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

Recent progresses of the Dark Matter Particle Explorer (DAMPE)

Qiang Yuan (袁强)
Purple Mountain Observatory
(on behalf of the DAMPE collaboration)

NextGAPES-2019 workshop, Moscow, June 21-22, 2019

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

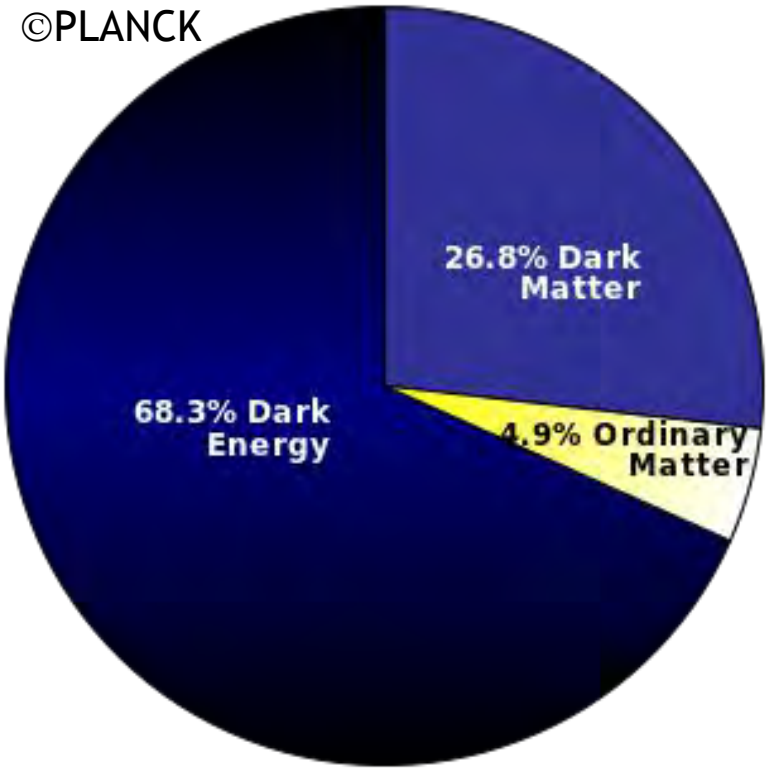
- ITALY
  - INFN Perugia and University of Perugia
  - INFN Bari and University of Bari
  - INFN Lecce and University of Salento
  - INFN LNGS and GSSI

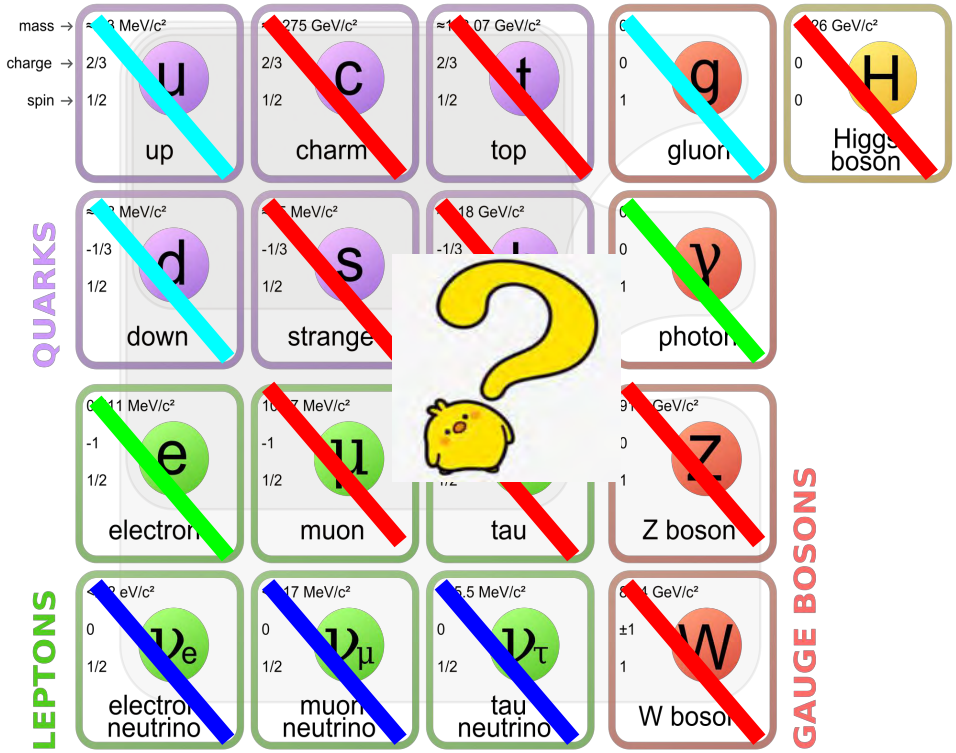
- SWITZERLAND
  - University of Geneva

Outline

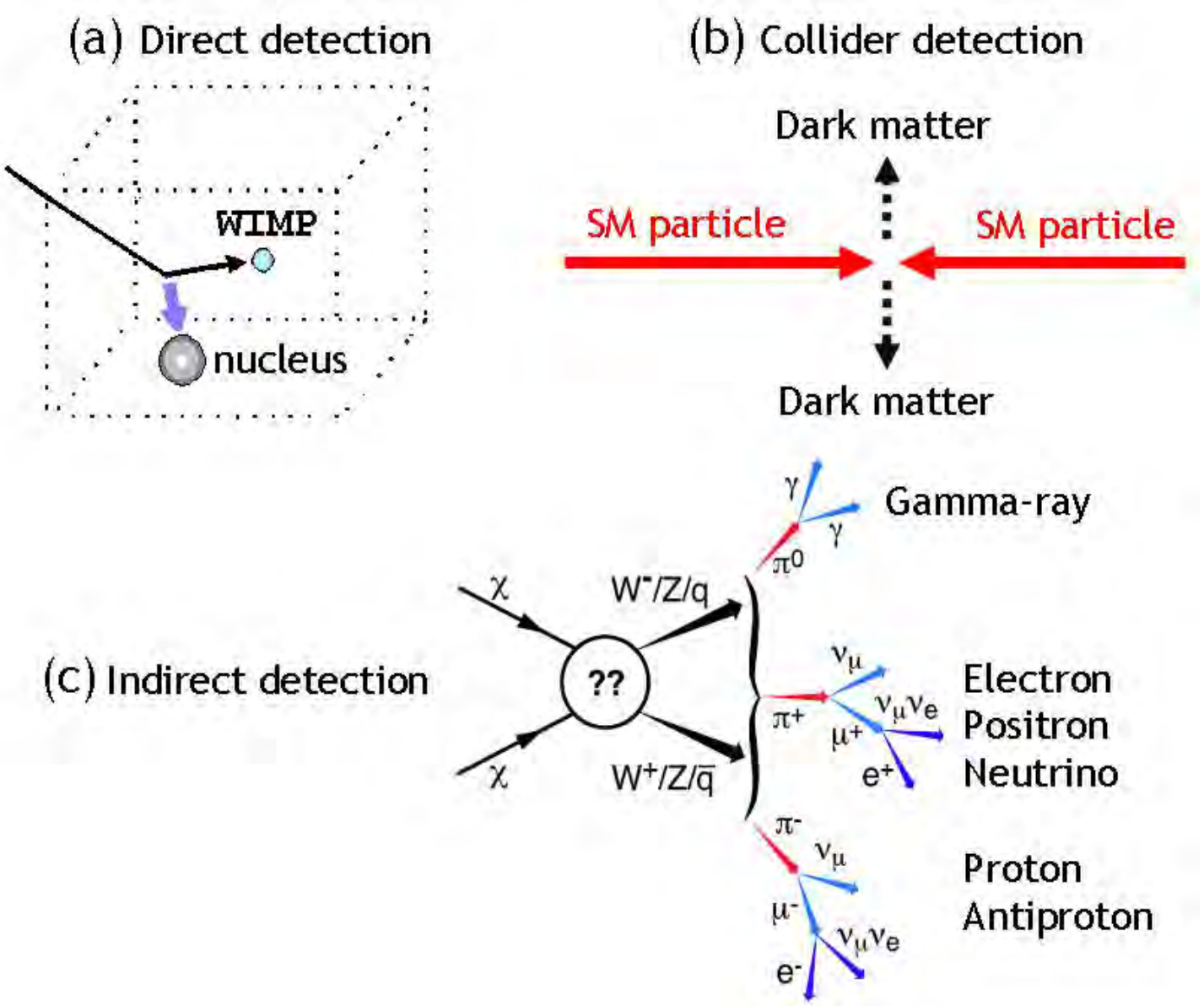
- Introduction of DAMPE science
- DAMPE instrument
- On-orbit performance
- Physical Results
- Summary

Composition of the Universe

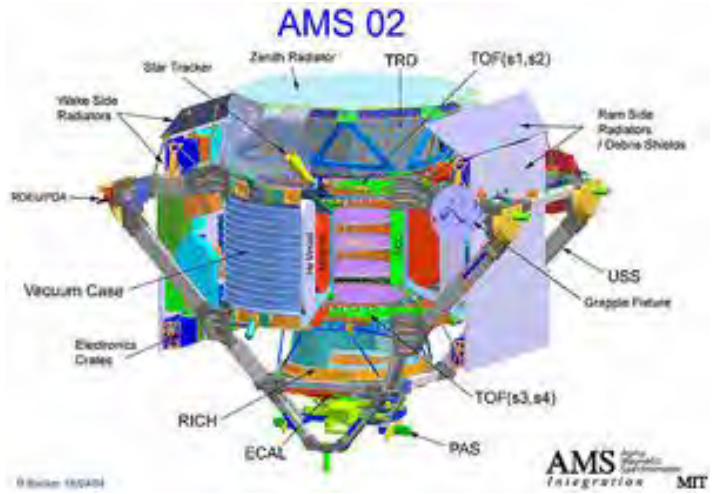




Detection of dark matter particles

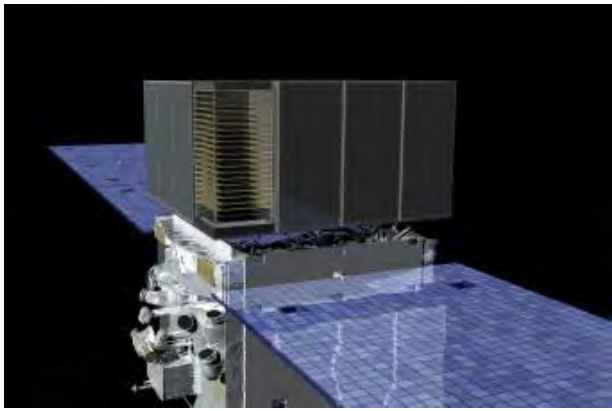


Dark matter indirect detection experiments

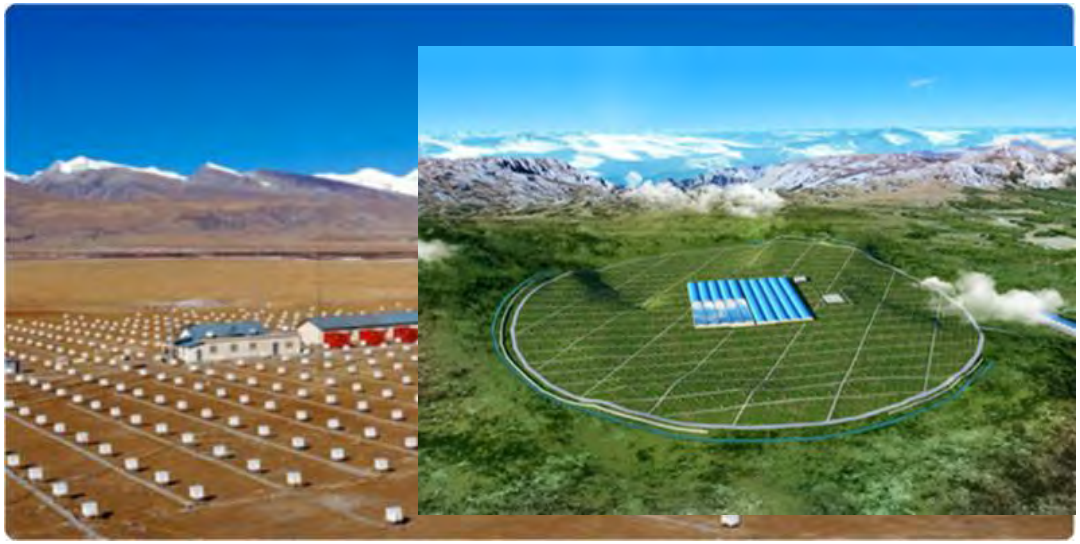


CALET

Fermi



Yangbajing/LHAASO



HESS/MAGIC/VERITAS

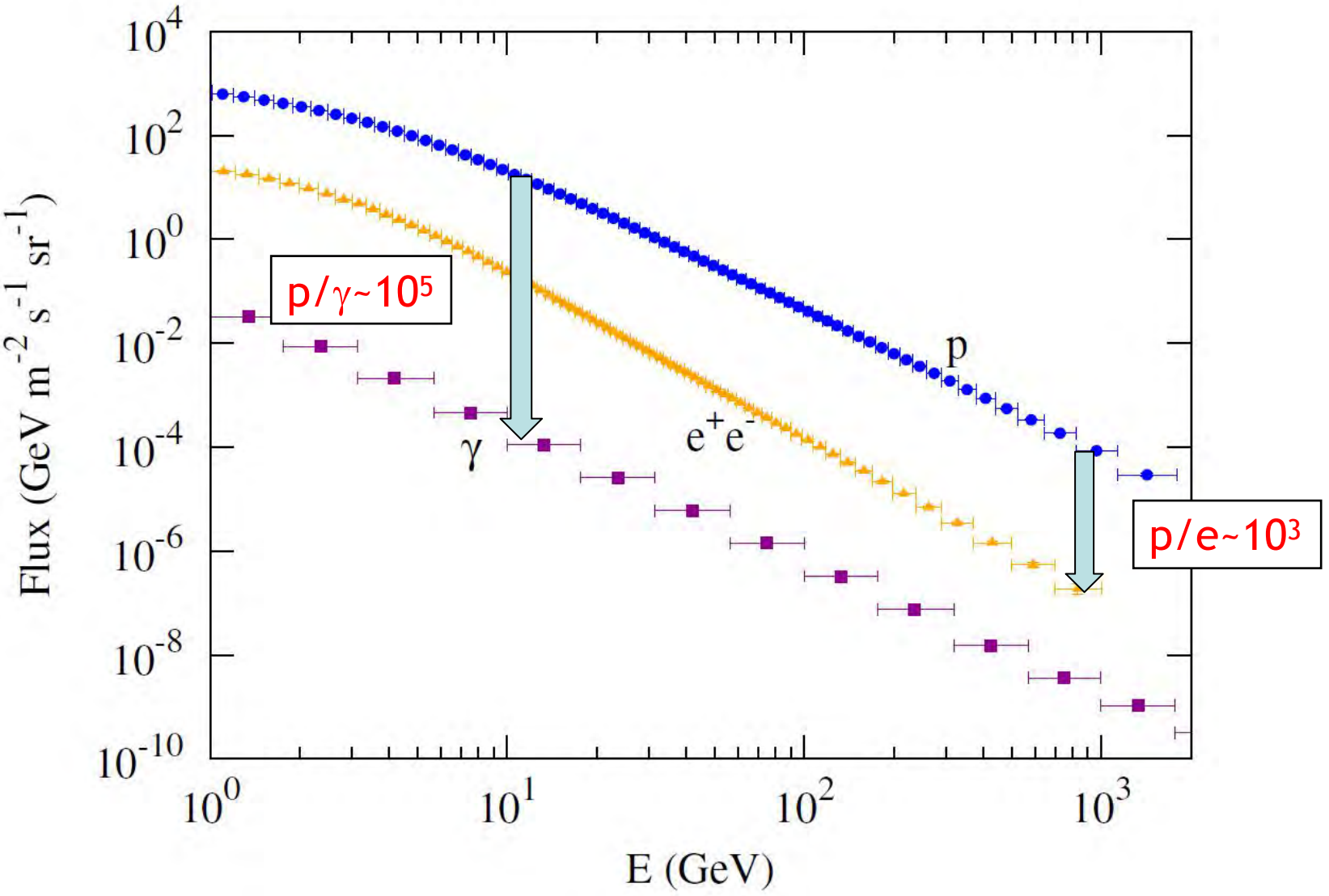
Dark Matter Particle Explorer

Cosmic ray origin & propagation

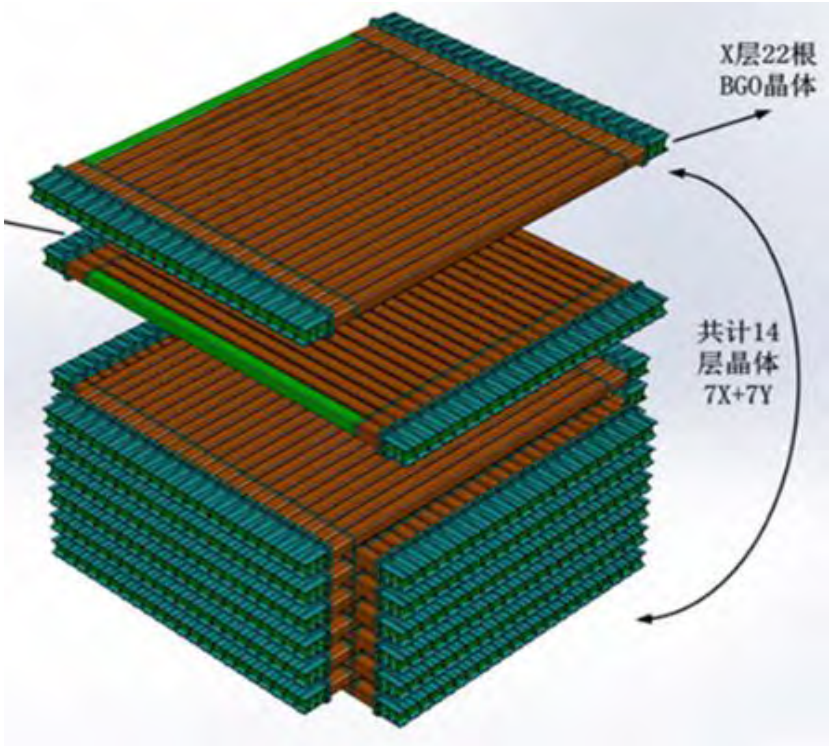
Gamma-ray astronomy

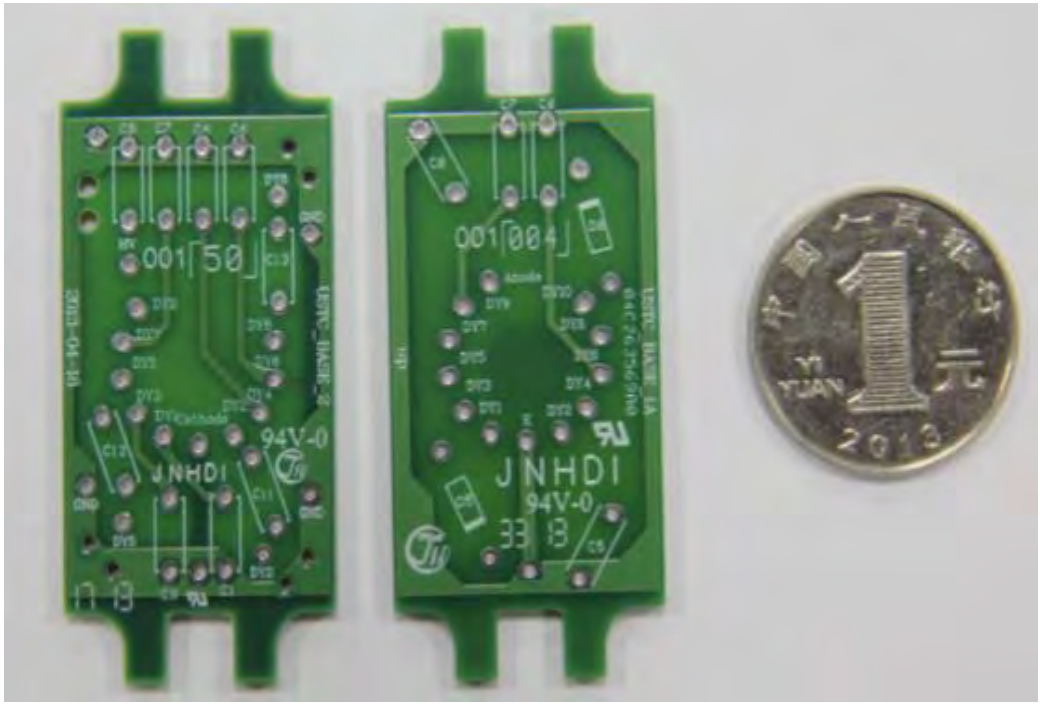
Indirect detection of dark matter particles

Challenge 1: Particle identification



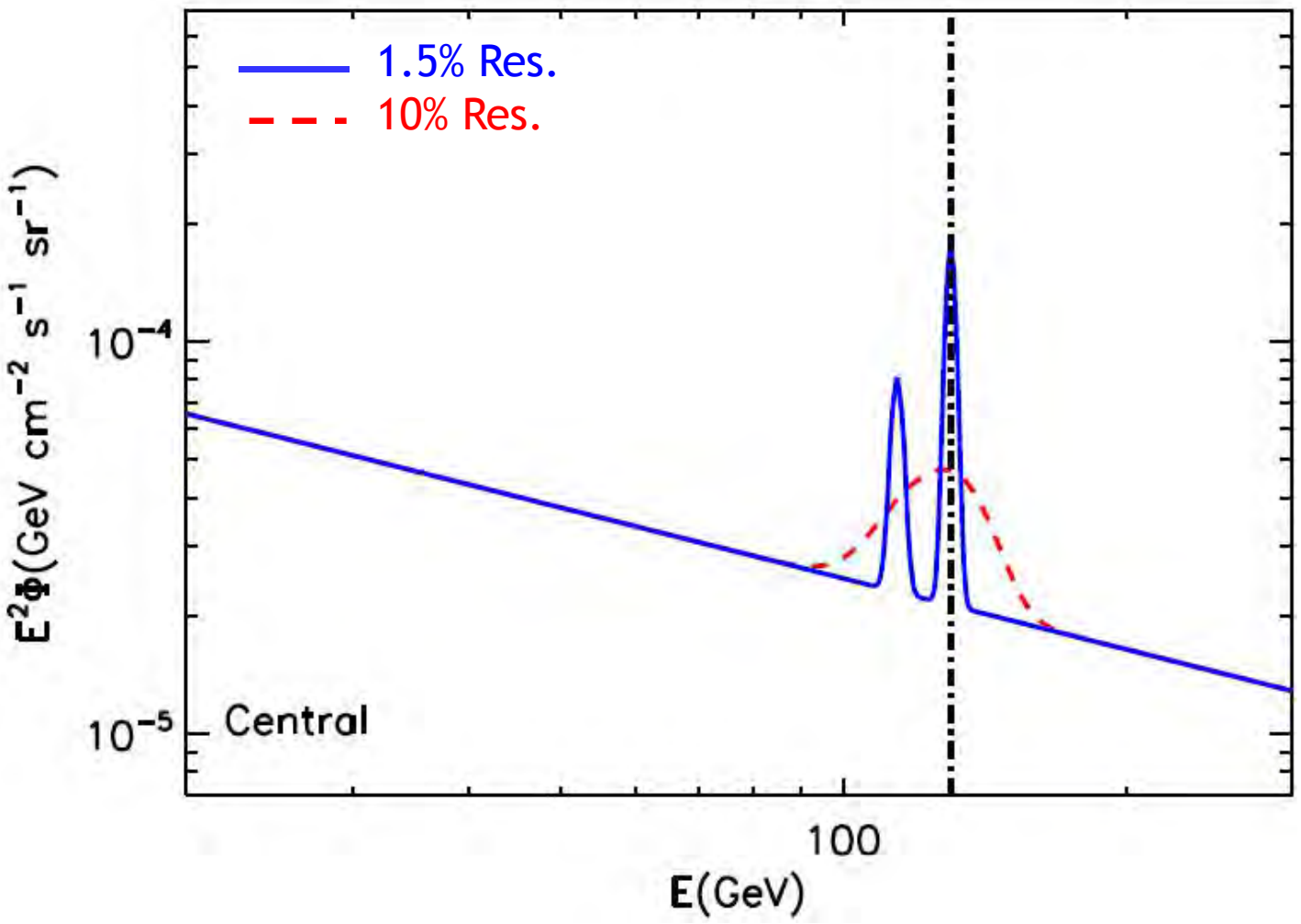
Challenge 2: large dynamic range





To observe electrons/photon from GeV-10 TeV and nuclei to 100 TeV, the required dynamic range of a single bar is ~10^6

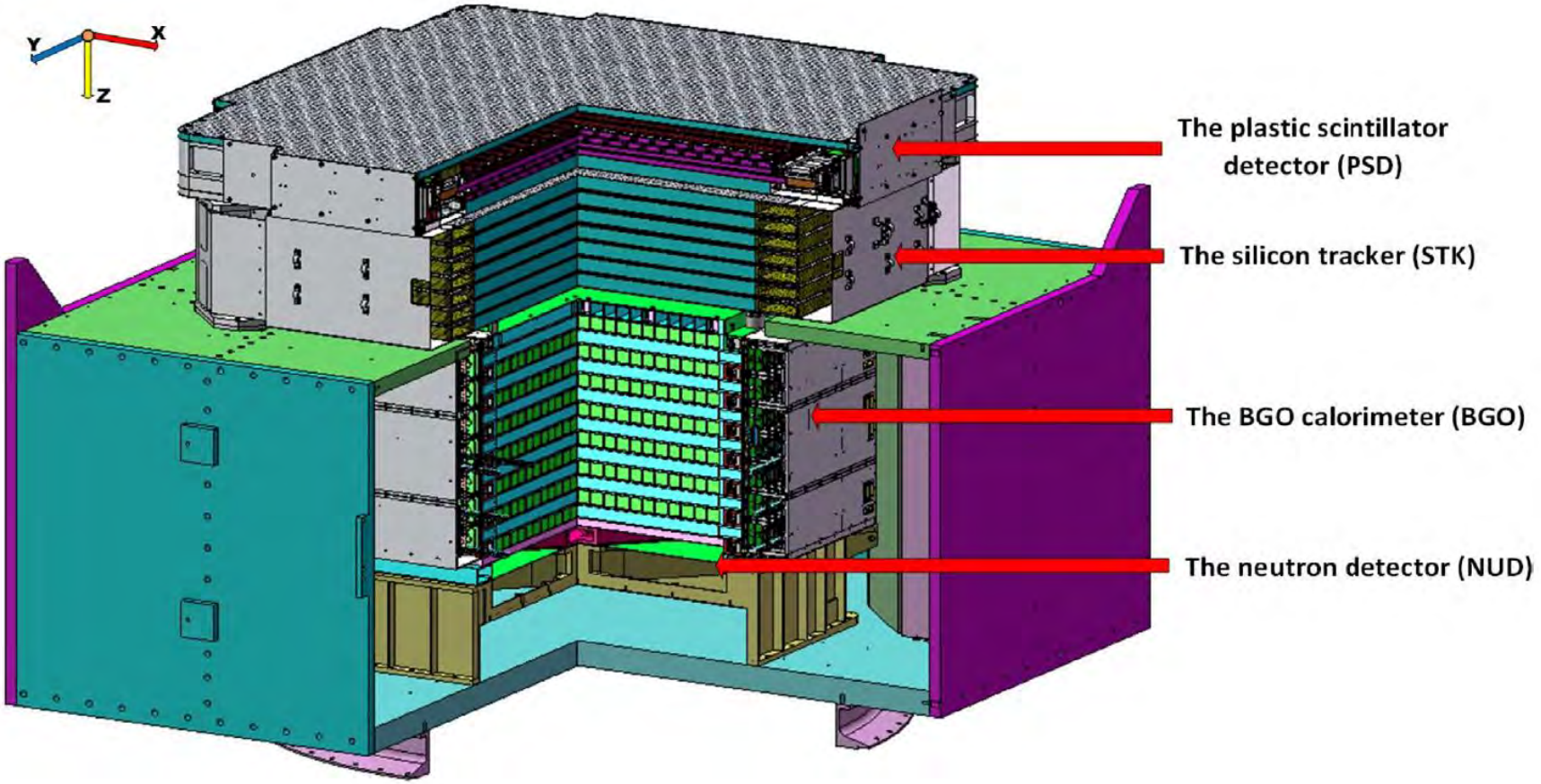
Challenge 3: energy resolution



(Phys. Lett. B 715 (2012) 35)

DAMPE instrument

Instrument Design

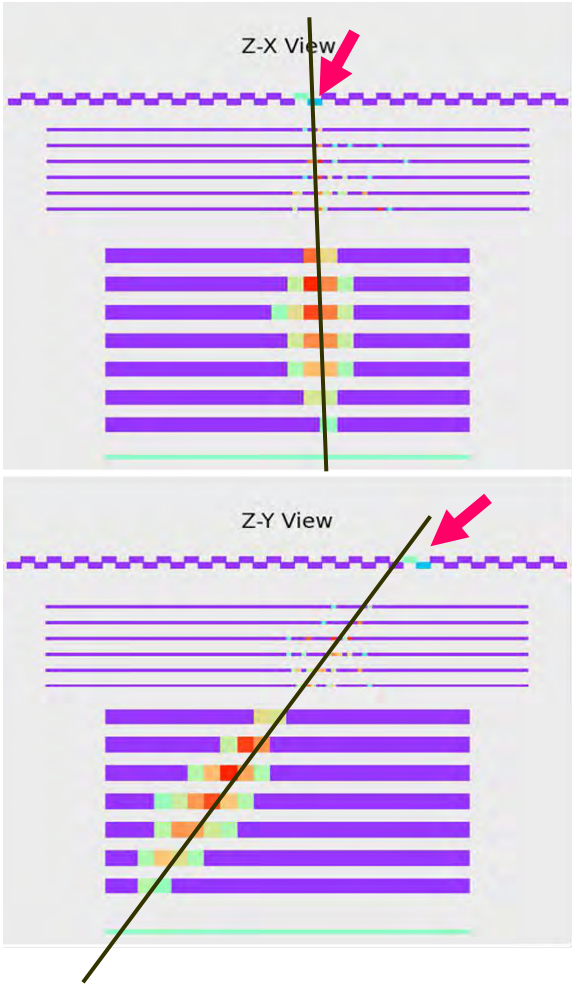


- PSD: charge measuresument via dE/dx and ACD for photons
- STK: track, charge, and photon converter
- BGO: energy measurement, particle (e-p) identification
- NUD: Particle identification

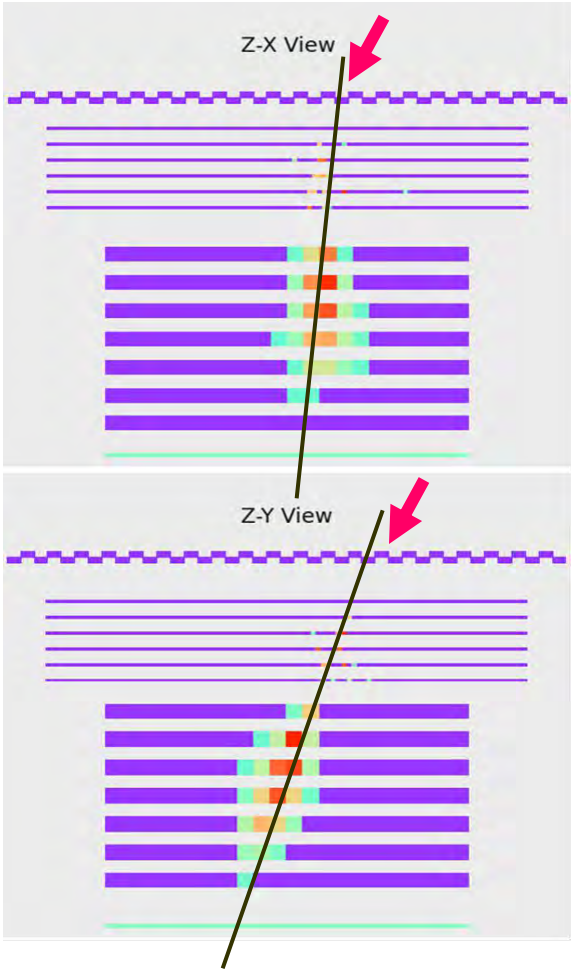
(Astropart.Phys. 95 (2017) 6–24)

Particle identification

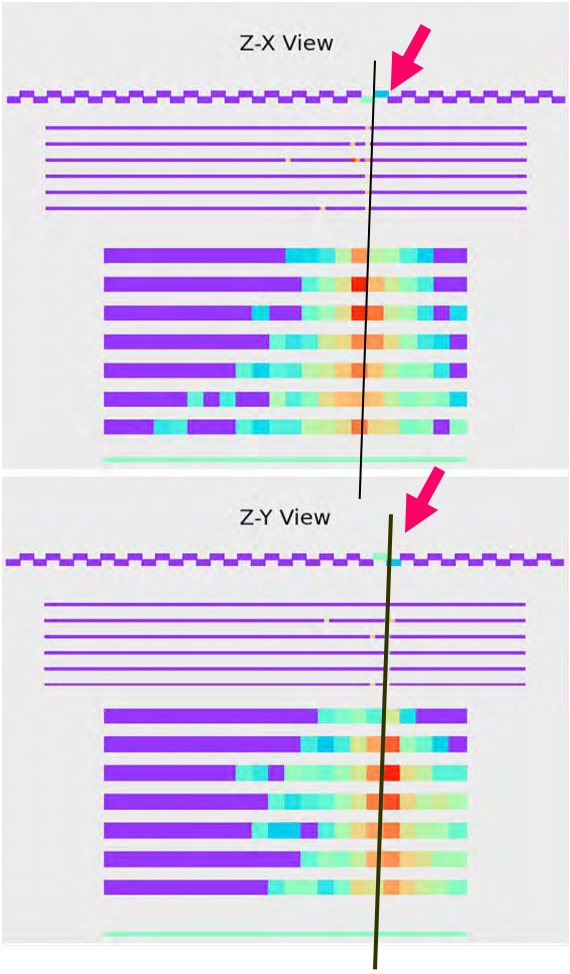
electron



gamma

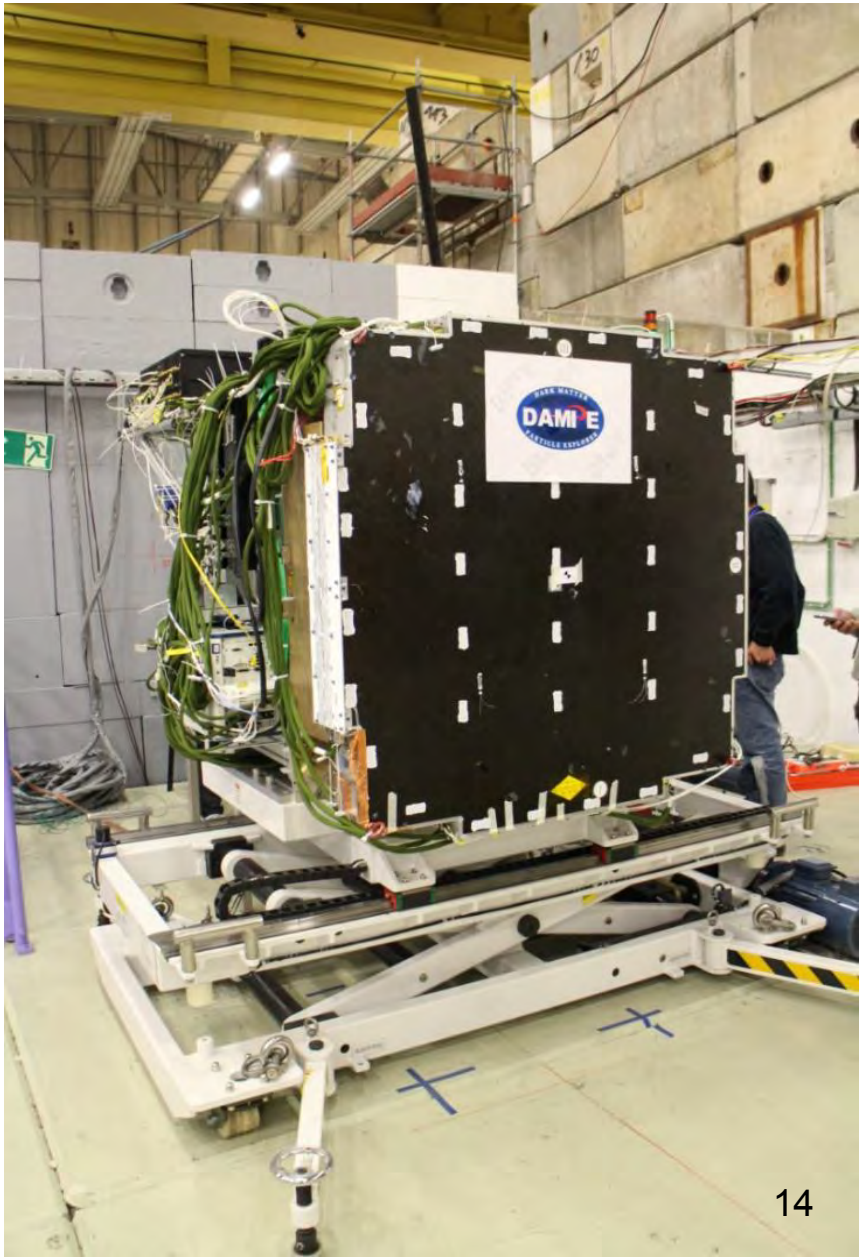


proton

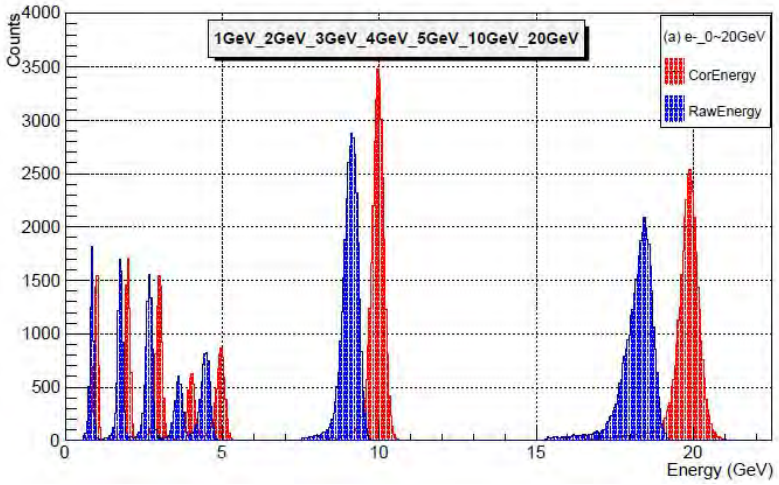


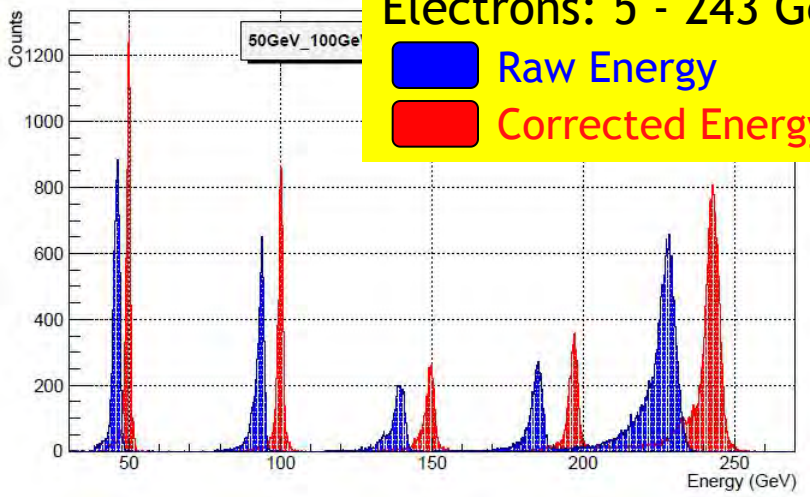
Beam test @ CERN

- 14 days@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
- 8 days@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,
- 17 days@SPS，16/3-1/4 2015
  - Fragments：66.67-88.89-166.67GeV/c
  - Argon：30A- 40A- 75AGeV/c
  - Proton：30GeV/c，40GeV/c
- 21 days@SPS，10/6-1/7 2015
  - Primary Proton: 400GeV/c
  - Electrons @ 20, 100, 150 GeV/c
  - g @ 50, 75 , 150 GeV/c
  - m @ 150 GeV /c
  - p+ @10, 20, 50, 100 GeV/c
- 6 days@SPS, 20/11-25/11 2015
  - -- Pb 030 AGeV/c (and fragments)



Beam test @ CERN

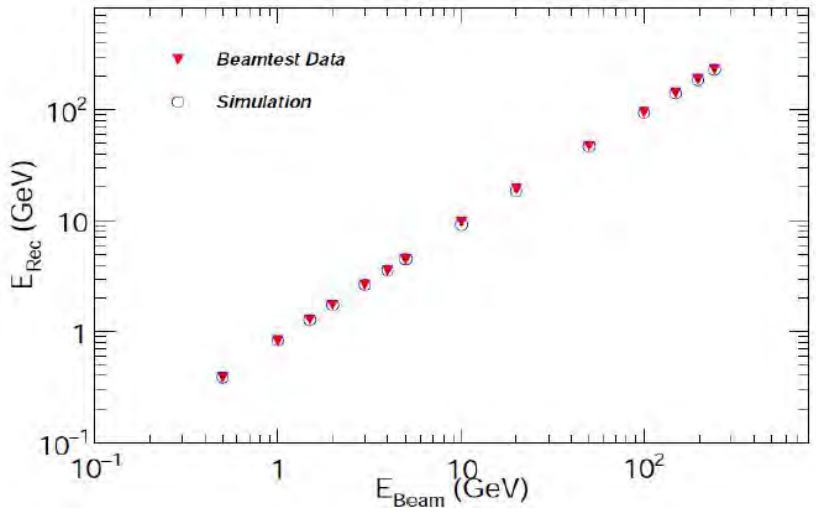


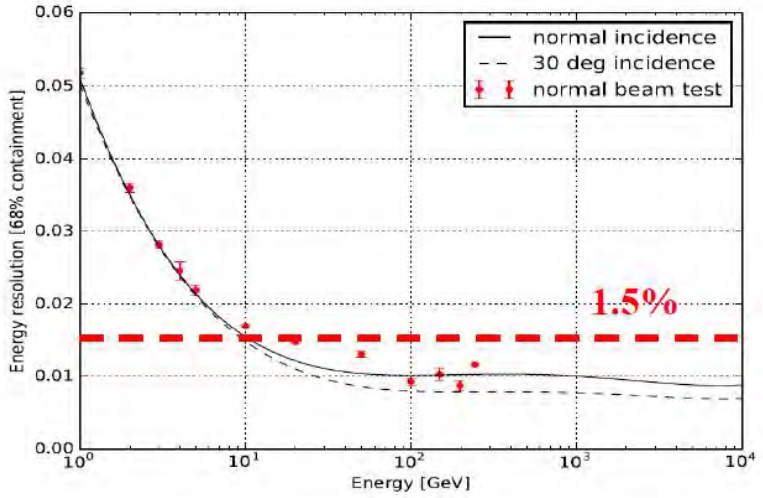


Electrons: 5 - 243 GeV

Raw Energy

Corrected Energy





(Astropart.Phys. 95 (2017) 6–24)

Launch on 17th Dec. 2015

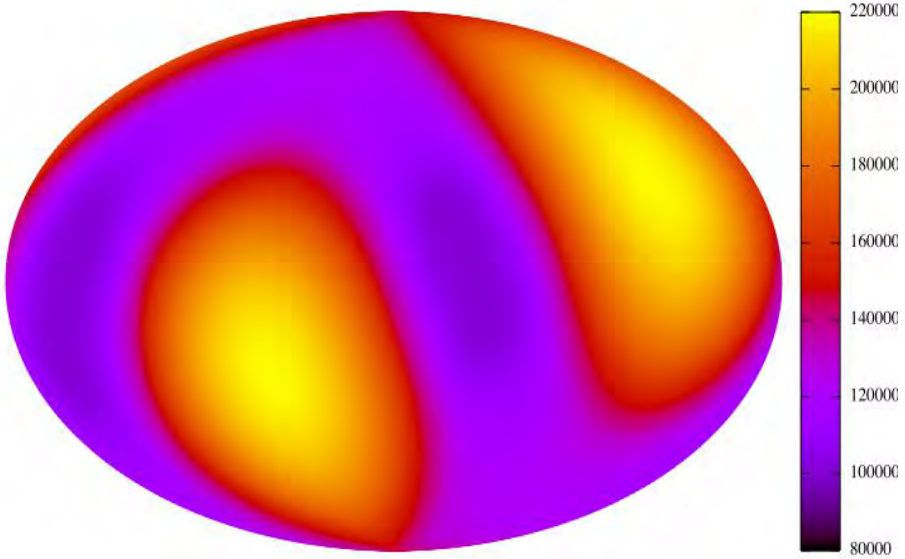
悟空号
Wukong
暗物质粒子探测卫星
Dark Matter Particle Explorer (DAMPE)
"Monkey King"

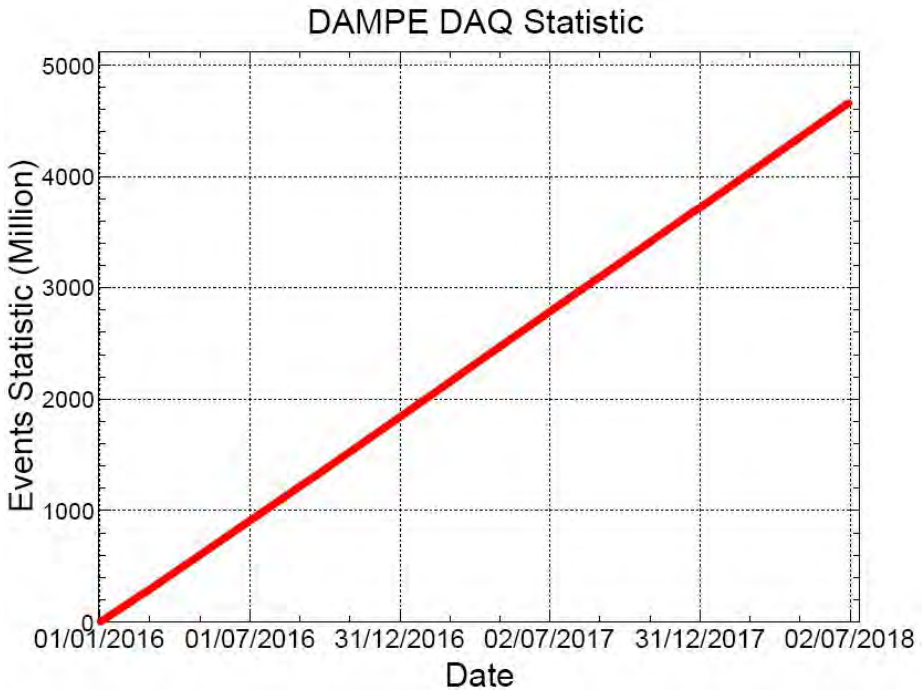
Jiuquan Satellite Launch Center

On-orbit performance

Observation overview

DAMPE 3 year counts map

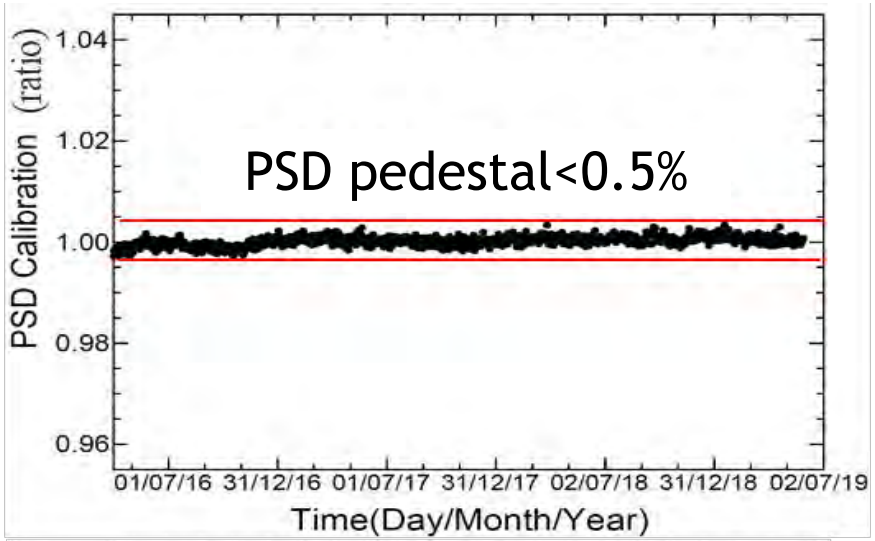


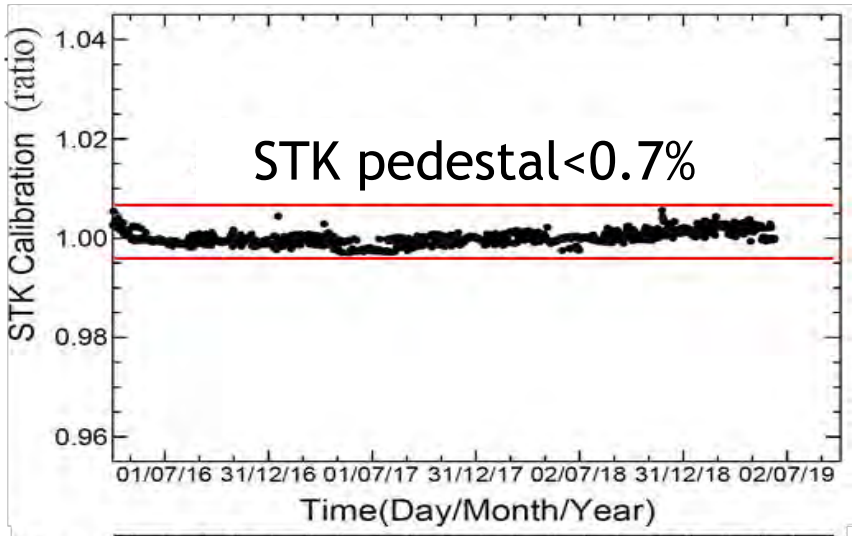


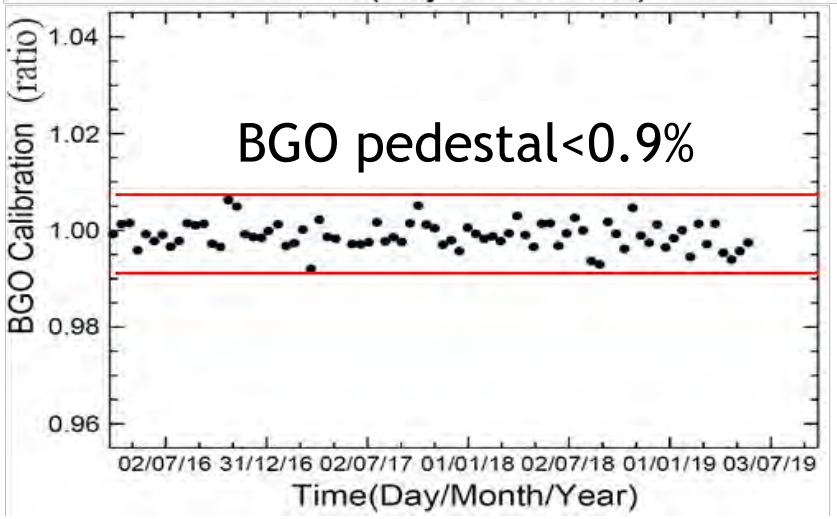
6 full scans of the sky

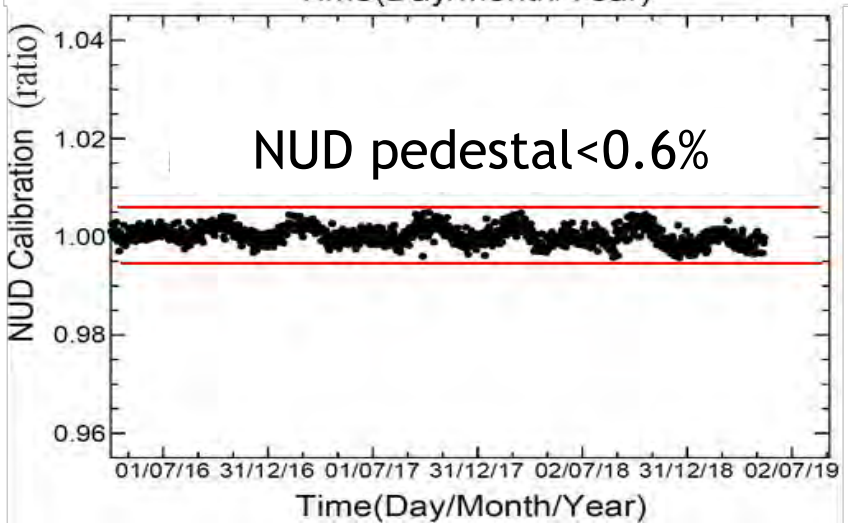
5M events/day
5.7 billion in total

Detector stability

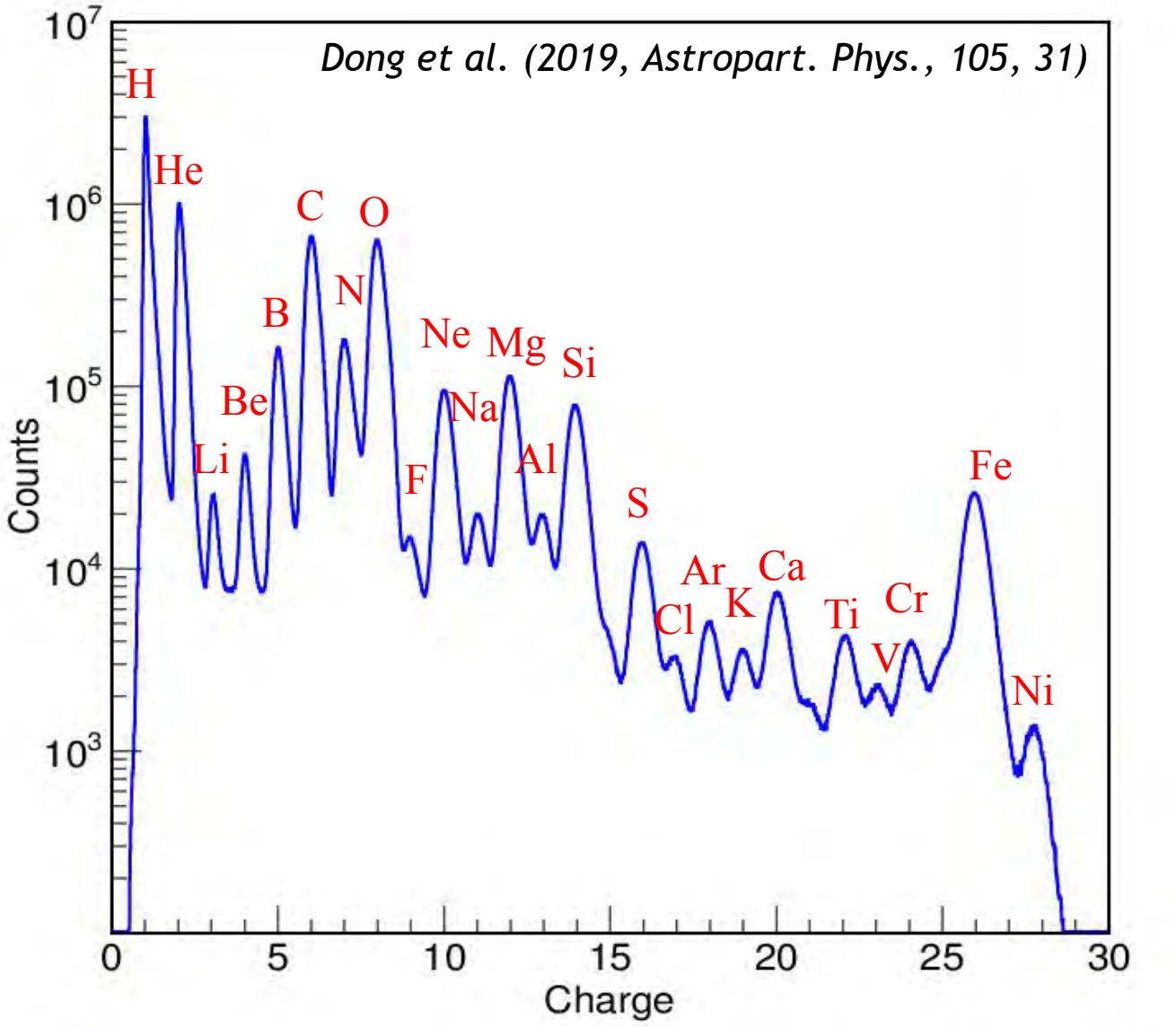






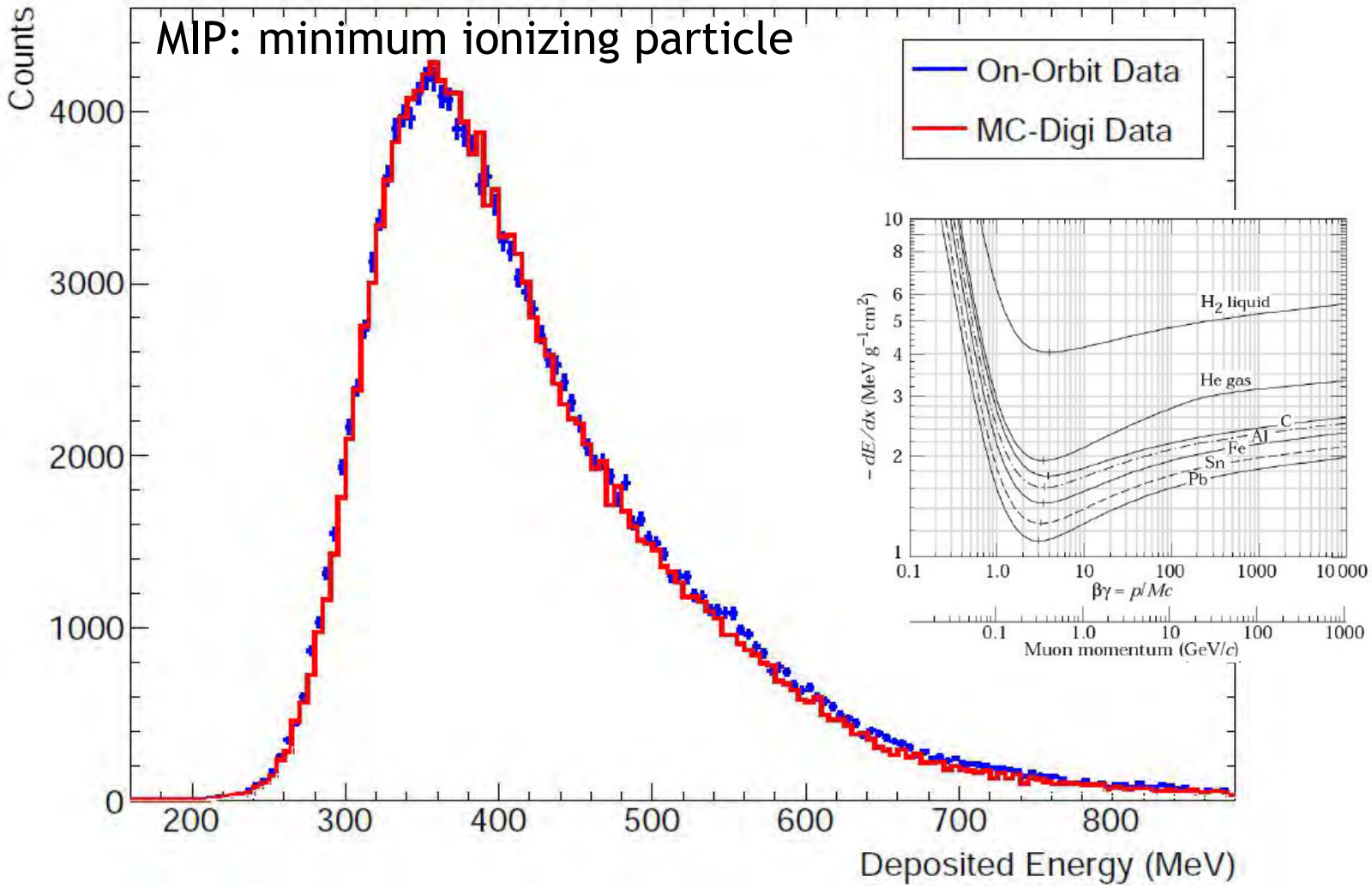


Charge measurement by PSD

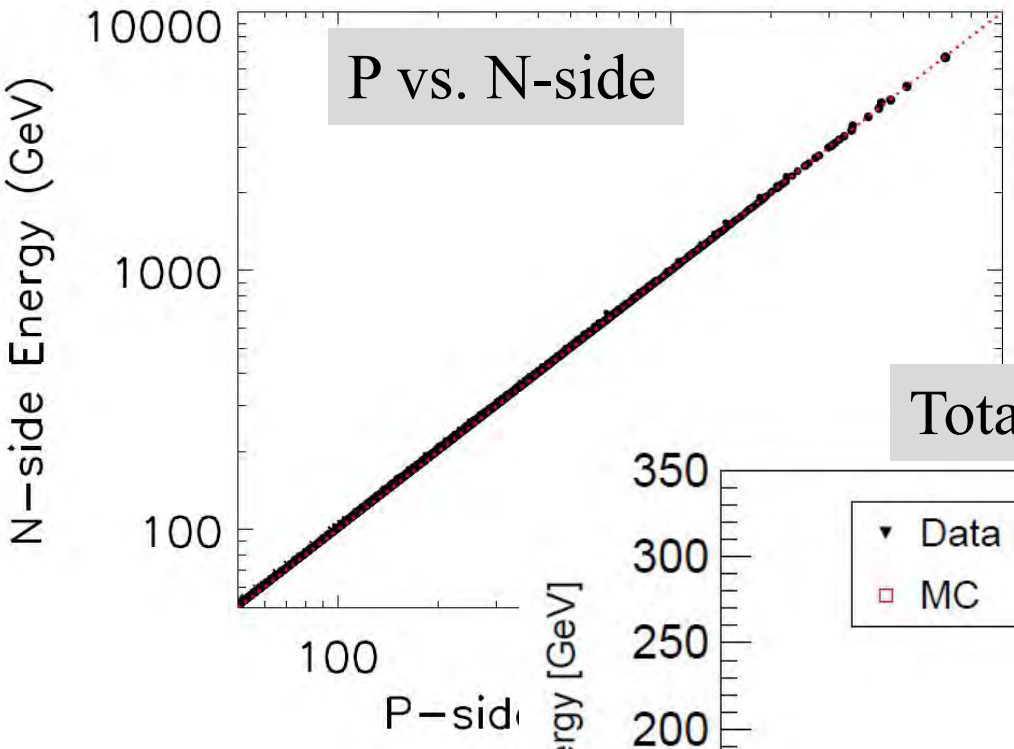


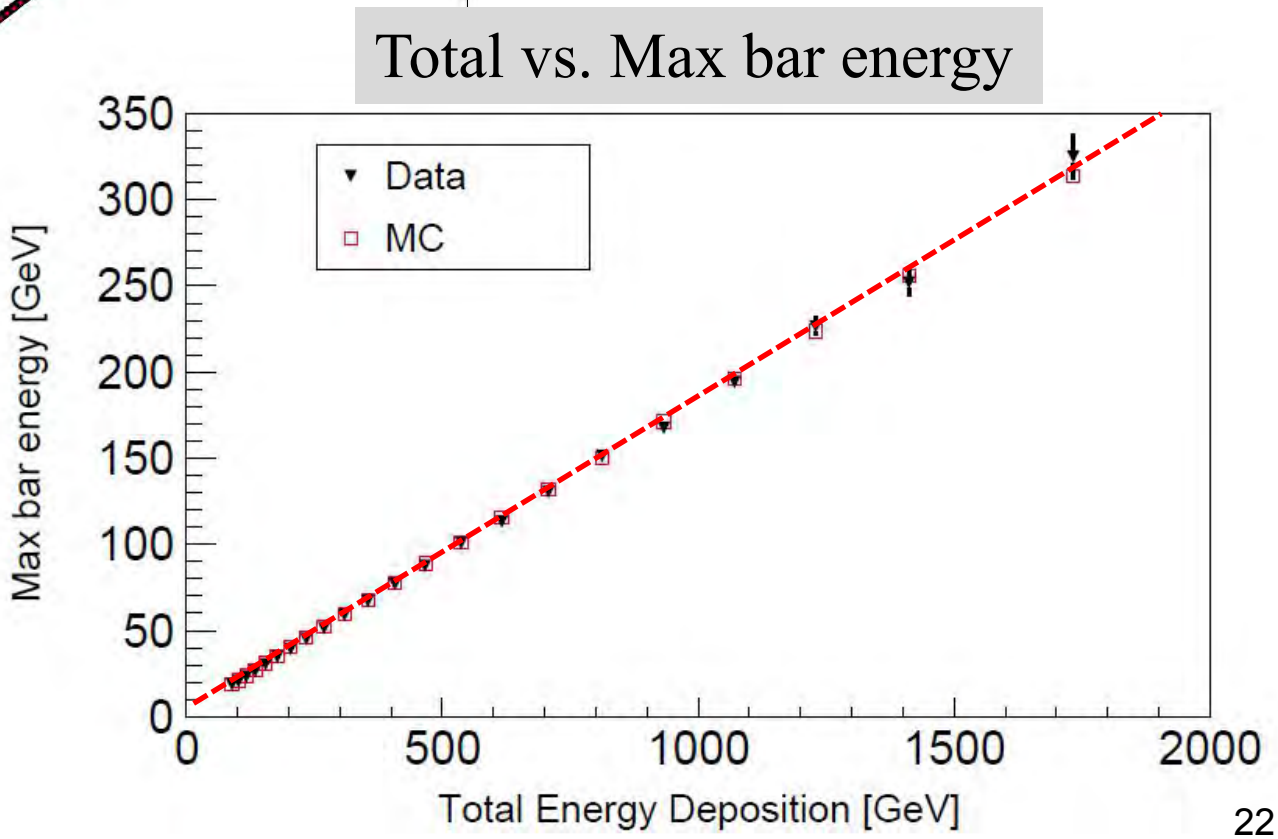
P	0.07
He	0.12
Li	0.14
Be	0.21
B	0.17
C	0.18
N	0.21
O	0.21

BGO energy calibration: MIPs

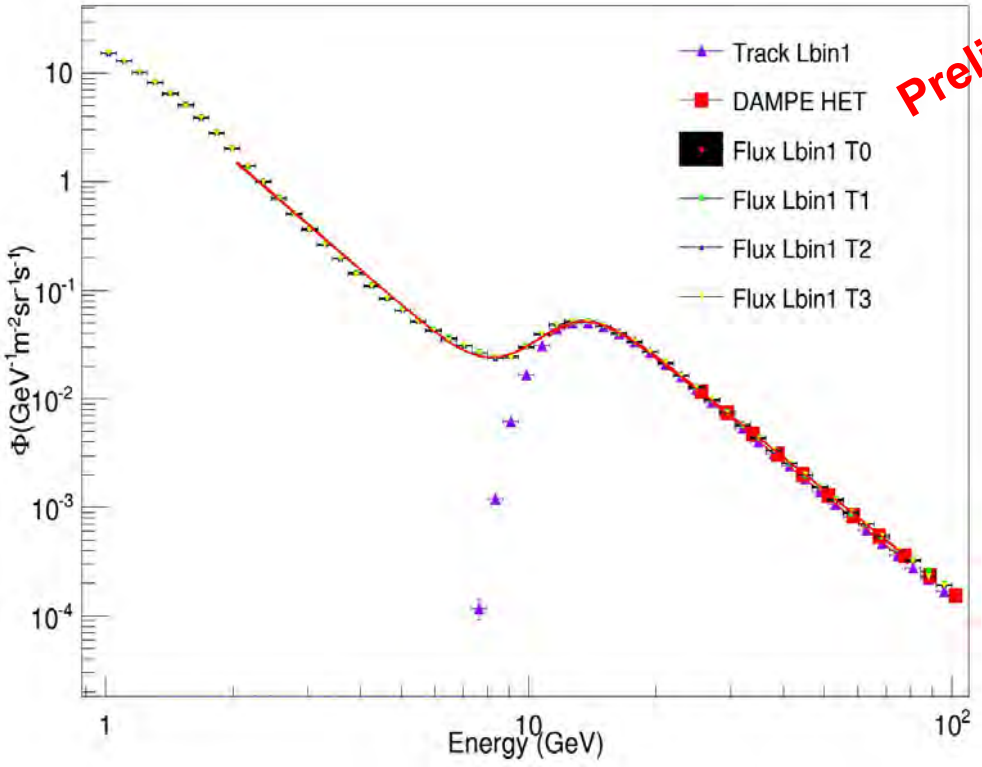


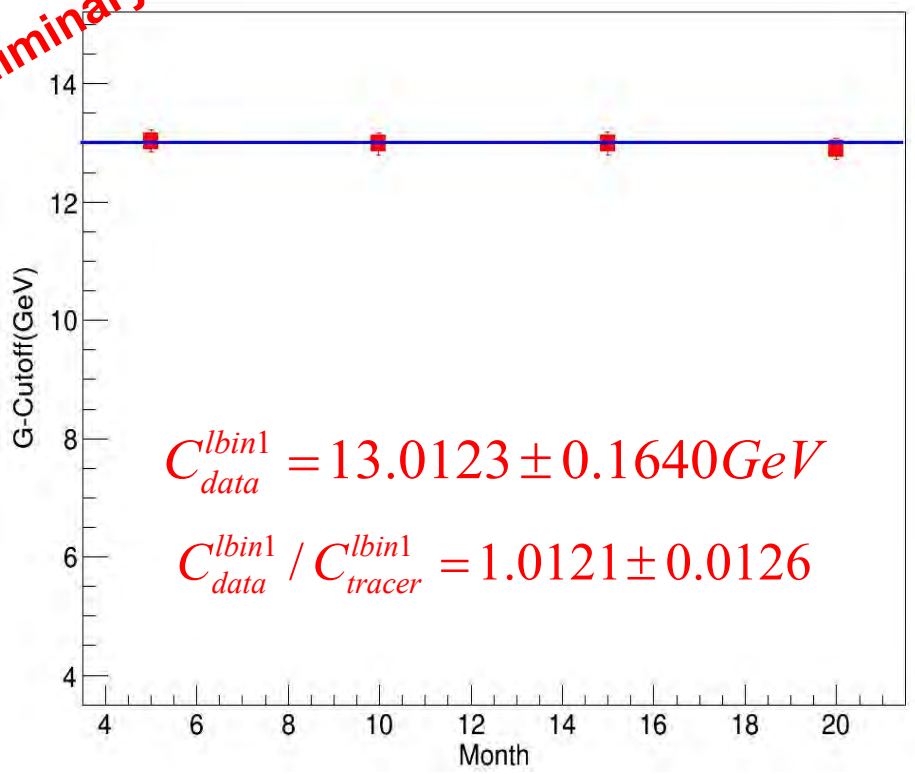
BGO energy measurement: linearity





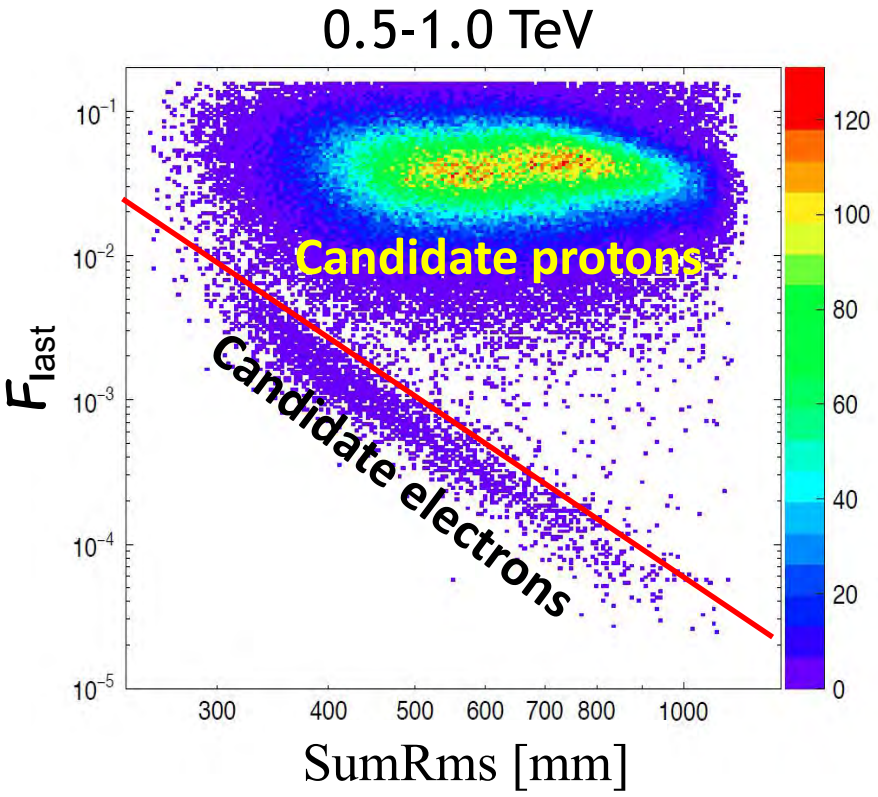
Absolute energy scale: geomagnetic cutoff

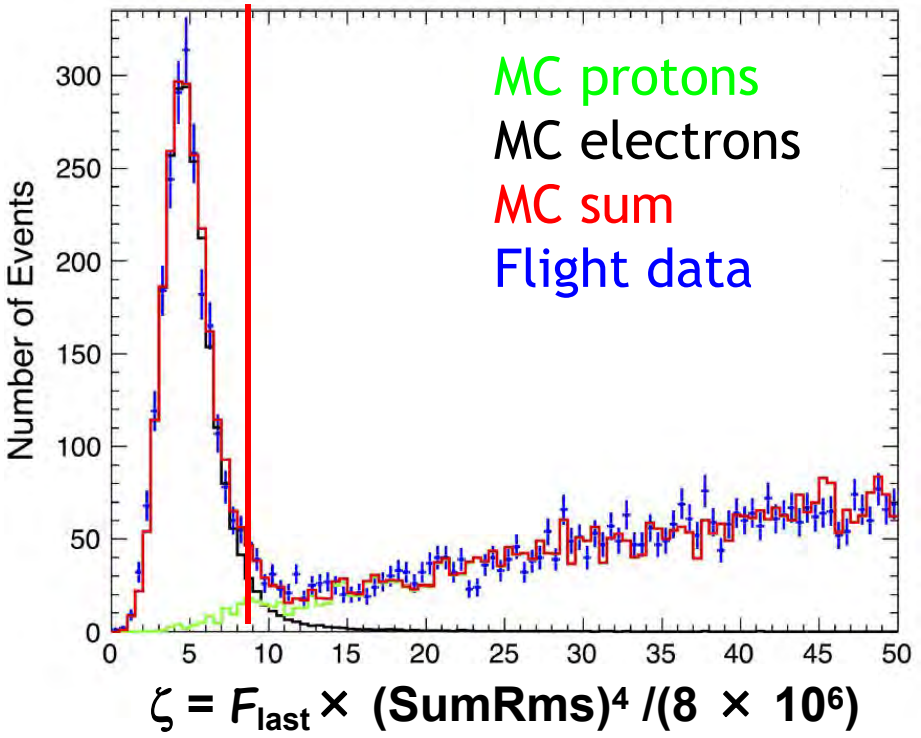




The cutoff energy is stable with time. A slight decrease is due to solar modulation of low energy primary electrons.

e/p separation: shower shapes

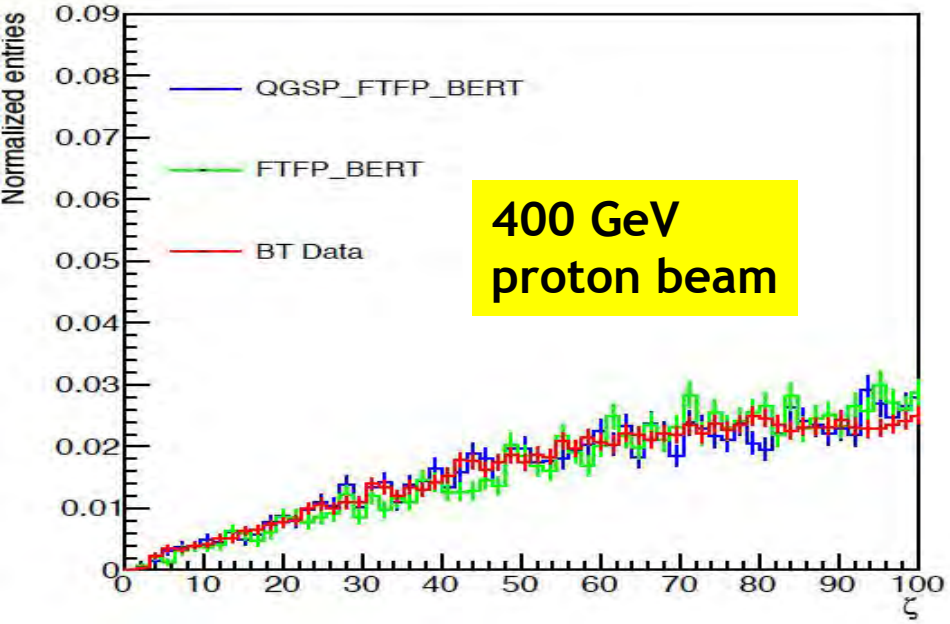


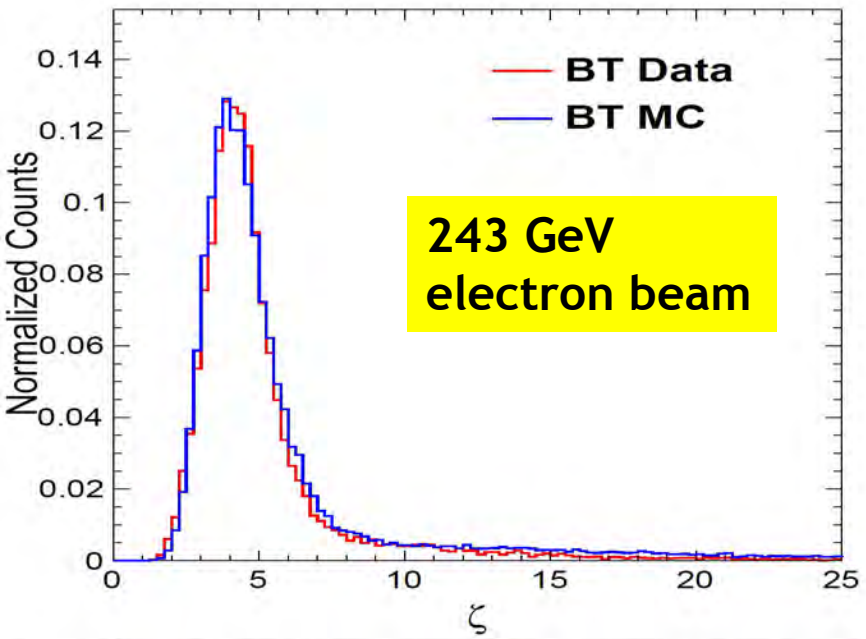


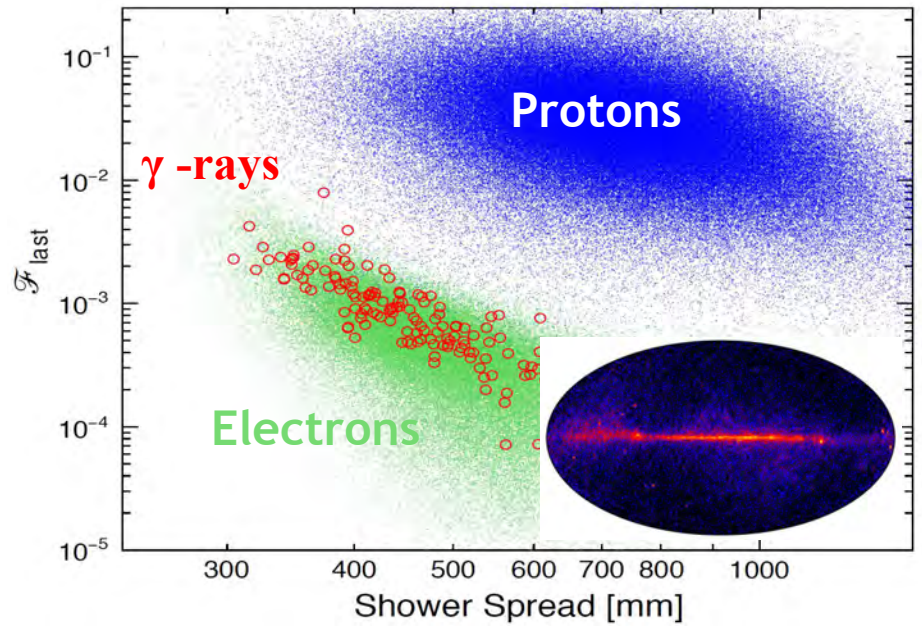
- We use the lateral (SumRMS) and longitudinal (energy ratio in last layer) developments of the showers to discriminate electrons from protons
- For 90% electron efficiency, proton background is ~2% @ TeV, ~5% @ 2 TeV, ~10% @ 5 TeV

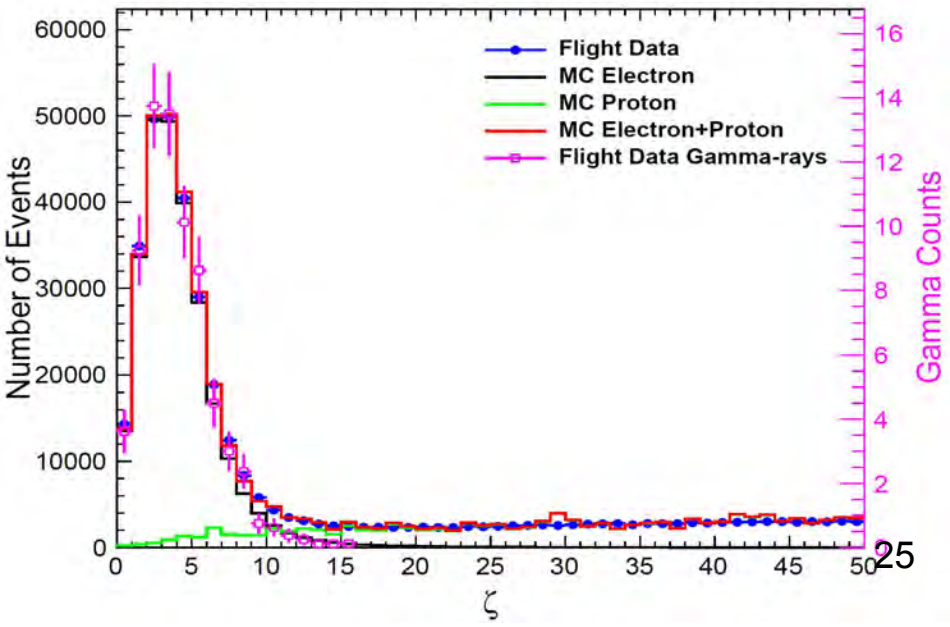
(Nature 552 (2017) 63-66)

Validation of shape parameter ζ with BT and photons



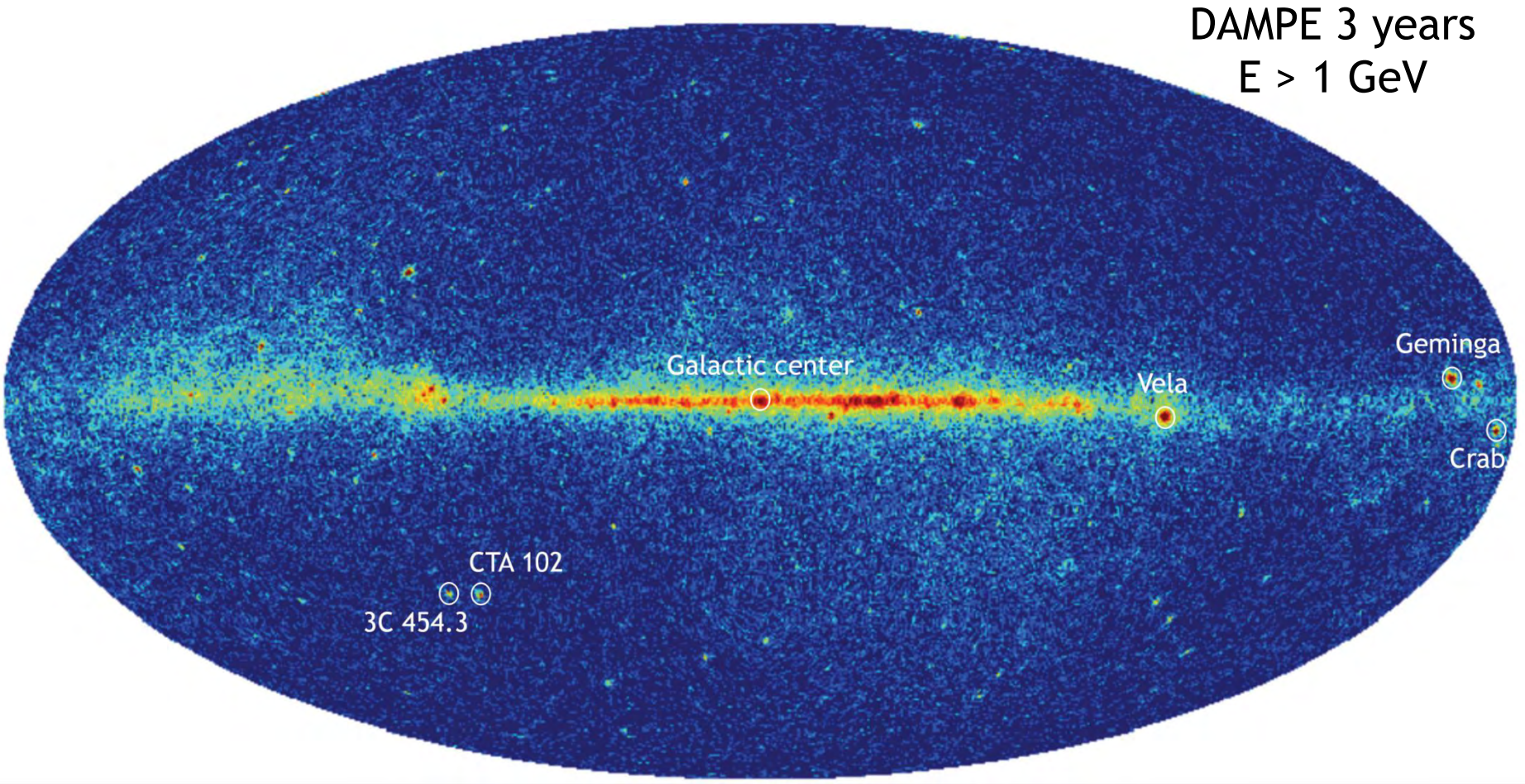




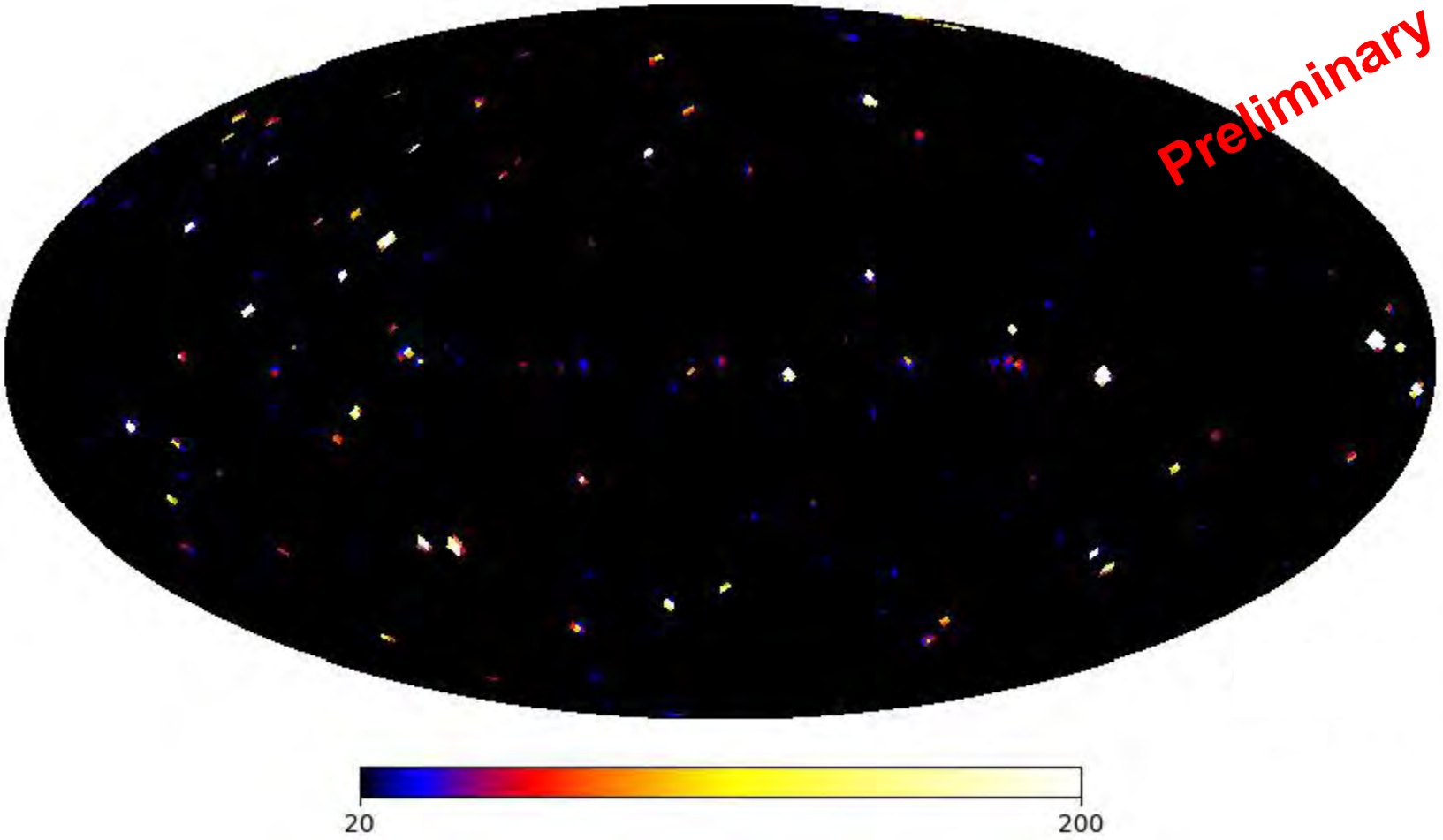


Physical results

γ-ray sky map

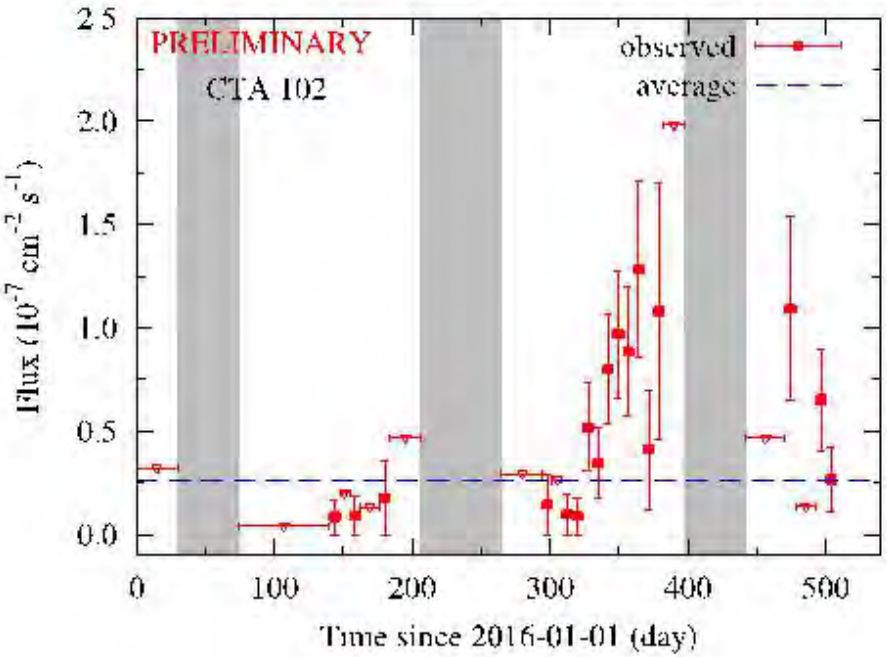

DAMPE 3 years
E > 1 GeV
Galactic center
Vela
Geminga
Crab
CTA 102
3C 454.3

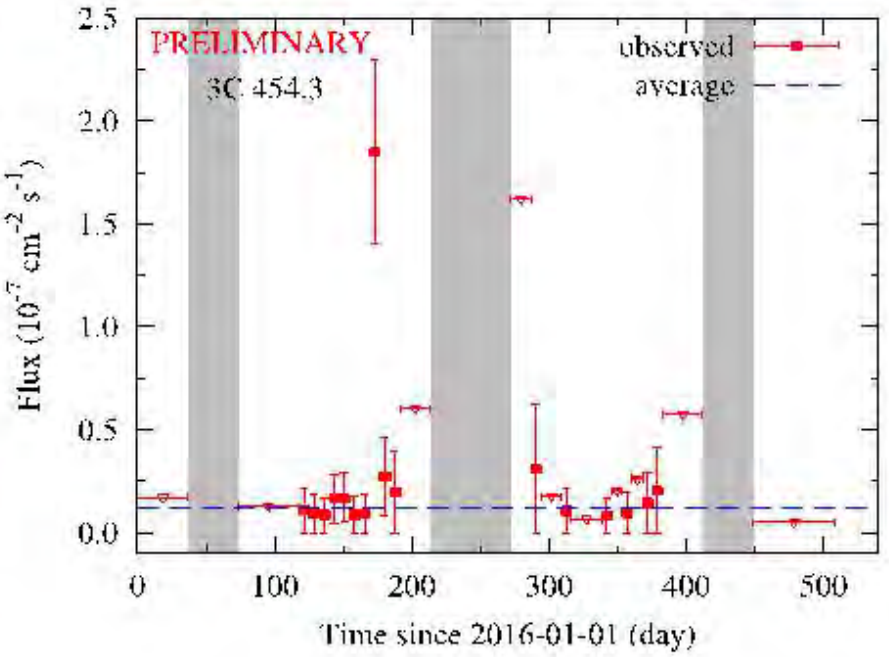
γ-ray point sources



- 143 sources with TS > 20
- Most are pulsars and AGNs

γ-ray variables

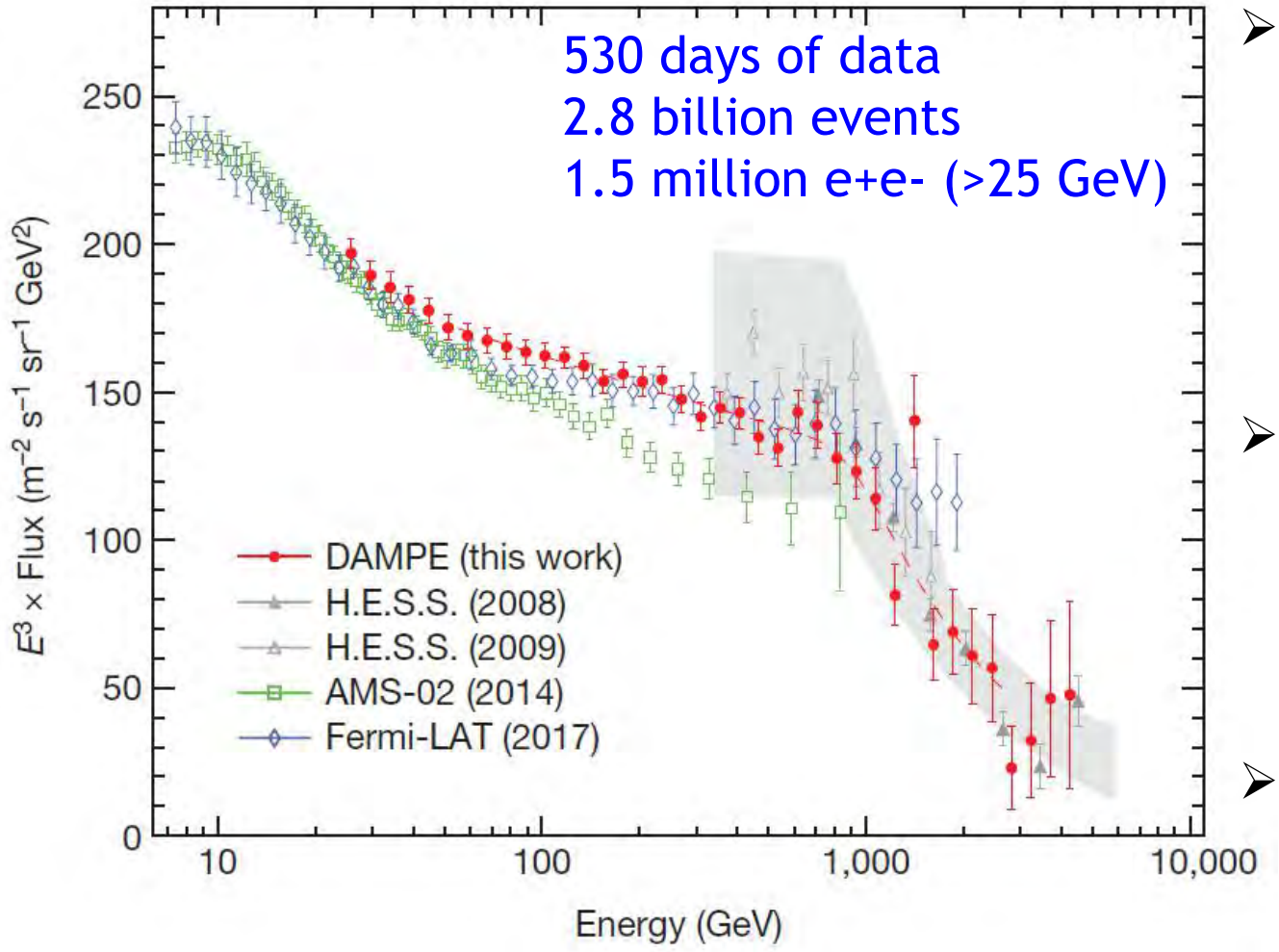




- Flares from AGNs : CTA 102 and 3C 454.3
- Coincident with other telescopes

(Yuan et al. PoS (ICRC2017) 617)

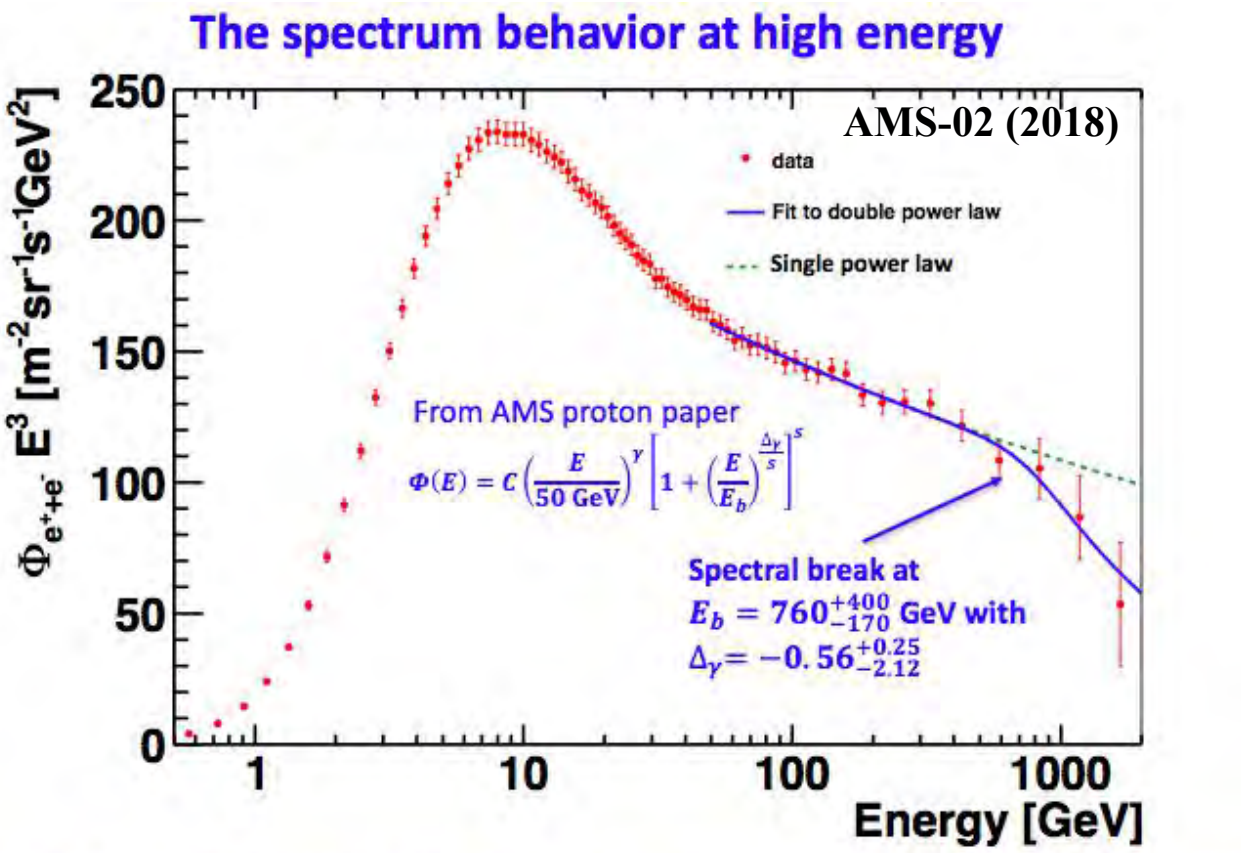
Total $e^+ + e^-$ spectrum



- Three different PID methods give very consistent results on event-by-event level
- Direct detection of a spectral break at ~1 TeV with 6.6σ confidence level
- Analysis with new data is on-going

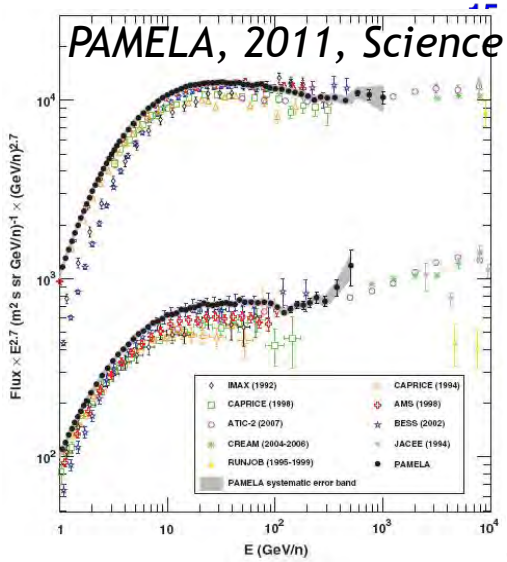
(Nature 552 (2017) 63-66)

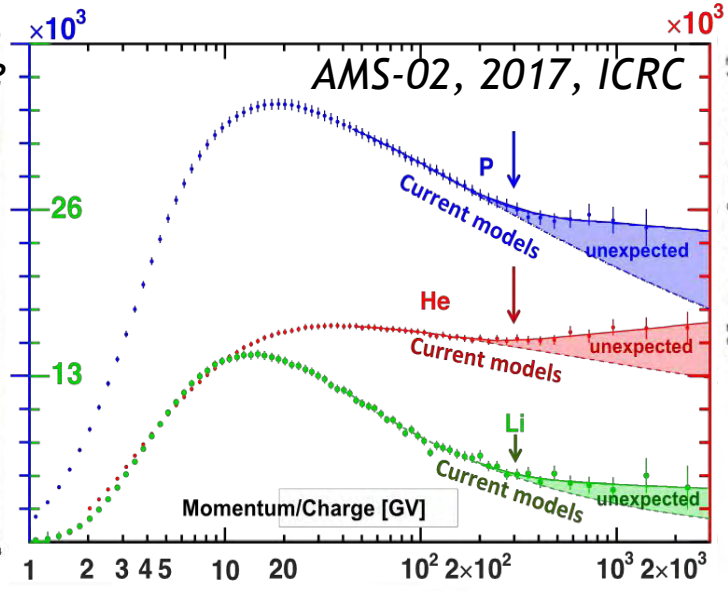
Spectral break observed by AMS-02

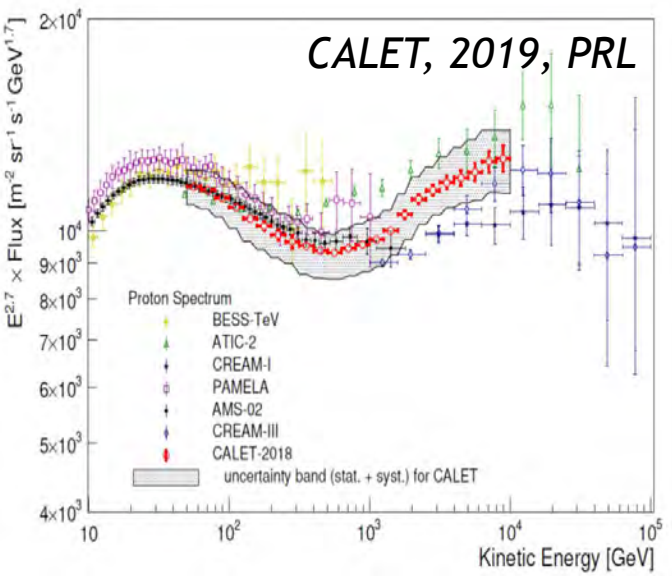


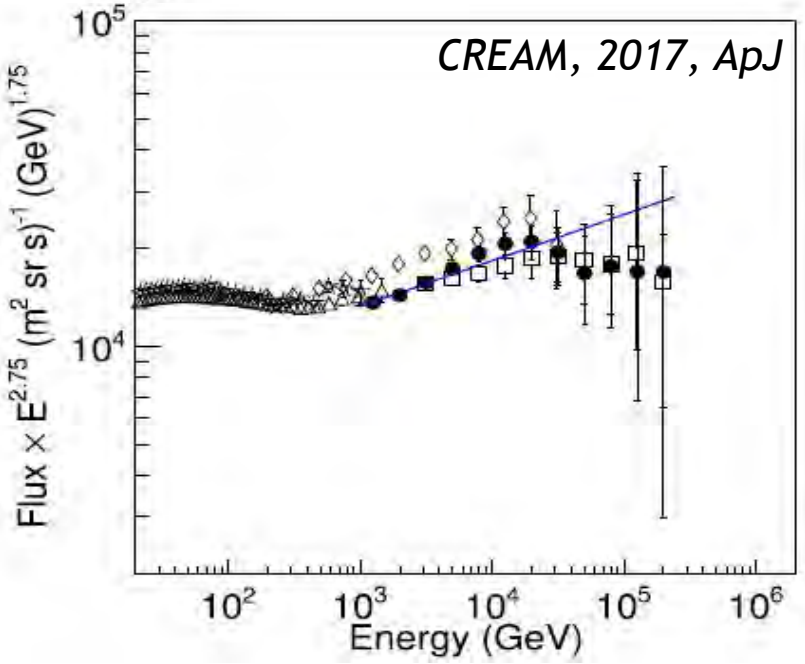
The TeV softening of the total e+e- spectrum has been well established. It may reflect the discreteness of the high-energy e+e- source distribution.

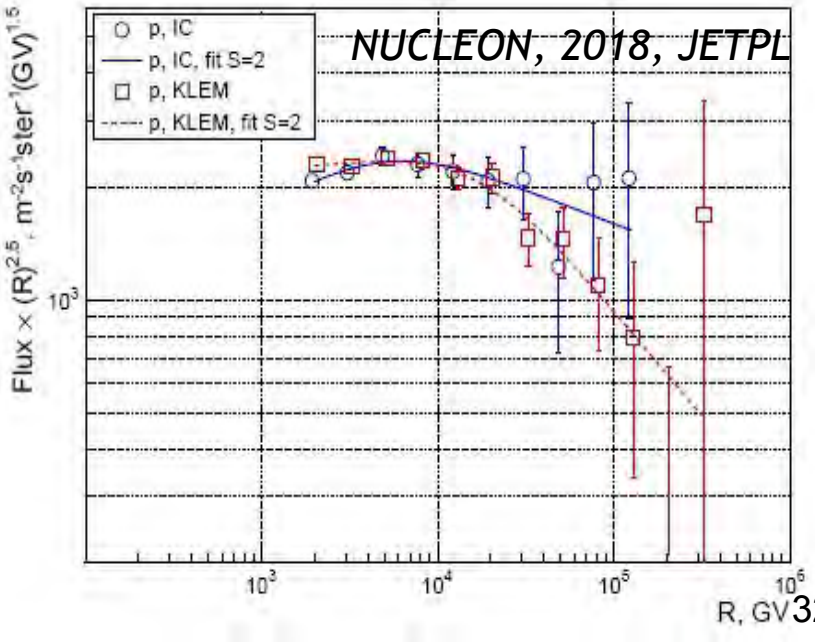
Spectral structures of nuclei



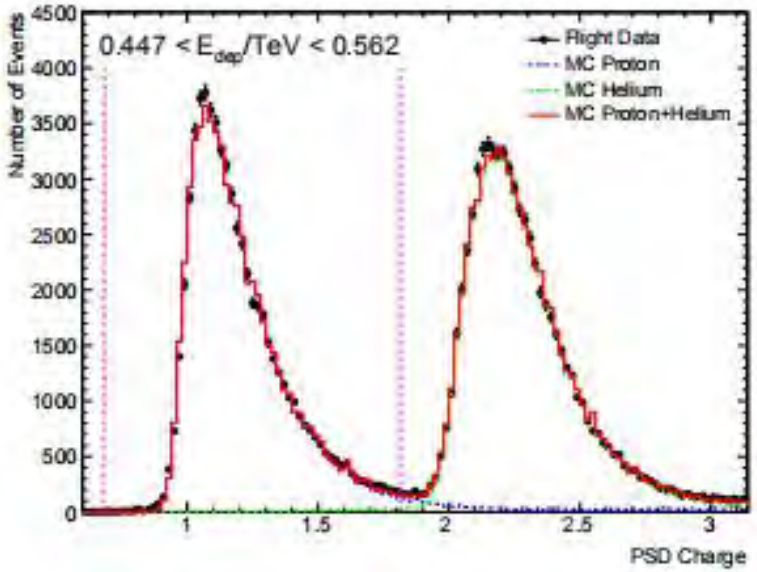


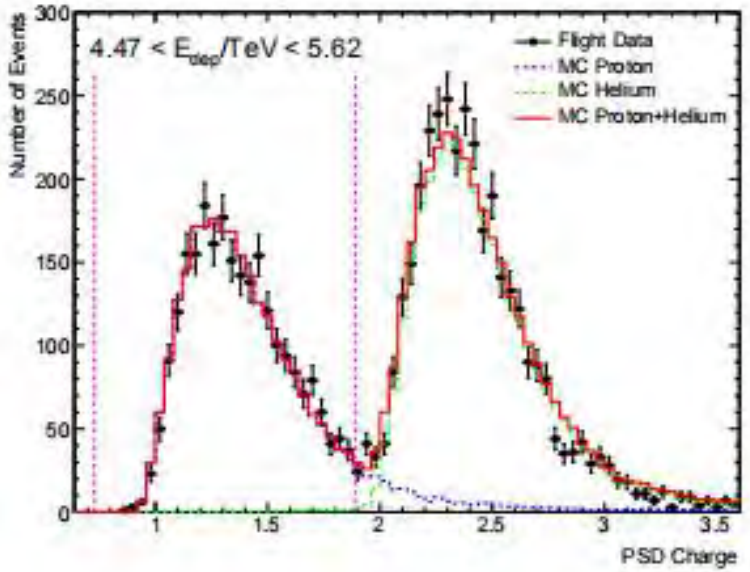






Proton spectrum by DAMPE

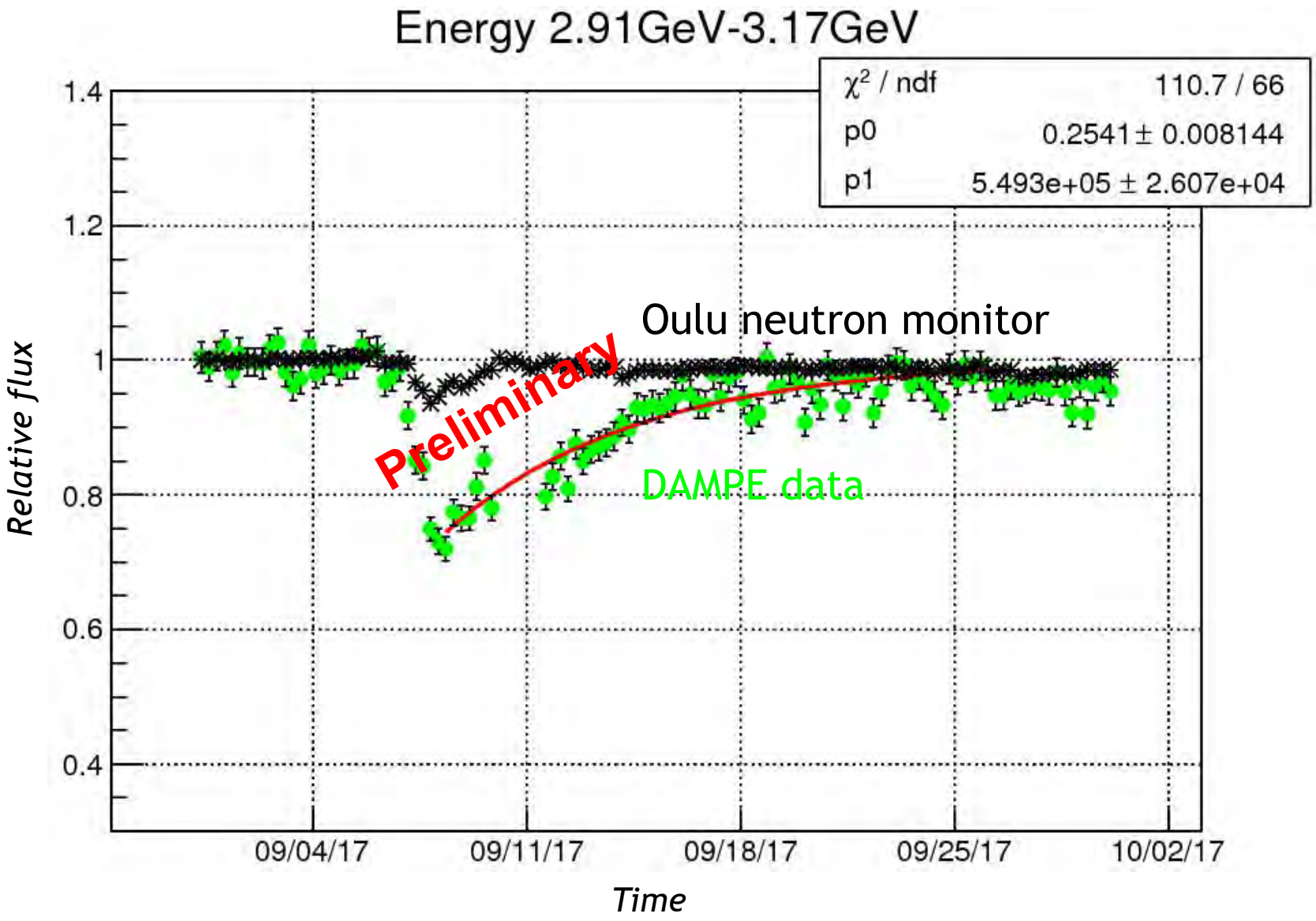




- Confirms the hundreds GeV hardening
- Detecting a softening at ~13 TeV with high significance

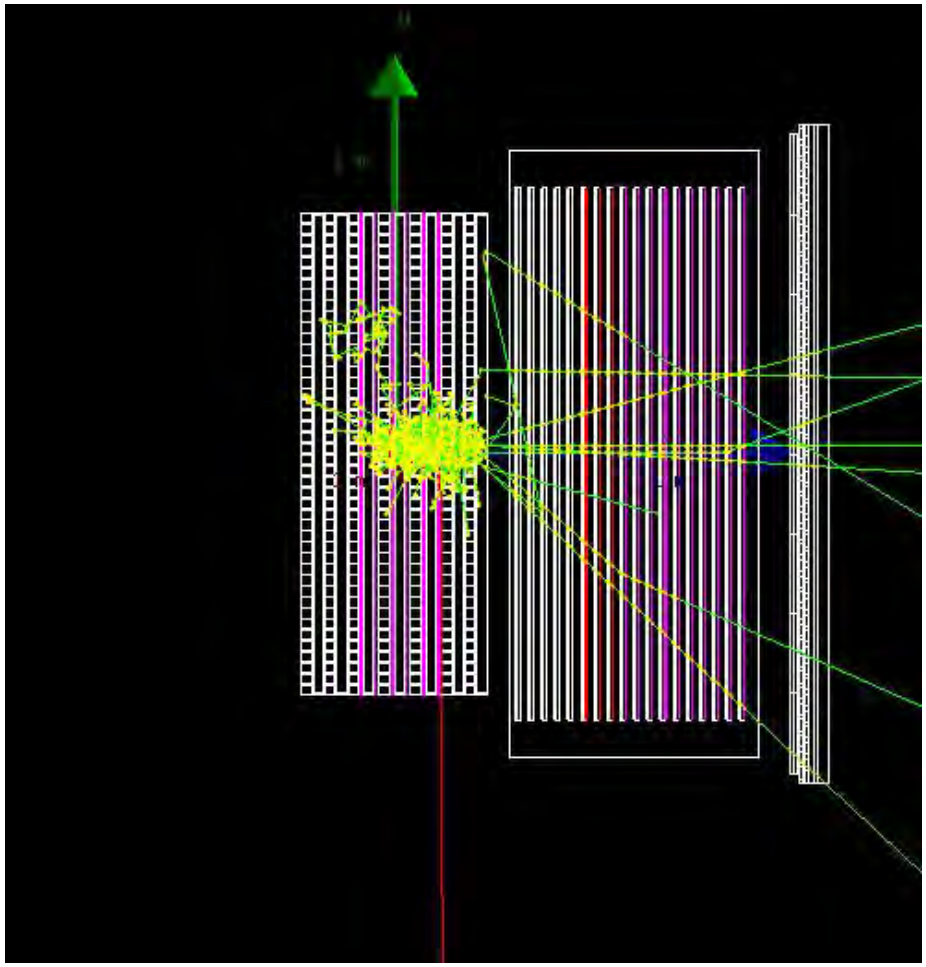
Coming soon!

Electron Forbush decrease (2017/09/06)



Possible successor of DAMPE: very large area gamma-ray space telescope (VLAST)

VLAST: designed performance



- Energy range: 0.2 GeV - 20 TeV
- Geometry factor: ~ 3 m^2sr
- Energy resolution: 1% @ 100 GeV
- Spatial resolution: 0.1° @ 100 GeV

Keep excellent performance of energy resolution and e/p separation capabilities of DAMPE, enhace substantially the gamma-ray potential

BGO(with tungsten) STK PSD

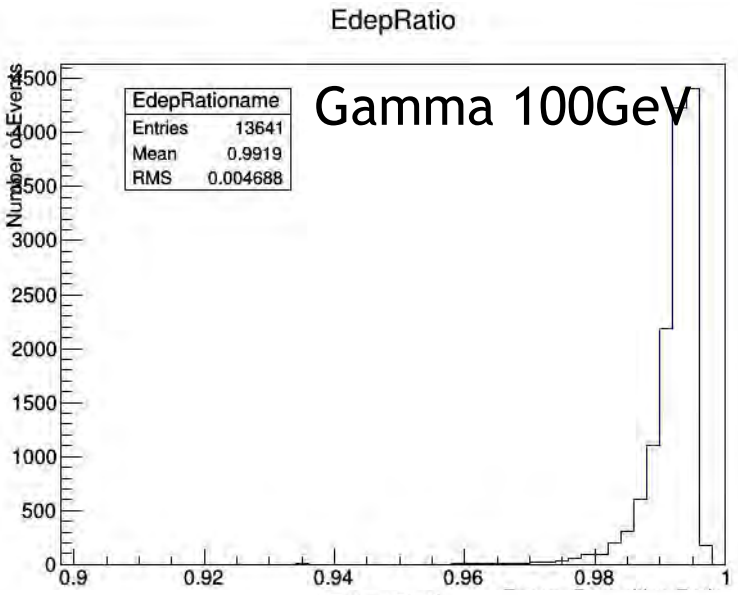
120×120 cm^2 133×133 cm^2 165×165 cm^2

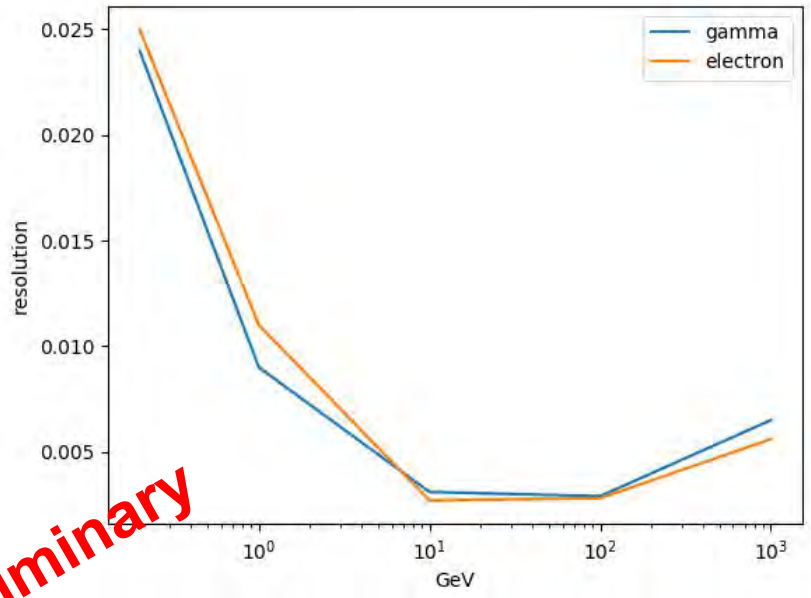
VLAST: scientific goals

- Dark matter indirect detection
- High-energy time-domain astrophysics
- Cosmic ray origin, acceleration, and propagation
- Cosmology and fundamental physics

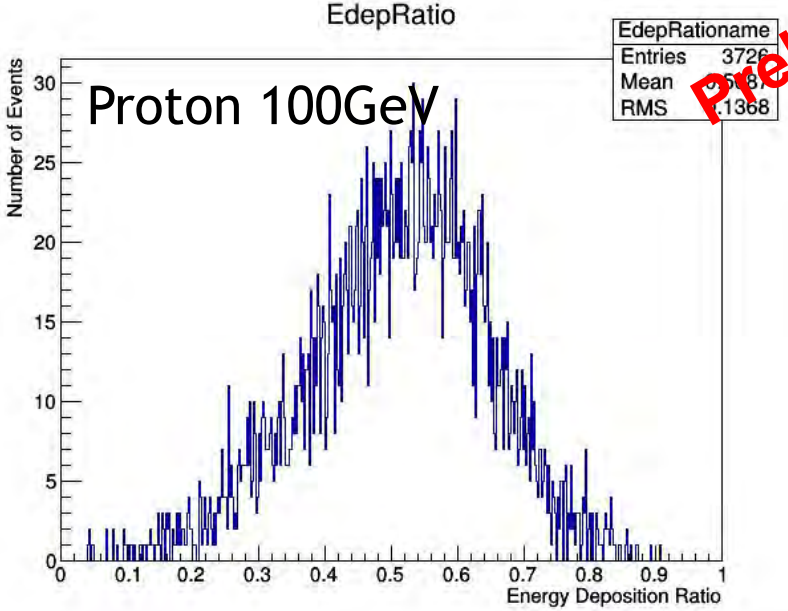
We want (need) a larger detector with (in particular) better performance for gamma-ray observations to study quite a lot of important, interesting problems in physics and astrophysics

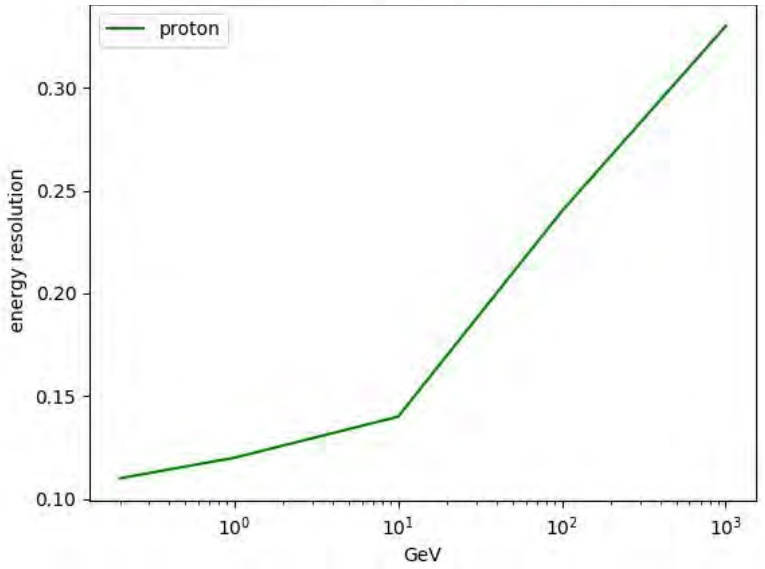
VLAST: preliminary simulation



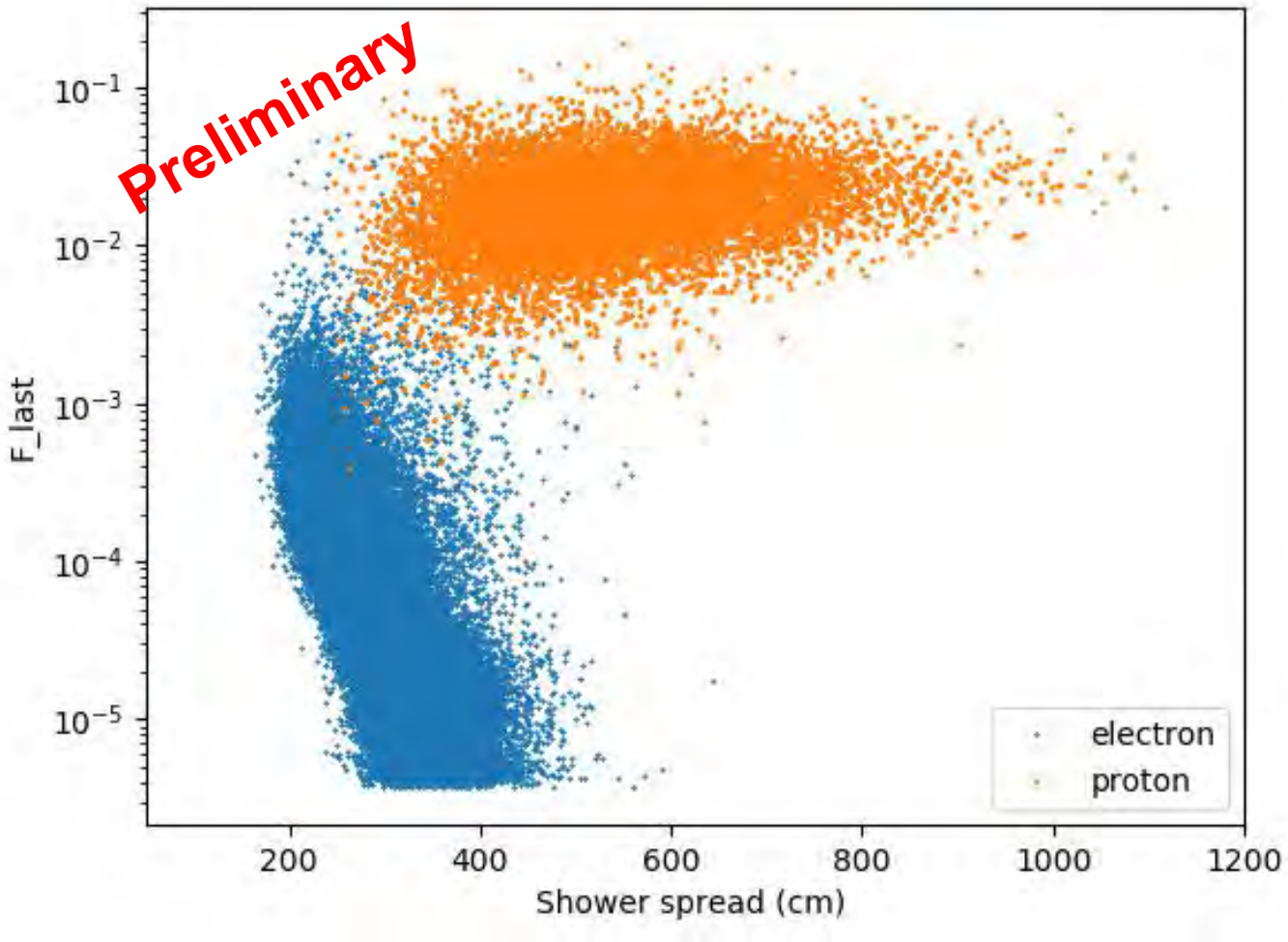


Preliminary





VLAST: preliminary simulation



Proton rejection by > 99.99% (for 90% electron eff.) at 500 GeV

Summary

- DAMPE detector is working extremely well since launch
- Very precise measurements of the $e^+ + e^-$ spectrum from 25 GeV to 4.6 TeV have been obtained, showing a spectral break at ~TeV energies and possible new spectral features
- Precise measurements of proton spectrum from 40 GeV to 100 TeV have been obtained, revealing interesting features at ~10 TeV
- More results are coming

Thank You!