

Latest results from the DAMPE space mission



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Topics in Astroparticle and Underground Physics
TAUP 2023
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DAMPE science goals



High energy particle detection in space

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

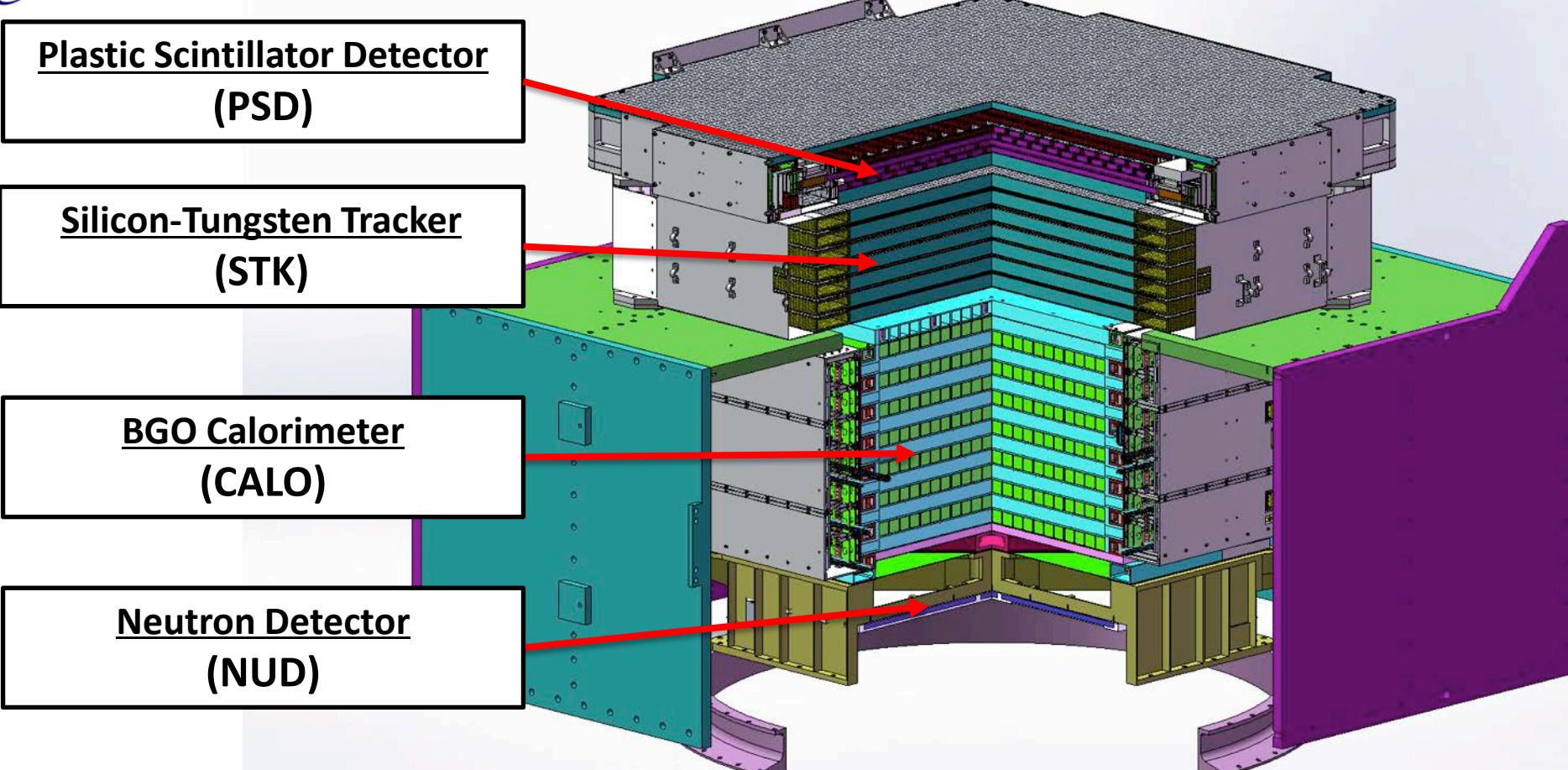
I will focus on
these topics, given
the talk duration



Detection of
10 GeV - 10 TeV e/ γ
50 GeV - 200 TeV protons and nuclei
with excellent energy resolution , tracking precision
and particle identification capabilities

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

The detector



- 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

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 synchronous

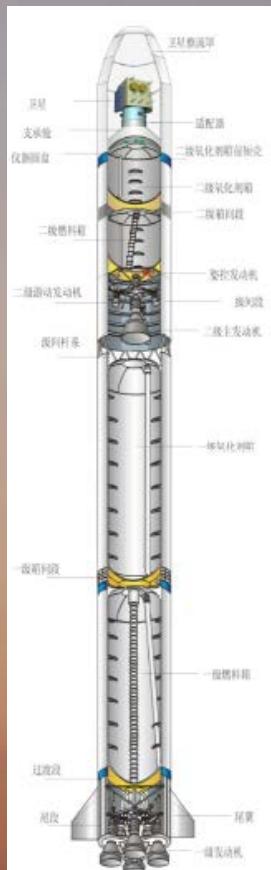
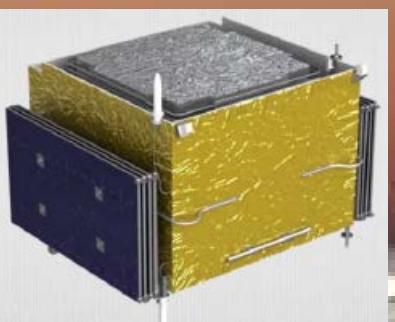
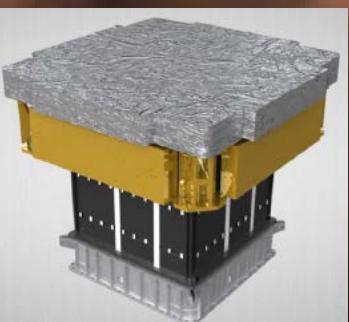
Altitude: 500km

Inclination: 97.41°

Period: 95 minutes

Downlink: 16 GB / day

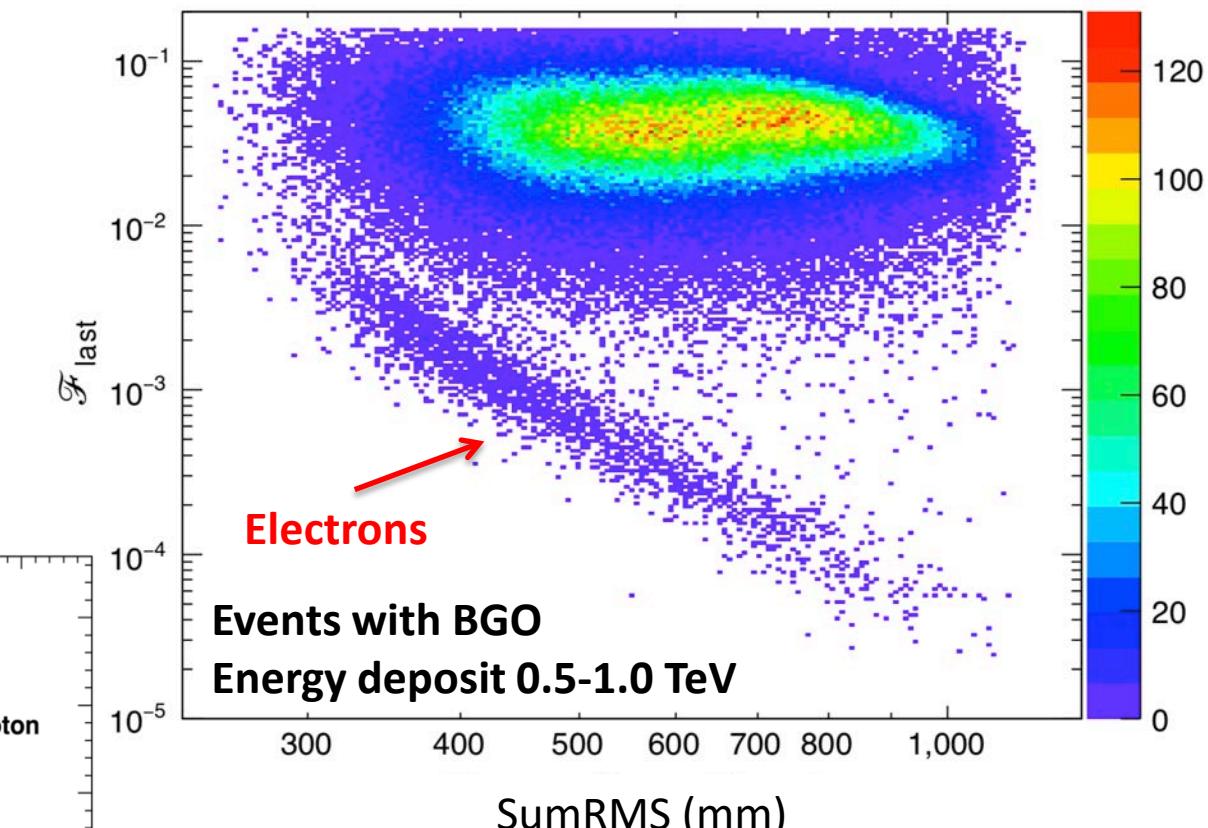
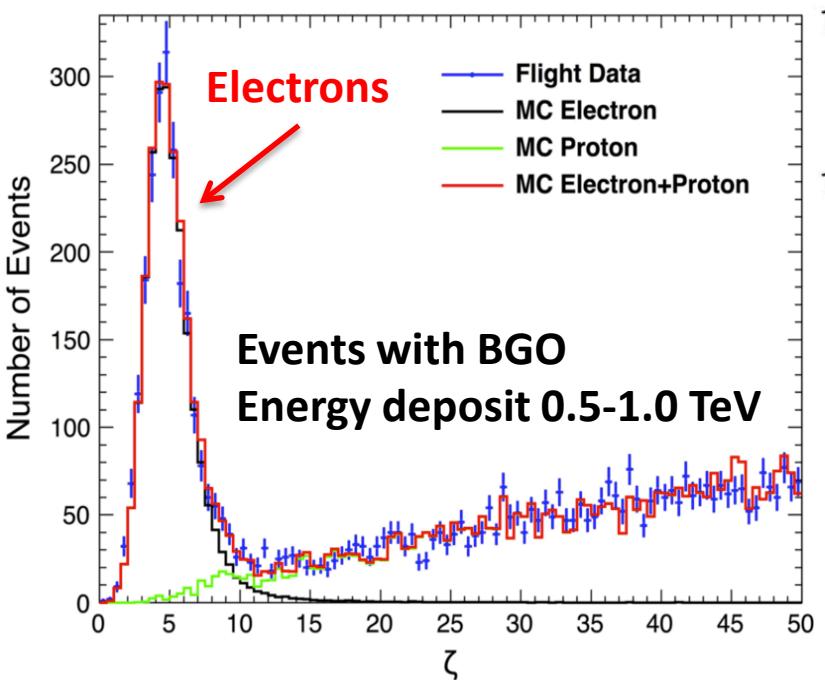
Lifetime: > 3 years



Electron IDentification

$\mathcal{F}_{\text{last}}$ = fraction of energy deposit in the last BGO layer with hits

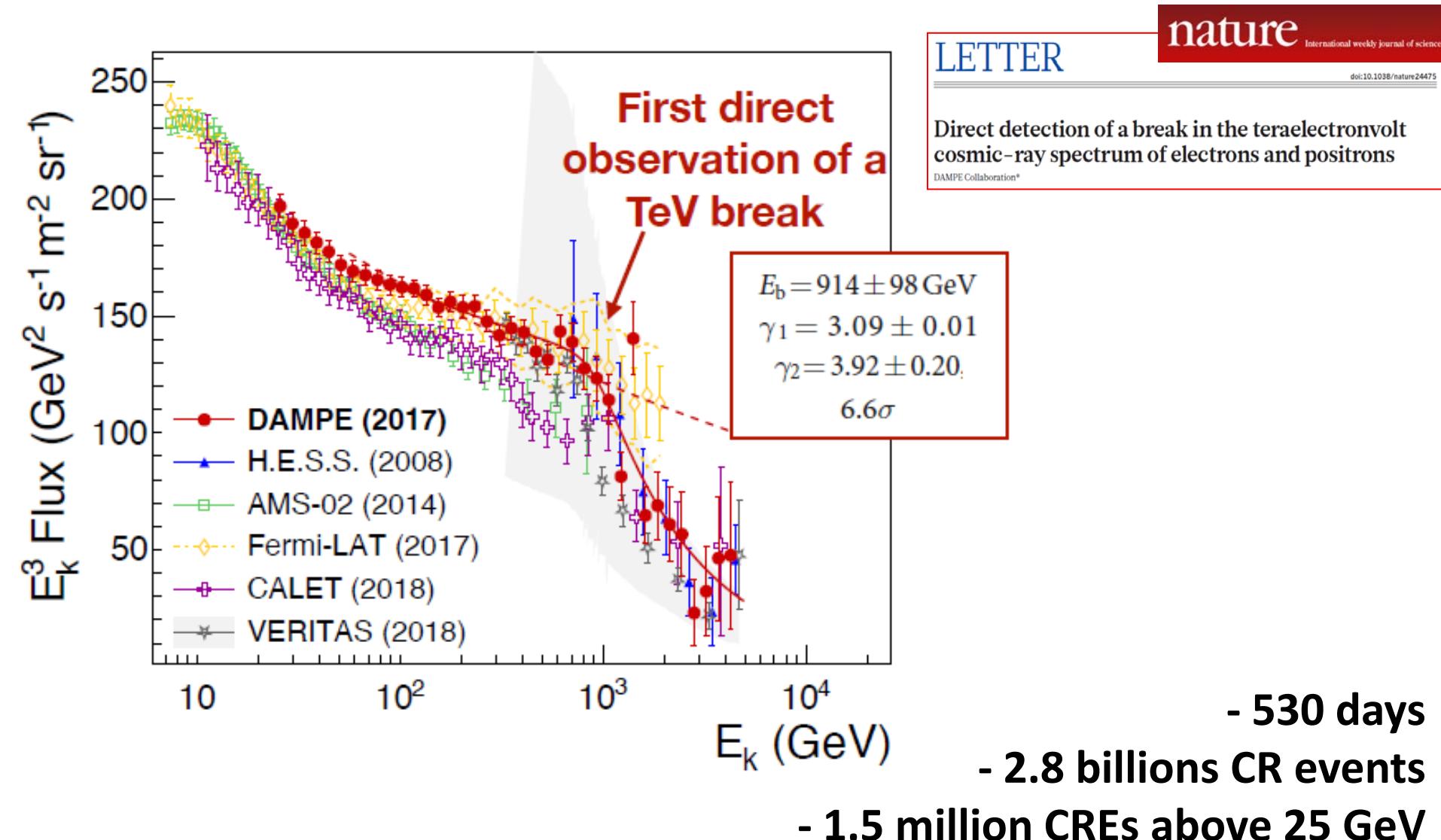
$$RMS_i = \sqrt{\frac{\sum_j (x_{j,i} - x_{c,i})^2 E_{j,i}}{\sum_j E_{j,i}}}$$



SumRMS = Sum of single layer RMS values

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

The DAMPE ($e^+ + e^-$) spectrum



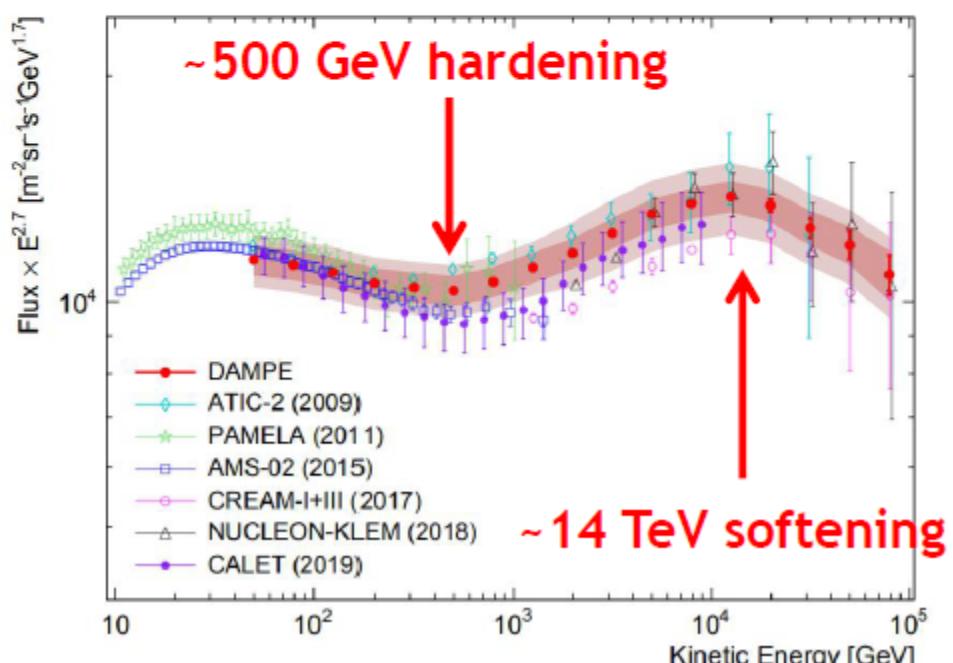
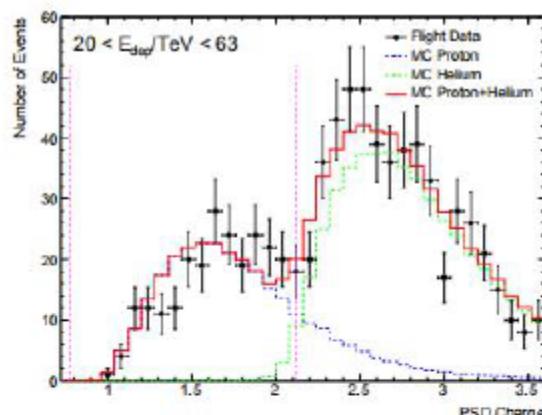
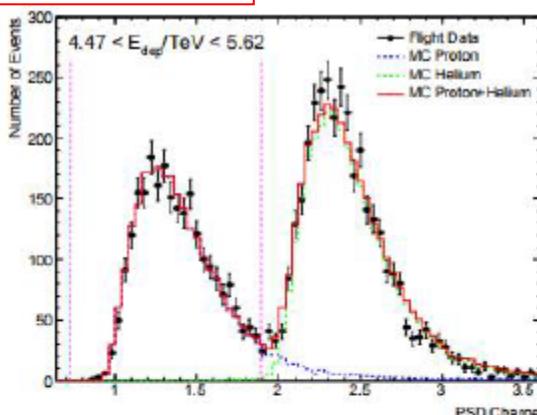
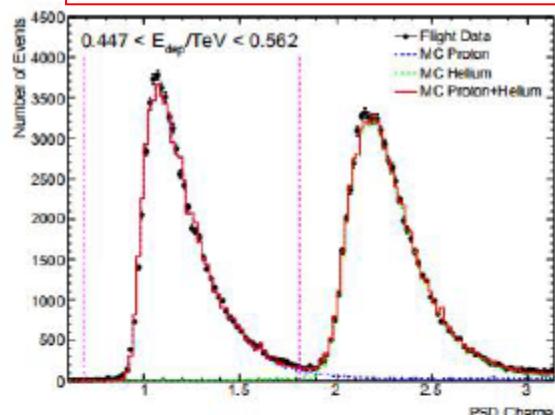
The DAMPE proton spectrum



SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

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



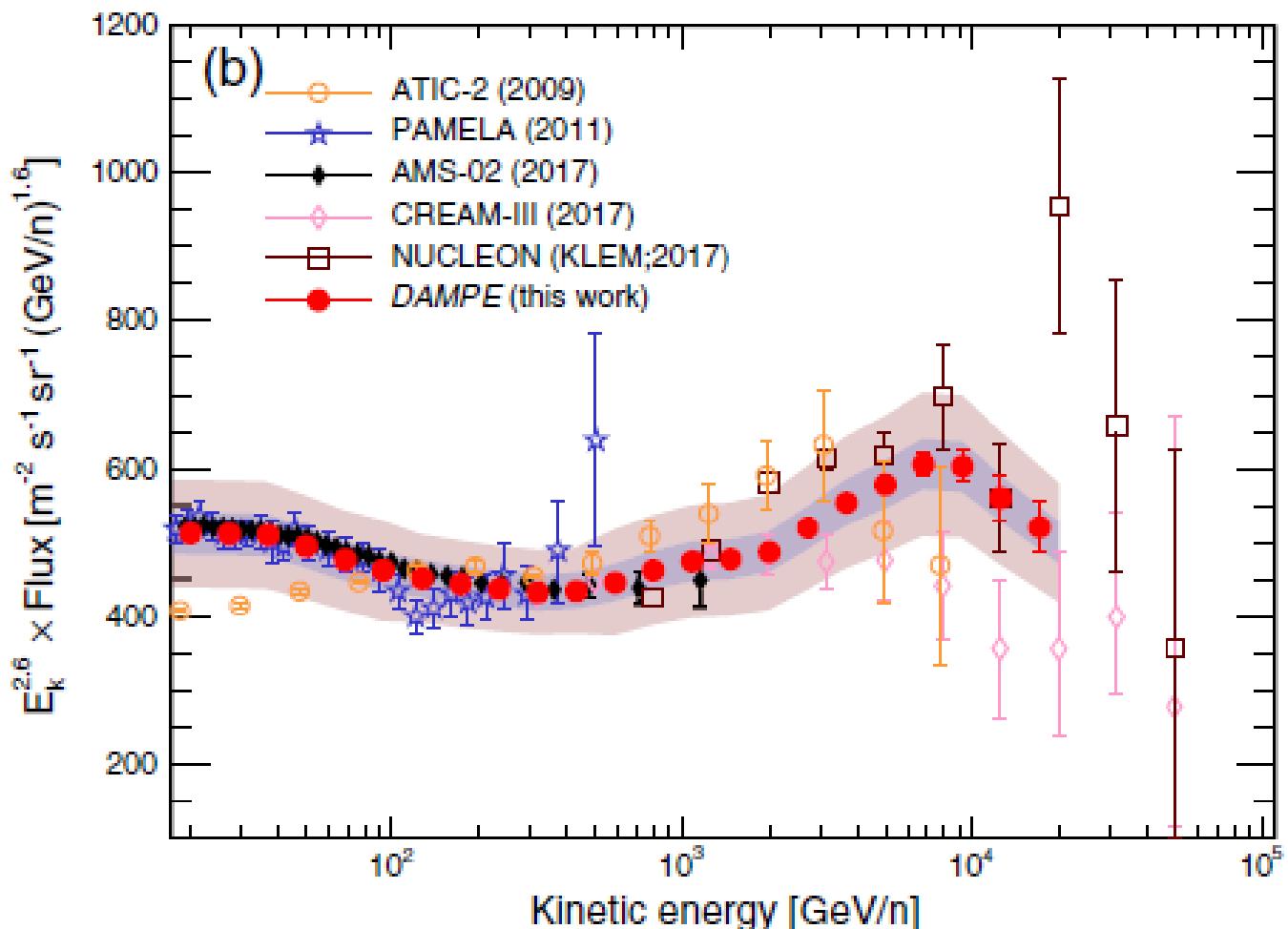
- Confirms the hundreds of GeV hardening
- Detecting a softening at ~ 14 TeV with high significance

The DAMPE helium spectrum

PHYSICAL REVIEW LETTERS 126, 201102 (2021)

Editors' Suggestion

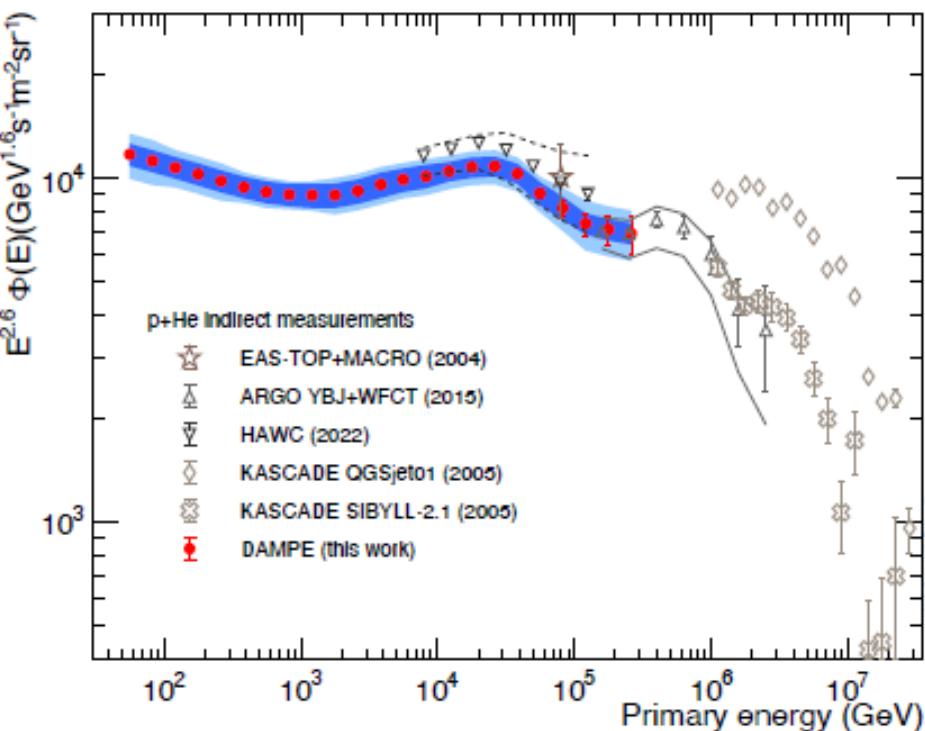
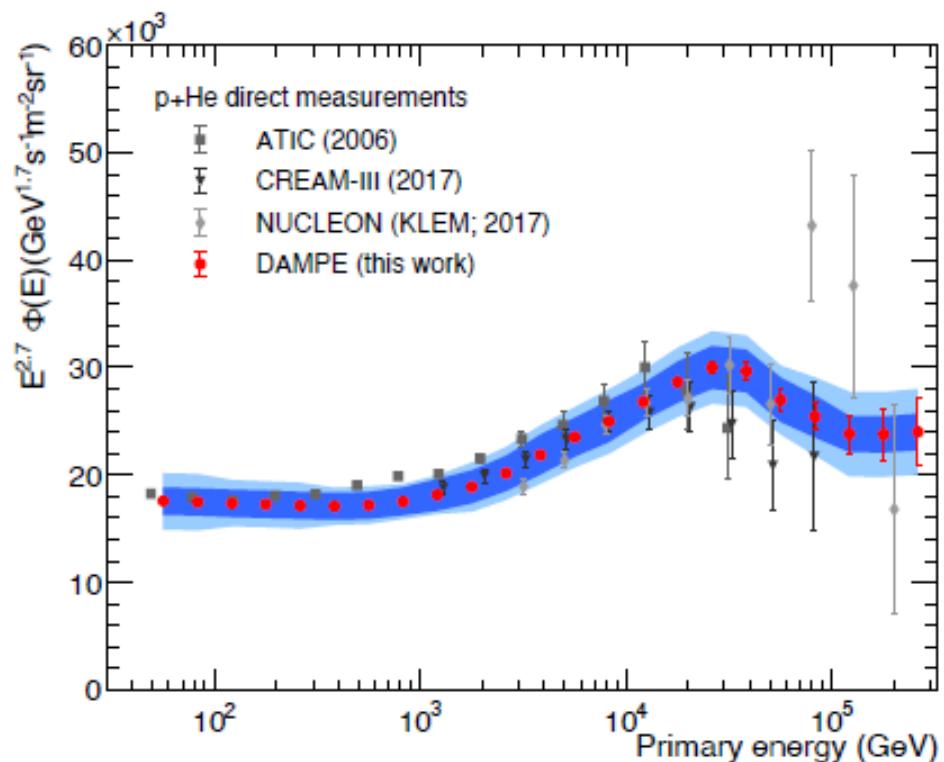
Featured in Physics

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)

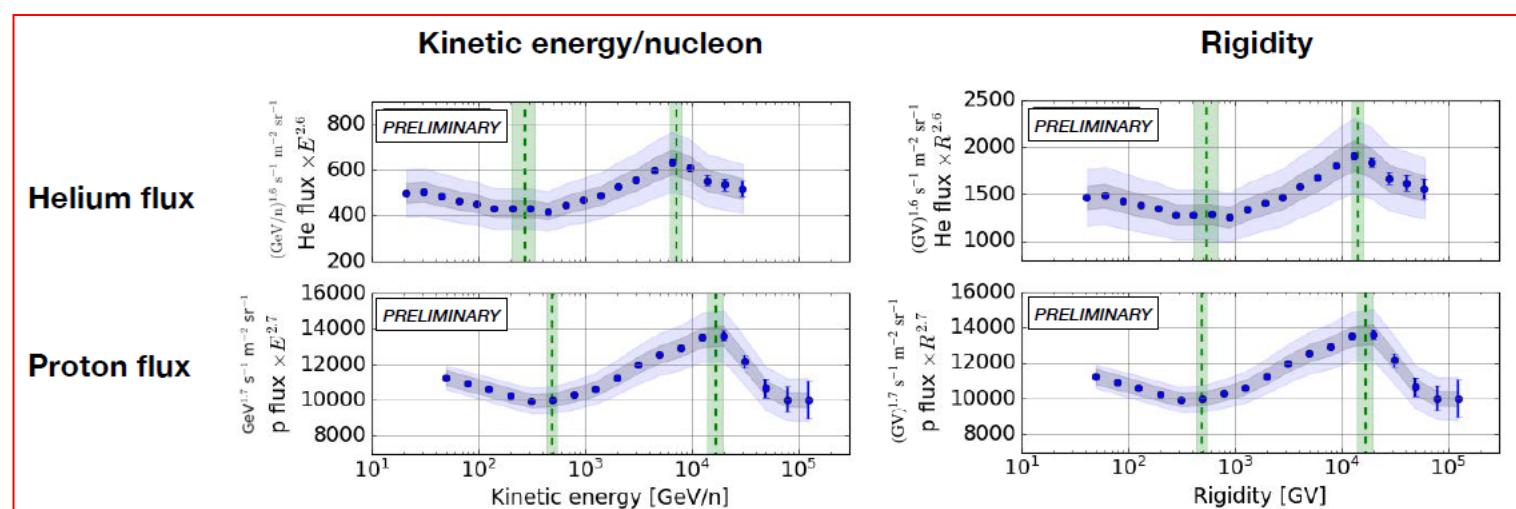
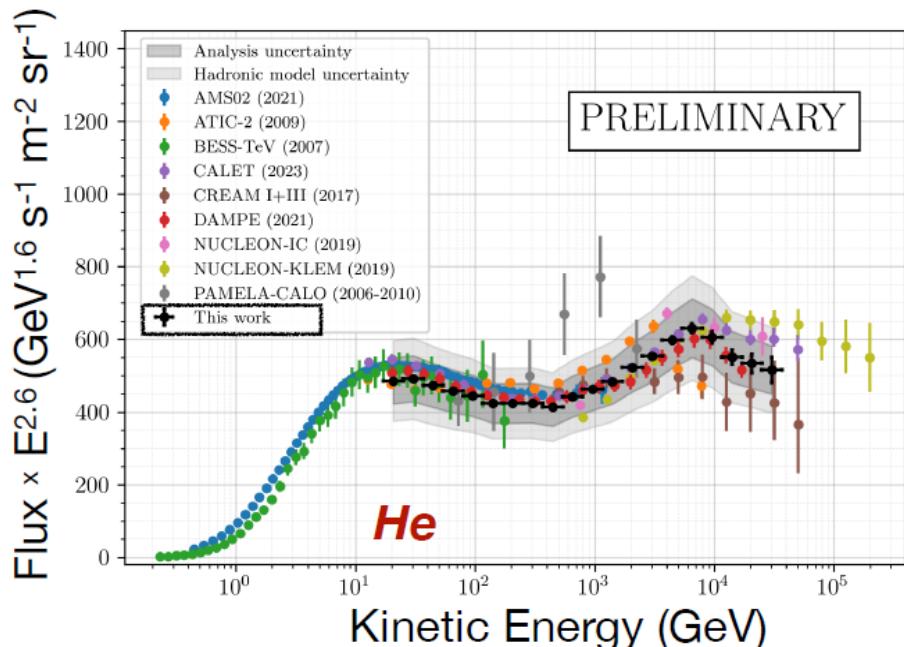
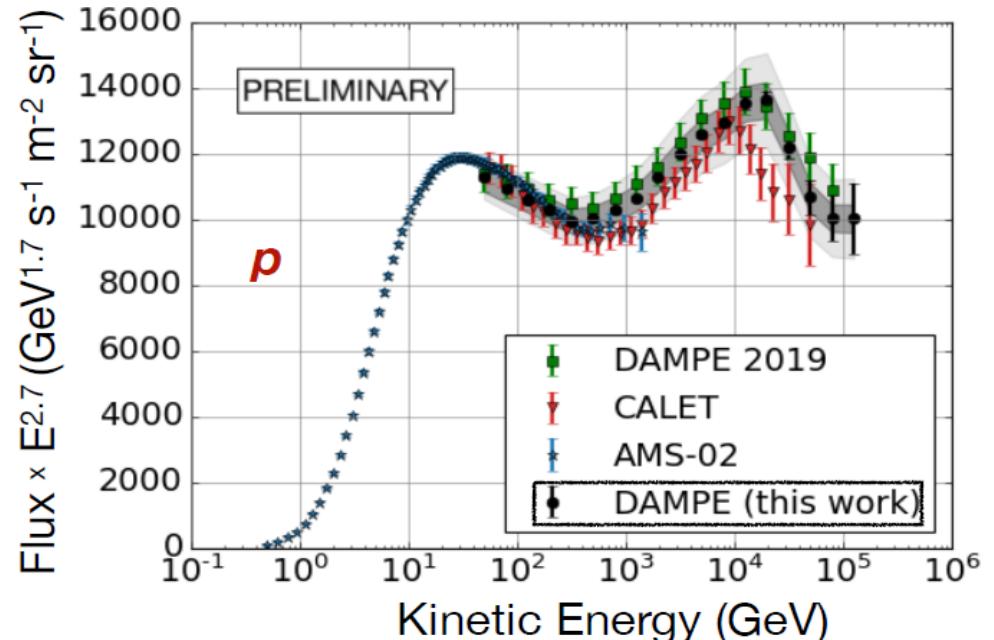
The DAMPE p+He spectrum



- ✓ Confirmation of the softening (at about 25 TeV due to the combination of p and He spectra)
- ✓ Suggesting a hardening at approx 100 TeV
- ✓ Overlapping with indirect measurements

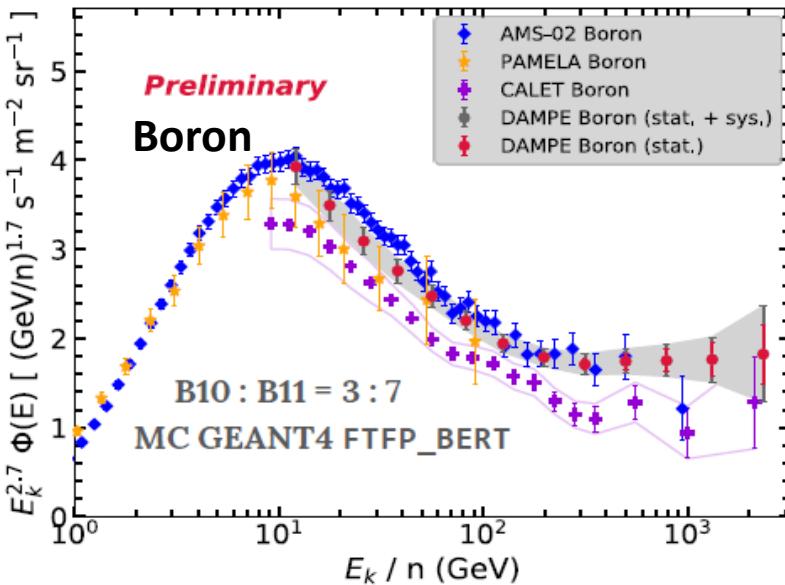
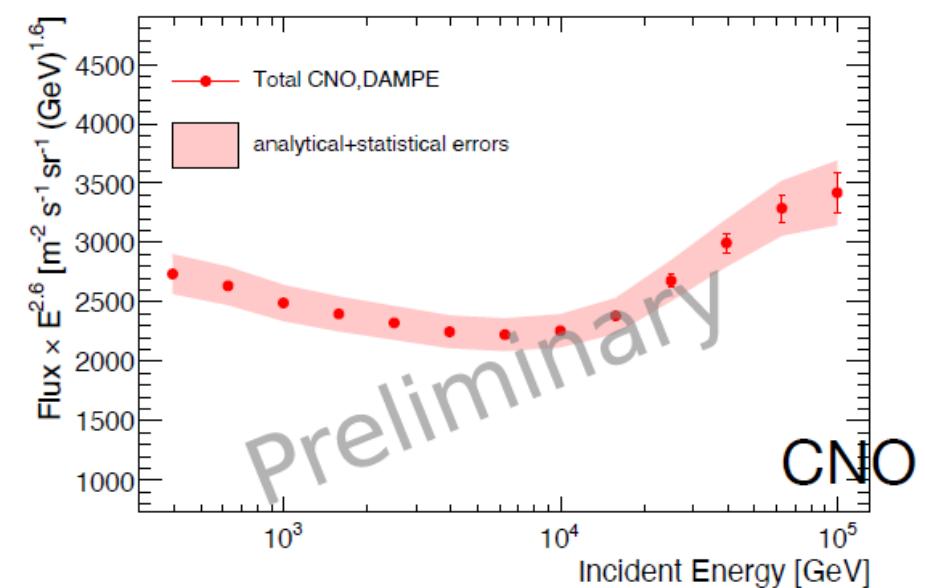
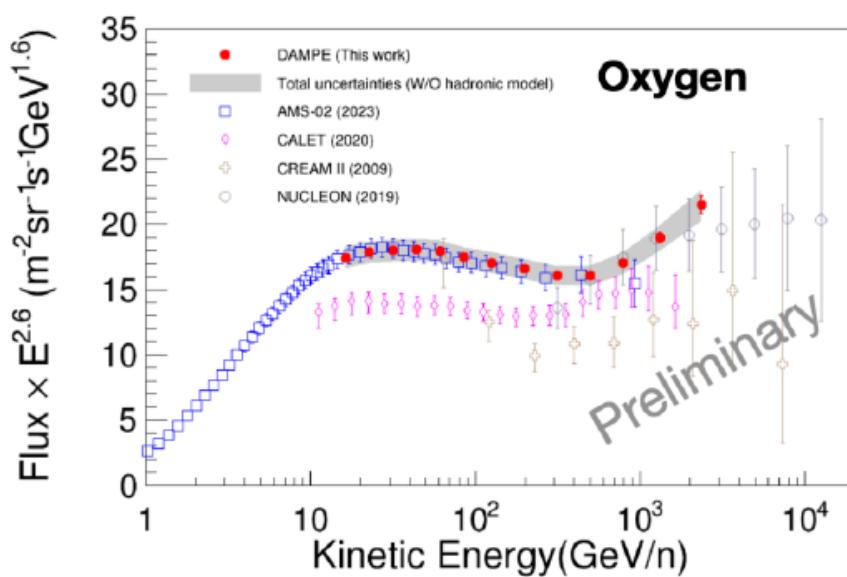
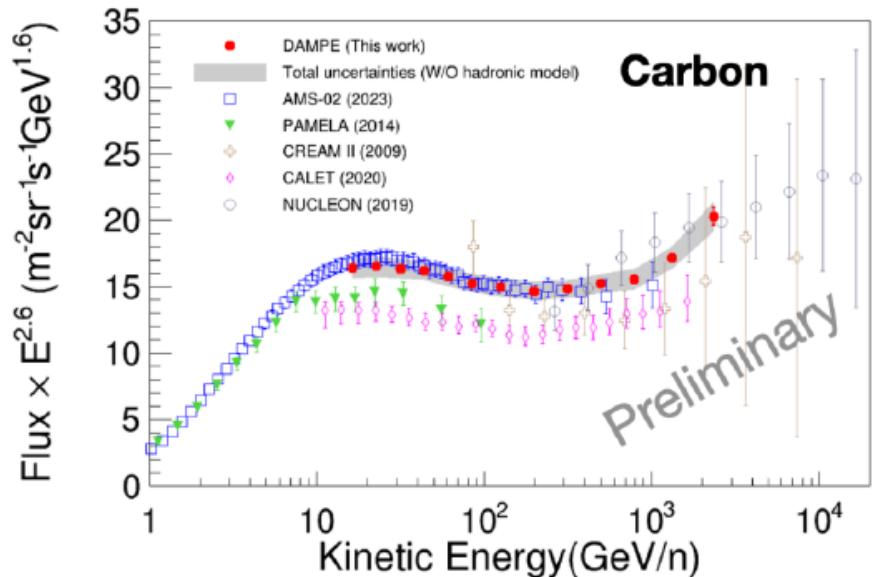
	Proton	Helium	Proton+Helium
E_b (TeV)	$13.6^{+4.1}_{-4.8}$	$34.4^{+6.7+11.6}_{-9.8-0.0}$	$28.8^{+6.2+2.9}_{-4.4-0.0}$
γ	2.60 ± 0.01	$2.41^{+0.02+0.02}_{-0.02-0.00}$	$2.51^{+0.021+0.01}_{-0.024-0.00}$
$\Delta\gamma$	-0.25 ± 0.07	$-0.51^{+0.18+0.01}_{-0.20-0.00}$	$0.43^{+0.066+0.066}_{-0.057-0.00}$

p and He spectra: updates



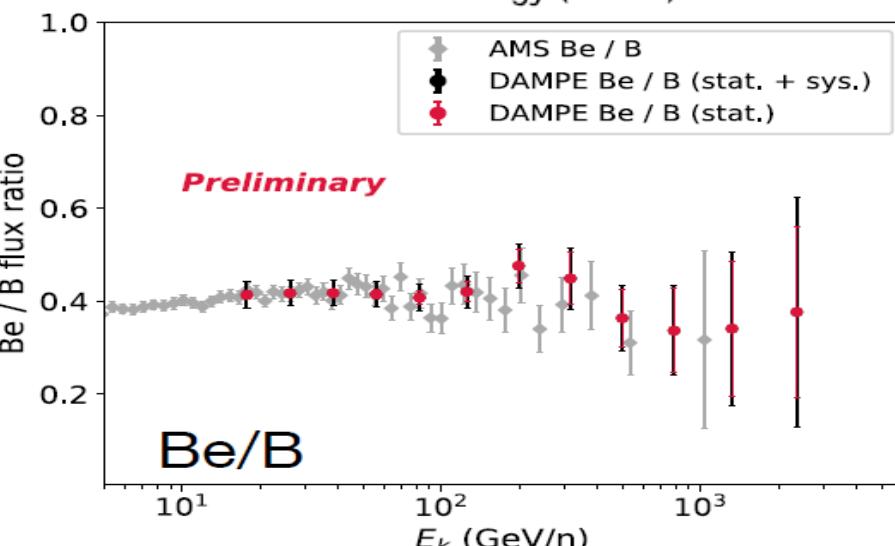
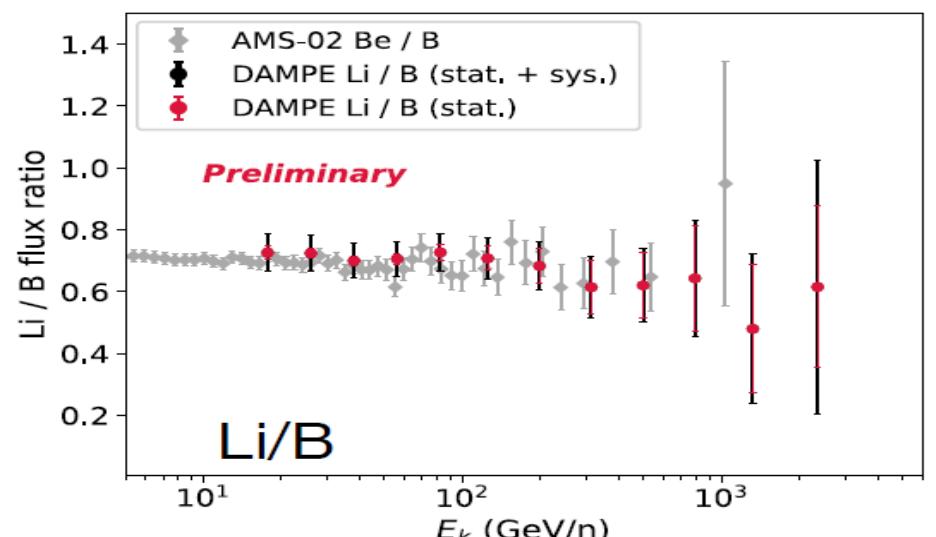
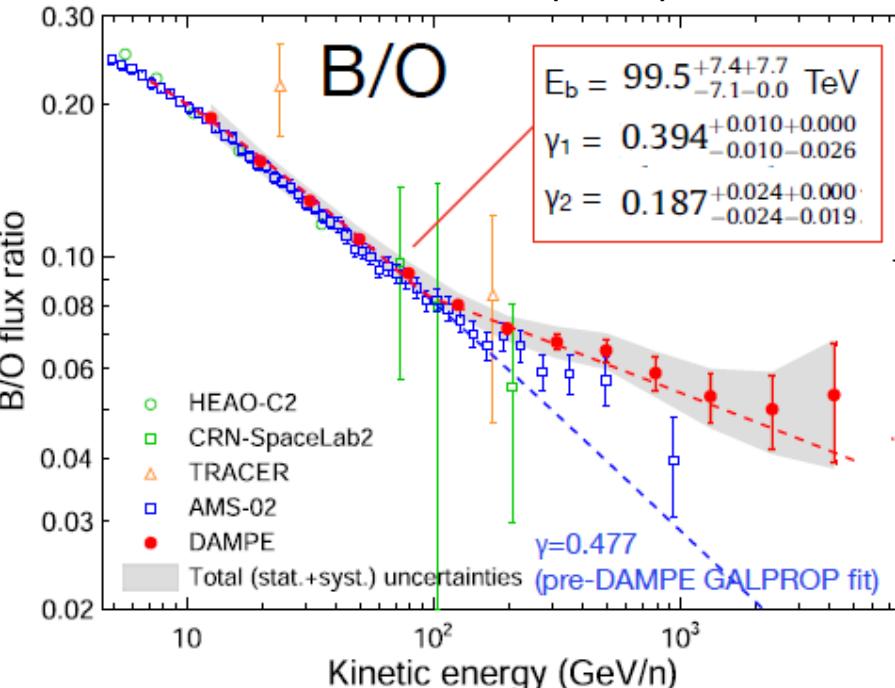
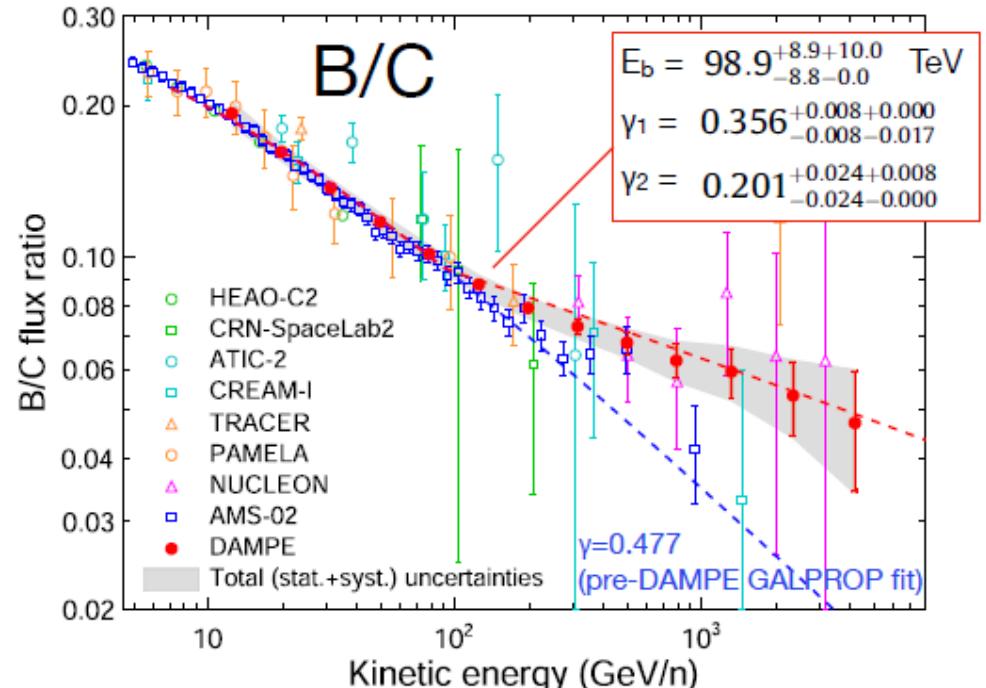
A rigidity dependence of both hardnening and softening is favoured by data

Heavier elements...



Flux ratios

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



DAMPE Summary

The detector

- Large geometric factor instrument ($0.3 \text{ m}^2 \text{ sr}$ for p and nuclei)
- Precision Si-W tracker ($40\mu\text{m}$, 0.2°)
- Thick calorimeter ($32 X_0$, 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 17, 2015
- On orbit operation steady and with high efficiencies
- Absolute energy calibration by using the geomagnetic cut-off
- Absolute pointing cross check by use of the photon map

For more information
see ICRC DAMPE
contributions. In particular
A.Tykhonov 's talk

Science:

- Evidence for a cutoff at $\sim 1 \text{ TeV}$ in the all electron spectrum
- Evidence for a softening in the proton spectrum at $\sim 14 \text{ TeV}$
- Evidence for a softening in the helium spectrum at $\sim 34 \text{ TeV}$ (suggest Z dependence)
- Measurement of p+He confirms the softening and suggest a hardening around 100TeV
- Undergoing spectral measurements of heavier nuclei and secondary-to-primary ratios
- Preliminary studies of gamma ray sources (250 sources, Fermi bubble, ...)
- Detected new features in Forbush decrease
- Search for dark matter signatures (upper limits from gamma line searches,...)
- Be ready for the “unexpected”: GW electromagnetic follow up in FoV,

More Stuff

The collaboration

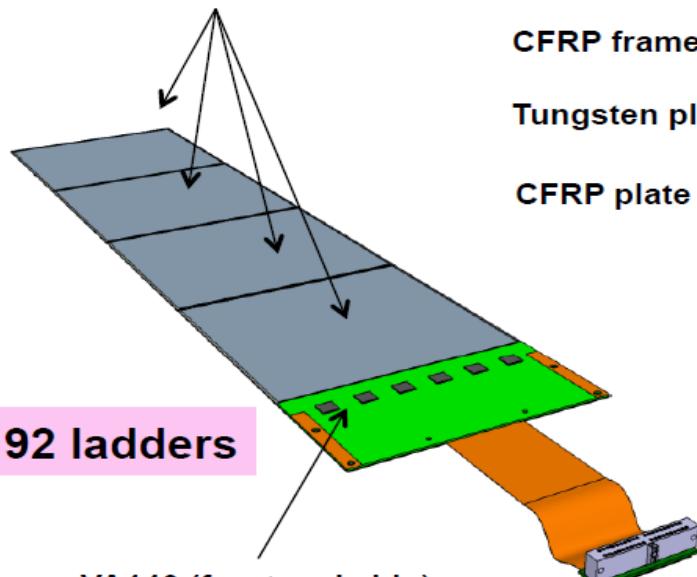
- **CHINA**
 - Purple Mountain Observatory, CAS, Nanjing
 - Institute of High Energy Physics, CAS, Beijing
 - National Space Science Center, CAS, Beijing
 - University of Science and Technology of China, Hefei
 - Institute of Modern Physics, CAS, Lanzhou
- **ITALY**
 - INFN Bari and University of Bari
 - INFN Lecce and University of Salento
 - INFN LNGS and Gran Sasso Science Institute
 - INFN Perugia and University of Perugia
- **SWITZERLAND**
 - University of Geneva



The Silicon Tracker (STK)

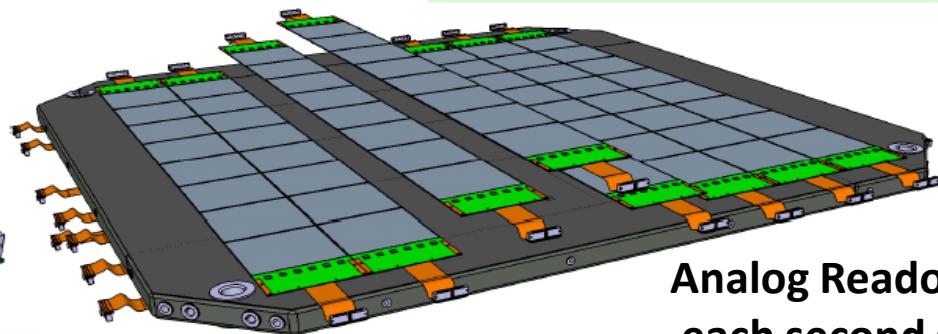
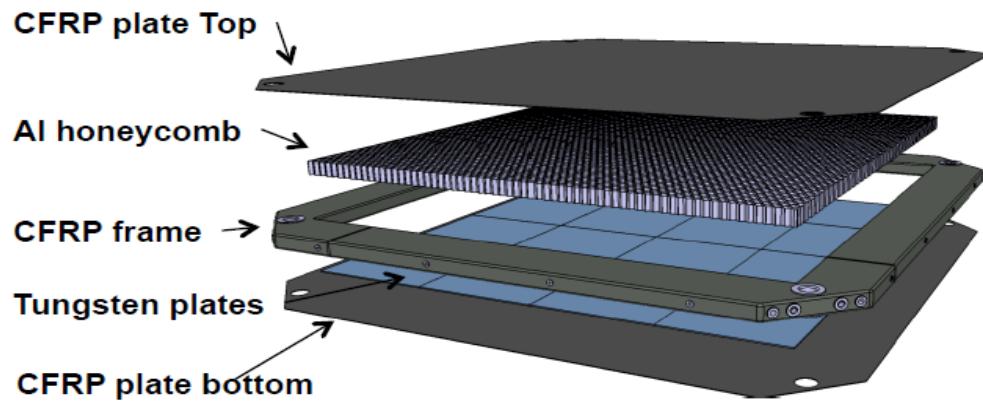
768 silicon sensors

Silicon detectors



1152 ASICs

73728 channels

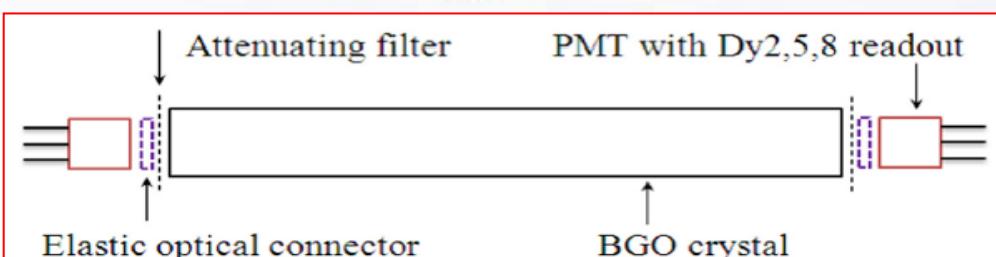
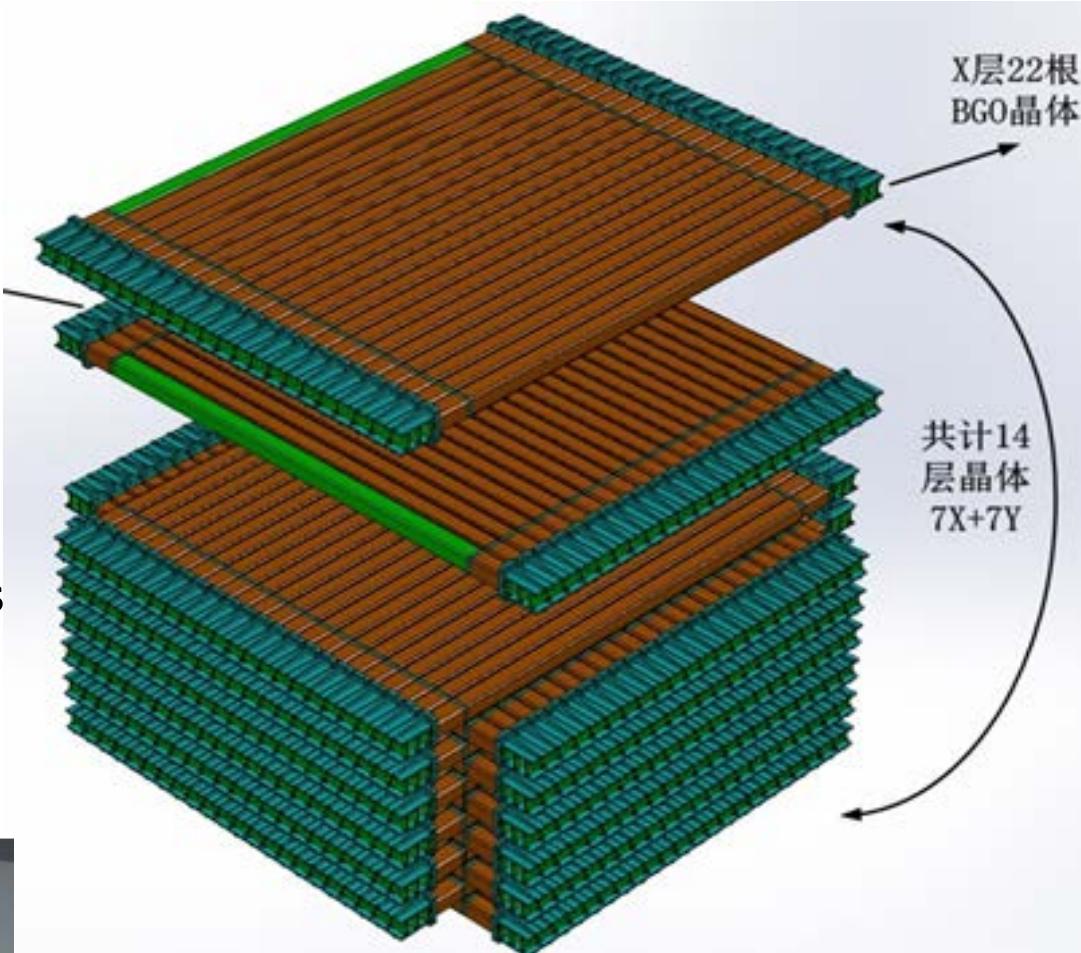
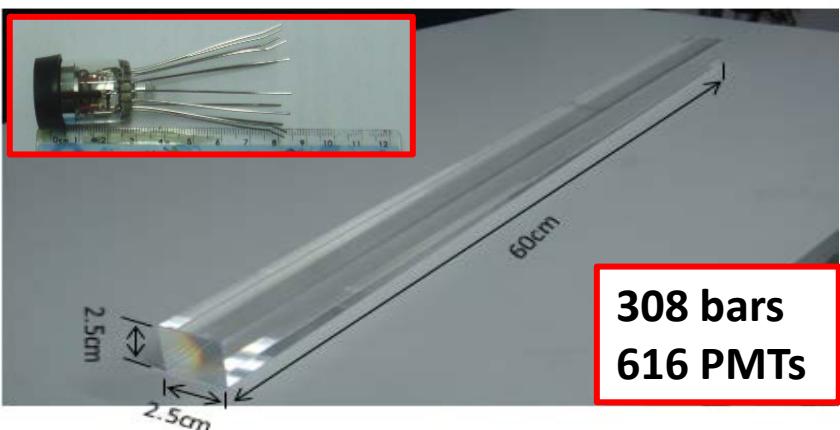


- 48 μm wide Si strips with 121 μm pitch
- (95 \times 95 \times 0.32 mm³) Silicon Strip Detector (SSD)
- 768 strips in each SSD
- One ladder composed by 4 (SSD)
- 16 Ladders per layer (76 cm \times 76 cm)
- 12 layers (6x + 6y)

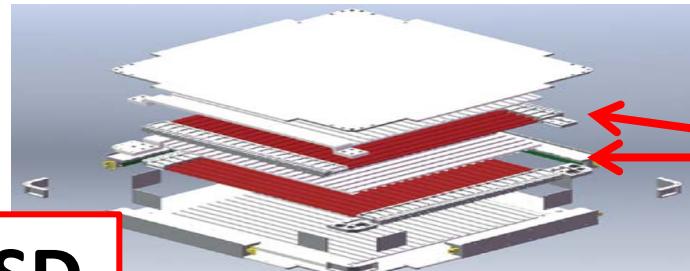


The CALOrimeter

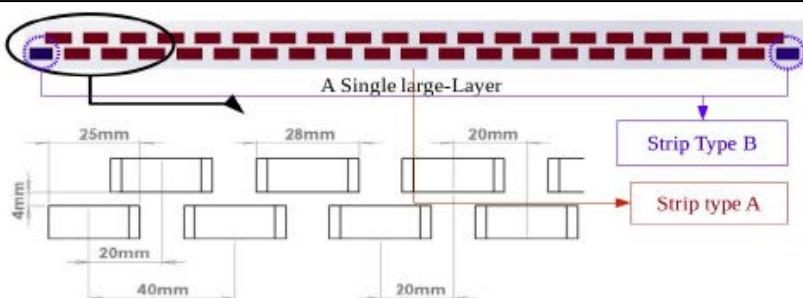
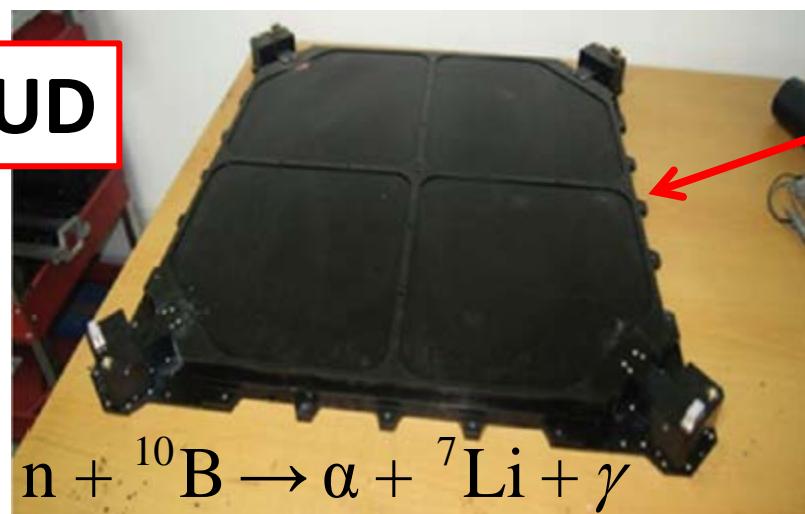
- **14 layers of 22 BGO bars**
 - $2.5 \times 2.5 \times 60 \text{ cm}^3$ bars
 - 14 hodoscopic stacking alternating orthogonal layers
 - depth $\sim 32X_0$
- **Two PMTs coupled with each BGO crystal bar at the two ends**
- **Electronics boards attached to each side of module**



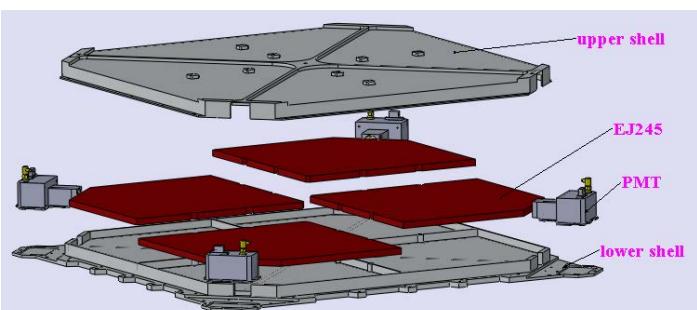
The Plastic Scintillator Detector and the Neutron Detector

**PSD**

- 1.0 cm thick ,2.8cm wide and 82.0 cm long scintillator strips
- staggered by 0.8 cm in a layer
- 82 cm × 82 cm layers
- 2 layers (x and y)

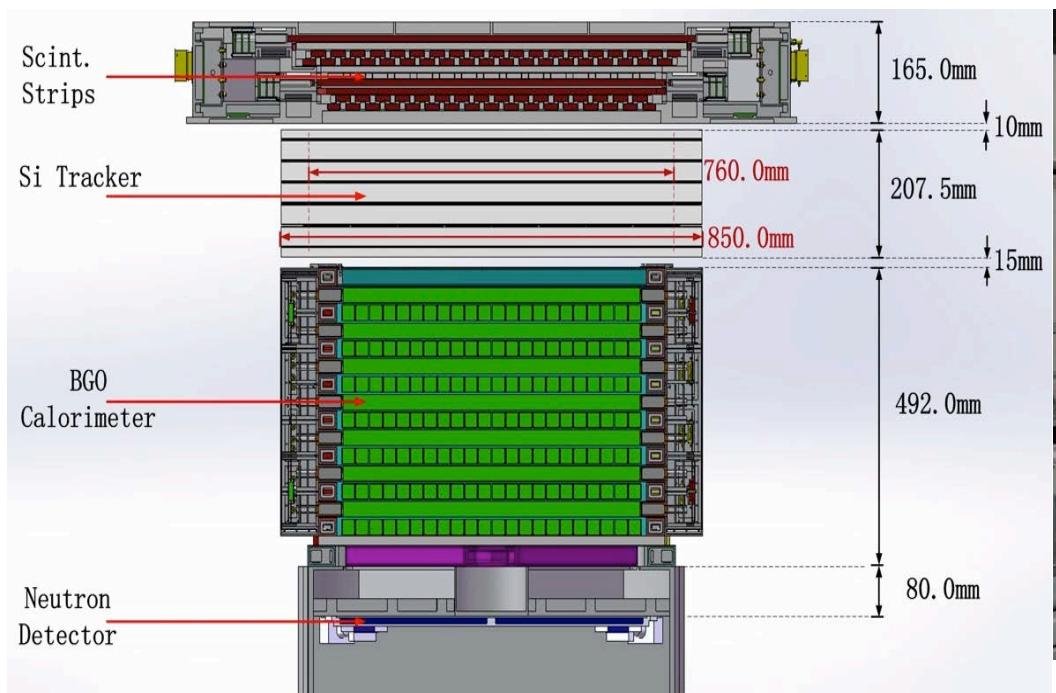
**NUD**

- 4 large area boron-doped plastic scintillators (30 cm × 30 cm × 1 cm)



Comparison with AMS-02 and FERMI

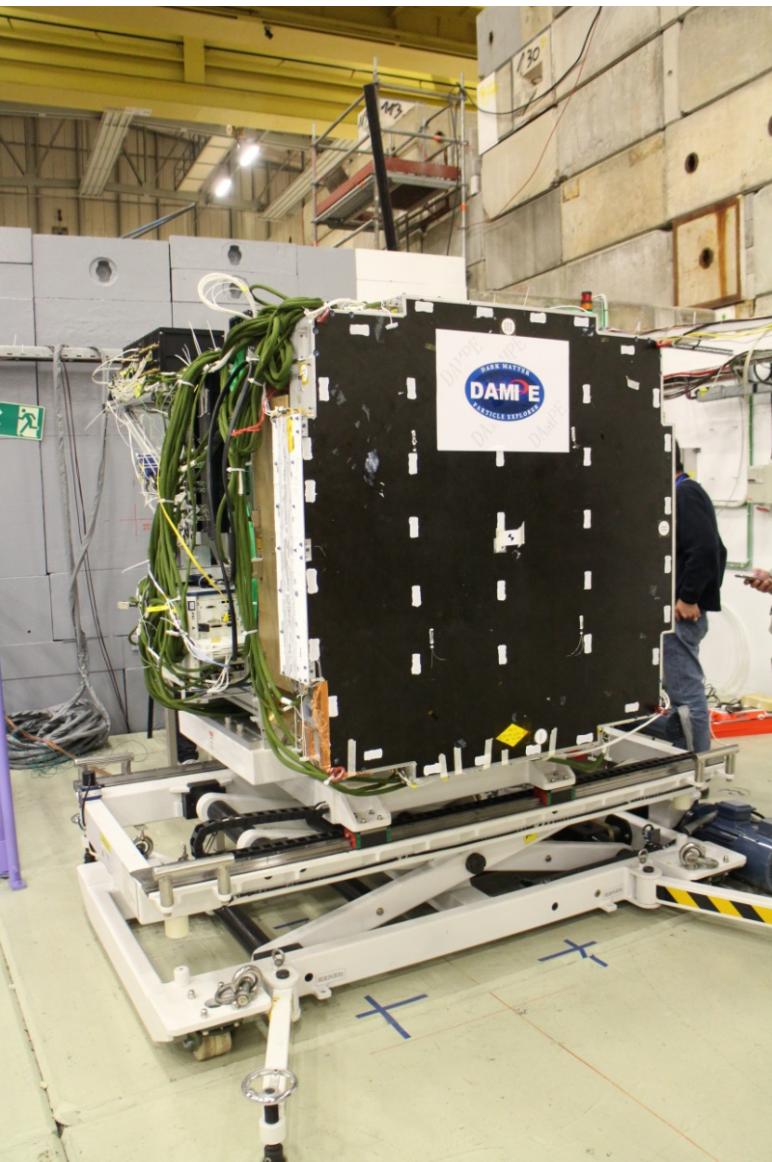
	DAMPE	AMS-02	Fermi LAT
e/ γ Energy res.@100 GeV (%)	1.2	3	10
e/ γ Angular res.@100 GeV (deg)	0.2	0.3	0.1
e/p discrimination	10^5-10^6	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	32	17	8.6
Geometrical accep. (m^2sr)	0.3	0.09	1



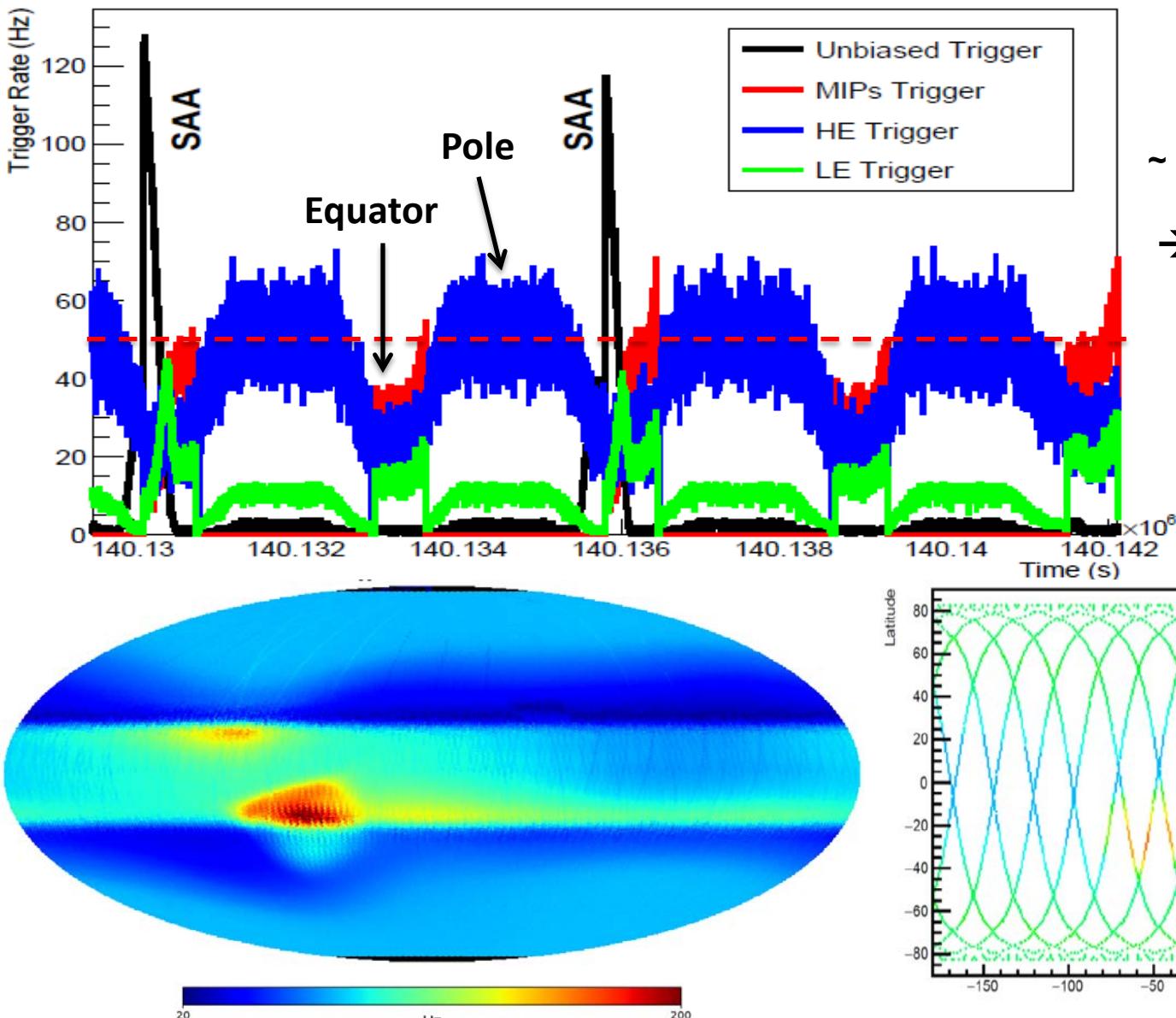
Mass: 1400 Kg
Power: ~ 400 W
Livetime: > 3 years

Test beam activity at CERN

- 14days@PS, 29/10-11/11 2014
 - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
 - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
 - π^- @ 3GeV/c, 10GeV/c
 - γ @ 0.5-3GeV/c
- 8days@SPS, 12/11-19/11 2014
 - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
 - p @ 400GeV/c (SPS primary beam)
 - γ @ 3-20GeV/c
 - μ @ 150GeV/c,
- 17days@SPS, 16/3-1/4 2015
 - Fragments: 66.67-88.89-166.67GeV/c
 - Argon: 30A- 40A- 75AGeV/c
 - Proton: 30GeV/c, 40GeV/c
- 21days@SPS, 10/6-1/7 2015
 - Primary Proton: 400GeV/c
 - Electrons @ 20, 100, 150 GeV/c
 - γ @ 50, 75 , 150 GeV/c
 - μ @ 150 GeV /c
 - π^+ @10, 20, 50, 100 GeV/c
- 10days@SPS, 11/11-20/11 2015
 - Pb 30AGeV/c (and fragments) (HERD)
- 6days@SPS, 20/11-25/11 2015
 - Pb 030 AGeV/c (and fragments)

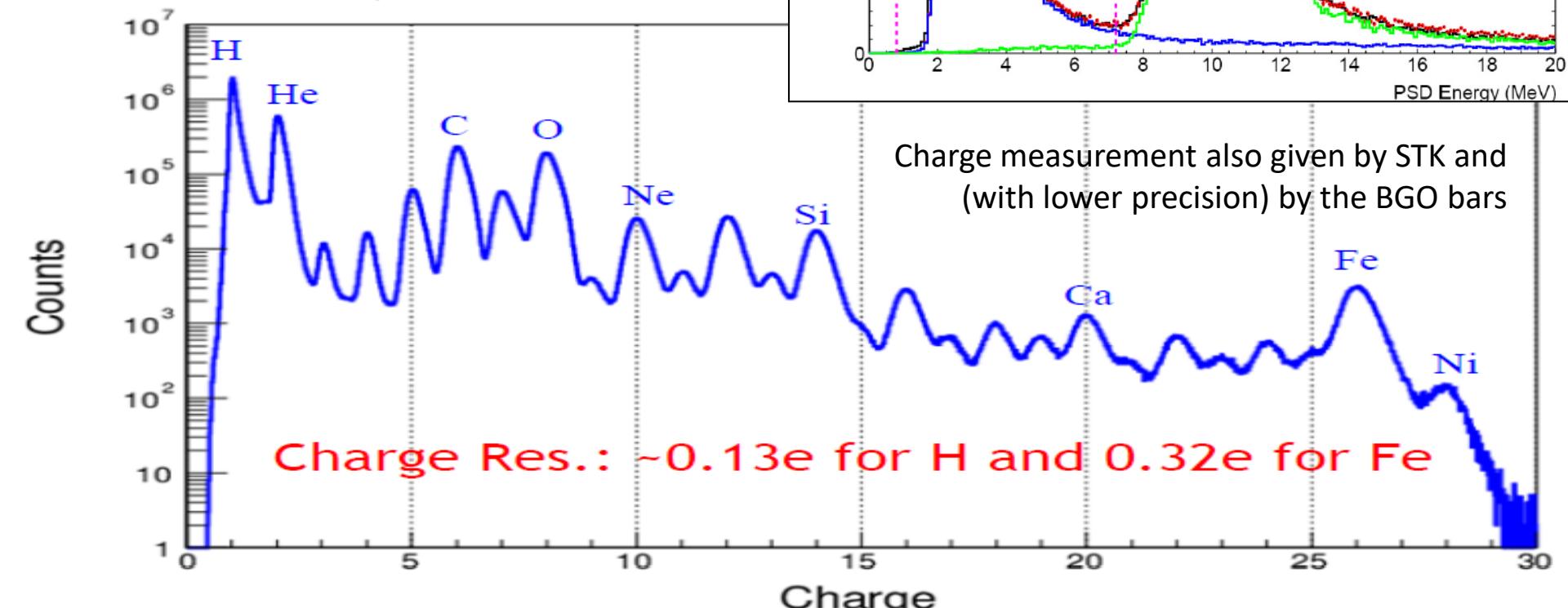
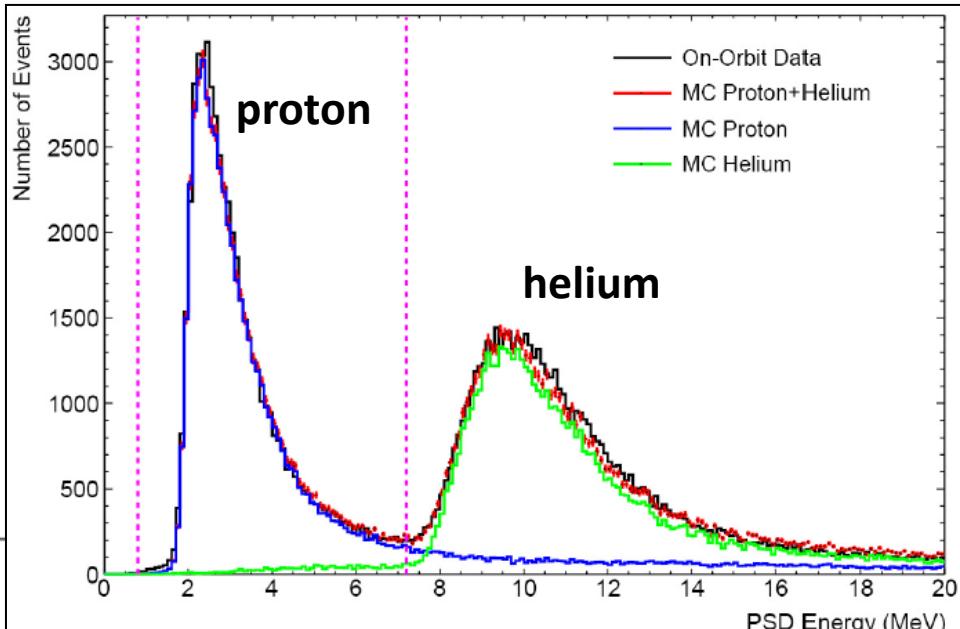
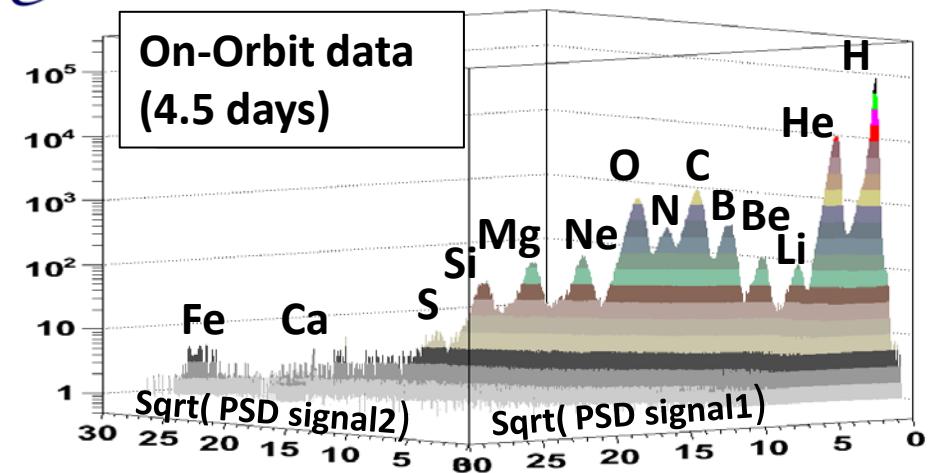


Trigger rate in orbit



~ 50 Hz average trigger rate
→ 100GB/day on ground
(about 5 M events)

Nuclei ID with PSD

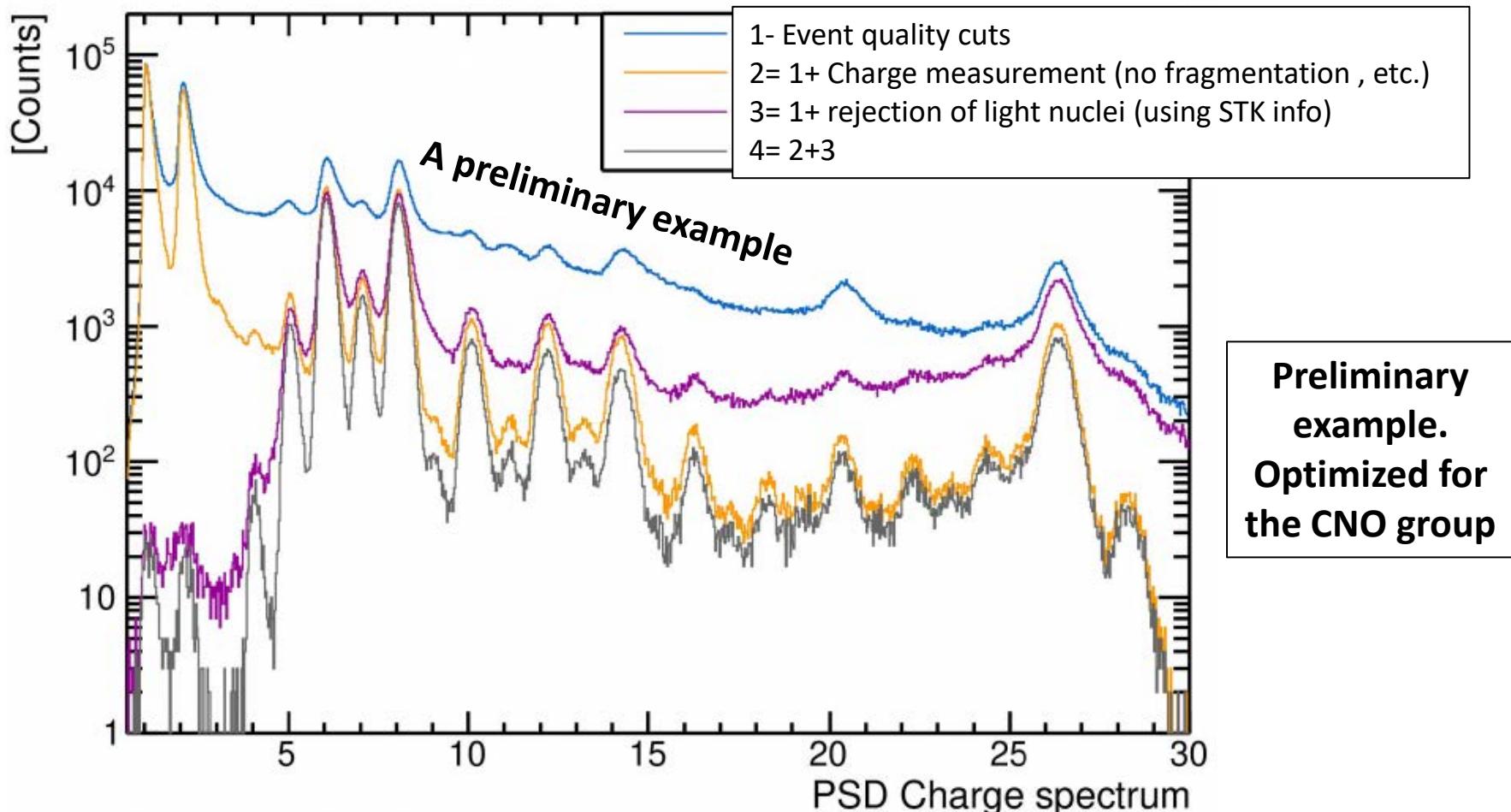


DAMPE: heavier nuclei

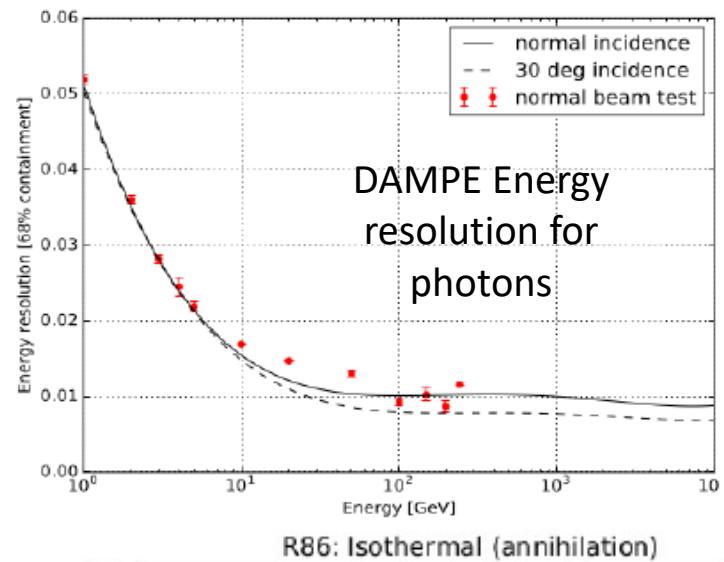
Several independent analyses are ongoing from Li up to Iron

Different selection criteria to reject other nuclei and avoid charge misidentification

Different approaches to limit and better evaluate the systematics.



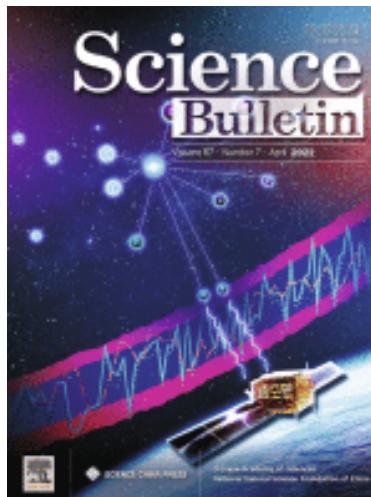
Indirect Dark Matter search



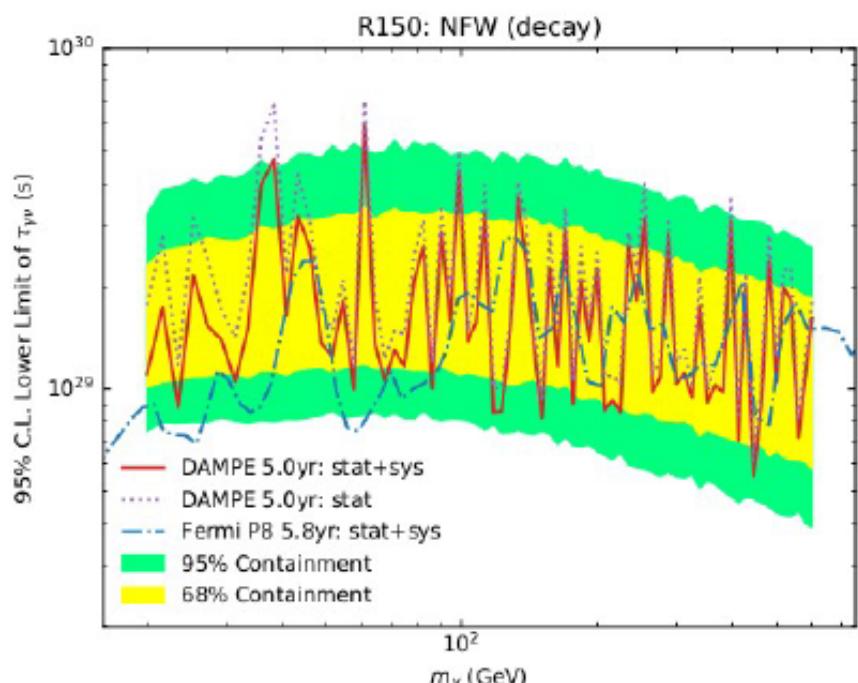
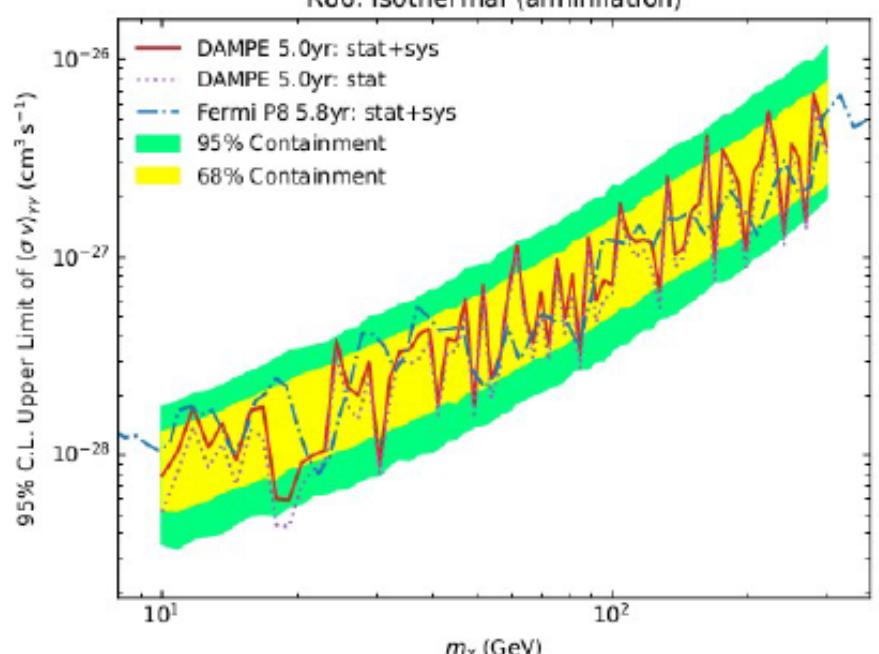
Search for gamma ray lines from neutralino annihilation or decay

Very high sensitivity due to:

- Effective area
- Energy resolution

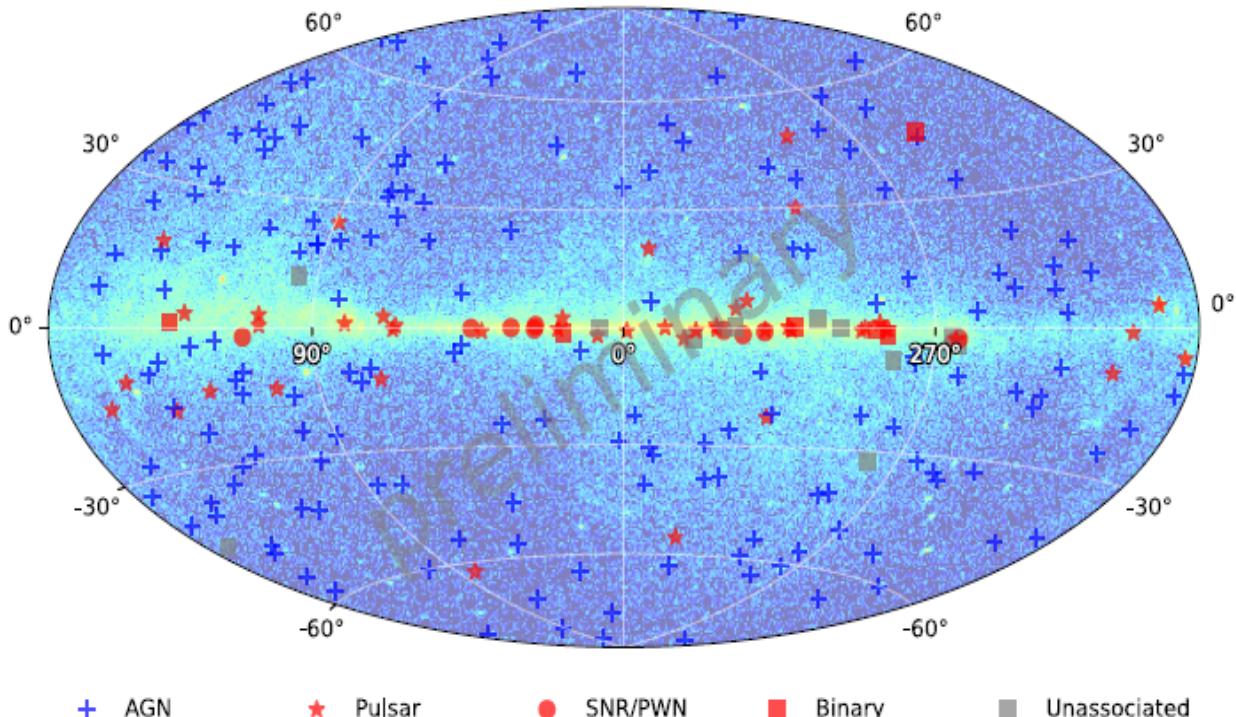


April 2022



The DAMPE gamma-ray sky

~250 point sources detected and studies in 7 years

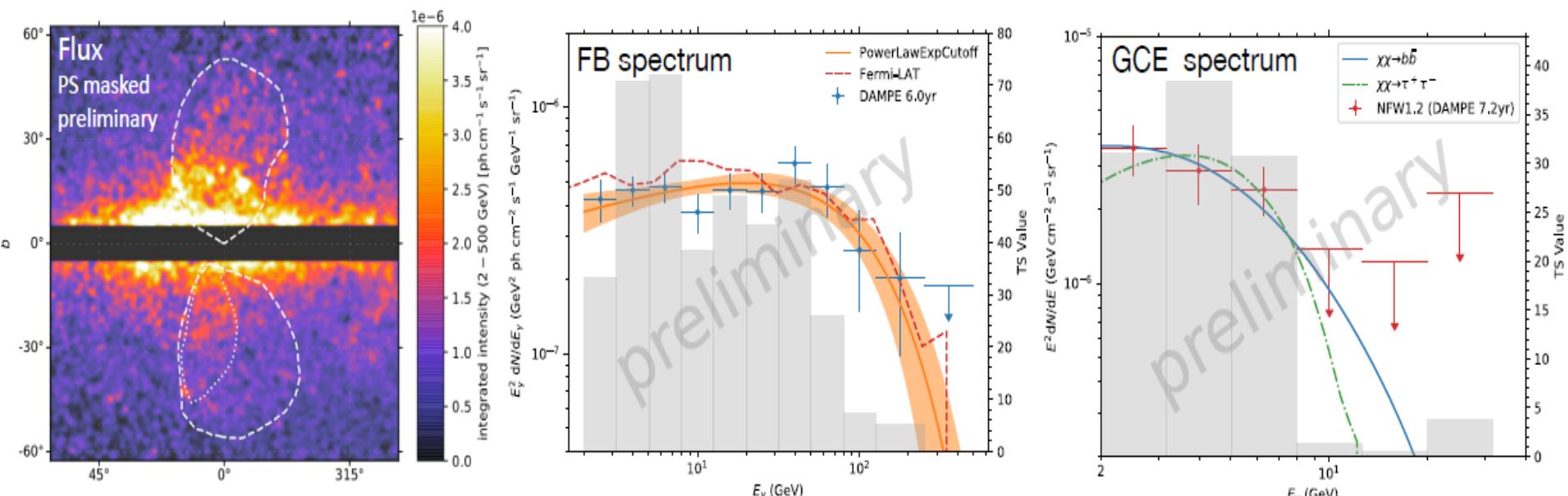


Source Type	Number
AGN	175
Pulsar	46
SNR/PWN	10
Binary	6
Unassociated	11
Total	248

14 times full-sky coverage in 7 years, ~ 300'000 photons total

γ -rays: large scale structures

Fermi Bubbles (FB) – diffuse structures discovered by FERMI LAT, associated with Galactic Centre
(DAMPE FB detection at $\sim 17.8\sigma$)



- FB: 6-year spectrum well consistent with FERMI, curved at 3.7σ , weak excess in the Cocoon ($\sim 3.3\sigma$)
- **Galactic Center Excess (GCE)** detected at $\sim 7.9\sigma$, with 7.2 years of DAMPE data

Hadronic interaction studies

- Good segmentation of BGO calorimeter allows to use DAMPE for cross-section measurements:
 - p, He
 - C, O

