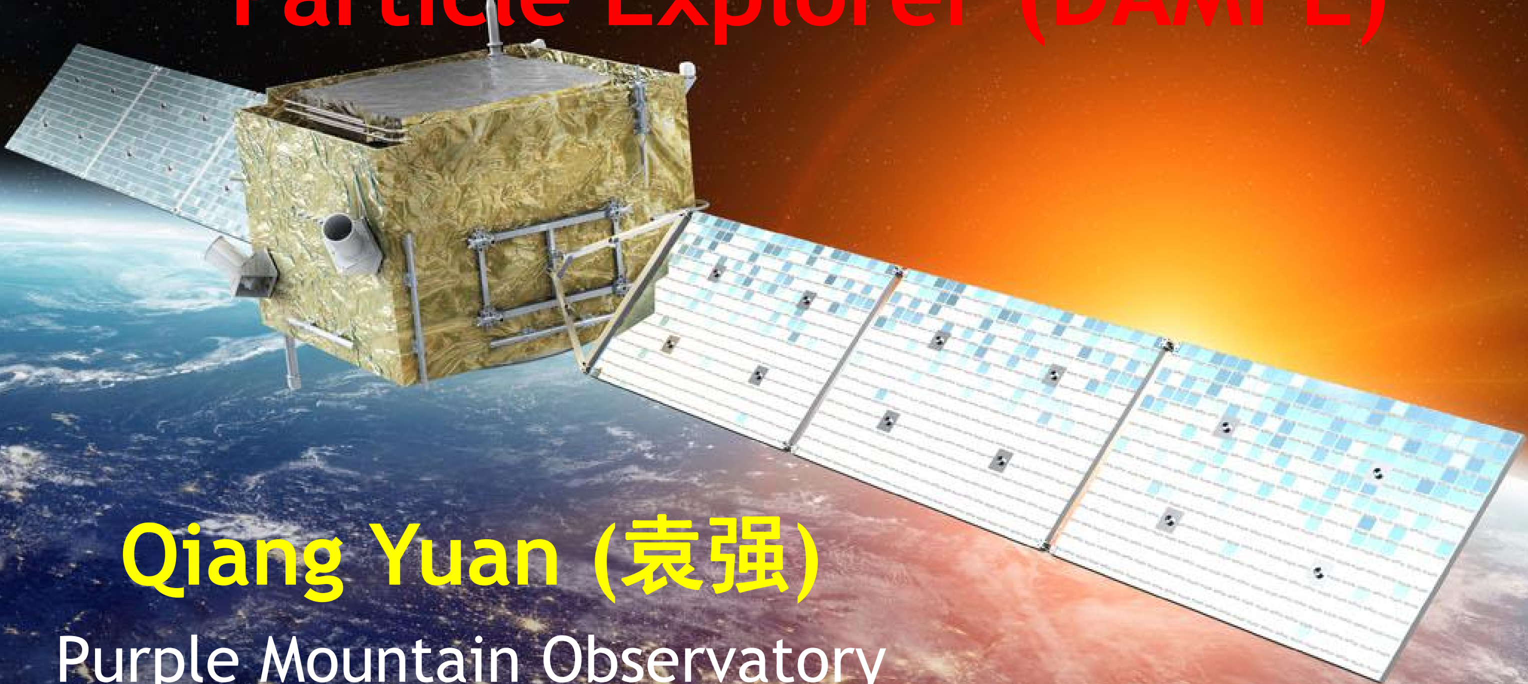
中国科学院暗物质与空间天文重点实验室

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)

SYSU, Guangzhou, Jan. 21, 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

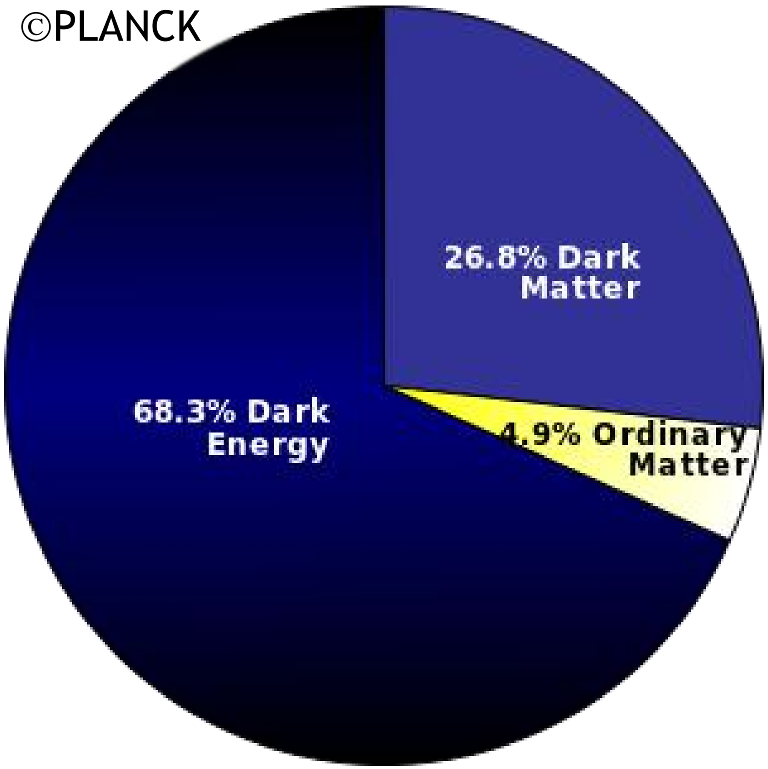
- ITALY
  - INFN Perugia and University of Perugia
  - INFN Bari and University of Bari
  - INFN Lecce and University of Salento
  - INFN LNGS and GSSI

- SWITZERLAND
  - University of Geneva

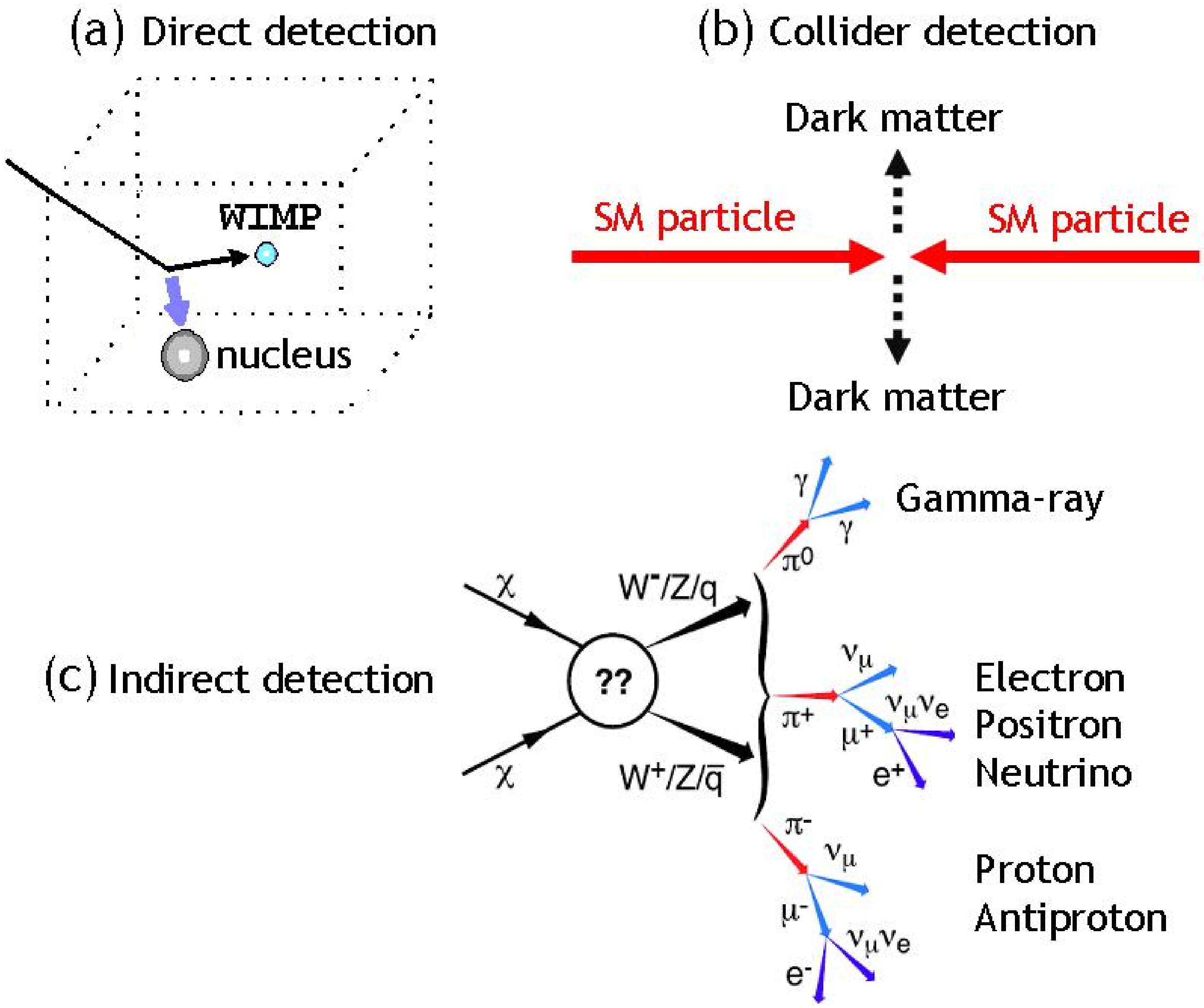
Outline

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

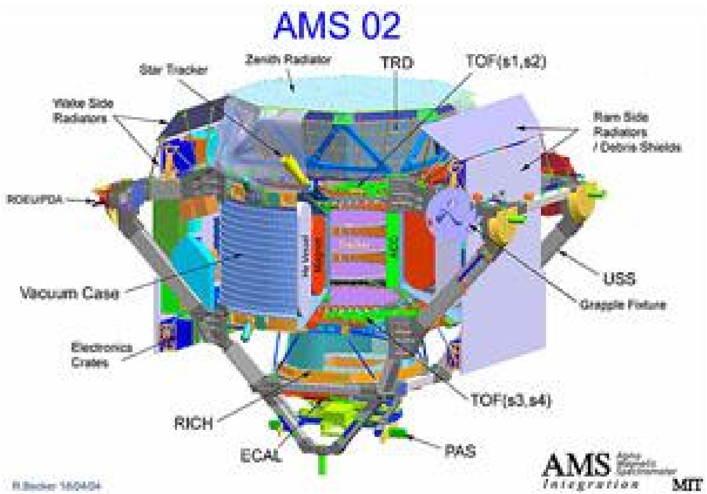
Composition of the Universe



Detection of dark matter particles

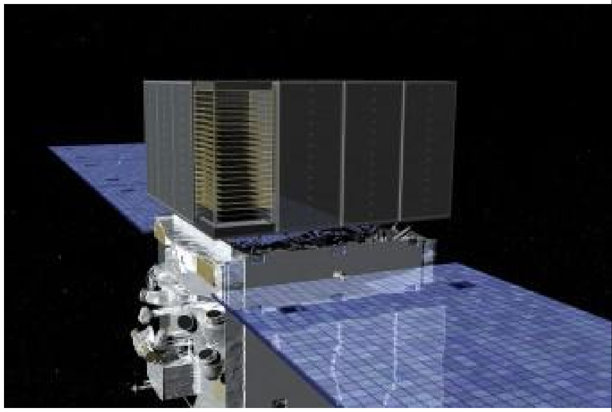


Dark matter indirect detection experiments

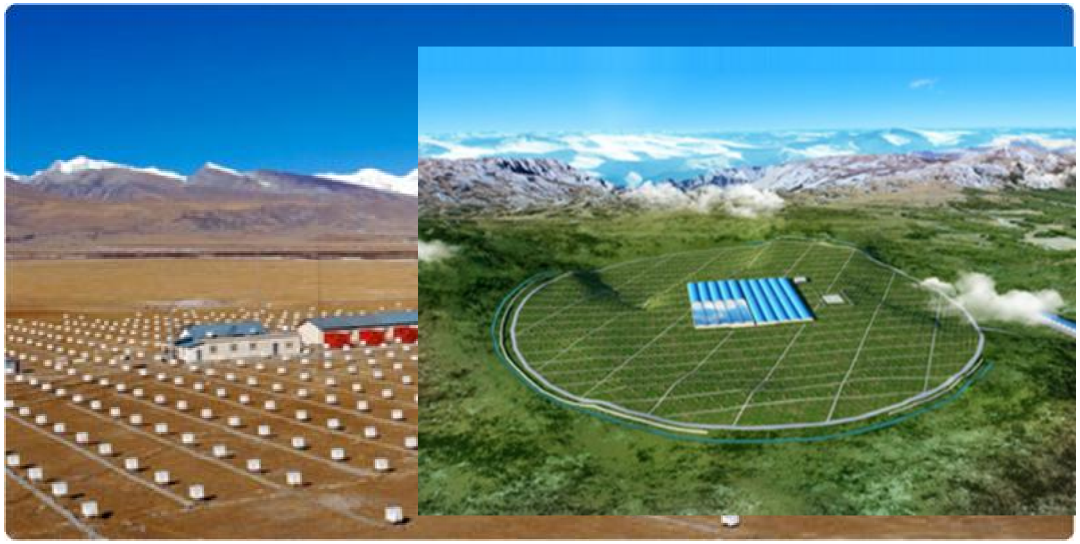


CALET

Fermi



Yangbajing/LHAASO



HESS/MAGIC/VERITAS

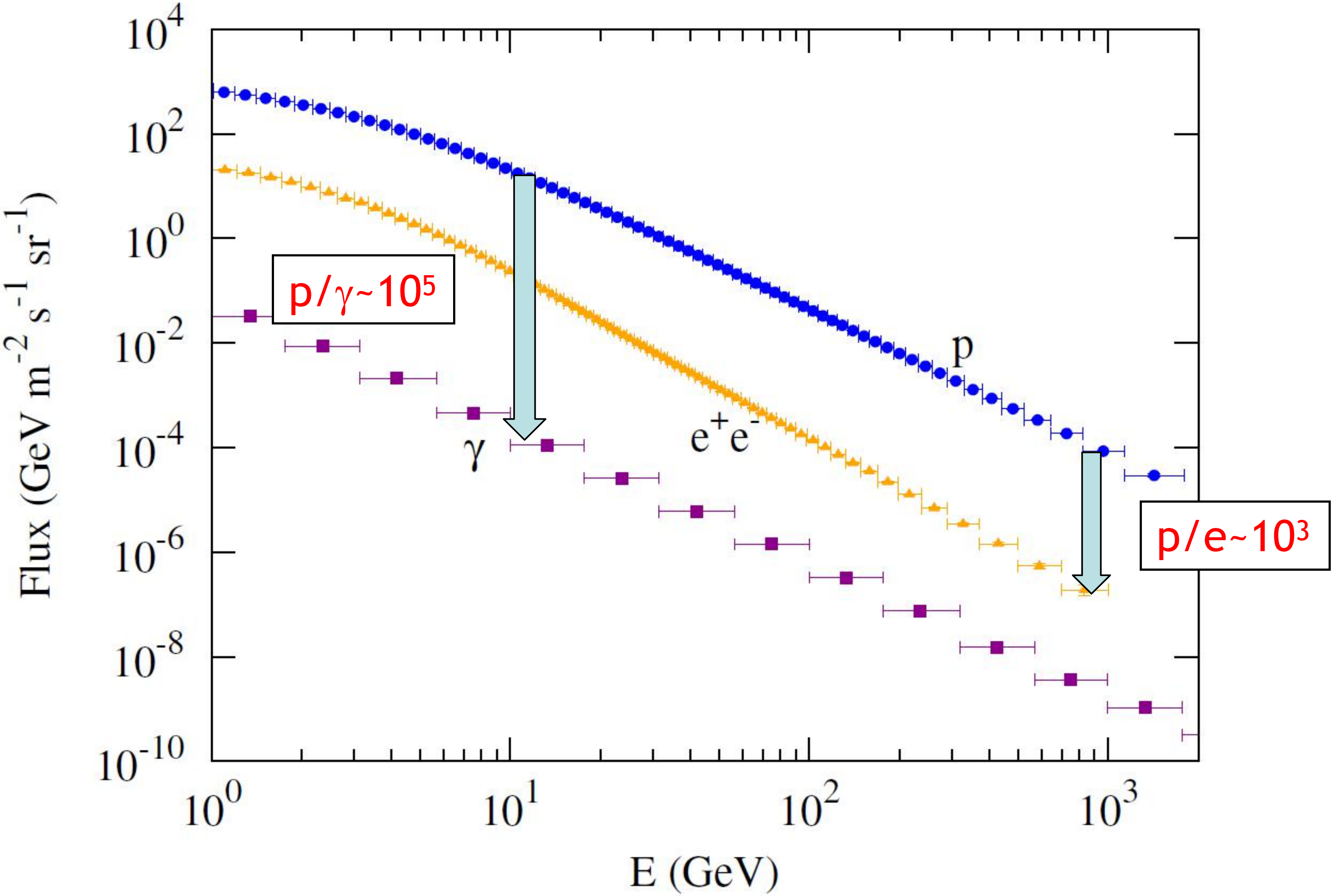
Dark Matter Particle Explorer

Cosmic ray origin & propagation

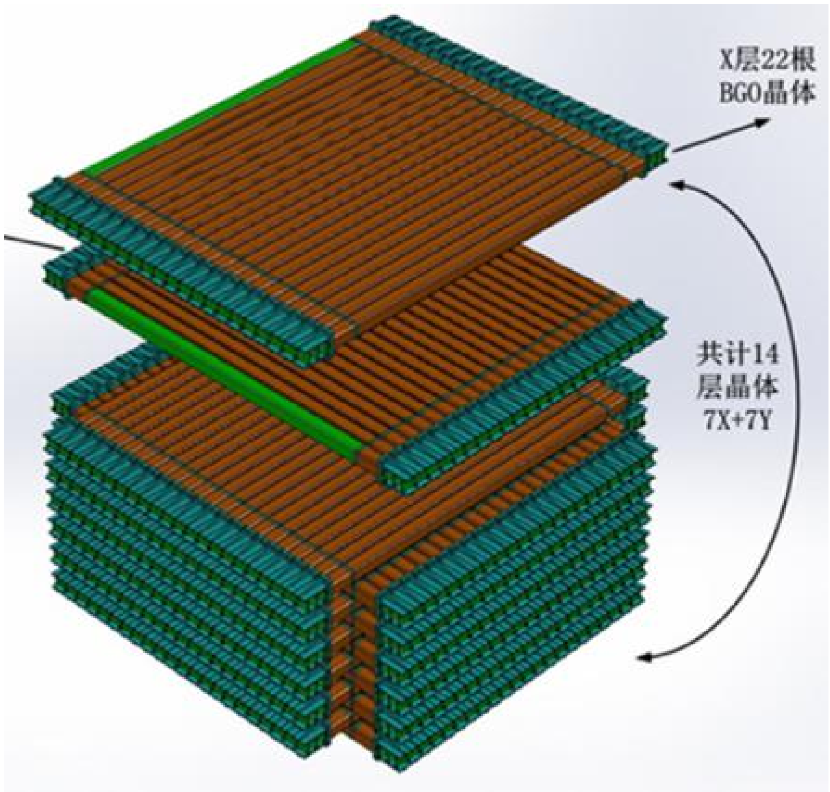
Gamma-ray astronomy

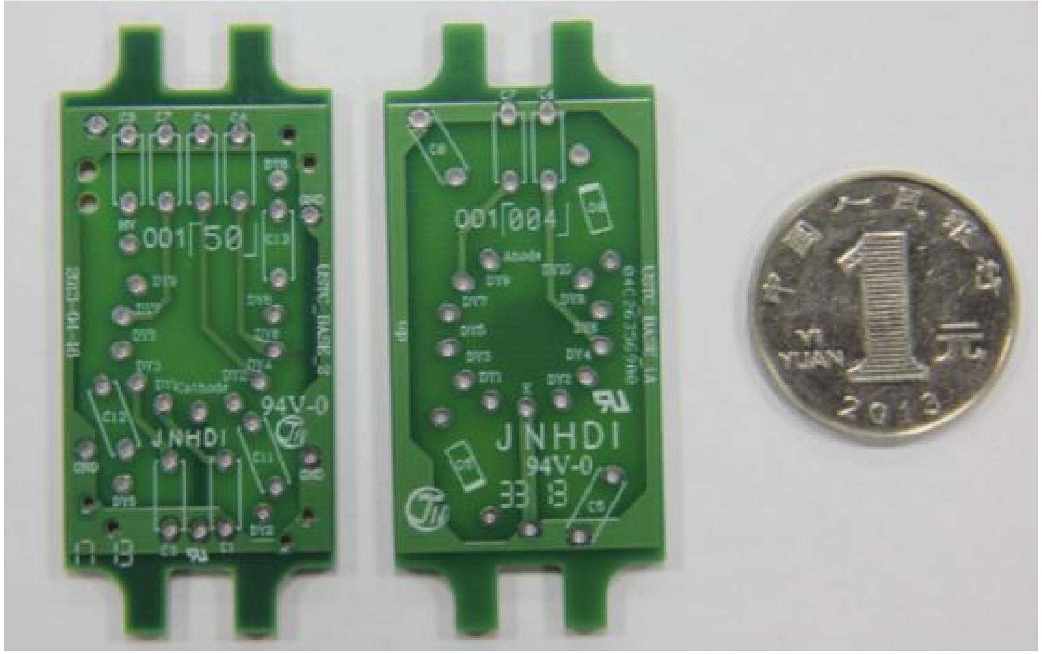
Indirect detection of dark matter particles

Challenge 1: Particle identification



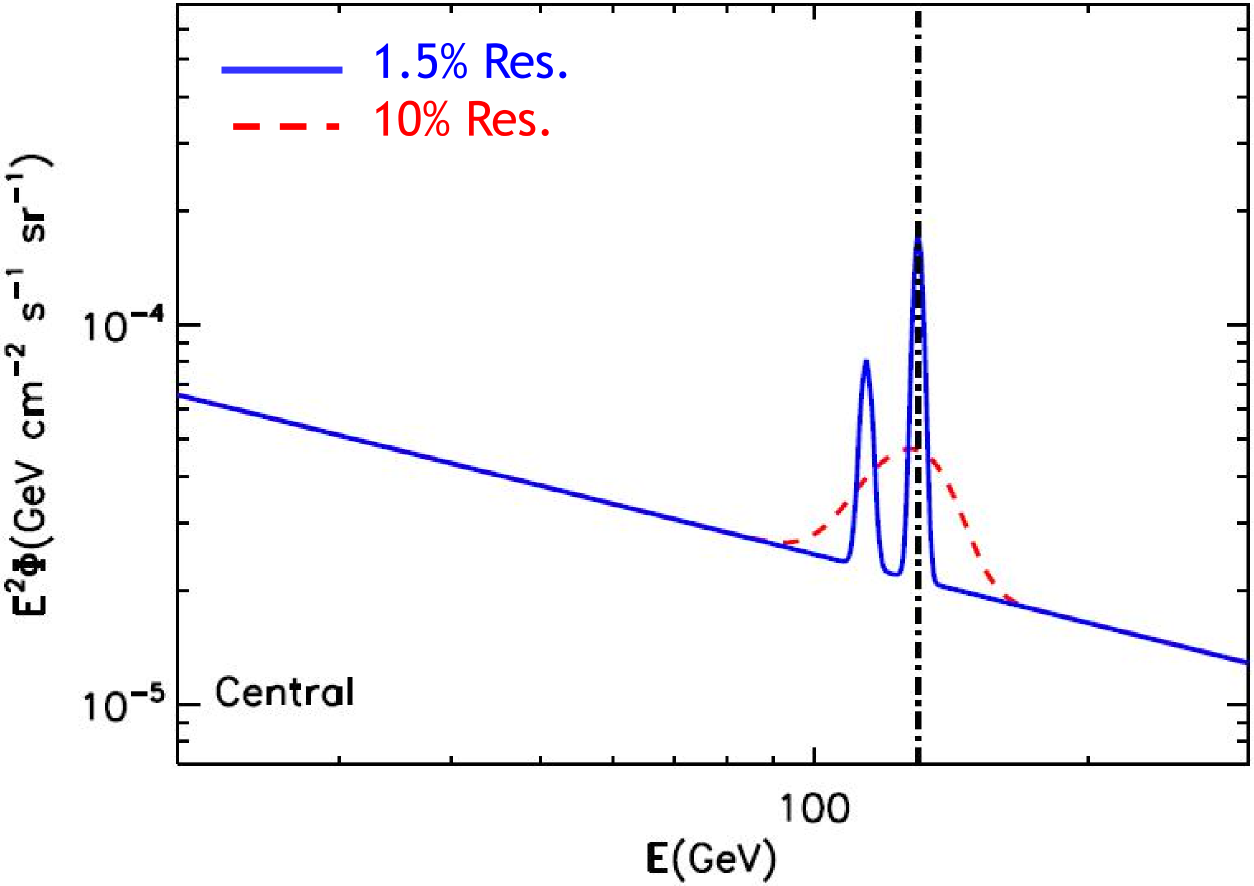
Challenge 2: large dynamic range





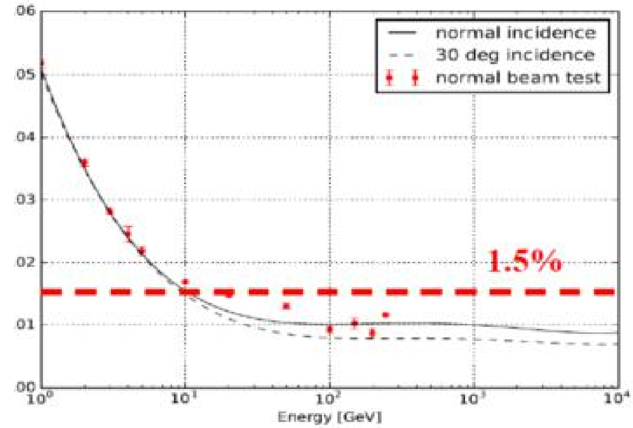
To observe electrons/photon from GeV-10 TeV, the required dynamic range of single bar is MeV-TeVs (10^6)

Challenge 3: energy resolution



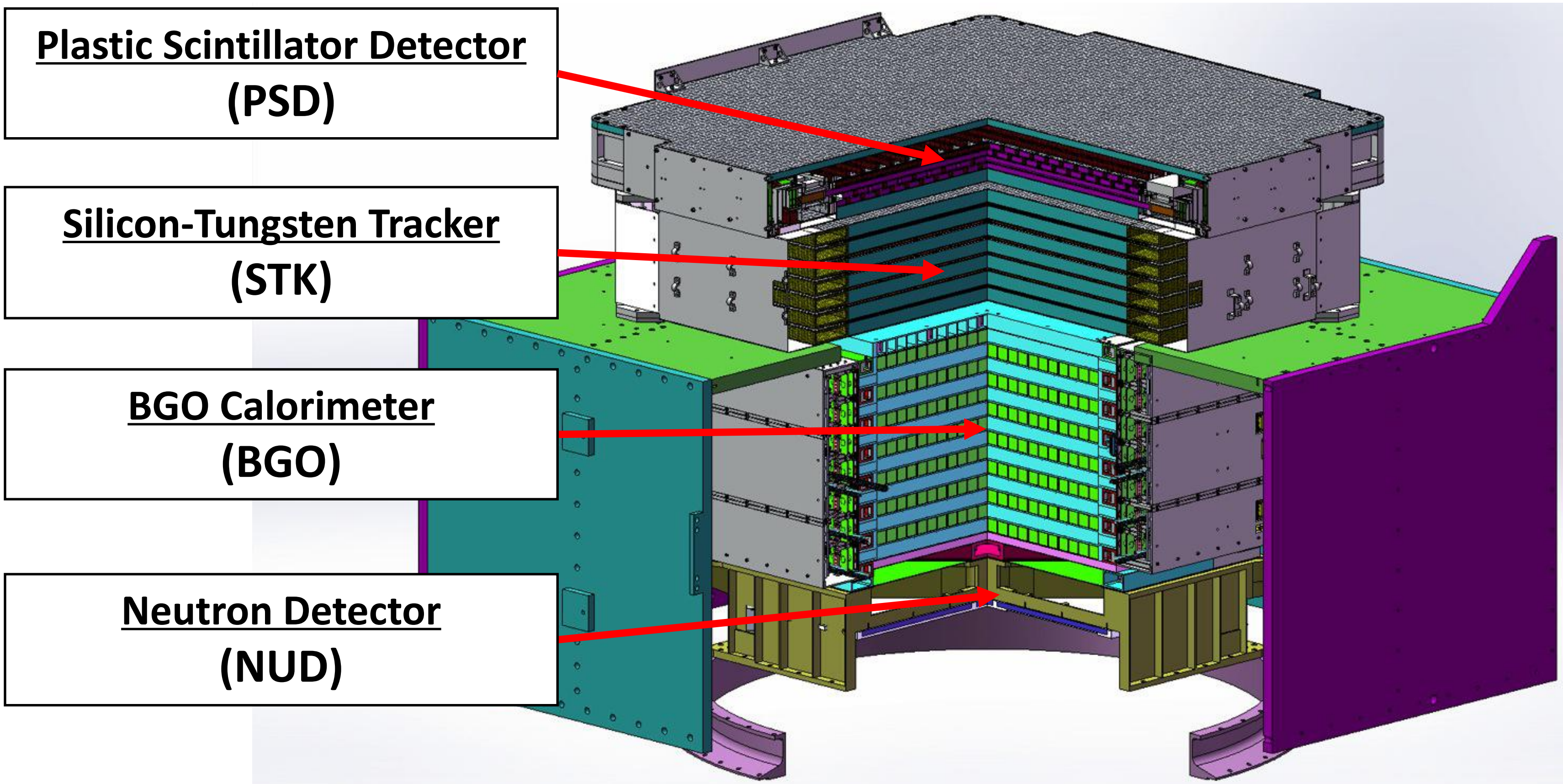
(Phys. Lett. B 715 (2012) 35)

Thick calorimeter with 32 X0 enables an energy resolution of <1.5% for e/γ



DAMPE instrument

Instrument Design

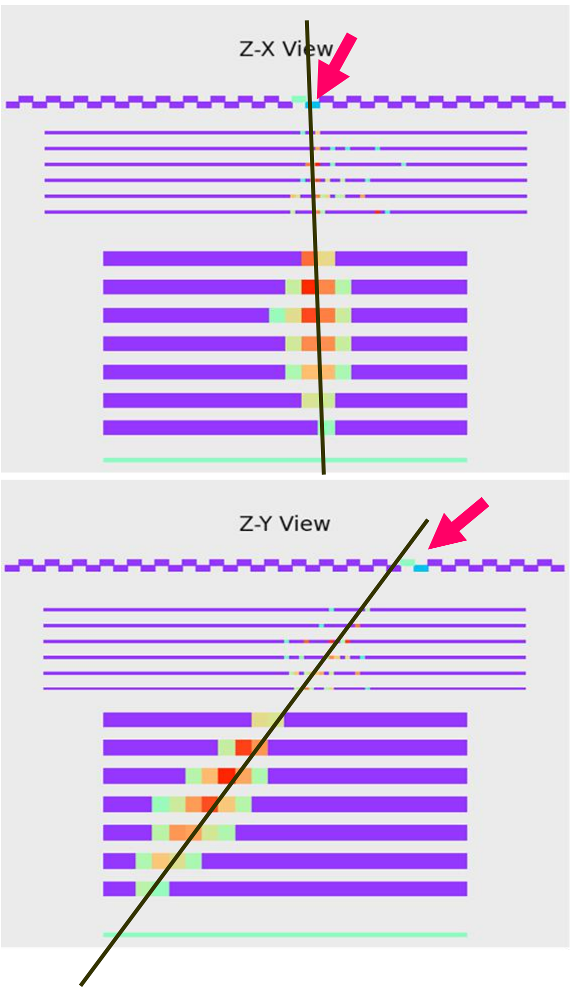


- PSD: charge measuresument via dE/dx and ACD for photons
- STK: track, charge, and photon converter
- BGO: energy measurement, particle (e-p) identification
- NUD: Particle identification

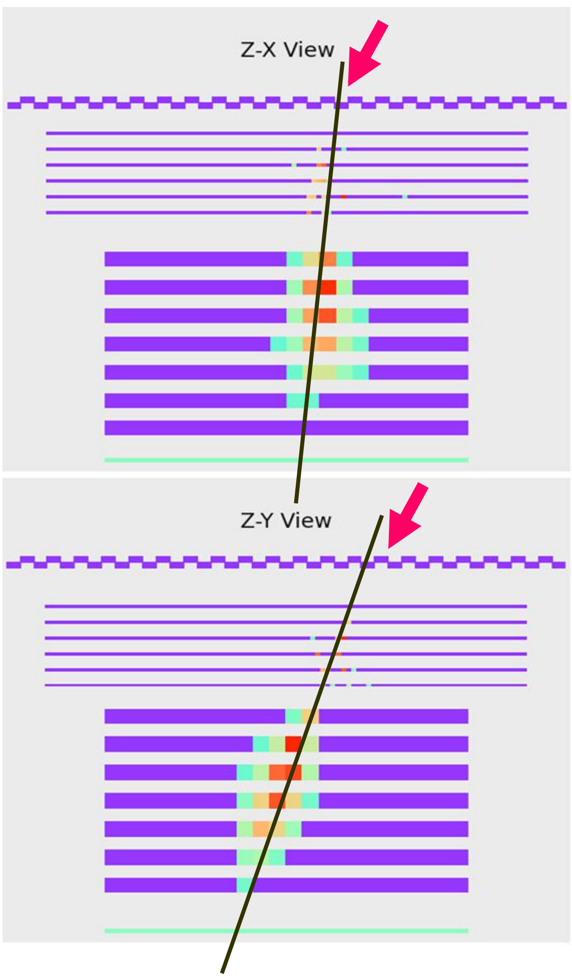
(Astropart.Phys. 95 (2017) 6–24)

Particle identification

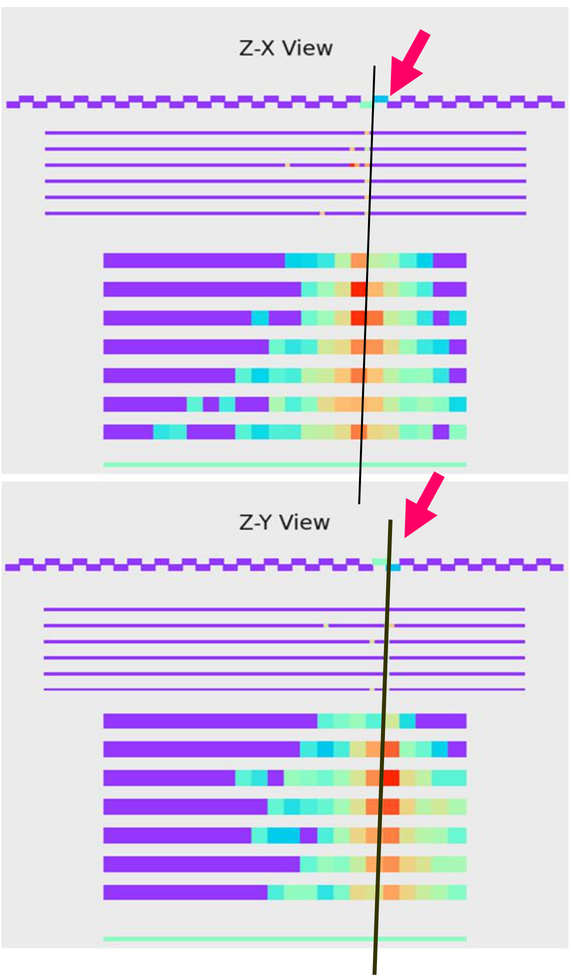
electron



gamma

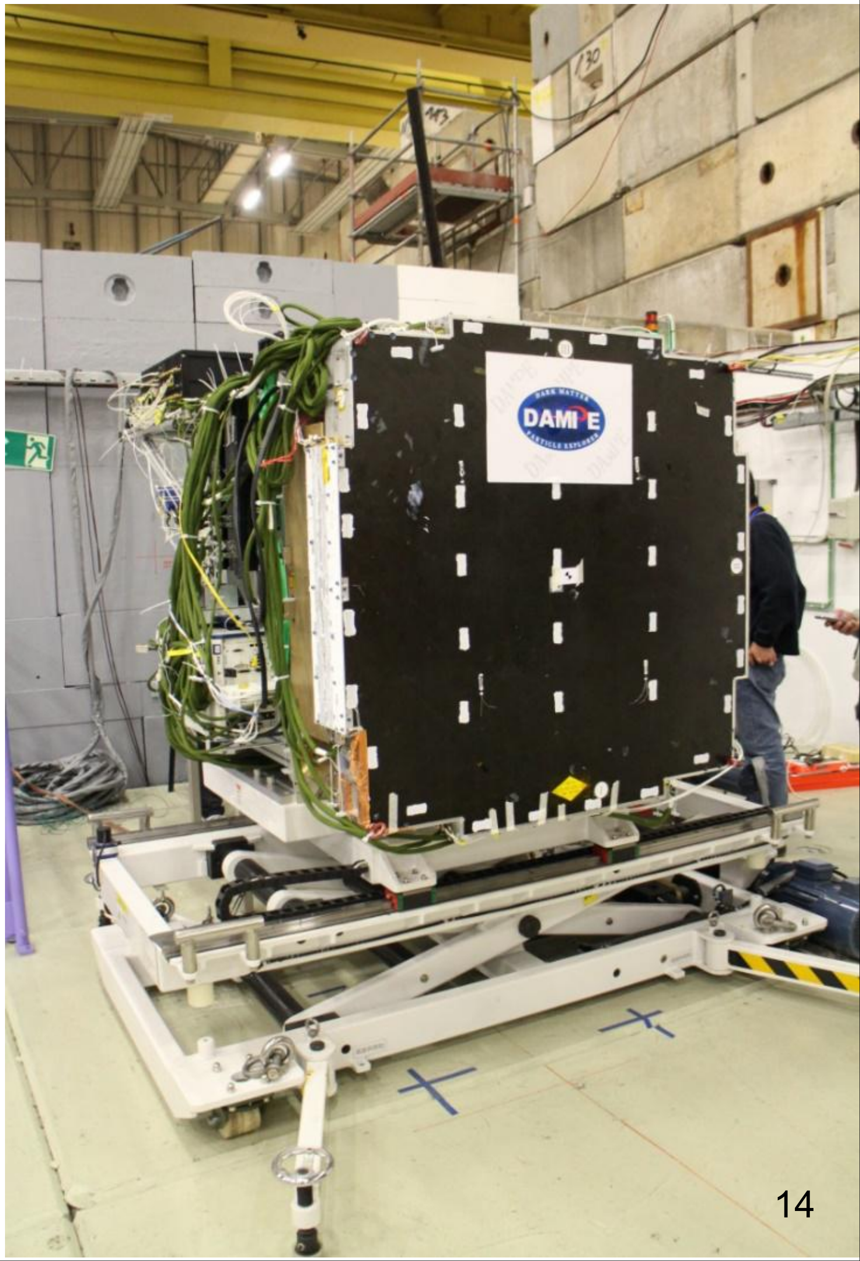


proton

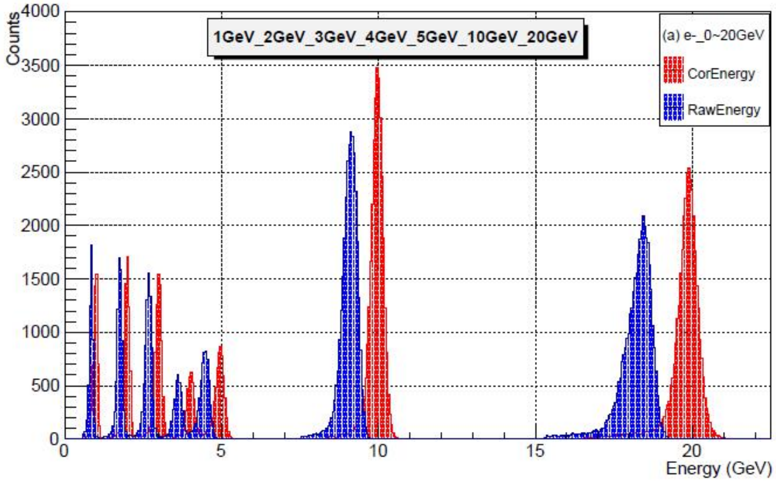


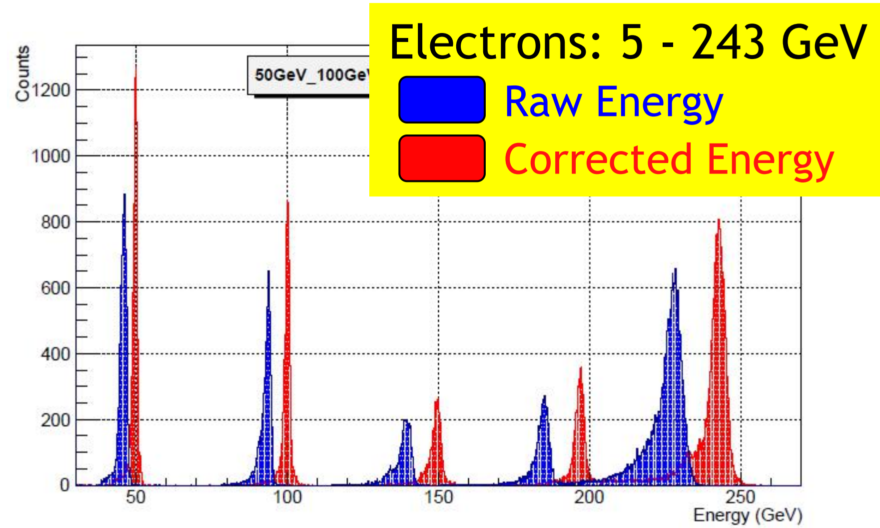
Beam test @ CERN

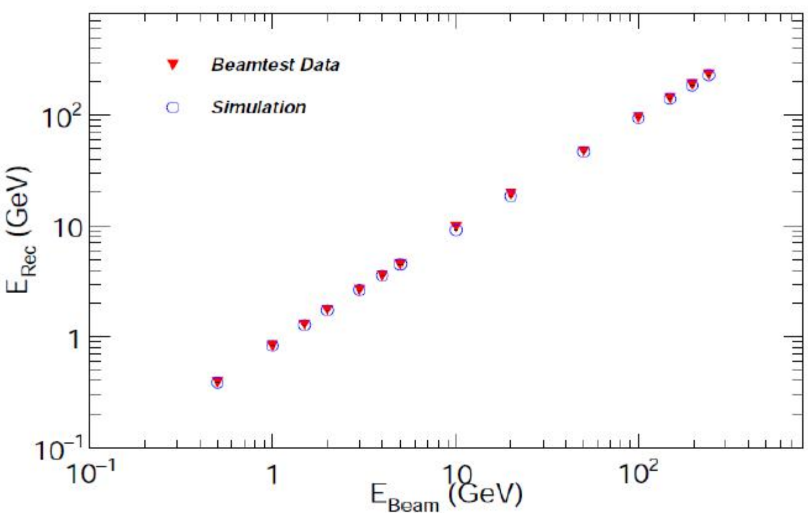
- **14 days@PS**，29/10-11/11 2014
  - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
  - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
  - π-@ 3GeV/c, 10GeV/c
  - γ @ 0.5-3GeV/c
- **8 days@SPS**，12/11-19/11 2014
  - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
  - 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)

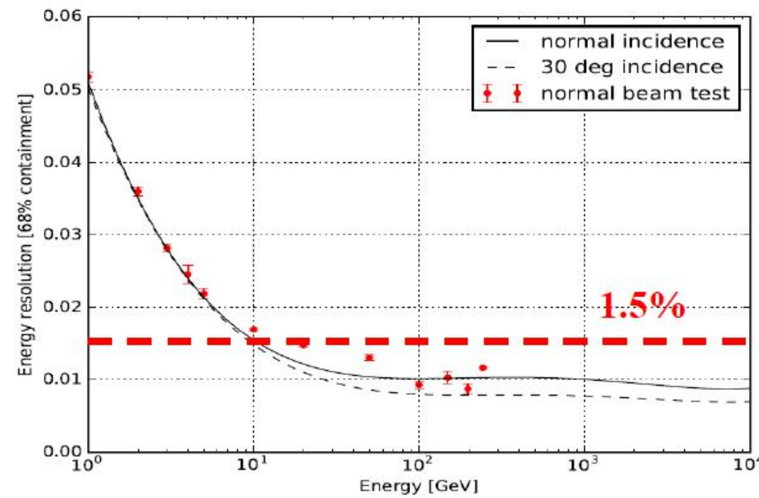


Beam test @ CERN









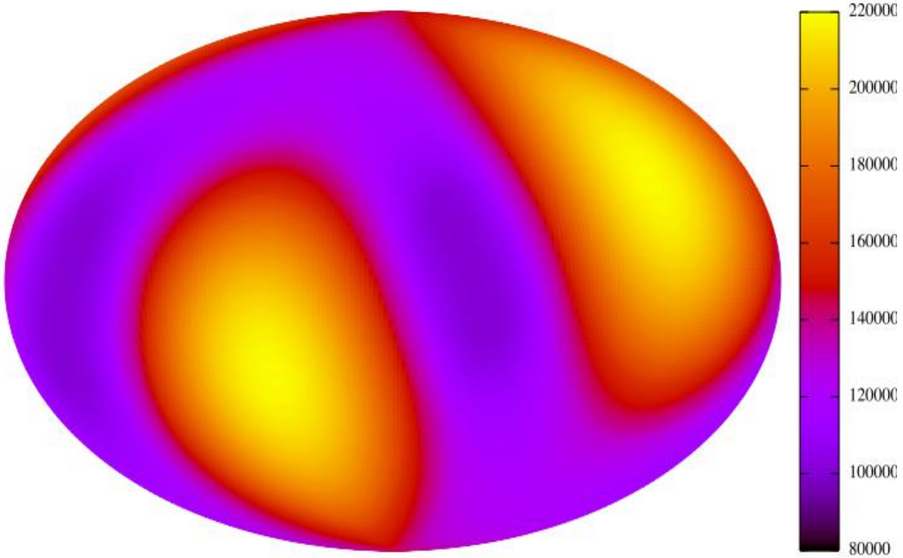
(Astropart.Phys. 95 (2017) 6–24)

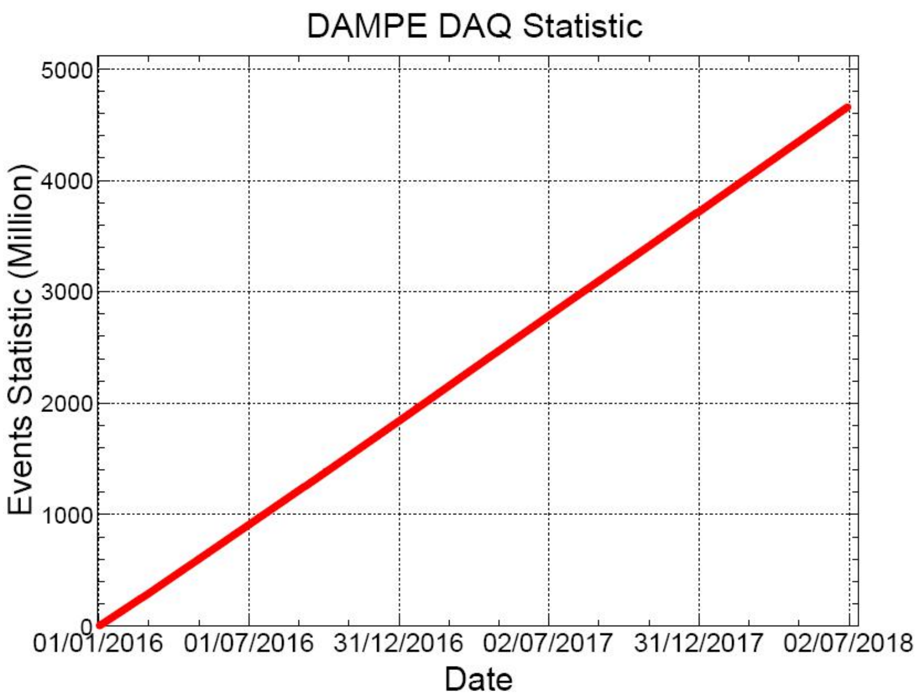
Launch on 17th Dec. 2015

On-orbit performance

Observation overview

DAMPE 3 year counts map

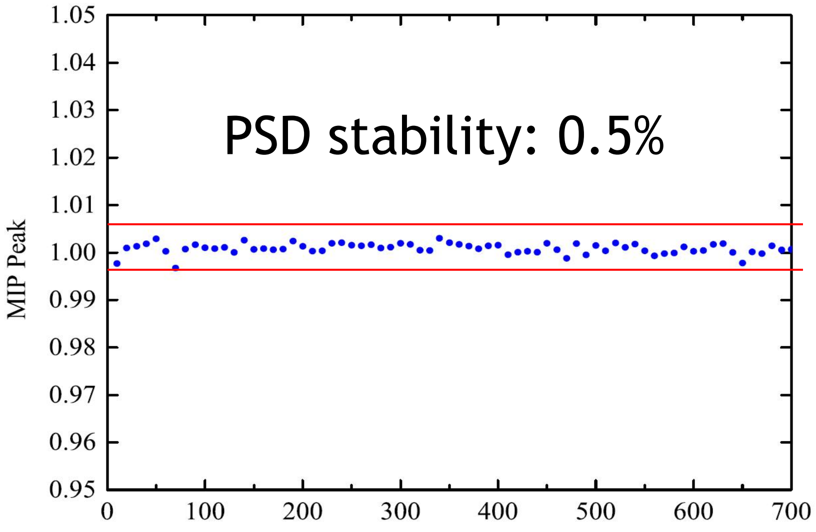




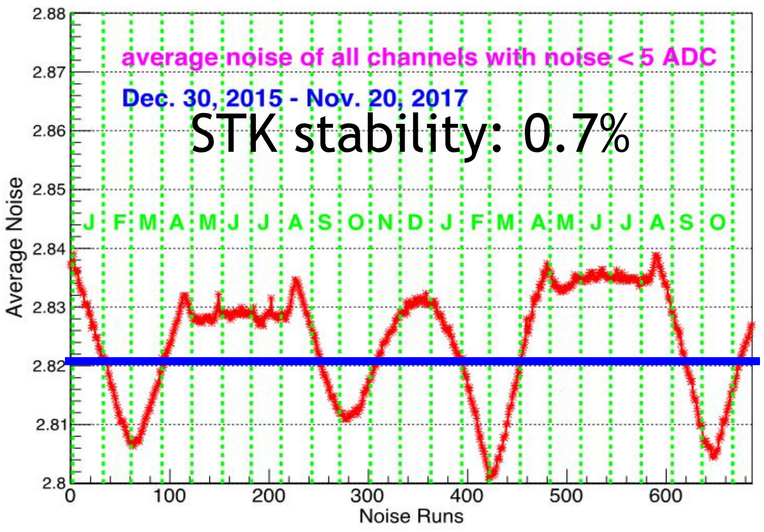
6 full scans of the sky

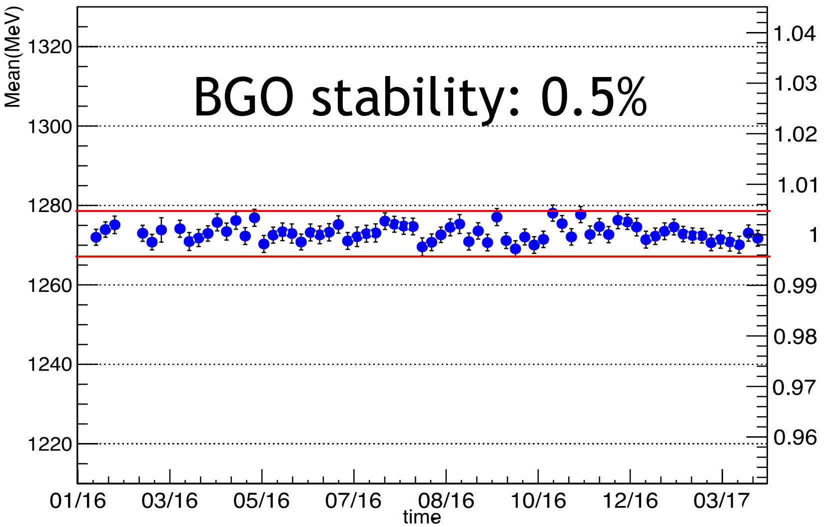
5M events/day
5.7 billion in total

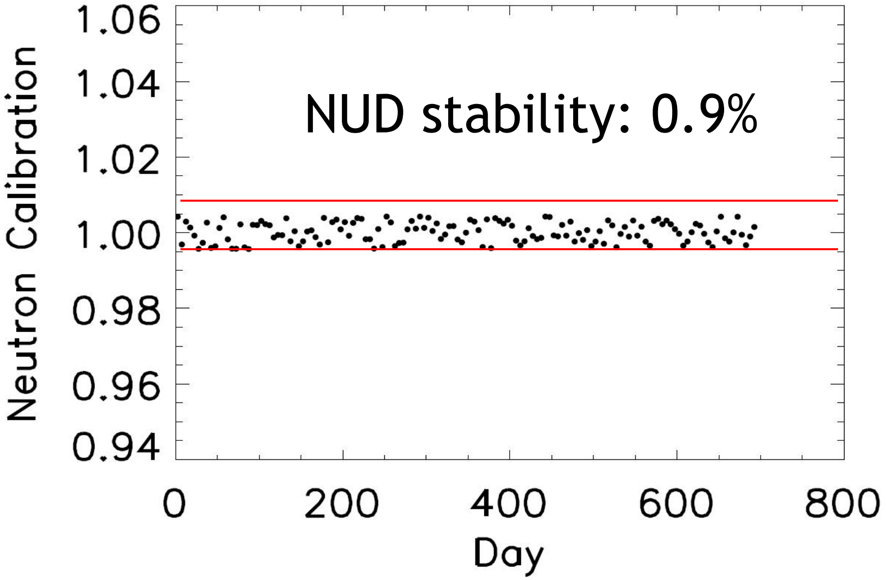
Detector stability



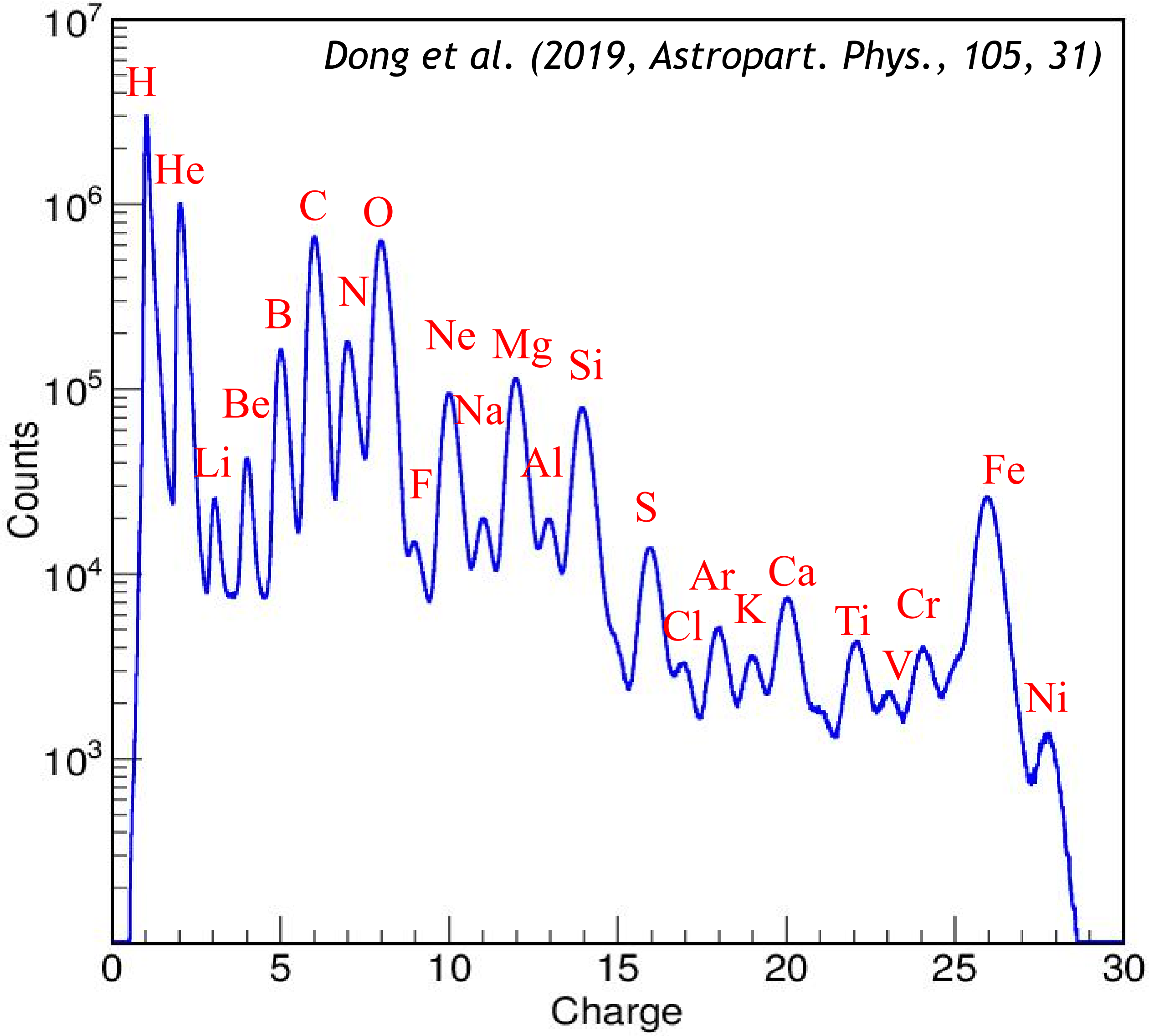
Stability of Helium MIPs





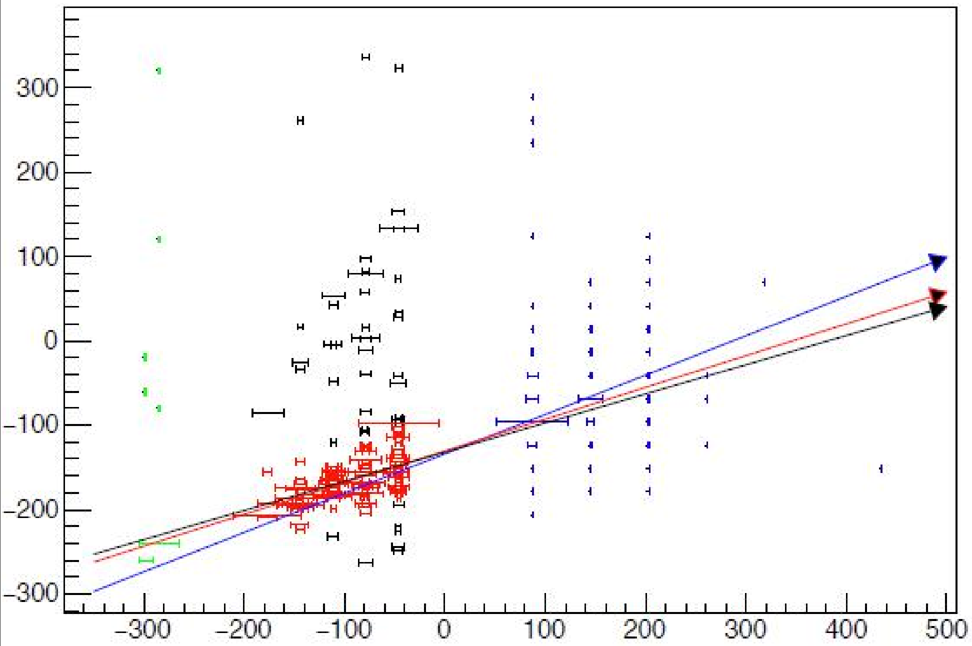


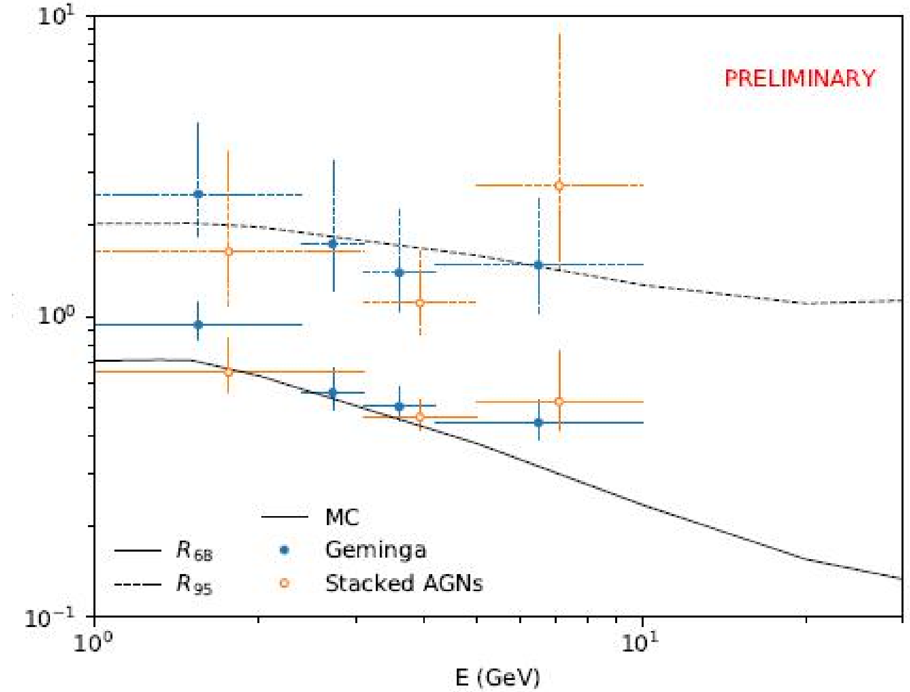
Charge measurement by PSD



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

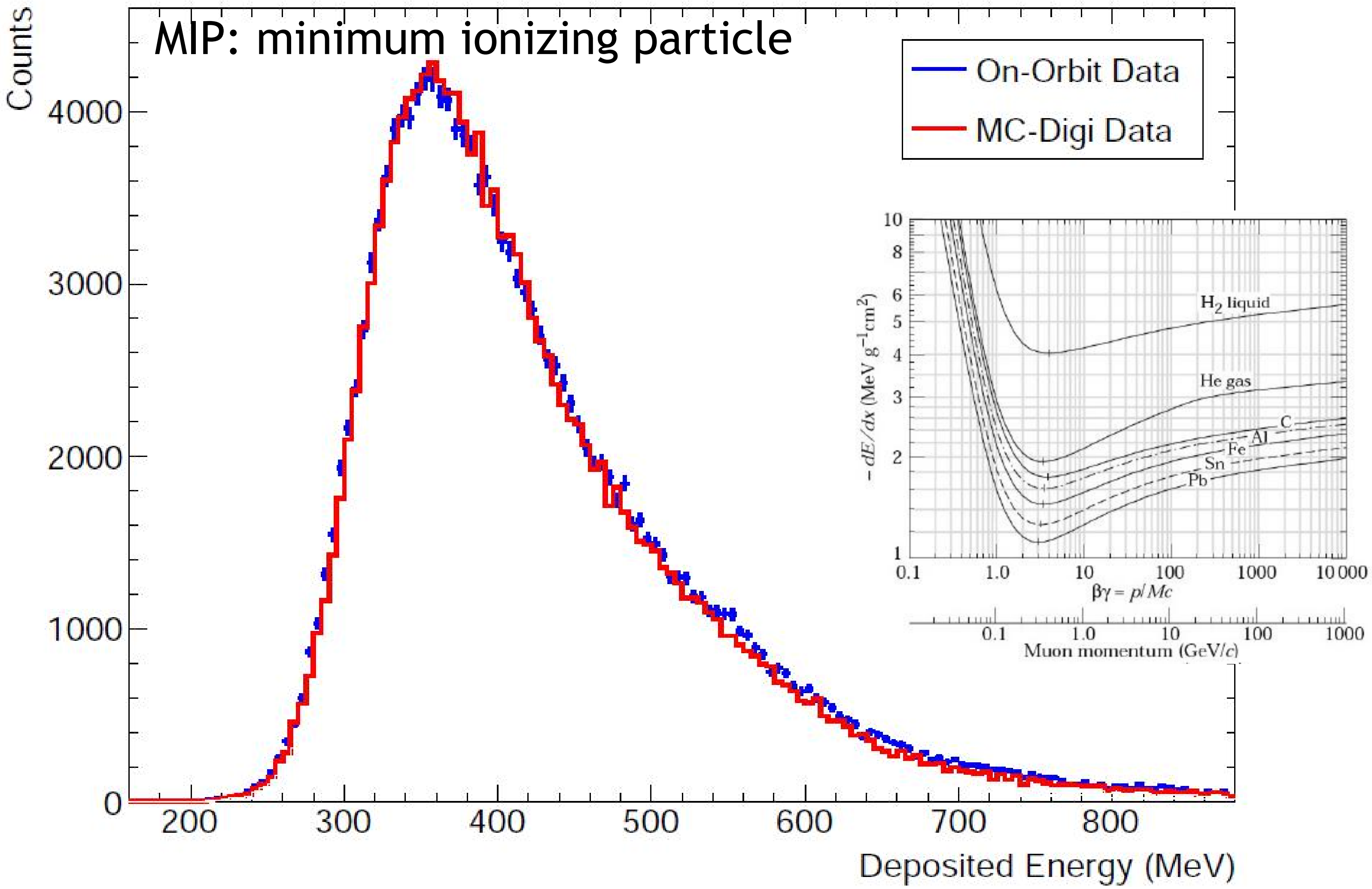
Direction measurement by STK



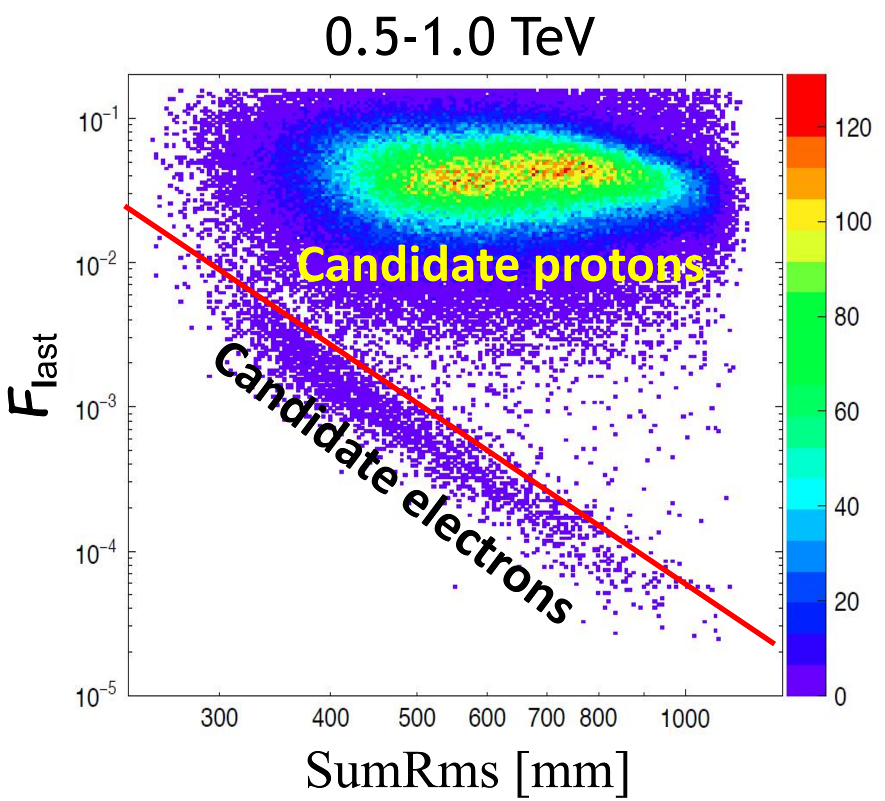


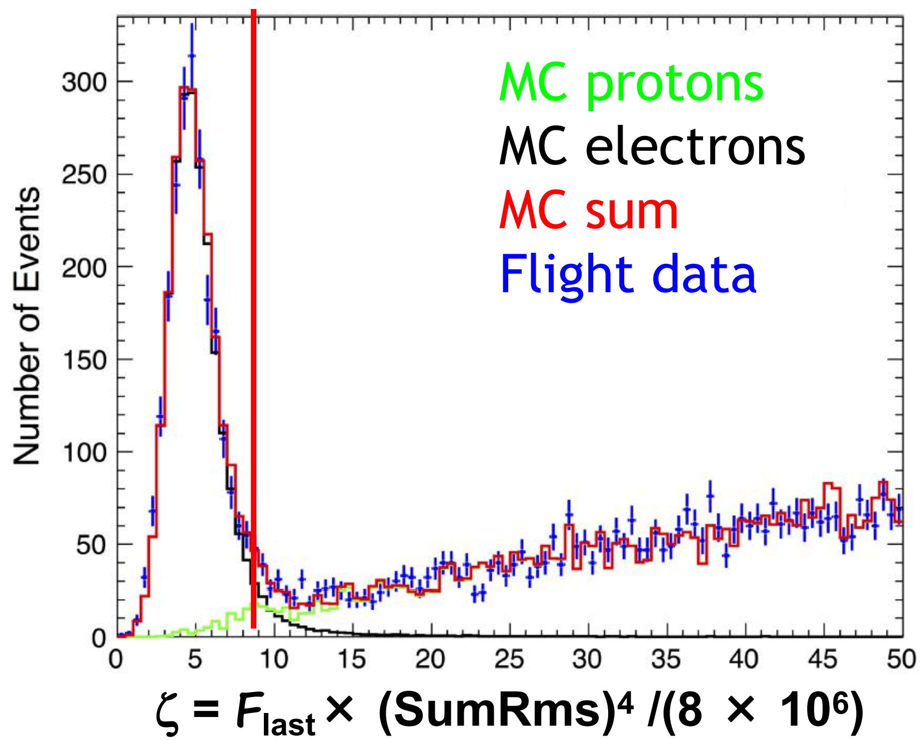
PSF calibrated with bright gamma-ray sources：~0.5 degree @5 GeV

Energy calibration: MIPs



e/p separation: shower shapes

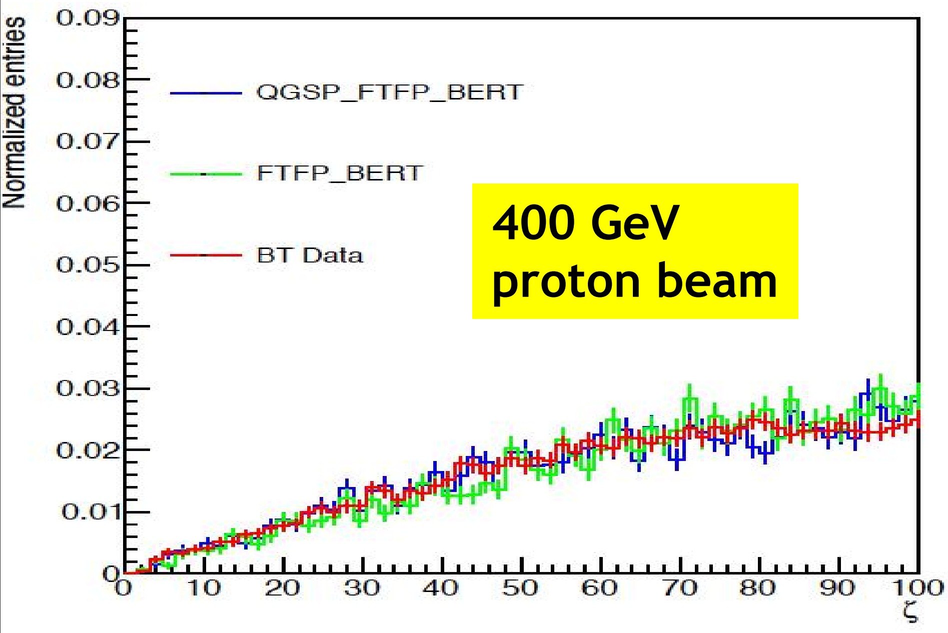


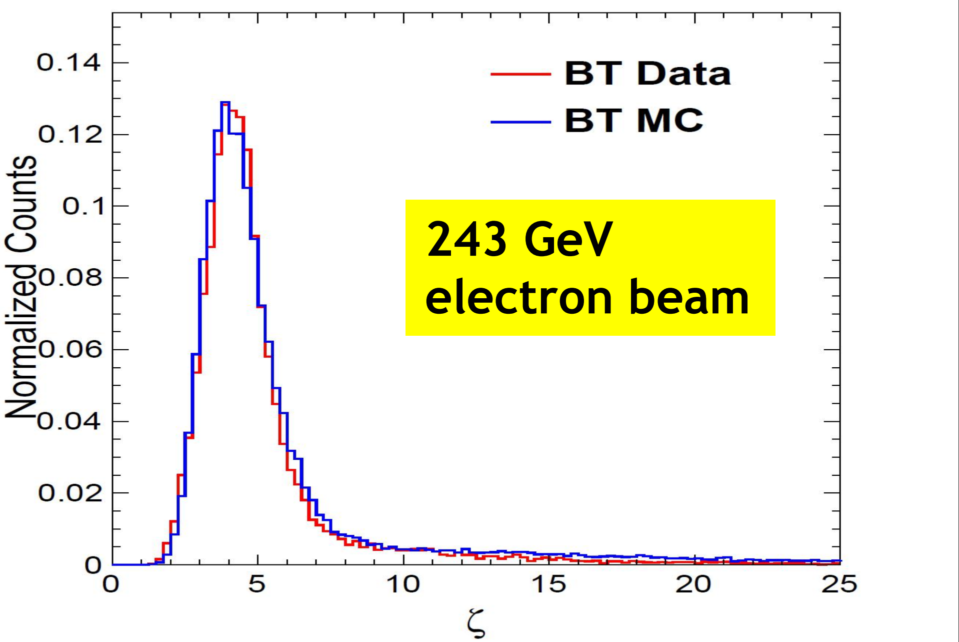


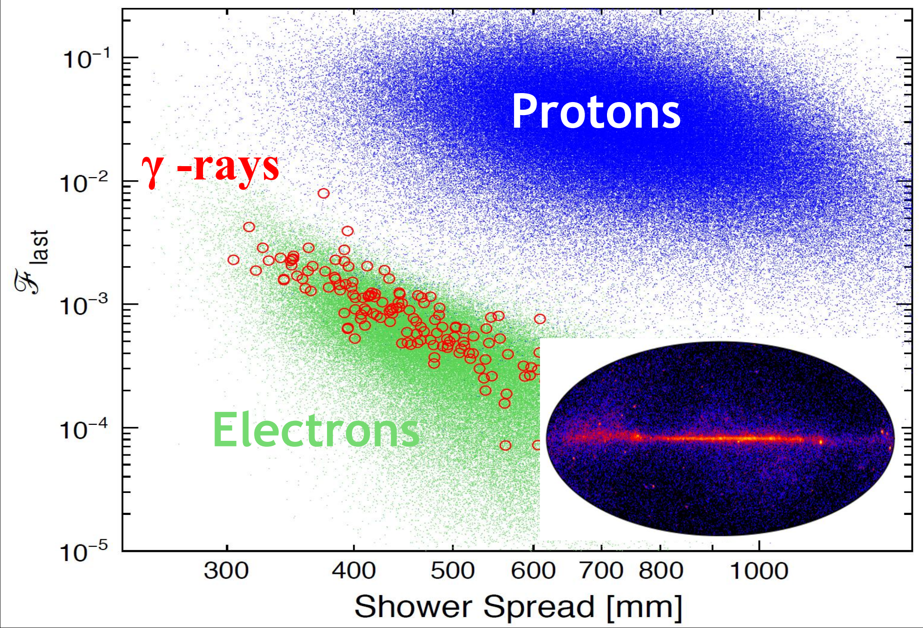
- We use the lateral (SumRMS) and longitudinal (energy ratio in last layer) developments of the showers to discriminate electrons from protons
- For 90% electron efficiency, proton background is ~2% @ TeV, ~5% @ 2 TeV, ~10% @ 5 TeV

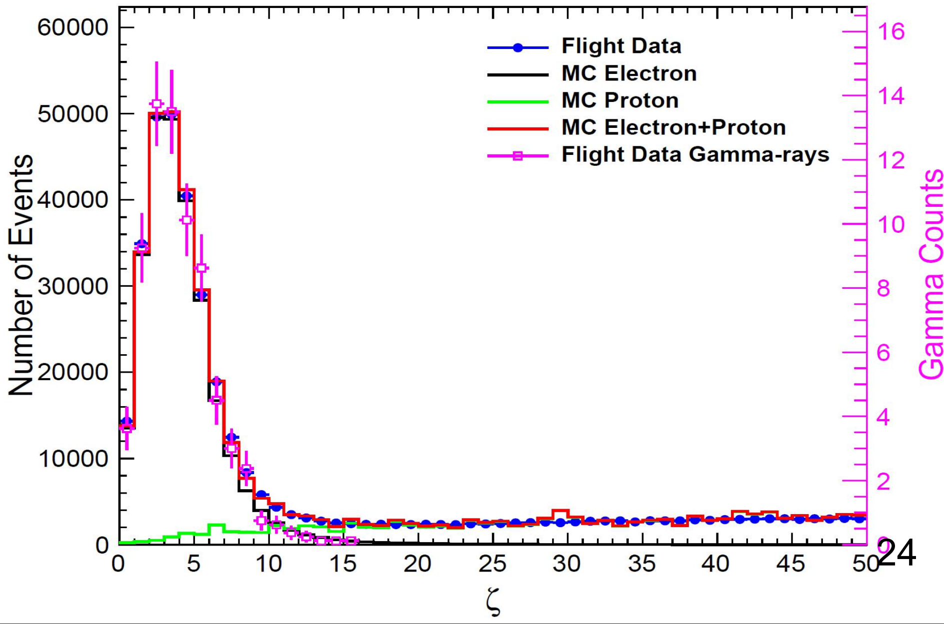
(Nature 552 (2017) 63-66)

Validation of shape parameter ζ with BT and photons



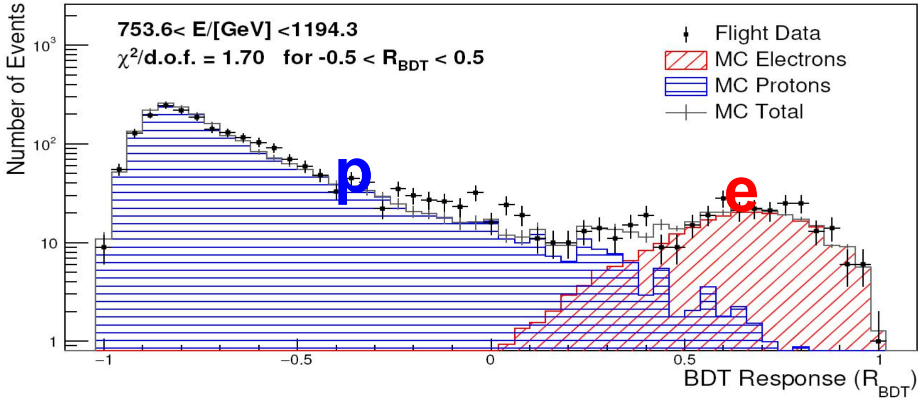




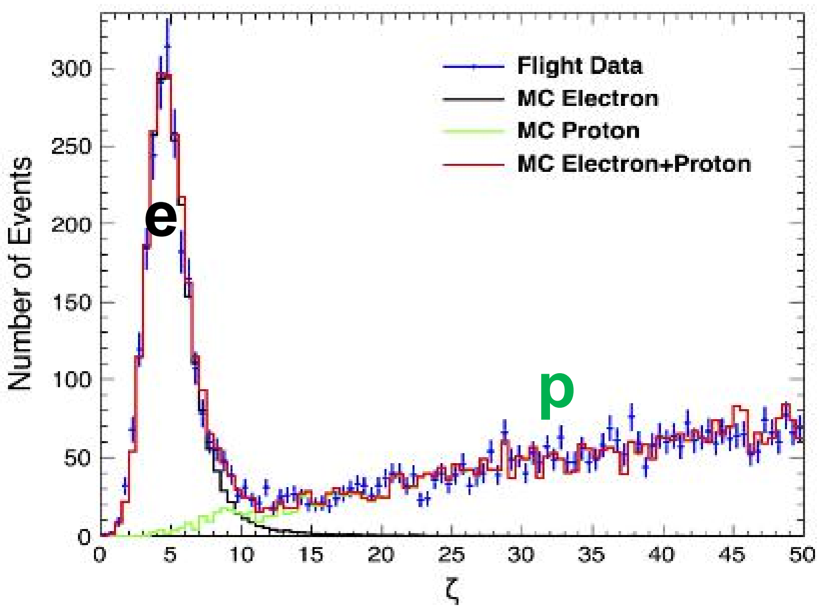


Comparison among various experiments

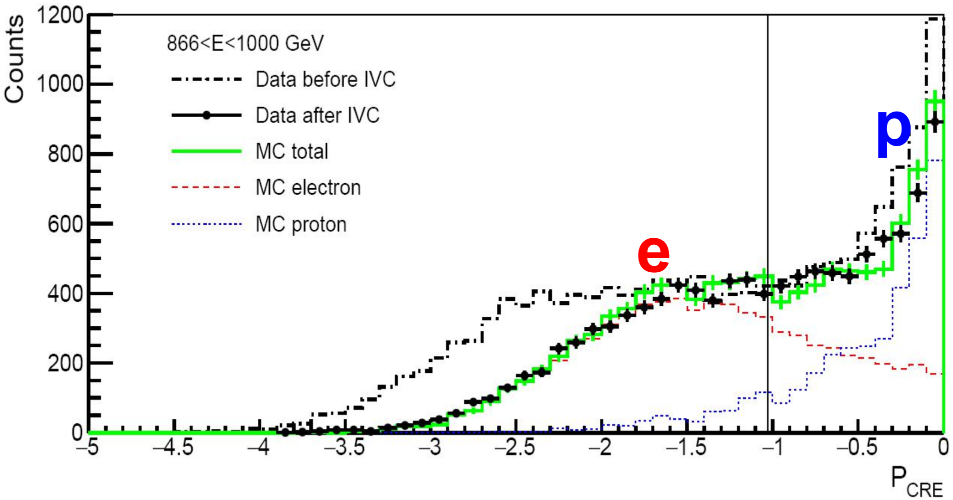
CALET: PRL, 120, 261102 (2018)



DAMPE: Nature, 552, 63 (2017)

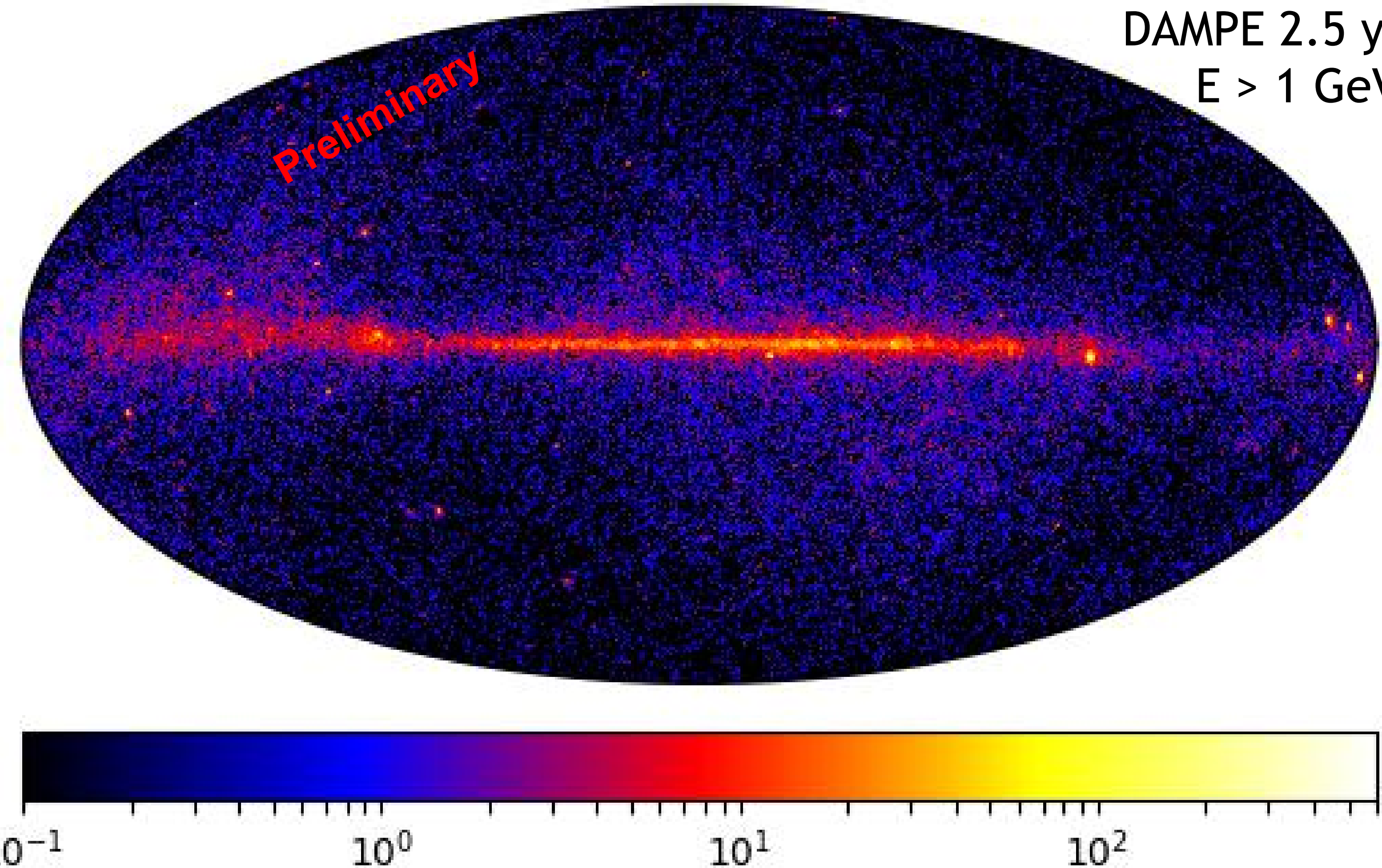


FERMI: PRD 95, 082007 (2017)

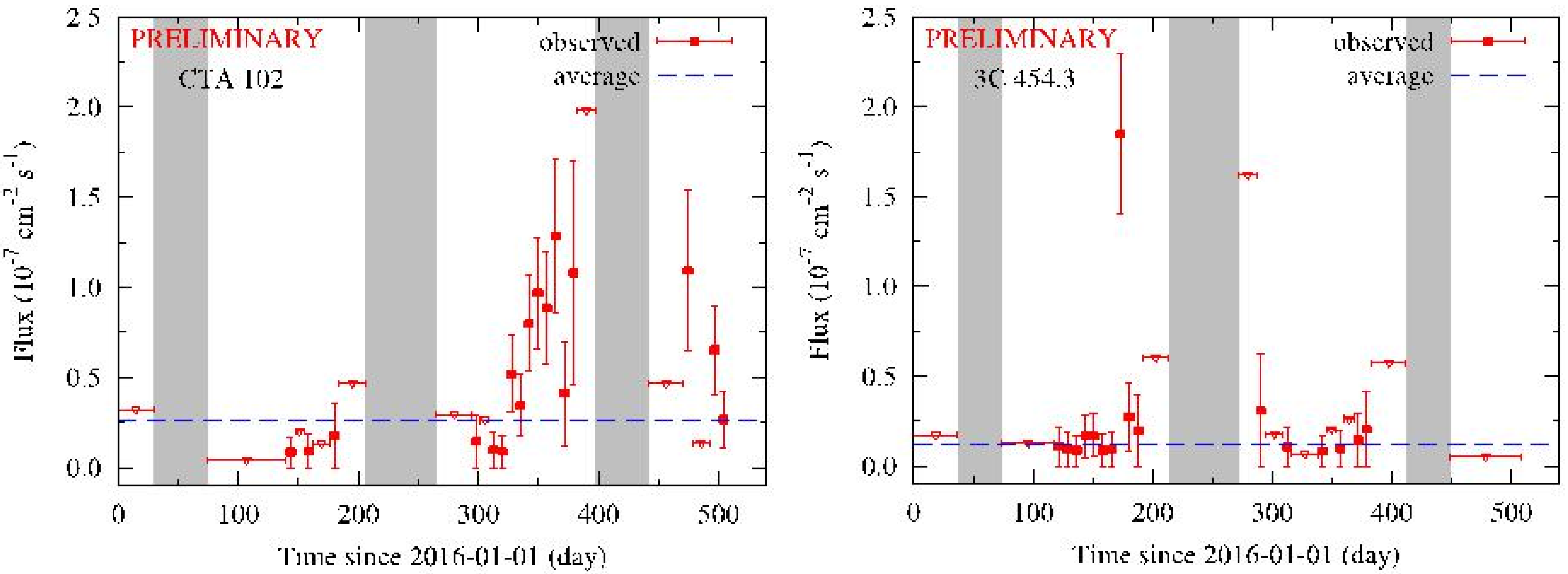


Physical results

Physical results: γ-ray sky map



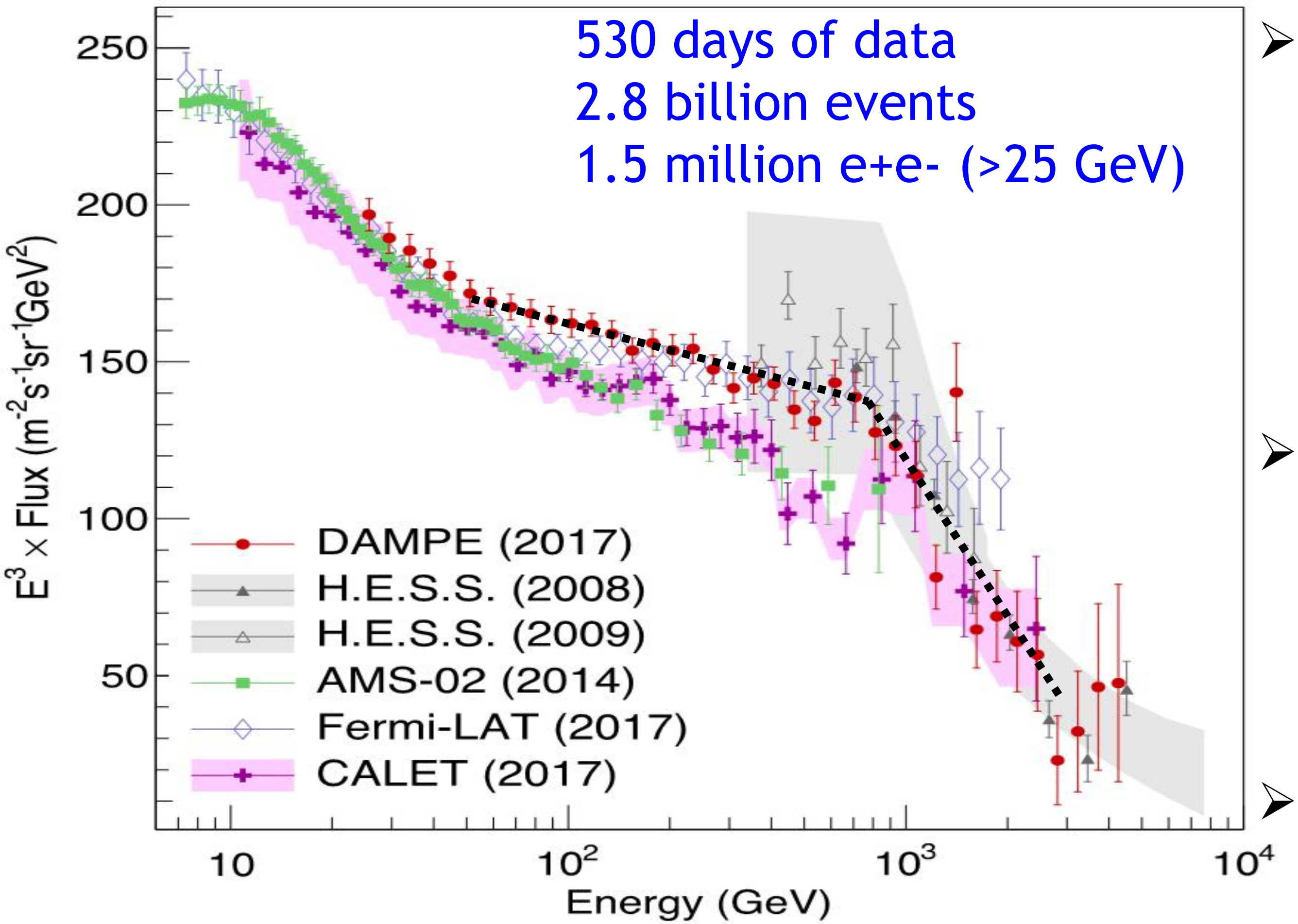
Physical results: γ-ray variables



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

(Yuan et al. PoS (ICRC2017) 617)

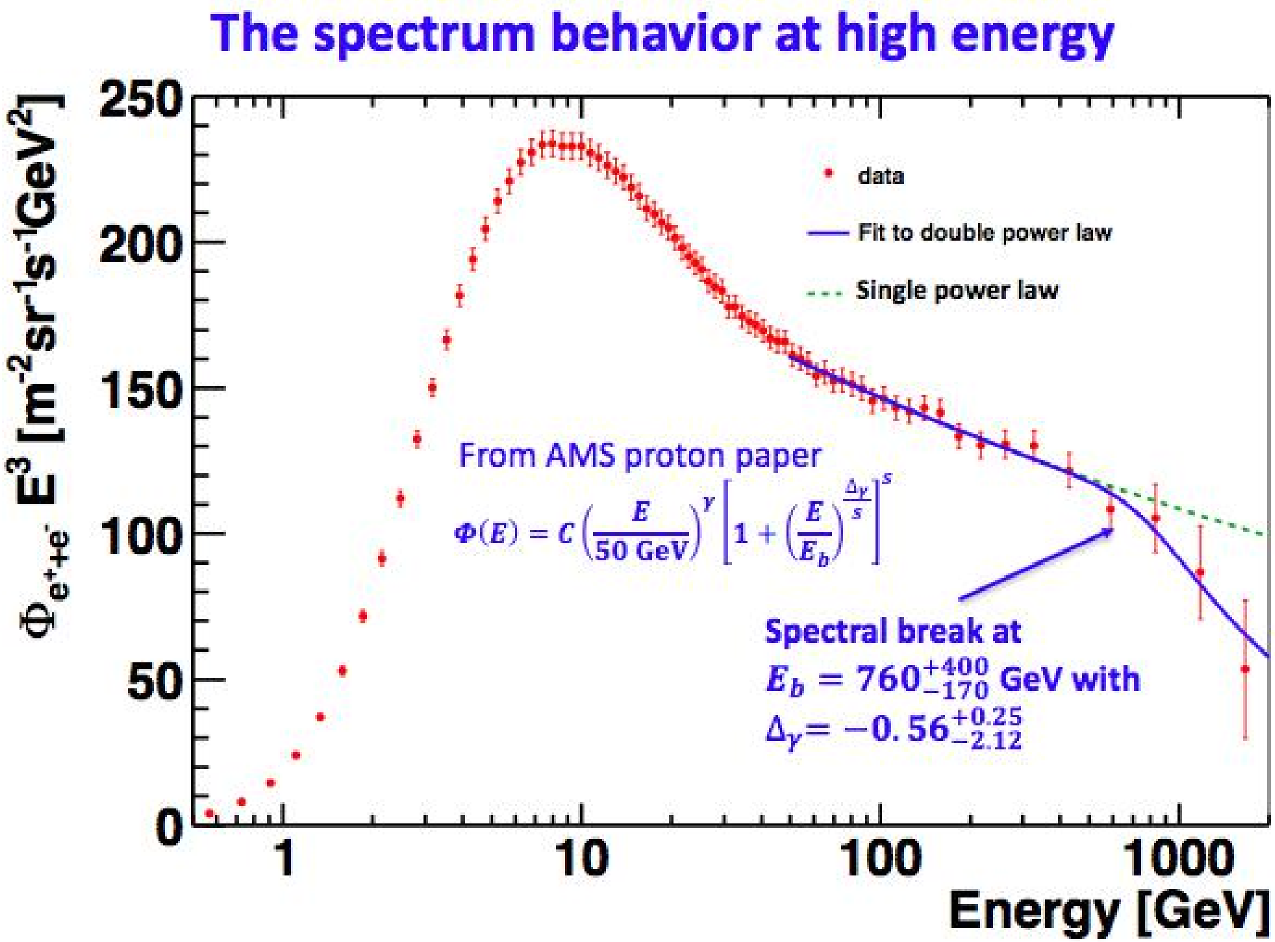
Physical results: $e^+ + e^-$ spectrum



- 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 + CALET result)

AMS-02 2018 result on $e^+ + e^-$ spectrum



The $(e^+ + e^-)$ flux deviates from a single power law above ~800 GeV

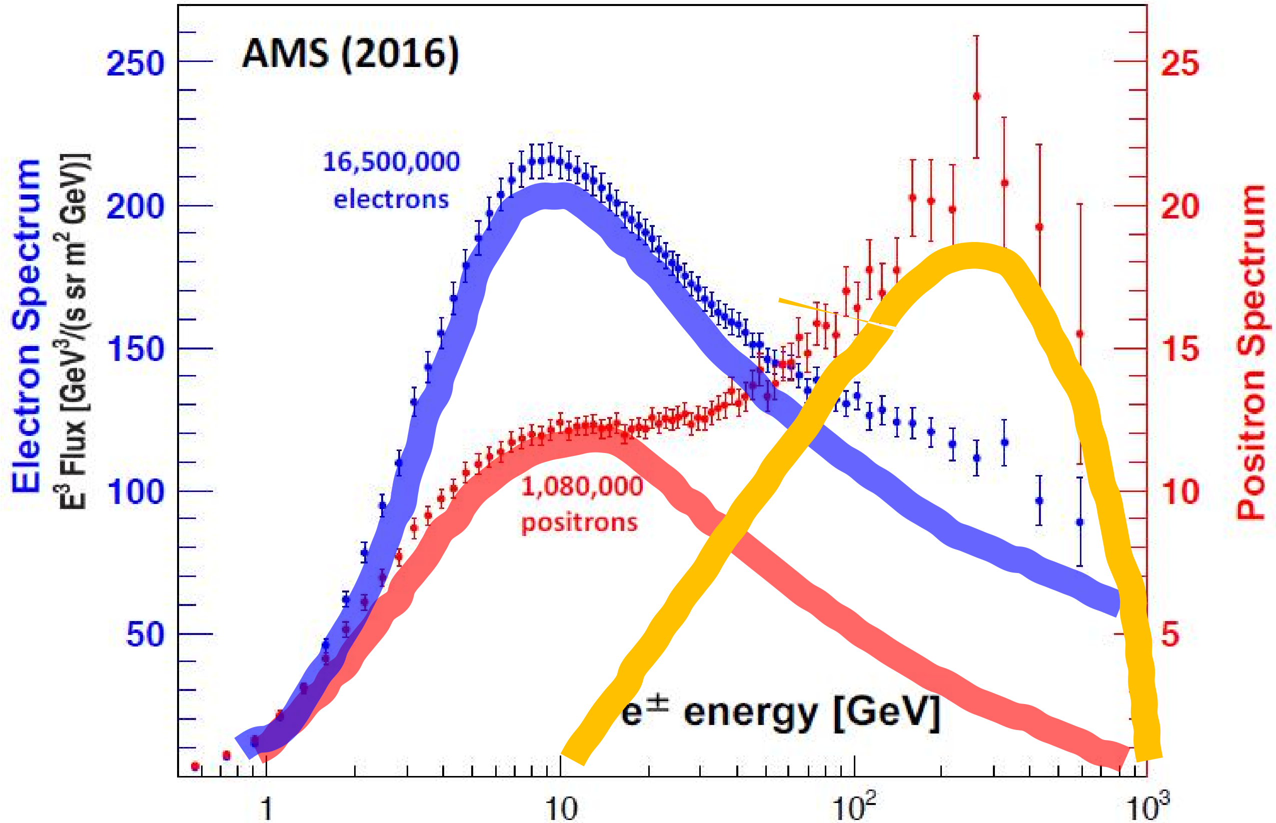
Summary

- 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
- Analyses of spectra of cosmic ray nuclei are on-going
- More results are coming

Thank You!

Backup

Three-component e^+e^- model



- Primary e- accelerated together with ions (in e.g., supernova remnants)
- Secondary e- and e+ from hadronic interaction of cosmic ray nuclei
- Additional e- and e+ from extra sources (e.g., pulsars, ...)

Implication of the spectral break: break of continuous source distributions in space and time

- Cooling time of TeV electrons ~ Myr, effective propagation range ~ kpc
- Assuming a total SN rate of 0.01 per year, the total number of SNRs within the effective volume and cooling time is O(10)