ICHEP 2022
BOLOGNA

Properties of Cosmic Beryllium Isotopes

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On behalf of the AMS collaboration

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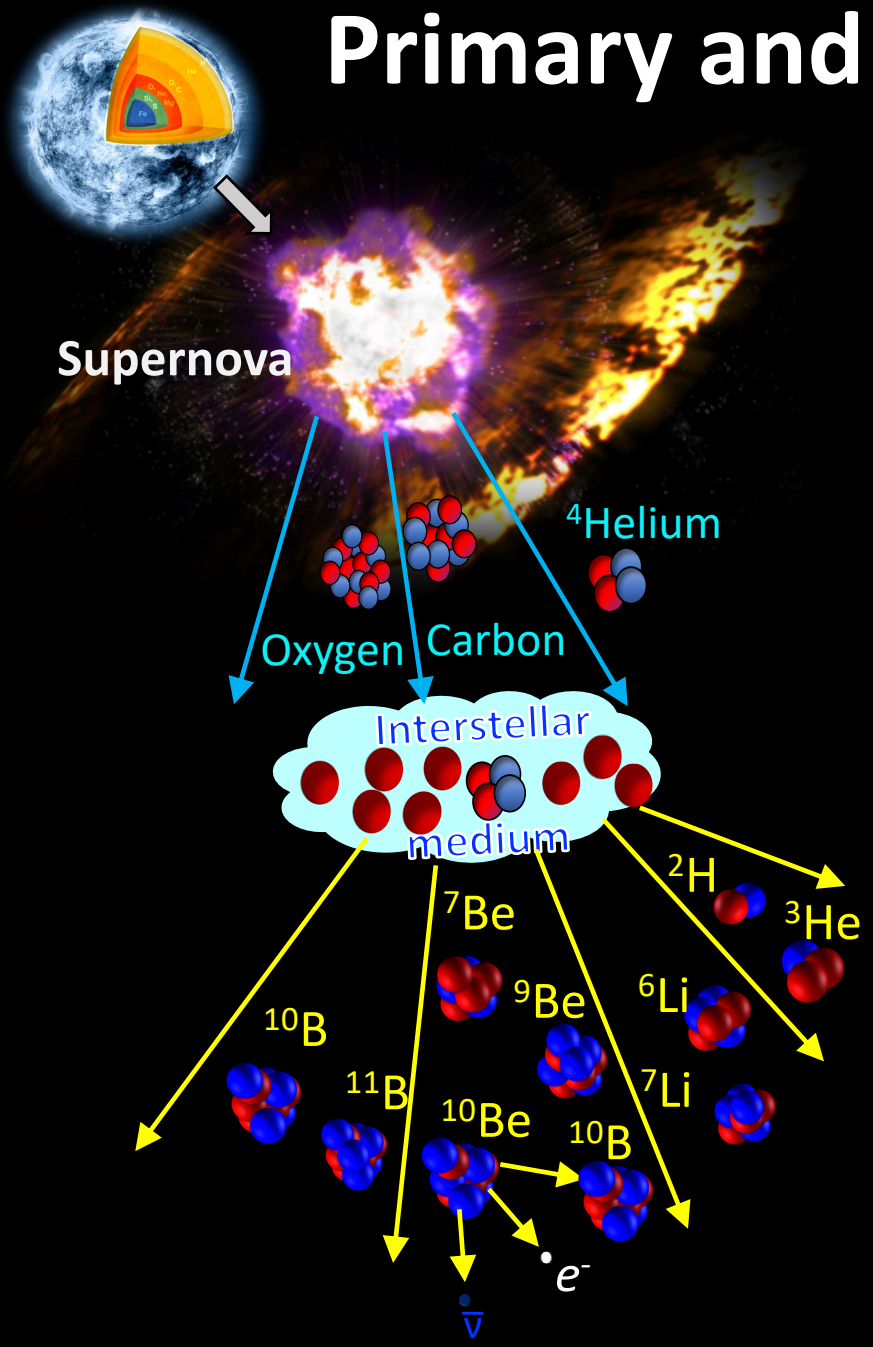
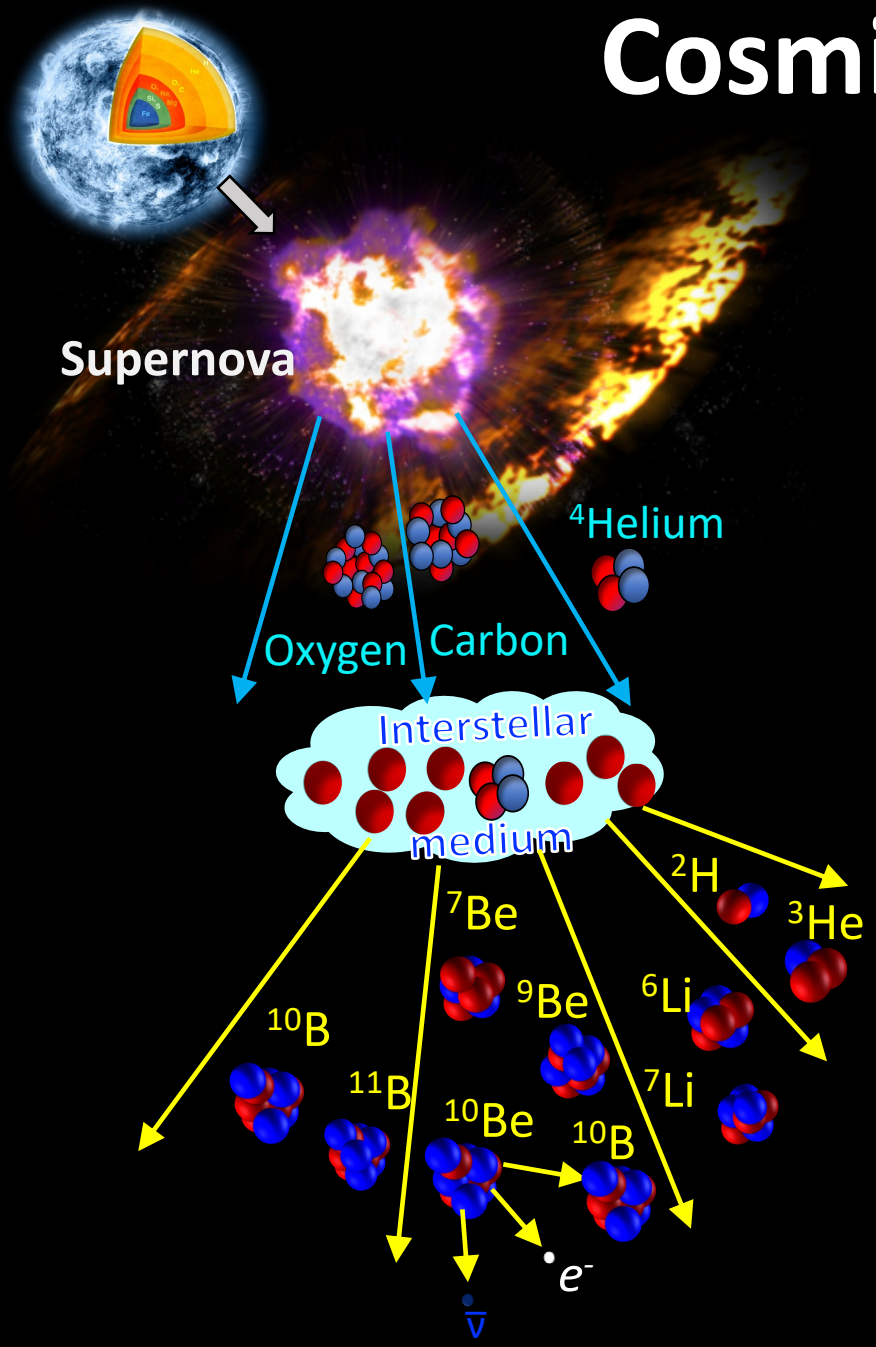
Primary and Secondary Cosmic Rays



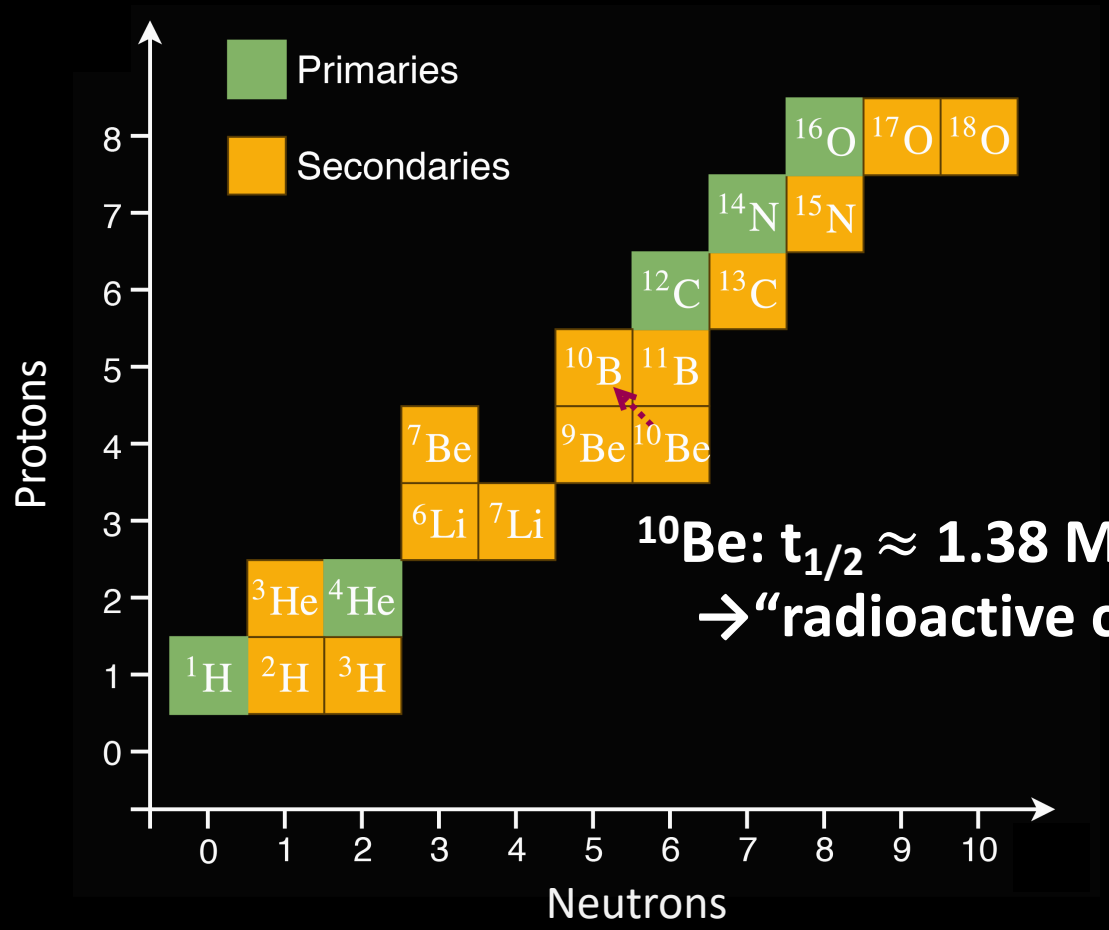
Primary cosmic rays (p, He, C, O, ...) are mostly produced during the lifetime of stars and are accelerated in supernovae shocks.

Secondary cosmic nuclei (Li, Be, B, ...) are produced by the collisions of primary cosmic rays and interstellar medium.

Cosmic Light Isotopes



Isotope studies give unique information on propagation (D, ^{3}He), production mechanism (^{6,7}Li, ^{9,7}Be) and independently measure age of cosmic rays (^{9,10}Be).

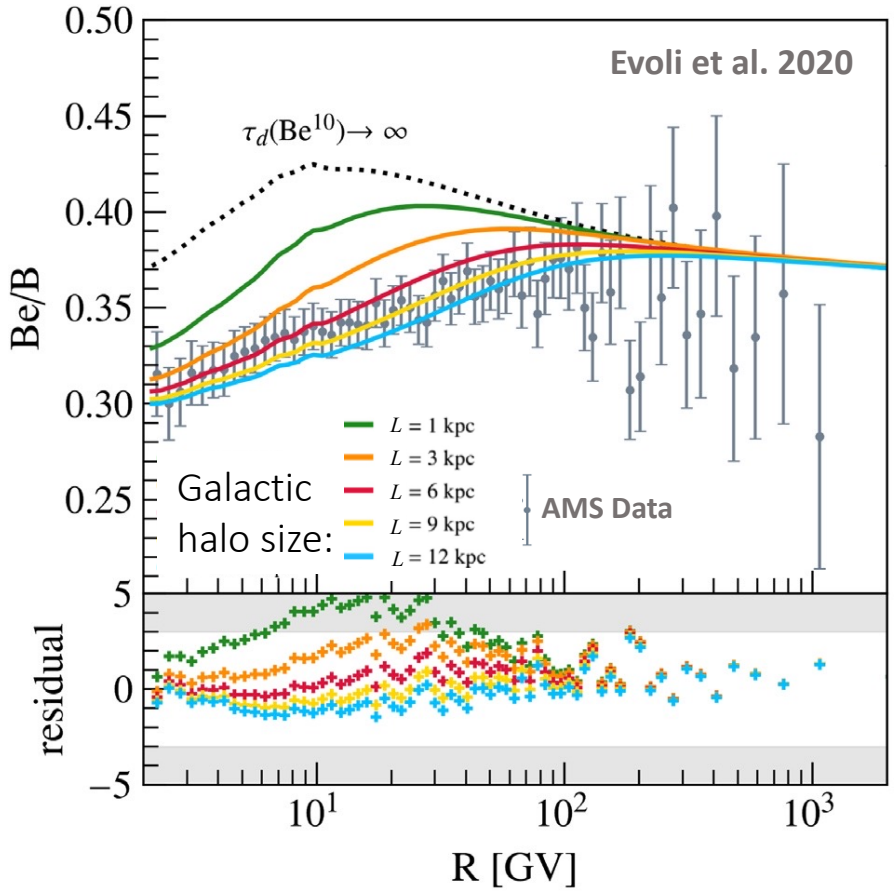


^{10}Be: $t_{1/2} \approx 1.38$ My
→"radioactive clock"

Cosmic Beryllium Isotopes

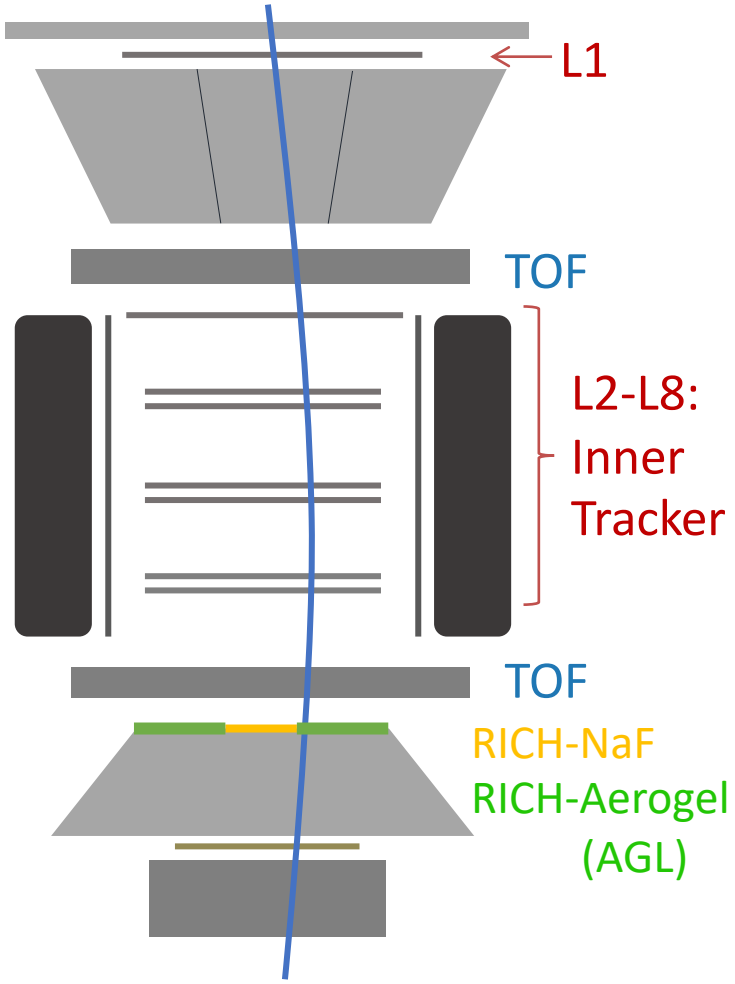
- Recent studies of cosmic ray propagation using $^{10}Be \rightarrow ^{10}B$ can be found in
  - Evoli, C., Morlino, G., Blasi, P., & Aloisio, R. , 2020, PRD, 101(2), 023013.
  - N. Weinrich, M. Boudaud, L. Derome, Y. Génolini, J. Lavalle, D. Maurin, P. Salati, P. Serpico, G. Weymann-Despres, 2020, A&A 639, A74

- $^{10}Be/^{9}Be$ provides more sensitive measurement of the age of cosmic rays.



→ AMS is able to measure Be isotopes up to 12 GeV/n (~30 GV).

Measurement of Be Isotopes with AMS-02

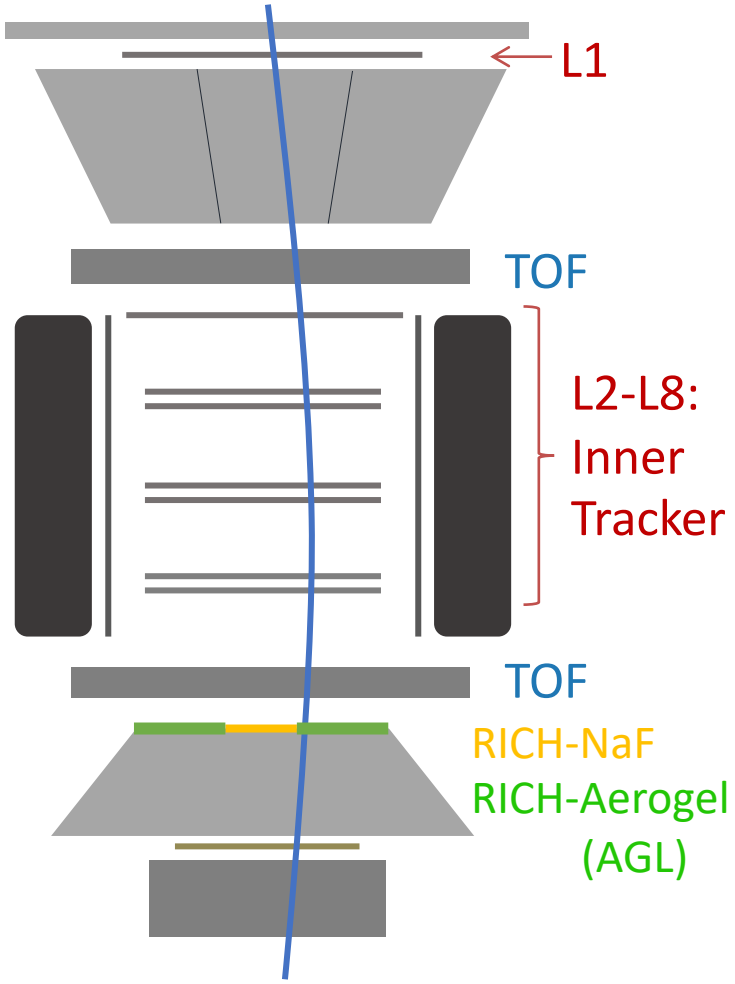


$$M = \frac{RZ}{\beta\gamma}, \qquad \gamma = 1/\sqrt{1-\beta^2}$$

- *R* measurement :
  - Tracker, $\Delta R/R \sim 10\%$ at 10 GV
- β measurements:

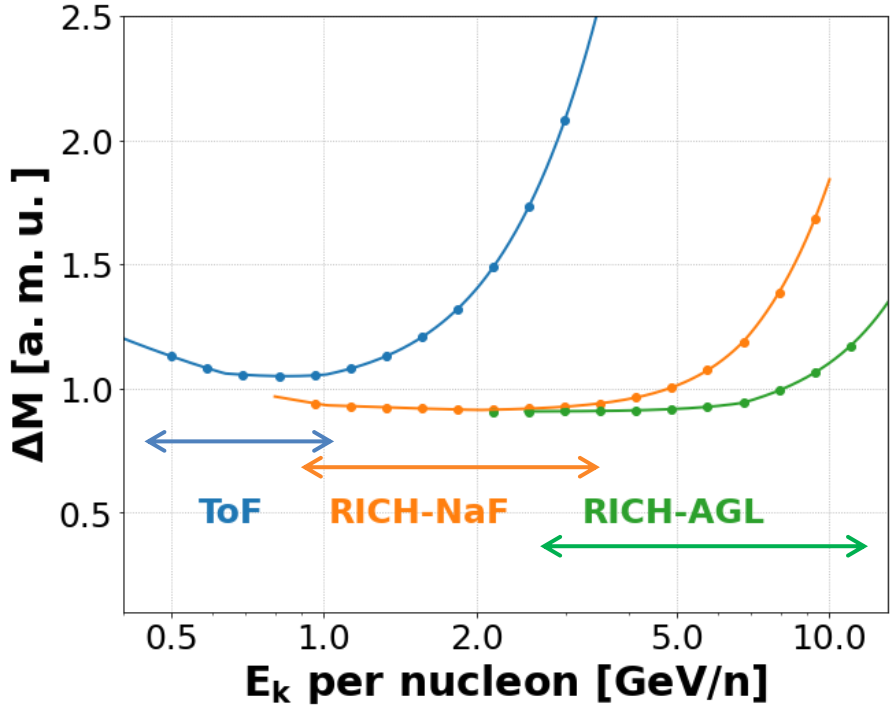
	E_{kn} range (GeV/n)	$\Delta\beta/\beta$
TOF (4 layers)	(0.5, 1.2)	~ 1.5%
RICH-NaF (n=1.33)	(0.8, 4.0)	~ 0.15%
RICH-AGL (n=1.05)	(3.0, 12)	~ 0.05%

Measurement of Be Isotopes with AMS-02



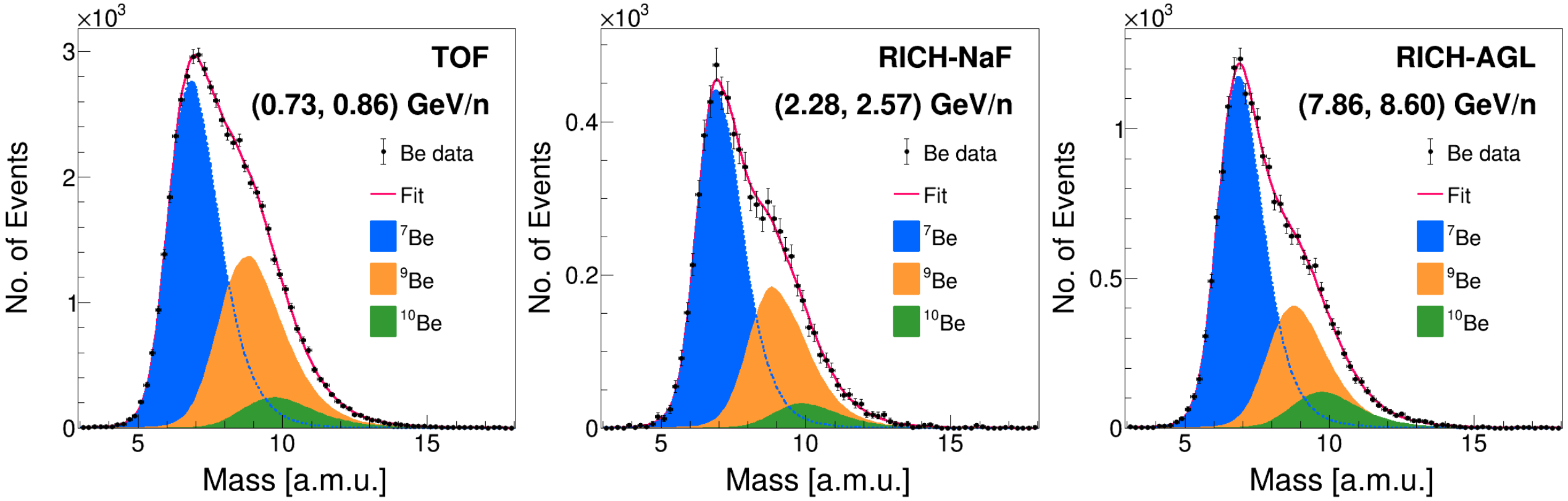
$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left(\gamma^2 \frac{\Delta \beta}{\beta}\right)^2}$$

^{9}Be Mass Resolution



$\Delta M \sim 1$ a.m.u.→ Unable to do event-by-event isotope identification

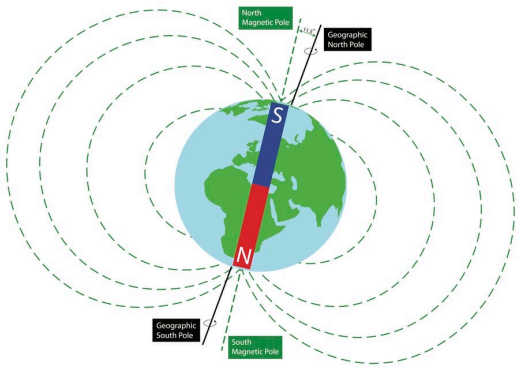
Mass Template Fit Method

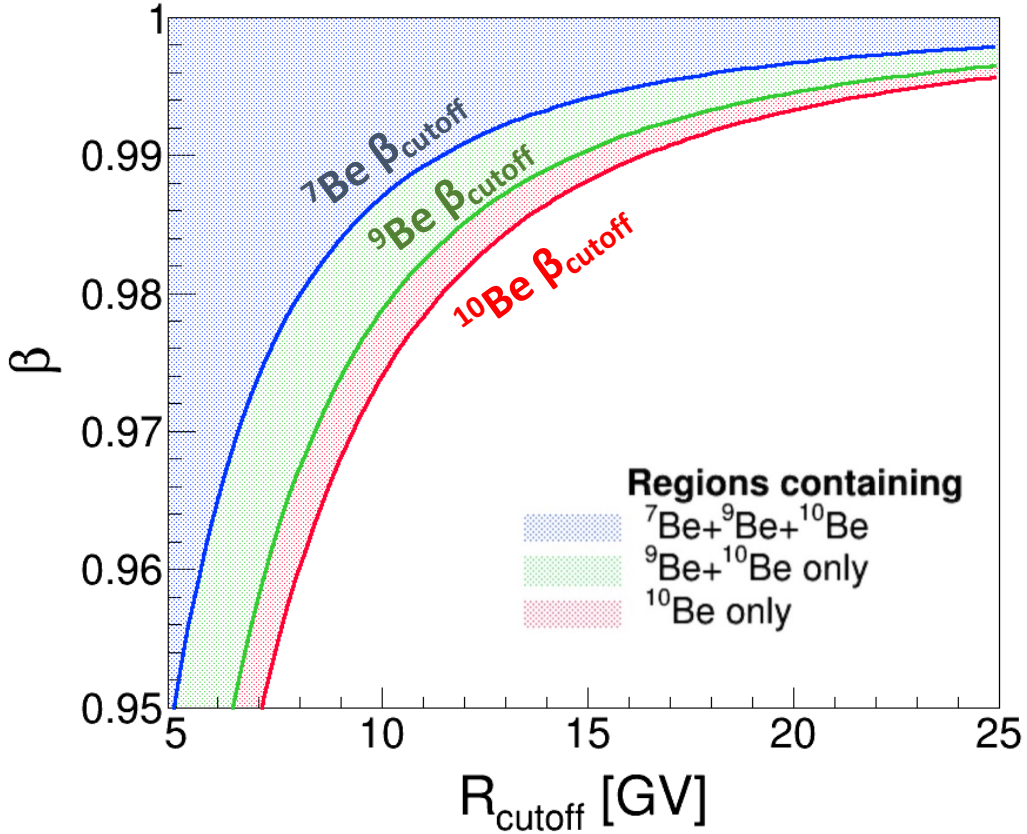


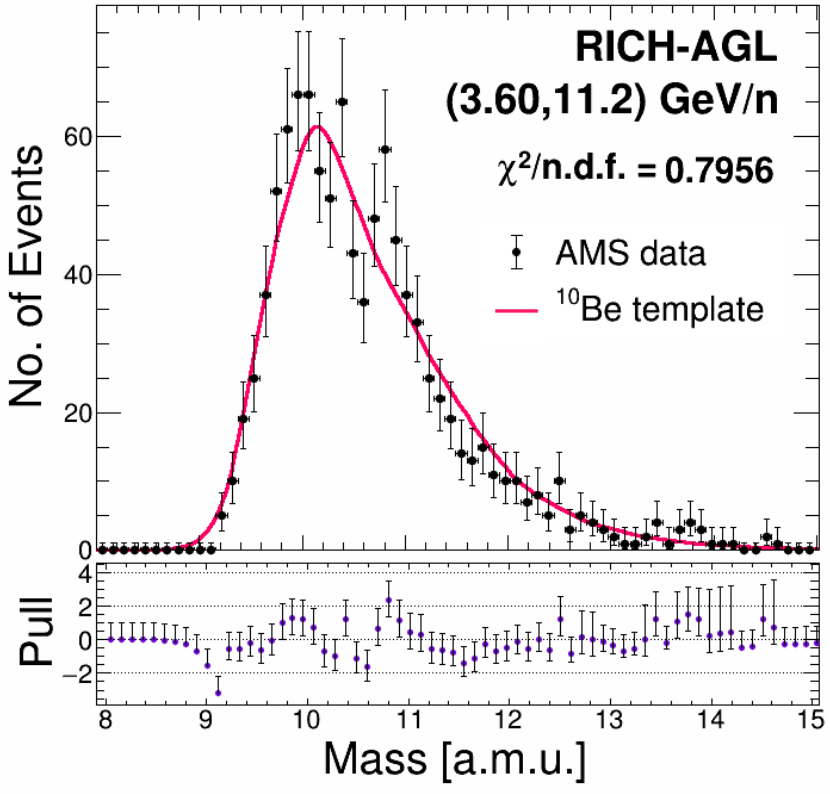
- Isotopic abundances obtained from mass template fit carried out in difference energy ranges.
- Mass templates are based on Monte Carlo simulation validated by data.

Validation of Mass Templates

$$\beta_{cutoff} = \sqrt{\frac{R_{cutoff}^2}{M^2 + R_{cutoff}^2}}$$



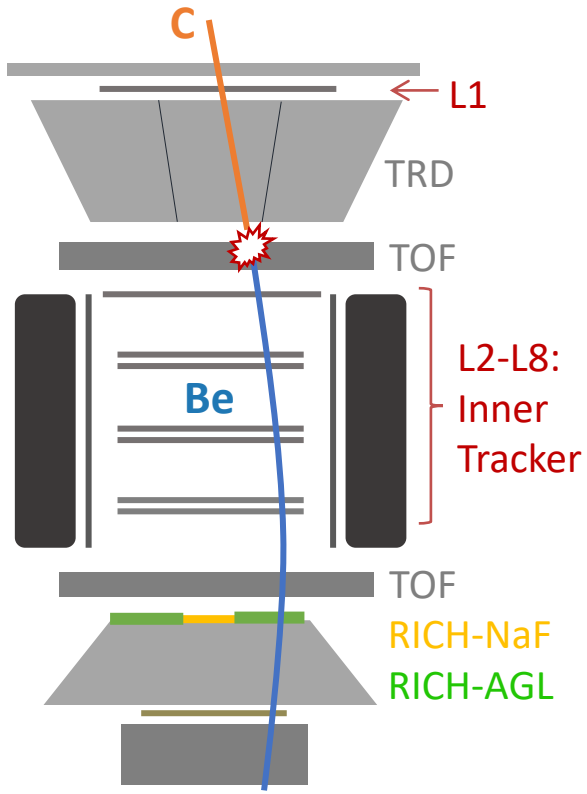




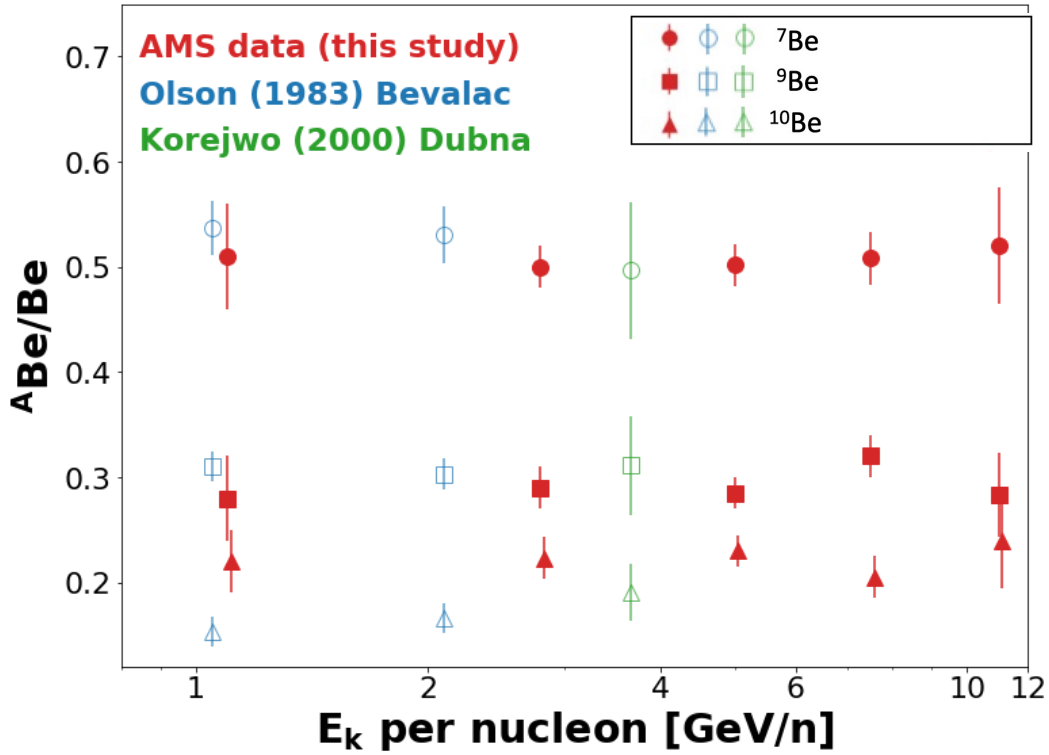
- Mass templates can be validated using samples selected by the geomagnetic cutoff.
- Samples containing only one isotope, lighter isotopes are shielded.

Validation of Fragmentation Cross Sections

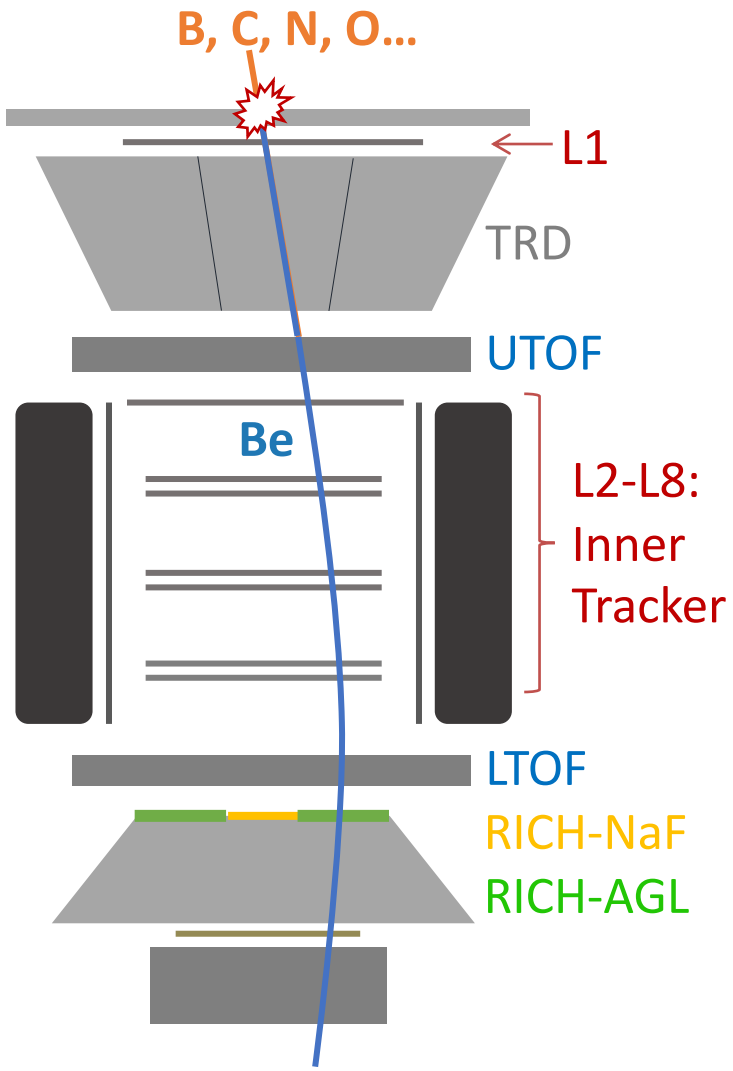
- The fragmentation background is not negligible in the Be sample.
- The knowledge of nuclei interaction cross sections is important.
- Using AMS material as the target, the fragmentation cross sections are validated.
- With the mass template fit technique, isotopic cross sections can also be validated.



Carbon nuclei fragmenting to beryllium isotopes in TRD+TOF



Fragmentation Background



- Charge measurements at

  L1 - UTOF - Inner Tracker - LTOF

  ensure negligible fragmentation background below L1.

- Selections defined to identify and reduce fragmentation events.

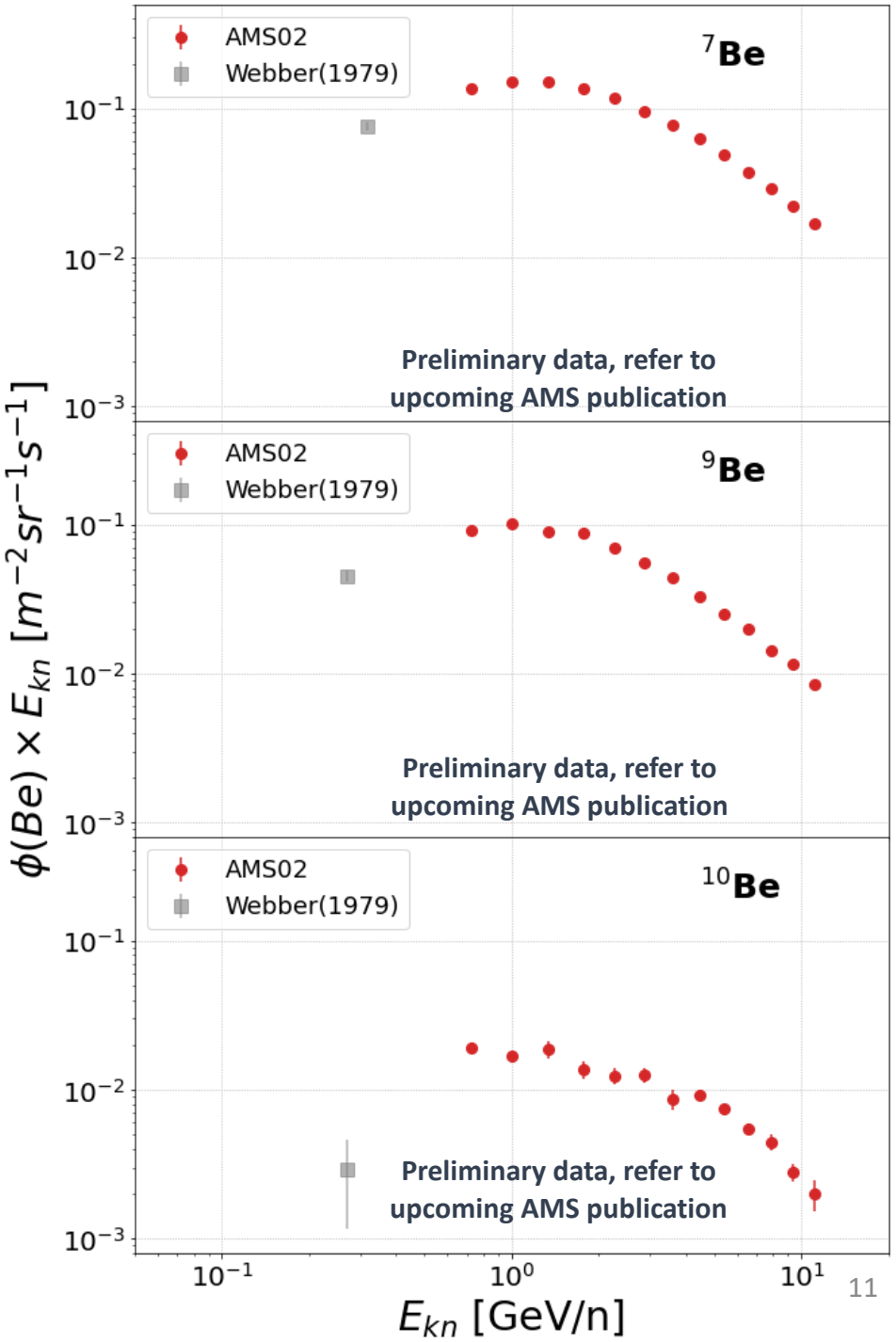
- Background mainly from the fragmentation of heavier nuclei above Tracker L1.

→ **The total fragmentation background is $\sim 2\%$ in the energy range of measurements.**

Beryllium Isotopic Fluxes

- Based on 0.4 million beryllium events.
- Combined three analyses using TOF, RICH-NaF and RICH-AGL.

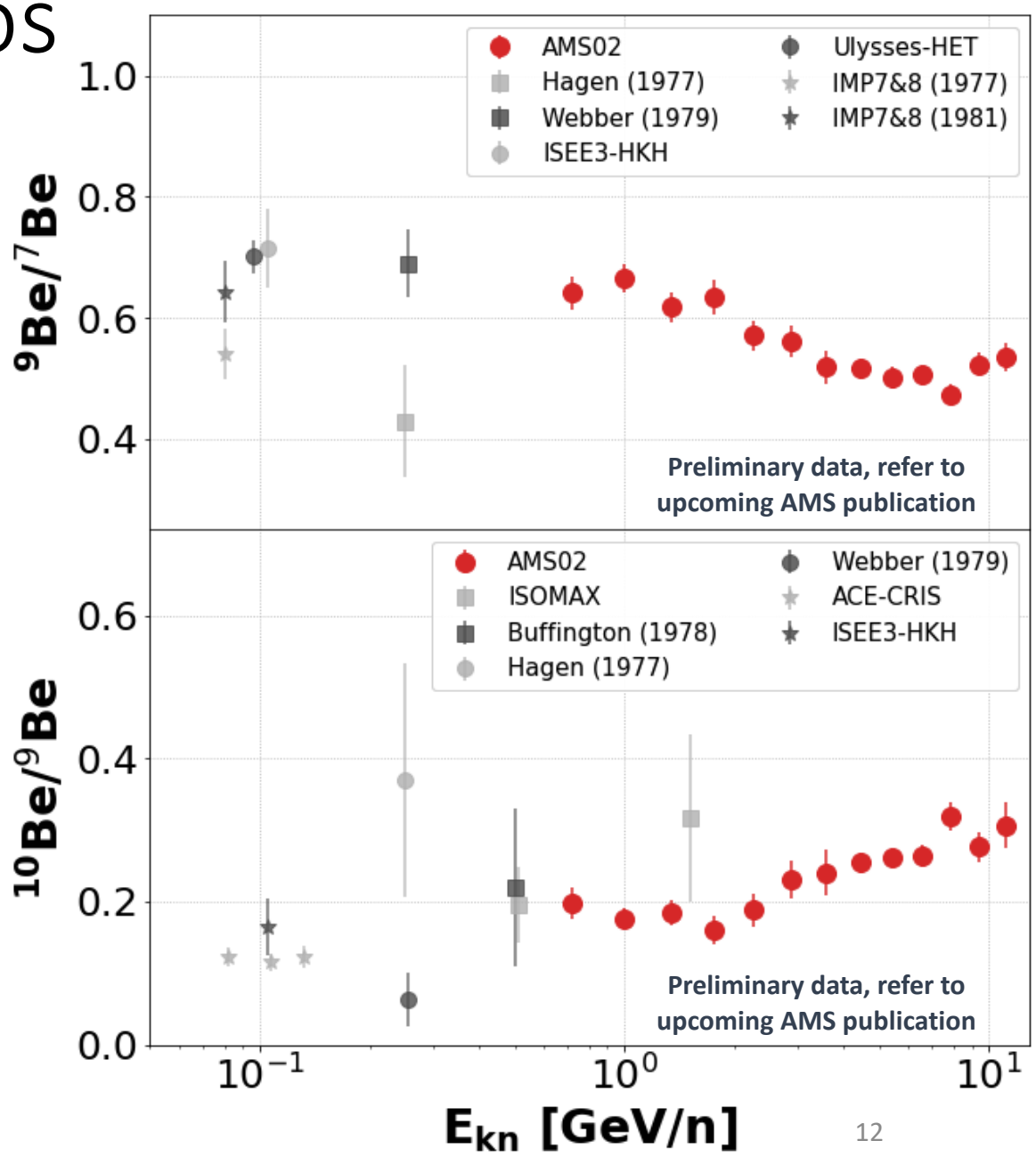
→ First measurement of ^{7}Be, ^{9}Be and ^{10}Be fluxes above 0.5 GeV/n and up to 12 GeV/n.



Beryllium Isotopic Flux Ratios

- $^{9}Be/^{7}Be$ and $^{10}Be/^{9}Be$ flux ratios and comparison with previous experiments:

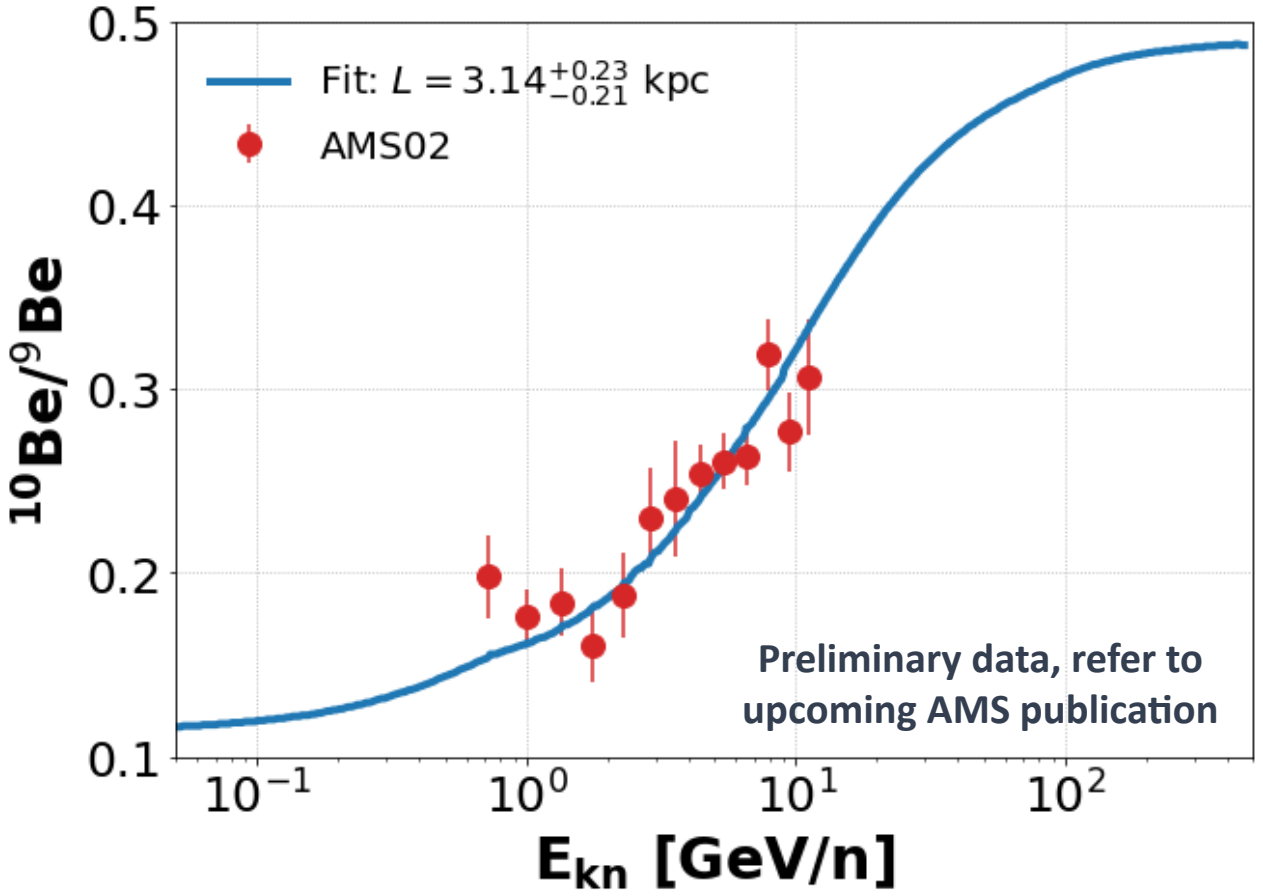
→ **First measurement of**
- **$^{9}Be/^{7}Be$ flux ratios above 0.5 GeV/n.**
- **$^{10}Be/^{9}Be$ flux ratios above 2 GeV/n.**



Fitting the ^{10}Be/^{9}Be Flux Ratios

- Galactic diffusion halo size L fitted on AMS02 data with an analytical formula:
  (D. Maurin *et al.*, arXiv:2203.07265)

- **Precision on L from AMS02 data $\Delta L_{\mathrm{AMS02}} \sim 0.2$ kpc.**
- **Error dominated by uncertainty from production cross-section (1 kpc).**



Conclusions

- The method based on mass template fit to study cosmic-ray isotopes with AMS-02 was presented.
- In the energy range of 0.5 GeV/n up to 12 GeV/n, the following preliminary results were presented:
  - ^{7}Be, ^{9}Be and ^{10}Be fluxes;
  - ^{9}Be/^{7}Be and ^{10}Be/^{9}Be flux ratios.
- The measurement of cosmic-ray Beryllium isotopes provides important information to measure the age of cosmic rays.