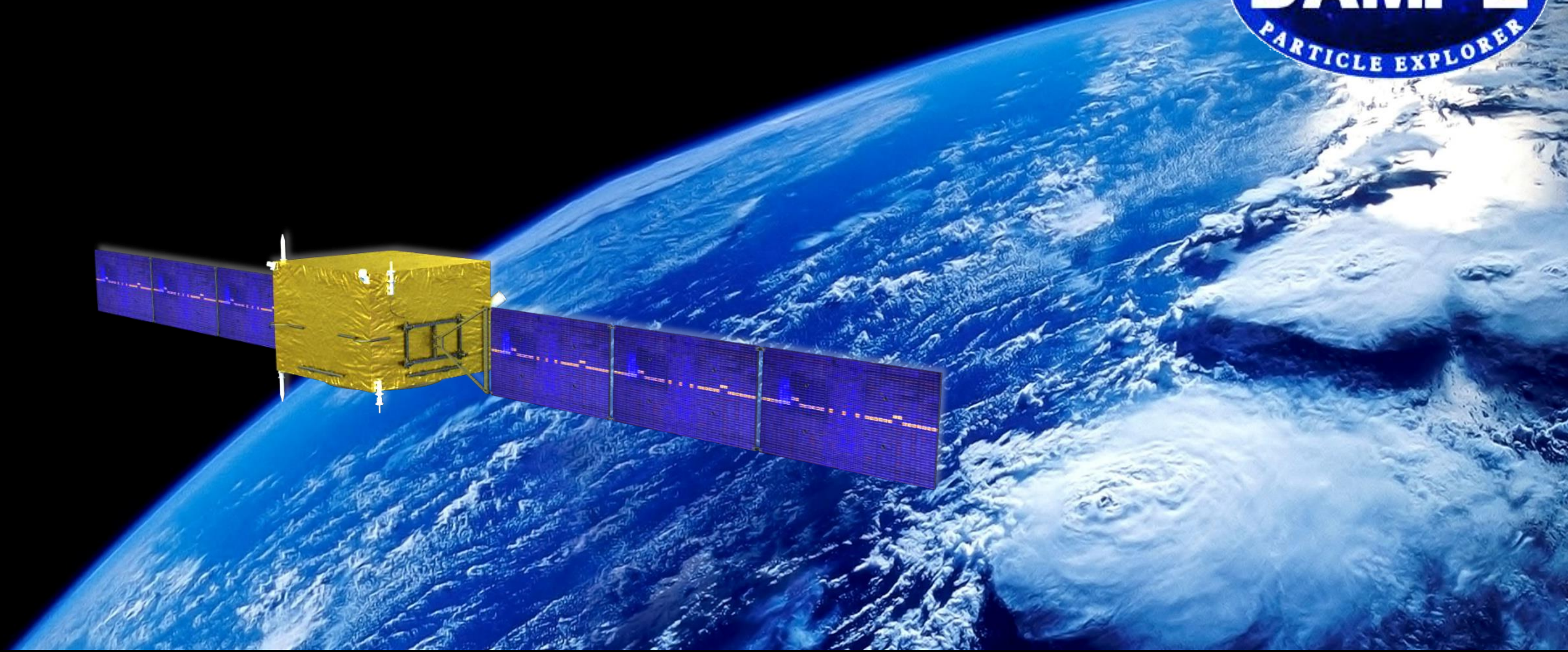
36° International Cosmic Ray Conference – Madison, WI, USA

ICRC 2019

THE ASTROPARTICLE PHYSICS CONFERENCE

DARK MATTER PARTICLE EXPLORER DAMPE



Helium spectrum in the Cosmic Rays measured by the DAMPE detector

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On behalf of the DAMPE Collaboration

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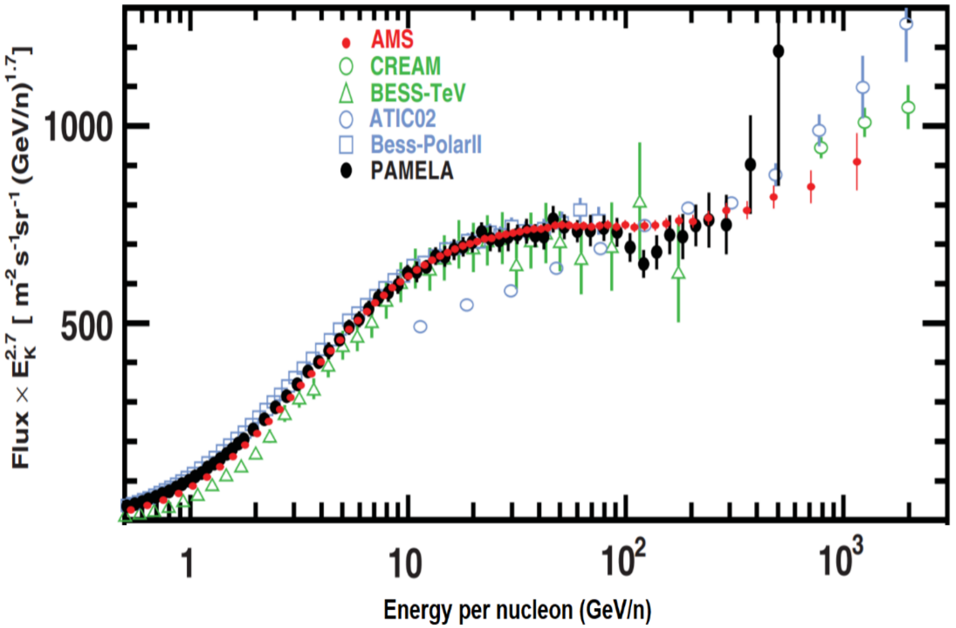
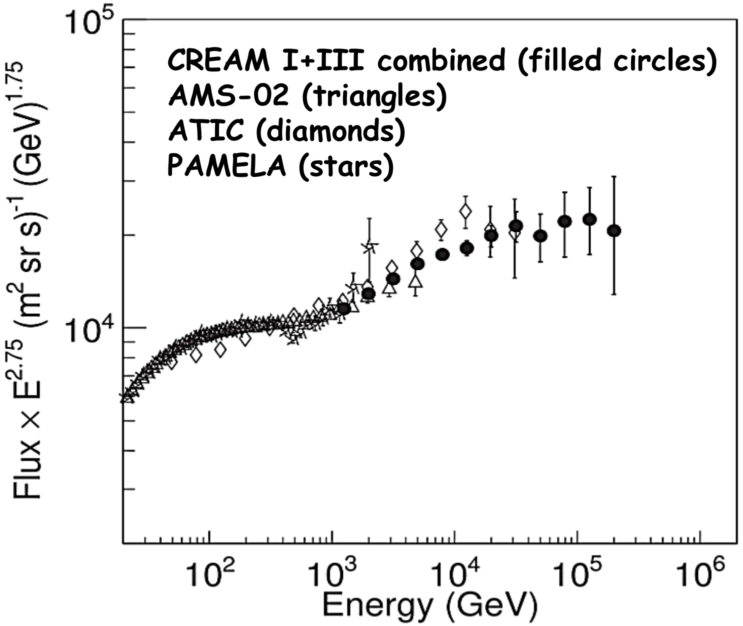
Outline

- Introduction
- DAMPE mission & detector
- Helium selection
- Proton background
- Efficiencies
- Acceptance
- Preliminary Helium flux
- Conclusions & Outlooks

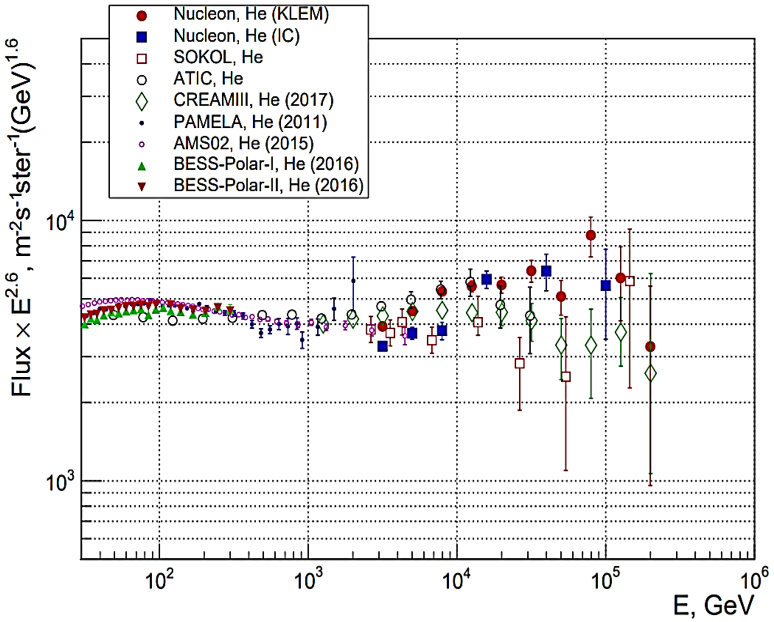
Introduction/Scientific case



M. Aguilar *et al.* (AMS Collaboration) PRL 119 (2017)



Y.S. Yoon *et al.* (CREAM Collaboration) Astrophys. J. 839 (2017)



E. Atkin *et al.* (NUCLEON Collaboration) arXiv:1702.02352 (2018)

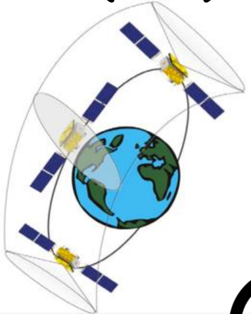
SPECTRAL HARDENING AT HUNDREDS OF GeV AND SOFTENING AT TeV-ENERGIES

CRs coming from different galactic sources?
different acceleration mechanisms that we should understand?
different propagation effects?

Dark Matter Particle Explorer

Satellite-borne particle detector, project of the *Strategic Pioneer Program on Space Science*, promoted by the *Chinese Academy of Sciences (CAS)*.

ALTITUDE: 500 km
PERIOD: 95 minutes
ORBIT: Sun-synchronous



- Study of Cosmic Rays composition, origin and propagation
- Search for Dark Matter signatures in lepton and photon spectra
- High Energy Gamma-Ray Astronomy

- Purple Mountain Observatory
- University of Science and Technology
- Institute of High Energy Physics
- Institute of Modern Physics
- National Space Science Center

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

- Geneva University

DAMPE detector

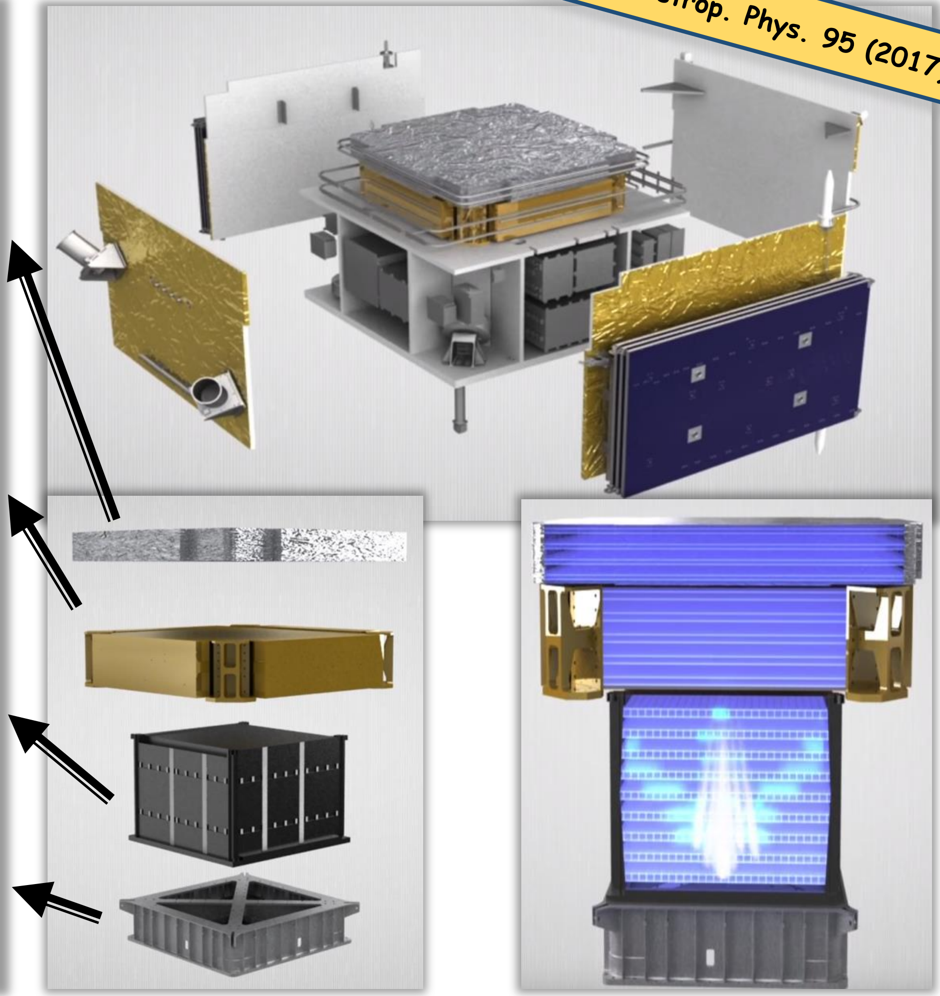
J. Chang et al., Astrop. Phys. 95 (2017) 6-24

PSD	• 2 planes with double layer configuration • 82 bars of plastic scintillator ❑ CHARGE MEASUREMENT ($Z<28$, $Z \propto \sqrt{E}$) ❑ γ-RAYS VETO

STK	• 6 planes with 2 single-sided silicon layers
	• 3 thin tungsten layers (for γ conversion in e^+/e^-)
	❑ TRACK RECONSTRUCTION
	  ❑ spatial resolution $<70\ \mu m$ for CR ($\theta_{inc} < 60°$)
	  ❑ angular resolution ~0.2° for γ at 10 GeV
	❑ CHARGE MEASUREMENT ($Z \propto \sqrt{ADC}$)

BGO	• 14 layers, each one with 22 bars of $Bi_3Ge_4O_{12}$,~32 X_0
	❑ ENERGY MEASUREMENT
	  ❑ 1 GeV - 10 TeV for electrons and γ
	  ❑ 50 GeV - 100 TeV for nuclei

NUD	• 1 layer, 4 boron-doped plastic scintillators ❑ detection of neutrons generated in the BGO for hadron/e.m. showers discrimination



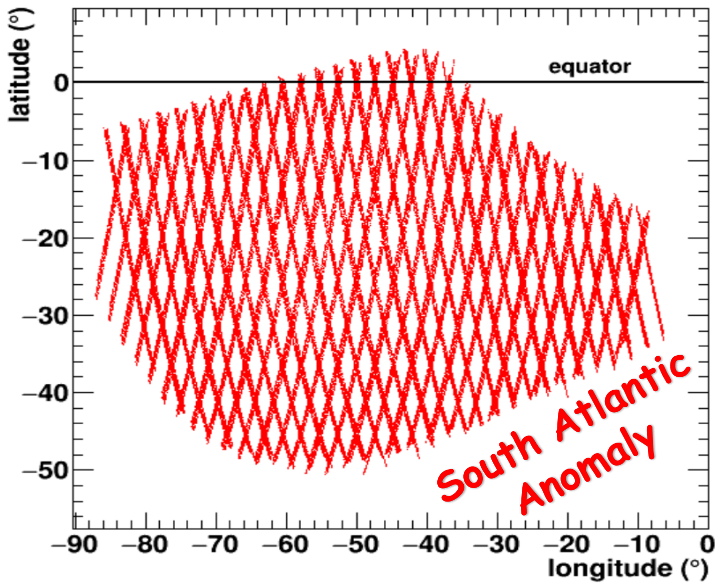
Event selection (I)

DATA SAMPLE: January 1st, 2016 to March 31th, 2019

EXPOSURE TIME: $7.86 \cdot 10^7$ s

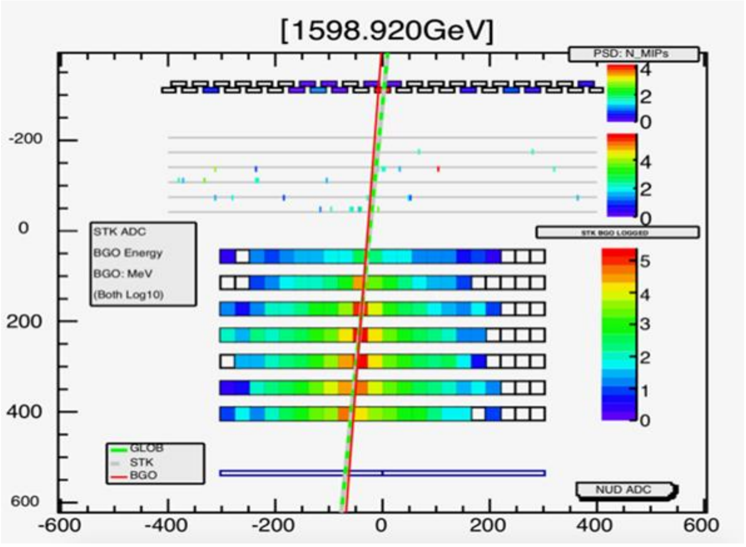
Exposure time affected by:

- South Atlantic Anomaly (SAA) region (~4.5% of the operation time)
- on-orbit calibration data-taking (~1.5% of the operation time)
- instrumental dead time (~18.5% of the operation time)



Pre-Selection

1. South Atlantic Anomaly events excluded
2. E_{dep} > 20 GeV inside the BGO calorimeter
3. $N_{STKTrack}$ ≥ 1 & full containment of the track
4. match STK track direction/hit position on the fired PSD bars
5. match STK track direction/BGO shower direction

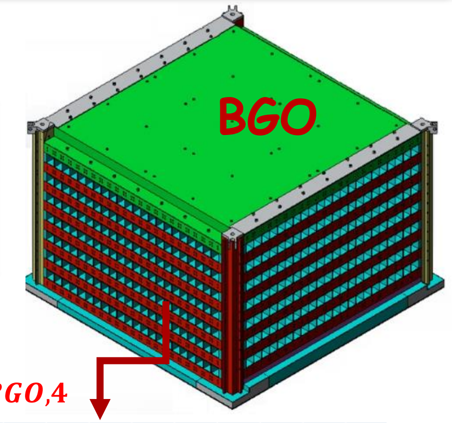


Event selection (II)

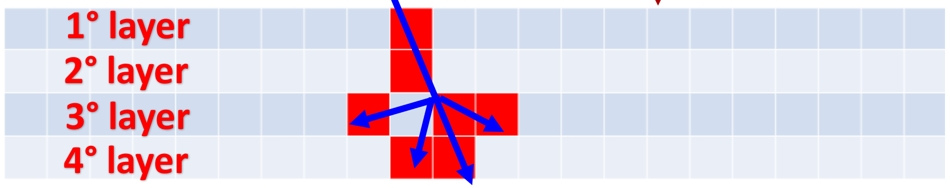
Charge Selection

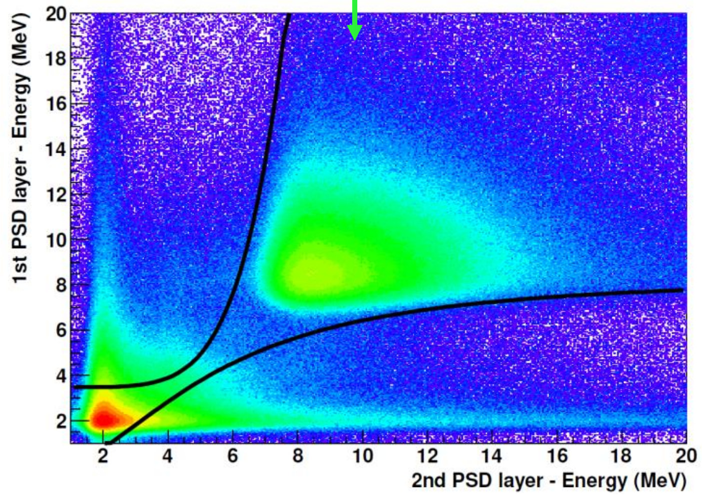
- High Energy Trigger activation
- Top-down development of the shower in the BGO
- Charge measurement agreement in both PSD views
- Charge measurement agreement in PSD and STK 1st layer

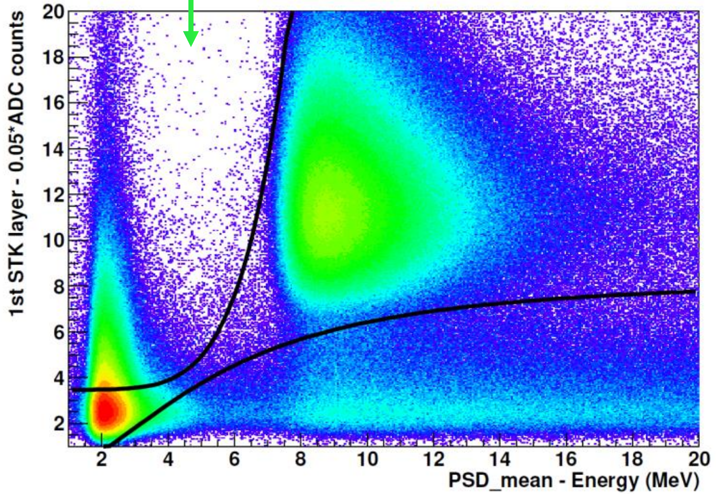
E_{dep} > 10 MIPs in first three BGO layers
E_{dep} > 2 MIPs in 4th BGO layer
(1 MIP_{BGO} = 23 MeV)

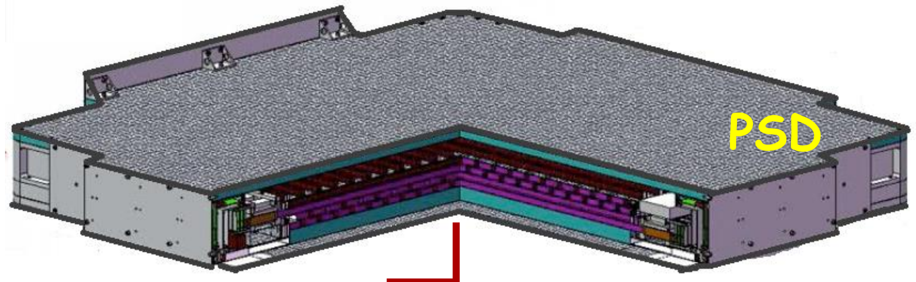


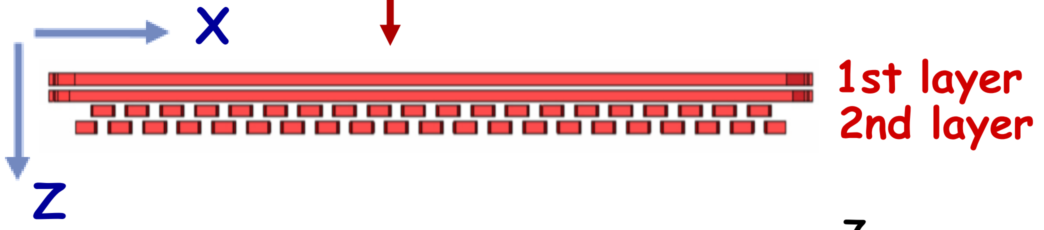
$$E_{BGO,1} + E_{BGO,2} < E_{BGO,3} + E_{BGO,4}$$



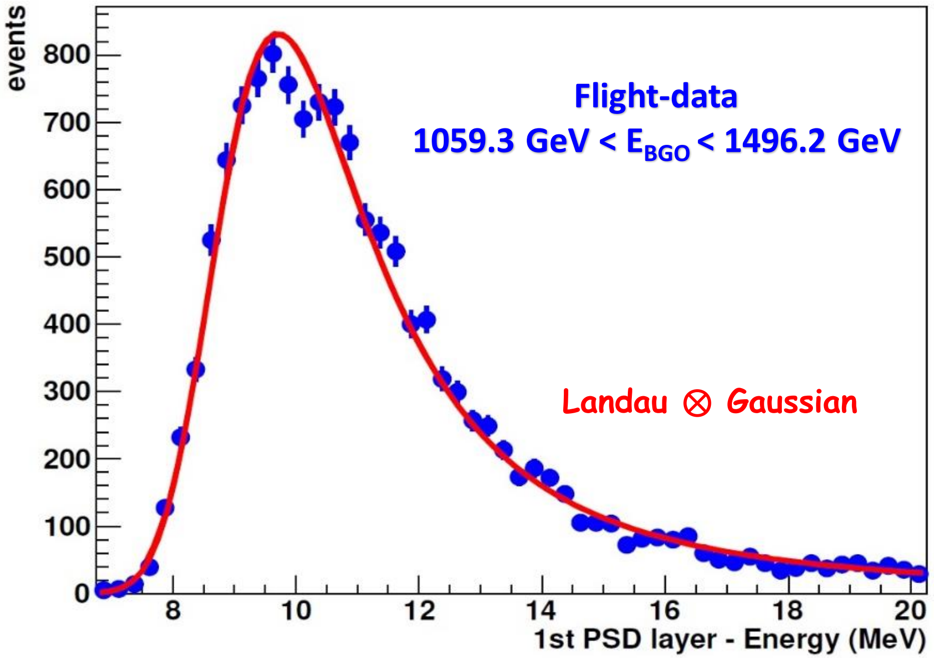


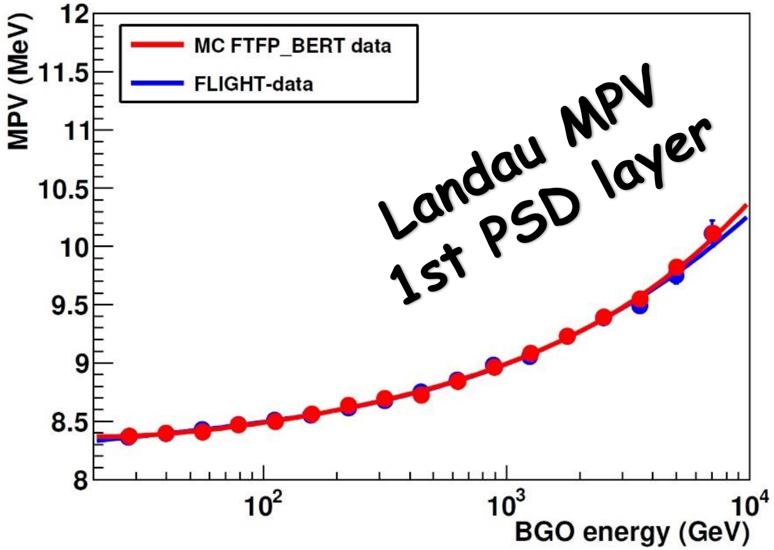


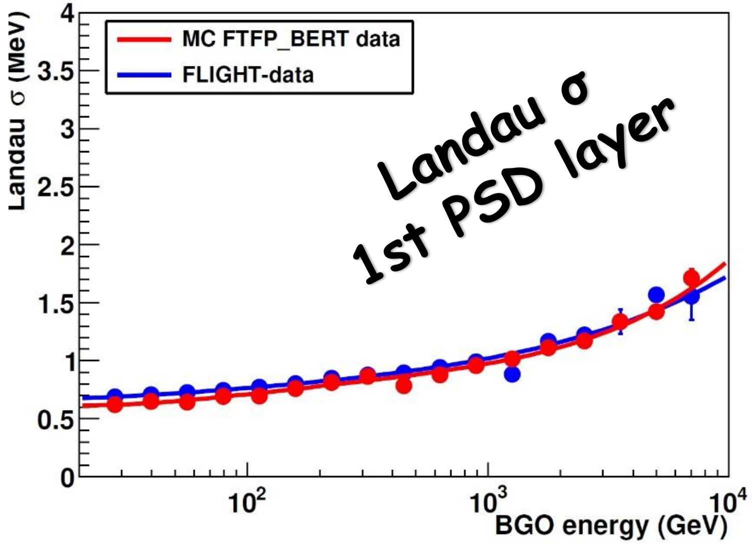


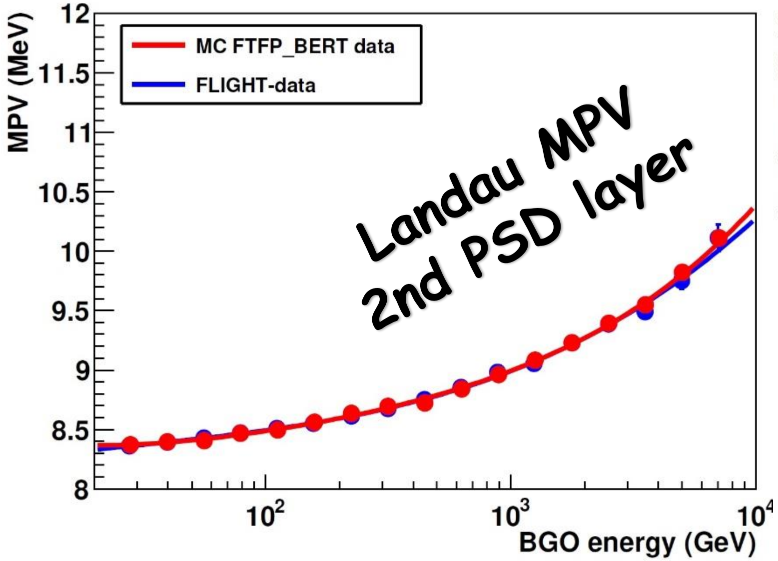


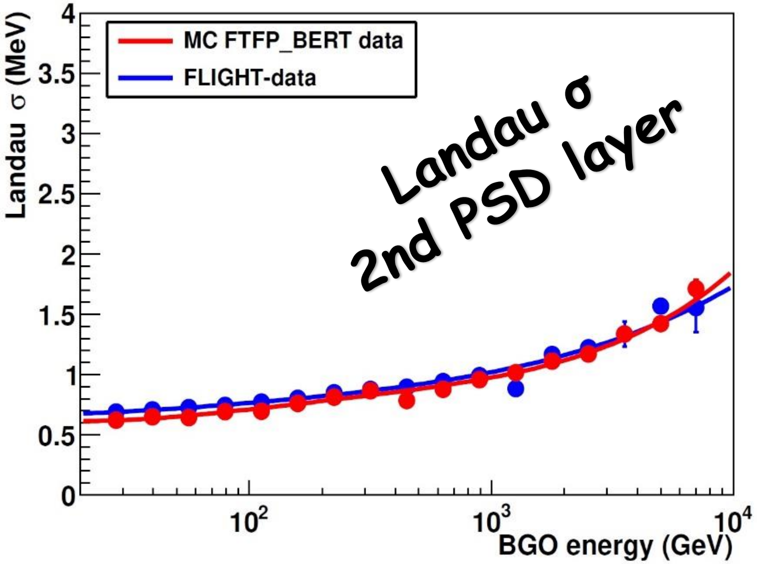
Charge Selection









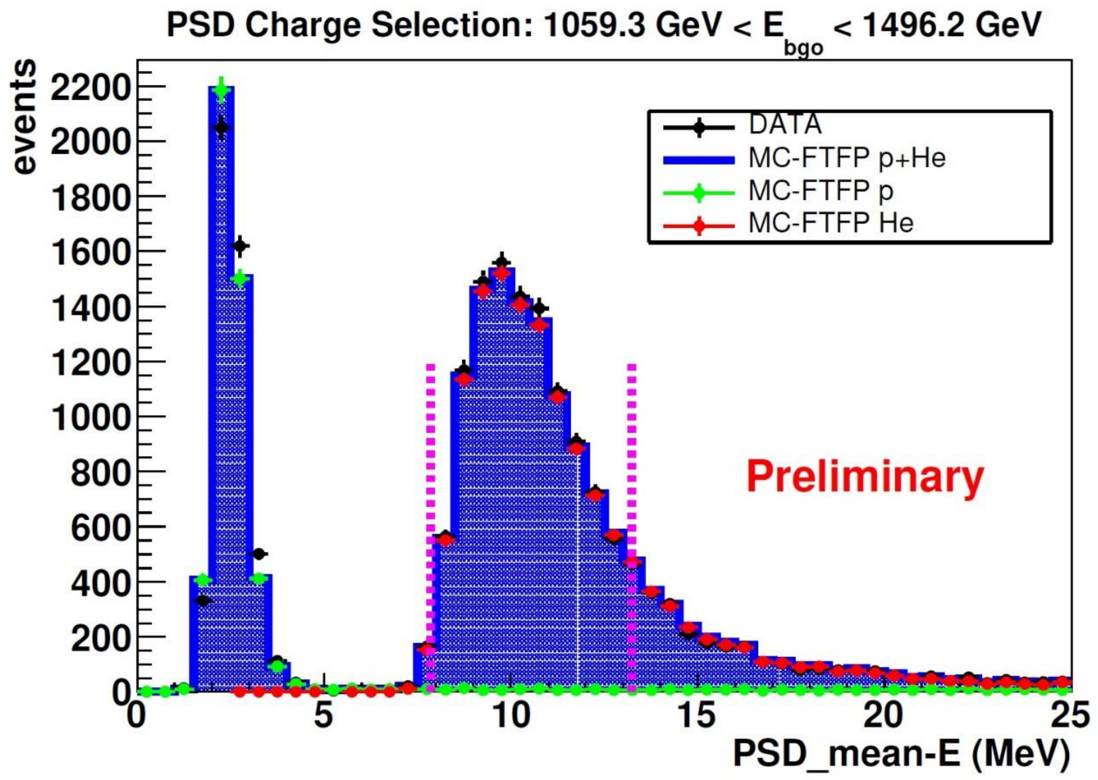


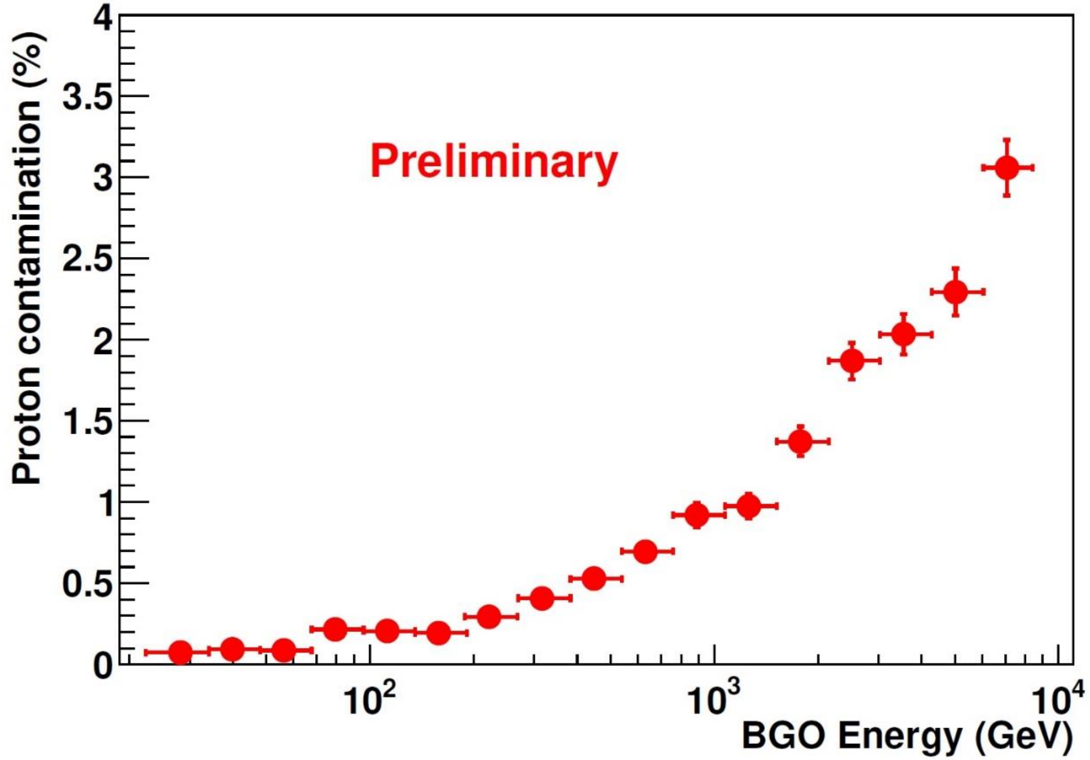
CHARGE SELECTION:

$$\mathrm{MPV} - 2\sigma < \mathrm{E_{PSD}} < \mathrm{MPV} + 4\sigma$$

with $\sigma = \sqrt{\sigma^2{}_{Landau} + \sigma^2{}_{Gaussian}}$

Proton Background





Template-Fit based on GEANT4 MC simulation data :

- FTFP_BERT Helium MC (10 GeV - 200 TeV)
- FTFP_BERT Proton MC (10 GeV - 100 TeV)
- DPMJET Proton MC (100 TeV - 1 PeV)

Systematic uncertainty due to proton background:

$\sigma_{bg} \sim 3\%$ **up to 10 TeV**

High Energy Trigger Efficiency

Unbiased Trigger: E_{dep}>0.4 MIPs in first 2 BGO layers

Pre-scaling factors of Unbiased Trigger:

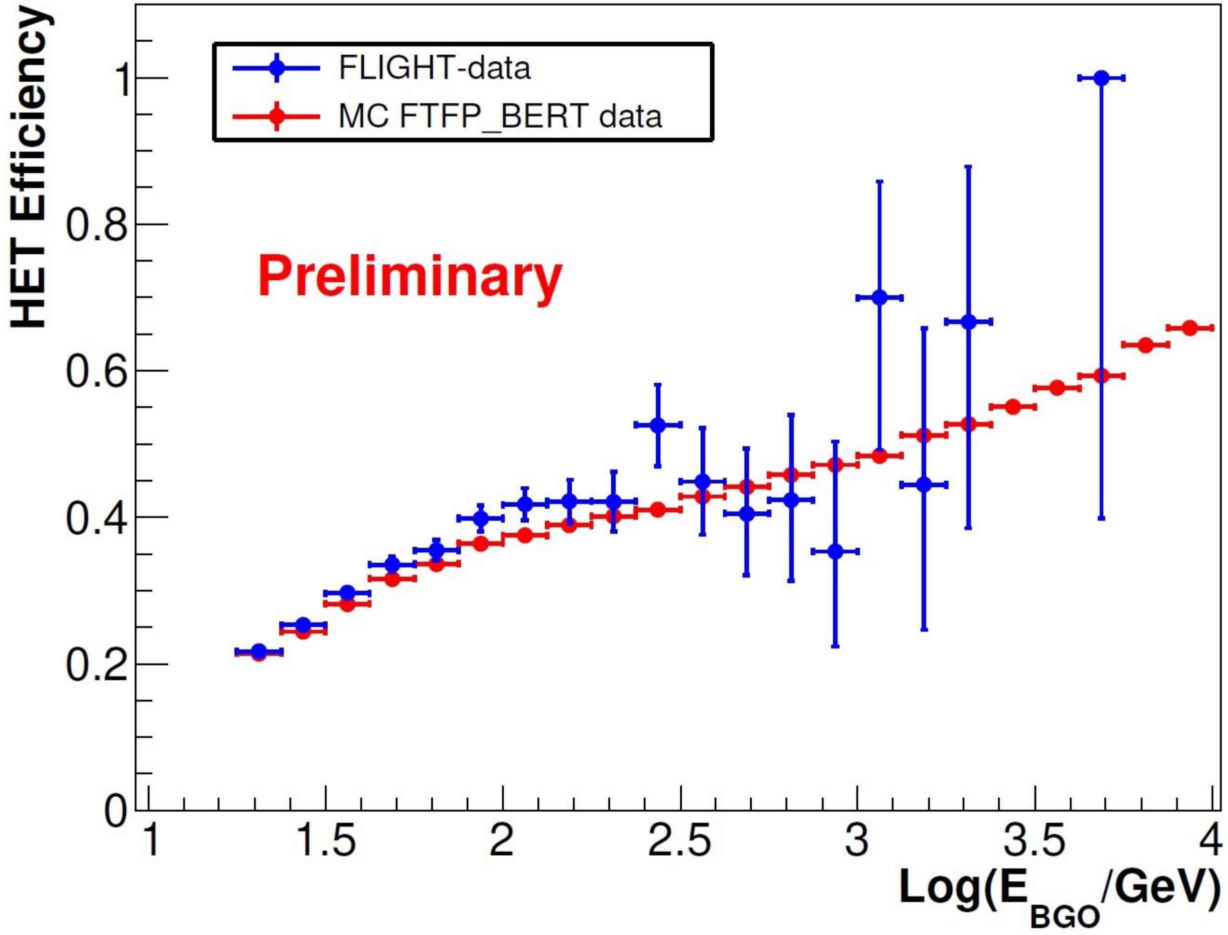
- 1/512 in the latitude range [-20°;20°]
- 1/204 at higher latitudes

$$\varepsilon_{HET} = \frac{N_{HET|Unb}}{N_{Unb}}$$

- $N_{HET|Unb}$: HE & Unb triggers activated
- N_{Unb} : Unb trigger activated

Systematic uncertainty due to HET:

$$\sigma_{HET} \sim 5\%$$



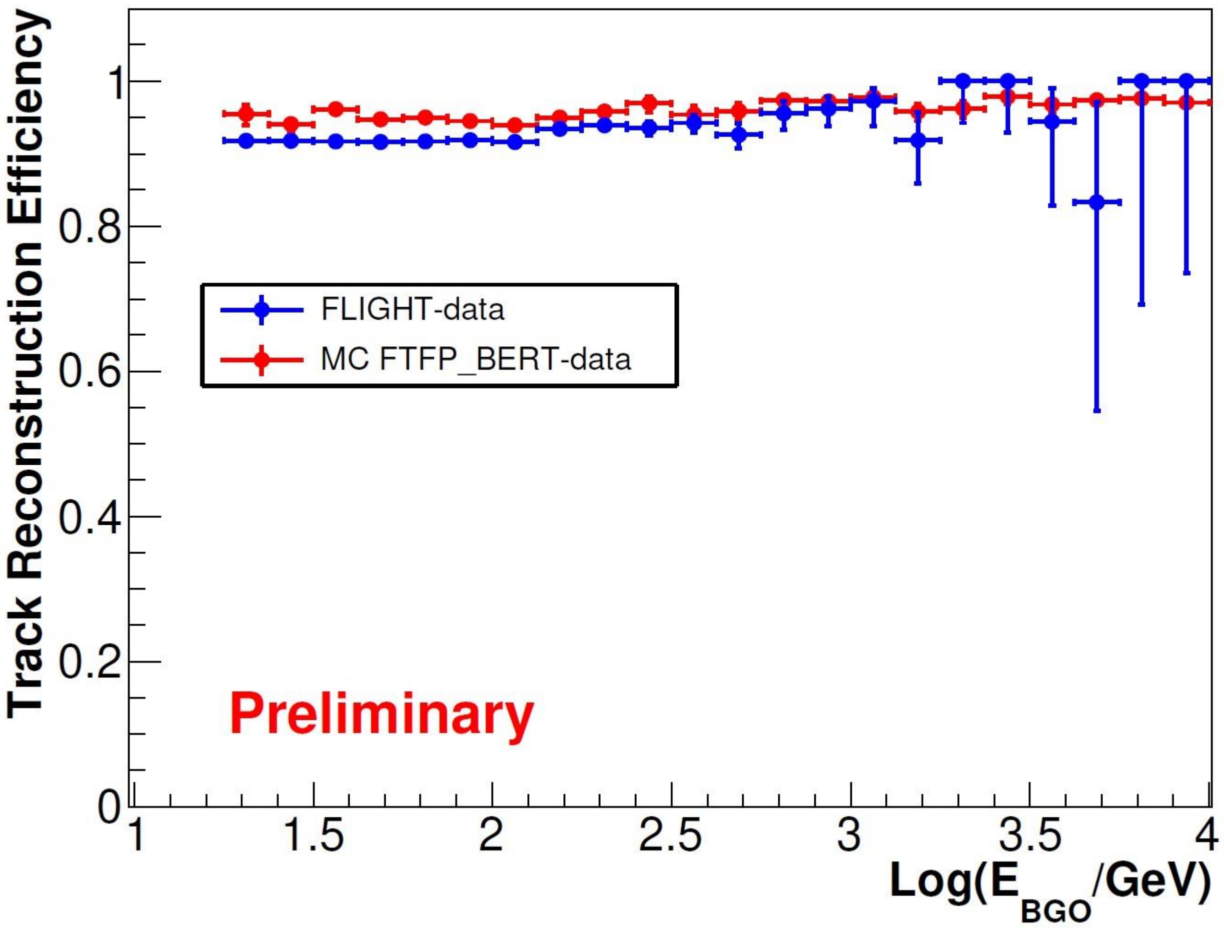
Track reconstruction Efficiency

$$\varepsilon_{Track} = \frac{N_{PSD|STK|BGO}}{N_{PSD|BGO}}$$

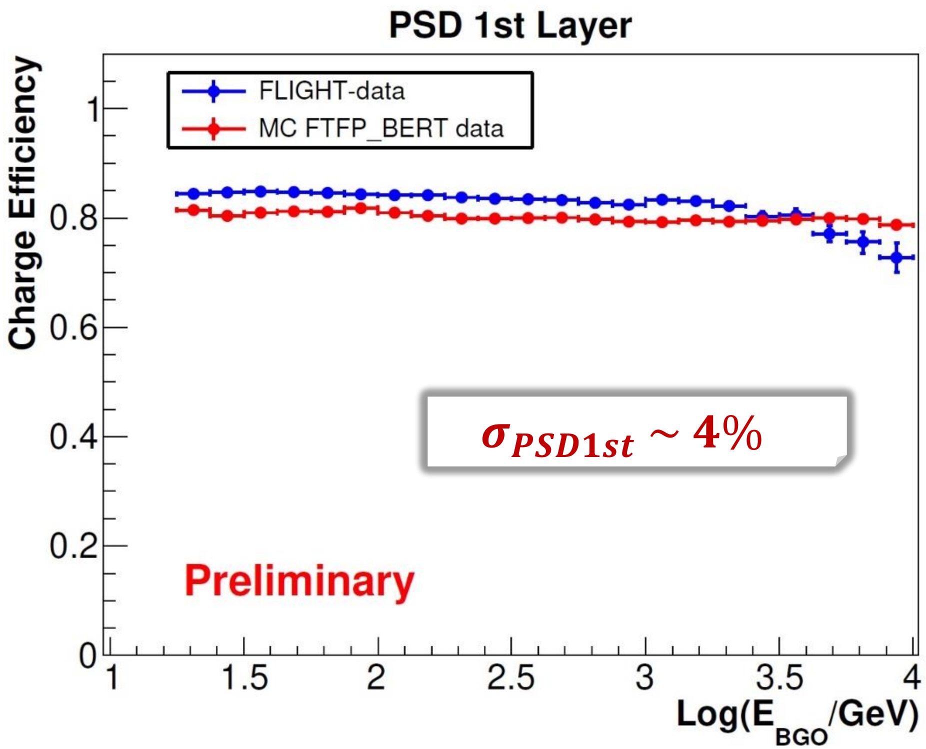
- $N_{PSD|STK|BGO}$: number of events selected by the analysis
- $N_{PSD|BGO}$: number of events selected by using track information provided only by PSD and BGO

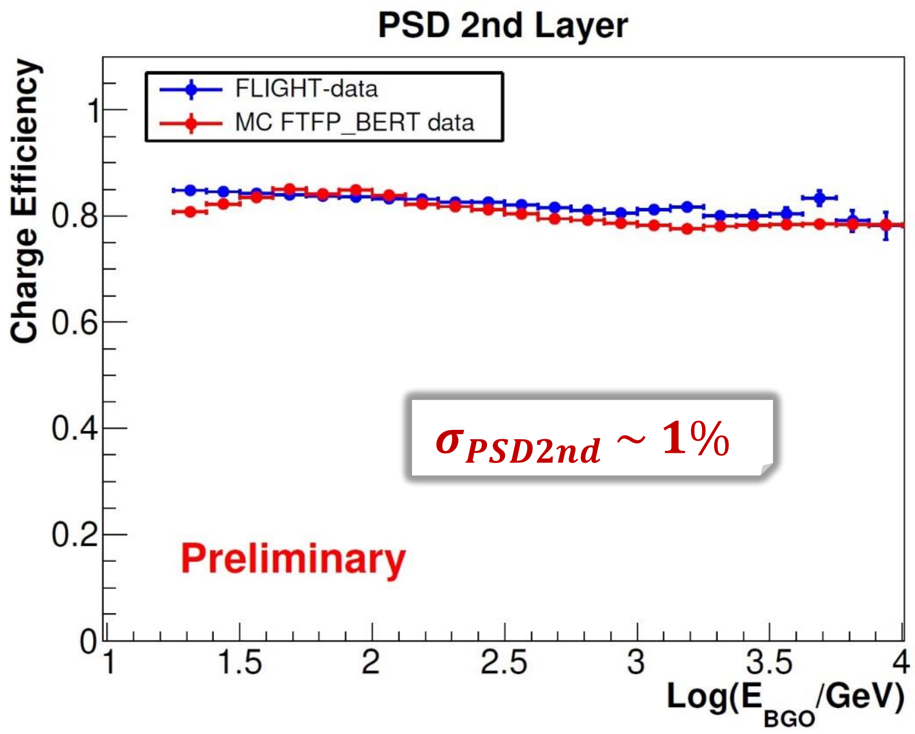
Systematic uncertainty due to Track selection:

$$\sigma_{Track} \sim 3\%$$



Charge reconstruction Efficiency





Charge reconstruction efficiency computed for both the PSD layers separately with the help of the 1st STK layer.

$$\varepsilon_{PSD1st} = \frac{N_{PSD1st|PSD2nd|STK}}{N_{PSD2nd|STK}}$$

$$\varepsilon_{PSD2nd} = \frac{N_{PSD1st|PSD2nd|STK}}{N_{PSD1st|STK}}$$

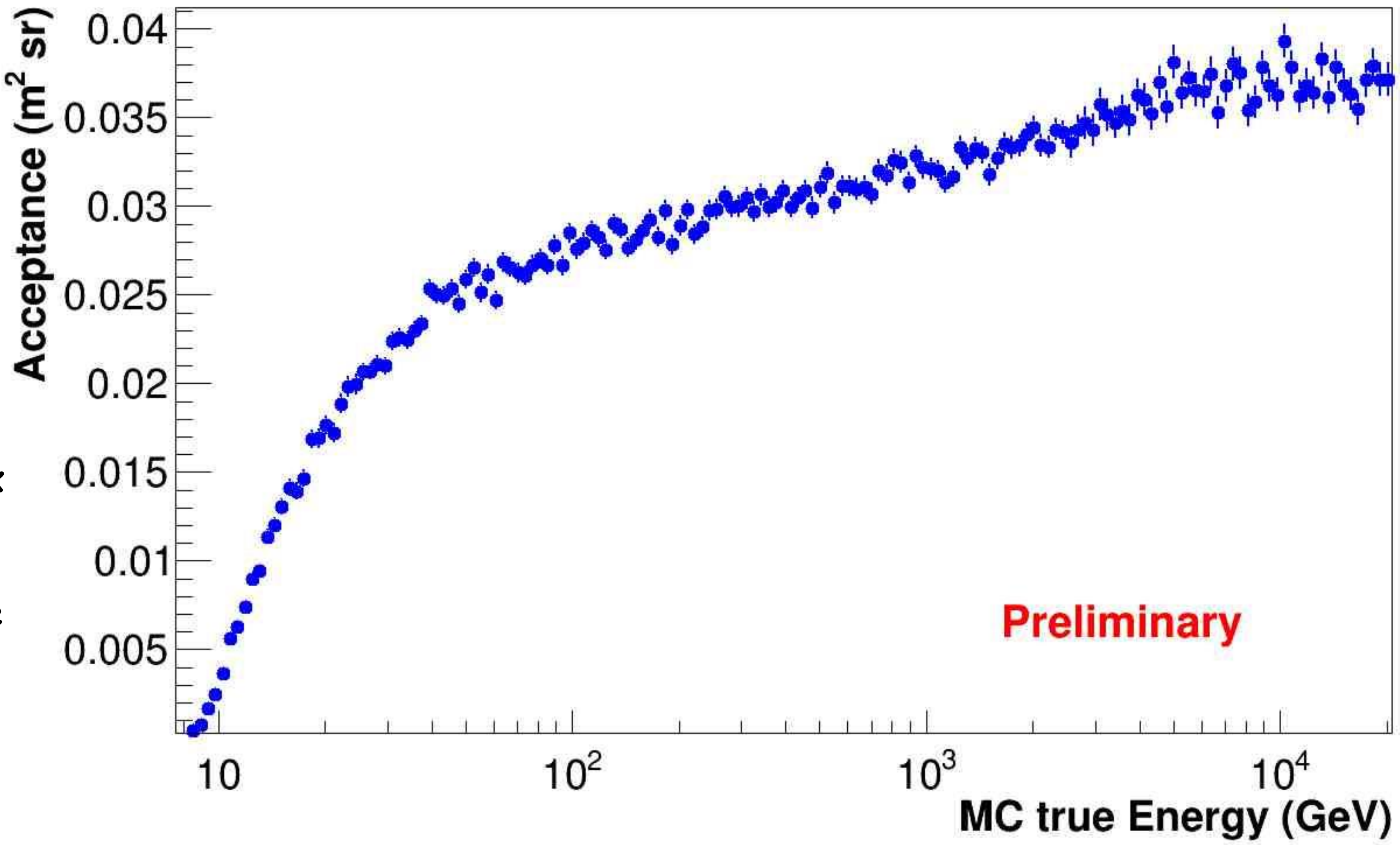
Systematic uncertainty due to Charge reconstruction:

$$\sigma_{Charge} \sim 4.1\%$$

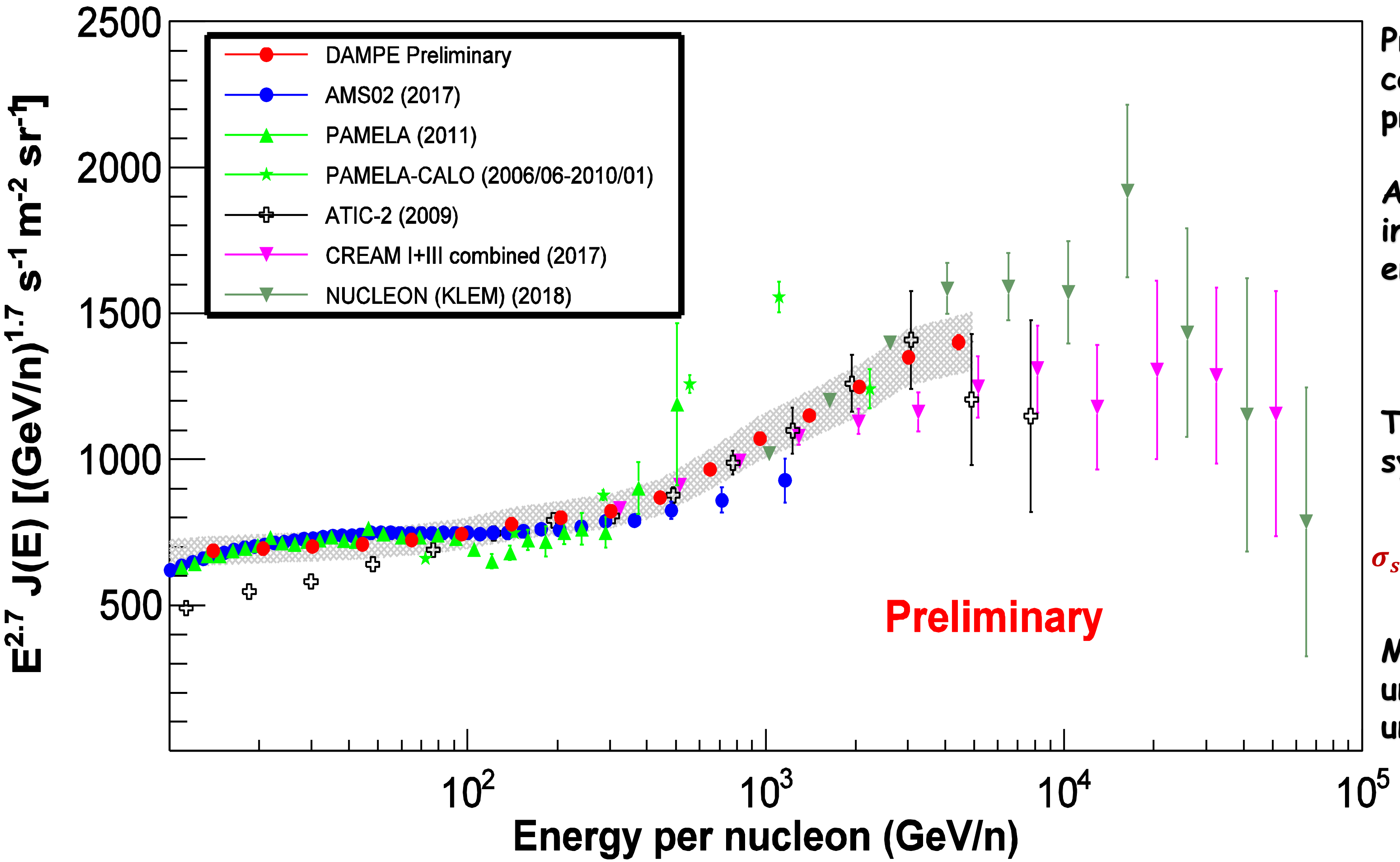
Acceptance

$$A_{eff,i} = A_{gen} \frac{N_{pass,i}}{N_{gen,i}}$$

- A_{gen} : geometrical factor used in MC simulation of an isotropic CR Helium nuclei flux generated above a sphere with R=1.0 m
- $N_{pass,i}$: number of events selected by the the analysis, in a given i-bin of primary energy
- $N_{gen,i}$: total number of generated events in the i-bin of primary energy



Preliminary Helium Flux



Preliminary Helium flux per nucleon compared with results obtained by previous experiments.

An unfolding method has been adopted in order to reconstruct the primary energy of Helium nuclei.

The grey band represents the total systematic uncertainty:

$$\sigma_{sys} = \sqrt{\sigma^2_{HET} + \sigma^2_{Track} + \sigma^2_{Charge} + \sigma^2_{bg}} \cong 7.2\ \%$$

More studies on systematic uncertainties (hadronic model, unfolding, etc..) are in progress.

Conclusions & Outlooks

- The DAMPE detector is in a stable data-taking at 500 km of altitude since Dec. 17, 2015
- The Helium flux has been measured up to ~5 TeV/nucleon
- A spectral hardening in the Helium flux has been observed at hundreds of GeV, confirming previous experiments results
- The evaluation of all the systematics and other uncertainties (energy scale, unfolding,...) is in progress
- In next future the He-flux measurement will be extended to higher energies

THANK YOU

BACKUP

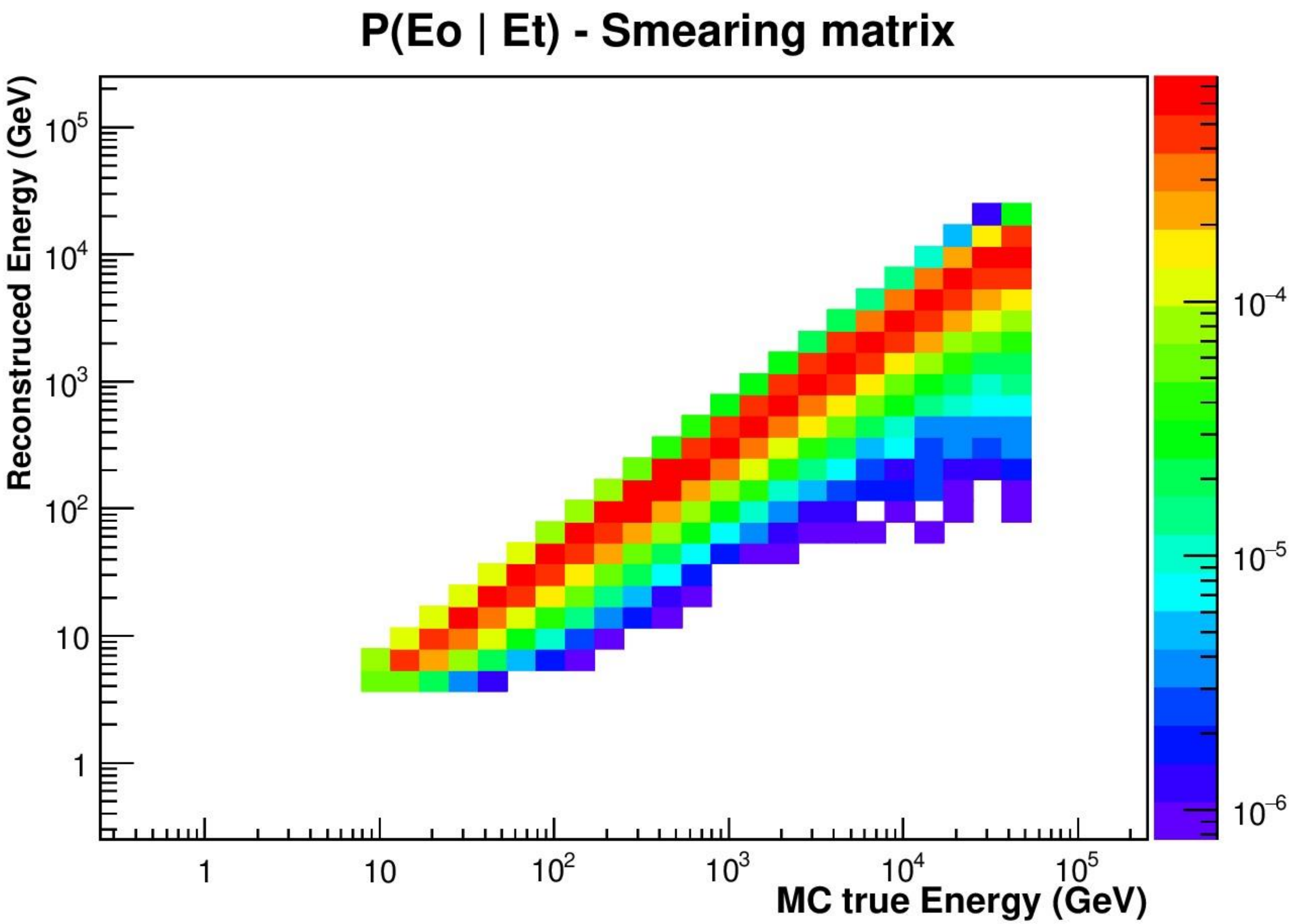
Unfolding Method

Only a part of the total energy is deposited inside the detector (~40% at 10 TeV)

Unfolding procedure:

$$N_{dep,i} = \sum_i M_{ij} N_{pri,j}$$

G. D'Agostini, Nucl. Instrum. Meth. A 362 (1995)



MC PSD ENERGY CORRECTION

Difference between MC data and Flight-data (Fd) in PSD energy distributions as a function of the BGO energy deposition due to back-splash effects

A correction on MC simulations has been applied in order to achieve the agreement with on-orbit data

$$E_{MC,corr} = \left(E_{MC} - f_{MPV,MC}(E_{BGO})\right)\frac{f_{\sigma,Fd}(E_{BGO})}{f_{\sigma,MC}(E_{BGO})} + f_{MPV,Fd}(E_{BGO})$$

Corrected PSD energy deposition for MC

PSD energy deposition for MC

BGO energy

Parametrization functions for MC and Flight-data sigmas of Landau ⊗ Gaussian fits on PSD energy distributions

Parametrization functions for MC and Flight-data Most Probable Values (MPV) of Landau ⊗ Gaussian fits on PSD energy distributions