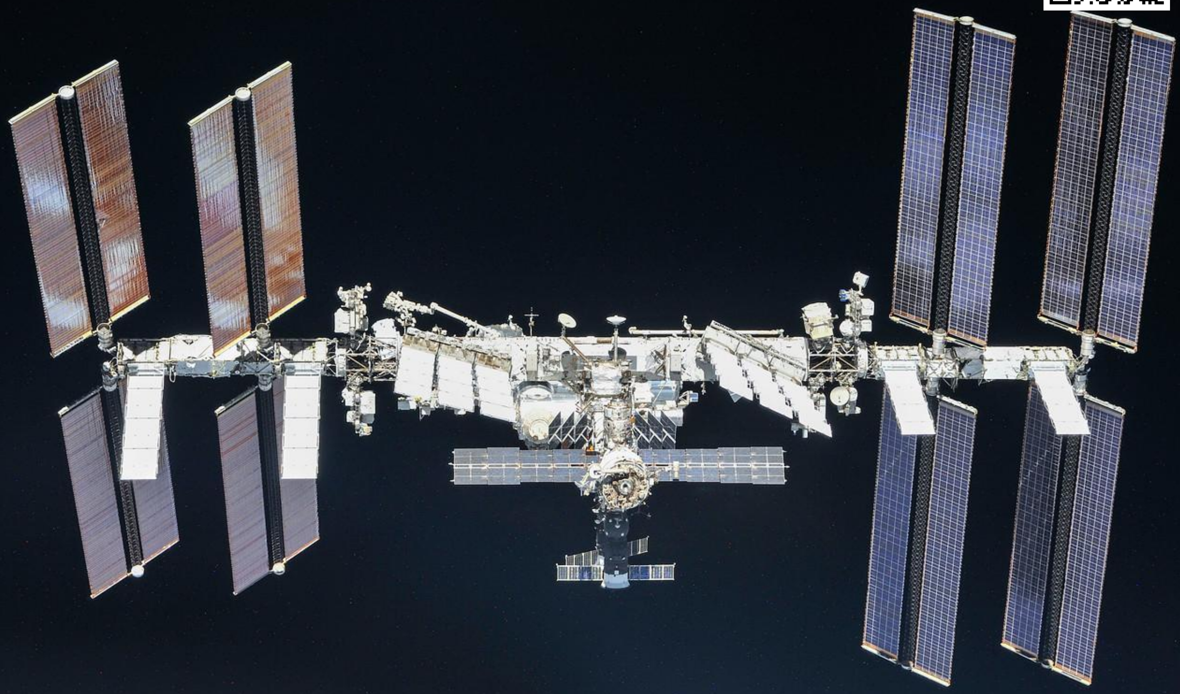
Properties of Cosmic Deuterons Measured by the Alpha Magnetic Spectrometer

Based on Phys. Rev. Lett. **132**, 261001, 2024



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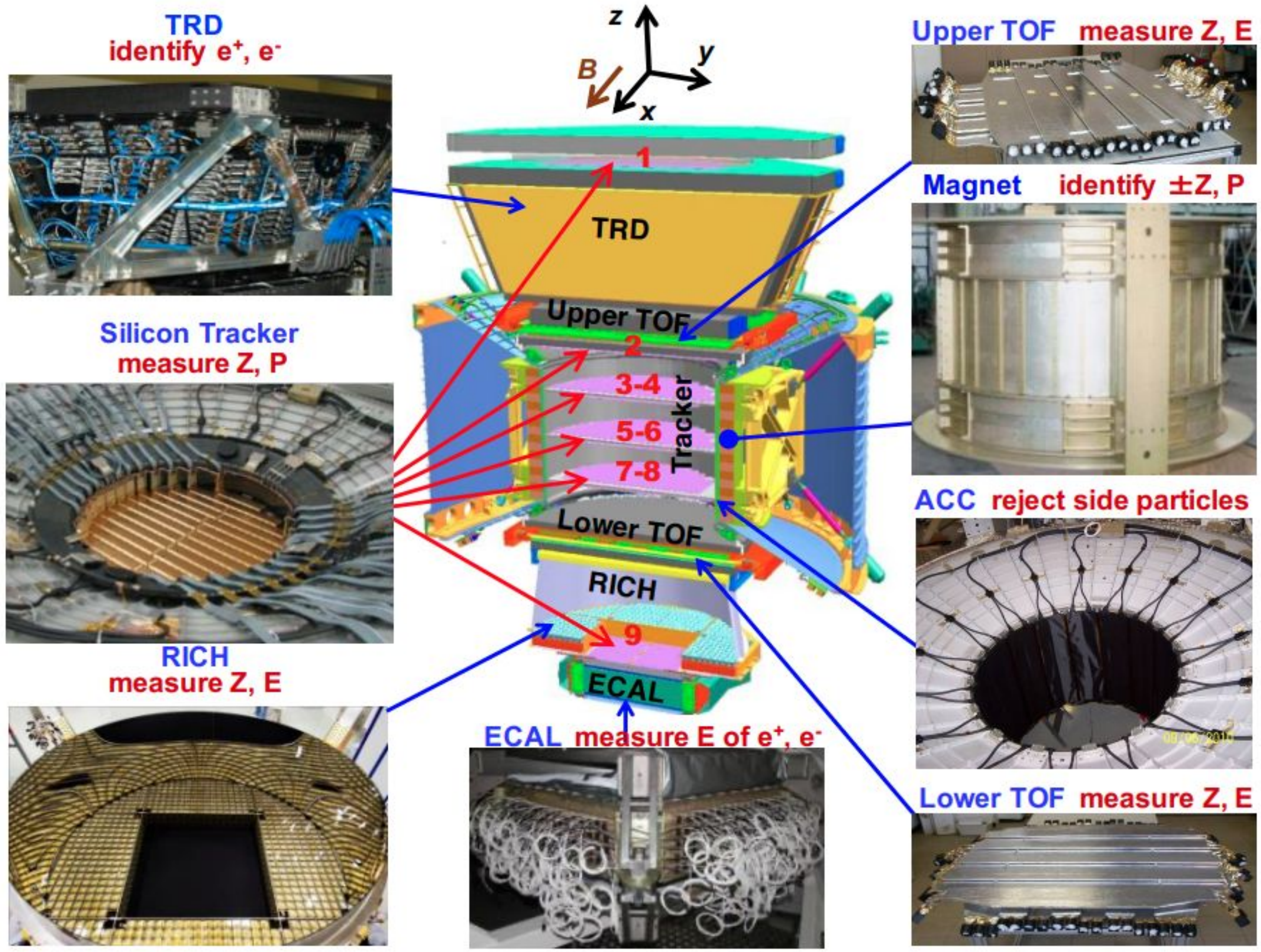
Rome International Conference on Astroparticle Physics - 24th of September 2024

The AMS-02 experiment in space

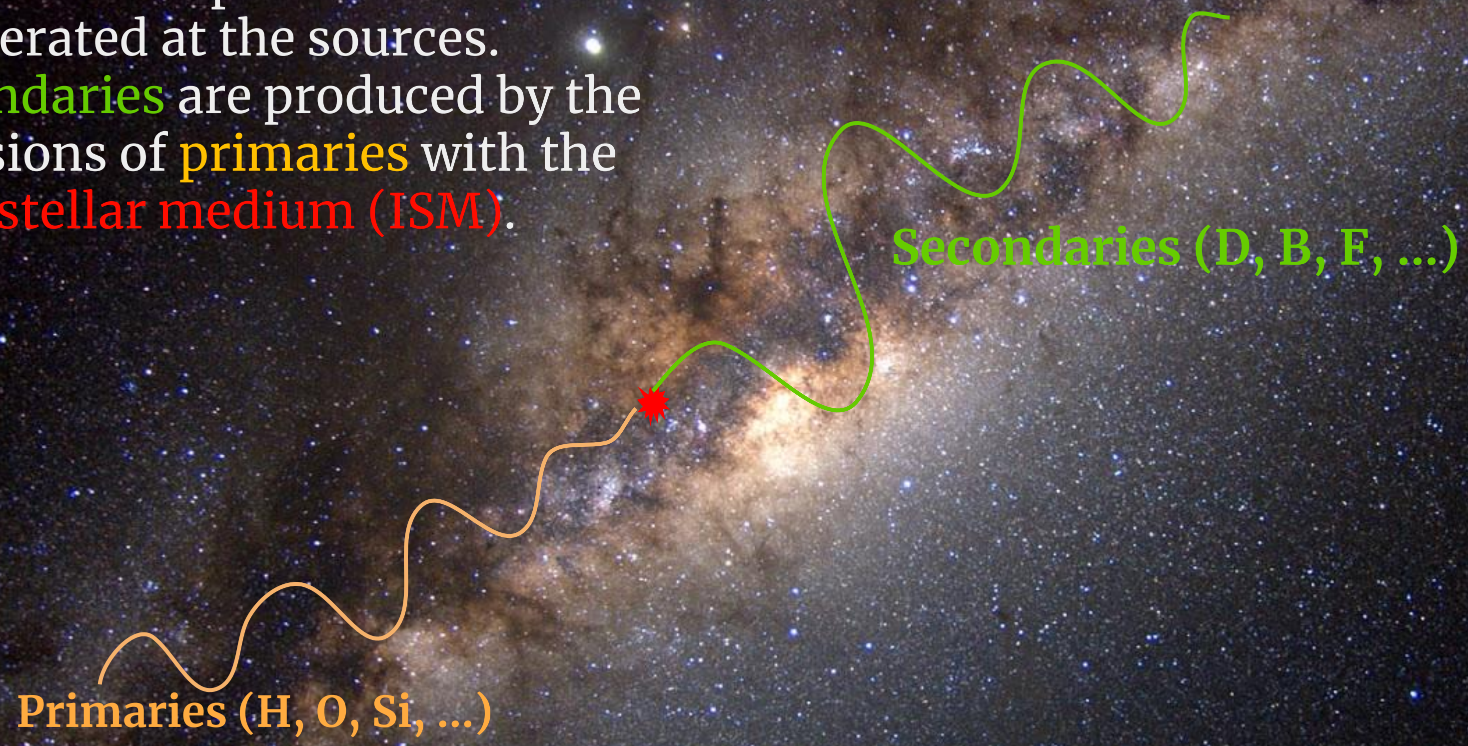
Operating on the ISS since May 2011, more than 240 billion events detected



Zhili Weng's plenary talk tomorrow

Cosmic-ray nuclei

Primaries are produced and accelerated at the sources. Secondaries are produced by the collisions of primaries with the interstellar medium (ISM).

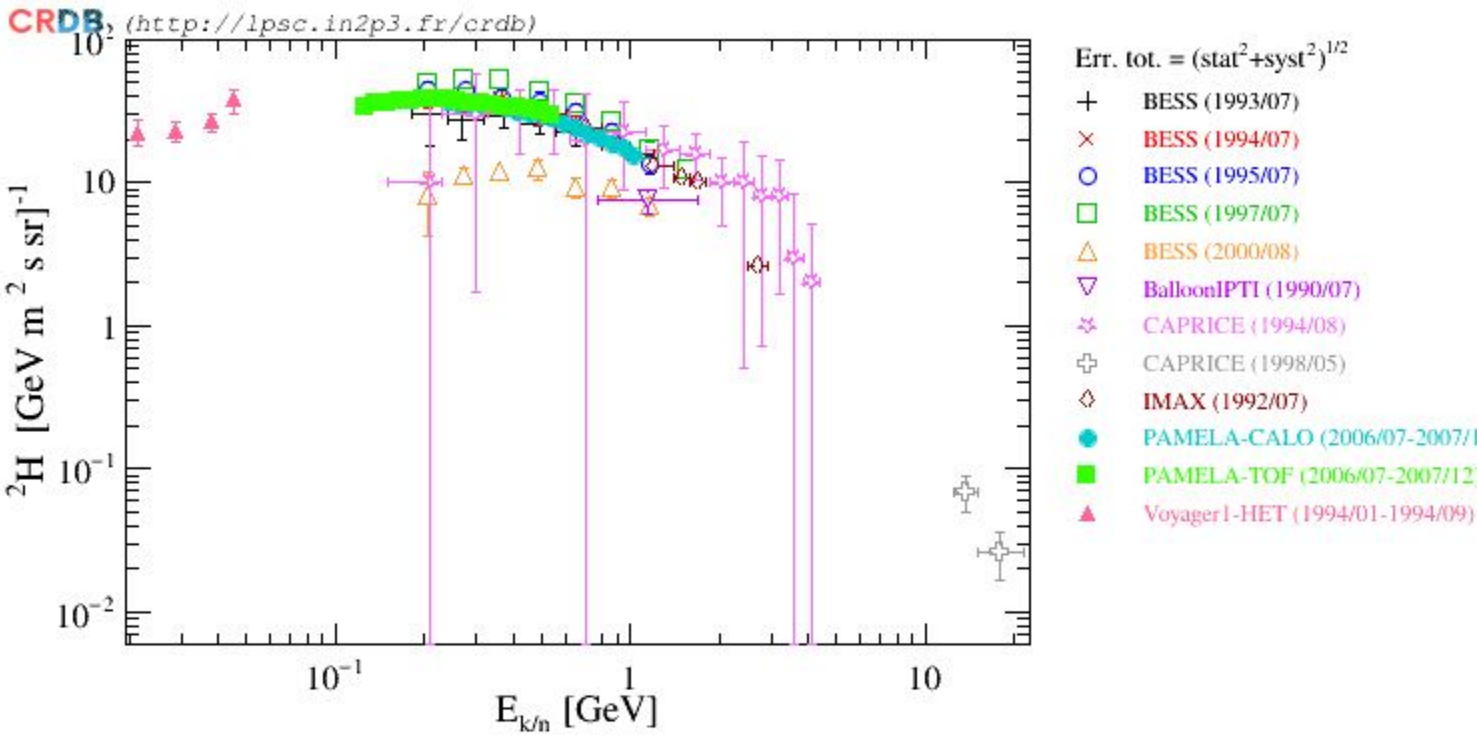


Secondary-to-primary flux ratios, such as B/C or F/Si, are key observables to constrain the propagation processes in the Galaxy.

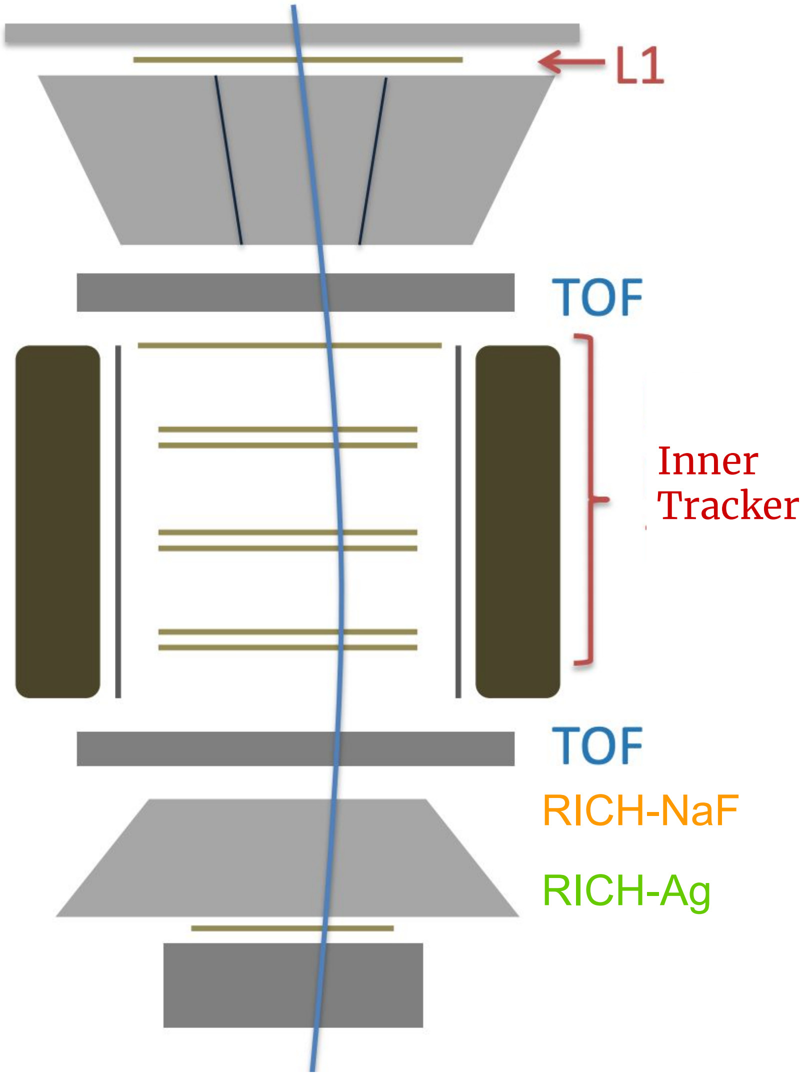
Slide E. Ferronato Bueno

Why studying cosmic-ray deuterons?

- Galactic cosmic-ray propagation is constrained using secondary-to-primary ratios, such the B/C flux ratio.
- The measurements of ^{2}H, ^{3}He and ^{4}He probe different Z/A regime, testing the universality of propagation.
- Light isotopes probe diffusion at different distances.



Isotope identification



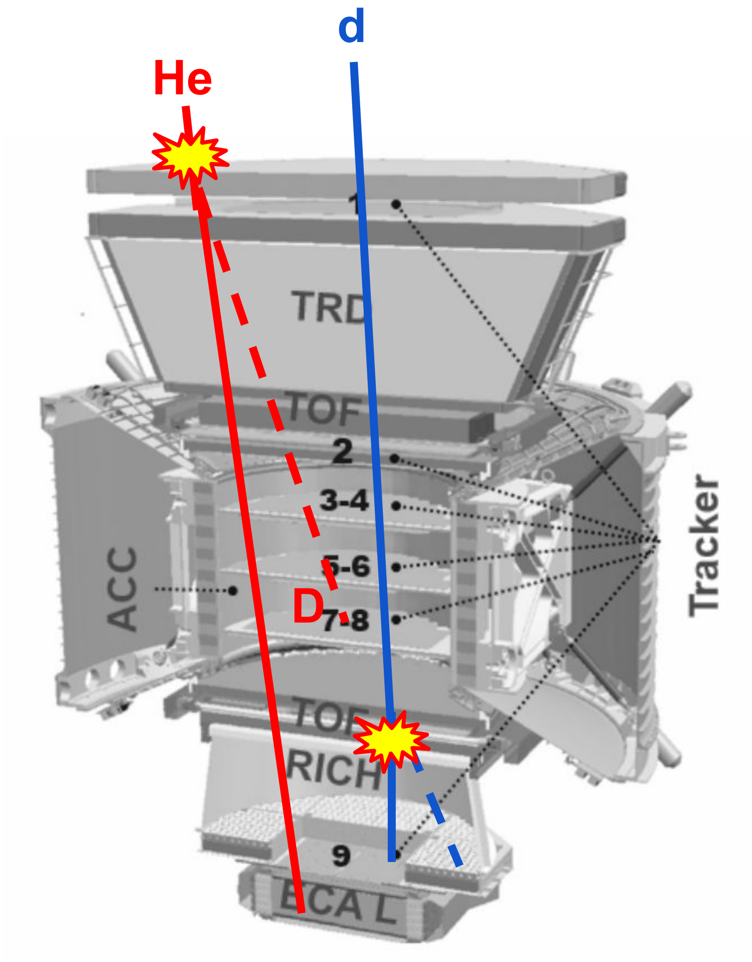
The mass is given by:

$$M = \frac{RZ\sqrt{1-\beta^2}}{\beta}$$

In this analysis:

- Charge (Z=1) **L1, TOF, Inner tracker**
- Rigidity from the inner tracker
- 3 complementary measurements of velocity (**TOF**, **RICH-NaF**, **RICH-Ag**)

Signal and Background for Z=1

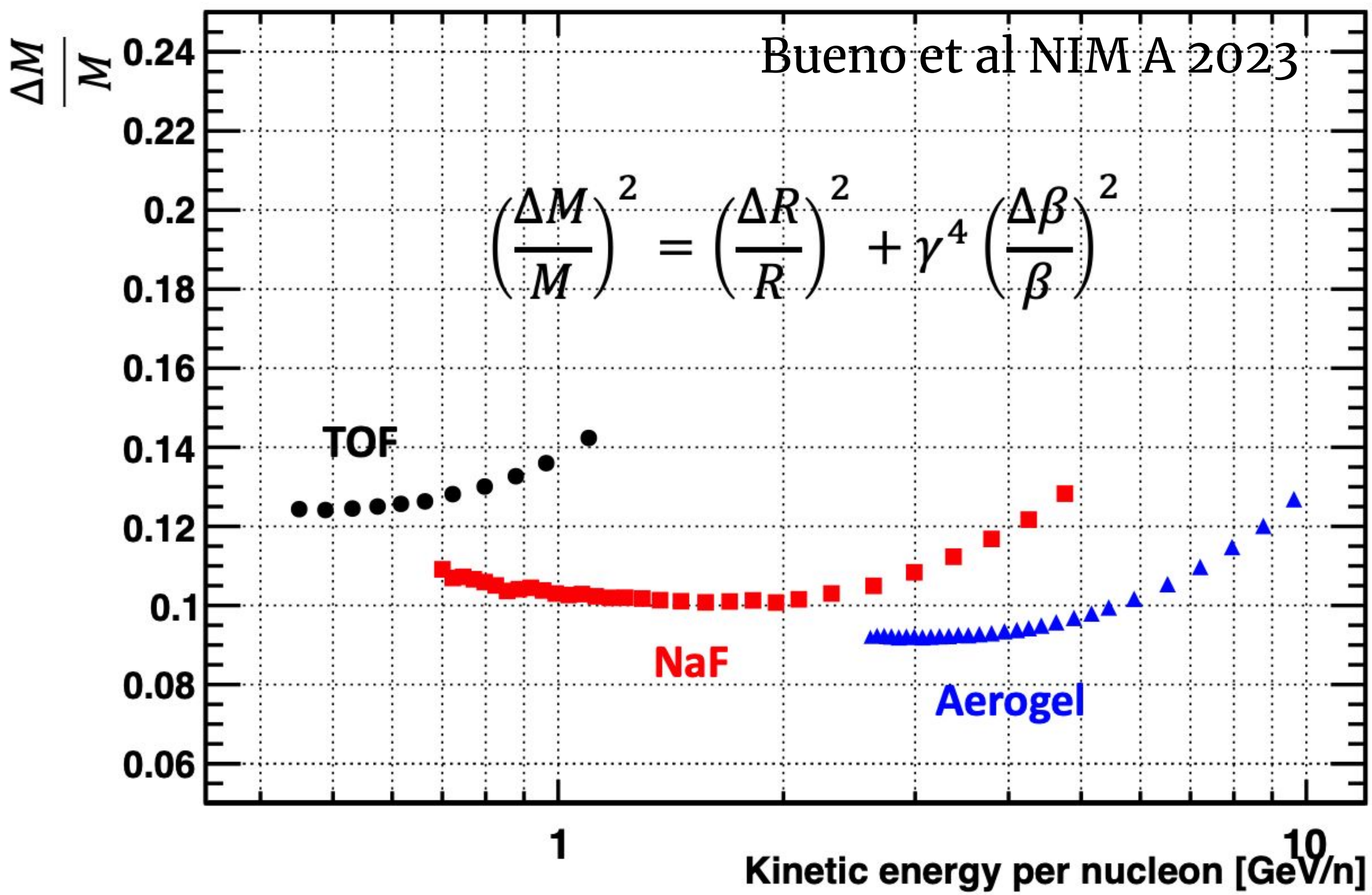


- Cosmic-ray protons
- Cosmic-ray deuterons

- Protons from deuteron fragmentation inside AMS

- Protons from helium fragmentation inside AMS
- Deuterons from helium fragmentation inside AMS
- Tritium from helium fragmentation inside AMS

Mass resolution



Deuteron flux analysis

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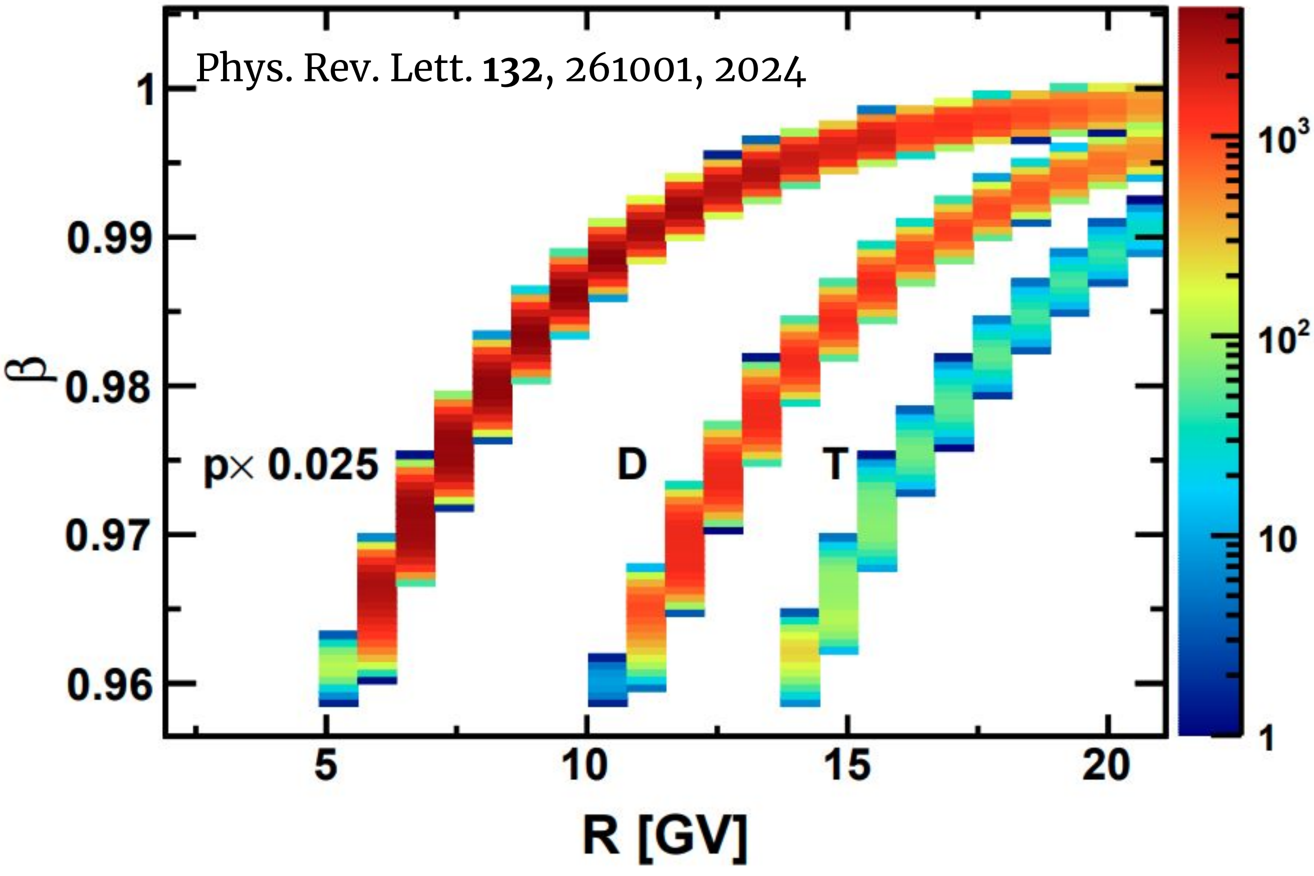
$$\Phi(R) = \frac{N(R)}{T_{exp}(R) A_{eff}(R) \epsilon(R) \Delta R}$$

- $\Phi(R)$: Absolute differential flux [$s^{-1} m^{-2} sr^{-1} GV^{-1}$]
- R: Rigidity (momentum/charge) [GV]
- N(R): Number of signal events
- $T_{exp}(R)$: Exposure time [s]: May 2011 and April 2021
- $A_{eff}(R)$: Effective acceptance [$m^{-2} sr^{-1}$]
- $\varepsilon(R)$: Trigger efficiency
- ΔR: Rigidity bin width [GV]

Signal extraction: Deuteron identification

Deuteron events in each rigidity bin are obtained by unfolding the 2D event distribution in rigidity and beta.



Signal extraction: independent cross-check

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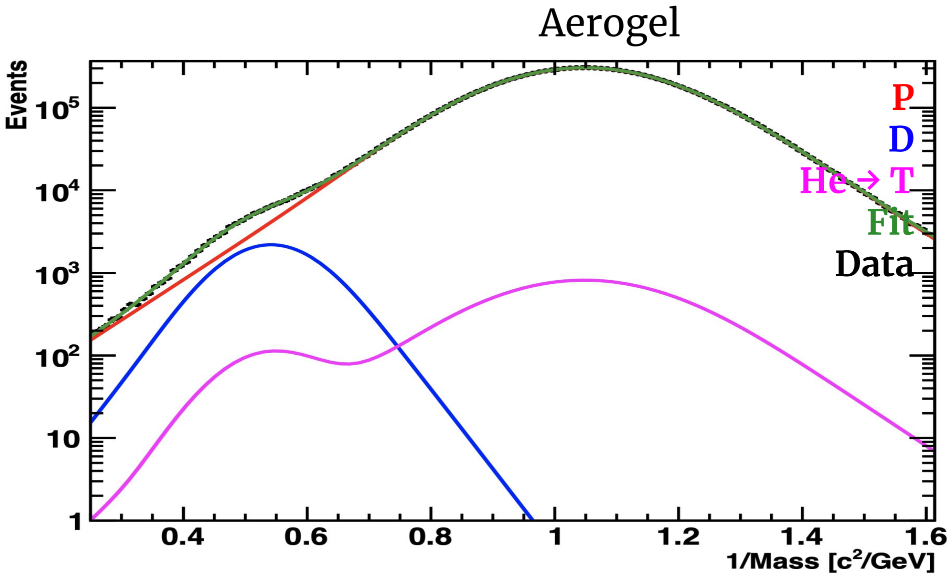
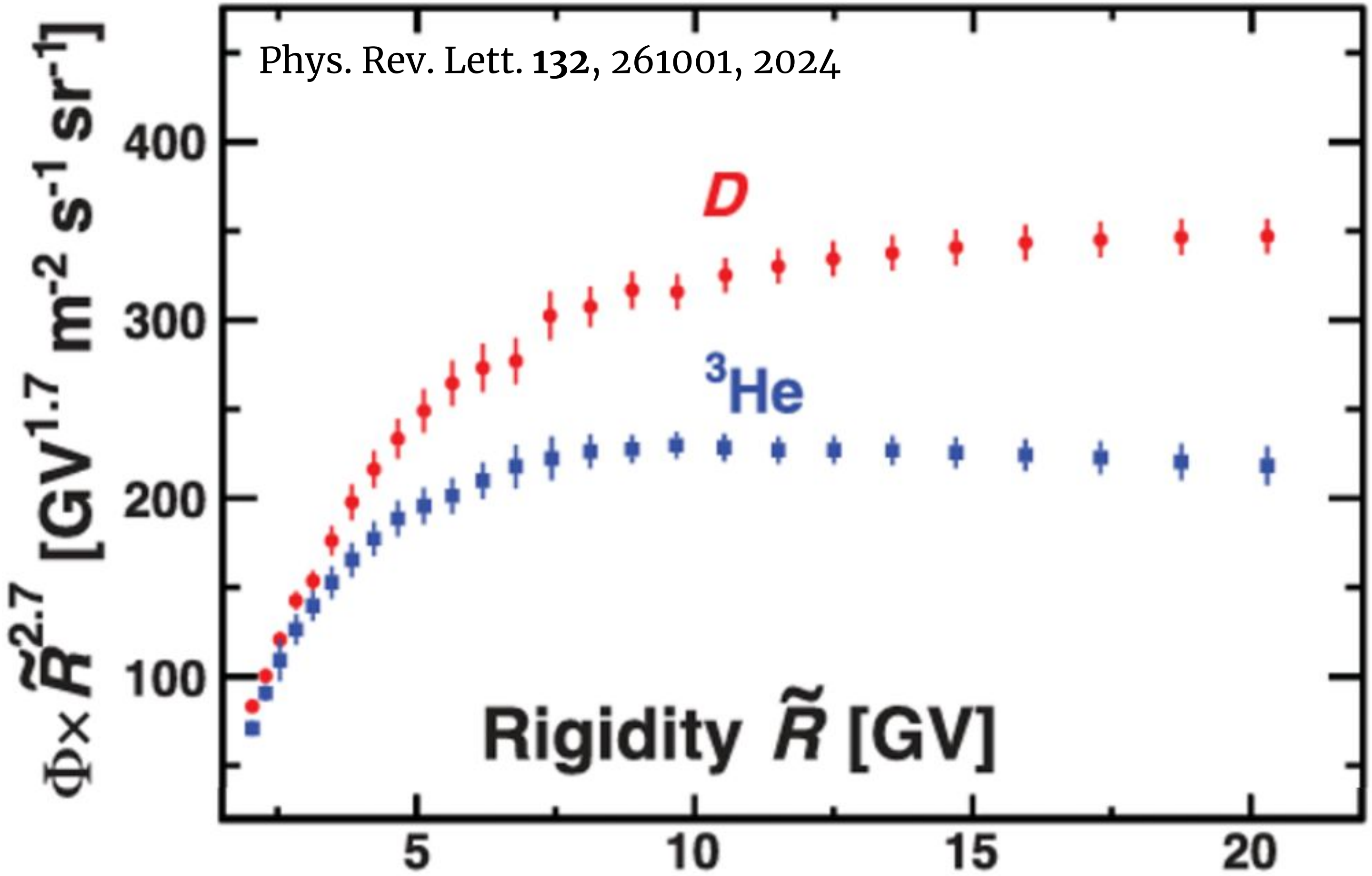
- The number of deuteron events and its statistical error is extracted by fitting the inverse mass distribution for each rigidity bin.
- Data are compared to the parametric model for the 3 velocity ranges.



Bueno et al NIM A 2023

Flux measurement

21 million deuteron events between 1.9 and 21 GV, collected by AMS-02 between May 2011 and April 2021



Time dependence

- The D flux is measured over 33 periods of four Bartel's rotations (108 days) each.
- p, ^{3}He, ^{4}He, D show nearly identical time dependence
- Time dependence decreases with increasing rigidity

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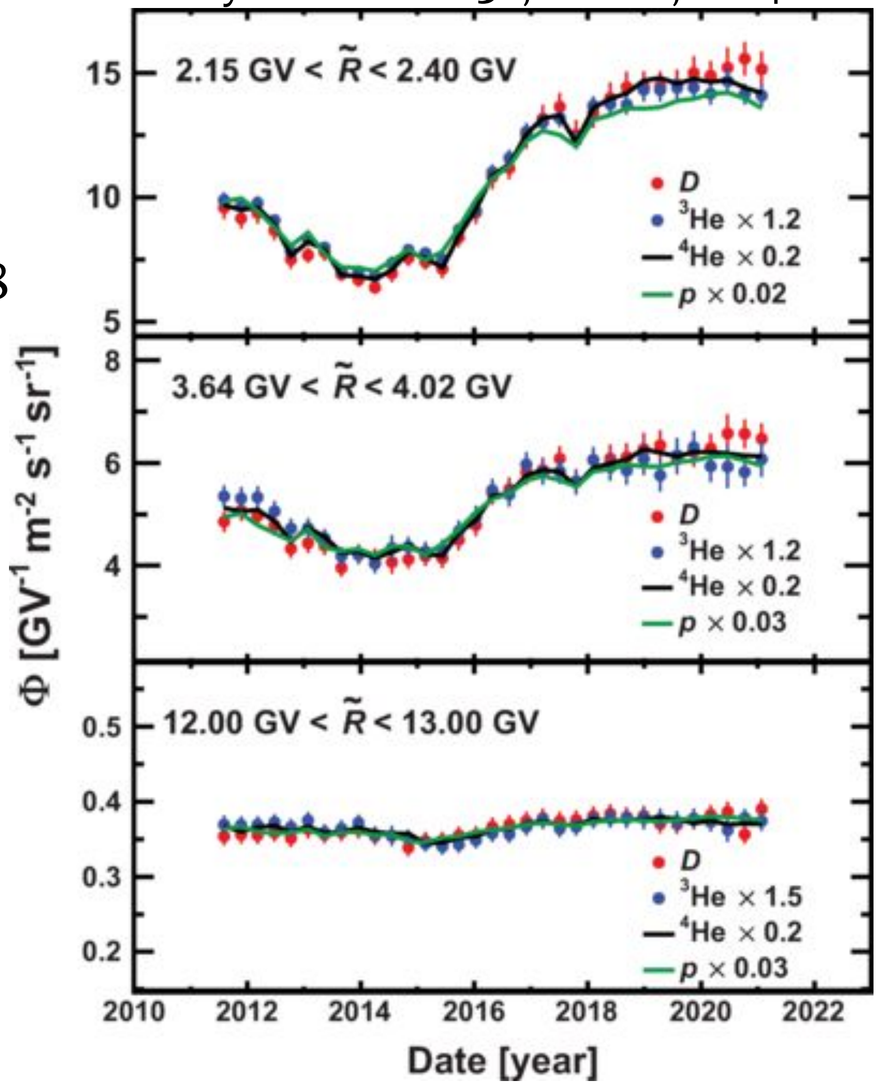

Deuteron to ^{4}He flux ratio VS rigidity

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- ^{4}He is a pure primary species and the main progenitor of D
- Secondary to primary flux ratios are **expected to be a decreasing** function of rigidity/kinetic energy per nucleon **owing their connection to the diffusion coefficient**

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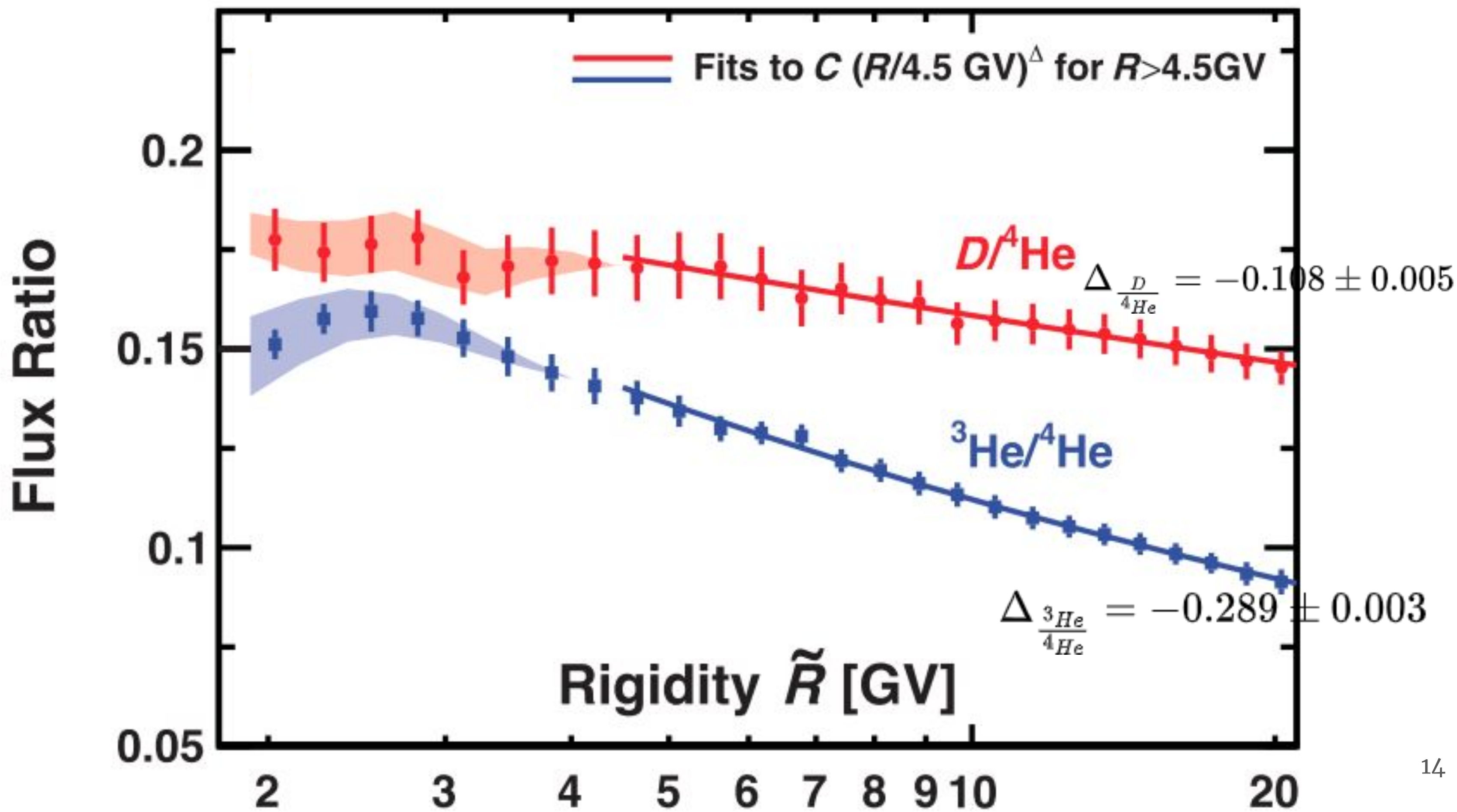

Deuteron to proton flux ratio VS rigidity

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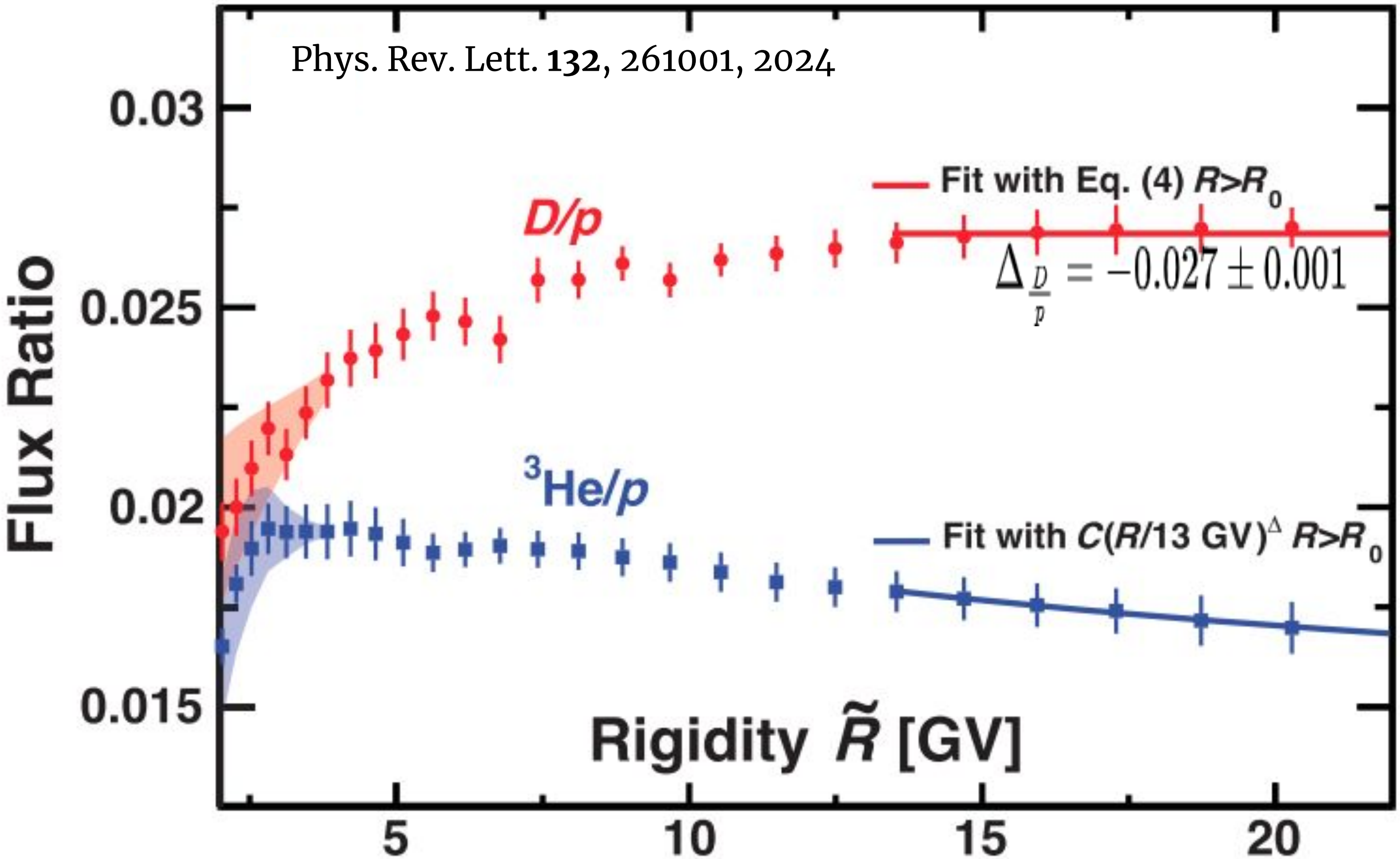
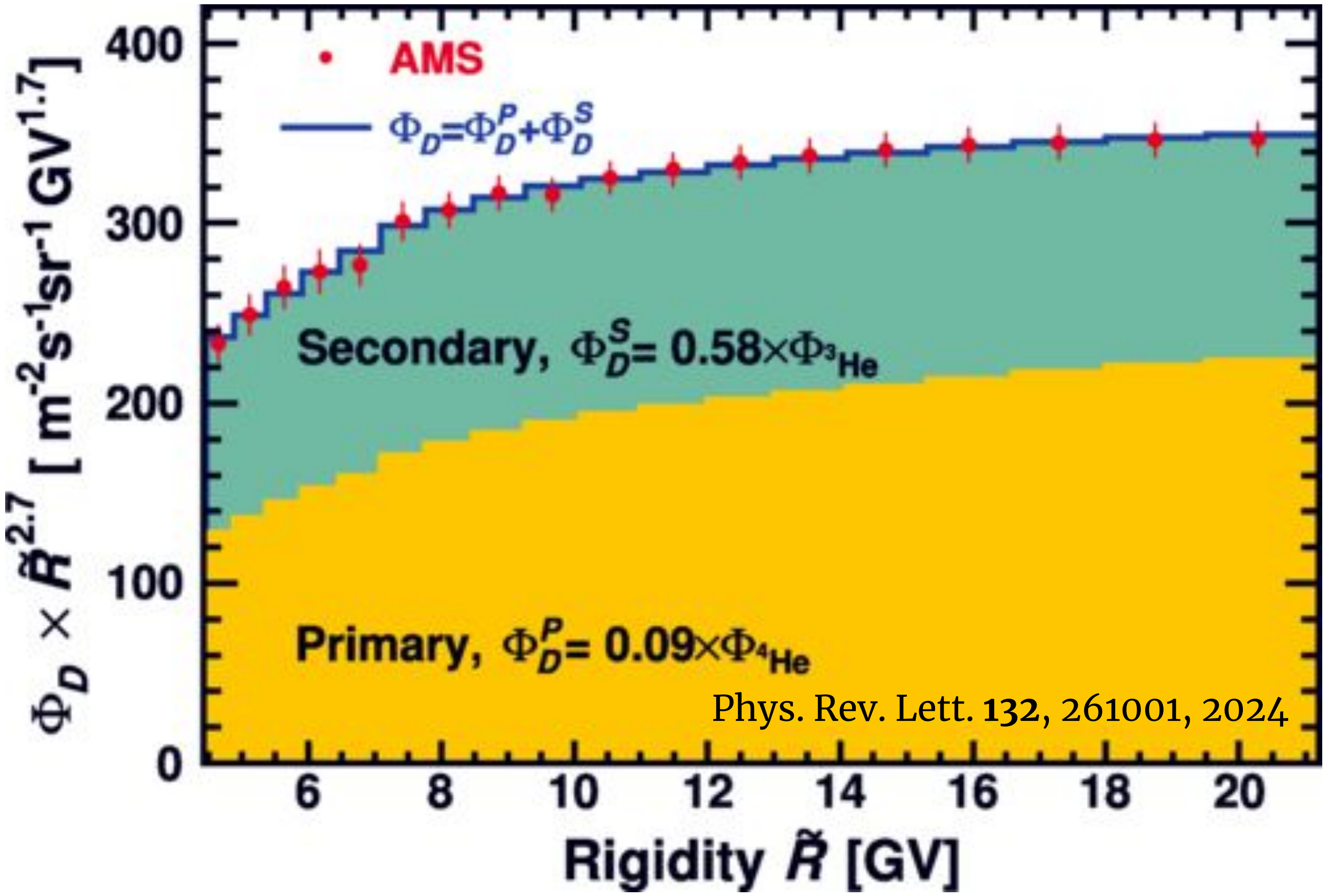
- ^{1}H is a pure primary species and a progenitor of D
- The D/p ratio is increasing with rigidity.
- D and p have nearly the same rigidity behavior above ~ 13 GV.



Primary-like and secondary component



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D/^{4}He: comparison with models

AMS results on D/^{4}He flux ratio disagree with theoretical predictions.

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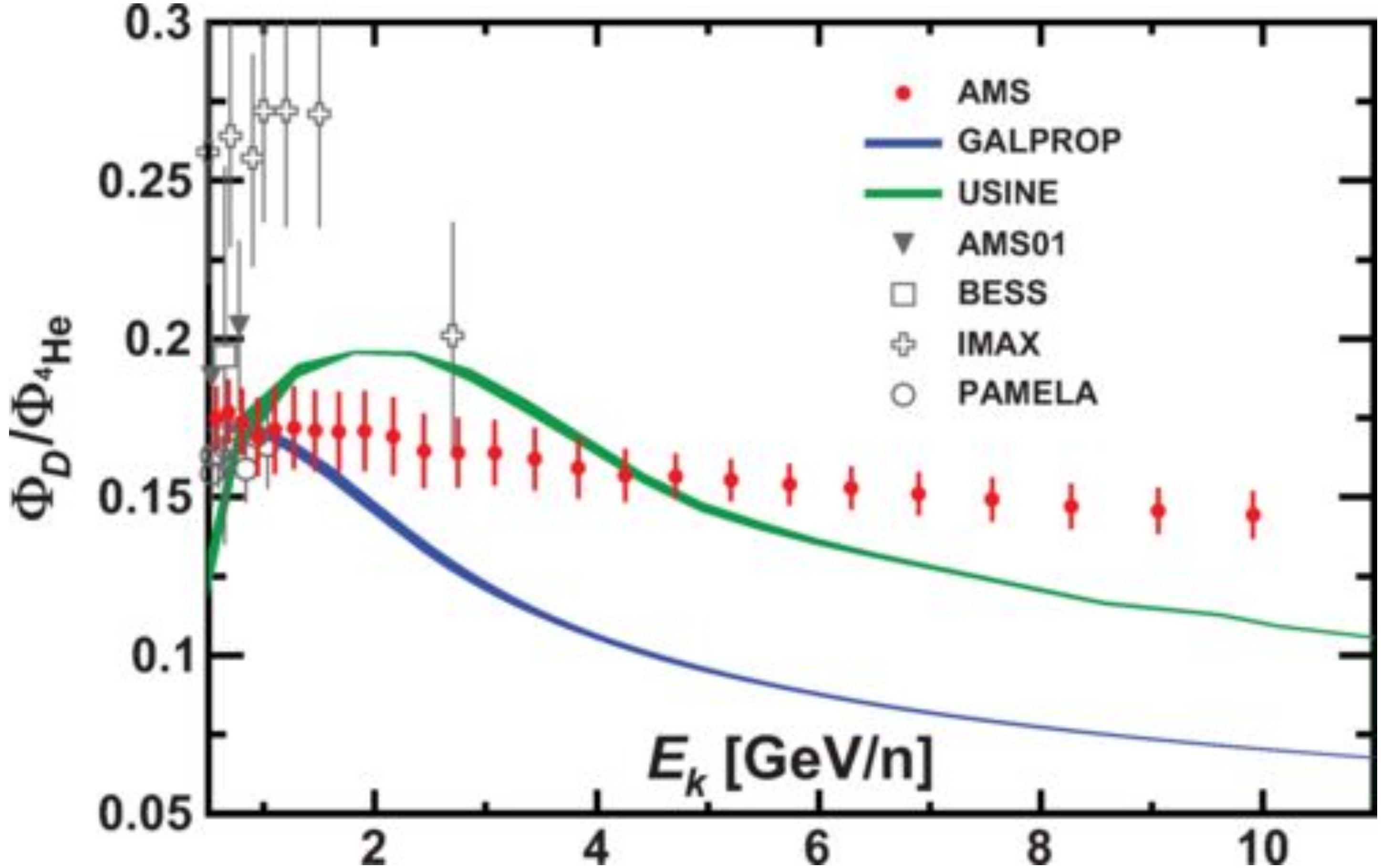

Conclusions

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- The deuteron flux was presented between 1.9 and 21 GV, based on 21 million deuteron events collected by AMS-02 between May 2011 and April 2021.
- The deuteron flux exhibits nearly identical time variation with respect to p, ^3He, and ^4He.
- Above 4.5 GV the $D/^4He$ is time independent and it can be described as as single power law in rigidity, whose spectral index is inconsistent with the one of the $^3He/^4He$.
- Deuteron to proton flux ratio is flat above 13 GV.
- These unexpected observations indicate that cosmic deuterons have a sizable primary-like component.