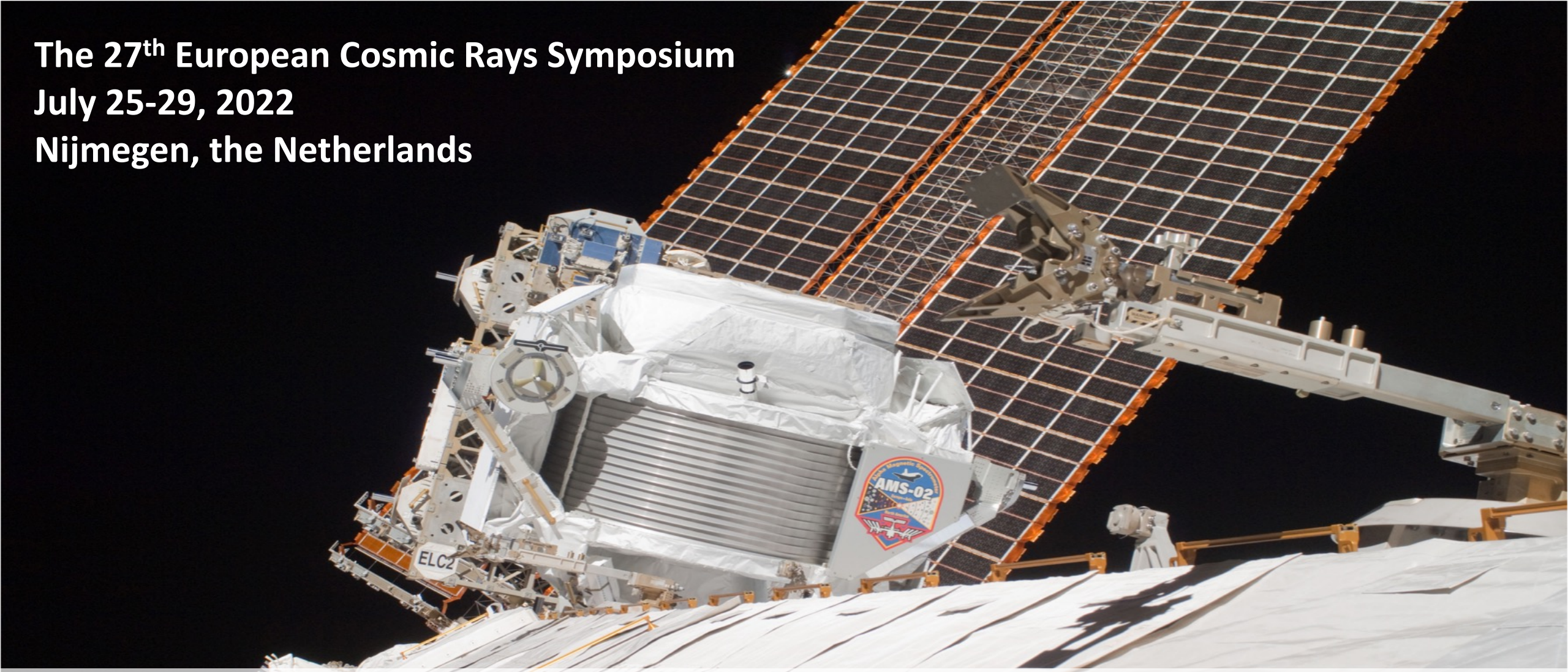
The 27th European Cosmic Rays Symposium
July 25-29, 2022
Nijmegen, the Netherlands



Properties of Cosmic Deuterons and ^{3}He

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on behalf of the AMS Collaboration

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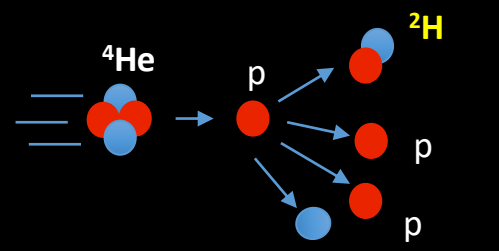
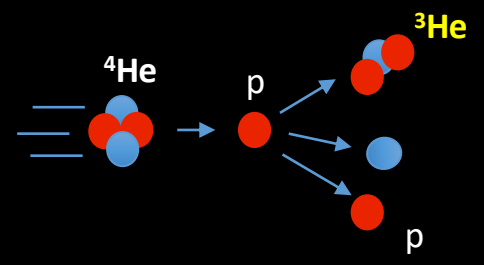
Deuterium and Helium Isotopes in Cosmic Rays

Precise measurements of primaries and secondary elemental fluxes by AMS
→ important information to understand the origin and the propagation of Cosmic Rays

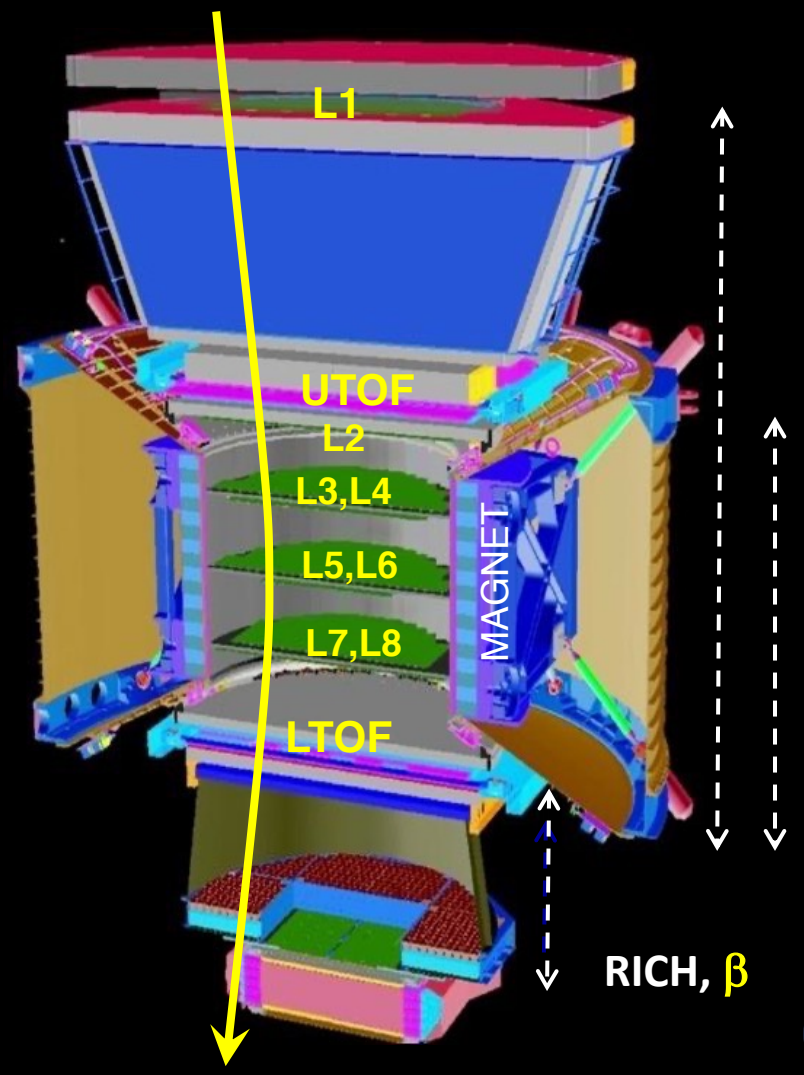
More detailed insight from isotopic composition (see F. Dimiccoli: Be isotopes).

- Helium nuclei are the second most abundant nuclei in cosmic rays.
- **^{2}H** and **^{3}He** are mostly produced by the fragmentation of **^{4}He:** simpler comparison with propagation models than with heavier secondary to primary nuclei ratios.
- The small cross section of He with respect to heavier nuclei, allows ^{2}H/^{4}He and ^{3}He/^{4}He to probe the properties of diffusion at larger distances than any secondary to primary ratio.
- In addition, the different A/Z ratios of ^{2}H and ^{3}He allow to disentangle kinetic energy and rigidity dependence of propagation.





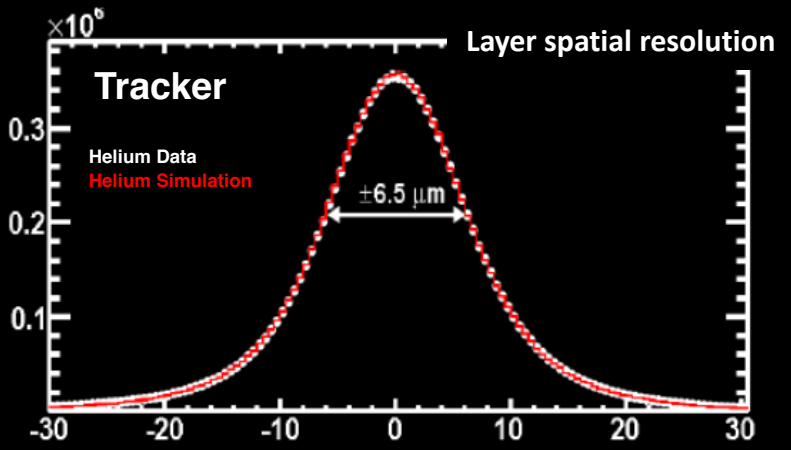
Isotopes identification in AMS

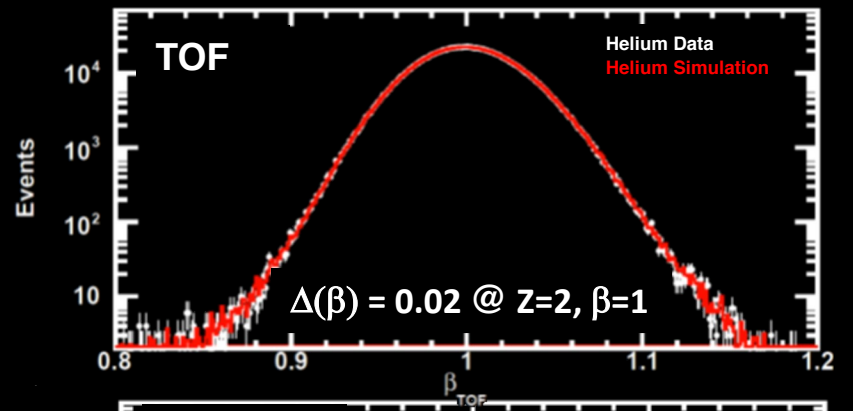


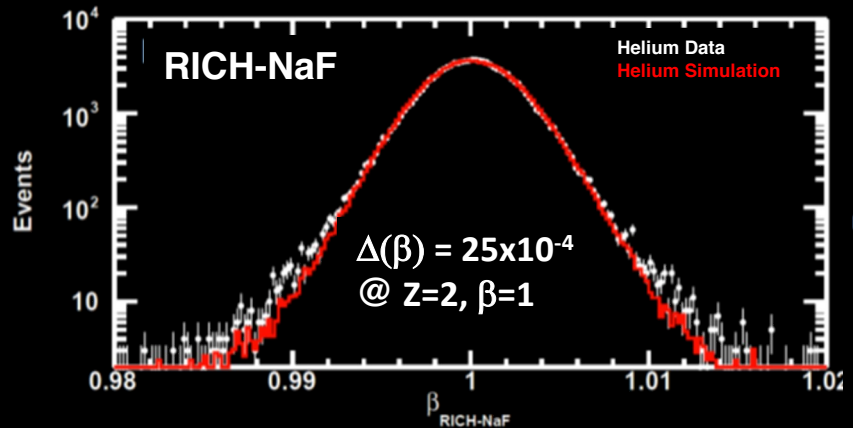
$$m = ZR / \beta\gamma$$

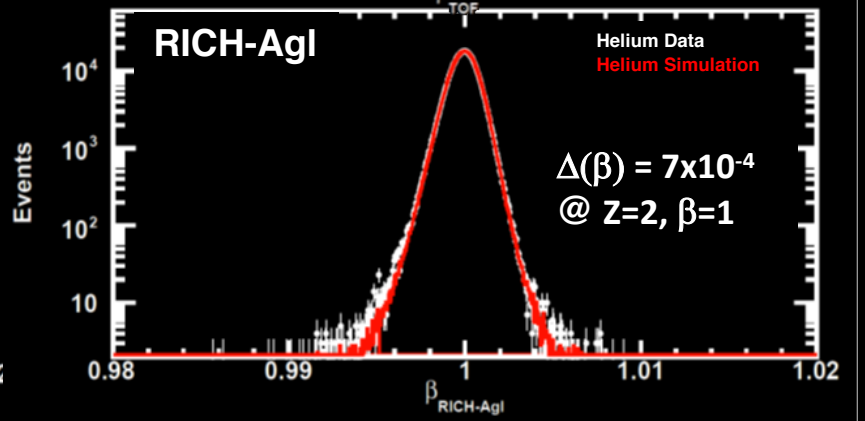
Tracker, R=*p/Z*

TOF, β









Data sample

10 Years AMS Data: from May 2011 to May 2021

Total exposure time 2.2×10^8 seconds

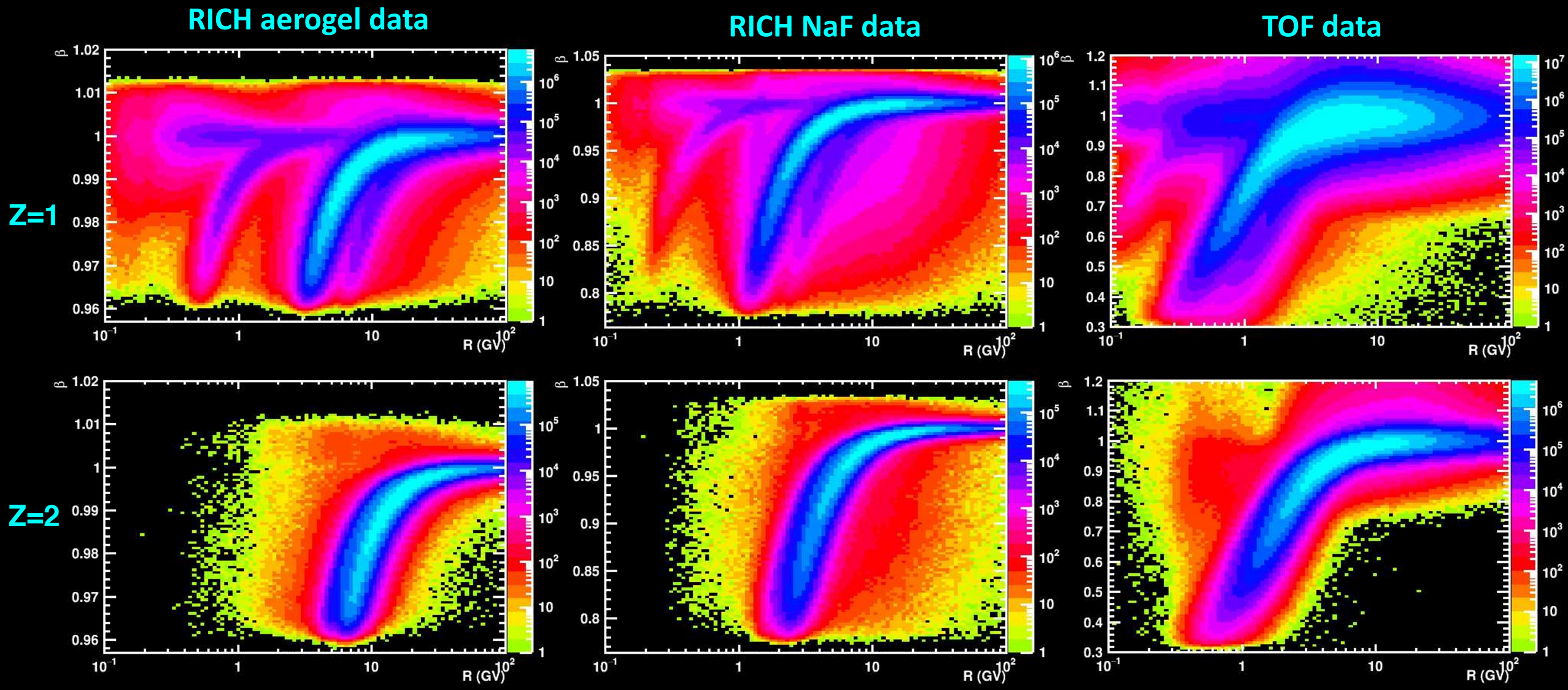
Z=1

Selected events	Above cutoff	Protons	Deuterons
$8.7\ 10^9$	$5.0\ 10^9$	$4.9\ 10^9$	$1.0\ 10^8$

Z=2

Selected events	Above cutoff	^{4}He	^{3}He
$1.2\ 10^9$	$7.2\ 10^8$	$6.5\ 10^8$	$6.9\ 10^7$

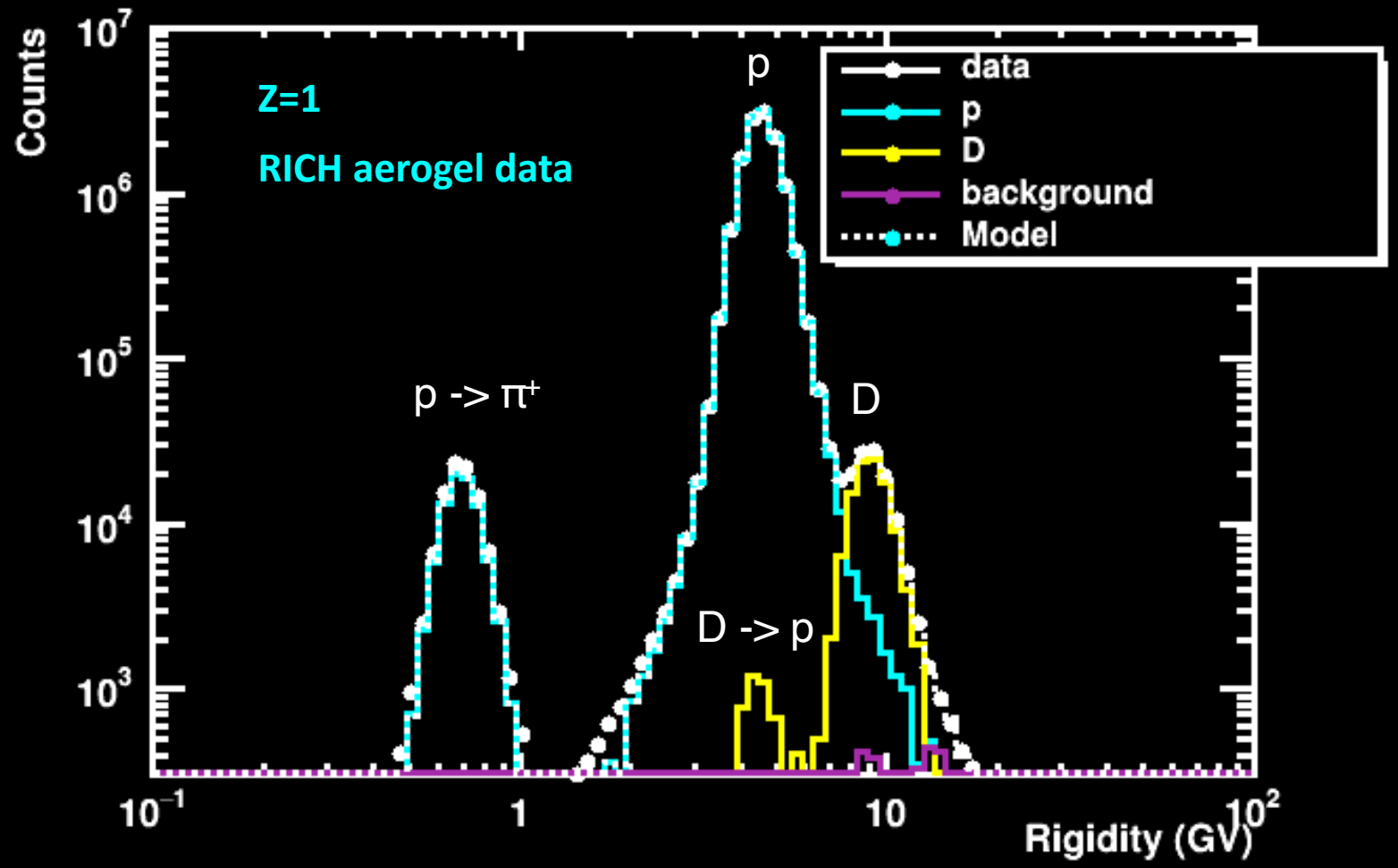
He & H Isotopes identification in AMS



H Isotopes identification in AMS
Analysis methodology

Global fit of R vs β with a common flux for each data sample

Beta ~ 0.985



He Isotopes identification in AMS
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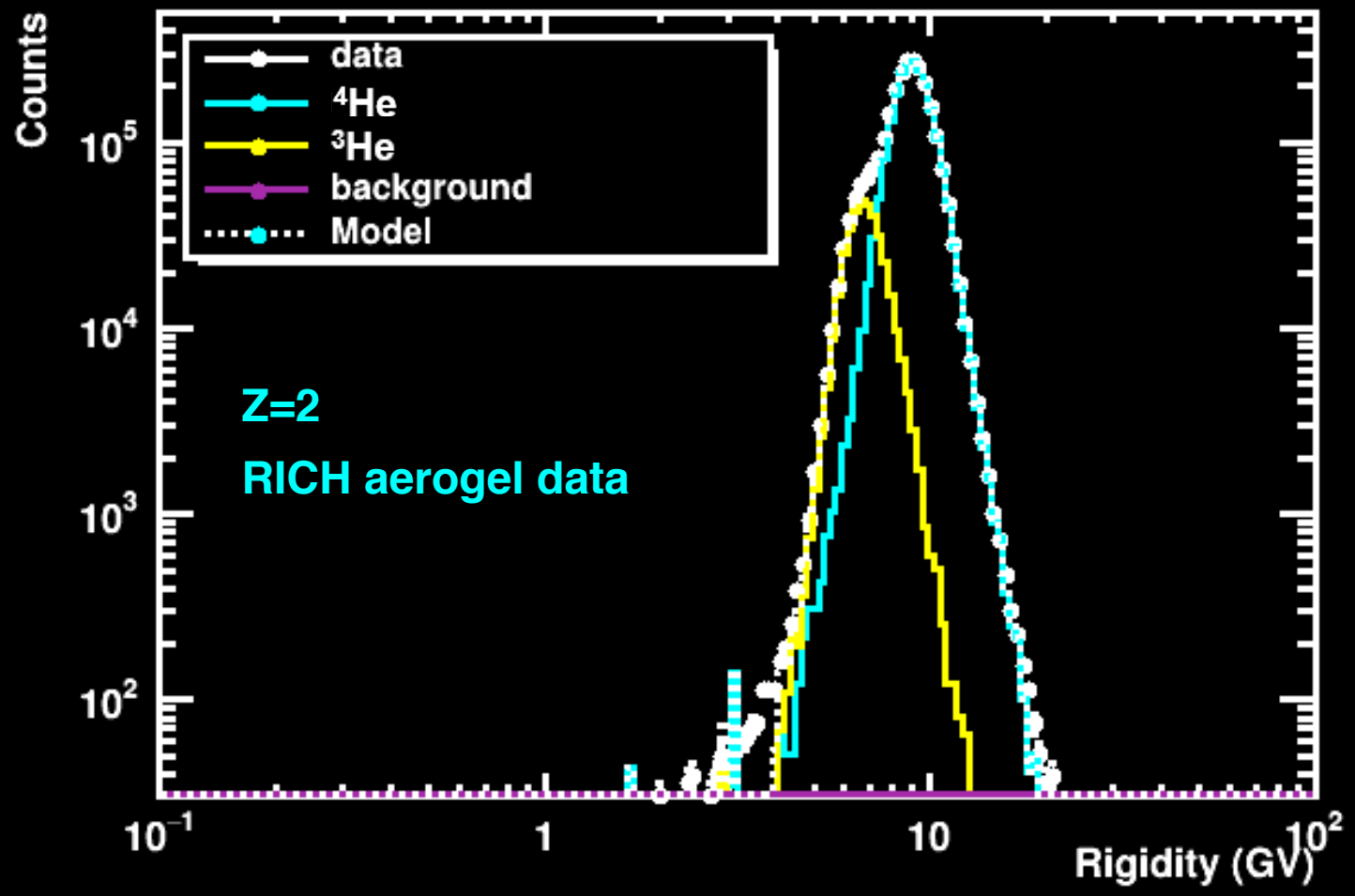


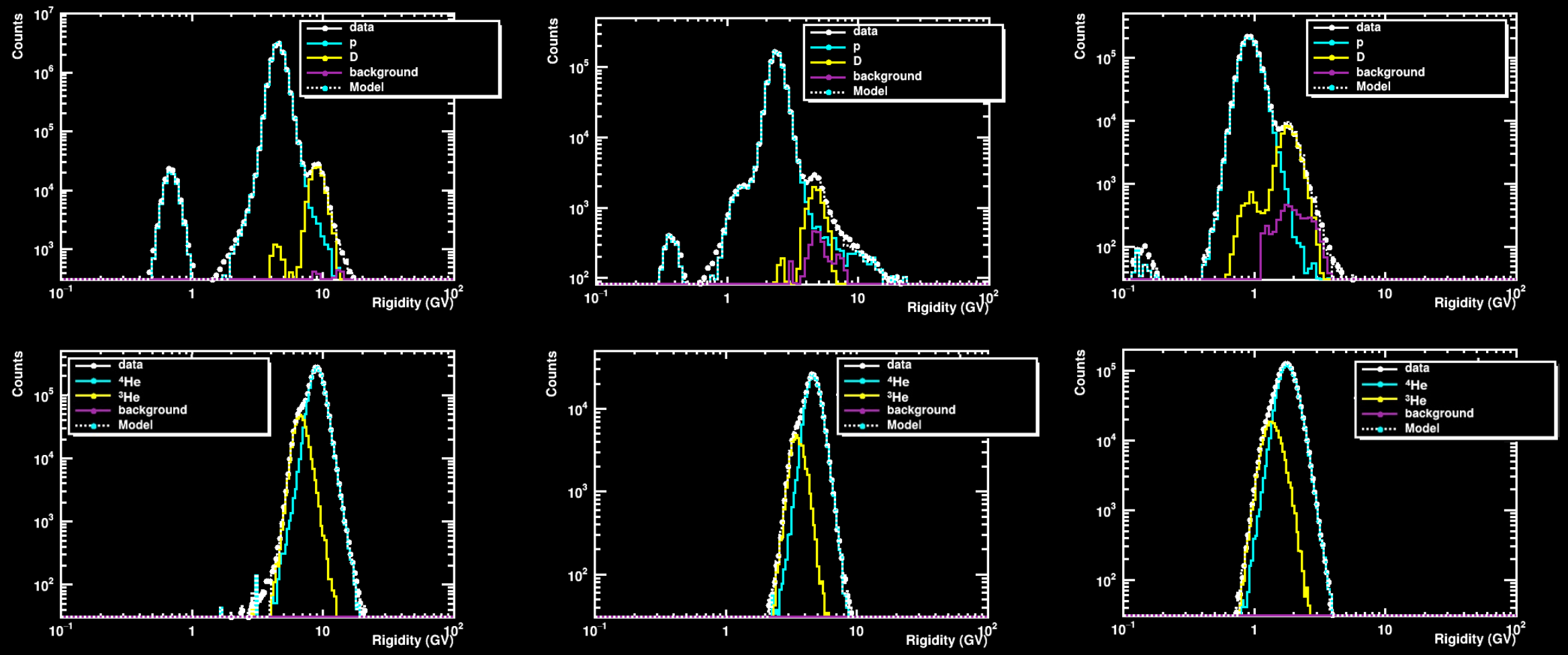
He & H Isotopes identification in AMS

Separation results

RICH aerogel data | RICH NaF data | TOF data

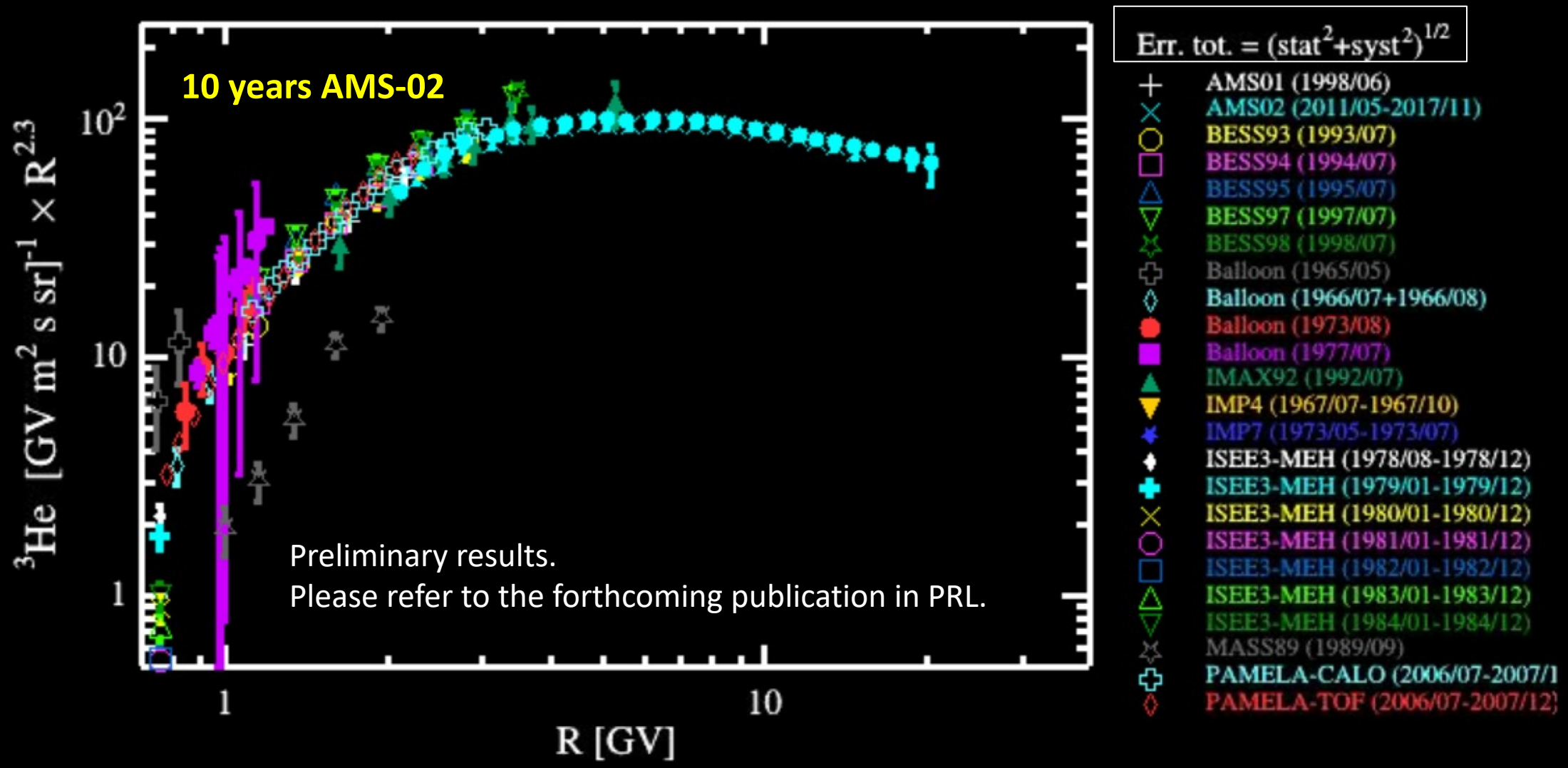
Z=1

Z=2



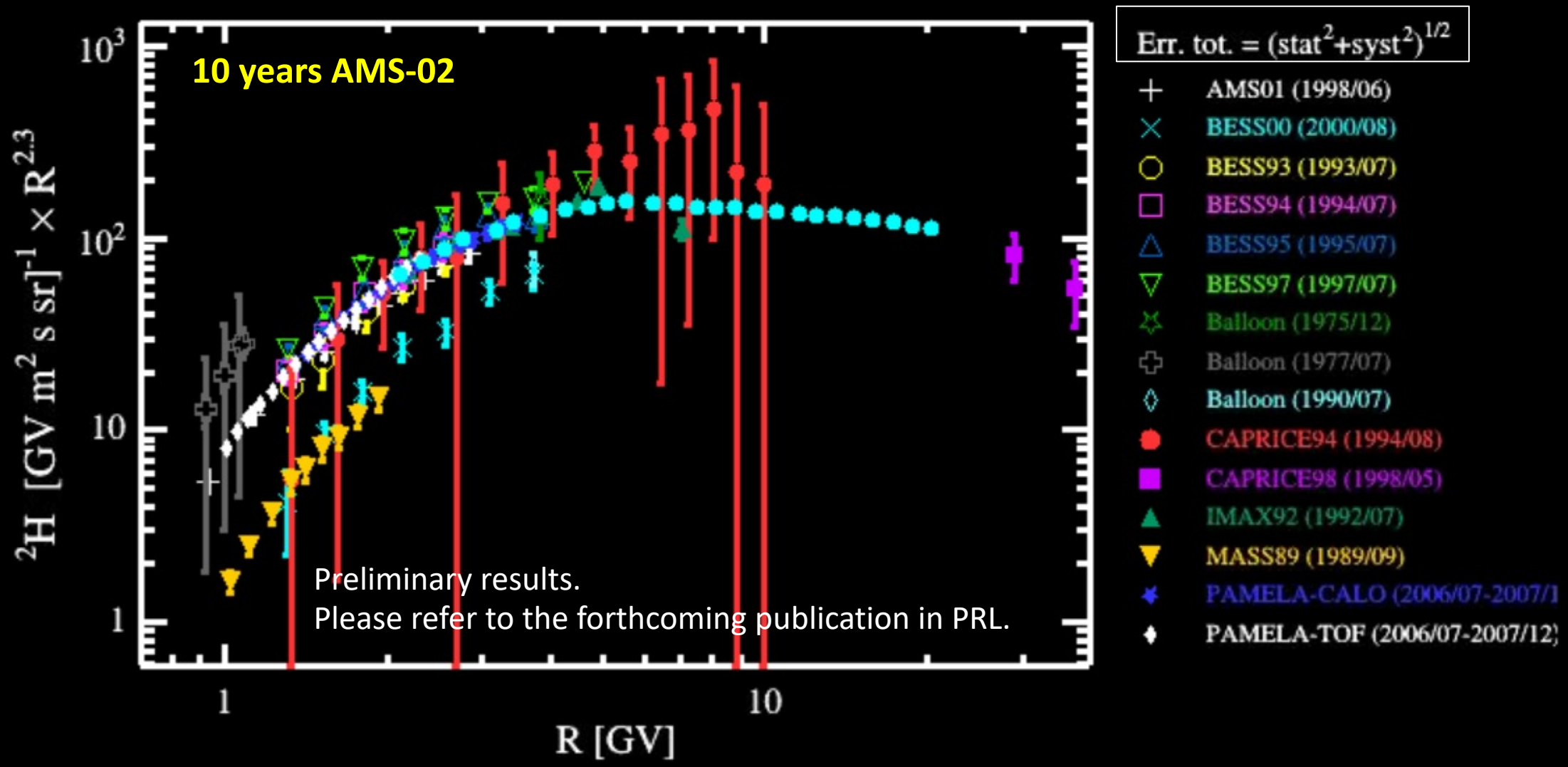
^{3}He Flux

^{3}He flux averaged in time as a function of rigidity



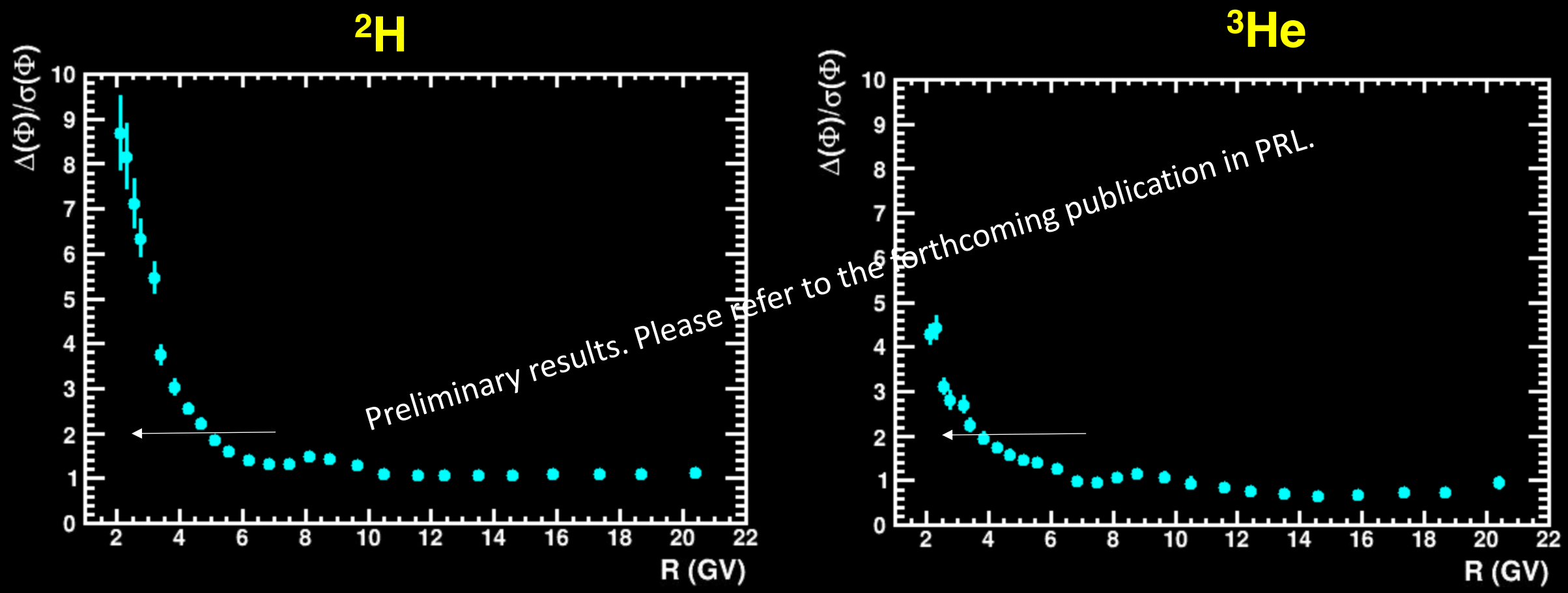
^{2}H Flux

^{2}H flux averaged in time as a function of rigidity

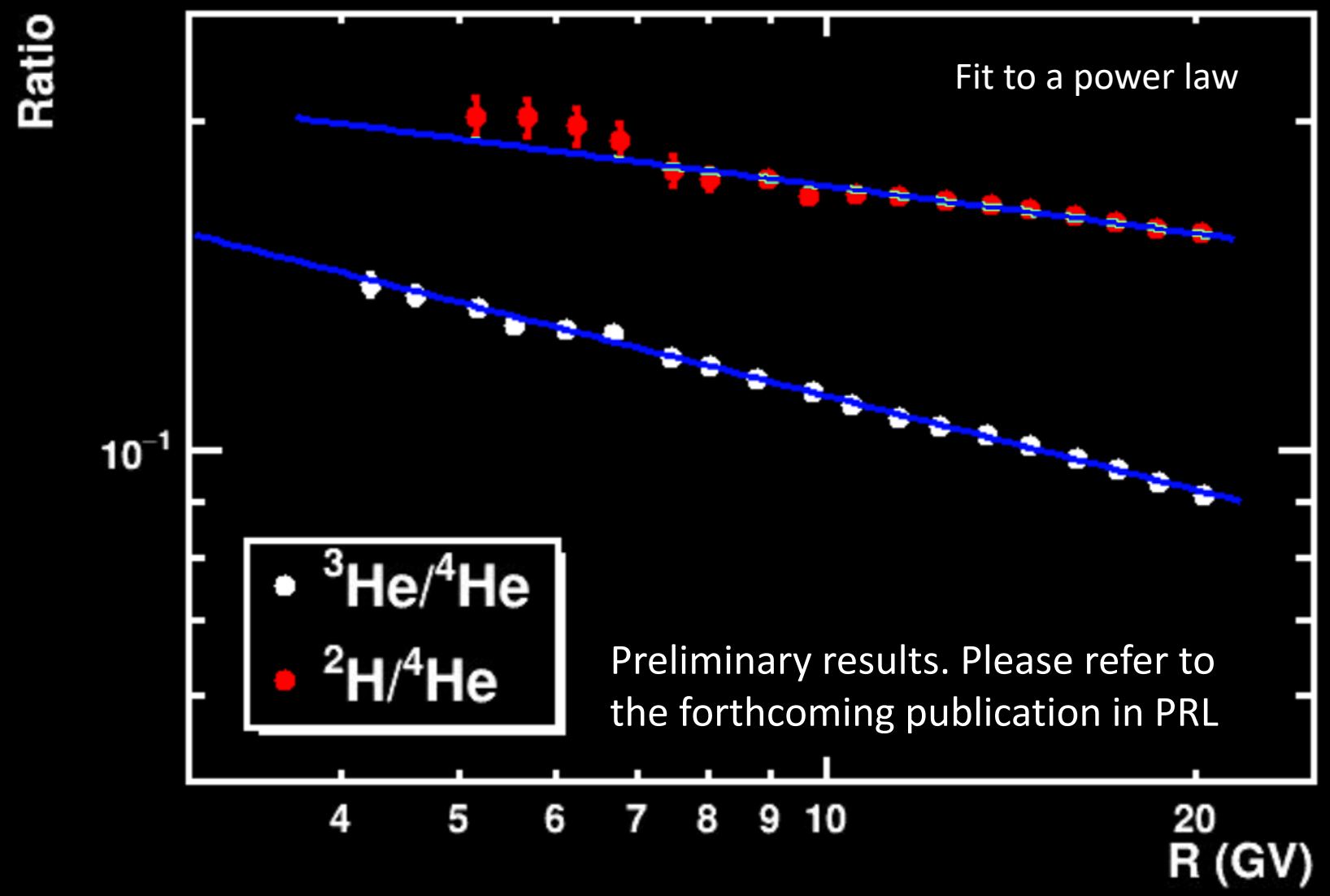


Flux temporal variation

RMS of data compared with total error.
Time variations are not compatible with systematics below ~5 GV.

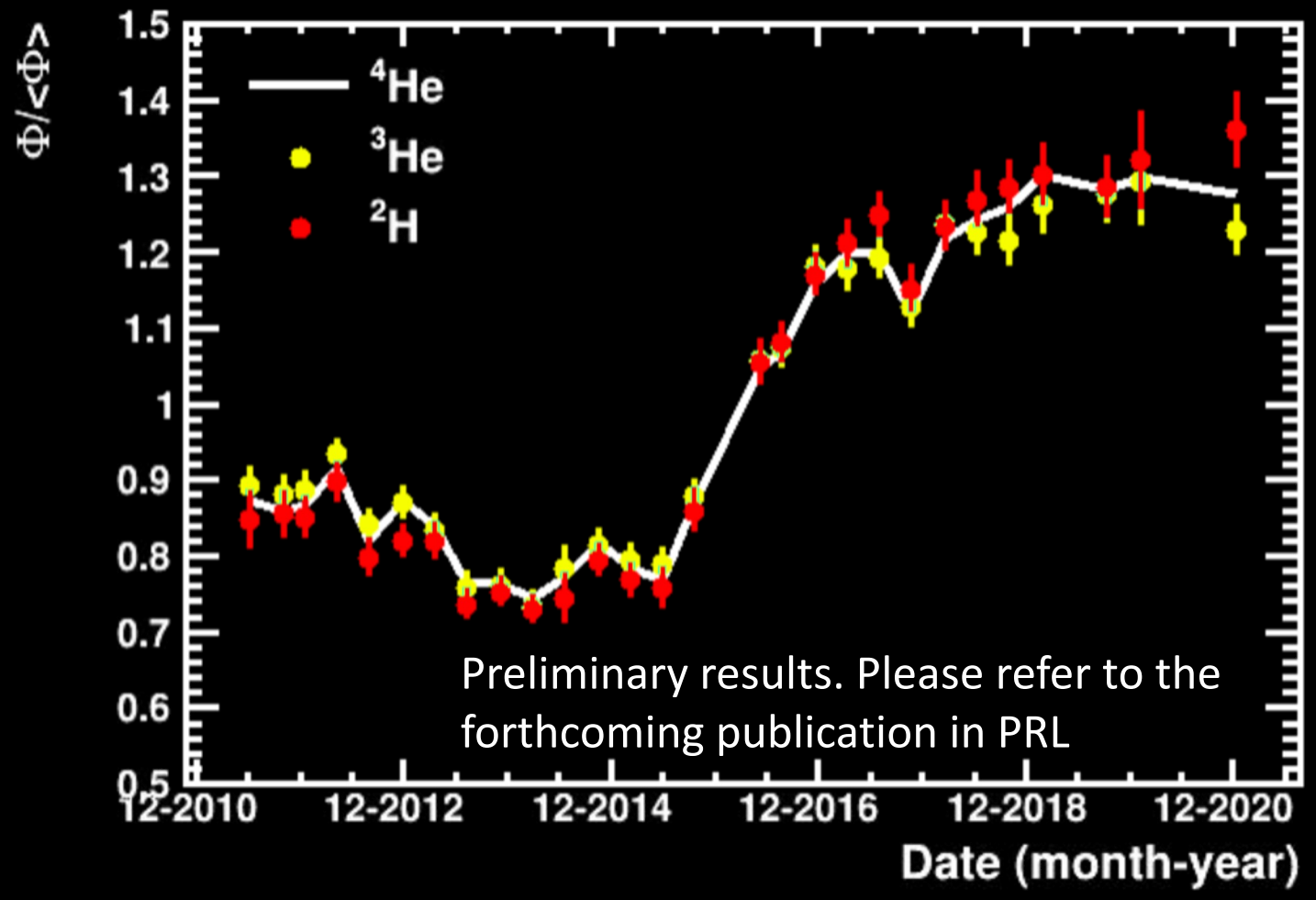


$^3He/^4He$ and $^2H/^4He$ Flux ratios



10 years AMS-02

Flux ratio: time evolution



R<5GV

Summary

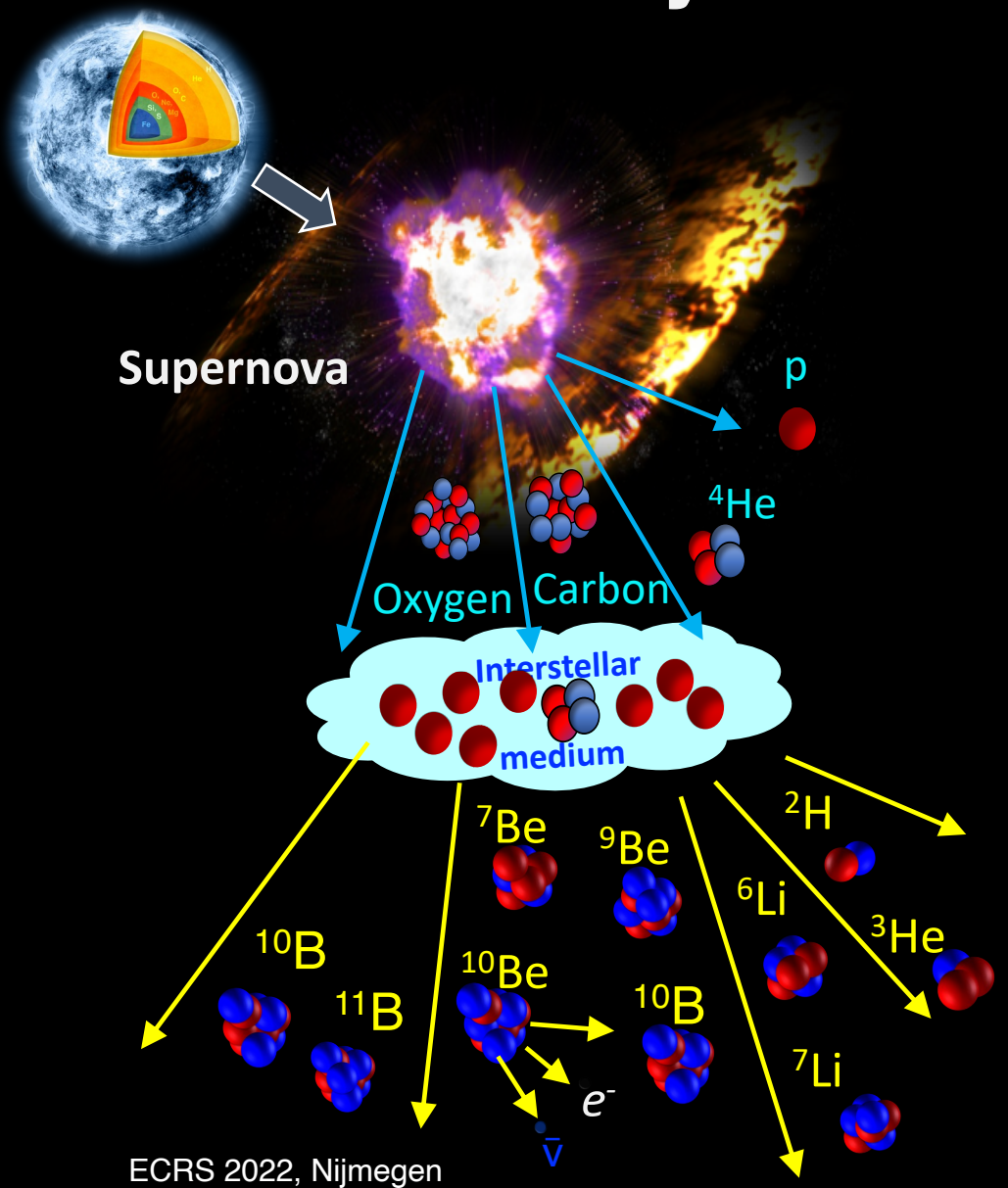
- We presented the AMS-02 measurement of the ^{3}He and ^{2}H fluxes based on 10 years data. The measurements cover the rigidity range from 2 GV to 20 GV where there was substantially no data.

- Above ~ 5 GV the $^{3}He/^{4}He$ and $^{2}H/^{4}He$ flux ratios are time independent and their rigidity dependences are well described by single power laws. The spectral indexes seem to be different for the two species.

- The AMS-02 large acceptance allow for study of the flux variability with time. Below ~ 5 GV we can observe time evolution in ^{3}He and ^{2}H fluxes which are qualitatively similar to those of ^{4}He. However, the relative amplitudes among the two species are slighly different.

Thank you!

Primary and secondary Cosmic Rays

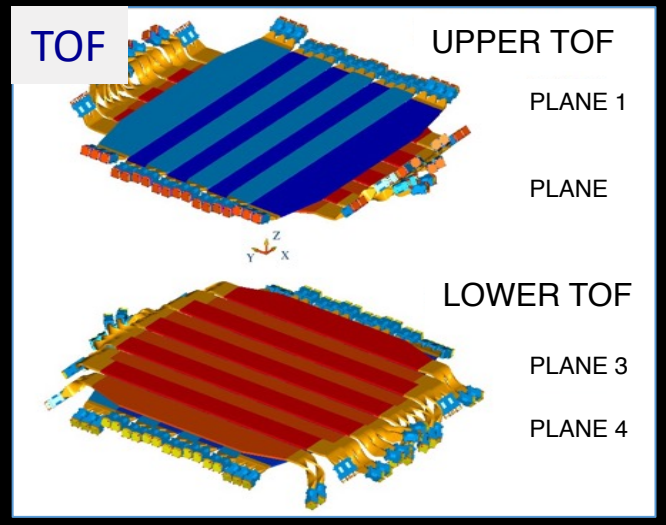


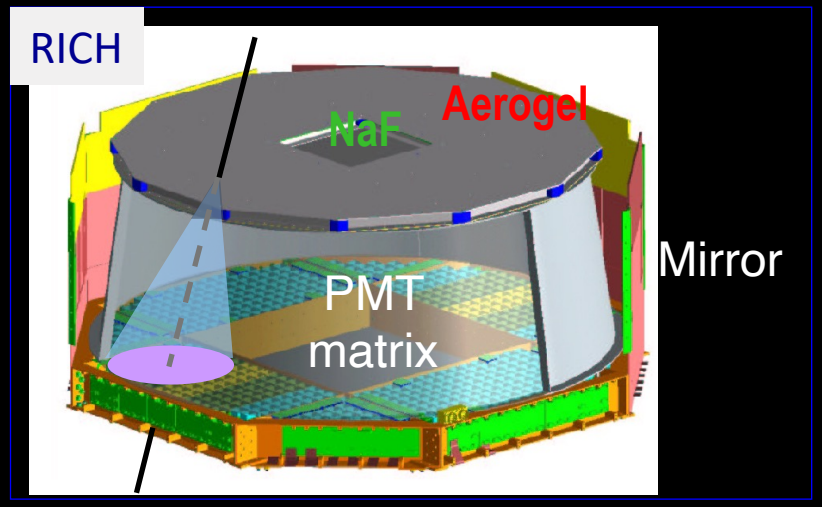
Primary cosmic rays (p, He, C, O, ...) are mostly produced during the lifetime of stars and are accelerated in supernovae shocks.

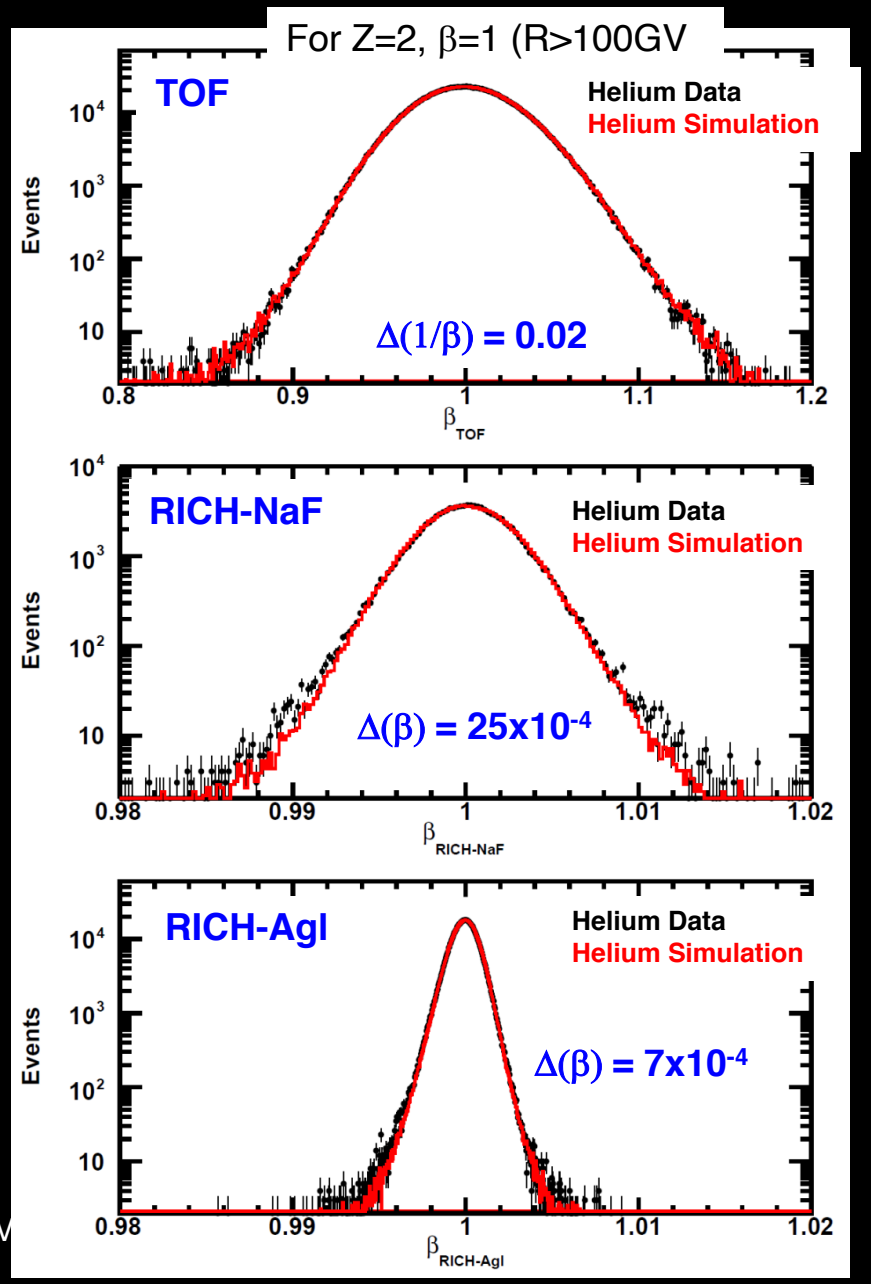
Secondary cosmic nuclei (^{2}H, ^{3}He, Li, Be, B, ..) are produced by the collision of primary cosmic rays and the interstellar medium.

He isotopes identification with AMS

β Measurement: TOF, RICH







Light Isotope separation with Templates

Three concurrent analysis approaches

Templates Based

INFN-TIFPA (Trento - ITA)

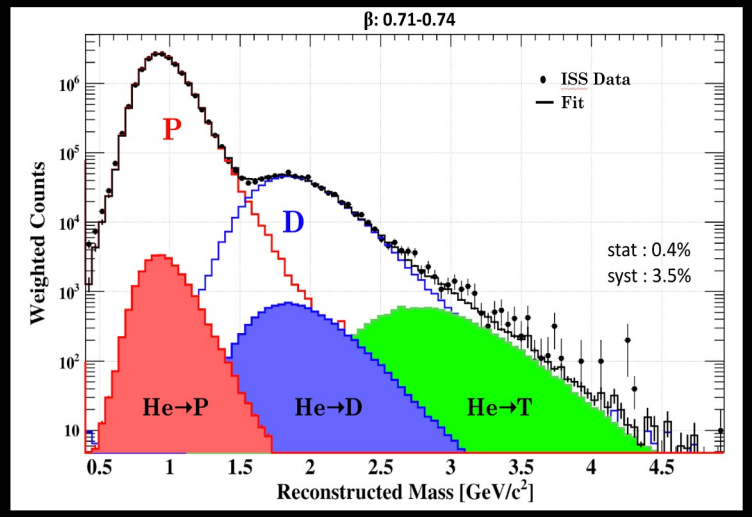
UNIV. OF HAWAI'I (USA)

2D Unfolding

CIEMAT (Madrid - Spain)

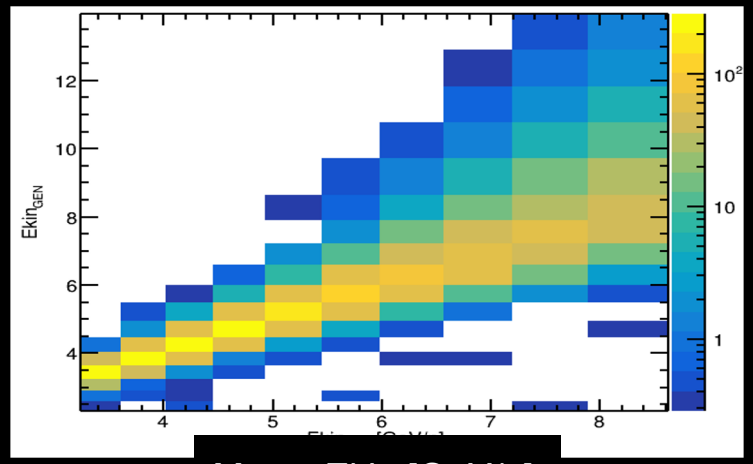
Mass Template Fit

- Templates from MC sim.
- Fine tuning of β resp. function
- Time dependence of templates
- p and Ds from CR
- T from He internal fragmentation ->
  - constraints to He->p and He->D



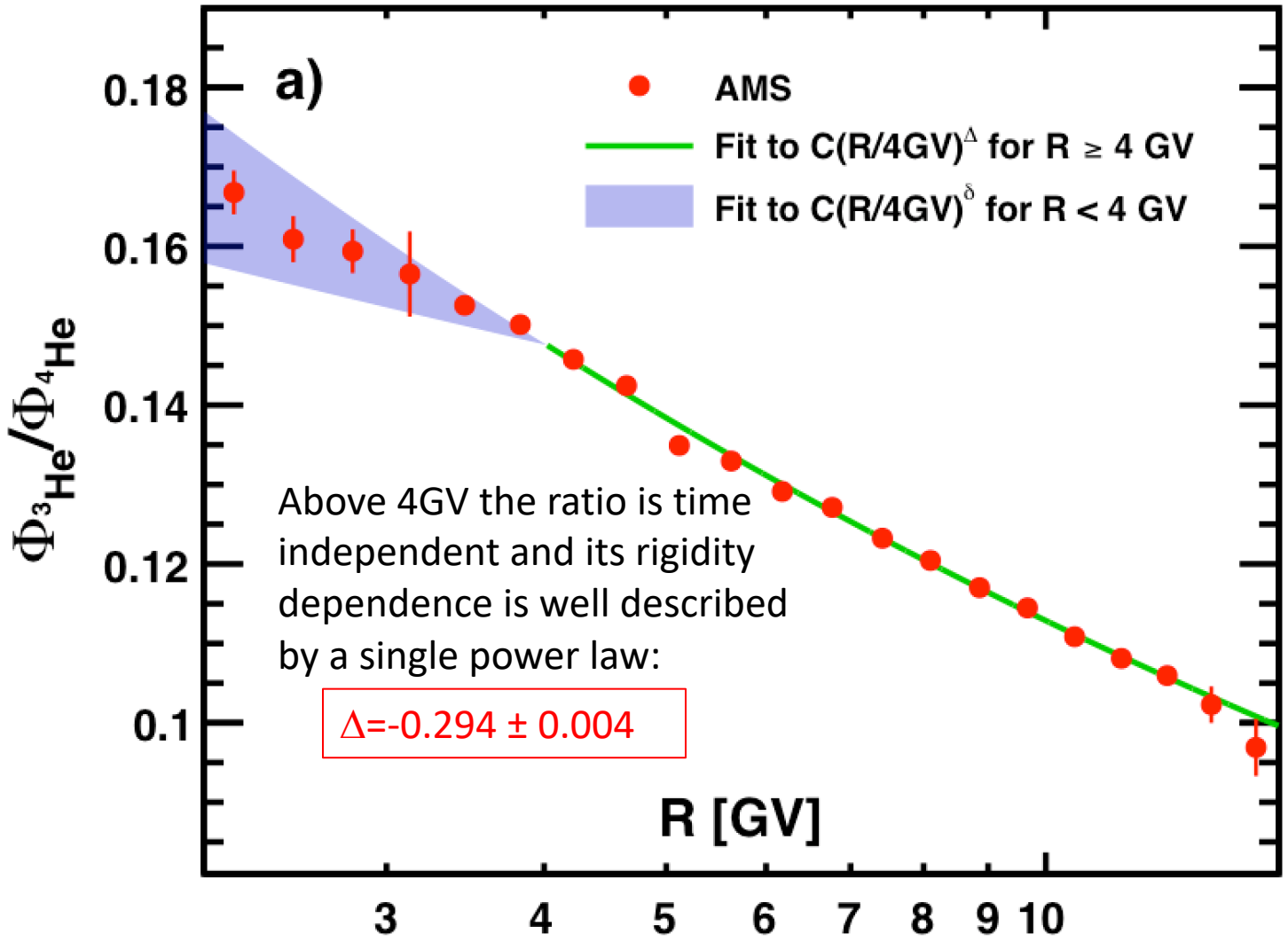
Flux Unfolding

- D'Agostini iterative unfolding method
- Migration matrix from tuned MC sim.
- Applied independently for each sub-detector



Helium Isotopes ratio vs R

The time-averaged $^3He/^4He$ flux ratio as function of rigidity [2.1-15GV]

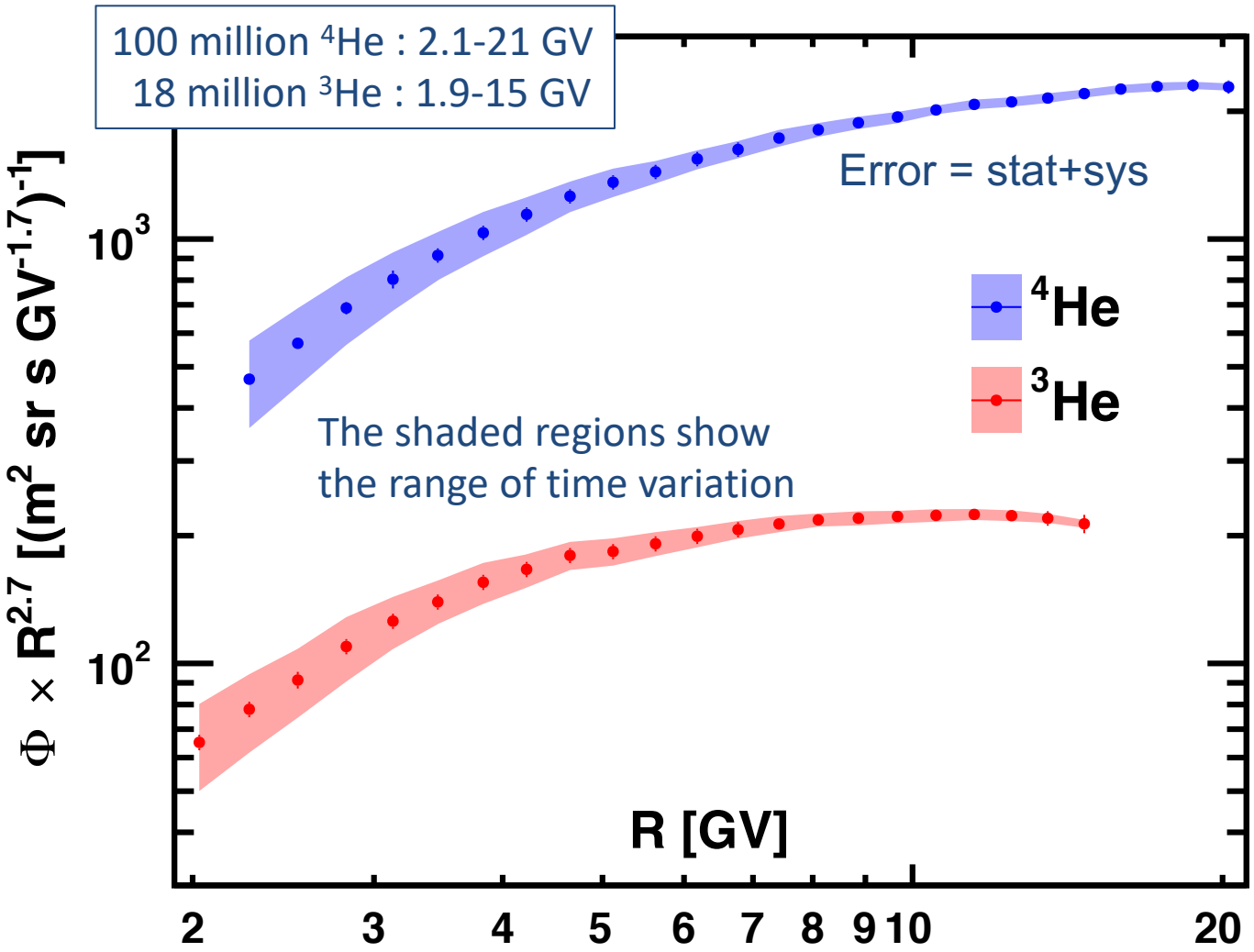


Above 4GV the ratio is time independent and its rigidity dependence is well described by a single power law:

Δ=-0.294 ± 0.004

Helium Isotopes Flux vs R

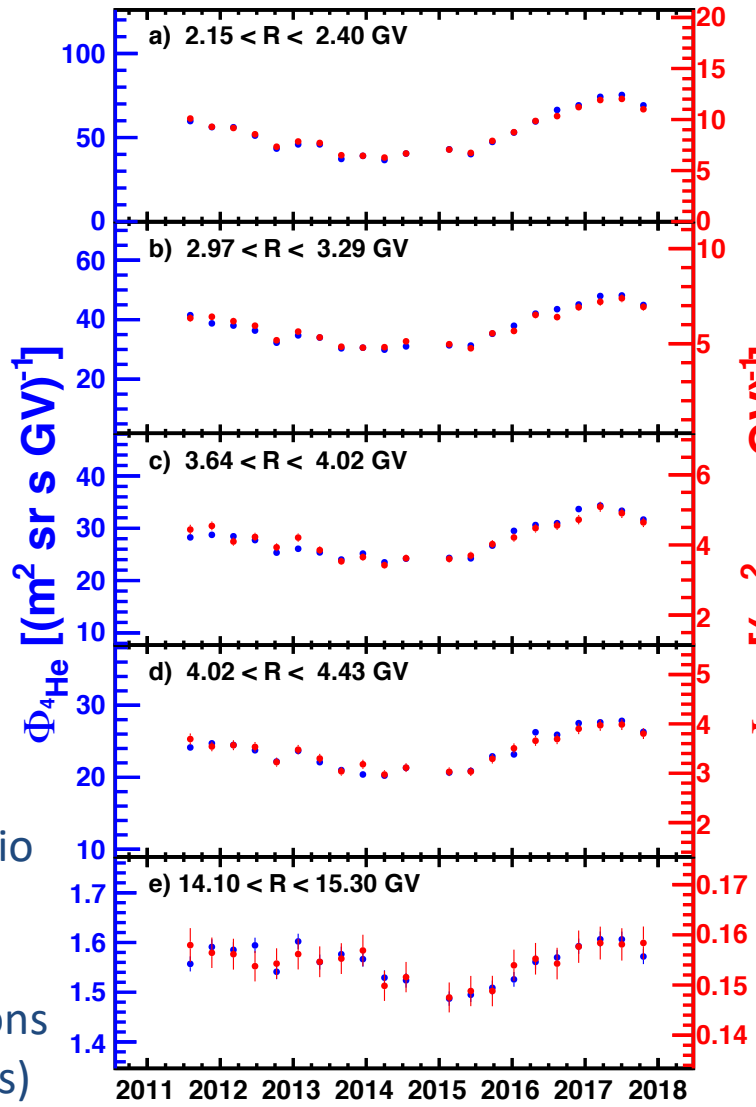
The ^{3}He and ^{4}He fluxes averaged in time as function of rigidity

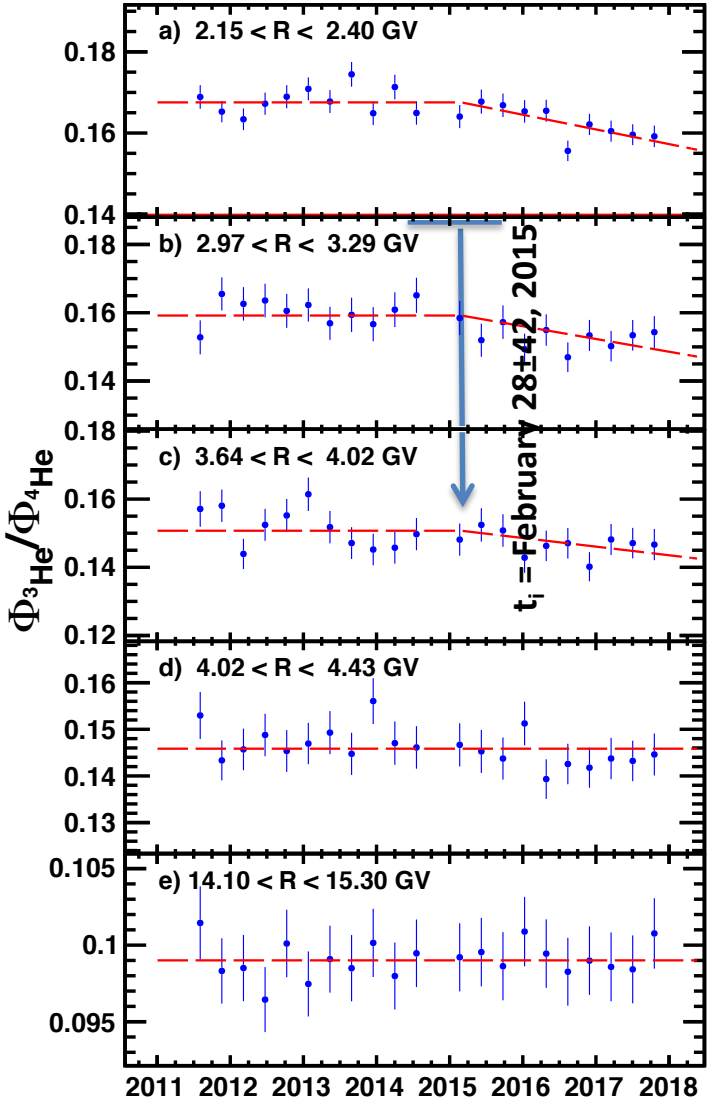


^{3}He and ^{4}He and ratio time variation

[PLR 123.181102(2019)]

Data: 6.5 yr (05/2011 to 11/2017)





Above 4GV the ratio is time independent

^{4}He and ^{3}He Fluxes and ratio vs time in 21 periods of 4 Bartels rotations each (108 days)