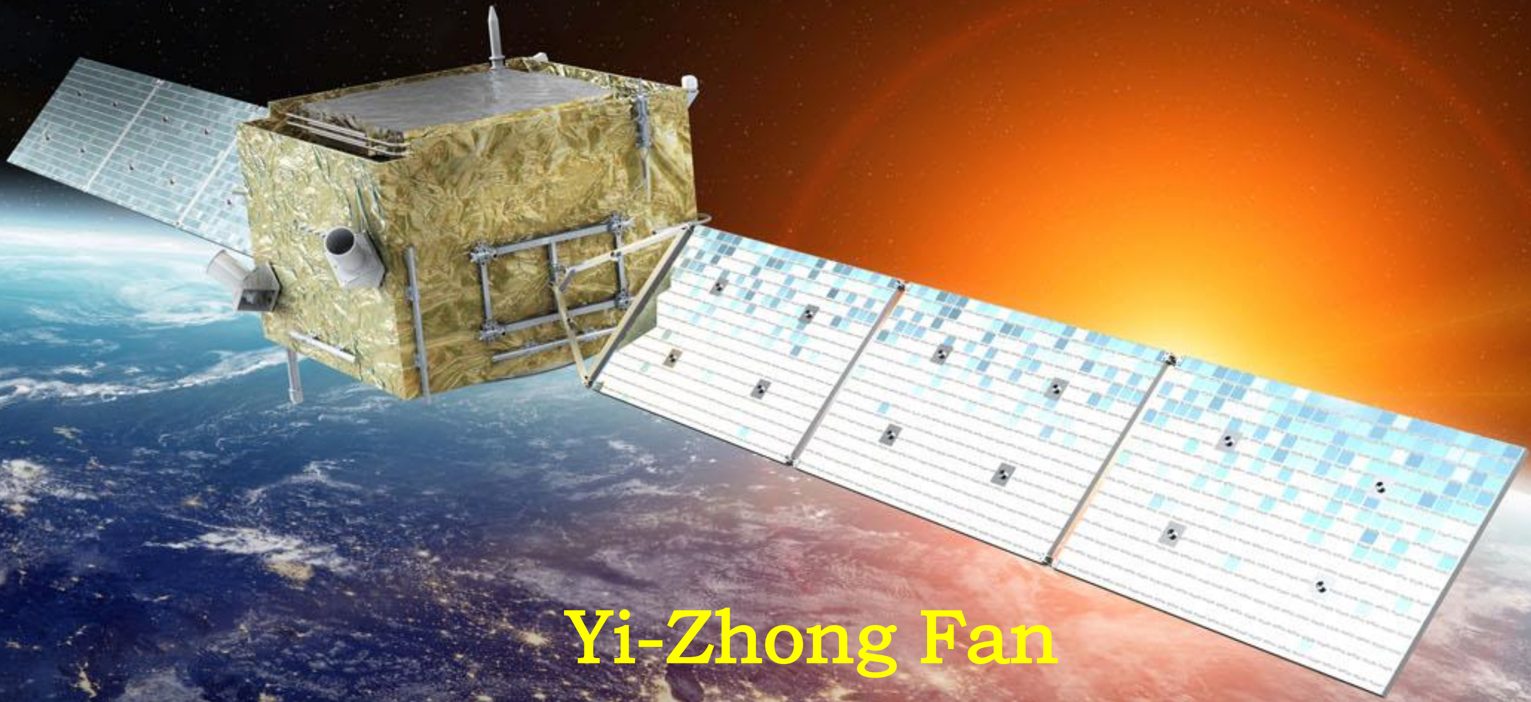
中国科学院暗物质与空间天文重点实验室
DSA Key Laboratory of Dark Matter and Space Astronomy, CAS
白春礼题

International Symposium on Cosmology and Particle Astrophysics 2017
Yukawa Institute for Theoretical Physics, Kyoto Univ., Dec. 11–15, 2017

DAMPE mission and its first results



Yi-Zhong Fan
Purple Mountain Observatory
(on behalf of the DAMPE collaboration)

The collaboration

- **PI of DAMPE: Jin Chang from PMO**

- 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**

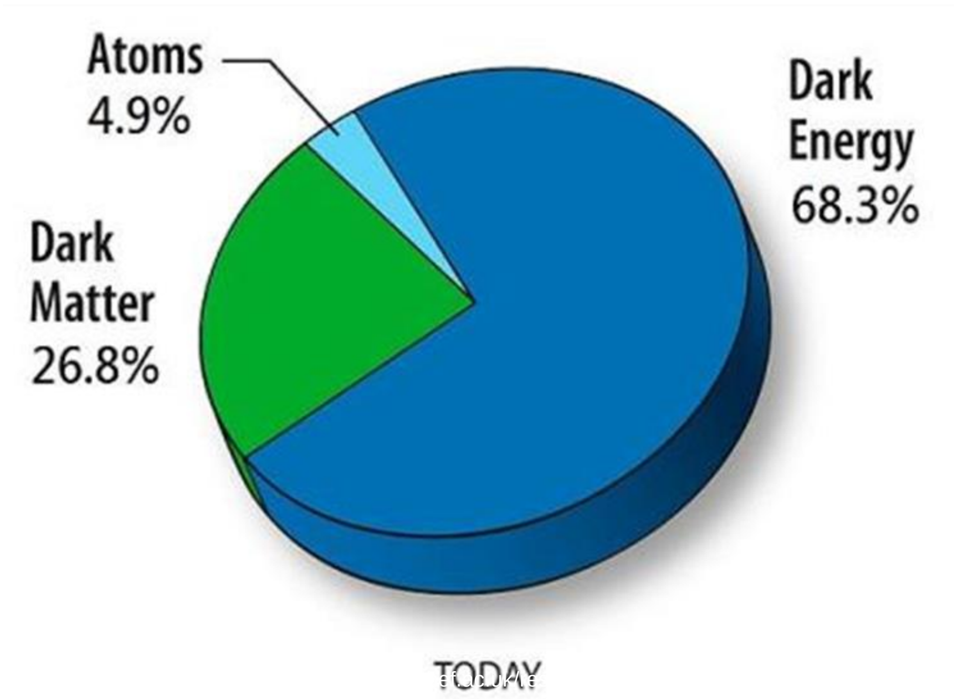
- ITALY
  - **INFN Perugia**
  - **INFN Bari**
  - **INFN Lecce**

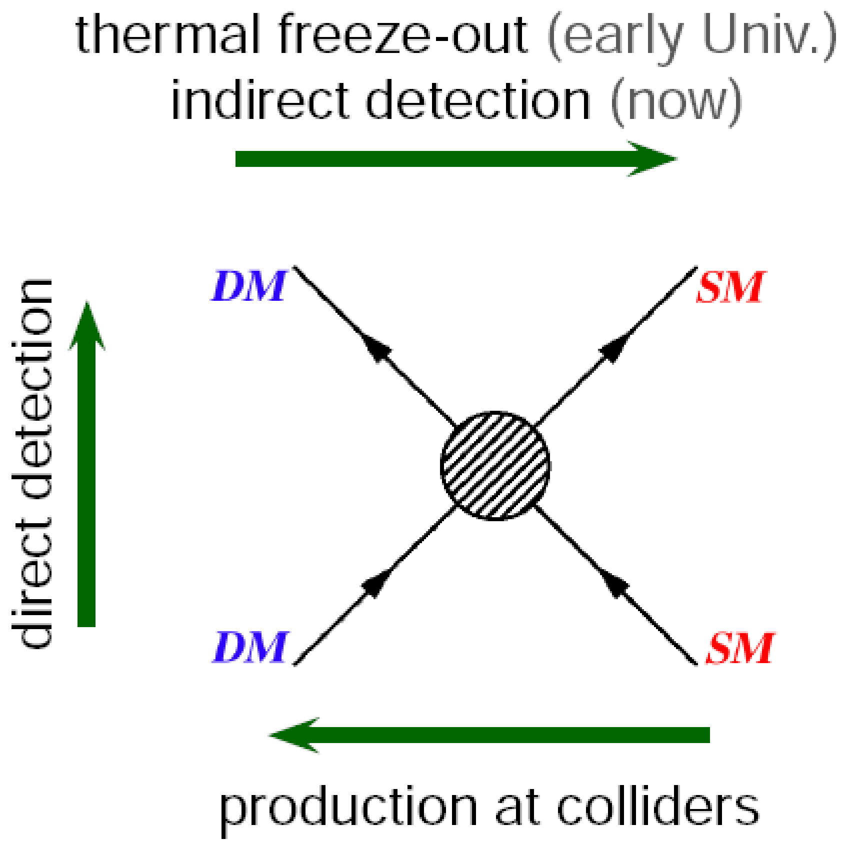
- SWITZERLAND
  - **University of Geneva**

Outline

- **Background**
- **DAMPE mission**
- **First Results**

Dark matter



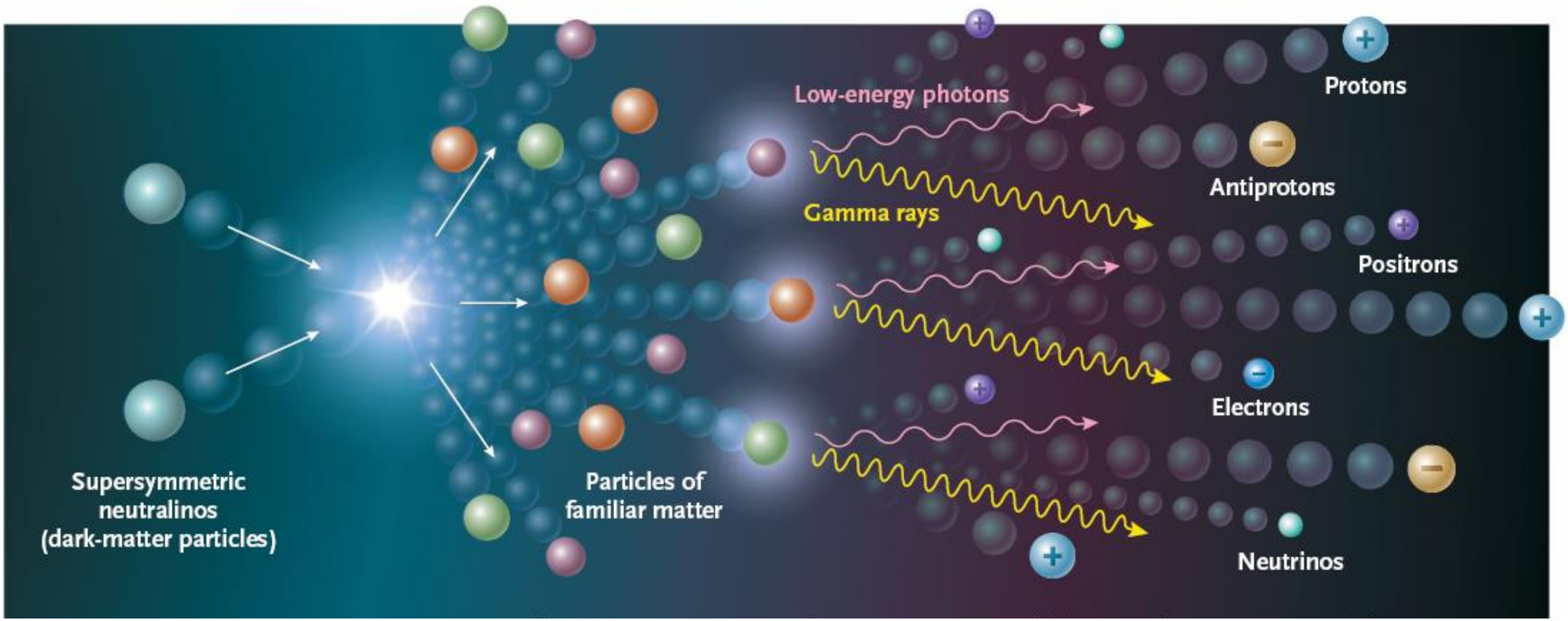

thermal freeze-out (early Univ.)
indirect detection (now)

direct detection

production at colliders

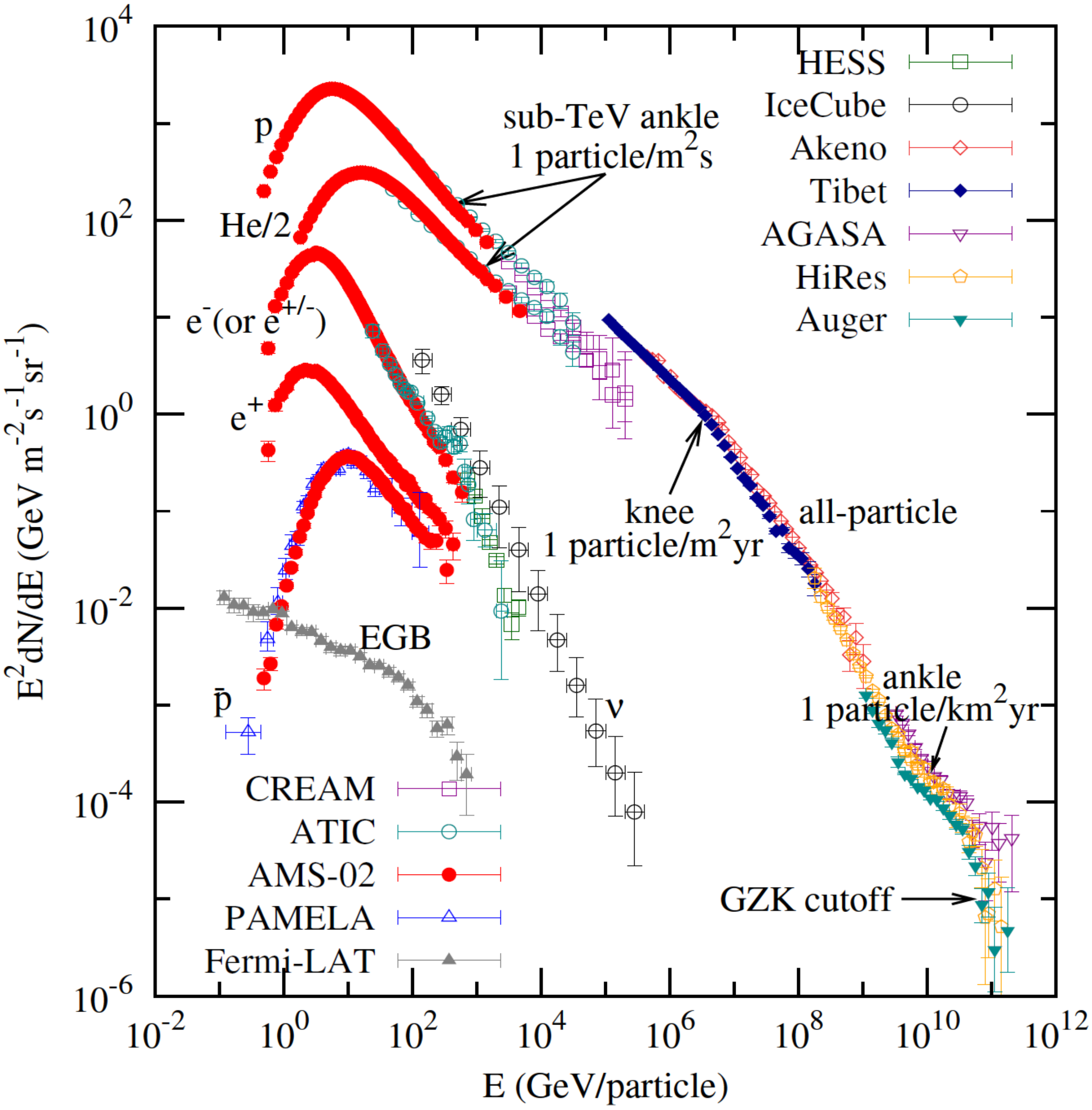
- **Compelling astrophysical evidence for dark matter**
- **New particle or modified gravity?**
- **Three detection methods**

Dark matter indirect detection



Dark matter particles may annihilate and then generate pairs of particles and anti-particles (gamma-rays, electrons/positrons, proton and antiprotons)，see e.g., Bergström & Snellman 1988, Turner &Wilczek 1990

Dark matter indirect detection



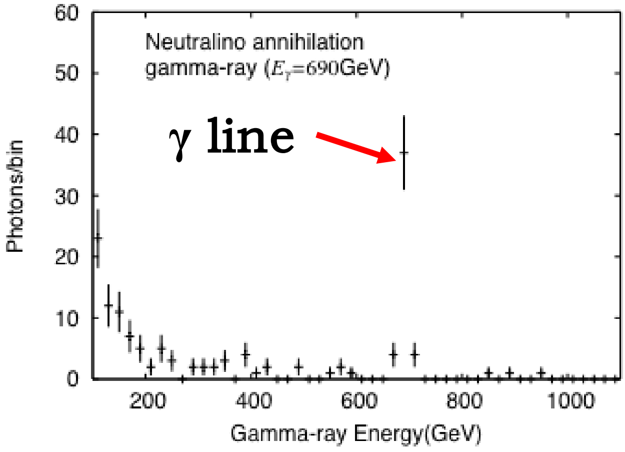
DM signal in anti-particles (AMS-02 like detectors): lower background

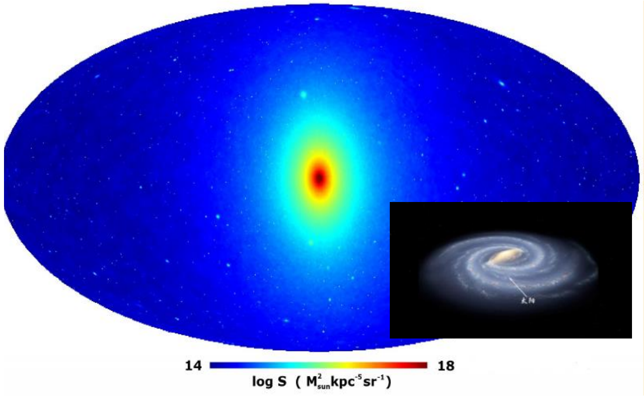
Electrons: relatively small contrast between the electron and positron flux

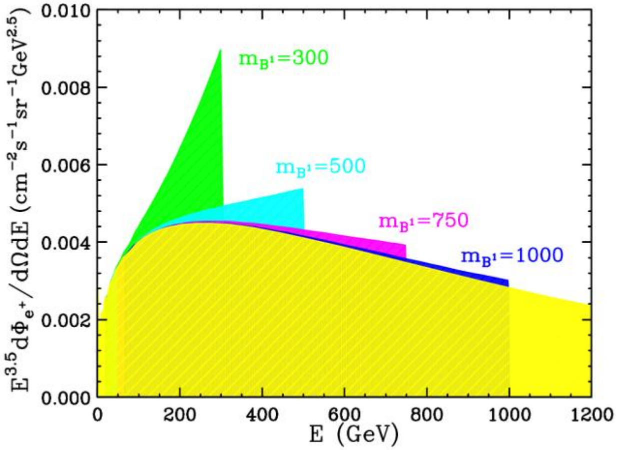
Gamma-rays and neutrinos: trace the source

Dark matter indirect detection

Possible DM signal in γ-rays and electrons



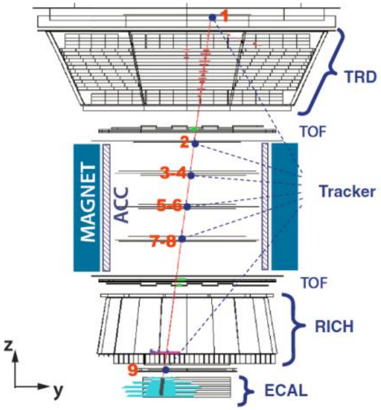


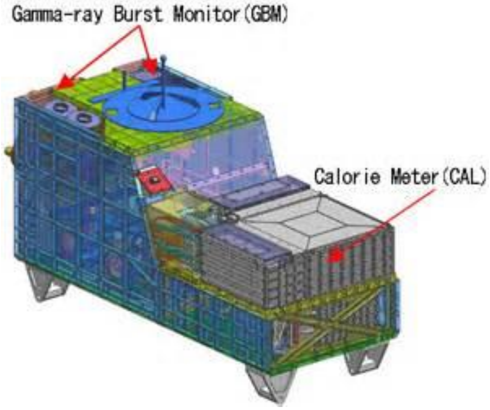


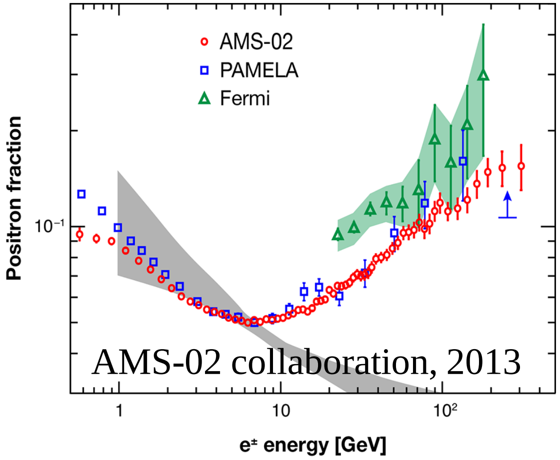
- The γ-ray line
- Continual γ-ray emission spatially correlated with the DM distribution
- Electrons with unusual spectrum

Dark matter indirect detection

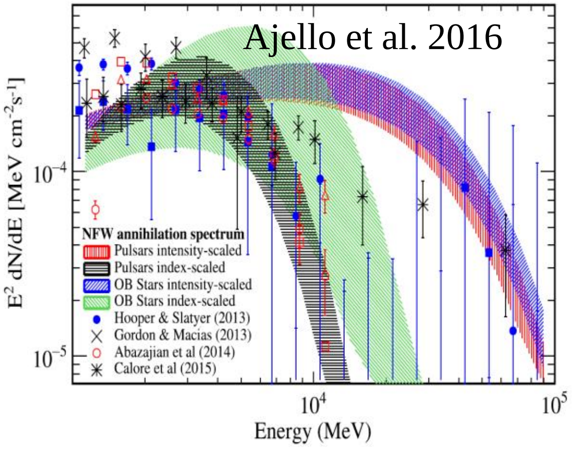
Some previous/current experiments and hints



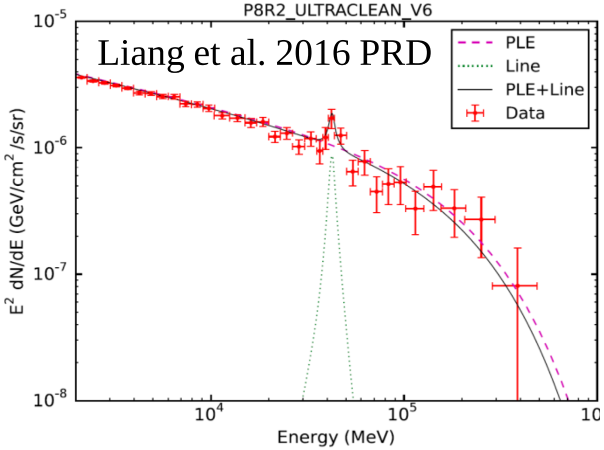




AMS-02 collaboration, 2013

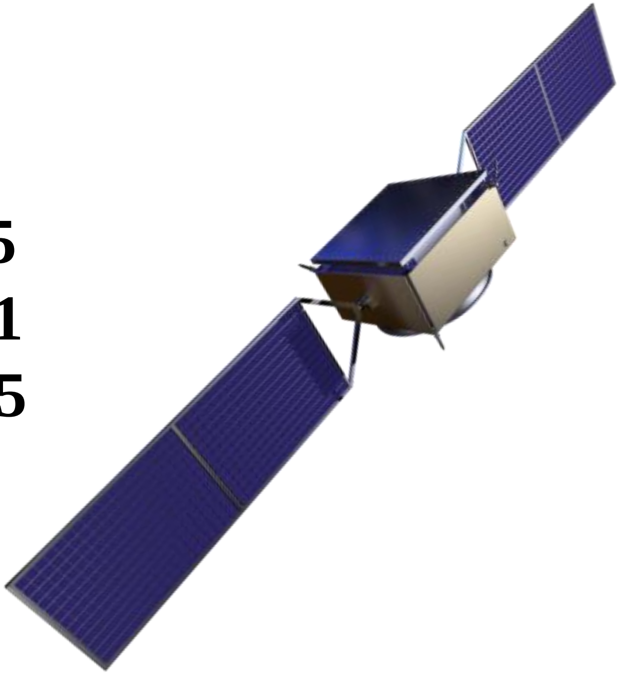


Ajello et al. 2016



Liang et al. 2016 PRD

DArk Matter Particle Explorer

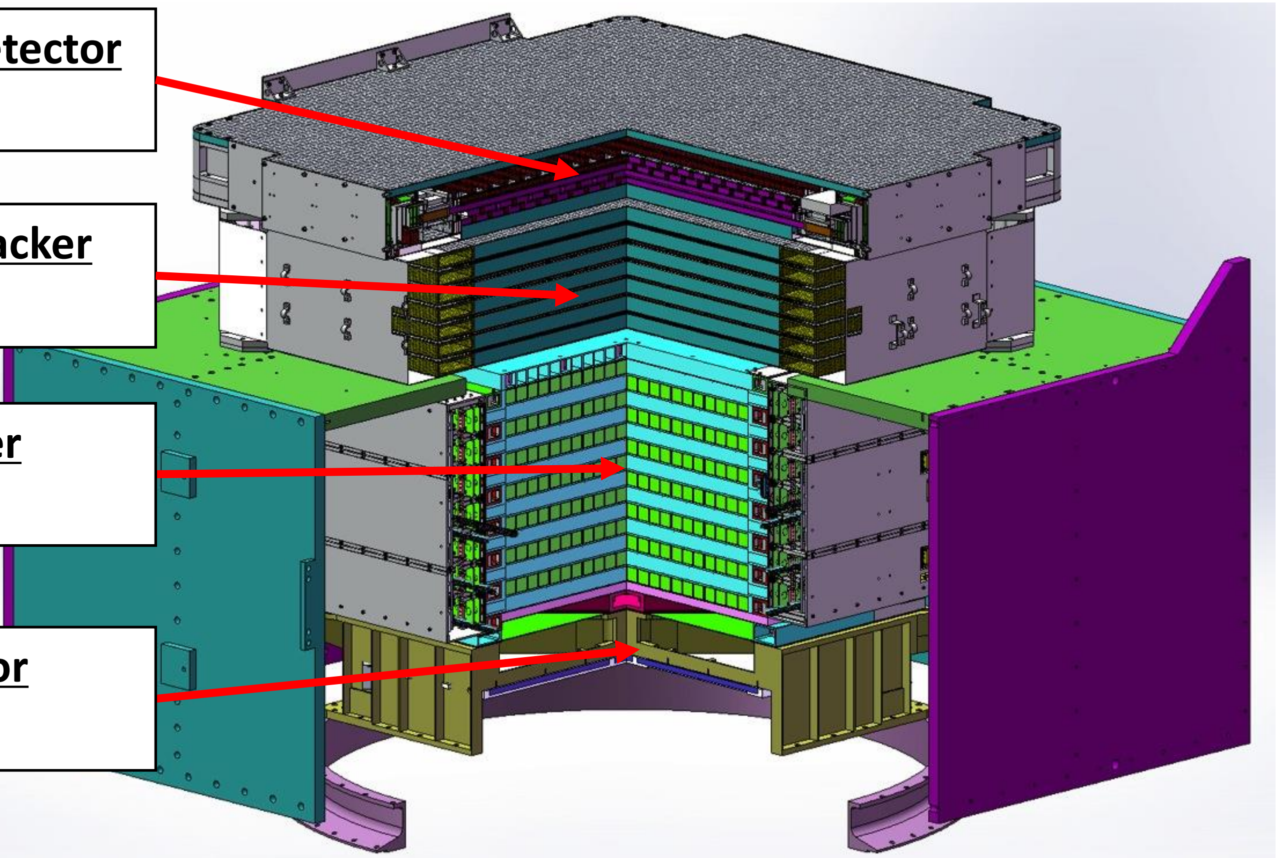


悟空

Proposed: 2005
Founded: 23 Dec. 2011
Launched: 17 Dec. 2015

●Scientific objectives：
(a)Probing the nature of dark matter
(b)Understanding acceleration and propagation of cosmic rays
(c)Studying γ-ray emission from Galactic and extragalactic sources

The payload



Plastic Scintillator Detector
(PSD)

Silicon-Tungsten Tracker
(STK)

BGO Calorimeter
(BGO)

Neutron Detector
(NUD)

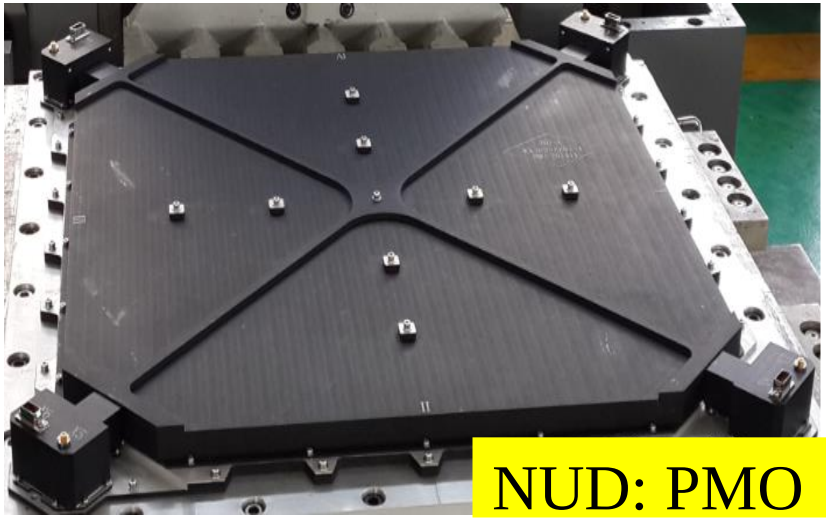
- Charge measurement (dE/dx in PSD, STK and BGO)
- Pair production and tracking (STK and BGO)
- Precise energy measurement (BGO bars)
- Hadron rejection (BGO and neutron detector)

Flight Model: four sub-detectors


PSD: IMP

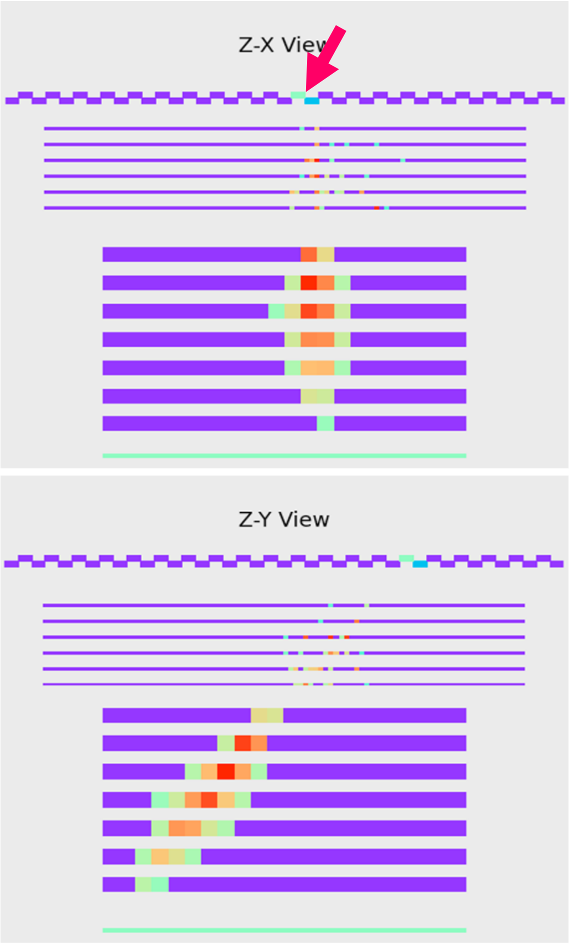

STK: IHEP, UG, INFN Perugia


BGO: USTC & PMO

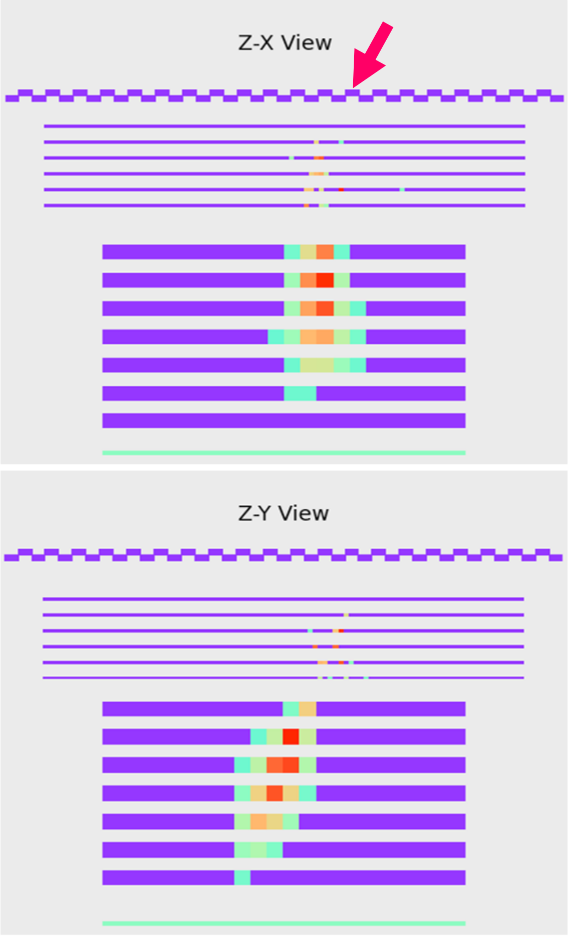

NUD: PMO

Signals for different particles

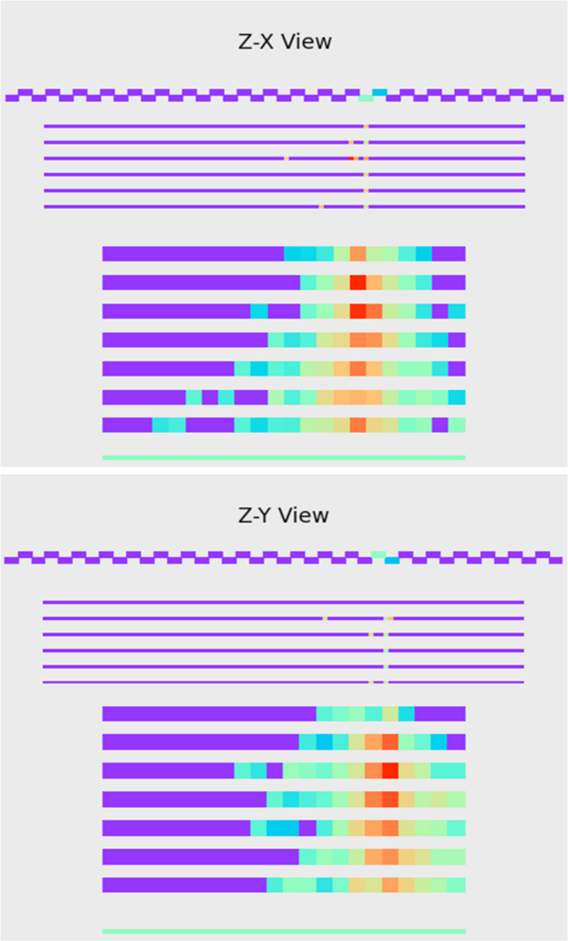
electron



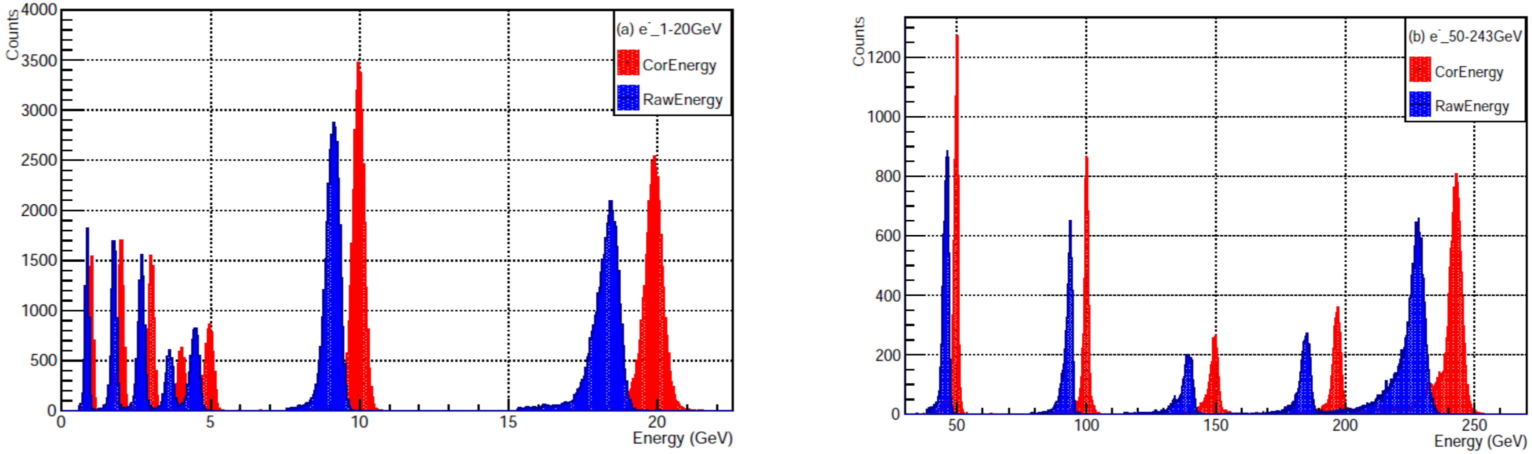
gamma

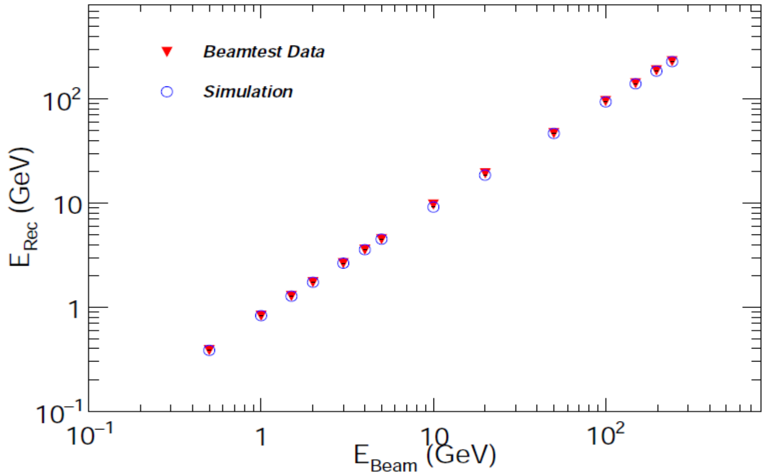


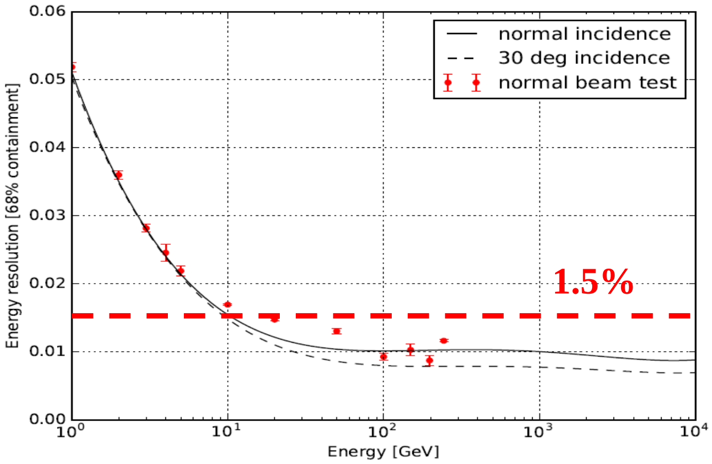
proton



Beam test @ CERN







Energy linearity of electrons

Energy resolution of electrons

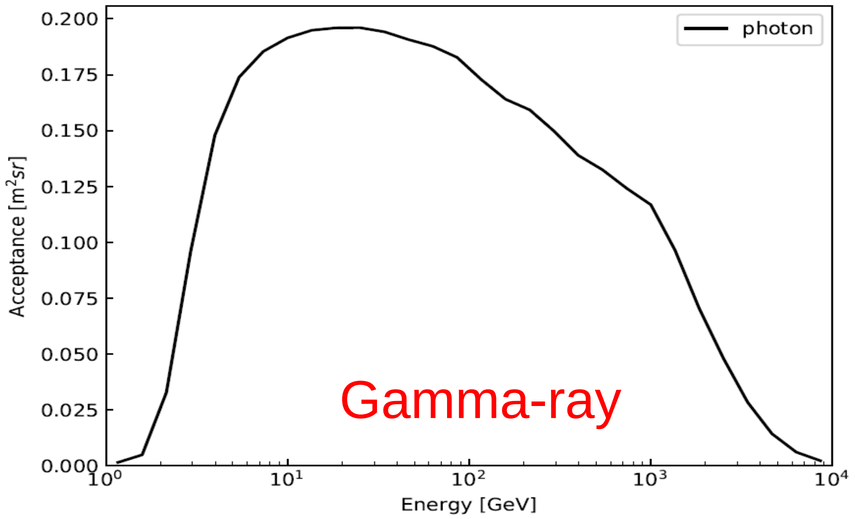
(Chang et al. [DAMPE collaboration] 2017 Astropart. Phys.)

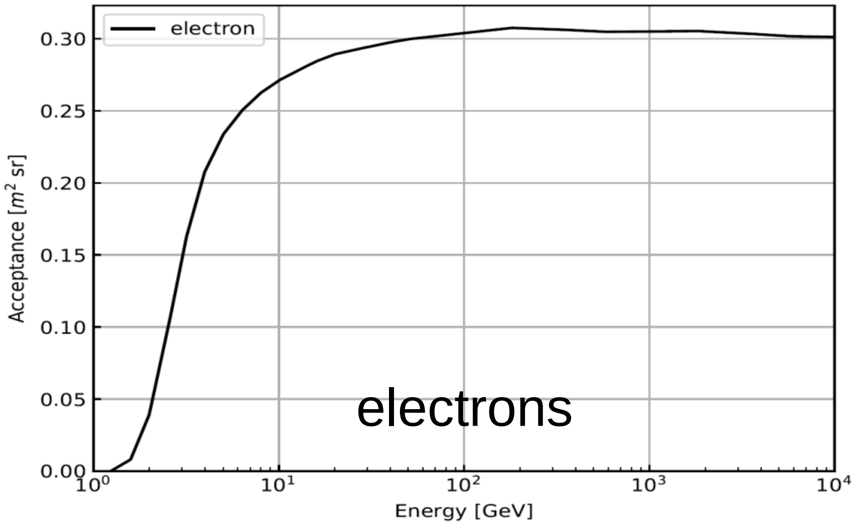
Expected performance

Parameter	Value
Energy range of gamma-rays/electrons	5 GeV to 10 TeV
Energy resolution(electron and gamma)	1.5% at 800 GeV
Energy range of protons/heavy nuclei	50 GeV to 500 TeV
Energy resolution of protons	40% at 800 GeV
Eff. area at normal incidence (gamma)	1100 cm^2 at 100 GeV
Geometric factor for electrons	0.3 m^2 sr above 30 GeV
Photon angular resolution	0.1 degree at 100 GeV
Field of View	1.0 sr

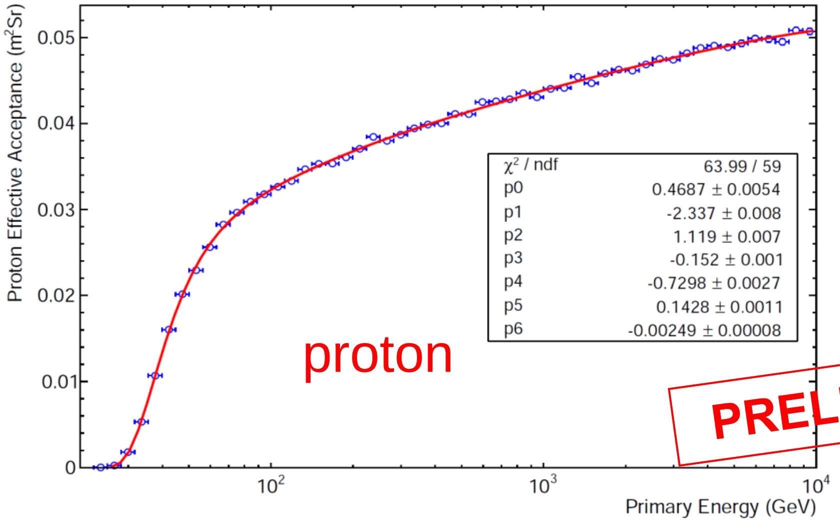
(Chang et al. [DAMPE collaboration] 2017 Astropart. Phys.)

Expected performance



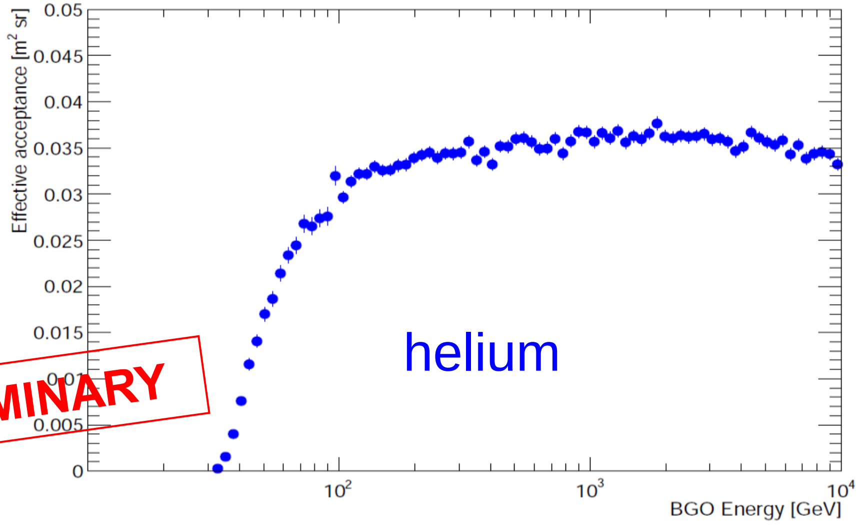


(Chang et al. [DAMPE collaboration] 2017 Astropart. Phys.)

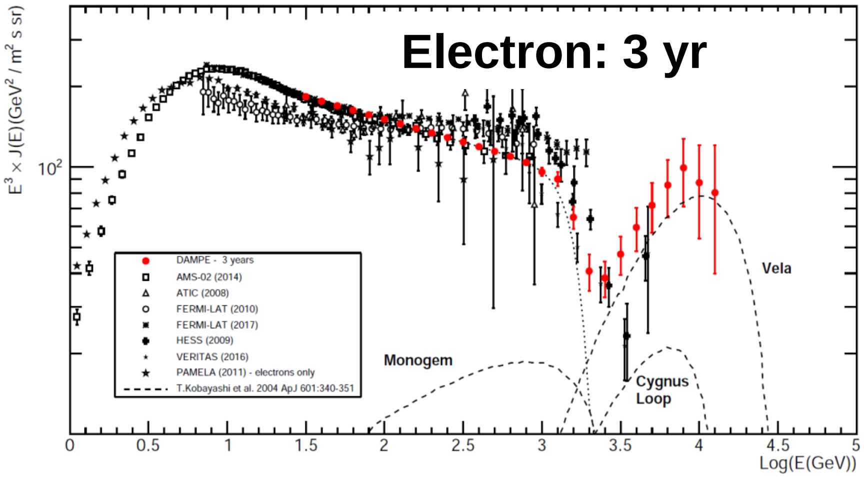


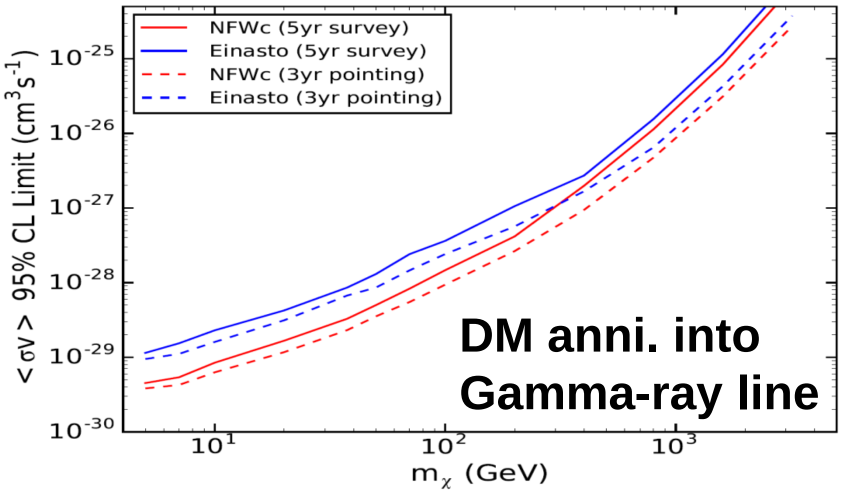
χ^2 / ndf	63.99 / 59
p0	0.4687 ± 0.0054
p1	-2.337 ± 0.008
p2	1.119 ± 0.007
p3	-0.152 ± 0.001
p4	-0.7298 ± 0.0027
p5	0.1428 ± 0.0011
p6	-0.00249 ± 0.00008

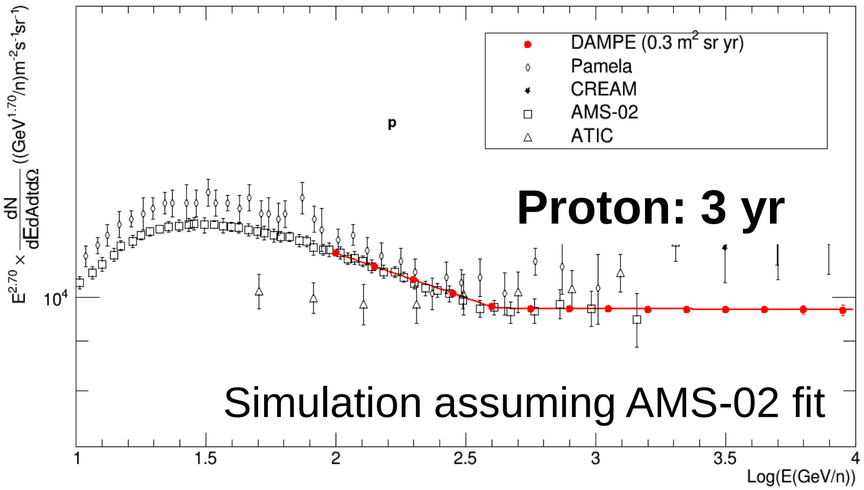
PRELIMINARY

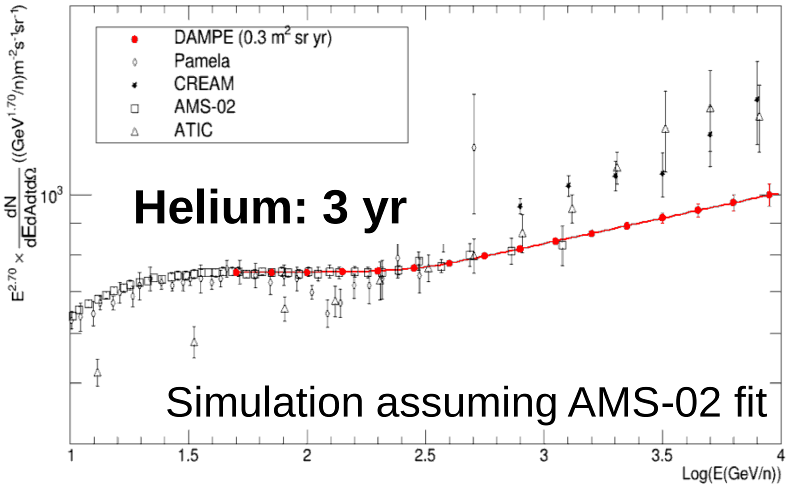


Expected performance



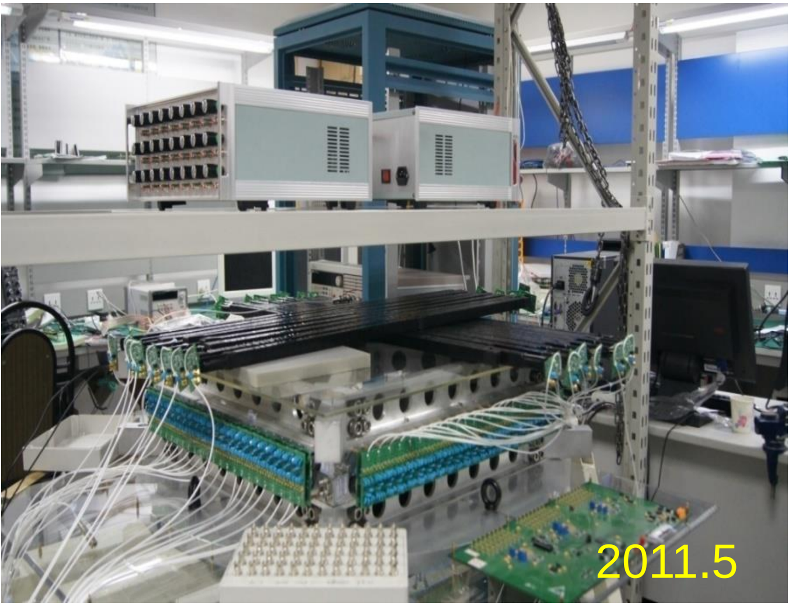


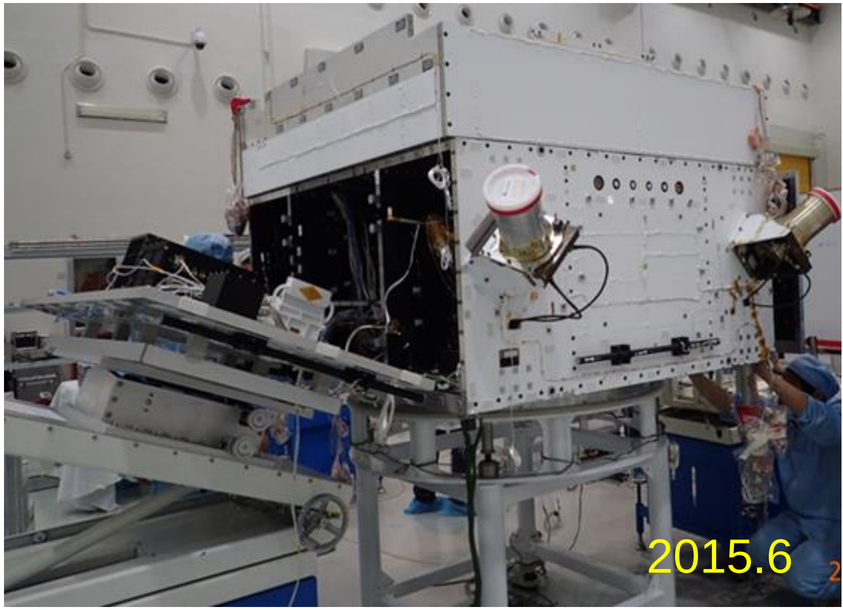




(Chang et al. [DAMPE collaboration] 2017 Astropart. Phys.)

DAMPE mission

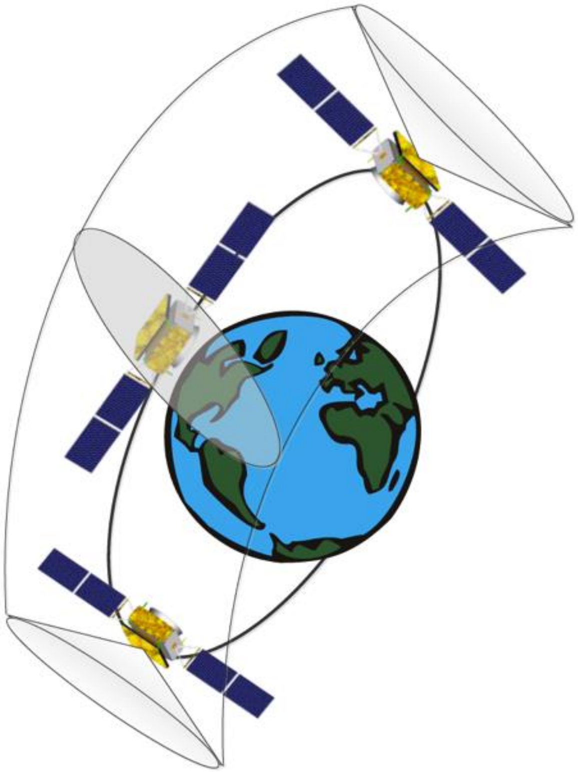

2011.5

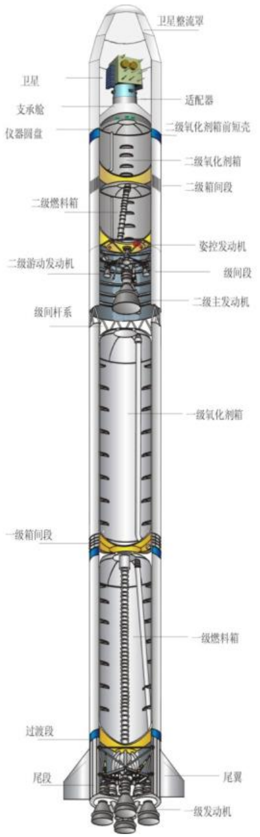

2015.6

DAMPE mission

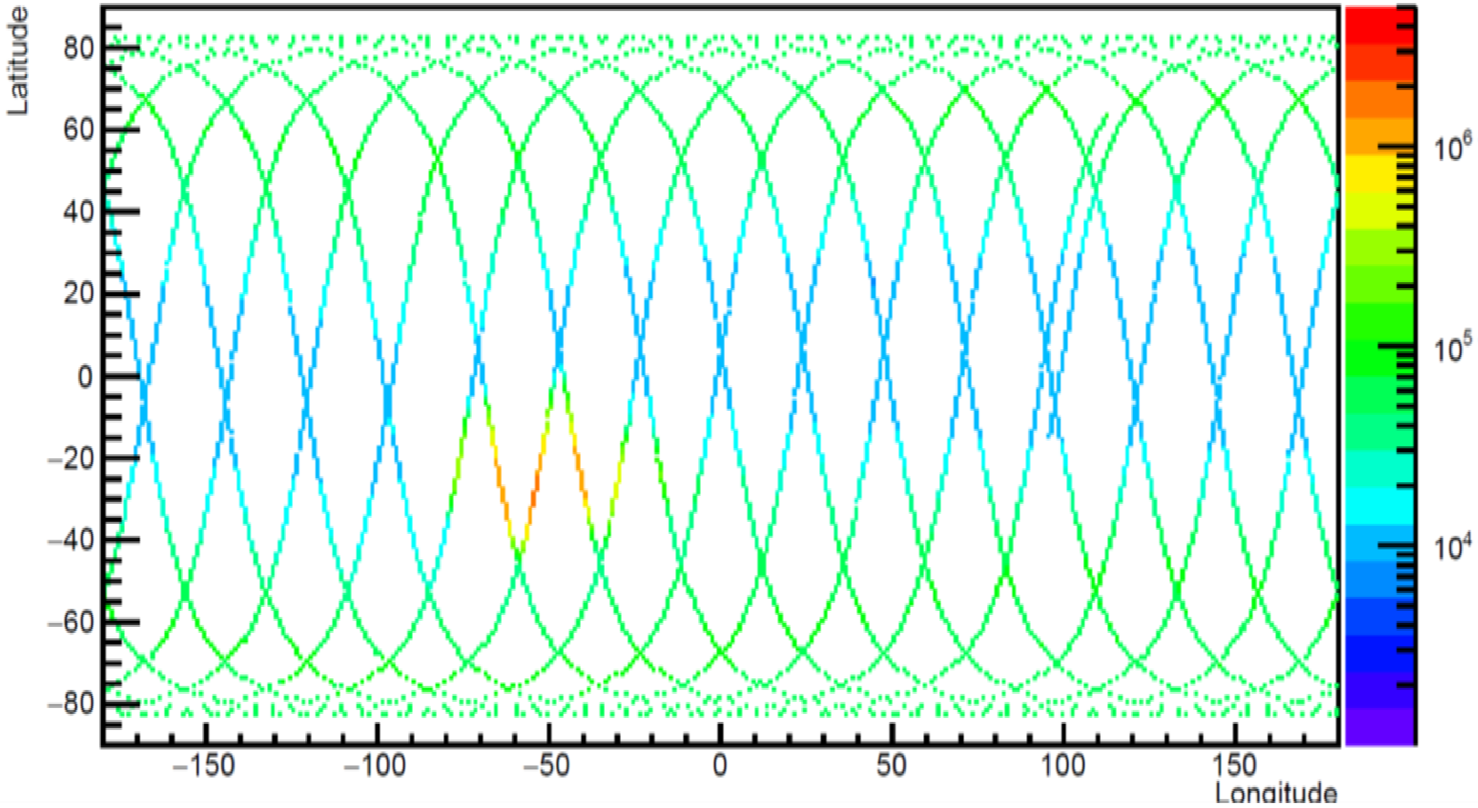
- Launch: December 17th 2015, CZ-2D rocket
  - Total weight ~1850 kg, power consumption ~640 W
    - Scientific payload ~1400 kg, ~400 W
  - Lifetime > 3 year

- Altitude: 500 km
- Inclination: 97.4065°
- Period: 95 minutes
- Orbit: sun-synchronous
- 16 GB/day downlink





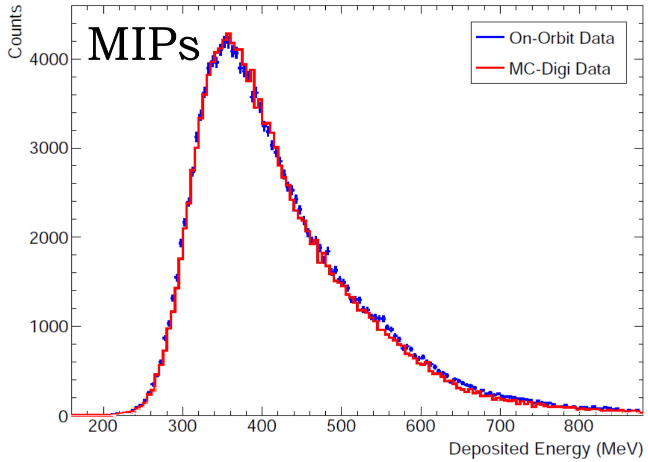
On-orbit trigger rate

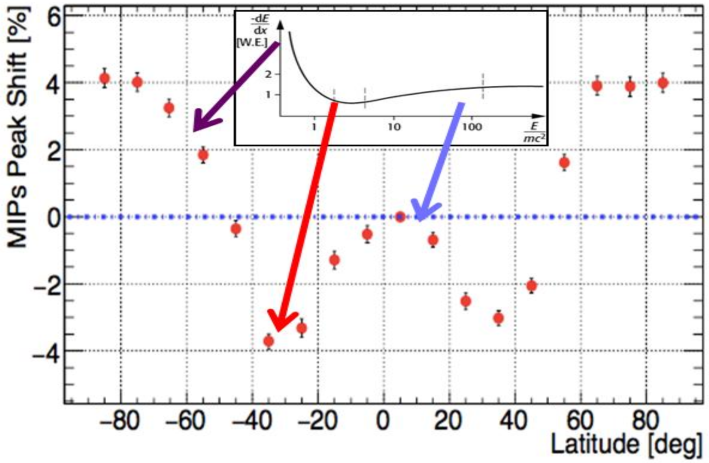


~60 Hz average trigger rate

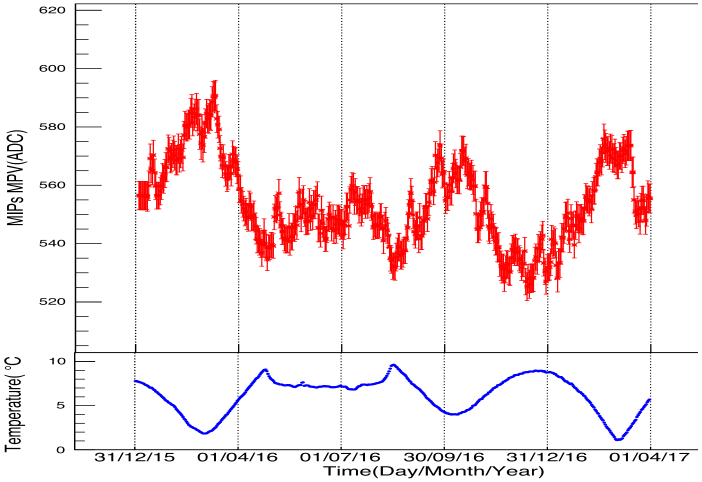
→100GB (H.L.)/day on ground (about 5 M events)

BGO on-orbit calibration: MIPs

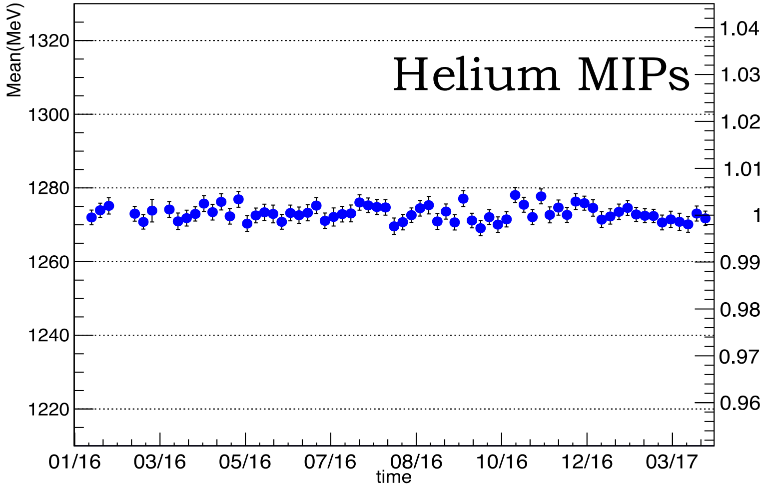




Before temperature correction

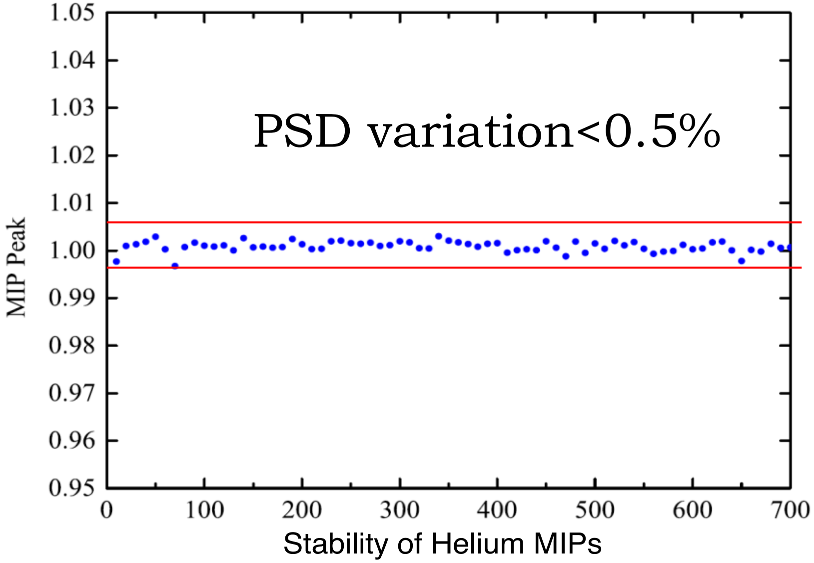


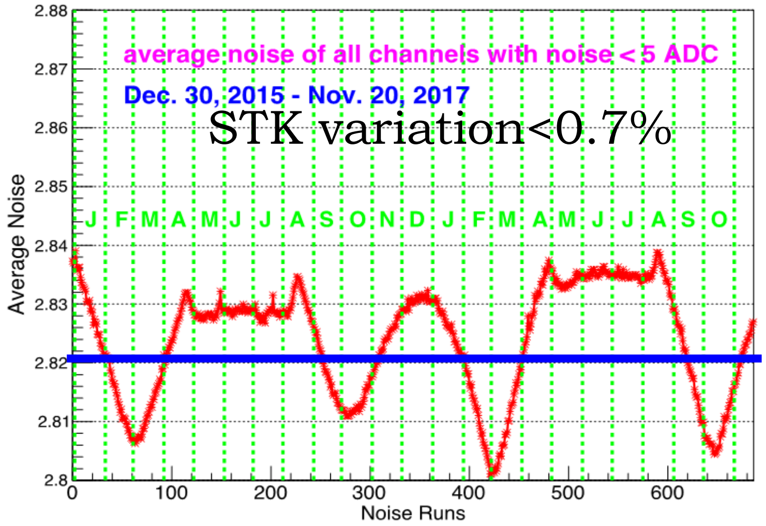
After temperature correction

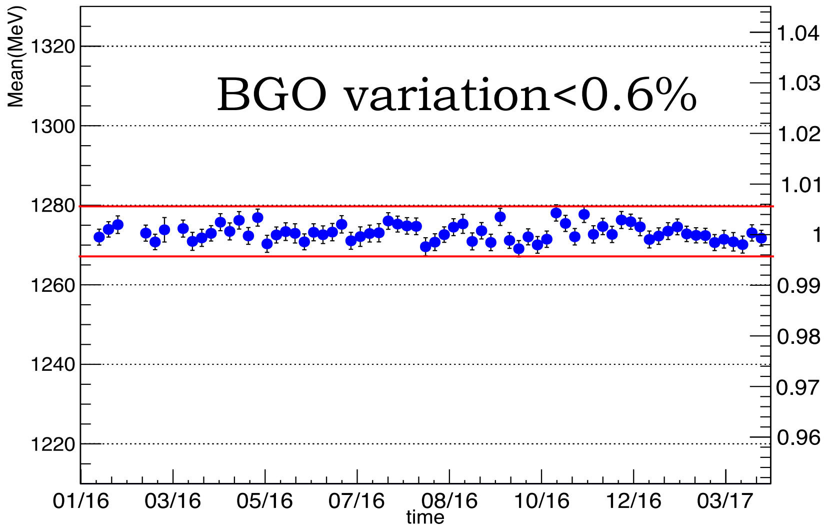


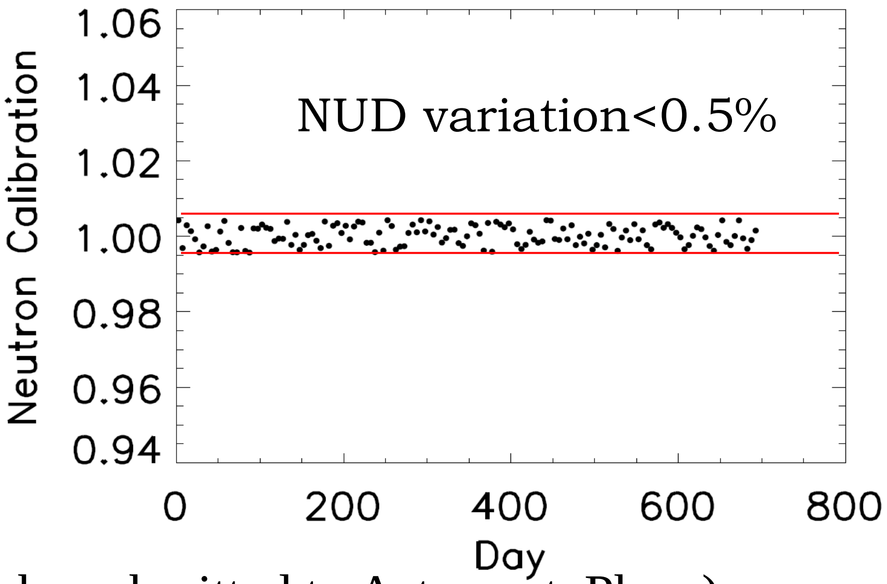
(DAMPE collaboration. 2018, to be submitted to Astropart. Phys.)

Satbility of on-orbit performance


PSD variation<0.5%

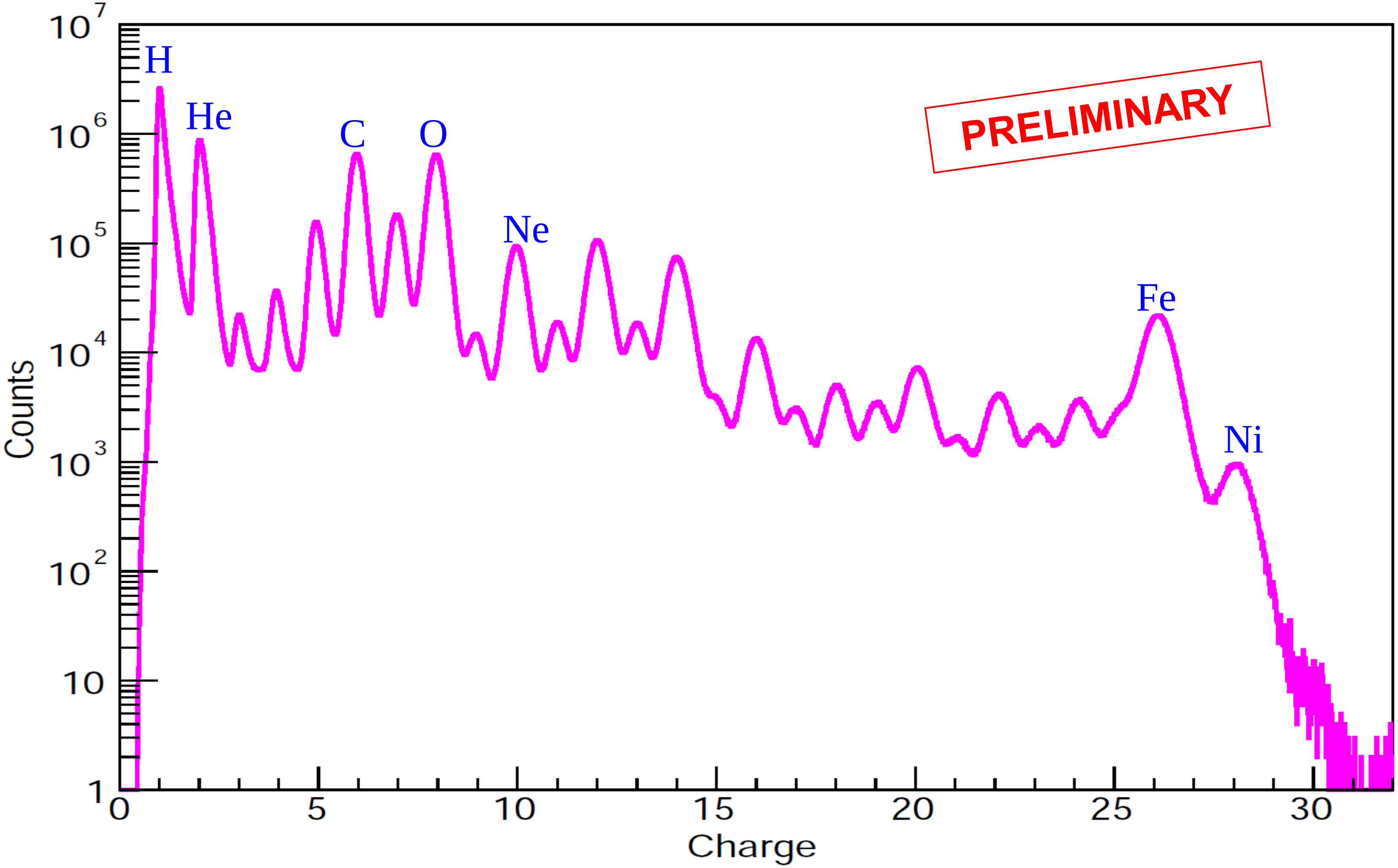

STK variation<0.7%


BGO variation<0.6%


NUD variation<0.5%

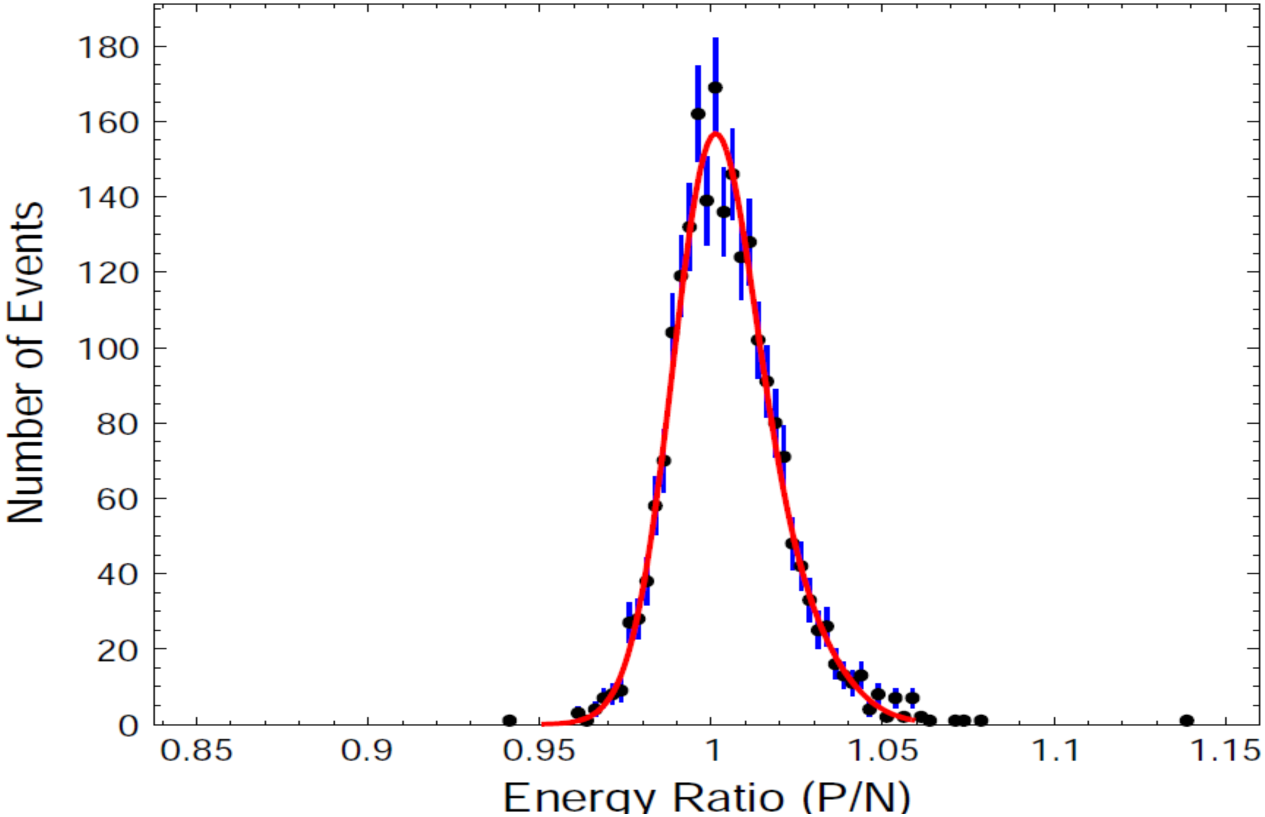
(DAMPE collaboration. 2018, to be submitted to Astropart. Phys.)

On-orbit performance: Charge measurement by PSD



(H, Fe)=(0.12, 0.28)e

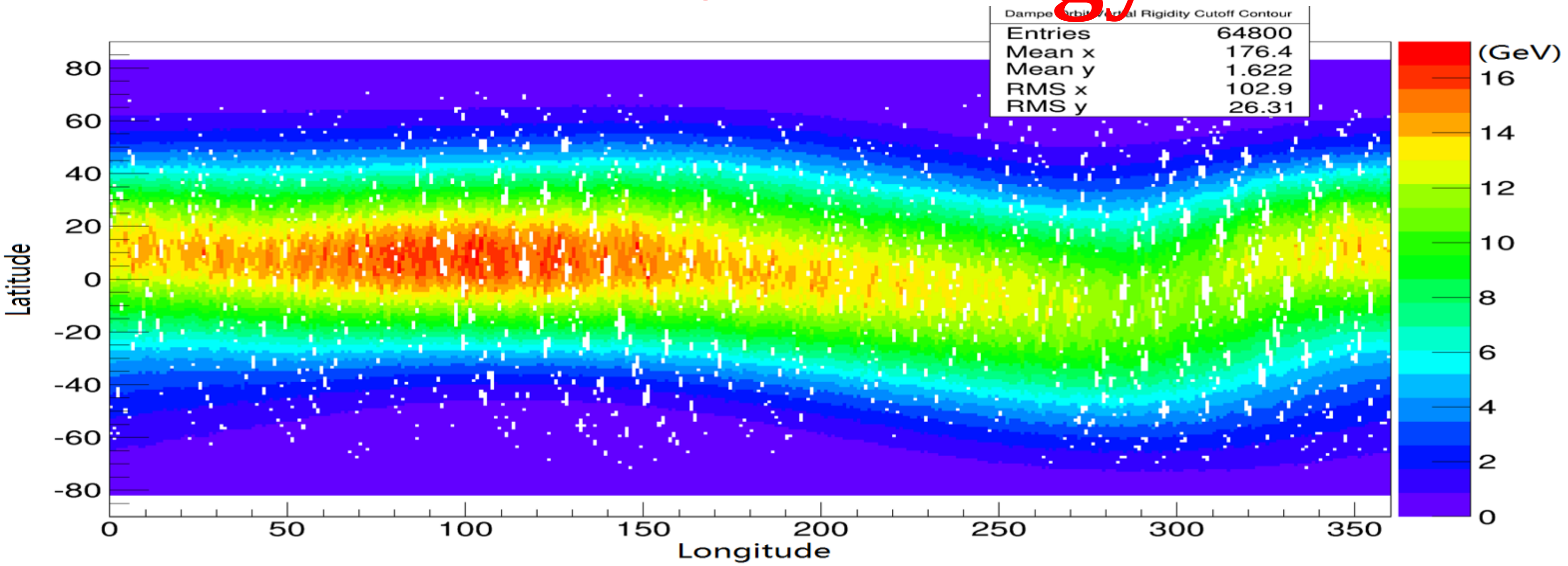
On-orbit performance: energy measurement by BGO

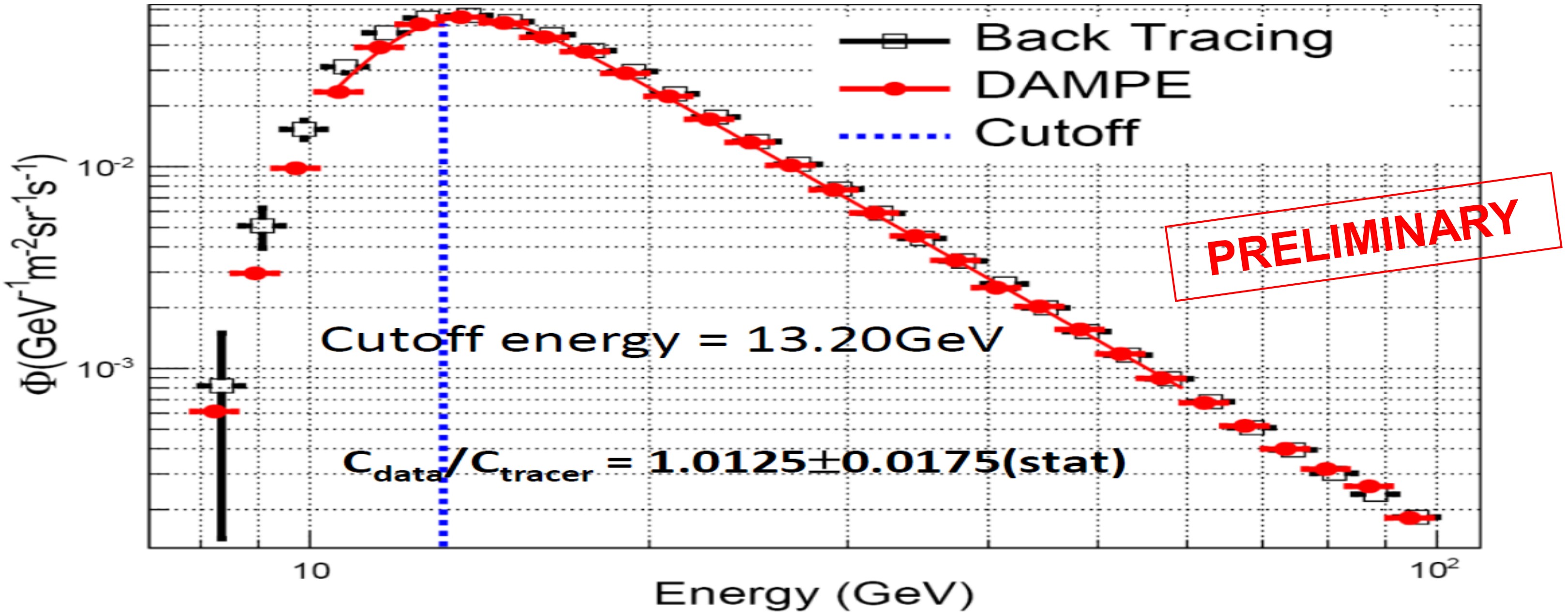


The ratio of the energies reconstructed with positive and negative side readout data of BGO crystals, for CRE candidates with deposit energy of 0.5-1.0 TeV

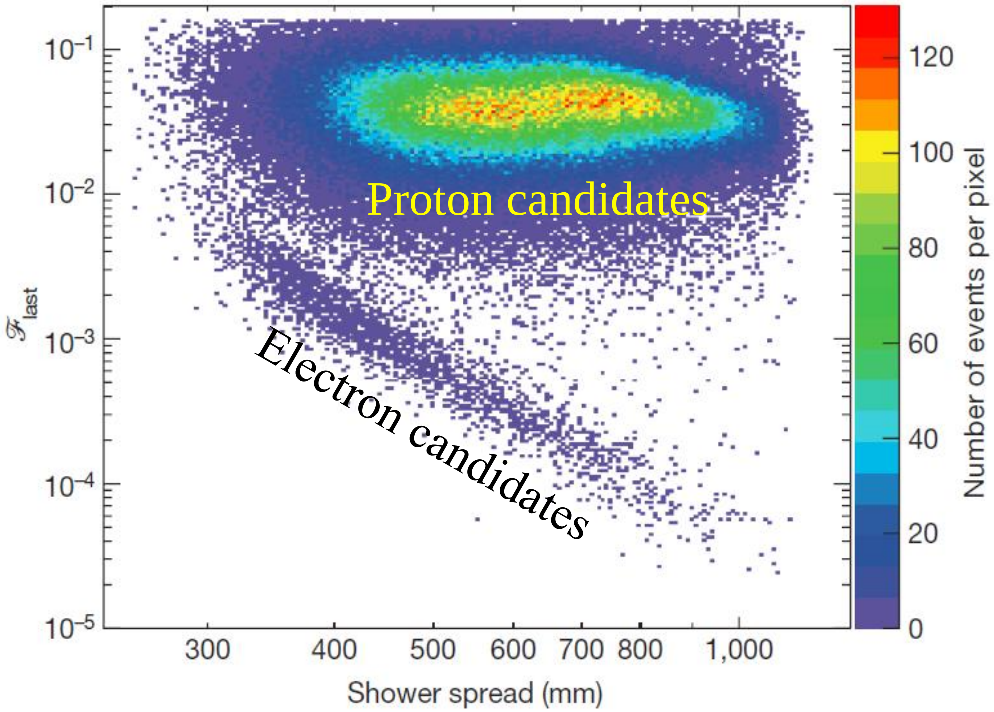
(DAMPE collaboration. 2017, Nature, 552, 63)

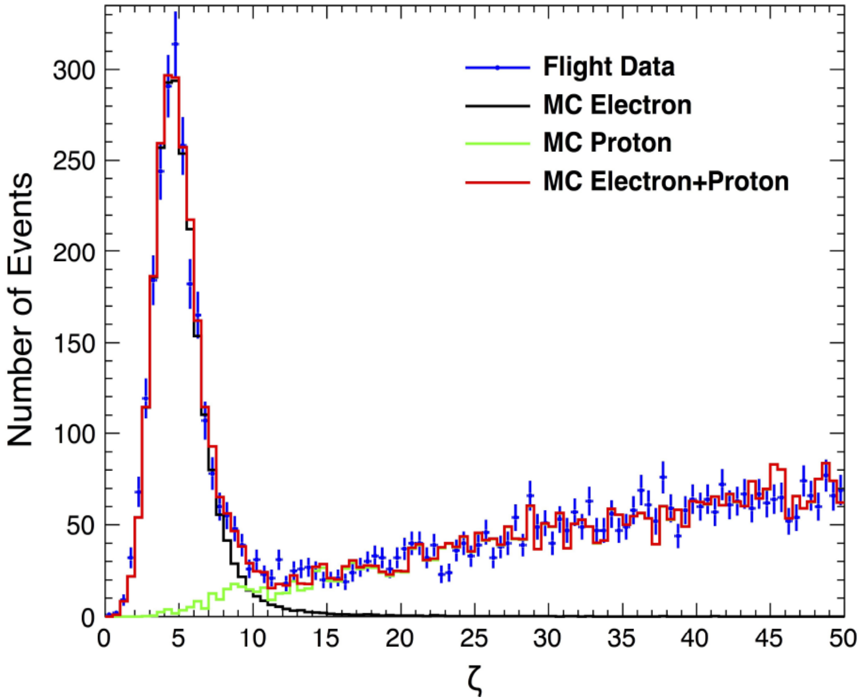
On-orbit performance: Absolute energy scale





On-orbit performance: e/p separation

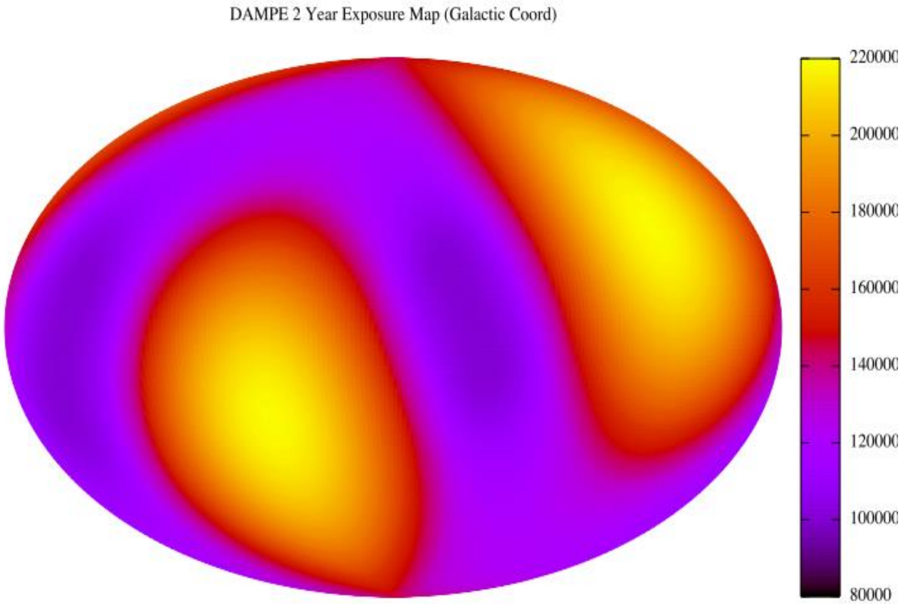


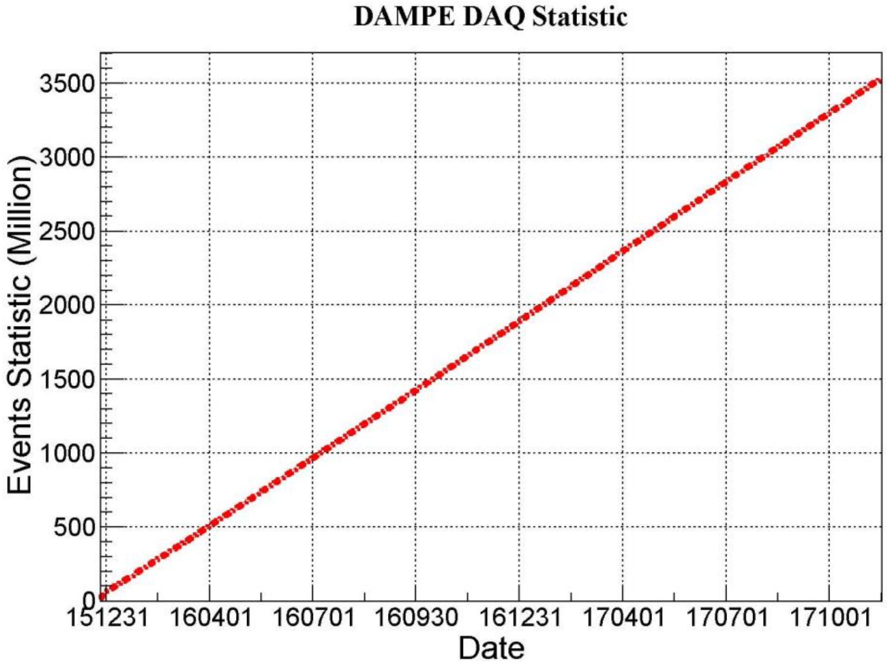


For events with deposit energy of 0.5-1.0 TeV； the proton contamination fraction is found to be <3% below 1TeV and <6% in the energy range of 1-2 TeV.

(DAMPE collaboration. 2017, Nature, 552, 63)

Summary of current data

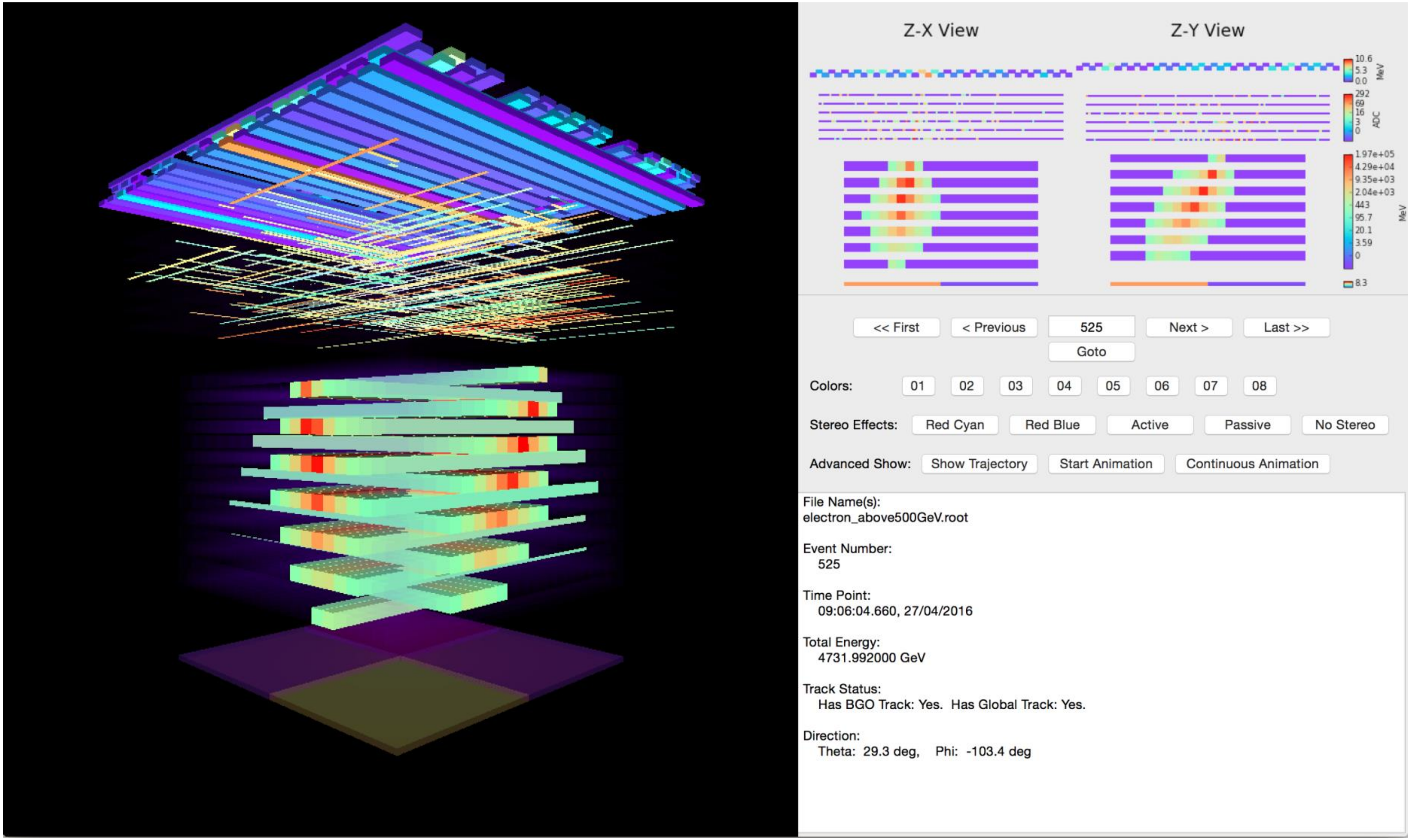




Full sky survey: 4 times

3.5 billion CRs (~5 million/day)

Event: ~5 TeV electron candidate



File Name(s):
electron_above500GeV.root

Event Number:
525

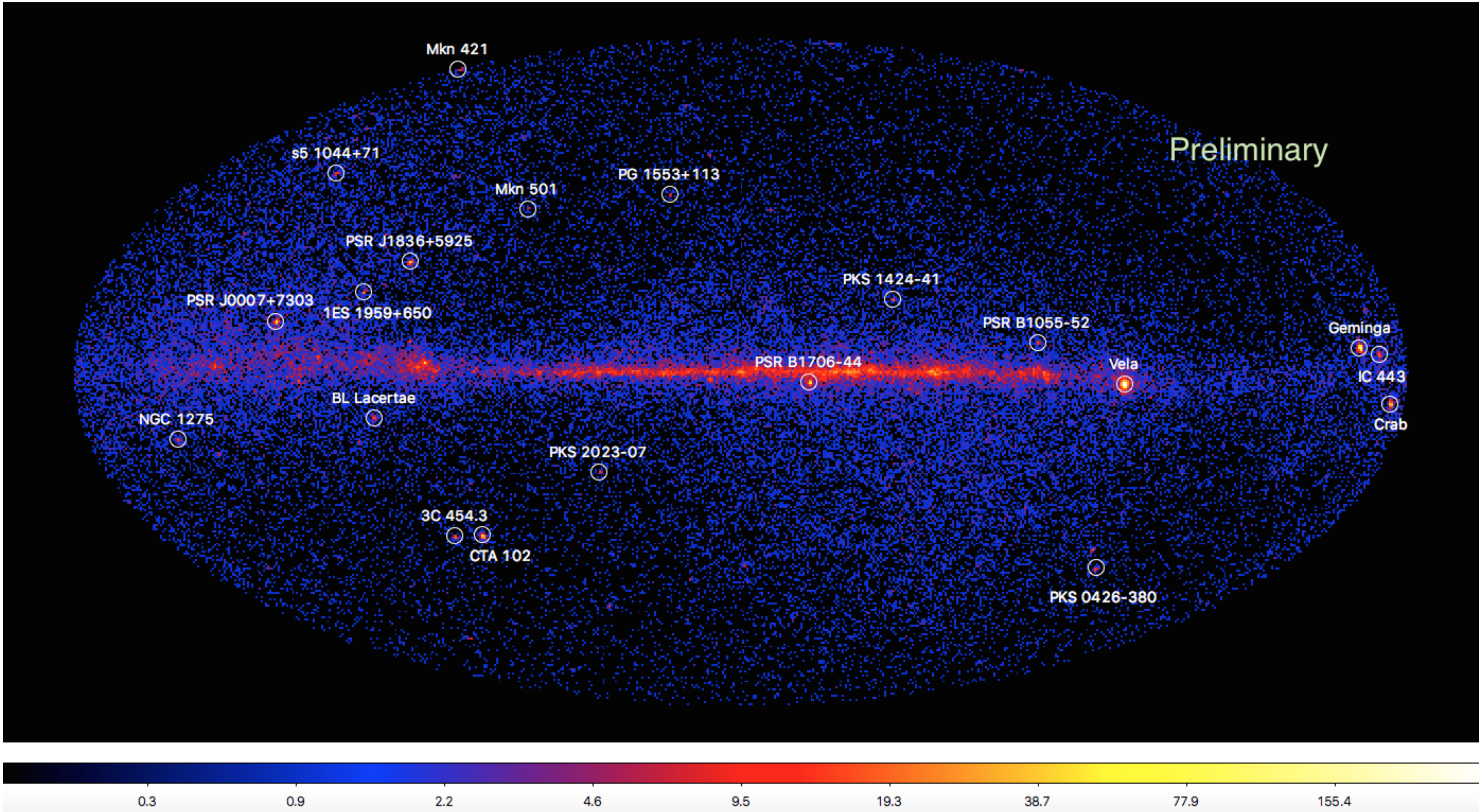
Time Point:
09:06:04.660, 27/04/2016

Total Energy:
4731.992000 GeV

Track Status:
Has BGO Track: Yes. Has Global Track: Yes.

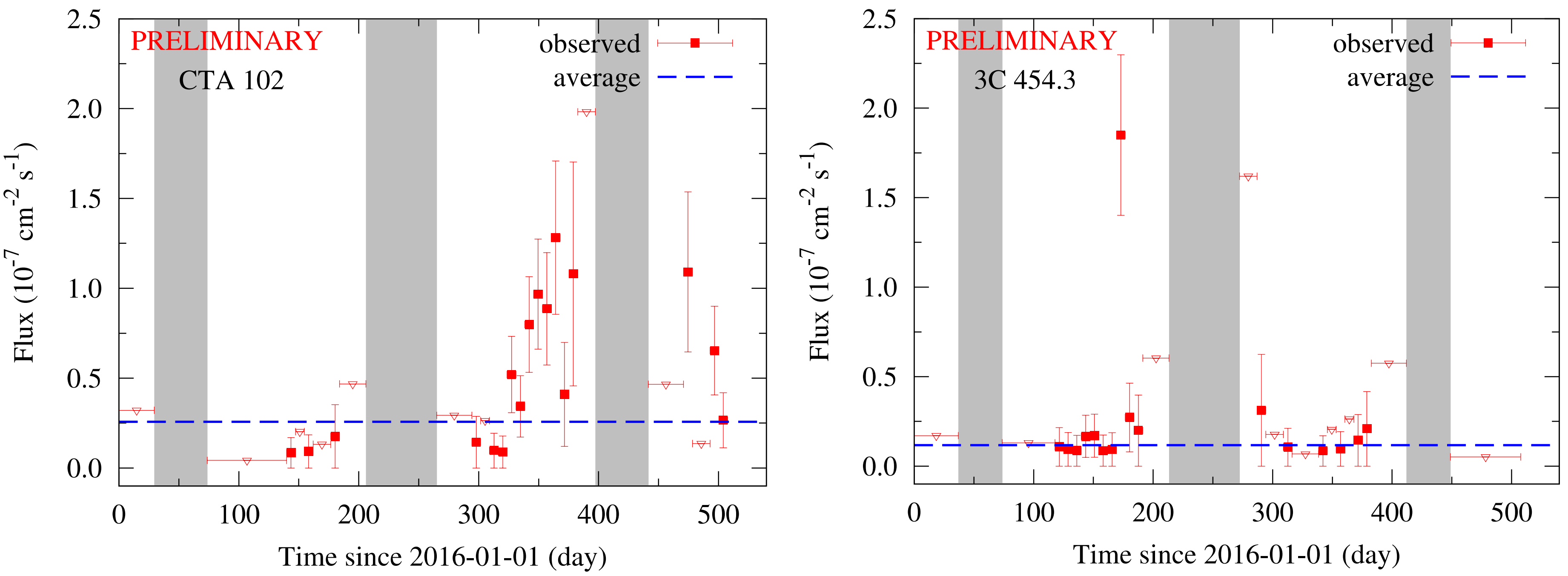
Direction:
Theta: 29.3 deg, Phi: -103.4 deg

First results: gamma-ray sky map

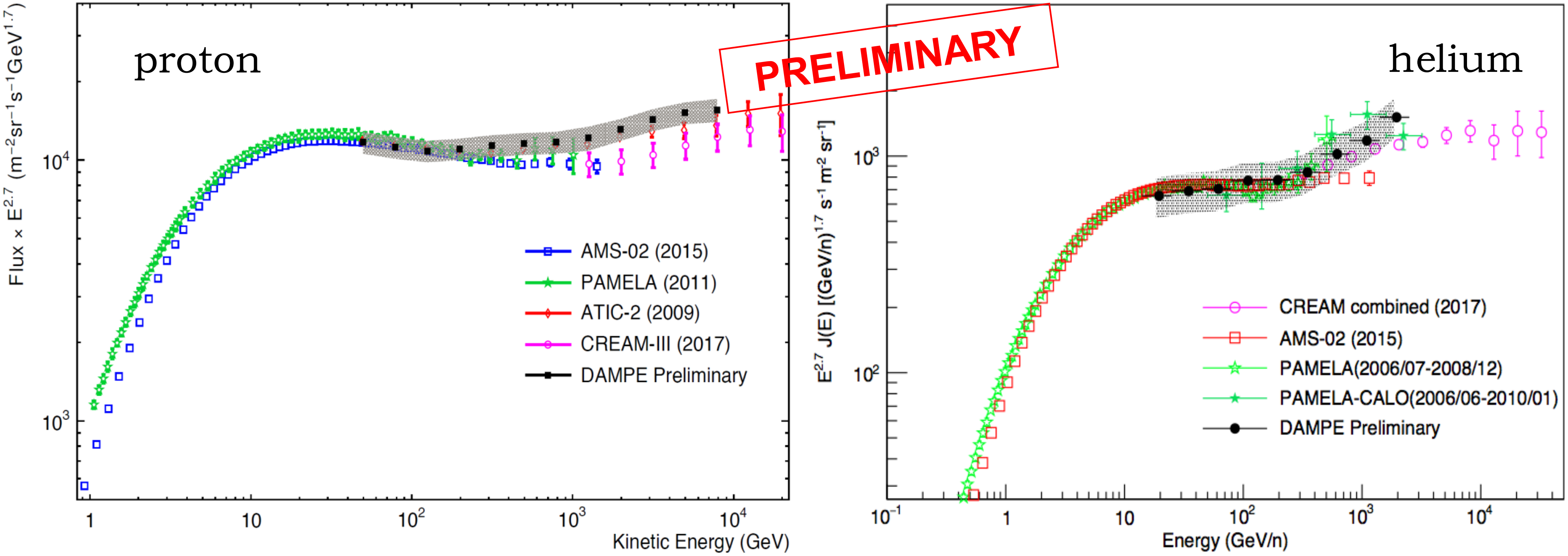


(The gamma-ray identification of DAMPE is in Xu et al. 2018, RAA)

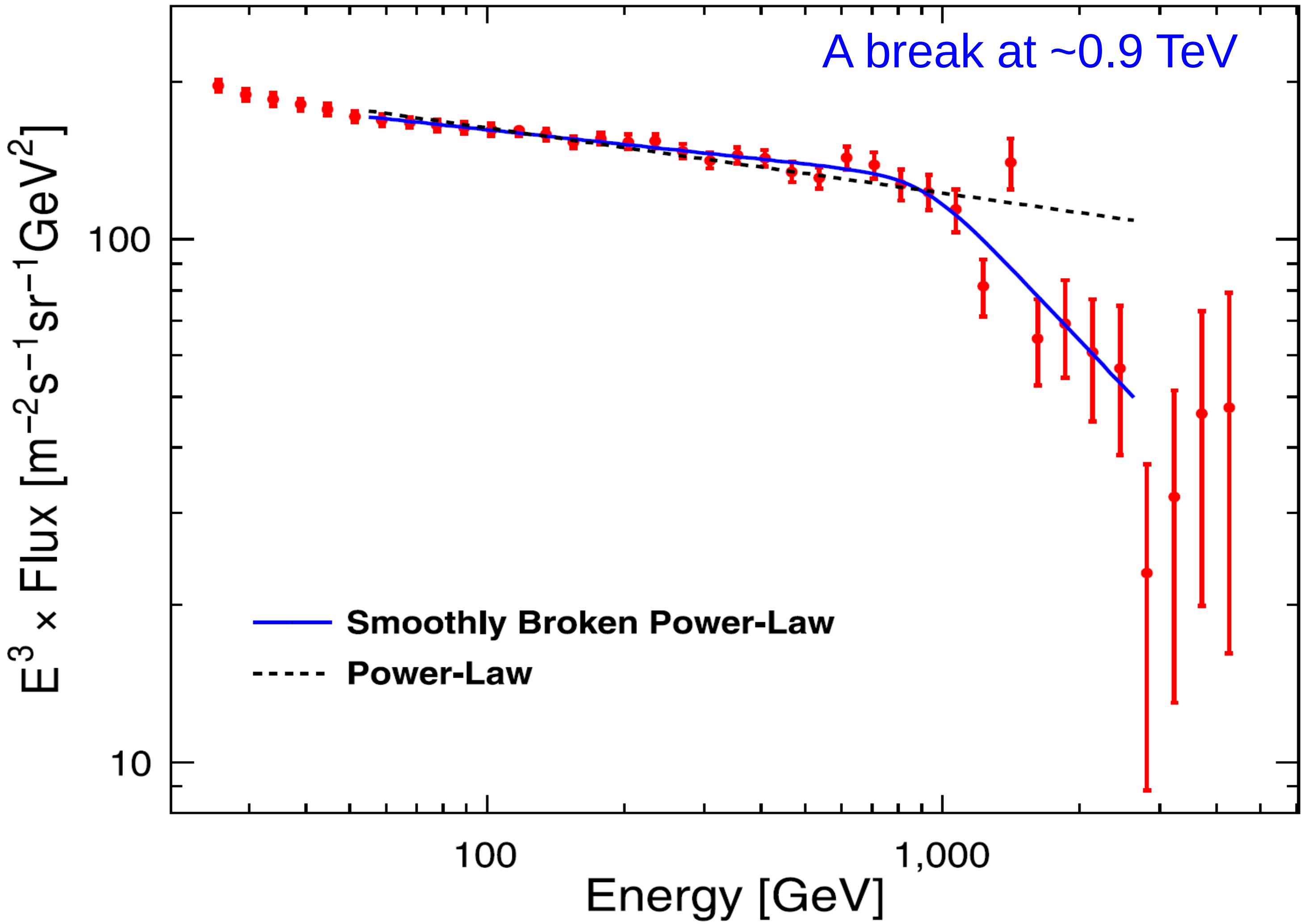
First results: GeV outbursts



First results: proton, helium spectra

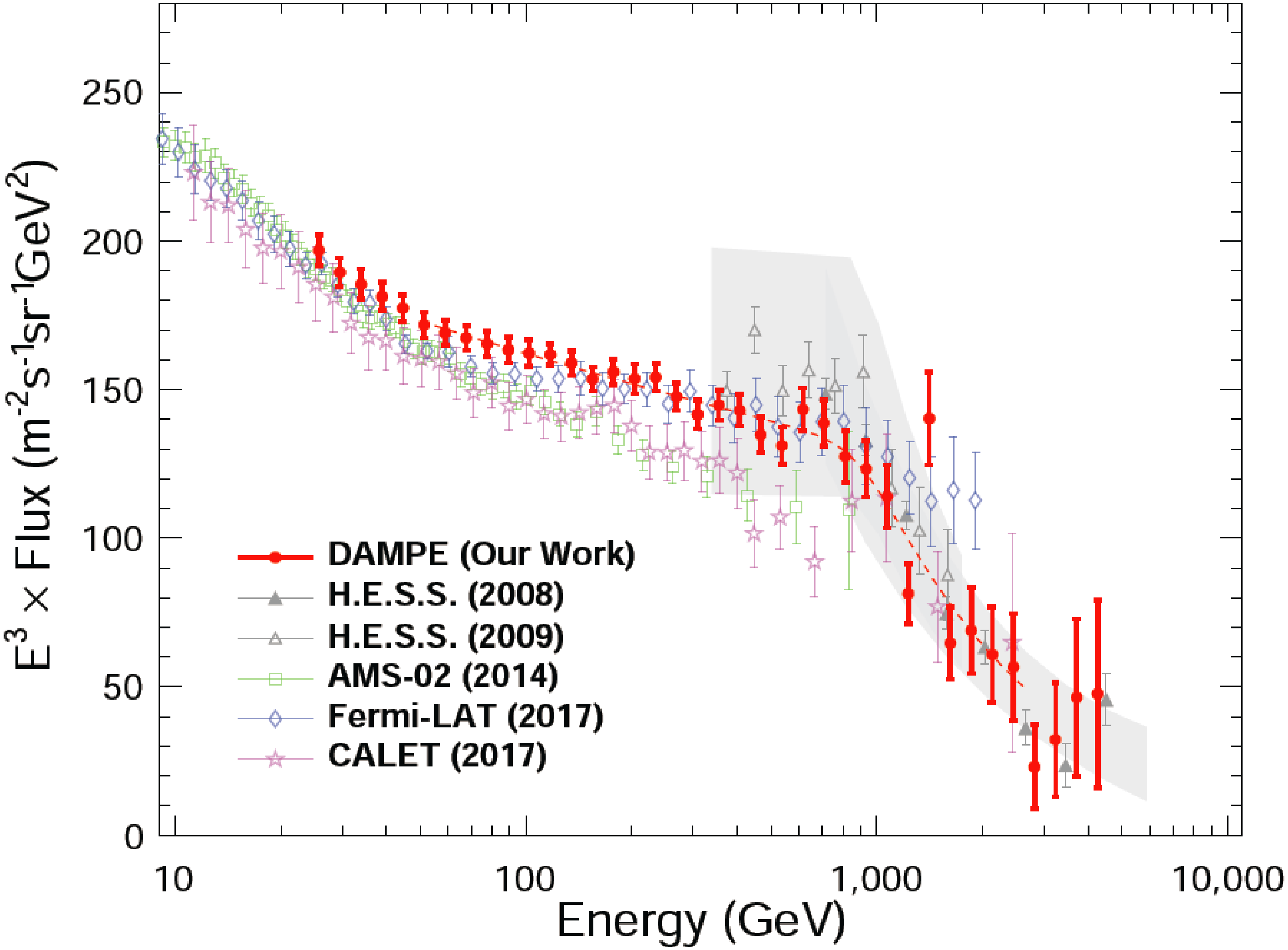


First results: CRE spectrm



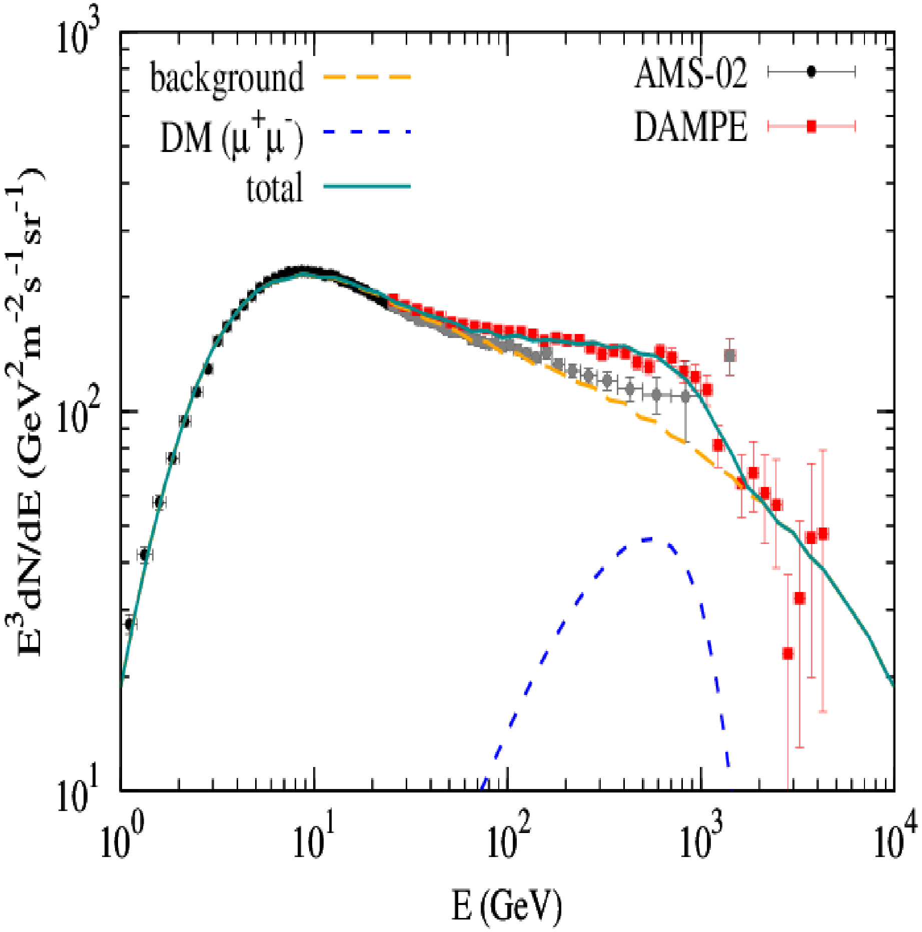
(DAMPE collaboration, 2017, Nature, 552, 63)

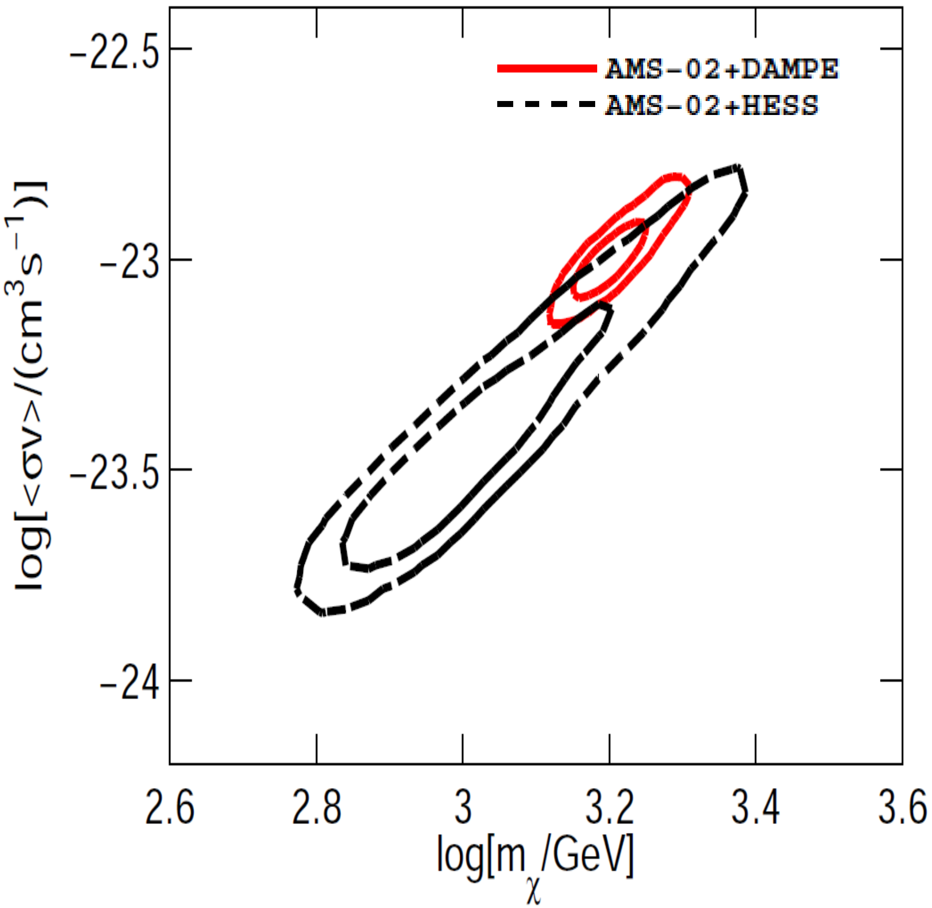
Some high energy CRE spectra



Error bars: systematic and statistical uncertainties added in quadrature for direct measurements. For H.E.S.S the grey band represents its systematic errors apart from the approximately 15% energy scale uncertainty.

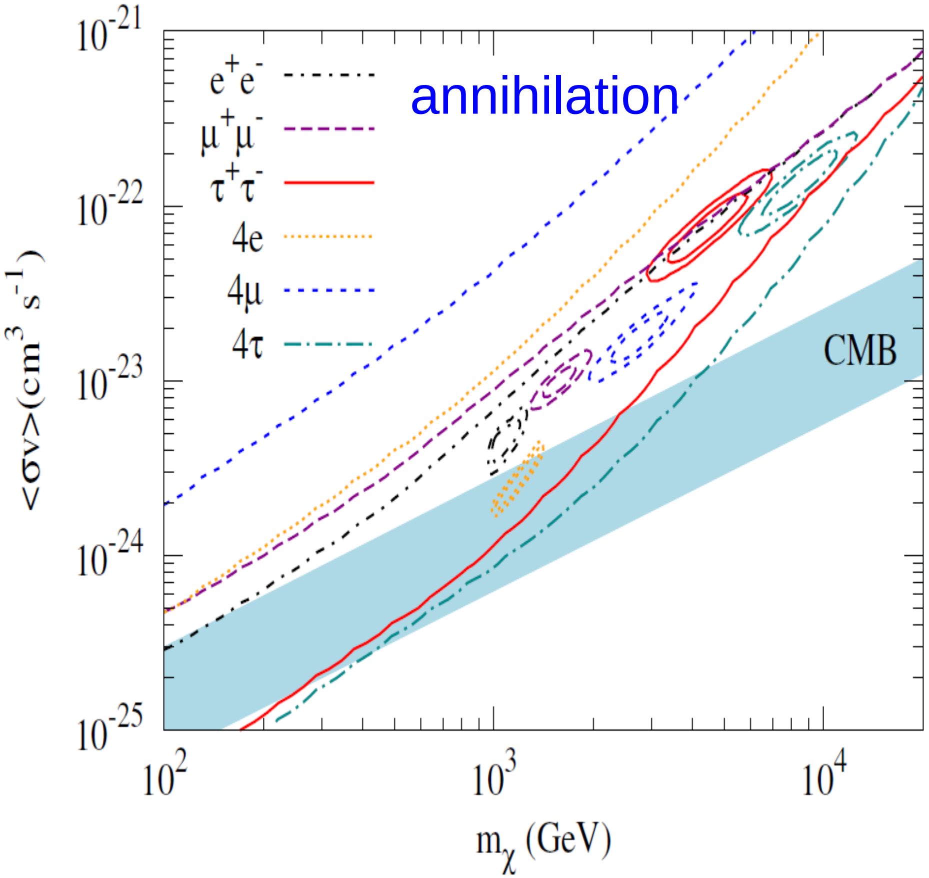
DAMPE CRE data: modeling

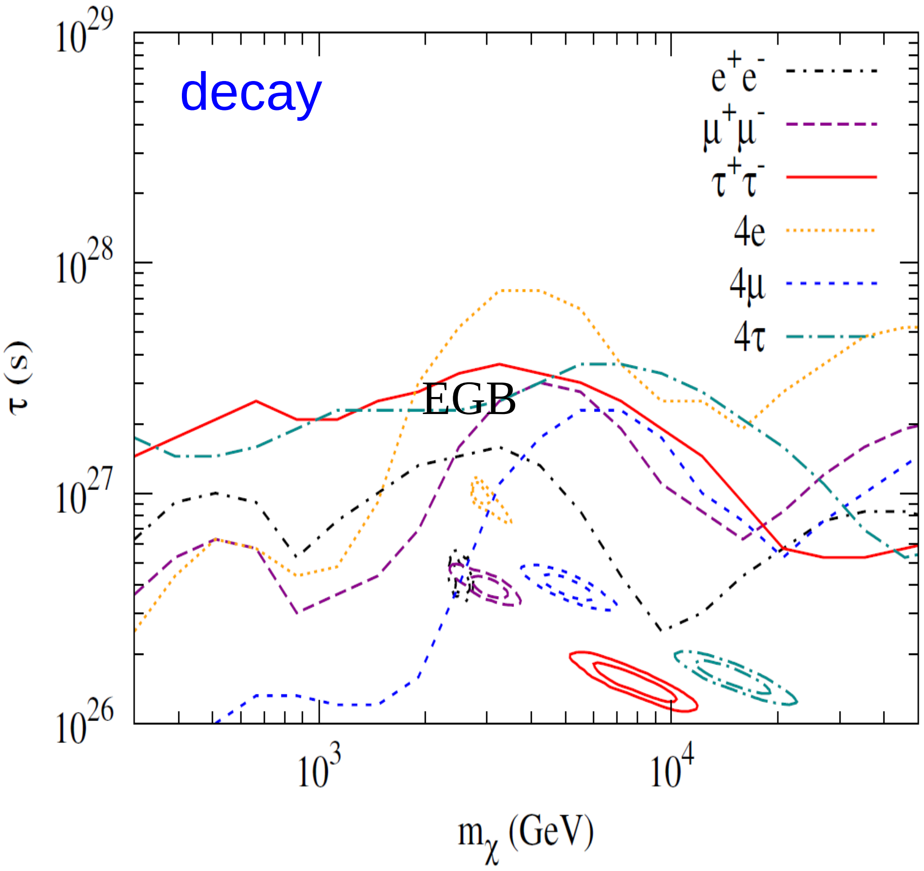




DM model can reproduce the data, and the constraints on the parameters have been significantly improved (Yuan et al. arXiv:1711.10989).

Constraints on the DM models





The simplest DM models for low energy CRE anomaly are in tension with other data (Yuan et al. arXiv:1711.10989). More complicated DM model? Astrophysical source?

Summary

The detector

- Large geometric factor instrument (0.3 m^2 sr for electrons)
- Precision Si-W tracker (40μm , 0.2°)
- Thick calorimeter (32 X_0 , σ_E/E better than 1.5% above 50 GeV for e/γ , (20~35)% for hadrons)
- "Mutiple" charge measurements (0.1-0.3 e resolution)
- e/p rejection power ~10^5 (topology alone, higher with 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
- The first CRE spectrum has been published in Dec. 2017

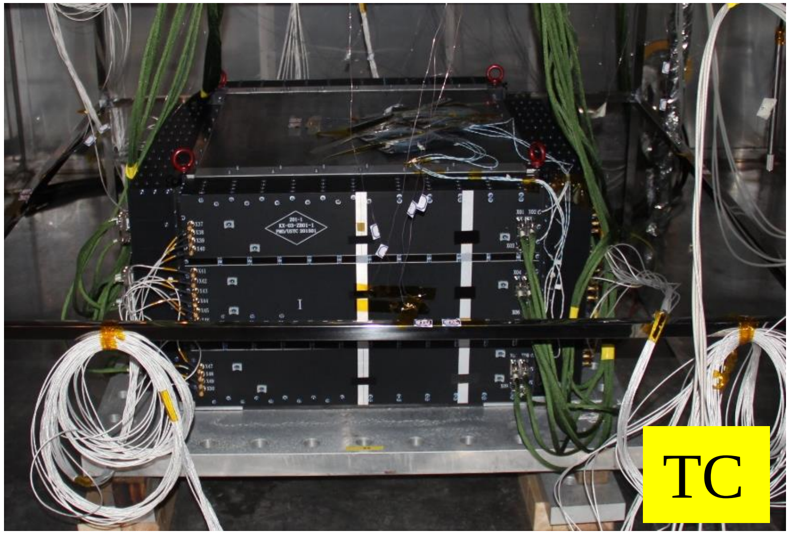
Some members and partners

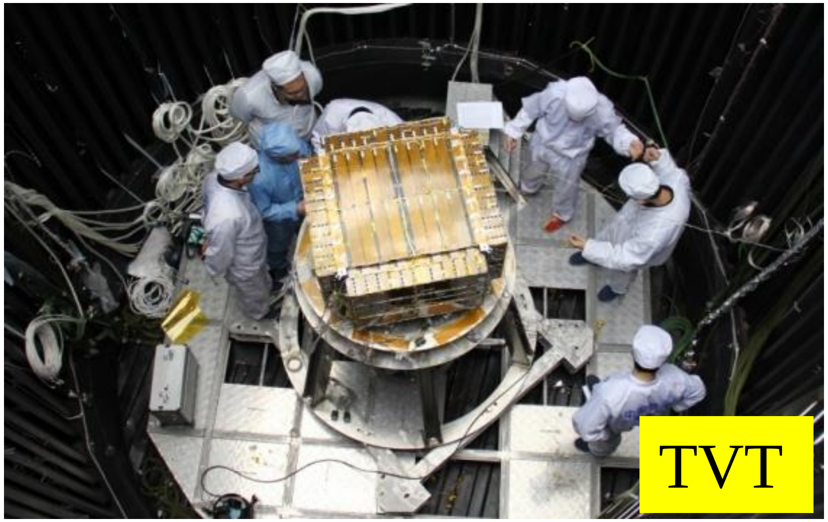
Thank you!

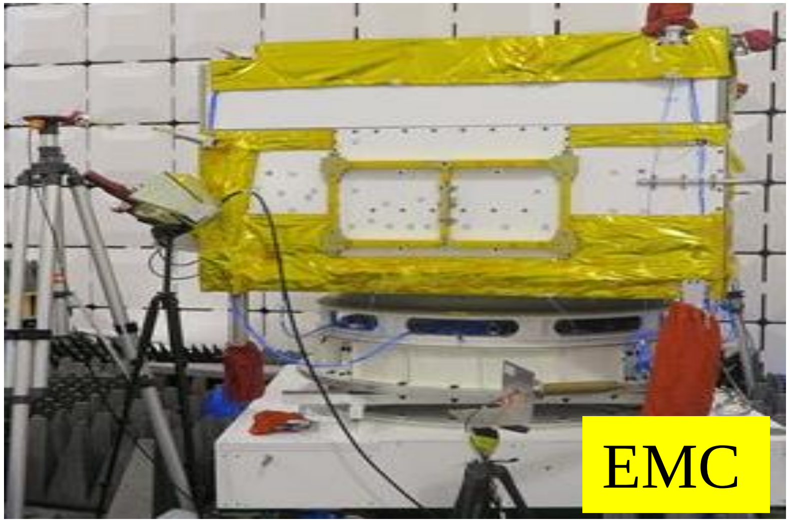
Back up

Flight model: environmental tests

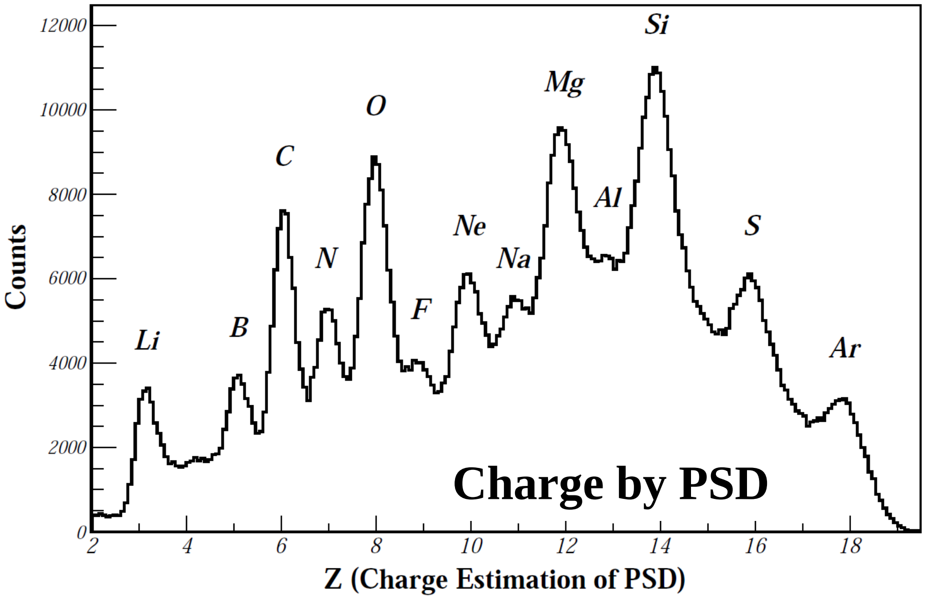

vibration

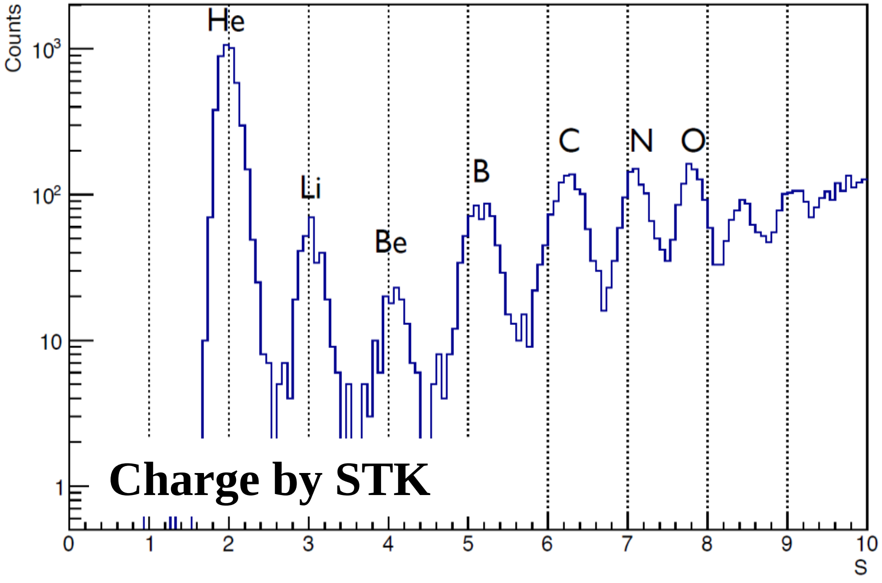

TC


TVT


EMC

Beam test @ CERN





(Chang et al. [DAMPE collaboration] 2017 Astropart. Phys.)

METHODS

Discrimination between electrons and protons. The method of electron selection in this work relies on the differences in the development of showers initiated by protons and electrons[23,31,32]. The procedure is as follows. First, we search for events passing through the entire BGO calorimeter. We select events with hit positions from −28.5 cm to 28.5 cm for the top layer and −28 cm to 28 cm for the bottom layer (each BGO bar lies between −30 cm and 30 cm). Second, we calculate the shower spread, expressed by the energy-weighted root-mean-square value of hit positions in the calorimeter. The root-mean-square value of the *i*th layer is calculated as:

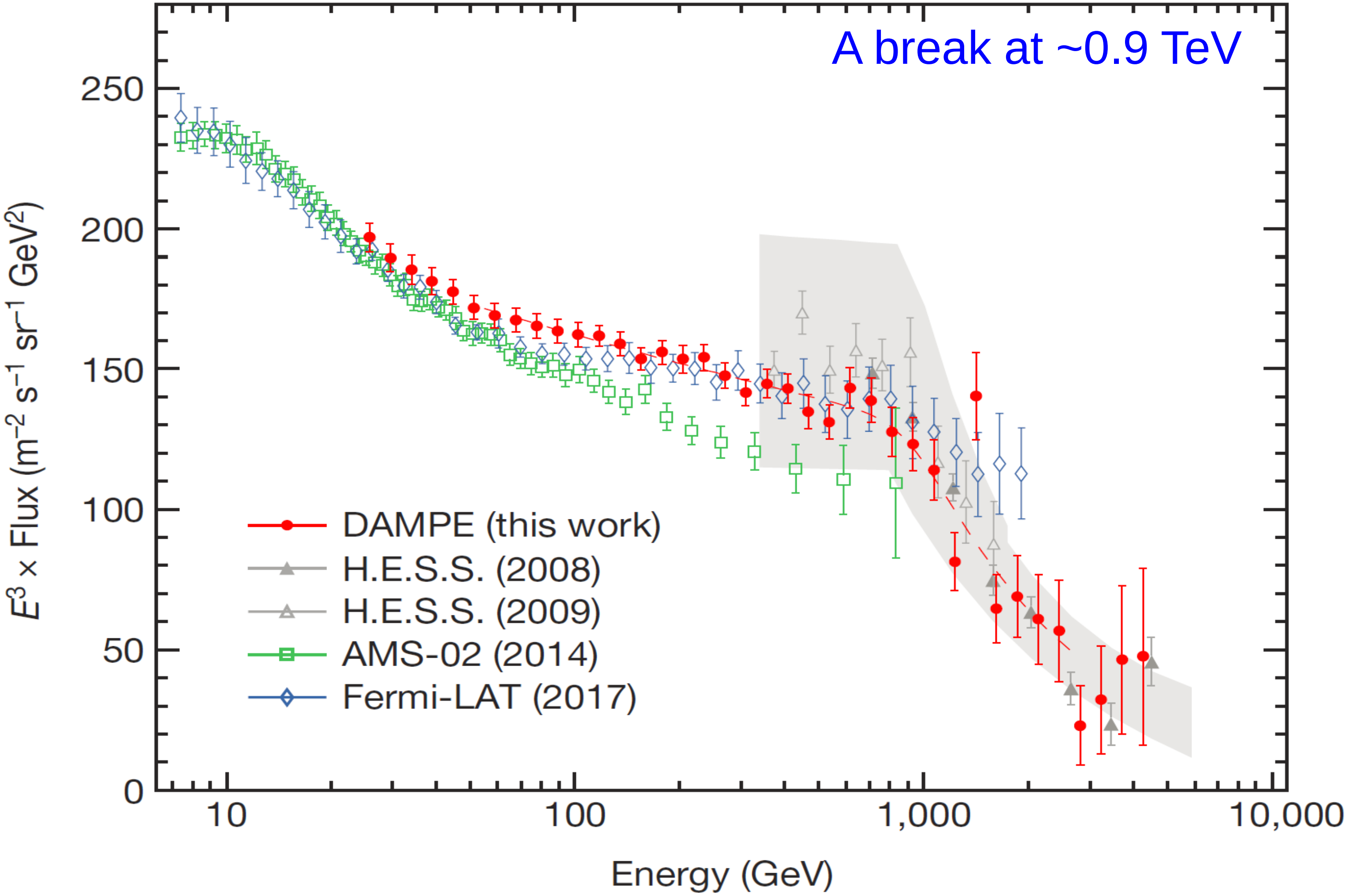
$$\mathrm{RMS}_i = \sqrt{\frac{\sum_j (x_{j,i} - x_{\mathrm{c},i})^2 E_{j,i}}{\sum_j E_{j,i}}} \tag{1}$$

where $x_{j,i}$ and $E_{j,i}$ are the coordinates and deposited energy of the *j*th bar in the *i*th layer, and $x_{\mathrm{c},i}$ is the coordinate of the shower centre of the *i*th layer. Figure 1 shows the deposited energy fraction in the last BGO layer ($\mathcal{F}_{\mathrm{last}}$) versus the total root-mean-square value of all 14 BGO layers (that is, $\sum_i \mathrm{RMS}_i$). We can see that electrons are well separated from protons. Note that in Fig. 1 and Extended Data Fig. 1, heavy ions have already been effectively removed by selection through the plastic scintillator detector, on the basis of the charge measurement.

For a better evaluation of the electron/proton discrimination capabilities, we introduce a dimensionless variable, ζ, defined as

$$\zeta = \mathcal{F}_{\mathrm{last}} \times (\Sigma_i \mathrm{RMS}_i/\mathrm{mm})^4/(8 \times 10^6) \tag{2}$$

First results: CRE spectrm



(DAMPE collaboration, 2017, Nature)