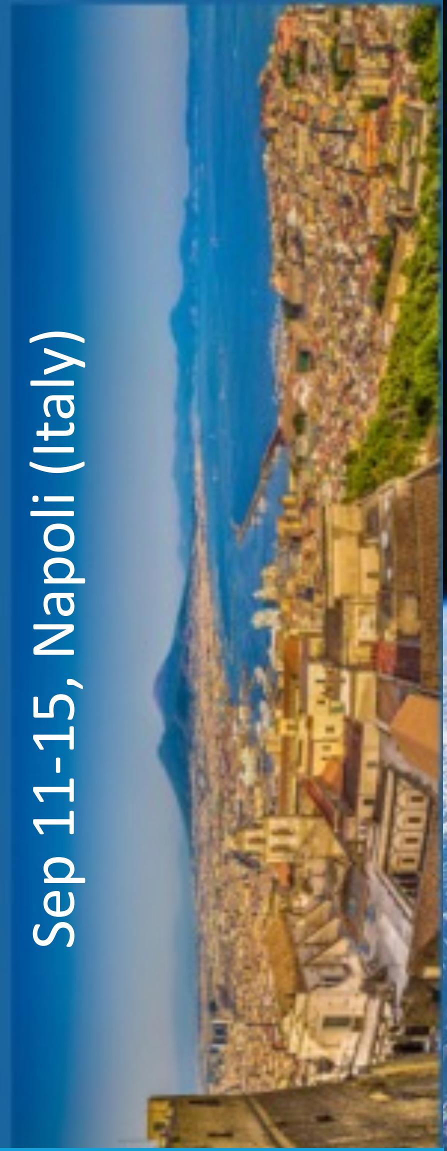
Cosmic-Ray Lithium and Beryllium Isotopes with the Alpha Magnetic Spectrometer

F. Giovacchini - CIEMAT
on behalf of the AMS Collaboration



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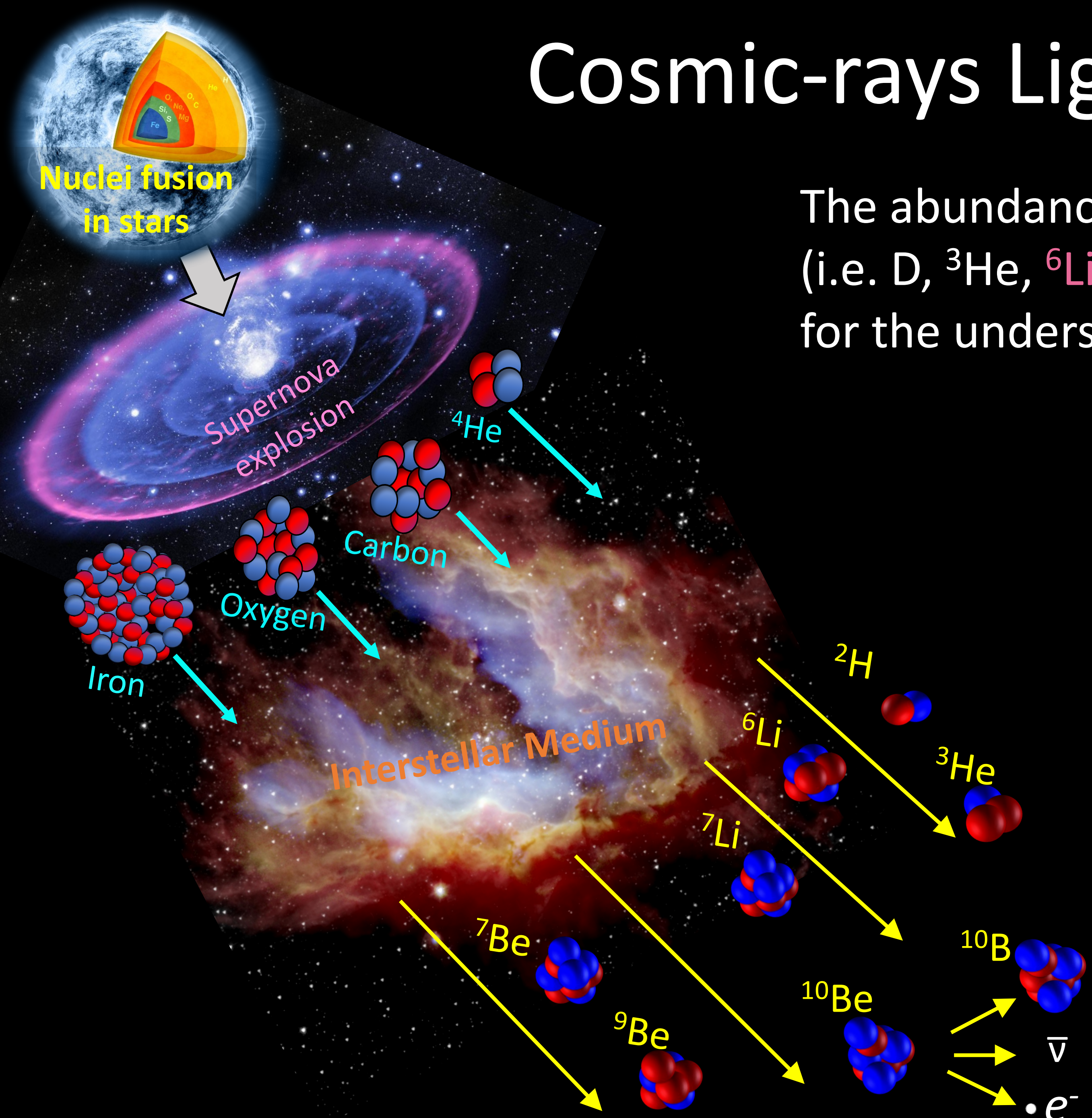
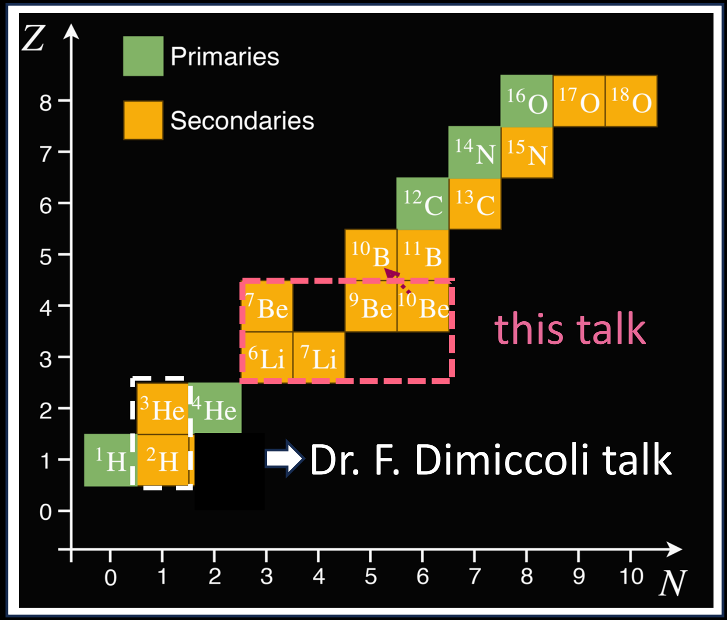
Cosmic-rays Light Isotopes



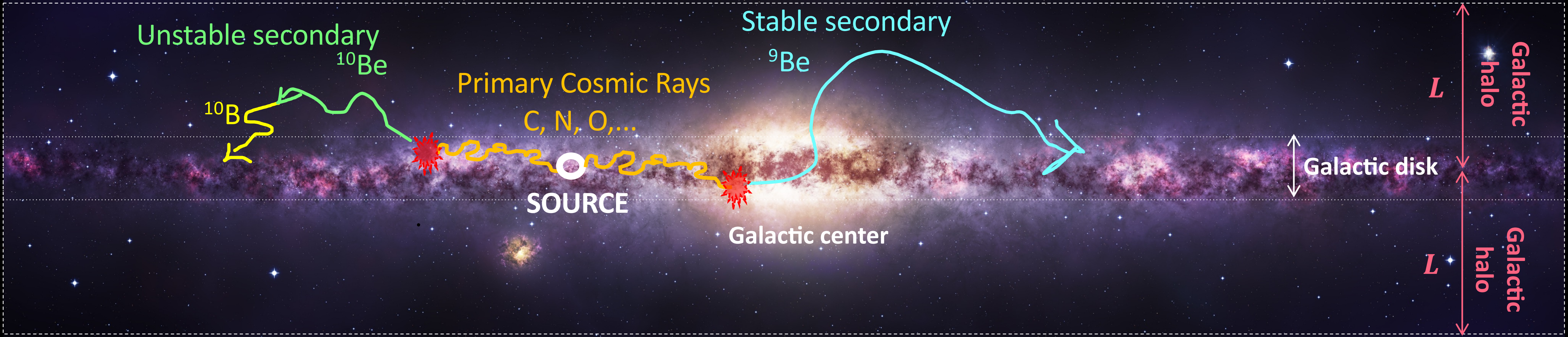
The abundances of light secondary cosmic ray isotopes (i.e. D, ^{3}He, ^{6}Li, ^{7}Li, ^{7}Be, ^{9}Be, ^{10}Be) provide unique clues for the understanding of their propagation in the galaxy.



Cosmic-ray Beryllium Isotopes

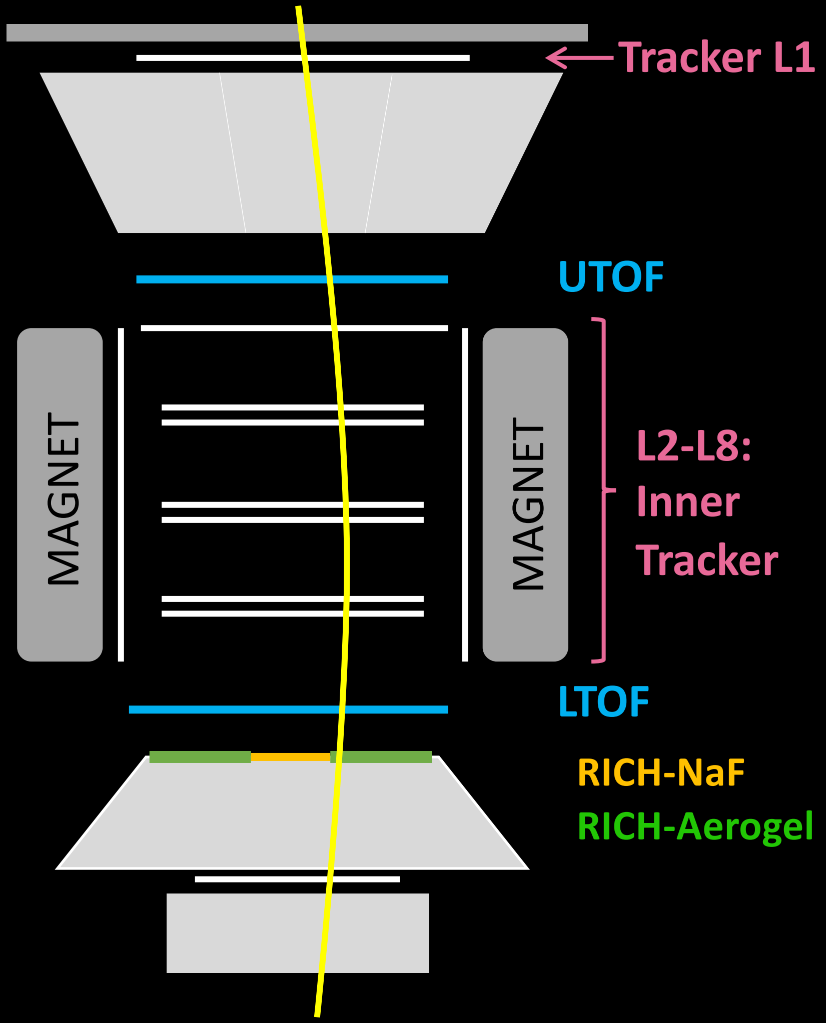
Beryllium nuclei are secondary cosmic rays.
They include three isotopes, two stable, ^{7}Be and ^{9}Be, and one unstable, ^{10}Be ($t_{1/2} \approx 1.39$ My).

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



The ratio of unstable-to-stable secondary cosmic rays ^{10}Be/^{9}Be is used to infer the Galactic halo size *L*, i.e. the galactic cosmic ray propagation volume.

Isotopes identification in AMS



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

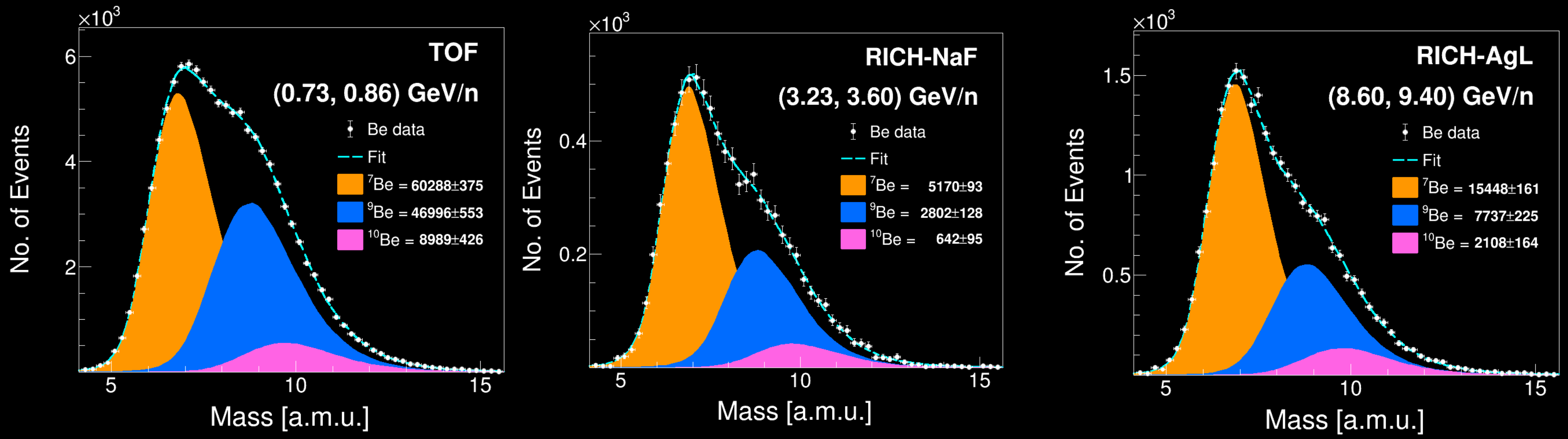
$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left(\gamma^2 \frac{\Delta\beta}{\beta}\right)^2}$$

- Charge measurements: Tracker layers, UTOF, LTOF, RICH
- *Rigidity (R=P/Z)* measurement:
  Tracker with $\Delta R/R \sim 10\%$ @ 10 GV
- β measurements:

	E_k/n range (GeV/n)	$\Delta\beta/\beta$ (Z>2, β=1)
TOF	(0.4, 1.2)	~1.5%
RICH-NaF	(0.8, 4.0)	~0.15%
RICH-Aerogel	(3.0, 12)	~0.05%

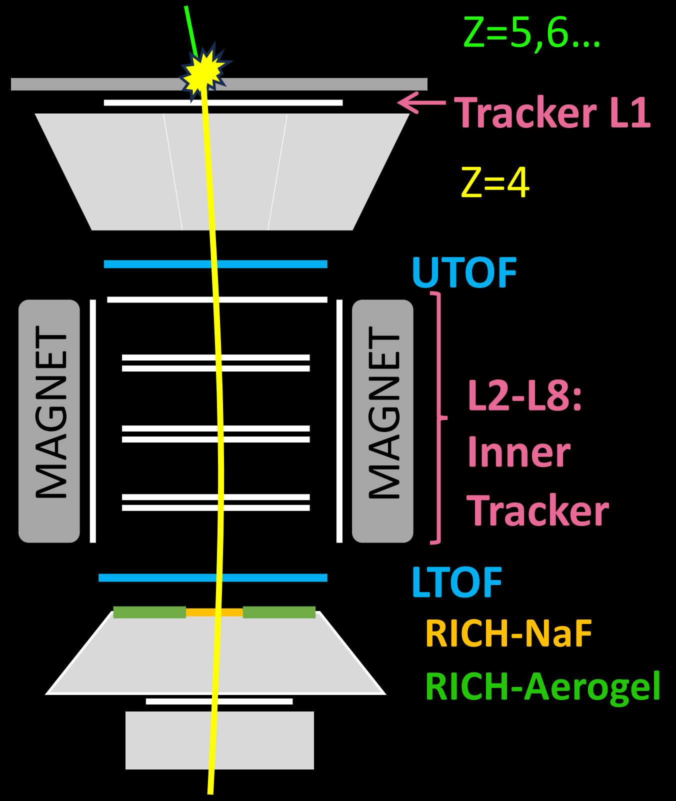
Isotopic Abundances Measurement

Beryllium



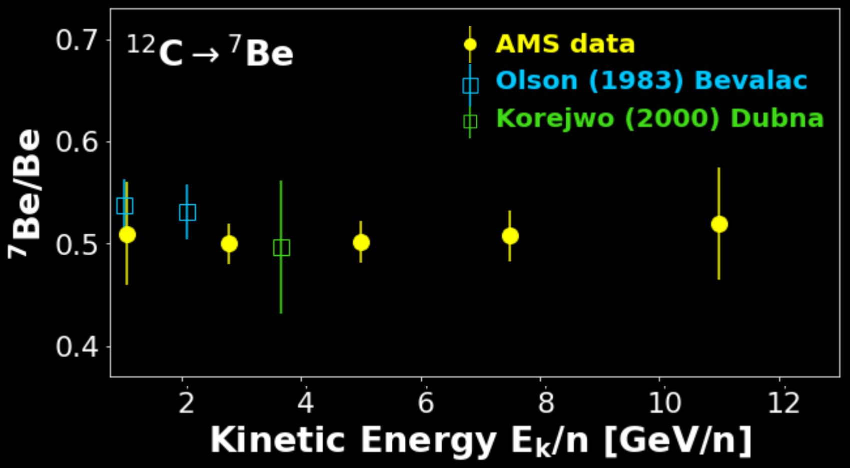
- Isotopic abundances obtained from mass template fits carried out for each energy bin.
- Mass templates are based on Monte Carlo simulation and validated with data (using for example the geomagnetic cutoff to extract pure ^{10}Be).

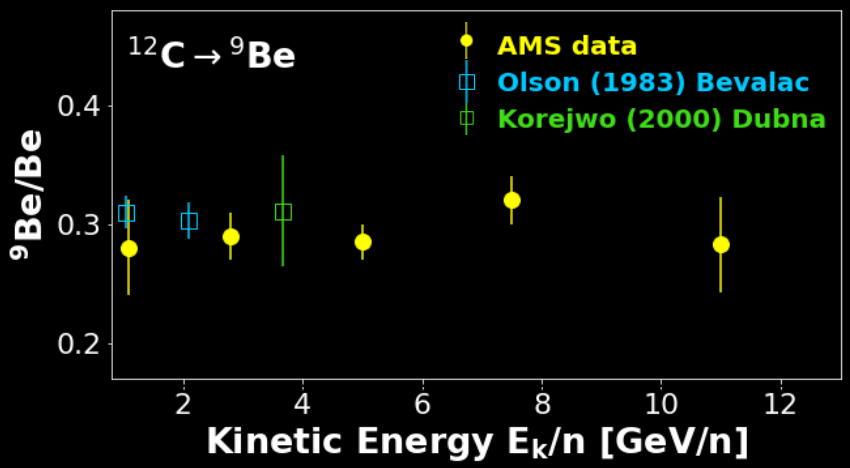
Top of the Instrument Flux

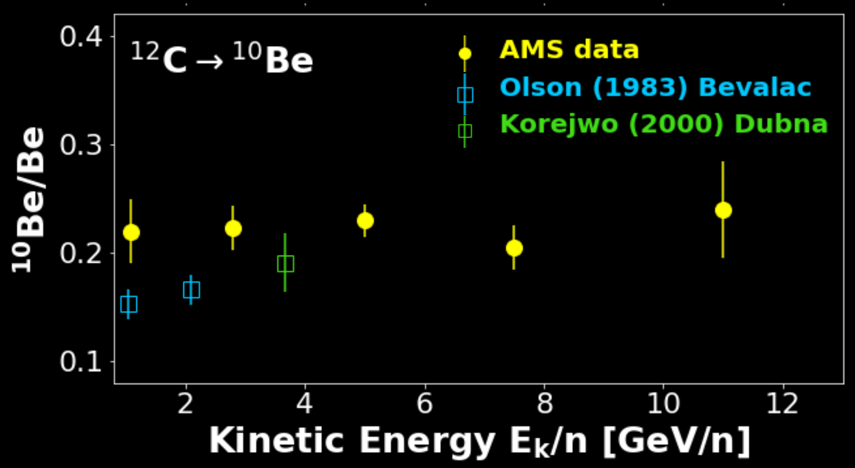


Contamination due B,C,O → $^{7/9/10}$Be

- The Top of the Instrument corrections are estimated from simulation tuned using direct AMS measurement of the fragmentation cross sections (Q. Yan et al. Nucl. Phy. A 2020).
- We used direct AMS data to validate the relevant isotopic branching ratios.

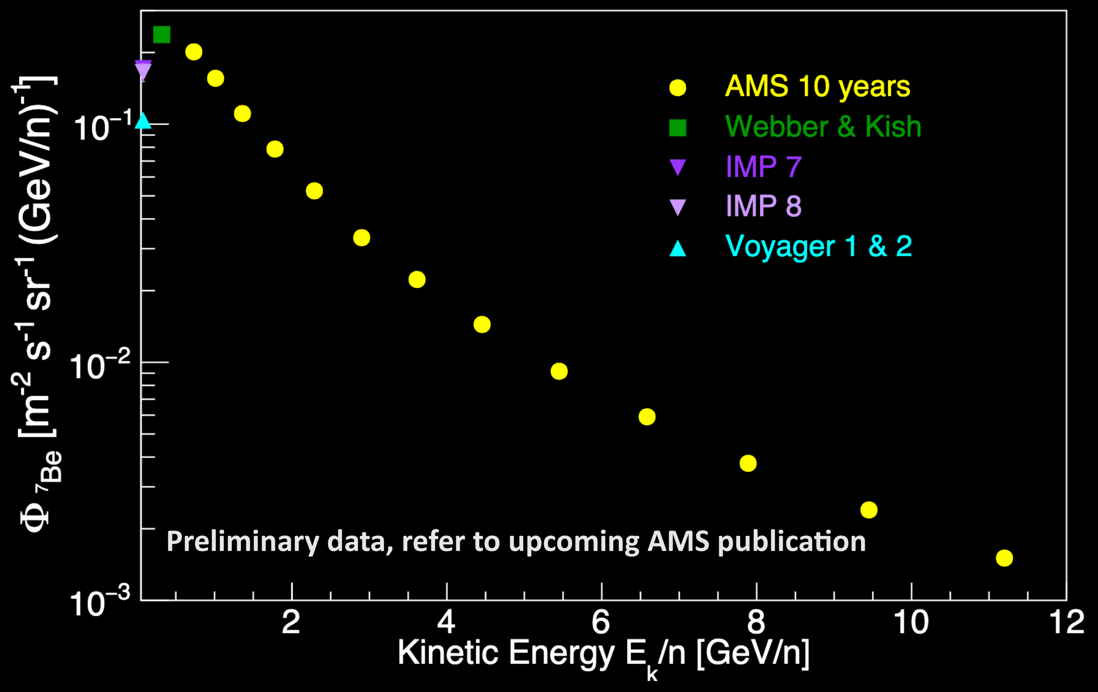


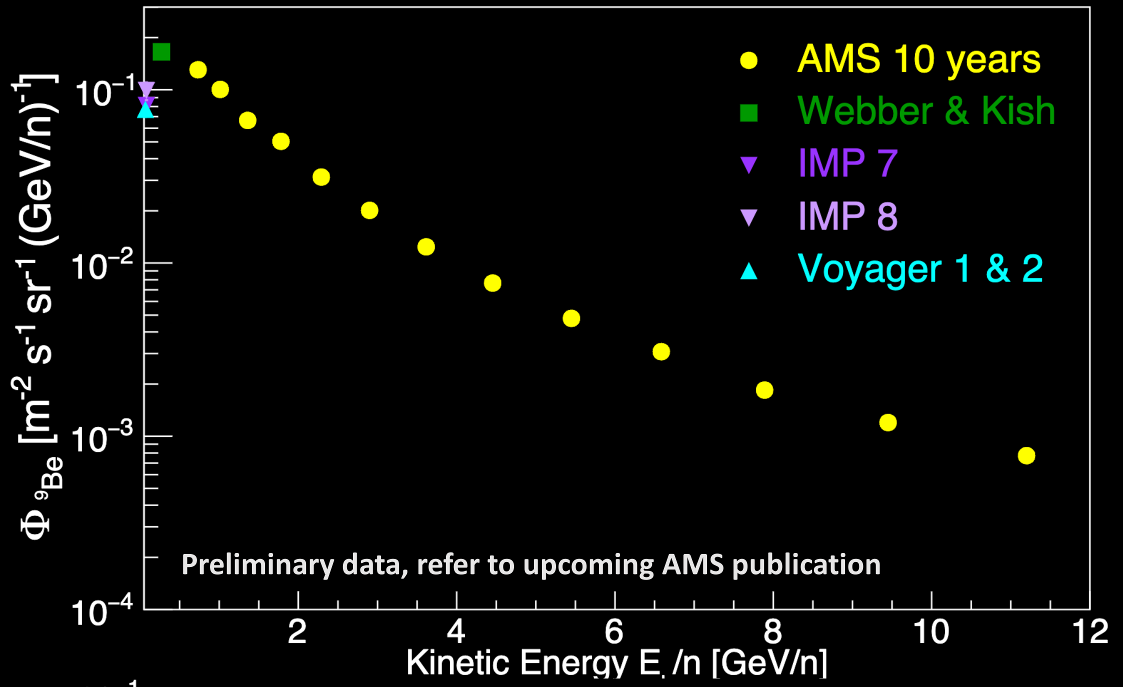


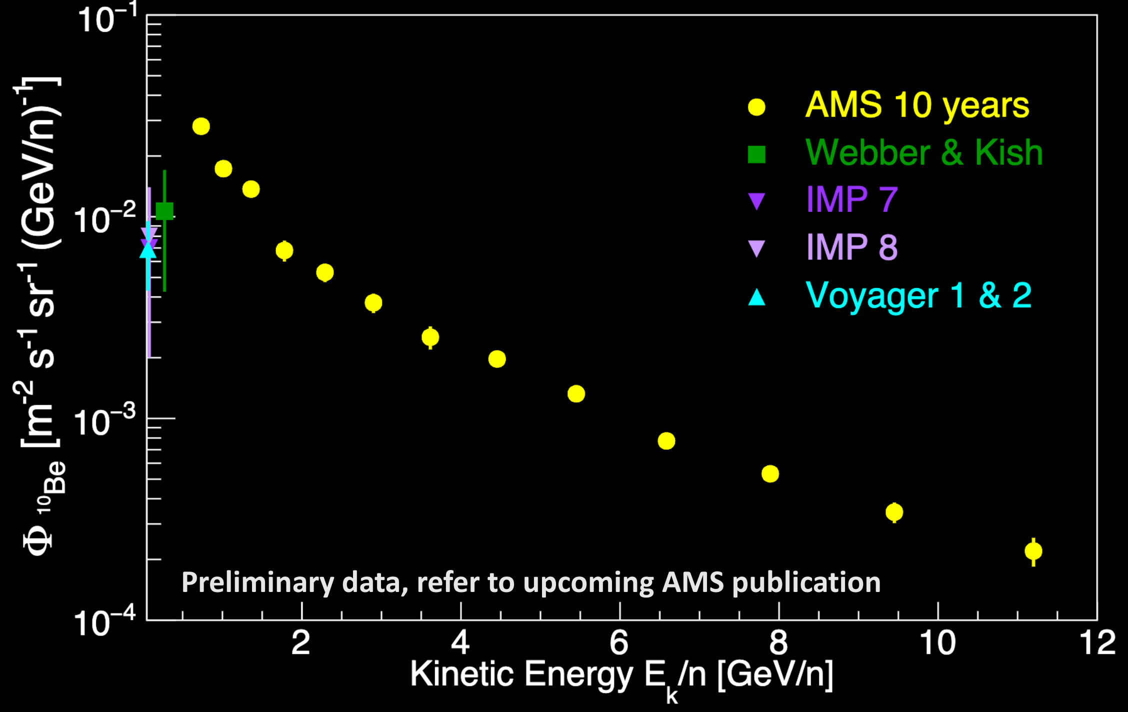


Beryllium Isotope Fluxes

- Based on 0.7 million beryllium events.



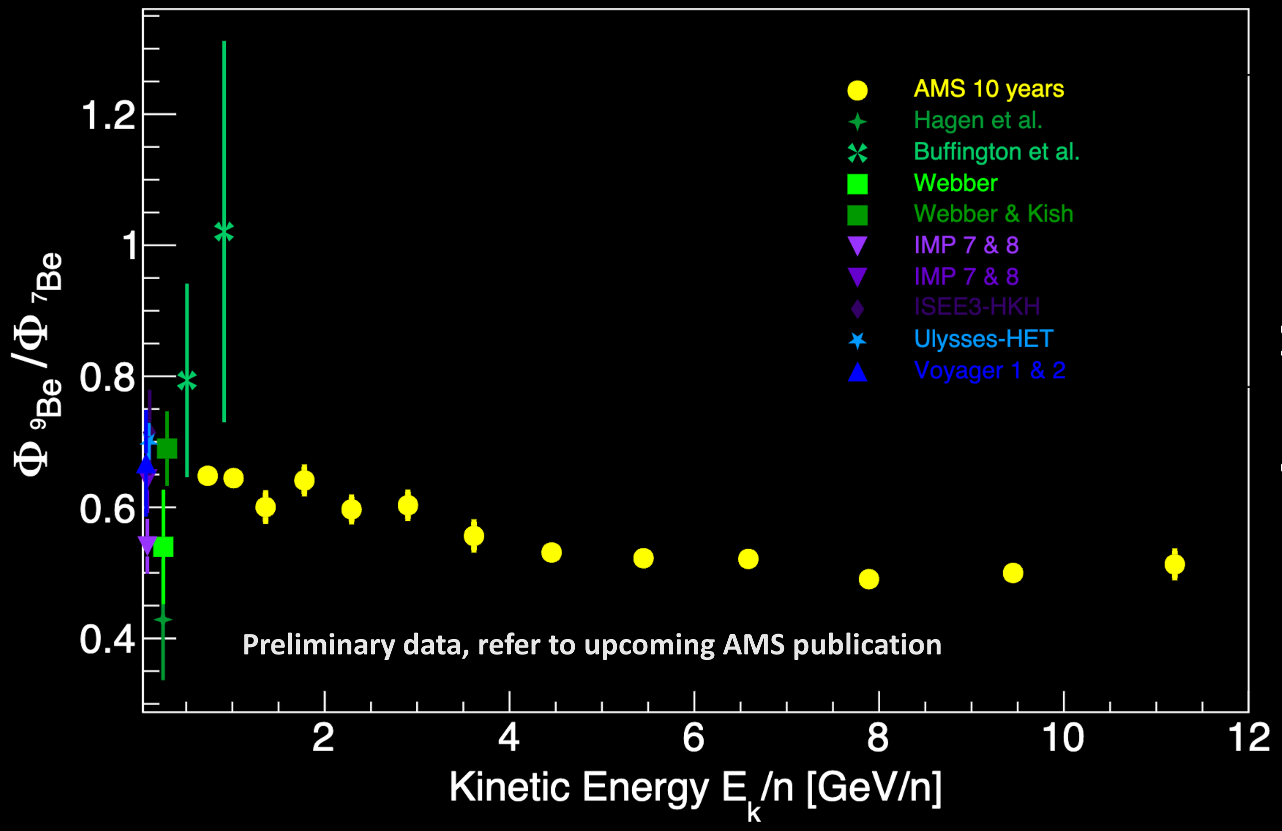


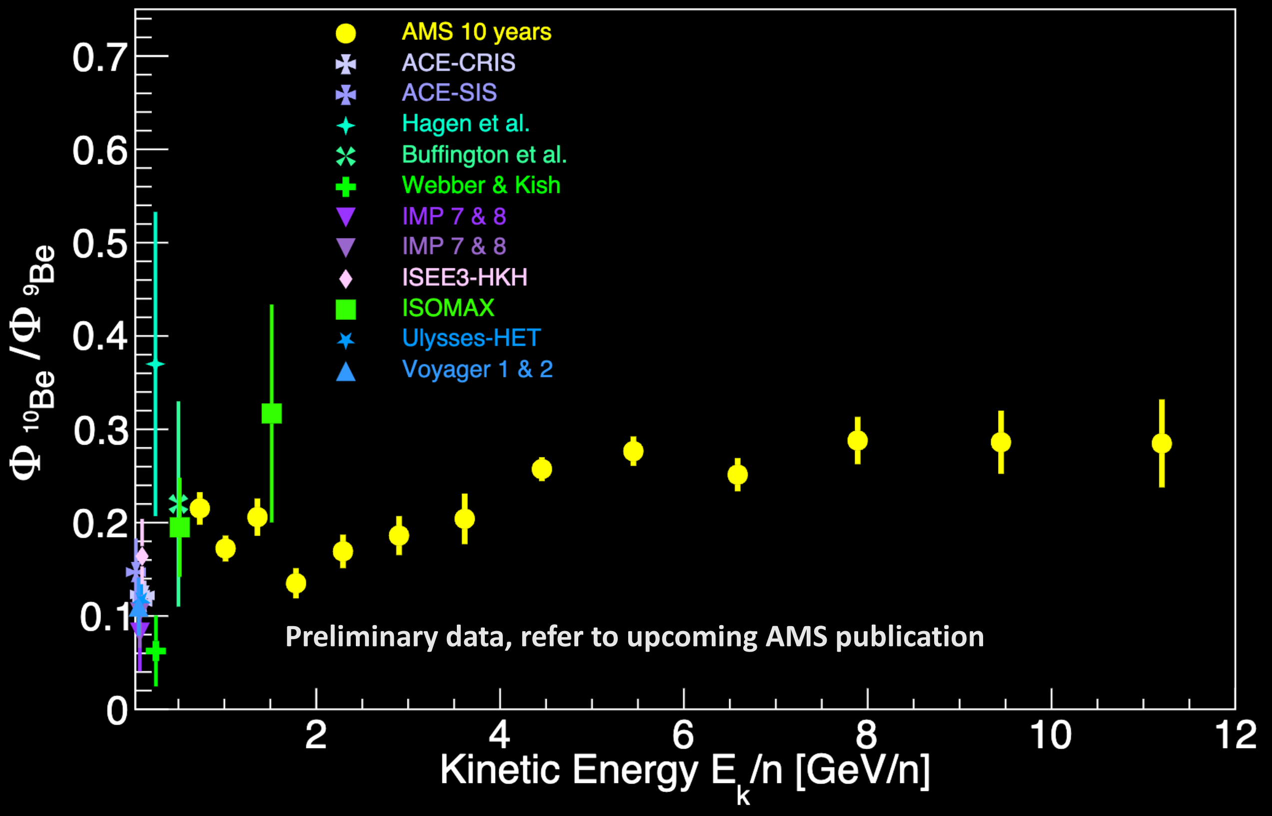


Beryllium Isotope Flux Ratios

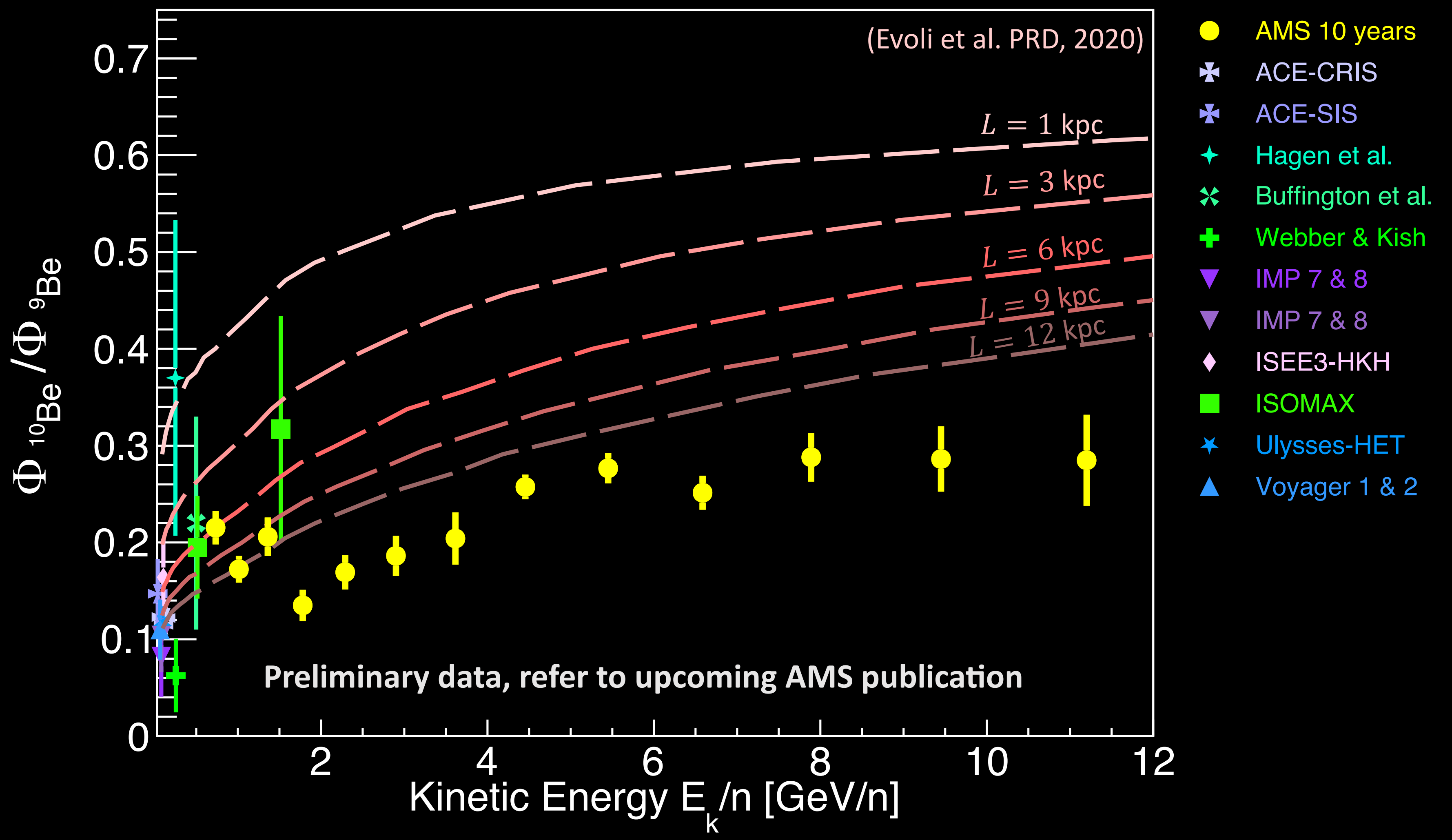
→First measurement of:

- ^{9}Be/^{7}Be flux ratios above 0.6 GeV/n.
- ^{10}Be/^{9}Be flux ratios above 2 GeV/n.





$^{10}Be/^{9}Be$ flux Ratio and Halo Size



The AMS data can provide significant new constraints on the galactic halo size L

Cosmic-ray Lithium Isotopes

Both ^{6}Li and ^{7}Li are assumed to be of secondary origin.

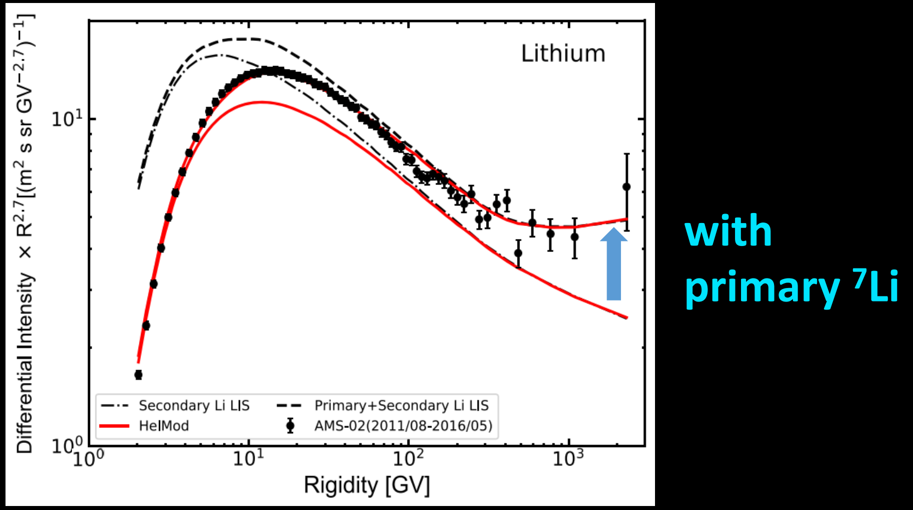
Some studies show that the elemental lithium flux measured by AMS is higher than model prediction:

- Indication of primary source of ^{7}Li ?

  (Boschini et al. APJ, 2020)

- Uncertainty in the production cross-section?

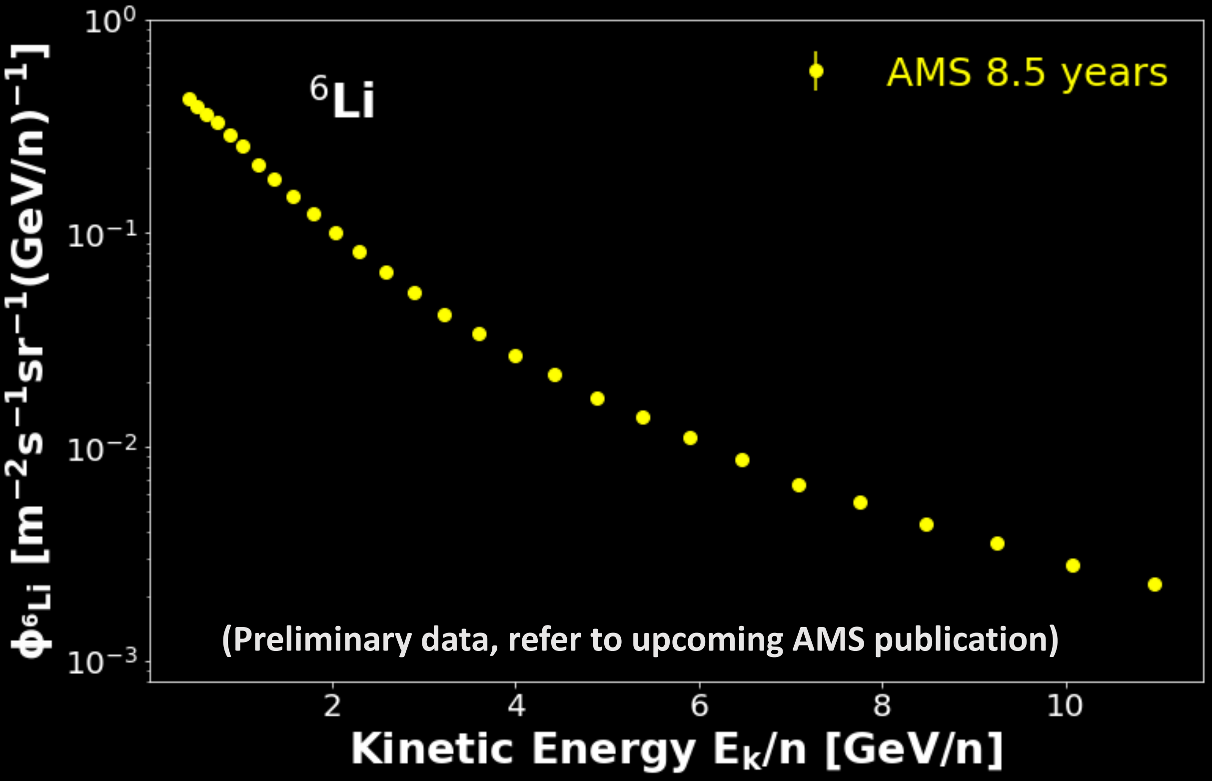
  (Weinrich et al. A&A, 2020; Maurin et al. A&A,2022);

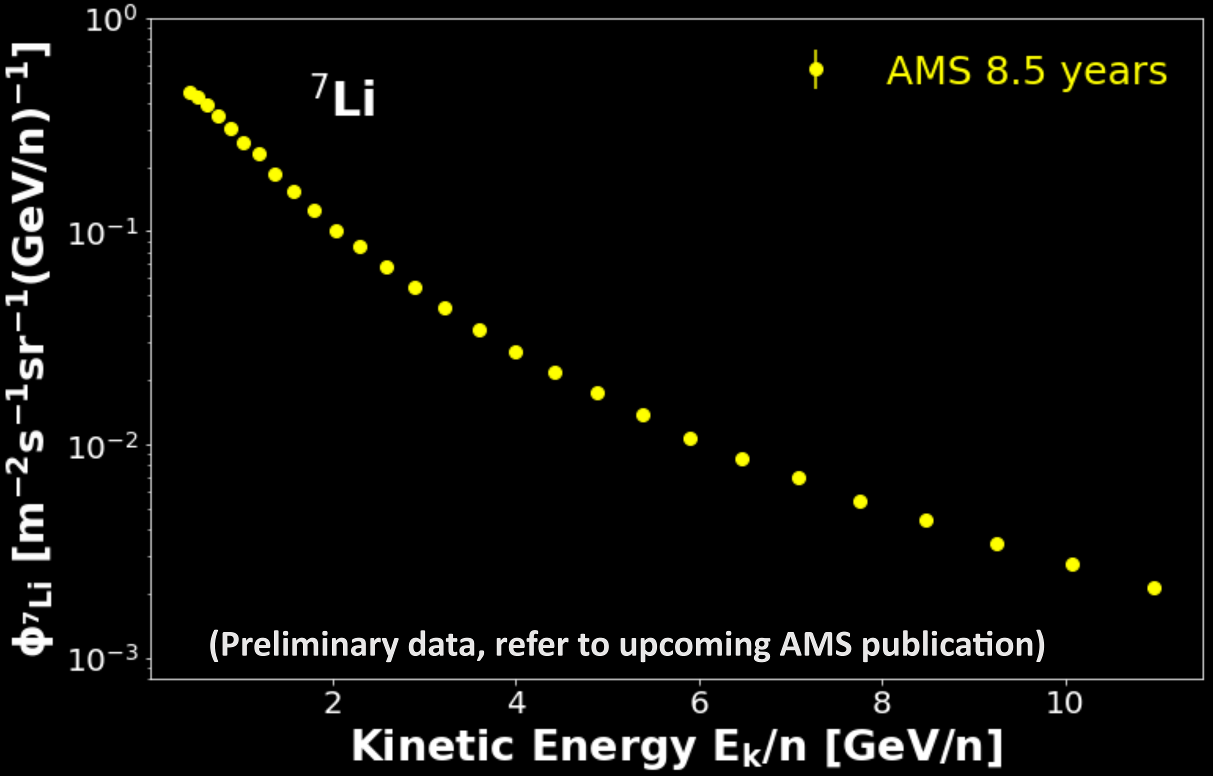


Boschini et al. APJ, 2020

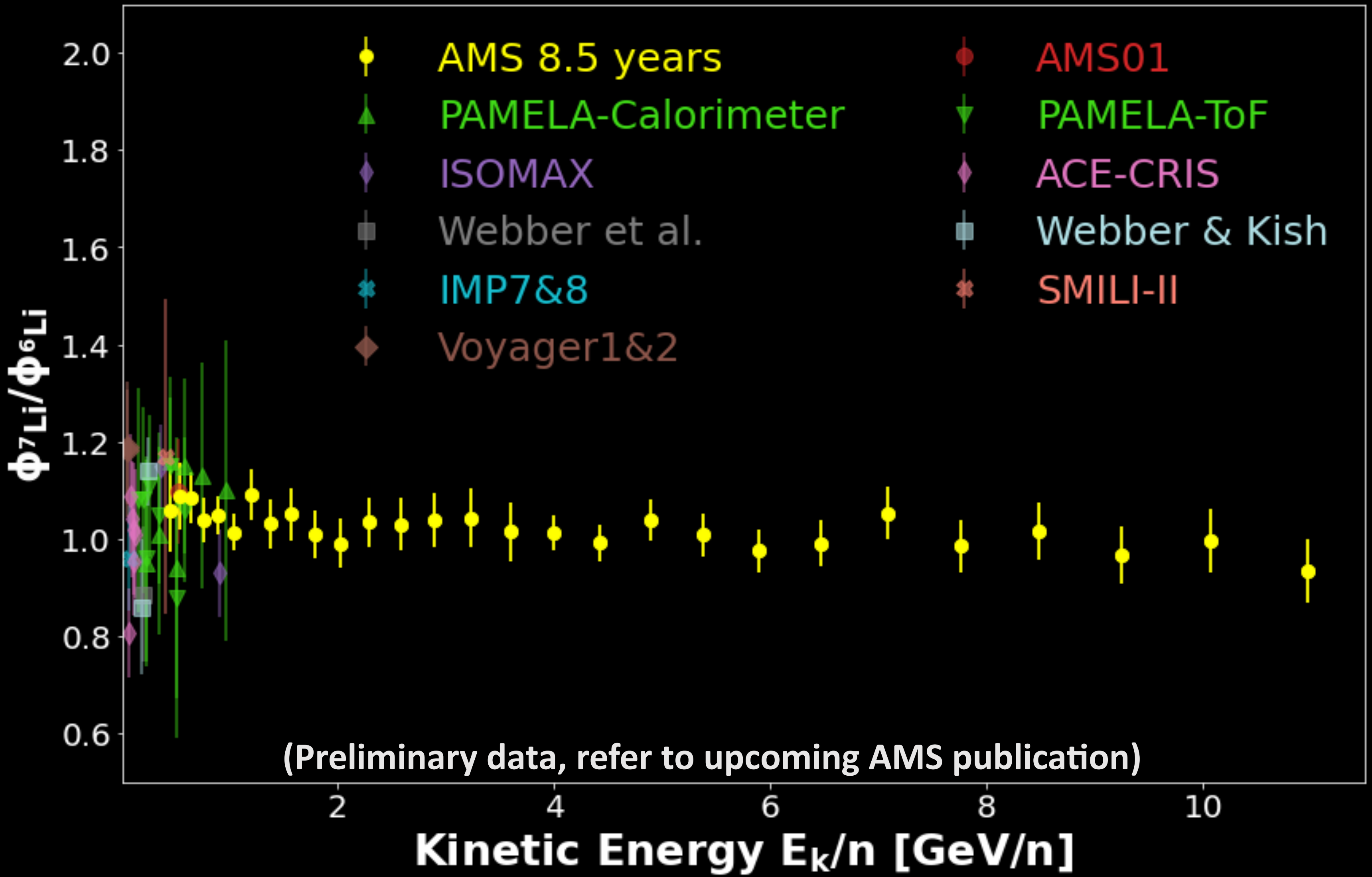
Lithium Isotope Fluxes

Based on 0.9 million Lithium events.

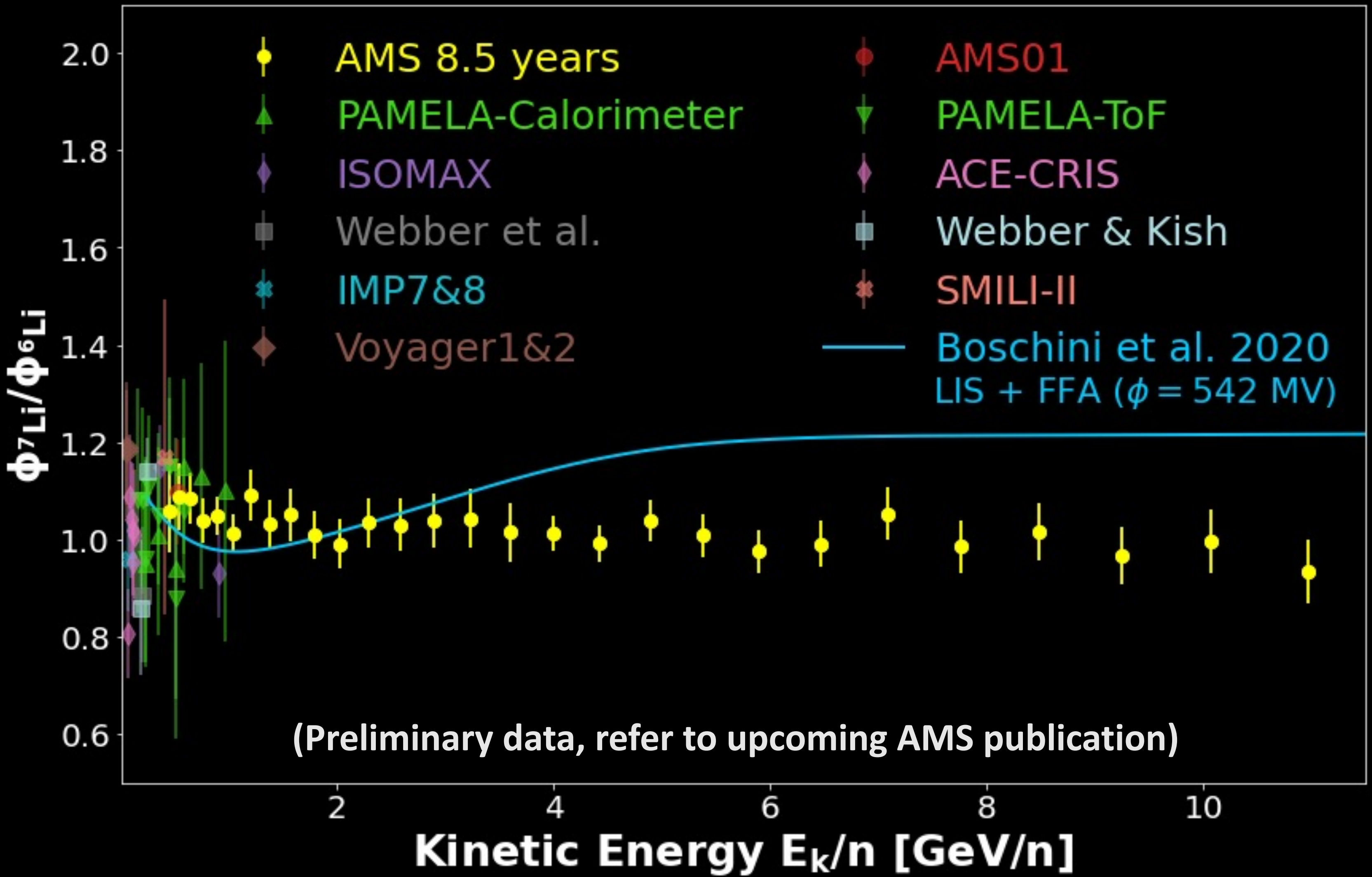




Lithium Isotope Flux Ratios



Lithium Isotope Flux Ratios



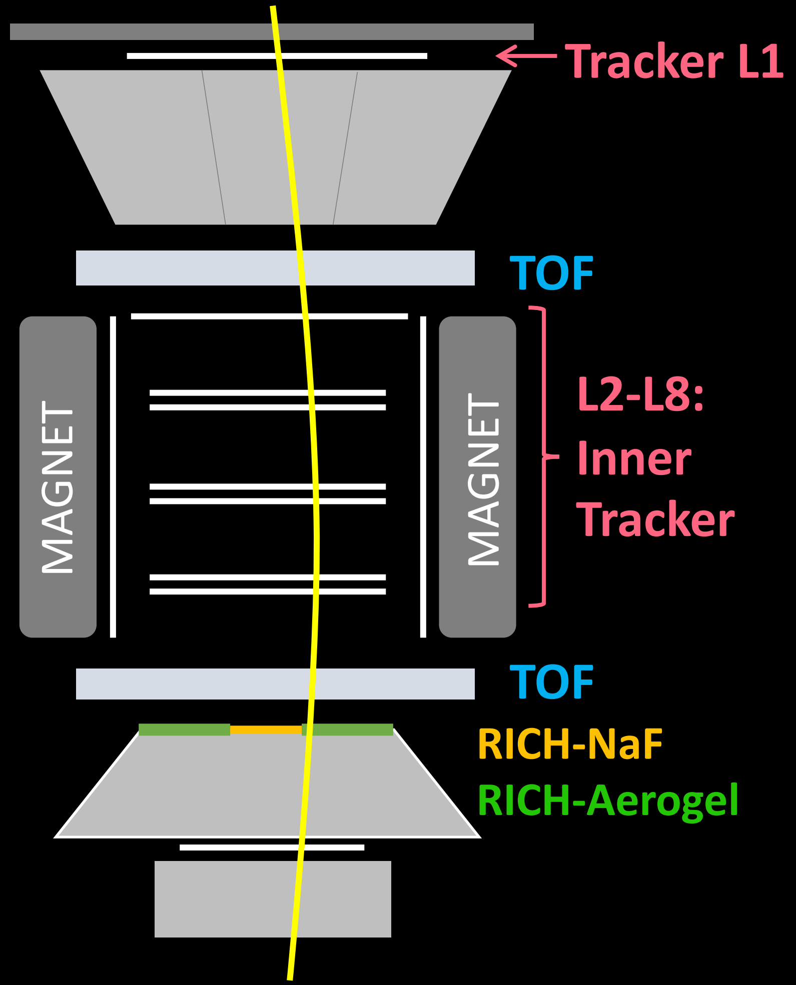
Conclusions

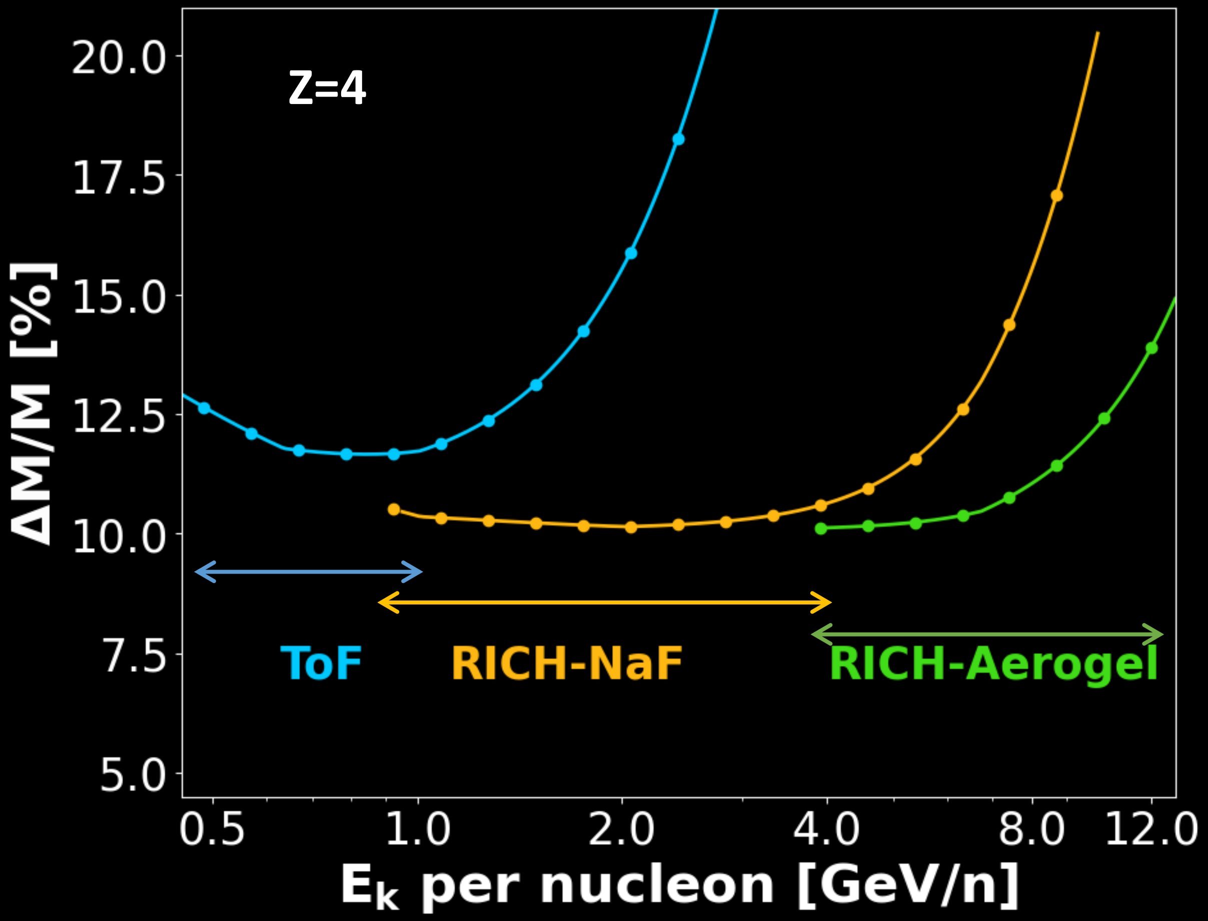
- The measurement of the isotopic composition of light nuclei in cosmic rays is fundamental for the understanding of cosmic ray origin and propagation.
- AMS-02 measurements of cosmic-ray isotope fluxes based on 0.9 M Lithium and 0.7 M Beryllium events have been presented.
- Preliminary results of Li and Be isotope fluxes, and their ratios, have been shown in the energy range from 0.4 GeV/n to 12 GeV/n, almost uncovered by previous measurements.
- The precision of the Beryllium and Lithium measurements can provide stringent constrain to the propagation models.

Thank you!

Isotopes identification in AMS

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

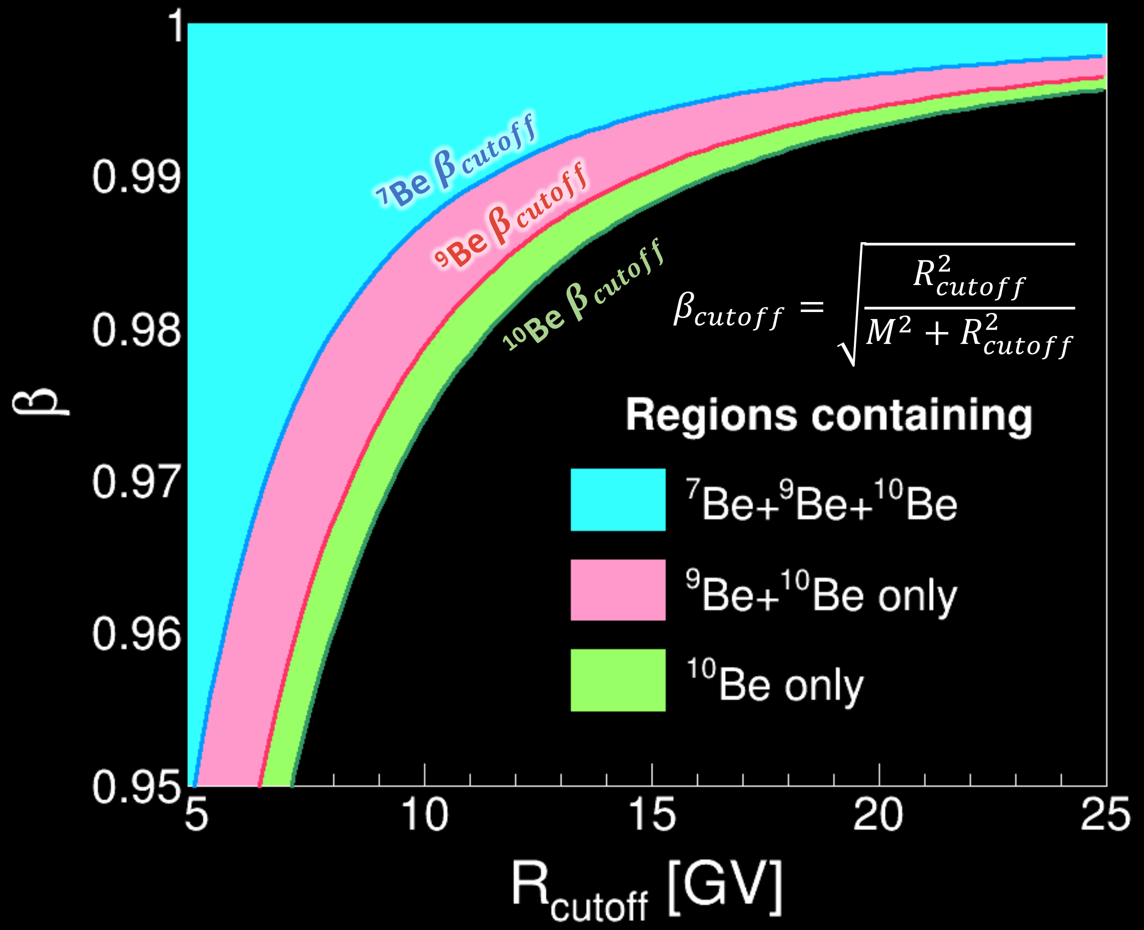


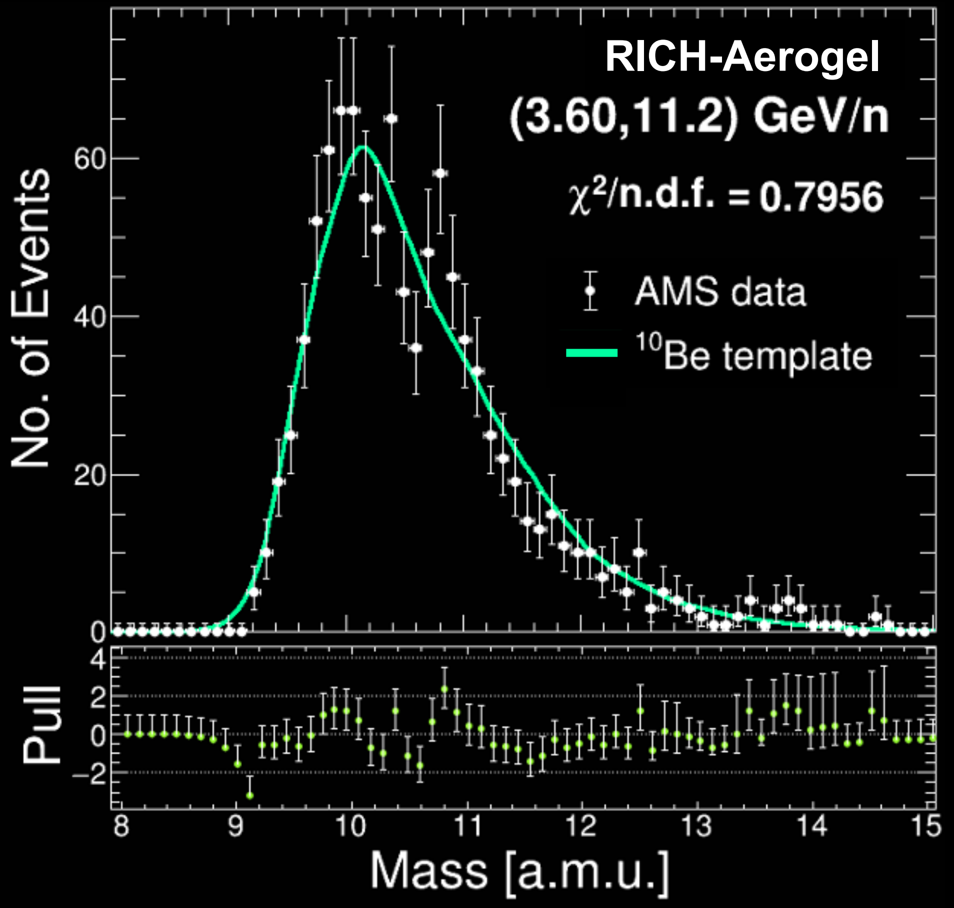


Validation of Mass Templates

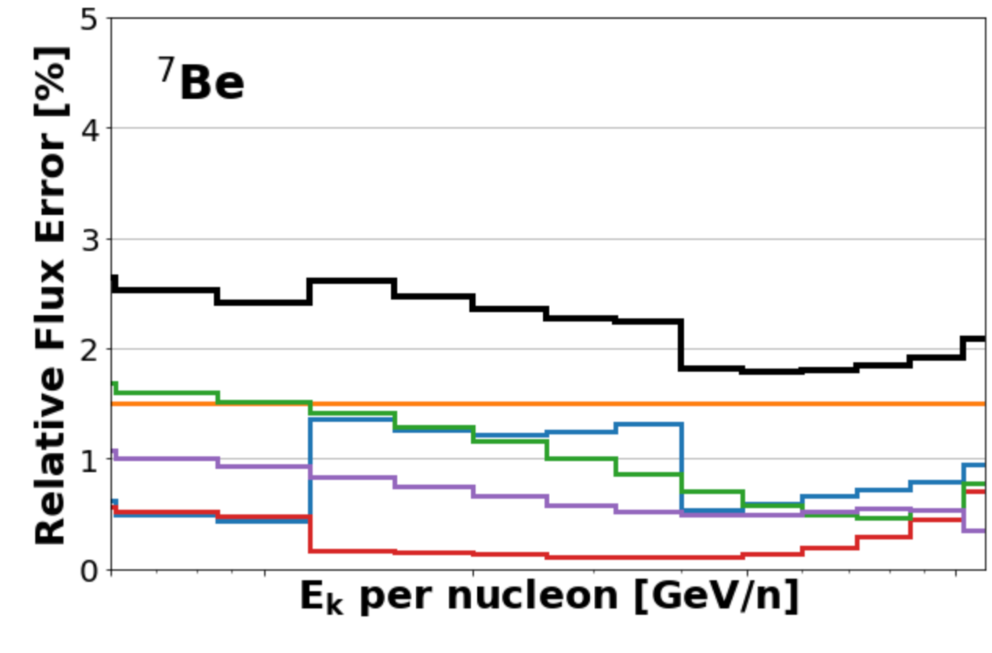
- Mass templates are obtained from Monte Carlo simulated events.
- Extensive checks of mass templates are done.

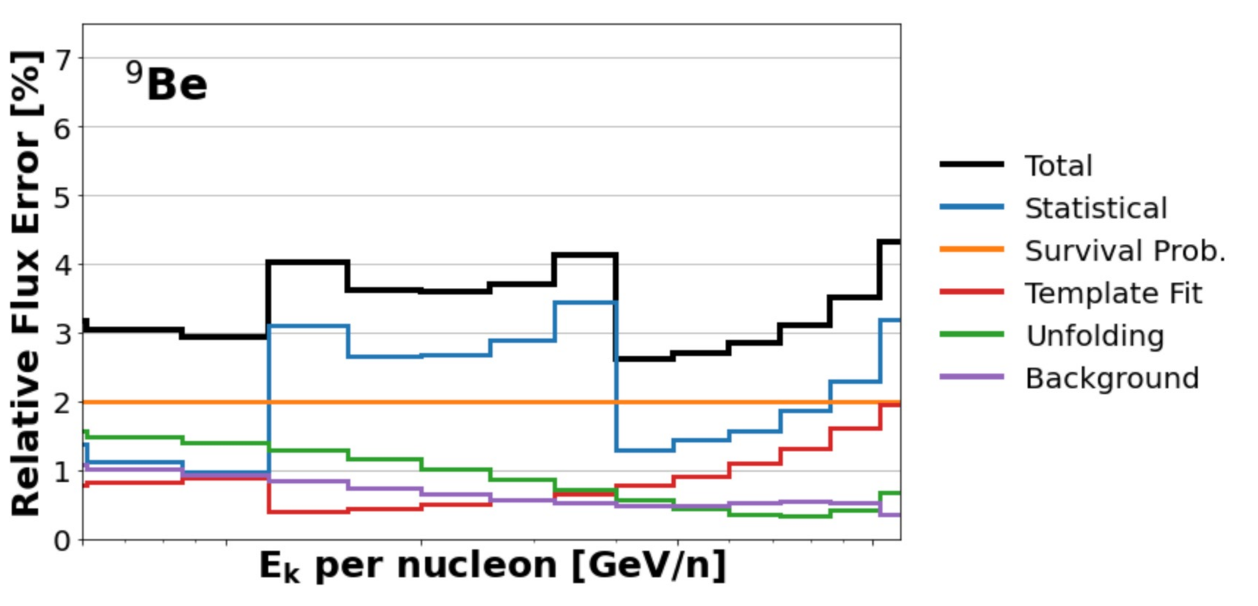
Example: check of mass template using the geomagnetic cutoff

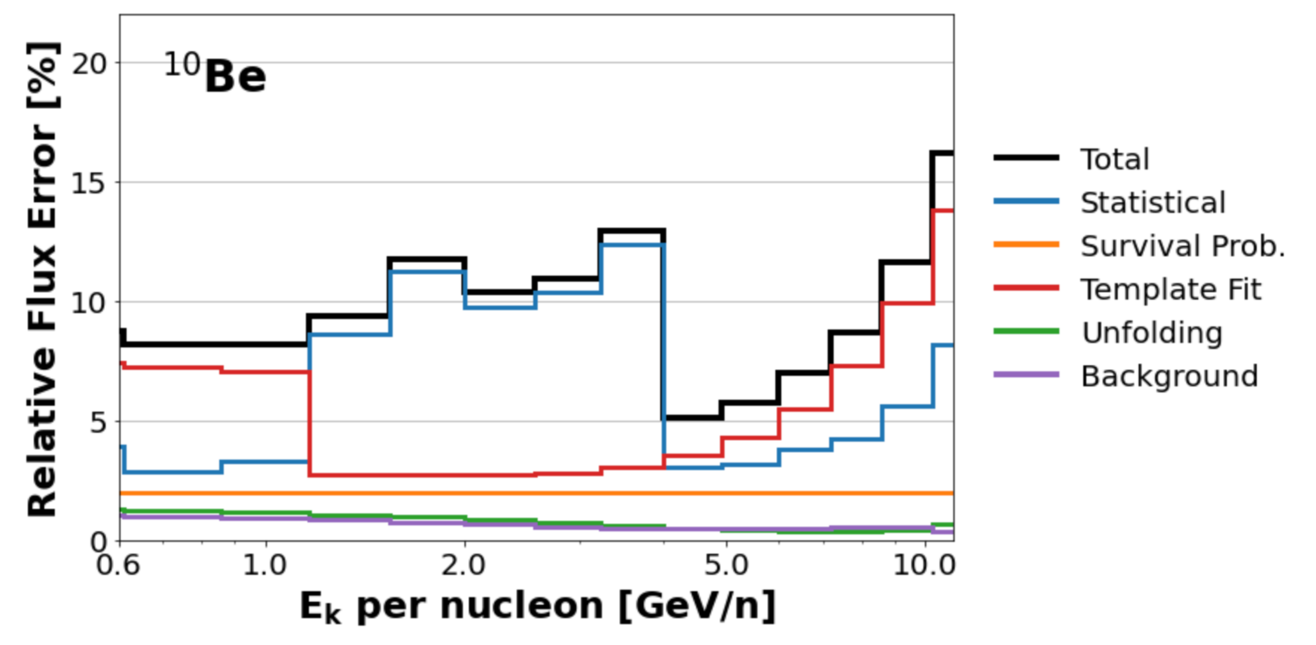




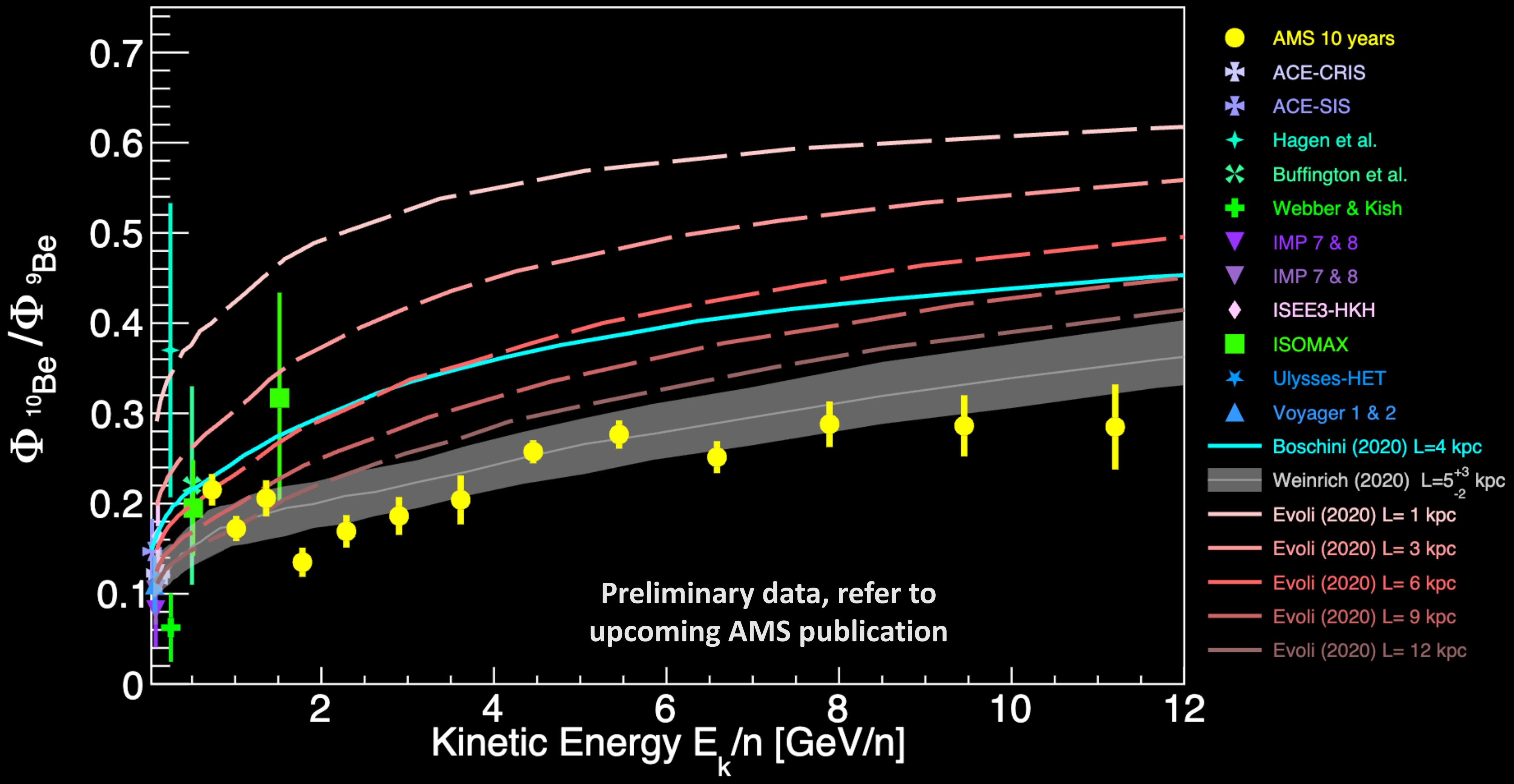
Beryllium Flux Error Break down





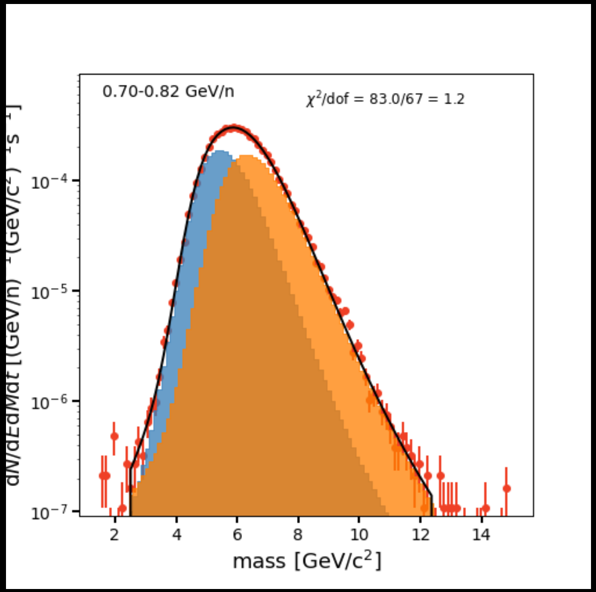


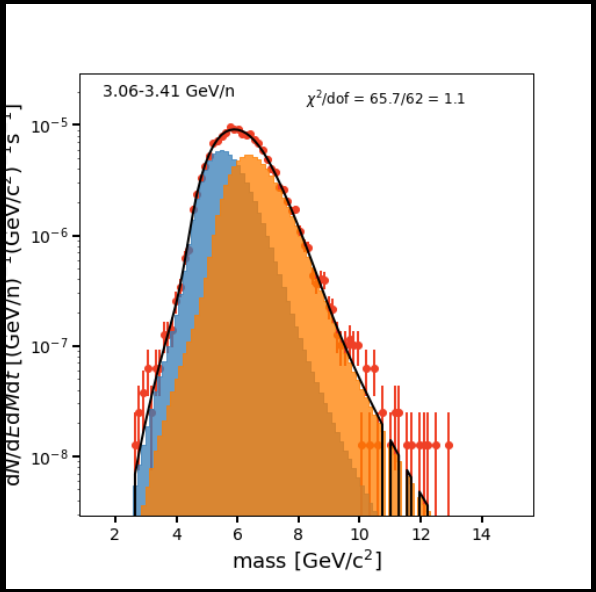
AMS $^{10}Be/^{9}Be$ flux Ratio Compared to Previous Measurements and Models

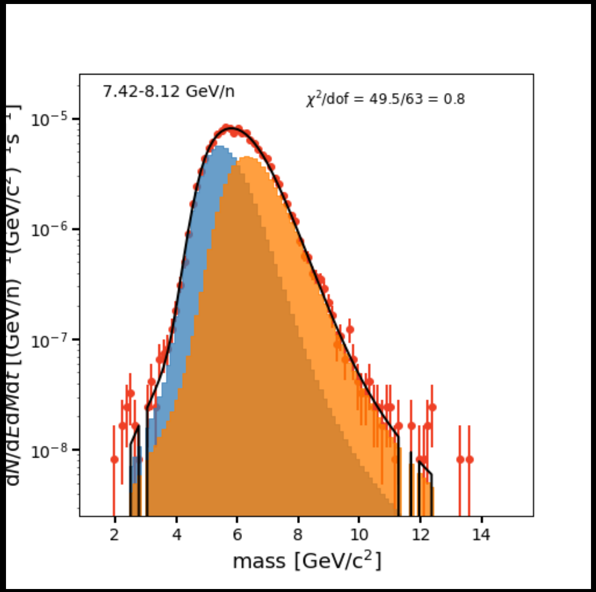


The AMS data provide significant new constraints on the galactic halo size L.

Lithium Templates

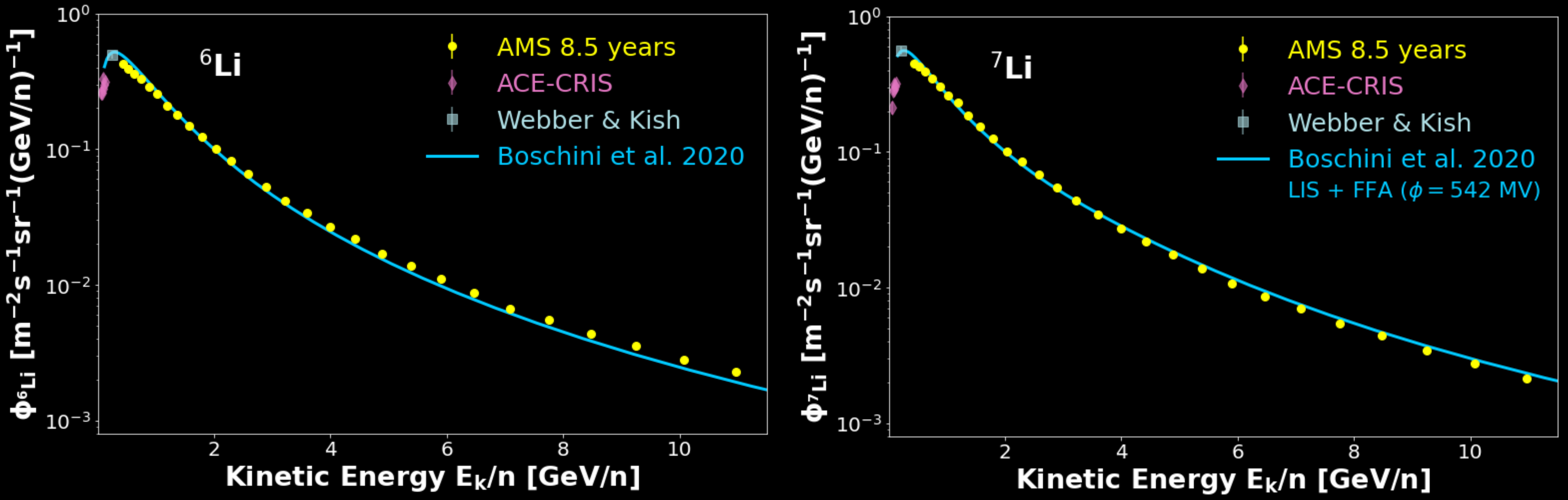






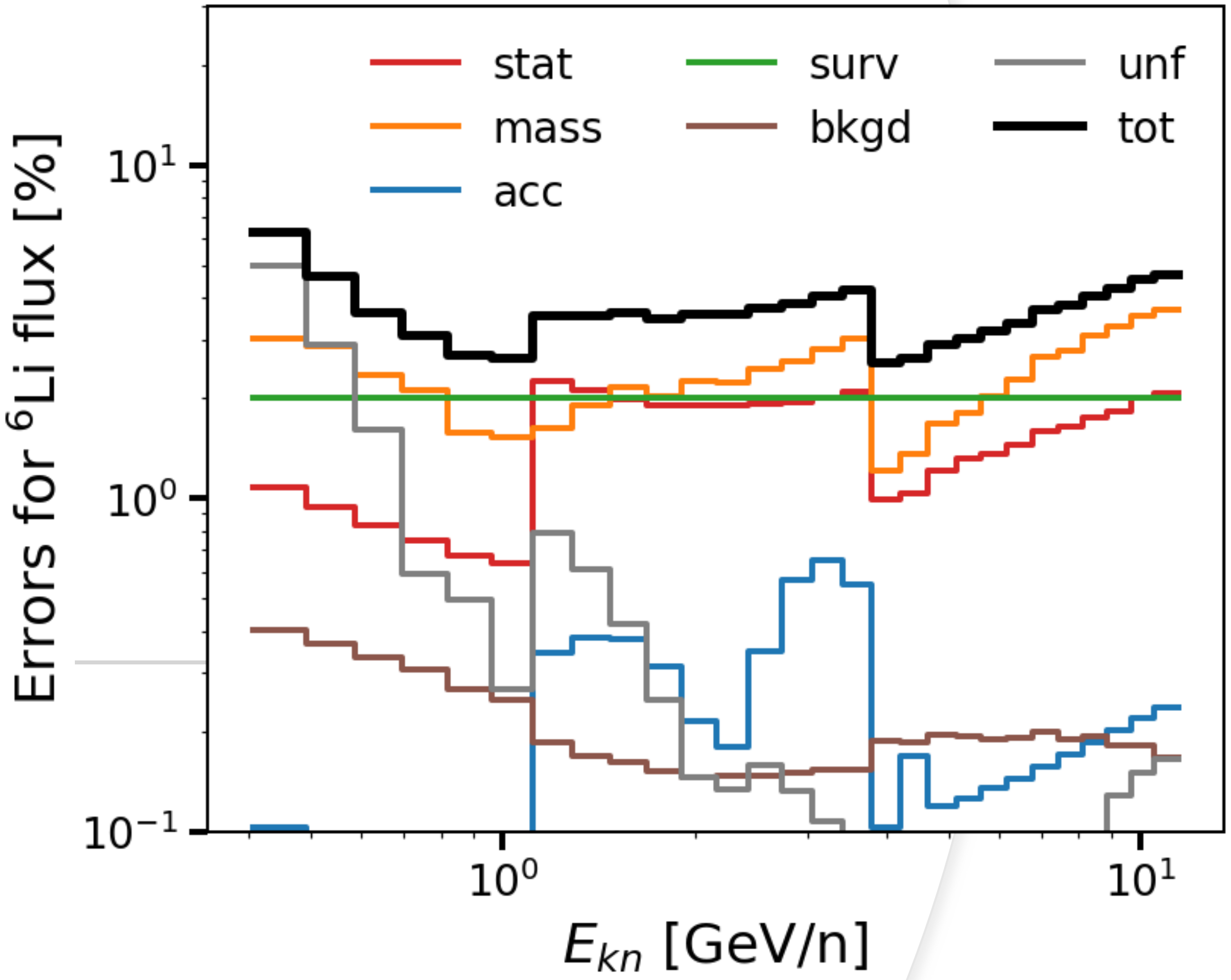
Lithium Isotope Fluxes

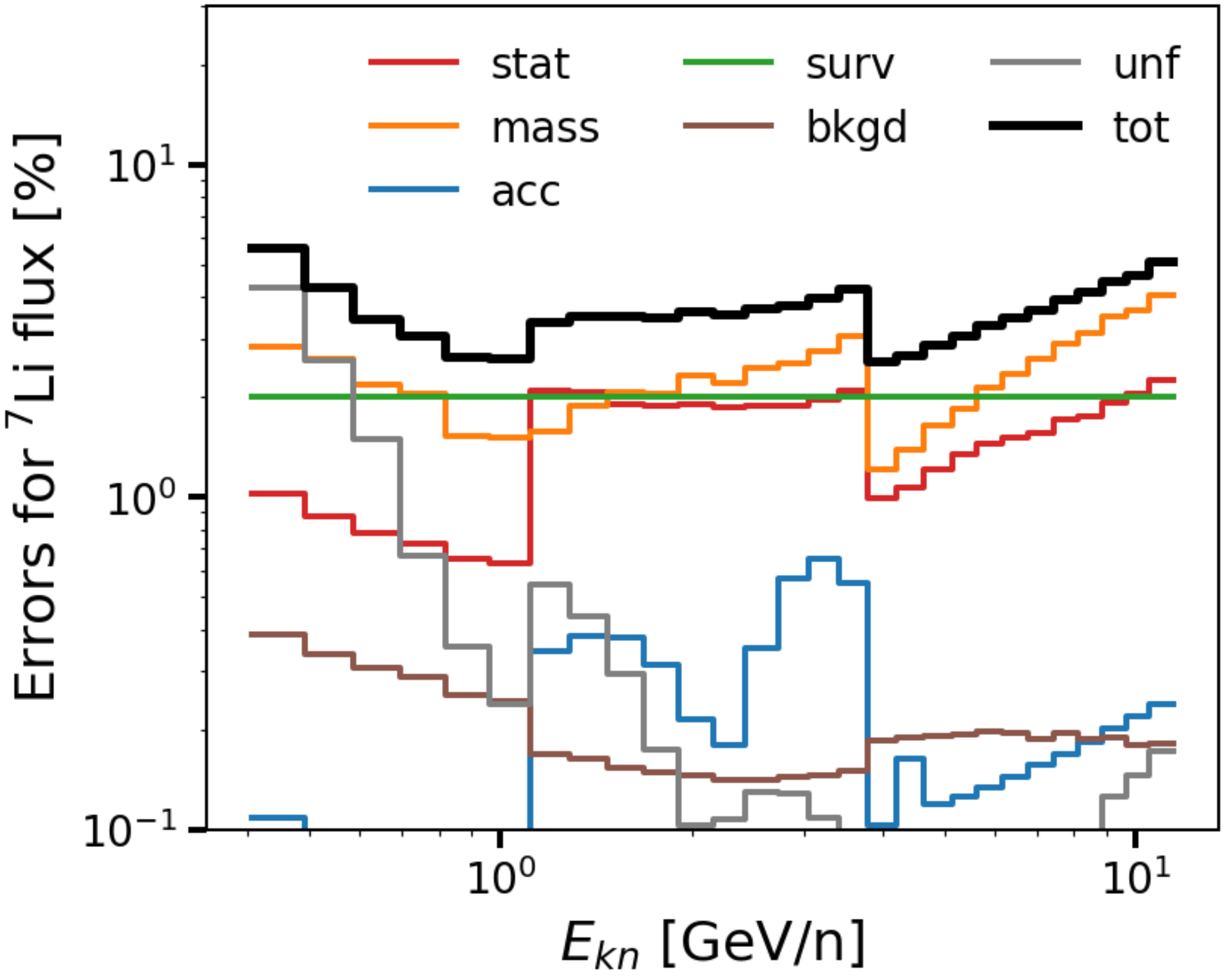
Based on 0.9 million lithium events.



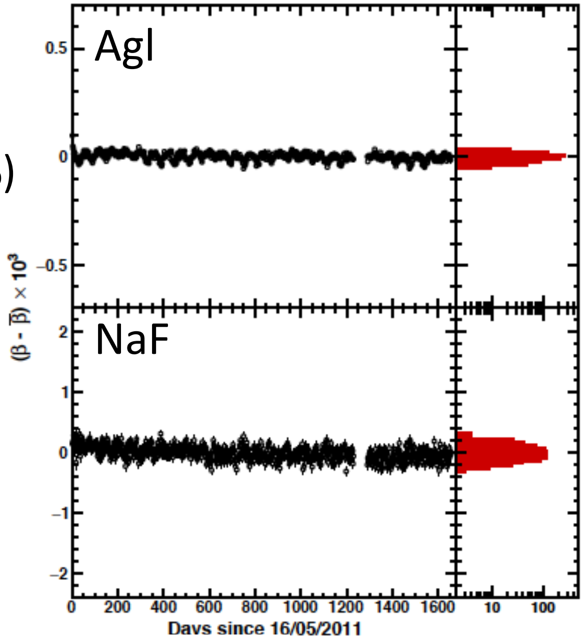
(Preliminary data, refer to upcoming AMS publication)

Lithium Flux Errors Beak-down





RICH Performances on ISS



Response stability

Charge: after temperature corrections the detectors response is stable

- The residual Photon Yield variation < 2 x 10^{-3} (95% CL) well within requirements (1%)

Beta: Residual effect on beta are small enought to have no impact in the resolution

Resolution

Beta: AgI(NaF) resolution ~ 0.7 (1.2) per mil per Helium and better for higher Z

Charge: Resolution ~ 0.3 for Helium