Cosmic ray physics with HERD

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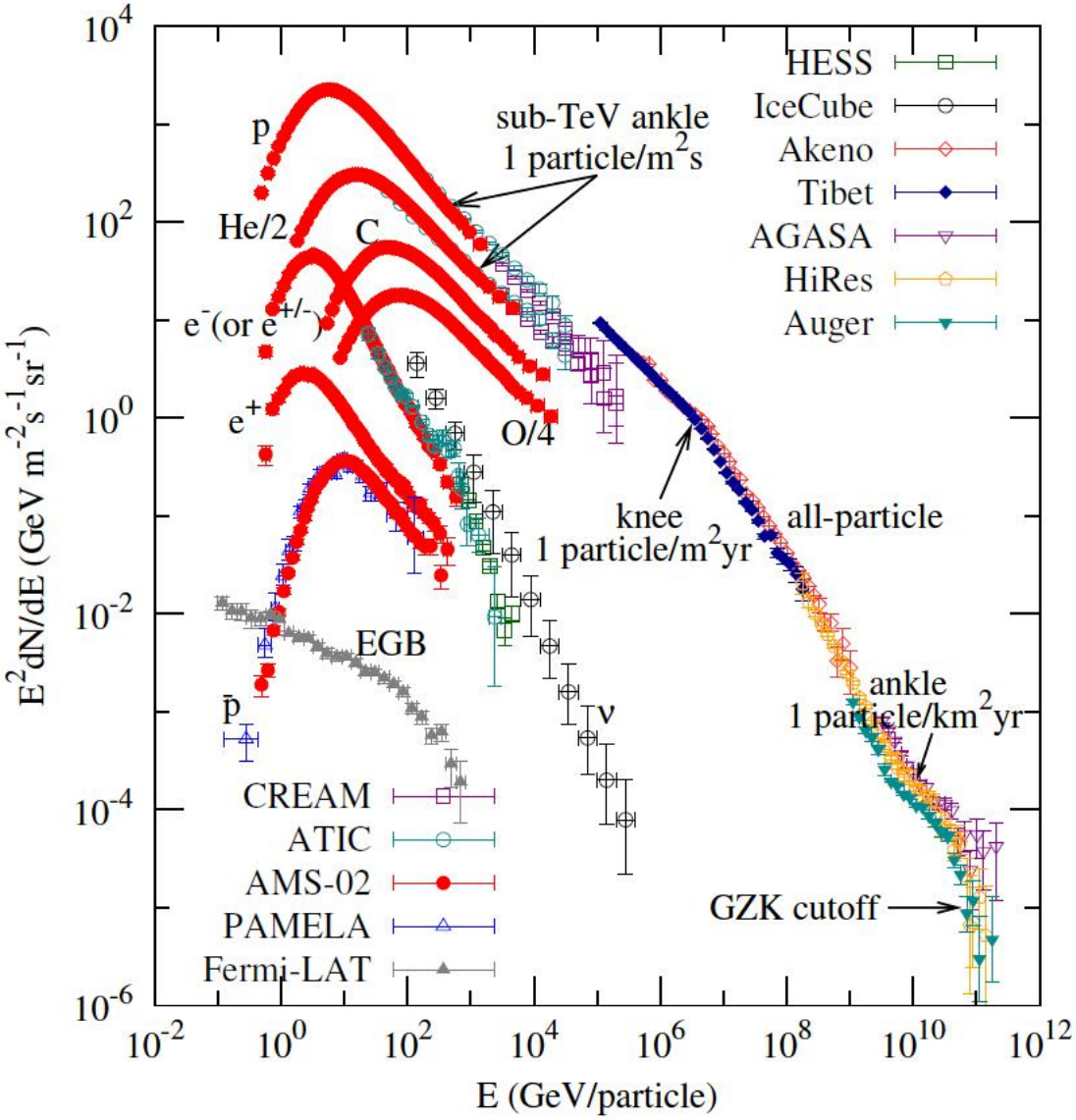
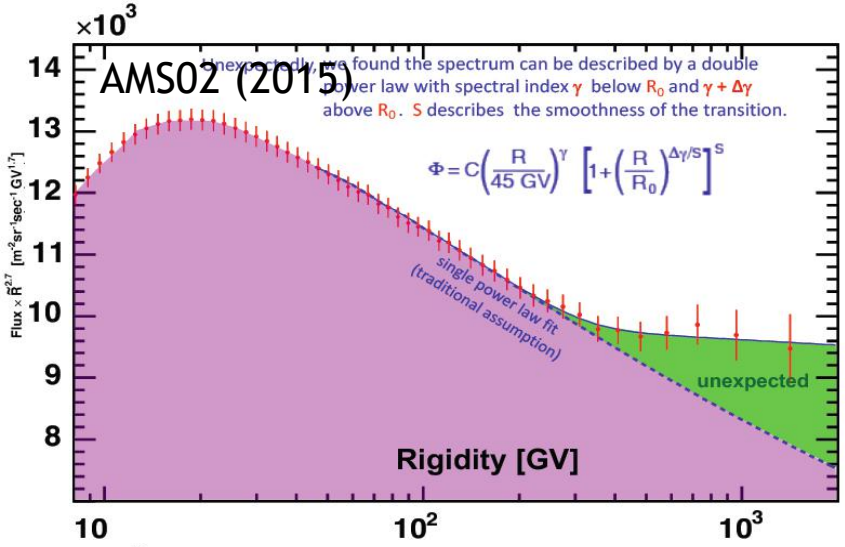
2018-03-26

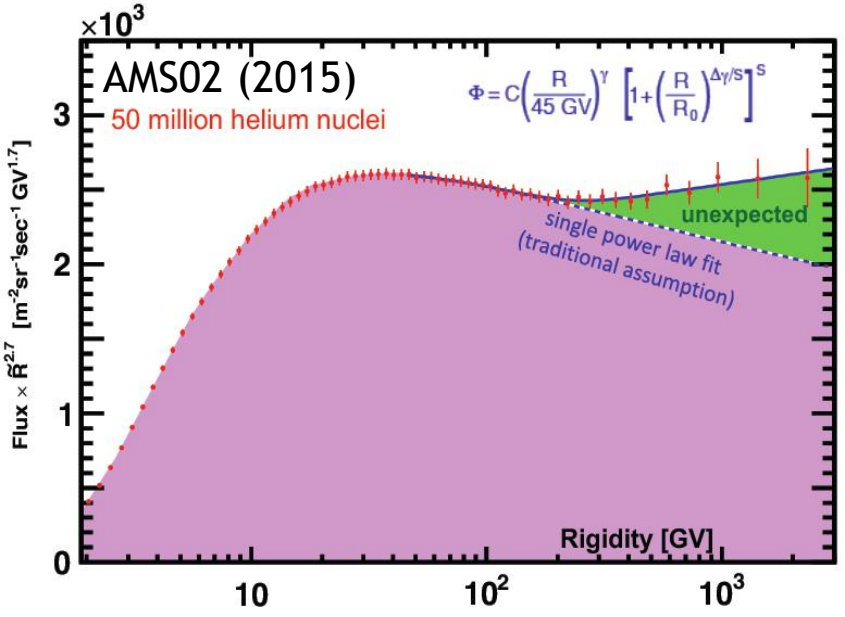
Summary of observations of major cosmic ray compositions

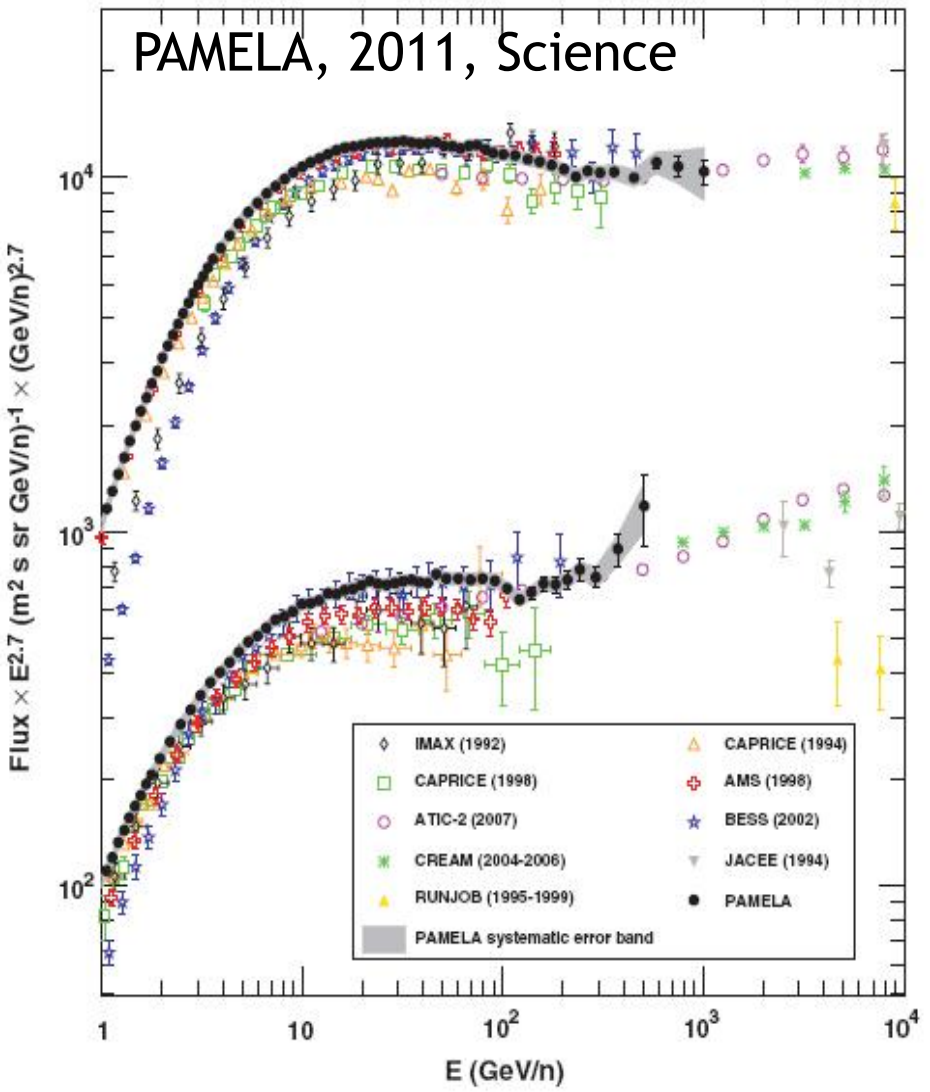


- Current status: precise measurements up to TV rigidities by AMS-02
- Goal of HERD: extend the precise measurements of individul species to PeV energies

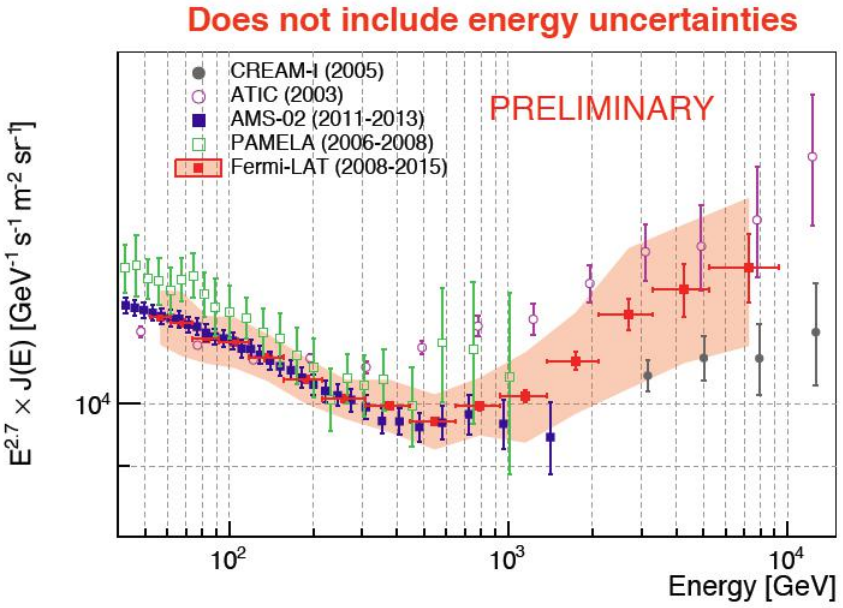
Proton and Helium spectra

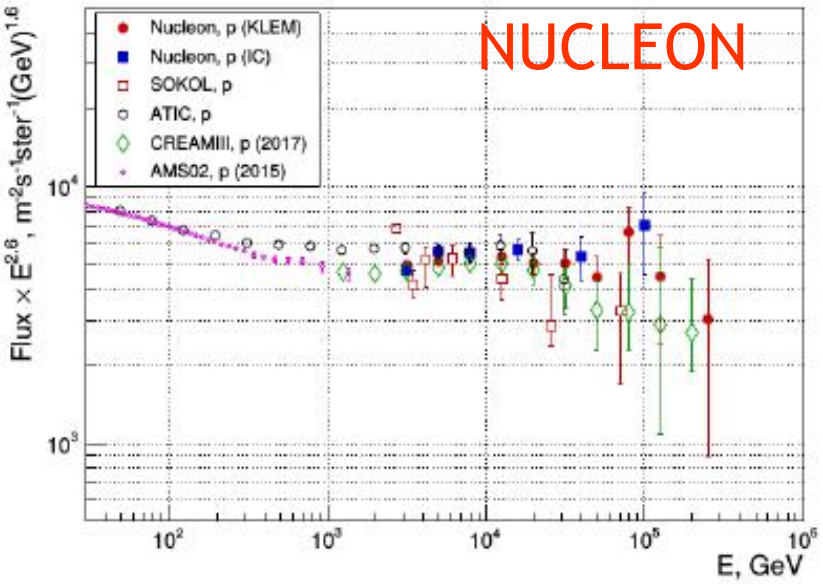


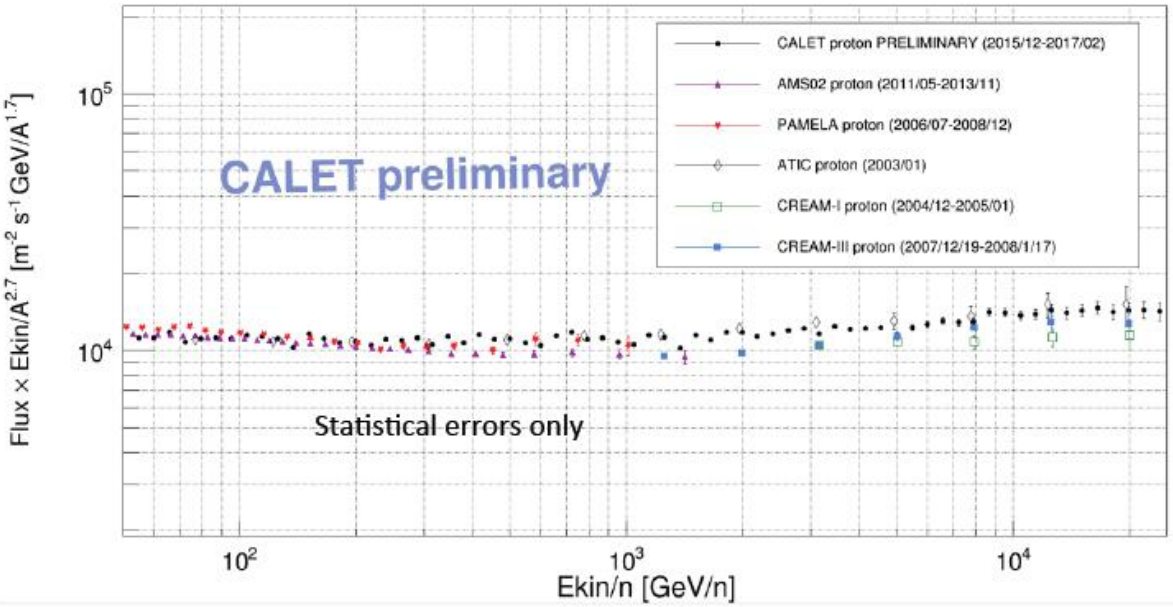




Proton results from ICRC2017



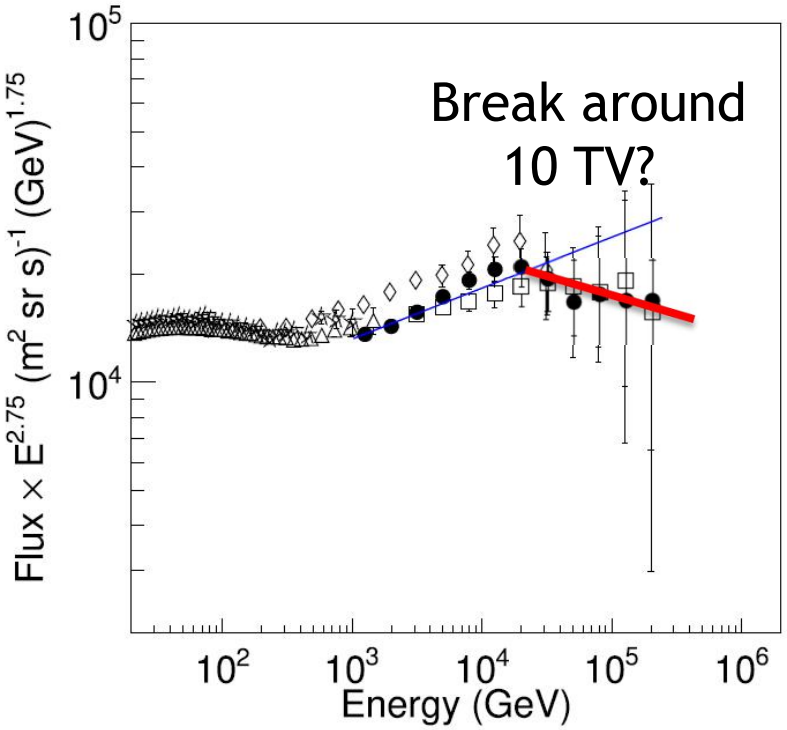


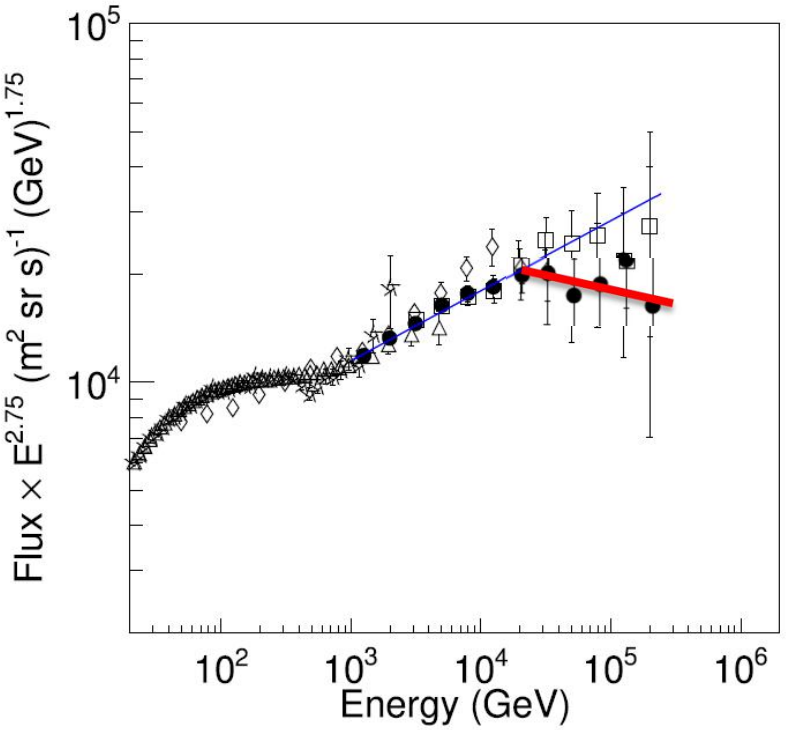


Proton and Helium spectra from CREAM-III

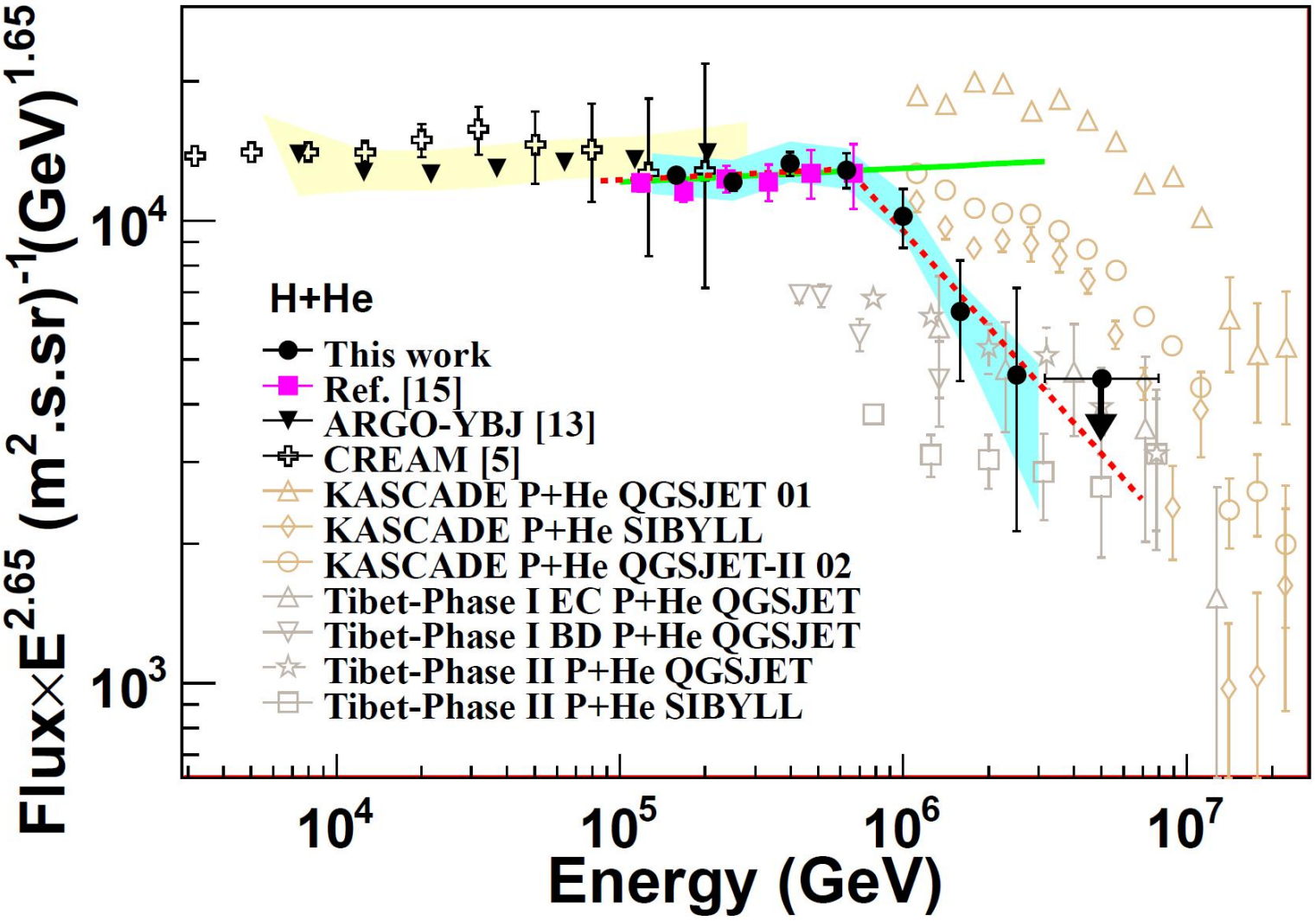
THE ASTROPHYSICAL JOURNAL, 839:5 (8pp), 2017 April 10

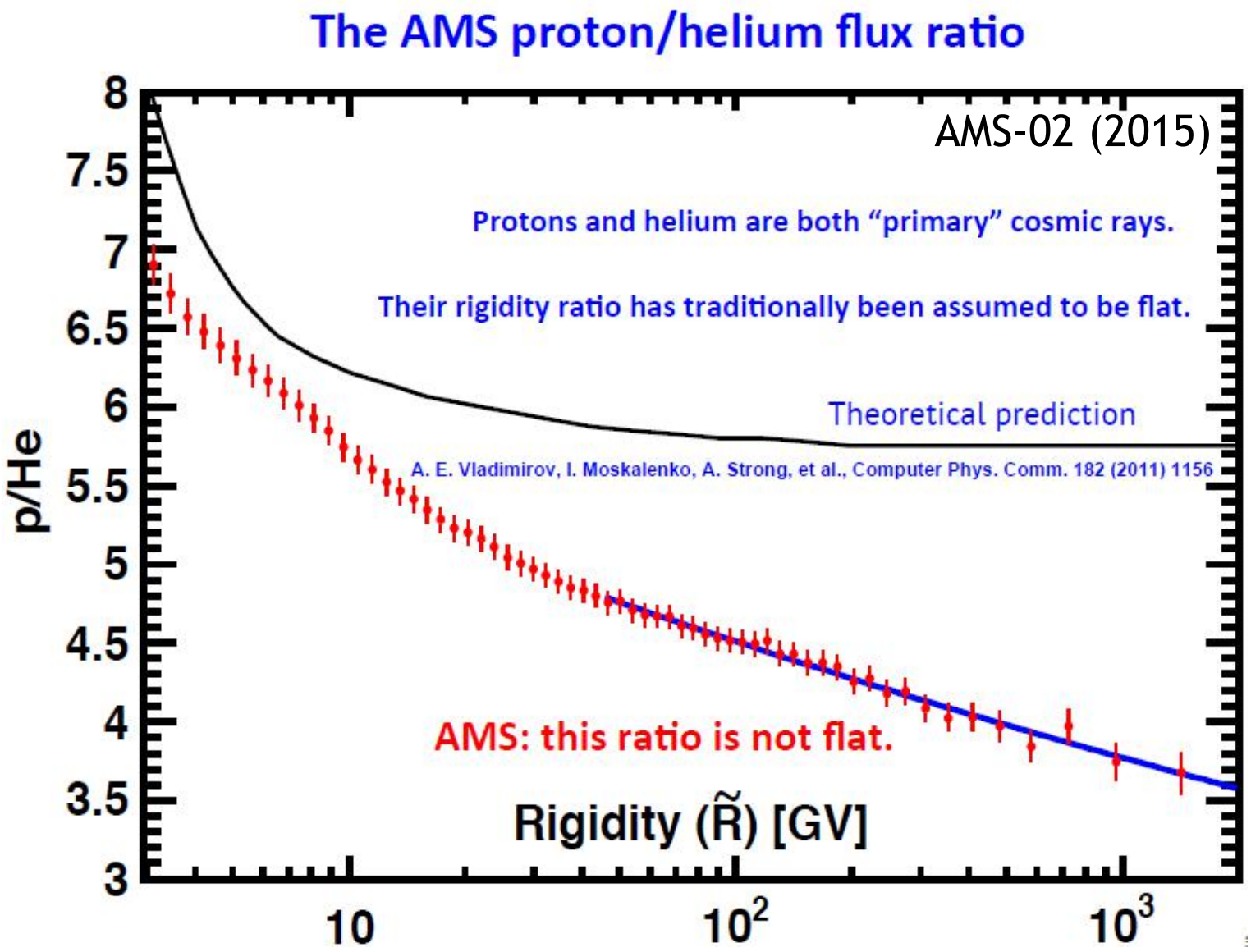
Yoon et al.





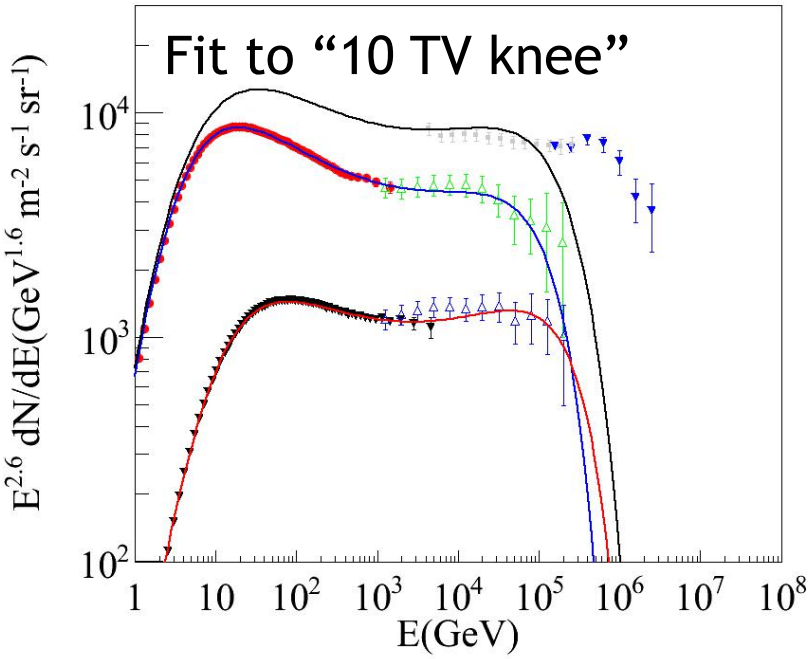
Proton + Helium spectra from ARGO-WFCTA

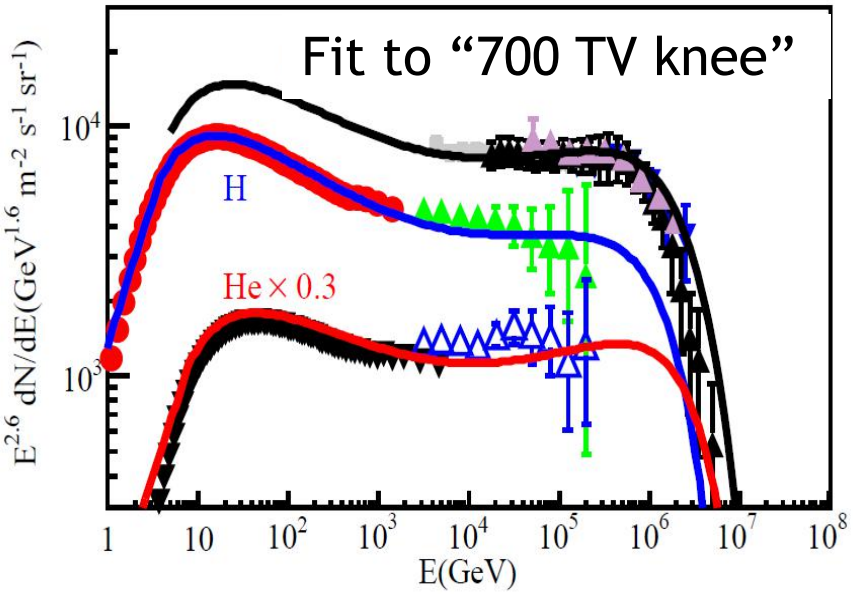



The AMS proton/helium flux ratio
AMS-02 (2015)
Protons and helium are both "primary" cosmic rays.
Their rigidity ratio has traditionally been assumed to be flat.
Theoretical prediction
A. E. Vladimirov, I. Moskalenko, A. Strong, et al., Computer Phys. Comm. 182 (2011) 1156
AMS: this ratio is not flat.
p/He
Rigidity (R̃) [GV]
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
10
10^2
10^3

Summary of p and He observations

- Spectral hardening at ~200 GV
- Possible spectral softening at ~10 TV?
- Featureless spectrum of p+He below ~700 TeV from groundbased measurements?
- Harder spectrum of Helium than protons





Guo & Yuan (2017)

Proposals of 200 GV spectral hardenings

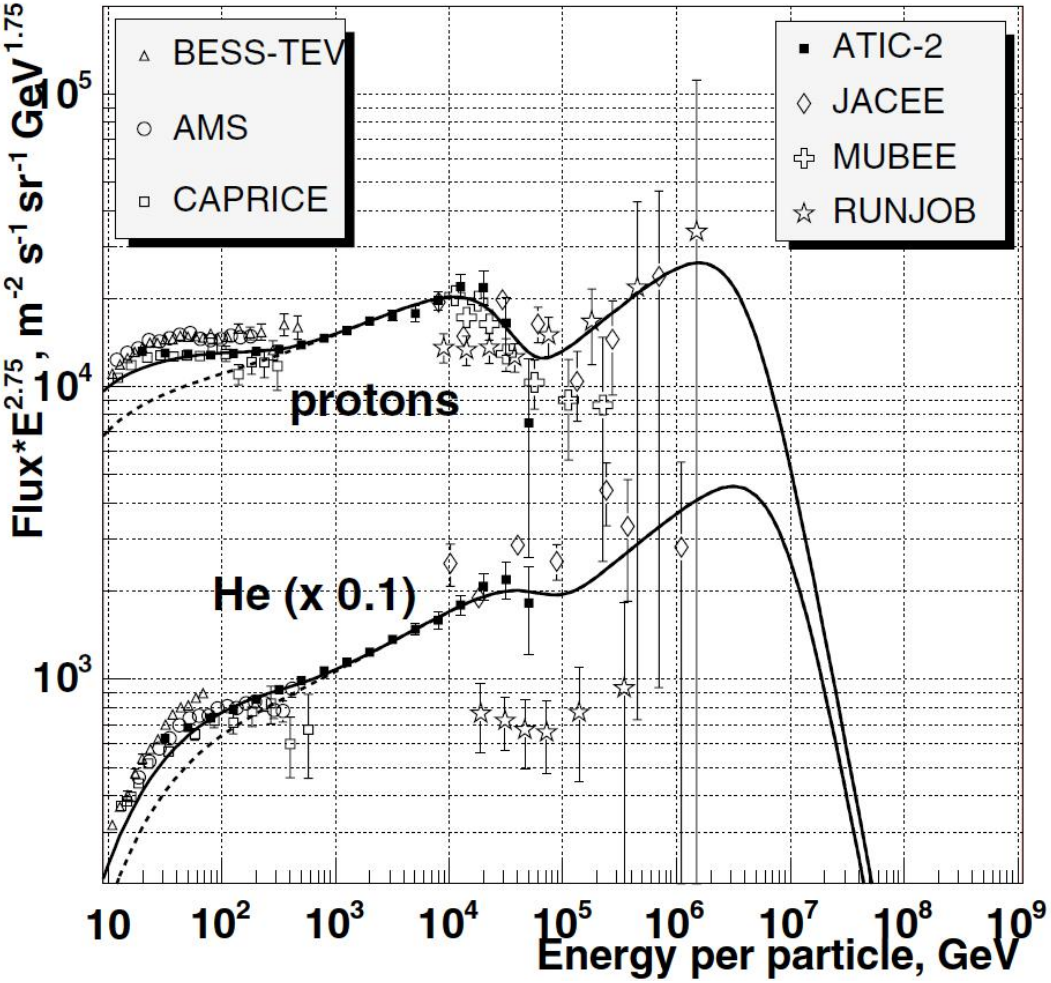
- Different source populations (e.g., Zatsepin et al. 2006; Yuan et al., 2011; Thoudam & Hoerandel, 2012; Erlykin & Wolfendale, 2012; Bernard et al. 2012)

- Nonlinear particle acceleration (e.g., Biermann et al., 2010; Ptuskin et al. 2013)

- Propagation effect (Vladimirov et al., 2011; Tomassetti, 2012; Blasi et al., 2012; Guo et al., 2014, 2016)

- Preliminary evidence from the masurements of secondary nuclei by AMS-02 seems to support the propagation scenario.

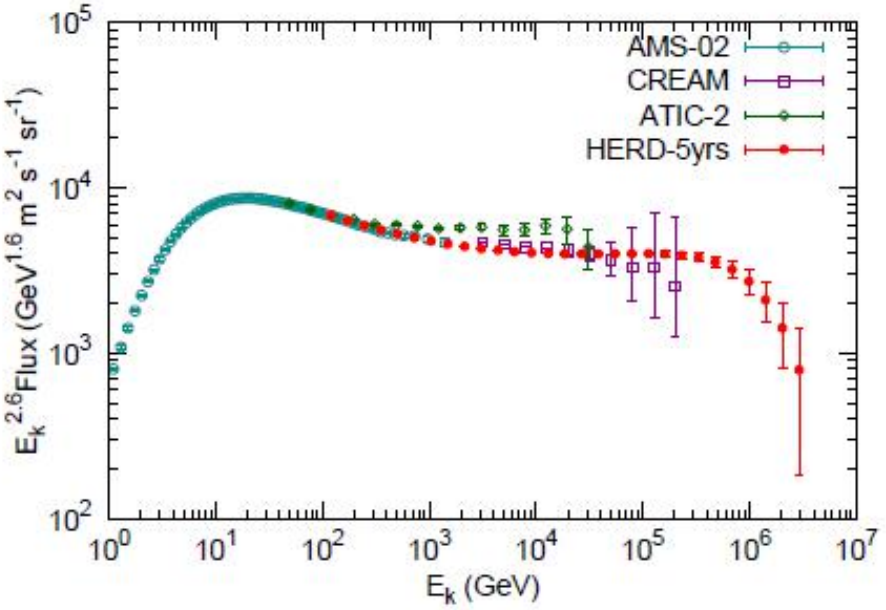
A three-component model

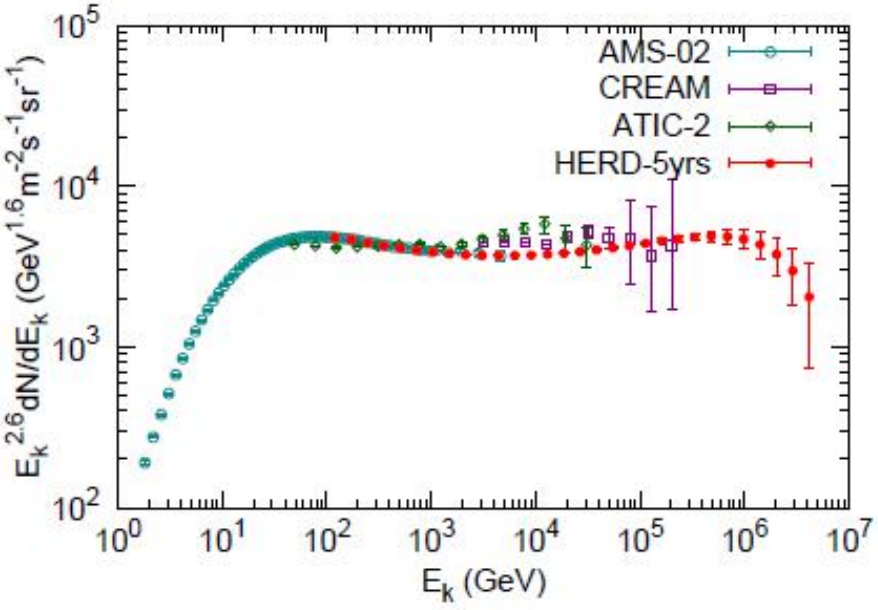


- Medium-mass star explosion in the ISM (8-15 Msun)
- High-mass star explosion in their wind (>15 Msun)
- Nova explosion for the low energy spectra

Zatsepin & Sokolskaya (2006)

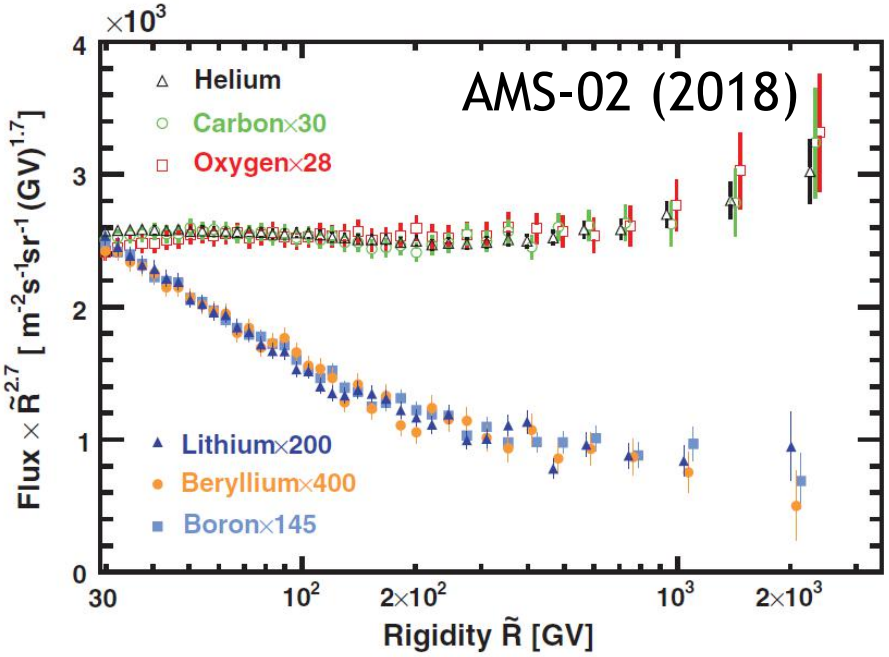
Perspective of HERD

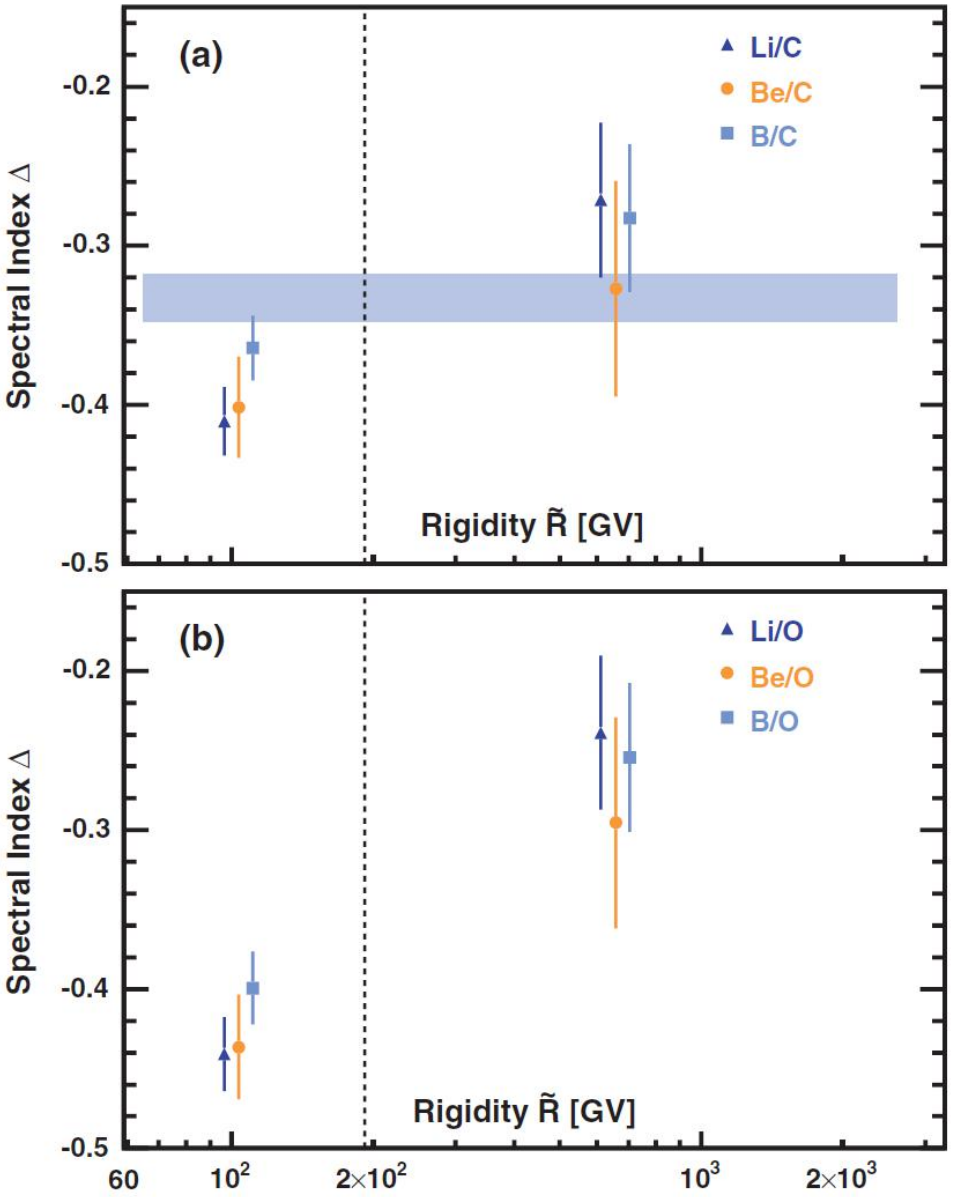




- Well extended to PeV energies
- Critically test any structures between TeV and PeV
- Clearly reveal the knee of light components (Z- or A-dependence)

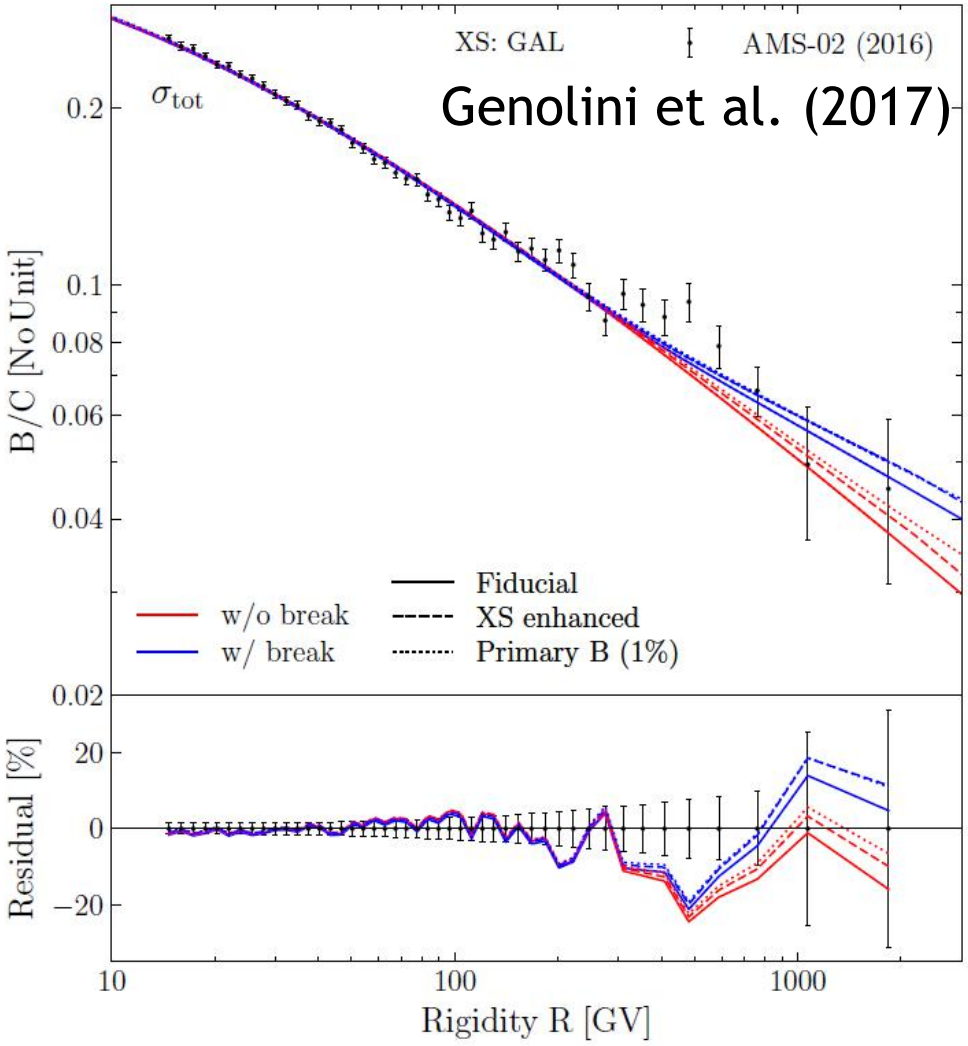
Spectra of nuclei



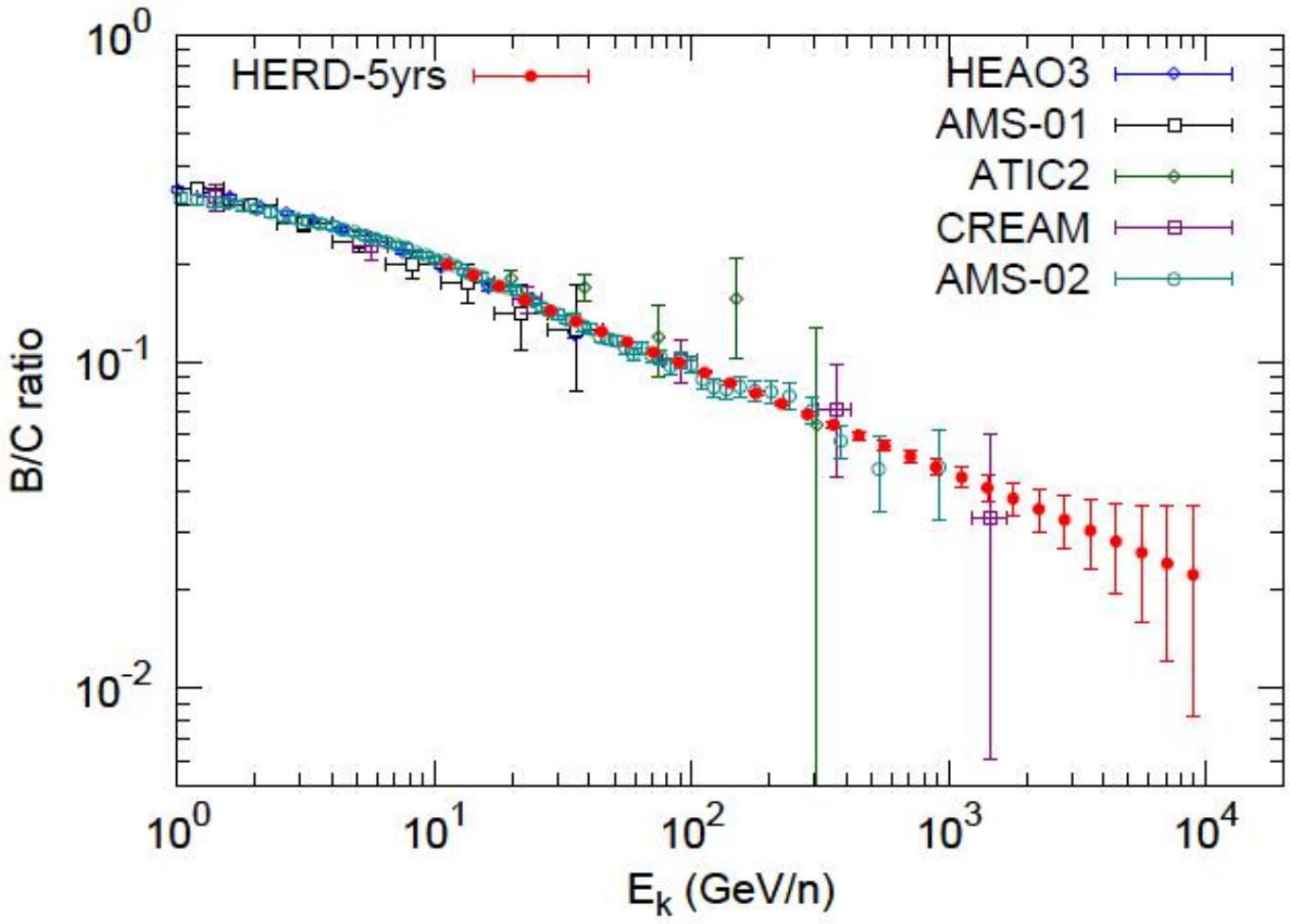


- AMS-02 data show similar spectra of He-C-O and Li-Be-B groups, all of which harden around 200 GV
- Secondary nuclei harden by $E^{0.13}$ more than primary nuclei

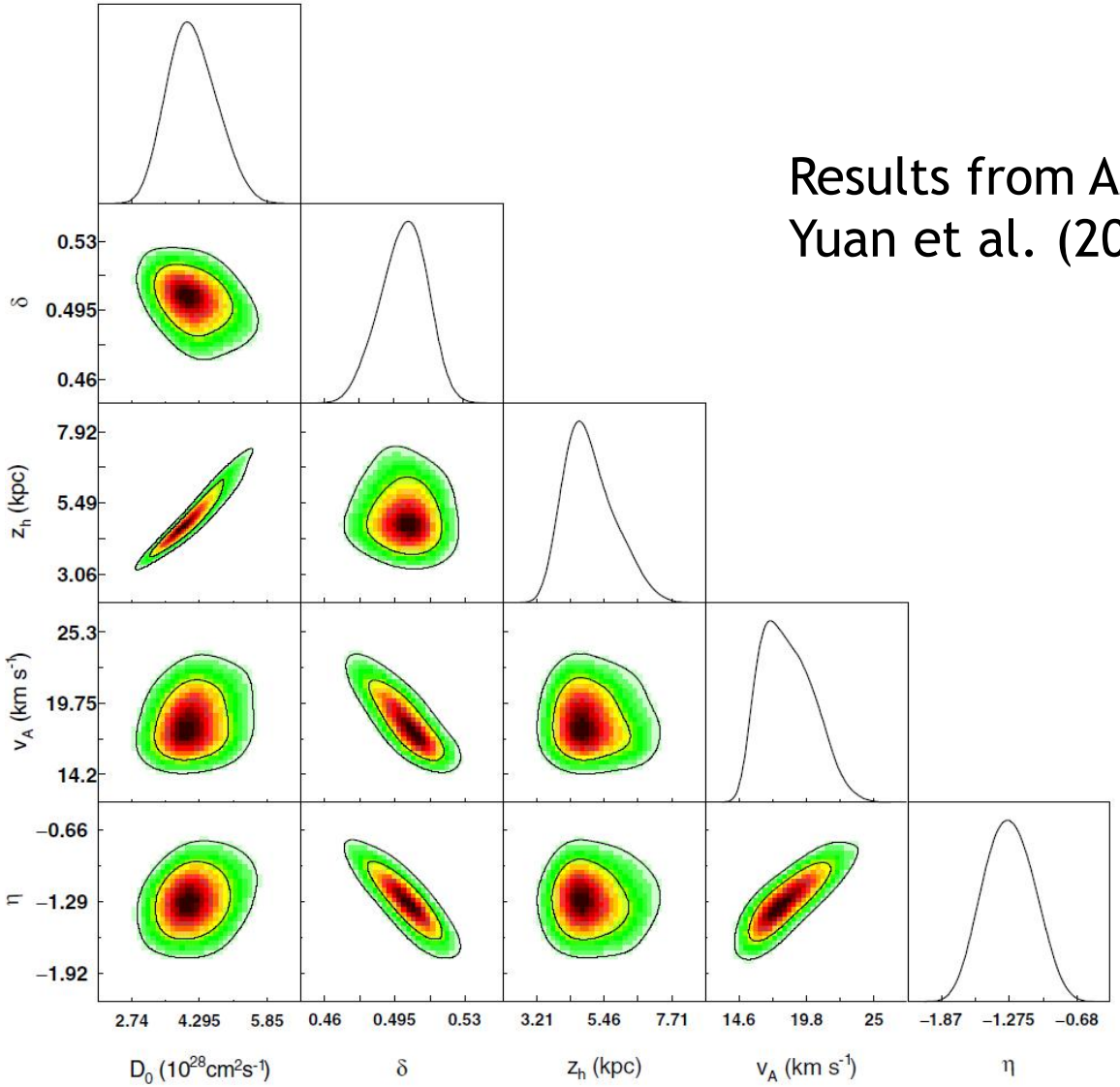
Break of Boron-to-Carbon ratio?



Perspective of HERD

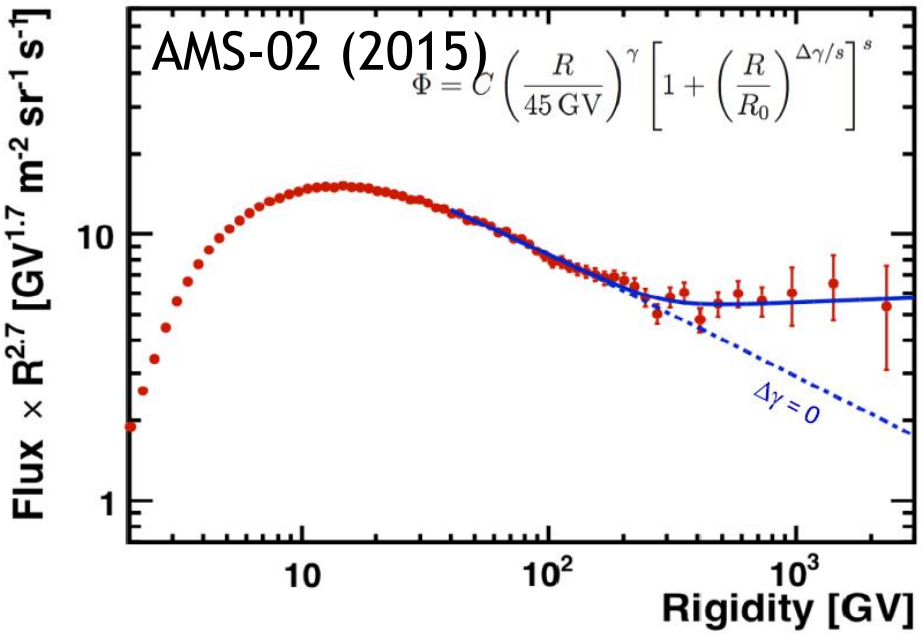


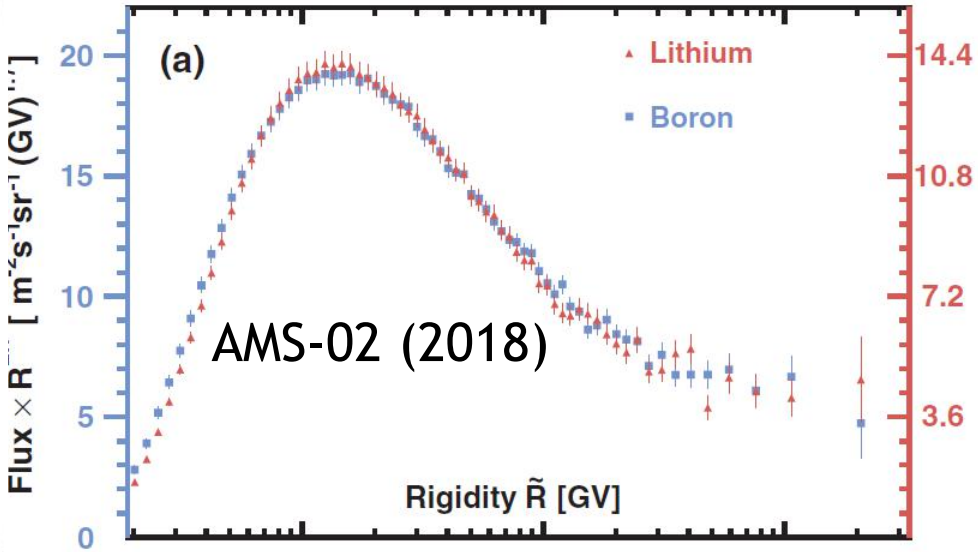
Constraints on CR propagation parameters



Results from AMS-02
Yuan et al. (2017)

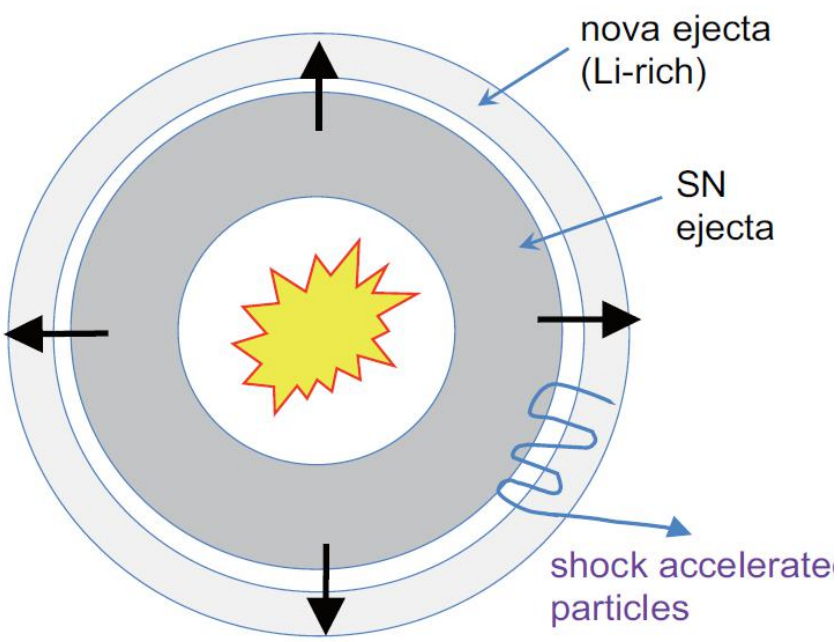
Lithium anomaly?

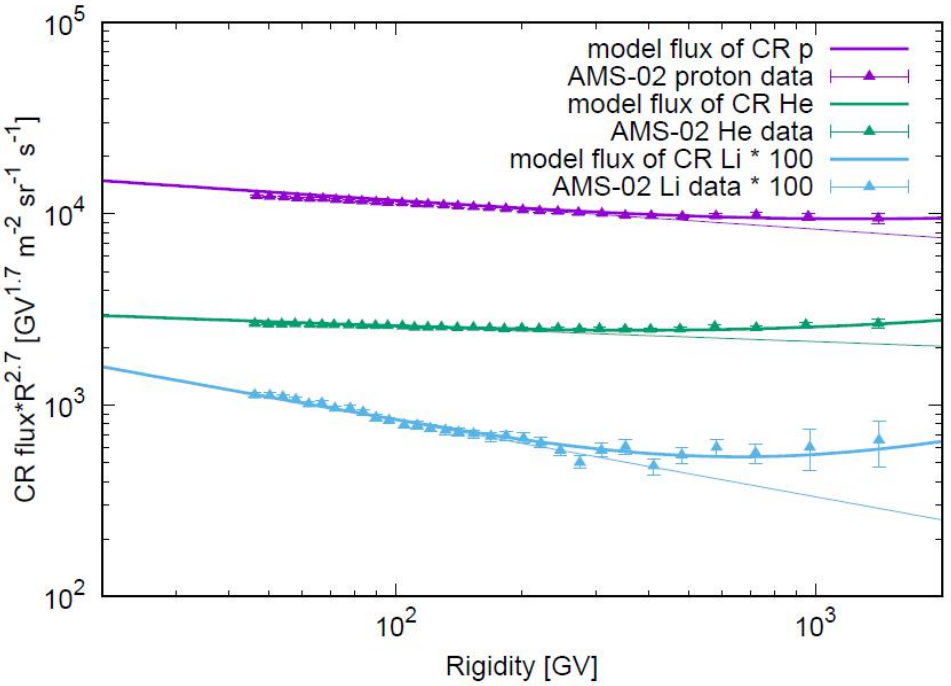




- Li, Be, and B nuclei are secondary products of CRs
- Precise comparison of their spectra at higher energies are very important for particle/nuclear physics, astrophysics, and/or cosmology

Discussion on primary source of Lithium



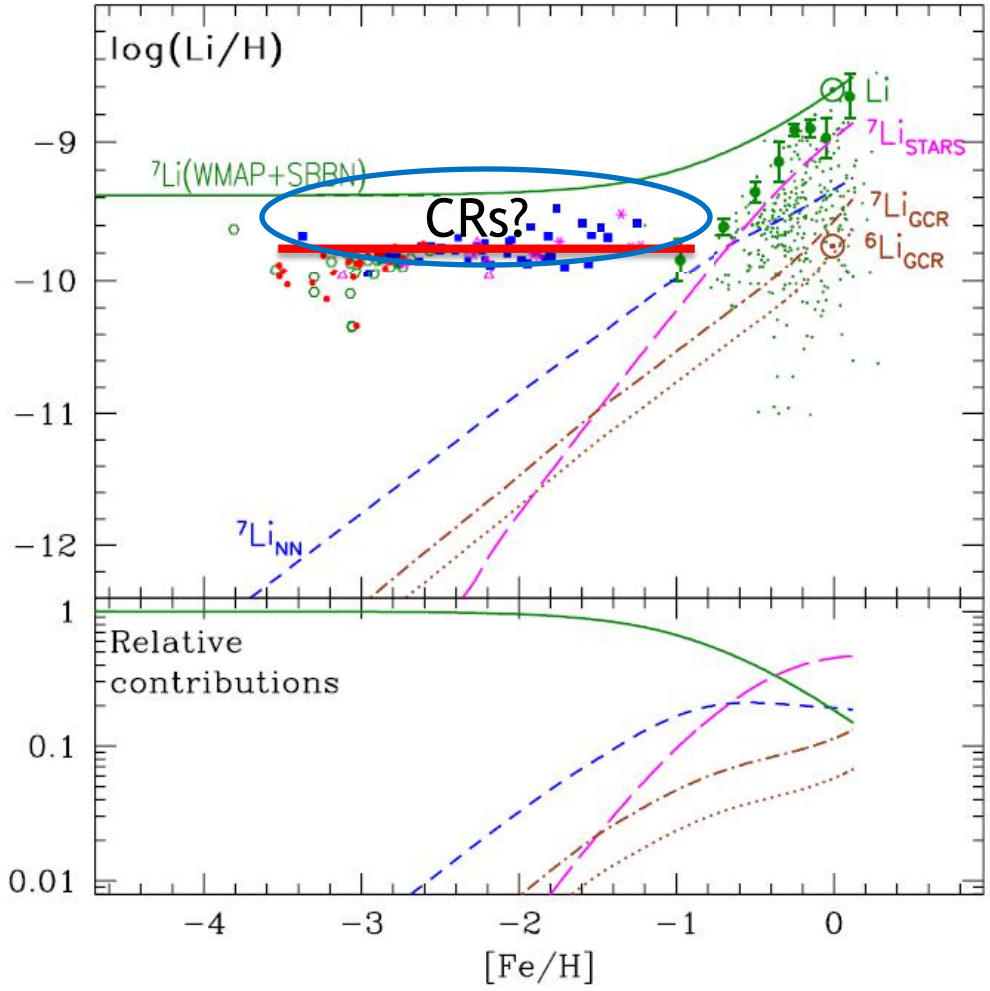


- Li-rich ejecta from nova explosions before the (Type-Ia) supernova
- SN shock acceleration produces high-energy primary Li

Kawanaka & Yanagita (2018)

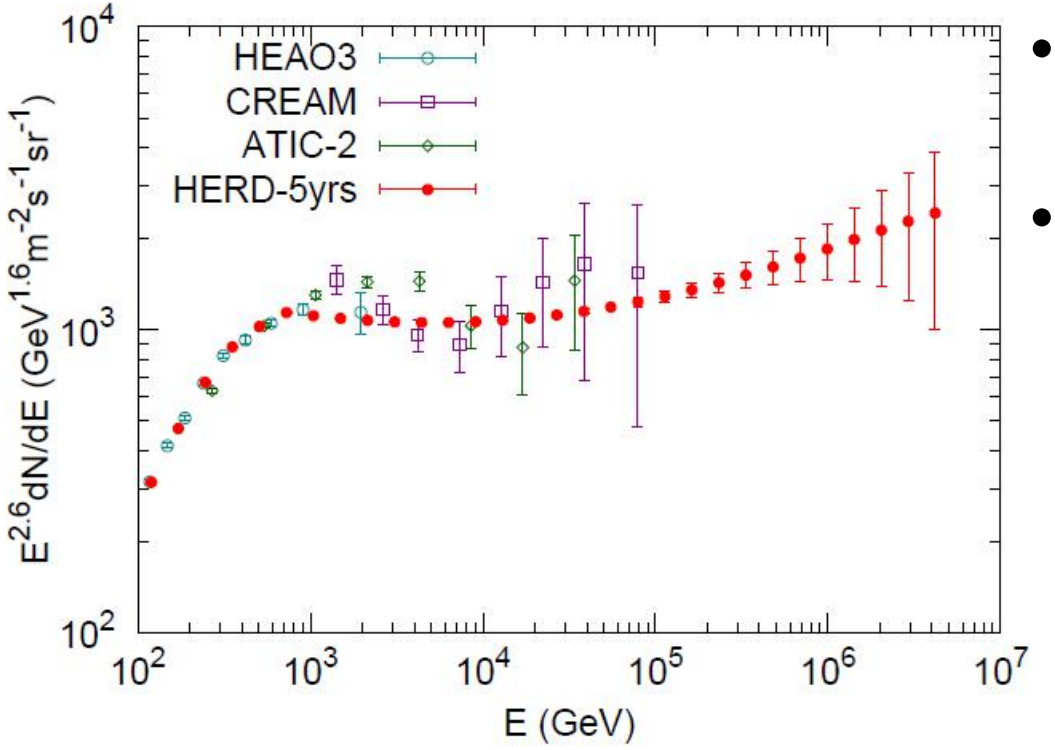
Discussion on primary source of Lithium

Prantzos (2012)



- Lithium is the 5th (H, D, 3He, 4He) abundant nuclei produced during the BBN
- A fraction of BBN Li could be accelerated to CRs

Heavy and super-heavy nuclei



- Iron is the end product of stellar synthesis
- CR fluxes of iron and heavier nuclei are crucial to probing the acceleration sites of CRs (e.g., massive stars or supernovae)

Summary and discussion

- The key to understand fundamental questions of CRs (origin, propagation, interaction etc.) is high-precision measurement of the spectra of various compositions in a wide energy band

- HERD's unprecedented capability on CR observations is expected to significantly promote such studies

- Expected milestones include (but not limited in): first measurements of the “knee” of light components; significantly improved constraints on the CR propagation models; crucially addressing of the origin of CRs; related particle or nuclear physics or astrophysics studies

- Others: anisotropies, time variabilities ...