36th International Cosmic Ray Conference - Madison, WI, USA
THE ASTROPARTICLE PHYSICS CONFERENCE

Measurement of cosmic-ray proton spectrum with the Dark Matter Particle Explorer

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(on behalf of the DAMPE Collaboration)

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悟空
"WuKong"

DAMPE Collaboration

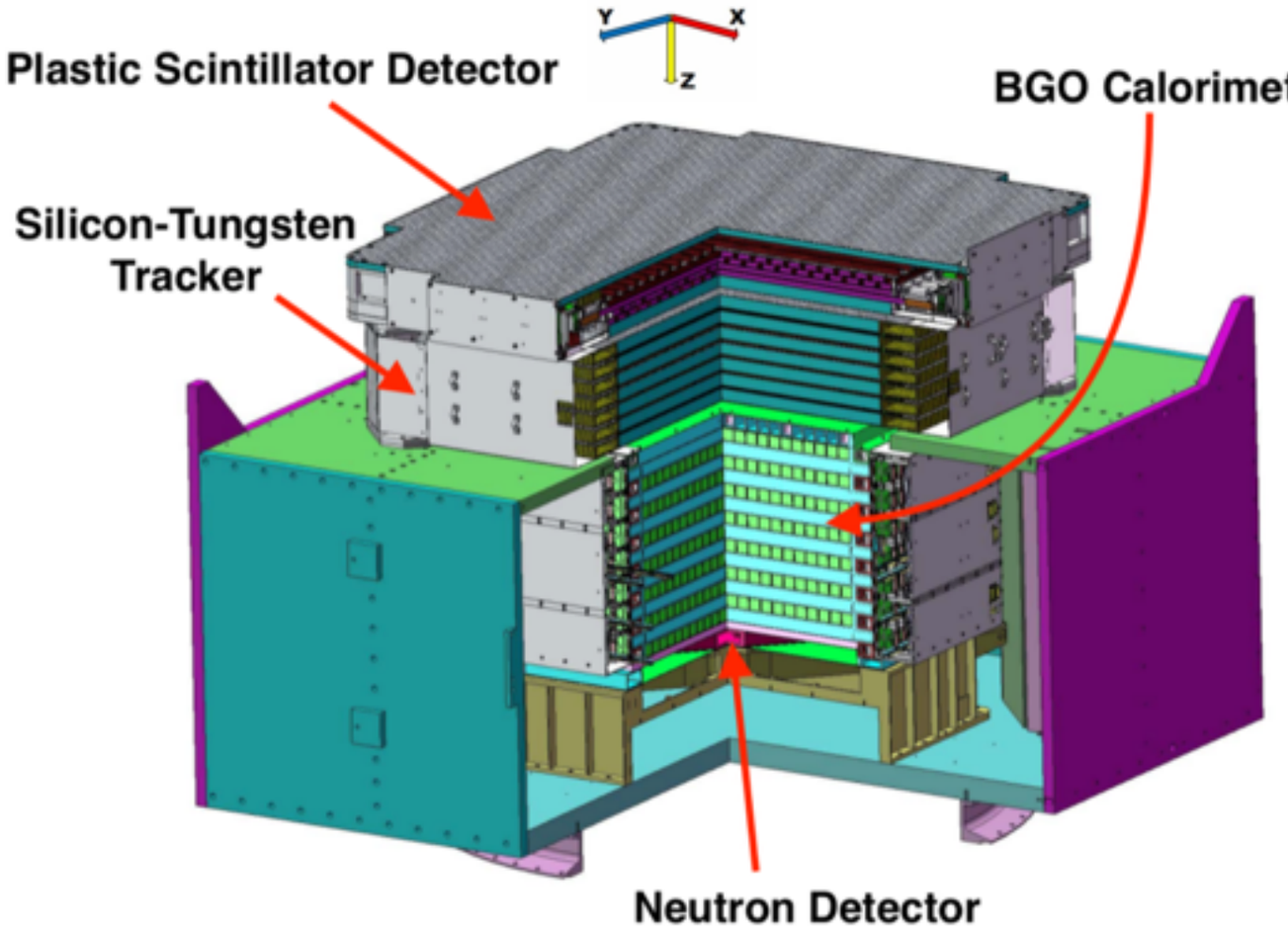
- CHINA
  - Purple Mountain Observatory, CAS
  - University of Science and Technology of China
  - Institute of High Energy Physics, CAS
  - Institute of Modern Physics, CAS
  - National Space Science Center, CAS

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

- SWITZERLAND
  - University of Geneva

for collaboration list see PoS(ICRC2019)1177

DAMPE Instrument



Orbit Information:

Sun-synchronous Orbit
Altitude: ~ 500 km
Inclination: ~ 97 deg
Launch Date: Dec.17th, 2015

Main Scientific Goals:

Origins and Propagations of Cosmic-Rays
Dark Matter Indirected Detection
High Energy Gamma-ray Astronomy

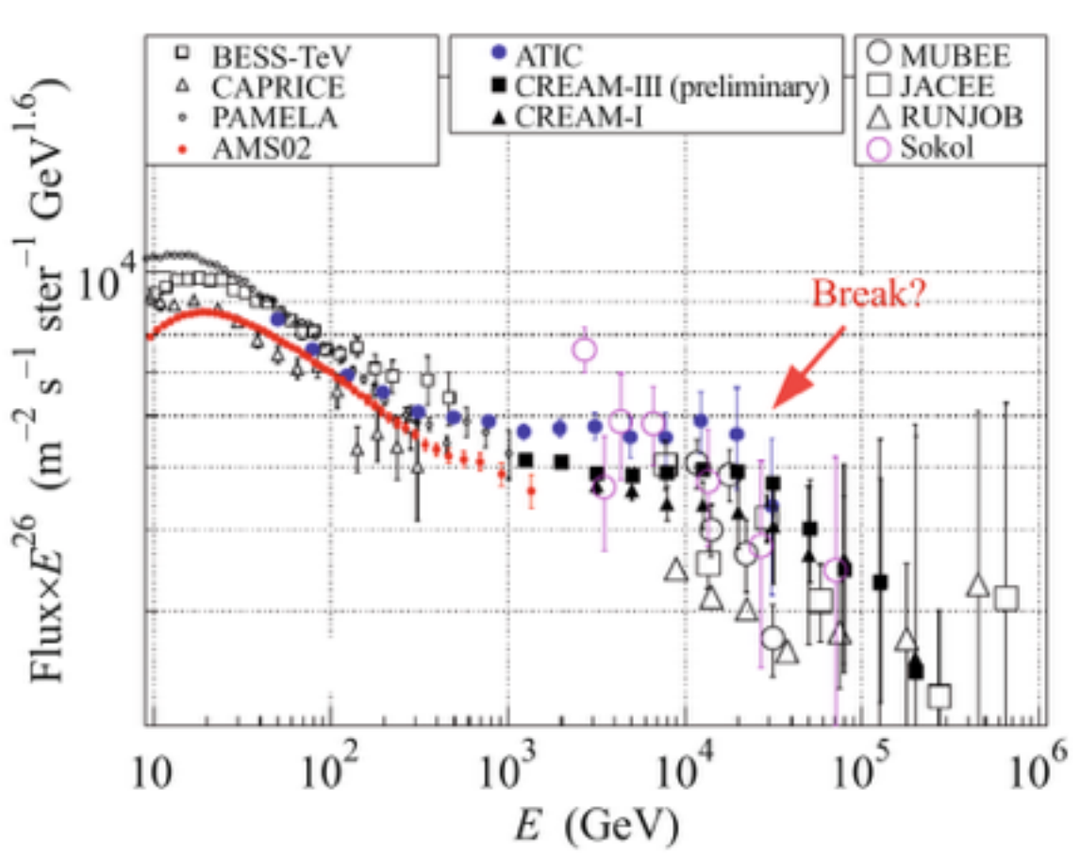
- Charge measurement (dE/dx in PSD, STK and BGO)
- Gamma-ray converting and tracking (STK and BGO)
- Precise energy measurement (BGO Crystals)
- Hadron rejection (BGO and Neutron Detector)

(Chang et al. Astropart.Phys. 95 (2017) 6–24)

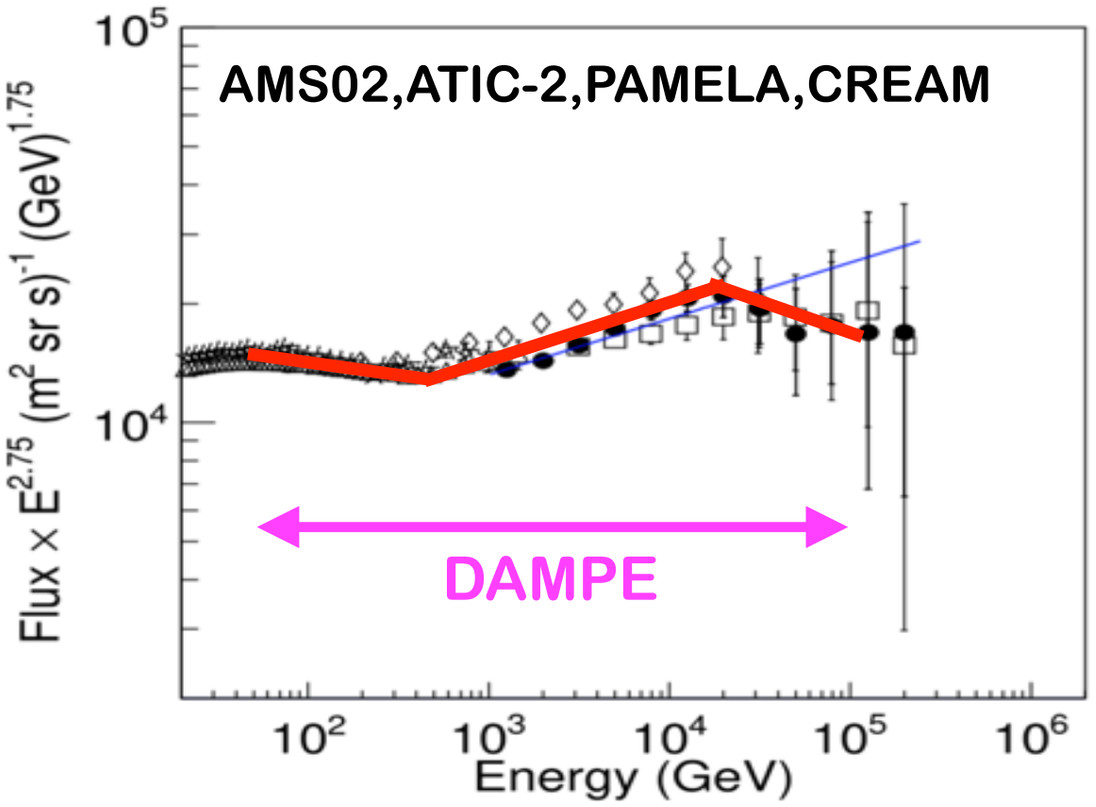
Introduction

Proton spectrum has been measured with high precision up to TeV

Measurements in high energy range (TeV ~ PeV) have large uncertainties



(E. Atkin et al., NUCLEON, 2018)



(Y.S. Yoon et al., CREAM, 2017)

Interesting Scientific Issues:

Proton Spectral Hardening at ~400 GeV

Other structures beyond TeV Range?

On-orbit Data Sample

Data Sample:

Jan. 1st 2016 to Jun. 30th 2018

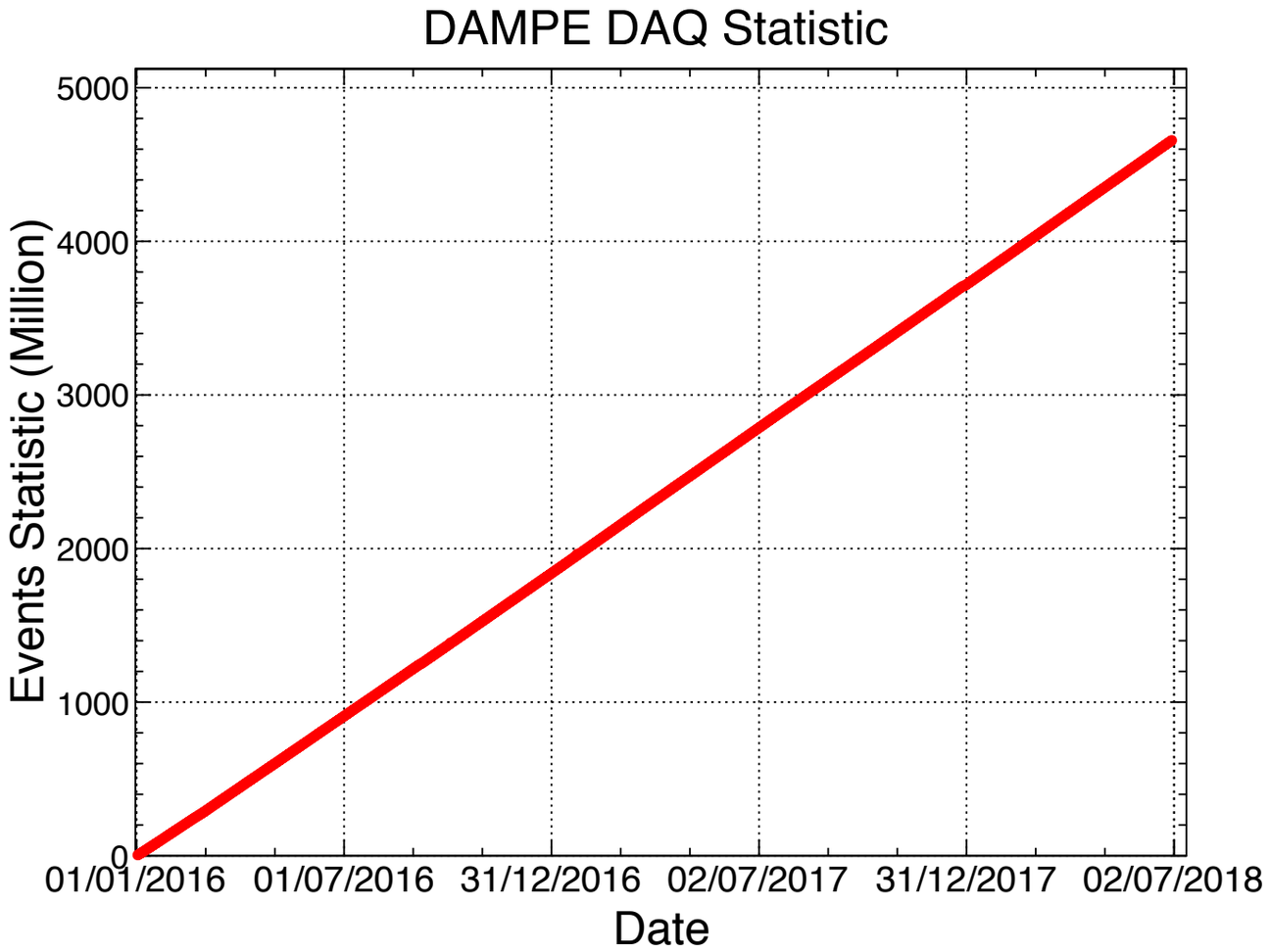
Total Events:

4.68 Billion Events

Live Time:

5.9670276 * 10^7 s

(75.73%)



Dead Time: Instrument Recovery, On-orbit Calibration, etc

Data in SAA region are excluded

Data during Sep2017 Solar Flare (20170908~20170913) are excluded

Proton Selections

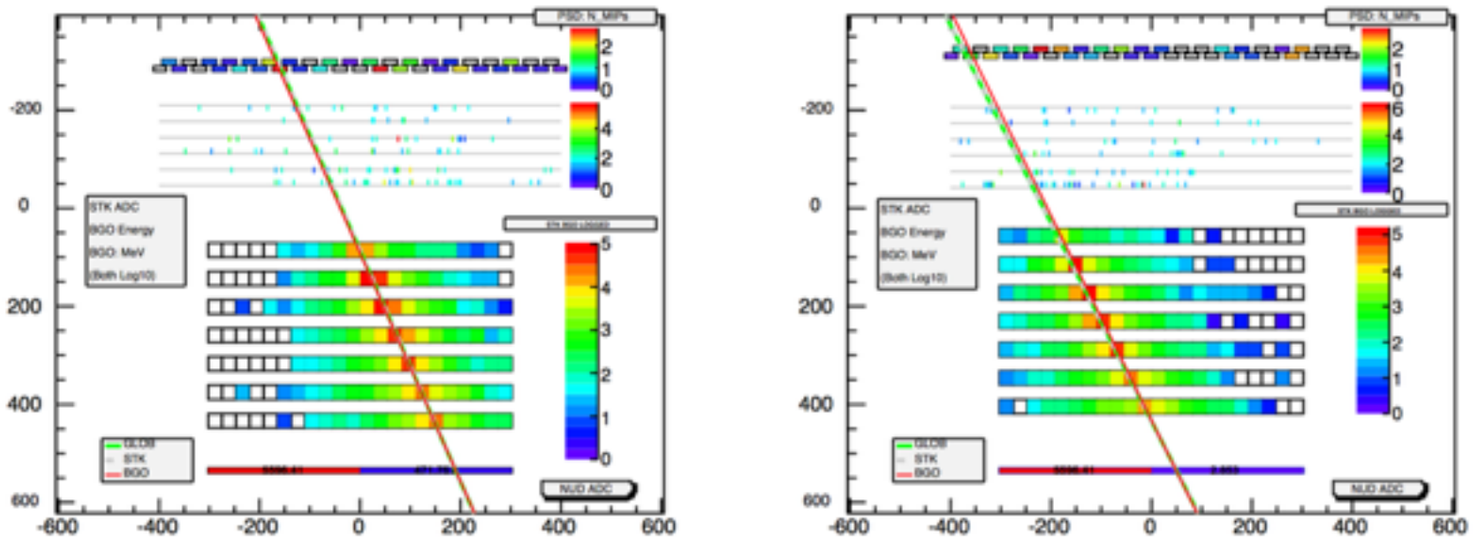
Pre-selections

- Cut 0: BgoEnergy > 20 GeV
- Cut 1: HE-Trigger
- Cut 2: STK Track
- Cut 3: Track-PSD Match
- Cut 4: Track-BGO Match
- Cut 5: PSD pre-selection
- Cut 6: BGO pre-selection

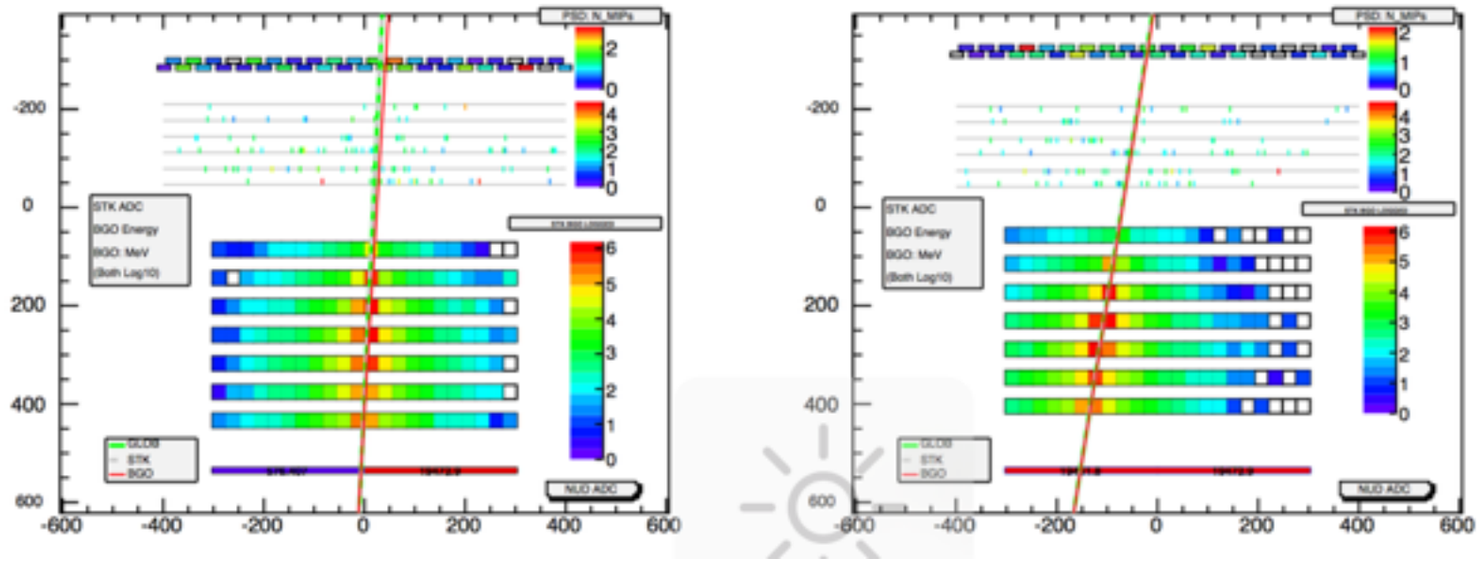
Particle Identification

- Cut 7: e/p Separation
- Cut 8: Charge Selection

Flight-Data Proton (BGO-Energy: 1.2 TeV)



Flight-Data Proton (BGO-Energy: 12.1 TeV)



HE-Trigger Efficiency

- ☐ Unbias Trigger (G0)
- ☐ MIPs Trigger (G1&G2)
- ☑ High Energy Trigger (G3)
- ☐ Low Energy Trigger (G4)

G3 Trigger Efficiency：

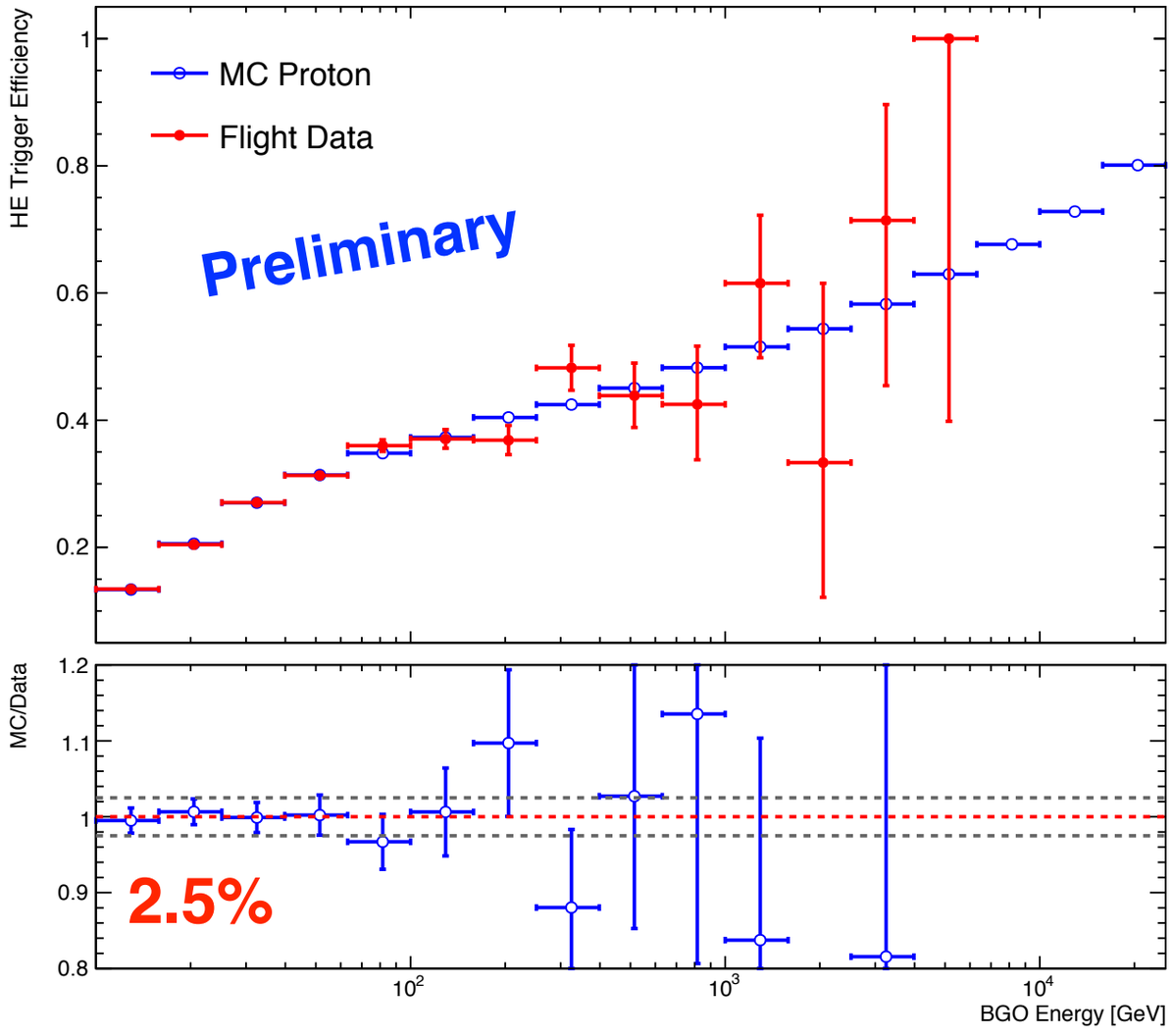
$$\varepsilon_{\mathrm{trigger}} = \frac{N_{\mathrm{he|unb}}}{N_{\mathrm{unb}}}$$

Uncertainty mainly comes from the threshold calibration and the limited statistics of unbias trigger events

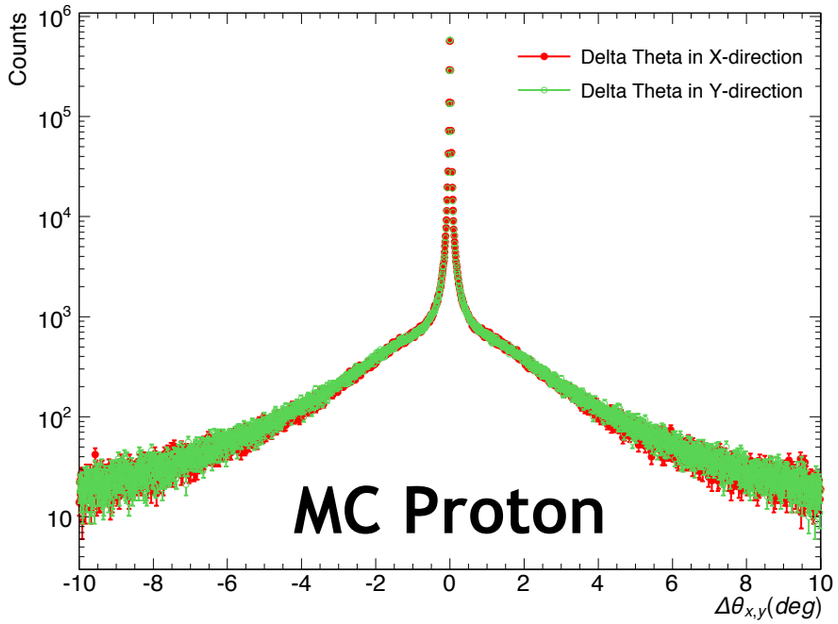
(unbias trigger pre-scaled by 1/512 at low latitudes <20deg and 1/2048 at high latitudes)

Efficiency Validation (“N-1”):

High-Energy (G3) trigger efficiency can be obtained by applying all other proton selections (“N-1”) to unbias (G0) sample



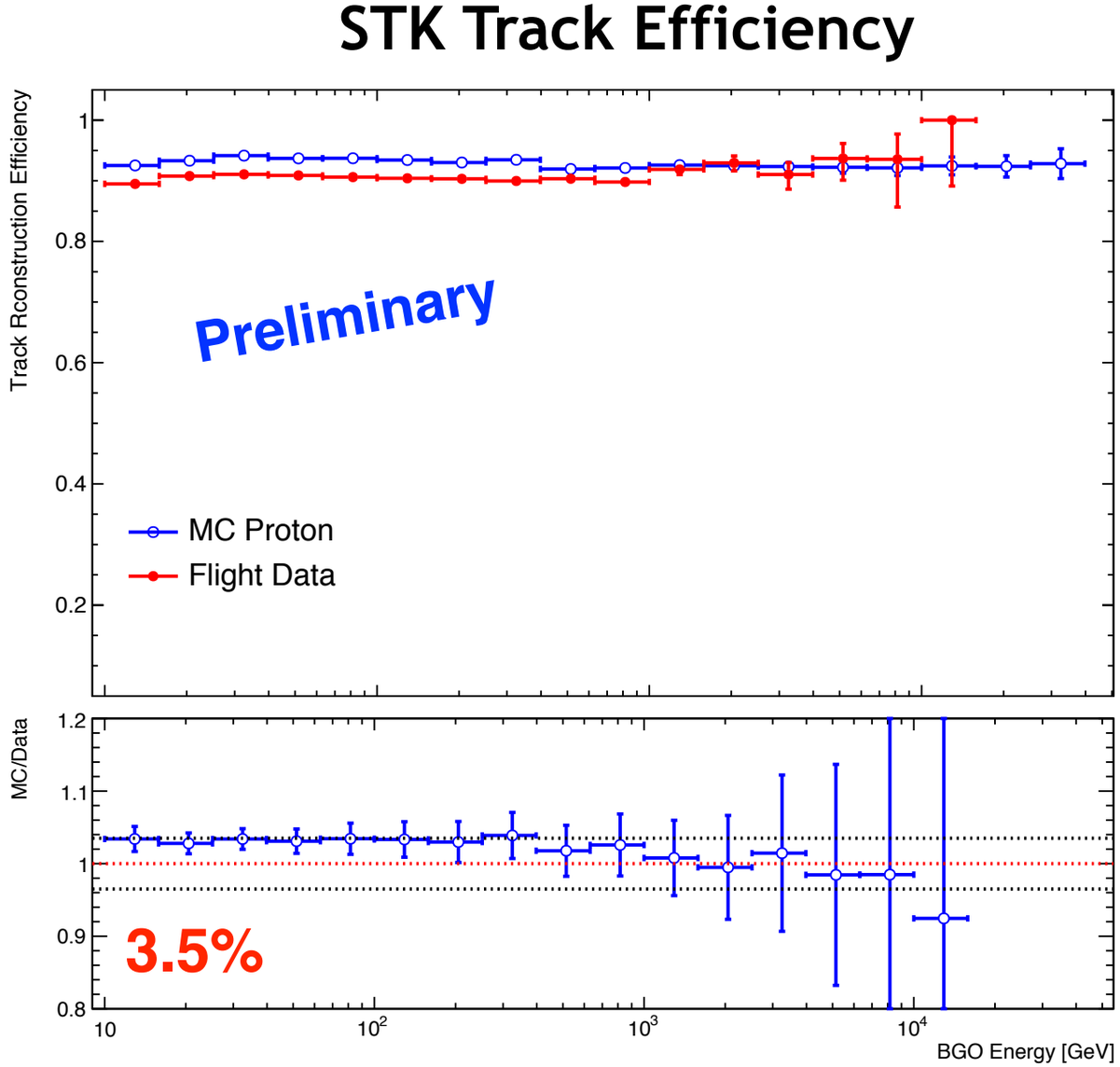
STK Track Efficiency



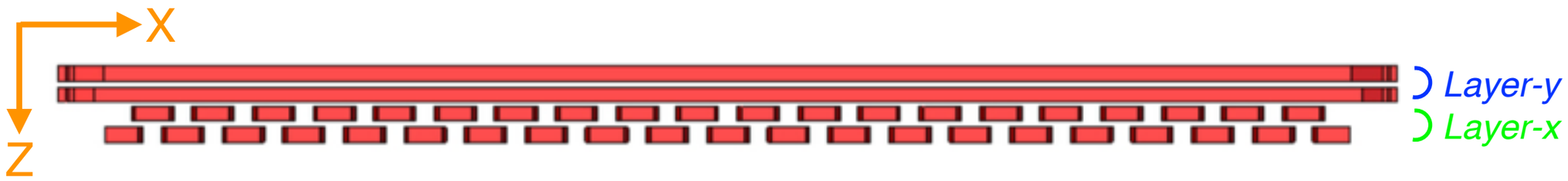
STK track Efficiency Validation

Selecting a "pure" proton sample by applying BGO shower-axis based proton selections ("N-1") to estimate STK track reconstruction efficiency

$$\varepsilon_{track} = \frac{N_{track|BGOtrack}}{N_{BGOtrack}}$$



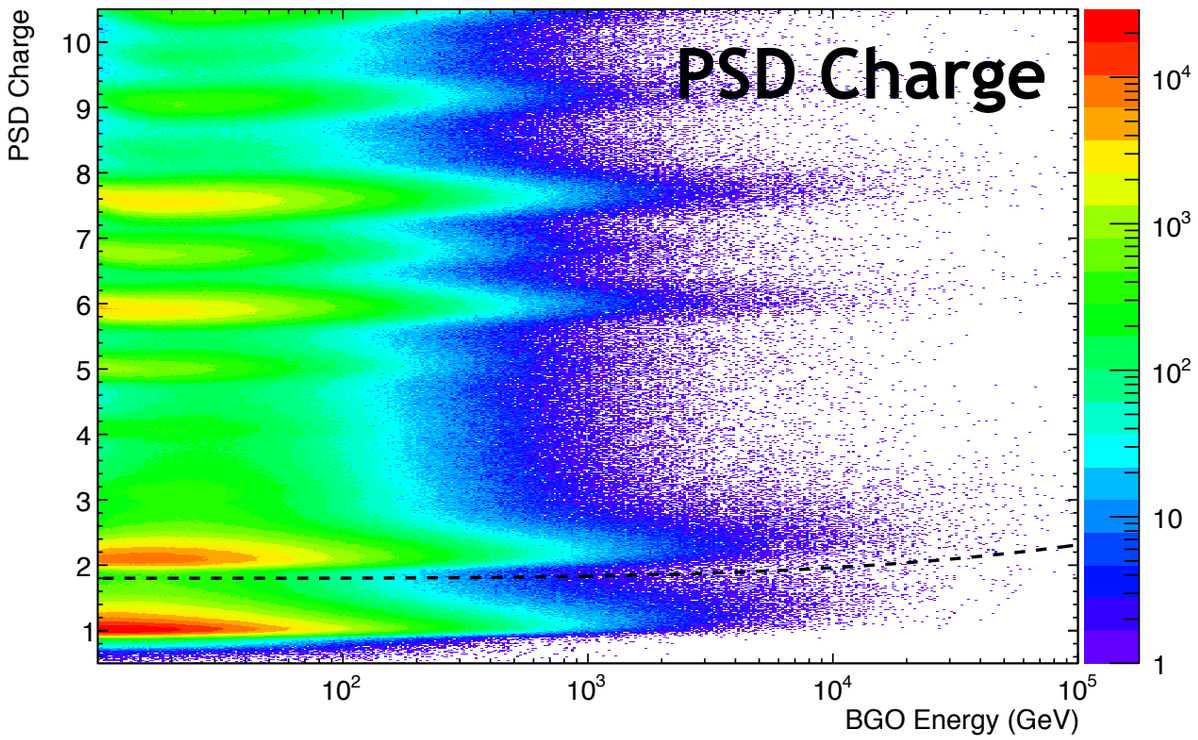
Charge selection

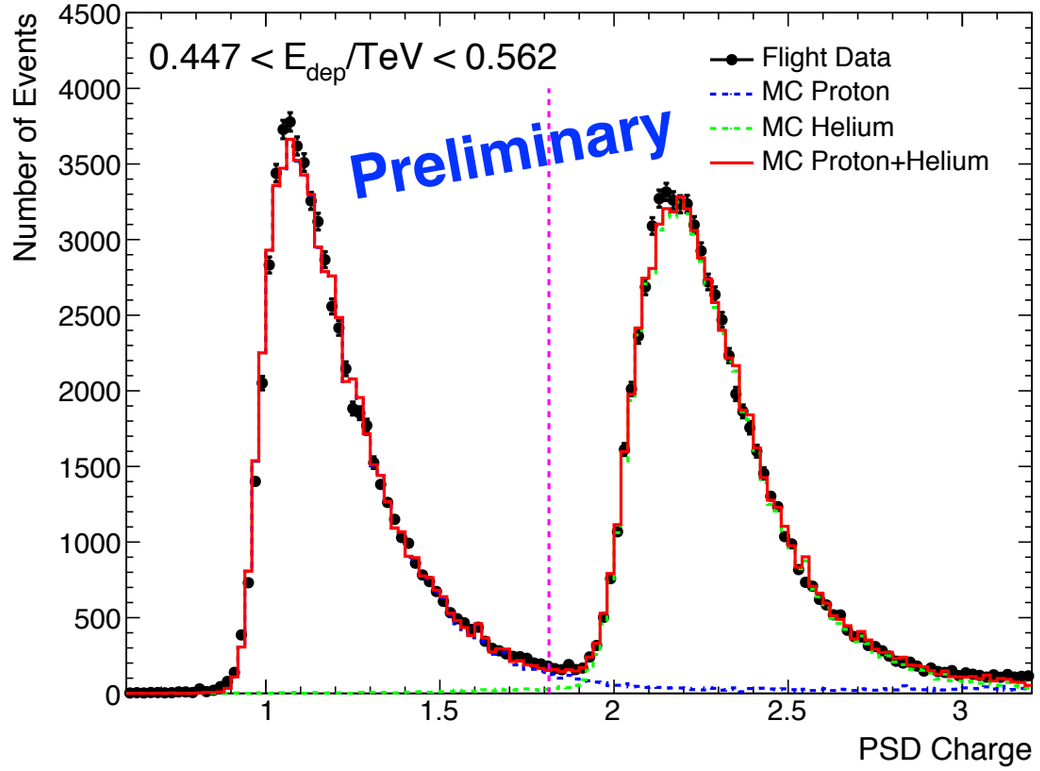


Bethe-Bloch $-\left\langle \frac{dE}{dx} \right\rangle = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0} \right)^2 \cdot \left[\ln\left(\frac{2m_e c^2 \beta^2}{I \cdot (1-\beta^2)} \right) - \beta^2 \right]$

(see more in talk CRD7b by Zhang Y.P.)

$$Z_y = \sqrt{PsdE_y/MipE} \quad Z_x = \sqrt{PsdE_x/MipE} \quad Z_{PSD} = (Z_y + Z_x)/2$$





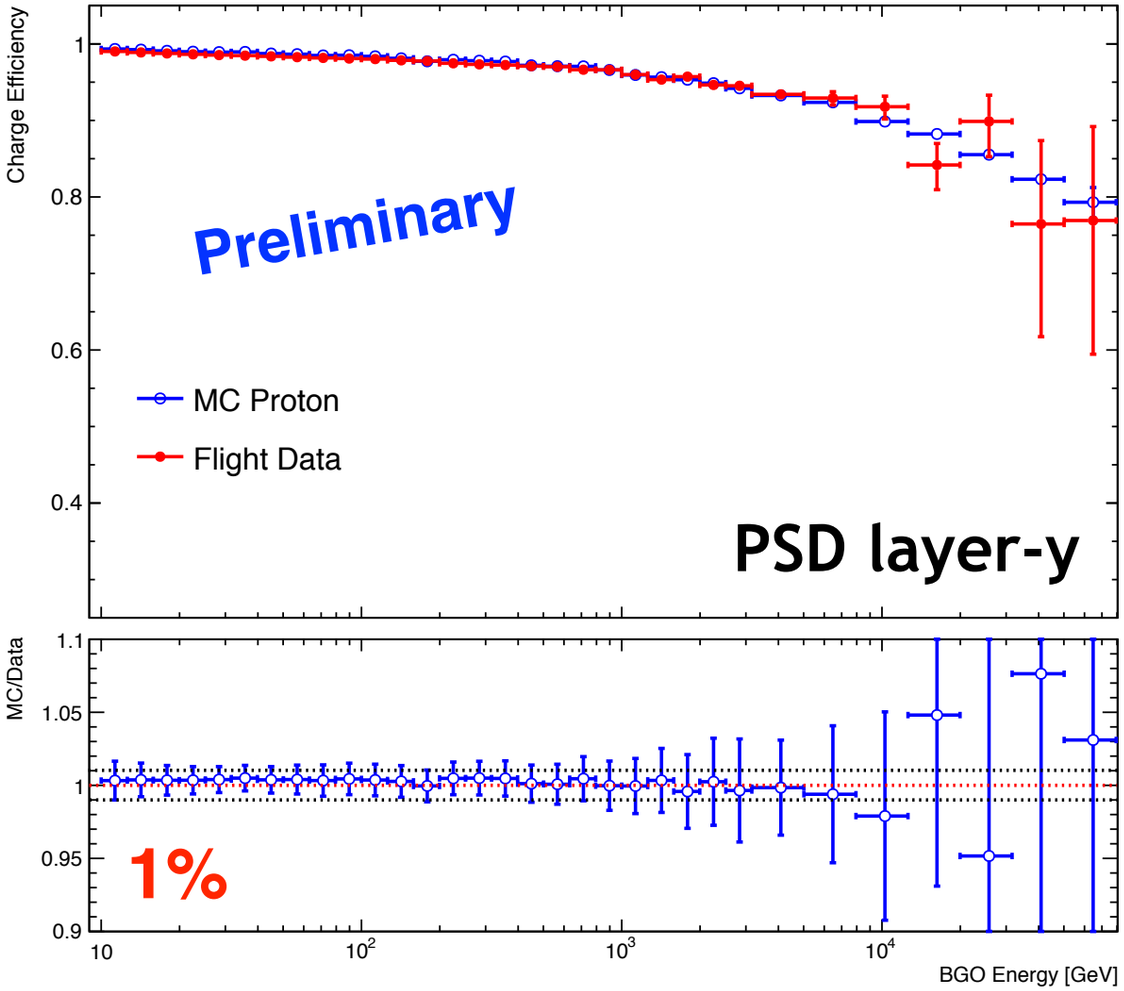
Charge selection

PSD Charge Efficiency Validation：

√ Ask the help of the first layer of STK

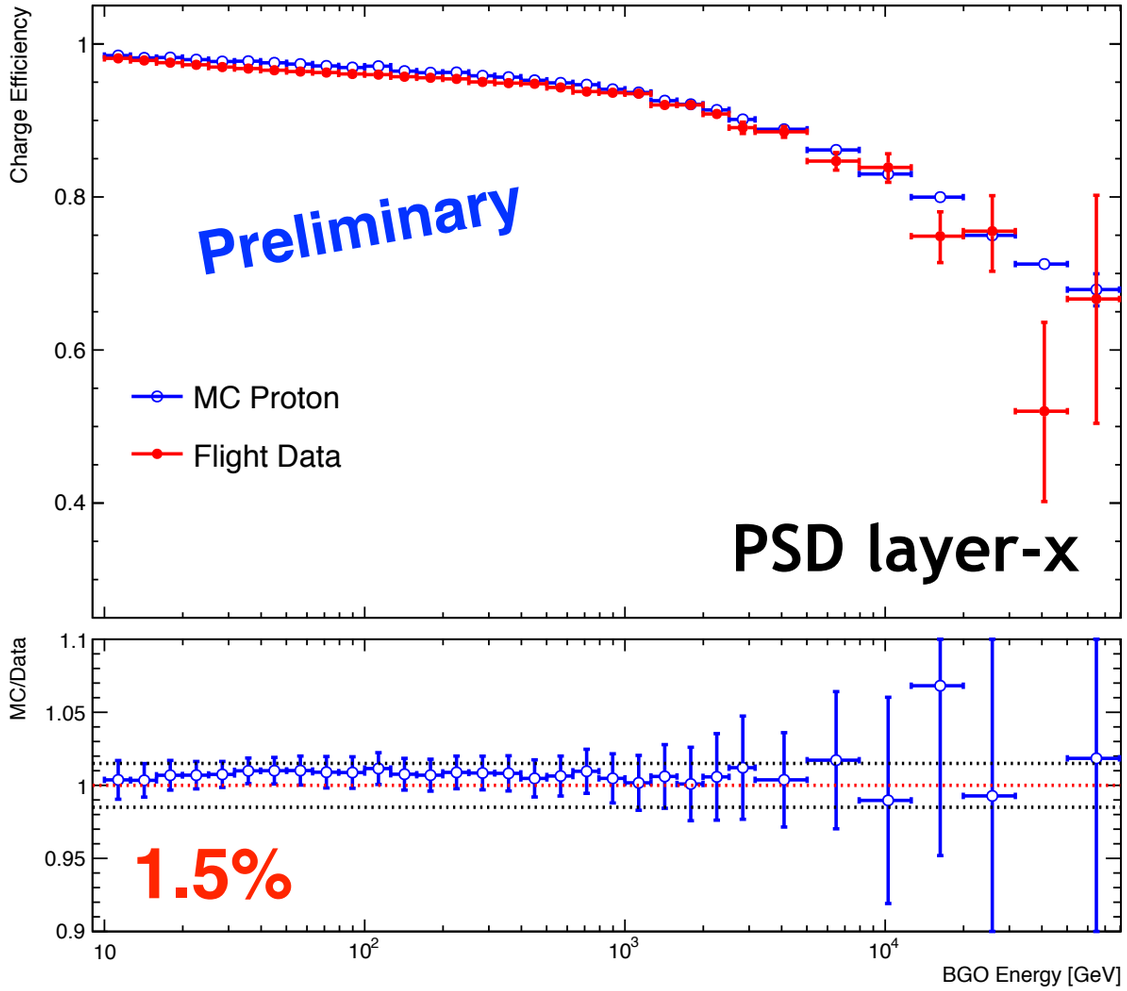
- **To Study PSD layer-1**

  Selection: PSD_L2 && STK_L1



- **To Study PSD layer-2**

  Selection: PSD_L1 && STK_L1



Energy Unfolding

Bayesian Unfolding Method
[Giulio D'Agostini, NIM A362(1995), 487]

$$N_i = \sum_{j=1}^{n} \alpha_{ij} M_j (1 - \beta_j)$$

$$\alpha_{ij} = \frac{P(E_{d,j}|E_{0,i})\hat{N}_i}{\epsilon_i \sum_{i=1}^{n} P(E_{d,j}|E_{0,i})\hat{N}_i}$$

N_i : **Unfolded event number**

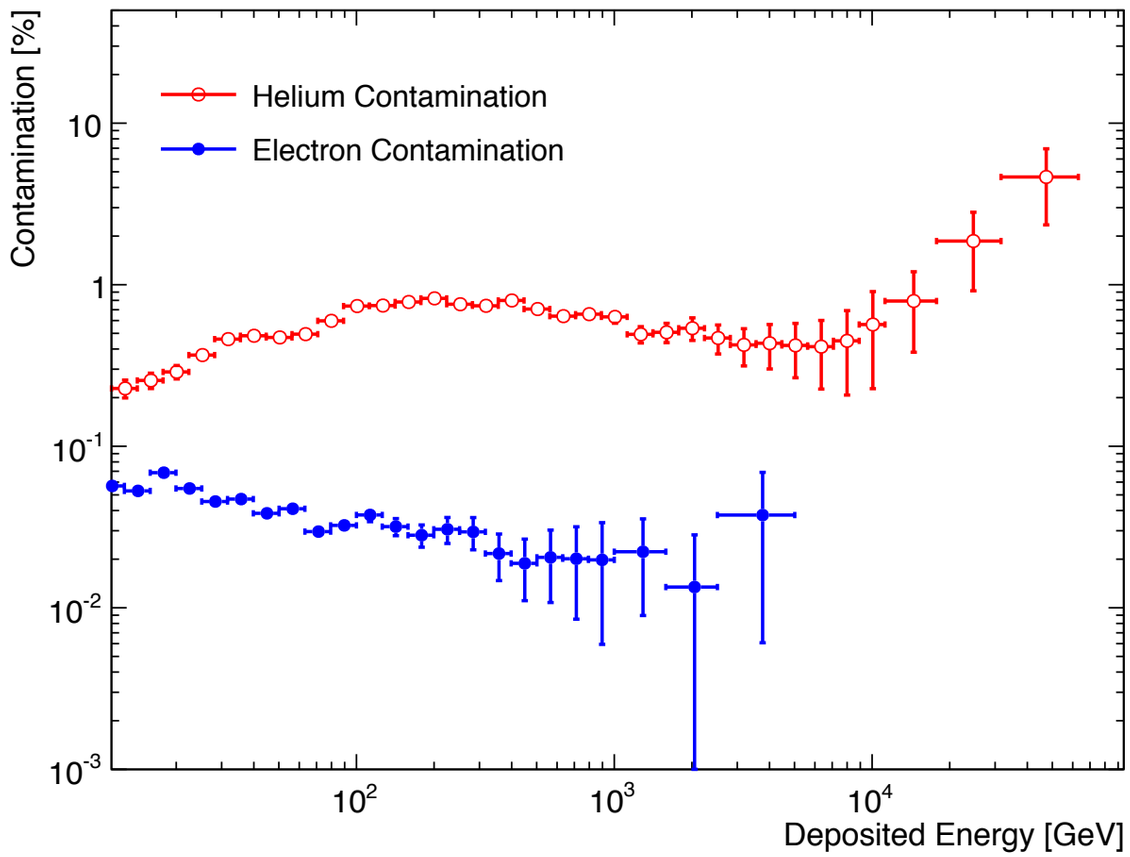
M_j : **Measured event number**

β_j : **Background**

$P(E_{d,j}|E_{0,i})$: **Response Matrix (MC)**

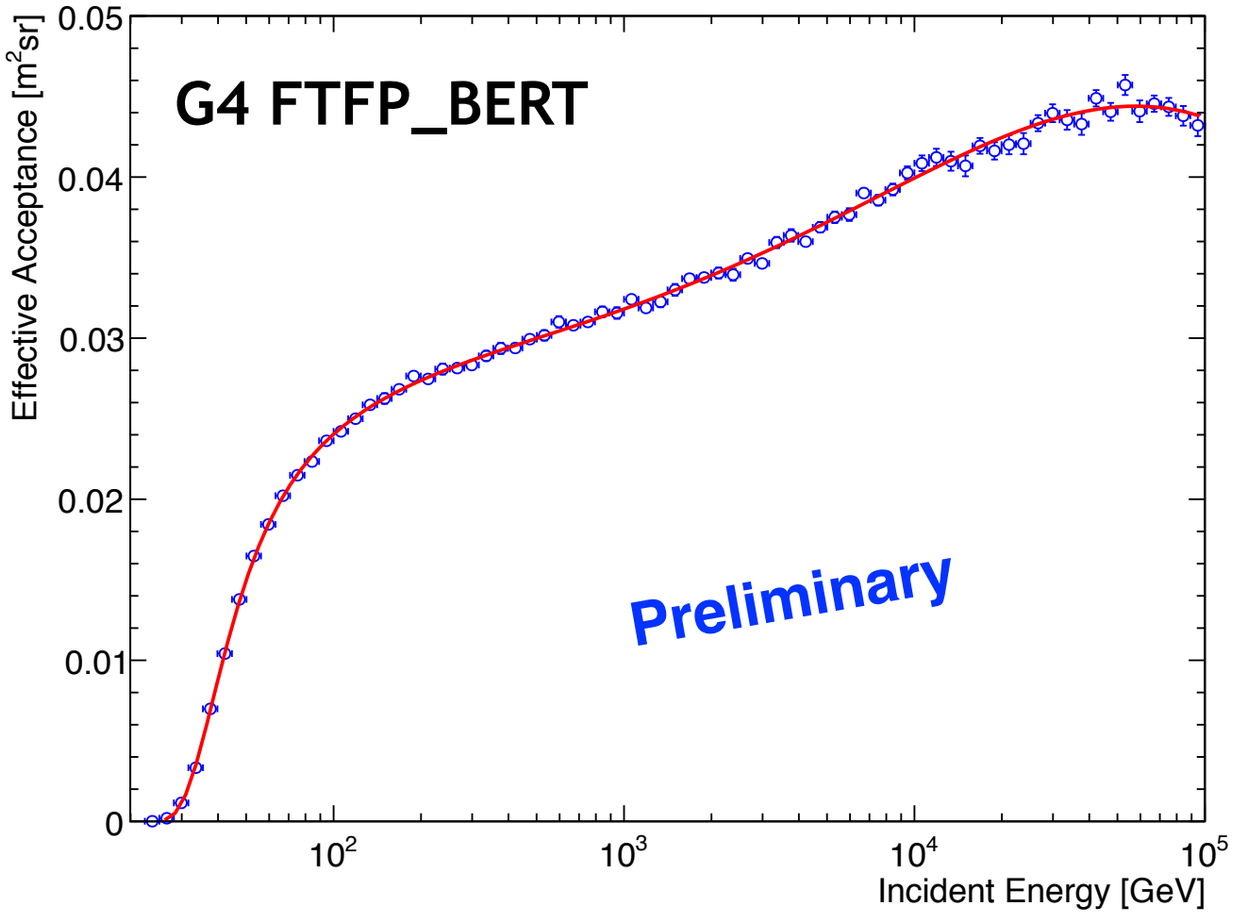
$\hat{N}_i$: **Prior ($E^{-2.7}$)**

Background



Effective Acceptance

$$J(E) = \frac{\Delta N}{\Delta E} \frac{1}{T_{exp} A_{eff}} \qquad A_{\mathrm{eff},i} = A_{\mathrm{gen}} \times \frac{N_{\mathrm{pass},i}}{N_{\mathrm{gen},i}}$$



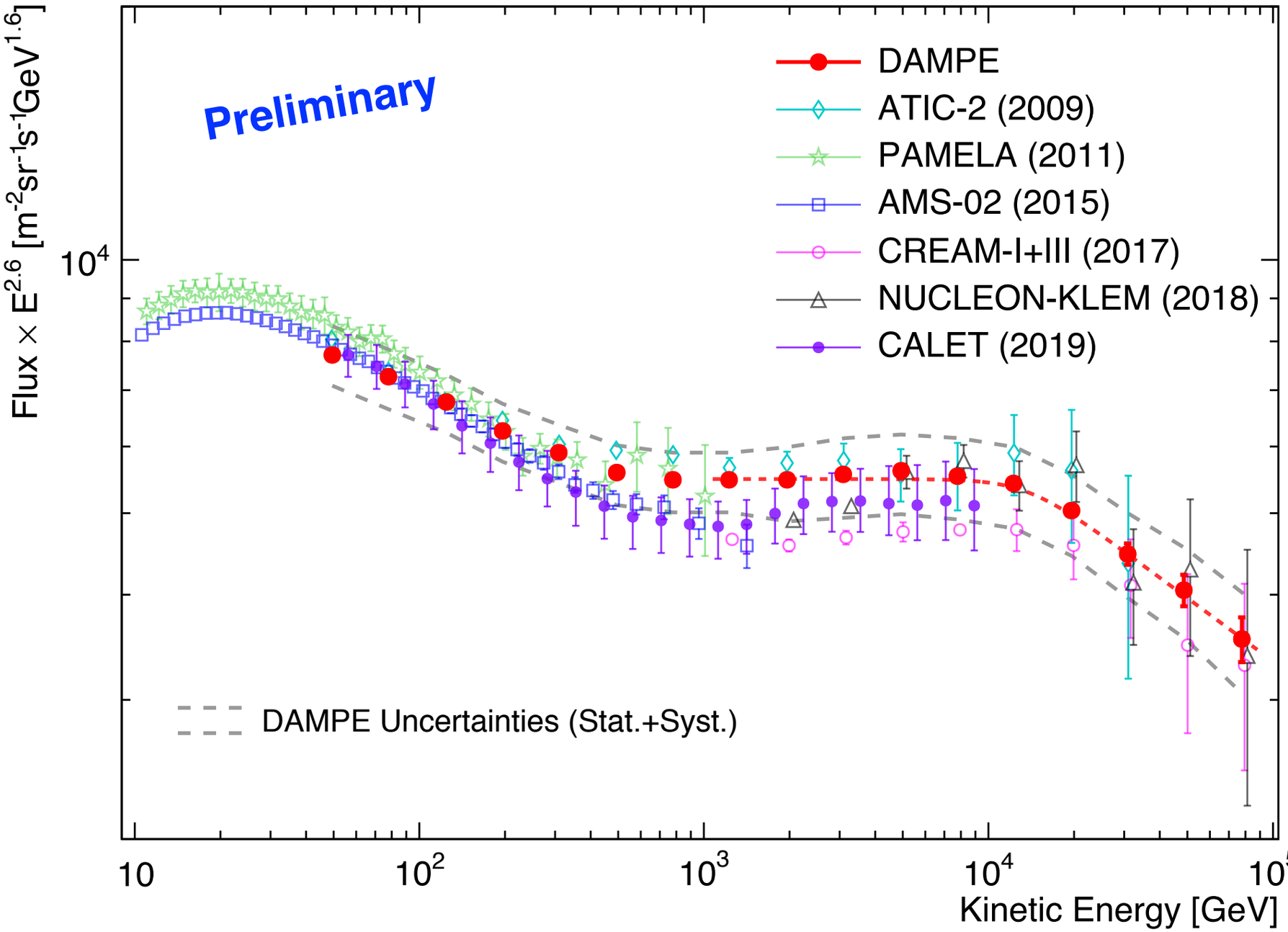
$$\sigma_{\mathrm{sel}} = \sqrt{\sigma^2_{\mathrm{trigger}} + \sigma^2_{\mathrm{track}} + \sigma^2_{\mathrm{charge}}} \approx 4.7\%$$

HE Tigger: ~2.5%

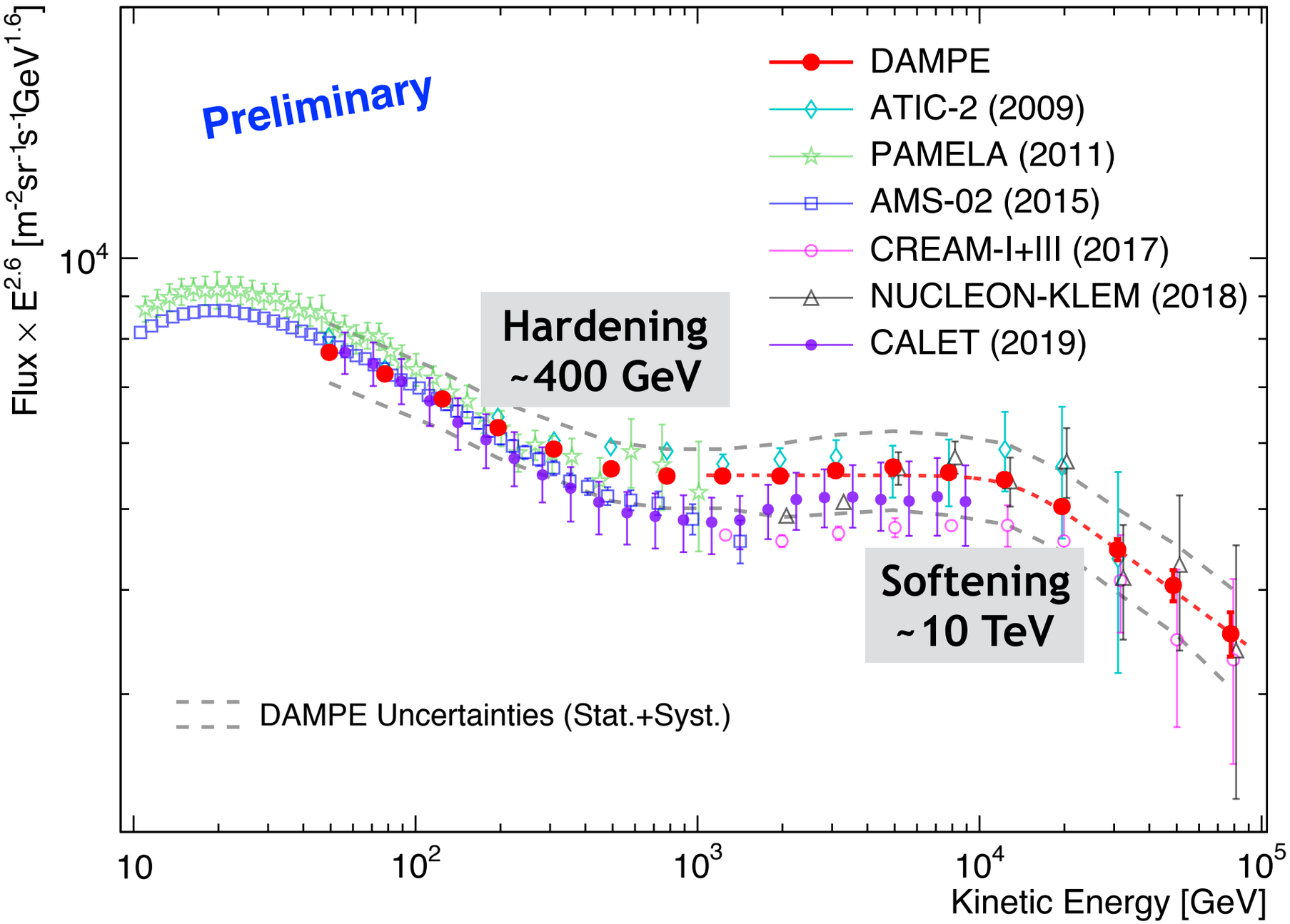
Track Reconstruction: ~3.5%

Charge Identification: ~1.8%

Proton Spectrum



Proton Spectrum



Conclusions

- Since launch on Dec. 17, 2015, DAMPE ("WuKong") has been operated for more than three years.

- Thirty months of on-orbit data with live time fraction of 75.73% are analysed for cosmic-ray proton spectrum.

- The analysis of proton spectrum for energy range 40GeV-100TeV is reported.

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Thanks for your attentions!