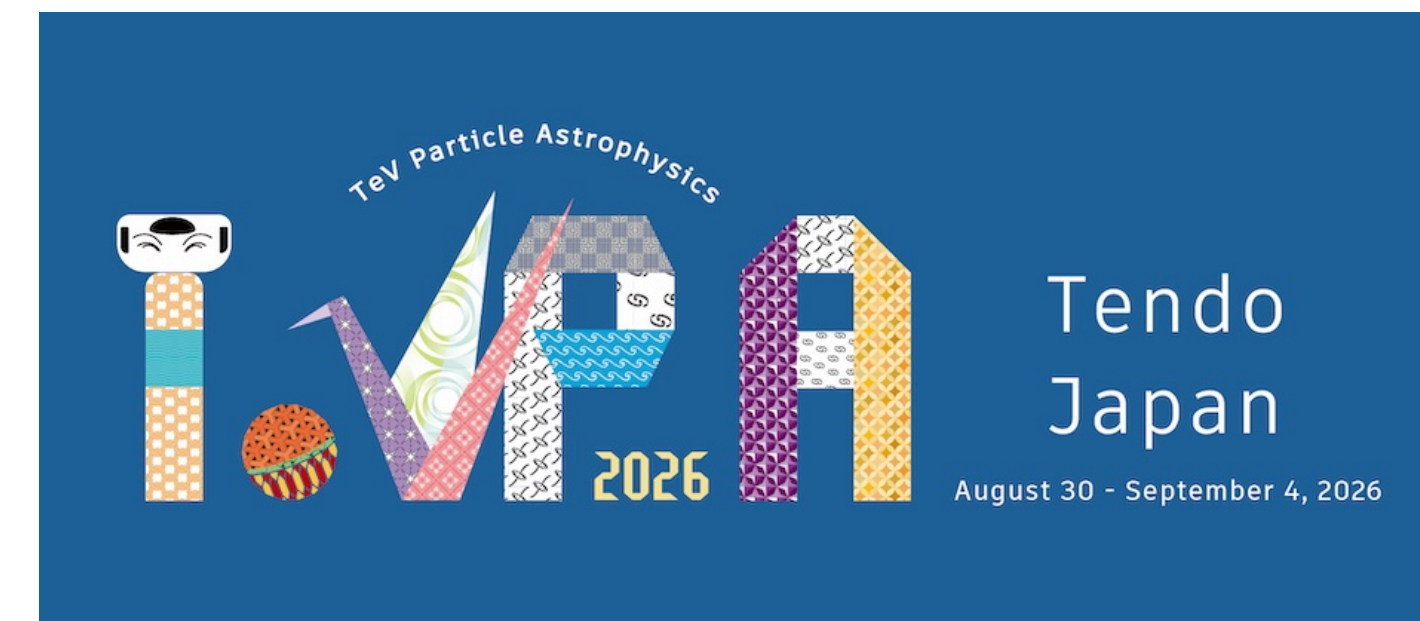




DAMPE results after the first 10 years of operation

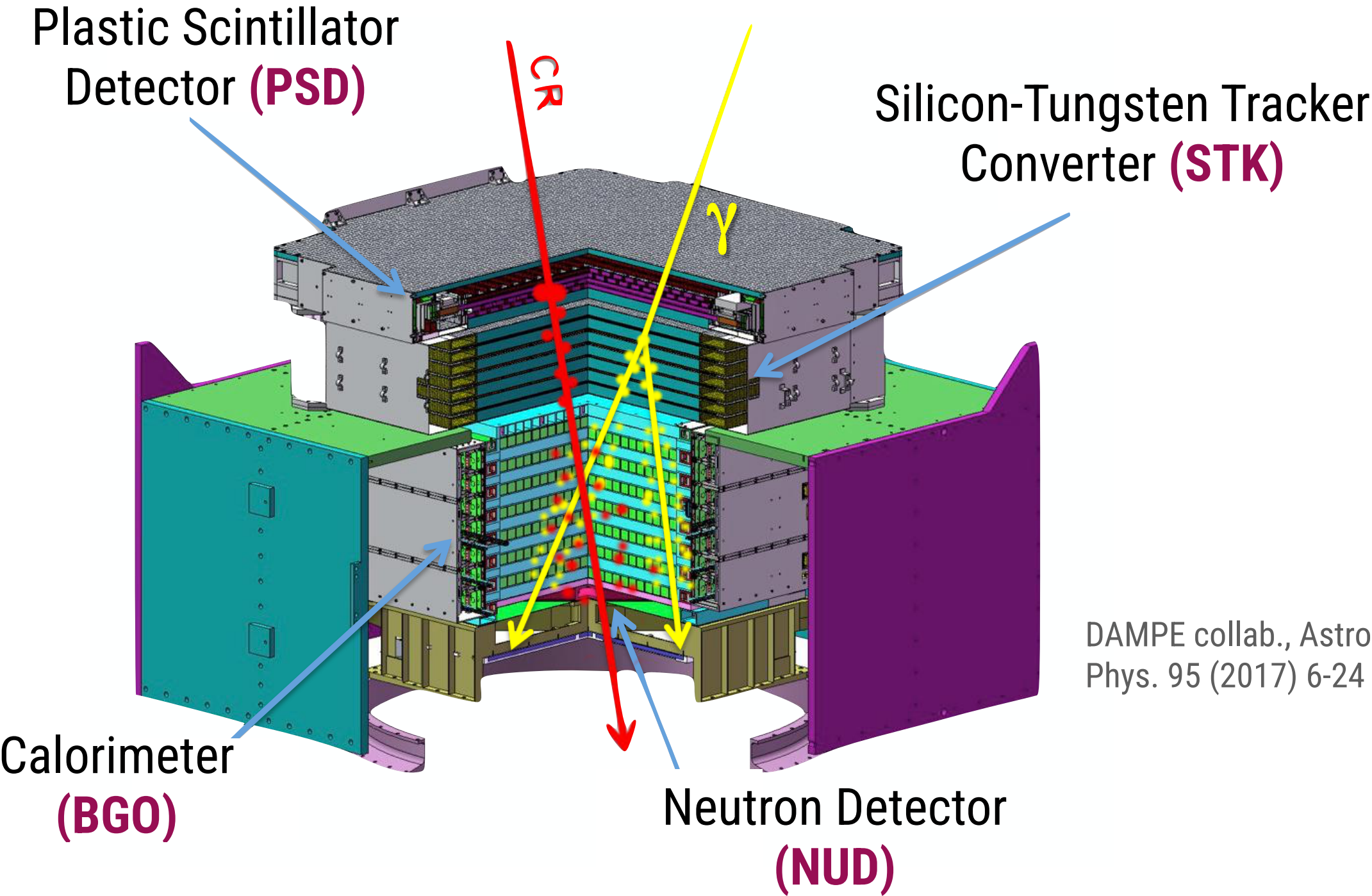
Andrii Tykhonov (for the DAMPE collaboration)



UNIVERSITÉ
DE GENÈVE

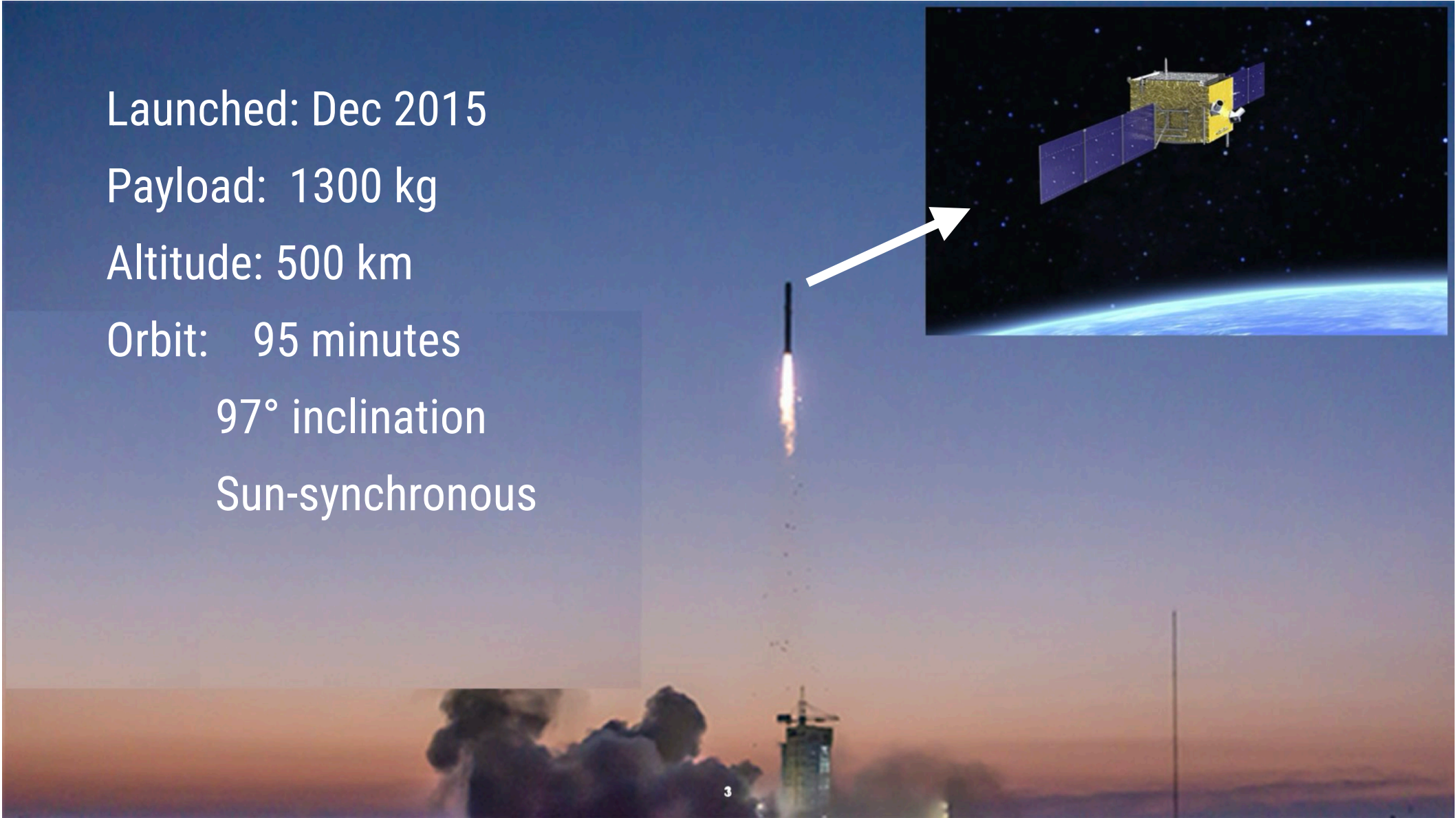


DARk Matter Particle Explorer (DAMPE)



DAMPE collab., Astropart. Phys. 95 (2017) 6-24

Launched: Dec 2015
Payload: 1300 kg
Altitude: 500 km
Orbit: 95 minutes
97° inclination
Sun-synchronous

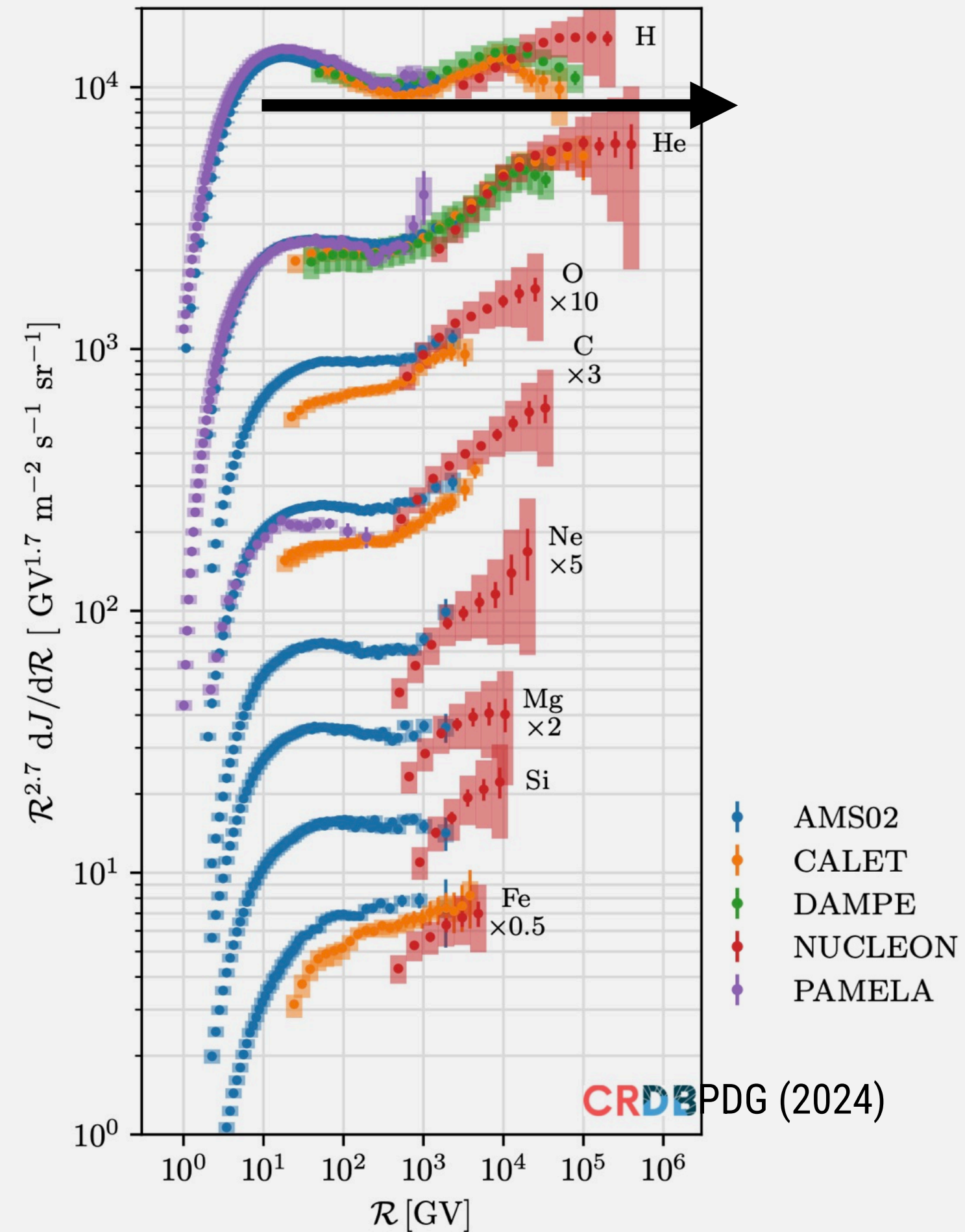


Energy range	GeV   s - PeV
Energy resolution (e, γ):	1.2% (above 100 GeV)
Geometric factor (e):	0.3 m ² sr
Calorimeter thickness:	32 X ₀ (1.6 λ)

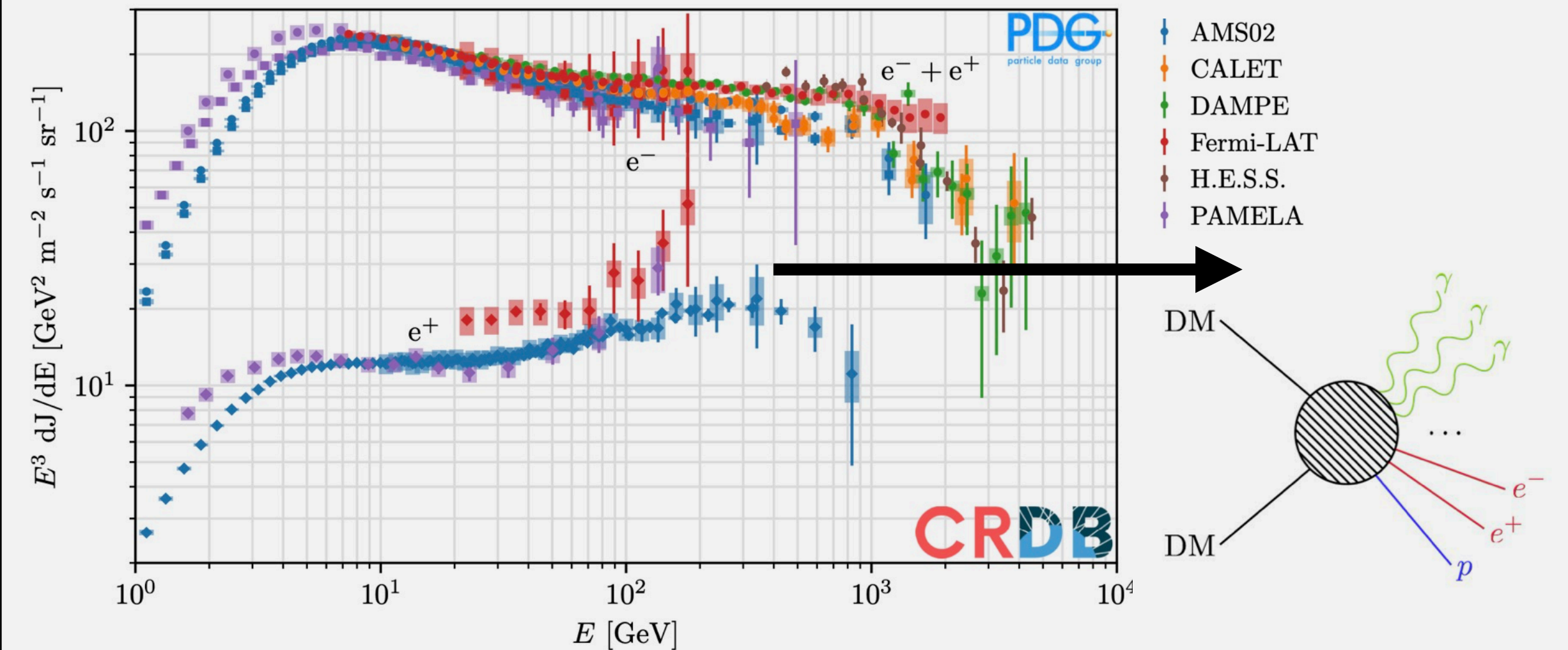


* 10th year Anniversary of DAMPE in space Nanjing, China, Dec 2025

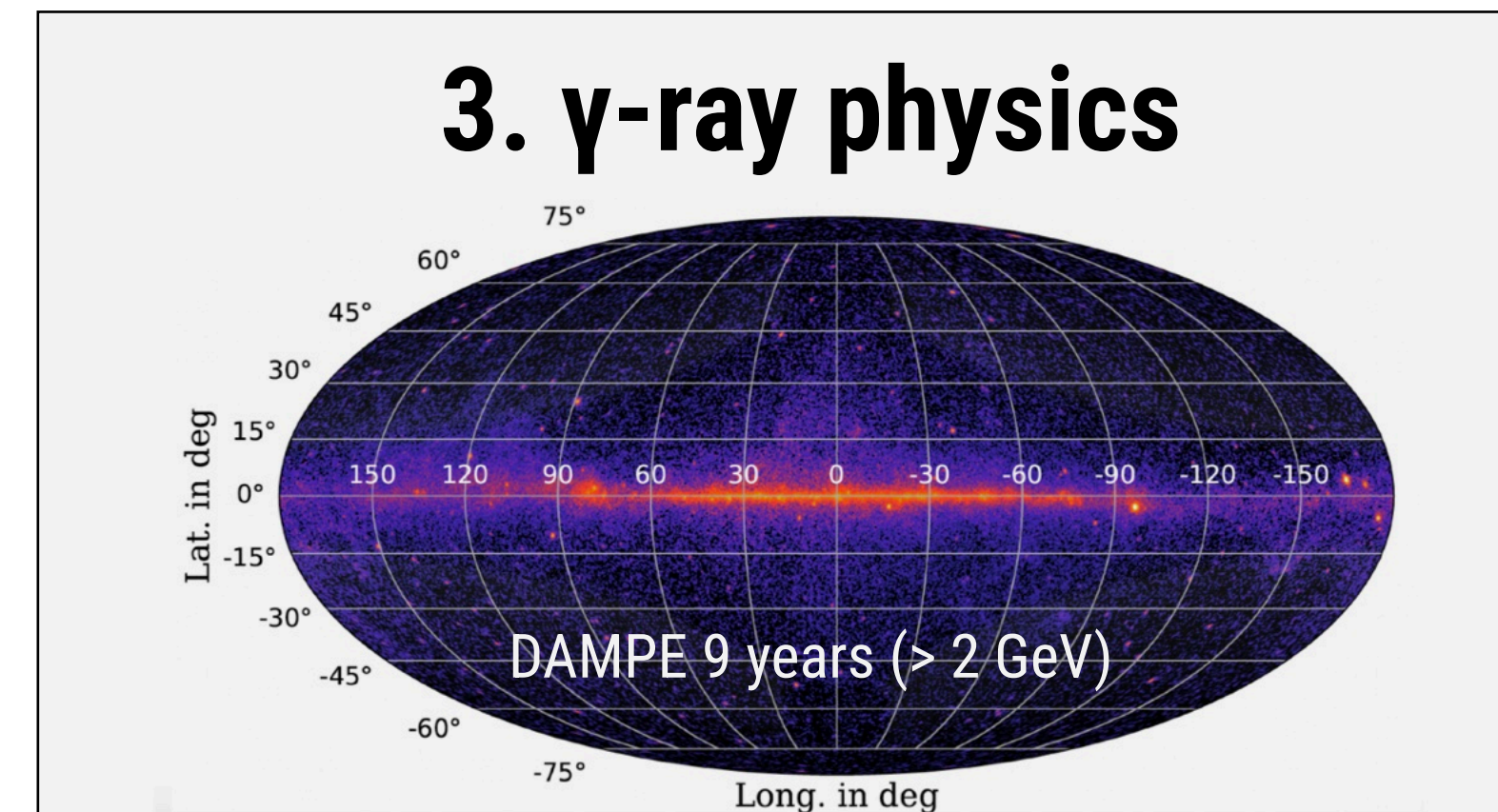
1. Cosmic Ray spectra at GeV - PeV



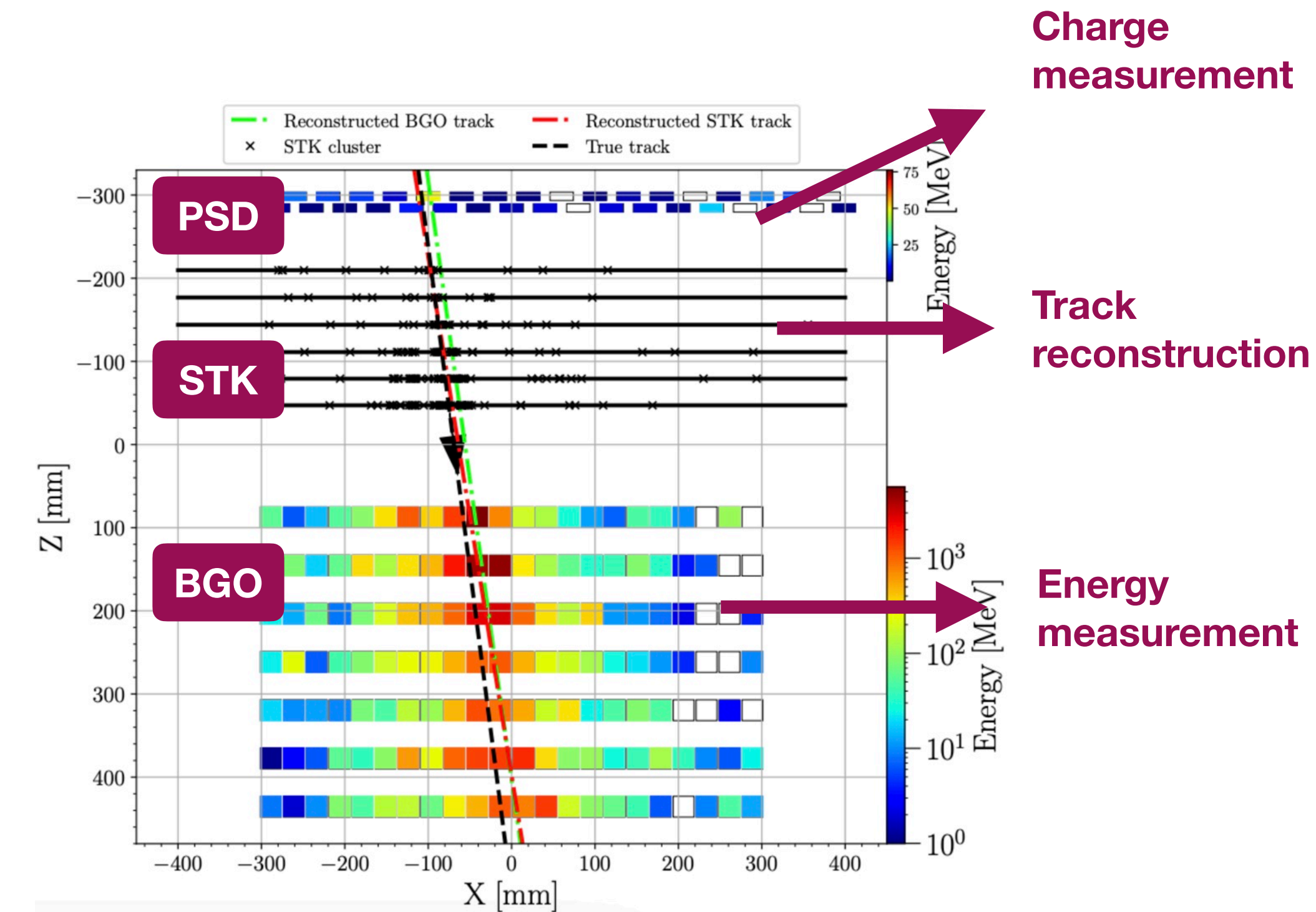
2. Indirect DM search (e^+e^- , γ -ray lines)



3. γ -ray physics

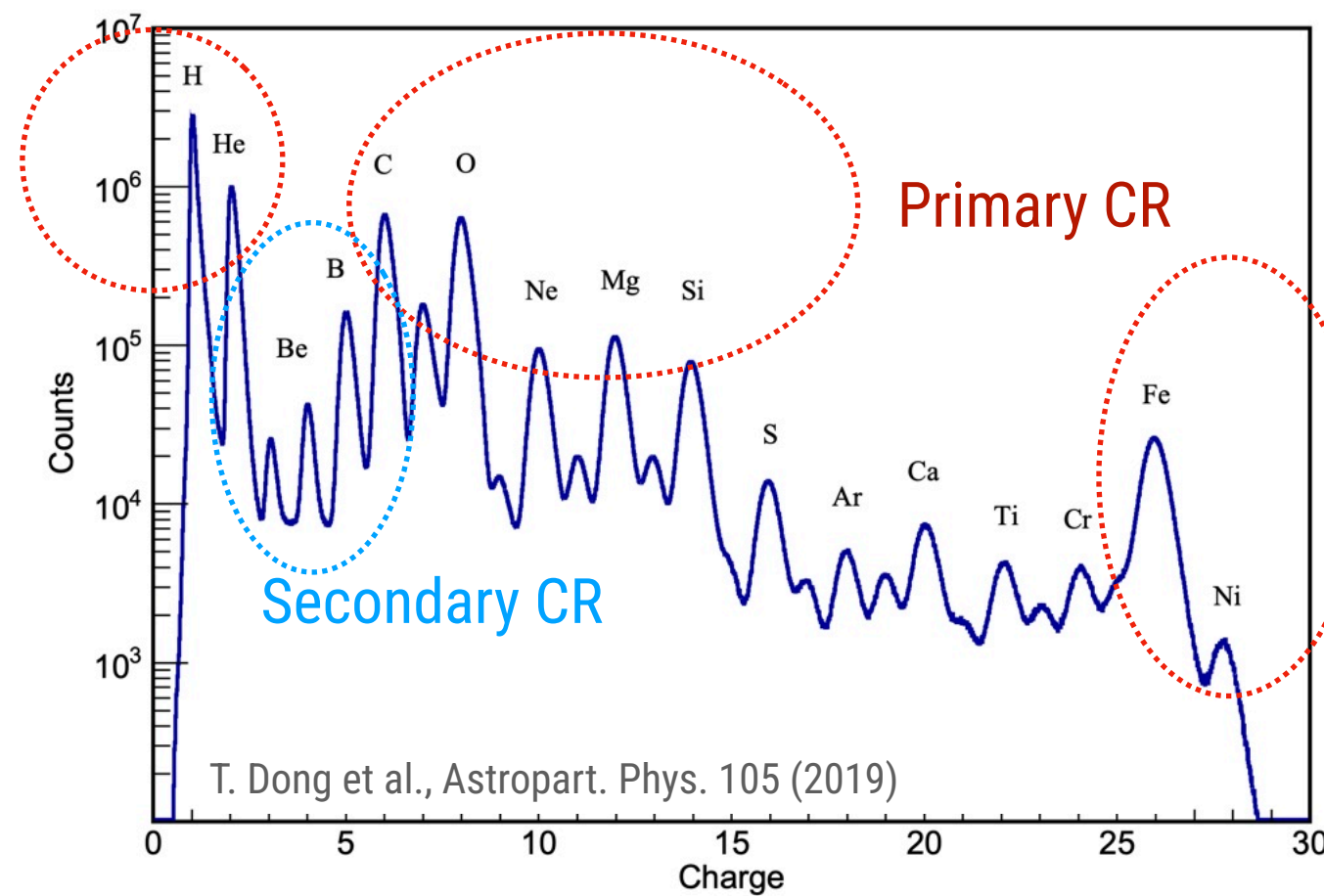


DAMPE Detector Calibration

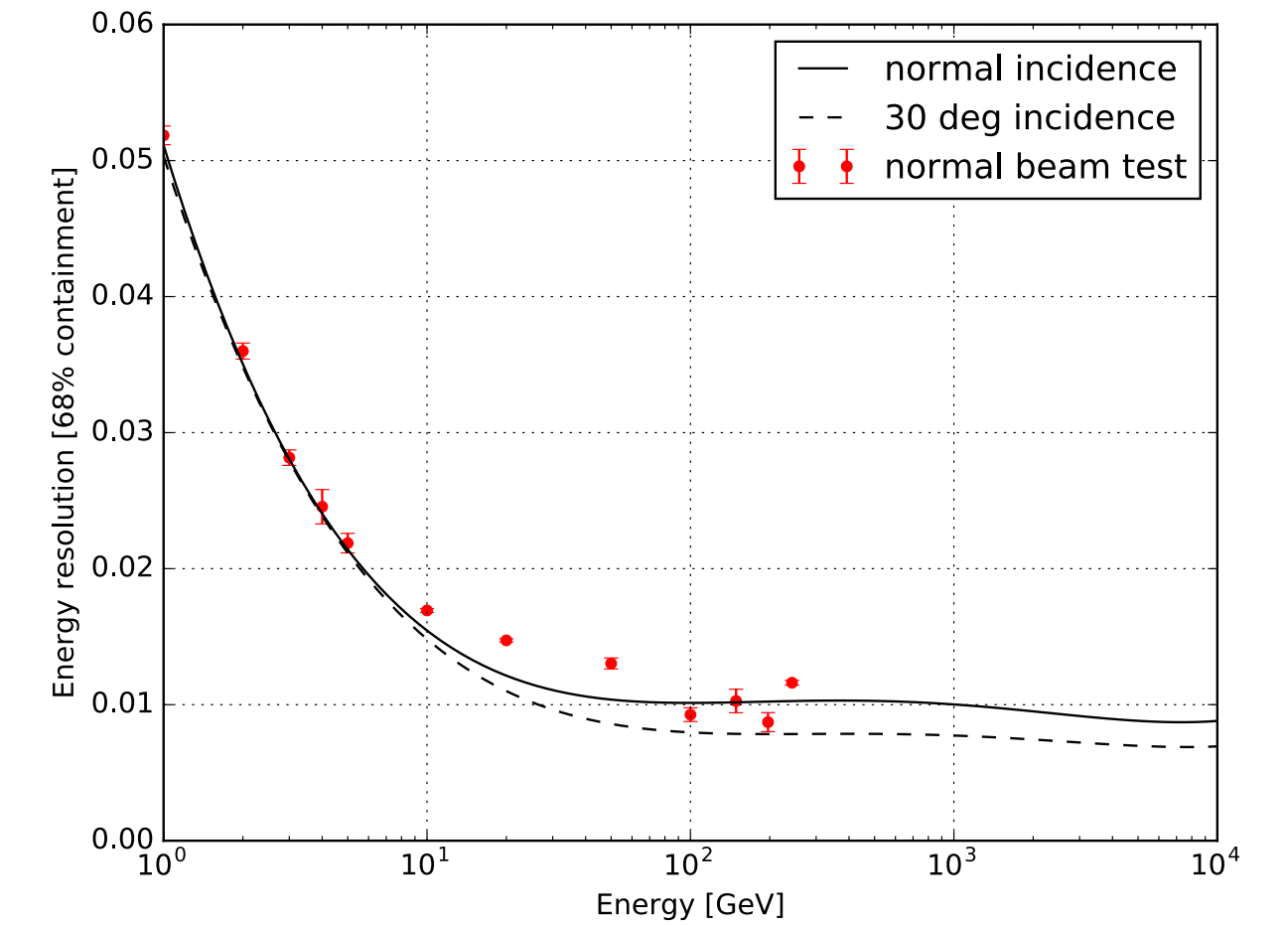


Energy reconstruction first tested on-ground with beams at CERN PS and SPS (e, p, ions)

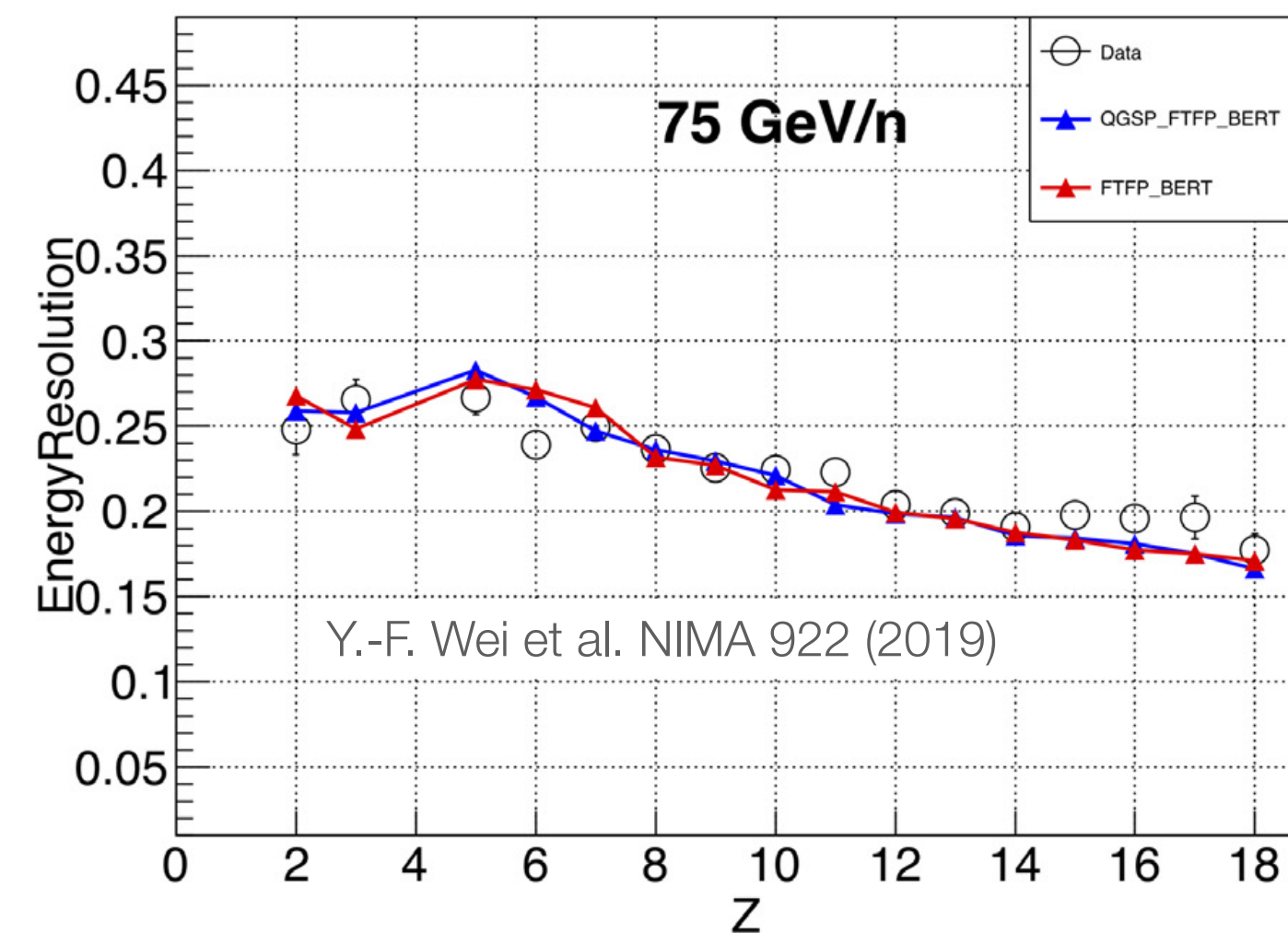
Charge reconstruction (flight data)



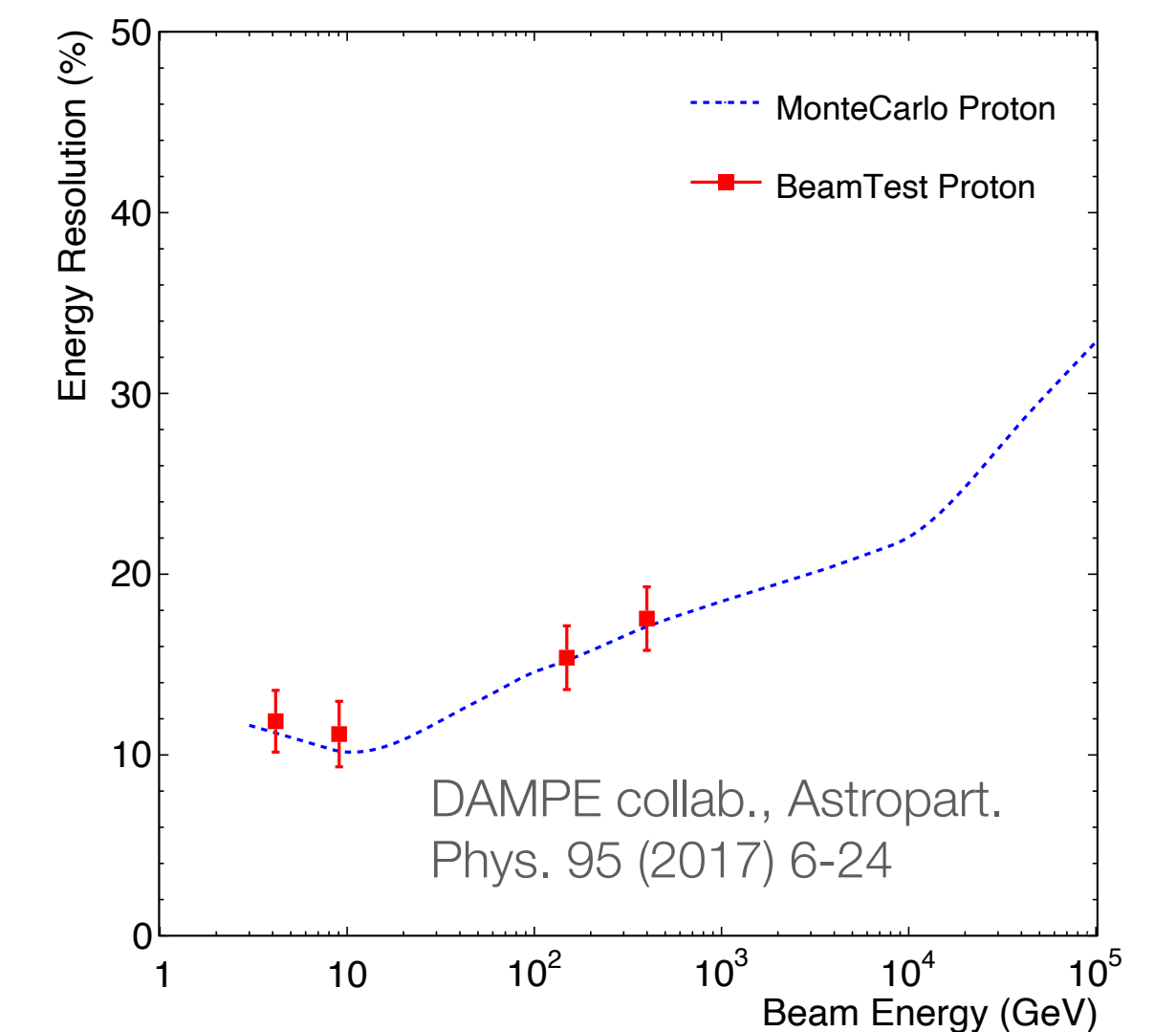
Energy resolution: electrons



Energy resolution: ions



Energy resolution: protons





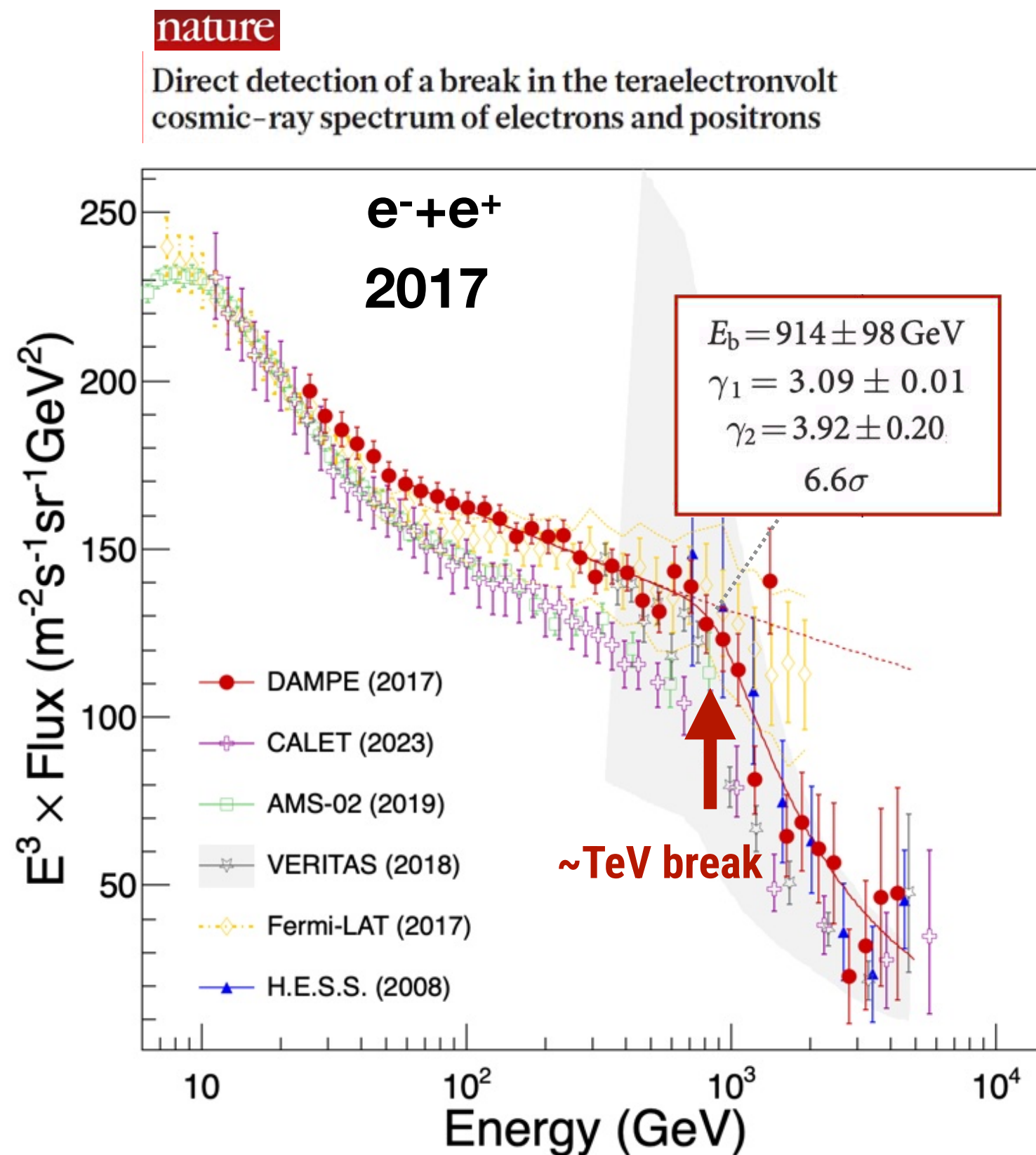
DAMPE's science (focus on recent results)

Electrons & Positrons

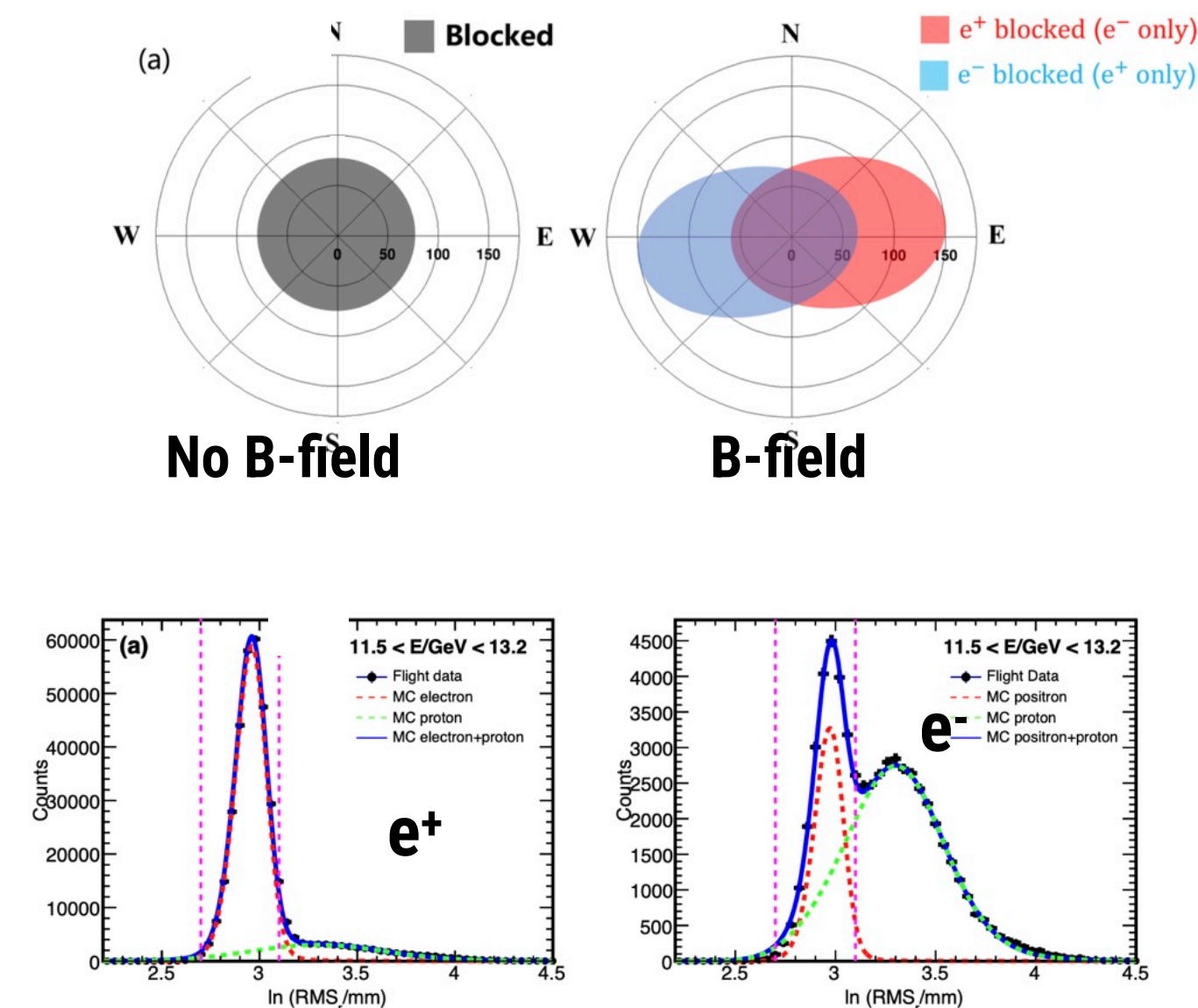


- Direct detection of a TeV break in CR electrons (2017)
➔ **measurement reaching 4.6 TeV**

- Exploit Earth shadow distorted by geomagnetic field to **measure e⁺ and e⁻ separately** (method pioneered by Fermi-LAT)



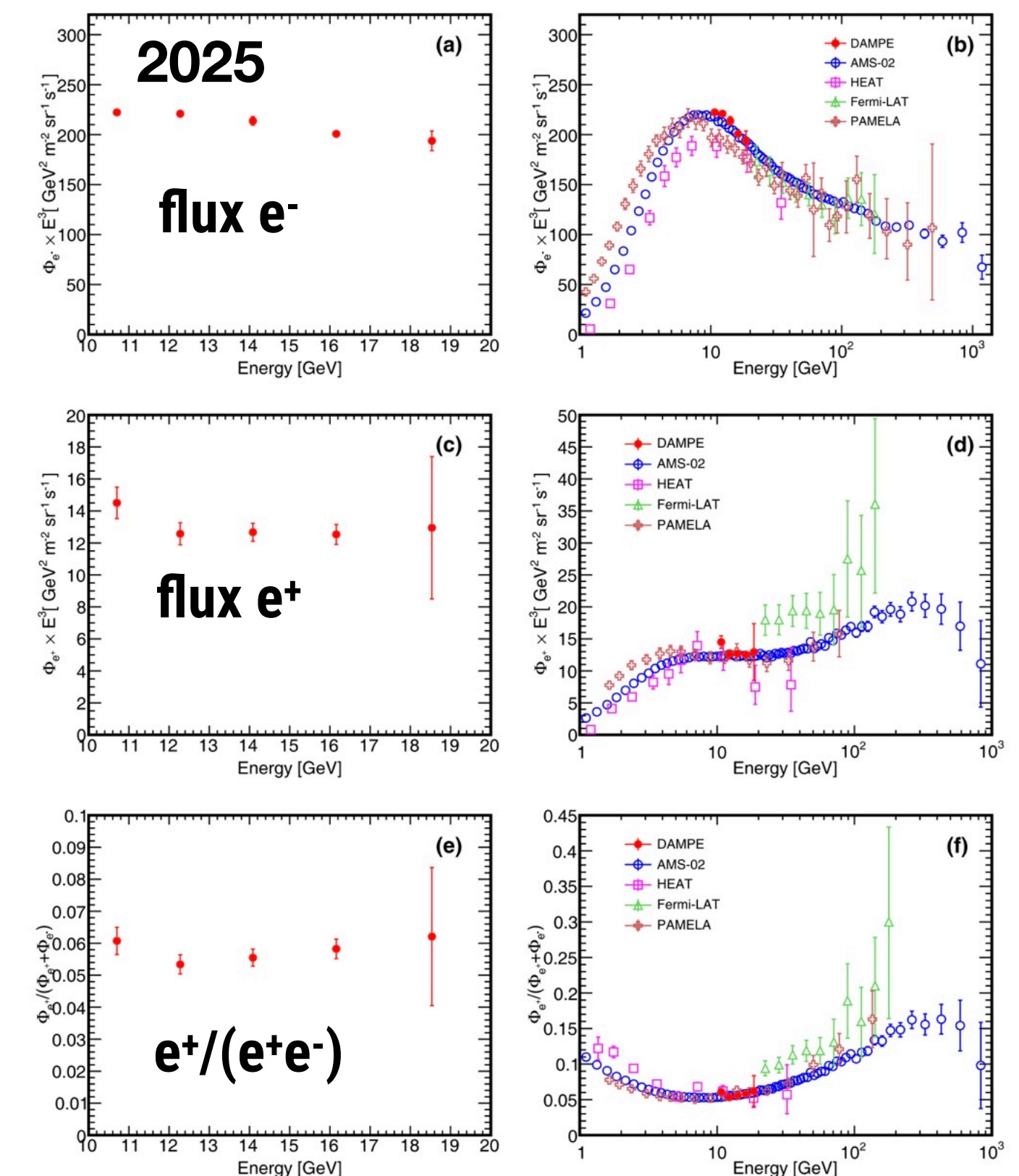
- ➔ **Analysis of 10 TeV region ongoing (extending fiducial volume, AI-based particle identification)...**



IOPscience

Chinese Physics C

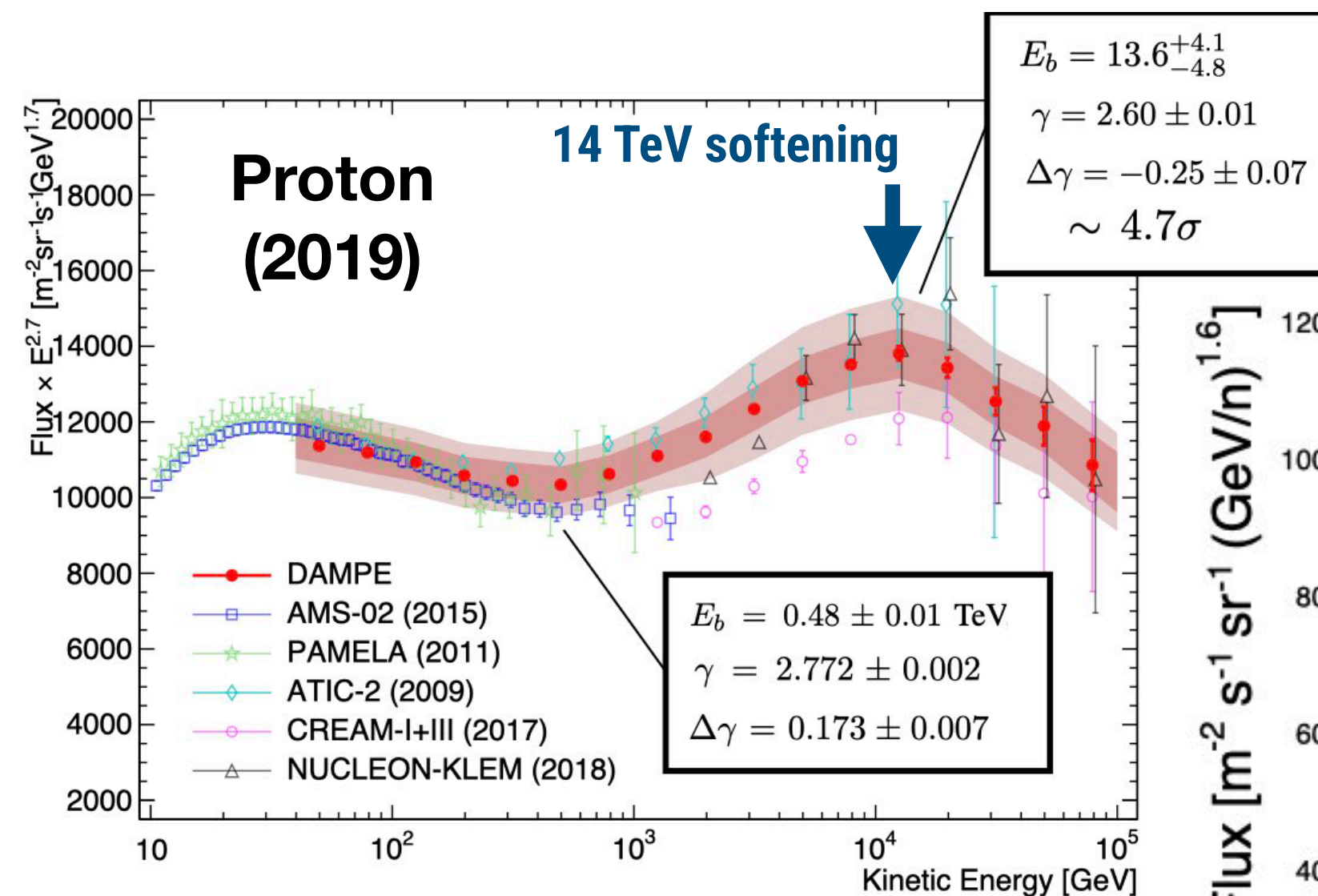
Measurement of separate electron and positron spectra from 10 to 20 GeV with the geomagnetic field on DAMPE*



Proton and Helium (published)

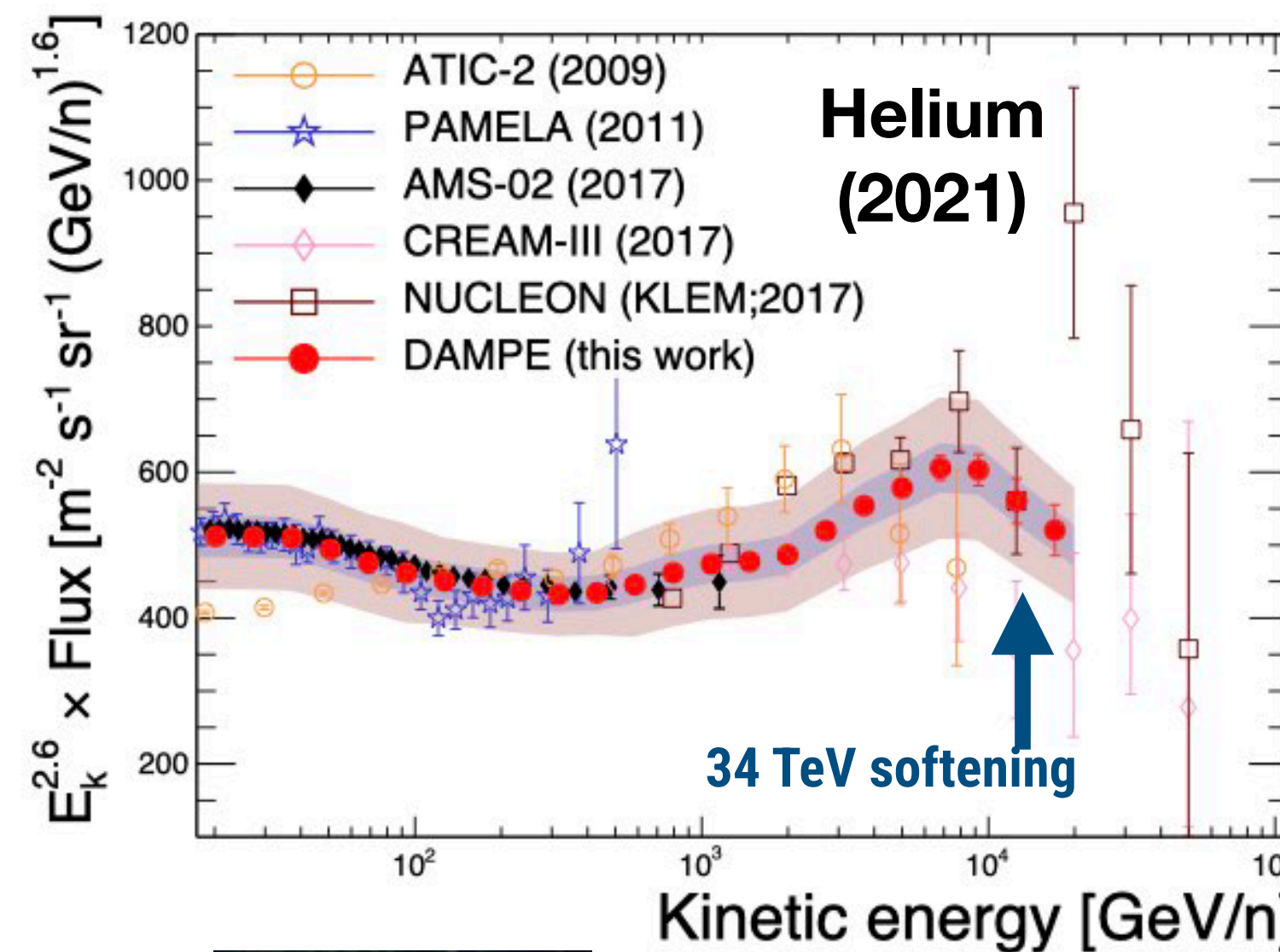


- Proton and helium spectra:
 - ➡ Detection of softening softening at high energies
 - ➡ Energy reach: 100 TeV for proton, 80 TeV for He



ScienceAdvances

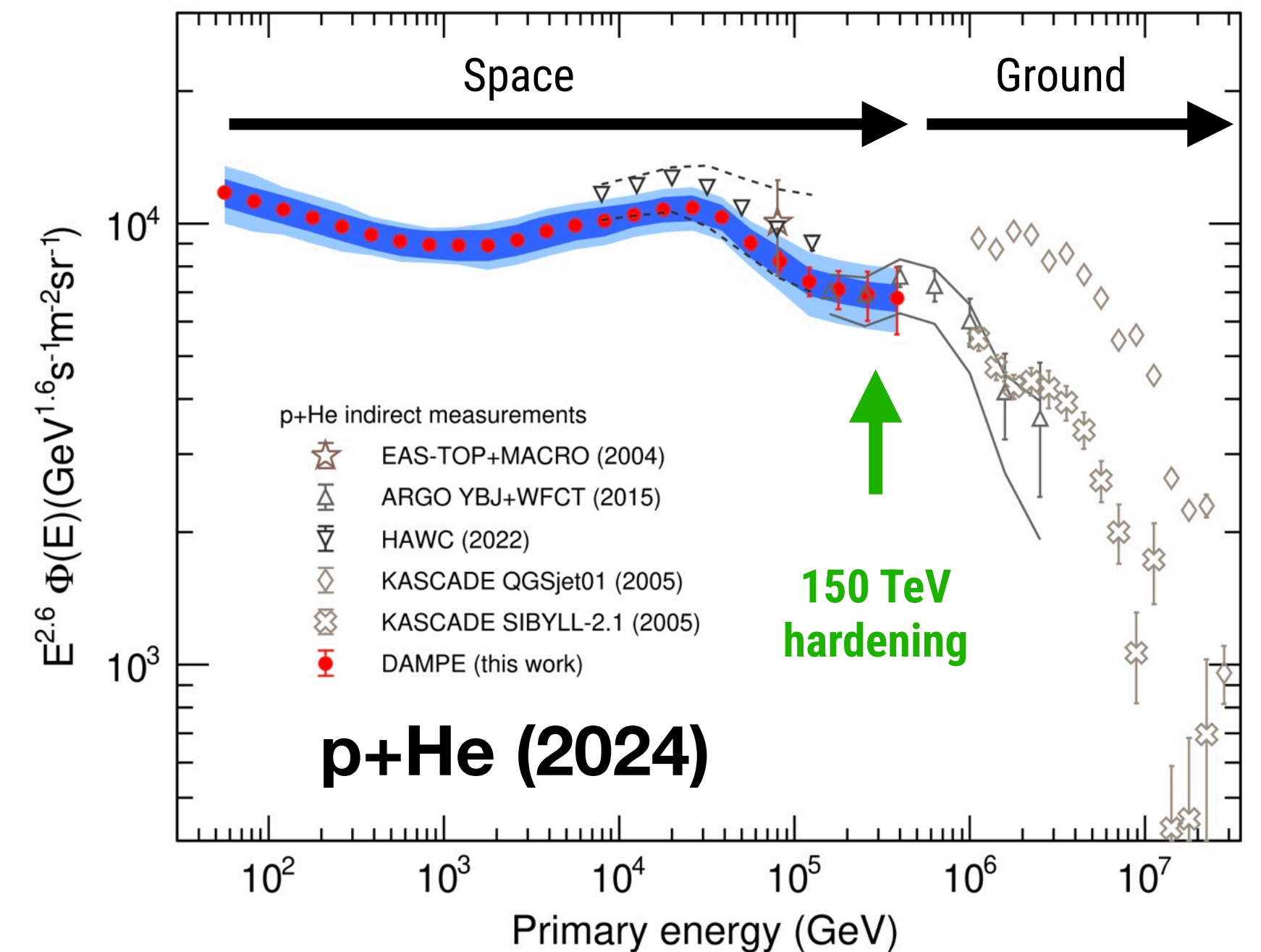
Measurement of the cosmic ray proton spectrum from 40 GeV to 100 TeV with the DAMPE satellite



Physical Review Letters

Measurement of the Cosmic Ray Helium Energy Spectrum from 70 GeV to 80 TeV with the DAMPE Space Mission

- Combined proton + helium:
 - ➡ Connection with ground based experiments
 - ➡ Confirms $> \sim 10$ TeV softening
 - ➡ Hint of a **hardening at ~ 150 TeV**



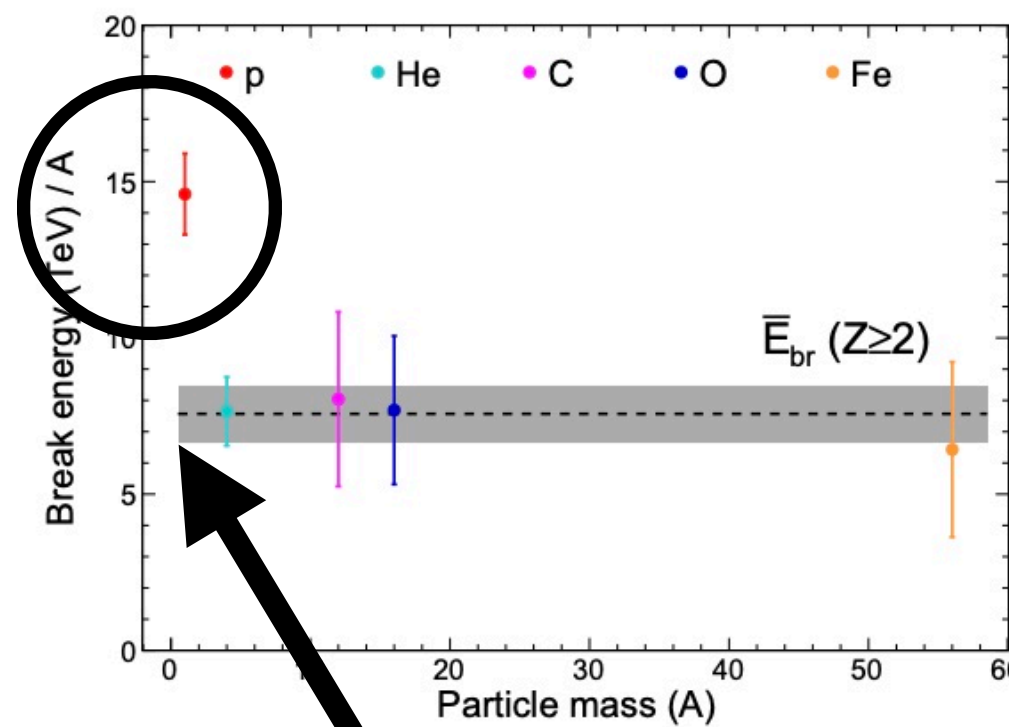
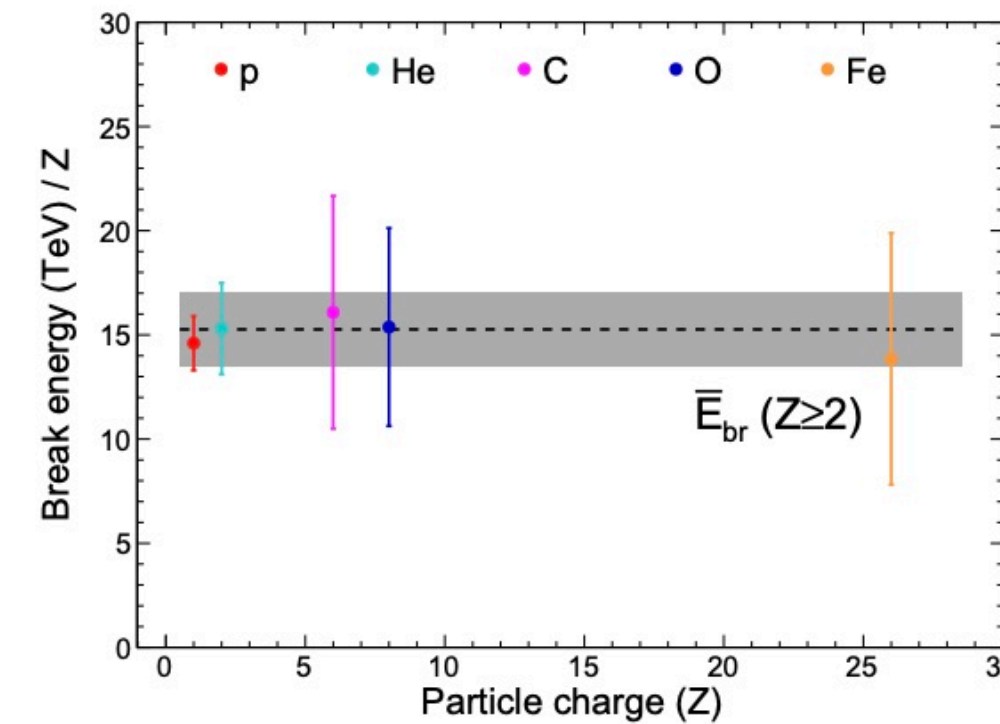
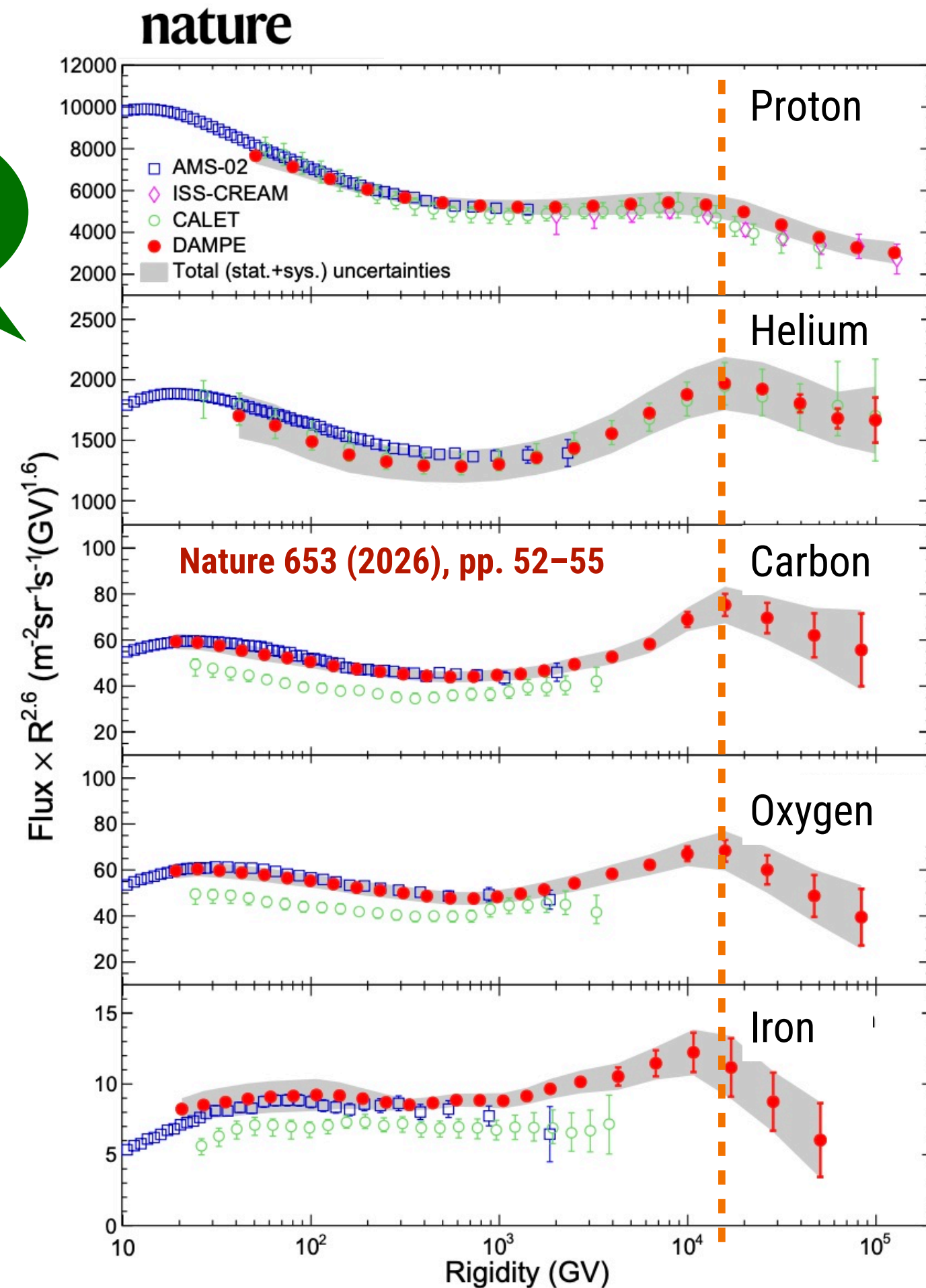
Physical Review D

Measurement of the cosmic $p + \text{He}$ energy spectrum from 50 GeV to 0.5 PeV with the DAMPE space mission

Universal softening in primaries (H, He, C, O, Fe)

- Updated proton and helium spectra, **newly released carbon, oxygen and iron spectra**:
 - ➔ 9 years of data, AI techniques used for improved particle ID (tracking, also in calorimeter reconstruction at high energies)
 - ➔ **Softening structure is universal for all measured primary CR → takes place at 15 TV!**

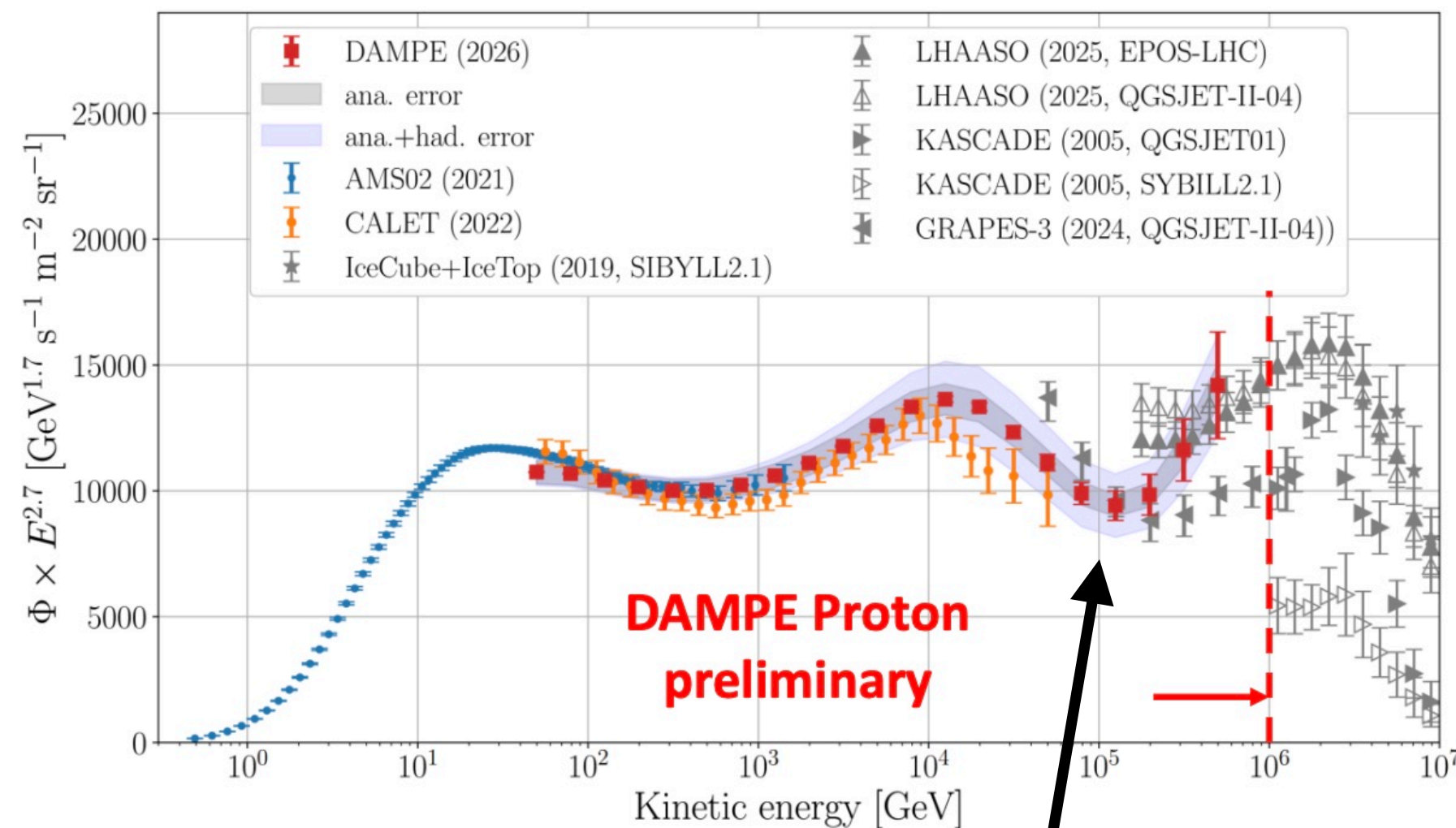
New!!!



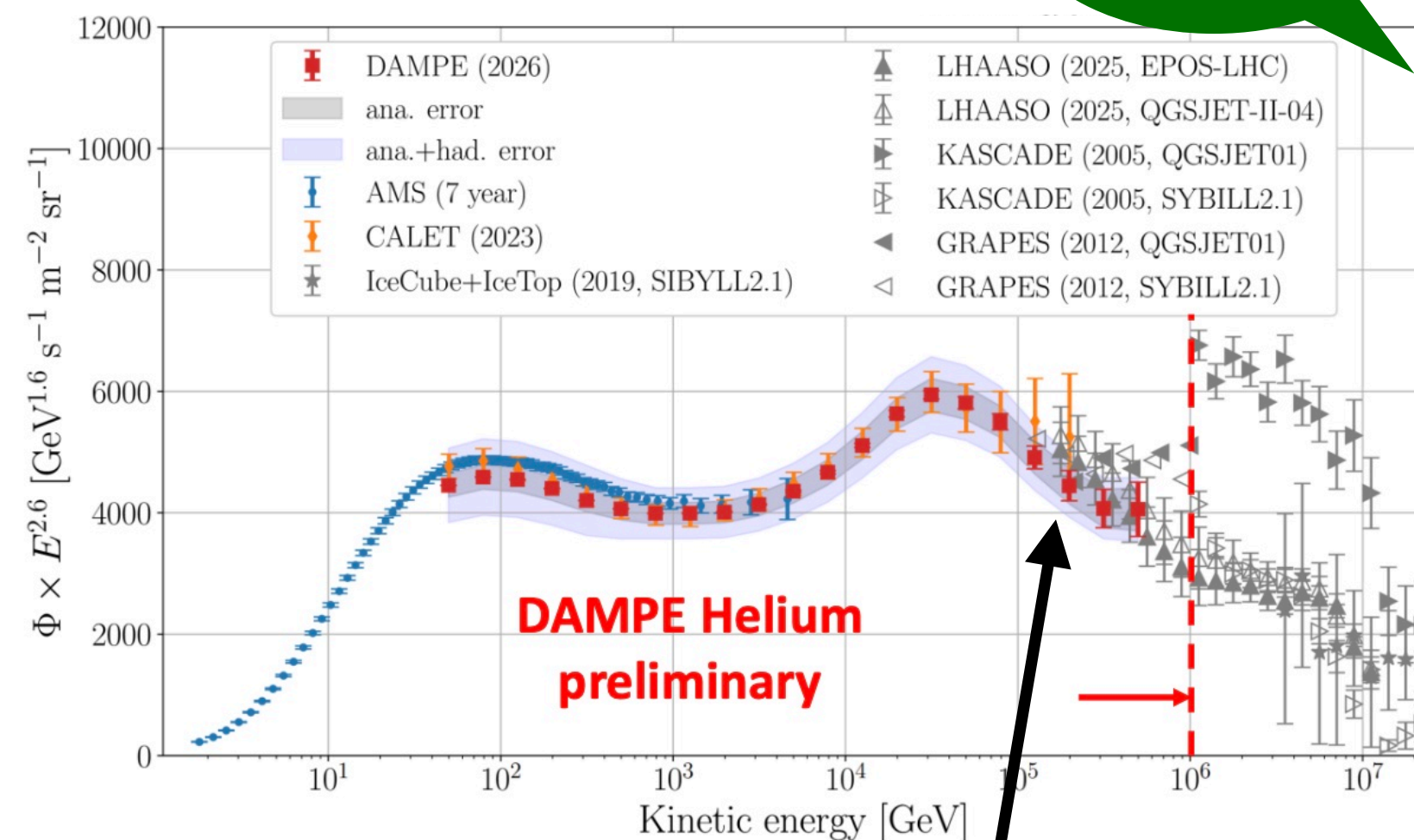
Proton and Helium (update towards PeV)



- Update proton and helium spectra:
 - ➡ 10 years of data
 - ➡ Novel particle ID using AI cosmic ray track reconstruction (+30% increased acceptance)
 - ➡ Improved hadronic model (using DAMPE-measured cross sections)

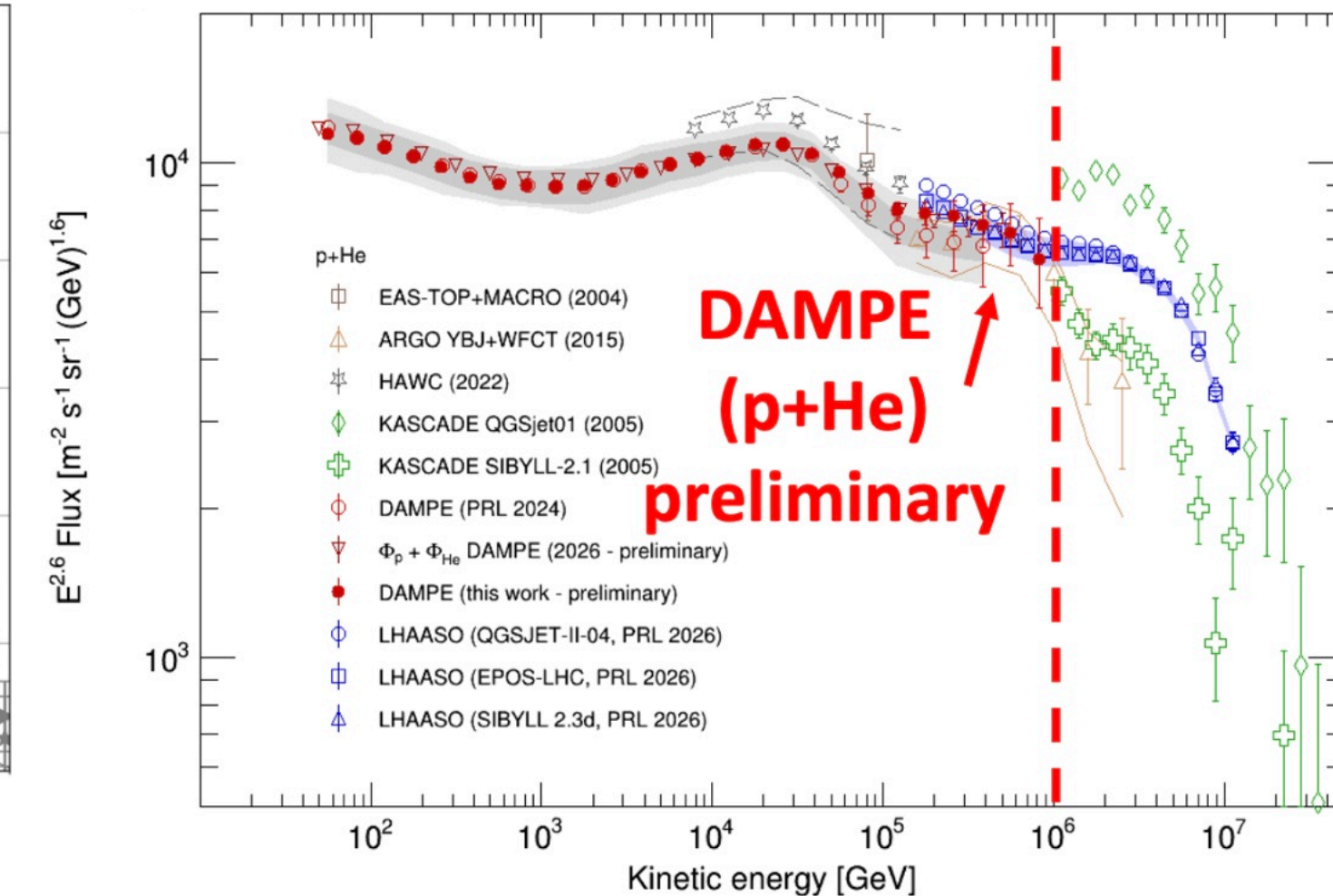


Proton flux shows a hardening at ~150 TeV



Not enough statistics above 300 TeV to check for a new hardening for He

New!!!

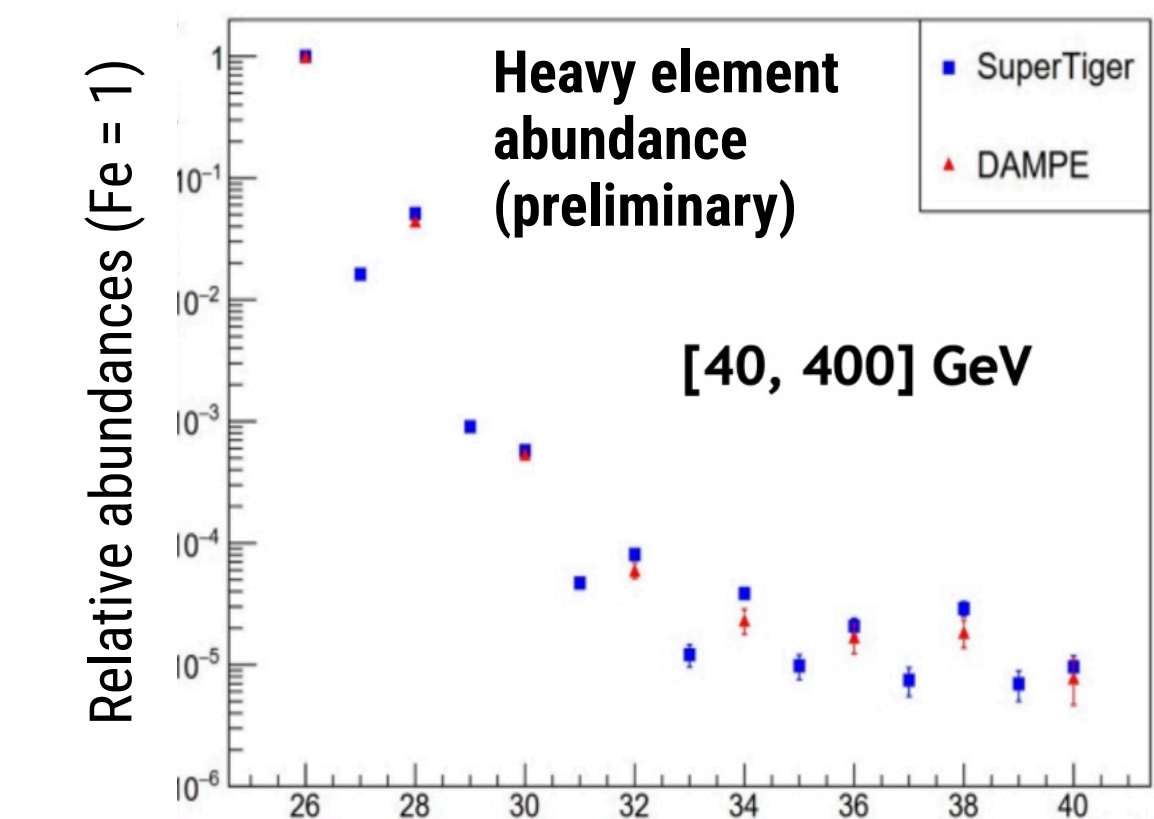
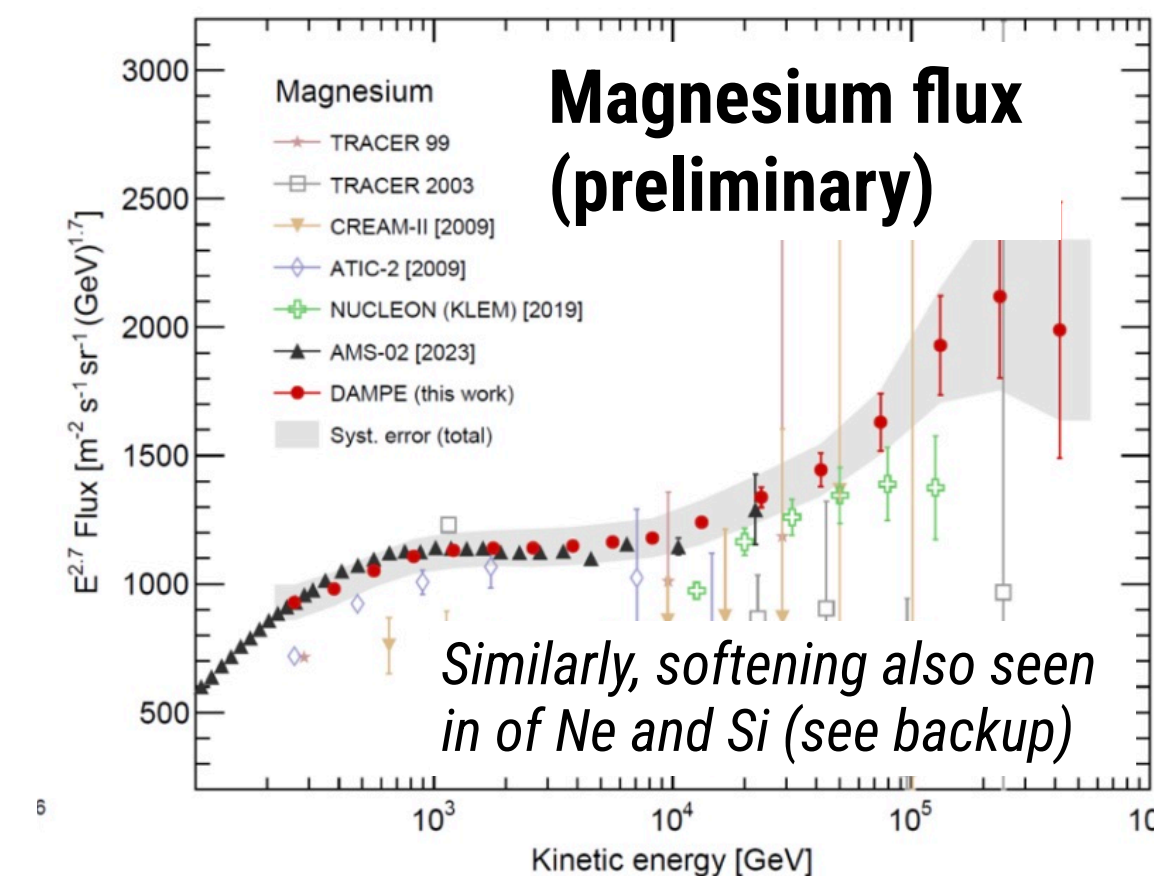
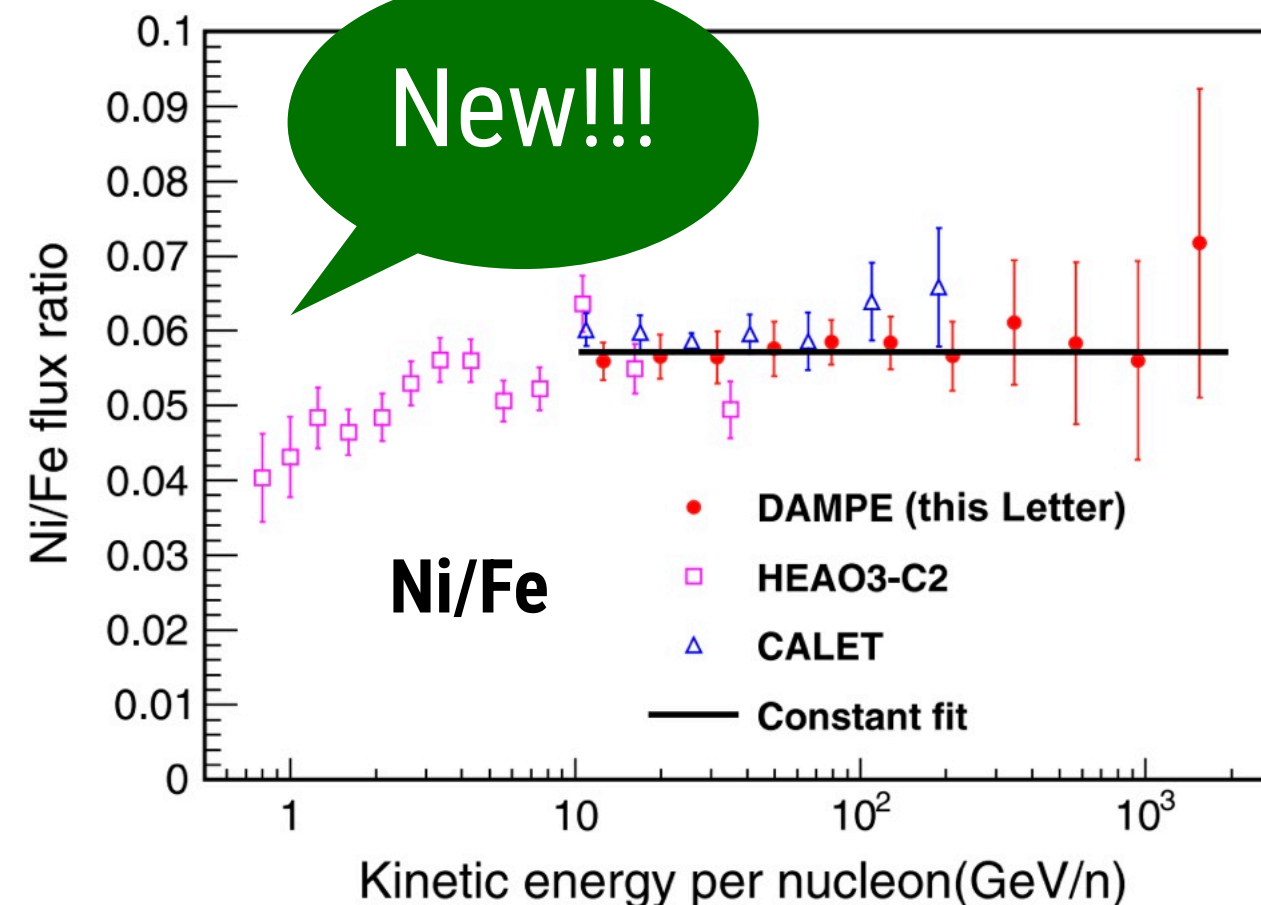
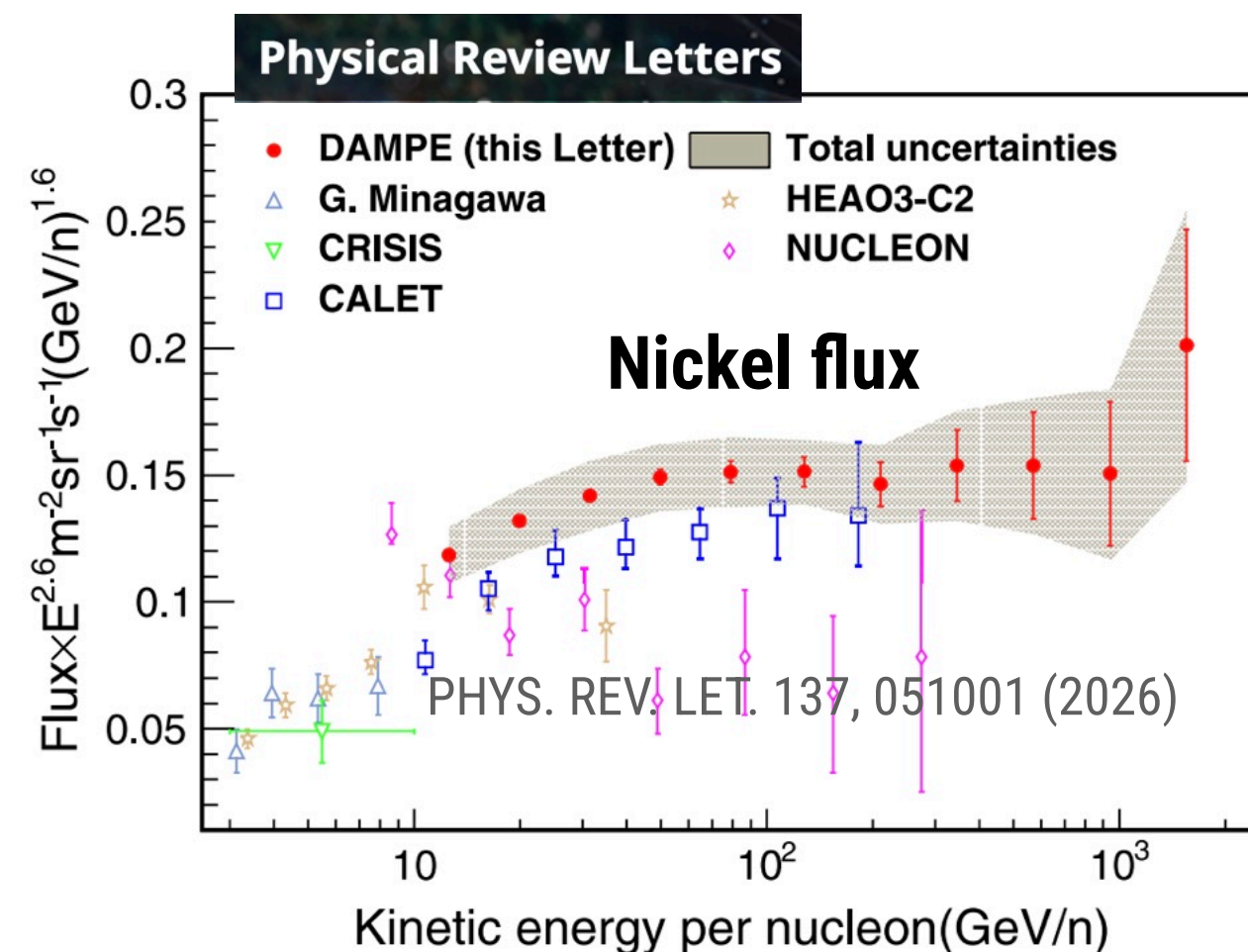


Independent (p+He) measurement is consistent with the sum of the individual p and He fluxes

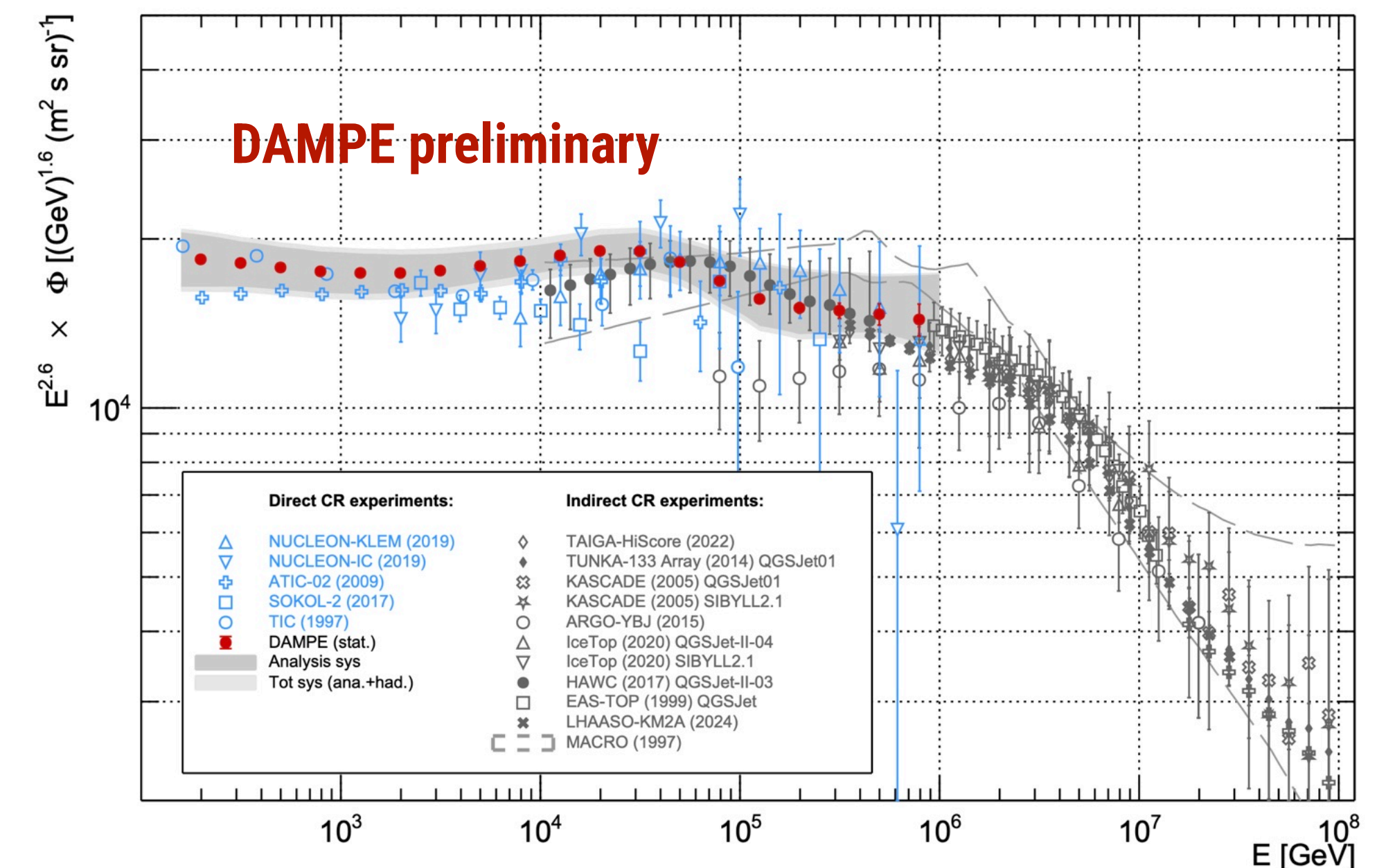
Beyond Fe, intermediate nuclei, all-particle spectrum



- First direct measurement of cosmic ray Nickel spectrum reaching to ~2TeV/n!
- Intermediate nuclei spectra (Ne, Mg, Si group and S, Ar, Ca group) in process ...
- Measurement of trans-iron element abundances in process ...

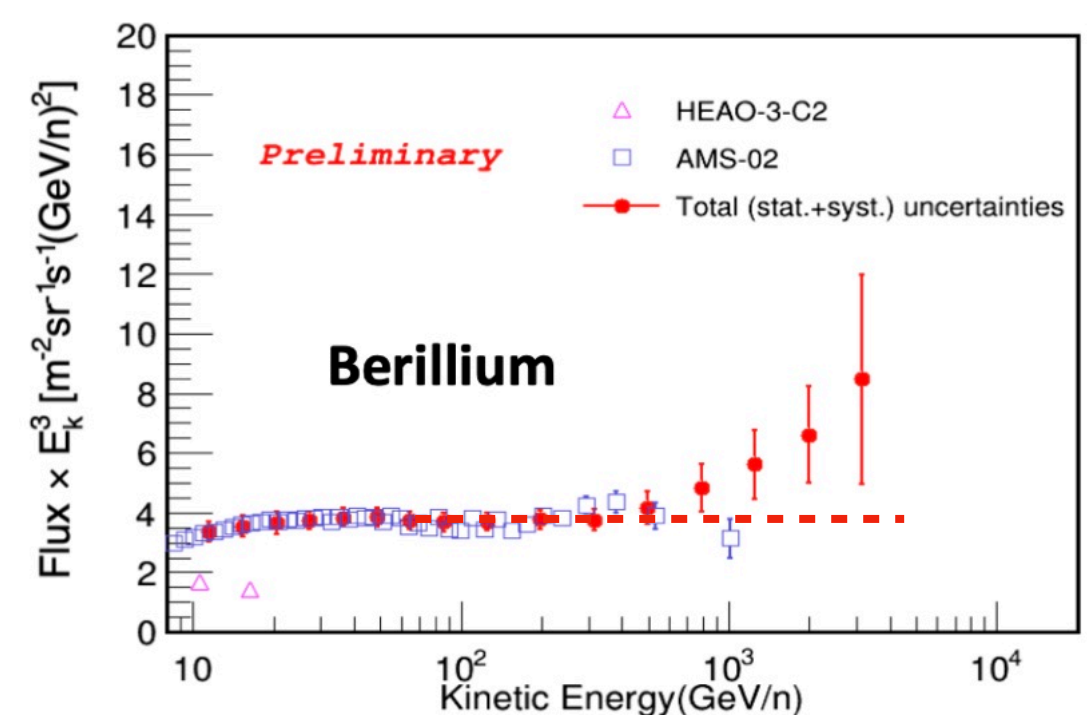
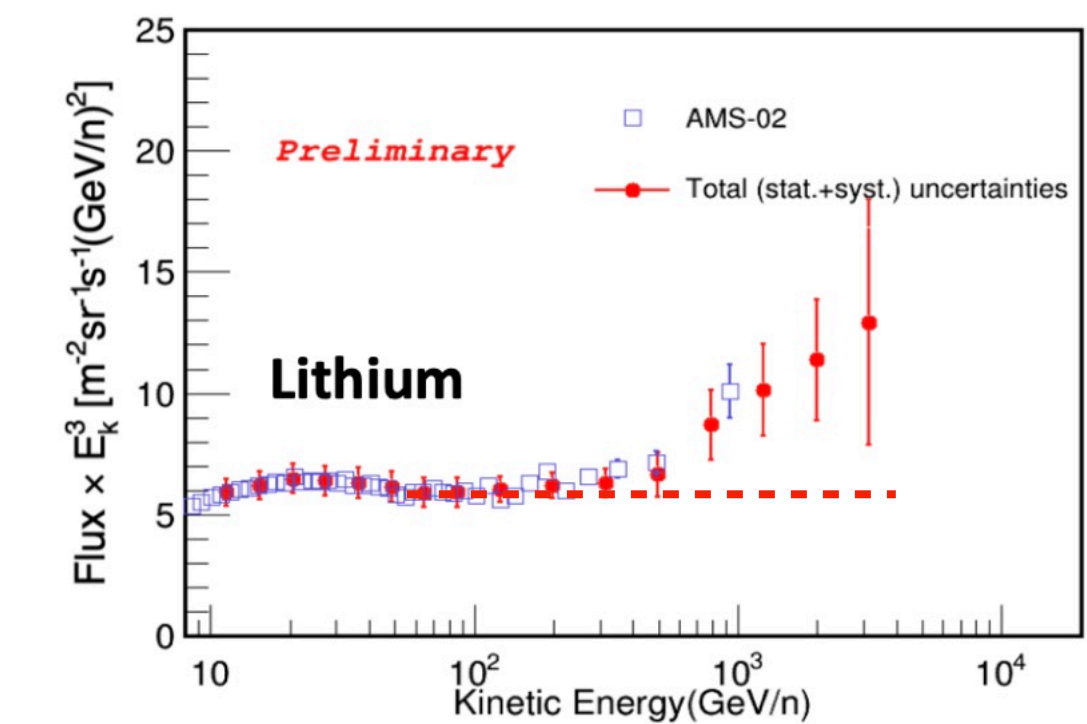
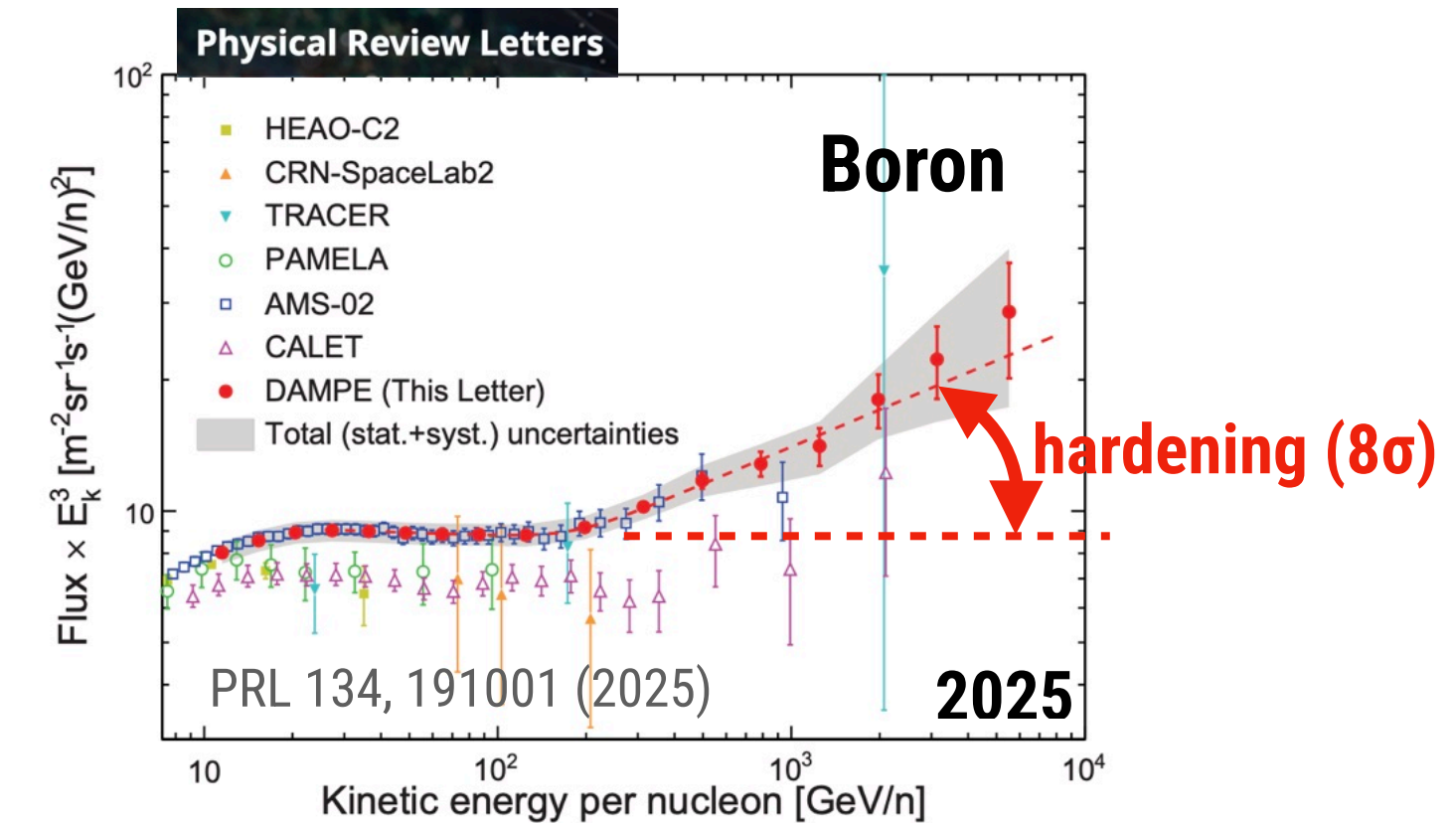
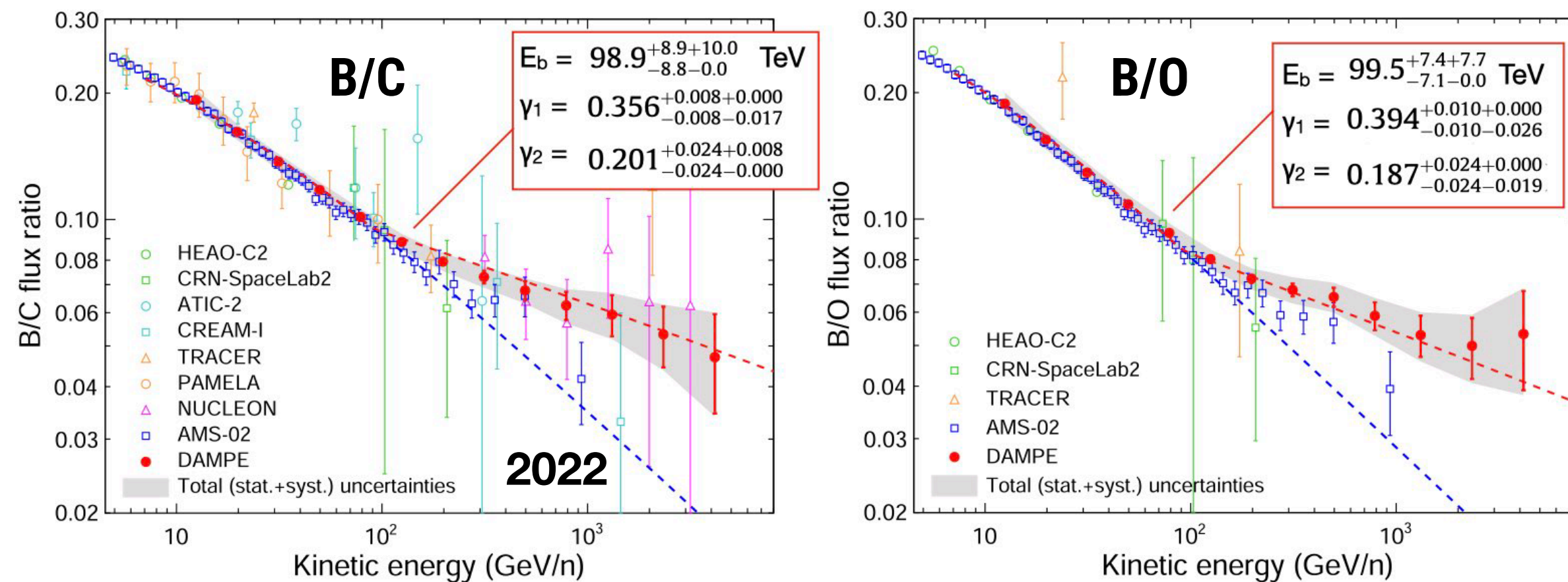


- All-particle spectrum measurement spanning 4 orders of magnitude in energy!

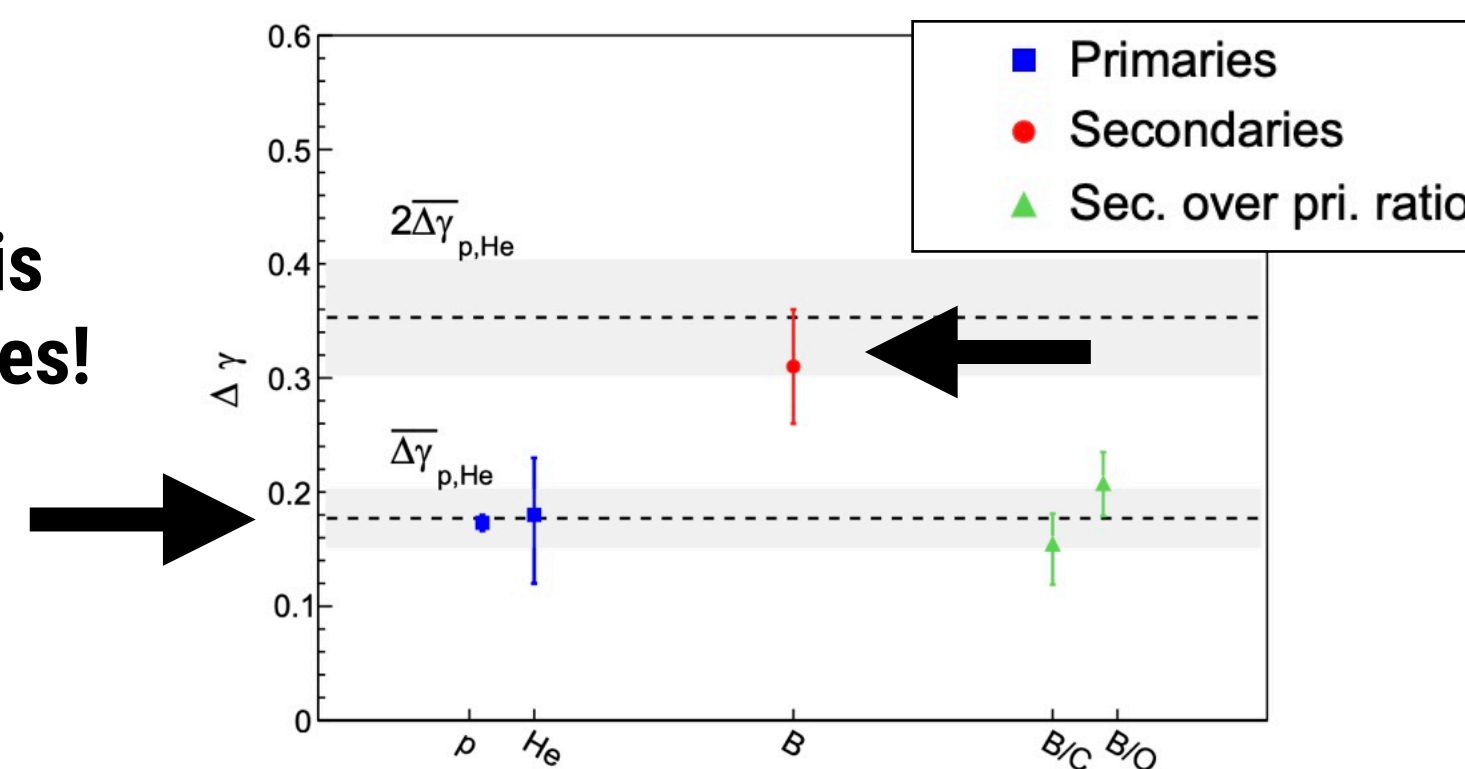


CR secondaries, ratios

- Detection of spectral hardening at ~ 100 GeV/n.
Indication of change of the CR diffusion coefficient?
- Observation of Hardening in Boron,
Preliminary lithium and beryllium
fluxes exhibit similar behavior



Spectral break in secondaries is
~2 times larger than in primaries!

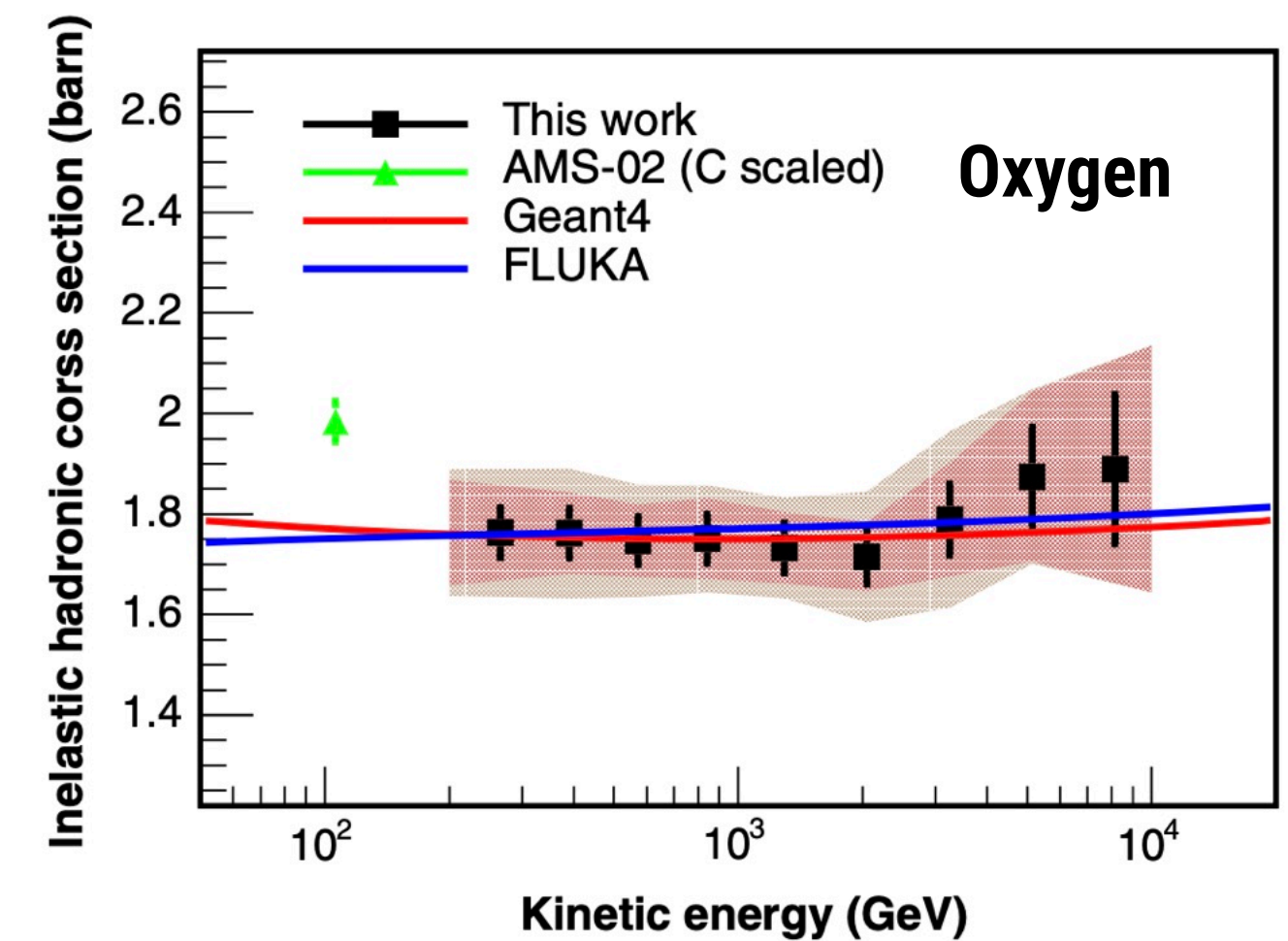
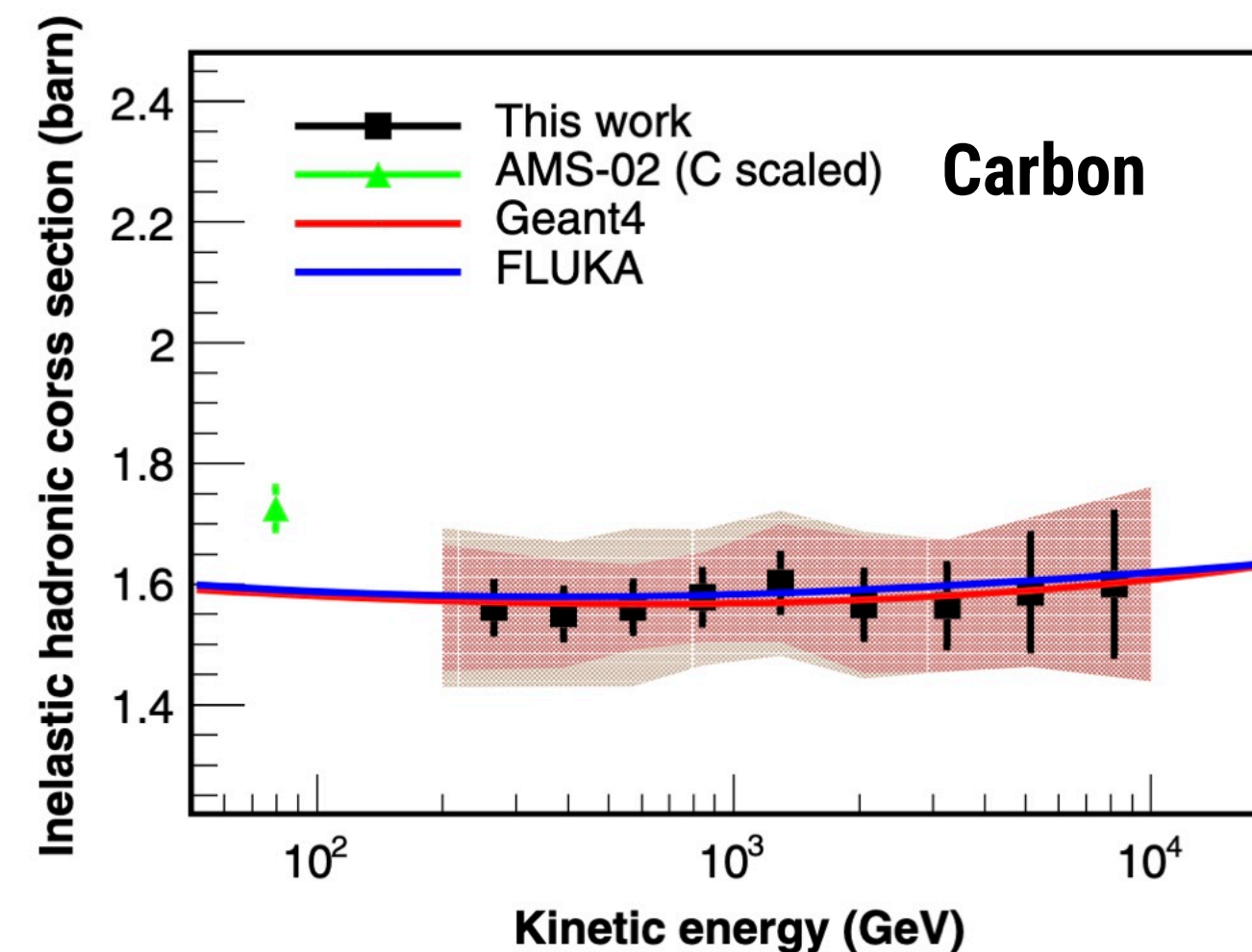
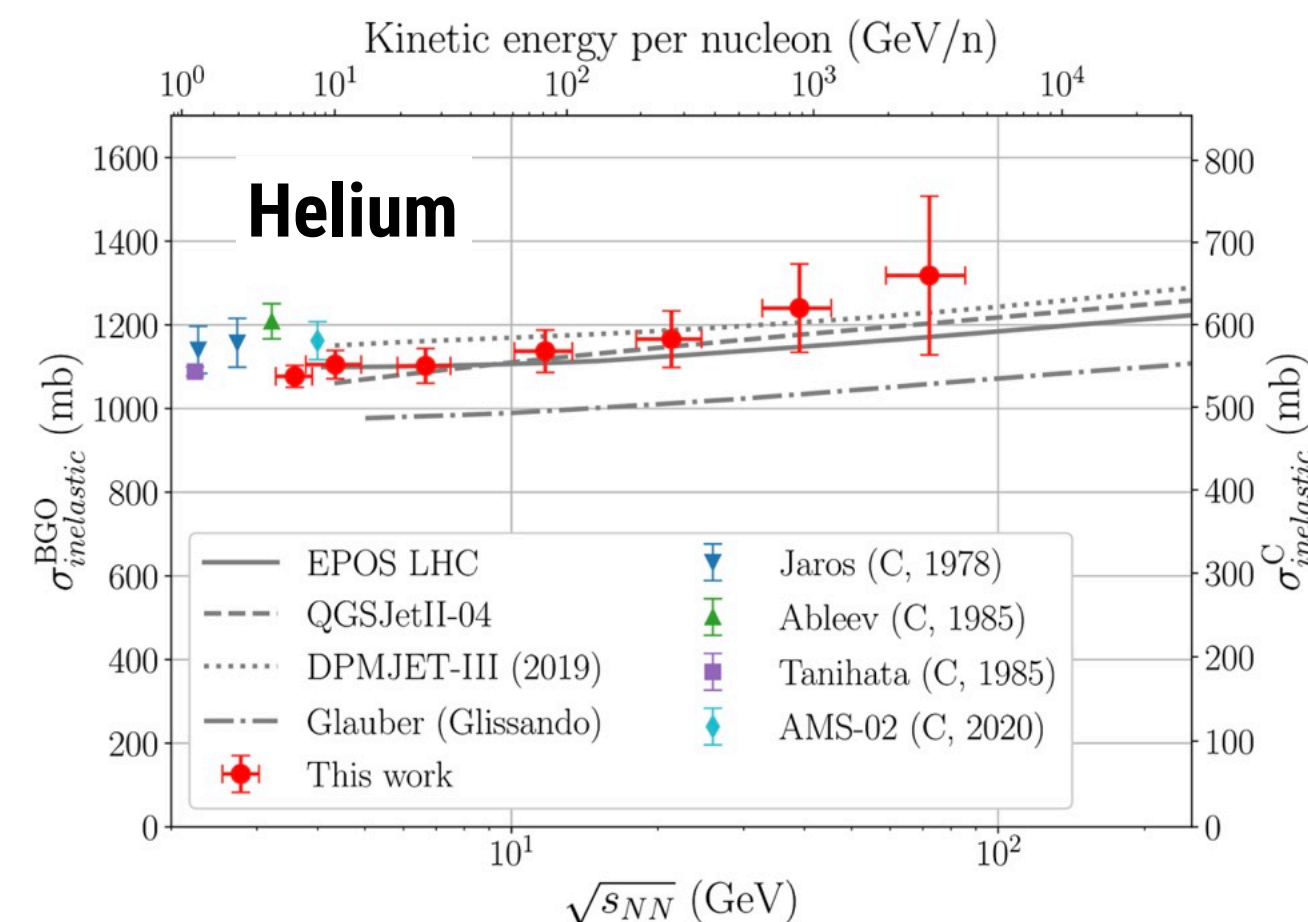
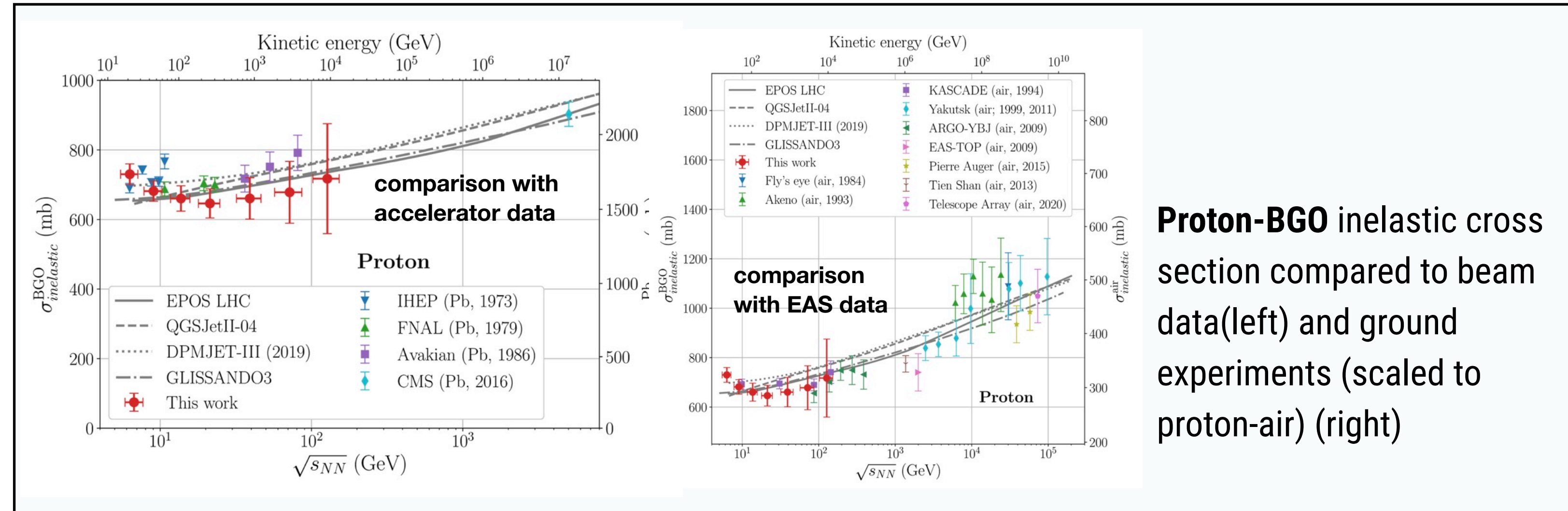
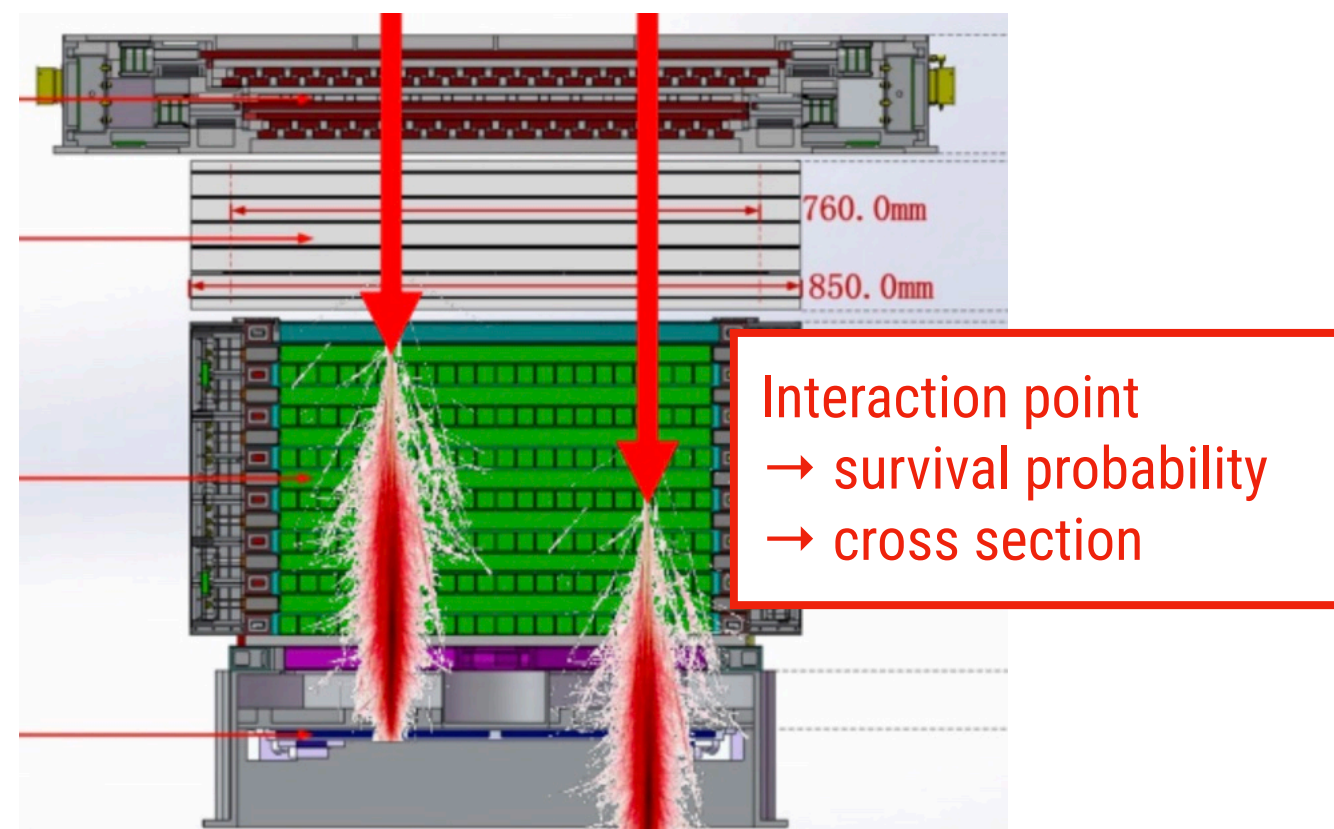


No structure in secondary ratios
(Li/B, Be/B - see backup)

Inelastic cross sections on BGO target (H, He, C, O)

DAMPE as "beam-target" experiment:

- Beam: Cosmic Rays
- Target: BGO ($\text{Bi}_4\text{Ge}_4\text{O}_{12}$)



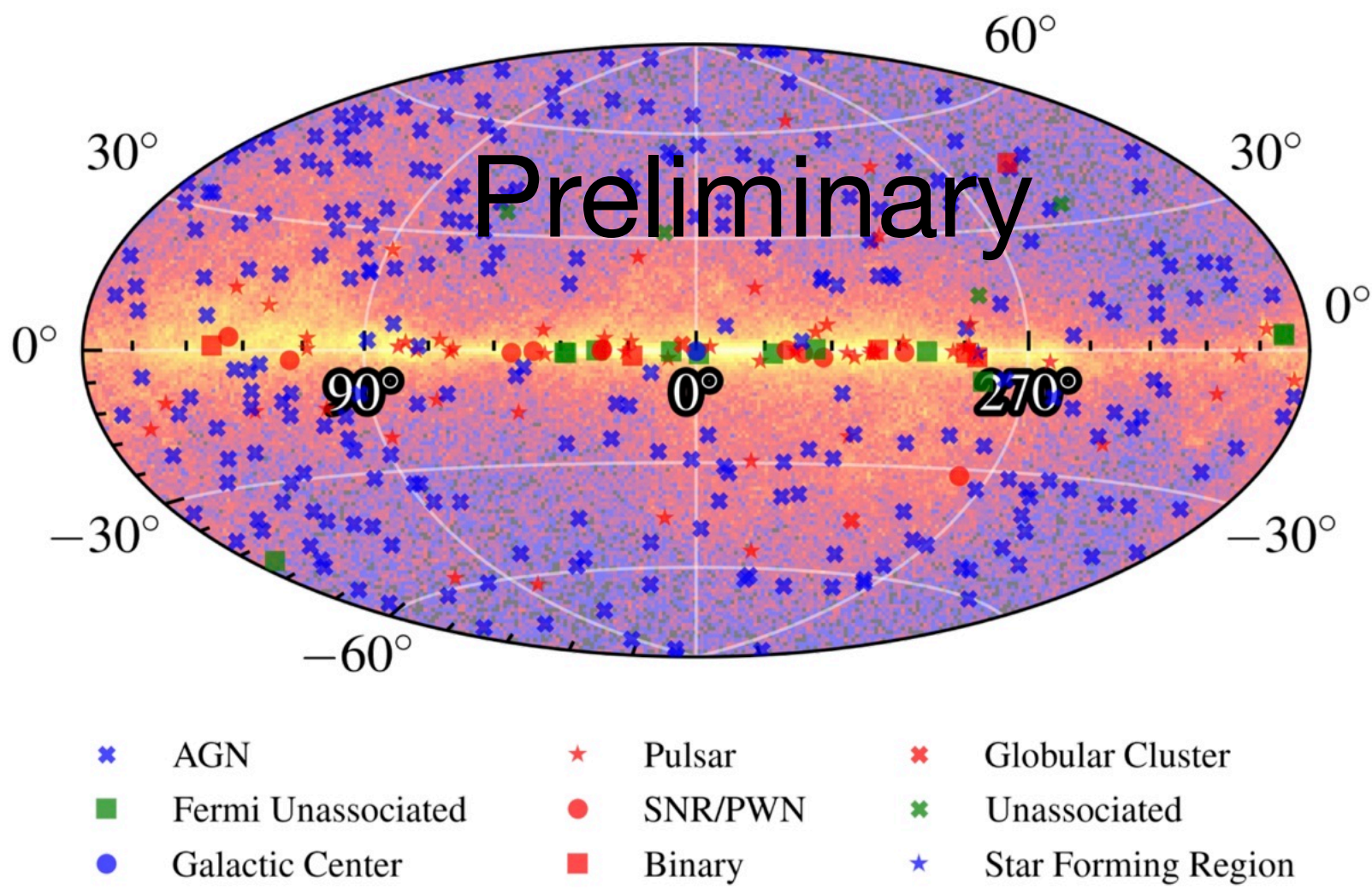
Physical Review D

PHYS. REV. D 111, 012002 (2025)
PHYS. REV. D 112, 022004 (2025)

Gamma rays: sources, dark matter



- Point sources



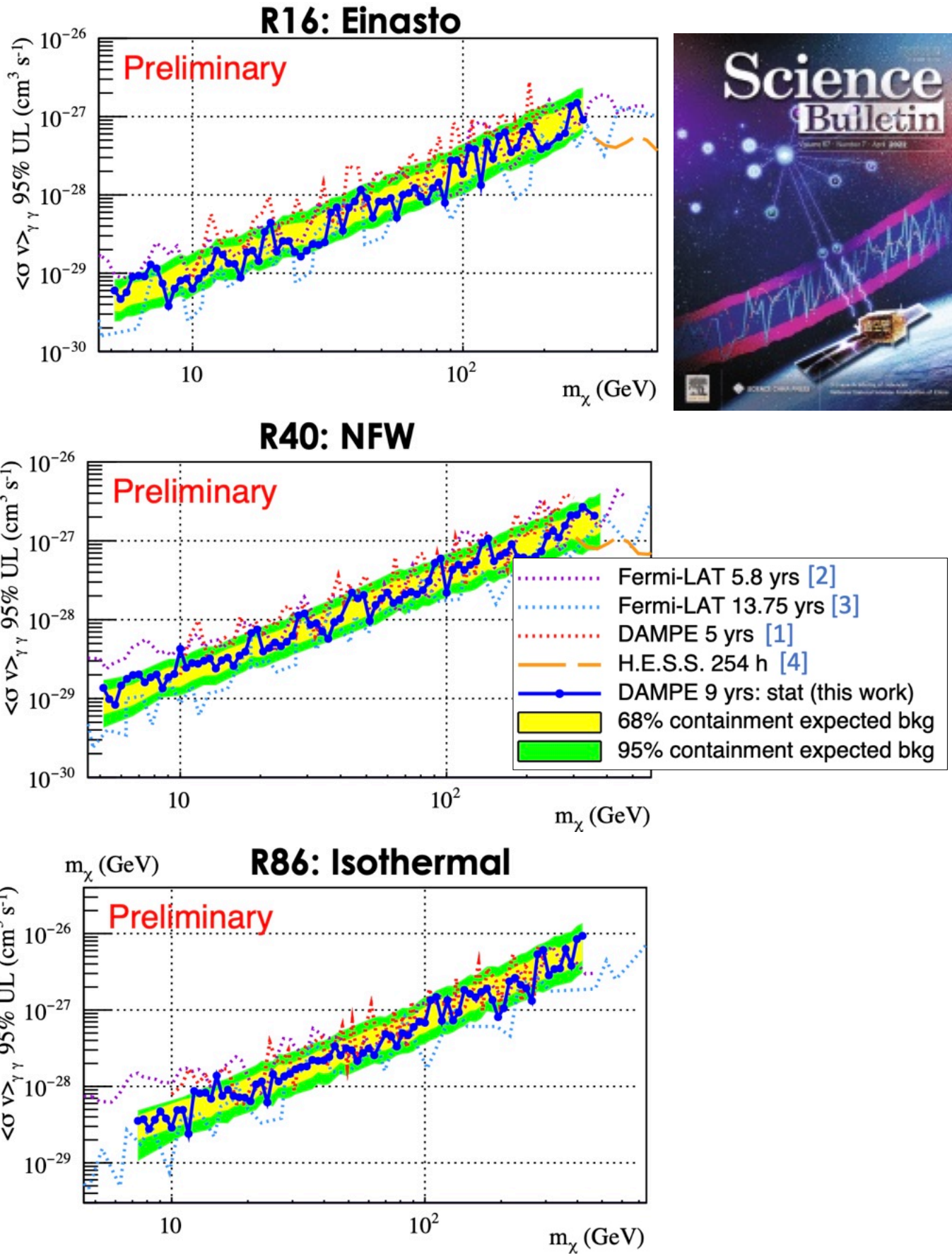
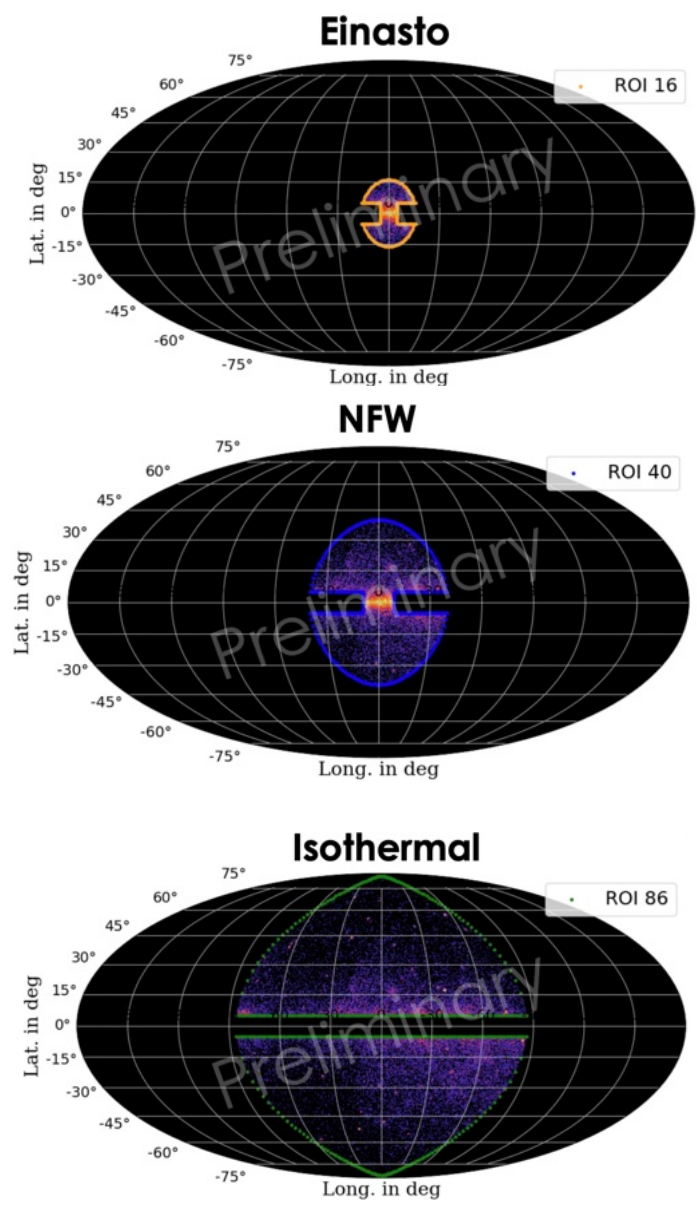
Source type	Number
AGN	261
Pulsar	61
SNR/PWN	11
Binary system	6
Globular Cluster	2
Star Forming Region	1
Galactic Center	1
Fermi Unassociated	12
Unassociated	4
Total	359

73% are AGNs.

(8.6 years of data)

<http://dgdb.pmo.ac.cn/dampe/>

- Dark Matter line search



- Gamma-ray line → DM signal
 - ➡ Excellent energy resolution of DAMPE → **ideal for line search**
 - ➡ 9 years of data (previously published with 5 years)
 - ➡ improved gamma-ray reconstruction techniques (ML)

Gamma rays: Fermi Bubbles, Galactic Center Excess



Fermi Bubbles (FB) diffuse structures discovered by Fermi-LAT

- DAMPE FB detection at $\sim 26\sigma$ with 8.5 years of data
- Spectrum consistent with Fermi-LAT

Galactic Center Excess:

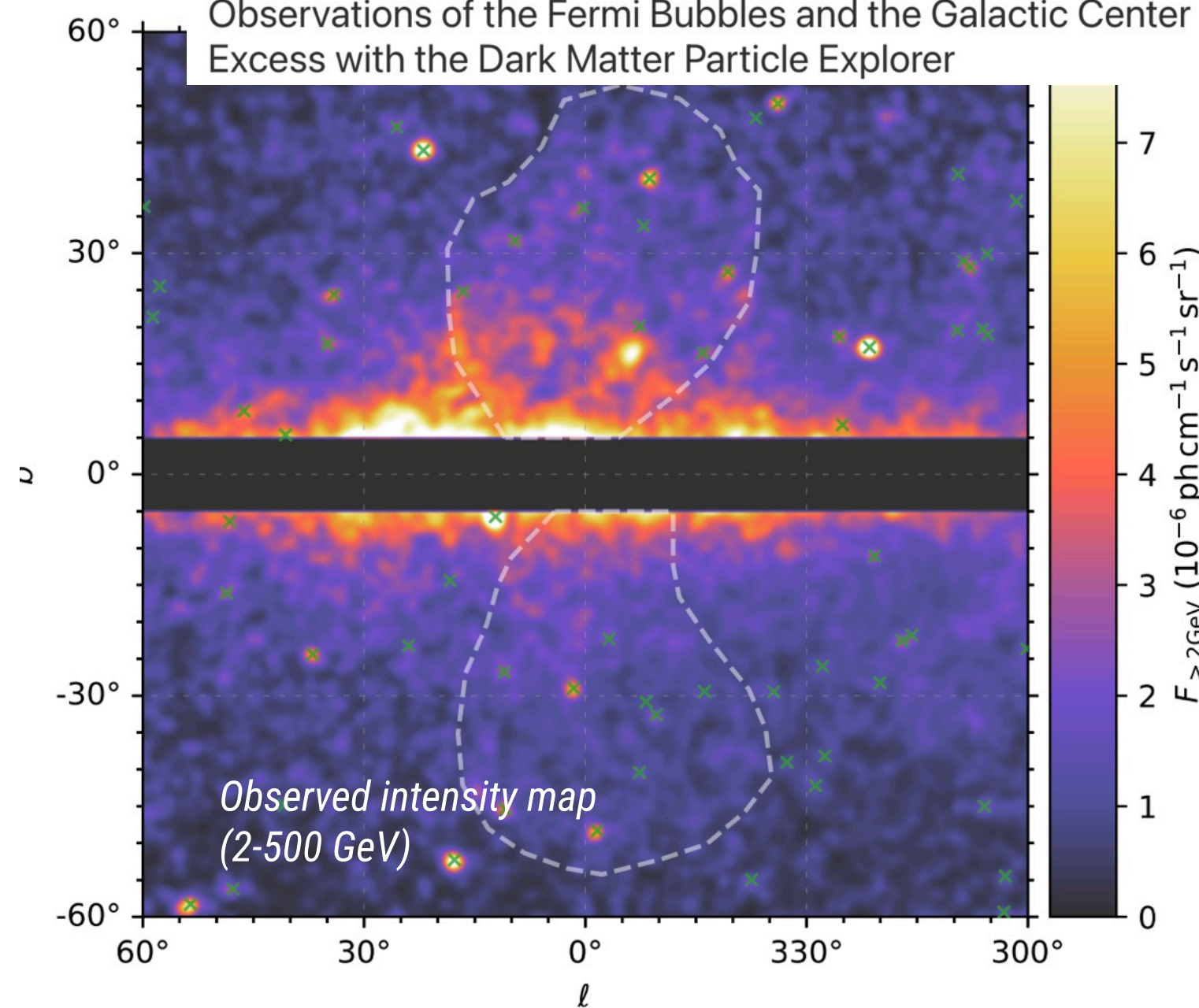
- $\sim 7\sigma$ with 8.5 yr of data

IOPscience Journals Books Publishing Support Login

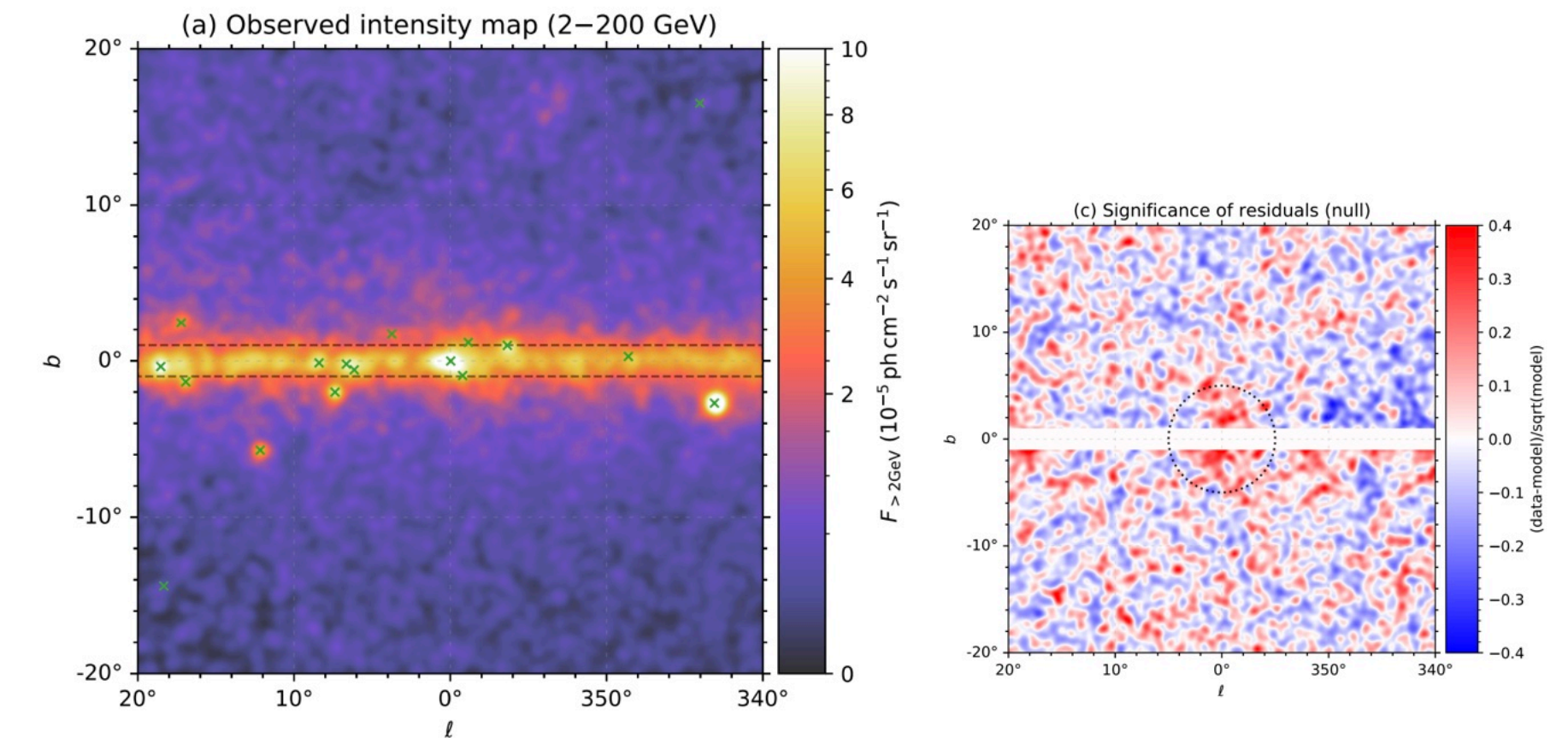
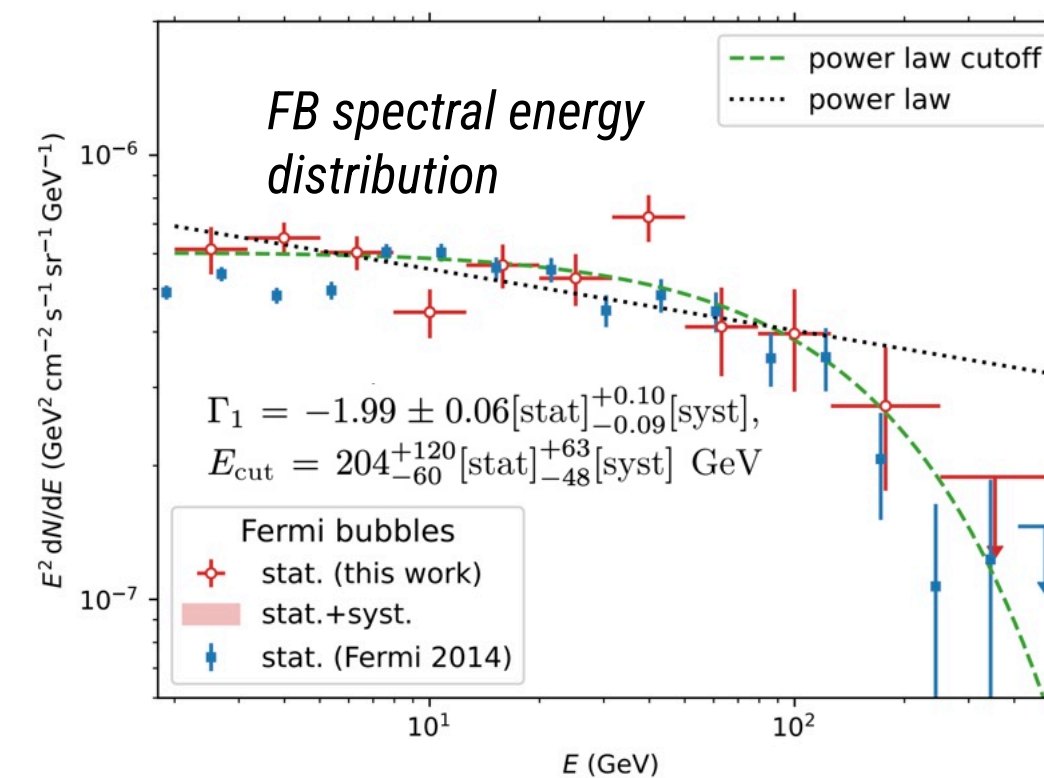
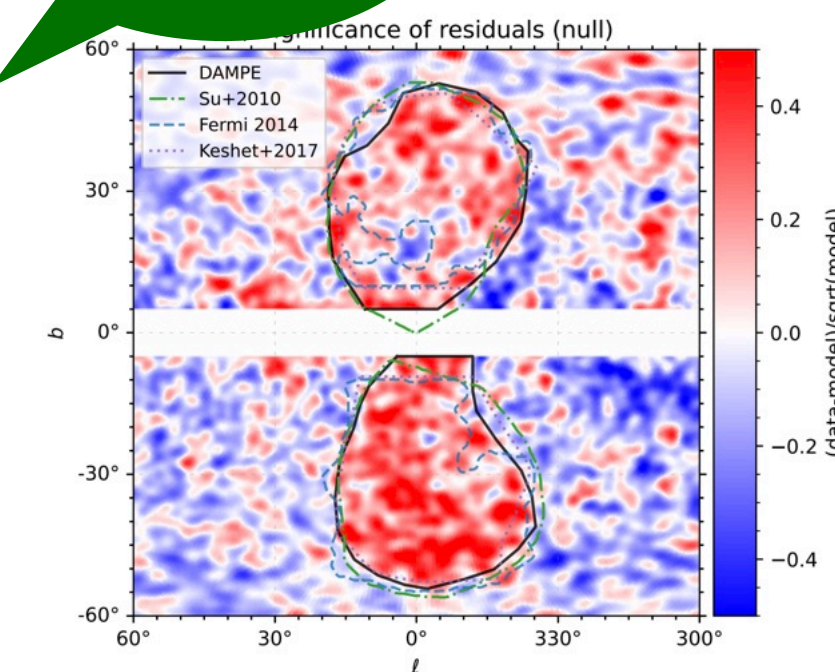
THE ASTROPHYSICAL JOURNAL
SUPPLEMENT SERIES

OPEN ACCESS

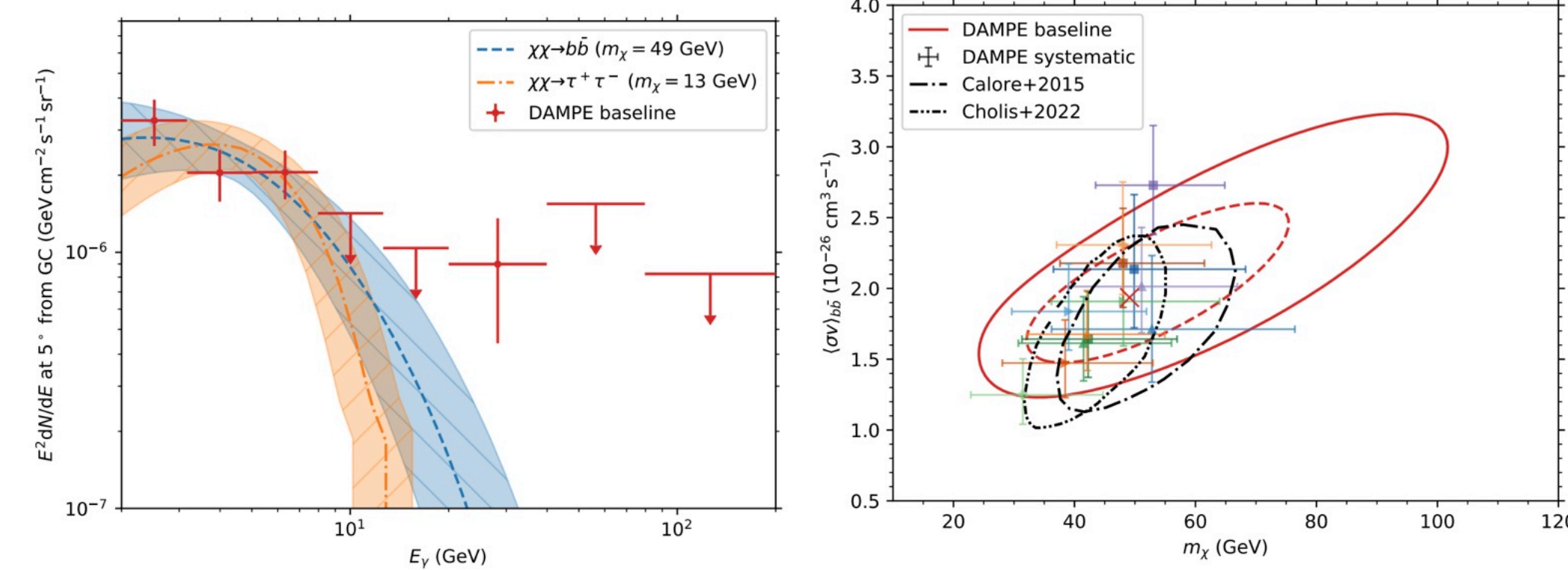
Observations of the Fermi Bubbles and the Galactic Center Excess with the Dark Matter Particle Explorer



New!!!



SED of Galactic Center Excess



DAMPE Status

- In-flight operation since 2015 → excellent performance & stability
- Unique for multi-TeV Cosmic Rays (CR)

Cosmic Rays:

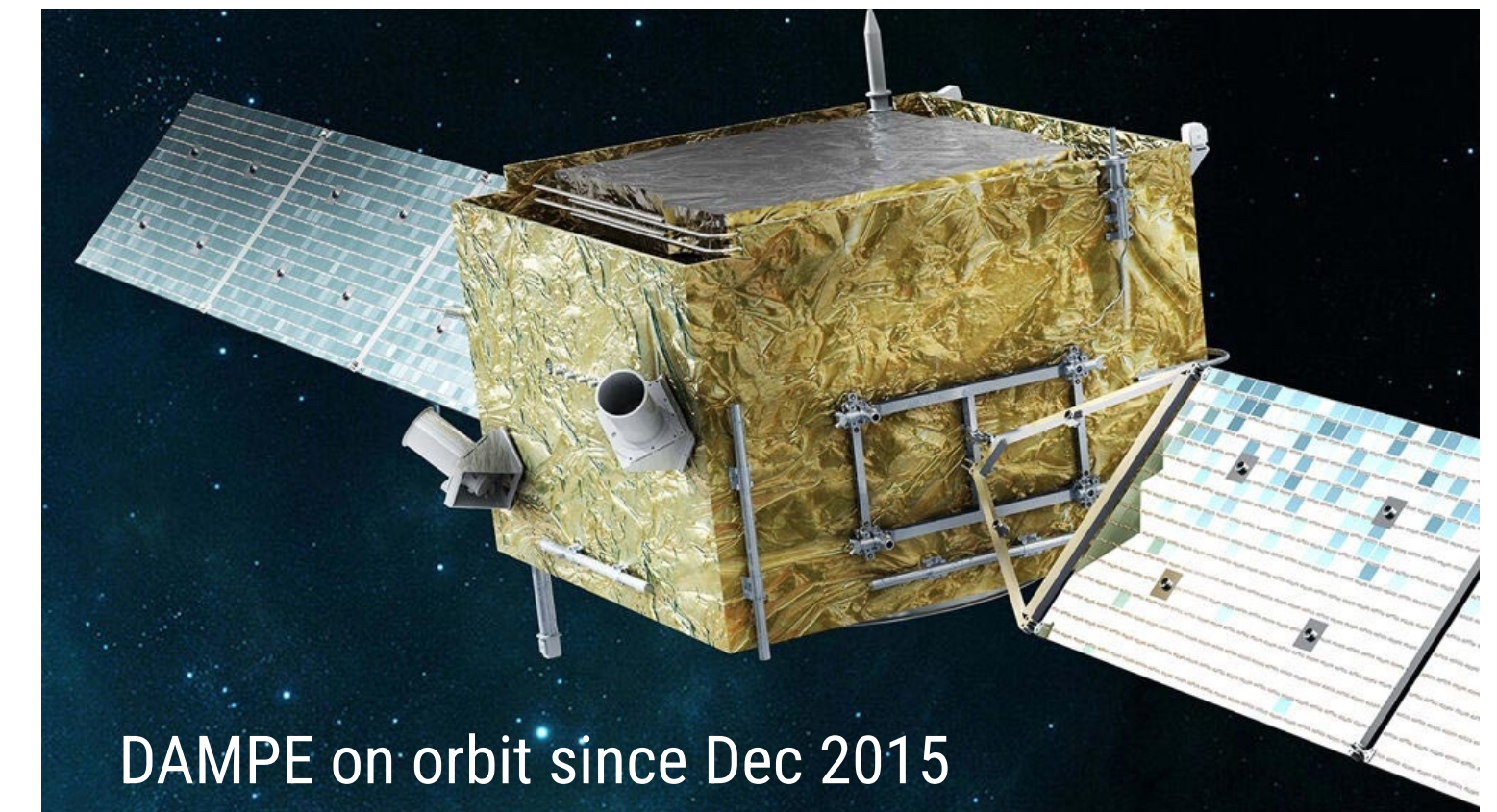
- Evidence for a cutoff at ~ 1 TeV in e^+e^+ → extending to multi TeV region
- Detection of universal 15 TV structure in all CR primaries (from H to Fe)!
- p & He extension of spectra towards PeV energies
- Observation of hardening in secondaries (Li , Be , B)
- *Heavy elements: first Nickel spectrum measurement up to 2 TeV/n*
- Many other analyses in process: intermediate nuclei, all-particle,...

Particle Physics:

- p , He , C , and O cross sections on heavy target measured up to 10 TeV
- Exotics searches (FCPs)

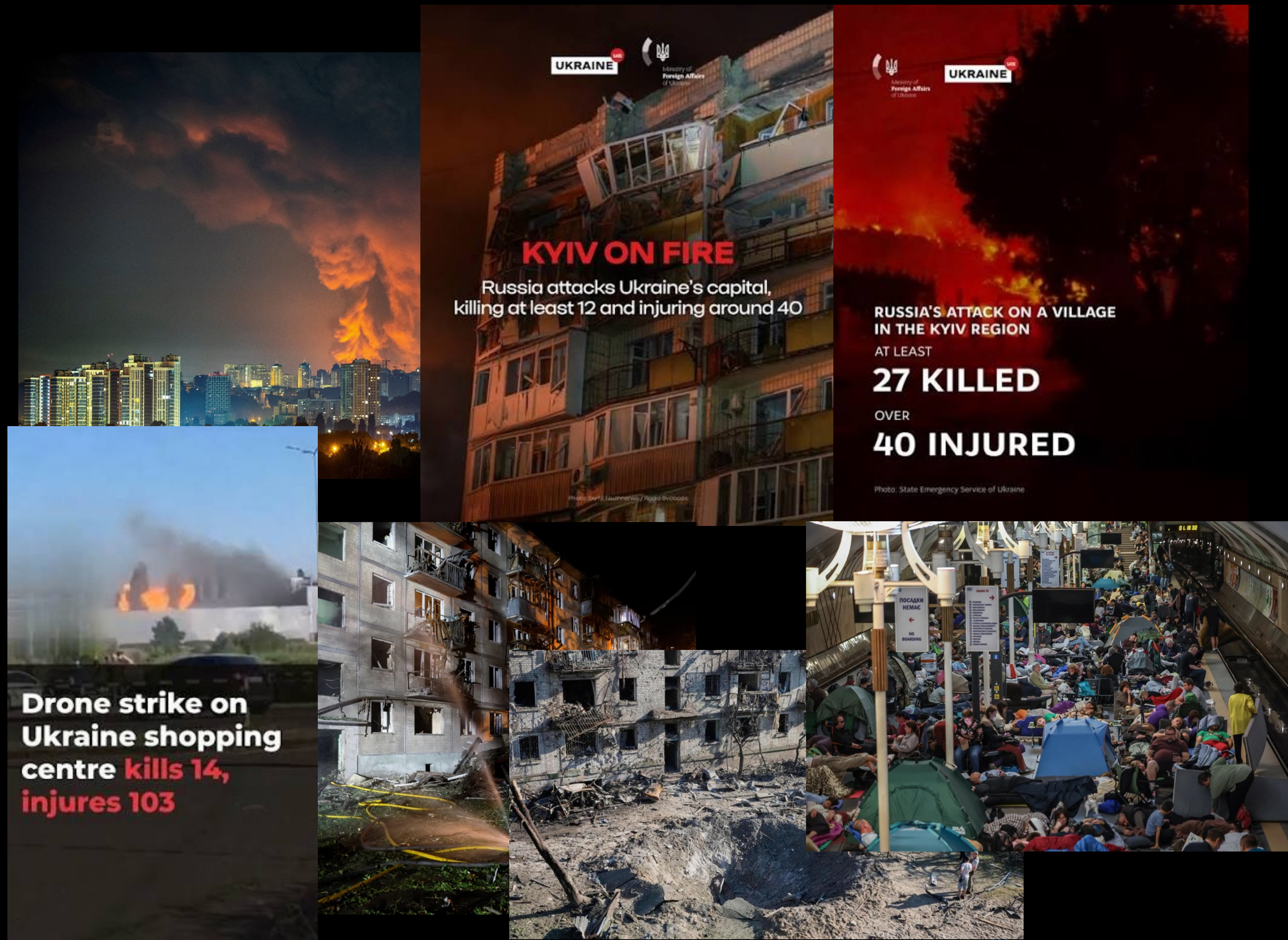
Gamma Rays:

- First verification of Fermi bubbles and GCE by independent telescope!
- Source analysis, Dark Matter line searches



Thank you!

Realities of doing physics in Ukraine amid Russian terror..



Tens of people killed and hundreds wounded, including children (**just this August!**), as Russia intensifies ballistic/drone attacks on civil population across Ukraine

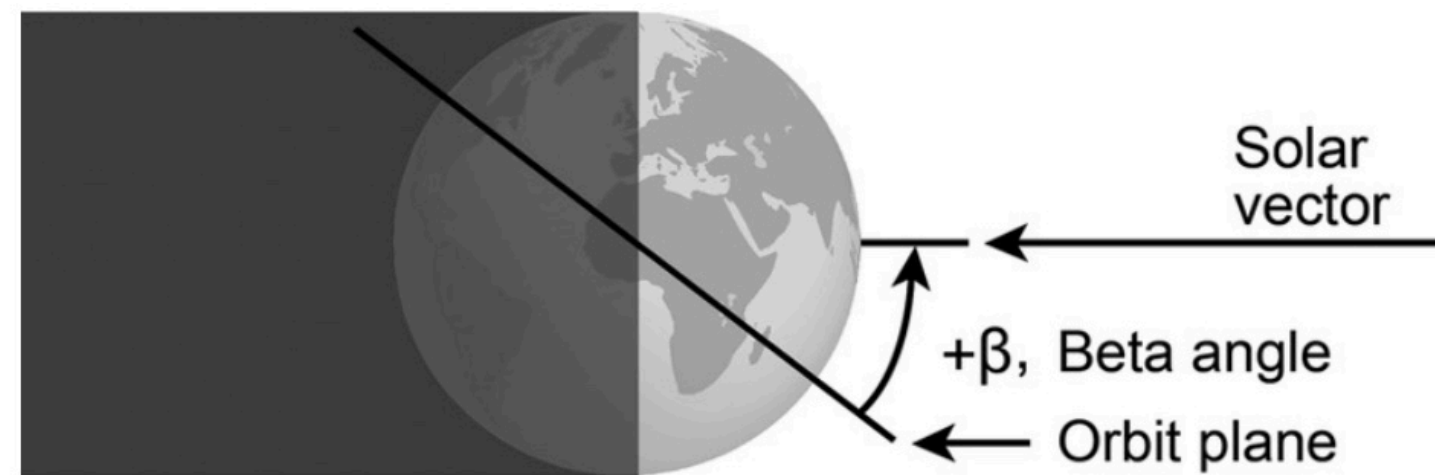
Ukrainian theoretical physicist lost his home in one of the many Russian attacks on Kyiv this August...



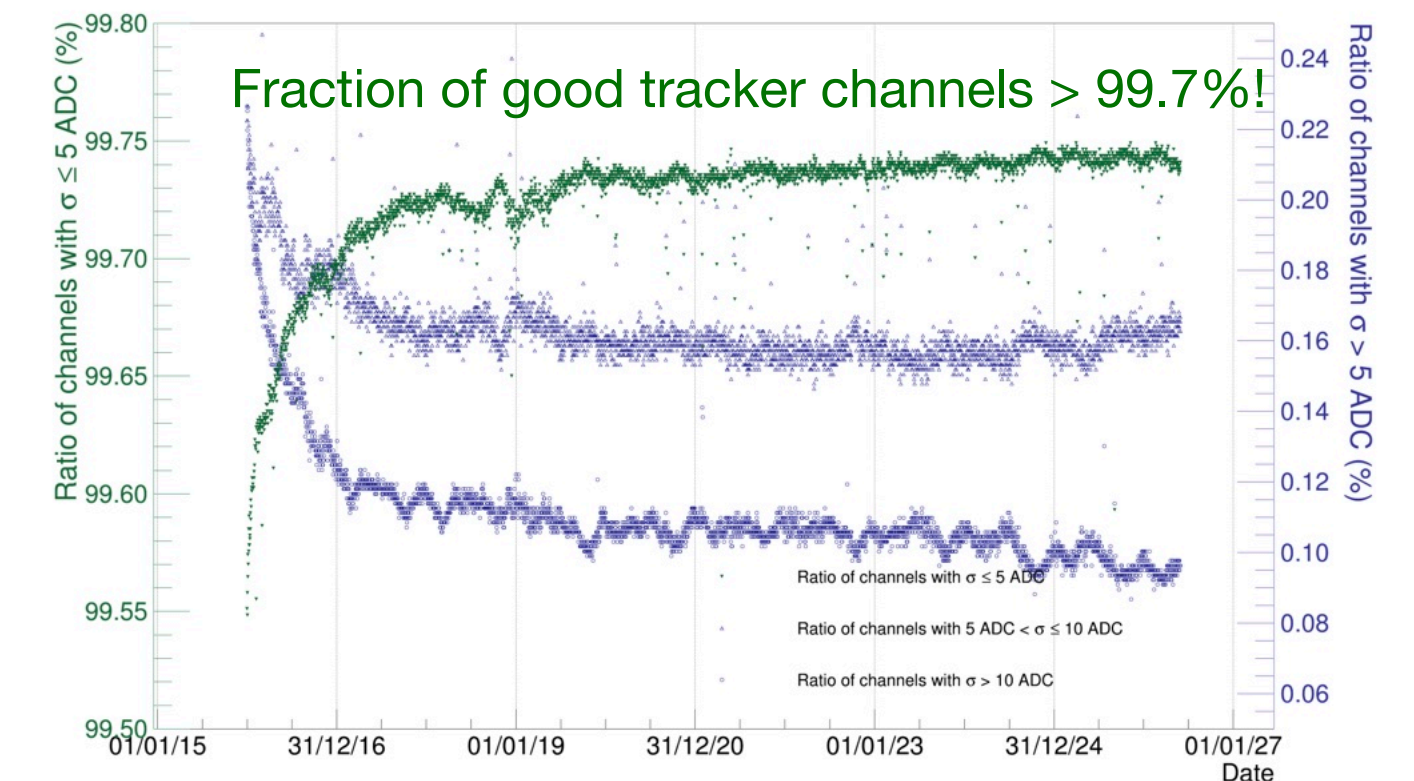
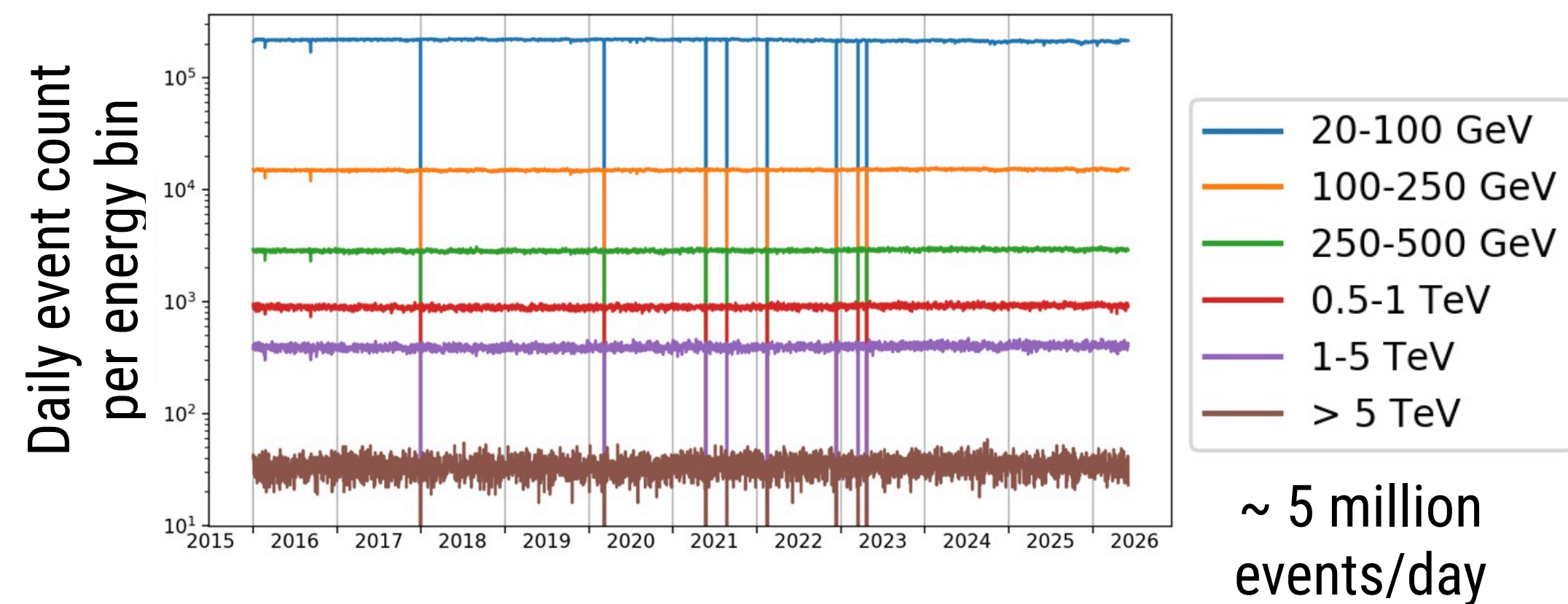
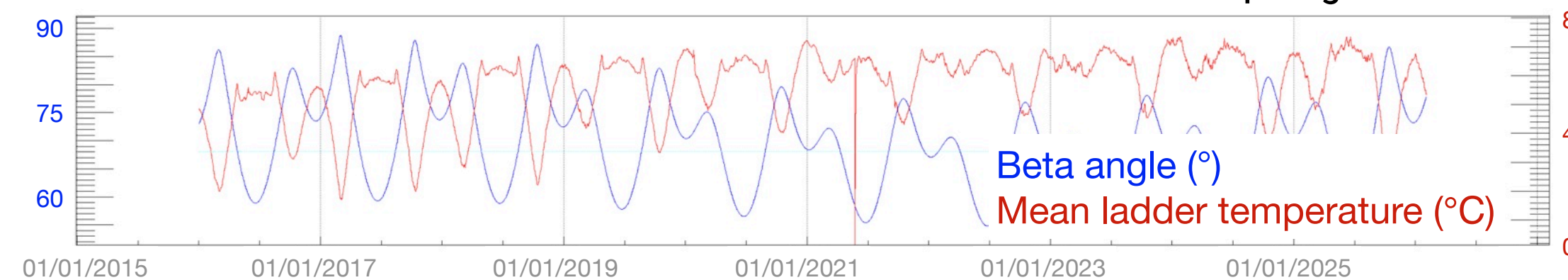
If you want to help
PayPal: mihas1984@gmail.com

Backup slides

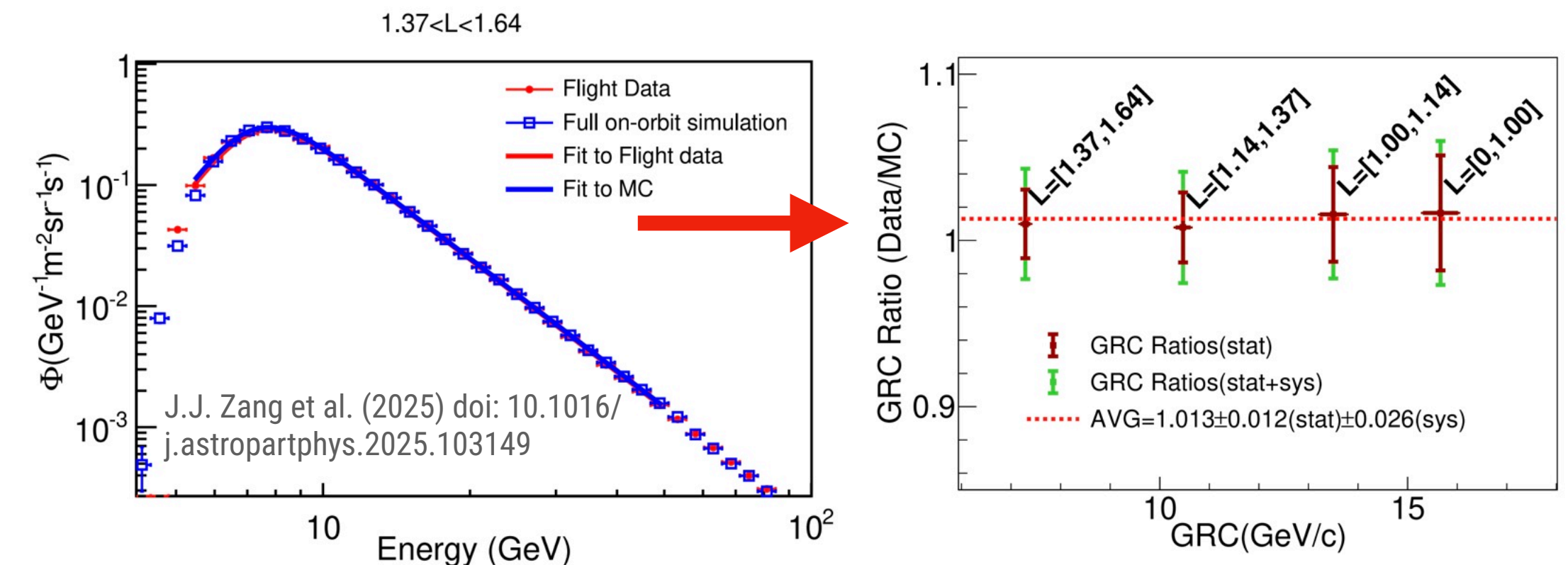
DAMPE on-orbit status



Instrument temperature anti-correlation with β angle:



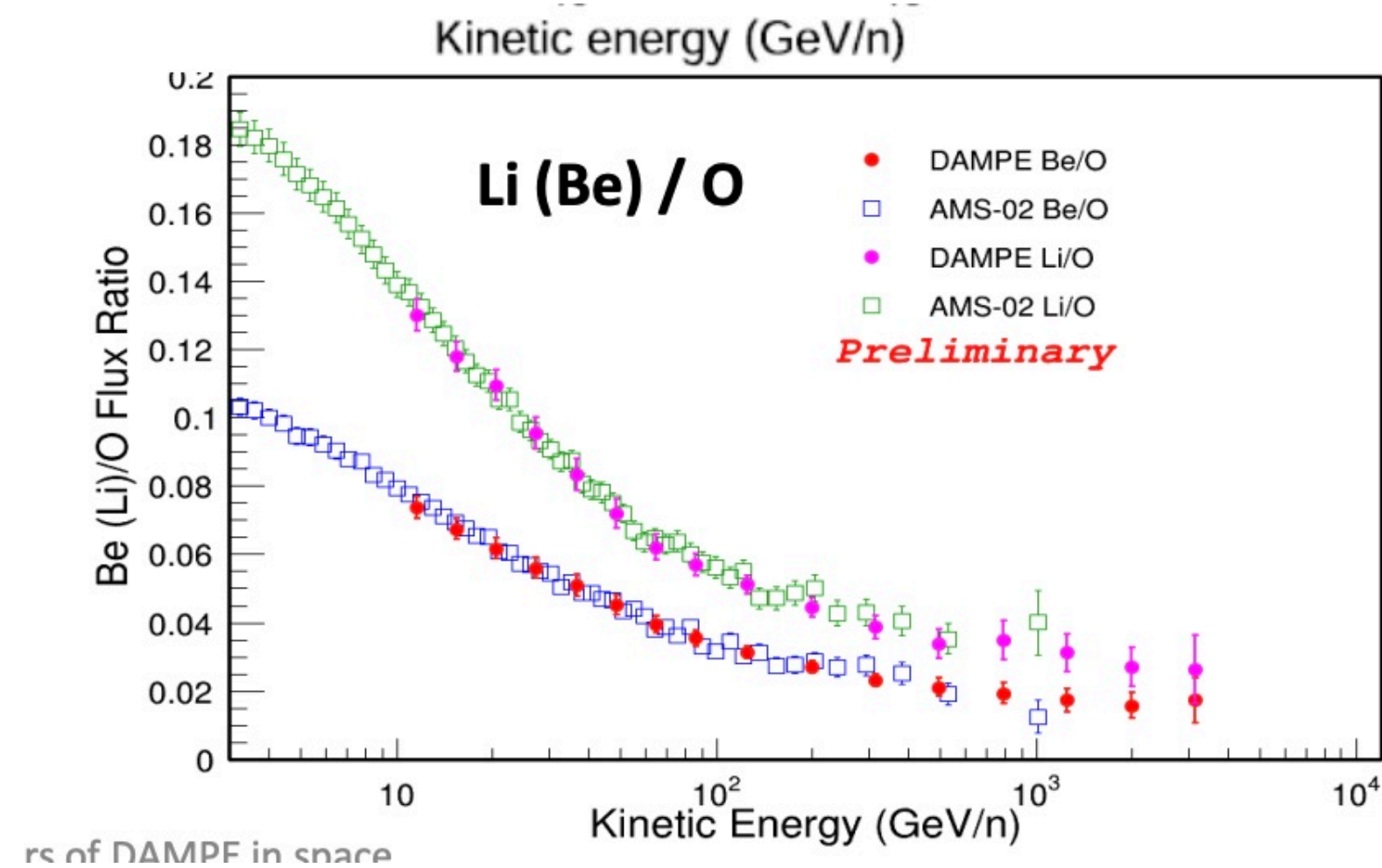
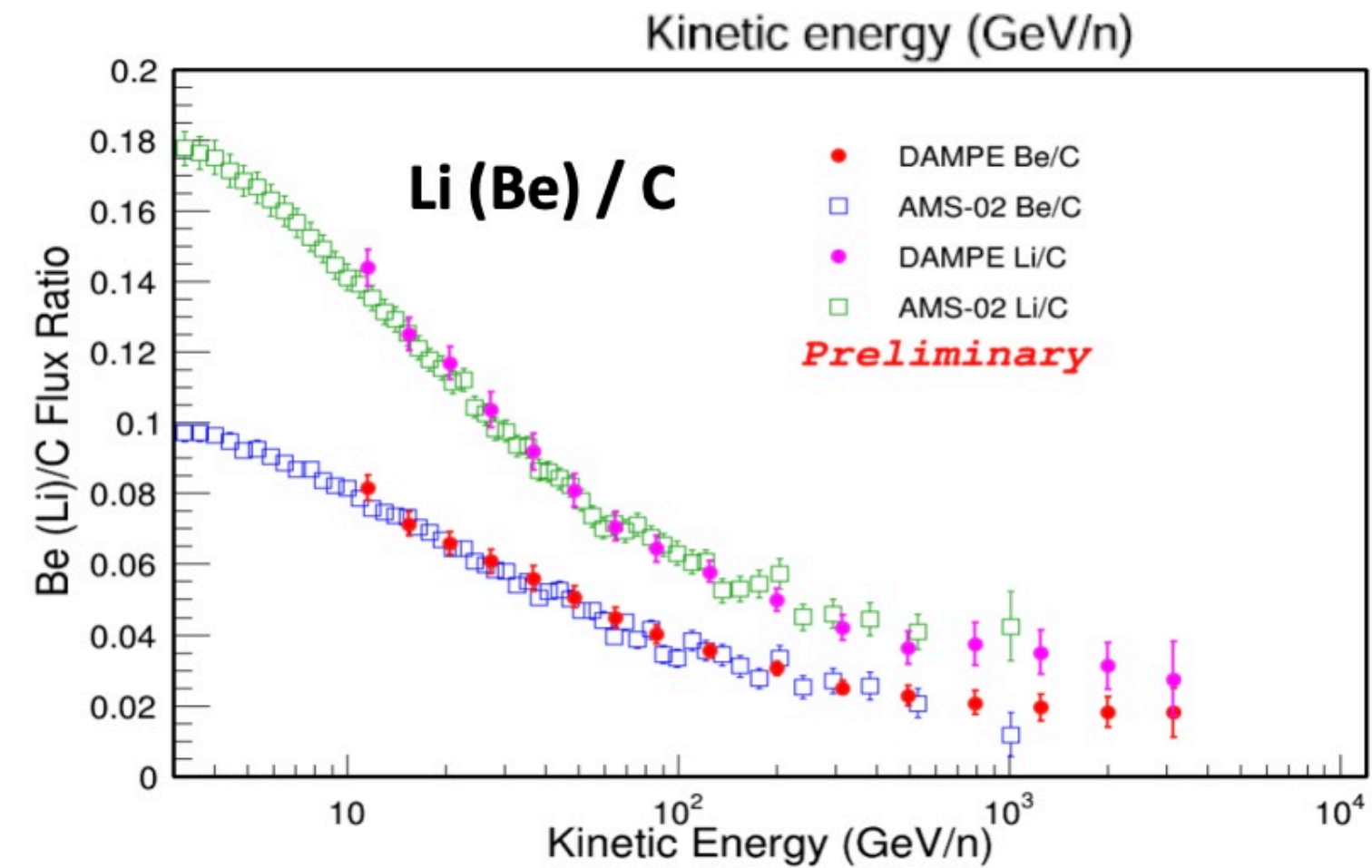
Energy scaled confirmed with the Earth geomagnetic cutoff down to $\sim 1.3\%$:



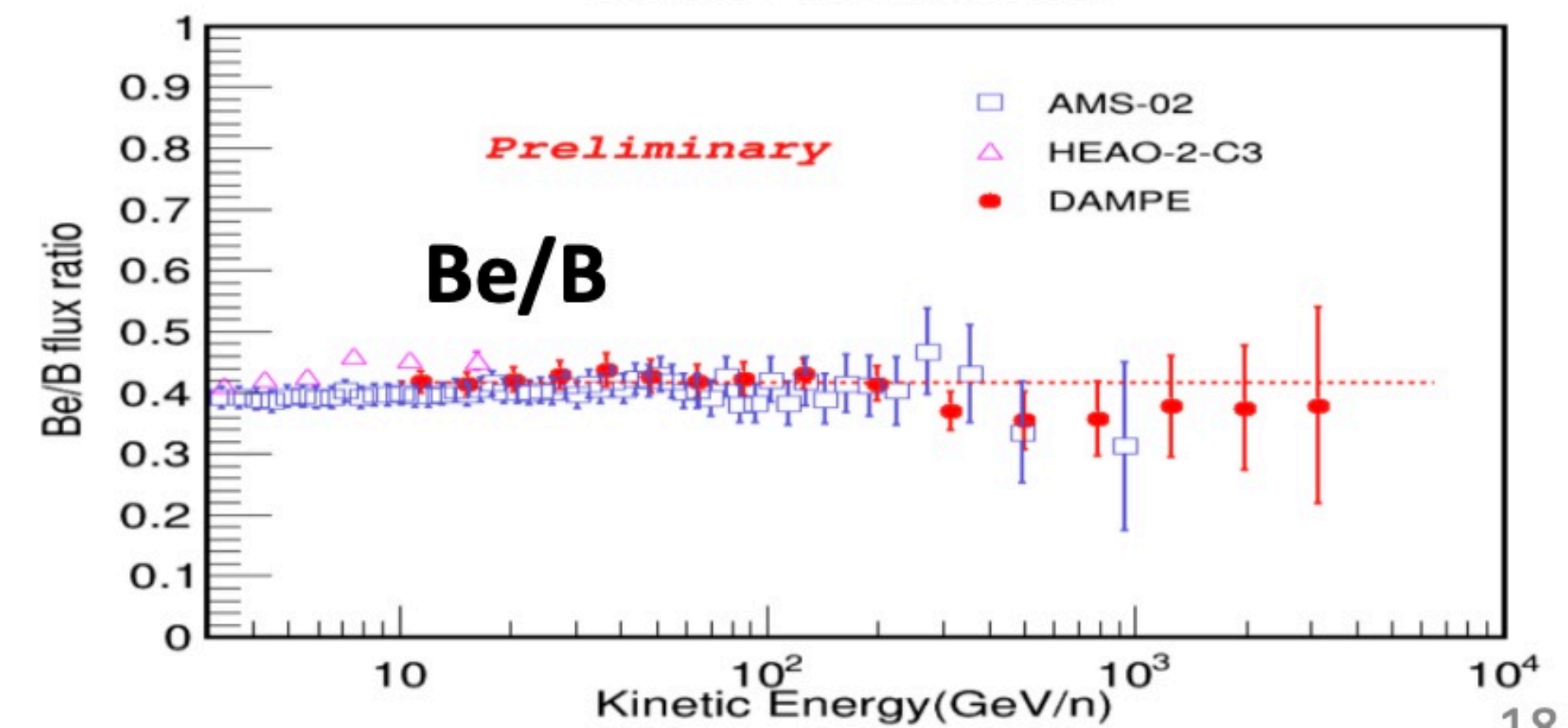
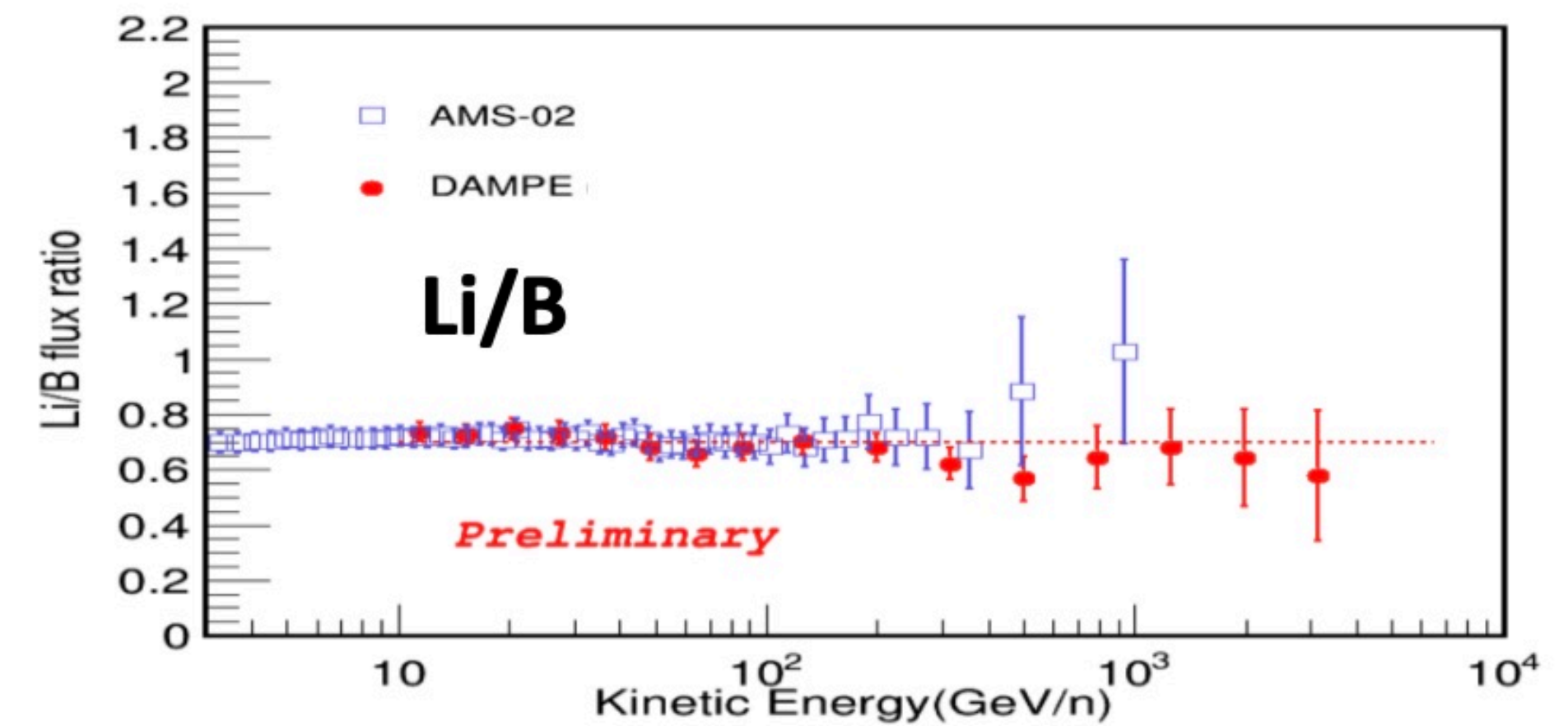
Excellent stability of all DAMPE sub-systems after 10 years on orbit!

More ratios

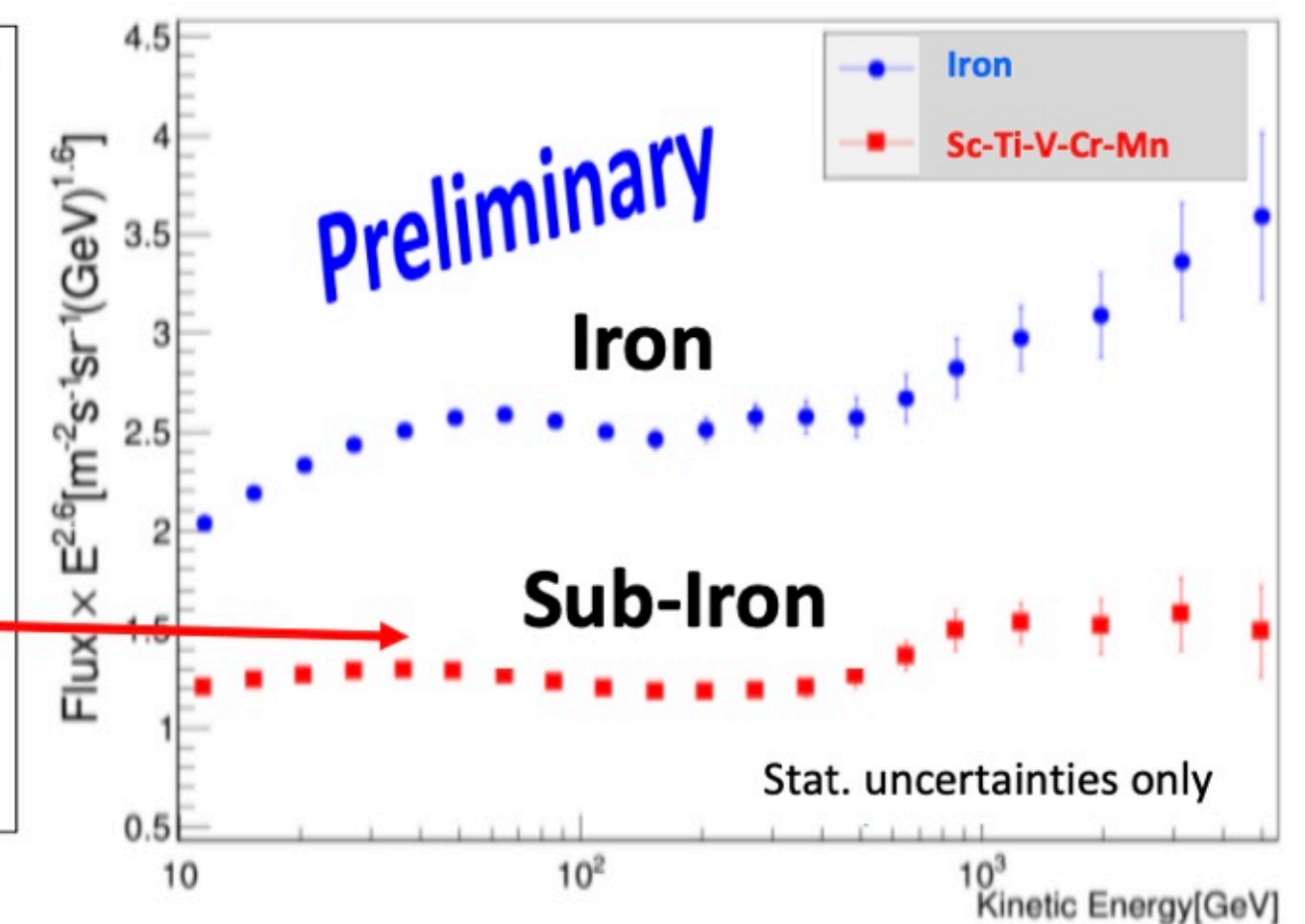
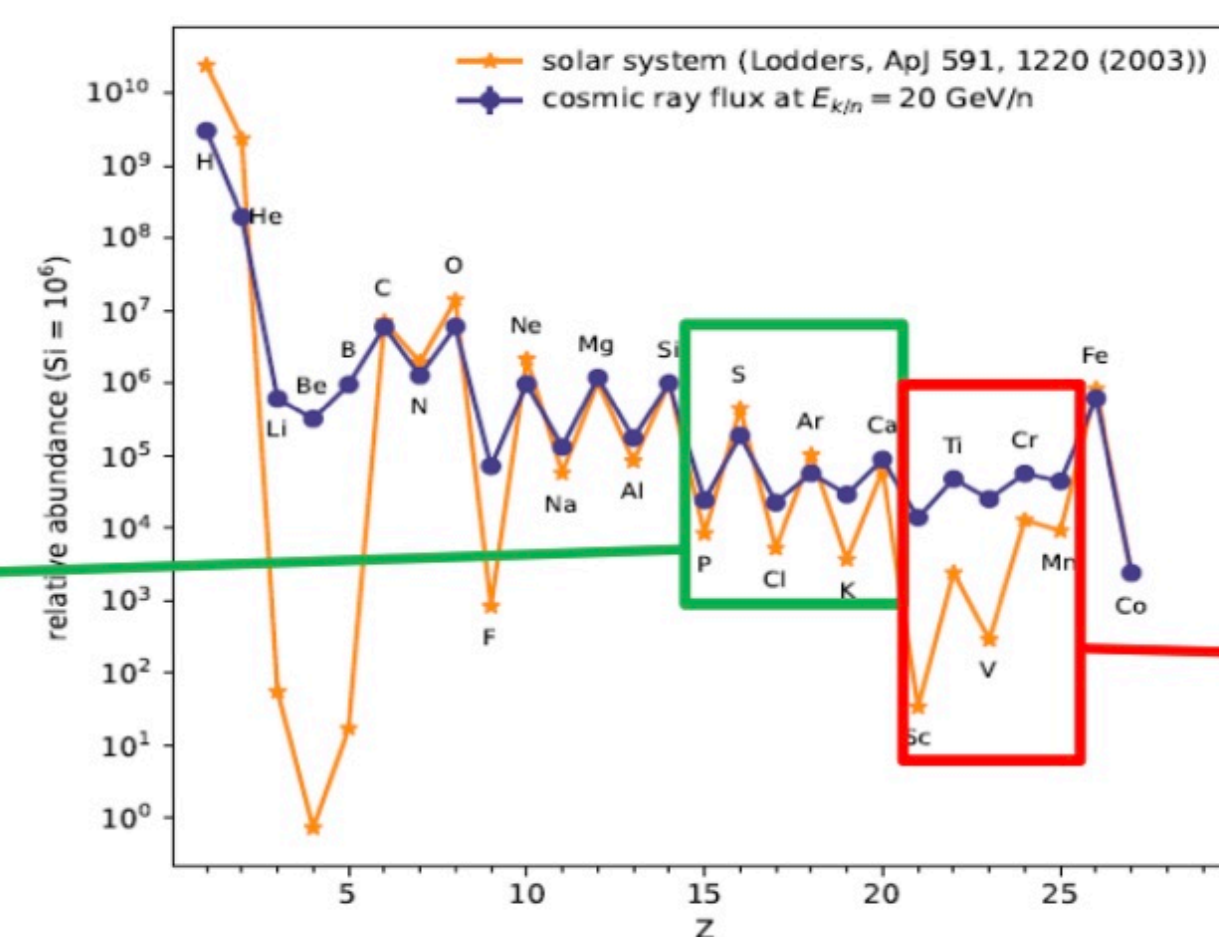
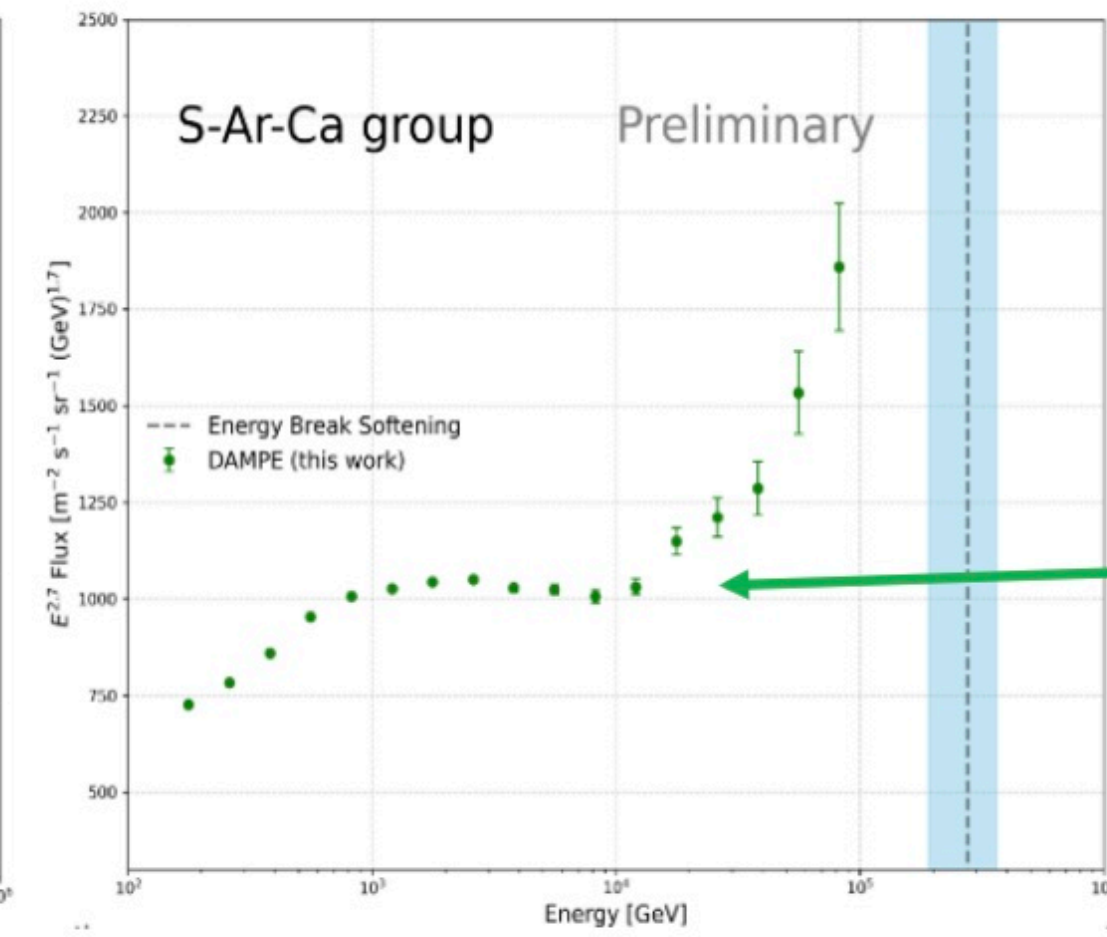
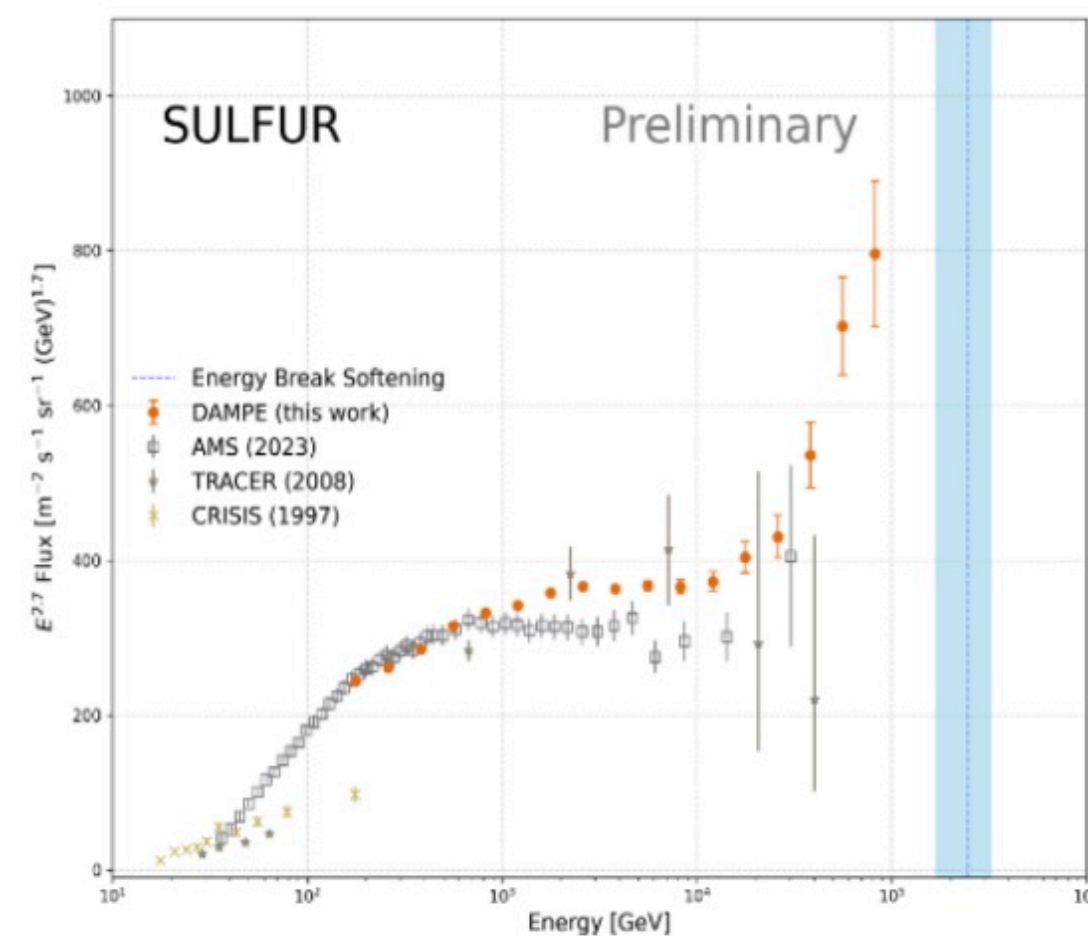
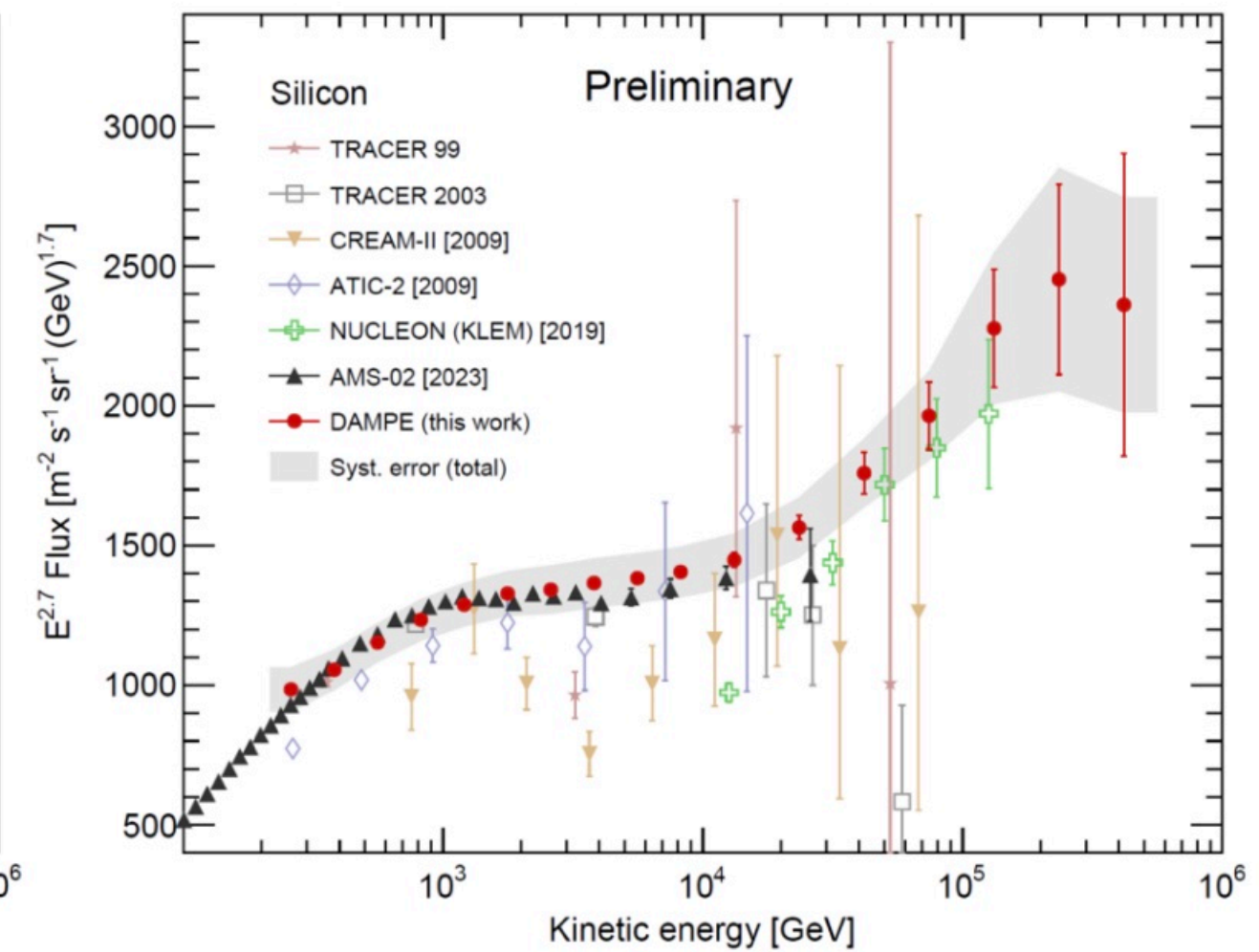
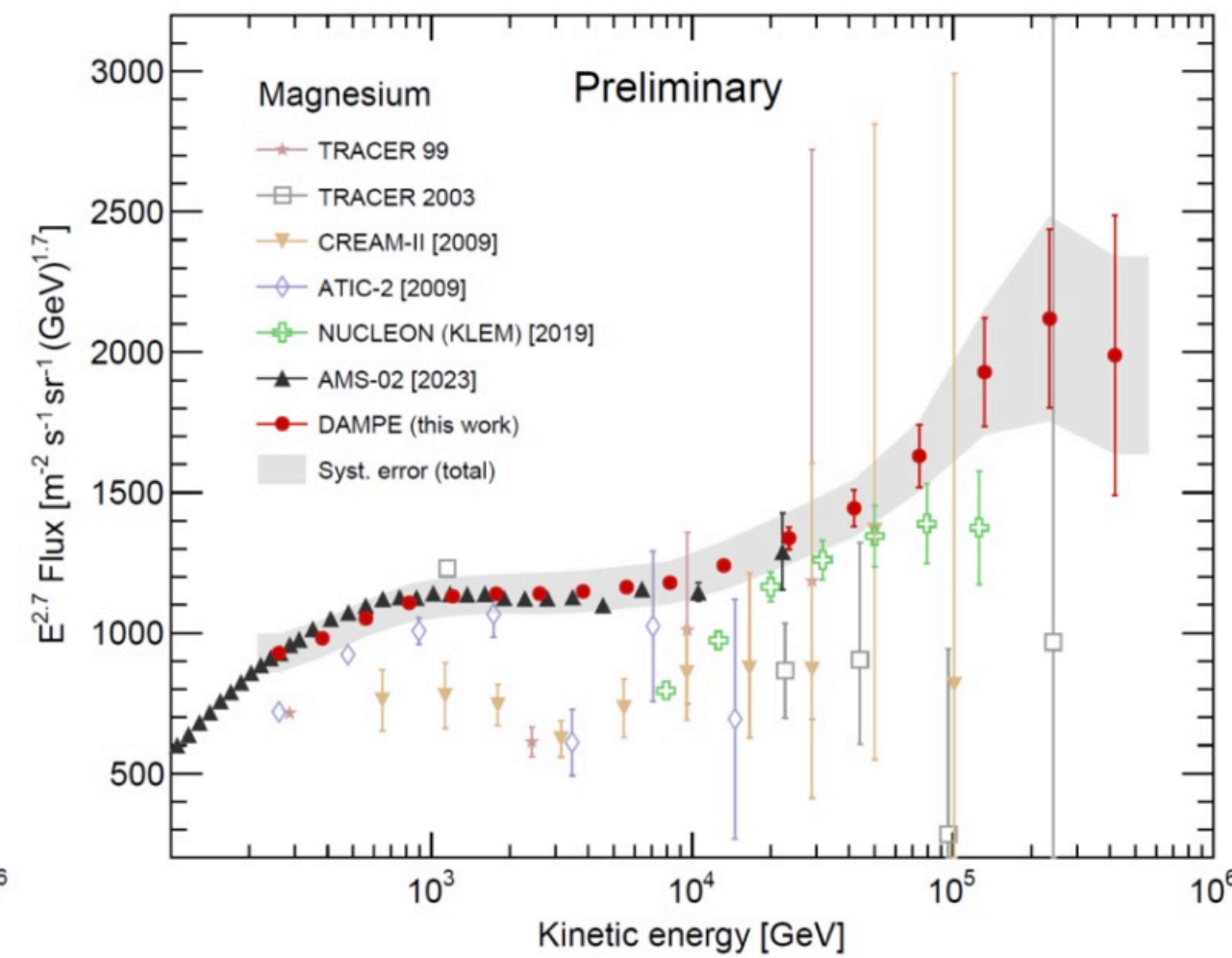
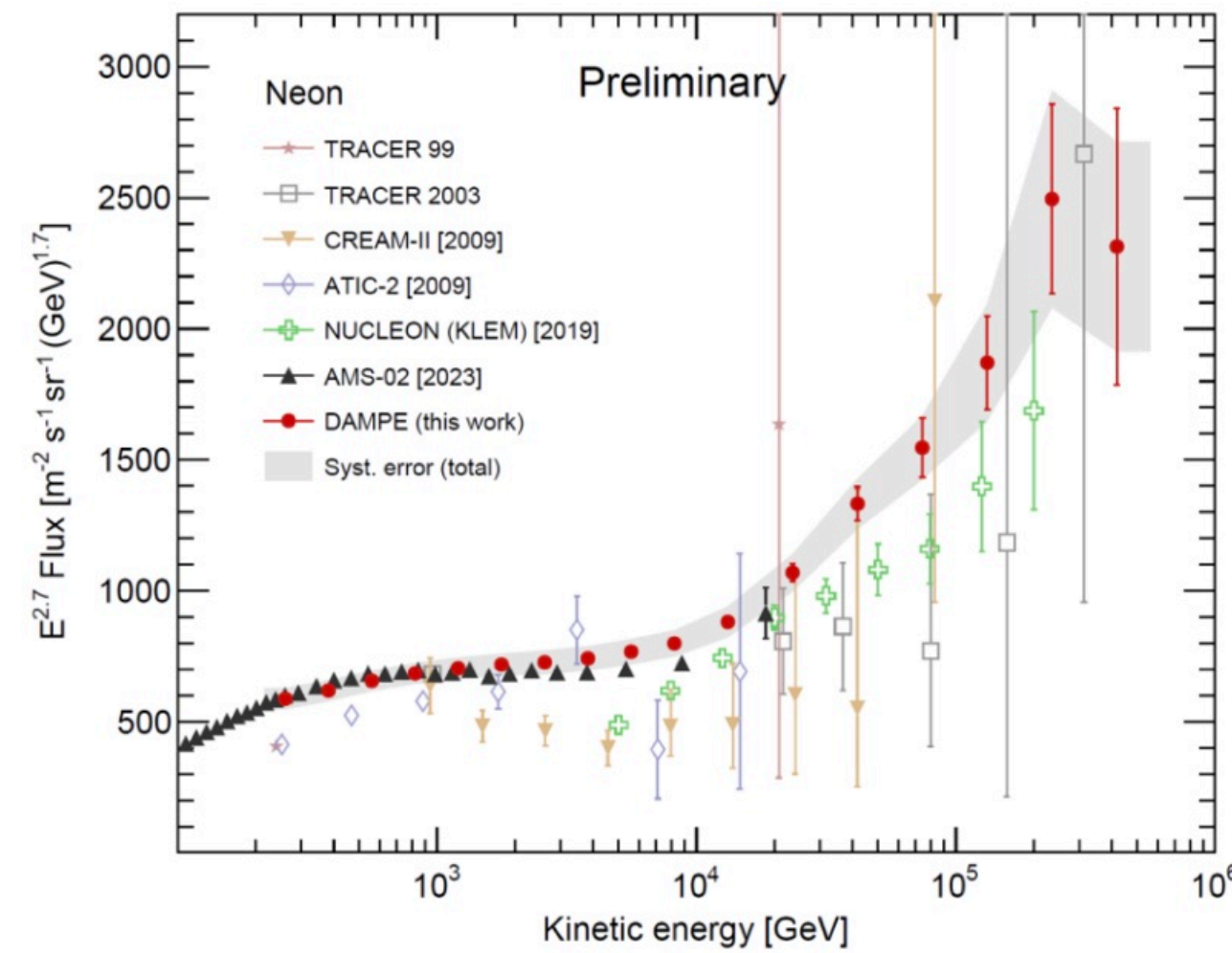
- Secondary to primary:



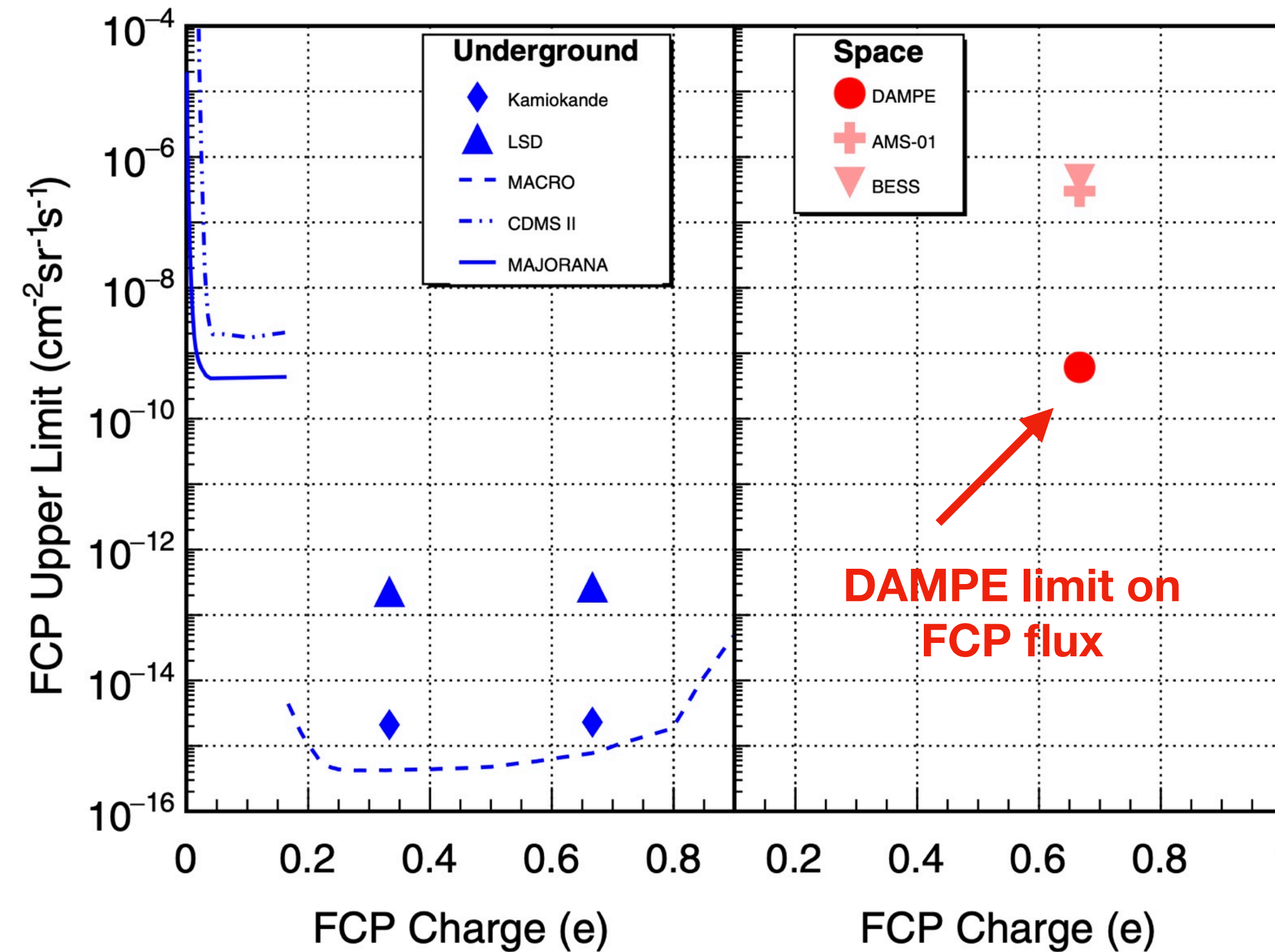
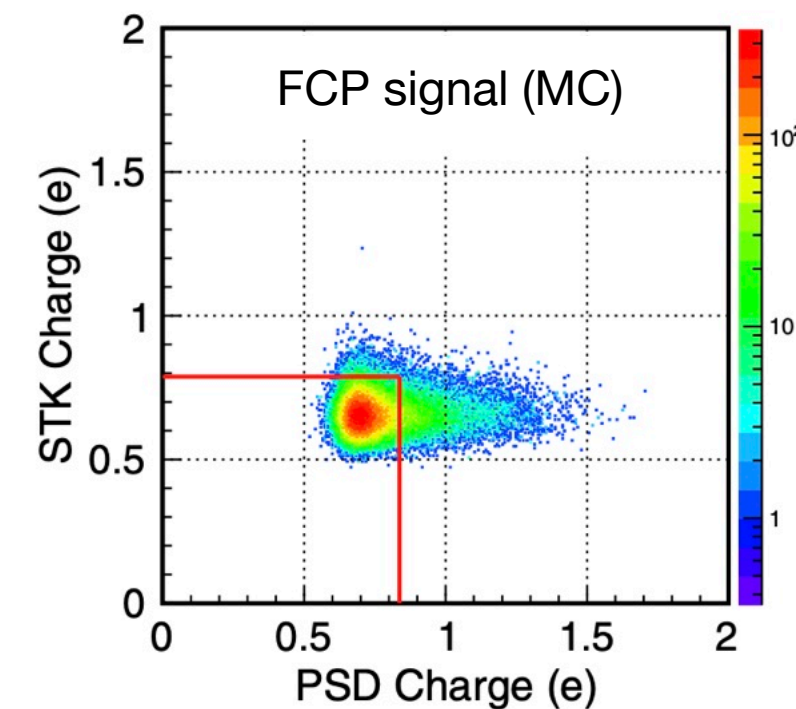
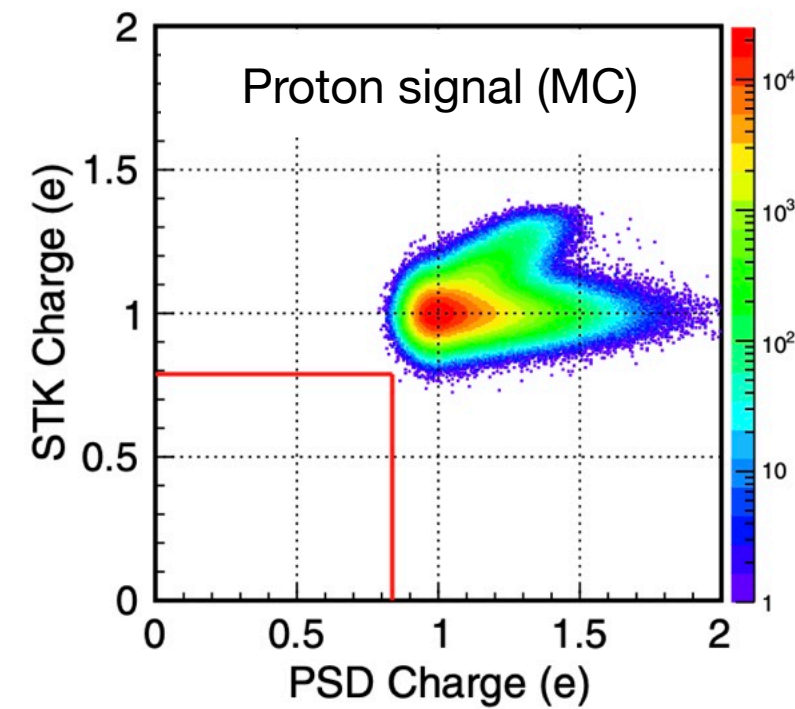
- Secondary to secondary:



Ne-Mg-Si and S-Ar-Ca groups



Exotics: Fractionally-Charged Particles



DAMPE collab., Phys. Rev. D 106 (2022)

- Fractionally-Charged Particles:
- Beyond Standard Model
(e.g. SU(5) extensions of SM)

- DAMPE provides the most stringent constraints on the FCPs flux upper limit in space at a few GeV
(Ground-based results – above hundreds GeV)