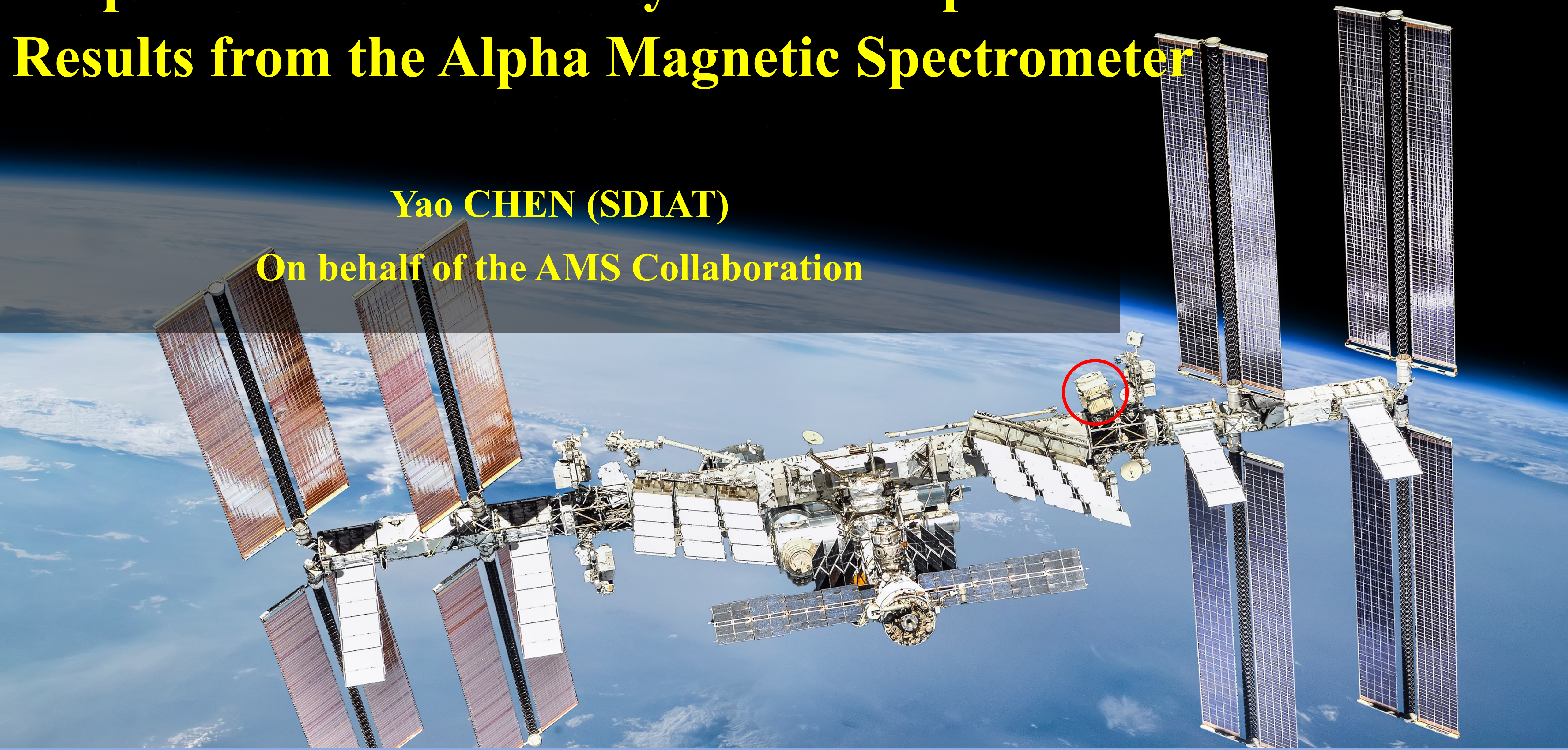
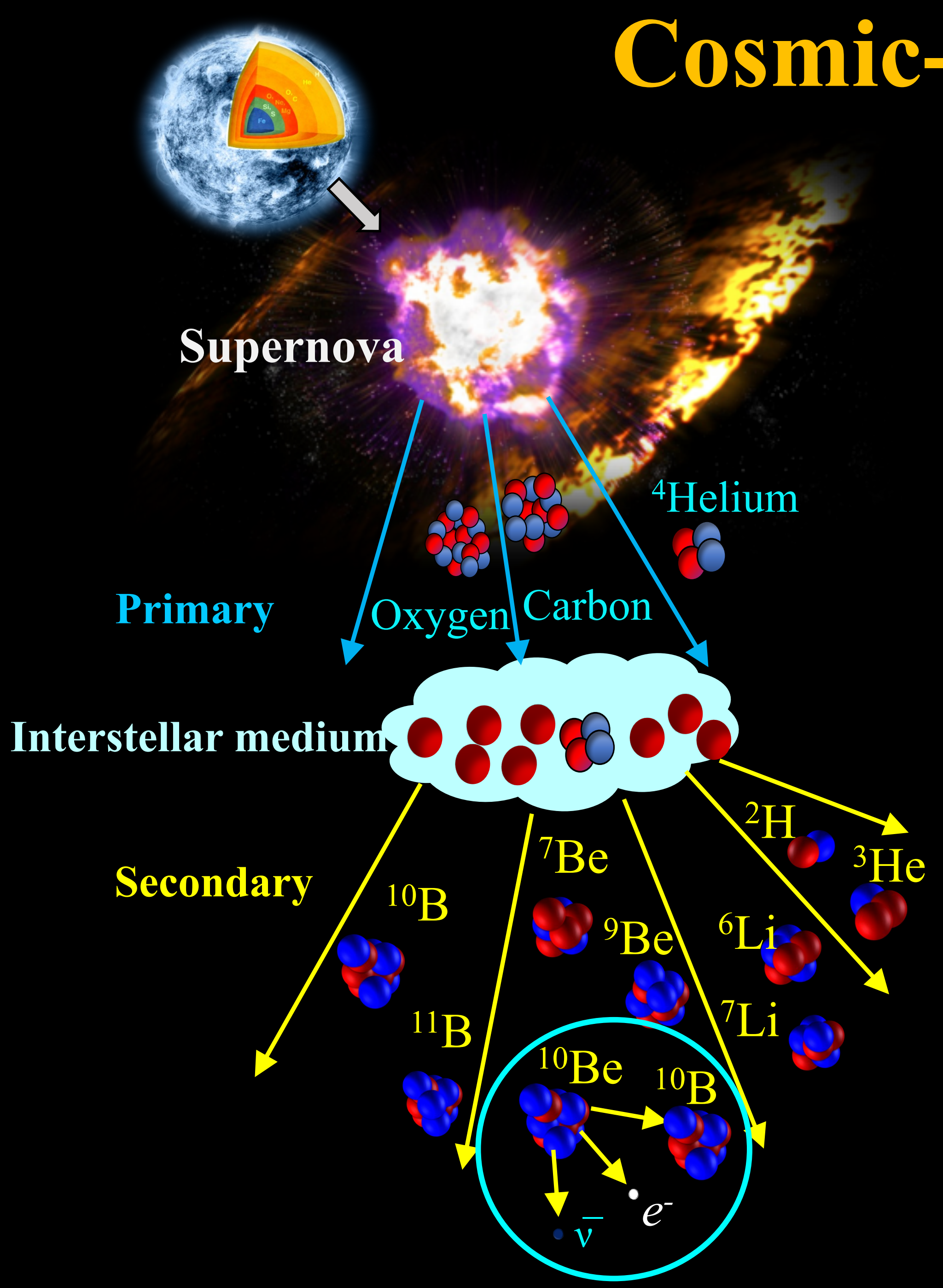
Properties of Cosmic Beryllium Isotopes: Results from the Alpha Magnetic Spectrometer



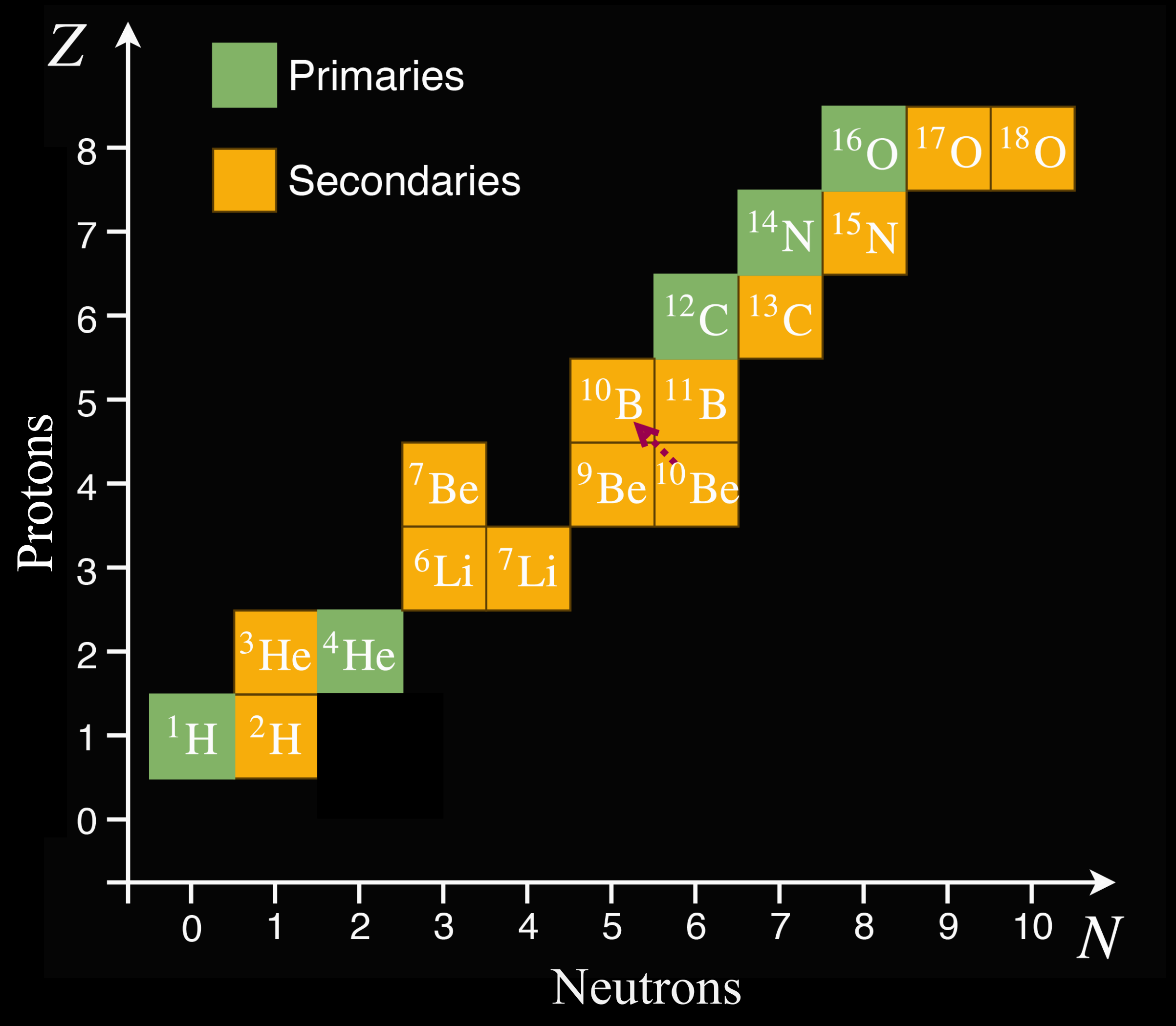
Yao CHEN (SDIAT)

On behalf of the AMS Collaboration

Cosmic-ray Light Isotopes



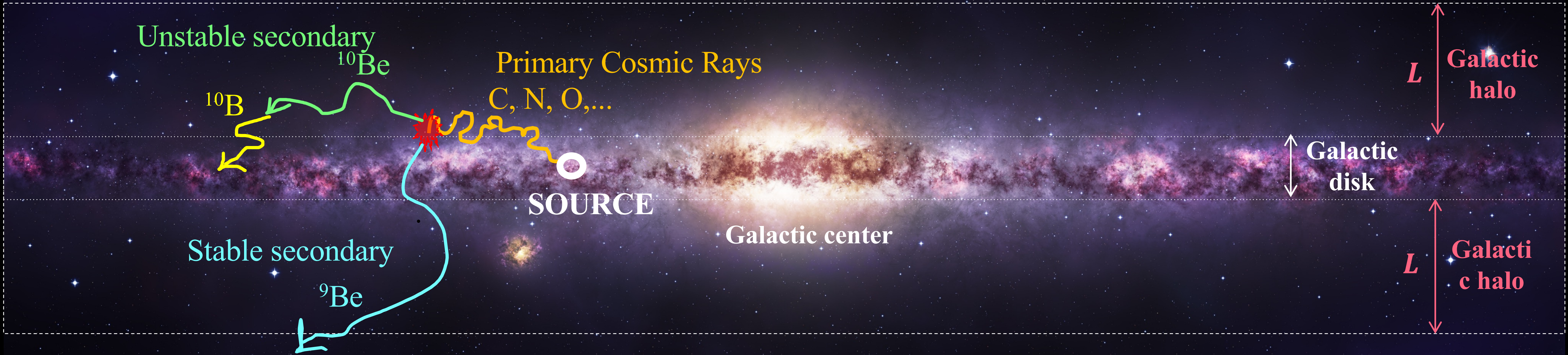
Cosmic ray isotope fluxes provide unique insight.



Cosmic-ray Beryllium isotopes

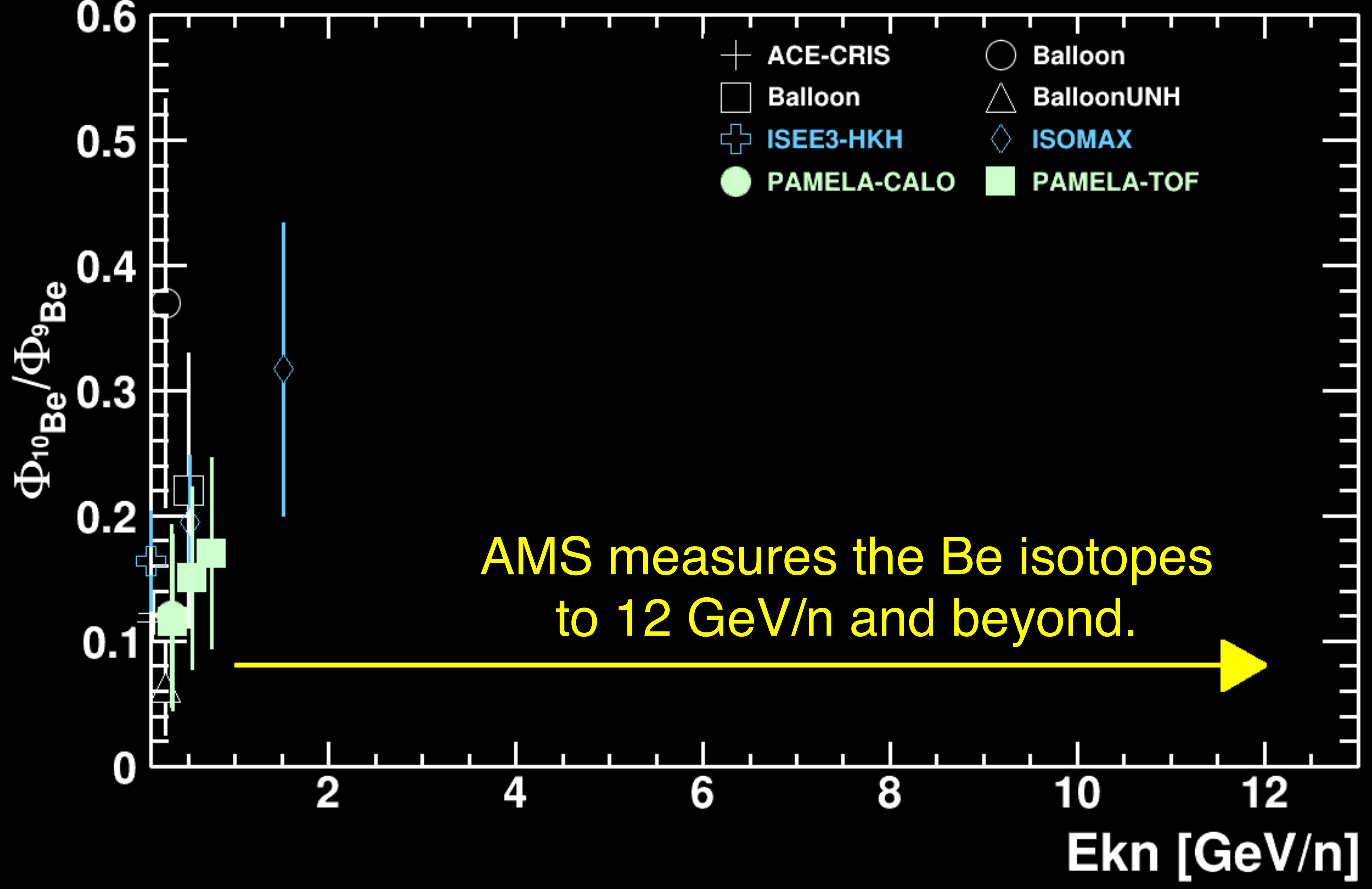
Beryllium nuclei are secondary cosmic rays.
They include three isotopes, two stable, ^{7}Be and ^{9}Be, and one unstable, ^{10}Be.

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

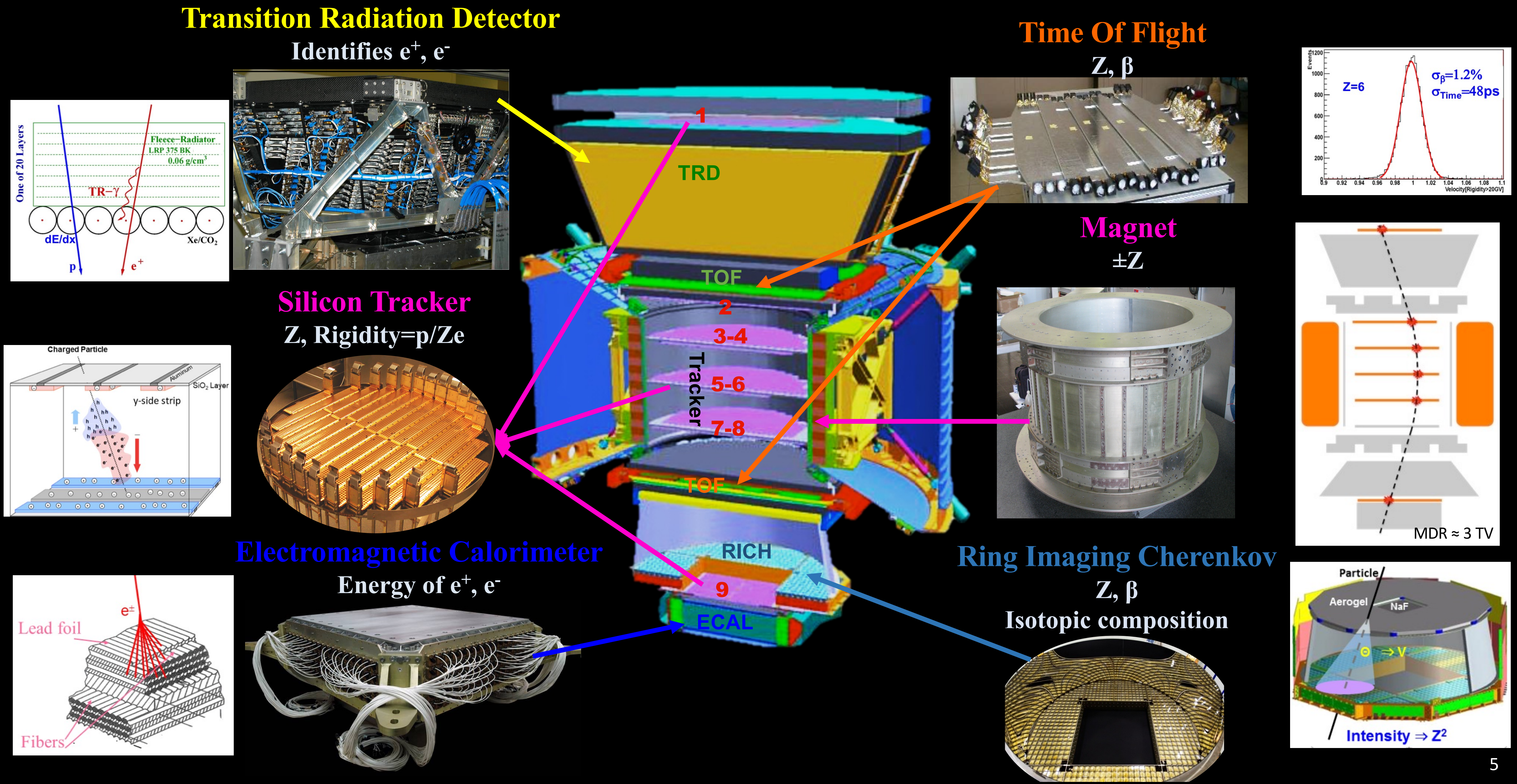


The ratio of unstable-to-stable secondary cosmic rays ^{10}Be/^{9}Be measures the Galactic halo size L,
which determines the galactic cosmic ray propagation volume .

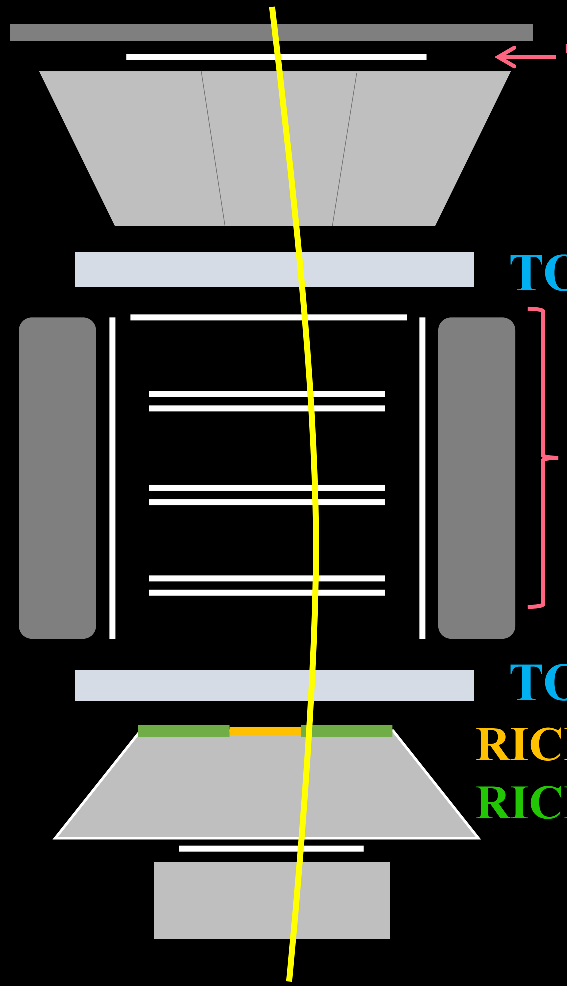
Cosmic $^{10}Be/^{9}Be$ Flux Ratio Before AMS-02



AMS-02: A TeV precision magnetic spectrometer in space



Key Detector for Measuring Isotopes with AMS-02



- AMS mass resolution depends on rigidity $(R = P/Z)$ and velocity ($\boldsymbol{\beta}$) resolutions:

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

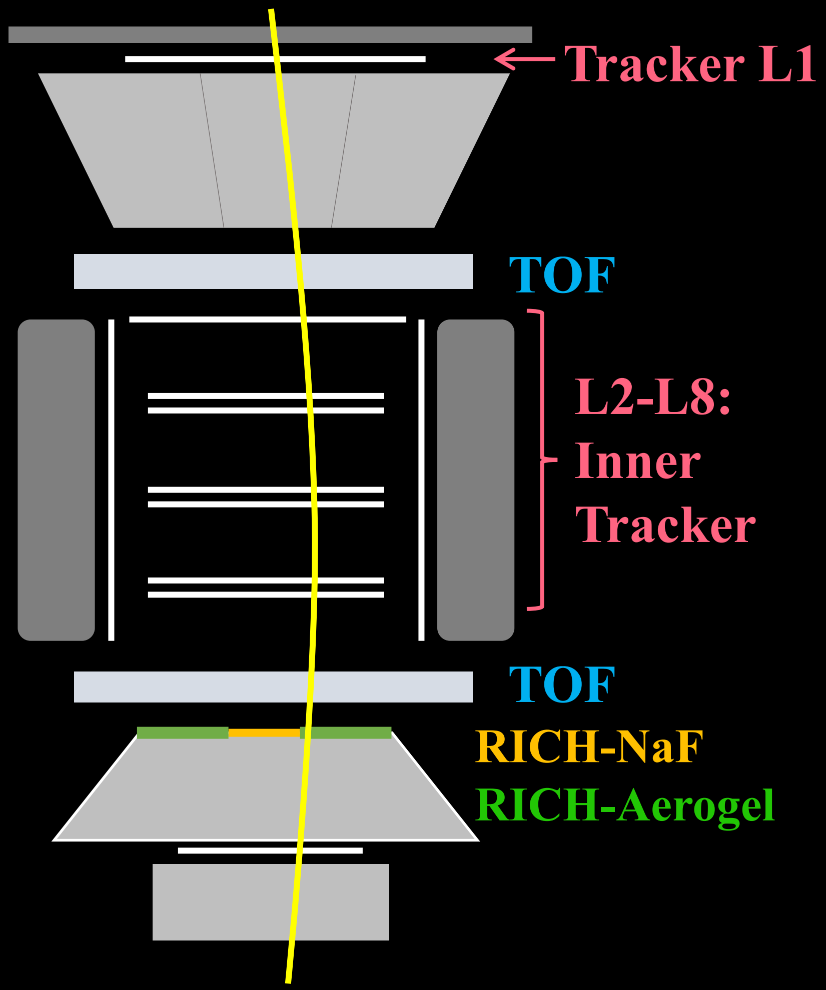
$$\boldsymbol{\gamma = 1/\sqrt{1-\beta^2}}$$

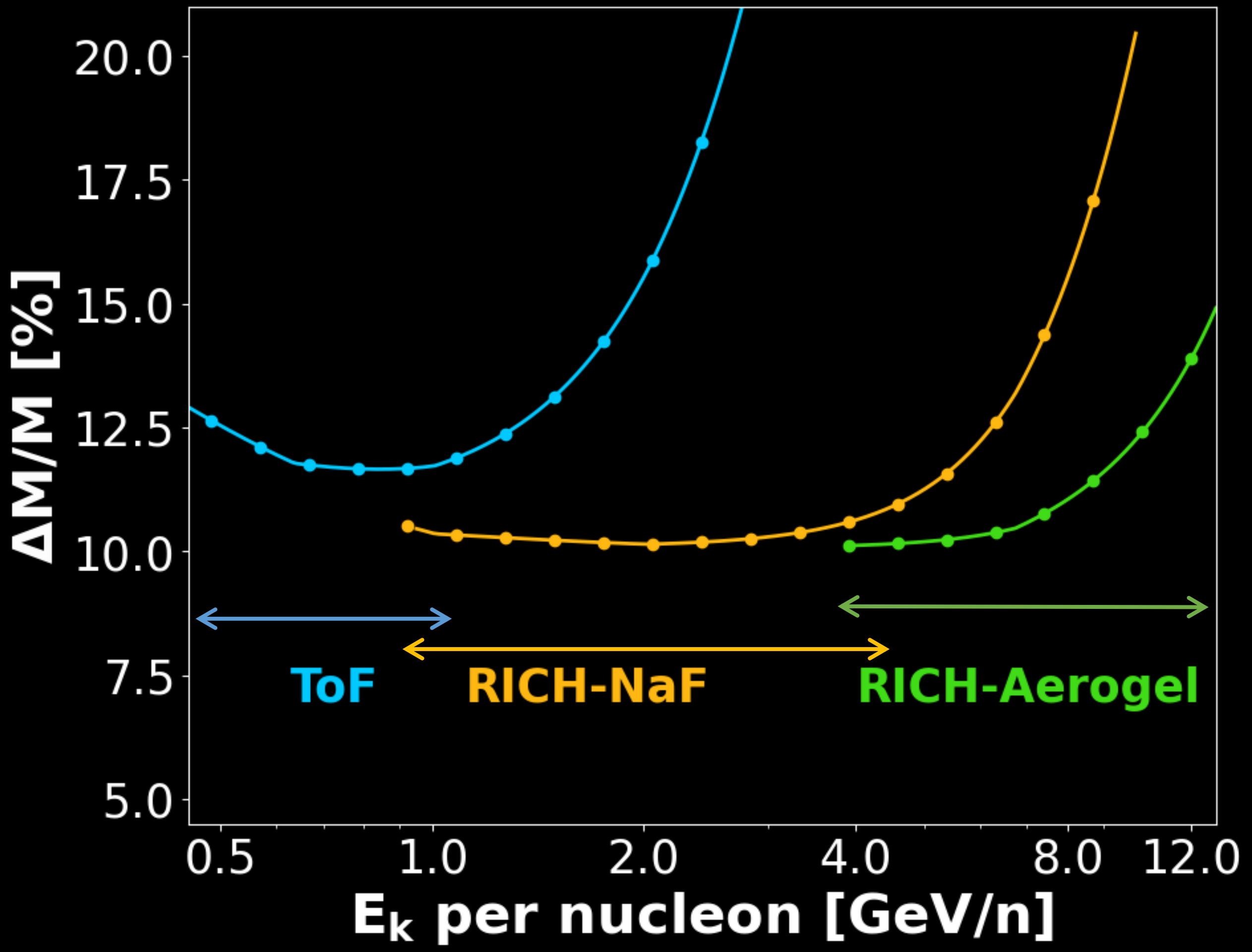
- R measured with Tracker :
  - $\boldsymbol{\Delta R/R \sim 10\%}$ below 20 GV
- $\boldsymbol{\beta}$ measurements:

	E_k/n range (GeV/n)	$\boldsymbol{\Delta\beta/\beta}$
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

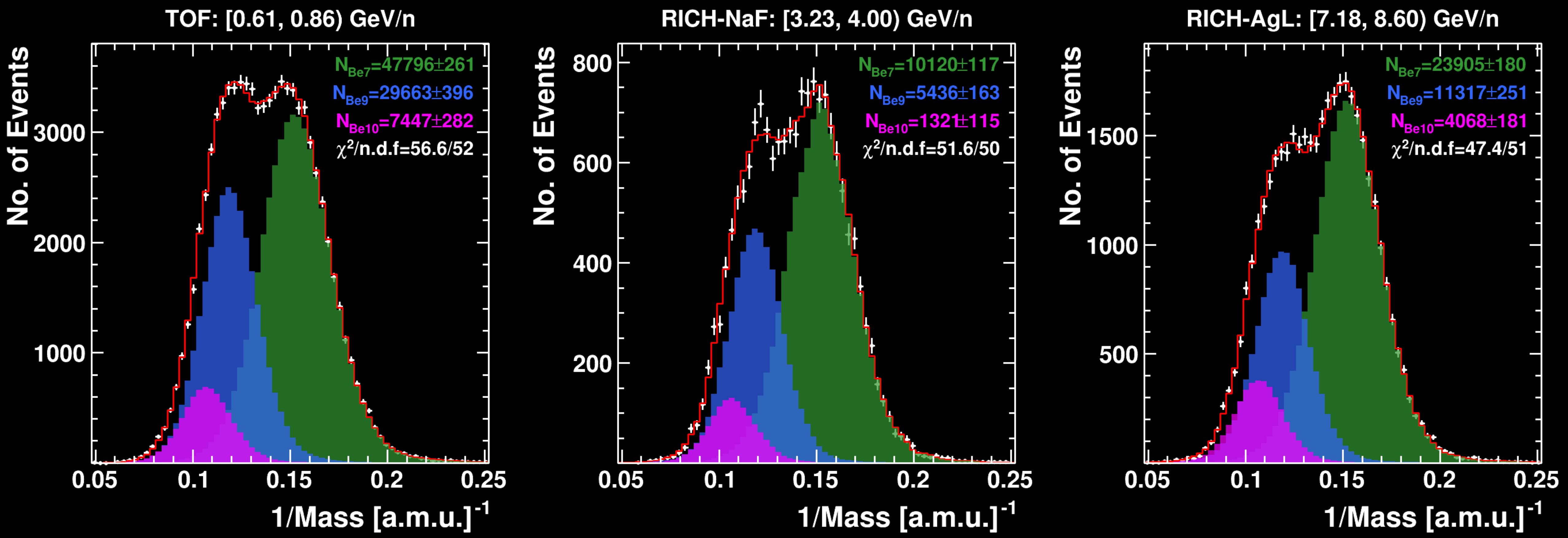
$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left(\frac{1}{1-\beta^2}\cdot\frac{\Delta\beta}{\beta}\right)^2}$$





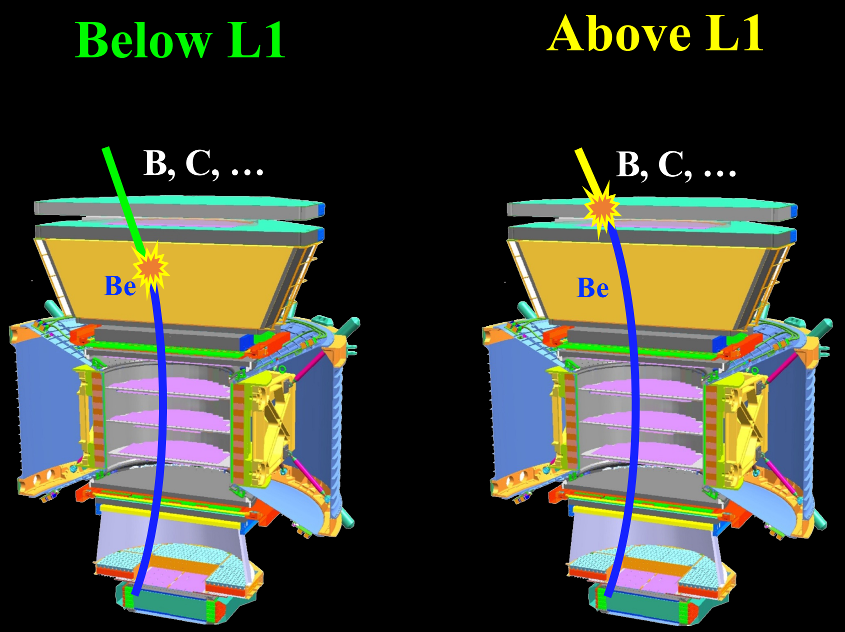
Cross validation with TOF, RICH-NaF and Rich-Aerogel.

Mass Template Fit to for Be Isotope Composition



In total, we have analyzed 0.7 million beryllium events.

Background from Heavier Nuclei Fragmentation



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

Background contamination | Flux ratio | Acceptance ratio with Be selection

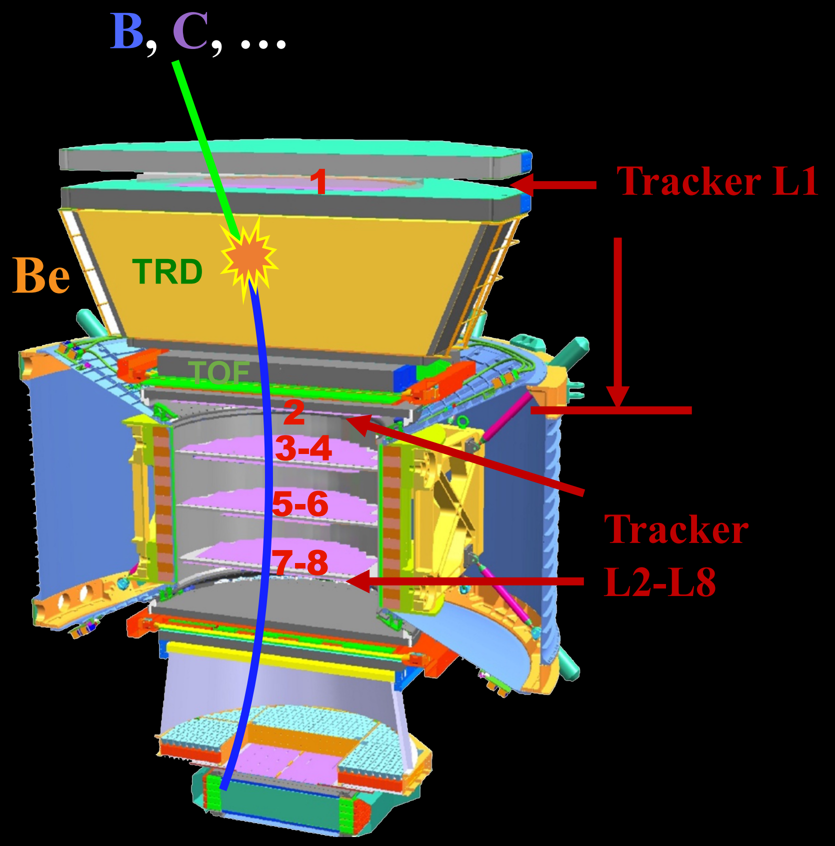
From heavier nuclei (Boron, Carbon……):

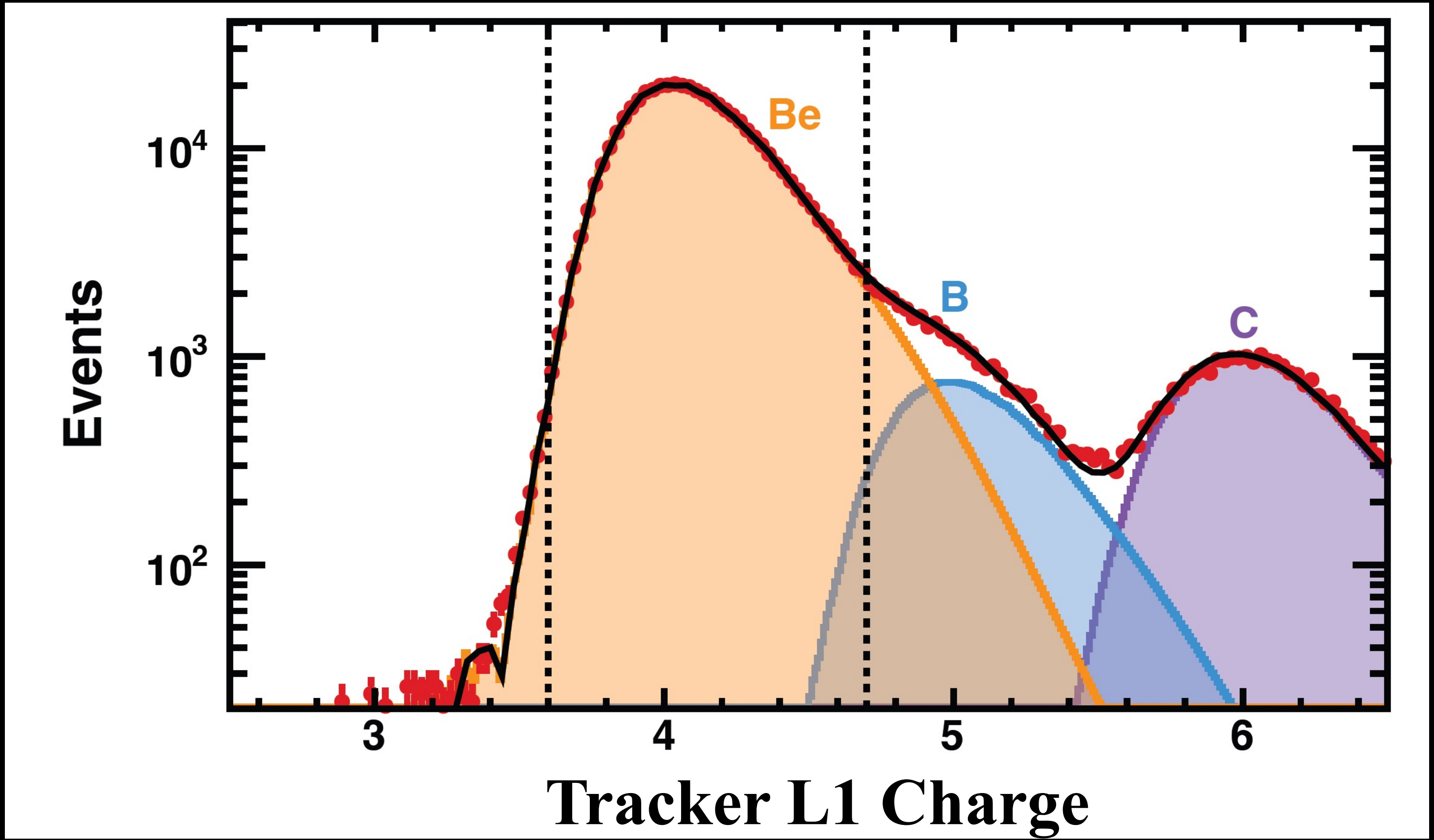
- **Below L1 background:** from interactions with materials between Tracker L1 and L2.
- **Above L1 background:** from interactions with supporting structures above Tracker L1.

From Be isotope:

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

Estimation of Below-L1 Background



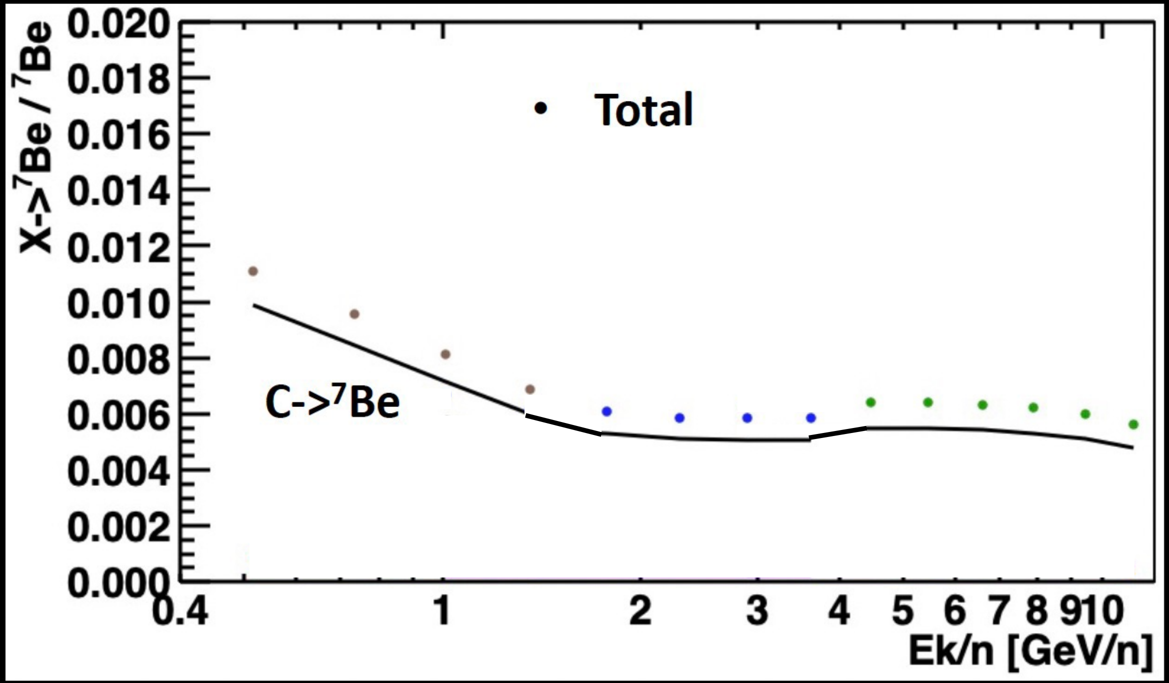


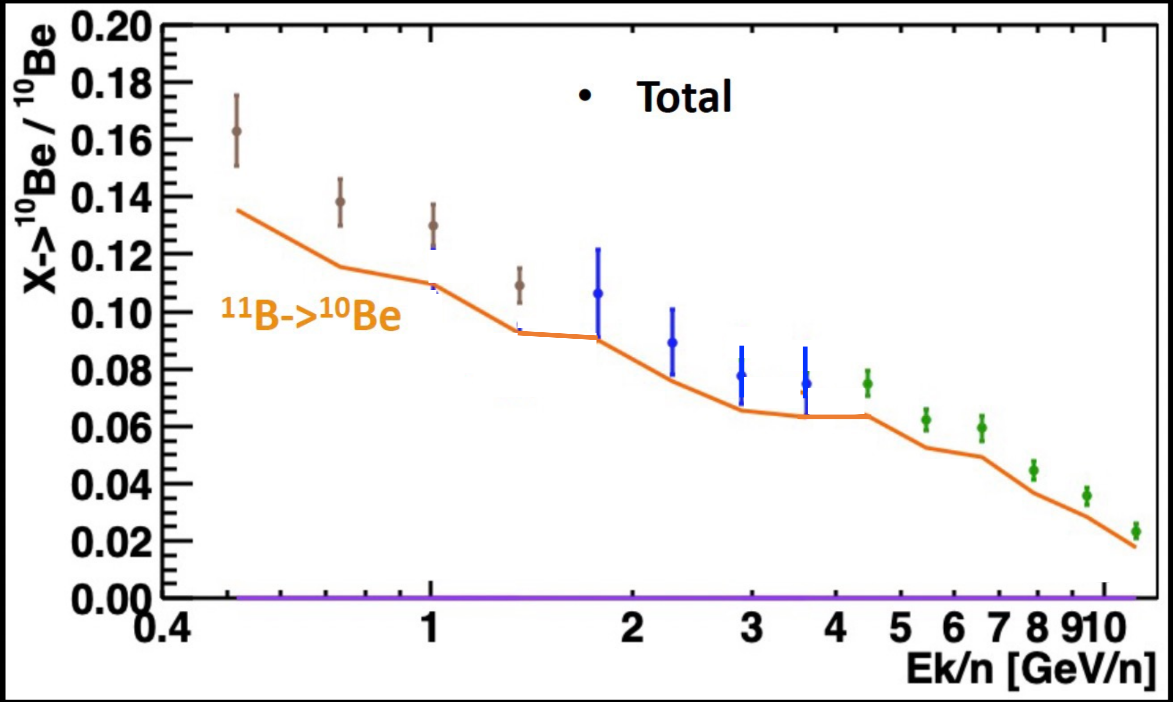
Residual background found to be <0.3 %

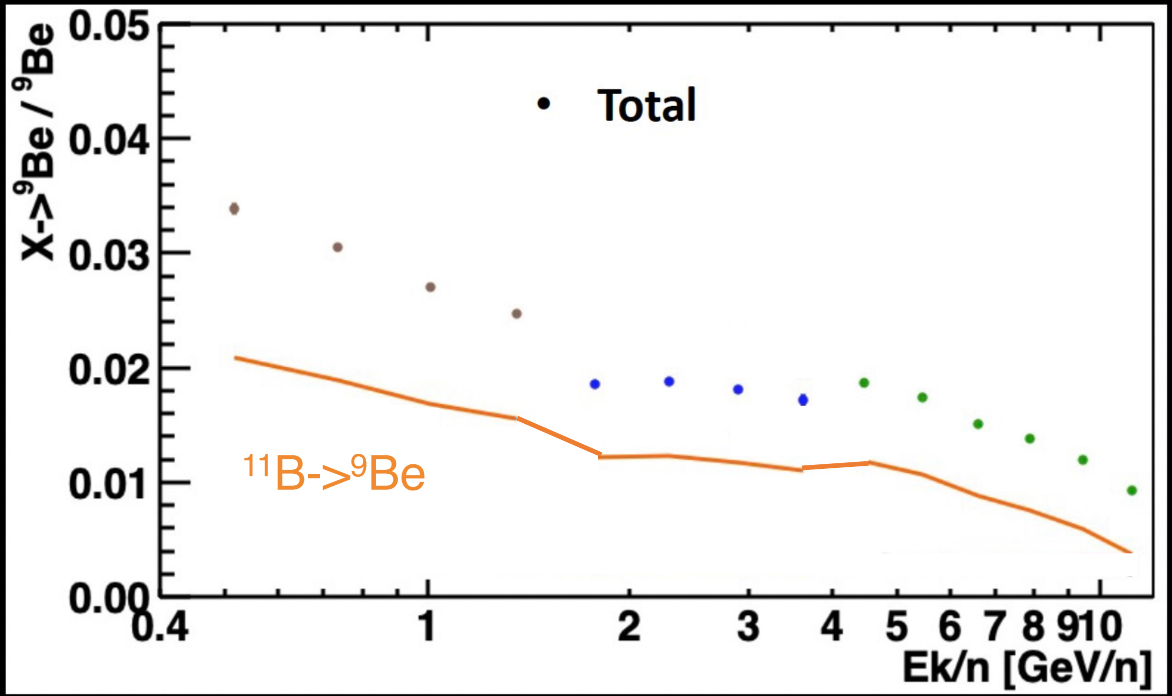
Estimation of Above-L1 Background

The background mainly from boron and carbon.

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







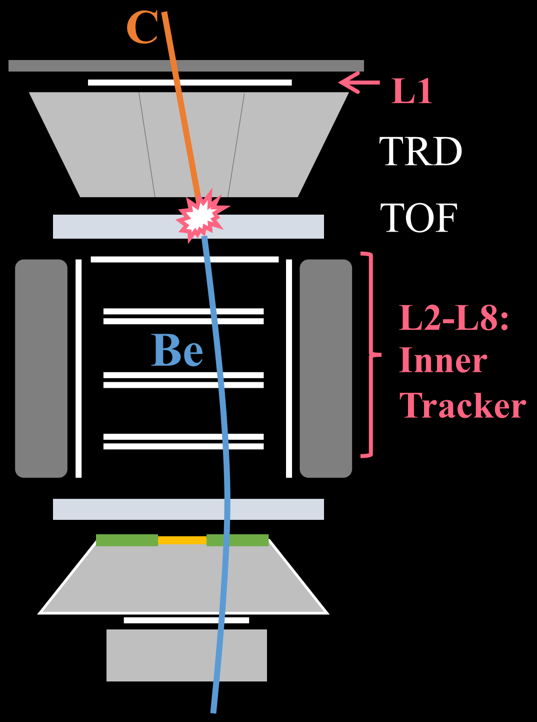
Validation of Fragmentation Cross Sections

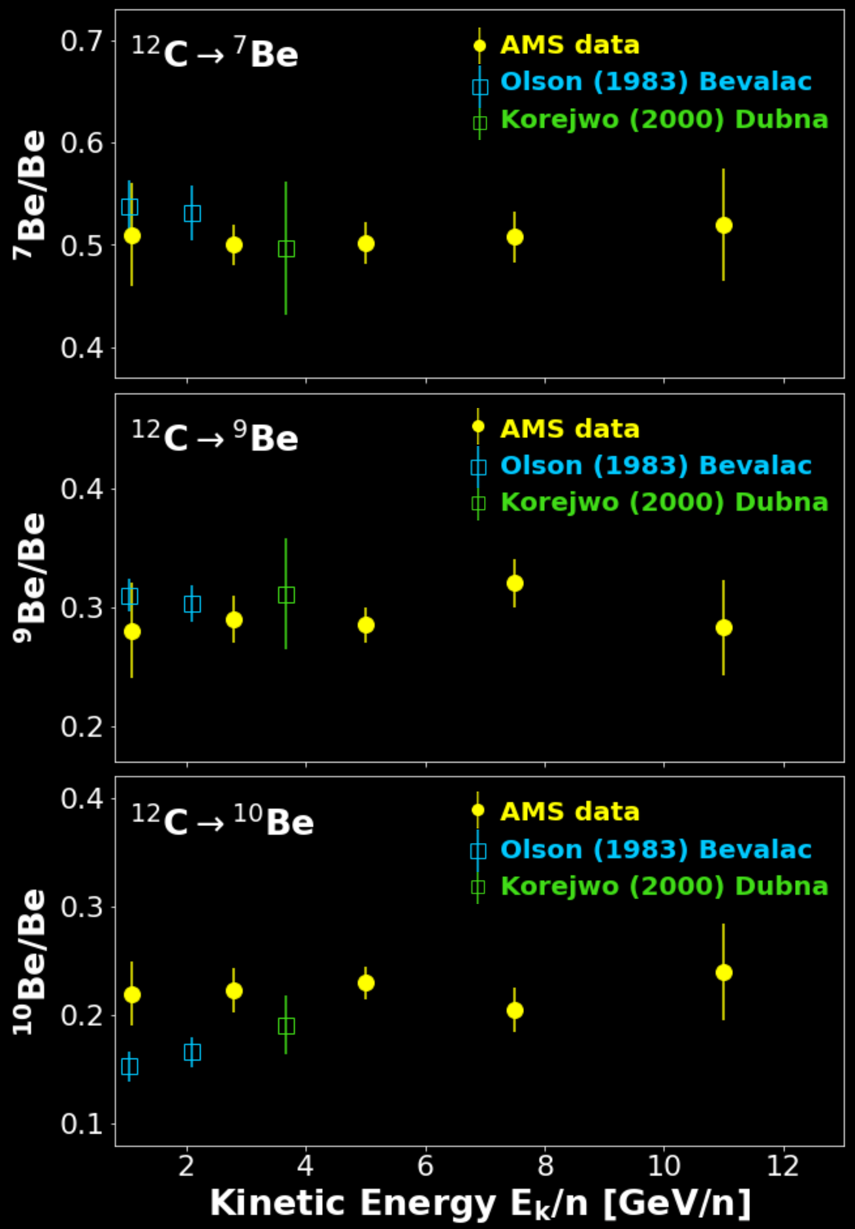
Measurements of nuclei interaction cross sections were limited to few projectiles and low energy.

With cosmic ray data,

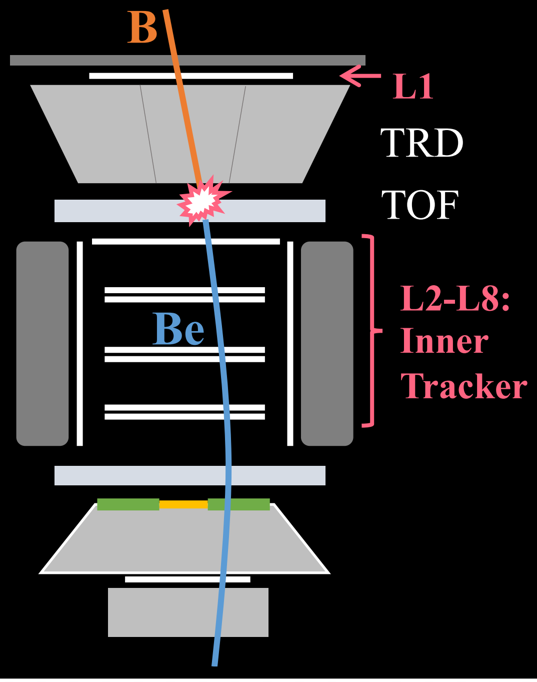
AMS measured the total and isotopic fragmentation cross sections

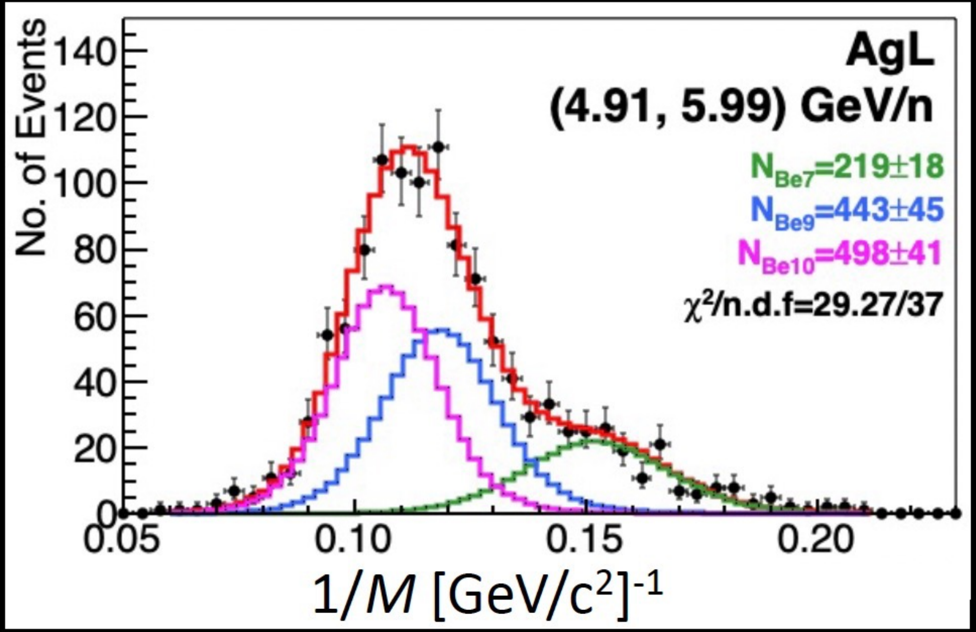
and improved the MC simulation.

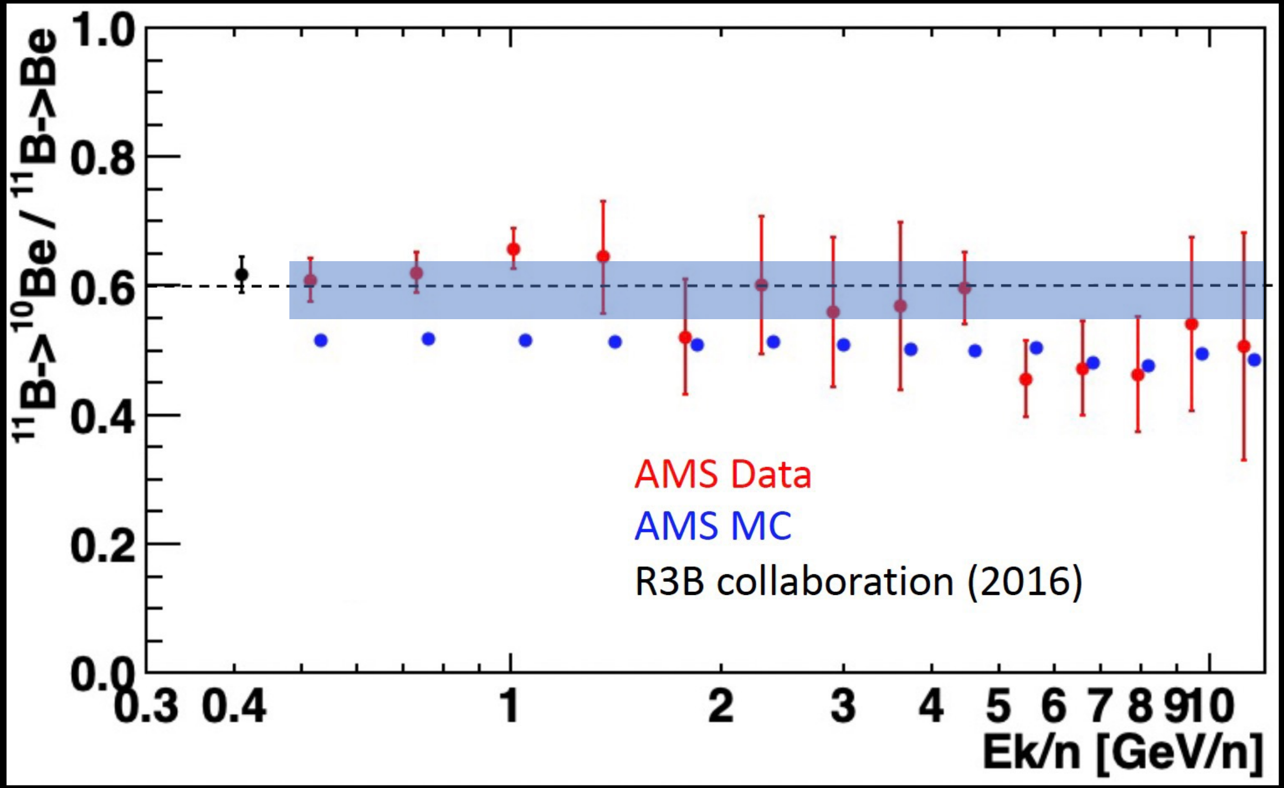




Measurement of $^{11}B \rightarrow ^{10}Be$ Fragmentation Cross Section

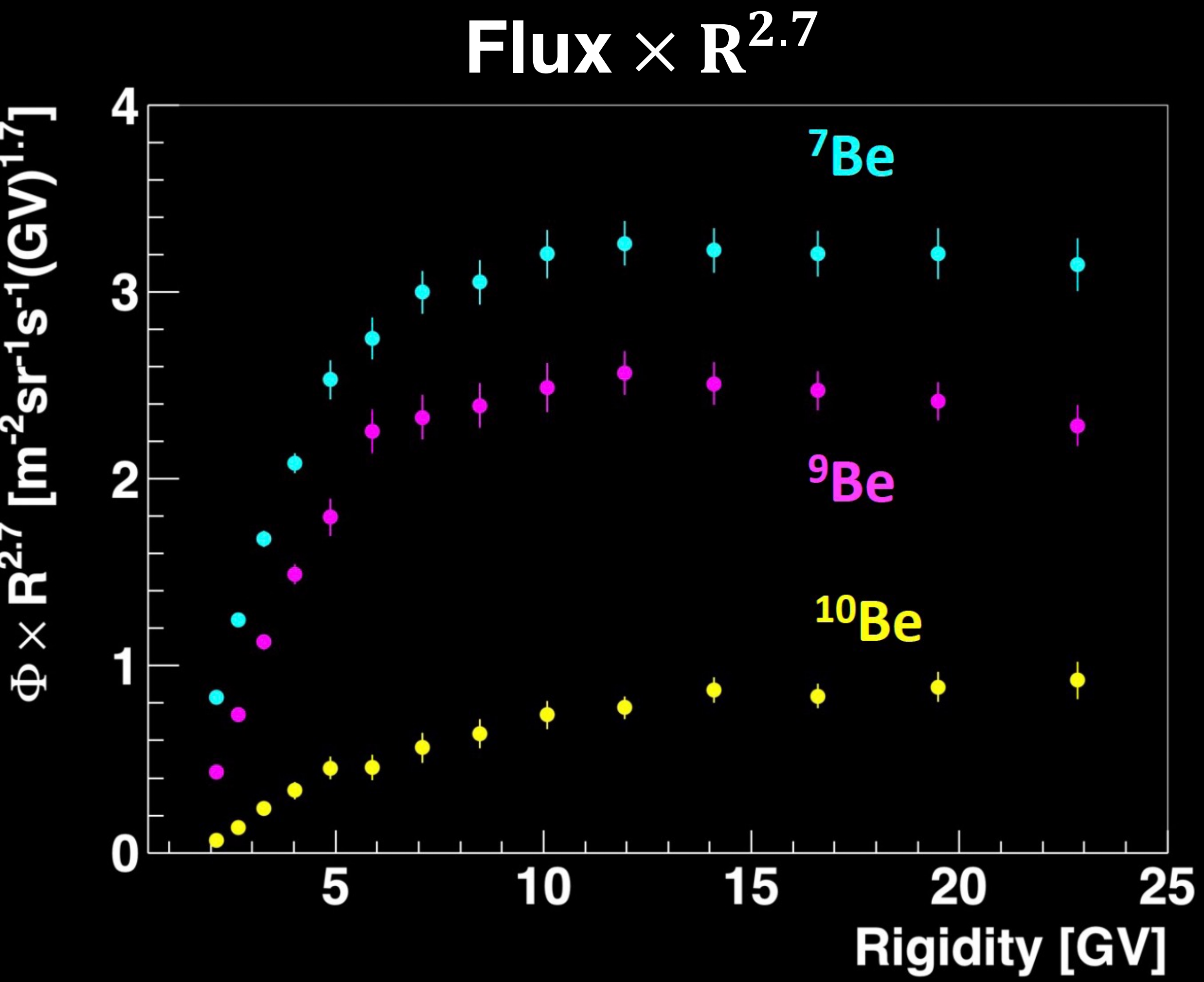


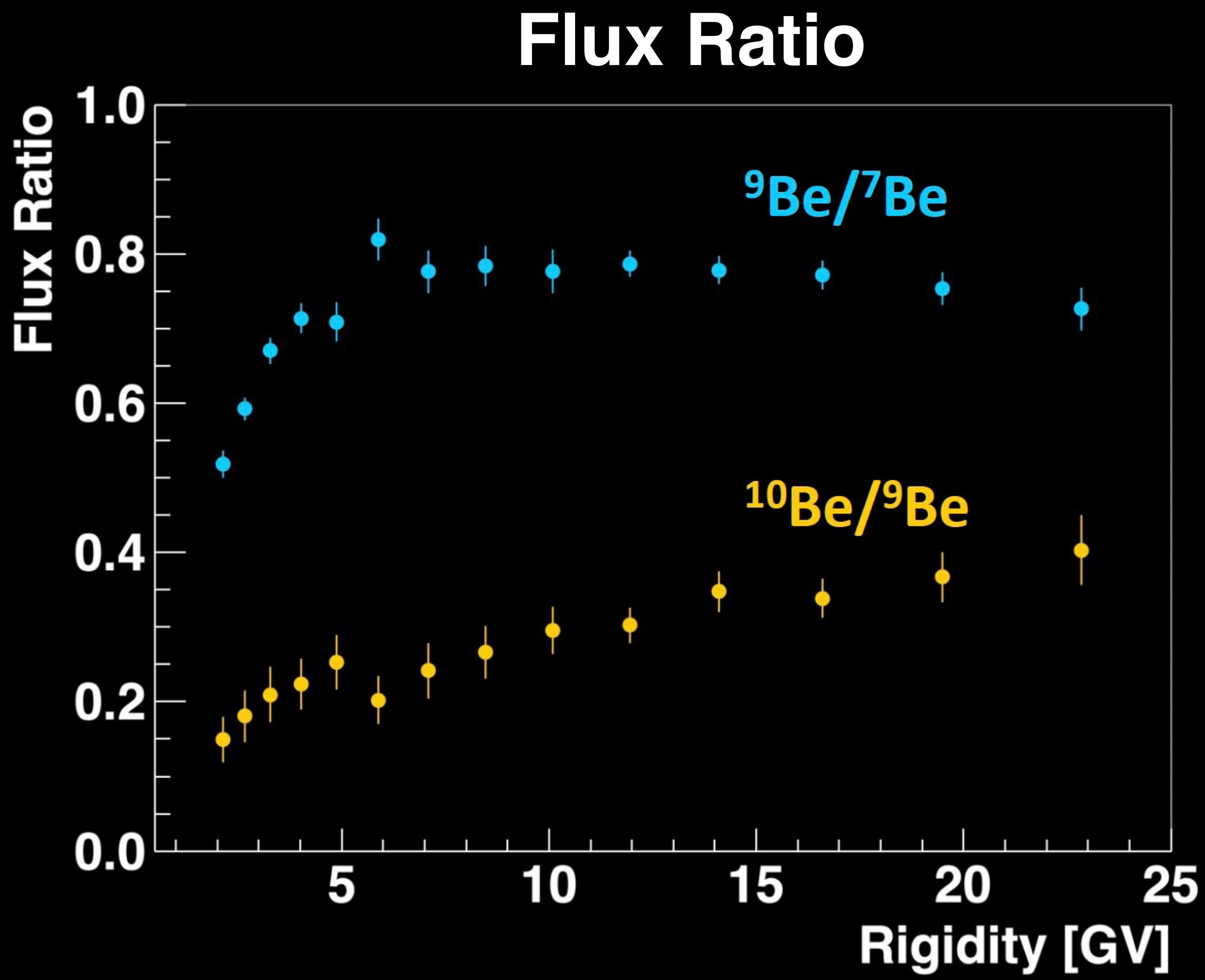




AMS results extrapolation to low energy agrees with R3B results.

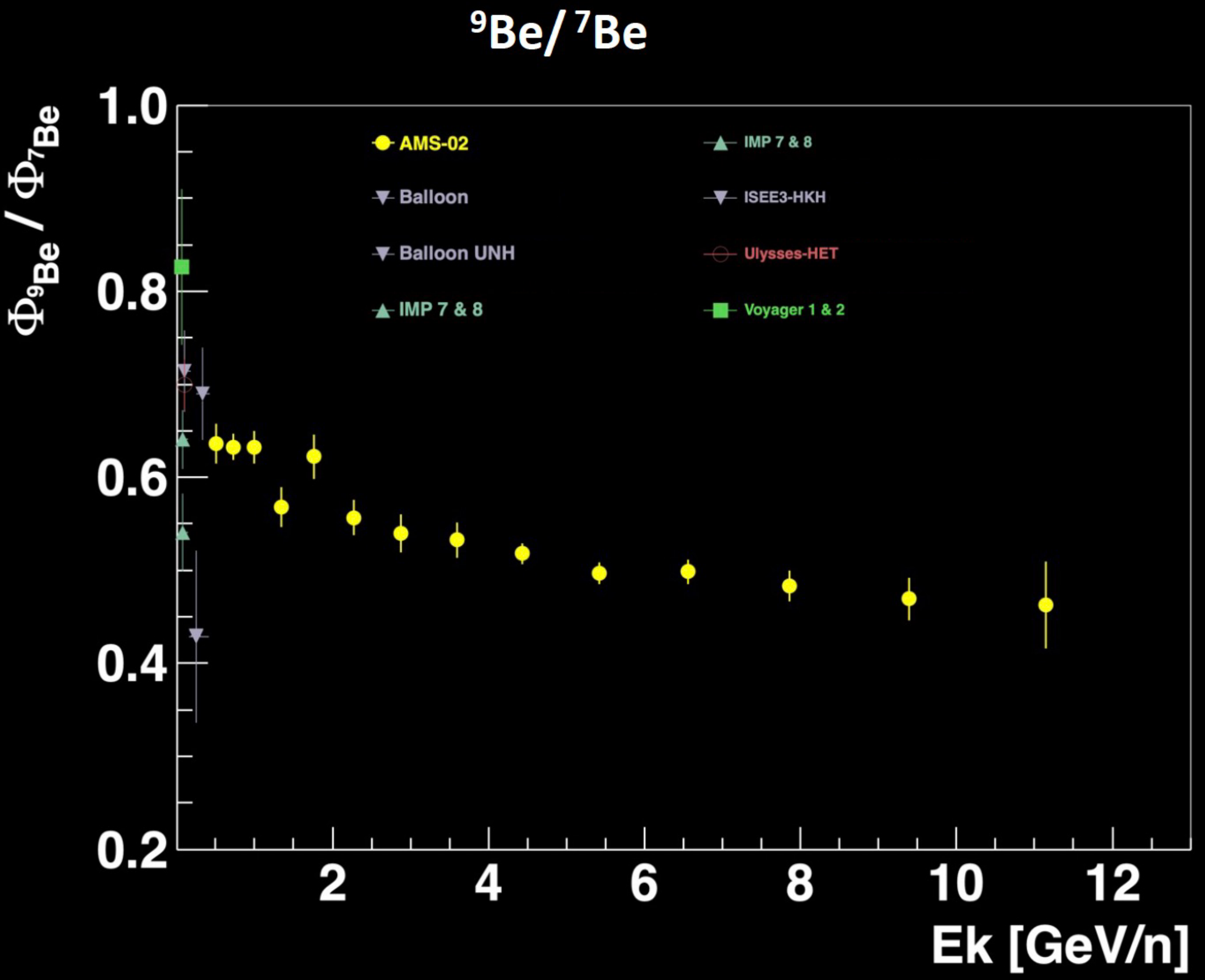
Beryllium Isotope Fluxes and Ratios vs Rigidity

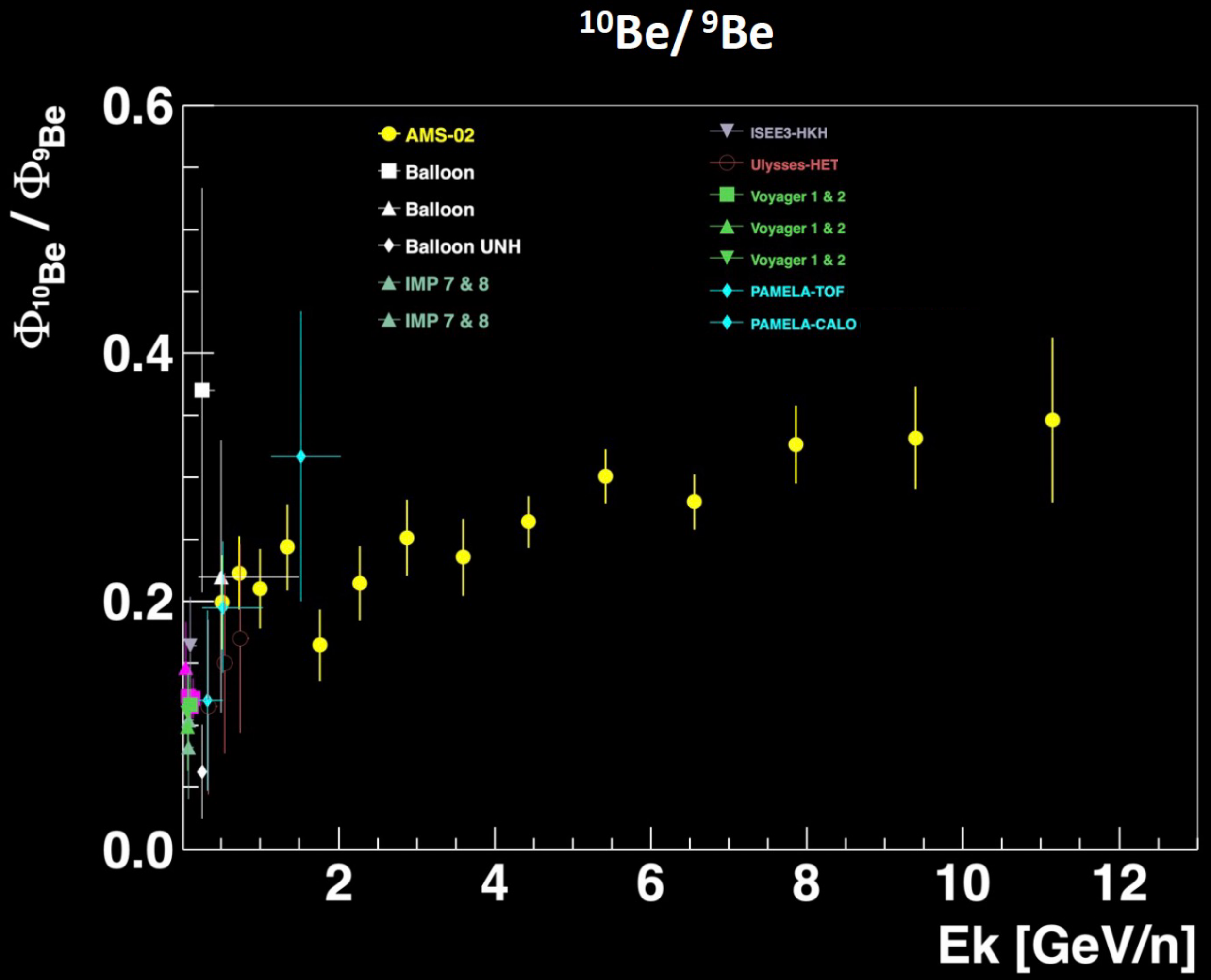




(Preliminary data, refer to upcoming AMS publication)

Beryllium Isotope Flux Ratios

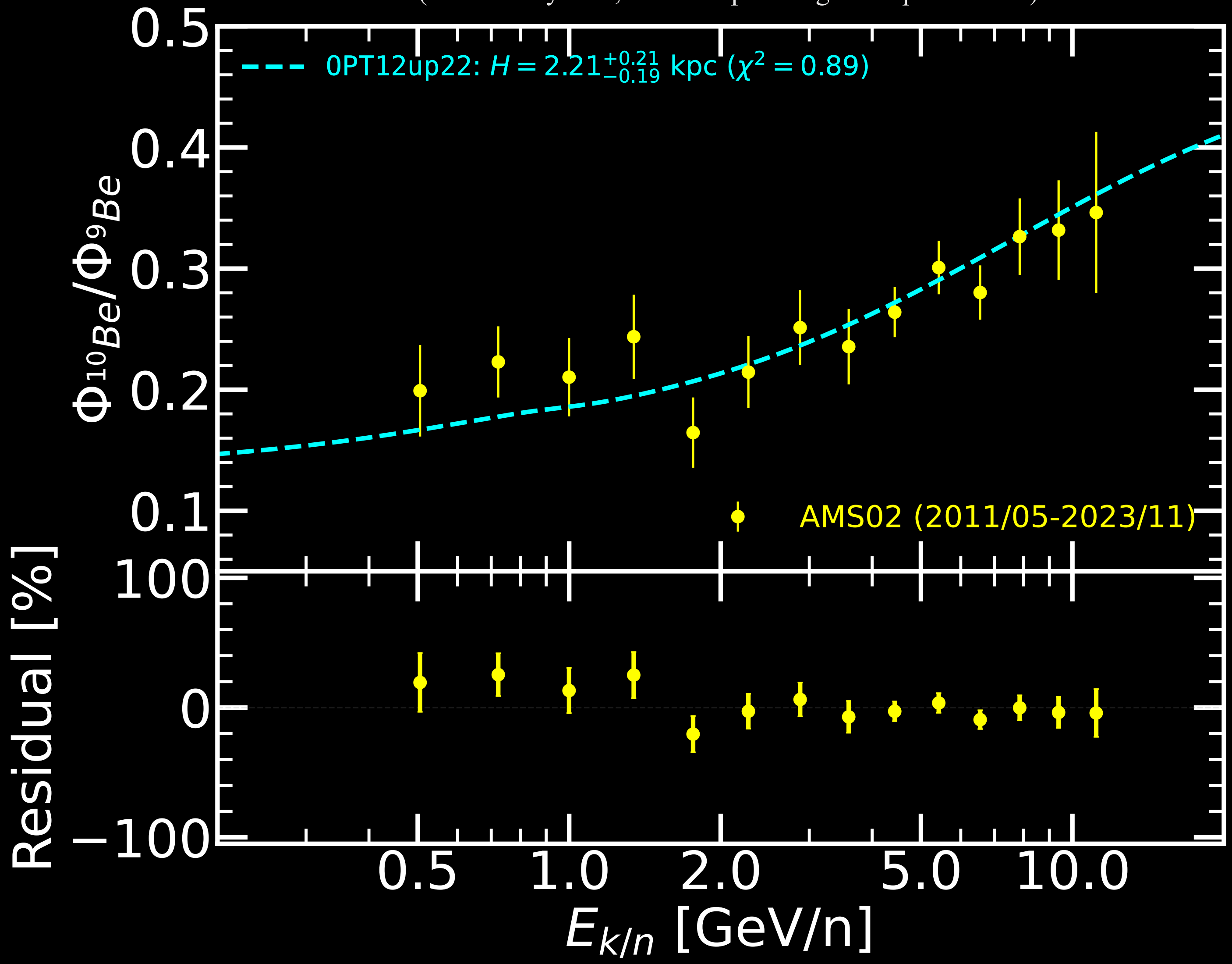




(Preliminary data, refer to upcoming AMS publication)

Implication for the Halo Size

(Preliminary data, refer to upcoming AMS publication)



- **The fits to the USINE model shows that the Halo size depends strongly on the high energy asymptotical value F_{he}**

- **OPT12up22: updated with latest AMS nuclei measurements, F_{he}=0.51**

$$H = 2.21^{+0.29}_{-0.19}\ \text{kpc}\ (F_{he}=0.51)$$

D. Maurin et al. Astron. Astrophys., 2022, 667.

It is crucial to measure $^{10}Be/^{9}Be$ to the highest possible energy.

Summary

- **Be isotopes carry the unique information of cosmic ray 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 new measurement 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.**