Galactic Cosmic Ray Studies with the DAMPE space mission

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on behalf of the DAMPE Collaboration

NOW 2024
Neutrino Oscillation Workshop

Neutrino Oscillation Workshop 2024
Otranto (Italy), September 3-7, 2024

DAMPE science goals

High energy particle detection in space

- Study of the cosmic electron spectrum
- Study of cosmic ray protons and nuclei
- High energy gamma ray astronomy
- Search for dark matter signatures in e/γ spectra

Detection of

10 GeV - 10 TeV e/γ

50 GeV – 0.5 PeV protons and nuclei

with excellent (e.m.) energy resolution , tracking precision and particle identification capabilities

- Exotica and “unexpected” , e.g. GW e.m. counterpart in the FoV

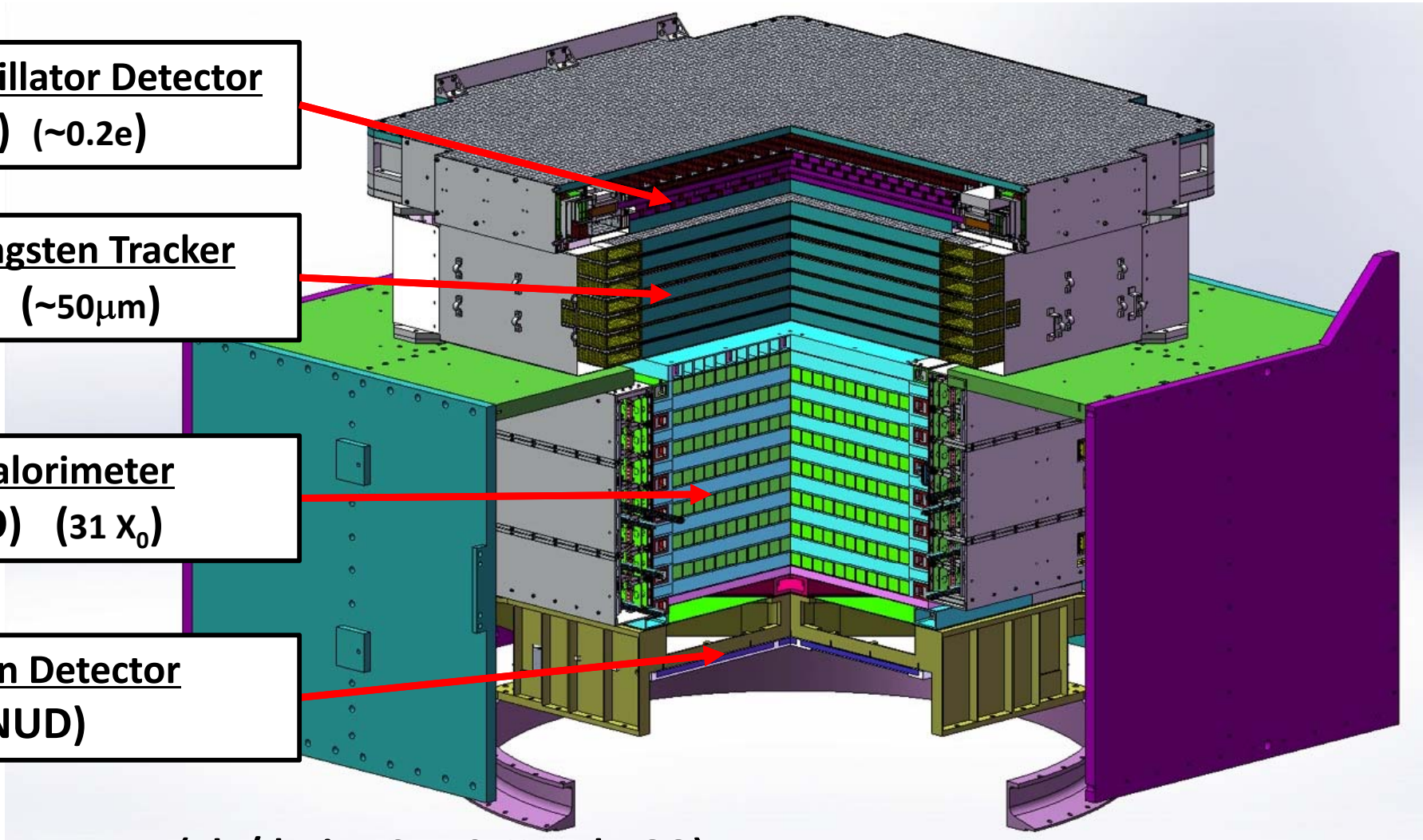
The detector

Plastic Scintillator Detector
(PSD) (~0.2e)

Silicon-Tungsten Tracker
(STK) (~50μm)

BGO Calorimeter
(CALO) (31 X_0)

Neutron Detector
(NUD)



- **Charge measurement (dE/dx in PSD , STK and BGO)**
- **Tungsten converter (pair production)**
- **Precise tracking (silicon strips)**
- **Thick calorimeter (BGO bars)**
- **Hadron rejection (neutron detector)**

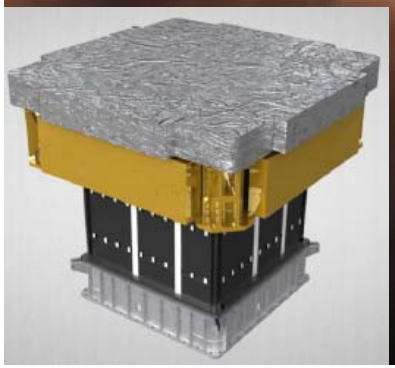
high energy
γ-ray, electron and cosmic ray
telescope

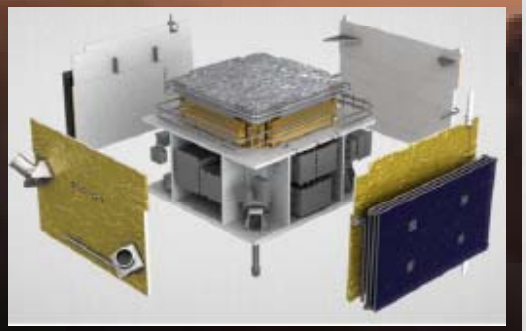
The launch: Dec 17th 2015, 0:12 UTC

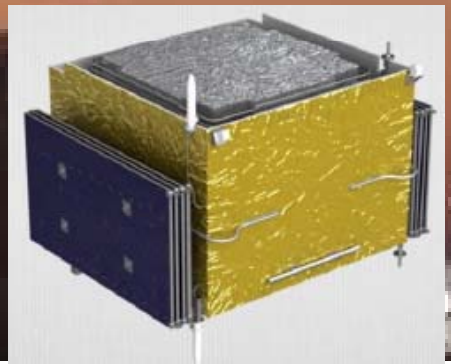
Jiuquan Satellite Launch Center
Gobi desert

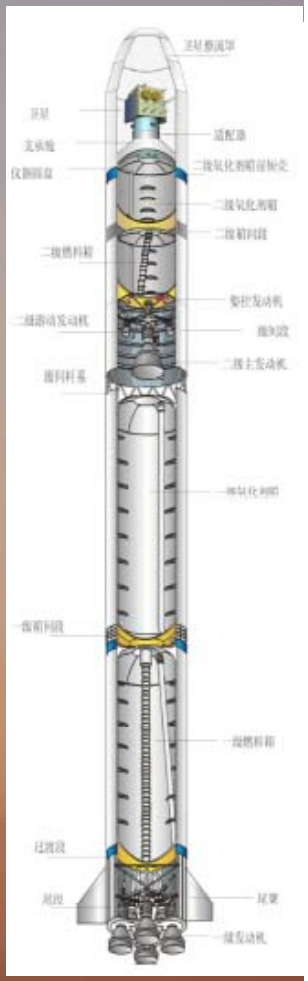
CZ-2D rocket

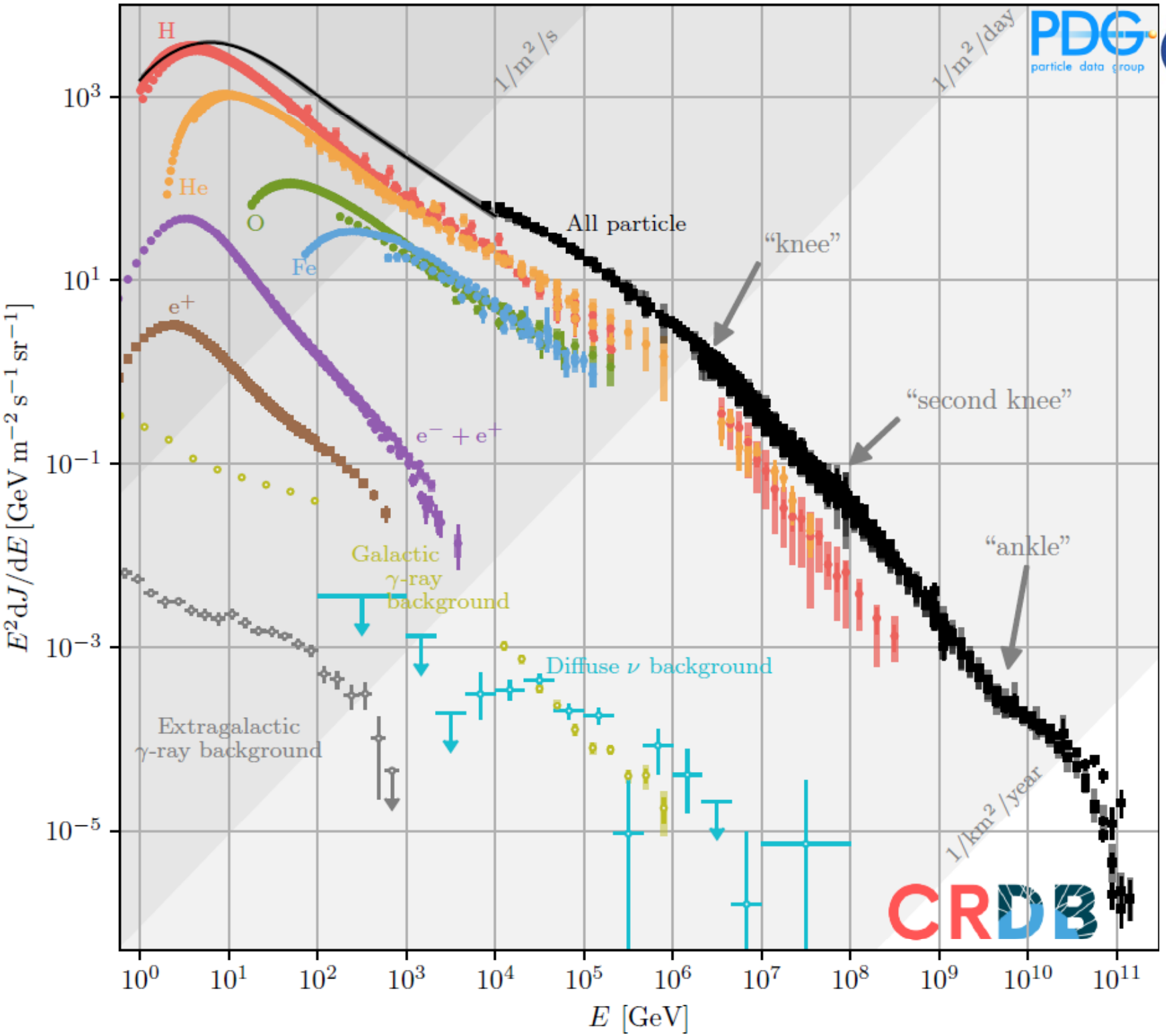
Mass: 1850 kg (scientific payload 1400 kg)
Power : 640 W (scientific payload 400 W)
Orbit: sun syncronous
Altitude: 500km
Inclination: 97.41°
Period: 95 minutes
Downlink: 16 GB / day
Lifetime: > 3 years










H
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All particle
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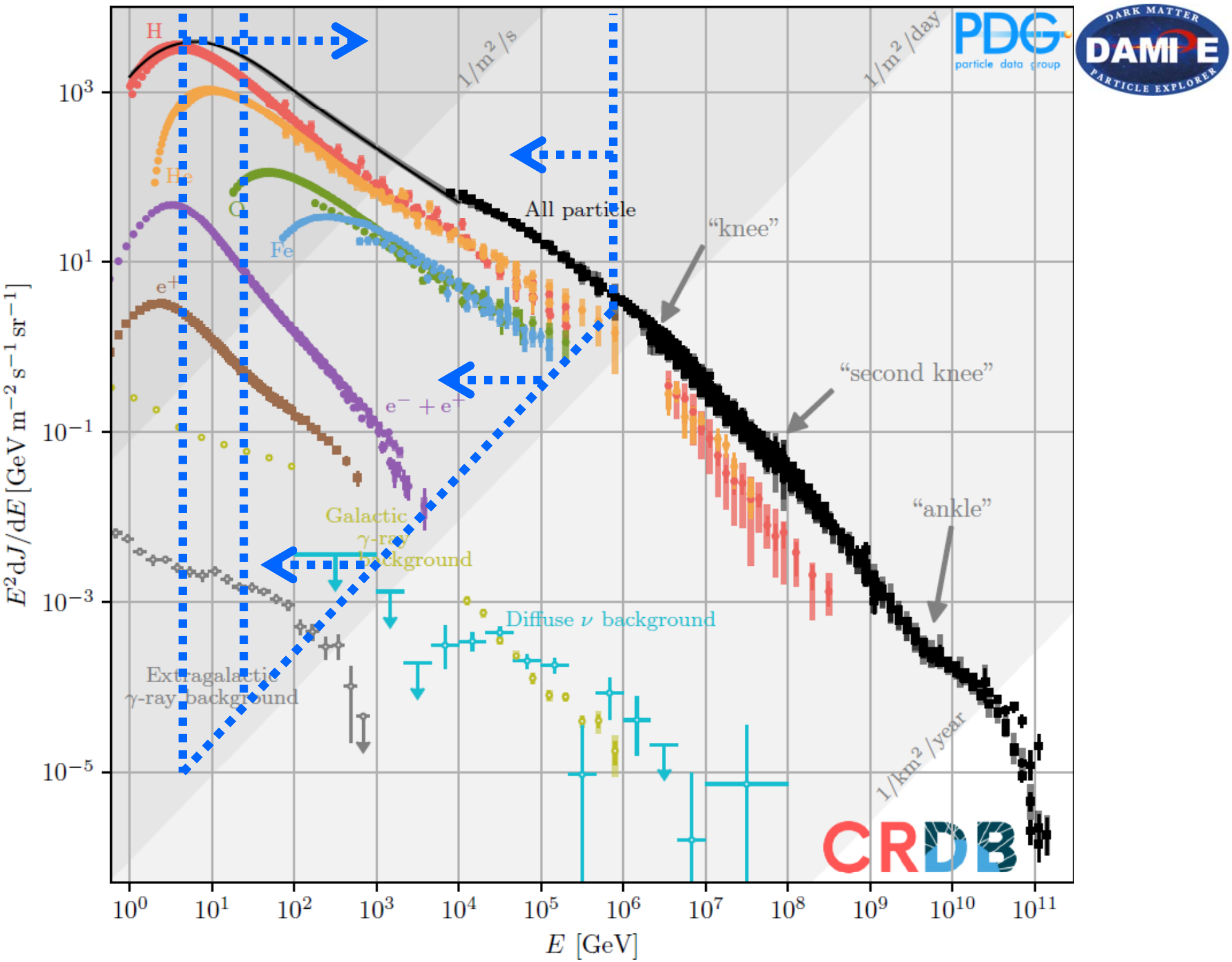
"ankle"
Galactic γ-ray background
Diffuse ν background
Extragalactic γ-ray background
1/m²/s
1/m²/day
1/km²/year
PDG particle data group
DARK MATTER PARTICLE EXPLORER
CRDB
$E^2 dJ/dE$ [GeV m^{-2} s^{-1} sr^{-1}]
E [GeV]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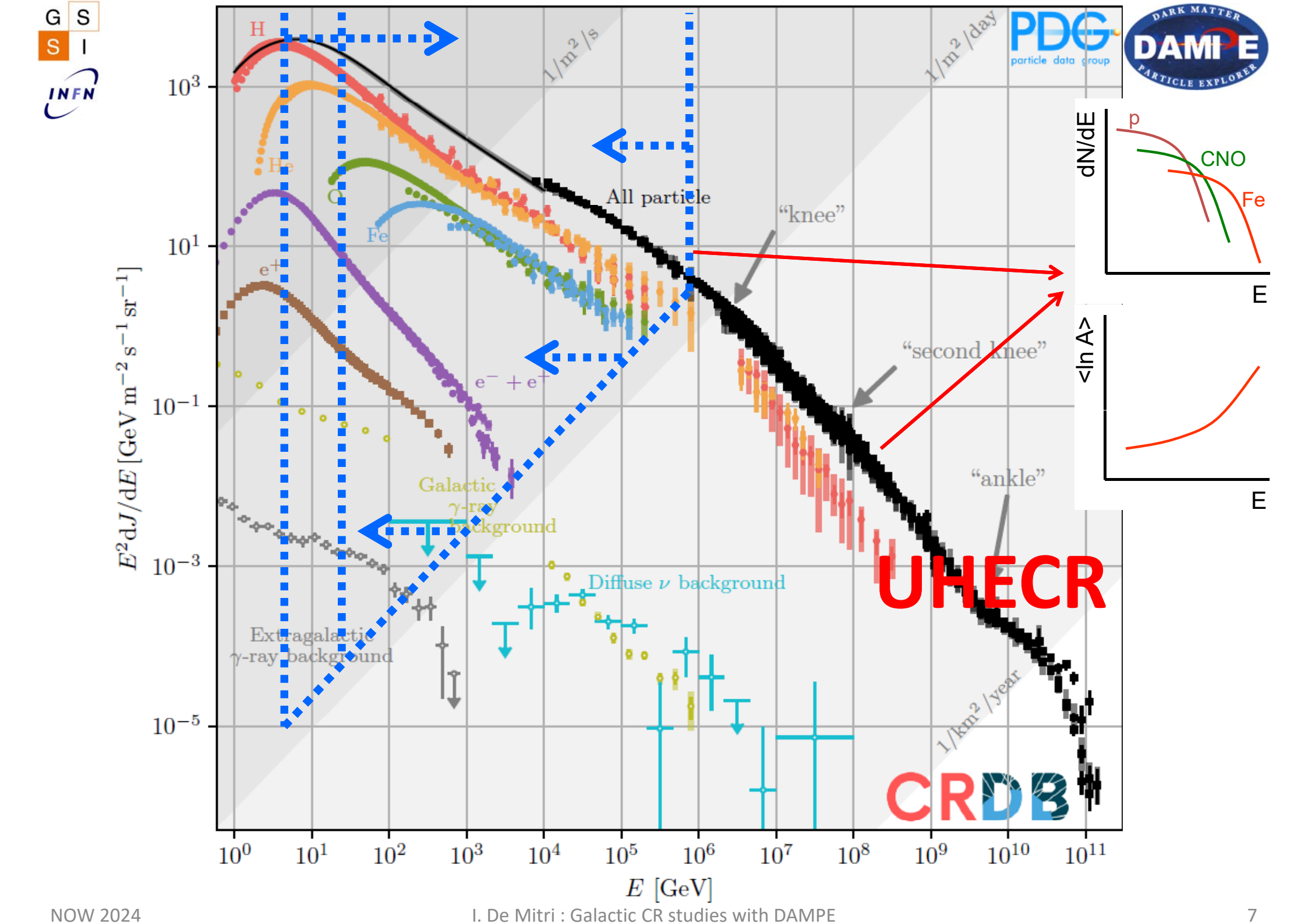
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DARK MATTER DAMPE PARTICLE EXPLORER
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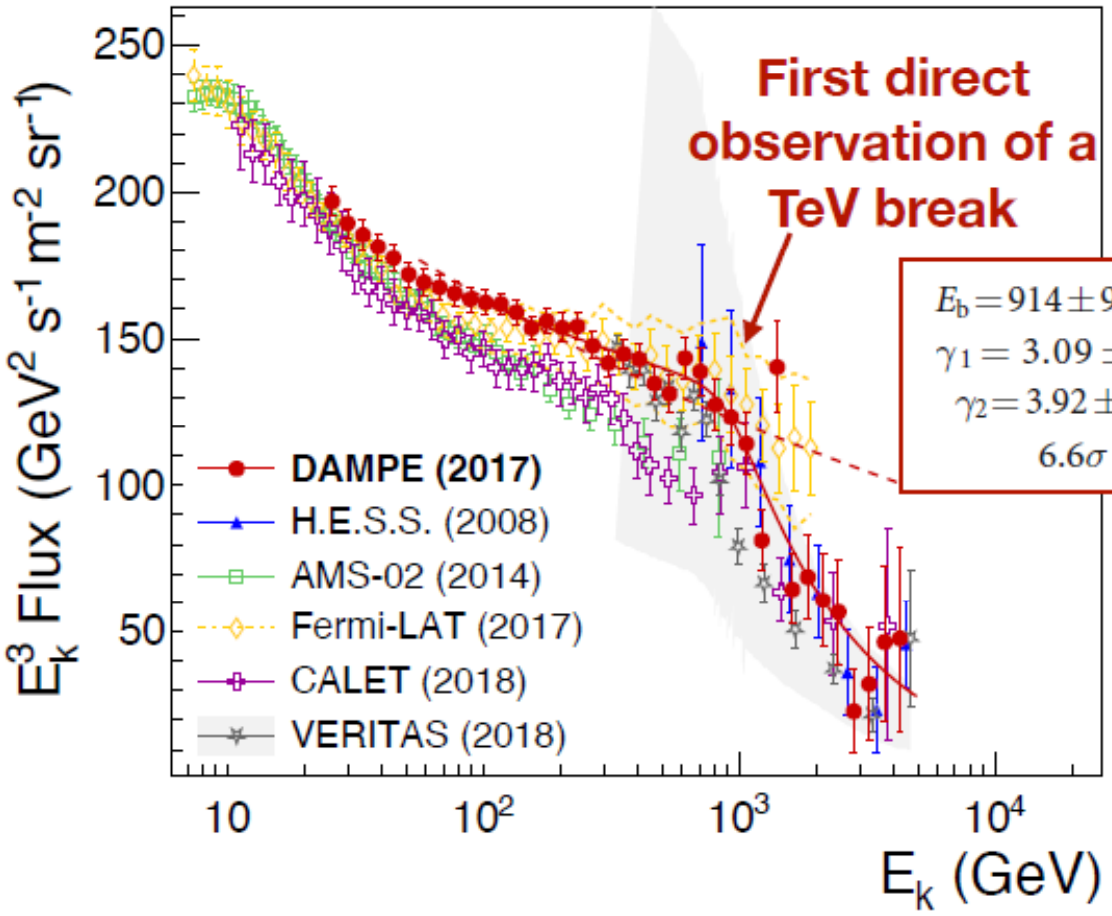
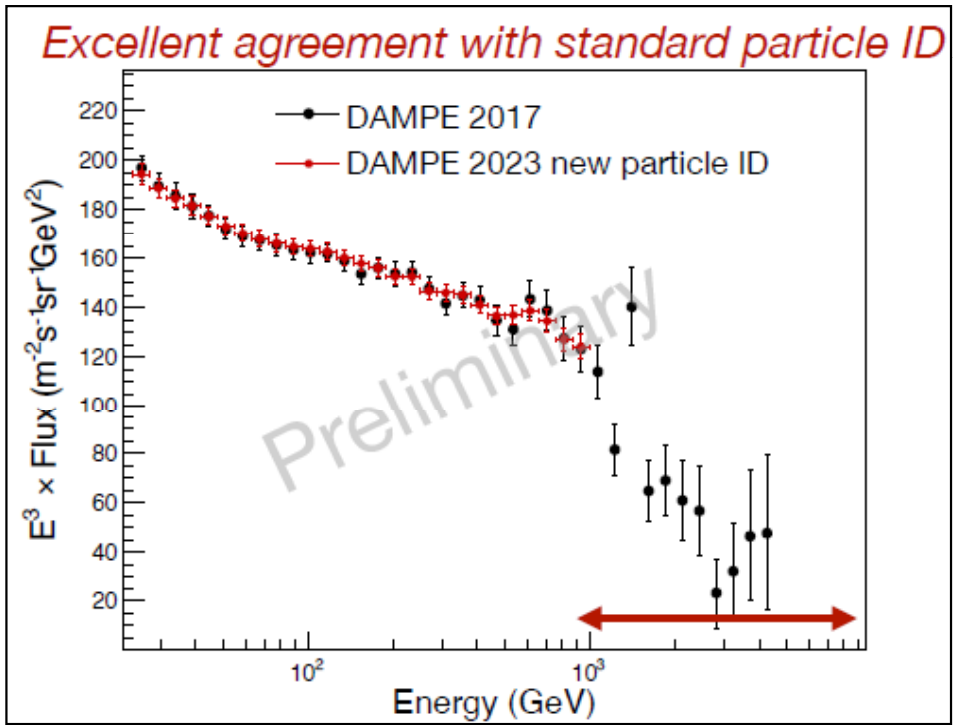
The DAMPE (e^++e^-) spectrum

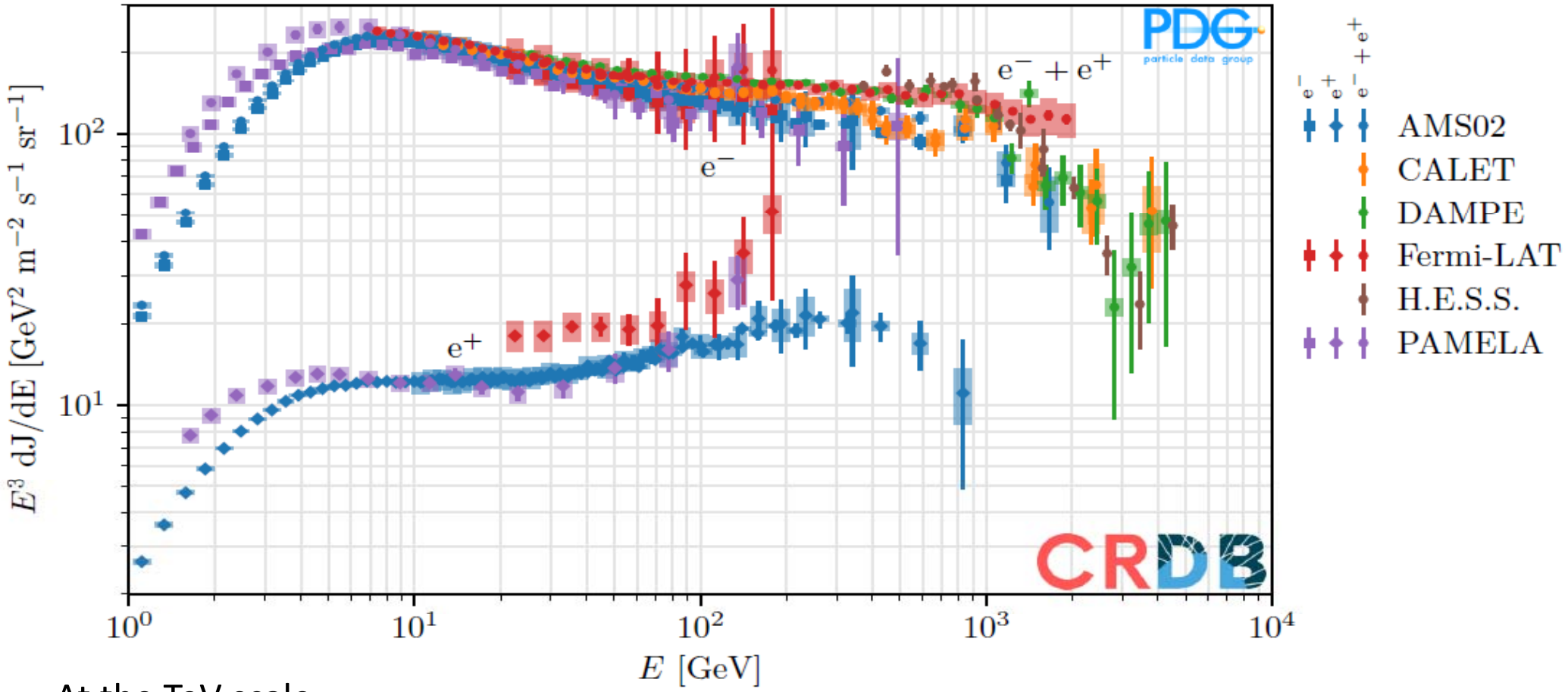


- 530 days
- 2.8 billions CR events
- 1.5 million CREs above 25 GeV



New analyses (NN, NL, ..) ongoing

“electron” spectra



At the TeV scale:

- diffusion-loss length is approx 300pc
- confinement time is approx 100 kyr

→ The spectra at high energies are dominated by **close and young cosmic ray sources**

→ Bumps might appear in the spectra above few TeV due to local sources

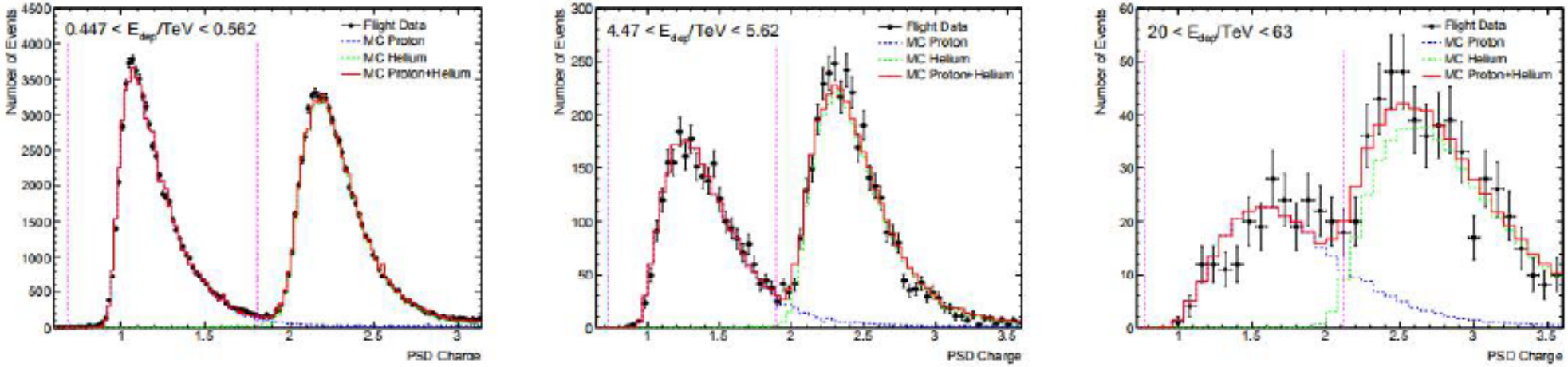
→ Possible anisotropies

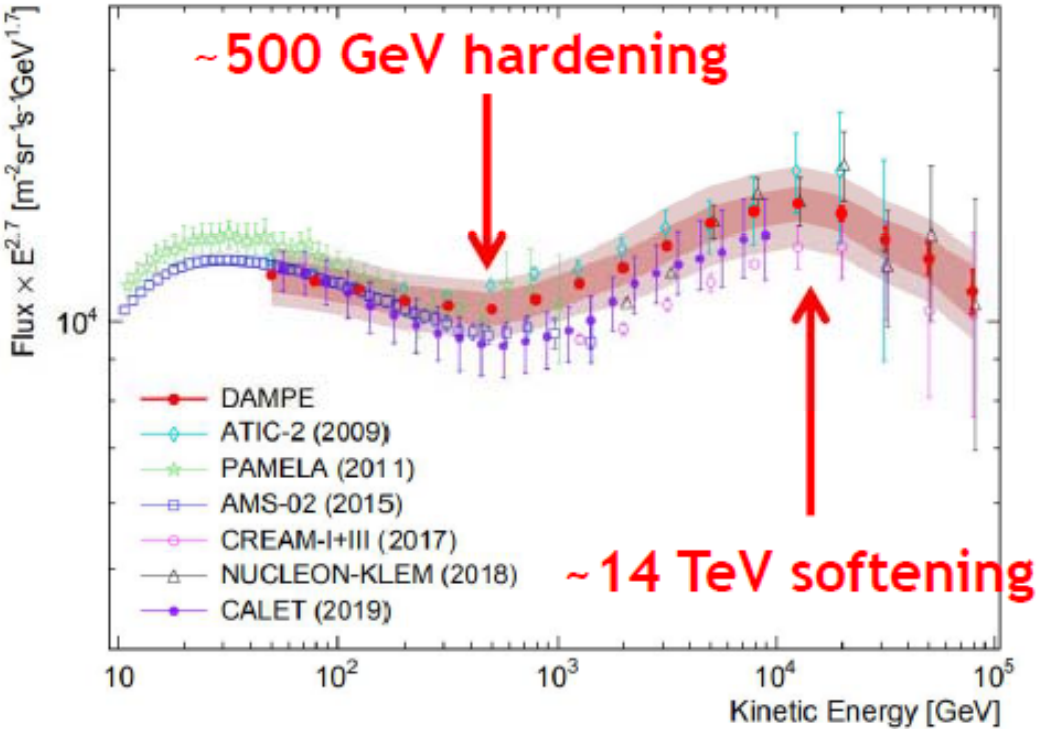
The DAMPE proton spectrum

SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

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





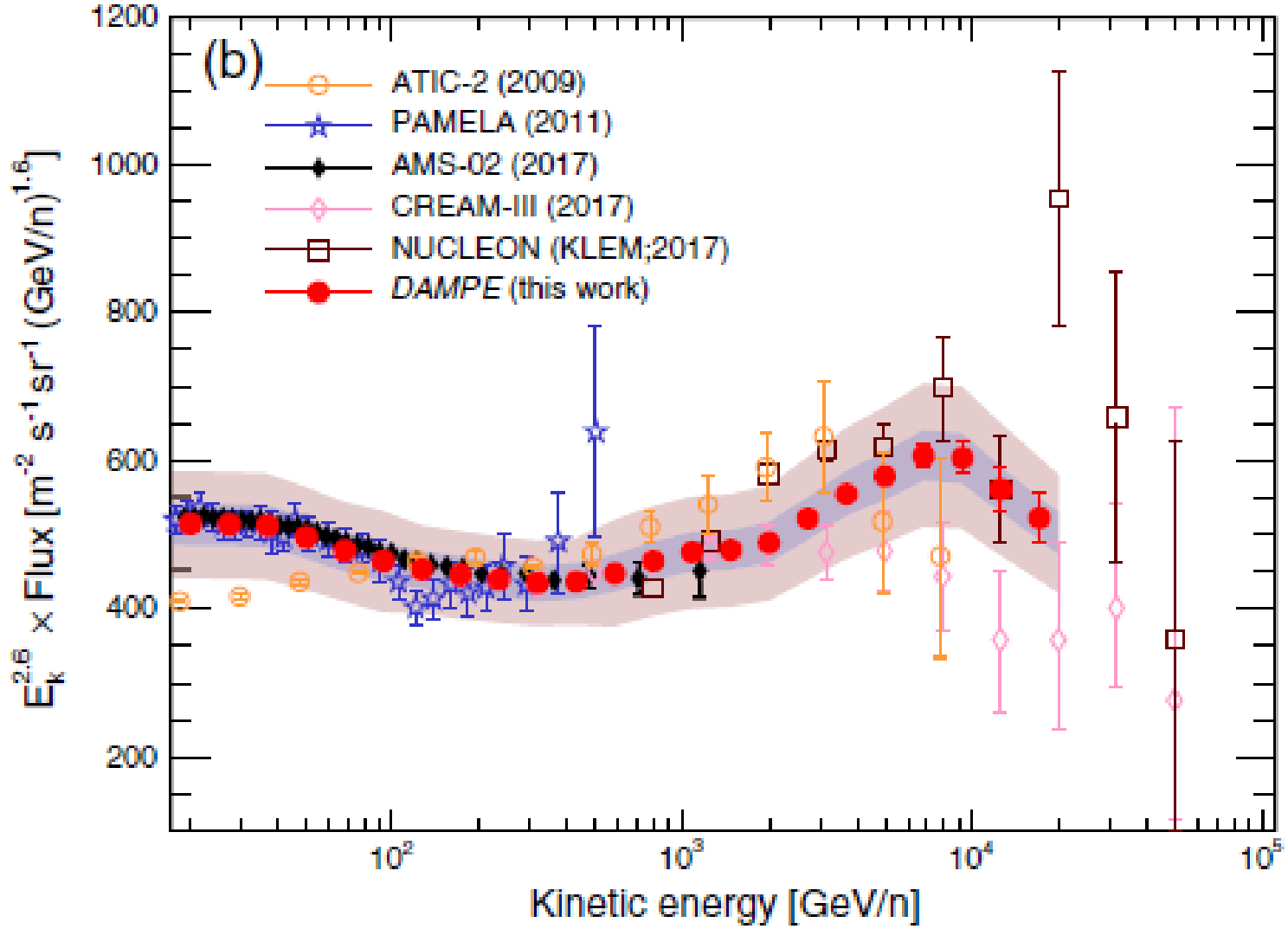
- Confirms the hundreds of GeV hardening
- Detecting a softening at ~14 TeV with high significance

The DAMPE helium spectrum

PHYSICAL REVIEW LETTERS **126,** 201102 (2021)

Editors' Suggestion | Featured in Physics

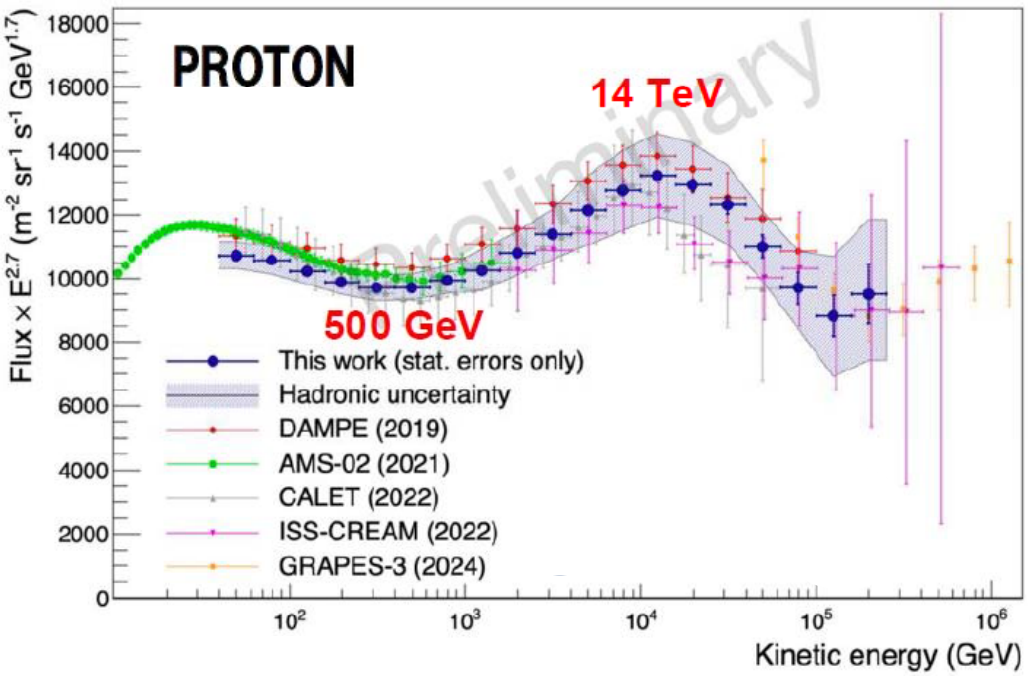
Measurement of the Cosmic Ray Helium Energy Spectrum from 70 GeV to 80 TeV with the DAMPE Space Mission

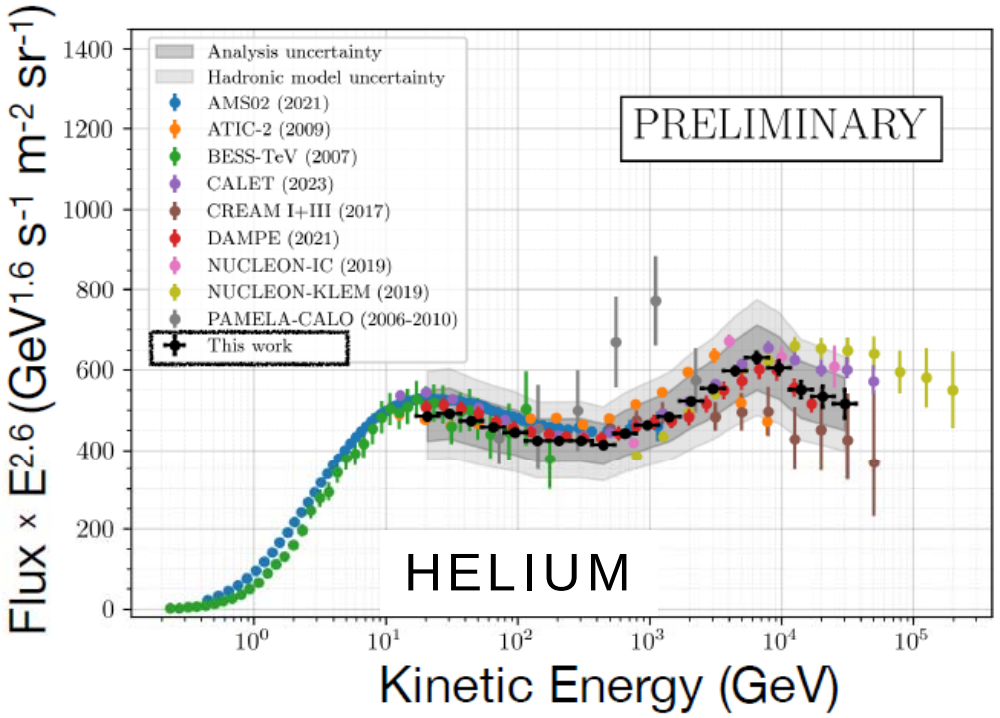


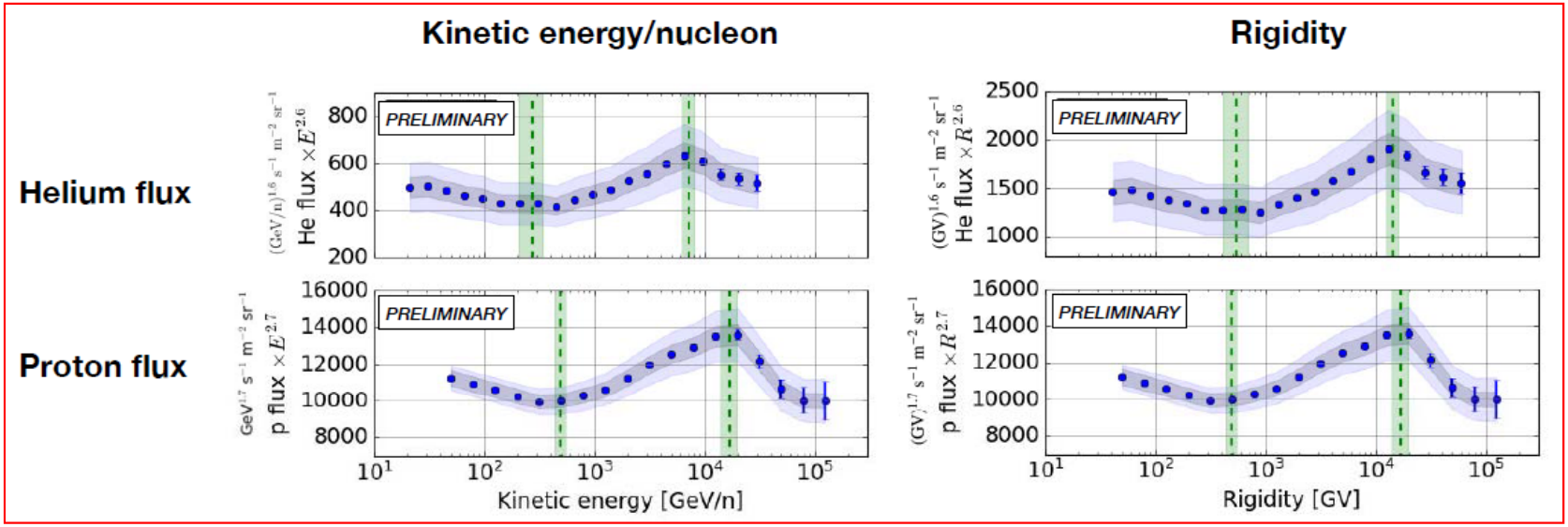
First clear evidence for a softening at about 34 TeV

Suggesting a Z dependent softening energy (~ 14 TeV for protons)

p and He spectra: updates

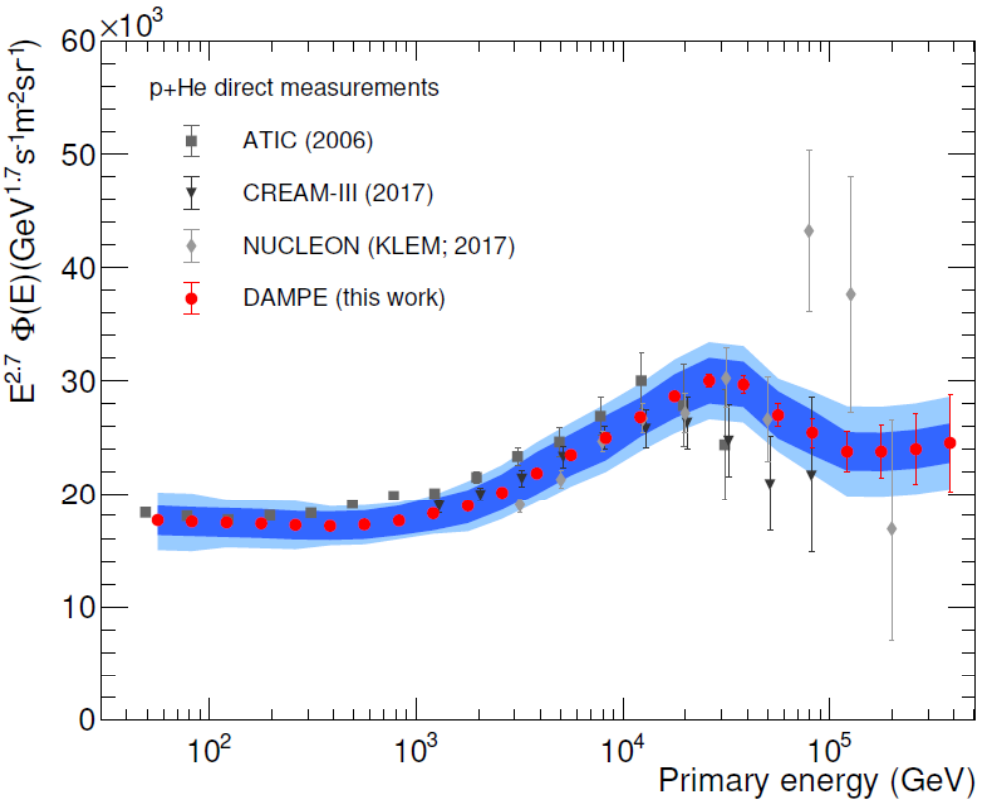


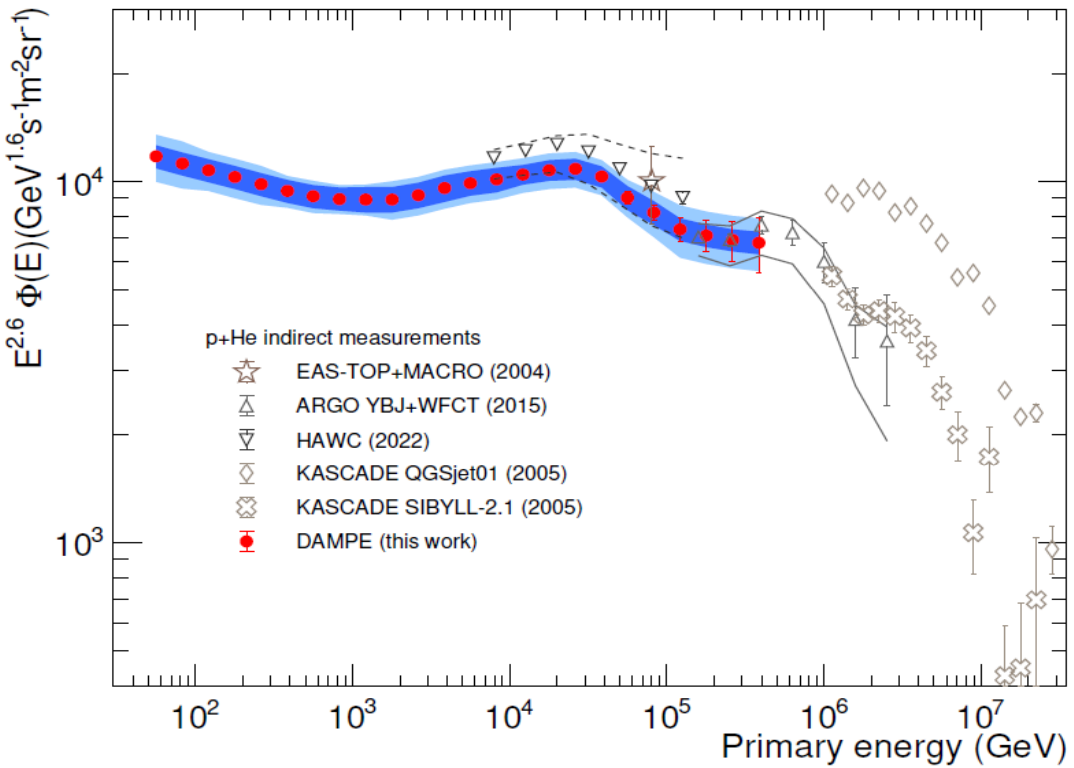




A rigidity dependence of both hardening and softening is favoured by data

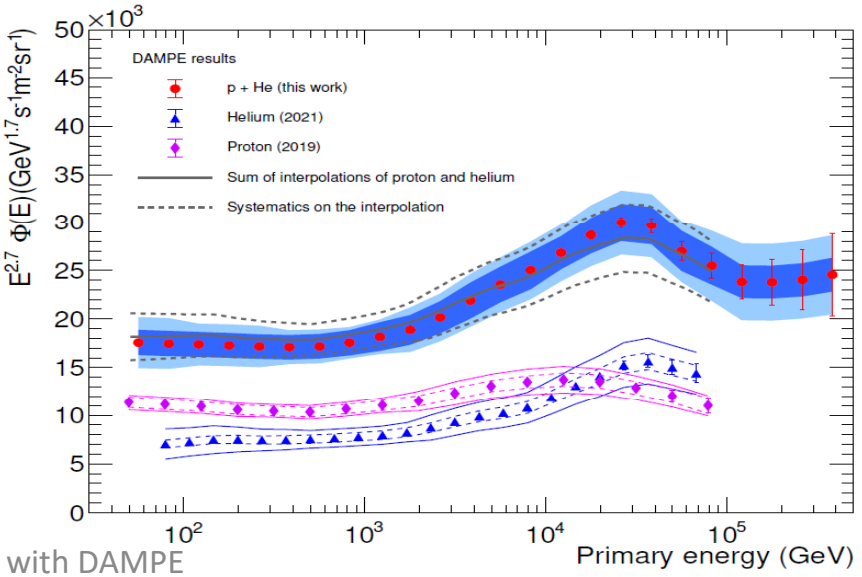
The p+He spectrum (up to 0.5 PeV)

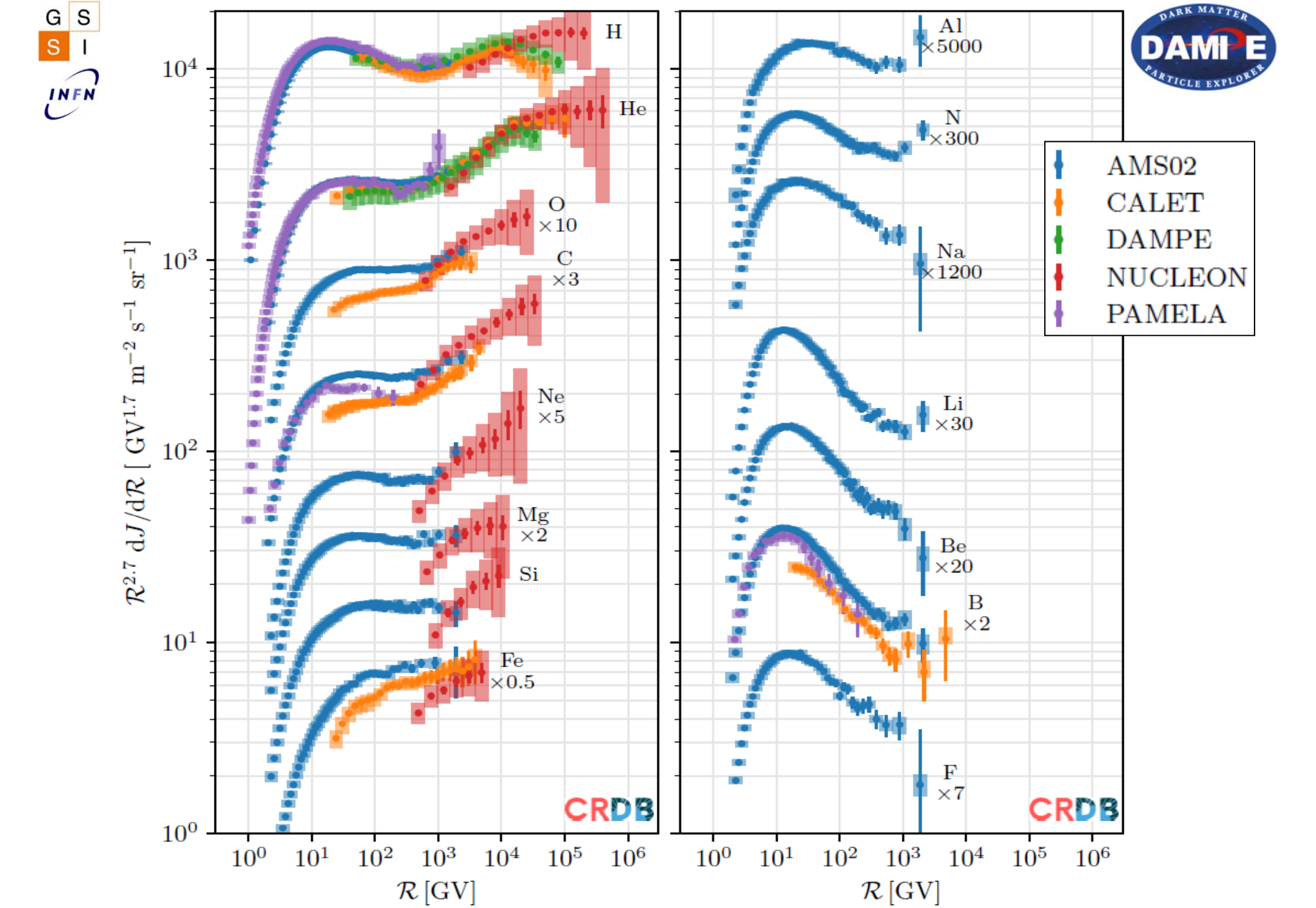




- Confirmation of the softening at 15TV
- Hint for a hardening above 100 TeV
- bridge with indirect measurements

(Phys. Rev. D June 2024)

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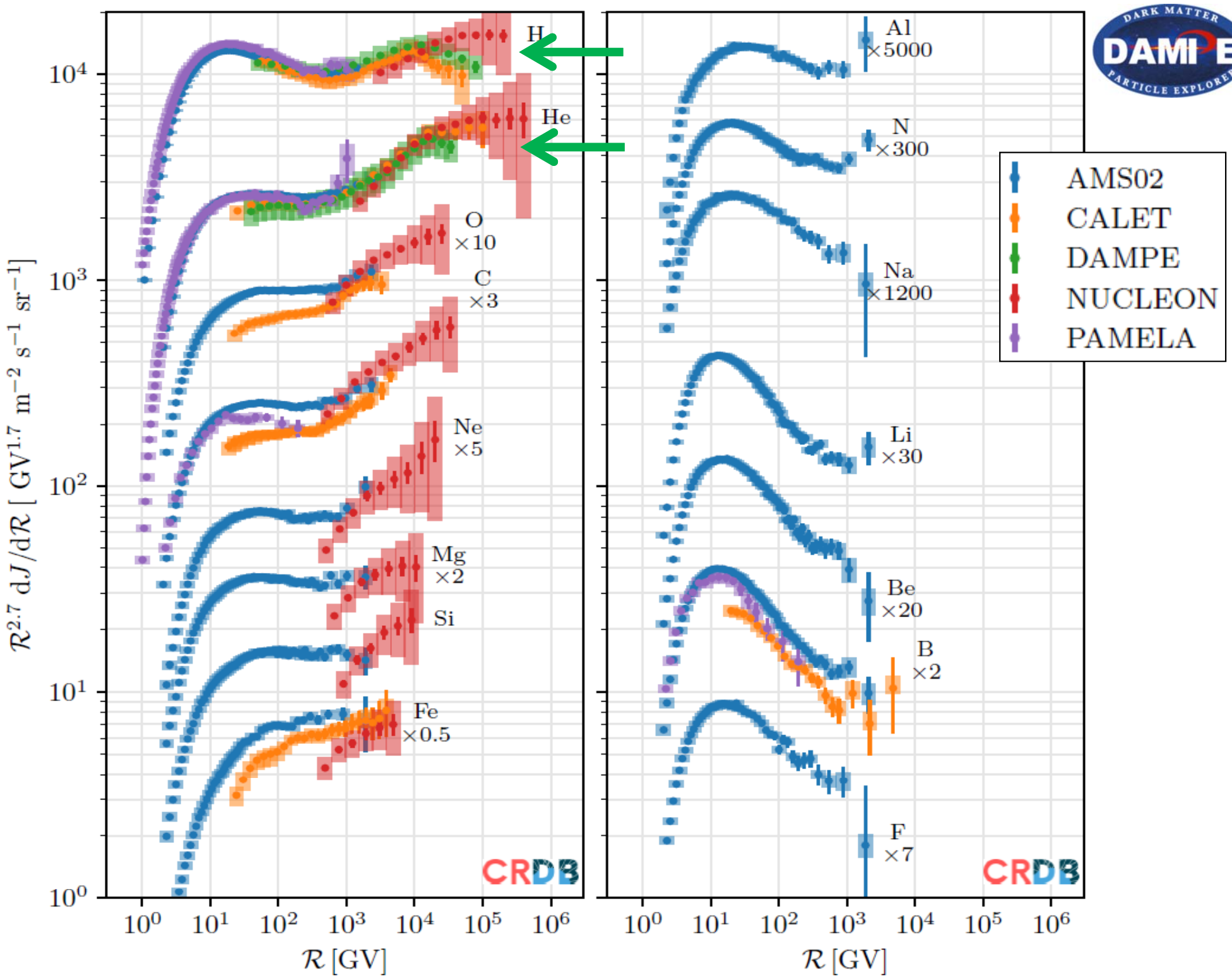
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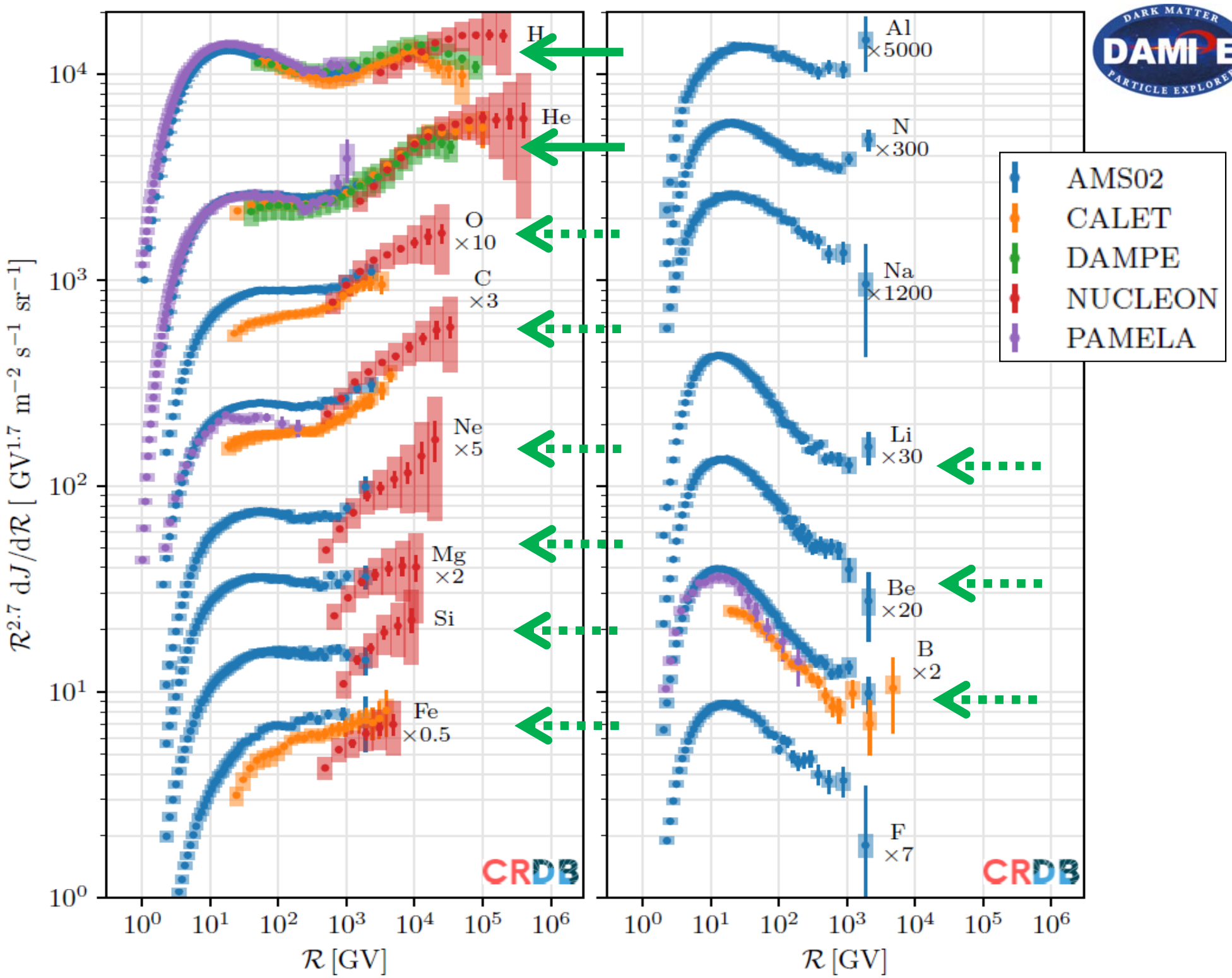
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$\mathcal{R}^{2.7}\,\mathrm{d}J/\mathrm{d}\mathcal{R}$ [$\mathrm{GV}^{1.7}\ \mathrm{m}^{-2}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}$]
$\mathcal{R}$ [GV]
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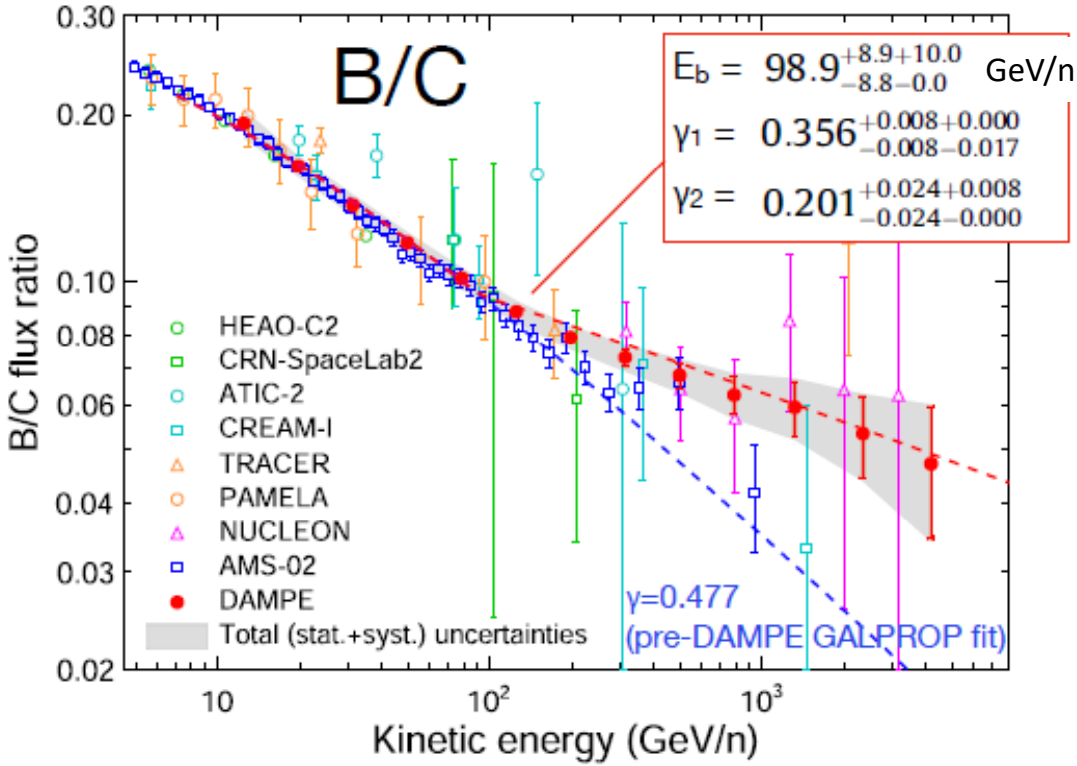
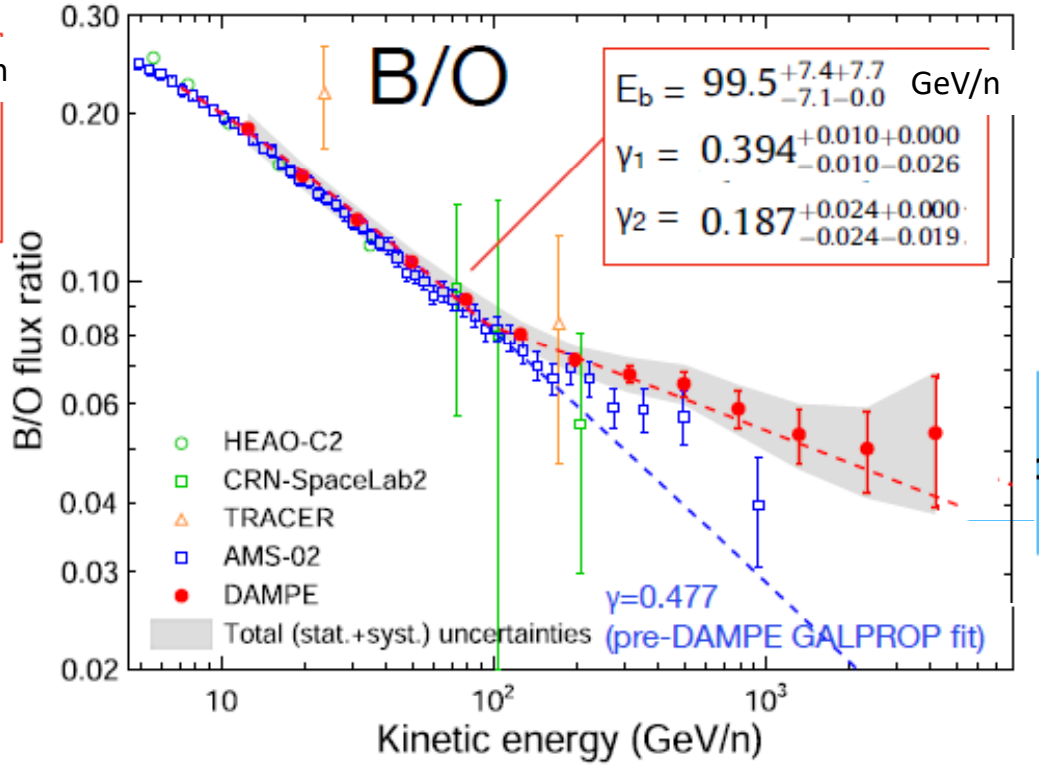
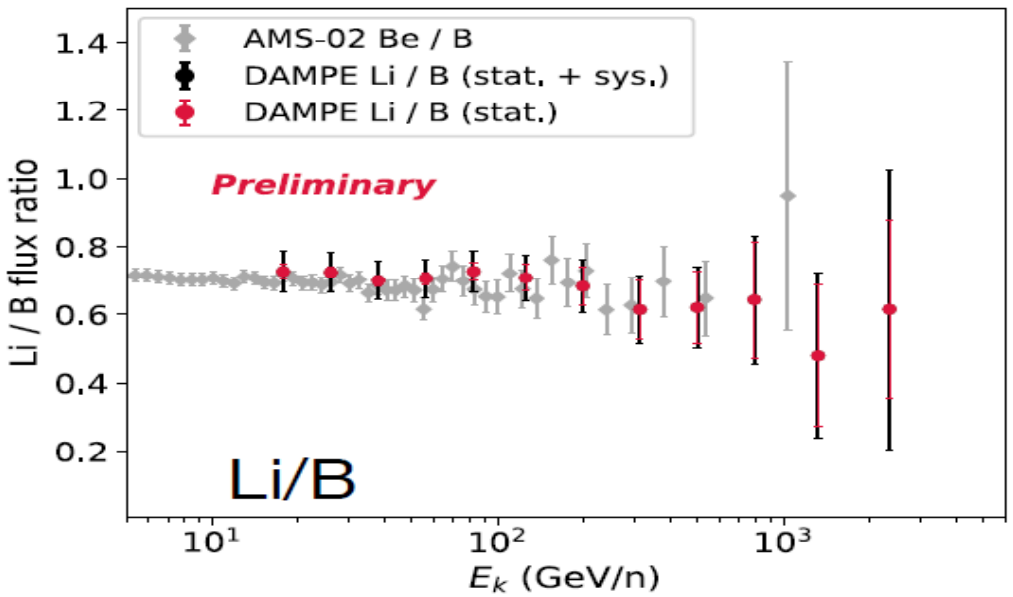
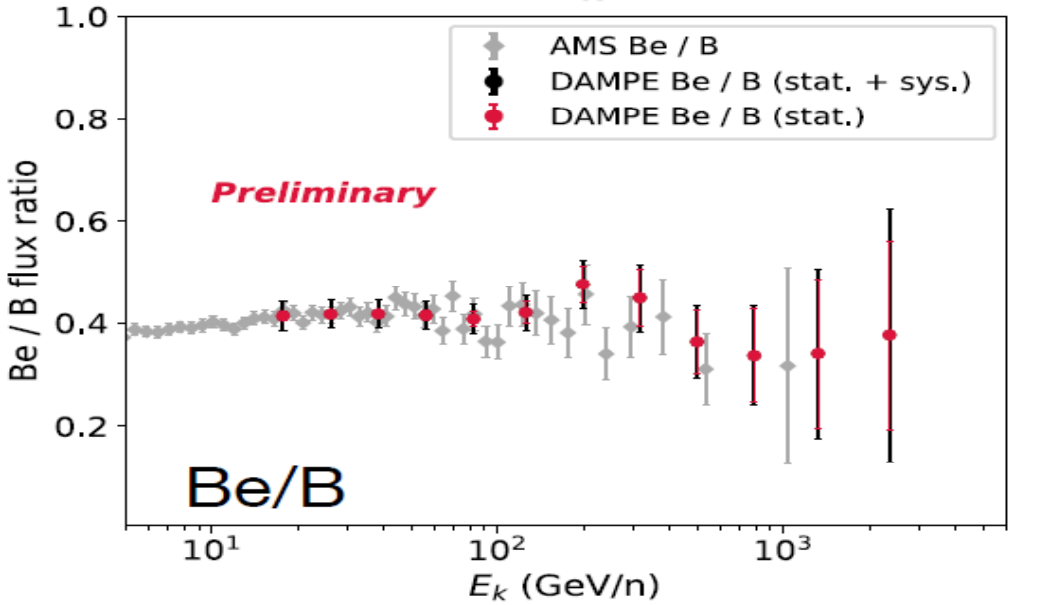
Flux ratios

B/C and B/O
DAMPE Coll. Science Bull. 67 (2022) 21

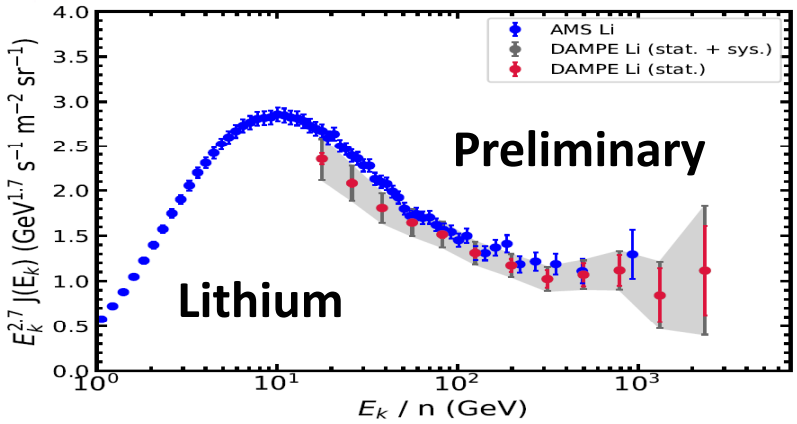


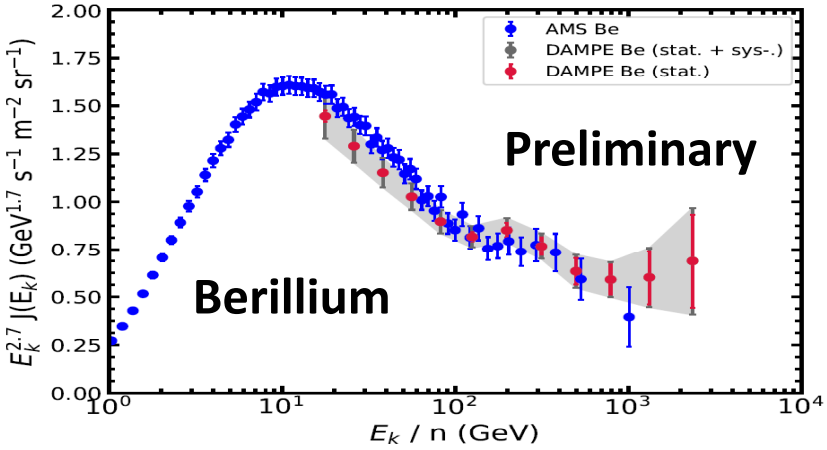


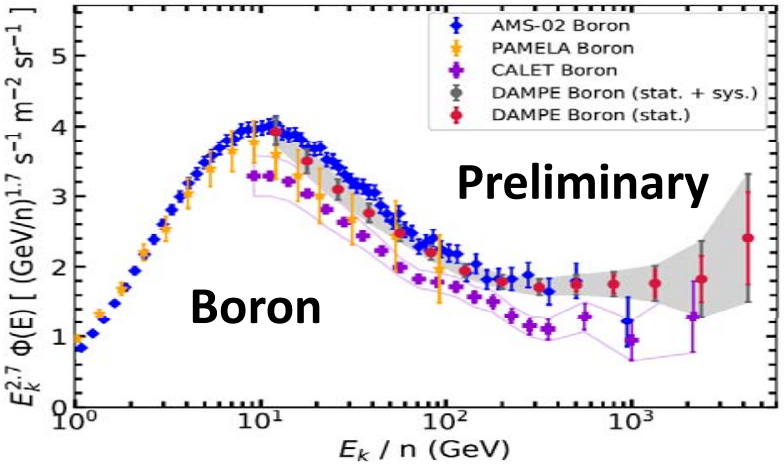


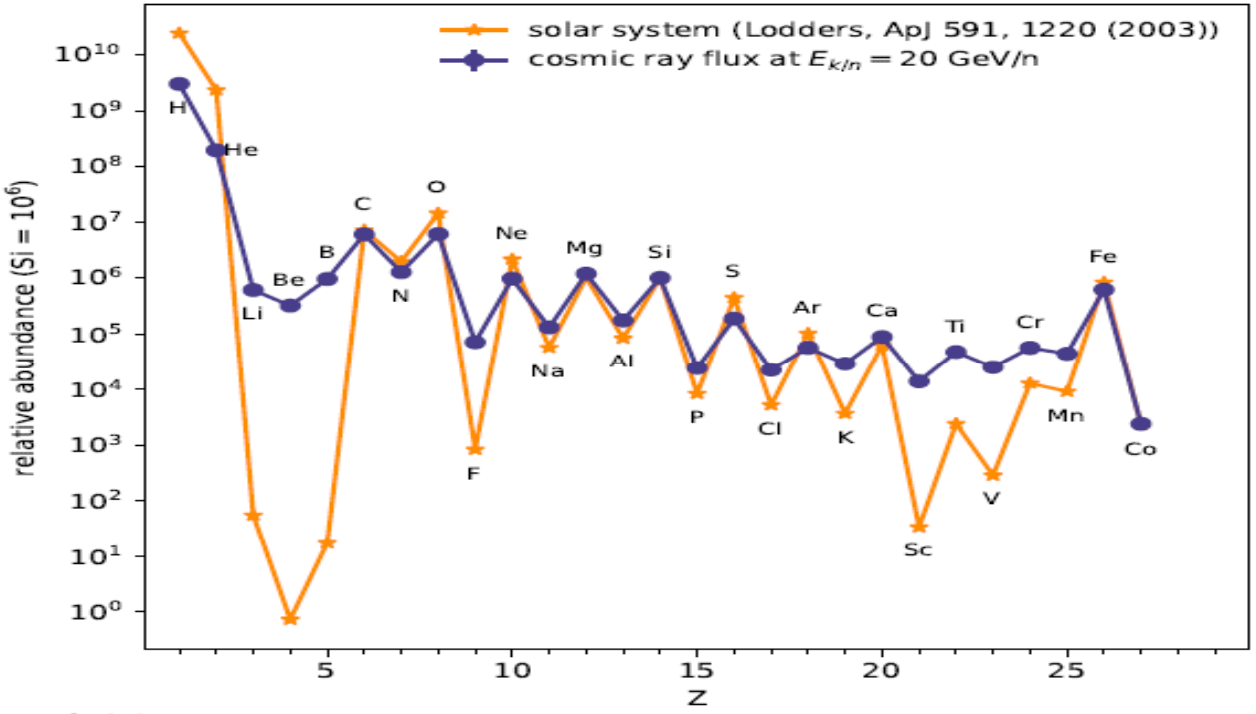


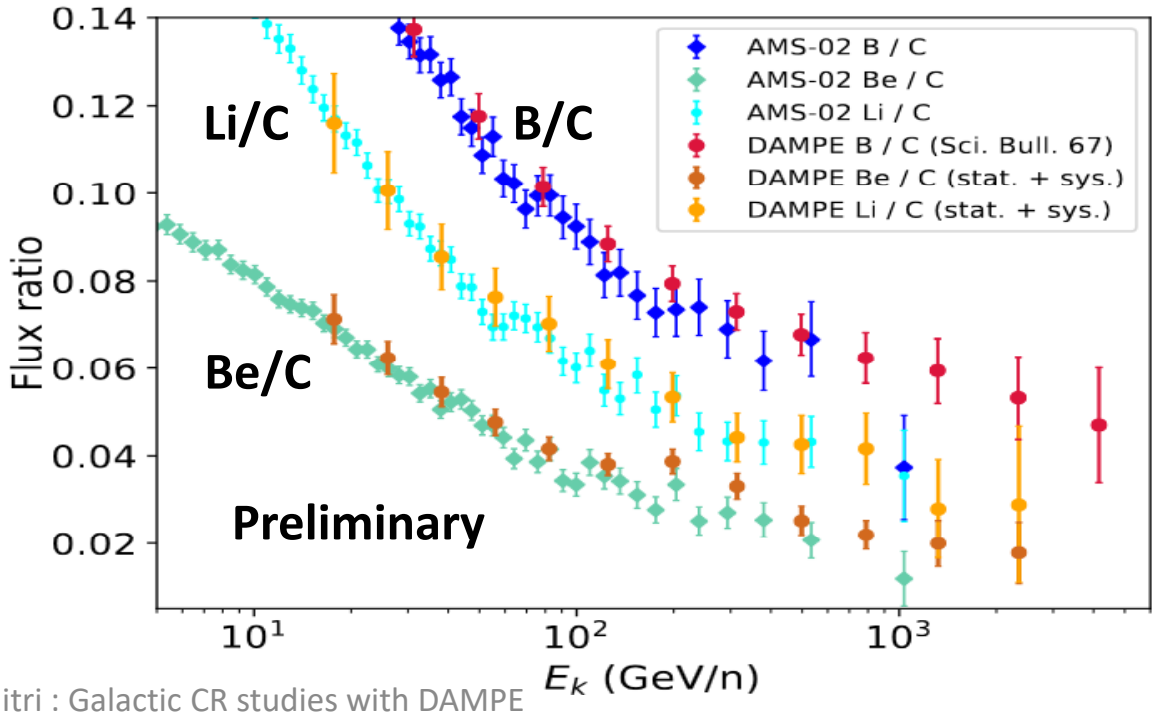
Secondaries: Li, Be and B





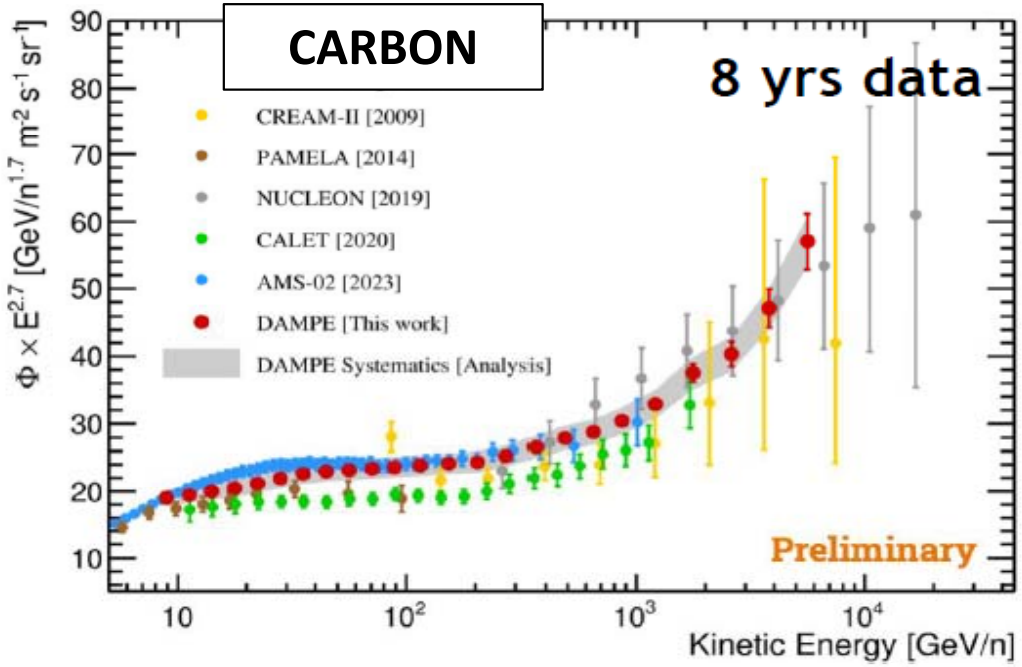


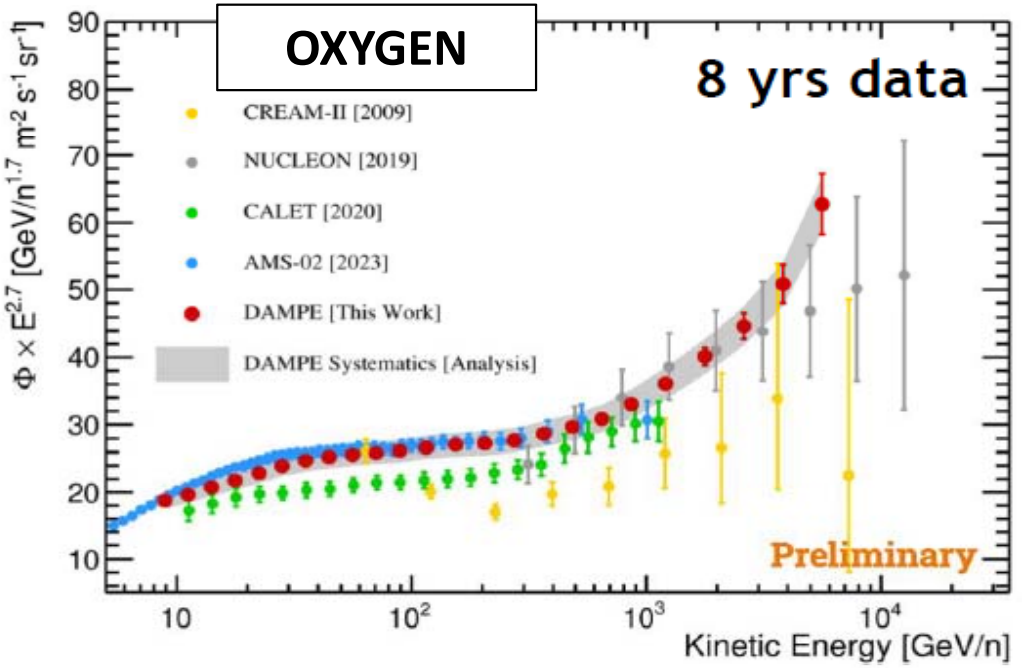


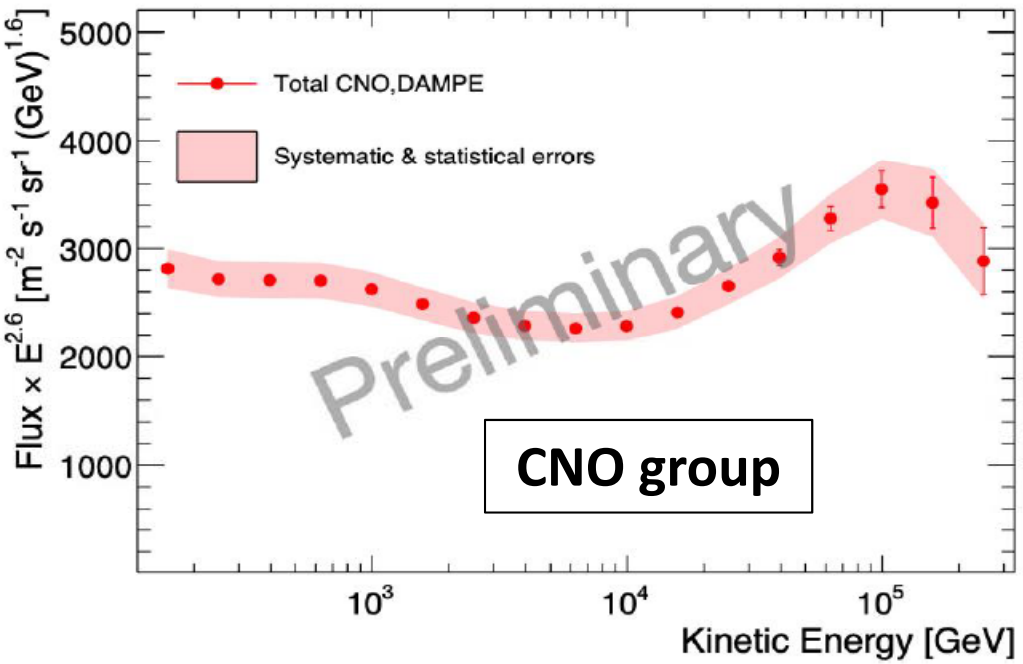


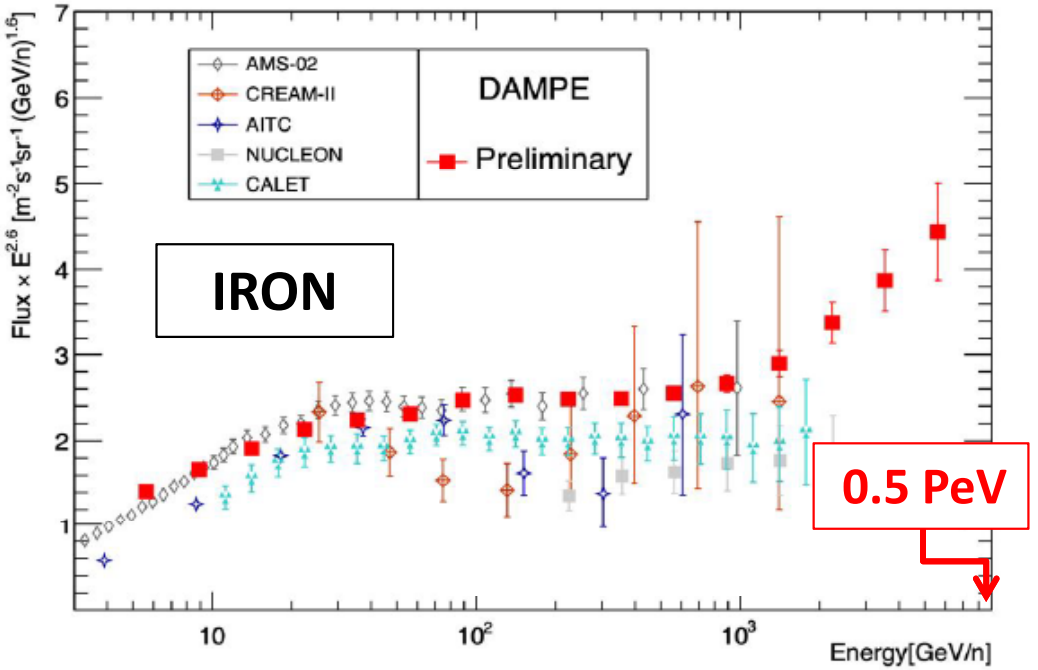
Heavier elements…

Several analyses are in progress towards the highest energies (~0.8 PeV for Fe)



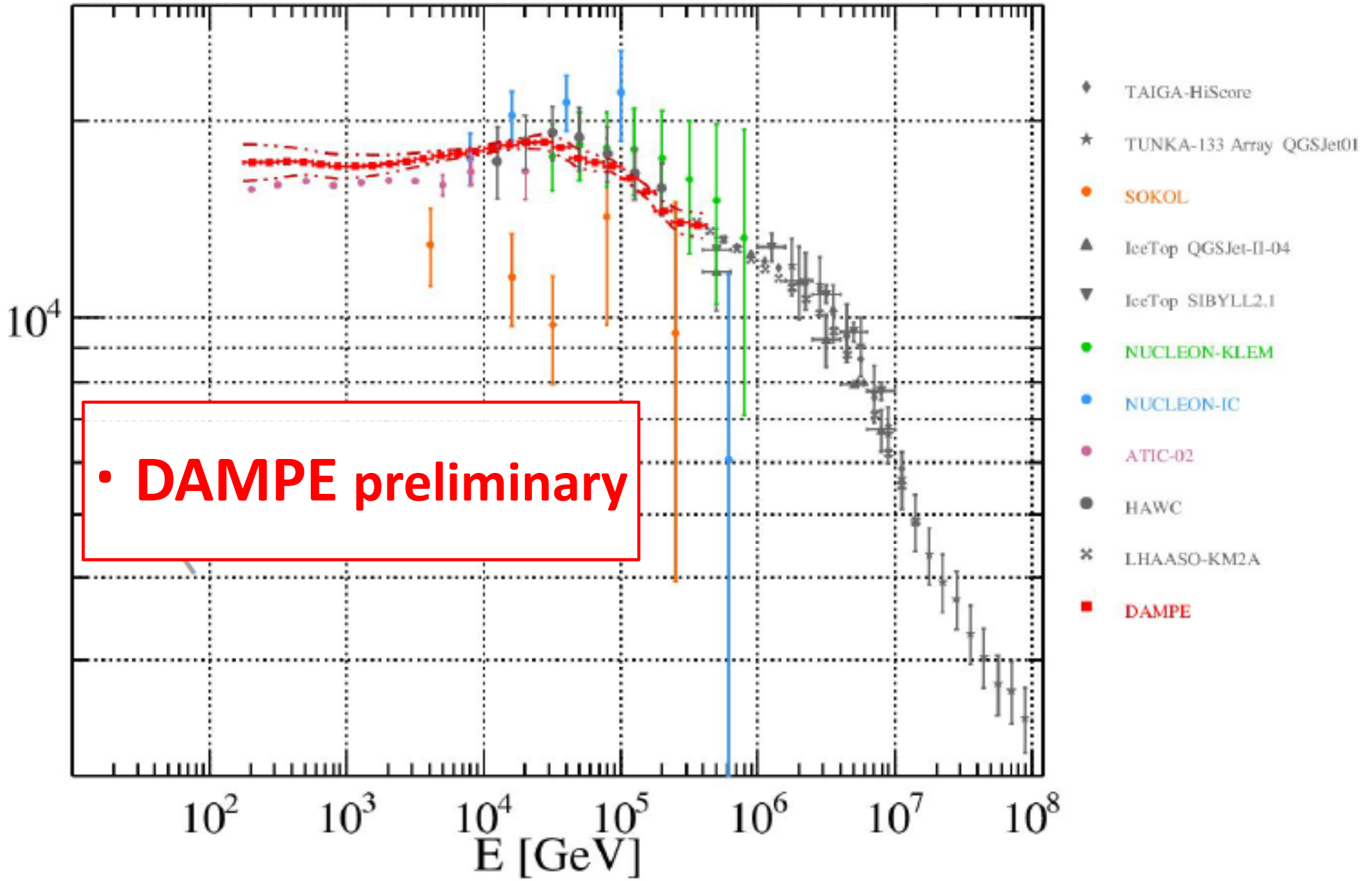




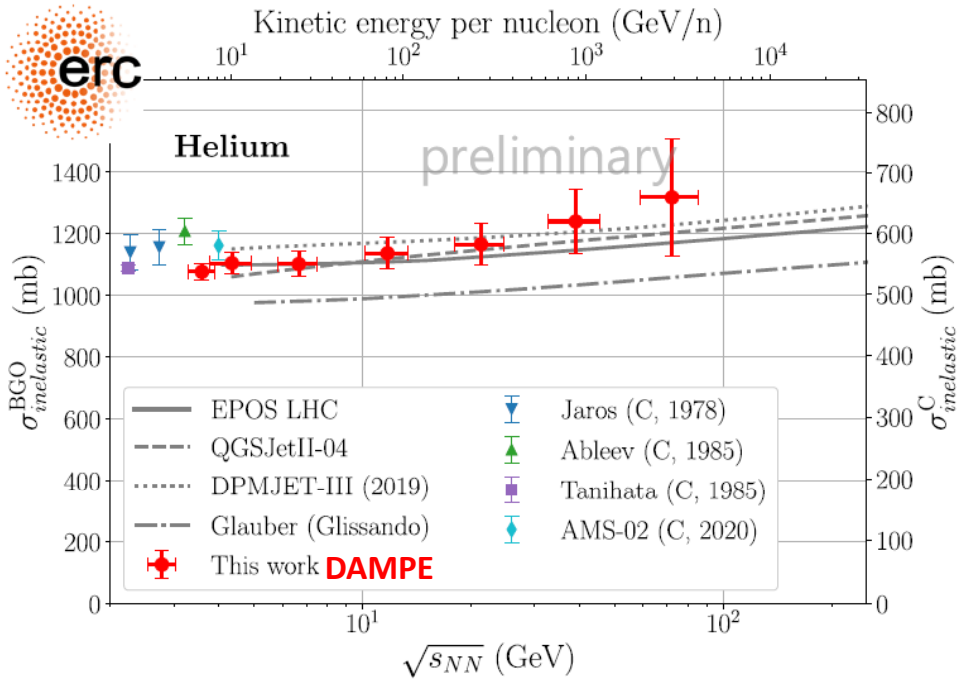


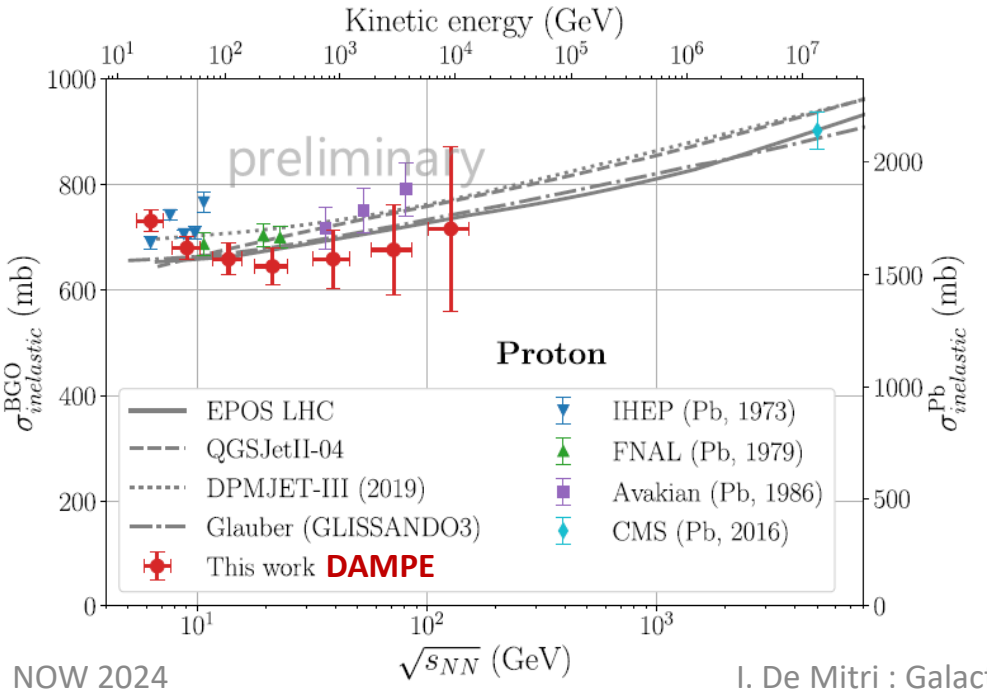
The all-particle spectrum

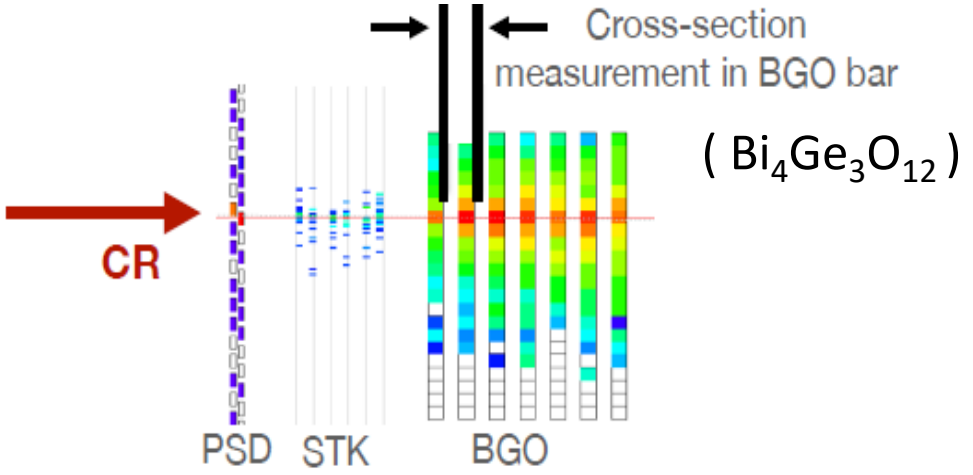
A single measurement across almost 4 orders of magnitude

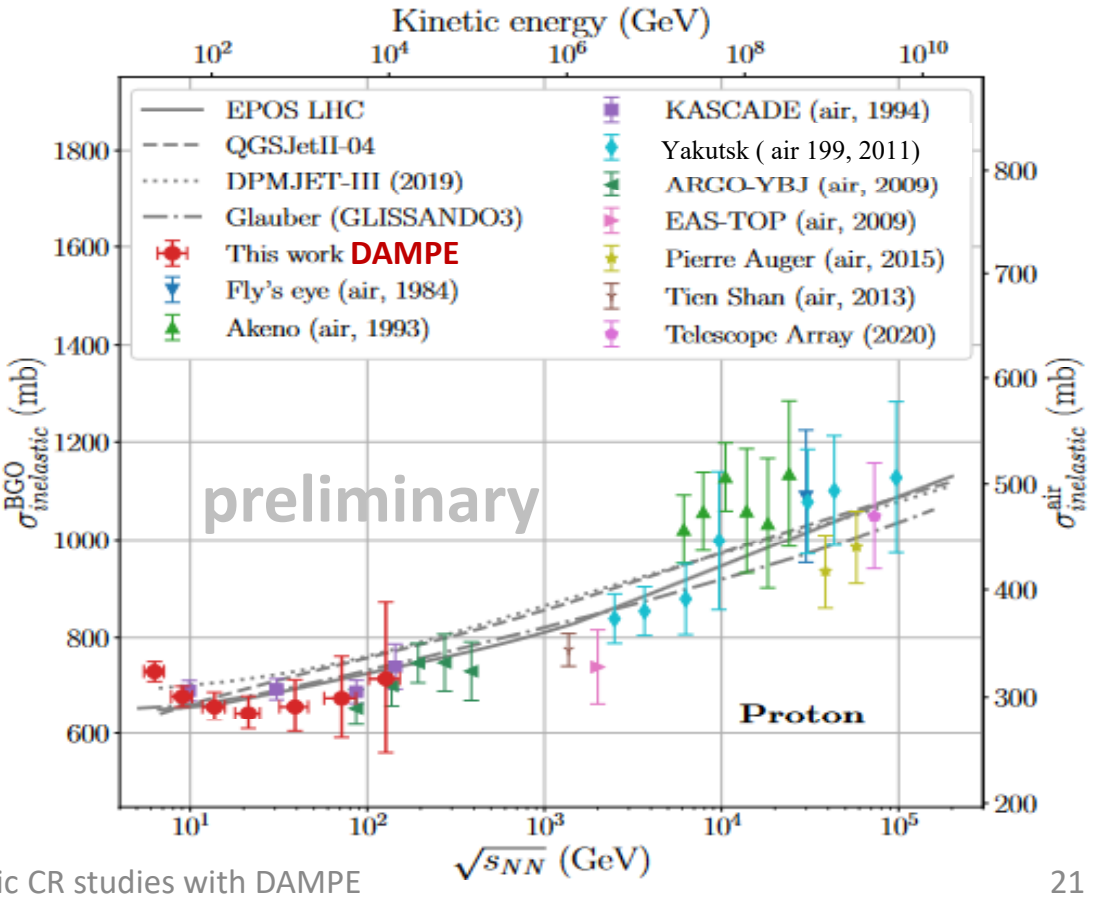


Hadronic cross section measurements









Summary

The detector

- Large geometric factor instrument (0.3 m^2 sr for p and nuclei)
- Precision Si-W tracker (50μm , 0.2°)
- Thick calorimeter (31 X_0 , σ_E/E better than 1% above 50 GeV for e/γ , ~35% for hadrons)
- "Mutiple" charge measurements (0.2-0.3 e resolution)
- e/p rejection power > 10^5 (topology alone, plus neutron detector)

Launch and performances

- Succesfull launch on Dec 17th, 2015
- On orbit operation steady and with high efficiencies (50 Hz, more than 13 billion events)
- Absolute energy calibration by using the geomagnetic cut-off (+1.25% at 13 GeV)
- Absolute pointing cross check by use of the photon map (PSF = 0.3° for 10GeV photons)

Science:

- Evidence for a cutoff at ~1 TeV in the all electron spectrum
- Evidence for a softening in the proton spectrum at ~ 14 TeV
- Evidence for a softening in the helium spectrum at ~ 34 TeV (suggest Z dependence)
- Measurement of p+He confirms the softening and suggest a hardening around 100TeV
- Break in secondary to primary ratios (B/C and B/O) at 100 GeV/n
- Undergoing spectral measurements of heavier nuclei and light secondaries (Li, Be, B)
- …..
- Preliminary studies of gamma ray sources (250 sources, Fermi bubble, …)
- Detected new features in Forbush decrease
- Upper limits for dark matter signatures, fractionally charged particles, …