

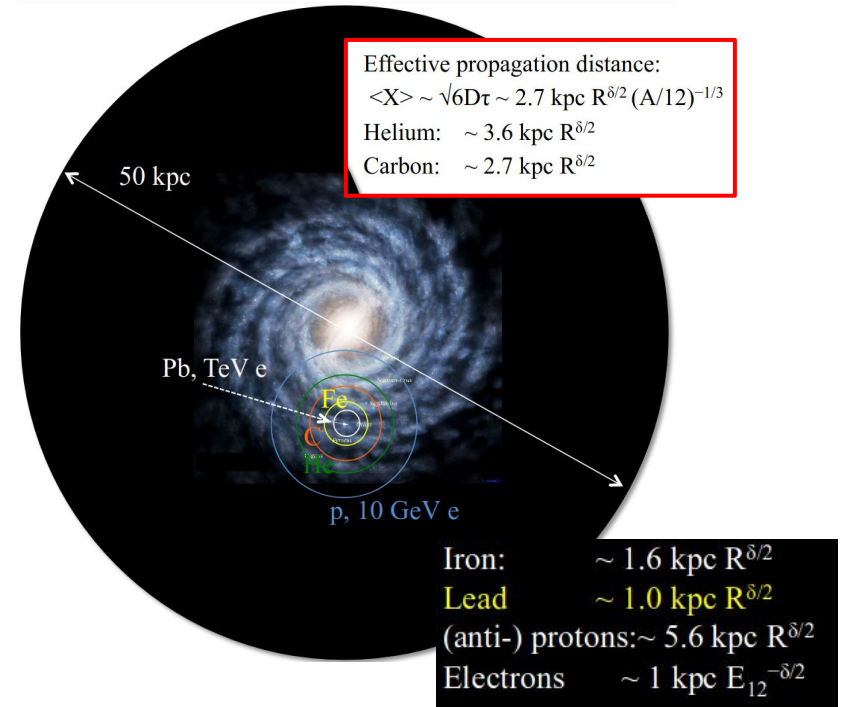
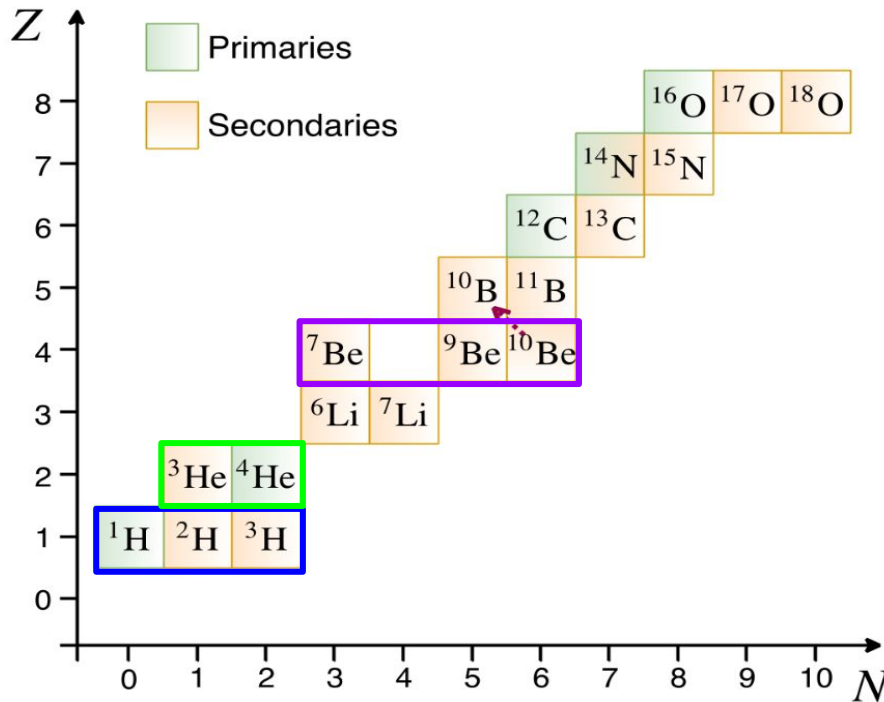
AMS Italia Meeting

Measurements of light Isotopes

11/03/21 - TIFPA Group

Light isotopes in cosmic rays

- B/C probes mostly “local” propagation
- p-bar come from much further
- light secondary like D, ^3He and Be constrain better the p-bar secondary prod.



- $^{10}\text{Be}/^9\text{Be}$: independent measurement of H
- $^3\text{He}/^4\text{He}$: sec/primary
- D/p and $\text{D}/^4\text{He}$: sec/primary, D-bar searches

Berillium in Cosmic Rays (CR)

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

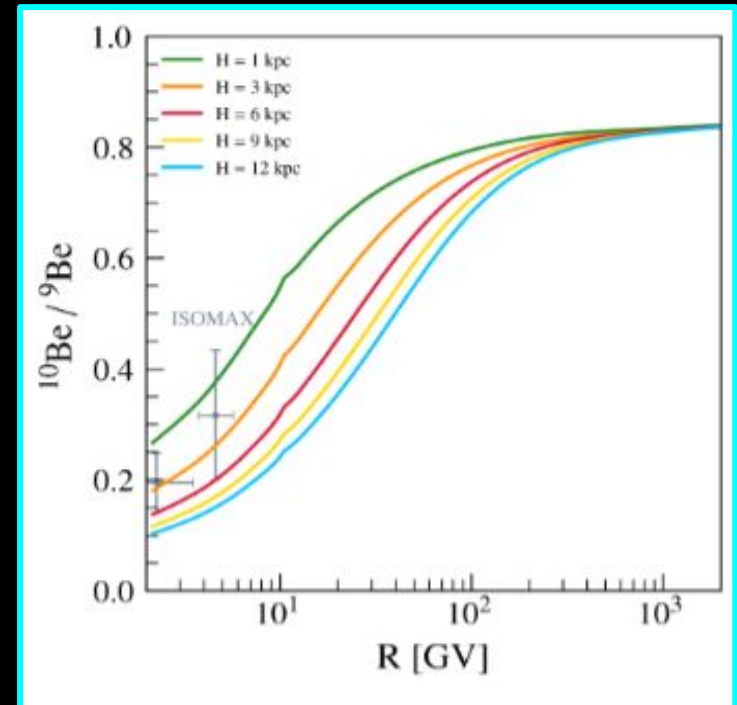
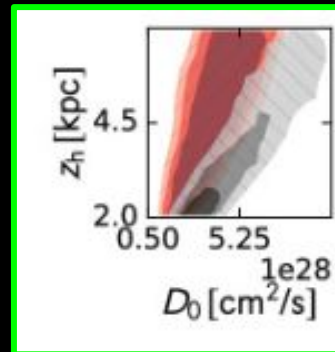
${}^{10}\text{Be}/{}^9\text{Be}$ is a powerful “radioactive clock” for the measurement of residence time

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

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

which is prop. to H/D

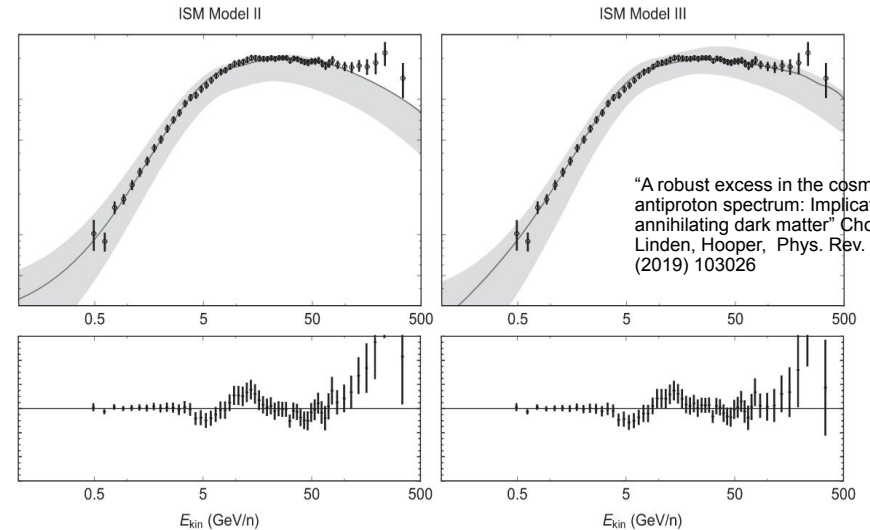
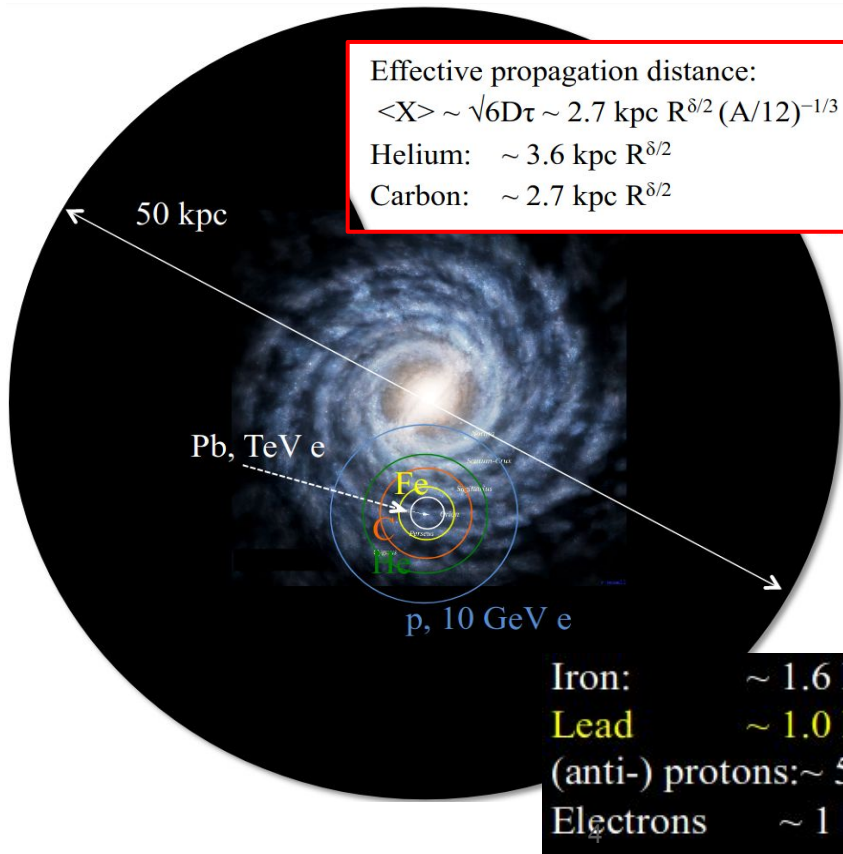
- H and D are thus dependent in many prop. models
- Adding a time dependence, ${}^{10}\text{Be}/{}^9\text{Be}$ can constrain D, allowing an independent measurement of H



Deuterons in CR

P-bar:

- Excess from DM
- Background for anti-nuclei searches

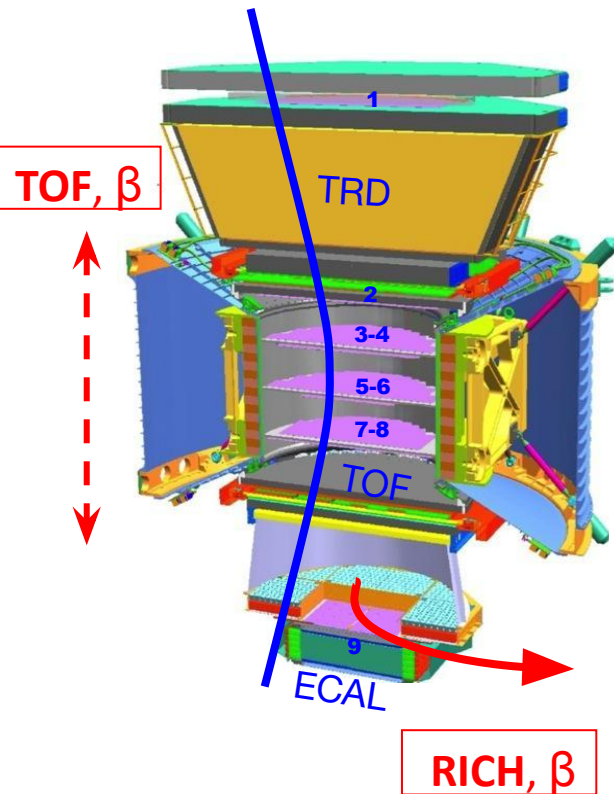


- Deuteron analysis is performed independently by **4 other groups in AMS**:
 - P. van Doethichen - University of Hawaii - USA
 - M. Vecchi - University of Sao Paulo - Brazil
 - Carlos Delgado - CIEMAT - Spain
 - Fernando M. Bueno - Groningen - Germany
- **D/⁴He time dependence** is the main focus of the effort

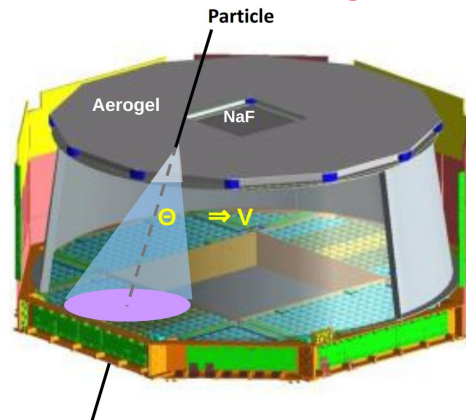
AMS: Identification of isotopes

Isotopes: Identified from the concurrent measurement of **Rigidity (p/Z)** and **Velocity**

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



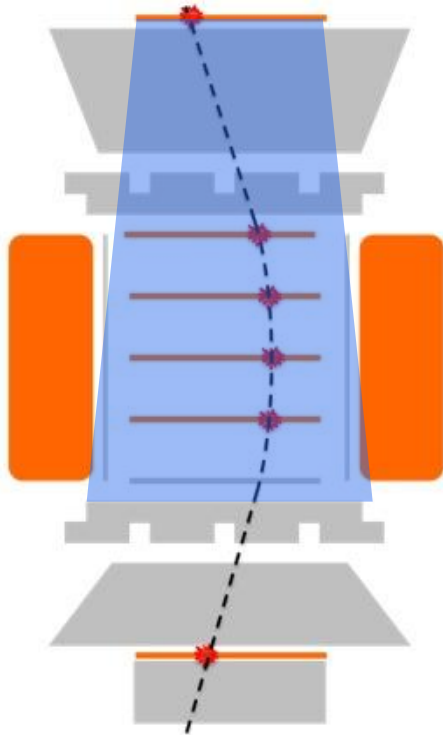
RICH radiators:
NaF and Aerogel



- **Z measurement:**
L1->UTof->(L1-L8)Tracker->LToF:
negligible charge confusion
- **R measurement:**
(L1-L8) Tracker
- **Velocity measurement:**
 - ToF: 4 Layers, $\Delta\beta/\beta \sim 1-2\%$
 - RICH NaF: $\Delta\beta/\beta \sim 0.3\%$, $\beta > 0.75$
 - RICH AgI: $\Delta\beta/\beta \sim 0.1\%$, $\beta > 0.95$

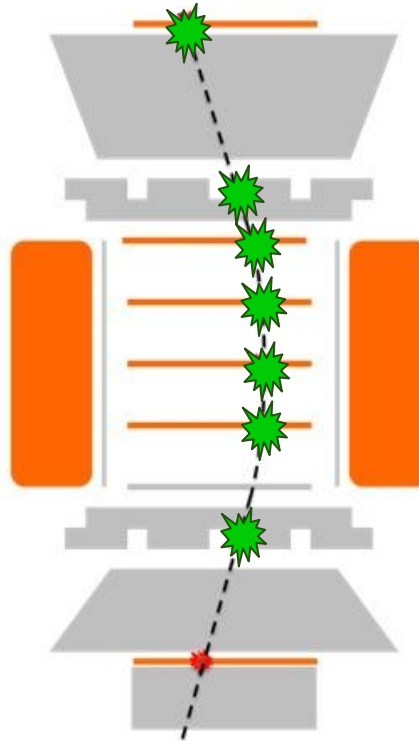
Selections on data

Step 1:
Definition of geometry



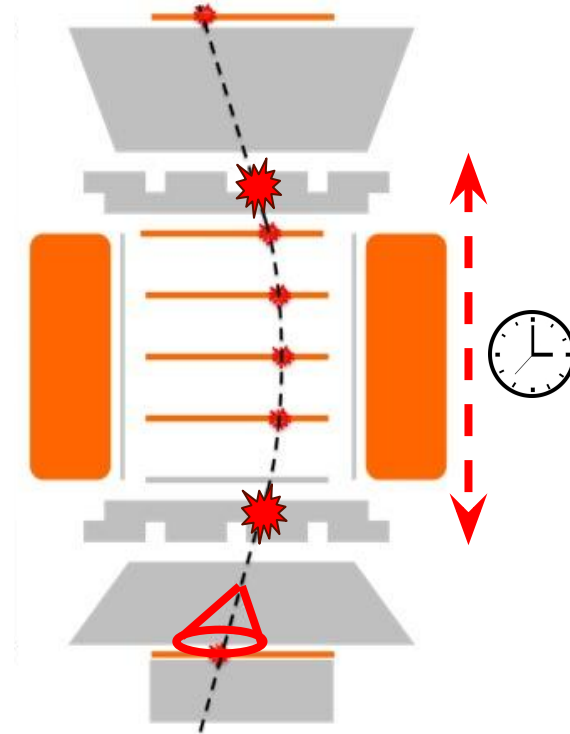
- L1 + Inner Tracker

Step 2:
Definition Z=1 sample



- Z = 1 at different levels

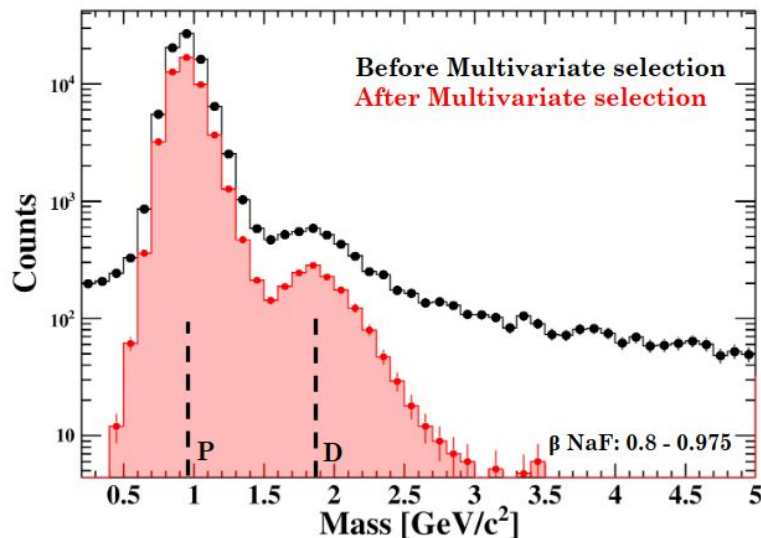
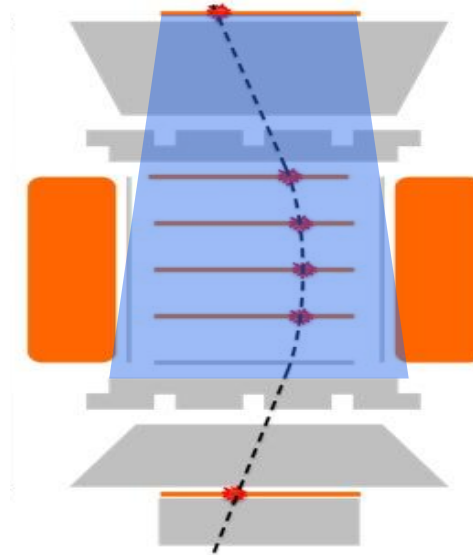
Step 3:
Good measurement of β



- Quality of Time of Flight
- Multivariate analysis for RICH

Più in dettaglio...

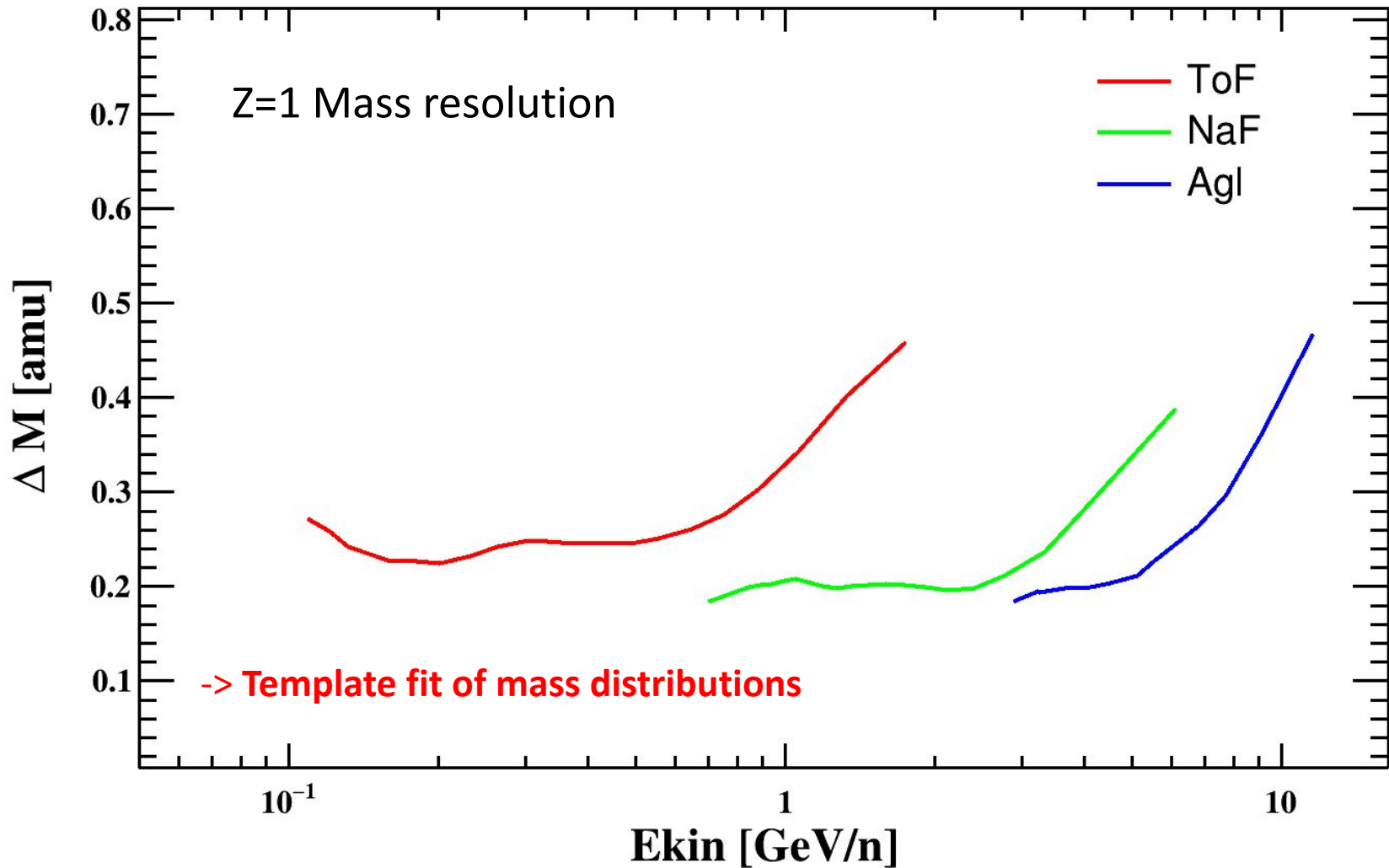
	Resolution	Effective interval
Inner+L1 Tracker	$\sigma_R/R \sim 10\%$	$0.2 < E_k < 120$ GeV/n
TOF	$\sigma_\beta/\beta \sim 3\%$	$0.2 < E_k < 1.1$ GeV/n
RICH NaF	$\sigma_\beta/\beta \sim 0.3\%$	$0.7 < E_k < 3.7$ GeV/n
RICH AgI	$\sigma_\beta/\beta \sim 0.1\%$	$2.6 < E_k < 8.9$ GeV/n



- **Tre range di energia** limitati dalla risoluzione in velocità dei sub-detectors
- Geometria **Inner + L1**: Ottimizziamo l'accettazione controllando le interazioni al top dello strumento
- **Selezioni sulla carica** a tutti i livelli per un segnale pulito di $Z=1$, $Z=2$ o $Z=4$
- **per Deuterio**: Selezioni avanzate sulla qualità della ricostruzione RICH

AMS: Identification of isotopes

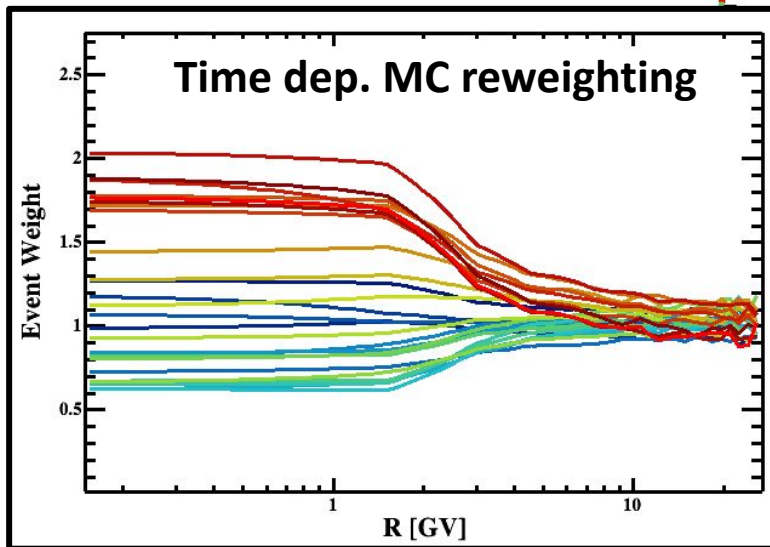
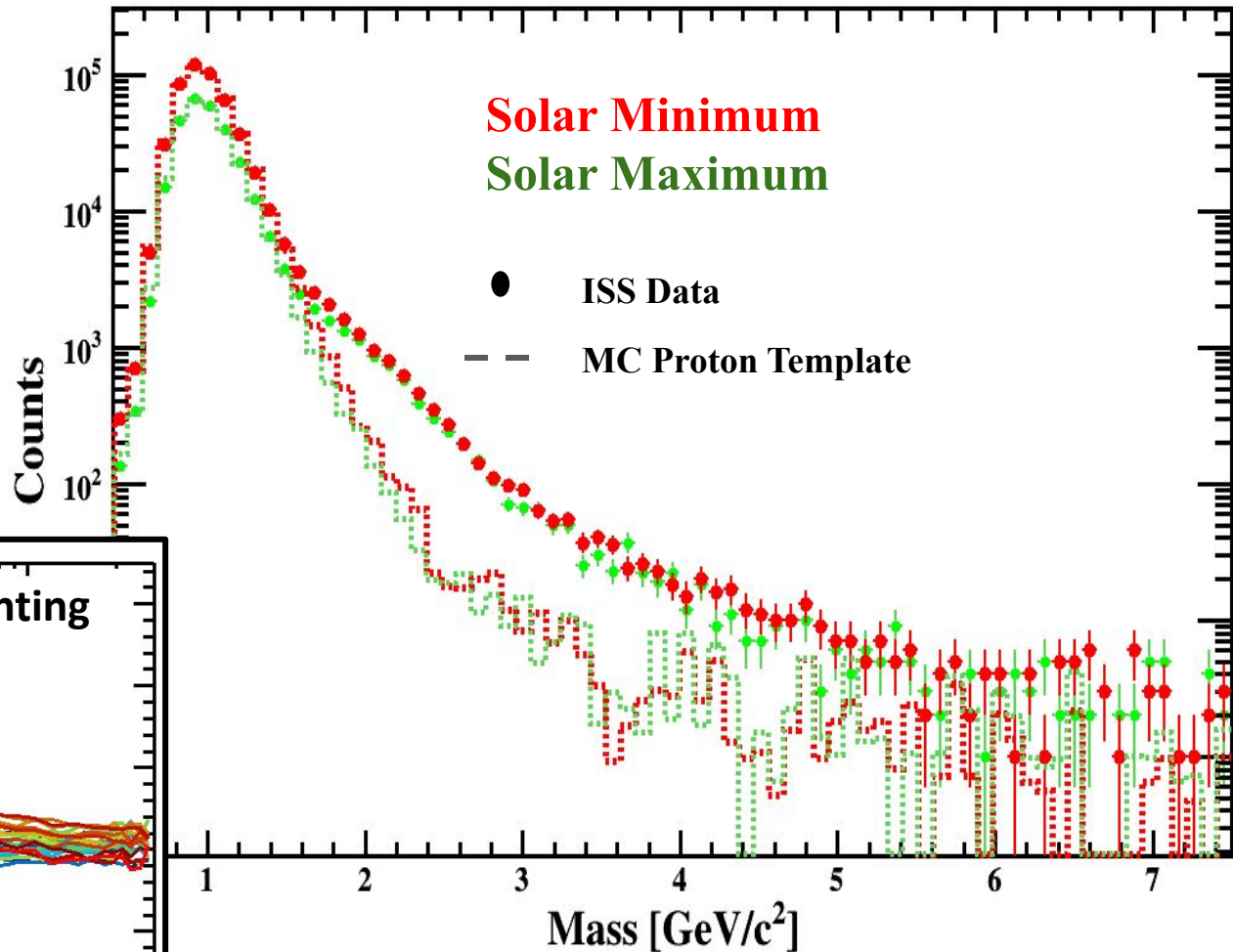
$$M = \frac{RZ}{\gamma\beta} \Rightarrow \frac{\Delta M}{M} = \sqrt{\left(\frac{\Delta R}{R}\right)^2 + \left(\gamma^2 \frac{\Delta\beta}{\beta}\right)^2}$$



Simulazione MC “Realistica” (Time dependent)

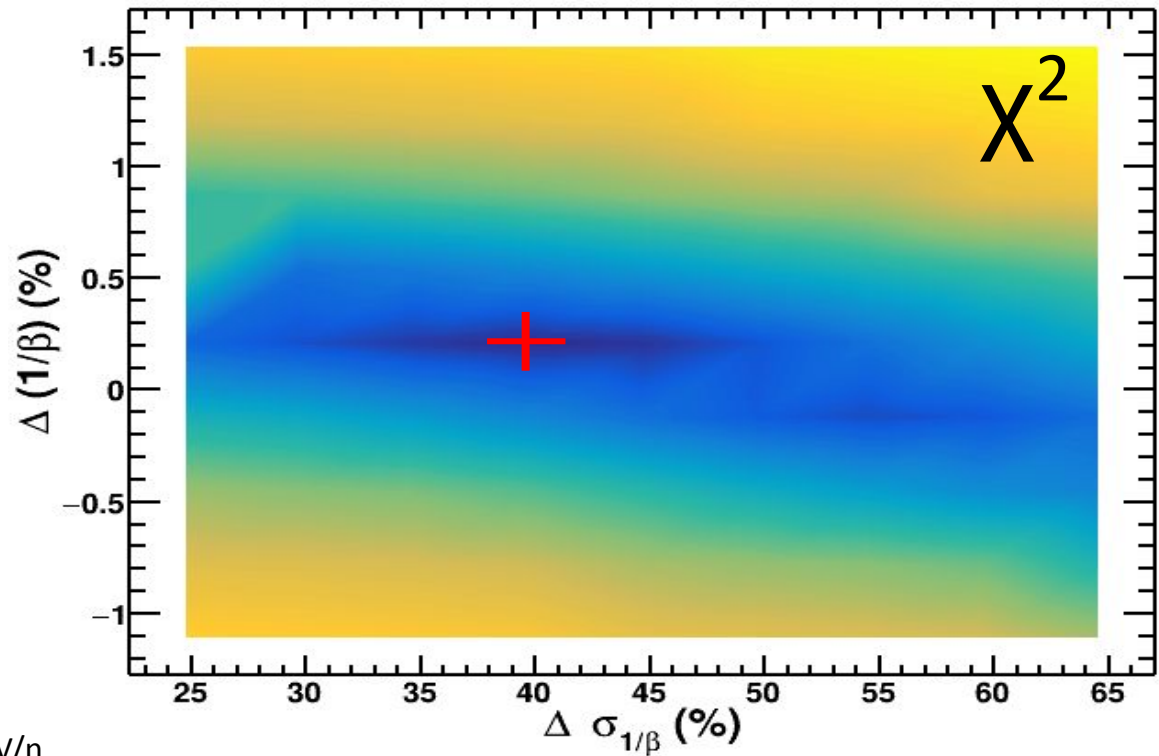
1. **Cutoff:** $\beta_{\text{meas}} > \beta(R_{\text{IGRF}})$
2. Time dependent reweighting (to take into account Sol. Mod.)
3. Realistic isotopic mixture

$$0.831 < \beta < 0.843$$

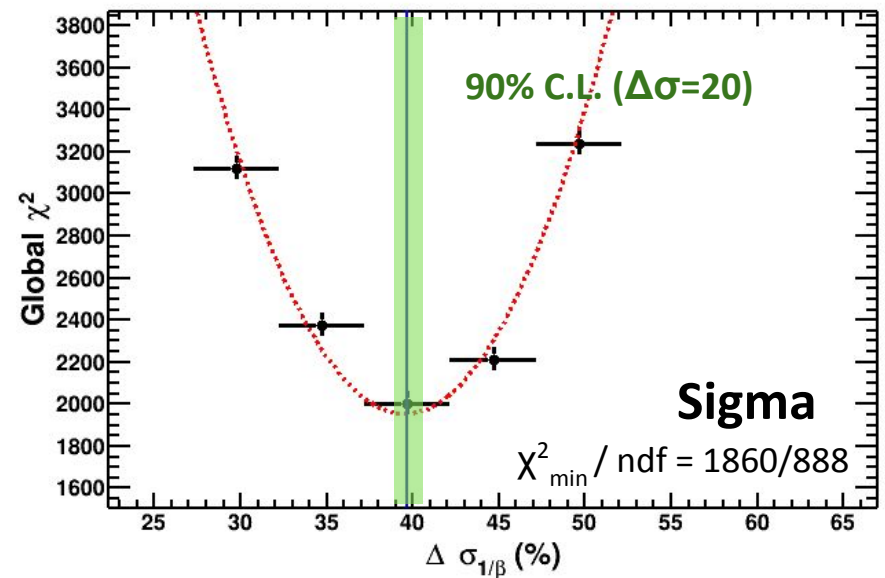
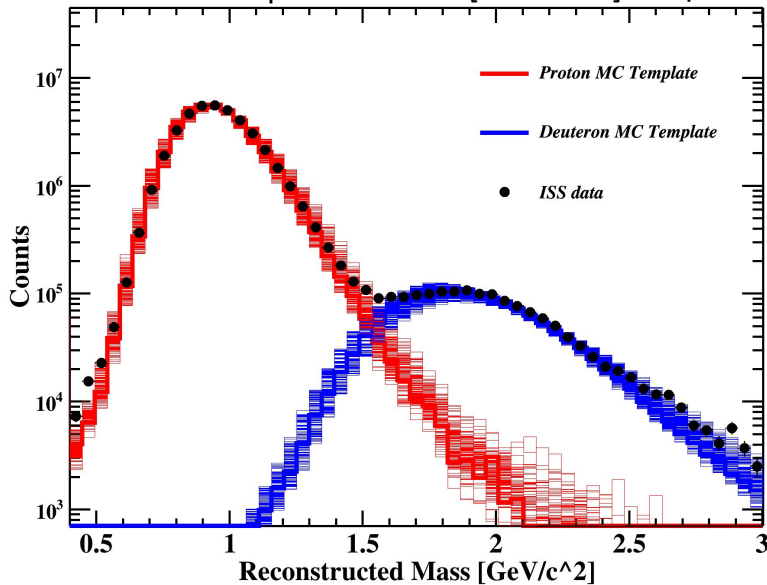


Fit of Mass

- Smearing of $1/\beta$ with a 3 gaussian model
- Combination of smearing parameter to optimize χ^2 of fit
- Join flexibility of fit with tail simulation of MC

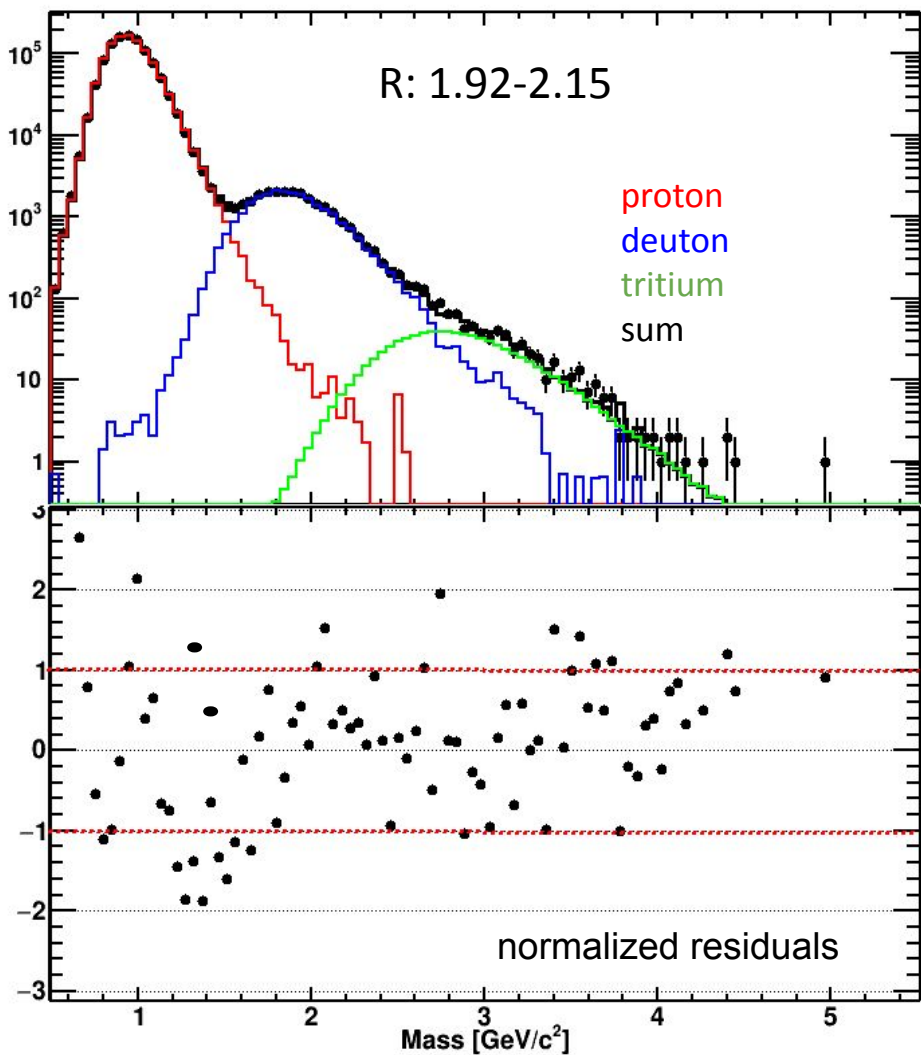


ToF mass templates : $E_{kin} = [0.40-0.45]$ GeV/n

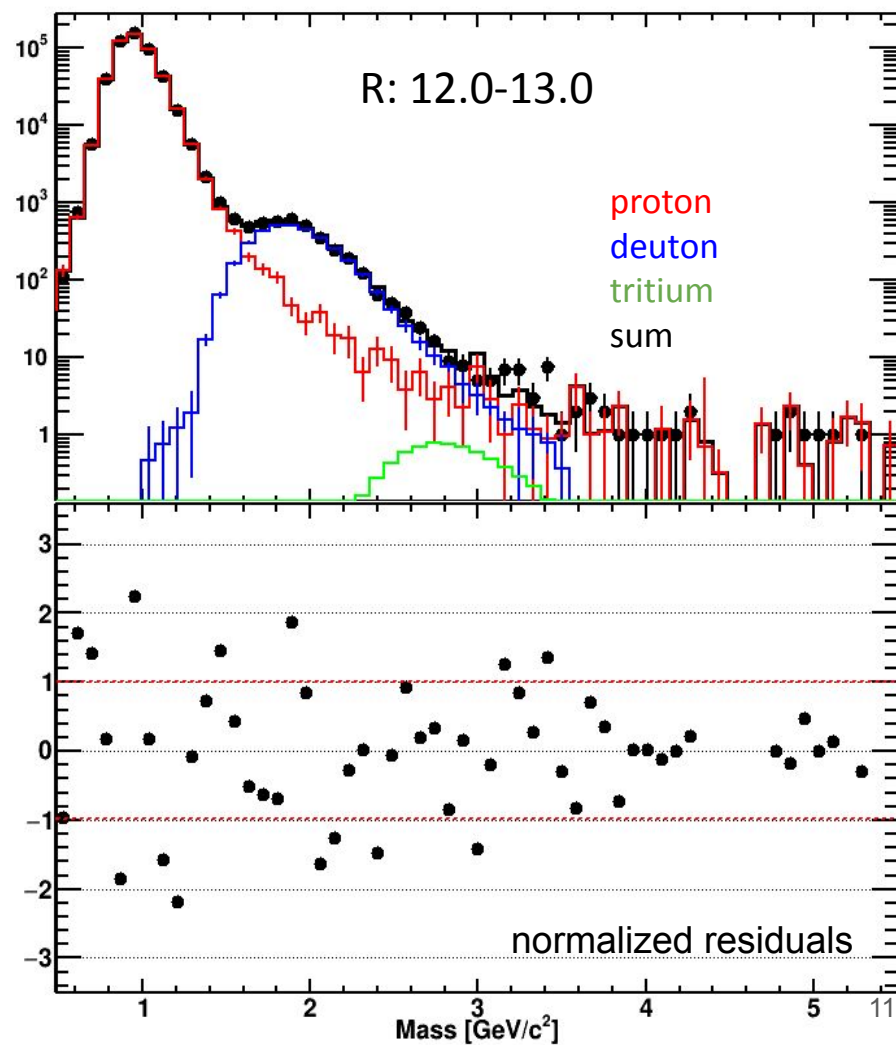


Z=1 Isotopes

T.o.F.

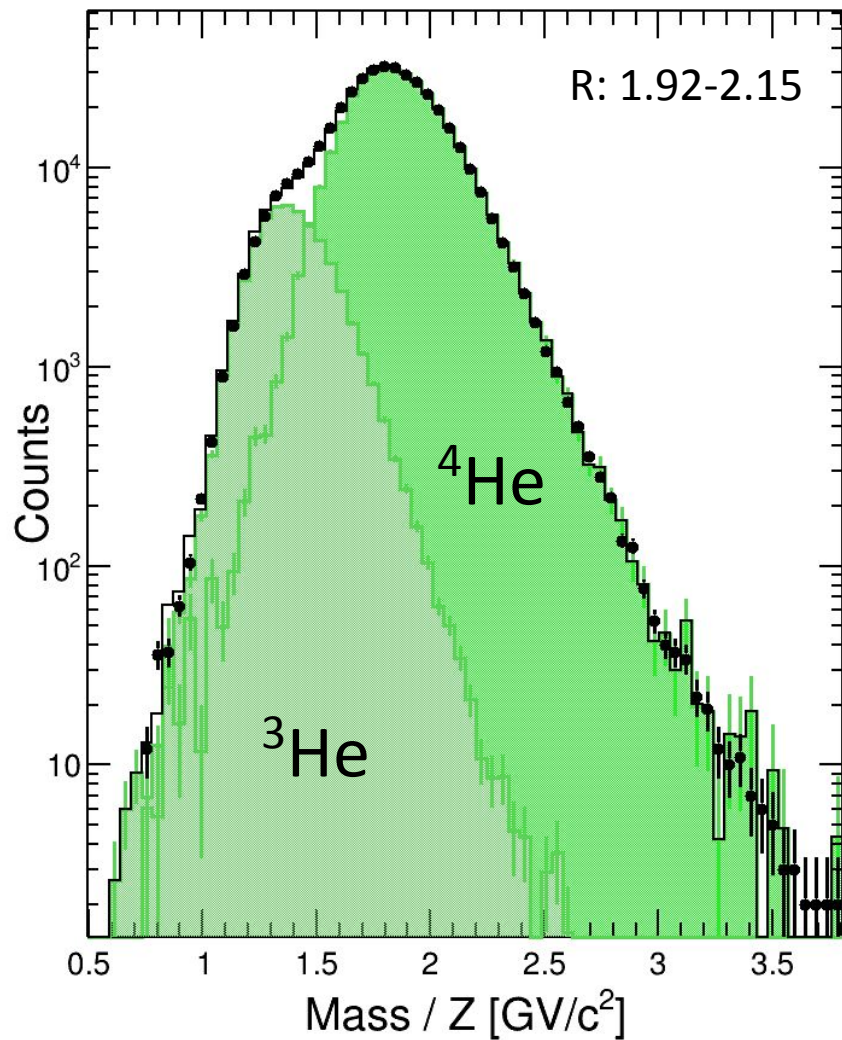


RICH

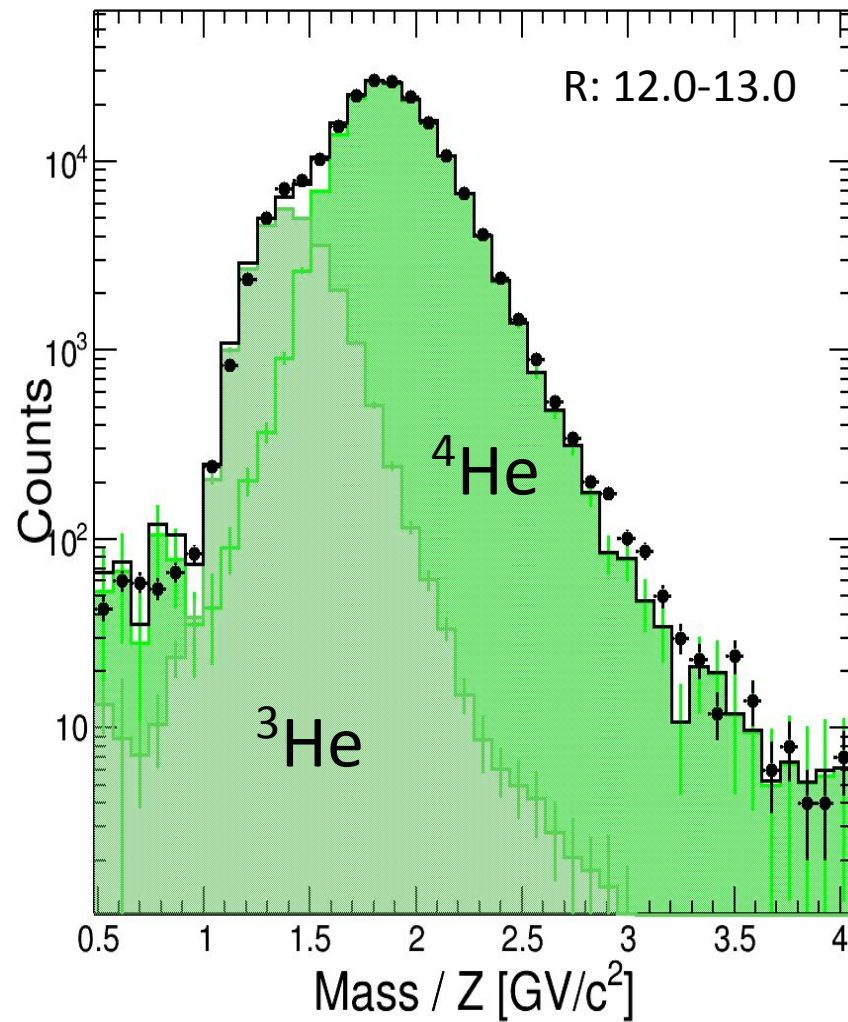


Z=2 Isotopes

T.o.F.



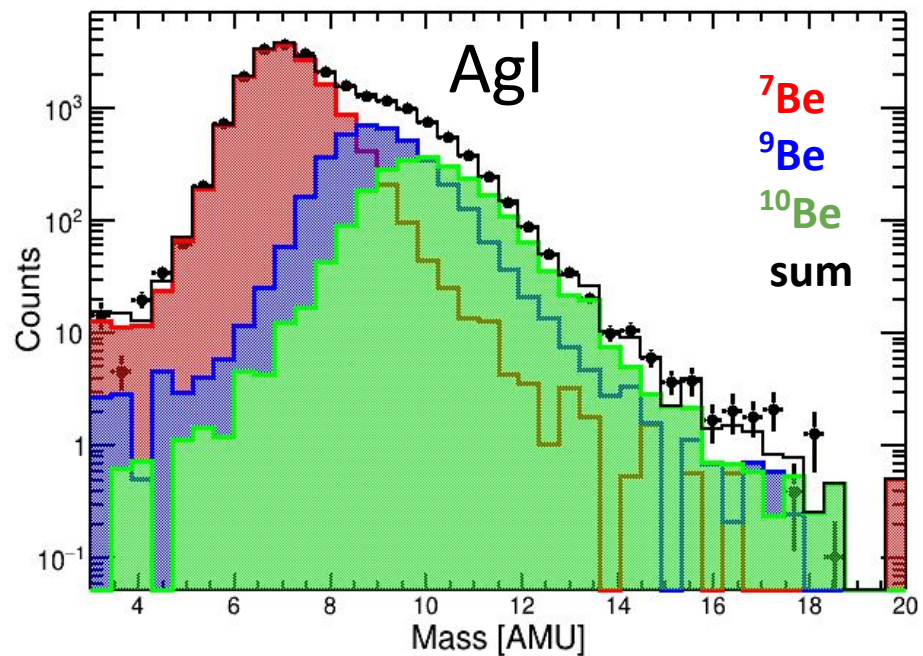
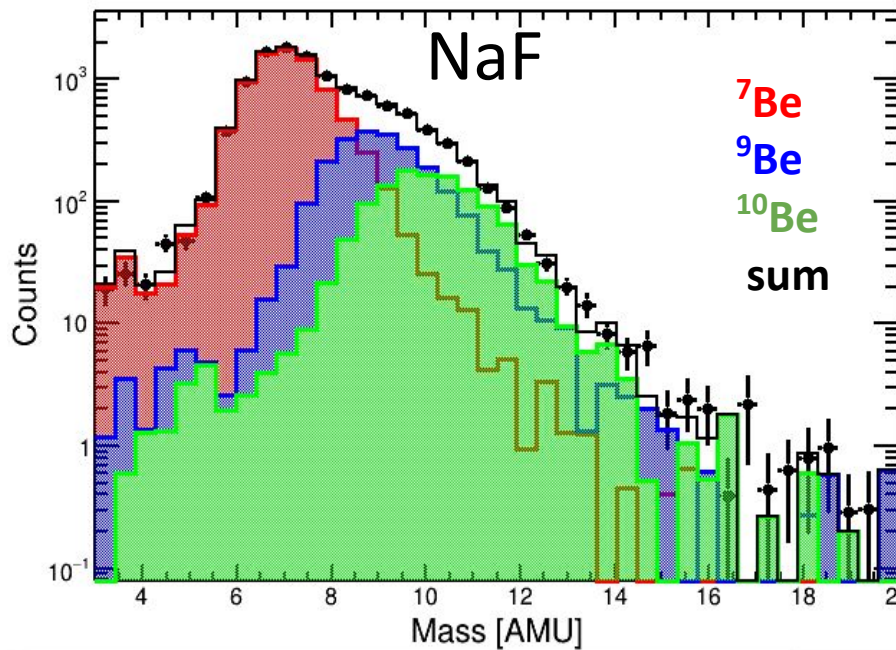
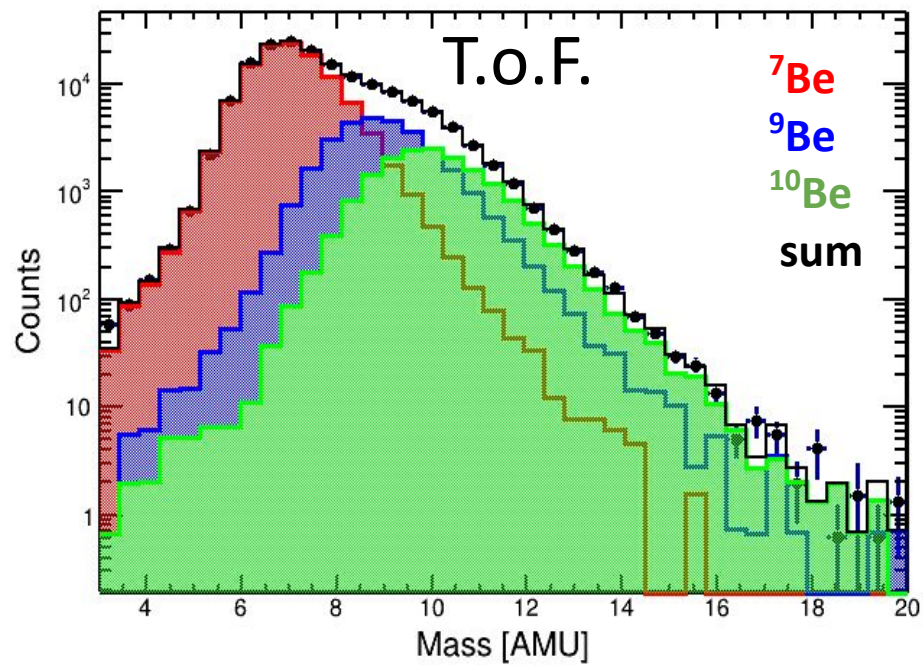
RICH



preliminary

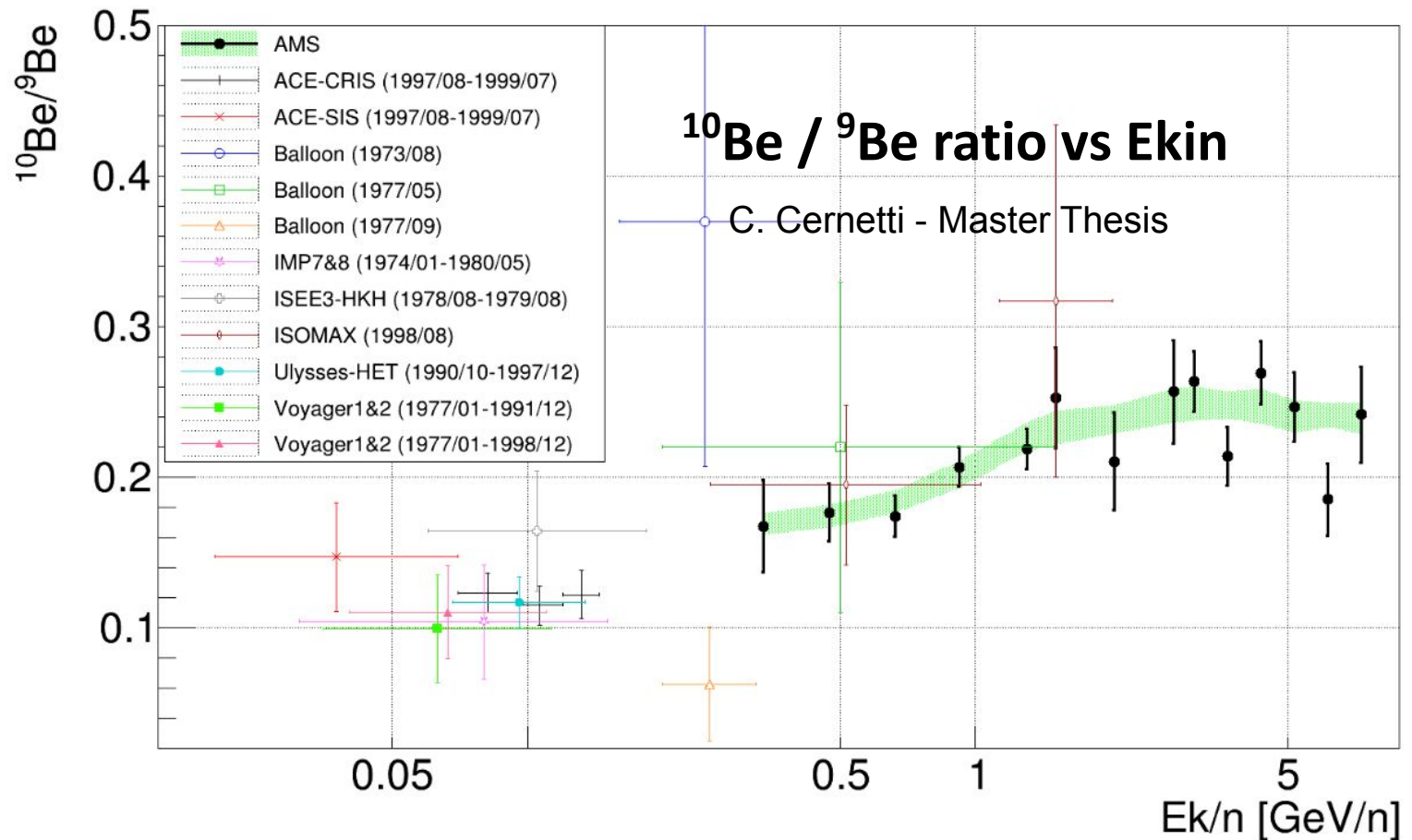
Z=4 Isotopes

- Cinzia Cernetti (Master Thesis)
- Abhinandan Dass (PhD Thesis)



Conclusion (1)

- General methodology for light isotopic analysis in AMS
- Time dependence of $D/{}^4\text{He}$ ratio
- Precision measurement of ${}^{10}\text{Be} / {}^9\text{Be}$



Conclusion (2)

- General methodology for light isotopic analysis in AMS
- Time dependence of D/⁴He ratio
- Precision measurement of ¹⁰Be / ⁹Be

D/⁴He Time dependence

