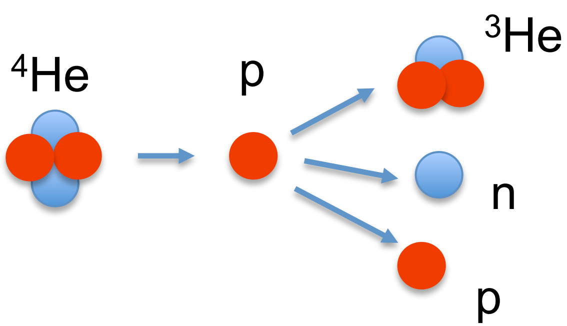
Precision measurement of ^{3}He to ^{4}He ratio in Cosmic Rays with AMS-02

F. Giovacchini - CIEMAT
on behalf of the AMS-02 collaboration

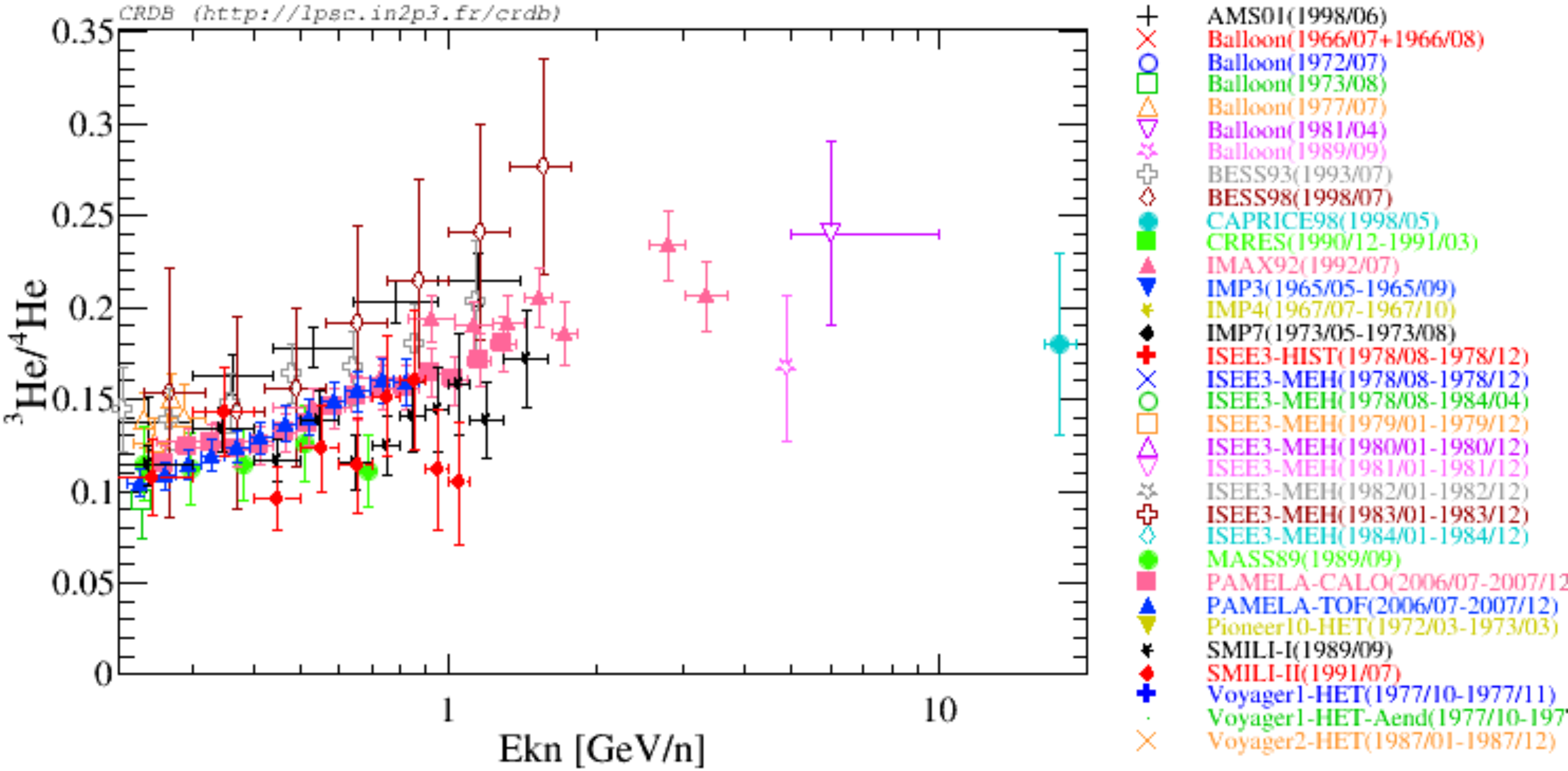
Motivation

- Understanding the propagation processes in the galaxy is crucial for modeling the background for the search of new physics;
- Secondary to primary ratios provide valuable information to study the propagation parameters;
- As most of B in CR is produced by C, most of ^{3}He is belived to be of secondary origin, produced from nuclear interactions of ^{4}He with the ISM:

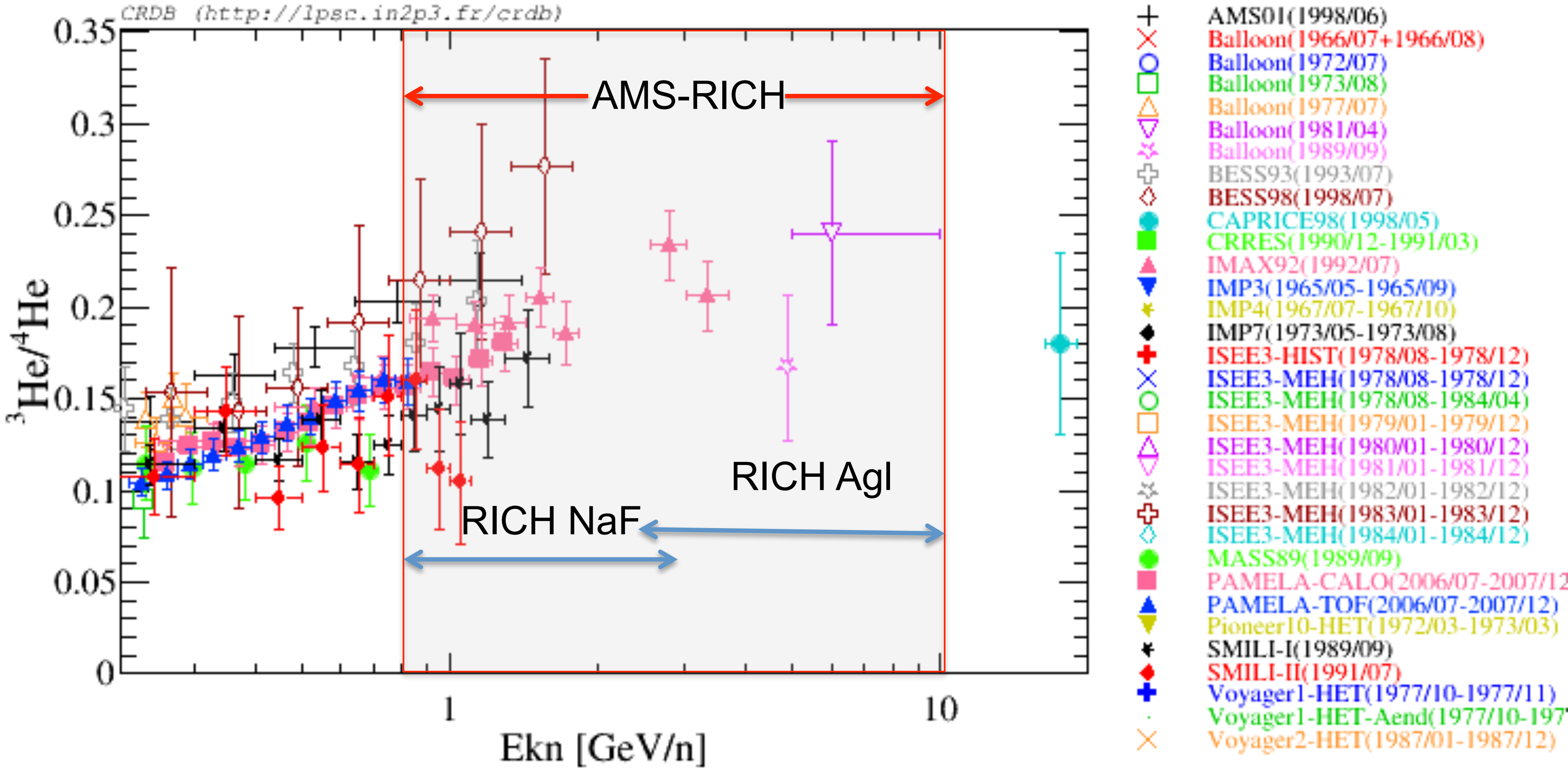


- B/C and ^{3}He/^{4}He are probing different propagation distances, accounting for the smaller ^{4}He spallation cross section, when compared to the C one;
- ^{3}He/^{4}He allows to test the universality of propagation for different A/Z.

Available measurements



AMS measurement range



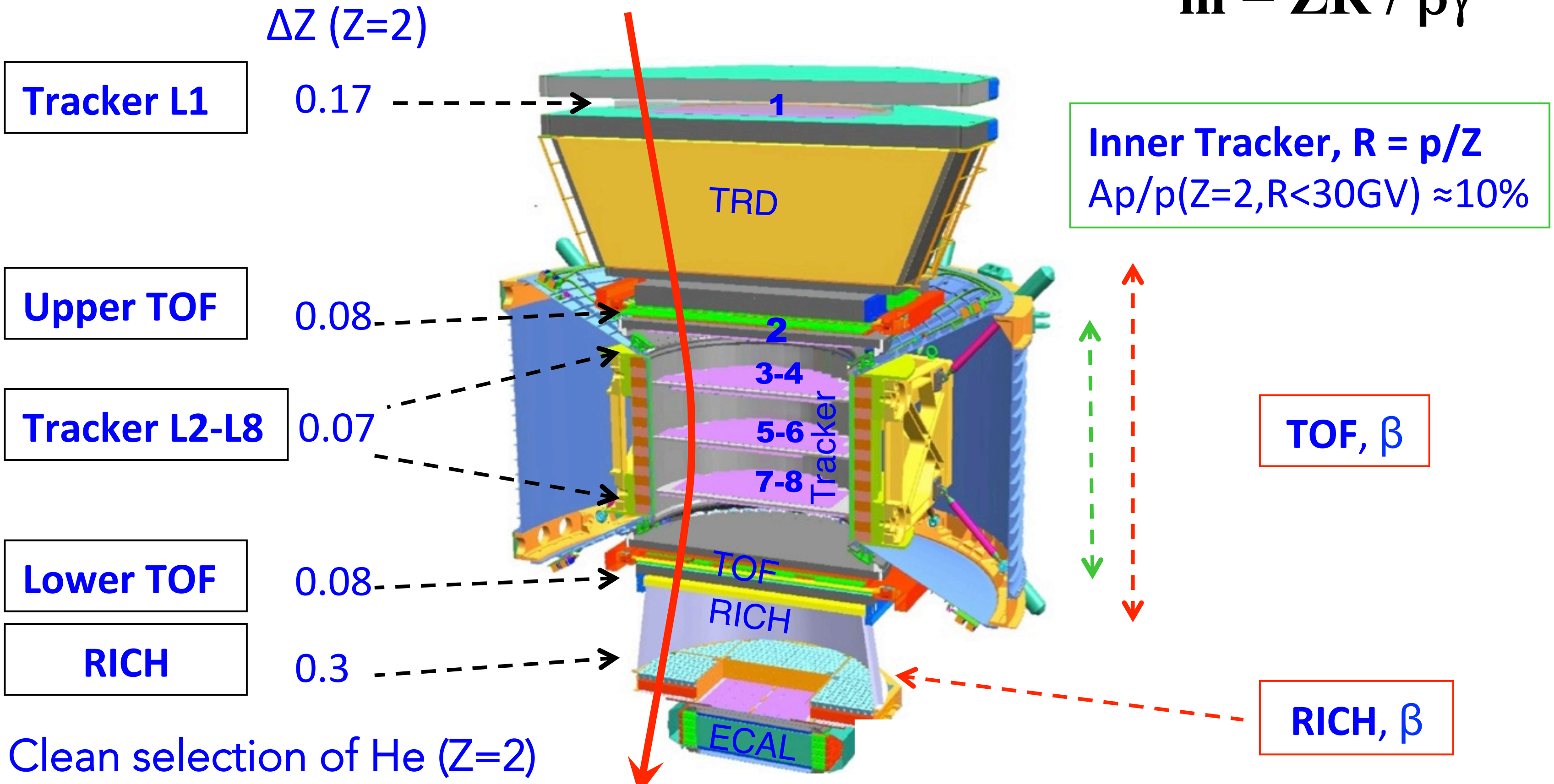
NaF: $0.8 < E_{kn} < 3$ GeV/n

Agl: $2.6 < E_{kn} < 10$ GeV/n

AMS and $^3He/^4He$ measurement

AMS-02 is a precision multiporpose spectrometer operating at 400 km orbit.
It is made of varius sub-detectors for a redundant Particle Identification.
Mass is determined through the simultaneous measurement of particle Charge (Z), Rigidity (R) and velocity (β)

$$m = ZR / \beta\gamma$$

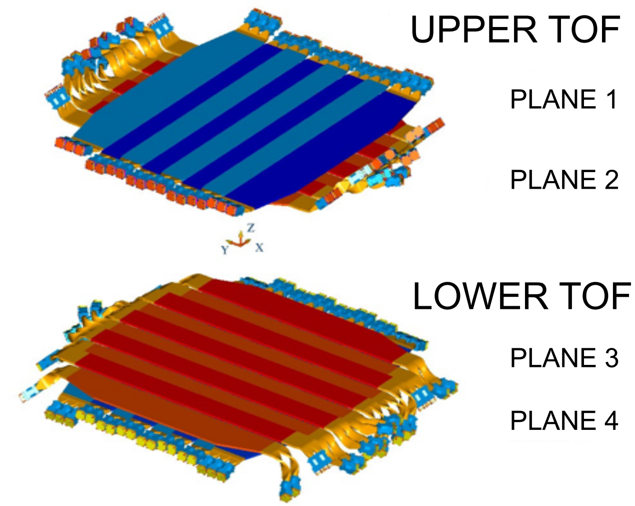


Clean selection of He (Z=2)

Isotopic composition with AMS

Velocity from TOF:

- $\Delta_\beta/\beta^2 \approx 2\%$ (He)
- $E_{kin}>0.3$ GeV/n



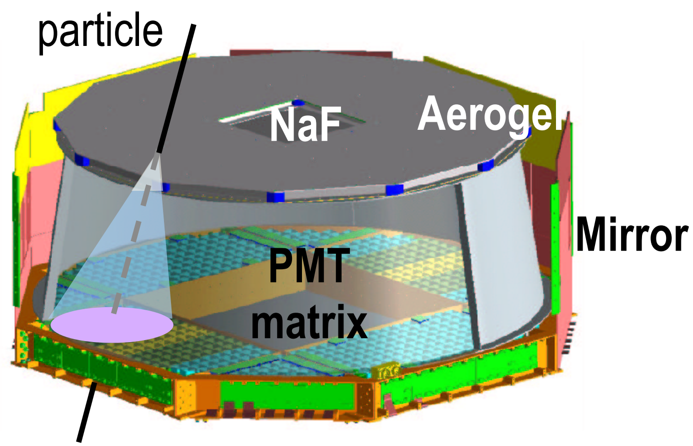
Velocity from RICH (2 radiators):

NaF crystals

- $\Delta_\beta/\beta \approx 0.3\%$ (He)
- $n=1.33$, $E_{kin}>0.5$ GeV/n

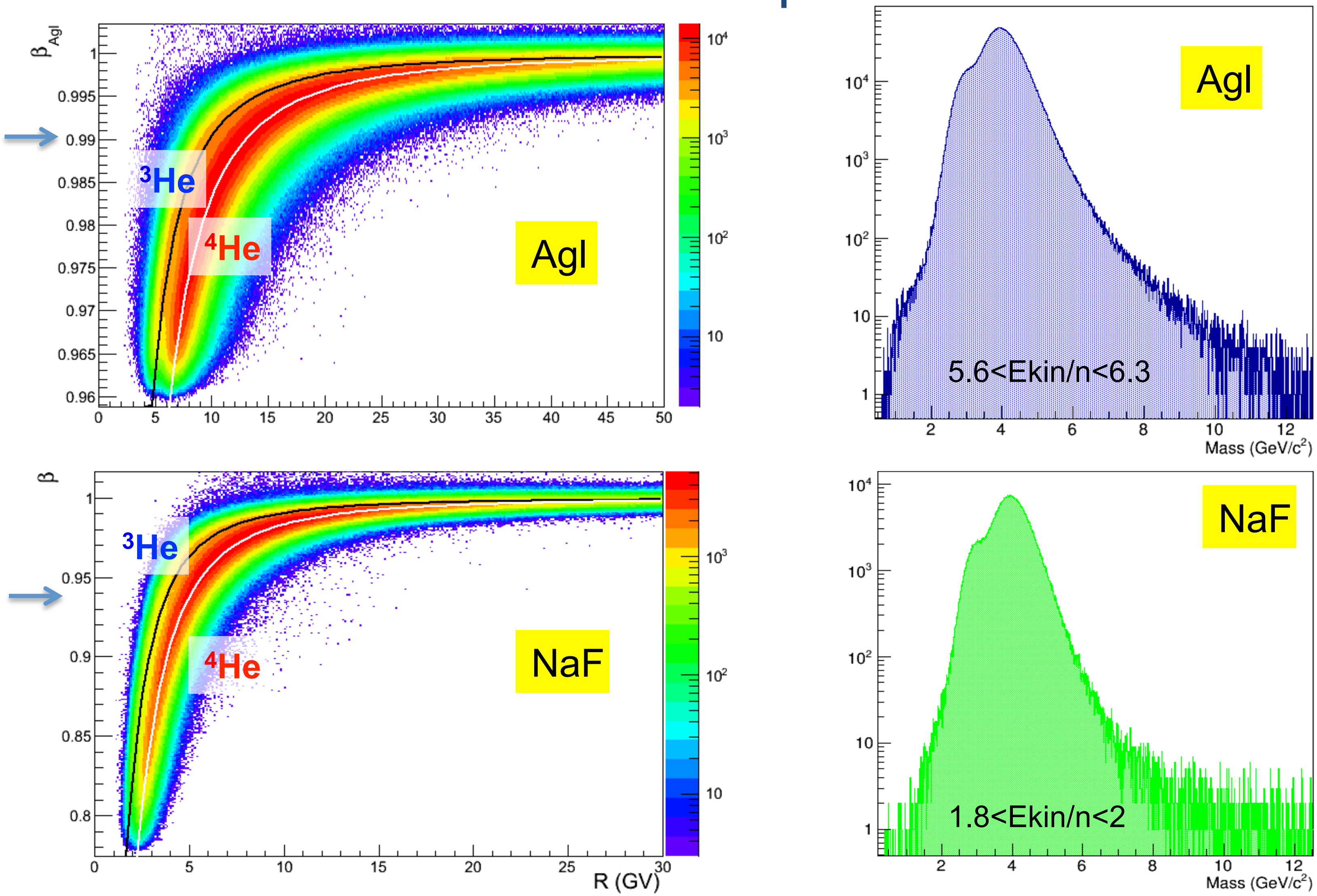
Silica aerogel (Agl)

- $\Delta_\beta/\beta \approx 0.08\%$ (He)
- $n=1.05$, $E_{kin}>2.1$ GeV/n



This analysis is based on RICH detector

$^3He/^4He$ separation



^3He and ^4He peaks are not separated, therefore we follow a stastistical approach

Analysis Methods

3 independent methods have been developed:

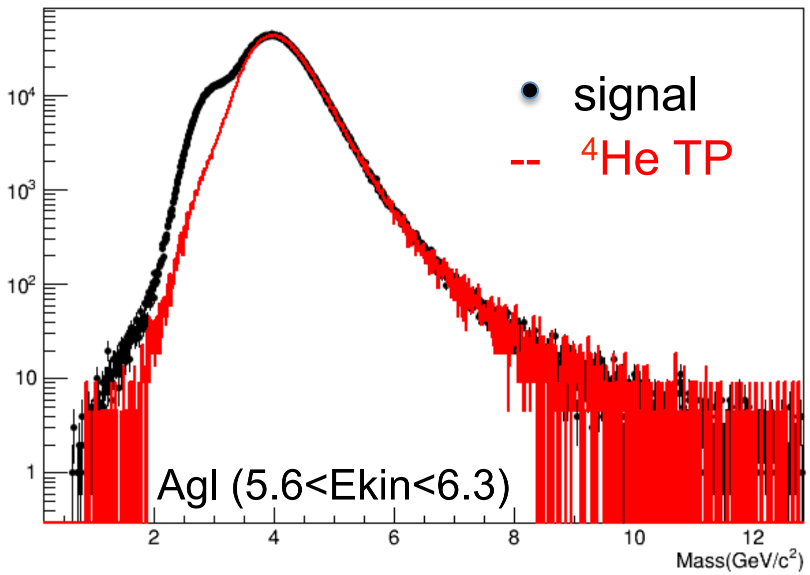
1. Mass Template extracted from data (DATA driven)
2. Parametrization of 1/M distribution with analytical function
3. Unfolding of the momentum distribution (MC driven)

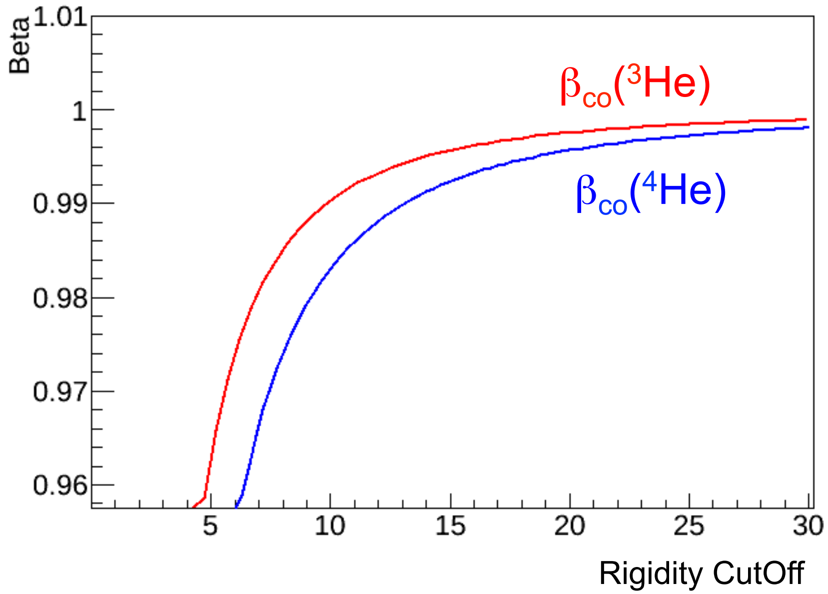
In all approaches we select bins in beta and perform the measurement as a function of the kinetic energy per nucleon.

Analysis Method (I):Data Template

- The idea is to extract a Template for ^4He directly from data, taking advantage from the screening effect of the geomagnetic field.

For a given geographic location (R_{co}), the geomagnetic field screens lighter isotopes (^3He) which are below a certain velocity $\beta_{co}(^3He)$





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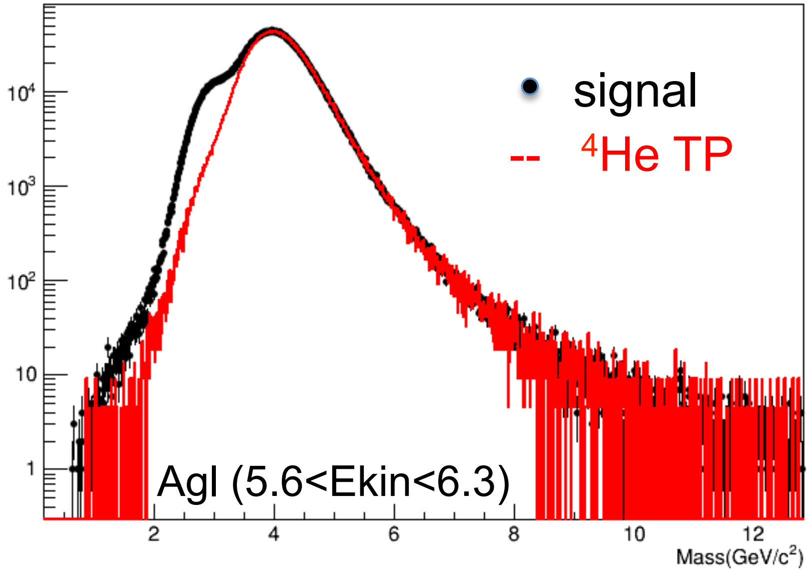
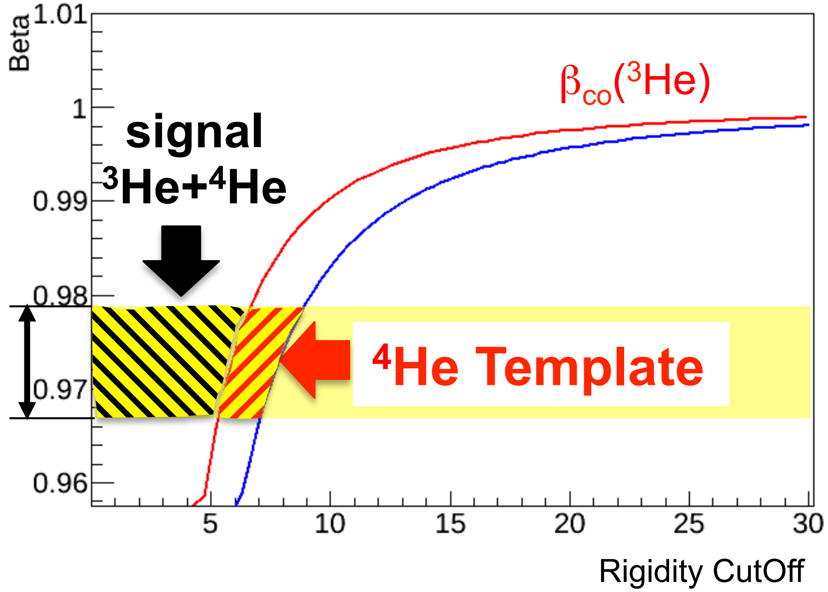
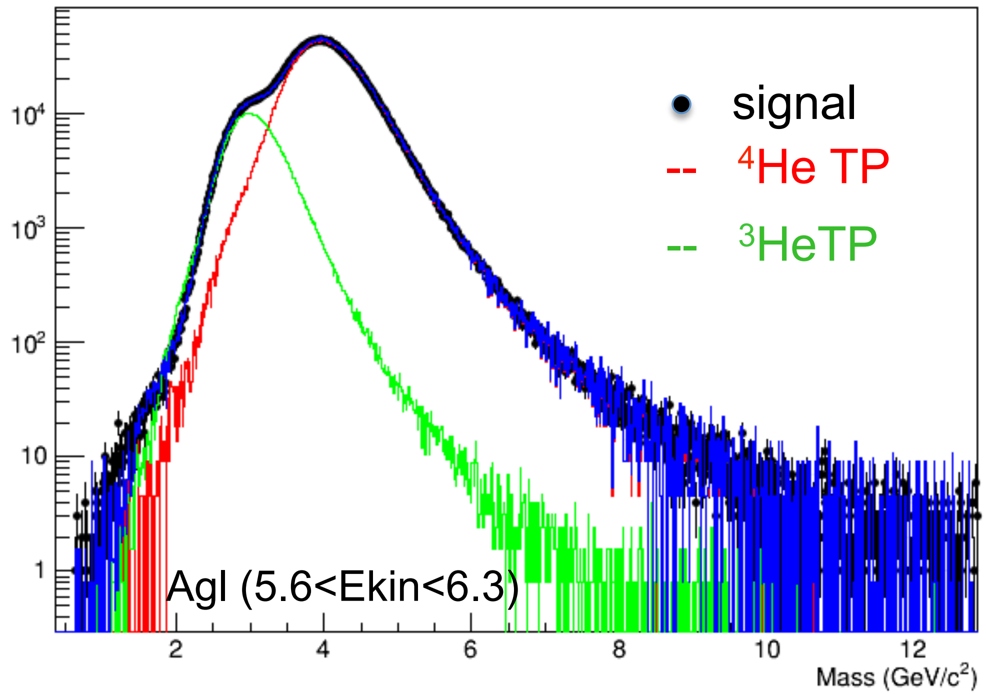




Analysis Method (I): Data Template

- ^{4}He Template comes directly from data (not dependent on Monte Carlo simulation fine tuning);
- ^{3}He Template is obtained from scaling ^{4}He one accordingly with mass ratio

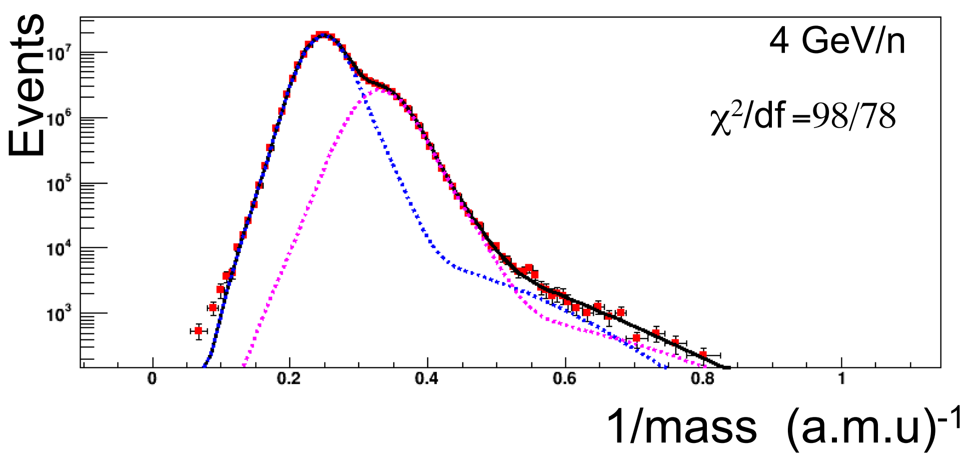


- ^{4}He Template is not completetly pure: residual ^{3}He, mainly due to limited GeoCutoff knowledge

Analysis Method (II): Parametrization of 1/M

- ➢ The idea is to obtain an analytical form for 1/mass template (both for ^{4}He and ^{3}He) from the resolution functions for 1/R and velocity, extracted from MC.

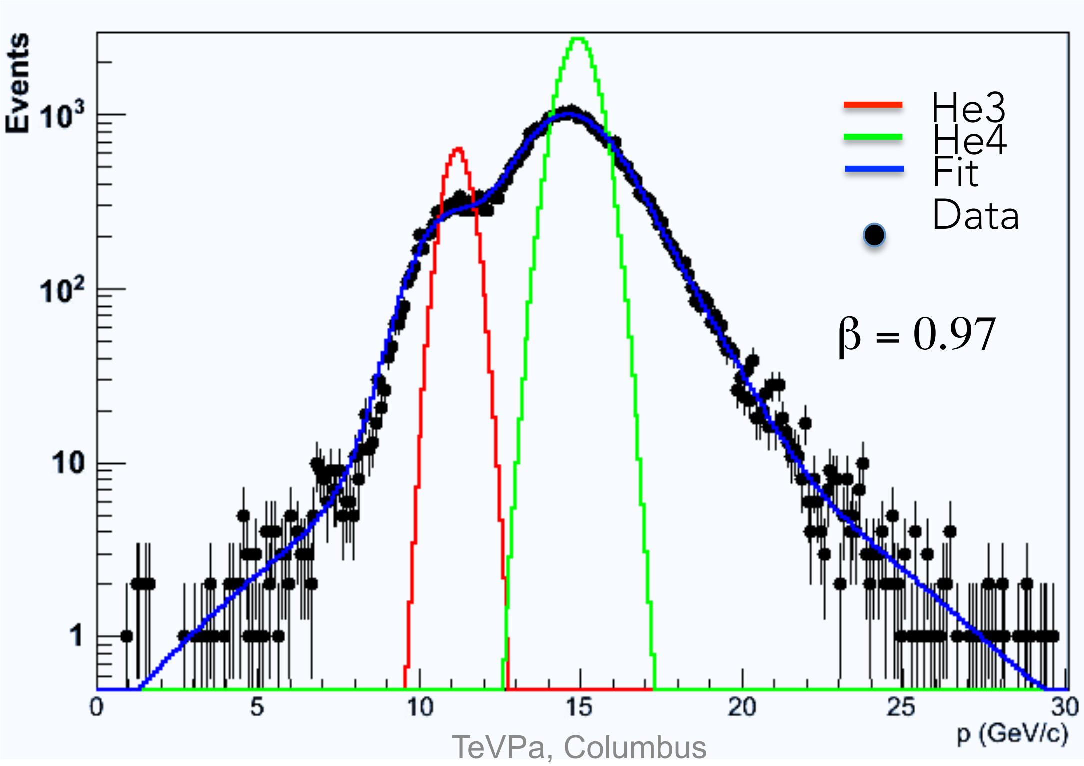
- Data are then fitted with ^{4}He and ^{3}He TP imposing 2 conditions:
  - ratio of ^{4}He and ^{3}He peak position is a constant;
  - ratio of the peak width scales accordingly with the mass ratio.



Analysis Method (III): Unfolding

➢ The idea is to get a description of the momentum resolution, taking advantage of the effort on MC fine tuning done for He flux.

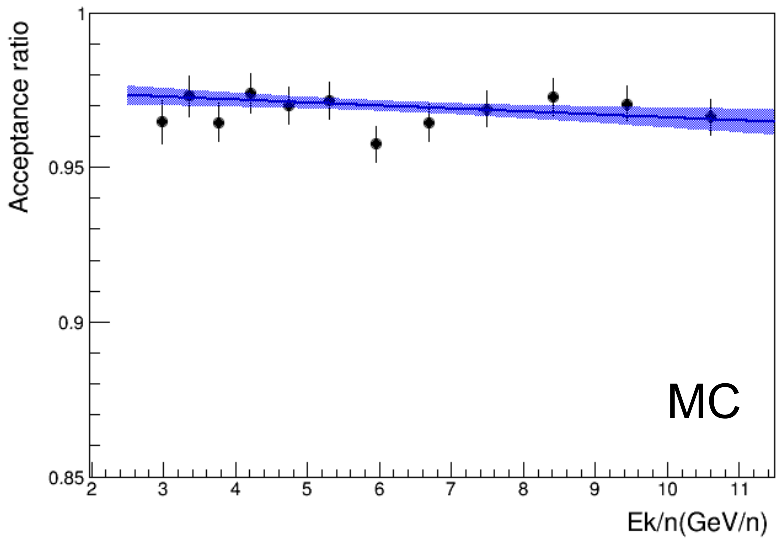
- Select fine beta bins compared with beta resolution (inside each bin momentum is "monochromatic" compared with Rigidity resolution).
- Use unfolding of momentum within the beta bin, with the tracker resolution matrix to get ^{3}He and ^{4}He peaks and count events.
- Fold back the results and check they agree with data.



Study of Systematics

All methods provide results with statistical error <1%.
The study of the systematic has been addressed independently for each of the analysis methods:

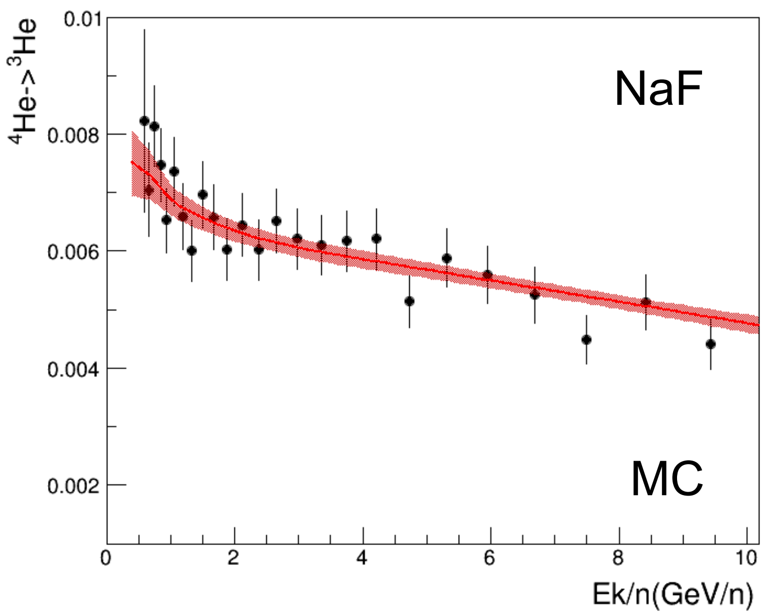
- Systematics specific of each methodology and fitting procedure
- Knowledge of the beta and rigidity resolution
- ^{3}He and ^{4}He different acceptance (ToI corrections)

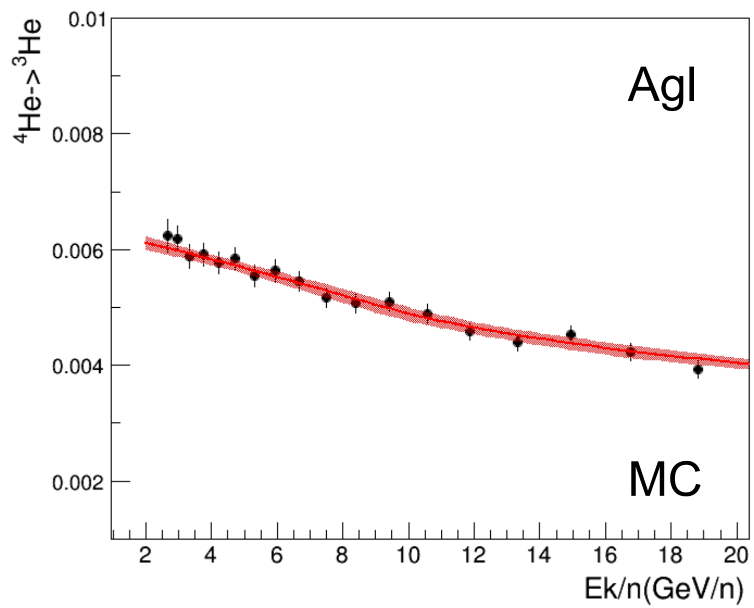


Study of Systematics

Common systematics: estimation of the fragmentations inside the detector

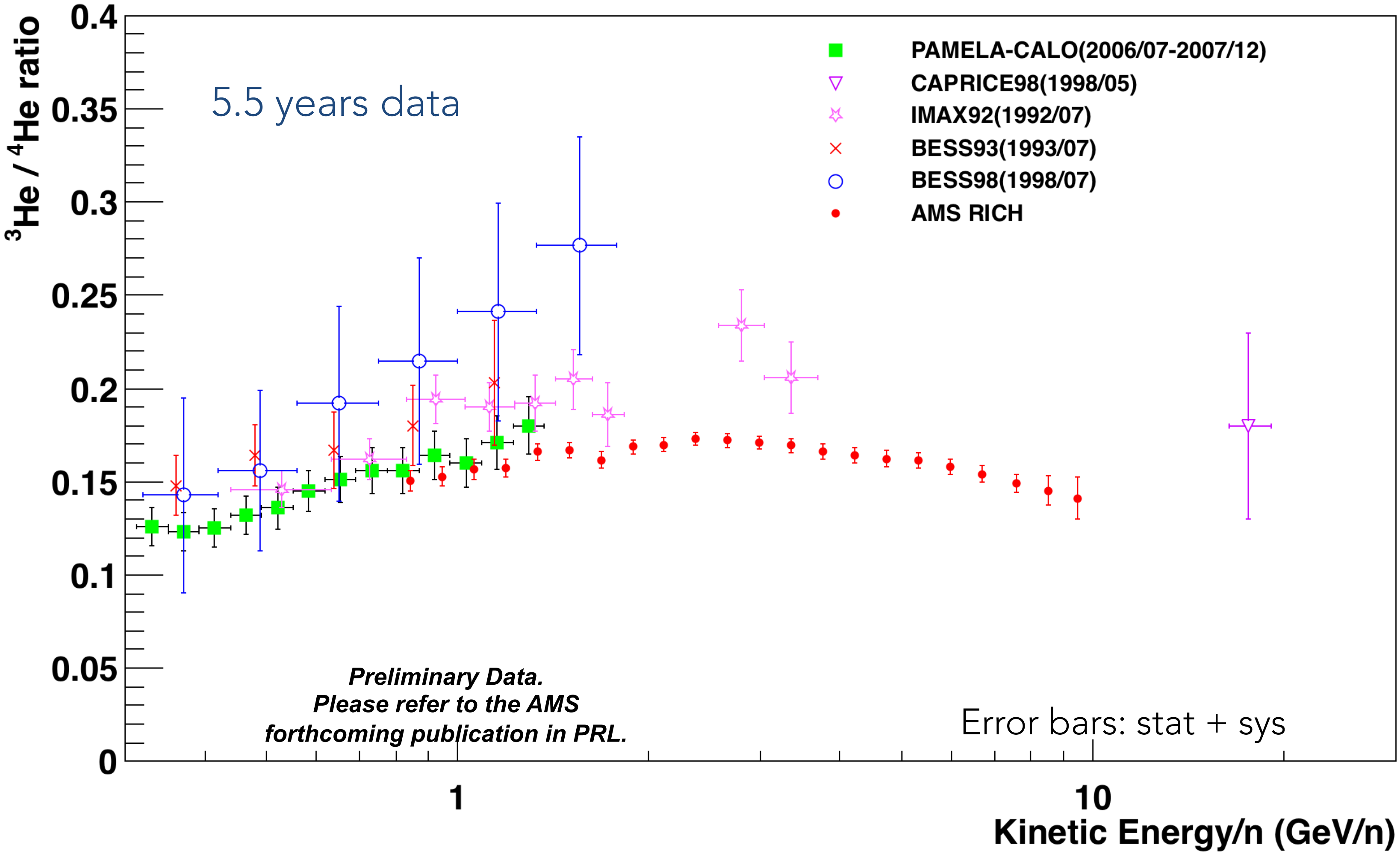
- Z>2 fragmentations into He is negligible and removed with L1 charge
- ^{4}He->^{3}He interactions are estimated from MC





- Validation with data has been addressed by means of:
  - ^{4}He->^{3}H
  - measurement of residual ^{3}He under cutoff
- Total sys error of the order of 1-5% (1-10GeV)

Results



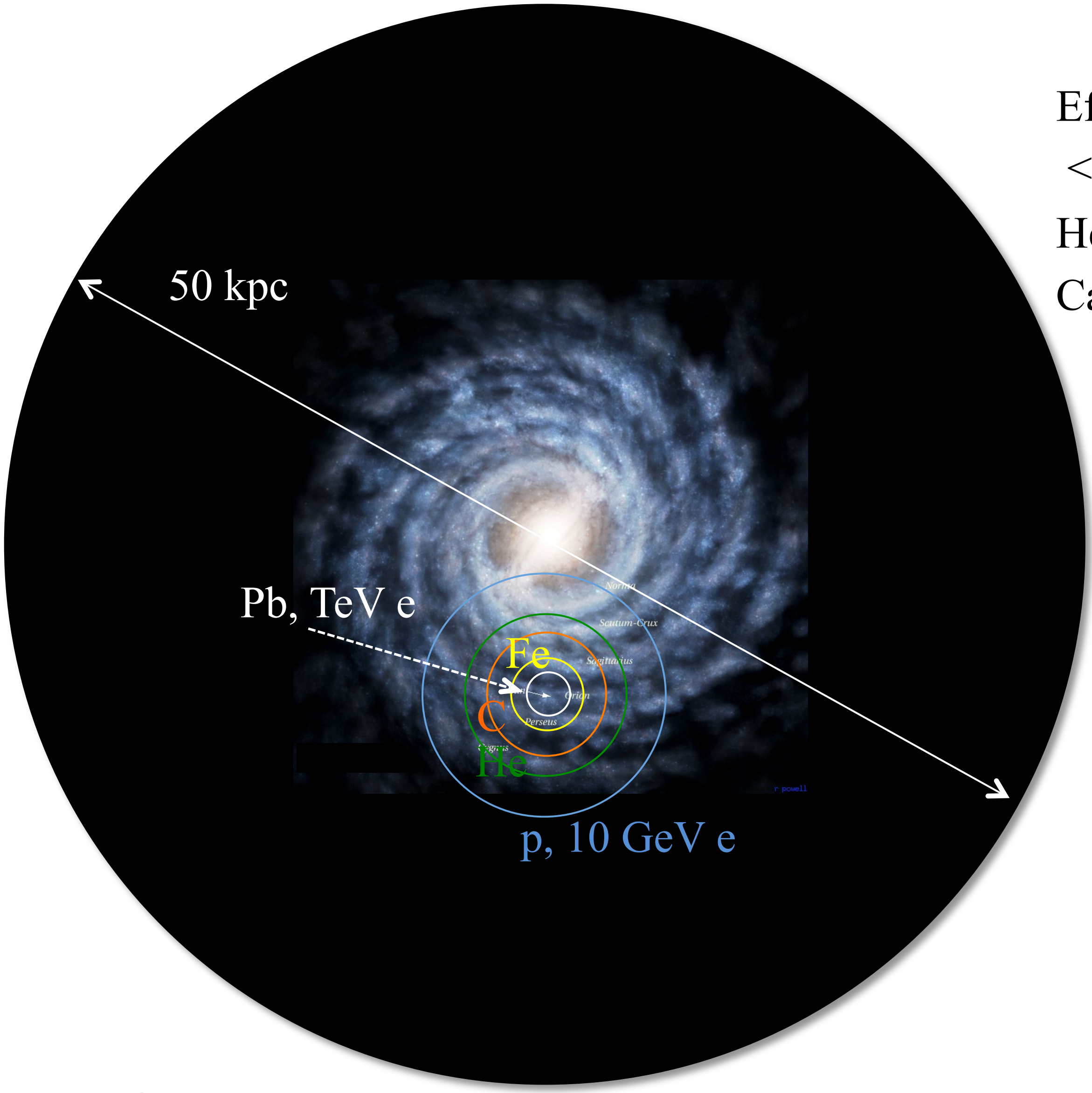
- The 3 presented independent methods agree within 4%

Conclusions

- A preliminary measurement of $^{3}He/^{4}He$ ratio in cosmic rays with AMS has been presented;
- This measurement is important to constrain GCR propagations models;
- The results cover a kinetic energy range (from 0.8 to 10 GeV/n) where previous measurement are sparse and affected by large errors;
- Three independent approaches developed to extract the isotopic ratio provide results within 4%.


AMS-02
Alpha Magnetic Spectrometer
AMS-02
ELC2
THANK YOU!

Motivation



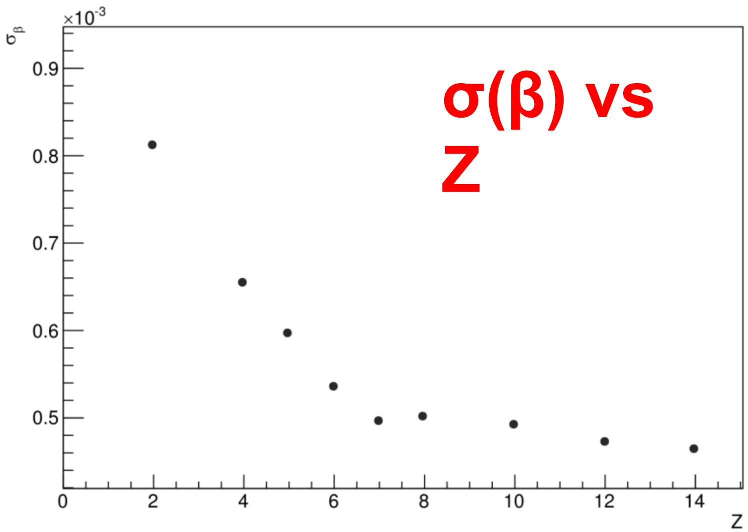
Effective propagation distance:

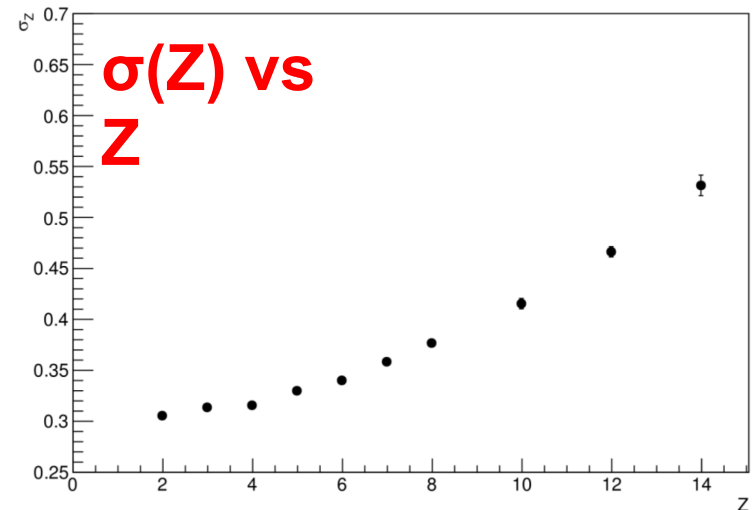
$<X> \sim \sqrt{6D\tau} \sim 2.7$ kpc $R^{\delta/2} (A/12)^{-1/3}$

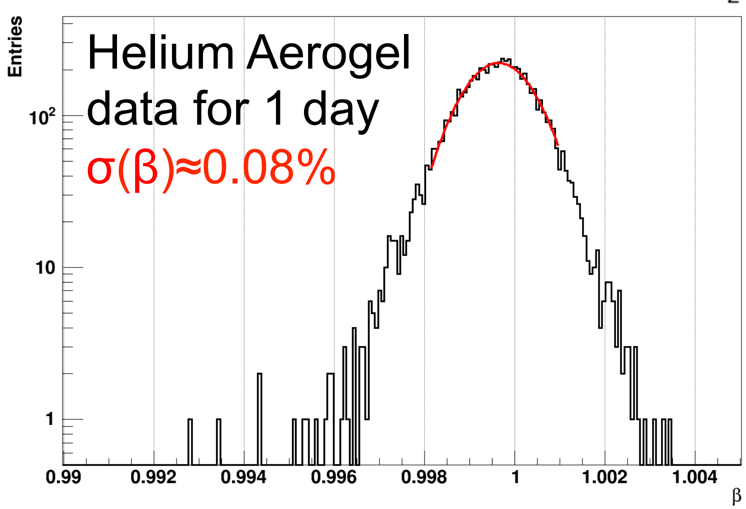
Helium: ~ 3.6 kpc $R^{\delta/2}$

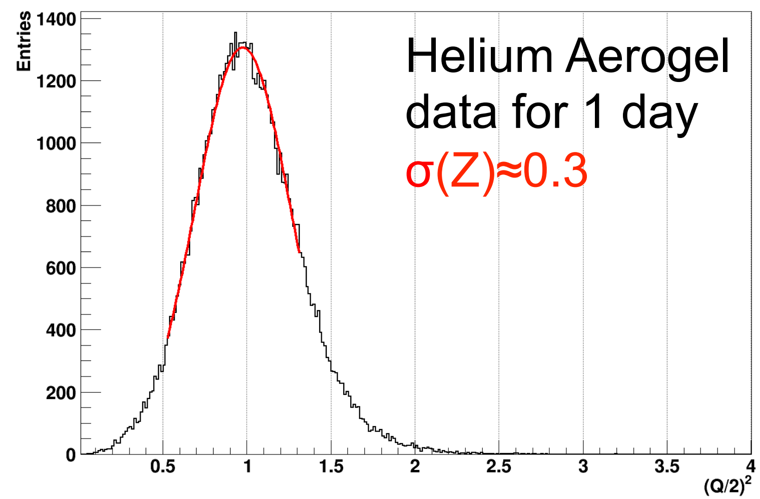
Carbon: ~ 2.7 kpc $R^{\delta/2}$

RICH Performance on ISS (Aerogel)







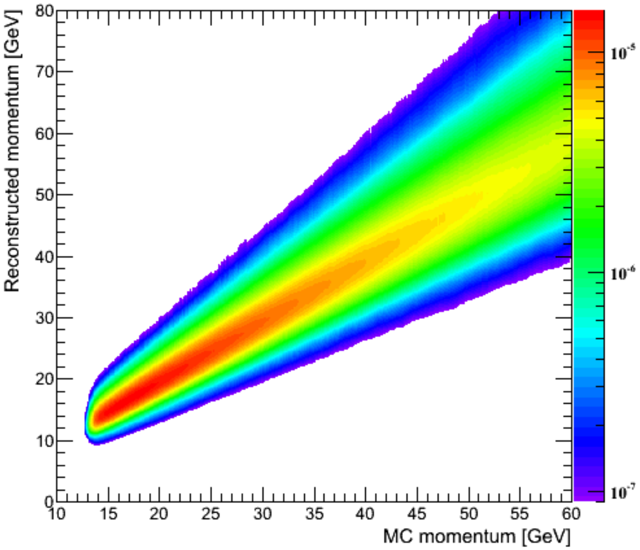


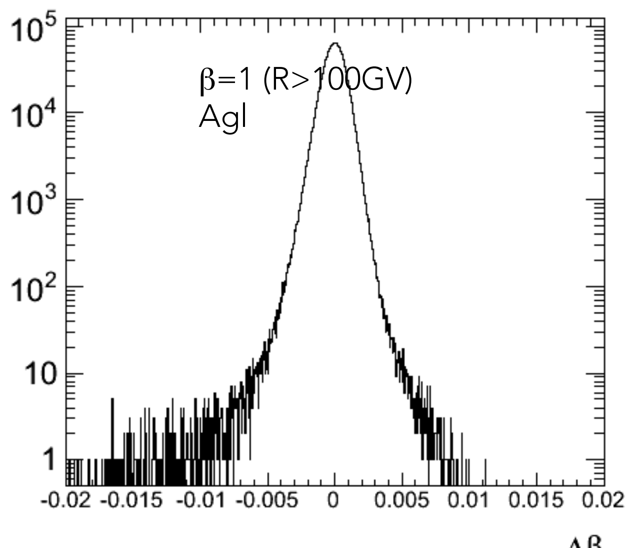
Analysis Method (III):Unfolding

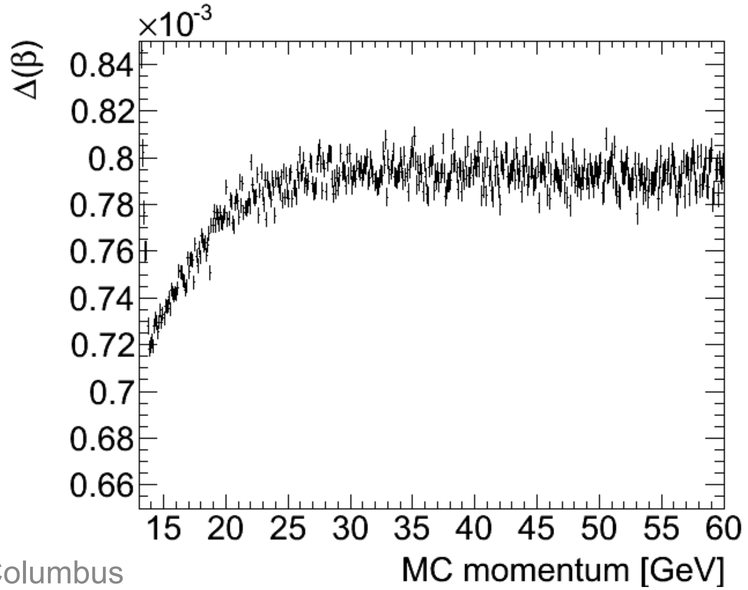
Main ingredients:

-Smoothed migration matrix from MC

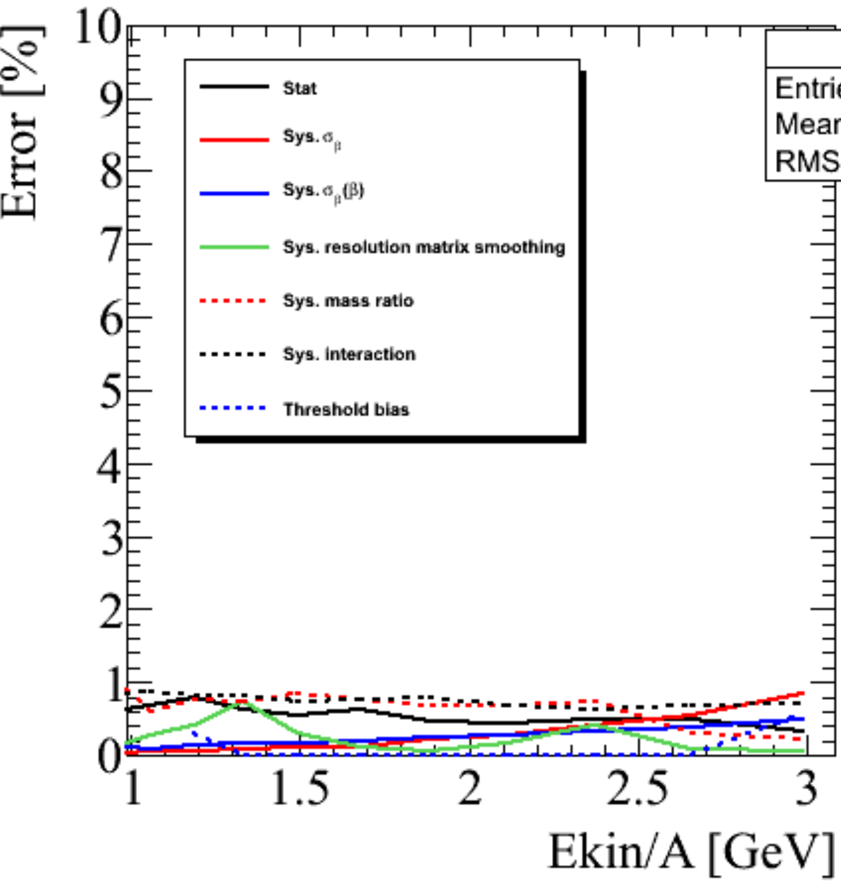
-Beta resolution

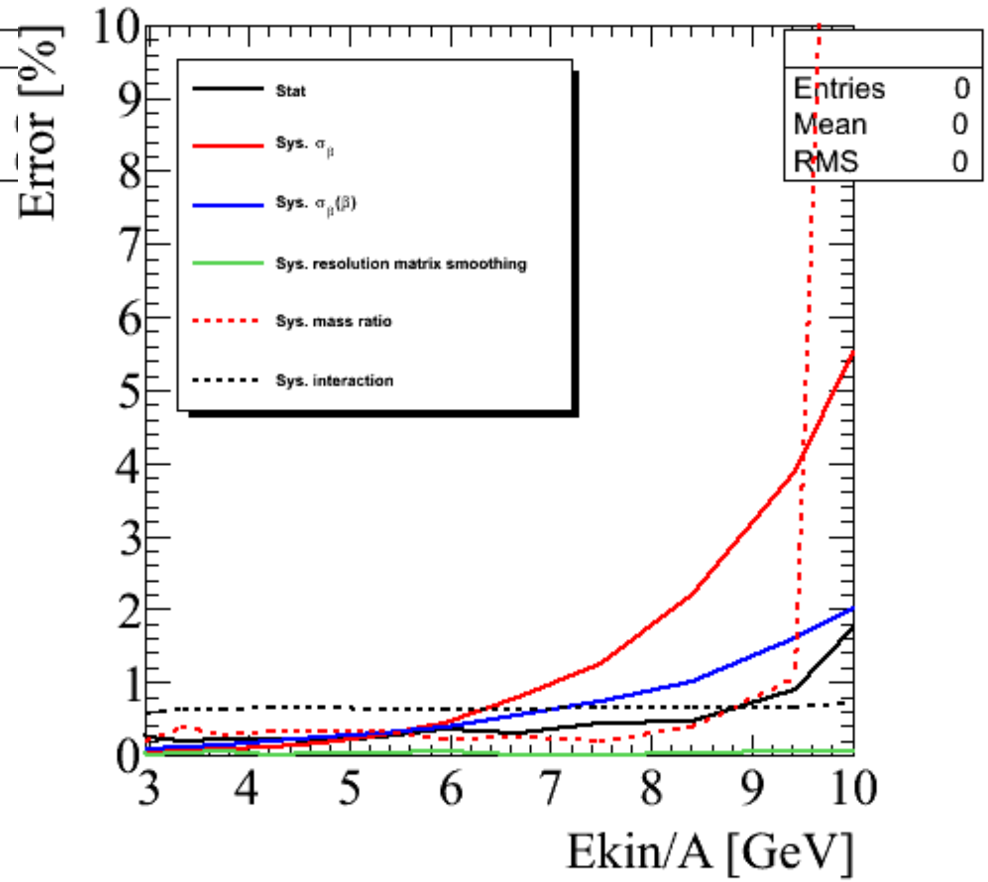




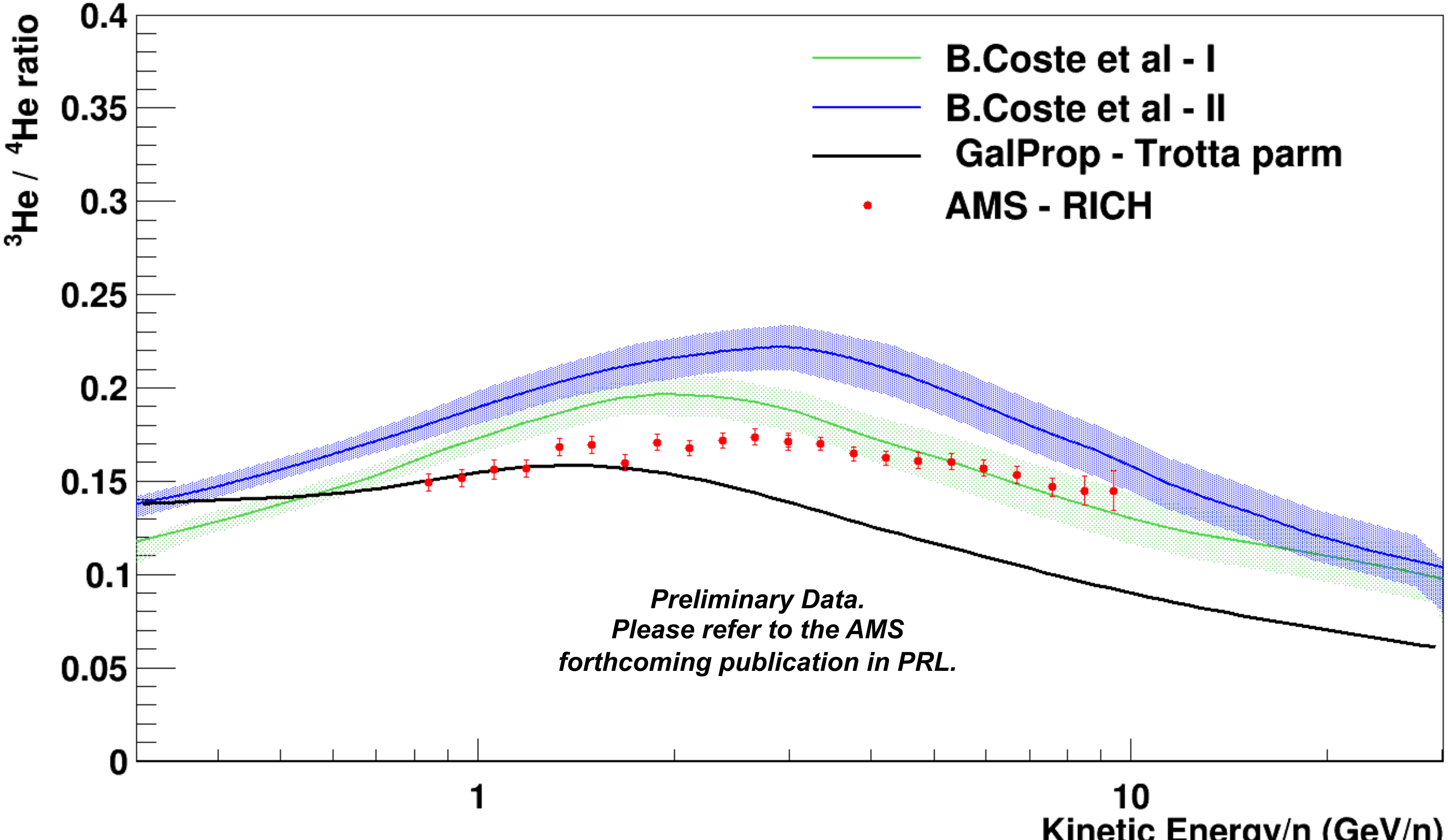


Systematics Unfolding





AMS measurement compared to propagation models



Models from: B.Coste et al. A&A 539, A88 (2012)

- **Model I**
  - fit to: **B/C** (pre-AMS) + PAMELA **^{3}He/^{4}He**
  - Diffusion Coefficient $D(E) \propto E^{\delta}$ **$\delta \approx 0.2$**

- **Model I I**
  - fit to: **B/C** (pre-AMS) + BESS and IMAX **^{3}He/^{4}**
  - Diffusion Coefficient $D(E) \propto E^{\delta}$ **$\delta \approx 0.6$**