



## Results overview from the DAMPE space mission in orbit

Dimitrios Kyratzis

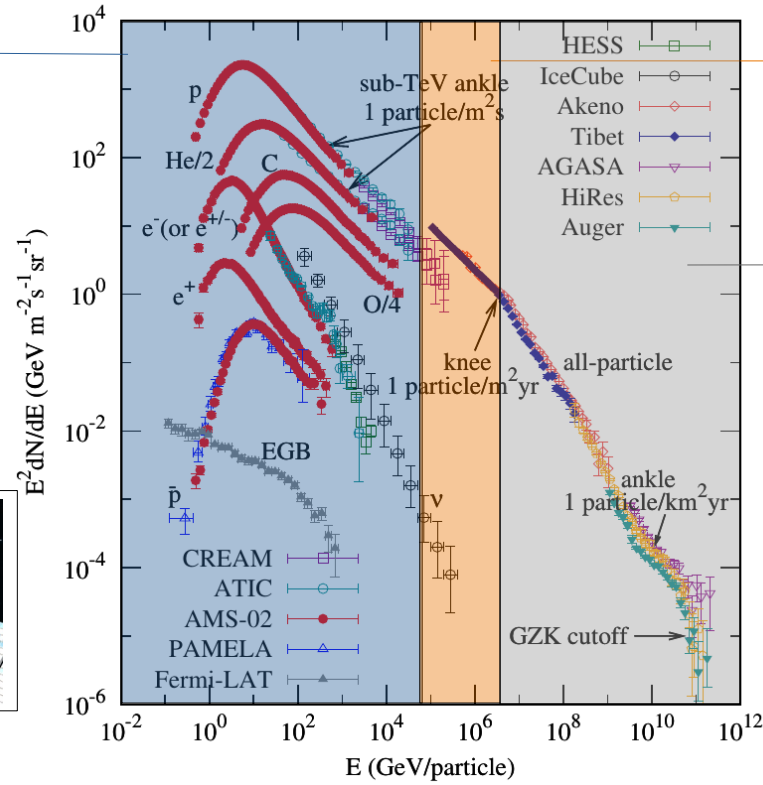
on behalf of the DAMPE collaboration

Gran Sasso Science Institute (GSSI) & INFN-LNGS

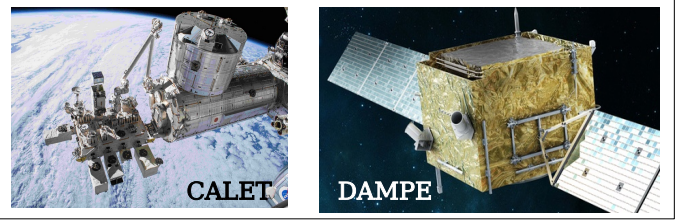
Energies achieved with current space-borne direct CR experiments (~ few hundred TeV)

Maximal energies achieved with direct detection CR experiments (~ PeV energies)

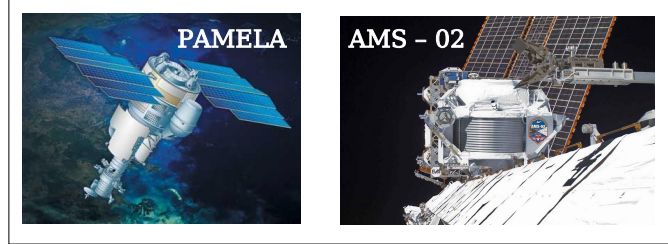
Region covered by indirect CR experiments (~  $10^{20}$  eV)



Calorimeter – based experiments



Spectrometer – based experiments



## Research Goals & Open Questions

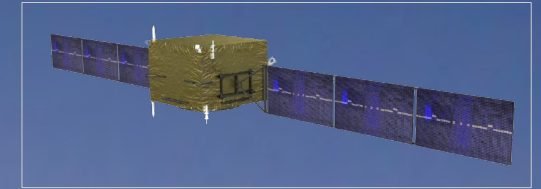
- Precise measurements of CR spectra & mass composition
- Directly probing fine spectral structures (hardening/softenings)
- Understanding CR acceleration & propagation mechanisms



**Orbit:** Sun – synchronous, 95 min, 97° inclination

**Altitude:** 500 km (LEO)

**Payload:** 1300 kg



**Launched on Dec 17<sup>th</sup> 2015**

Jiuquan Satellite Launch Center  
Gobi desert, China

## The Collaboration

An international synergy between **Chinese, Italian & Swiss institutes/universities**, formed around the DAMPE initiative.



## China

Purple Mountain Observatory, CAS, Nanjing  
University of Science and Technology of China, Hefei  
Institute of High Energy Physics, CAS, Beijing  
Institute of Modern Physics, CAS, Lanzhou  
National Space Science Center, CAS, Beijing

## Italy

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

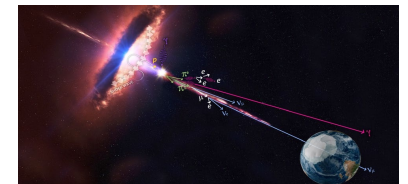
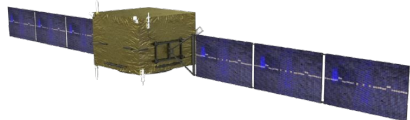
## Switzerland

University of Geneva  
EPFL Lausanne (joined in 2021)

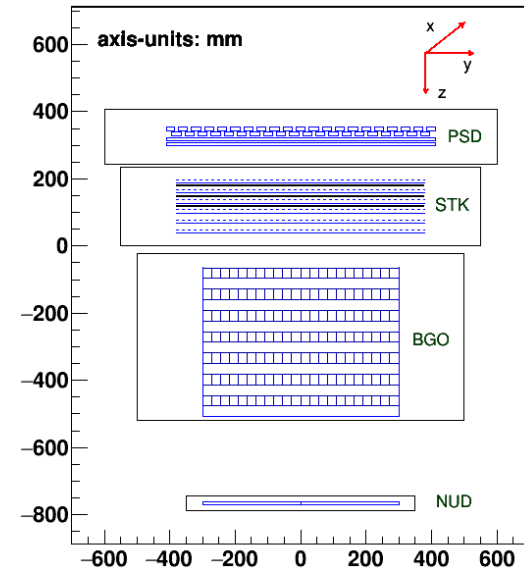
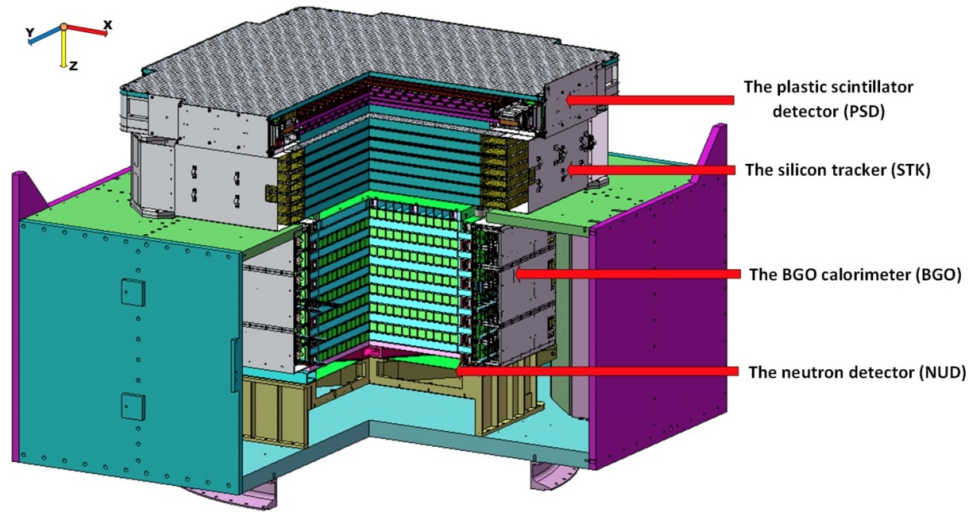


## Main scientific objectives

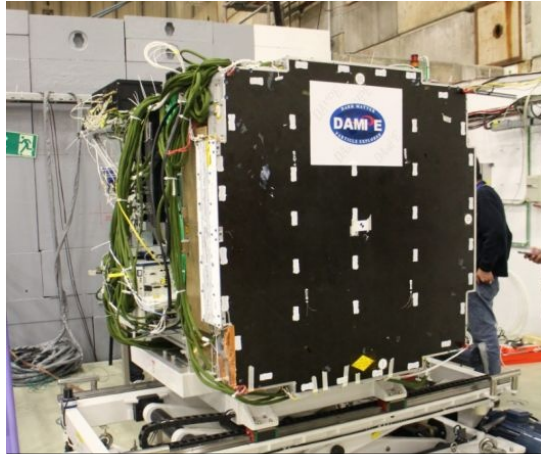
**Cosmic Rays:** All-electron, proton & nucleonic spectra w/ great precision  
**Gamma – rays:** Insight on high-energy  $\gamma$  astronomy, transient studies, etc  
**Dark Matter:** Indirect studies on possible DM candidates



[Astropart. Phys., 95, 6 \[2017\]](#)



- PSD:** Anti - coincidence detector for gammas and charge measurement
- STK:** Particle tracker, photon converter & additional charge measurement
- BGO:** Energy measurement & particle identification via shower topology
- NUD:** Further particle ID from electromagnetic & hadronic showers



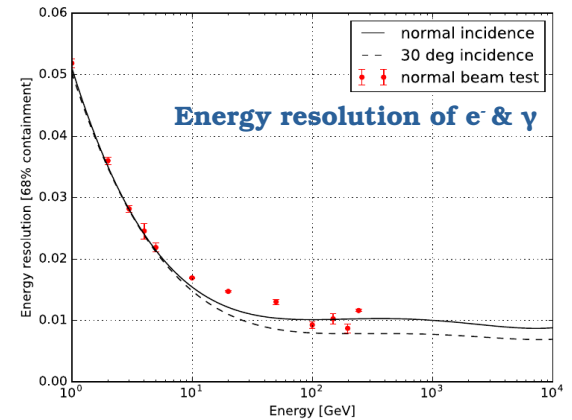
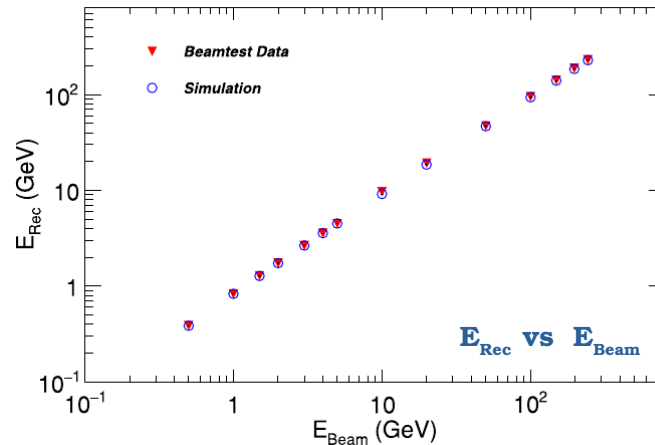
**DAMPE @ CERN - SPS**

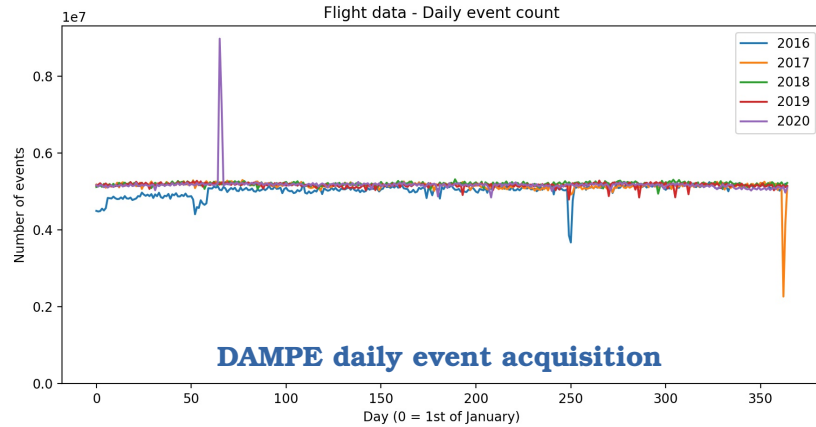
## Main Features

Energy range (e/ $\gamma$ )	10 GeV - 10 TeV
Energy range (CRs)	50 GeV - 200 TeV
Energy resolution (e/ $\gamma$ )	< 1.5% @ 800 GeV
Energy resolution (p)	< 40% @ 800 GeV
G.F. (e)	> 0.3 m <sup>2</sup> sr @ 30 GeV
Calorimeter specs	32 X <sub>0</sub> , 1.6 $\Lambda_1$
Field of View	~1.0 sr

## Test beam campaign @ CERN SPS [2014 - 15]

Performance validation & response to electrons, gammas, hadrons

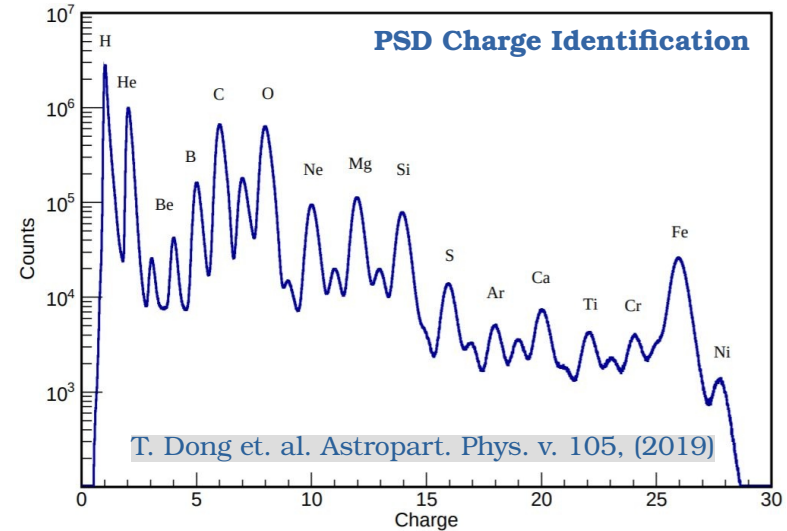
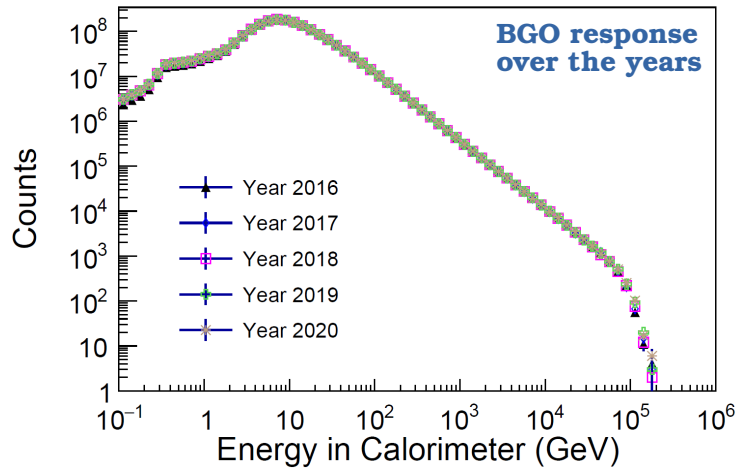




Excellent PSD charge & STK track resolutions  
 Stable BGO operation for more than 5 years of DAMPE live – time

**...with more than 10 billion events collected**

**Stable & continuous data taking from Dec 2015 up to now**



Probing the CRE spectrum at ~ TeV energies with great precision

nature

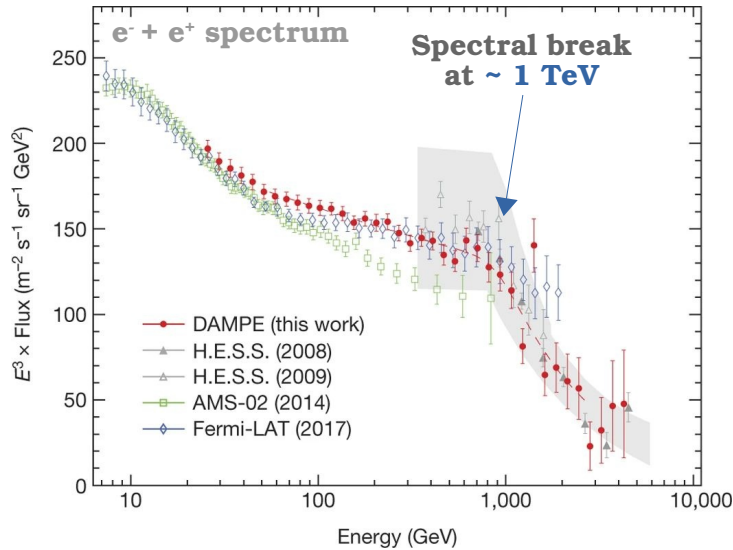
Ambrosi et al Nature vol 552, (2017)

LETTER

doi:10.1038/nature24475

Direct detection of a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons

DAMPE Collaboration\*

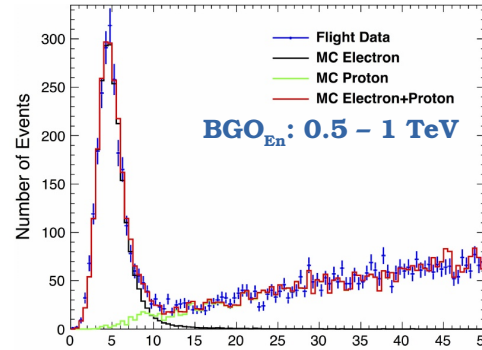
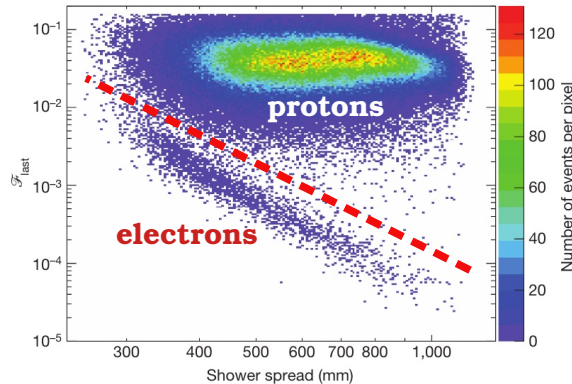


Direct detection of a spectral break at ~ 1 TeV in the all-electron spectrum

- **Sample:** 530 days of data
- **Measurement range:** 25 GeV – 4.6 TeV
- **Number of events:** 1.5 million CREs

Discrimination between electrons & protons in the BGO

$\mathcal{F}_{last}$ : BGO energy in the last layer over total deposited energy



e/p discrimination:  $10^4 - 10^5$

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



Confirming spectral hardening around 500 GeV + revealing a novel softening at ~ 14 TeV

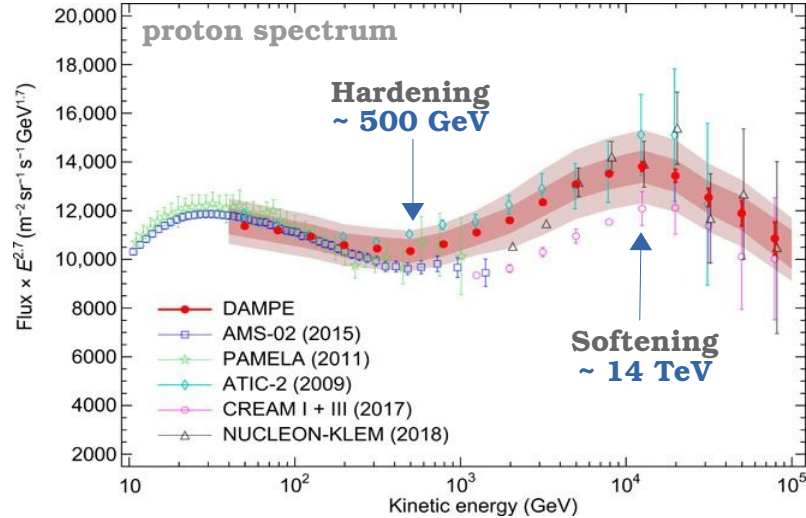
ScienceAdvances

Q. An et al, Sc. Adv. Vol. 5 no. 9 (2019)

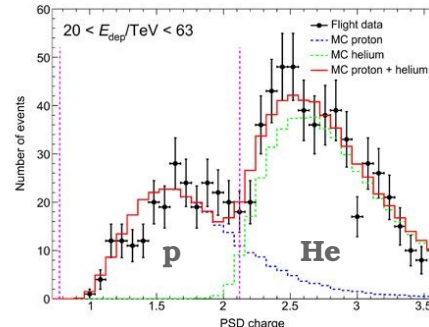
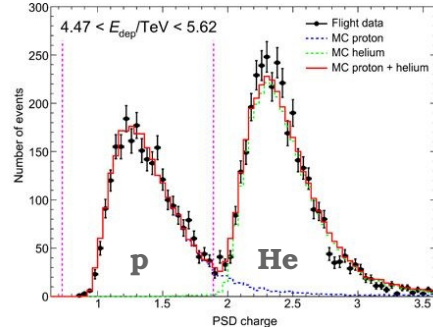
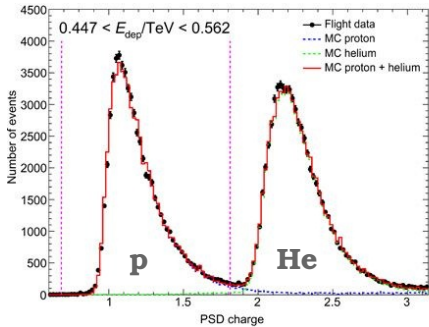
SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

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



- **Sample:** 30 months of data
- **Measurement range:** 40 GeV – 100 TeV



Proton & Helium charge in the PSD in various increasing energy bins

Uncertainties concerning:

- hadronic model simulations
- Separation of p/He at higher energies

## Confirming observed hardening around 1 TeV + revealing a novel softening at ~ 34 TeV

PHYSICAL REVIEW LETTERS

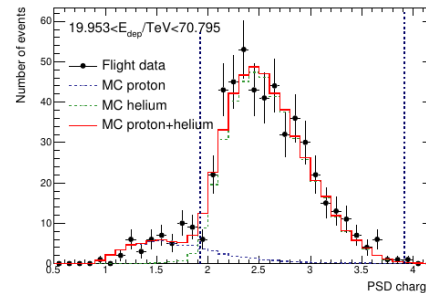
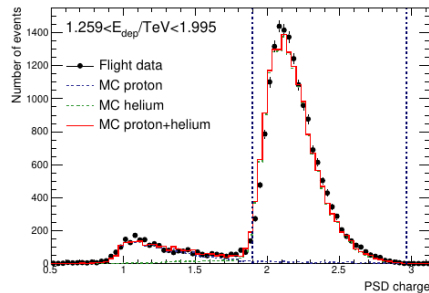
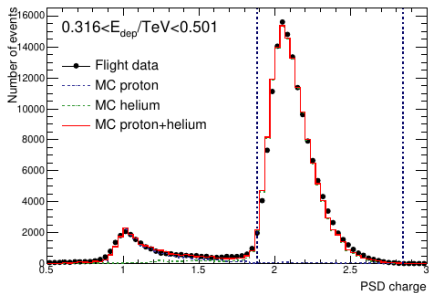
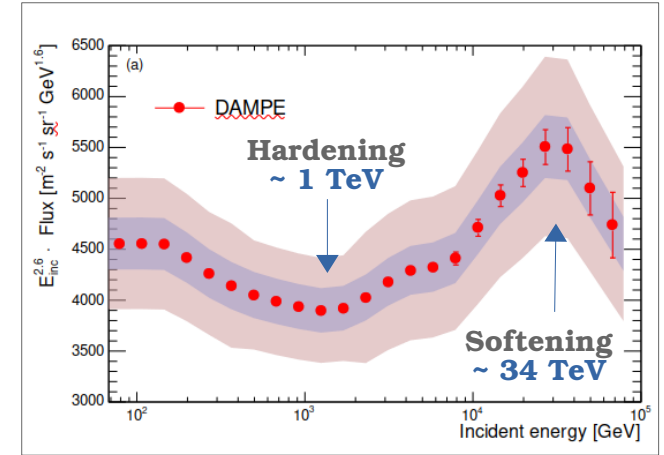
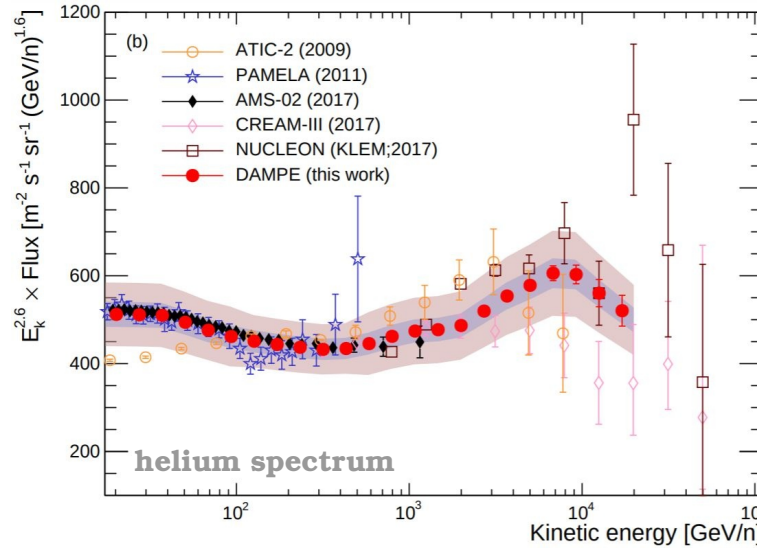
Alemanno et. al. PRL 126, 201102 (2021)

Featured in Physics Editors' Suggestion

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

**Sample:** 54 months of data

**Measurement range:** 70 GeV – 80 TeV



## Helium charge selection in the PSD in various increasing energy bins

### Uncertainties concerning:

- hadronic model simulations

## Independent analysis regarding the proton + helium spectrum

F. Alemanno et. al. PoS, ICRC 2021, 117

**Sample:** 60 months of data

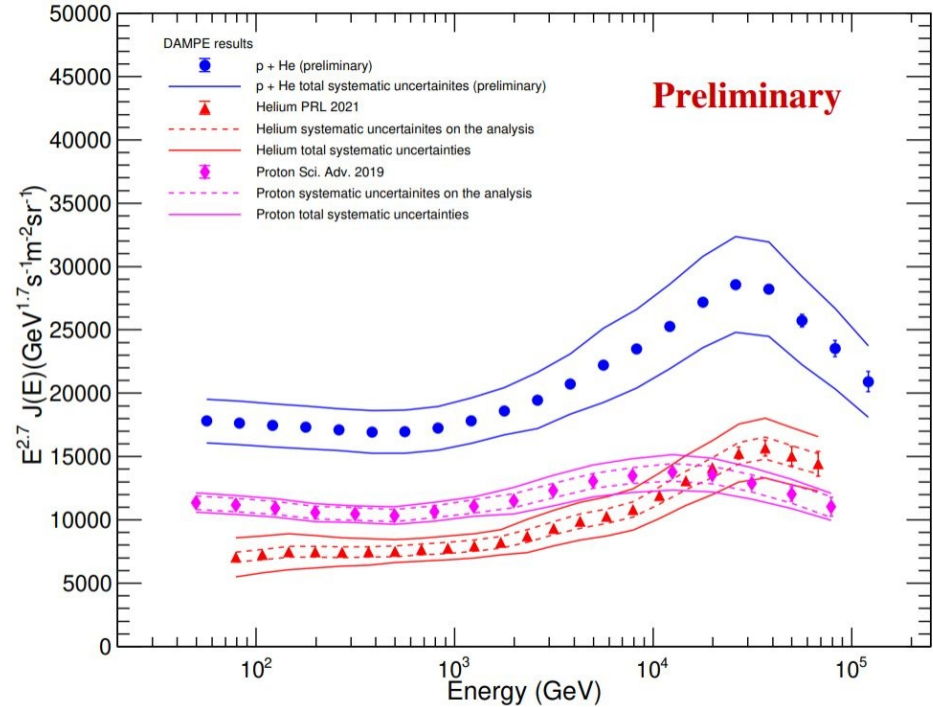
**Energy range:** 50 GeV – 150 TeV

### Motivation

**Low background – high sample purity**  
**Extension up to higher energies\***  
 \*wrt to individual p & He analyses

### Preliminary features:

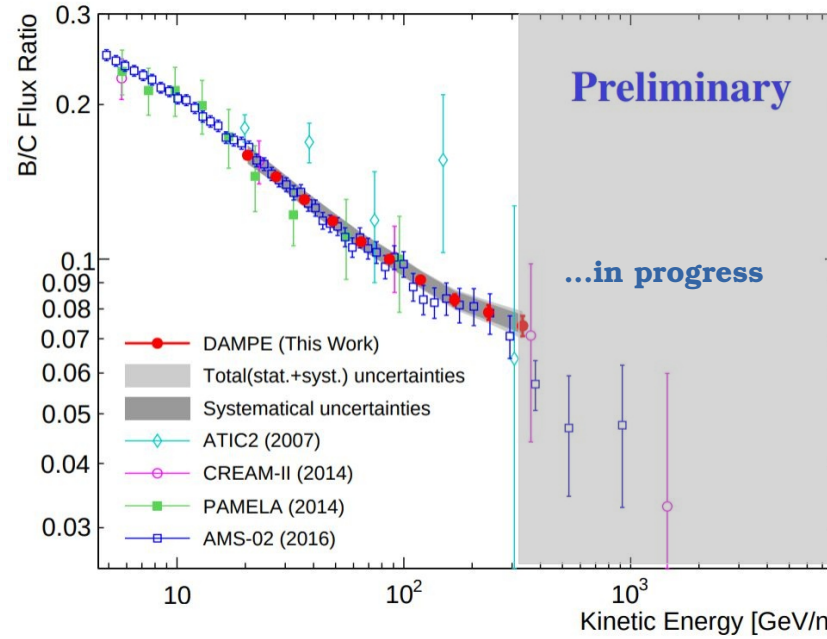
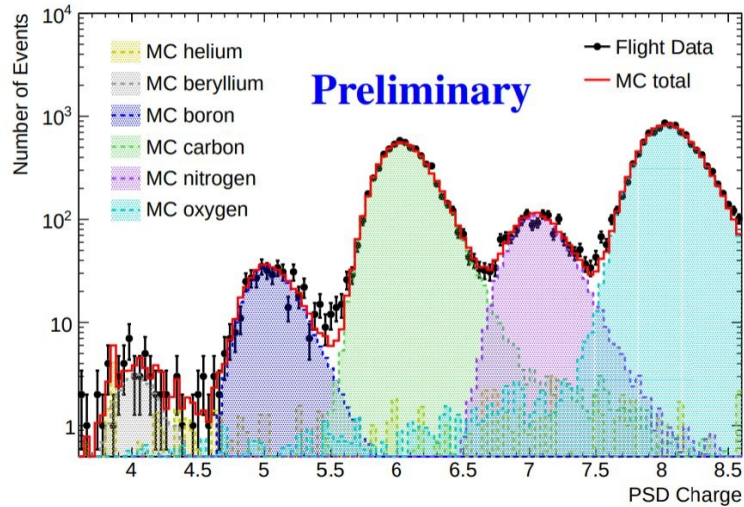
- Hardening @ ~ 600 GeV
- Softening @ ~ 25 TeV



...evaluation of systematics & extension to higher energies is **ongoing**

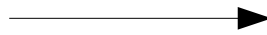
**B/C, B/O – Customarily used to probe CR propagation in the Interstellar Medium**

C. Yue et. al. PoS, ICRC 2021, 126



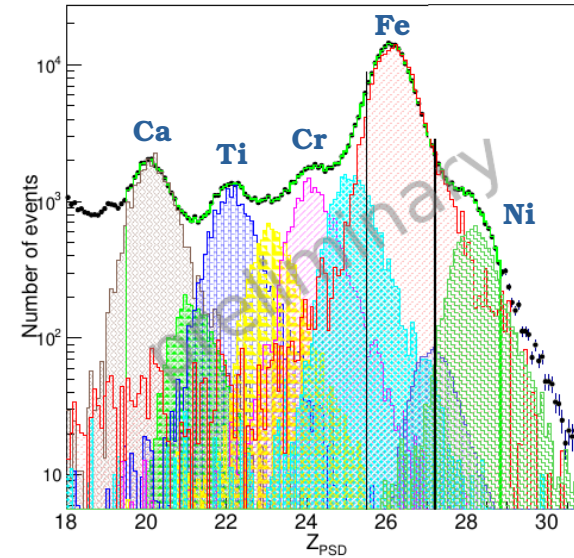
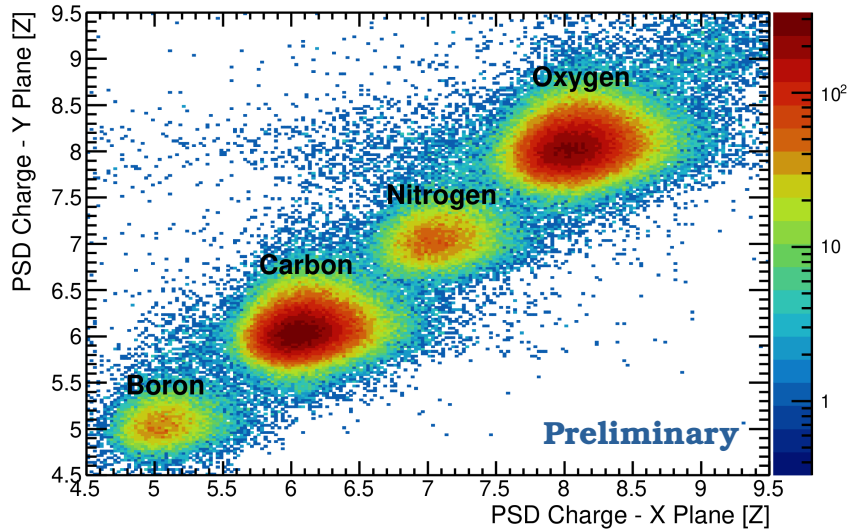
## Understanding the CR propagation mechanism (and more...)

**Secondary nuclei (Li, Be, B)** produced via **spallation** from interactions of **heavier nuclei (C, N, O)** with the Interstellar Medium (ISM)



**Secondary – to – primary ratios** provide crucial information on the **CR propagation mechanism**

Analyses regarding Carbon, Oxygen & Iron spectra are ongoing



Important analyses to reveal possible new structures in the TeV region

**Rigorous efforts in:**

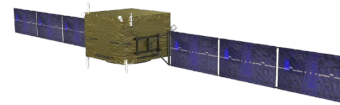
- evaluating systematics,
- optimizing selection cuts,
- understanding nuclear fragmentation effects
- extension of measurements in the multi-TeV region

## DARK MATTER PARTICLE EXPLORER (DAMPE)

- In – orbit since 2015
- Stable data taking & excellent performance
- Unique instrument in probing Galactic Cosmic Rays

## Scientific results & ongoing work

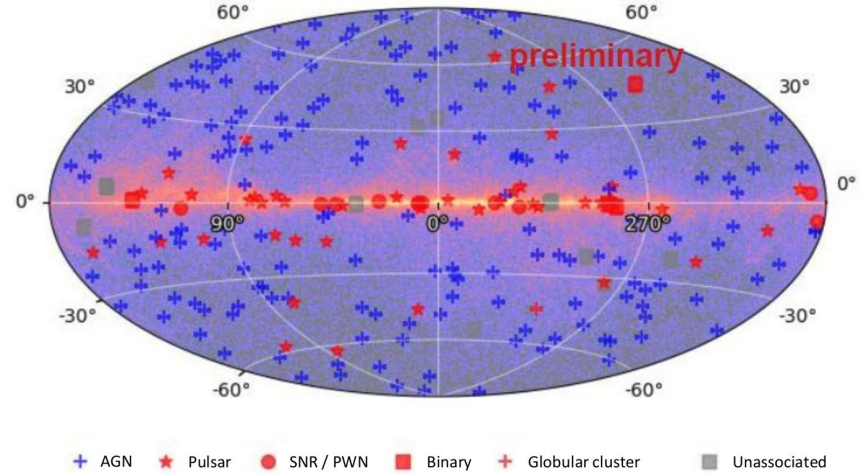
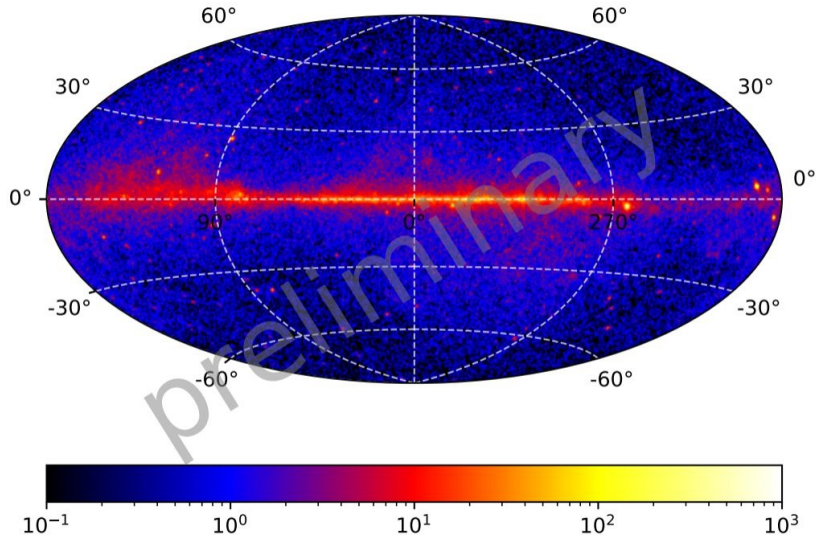
- Intriguing features revealed in all-electron, proton & helium CR spectra
- Extension of previous measurements to higher energies w/ great precision
- Ongoing CR analyses: p+He, B/C, C, O, Fe...
- Insightful work on gamma – rays: 5-year source catalog, limits on decaying DM...



# Additional Info

5 – year exposure map

Identified sources



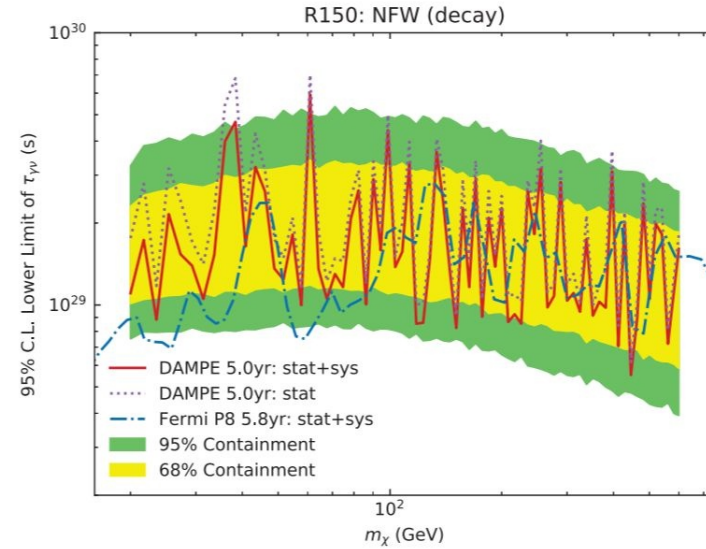
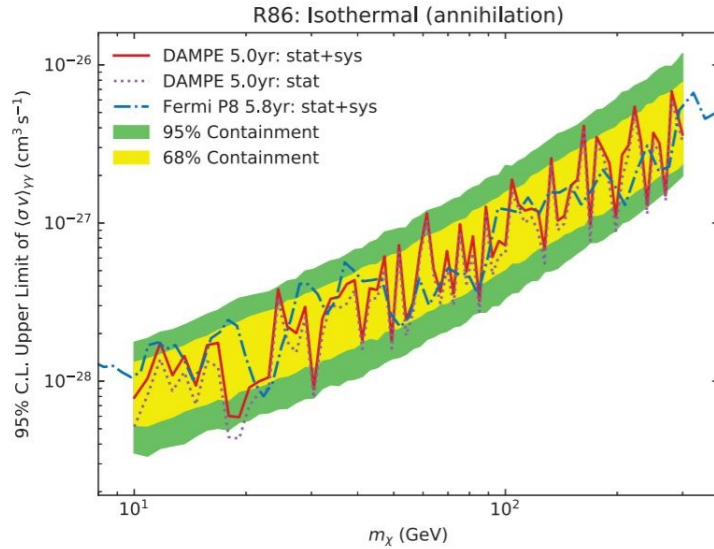
[K.K. Duan et. al. PoS, ICRC 2021, 631](#)

## 5 years of data: large source catalog

222 sources identified including > 170 AGNs & > 40 pulsars



Z.L. Xu et. al. PoS, ICRC 2021, 632



## Indirect searches for DM signatures by detecting possible line-like features in the gamma-ray spectrum

Excellent energy resolution – sensitivity comparable to Fermi – LAT  
Improvement on decaying DM limits for  $< 100$  GeV mass