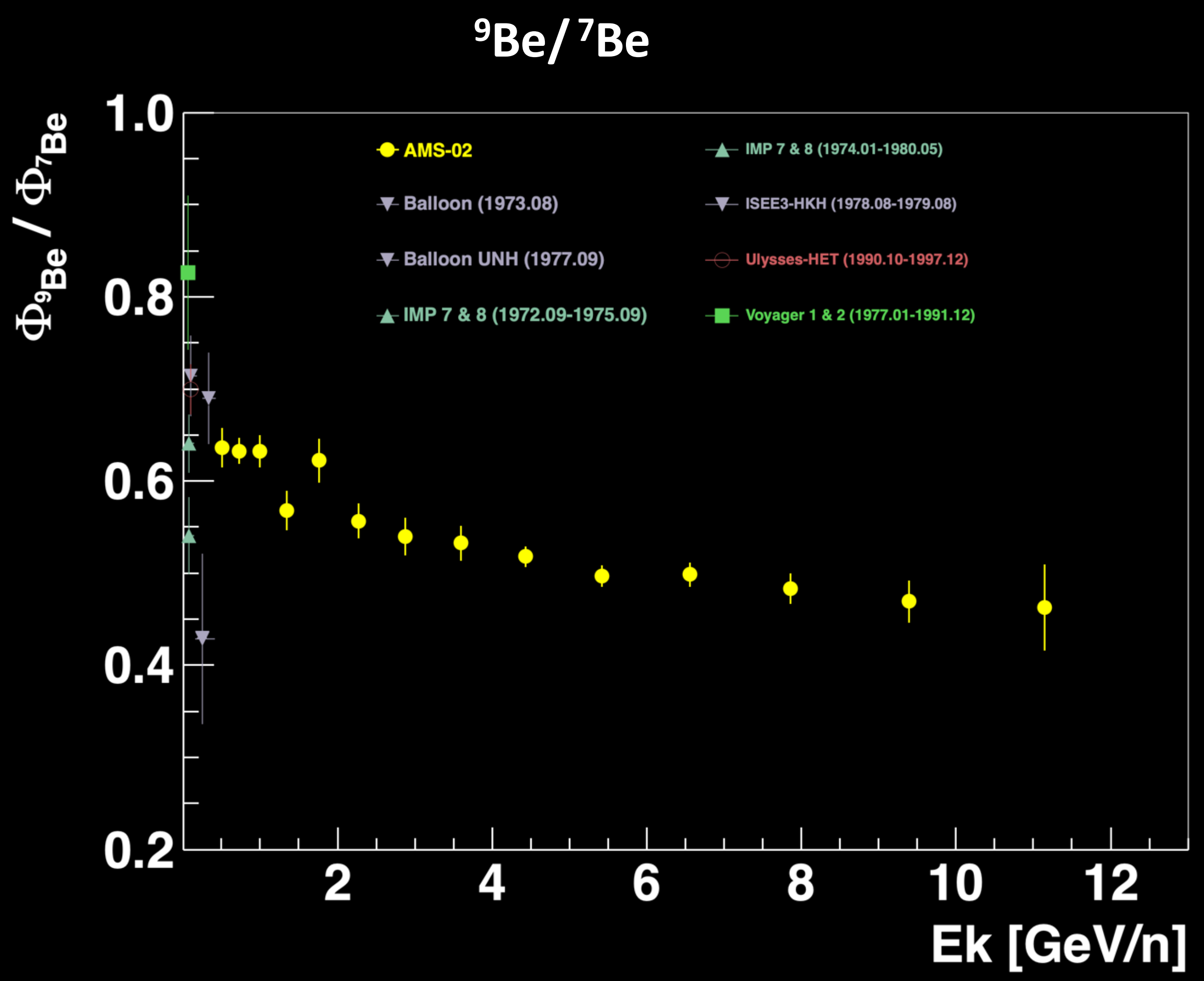
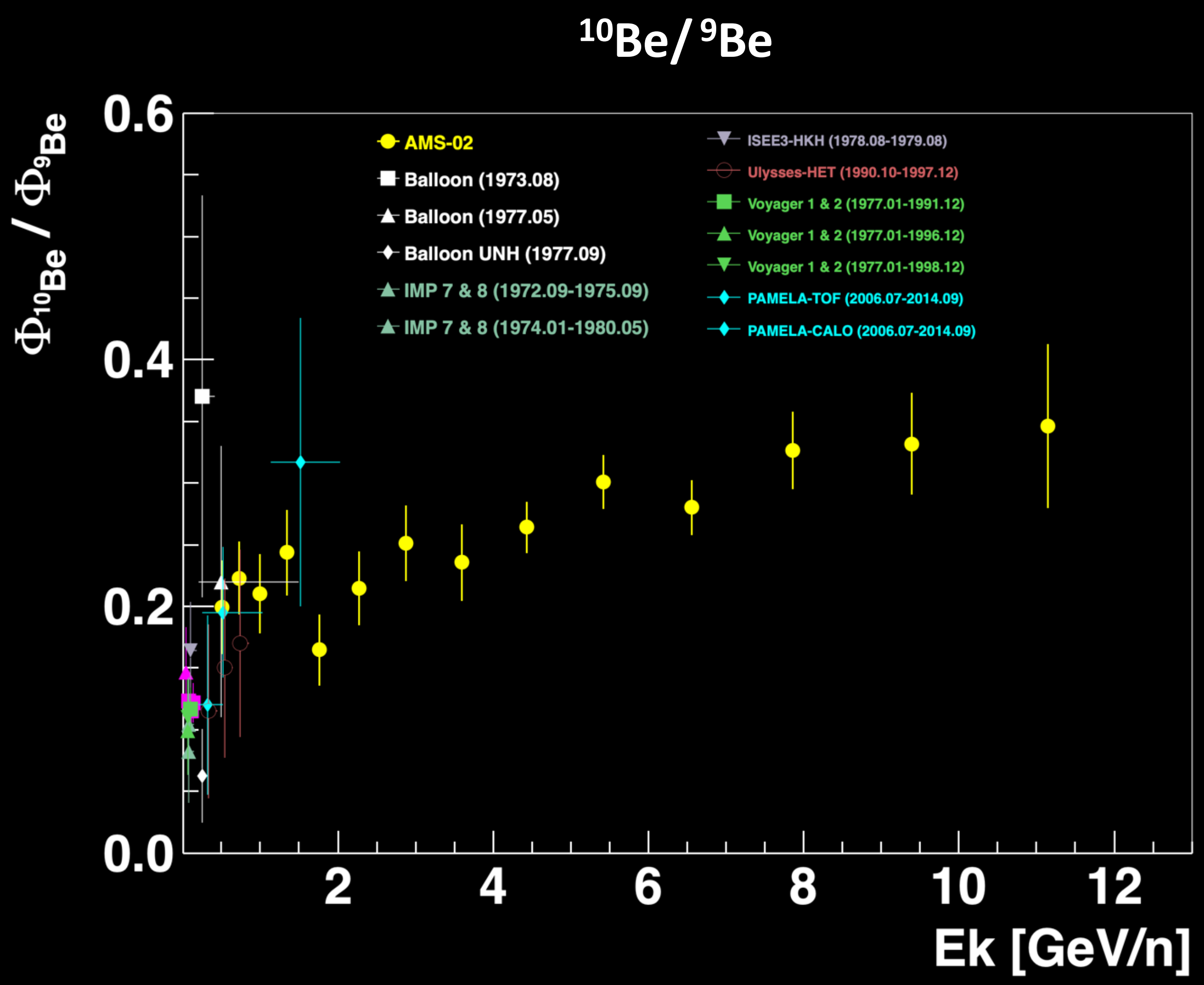
Beryllium Isotope Flux Ratios vs Kinetic Energy





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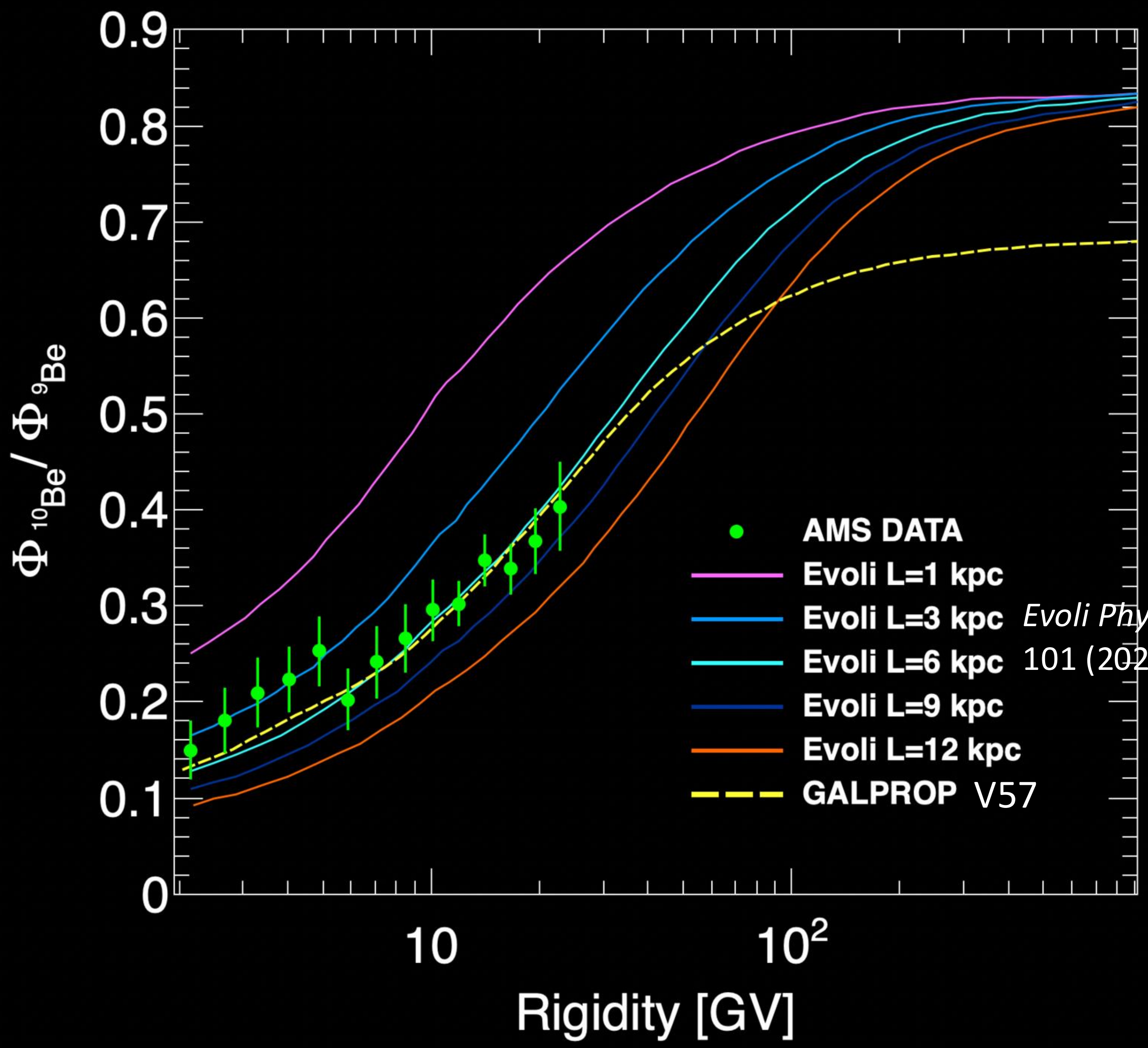
Comparison with models



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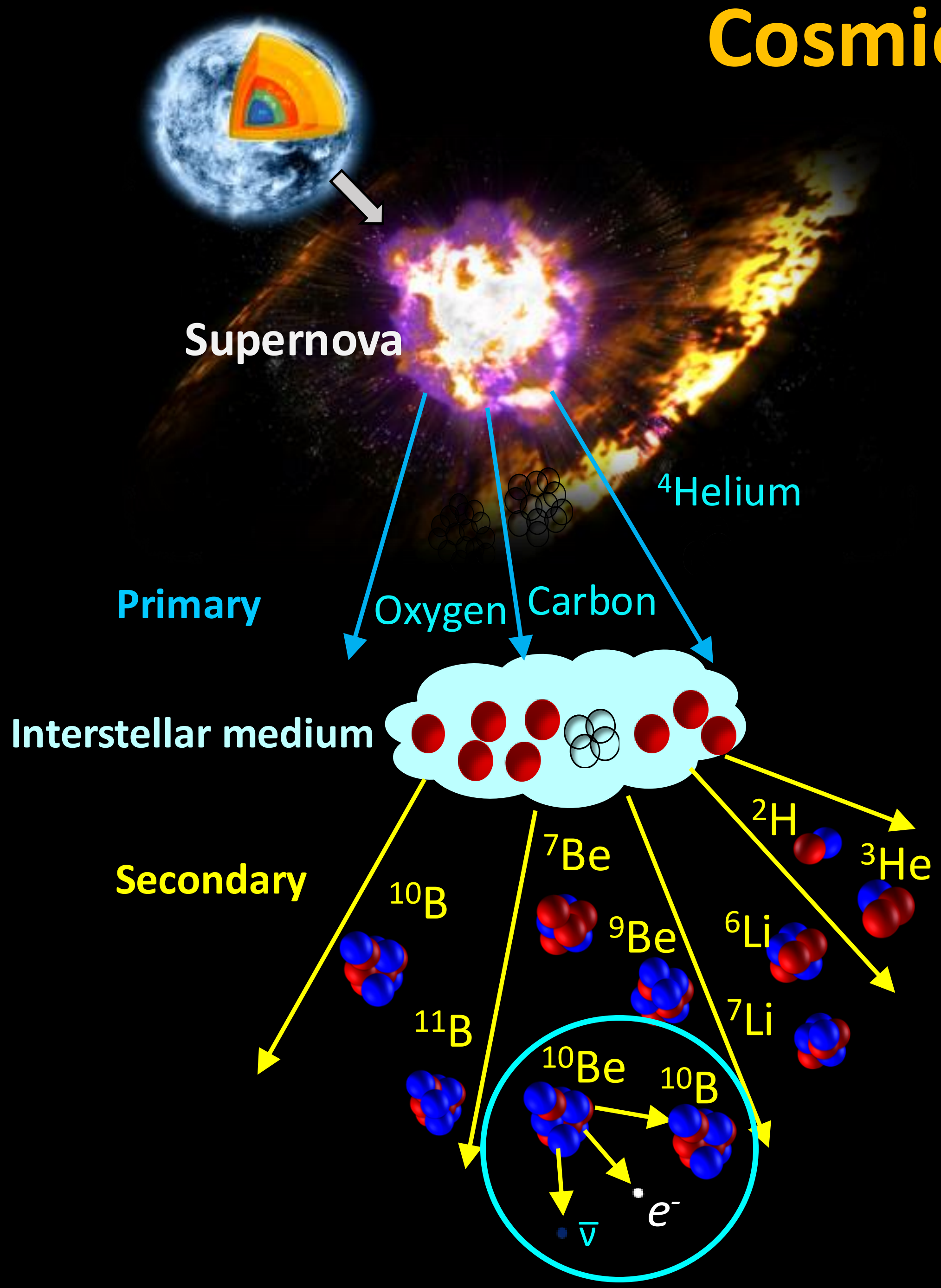
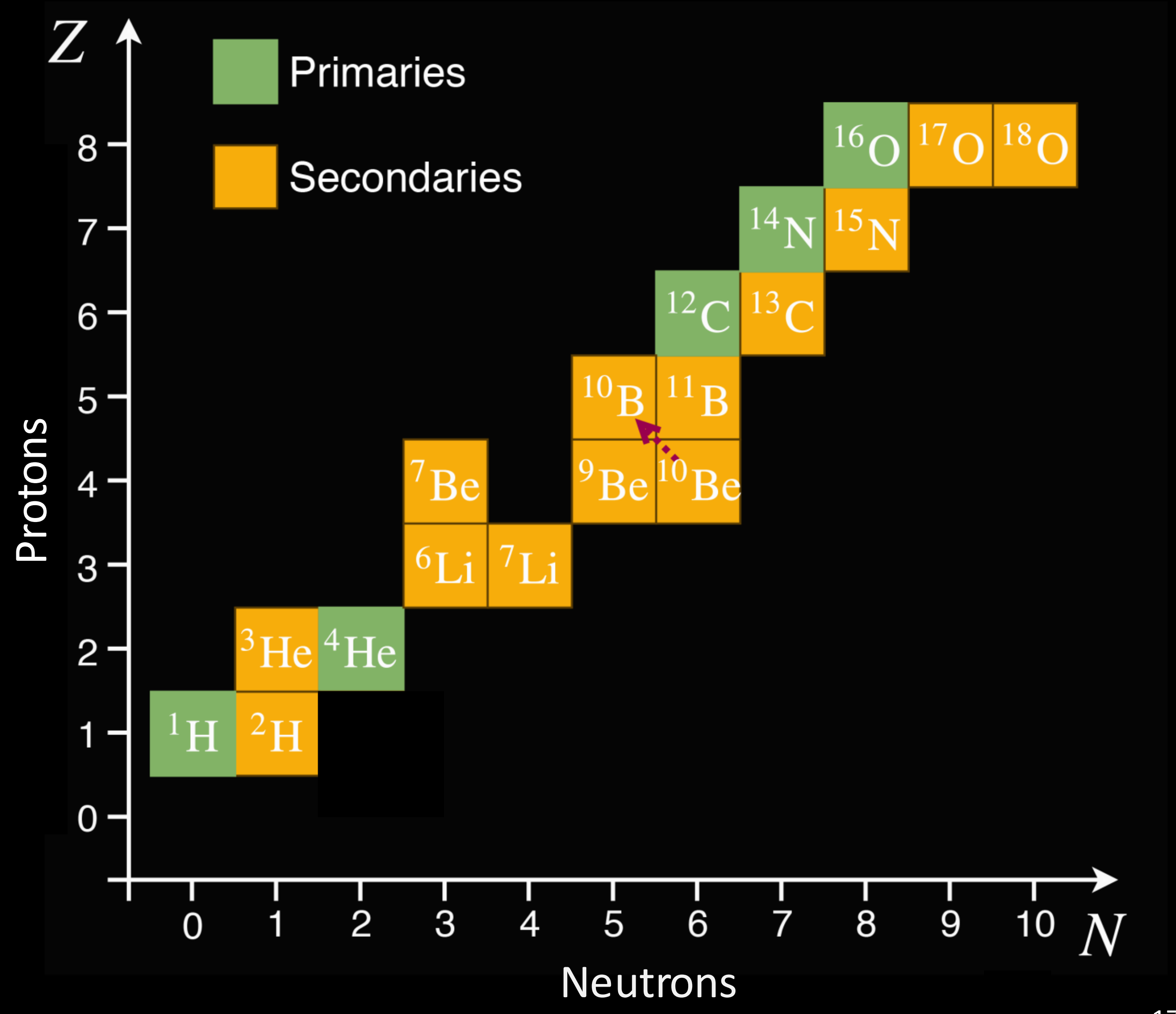
Summary

- Be isotopes carry unique information of cosmic rays propagation time in the Galaxy or the Galactic halo size.
- AMS measured cosmic-ray Be isotope fluxes based on 0.7 million Be nuclei.
- The AMS measurements cover the energy range from 0.4 GeV/n to 12 GeV/n, of which above 2 GeV is uncharted by previous experiments.
- AMS is extending the Be isotope measurement to higher energy, which is crucial for the understanding of the galactic halo size.

Cosmic-ray Light Isotopes





Isotope Fluxes

$$\Phi_i^a = \frac{N_i^a}{A_i^a \times \varepsilon_i^{\text{trigger}} \times T_i^a \times \Delta E_{k,i}}$$

- Φ_i^a: Isotropic isotope flux
- N_i^a: Isotope event number after background subtraction and bin-to-bin migration correction.
- A_i^a: Effective acceptance calculated using MC and corrected for data/MC efficiency difference
- $\varepsilon_i^{\text{trigger}}$: Trigger efficiency
- T_i^a: Exposure time
- $\Delta E_{k,i}$: Bin width

Validation of Mass Templates

- Mass templates are obtained from Monte Carlo simulated events.
- Extensive checks of mass templates are done.

Example: check of mass template using the geomagnetic cutoff