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Status of a 3D Imaging Calorimeter of DAMPE for Cosmic Ray Physics on Orbit

Libo Wu

(on behalf of the DAMPE collaboration)

State Key Laboratory of Particle Detection and Electronics

University of Science and Technology of China

DARK MATTER DAMPE PARTICLE EXPLORER

Outline

- DAMPE Experiment
- Instrument design
- In-flight calibration and status
  - Pedestal
  - MIPs MPV value
  - Attenuation length
  - Dynode ratio
- Summary

DAMPE experiment

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The collaboration of DArk Matter Particle Explorer (DAMPE)

- CHINA
  - Purple Mountain Observatory, CAS, Nanjing
  - University of Science and Technology of China, Hefei
  - Institute of High Energy Physics, CAS, Beijing
  - National Space Science Center, CAS, Beijing
  - 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
- SWITZERLAND
  - University of Geneva

DAMPE experiment

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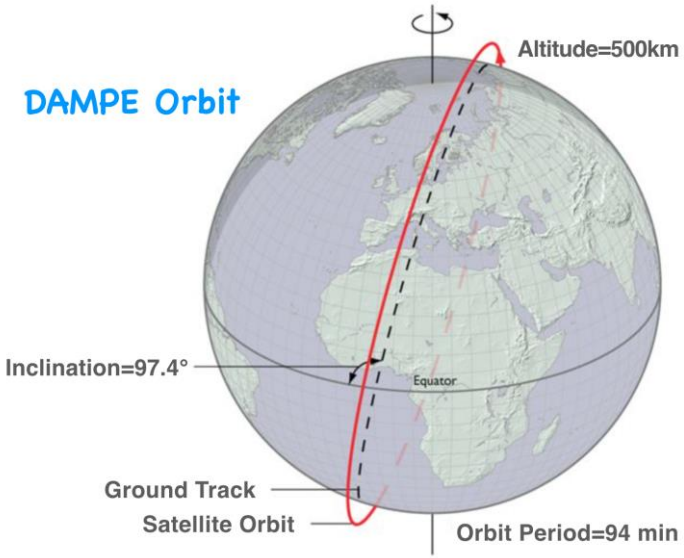
DAMPE mission

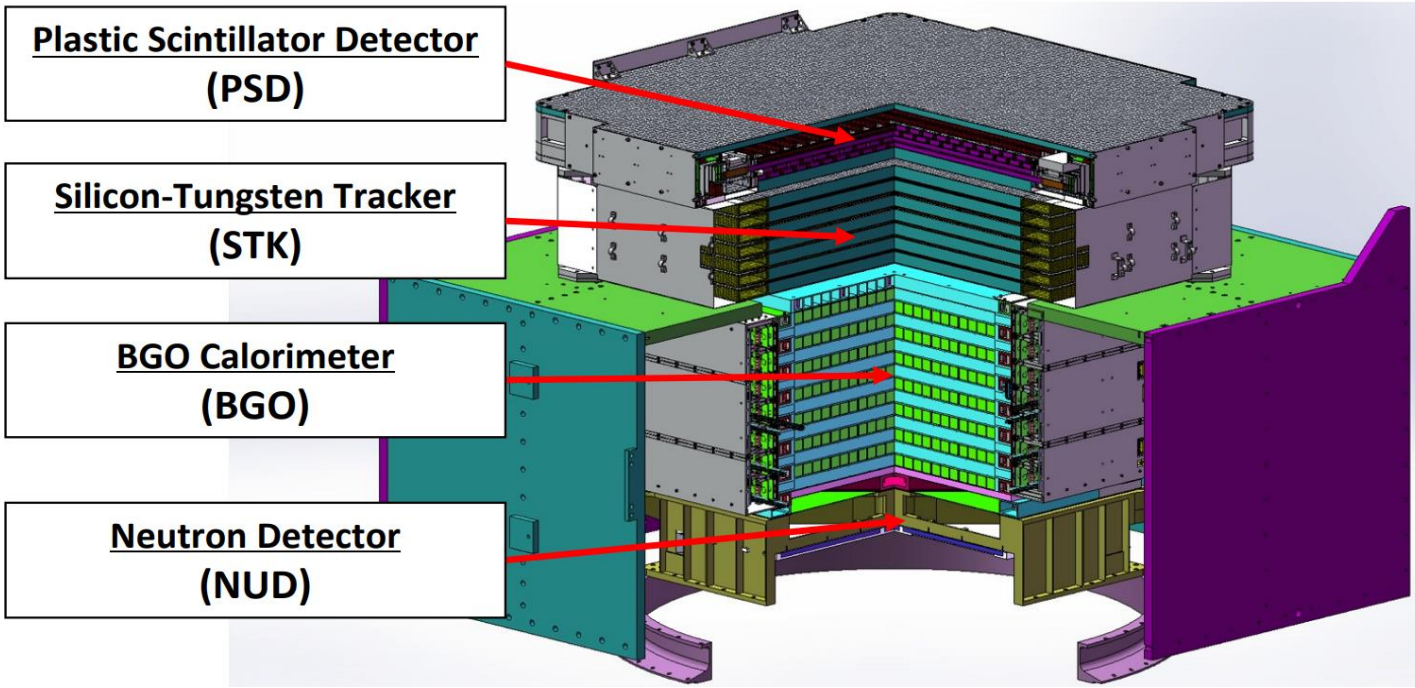
- DAMPE is an orbital experiment for searching dark matter particle indirectly
- Launch: December 17th 2015, CZ-2D rocket
  - Total weight ~1850 kg, power consumption ~640 W
    - Scientific payload ~1400 kg, 400 W
  - Lifetime > 3 years

- Orbit: sun-synchronous
- Altitude: 500 km
- Period: 94 minutes
- 16 GB/day downlink



Instrument design

DAMPE detector



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

3D Imaging BGO ECAL

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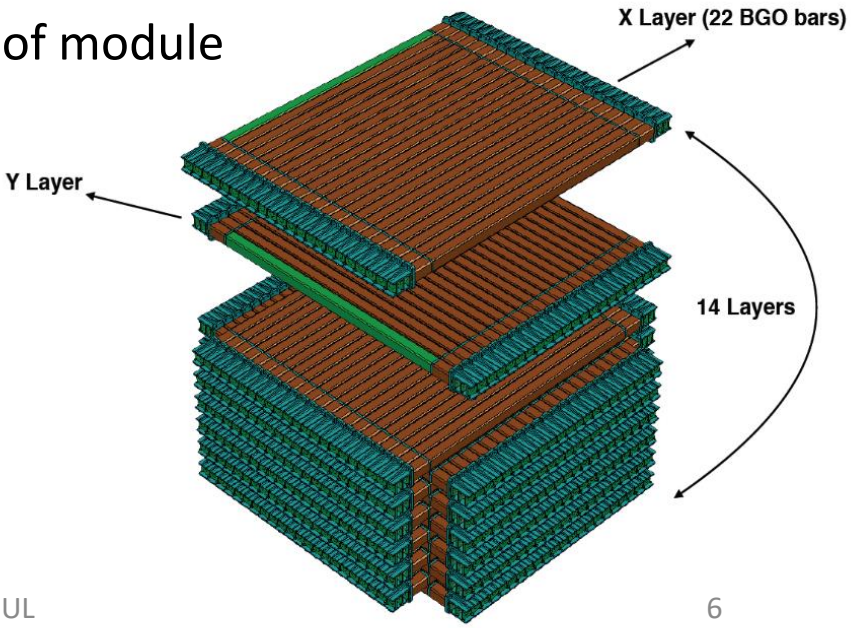
- 14 layers of 22 BGO crystals
  - Dimension of BGO bar: 2.5×2.5×60 cm^3
  - Hodoscopic stacking alternating orthogonal layers
  - r.l: ~32 X_0
  - NIL: 1.6 λ_I
- Two PMTs coupled with each BGO crystal bar in two ends
- Electronics boards attached to each side of module
- Energy range: 5GeV-10TeV (e/γ)
- Energy resolution: 1.5% @800GeV



3D Imaging BGO ECAL

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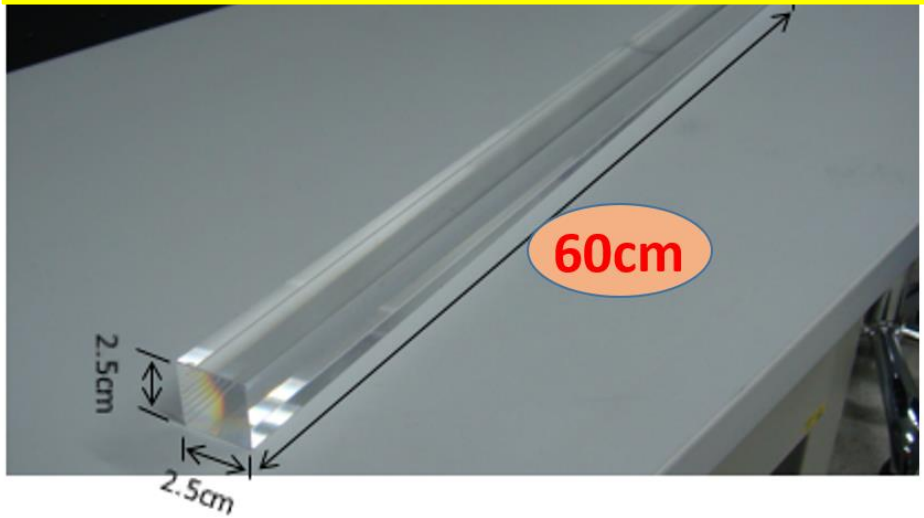
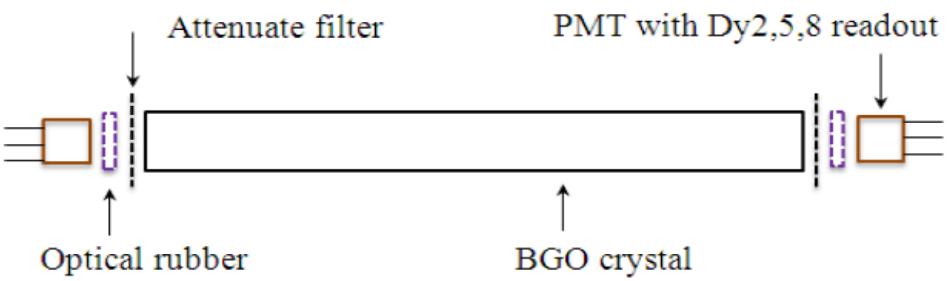
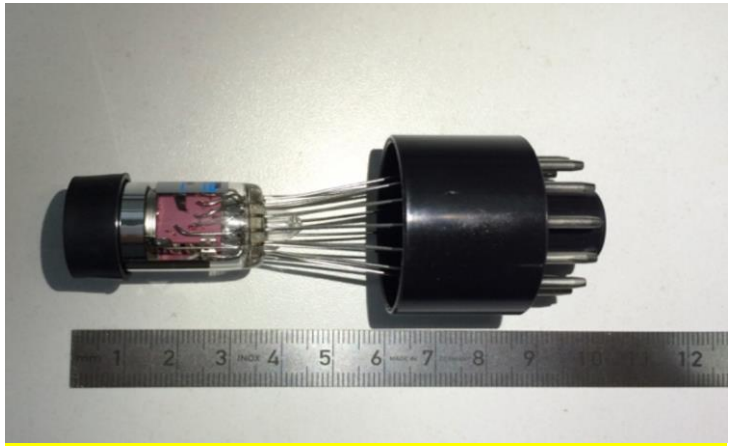
BGO ECAL elements

308 BGO bars (Produced by Shanghai Institute of Ceramics)

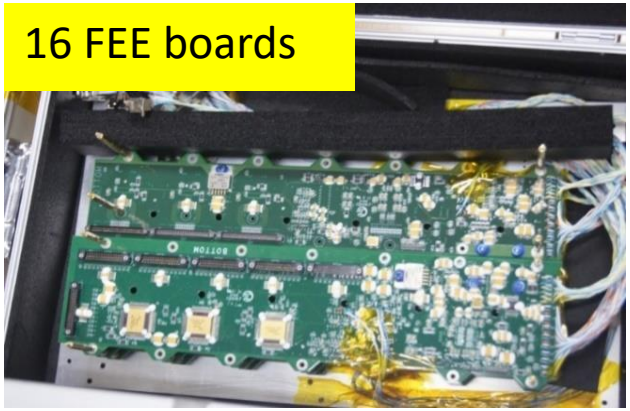






616 PMTs (Hamamatsu R5610A-01)

16 FEE boards



3D Imaging BGO ECAL

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Some tests on ground

(a) Remanence Test

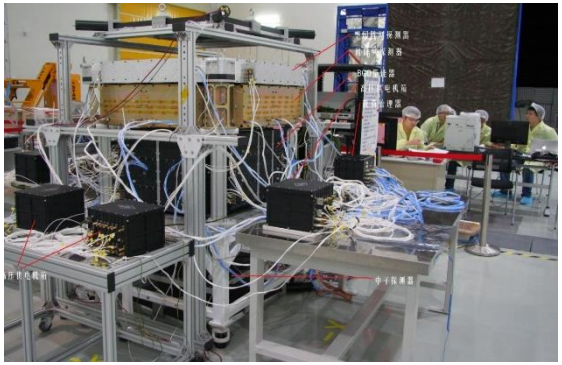
(b) EMC Test

Environment Tests

(c) Vibration Test

(d) Thermal Test

Cosmic ray Test



Beam Test

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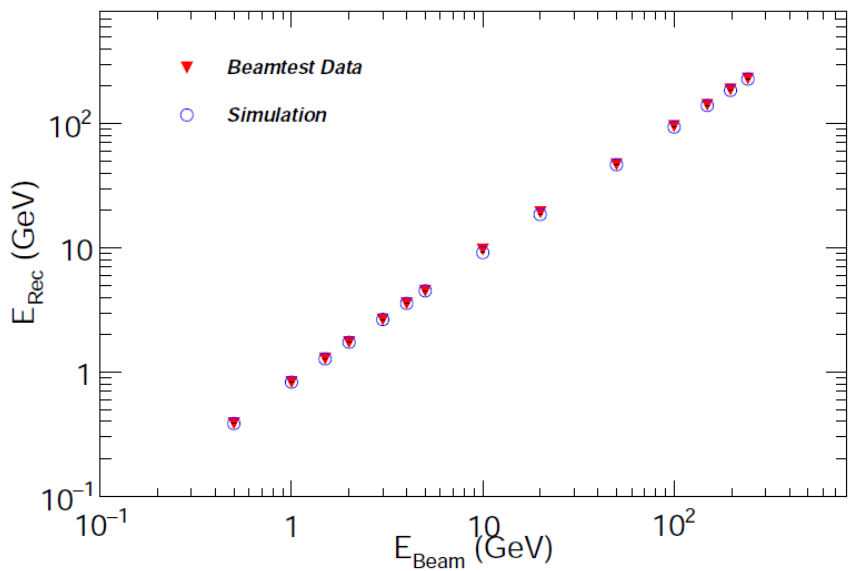
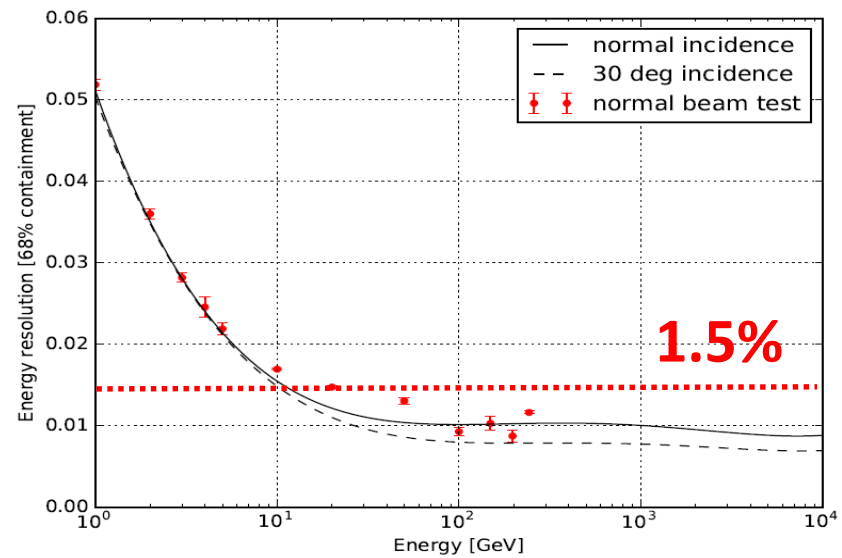
Results of beam test

Energy linearity of electrons



Energy resolution of electrons



Launched on 17th Dec. 2015
Jiuquan Satellite Launch Center, Gobi desert

In-flight calibration and status

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- Pedestal
- MIPs MPV value
- Attenuation length
- Dynode ratio

In-flight calibration and status

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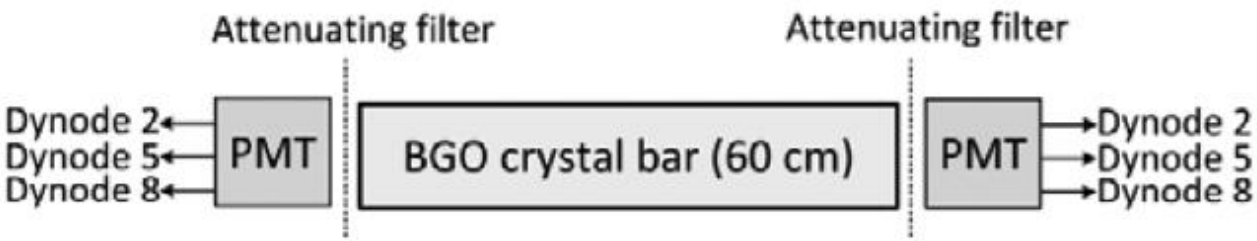
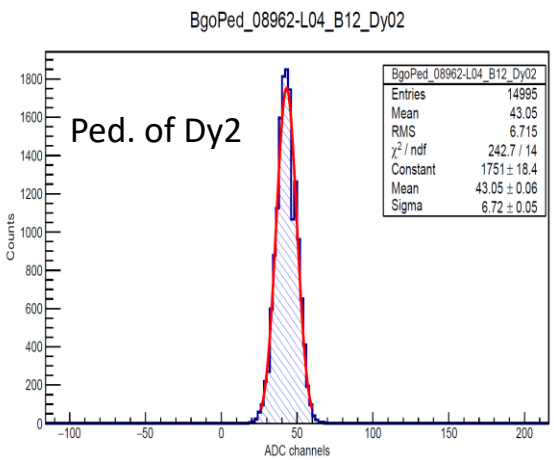
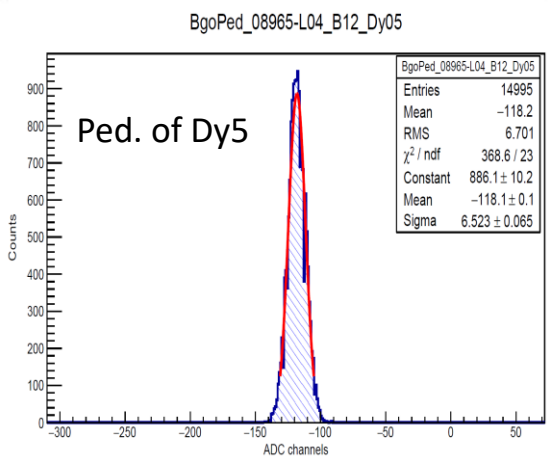
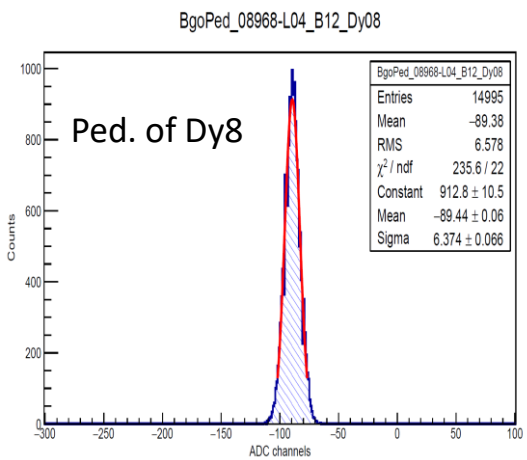
Pedestal calibration

- 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 calibration and status

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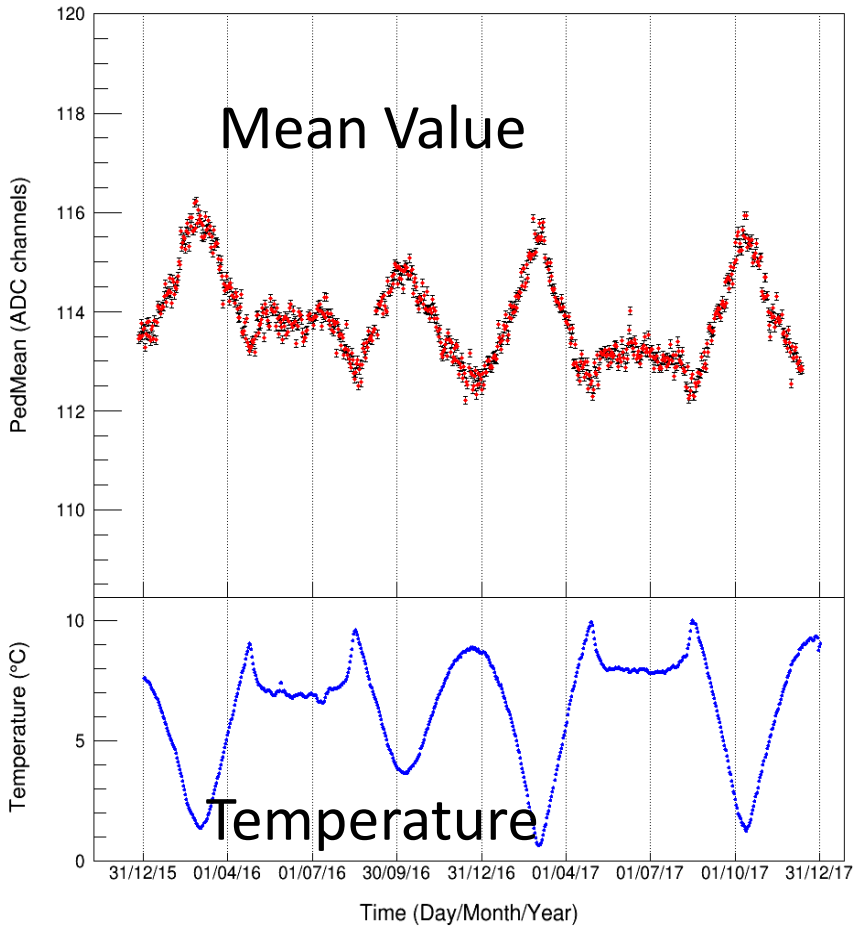
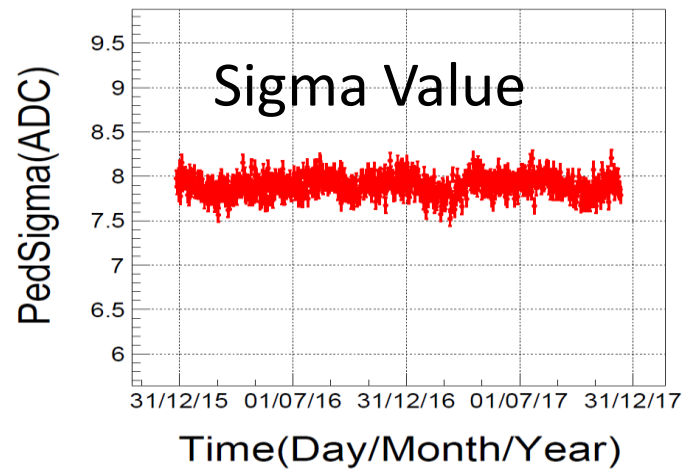
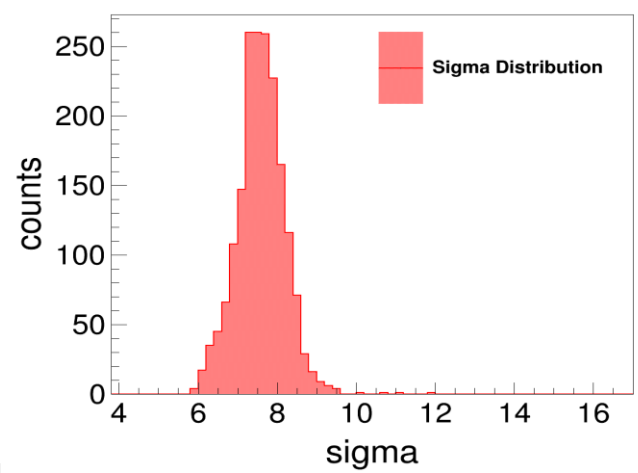
Results of pedestal calibration (From 201601 - 201712)







In-flight calibration and status

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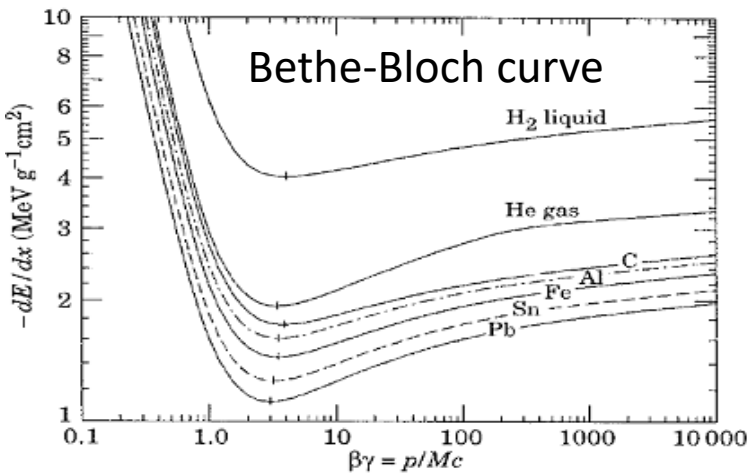
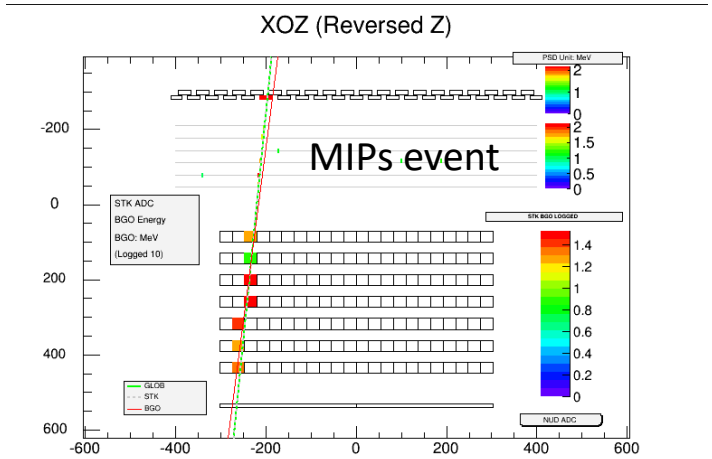
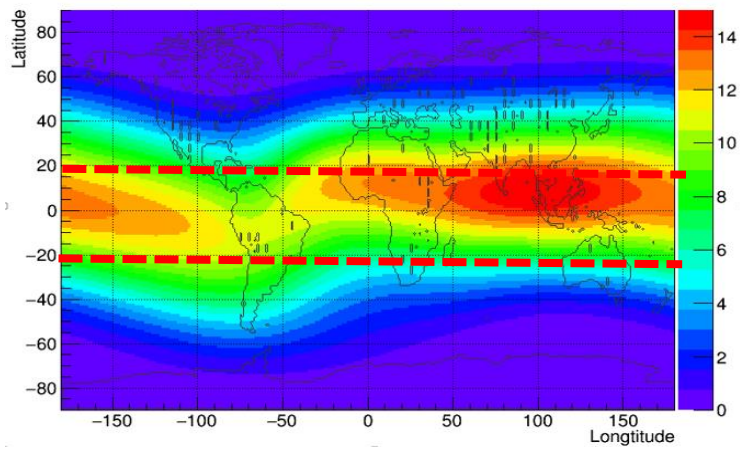
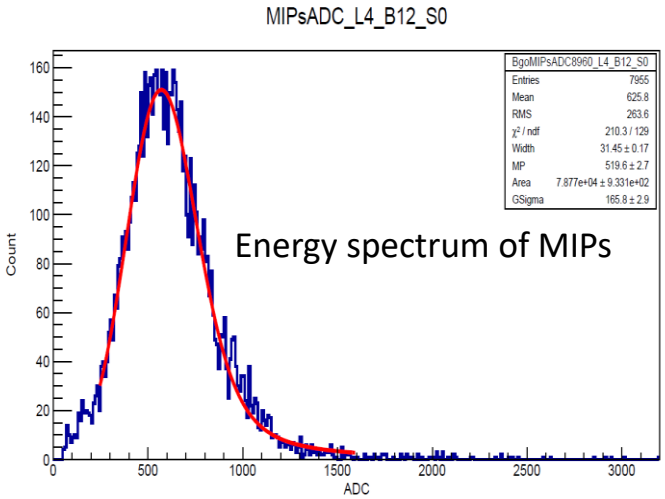
The response of BGO units to Minimum-Ionization Particles (MIPs)









In-flight calibration and status

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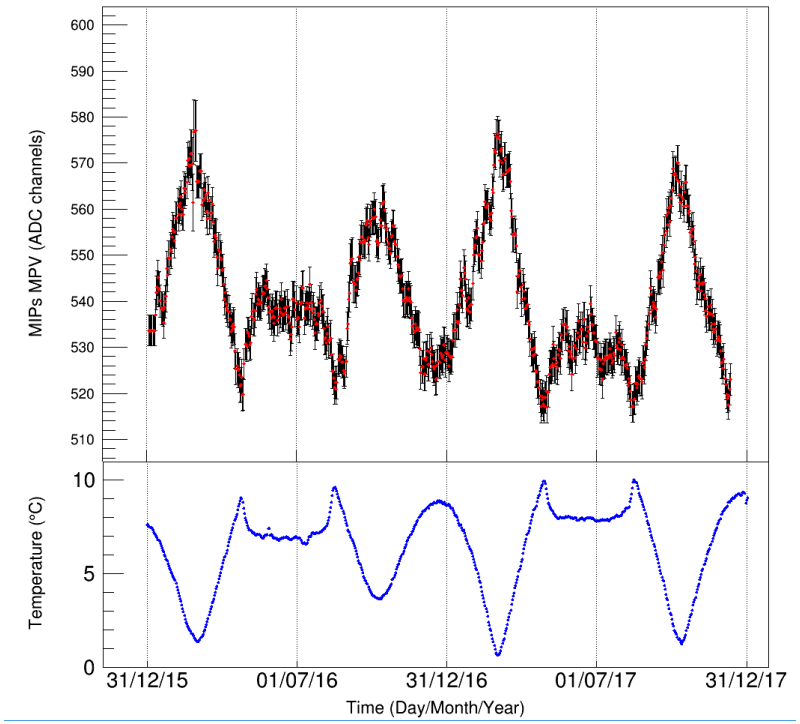
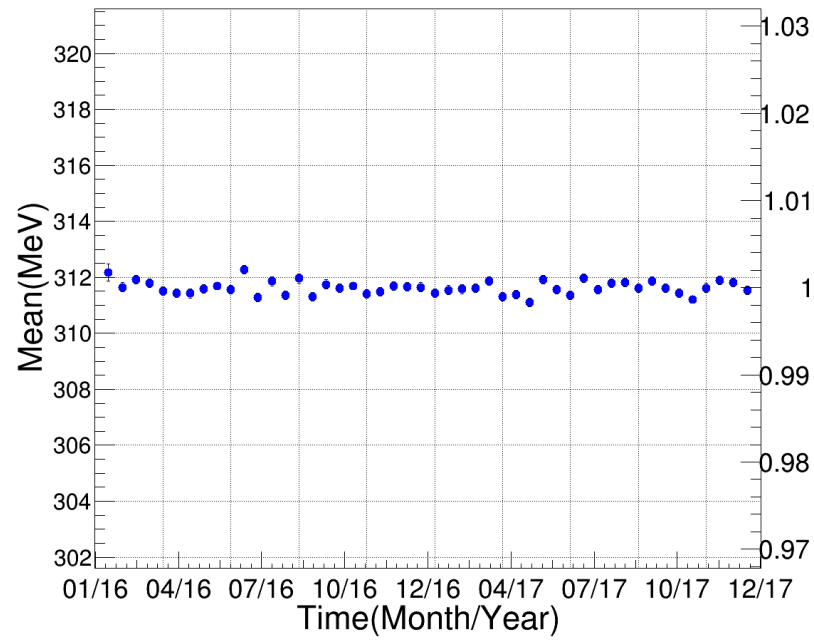
Stability of MIPs

Before temperature correction



After temperature correction



- Caused by the negative correlation between fluorescent yield and temperature
- The energy of MIPs is about 312 MeV

In-flight calibration and status

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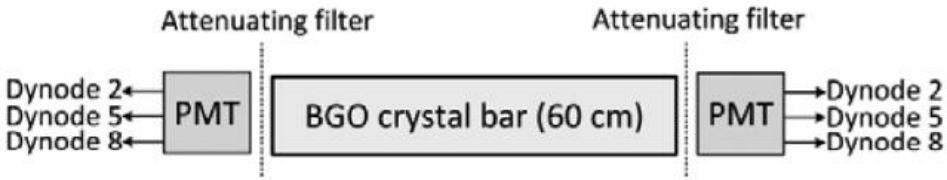
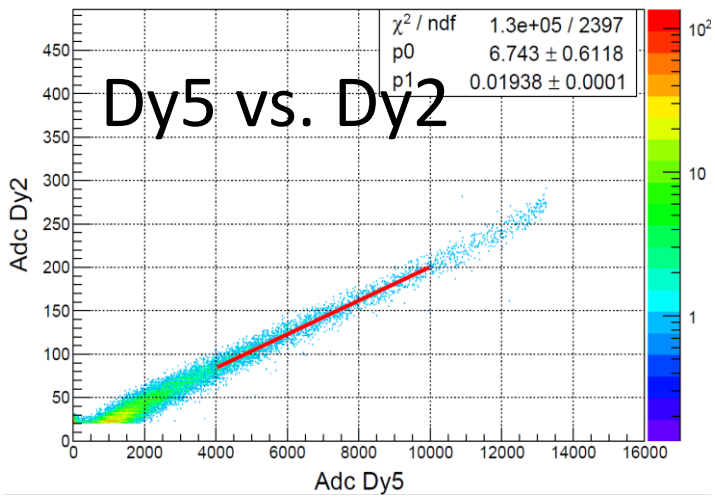
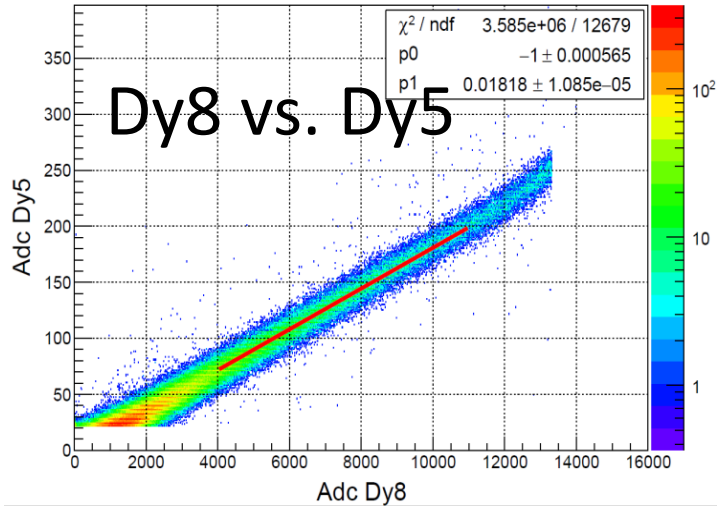
Dynode ratio calibration

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







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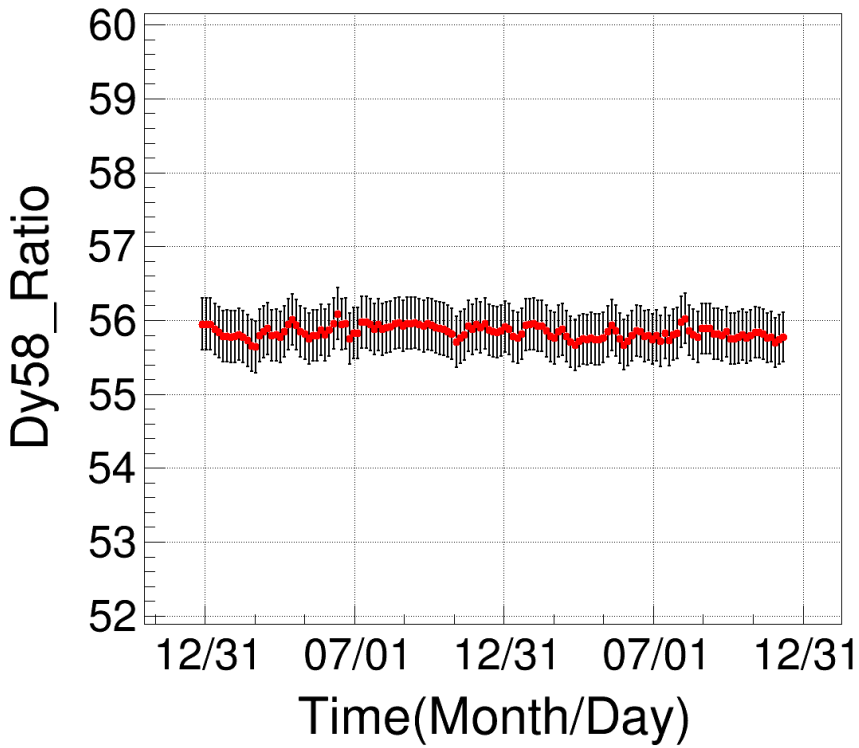
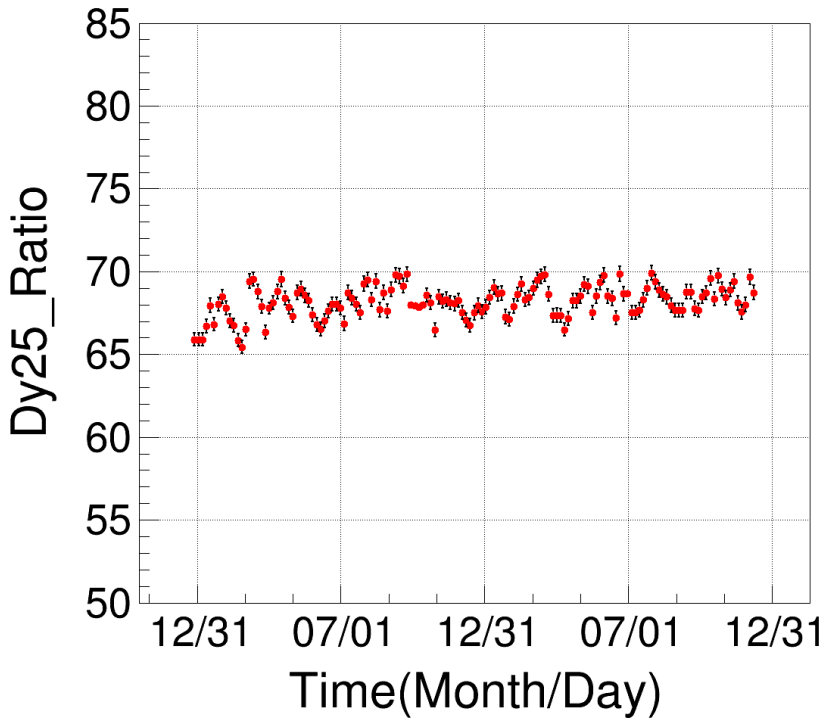
Stability of dynode ratio (From 201601 - 201712)





In-flight calibration and status

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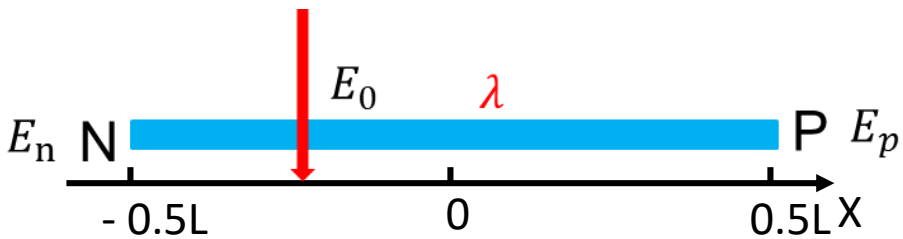
Attenuation length calibration

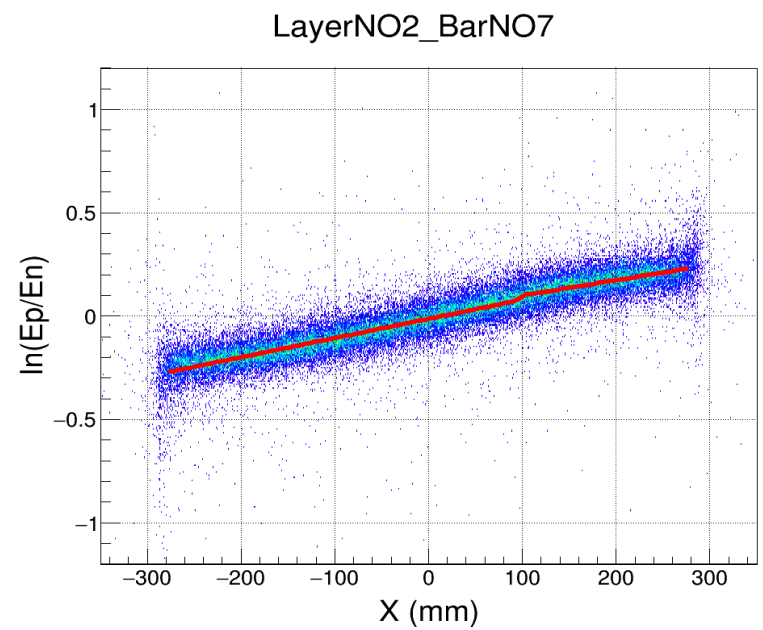
- The length of BGO crystal is 60 cm.
- The attenuation of the scintillation light during propagation should be considered.



$$E_p = E_0 * e^{-\frac{\frac{L}{2} - x}{\lambda}}$$

$$E_n = E_0 * e^{-\frac{\frac{L}{2} + x}{\lambda}}$$

$$\ln\left(\frac{E_p}{E_n}\right) = \frac{2x}{\lambda}$$



In-flight calibration and status

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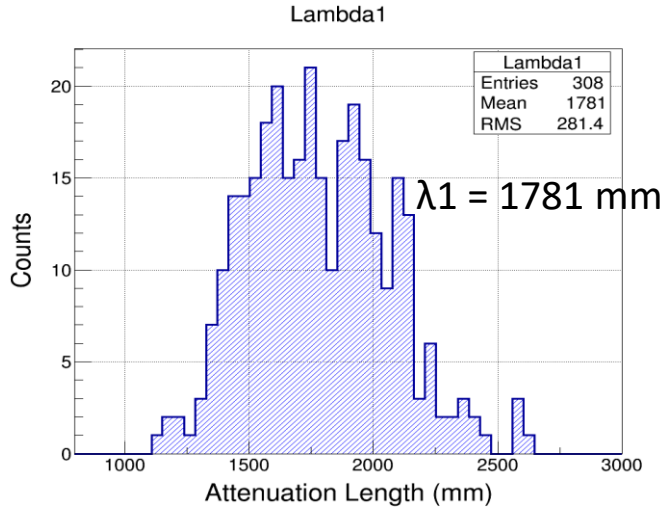
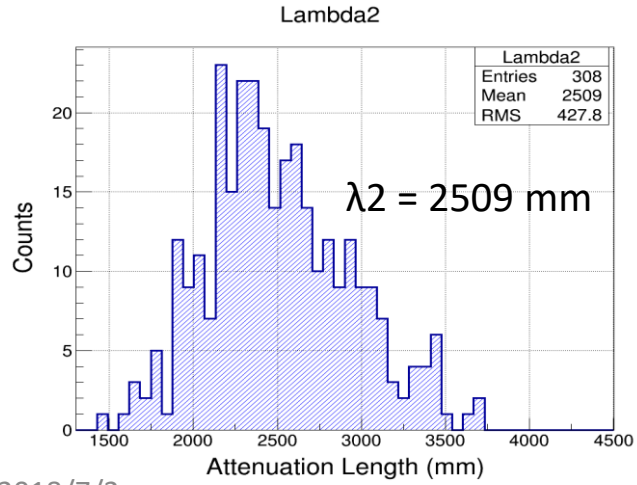
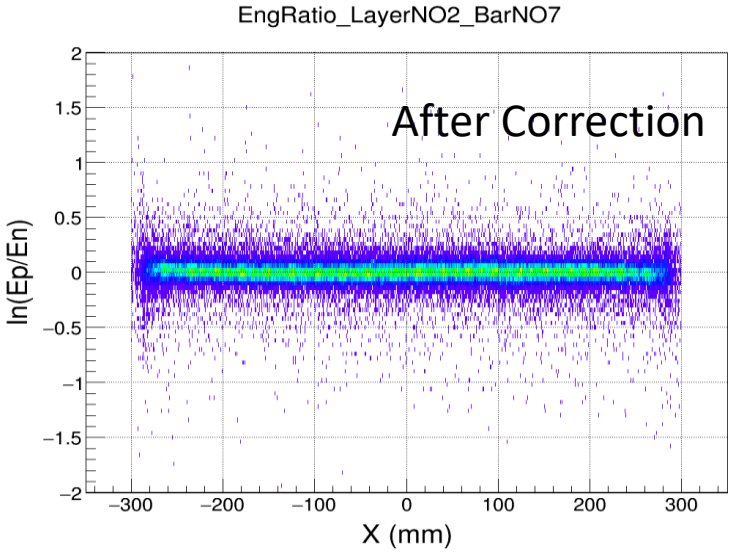
Results of attenuation calibration





The attenuation length of BGO crystal can be used to correct the energy deposition in calorimeter



In-flight calibration and status

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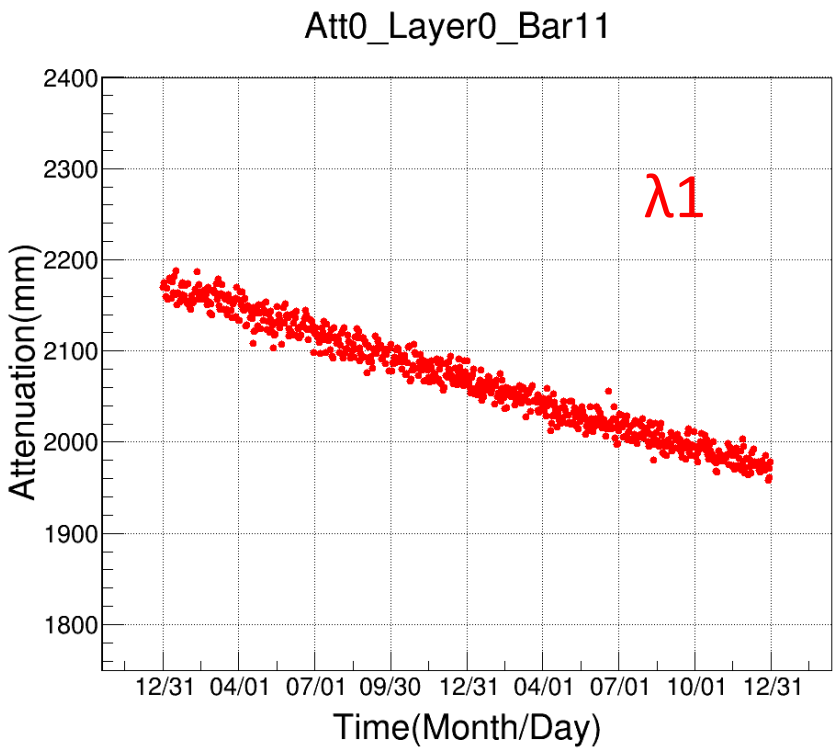
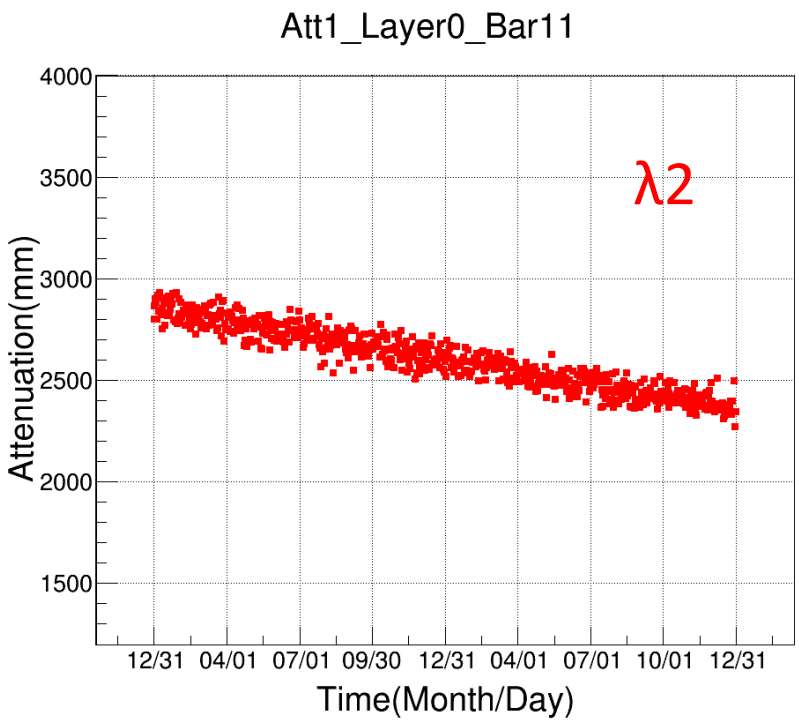
Long time stability of Attenuation (From 201601 - 201712)





In-flight calibration and status

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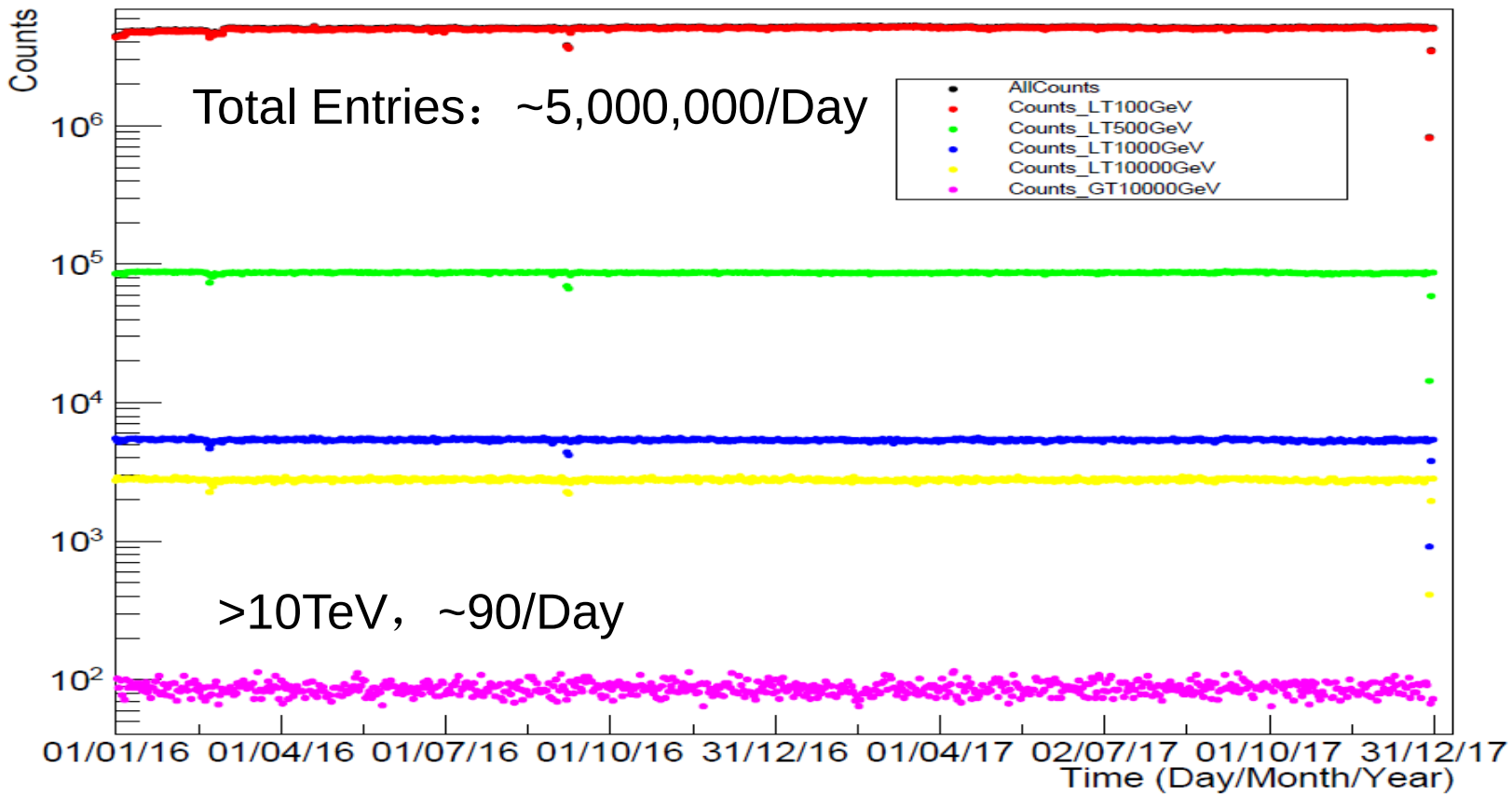
Dataset acquired during two years



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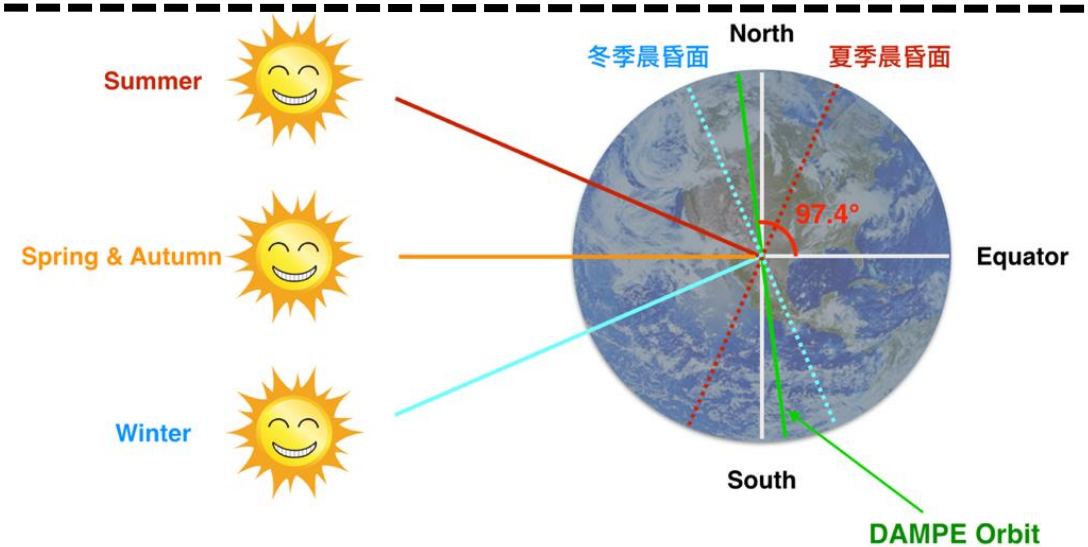

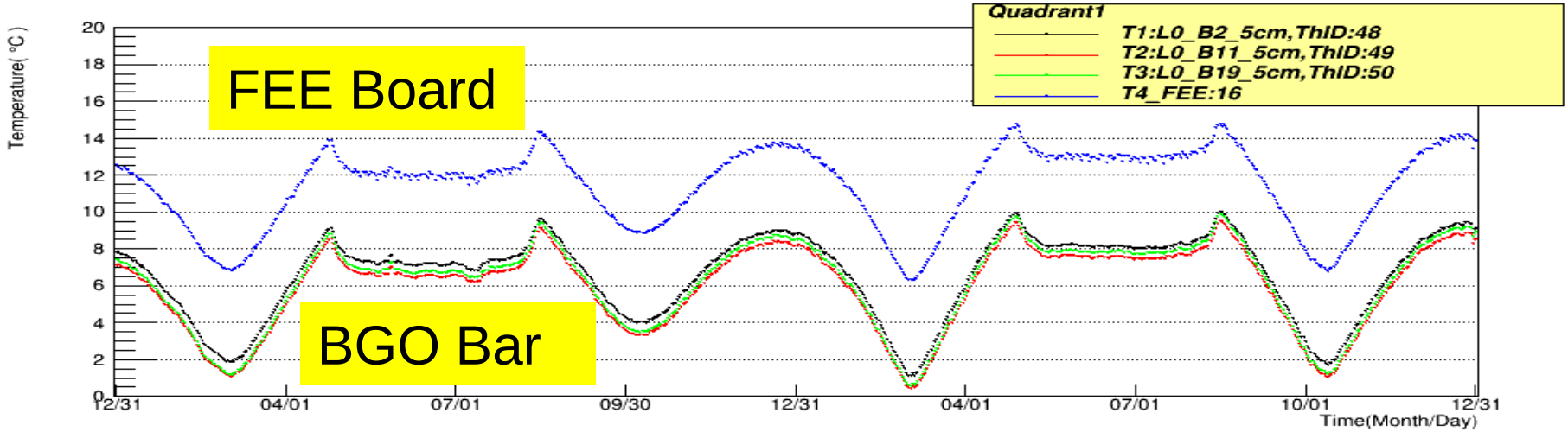

In-flight calibration and status

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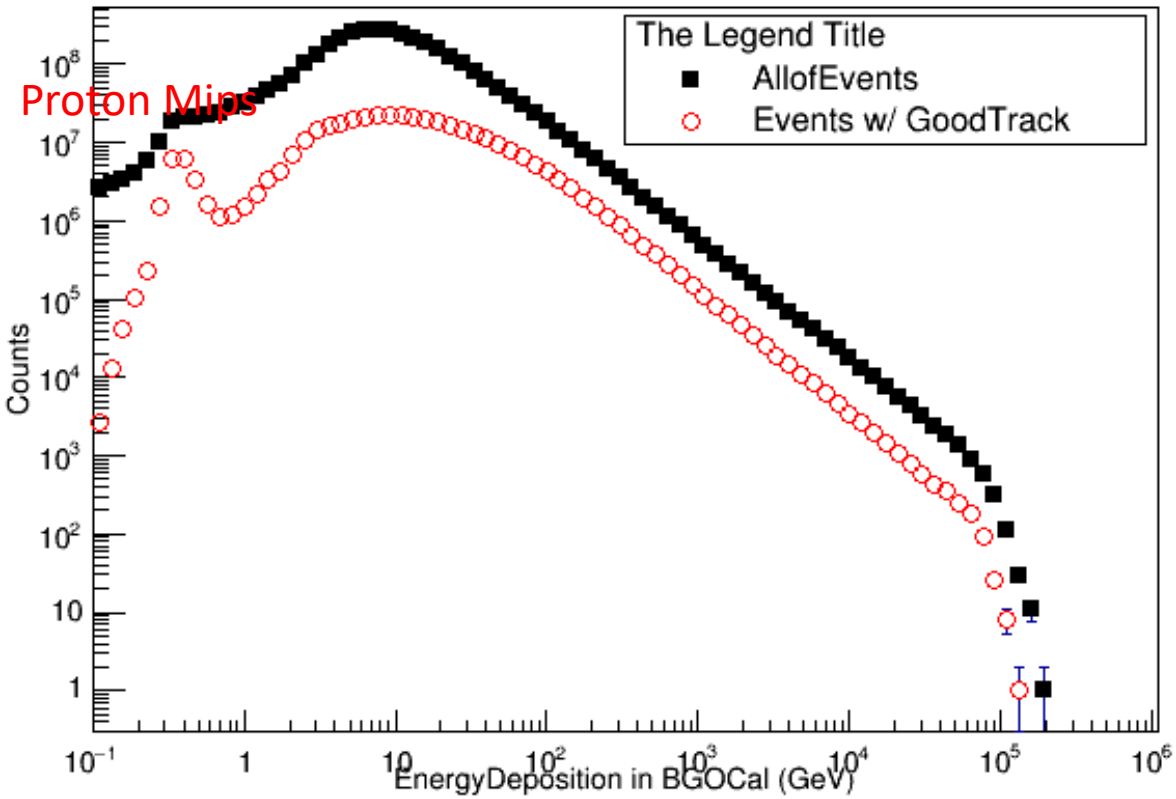
Energy Spectrum during two years on orbit



In-flight calibration and status

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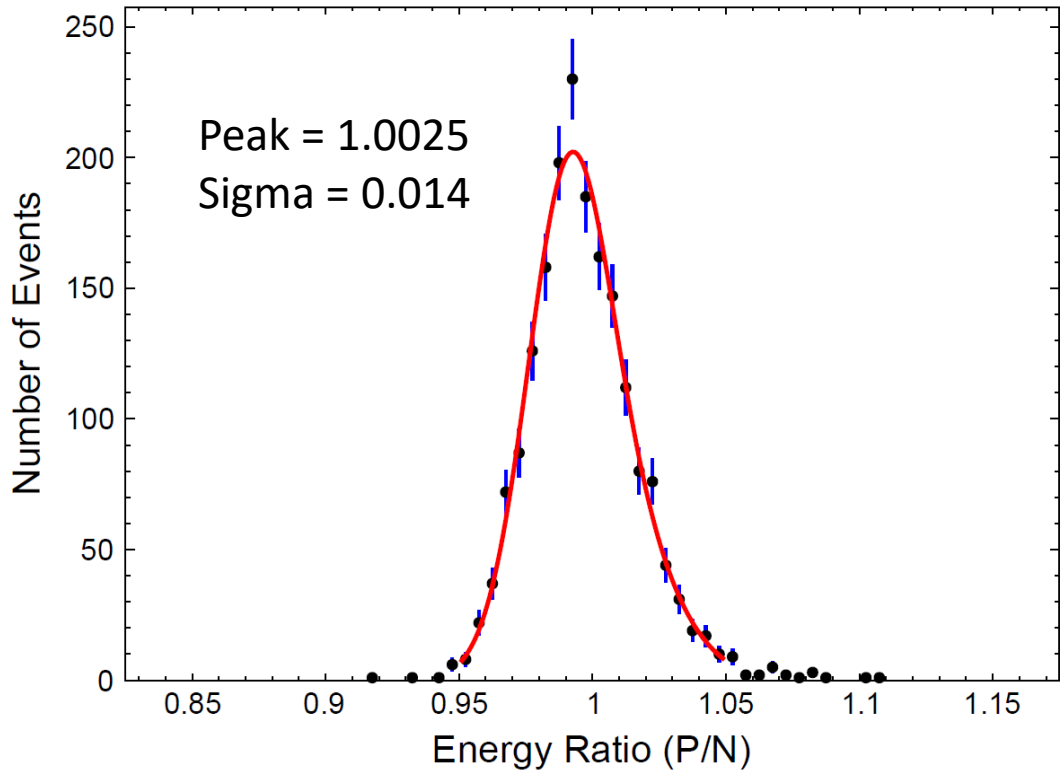
Energy measurement



For events with deposit energy of 0.5 – 1.0 TeV

In-flight calibration and status

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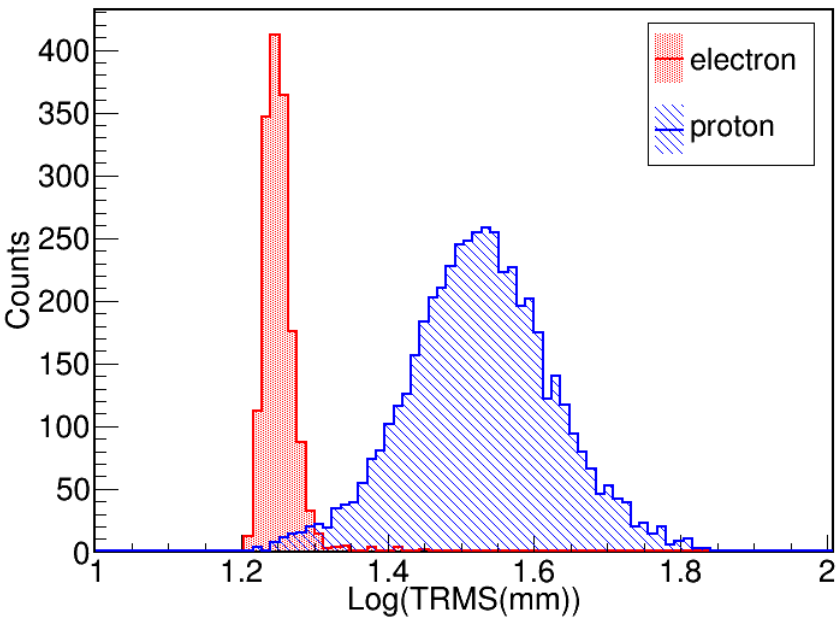
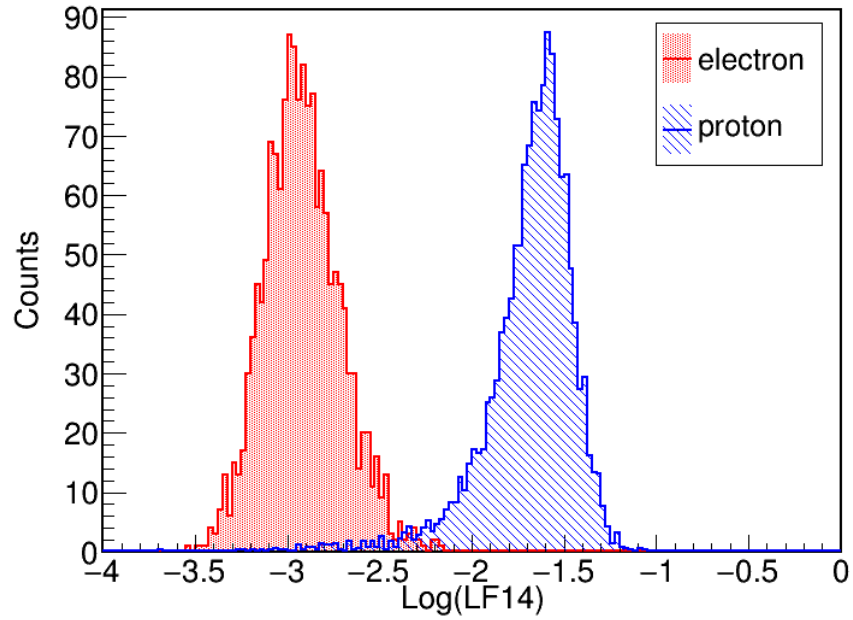
Events selection and reconstruction





LF14: describe the longitudinal development of shower.
TRMS: describe the lateral development of shower.

In-flight calibration and status

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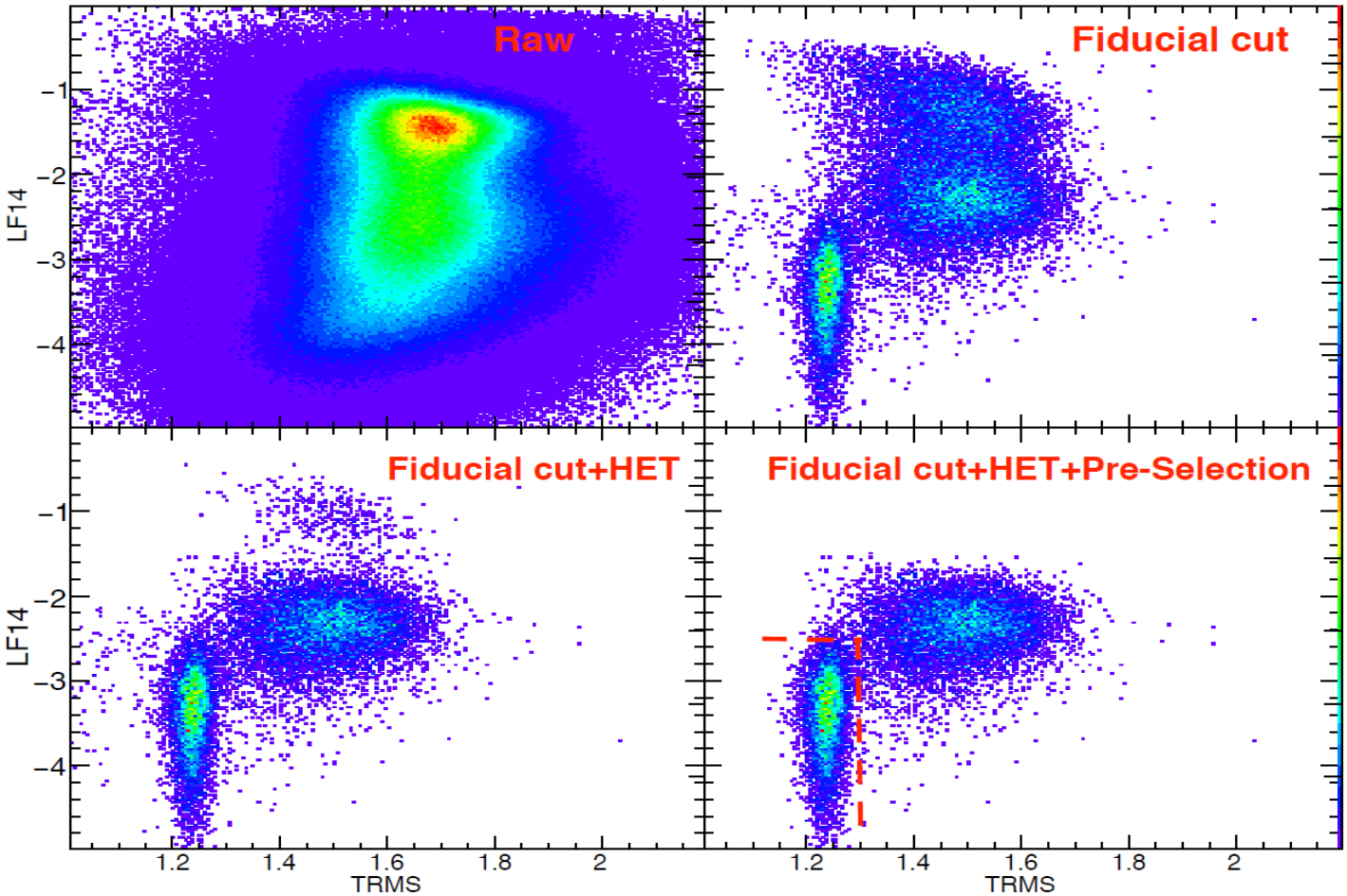

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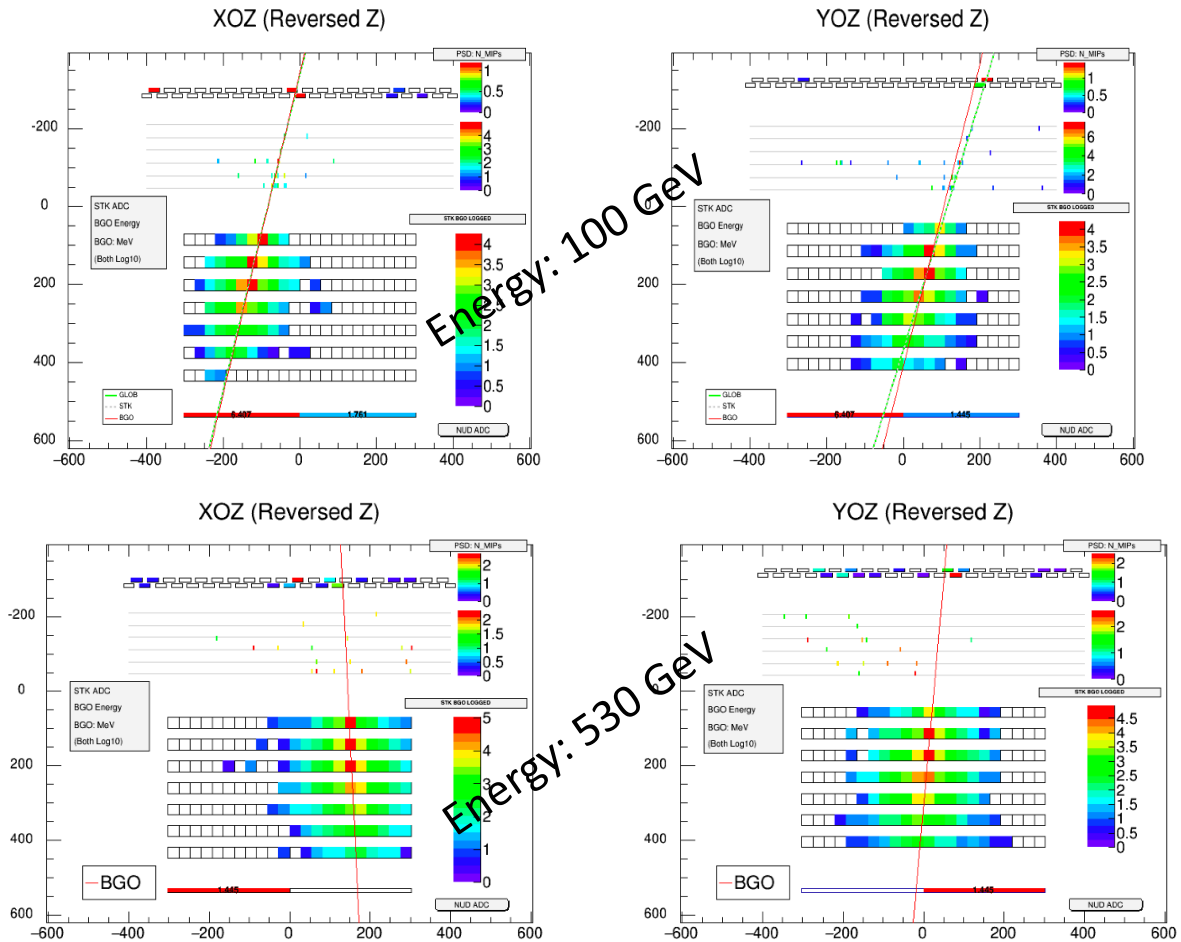
Electron candidate



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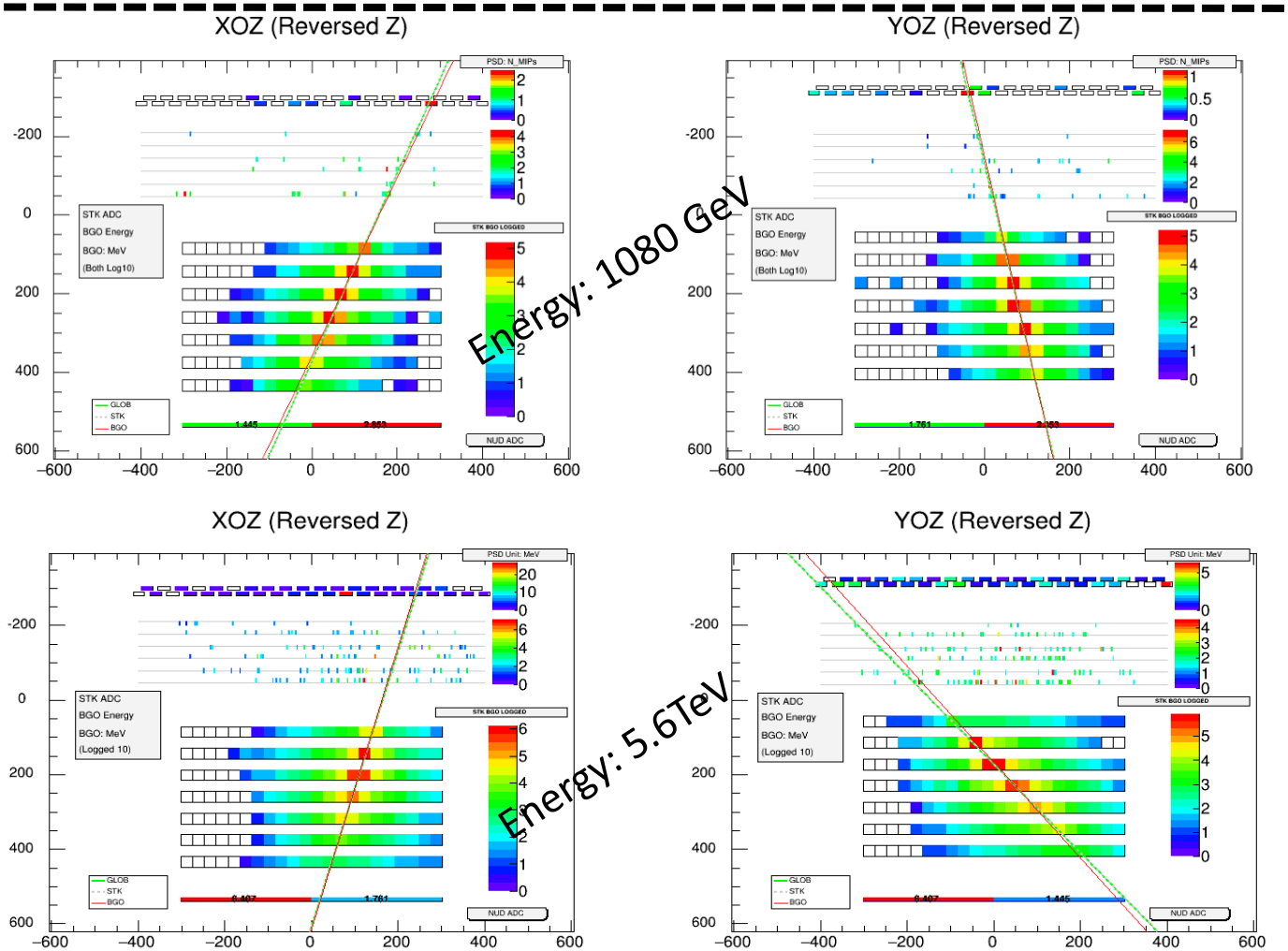

Summary

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- DArk Matter Particle Explorer (DAMPE) was launched successfully on Dec. 17th, 2015
- DAMPE has been working very well since then.
- Physics goals
  - Search for possible dark matter signals
  - Study the origin and propagation of cosmic ray
  - Study the astronomy of gamma ray
- Status of BGO ECAL is very stable on orbit.
  - Pedestal
  - MIPs MPV value
  - Attenuation length
  - Dynode ratio

Thank you

Backup

In-flight calibration and status

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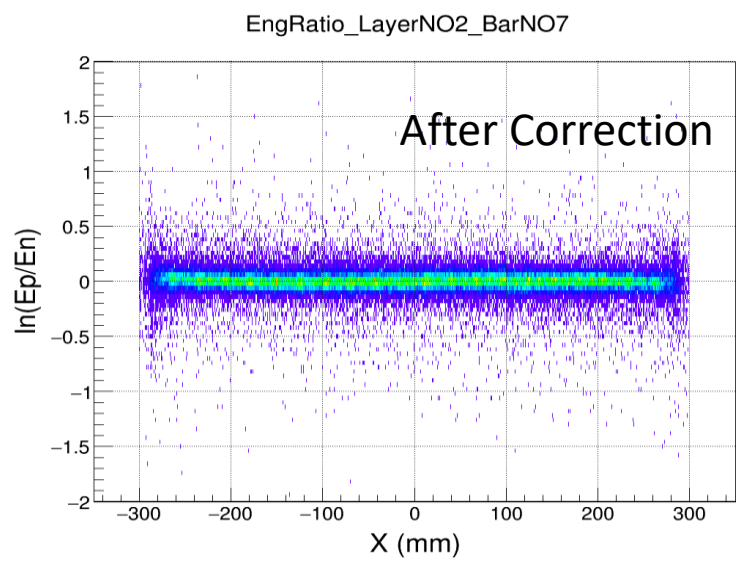
Energy correction by hit position

$$E_{0\_p} = E_p * e^{\frac{\frac{L}{2} - x}{\lambda}}$$

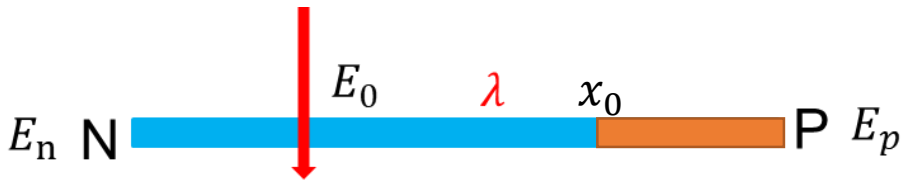
$$E_{0\_n} = E_n * e^{\frac{\frac{L}{2} + x}{\lambda}}$$

$$\ln\left(\frac{E_{0\_p}}{E_{0\_n}}\right) = 0$$



Advantage of correction

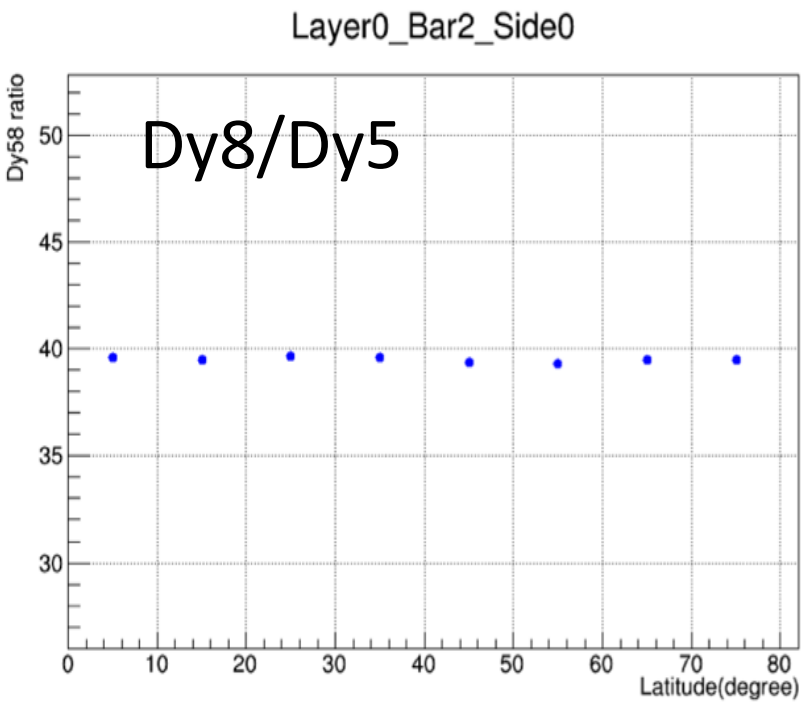
- Eliminate the influence of hit position.
- Detect the particle with higher energy.
- Check each other.

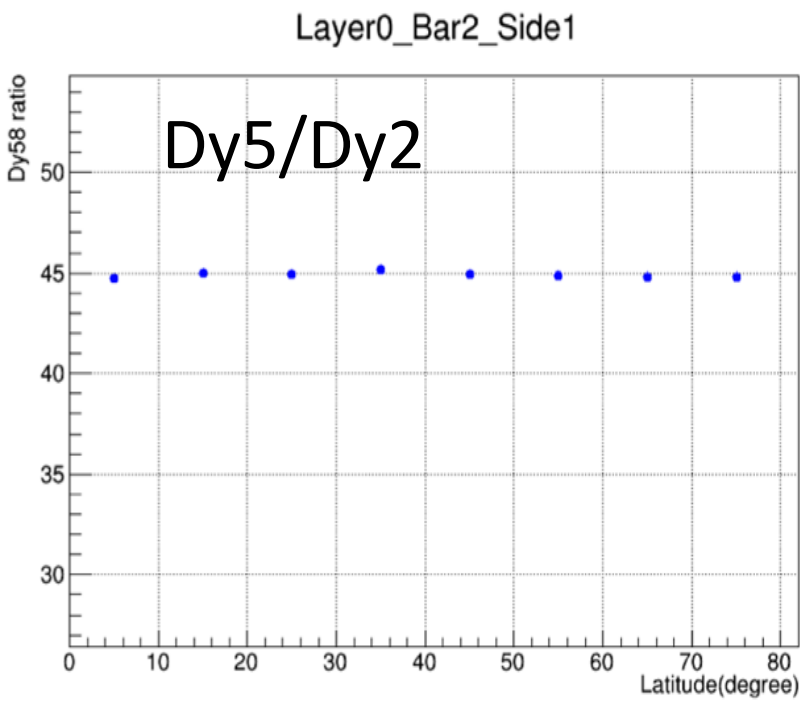


$$E_p = E_0 \cdot e^{-\frac{(x_0 - x)}{\lambda_1}} \cdot e^{-\frac{(300 - x_0)}{\lambda_2}} \cdot \mathrm{R} \quad (\mathrm{x} < x_0)$$

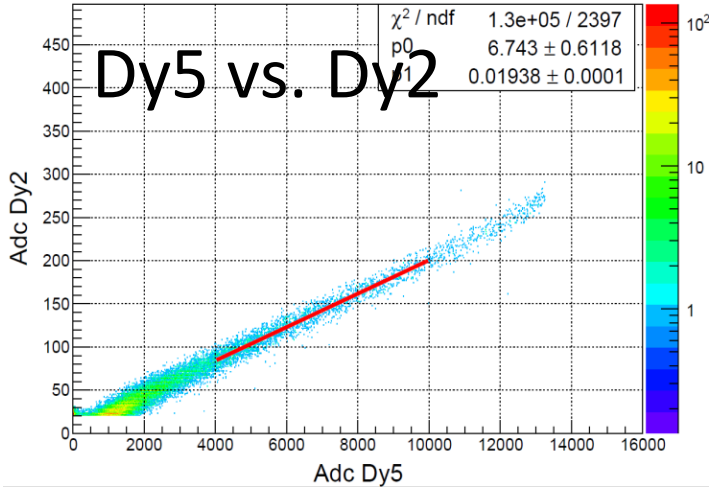
$$E_p = E_0 \cdot e^{-\frac{(300 - x)}{\lambda_2}} \quad (\mathrm{x} >= x_0)$$

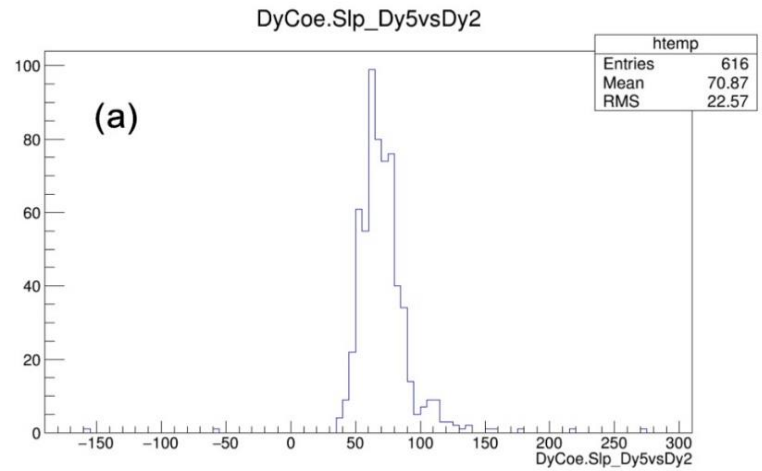
Stability of dynode ratio at different latitude

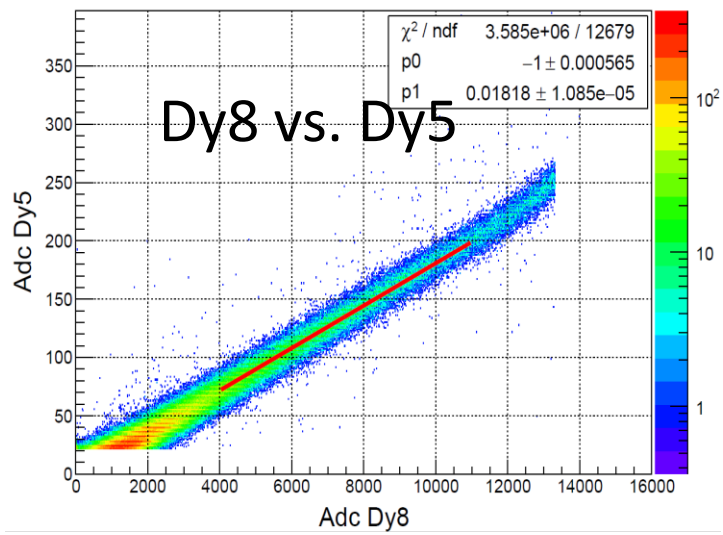


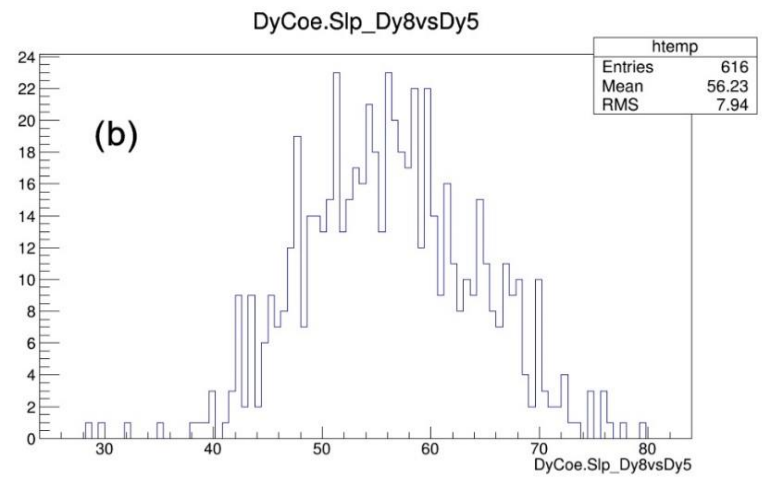


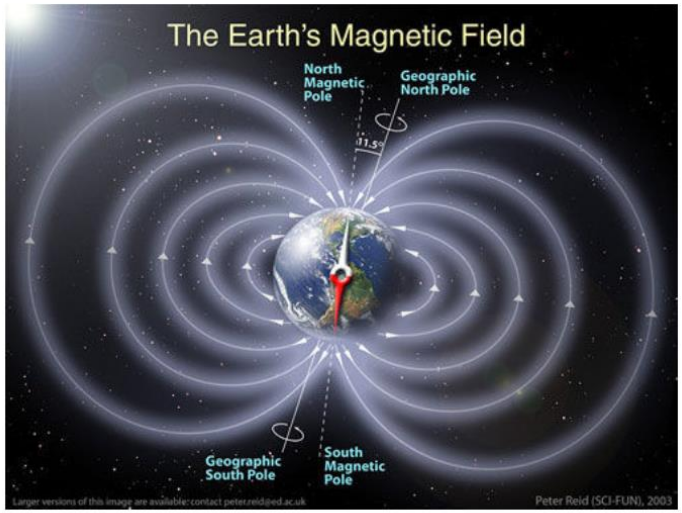
Results of dynode ratio calibration

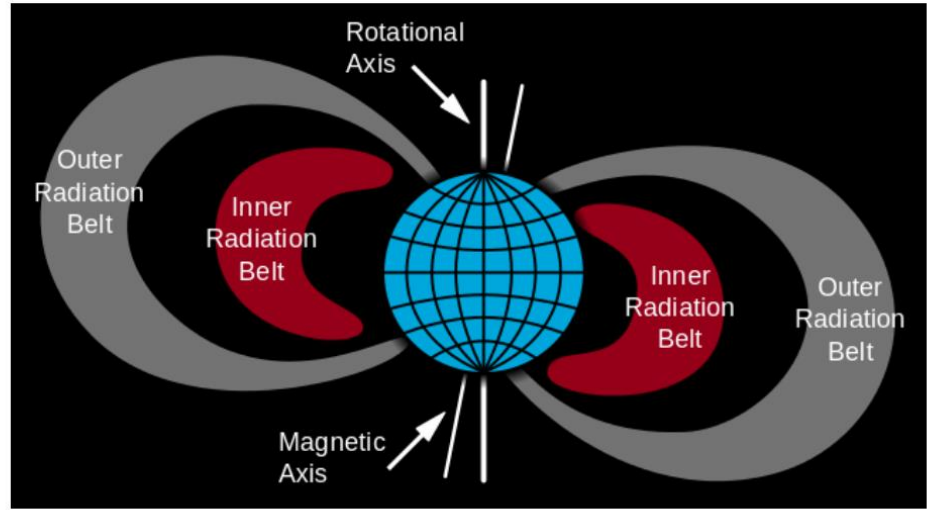


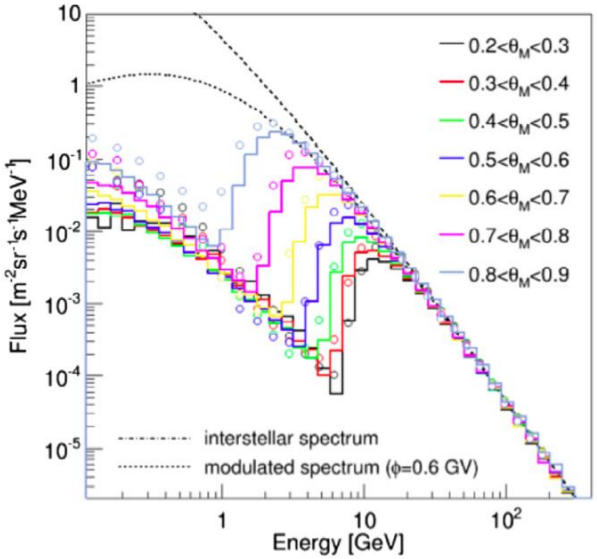




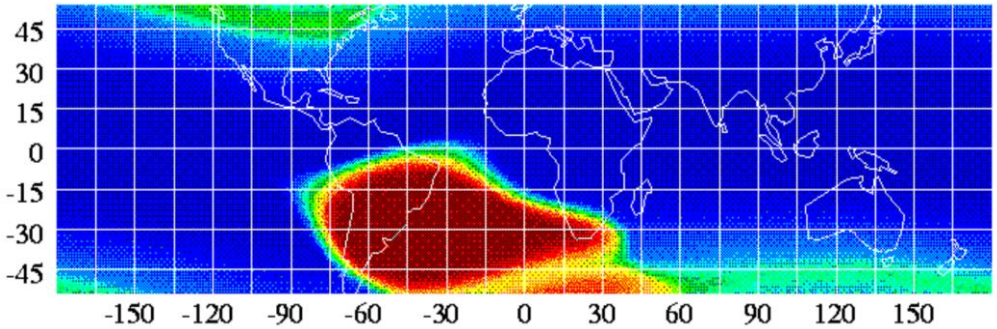


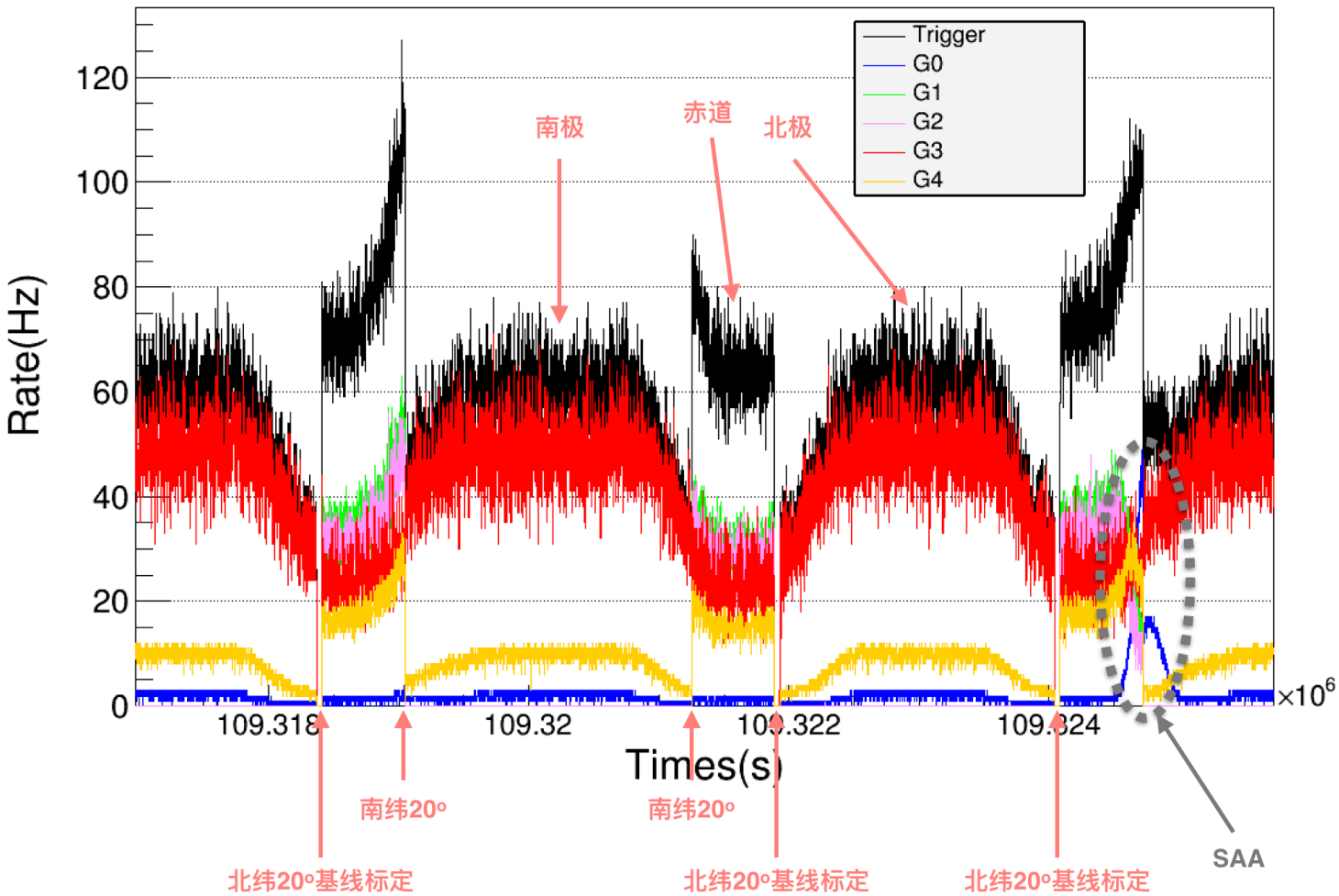


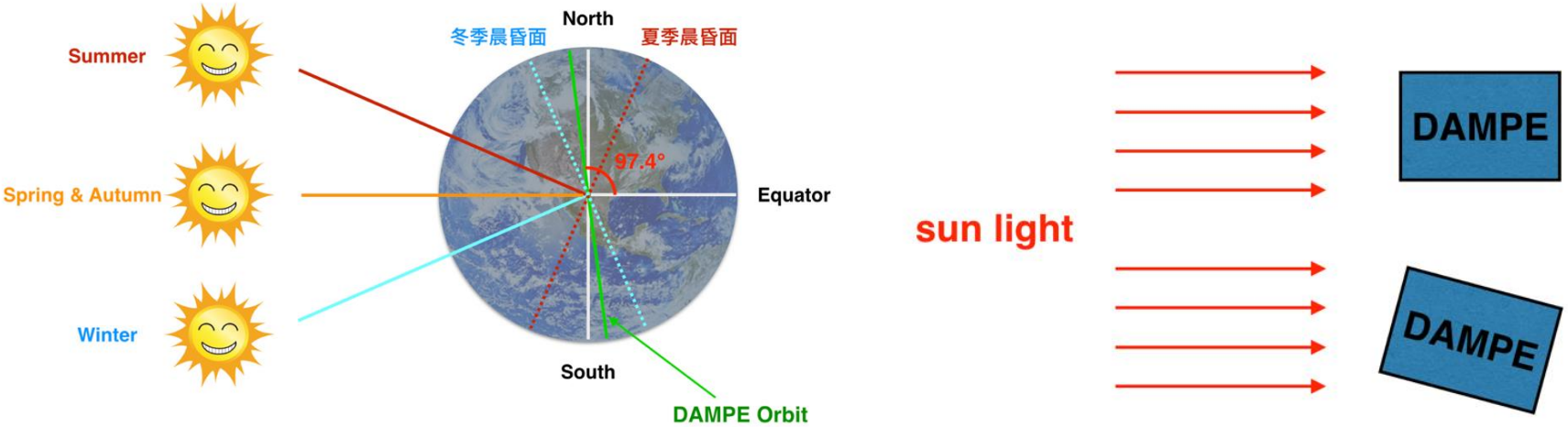


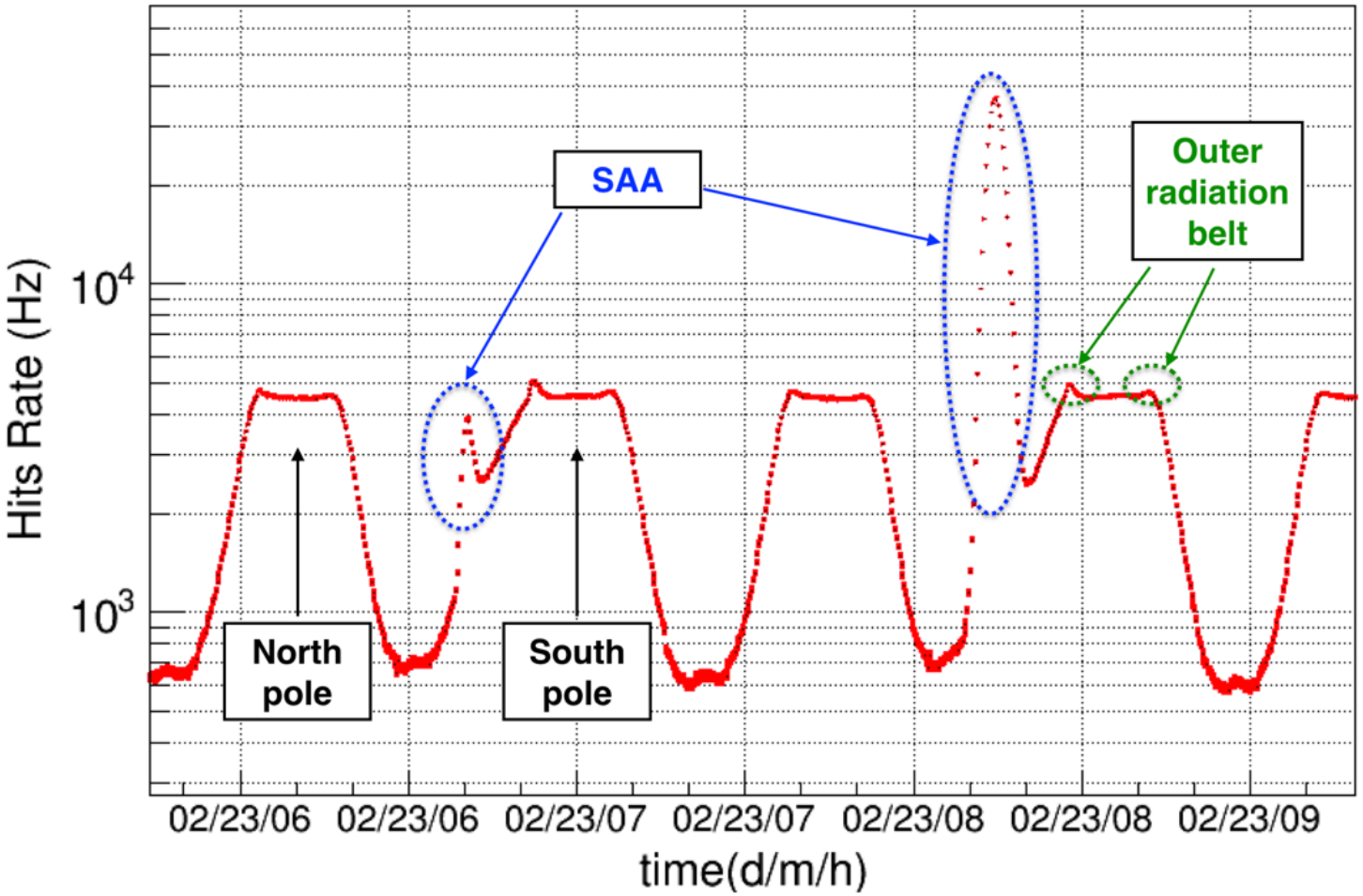


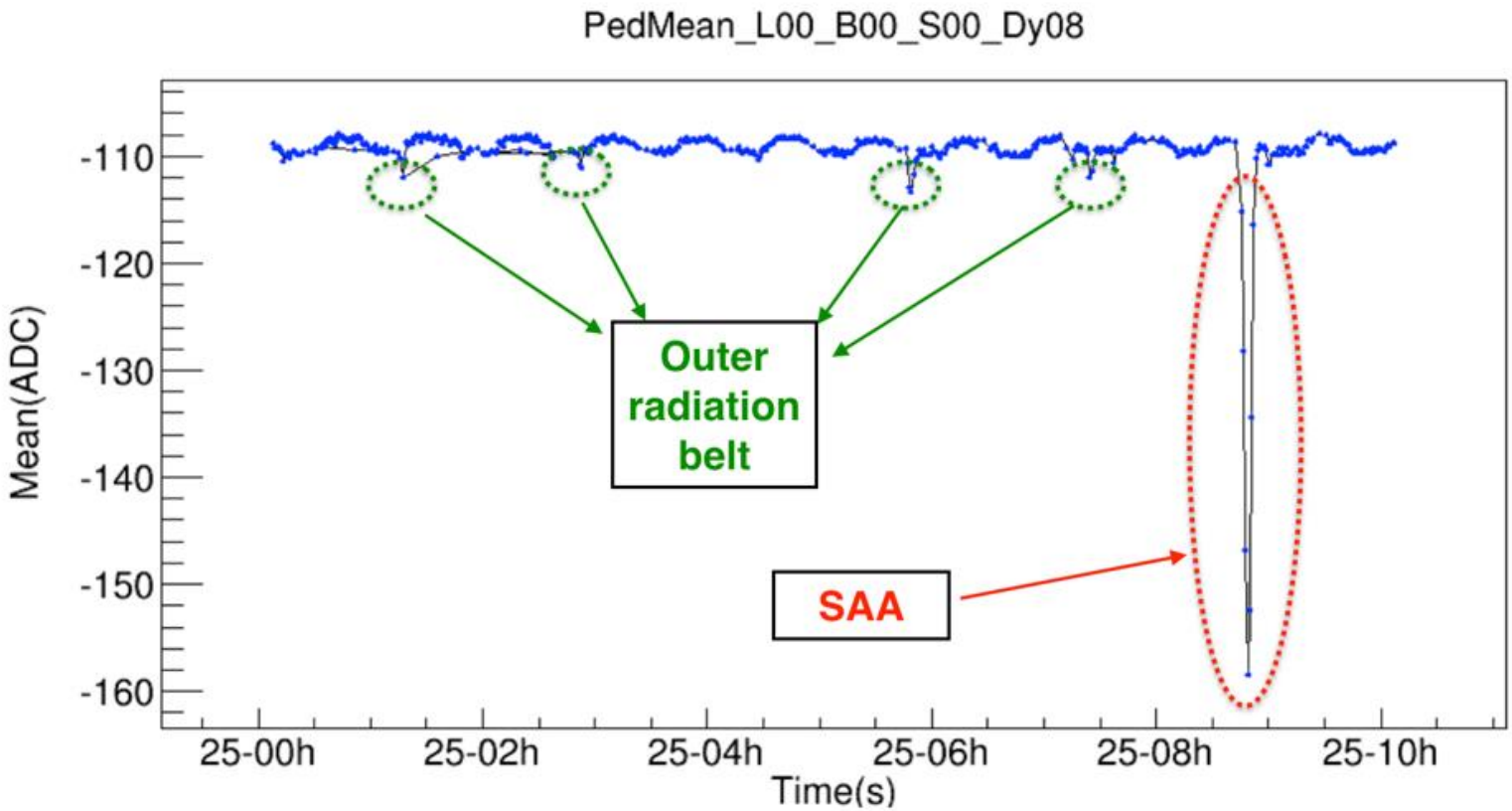
South Atlantic Anomaly (SAA)

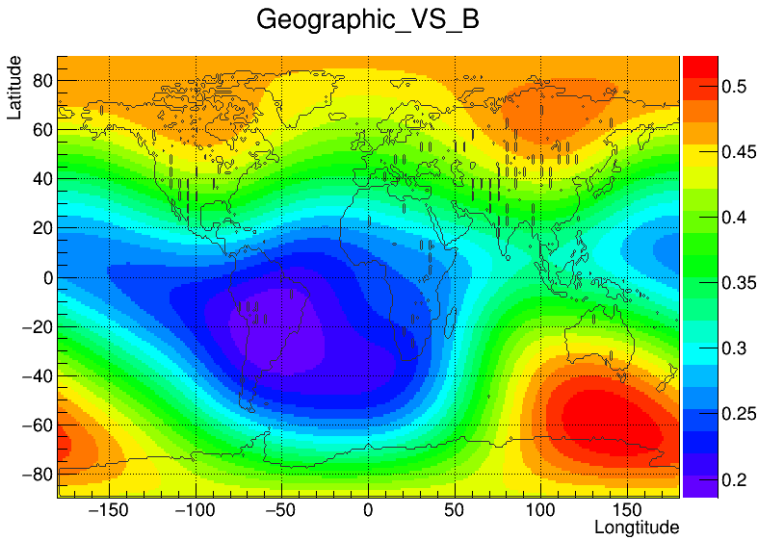


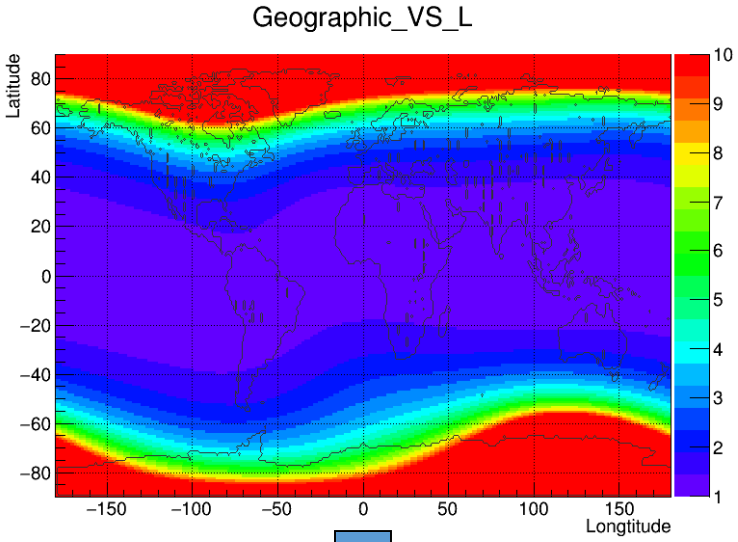

Trigger
G0
G1
G2
G3
G4
Rate(Hz)
Times(s)
×10^6
南极
赤道
北极
南纬20°
南纬20°
北纬20°基线标定
北纬20°基线标定
北纬20°基线标定
SAA

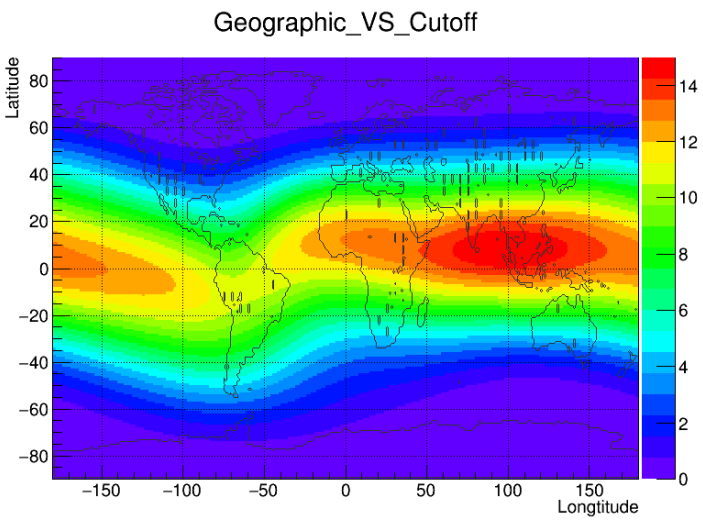

Summer
Spring & Autumn
Winter
North
冬季晨昏面
夏季晨昏面
97.4°
Equator
South
DAMPE Orbit
sun light
DAMPE
DAMPE


SAA
Outer radiation belt
North pole
South pole
Hits Rate (Hz)
10^4
10^3
02/23/06
02/23/06
02/23/07
02/23/07
02/23/08
02/23/08
02/23/09
time(d/m/h)


PedMean_L00_B00_S00_Dy08
Mean(ADC)
-110
-120
-130
-140
-150
-160
25-00h
25-02h
25-04h
25-06h
25-08h
25-10h
Time(s)
Outer radiation belt
SAA


Geographic_VS_B
Latitude
Longtitude


Geographic_VS_L
Latitude
Longtitude


Geographic_VS_Cutoff
Latitude
Longtitude

IGRF model