Cosmic-Ray Beryllium Isotopes with AMS02

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On behalf of the AMS-02 Collaboration

AMS - 02

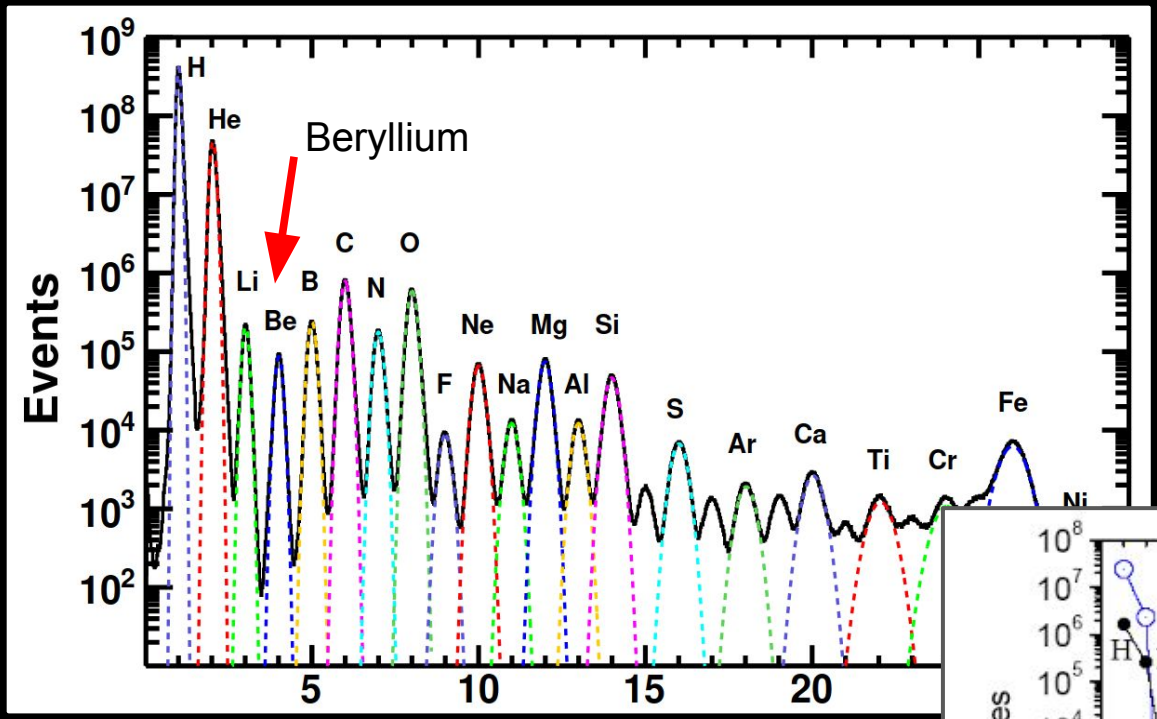
AMS was installed on ISS in May 2011.

An unique TeV precision, accelerator-type spectrometer in space

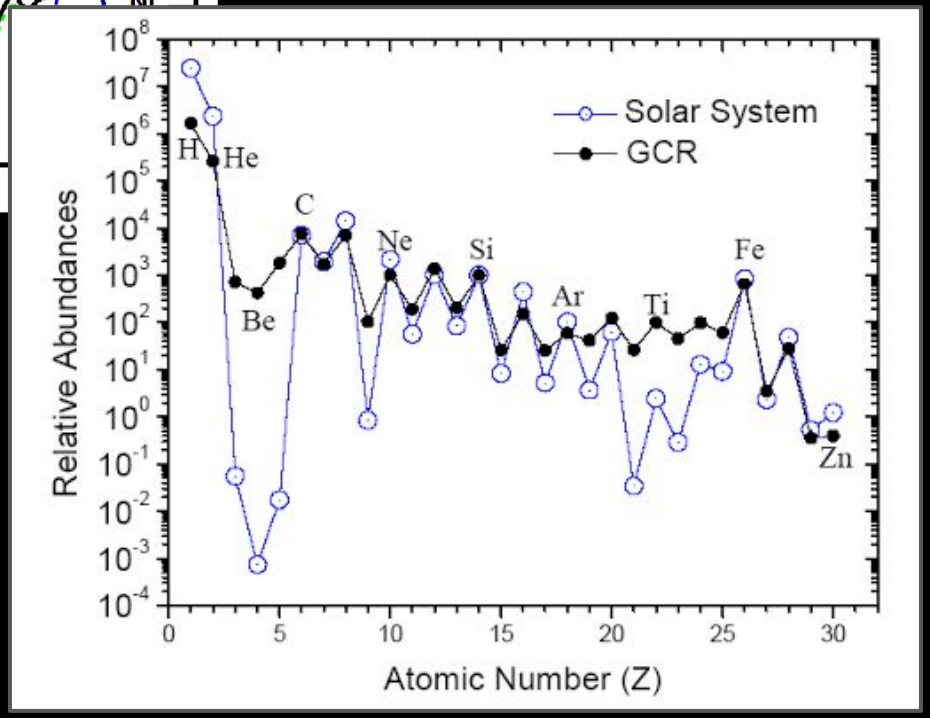
To date, it collected more than 200 billions of charged particles: e^+, e^-, p, pbar, nuclei...

Thanks to UTTPS, it will continue through the lifetime of ISS

Berillium in Cosmic Rays (CR)



- Beryllium amount is very small in CR
- Why it is so interesting?



Beryllium (Li and B) are not produced in Stellar-Nucleo-Synthesis

Abundance due to "**secondary production**"

Collisions of primary CR with Interstellar medium

Berillium in Cosmic Rays (CR)

- ^{7}Be is stable if completely ionized, otherwise decays rapidly by electronic capture
- ^{9}Be is stable
- ^{10}Be is unstable, with a decay time comparable with residence time of CR in the Galaxy (~ 1.39 x 10^{6} anni)

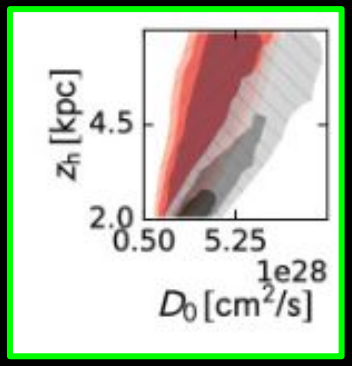
^{10}Be/^{9}Be is a powerful "radioactive clock" for the measurement of residence time

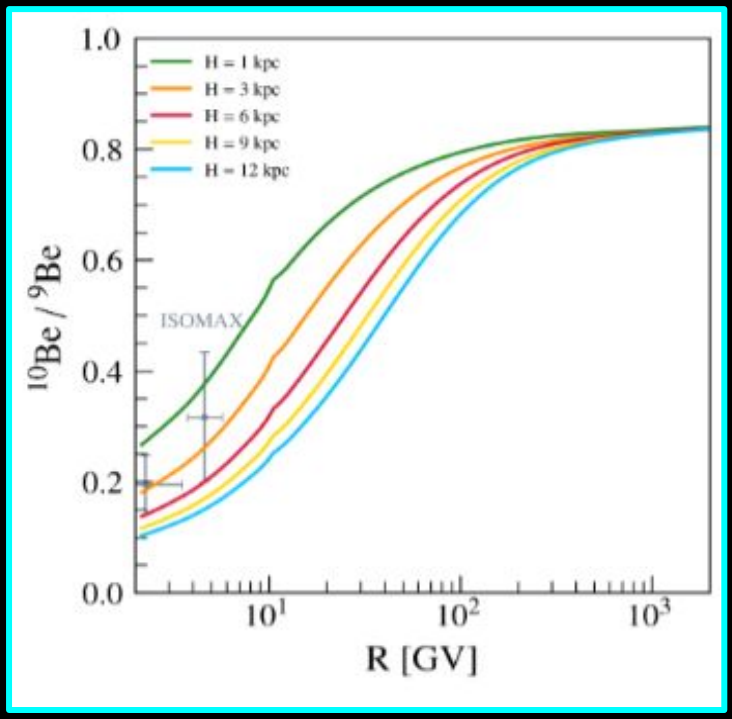
- As every sec/prim ratio, it can constrain the grammage

$$X(E) = \int dl \rho(l)$$

which is prop. to H/D

- H and D are thus dependent in many prop. models
- Adding a time dependence, ^{10}Be/^{9}Be can constrain D, allowing an independent measurement of H

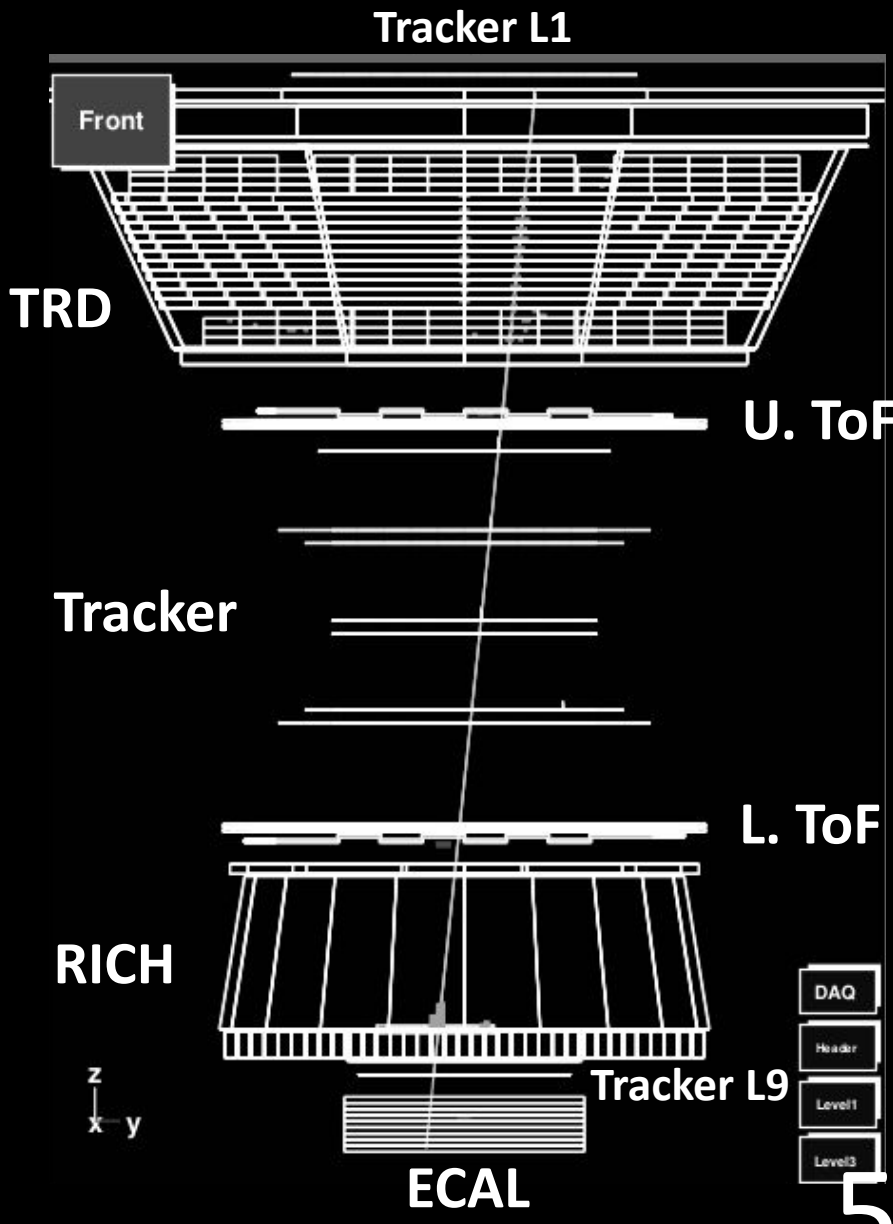




AMS and light isotope measurements

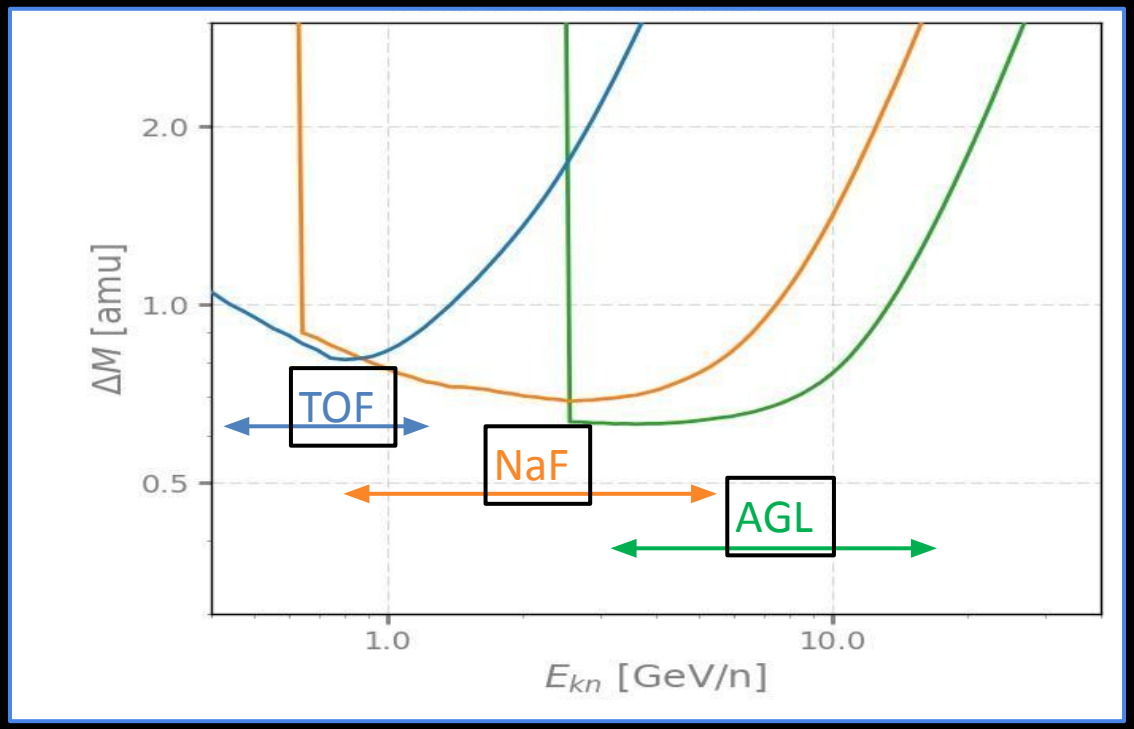
- AMS is composed by different sub-detectors for the redundant ID of the elements in CR
- The **Mass** is identified from the concurrent measurement of **Rigidity, Velocity** and **Charge**

TOF	$\sigma_\beta/\beta \sim 1\%$	$0.2 < E_k < 1.1$ GeV/n
RICH NaF	$\sigma_\beta/\beta \sim 0.3\%$	$0.7 < E_k < 3.7$ GeV/n
RICH AgI	$\sigma_\beta/\beta \sim 0.1\%$	$2.6 < E_k < 8.0$ GeV/n



Isotopic identification with AMS02

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

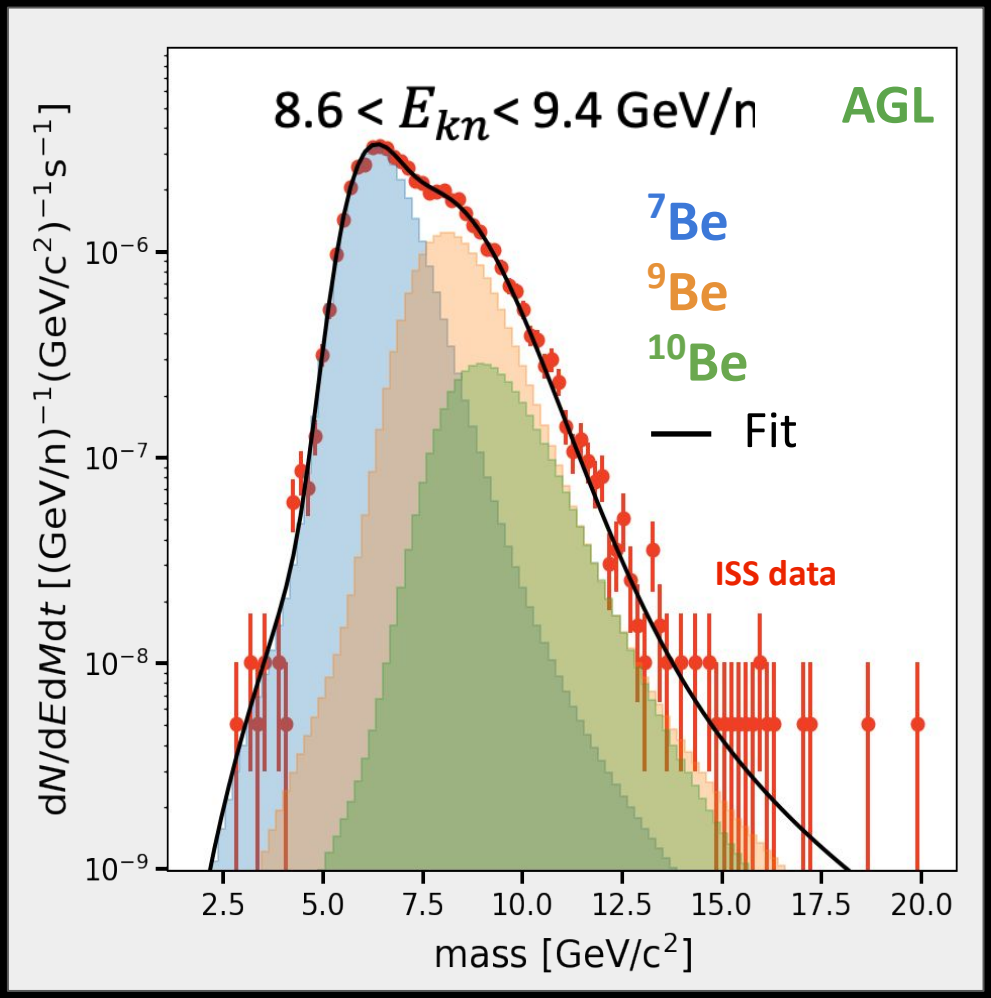


Δm ≈ 1 amu: Event by event ID not reachable

isotopic abundance from shape of the mass distributions

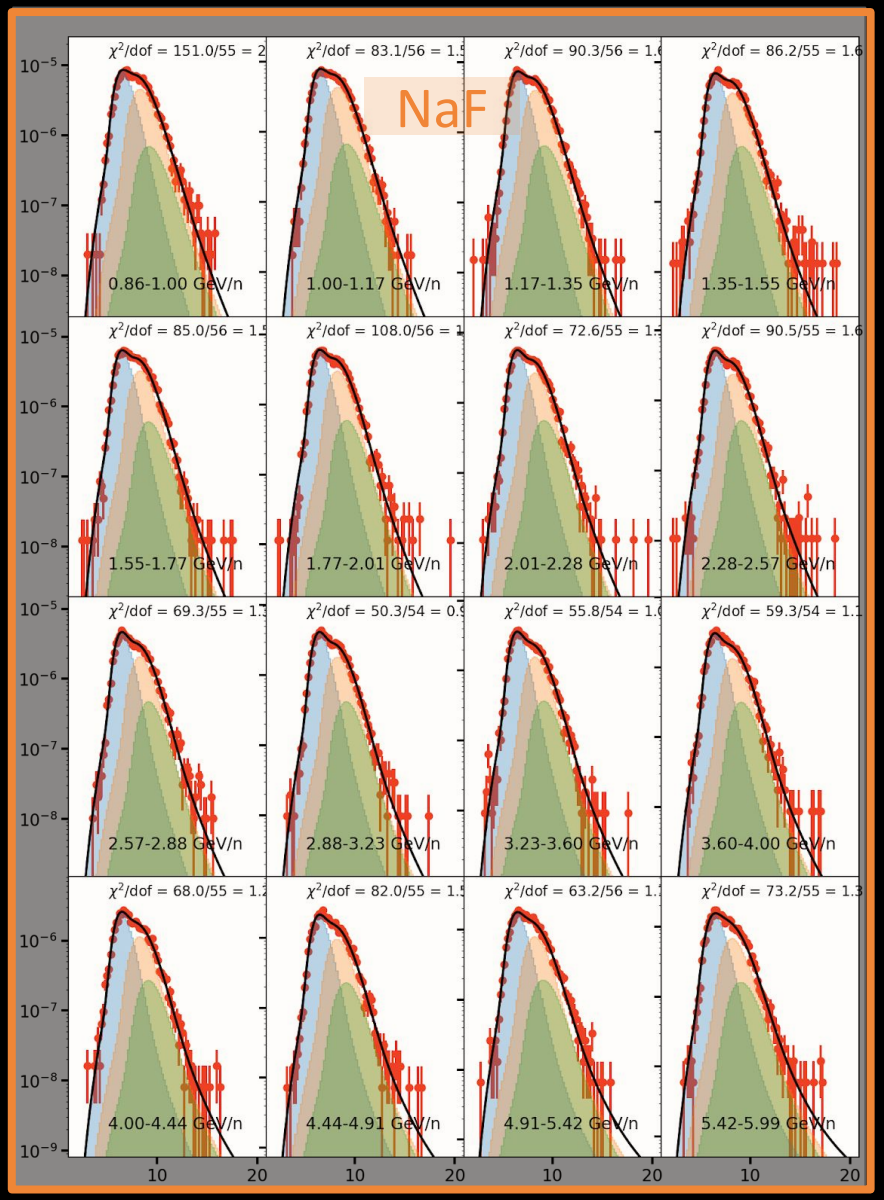
Measurement of Isotopic Fluxes

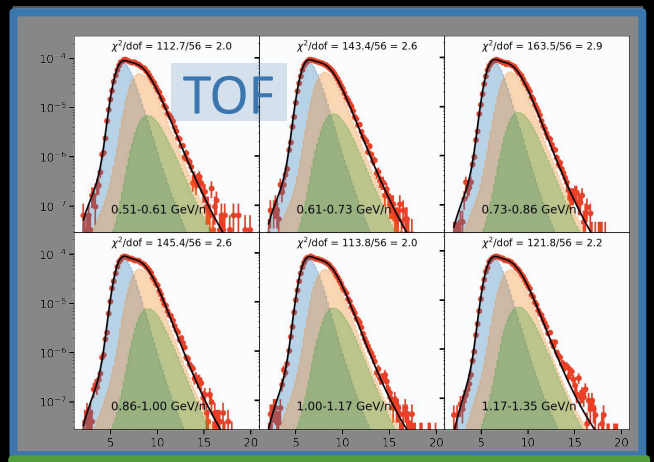
- Isotopic fluxes estimated from the event rates vs. mass for each Ekin bin obtained from beta measurements by TOF, NaF, Agl
- Fitted with the sum of scaled mass templates for each isotope
- Mass templates include:
  - Detector Acceptance from MC
  - Data/MC correction
  - Energy migration
  - R and beta responses

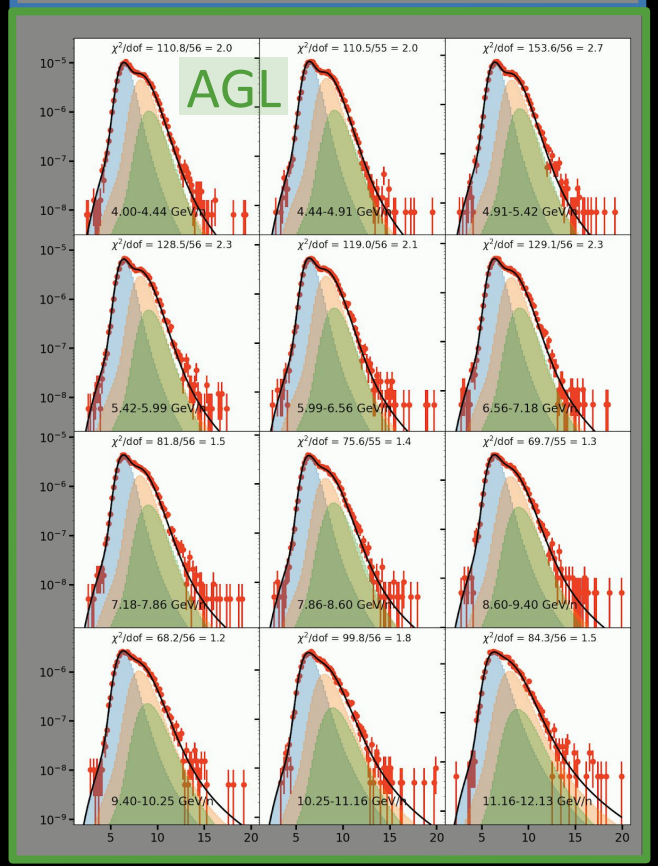


➔ **Unfolded fluxes directly obtained from fitting procedure**

Fitting of Be rates







^{7}Be

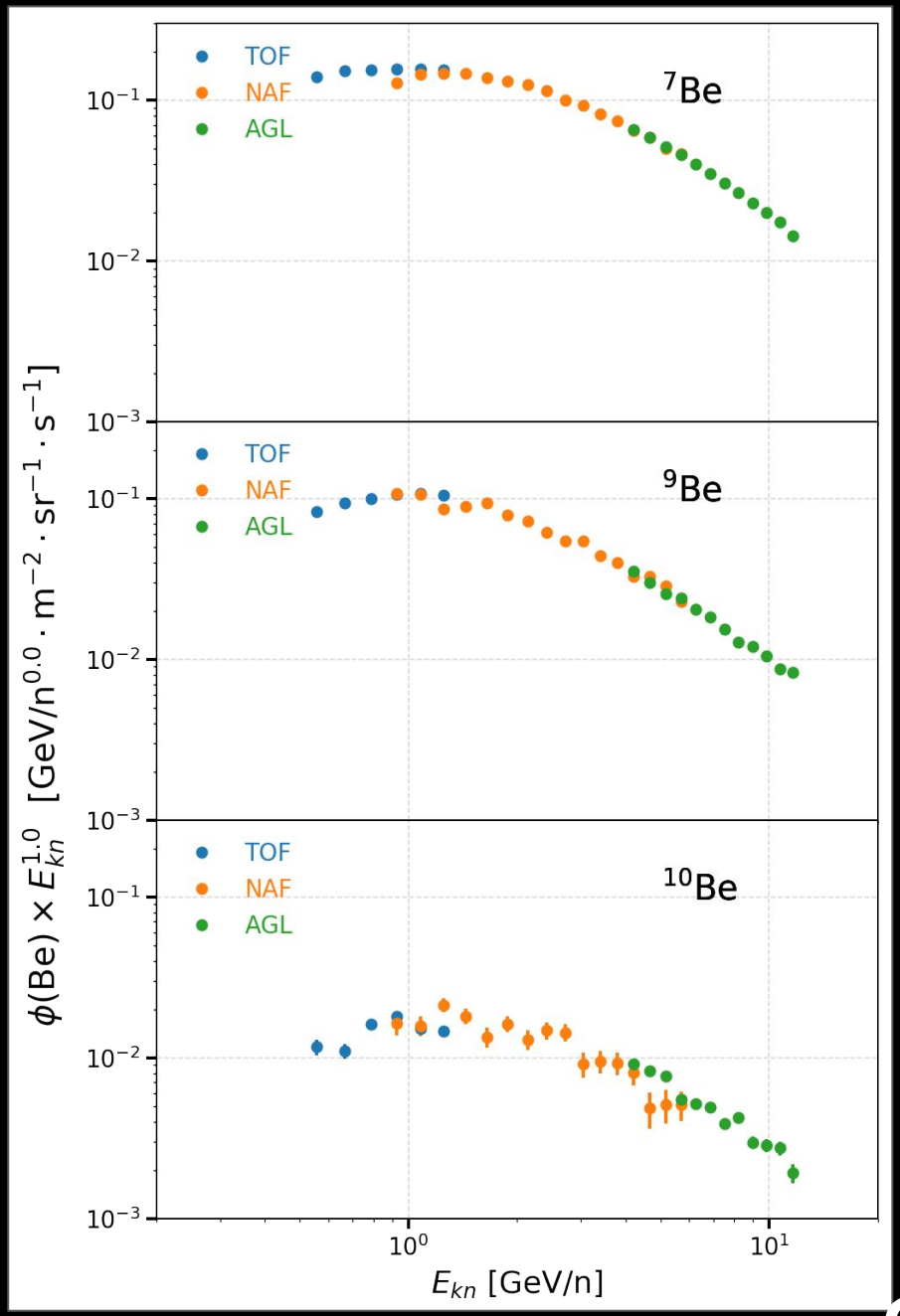
^{9}Be

^{10}Be

ISS data

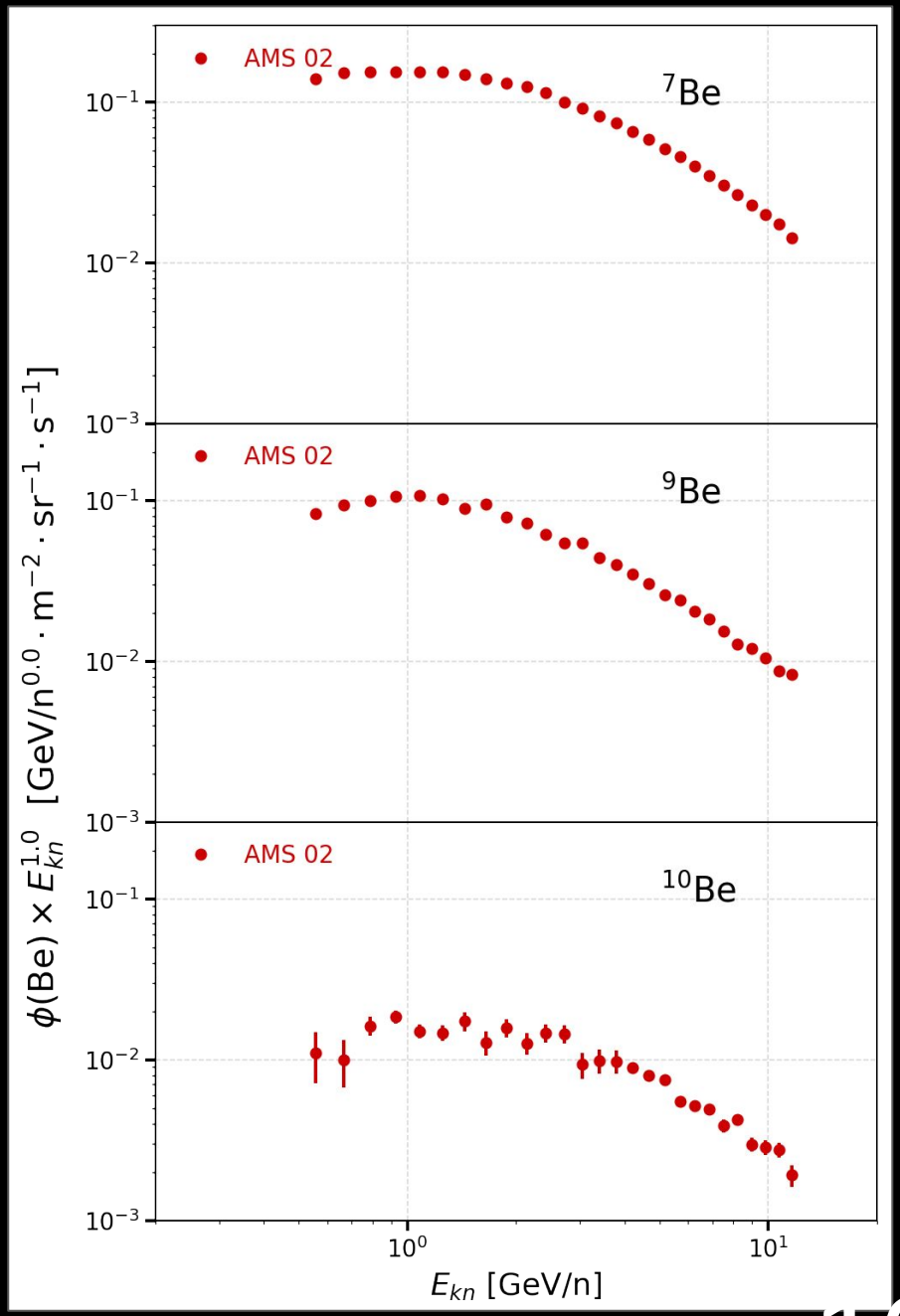
Be Isotopic fluxes

- Isotopic fluxes obtained from the fit for the 3 ranges
- Based on 0.4 millions beryllium events
- Include Data/MC and unfolding corrections
- Correction from bkgnd coming from interaction of heavier nuclei above L1
- Statistical error only



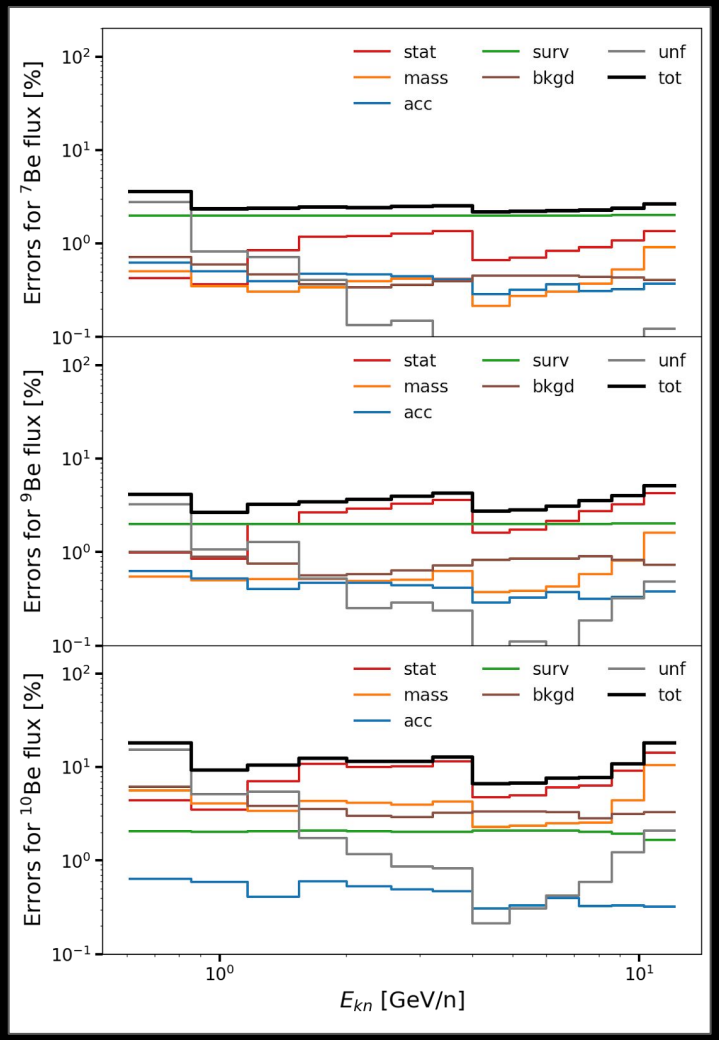
Be Isotopic fluxes

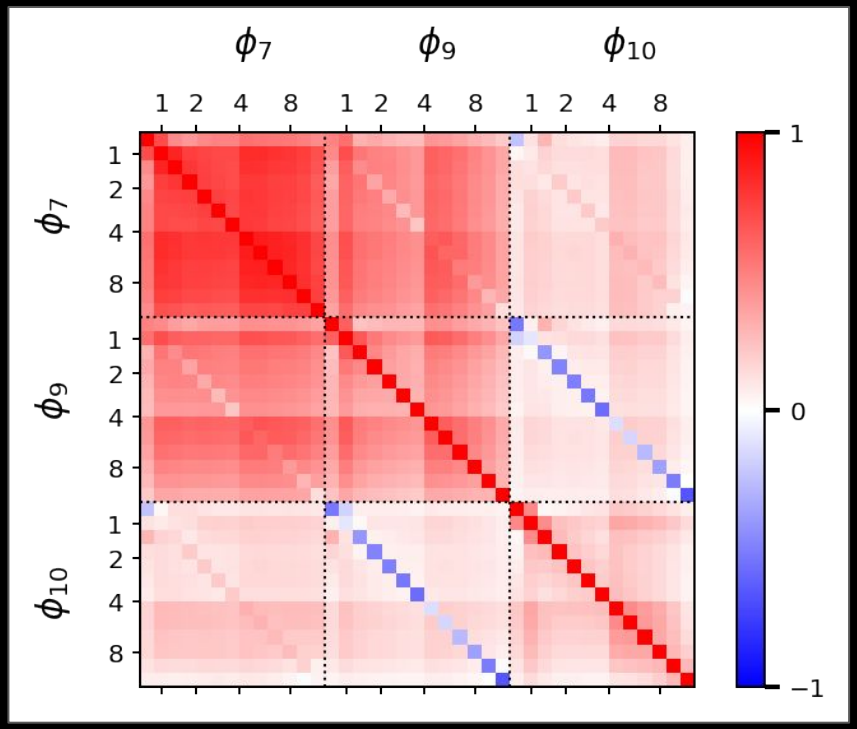
- Combining the overlapping Ekin regions.
- Statistical error only



Errors on Isotopic fluxes

- Stat. and syst. (mass id.-acceptance-survival prob.-background-unfolding) errors.
- Estimated with the full covariance matrix: important to describe correlation between energy bins and different isotopes.





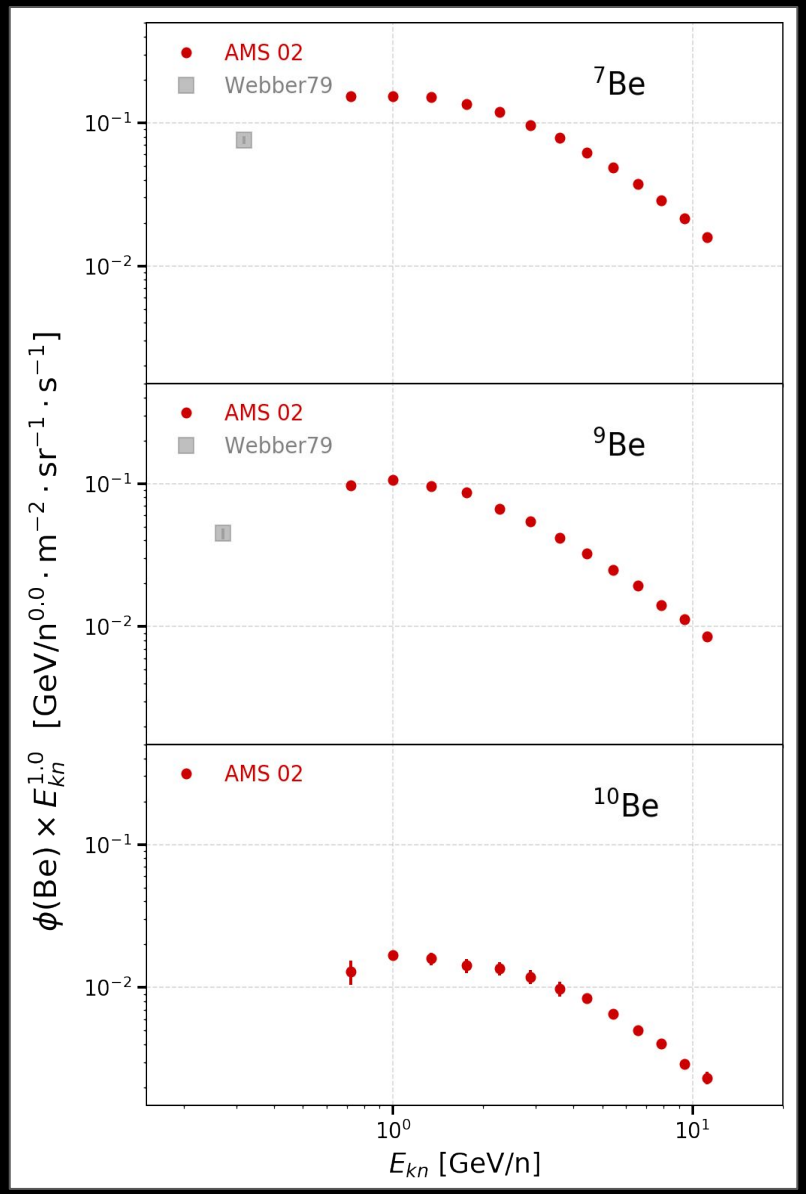
→Total (stat+sys) correlation matrix used to compute errors for rebinned flux and ratios.

Be Isotopic fluxes

Combined and rebinned fluxes from AMS 02 and comparison with previous experiments.

Stat+Sys errors computed from covariance matrix.

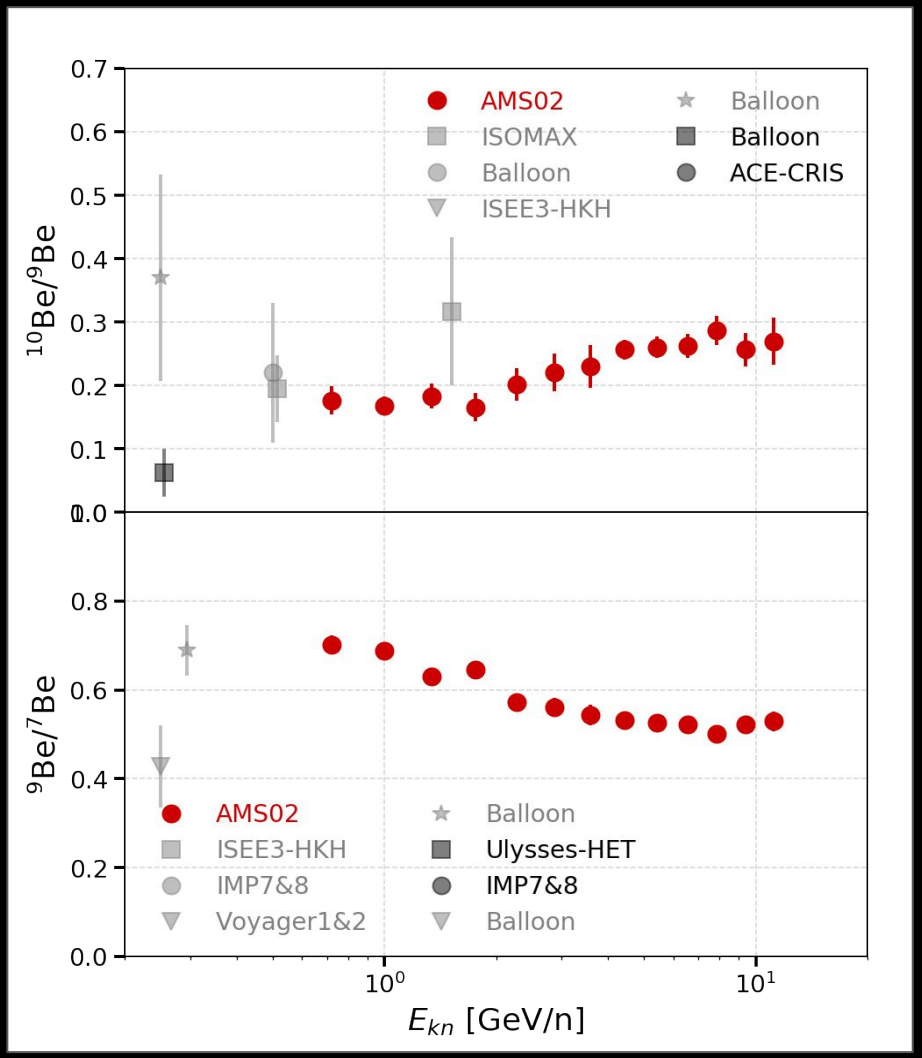
- First measurement of ^{7}Be, ^{9}Be and ^{10}Be fluxes above 0.4 GeV/n and up to 11 GeV/n.



Be Isotopic fluxes ratio against Ekin

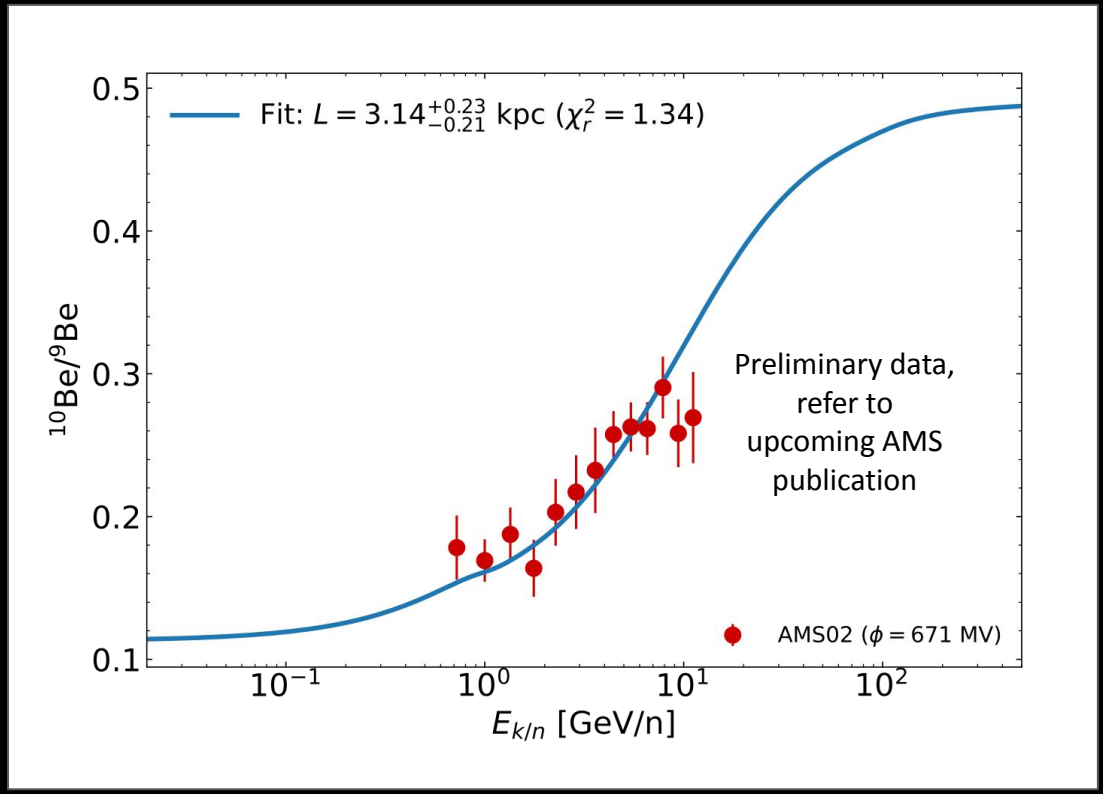
- Ratios computed from the fluxes.
- Errors from the total covariance matrix to take into account correlations between isotopes.

- First measurement of
- $^{9}Be/^{7}Be$ fluxes ratio above 0.5 GeV/n
- $^{10}Be/^{9}Be$ fluxes ratio above 2 GeV/n



Fitting $^{10}Be/^{9}Be$ Isotopic ratio

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



- Precision on L from AMS02 data $\sim \pm 0.2 kpc$
- Error dominated by uncertainty from production cross-section $\pm 1 kpc$.

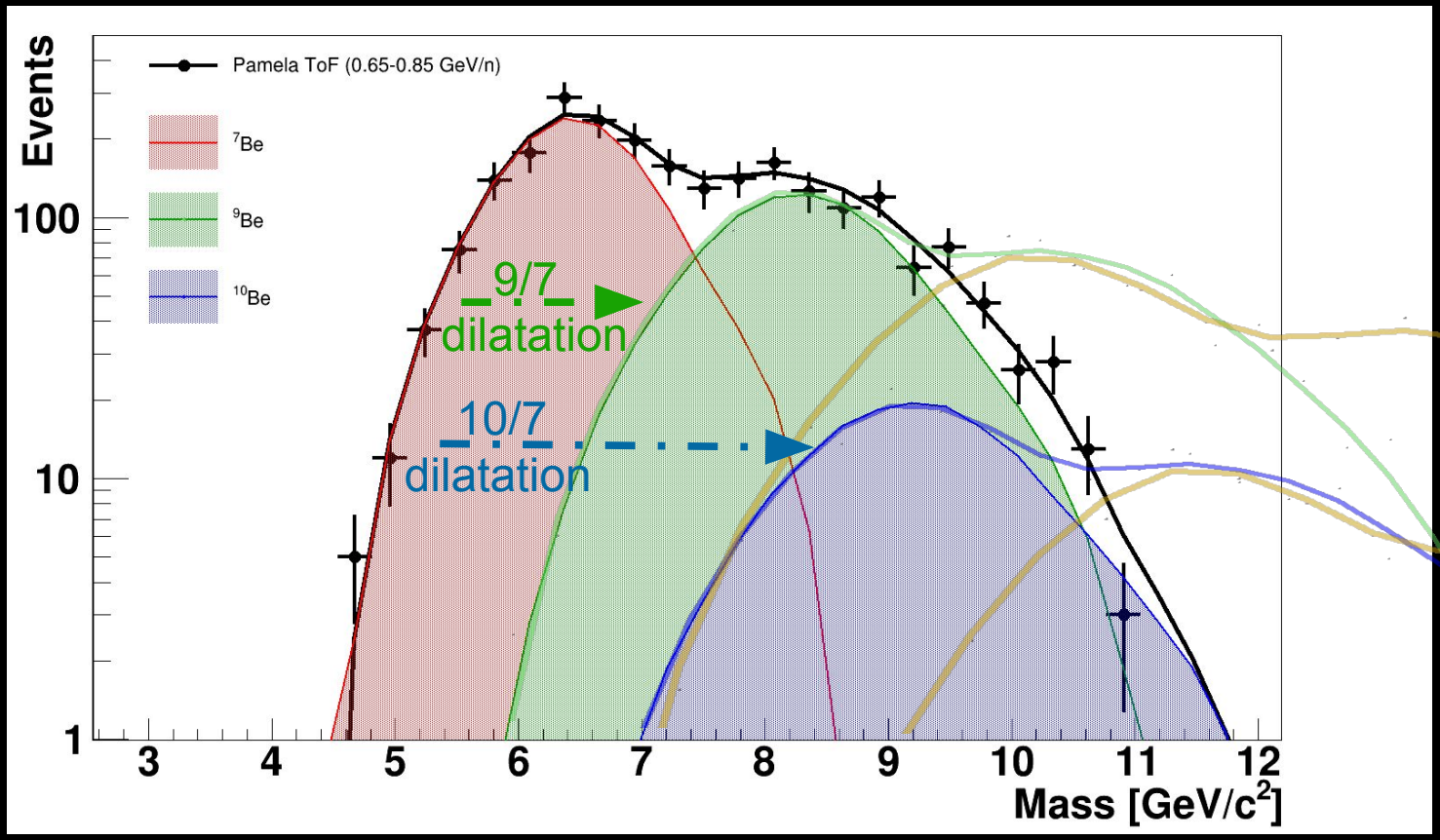
Conclusions

- Isotopic composition of Beryllium in cosmic rays is a key measurement to understand cosmic rays origin and propagation.
- Dedicated method based on template used to fit the event rates vs. mass to measure the isotopic fluxes.
- Measurement of Beryllium isotopic fluxes and ratios between 0.4 GeV/n and 11 GeV/n with systematic errors and associated covariance matrices have been presented.
- Provides precise data, on an extended energy range, to constrain the galactic halo size and the age of CRs.

The “Data Driven” approach (how to get rid of MC)

A self-consistent approach to extract isotope mass distributions from data itself.
(it is a solution of the 3x3 equation system of the mass distributions: “templates”)

An intuitive/graphical view: The unknown templates are related by: dM/M = constant
Linear transf. approximation: templates are related by (known) coordinate dilatation



Then some additional “ghost-templates” have to be evaluated (in the same way) and removed