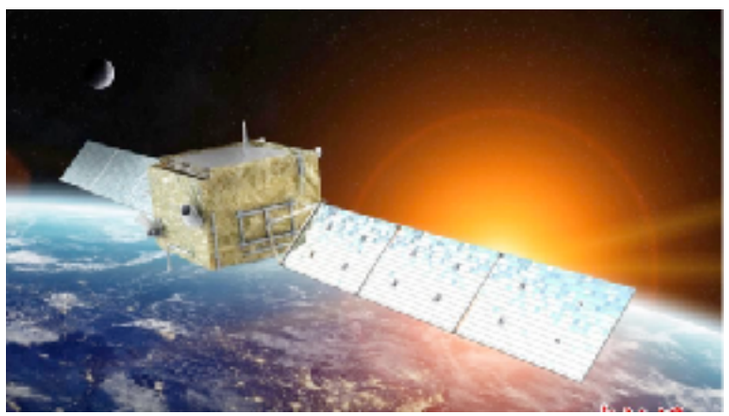
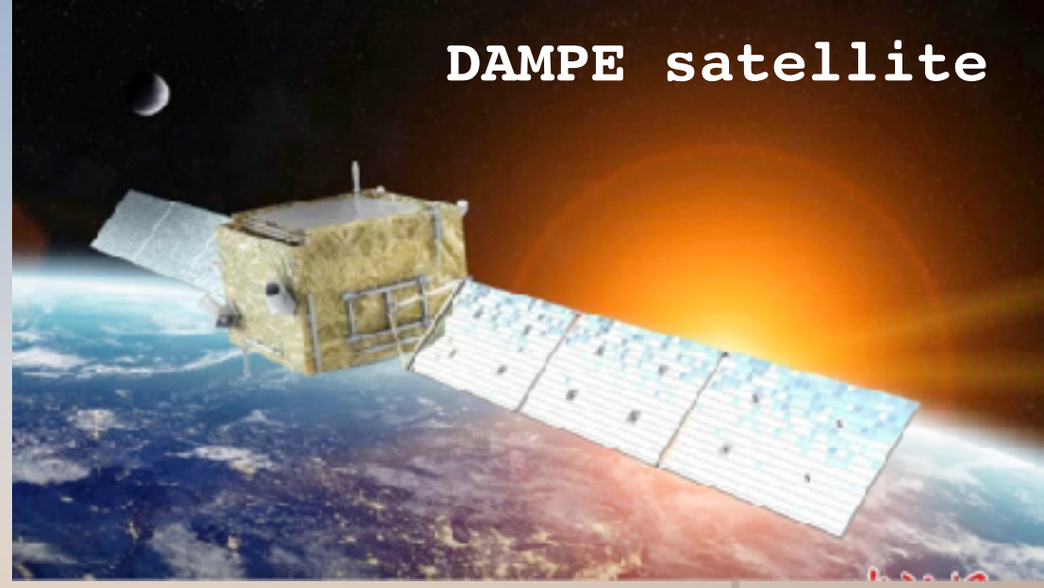
DAMPE space mission for GeV - 10 TeV electron/gamma and 10 GeV - 100 TeV comic-ray detection

Andrii Tykhonov
University of Geneva



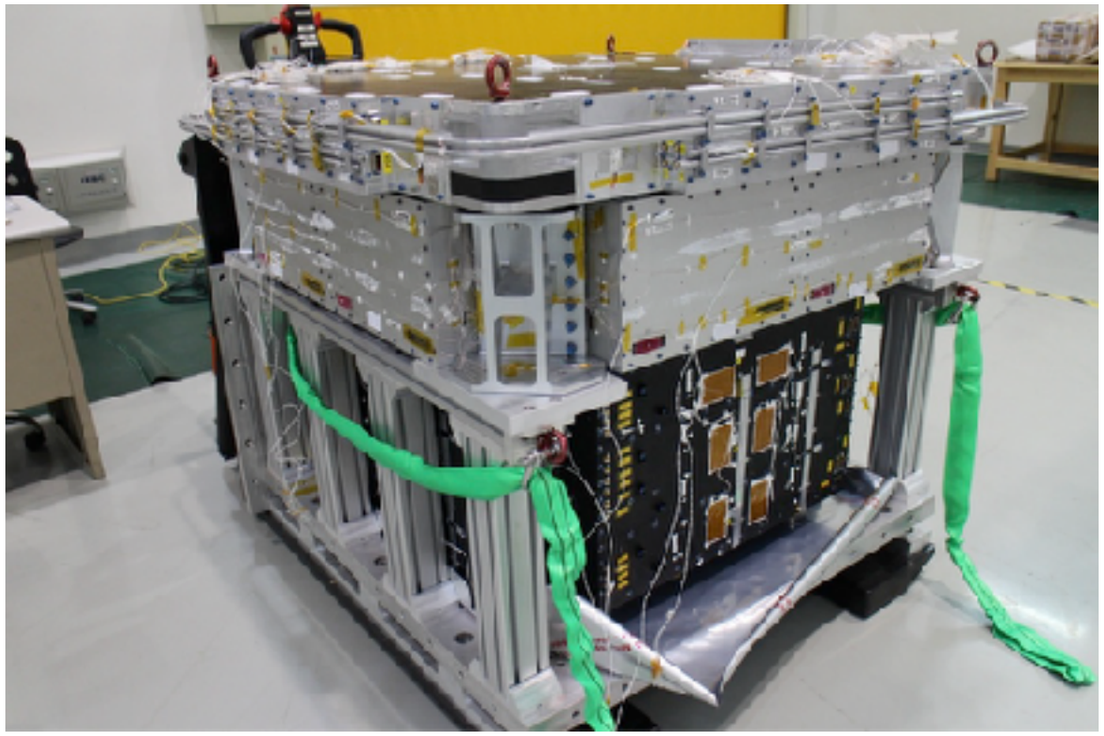


DArk Matter Particle Explorer (DAMPE)

Launched on Dec 17, 2015,
from the Jiuquan Satellite Launch Center,
Gobi desert, China.

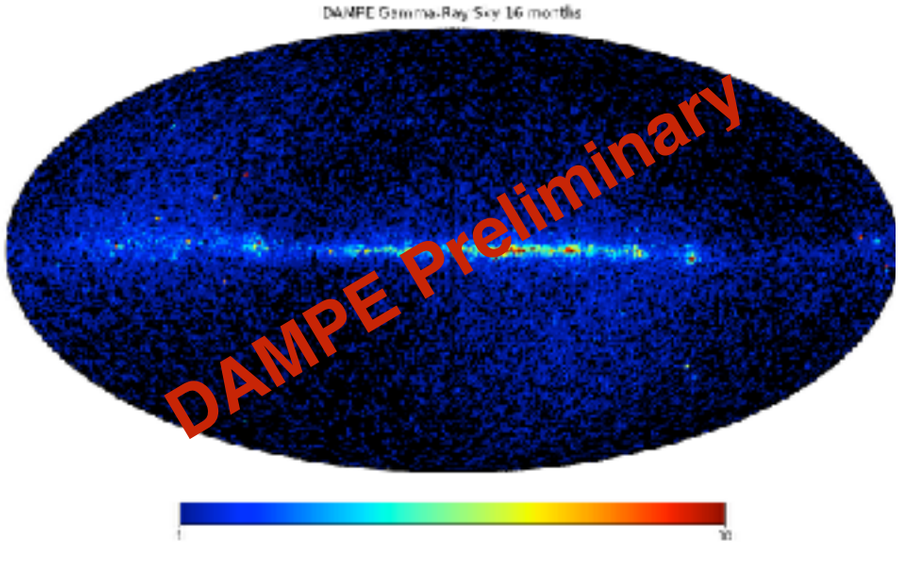
Operates on a sun-synchronous
Sky-survey mode,permanently oriented to zenith

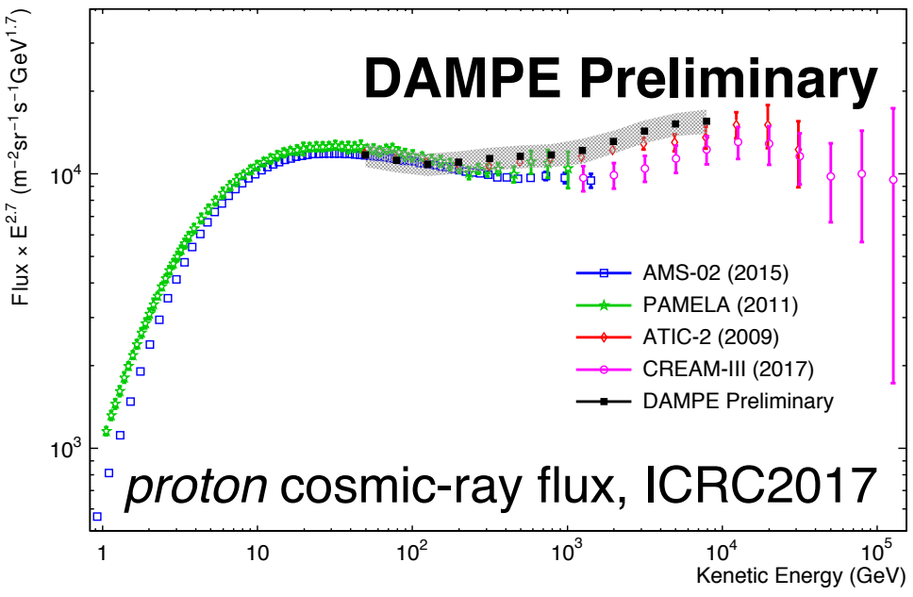
Part1: The DAMPE detector



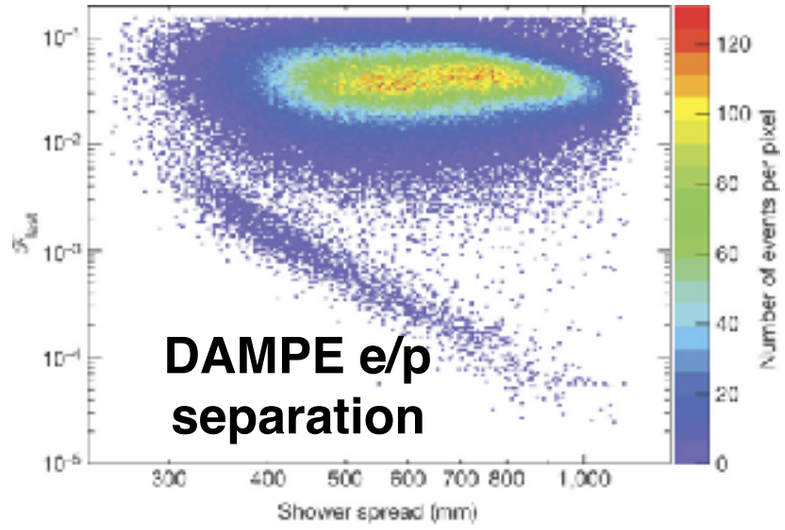
DAMPE physics goals

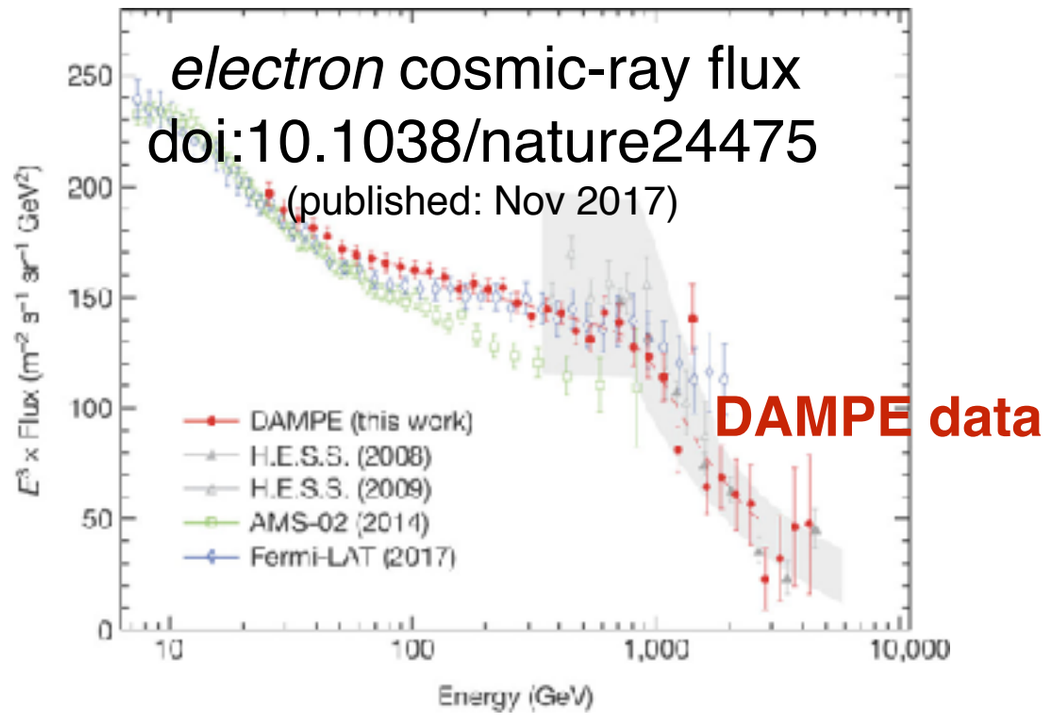
Gamma-ray astronomy





Search for indirect Dark Matter signatures
Astro-particle physics at GeV multi-TeV region





The DAMPE detector

Silicon-Tungsten tracKer converter (STK)

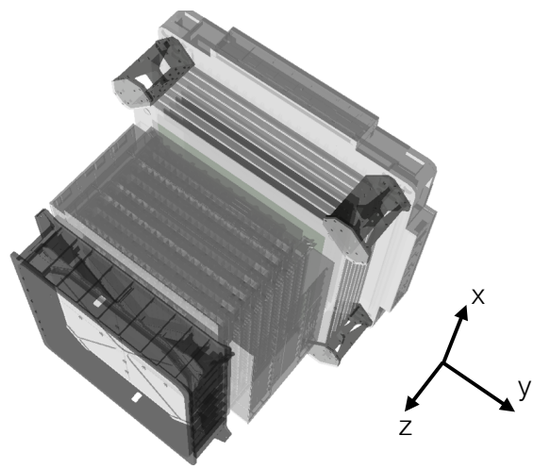
Plastic Scintillator-strip Detector

Bismuth Germanium Oxide calorimeter (BGO) 32 X_0

Carbon-Fibre Satellite Housing

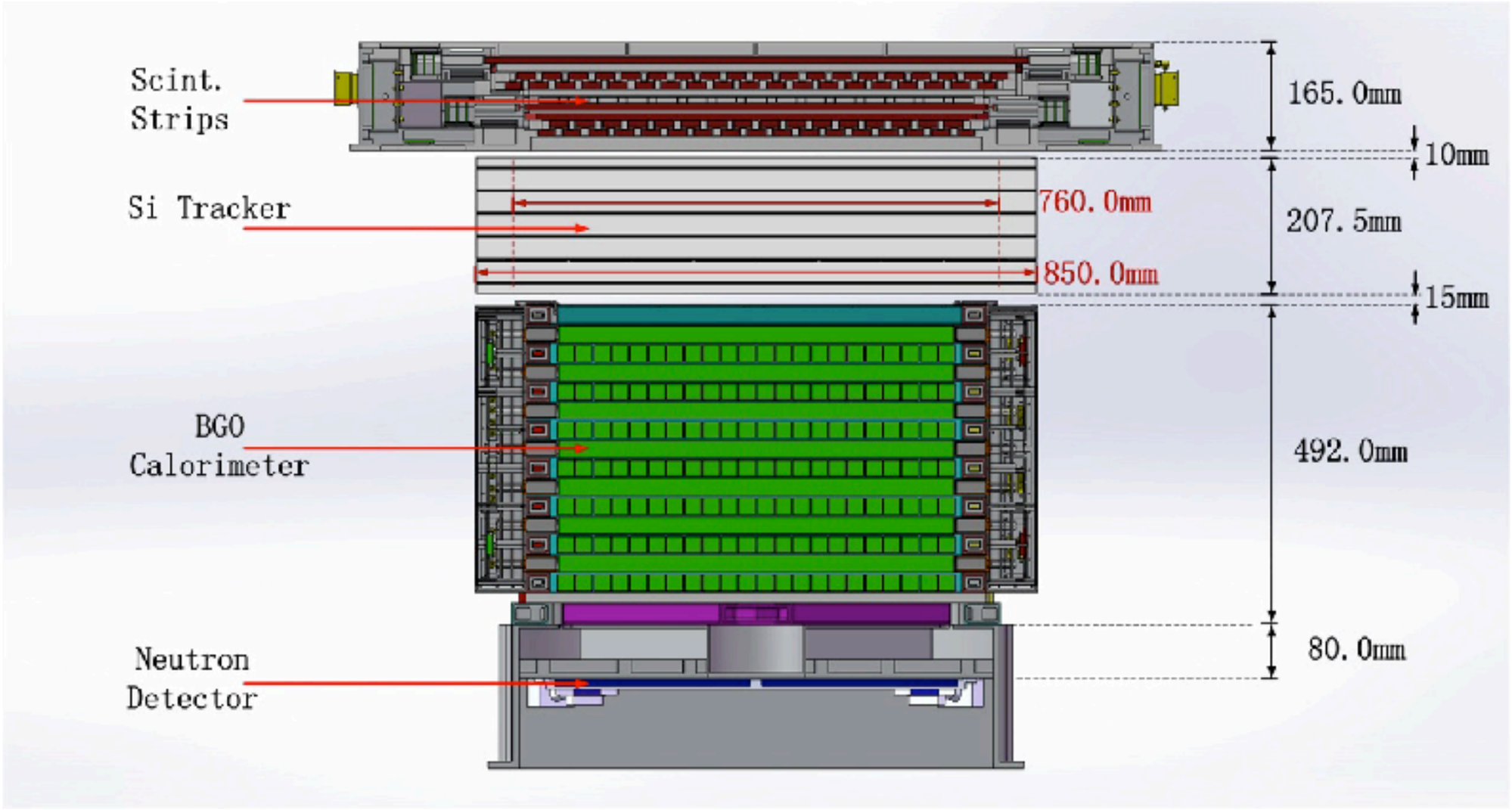
Neutron detector

particle



3D view of DAMPE (Geant4)

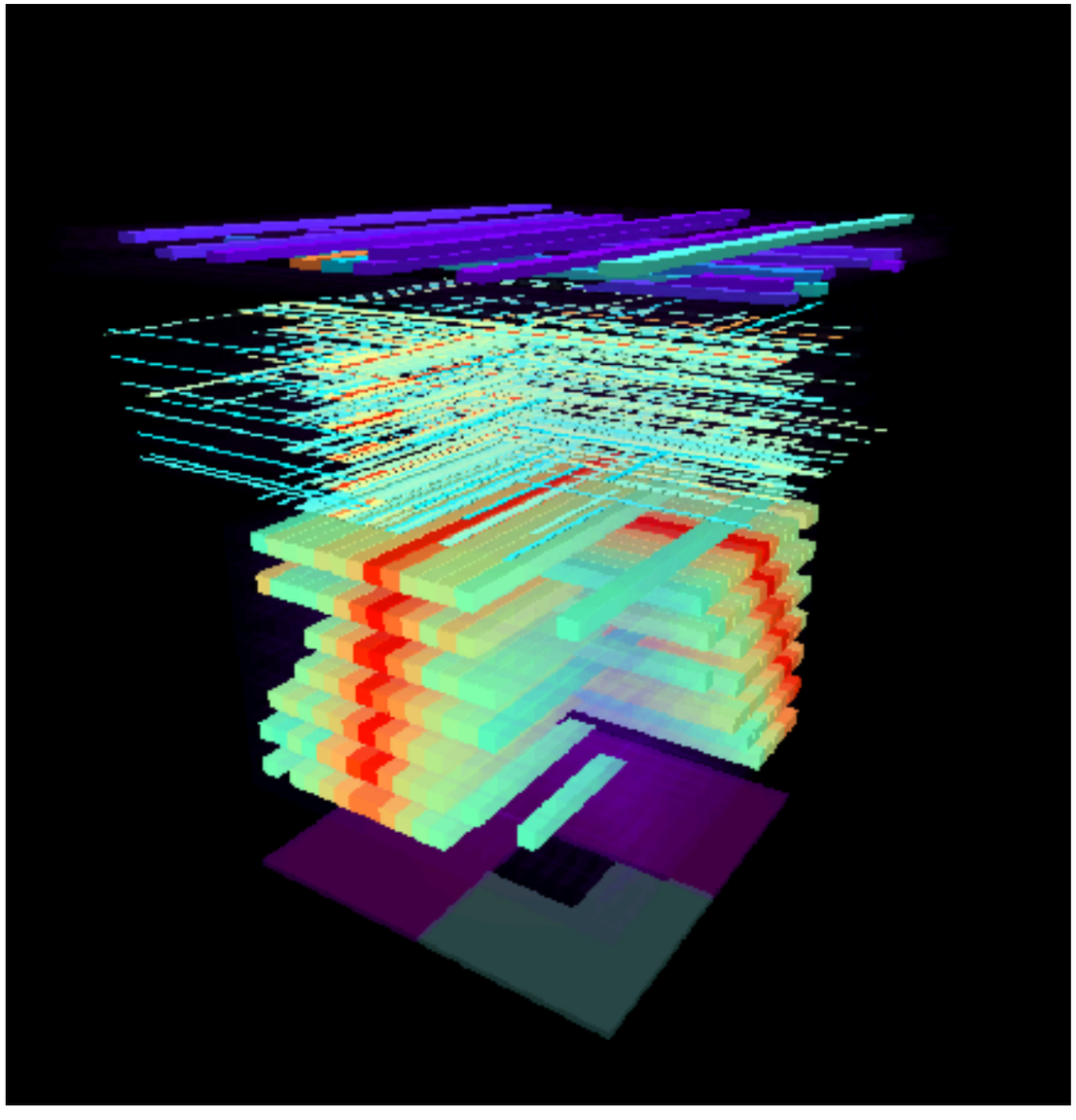
The DAMPE detector



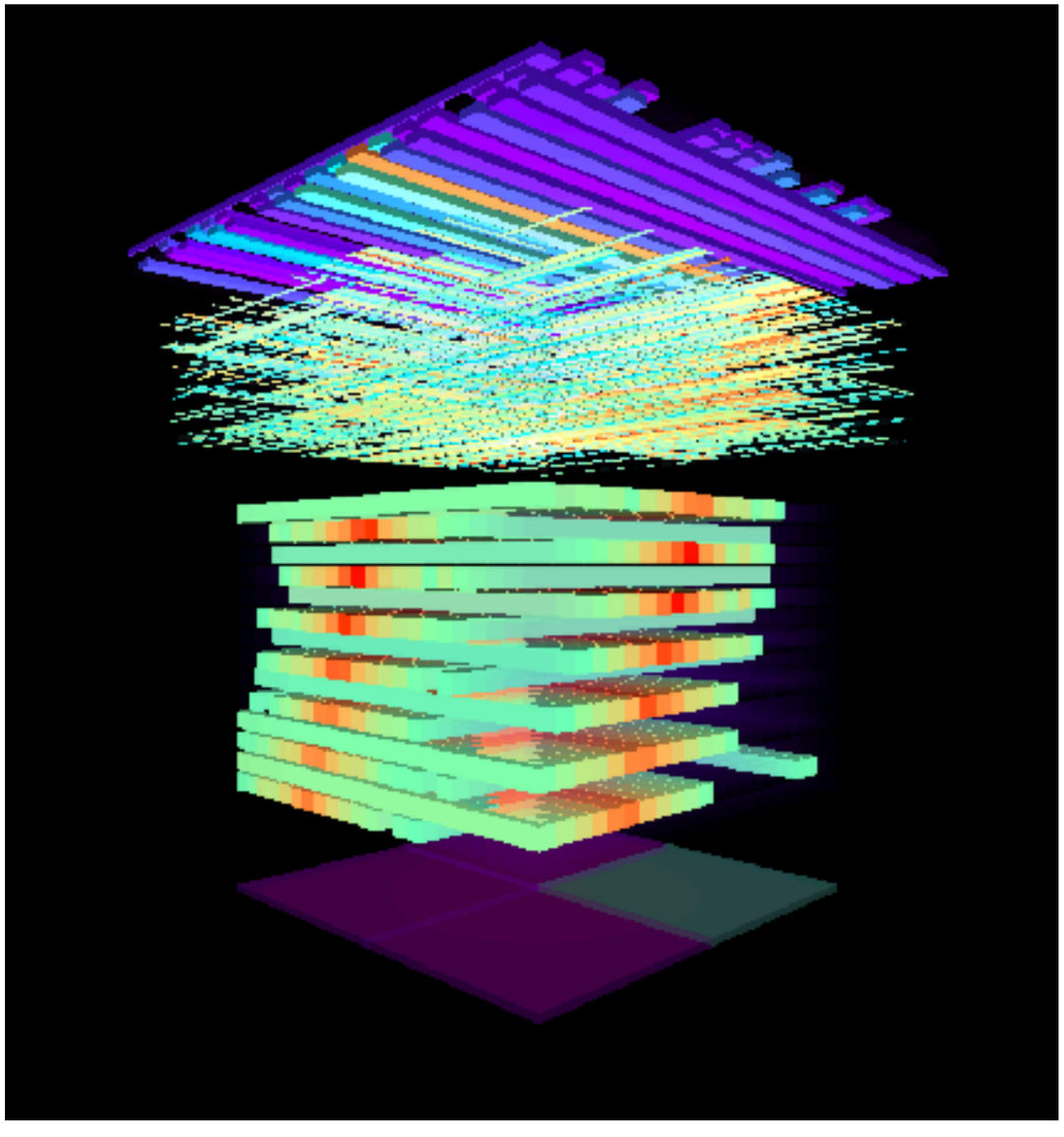
Mass: 1400 Kg
Power: 400 W
Data: 13 GB/day
Lifetime: 5 years

The DAMPE detector

Event Display of 330 GeV electron candidate in DAMPE

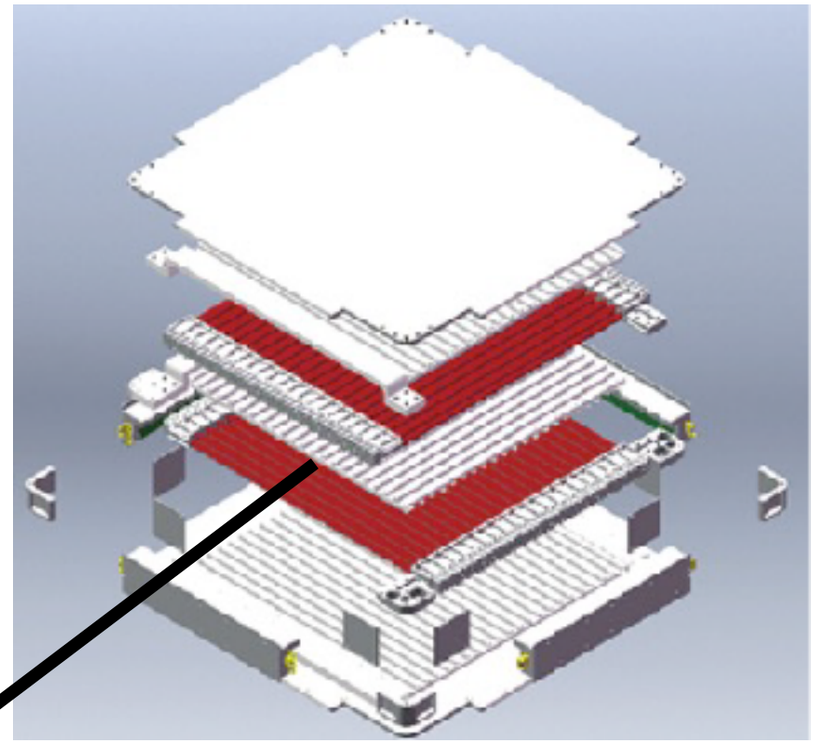


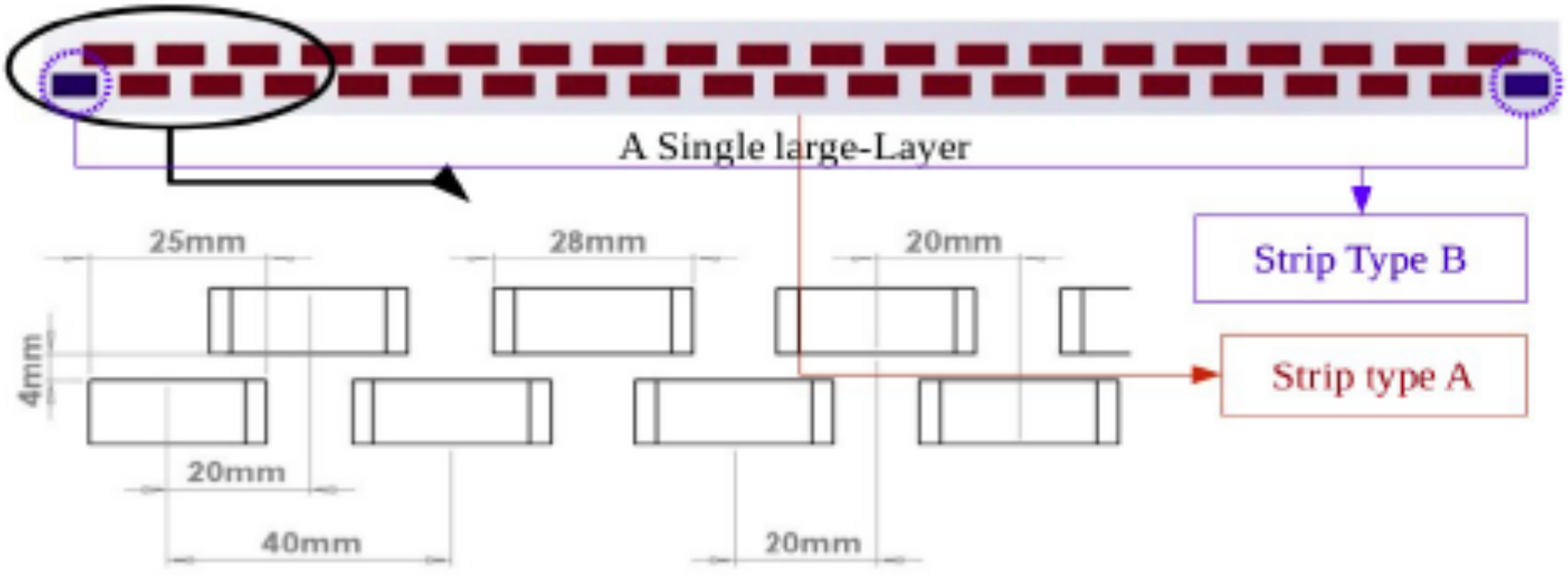
Event Display of 1.3 TeV carbon candidate in DAMPE



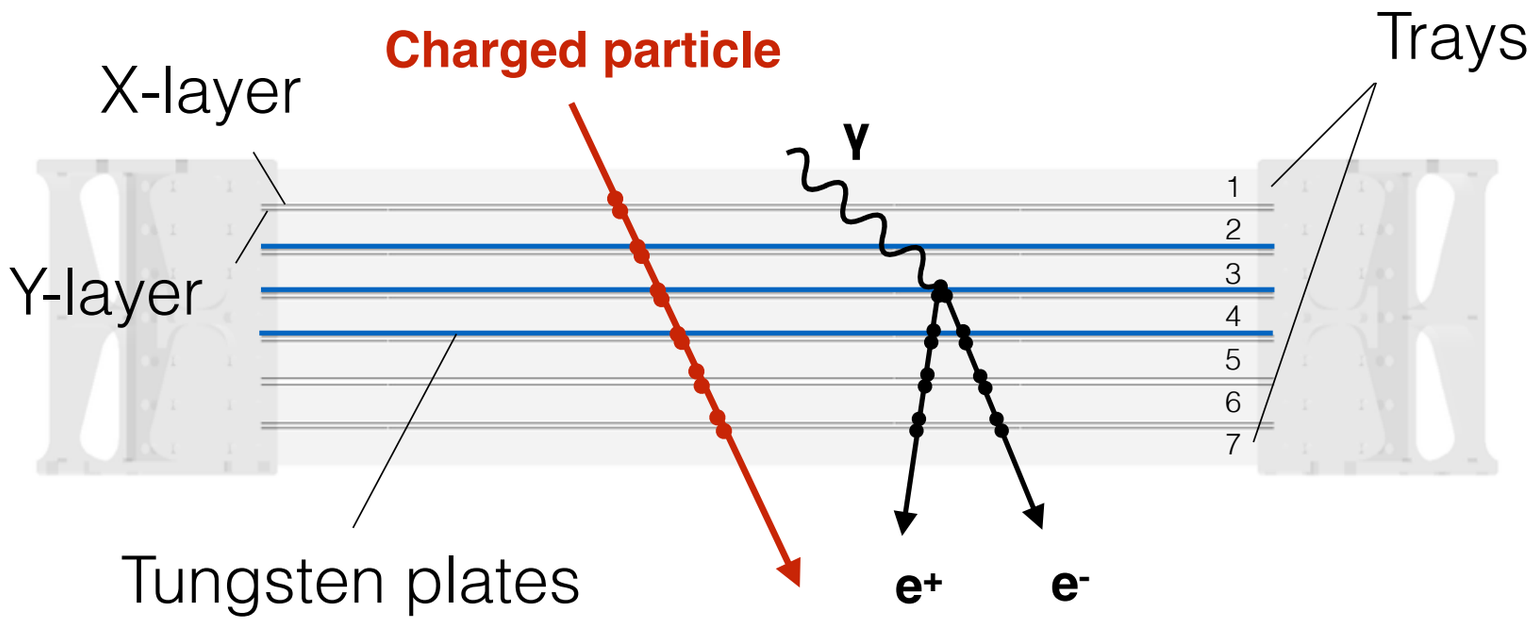
Plastic scintillator (PSD)

- **1 X double-layer and 1 Y double layer**
- **82 x 82 cm layer dimension**
- **Scintillator bar dimension:**
  1.0 (thick) x 2.8 (wide) x 82.0 (long) cm^3
- **Bars staggered by 0.8 cm in a layer**

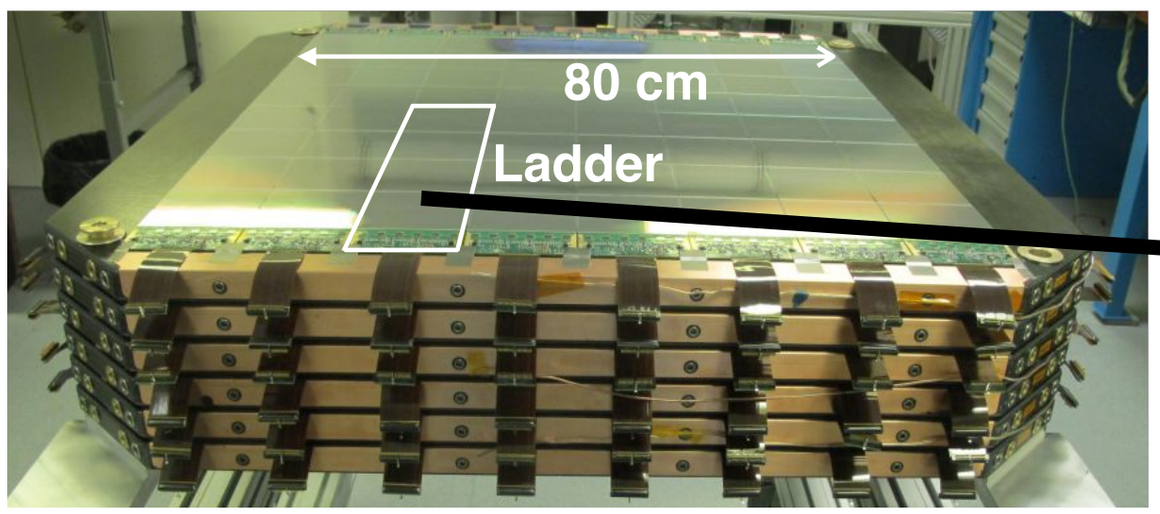




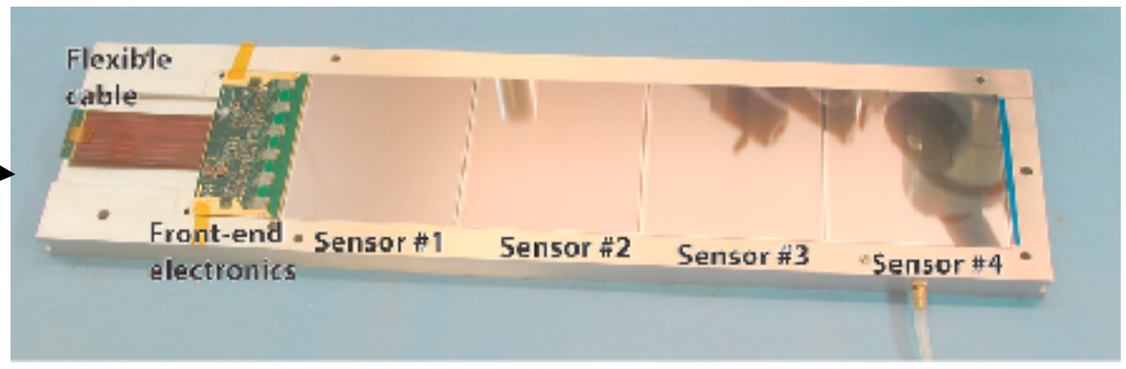
Silicon TracKer (STK)



6.6 m² of Si, 768 wafers



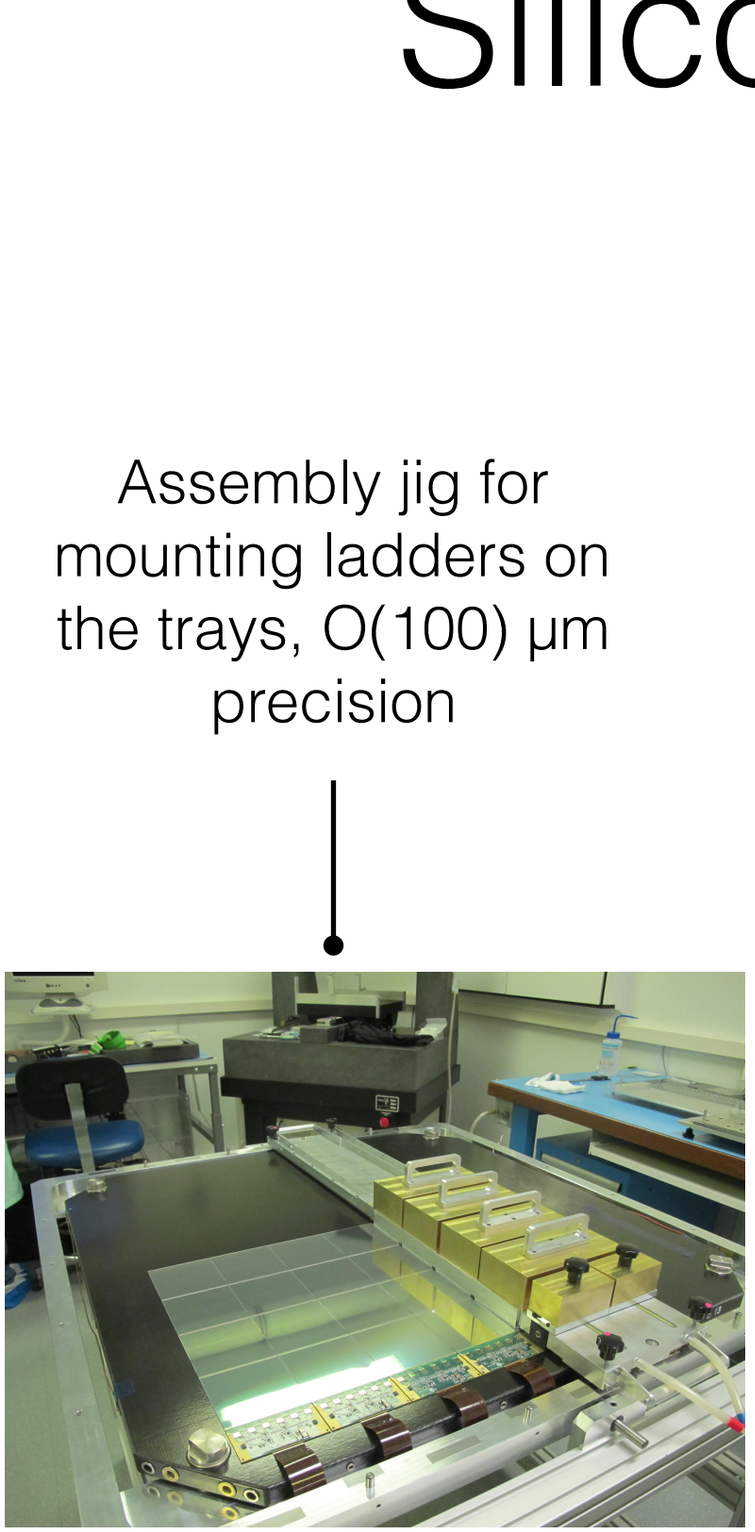
192 ladders in the STK

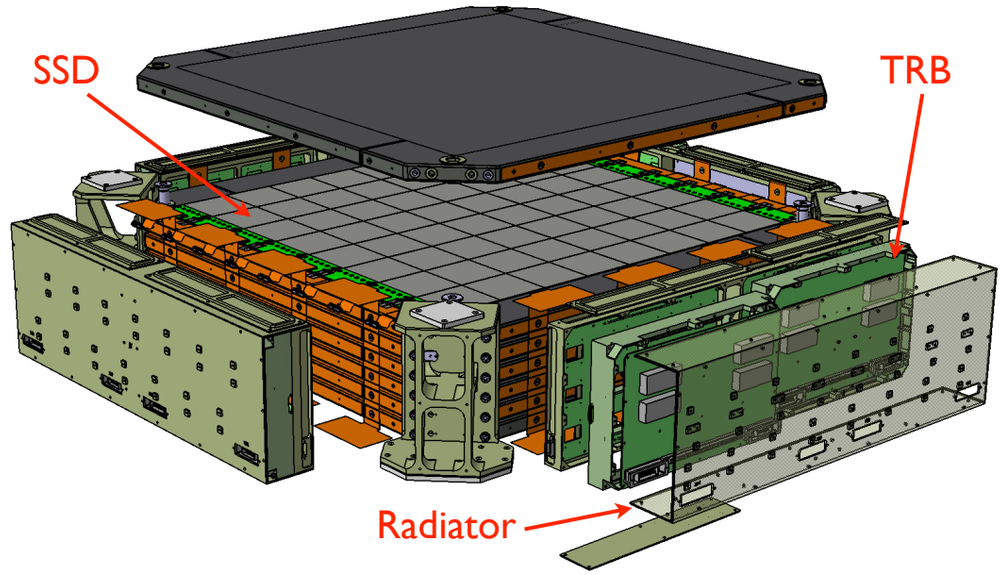


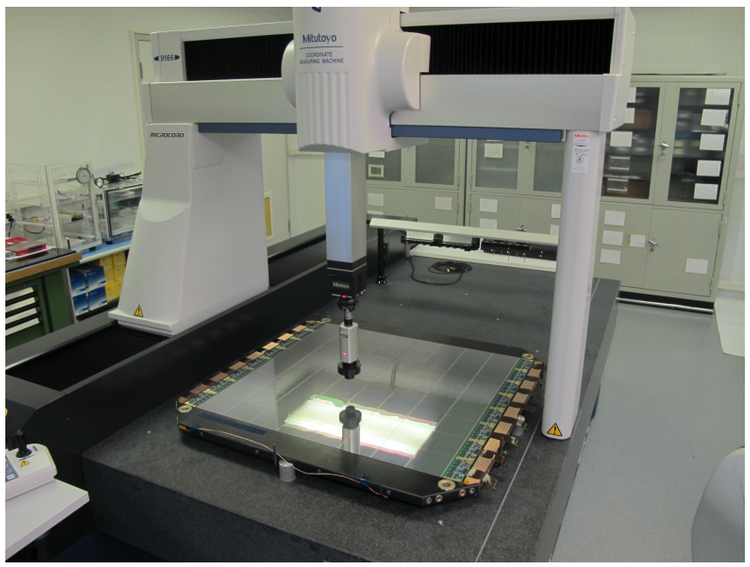
4 silicon sensors daisy chained via micro-bonds

Silicon TracKer (STK)

Assembly jig for mounting ladders on the trays, O(100) μm precision

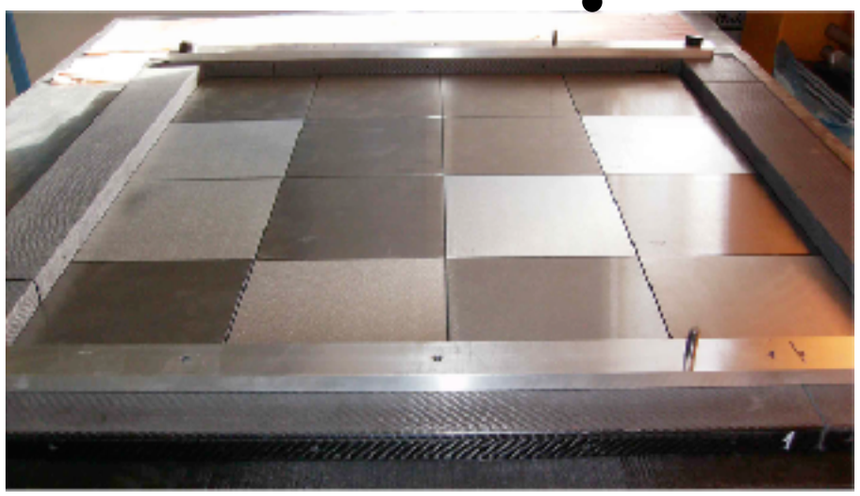






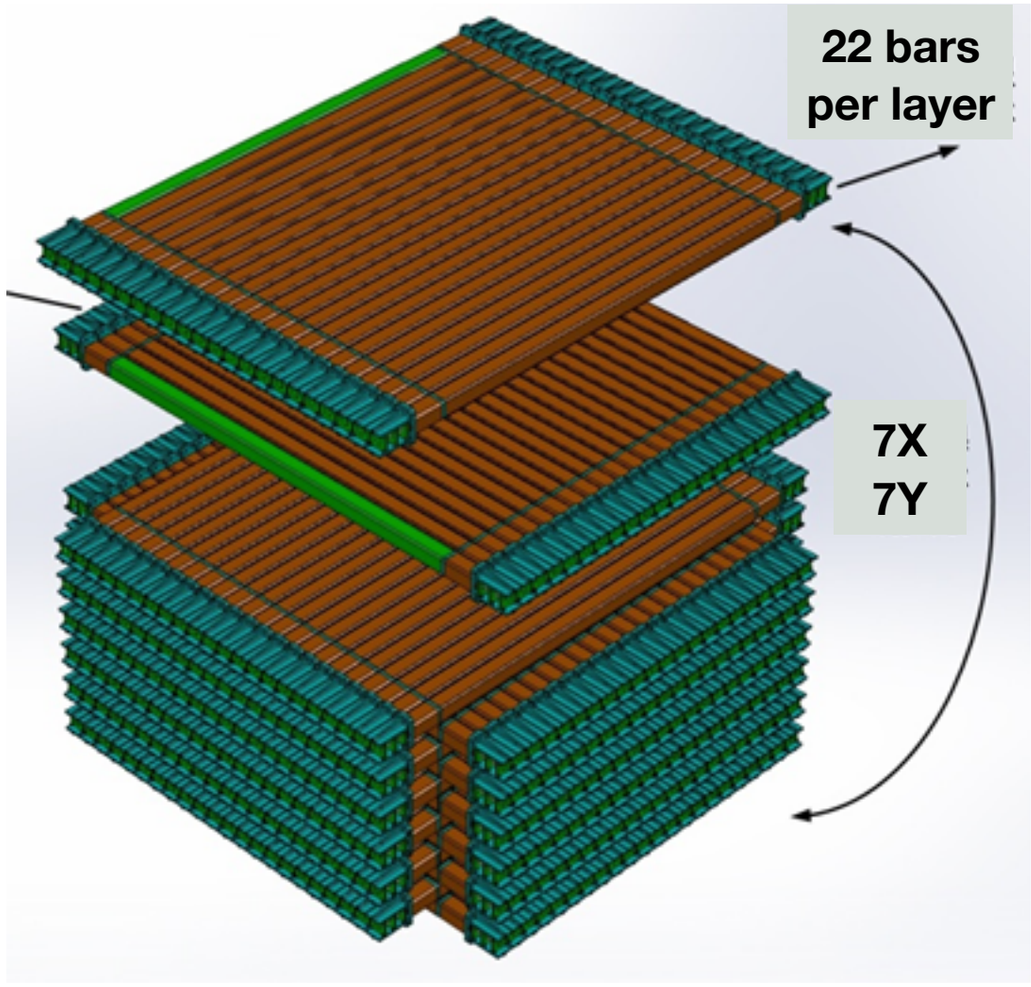
The trays' metrology procedure

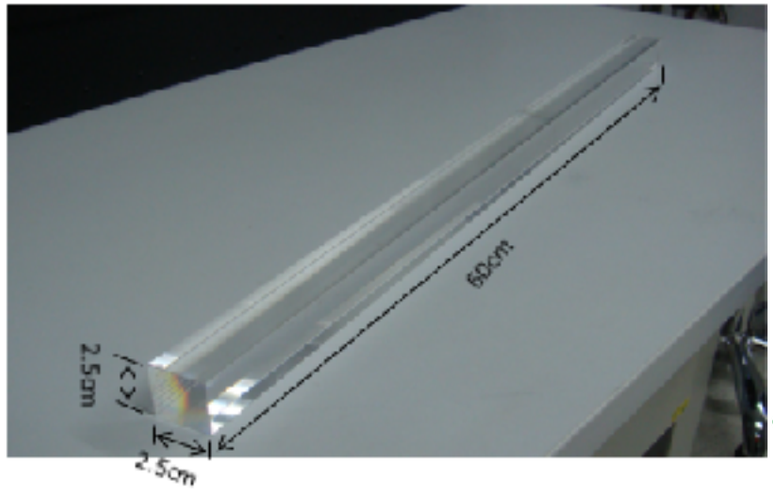
Tungsten converter plates (16 per tray)

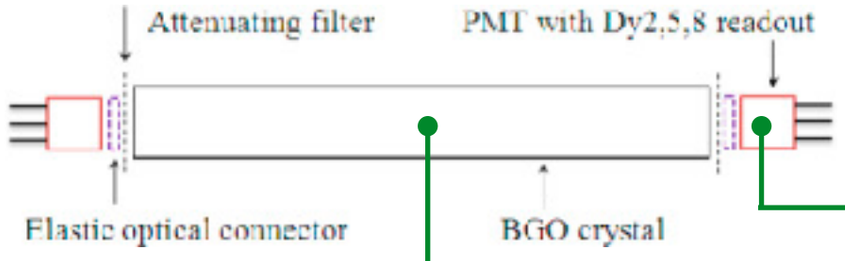


BGO calorimeter

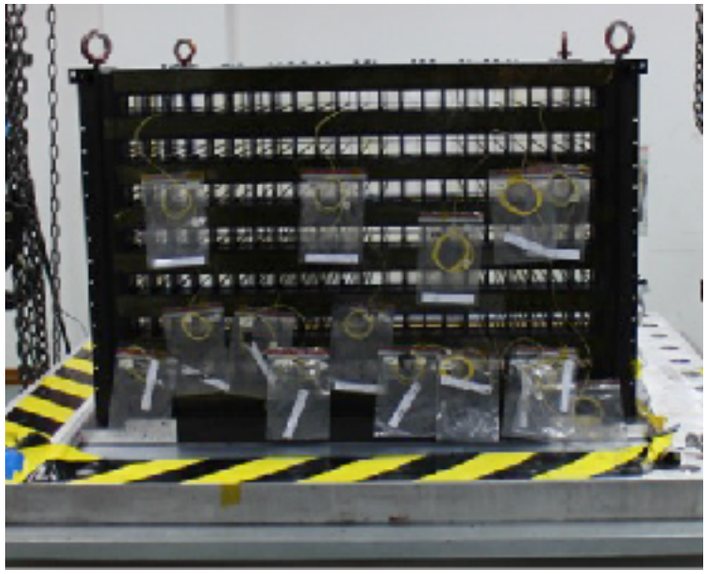
- **14 layers (7X and 7Y):**
  - **horoscopic arrangement, alternating X and Y layers**
  - **22 bars per layer**
  - **Total 32 X_0**
  - **Bar dimension: 2.5 x 2.5 x 60 cm^3**
  - **Two PMTs coupled to each bar in two ends**





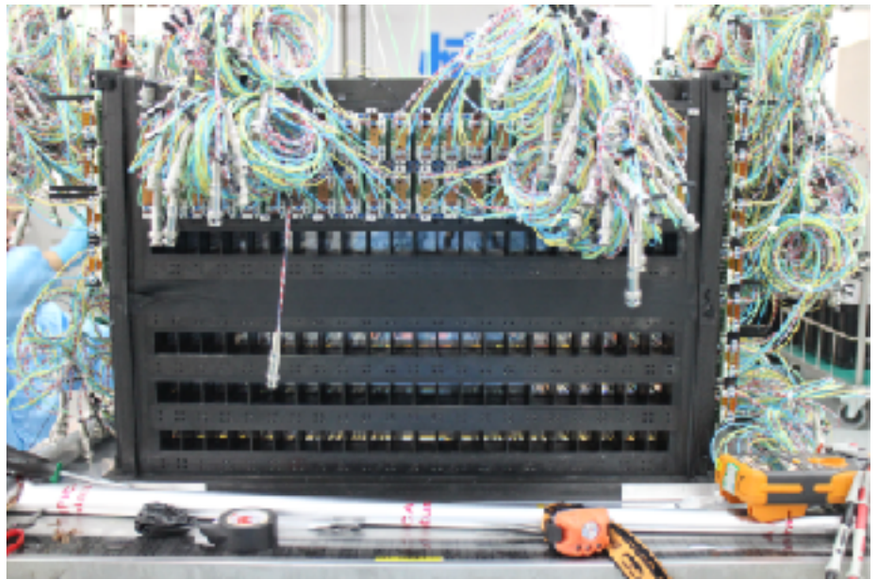


BGO calorimeter

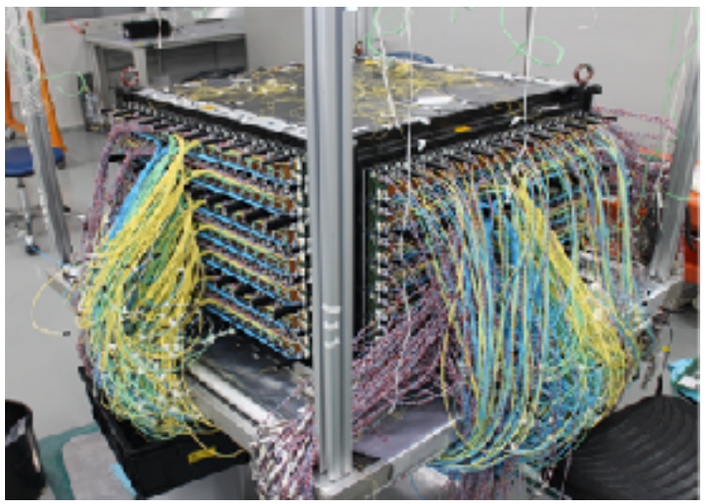


Carbon Fiber Structure

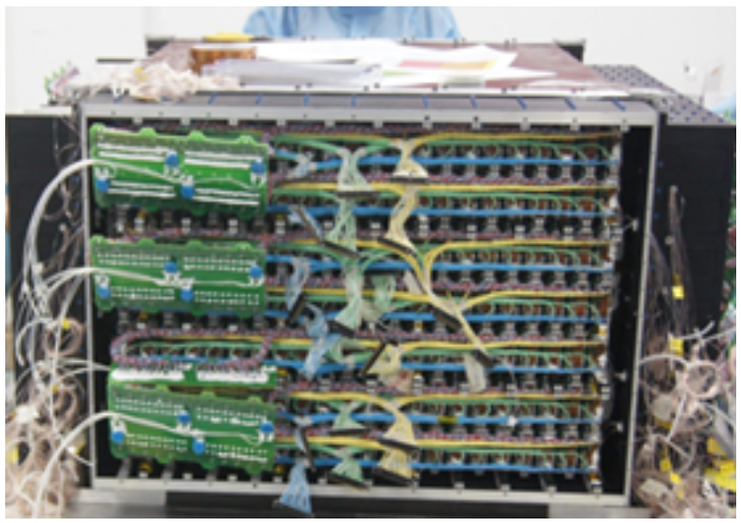
BGO crystal installation



PMT installation



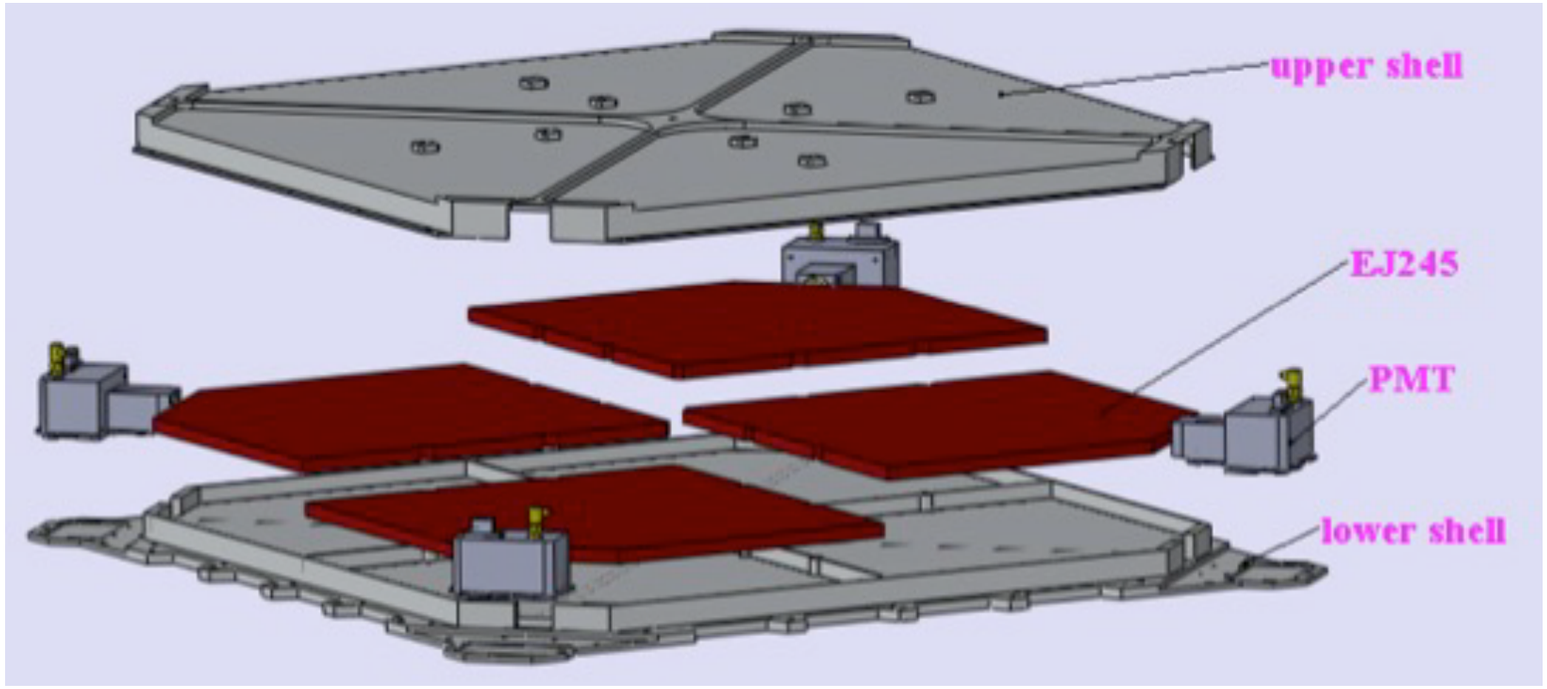
Cable arranging



Cable connectors

BGO calorimeter

Neutron detector (NUD)

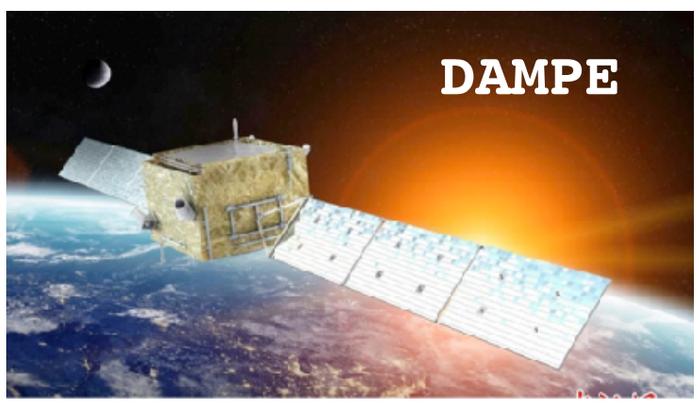


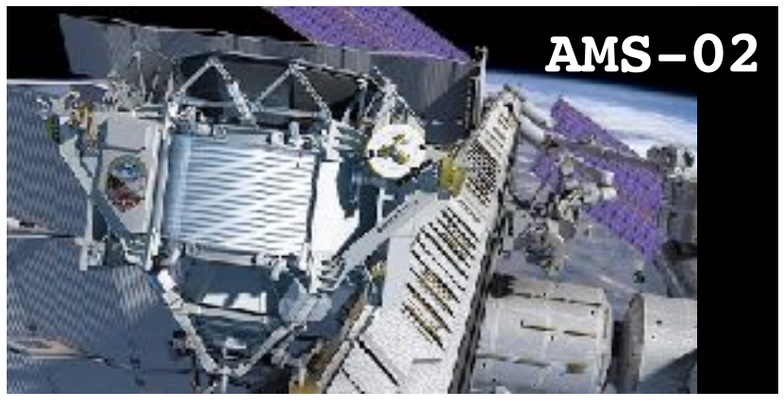
- **4 large-area boron doped plastic scintillators**
- **30 x 30 x 1 cm^3 scintillator dimension**

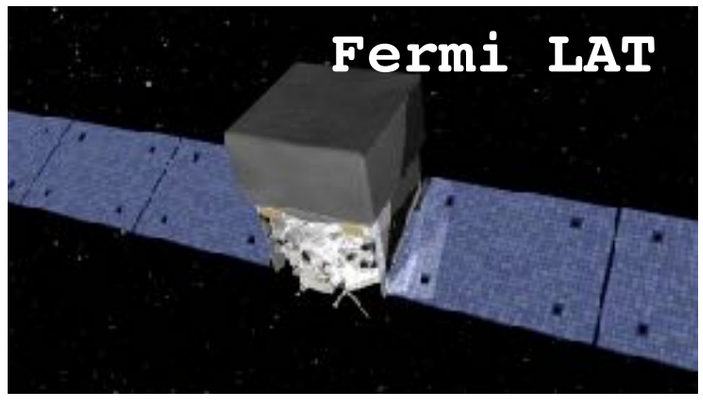
$$n + {}^{10}B \rightarrow \alpha + {}^{7}Li + \gamma$$

Comparison with AMS-02 and FERMI

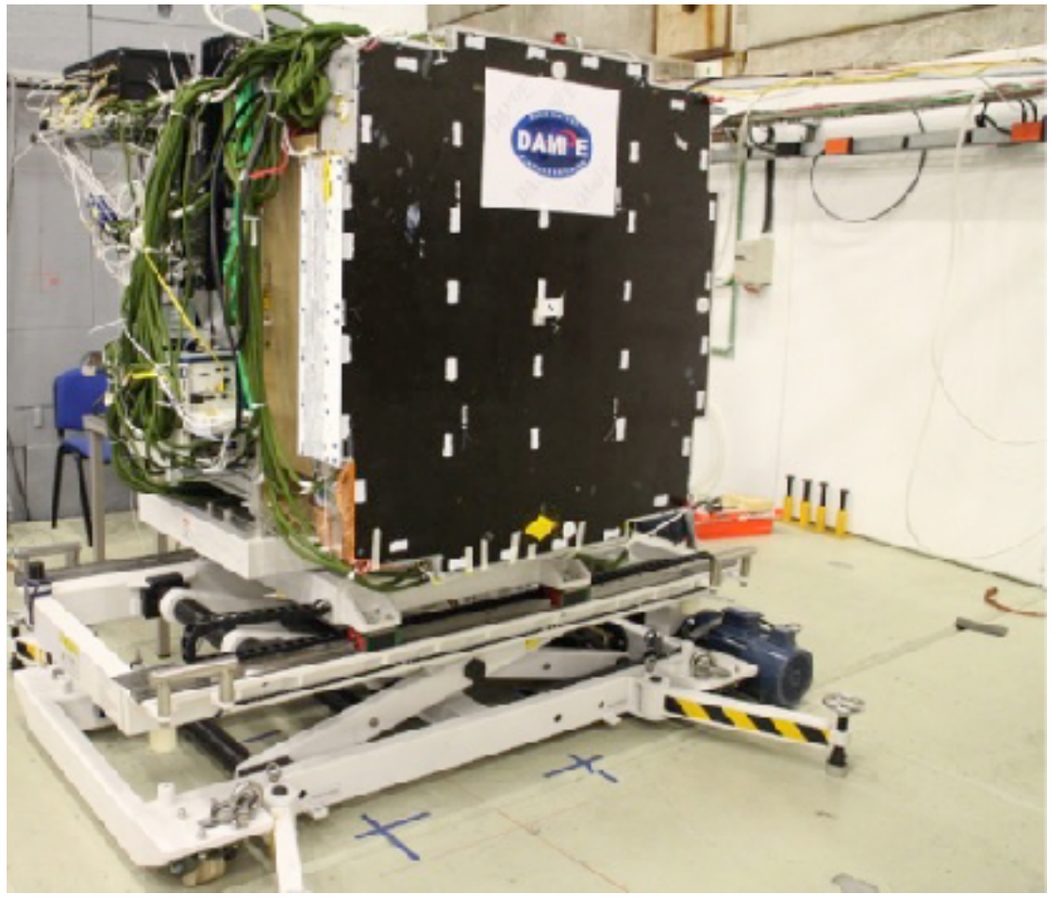
	DAMPE	AMS-02	Fermi LAT
e/γ Energy res.@100 GeV (%)	**1.5**	3	10
e/γ Angular res.@100 GeV (°)	0.1	0.3	0.1
e/p discrimination	10^5	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	**32**	17	8.6
Geometrical accep. (m^2sr)	**0.29**	0.09	1



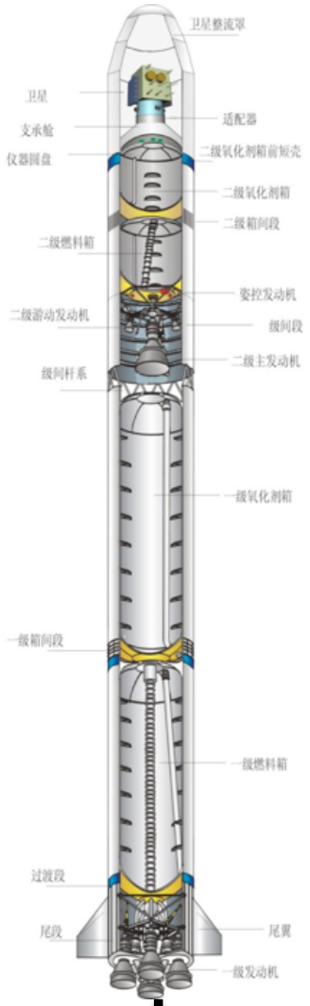




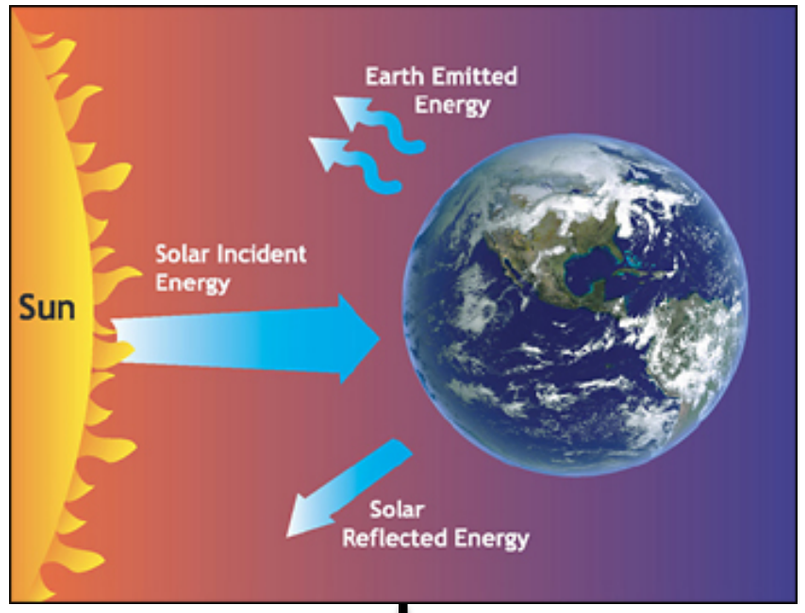
Part 2: Beam Tests and Space Qualifications



Operation in space



Mechanical stress at launch:
- Static acceleration
- Random vibration
- Sinusoidal vibration
- Pyroshock

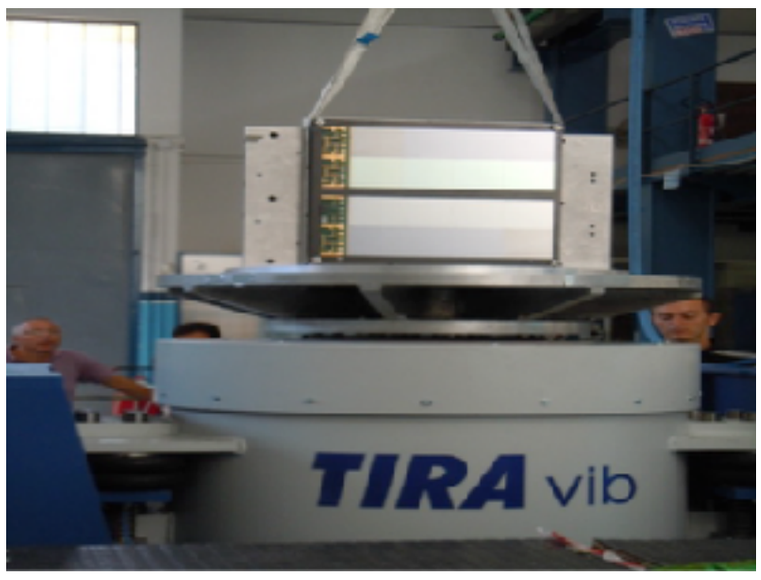


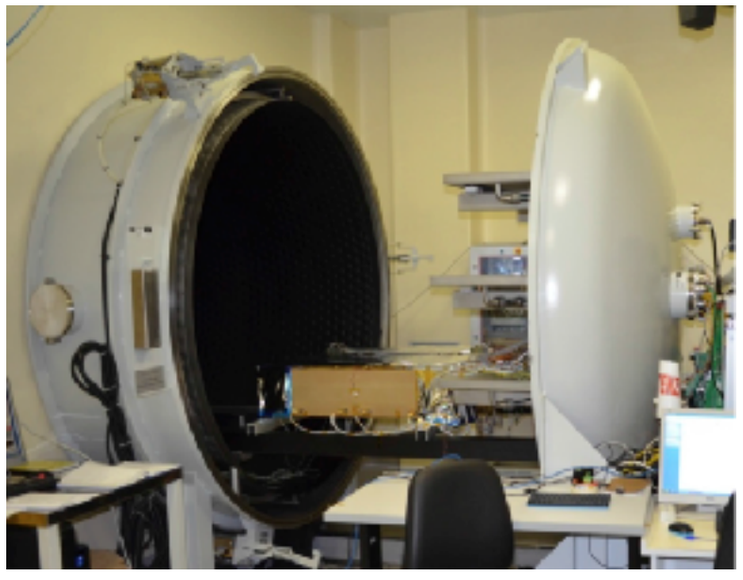
Life in space:
- Thermal stresses due to Sun-light (seasonal / day-night effects)
- Vacuum

Careful Design, Model validation and Qualification are needed to ensure *highest possible reliability*

DAMPE engineering qualification model (EQM)

- **An EQM has been constructed in July 2014**
- **Full size model as the final Flight Model (FM)**
    - **but, only 26 / 192 STK ladders are quipped with real silicon sensors, the rest are dummy sensors**
- **EQM passed a series of space environmental qualification tests:**
    - **vibration**
    - **acceleration**
    - **shock**
    - **thermal cycling**
    - **thermal vacuum**





SERMS facility, Terni, Italy

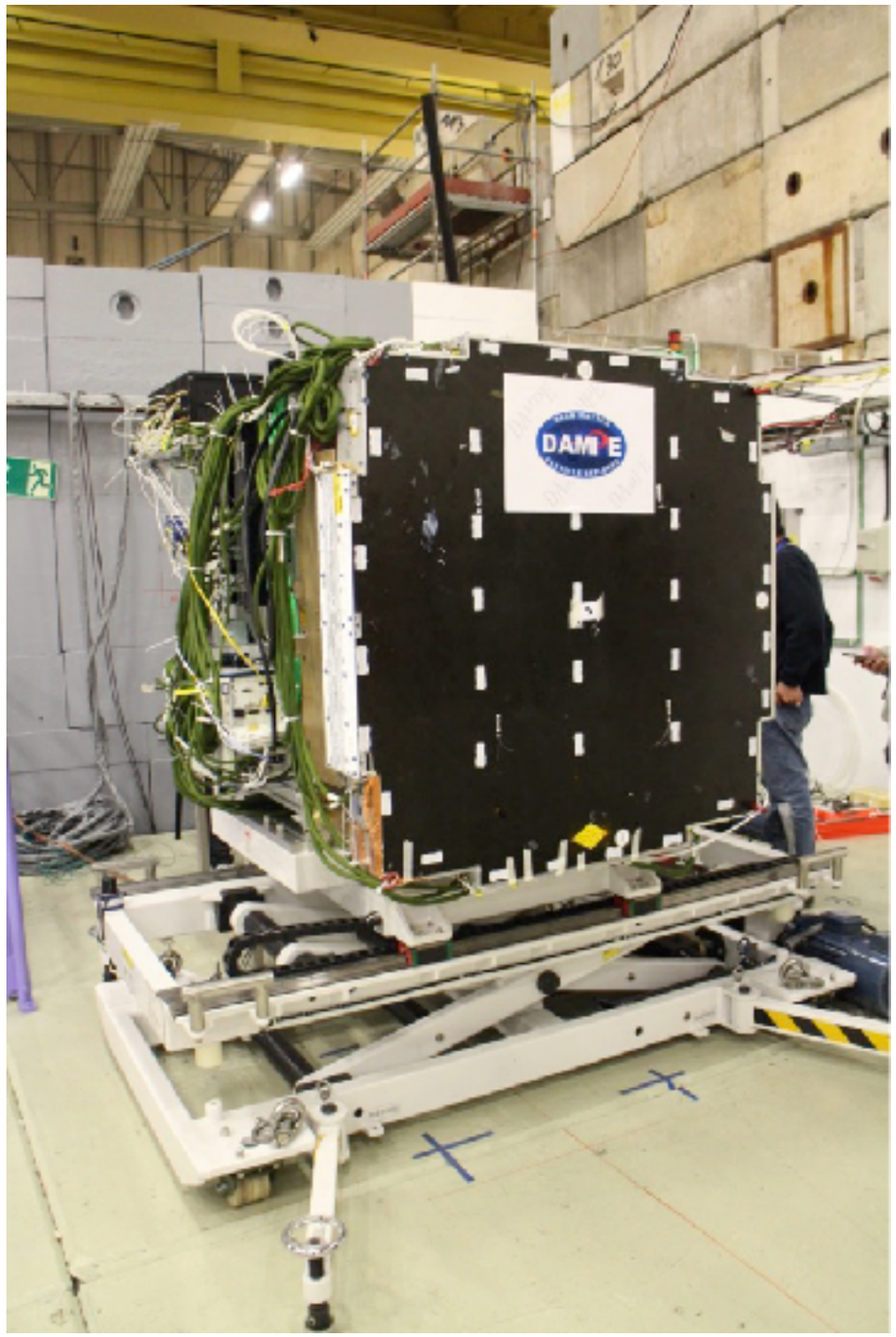
DAMPE EQM beam tests @ CERN

14days@PS, 29/10-11/11 2014
- e @ 0.5 — 5 GeV/c
- p @ 3.5 —10GeV/c
- π-@ 3.0 —10GeV/c
- γ @ 0.5 — 3GeV/c

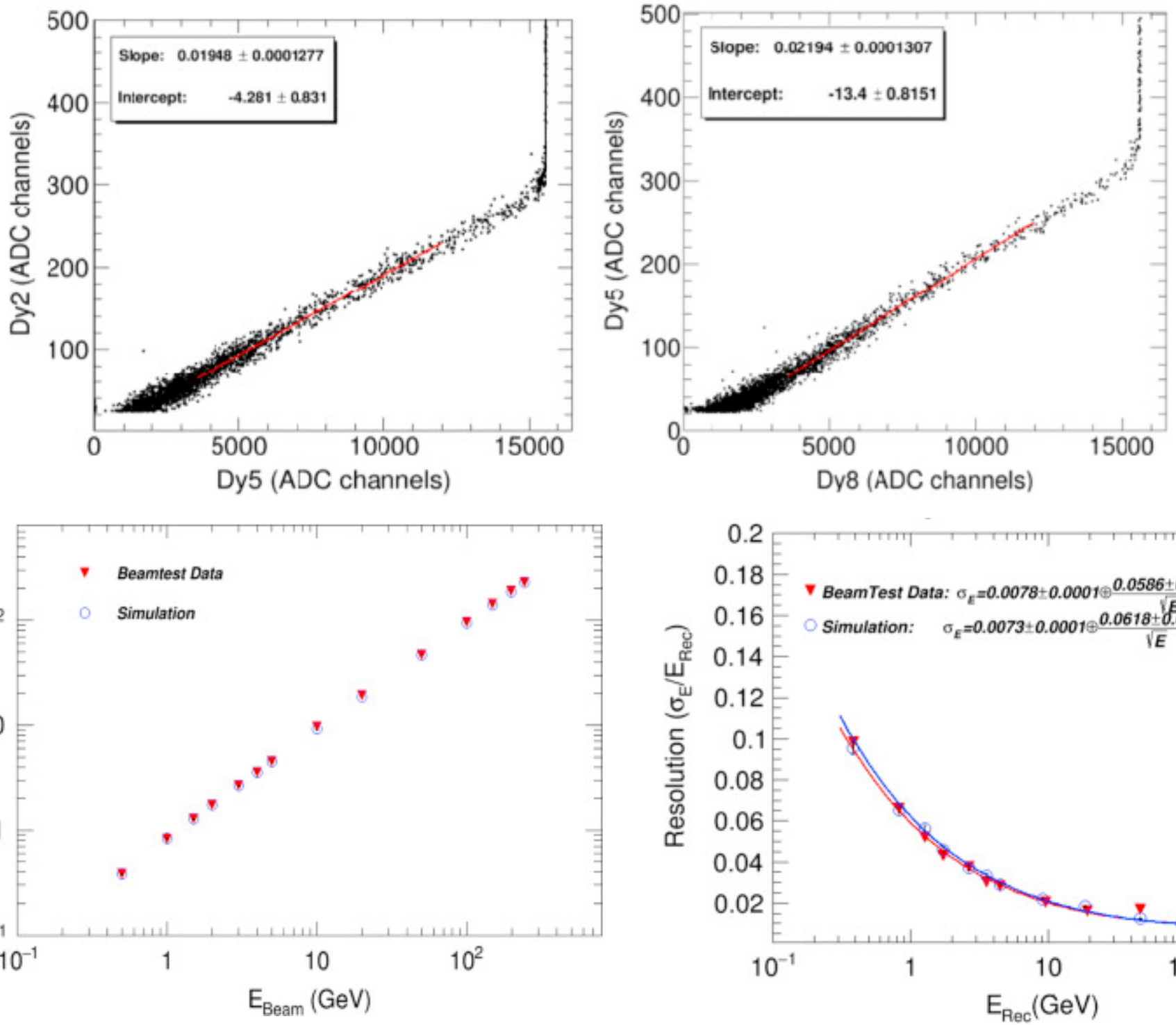
8days@SPS,12/11-19/11 2014
- e @ 5 — 250 GeV/c
- p @ 400GeV/c (SPS primary beam)
- γ @ 3 — 20GeV/c
- μ @ 150GeV/c

17days@SPS,16/3-1/4 2015
- Fragments: 67 — 167 GeV/c
- Argon: 30A — 40A, 75AGeV/c
- p: 30GeV/c, 40GeV/c

21days@SPS,10/6-1/7 2015
- p @ 400GeV/c (SPS primary beam)
- e @ 20 — 150 GeV/c
- γ @ 50, 75 , 150 GeV/c
- μ @ 150 GeV /c
- π+@10, 20, 50, 100 GeV/c



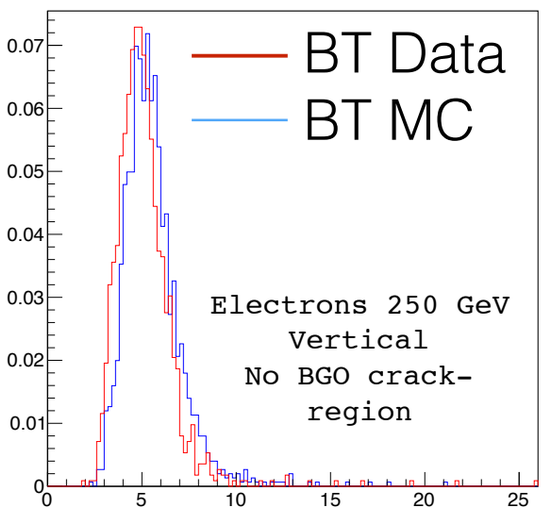
DAMPE EQM beam tests @ CERN

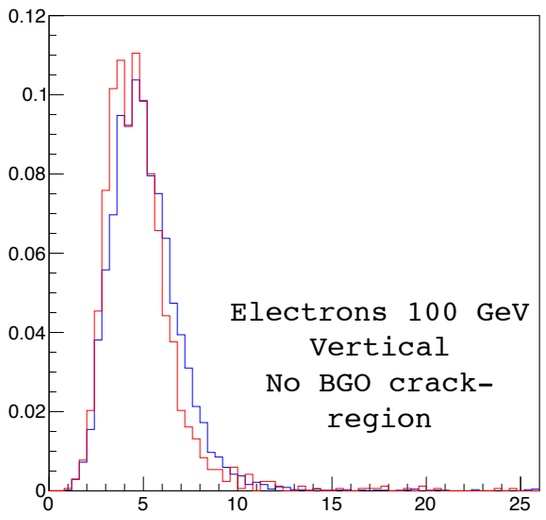


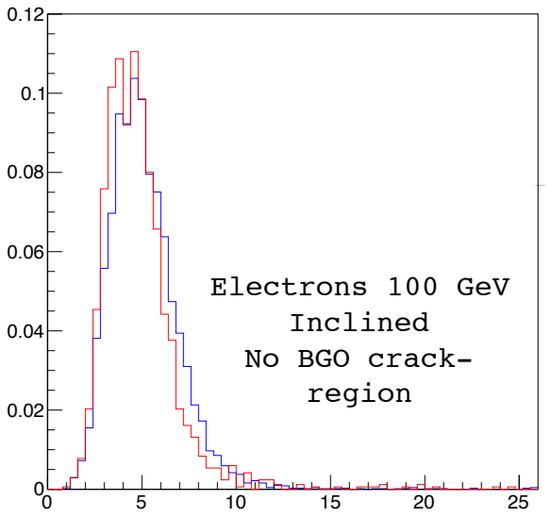
- **3 dynodes per BGO PMT to cover wide energy range**
- **1% energy resolution @ 100 GeV**

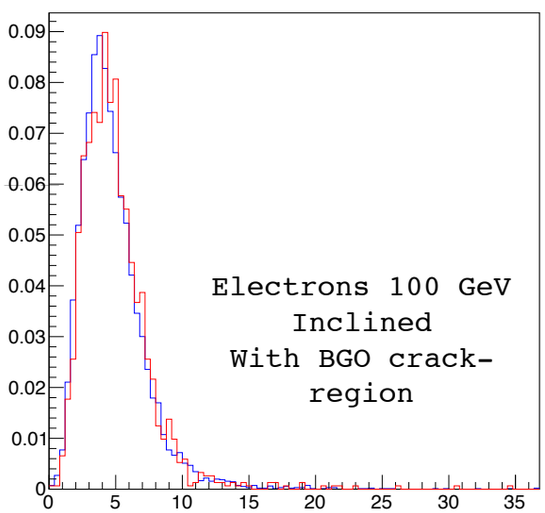
e/p separation: BT validations

electrons



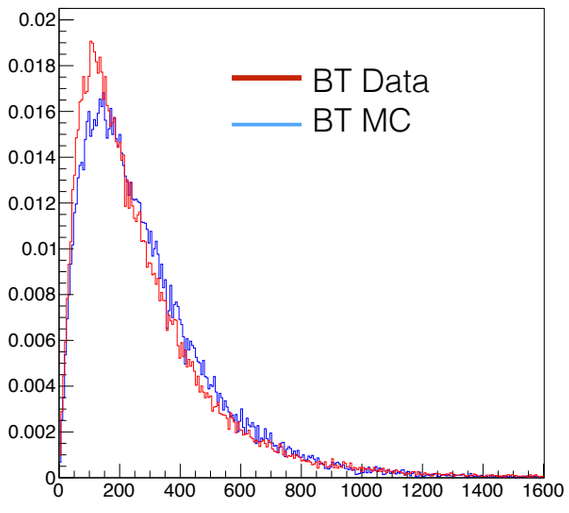


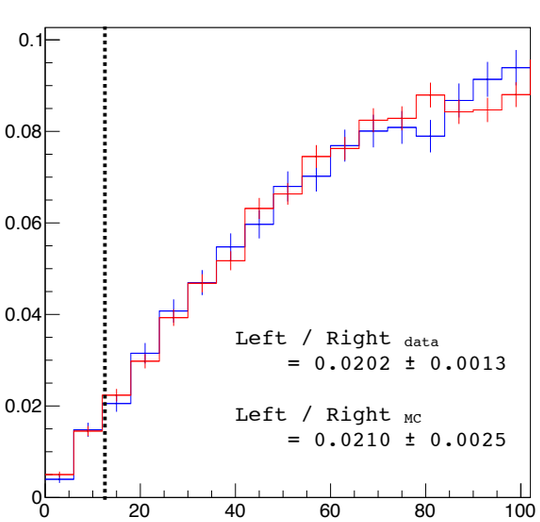




e/p discriminator variable

protons





e/p discriminator variable

@ 400 GeV primary SPS beam

Good data / MC agreement!

DAMPE EQM beam tests @ CERN: ions

Beam Test Setup

- Primary ion: ^{40}Ar
- Secondary ions: Z=2-18, A/Z=2
- Energy: 40 GeV/nucleon, 75 GeV/nucleon
- PID for secondary ions with dE/dx detectors on beam line:

Fig1. Beam line

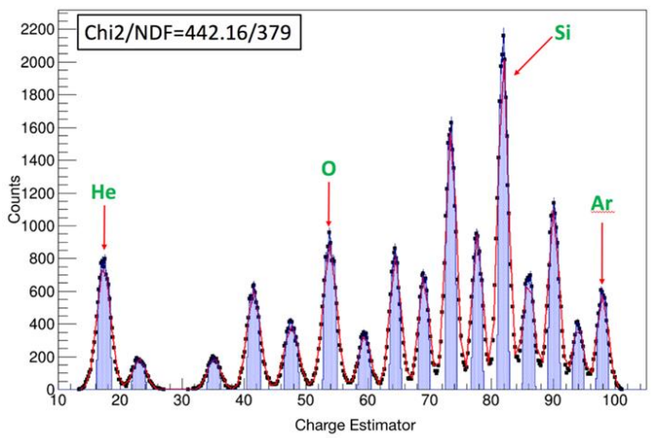
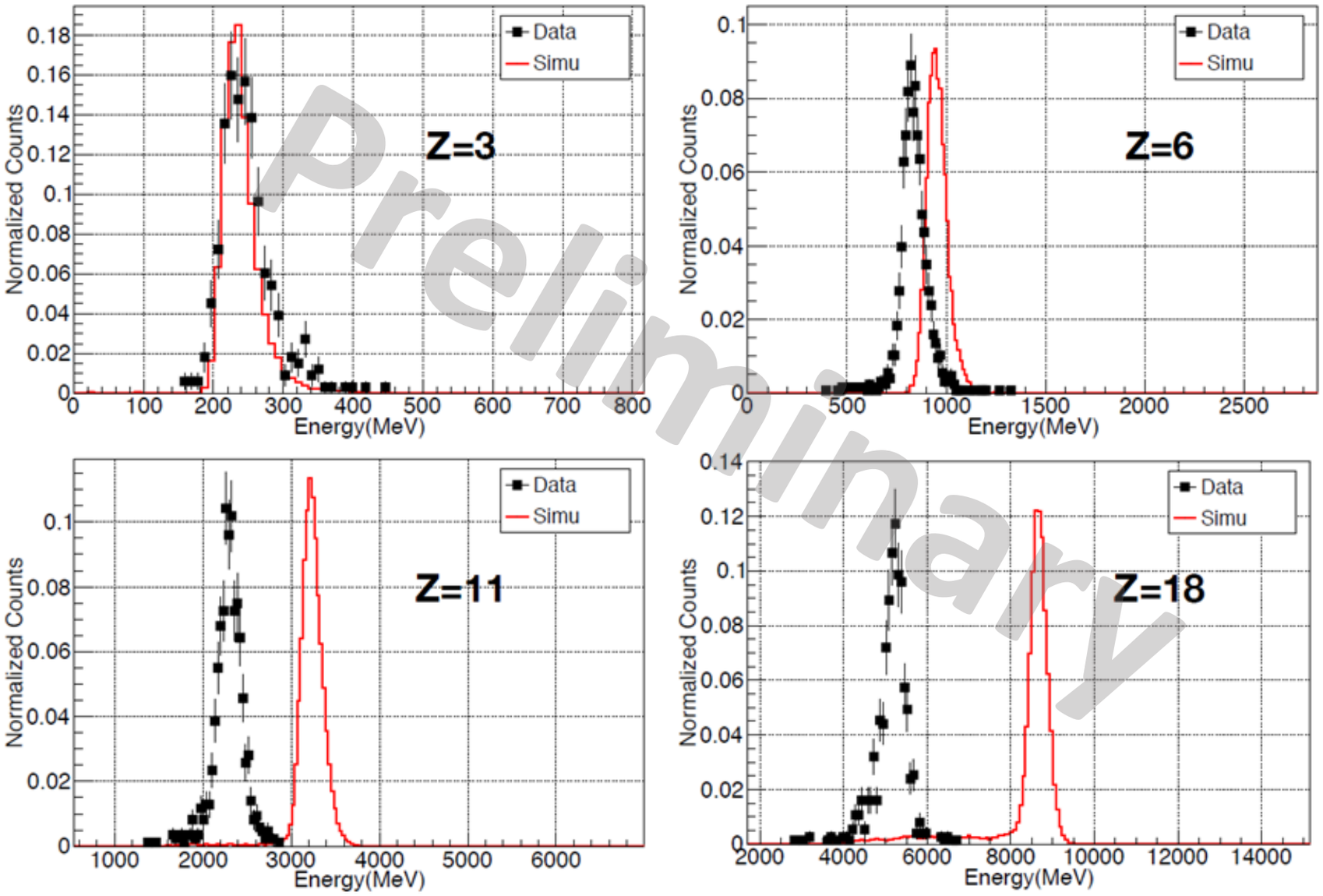


Fig2. PID for secondary ions

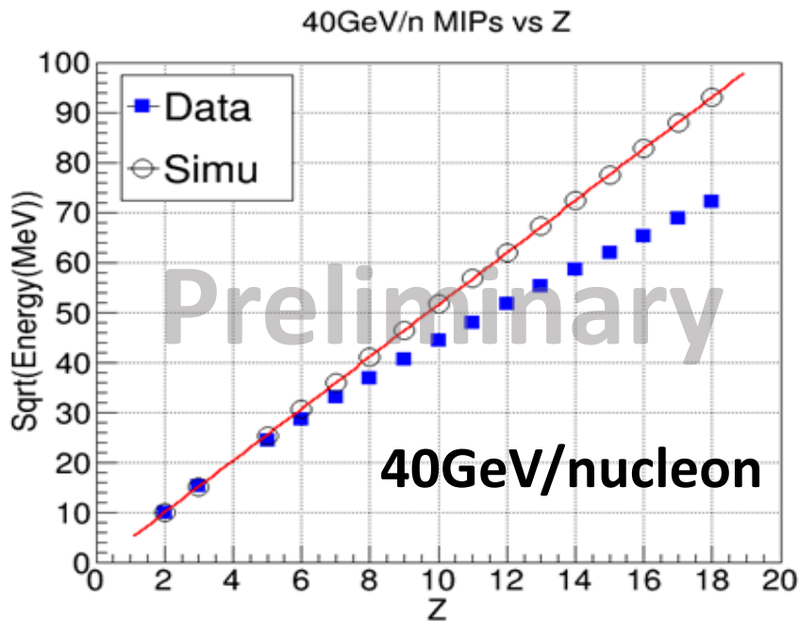
DAMPE EQM beam tests @ CERN: ions

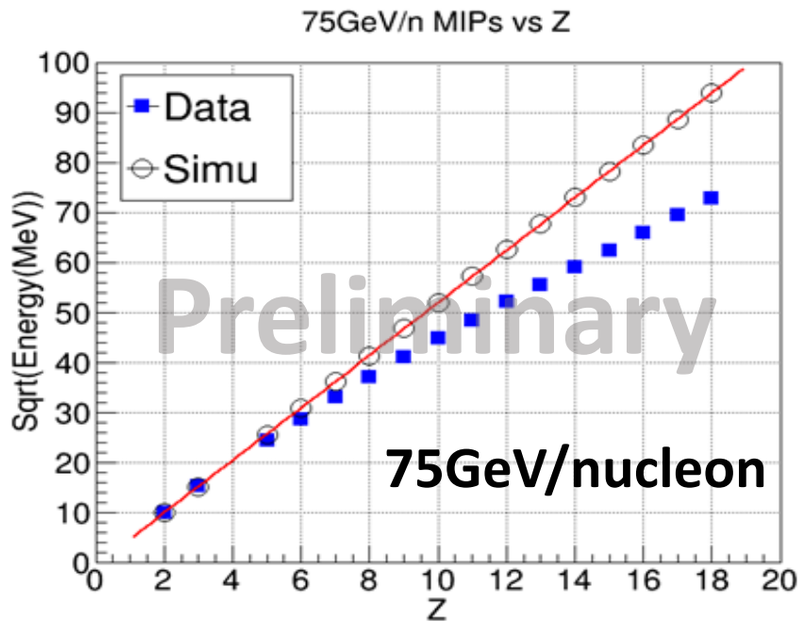
MIPs spectrum in the BGO crystal (40 GeV/nucleon)



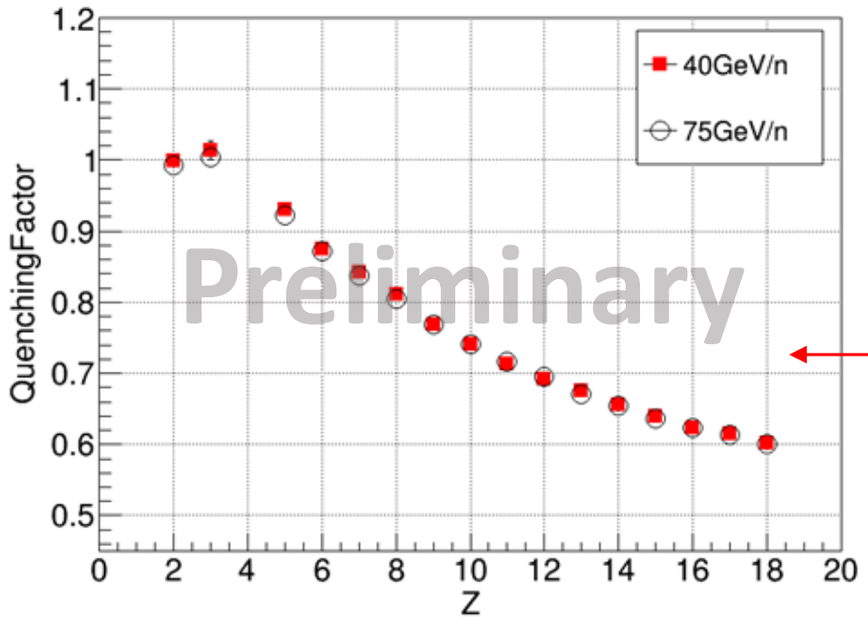
DAMPE EQM beam tests @ CERN: ions

Quenching effect of BGO



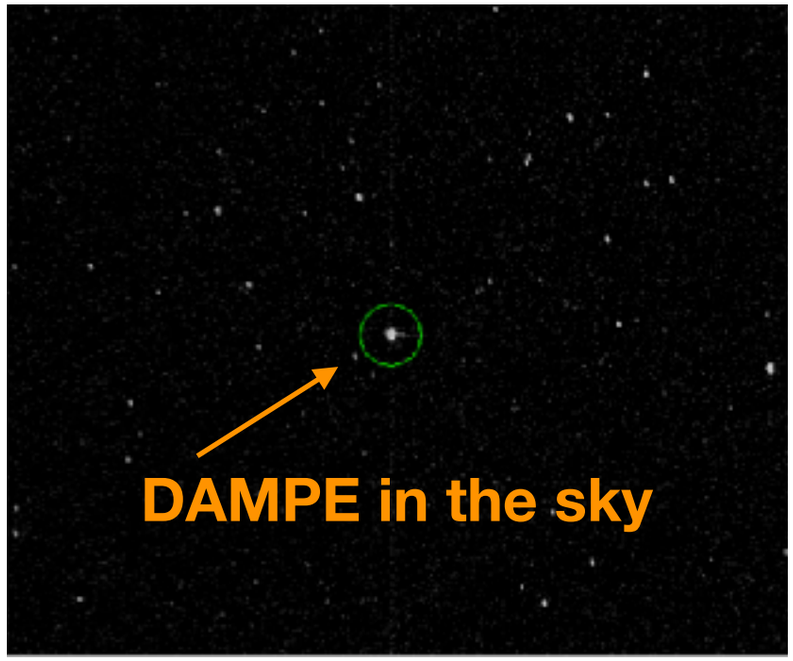


Sqrt(MIPs Peak Energy) vs atomic number

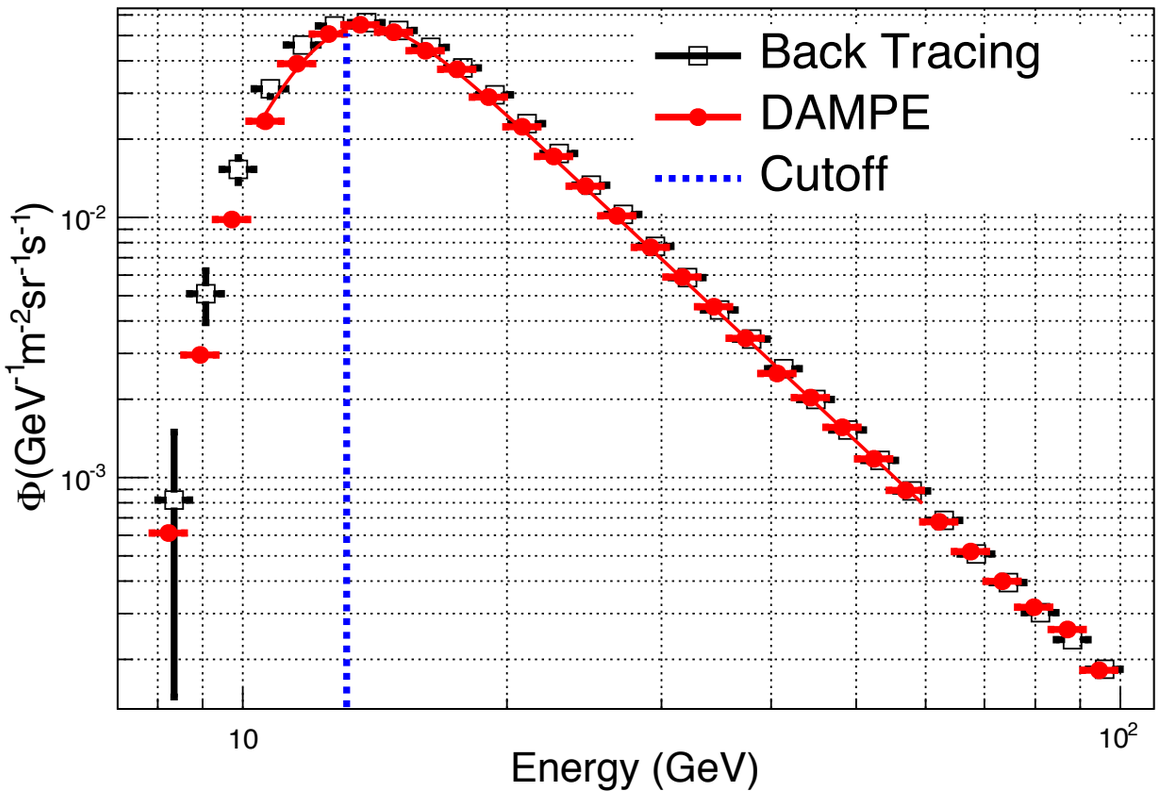


$$QuenchingFactor = \frac{MIPsEnergy\_Data}{MIPsEnergy\_Simu}$$

Part 3: In-Flight Performance and First Results



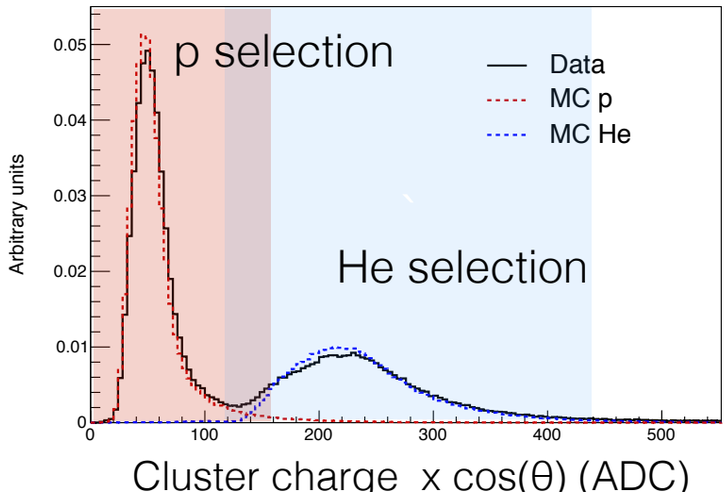
BGO energy scale studies

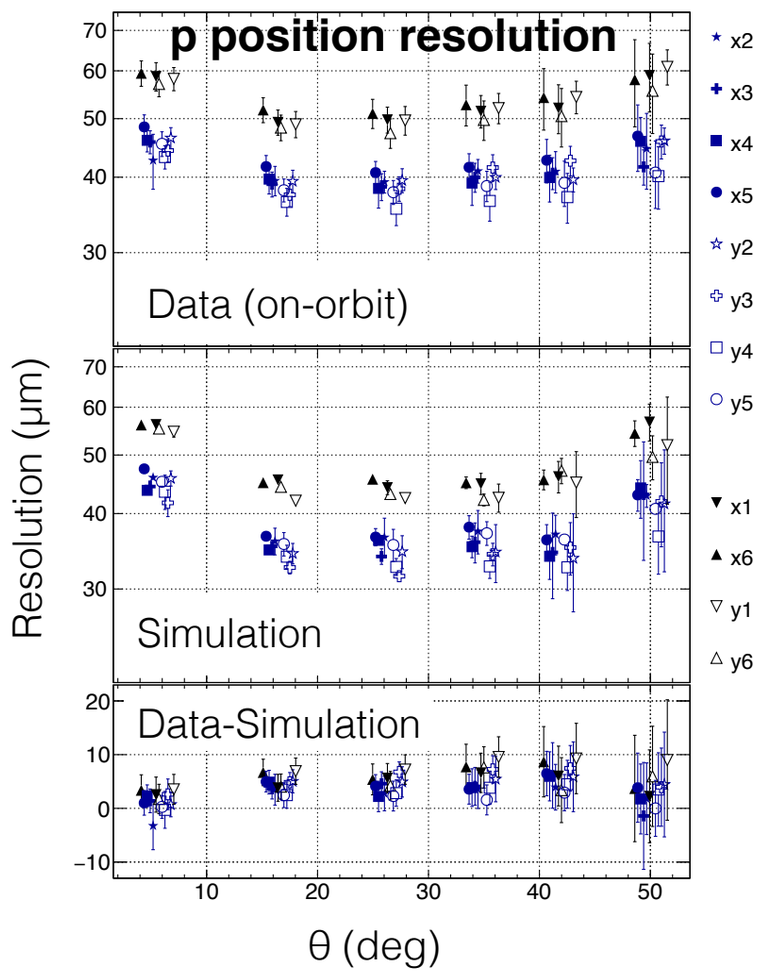


- **Cosmic-rays with certain rigidity will be bent back to space by geomagnetic field:**
  - **causes a cutoff on spectrum of cosmic ray e^++e^- @ ~ 10GeV**
  - **Allows to estimate absolute energy scale by comparing calculated geomagnetic cutoff with the DAMPE measured one**

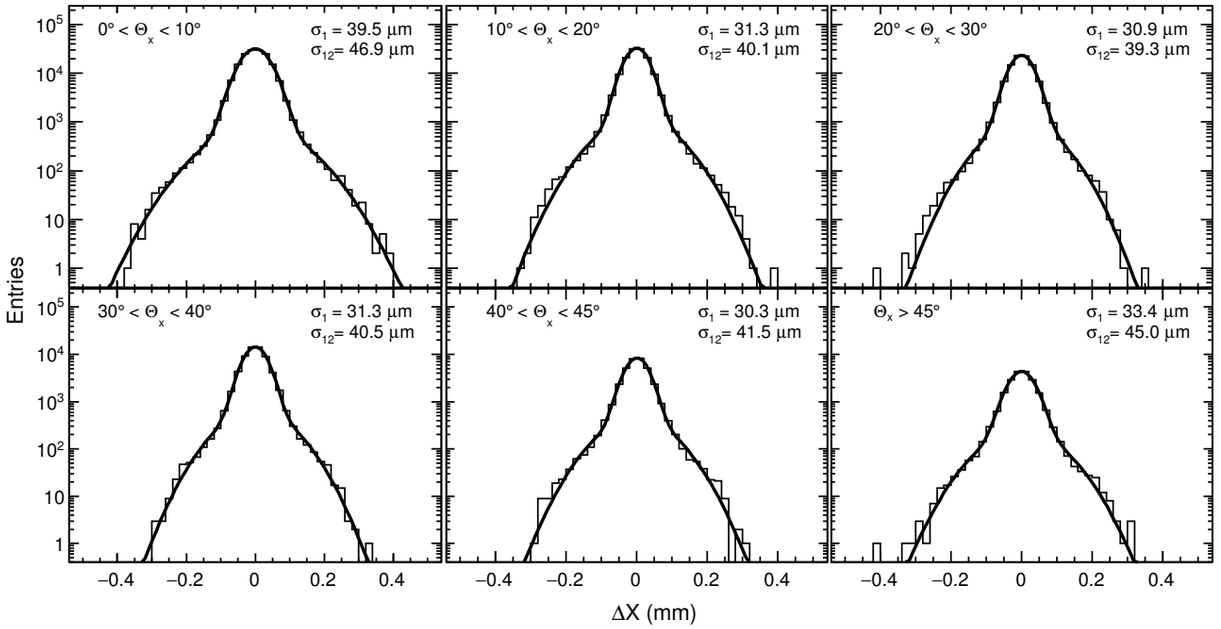
Energy scale correction (@13 GeV) = 1.25% ± 1.75% (stat) ± 1.34% (syst)

The STK position resolution

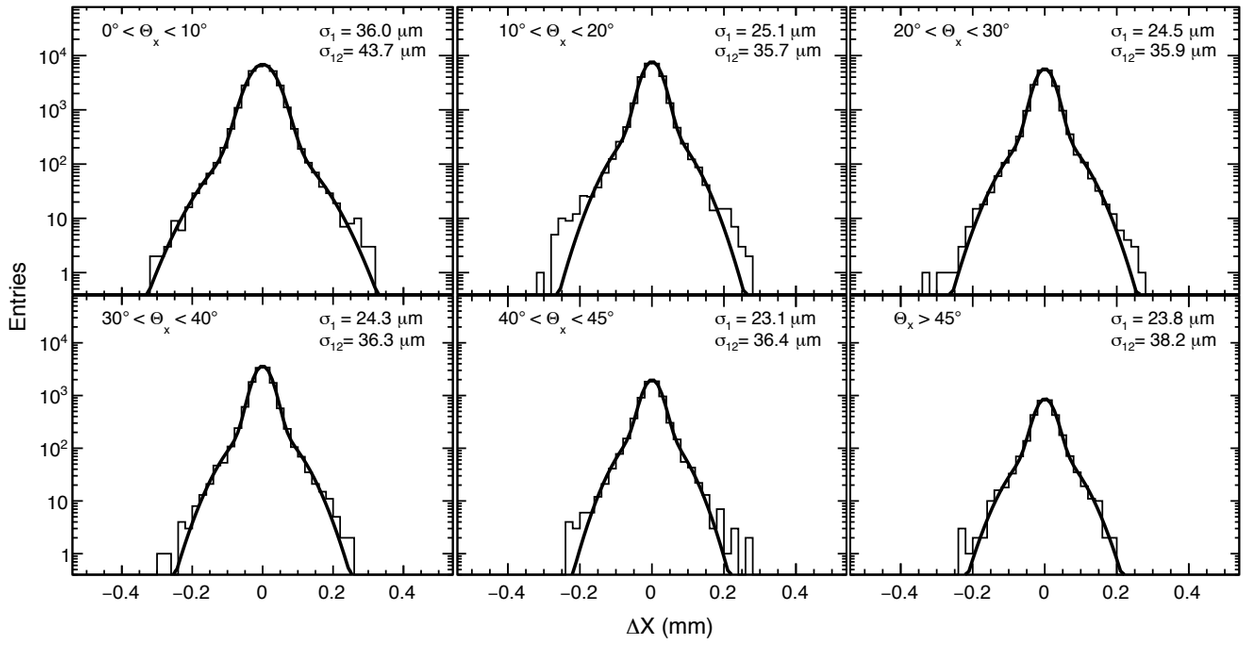




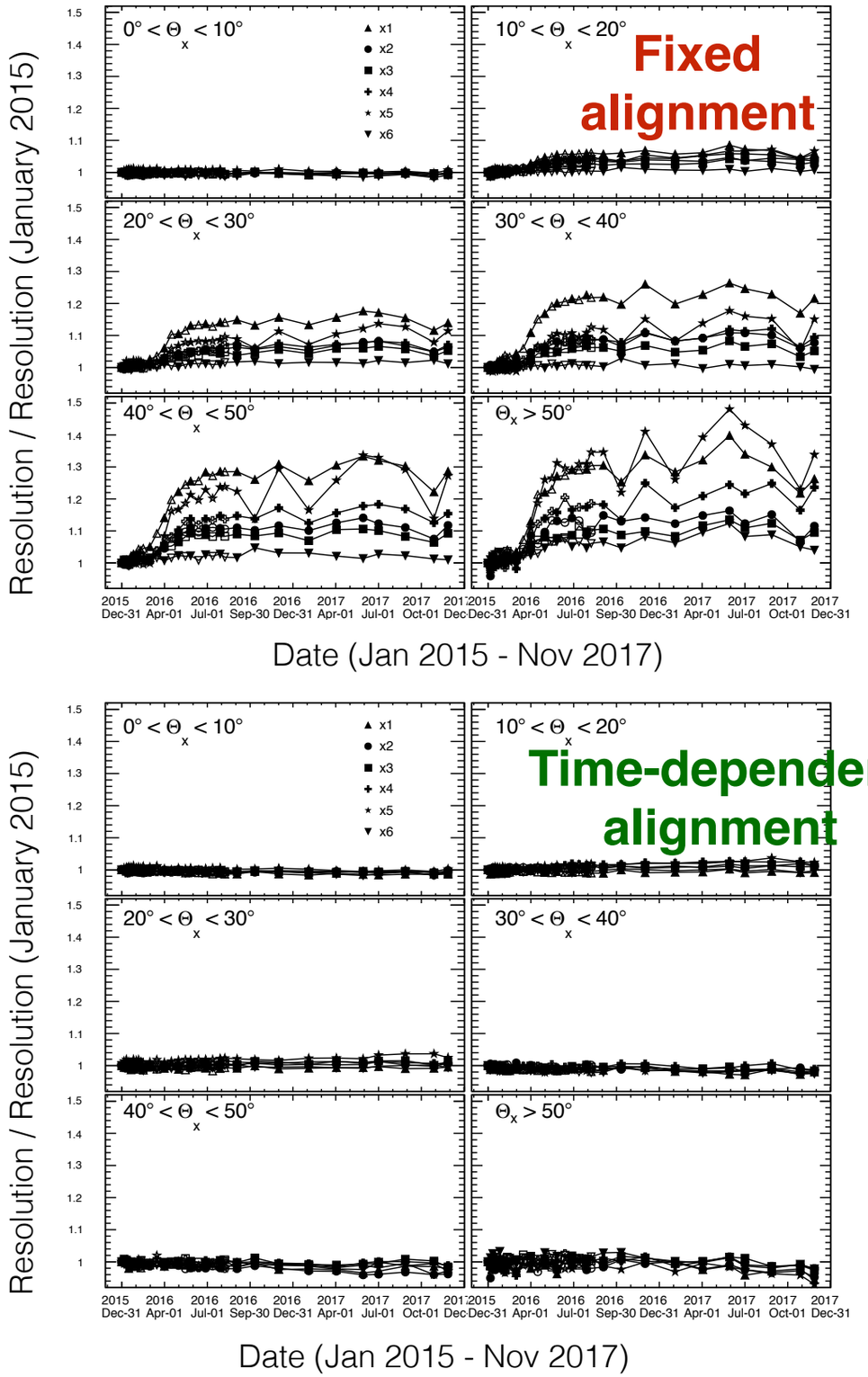
p resolution: **~ 41 μm** (intermediate angles)



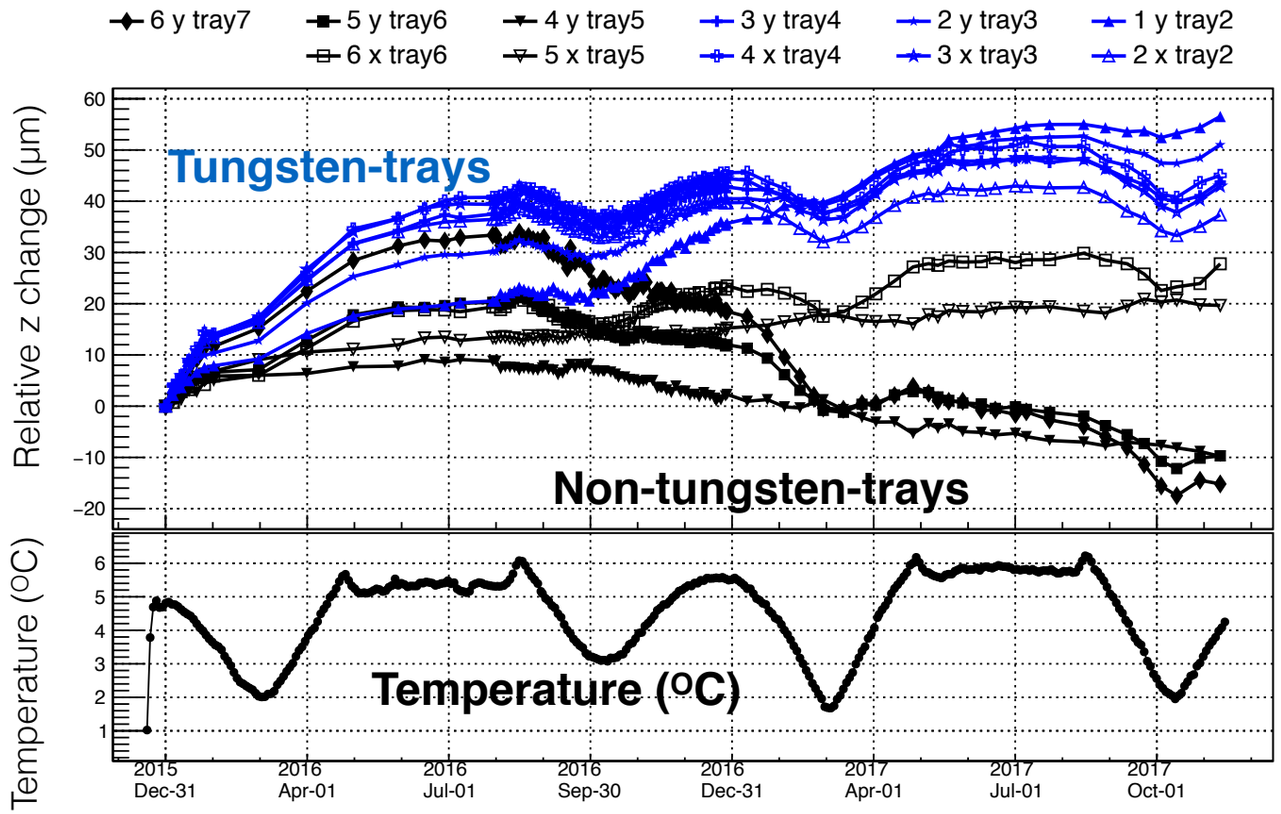
He resolution: **~ 36 μm** (intermediate angles)



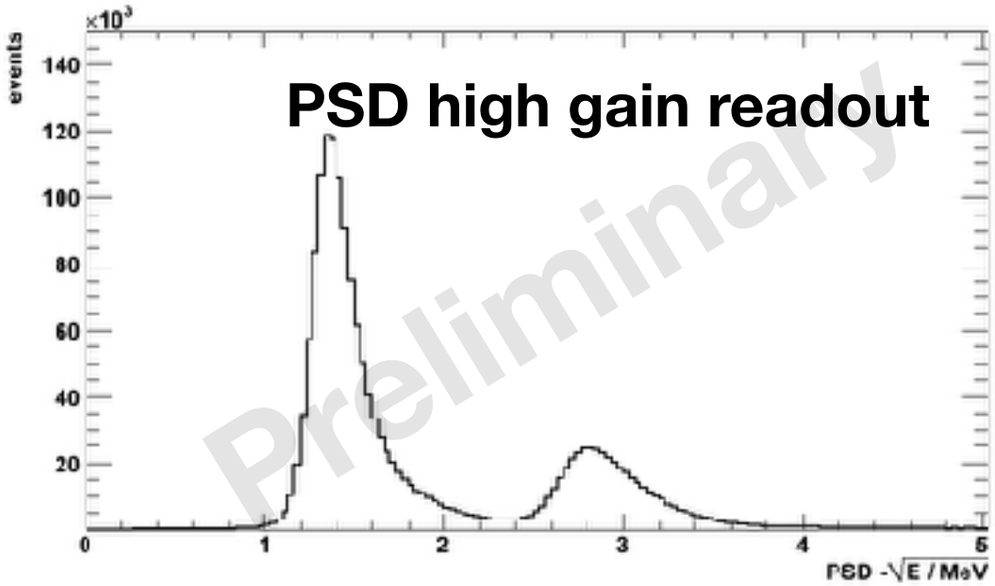
Stability of the STK alignment

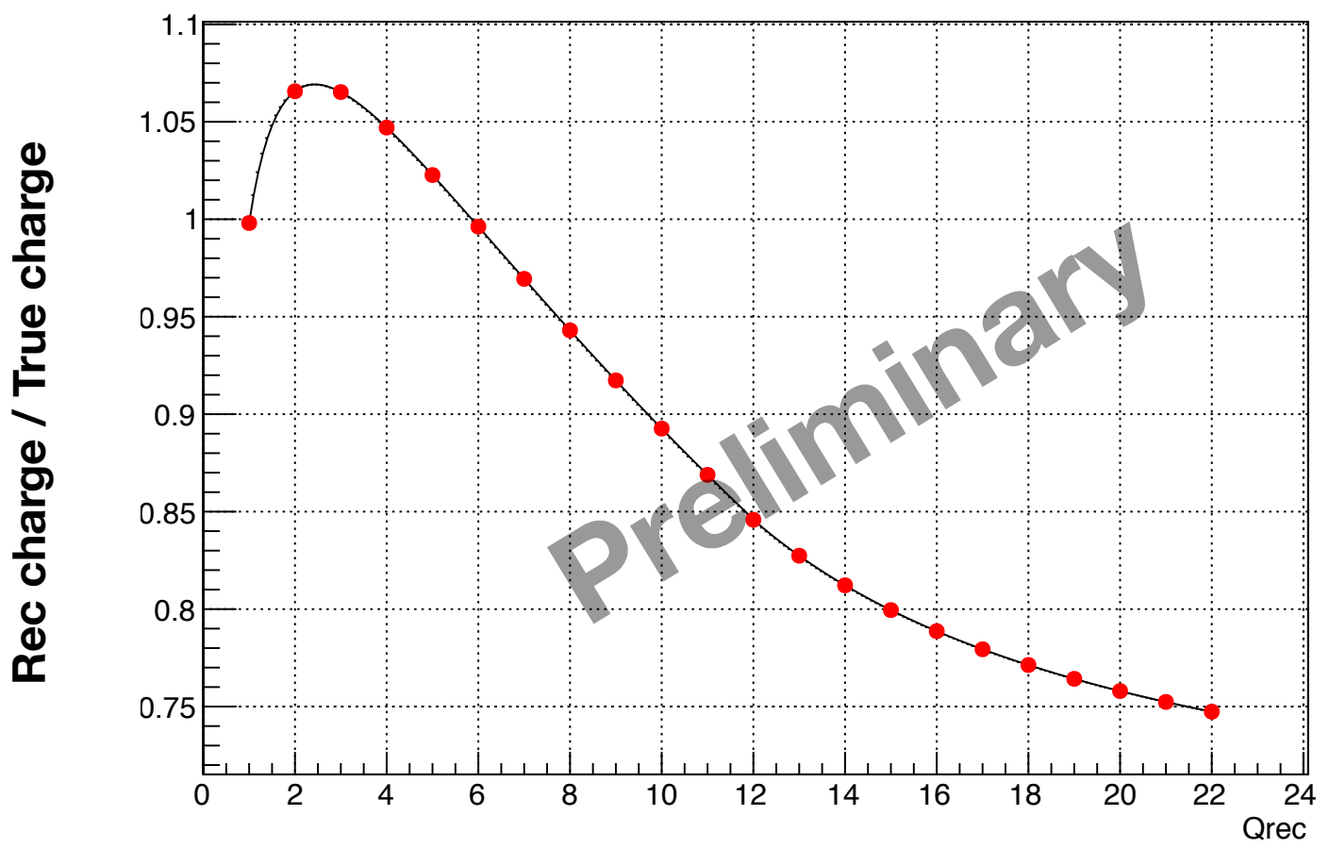


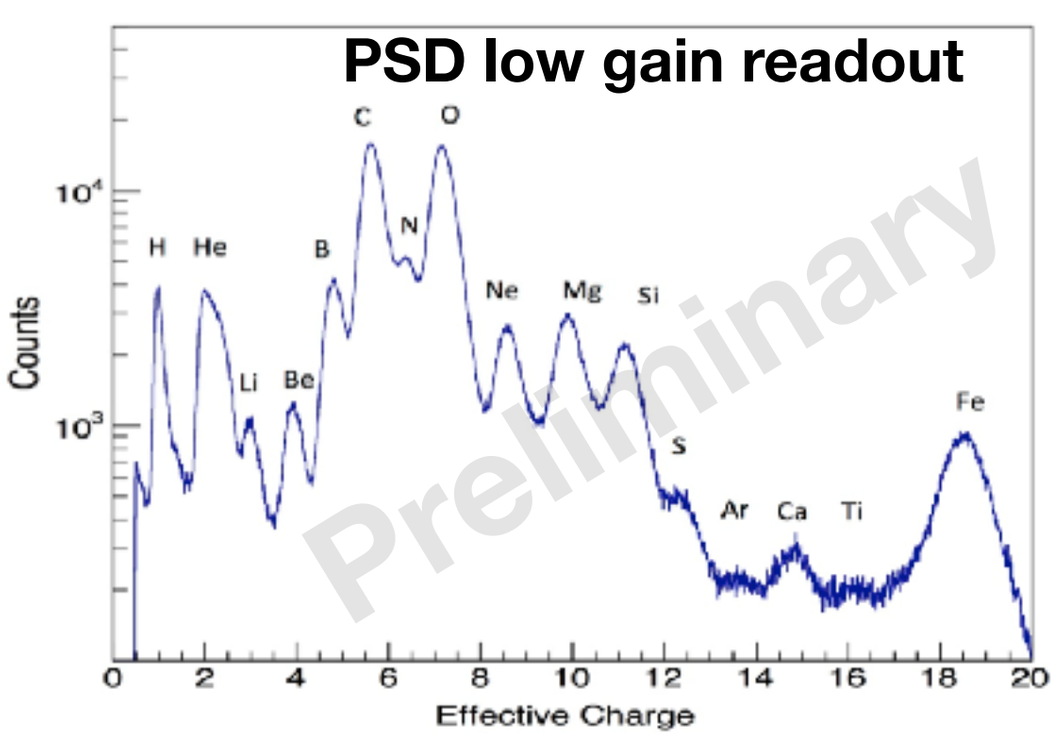
Re-alignment is performed on-orbit twice per month to ensure optimal performance of the STK



Charge ID

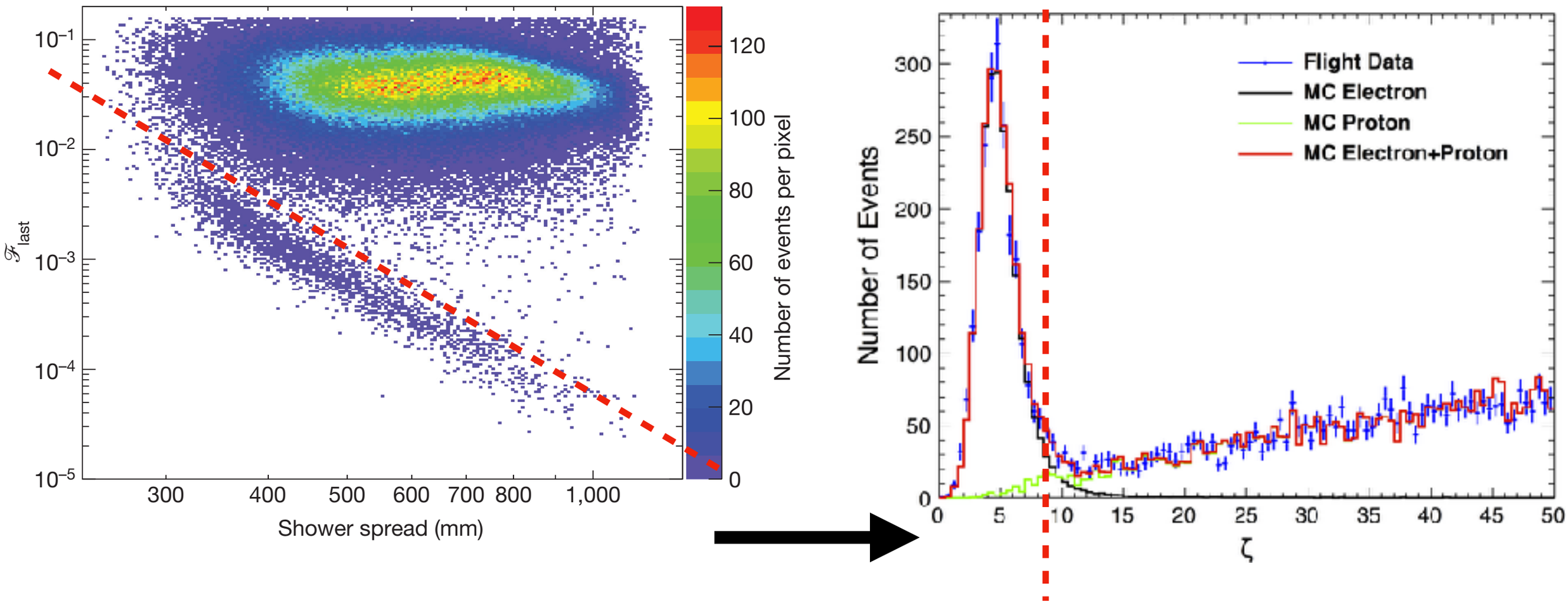






Based on Orbit data, PSD quenching parameters were extracted from H to Fe

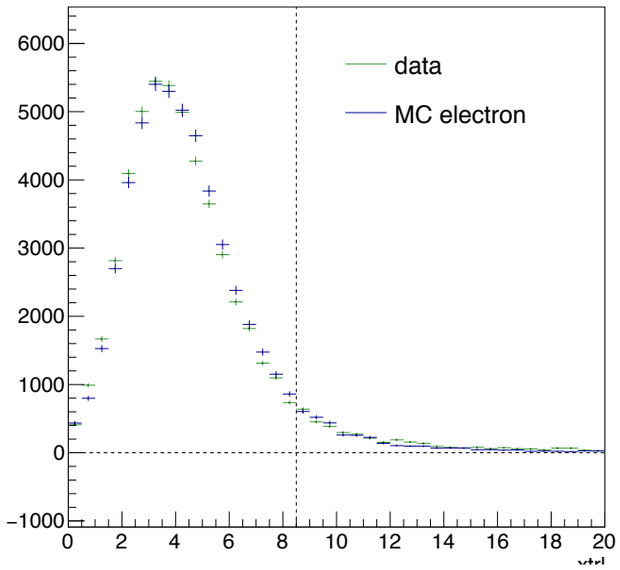
e/p discrimination



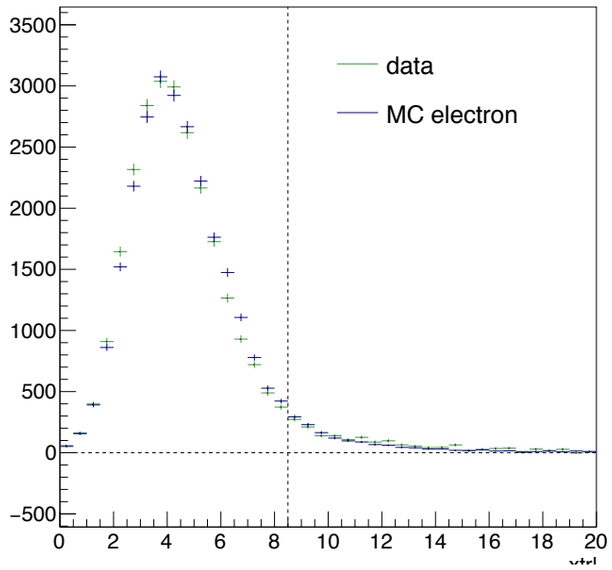
- **Rejects 99.99% protons @ 90% electron selection efficiency**

e/p discrimination

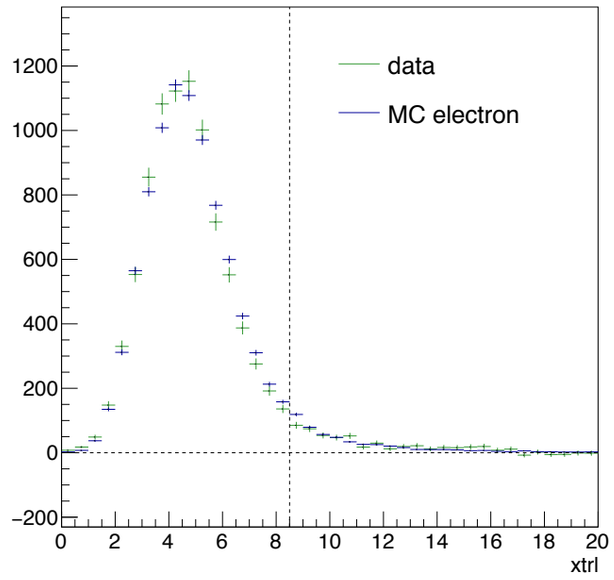
95 - 144 GeV



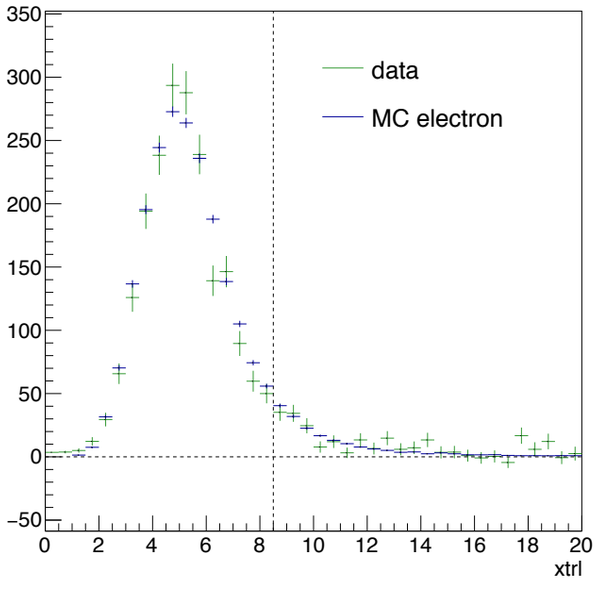
144 - 251 GeV



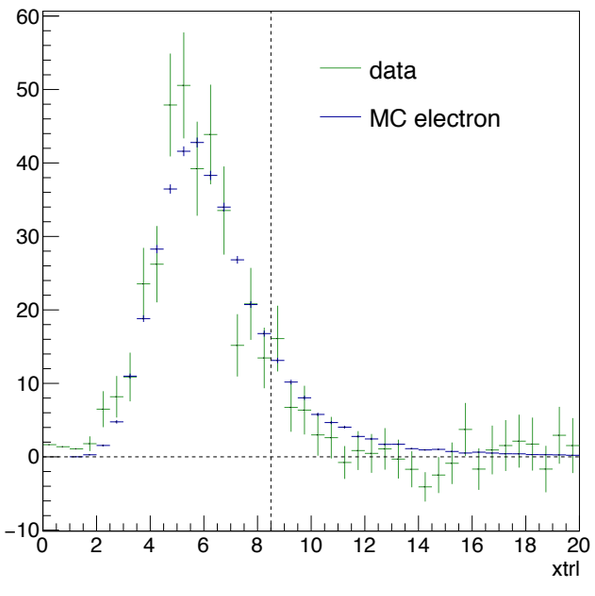
251 - 501 GeV



501 - 1000 GeV

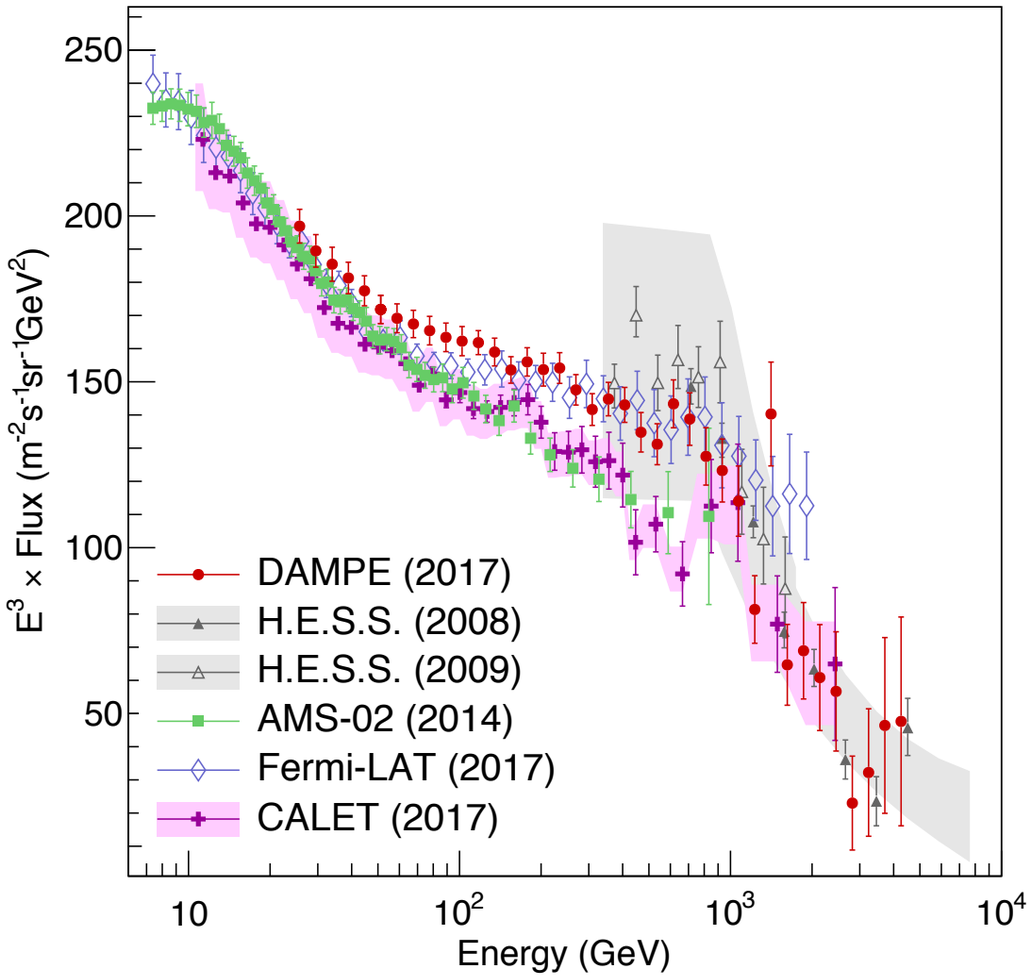


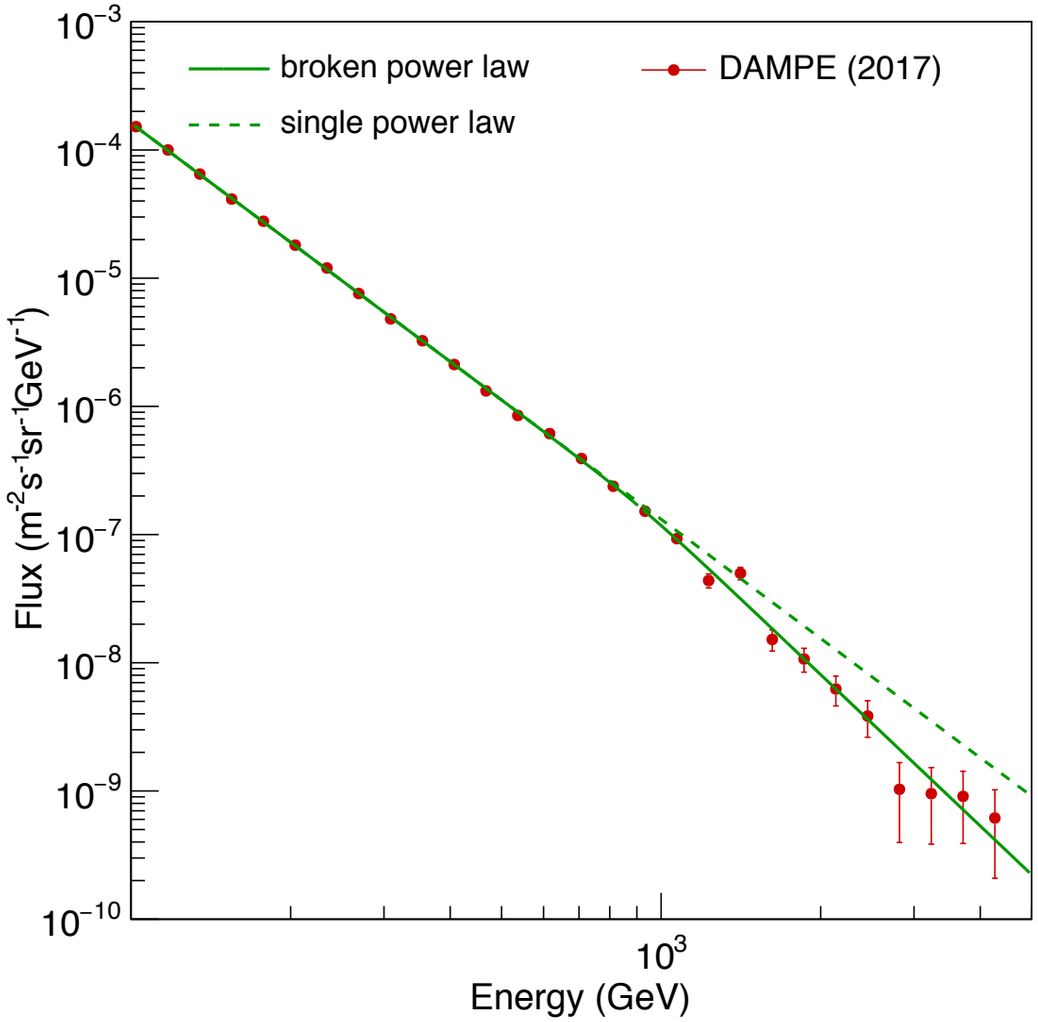
1000 - 2023 GeV



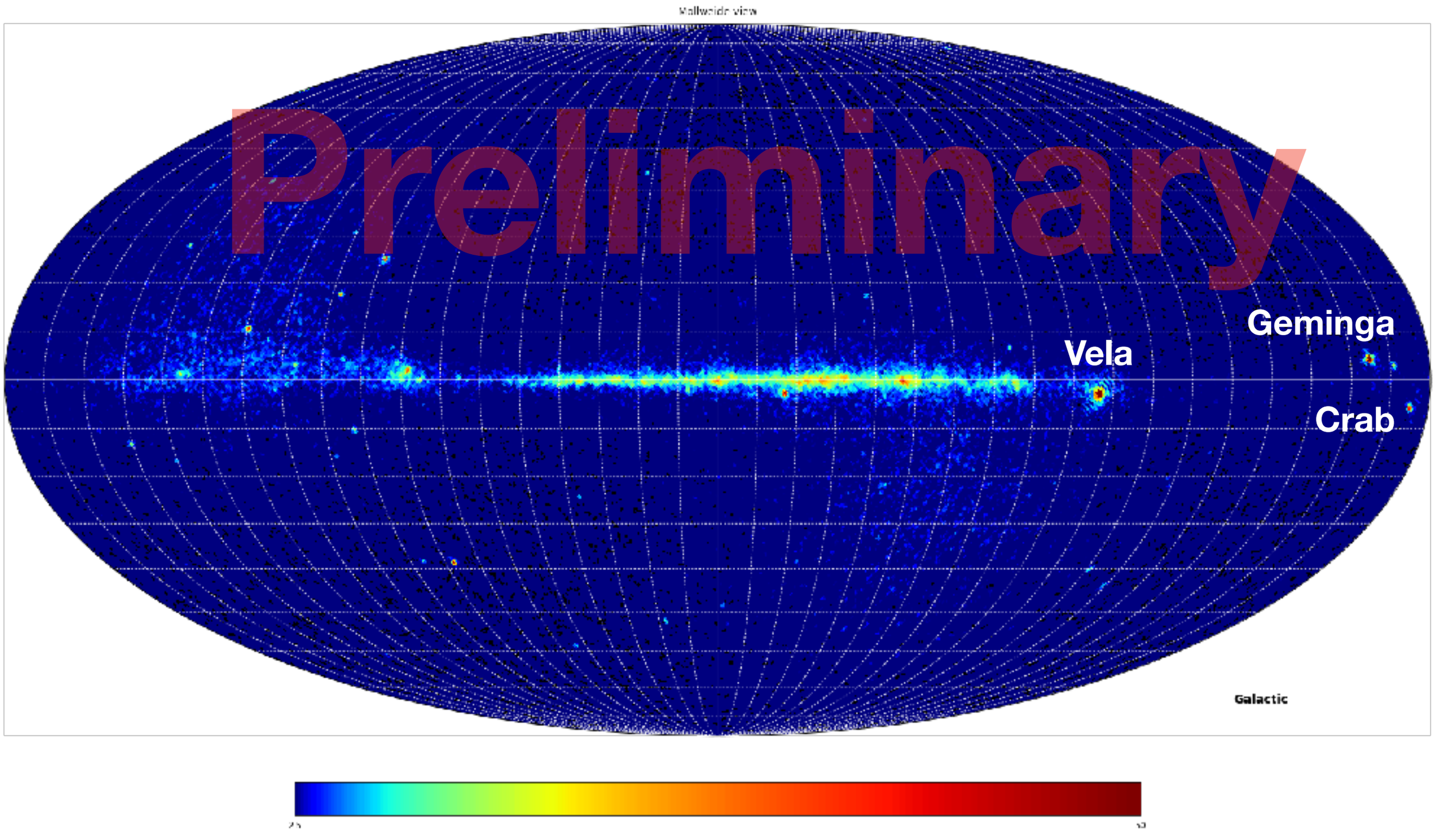
- **1.9% (25 GeT) — 8.4% (2TV) electron-selection efficiency correction applied, based on orbit data**

Direct detection of a break in the TeV cosmic-ray spectrum of $e^+ + e^-$





All-photon sky map



Summary

Detector:

- 0.3 m^2 x sr acceptance (e/γ)
- 32 X_0 thick calorimeter, 1% energy resolution.
- Precise silicon—tungsten tracker, 40 μm 0.2° resolution.
- 10^4 — 10^5 p rejection power (without NUD).

Performance:

- Successfully launched on December 17, 2015.
- Steady in-flight operation with high efficiency.
- Absolute energy scale using geomagnetic cutoff.
- Pointing direction cross checked using the photon sky map.

DAMPE → WUKONG (Monkey King)

Thank You!