

Latest results from the DAMPE space mission



Ivan DE MITRI

Gran Sasso Science Institute (GSSI)
& INFN Laboratori Nazionali del Gran Sasso



RICAP-2022

Roma International Conference on AstroParticle Physics
September 6-9, 2022
Rome, Italy

DAMPE science goals



High energy particle detection in space

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



Detection of
10 GeV - 10 TeV e/ γ
50 GeV - 200 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

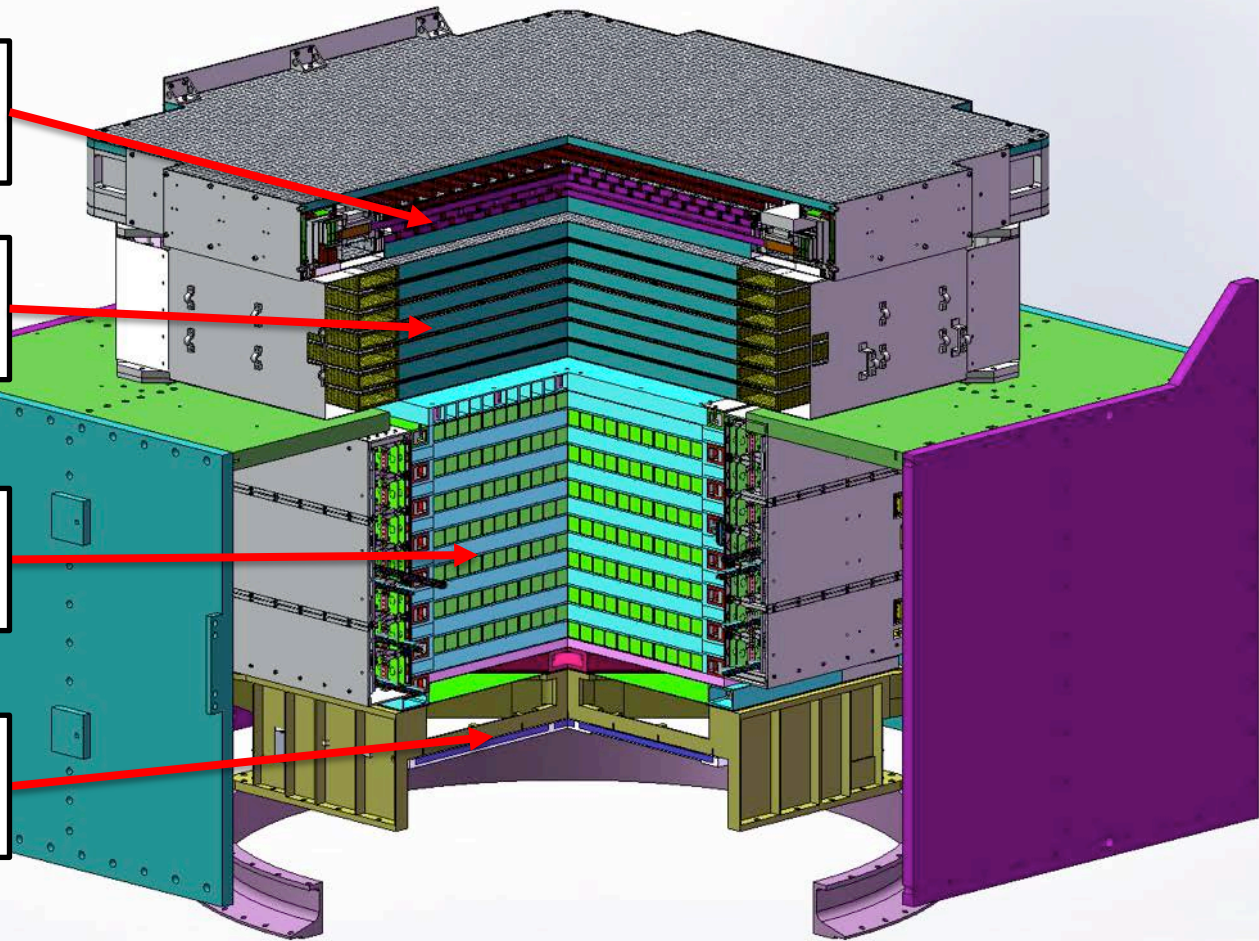
The detector

Plastic Scintillator Detector
(PSD)

Silicon-Tungsten Tracker
(STK)

BGO Calorimeter
(CALO)

Neutron Detector
(NUD)



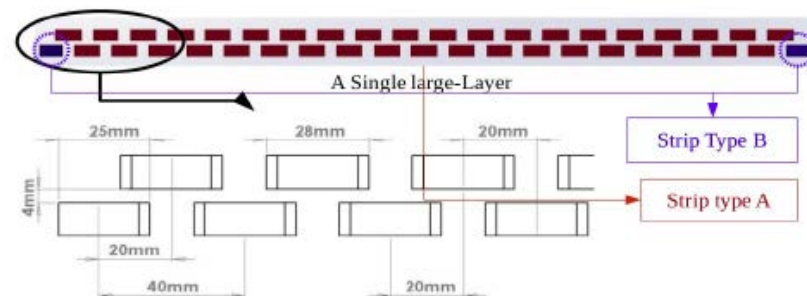
- Charge measurement (dE/dx in PSD , STK and BGO)
- Tungsten converter (pair production)
- Precise tracking (silicon strips)
- Thick calorimeter (BGO bars)
- Hadron rejection (neutron detector)



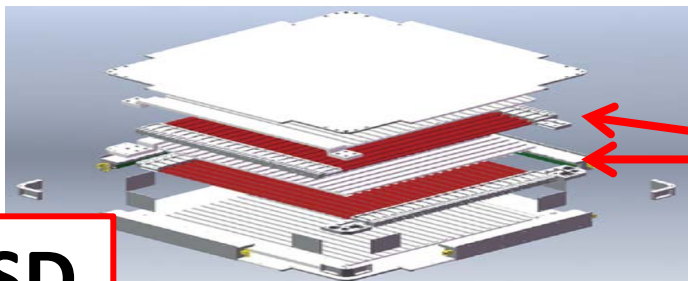
high energy
 γ -ray, electron and cosmic ray
 telescope

The Plastic Scintillator Detector and the NeUtron Detector

- 1.0 cm thick ,2.8cm wide and 82.0 cm long scintillator strips
- staggered by 0.8 cm in a layer
- 82 cm × 82 cm layers
- 2 layers (x and y)

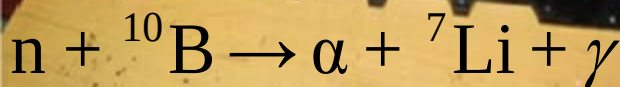
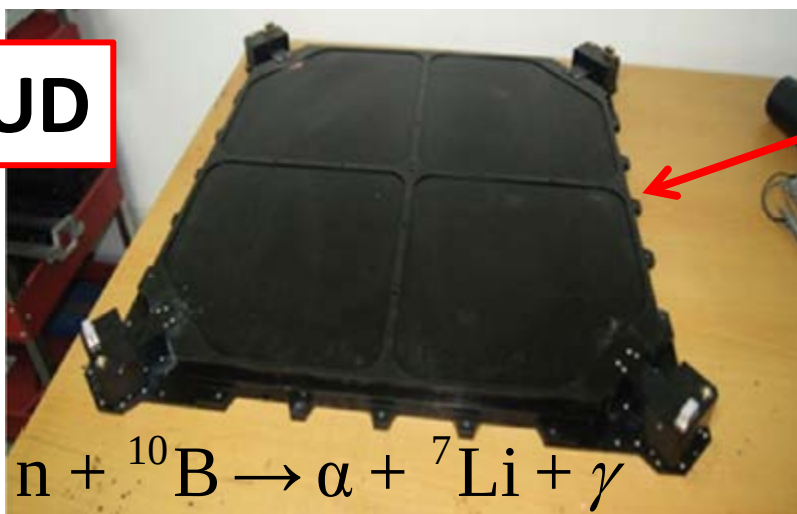
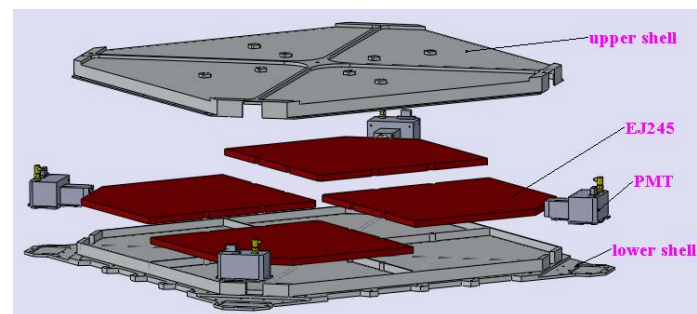


PSD

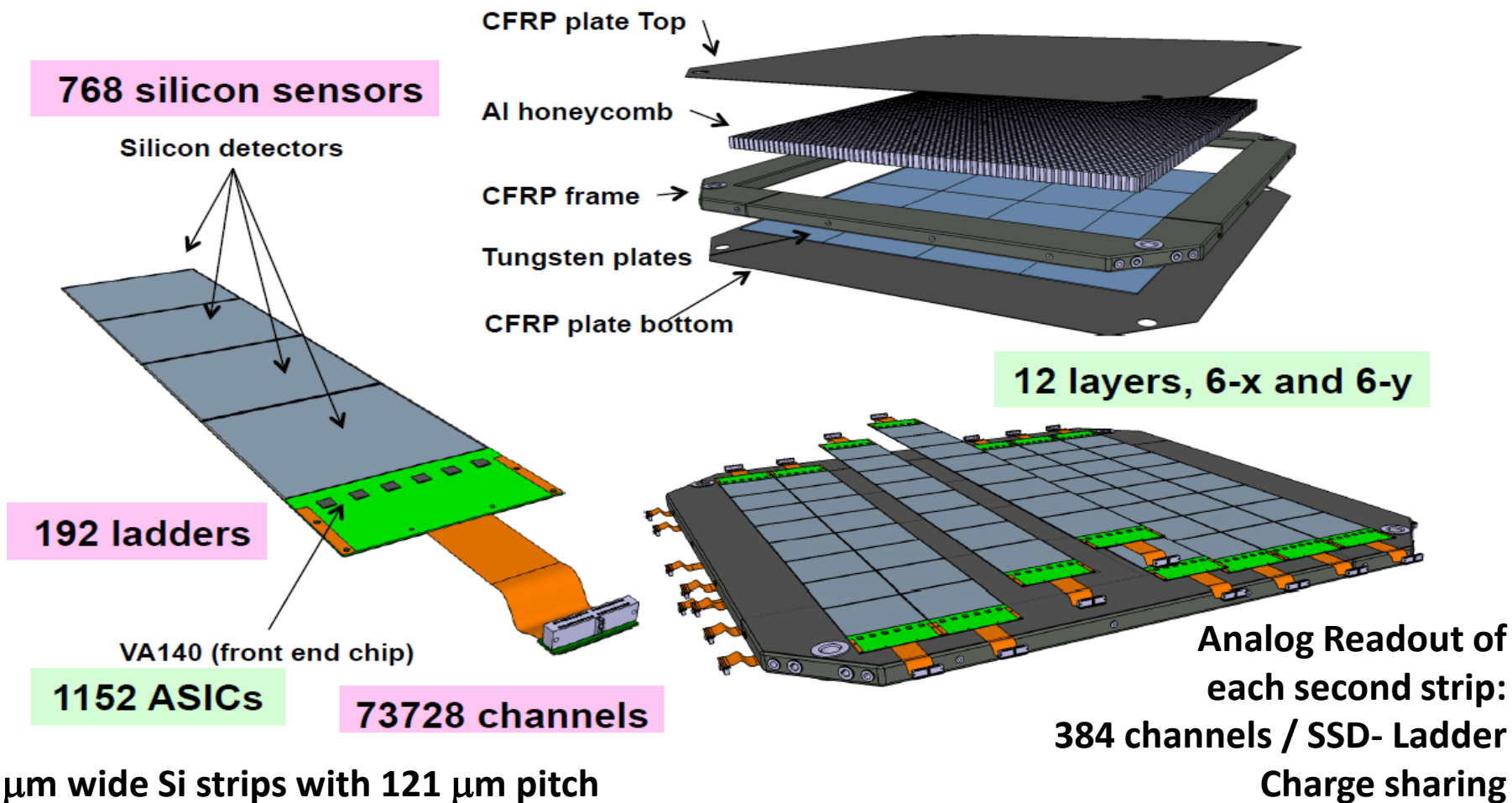


NUD

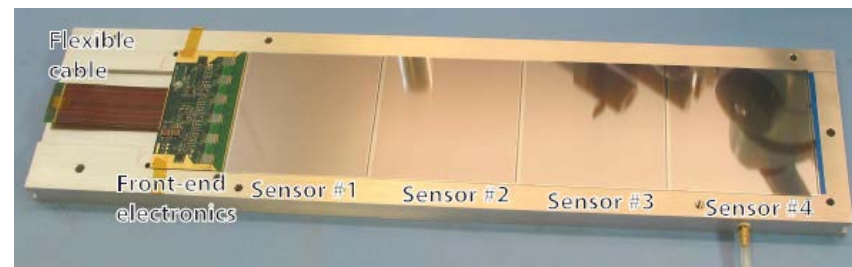
- 4 large area boron-doped plastic scintillators (30 cm × 30 cm × 1 cm)



The Silicon Tracker (STK)

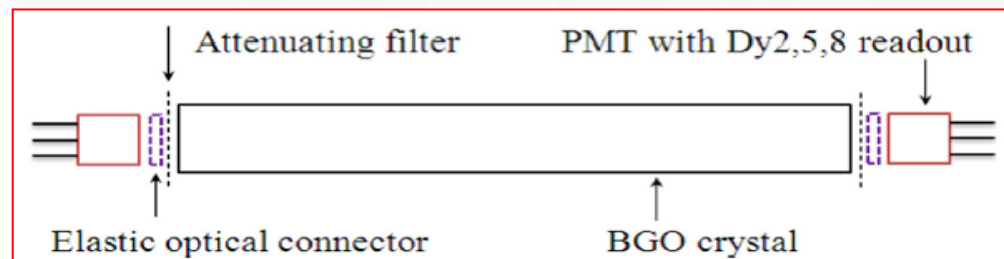
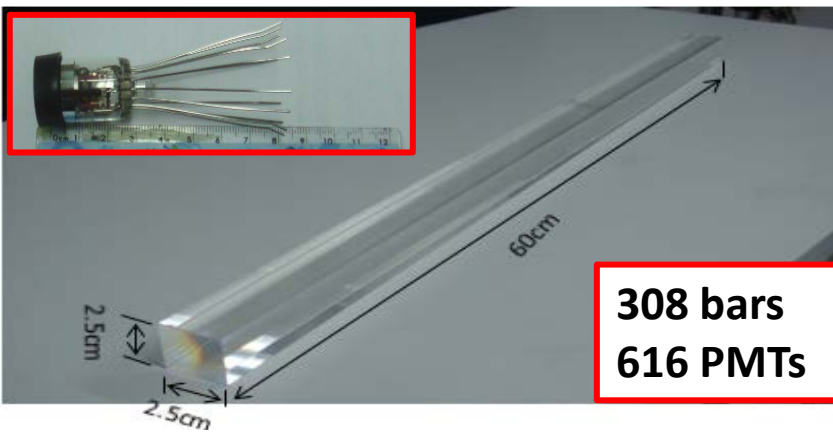
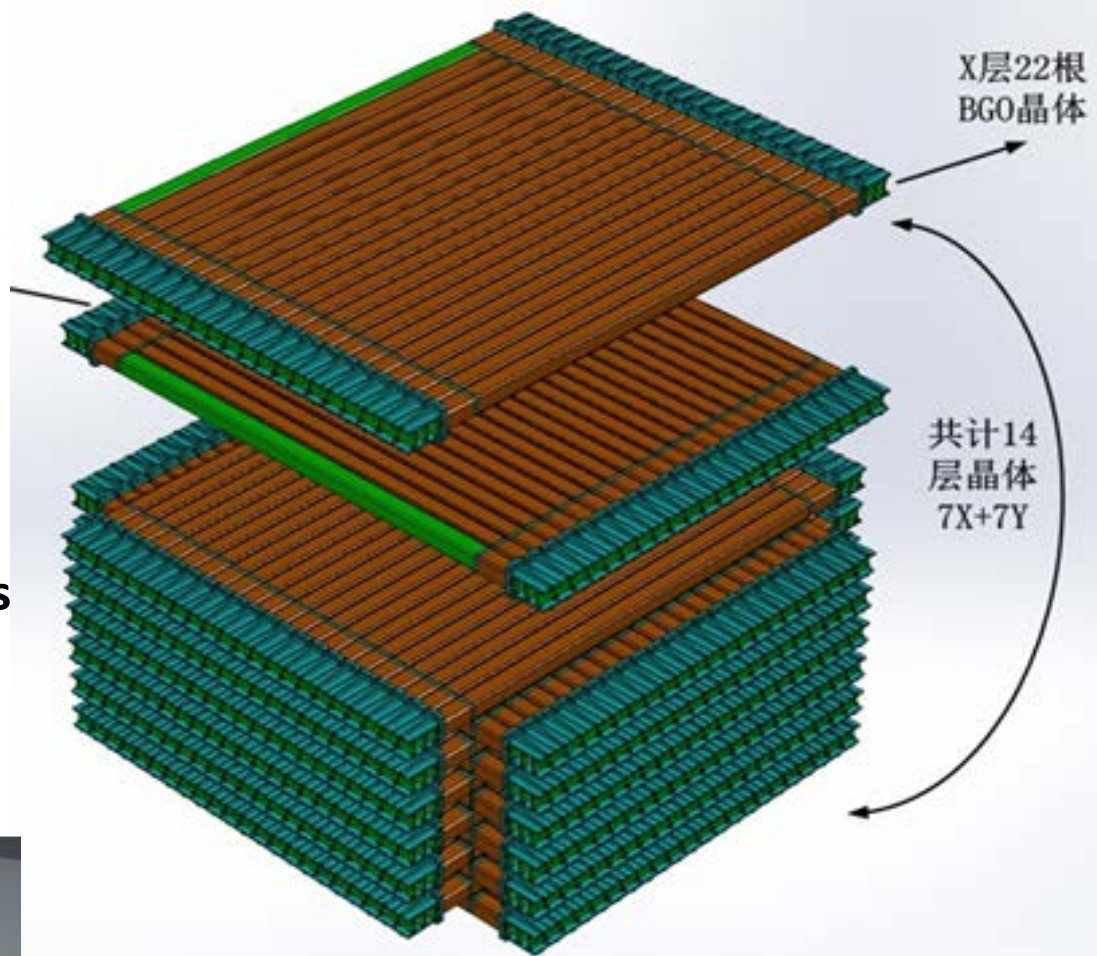


- 48 μm wide Si strips with 121 μm pitch
- (95 $\times$ 95 $\times$ 0.32 mm³) Silicon Strip Detector (SSD)
- 768 strips in each SSD
- One ladder composed by 4 (SSD)
- 16 Ladders per layer (76 cm $\times$ 76 cm)
- 12 layers (6x + 6y)



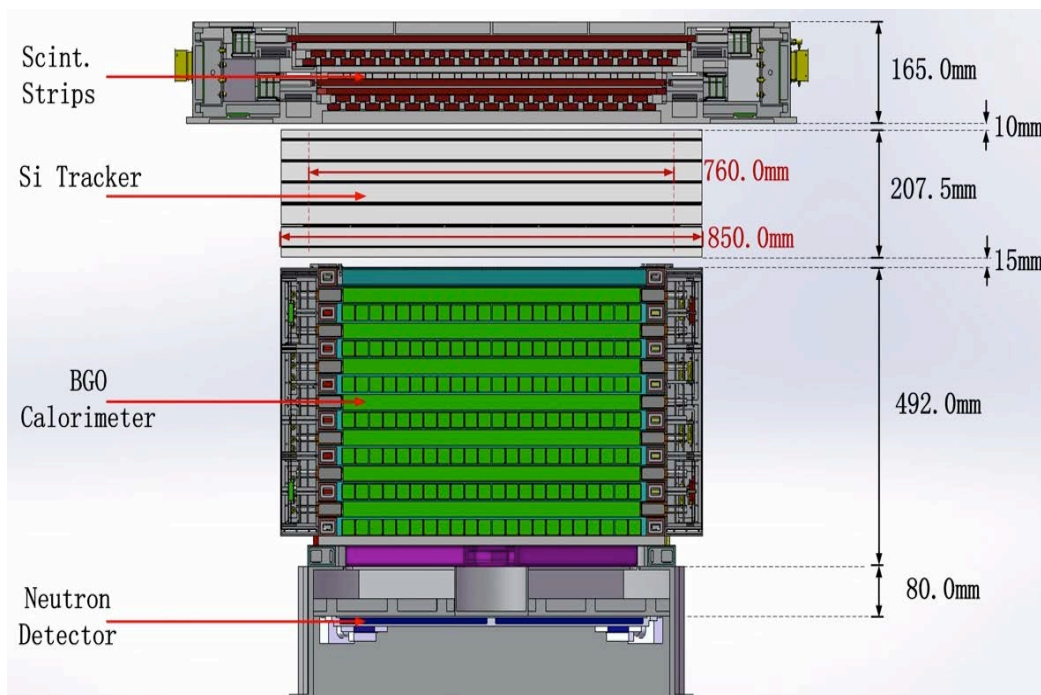
The CALOrimeter

- 14 layers of 22 BGO bars
 - $2.5 \times 2.5 \times 60 \text{ cm}^3$ bars
 - 14 hodoscopic stacking alternating orthogonal layers
 - depth $\sim 32X_0$
- Two PMTs coupled with each BGO crystal bar at the two ends
- Electronics boards attached to each side of module



Comparison with AMS-02 and FERMI

	DAMPE	AMS-02	Fermi LAT
e/ γ Energy res.@100 GeV (%)	1.2	3	10
e/ γ Angular res.@100 GeV (deg)	0.2	0.3	0.1
e/p discrimination	10^5-10^6	$10^5 - 10^6$	10^3
Calorimeter thickness (X_0)	32	17	8.6
Geometrical accep. (m^2sr)	0.3	0.09	1

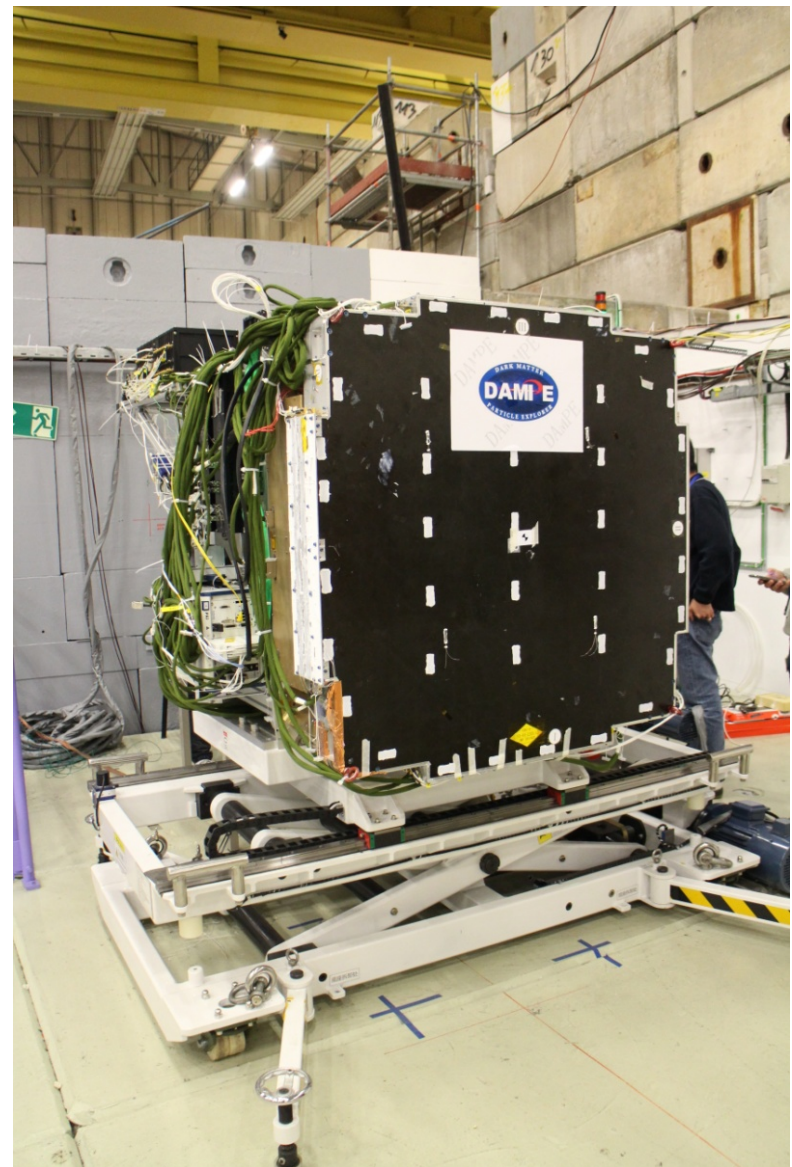


Mass: 1400 Kg
Power: ~ 400 W
Livetime: > 3 years

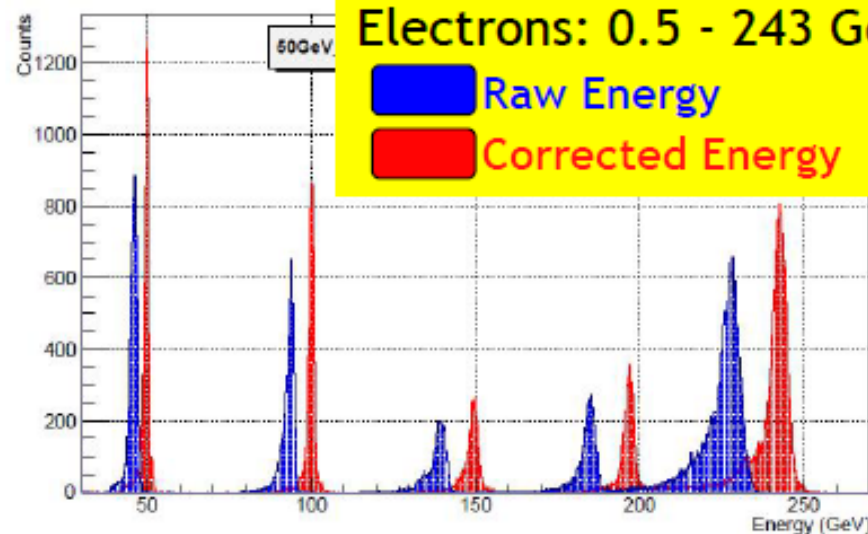
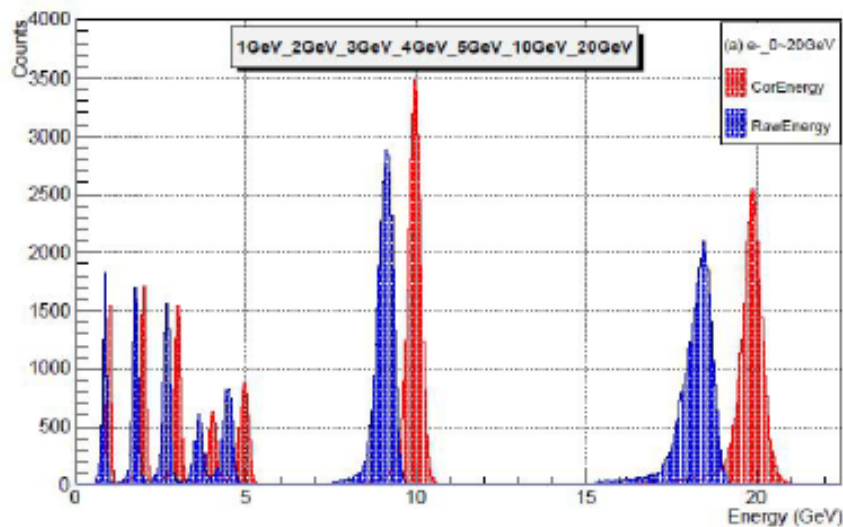
2015/06/18

Test beam activity at 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
 - γ @ 50, 75 , 150 GeV/c
 - μ @ 150 GeV /c
 - π^+ @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)



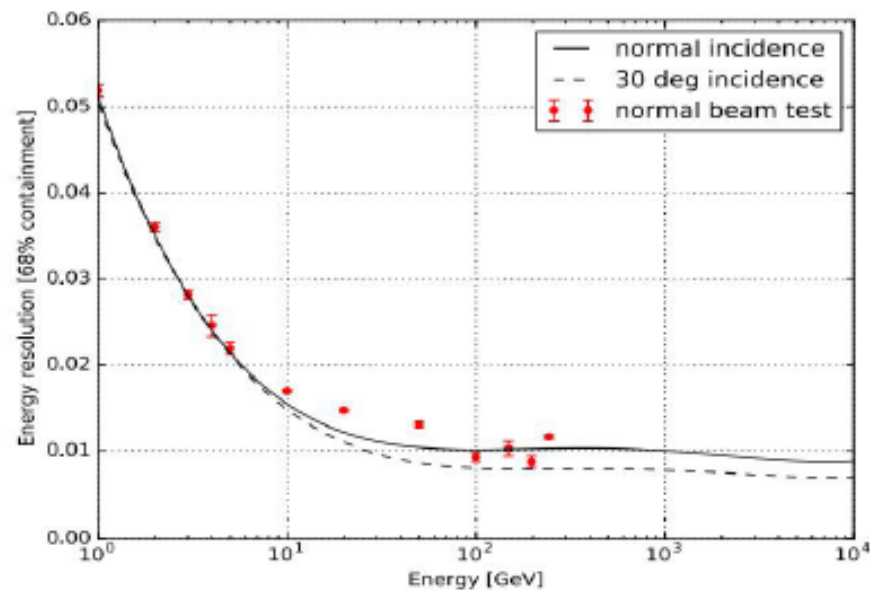
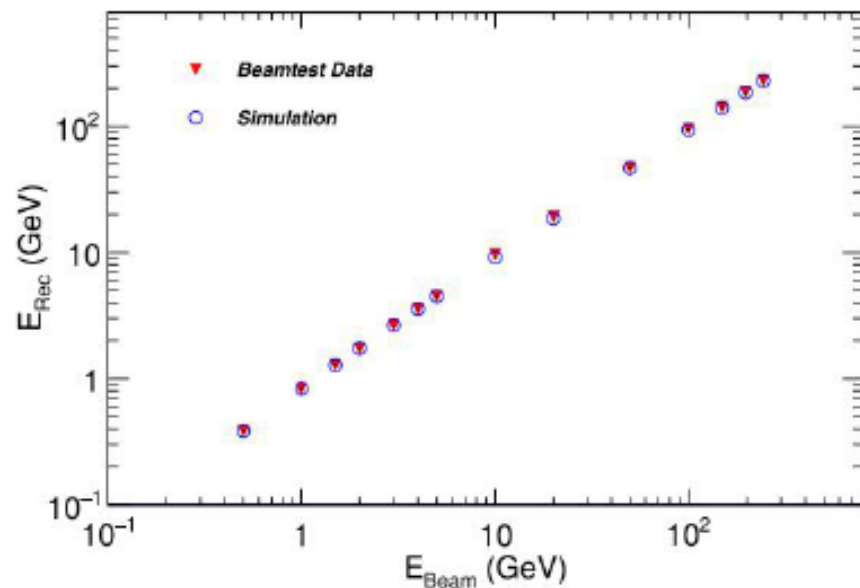
Test beam activity at CERN



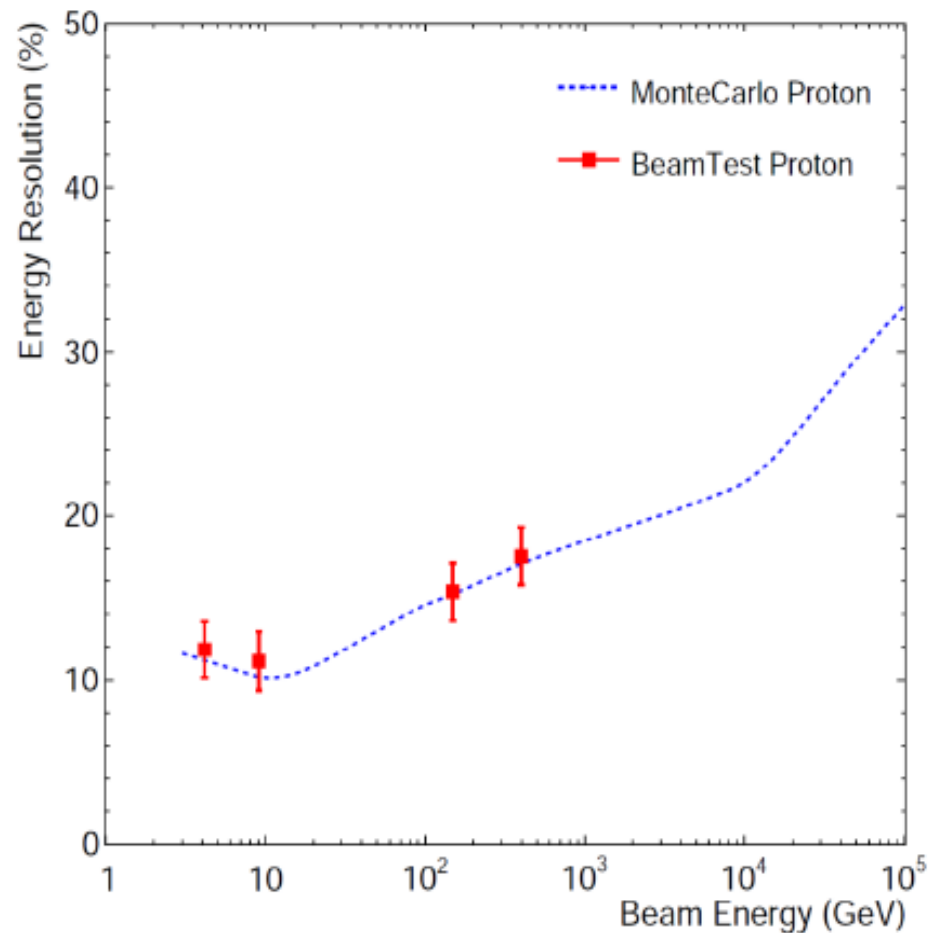
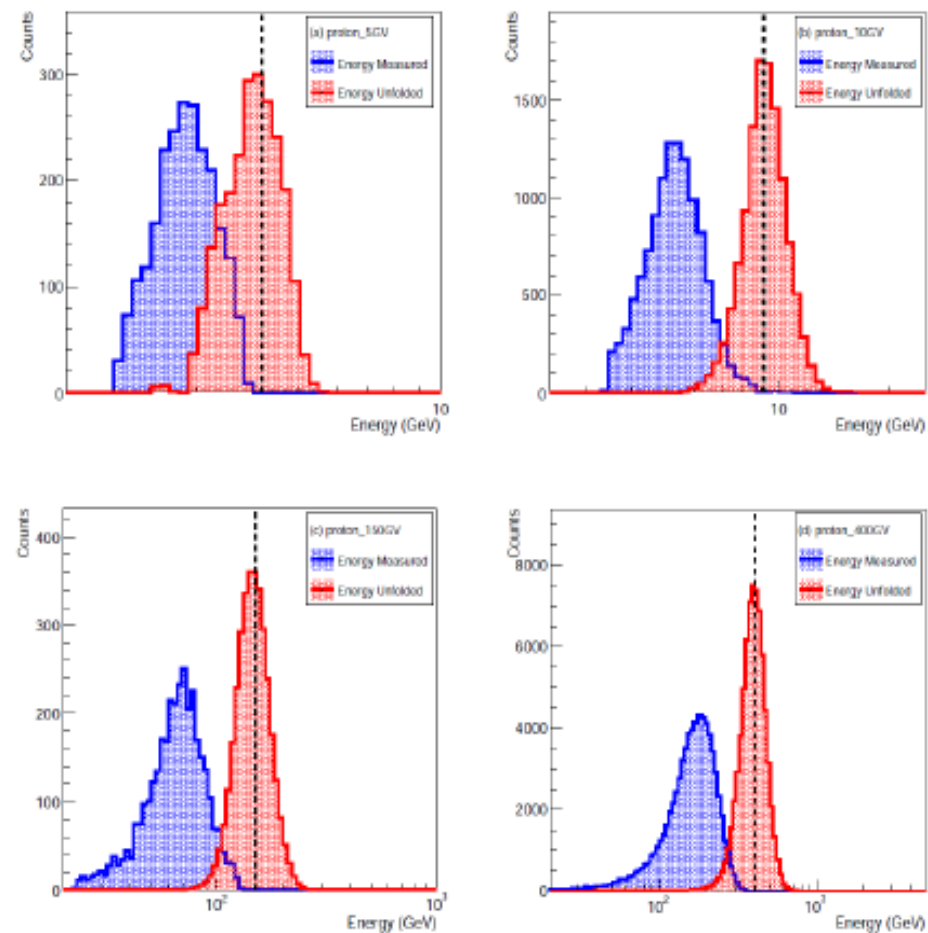
Electrons: 0.5 - 243 GeV

Raw Energy

Corrected Energy



Test beam activity at CERN: protons



Jiuquan Satellite Launch Center

Gobi desert

CZ-2D rocket

Mass: 1850 kg (scientific payload 1400 kg)

Power : 640 W (scientific payload 400 W)

Orbit: sun synchronous

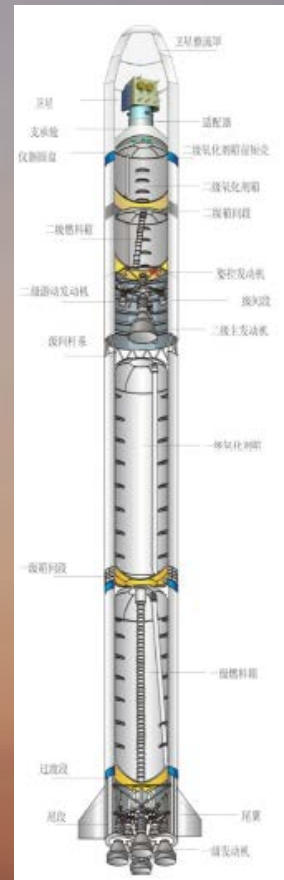
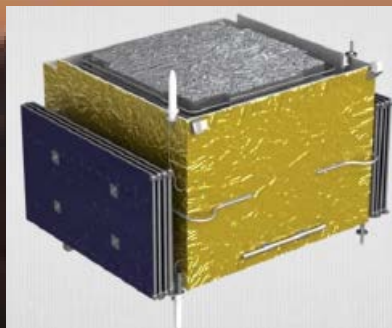
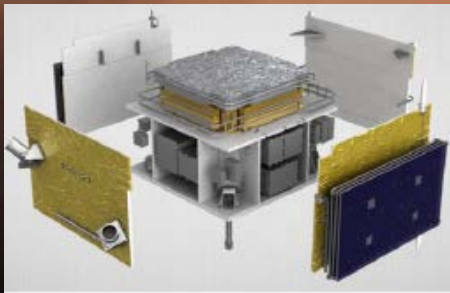
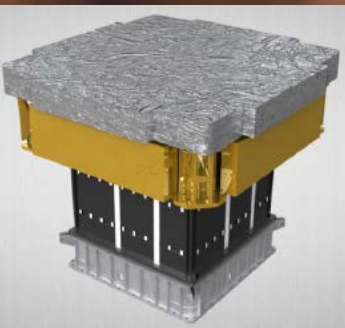
Altitude: 500km

Inclination: 97.41°

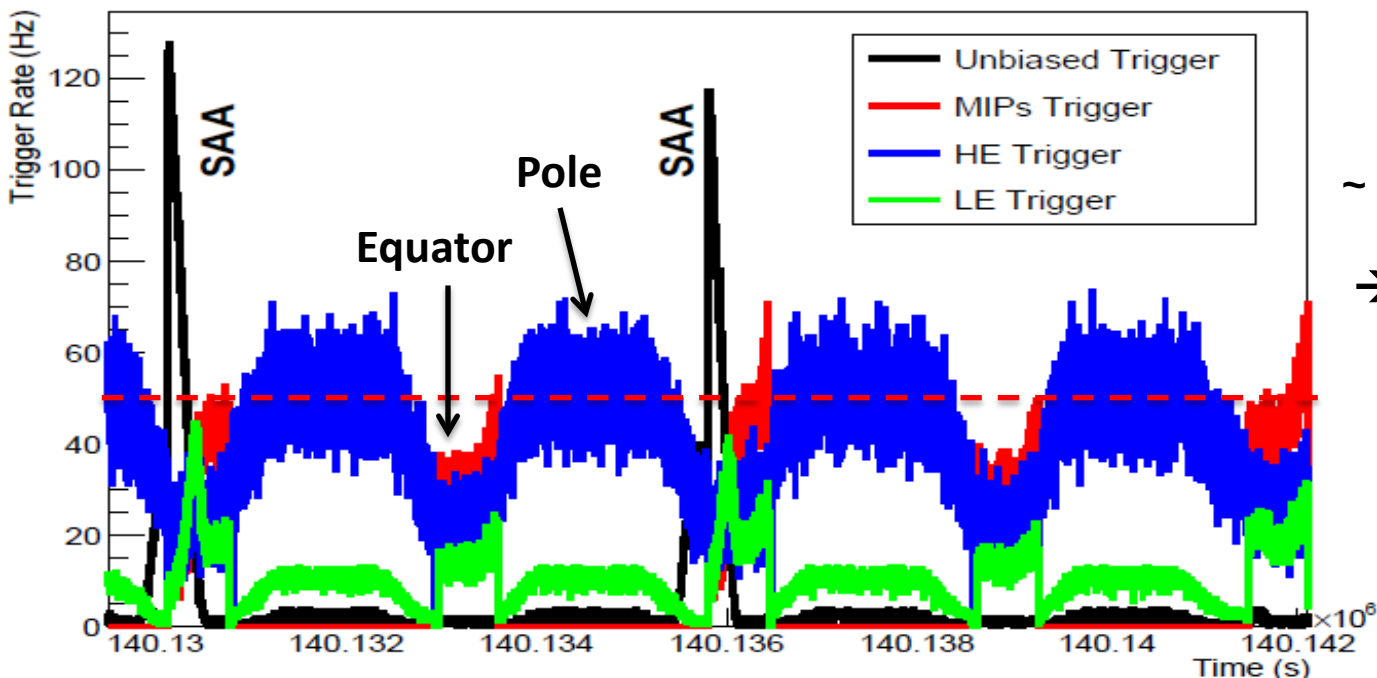
Period: 95 minutes

Downlink: 16 GB / day

Lifetime: > 3 years

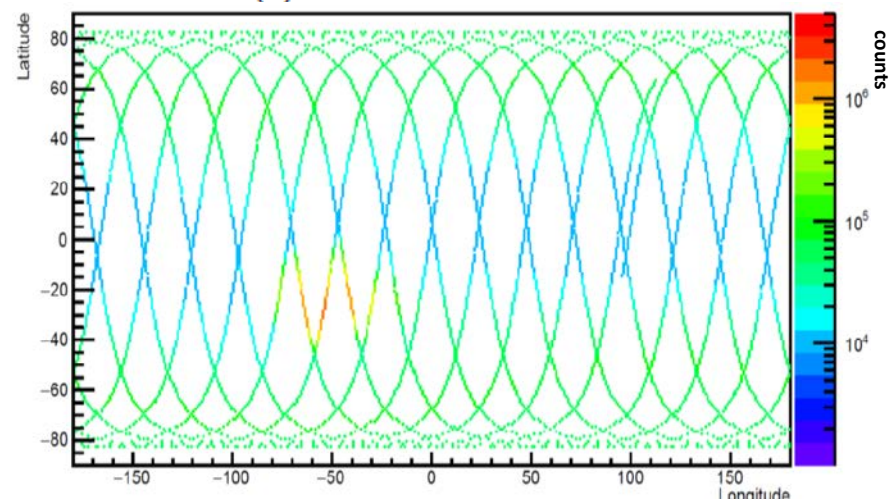
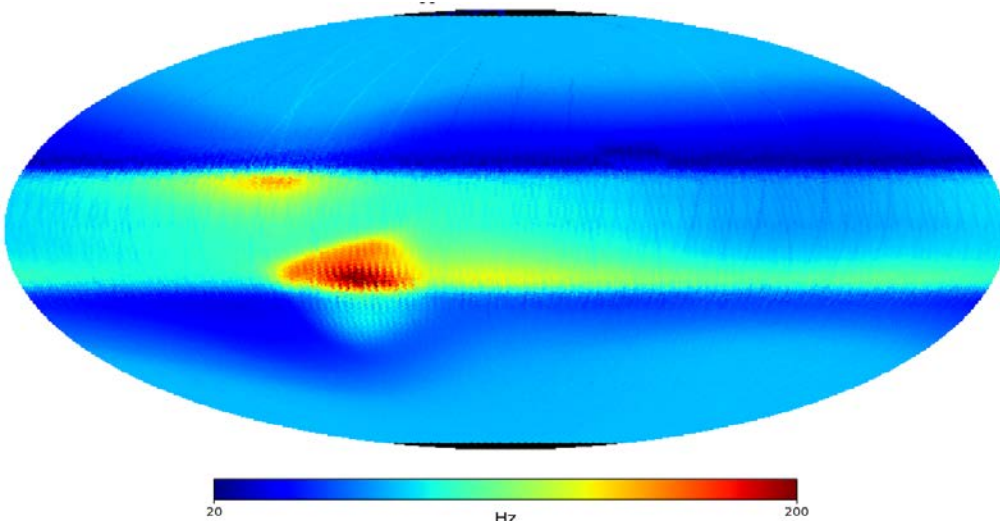


Trigger rate in orbit

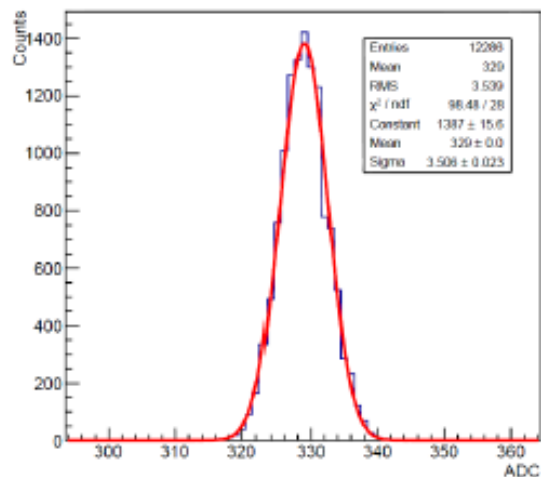


~ 50 Hz average trigger rate

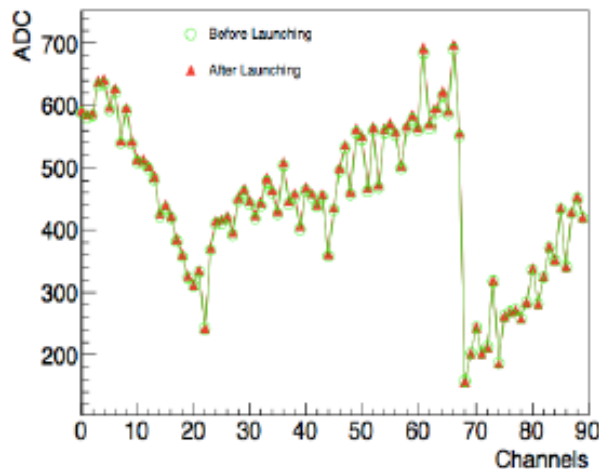
→ 100GB/day on ground (about 5 M events)



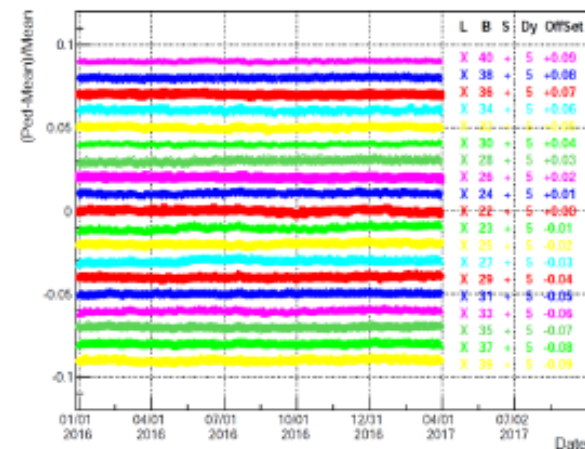
On orbit performance: PSD



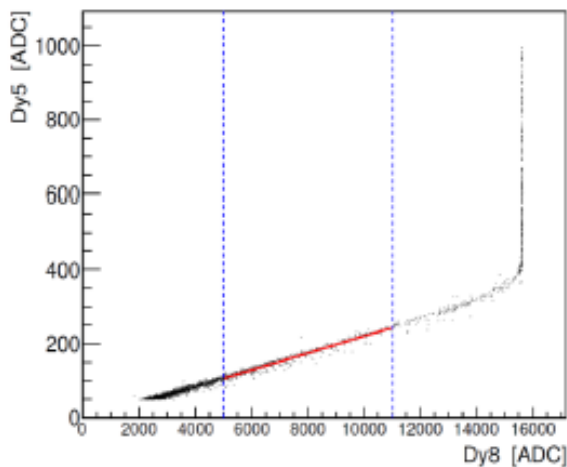
Pedestal distribution



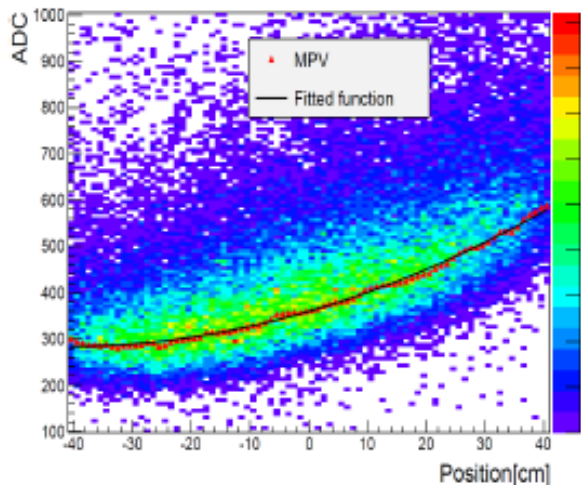
Pedestal comparison



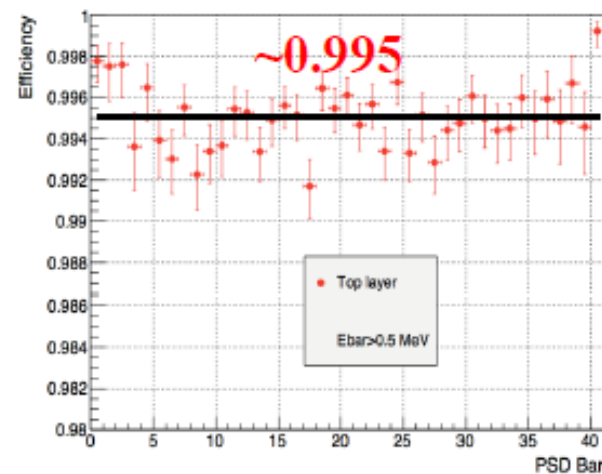
Pedestal variation



Dynode 5 and 8 correlation

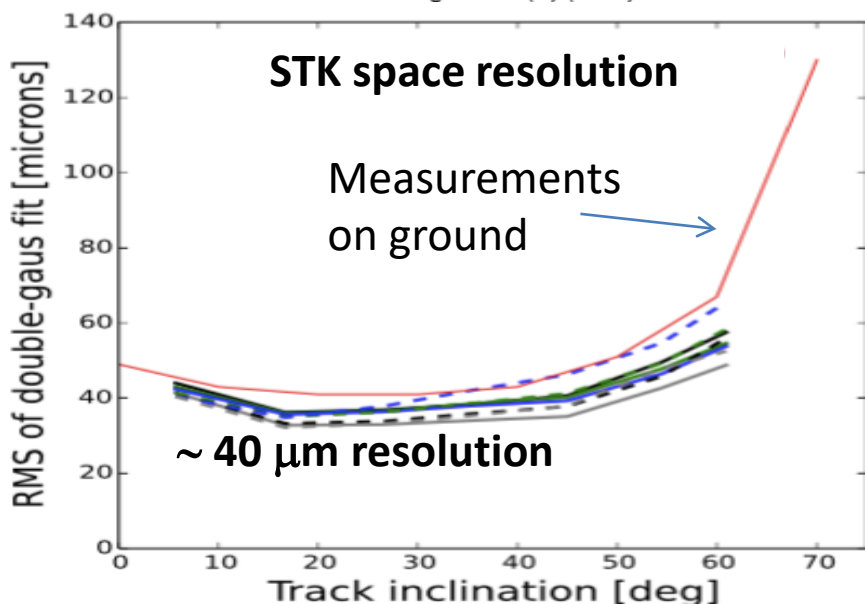
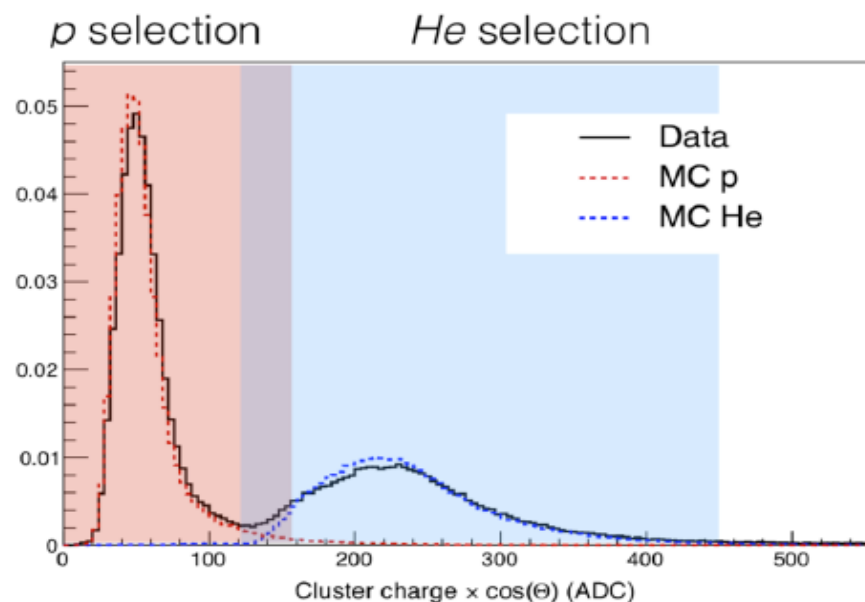
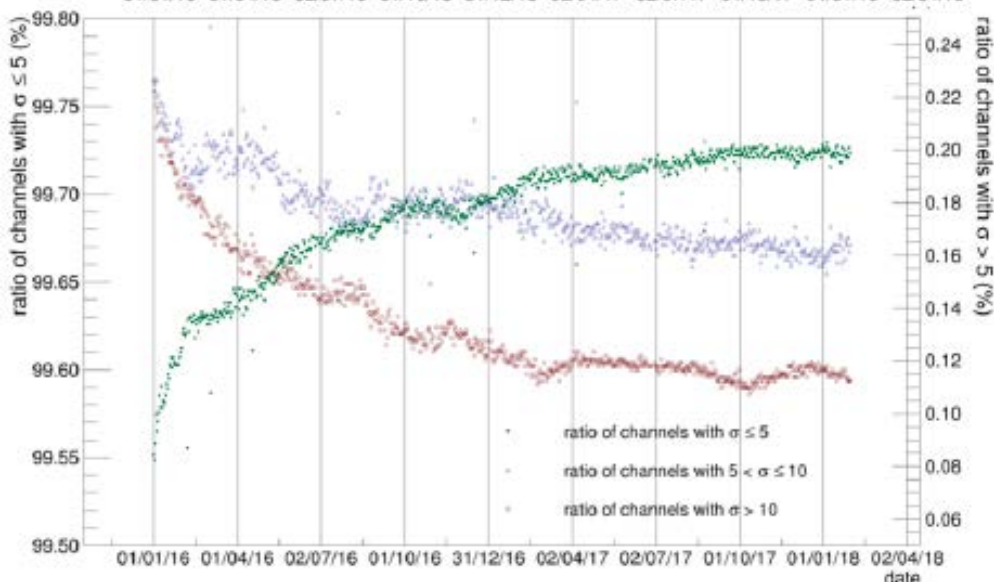
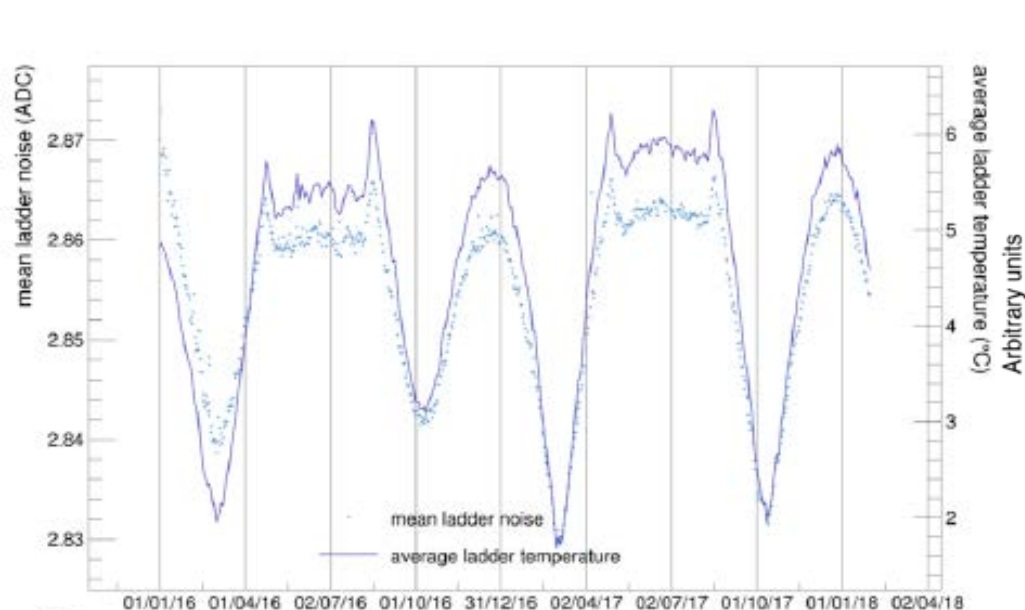


Light attenuation calibration



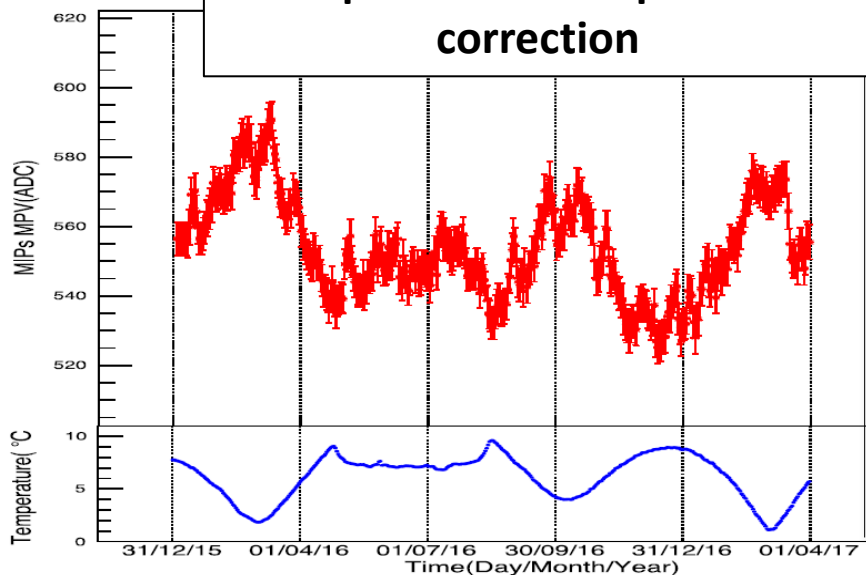
Single layer efficiency

On orbit performance: STK

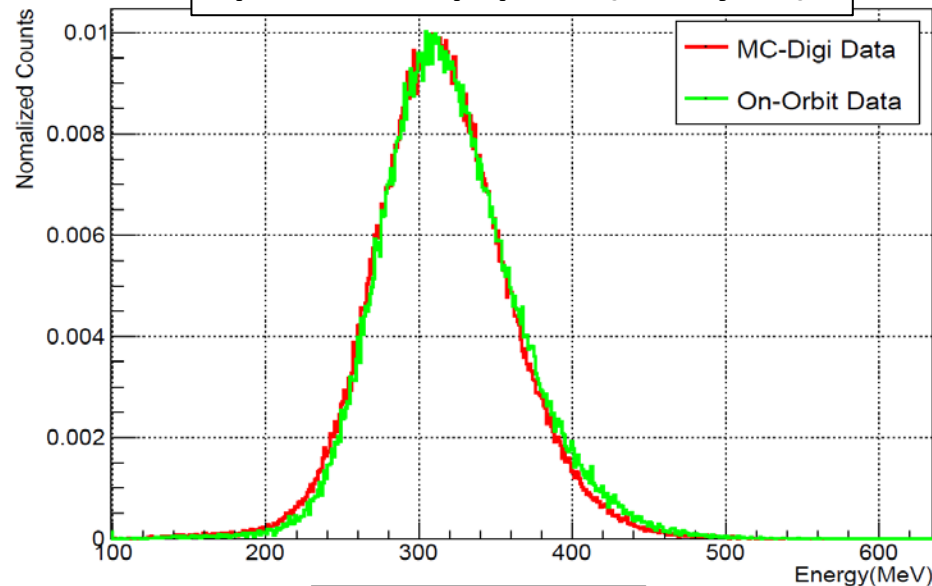


On orbit performance: BGO

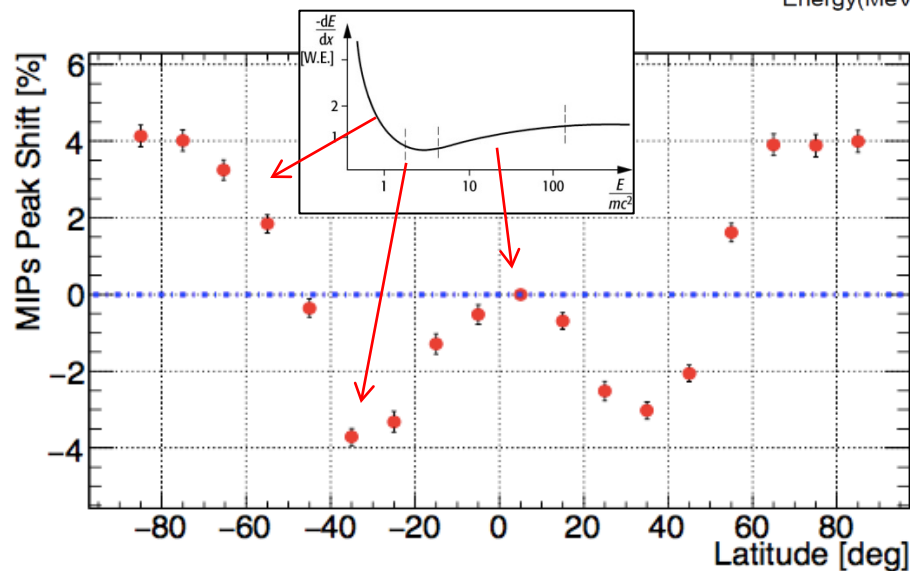
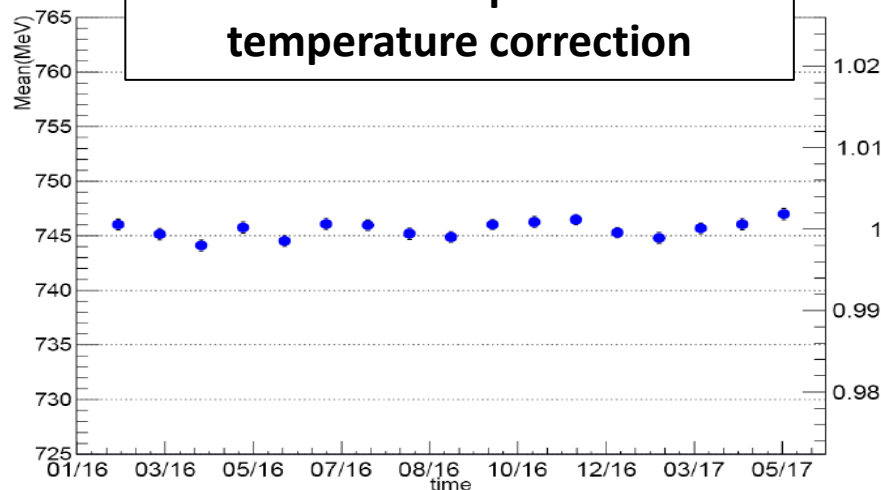
"Mip"s before temperature correction



proton "mip"peak (14 layers)



Carbon "Mip"s after temperature correction

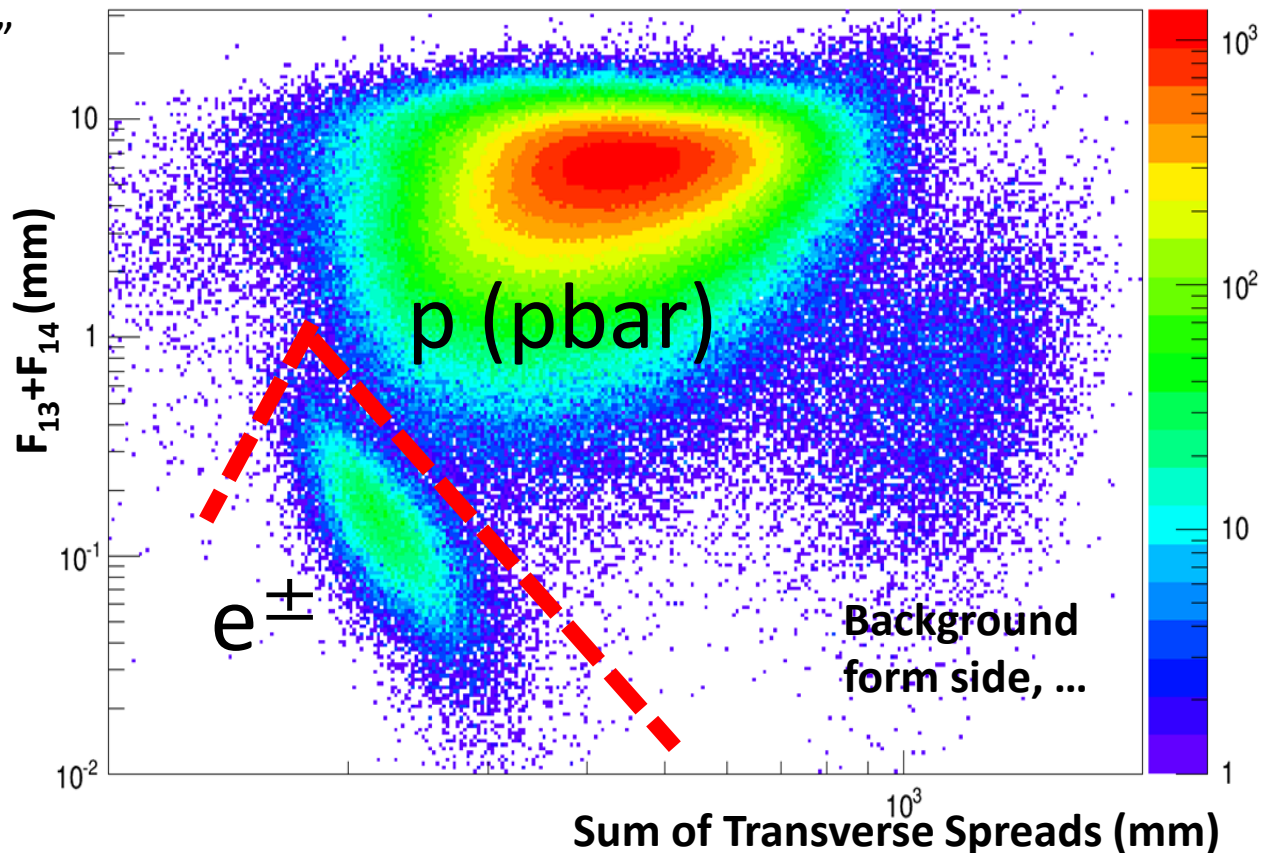
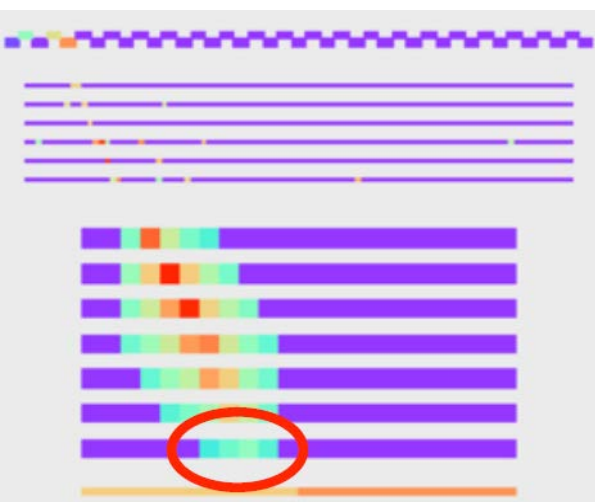


Study of the shower topology

One possible “shape parameter”

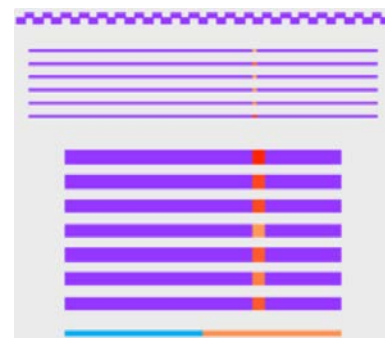
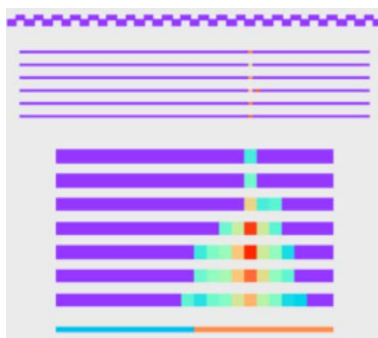
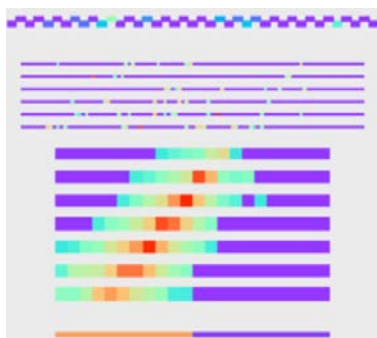
$$F_i = Spread_i \times \frac{E_i}{E_{tot}}$$

Rejection power $> 10^5$



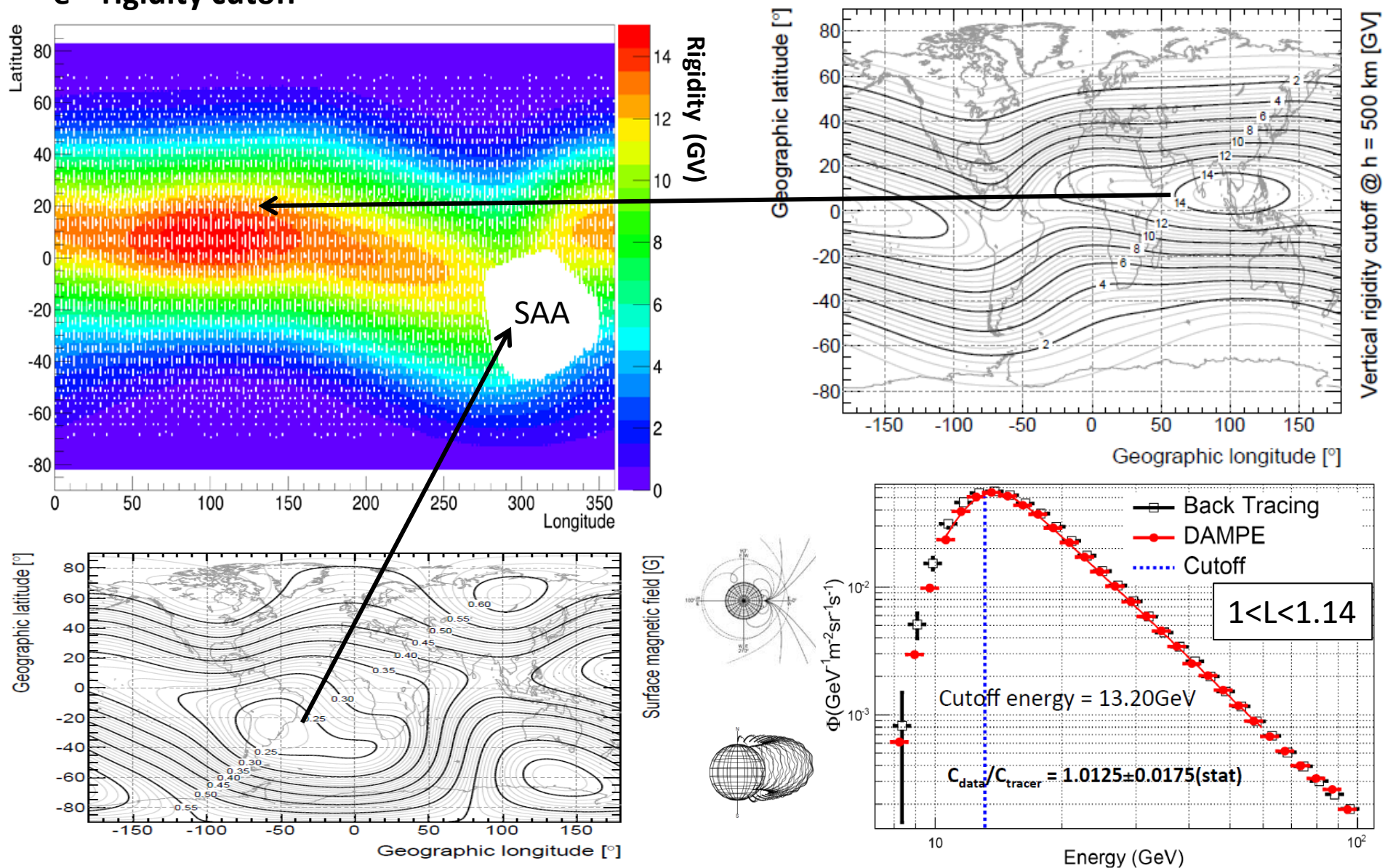
Electrons
and
positrons

Protons
and
nuclei



On-orbit energy scale calibration

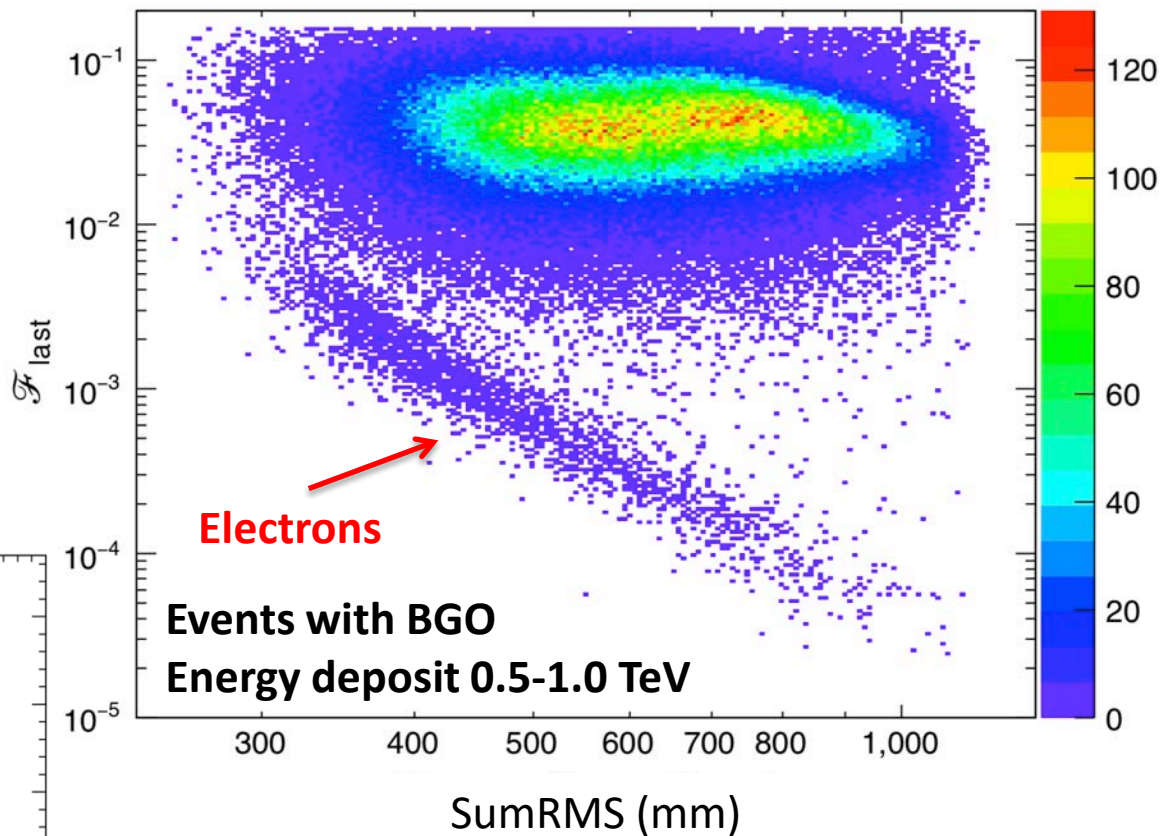
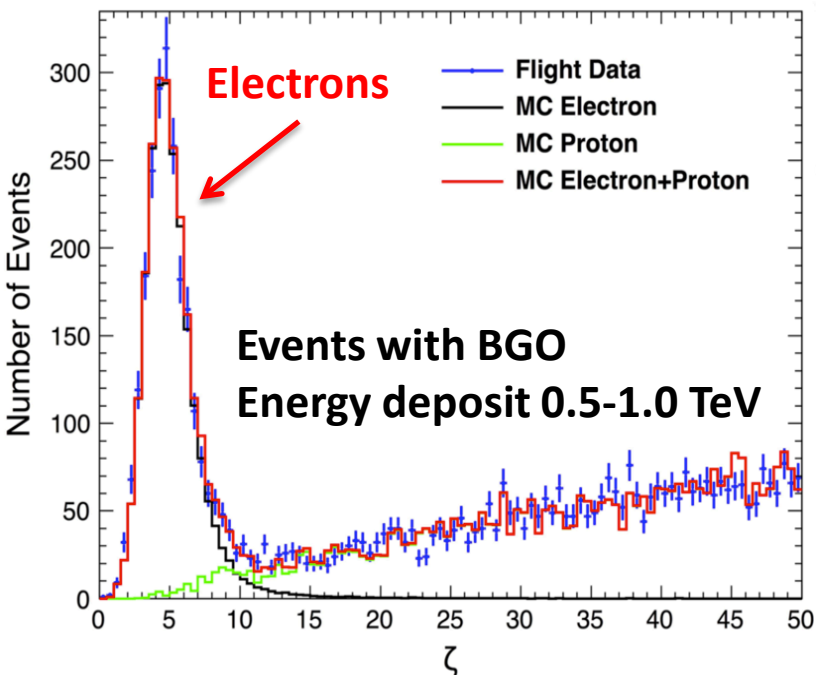
$e^\pm$ rigidity cutoff



Electron IDentification

$\mathcal{F}_{\text{last}}$ = fraction of energy
 deposit in the last BGO
 layer with hits

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



SumRMS = Sum of single layer
 RMS values

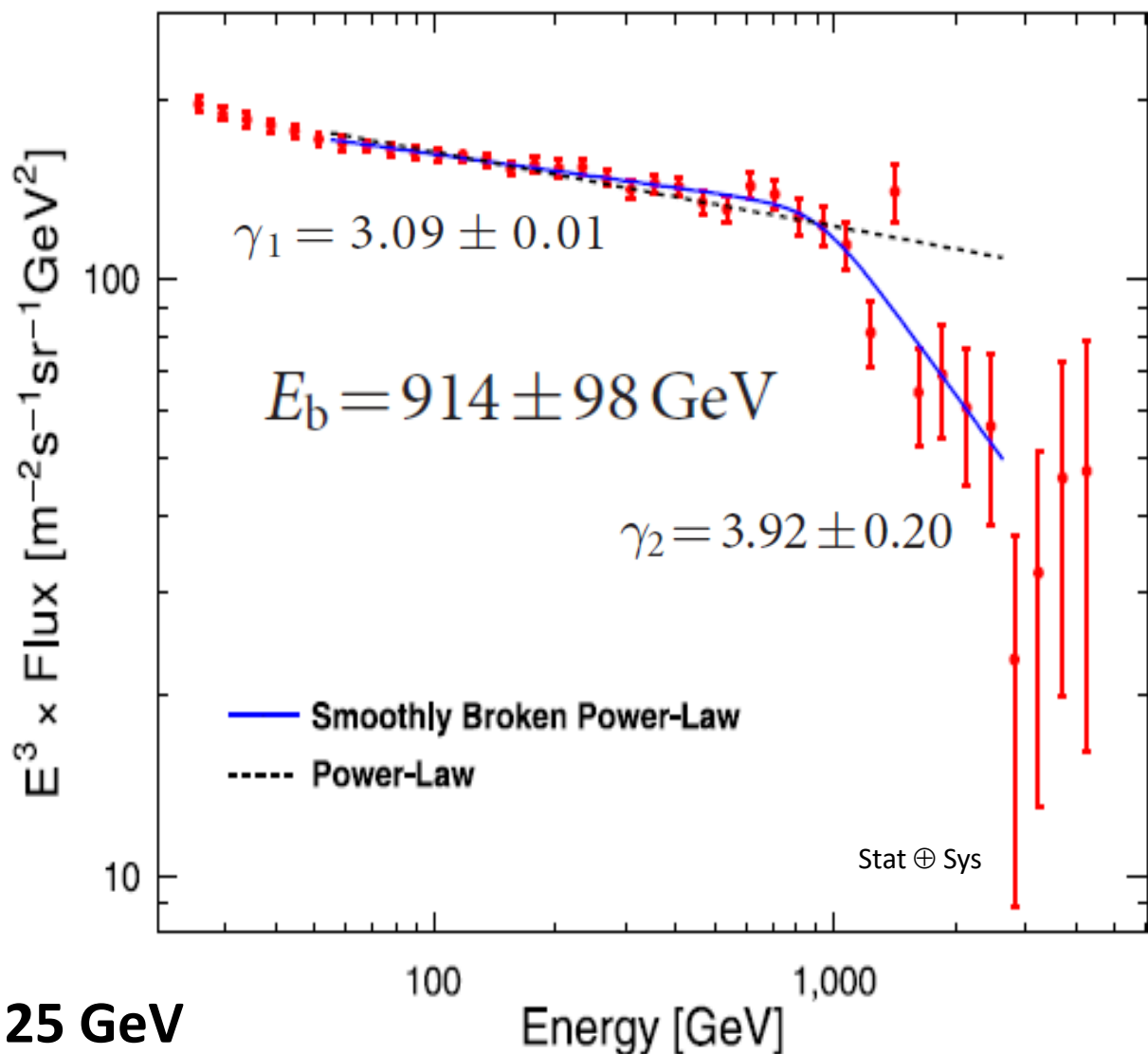
$$\zeta = \mathcal{F}_{\text{last}} \times (\sum_i RMS_i / \text{mm})^4 / (8 \times 10^6)$$

The DAMPE ($e^+ + e^-$) spectrum



**First Direct Evidence for
 a spectral break in the
 all-electron spectrum
 at 0.9 TeV**

- 530 days
- 2.8 billions CR events
- 1.5 million CREs above 25 GeV

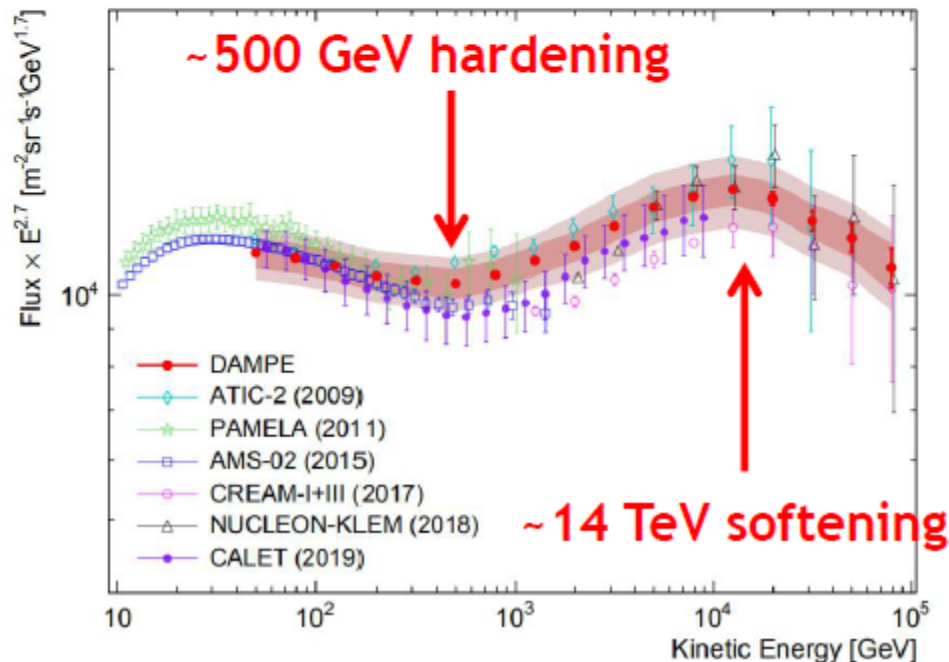
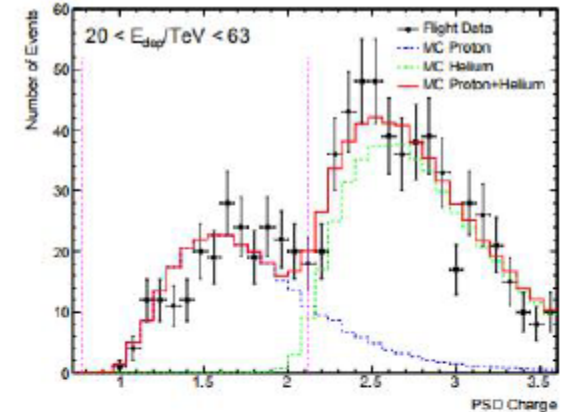
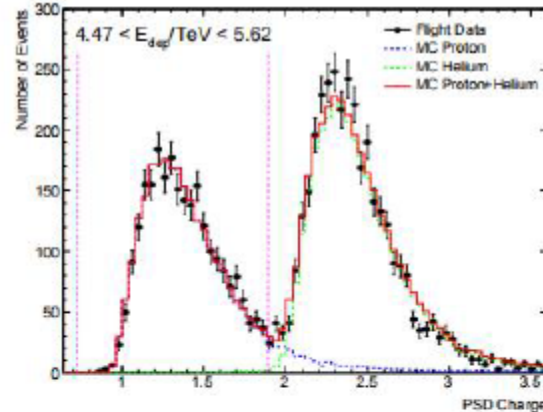
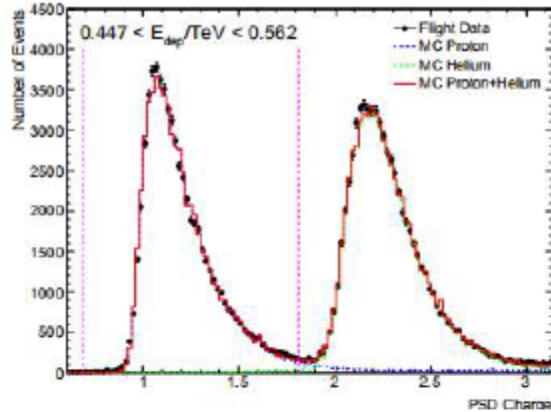


The DAMPE proton spectrum

SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

Measurement of the cosmic ray proton spectrum from 40 GeV to 100 TeV with the DAMPE satellite



- Confirms the hundreds of GeV hardening
- Detecting a softening at ~14 TeV with high significance

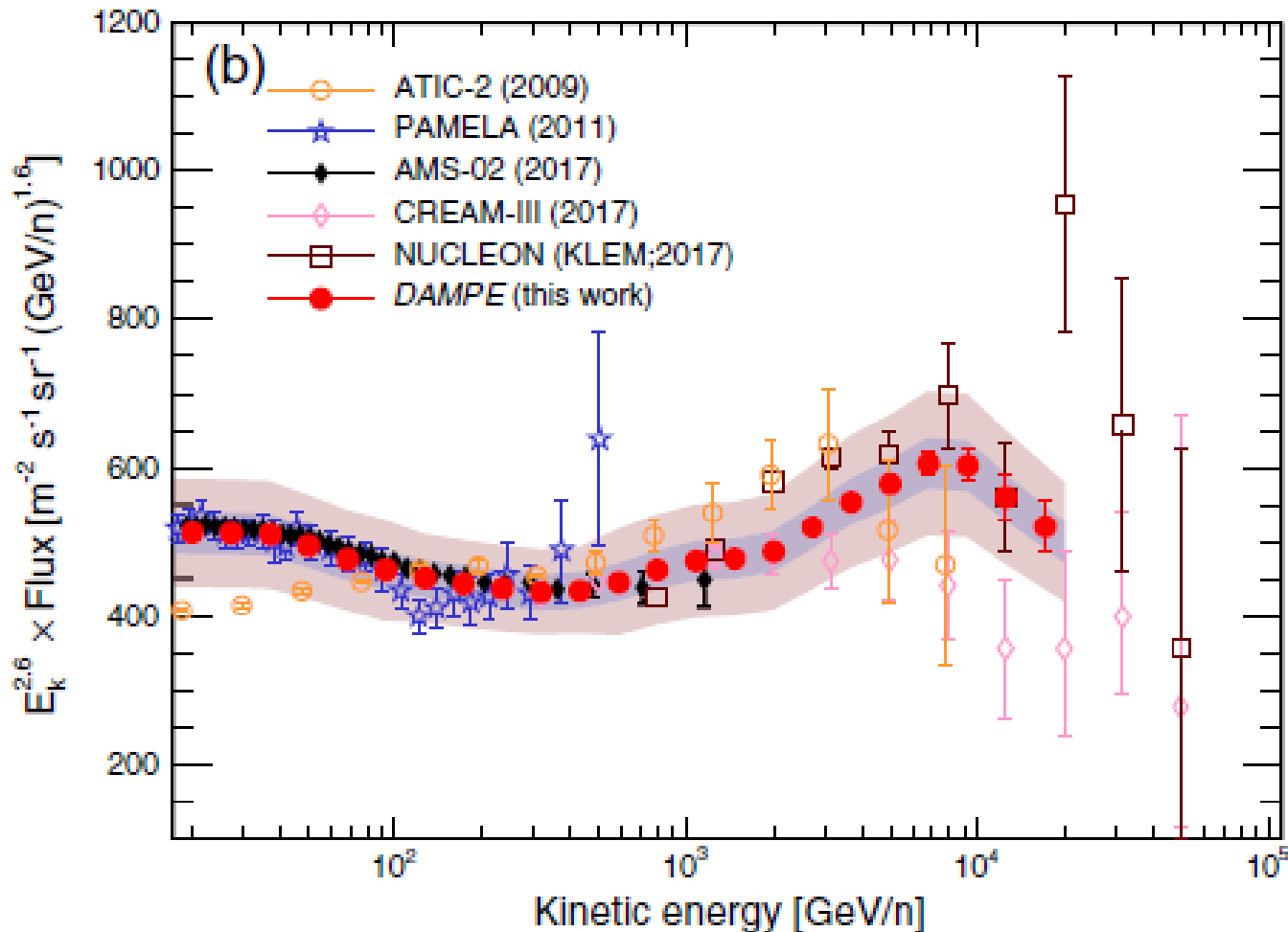
The DAMPE helium spectrum

PHYSICAL REVIEW LETTERS 126, 211102 (2021)

Editors' Suggestion

Featured in Physics

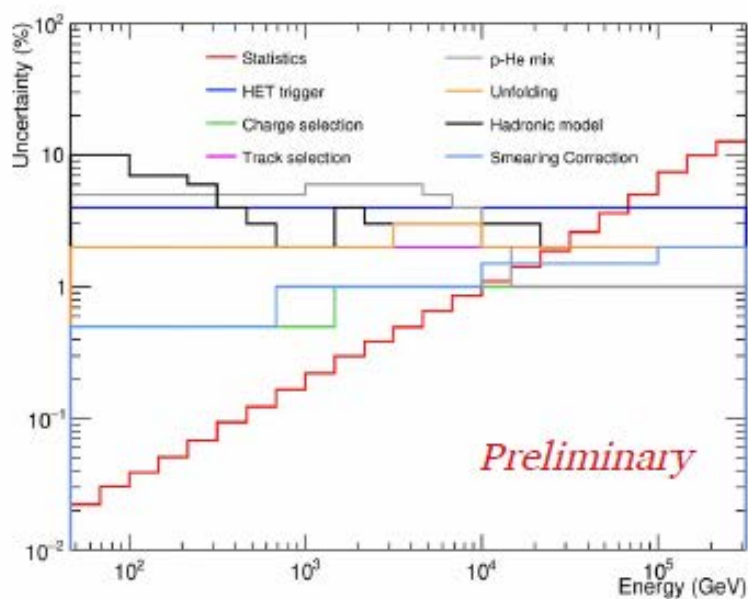
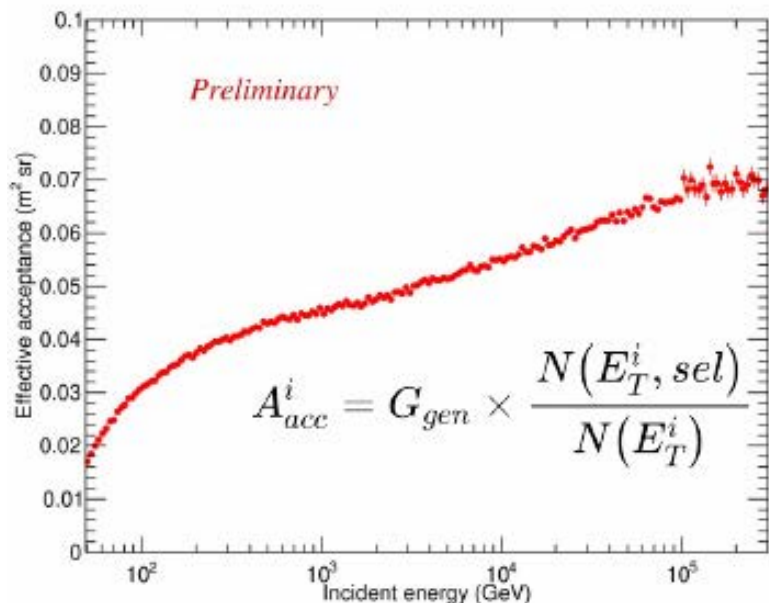
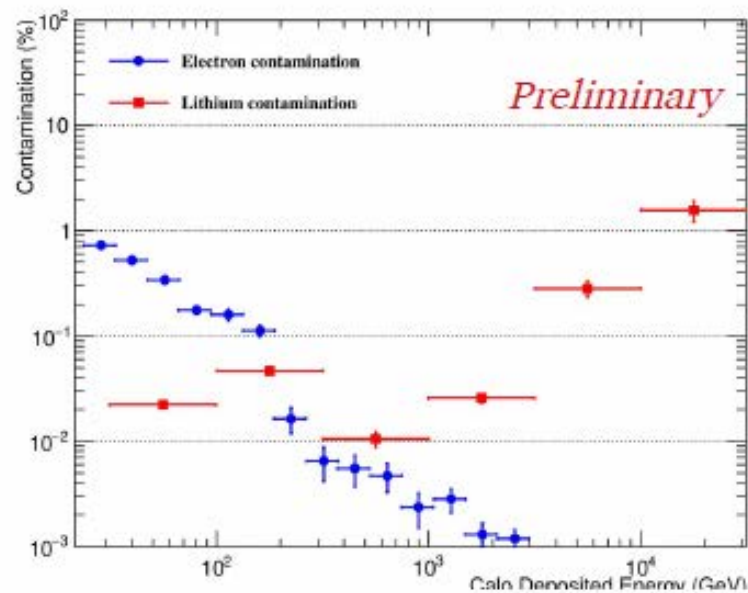
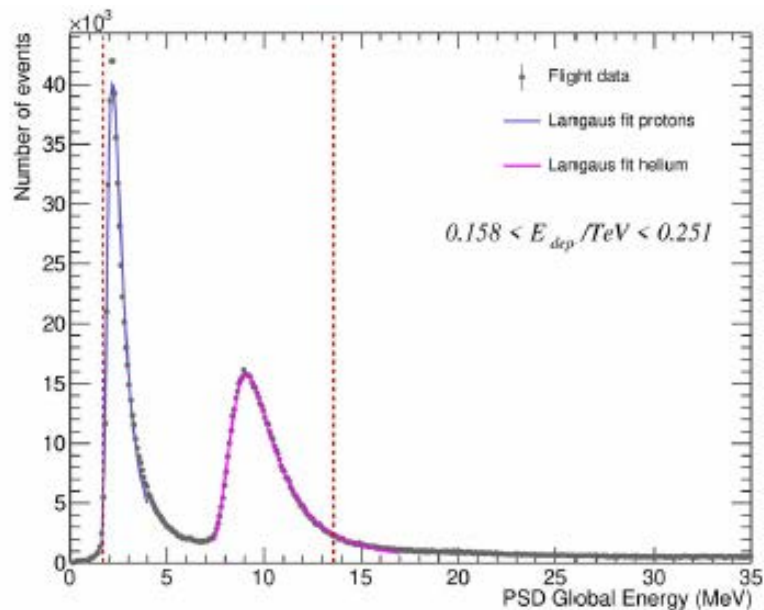
Measurement of the Cosmic Ray Helium Energy Spectrum
from 70 GeV to 80 TeV with the DAMPE Space Mission



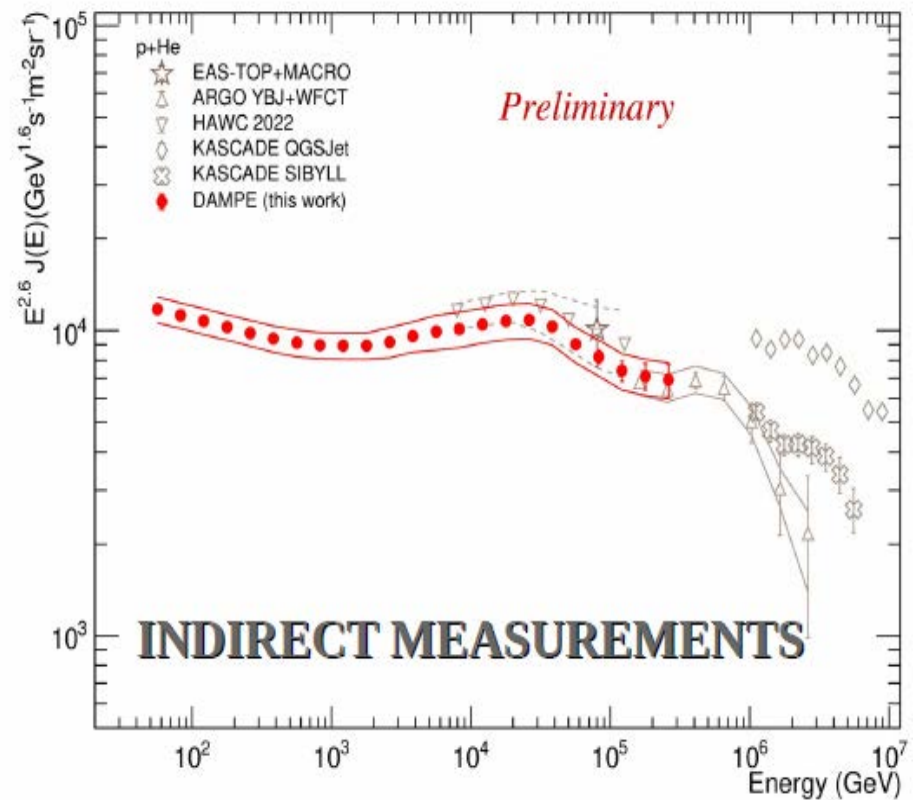
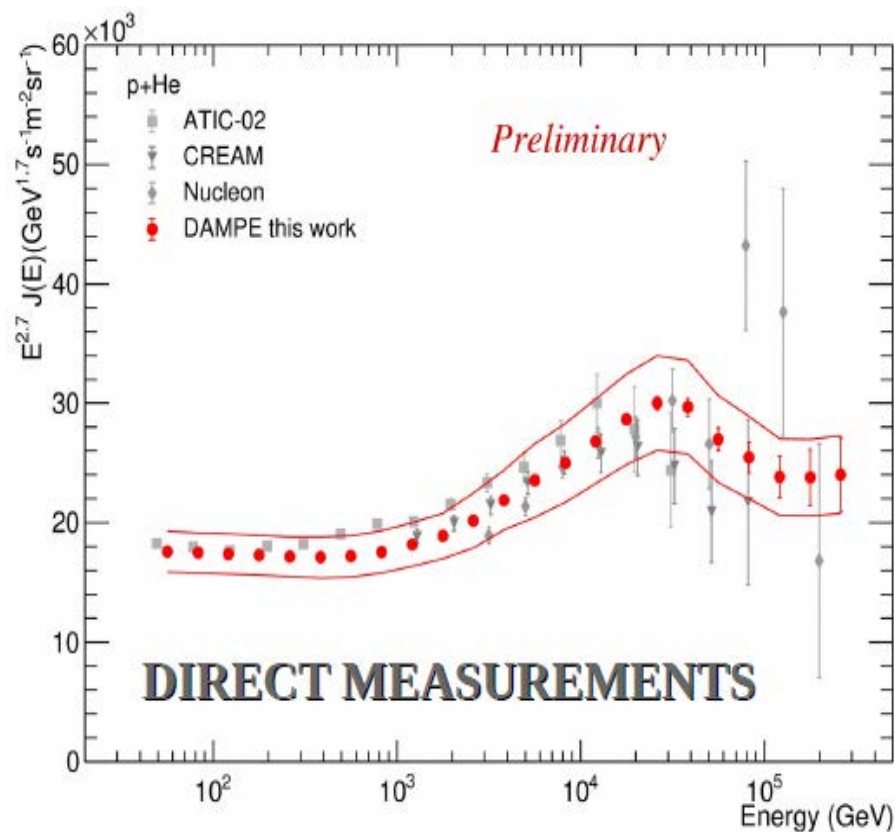
First clear
evidence for a
softening
at about 34 TeV

Suggesting a Z
dependent
softening energy
(~ 14 TeV for protons)

The DAMPE p+He spectrum



The DAMPE p+He spectrum



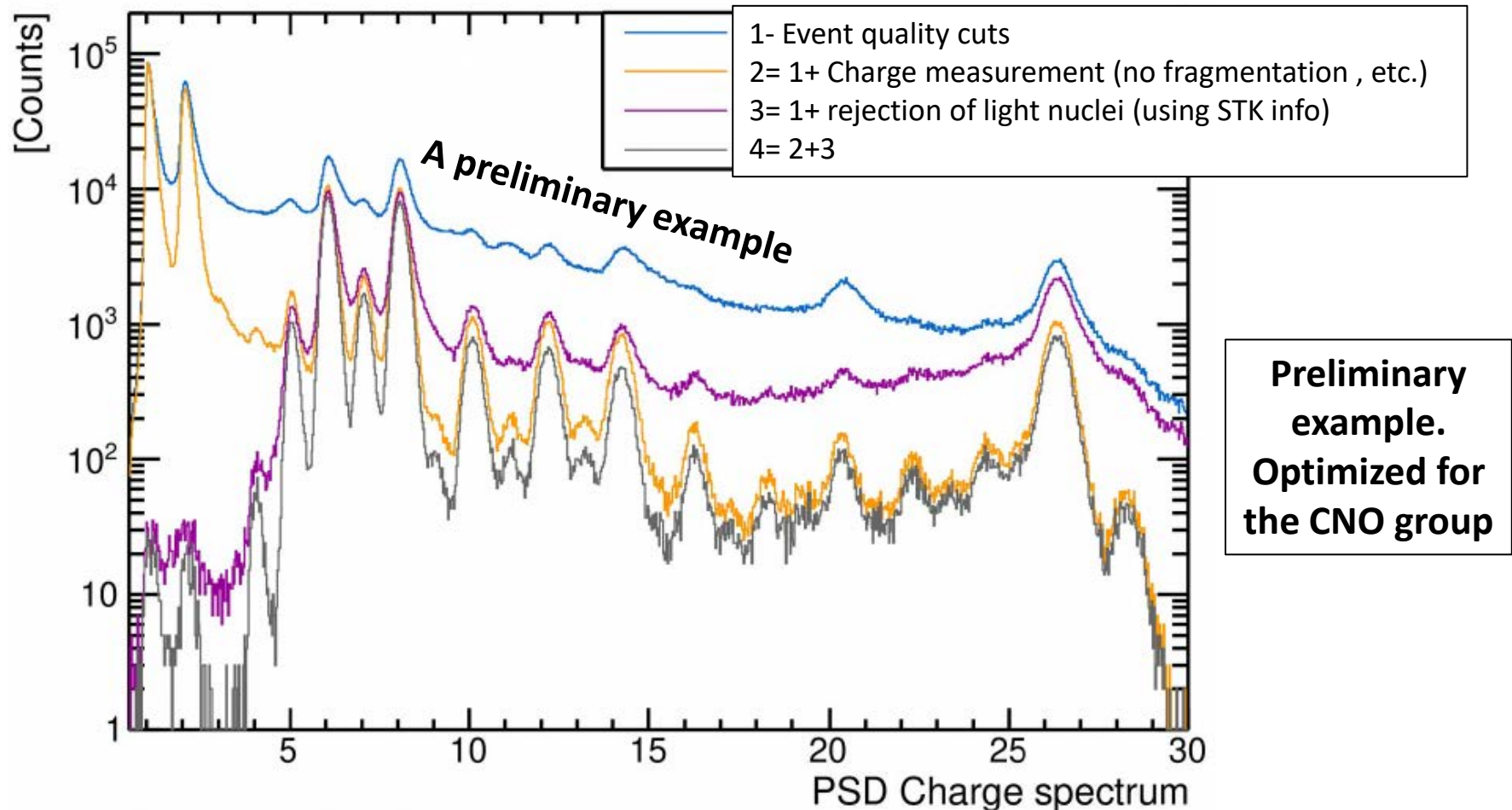
- ✓ Confirmation of the softening
(at about 25 TeV due to the combination of p and He spectra)
- ✓ Extension to 300 TeV
- ✓ Overlapping with indirect measurements

DAMPE: heavier nuclei

Several independent analyses are ongoing from Li up to Iron

Different selection criteria to reject other nuclei and avoid charge misidentification

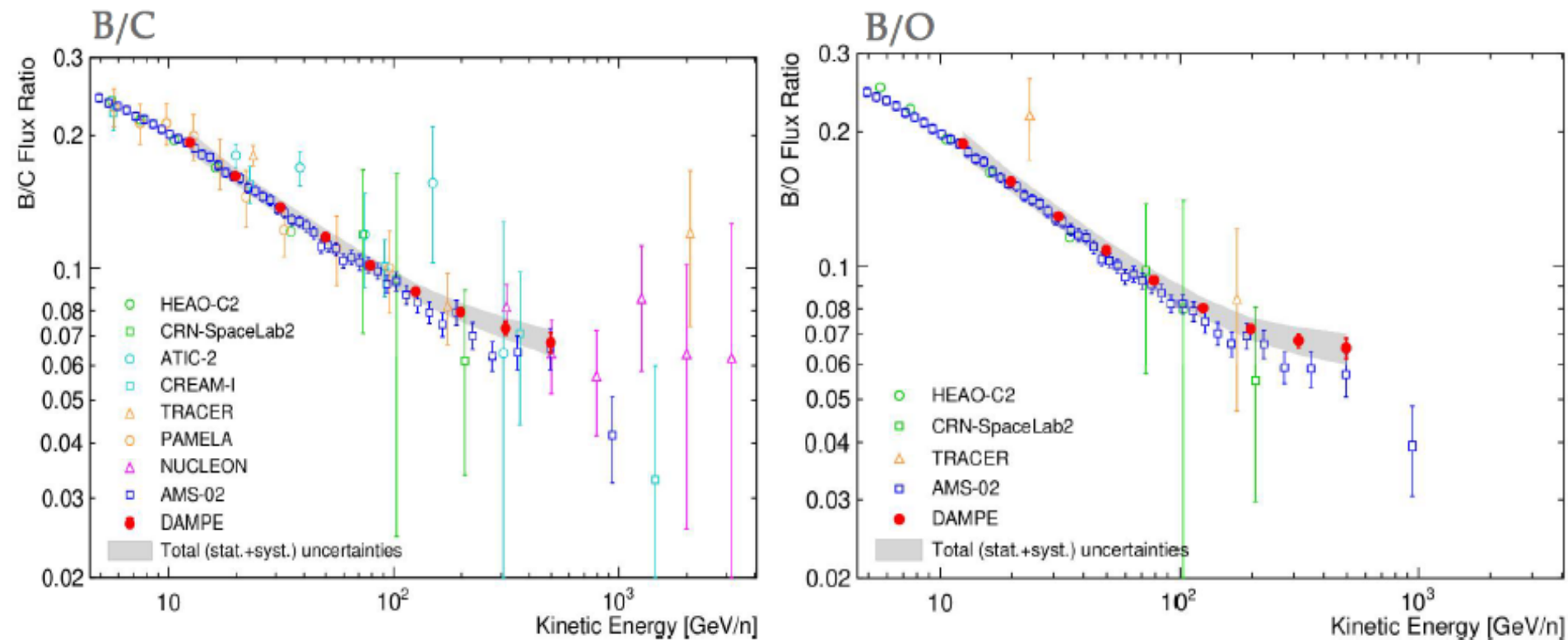
Different approaches to limit and better evaluate the systematics.



Secondary-to-primary ratios

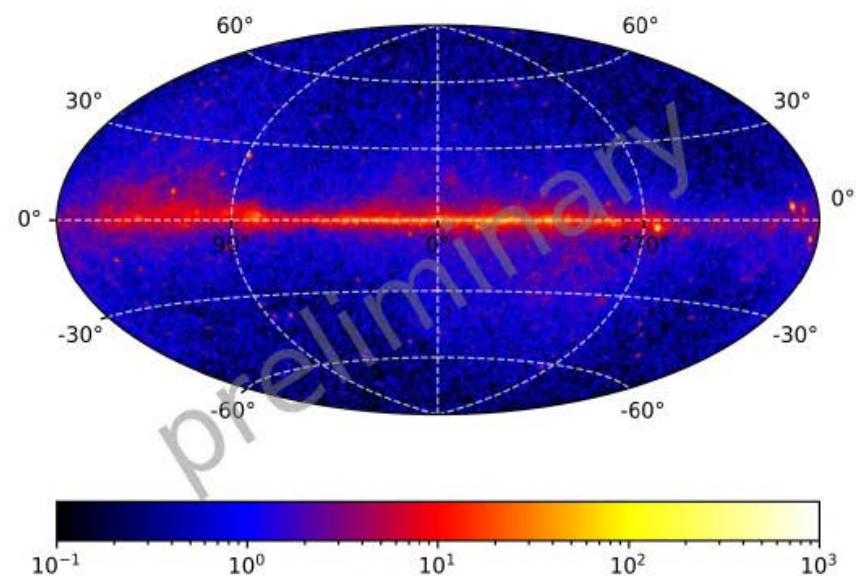
As a further cross check, several secondary-to-primary ratios are being measured with different analysis approaches

Preliminary results for B/C and B/O. Extension to few TeV/n in progress.



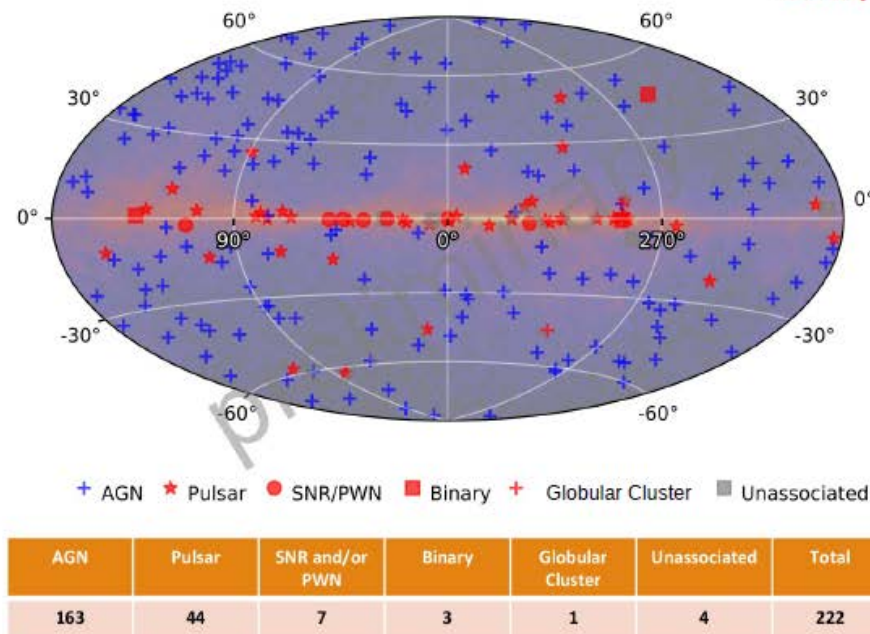
The gamma ray sky

5-years gamma-ray data



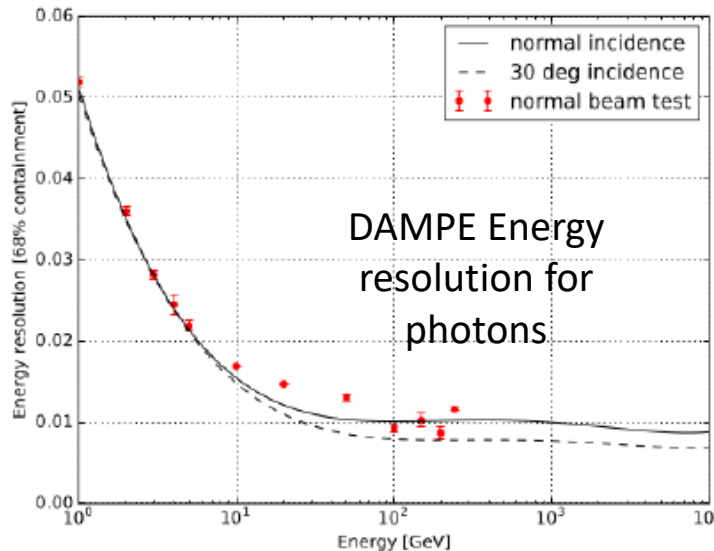
120 M seconds livetime and
more than 220'000 photons above 2 GeV

ICRC 2021 – Duan Kai-Kai, Observation of
gamma-ray sources with DAMPE



Associated with the 4FGL

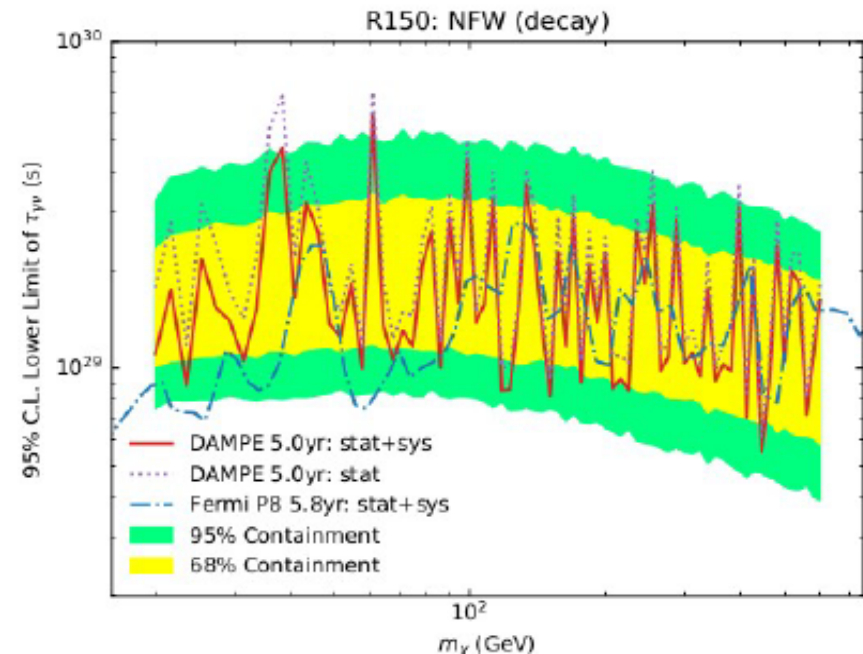
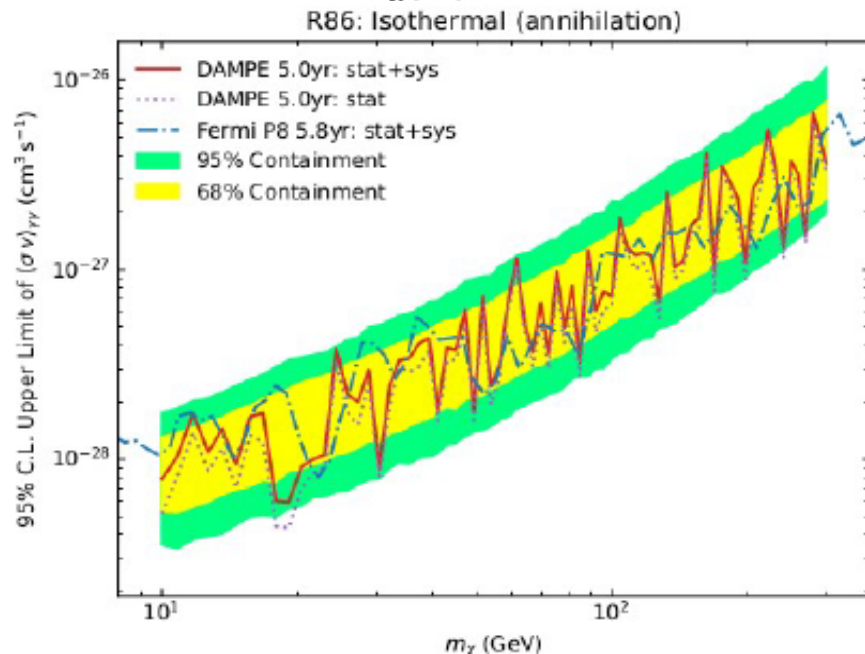
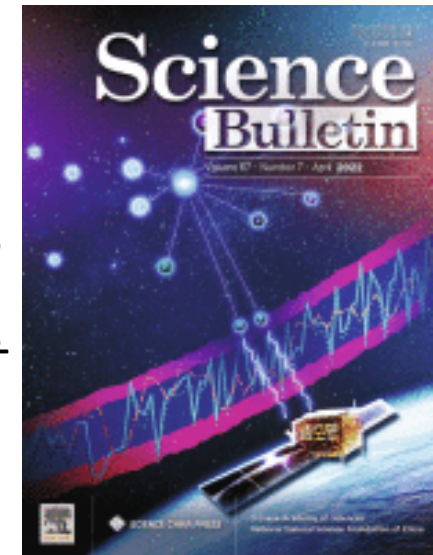
Indirect Dark Matter search



Search for gamma ray lines from neutralino annihilation or decay

Very high sensitivity due to:
-Effective area
-Energy resolution

April 2022



DAMPE Summary



The detector

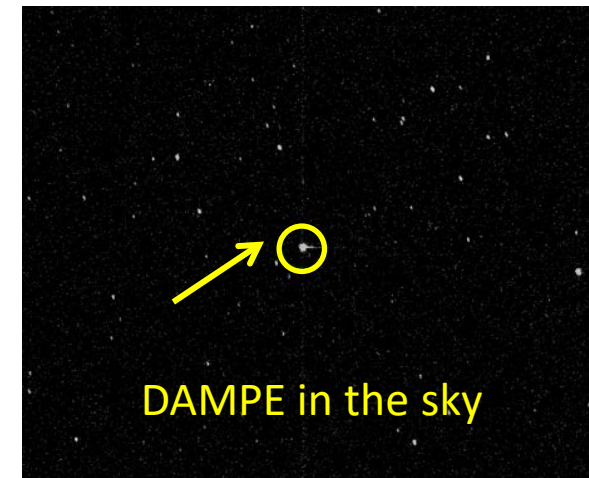
- Large geometric factor instrument ($0.3 \text{ m}^2 \text{ sr}$ for p and nuclei)
- Precision Si-W tracker ($40\mu\text{m}$, 0.2°)
- Thick calorimeter ($32 X_0$, σ_E/E better than 1% above 50 GeV for e/γ , $\sim 35\%$ for hadrons)
- “Multiple” charge measurements (0.2-0.3 e resolution)
- e/p rejection power $> 10^5$ (topology alone, plus neutron detector)

Launch and performances

- Successful 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

Science:

- Evidence for a cutoff at $\sim 1 \text{ TeV}$ in the all electron spectrum
- Evidence for a softening in the proton spectrum at $\sim 14 \text{ TeV}$
- Evidence for a softening in the helium spectrum at $\sim 34 \text{ TeV}$ (suggest Z dependence)
- Measurement of p+He confirms the softening and extend till 300 TeV
- Undergoing spectral measurements of heavier nuclei and secondary-to-primary ratios
- Preliminary studies of gamma ray sources (250 sources, Fermi bubble, ...)
- Detected new features in Forbush decrease
- Search for dark matter signatures (upper limits from gamma line searches,...)
- Be ready for the “unexpected”: GW electromagnetic follow up in FoV,



DAMPE in the sky

More Stuff

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 Bari and University of Bari
- INFN Lecce and University of Salento
- INFN LNGS and Gran Sasso Science Institute
- INFN Perugia and University of Perugia

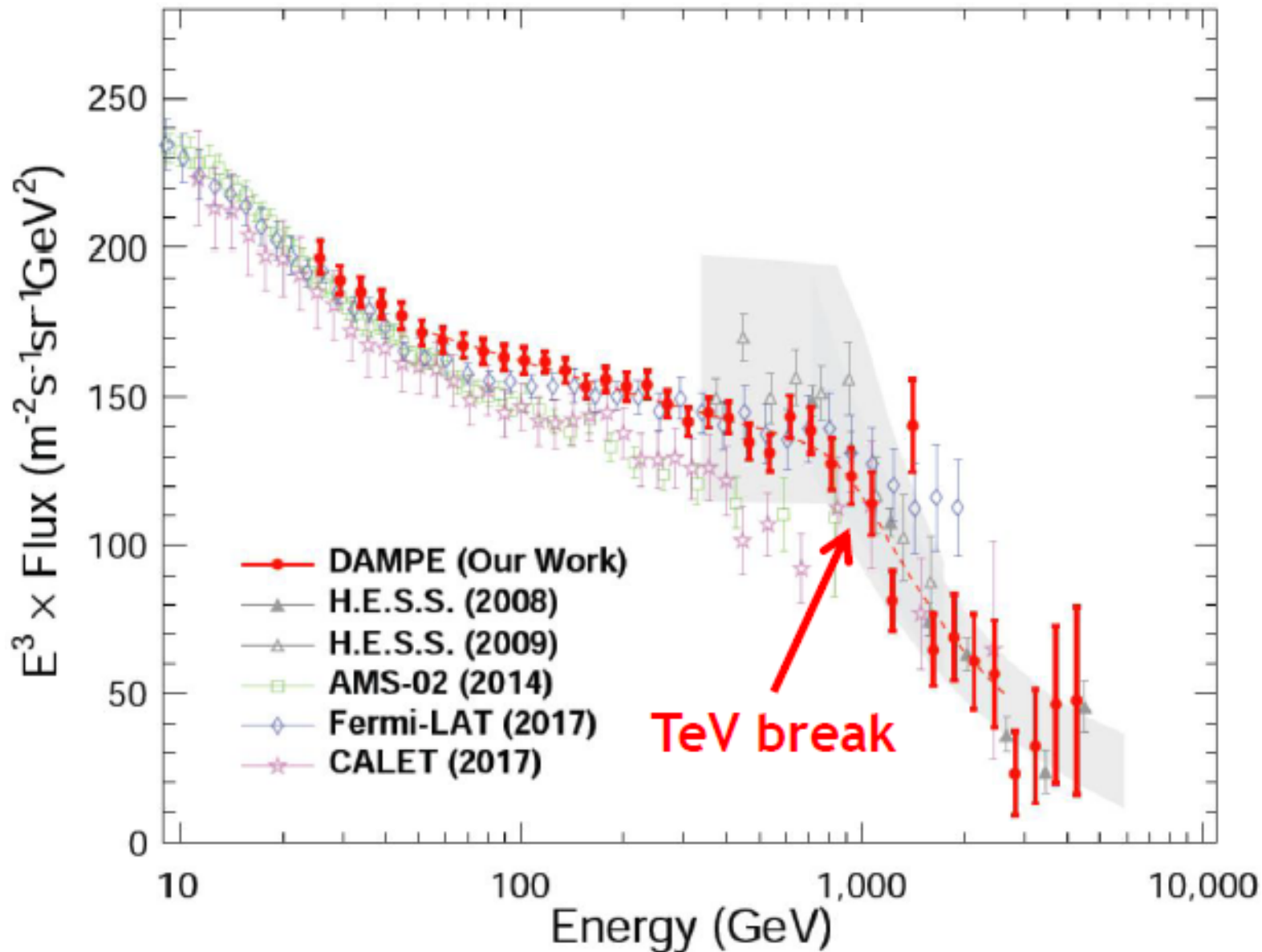


- SWITZERLAND**

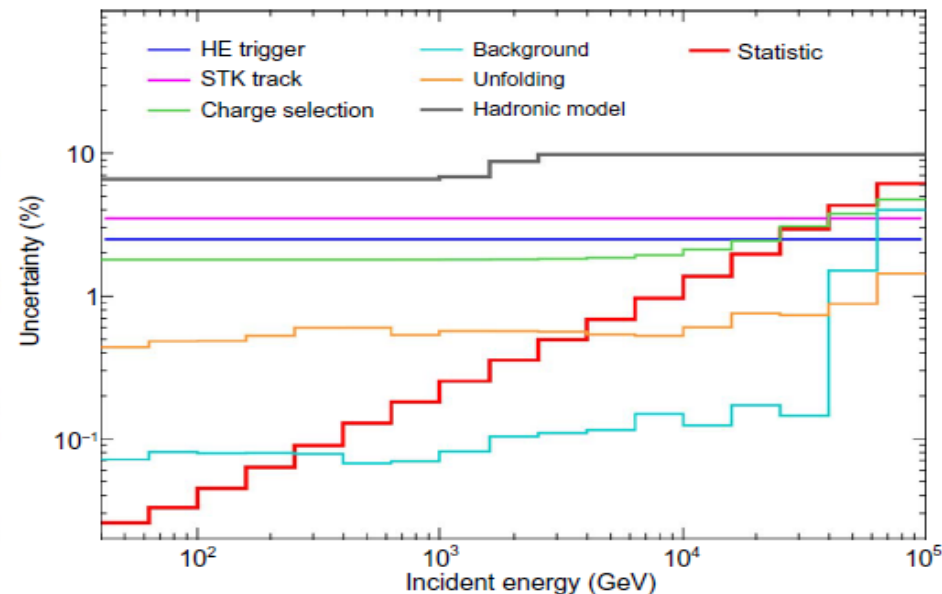
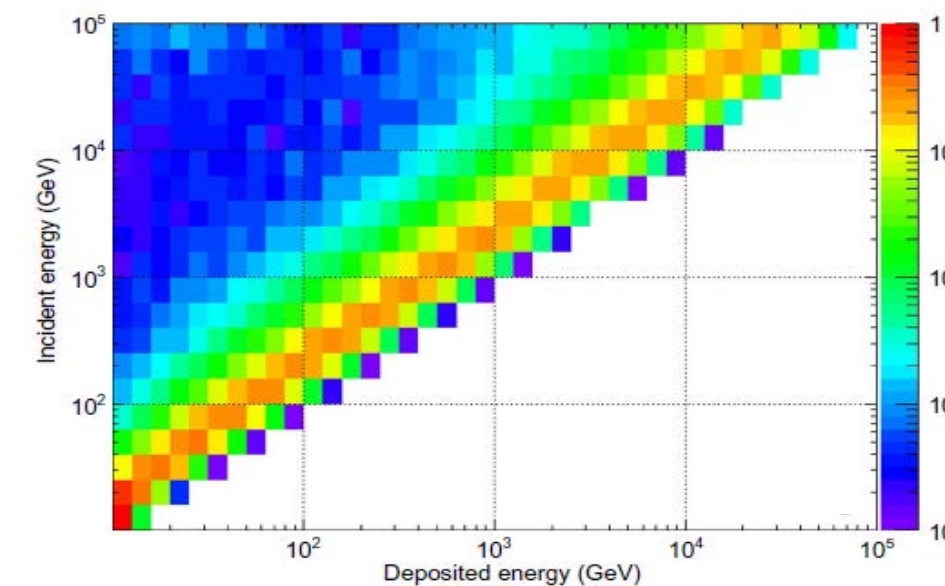
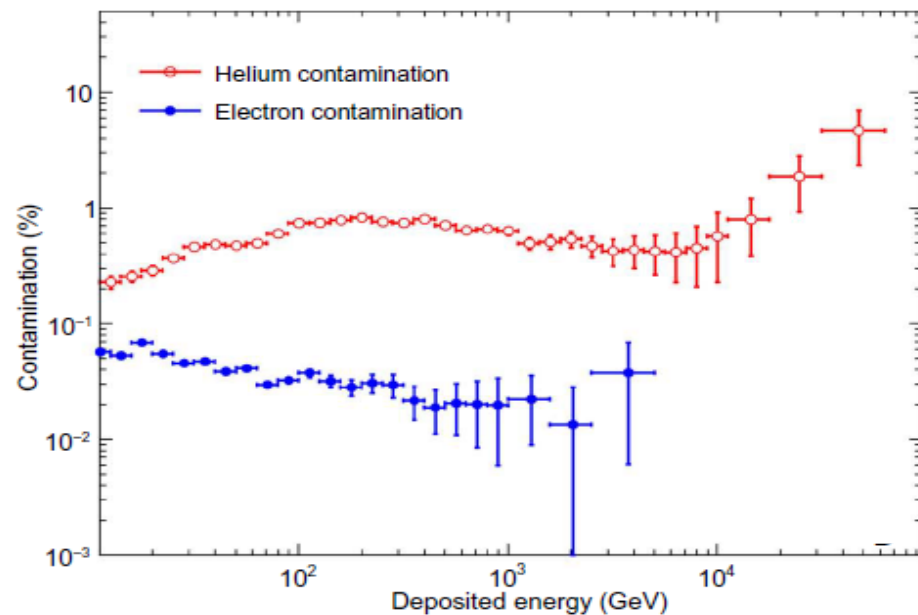
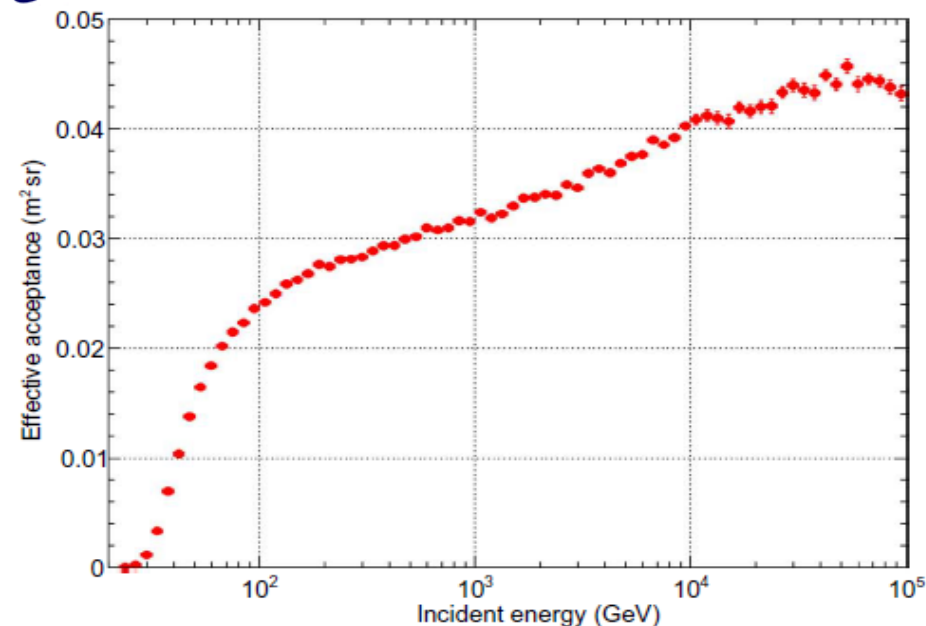
- University of Geneva



The all-electron spectrum



The DAMPE proton spectrum



The DAMPE helium spectrum

YOZ view [1848.225 GeV]

