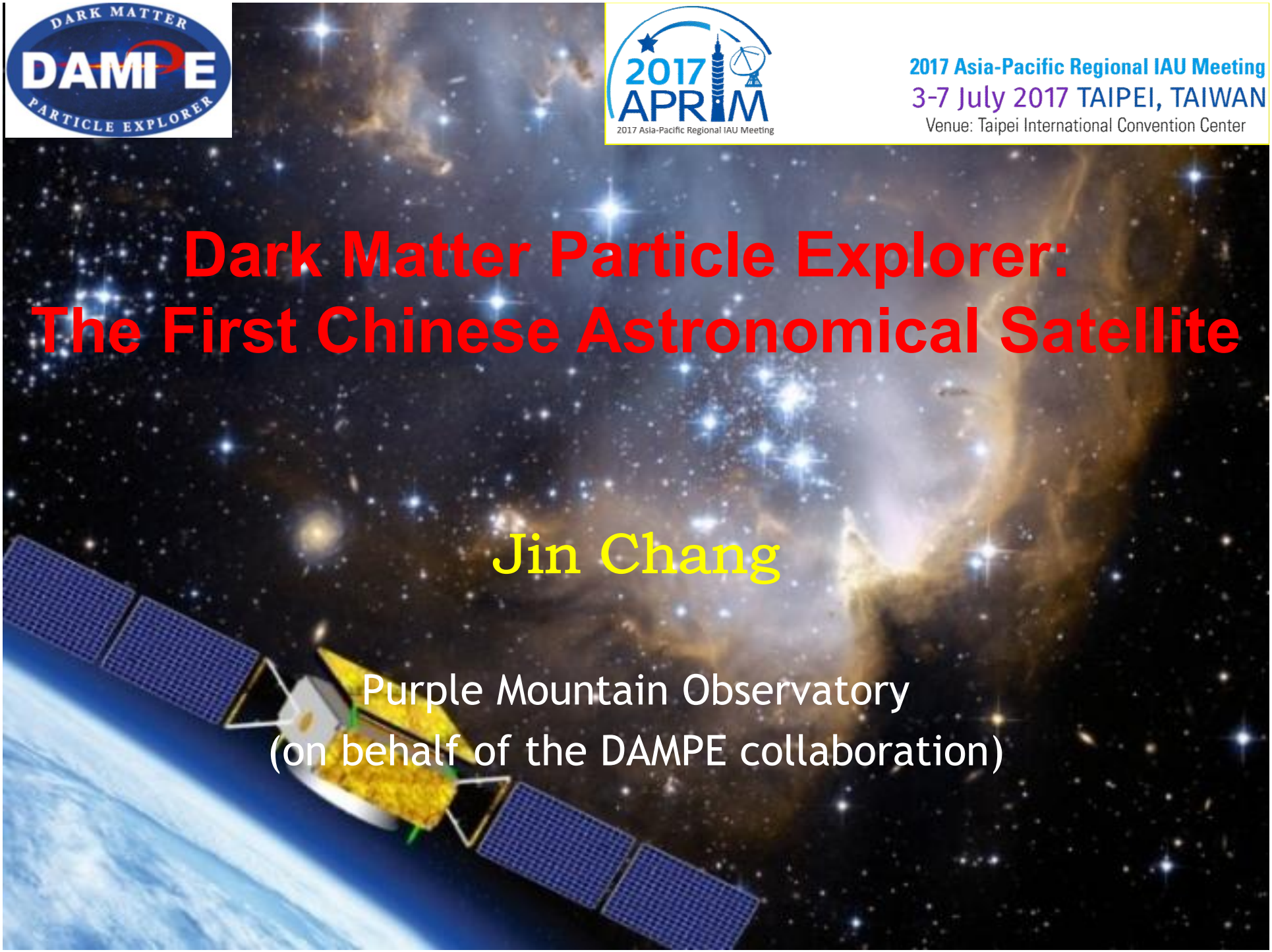

DARK MATTER
DAMPE
PARTICLE EXPLORER
2017
APRIM
2017 Asia-Pacific Regional IAU Meeting
2017 Asia-Pacific Regional IAU Meeting
3-7 July 2017 TAIPEI, TAIWAN
Venue: Taipei International Convention Center
Dark Matter Particle Explorer:
The First Chinese Astronomical Satellite
Jin Chang
Purple Mountain Observatory
(on behalf of the DAMPE collaboration)

The 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

- **SWITZERLAND**
  - University of Geneva

Outline

- Scientific Objectives
- Instrument Design
- Expected Performance
- Beam Test
- In-flight calibration and performance
- First Results

Scientific Objectives

- **Probing the nature of dark matter**
- **Understanding the particle acceleration in astrophysical sources, and the propagation of cosmic rays in the Milky Way**
- **Studying the gamma-ray emission from Galactic and extragalactic sources.**

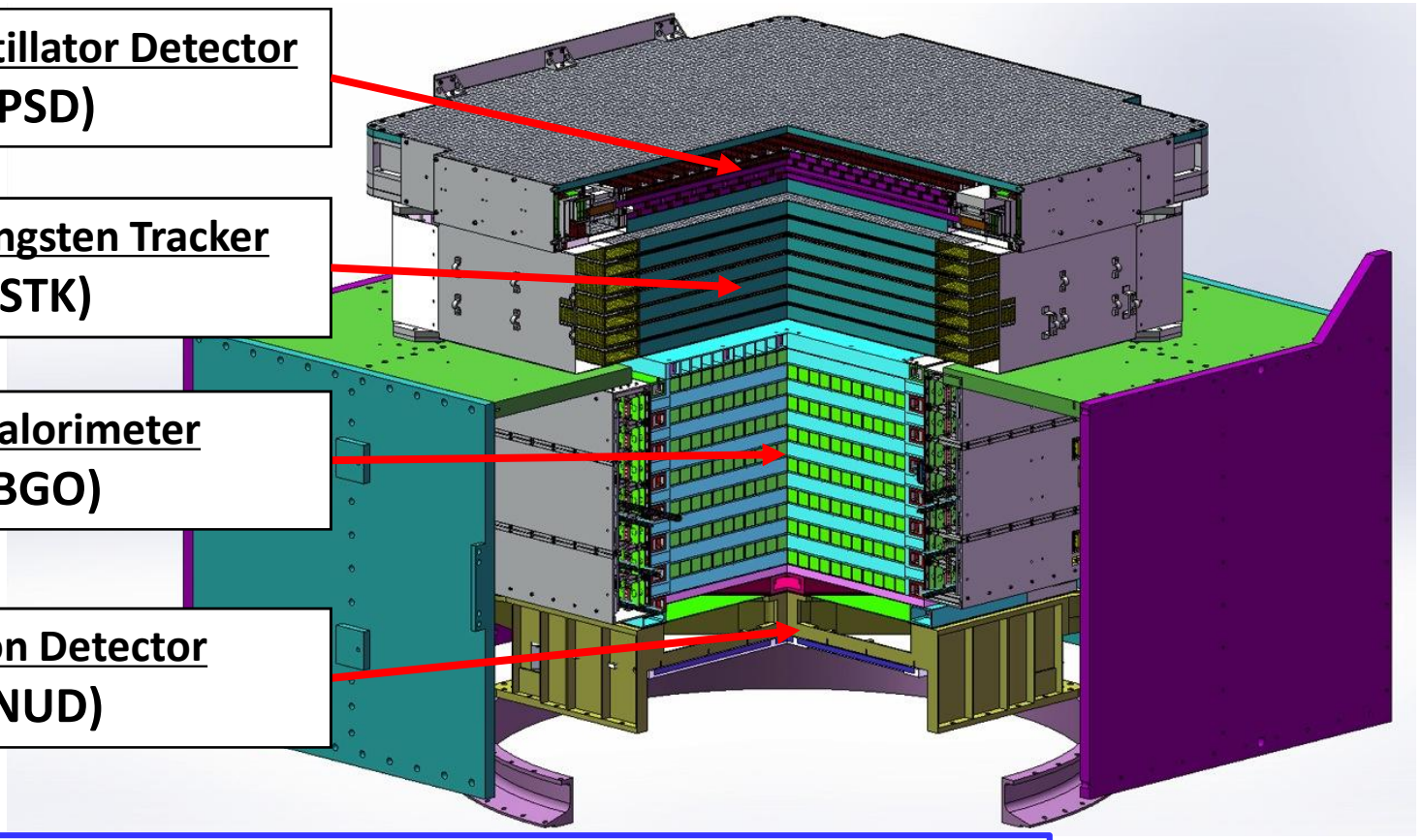
Instrument Design

Plastic Scintillator Detector (PSD)

Silicon-Tungsten Tracker (STK)

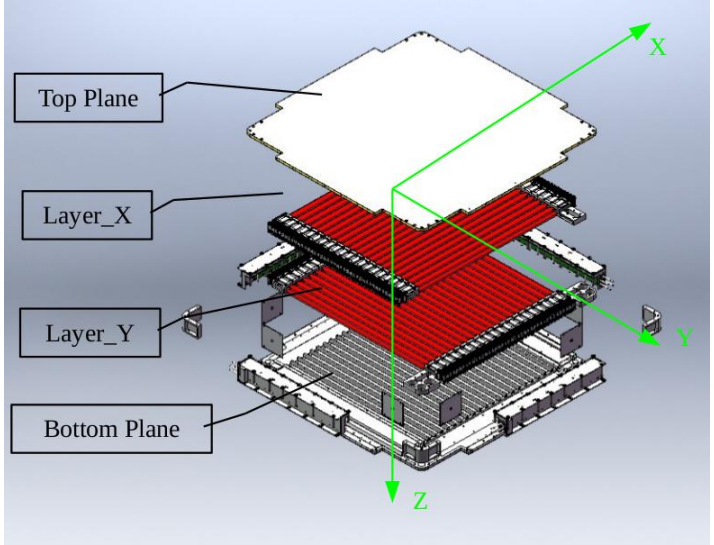
BGO Calorimeter (BGO)

Neutron Detector (NUD)

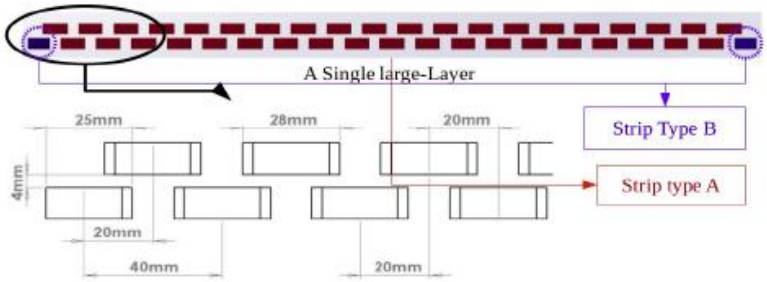


- Charge measurement (dE/dx in PSD, STK and BGO)
- Pair production and precise tracking (STK and BGO)
- Precise energy measurement (BGO bars)
- Hadron rejection (BGO and neutron detector)

Instrument development: PSD

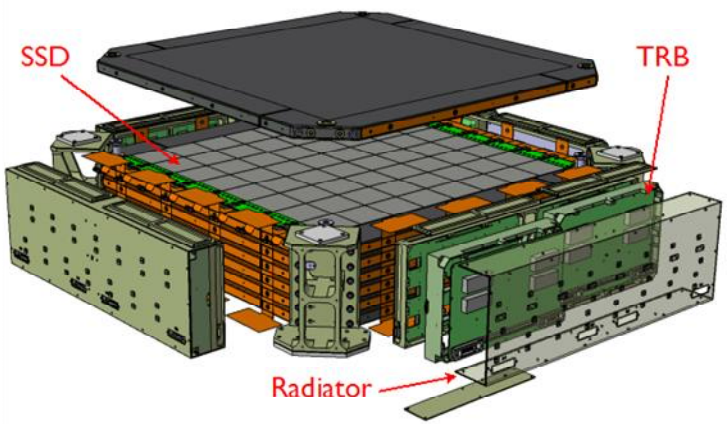


- Active area: 82 cm x 82 cm
- Number of layers: 2
- 41 modules each layer
- A PMT at each end of plastic scintillator bar
- Each PMT provides two signals
  （from Dy5 and Dy8 for large dynamic range）
- Charge resolution: 12.5% for Z = 1



(see arXiv:1703.00098)

Instrument development: STK



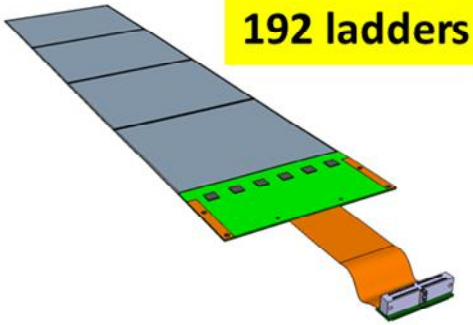
- 12 layers (6x, 6y) of single-sided Si strip detector mounted on 7 support trays
- Tungsten plates (1mm thick) integrated in trays 2, 3, 4 (from the top)
  - Total 0.85 X_0 for photon conversion

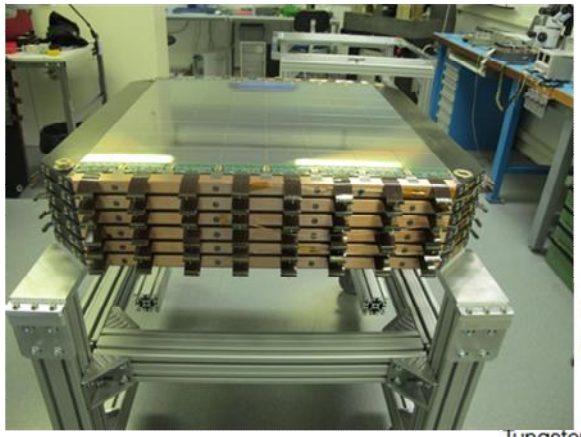
768 silicon sensors
95 x 95 x 0.32 mm^3

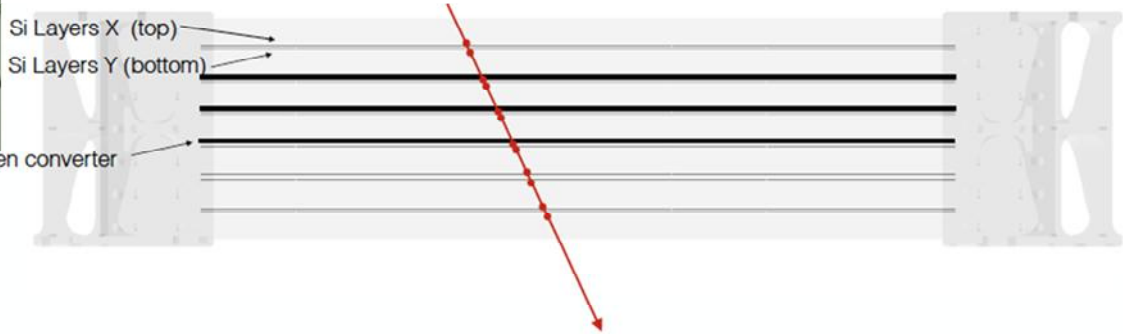
1,152 ASICs

73,728 channels

192 ladders

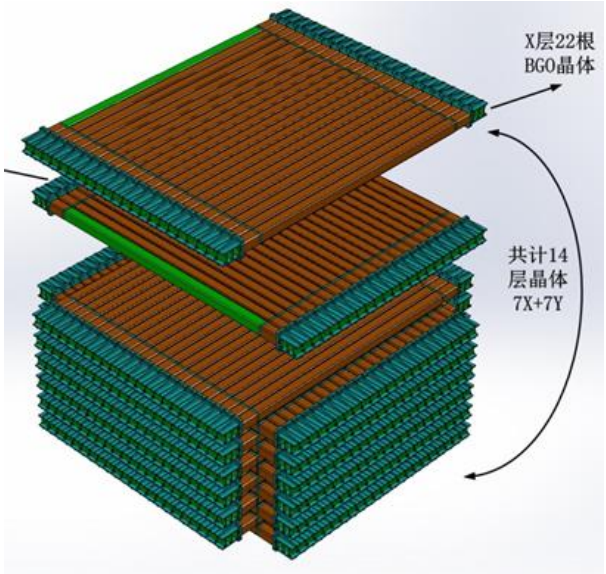




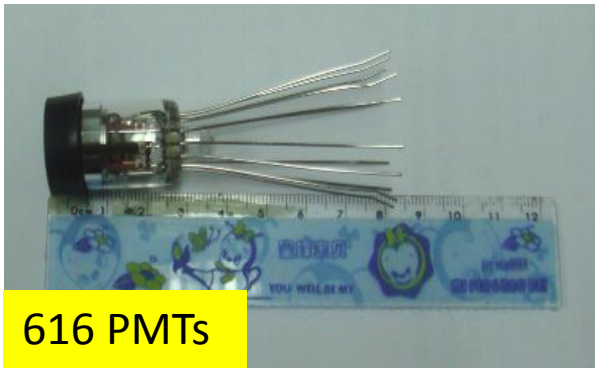


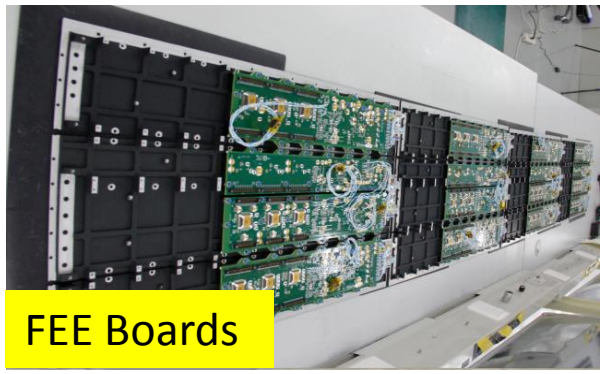
Instrument development: BGO

- 14 layers of 22 BGO crystals
  - Dimension of BGO bar: $2.5 \times 2.5 \times 60 cm^3$
  - Hodoscopic stacking alternating orthogonal layers
  - r.l: ~$32X_0$, NIL:1.6
- Two PMTs coupled with each BGO crystal bar in two ends
- Electronics boards attached to each side of module



308 BGO bars


616 PMTs

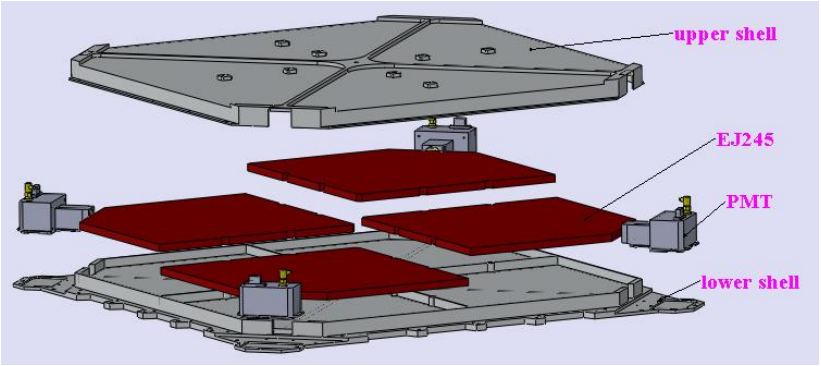

FEE Boards

Instrument development: NUD

$$n + {}^{10}B \rightarrow \alpha + {}^{7}Li + \gamma$$

Table 5: NUD designed parameters.

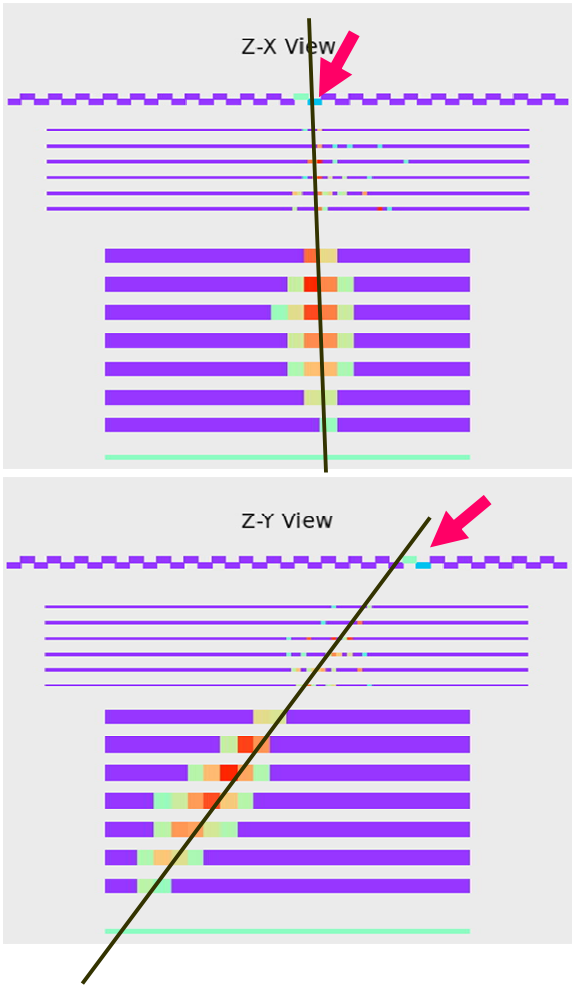
Parameter	4 Plastic Scintillators (^{10}B)
Active area	61 cm × 61 cm
Energy range	2 – 60 MeV for single detector
Energy resolution[a]	≤10% at 30 MeV
Power	0.5 W
Mass	12 kg



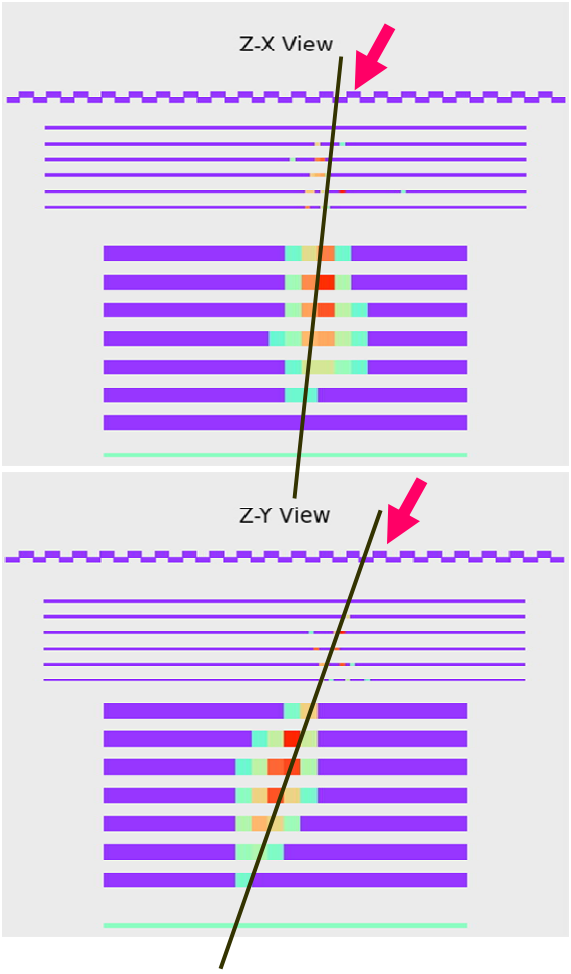
4 large area boron-doped plastic scintillators (30 cm × 30 cm × 1 cm)

Signals for different particles

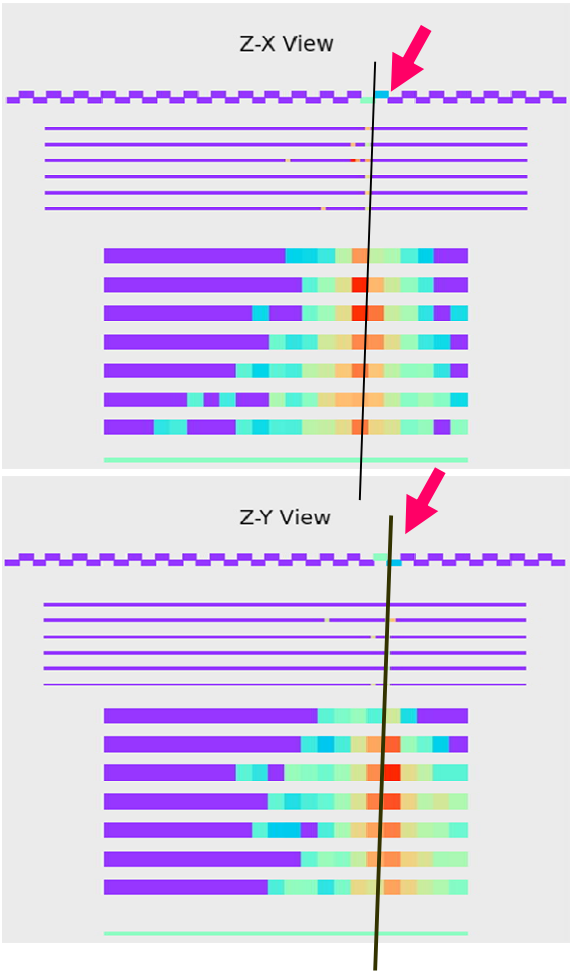
electron



gamma



proton



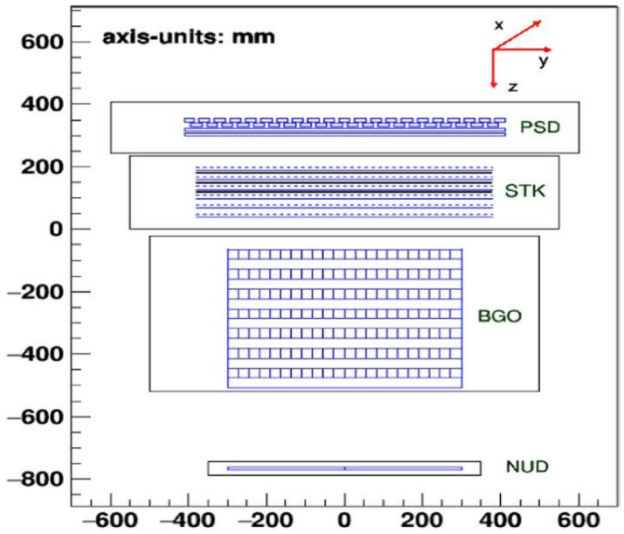
Expected performance

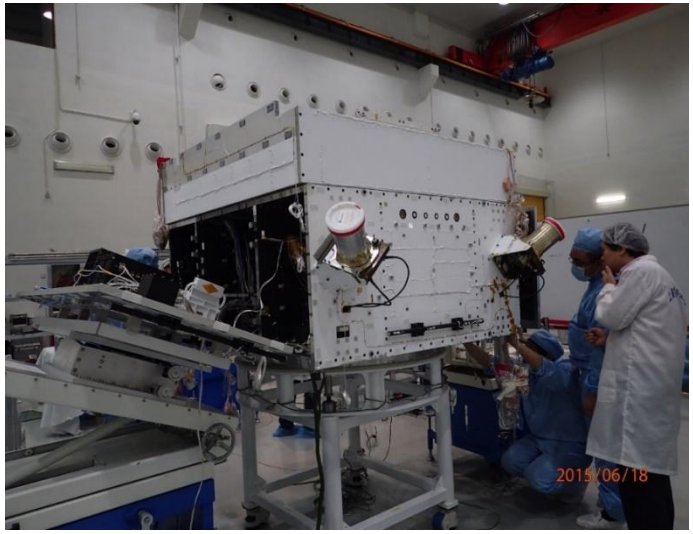
Parameter	Value
Energy range of gamma-rays/electrons	5 GeV to 10 TeV
Energy resolution(electron and gamma)	1.5% at 800 GeV
Energy range of protons/heavy nuclei	50 GeV to 500 TeV
Energy resolution of protons	40% at 800 GeV
Eff. area at normal incidence (gamma)	1100 cm^2 at 100 GeV
Geometric factor for electrons	0.3 m^2 sr above 30 GeV
Photon angular resolution	0.1 degree at 100 GeV
Field of View	1.0 sr

(see arXiv:1706.08453)

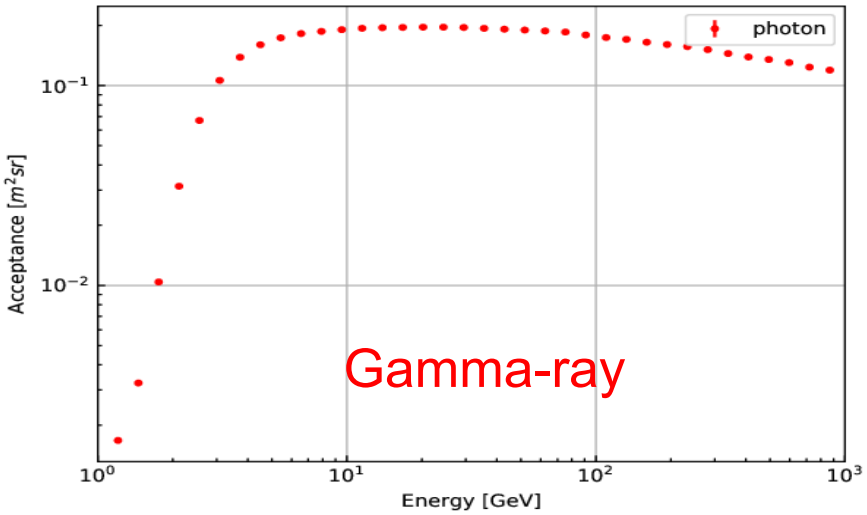
Comparision with other missions

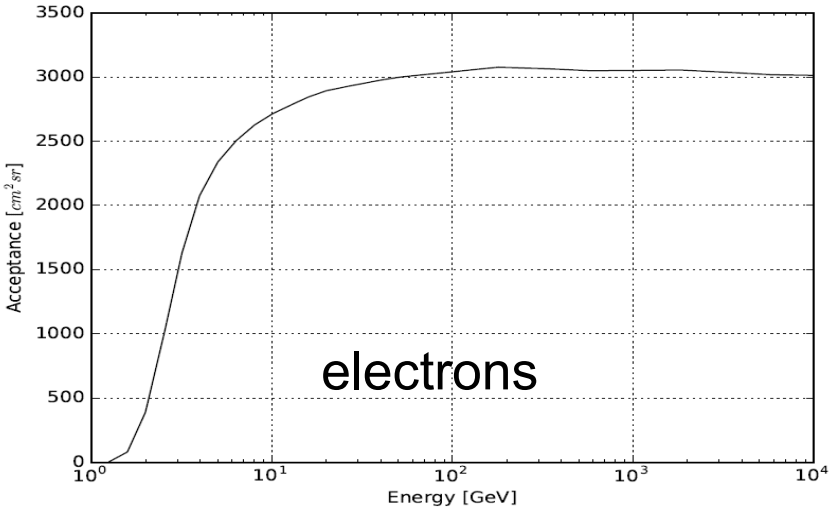
	DAMPE	AMS-02	Fermi LAT
e/γ Energy res.@100 GeV (%)	**1.2**	2	10
e/γ Angular res.@100 GeV (deg)	0.2	0.2	0.1
e/p discrimination	10^5	10^5 - 10^6	10^5
Calorimeter thickness (X_0)	**32**	17	8.6
Geometrical accep. (m^2sr)	**0.3**	0.06	2

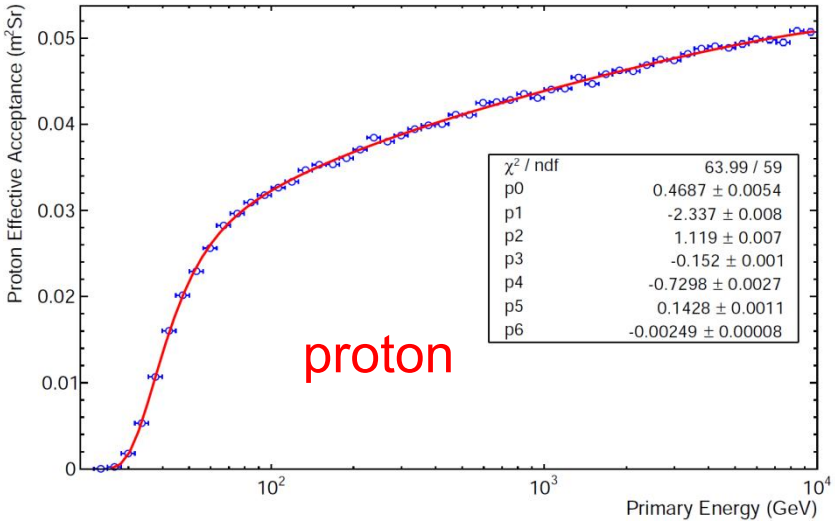


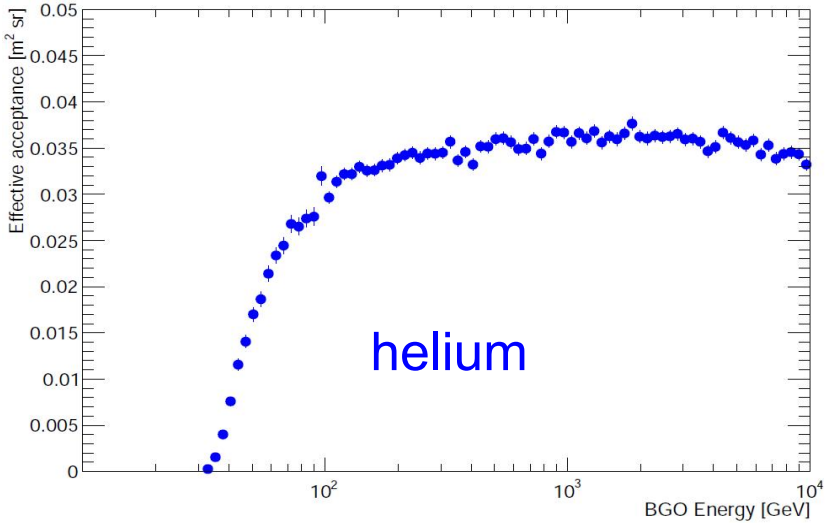


Expected performance

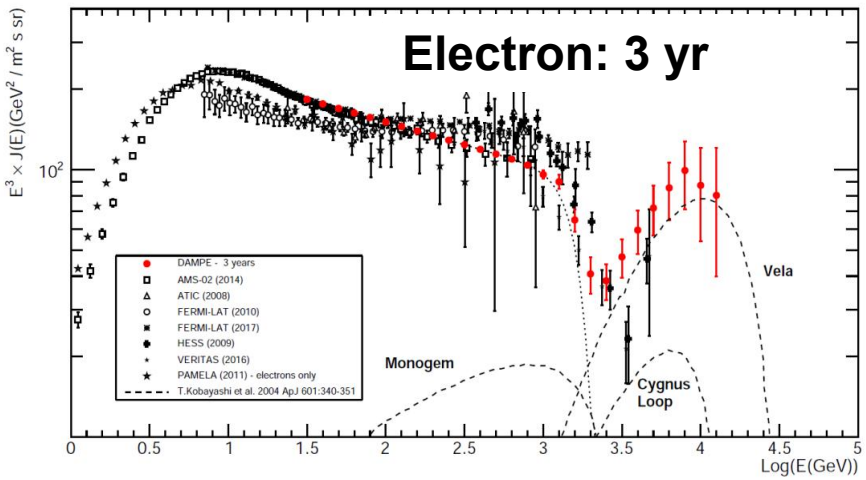


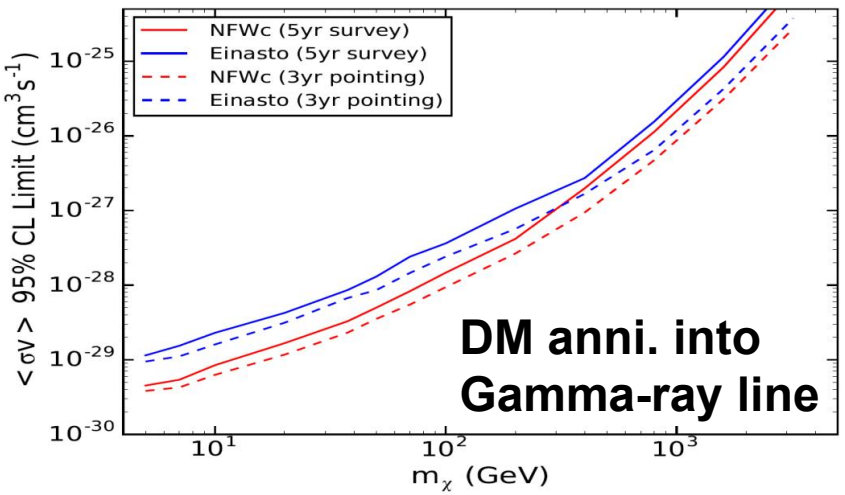


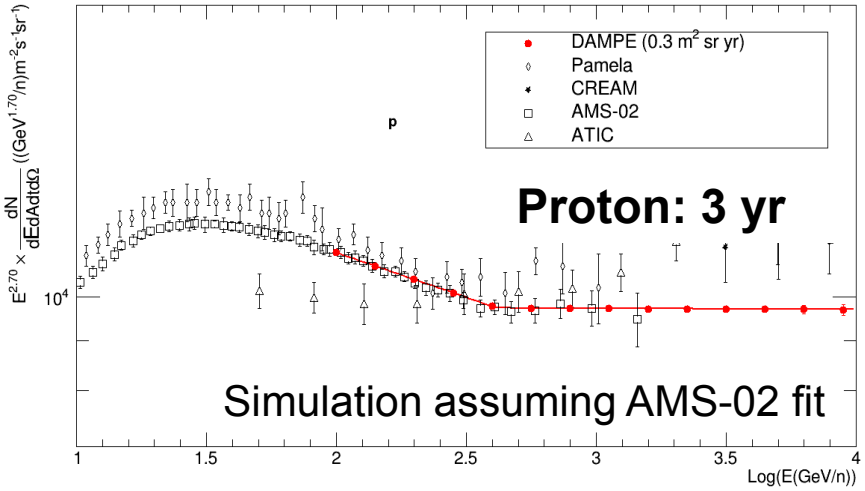


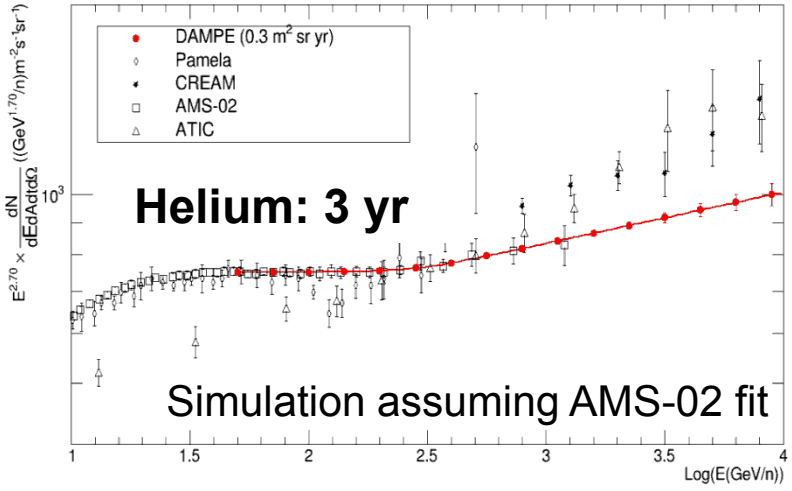


Expected performance



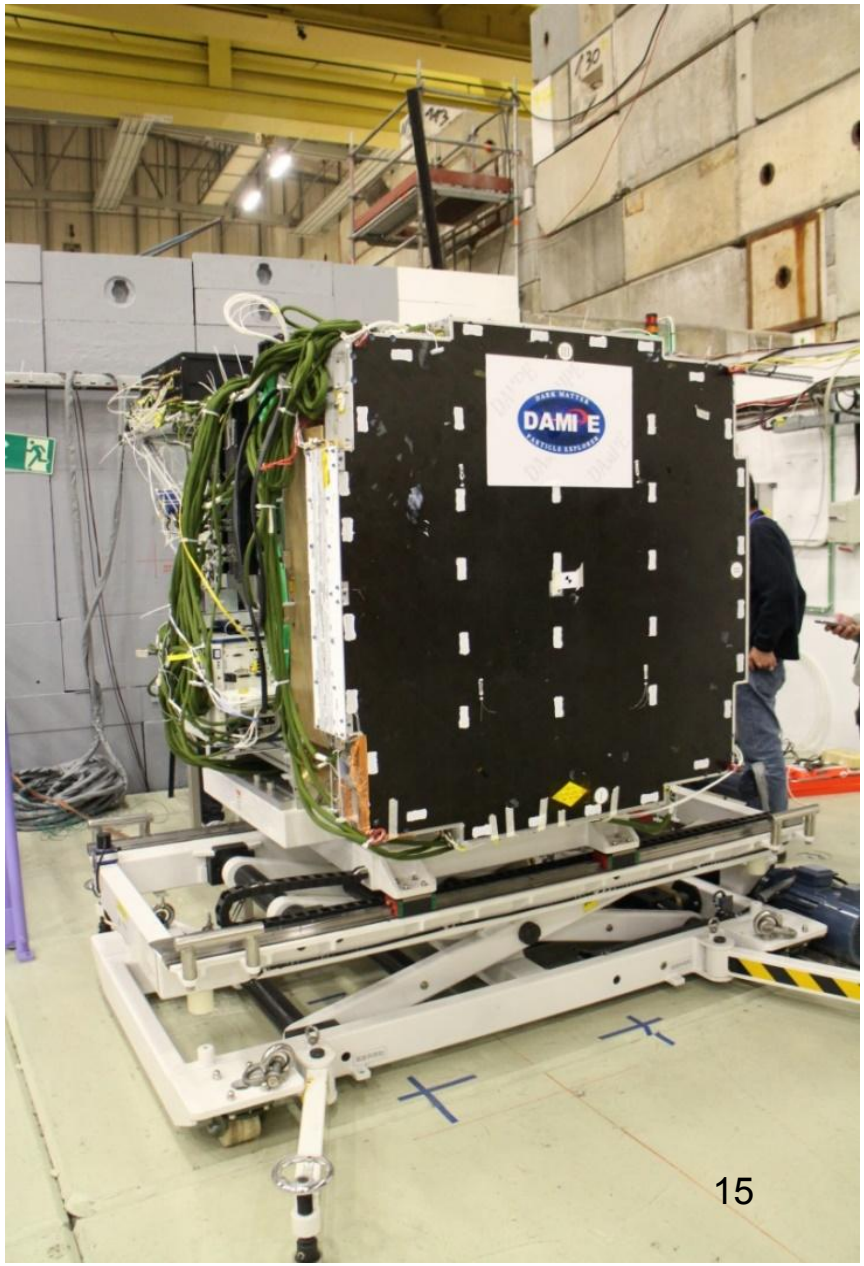




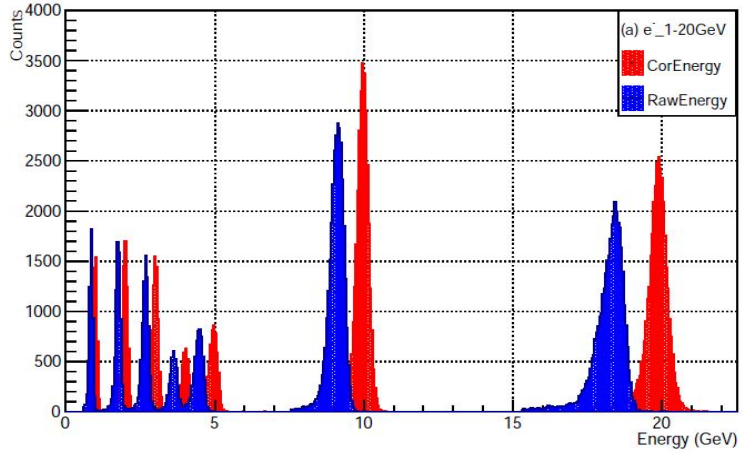


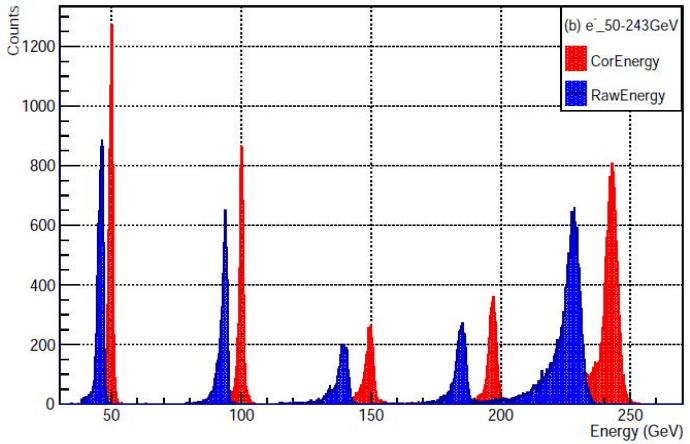
Beam test @ CERN

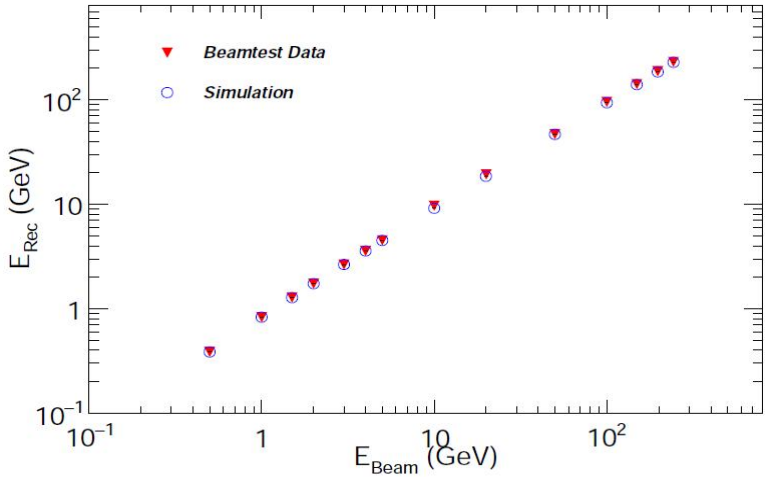
- 14days@PS，29/10-11/11 2014
  - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
  - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
  - π-@ 3GeV/c, 10GeV/c
  - γ @ 0.5-3GeV/c
- 8days@SPS，12/11-19/11 2014
  - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
  - p @ 400GeV/c (SPS primary beam)
  - γ @ 3-20GeV/c
  - μ @ 150GeV/c,
- 17days@SPS，16/3-1/4 2015
  - Fragments：66.67-88.89-166.67GeV/c
  - Argon：30A- 40A- 75AGeV/c
  - Proton：30GeV/c，40GeV/c
- 21days@SPS，10/6-1/7 2015
  - Primary Proton: 400GeV/c
  - Electrons @ 20, 100, 150 GeV/c
  - g @ 50, 75 , 150 GeV/c
  - m @ 150 GeV /c
  - p+ @10, 20, 50, 100 GeV/c
- 10days@SPS, 11/11-20/11 2015
  - -- Pb 30AGeV/c (and fragments) (HERD)
- 6days@SPS, 20/11-25/11 2015
  - -- Pb 030 AGeV/c (and fragments)



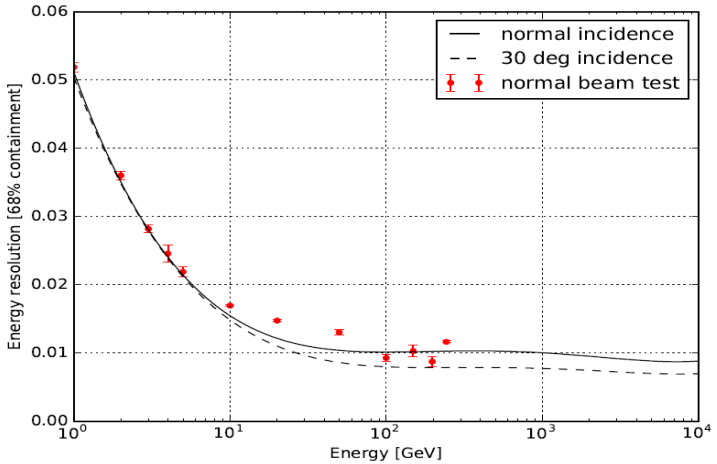
Beam test @ CERN





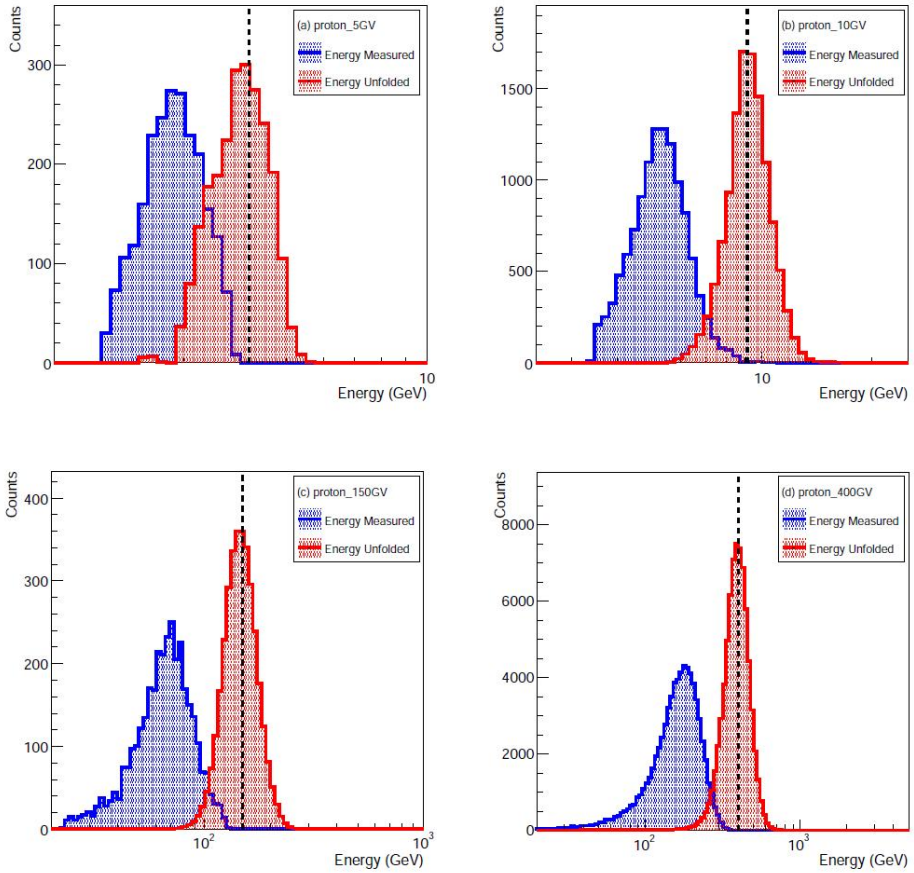


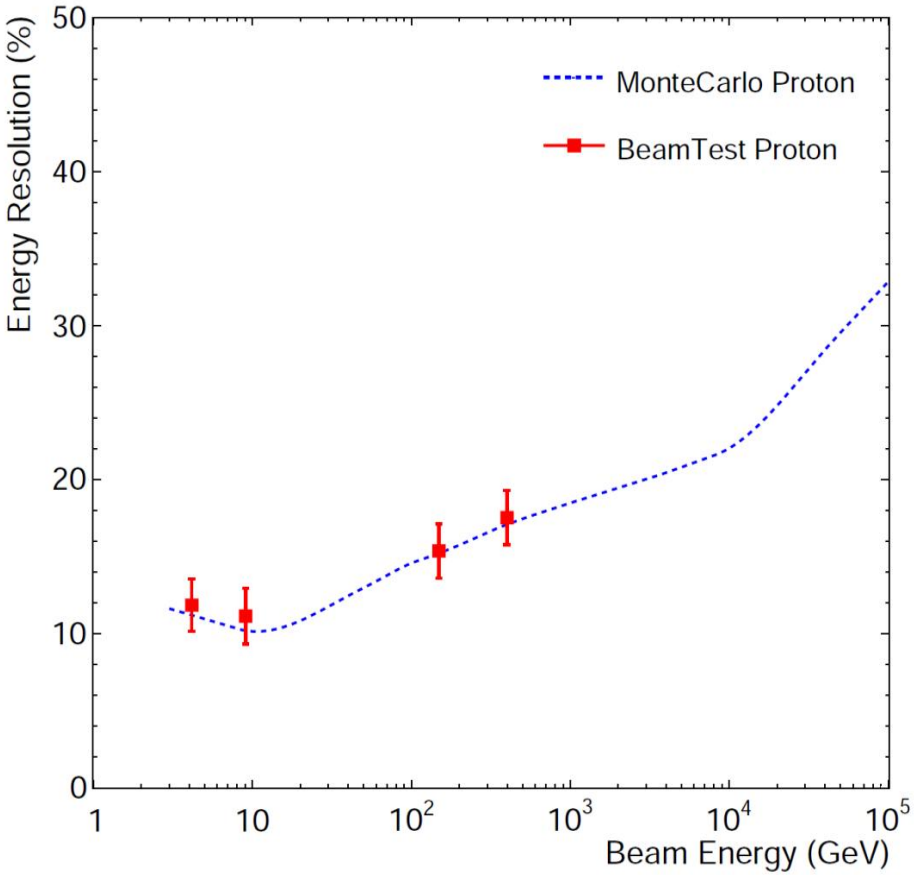
Energy linearity of electrons



Energy resolution of electrons

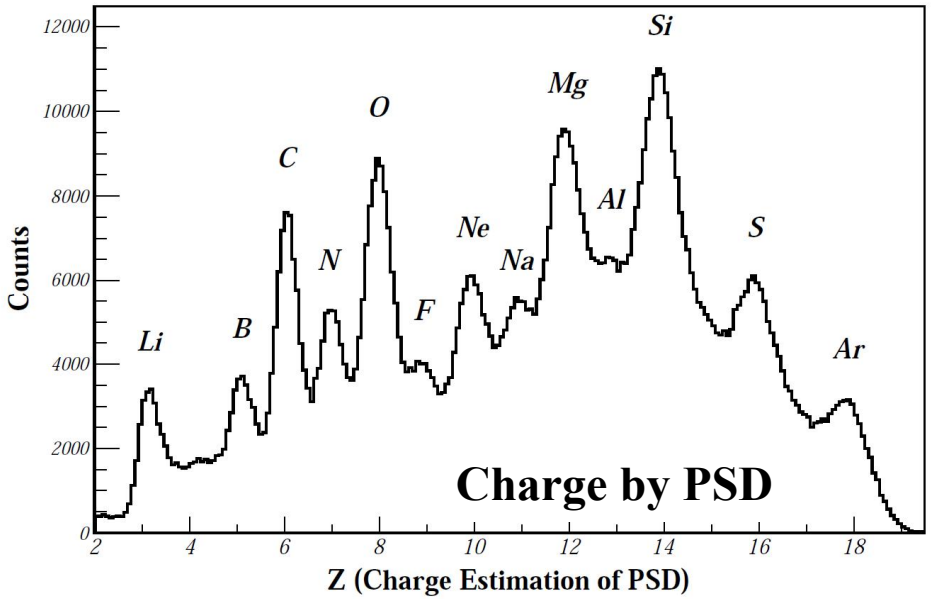
Beam test @ CERN

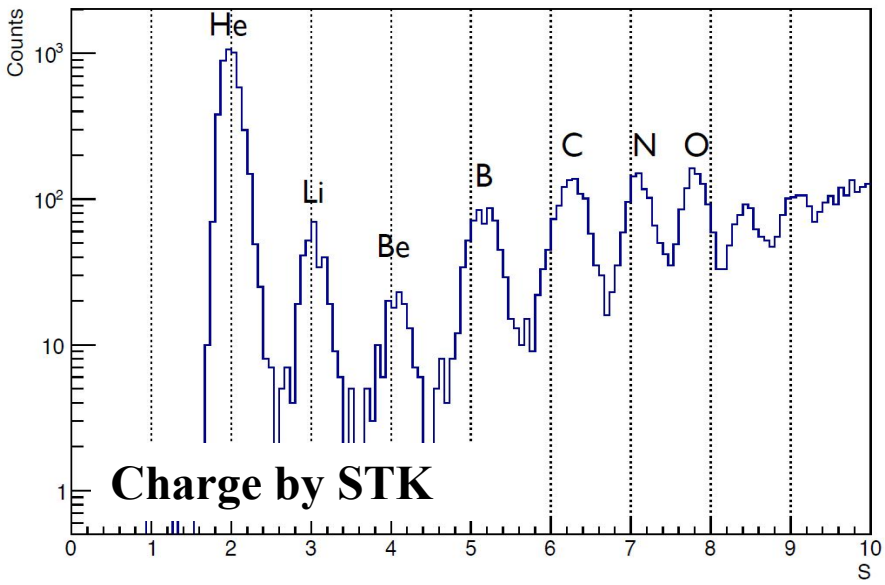




Energy resolution of protons

Beam test @ CERN



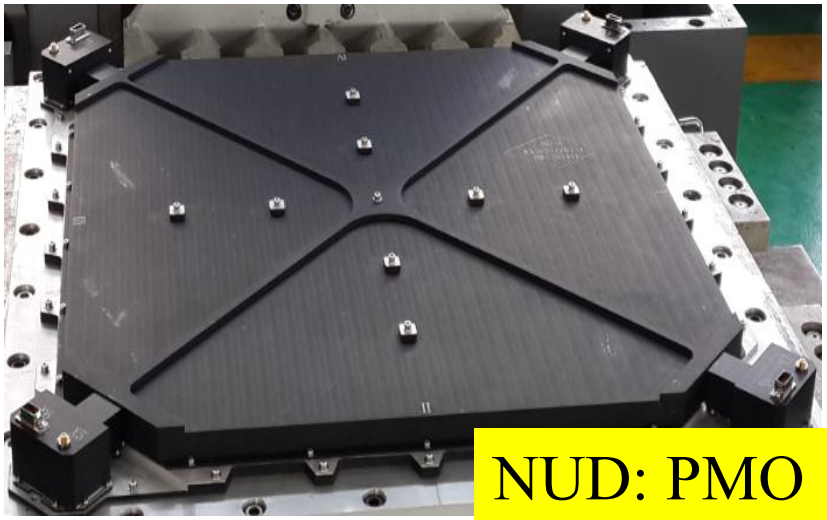


Flight Model: four detectors

PSD: IMP

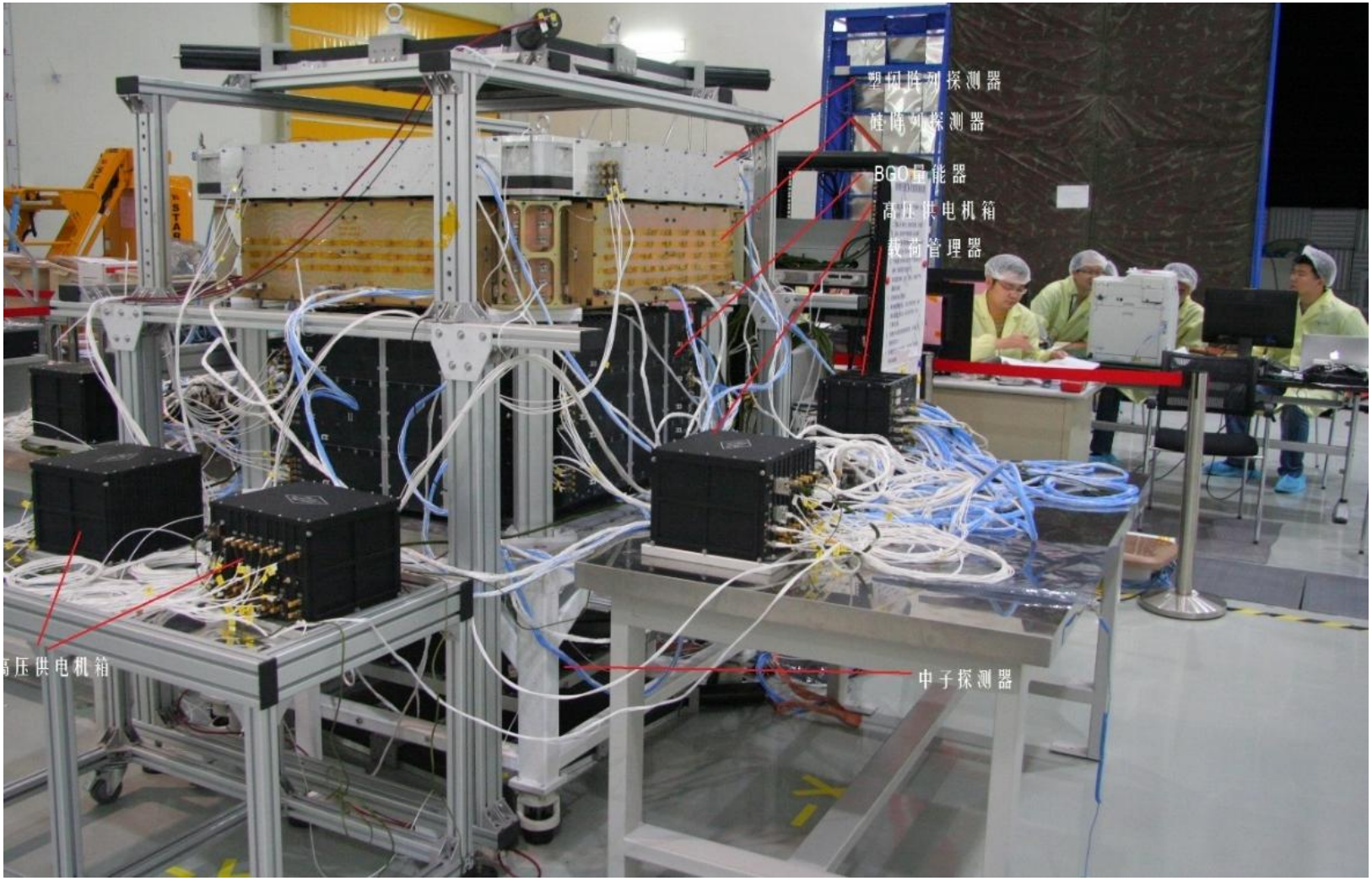
STK: IHEP, UG, INFN Perugia

BGO: USTC & PMO

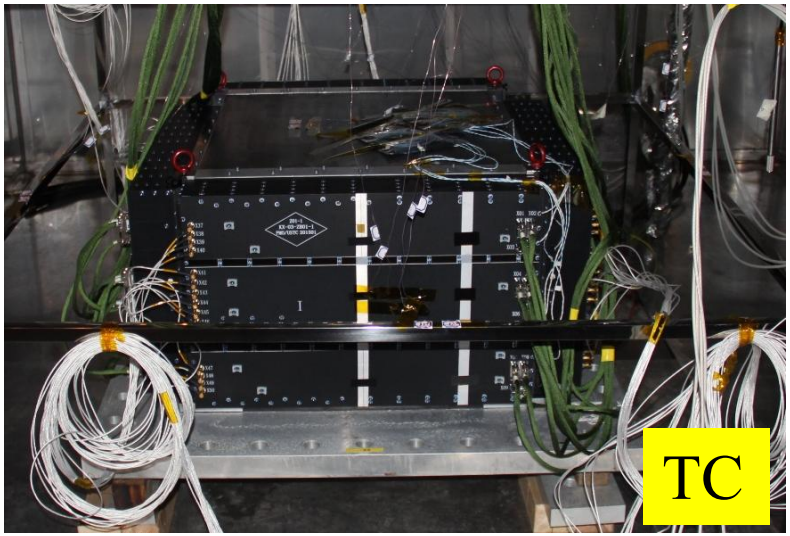


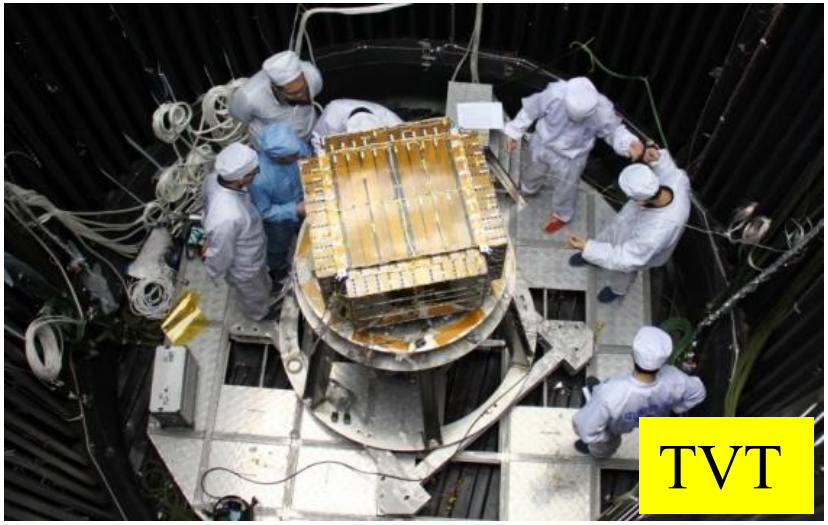
NUD: PMO

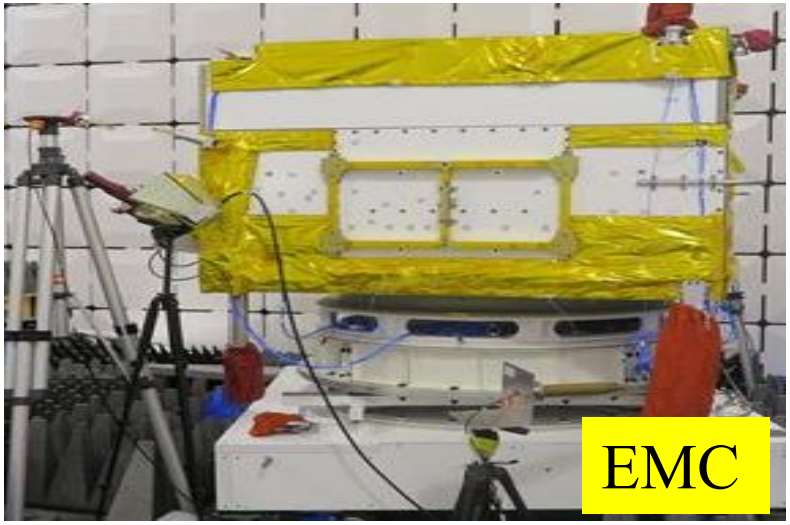
Flight Model: Cosmic Ray Test



Flight model: environmental tests



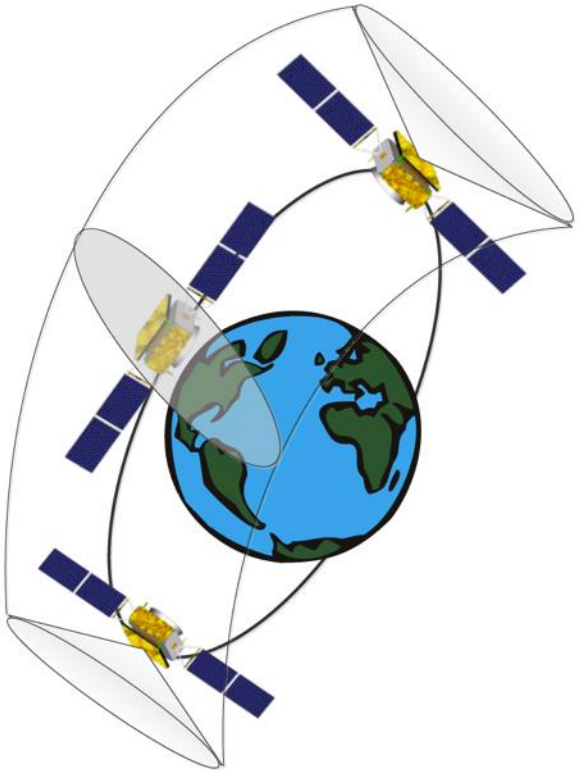


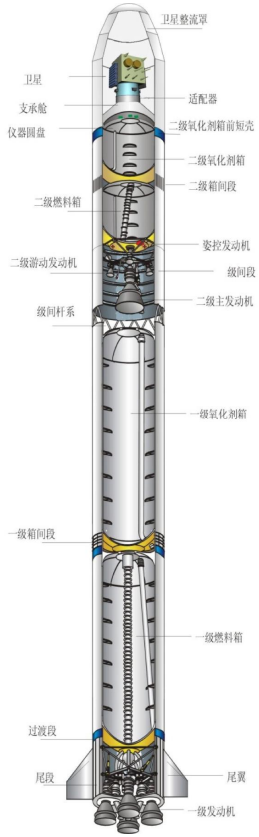


DAMPE mission

- **Launch: December 17th 2015, CZ-2D rocket**
  - **Total weight ~1850 kg, power consumption ~640 W**
    - **Scientific payload ~1400 kg, ~400 W**
  - **Lifetime > 3 year**

- **Altitude: 500 km**
- **Inclination: 97.4065°**
- **Period: 95 minutes**
- **Orbit: sun-synchronous**
- **16 GB/day downlink**

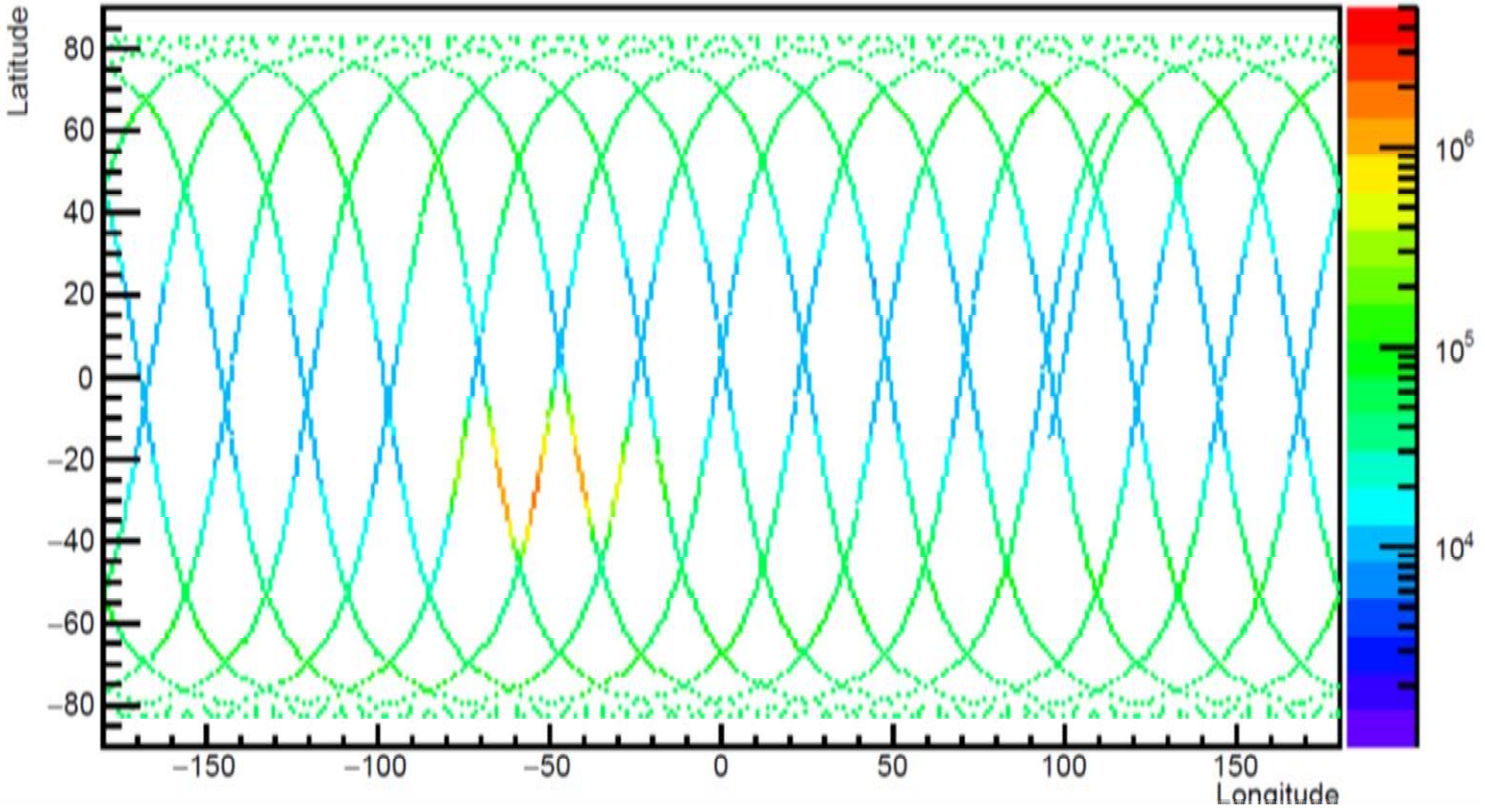




Launch on 17th Dec. 2015

Jiuquan Satellite Launch Center, Gobi desert

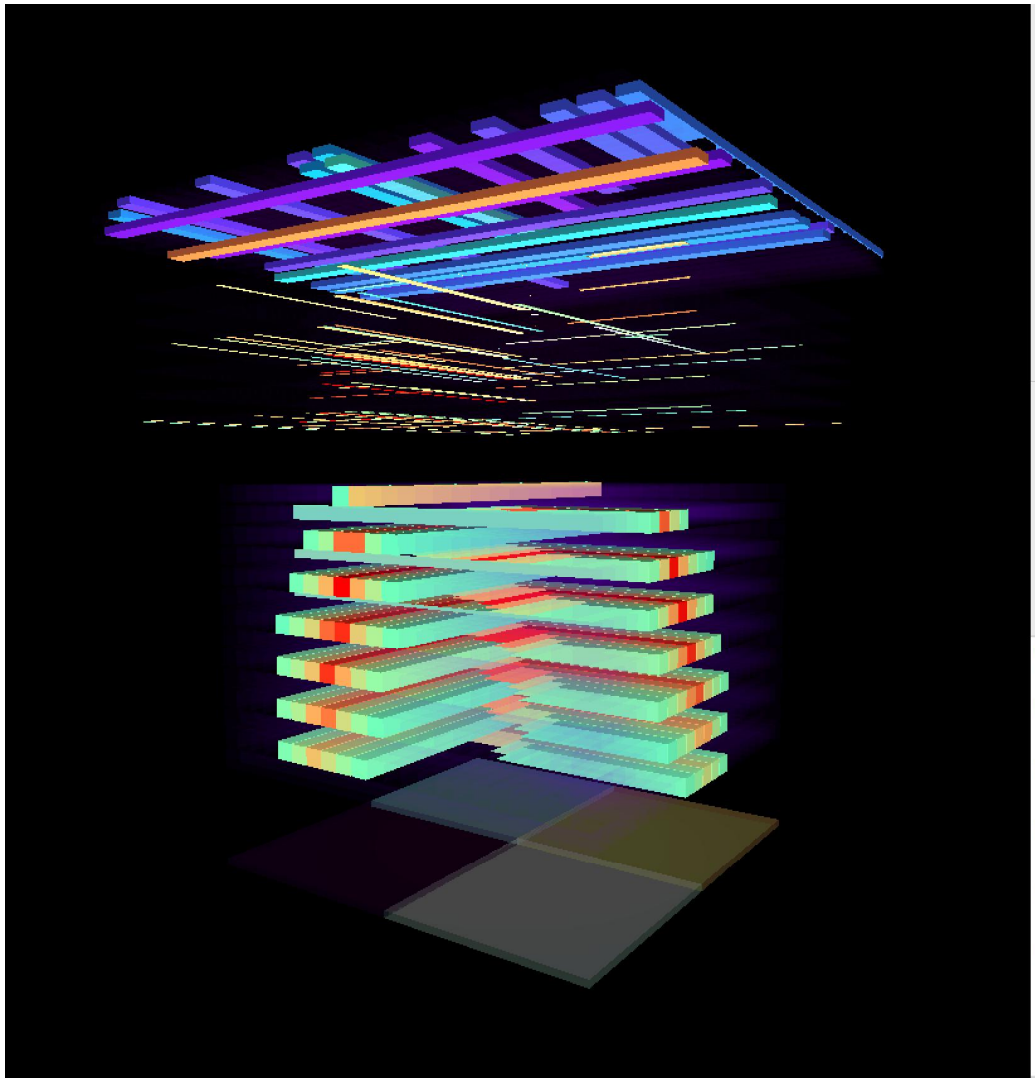
On-orbit trigger rate

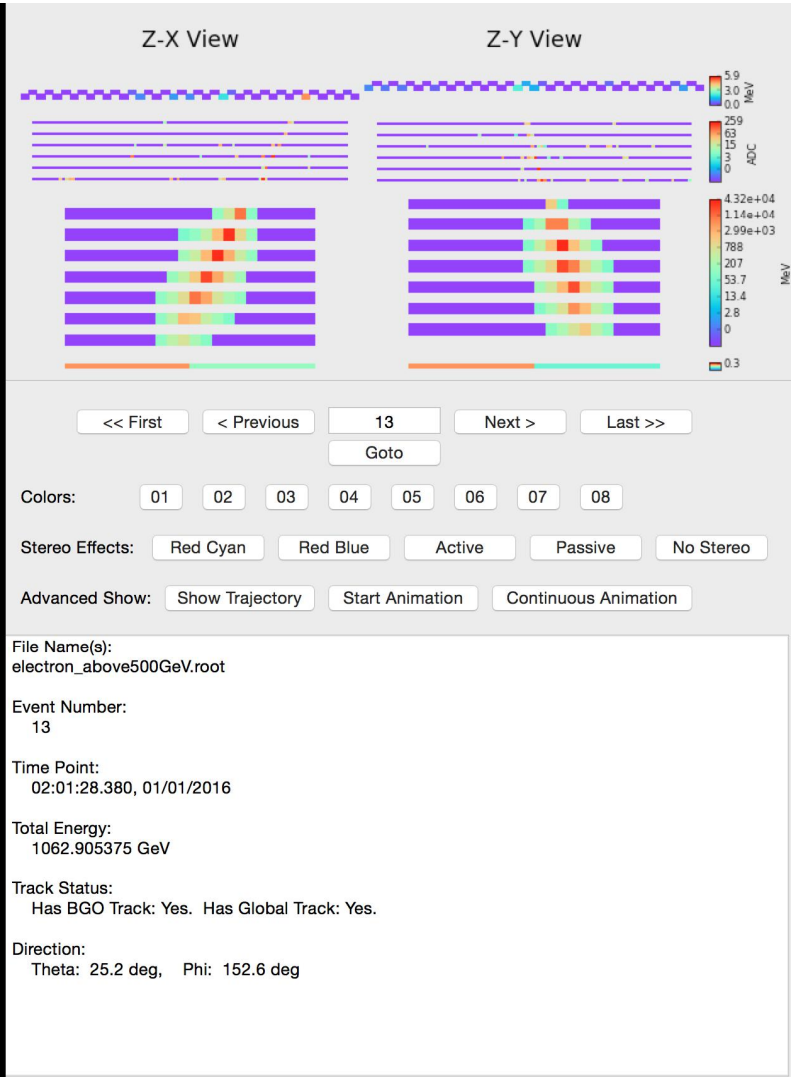


~50 Hz average trigger rate

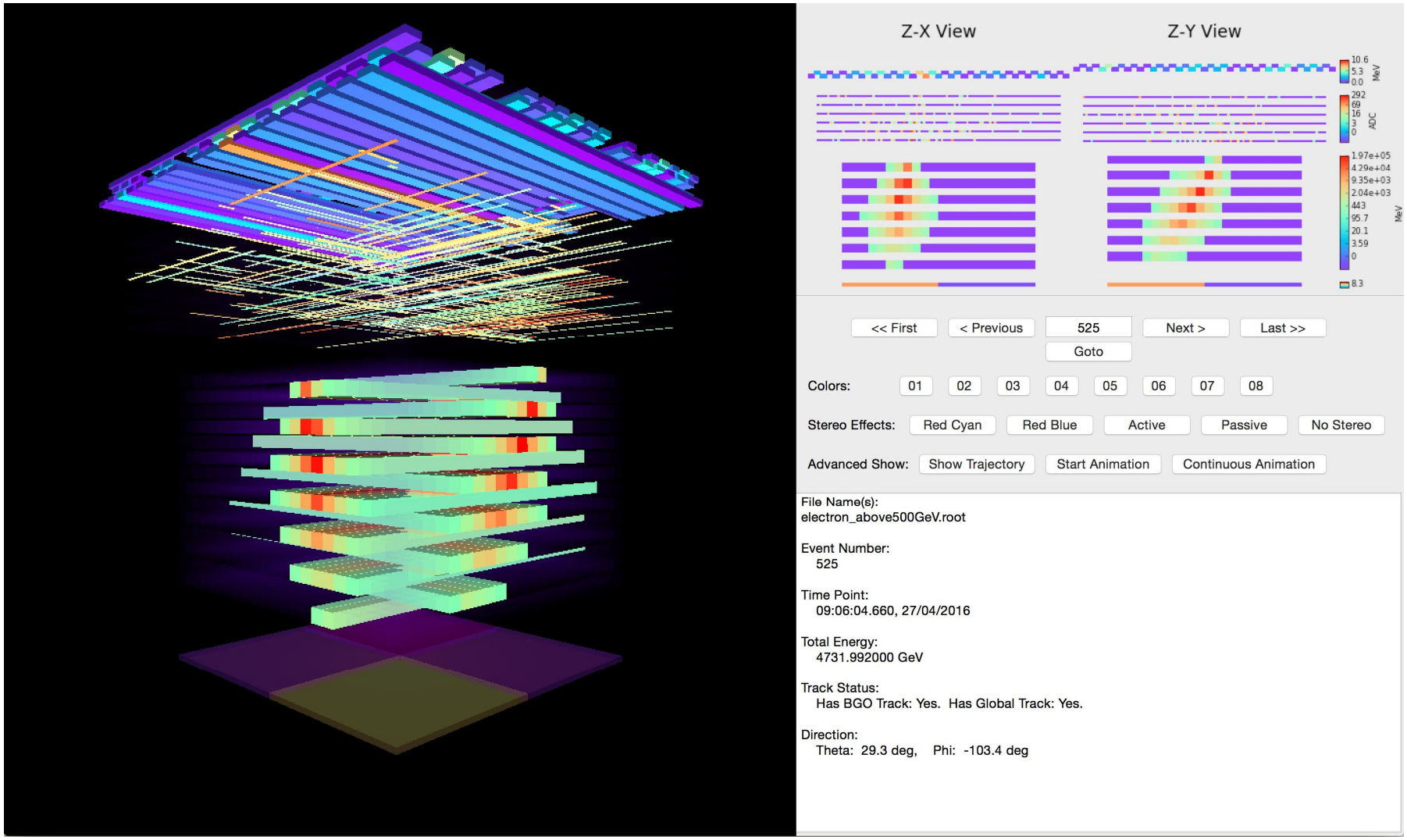
→100GB (H.L.)/day on ground (about 5 M events)

Event: ~1 TeV electron candidate

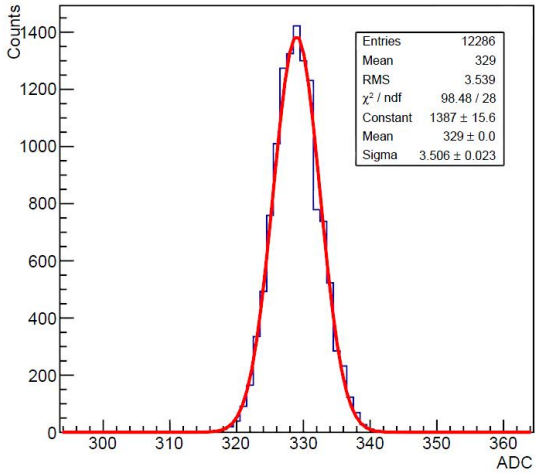




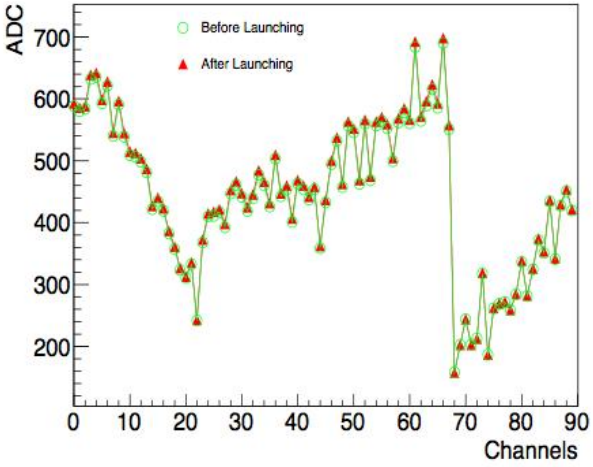
Event: ~5 TeV electron candidate



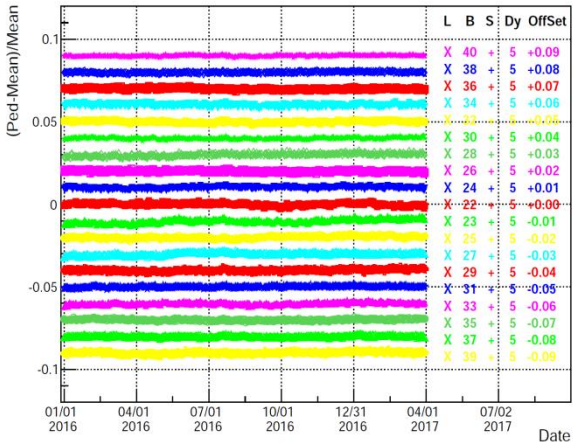
PSD on-orbit calibration



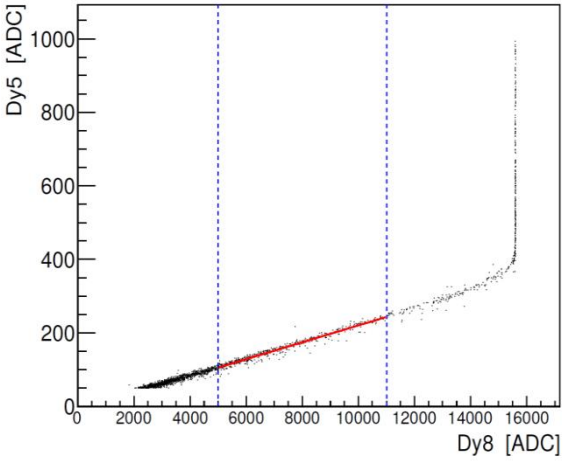
Pedestal distribution



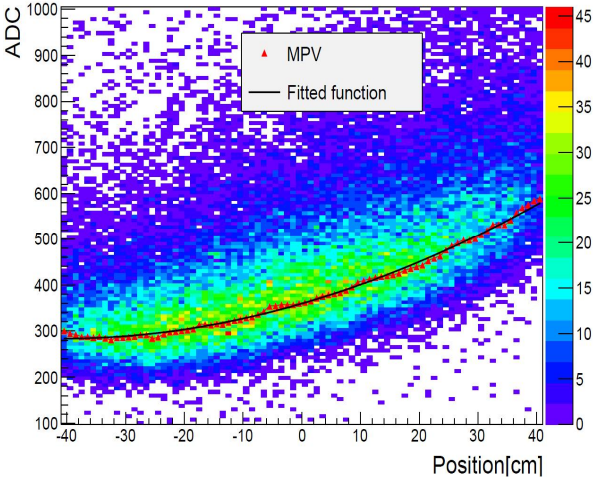
Pedestal comparison



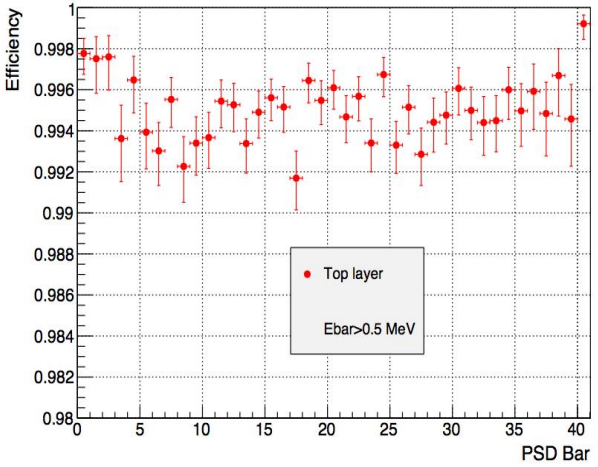
Pedestal variation



Dy5 and Dy8 correlation

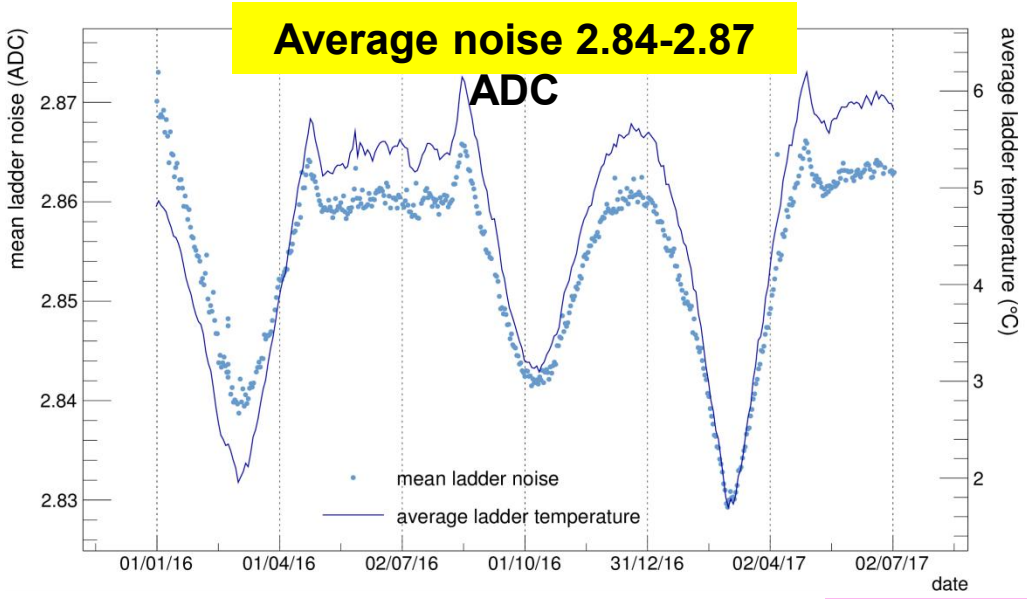


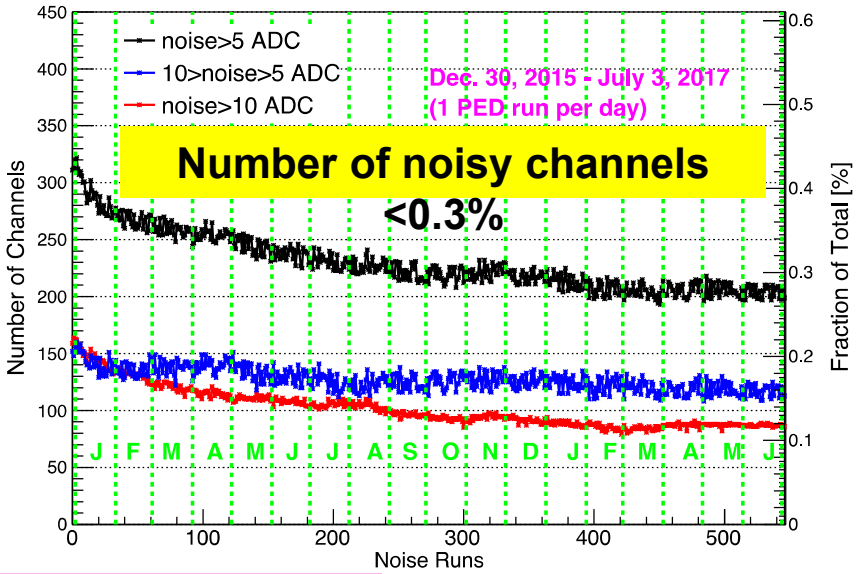
Light attenuation calibration



Efficiency

On-orbit STK noise: very stable





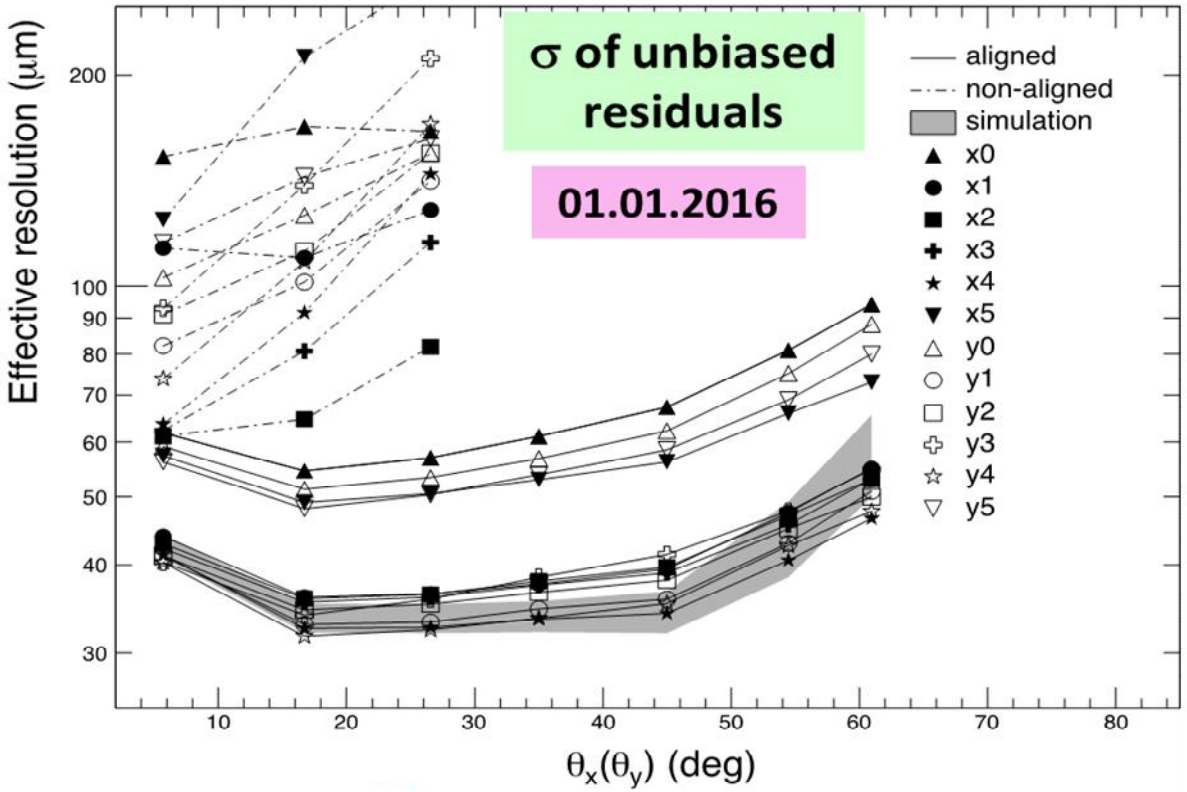
18 months since launch

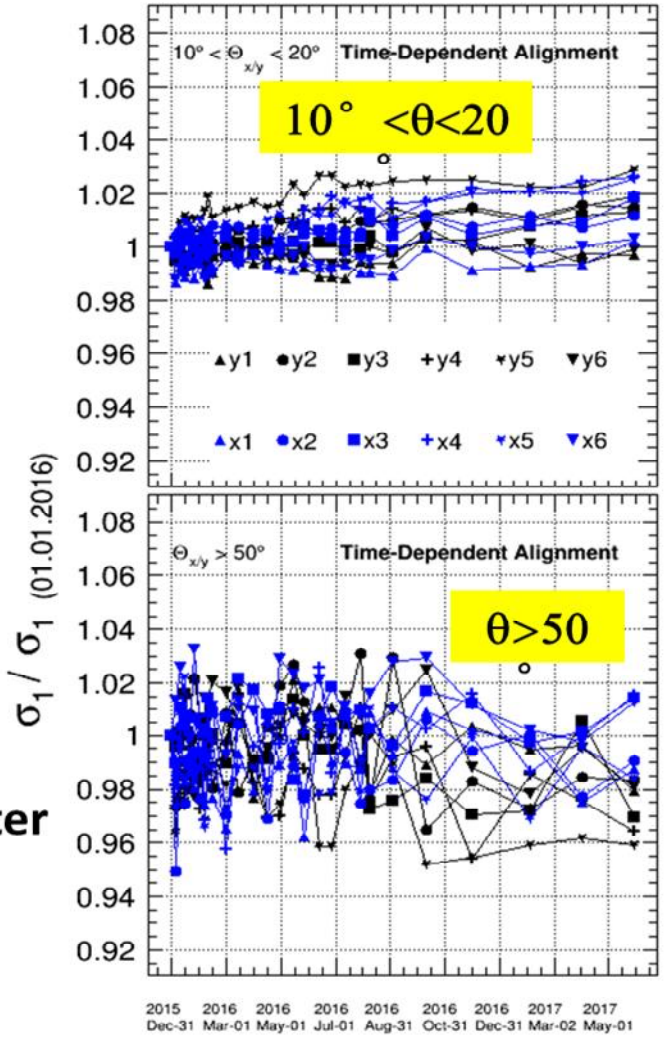
- Bulk of noise correlated with temperature
  - Very small temperature coefficient
    - ~0.01 ADC per 2°C
- Simplification for operation
  - data compression thresholds updated only once on Feb. 22, using average noise of Feb. 13-17

- Noisy channels stabilized to lower noise values
  - very small temperature effect

(See Xin Wu's talk DM030)

STK on-orbit alighment



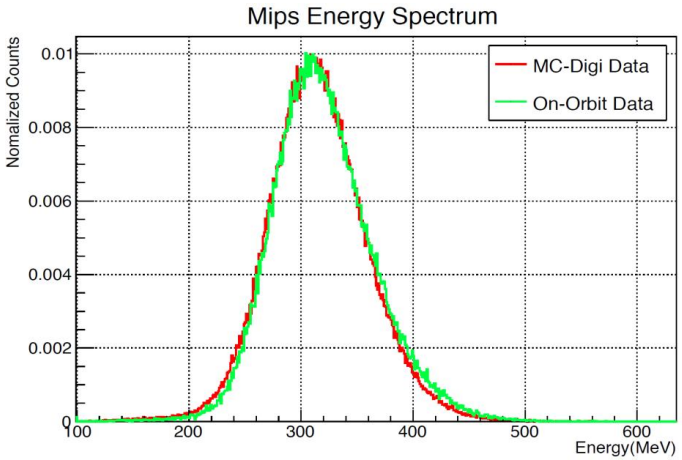


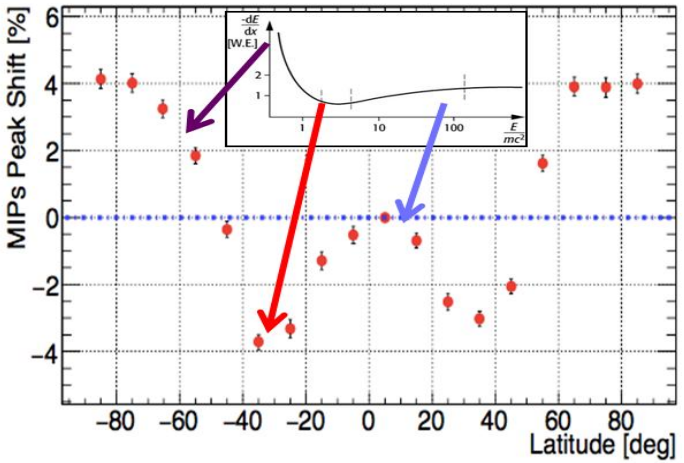
- Achieved ~40 μm intrinsic position resolution after on-orbit alignment
  - Good agreement with perfect aligned MC
  - Resolution stability ~2% over time

Bi-weekly update of alignment is sufficient!

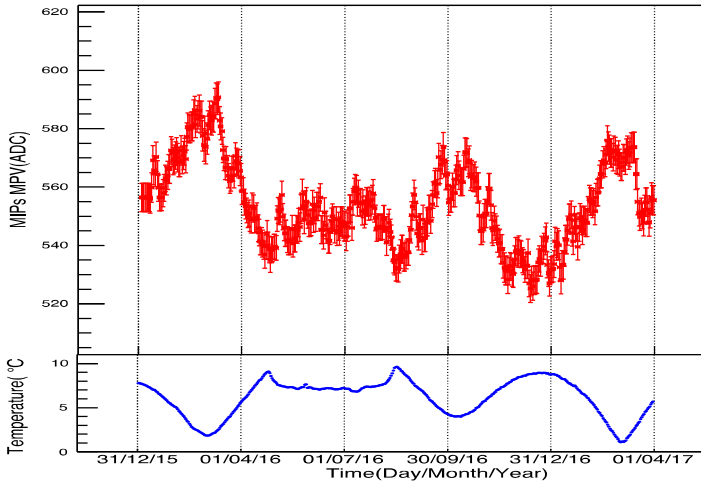
Jan. 2016 – June 2017

BGO on-orbit calibration: MIPs

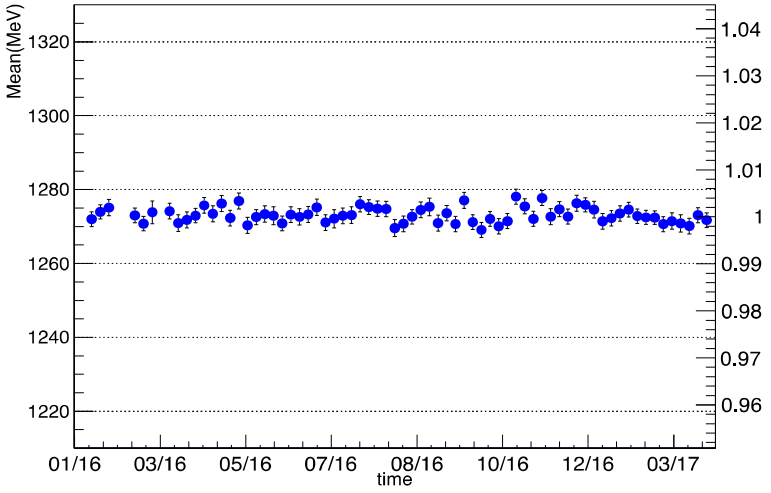




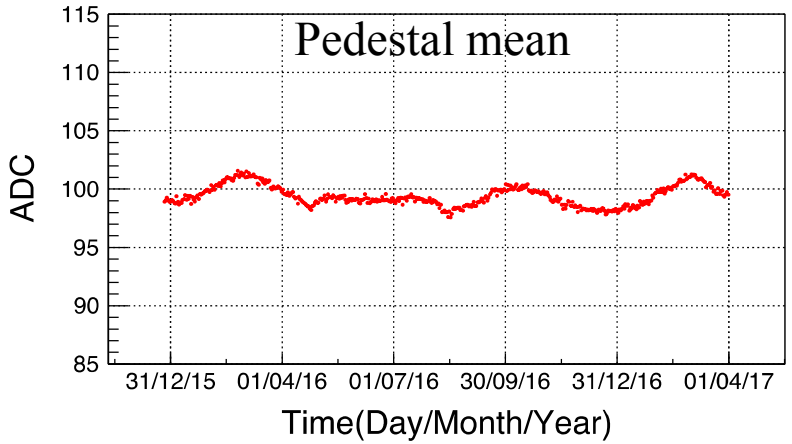
Before temperature correction

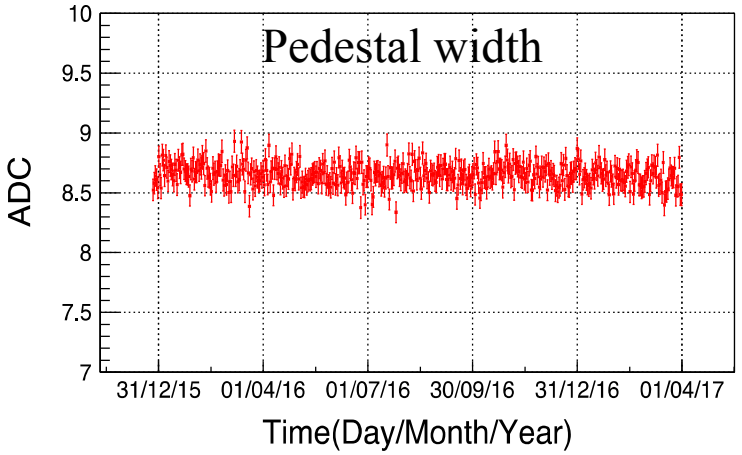


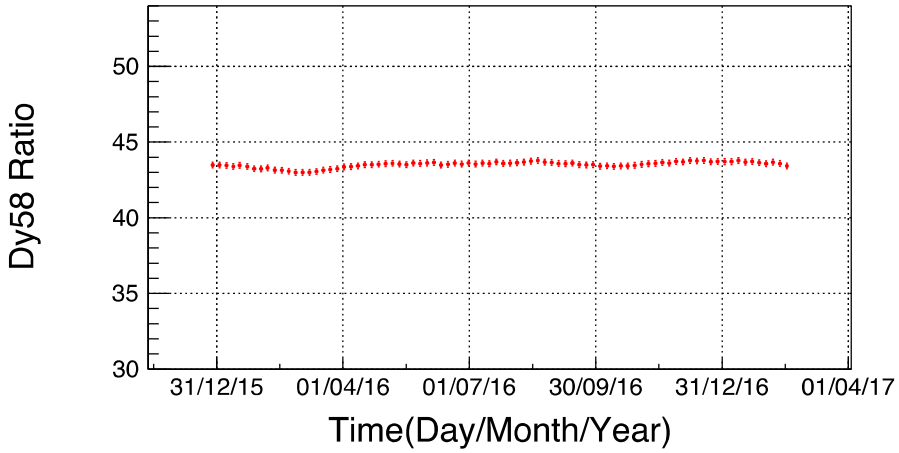
After temperature correction

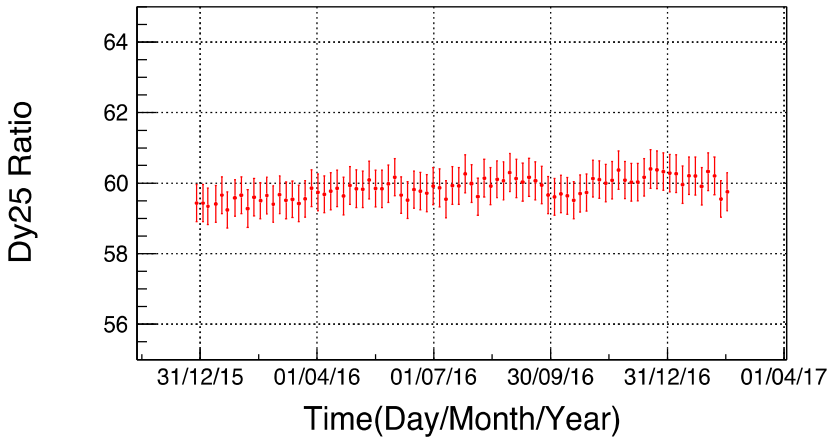


BGO on-orbit calibration: Stability of parameters





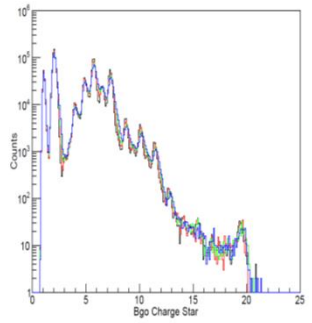


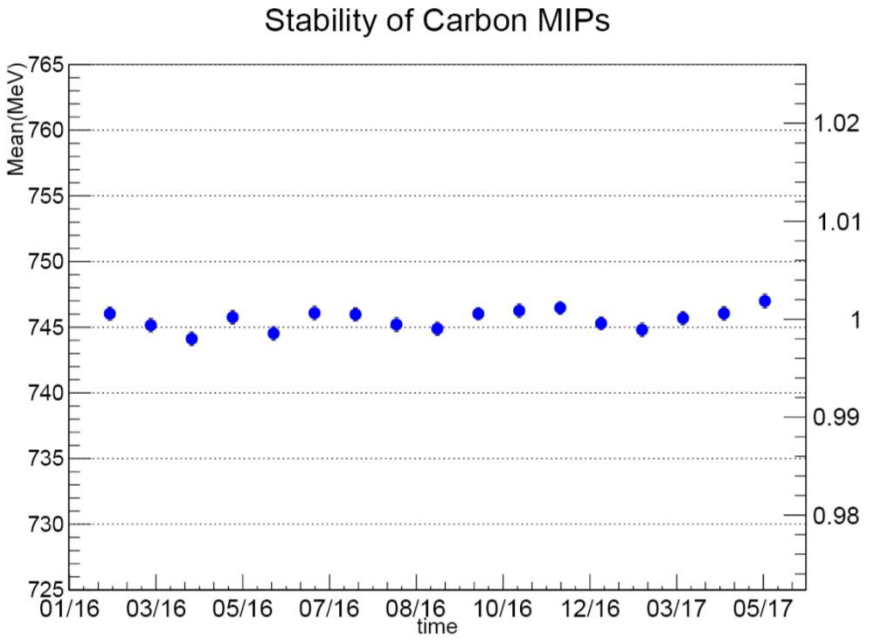


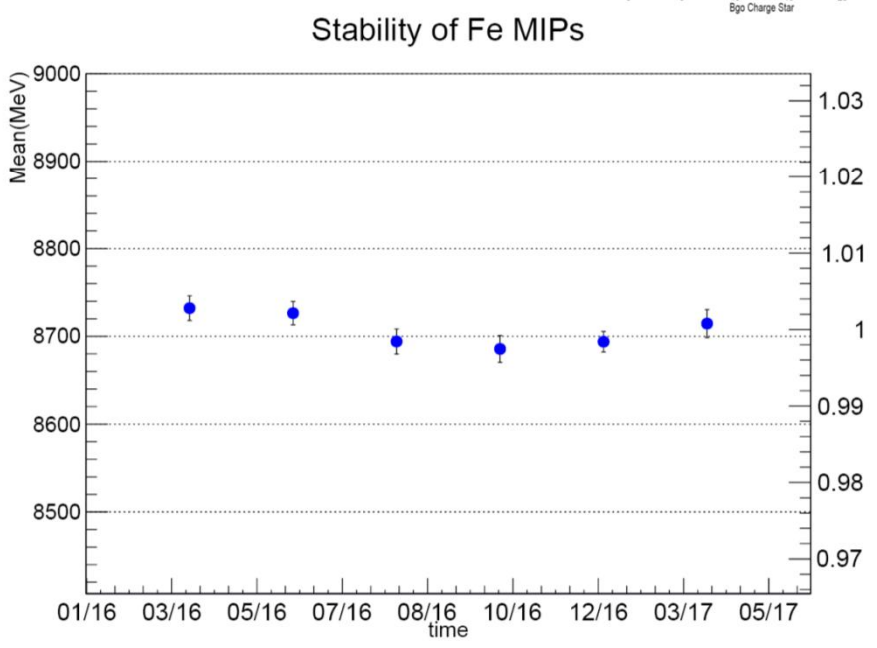
BGO on-orbit calibration: High Energy Stability

Carbon Peak

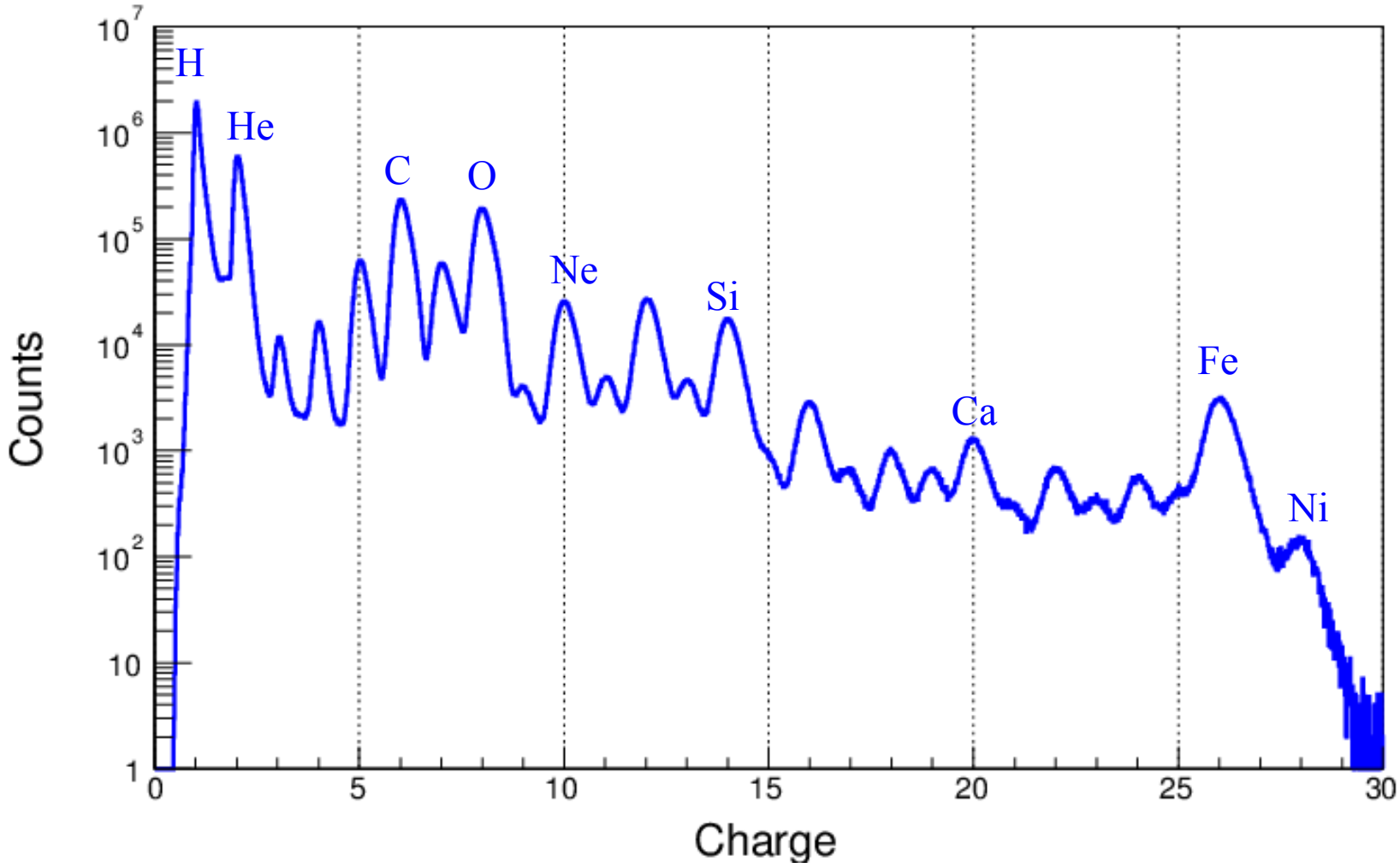
Fe Peak





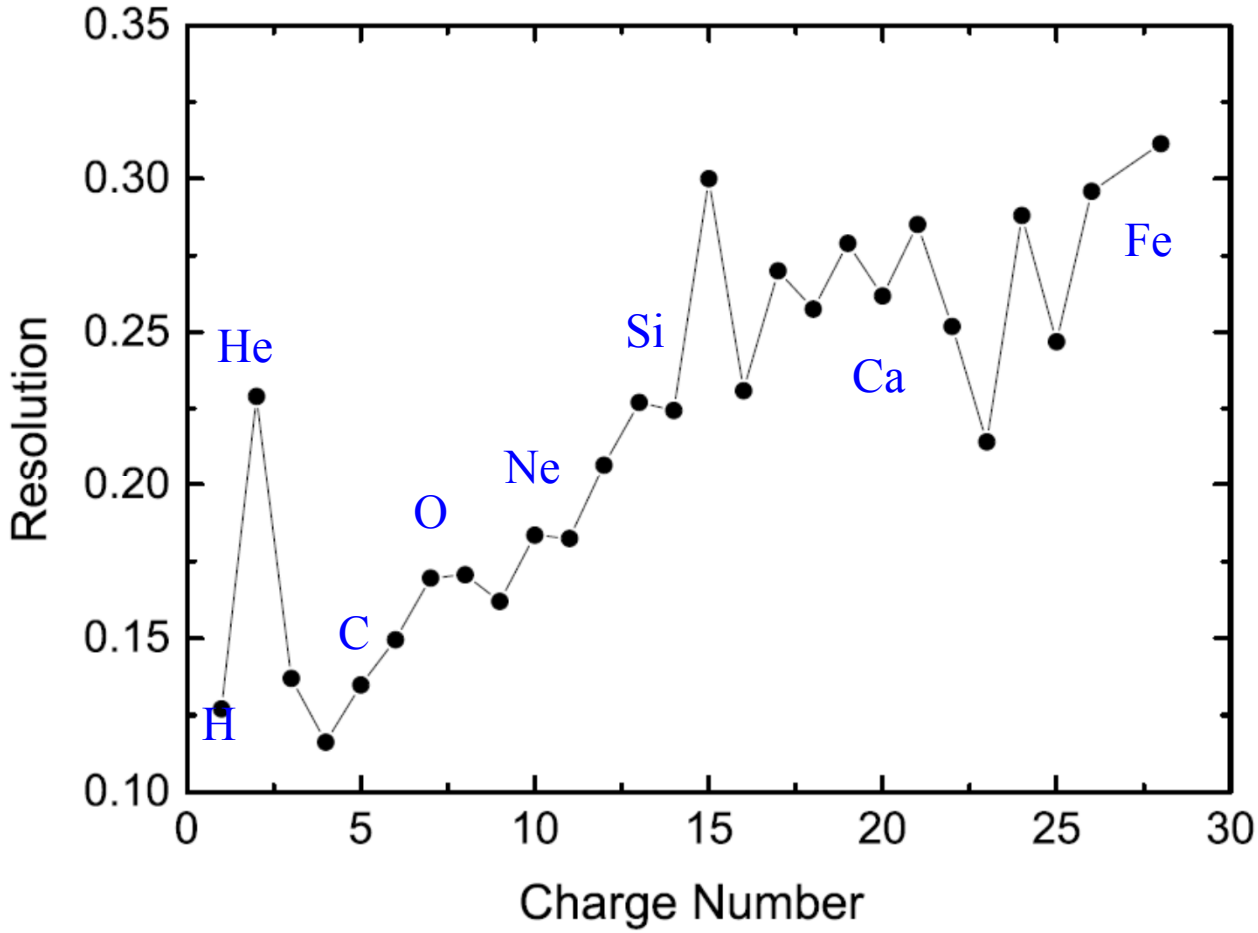


On-orbit performance: Charge measurement



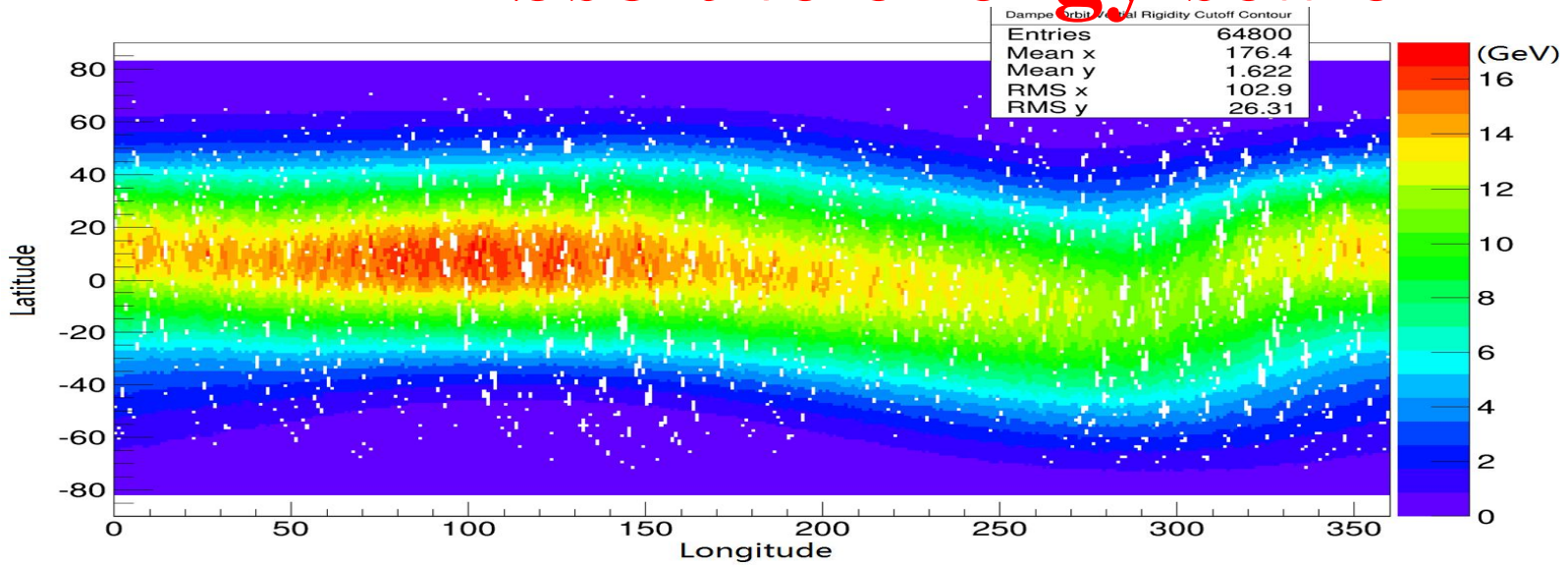
(See Yapeng Zhang's poster CRD098)

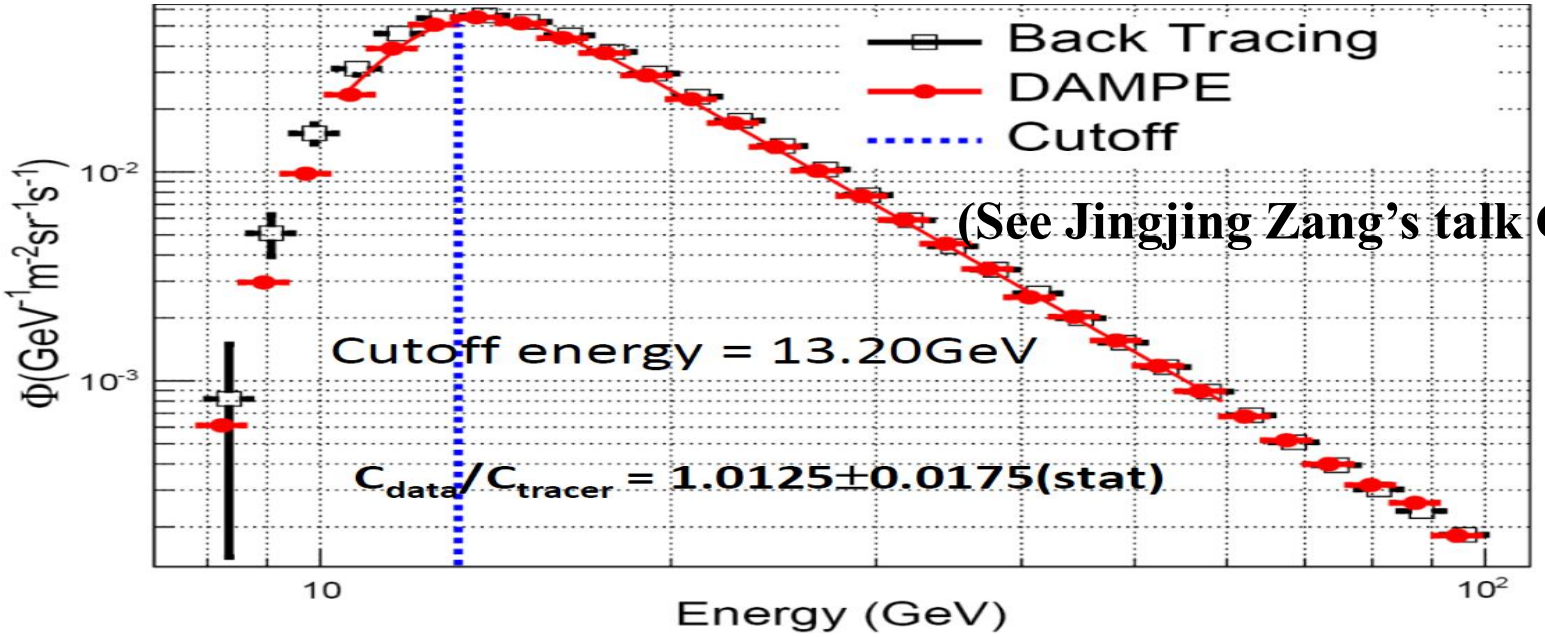
On-orbit performance: Charge measurement



(See Yapeng Zhang's poster CRD098)

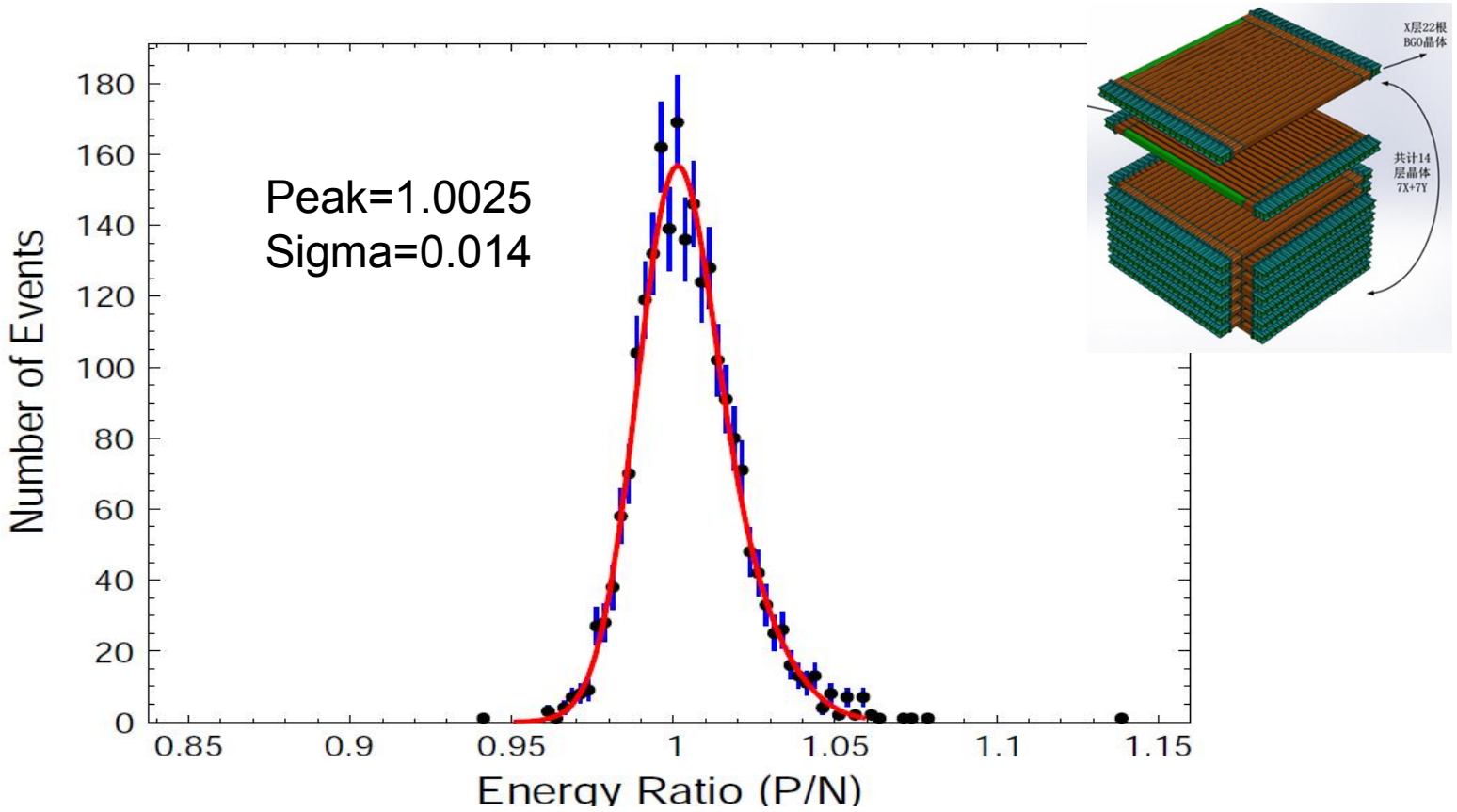
On-orbit performance: Absolute energy scale





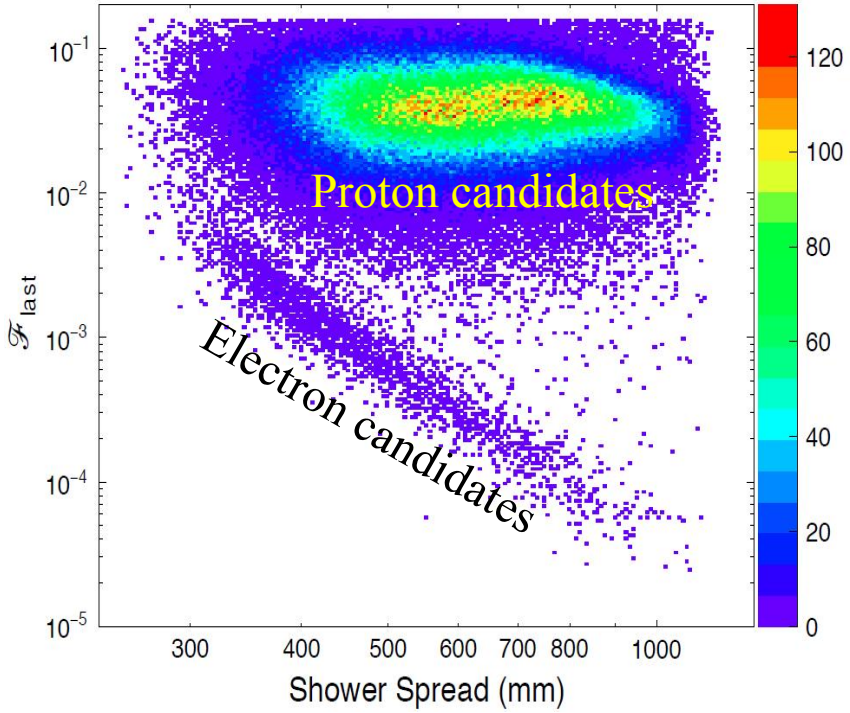
(See Jingjing Zang's talk CRD051)

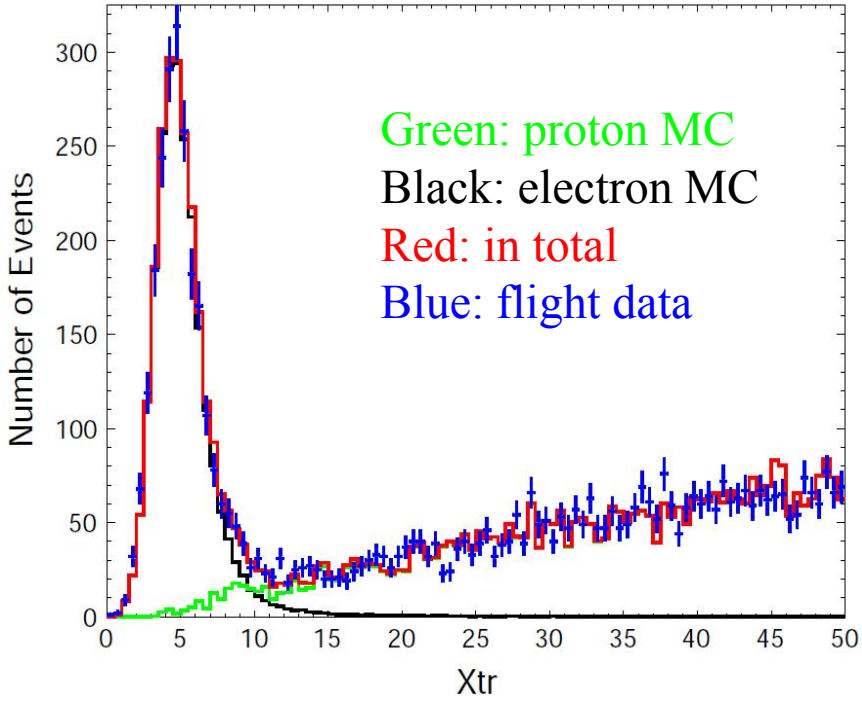
On-orbit performance: energy measurement



For events with deposit energy of 0.5-1.0 TeV

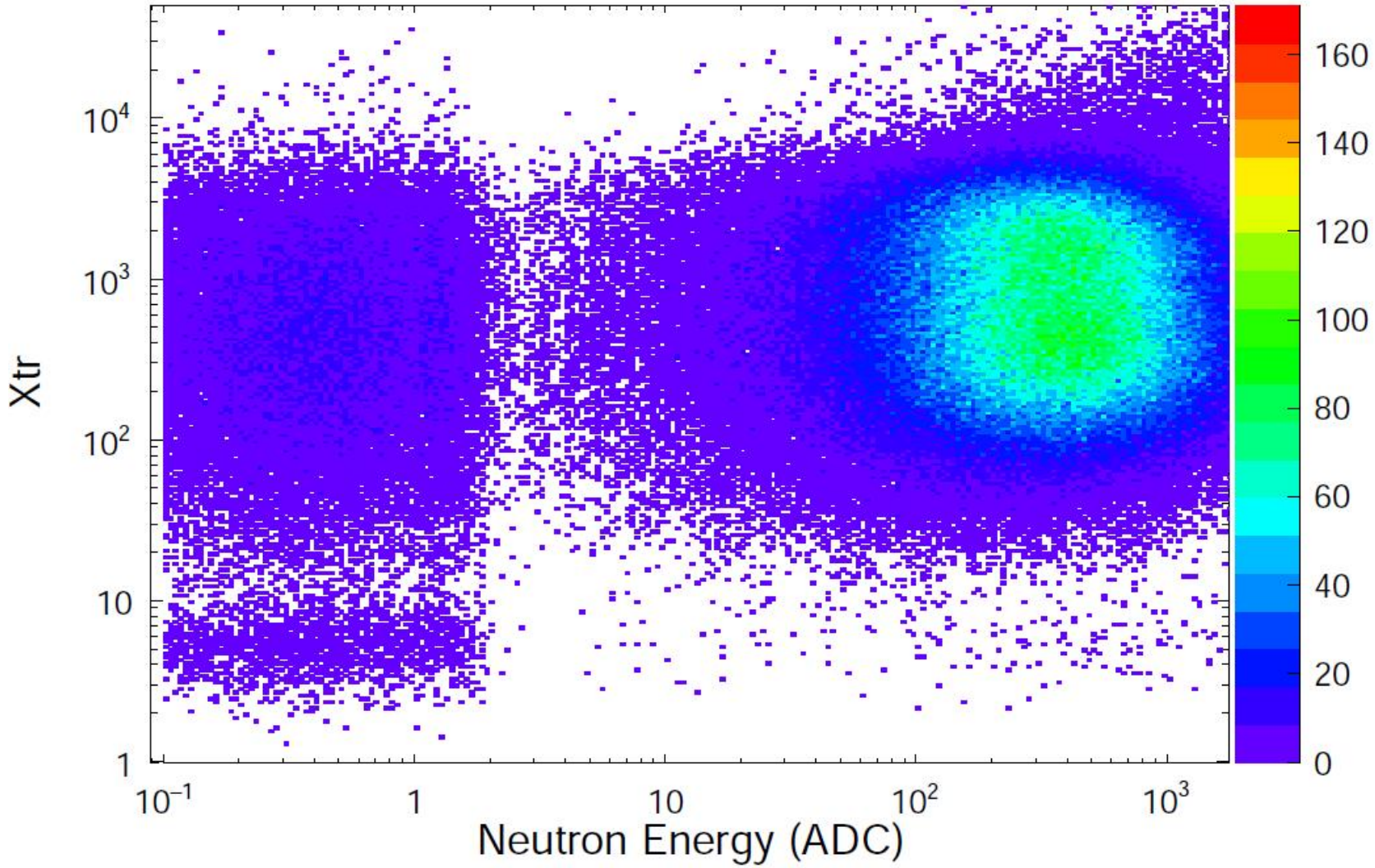
On-orbit performance: e/p separation



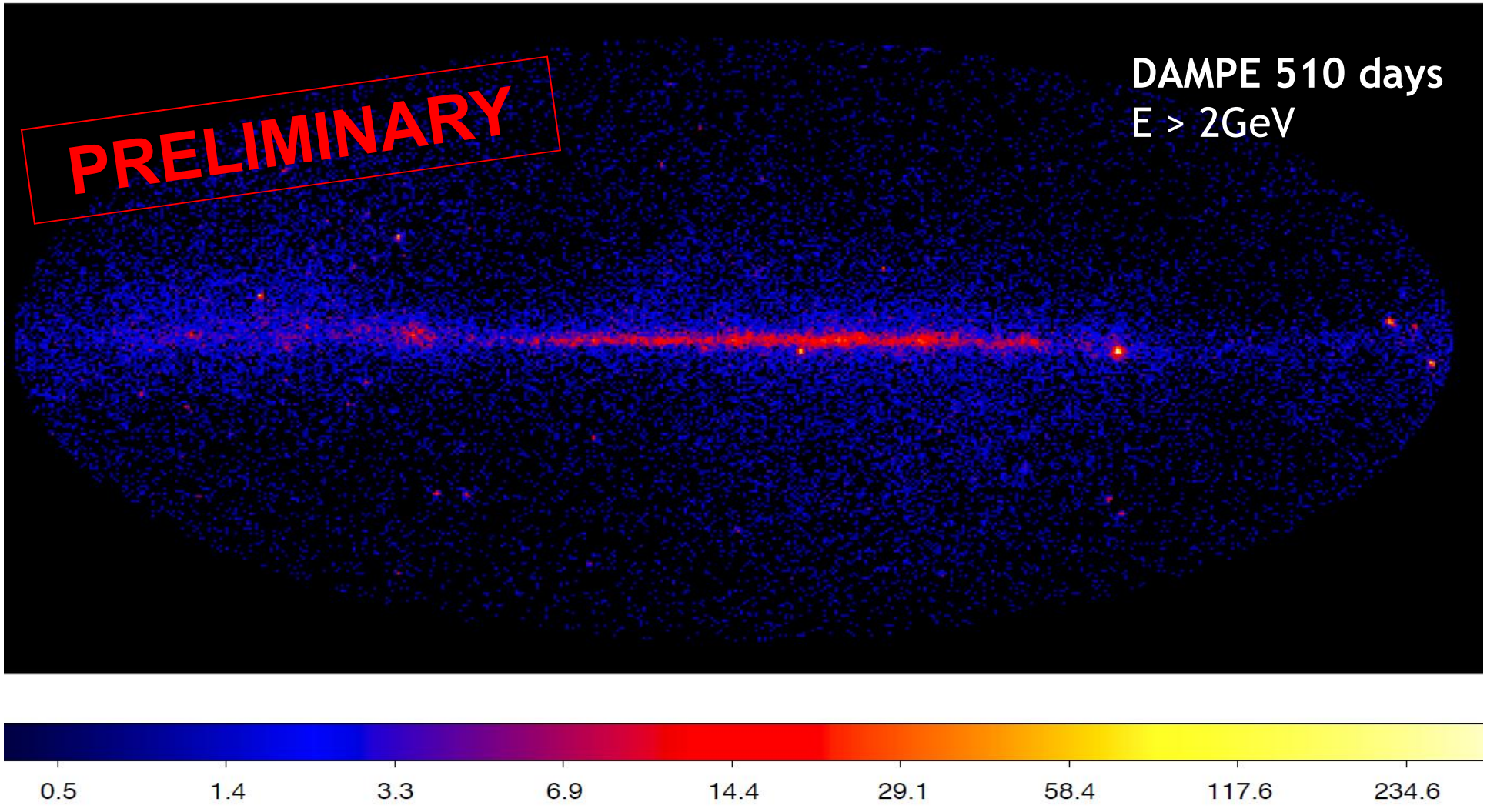


For events with deposit energy of 0.5-1.0 TeV; the proton contamination is found to be ~2% below 1TeV, ~5% @2TeV, and ~10%@5TeV.

On-orbit performance: NUD response

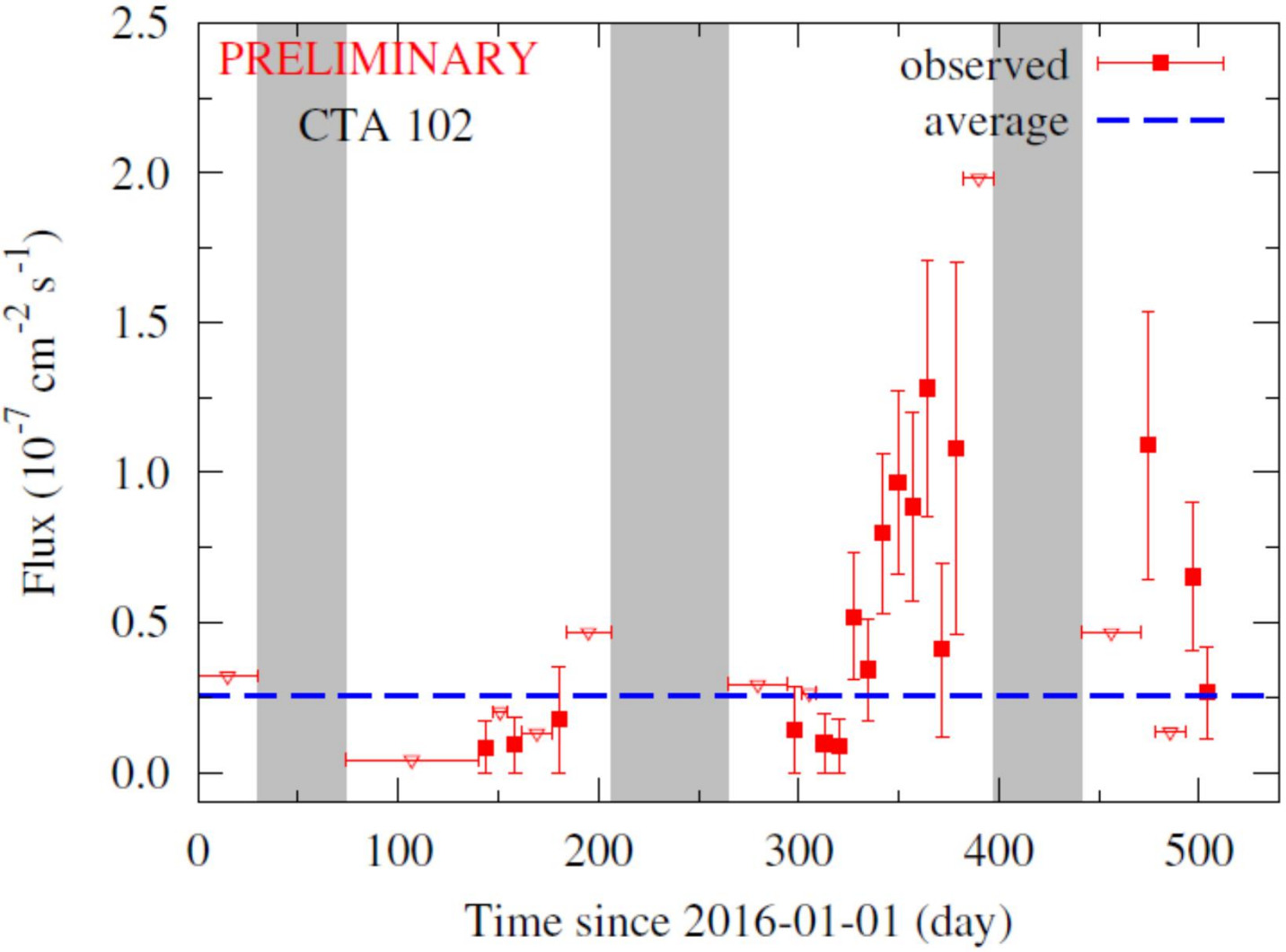


First results: gamma-ray sky map



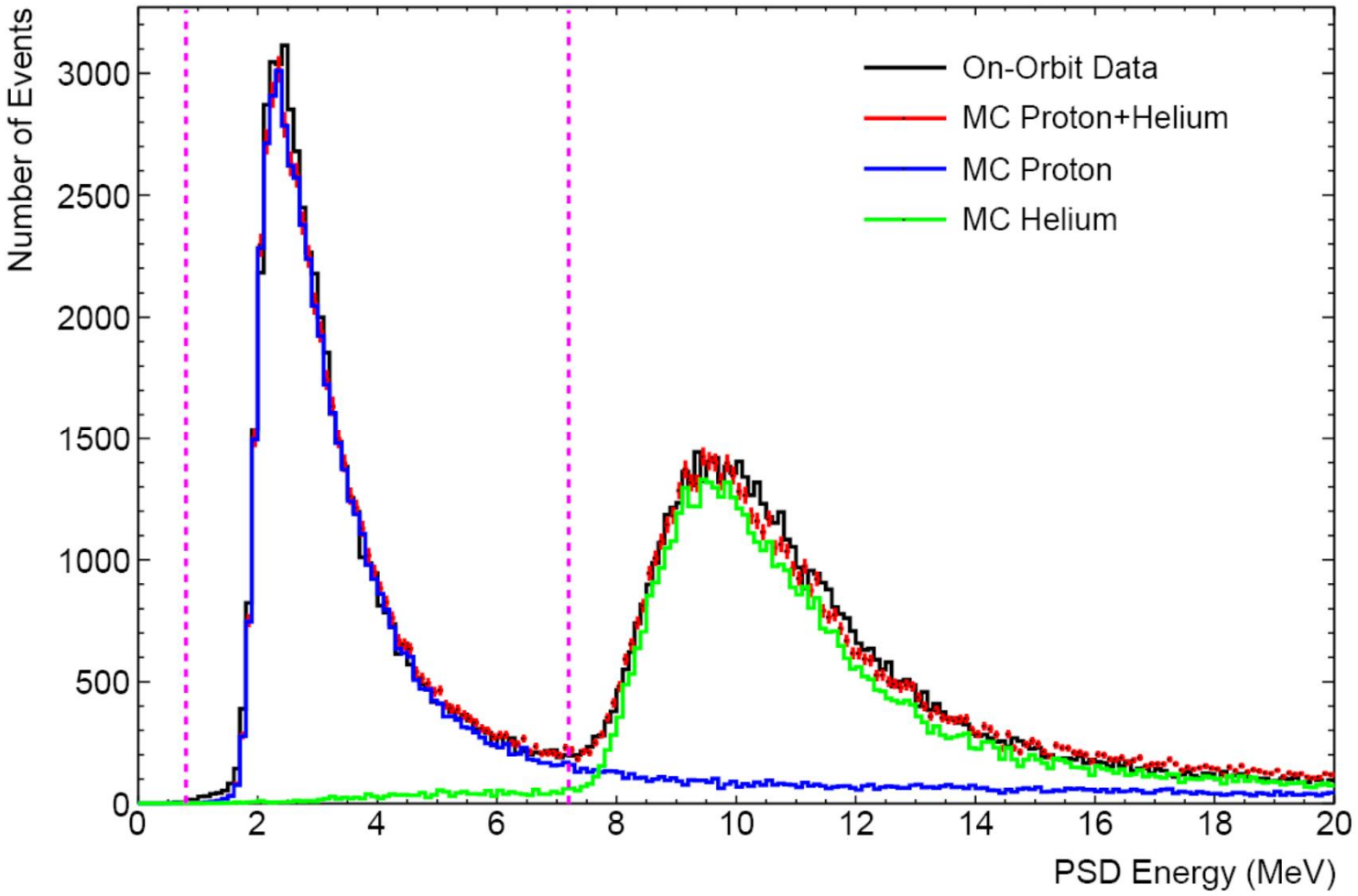
(See Shijun Lei's talk GA206)

First results: variable CTA 102

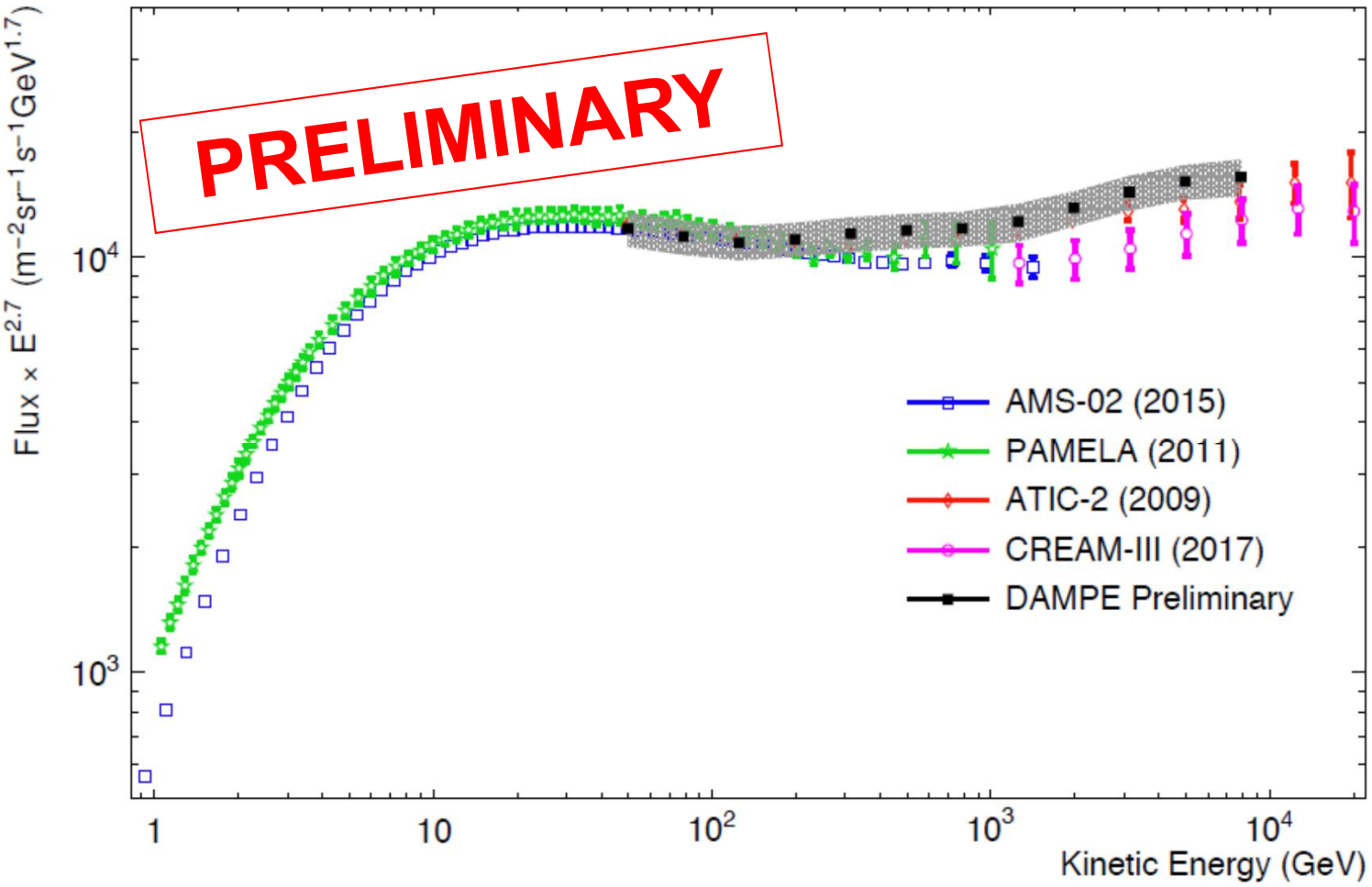


(See Shijun Lei's talk GA206)

First Results (P,He)

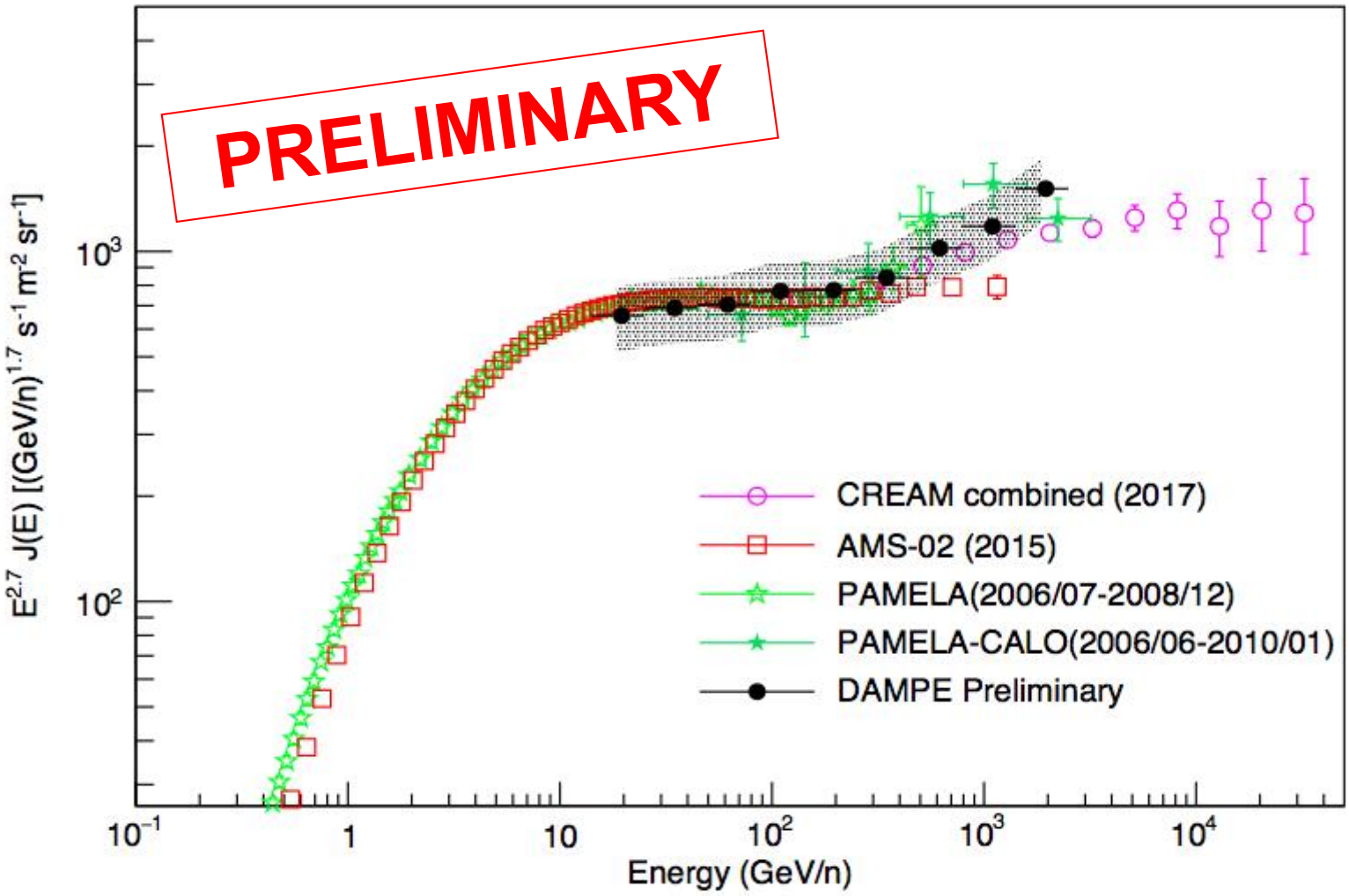


First results: proton flux



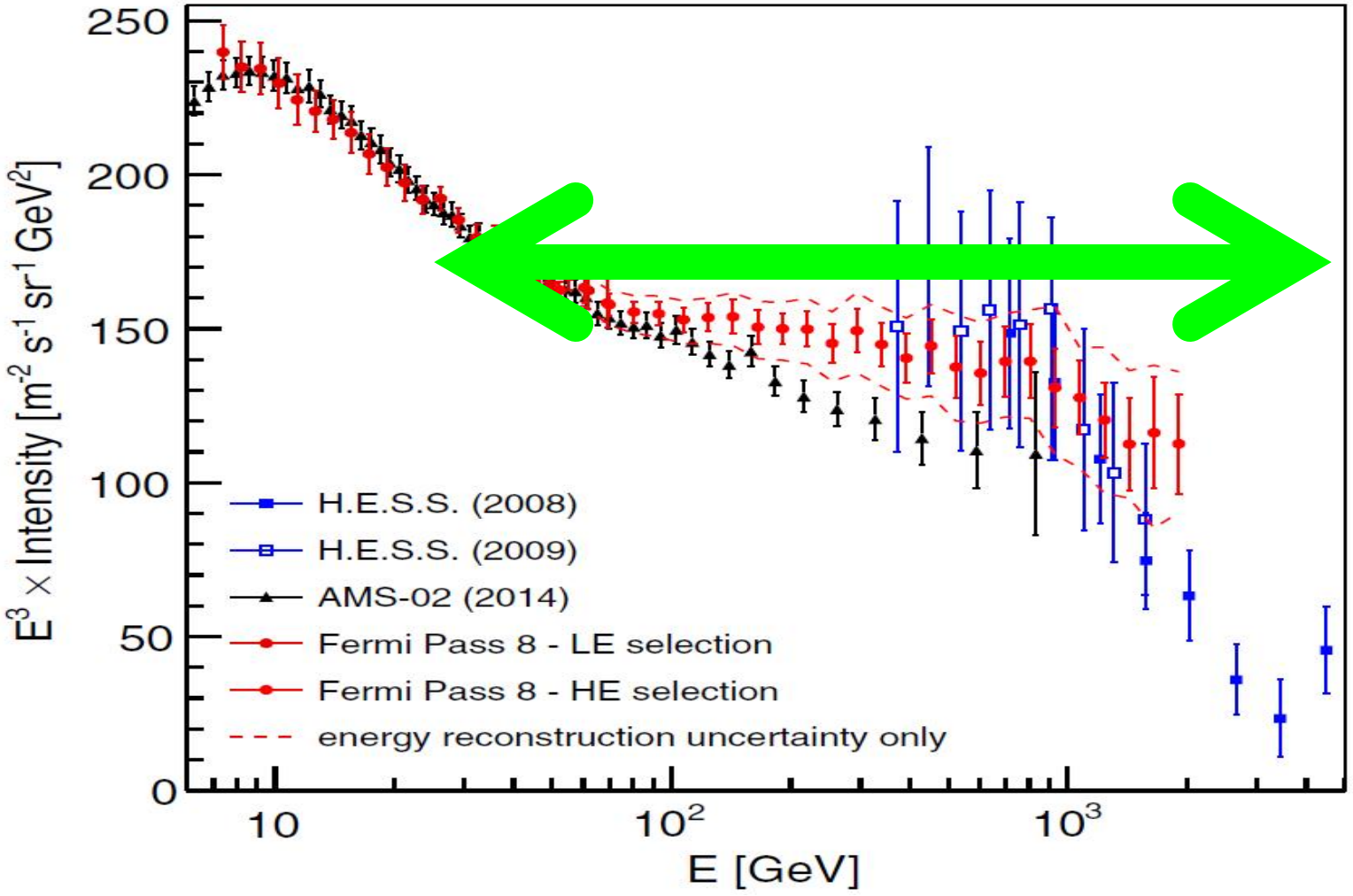
(See Chuan Yue's talk CRD082)

First results: helium flux



(See Paolo Bernardini's talk CRD096)

First results: $e^+ + e^-$ (upcoming)



DAMPE will publish the spectrum from 20 GeV to 5 TeV

Summary

The detector

- Large geometric factor instrument (0.3 m^2 sr for electrons)
- Precision Si-W tracker (40μm , 0.2°)
- Thick calorimeter (32 X_0 , σ_E/E better than 1% above 50 GeV for e/γ , (20~35)% for hadrons)
- "Mutiple" charge measurements (0.2-0.3 e resolution)
- e/p rejection power > 10^5 (topology alone, higher with neutron detector)

Launch and performances

- Succesfull launch on dec 17, 2015
- On orbit operation steady and with high efficiencies
- Absolute energy calibration by using the geomagnetic cut-off
- Absolute pointing cross check by use of the photon map

Physics goals

- Study of the cosmic electron/photon spectra and search for dark matter signals
- Study of cosmic ray protons and nuclei: spectrum (structure) and composition
- High energy gamma ray astronomy
- The "unexpected": GW electromagnetic follow up in FoV

Some members and partners

Thanks!