The Status of the DAMPE BGO calorimeter in space

Cong Zhao
(on behalf of the DAMPE Collaboration)

State Key Laboratory of Particle Detection and Electronics,
University of Science and Technology of China

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Outline

• DAMPE Experiment
• BGO Calorimeter
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• 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 ($2.5 \times 2.5 \times 60 \text{ cm}^3$)
- 14 layers, 22 bars per layer
- Hodoscopic stacking alternating orthogonal layers
- Depth: $32 X_0$, $1.6 \lambda_I$
- Energy resolution: 1.5% @800 GeV for $e/\gamma$

- 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

Total counts: ~5,000,000/day

>10 TeV, ~90/day
Stability of Temperatures

Temperature varies periodically and steadily

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

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

Pedestal stability

Pedestal Mean of Dy2

Pedestal Mean of Dy5

Pedestal Mean of Dy8

Pedestal Sigma of Dy2

Pedestal Sigma of Dy5

Pedestal Sigma of Dy8
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.
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.

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

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 $\zeta$ variable
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

- 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!