DAMPE: status and results after two years in space

G. Ambrosi, on behalf of the DAMPE Collaboration

La Thuile 2018

The collaboration

- **CHINA**
  - Purple Mountain Observatory, CAS, Nanjing — ***Prof. Jin Chang***
  - 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

The physics goals

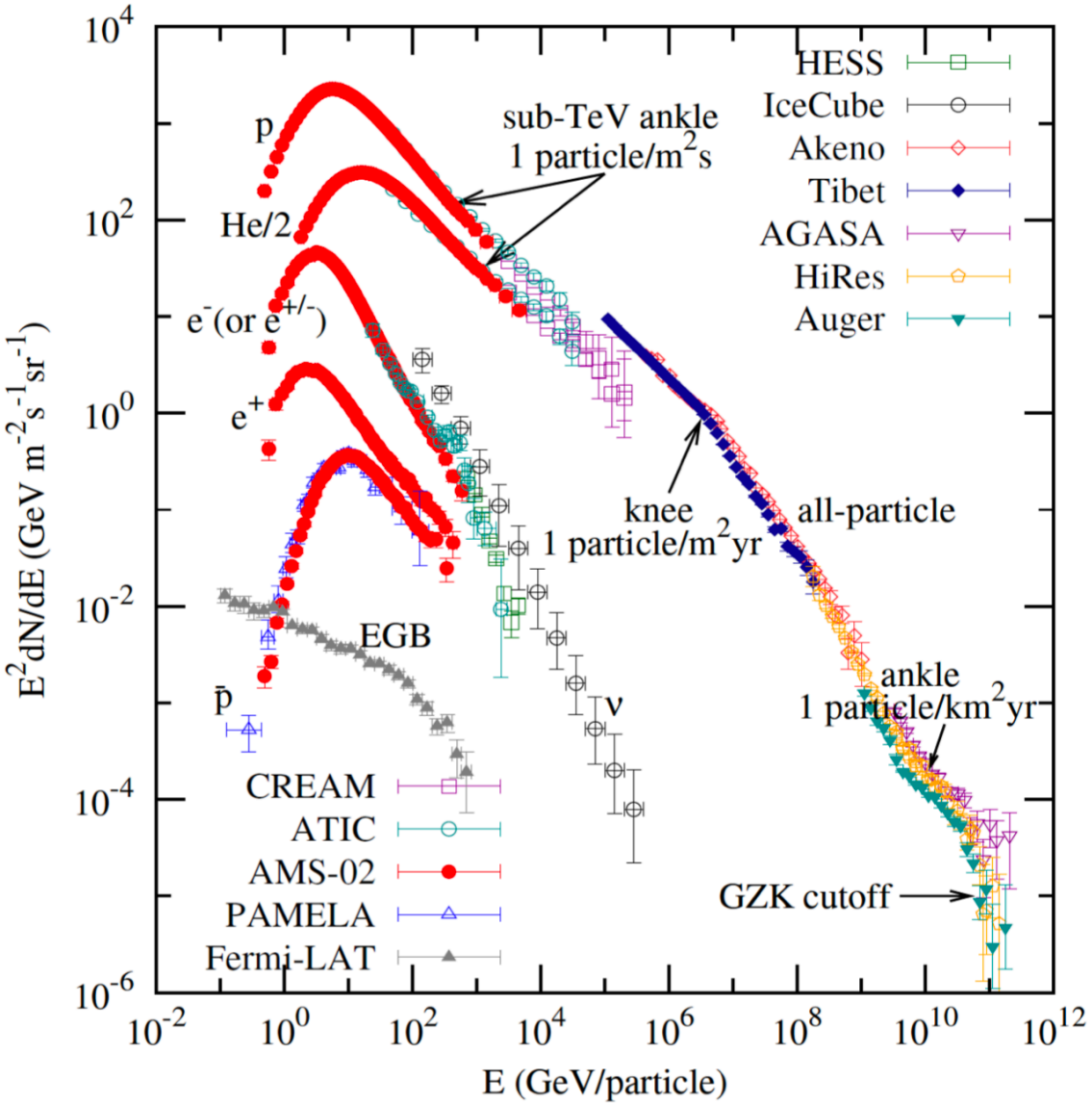
High energy particle detection in space

- Study of the cosmic electron and photon spectra
- Study of cosmic ray protons and nuclei: spectrum and composition
- High energy gamma ray astronomy
- Search for dark matter signatures in lepton spectra

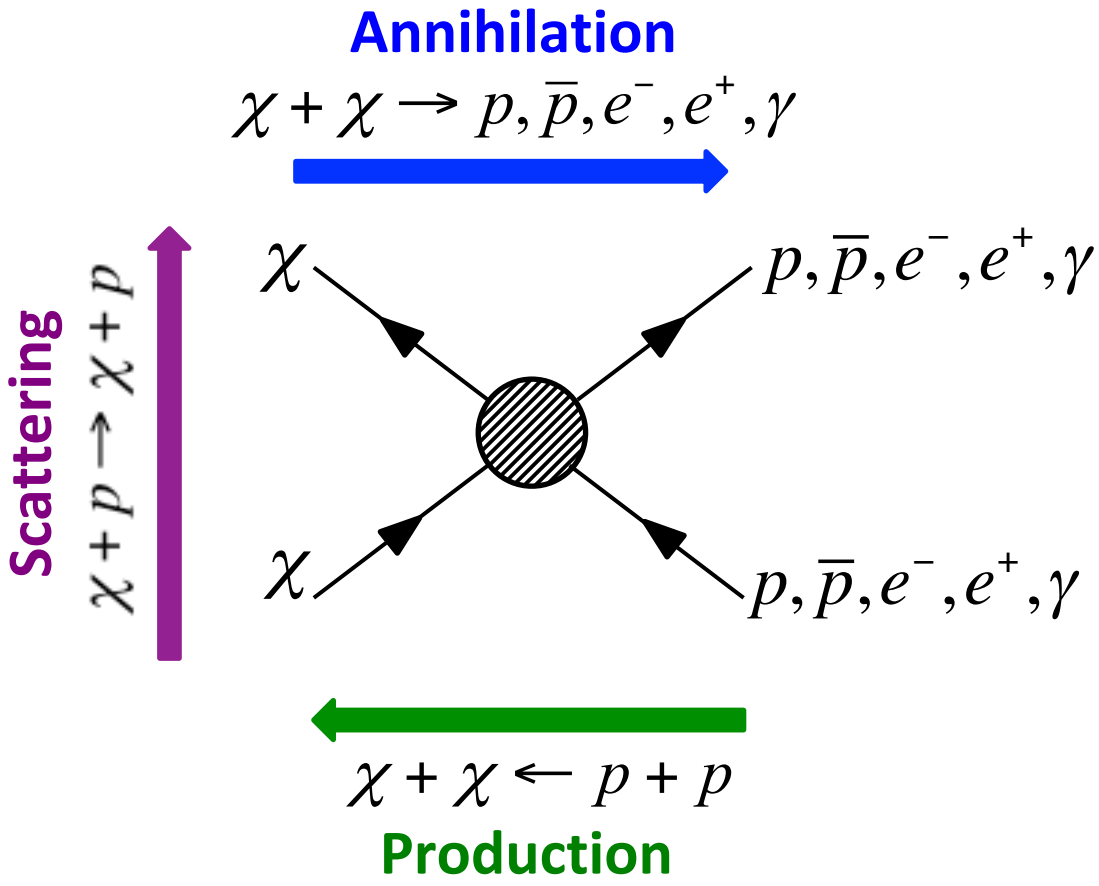
Detection of
2 GeV - 10 TeV e/γ
50 GeV - 500 TeV protons and nuclei
with excellent energy resolution , tracking precision and particle identification capabilities

- Exotica and “unexpected” , e.g. GW e.m. counterpart in the FoV

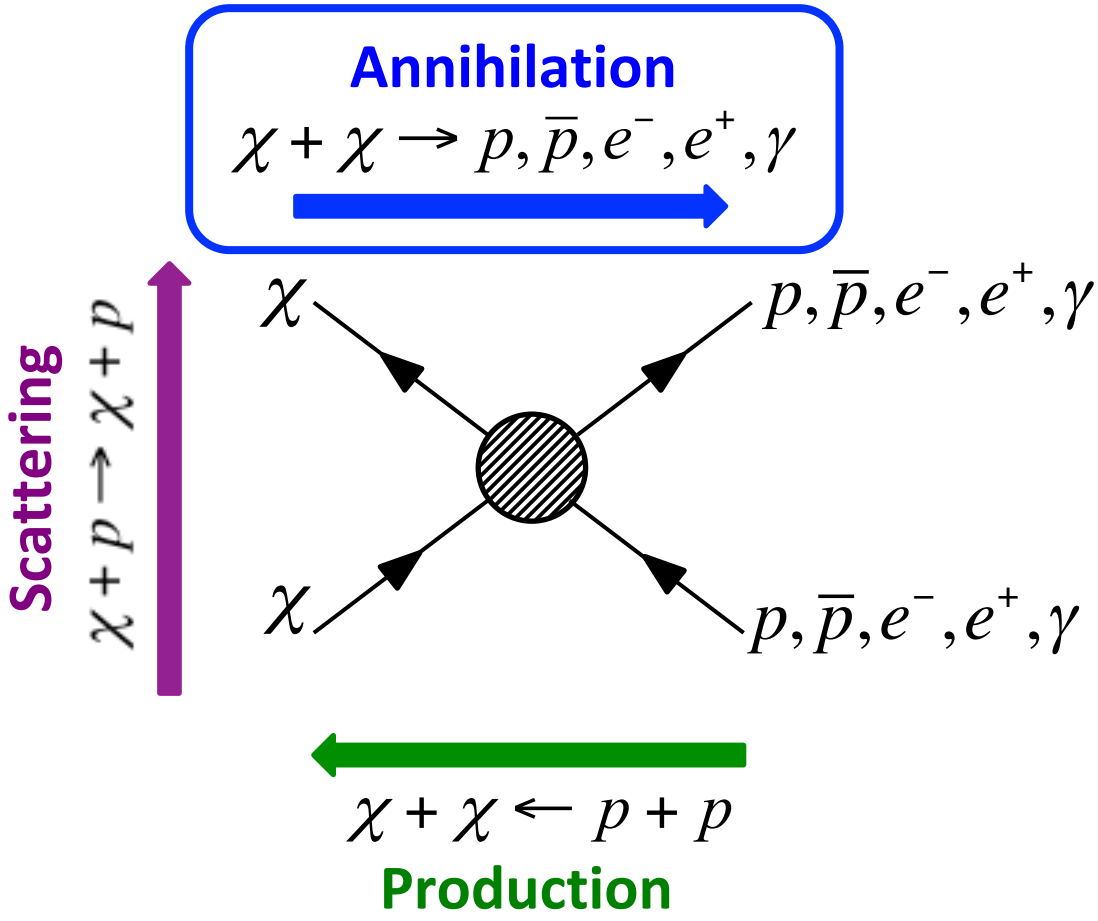
All particle spectrum



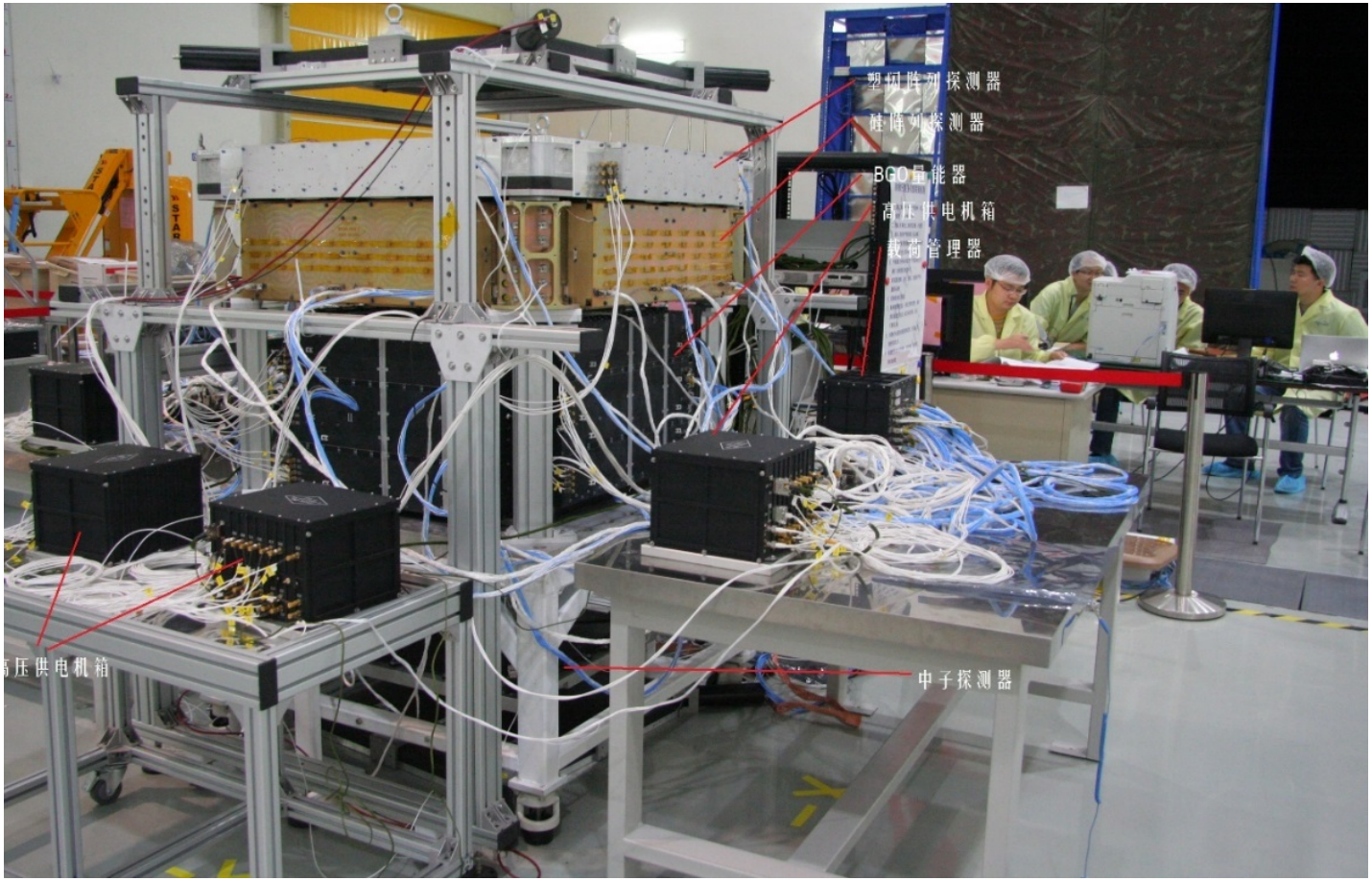
The quest for dark matter



The quest for dark matter

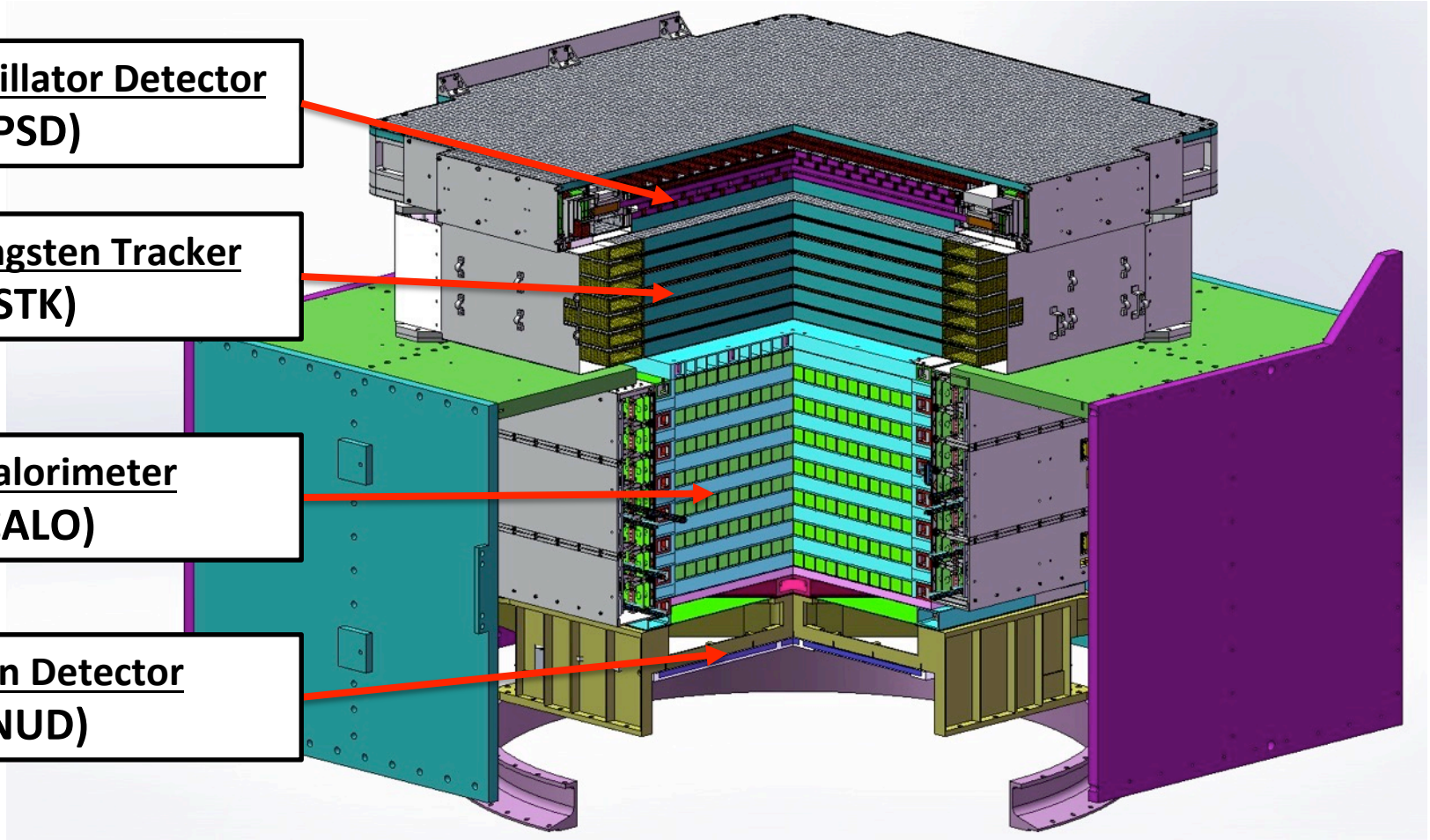


The detector during tests on ground



The detector final integration

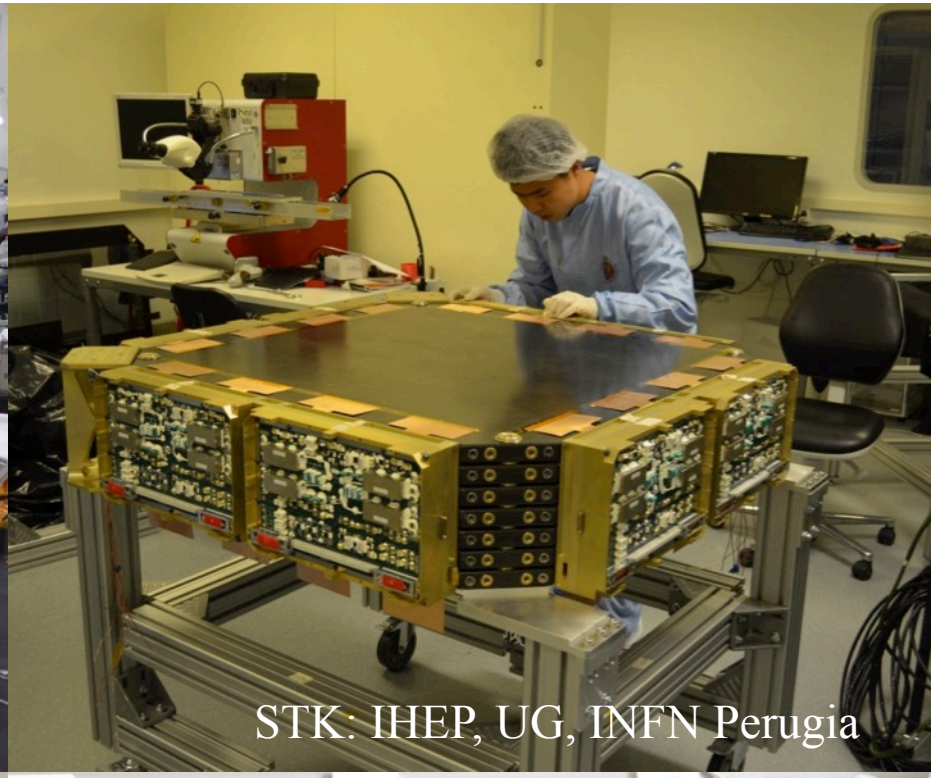
The detector



- Charge measurement (dE/dx in PSD , STK and BGO)
- Tungsten converter (pair production)
- Precise tracking (silicon strips)
- Thick calorimeter (BGO bars)
- Hadron rejection (neutron detector)

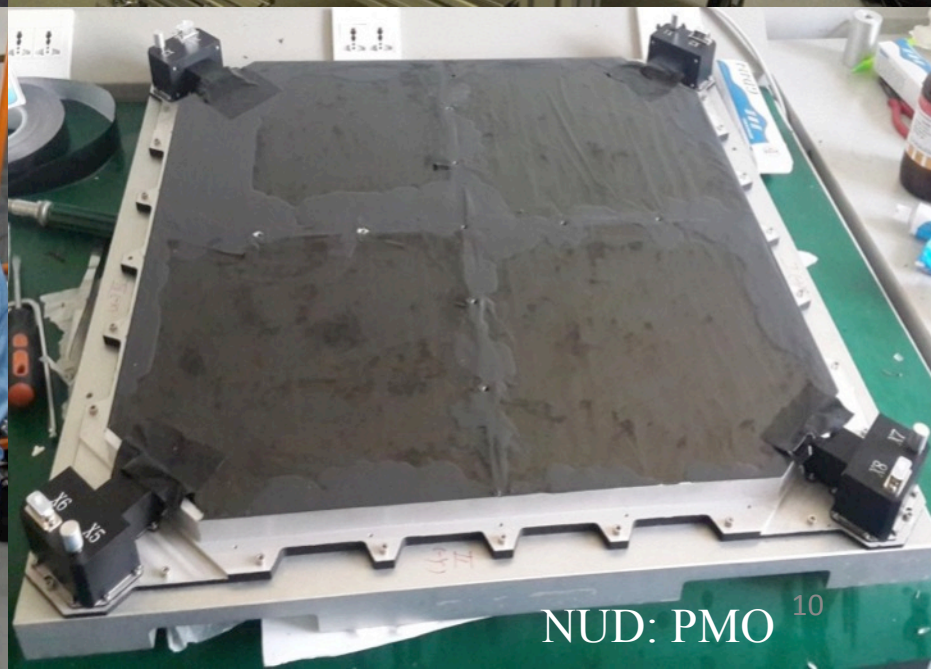
high energy
γ-ray, electron and cosmic ray
telescope

PSD: IMP



STK: IHEP, UG, INFN Perugia

BGO: USTC & PMO



NUD: PMO

Expected performance

Parameter	Value
Energy range of gamma rays/electrons	5GeV to 10 TeV
Energy resolution (e 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 (γ-rays)	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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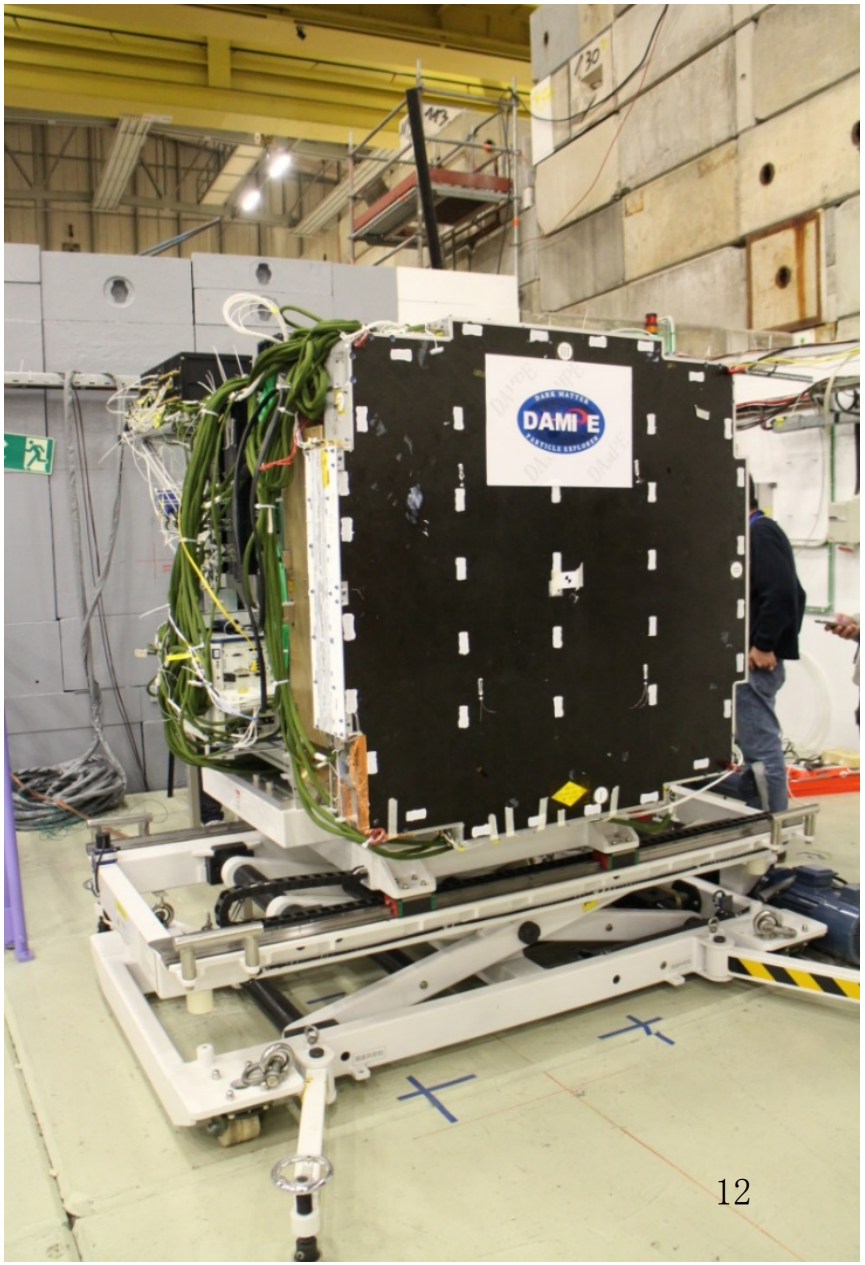
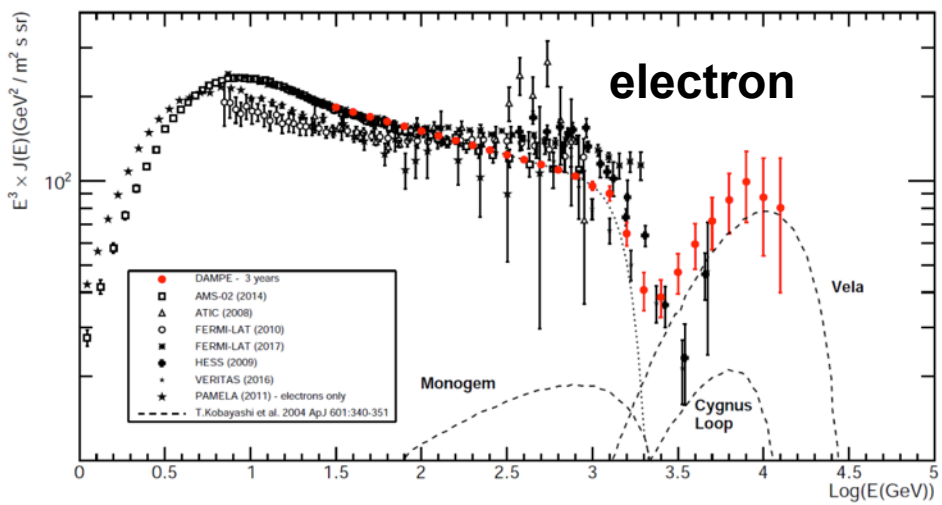
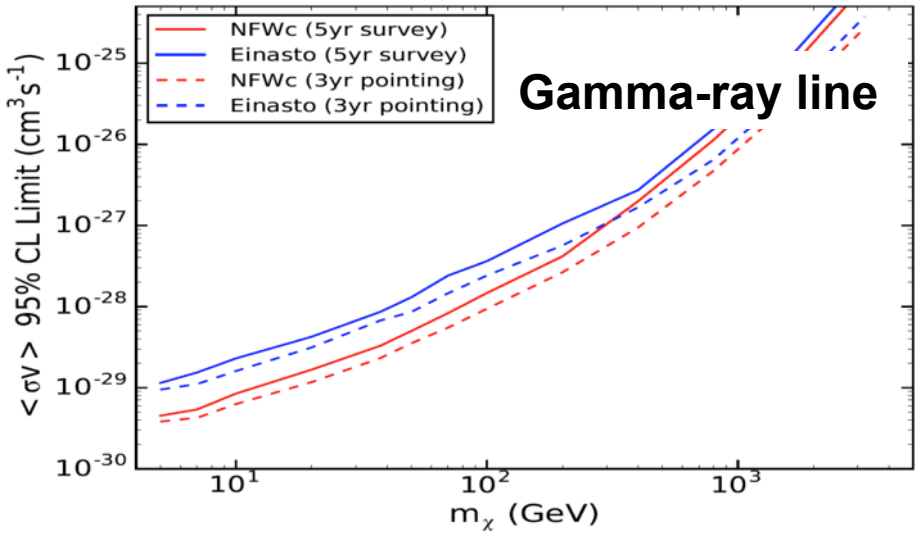
Beam test @ CERN

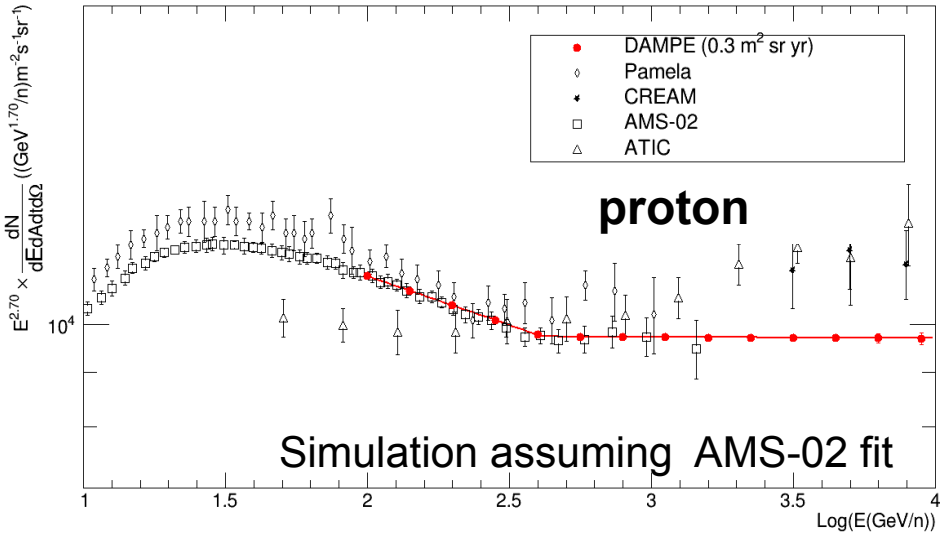
- 14days@PS，29/10-11/11 2014
  - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
  - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
  - π-@ 3GeV/c, 10GeV/c
  - γ @ 0.5-3GeV/c
- 8days@SPS，12/11-19/11 2014
  - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
  - 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

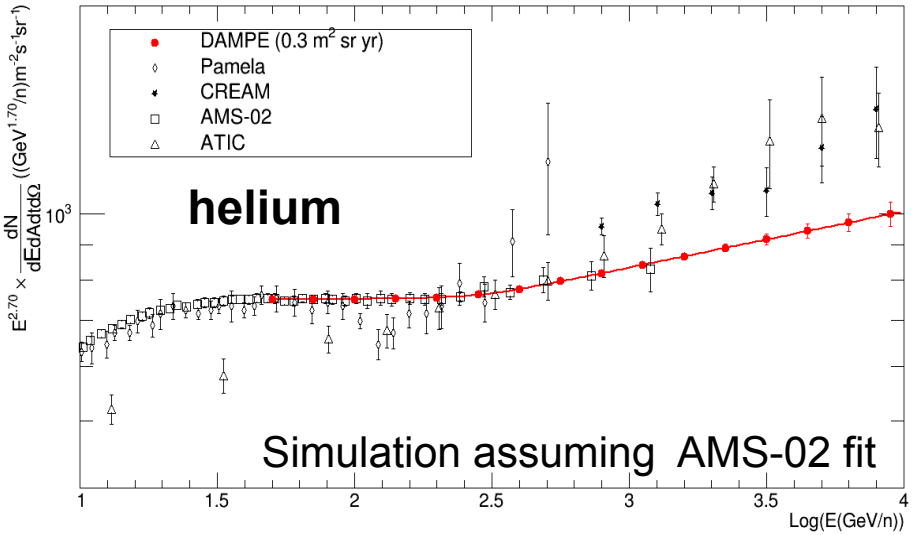


Expected performance





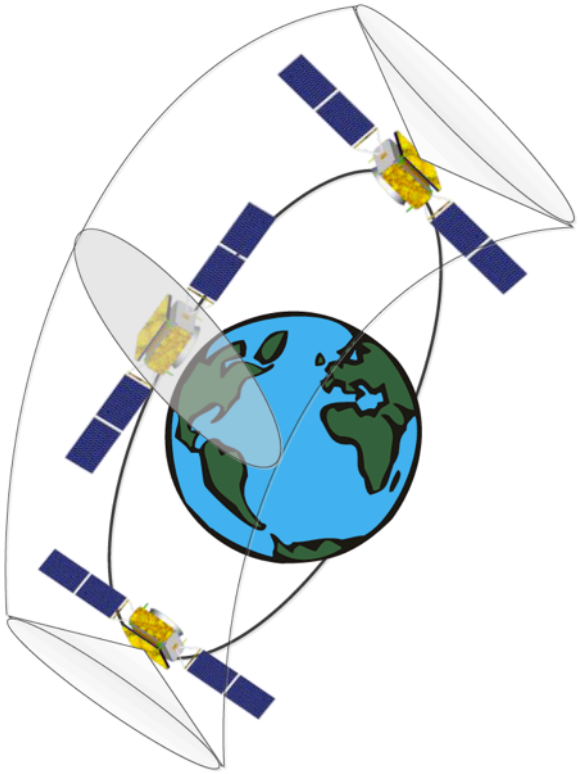


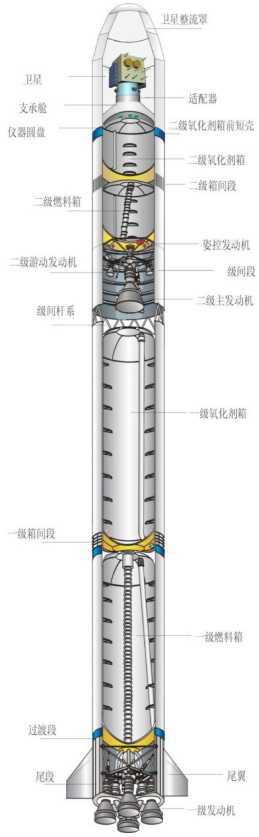


DAMPE mission

- 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



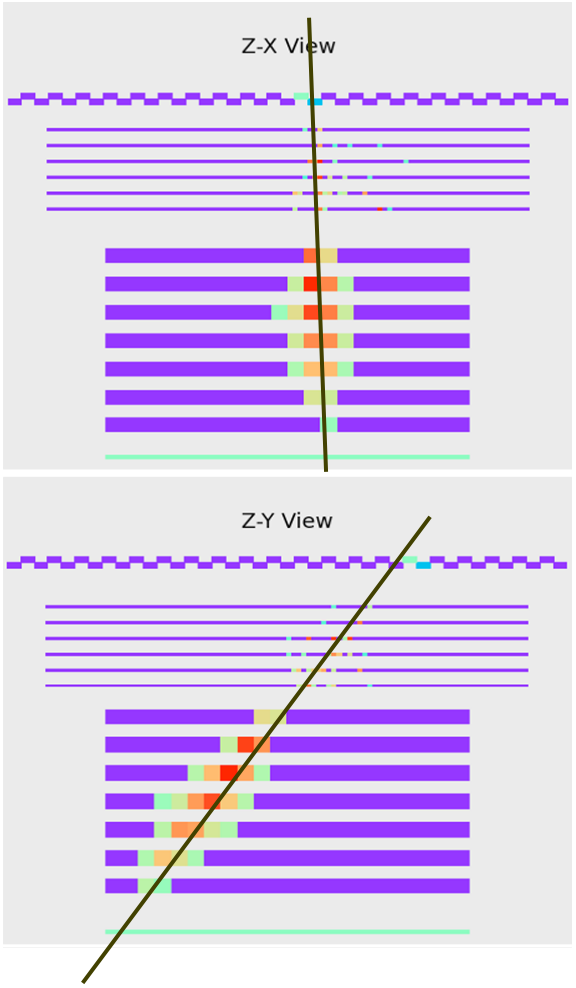


Launch on 17th Dec. 2015

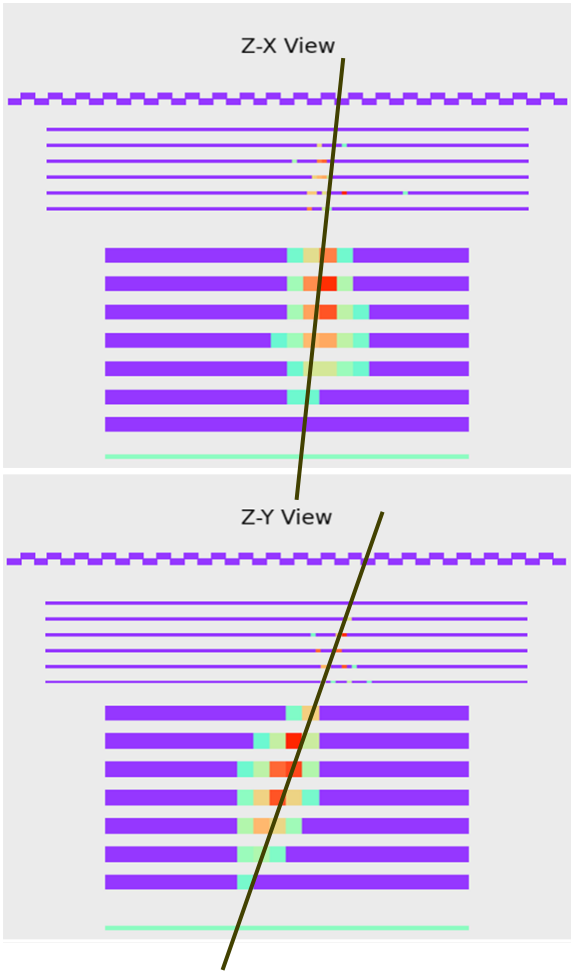
Jiuquan Satellite Launch Center, Gobi desert

Signals for different particles

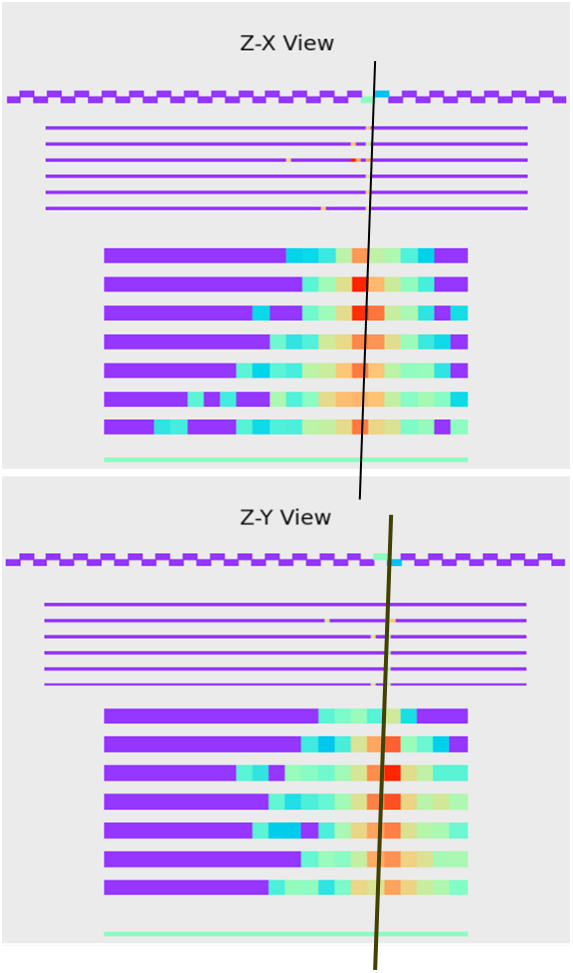
electron



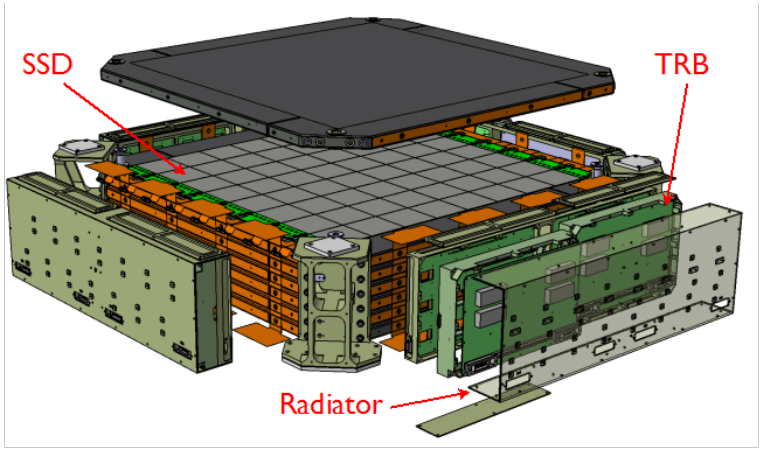
gamma



proton



Instrument development: STK

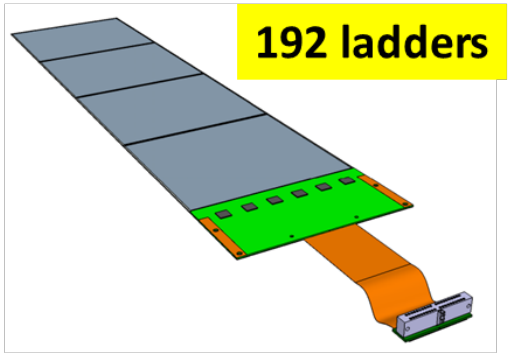


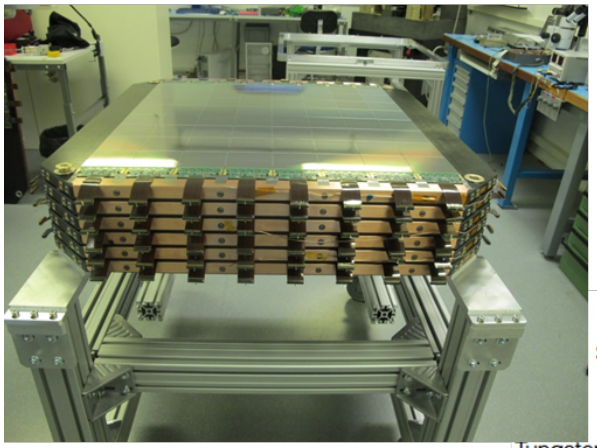
- 12 layers (6x, 6y) of single-sided Si strip detector mounted on 7 support trays
- Tungsten plates (1mm thick) integrated in trays 2, 3, 4 (from the top)
  - Total 0.85 X_0 for photon conversion

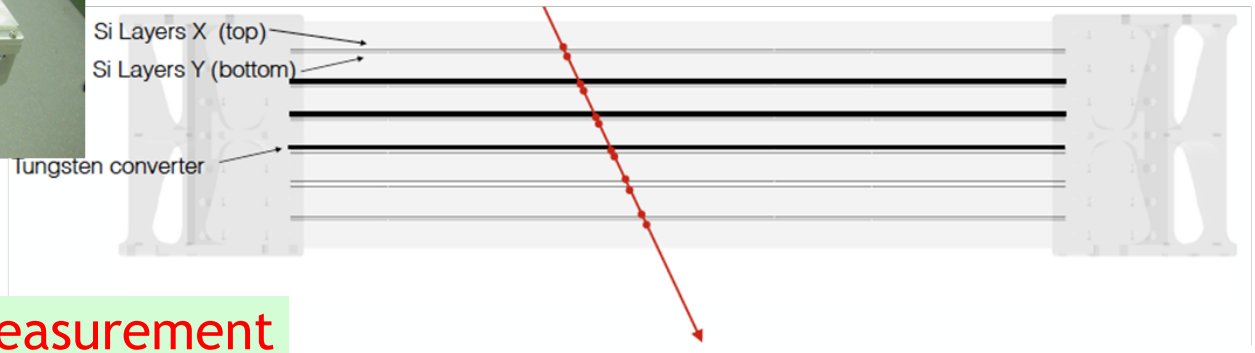
768 silicon sensors
95 x 95 x 0.32 mm^3

1,152 ASICs

73,728 channels

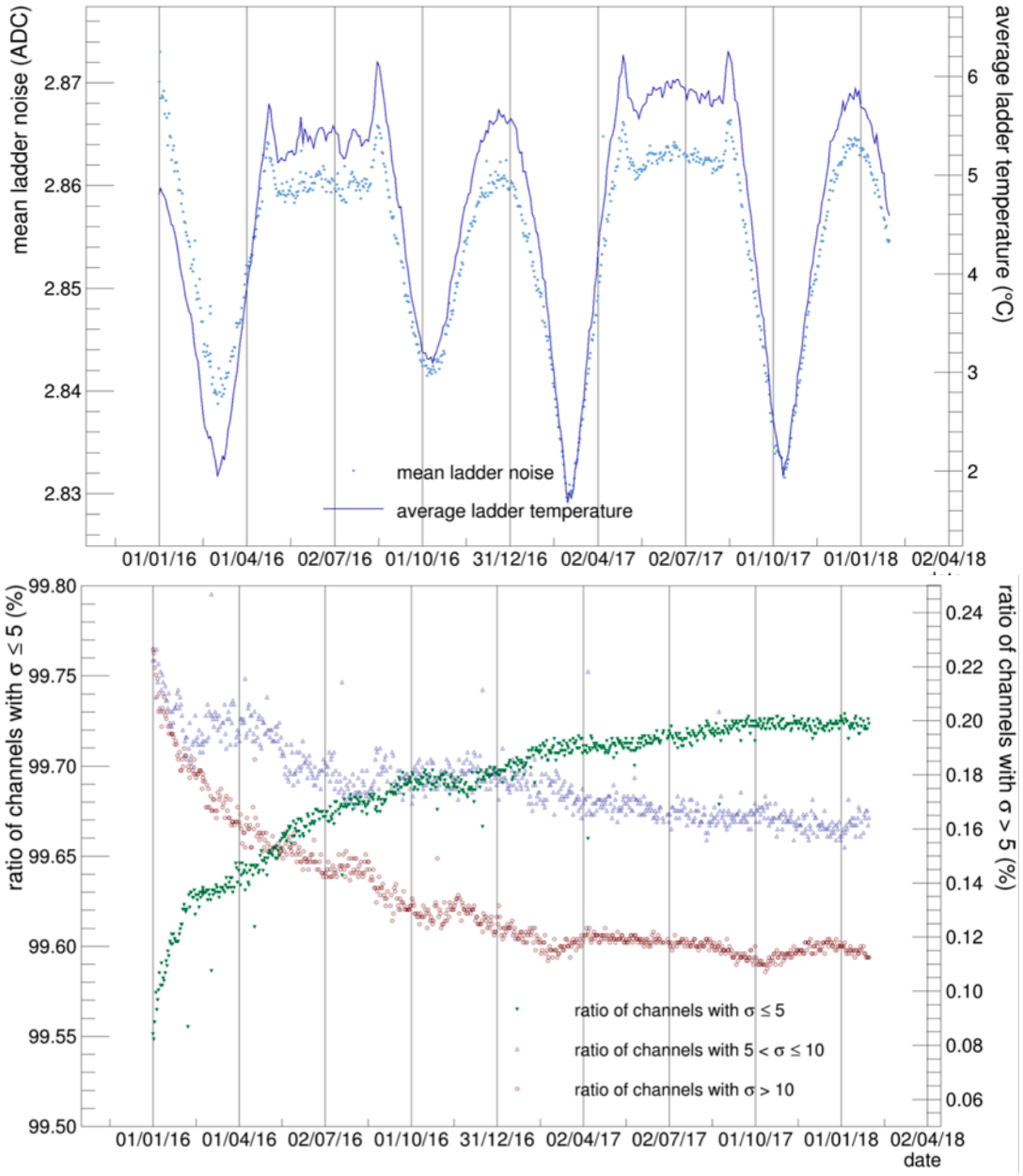




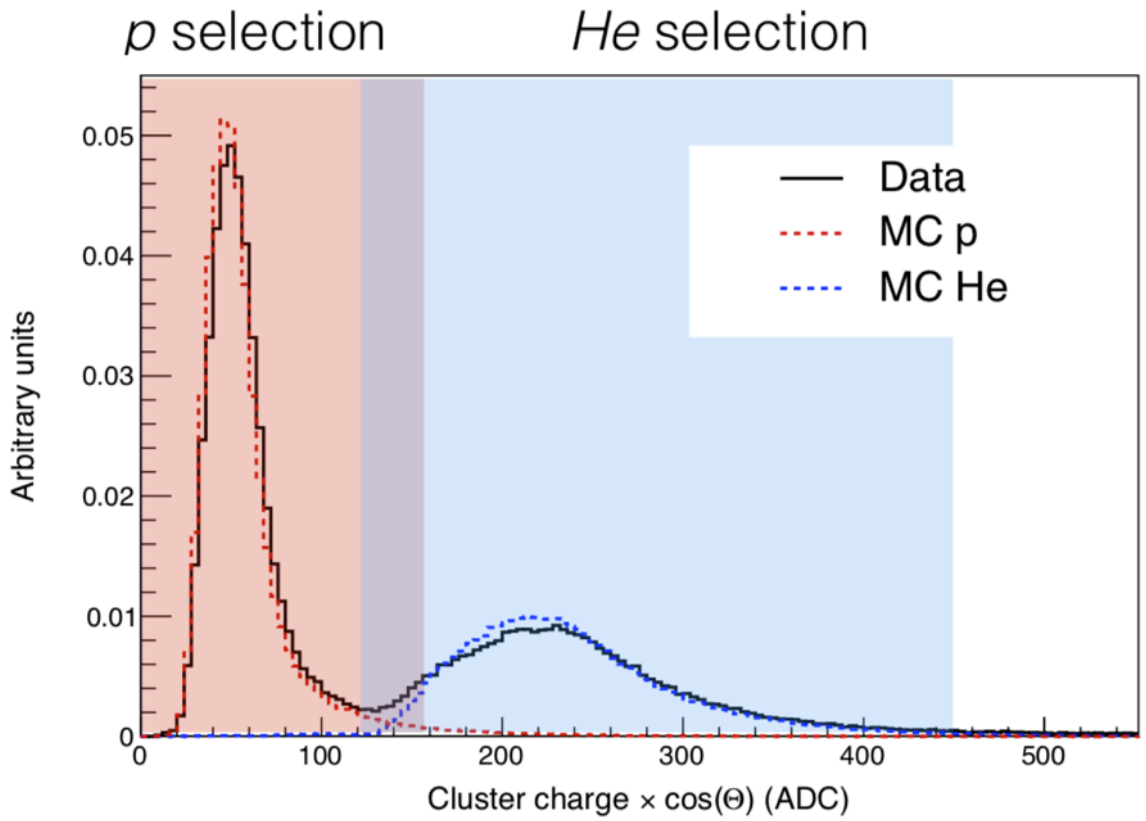


Charge and track measurement

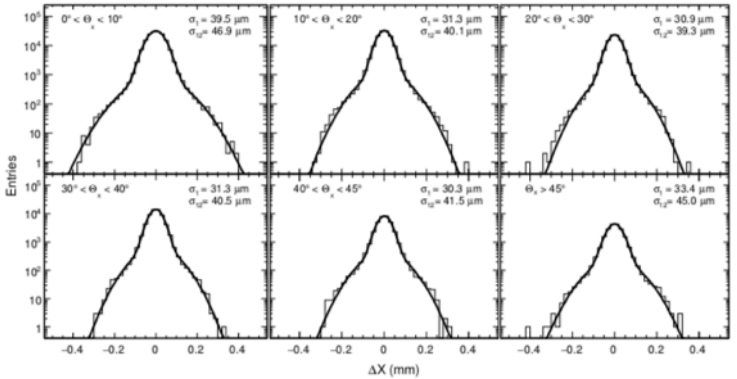
STK noise


mean ladder noise (ADC)
average ladder temperature (°C)
mean ladder noise
average ladder temperature
01/01/16 01/04/16 02/07/16 01/10/16 31/12/16 02/04/17 02/07/17 01/10/17 01/01/18 02/04/18
ratio of channels with σ ≤ 5 (%)
ratio of channels with σ > 5 (%)
ratio of channels with σ ≤ 5
ratio of channels with 5 < σ ≤ 10
ratio of channels with σ > 10
date

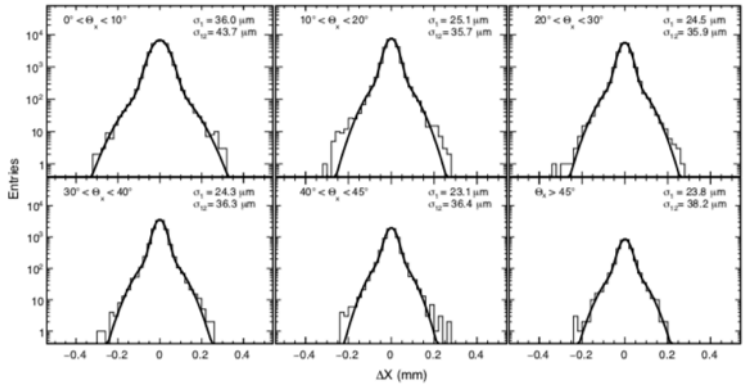
STK resolution



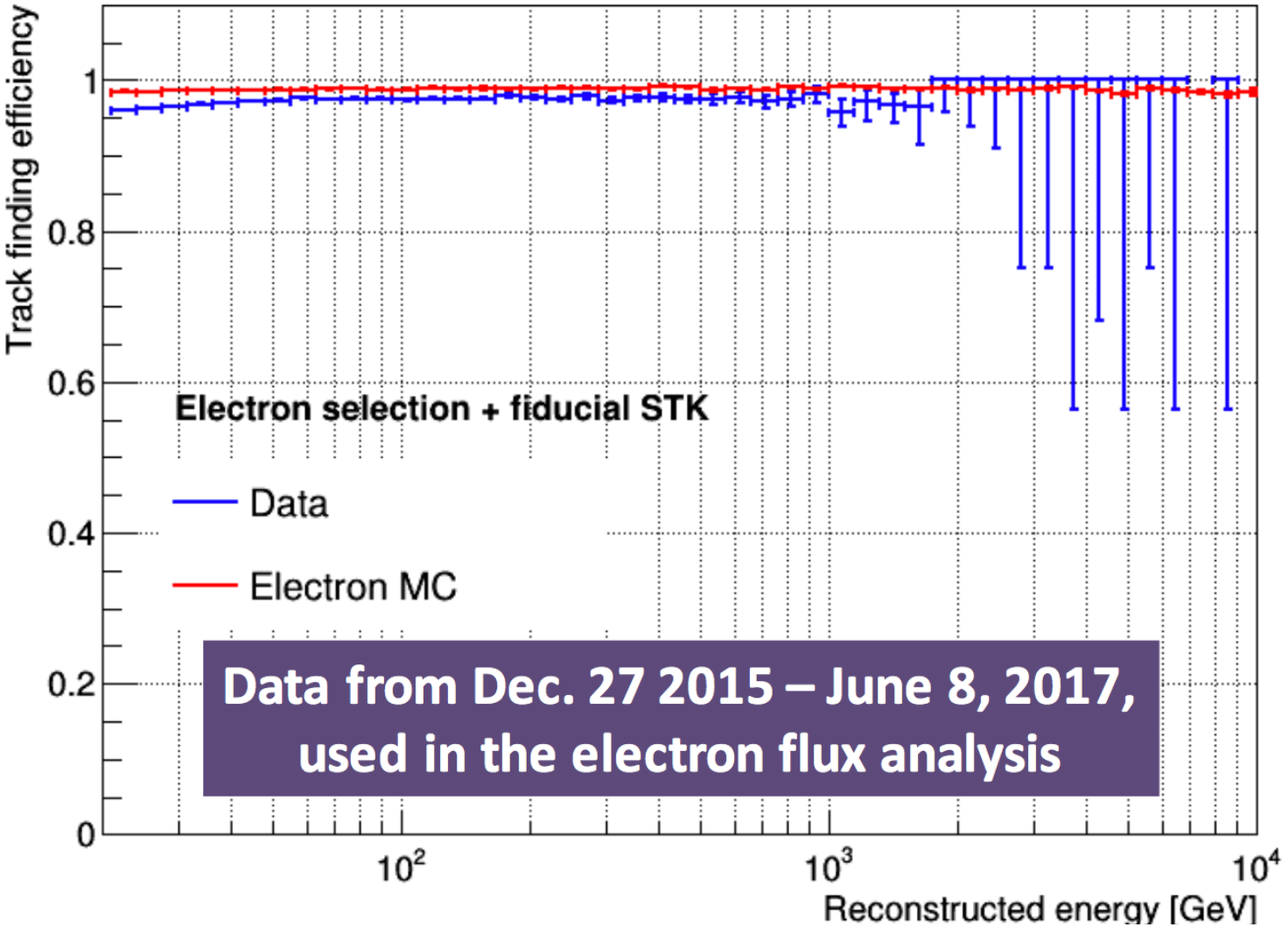
p resolution: **~ 41 μm** (intermediate angles)



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



STK tracking efficiency

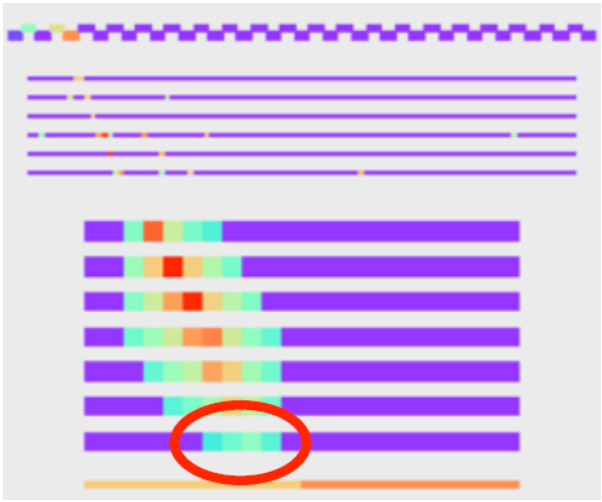


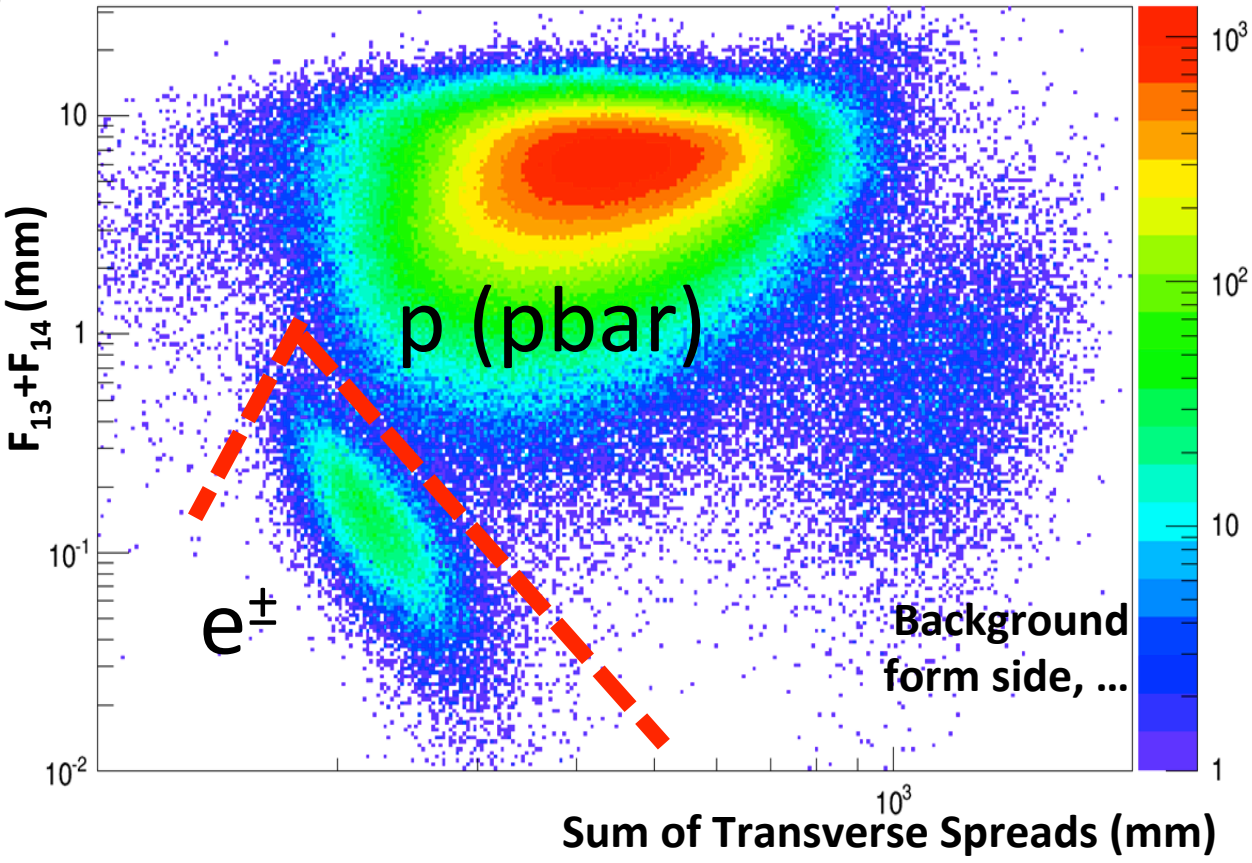
Electron identification

One possible "shape parameter"

$$F_i = Spread_i \times \frac{E_i}{E_{tot}}$$

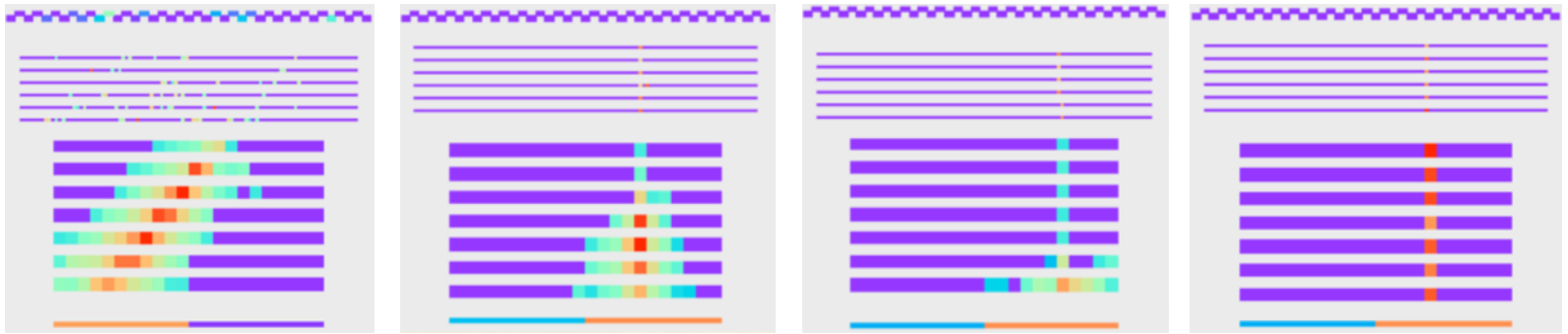
Rejection power > 10^5



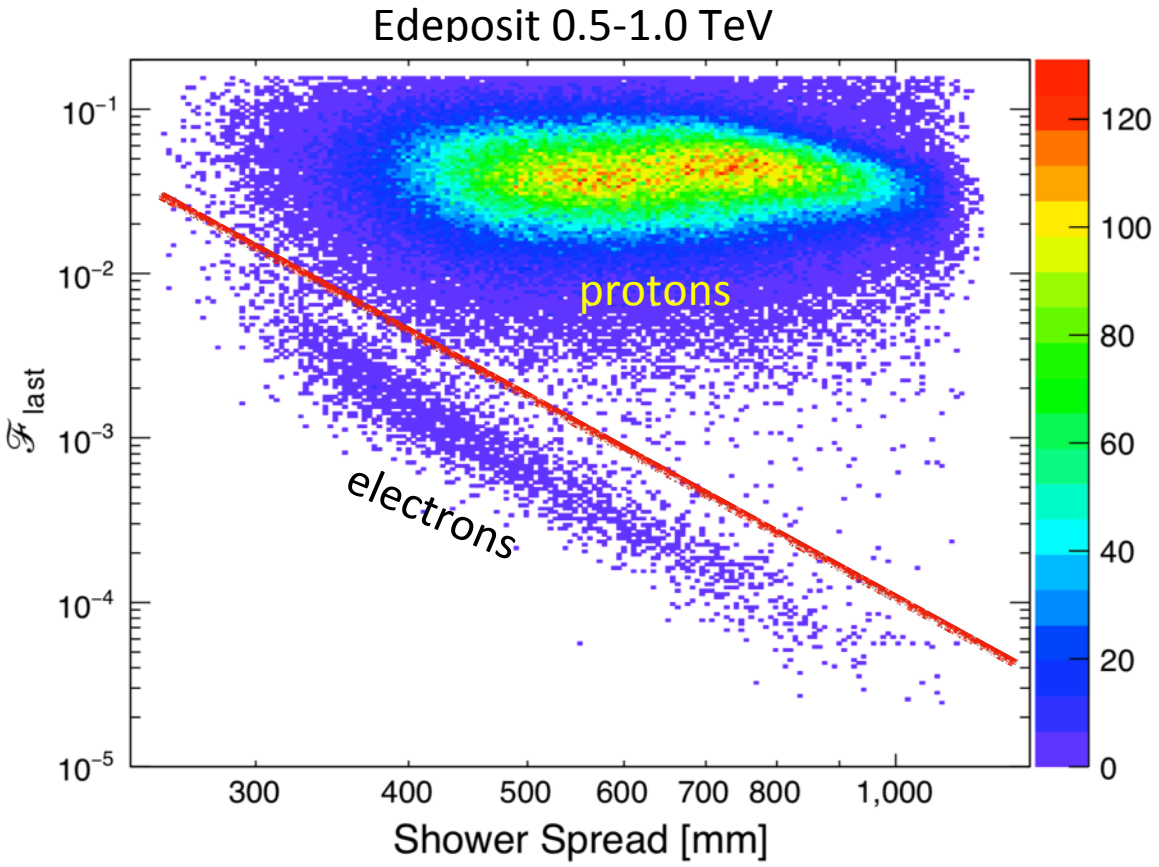


Electrons and positrons

Protons and nuclei

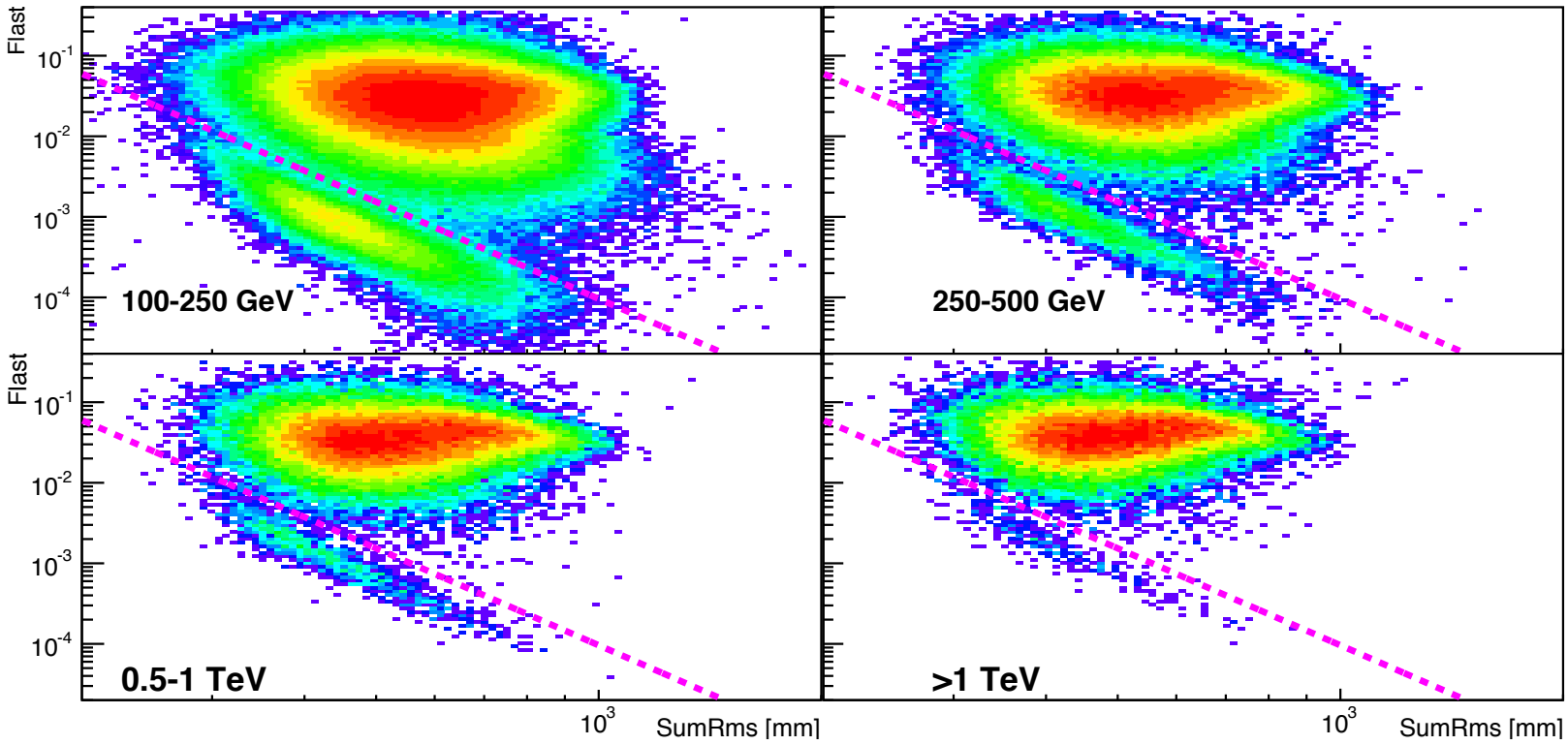


Electron identification

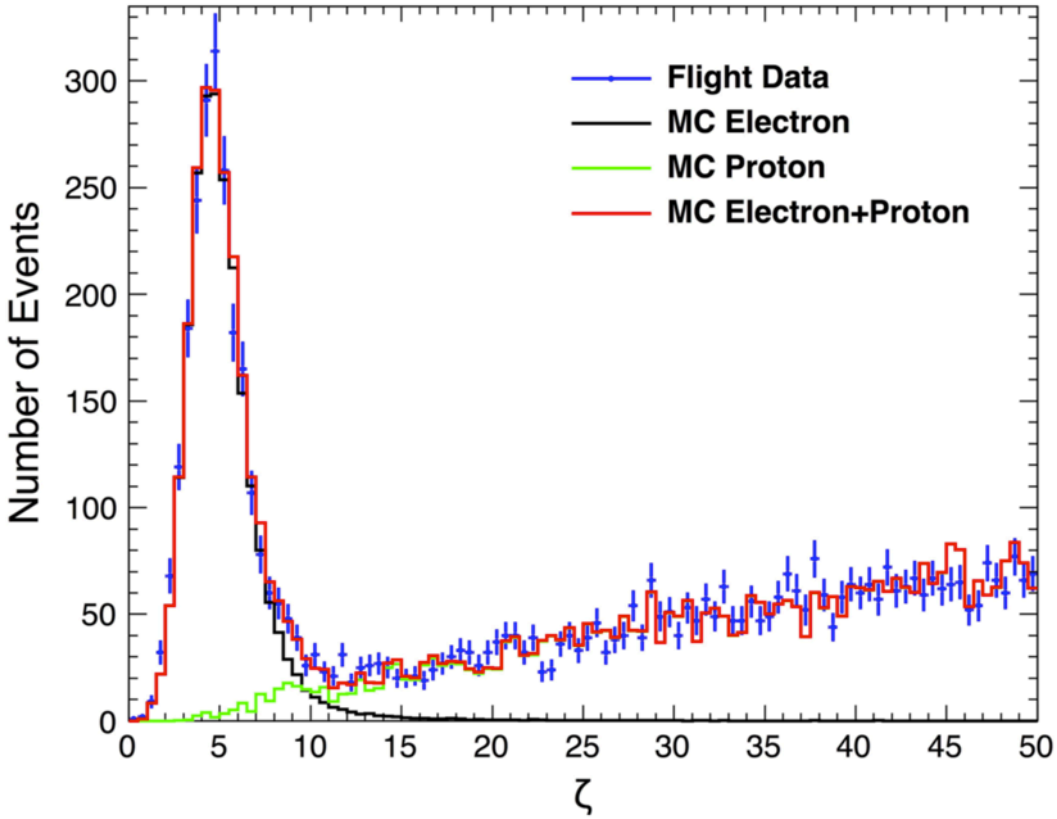


$$RMS_i = \sqrt{\frac{\sum_j (x_{j,i} - x_{c,i})^2 E_{j,i}}{\sum_j E_{j,i}}}$$

Electron identification

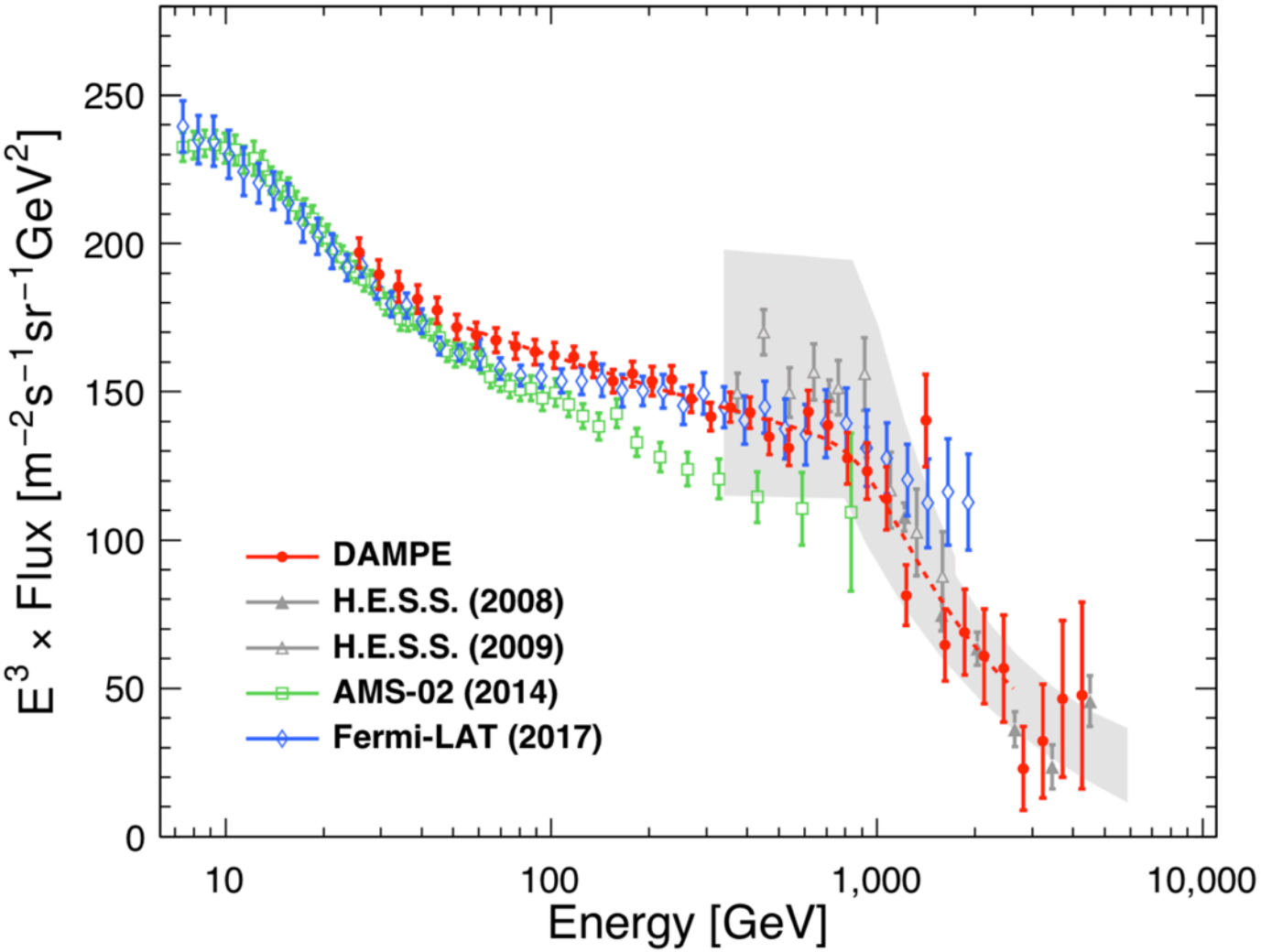


Electron identification



$$\zeta = \mathcal{F}_{\rm last} \times (\Sigma_i RMS_i/{\rm mm})^4/(8\times 10^6)$$

Electron flux



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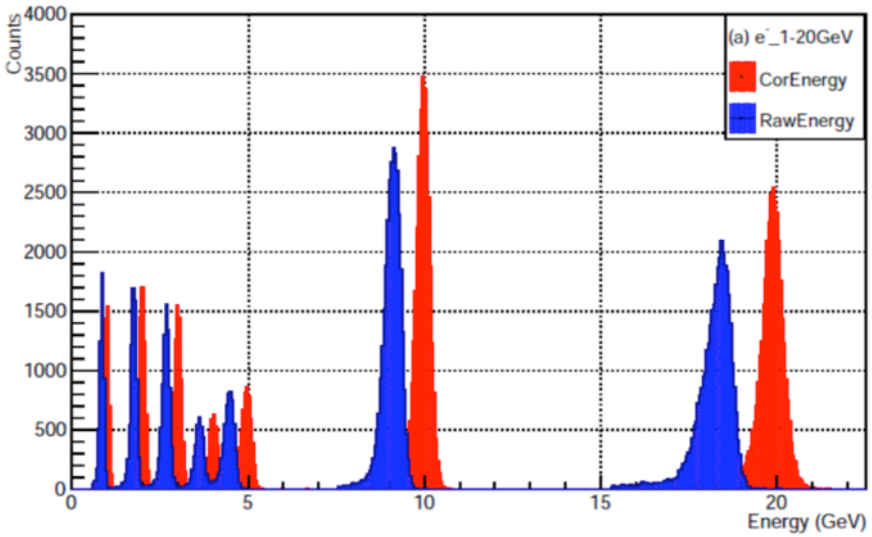
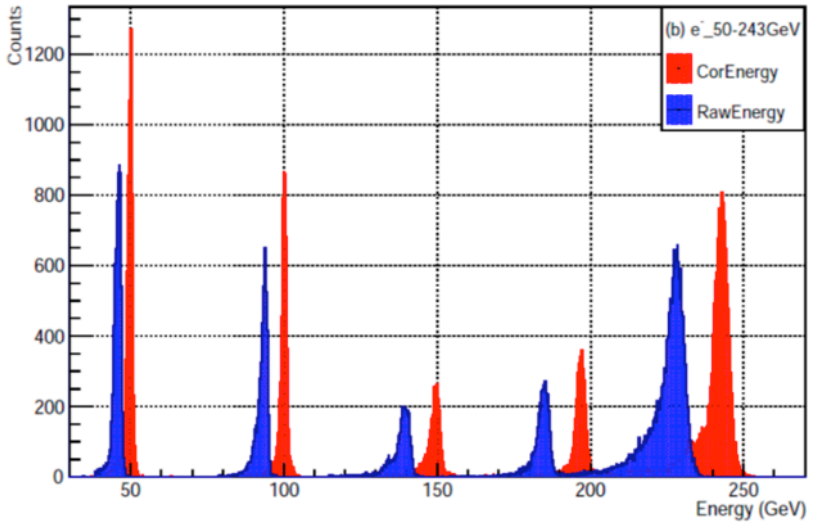
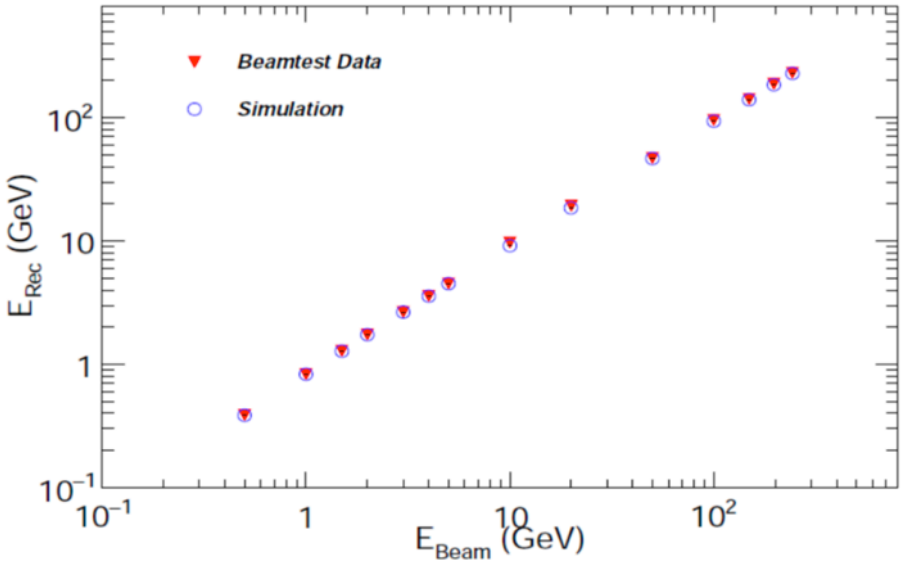
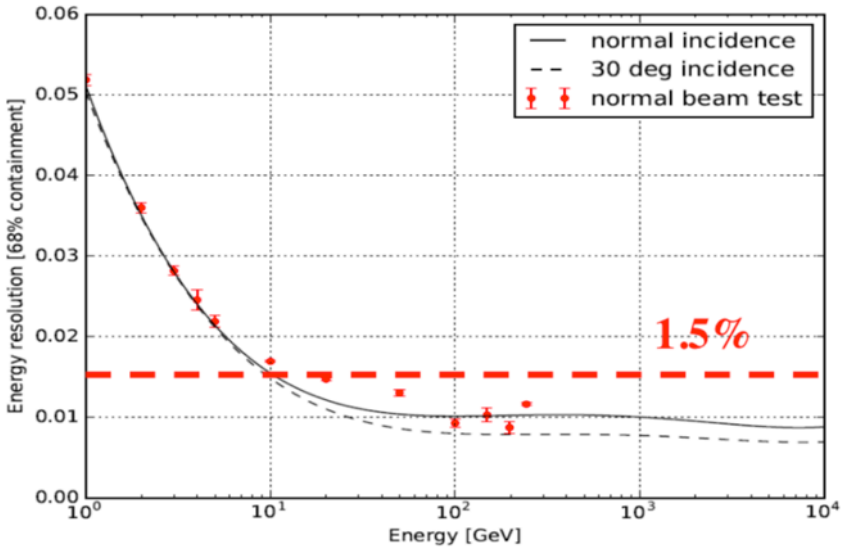
BGO energy lin. and res., beam test





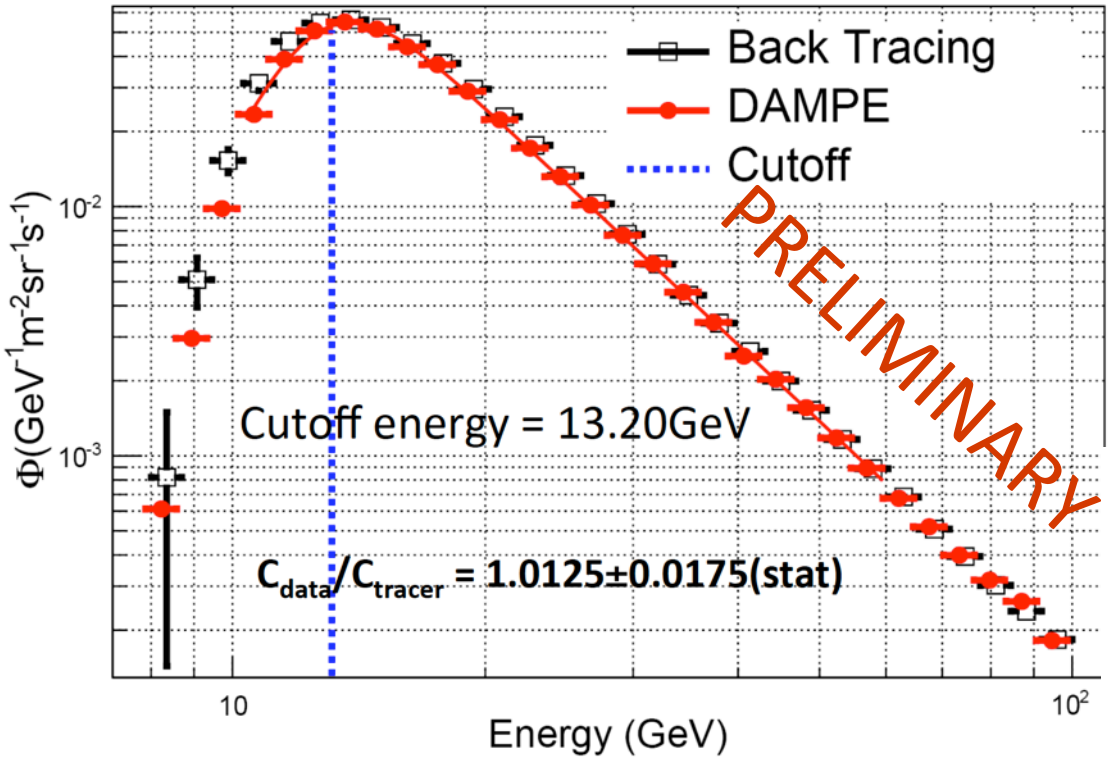


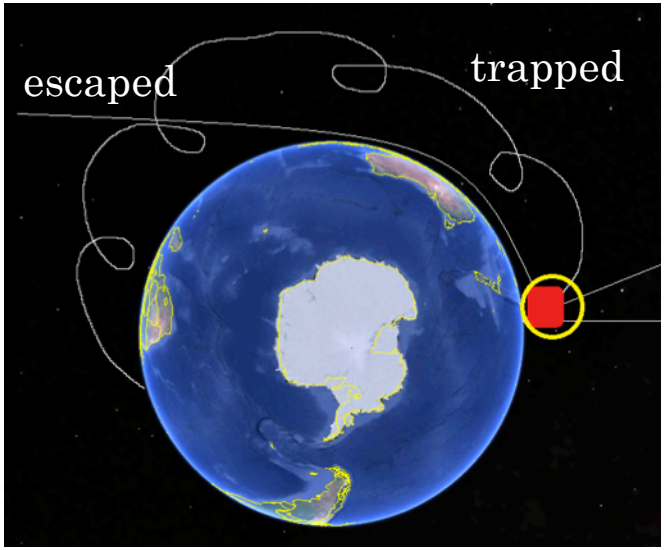
Energy linearity of electrons

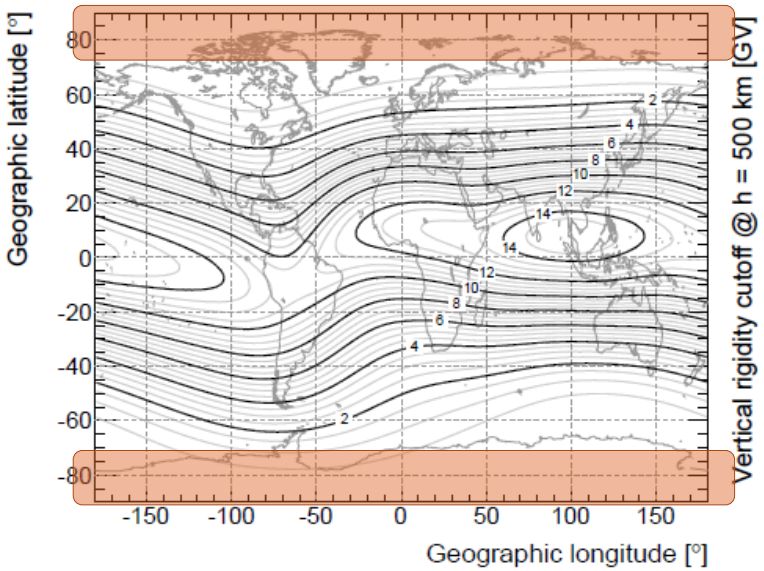


Energy resolution of electrons

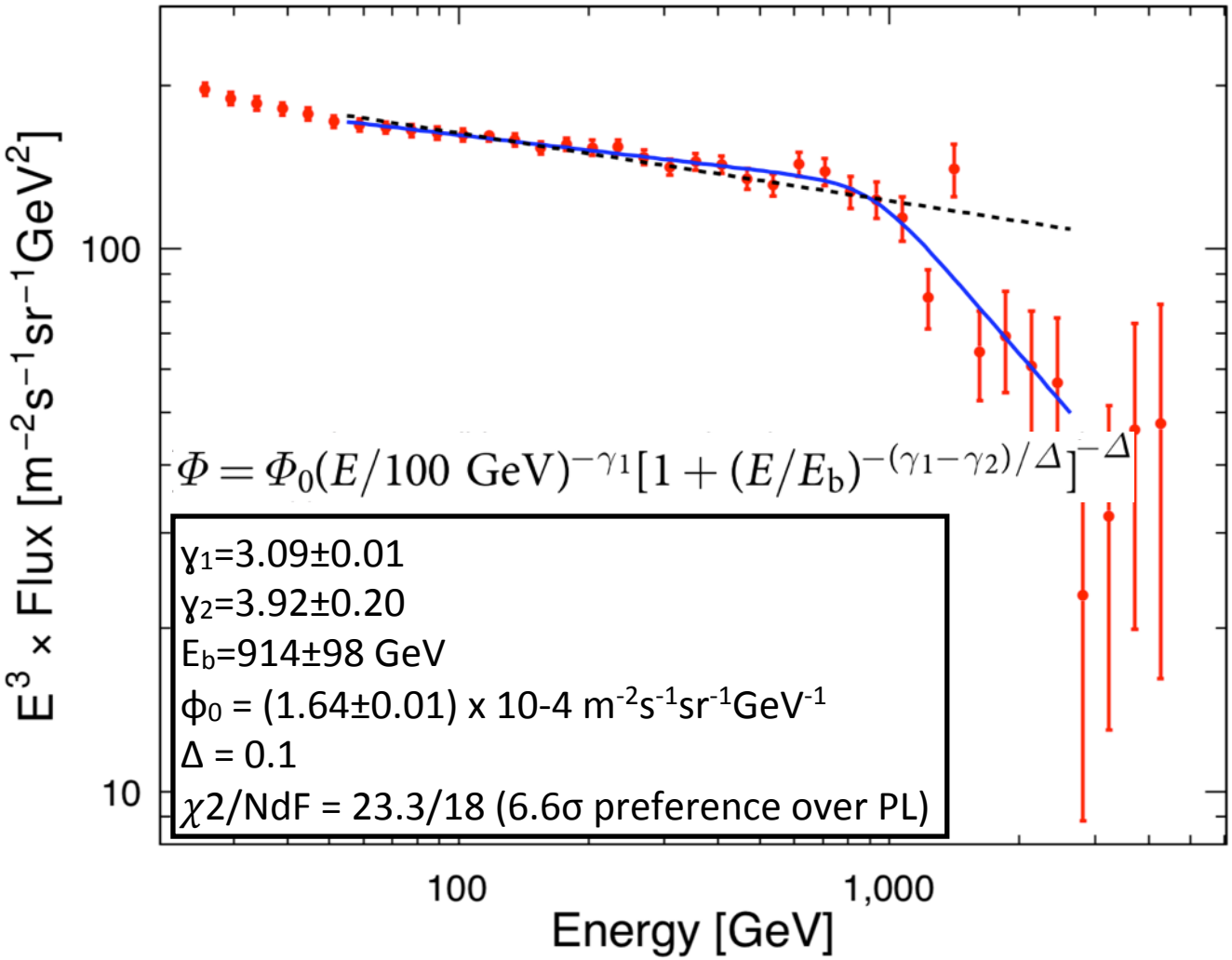
Absolute energy scale



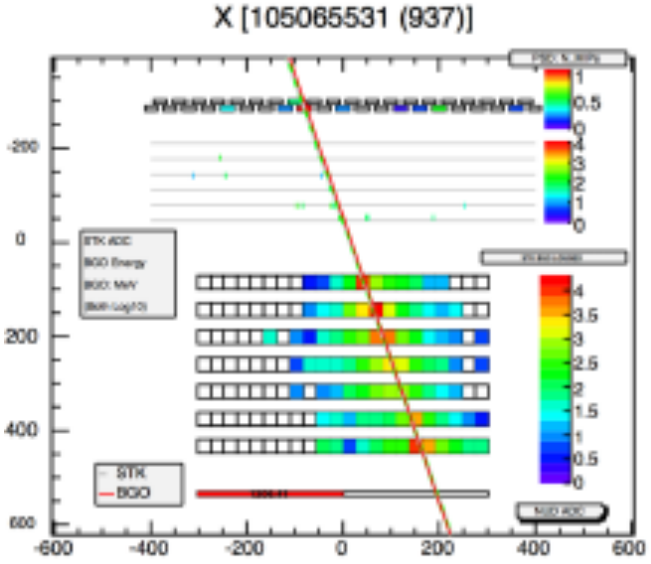




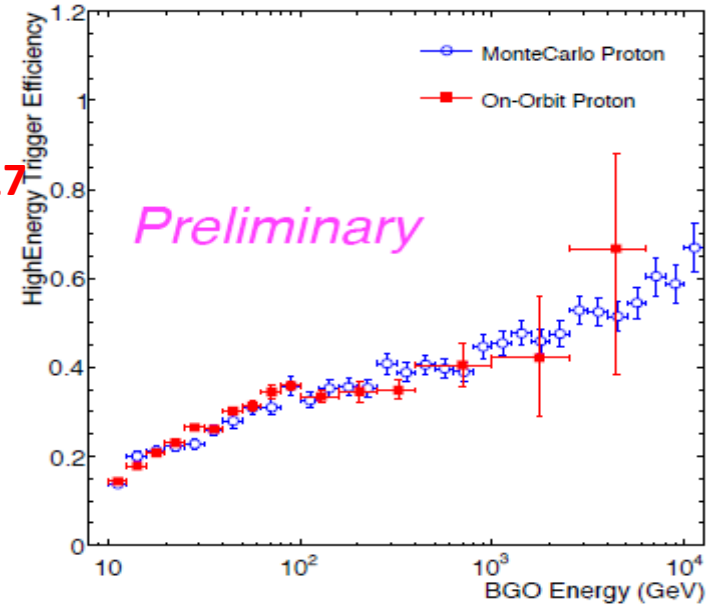
Electron spectrum

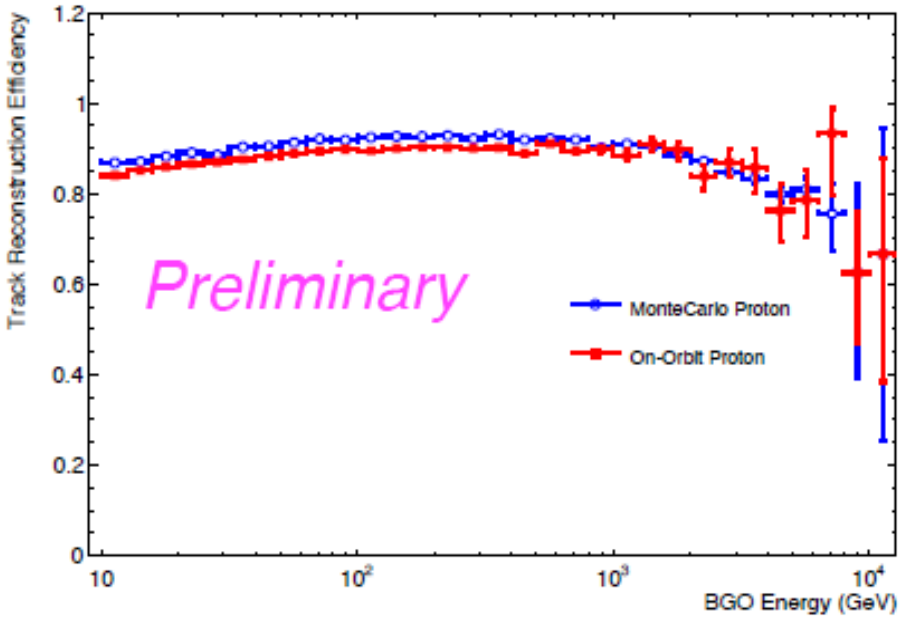


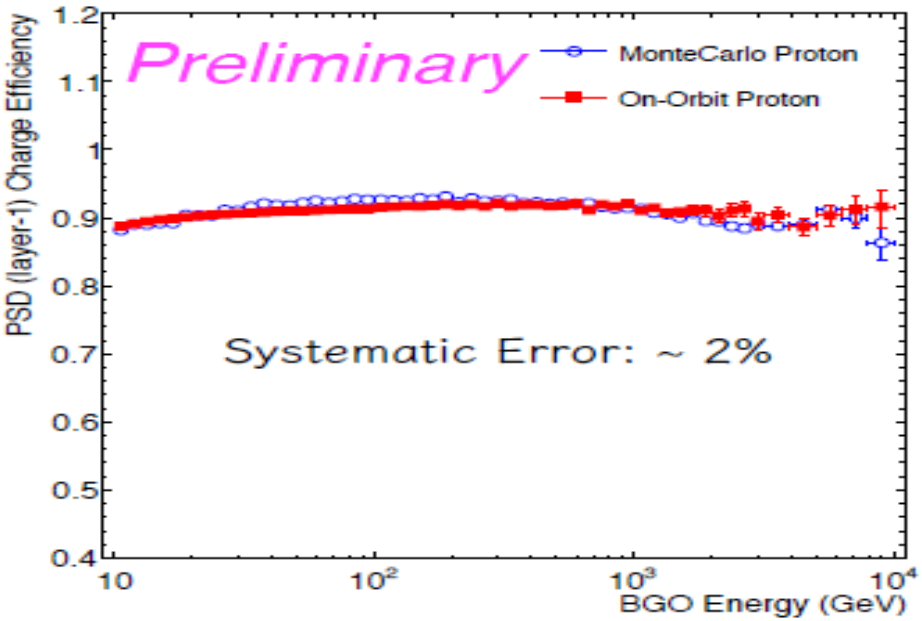
Proton analysis



Data set
Jan 1, 2016 – May 31, 2017
2.6 Billon events

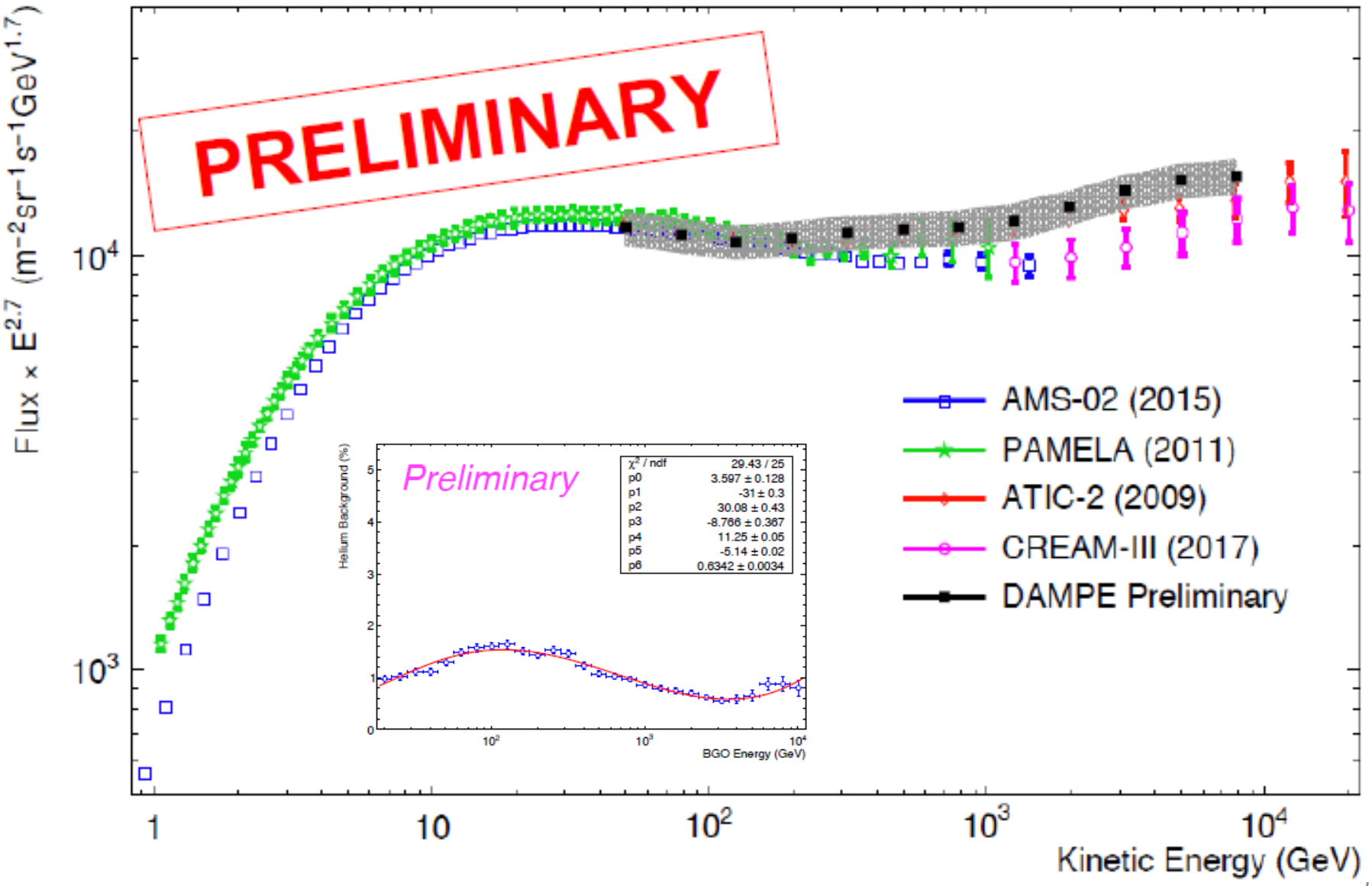




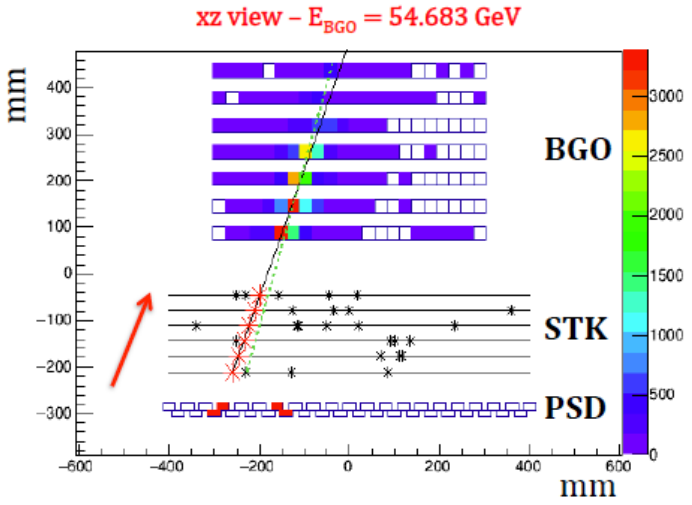


Proton spectrum

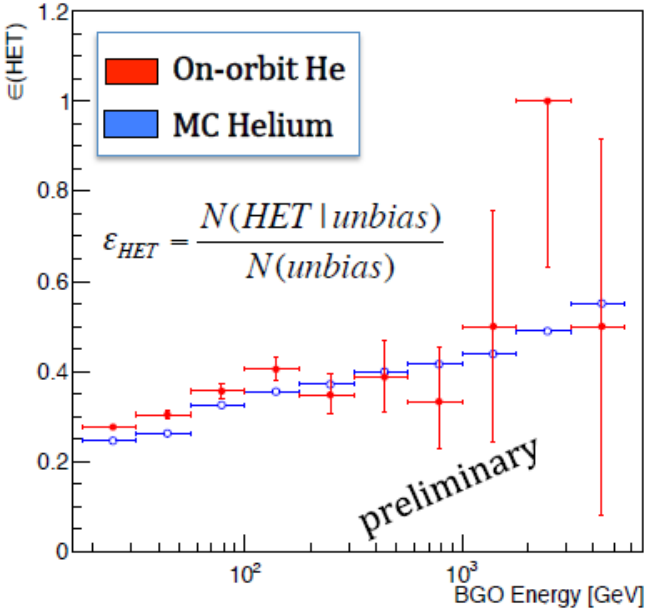
(three independent analyses ongoing)

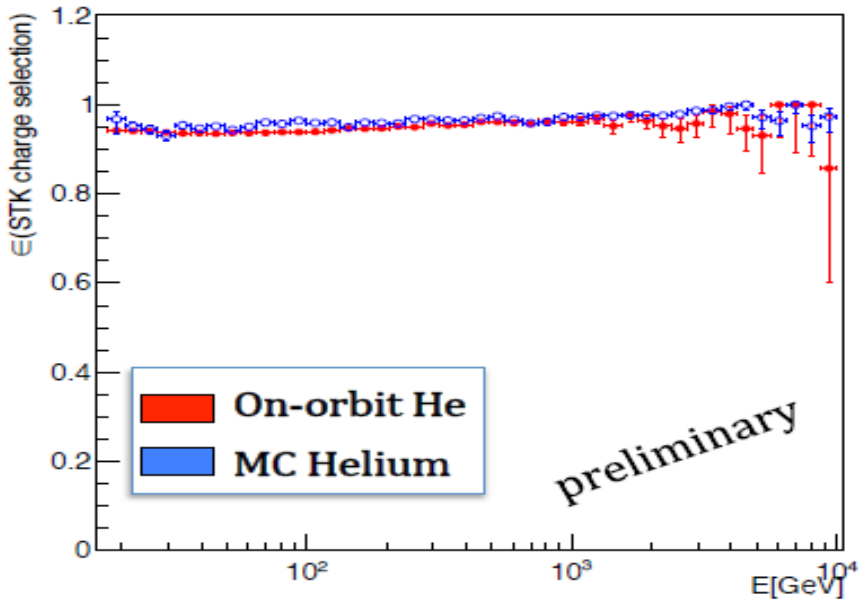


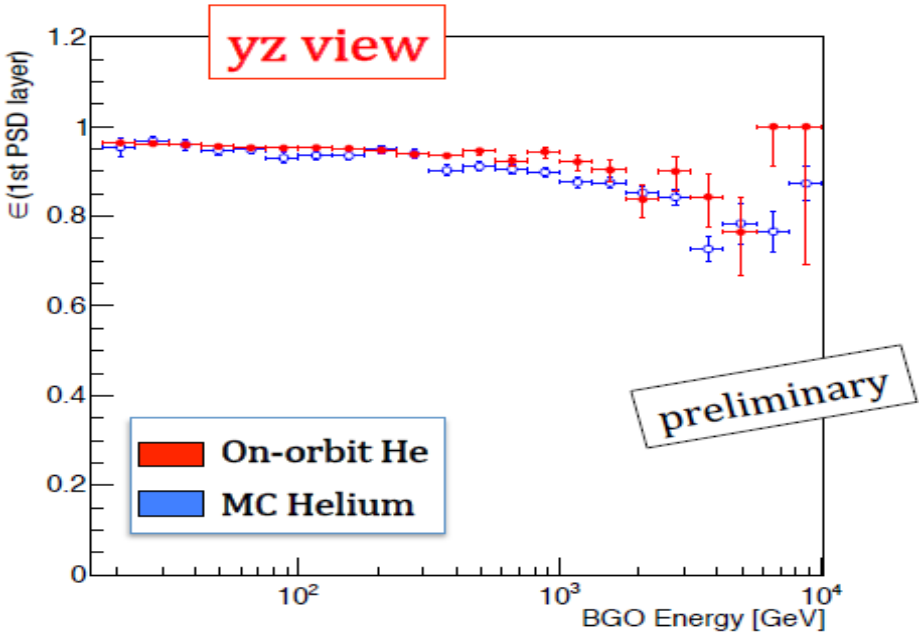
Helium analysis



Data set
Jan 1, 2016 – May 31, 2017
2.6 Billon events

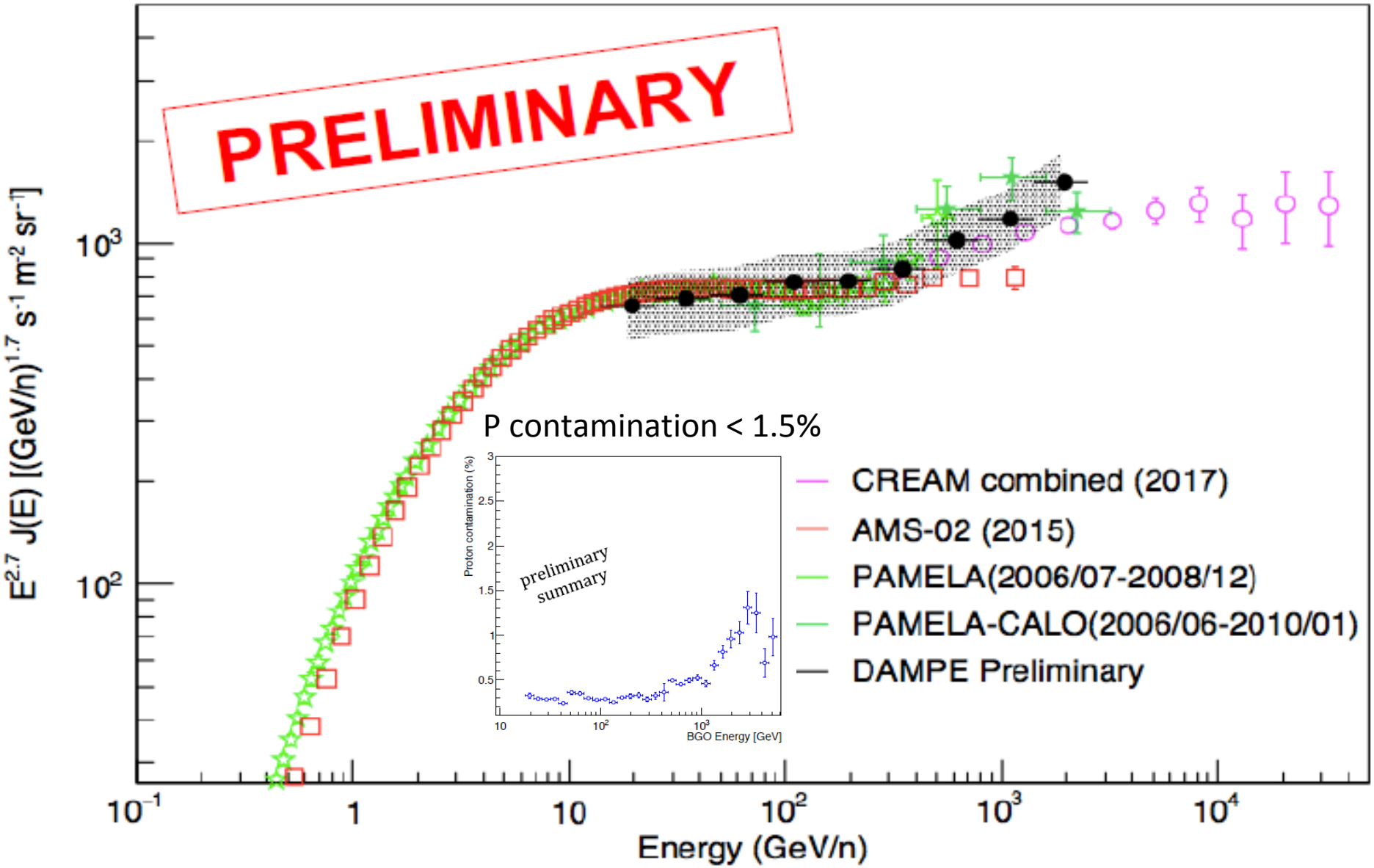




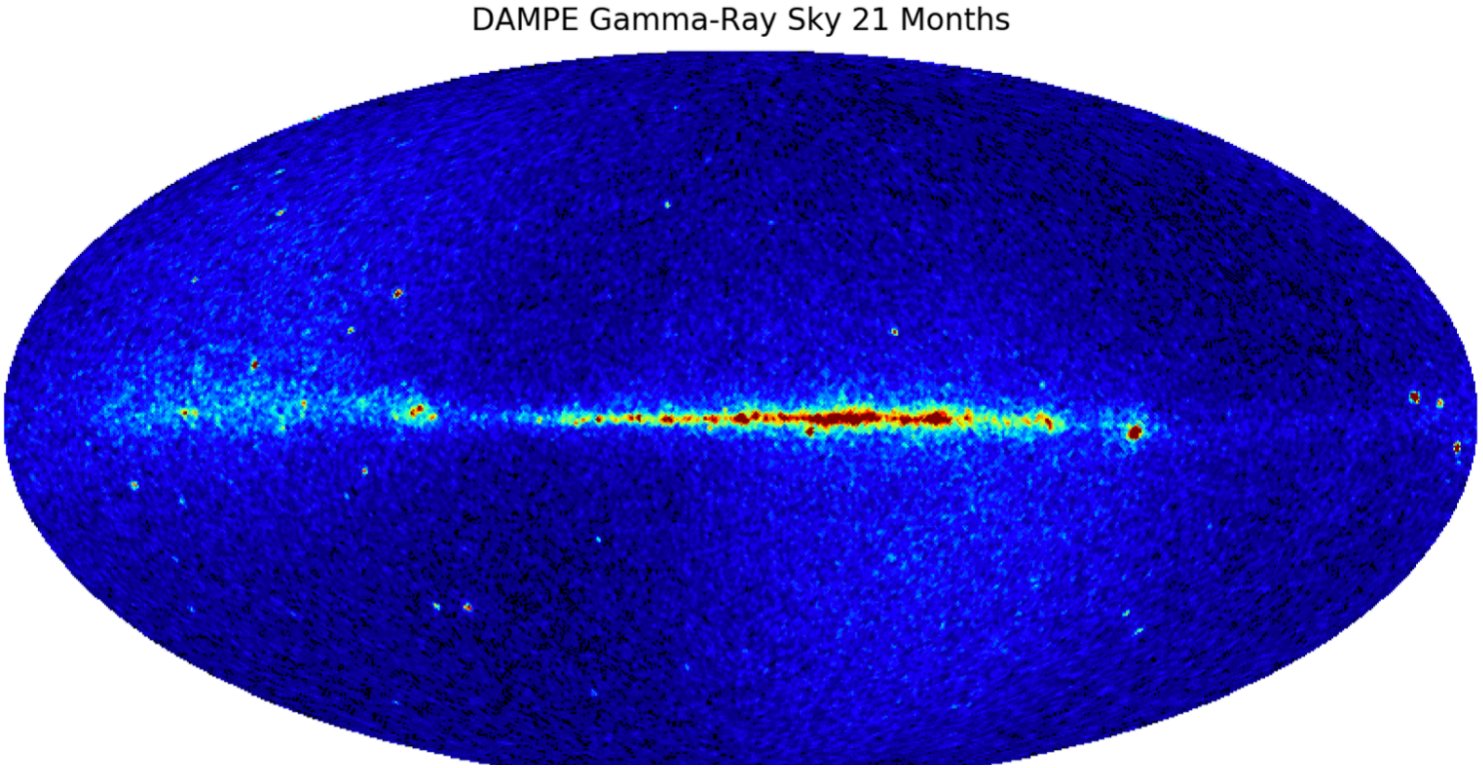


Helium spectrum

(three independent analyses ongoing)



Gamma-ray sky



- ~160 photons/day observed
- Electron contamination rate still compatible with that of an isotropic diffuse extra-galactic emission
- Healpix map with $N_{side} = 128$

Conclusions

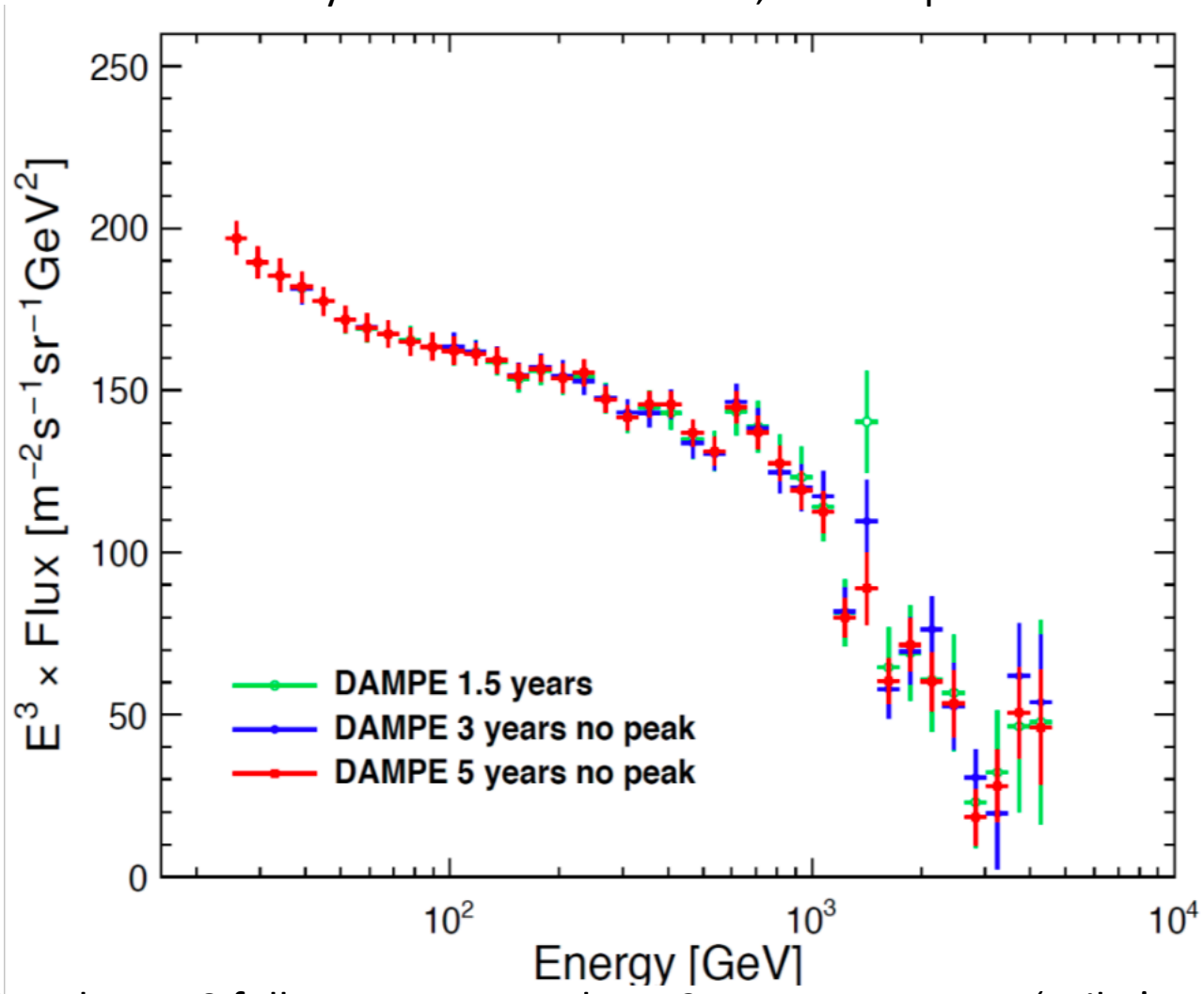
- The detector performance in flight are almost perfect
- The understanding of the detector behavior and calibration (alignments, gains, charge ID etc) is improving with the consequent improvements in reconstruction and simulation software
- Physics important results (CRE spectrum) have been published, more to come …

2016

2017

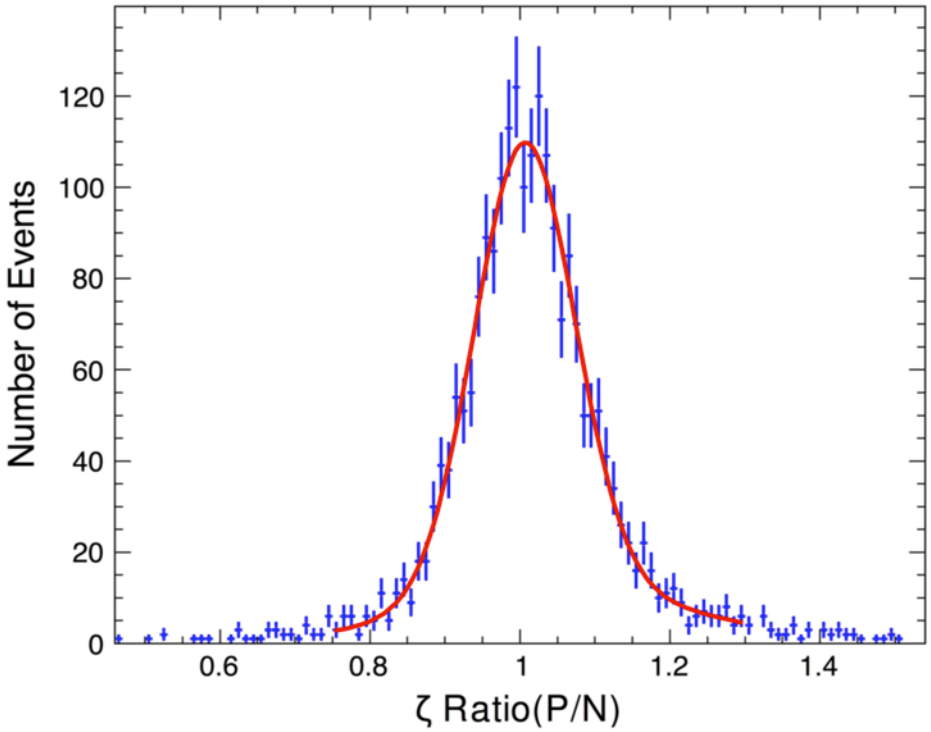
CRE flux in the future?

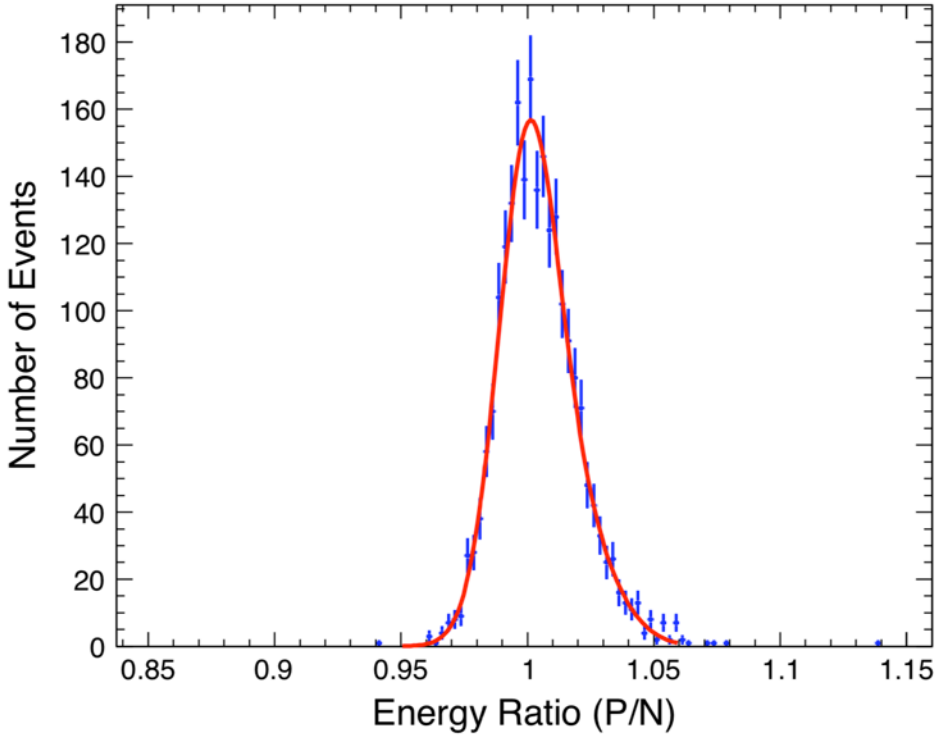
Only statistical fluctuations, no new phenomena



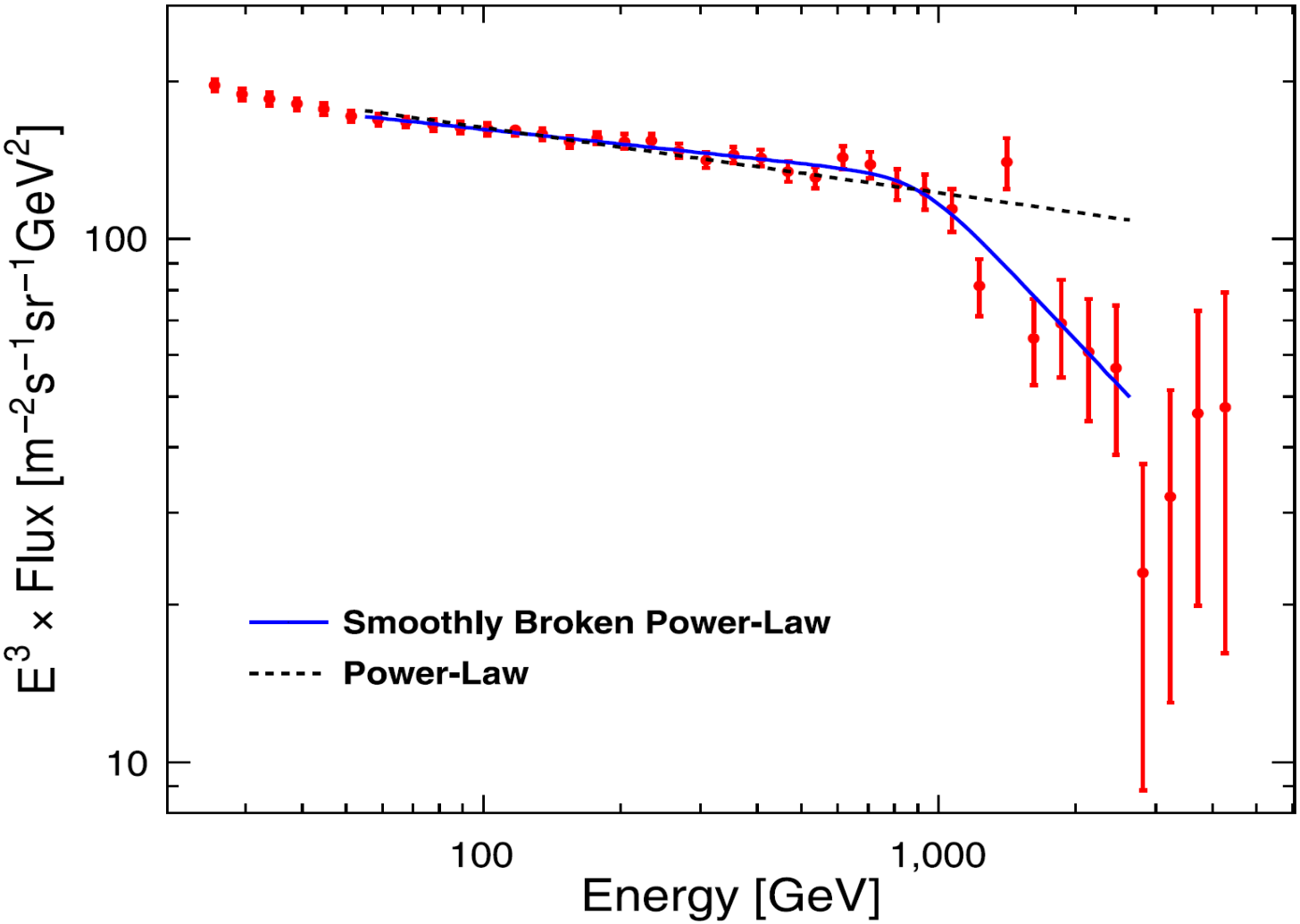
on arXive about 40 follow up papers, about 25 quote a 1.4 TeV ‘spike’ or ‘excess’

Electron identification



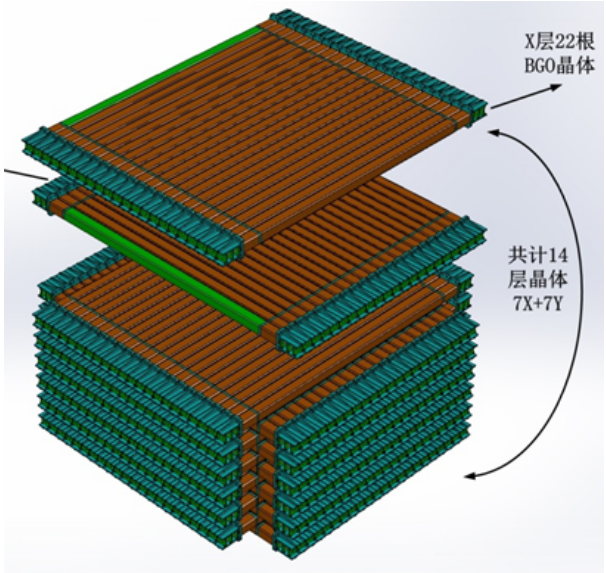


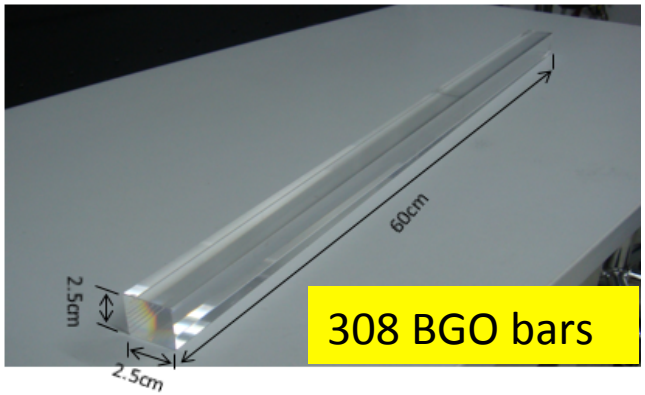
Electron spectrum



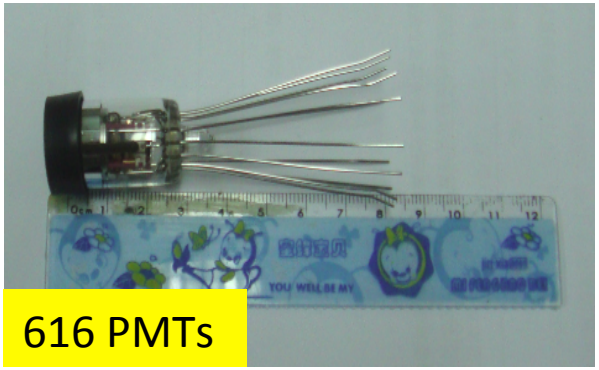
Instrument development: BGO

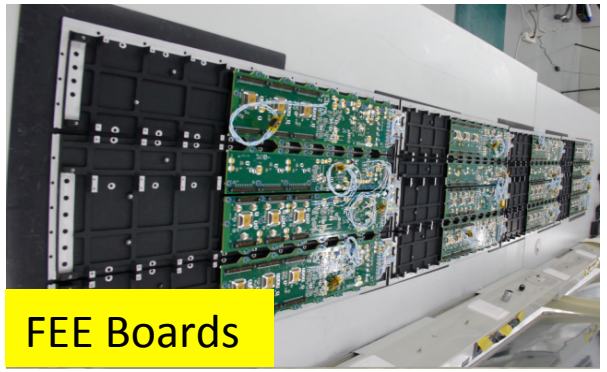
- 14 layers of 22 BGO crystals
  - Dimension of BGO bar: 2.5×2.5×60cm^3
  - Hodoscopic stacking alternating orthogonal layers
  - r.l.: ~32X_0, NIL:1.6
- Two PMTs coupled with each BGO crystal bar in two ends
- Electronics boards attached to each side of module





308 BGO bars


616 PMTs


FEE Boards

Charge, track, energy, and PID