中国科学技术大学

The Status of the DAMPE BGO calorimeter in space

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17/05/2022

Outline

- DAMPE Experiment
- BGO Calorimeter
- In-flight status
- Summary

DAMPE Experiment

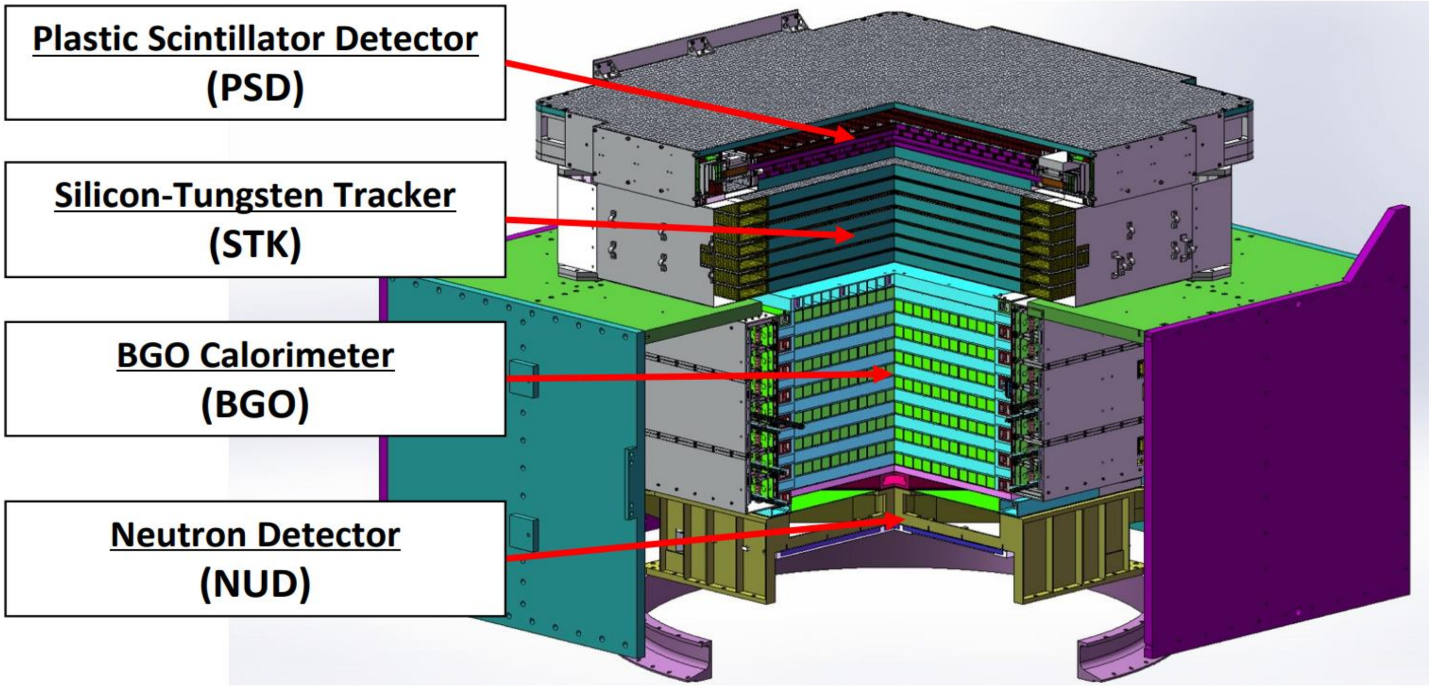
- DAMPE (DArk Matter Particle Explorer) is a spaceborne high-energy cosmic ray and gamma-ray detector
- Launch: December 17, 2015
  - sun-synchronous orbit at the attitude of 500 km
  - Total weight ~1850 kg, power consumption ~640 W
    - Scientific payload ~1400 kg, 400 W
  - Operation time > 6 years

Scientific goals

- Search for dark matter particles in electrons and γ-rays
- Study of cosmic ray acceleration, propagation, and interaction
- Study of high-energy γ-ray astronomy

DAMPE Experiment

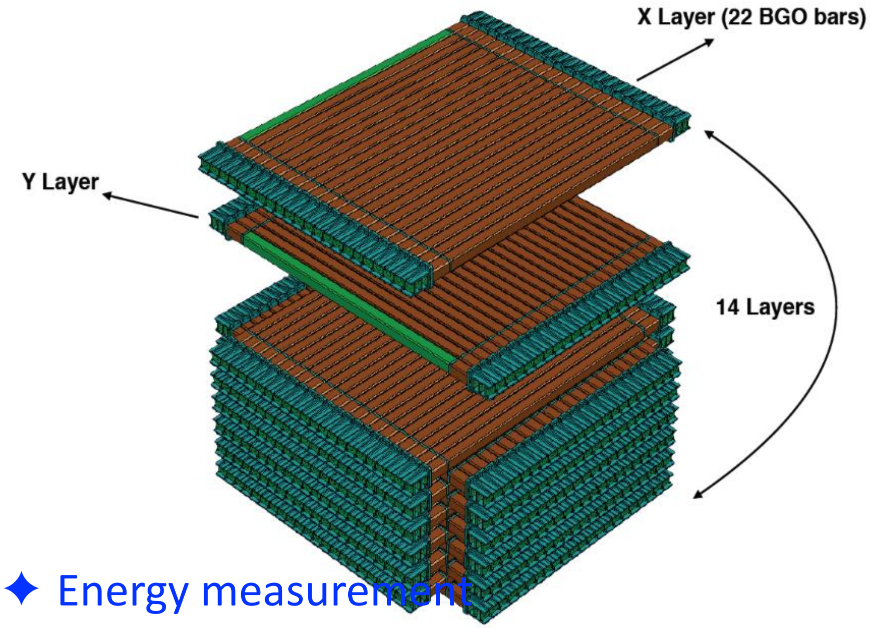
DAMPE detector

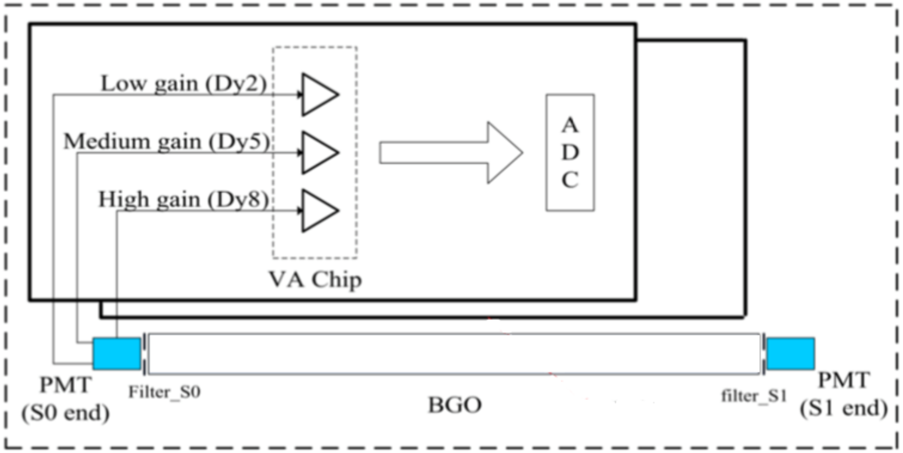


- Charge measurement (dE/dx in PSD, STK and BGO)
- Pair production and precise tracking (STK and BGO)
- Precise energy measurement (BGO)
- Electron/hadron identification (BGO and NUD)

BGO Calorimeter

- 308 BGO bars ($2.5 \times 2.5 \times 60\ \mathrm{cm}^3$)
- 14 layers, 22 bars per layer
- Hodoscopic stacking alternating orthogonal layers
- Depth: 32 X_0, 1.6 λ_I
- Energy resolution: 1.5% @800 GeV for e/γ





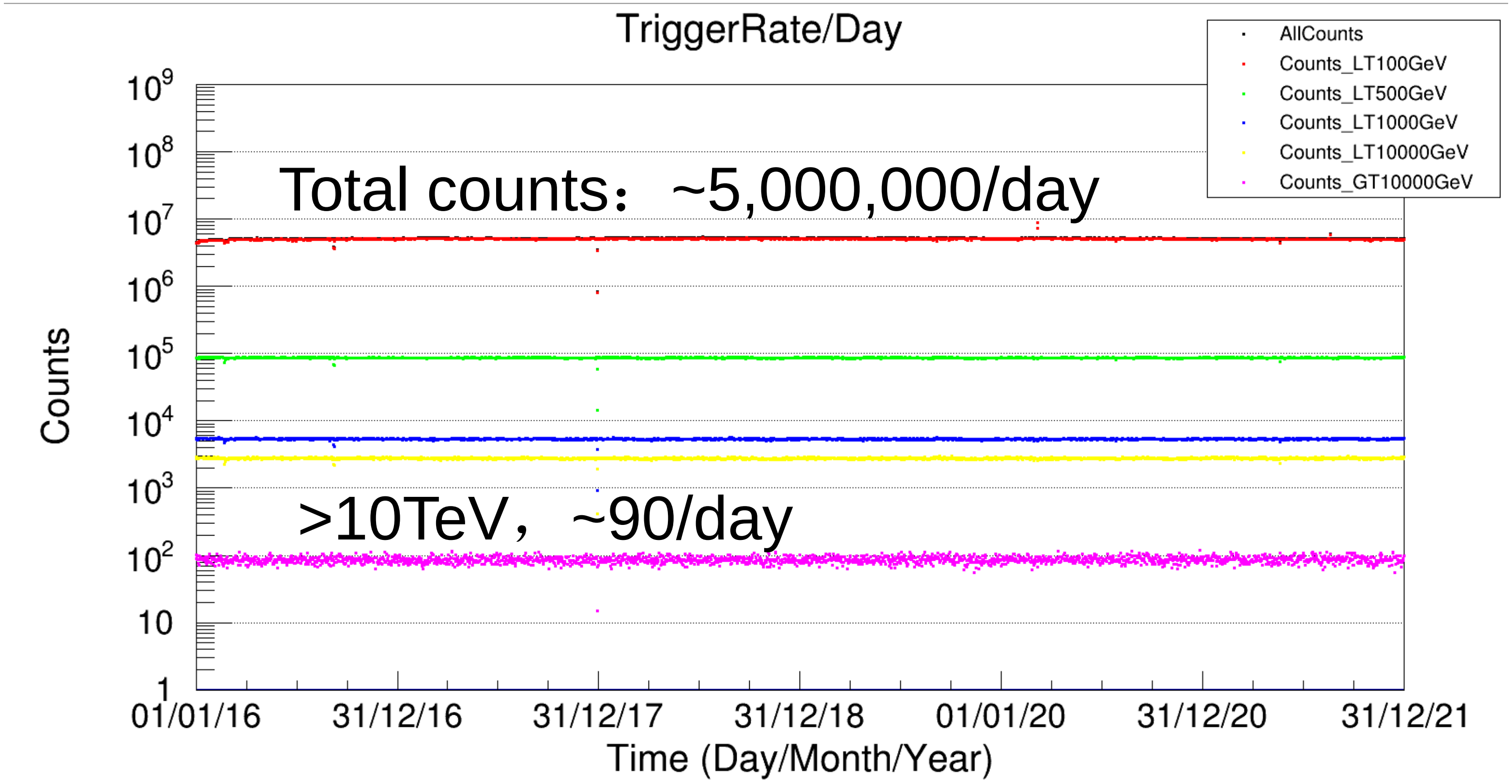
✦ Energy measurement
✦ e/p separation
✦ Provide trigger

Large dynamic range (5 GeV-10 TeV)
-Two PMTs with different attenuation filters coupled with each BGO crystal bar in two ends
-Multi-dynode readout of each PMT

In-flight status

Data acquired during six years

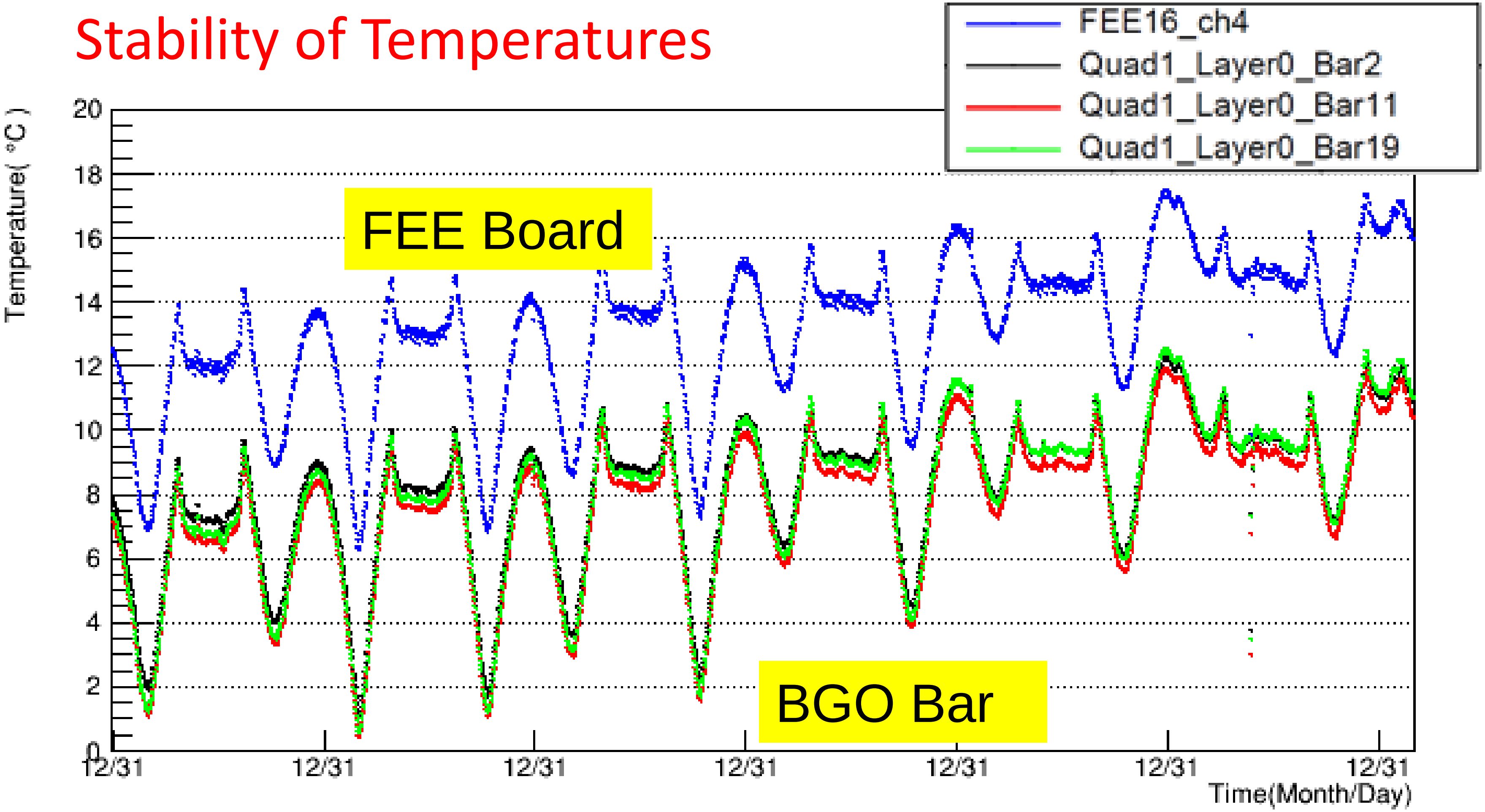
Time interval: 2016/01/01 - 2021/12/31



The amount of data collected every day is generally stable

In-flight status

Stability of Temperatures

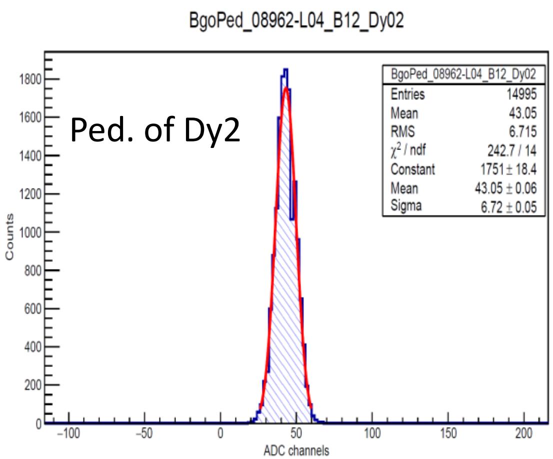


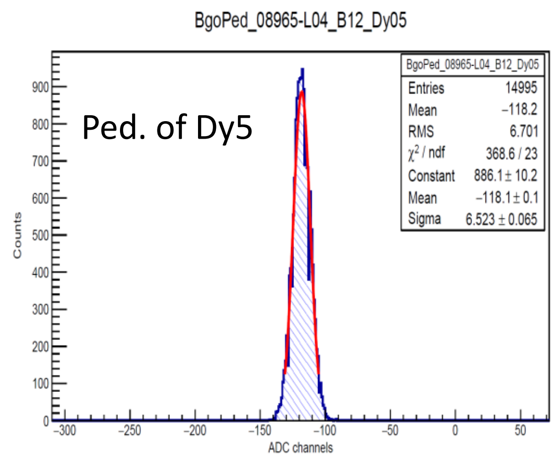
Temperature varies periodically and steadily

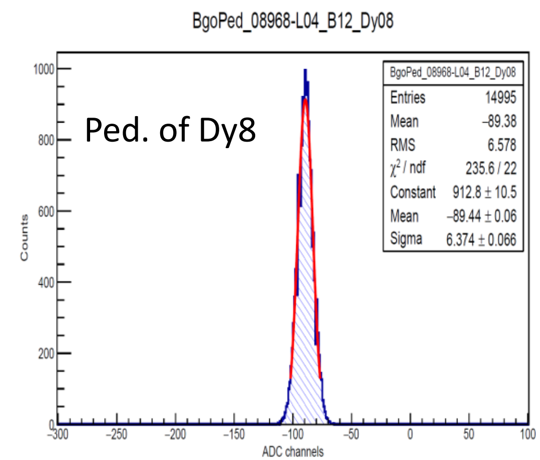
In-flight status

Pedestal

- The pedestal reflects the baseline and noise level of electronics.



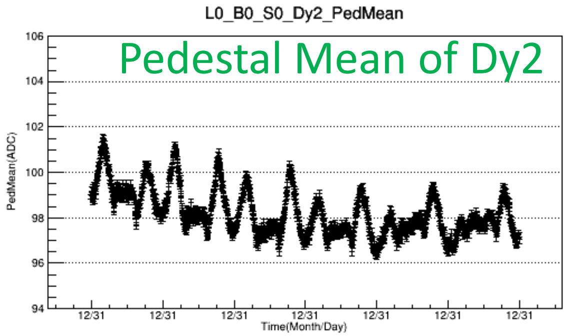


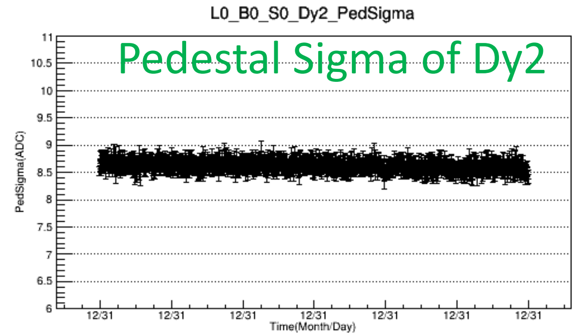


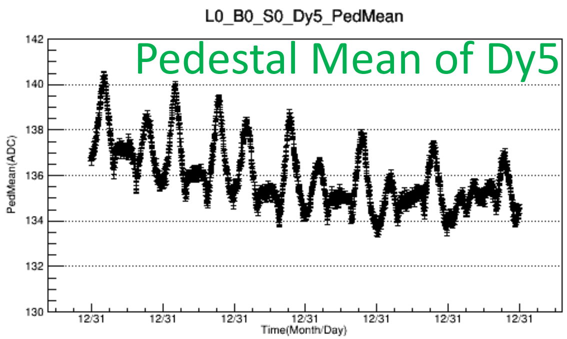
In order to measure the energy from 5GeV to 10TeV, a multi-dynode readout structure of PMT is designed.

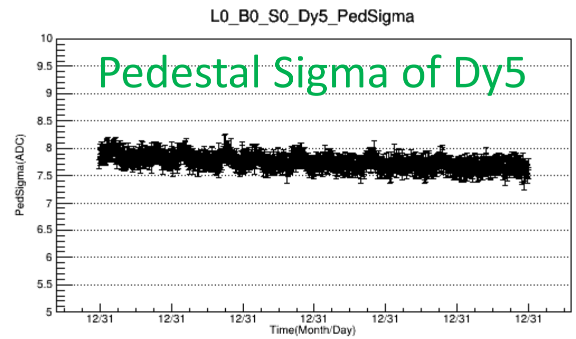
In-flight status

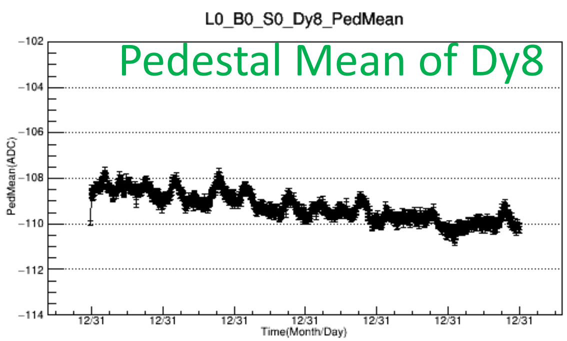
Pedestal stability

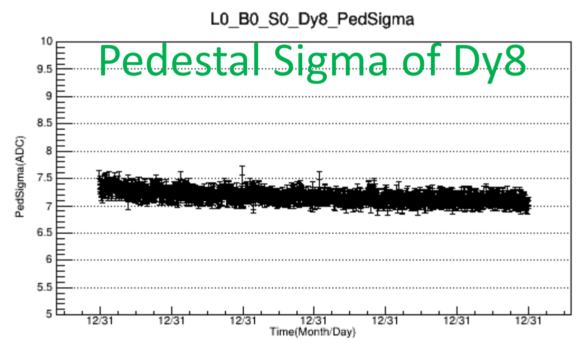






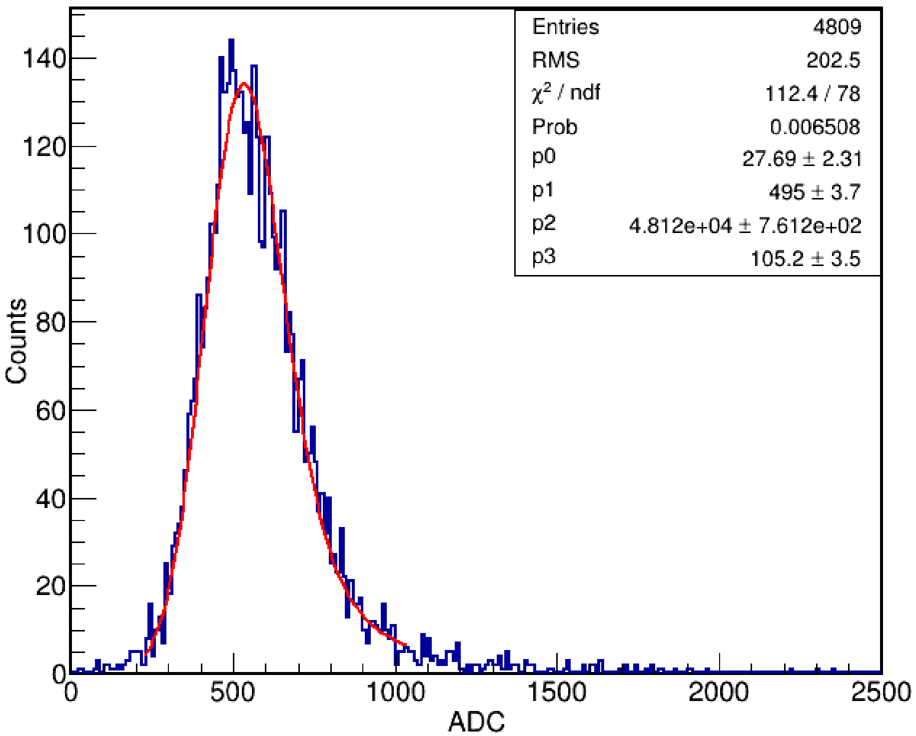


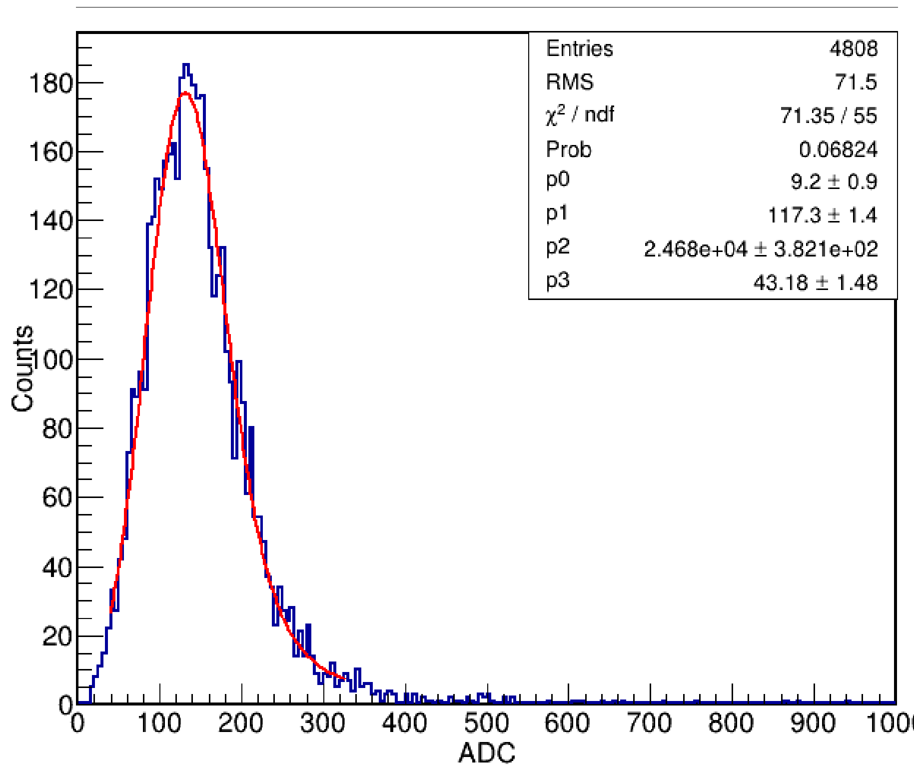




In-flight status

The MIP Spectra of a BGO bar



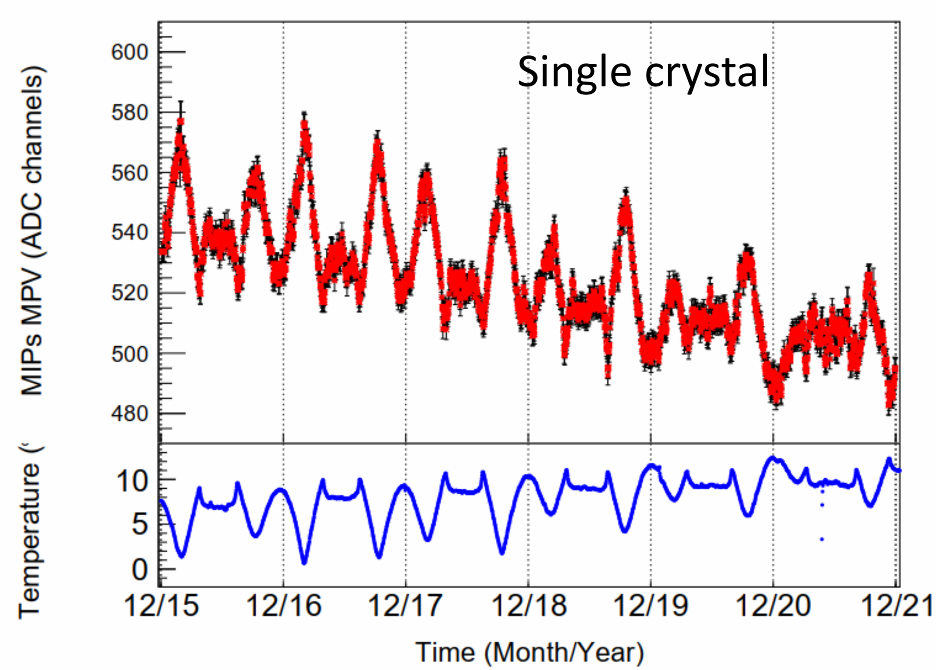


The response of the BGO Calorimeter to MIPs is the reference of energy reconstruction, and the precision of the MIP calibration influences the energy reconstruction directly.

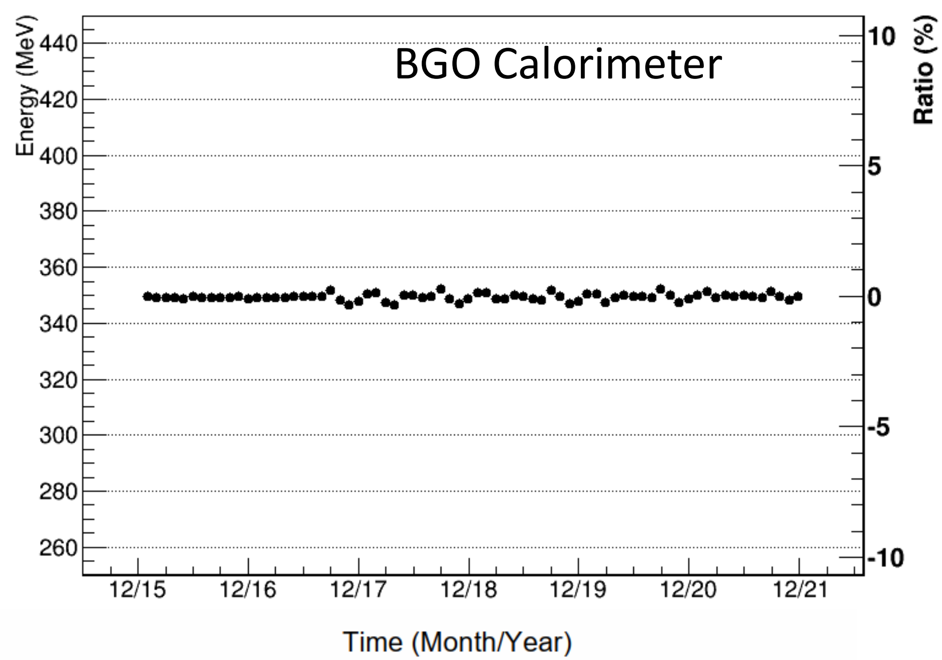
In-flight status

Stability of MPV for MIP proton events

before temperature correction



after temperature correction



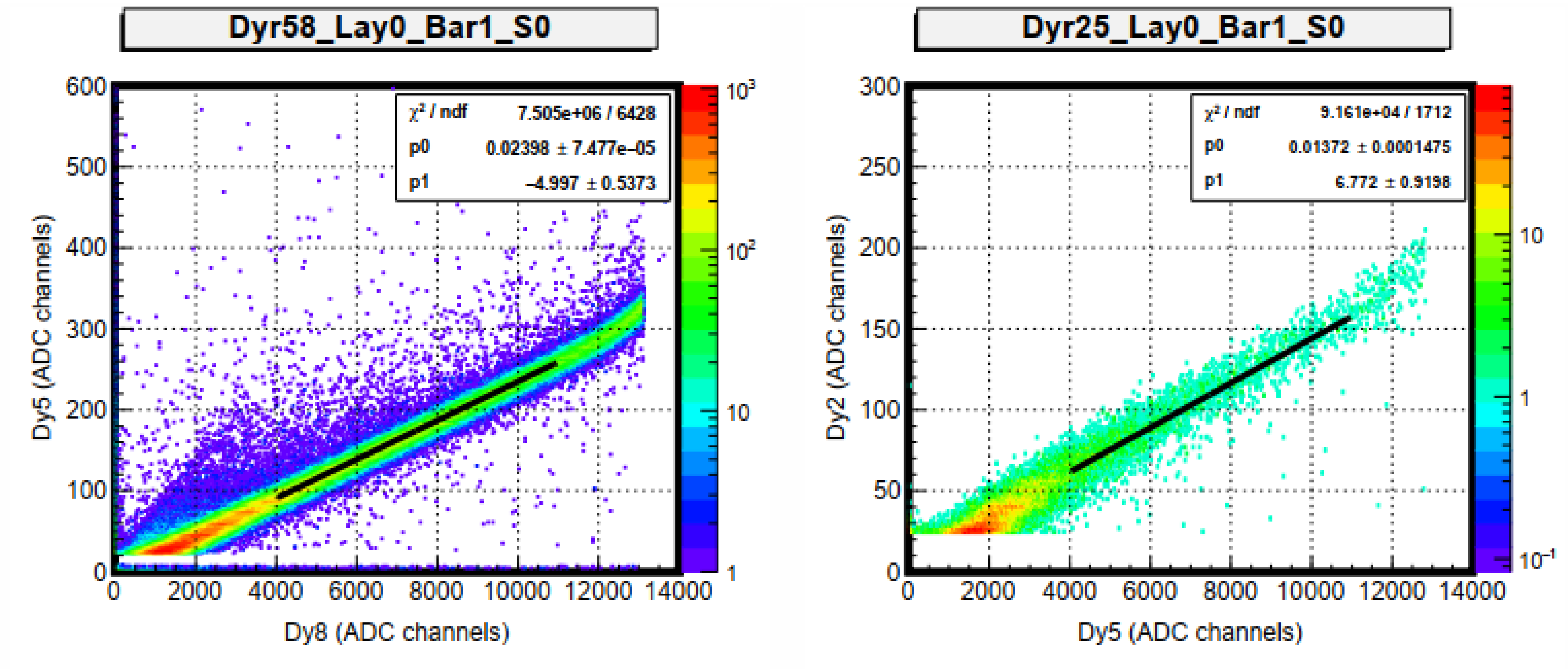
The MIPs MPV value and the temperature are roughly anti-correlated.

After temperature correction, Proton MIPs energy reconstruction stability is better than 1%

In-flight status

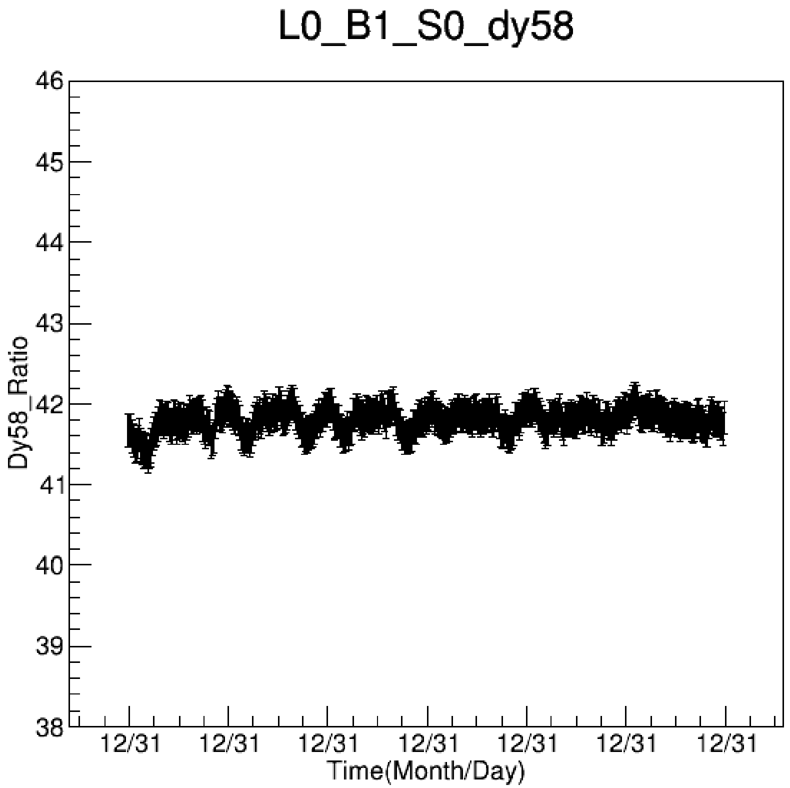
Dynode ratio

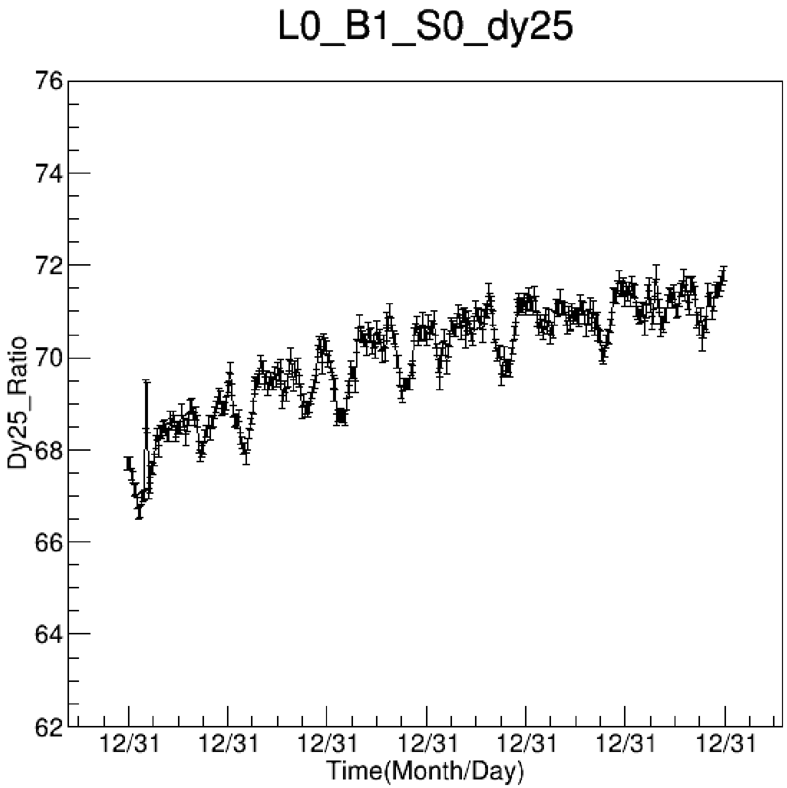
The ratios between the three dynodes are key parameters for energy reconstruction



In-flight status

Dynode ratio stability

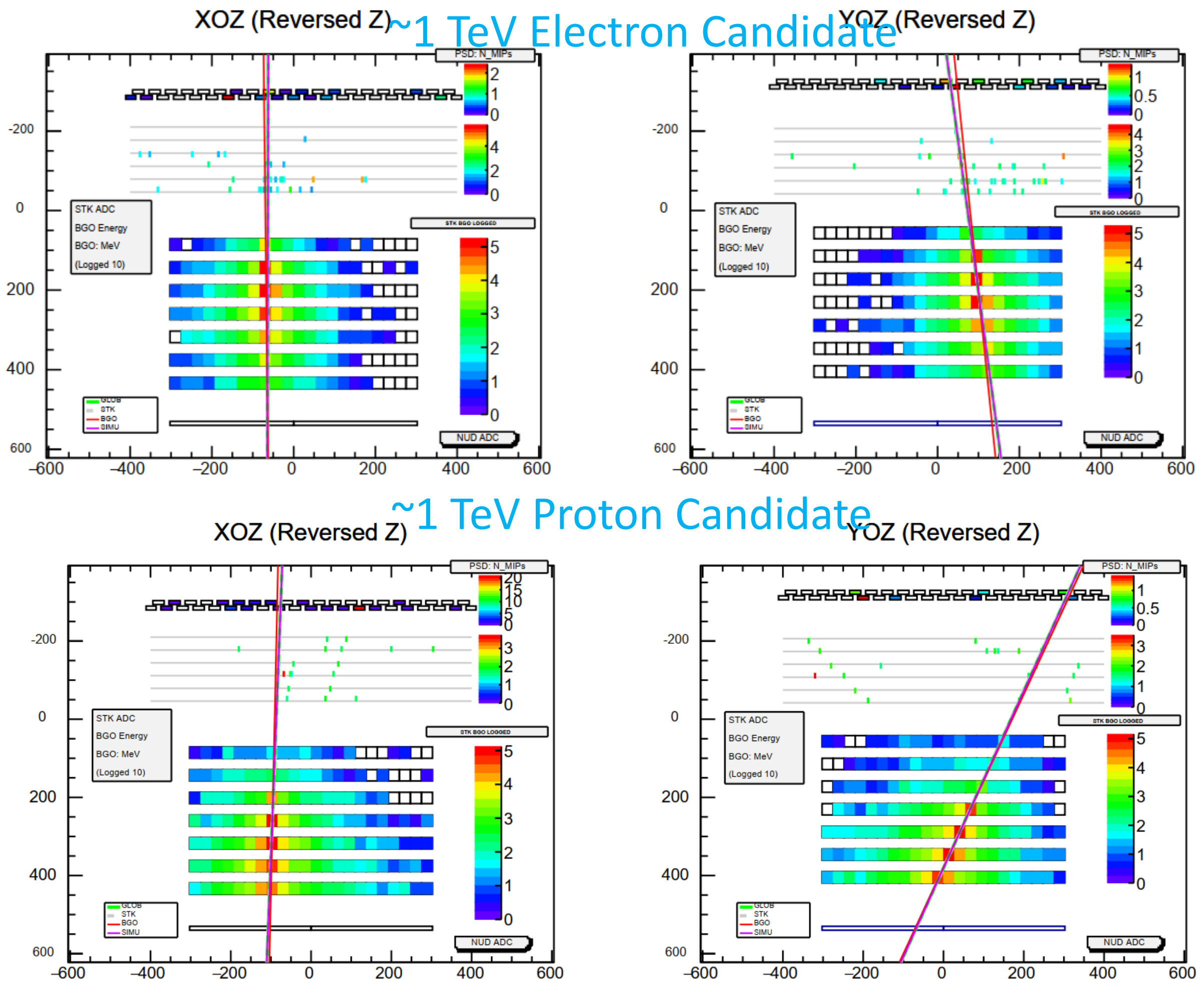




Most channels of PMT gains have slightly increased/decreased for several percent in whole operation time

In-flight status

e/p discrimination capability



The shower development of electron and proton in BGO calorimeter is different.

In-flight status

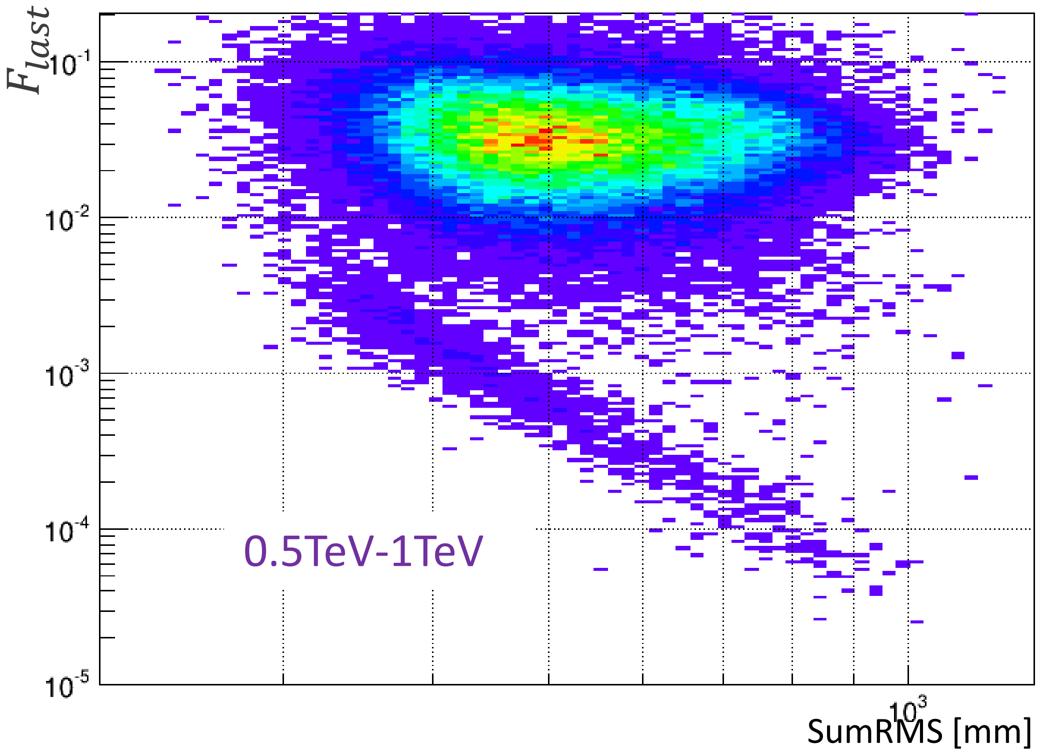
e/p discrimination capability

F_{last} represents the ratio of energy deposited in the last BGO layer that has energy to the total energy deposited in the BGO calorimeter.
SumRMS (shower spread) is defined as the summation of the energy-weighted shower dispersion of each layer.

$$\zeta = (SumRMS)^4 \times F_{last}/(8 \times 10^6)$$

$$SumRM = \sum_i RMS_i$$

$$RMS_i = \sqrt{\frac{\sum_j (x_{i,j} - COG_i)^2 * Energy_{i,j}}{\sum_j Energy_{i,j}}}$$



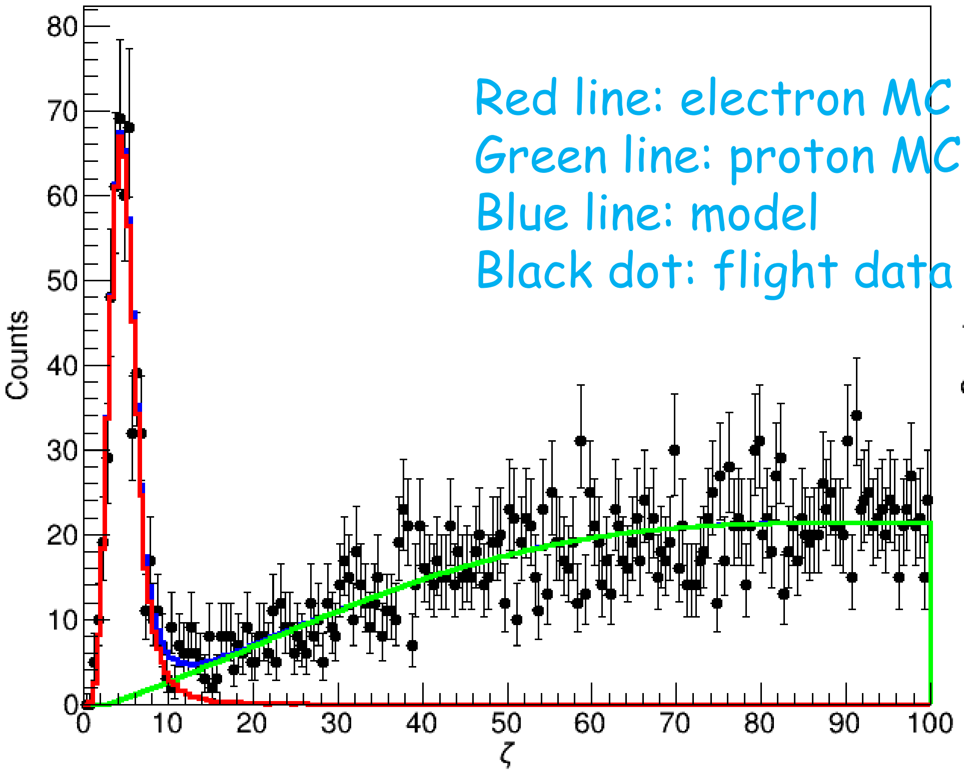
The "relative gap" between the electron and proton distributions in the right figure, it is clear that a curved 'cut line' is required.

Excellent electron/proton discrimination capability with ζ variable

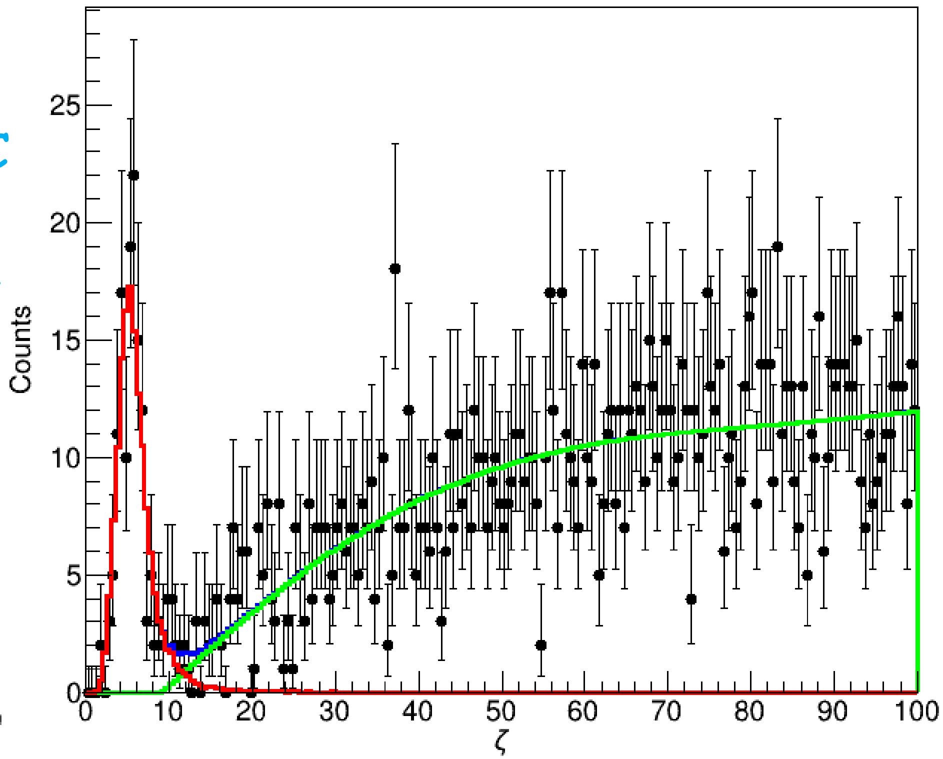
In-flight status

e/p discrimination capability

575.4 GeV – 660.7 GeV



1000.0 GeV – 1148.2 GeV



In signal region ($\zeta < 8.5$), the contamination of the proton background is estimated to be <3% below 1 TeV and <7% in the energy range of 1-2 TeV.

Summary

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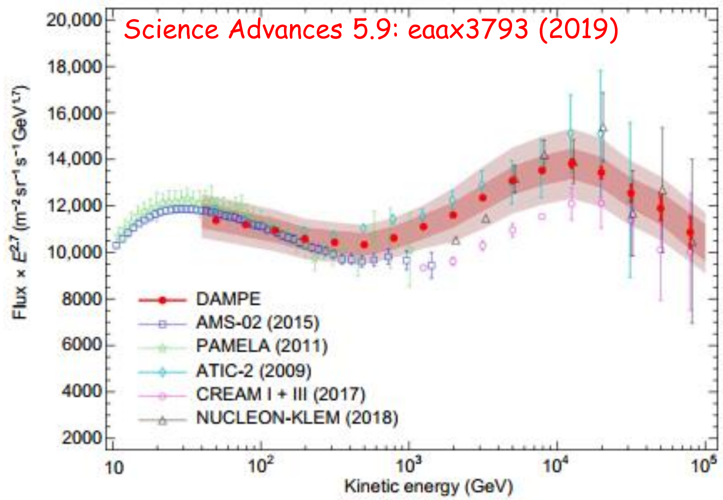
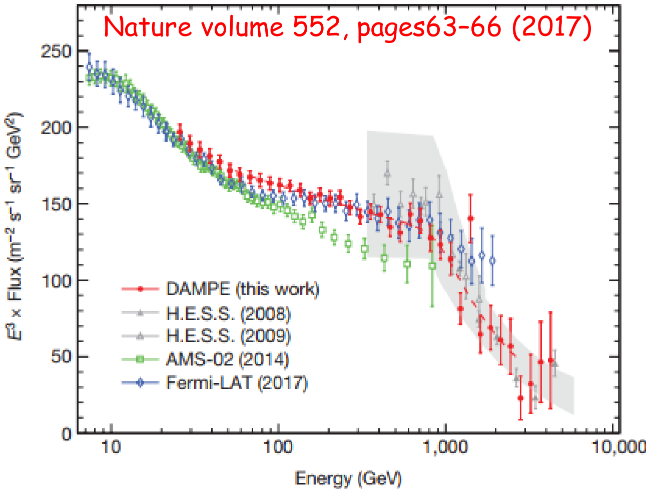
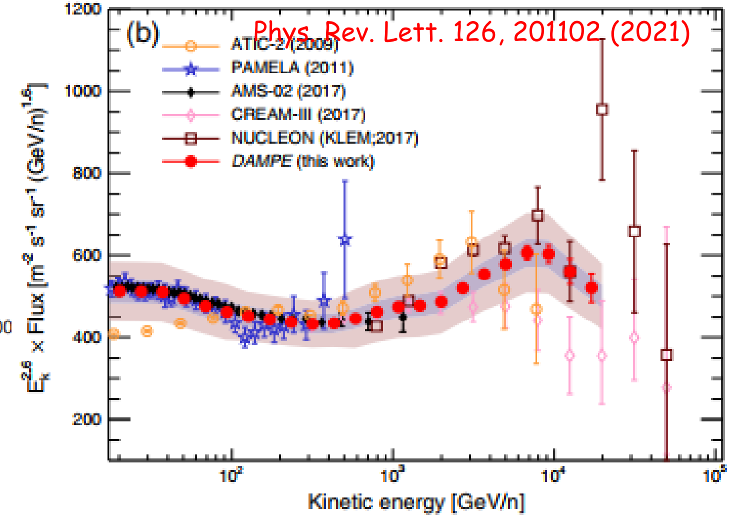
- DArk Matter Particle Explorer (DAMPE) has been working very well since launched successfully on Dec. 17th, 2015.
- Status of BGO Calorimeter is very stable on orbit.
  - Pedestal
  - MIP response
  - PMT Dynode ratio
  - e/p discrimination capability







Thank you！