

暗物质粒子探测卫星 与在轨观测结果

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on behalf of the DAMPE Collaboration

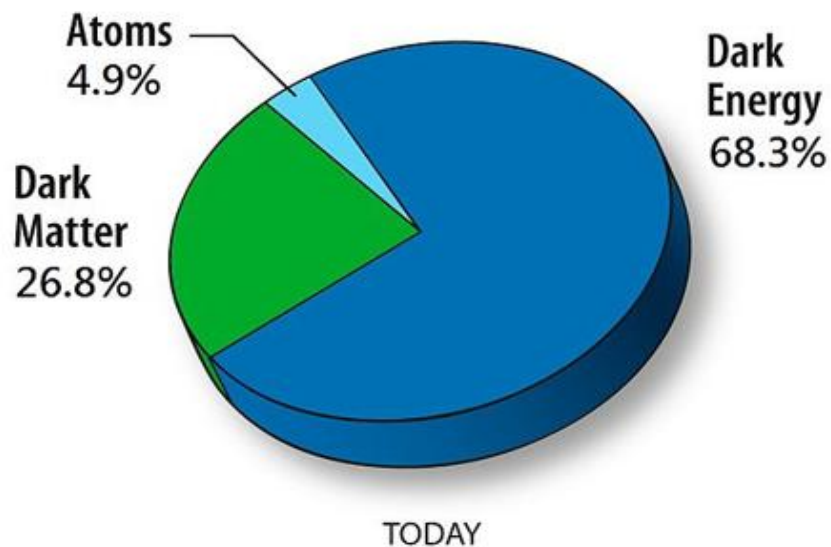


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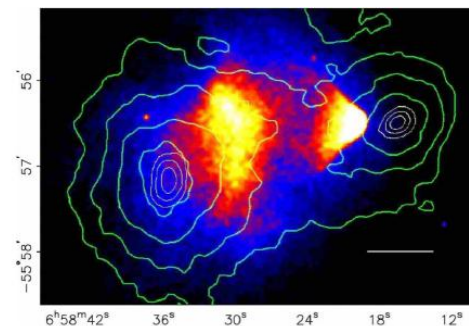
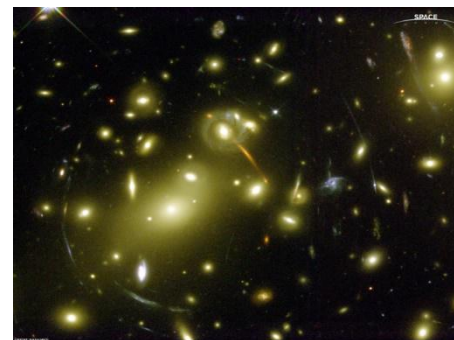
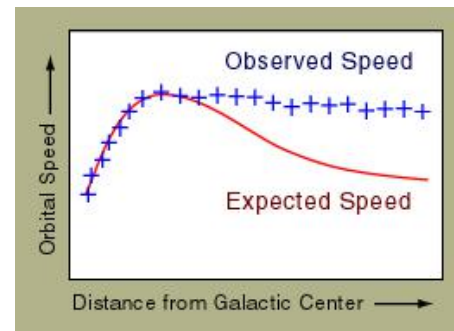
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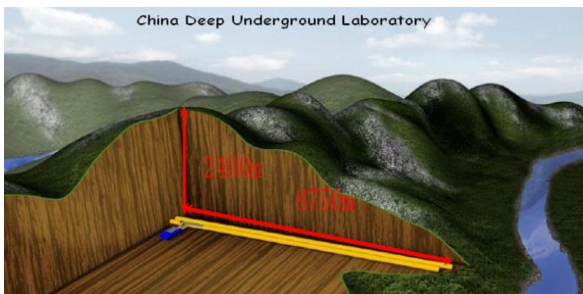
研究意义



- 人类现有物理理论可以解释的物质只占宇宙组成的不到5%
- 暗物质研究意味着对人类现有认知的突破，对探索宇宙起源、促进科学发展具有重大意义



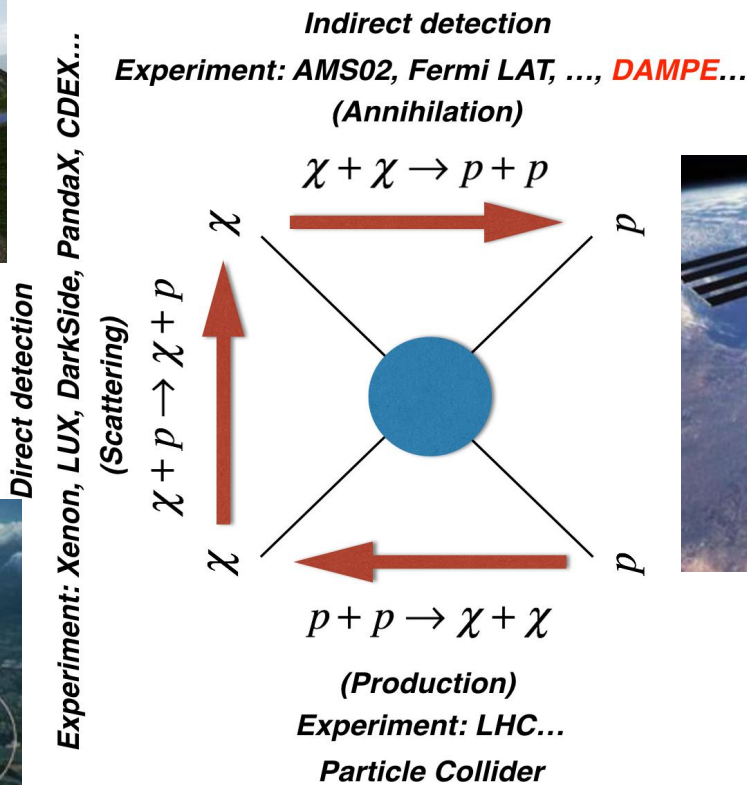
研究意义



地下直接测量



加速器对撞



空间间接测量

三种方法从不同的角度出发，相互补充！

暗物质粒子探测卫星

• 磁谱仪

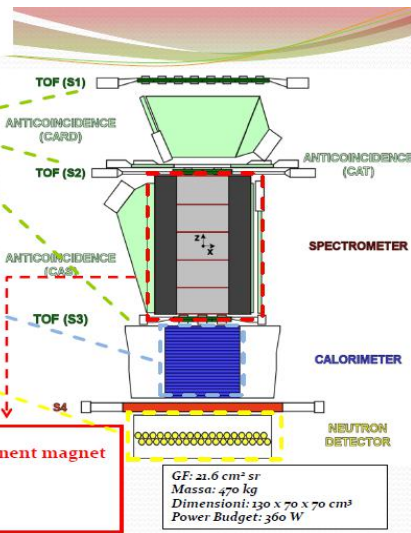
PAMELA experiment

Time-Of-Flight
plastic scintillators + PMT:
 - Trigger
 - Albedo rejection;
 - Mass identification up to 1 GeV;
 - Charge identification from dE/dX

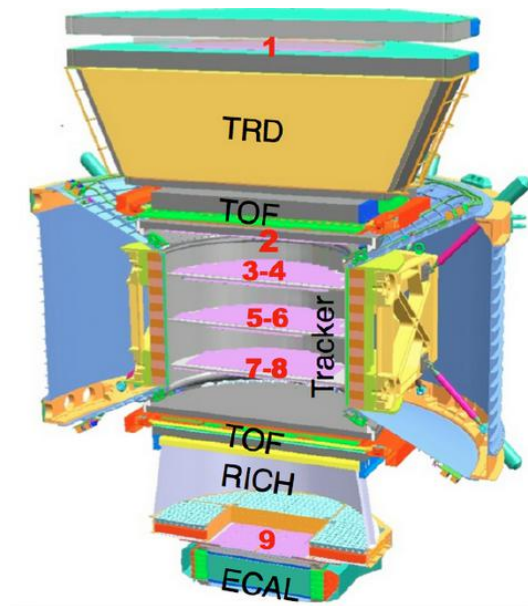
Electromagnetic calorimeter
 W/Si sampling (16.3 Xo, 0.6 λ I)
 - Discrimination e^+ / p , anti- p / e^-
 (shower topology)
 - Direct E measurement for e^-

Neutron detector
 36 He³ counters:
 - High-energy e/h
 discrimination

Spectrometer
microstrip silicon tracking system + permanent magnet
 It provides:
 - Magnetic rigidity $\rightarrow R = pc/Ze$
 - Charge sign
 - Charge value from dE/dx



PAMELA



AMS02



暗物质粒子探测卫星

• 望远镜+量能器

The Fermi LAT

- The Large Area Telescope (LAT) is one of two instruments on the *Fermi* Gamma-ray Space Telescope
- The LAT is a pair conversion telescope

Anti-coincidence Detector (ACD)

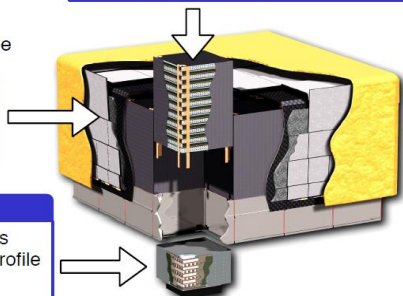
- 89 segmented plastic scintillating tiles
- Used for particle identification

Calorimeter (CAL)

- 1536 CsI(Tl) crystals arranged in 8 layers
- Hodoscopic, image shower shape and profile
- Used for energy measurement

Tracker (TKR)

- 18 x-y layers of silicon strip detectors
- Used for direction reconstruction and particle identification



NUCLEON mission

NUCLEON apparatus is placed on board of the **RESURS-P** regular satellite as an additional payload. The spacecraft orbit is a Sun-synchronous one with inclination **97.276°** and an average altitude of **475 km**. Lunched **December 28, 2014**. From July **2015** up to now - regular measurements. The planned exposition time is not less than **5 years** (more expected)

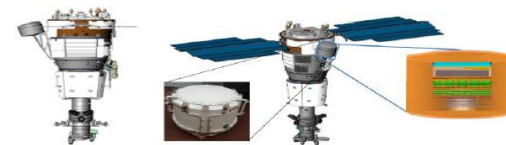


Vessel:

Weight ~360 kg

Power consumption ~160 W

Telemetry ~10 GB/day

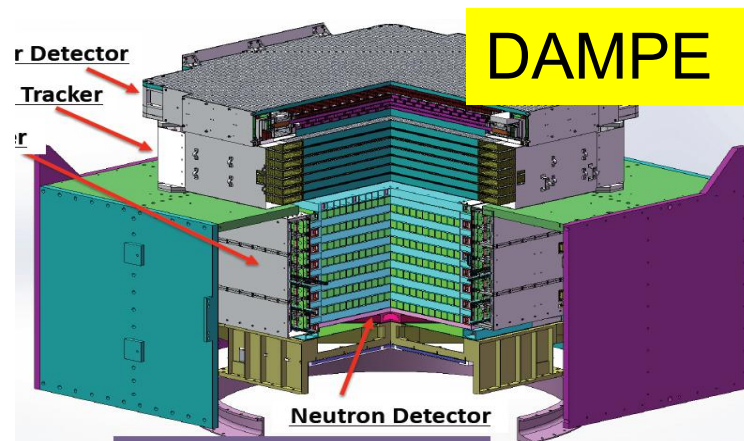
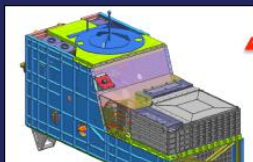
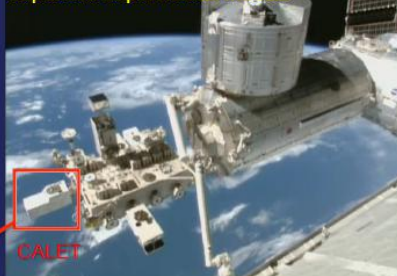


The NUCLEON detector on board of the satellite RESURS-P N2.

CALET: CALorimetric Electron Telescope

Launch: August 19, 2015
Observations: October 13, 2015

Japanese Experimental Module



暗物质粒子探测卫星

- 与国际同类探测器的比较

项目	实验类型	接收度 (m^2Sr)	量能器 辐射长度 (能区范围)	量能器 能量分辨率 @100GeV	发射时间
PAMELA	卫星	0.002	17	12%	2006.6
Fermi-LAT	卫星	2.4	8.6	8.5%	2008.6
AMS-02	空间站	0.05	17	2%	2011.5
CALET	空间站	0.1	28	2%	2015.8
DAMPE	卫星	0.3	32	1%	2015.12

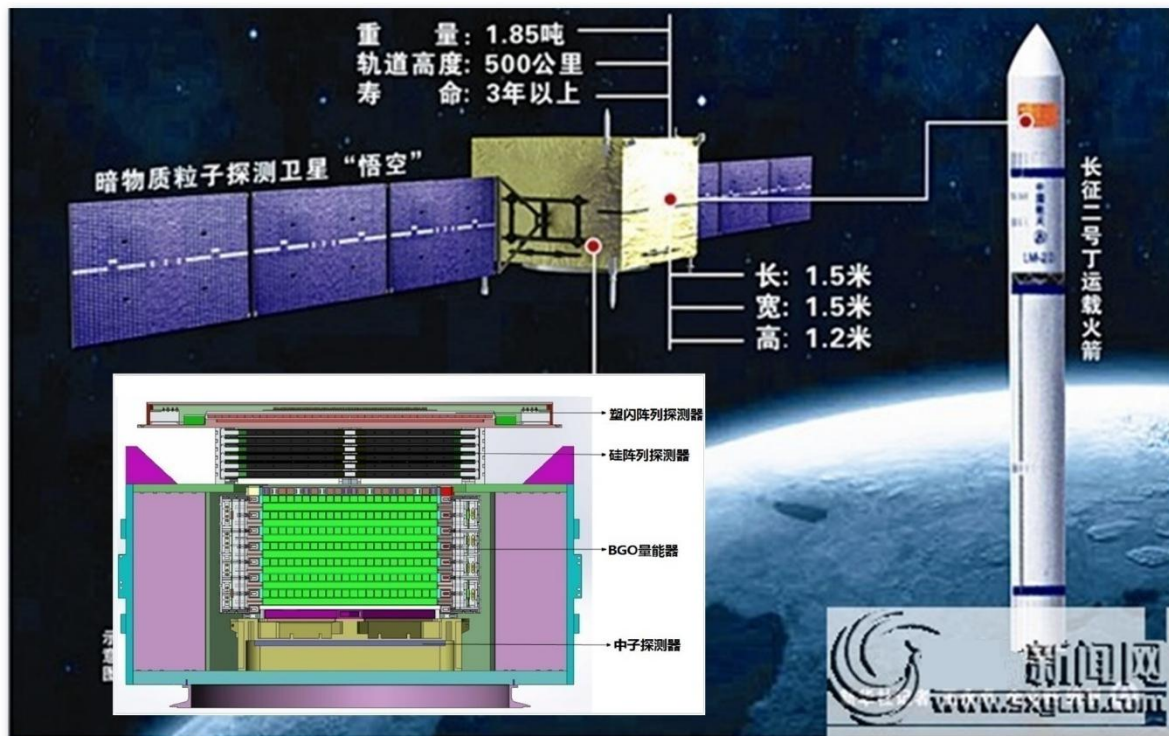
DAMPE: 接收度大、高能区灵敏



暗物质粒子探测卫星（悟空号）

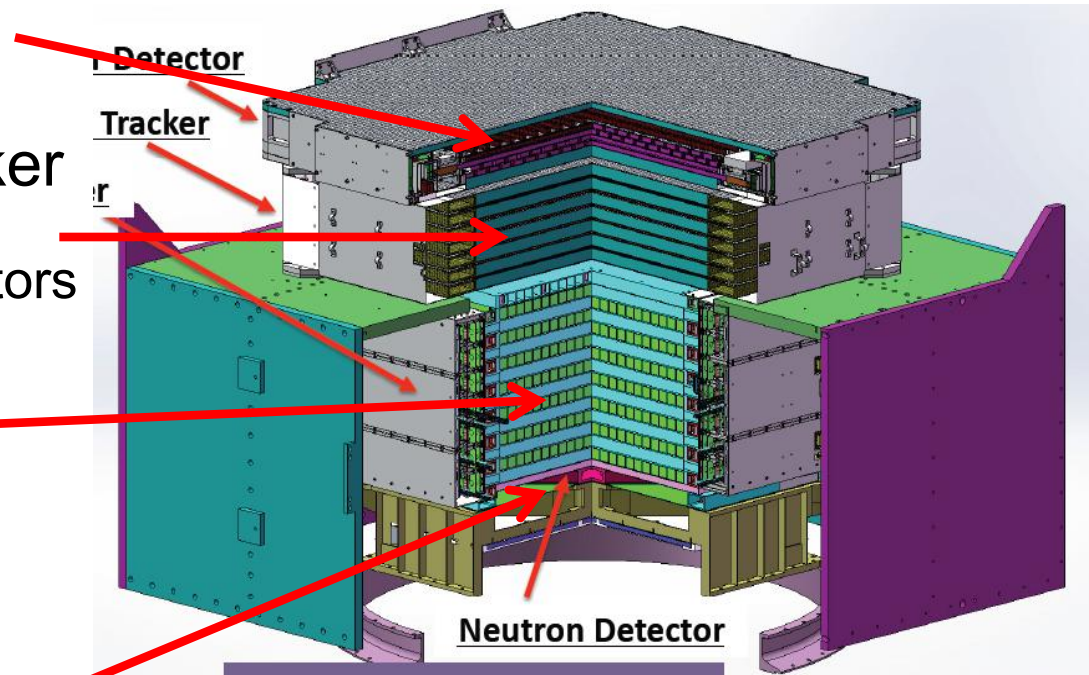
(DAMPE: DArk Matter Particle Explorer)

- 500km orbit
- e^{\pm} , gamma-rays
- 5GeV to 10TeV
- 1.5% @ 800GeV
- Total weight: ~1.4T



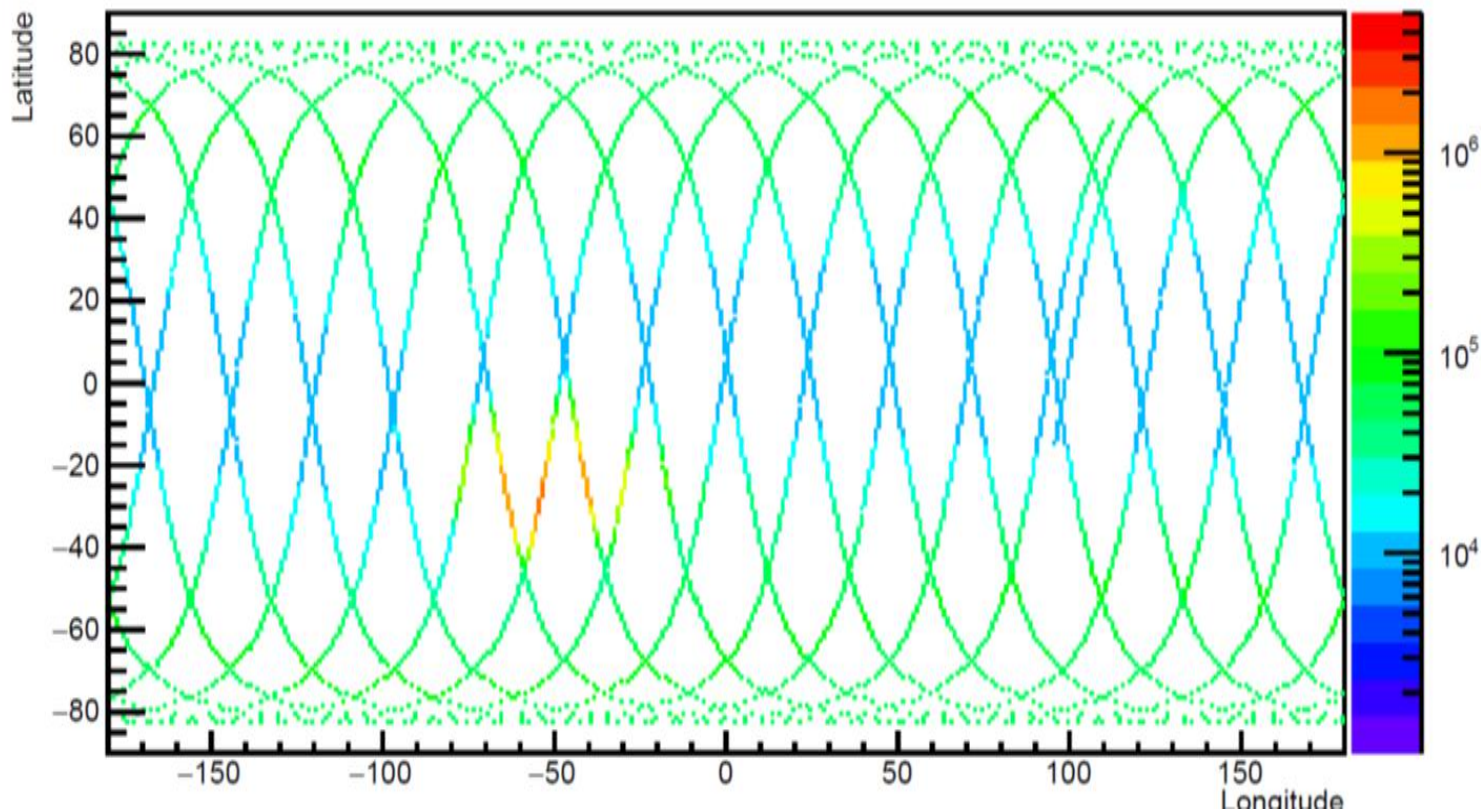
暗物质粒子探测谱仪

- Plastic Scintillator Array
 - Response : $Z=1\sim 20$
- Silicon Tungsten Tracker
 - 12 layers Si-strip detectors
- BGO Calorimeter
 - 14 layers BGO crystals
 - $\sim 32X_0$
- Neutron Detector
 - Plastic scintillator with Boron





2015年12月17日8时12分



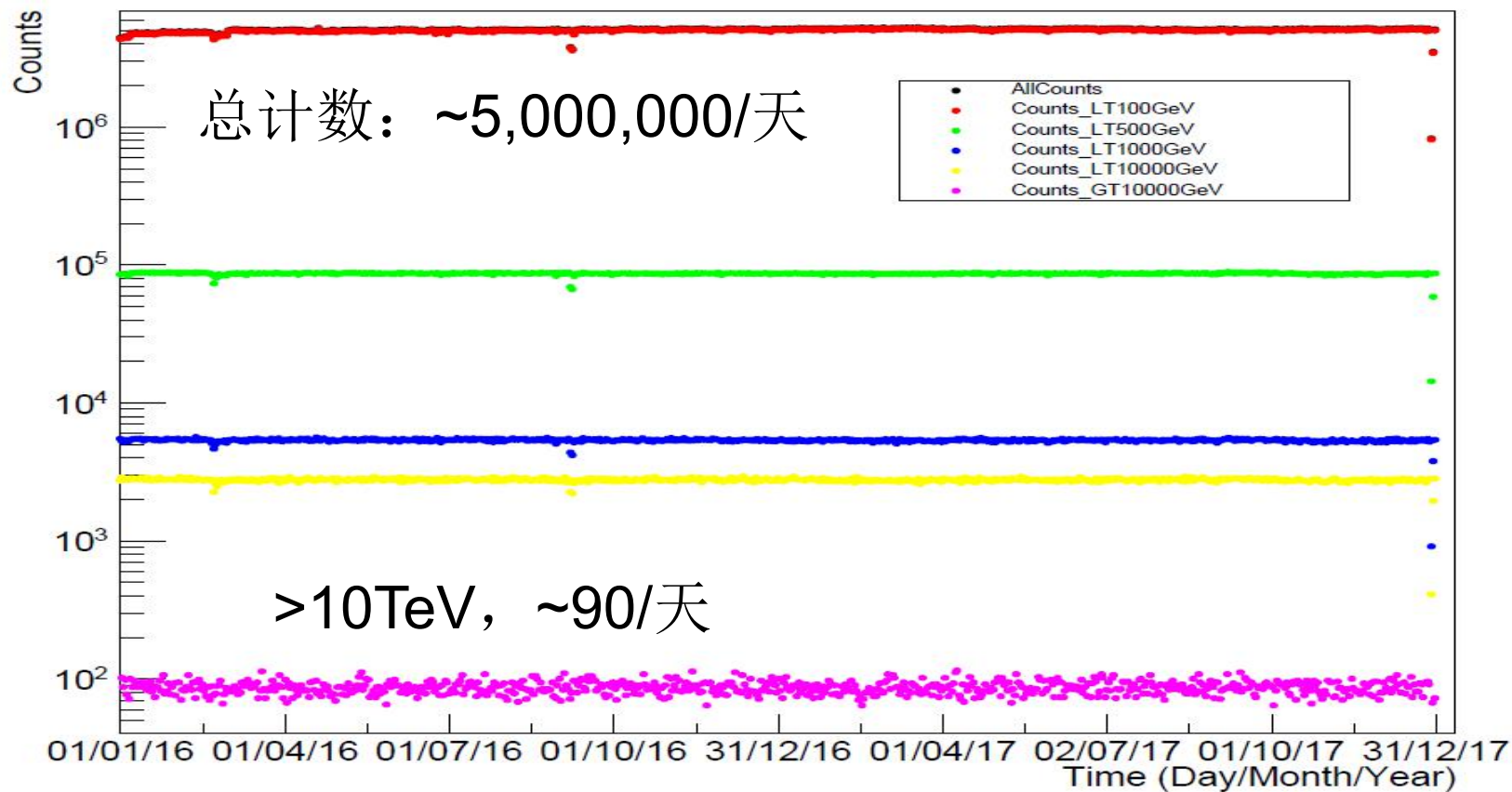
~50 Hz average trigger rate

→ 100GB (H.L.)/day on ground (about 5 M events)

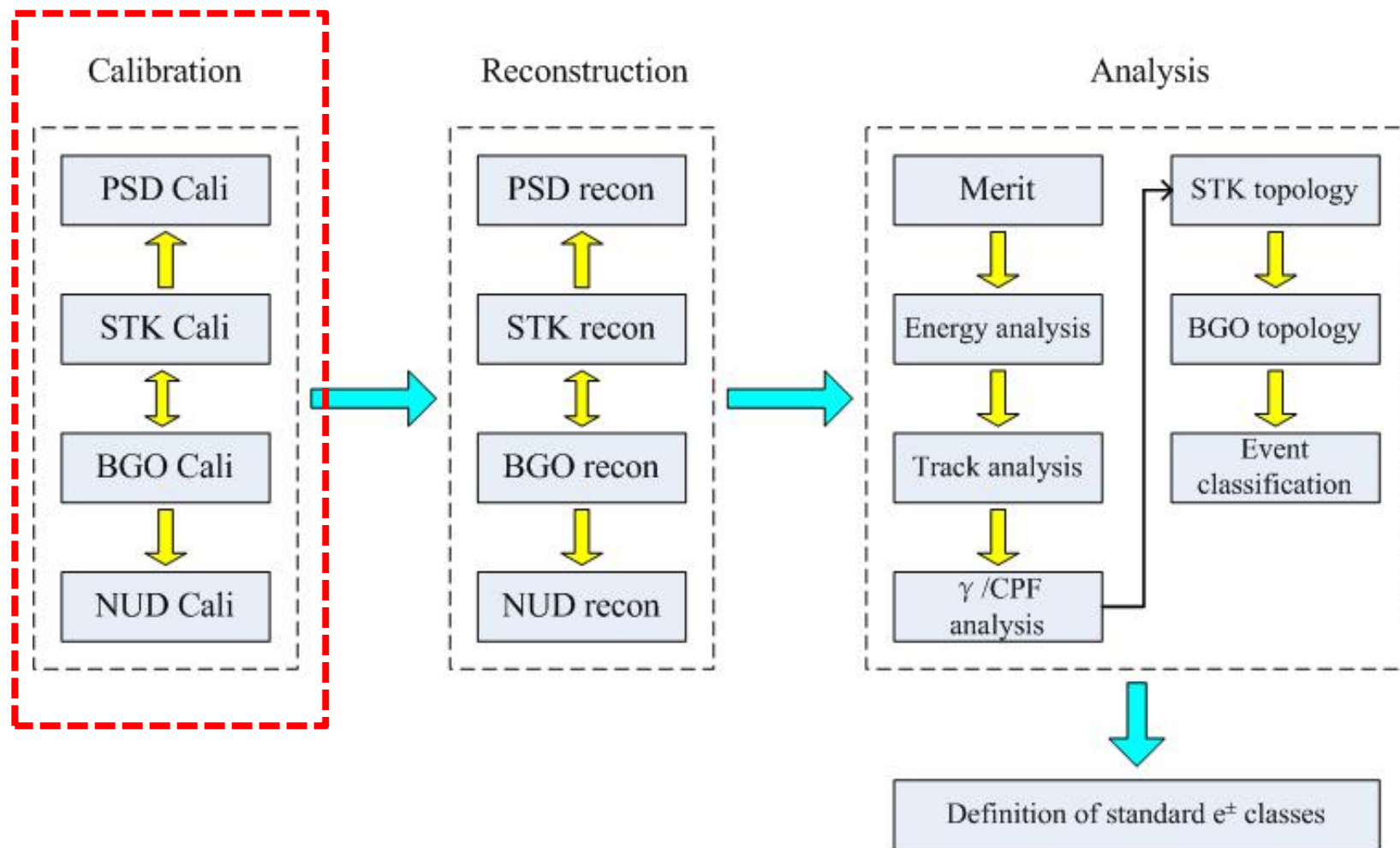


BGO量能器在轨状态

入轨两年来数据采集量:

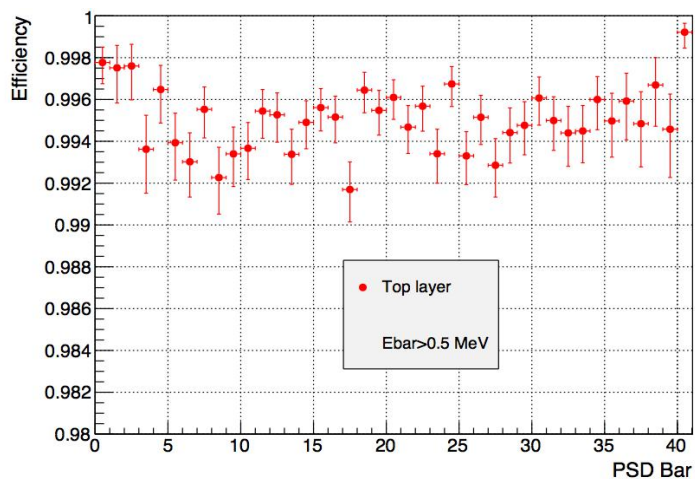


数据处理流程

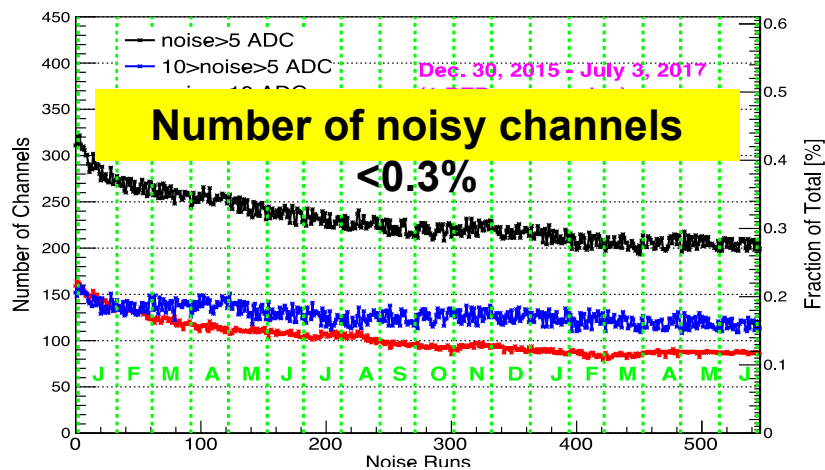


在轨刻度

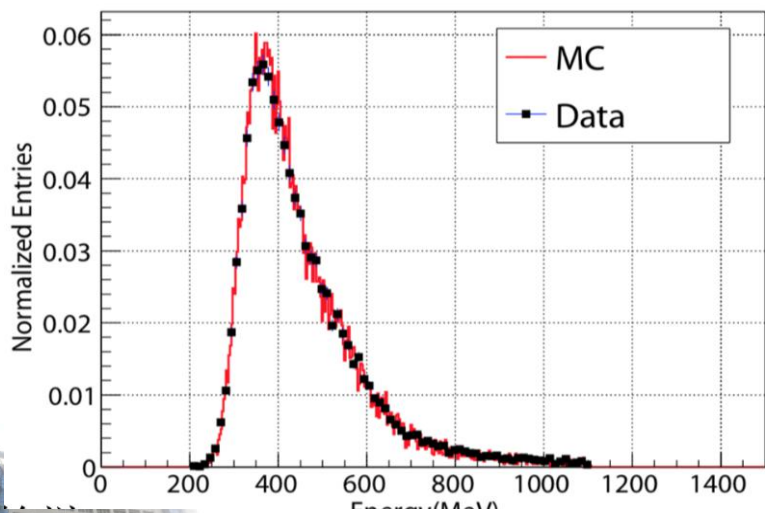
PSD的探测效率



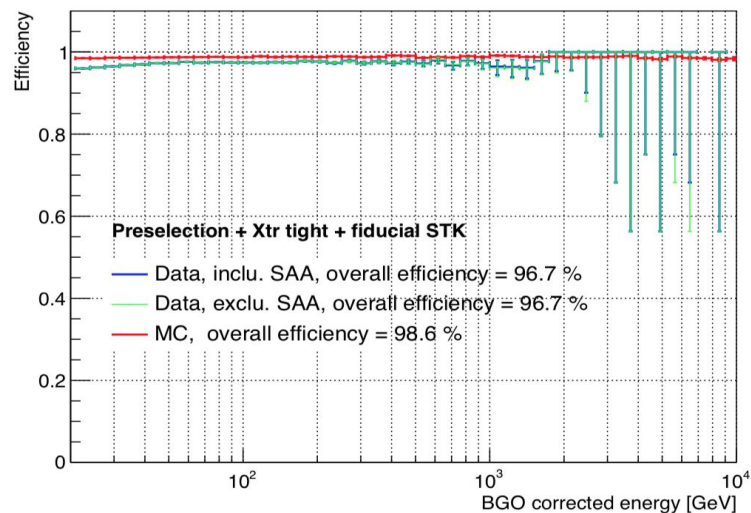
STK的噪声



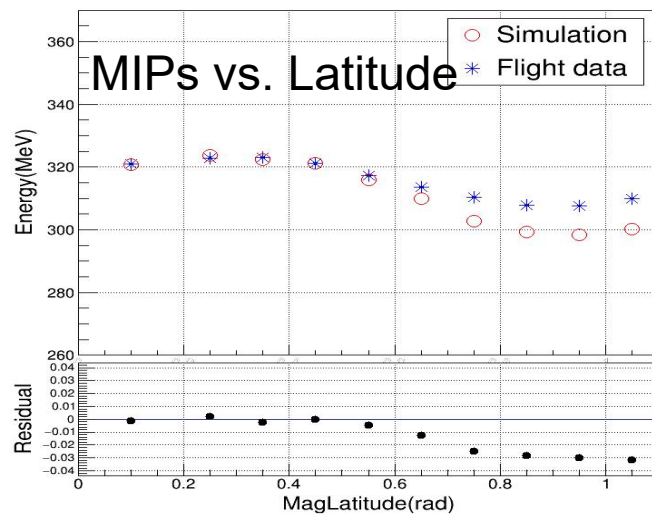
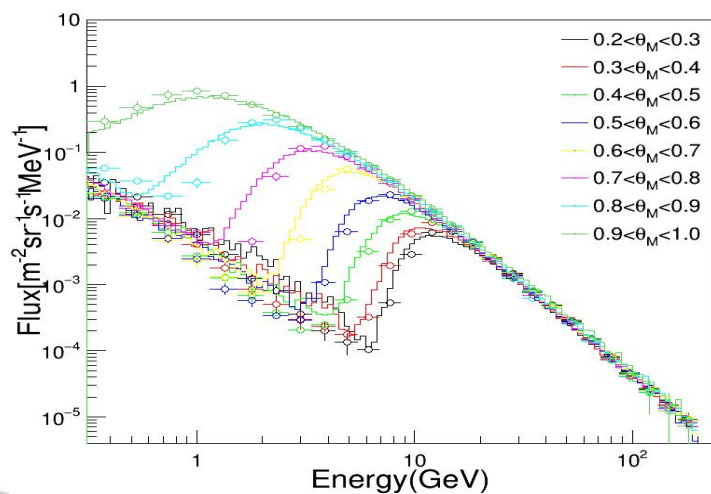
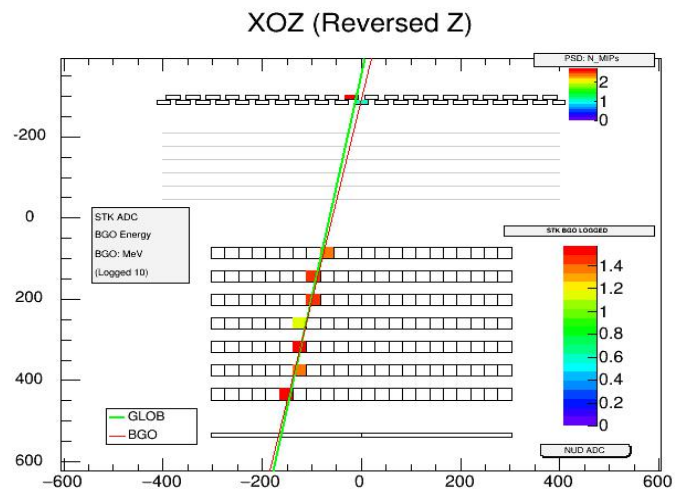
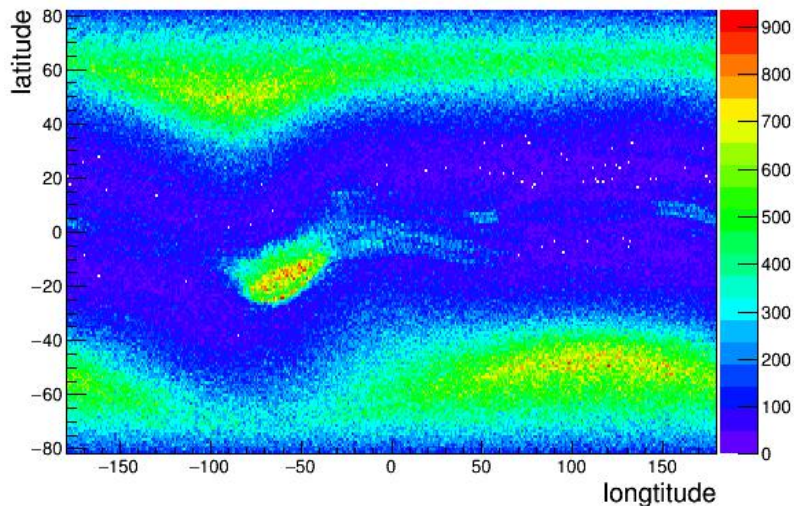
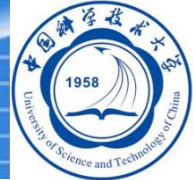
BGO量能器的MIPs谱



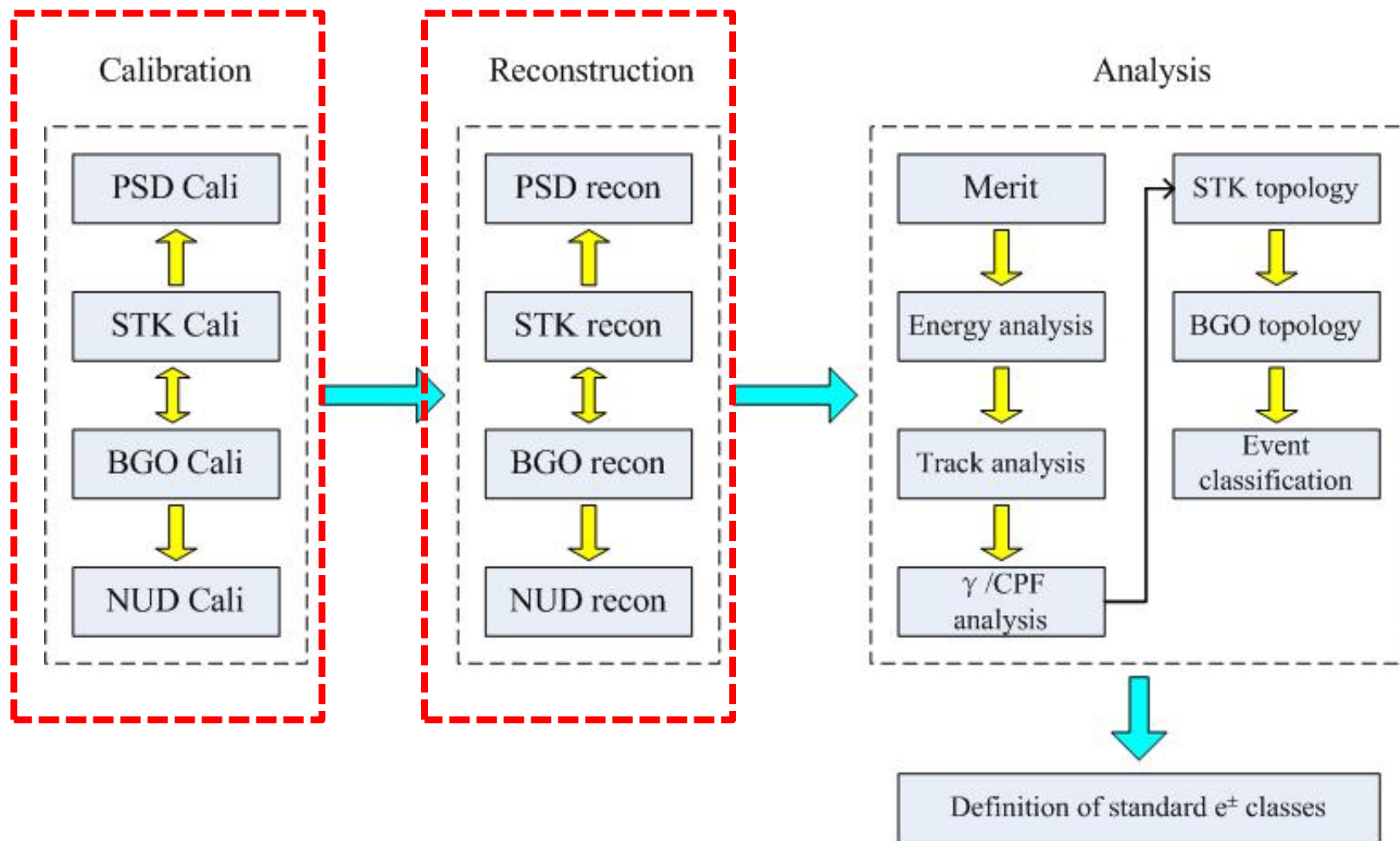
STK的径迹重建效率



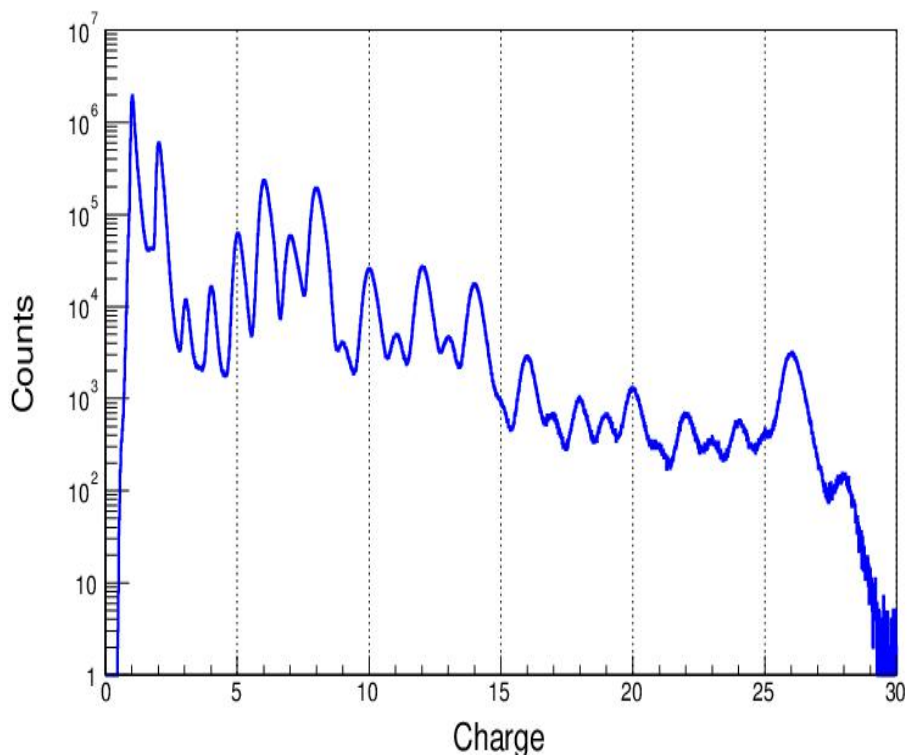
BGO量能器在轨标定



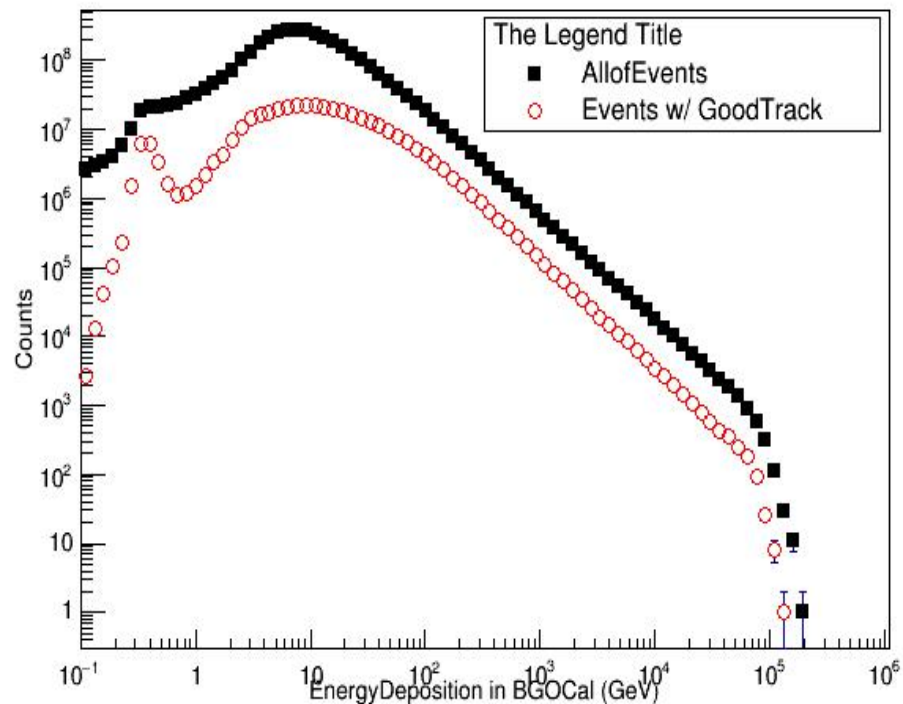
数据处理流程



重建



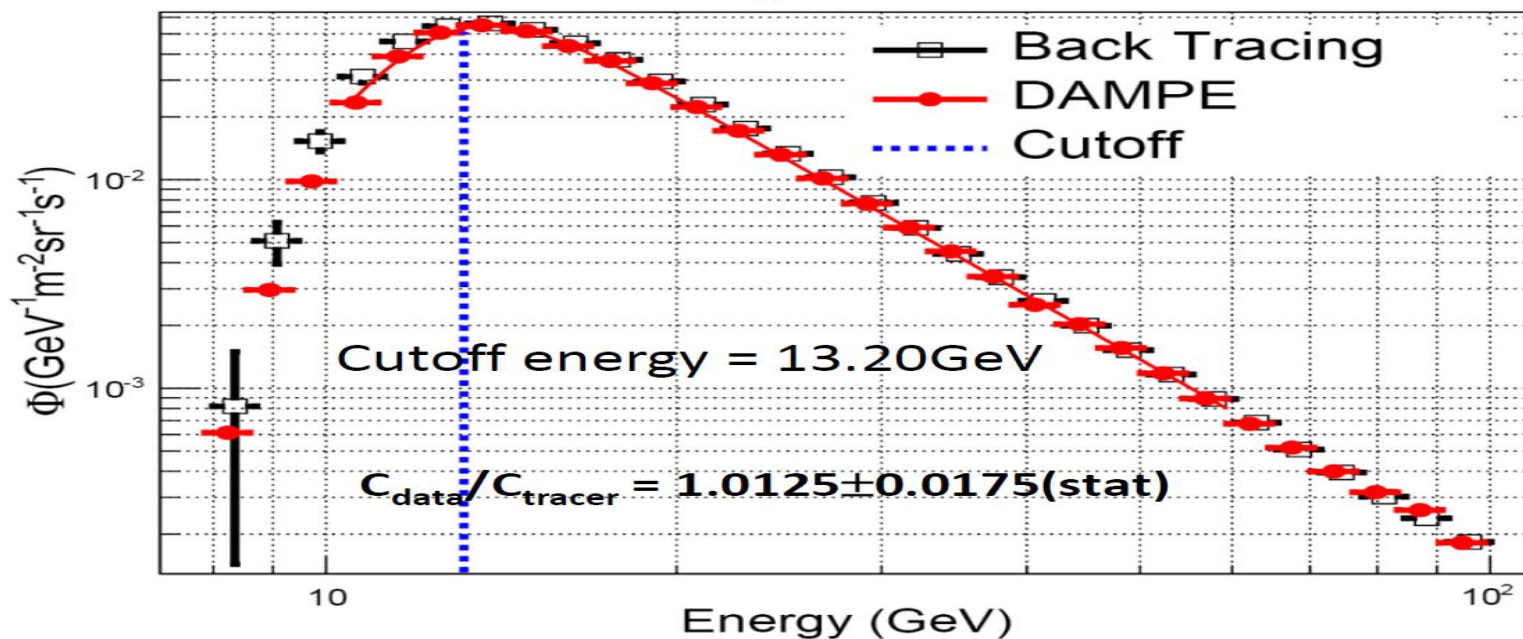
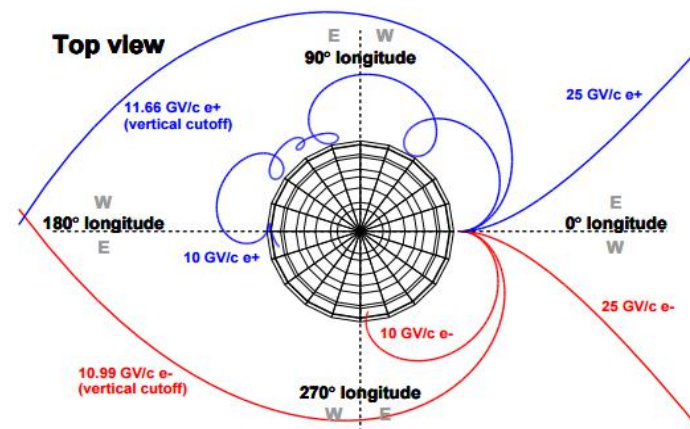
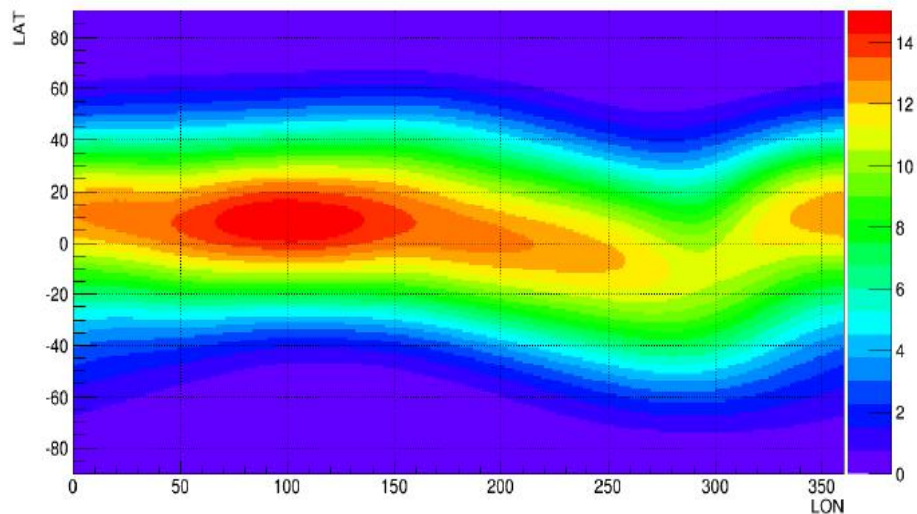
电荷 (塑料闪烁体探测器)



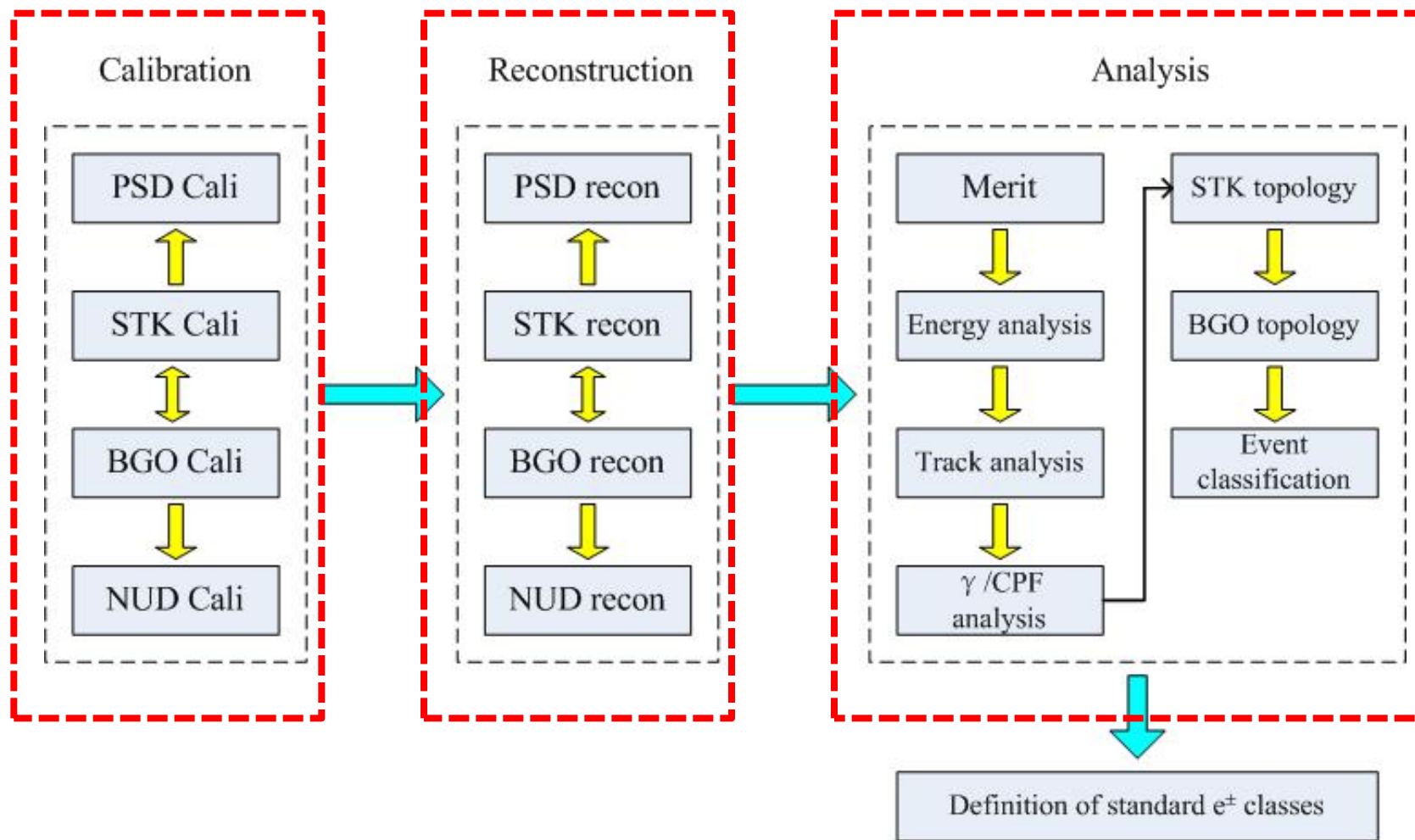
能量 (量能器)



地磁截断测量



数据处理流程



微分通量

$$\Phi(E, E + \Delta E) = \frac{N_{obs}(E, E + \Delta E)}{\Delta E \Delta T_{exp} A_{eff} \epsilon_{trig}}$$

Φ = Absolute differential flux ($\text{m}^{-2} \text{sr}^{-1} \text{GeV}^{-1}$)

N_{obs} = Number of observed events

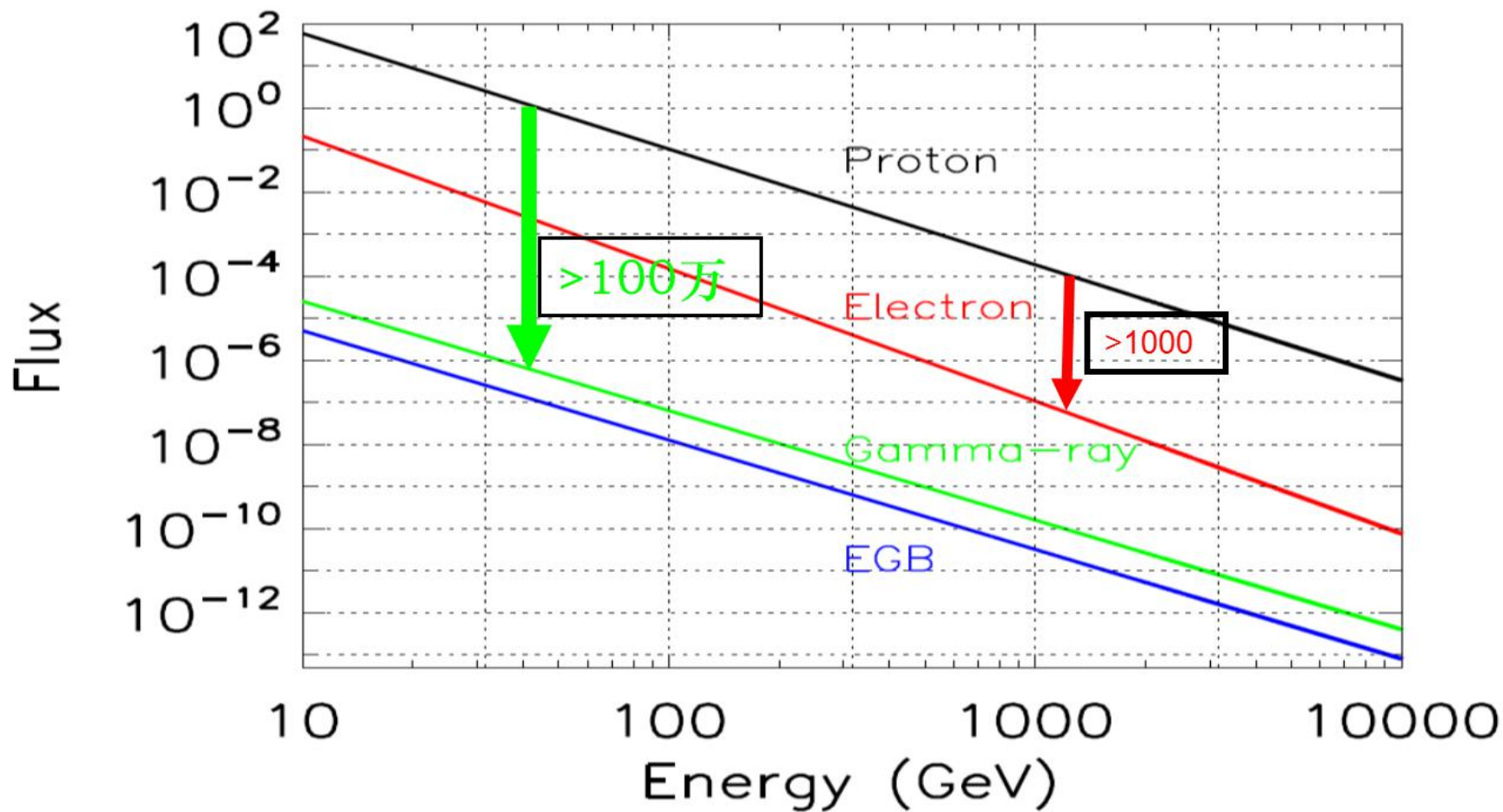
ΔT_{exp} = Exposure time (s)

A_{eff} = Effective acceptance (m^2sr)

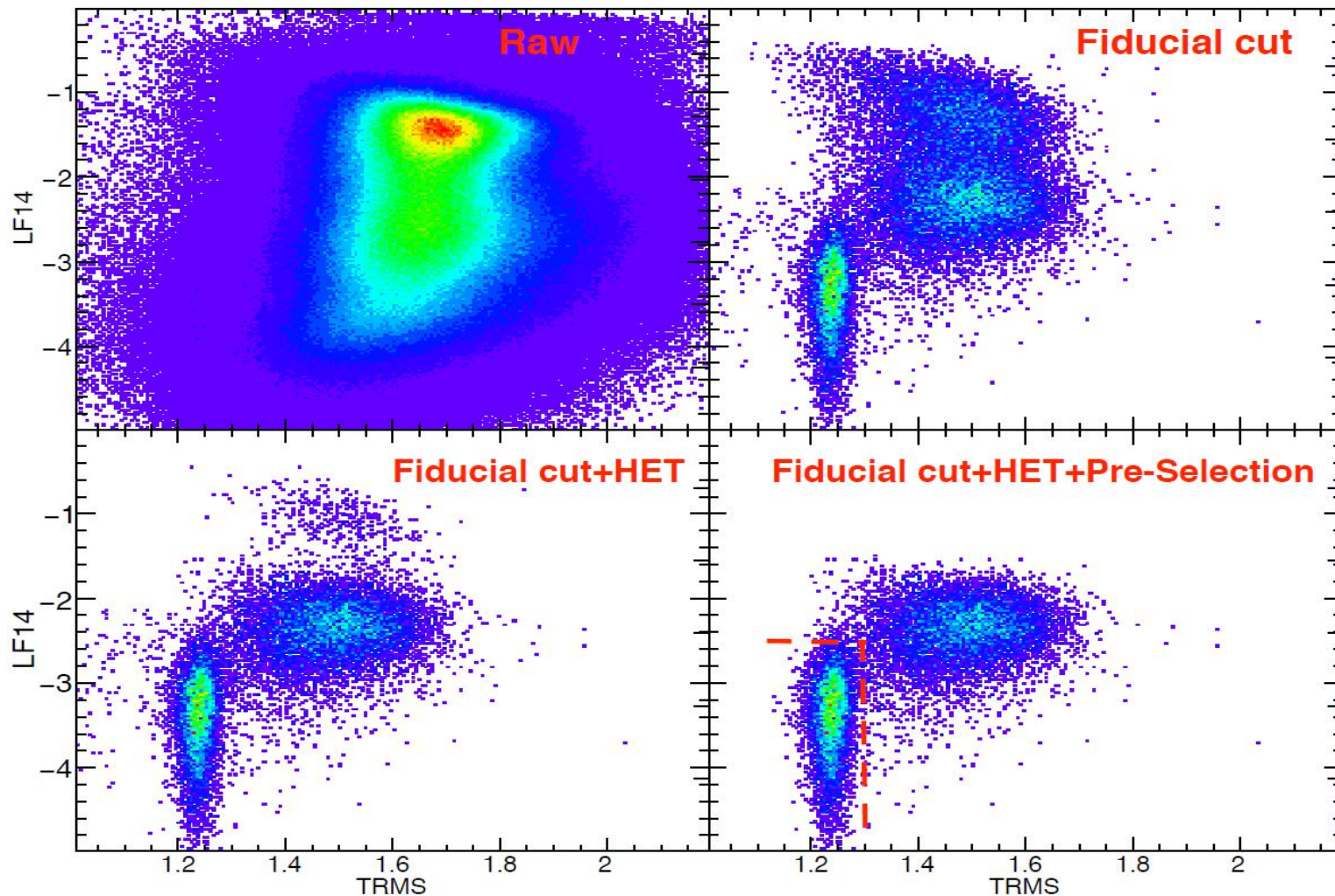
ϵ_{trig} = Trigger efficiency



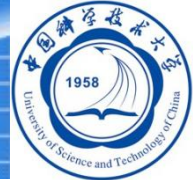
粒子鉴别



粒子鉴别

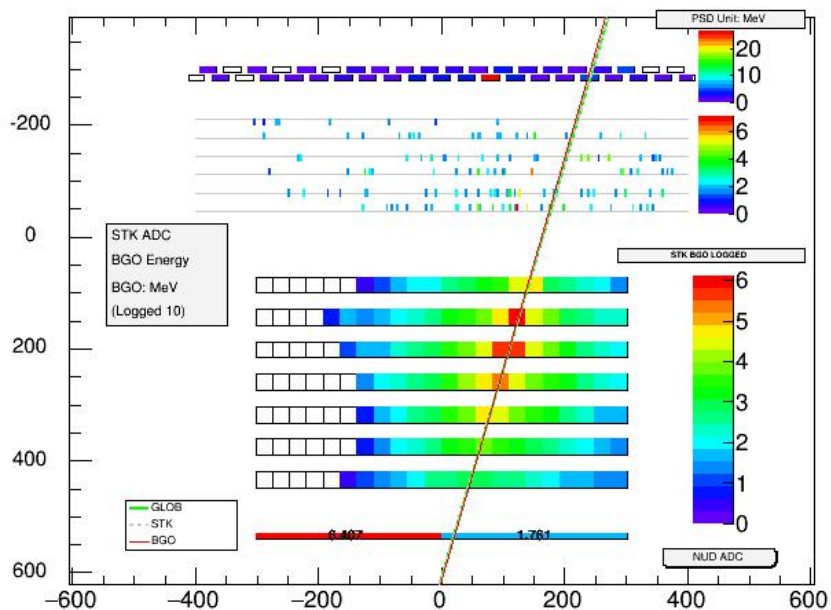


候选事件显示

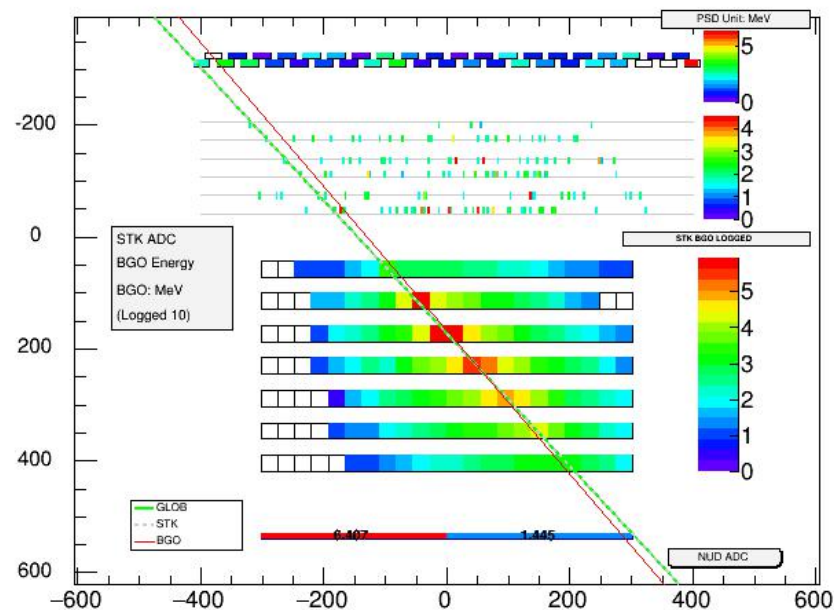


粒子种类：电子候选事例 能量：5.6TeV

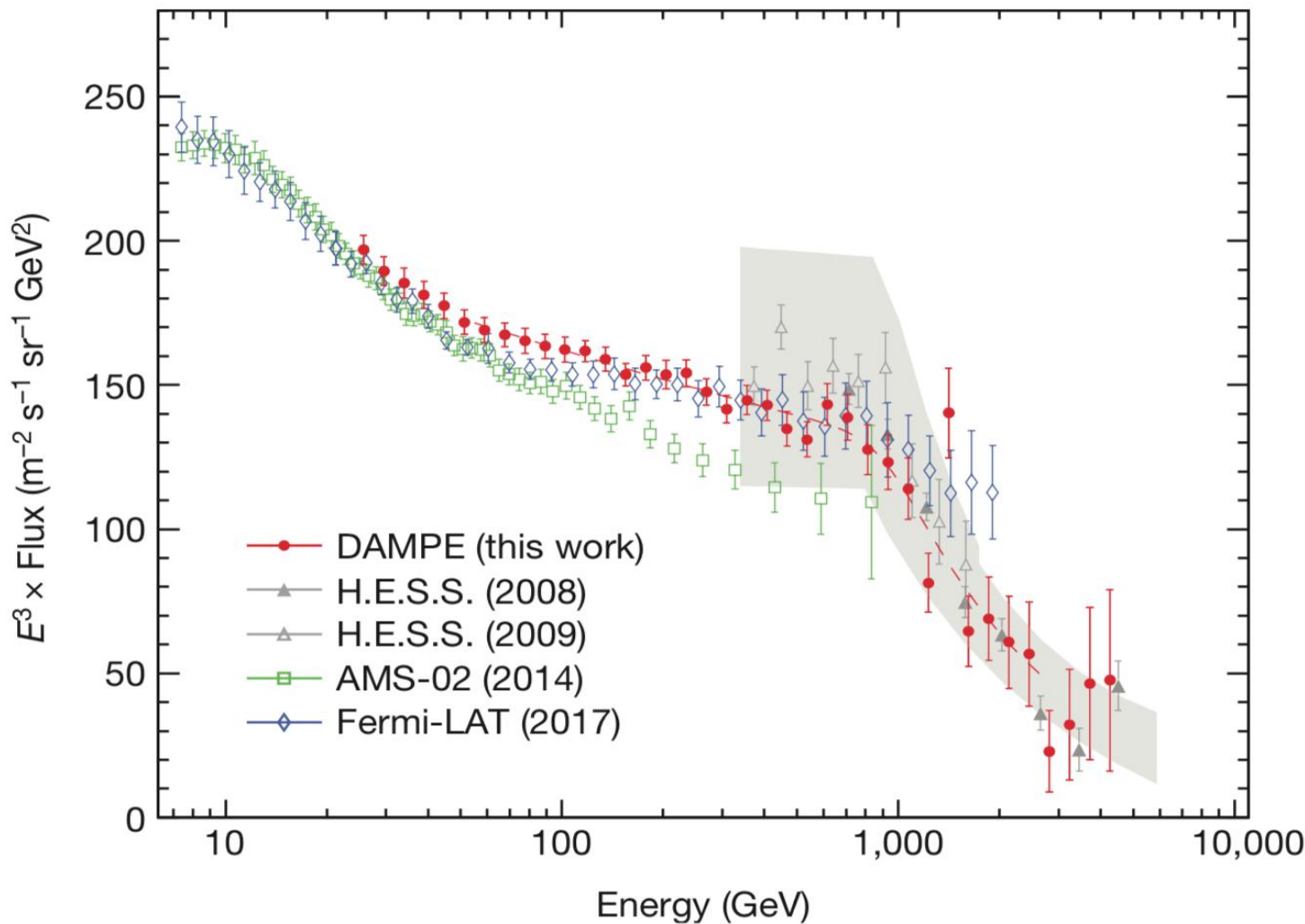
XOZ (Reversed Z)



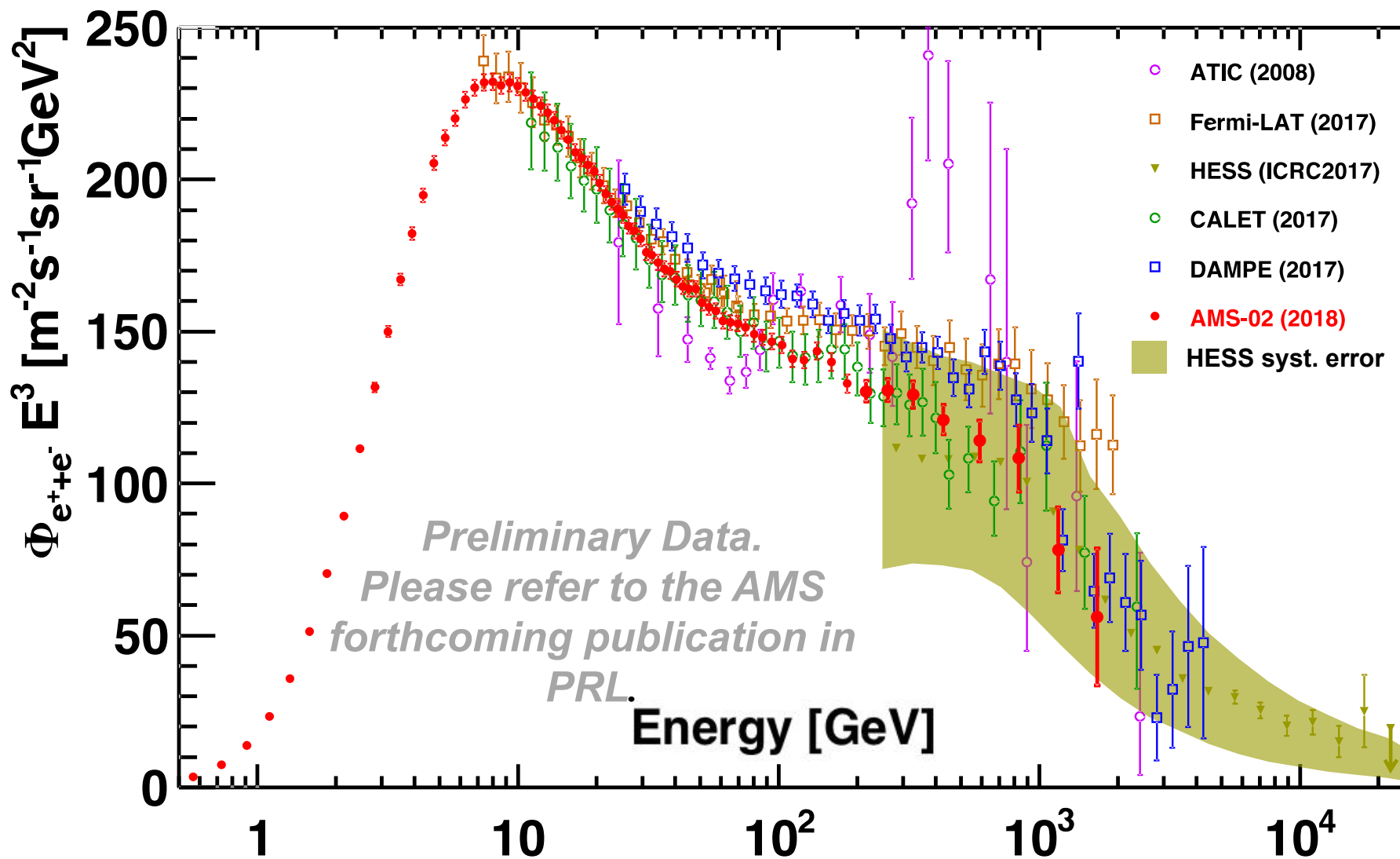
YOZ (Reversed Z)



电子谱



AMS(e⁺ + e⁻) 测量结果与其他非磁谱仪探测器结果比较



1. HESS, DAMPE 和 AMS 都观察到了在~1 TeV附近的拐折

2. e⁺ 的测量对 χ 寻找最灵敏 $\chi + \chi \rightarrow e^+, e^-, \dots$

由于e⁻本底非常大, (e⁺+e⁻)的测量对 χ 寻找的灵敏度低很多

第十九届核电子学与核探测技术学术年会, 烟台

全天区Gamma天图扫描

PRELIMINARY

DAMPE 510 days

$E > 2\text{GeV}$

Counts / $(0.5^\circ)^2$ pixel

$\sigma_\theta \approx 0.18^\circ$ @ 3 GeV

Vela

Geminga

Crab

FERMI 5 years

$E > 1\text{GeV}$

说明：DAMPE 工作状态稳定

方向重建、粒子鉴别、能量重建等性能优秀！

总结

- 空间实验作为粒子物理研究的一个重要方向，其中物理课题丰富，需要长期开展；
- 暗物质粒子探测卫星已成功在轨运行近两年时间，取得了大量的宇宙线数据；
- 首次在**TeV**能区成功打开了一扇观测宇宙的窗口，为寻找和研究暗物质奠定了坚实的基础；

“立足常规，着眼新奇！”



总结

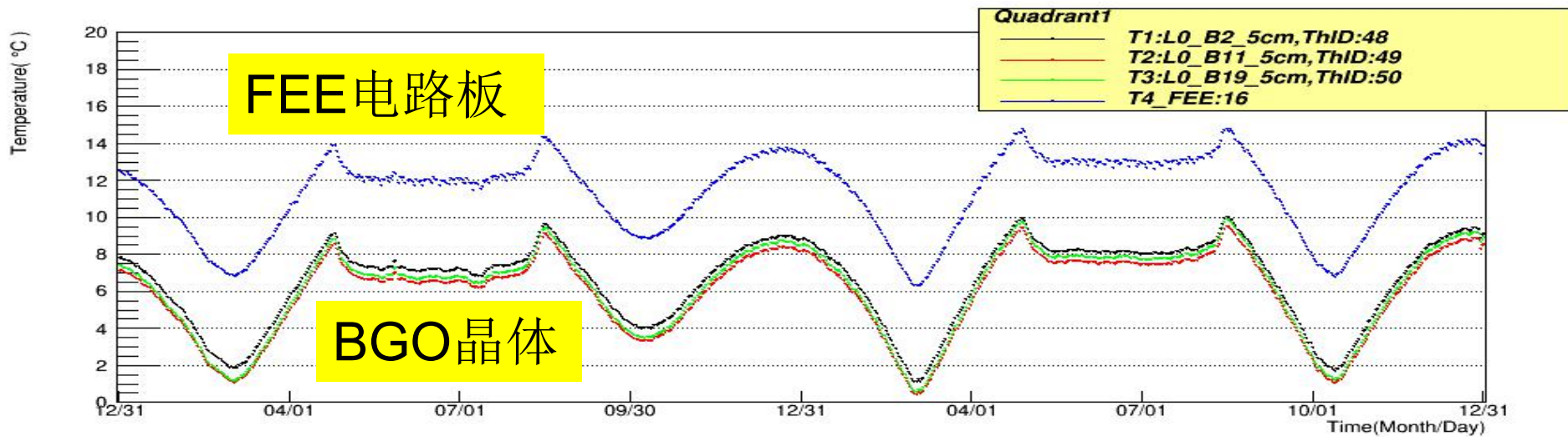
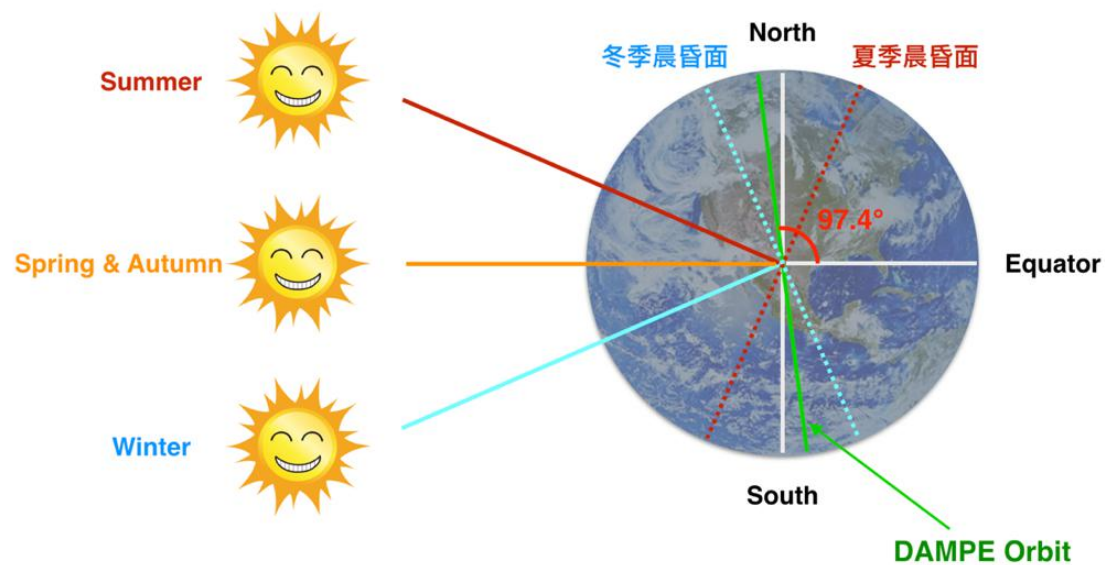
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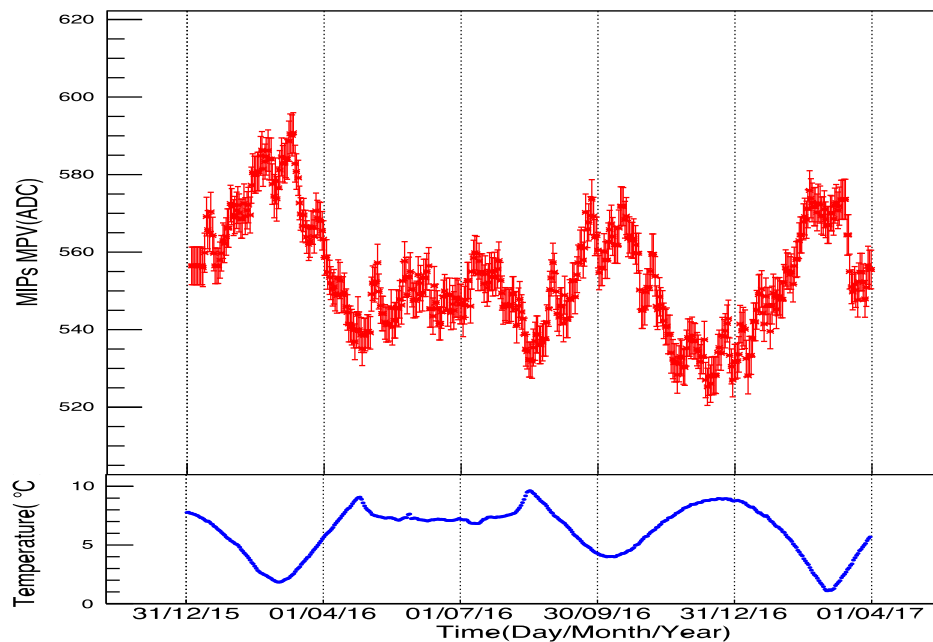
谢谢



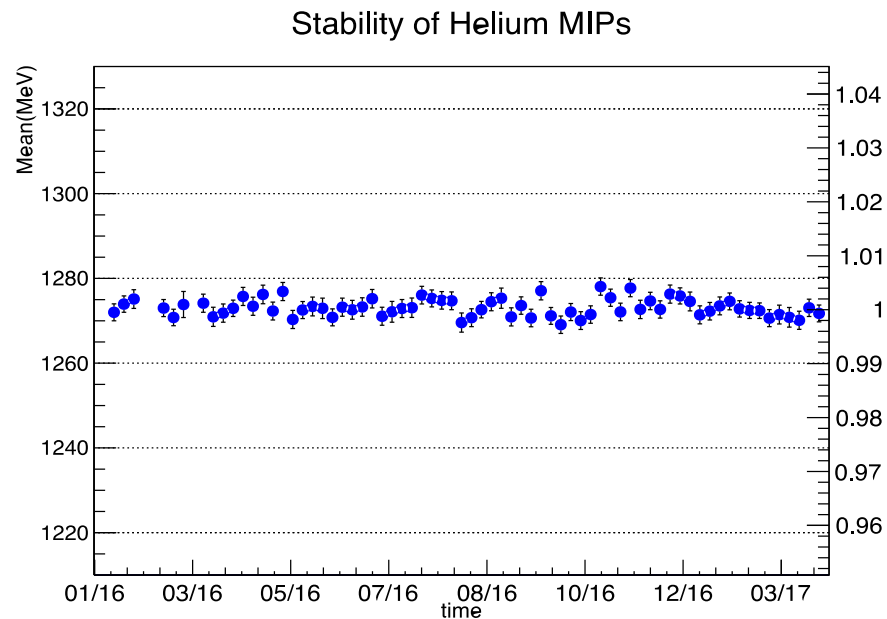
太阳光照角



BGO量能器在轨标定



Before temperature correction



After temperature correction

