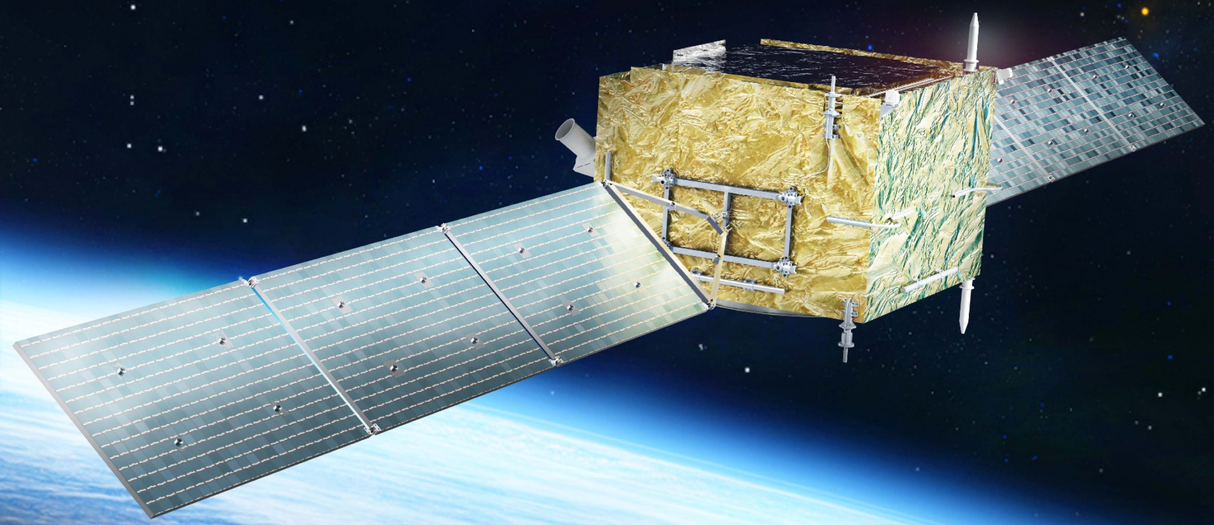
The latest results from the DAMPE experiment



Speaker: Pengxiong Ma
Purple mountain observatory, CAS, Nanjing,China
On bebalf of the DAMPE Collaboration.

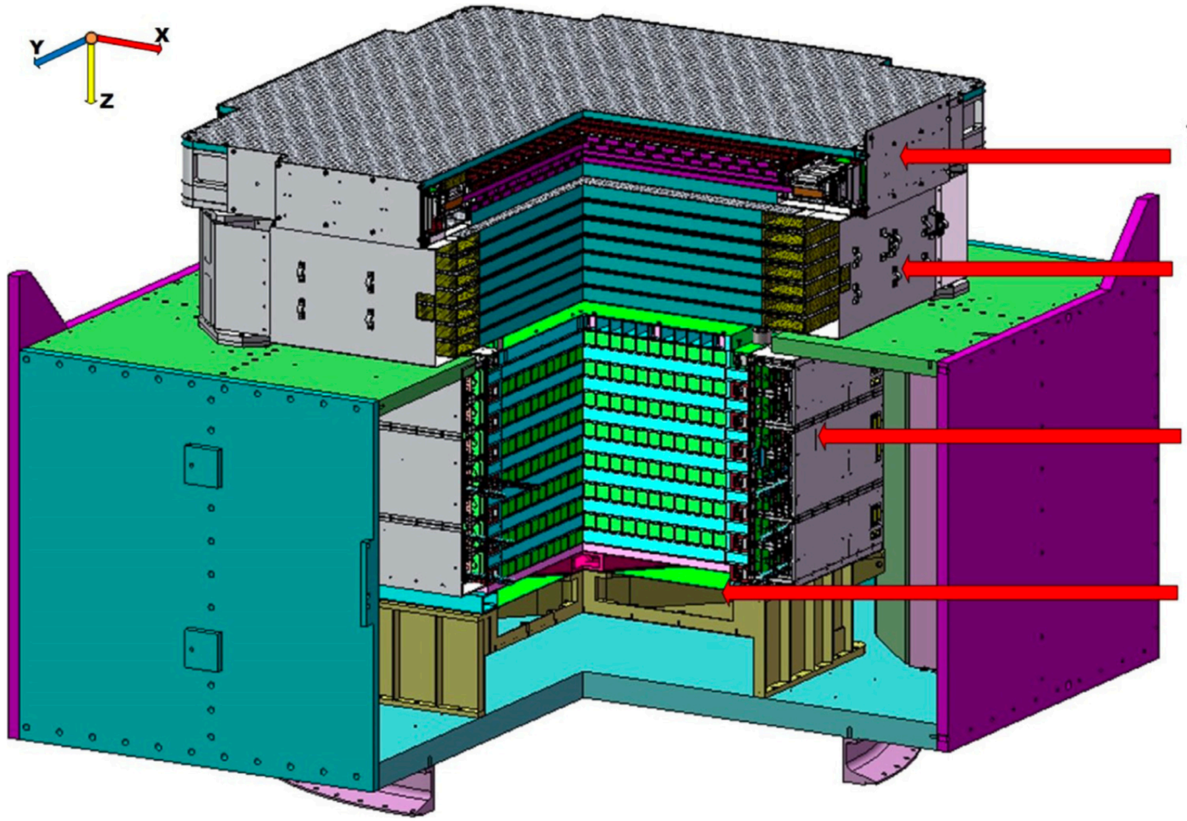
CRIS-MAC 2024
13th Cosmic-Ray International Studies and Multi-messenger Astroparticle Conference
@ Trapani, Italy. Jun.17-Jun.21 2024

DAMPE collaboration

- China
  - **1.Purple mountain observatory, CAS, Nanjing.**
  - 2.University of Science and Technology of China, Hefei.
  - 3.Institute of Modern Physics, CAS, Lanzhou.
  - 4.Insitute of High Energy Physics, CAS, Beijing.
  - 5.National Space Science Center, CAS, Beijing.
- Italy
  - 1.INFN Perugia and University of Perugia.
  - 2.INFN Bari and University of Bari.
  - 3.INFN-LNGS and Gran Sasso Science Institute.
  - 4.LNFN Lecce and University of Salento.
- Switzerland
  - 1.University of Geneva.

DAMPE

DArk Matter Particle Explorer



The plastic scintillator detector (PSD) — Charge, veto for gamma ray; 2x41

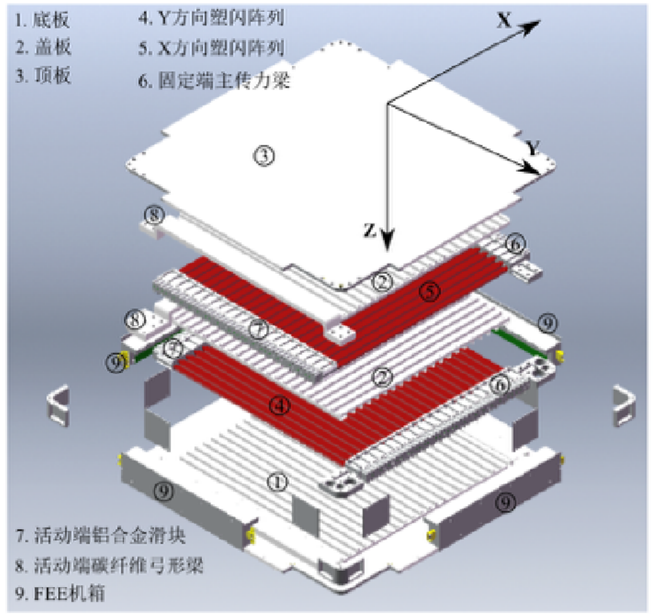
The silicon tracker (STK) — Direction, charge; 12 layers

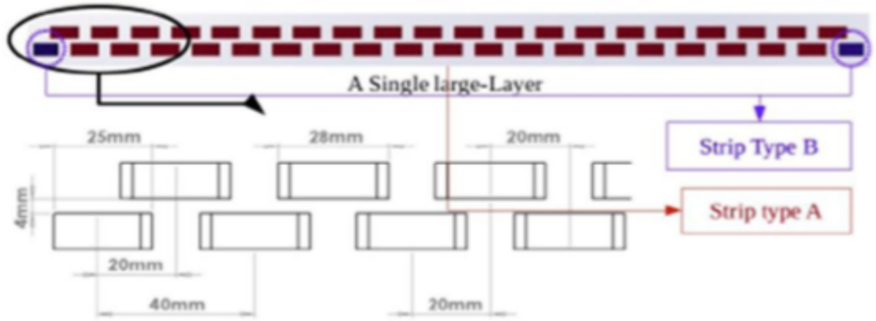
The BGO calorimeter (BGO) — Energy, direction, charge; 14x22 crystals

The neutron detector (NUD) — Proton electron seperation; 4 blocks

✓ Four sub-detectors, 1.4 tons in total. 32 radiation length & 1.6 nuclear interaction length

Plastic scintillator detector

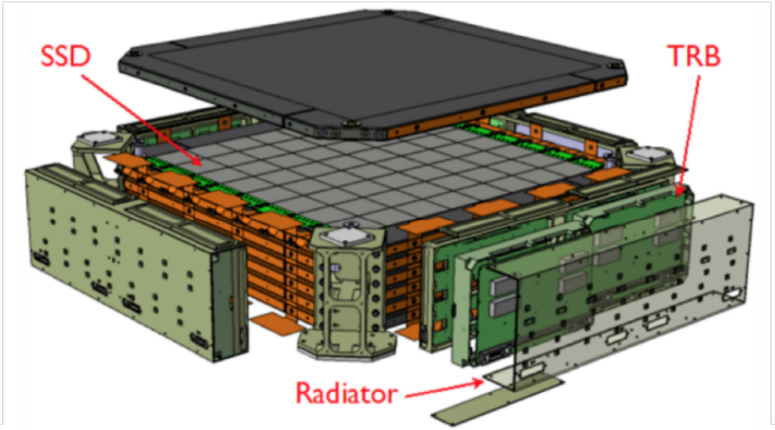




- 2 layers (x,y) of 88.4 cm × 2.8 cm × 1 cm
- Active area: 82 cm × 82 cm
- Weight : ~103 kg
- Power: ~ 8.5 W

100% effective area; high detection efficiency.

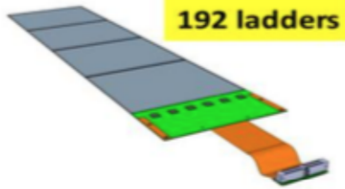
Silicon (tungsten) track detector

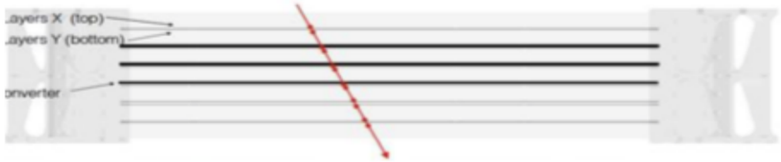


768 silicon sensors
95 x 95 x 0.32 mm³

1,152 ASICs

73,728 channels

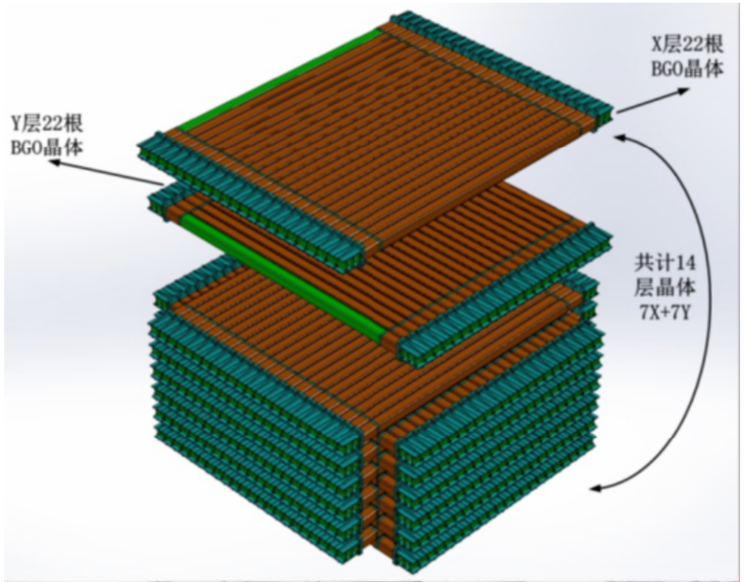


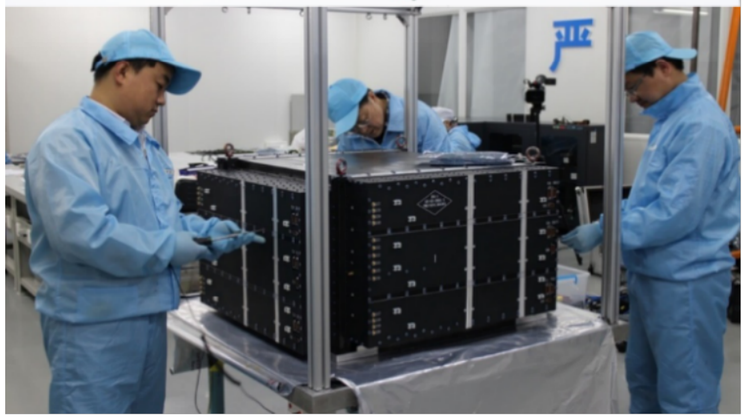


- Detection area: 76 cm x 76 cm
- Total weight: ~154 kg
- Total power consumption: ~ 82W
- Three 1 mm tungsten plates for photon conversion (0.86 X_0)

Total area is ~ 7 sqm; direction resolution ~ 0.1 degree

The BGO Colorimeter

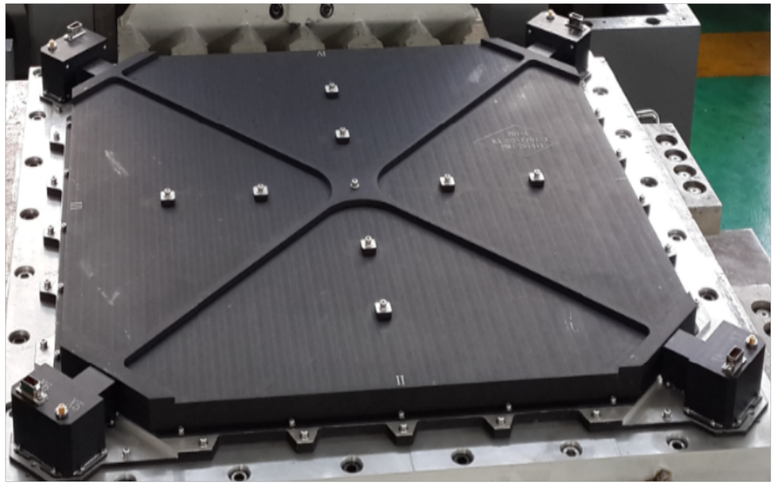


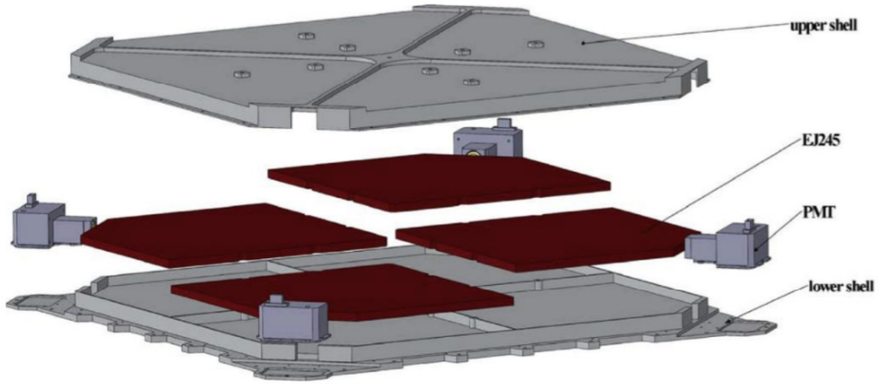


Parameter	Value
Active area	60 cm × 60 cm (on-axis)
Depth (radiation lengths)	32
Sampling	≥ 90%
Longitudinal segmentation	14 layers (≃ 2.3 rad. lengths each)
Lateral segmentation	∼1 Molière radius

Excellent energy resolution for electron/positron above ~10s GeV;
Excellent ability of separation between proton and electron(positron).

The Neutron detector



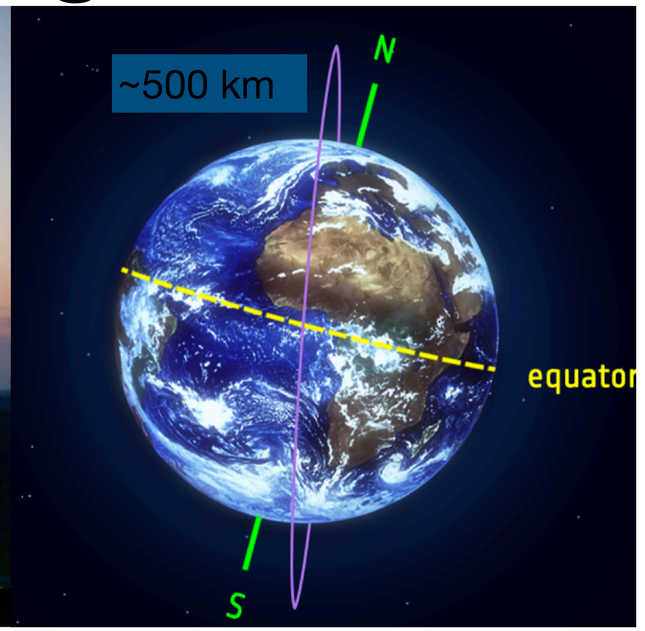


- $n + {}^{10}B \rightarrow \alpha + {}^{7}Li + \gamma$
- 4 plastic scintillators
- Active area: 60 cm x 60 cm
- Total weight: ~12 kg
- Total power: ~ 0.5 W

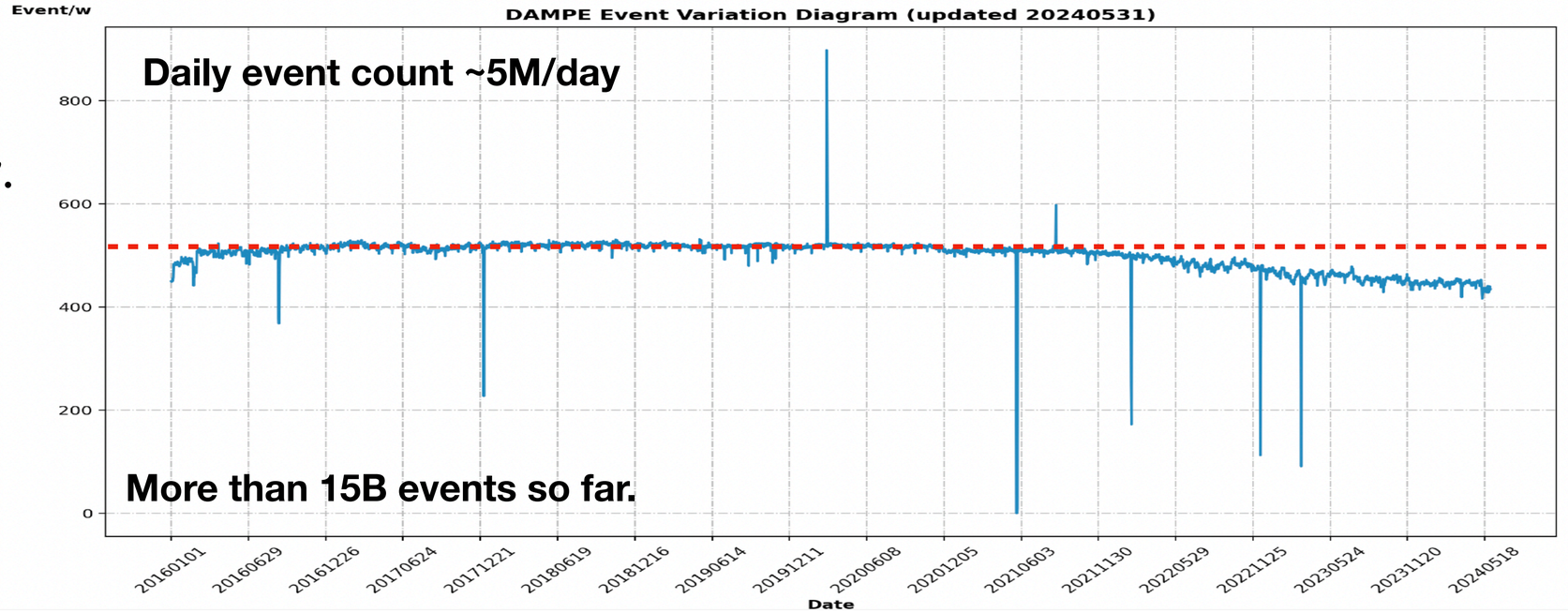
Extension of the ability for separation between p/e at high energy.

The launch: Dec 17th 2015 & long-term status

1. The first satellite dedicated to natural (astronomical) science from China.
2. 'Launches the (new) era of Chinese space science'- <Nature>



- Expected lifetime: 3 years
- Raw data: 16GB per day.
- Orbit: sun-sync. ~500km, ~95minutes
- Smoothly operated since launch for more than 8 years.



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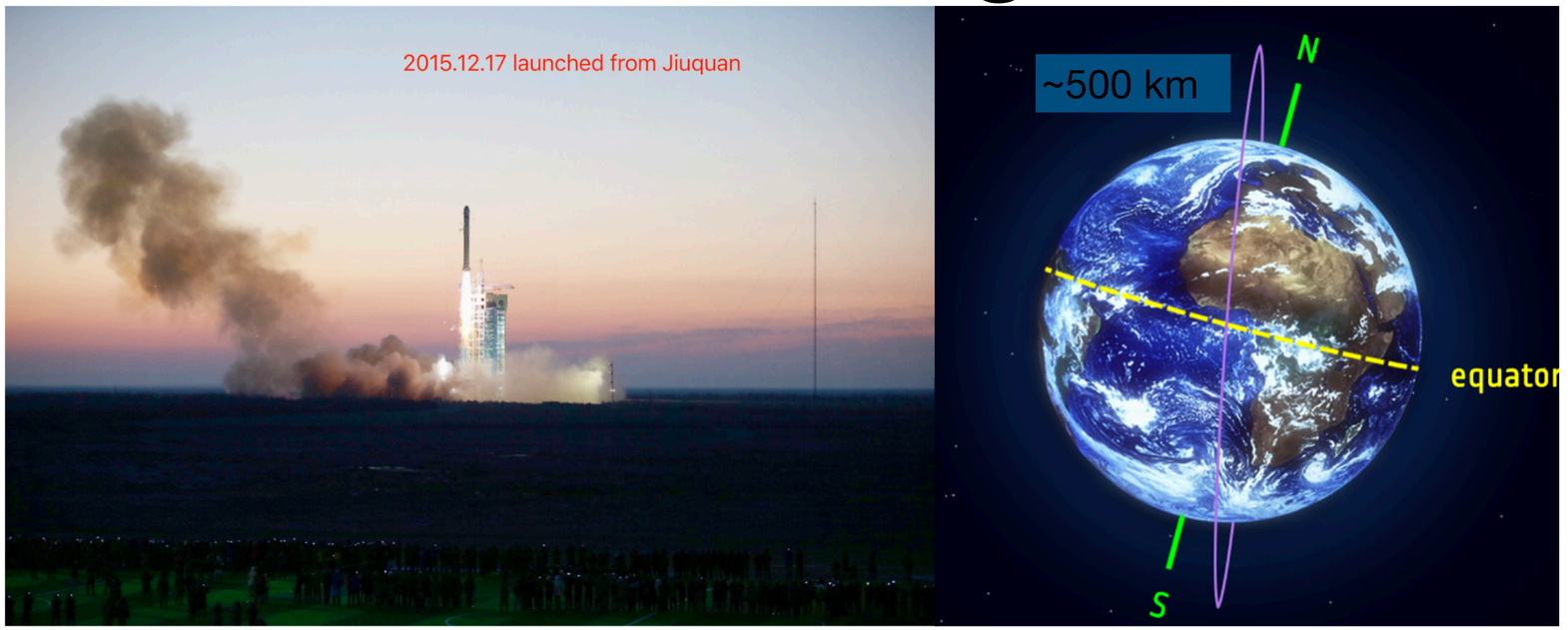

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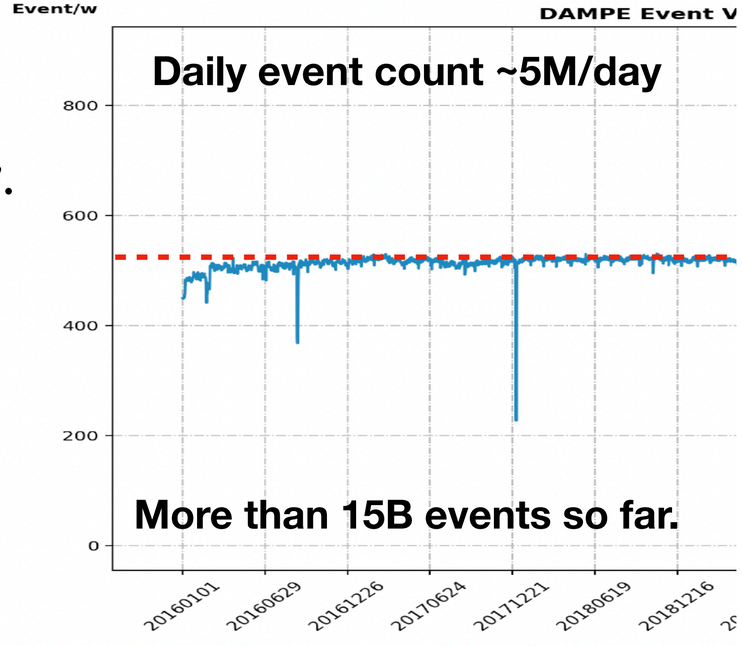
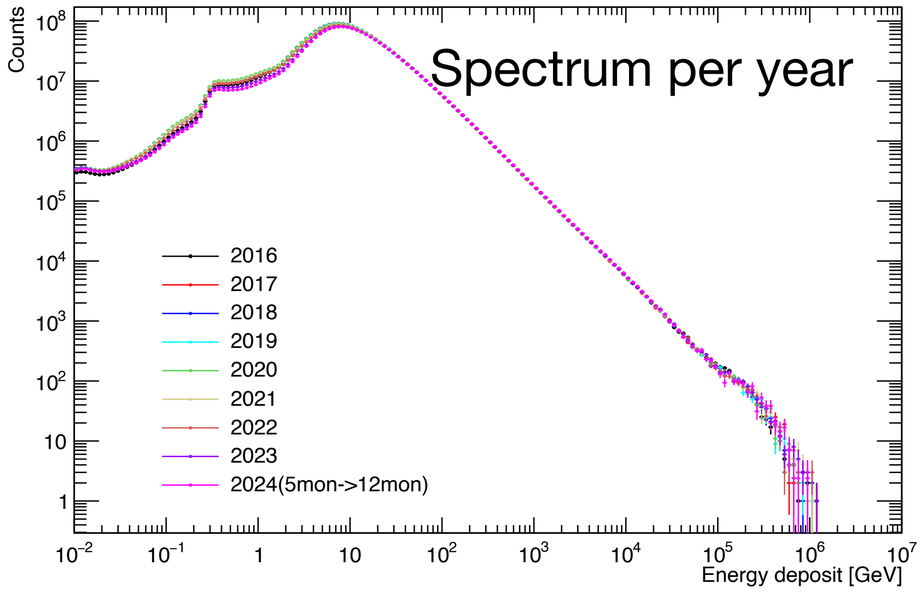


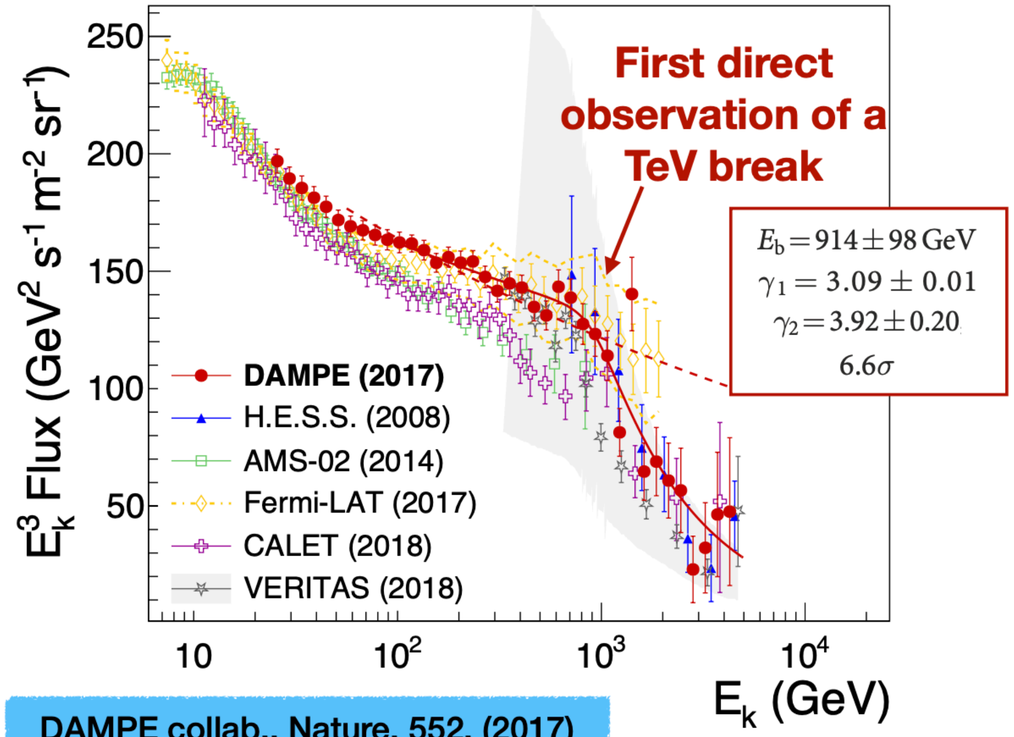


Results

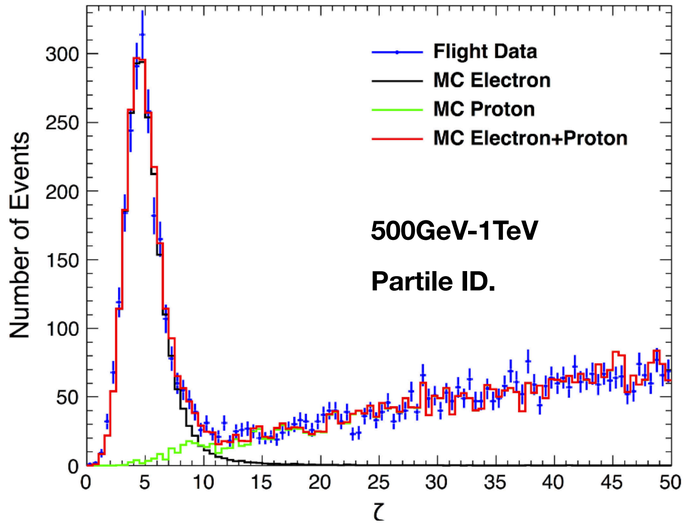
electron+positron spectrum

- Excellent ability of particle identification.
- Excellent energy resolution.

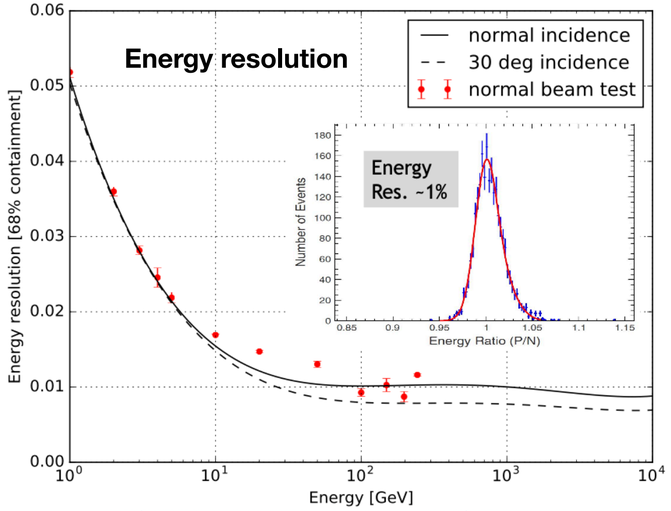
$e^- + e^+$ spectrum:



DAMPE collab., Nature, 552, (2017)



$$\zeta = \mathcal{F}_{\text{last}} \times (\Sigma_i \text{RMS}_i/\text{mm})^4/(8 \times 10^6)$$



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

electron+positron spectrum

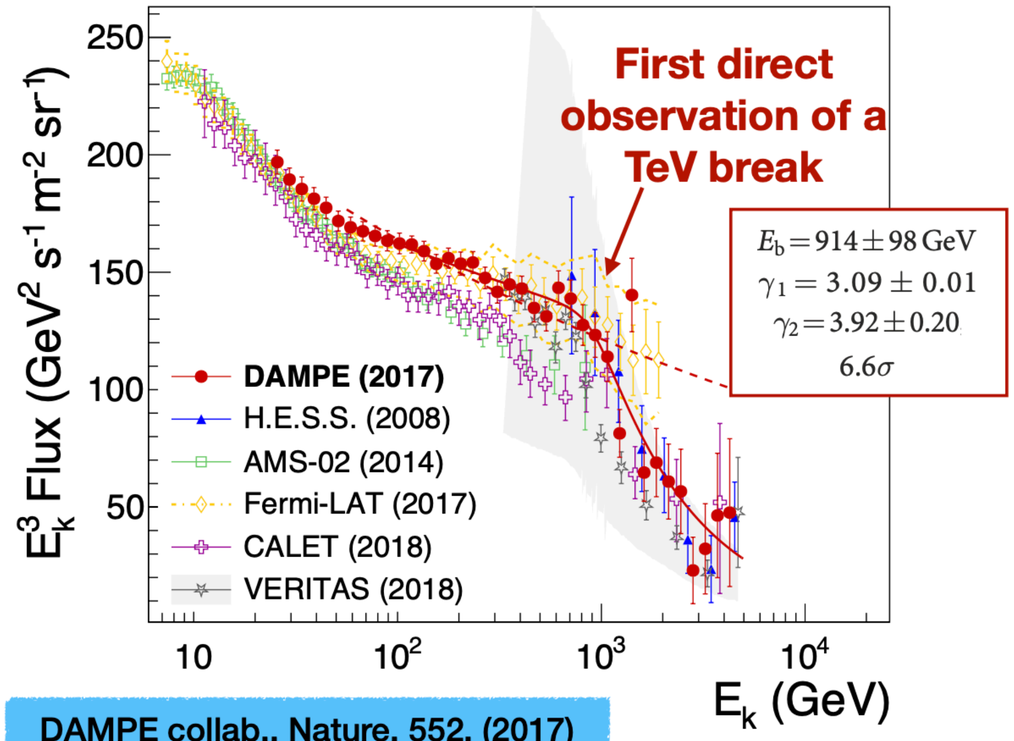
- **Ongoing work.**

  1. Understand and calibrate the detectors very carefully.

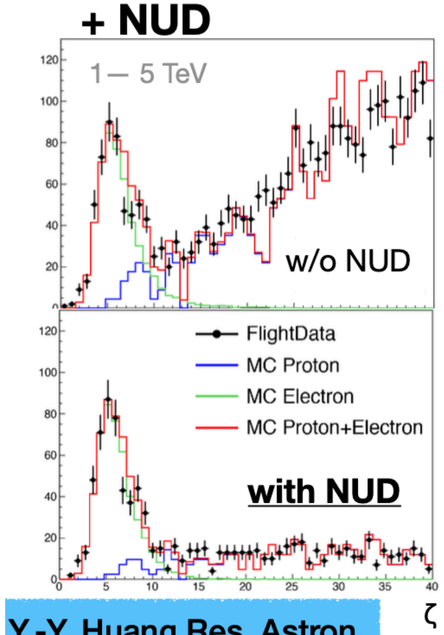
  2. Novel data processing approaches applied.

  3. Applying NUD into data analysis.

$e^- + e^+$ spectrum:

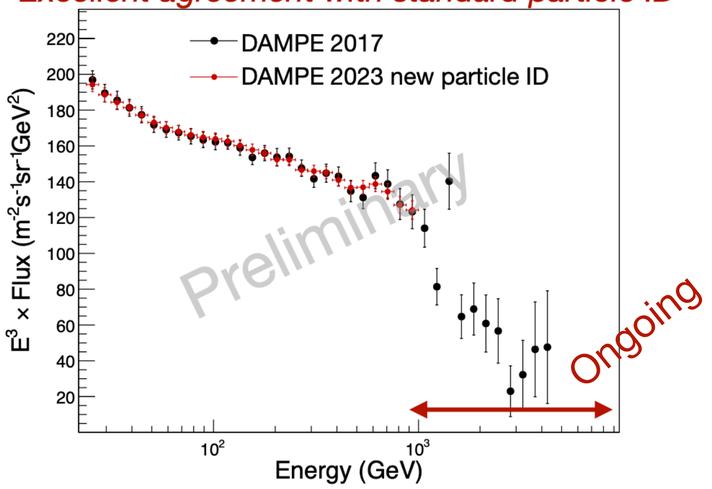


DAMPE collab., Nature, 552, (2017)

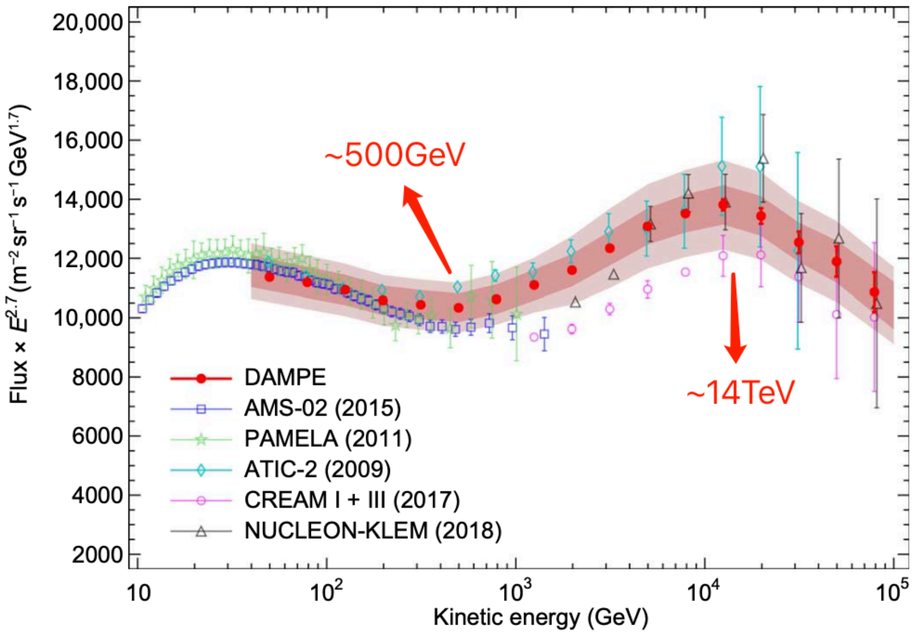


Y.-Y. Huang Res. Astron. Astrophys. (2020)

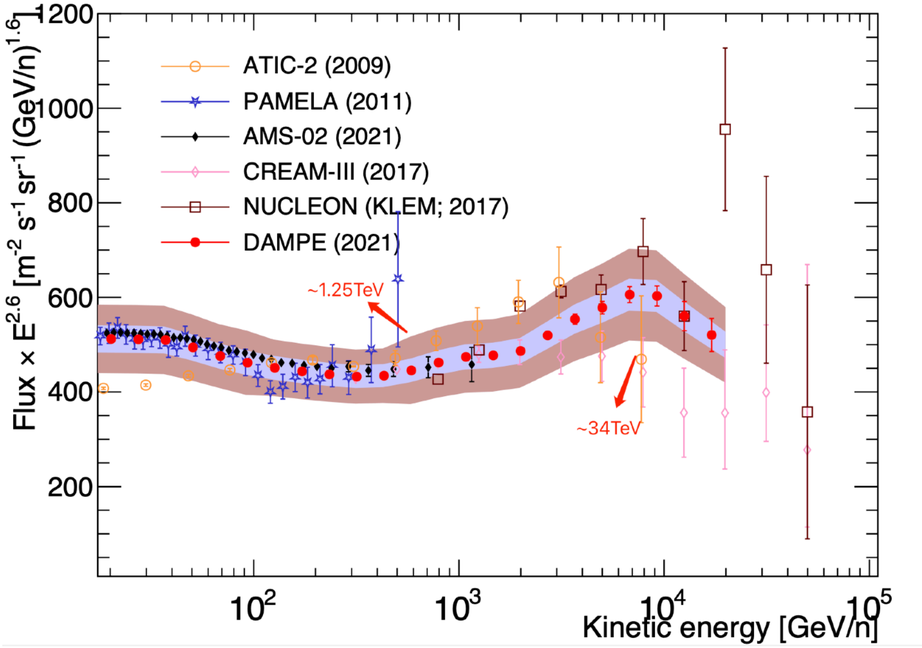
Excellent agreement with standard particle ID



Proton,Helium

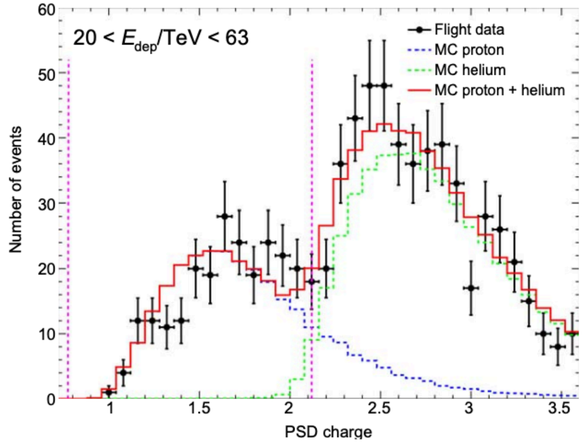


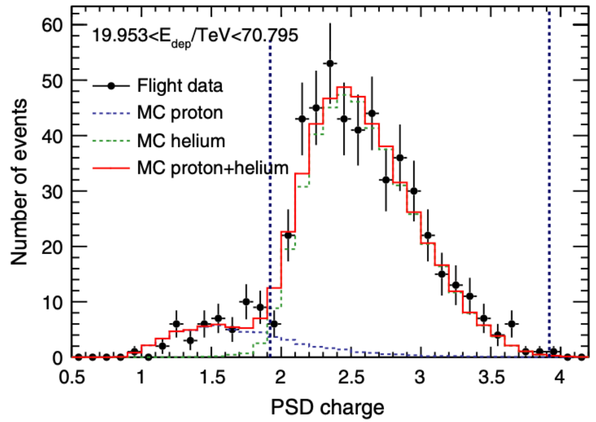
DAMPE Collaboration, *Sci. Adv.* 2019;**5**:eaax3793



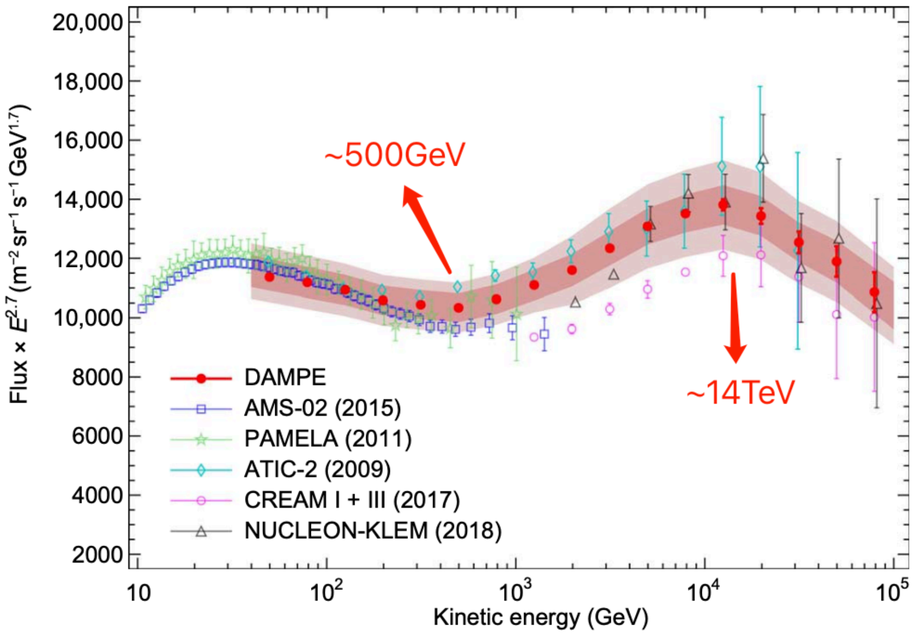
F. Alemanno et al. PRL 126, 201102 (2021).

1. **Large acceptance.**
2. **Good charge resolution.**

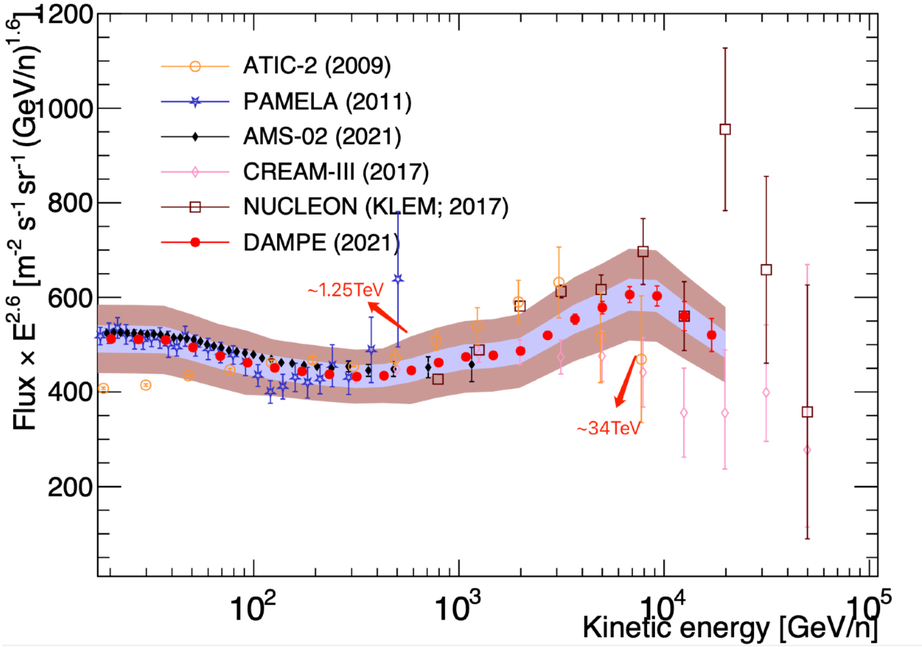




Proton,Helium



DAMPE Collaboration, *Sci. Adv.* 2019;**5**:eaax3793



F. Alemanno et al. PRL 126, 201102 (2021).

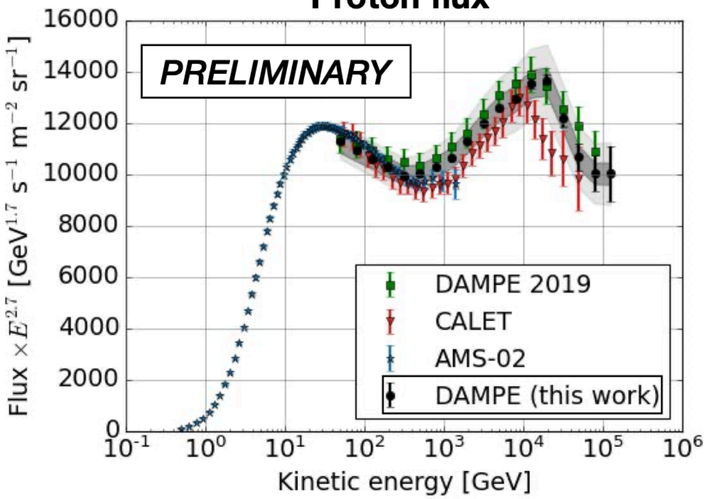
✓**Confirm the hardening at around hundreds of GV.**

✓**Strong detection of softening around ~10TeV with high confidence level.**

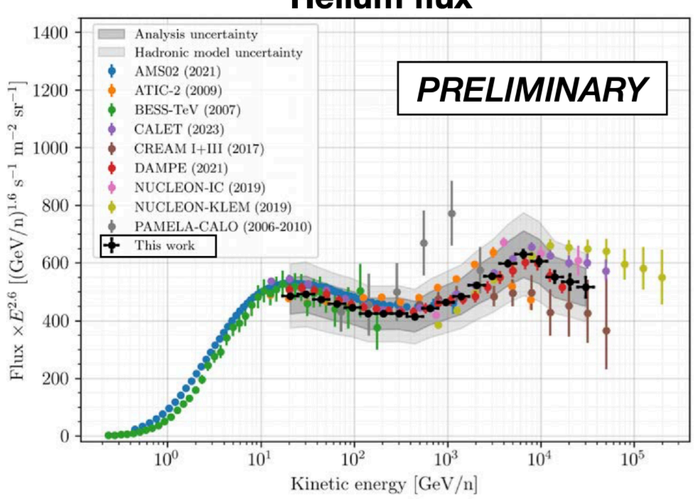
Proton,Helium (new updates)

1. Much more deepening understanding for the detectors and more statistics at higher energies.
2. New data processing approaches applied, i.e. ML tracking and Particle ID.
3. Updates and new approaches on detector calibration. Saturation.

Proton flux



Helium flux

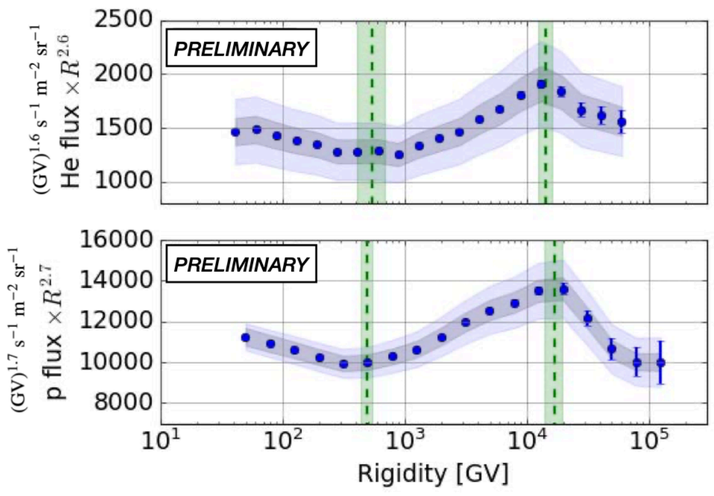


More data, reduced statistical uncertainty

Extension towards 1 PeV

A good match with previous DAMPE results on the proton flux (2019) and the helium flux (2021)

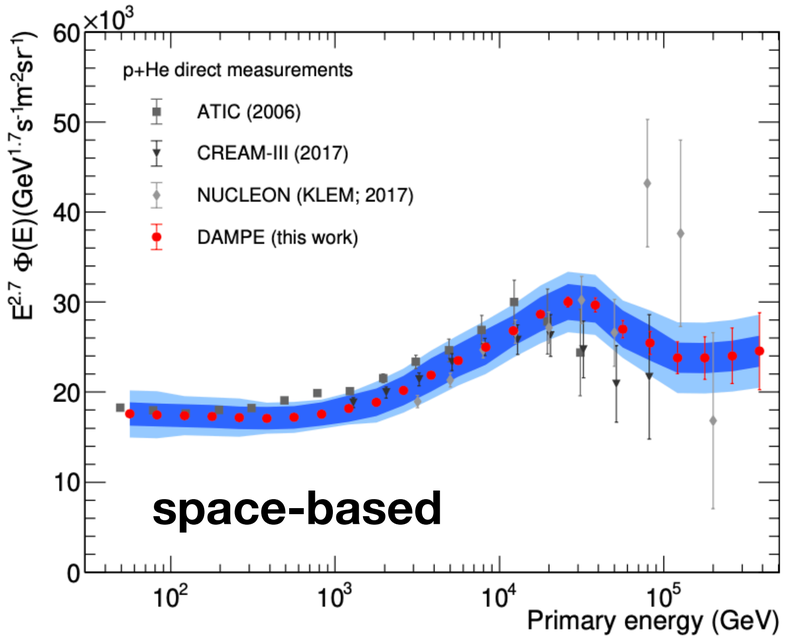
Rigidity

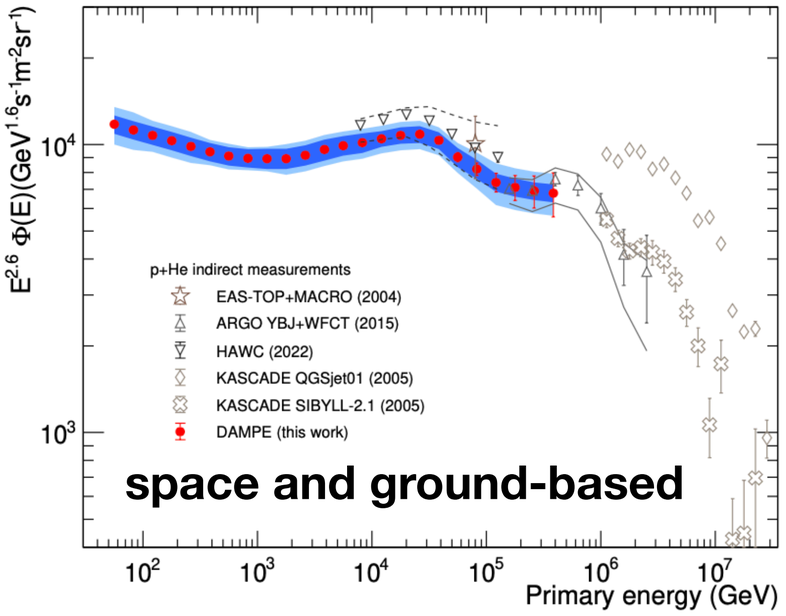


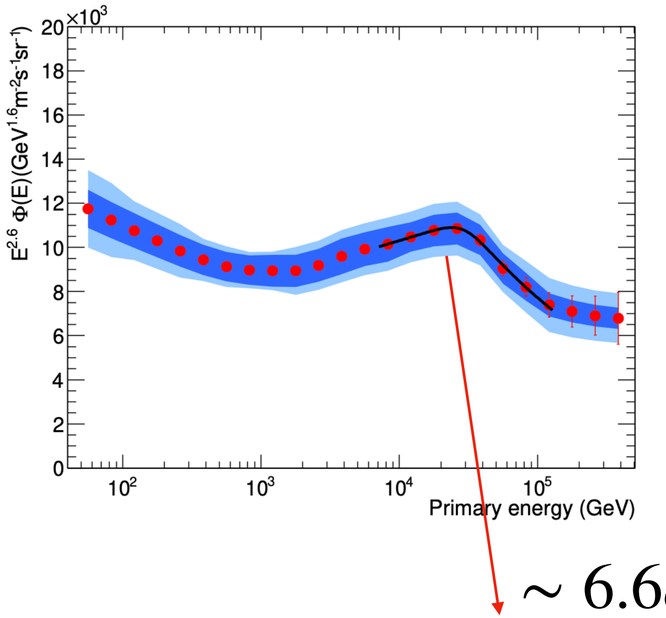
✓ Very consistent with published results.

✓ Fits for spectra breaks from DAMPE's proton and helium are both in favor of charge-dependent hypothesis.

Proton+Helium spectrum







Accepted by PRD. Letter in May 2024

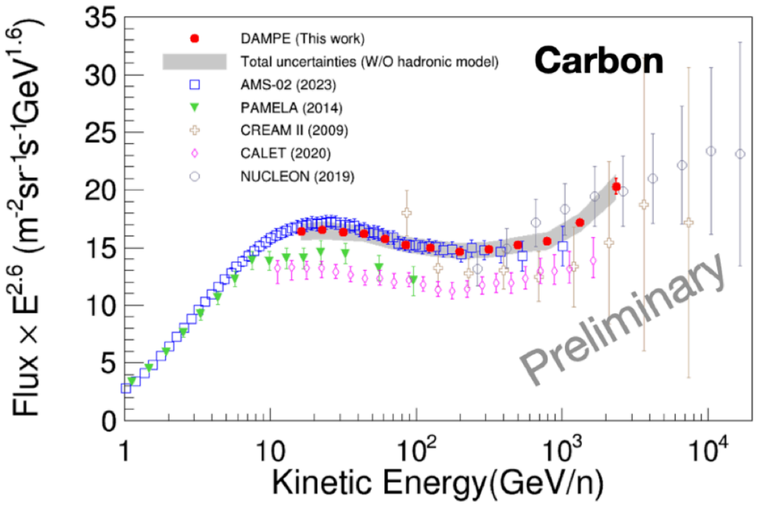
	Proton	Helium	Proton+Helium
E_b (TeV)	$13.6^{+4.1}_{-4.8}$	$34.4^{+6.7+11.6}_{-9.8-0.0}$	$28.8^{+6.2+2.9}_{-4.4-0.0}$
γ	2.60 ± 0.01	$2.41^{+0.02+0.02}_{-0.02-0.00}$	$2.512^{+0.021+0.01}_{-0.024-0.00}$
$\Delta\gamma$	-0.25 ± 0.07	$-0.51^{+0.18+0.01}_{-0.20-0.00}$	$-0.427^{+0.057+0.00}_{-0.066-0.066}$

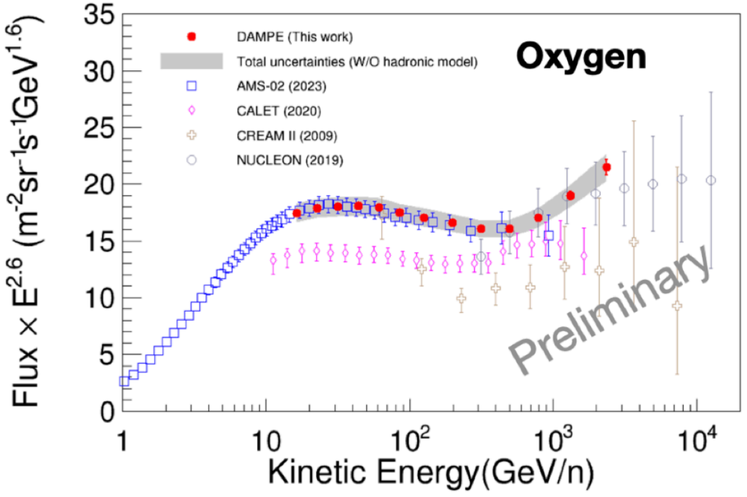
✓**Confirm the softening at ~15TV.**

✓**Showing the hint for a re-hardening above 100TeV.**

✓**Crucial bridge to ground-based experiments.**

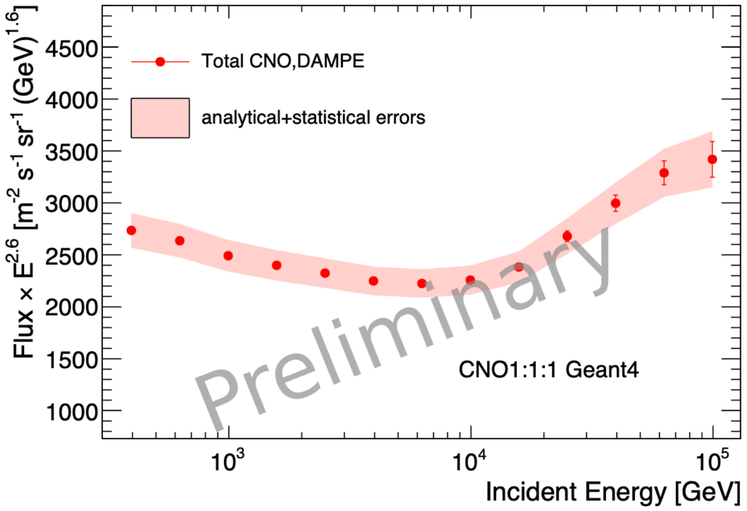
C,O and CNO

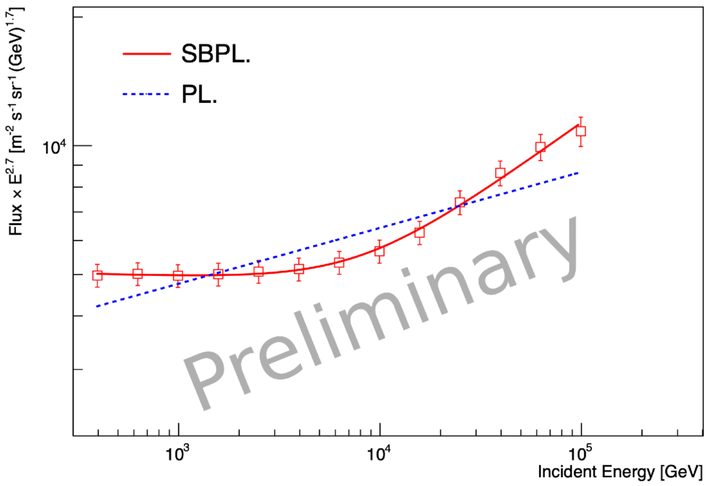




✓Hardening for both C and O are confirmed.

✓CNO combined spectrum also confirms the hardening at ~8TeV

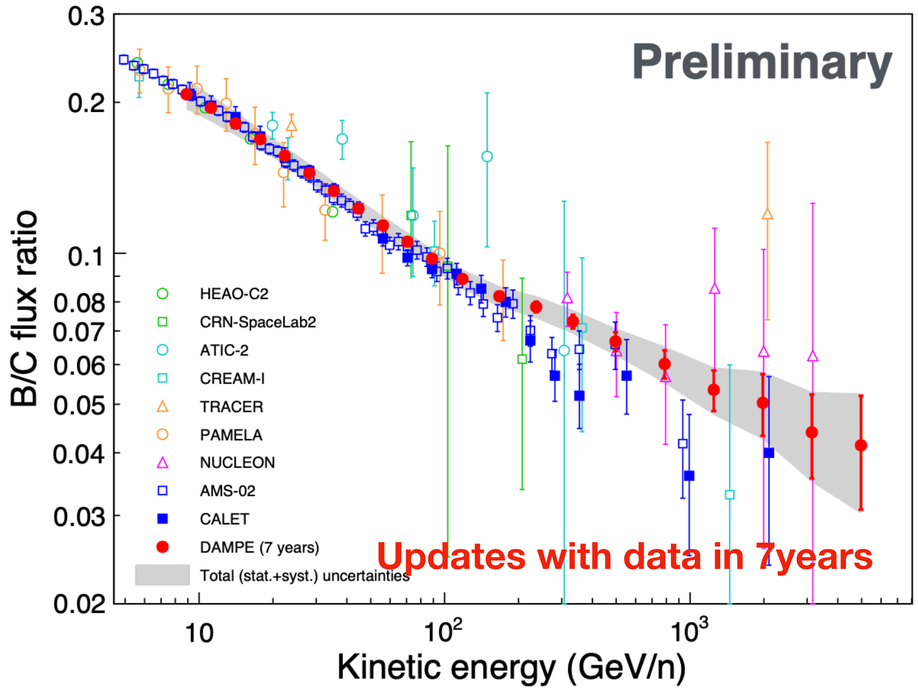




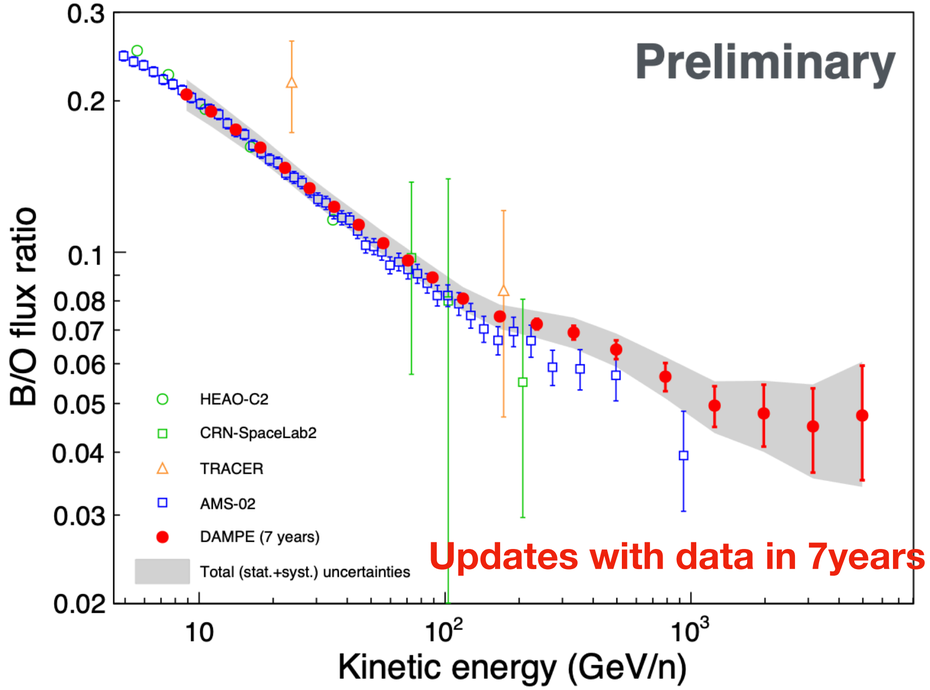
Parameters	Hardening
Fit range	[380 GeV-100 TeV]
F_0	3.94e-5 ± 1.2e-6 [$m^2 s^{-1} sr^{-1} GeV^{-1}$]
γ_0	−2.71 ± 0.04
E_b	8 TeV ± 4 TeV
$\Delta\gamma$	0.35 ± 0.04
s	5 (fixed)

Secondary-primary ratio

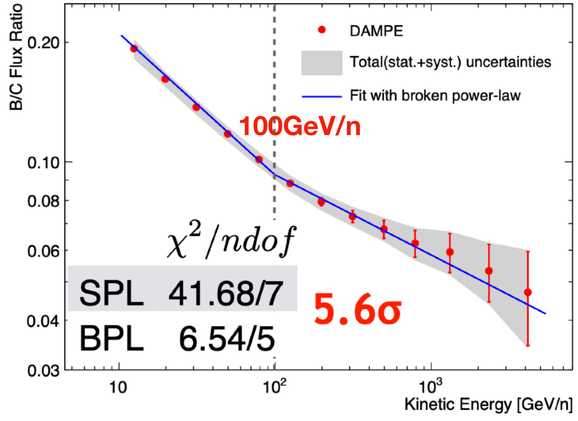
B/C flux ratio

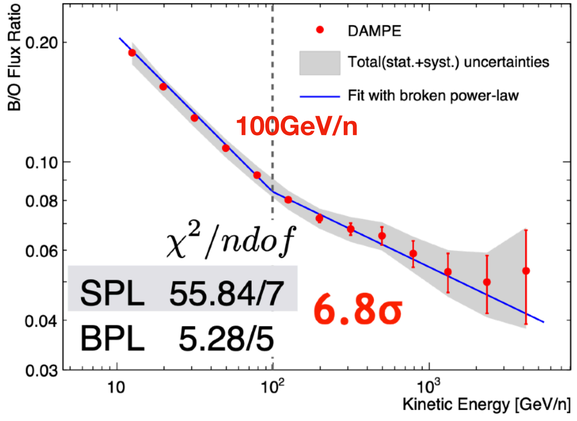


B/O flux ratio



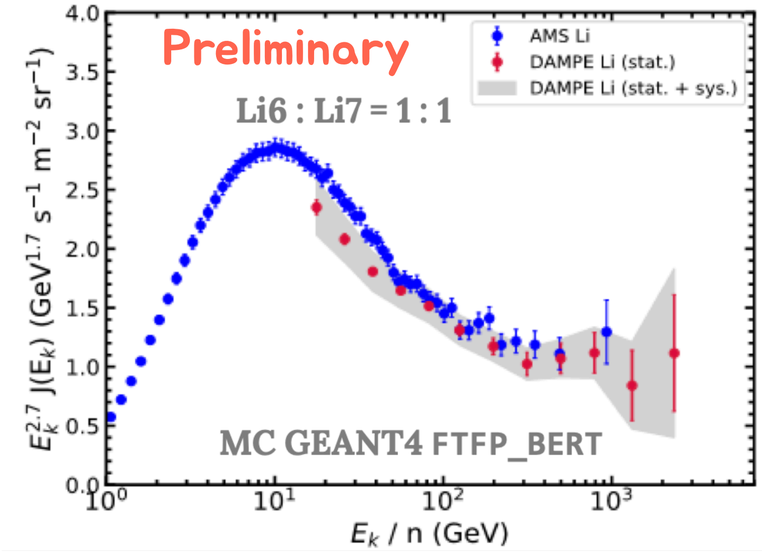
DAMPE Collaboration, Science Bulletin 67 (2022) 2162–2166

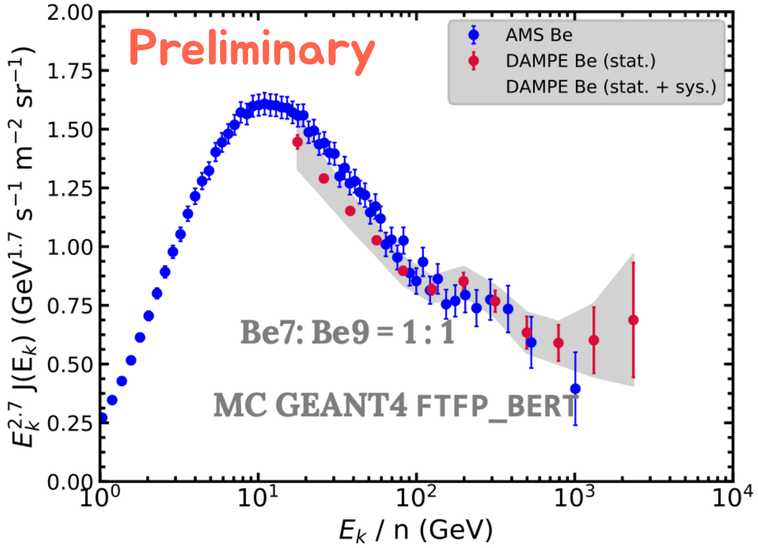


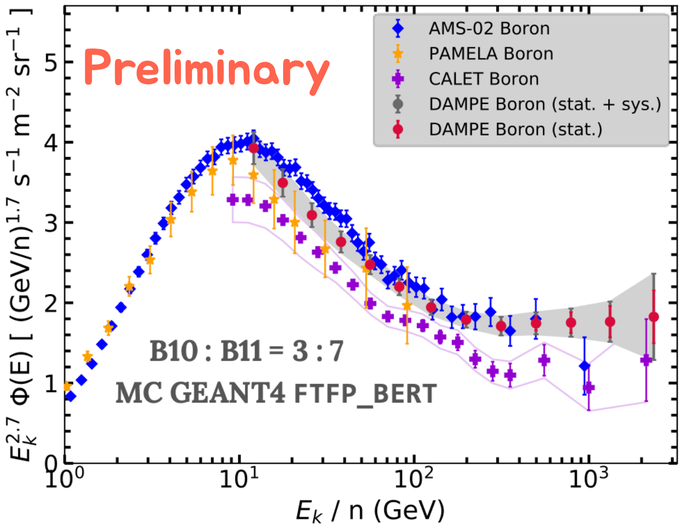


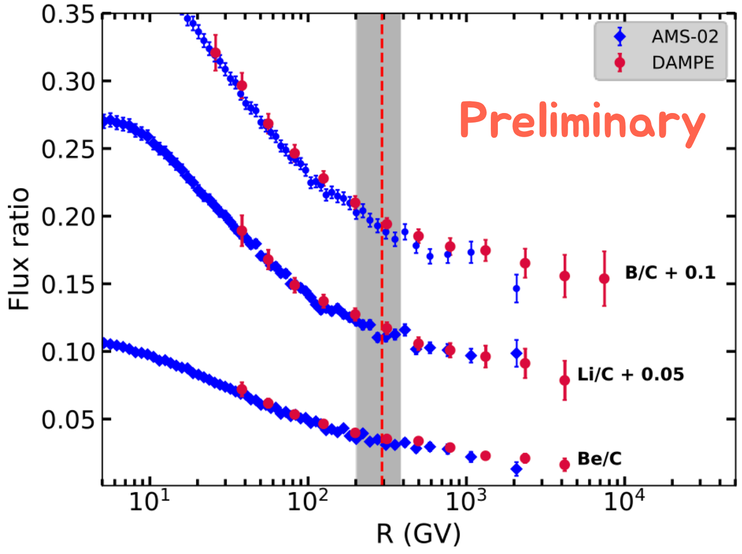
✓**Challenging the conventional propagation model of GCR.**

Secondary spectra, Li, Be and B.





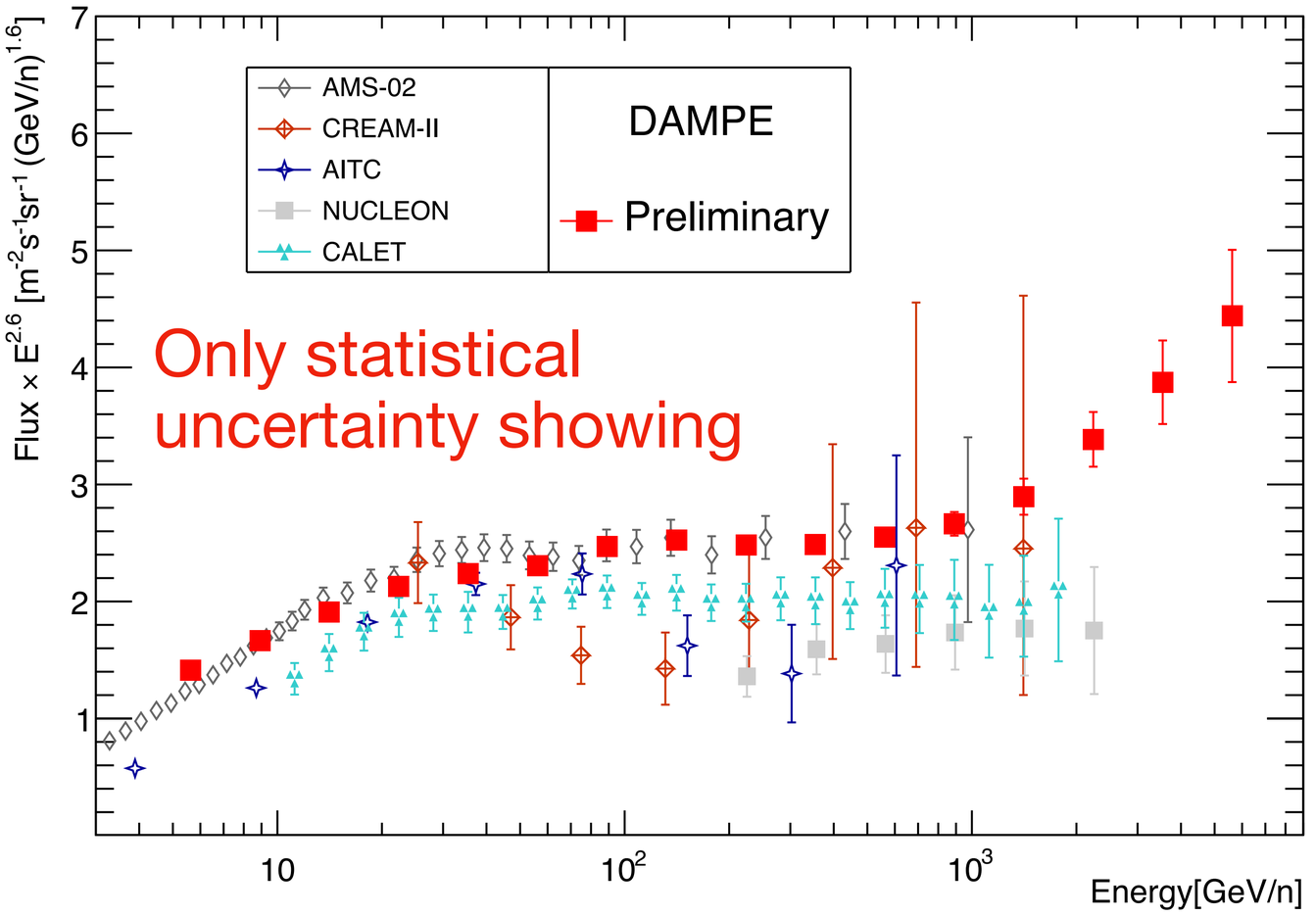




✓ **Hardening features in secondaries are also confirmed.**

✓ **Secondary-primary ratios show a rigidity-dependence hardening.**

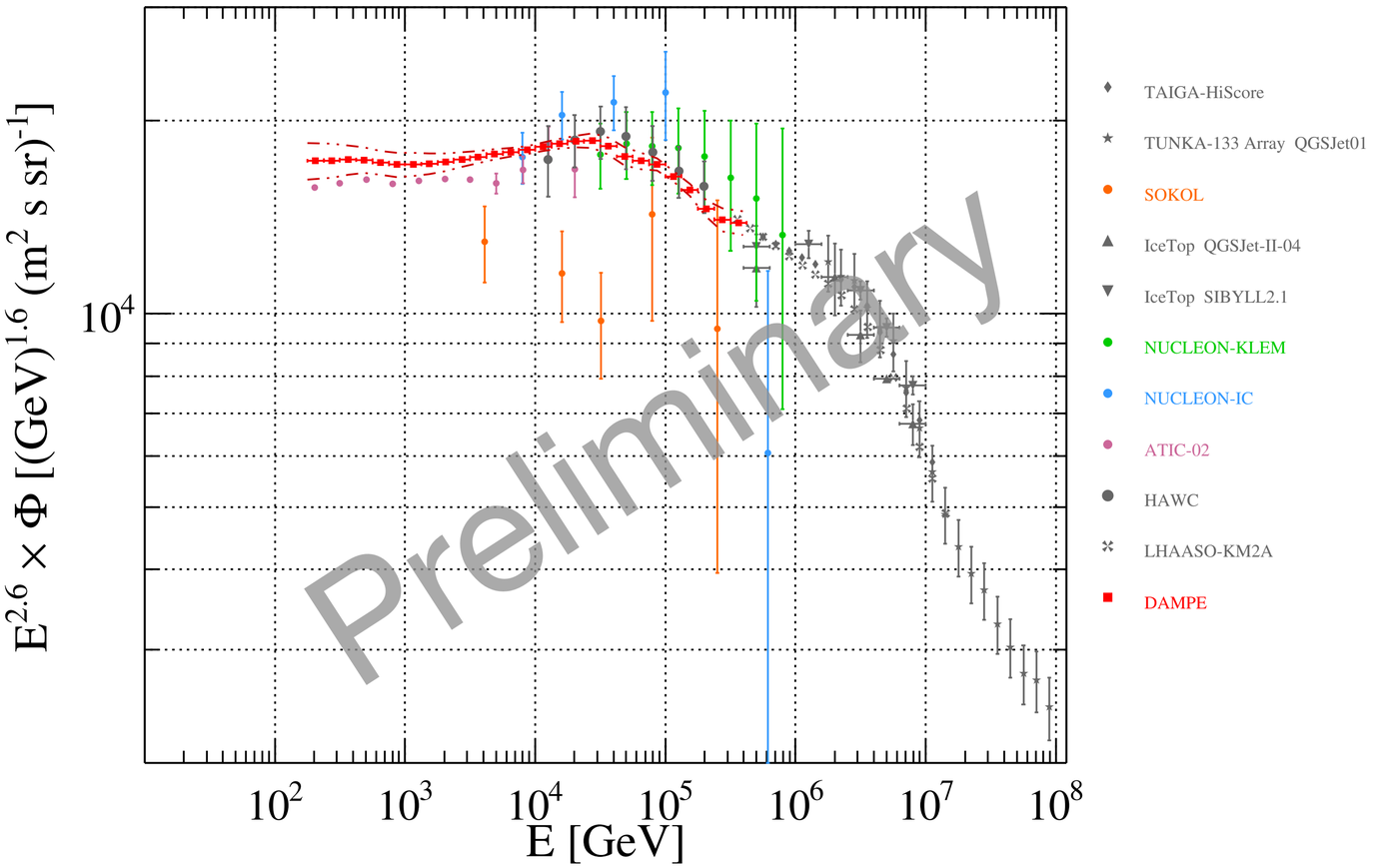
Iron spectrum



✓Preliminary, the hardening of iron spectrum with DAMPE is observed.

✓Spectrum shows similar feature below 1TeV/n with AMS-02 and CALET.

All-particle spectrum

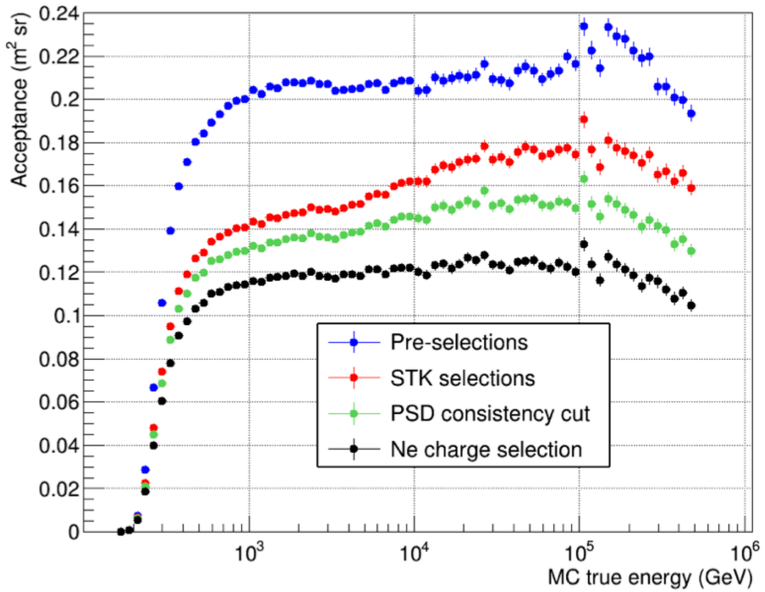


✓Preliminary, the hardening at around 1TeV is observed, the softening at around 30TeV is also observed.

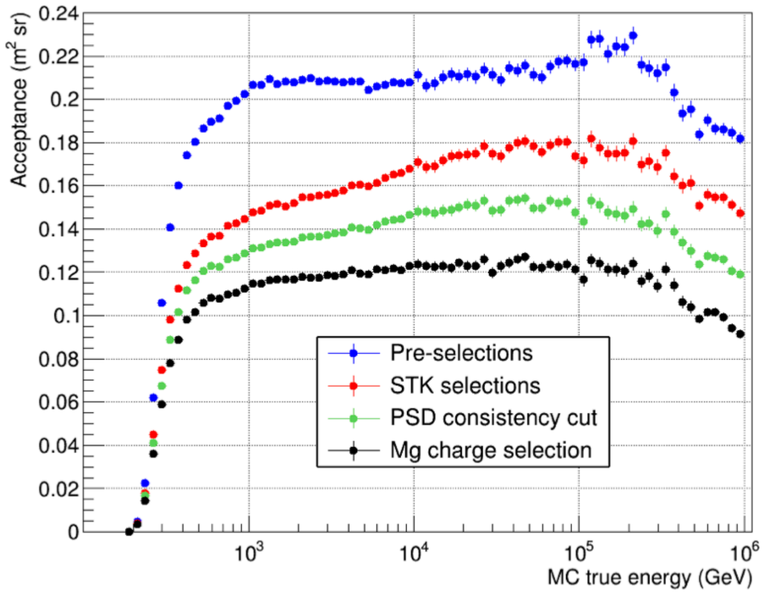
✓Much more and higher MC data is needed for extension to much higher energies (PeV).

Other elements.

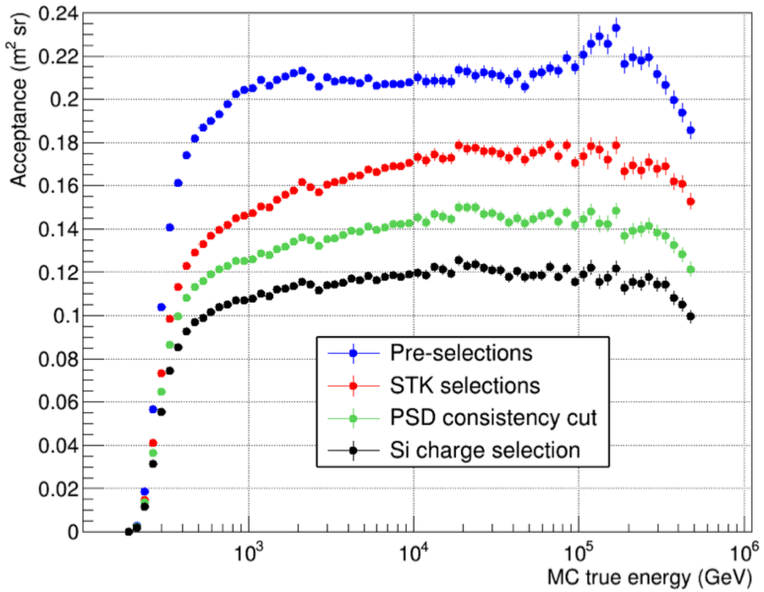
Neon



Magnesium



Silicon

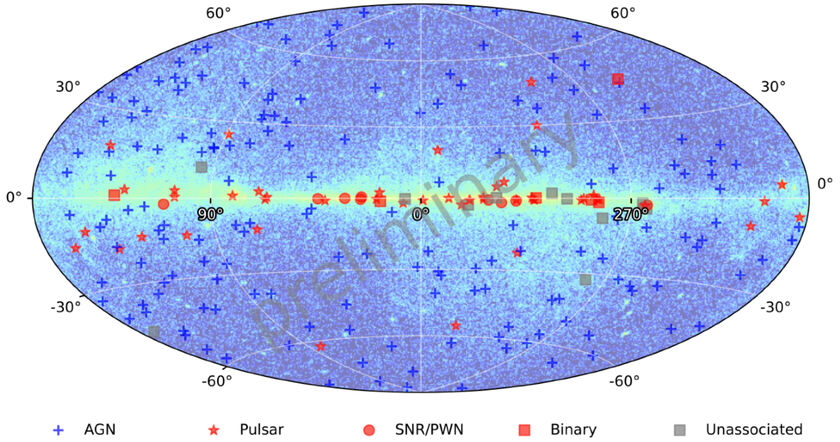


Ni spectrum

- **More studies are ongoing…**

Gamma-ray astronomy

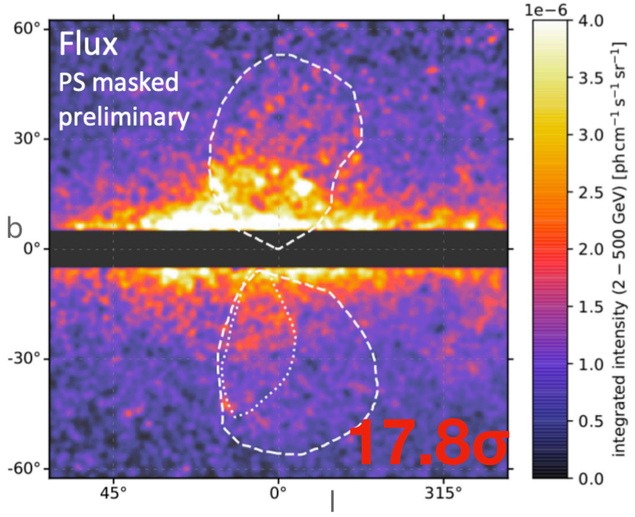
~250 point sources detected an studies in 7 years

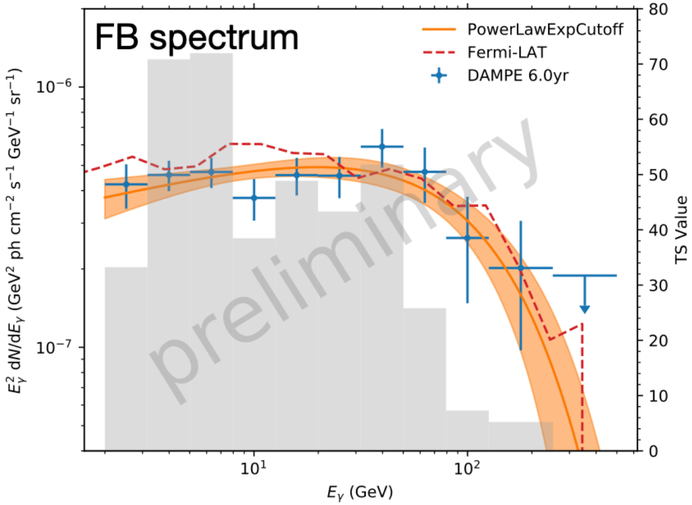


Sky map & Sources

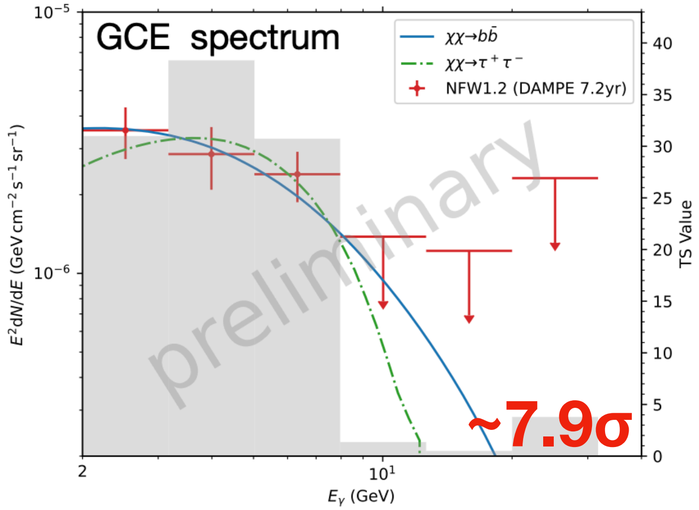
Source Type	Number
AGN	175
Pulsar	46
SNR/PWN	10
Binary	6
Unassociated	11
Total	248

FB map



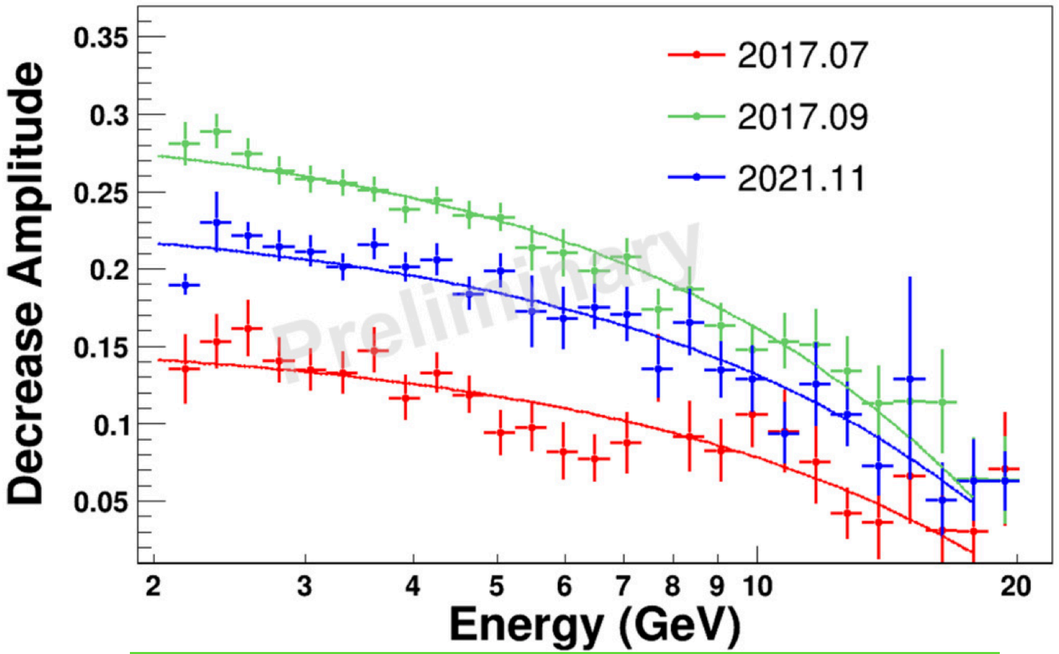


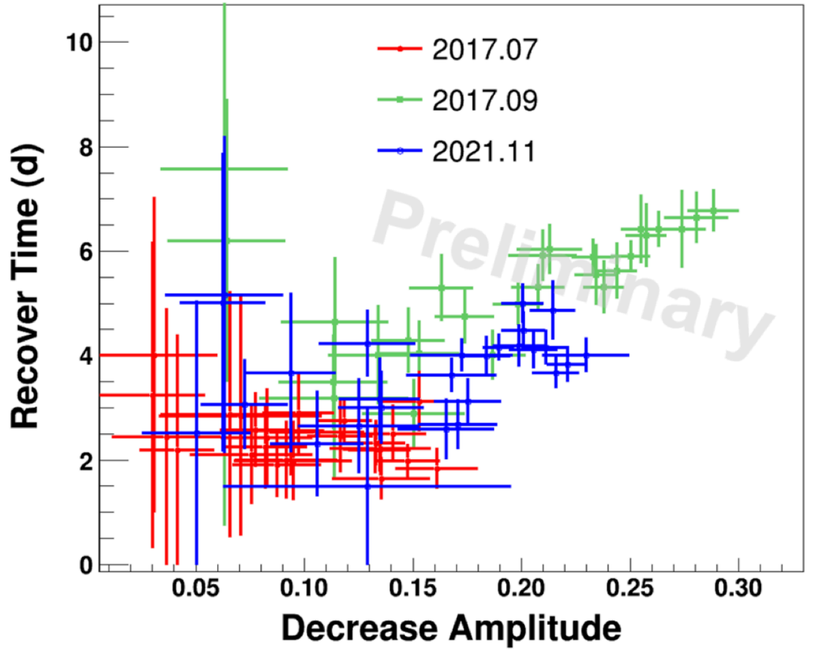
GCE



Heliosphere physics

Forbush decrease



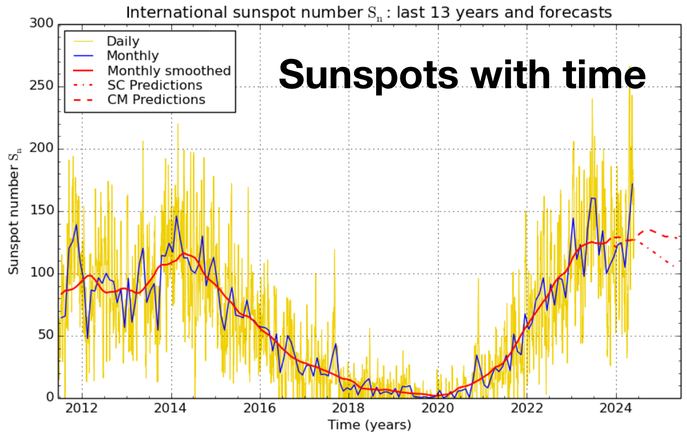


DAMPE Collaboration, 2021 ApJL. 920 L43

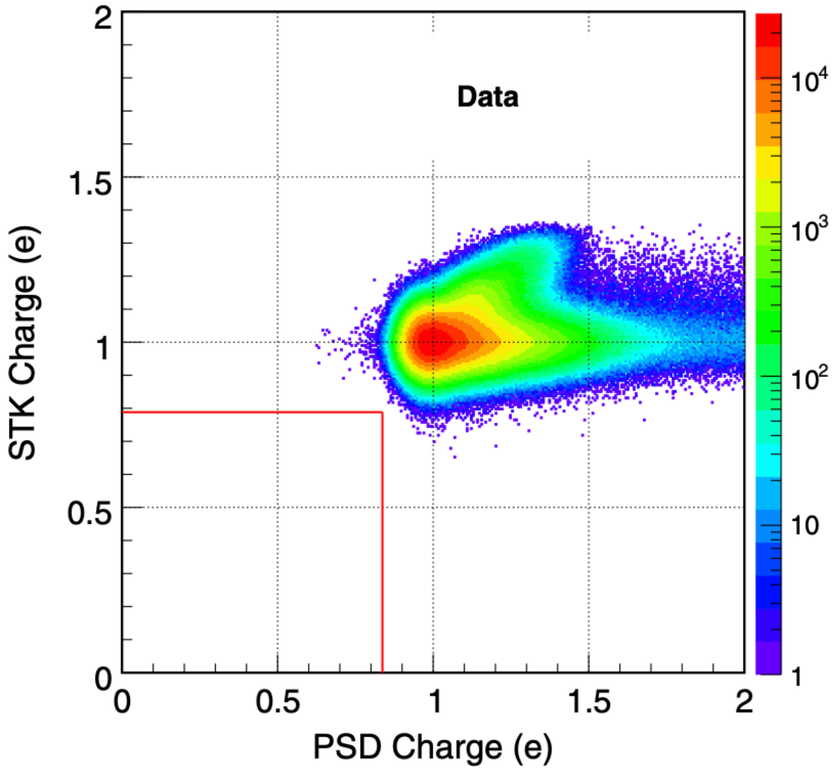
✓Approaching the maximum of solar cycle-25, DAMPE can play a key role in understanding the heliosphere.

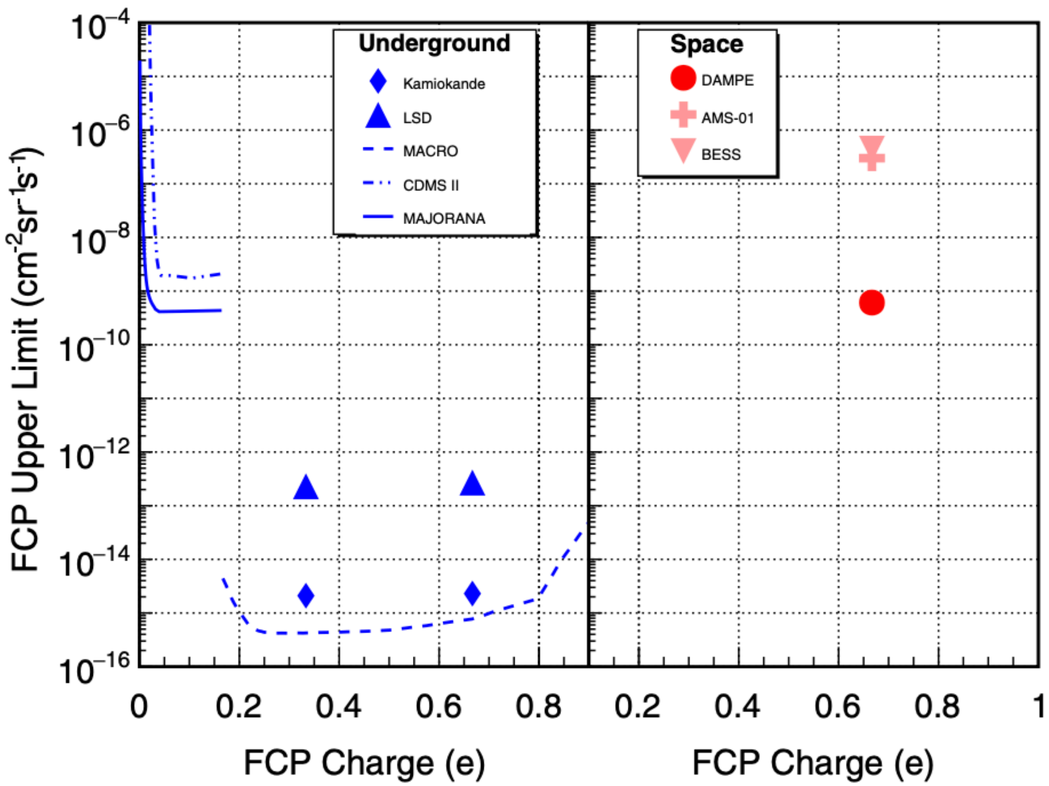
✓Particularly, DAMPE crosses over the Earth's two poles in each orbit.

✓More events observed.



Searching for fractional particles





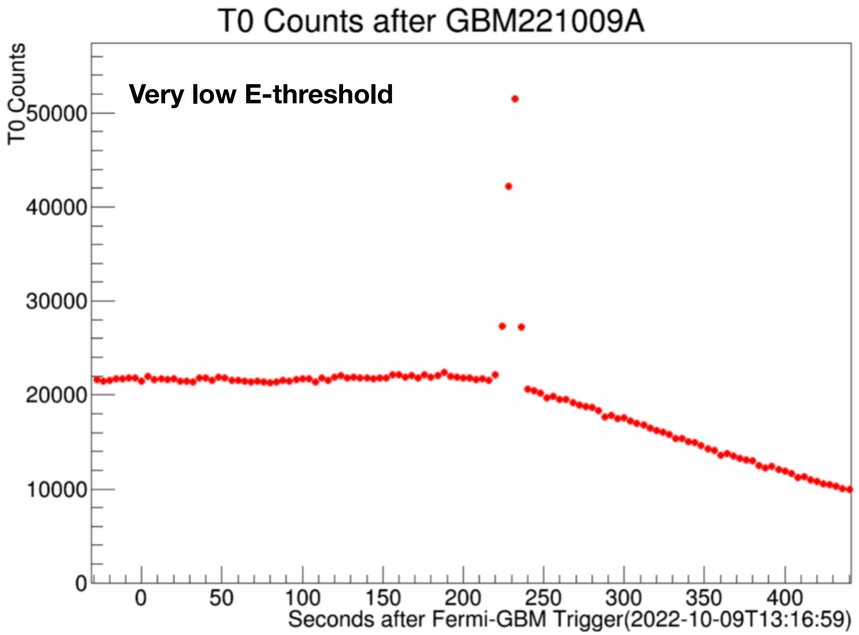
DAMPE Collaboration, PRD. 106, 063026 (2022)

✓**Most stringent limit among space-based experiments at a few GeV.**

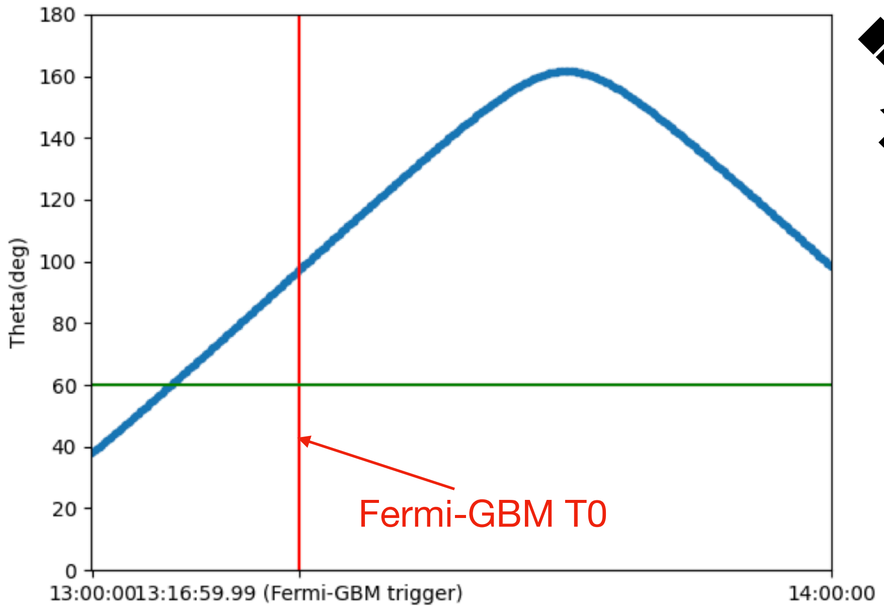
Potential in the era of MM.

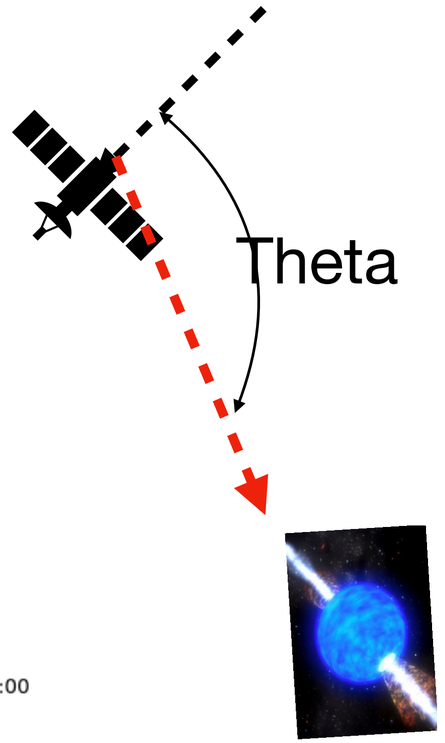
GRB221009A

T0 (trigger) counts



Observation_1hr





✓Not lucky enough, but we still recorded a significant excess of side-in “events”.

✓More patience.

Summary

- **DAMPE mission**

  1.DAMPE has been operating smoothly since Dec. 2015, for over 8 years.

  2.Largest acceptance in-flight and good performance.

  3.Good potential for extension above 100TeV.

  4.Stable operation to collect much more data.

- **Sciences**

  1.Direction observation of break at TeV in $e^{\pm}$ spectrum.

  2.P&He show the softening around ~14TV, suggesting Z-dependent.

  3.P+He confirms the softening and shows the hint above 100TeV.

  4.C,O and CNO confirm the hardening at hundreds of GV, suggesting a Z-dependent softening.

  5.B/C,B/O show the significant hardening above 100TeV/n, challenging the conventional models.

  6. Secondary elements, Li,Be,B confirm the hardening around hundreds of GV.

  7. Preliminary iron spectrum shows the hardening around 1TeV/n for the first time.

  8. Confirm the FB. and GCE as a independent measurement.

  9. Heliosphere physics in terms of low energy electron measurements, unique point of view.

  10.Most stringent constraint for FCP among space-based experiment.

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Thank you!