The latest results of DAMPE and the status of HERD

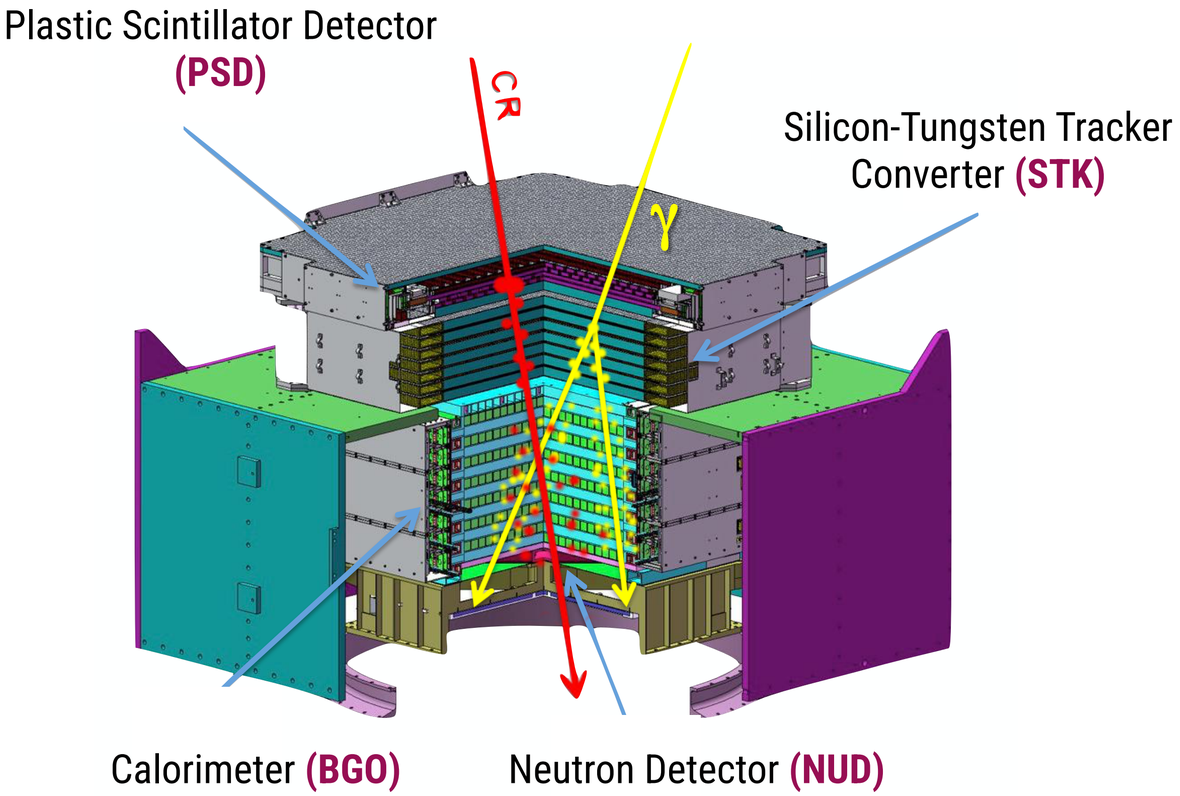
Andrii Tykhonov

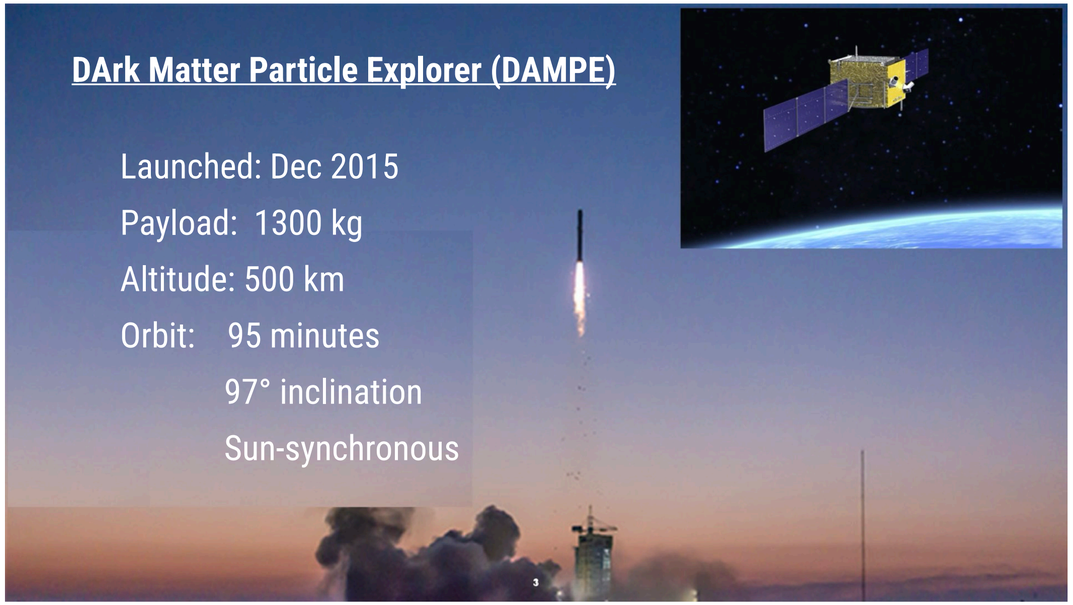
UNIVERSITÉ DE GENÈVE

French-Ukrainian Workshop 2026 | IJCLab Université Paris-Saclay

13 October, 2026

DArk Matter Particle Explorer (DAMPE)



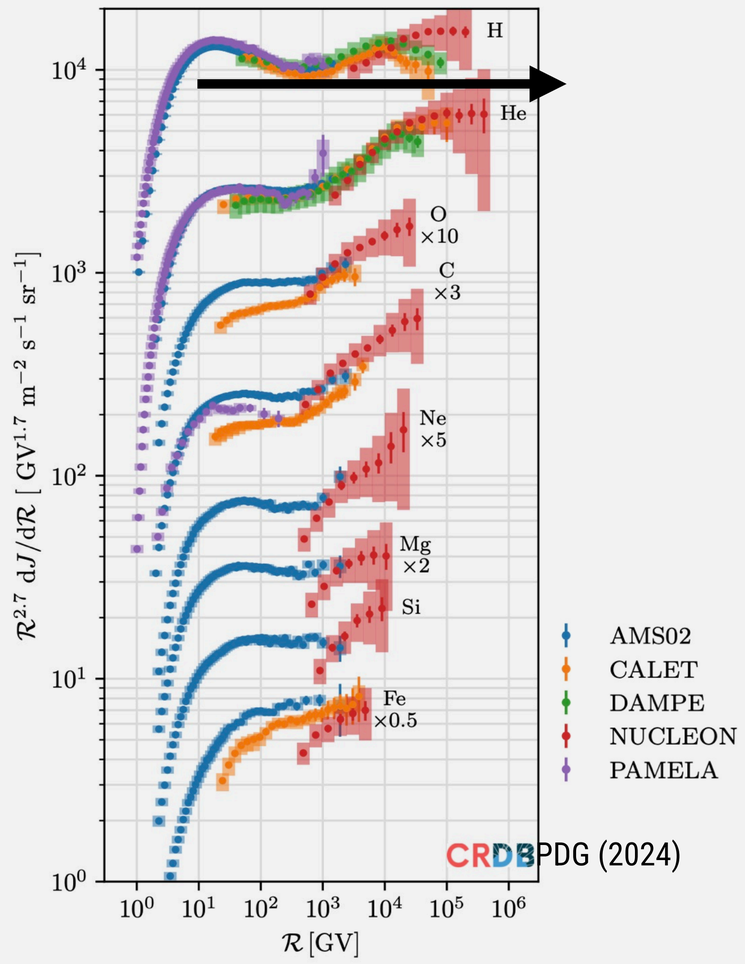


Energy range	**GeVs - PeV**
Energy resolution (e, γ):	**1.2% (above 100 GeV)**
Geometric factor (e):	**0.3 m² sr**
Calorimeter thickness:	**32 X_0 (1.6 λ)**

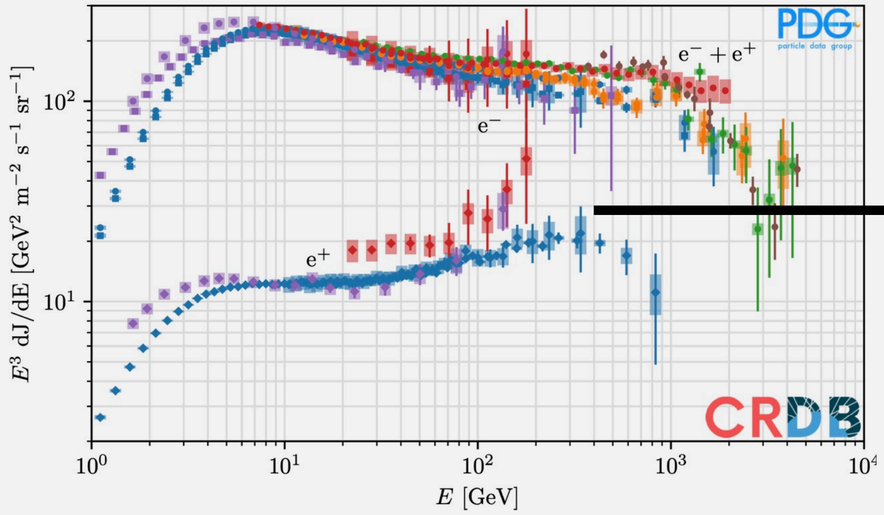
See: DAMPE collab., Astropart. Phys. 95 (2017) 6-24

DAMPE: science goals

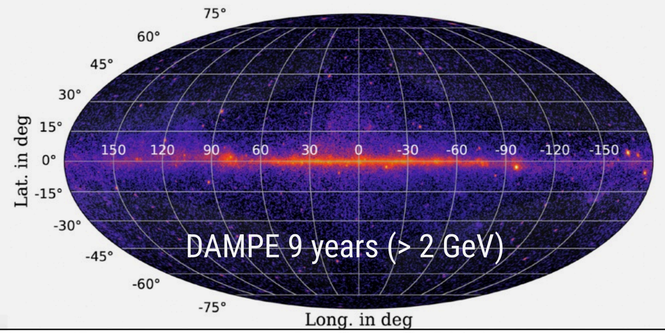
1. Cosmic Ray spectra at GeV - PeV



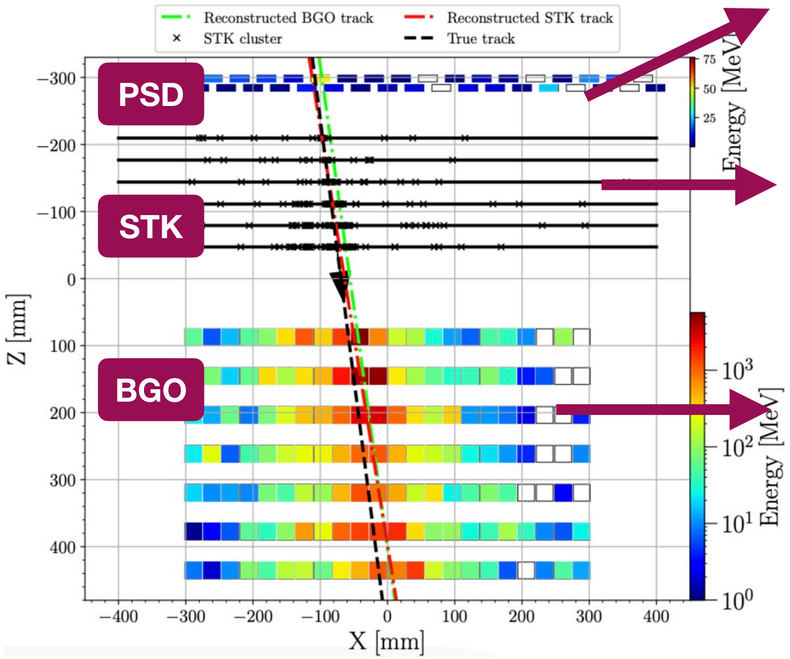
2. Indirect DM search ($e^+ + e^-$, γ-ray lines)



3. γ-ray physics



DAMPE: calibration



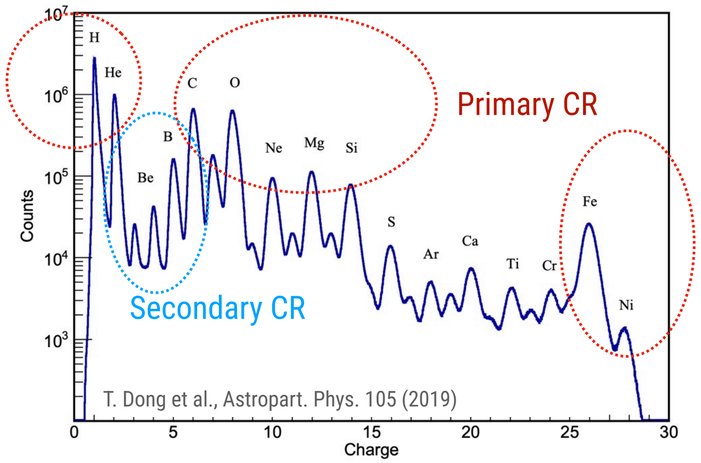
Charge measurement

Track reconstruction

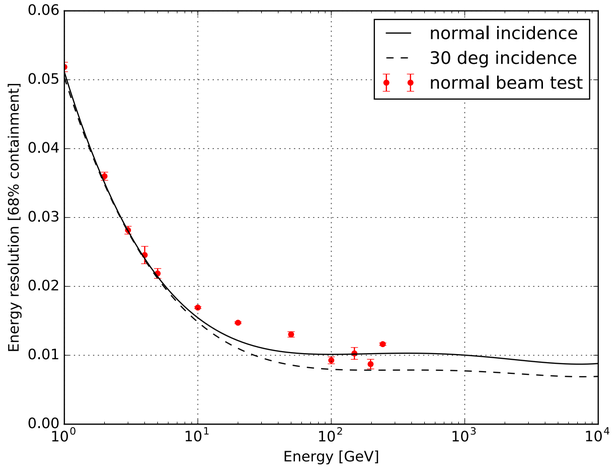
Energy measurement

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

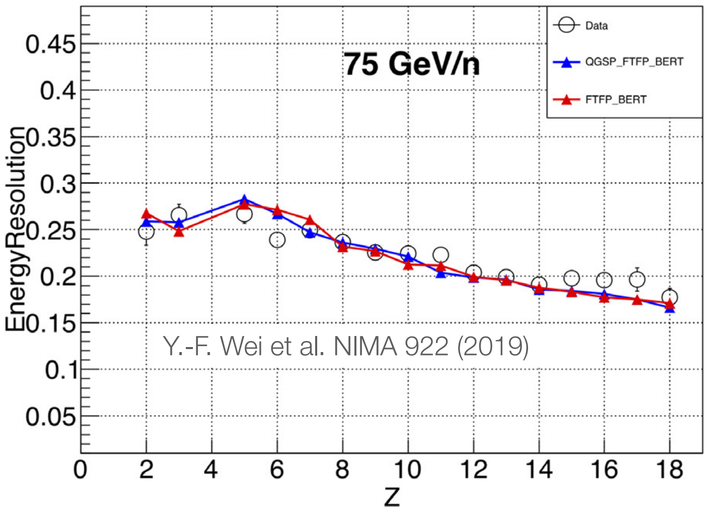
Charge reconstruction (flight data)



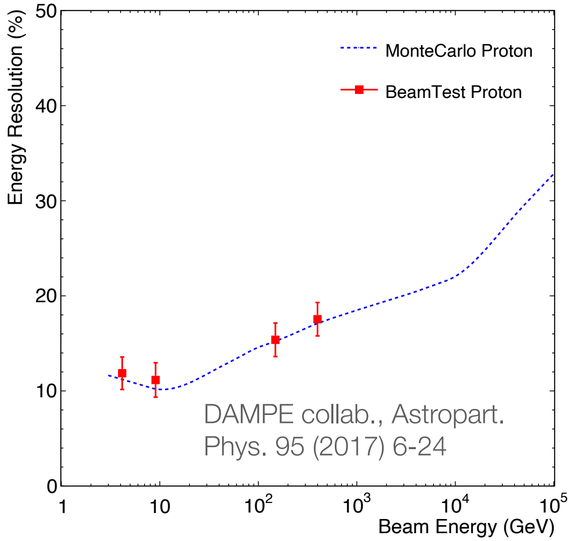
Energy resolution: electrons



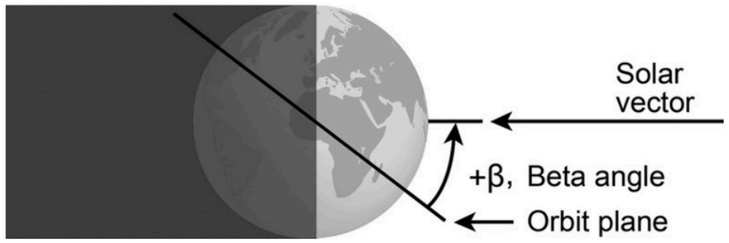
Energy resolution: ions



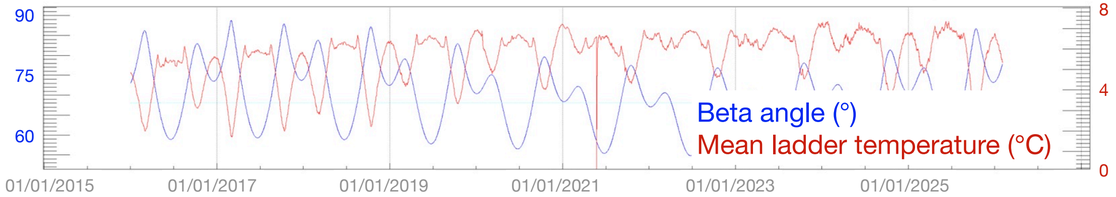
Energy resolution: protons

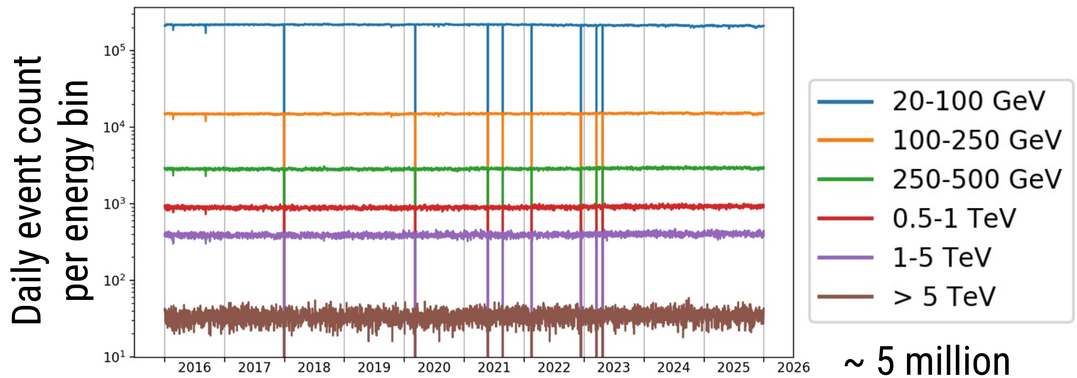


DAMPE: on-orbit status

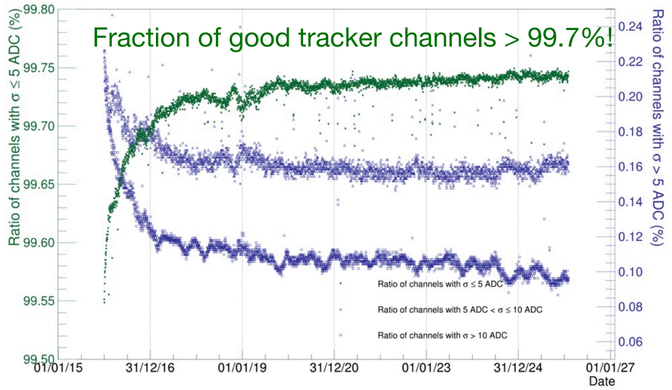


Instrument temperature anti-correlation with β angle:

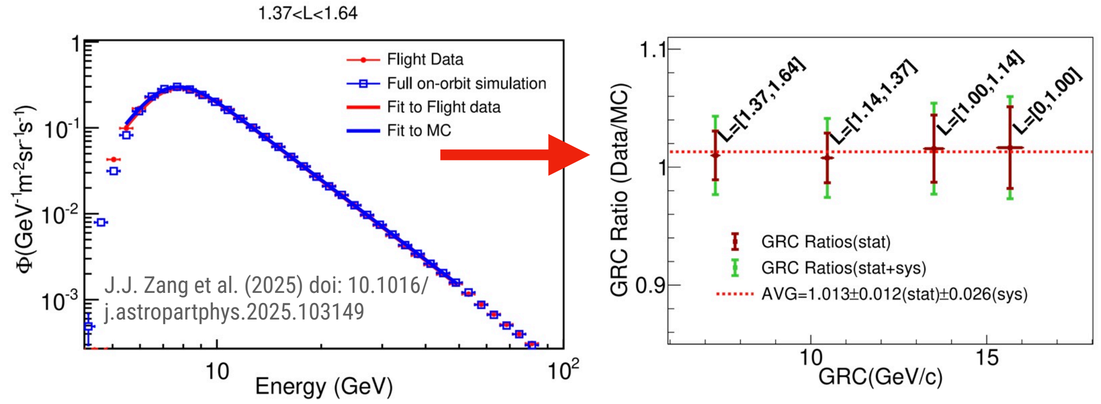




~ 5 million events/day



Energy scaled confirmed with the Earth geomagnetic cutoff down to ~1.3%:



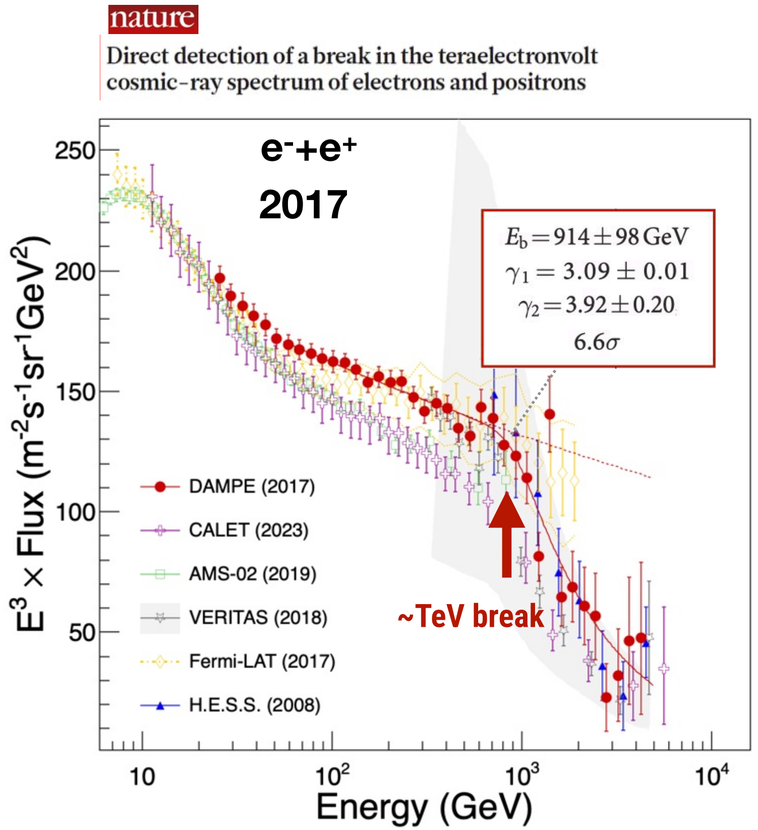
Excellent stability of all DAMPE sub-systems after 10 years on orbit!



DAMPE's science
(focus on recent results)

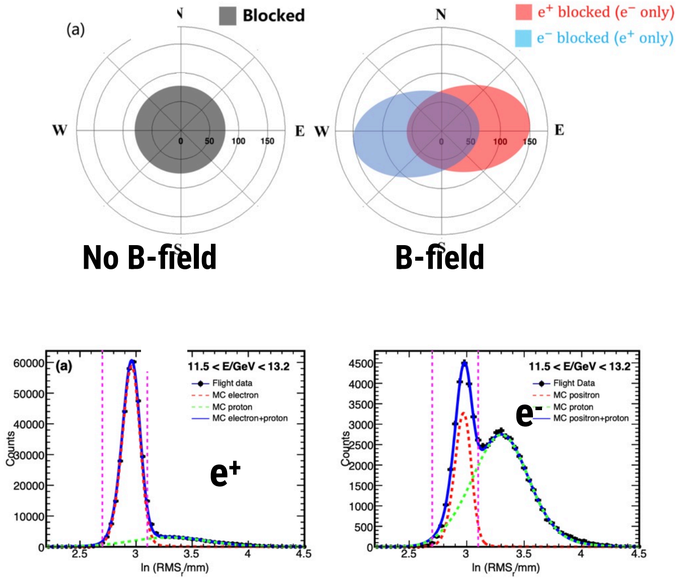
Electrons & Positrons

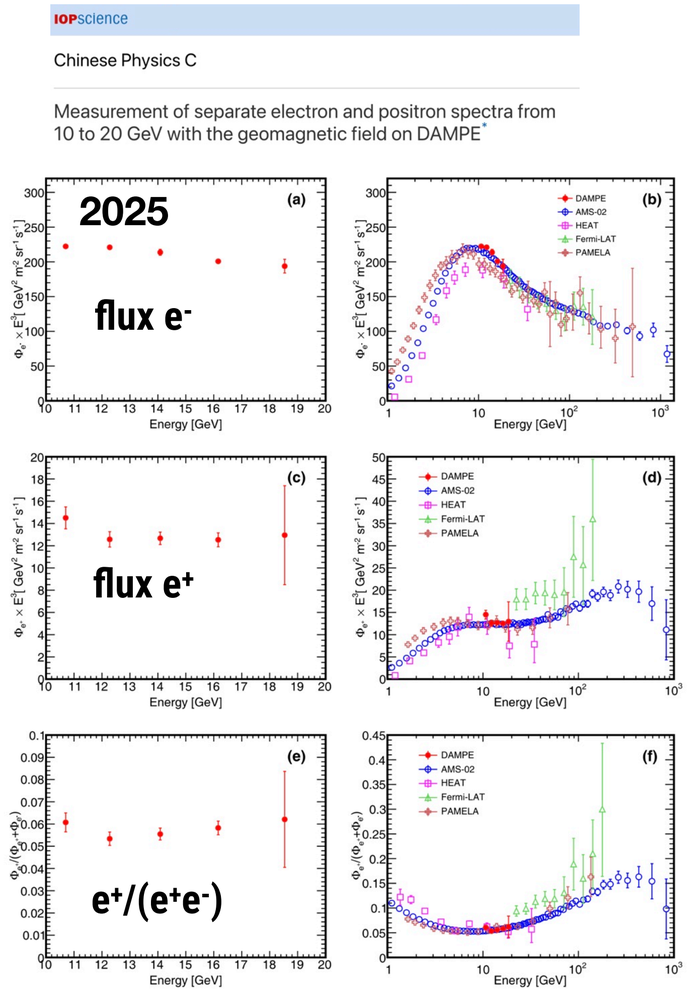
- Direct detection of a TeV break in CR electrons (2017)
  - ➡ **measurement reaching 4.6 TeV**



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

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

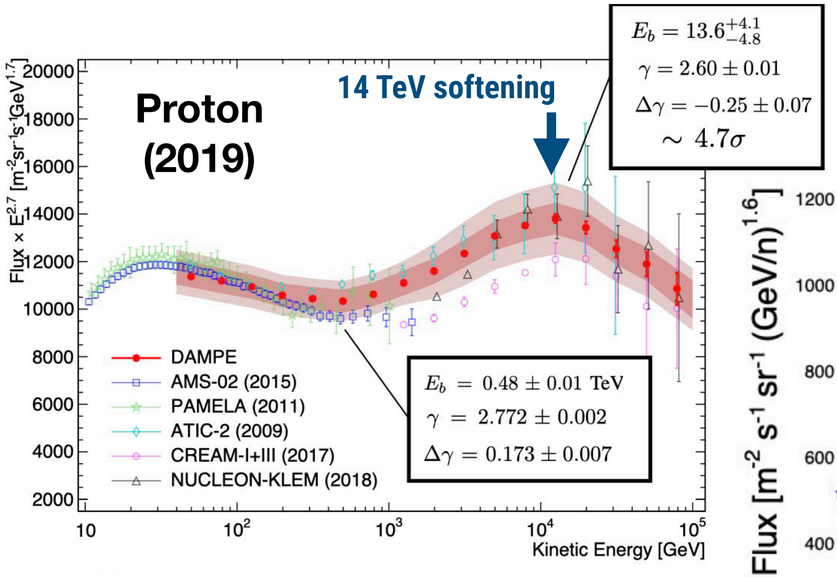




Proton and Helium (published)

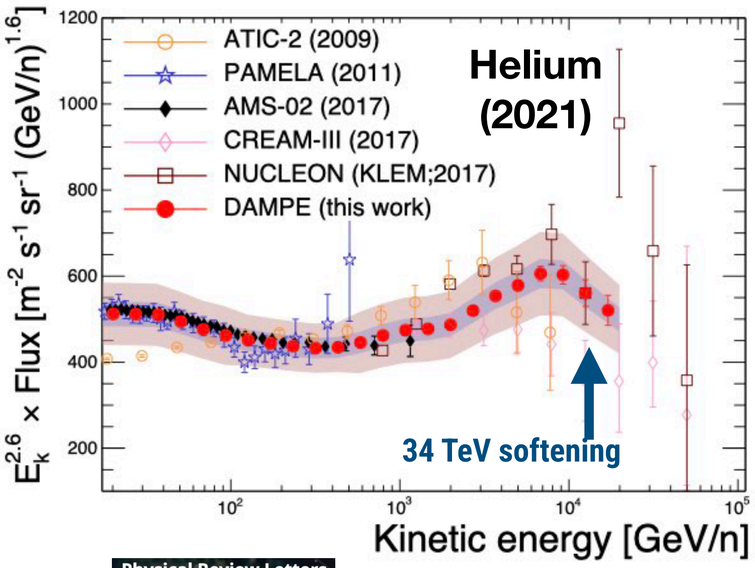
- Proton and helium spectra:
  - ➡ Detection of softening softening at high energies
  - ➡ Energy reach: 100 TeV for proton, 80 TeV for He

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



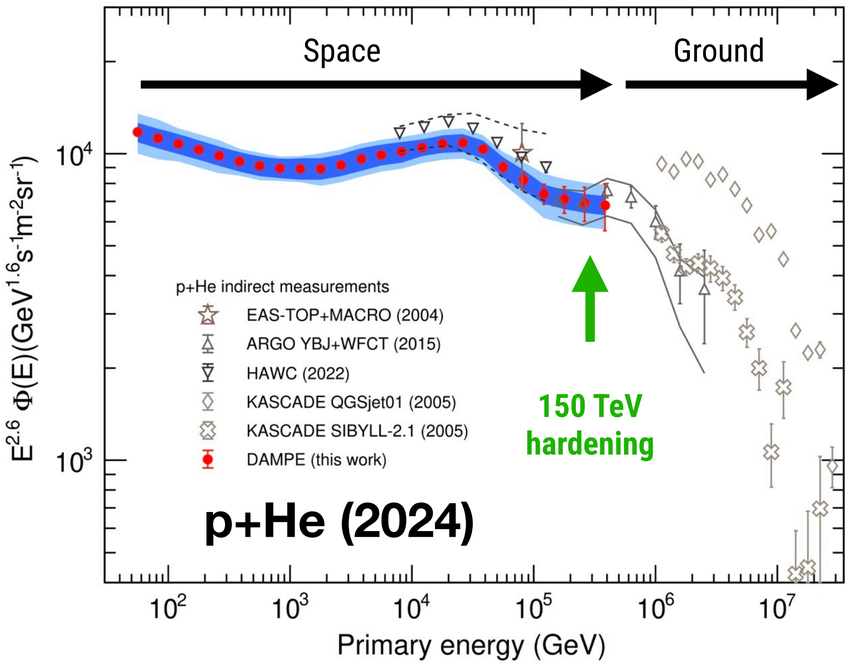
ScienceAdvances

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



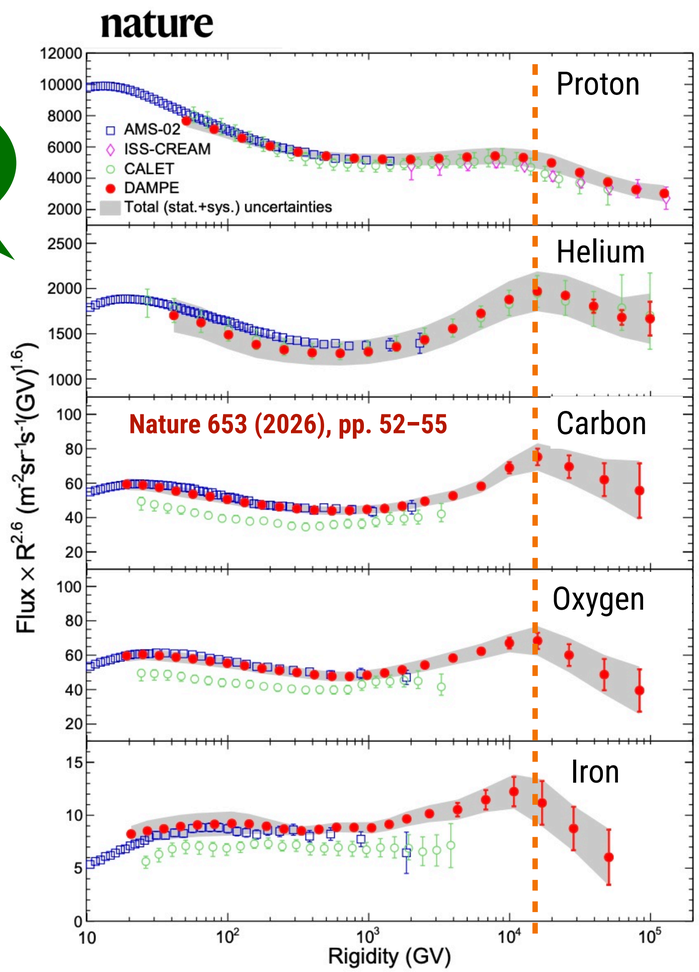
Physical Review D

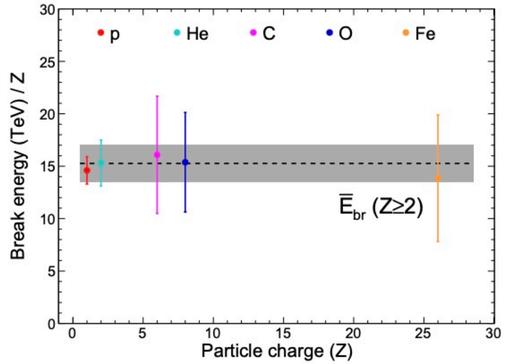
Measurement of the cosmic $p + \mathrm{He}$ energy spectrum from 50 GeV to 0.5 PeV with the DAMPE space mission

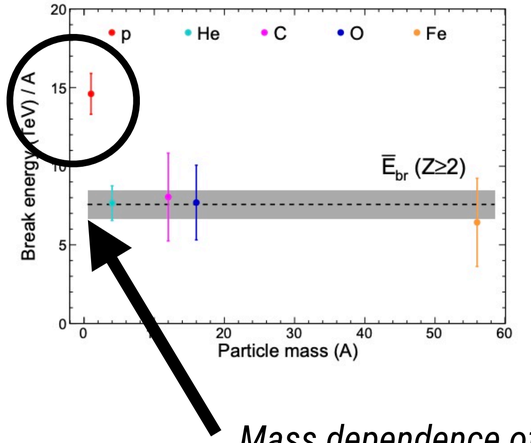
Universal softening in primaries (H, He, C, O, Fe)

- 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!!!



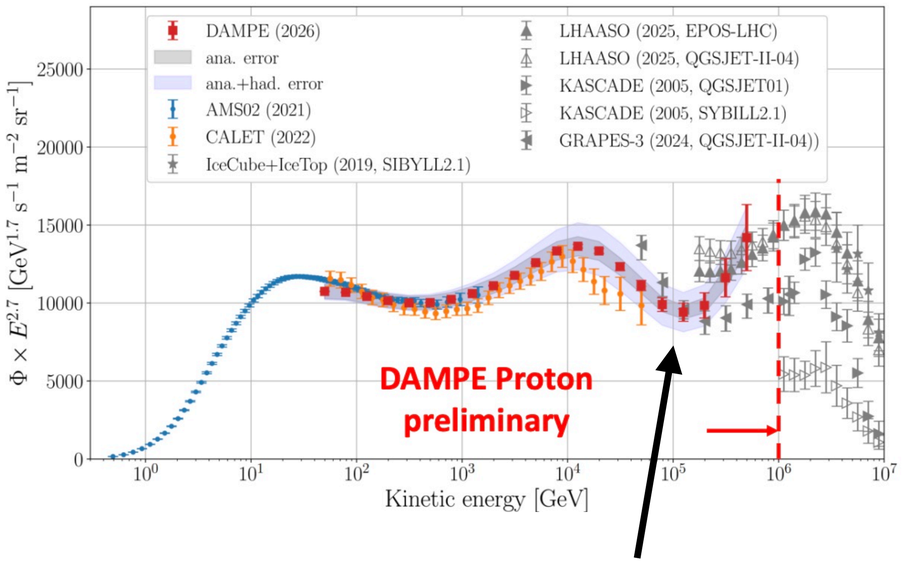




Mass dependence of softening excluded on 4.4σ level

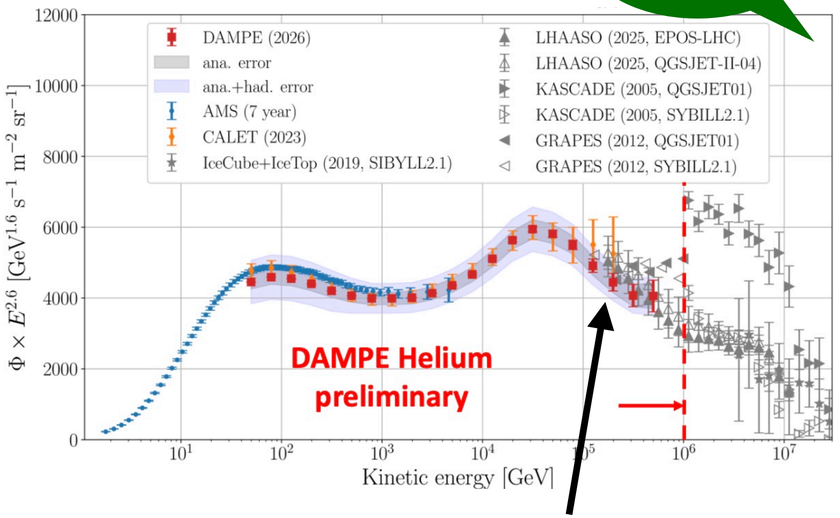
Proton and Helium (**update towards PeV**)

- 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)

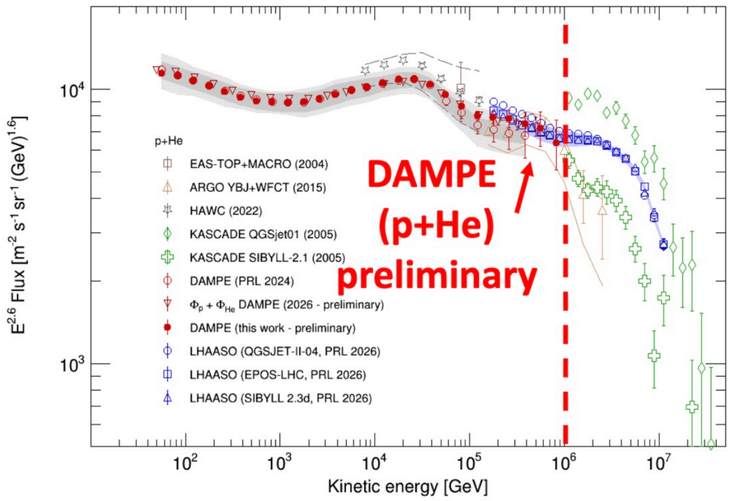


Proton flux shows a hardening at ~150 TeV

New!!!



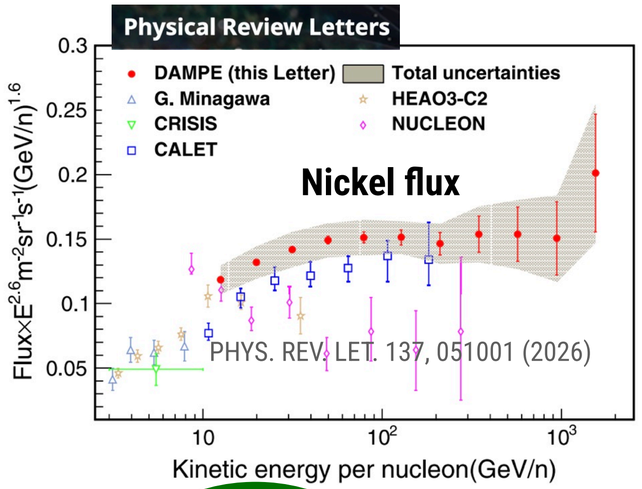
Not enough statistics above 300 TeV to check for a new hardening for He

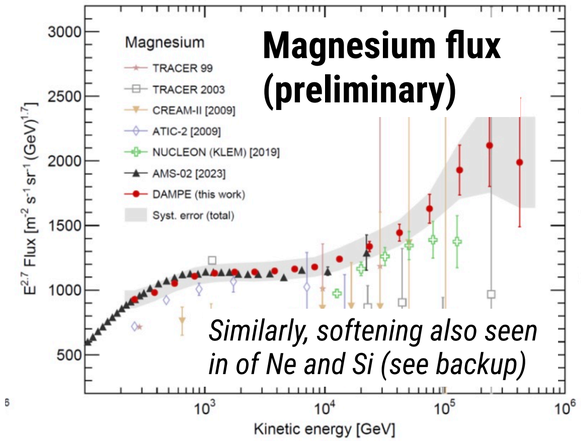


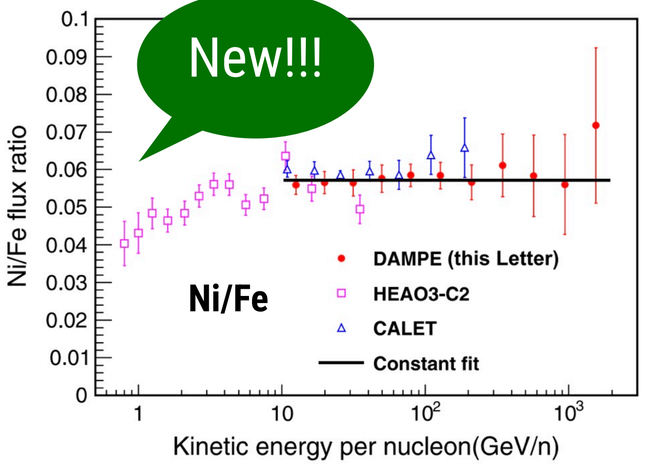
Independent (p+He) measurement is consistent with the sum of the individual p and He fluxes

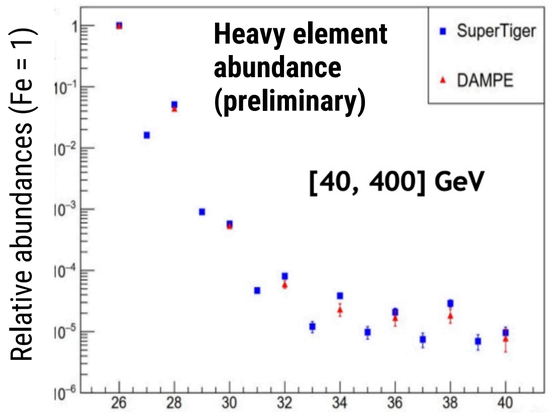
Beyond Fe, intermediate nuclei, all-particle spectrum

- 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 ...

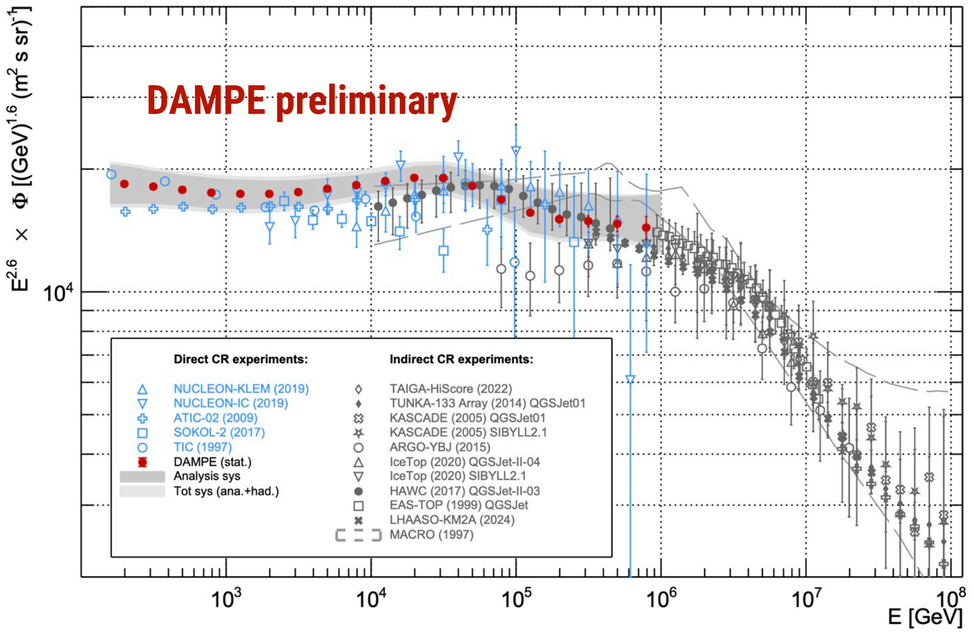






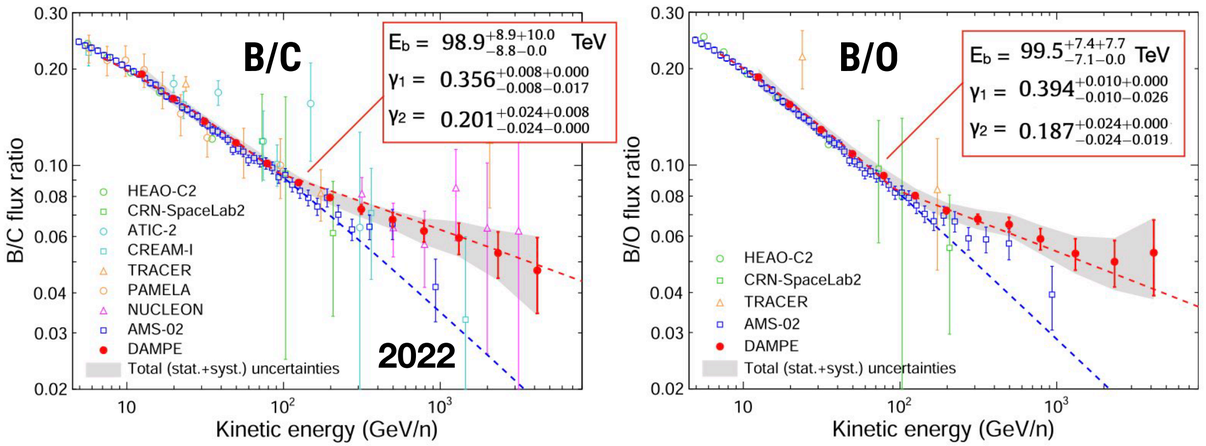


- All-particle spectrum measurement spanning 4 orders of magnitude in energy!

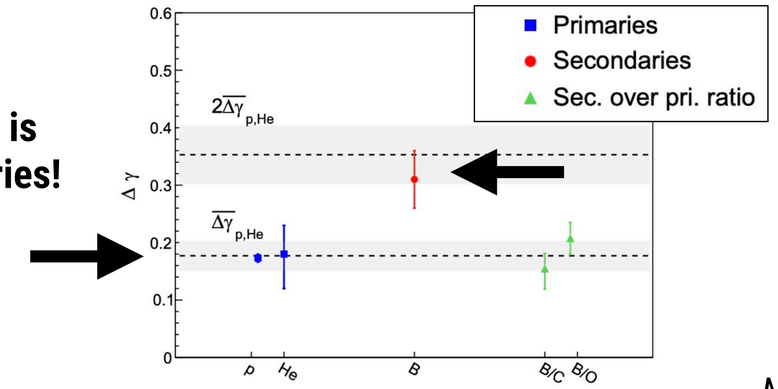


CR secondaries, ratios

- Detection of spectral hardening at ~ 100 GeV/n.
  Indication of change of the CR diffusion coefficient?

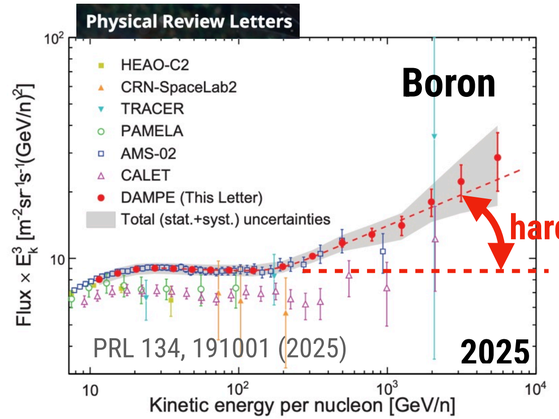


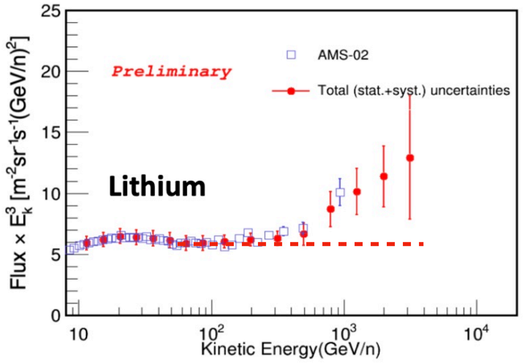
Spectral break in secondaries is ~2 tImes larger than in primaries!

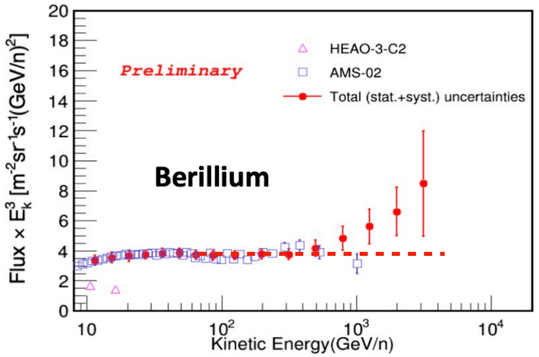


- Observation of Hardening in Boron,
- Preliminary lithium and beryllium fluxes exhibit similar behavior







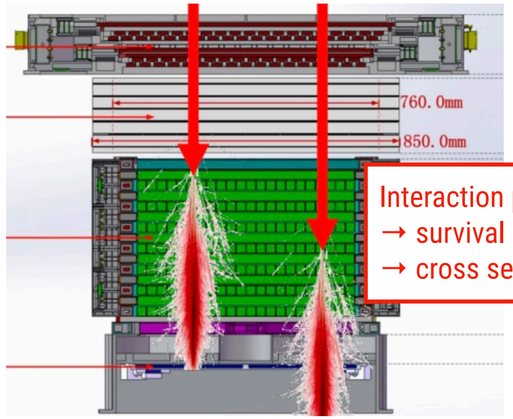


No structure in secondary ratios (Li/B, Be/B - see backup)

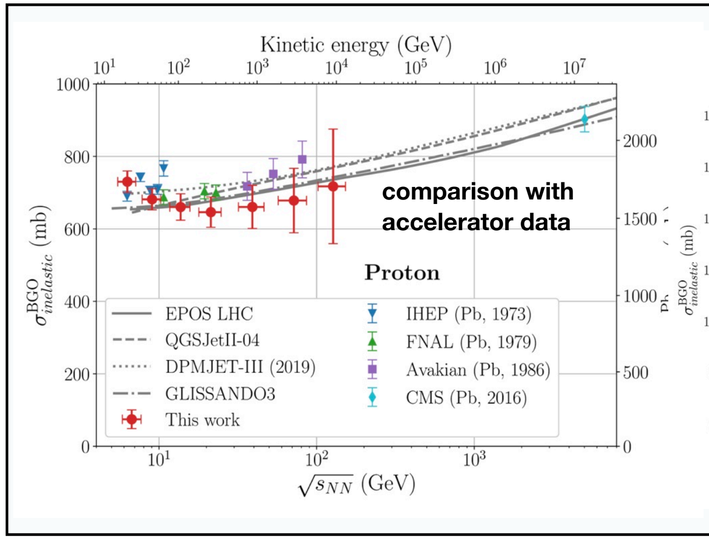
Inelastic cross sections on BGO target (*H, He, C, O*)

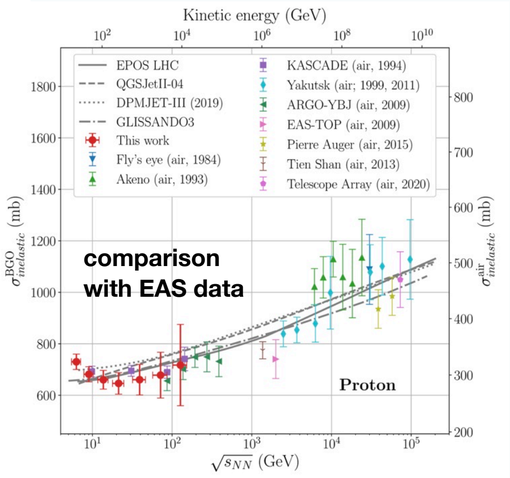
DAMPE as "beam-target" experiment:

- Beam: Cosmic Rays
- **Target: BGO (Bi4Ge4O12)**

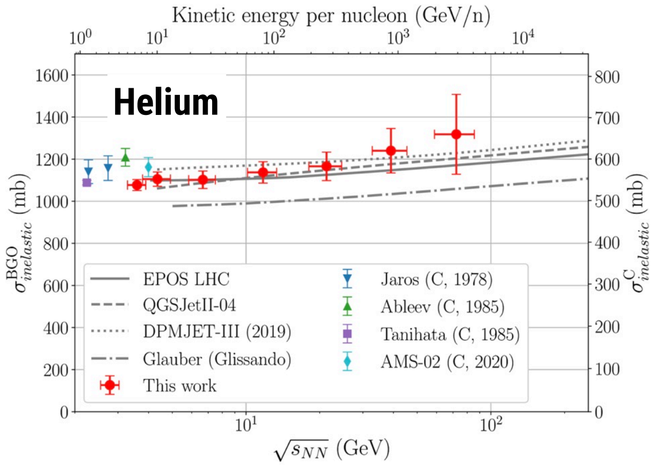


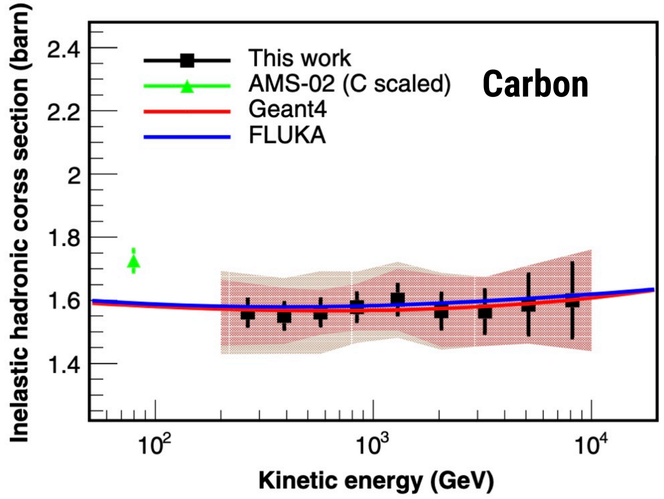
Interaction point
→ survival probability
→ cross section

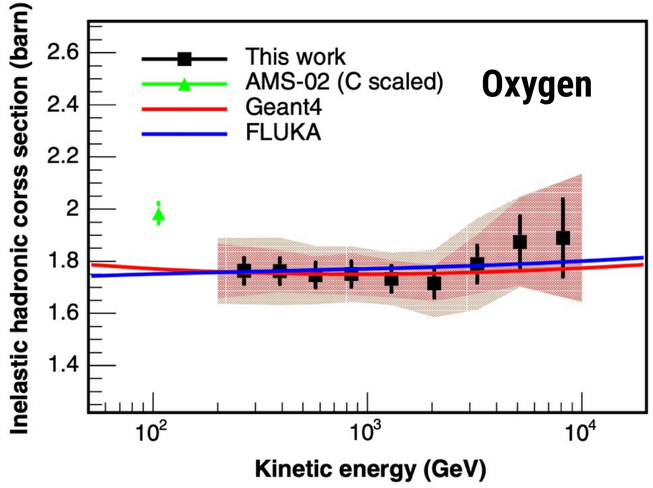




Proton-BGO inelastic cross section compared to beam data(left) and ground experiments (scaled to proton-air) (right)





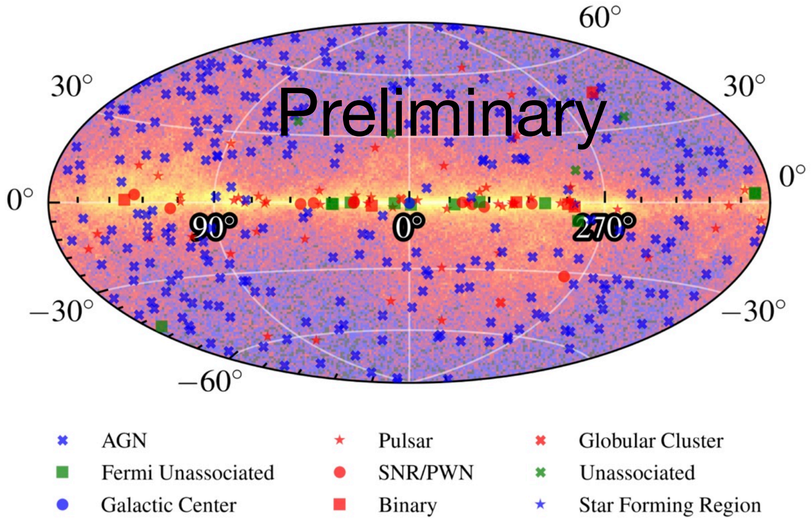


Physical Review D

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

Gamma rays: sources, dark matter

- Point sources



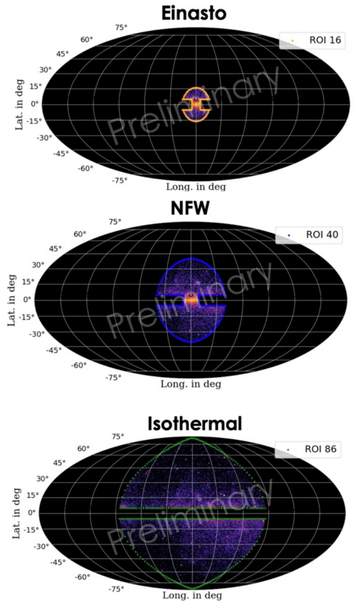
Source type	Number
AGN	261
Pulsar	61
SNR/PWN	11
Binary system	6
Globular Cluster	2
Star Forming Region	1
Galactic Center	1
Fermi Unassociated	12
Unassociated	4
Total	**359**

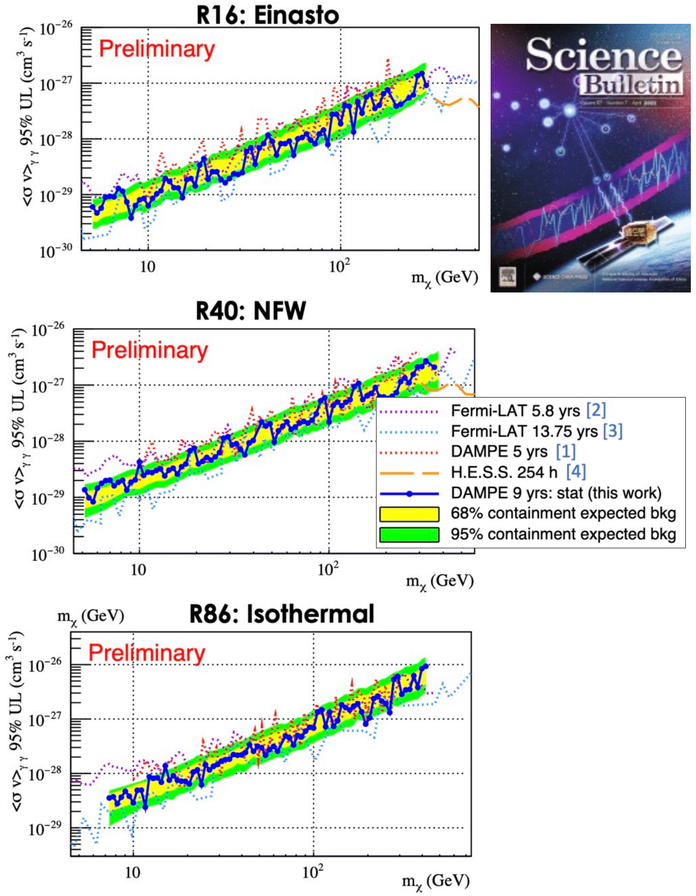
73% are AGNs.

(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)

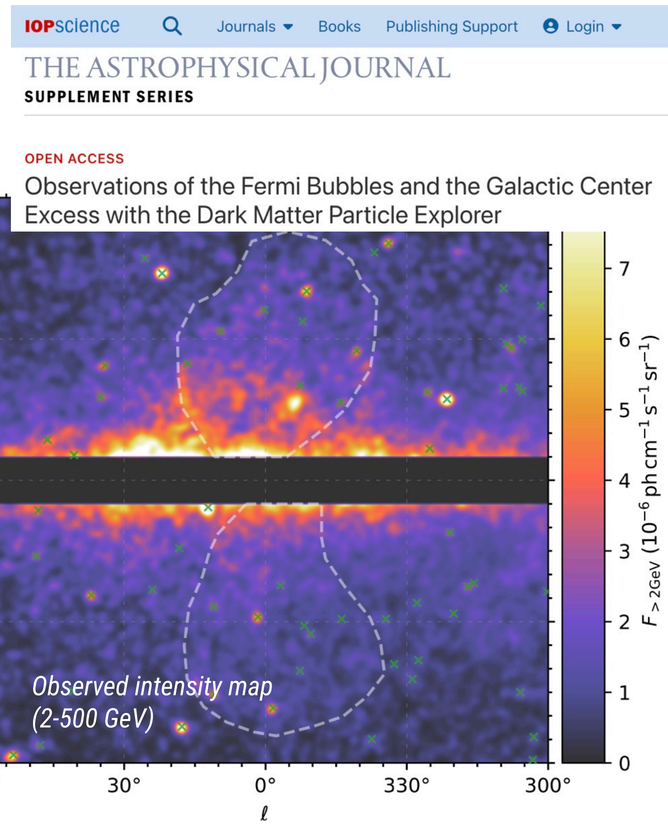
Gamma rays: Fermi Bubbles, Galactic Center Excess

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

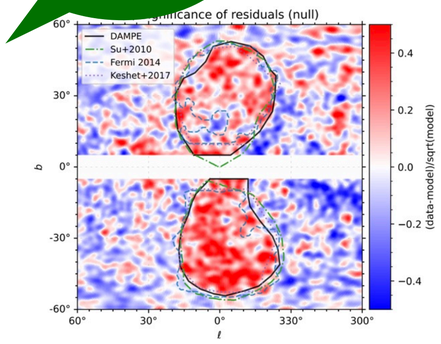
- DAMPE FB detection at ~26σ with 8.5 years of data
- Spectrum consistent with Fermi-LAT

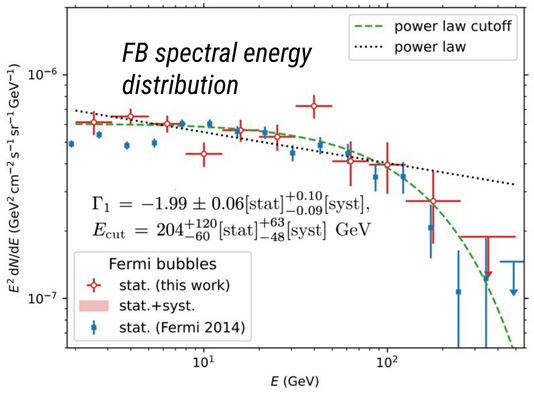
Galactic Center Excess:

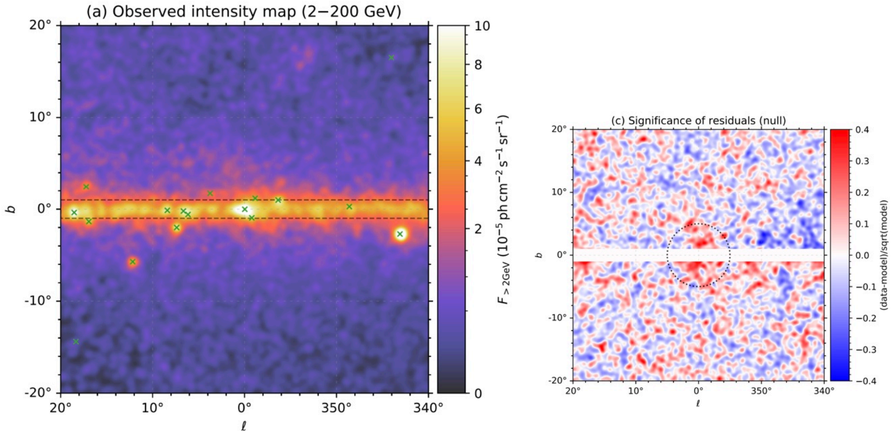
- ~7σ with 8.5 yr of data

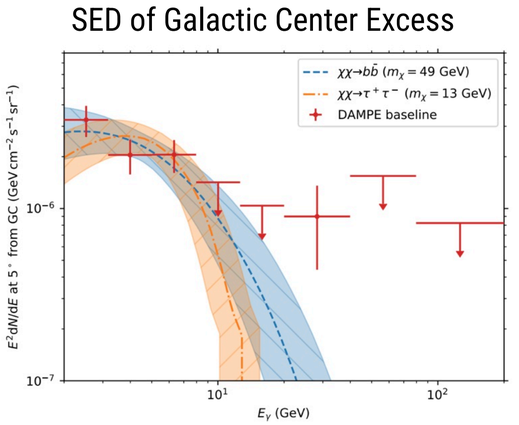


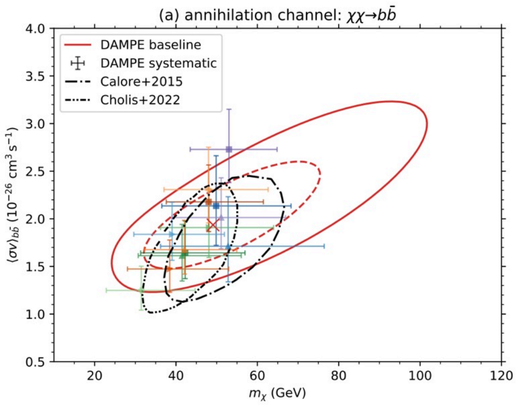
New!!!

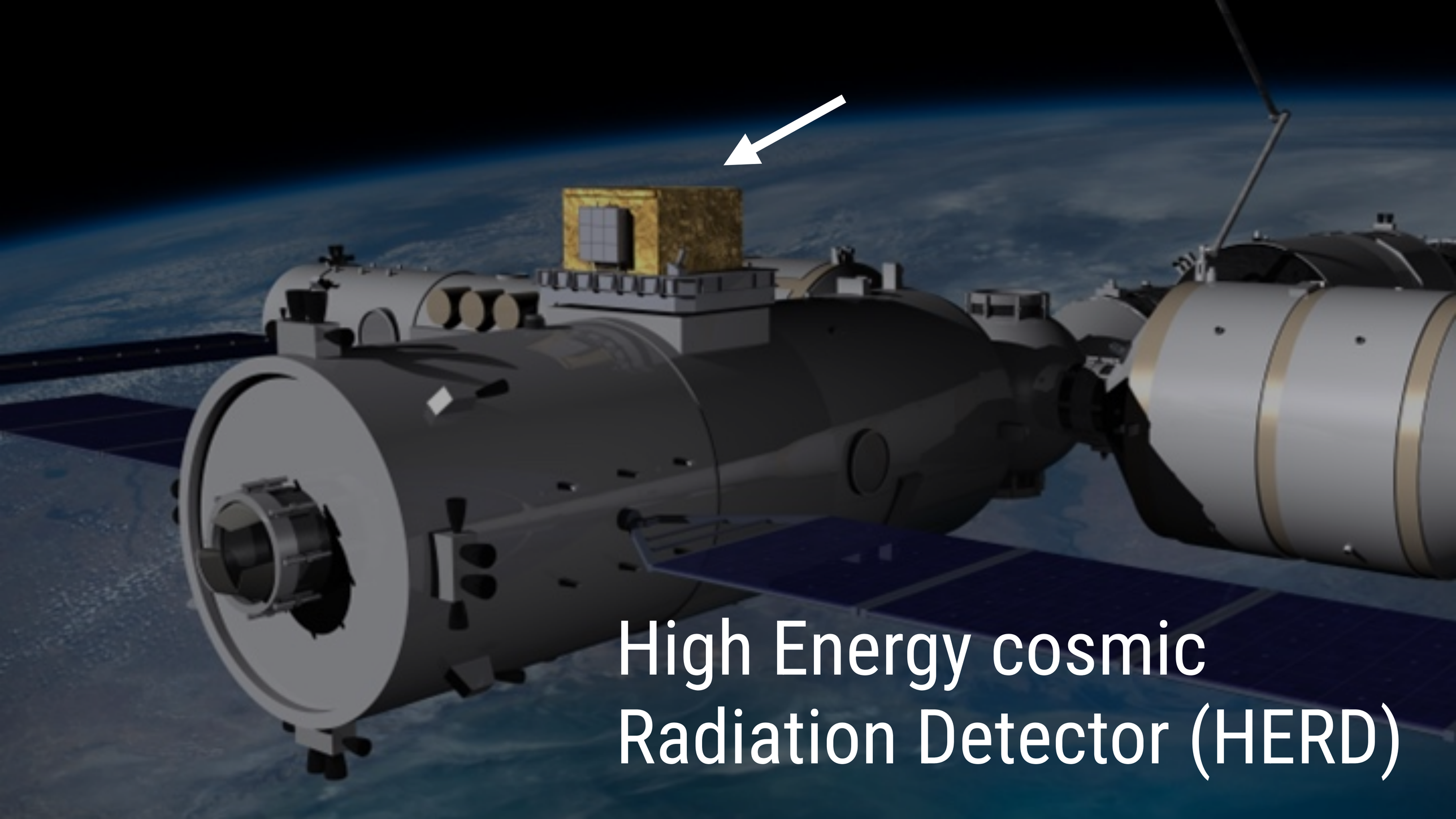




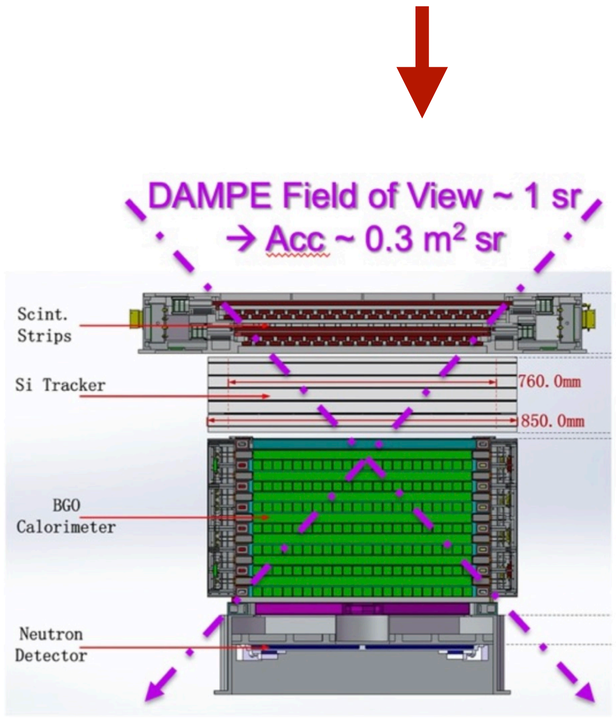


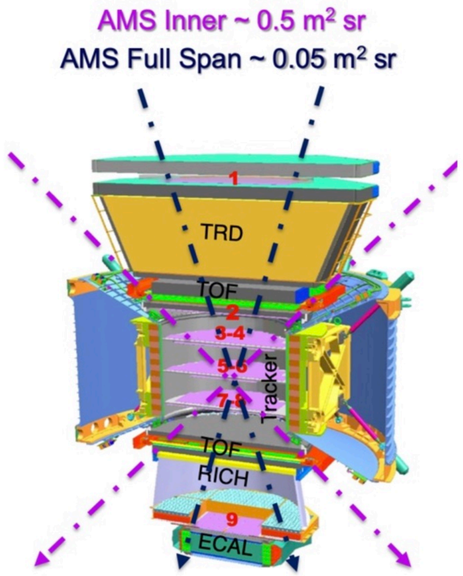




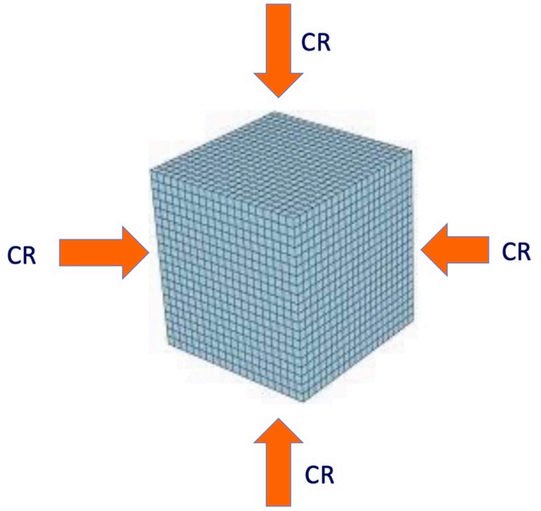

High Energy cosmic
Radiation Detector (HERD)

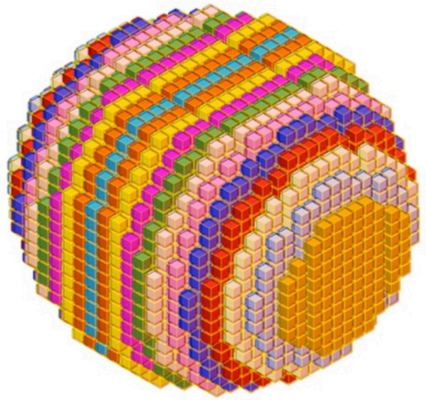
HERD/CALOCUBE: a new paradigm for calorimeters in space





Exploit the CR "isotropy" to maximize the effective geometrical factor, by using all the surface of the detector (aiming to reach Ω = 4π)



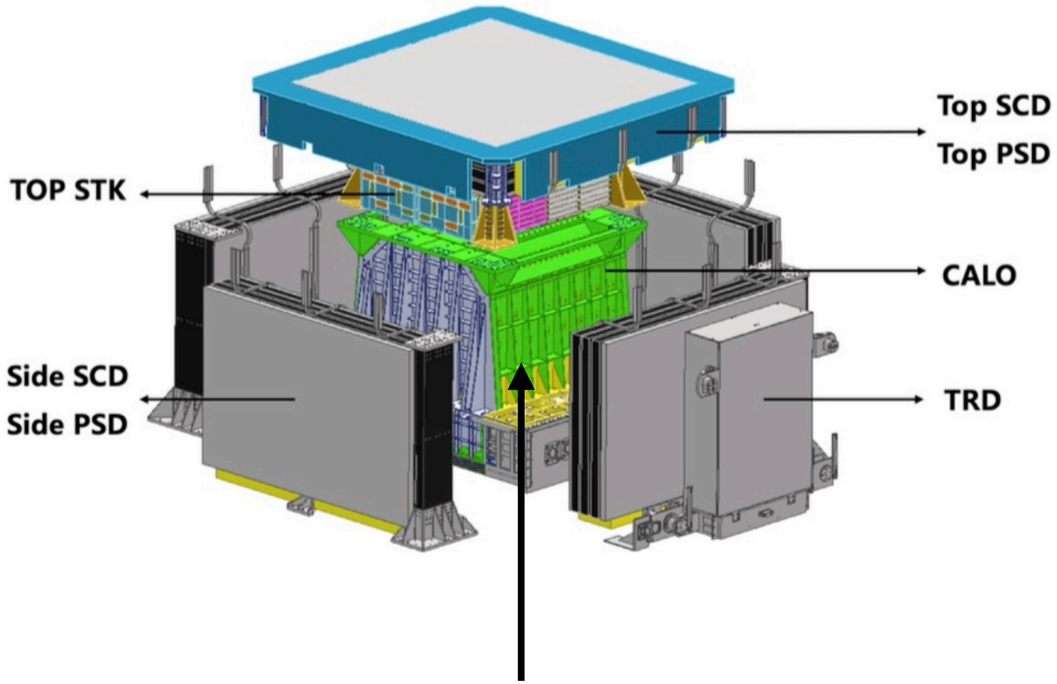


HERD calorimeter geometry

All current and past detectors are designed as "telescopes" - they accept particles from one direction (~1 sr)

HERD: the detector

HERD: flagship and landmark scientific experiment, China-led large international collaboration



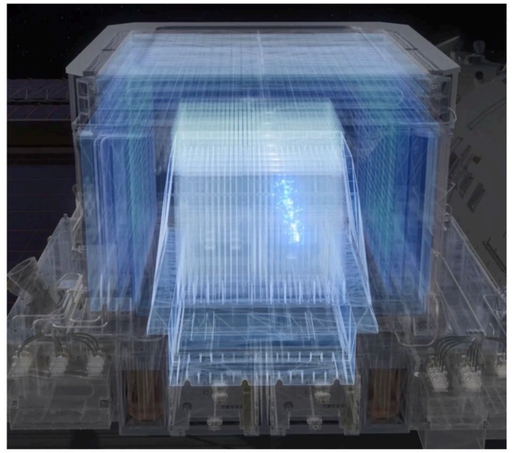
CALO: homogeneous 3D imaging calorimeter consisting of LYSO cubes, ~55X_0 (~3Λ)

SCD	Charge Reconstruction
PSD	Charge Reconstruction γ Identification
FIT	Trajectory Reconstruction Charge Identification
CALO	Energy Reconstruction e/p Discrimination
TRD	Calibration of CALO response for TeV protons

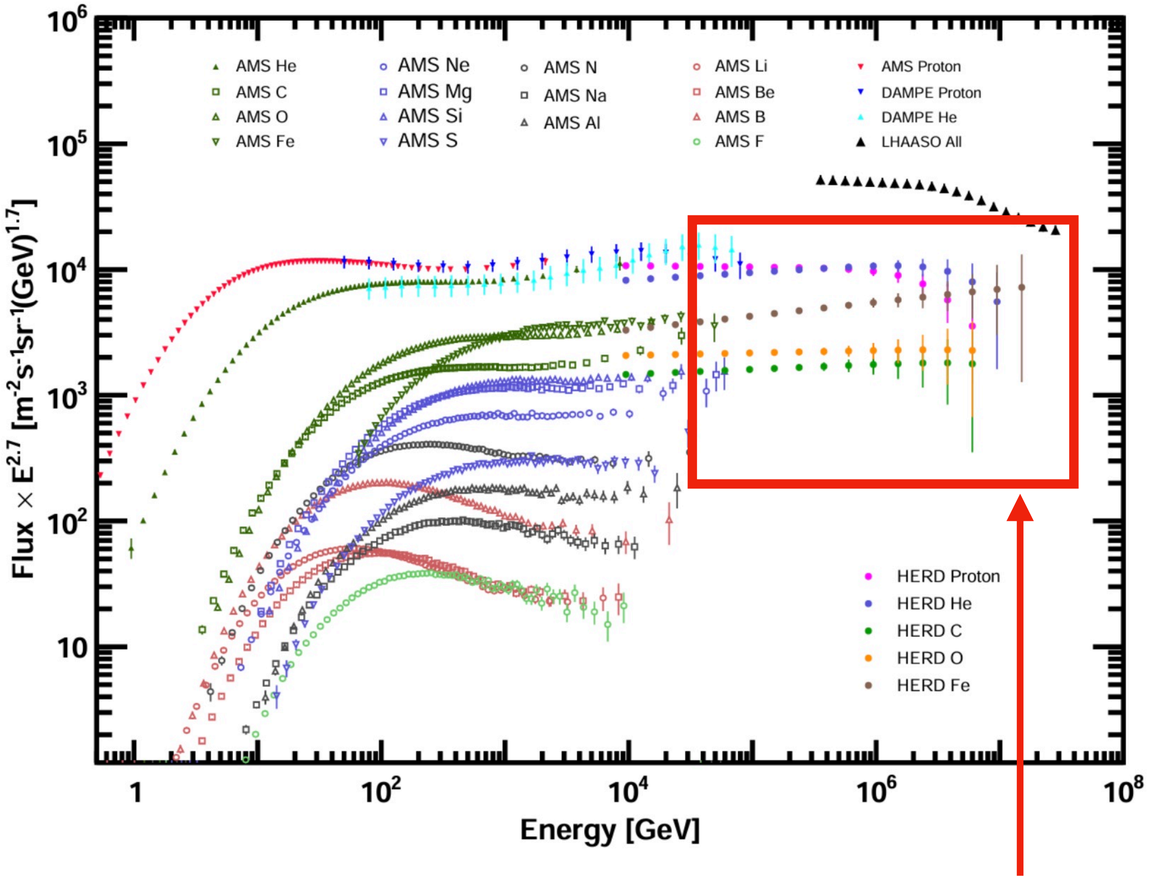
Main requirements			
	γ	e	p, nuclei
Energy Range	>100MeV	10 GeV 100 TeV	30 GeV 3 PeV
Energy resolution	1% @ 200 GeV	1% @ 200 GeV	20% @ 100 GeV -1 PeV
Effective Geometric Factor	>0.2 m^2sr @ 200 GeV	>2 m^2sr @ 200 GeV	>1 m^2sr @ 100 TeV

HERD: science

- **Cosmic-ray:** Precise cosmic ray spectrum and composition measurements up to the knee energy
- **Dark matter:** indirect dark matter search with unprecedented sensitivity
- **Gamma-ray:** Gamma-ray monitoring and full sky survey



Expected HERD results in cosmic rays

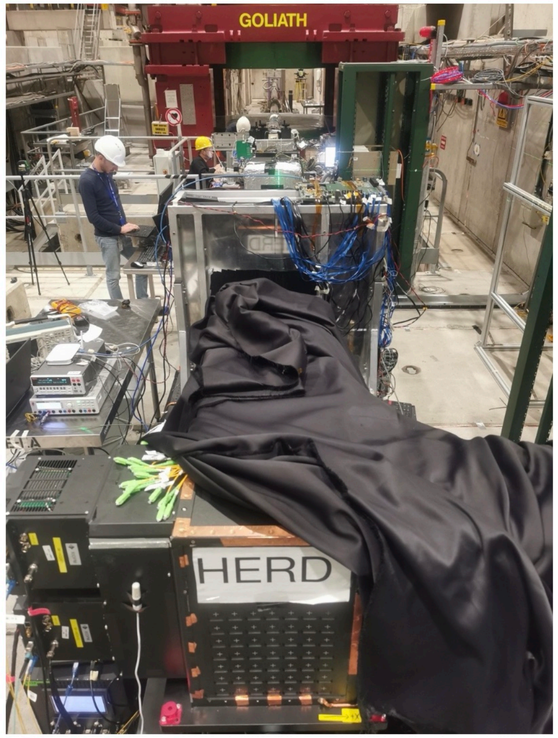


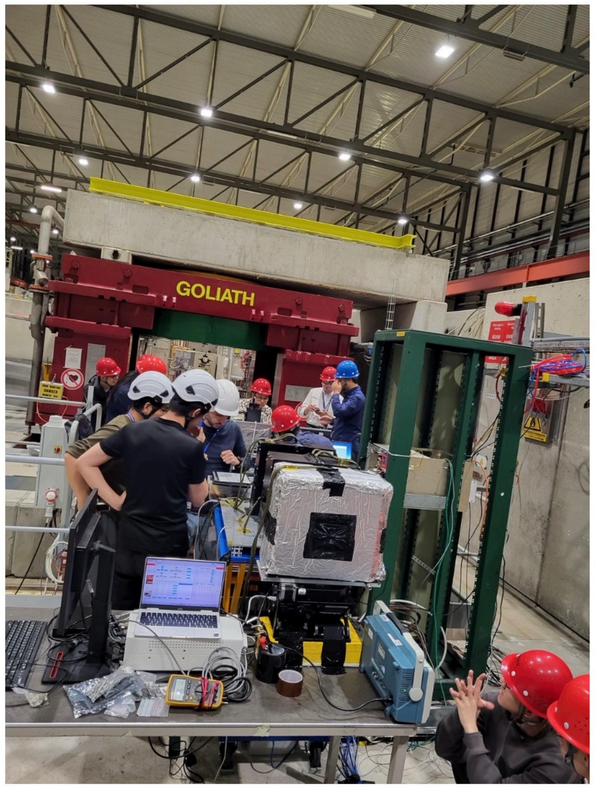
Direct cosmic ray measurement in space at multi-PeV energies (probing the individual *knees*)

HERD: on-ground tests

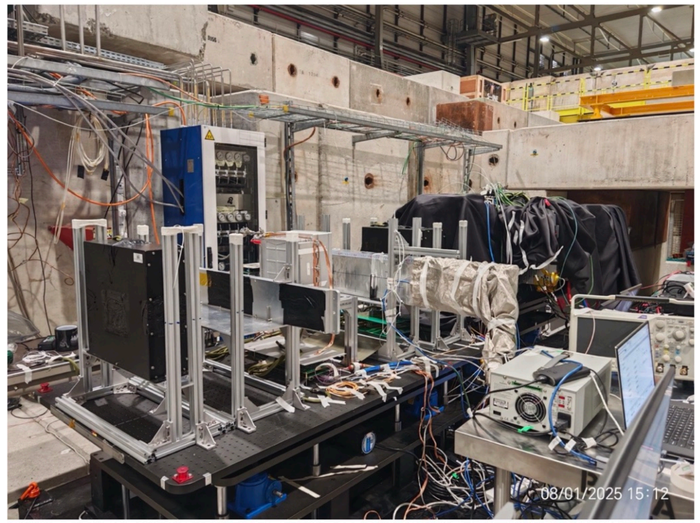
- Beam tests of HERD sub-detector prototypes at CERN in 2024 and 2025

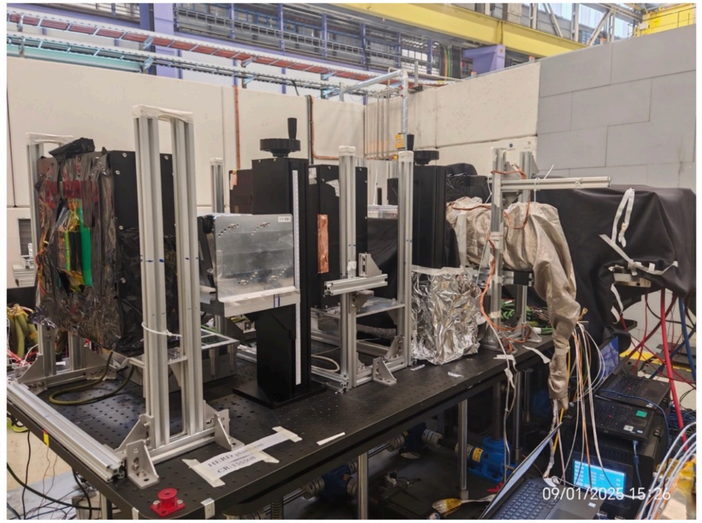
2024





2025

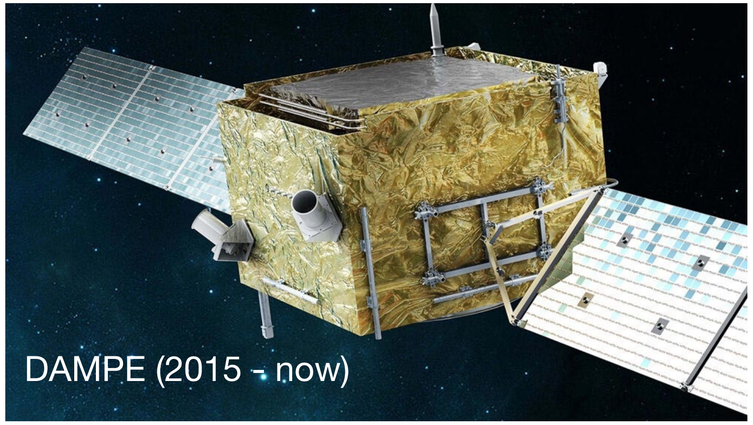




DAMPE & HERD summary

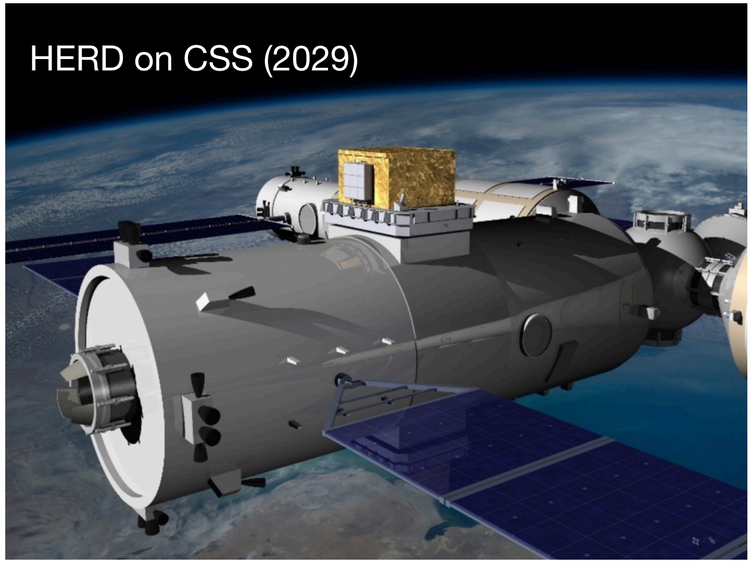
DArk Matter Particle Explorer (DAMPE)

- In-flight operation since 2015, unique for multi-TeV Cosmic Rays (CR):
  - ➡ e^-+e^+: evidence of cutoff at ~1 TeV in → extending to multi TeV region
  - ➡ Detection of universal 15 TV structure in all CR primaries (from H to Fe)!
  - ➡ *p & He* probing PeV frontier, approaching the "knee"
  - ➡ Probing CR propagation: observation of hardening in *Li, Be, B*
  - ➡ Link to particle physics: p,He,C and O cross sections on heavy target
  - ➡ γ-rays: Fermi bubbles, GCE, point sources, dark matter searches...
  - ➡ Many more: trans-iron elements, all-particle spectrum, exotics etc.



High Energy cosmic Radiation Detection facility (HERD)

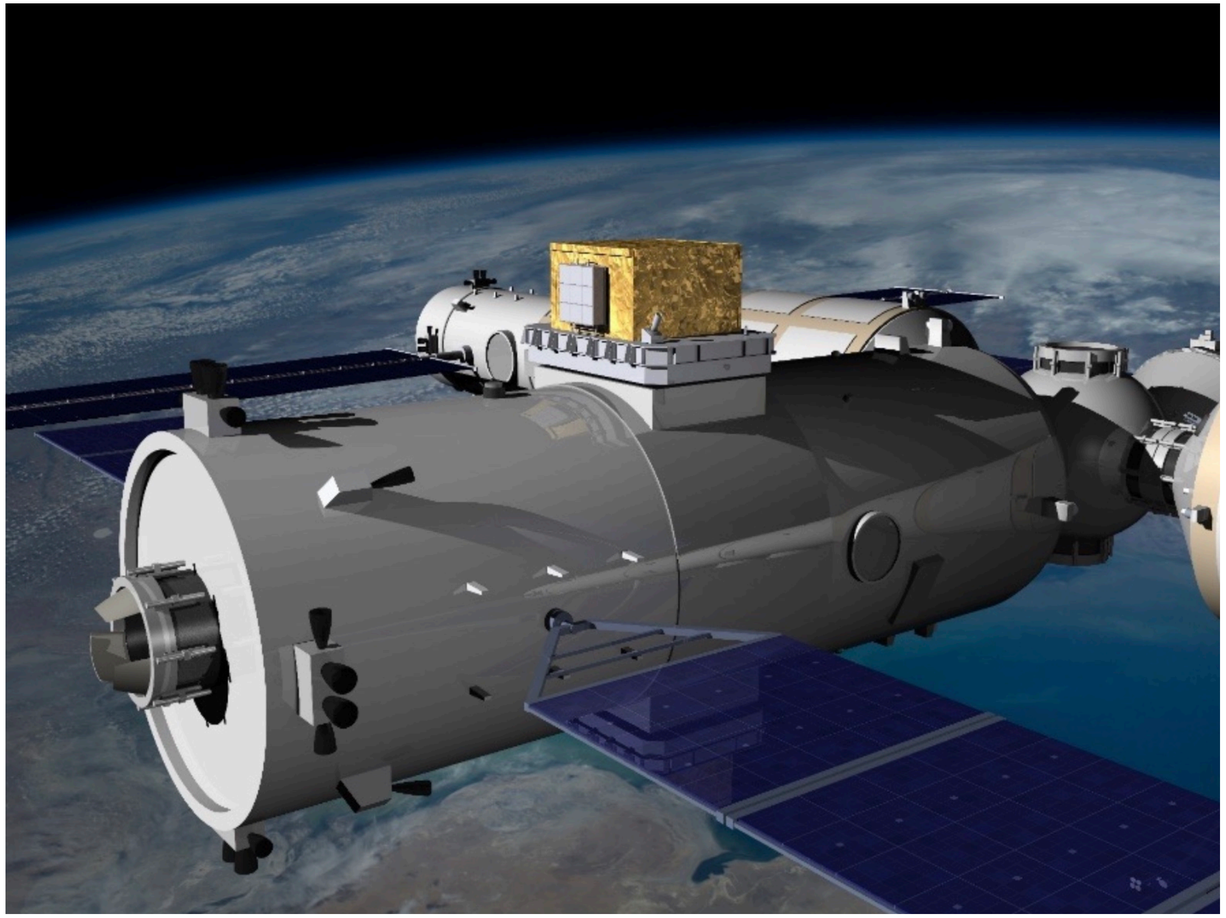
- Flagship experiment led by China and with key European contributions
  - ➡ Individual CR measurements up to tens of PeV
  - ➡ Probing fine structures in e^-+e^+ (astrophys. sources VS dark matter)
  - ➡ Large acceptance & sensitive high-E γ-ray sky monitoring
- Passed major adoption, scheduled deployment on CSS in 2029



Backup

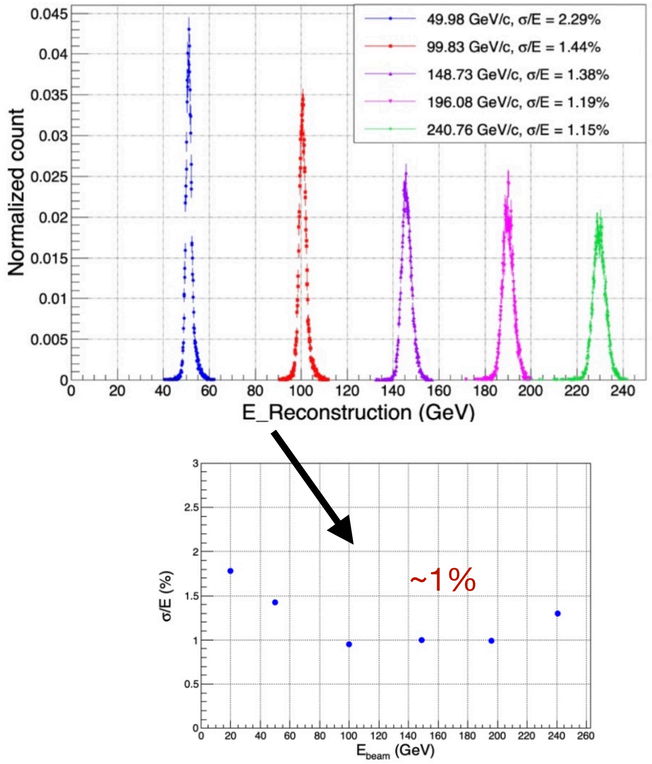
HERD status

- The mission proposal was positively reviewed by Italian Space Agency (ASI, Italy) and Centre for Space Utilization (CSU, China) in 2018
- Baseline design of the detector meets the scientific requirements
- The mission has passed all adoption reviews and financial reviews in China, in particular the evaluation review on engineering feasibility
- Scheduled deployment on Tiandong CSS (Chinese Space Station) in 2029, expected lifetime > 10 years

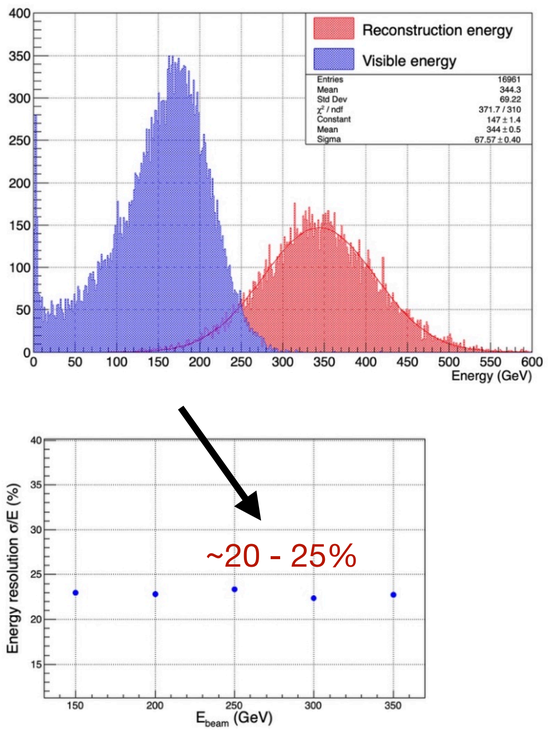


HERD: on-ground tests

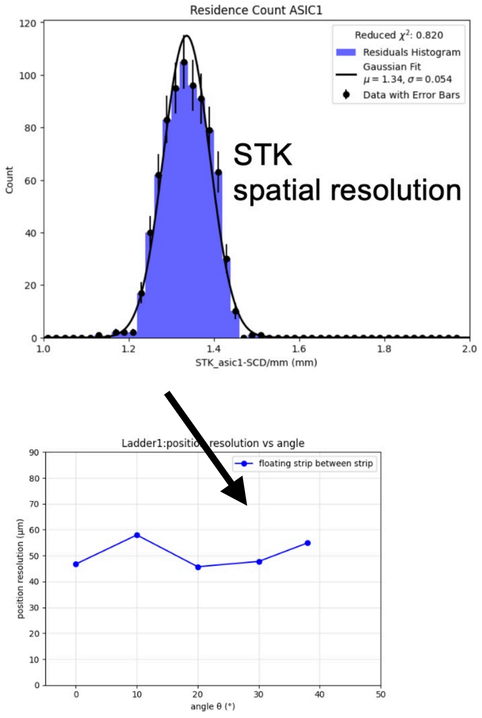
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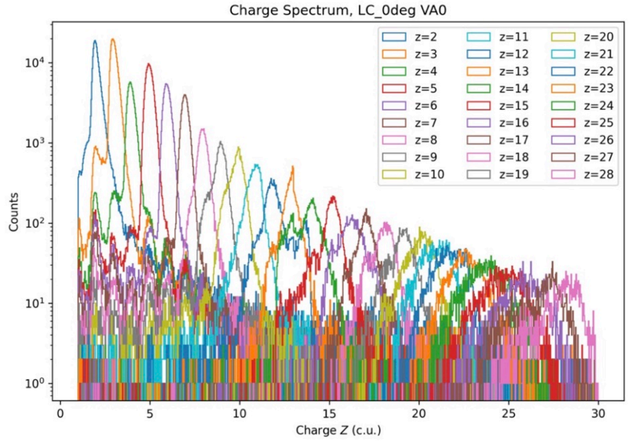
Electron energy resolution by CALO



Proton energy resolution by CALO



STK spatial resolution VS angle



SCD charge measurement