The DAMPE mission and its first results

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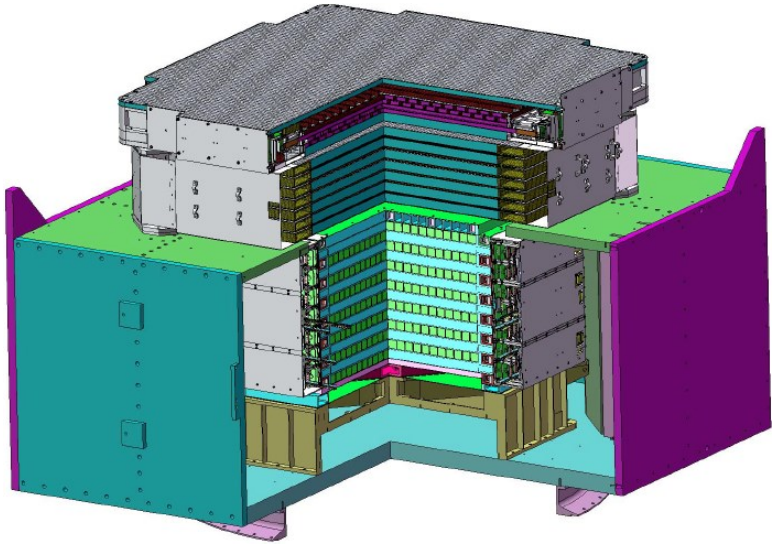
(on behalf of the DAMPE Collaboration)

2019.7.25, Hefei
8th FLASY Workshop

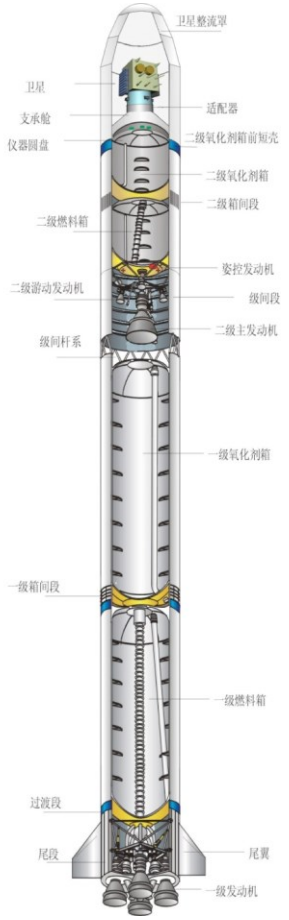
DAMPE: a space experiment

(DArk Matter Particle Explorer)

4 sub-detectors



Orbit at 500 km



Major scientific goals:

- Cosmic-ray physics: 100 GeV-100 TeV nuclei;
- γ-ray astronomy;
- Dark matter search.

} 1 GeV-10 TeV e/γ

The DAMPE Collaboration

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

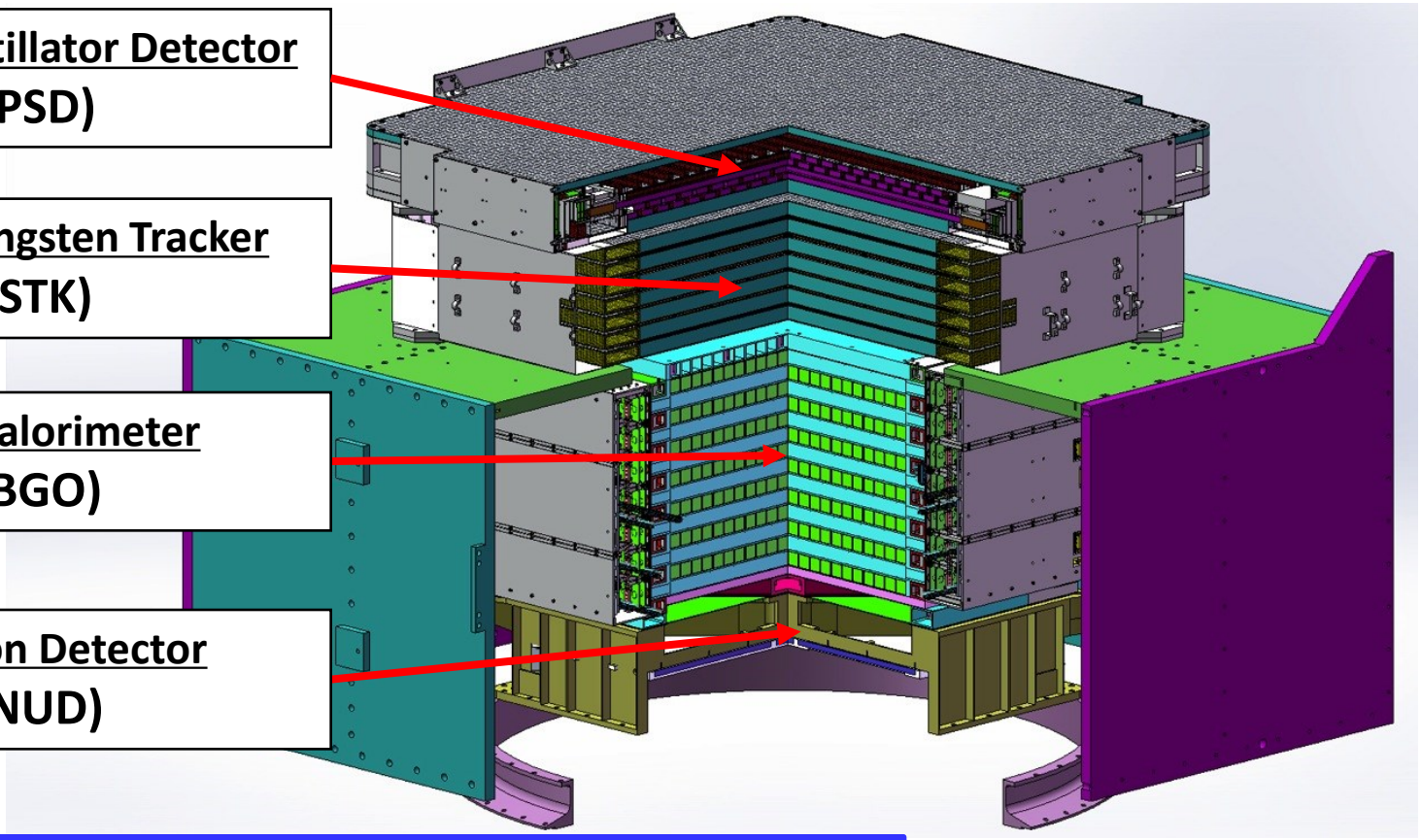
- **ITALY**
  - INFN Perugia and University of Perugia
  - INFN Bari and University of Bari
  - INFN Lecce and University of Salento

- **SWITZERLAND**
  - University of Geneva

Outline

- The Detector
- Performance
- Orbit Status
- First Results

Instrument Design

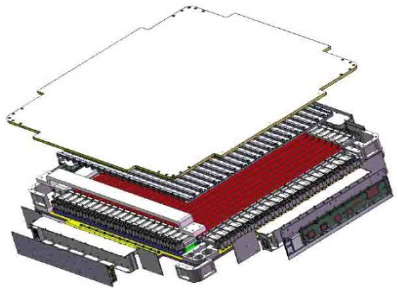


- Charge measurement (dE/dx in PSD, STK and BGO)
- Pair production and precise tracking (STK and BGO)
- Precise energy measurement (BGO bars)
- Hadron rejection (BGO and neutron detector)

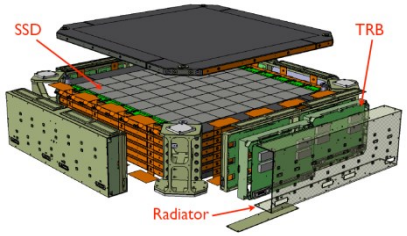
J. Chang et al. DAMPE Collaboration, Astroparticle Physics 95 (2017) 6–24

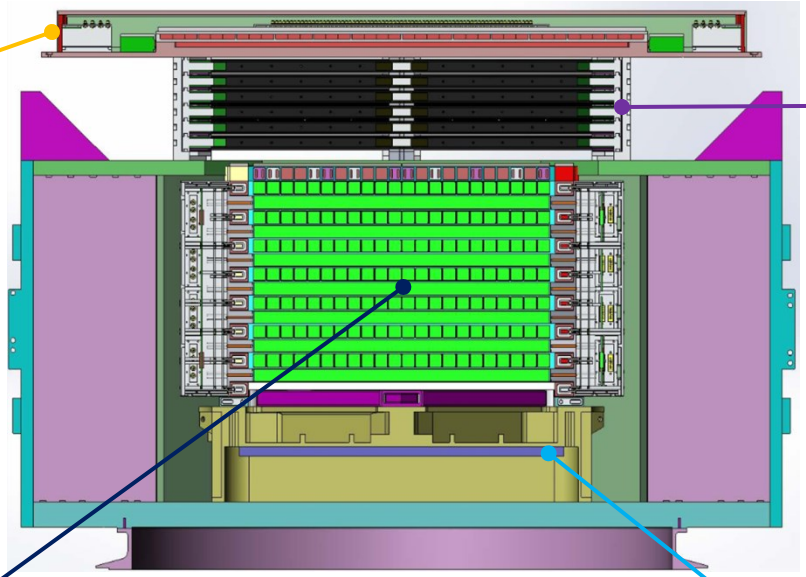
Sub-detectors

Plastic Scintillator Detector (PSD)
- ➢γ anti-coincidence
- ➢Z-measurement

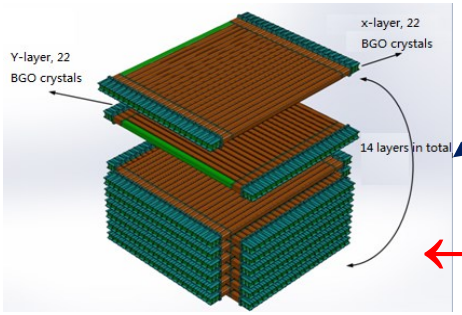


Silicon Tungsten Tracker (STK)
- ➢γ convertor, particle track
- ➢Z-measurement

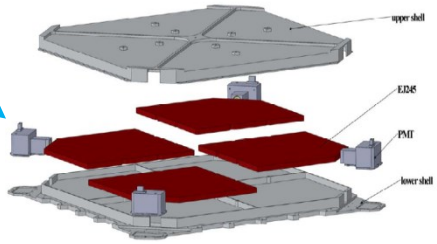




BGO Calorimeter (BGO)
- ➢Calorimeter ($32X_0$&$1.6\lambda_I$)
- ➢e/p separation
- ➢Trigger primitives



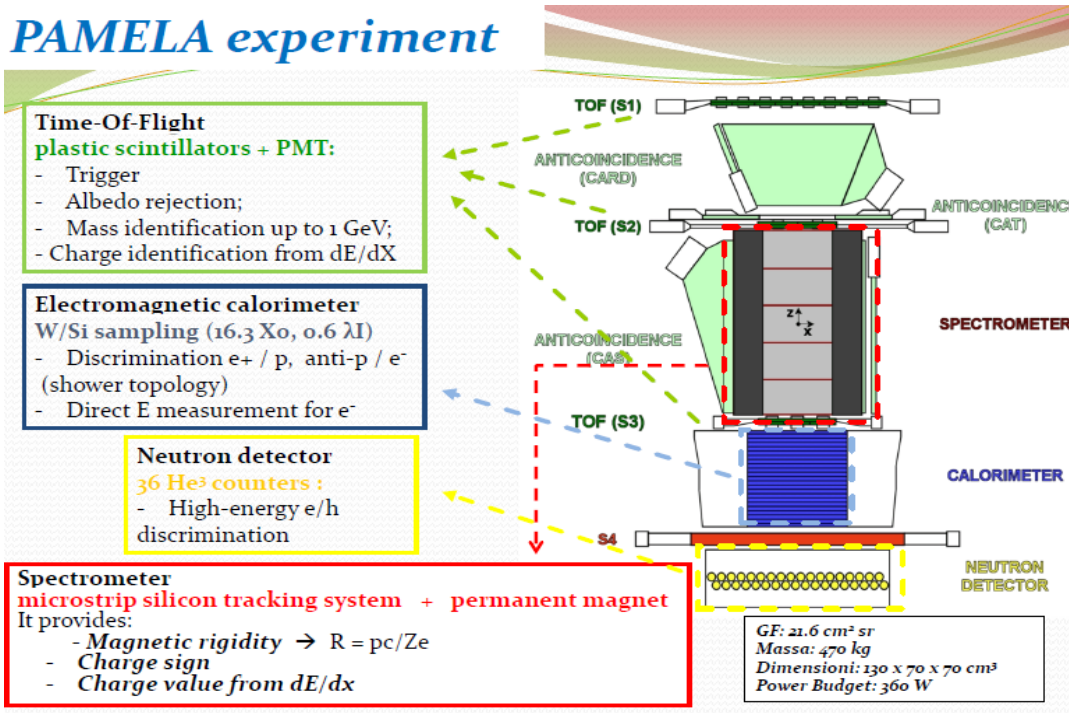
Neutron Detector (NUD)
- ➢e/p separation



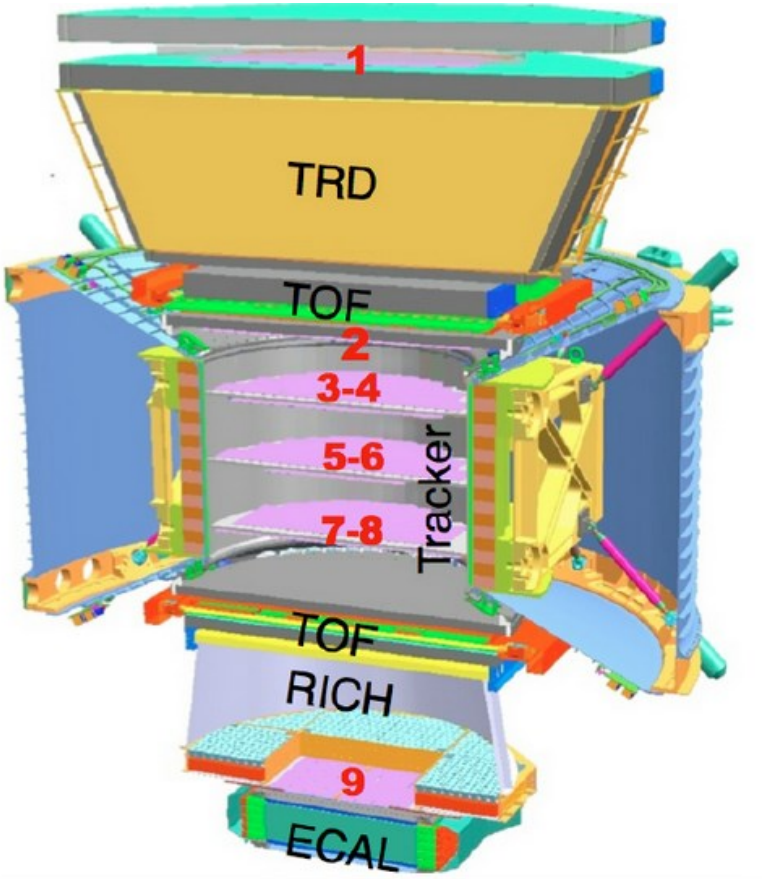
← **Key part of the instrument**

Other experiments in space

- Magnetic spectrometer



PAMELA



AMS02

Other experiments in space

- Telescope + calorimeter

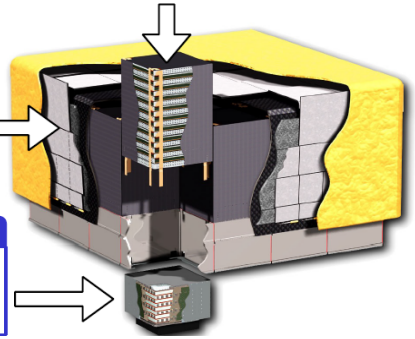
The Fermi LAT

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

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

Anti-coincidence Detector (ACD)
- 89 segmented plastic scintillating tiles
- Used for particle identification

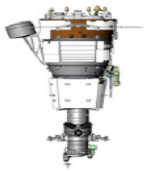
Calorimeter (CAL)
- 1536 CsI(Tl) crystals arranged in 8 layers
- Hodoscopic, image shower shape and profile
- Used for energy measurement

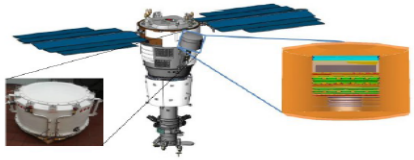


NUCLEON mission

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.
Lanched December 28, 2014.
From July 2015 up to now - regular measuremetns.
The planned exposition time is not less than 5 years (more expected)

Vessel:
Weight ~360 kg
Power consumption
~160 W
Telemetry ~10 GB/day

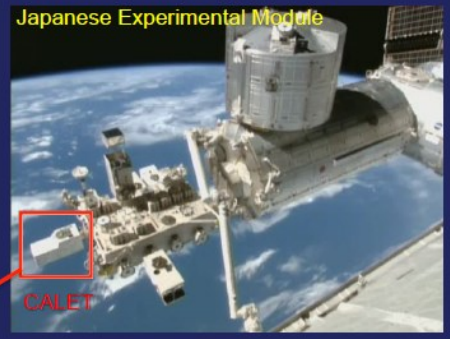


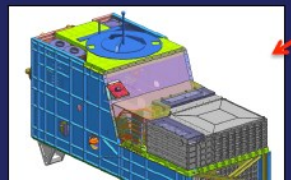


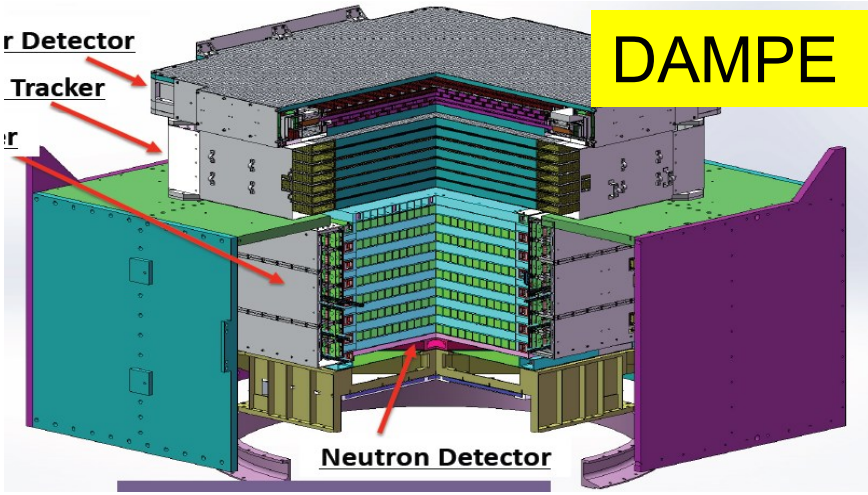
The NUCLEON detector on board of the satellite RESURS-P N2.

CALET:
CALorimetric Electron Telescope

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





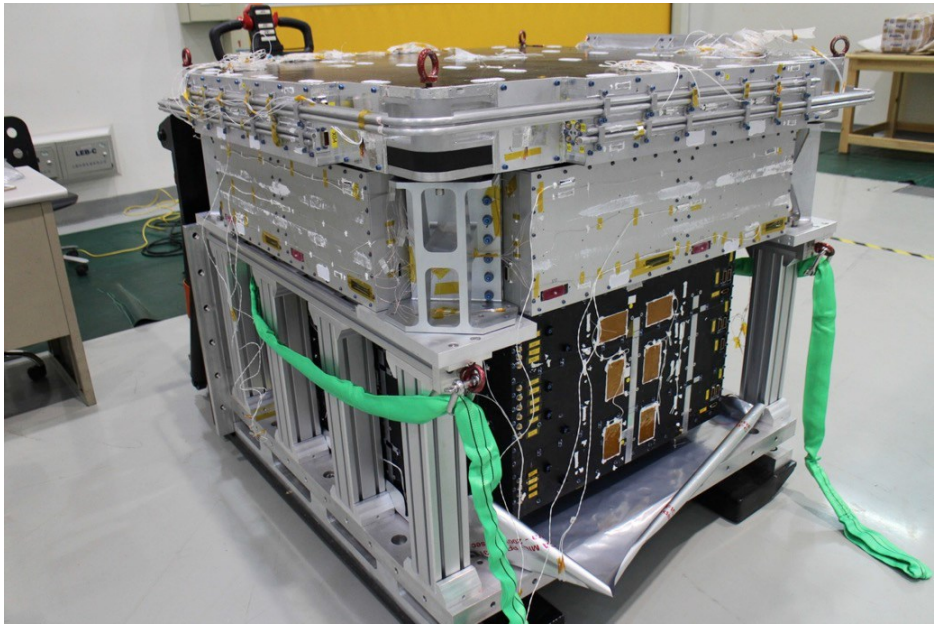


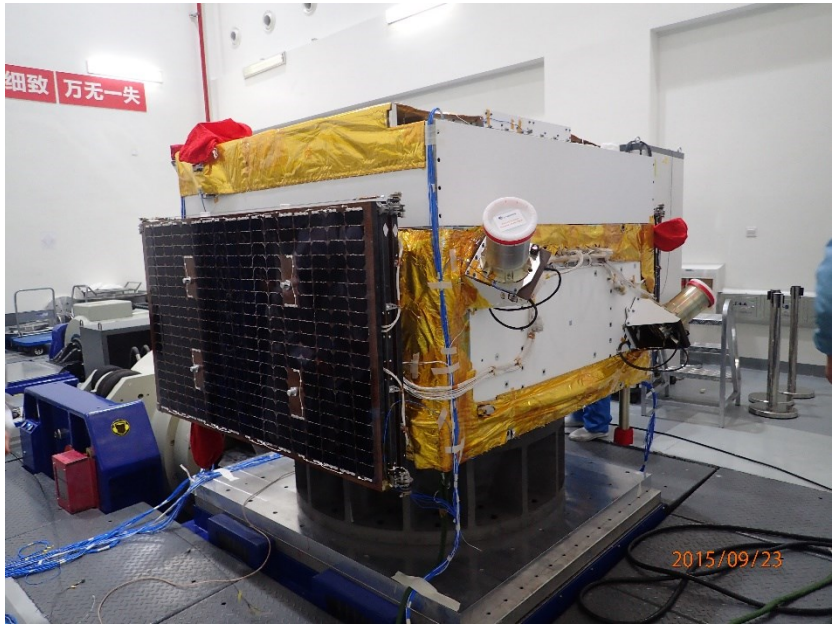
Comparison of performance

Detector	Acceptance (m^2Sr)	Radiation length	Energy resolution
PAMELA	0.002	17	12%@100GeV
AMS02	0.05	17	2%@100GeV
FERMI	2	8.6	>8.5%@100GeV
CALET	0.1	28	2%@100GeV
DAMPE	0.3	32	1.0%@100GeV

Larger acceptance, better resolution

The DAMPE Satellite



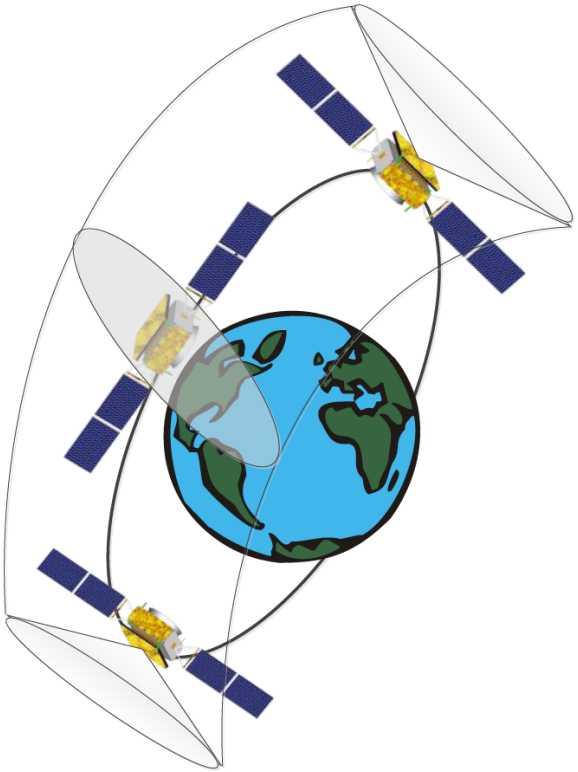


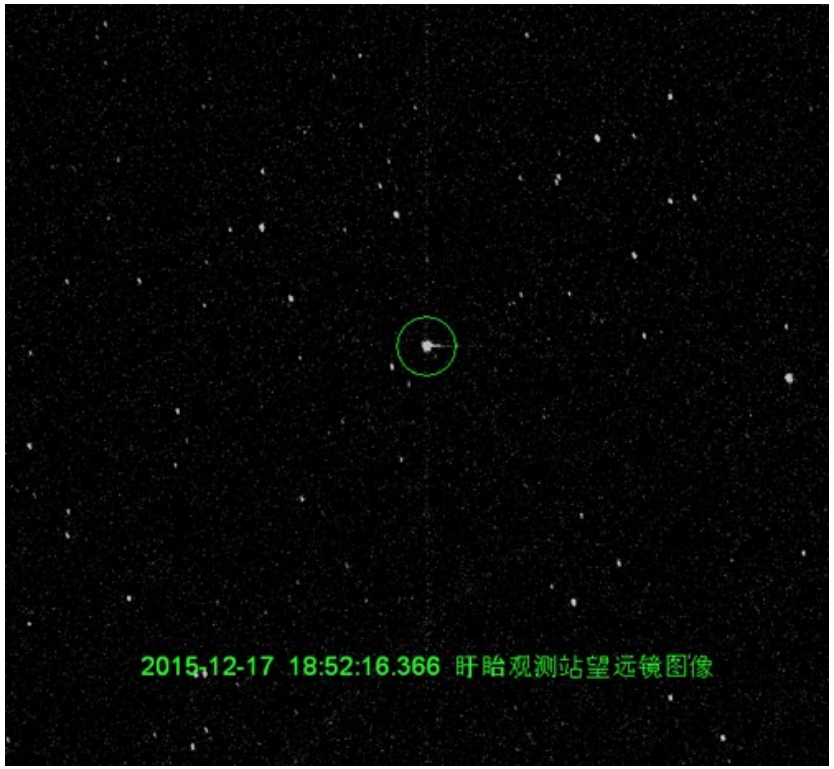
EQM, Oct. 2014, CERN → Integrated satellite, Sept. 2015, Shanghai

Weight : 1450/1850 kg (payload/satellite)
Power: 300/500 W (payload/satellite)
Readout channels: 75,916 (STK 73,728)
Size: 1.2 m x 1.2 m x 1.0 m

The Orbit

- Altitude: 500 km
- Inclination: 97.4065°
- Period: 95 minutes
- Orbit: sun-synchronous

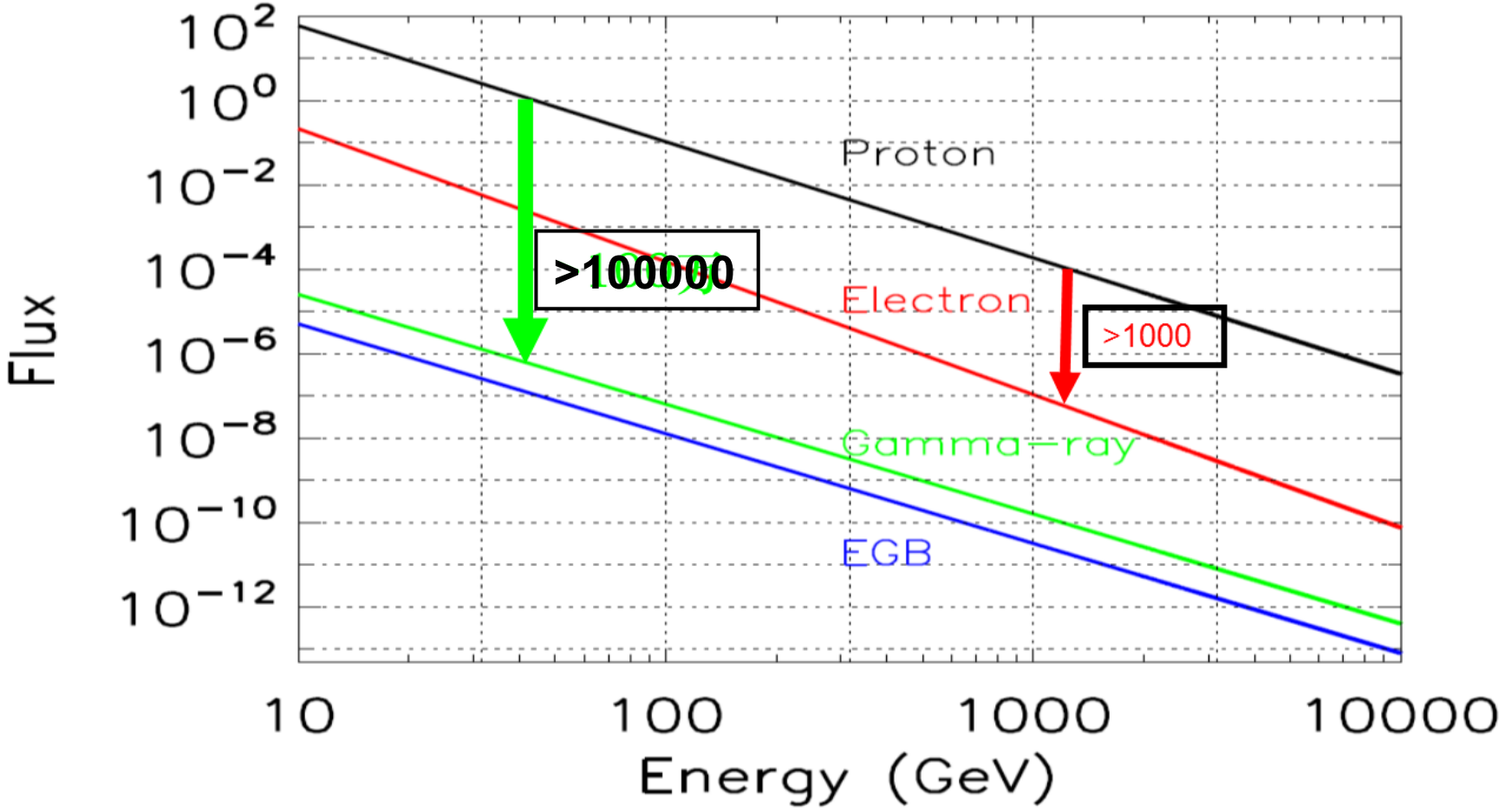




- Launched on Dec.17, 2015
- Dec. 20: all detectors powered on, except the HV for PMTs
- Dec. 24: HV on!
- Dec. 30: stable trigger condition
- Smooth operation since then!

Challenge 1: Particle ratios

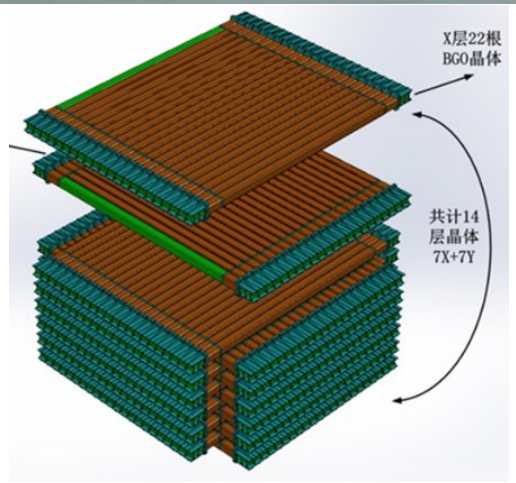
Requirement for e/p rejection power: > 10^5 !



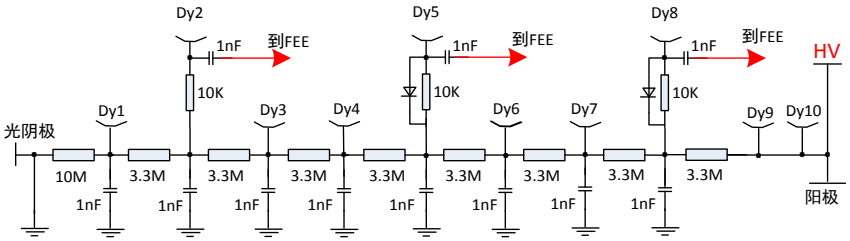
Challenge 2: 10^6 Dynamical Range

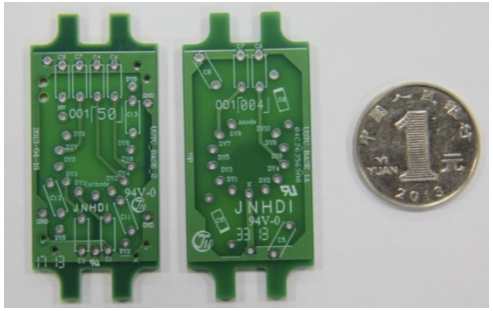
Electron & gamma-ray: GeV to tens TeV

Requirement for BGO bars: MeV to TeVs



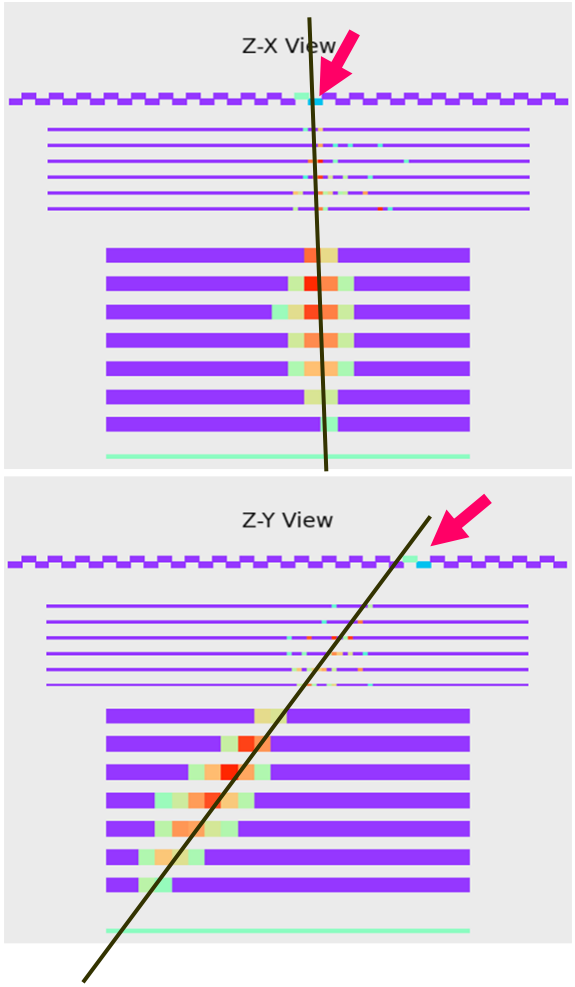
Multi-dynode readouts: 2, 5, 8



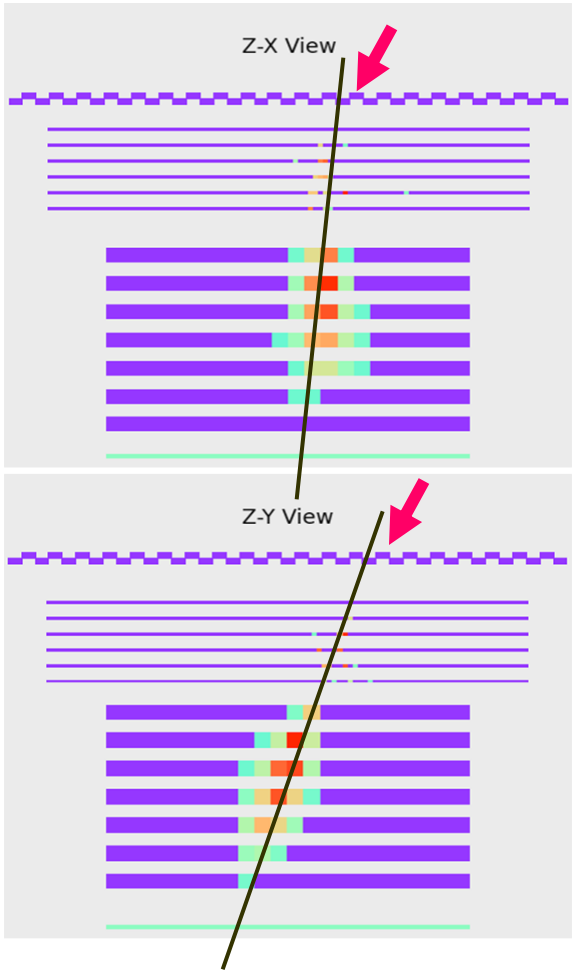


Signals for different particles

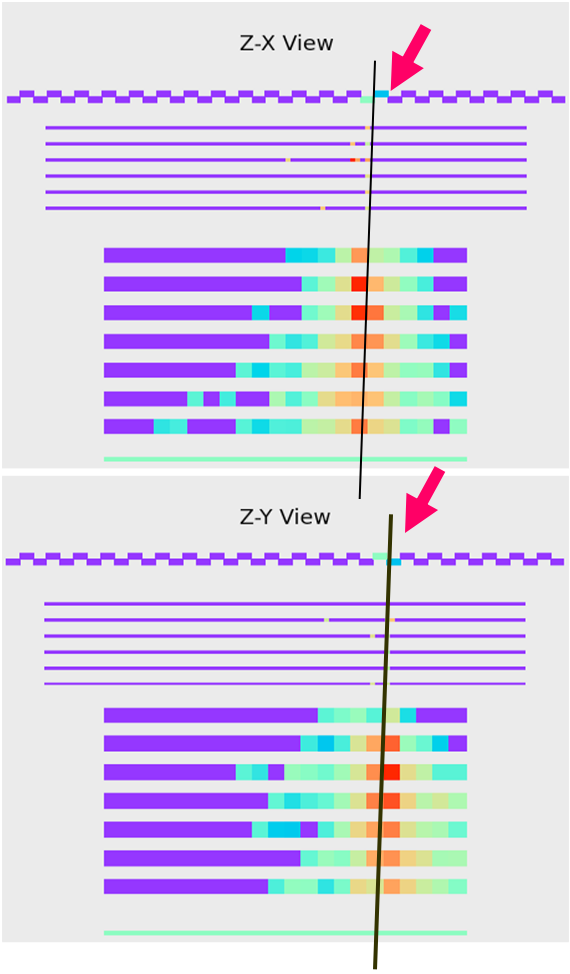
electron



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

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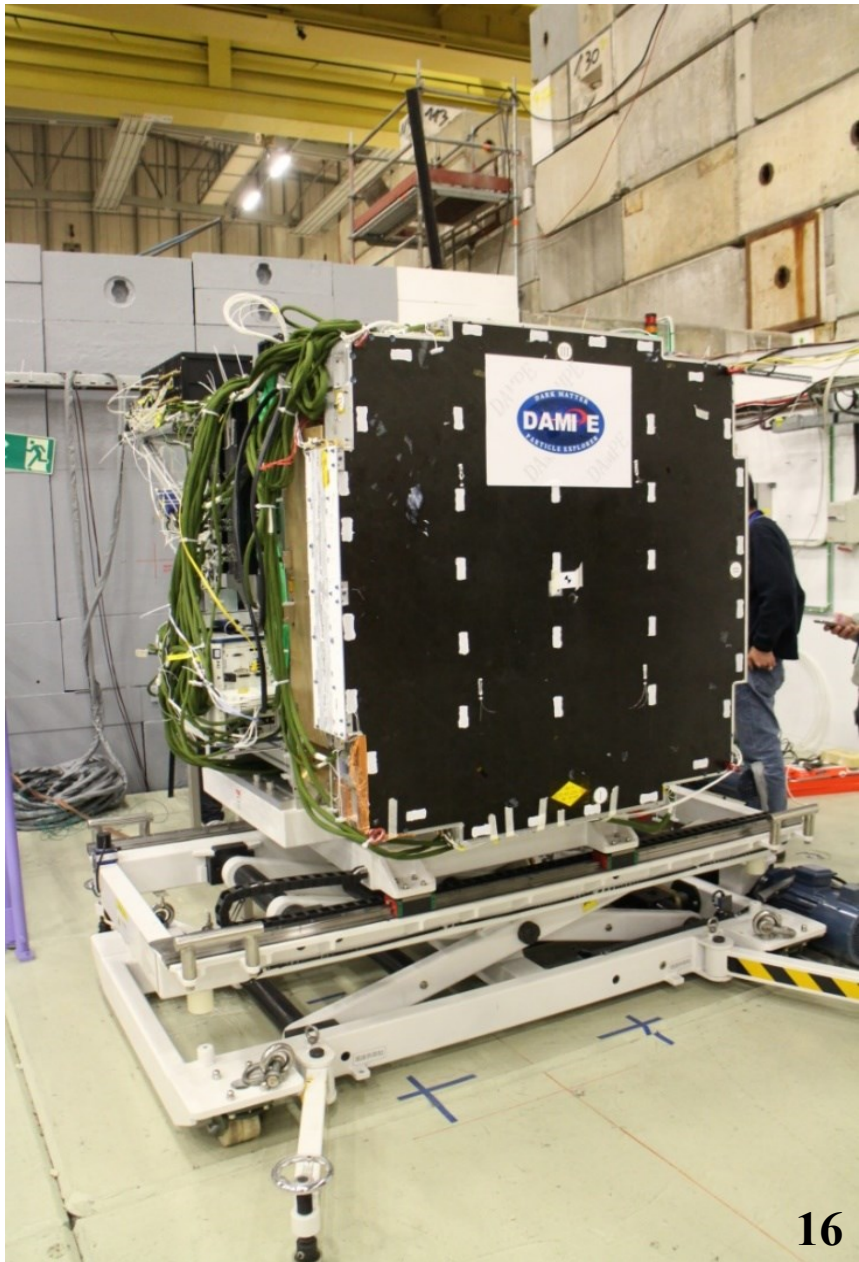
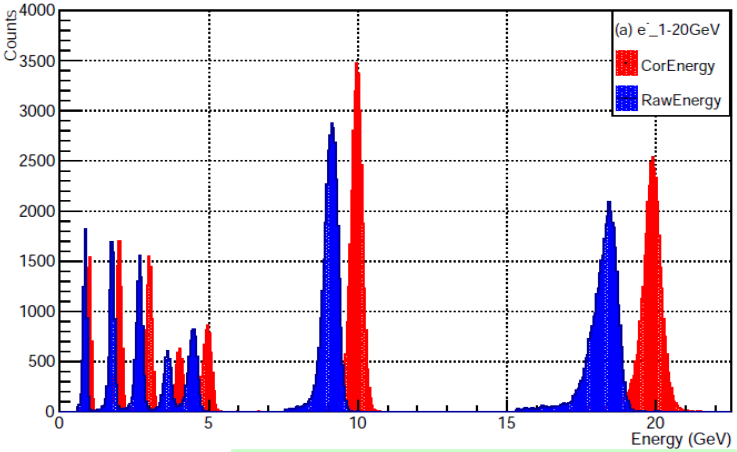
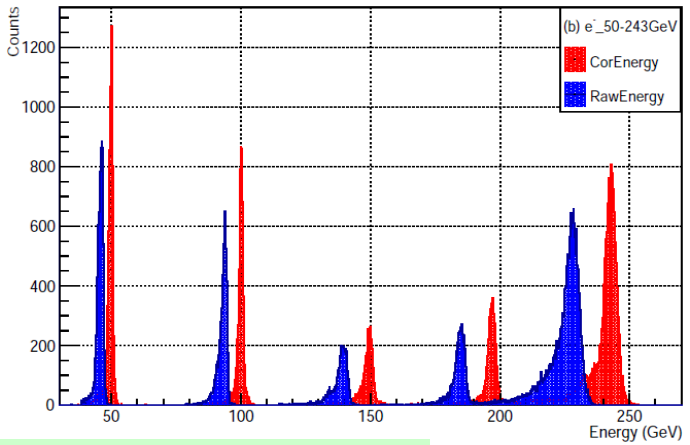
Beam test @ CERN

- 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)

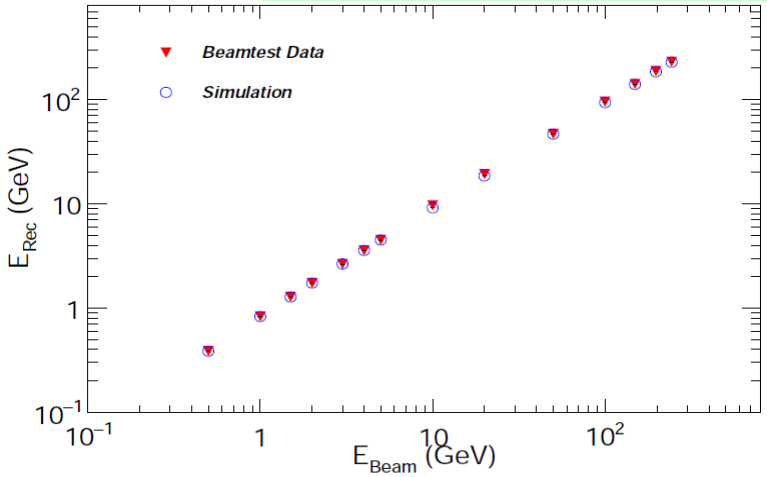


Beam test @ CERN

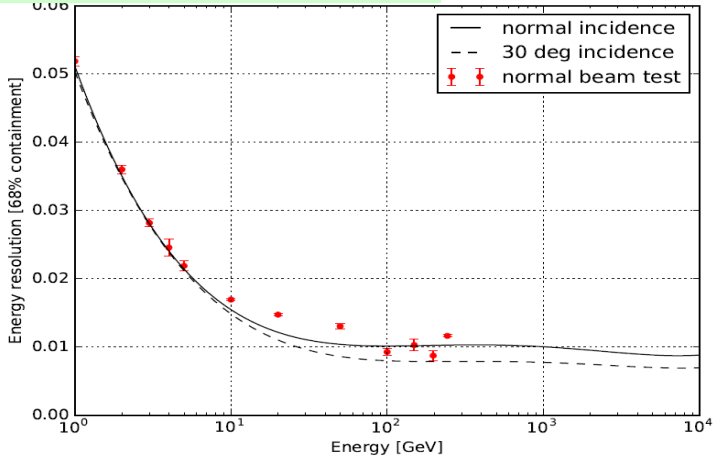




Energy correction: ~6-7% for 100 GeV – 1 TeV



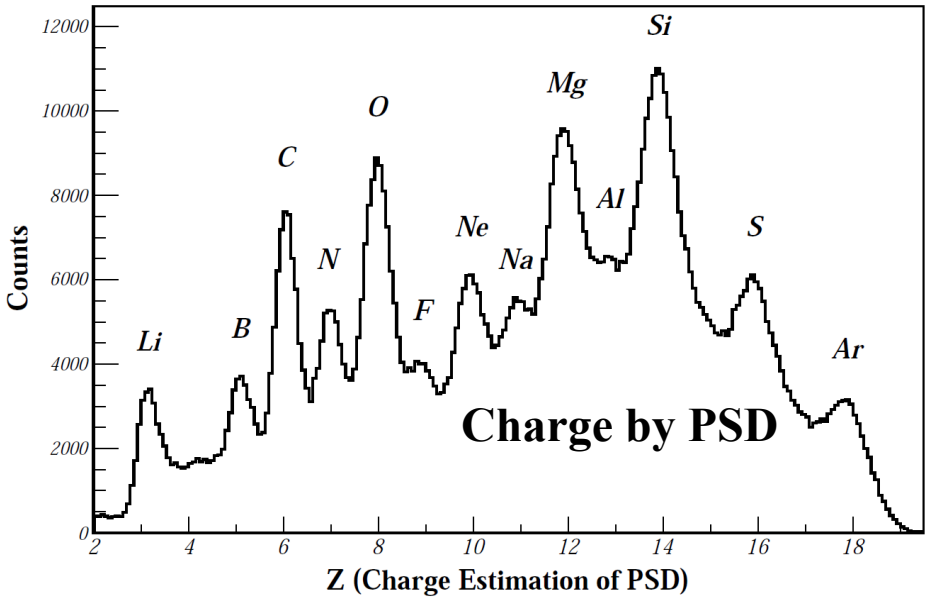
Energy linearity of electrons

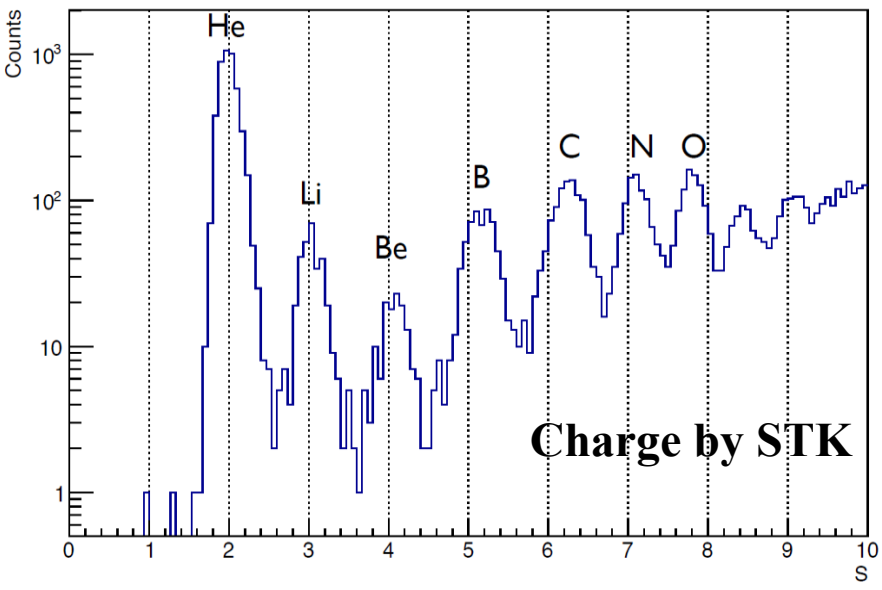


Energy resolution of electrons

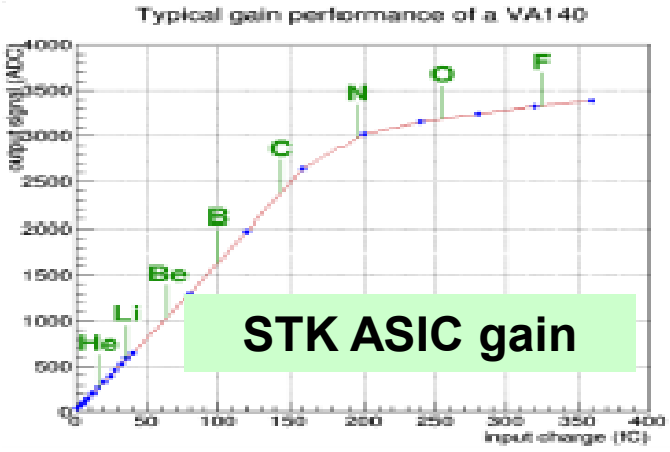
Good linearity and resolution, good agreement between test beam and simulation (NIM A 856 (2017)11)

Beam test @ CERN

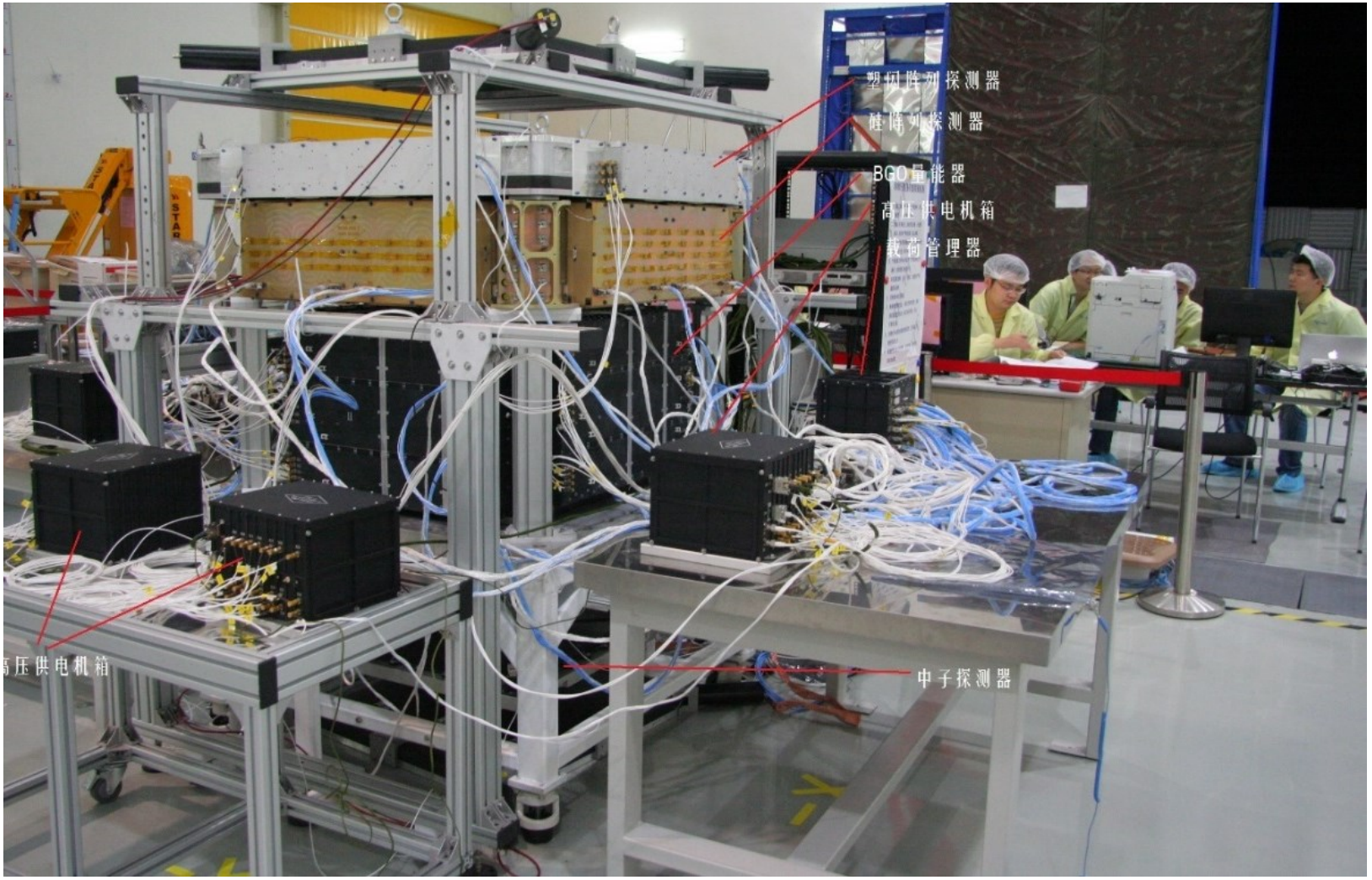




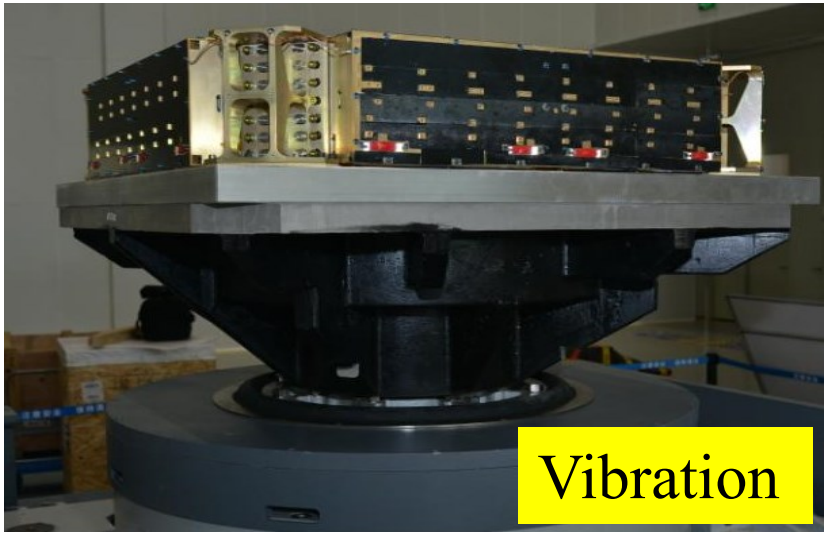
STK has better resolution at low Z, but saturate at Z ~ 8

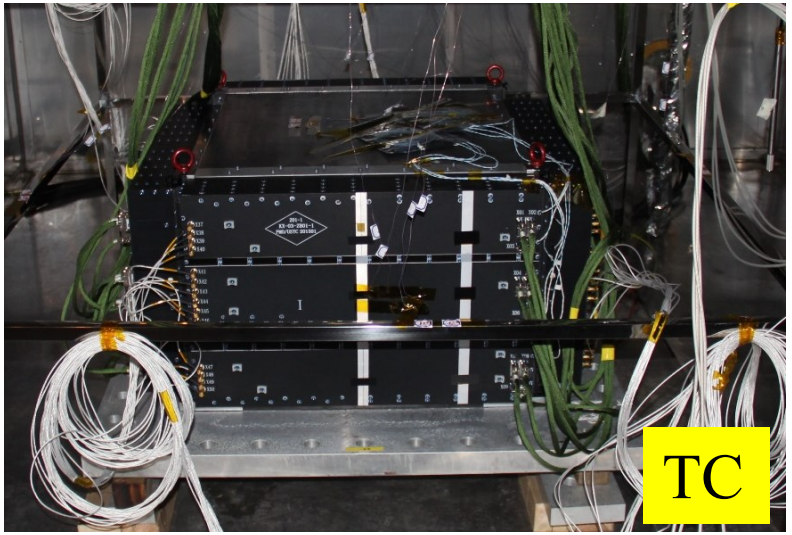


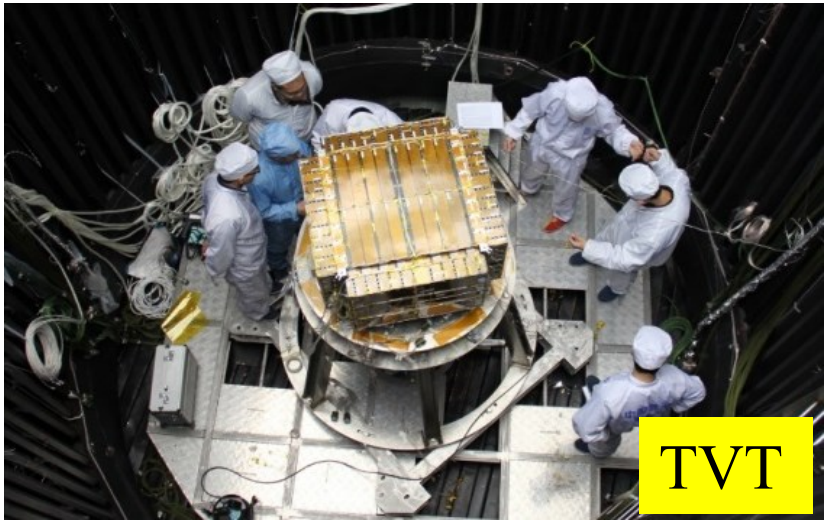
Flight Model: Cosmic Ray Test

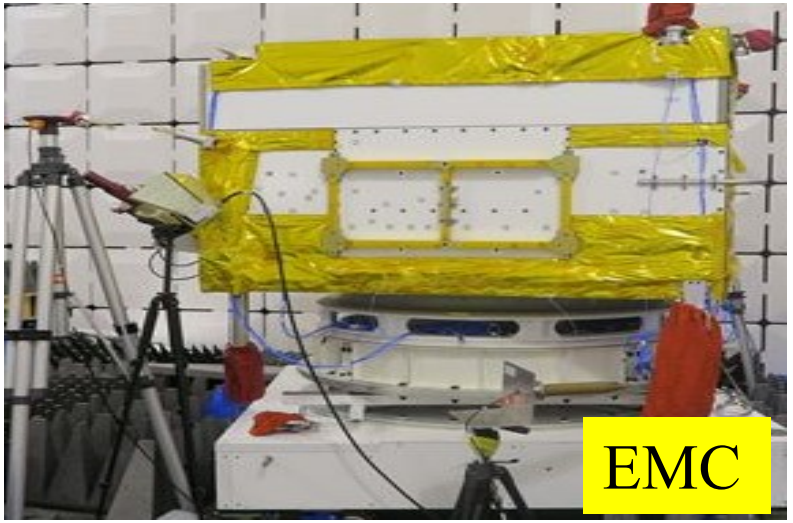


Flight model: environmental tests









Launched on 17th Dec. 2015

Jiuquan Satellite Launch Center, Gobi desert

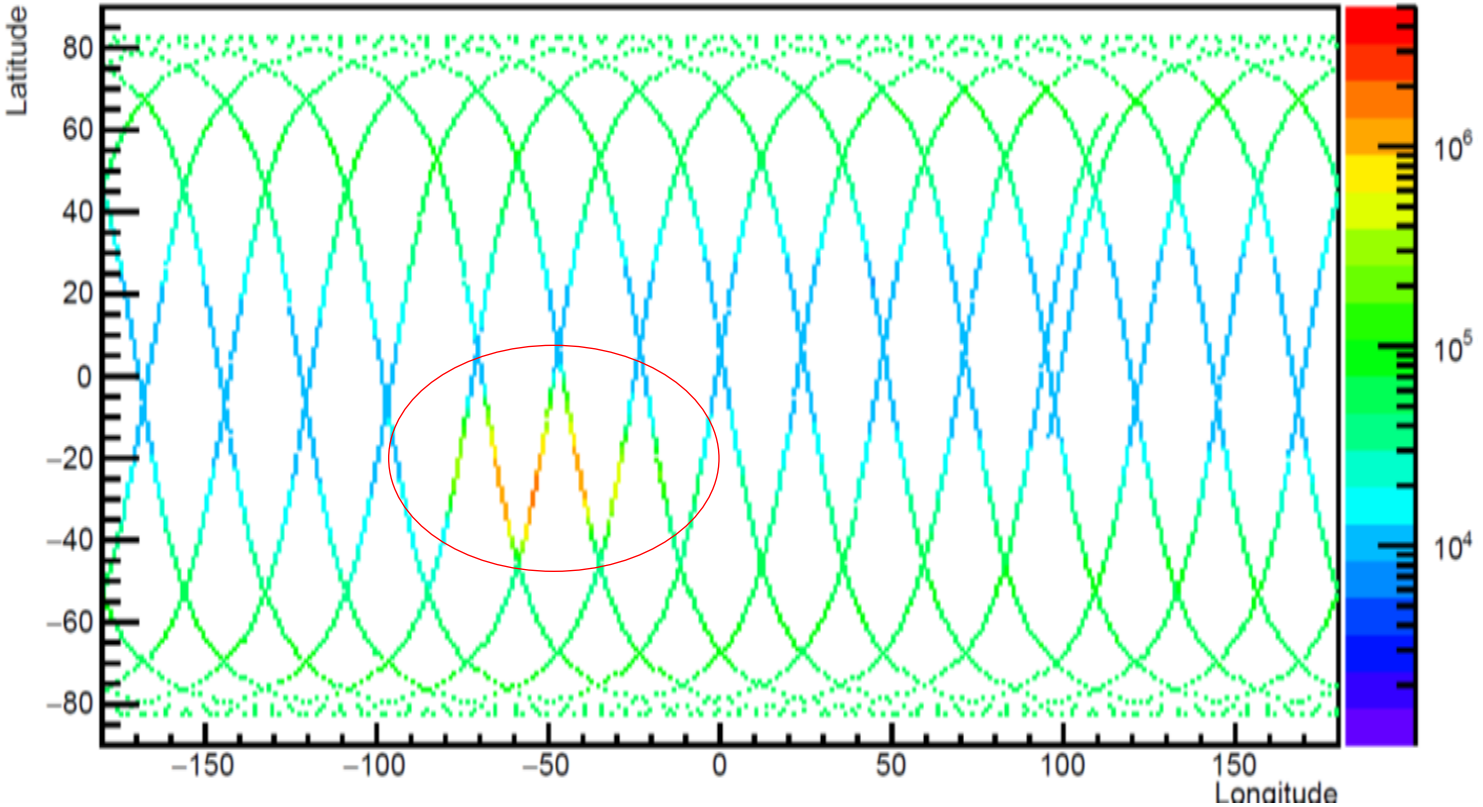
悟空, WuKong
(To probe the space.)

暗物质粒子探测卫星DAMPE:
DArk Matter Particle Explorer

The magic **golden cudgel**
Weighs 36000 jin, or 18000 kg

308 BGO bars

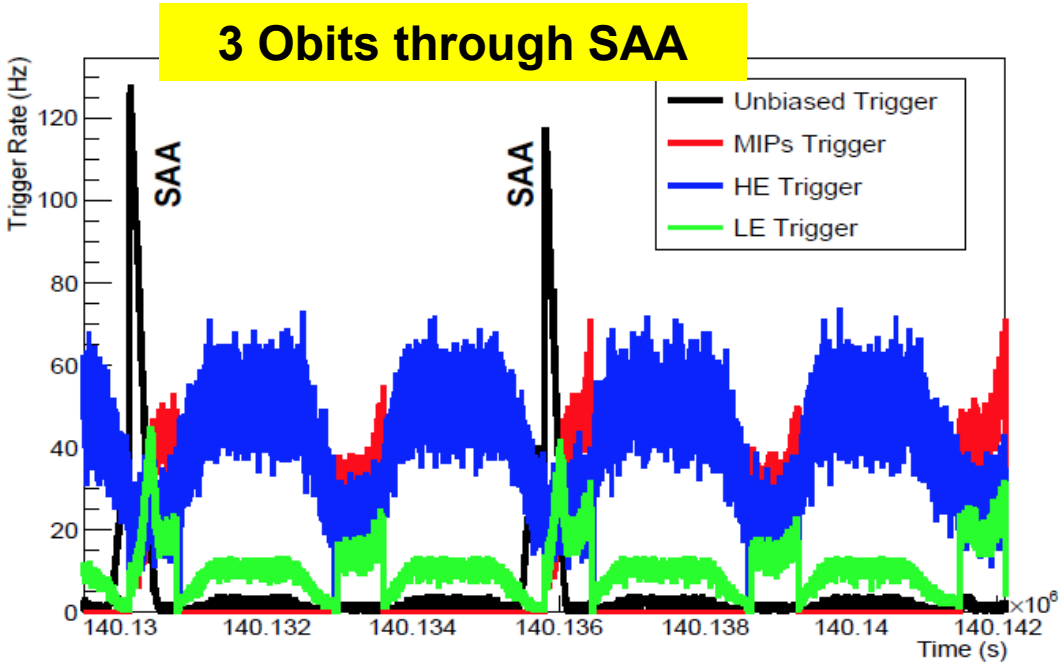
On-orbit trigger rate

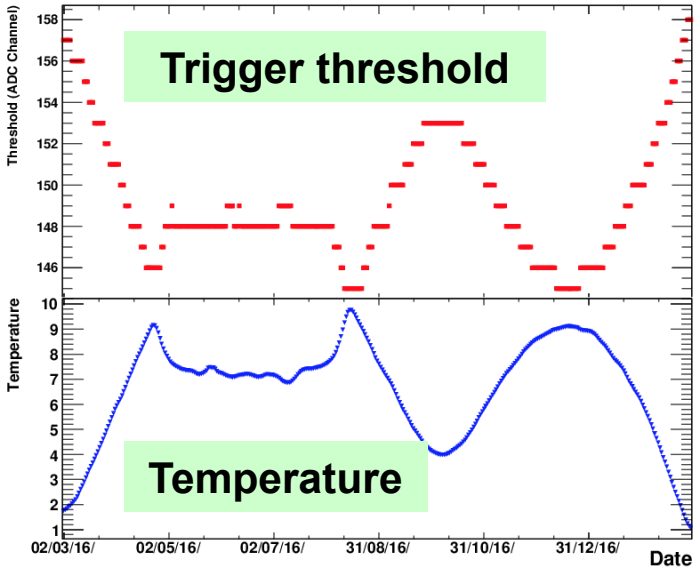


~50 Hz average trigger rate

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

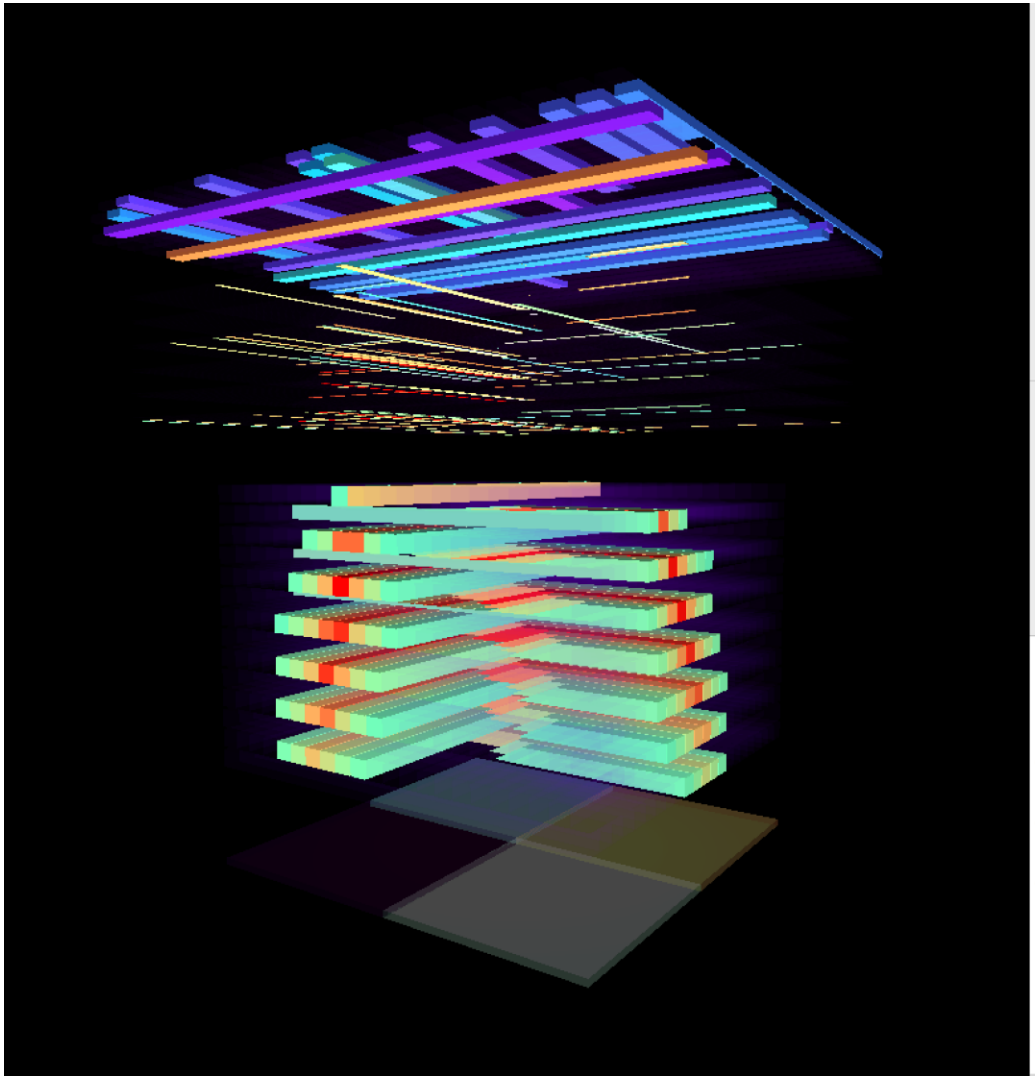
On-orbit trigger rate

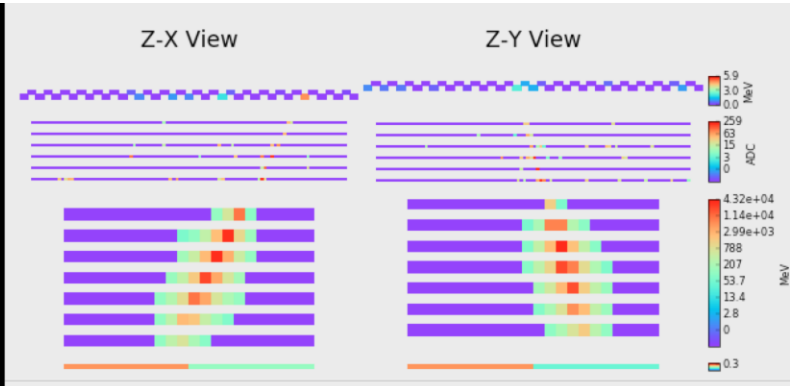




- **HET trigger rate 20 – 60 Hz**
  - **Events in South Atlantic Anomaly (SAA) regions not used**
- **Small trigger threshold variation with temperature**
  - **~13 ACD (0.04 MIP) in full temperature range**

Event: ~1 TeV electron candidate





<< First | < Previous | 13 | Next > | Last >>

Goto

Colors: 01 02 03 04 05 06 07 08

Stereo Effects: Red Cyan | Red Blue | Active | Passive | No Stereo

Advanced Show: Show Trajectory | Start Animation | Continuous Animation

File Name(s):
electron_above500GeV.root

Event Number:
13

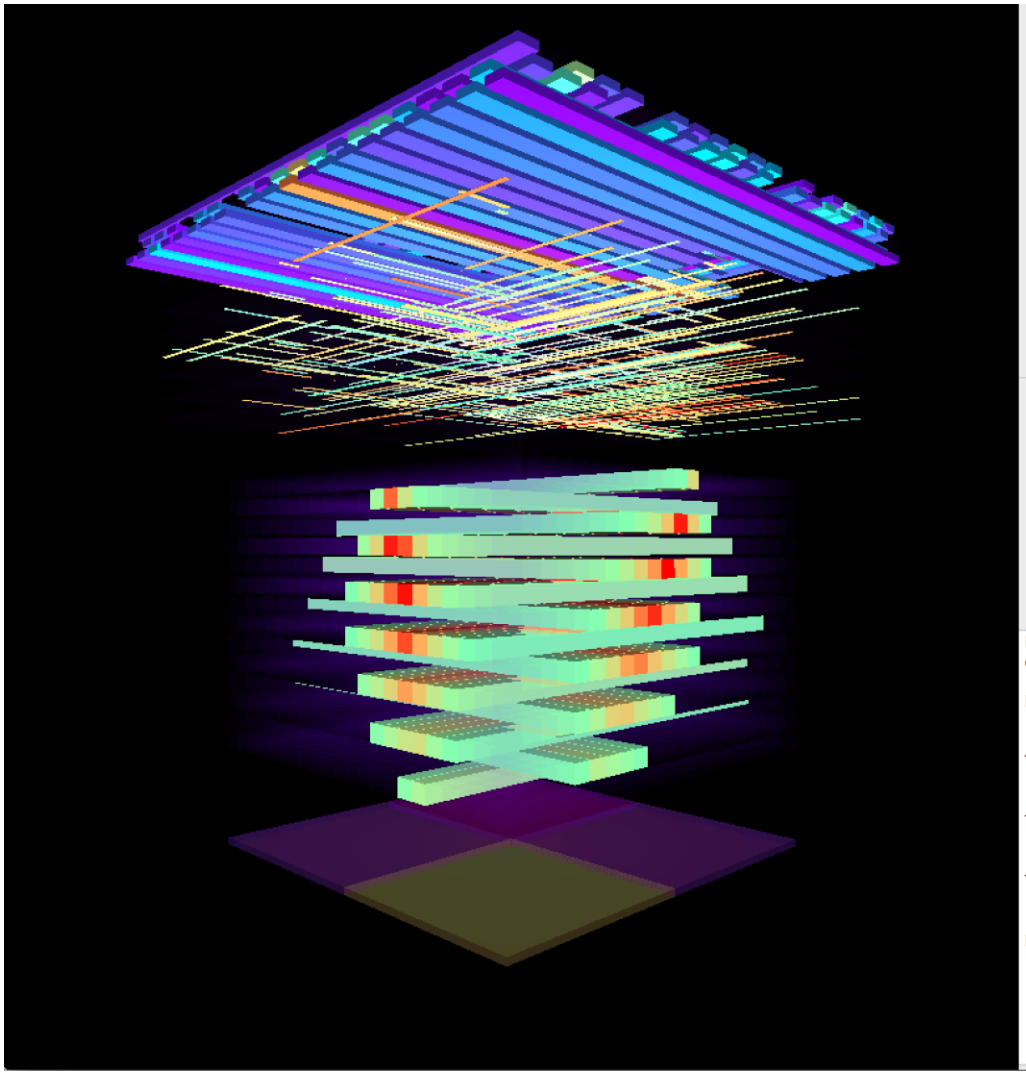
Time Point:
02:01:28.380, 01/01/2016

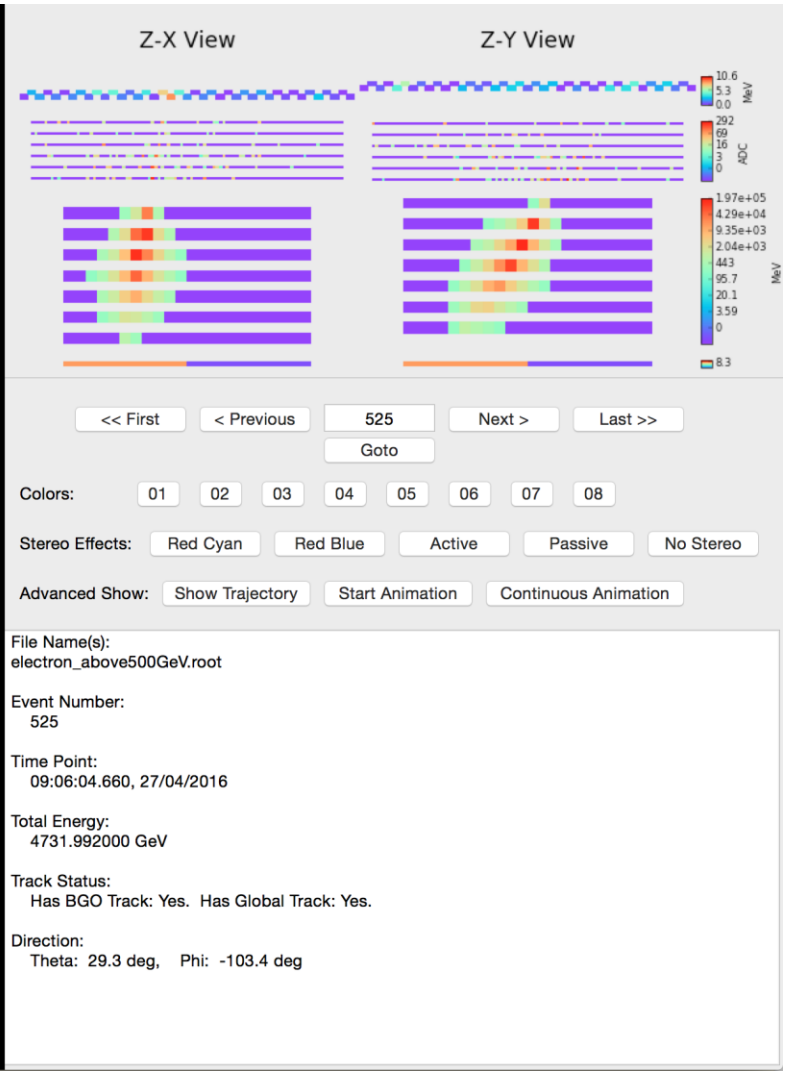
Total Energy:
1062.905375 GeV

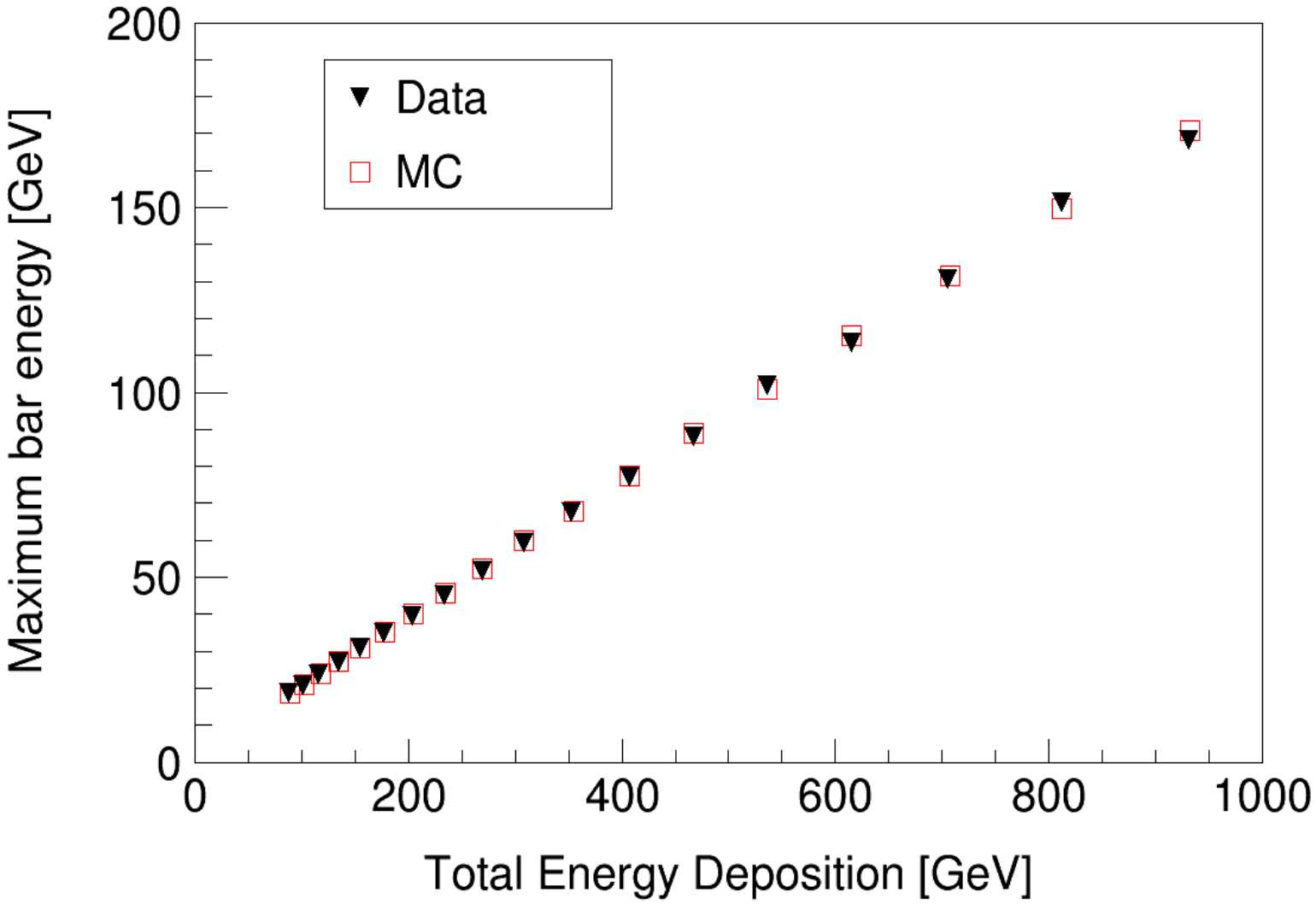
Track Status:
Has BGO Track: Yes. Has Global Track: Yes.

Direction:
Theta: 25.2 deg, Phi: 152.6 deg

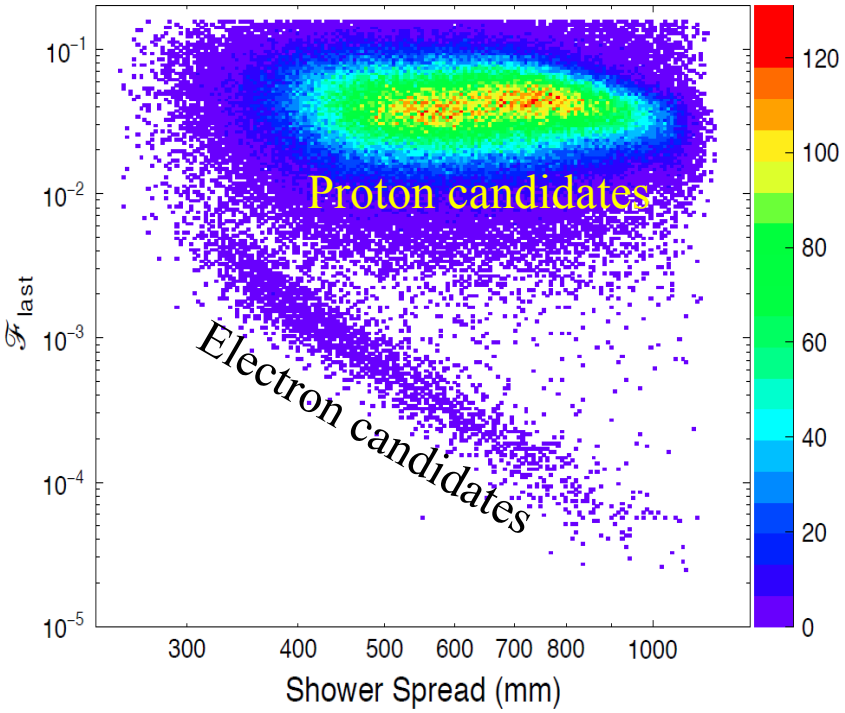
Event: ~5 TeV electron candidate

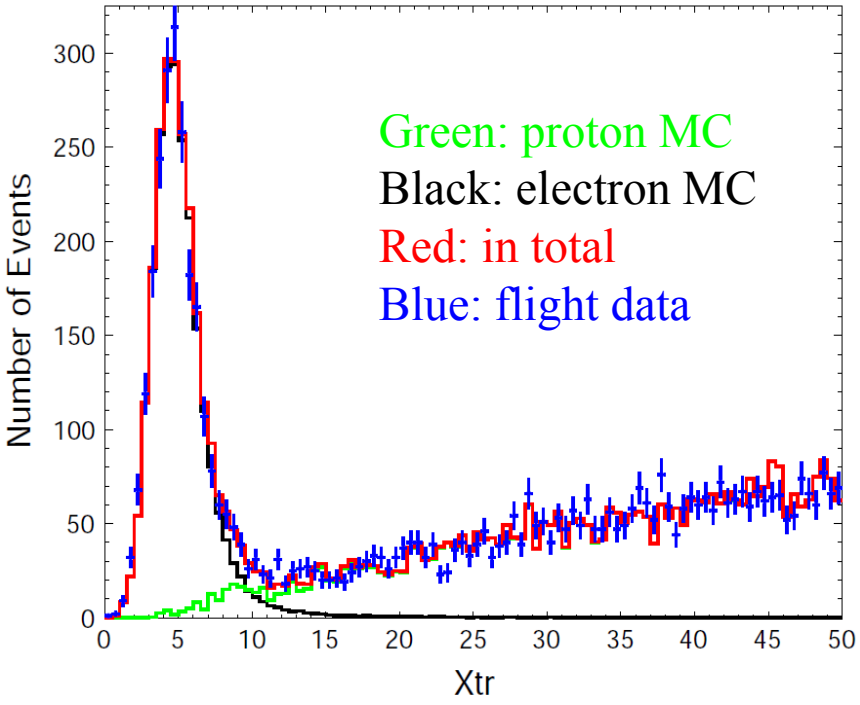





Data
MC
Maximum bar energy [GeV]
Total Energy Deposition [GeV]
0
50
100
150
200
0
200
400
600
800
1000

On-orbit performance: e/p separation

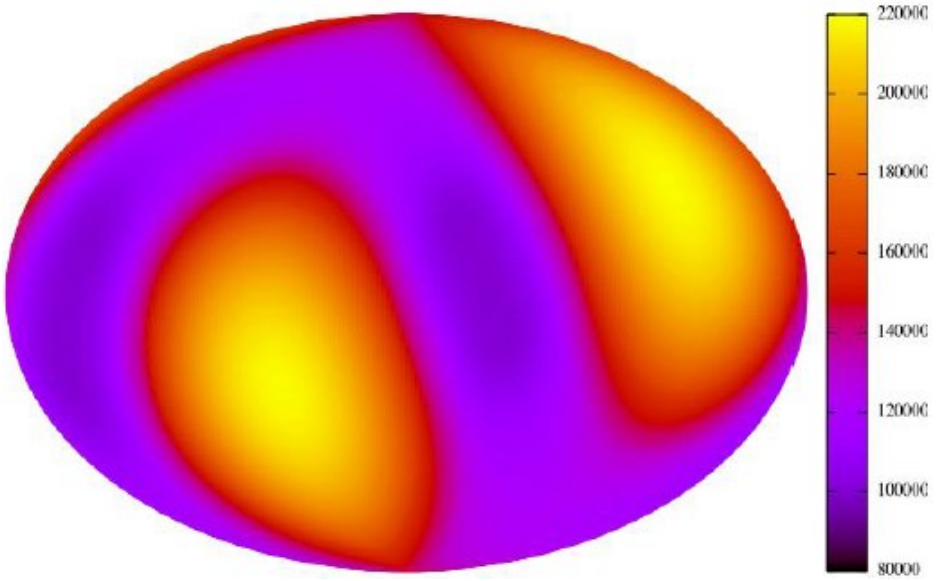




For events with deposit energy of 0.5-1.0 TeV； the proton contamination is found to be ~2% below 1TeV, ~5% @2TeV, and ~10%@5TeV.

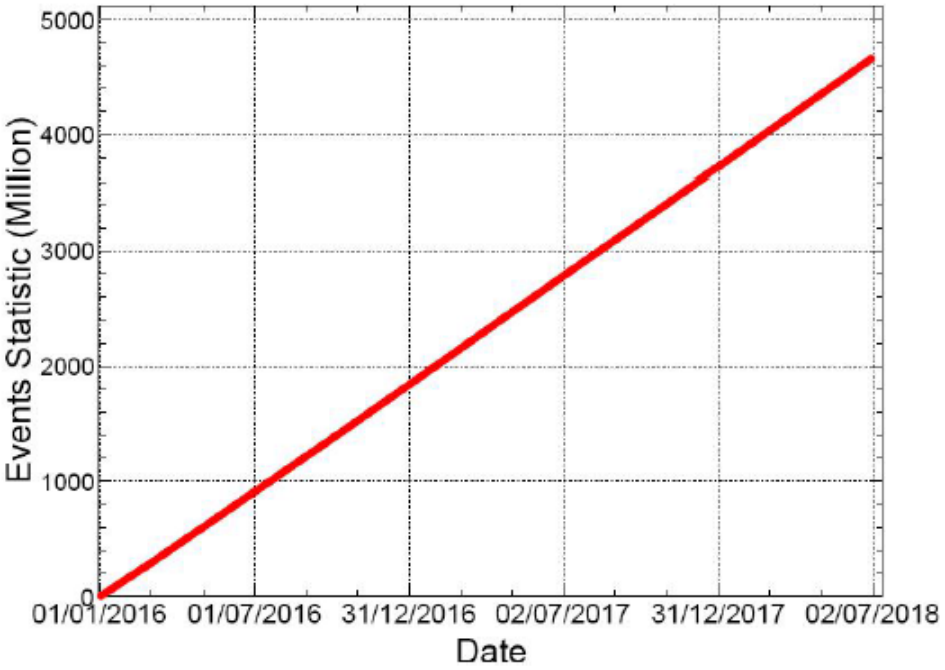
Status

DAMPE 3.5 year counts map



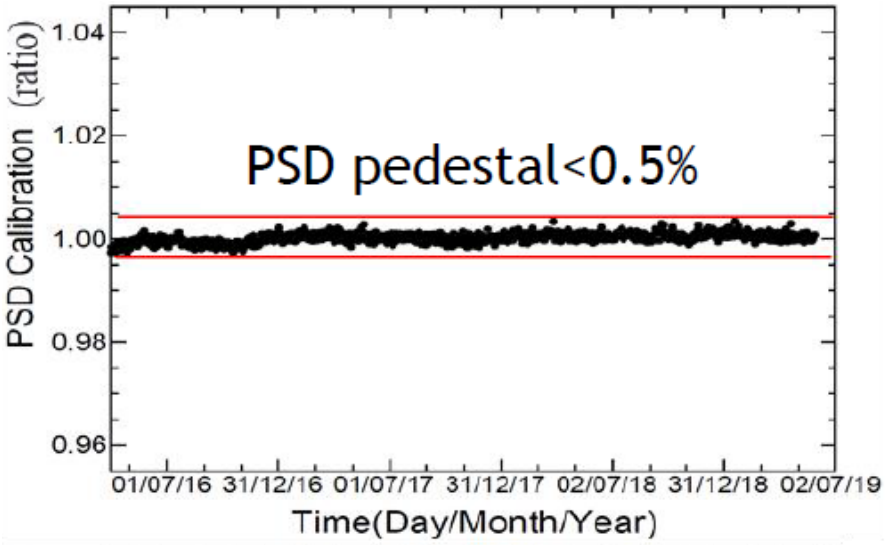
7 full scans of the sky

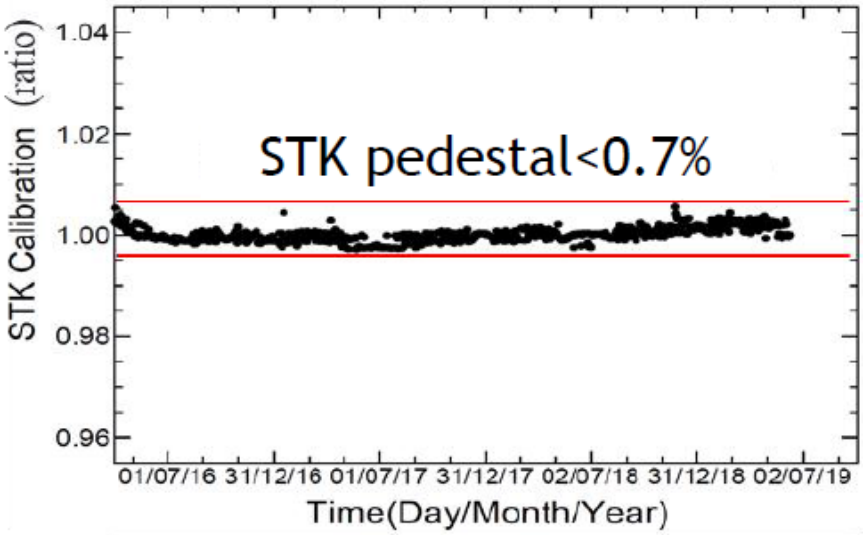
DAMPE DAQ statistics

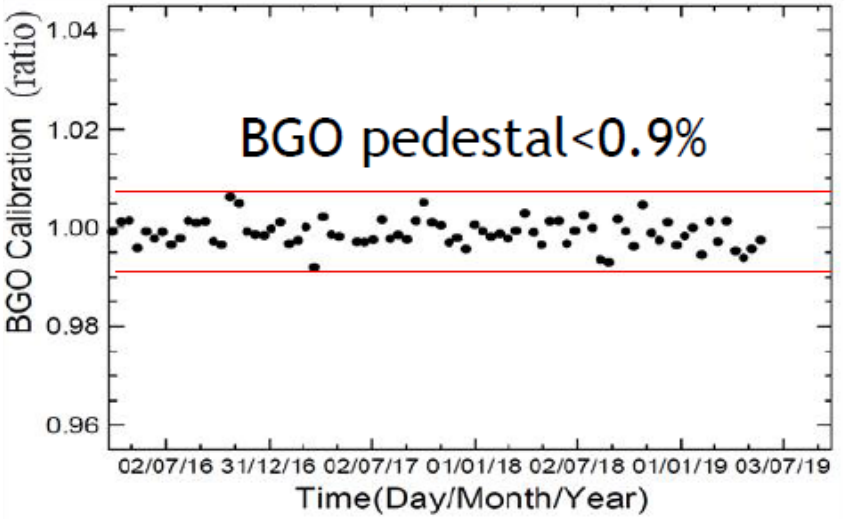


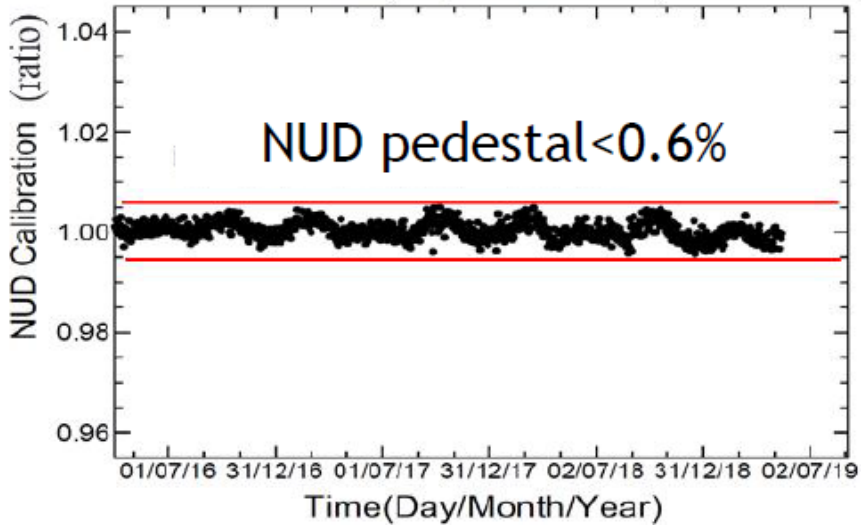
- 5M events/day
- 6.5 billion in total

Detector Stability

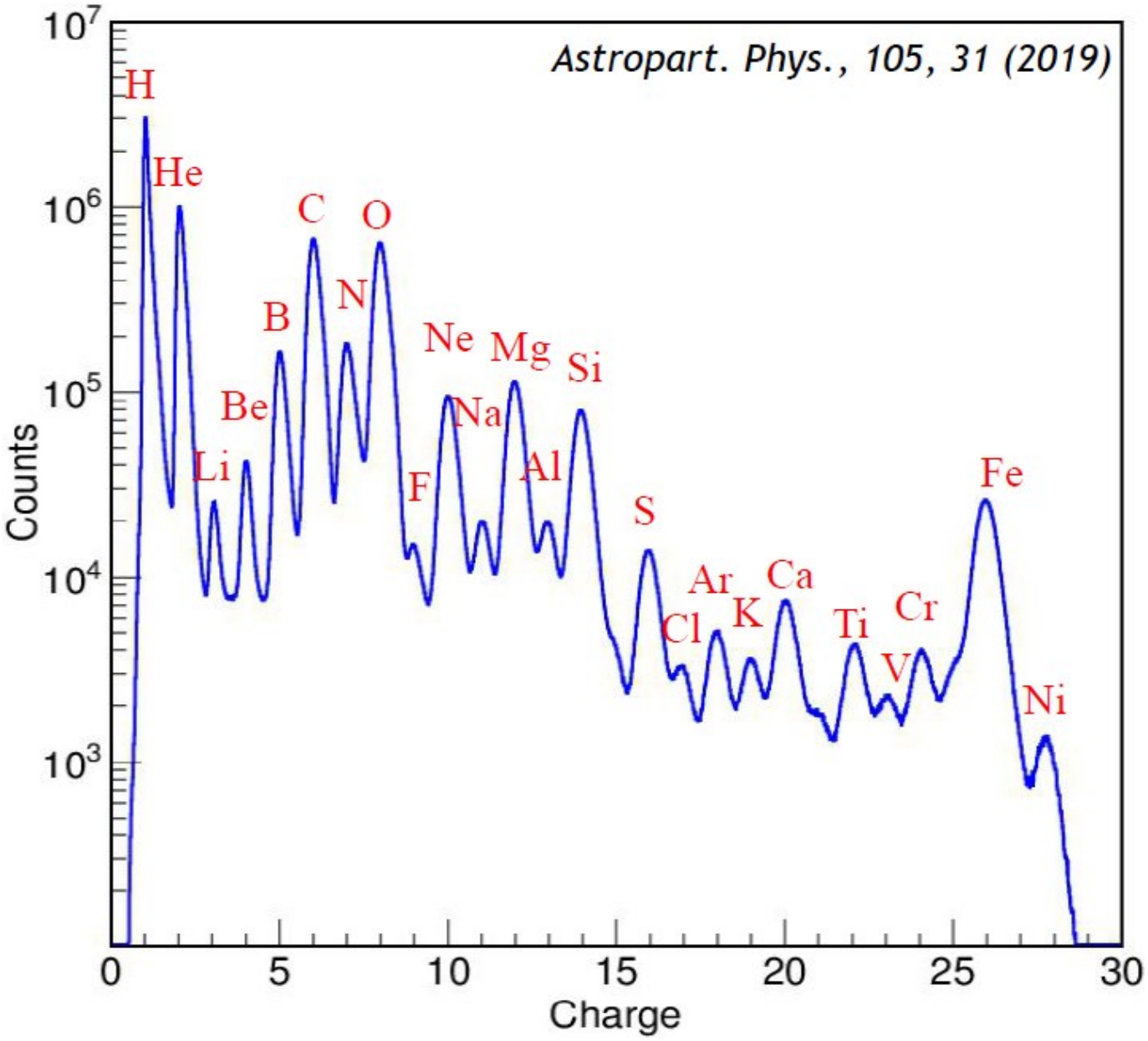






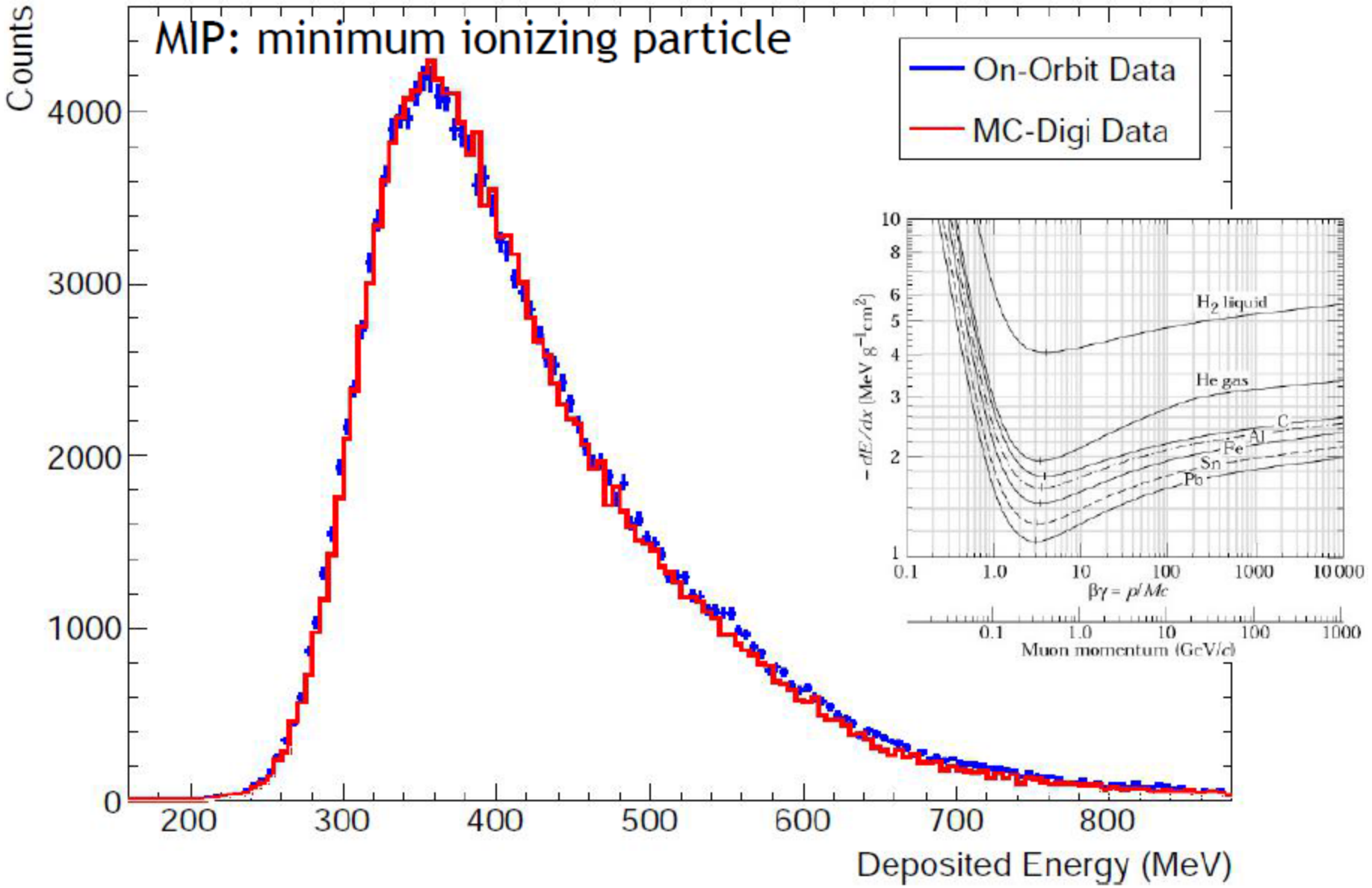


Charge measurement

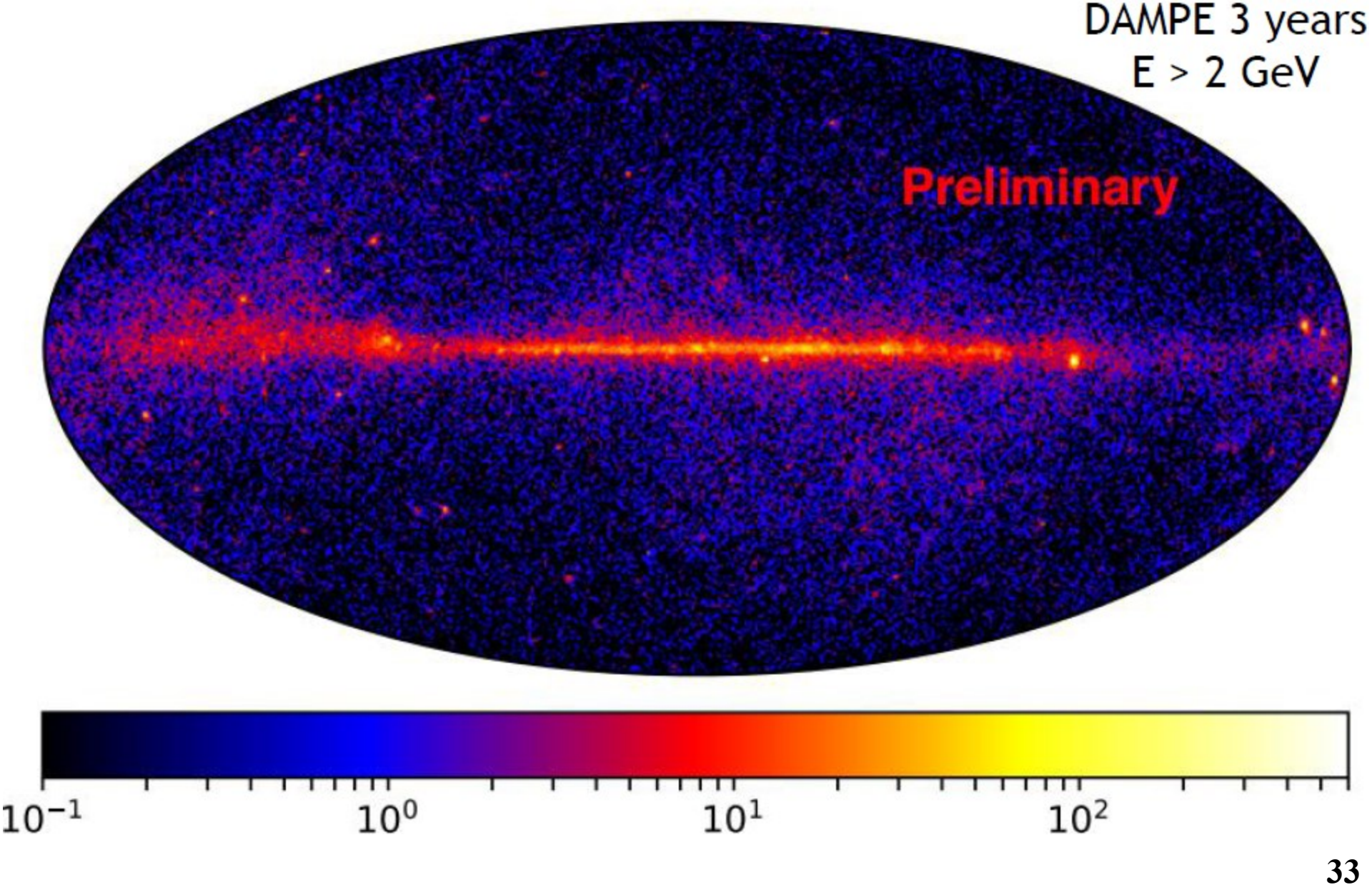


Nuclei	Res.
P	0.07
He	0.12
Li	0.14
Be	0.21
B	0.17
C	0.18
N	0.21
O	0.21

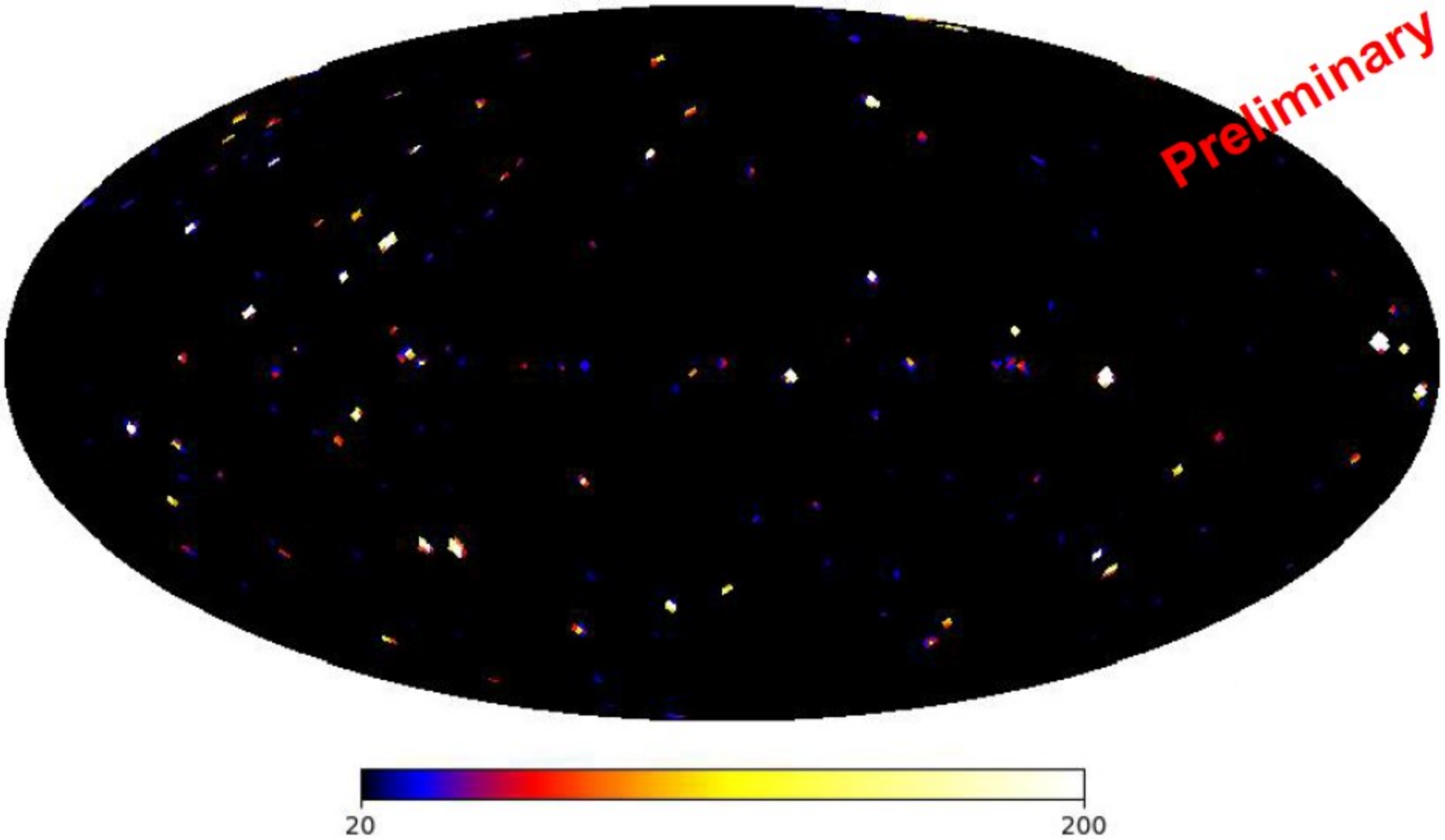
BGO energy calibration



First results: γ-ray sky map

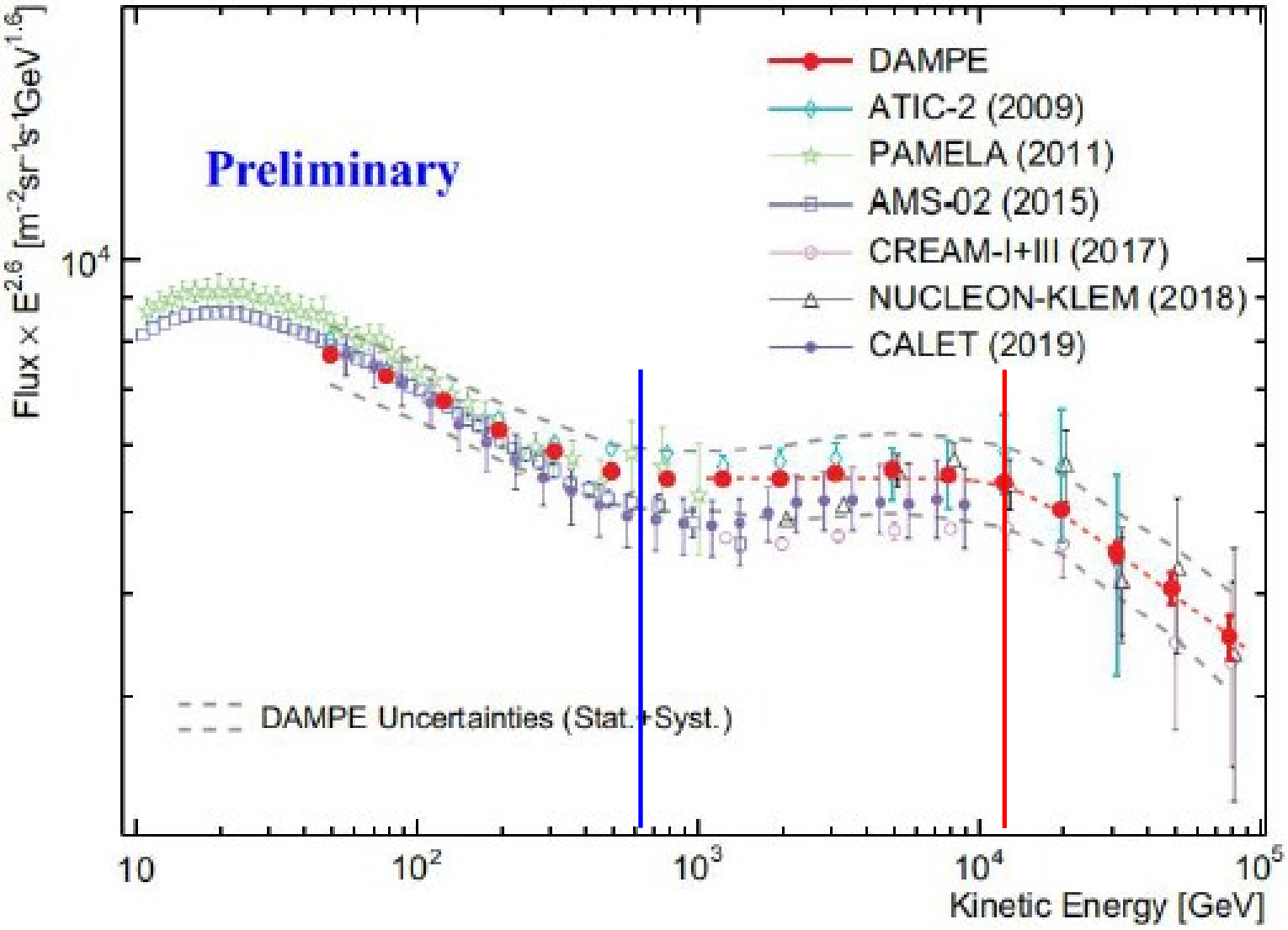


γ-ray point sources



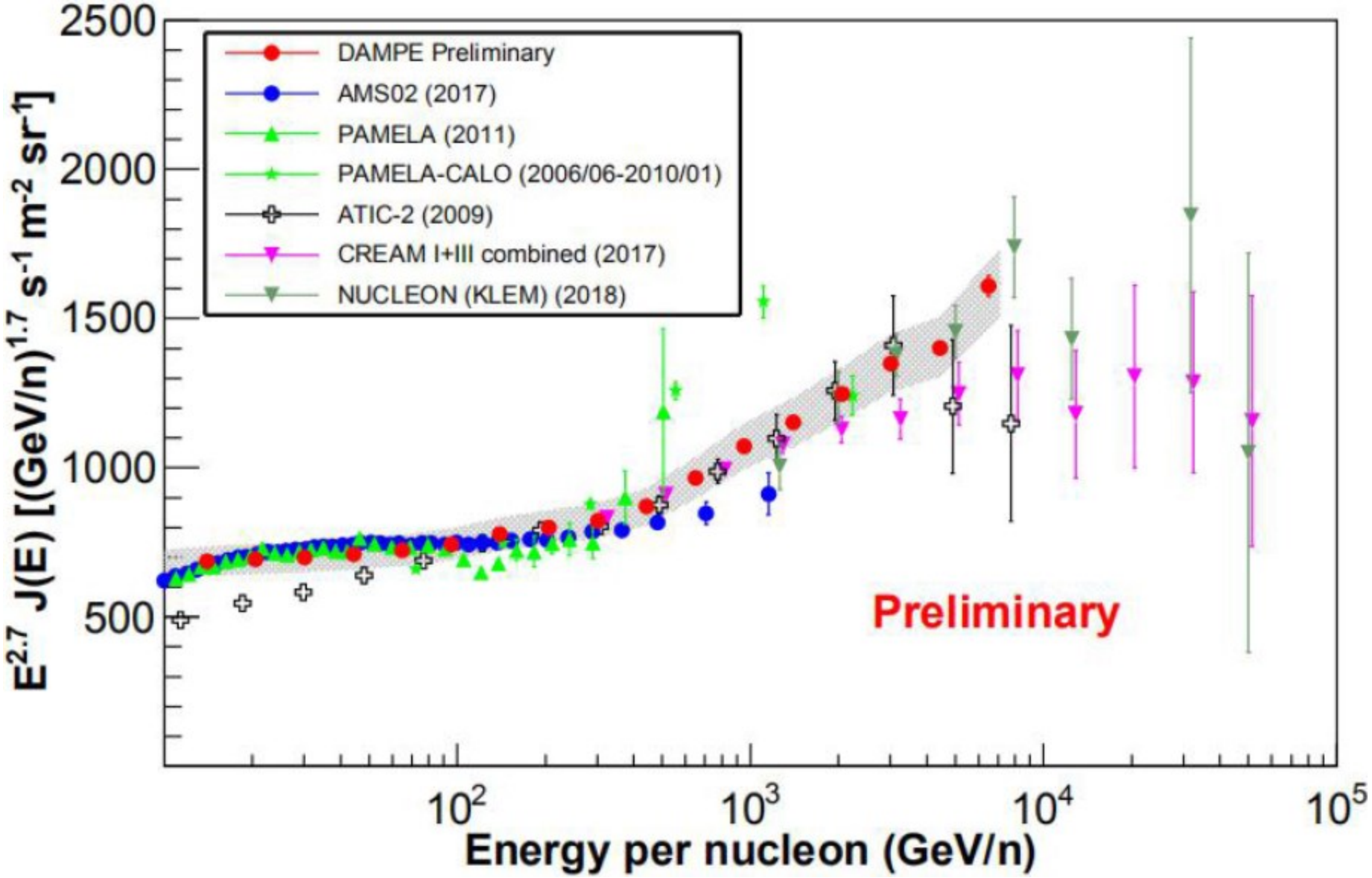
- 143 sources with TS > 20
- Most are pulsars and AGNs

First results: proton flux

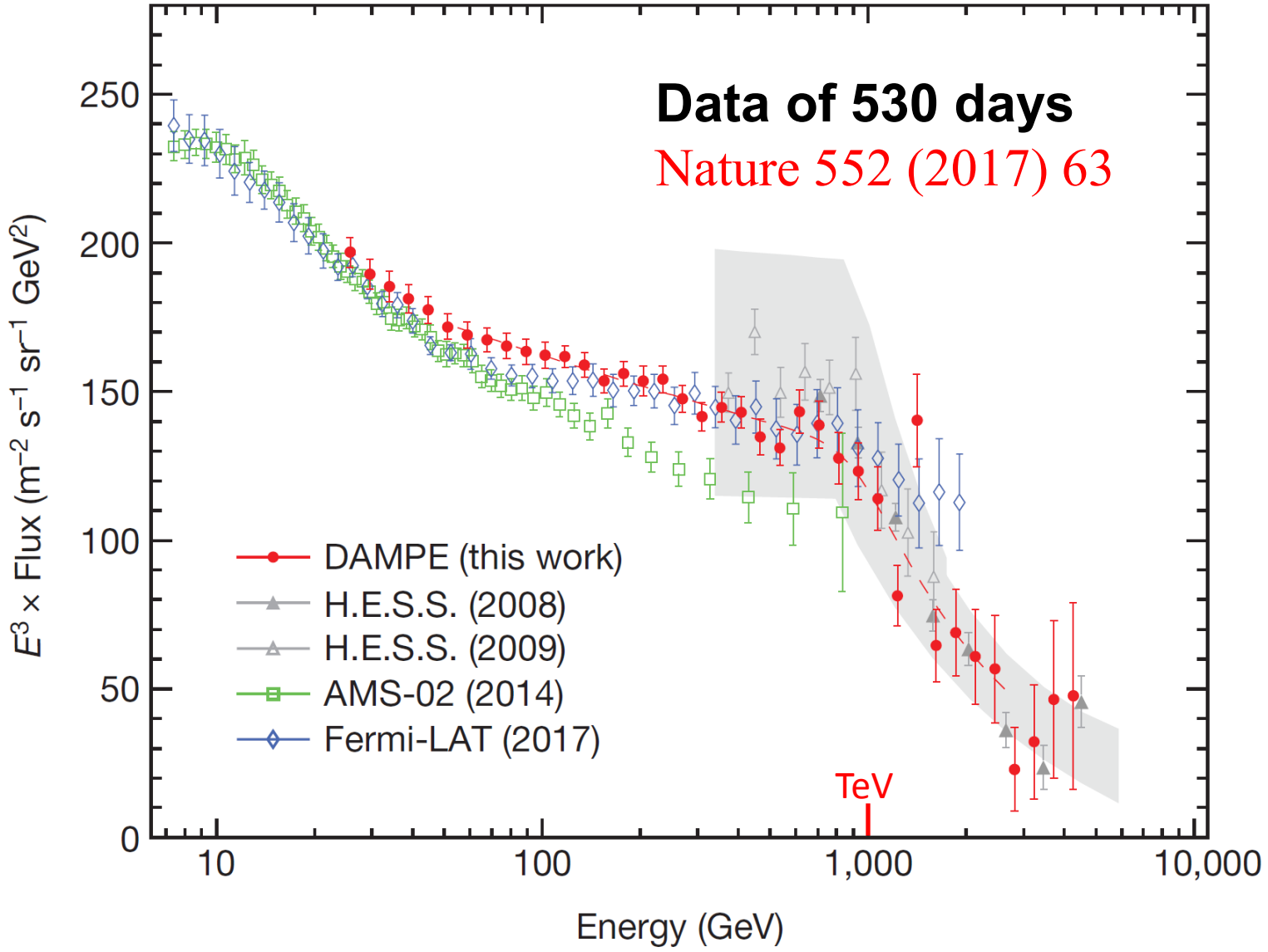


- Confirms the hardening at ~hundreds GeV
- Detecting a softening at ~13 TeV with high significance

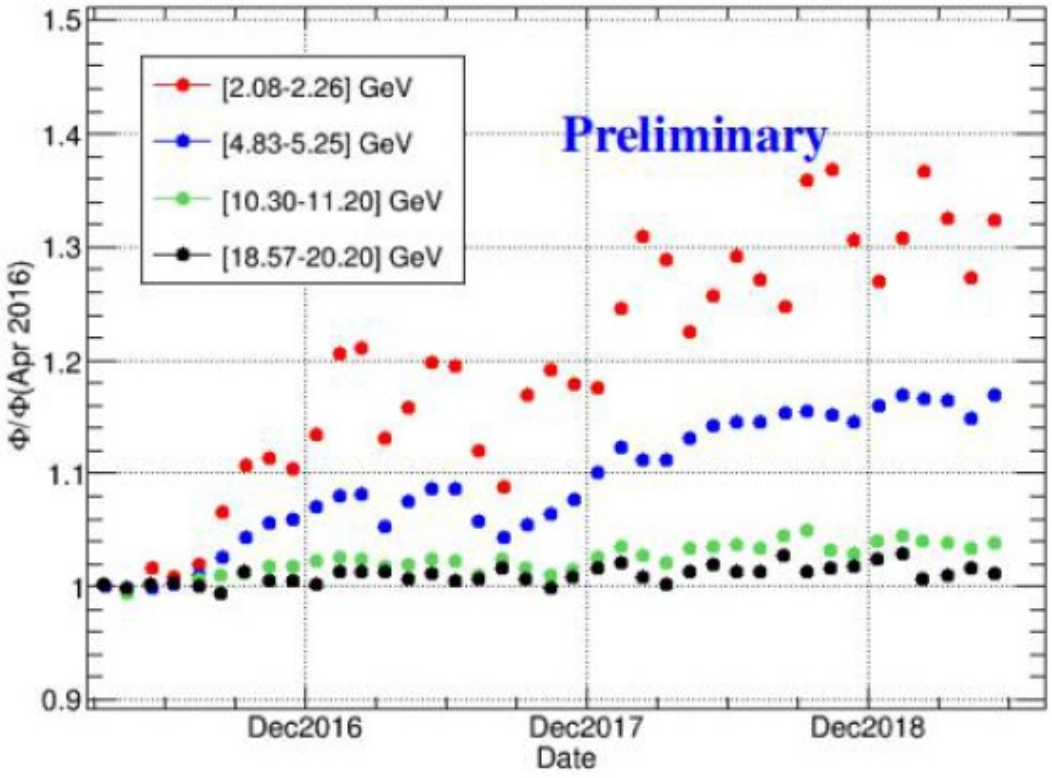
First results: helium flux

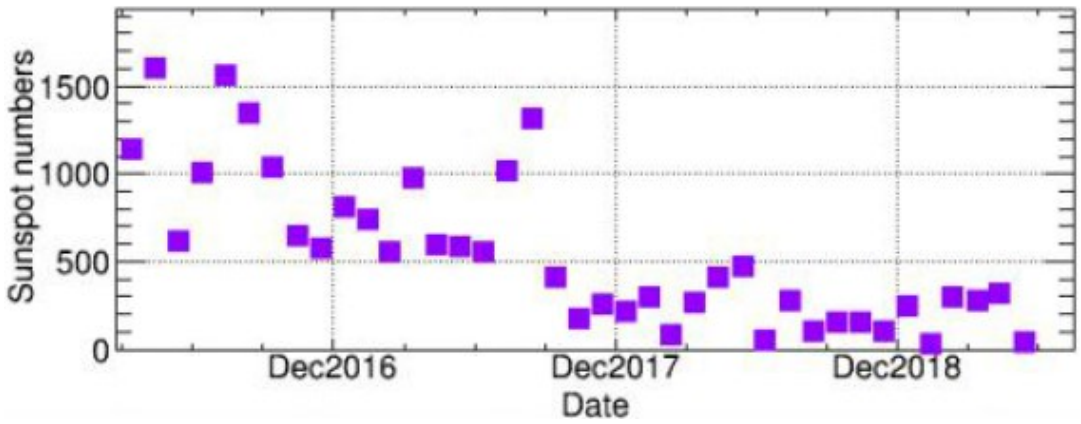


First results: electron+positron spectrum



Solar modulation of $e^+ + e^-$





- Anti-correlation with solar activities
- Monthly variation may be related to occasional solar activities
- Possible time delay between sunspot numbers and CR modulation

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

Summary

- DAMPE detector is working extremely well since launched more than 3.5 years ago
  - A very precise electron + positron flux in the TeV region has been measured:
    - A clear spectral break has been observed at ~ 1 TeV → **a new piece of puzzle to understand many mysteries in cosmic ray physics!**
  - Preliminary results on nuclei measurements (proton flux and Helium flux) have been obtained.
  - Photon detection capability is demonstrated. Need more statistics to profit the excellent energy resolution at high energy for photon measurements.
  - More results are coming…

Thank You!