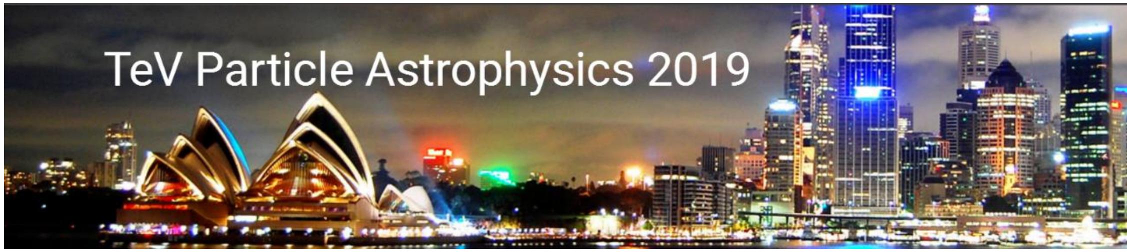
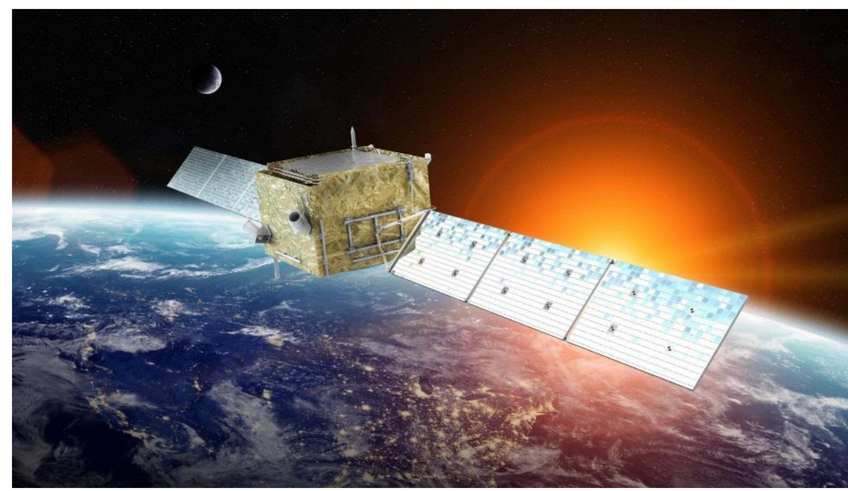


Latest Results of the Dark Matter Particle Explorer (DAMPE) experiment

Jingjing Zang(藏京京)
Purple Mountain Observatory, CAS
(on behalf of the DAMPE collaboration)



The DAMPE 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 Gran Sasso Science Institute

- SWITZERLAND
  - University of Geneva

DAMPE experiment is sponsored by Chinese Academy of Sciences and supported by many institutes from China, Italy and Switzerland.

Outline

- DAMPE instrument
- On-orbit performance
- Physical Results
- Summary

DAMPE instrument

DArk Matter Particle Explorer (DAMPE)

Dark Matter Particle Explorer is a space-borne cosmic ray detection experiment measuring energy to over 10TeV

Three major scientific goals

Cosmic ray physics

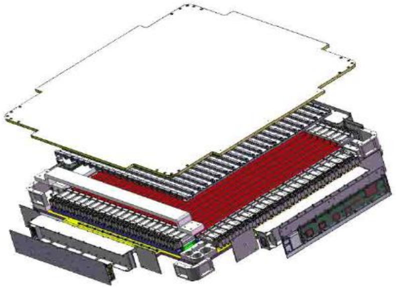
γ-ray astronomy

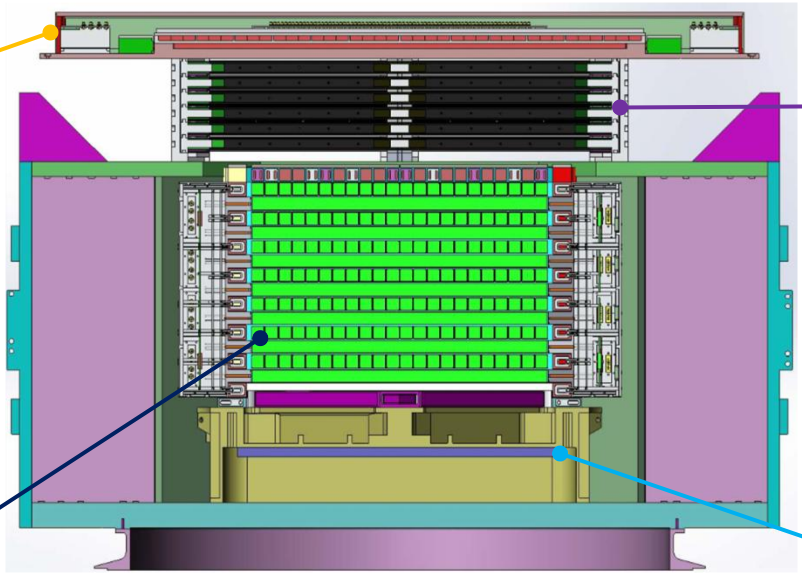
Dark matter indirect detection

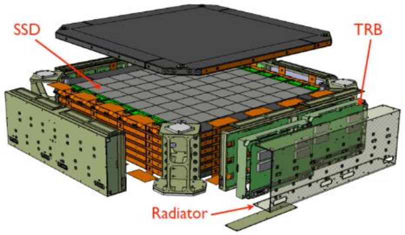
Instrument design

Plastic Scintillator Detector(PSD)
- ➢γ anticoincidence
- ➢Z-measurement

Silicon Tungsten Tracker(STK)
- ➢γ convertor, particle track
- ➢Z-measurement

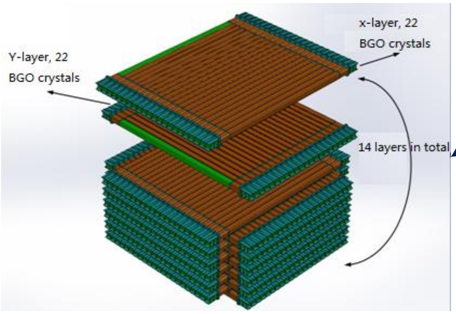


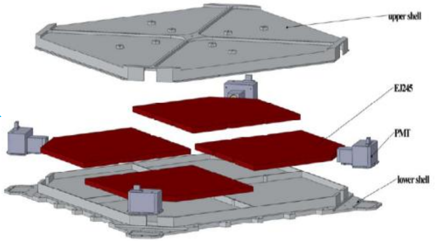




BGO Calorimeter(BGO)
- ➢Calorimeter ($32X_0$&$1.6\lambda_I$)
- ➢e/p separation
- ➢Trigger primitives

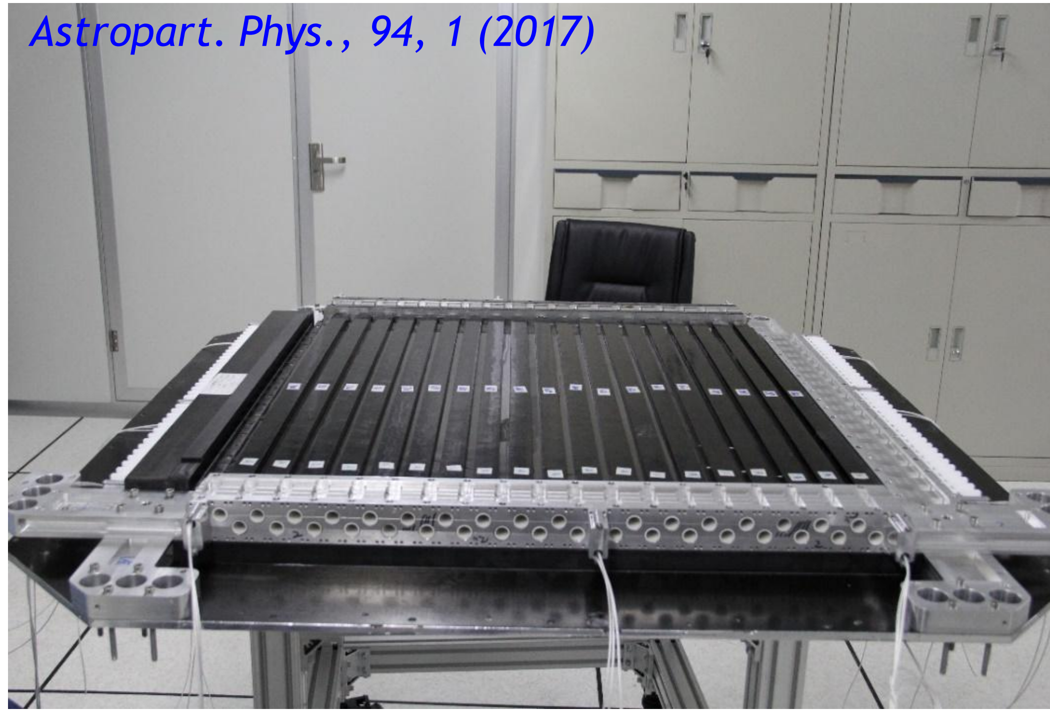
Neutron Detector(NUD)
- ➢e/p separation

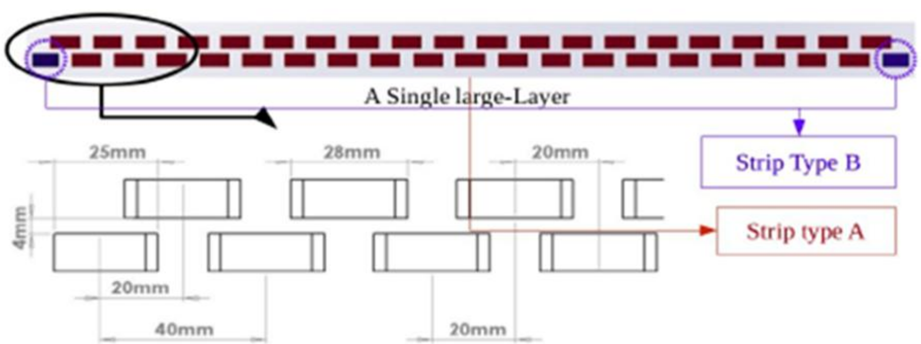




More details can be found at Astropart. Phys., 95, 6 (2017)

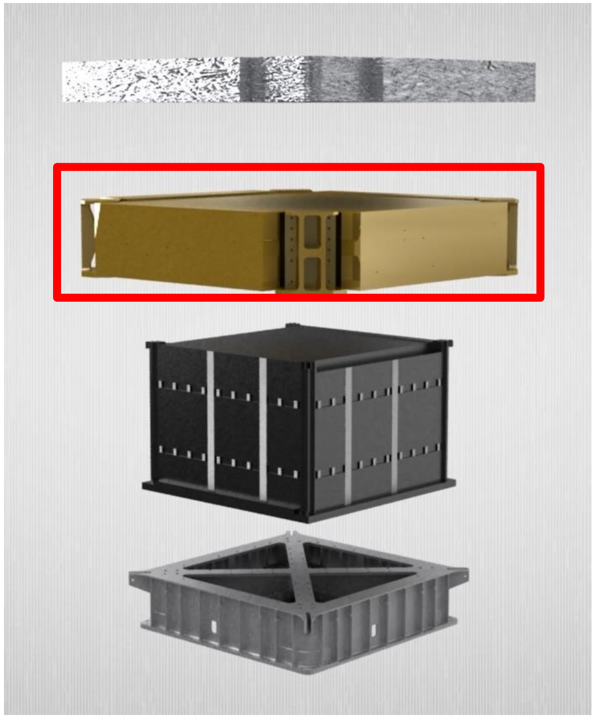
PSD detector

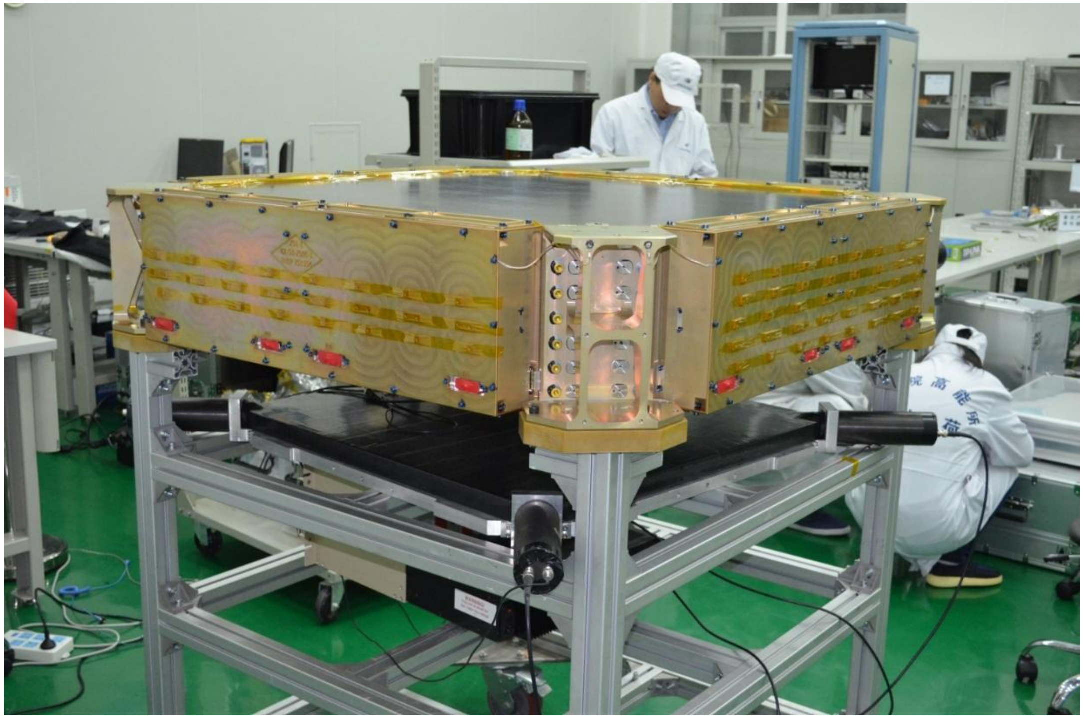


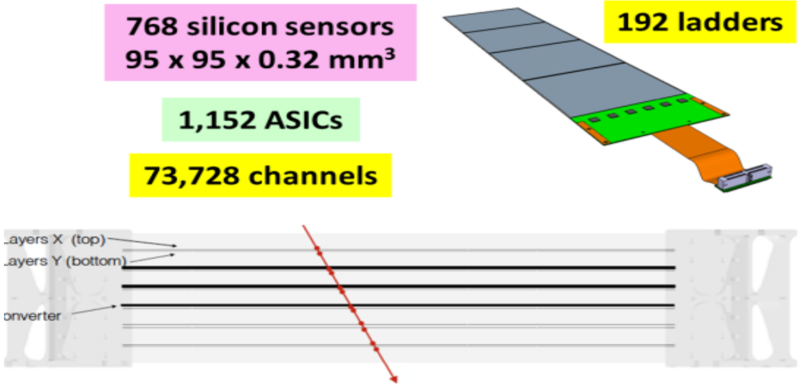


- 2 layers (x,y) of 88.4 cm × 2.8 cm × 1 cm
- Active area: 82 cm × 82 cm
- Weight : ~103 kg
- Power: ~ 8.5 W
- Charge Res.: 0.06 for Z=1 efficiency(99.99%)

Silicon tracker

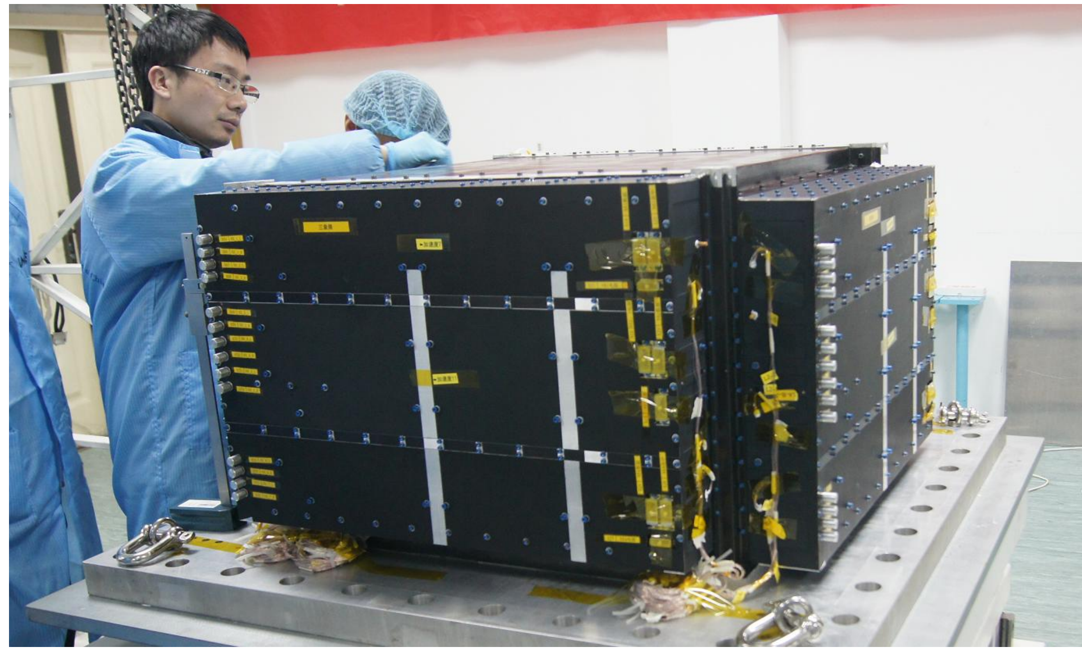


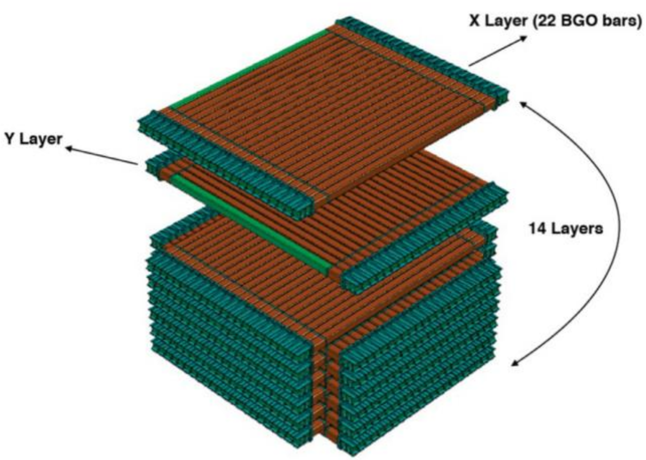




- Detection area: 76 cm x 76cm
- Total weight: ~154 kg
- Total power consumption: ~82W
- Three 1mm tungsten (0.86X0)
- Spatial resolution: 0.05mm

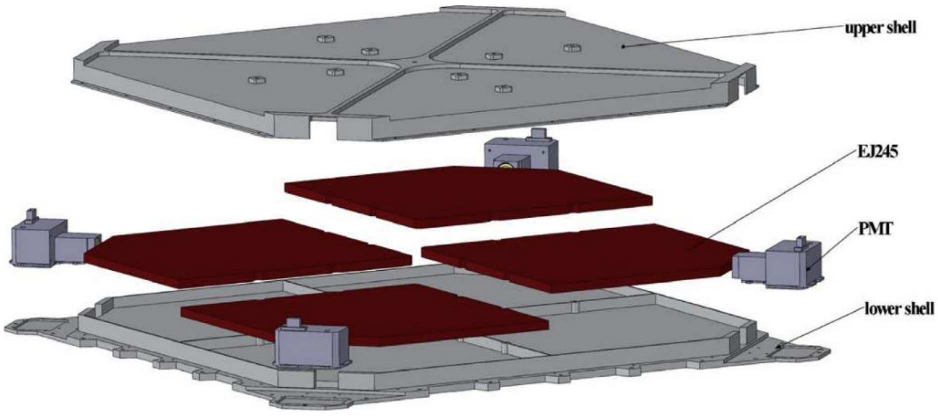
BGO calorimeter





- Outer envelop: 100 cm x 100 cm x 50 cm
- Detection area: 60 cm x 60 cm
- Total weight: ~1052 kg
- Total power consumption: ~ 41.6 W
- Energy res.: 1%@>50GeV

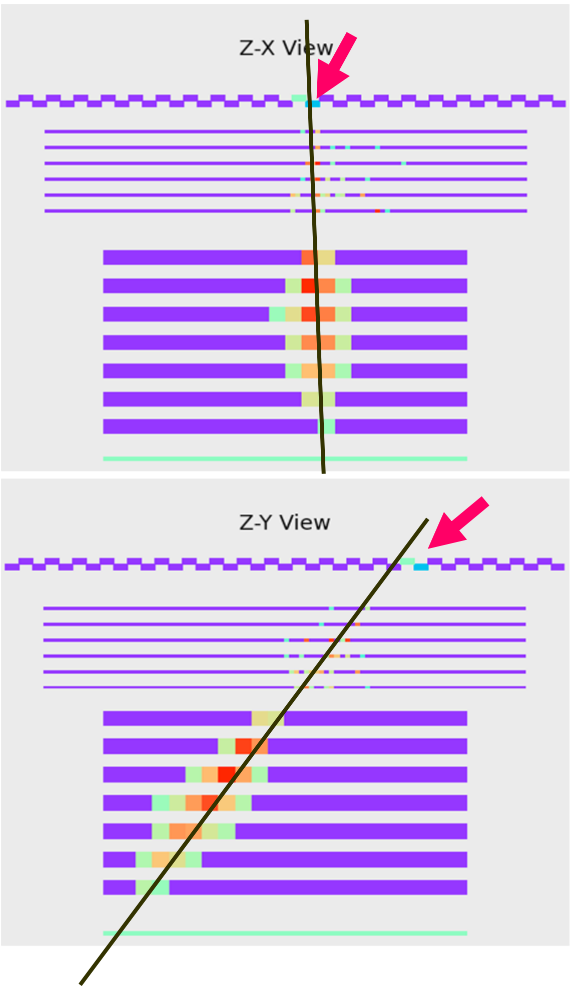
NUD neutron detector



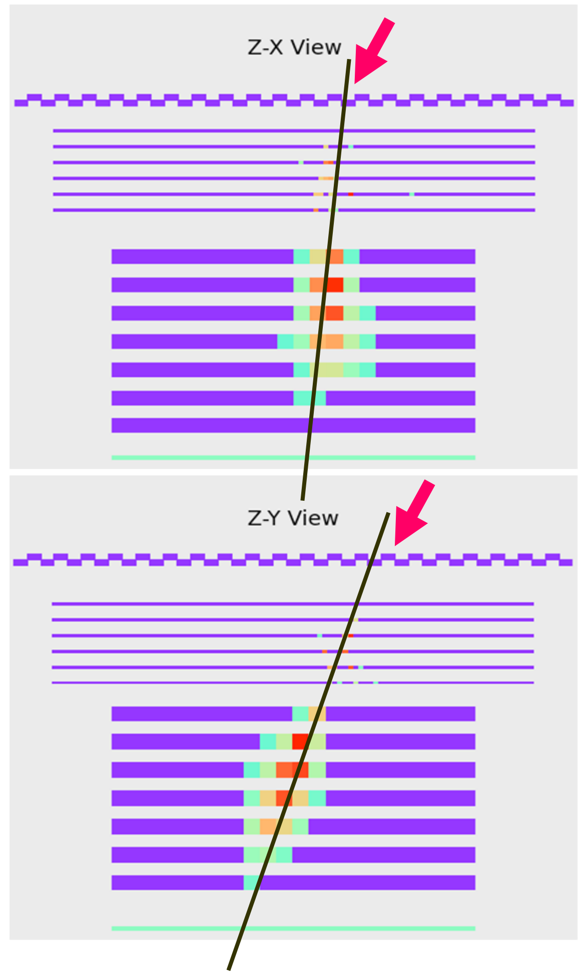
- $n + {}^{10}B \rightarrow \alpha + {}^{7}Li + \gamma$
- 4 plastic scintillators with boron doped
- Active area: 60 cm x 60 cm
- Total weight: ~12 kg
- Total power: ~ 0.5 W

Typical Event Show

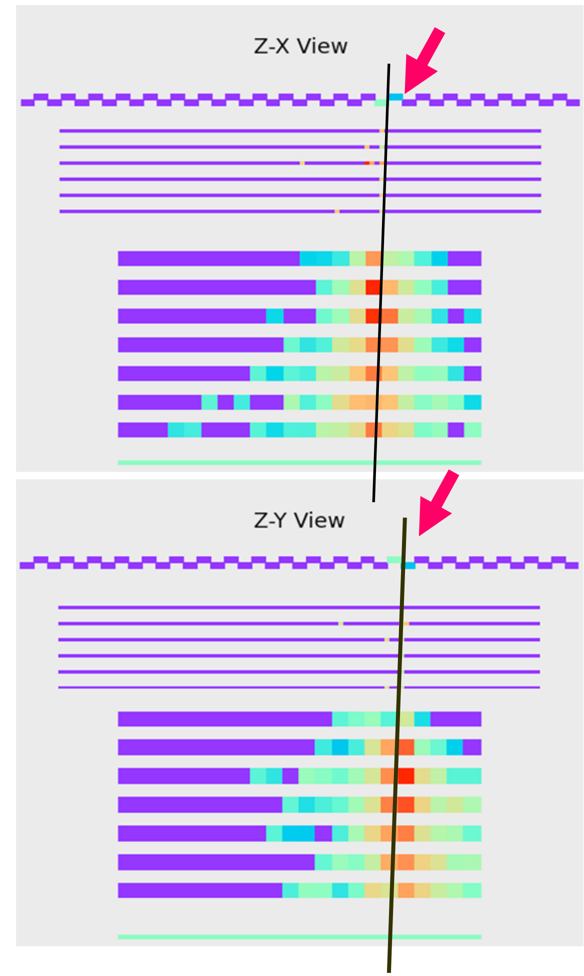
electron



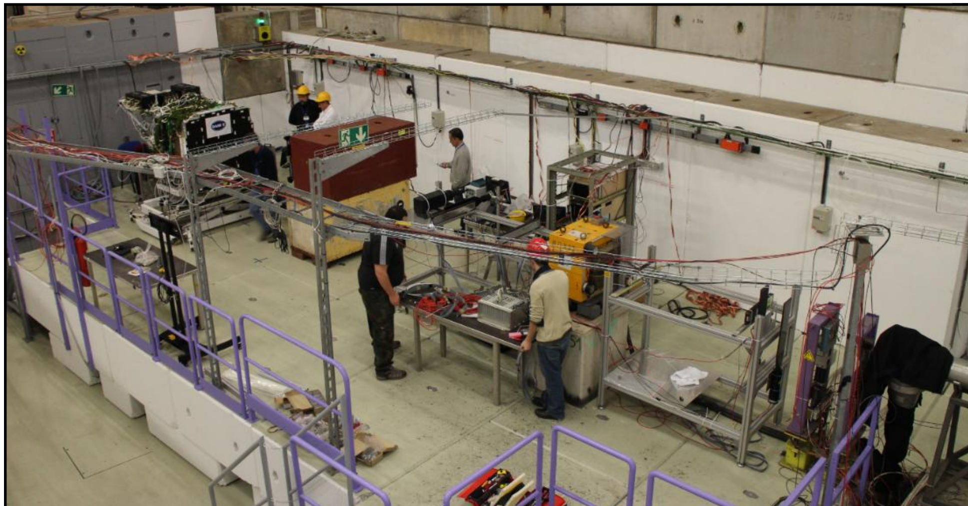
gamma

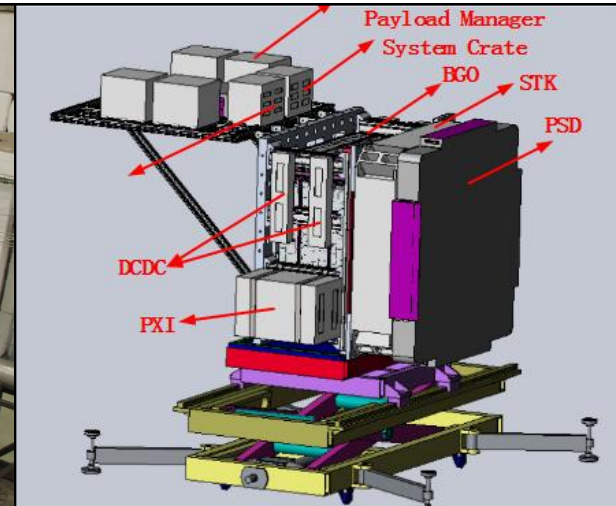


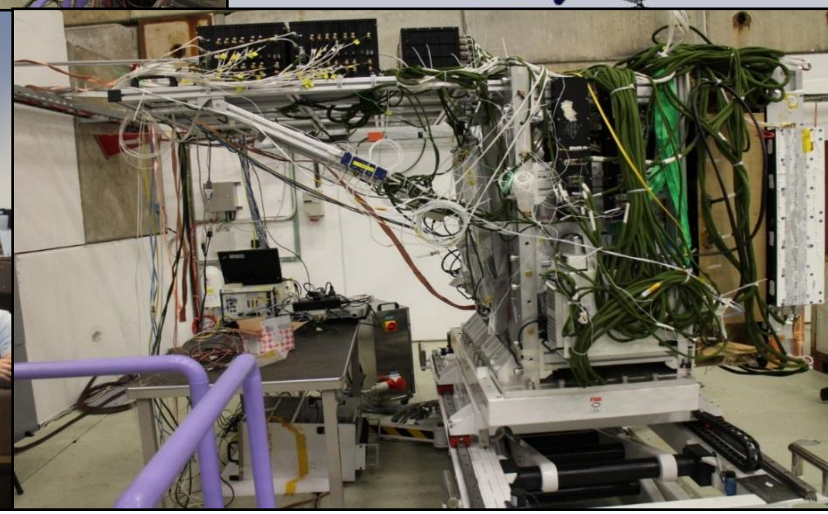
Proton & higher z particle



DAMPE Test beam @ CERN

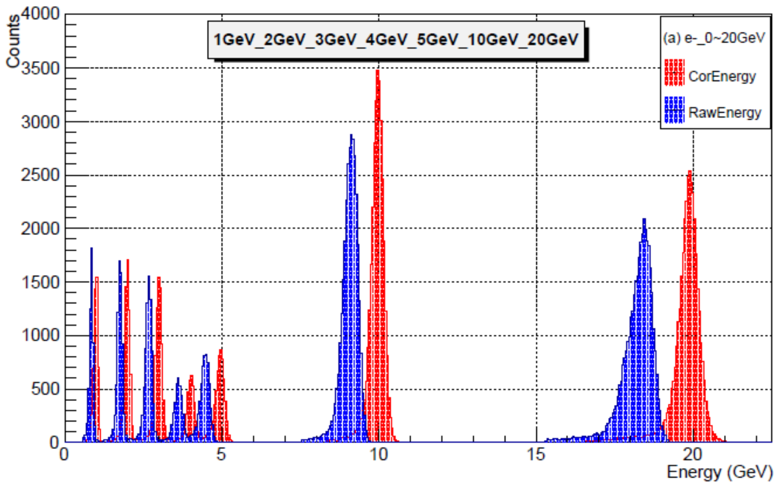


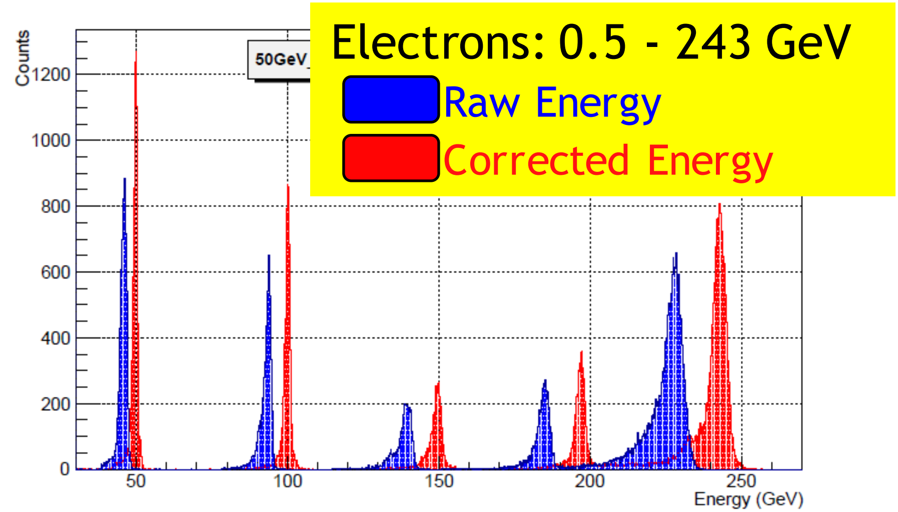


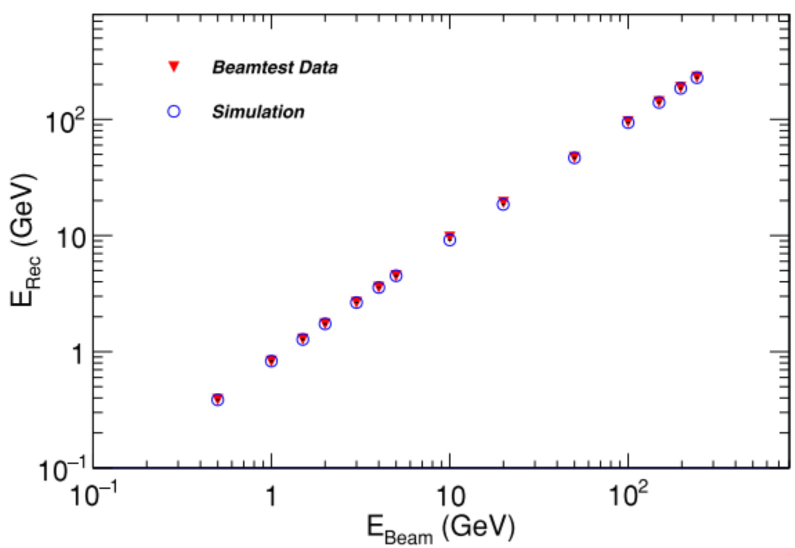


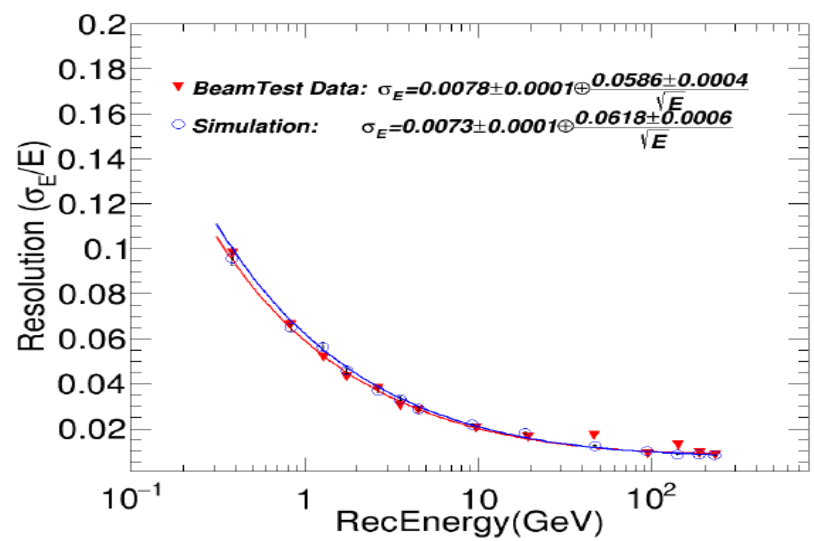
Over 500 configurations： $p, e^+, e^-, \pi^+, \gamma, \mu^+$, nuclear fragments with p=0.5GV~400GV

Test beam validation





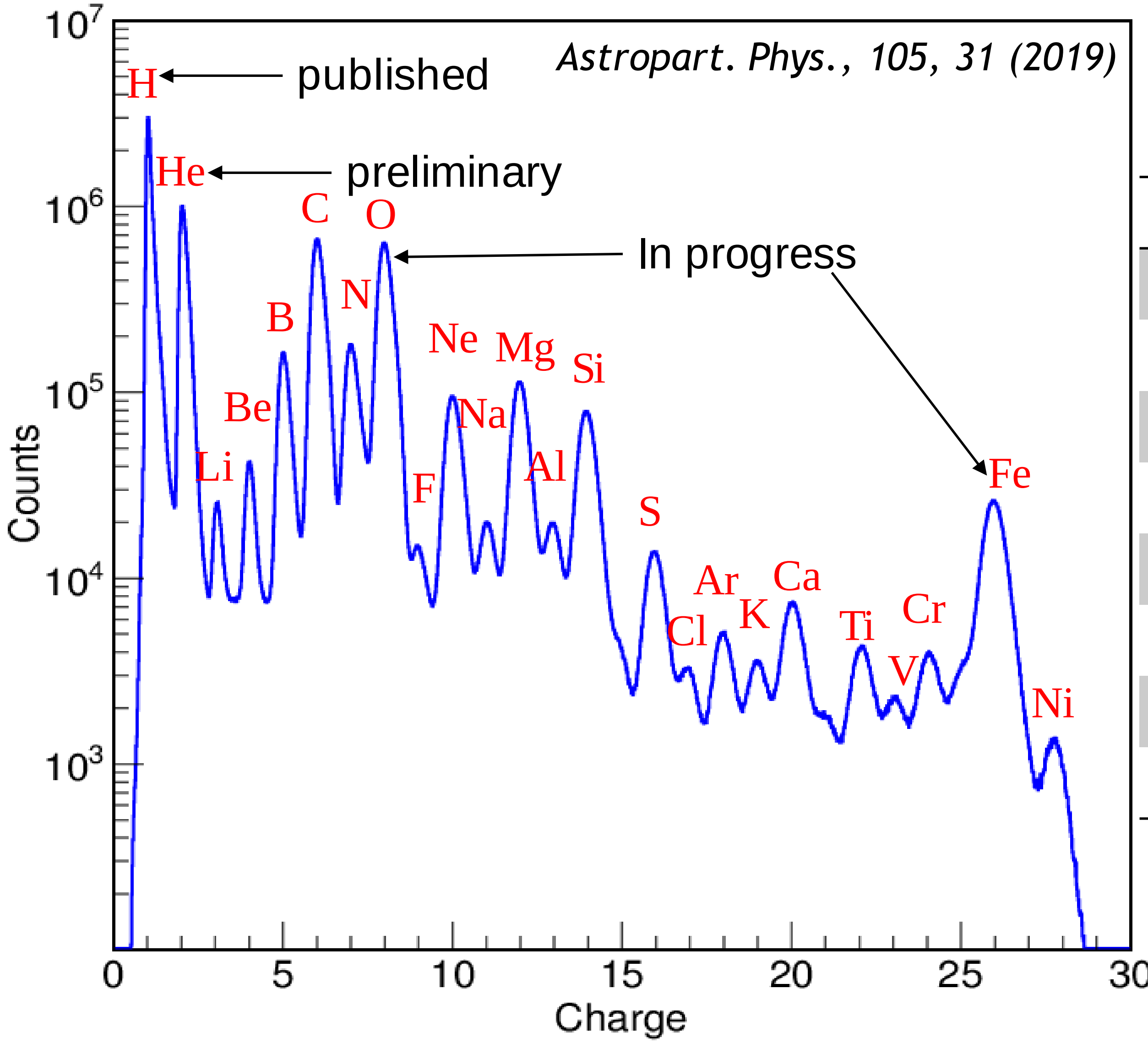




Astropart. Phys., 95, 6 (2017)

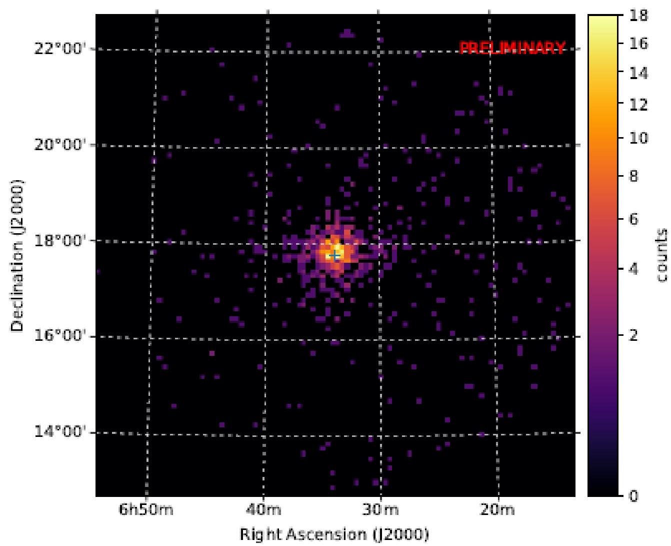
On-orbit performance

PSD charge measurement



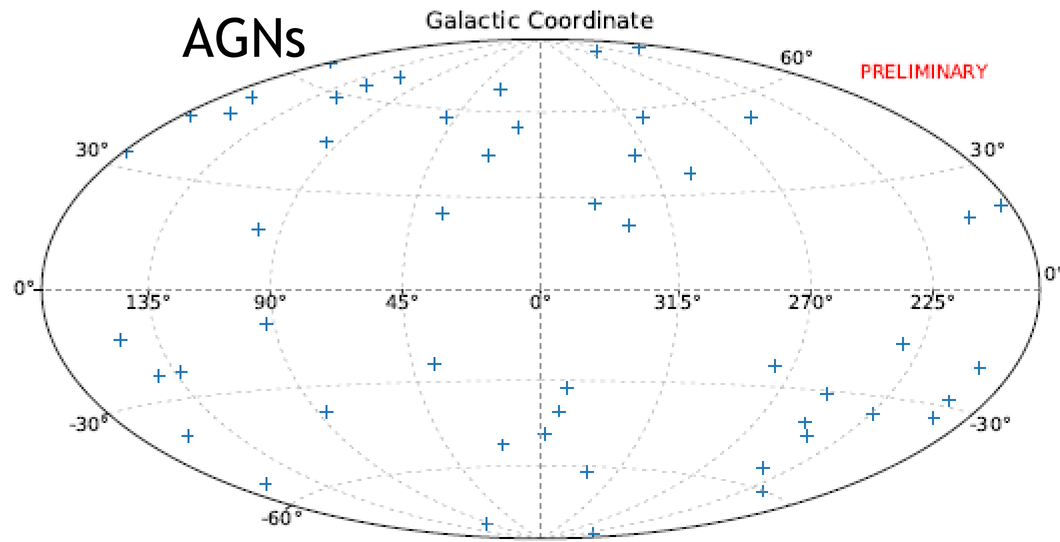
Species	Charge Res.(Δz)
p	0.06
He	0.10
Li	0.14
Be	0.21
B	0.17
C	0.18
N	0.21
O	0.20

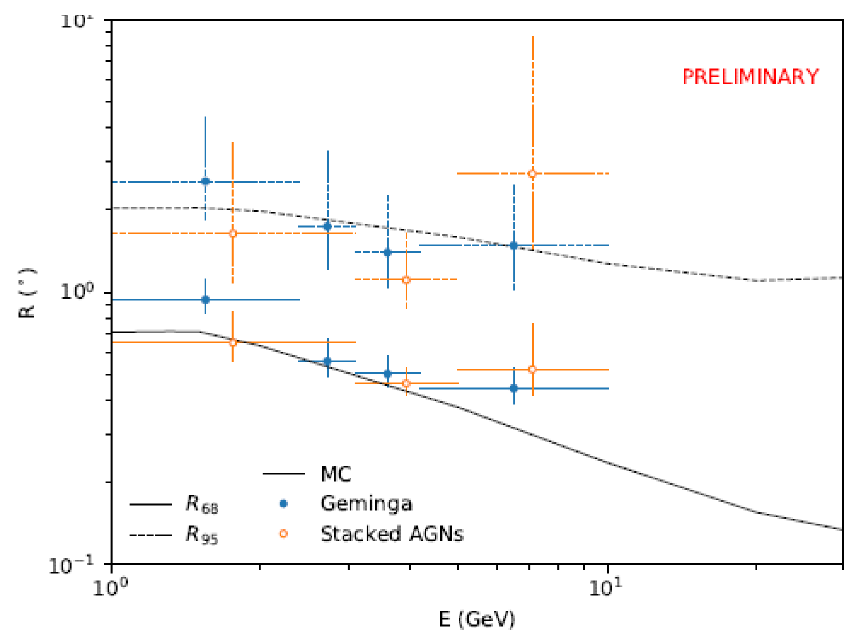
STK direction measurement



Geminga

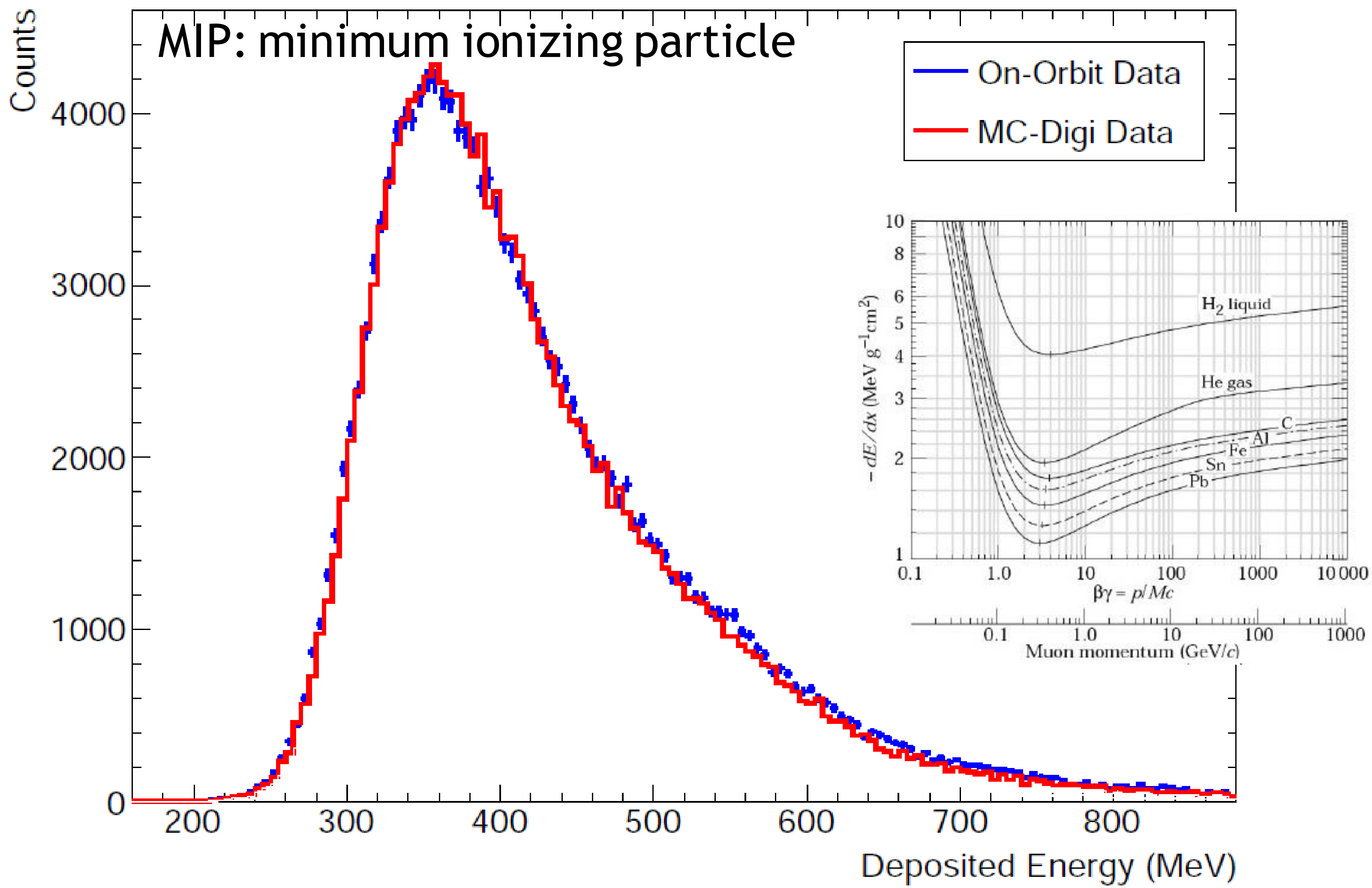
AGNs



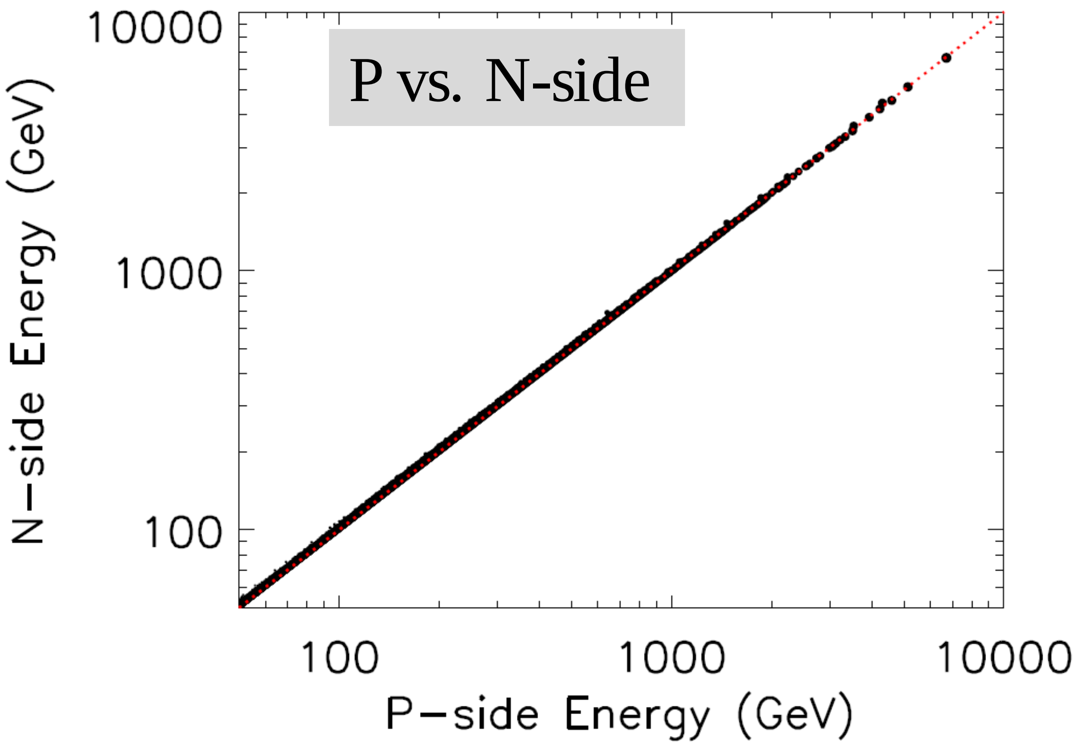


PSF calibrated with bright gamma-ray sources： ~0.5 degrees @ 5 GeV

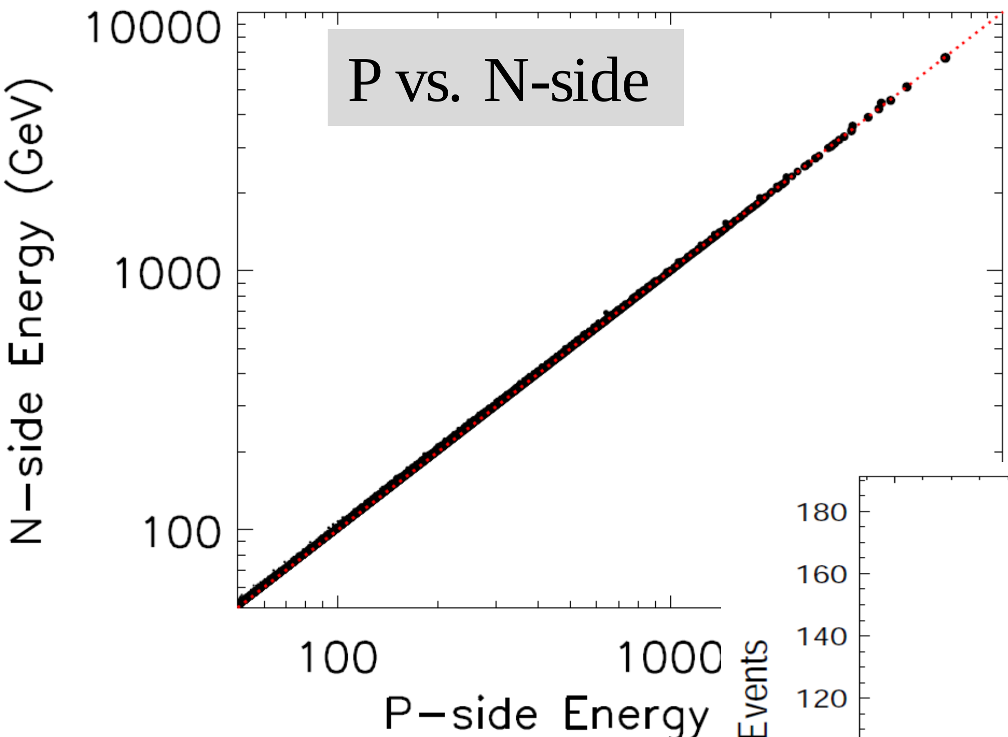
BGO energy calibration

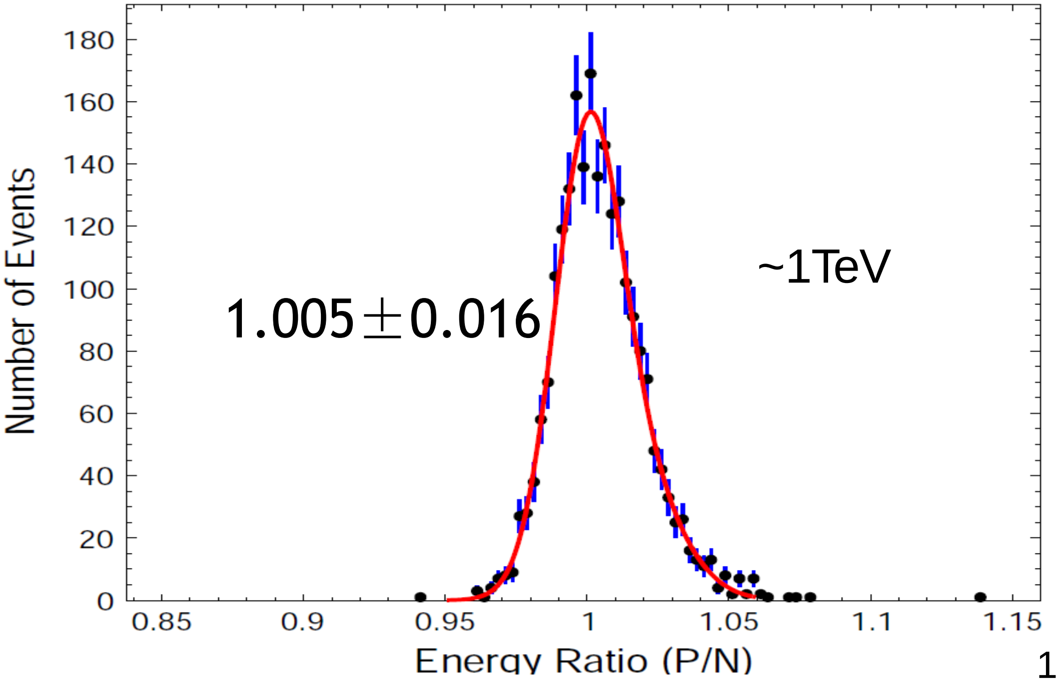


BGO energy linearity



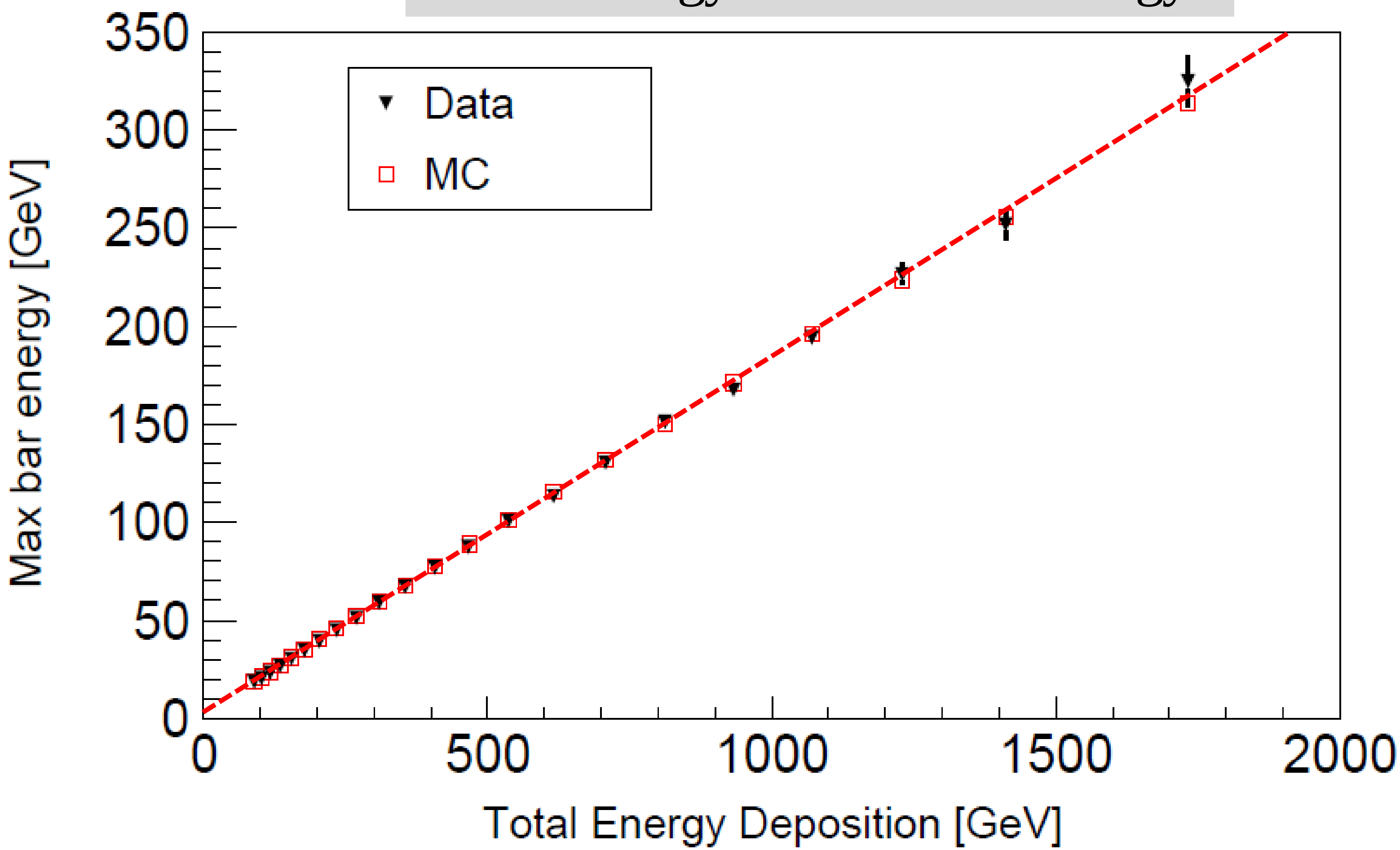
BGO energy linearity



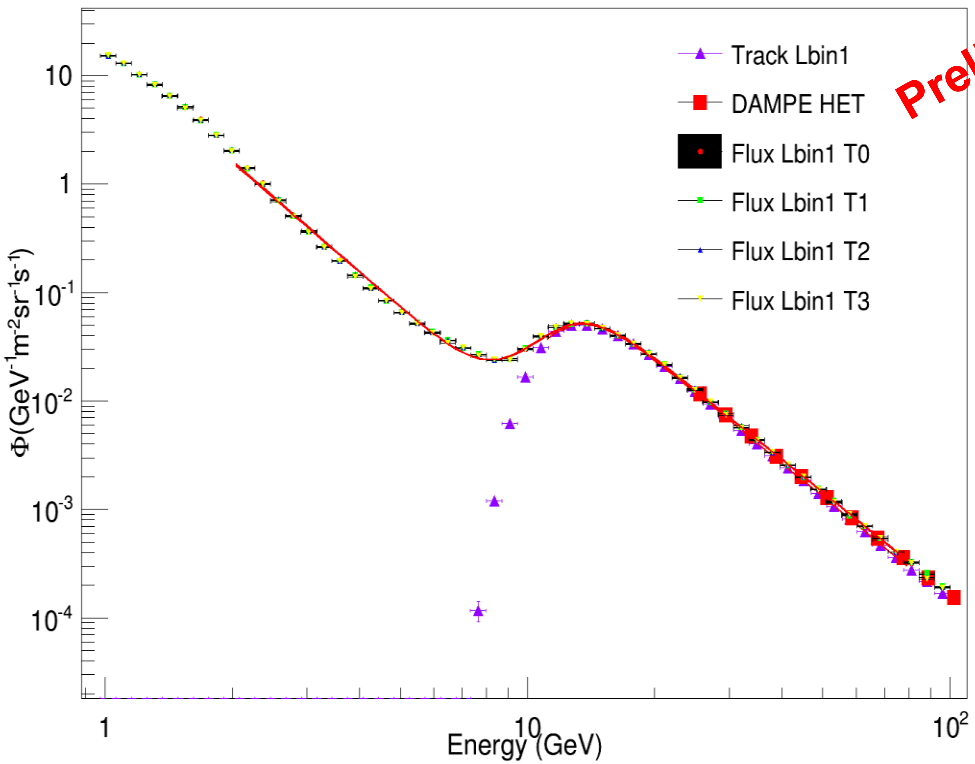


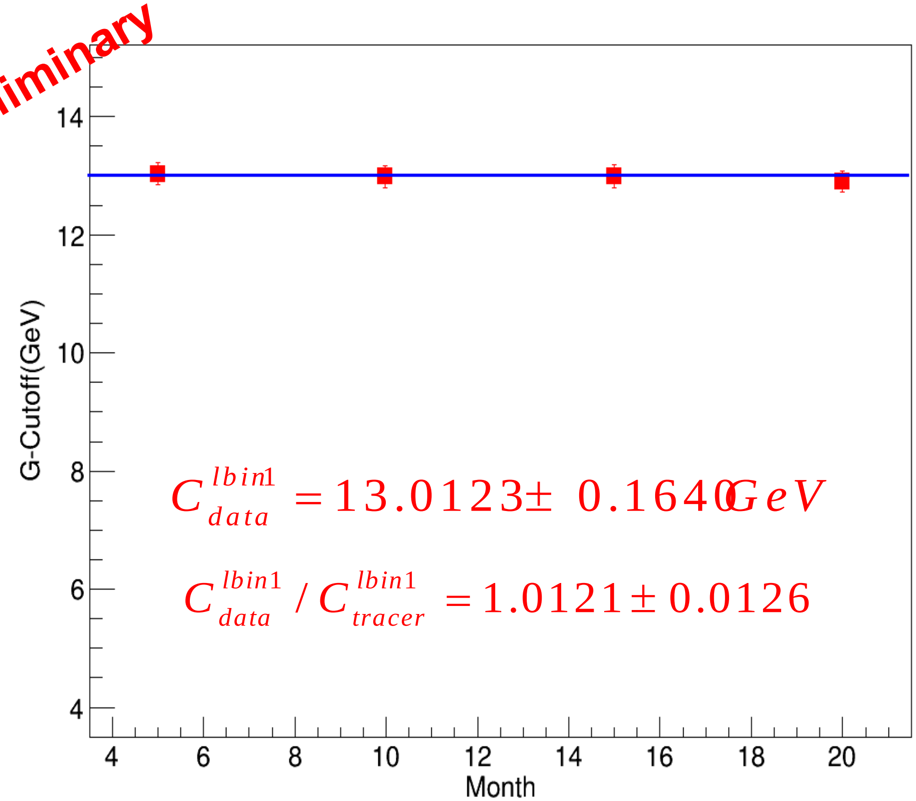
BGO energy linearity

Total energy vs. Max bar energy



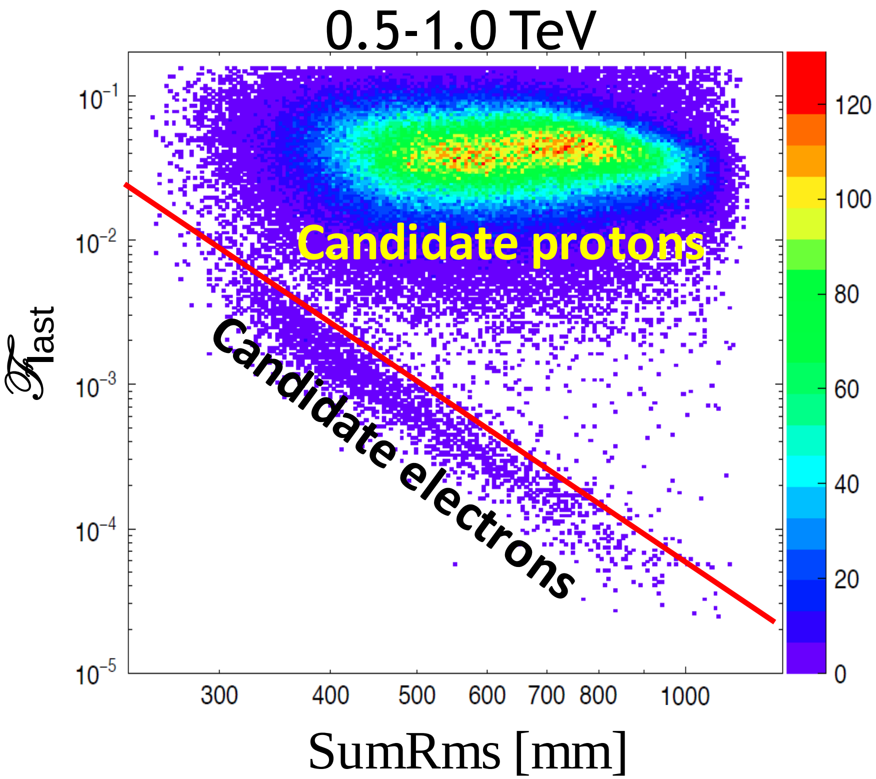
Absolute energy scale

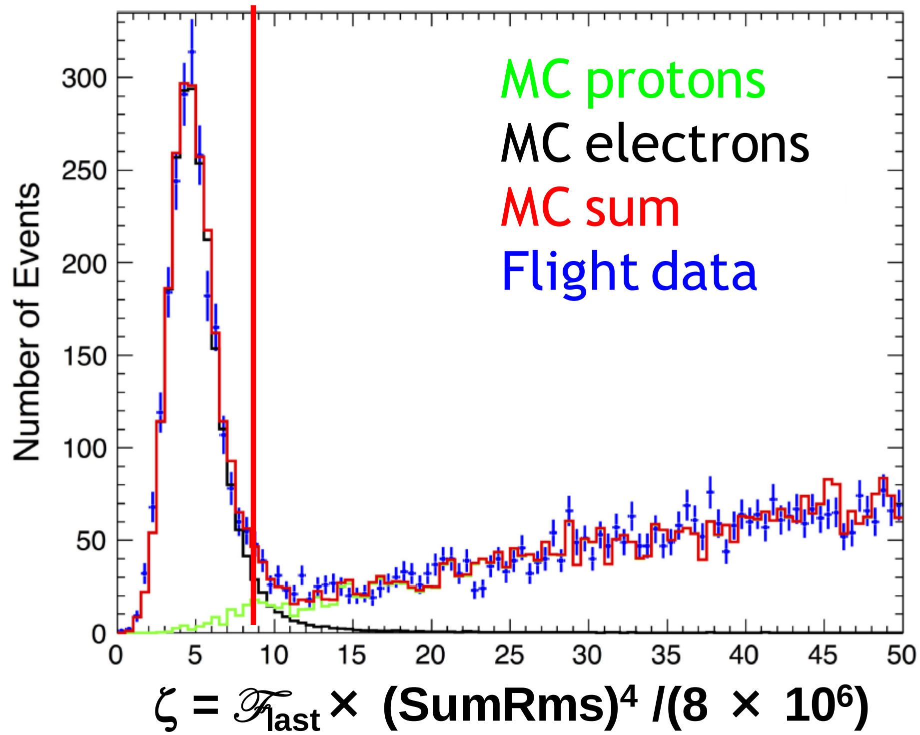




- An energy scale higher by (1.2+/-1.3)% from the geomagnetic cutoff
- Cutoff energy is stable with time (a slight decrease due to solar modulation)

e/p separation

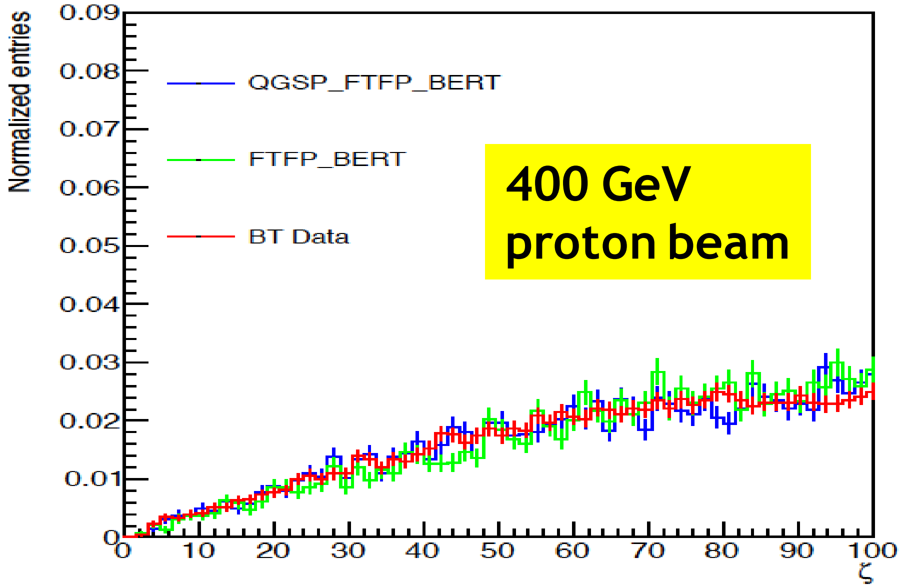


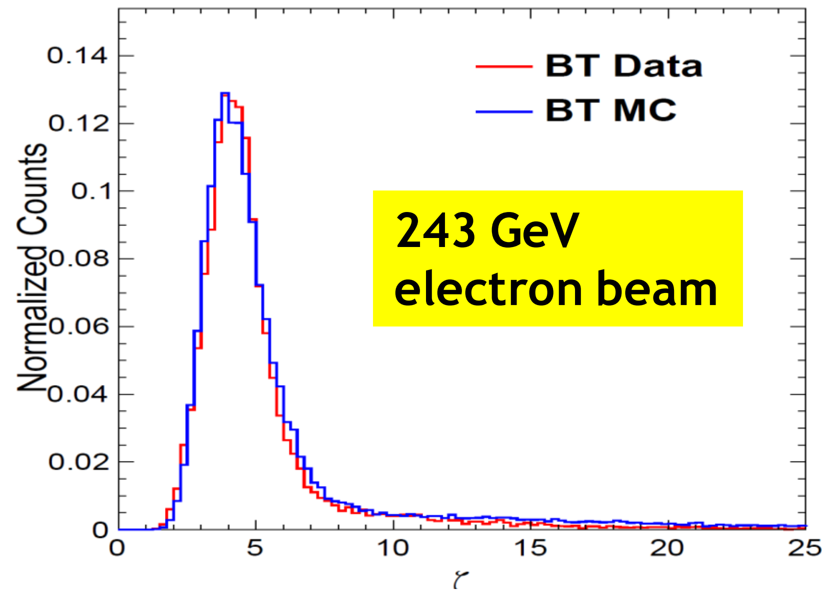


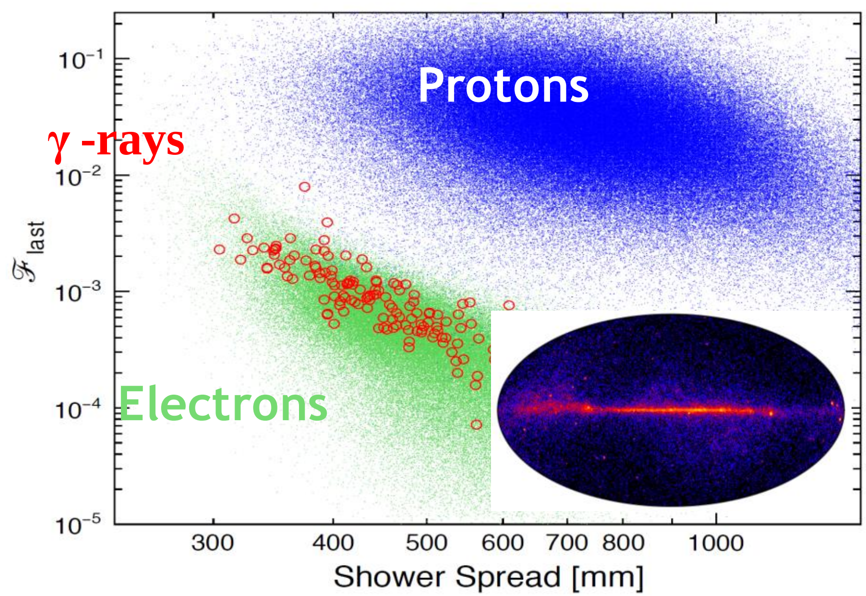
- We use the lateral (SumRMS) and longitudinal (energy ratio in last layer) developments of the showers to discriminate electrons from protons
- For 90% electron efficiency, proton background is ~2% @ 1TeV, ~5% @ 2 TeV, ~10% @ 5 TeV

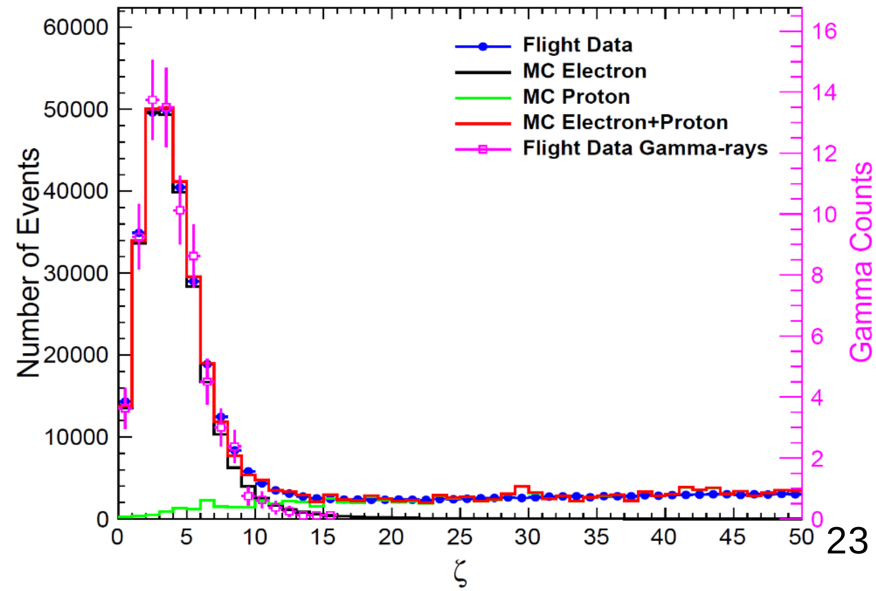
Nature, 552, 63 (2017)

Validation of e/p separation



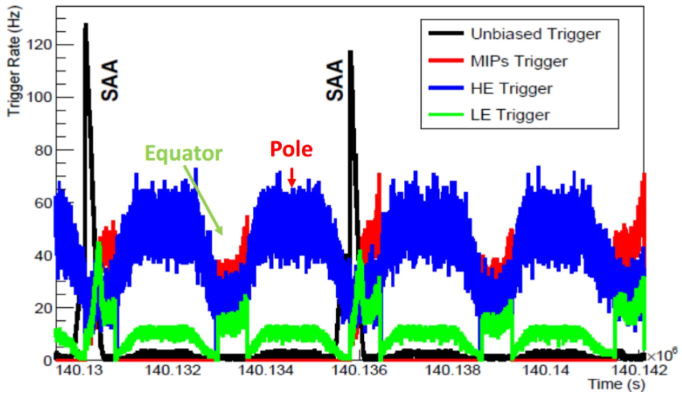


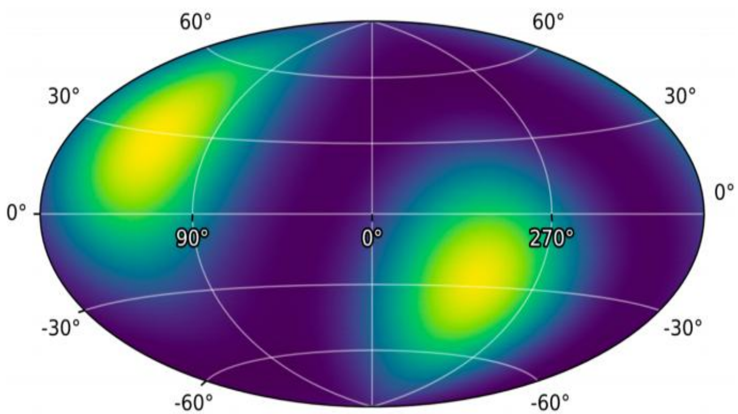




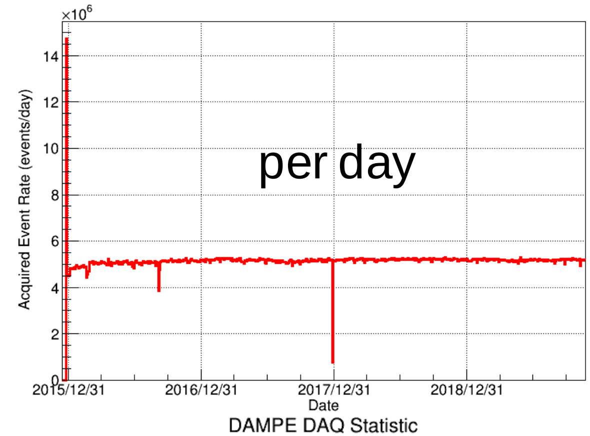
Stable Data Taking

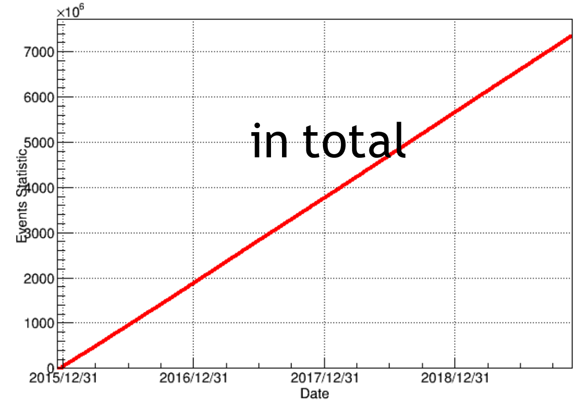
event rate in 2 orbits





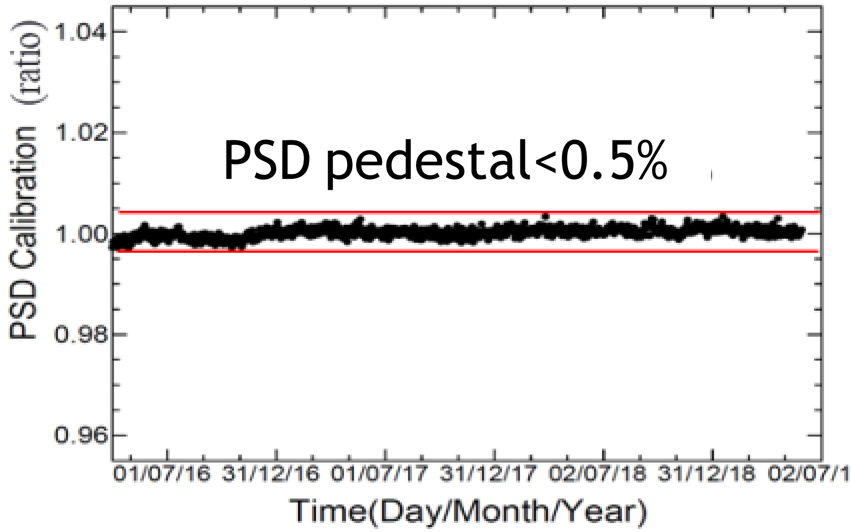
DAMPE 3.5 year counts map

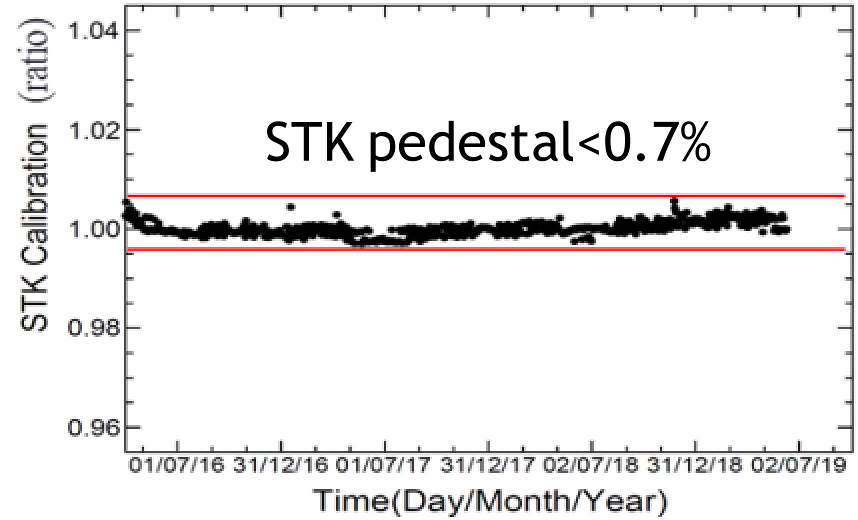


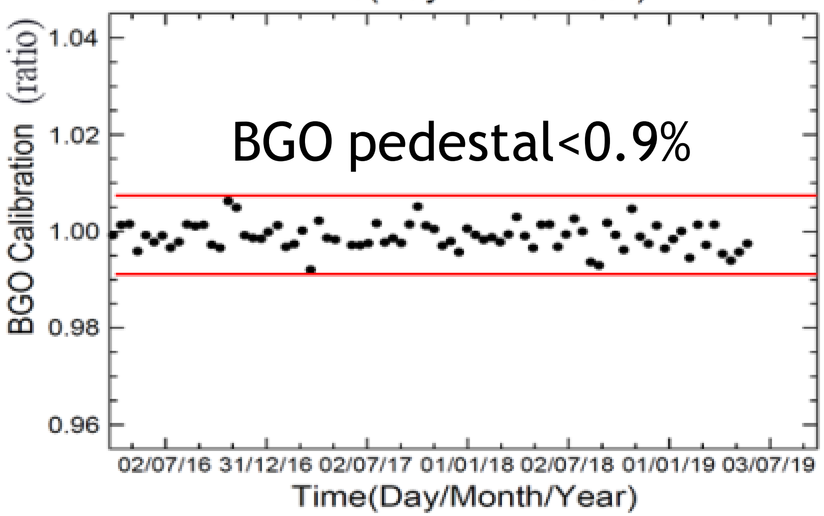


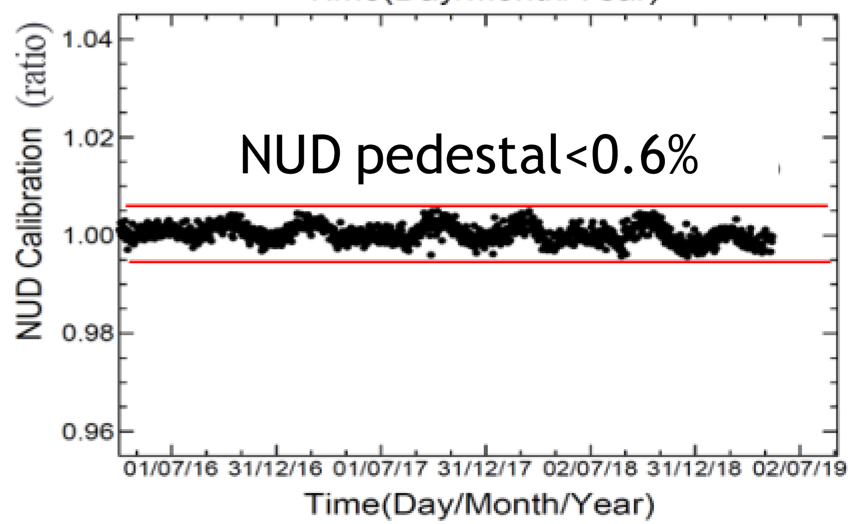
5M events/day
7.3 billion in total

Detector stability



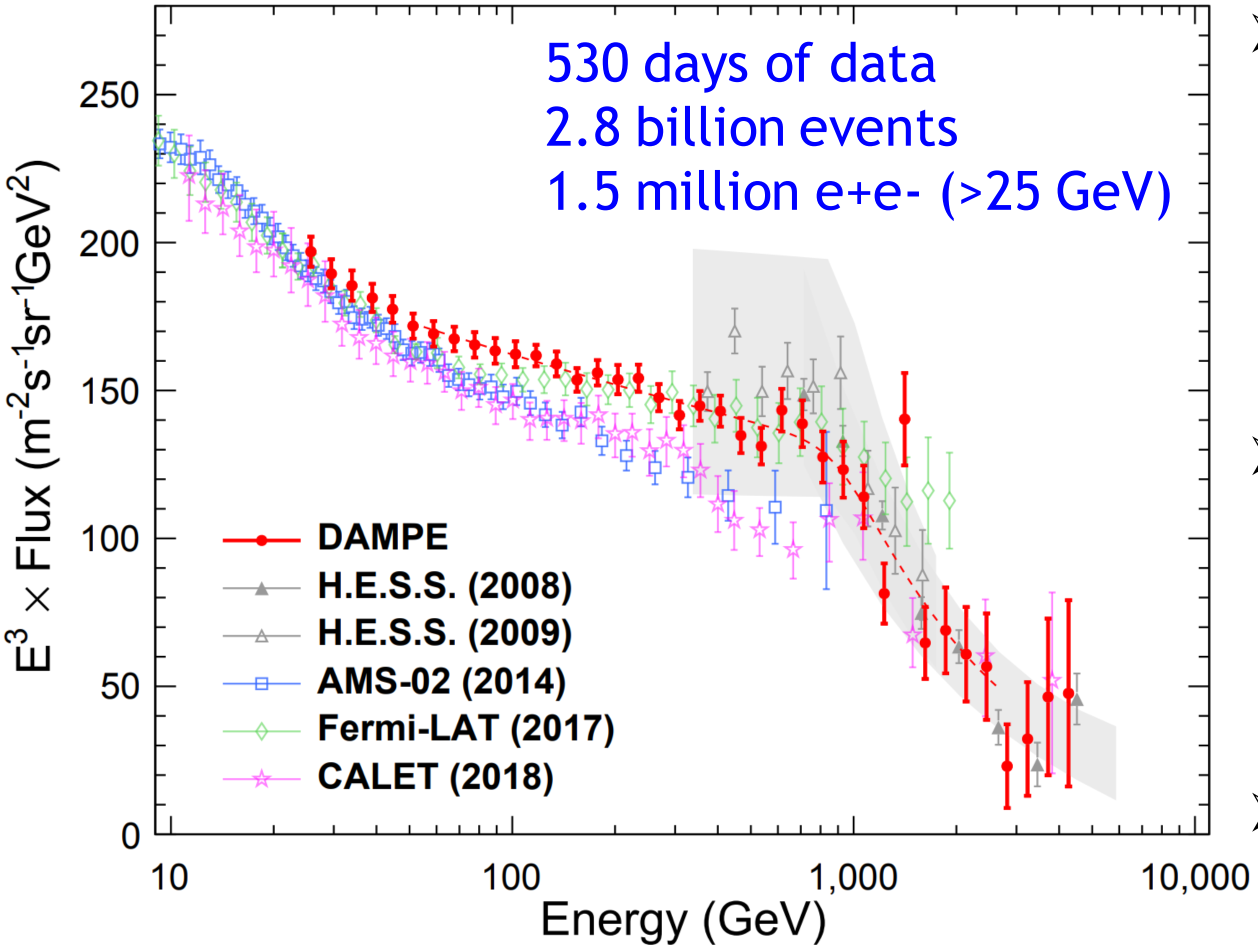






Physical results

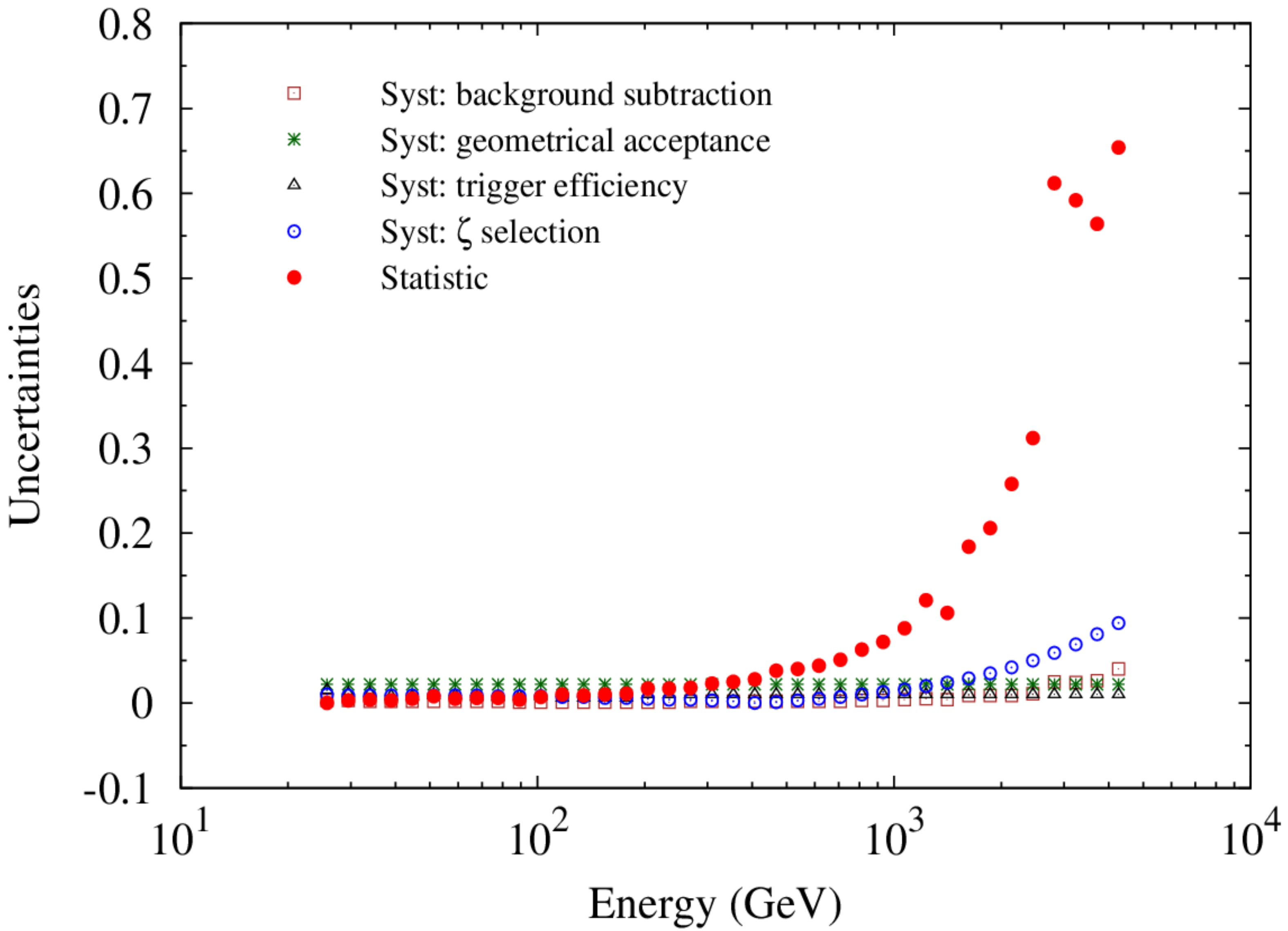
Total $e^{+}+e^{-}$ spectrum



- Three different PID methods give very consistent results on event-by-event level
- Direct detection of a spectral break at ~0.9TeV with 6.6σ confidence level
- Analysis with new data is on-going

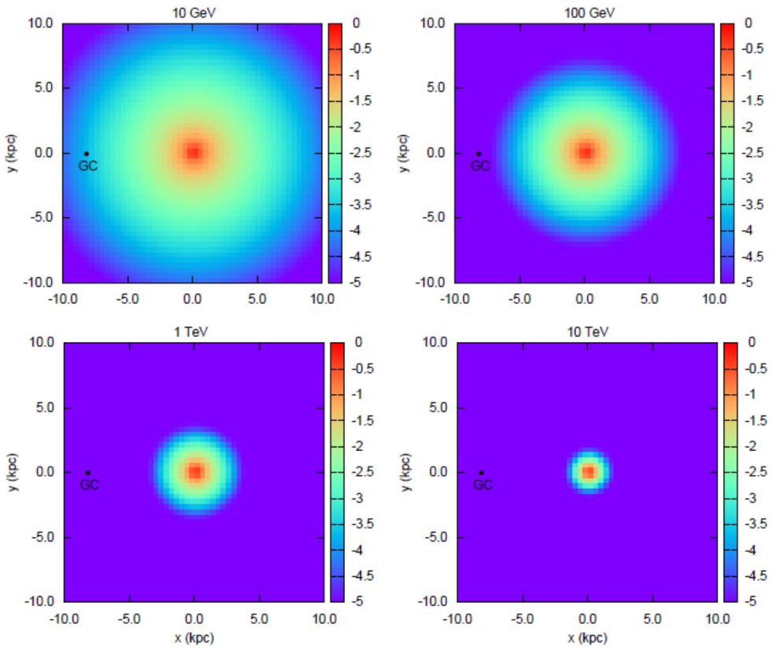
Nature, 552, 63 (2017)

Errors of $e^{+}+e^{-}$ spectrum

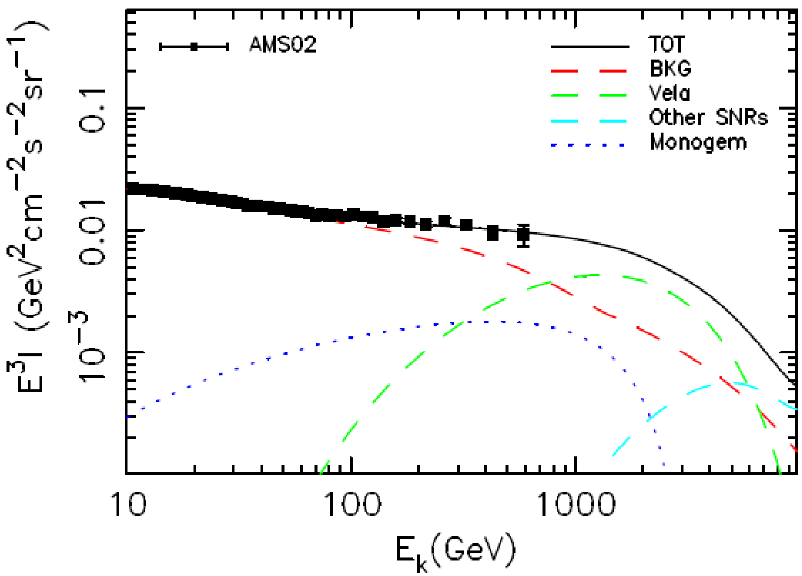


Implication of the spectral softening: discreteness of source distributions?

- 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)

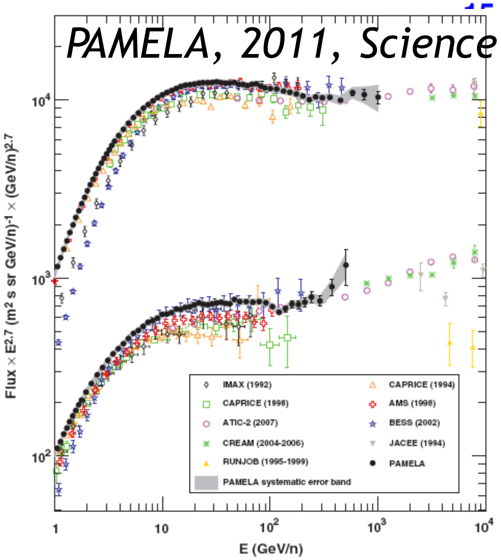


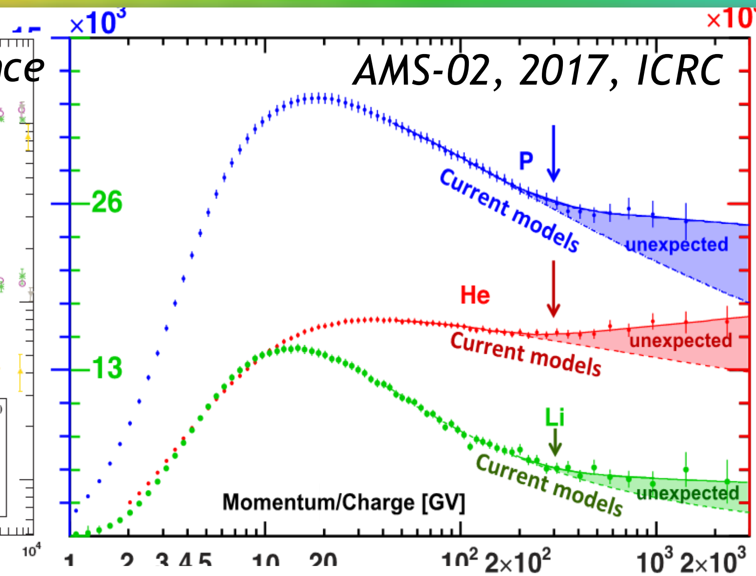
Astrophys. J., 836, 172 (2017)

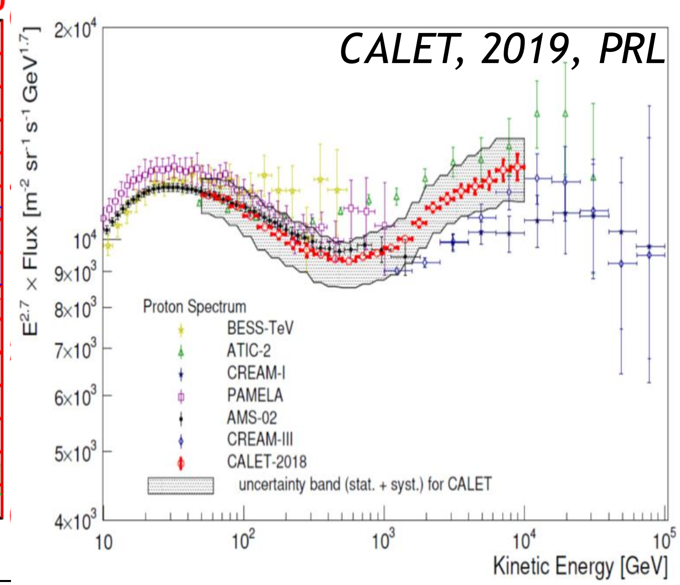


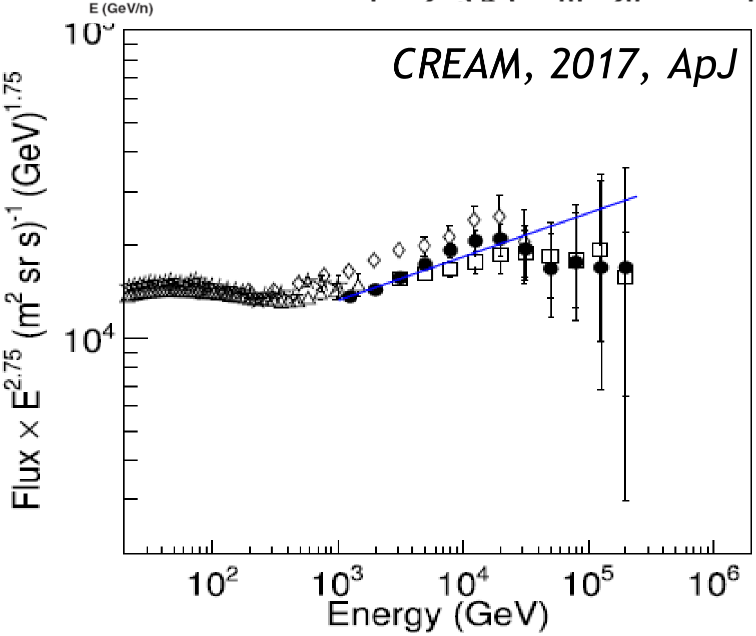
Fang et al. (2017)
Di Mauro et al. (2017)
Manconi et al. (2019)...

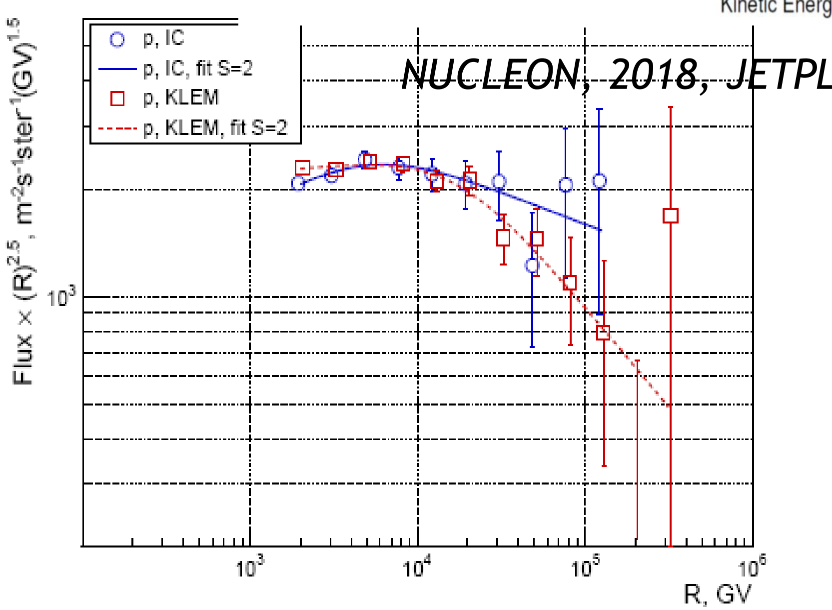
Spectral structures of nuclei



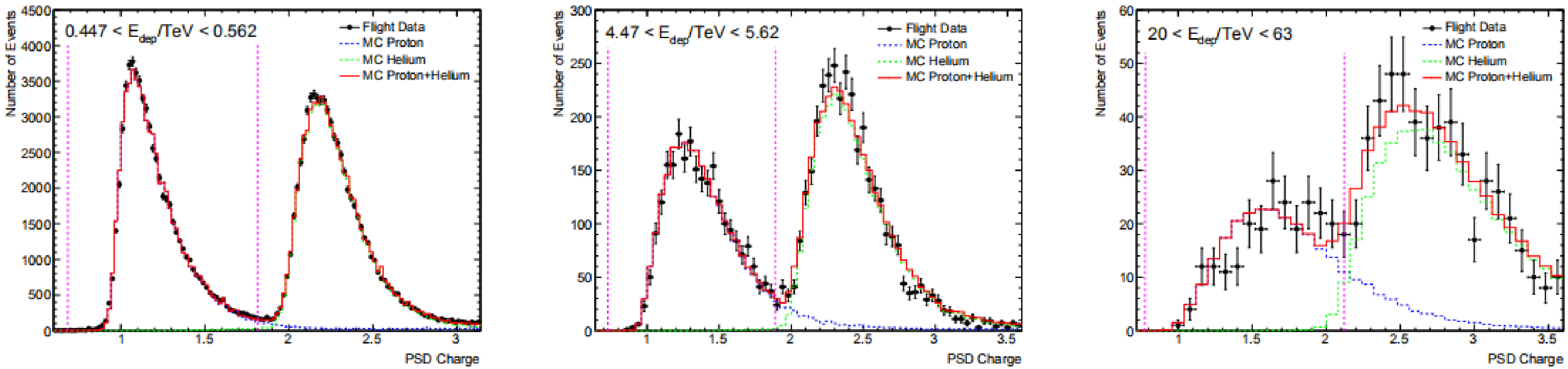




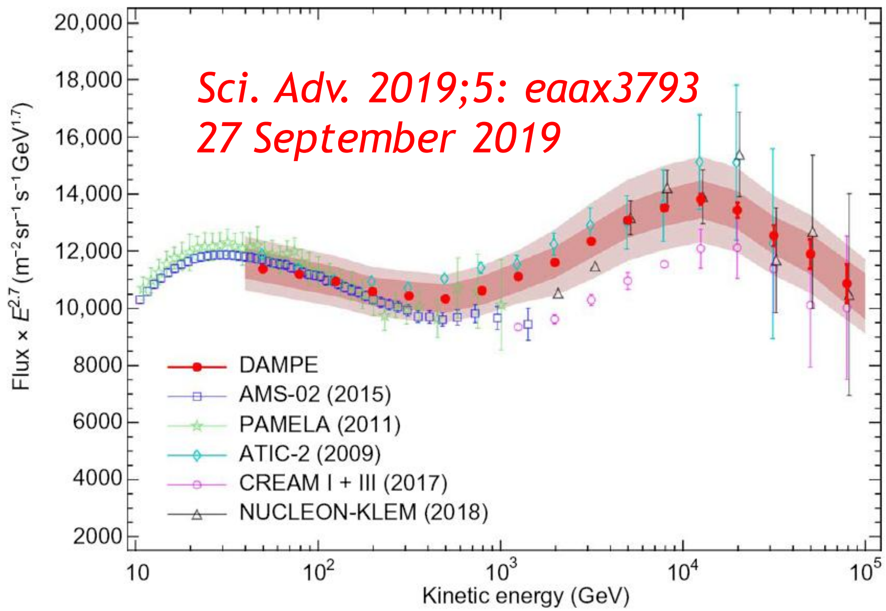




DAMPE proton spectrum

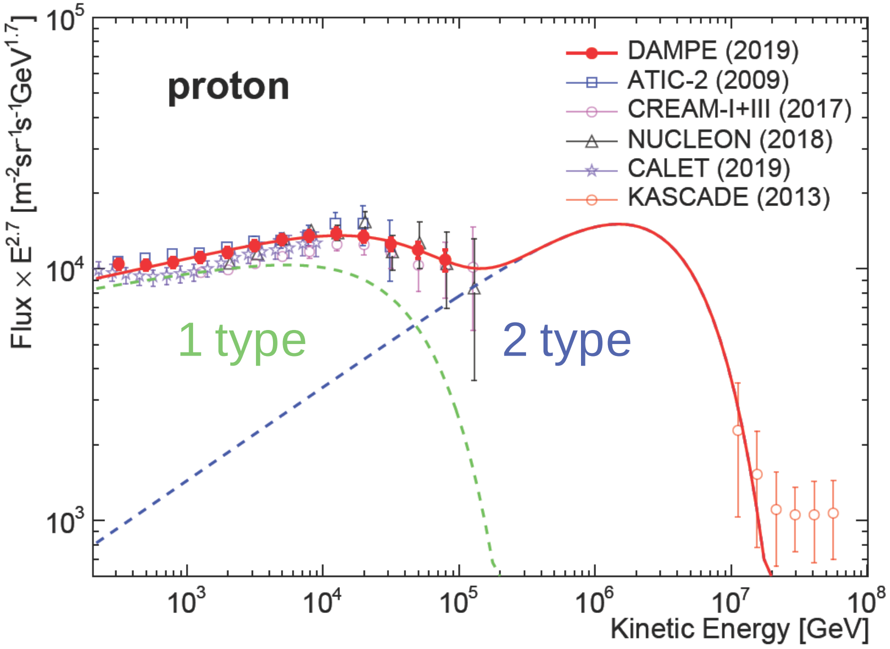


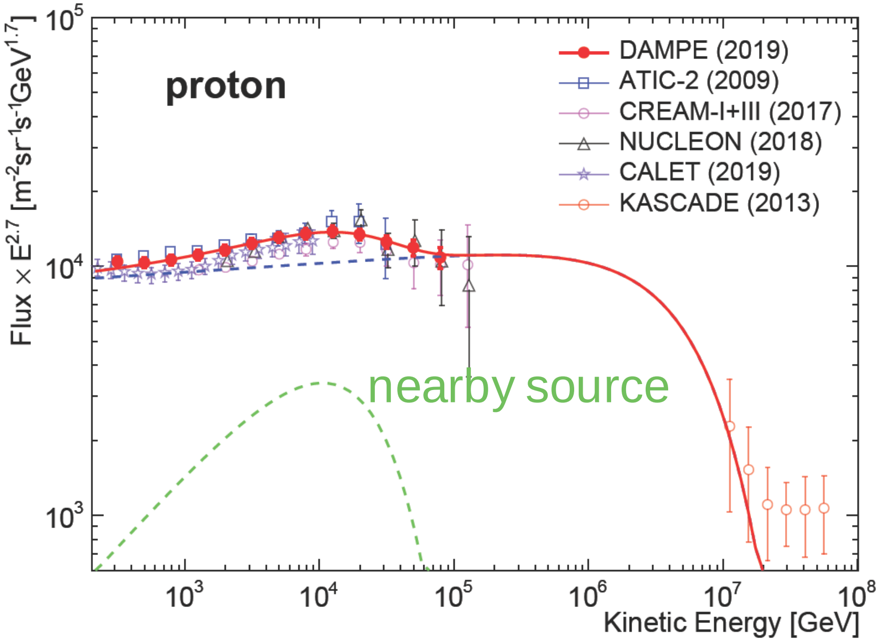
- Confirms the hundreds GeV hardening
- Reveals a softening at ~13 TeV with high significance



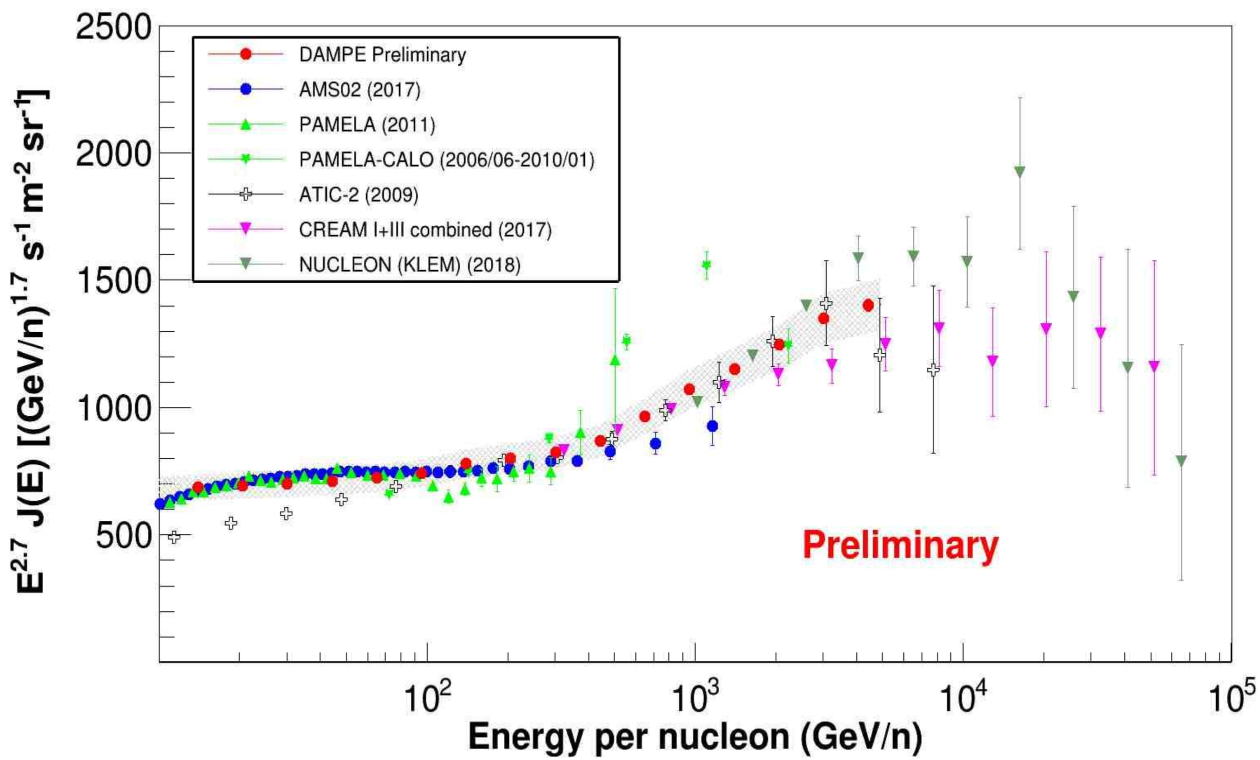
Implications: source population(?) Nearby source(?)

Chuan Yue et al.(2019) arxiv：1909.12857



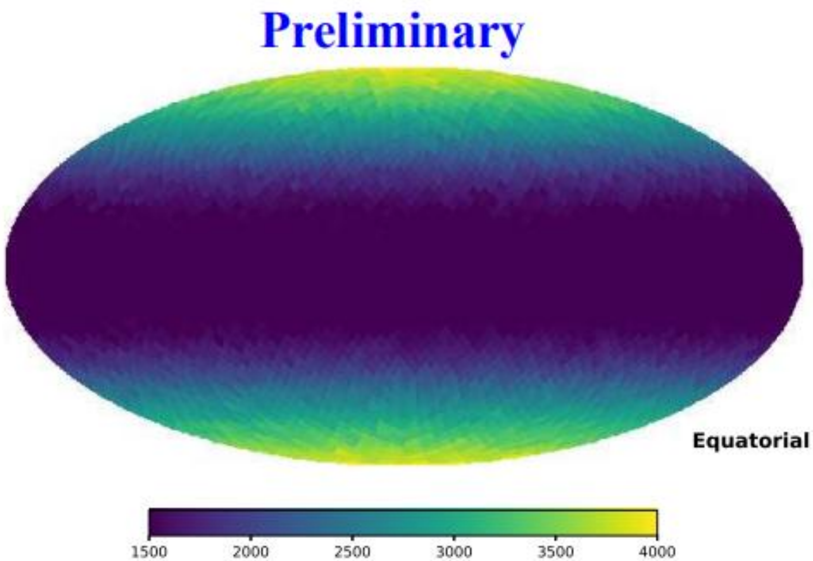


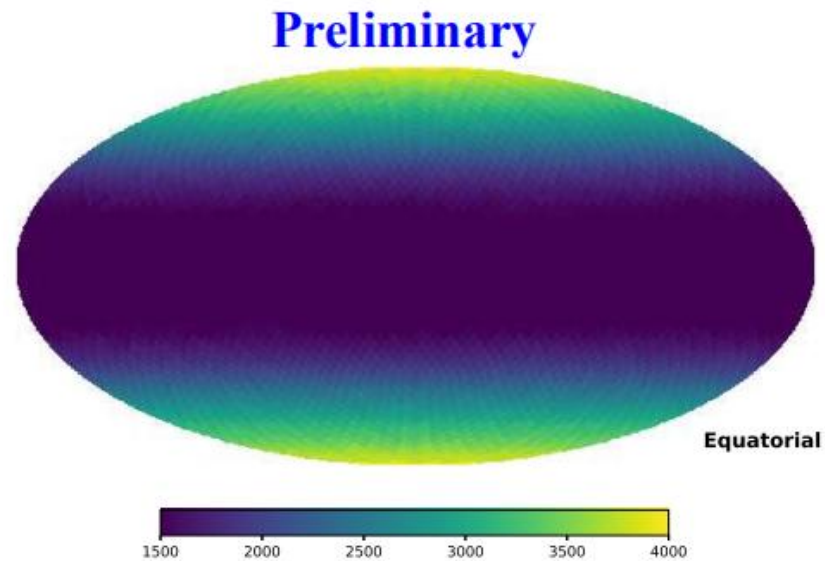
DAMPE helium spectrum

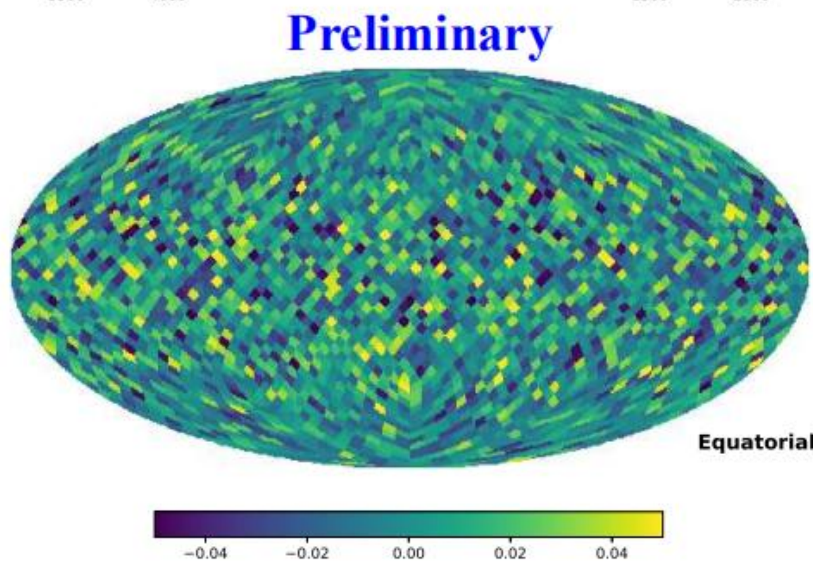


See:
Volume 358 - 36th International Cosmic Ray Conference (ICRC2019) - CRD
https://pos.sissa.it/358/058/

Cosmic ray anisotropies







95% UL of dipole amplitude for 1-yr data (>~300 GeV): 6.7×10^{-3}

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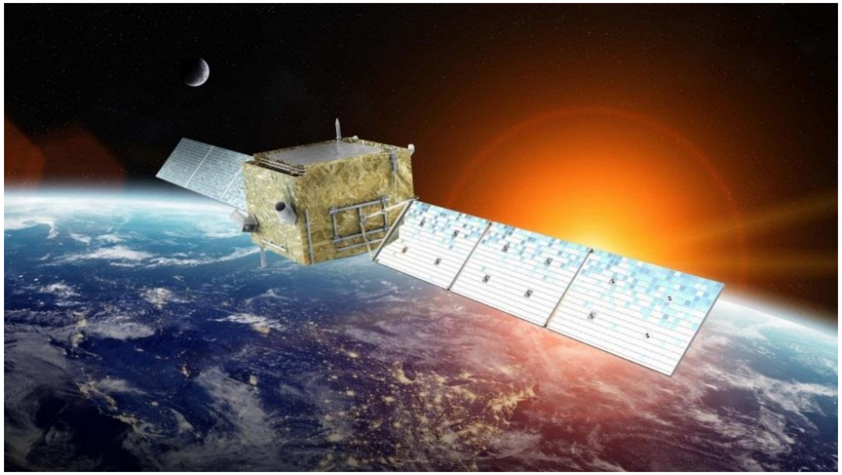
https://pos.sissa.it/358/113/

Summary

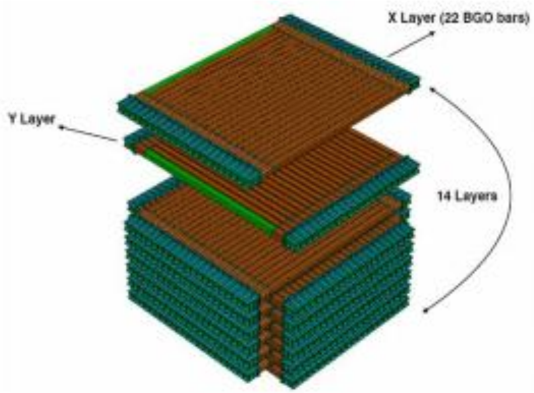
- DAMPE detector is working extremely well since launch
- Precise measurements of the e^{+}+e^{-} spectrum from 25 GeV to 4.6 TeV have been obtained, showing a spectral break at ~0.9 TeV energies
- Precise measurements of proton spectrum from 40 GeV to 100 TeV have been obtained, revealing interesting softening features at ~10 TeV
- More results are coming



Backup

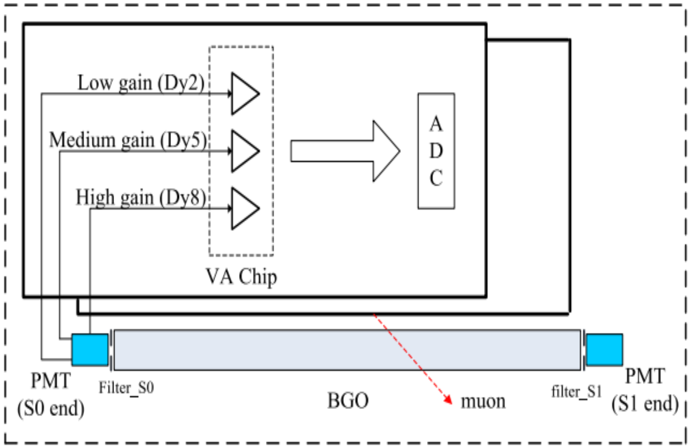
Energy measurement

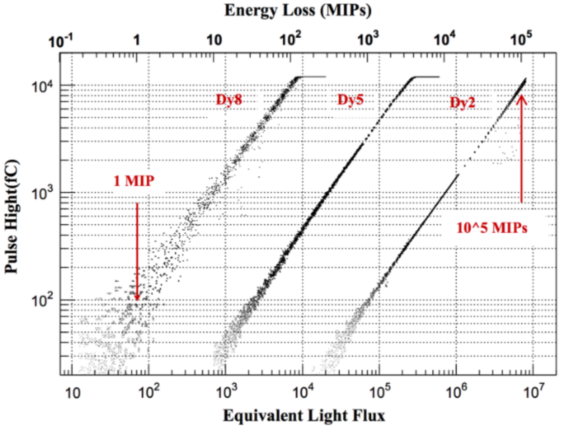
BGO calorimeter



308 BGO bars

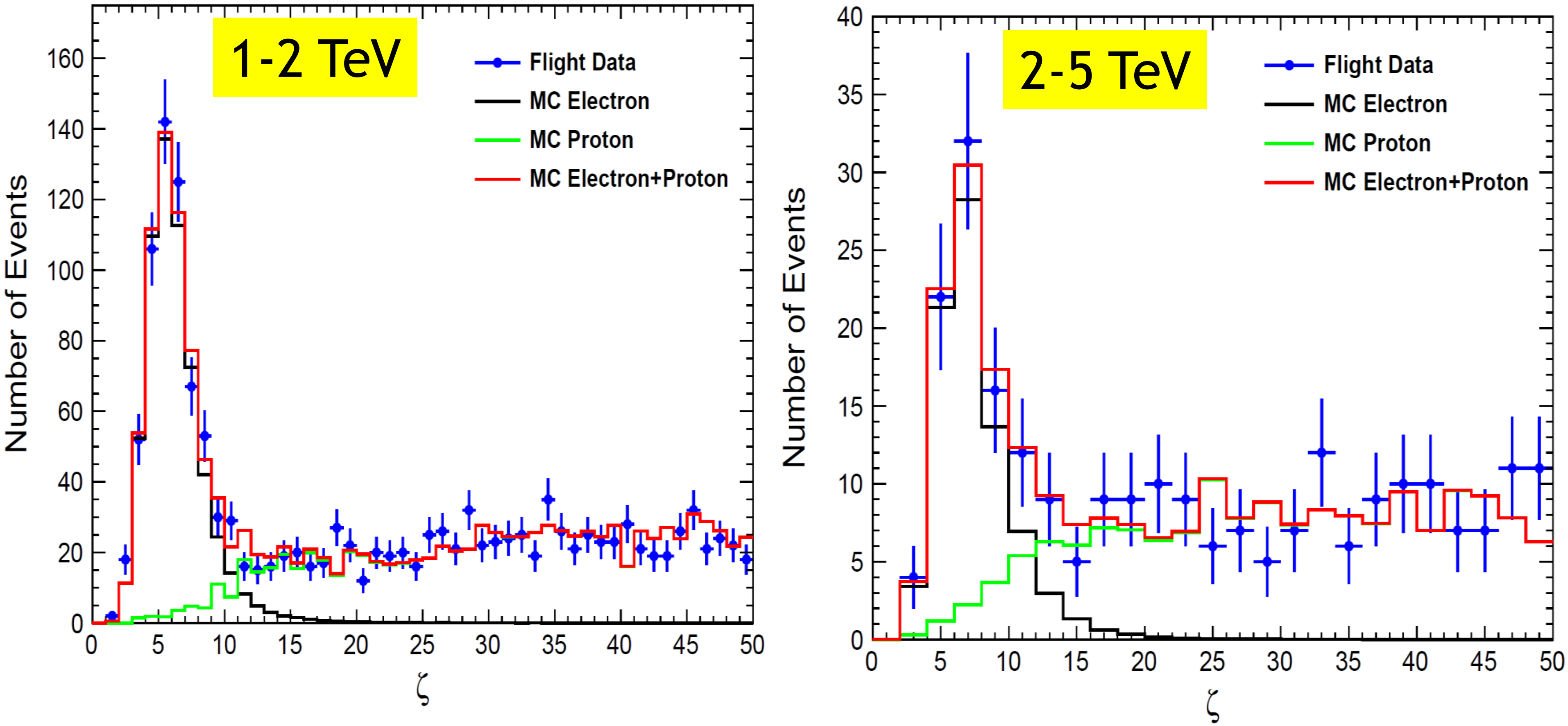
616 PMTs





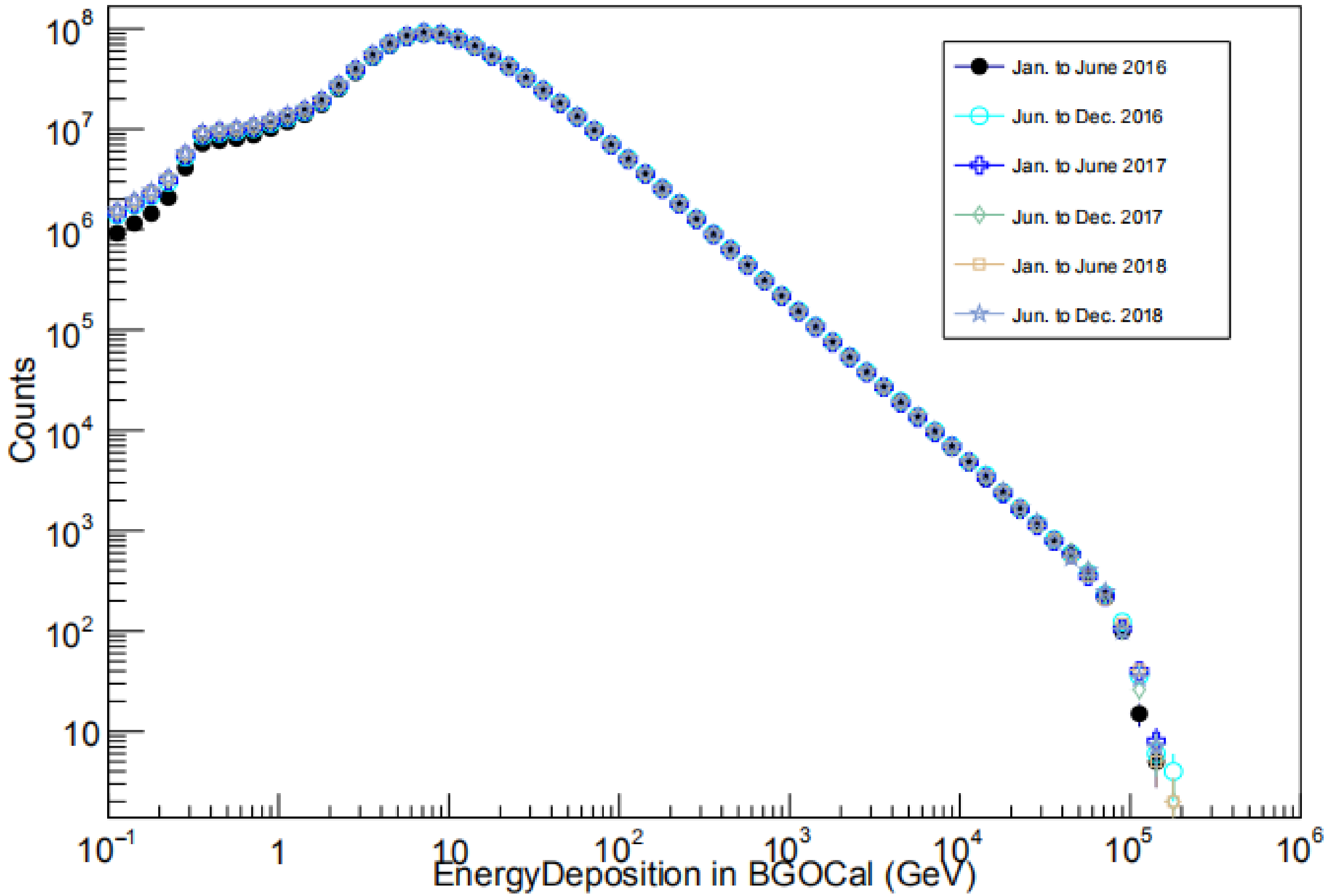
- Thick calorimeter (32 X_0): high-resolution
- Two-side readouts
- Three dynode outputs enable a $>10^6$ dynamic range

e/p separation at higher energies

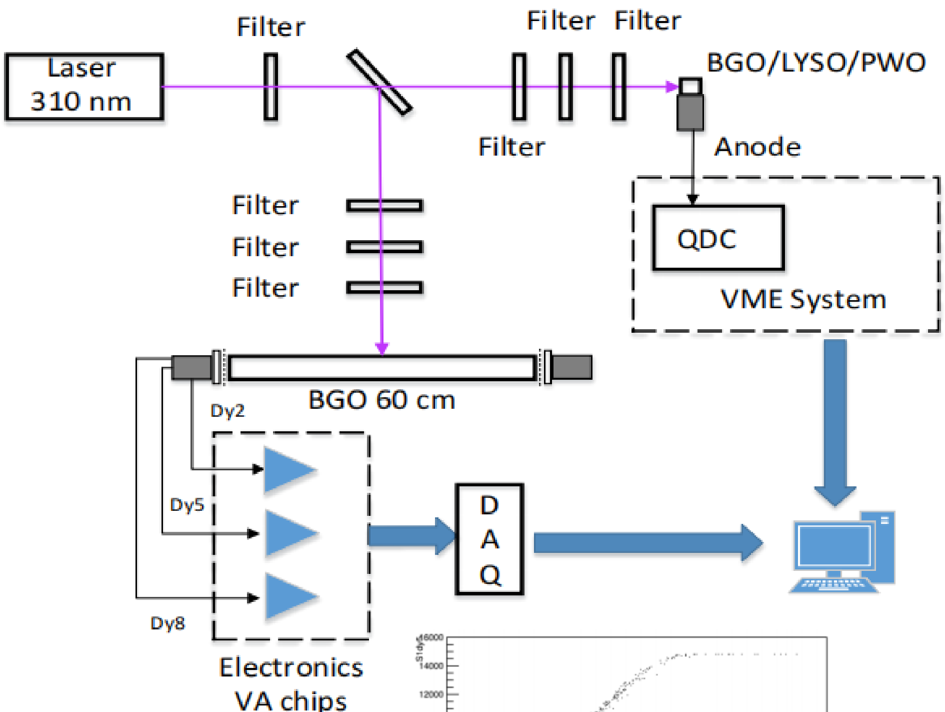


For 90% electron efficiency, proton background is ~2% @ TeV, ~5% @ 2 TeV, ~10% @ 5 TeV.

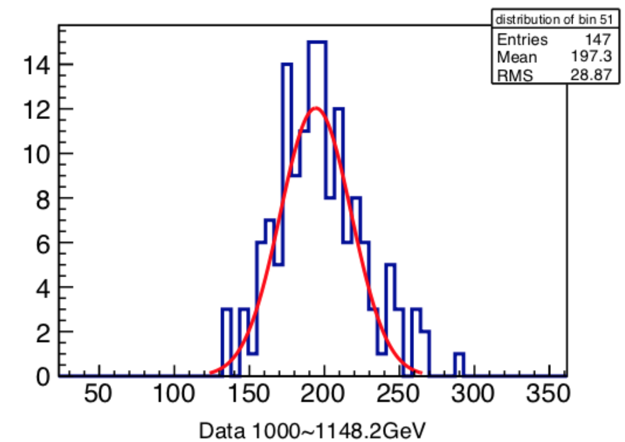
Raw count spectra

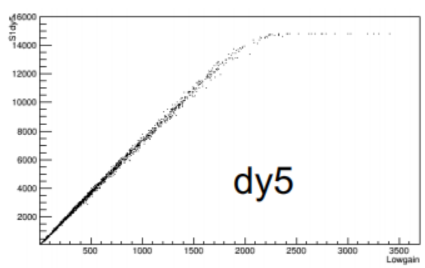


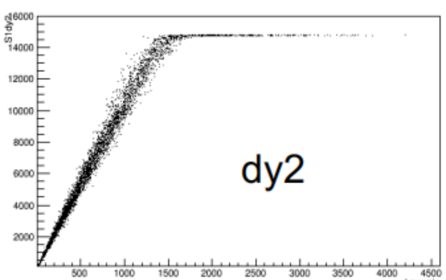
Laser experiment

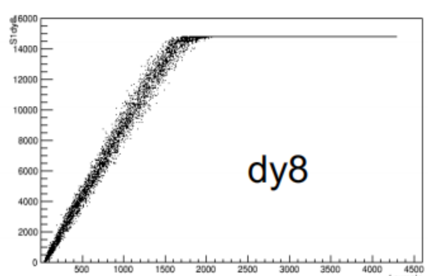


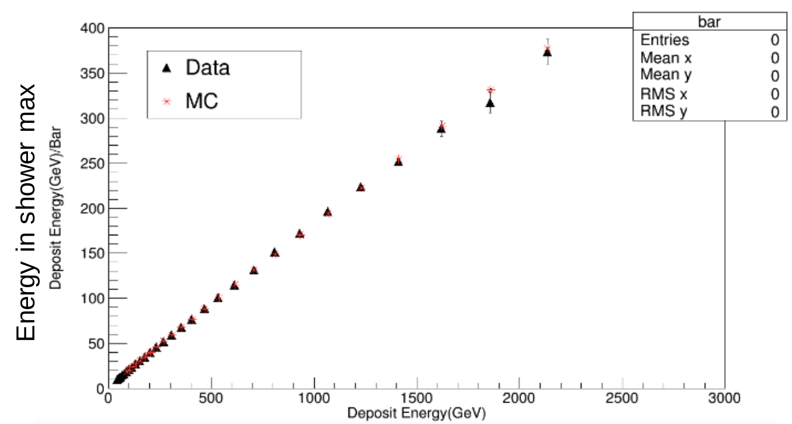
Energy in shower max



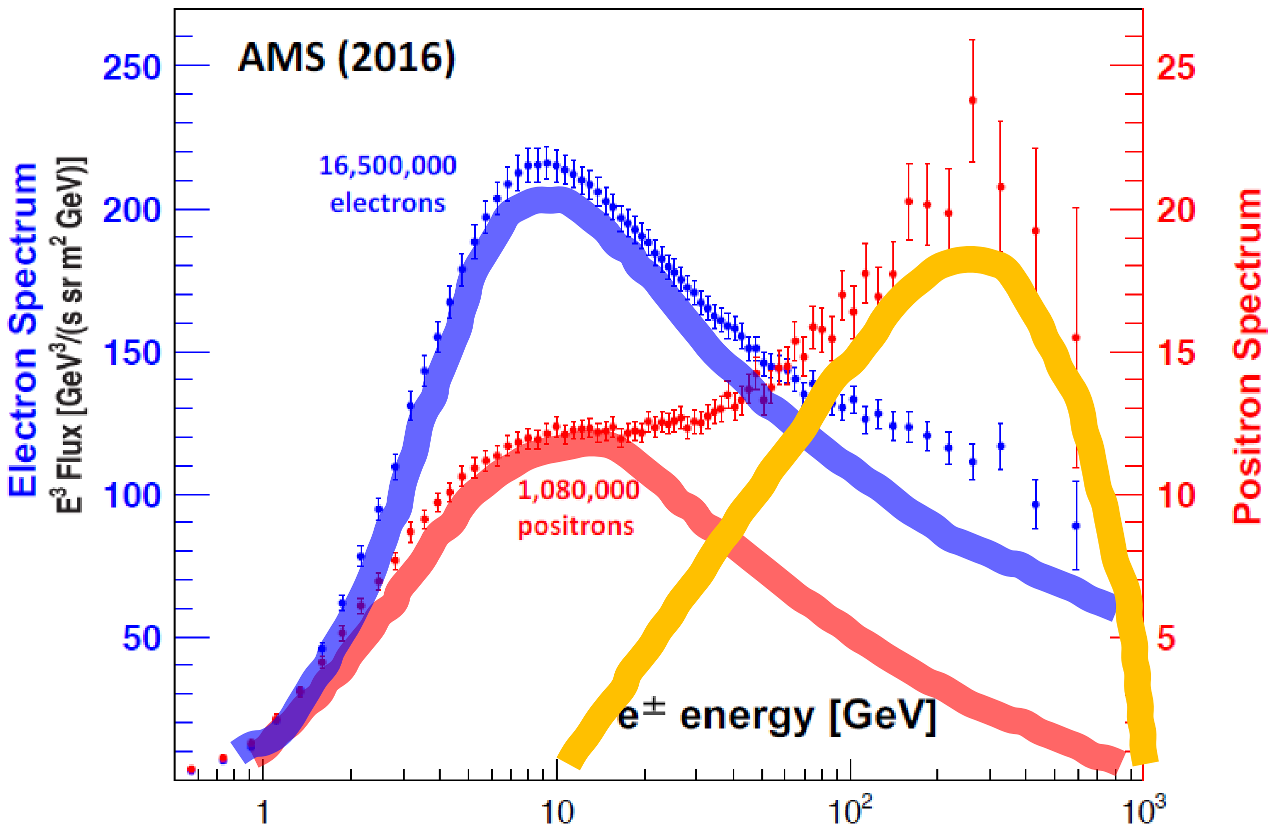








Three-component e^+e^- model



- 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, ...)