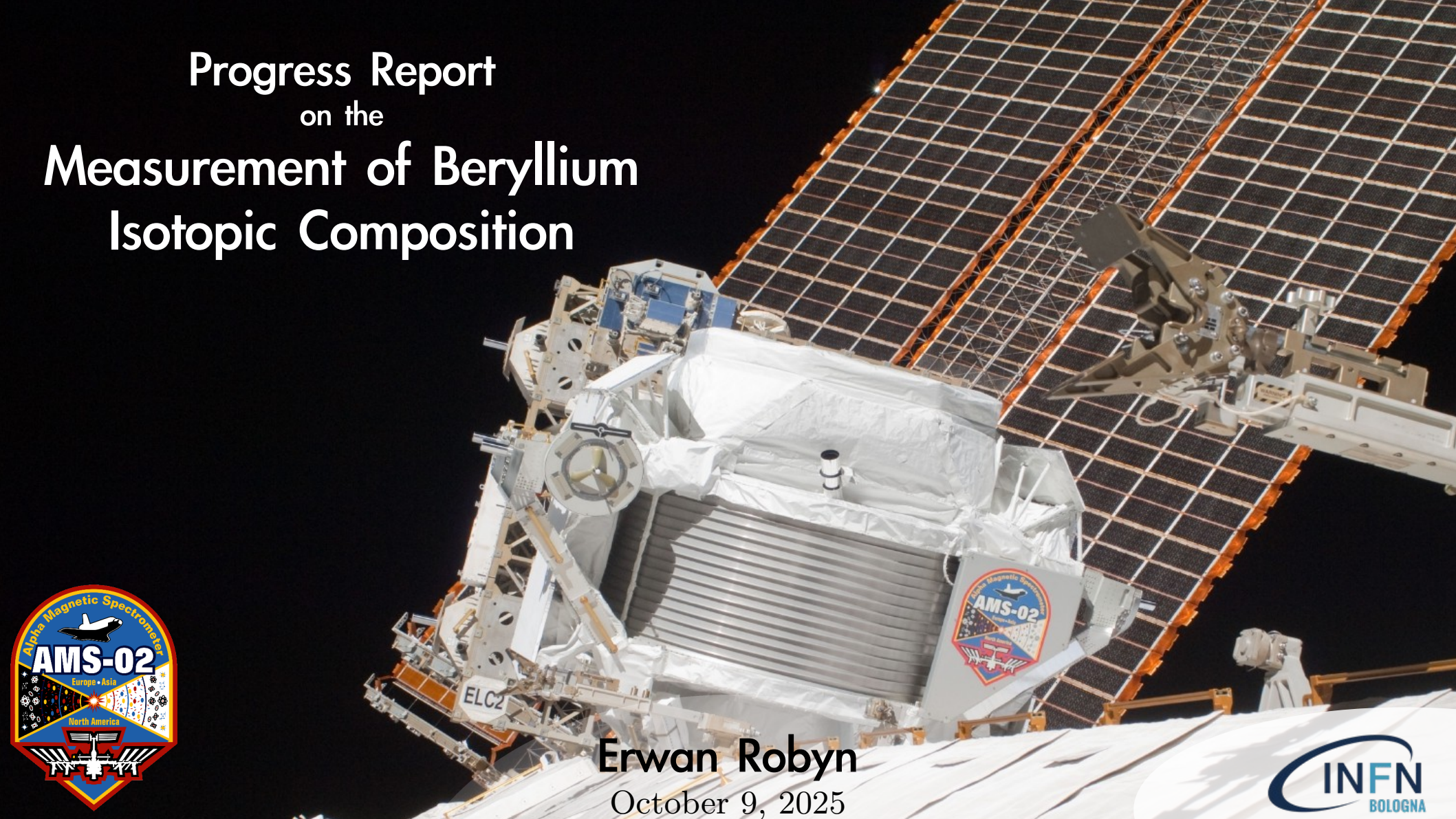
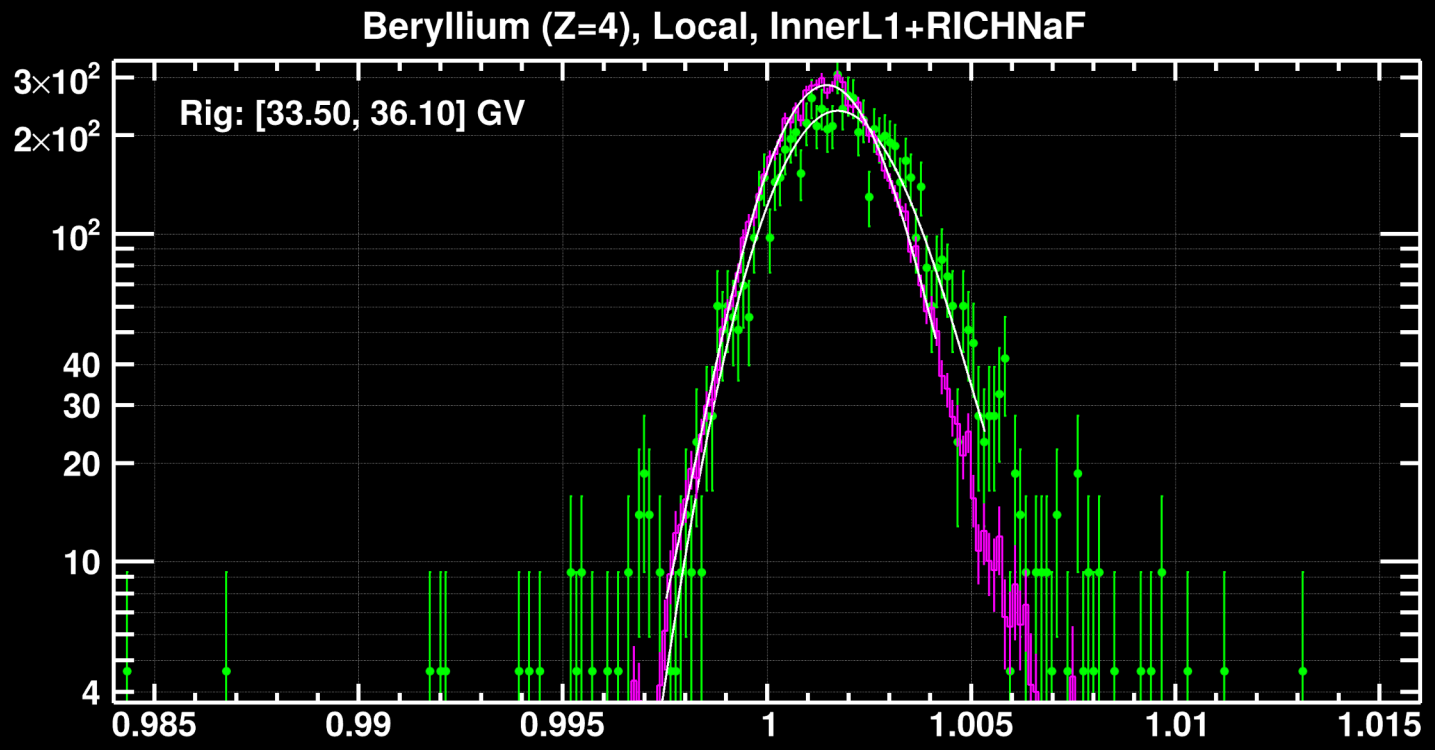
Progress Report on the Measurement of Beryllium Isotopic Composition



Erwan Robyn

October 9, 2025

Beta Distribution Estimation Methods

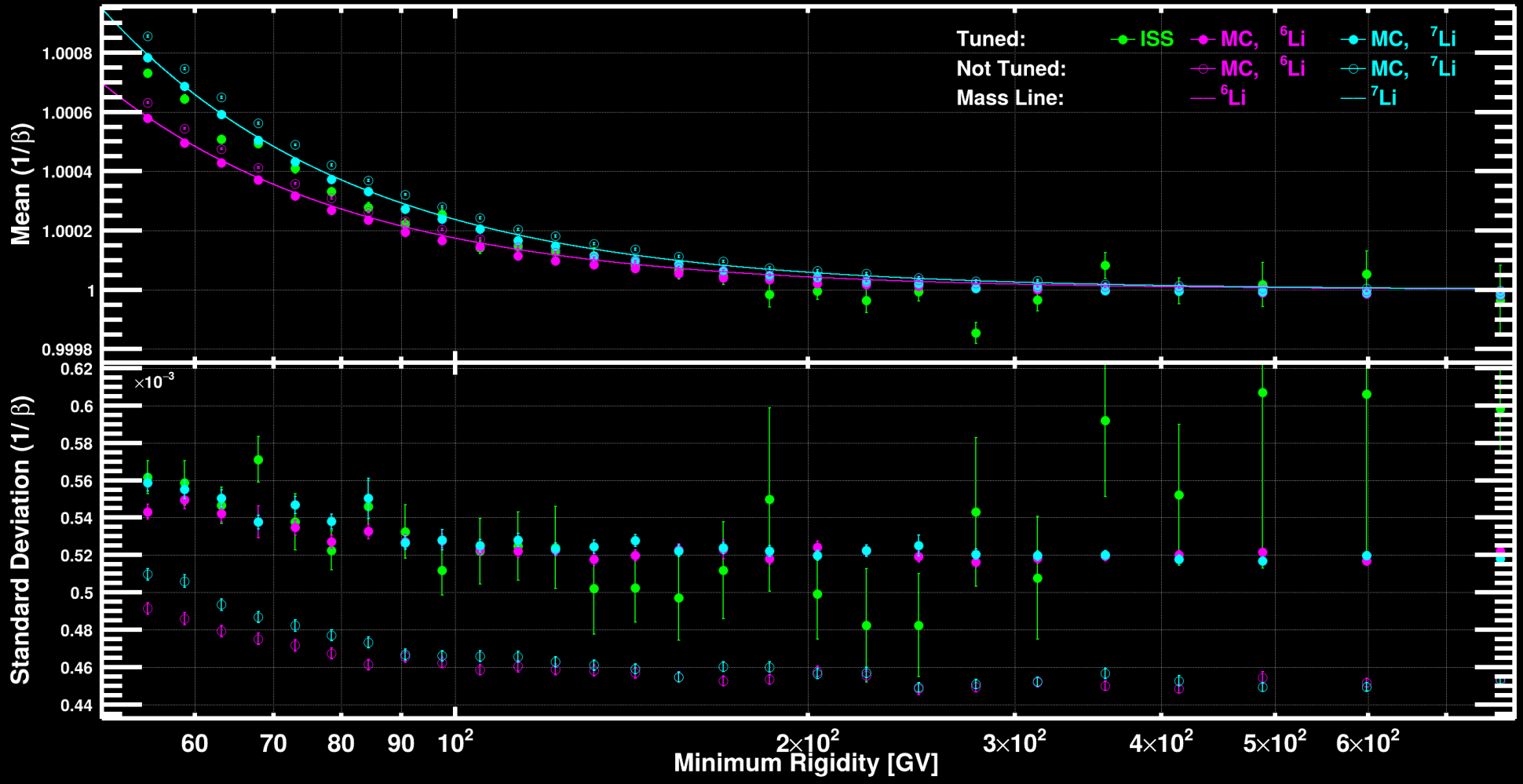


Fit of the distribution using an 80% core gaussian + asymmetrical gaussian.

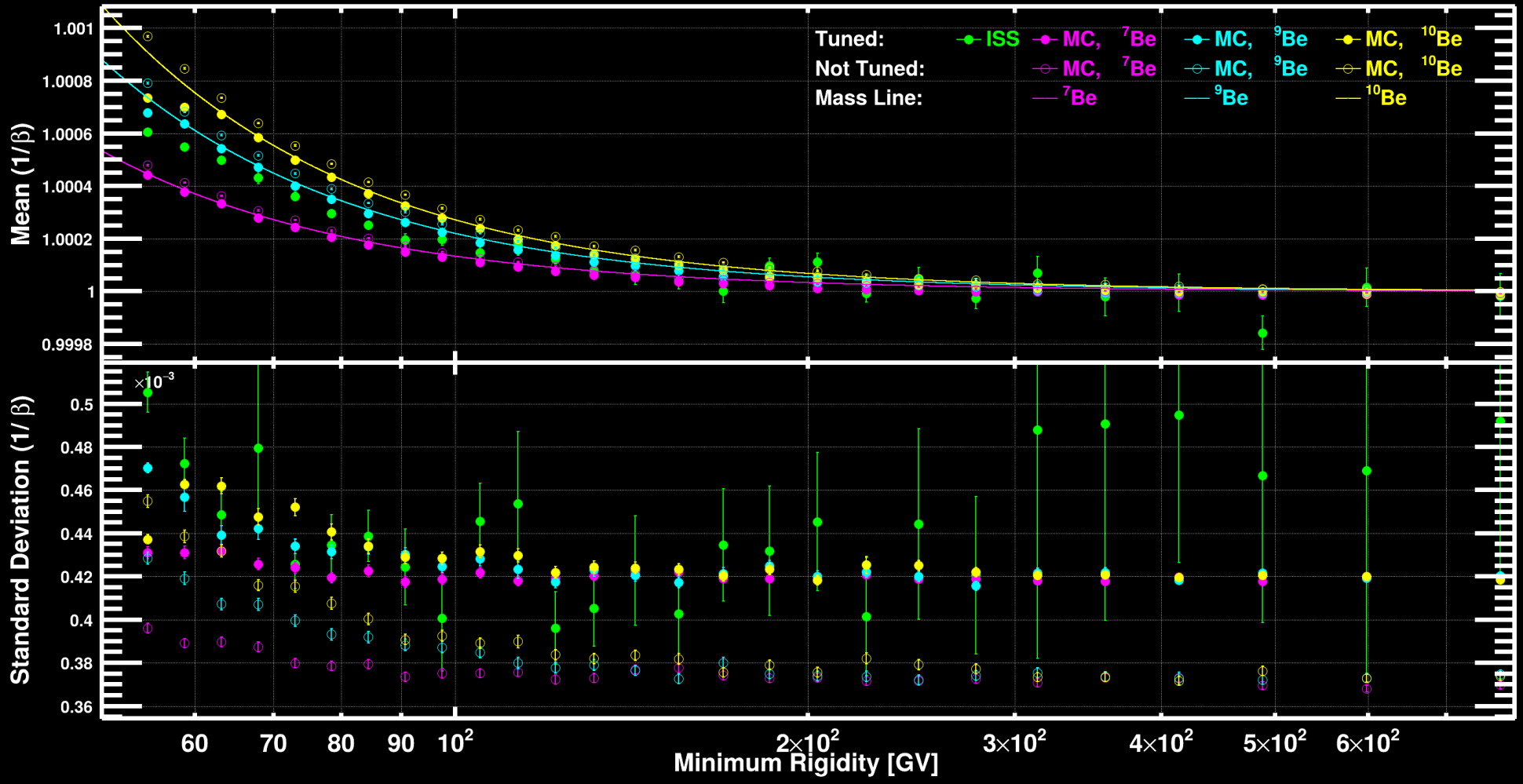
Results are confirmed comparing with the mean and standard deviation computed from the distribution itself.

AgI

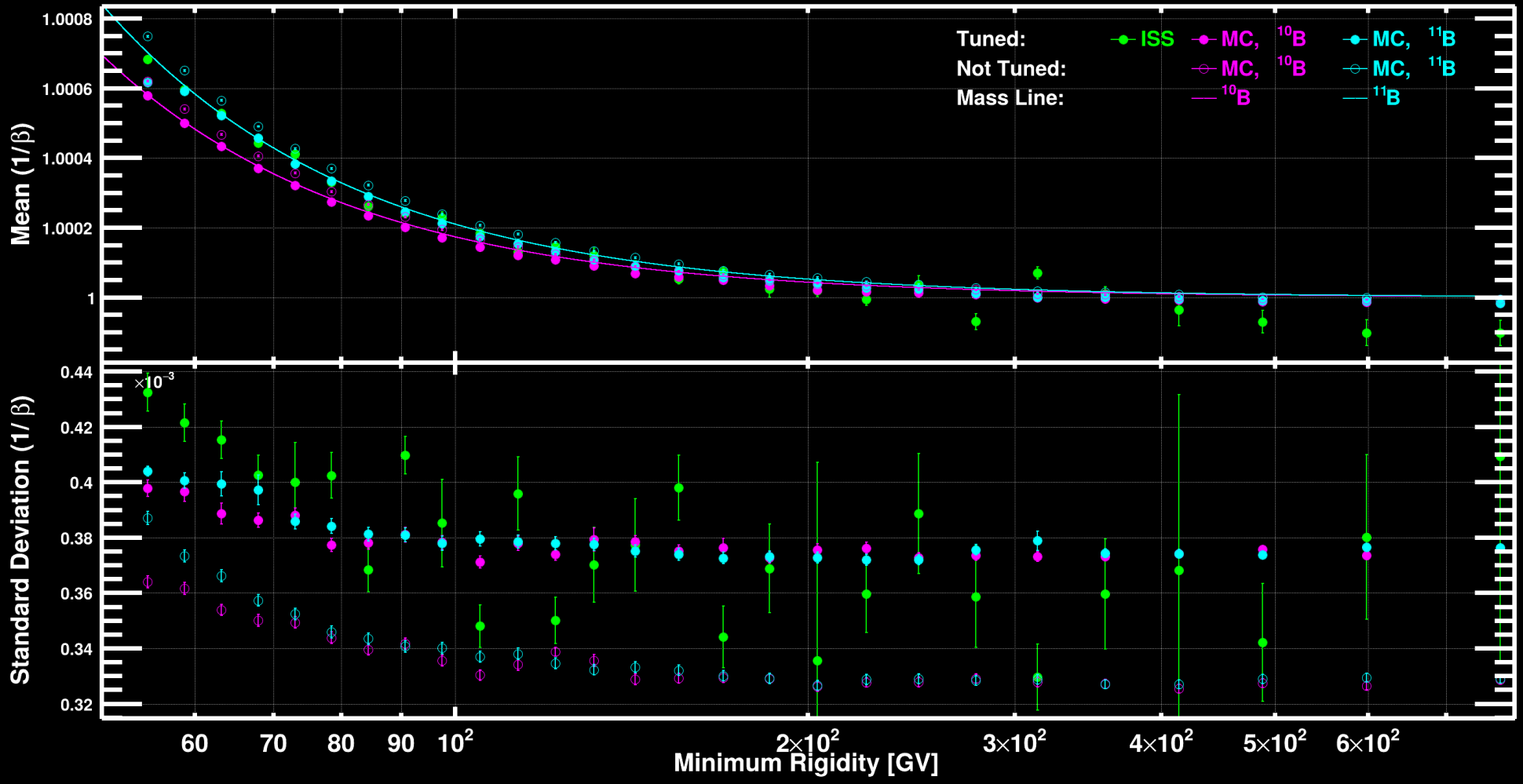
Lithium (Z=3), Local, InnerL1+RICHAgl



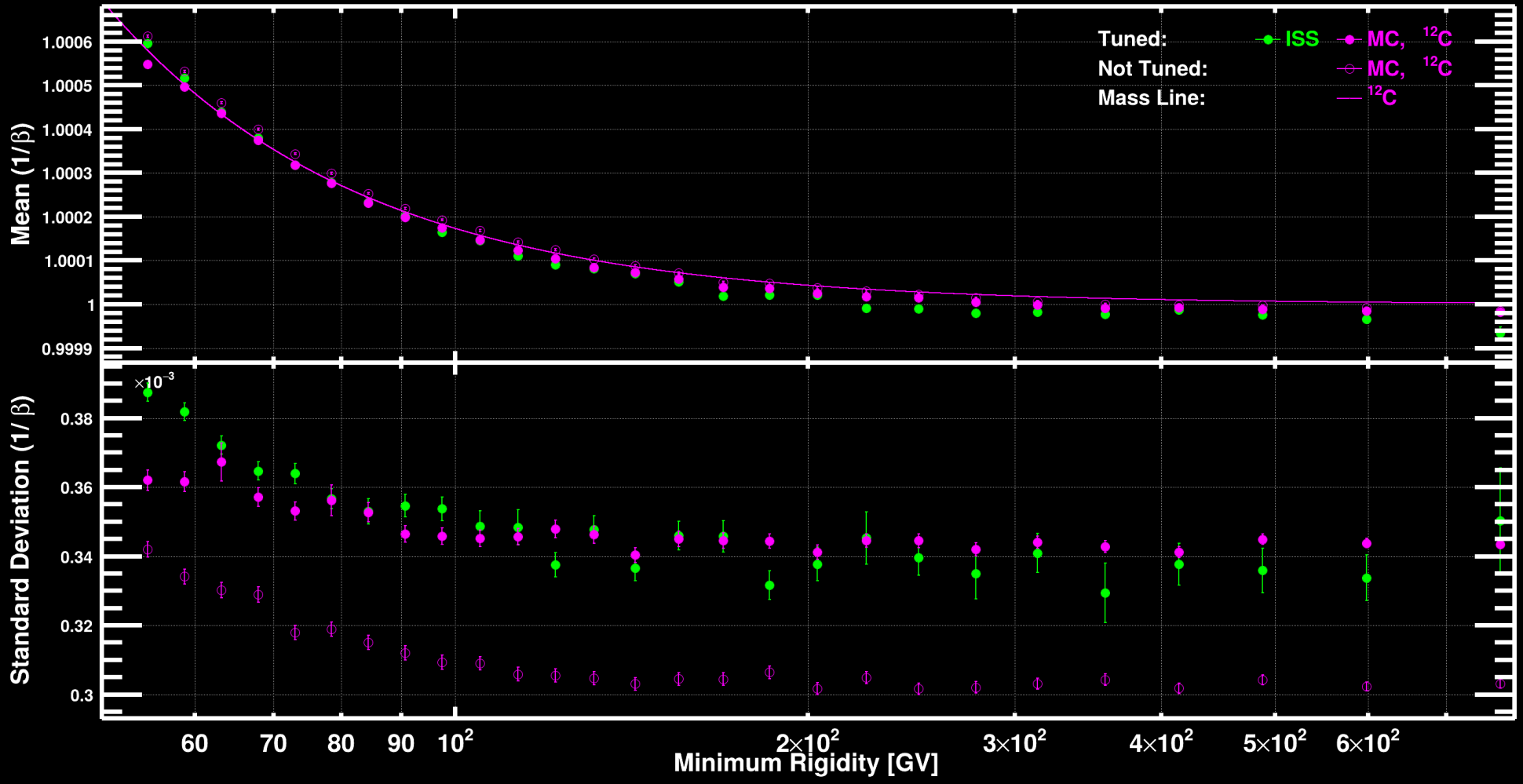
Beryllium (Z=4), Local, InnerL1+RICHAgl



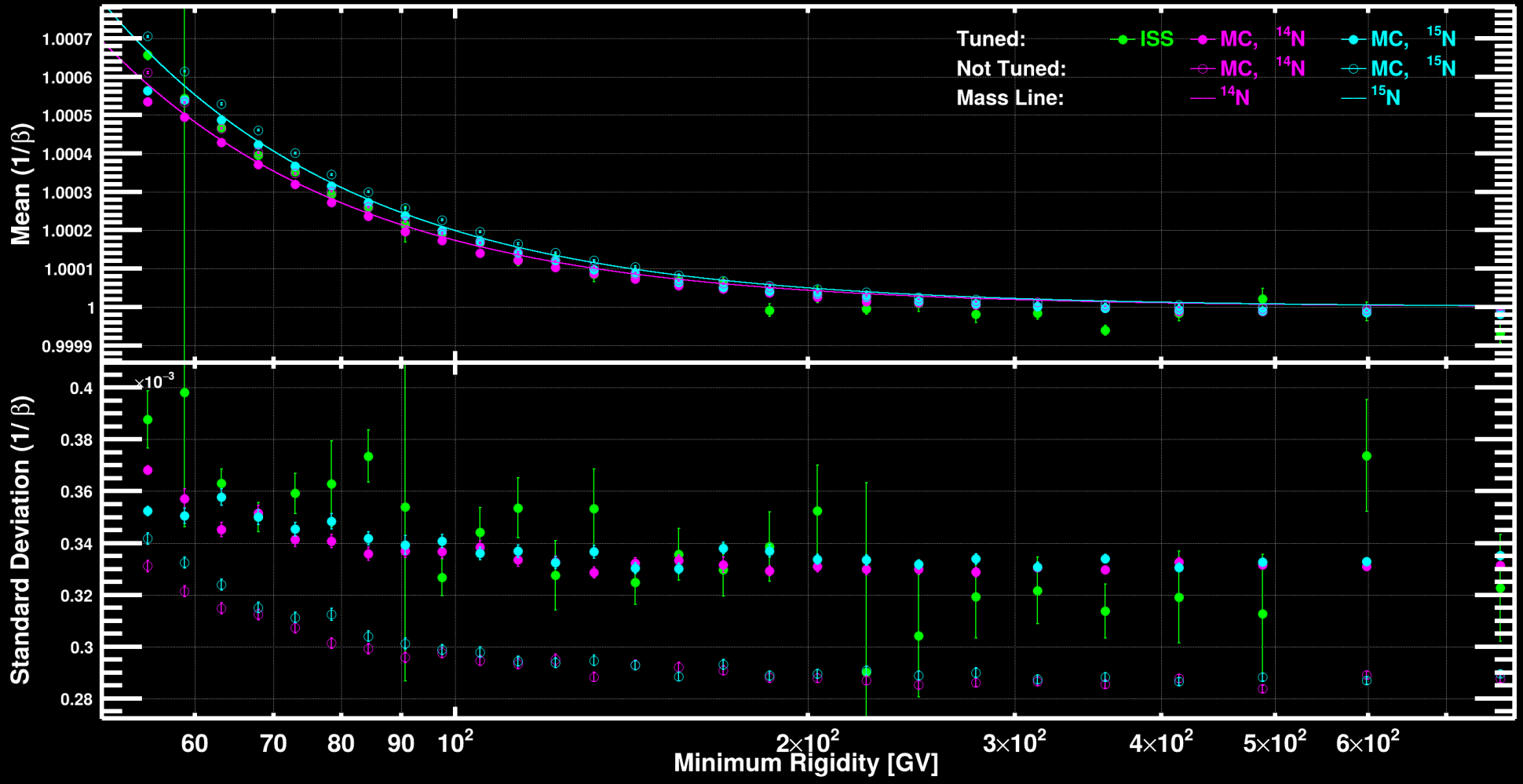
Boron (Z=5), Local, InnerL1+RICHAgl



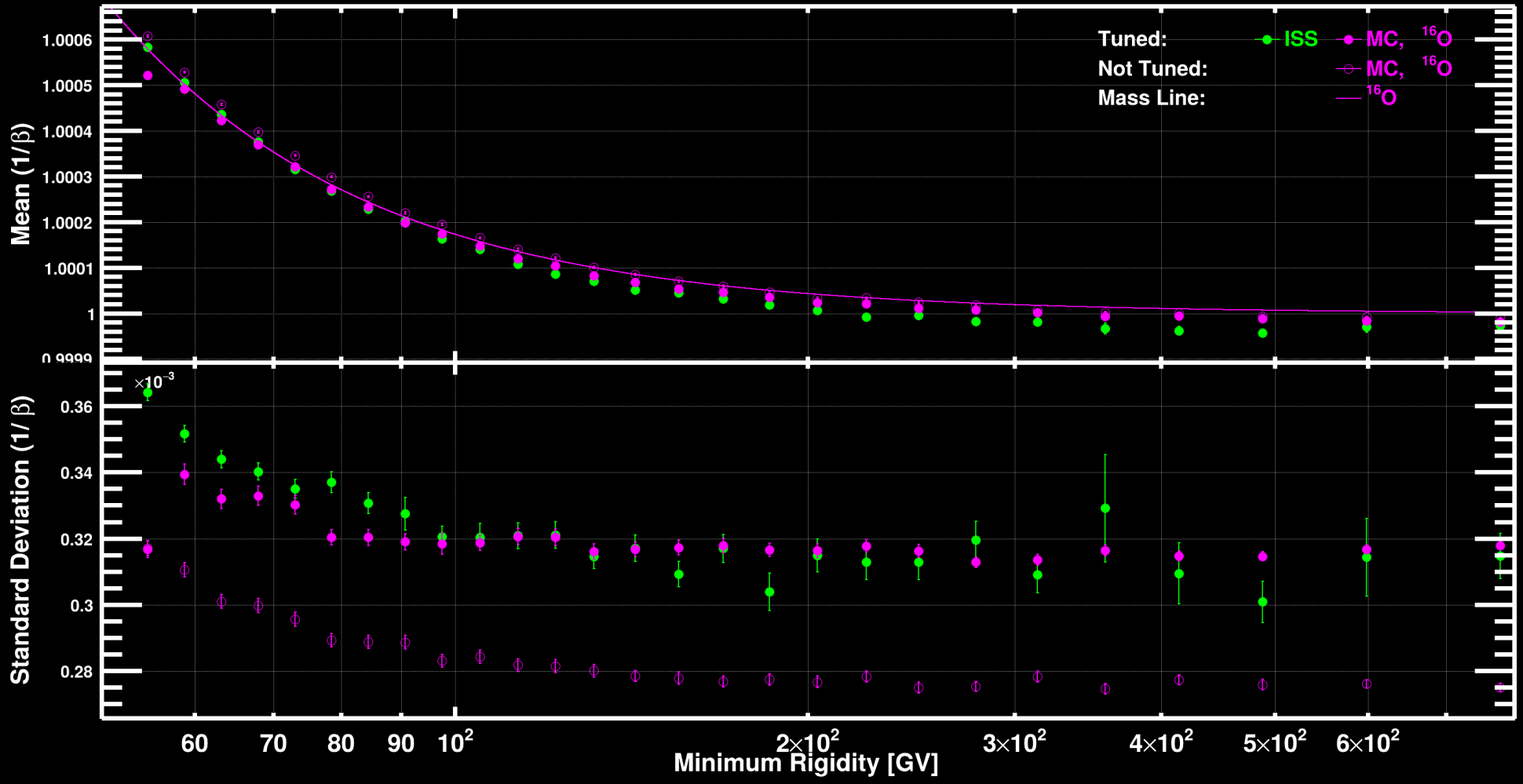
Carbon (Z=6), Local, InnerL1+RICHAgl



Nitrogen (Z=7), Local, InnerL1+RICHAgl

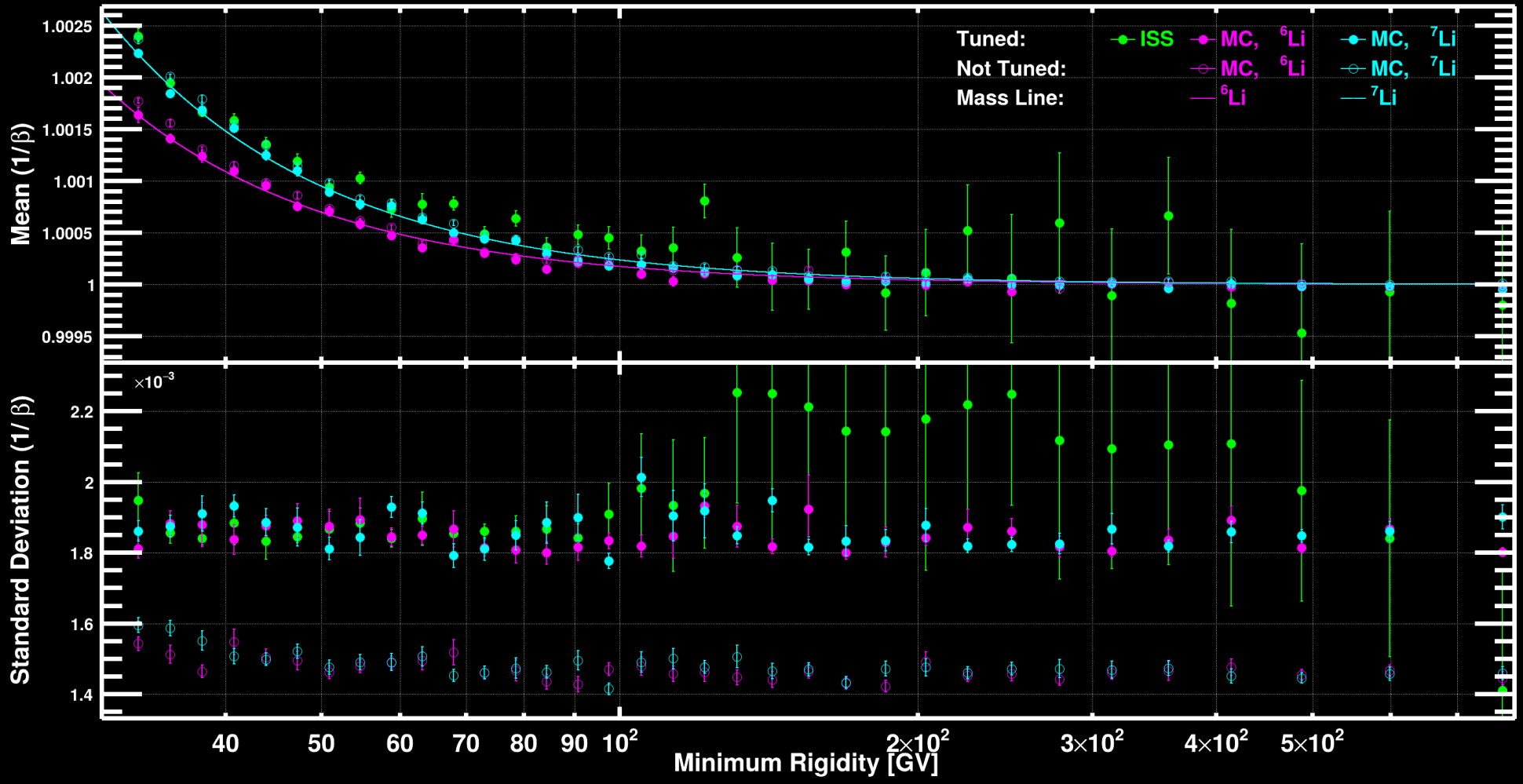


Oxygen (Z=8), Local, InnerL1+RICHAgl

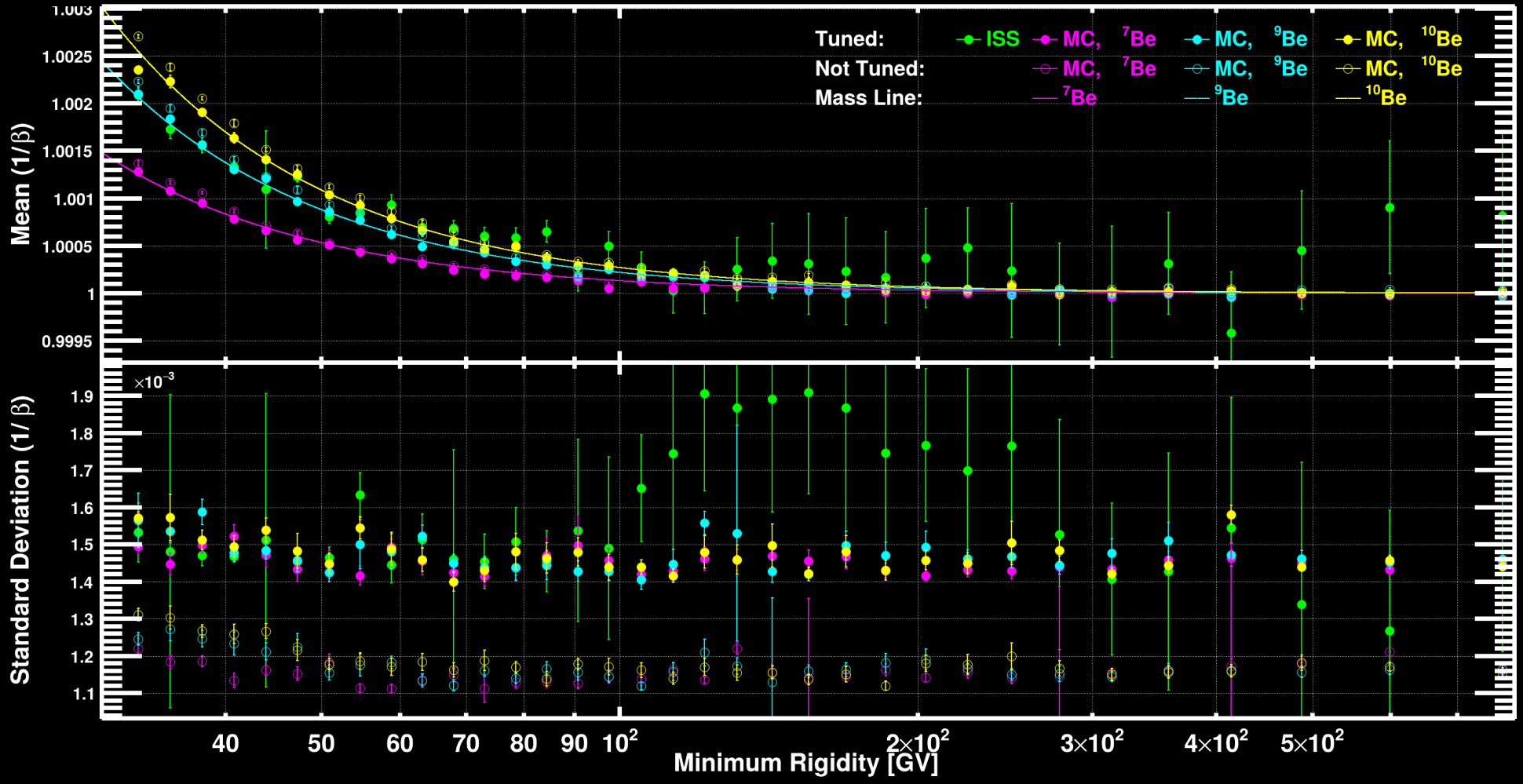


NaF

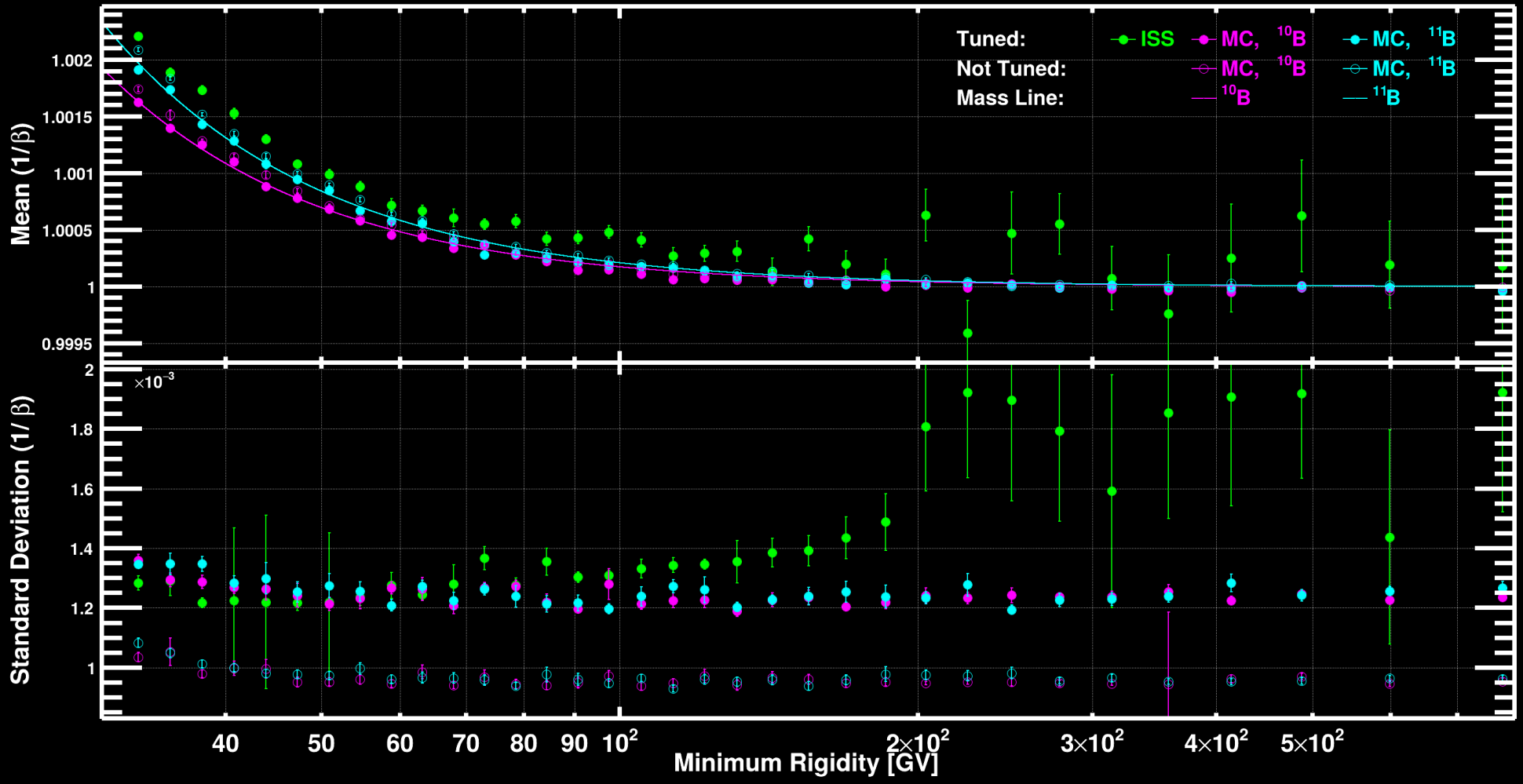
Lithium (Z=3), Local, InnerL1+RICHNaF



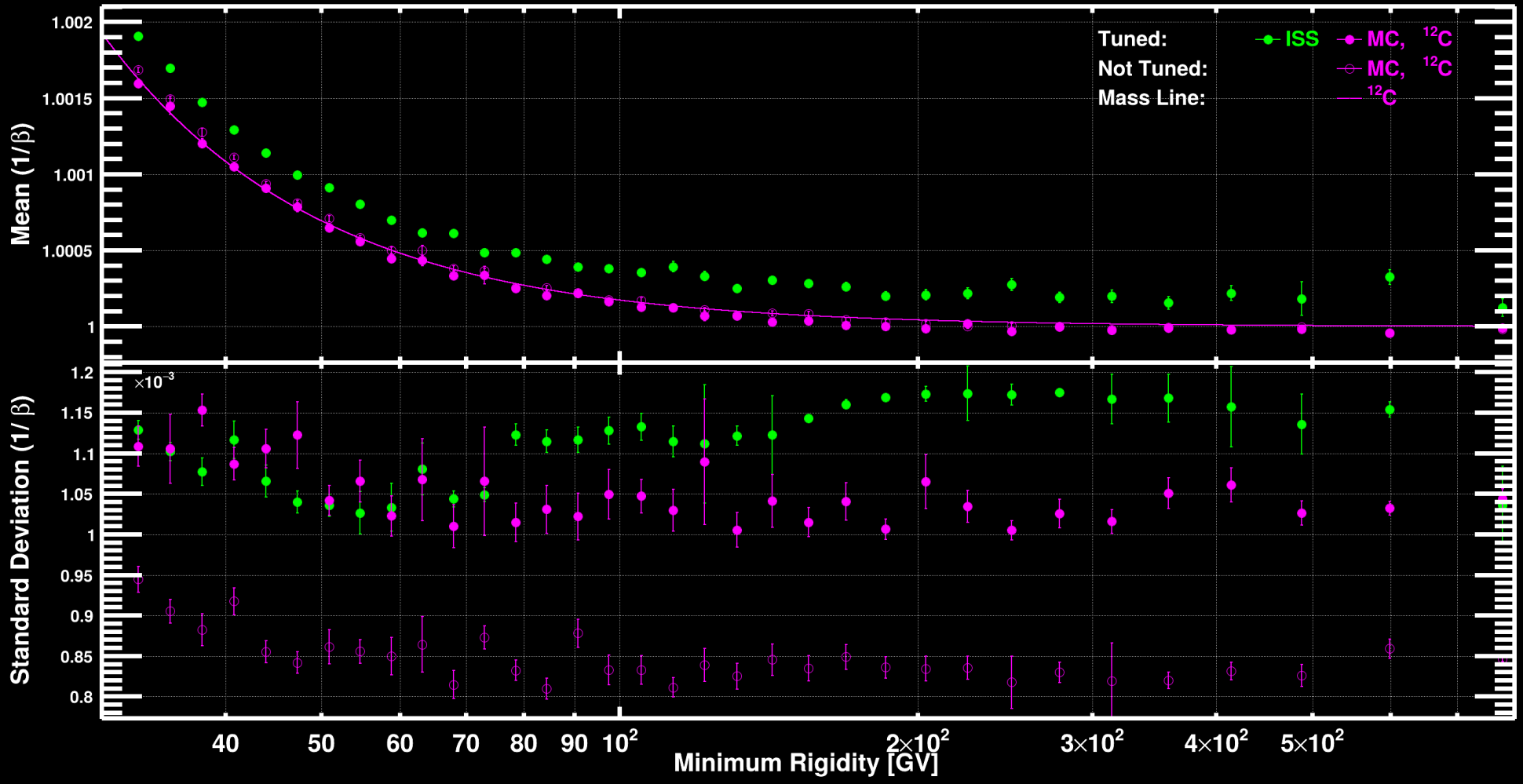
Beryllium (Z=4), Local, InnerL1+RICHNaF



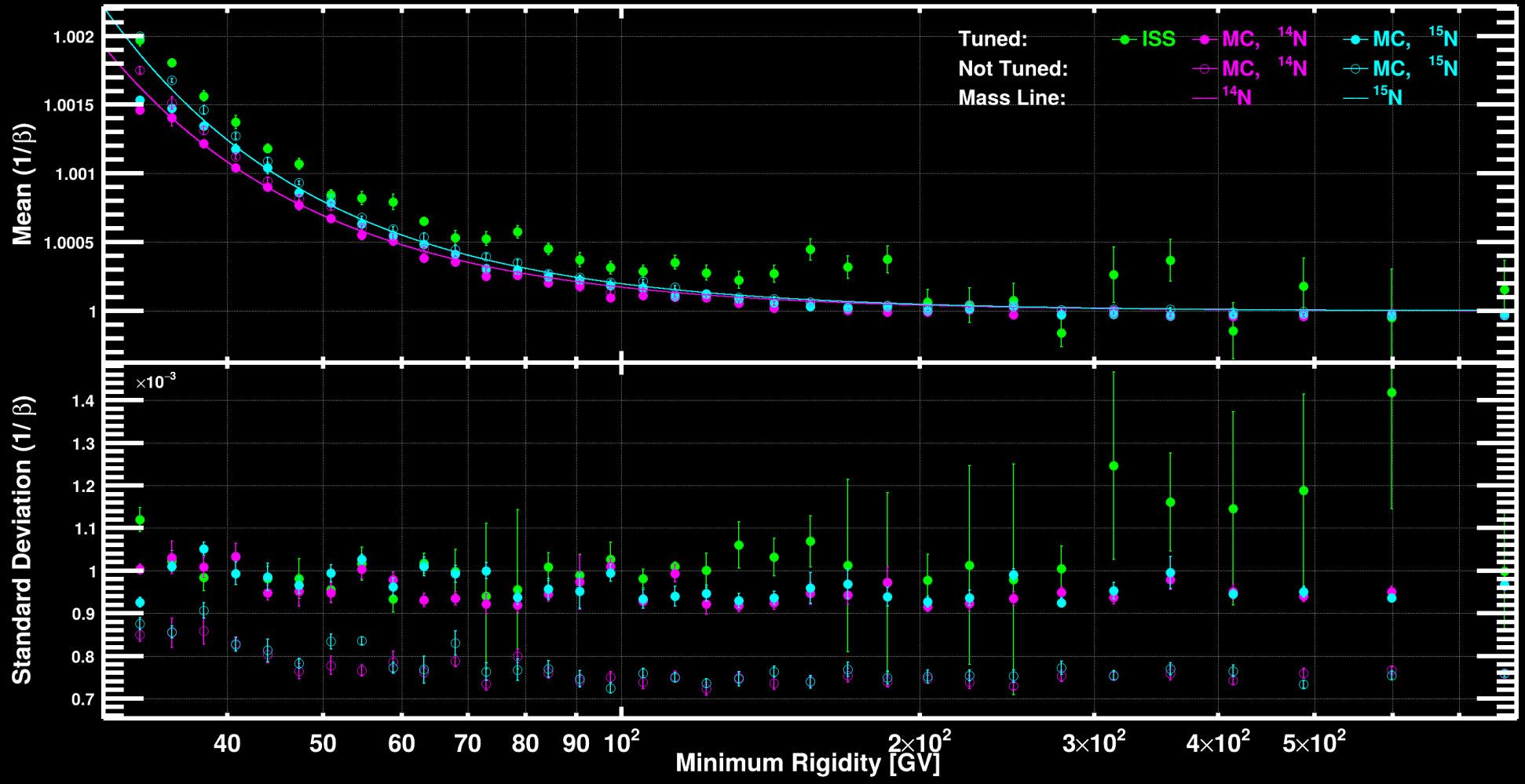
Boron (Z=5), Local, InnerL1+RICHNaF



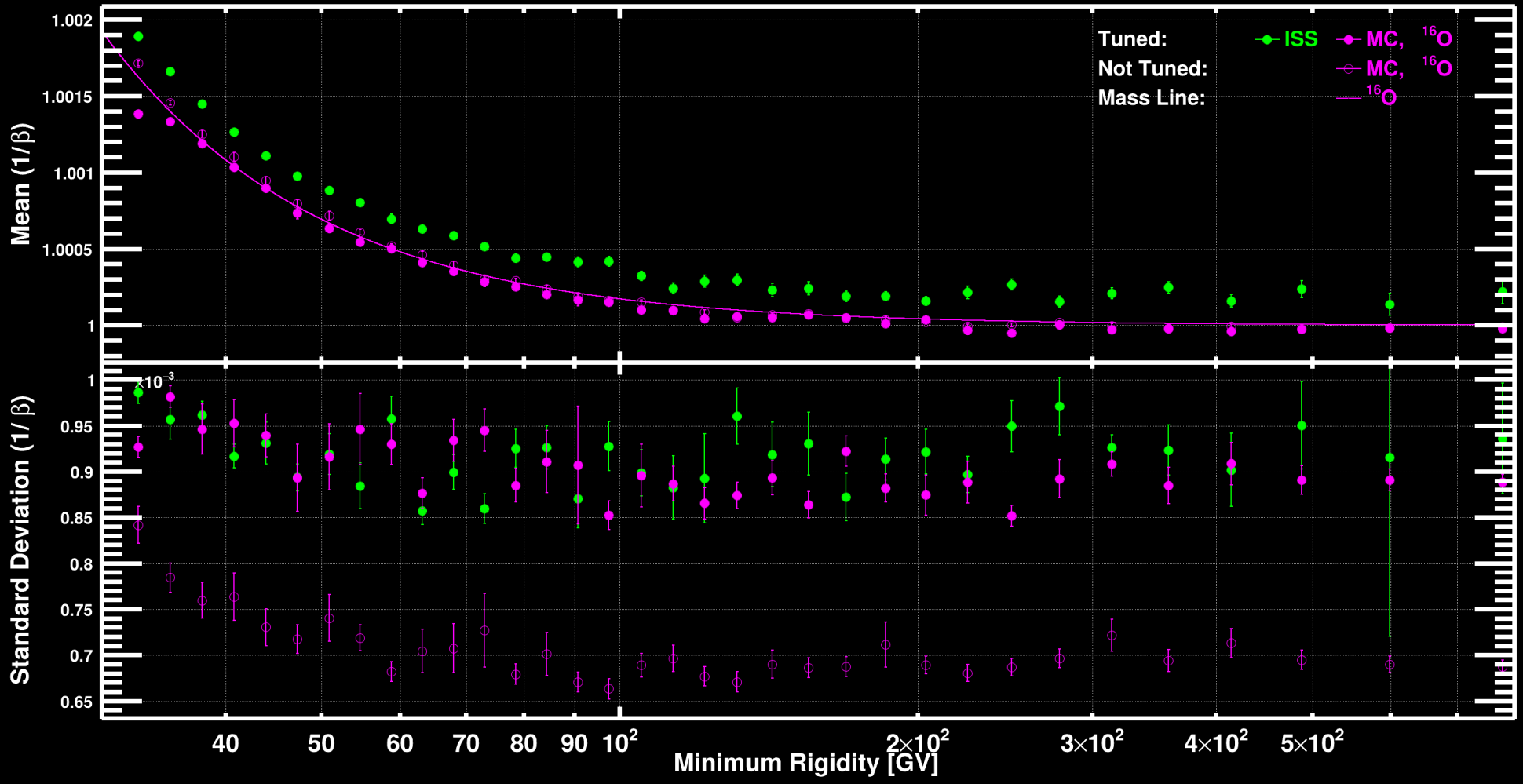
Carbon (Z=6), Local, InnerL1+RICHNaF



Nitrogen (Z=7), Local, InnerL1+RICHNaF



Oxygen (Z=8), Local, InnerL1+RICHNaF

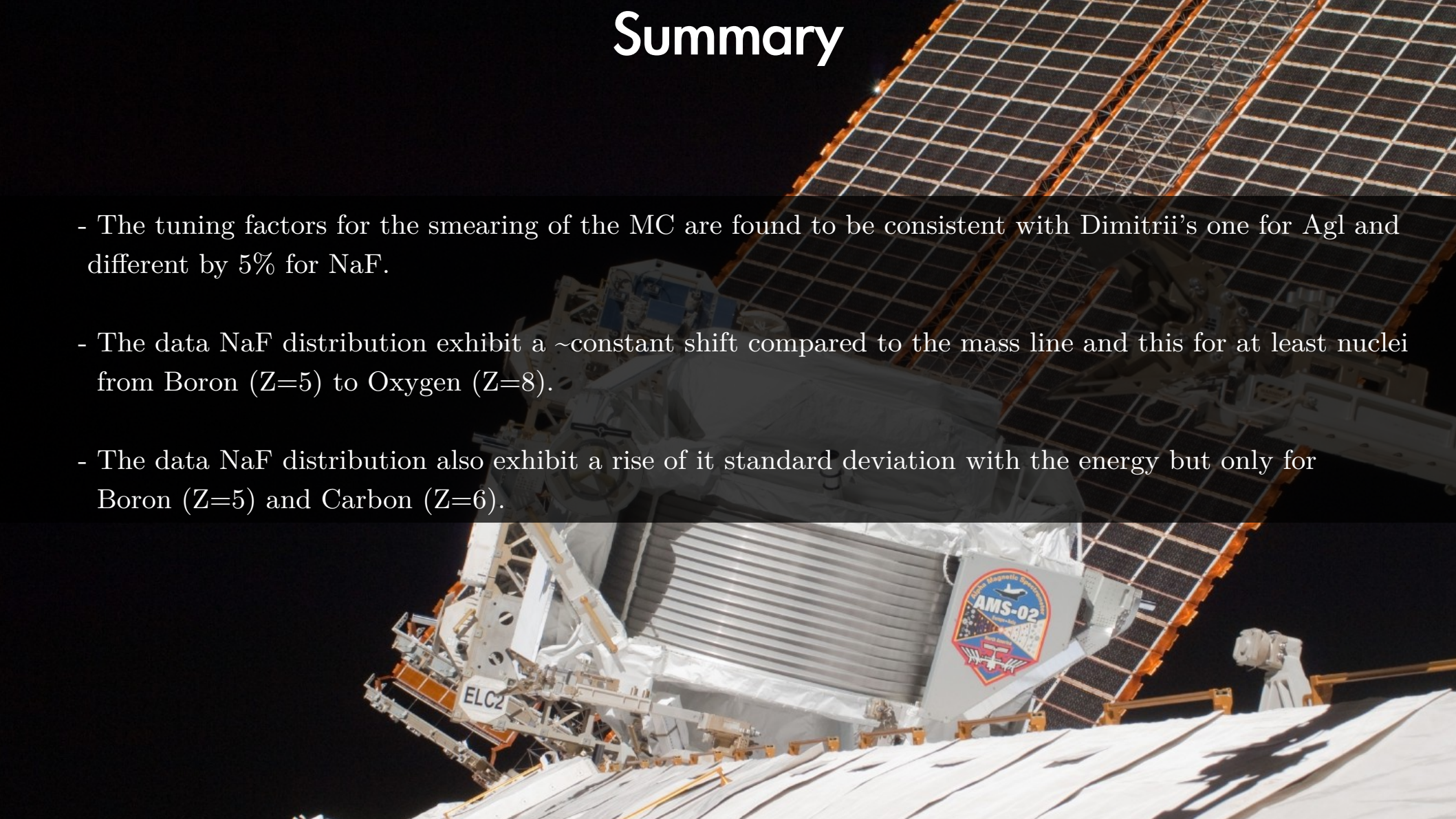


Summary

- The tuning factors for the smearing of the MC are found to be consistent with Dimitrii's one for Agl and different by 5% for NaF.

- The data NaF distribution exhibit a ~constant shift compared to the mass line and this for at least nuclei from Boron (Z=5) to Oxygen (Z=8).

- The data NaF distribution also exhibit a rise of it standard deviation with the energy but only for Boron (Z=5) and Carbon (Z=6).



2D Forward Unfolding

Event Count corrected for **background**

Integration over true rigidity

Sum over each isotopes

Effective Acceptance (from MC and corrected for differences with data)

$$\frac{N_{i,j}\left(R_i,\beta_j\right)}{\mathrm{T}_j} = \Delta R_i \Delta \beta_j \int_0^{\infty} \mathrm{d}R_0 \times \sum_A \phi_A\left(R_0\right) \times \mathrm{Acc}_A\left(R_0\right) \times \mathrm{R}_A\left(R_i,R_0\right) \times \mathrm{B}_A\left(\beta_j,R_0\right)$$

Exposure time above cutoff
The beta cutoff is calculated from the rigidity cutoff using the lightest isotope mass

Flux model (fitting parameters)

Rigidity and **beta resolutions**

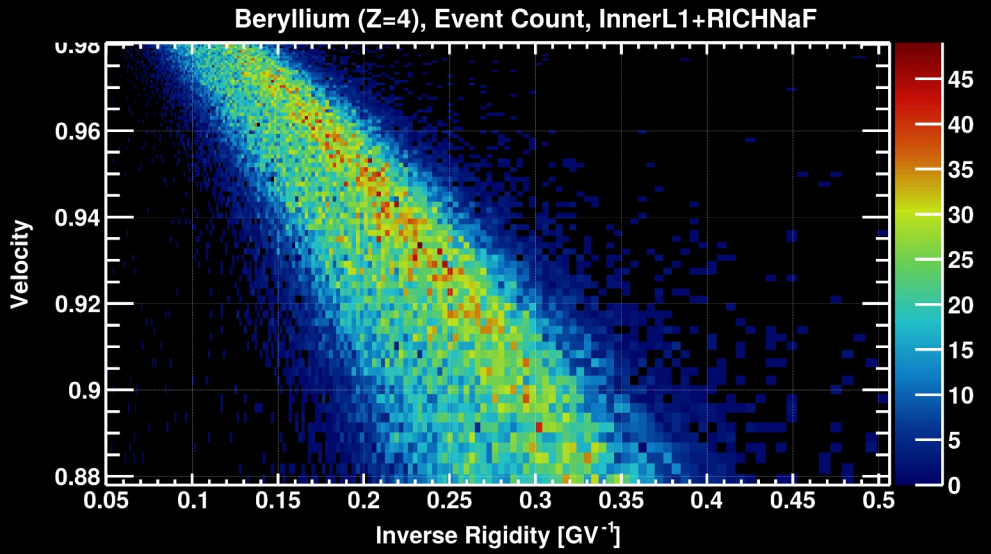
The formula can be used to write a minimization and fit a flux model describing isotope fluxes (and/or ratios) with a series of splines.

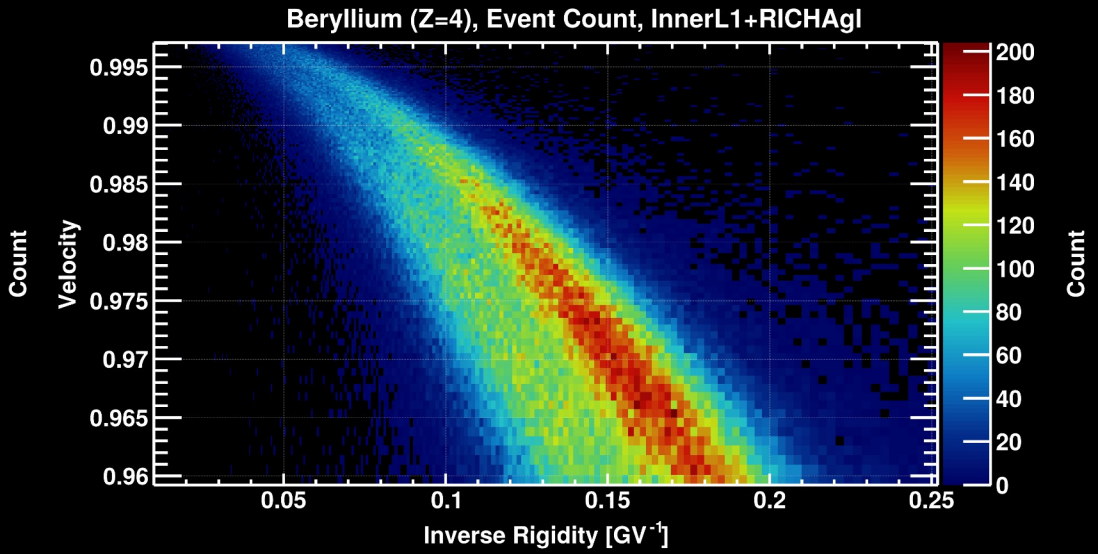
The fitting procedure has several advantages :

- Unfolding takes care of everything, mass composition and energy migration at the same time
- The total flux can be fixed to the AMS measurement one, providing further constrain
- The three different analysis (ToF, NaF and Agl) can be fitted at the same time providing a further constrain

Beryllium Event Count

The event count, selected in the (Rigidity, Velocity) space, is corrected for the background (José's presentation) before the unfolding.



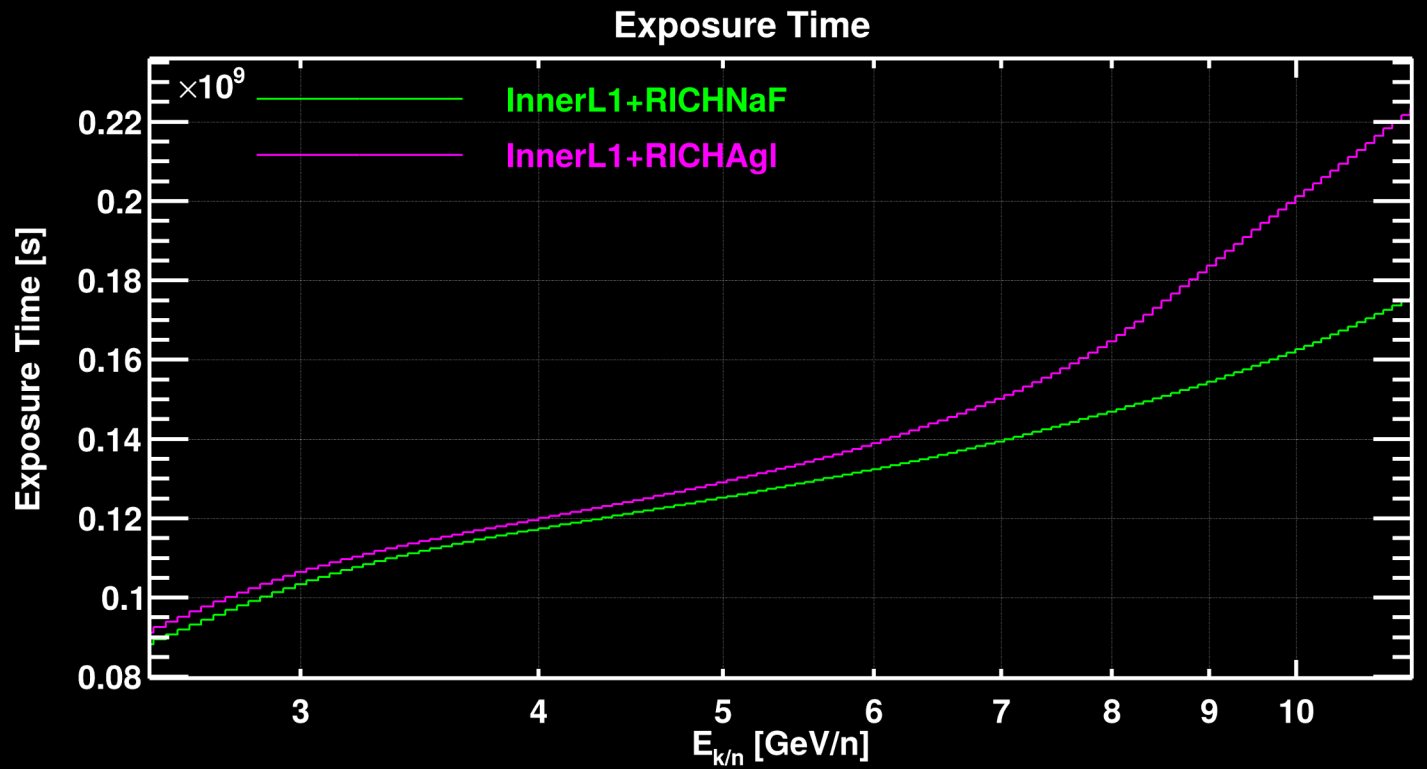


Exposure Time

The **Exposure Time** is computed versus the **velocity**.

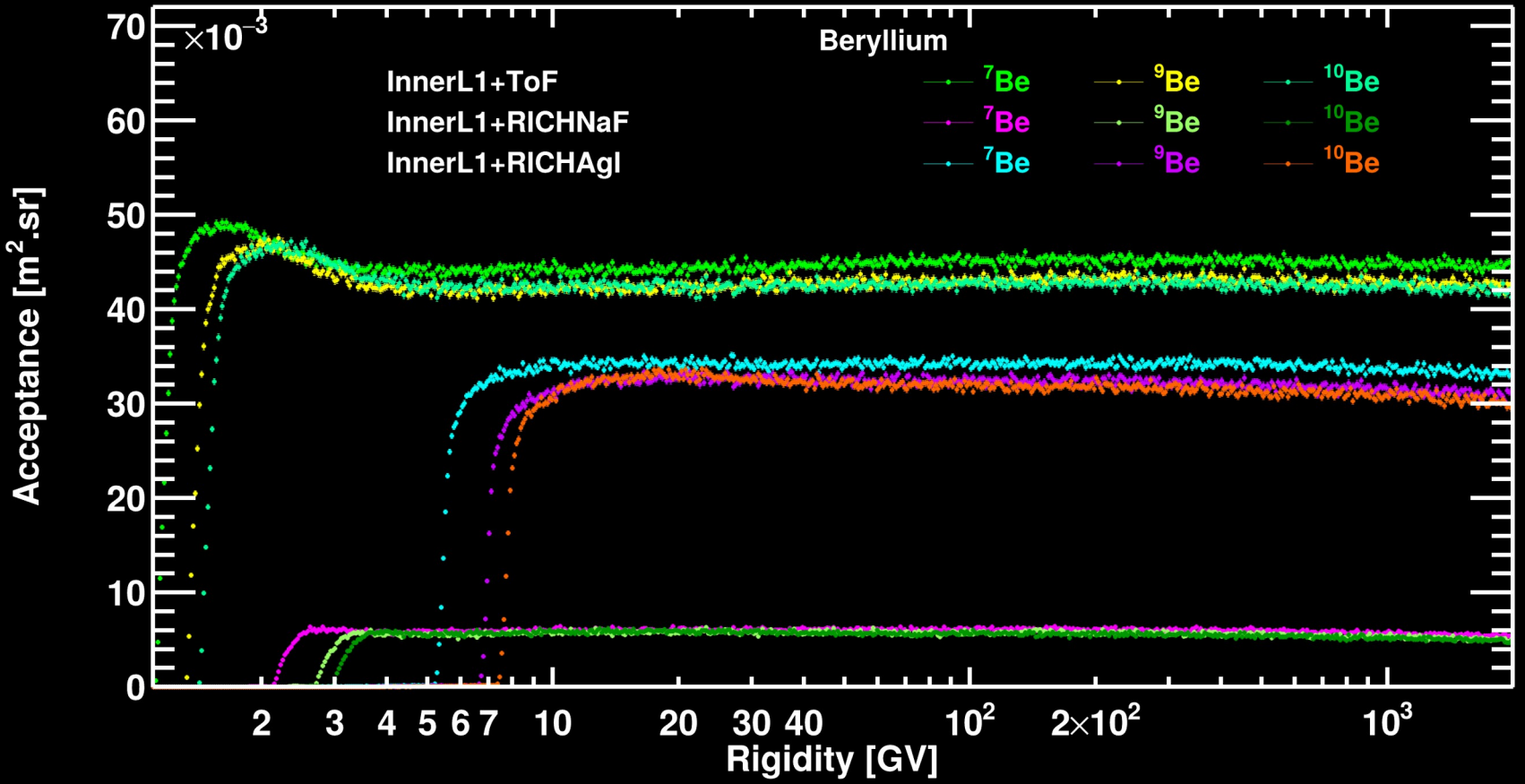
The geomagnetic cutoff in velocity is obtained by converting the rigidity cutoff into velocity taking the A and Z of ^{7}Be.

A safety factor of $1+\sigma_{\beta}$ is applied to the computed cutoff ($\sigma_{\beta,\,AGL} = 0.001$, $\sigma_{\beta,\,NaF} = 0.003$).

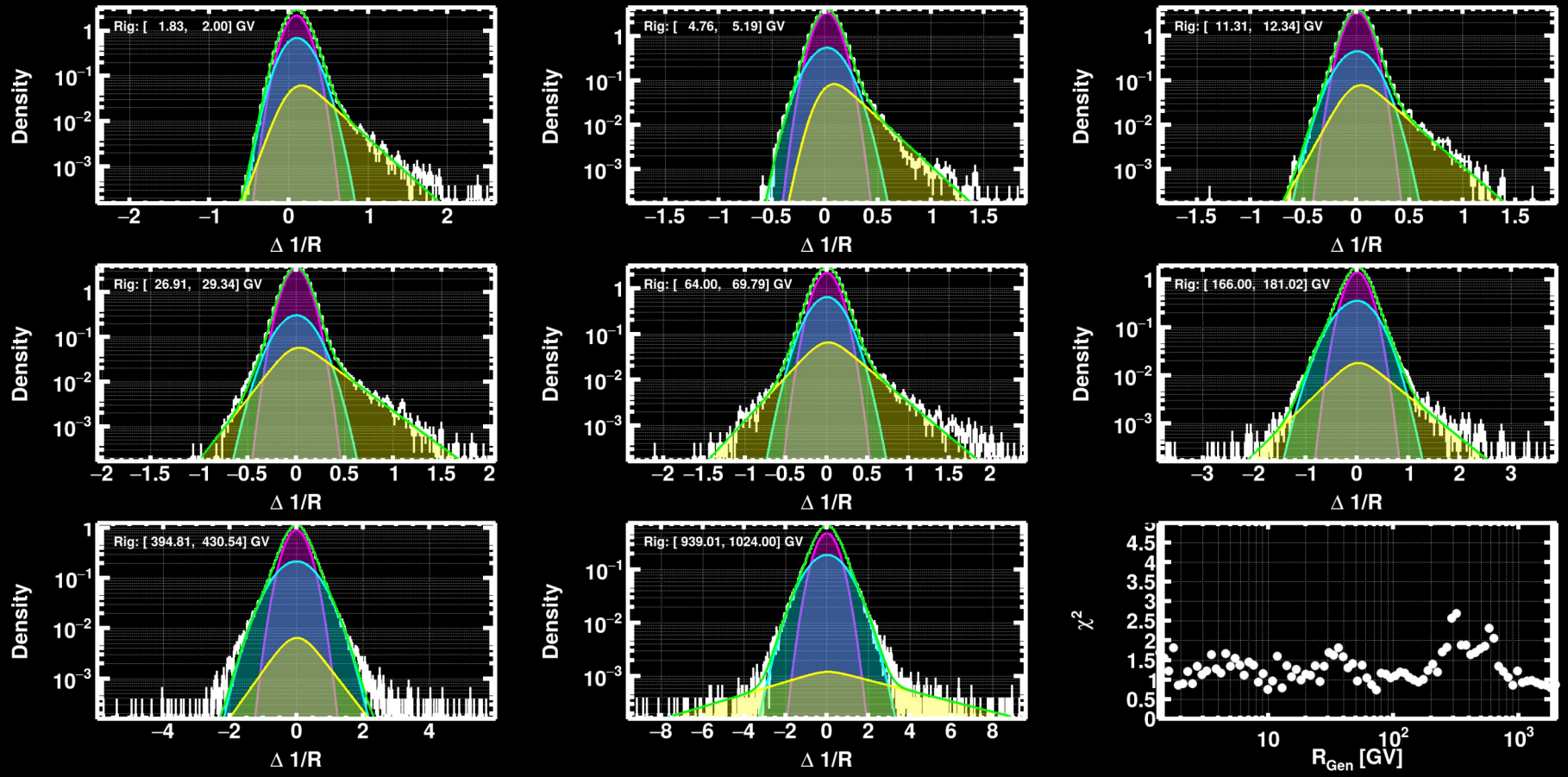


Raw Acceptances

The acceptance for each nuclei is calculated using MC for each selections and each isotopes and then corrected for Data/MC efficiency differences.

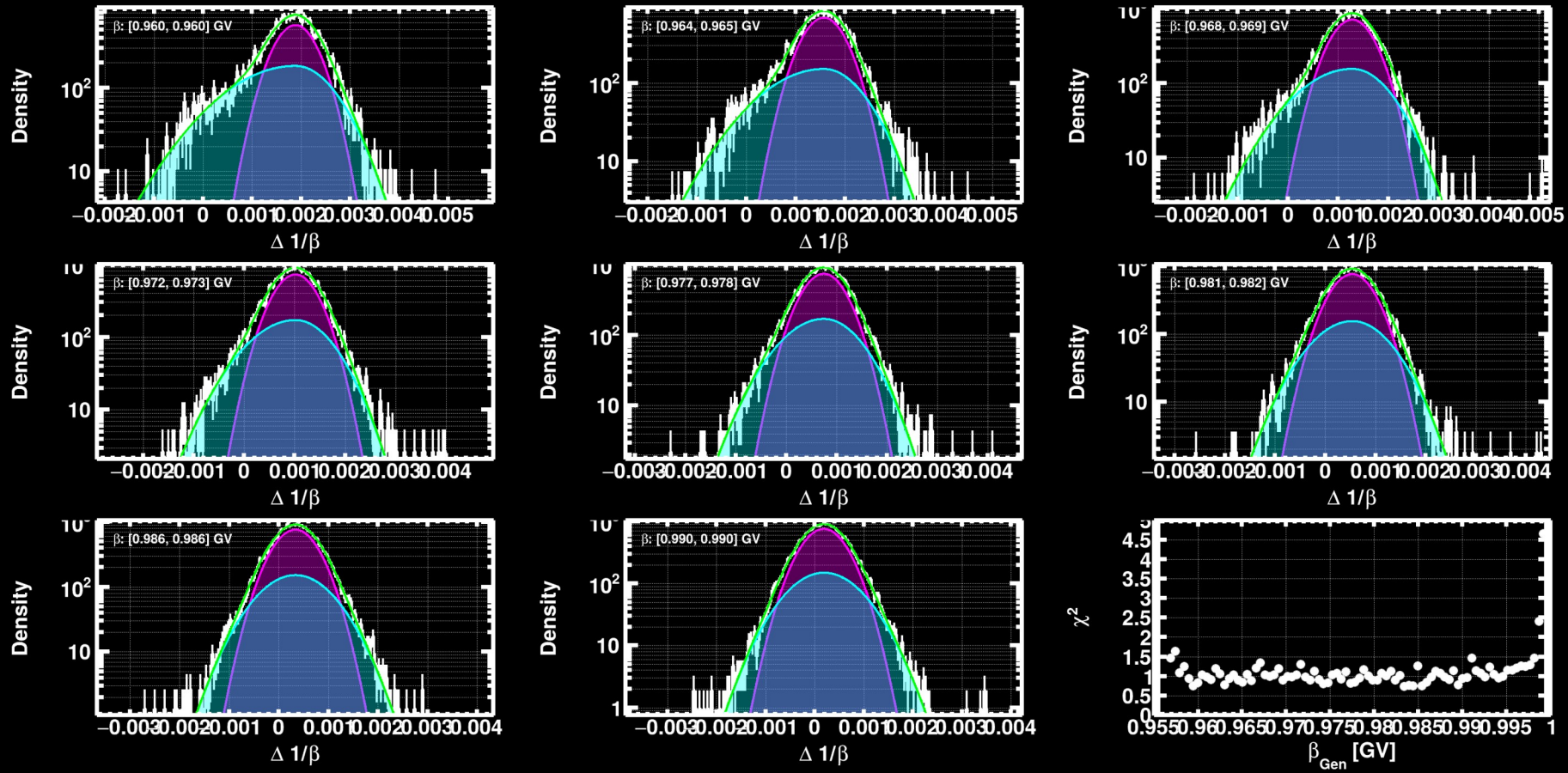


Rigidity Resolution



InnerL1 Rigidity resolution model obtained for each isotope.

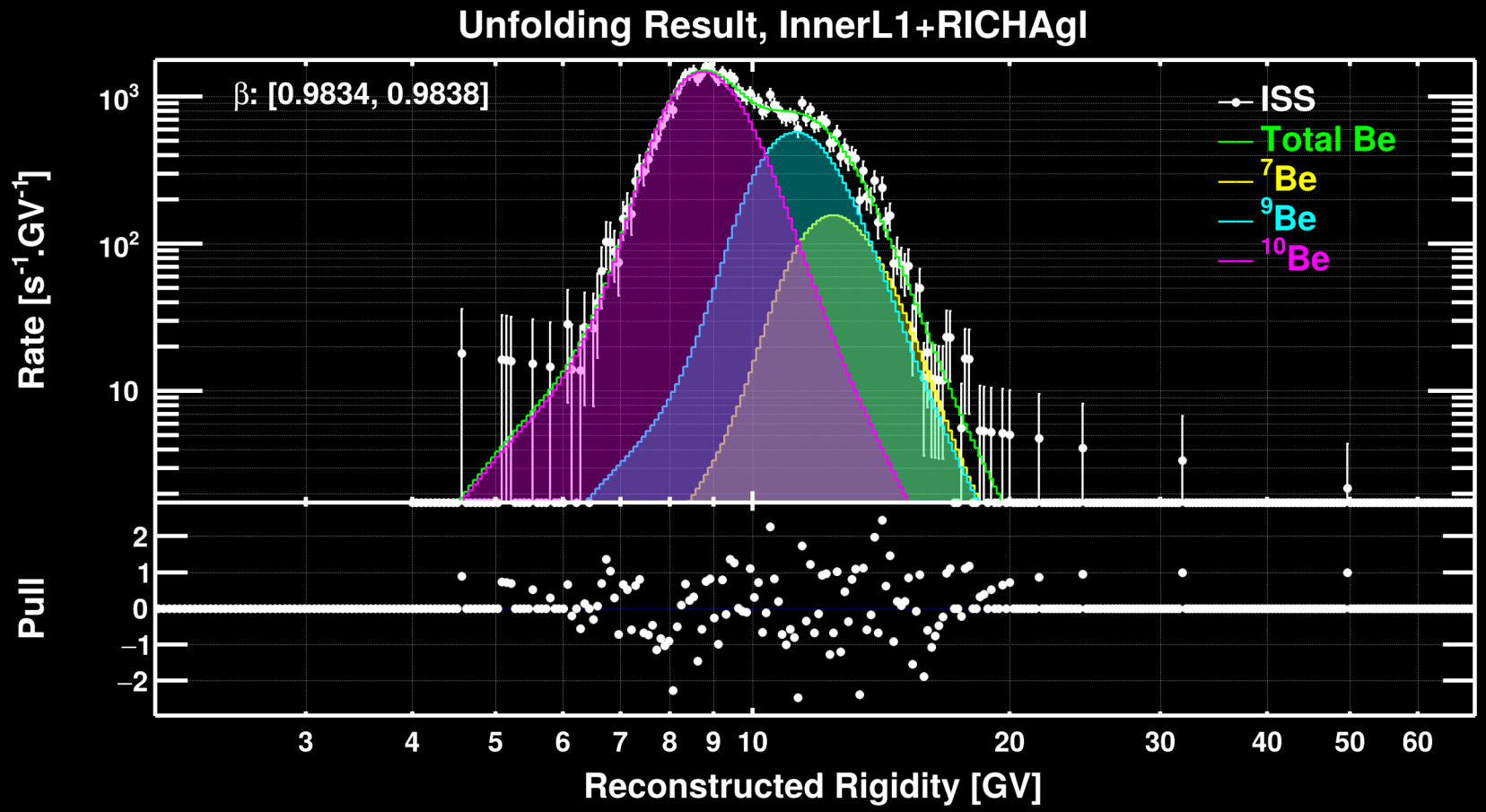
Velocity Resolution



Agl velocity resolution model obtained for each isotope.

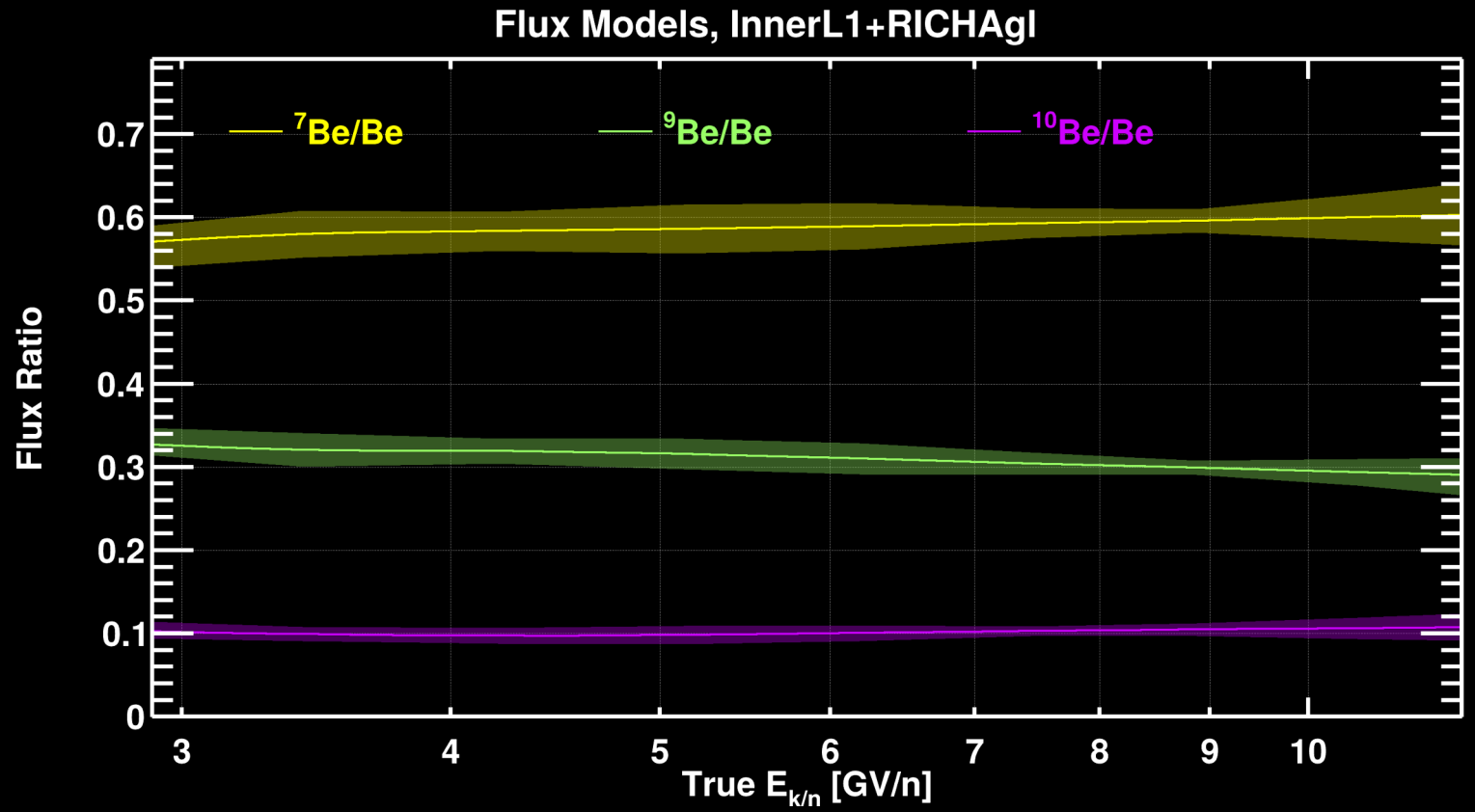
Minimization Method

The unfolding is performed using the Log Likelihood method.
And the total normalization is Be flux is a free parameter of the fit.



Unfolding Result

The free parameter of the unfolding are the nodes of splines.
The error resulting of the fitting procedure is computed from the correlation matrix of the free parameters via bootstrapping.



Unfolding Factors

Unfolding formula showed previously:

$$N_{ij} = T_j \Delta R_i \Delta \beta_j \int_0^\infty \mathrm{d}R_0 \times \sum_A \phi_A\left(R_0\right) \times \mathrm{Acc}_A\left(R_0\right) \times \mathrm{R}_A\left(R_i, R_0\right) \times \mathrm{B}_A\left(\beta_j, R_0\right)$$

$N_j = \sum_i N_{ij}$ Event count versus velocity

Once the fitting performed, one can define:

Folded count: $\bar{N}_j^A = T_j \Delta \beta_j \sum_i \Delta R_i \int_0^\infty \mathrm{d}R_0 \times \phi_A\left(R_0\right) \times \mathrm{Acc}_A\left(R_0\right) \times \mathrm{R}_A\left(R_i, R_0\right) \times \mathrm{B}_A\left(\beta_j, R_0\right)$

Unfolded count: $\tilde{N}_j^A = T_j \int_{\beta_i}^{\beta_i + \Delta\beta_j} \mathrm{d}\beta_0 \times \phi_A\left(\beta_0\right) \times \mathrm{Acc}_A\left(\beta_0\right)$

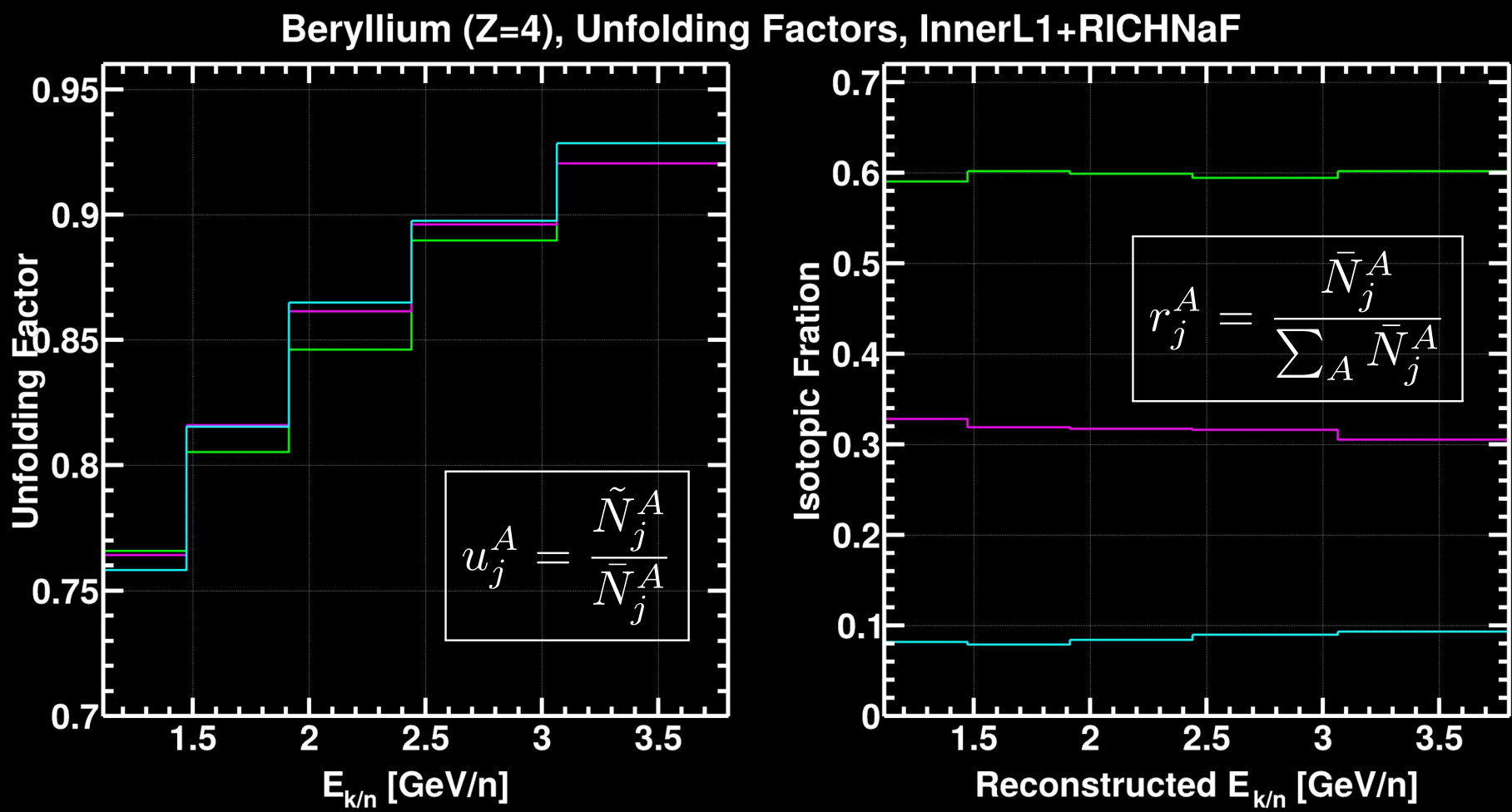
From which one can derive a migration-correction for each isotope to correct the measured count:

$$N_j^A = N_i \frac{\tilde{N}_j^A}{\sum_A \bar{N}_j^A} = N_j \frac{\tilde{N}_j^A}{\bar{N}_j^A} \frac{\bar{N}_j^A}{\sum_A \bar{N}_j^A} = N_j \times u_j^A \times r_j^A$$

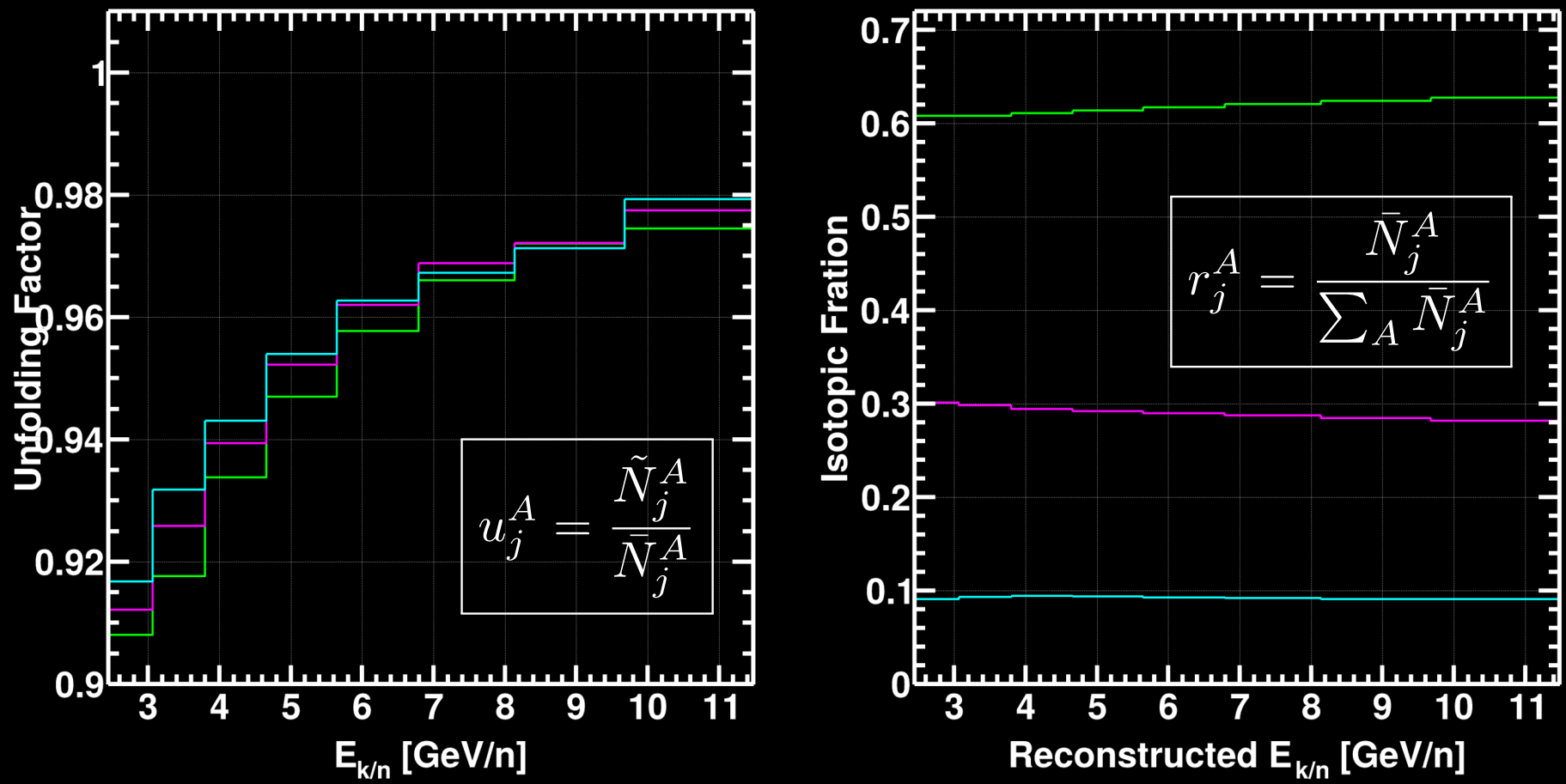
Unfolding factor (energy migration)

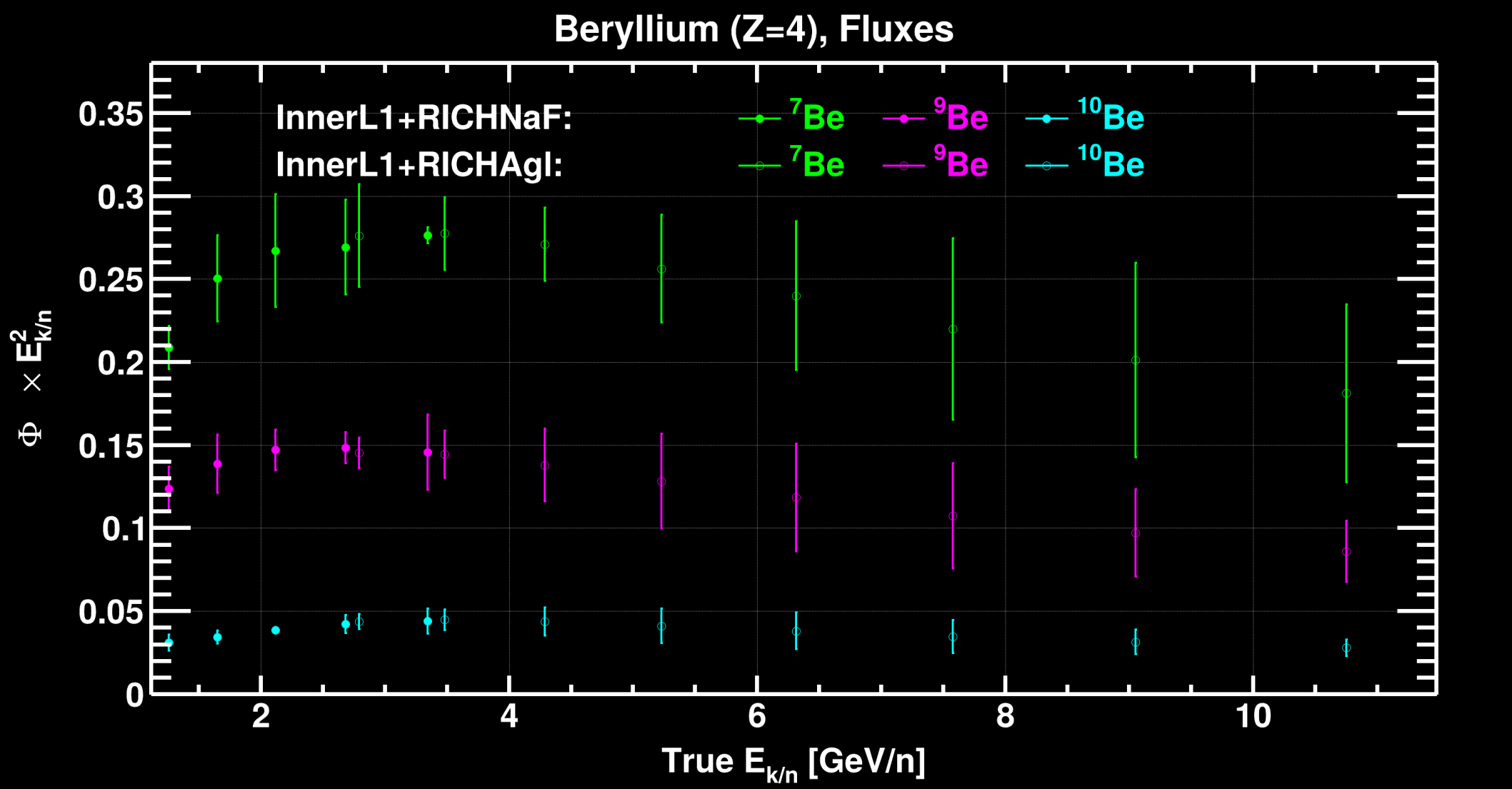
Isotopic fraction (in reconstructed space)

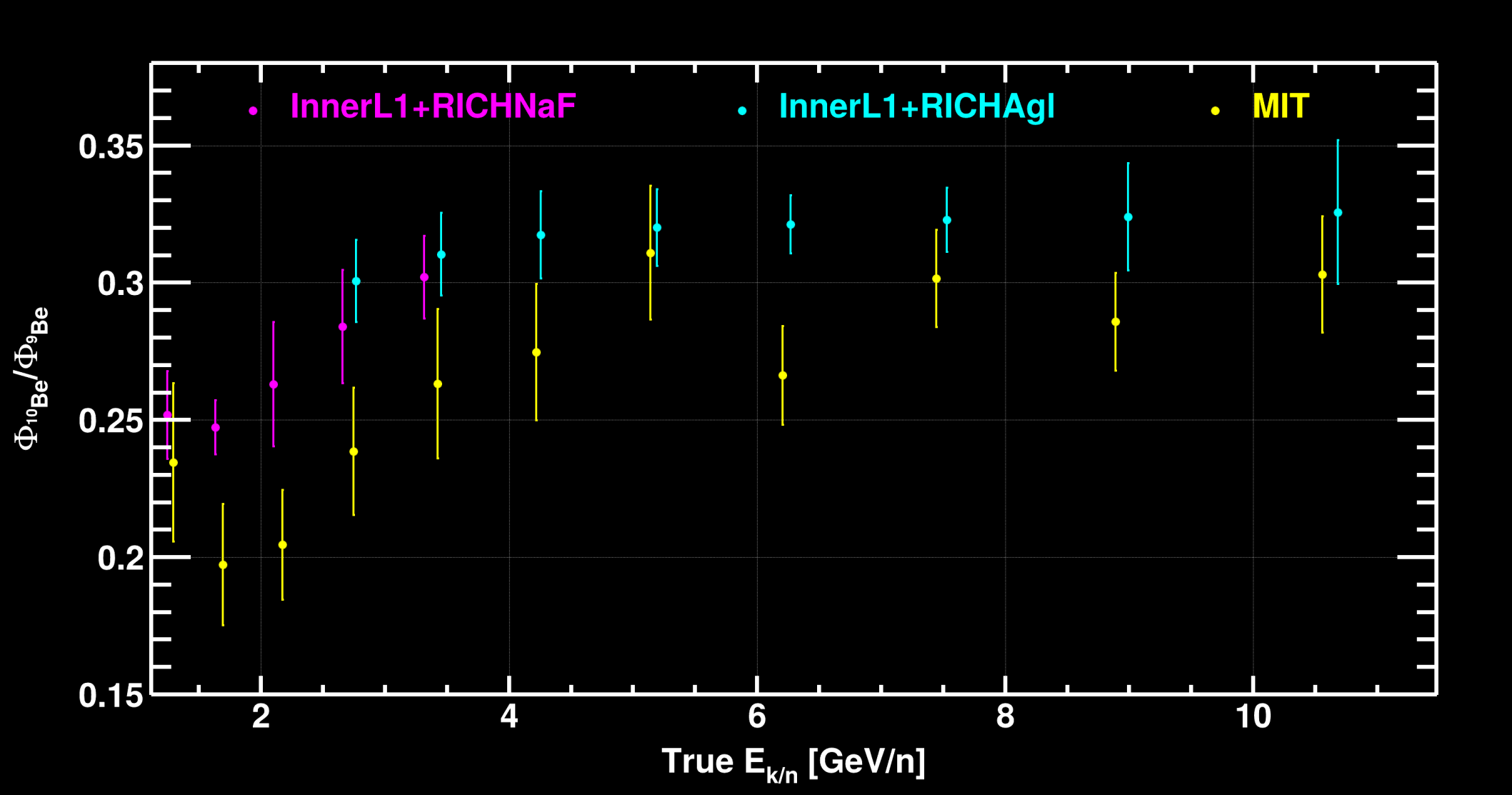
Unfolding Factors



Unfolding Factors




Beryllium (Z=4), Fluxes
InnerL1+RICHNaF:
InnerL1+RICHAgl:
^{7}Be
^{9}Be
^{10}Be
^{7}Be
^{9}Be
^{10}Be
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
$\Phi \times E_{k/n}^2$
2
4
6
8
10
True $E_{k/n}$ [GeV/n]


InnerL1+RICHNaF
InnerL1+RICHAgI
MIT
0.35
0.3
0.25
0.2
0.15
2
4
6
8
10
$\Phi_{^{10}Be}/\Phi_{^{9}Be}$
True $E_{k/n}$ [GeV/n]

Summary

- Has been presented the tuning of the MC RICH velocity to match data.
- Has been presented the measurements of the Beryllium isotope fluxes in NaF and Agl energy ranges.
- The $^{10}Be/^{9}Be$ flux ratio exhibit the same energy dependence as the one from MIT (Dimitrii) but a constant ~5% shift

- The tuning of the rigidity is missing in the analysis for now.
- A detailed study of the error estimation is needed.

Back Up