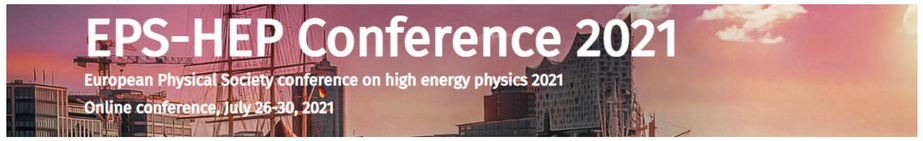
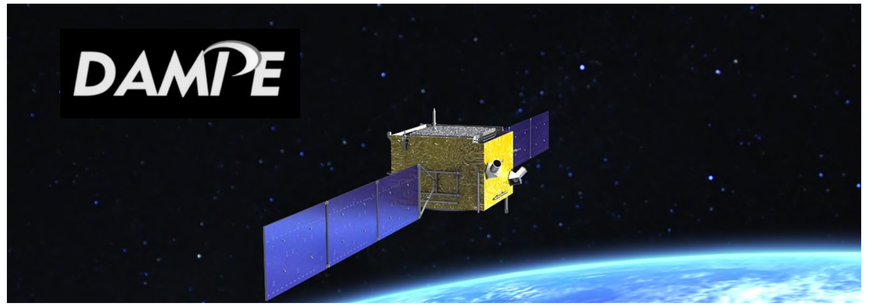


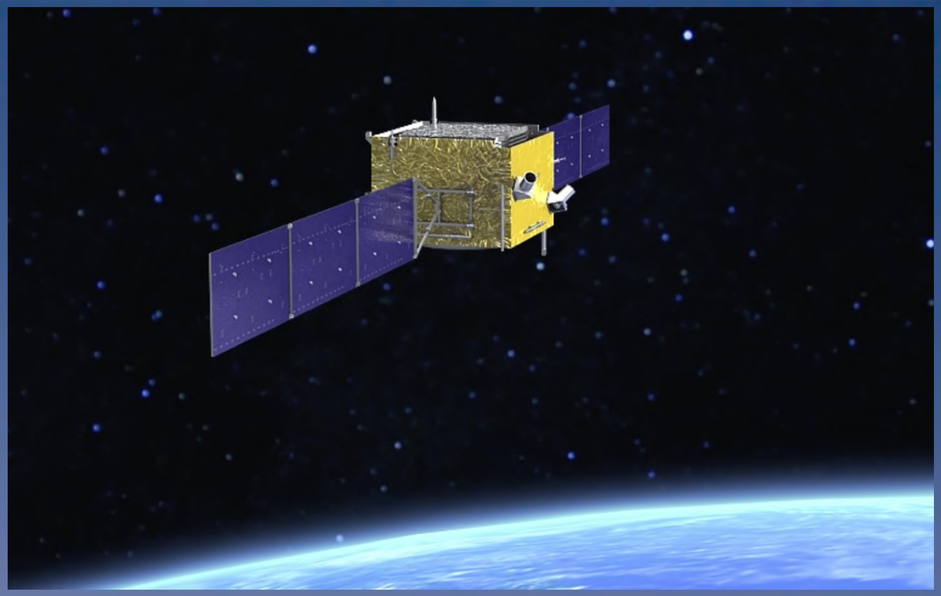


UNIVERSITÉ DE GENÈVE

Latest results from DAMPE

Andrii Tykhonov (for the DAMPE collaboration)

DArk Matter Particle Explorer (DAMPE)



Launched: Dec 2015
Payload: 1300 kg
Altitude: 500 km
Orbit: 95 minutes
97° inclination
Sun-synchronous

Jiuquan Satellite Launch Center, Gobi desert, China

DAMPE collaboration

China

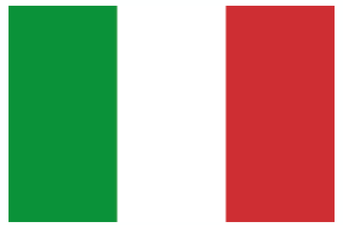
- Purple Mountain Observatory, CAS, Nanjing
- University of Science and Technology of China, Hefei
- Institute of High Energy Physics, CAS, Beijing
- Institute of Modern Physics, CAS, Lanzhou
- National Space Science Center, CAS, Beijing

Switzerland

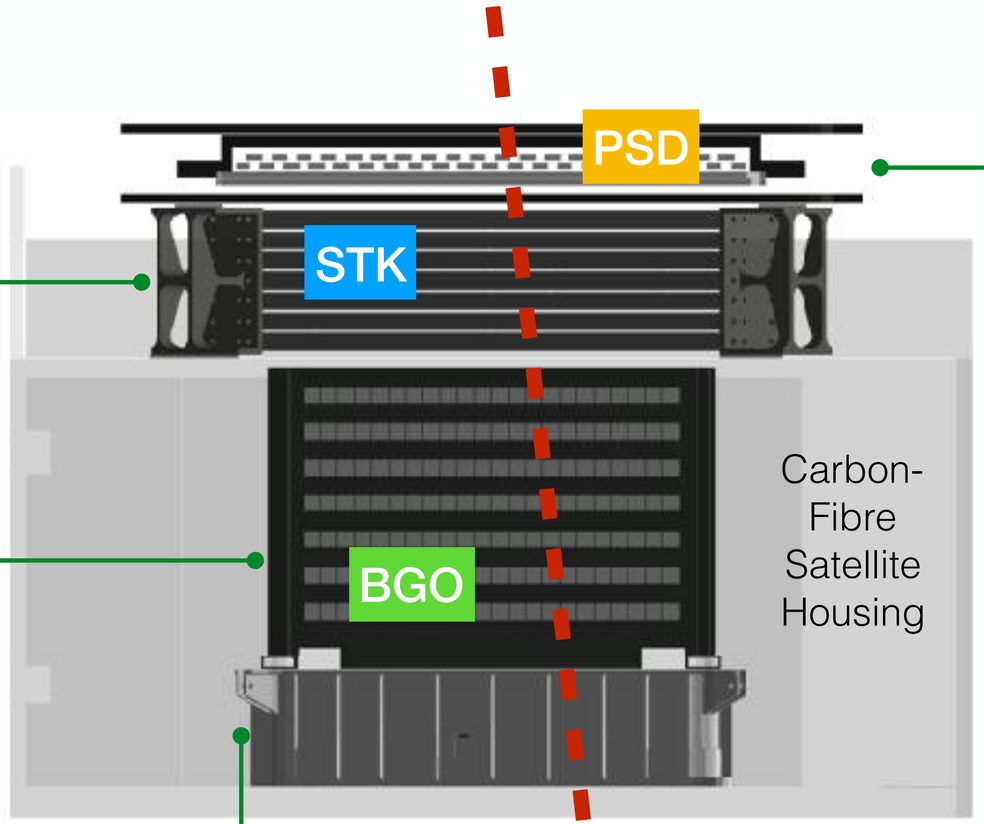
- University of Geneva
- EPFL Lausanne (joined in 2021)

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



DAMPE Detector



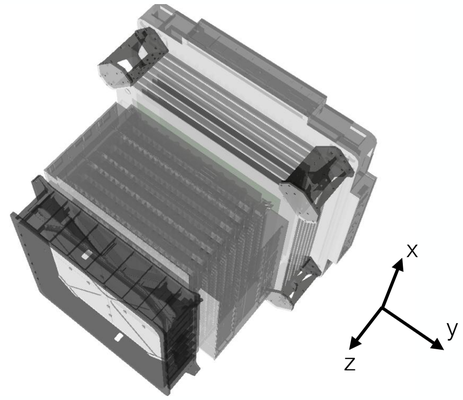
Plastic Scintillator-strip Detector **(PSD)**

Silicon-Tungsten tracKer converter **(STK)**

Bismuth Germanium Oxide calorimeter **(BGO)** 31 X_0

Neutron detector **(NUD)**

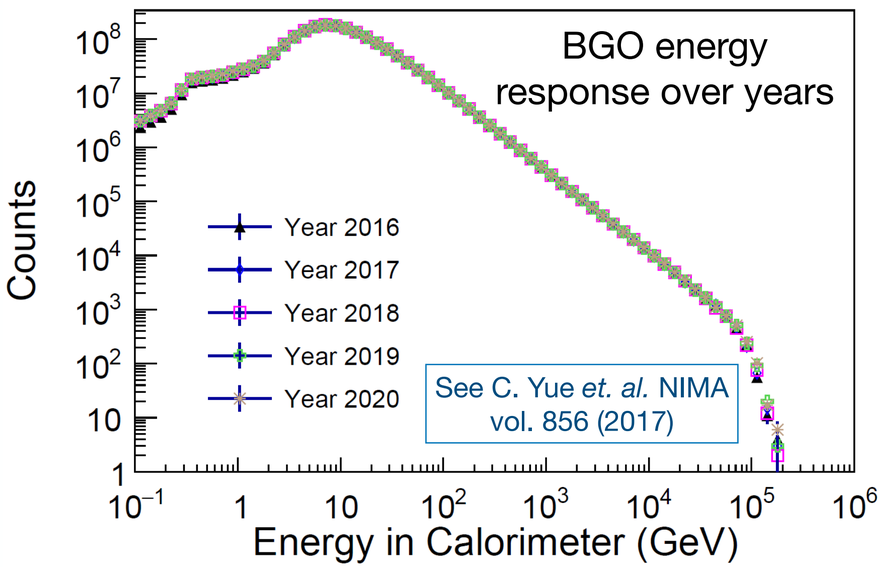
particle

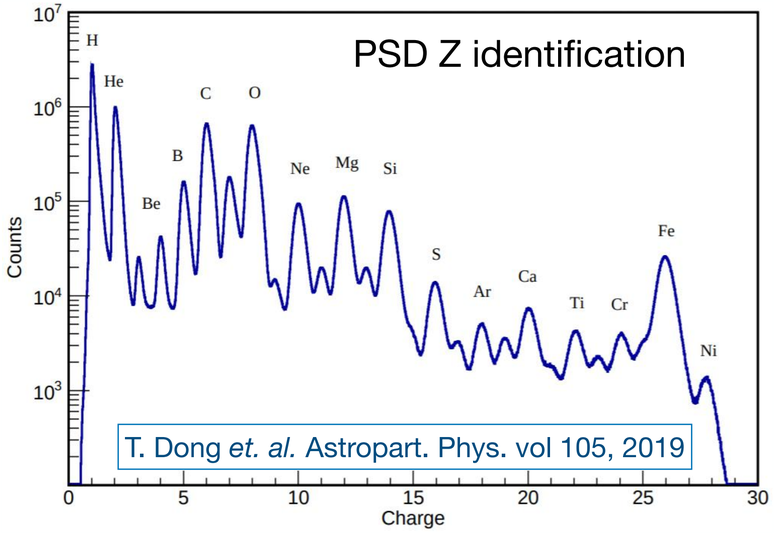


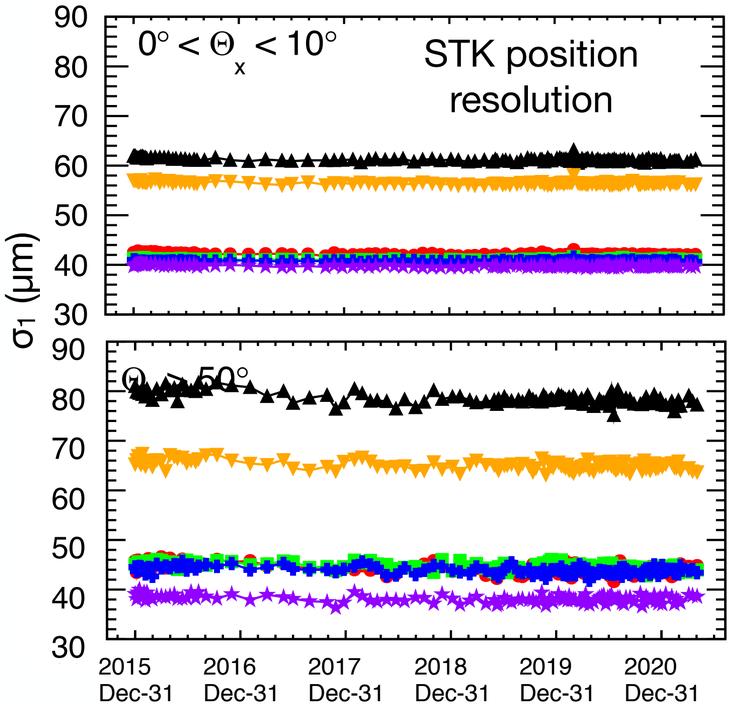
3D view of DAMPE (Geant4)

DAMPE Detector *on-orbit status*

- Stable BGO energy response throughout more than 5 years of operation
- Excellent PSD Z resolution (good job on alignment, light attenuation & quenching correction)
- Excellent STK noise stability and position resolution (alignment every 2 weeks)







Stable data taking since December 2015 up to now!

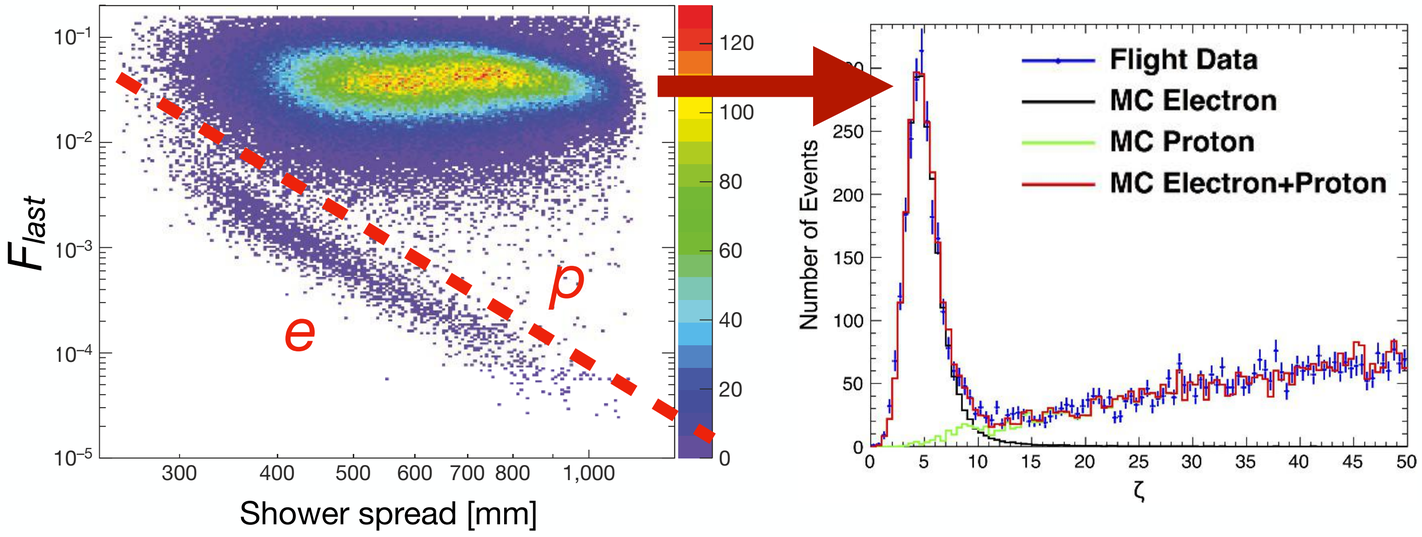
… 10 billion events collected for the analysis

See A. Tykhonov *et. al.* NIMA vol. 893 (2018), vol. 924 (2019)

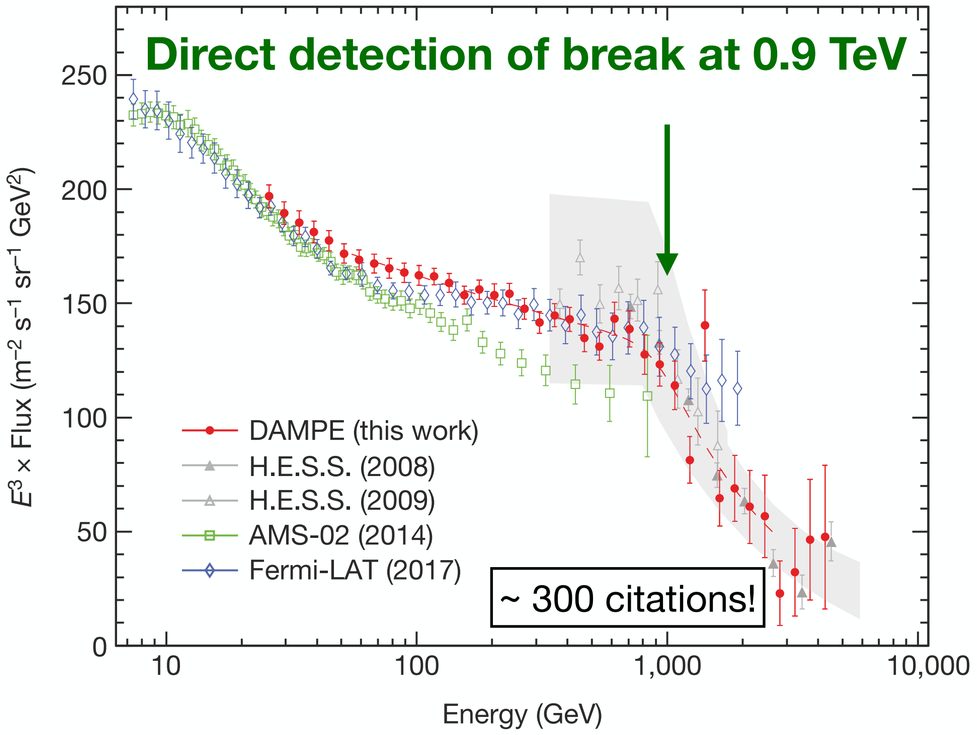
Cosmic Rays: $e^+ + e^-$

Ambrosi *et al* Nature vol 552, (2017)

- Relatively big geometric acceptance ~0.35 m² sr
- Deep granular calorimeter:
  - ~31 X_0, 14 layers, 22 bars / layer
  - Energy resolution ~ 1% (above 100 GeV)
  - *e/p* discrimination — *p* rejection 10^4 — 10^5



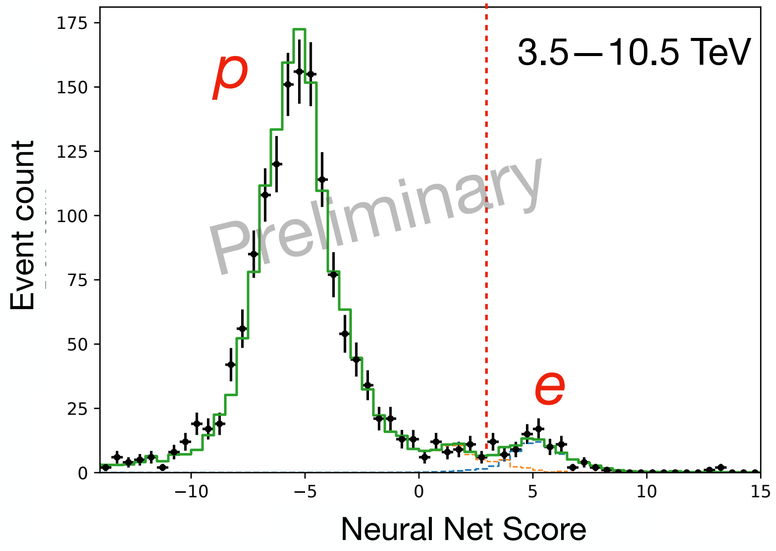
Cosmic Ray $e^+ + e^-$ spectrum

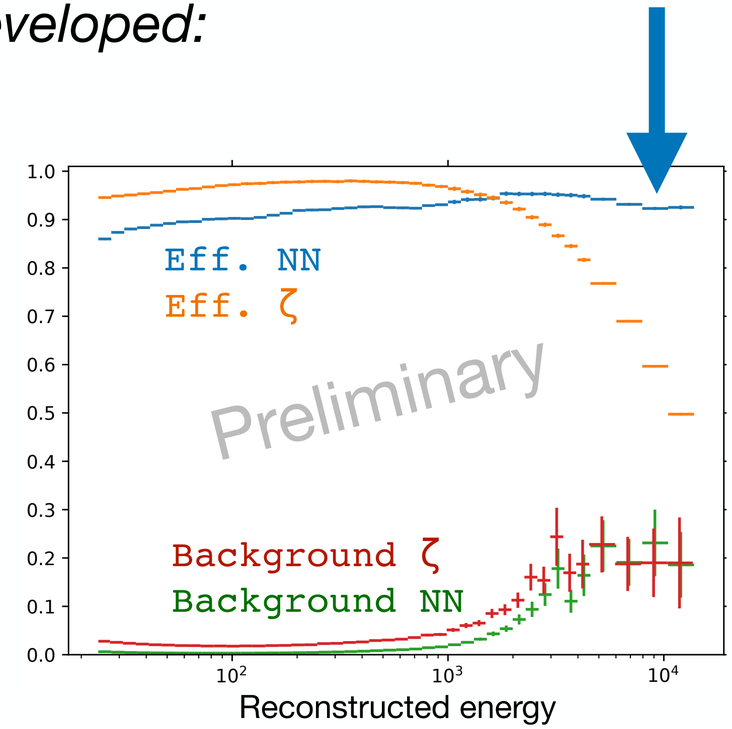


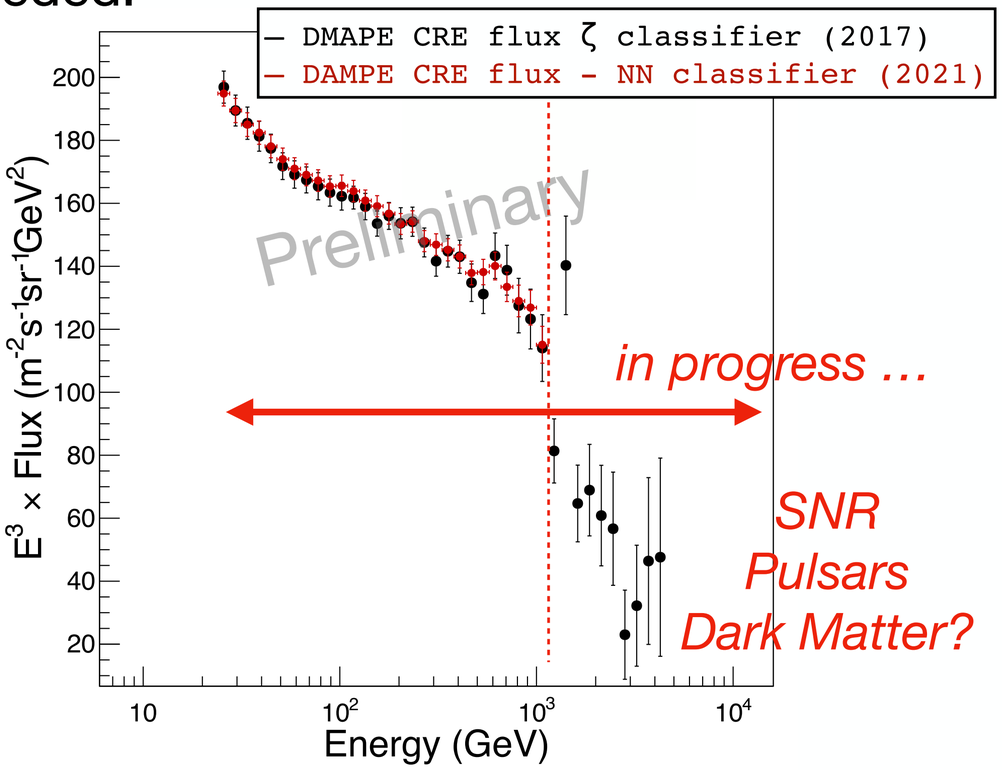
DAMPE — unique instrument for probing CR electron (CRE) spectrum at > ~ TeV!

Cosmic Rays: $e^+ + e^-$

- CRE rapidly loose energy due to synchrotron radiation — only local sources with 1 kpc >~ TeV
- *p* background critical at ~ 10 TeV → new *e/p* classifier needed!
  - *Neural Net classifier developed:*







See EPS-HEP2021 n. 47 (D. Droz)

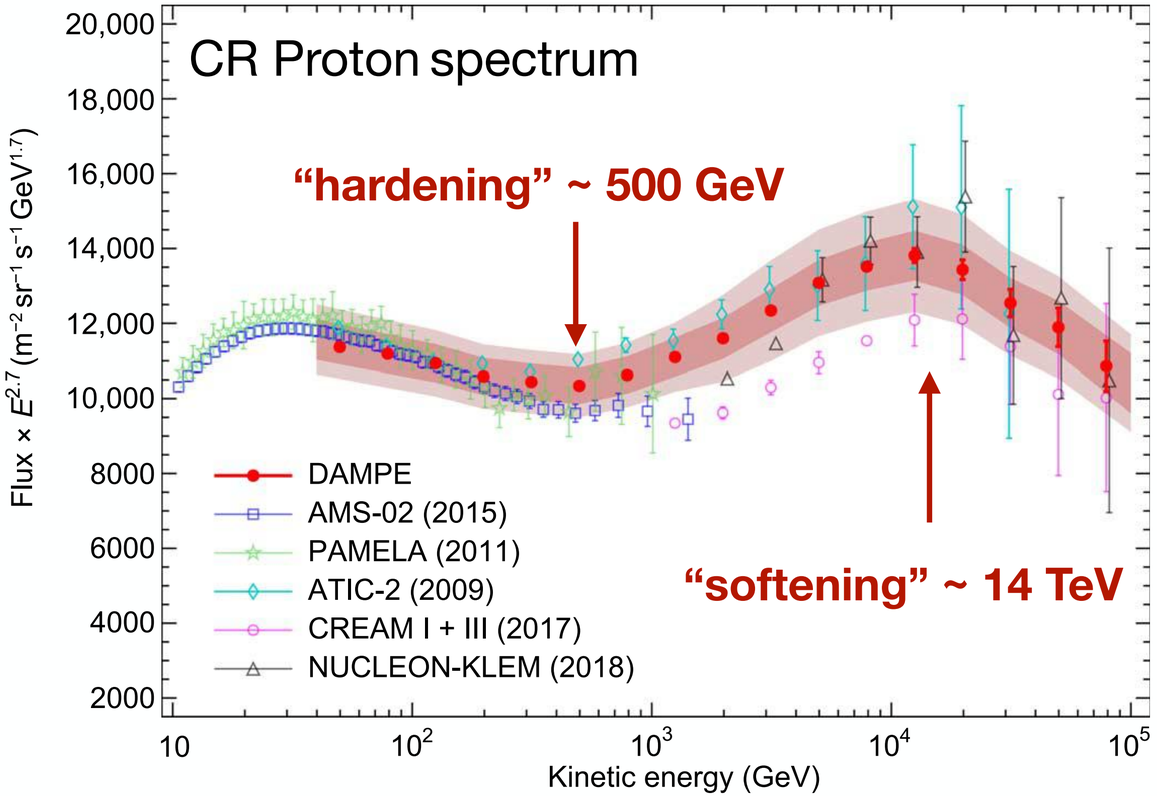
See *D. Droz et al 2021 JINST 16 P07036*

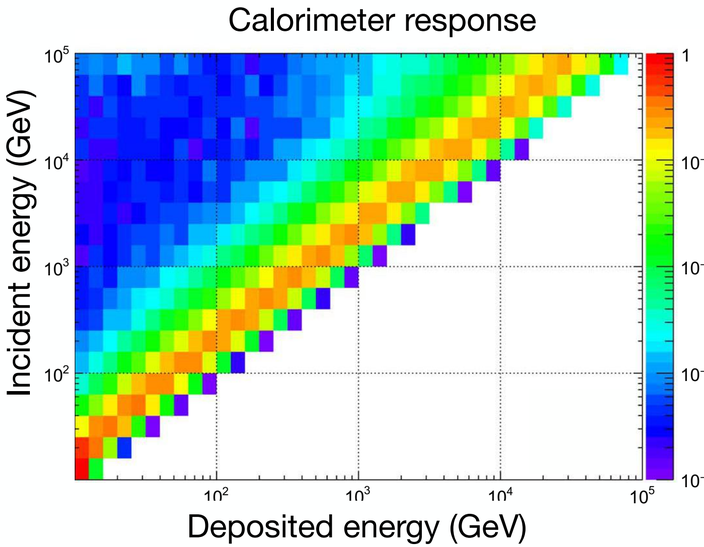
Cosmic Rays: *proton*

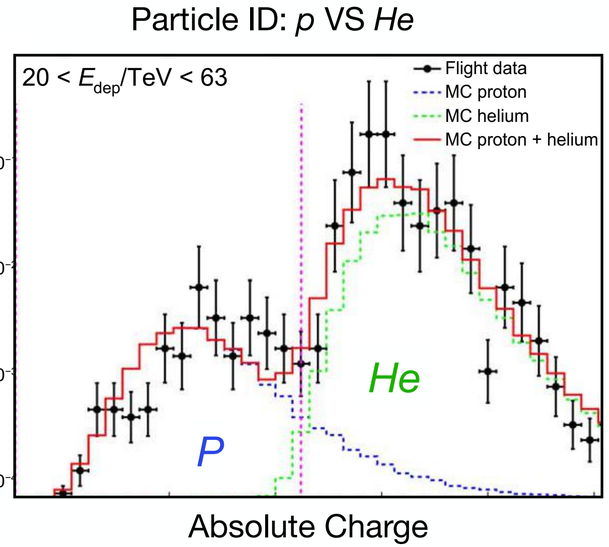
Q. An *et al.* Sc. Adv. 2019: Vol. 5, no. 9

DAMPE measurement: challenging conventional (single-component) CR-origin models

… new production or propagation mechanism, nearby sources?







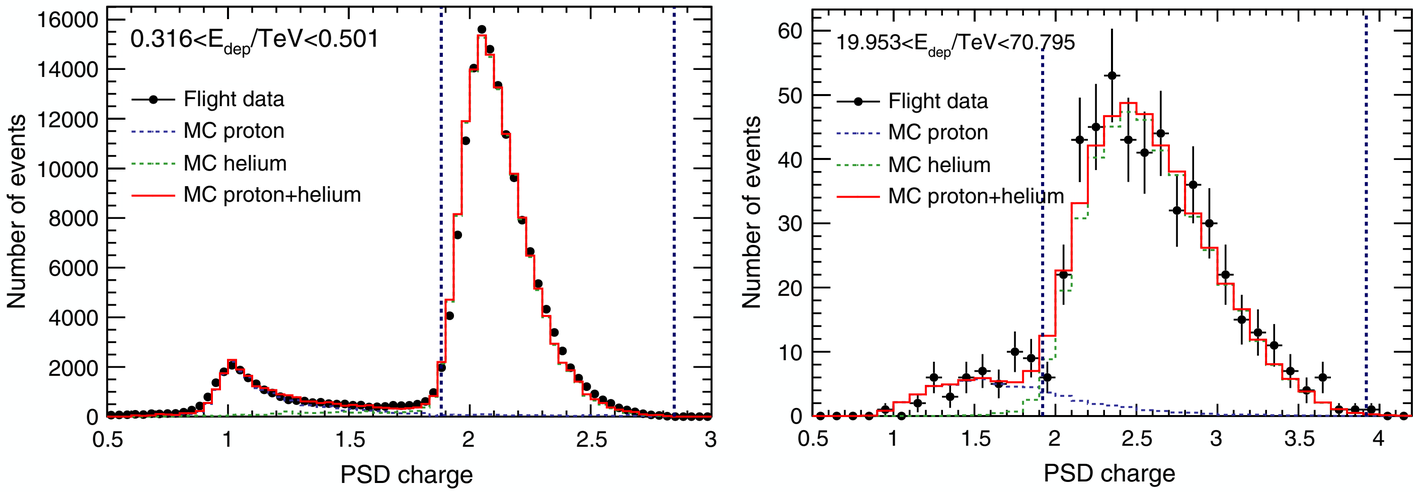
Key systematics: hadronic simulation uncertainty and p/He separation at highest energies

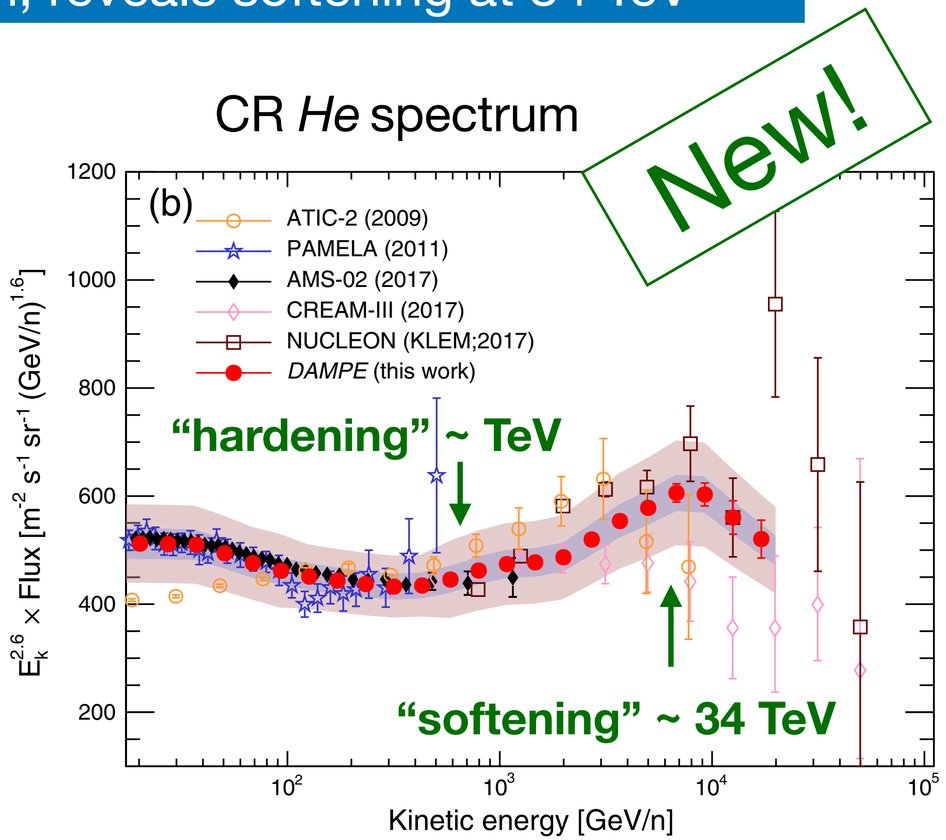
DAMPE measurement in 2019 confirms spectral hardening and reveals new structure at 14 TeV!

Cosmic Rays: *He*

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

2021 result: confirms hardening at few hundred GeV/n, reveals softening at 34 TeV



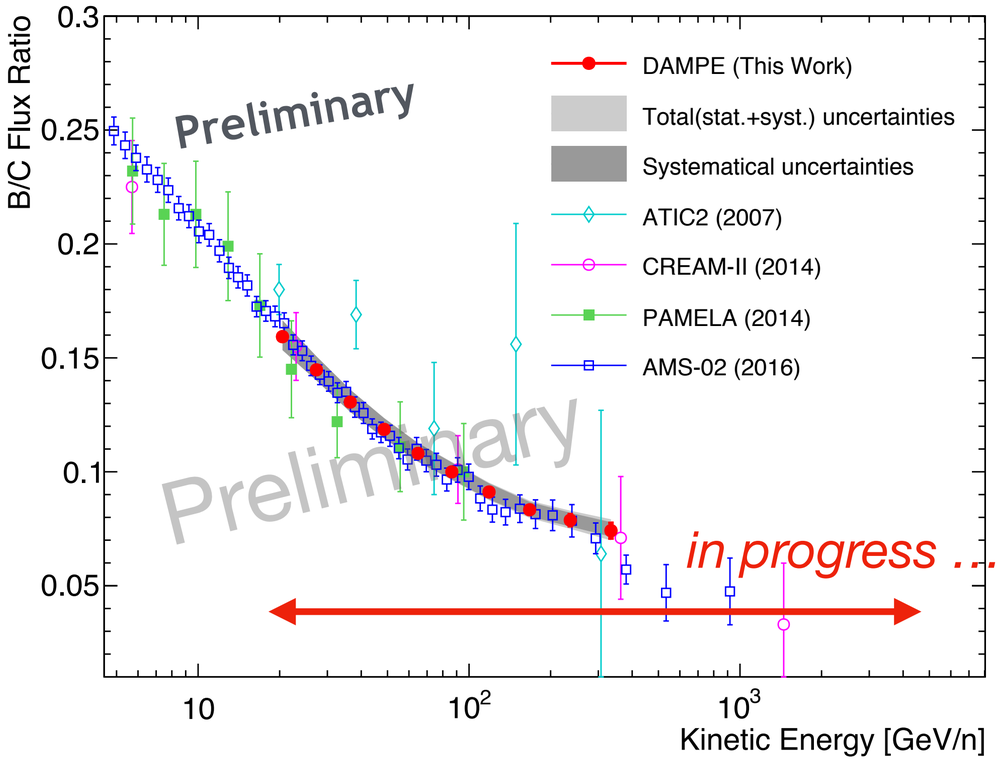


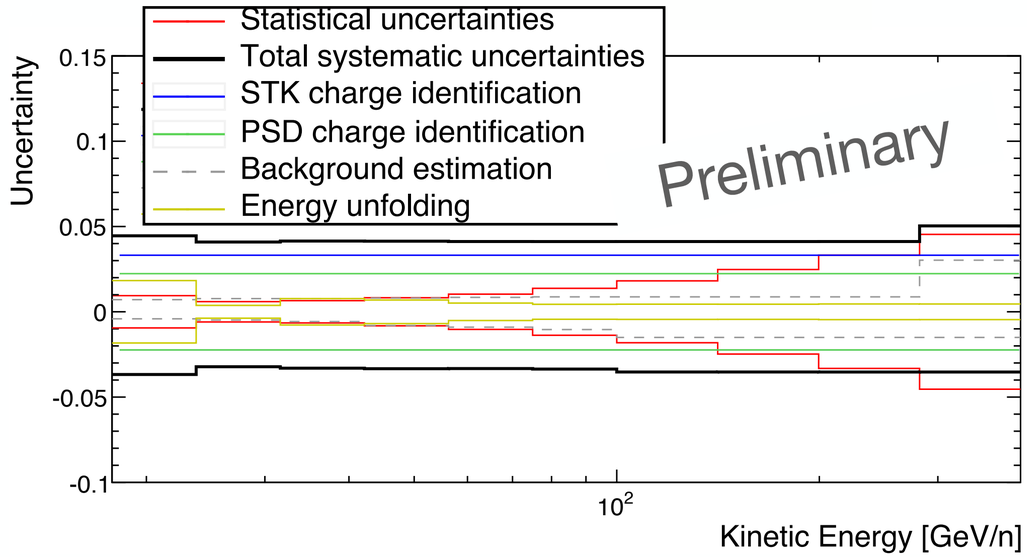
- *p* contamination reduced by Z pre-selection in the tracker
- Dominating uncertainty from Hadronic Simulation

… combined with p spectrum indicates of Z-dependent source (A-dependent not excluded)

Cosmic Rays: *B/C* ratio

- B/C ratio — representative of Cosmic Ray propagation, ideal for Interstellar Medium study
  - Existing measurements stop at ~ TeV → new data essential for understanding CR propagation



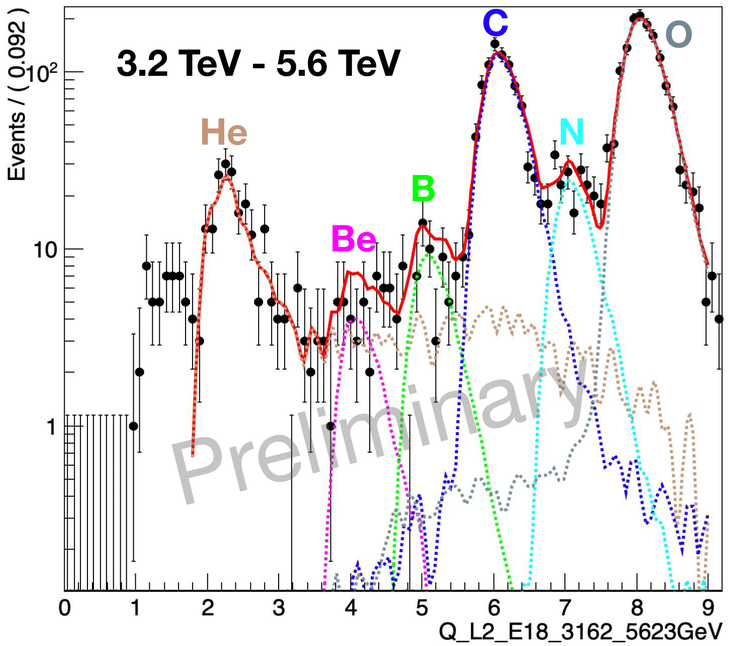


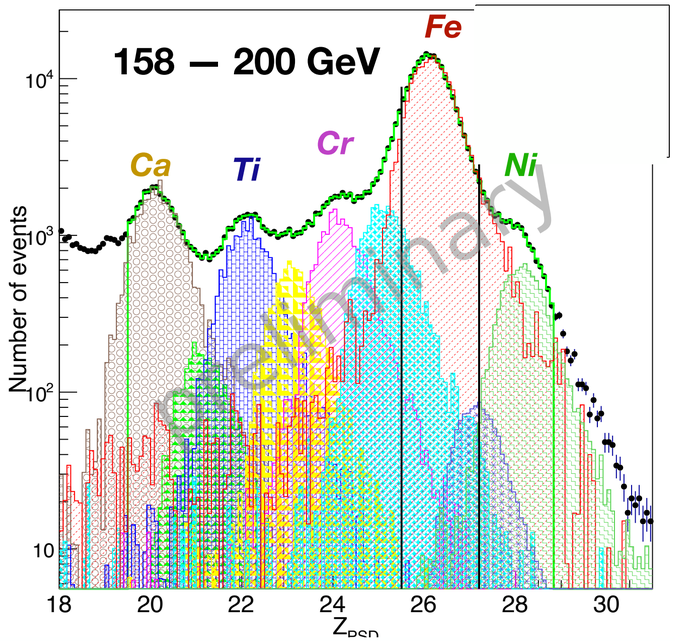
- Relatively low systematics — <u>(partial) compensation of hadronic uncertainties</u>

B/C analysis is well advanced — measurement up to few TeV/n in progress …

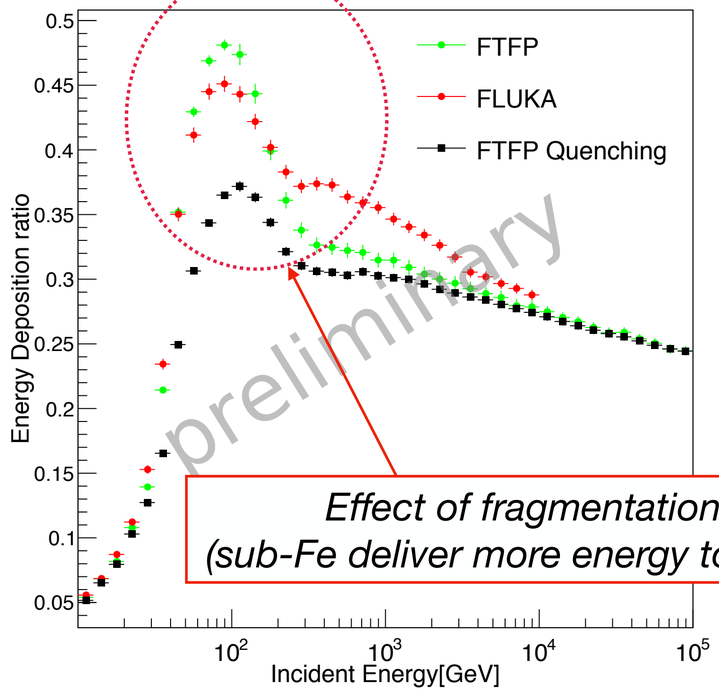
Cosmic Rays *C, O, Fe … in progress*

Signs of further structures (similar to p/He) beyond TeV ?





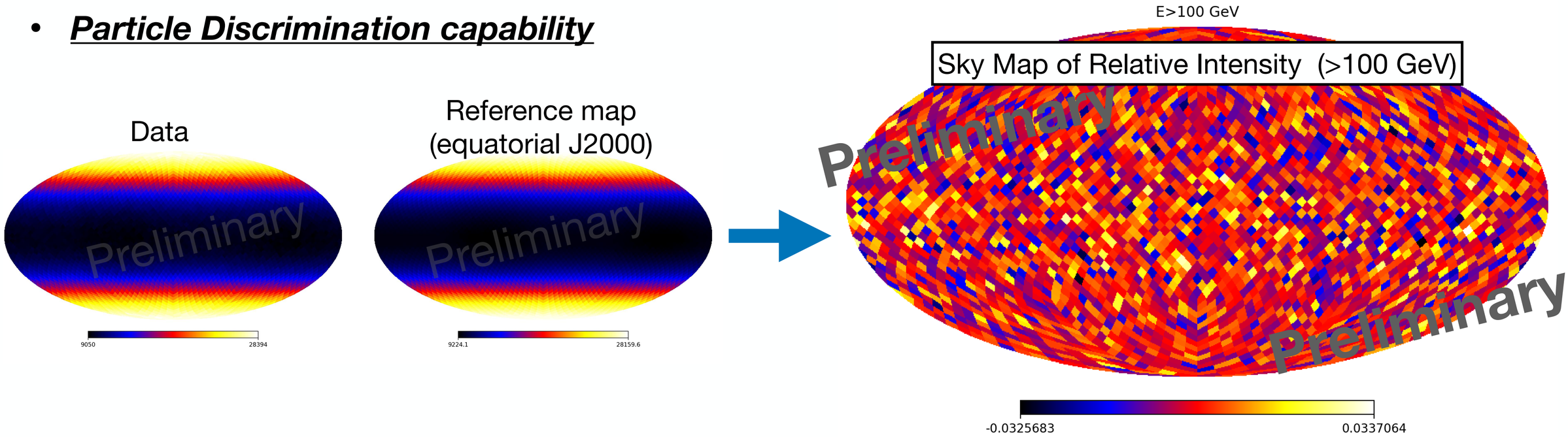
Fe — incident VS observed energy



- C & O analysis → consistent data /MC → uncertainties study in progress
- *Fe* spectrum up to few TeV/n in progress → fragmentation rate study (Geant FTFP vs FLUKA)
- Quenching of BGO calorimeter important …

Cosmic Rays *Anisotropy*

- CR — highly isotropic, small anisotropies seen by ground-based experiments
- No anisotropy so far with Space experiments (lower acceptance), however:
  - Much wider sky coverage — can probe ***Declination anisotropy***
  - ***Particle Discrimination capability***

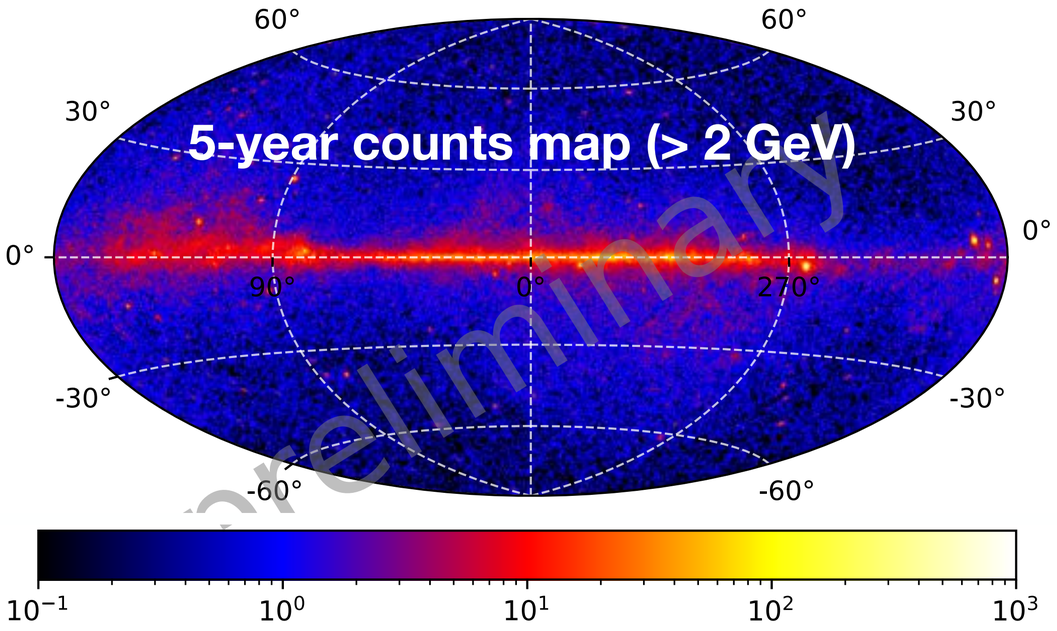


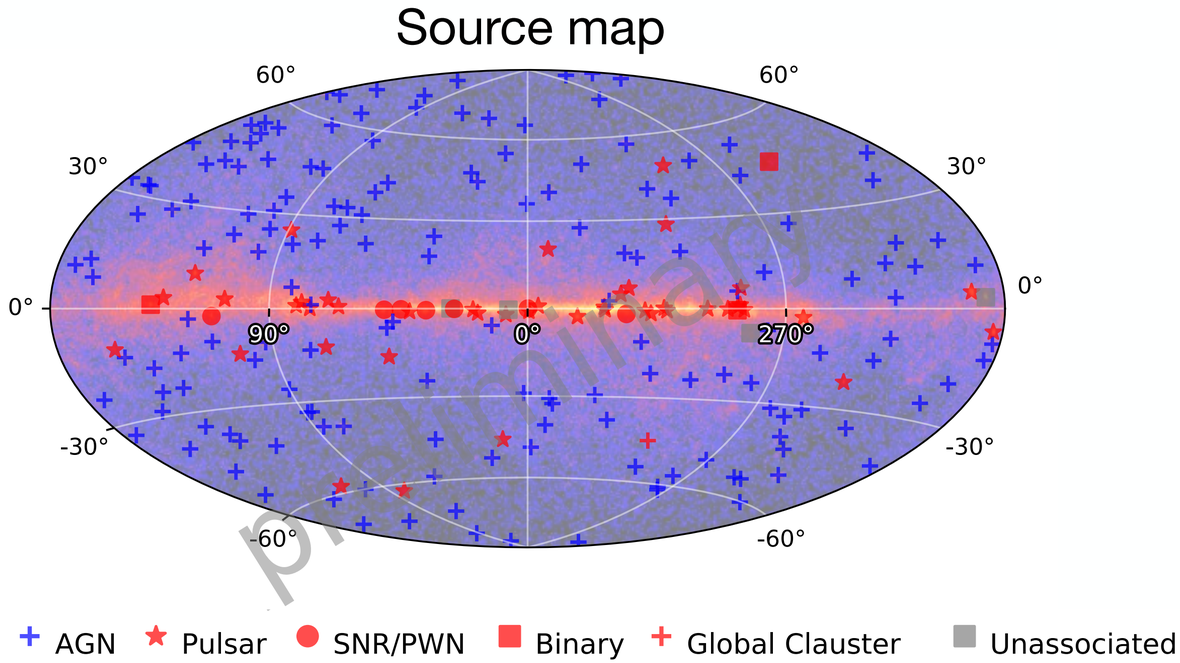
- Analysis developed & validated (East-West and Compton-Getting effect)

Results consistent with null-hypothesis (no anisotropy)

Gamma-Rays: Sky Map & Sources

Rich source catalog after 5 years



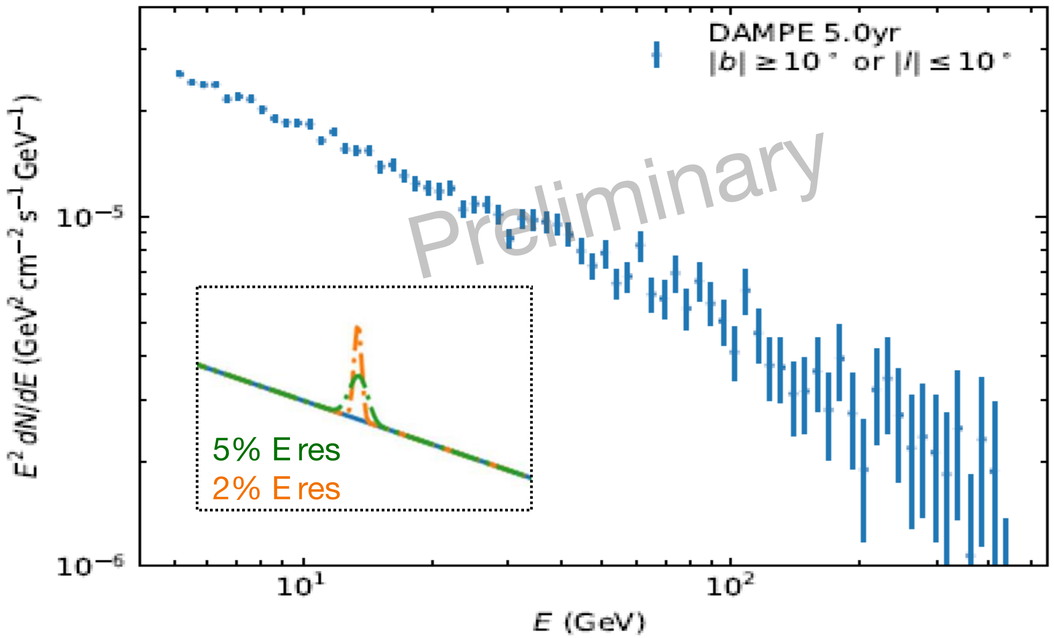


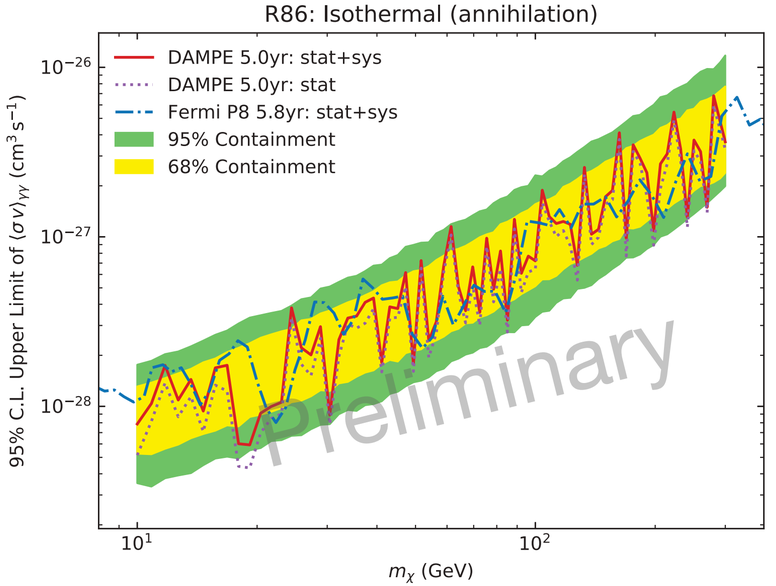
Type	AGN	Pulsar	SNR and/or PWN	binary	globular cluster	unassociated
Number	163	44	7	3	1	4

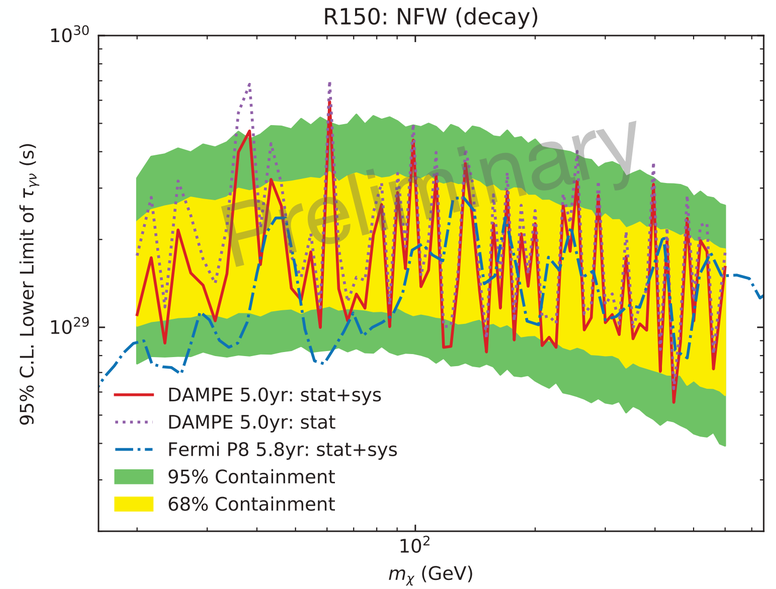
Gamma-Rays: Line Search

- **Excellent energy resolution**
  - Sensitivity comparable with Fermi LAT

    (in spite lower acceptance)



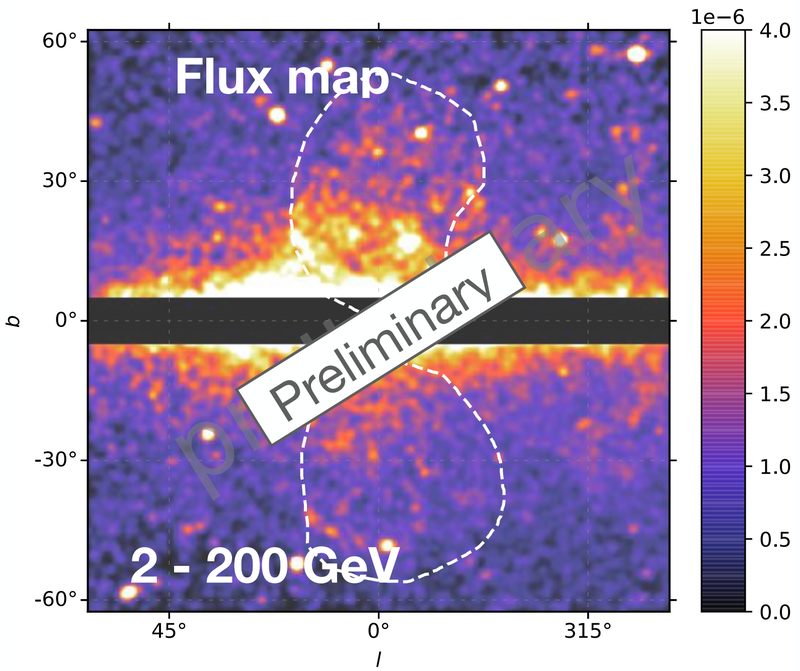


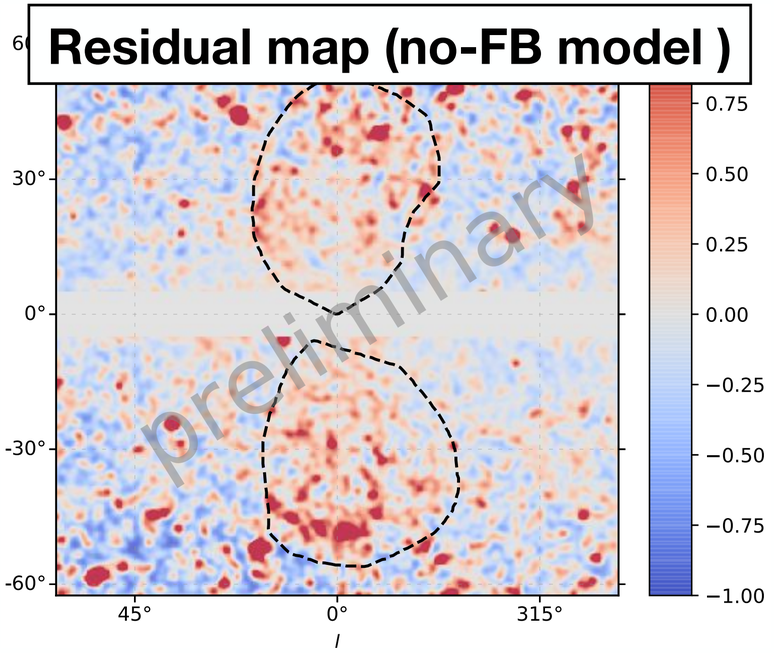


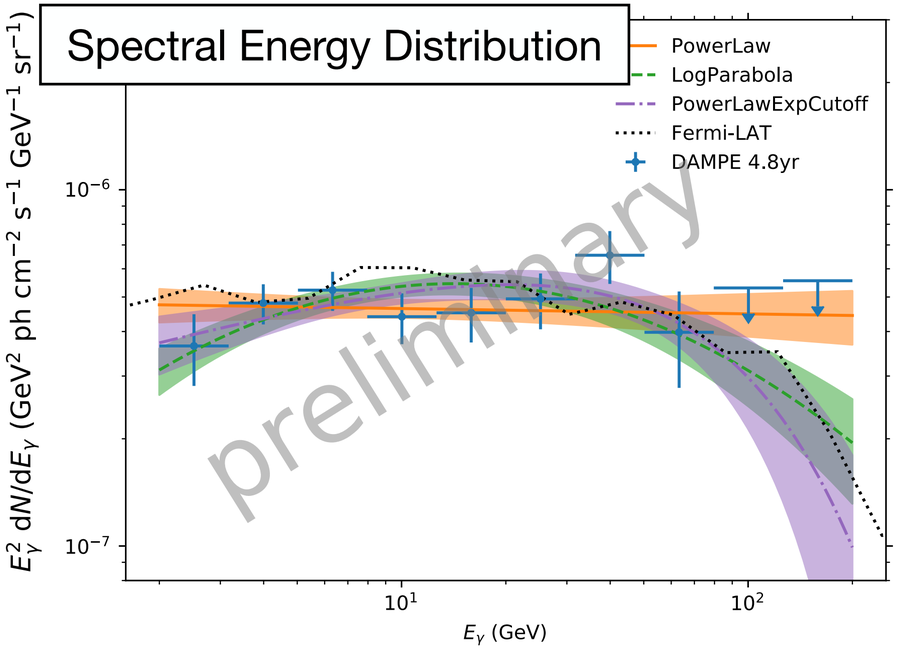
*For decaying **Dark Matter** — the most stringent limits on decay lifetime with DM mass < 100 GeV*

Gamma-Rays: Fermi Bubbles (FB)

FB — diffuse structures discovered by FERMI LAT, associated with Galactic Centre







- Spectrum well consistent with FERMI * M. Ackermann *et al* 2014 *ApJ* **793** 64
- Interesting features— mild curvature of spectrum (2.9σ), excess in cocoon (3σ)

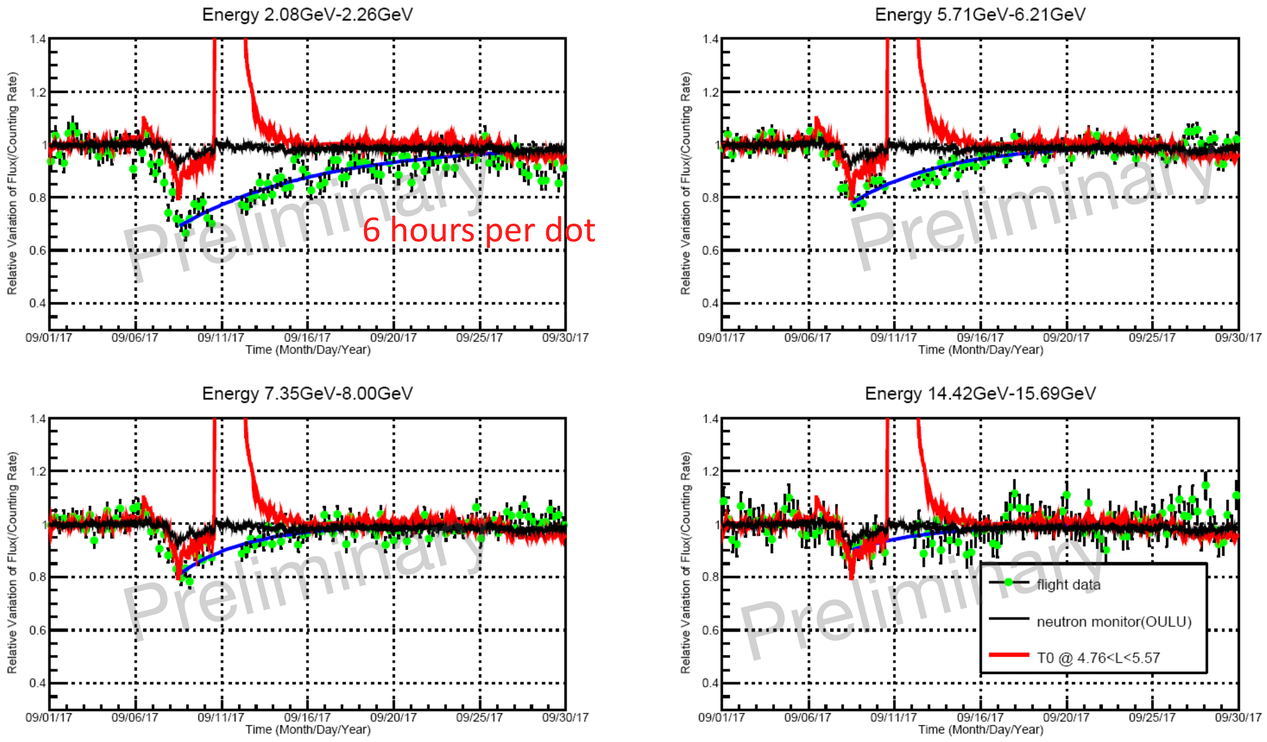
  … more to come

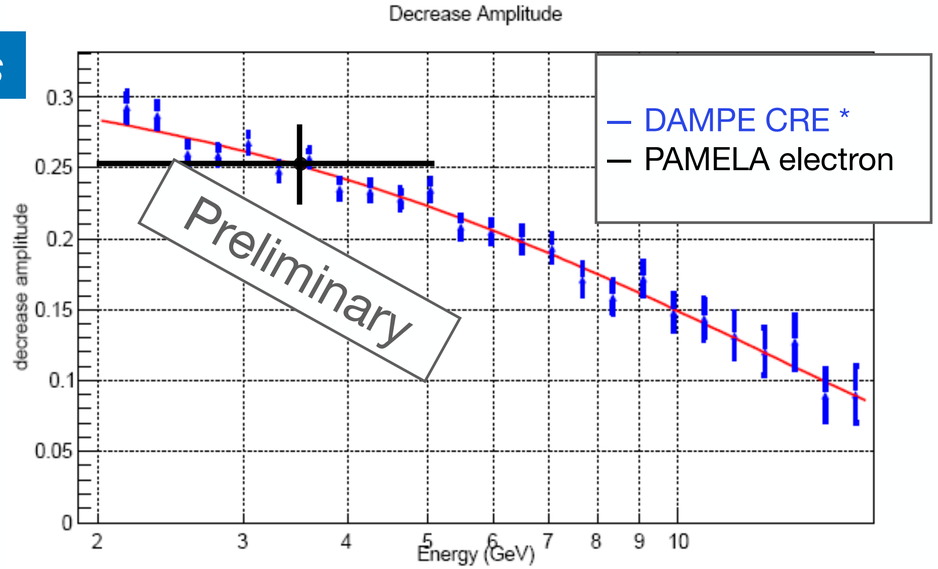
Heliophysics & Cosmic Rays

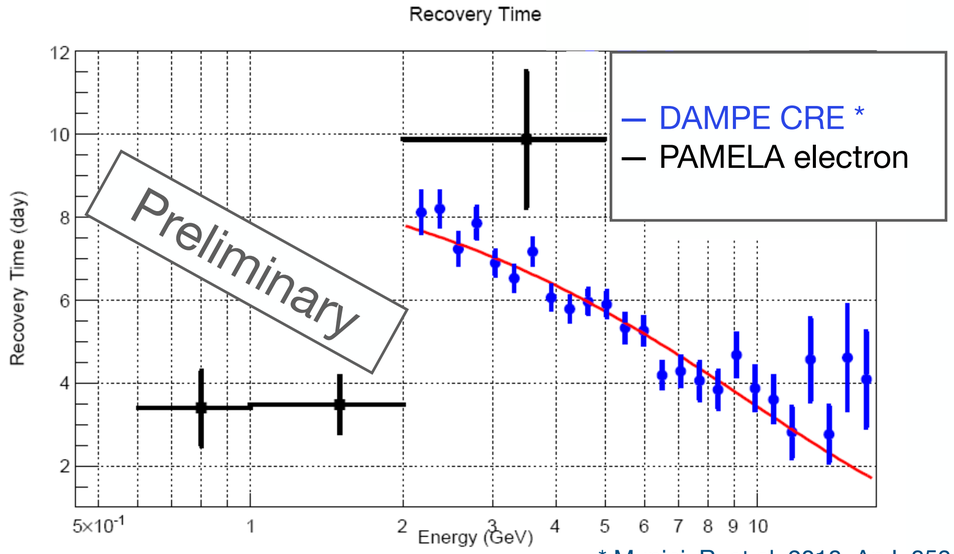
Forbush Decrease (FD) — CR follow-up of energetic solar flares

- Orbit reaching polar regions (reduced geomagnetic cutoff)
- 0.35 m^2 sr acceptance

→ High-Precision Measurement of FD





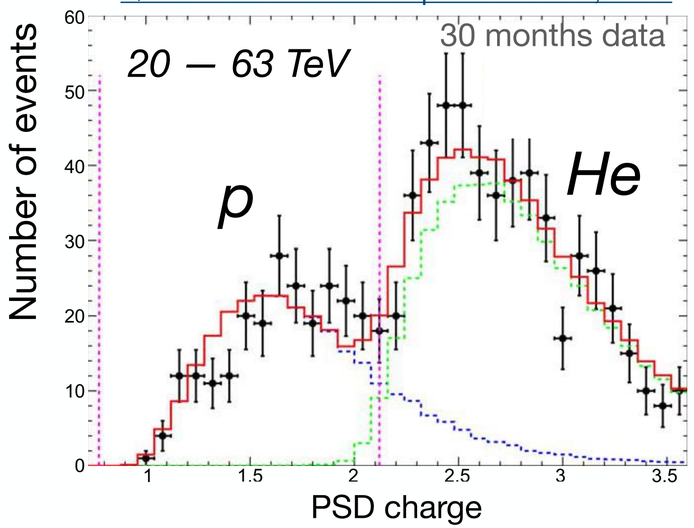


* Munini, R. et al. 2018, ApJ, 853, 76

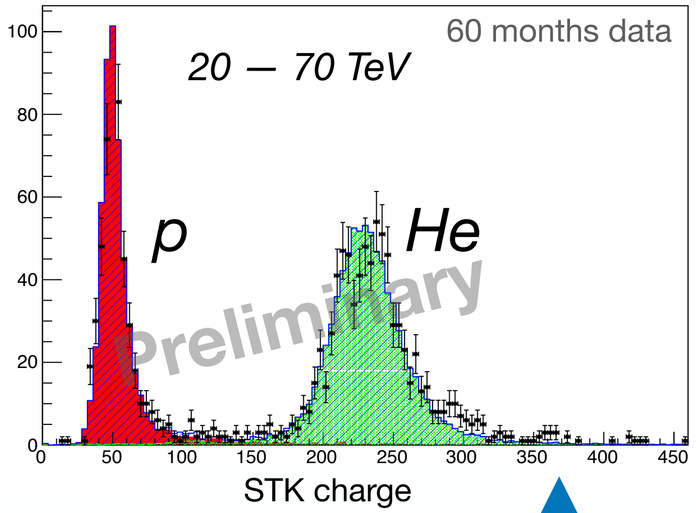
Coscmic Rays: *p & He* towards PeV

- Machine Learning (ML) track reconstruction → indication of advantage over classical approach at multi-TeV

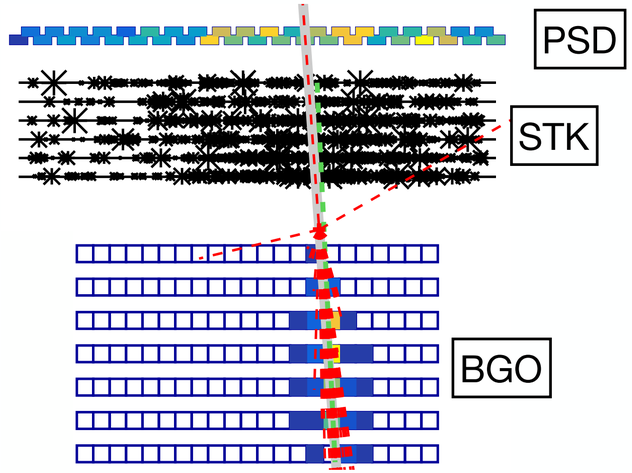
Q. An et al. Sc. Adv. Sep 2019: Vol. 5, no. 9



ML tracking → STK Z identification



High-Energy CR event example



E_{BGO} = 64 TeV

- Tracker can provide precise *p/He* identification — hard due to backscattering!
- Developed Deep Learning algorithm — accurate primary track finding

ERC Starting Grant

Conclusions

DArk Matter Particle Explorer (DAMPE)

- In-flight operation 2015 — now
- Excellent performance & stability
- Unique for multi-TeV Cosmic Rays (CR)

Rich Physics Program

- CR $e^+ + e^-$ — direct observation of TeV-break
- CR *p & He* — enter TeV—PeV frontier
- CR *B, C, O, Fe — in progress …*
- *γ-ray sky, Fermi Bubbles, DM search*
- *Heliophysics & CR*
- *ML R&D for high-energy CR frontier (ERC project)*