

Latest results of the DArk Matter Particle Explorer

Yifeng Wei (魏逸丰)

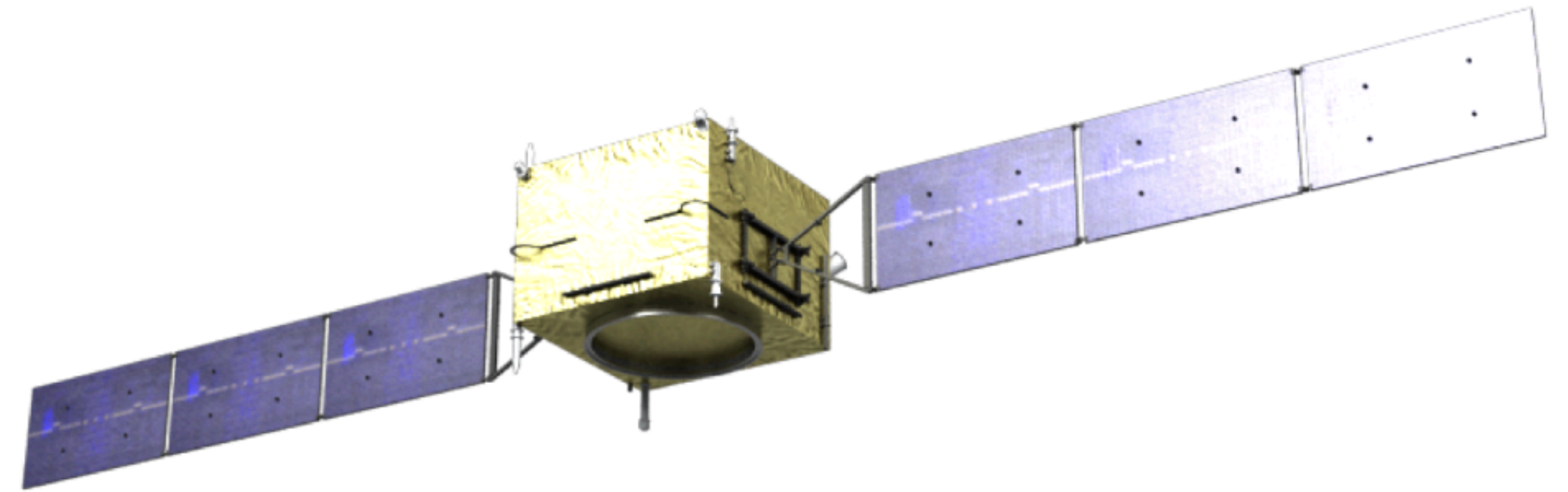
State Key Laboratory of Particle Detection and Electronics,
University of Science and Technology of China
(On behalf of the DAMPE Collaboration)

*Speaker: weiyf@ustc.edu.cn

高能宇宙线物理及下一代空间探测装置研讨会
Wulumuqi, China, July 31st, 2025

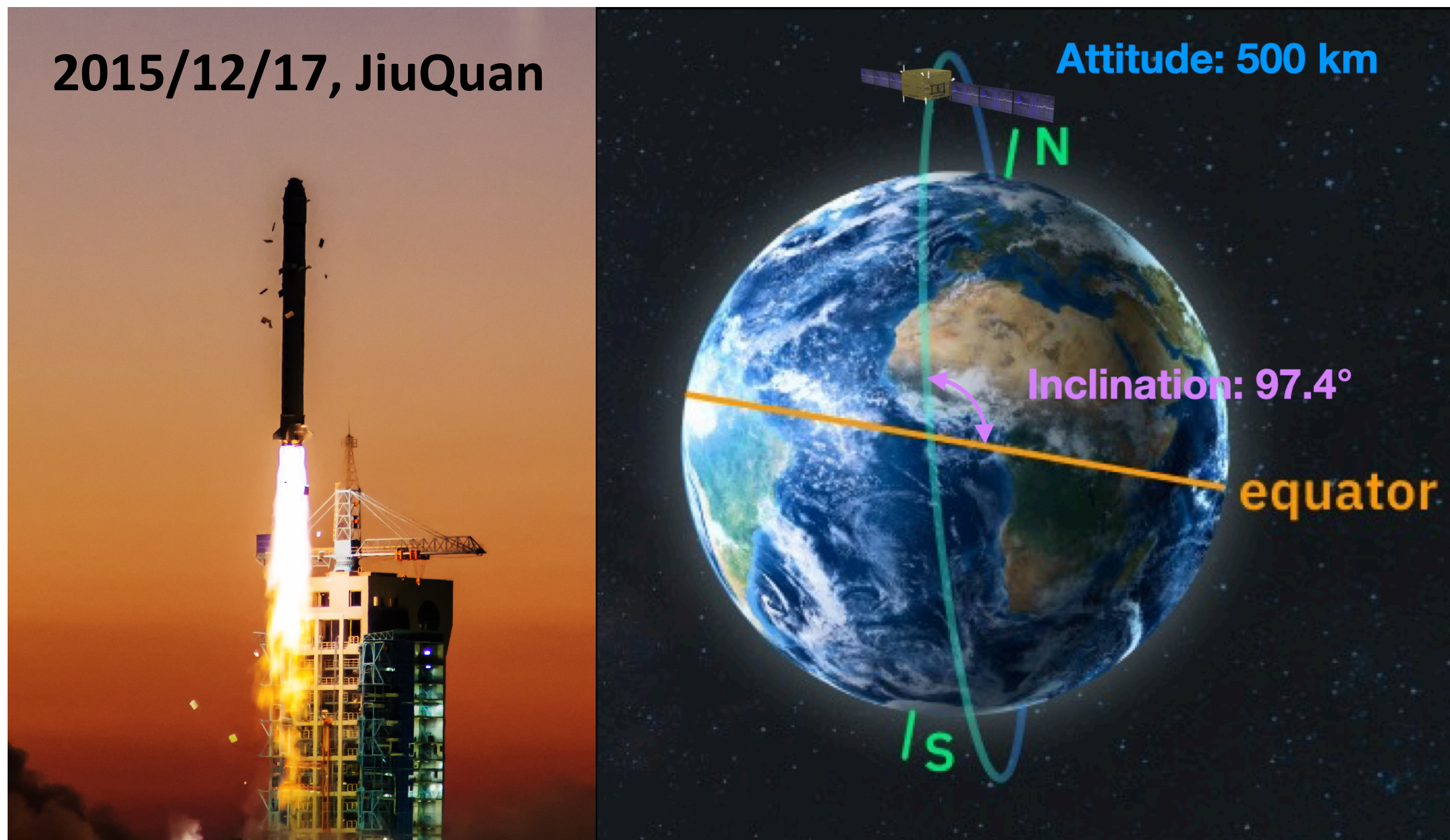
Outline

- DAMPE mission
- Detector performance
- Latest physics results
- Summary



DAMPE Mission

- **DAMPE (悟空)** is a **satellite-borne particle detector** proposed in the framework of the Strategic Pioneer Program on Space Science, promoted by the Chinese Academy of Sciences (CAS).



CNINA

- Purple Mountain Observatory, CAS
- University of Science and Technology of China
- Institute of High Energy Physics, CAS
- Institute of Modern Physics, CAS
- National Space Science Center, CAS



ITALY

- INFN Perugia and University of Perugia
- INFN Bari and University of Bari
- INFN Lecce and University of Salento
- INFN LNGS and Gran Sasso Science Institute



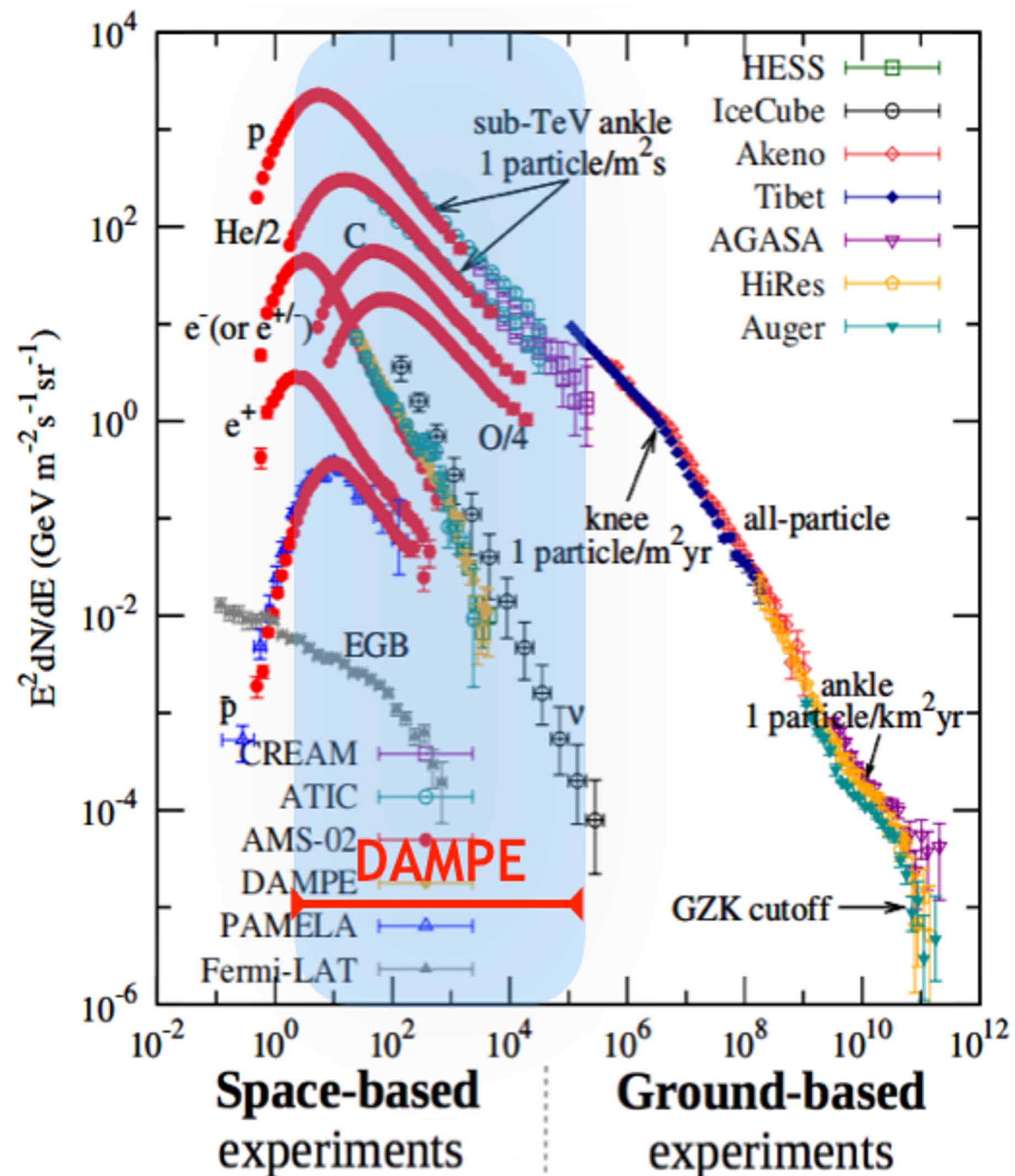
SWITZERLAND

- University of Geneva

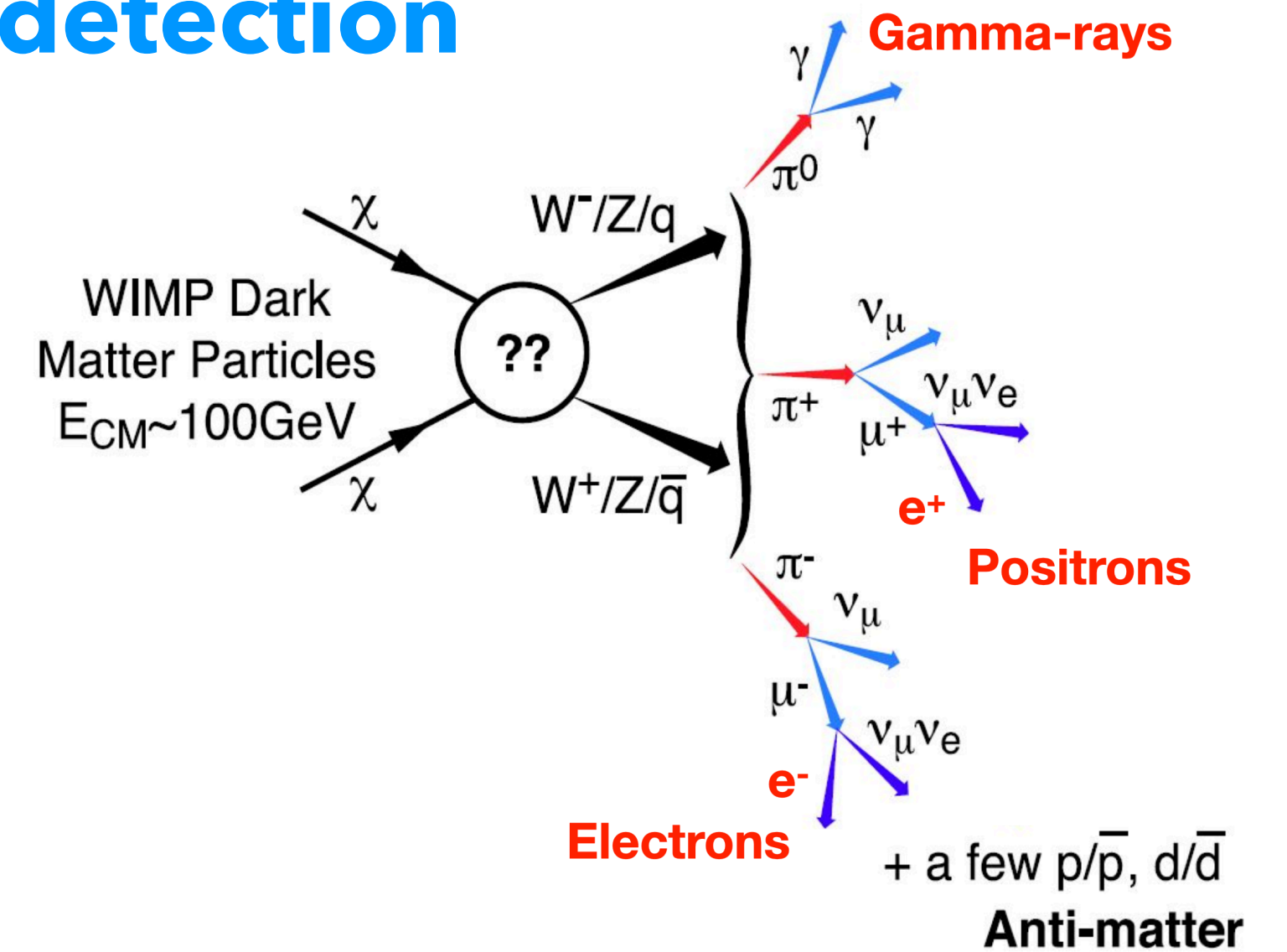
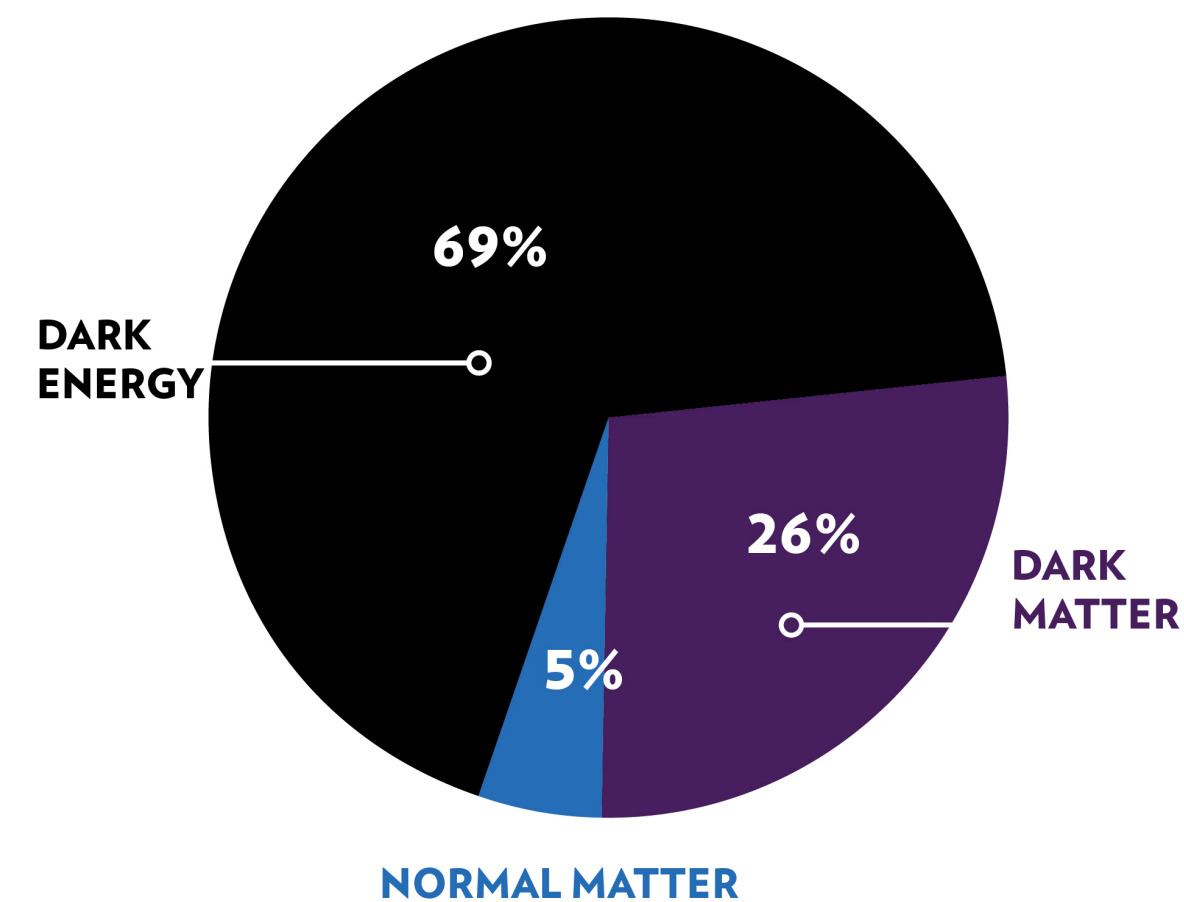


Scientific Objects

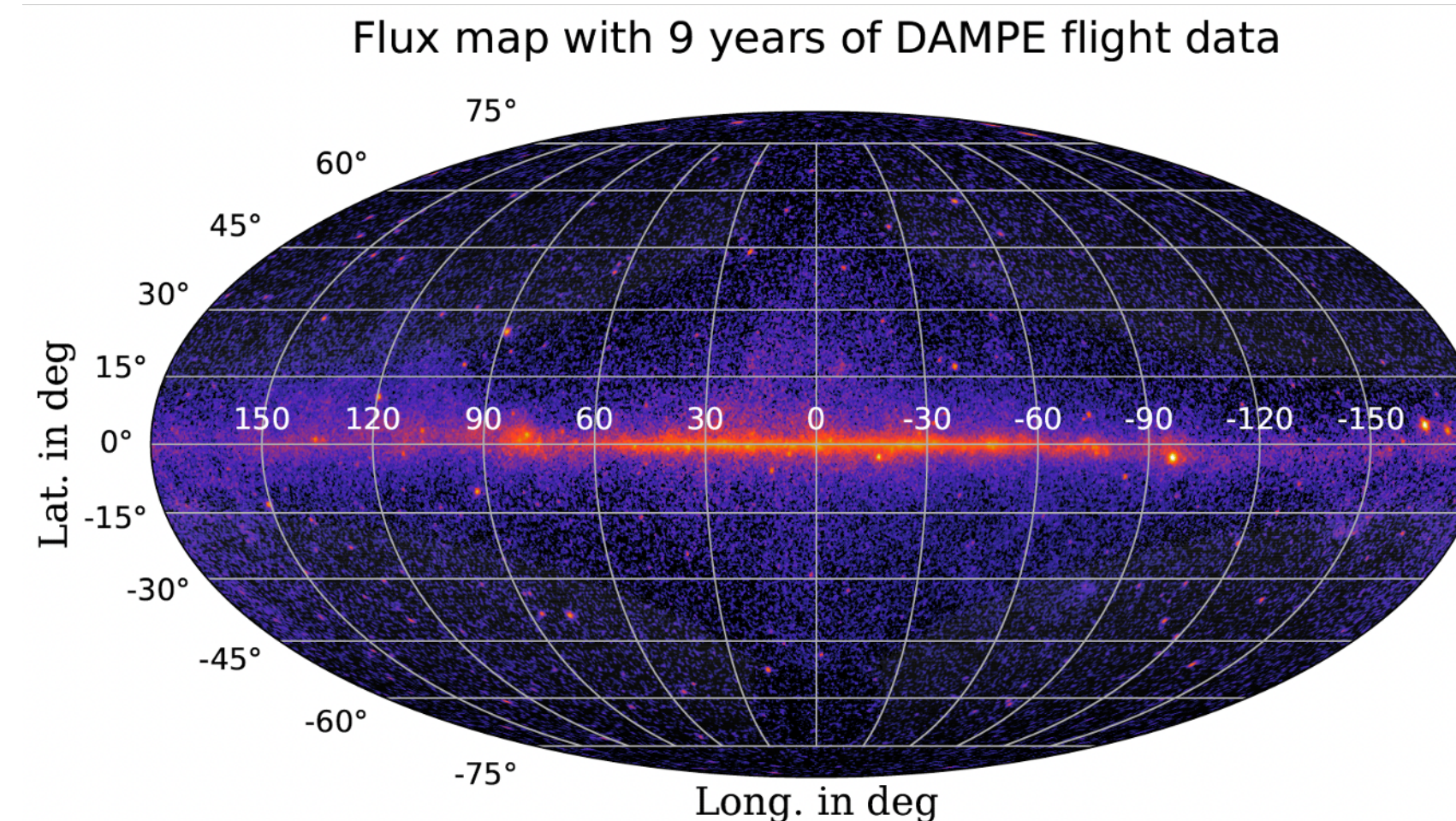
• Cosmic ray physics



• Dark matter indirect detection



• Gamma ray astronomy

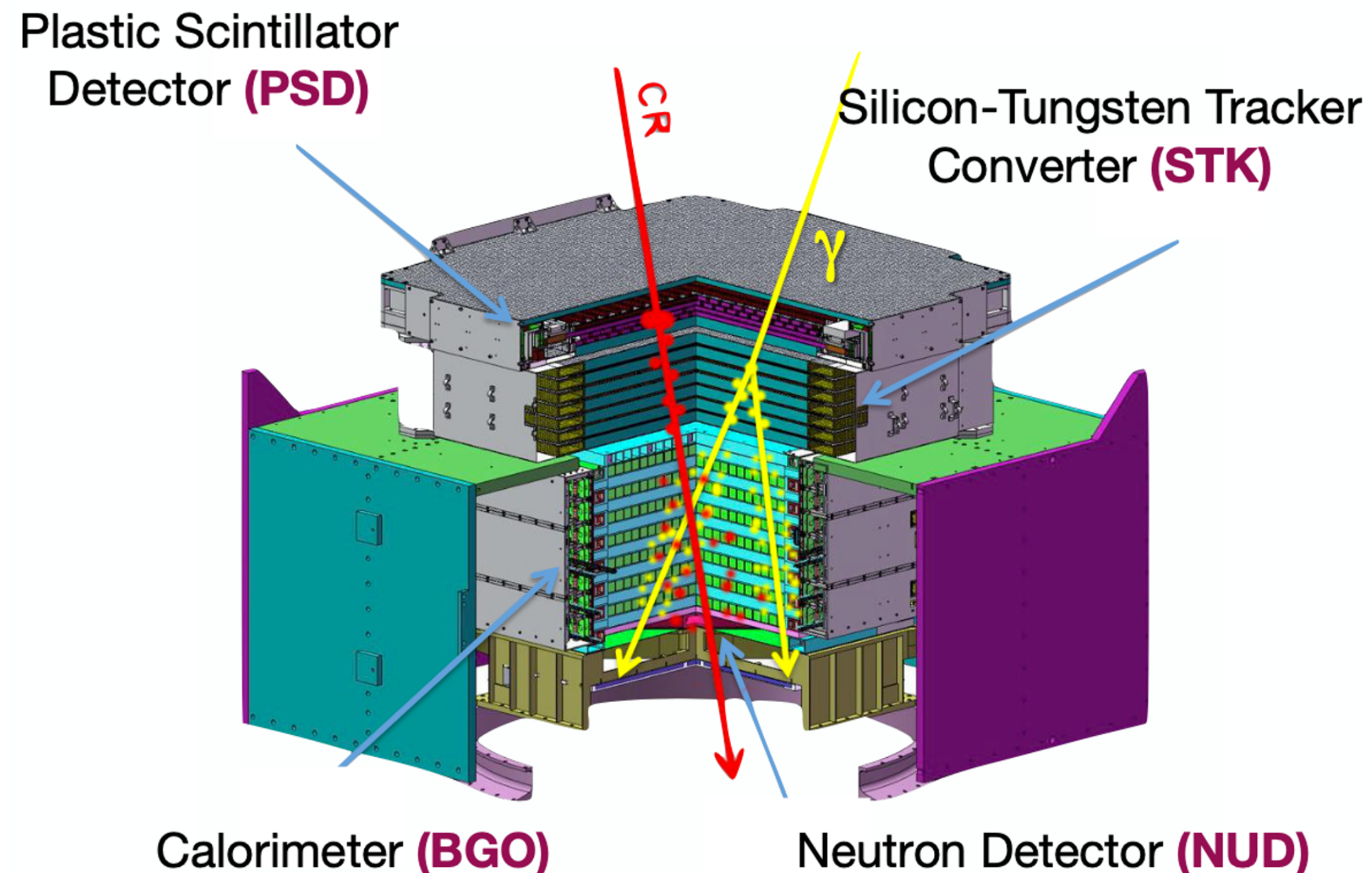


DAMPE Detector

Functions of sub-detectors:

- Charge measurement (dE/dx in PSD, STK)
- Tracking and Gamma-ray conversion (STK and BGO)
- Precise energy measurement (BGO)
- Electron-hadron separation (BGO and NUD)

DAMPE Collab.,
Astropart.Phys. 95 (2017)

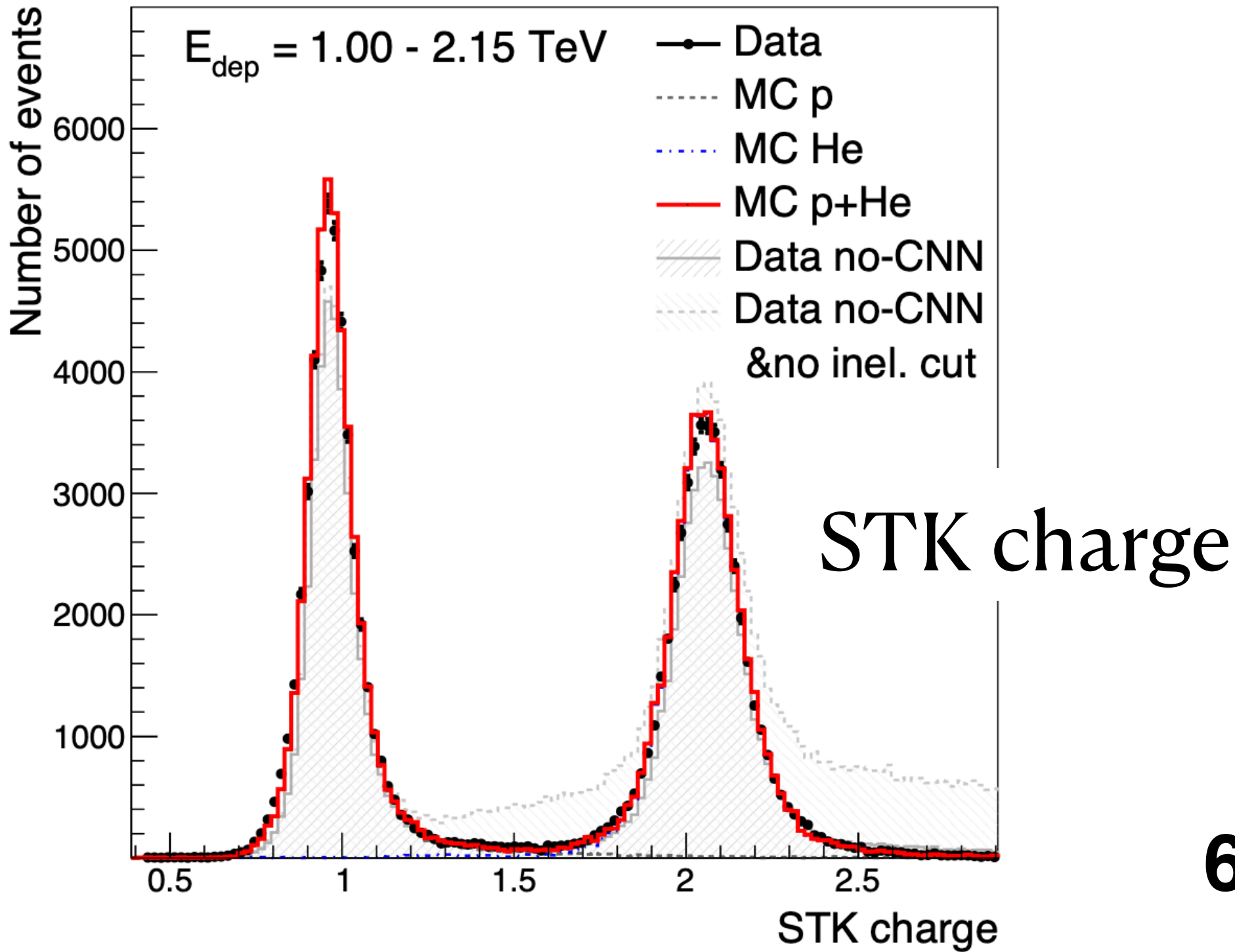
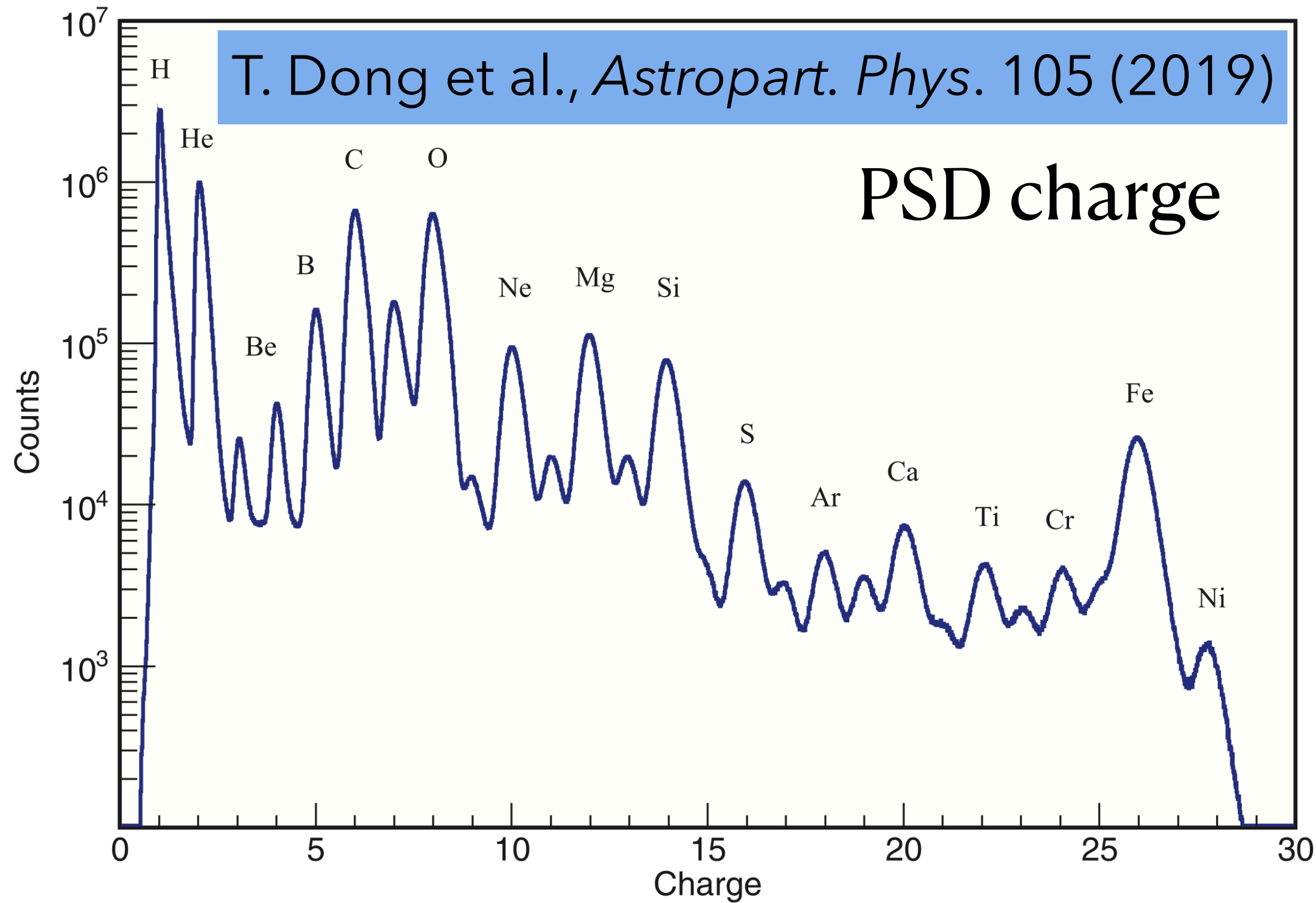


Parameter	Value
Energy range (e/ γ)	5 GeV to 10 TeV
Energy resolution (e/ γ)	1.5% at 800 GeV
Energy range (p/ion)	50 GeV to 500 TeV
Energy resolution (p)	40% at 800 GeV
Geometric factor (e)	0.3 m²sr above 30 GeV
Angular resolution (γ)	0.1 degree at 100 GeV
Field of view	0.1 sr

Charge Measurement

$$-\frac{dE}{dx} = K z^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

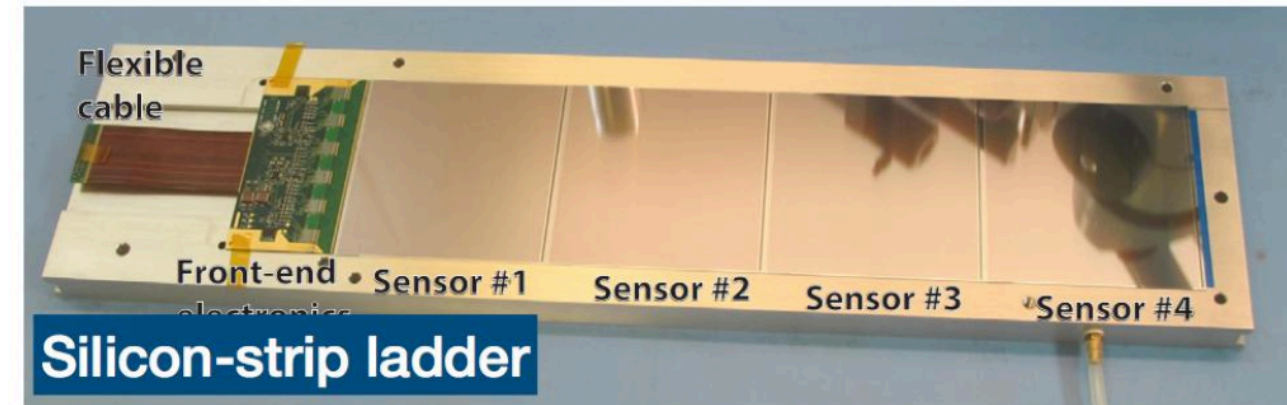
	PSD charge resolution (Charge unit, c.u.)	STK charge resolution (Charge unit, c.u.)
Proton	0.06	0.04
Helium	0.10	0.07



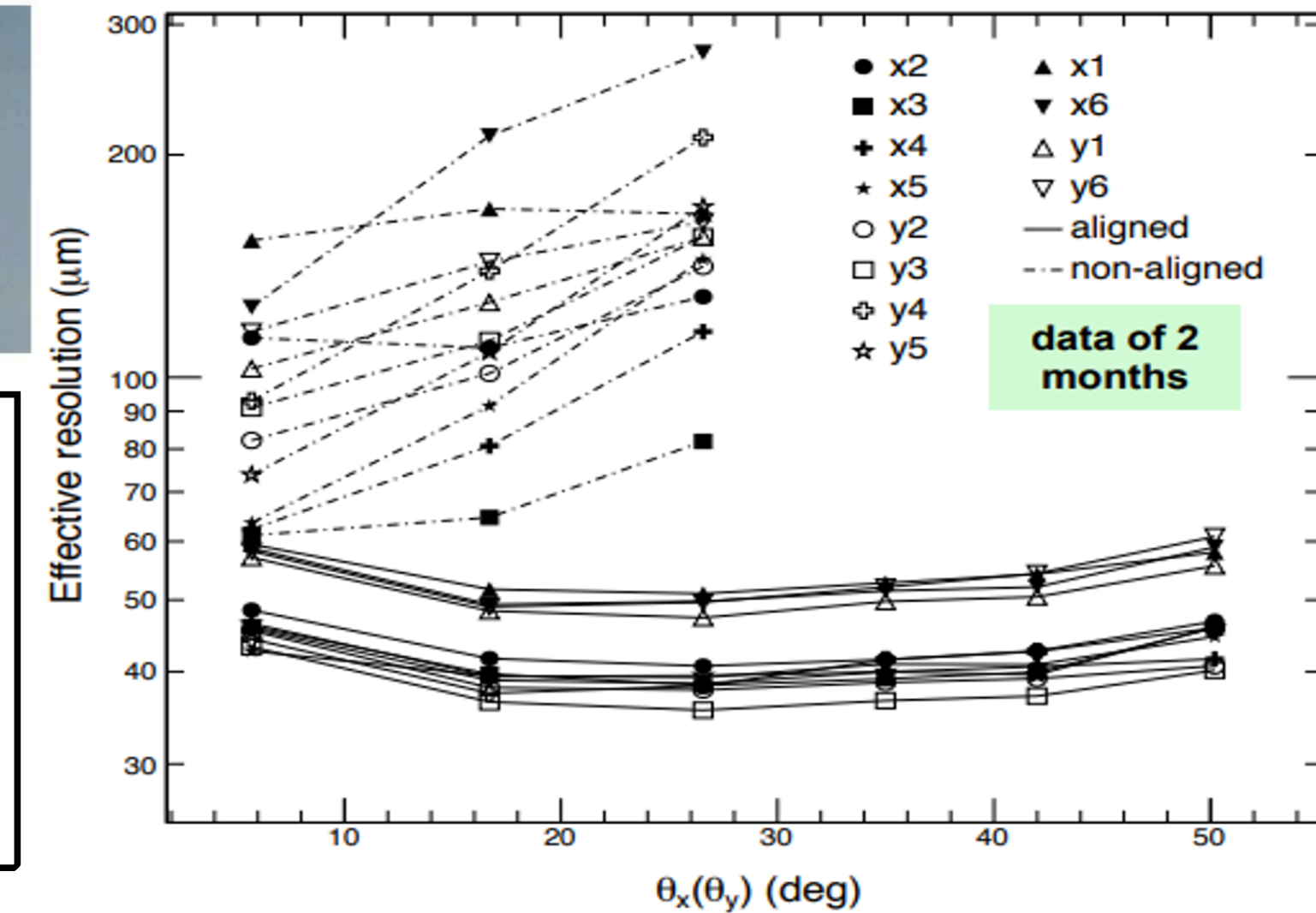
Track Measurement

Spatial resolution:

- Better than $60\text{ }\mu\text{m}$ after alignment

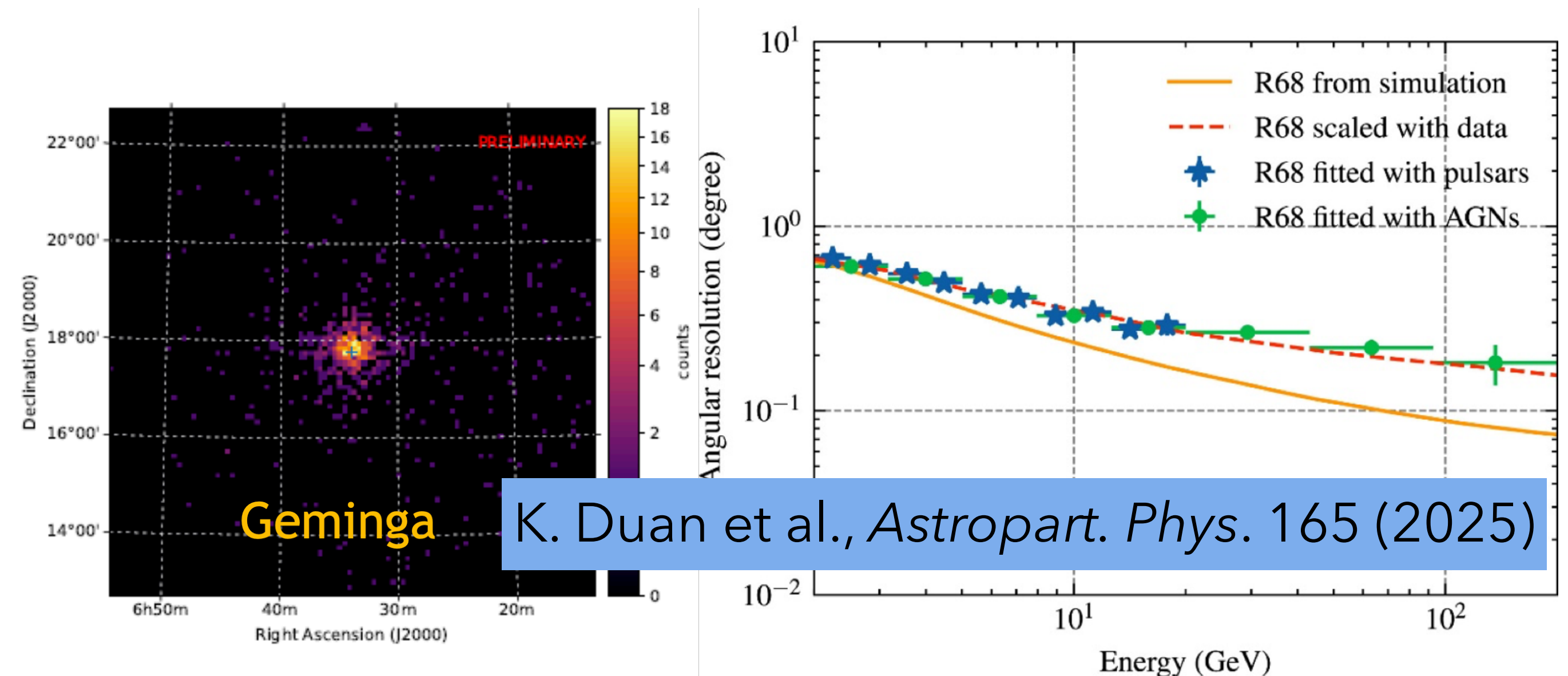


- 6 double-layers (x-y)
- 192 ladders
- Active area: $76 \times 76\text{ cm}^2$
- Silicon strip pitch: $121\text{ }\mu\text{m}$



Angular resolution:

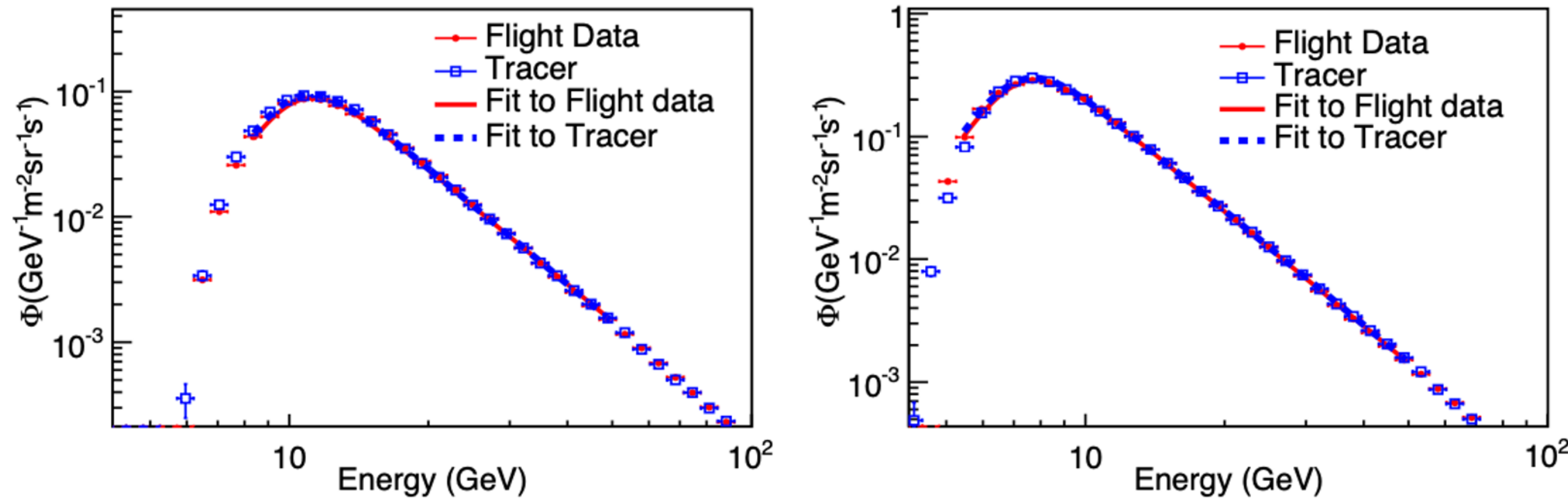
- The Point-Spread Function (PSF) is calibrated with photons from pulsars and stacked AGNs



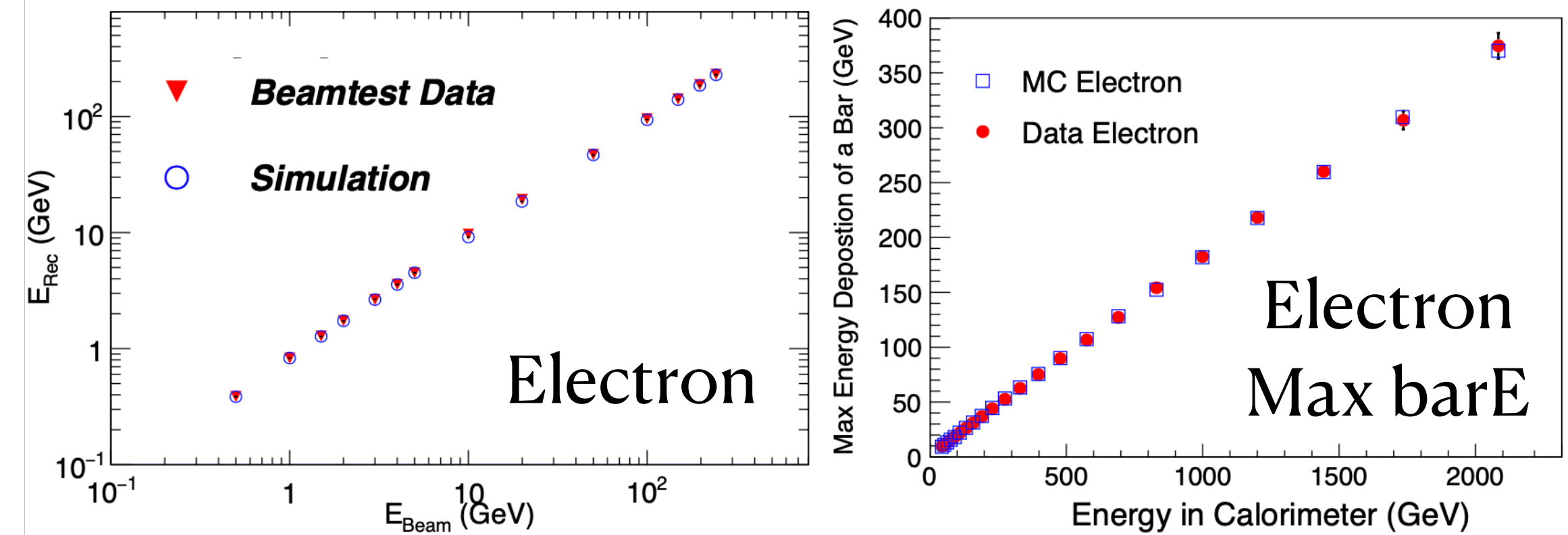
K. Duan et al., *Astropart. Phys.* 165 (2025)

Energy Scale and Linearity

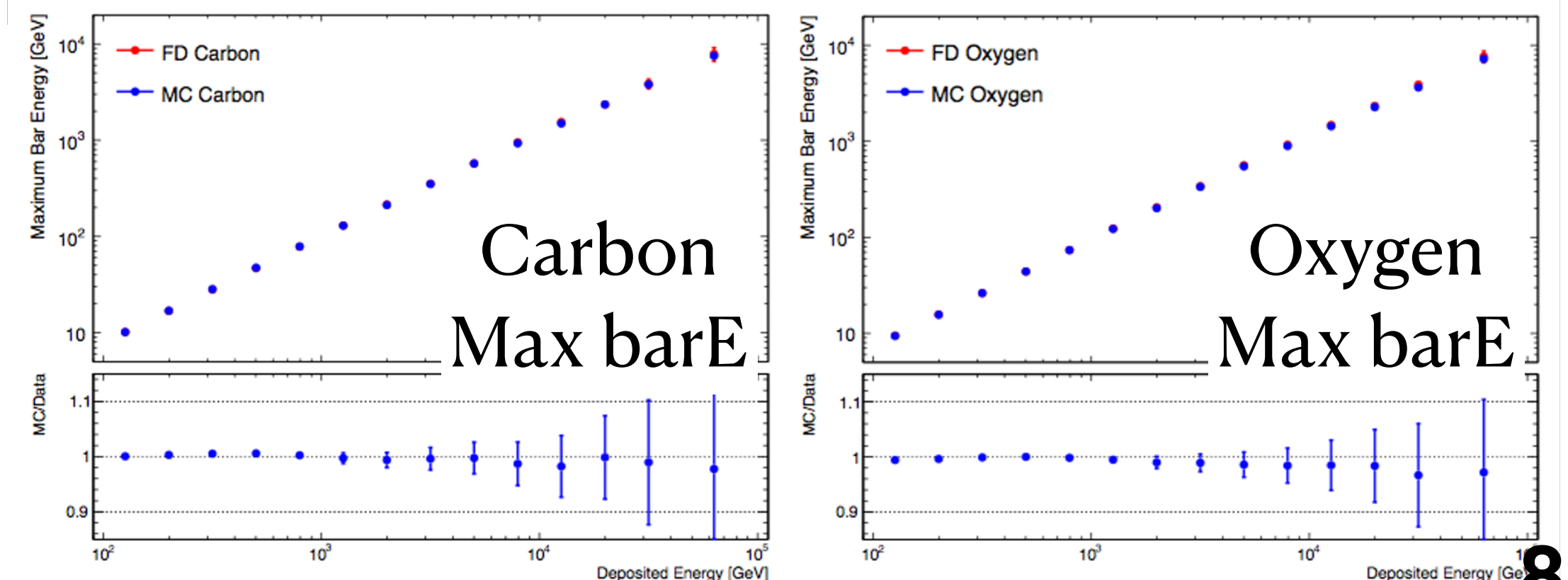
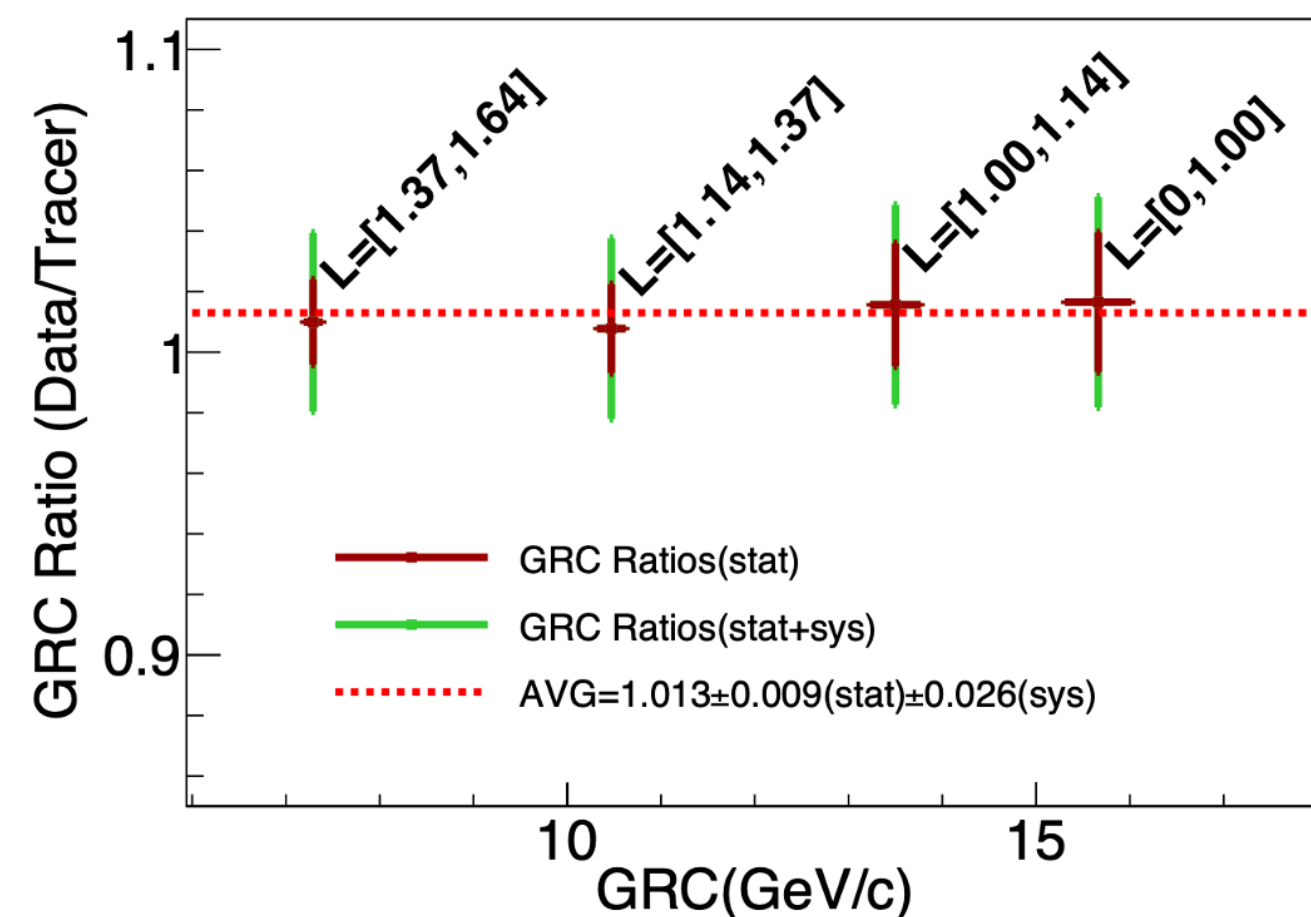
- In-orbit energy scale verified with geomagnetic cut-off
- Linearity verified with beam tests and MC simulations



C. Zhao et al. *Nucl. Instrum. Meth. A* 1092 (2022)

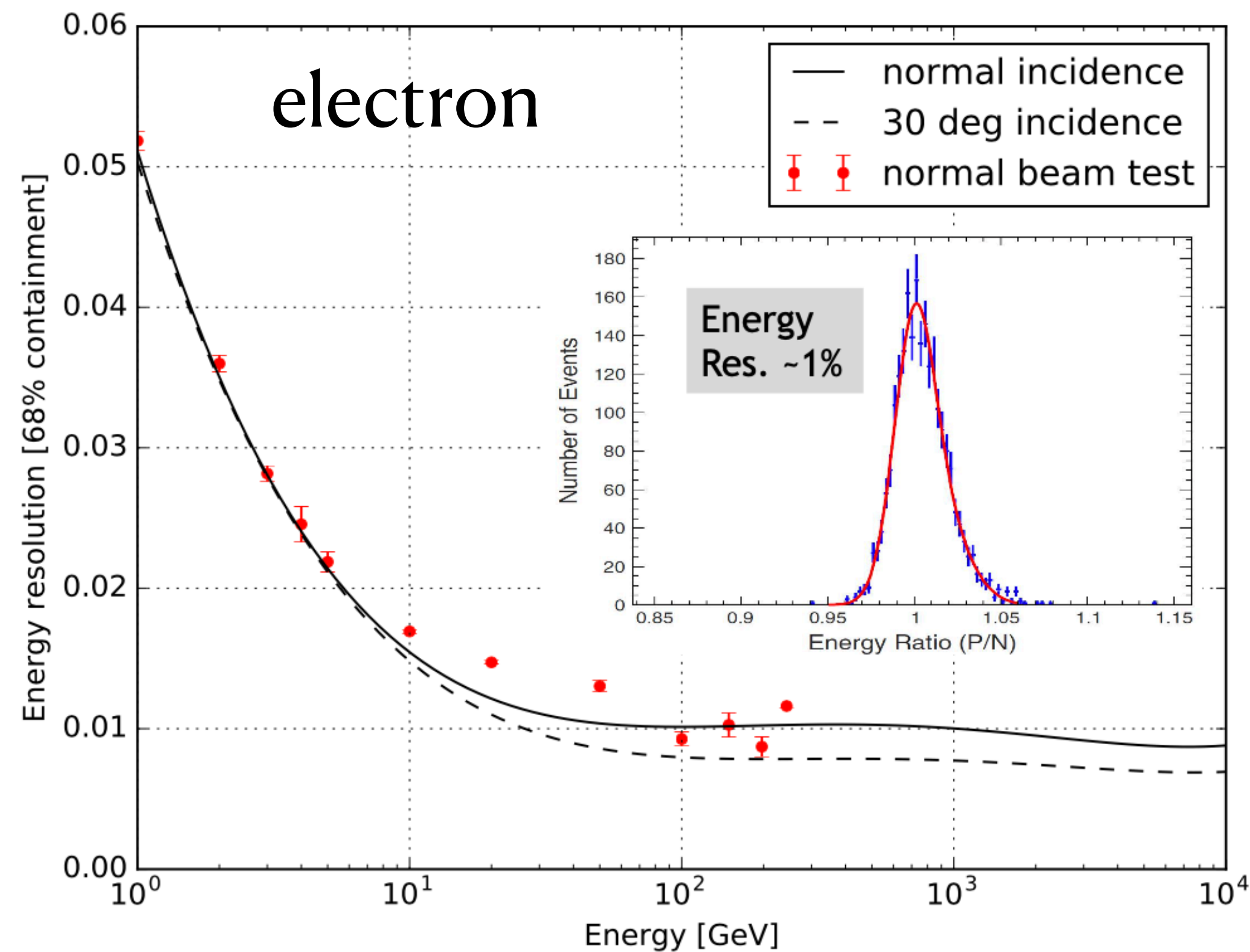


J. Zang et al. (2025)
Astropart. Phys. in print

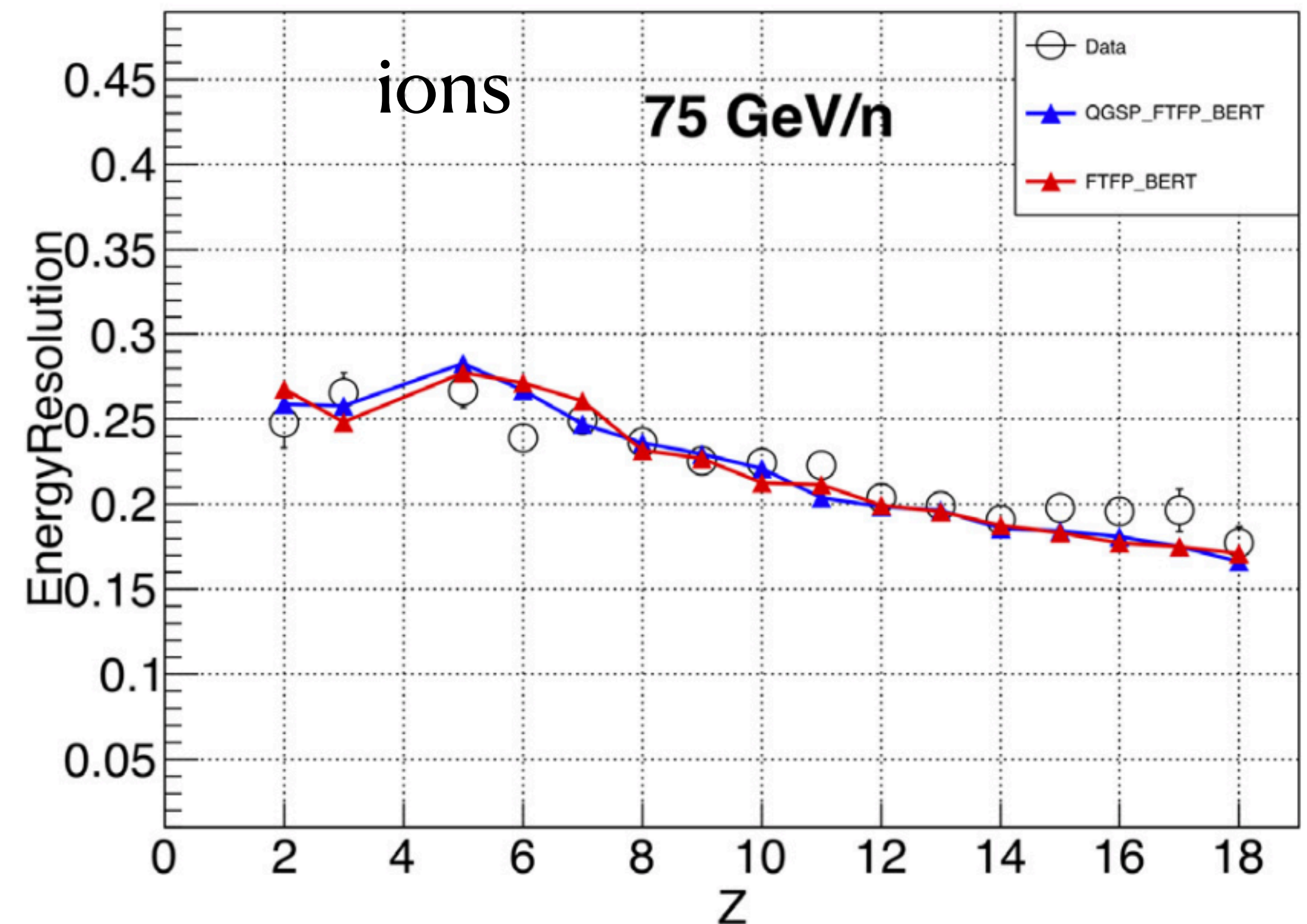


Energy Resolution

- Verified with beam tests at CERN SPS: $\sim 1\%$ (e/ γ) at 100 GeV and above, 20%–30% for protons/ions



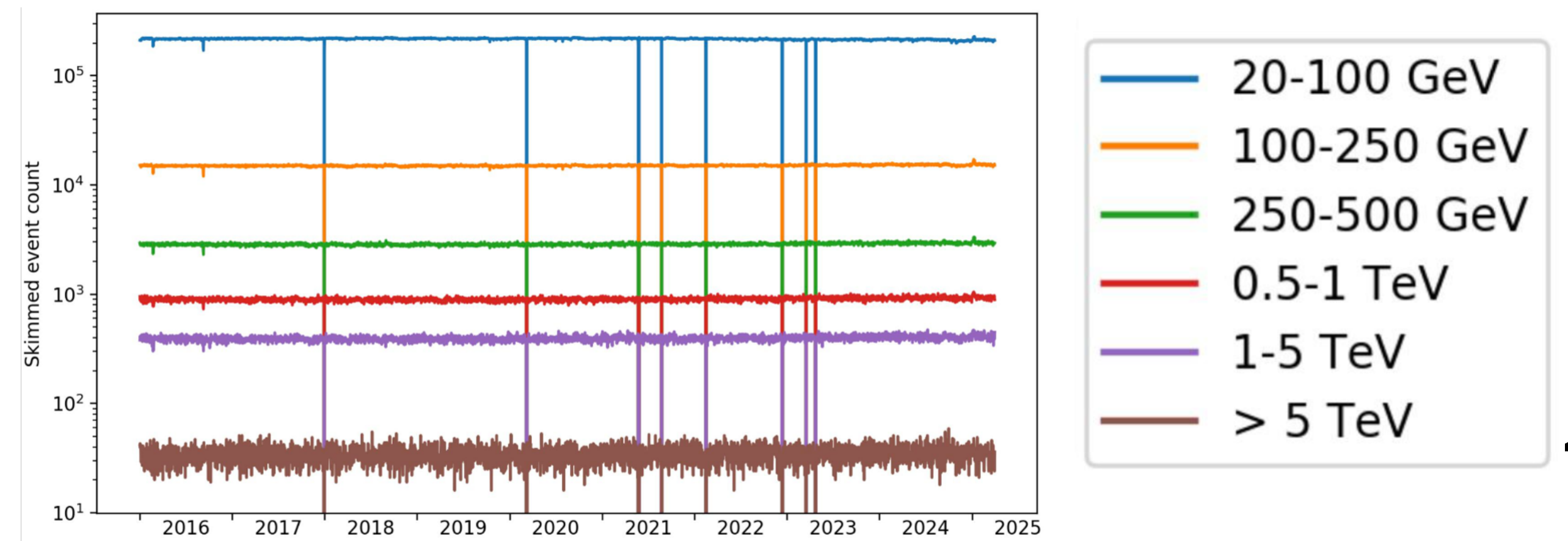
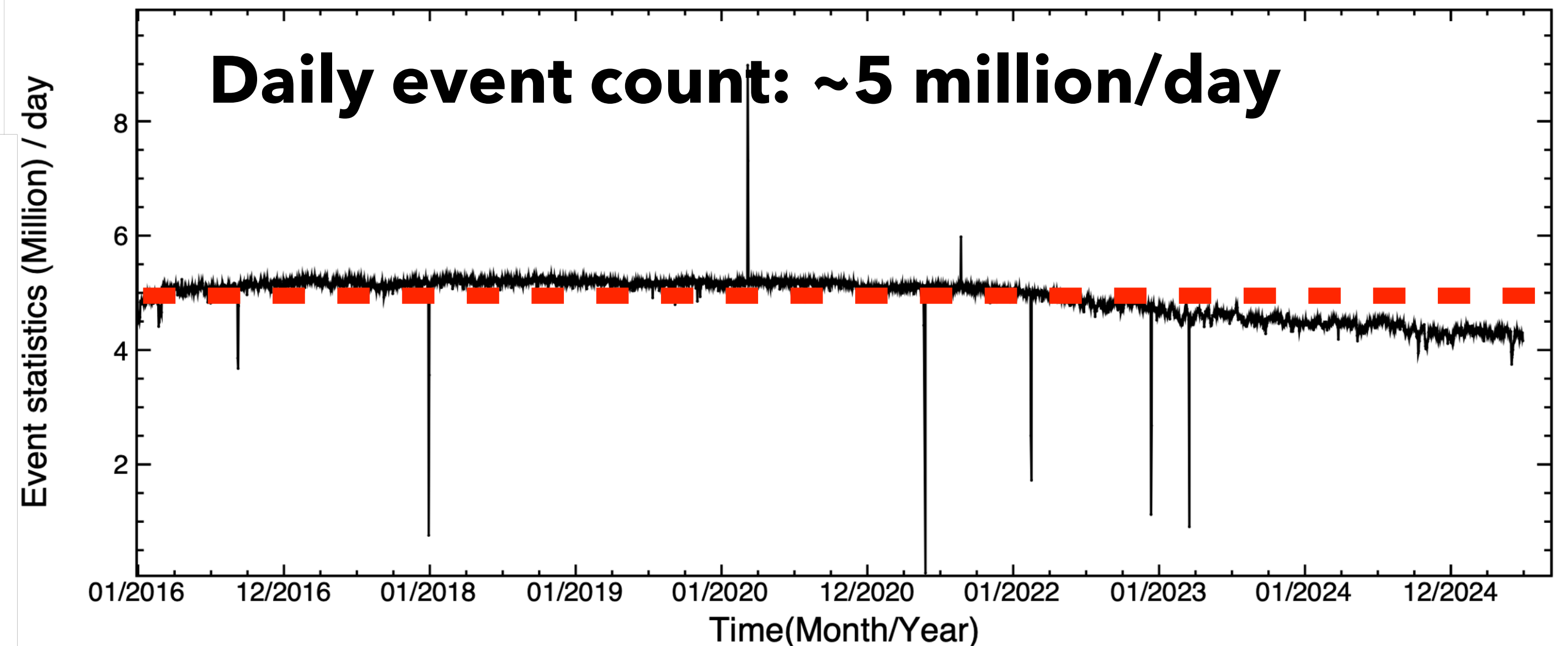
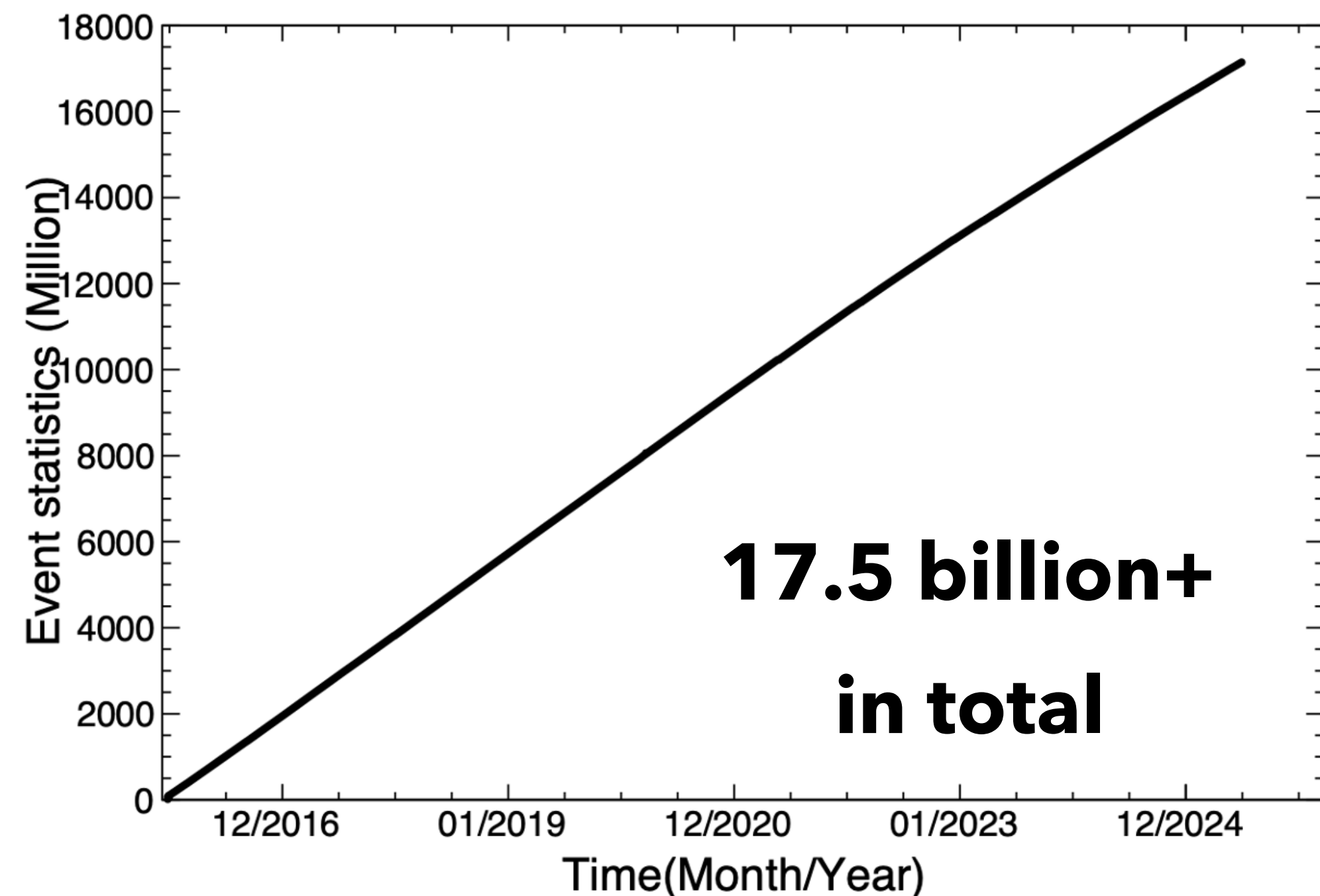
DAMPE Collab., *Astropart. Phys.* 95 (2017)



Y. Wei et al. *Nucl. Instrum. Meth. A* 922 (2019)

In-orbit Operation

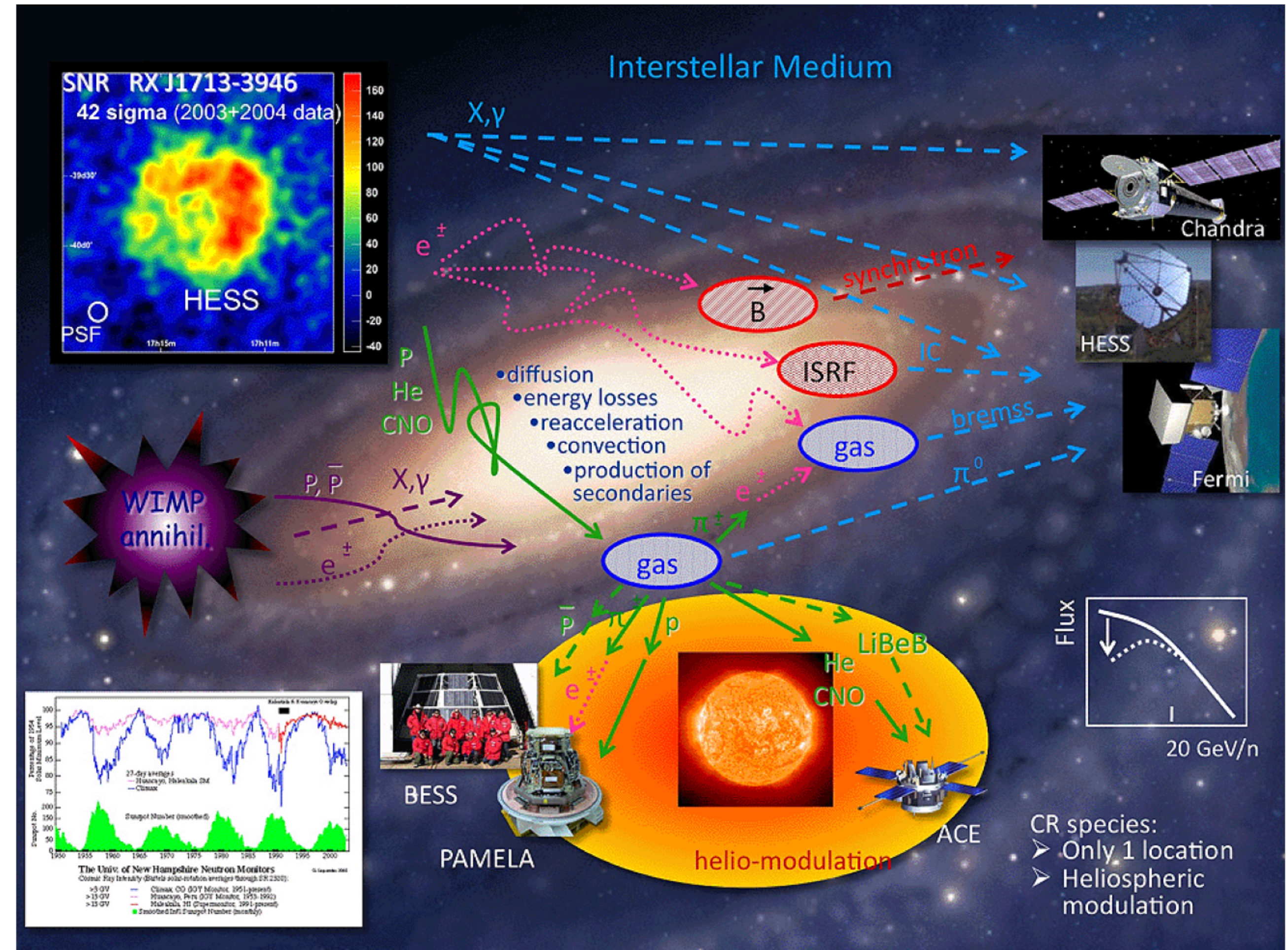
Smooth operation for 9.5 years since launch in Dec. 2017



Physical Results

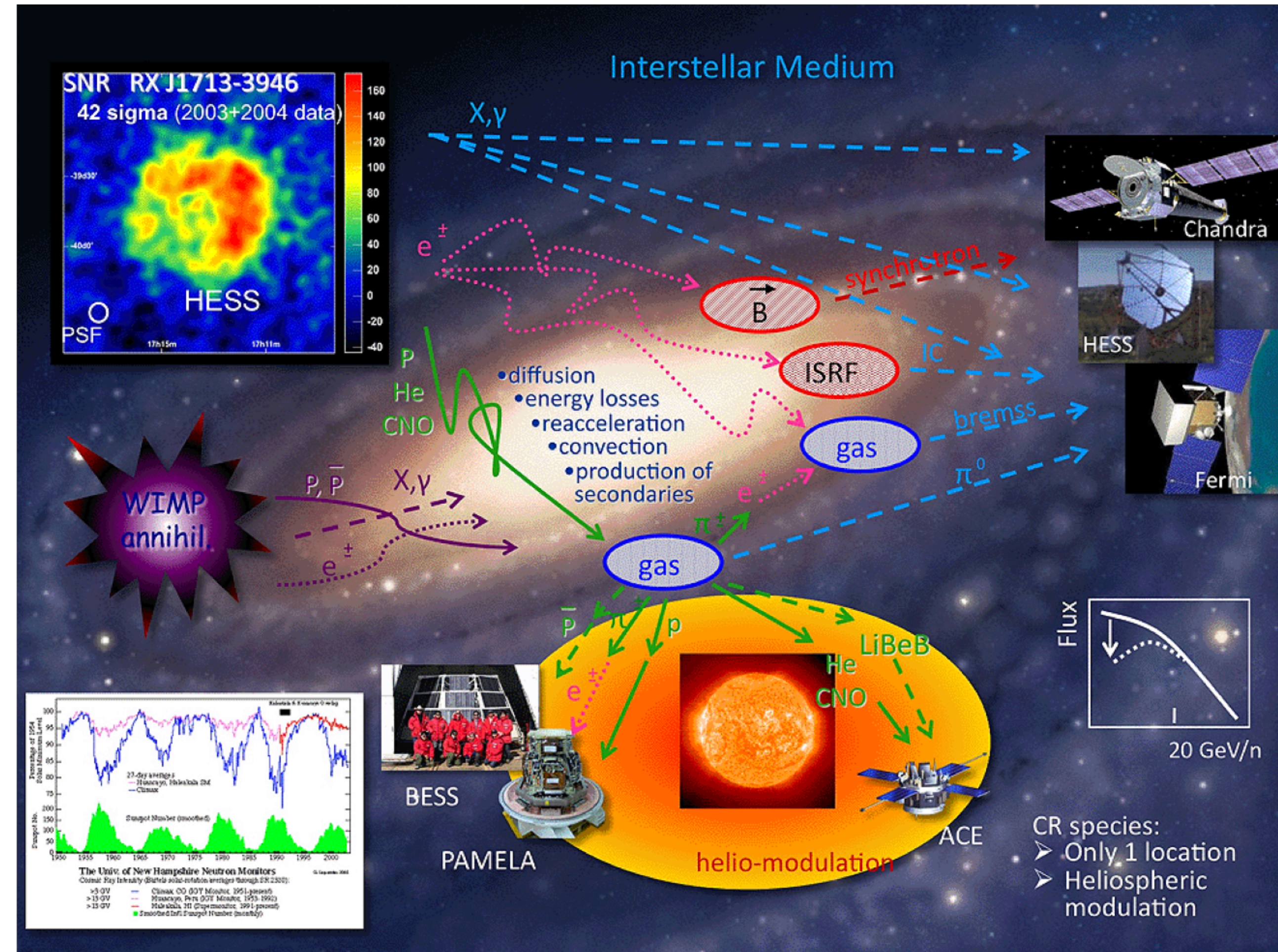
Physical Observations

- Cosmic ray (CR) **electron + positron** :
indirect detecting of dark matter
- Gamma ray
 - ❖ **Gamma ray line** search :
indirect detecting of dark matter
 - ❖ **Point sources catalog, Fermi
Bubble, ... :**
Gamma ray astronomy



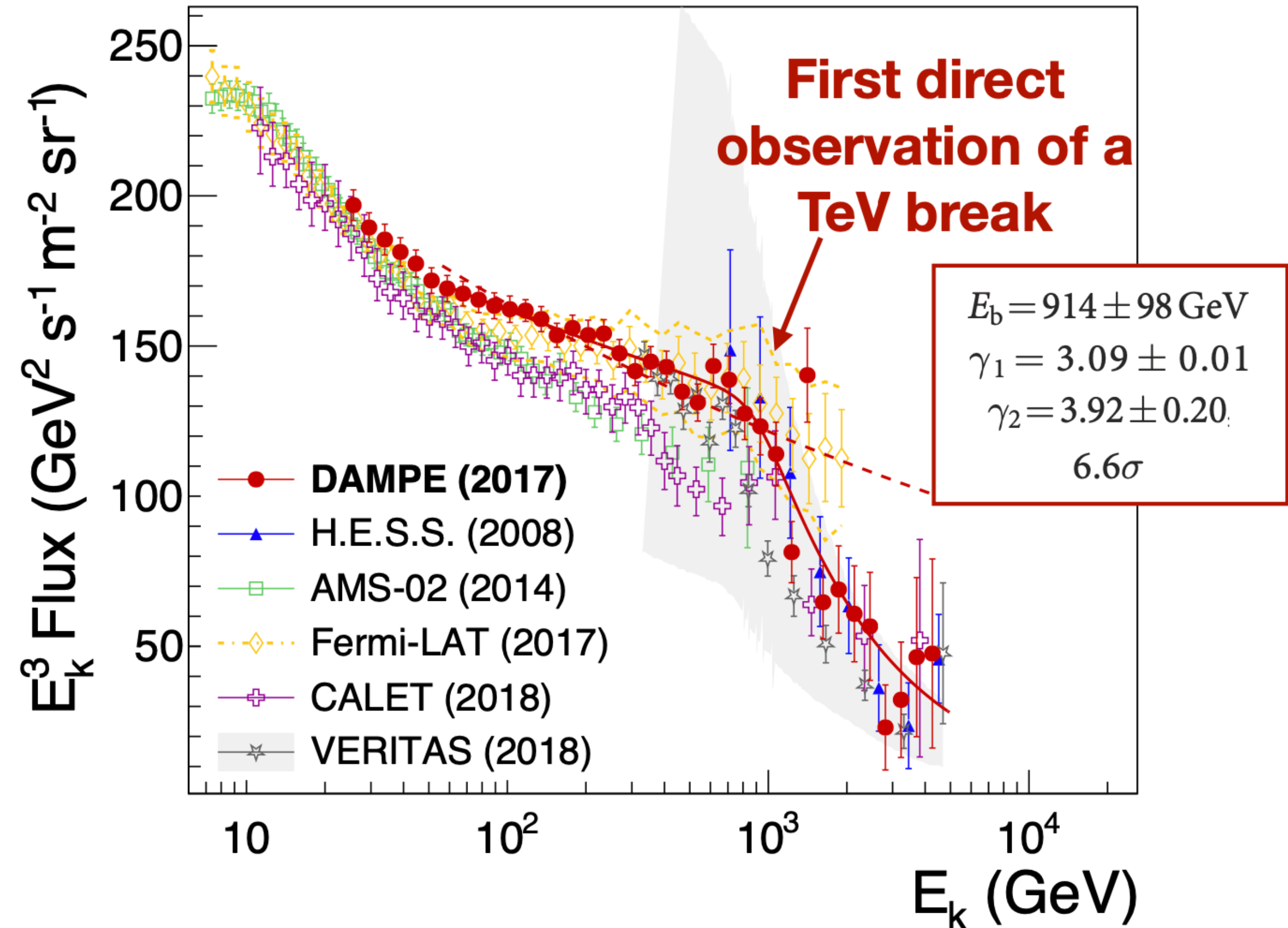
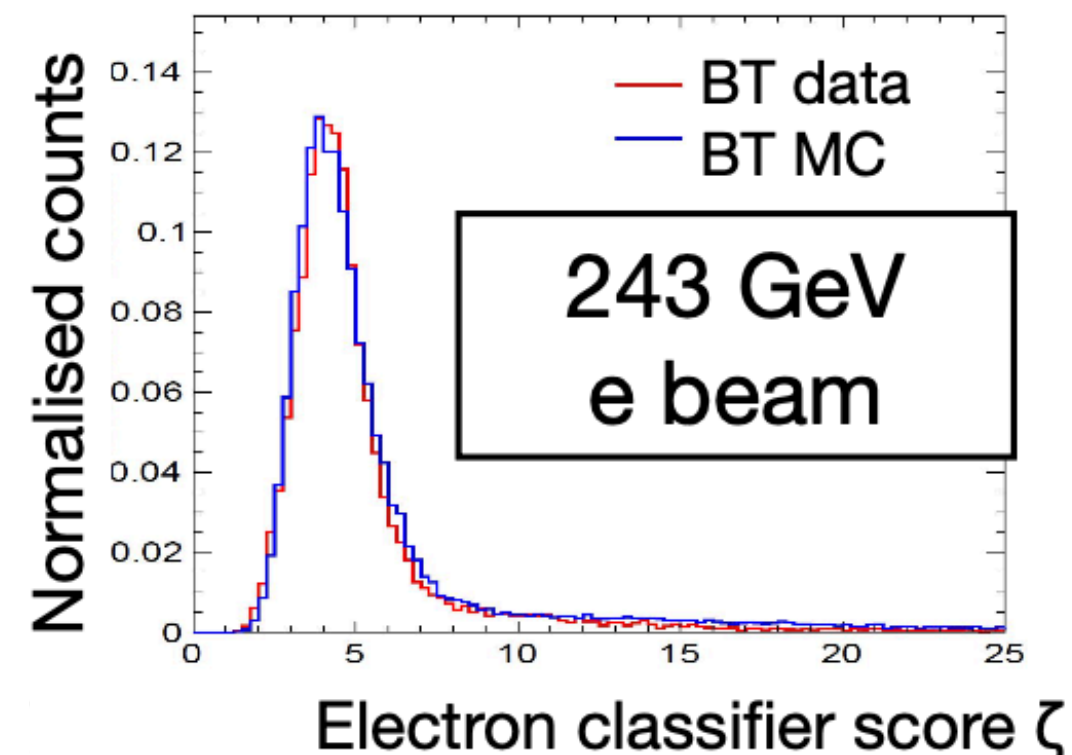
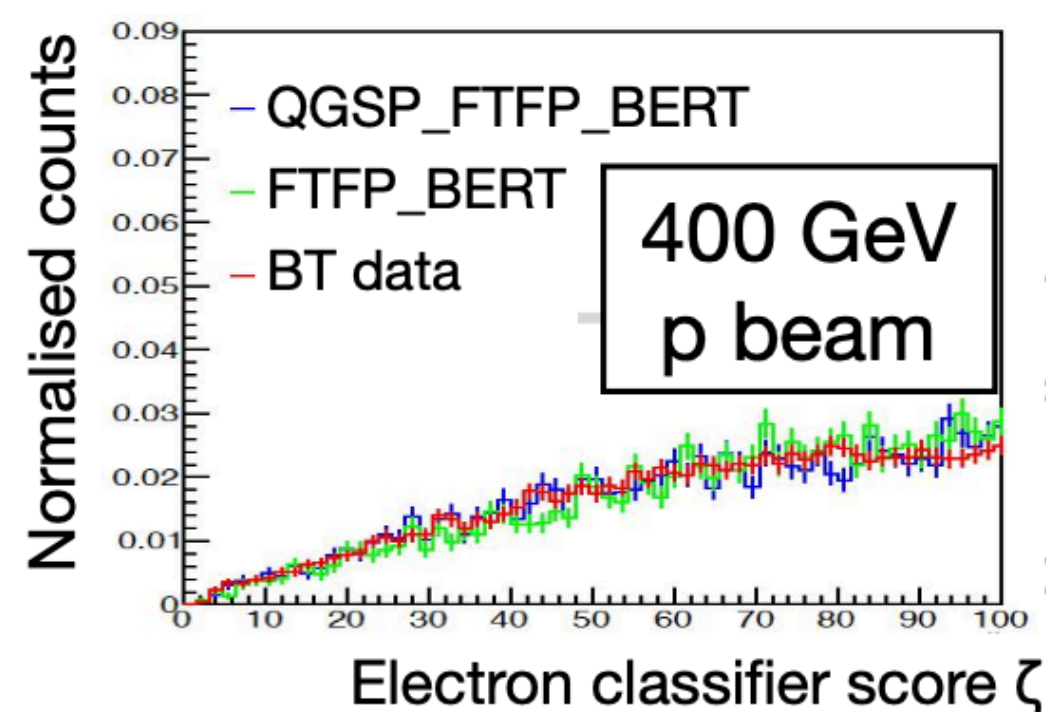
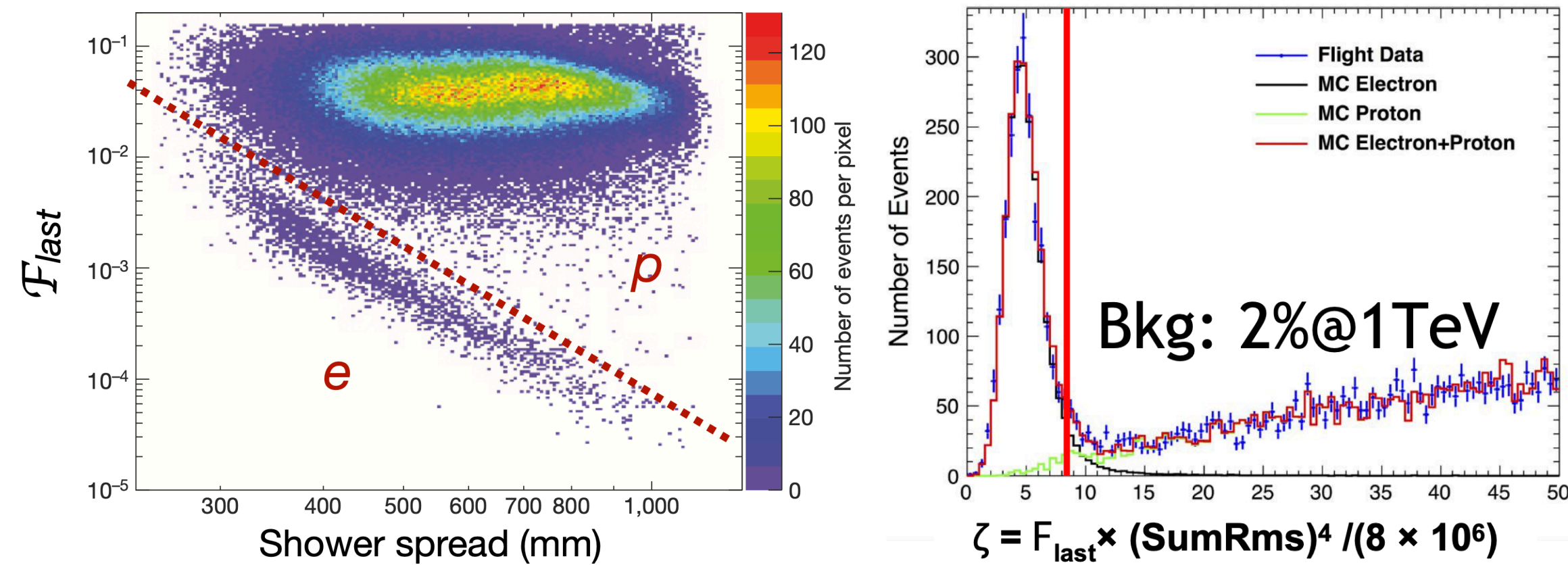
Physical Observations

- CR nuclei
 - ❖ **Primary components** (p, He, C, O, ..., Fe ...) : Studying the **origin and acceleration of cosmic rays**
 - ❖ **Secondary components** (Li, Be, B ...) : Studying the **propagation of cosmic rays**
- Other physical results
 - ❖ **Forbush Decrease** : **heliosphere physics**
 - ❖ **Fractional charged particle** : **new physics** beyond standard model



e^+e^- Spectrum

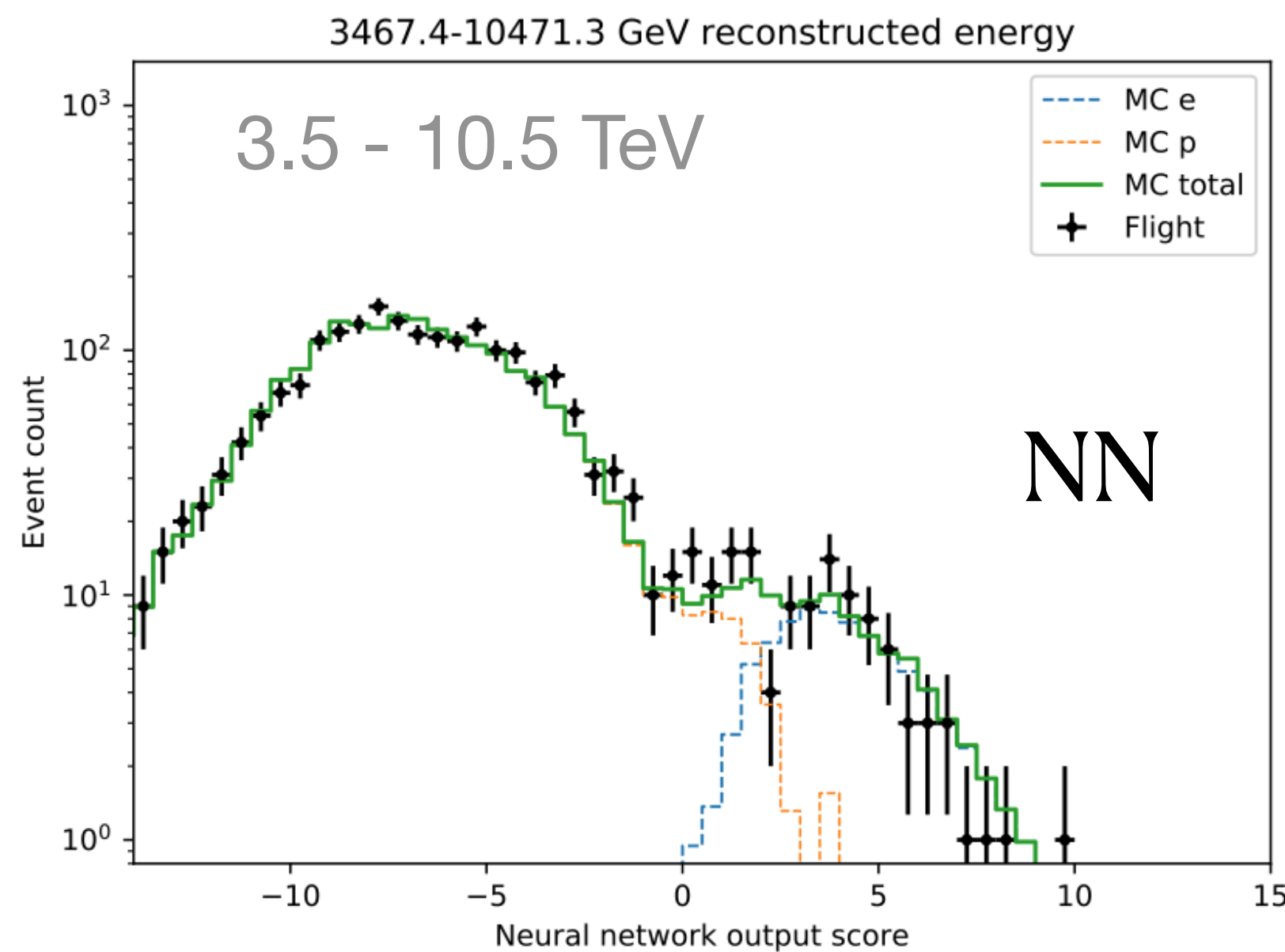
- Excellent energy resolution and powerful e/p identification
- Calibration/validation with beam test and γ ray sources



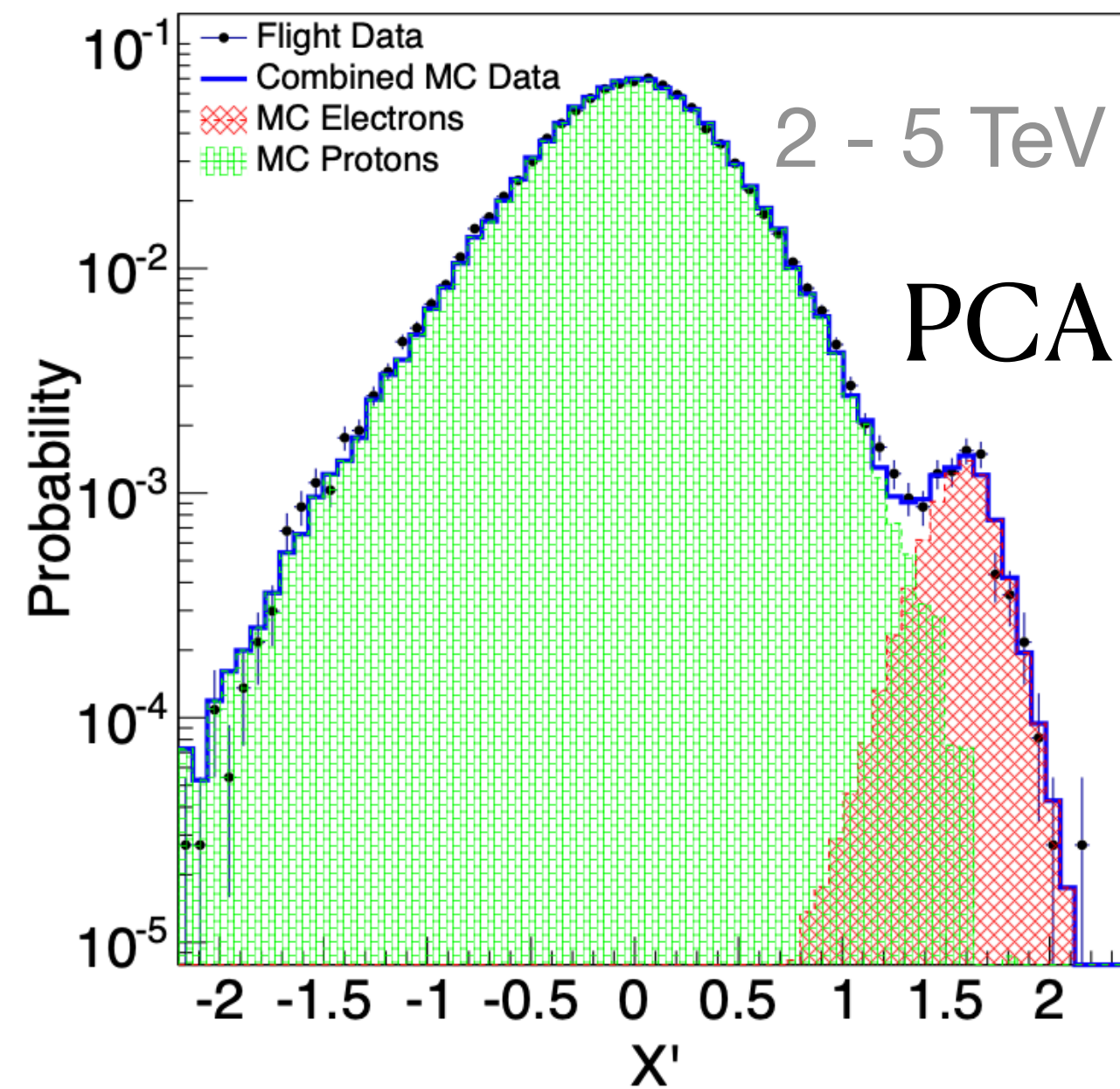
DAMPE Collab., *Nature* 552 (2017)

e^+e^- Spectrum (in progress)

- **Deep** and **long-term** detector calibration
- **New particle ID** for high energies: Neural Networks (NN), Principal Component Analysis (PCA), Application of Neutron Detector (NUD)

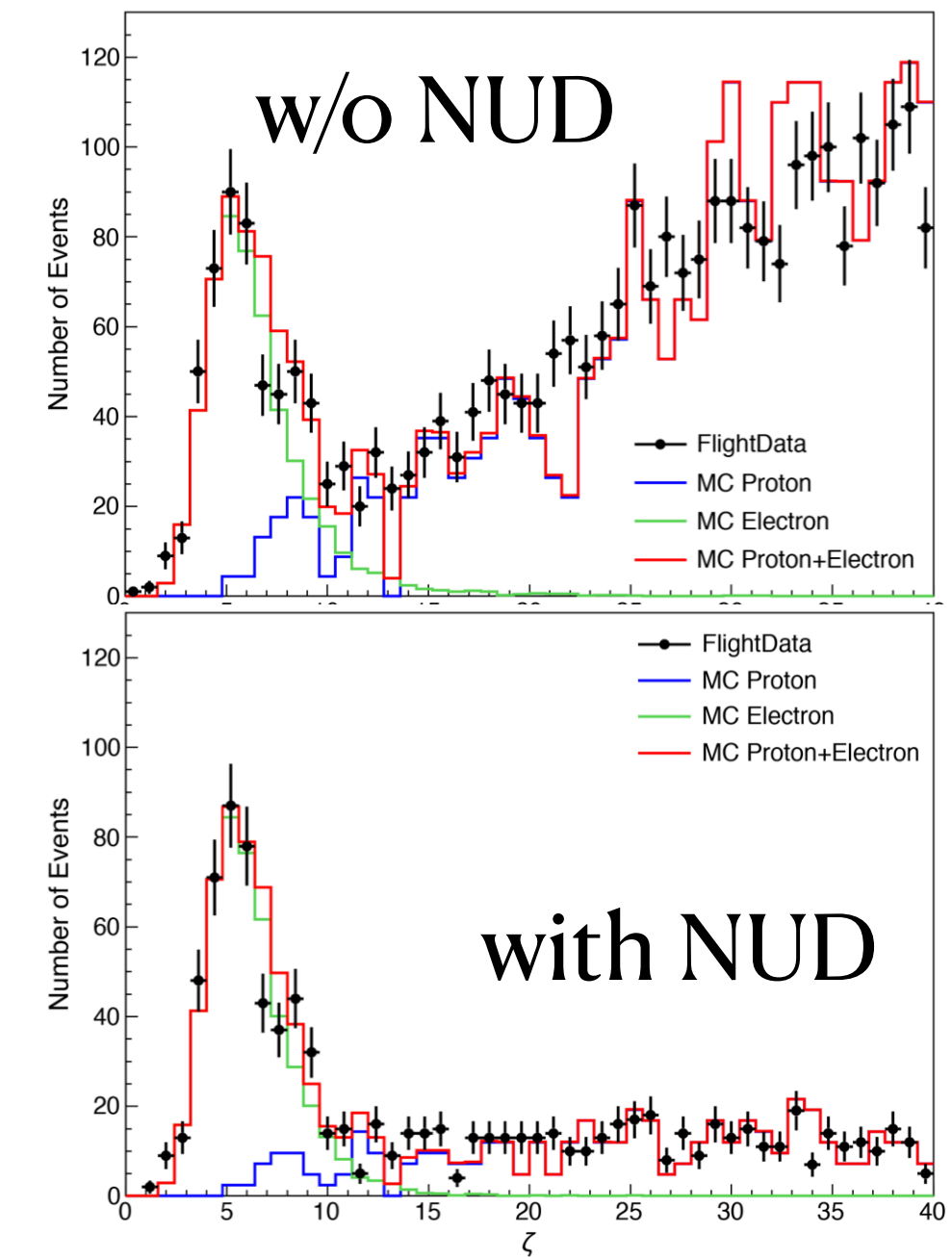


D. Droz et al. *J. Instrum.* 16 (2021)



Z. Xu et al. *Universe* 8 (2022)

+NUD 1 - 5 TeV

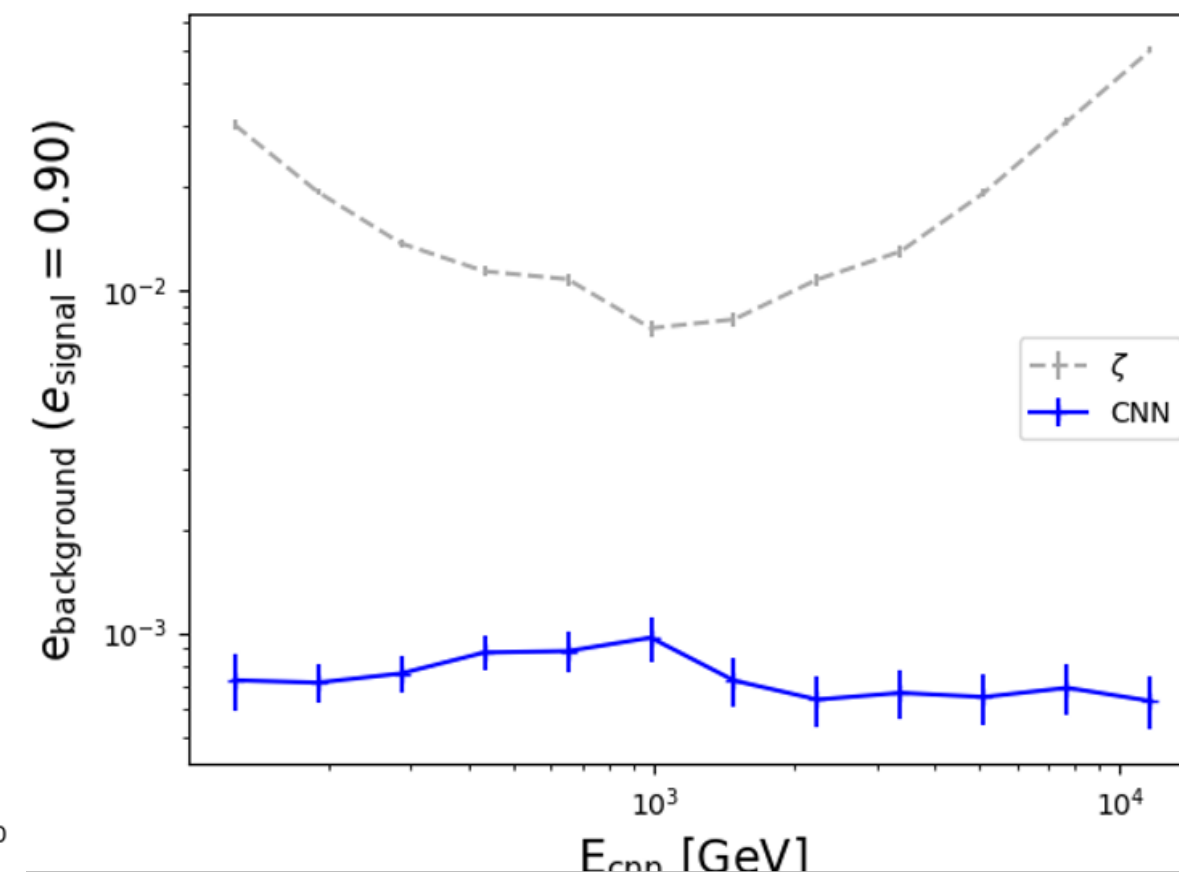
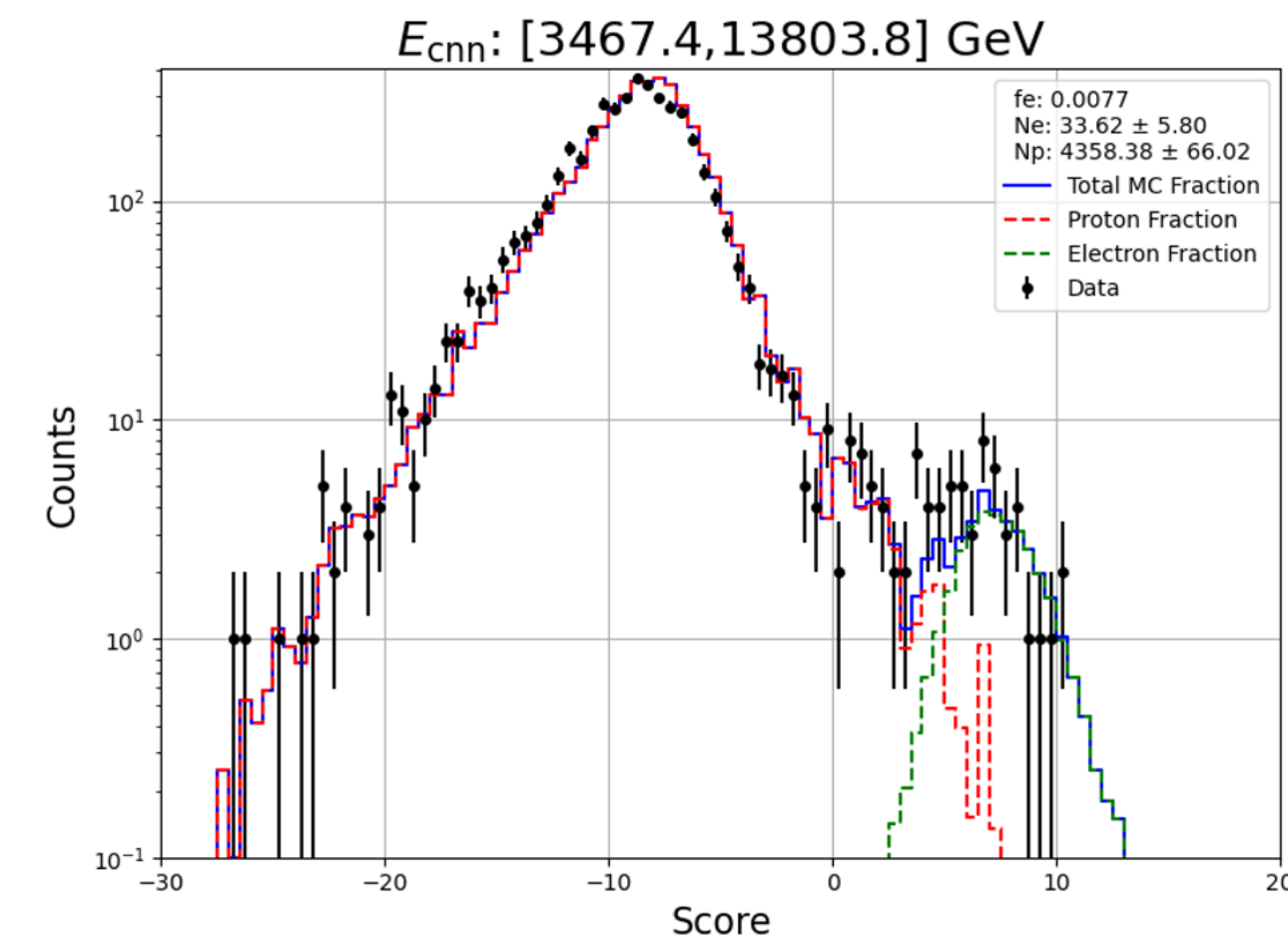
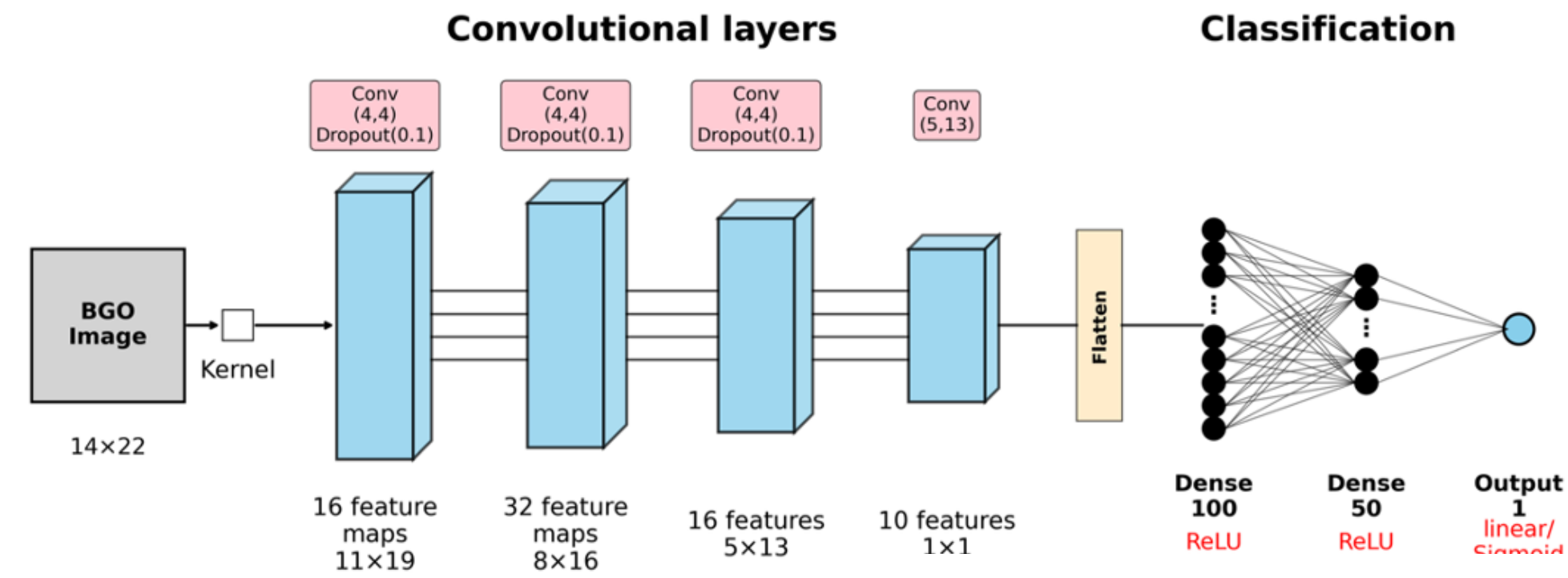


Y. Huang et al. *Res. Astron. Astrophys.* 20 (2020)

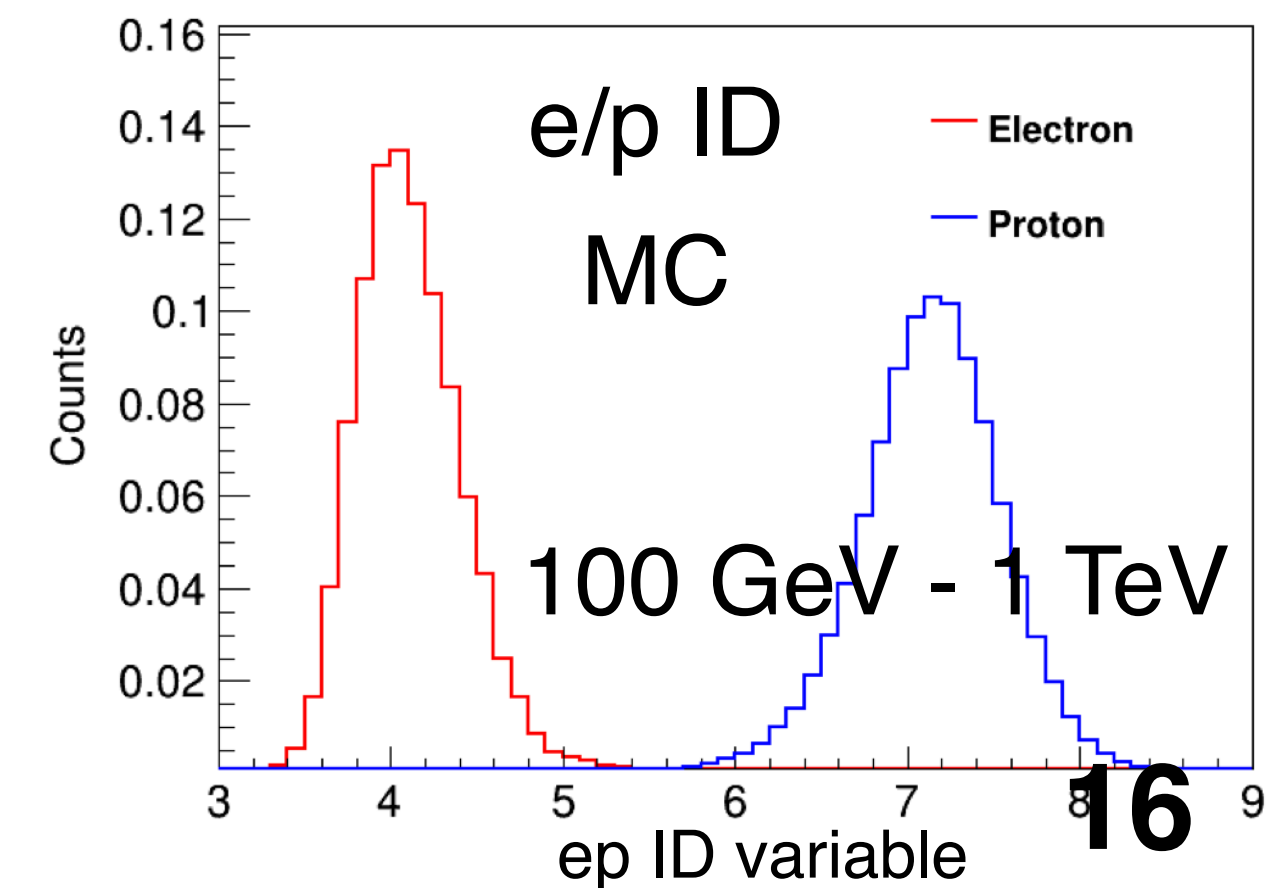
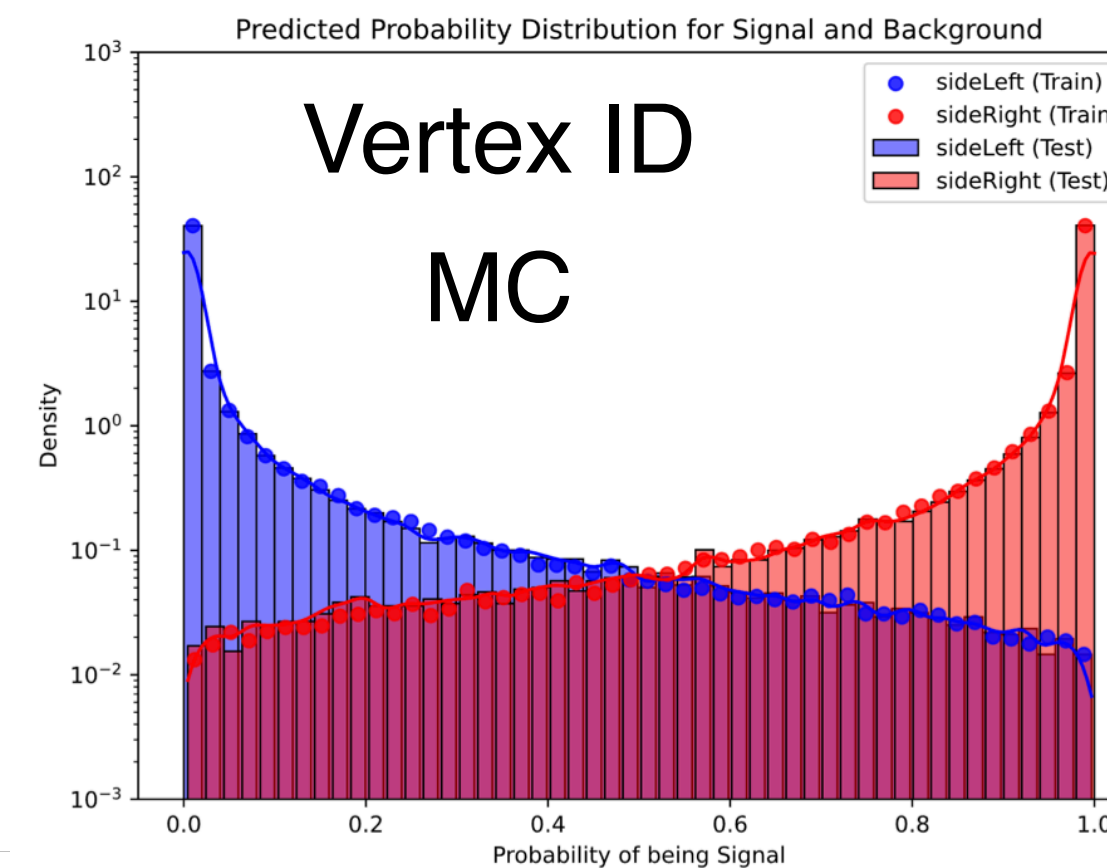
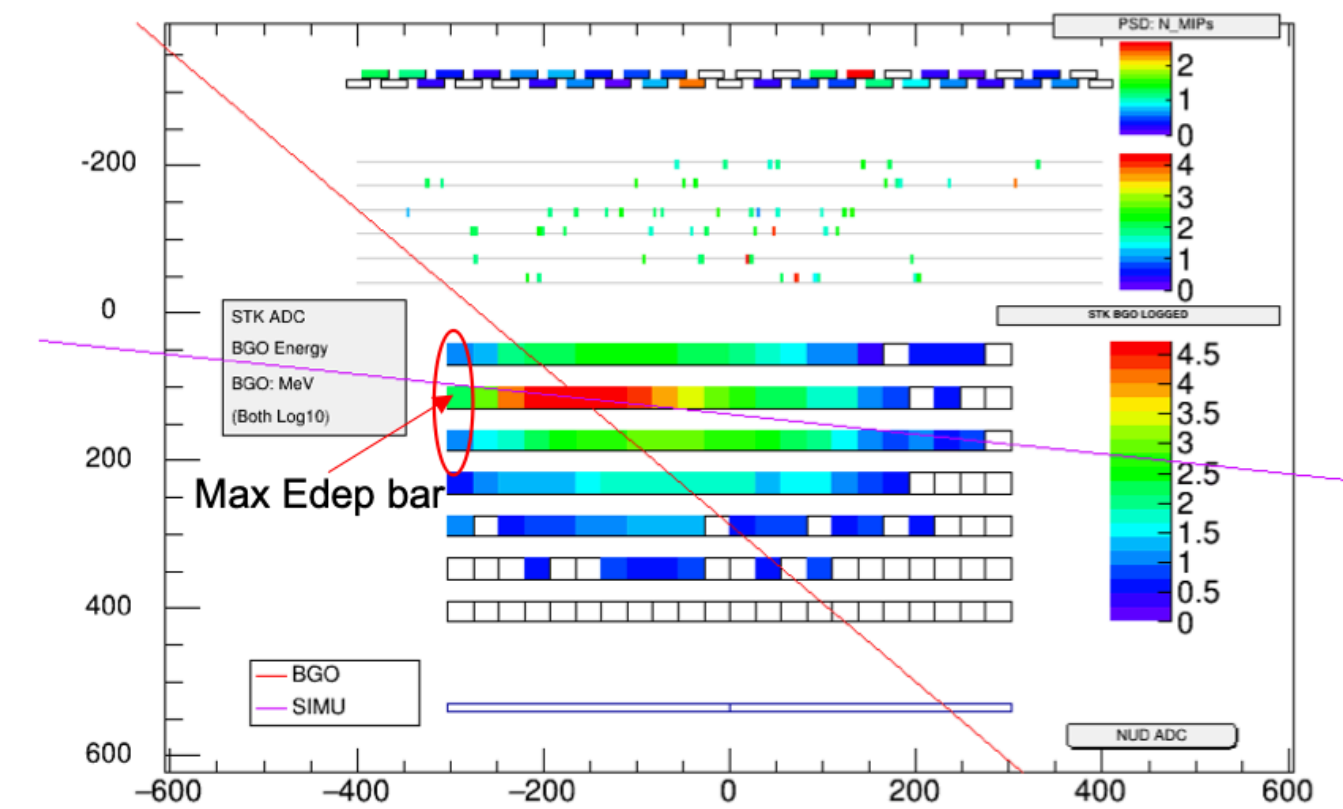
e^+e^- Spectrum (in progress)

- **Non-fiducial event** selection and reconstruction

No-fiducial e/p Identification (CNN Classifier)

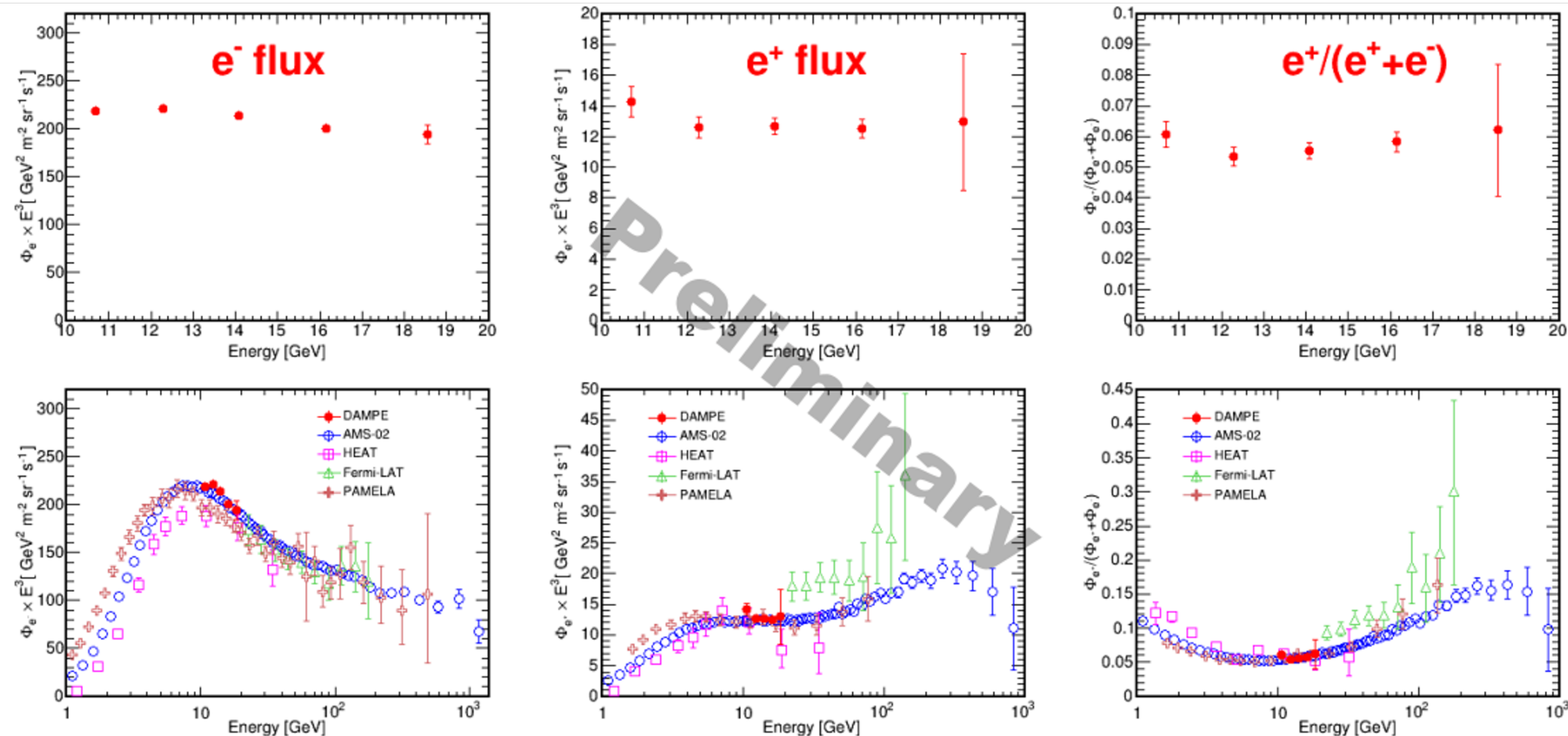
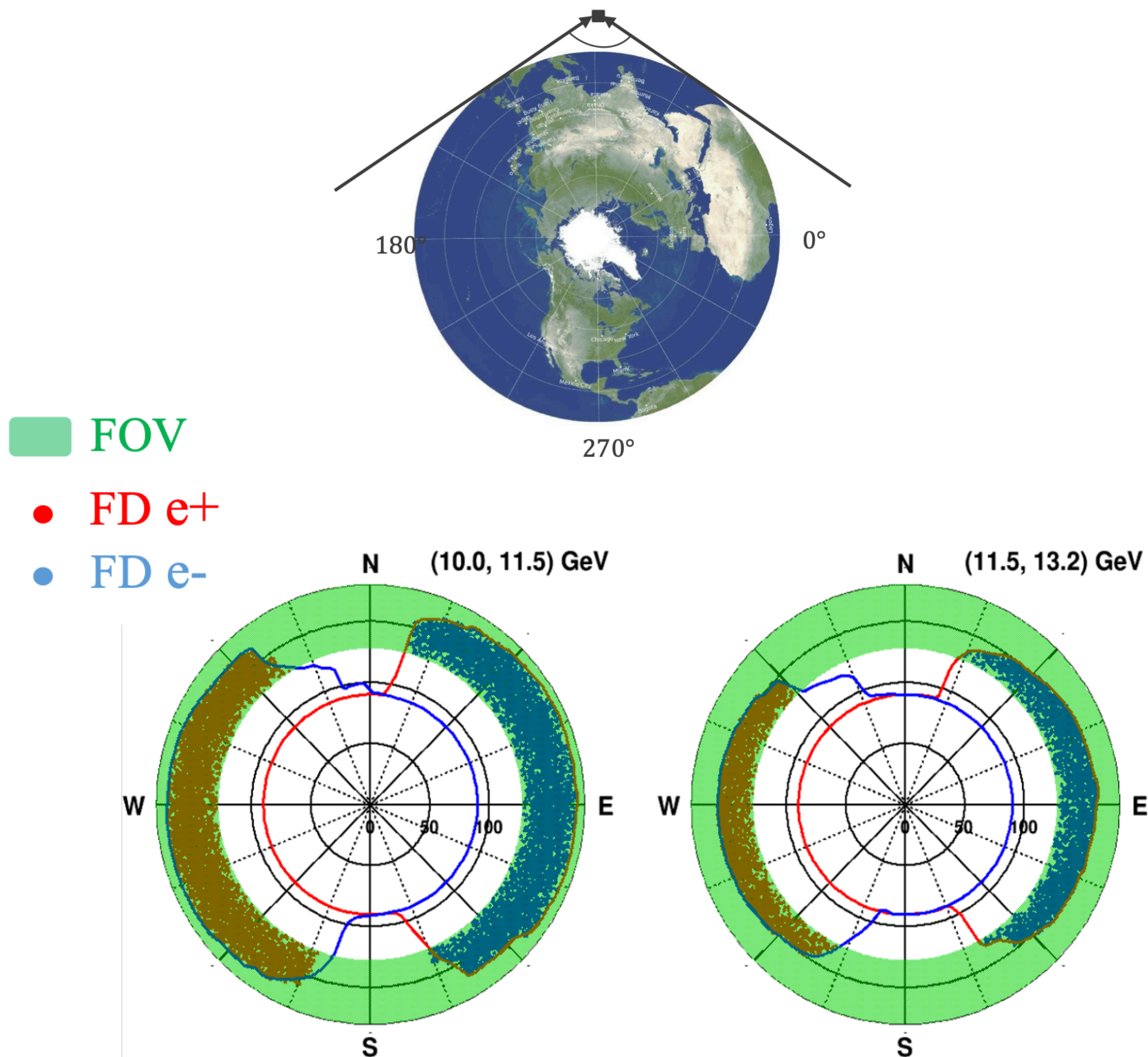


Side-events analysis (XGBoost)



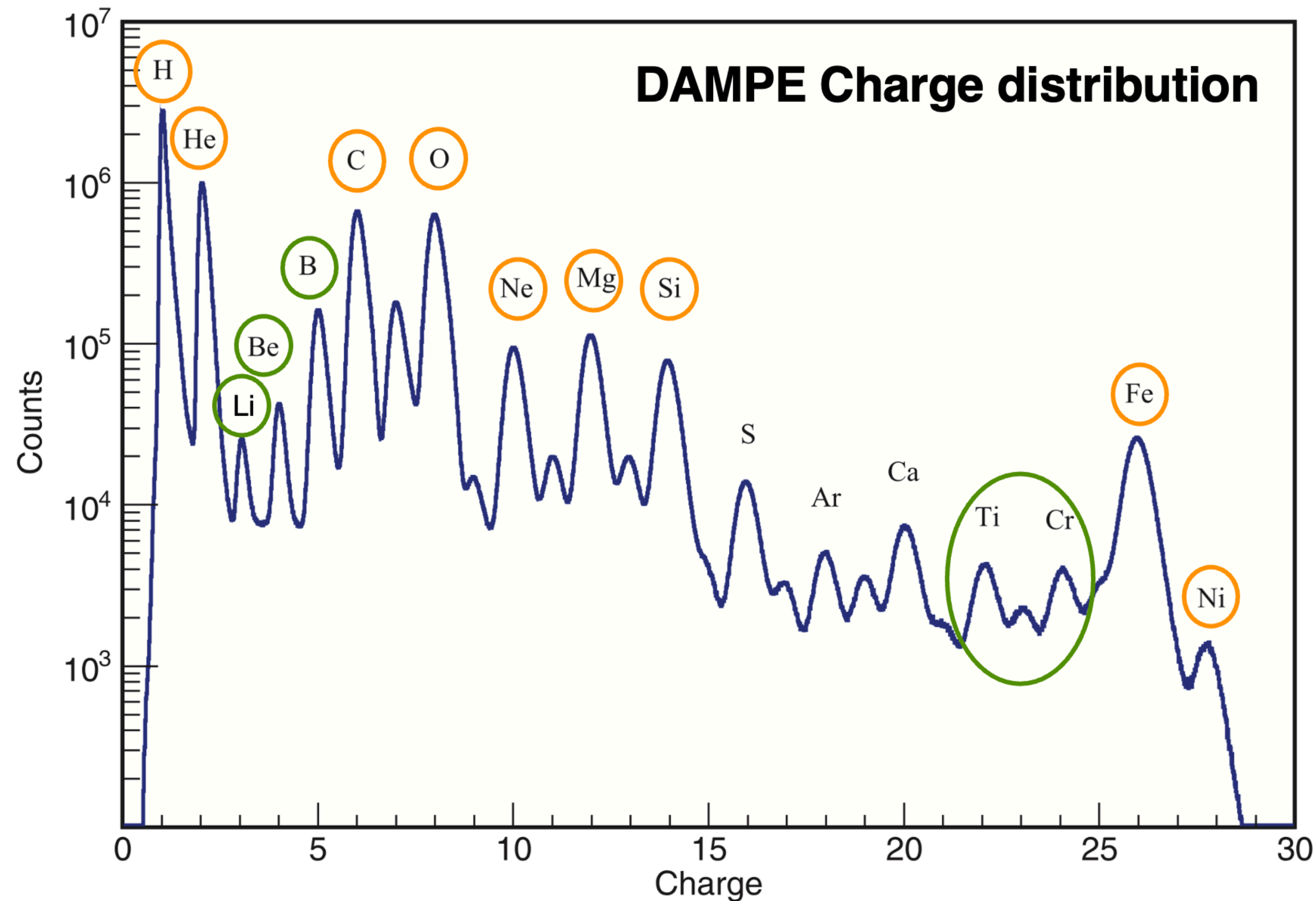
e^+ / e^- Spectrum

- CR e^+/e^- **discrimination** based on the **East-West effect** in the Geomagnetic field



- DAMPE measurements from 10 to 20 GeV are consistent with the previous results of AMS-02 and PAMELA
- Submitted to *Chinese Phys. C* (Accepted)

CR Proton & Nuclei



Primary CRs:

CR origin / acceleration

- proton, Helium, p+He
- C, O, Ne, Mg, Si, Fe, Ni,

Secondary CRs:

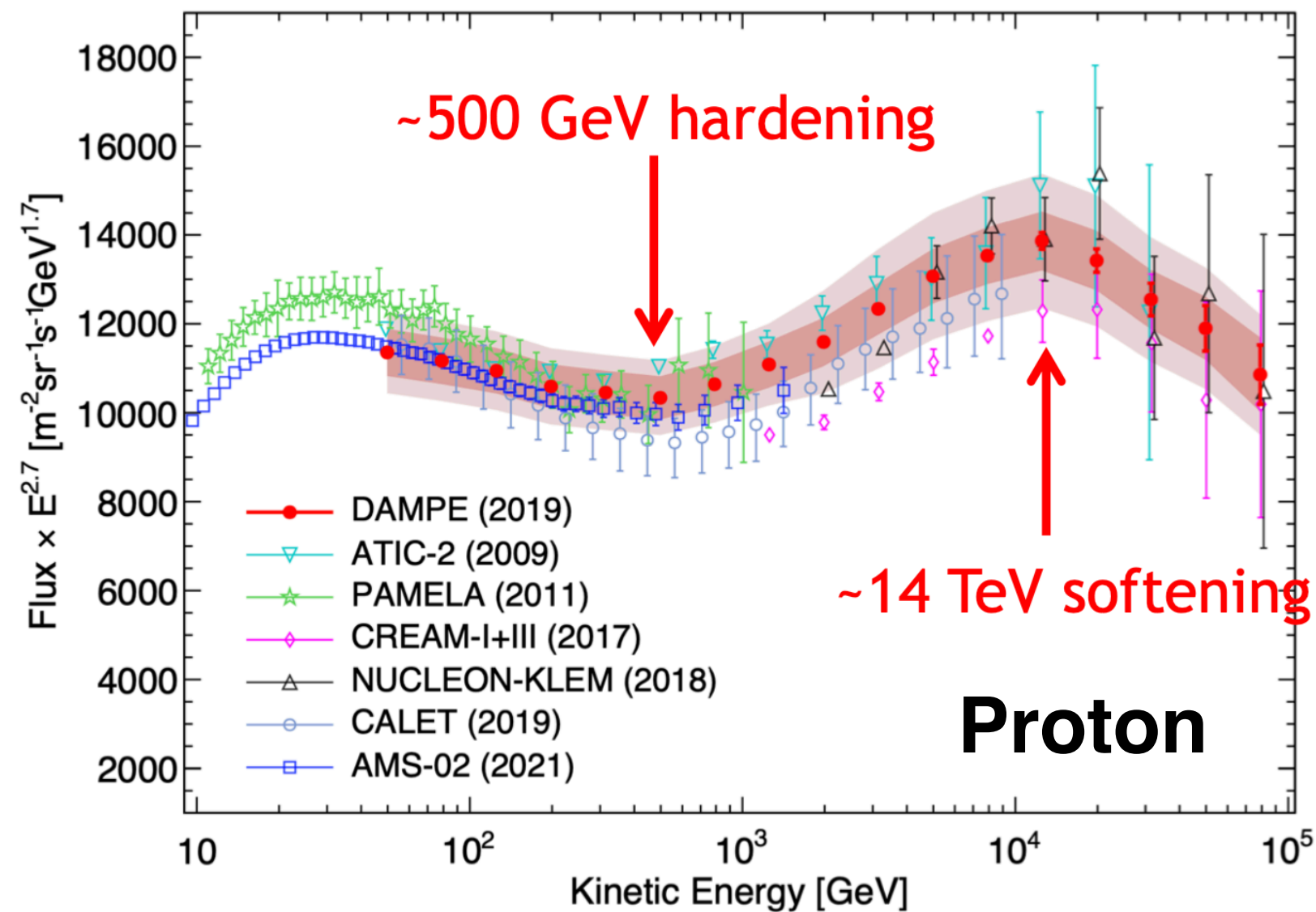
CR propagation

- Li, Be, B, ...
- Sub-Iron

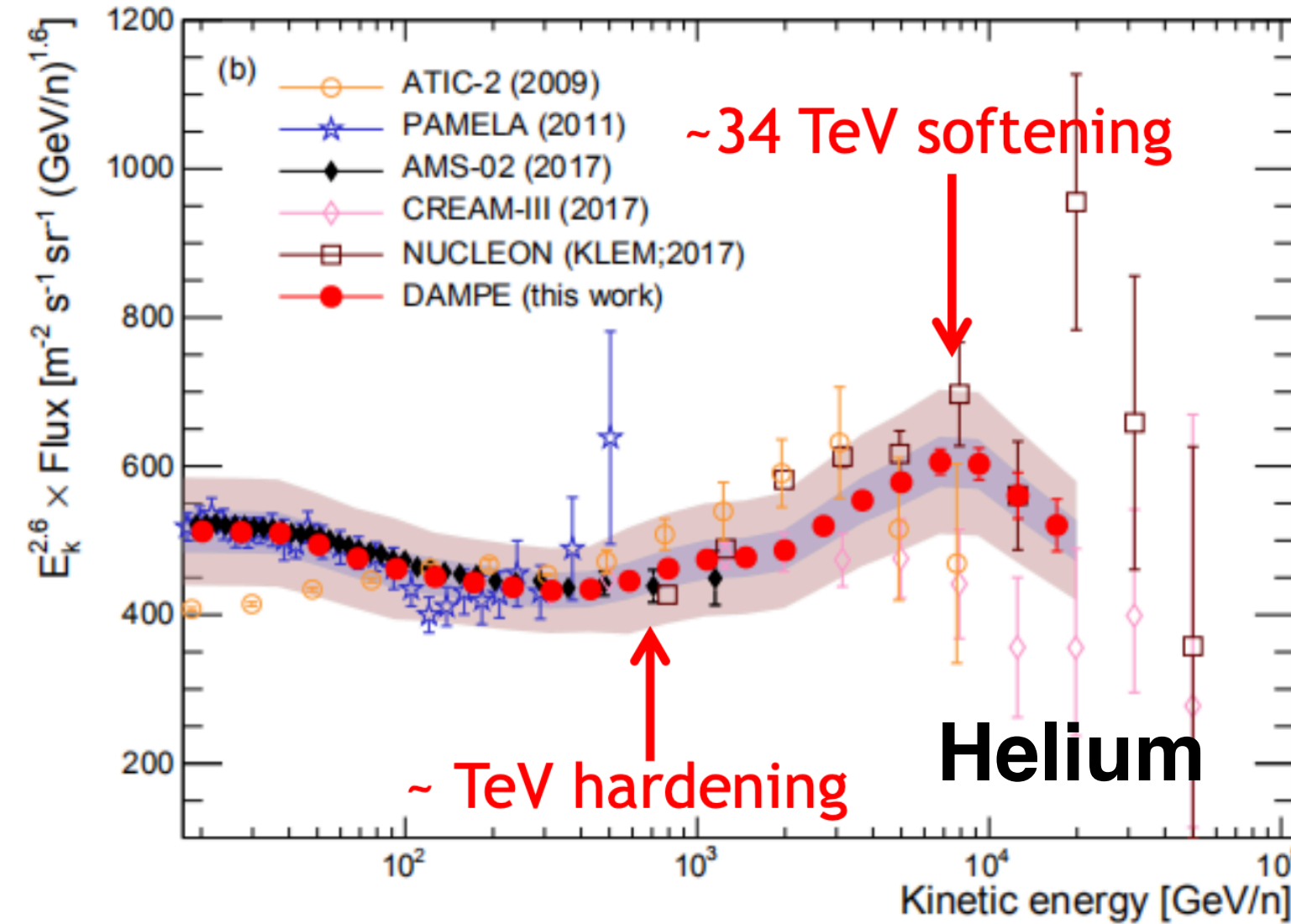
- **All particle spectrum**

p and He (Published)

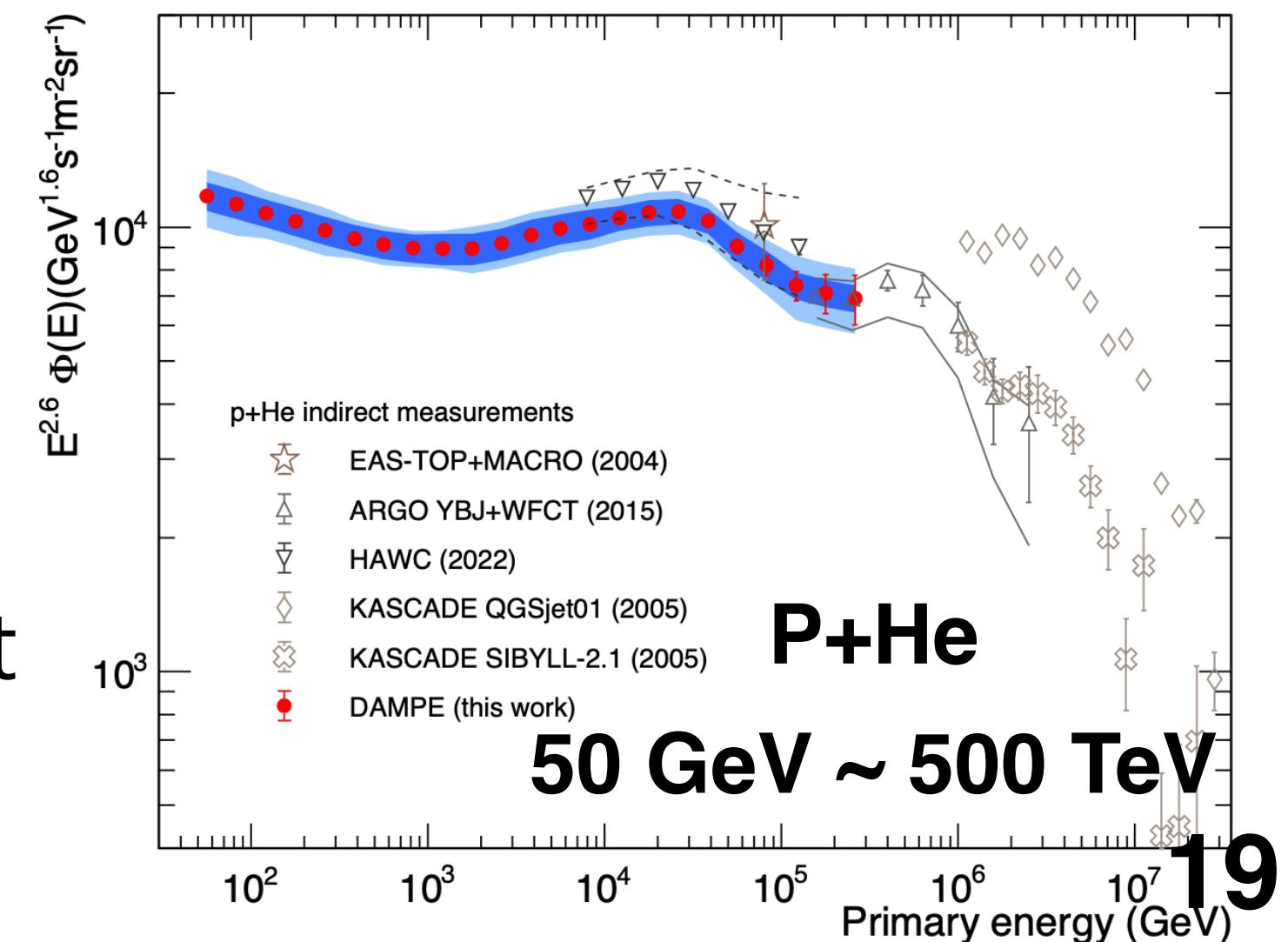
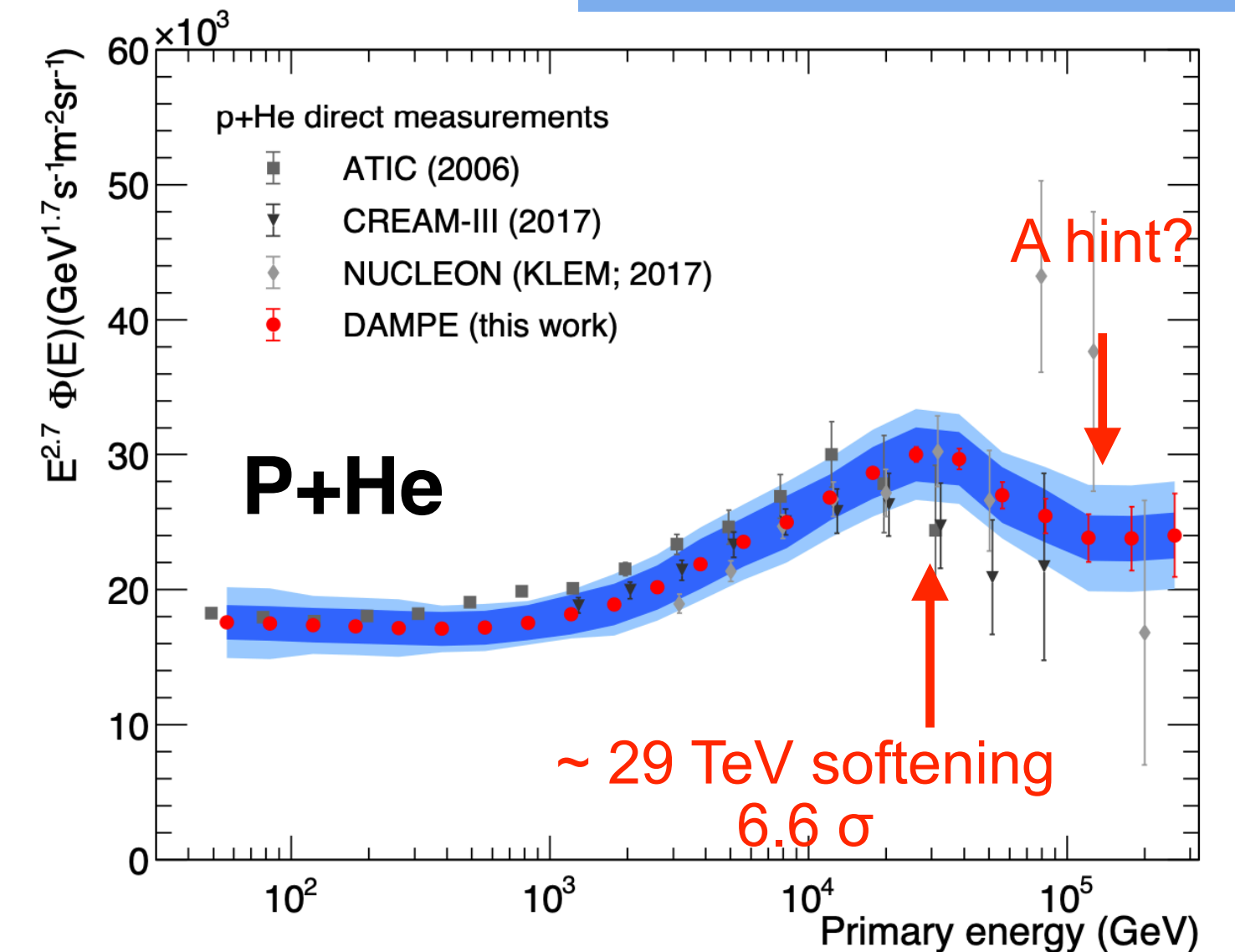
DAMPE Collab.,
Phys. Rev. D 109
(2024)



DAMPE Collab., *Sci. Adv.* 5.9 (2019)



DAMPE Collab., *Phys. Rev. Lett.* 126 (2021)



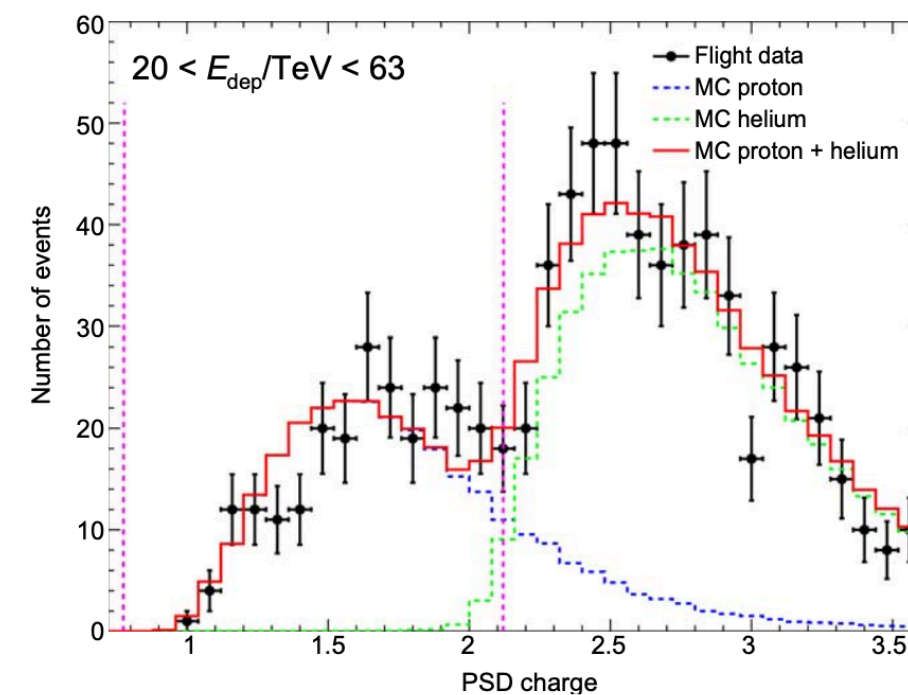
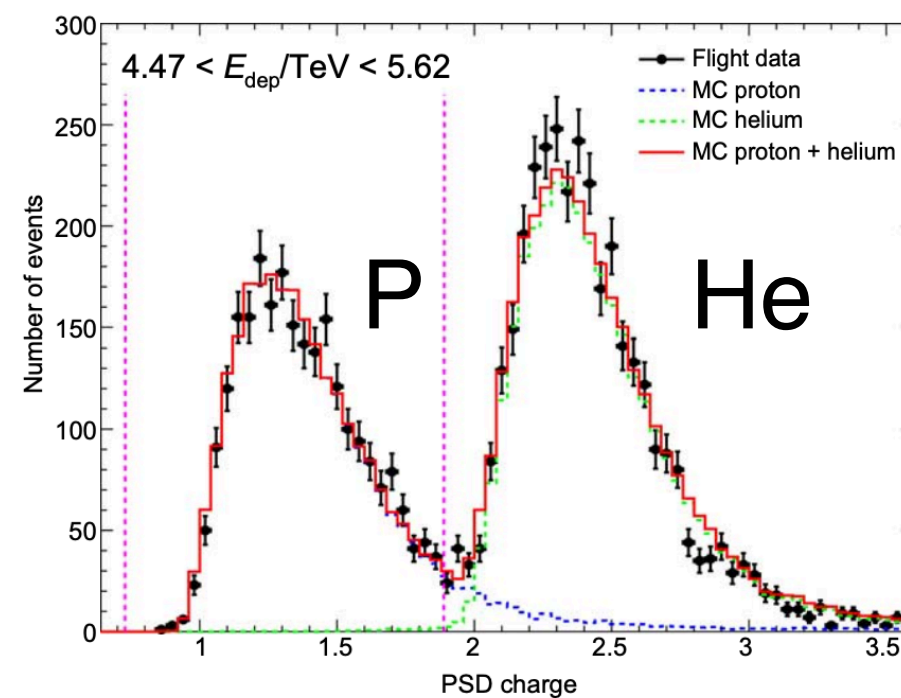
- CR proton and helium show **a very similar behavior**
- Link between space- and ground- based CR measurements
- Observation of the softening at 29 TeV and a hardening hint at ~150 TeV

p and He (in progress)

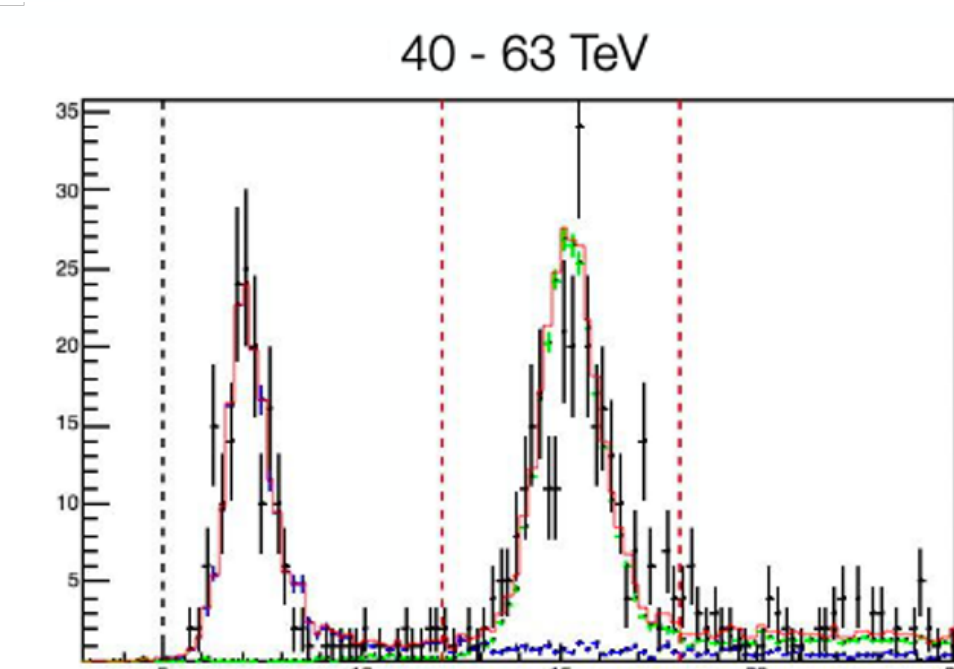
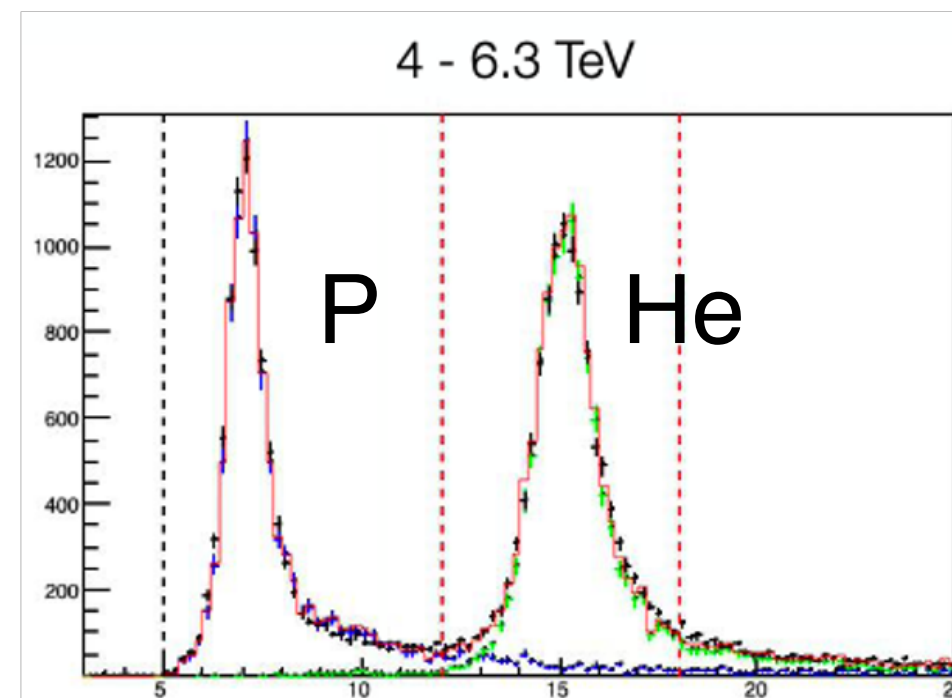
Advanced analysis in high energies:

- New ML track reconstruction & New charge identification : STK + PSD
- Quenching correction, cross-section correction and new saturation correction up to PeV

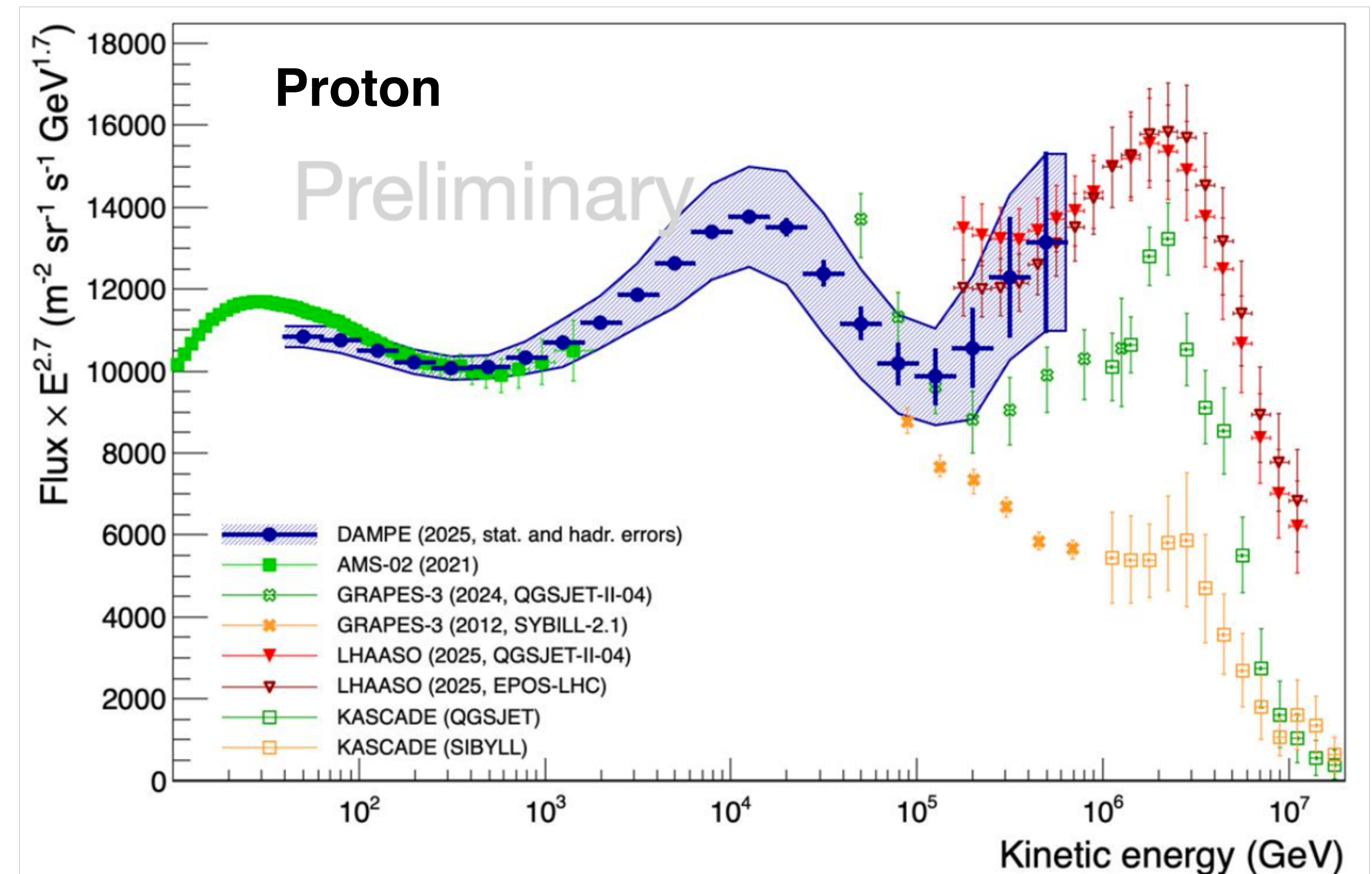
Previous




New



New Charge Signal



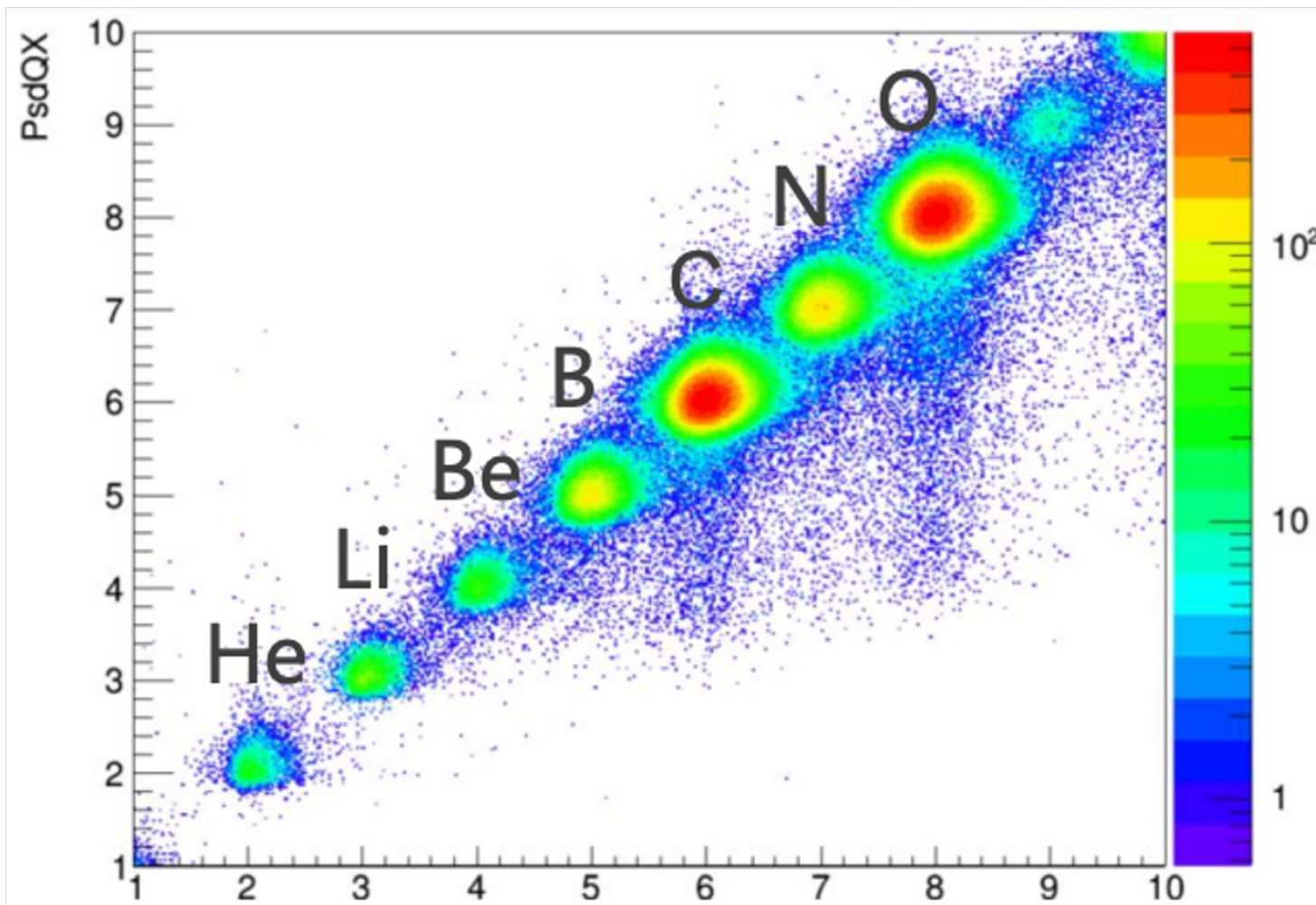
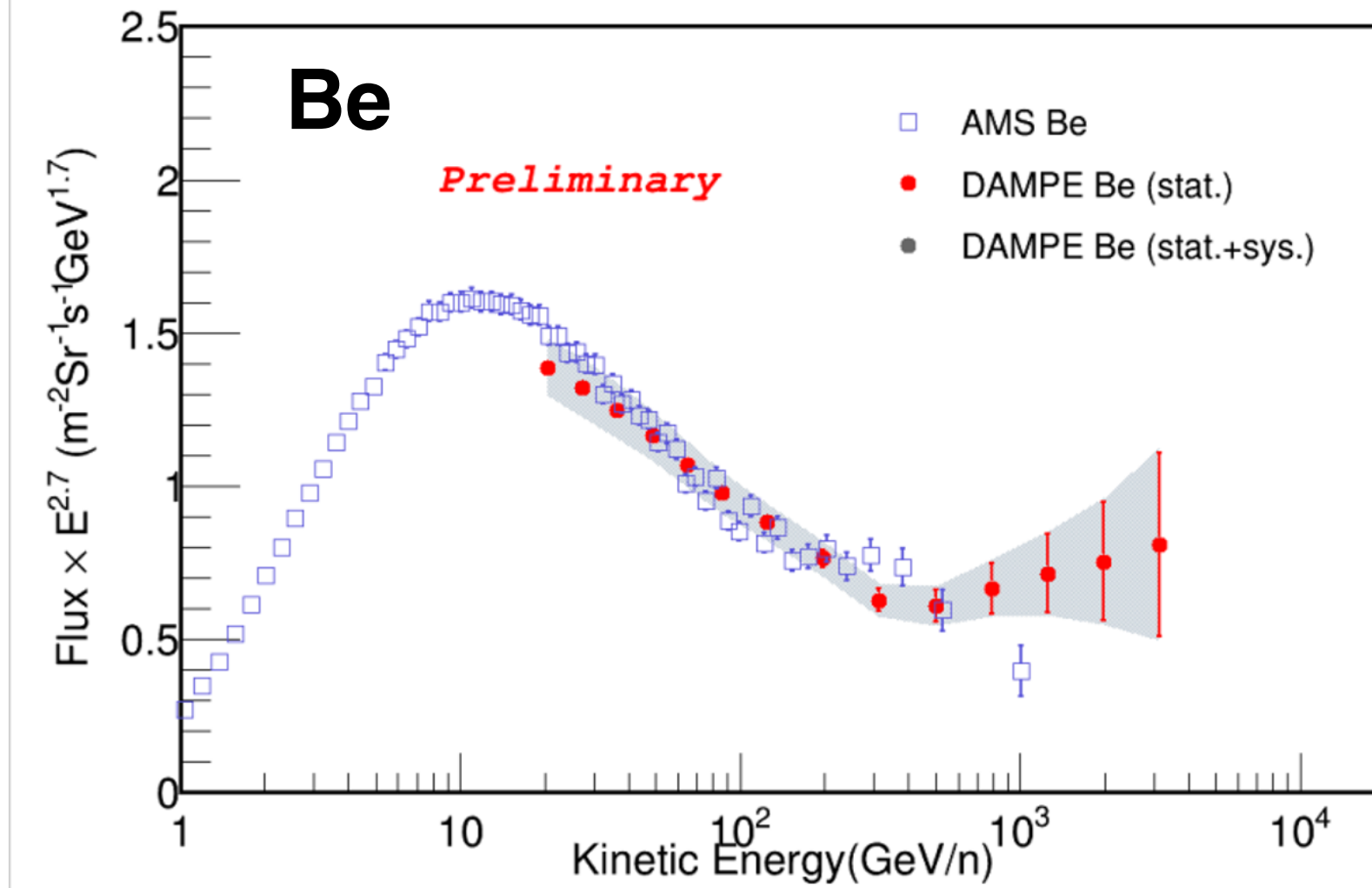
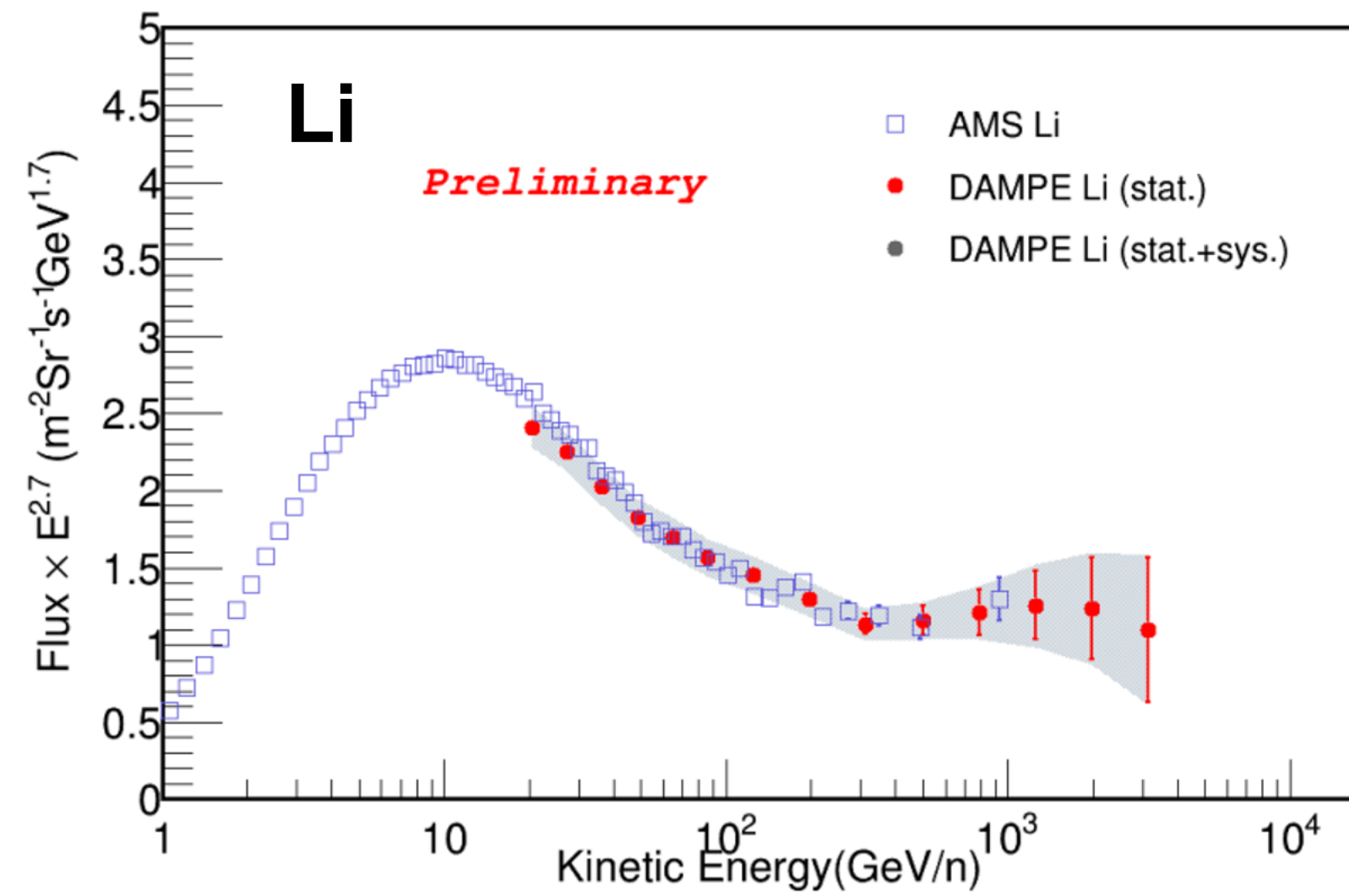
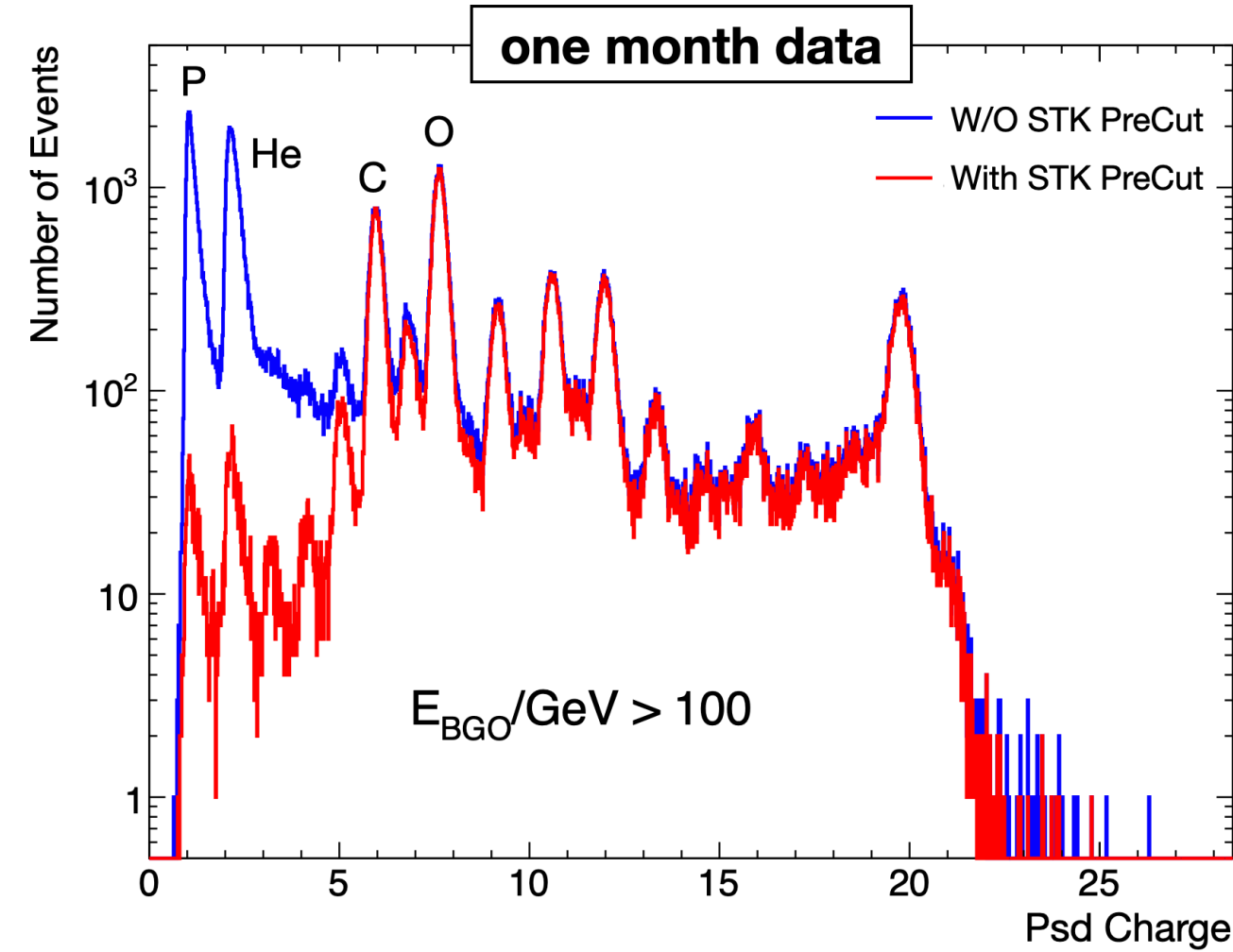
Li and Be



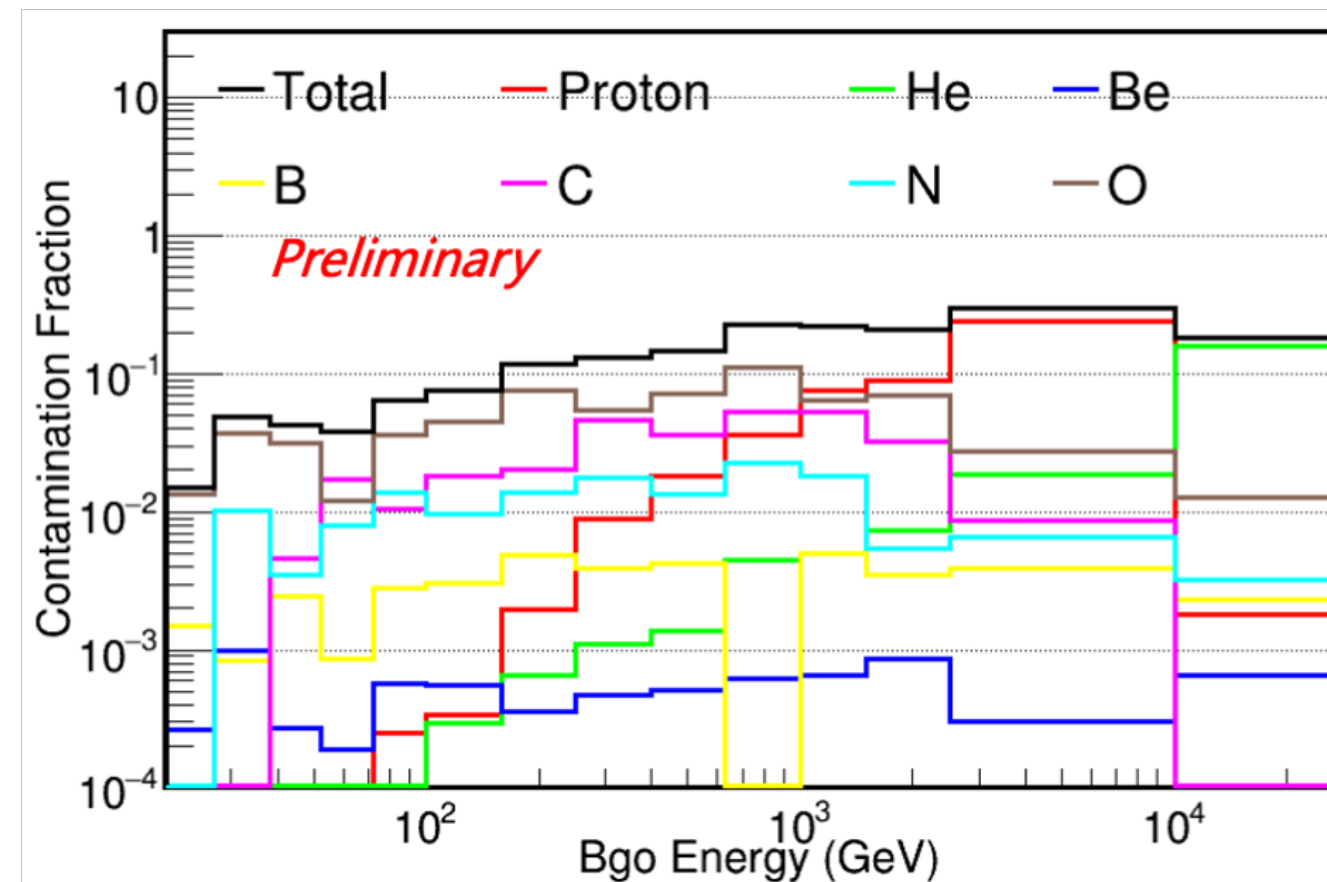
Bethe-Bloch

$$-\left\langle \frac{dE}{dx} \right\rangle = \frac{4\pi}{m_e c^2} \cdot \frac{n z^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\epsilon_0} \right)^2 \cdot \left[\ln \left(\frac{2m_e c^2 \beta^2}{I \cdot (1 - \beta^2)} \right) - \beta^2 \right]$$

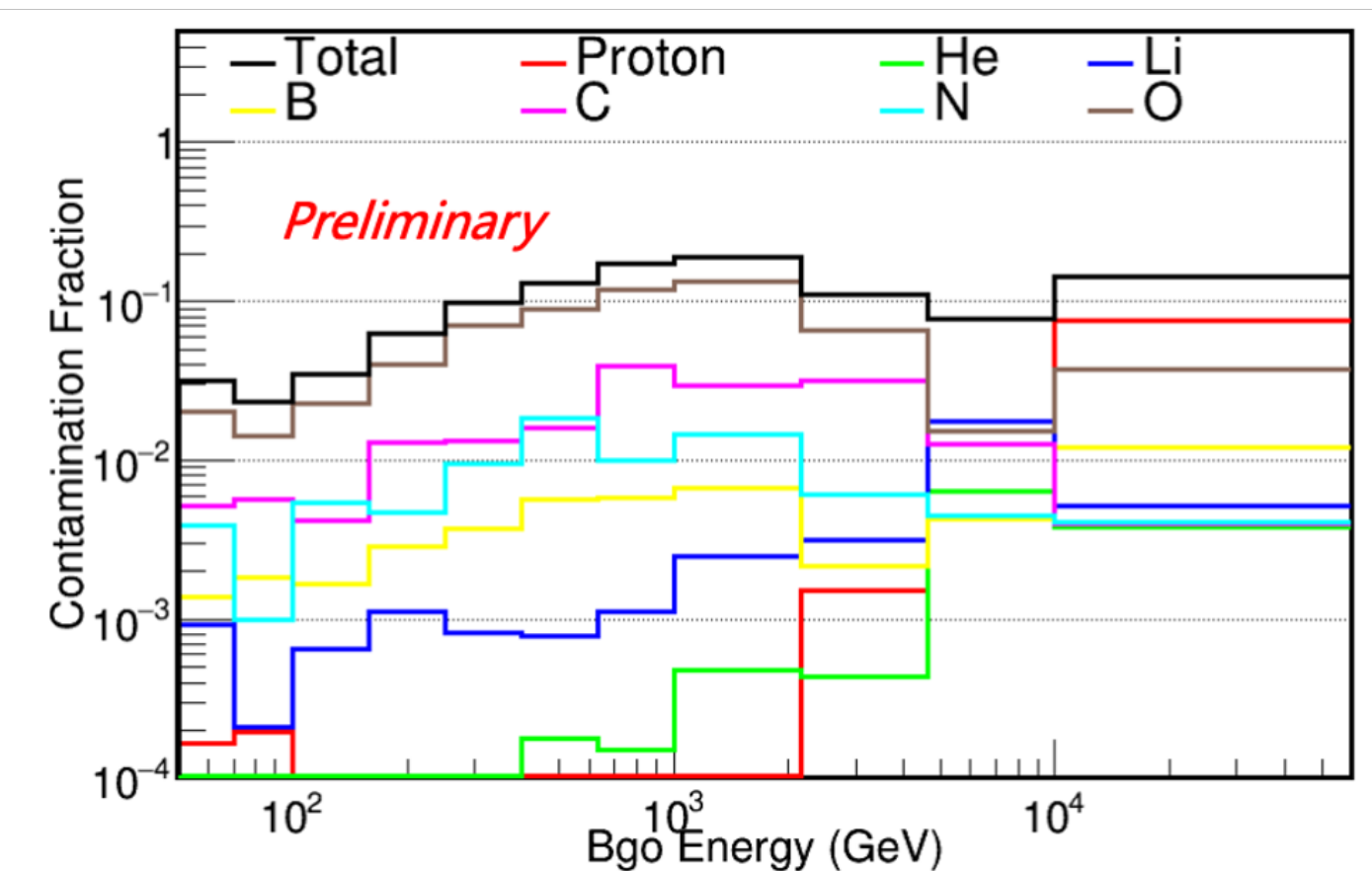
- Observe a spectral hardening at ~ 200 GeV/n



Li Contamination

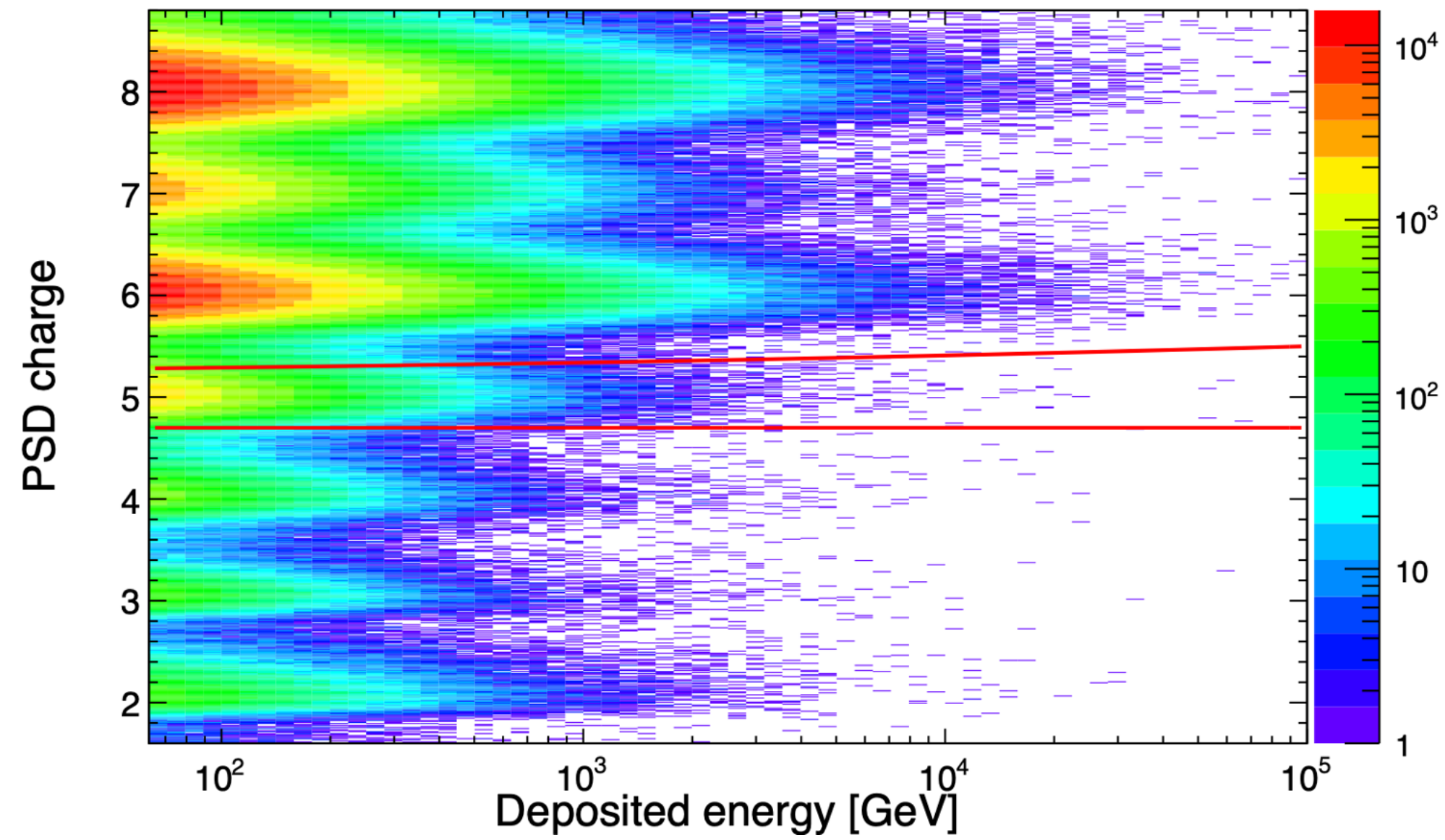


Be Contamination

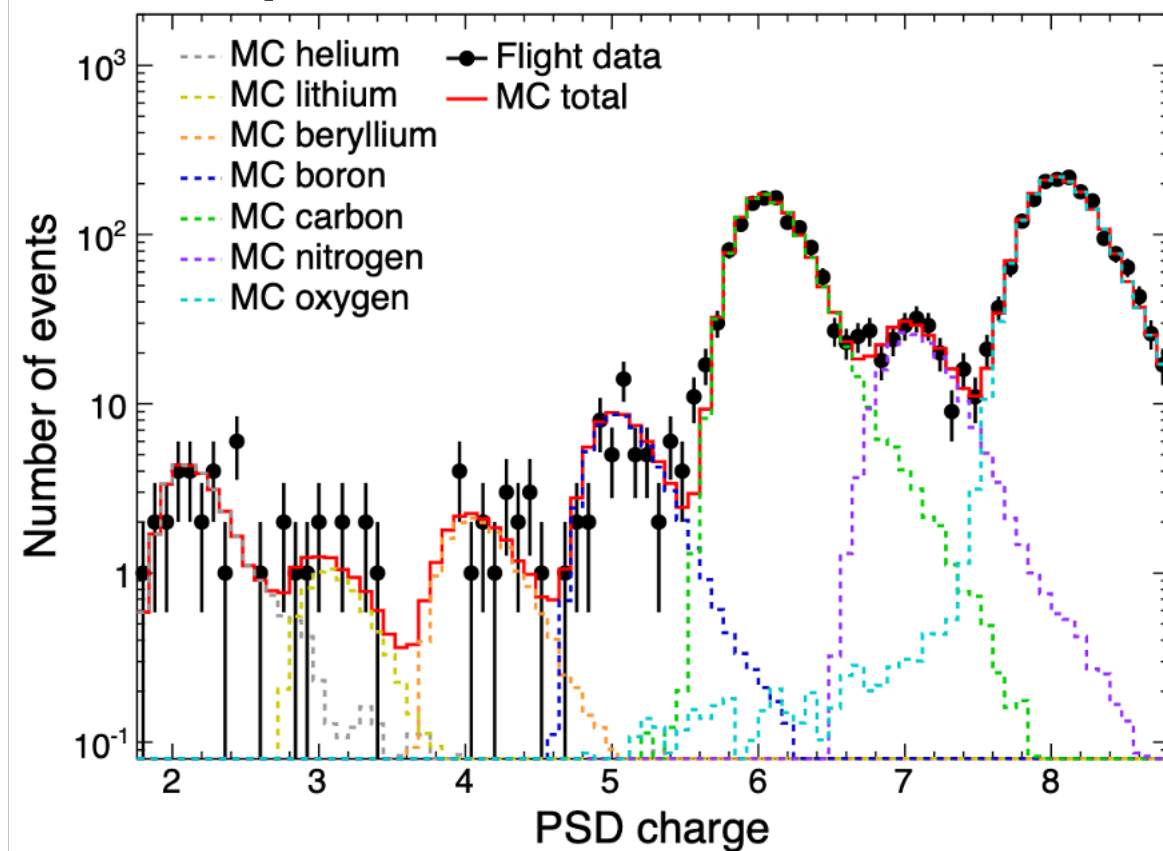


Boron

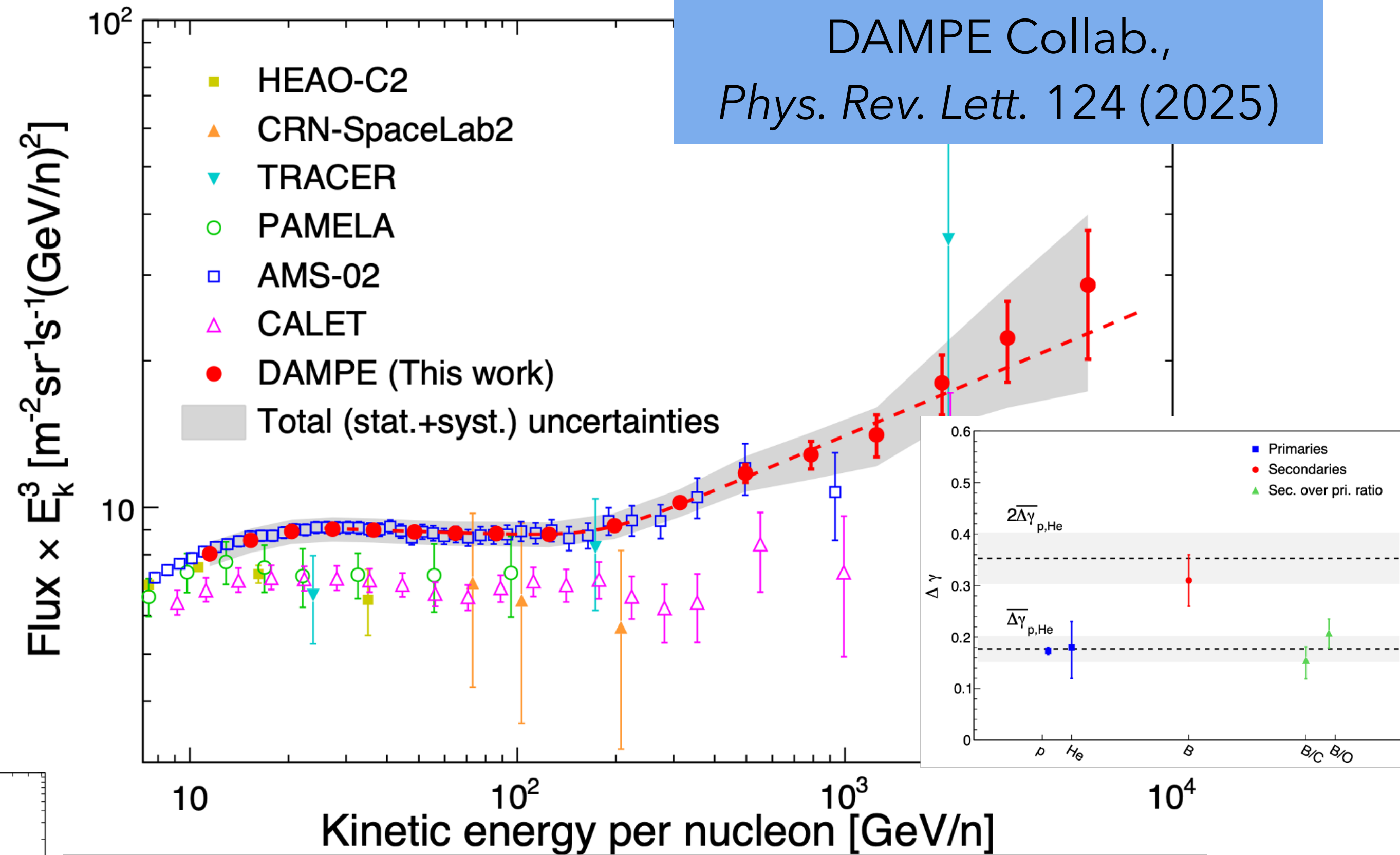
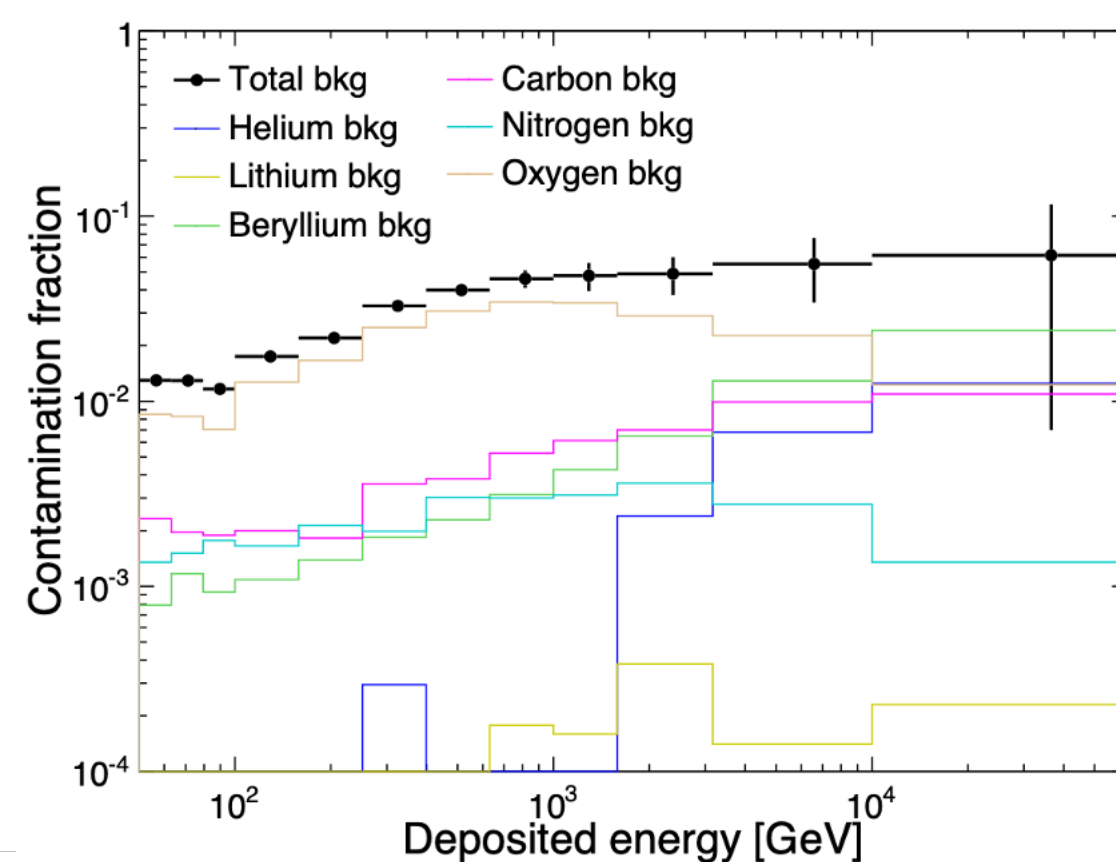
PSD Q vs Deposited E



Dep E: [6.3, 20] TeV



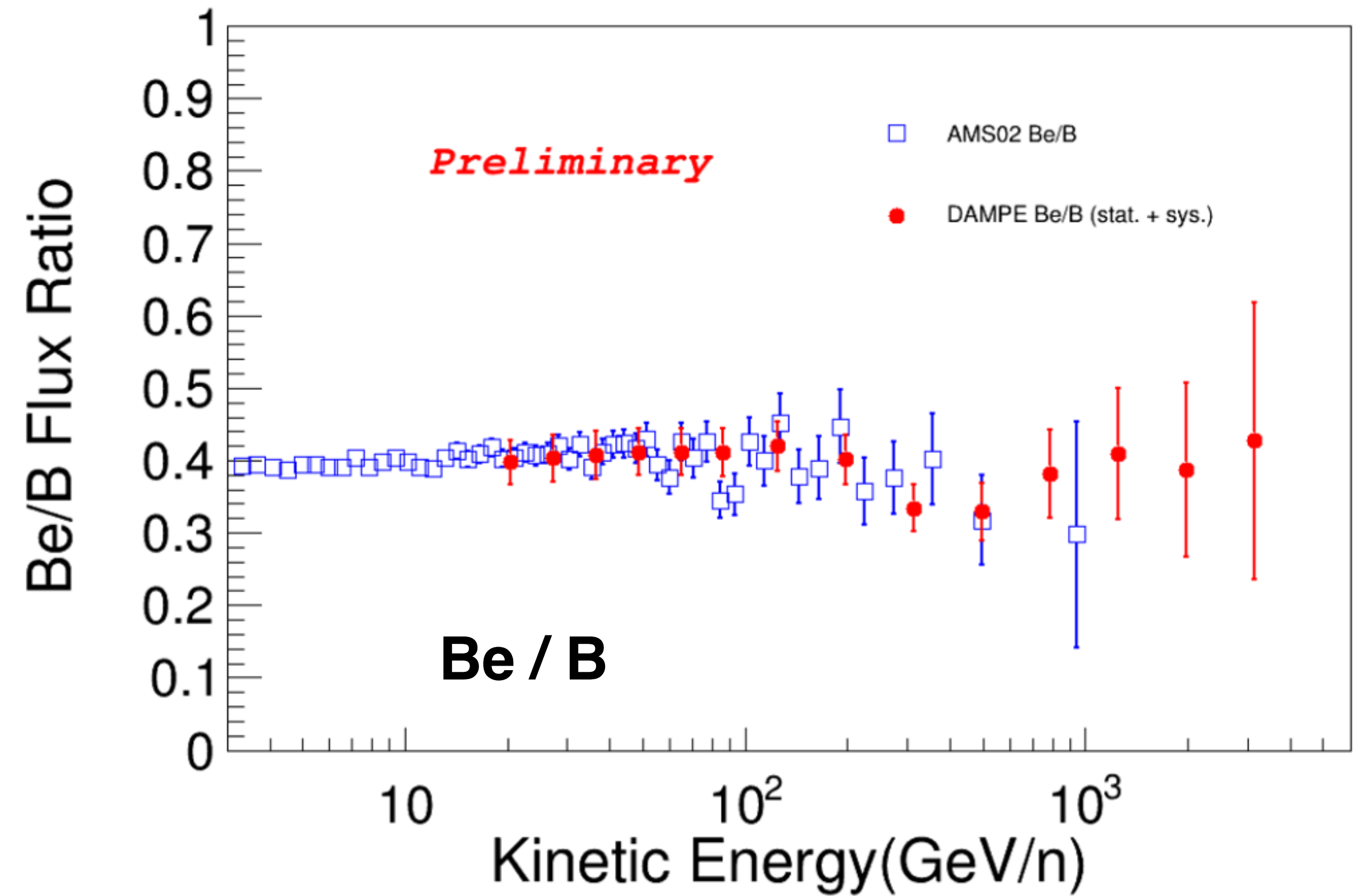
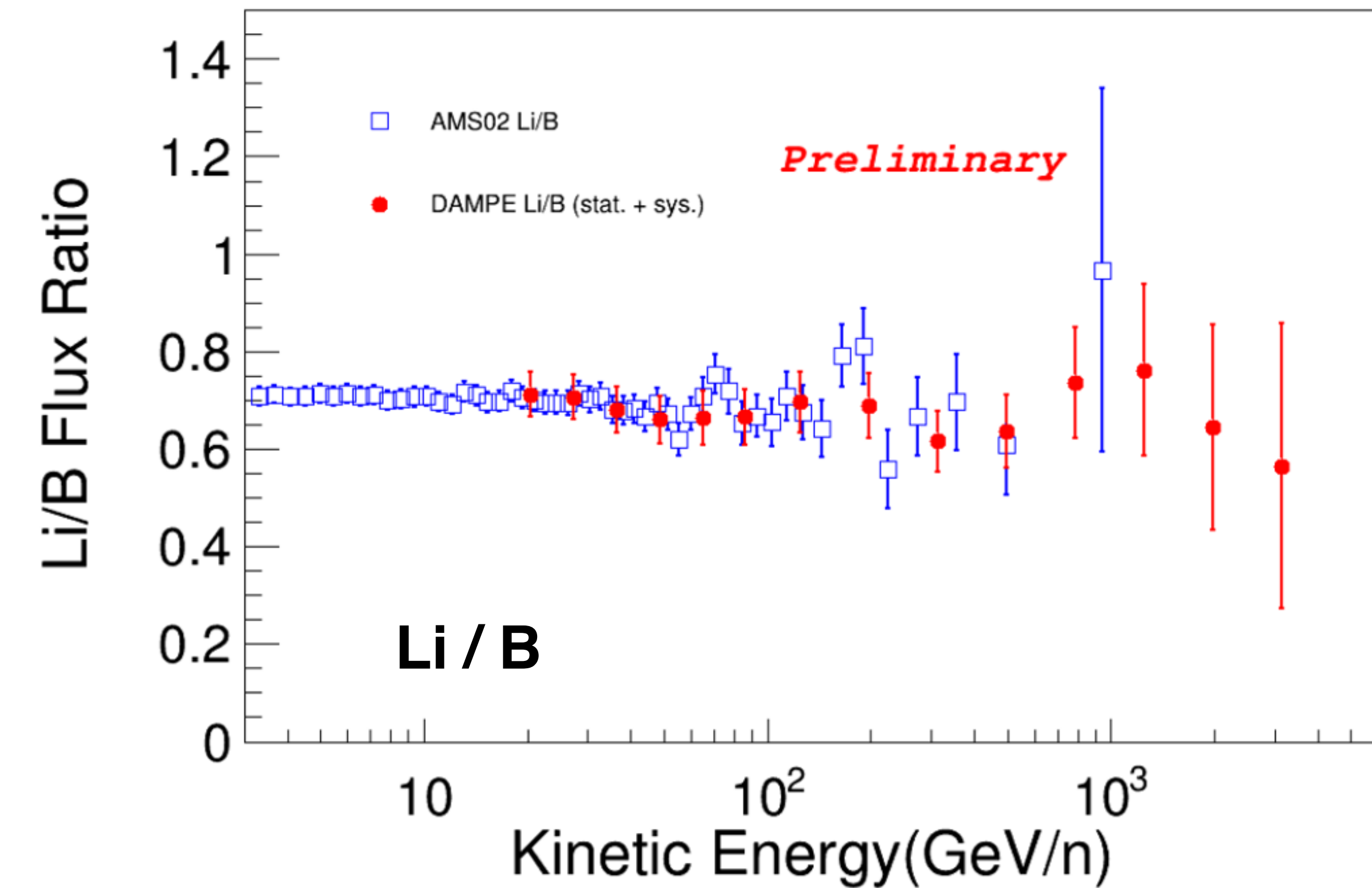
B contamination



DAMPE Collab.,
Phys. Rev. Lett. 124 (2025)

- A spectral hardening at ~ 200 GeV/n with 8 sigma of CL. is observed
- $\Delta\gamma$ is about twice vs. p & He

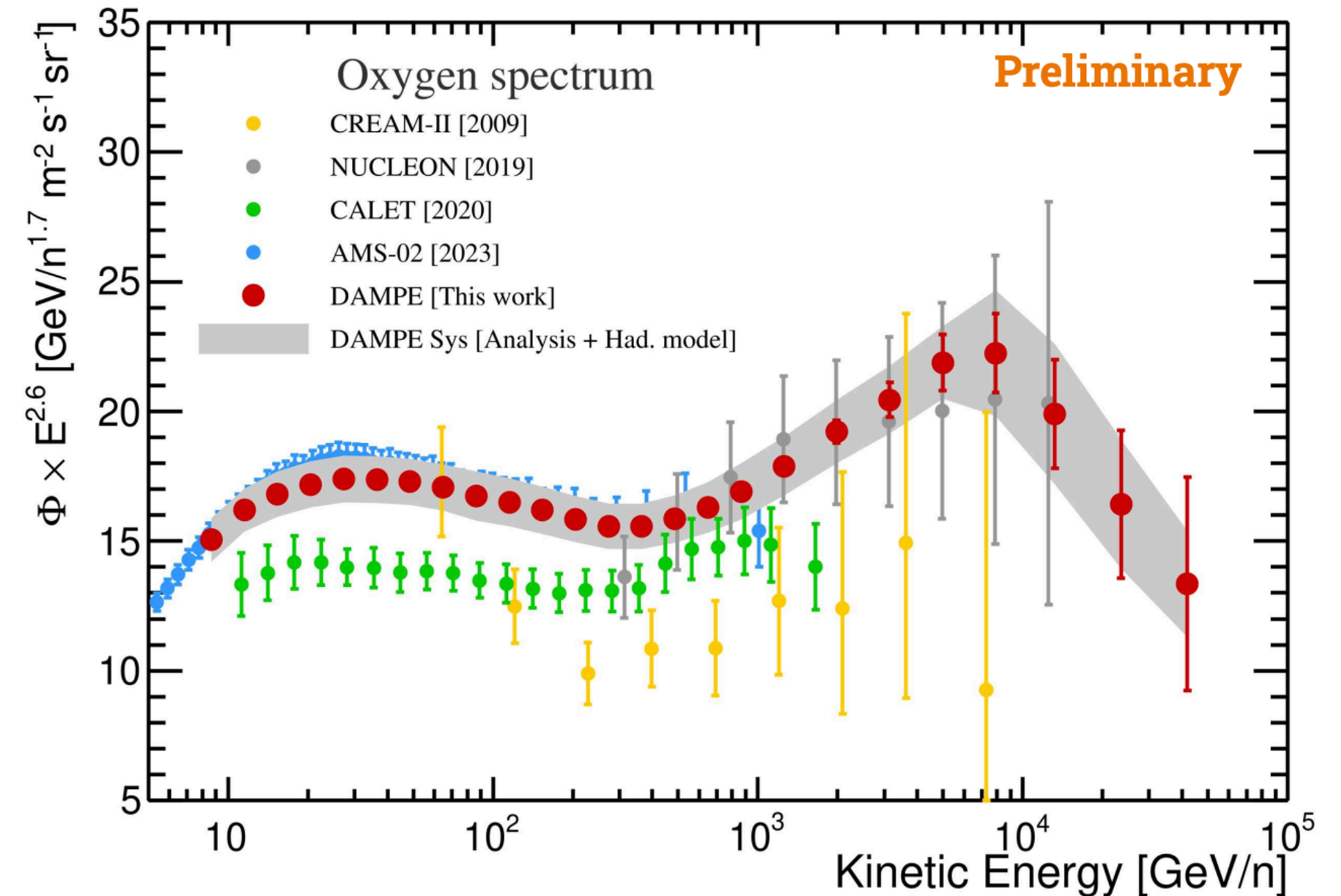
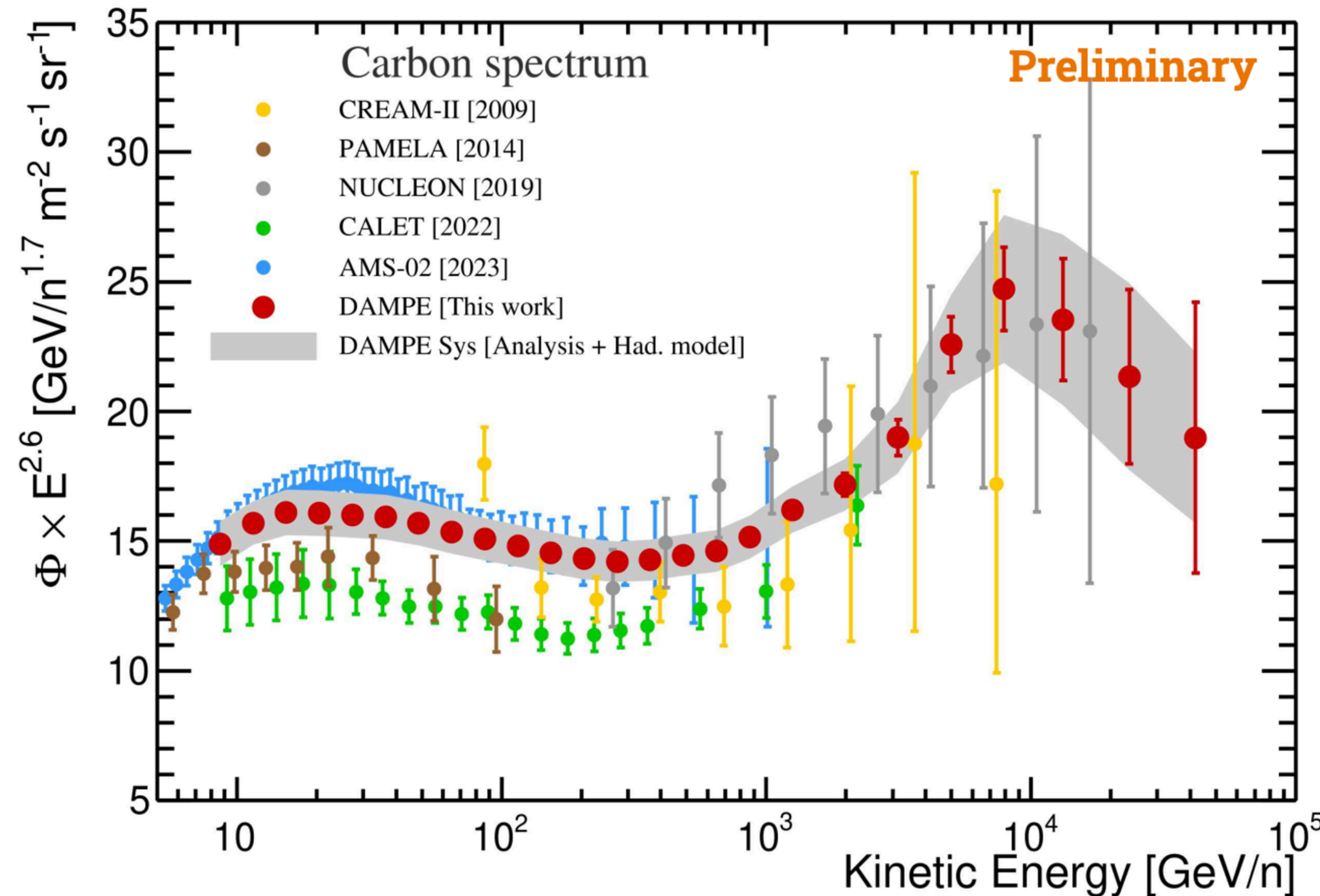
Flux Ratios 1



C and O

$$\Delta\Phi(E_i, E_i + \Delta E_i) = \frac{\Delta N_i}{\Delta E_i A_{\text{eff},i} \Delta T}$$

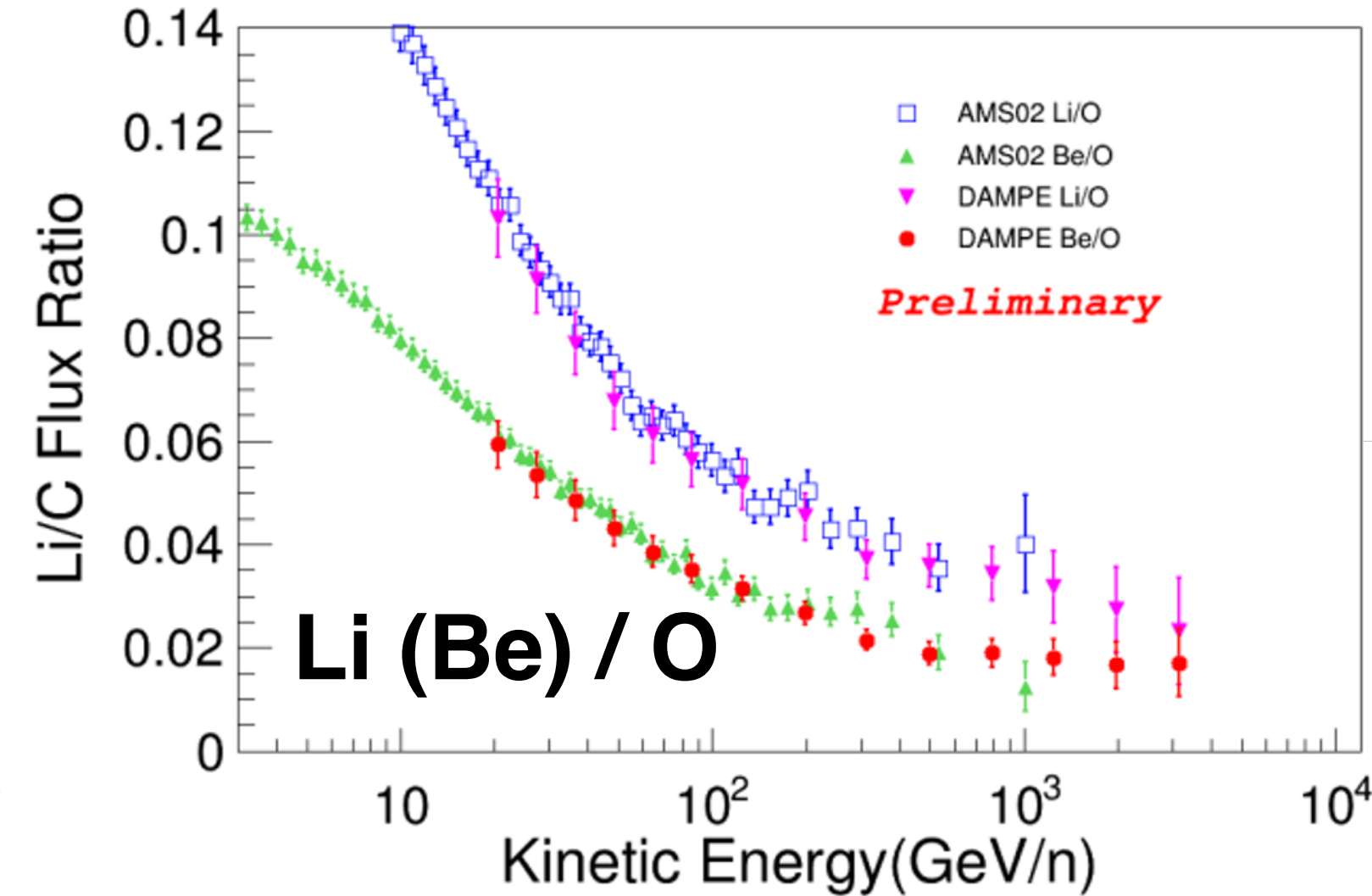
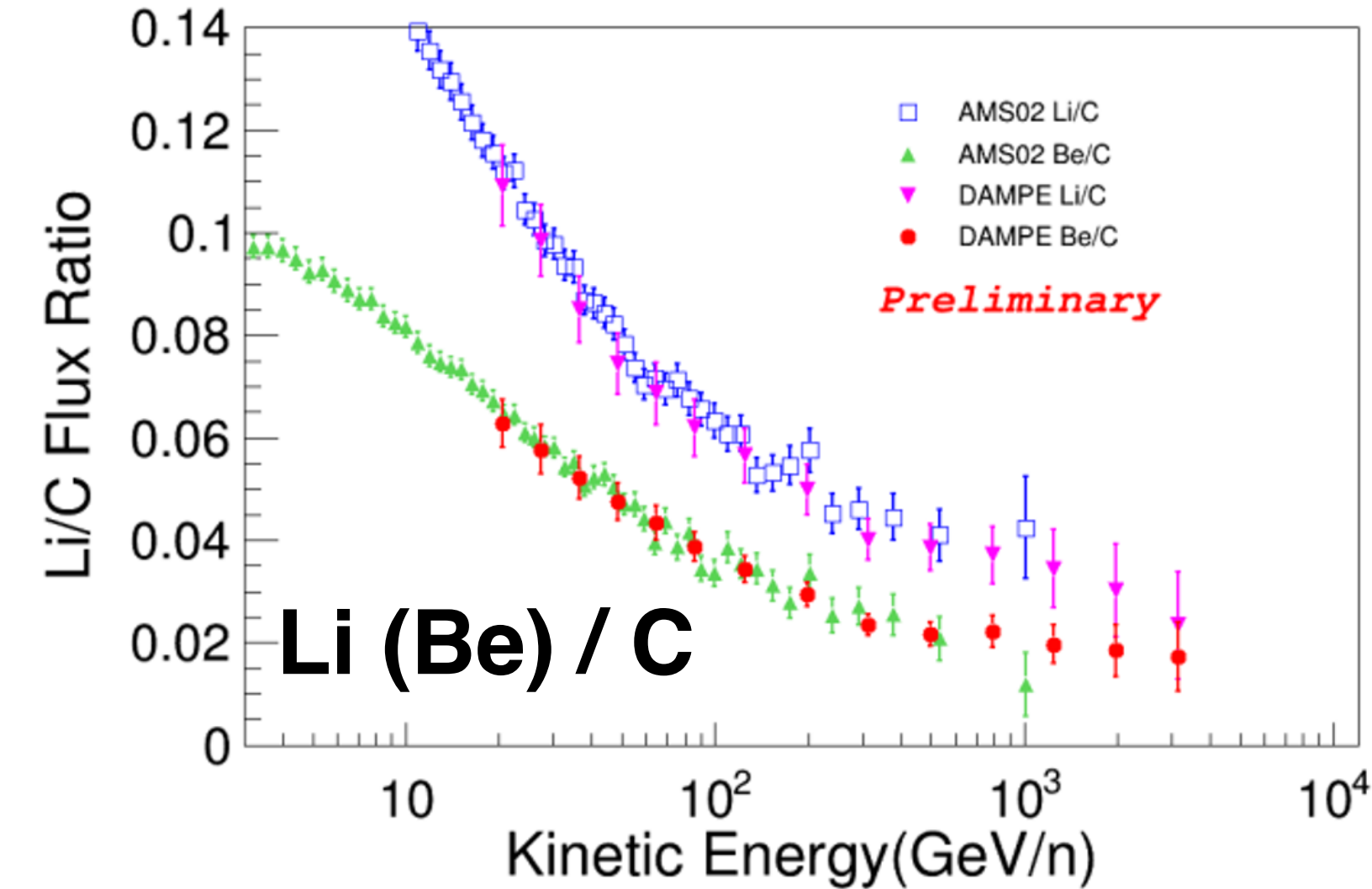
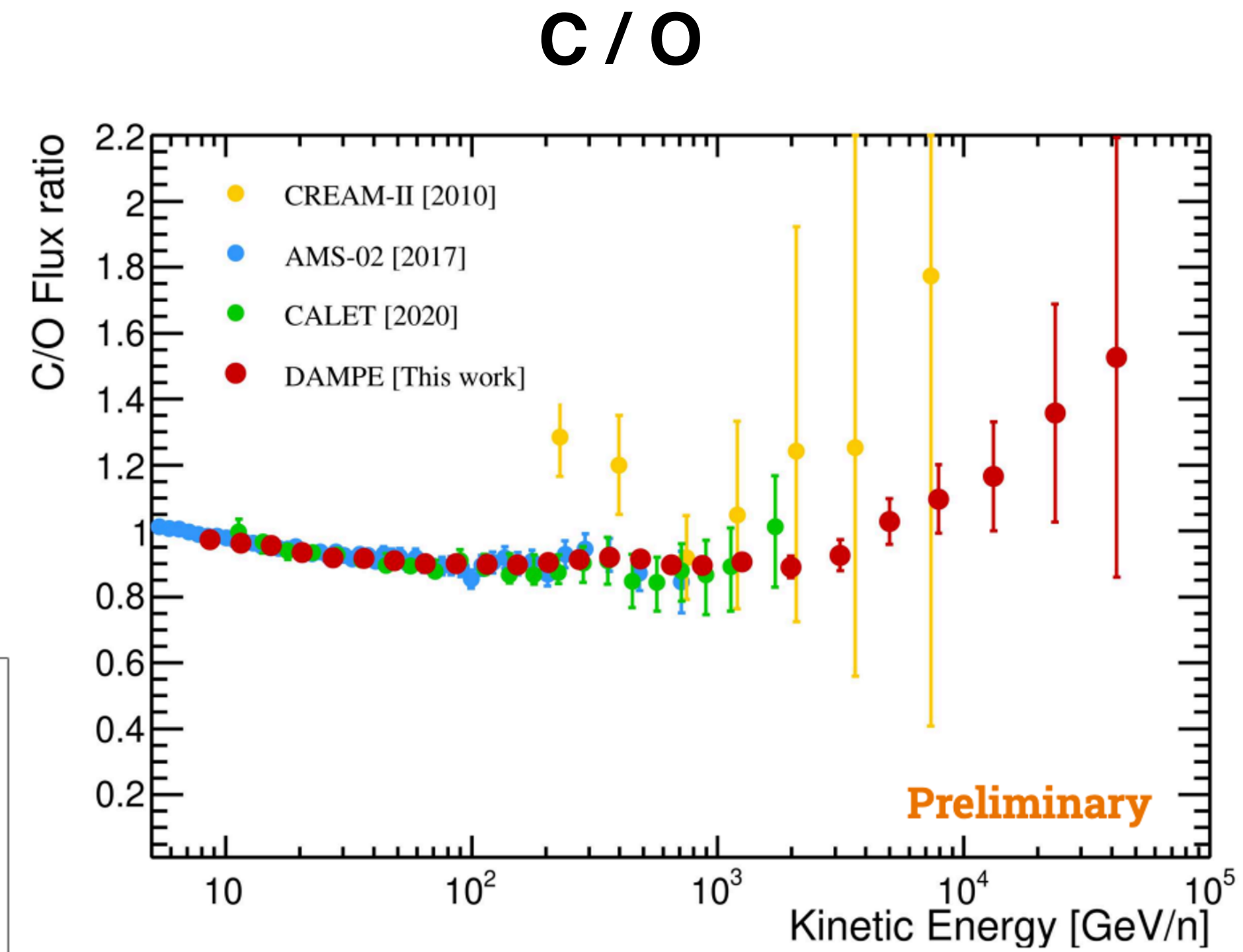
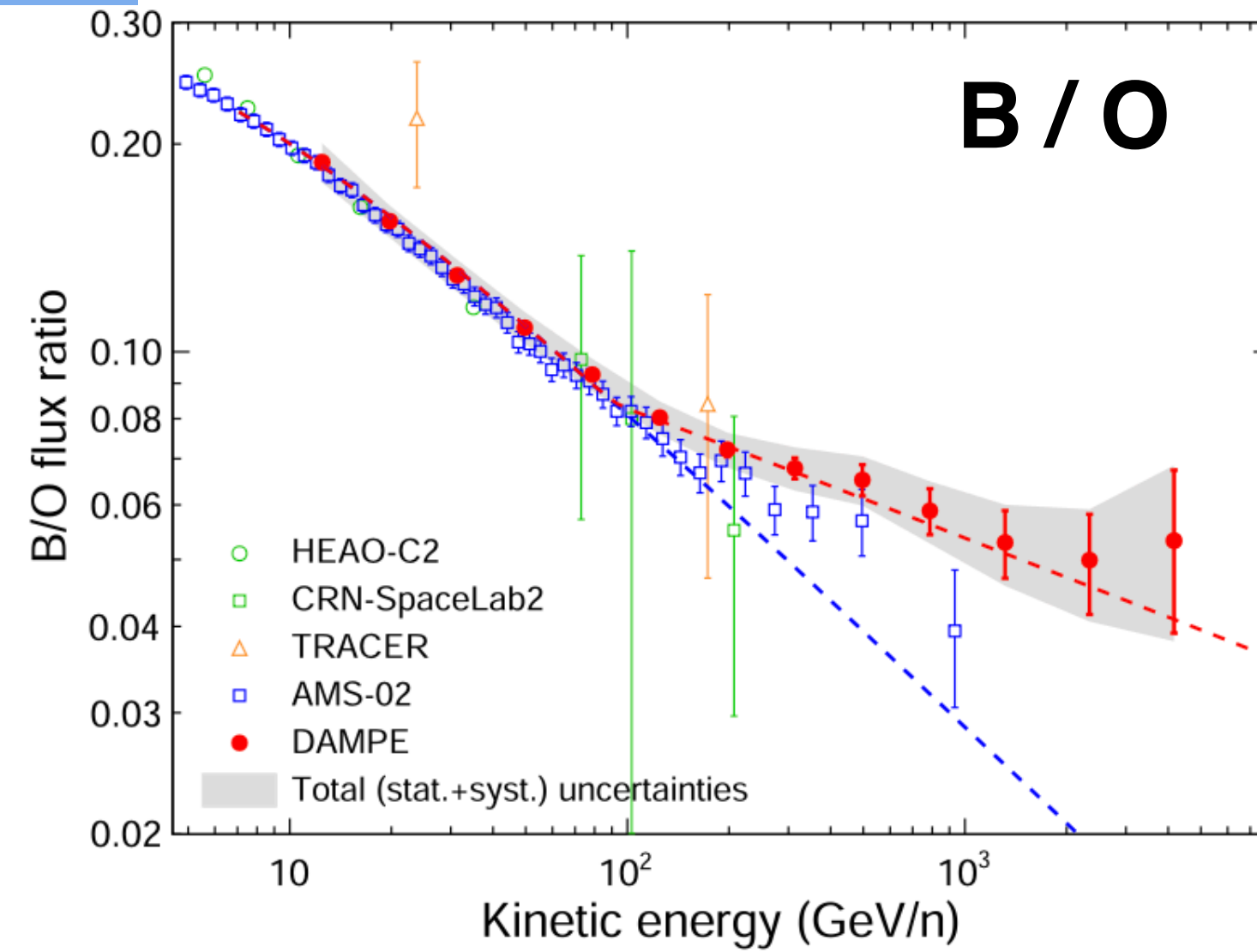
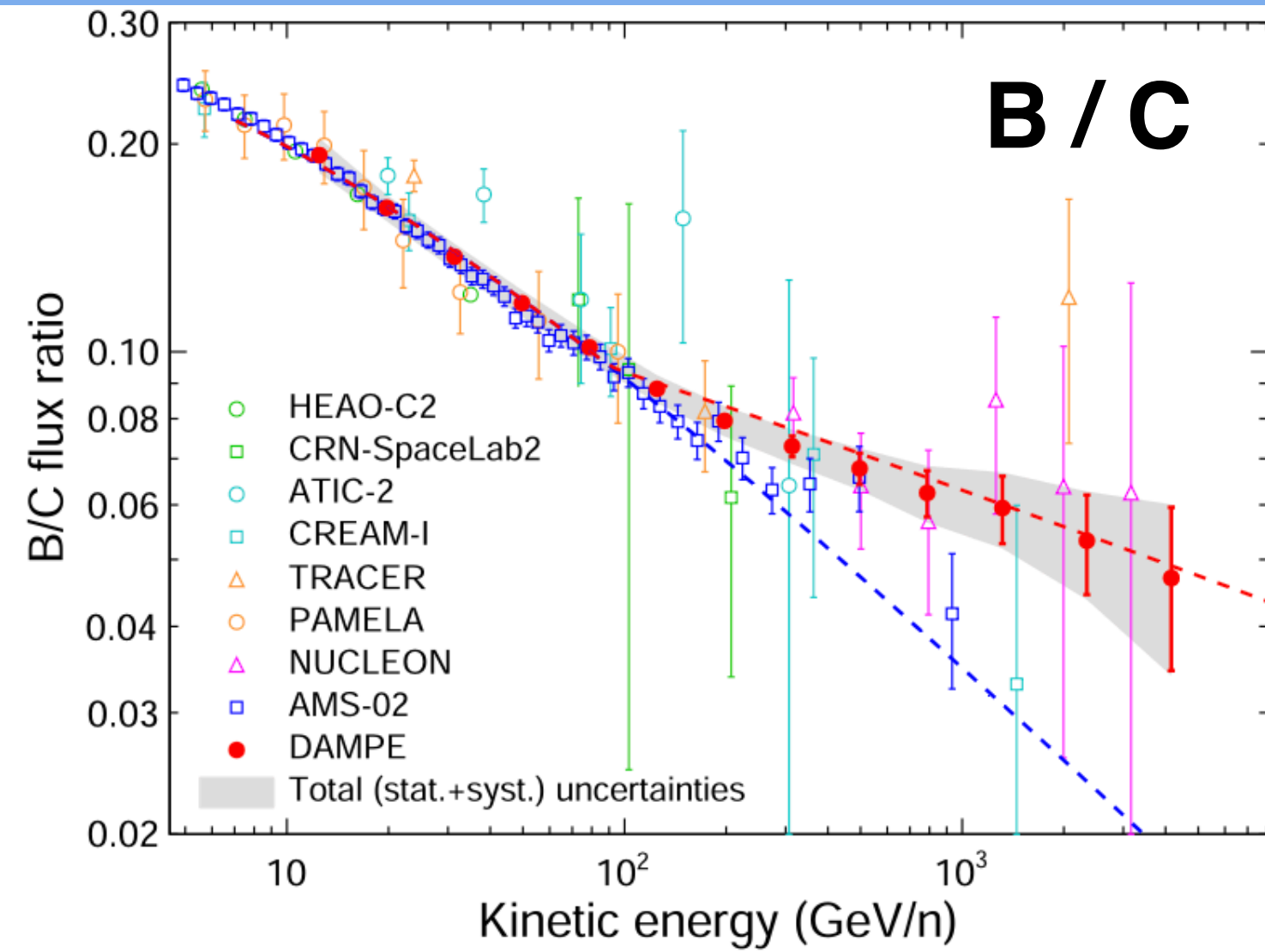
9 years of Flight Data
Good agreement among DAMPE analyses groups



- Extend to above 10 TeV/n with sufficient statistics in space
- Confirm the hardening at $\sim 300 \text{ GeV}/n$ and novel a softening at $\sim 7.5 \text{ TeV}/n$ (15 TV)

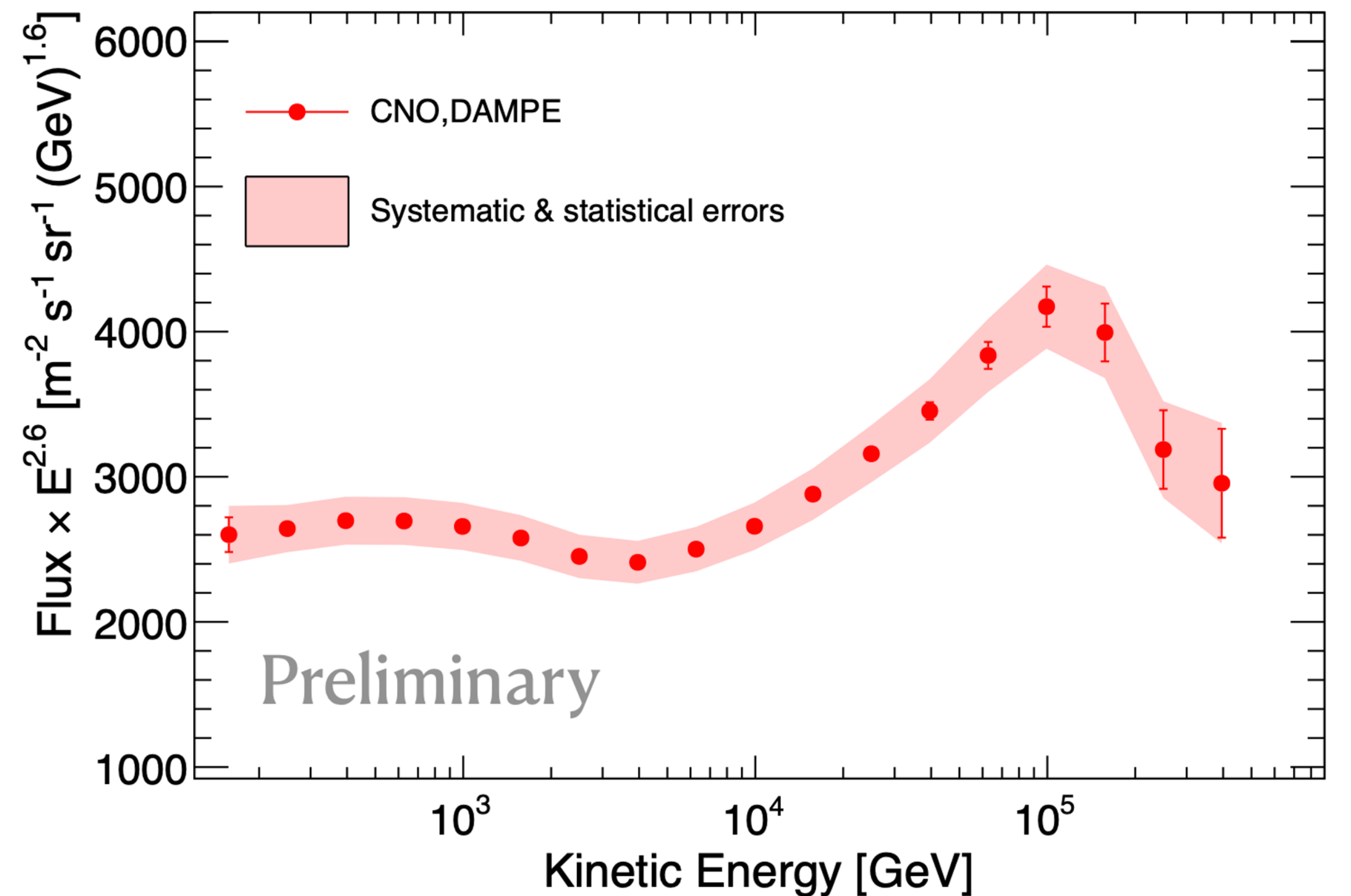
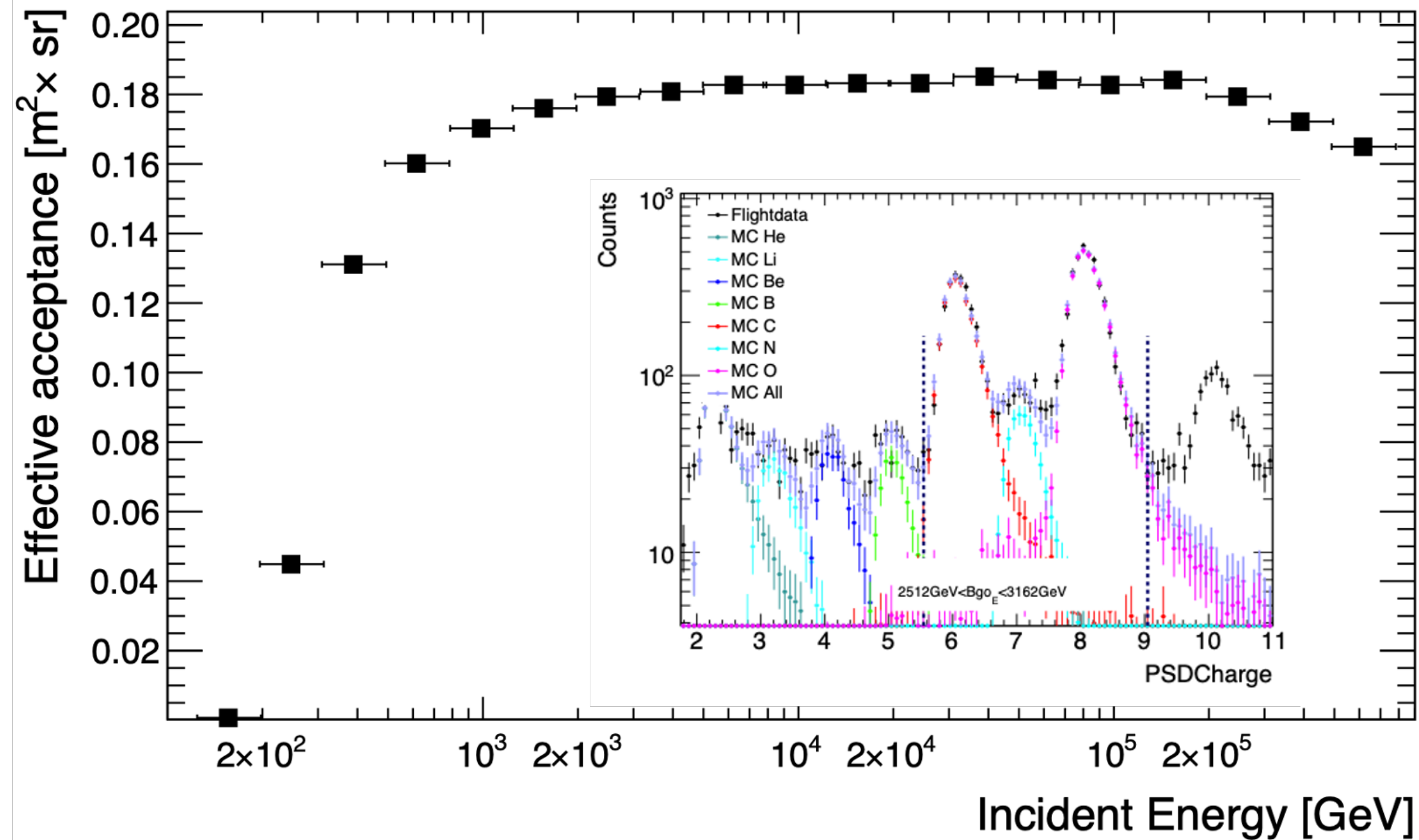
Flux Ratios 2

DAMPE Collab., *Sci. Bull.* 67 (2022)



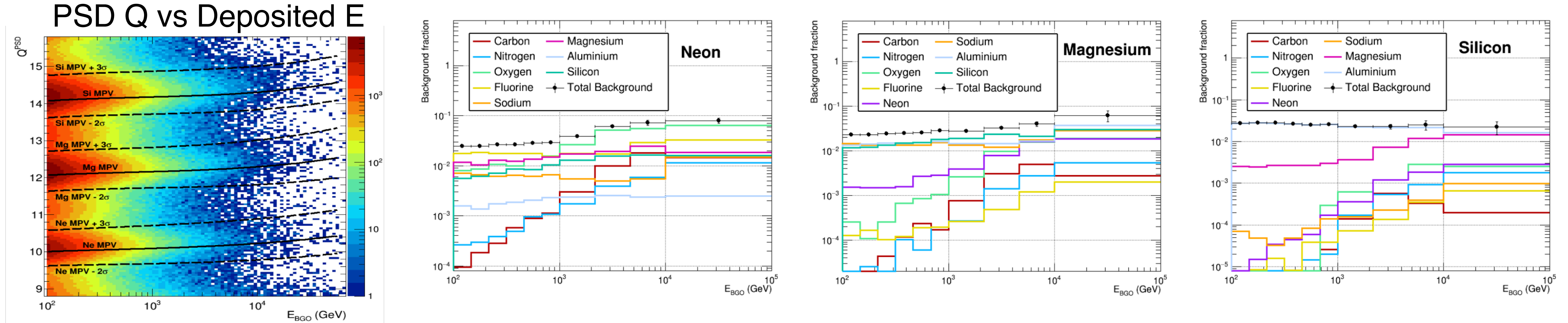
CNO Group

Acceptance (C:N:O = 1:1:1)

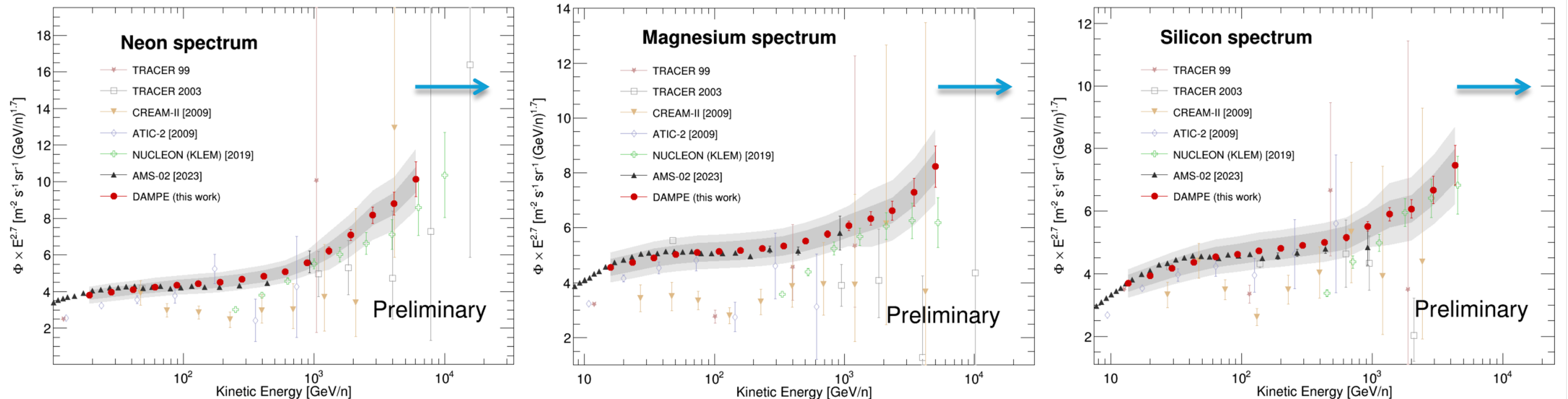


- The spectrum of CNO group is measured up to 500 TeV
- A spectral hardening at ~ 9 TeV with > 6 sigma of CL. is observed.

Ne, Mg and Si

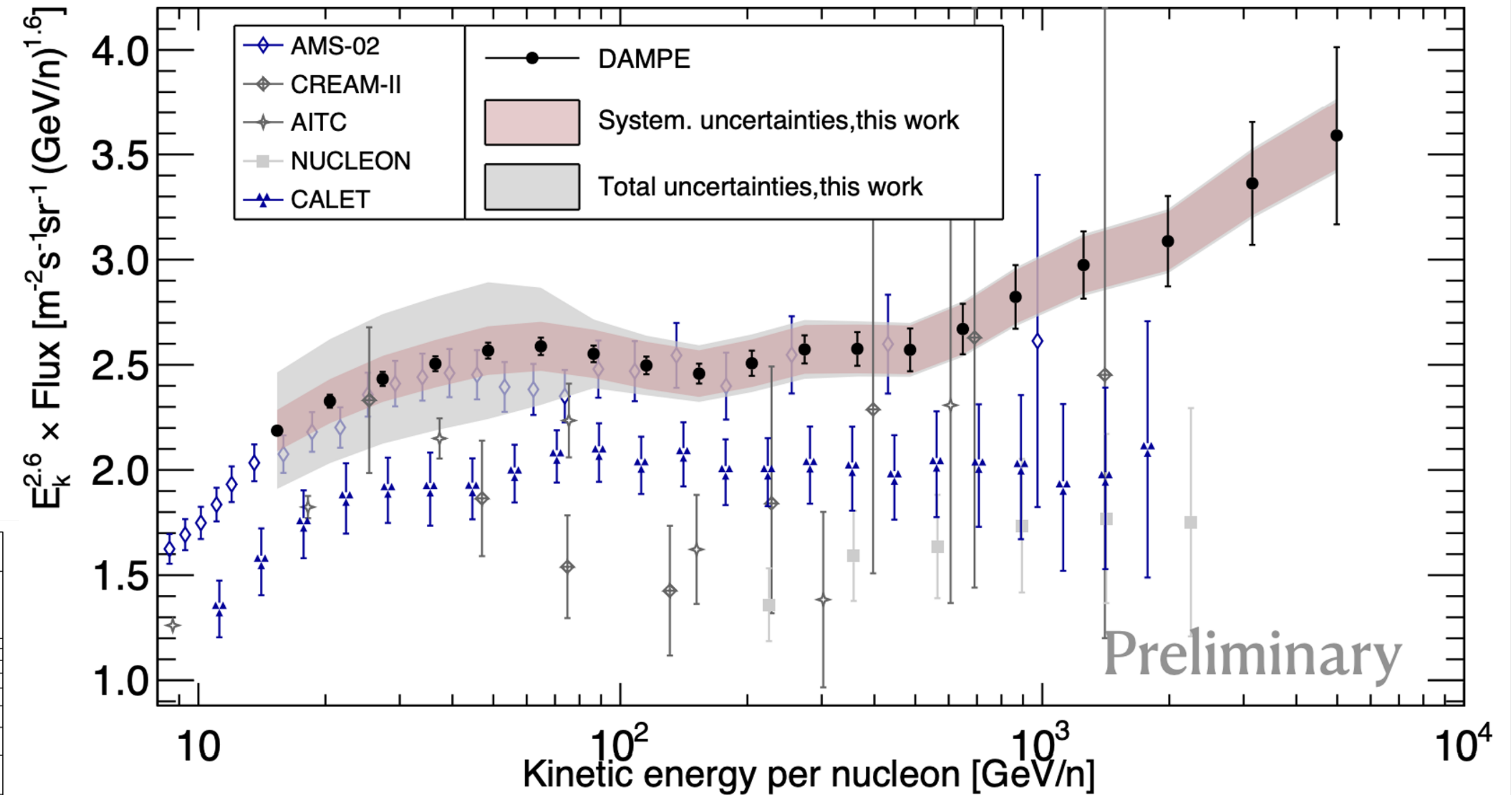
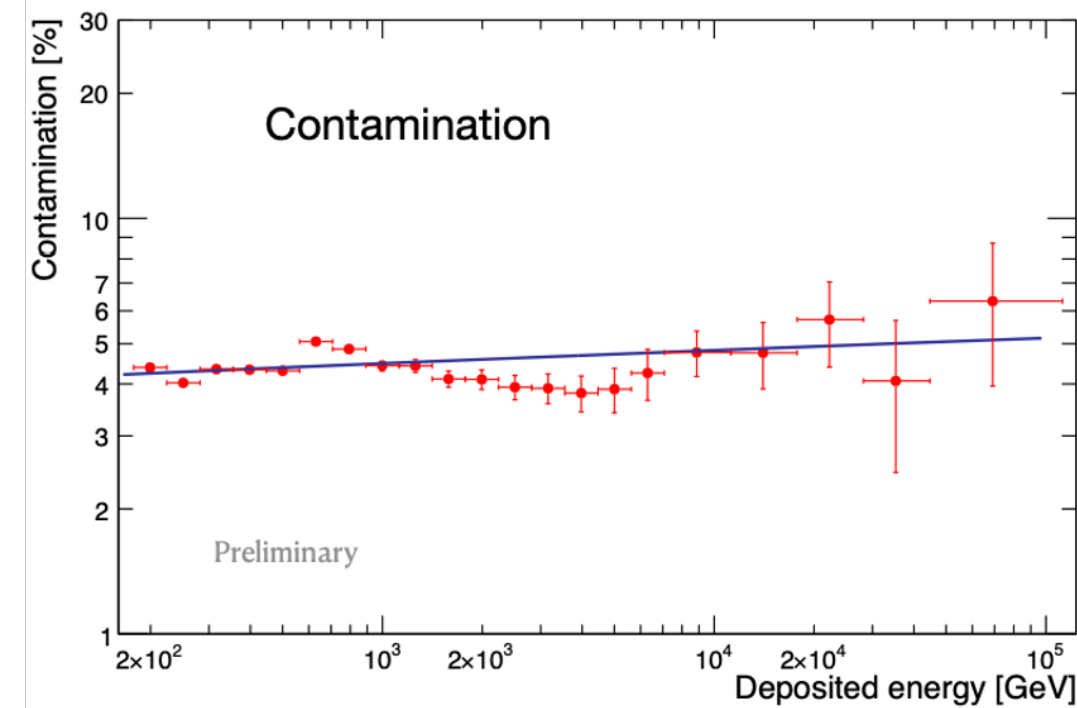
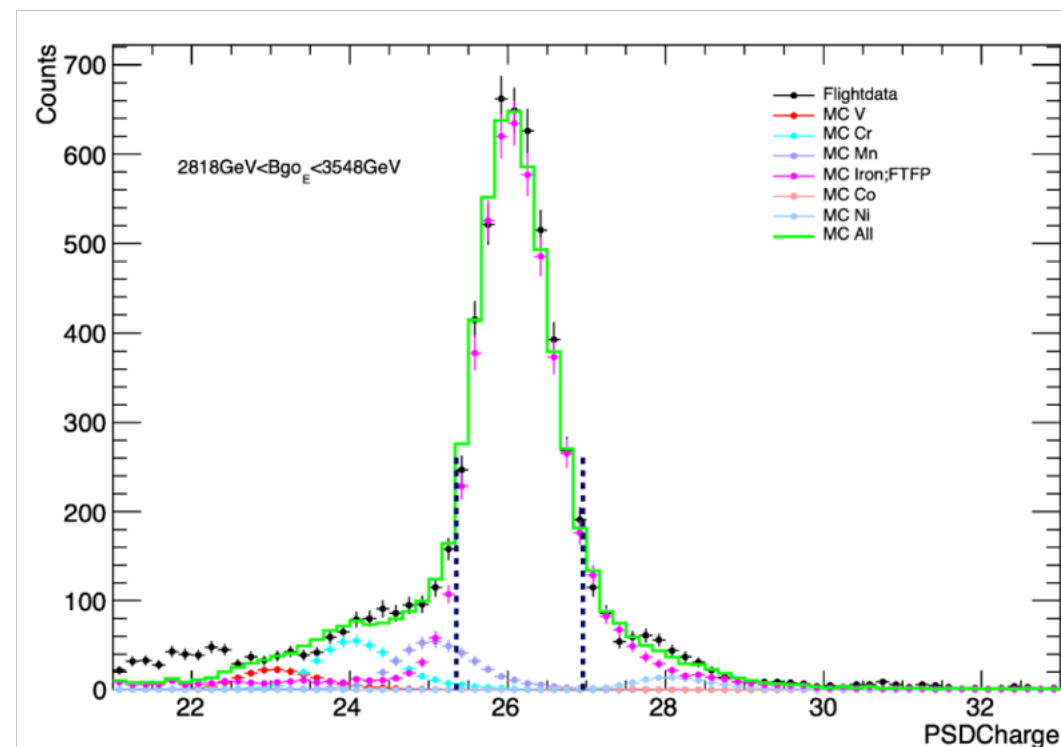
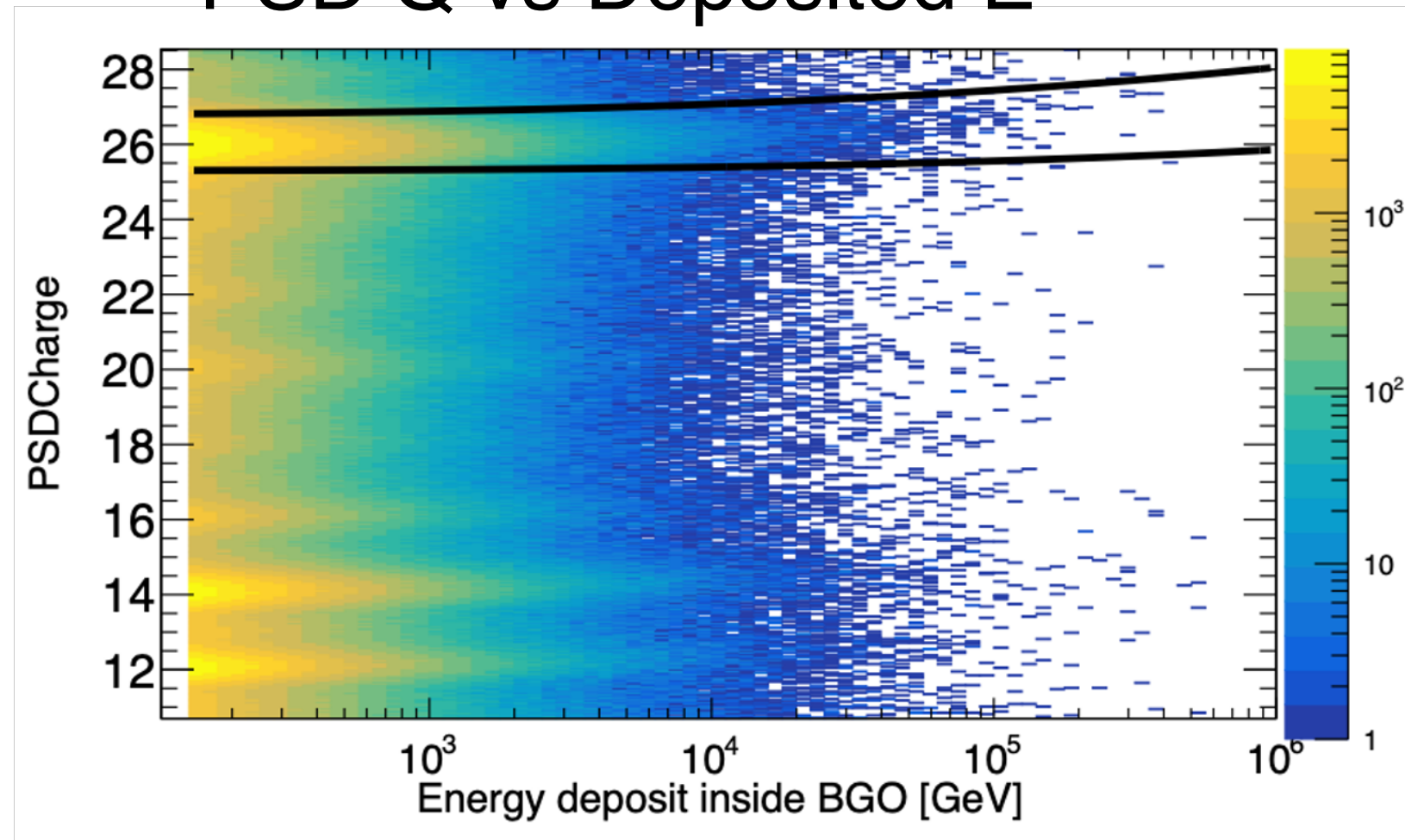


- Confirm the hardening, analysis for >10 TeV/n is in progress



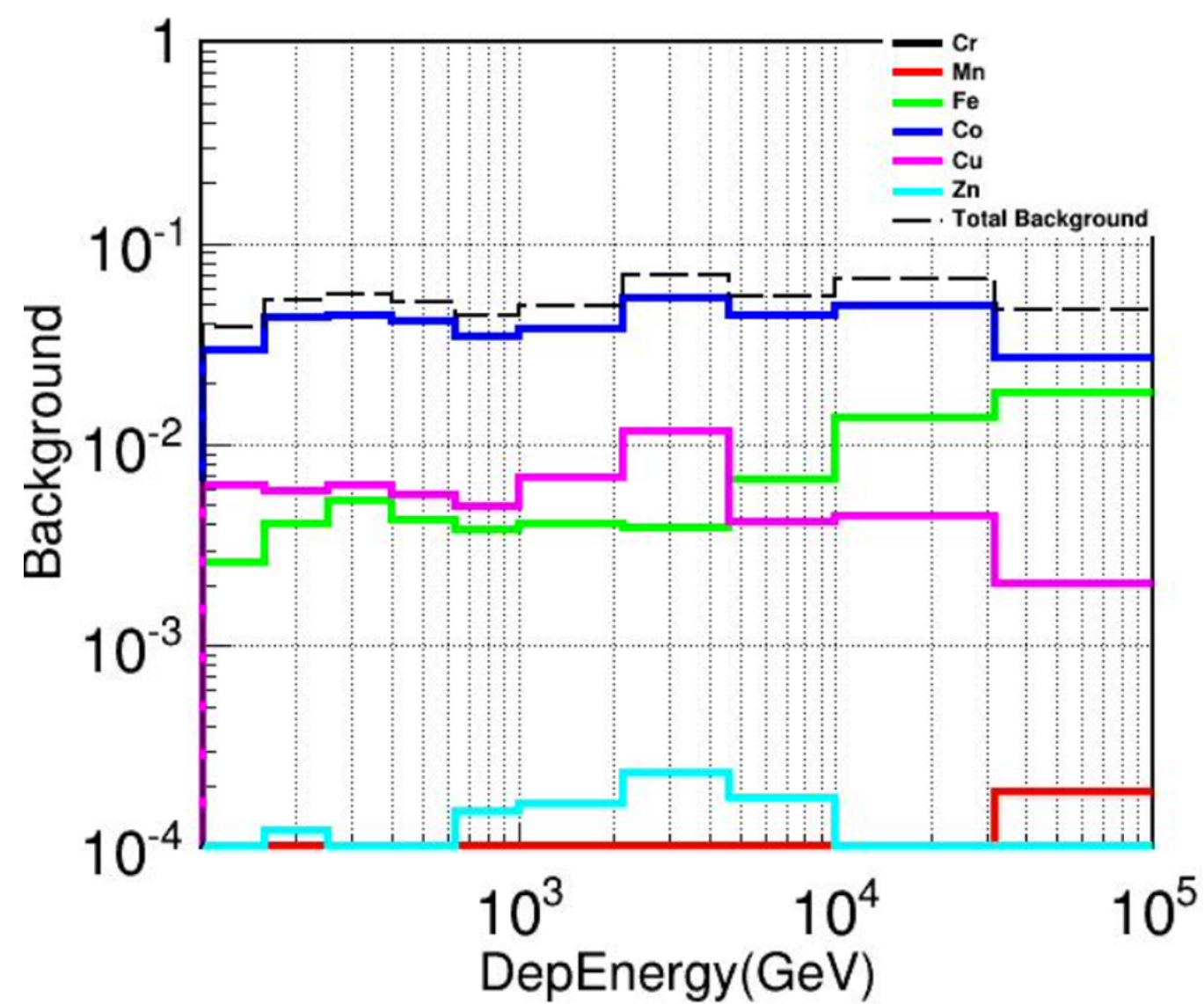
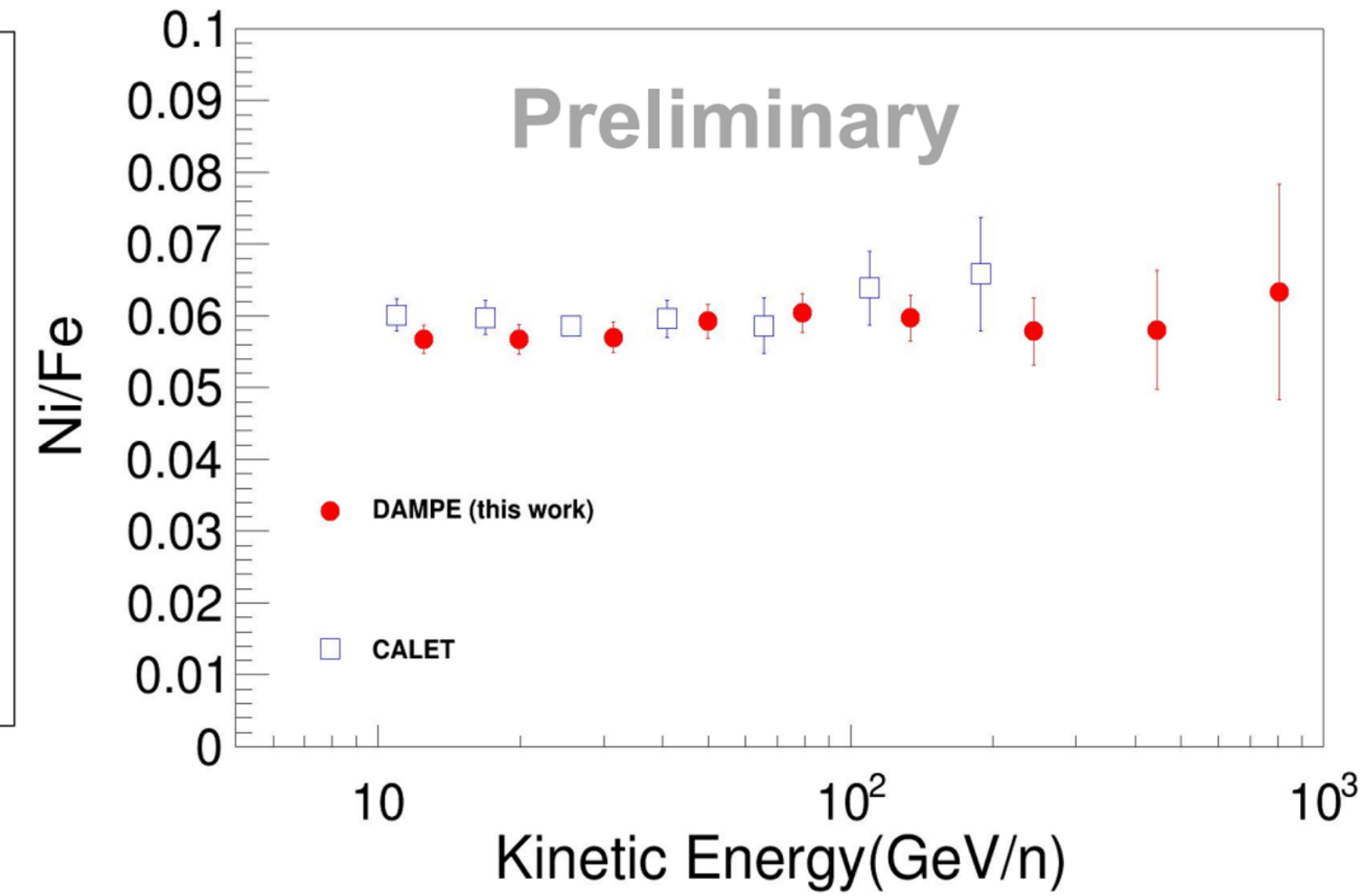
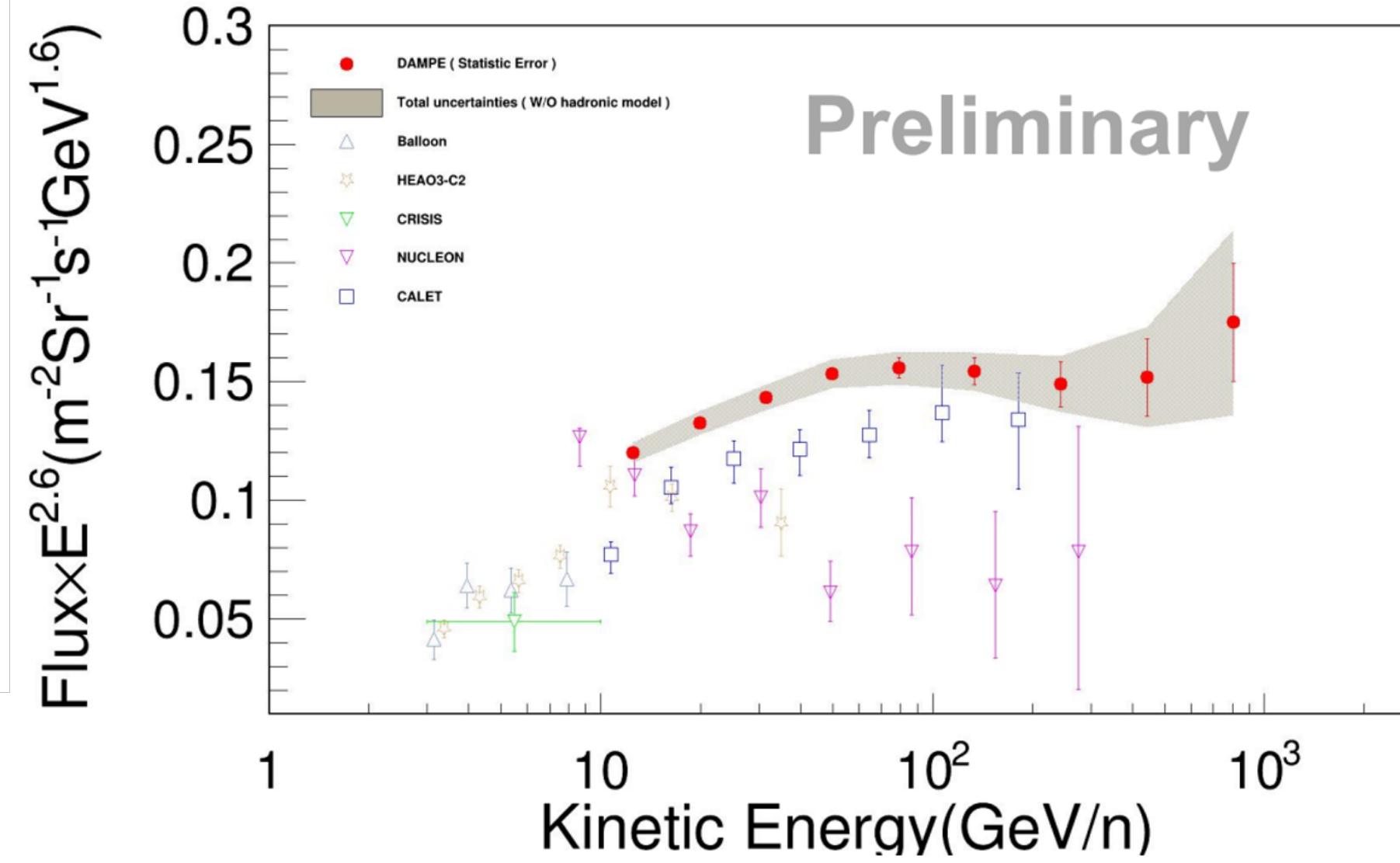
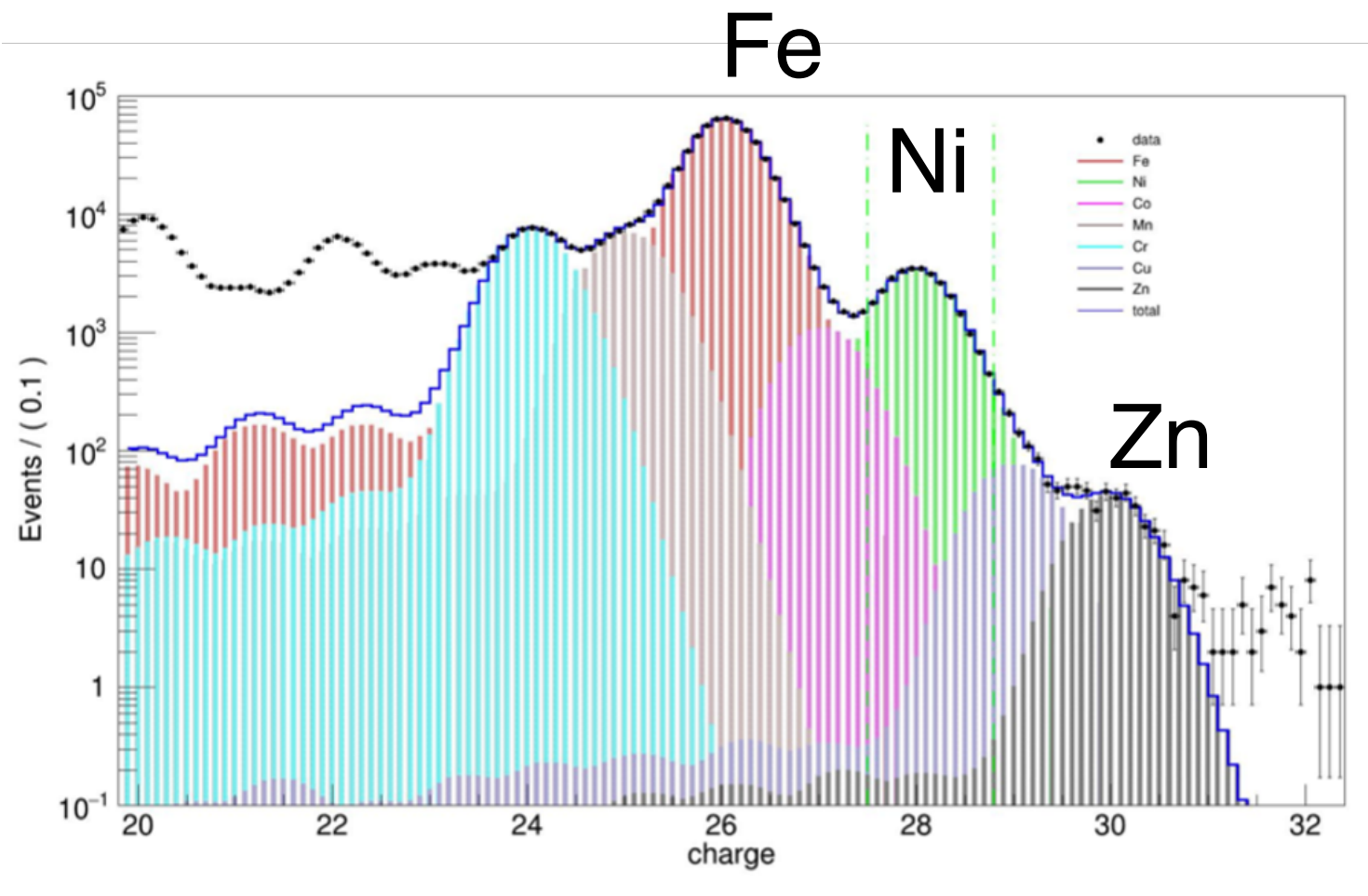
Fe

PSD Q vs Deposited E



- Extend to above TeV/n with sufficient statistics in space
- Observation of a hardening at $\sim 300 \text{ GeV/n}$, analysis for $>10 \text{ TeV/n}$ is in progress

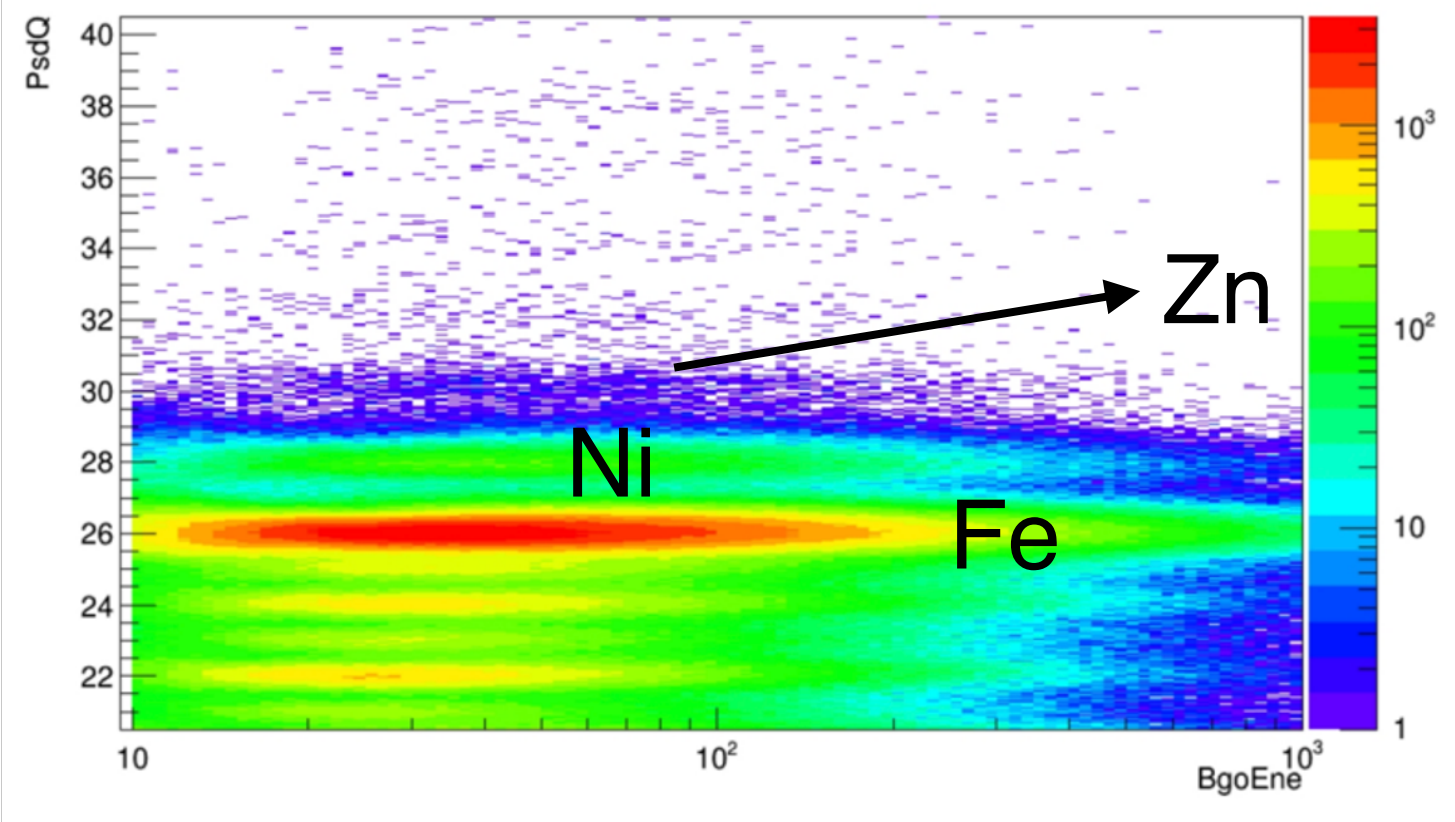
Ni



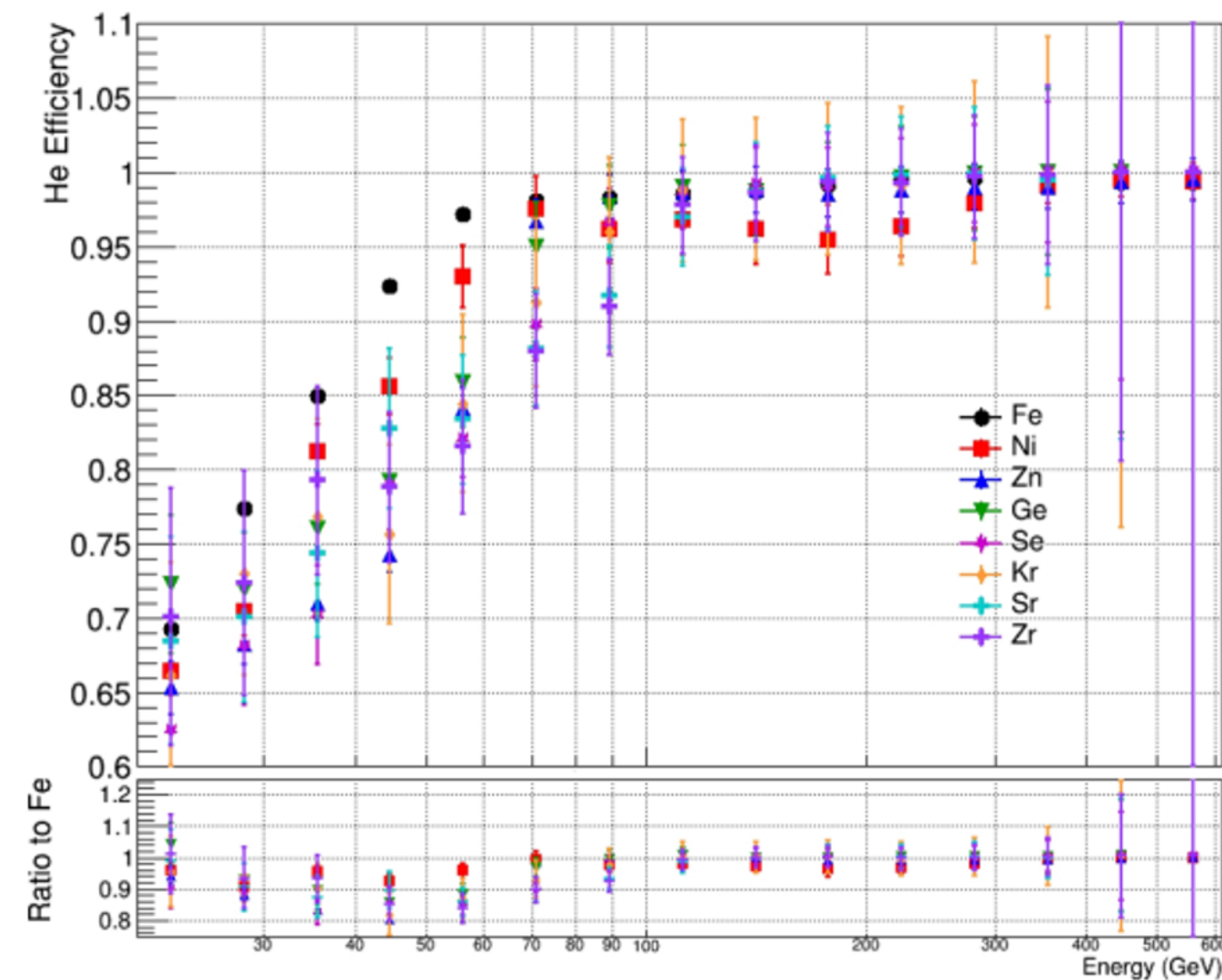
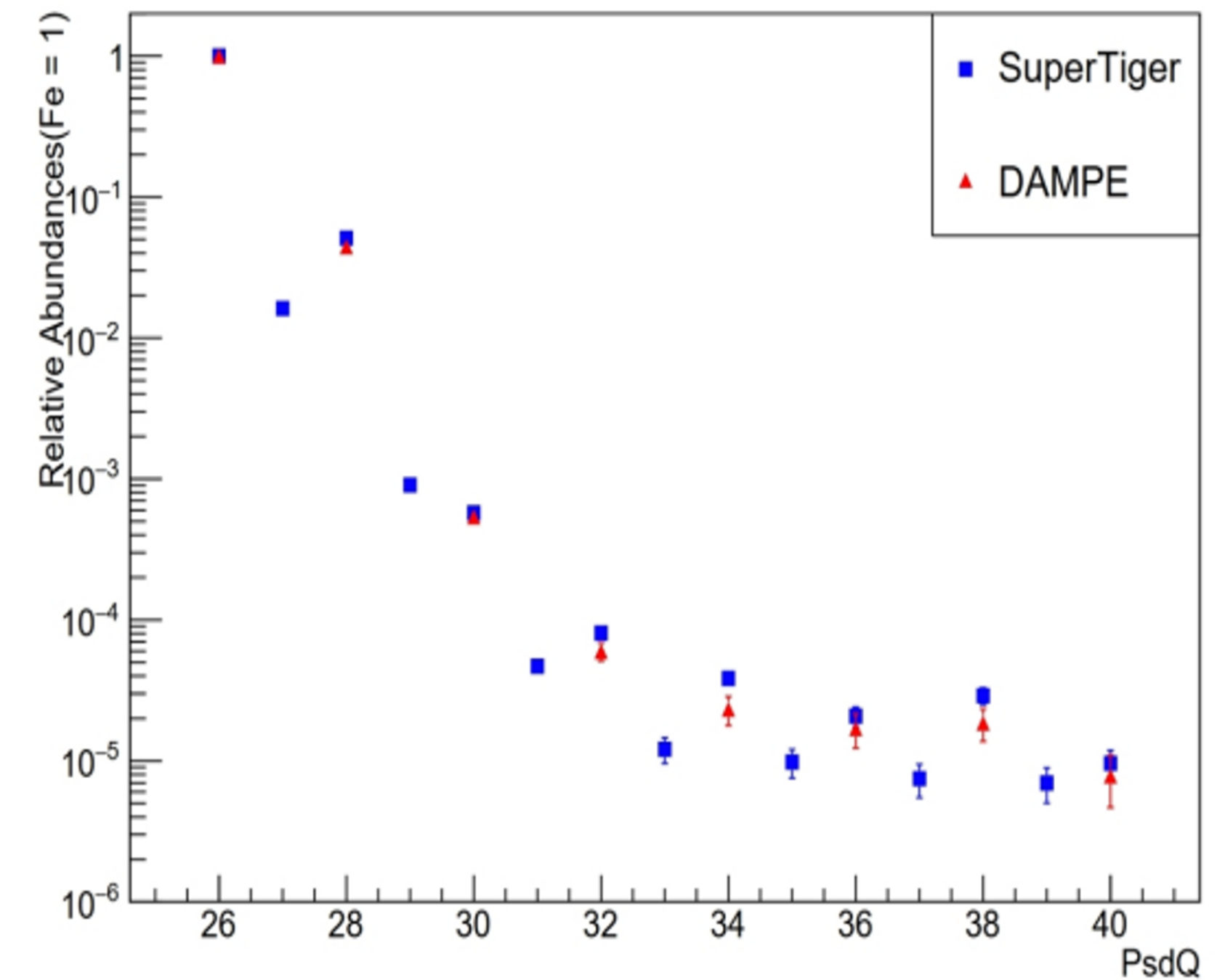
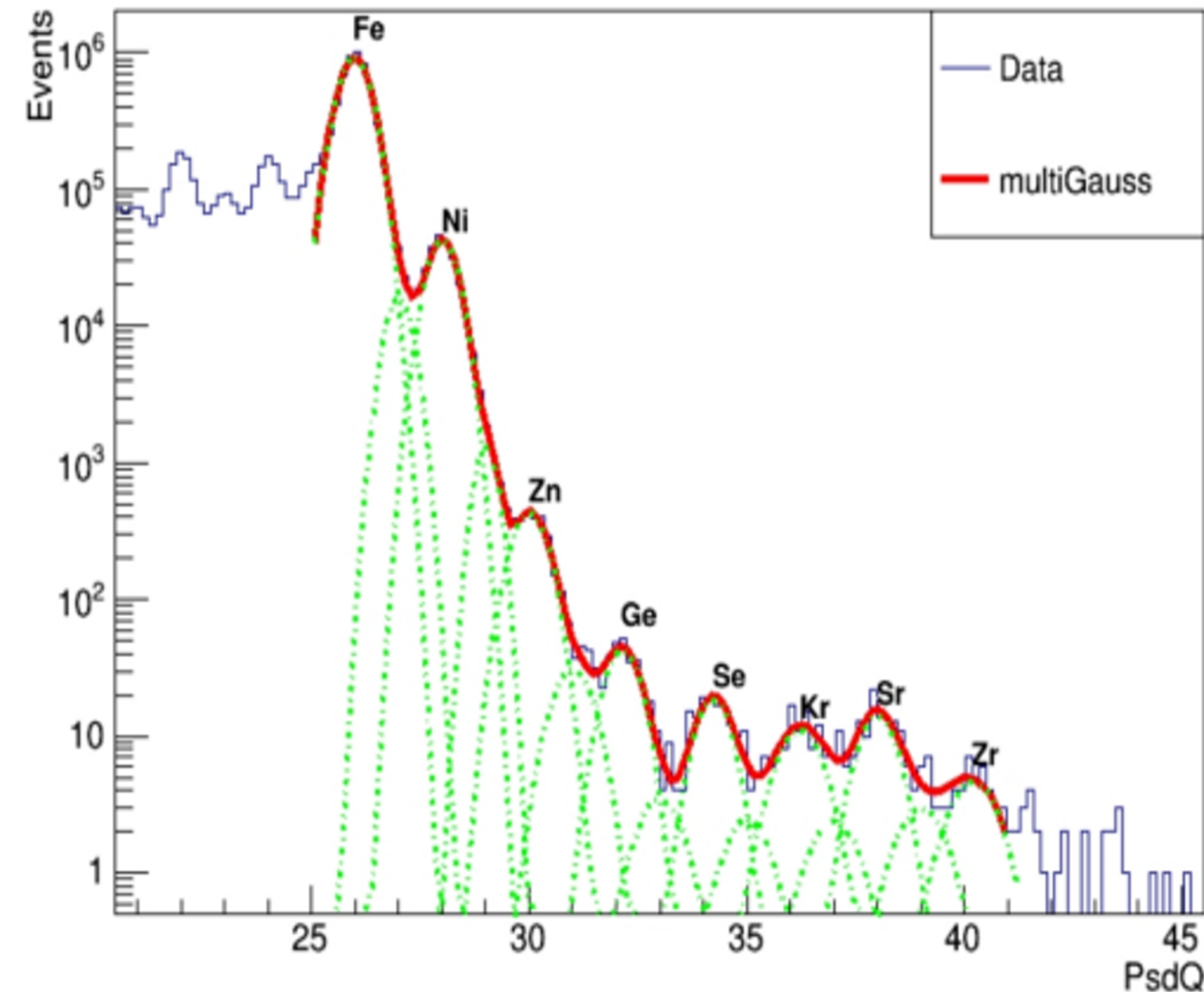
- First direct measurement of Nickel spectrum up to 1 TeV/n
- A hardening hint is consistent with the Iron spectrum

Nuclei beyond Iron

PSD Q vs Deposited E

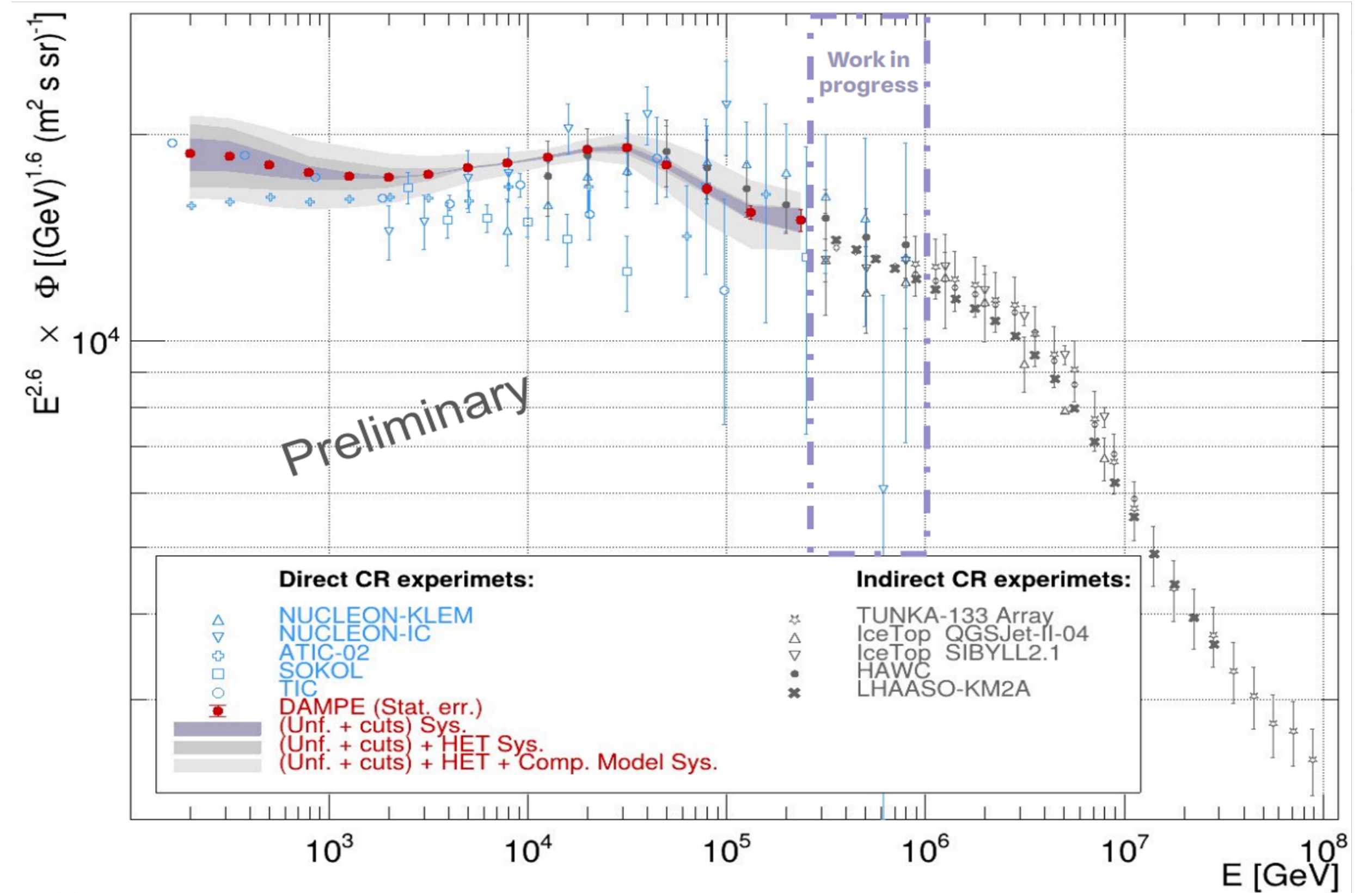
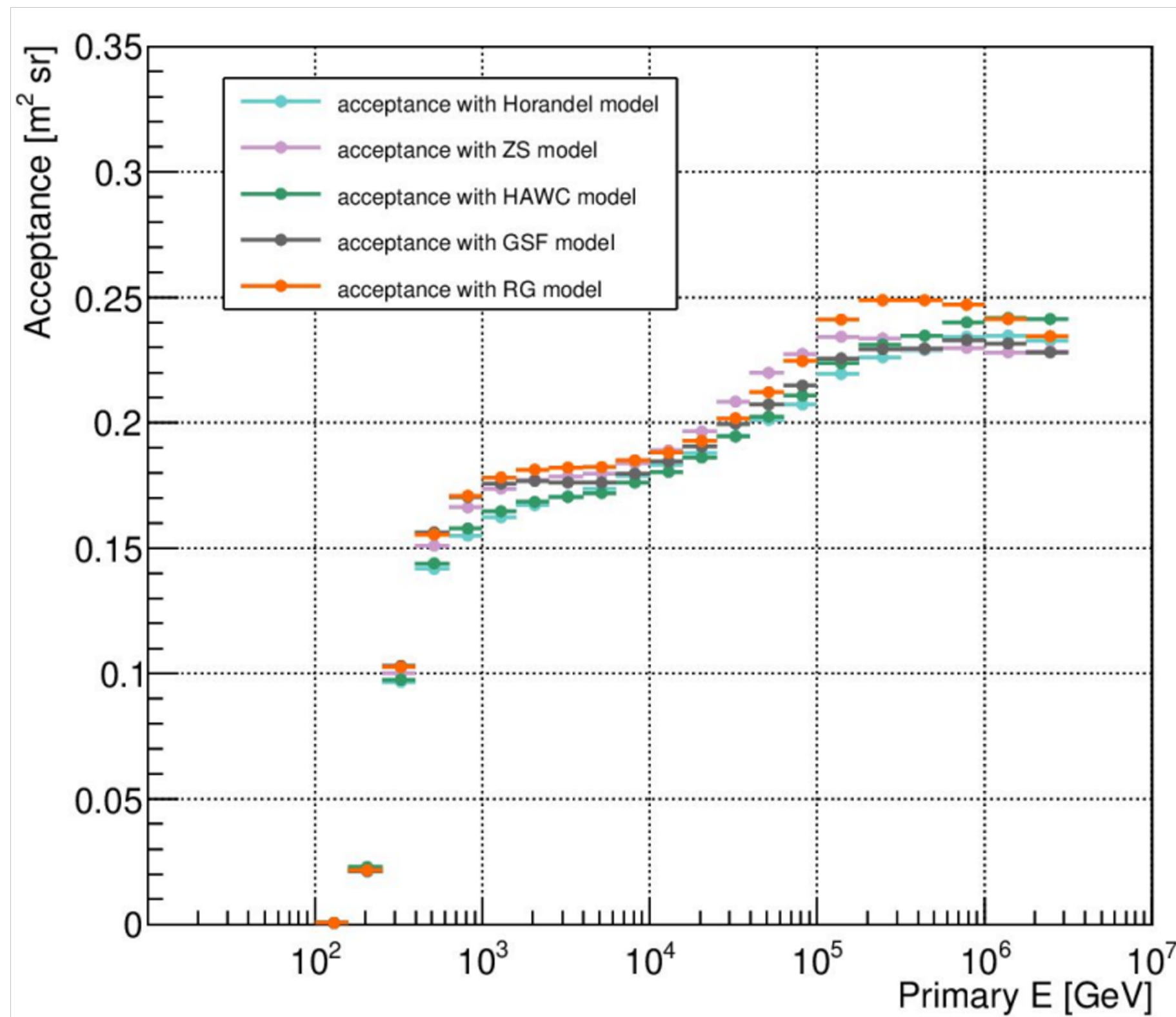


- Relative abundance of nuclei beyond iron (norm. to Iron)



All Particle Spectrum

Acceptance (diff. models)



- Different composition models are evaluated and applied in the analysis.
- Preliminary all-particle spectrum show a clear “knee” feature at tens of TeV, most probably due to the softening of different components (p, He dominant).

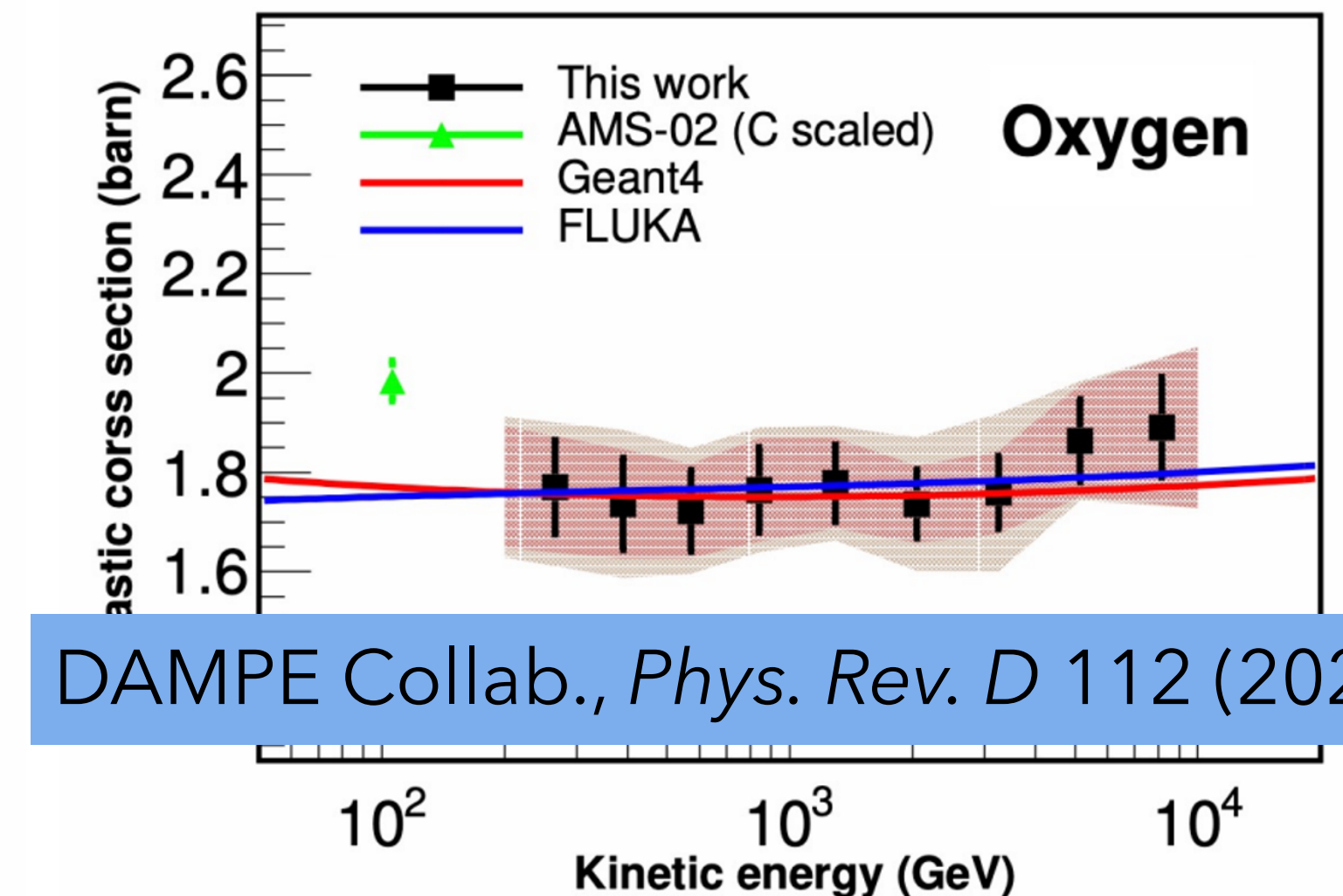
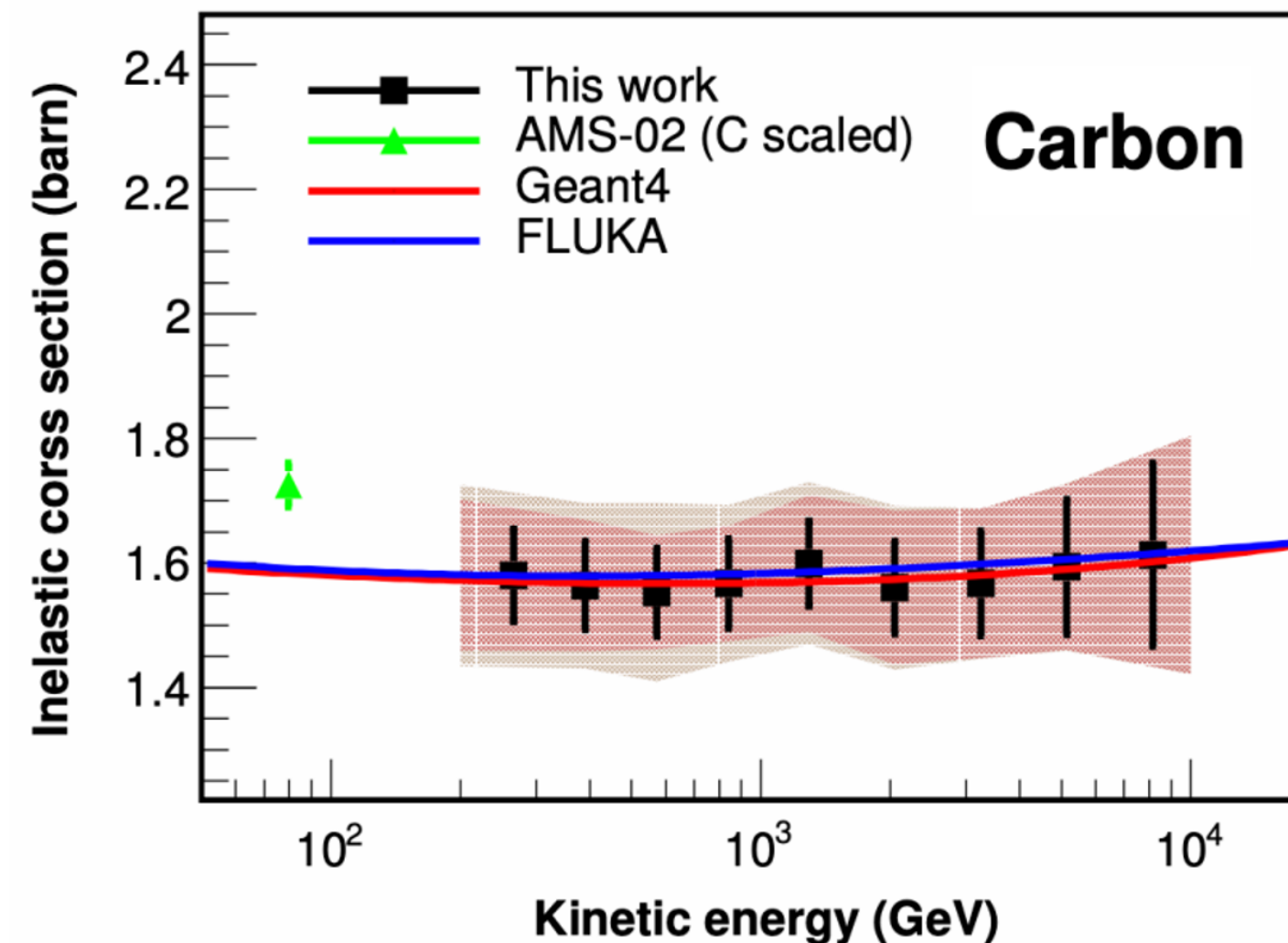
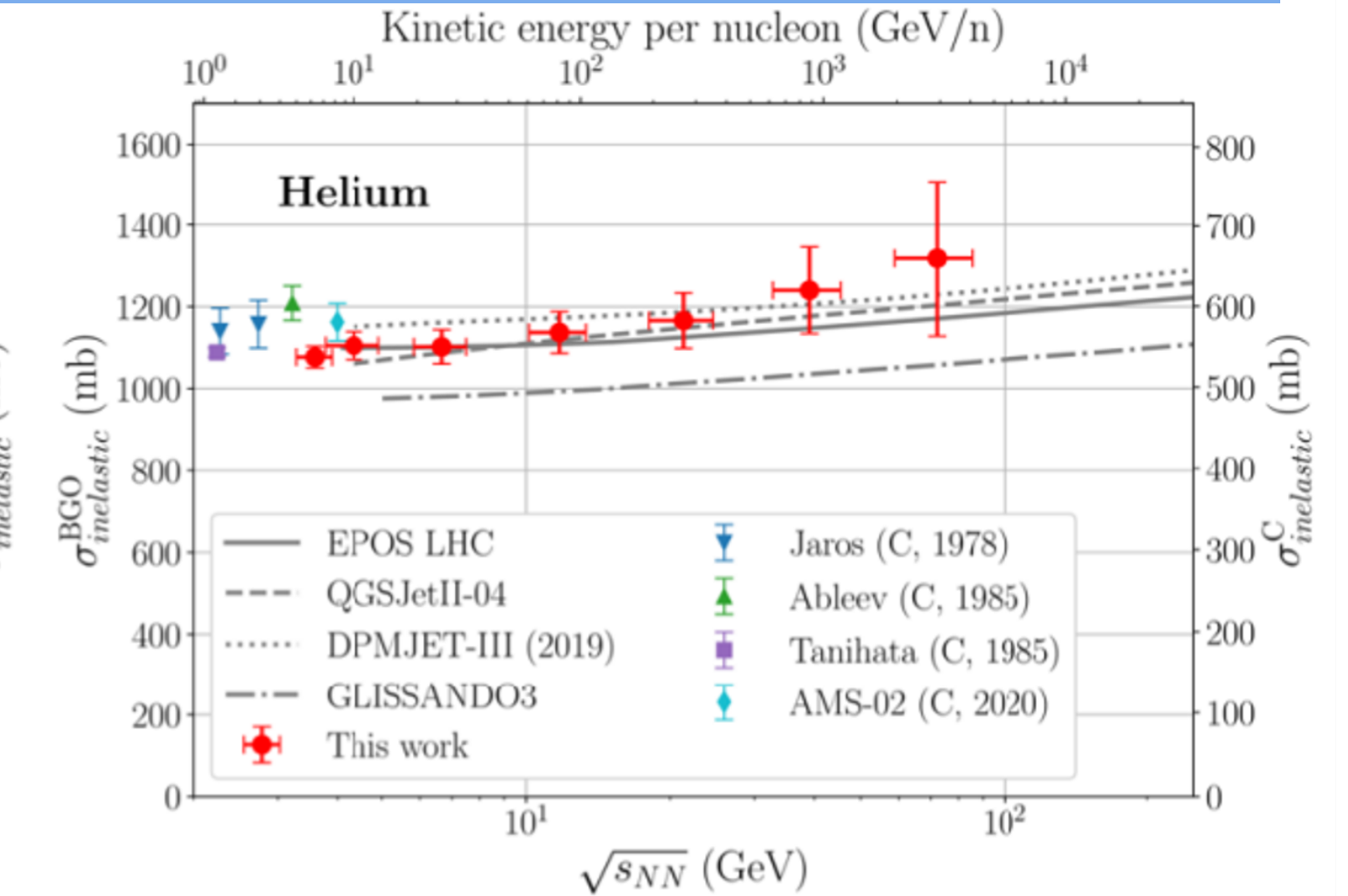
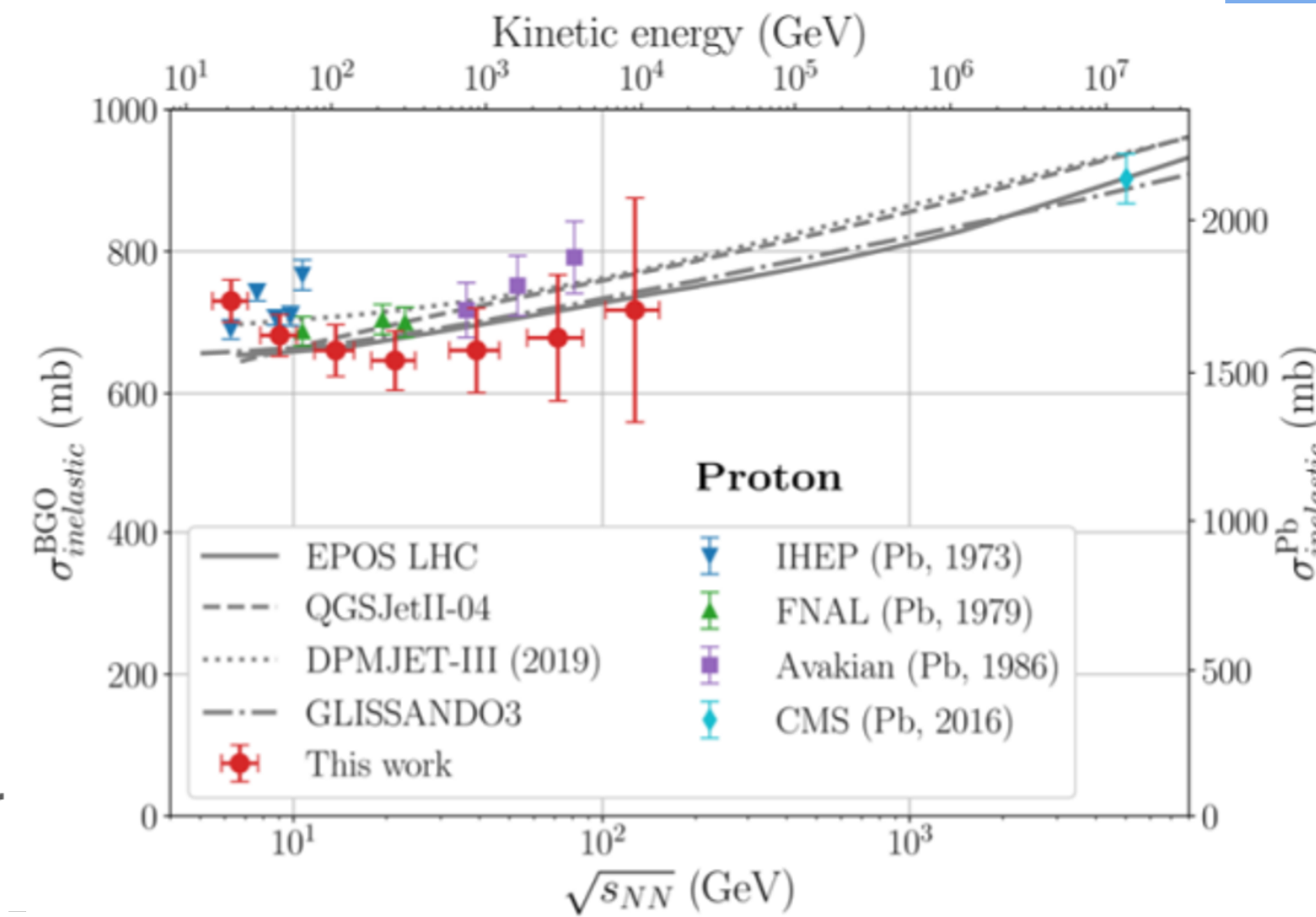
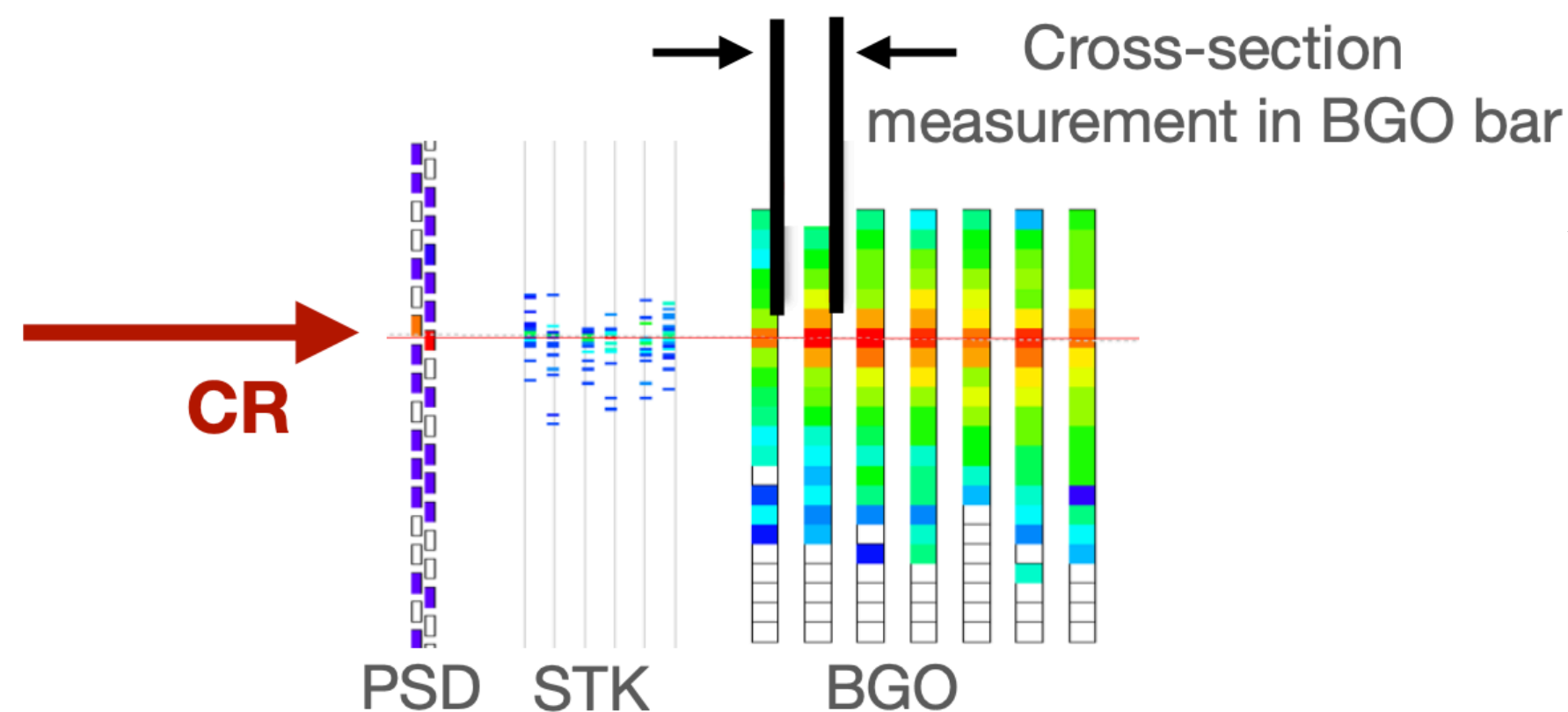
Cross Section: P, He, C & O

DAMPE Collab., *Phys. Rev. D* 111 (2025)

A beam-target experiment

Beam: CR nuclei

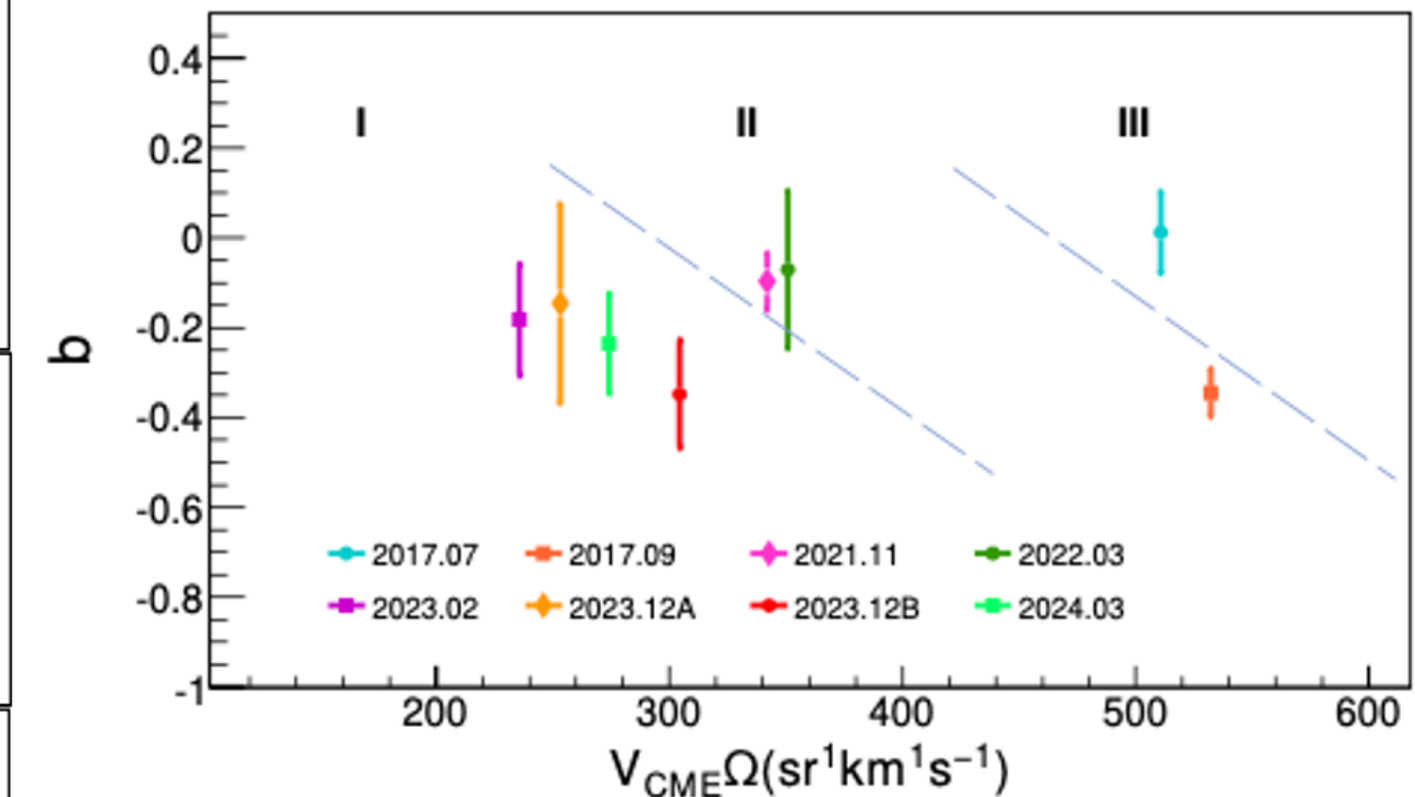
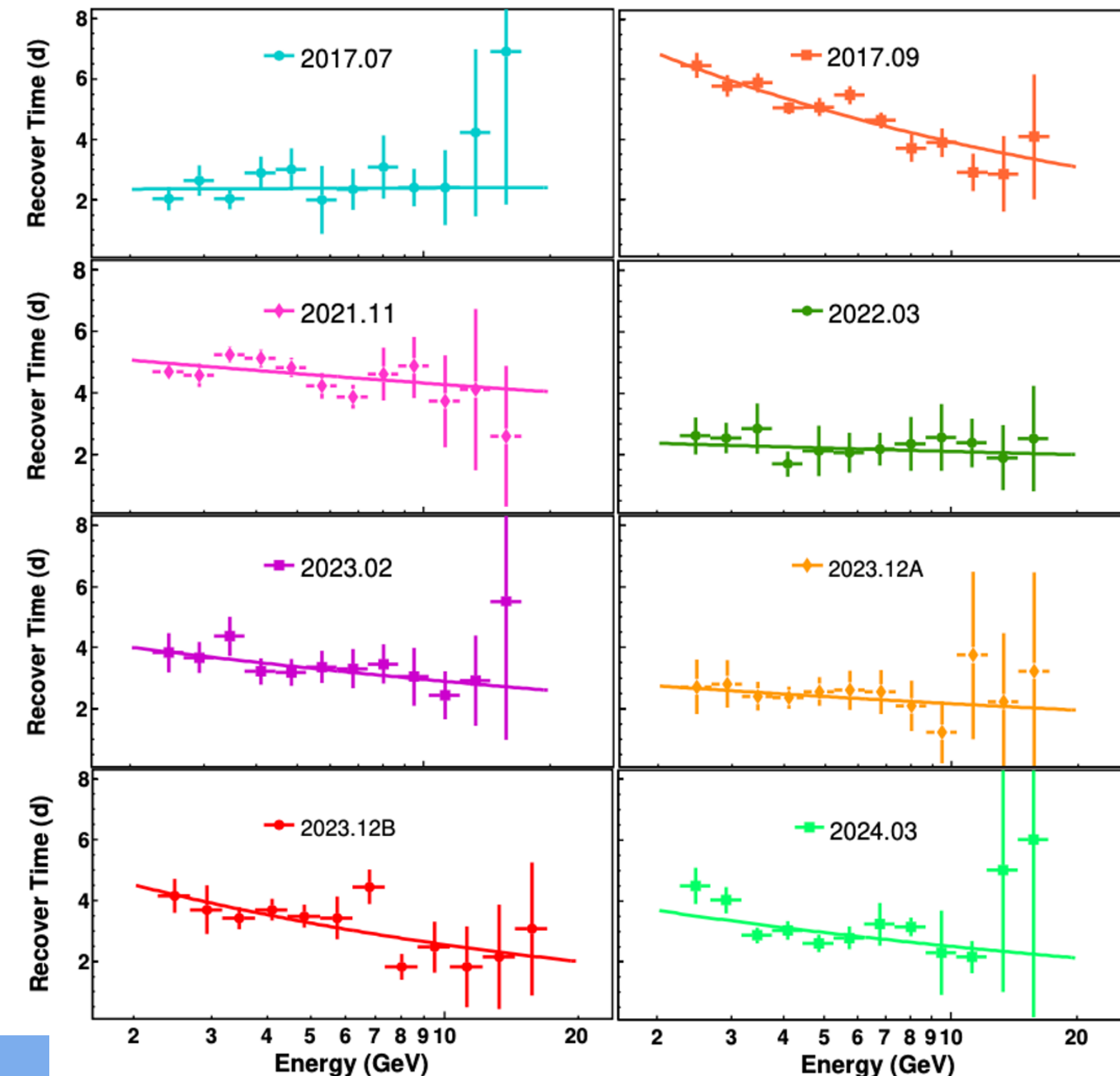
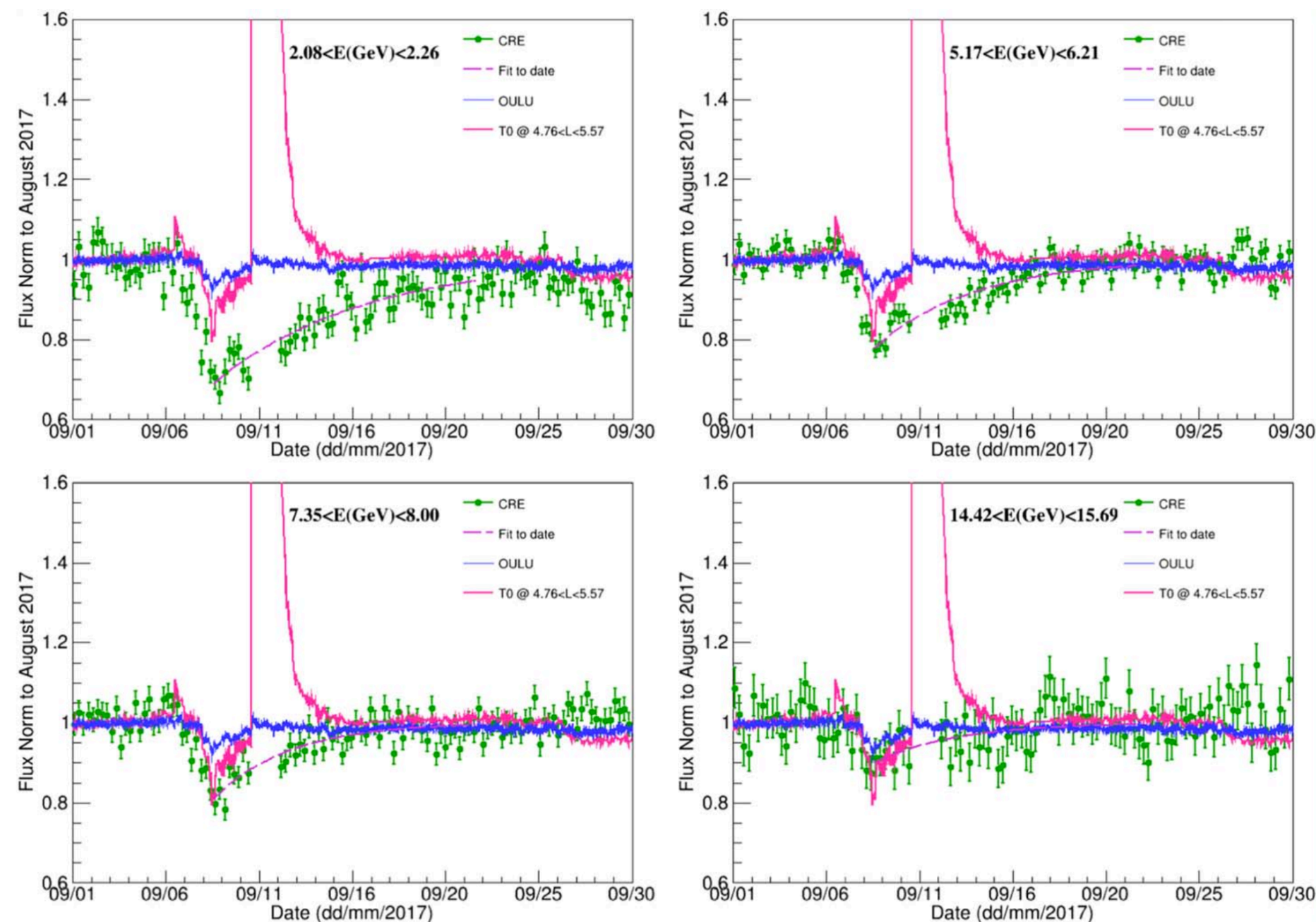
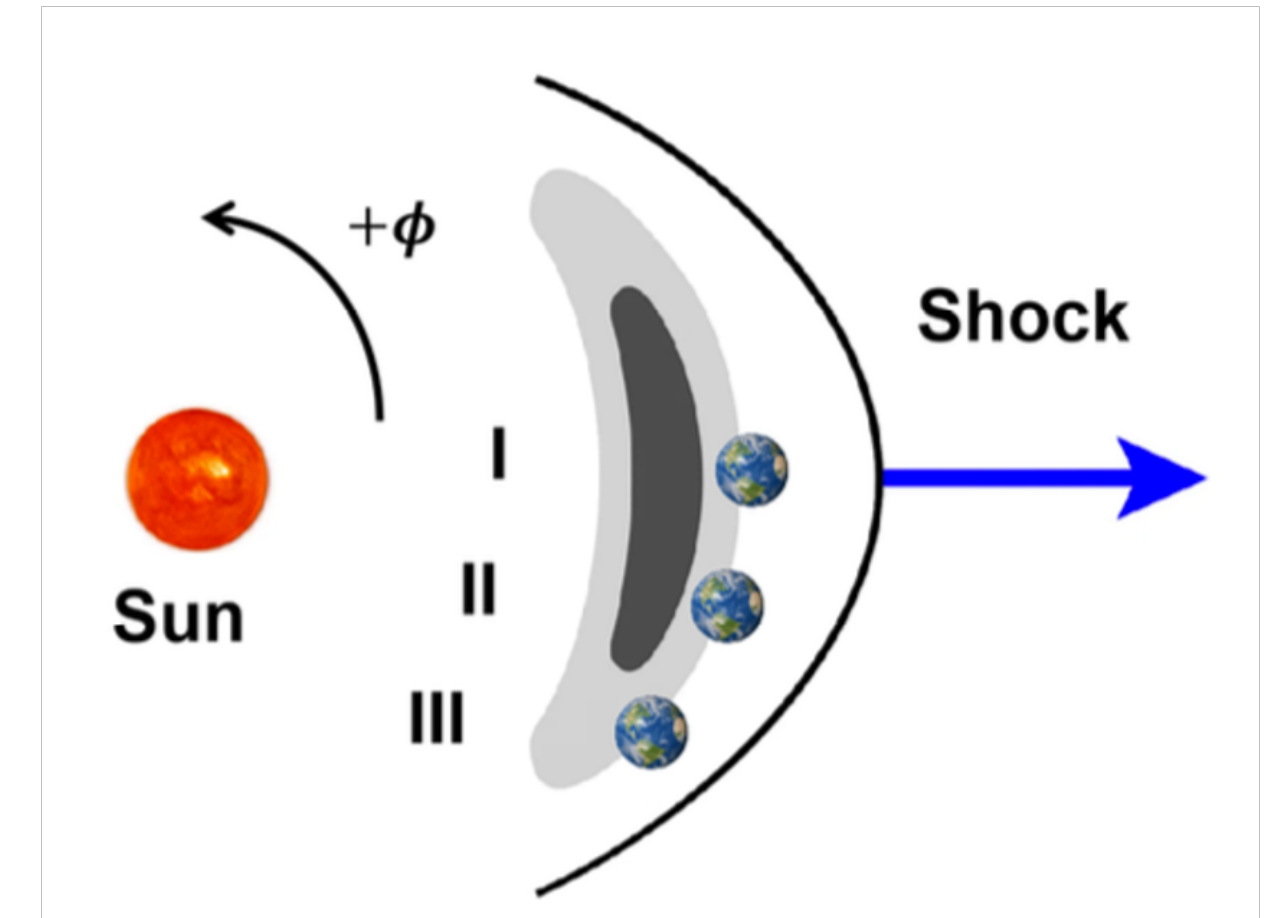
Target: BGO ($\text{Bi}_4\text{Ge}_3\text{O}_{12}$)



DAMPE Collab., *Phys. Rev. D* 112 (2025)

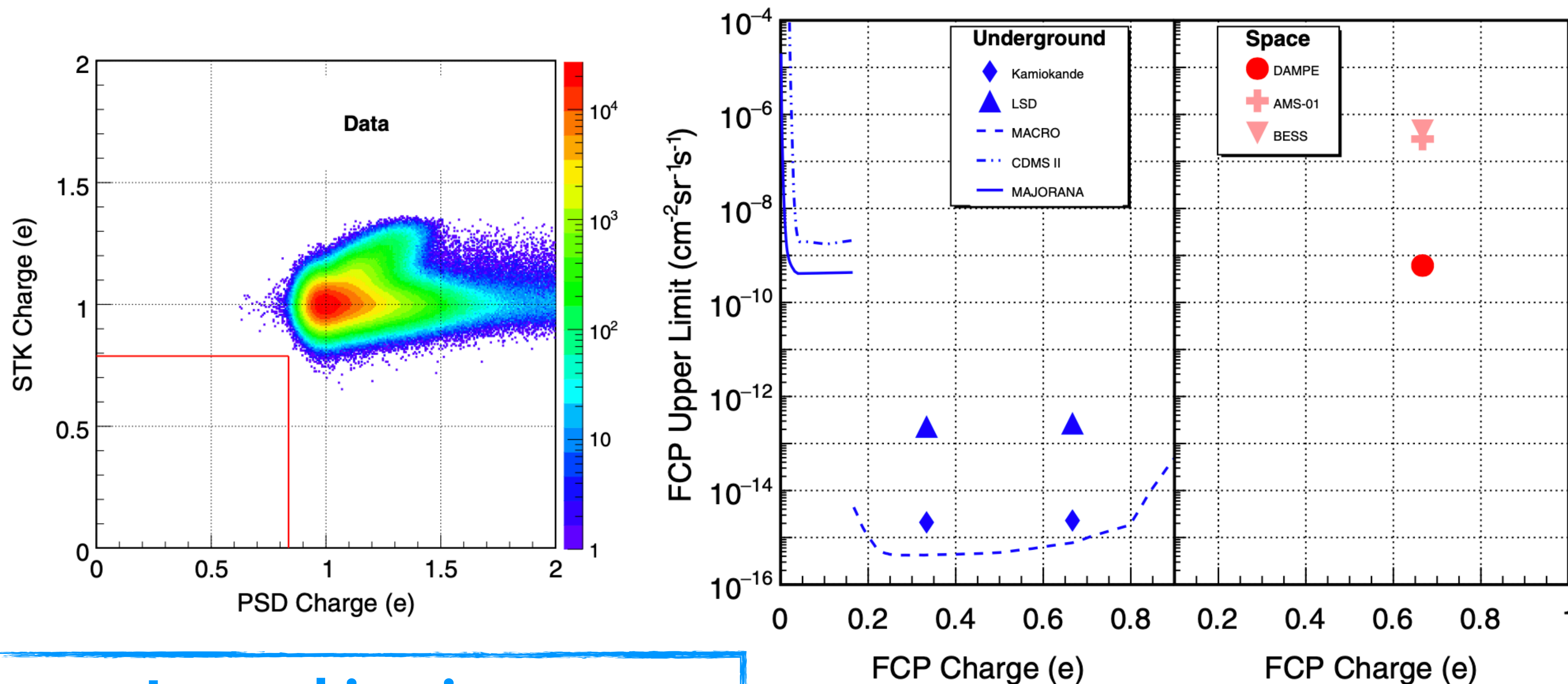
Heliosphere Physics

- **Forbush Decrease (FD)** – A rapid decrease in CR intensity following a CME
- Large acceptance and polar orbit of DAMPE – allows precise FD measurement



Exotics: Fractional Charged Particles (FCPs)

- Search for new physics beyond Standard Model
- DAMPE provides the **most stringent constrain** on the FCP flux upper limit in space



- Light FCP search (work in progress)

**note: Lower kinetic energy
limit for space experiment !**

DAMPE Collab., *Phys. Rev. D* 106, (2022)

Gamma-Ray

Welcome to use DAMPE photon data!

Data

Data Policy

Data Access

Software

FITS Tools

DmpST

Related Links

DAMPE Photon and Spacecraft Data Query

Coordinate system:

J2000

J2000 for equatorial coordinates, Galactic for Galactic coordinates

Coordinates(degree):

(RA, DEC) in J2000 or (L, B) in Galactic coordinate pair for a target, for example '128.84, -45.2' J2000 or '263.55, -2.79' in Galactic for Vela pulsar, the range of RA or L is from 0 to 360, the range of DEC or B is from -90 to 90.

Search radius (degree):

search radius around the target, for example '7', the range of search radius is from 0 to 180.

Time system:

UTC

UTC for Coordinated Universal Time or MET for Mission Elapsed Time

Observation starts:

for example '2016-01-01 00:00:00' or '2016-01-01' in UTC or '94608000' in MET

Observation ends:

for example '2016-02-01 00:00:00' or '2016-02-01' in UTC or '97286400' in MET

Energy range (GeV):

the minimum and maximum event energies, for example '3, 300', the ranges of minimum and maximum energy are from 3 to 1000.

Spacecraft data:

☐

use this option to download spacecraft data for the requested time range

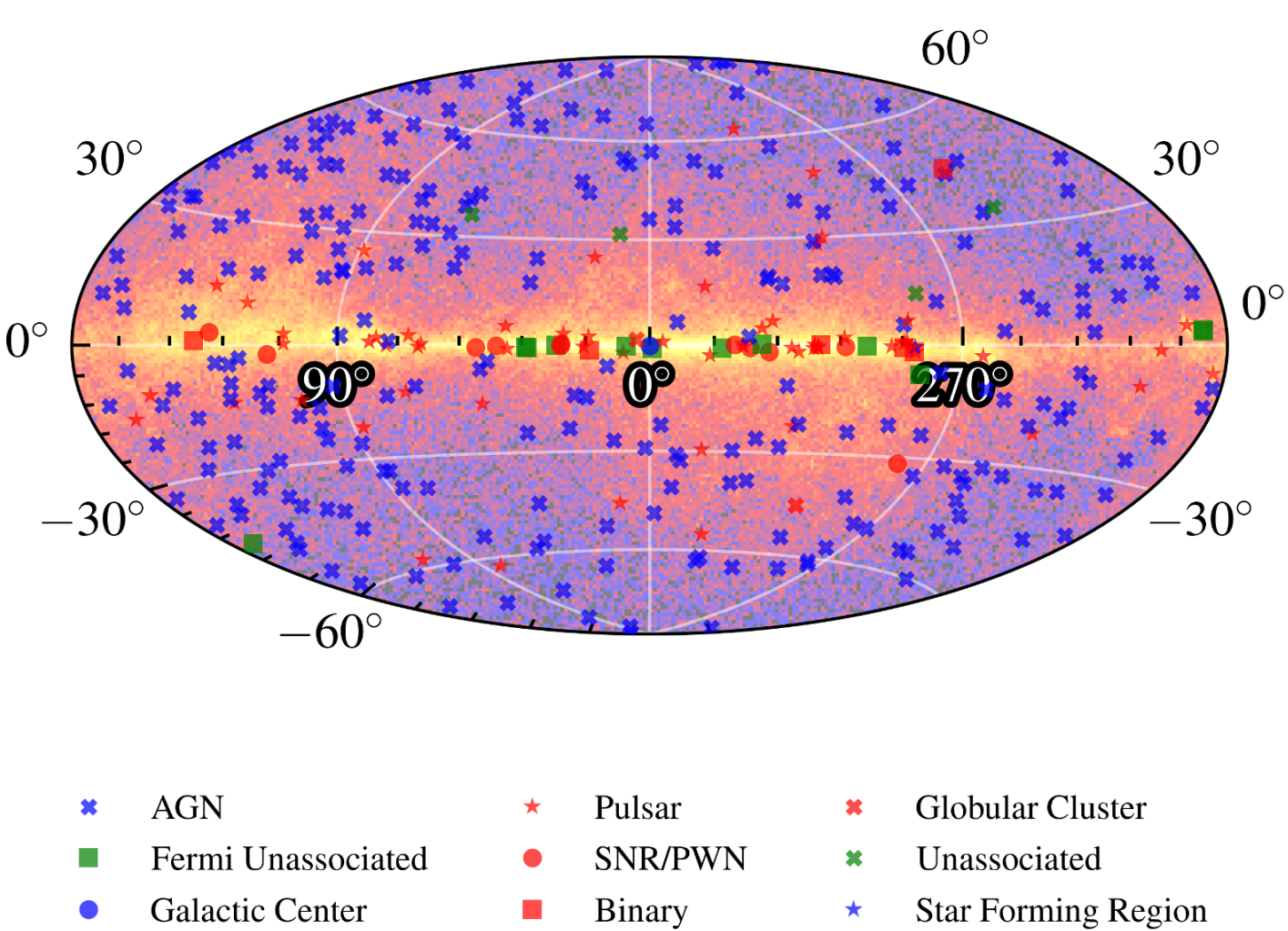
Start Search

Reset

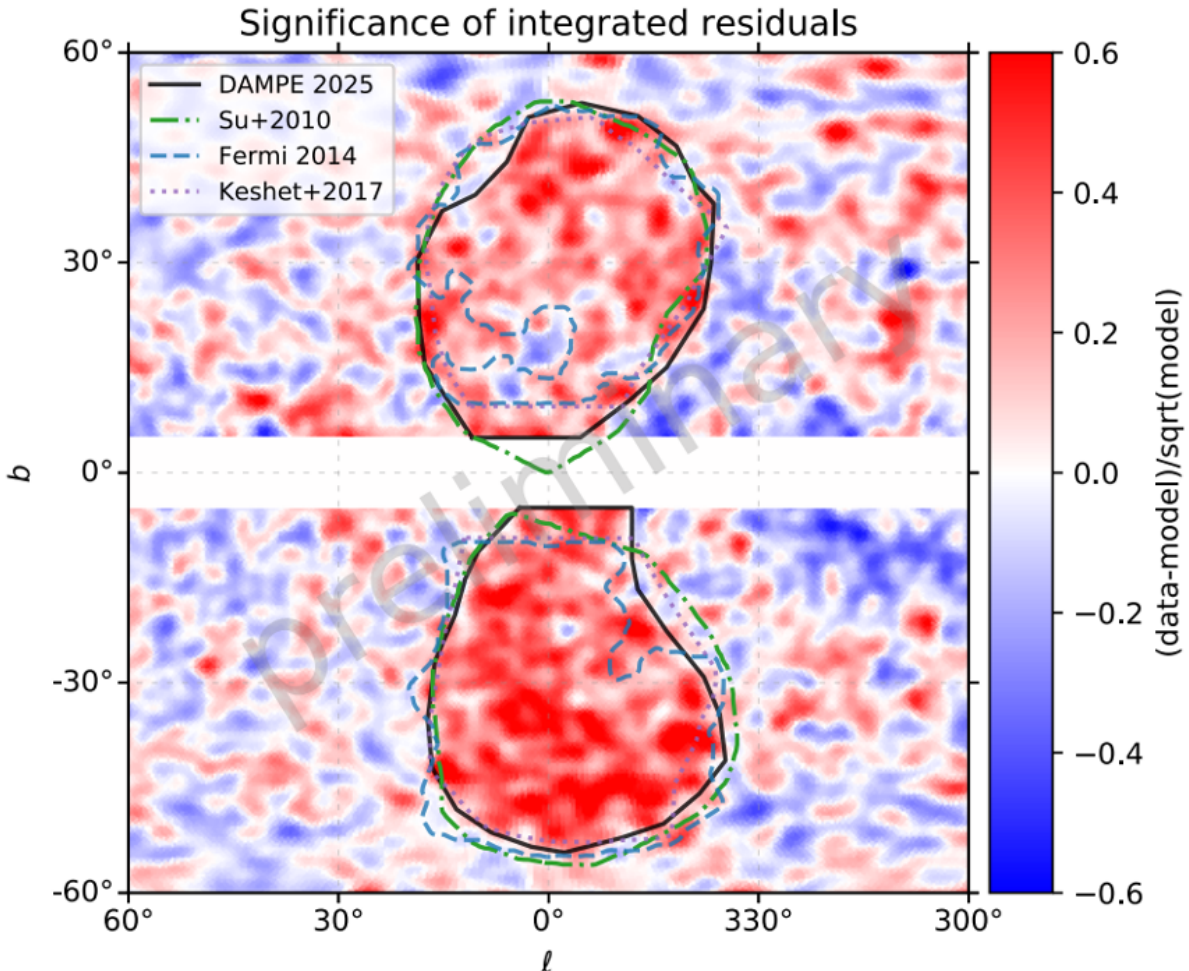
<https://dampe.nssdc.ac.cn/dampe/dataquerysc.php>
<http://dgdb.pmo.ac.cn/dampe/>

Point sources catalog (8.6 years data)

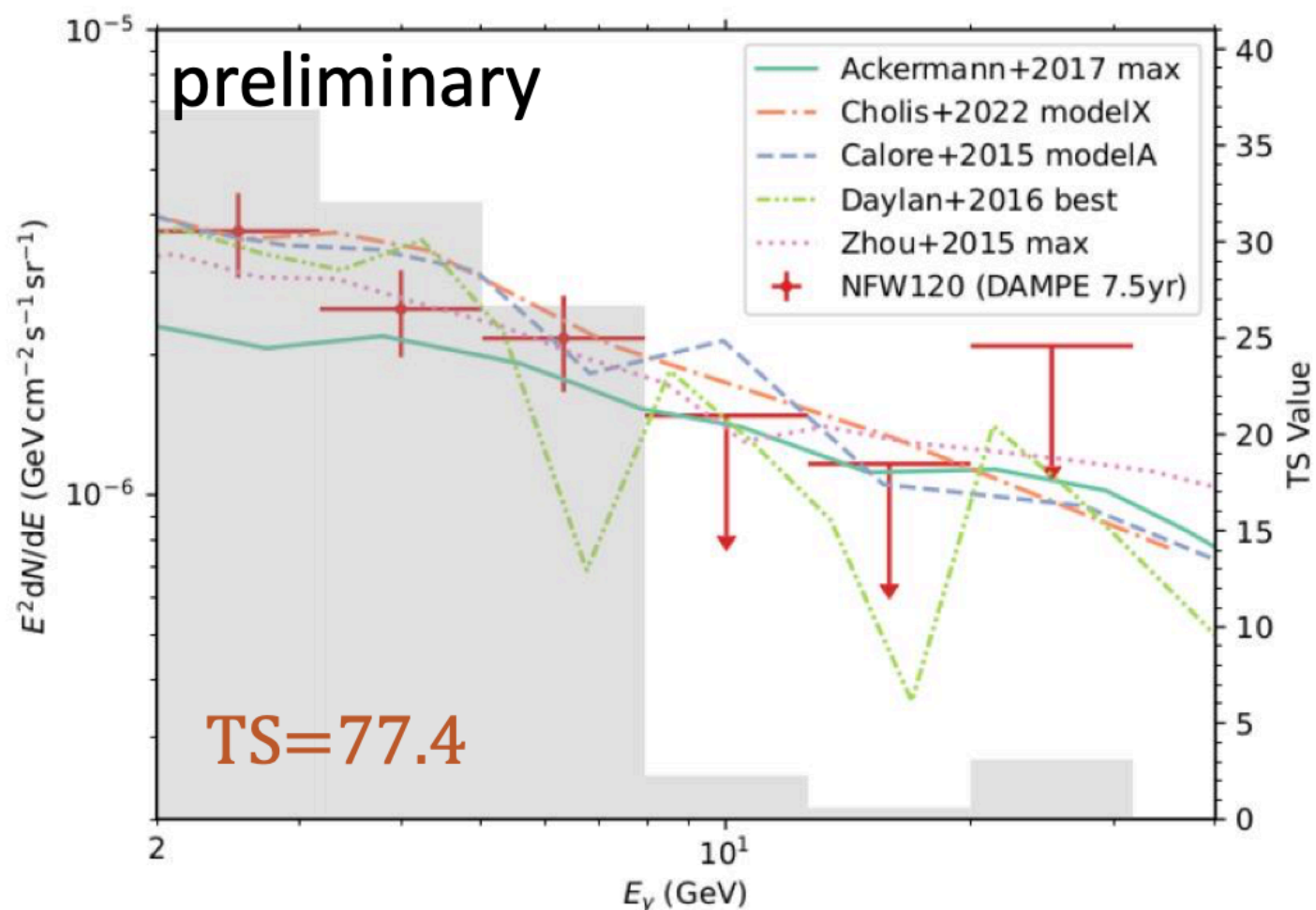
Source type	Number
AGN	261
Pulsar	61
SNR/PWN	11
Binary system	6
Globular Cluster	2
Star Forming Region	1
Galactic Center	1
Fermi Unassociated	12
Unassociated	4
Total	359



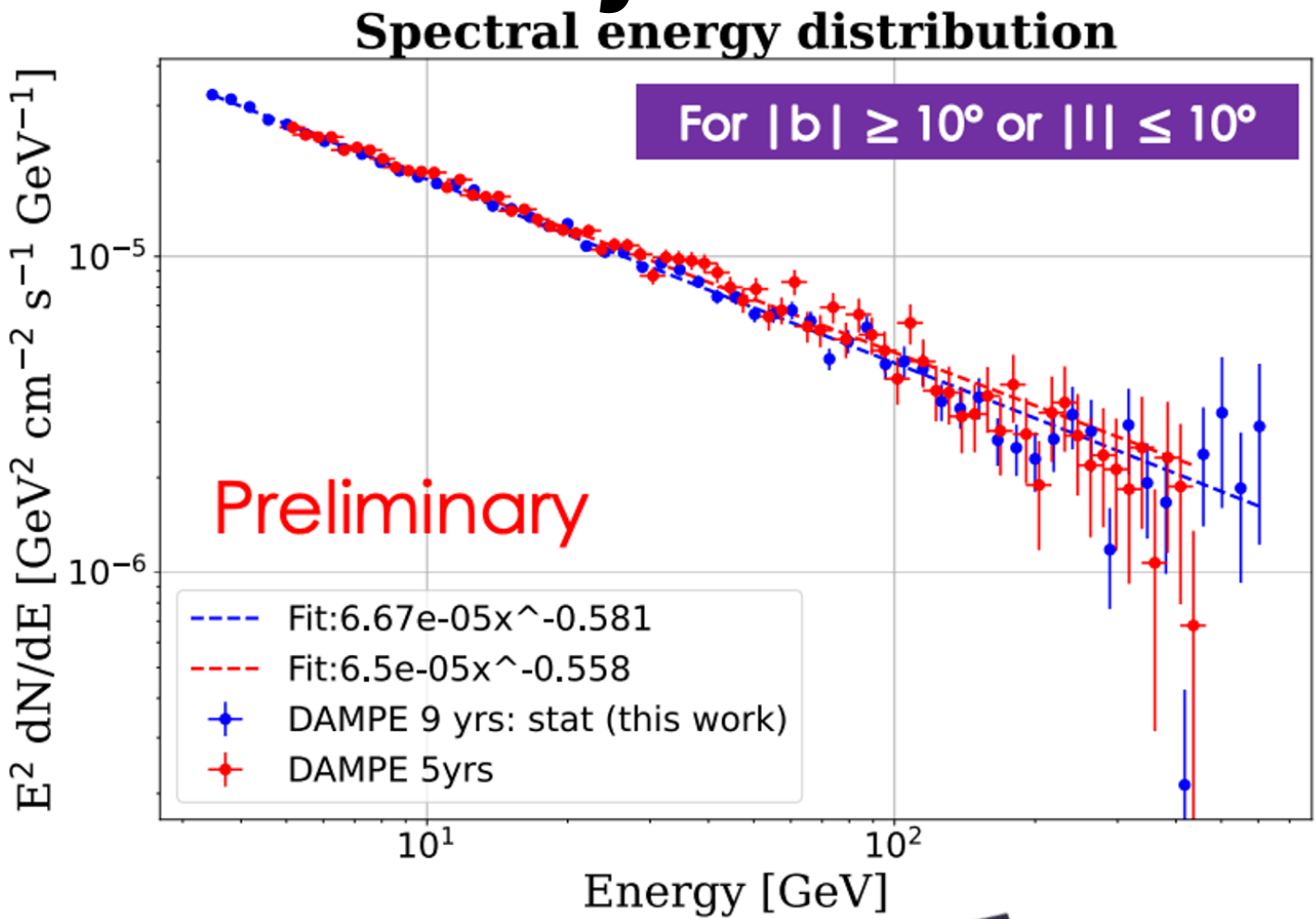
Fermi Bubble



Galactic Center Excess



Gamma-Ray Line Search



Summary

DAMPE Mission

- Smooth on-orbit operation for 9.5 years
- Excellent performance & stability
- Unique for multi-TeV Cosmic Rays (CR) in space



Physical program

- $e^+ + e^-$ – direct observation of TeV-break
- $p, He, p+He$ – universal softening at ~ 15 TV, approaching the PeV frontier
- C, O, CNO – observation of hardening, evident softening at ~ 15 TV (vs. p, He)
- Ne, Mg, Si, Fe – observation of hardening, extending to above 10 TeV/n
- **Secondaries: Li, Be, B** – observation of a twice hardening vs. primaries
- **Heliophysics & FCP**
- γ -ray sky, Fermi Bubbles, GCE, DM search, ...

Thank you ! 36