Measurement of the Boron to Carbon Flux Ratio in Cosmic Rays with the DAMPE Experiment

Chuan Yue*, Zhan-Fang Chen, Ming-Yang Cui
Dimitrios Kyratzis, Li-Bo Wu
(on behalf of the DAMPE Collaboration)

*speaker: yuechuan@pmo.ac.cn

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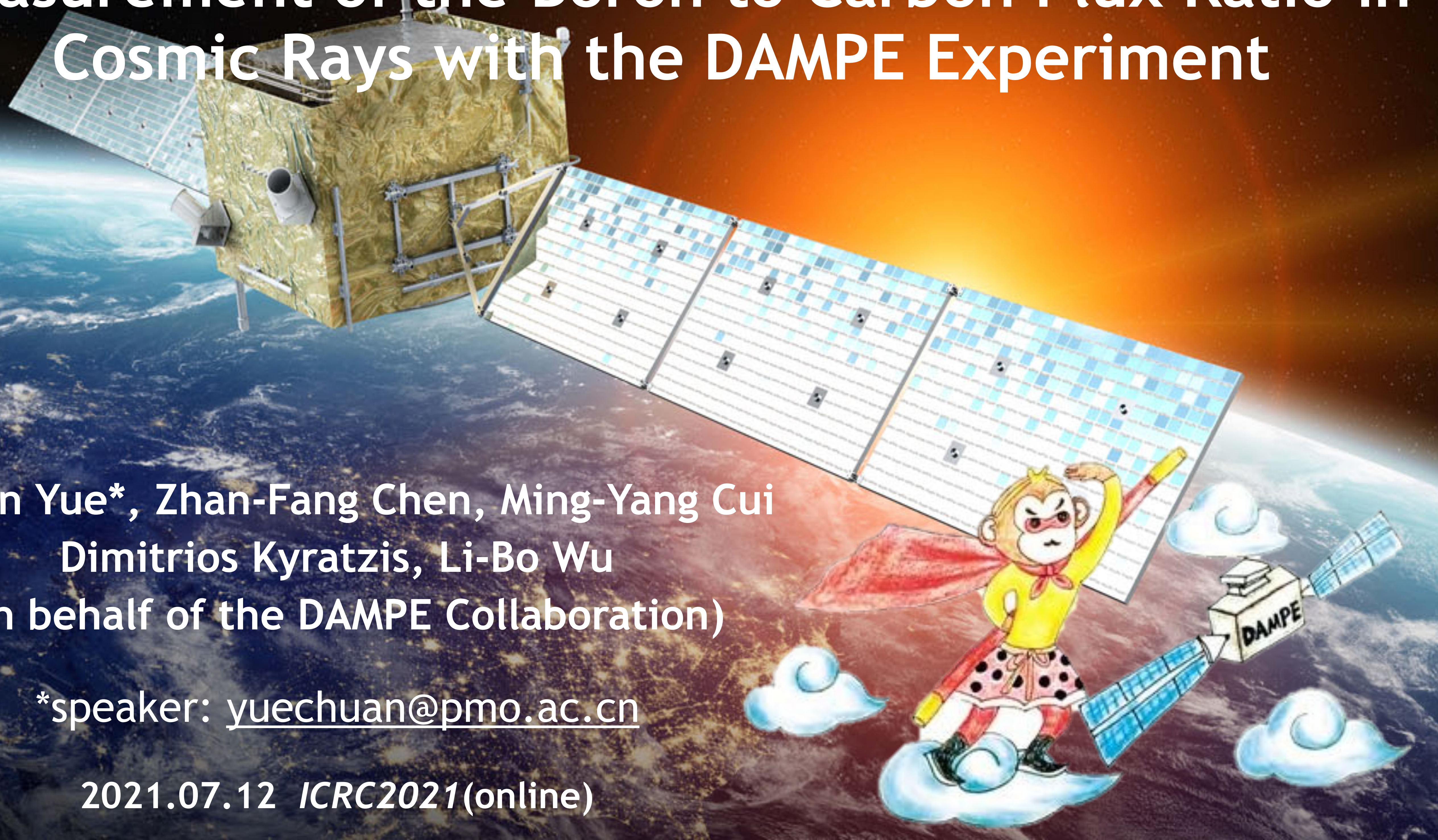
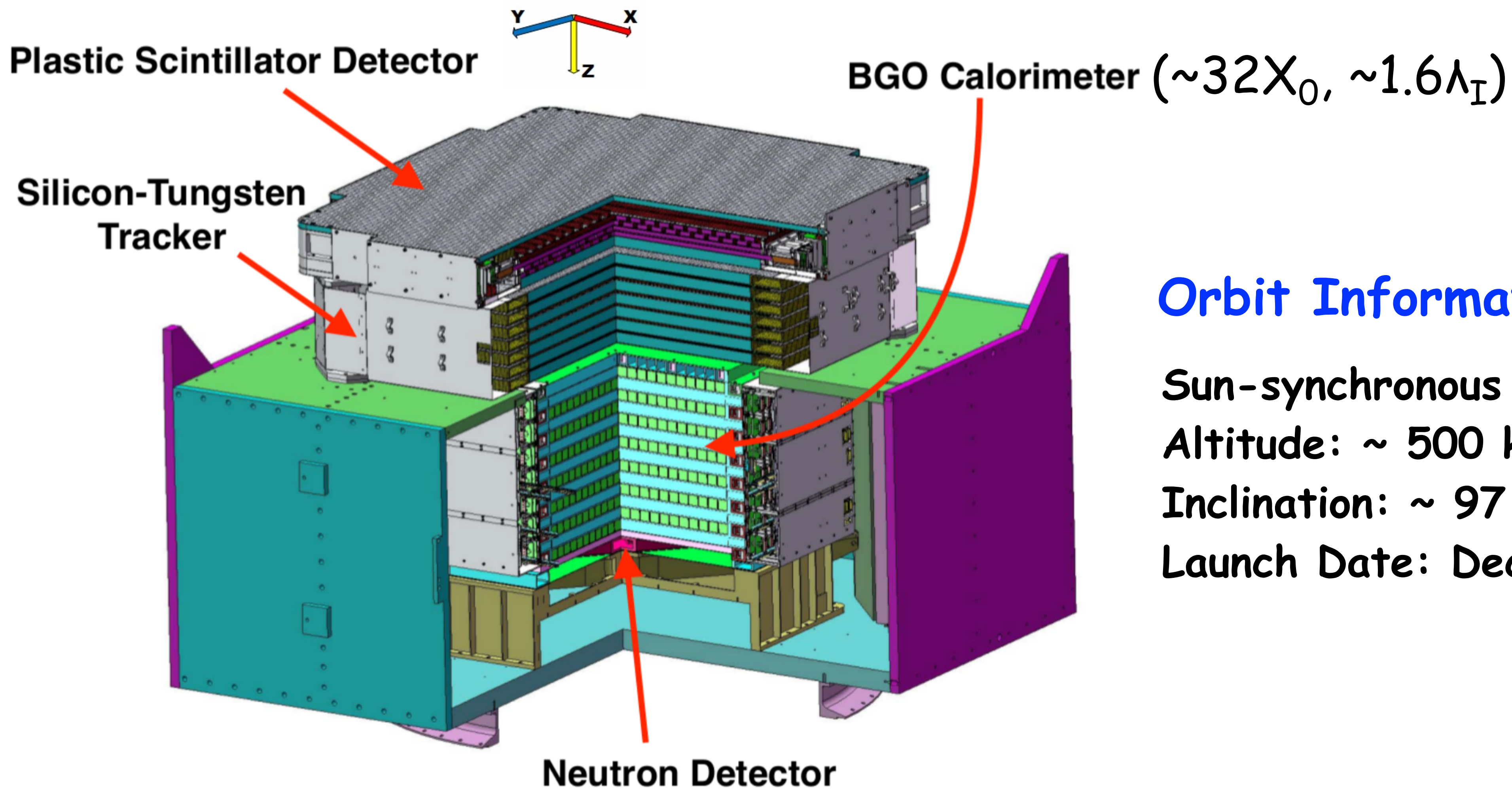


DAMPE Collaboration

- 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

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)

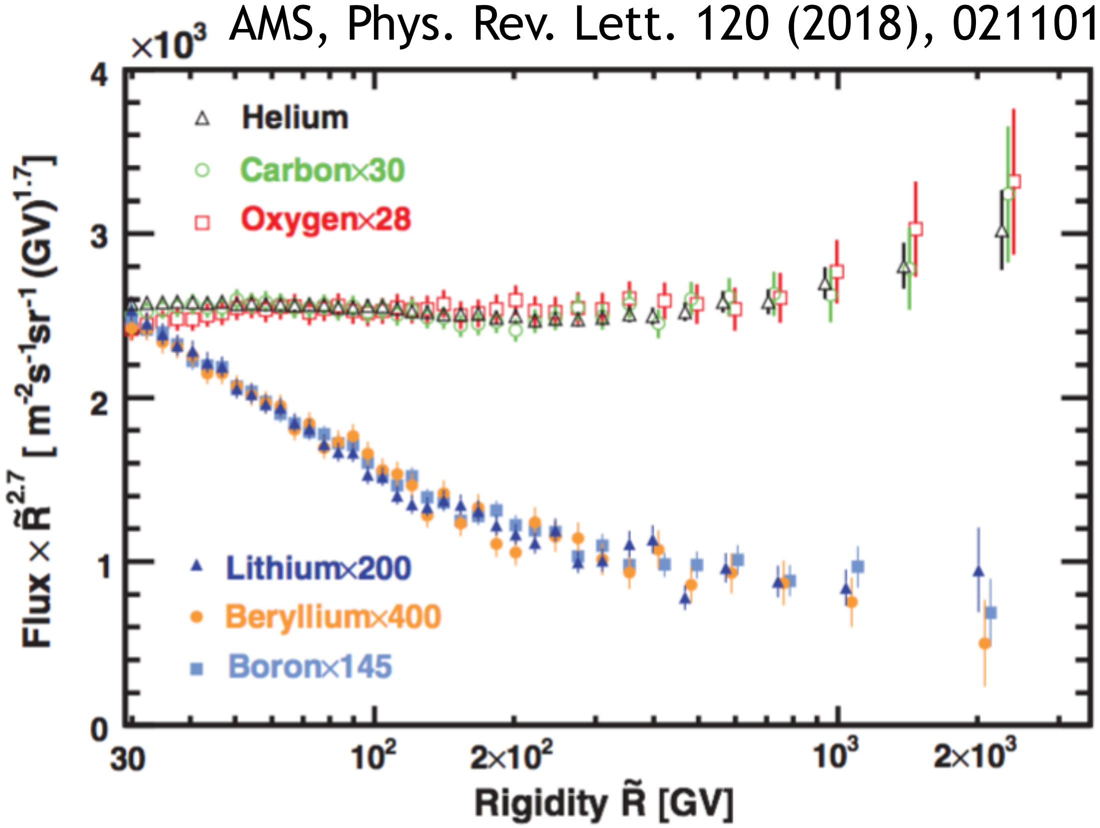
Introduction

The precise measurement of boron to carbon flux ratio is essential for the estimation of the average amount of interstellar material traversed by cosmic rays.

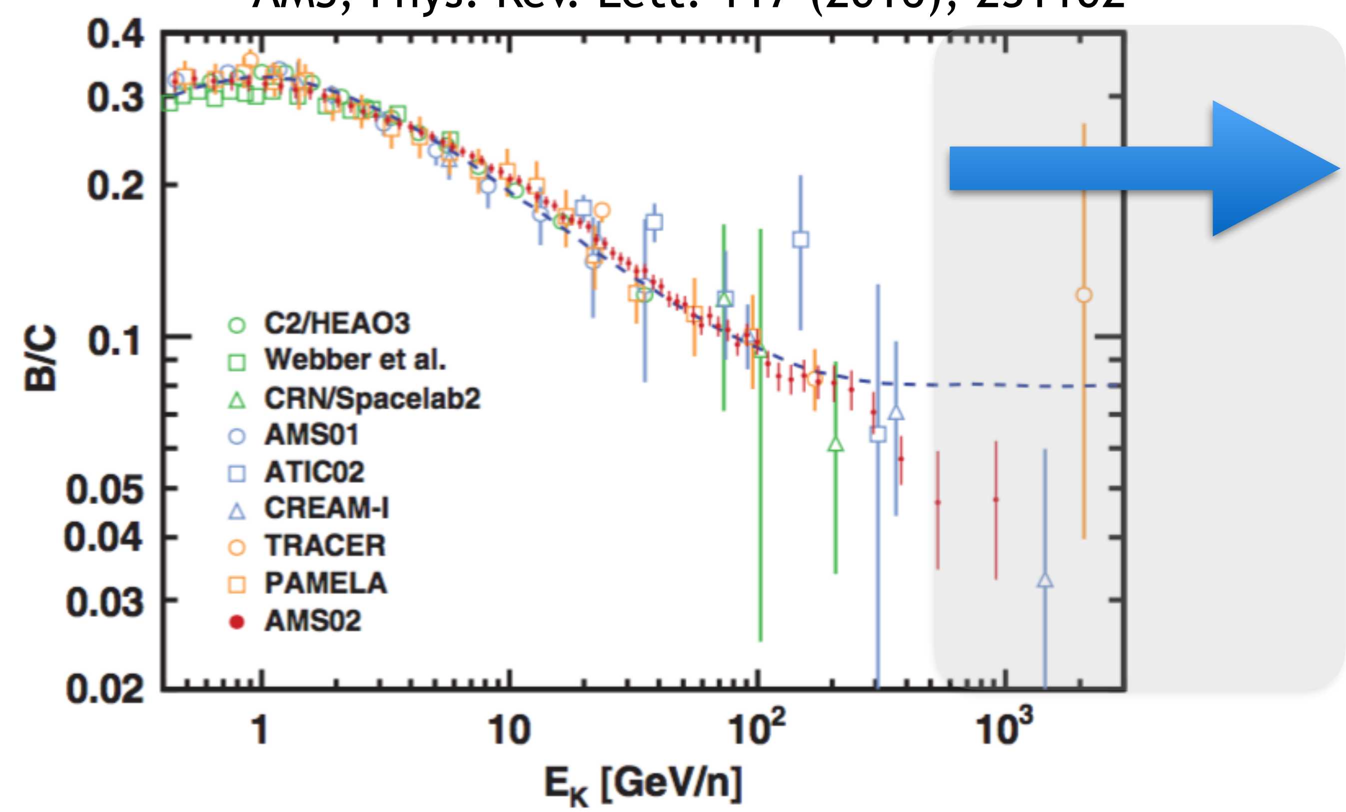
Thanks to AMS-02's precise measurements, now we know that the rigidity dependences of primary cosmic rays (e.g. He, C, O) and of secondary cosmic rays (e.g. Li, Be, B) are distinctly different.

The B/C flux ratio above TeV/n, however, remains to be precisely measured.

AMS, Phys. Rev. Lett. 120 (2018), 021101



AMS, Phys. Rev. Lett. 117 (2016), 231102



Data Sample

On-orbit Data Sample:

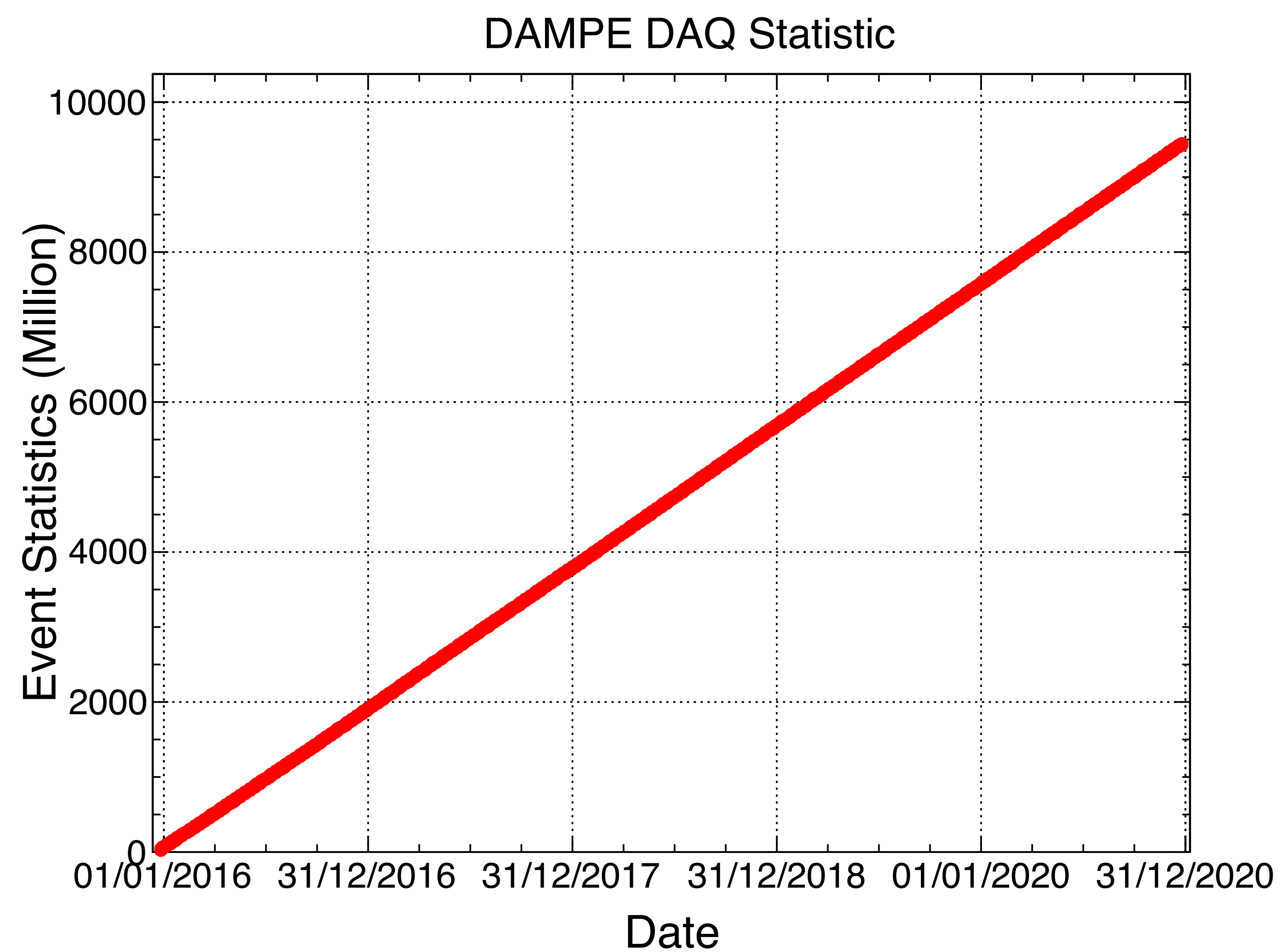
Jan. 1st 2016 to Dec. 31th 2020 (5 years)

Total Events:

9.46 Billion Events

Live Time:

1.1977446×10^8 seconds (~75.88 %)



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

Data in SAA region are excluded

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

MC Simu Sample: Geant4.10.5.p02 (FTFP_BERT)

Pre-Selections

- **Not in SAA region**
- **BgoEnergy > 100 GeV**
- **High Energy Trigger (G3)**
- **Track Selection**
- **PSD Fiducial**
- **BGO Fiducial**
- **PSD PreCut**

  track - MaxE Psd Hit (L0 & L1)
- **BGO PreCut**

  Gap-Incident Event Rejection

Track Selection:

- ☑ Has Cluster on plane0 (X||Y)
- ☑ MaxE Cluster on plane0 (X||Y)
- ☑ nHitXY >= 4
- ☑ Chi2/Ndof < 5.0
- ☑ Shower Match

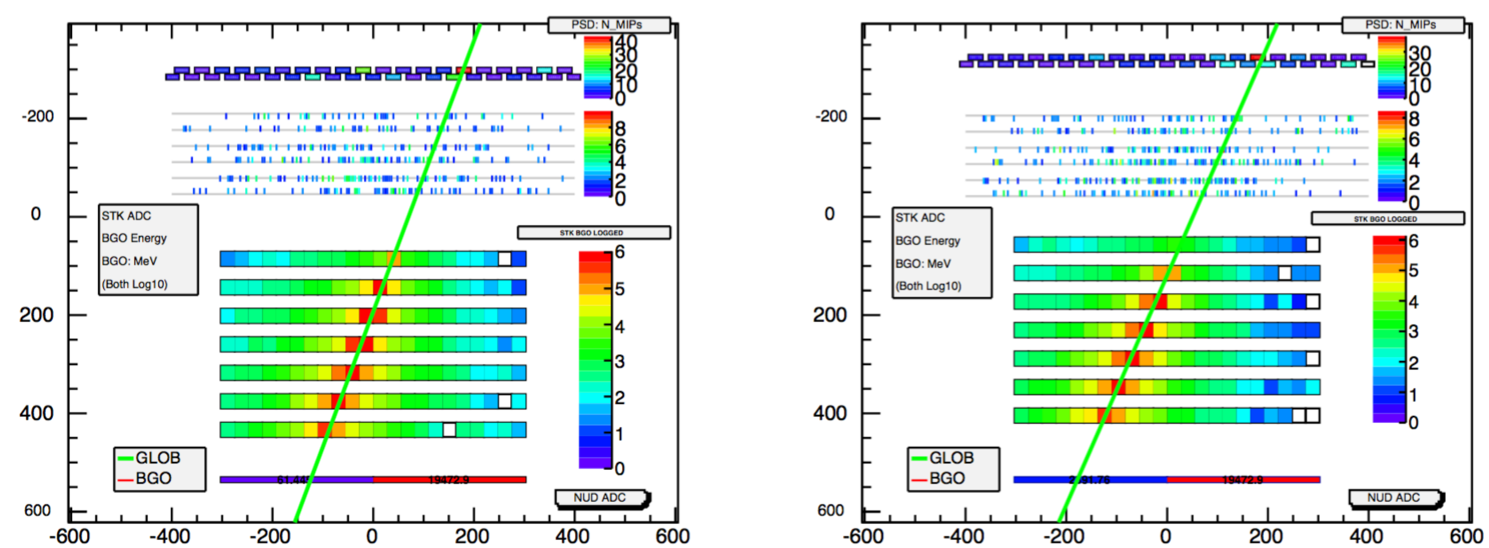
  (Distance with CogPos of BGO L0-L3 < 15 mm)
- ☑ StkQ_RMS < 1.2

Unique Selection

? GlbTrk: Longest & Max Average ClusterE

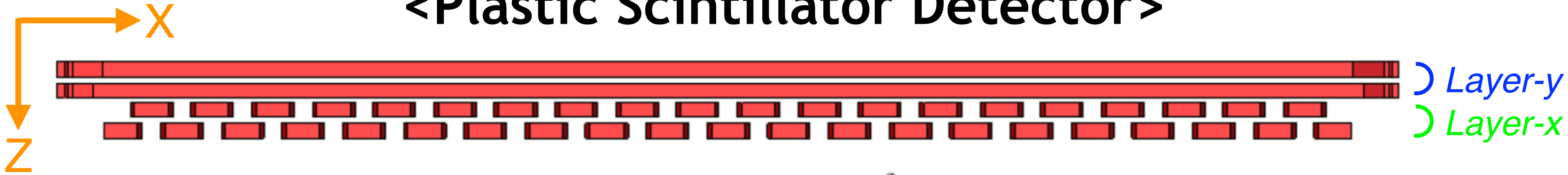
StkTrk: Longest & Max Average ClusterE & Best Shower Match

Flight-Data Carbon (Edep: 13.375 TeV)



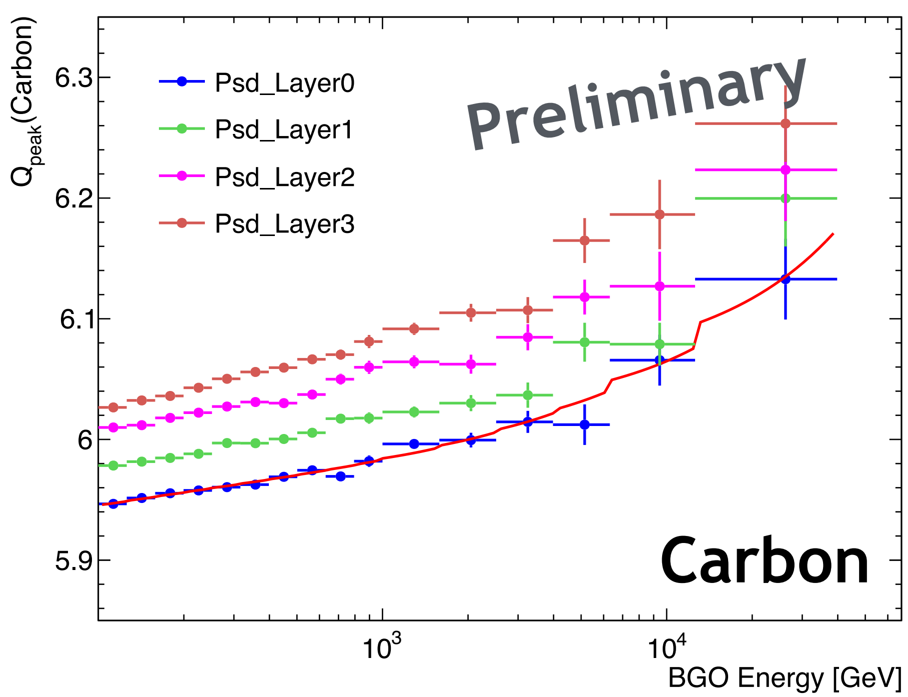
Charge reconstruction

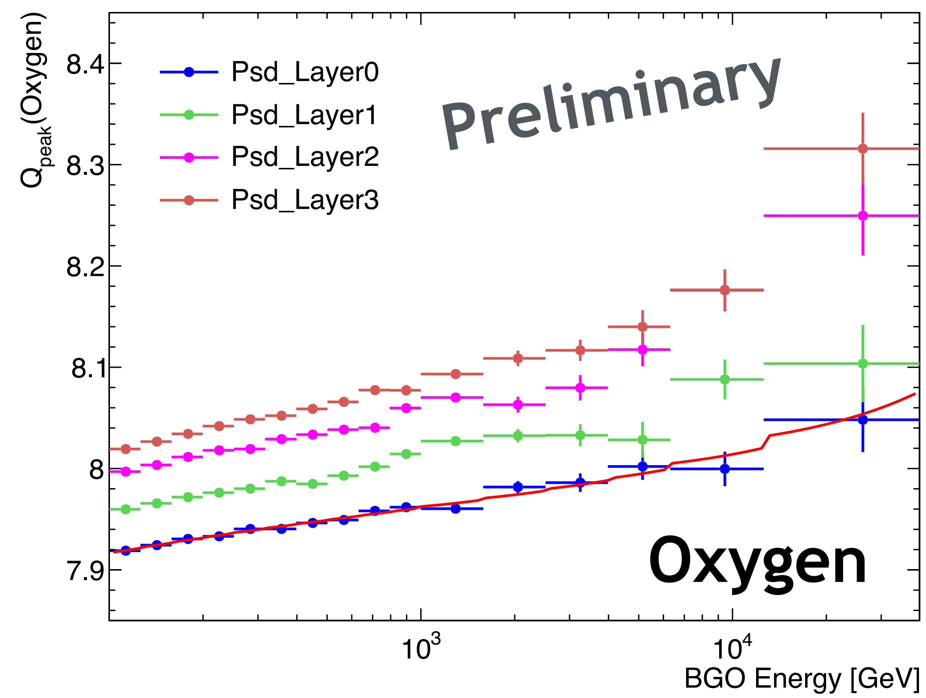
<Plastic Scintillator Detector>



Bethe-Bloch

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





Energy Independence:

1. Fit the function of C&O charge peak with BGO energy layer by layer

2. Modify the PsdQ(0,…,3) event by event:

$$Q_i^*(E) = \frac{8.0 - 6.0}{OP_i(E) - CP_i(E)} * (Q_i(E) - CP_i(E)) + 6.0,\ i = 0, ..., 3$$

*Similar procedure for MC data (i.e. B—>5.0, C—>6.0, N—>7.0, O—>8.0)

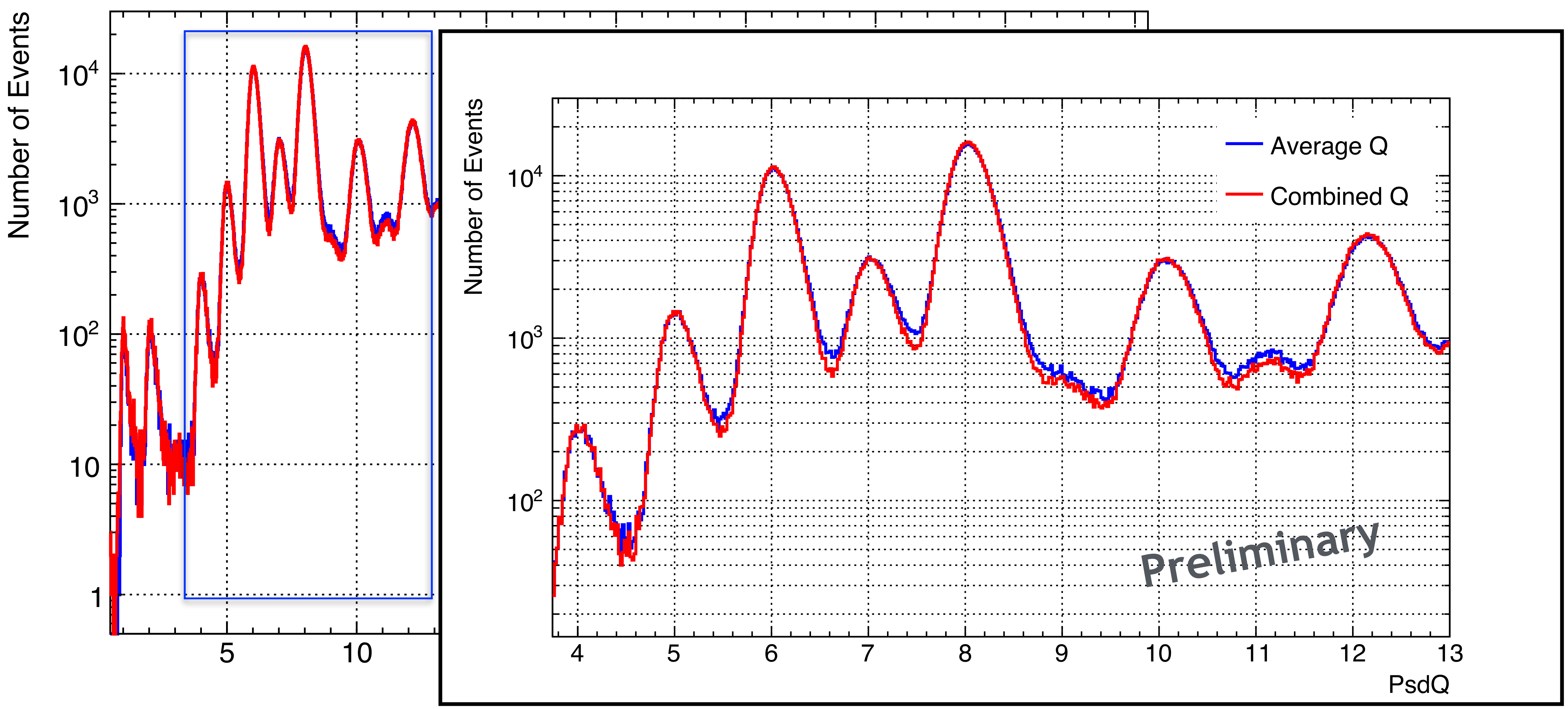
Charge reconstruction

PsdQ Combination:

$$PsdQ_{com} = \frac{\sum_0^k PsdQ_i}{k}, \; k \leqslant 3$$

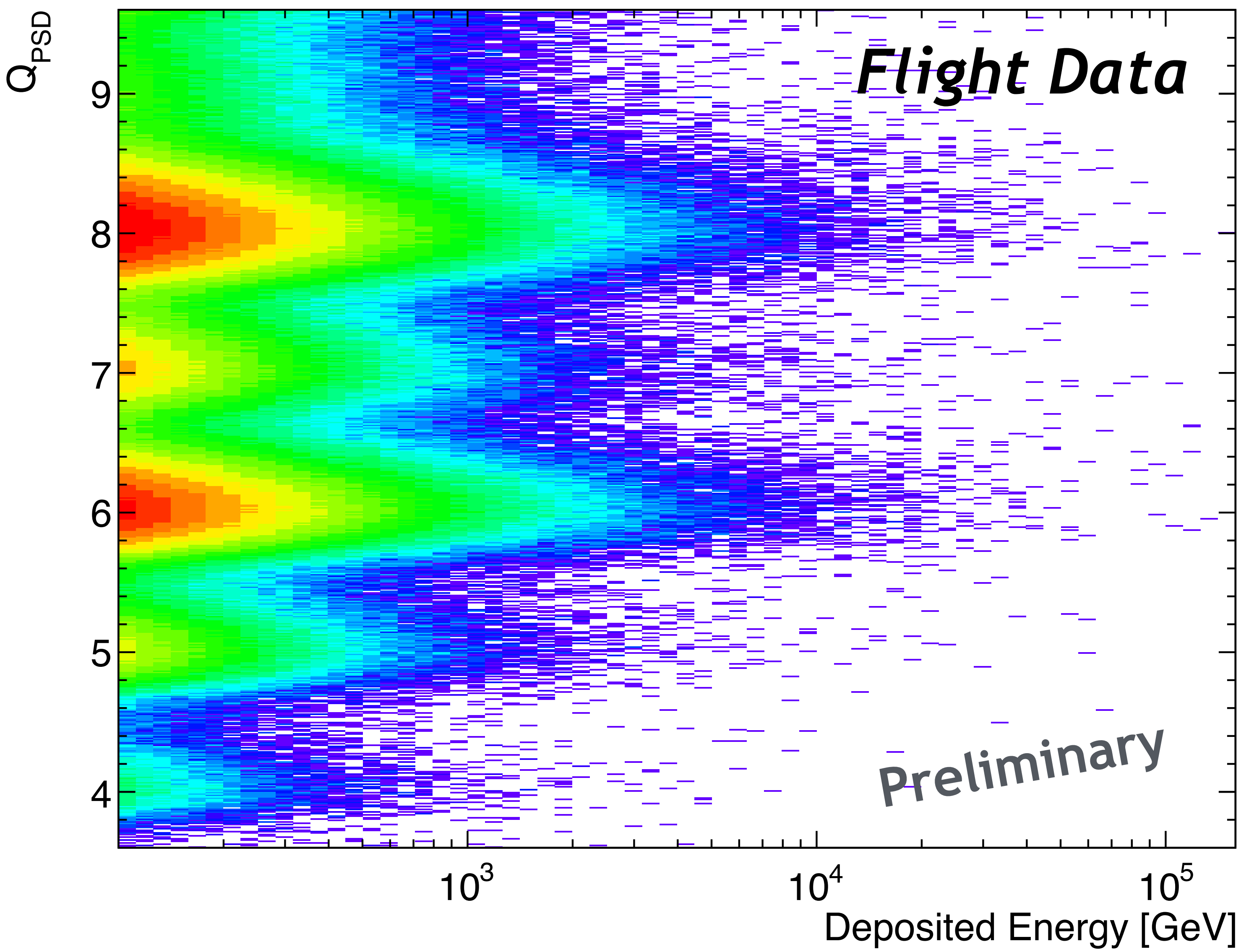
* k is the last layer before particle fragmentation

ClusterADC (StkPlane0) > 800



Charge selection

Charge measurement from two PSD layers (Z=4-9)



- ☑ Light attenuation (position) correction
- ☑ Light saturation (quenching) correction
- ☑ Charge energy-Independence

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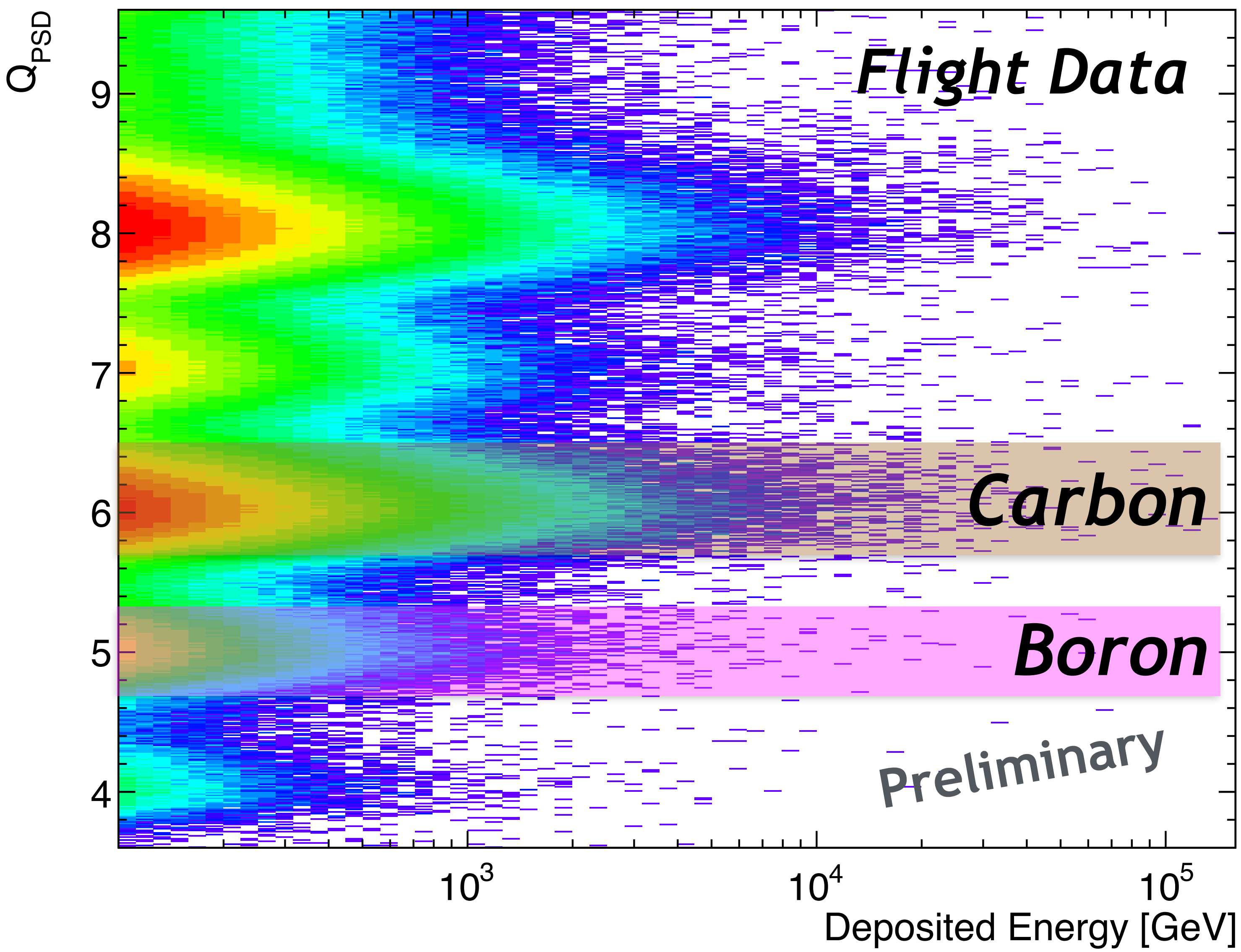


- Light attenuation (position) correction
- Light saturation (quenching) correction
- Charge energy-Independence

Boron selection: 4.75 < Z < 5.35

Carbon selection: 5.7 < Z < 6.5

Efficiency Validation

A "pure" boron/carbon sample is required for efficiency validation

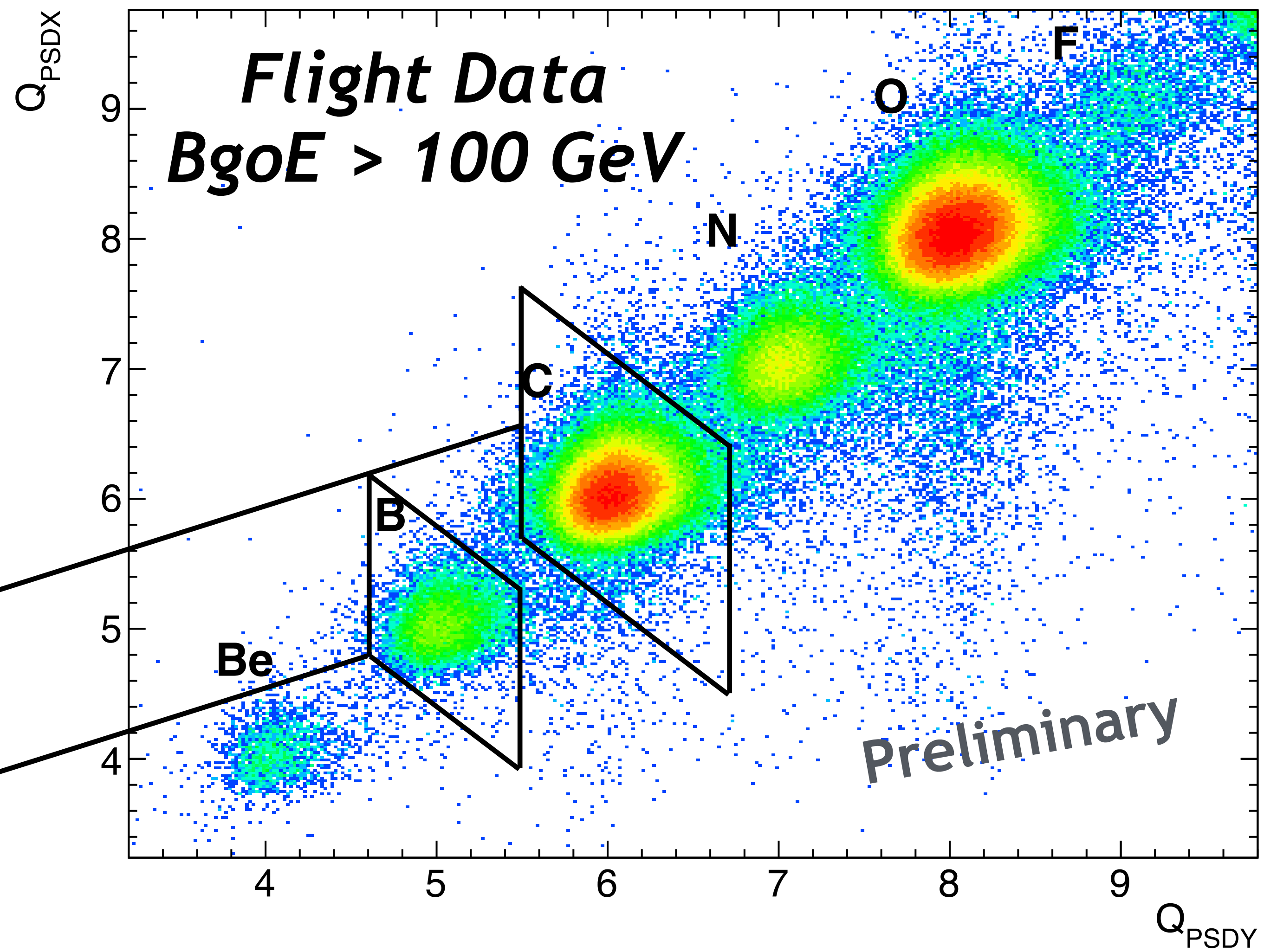
A much stricter PSD selection:

$PsdQ_{Y0} > 0$ & $PsdQ_{Y1} > 0$ & $|PsdQ_{Y0} - PsdQ_{Y1}| < 1$

$PsdQ_{X0} > 0$ & $PsdQ_{X1} > 0$ & $|PsdQ_{X0} - PsdQ_{X1}| < 1$

$$PsdQ_Y = \frac{PsdQ_{Y0} + PsdQ_{Y1}}{2}$$

$$PsdQ_X = \frac{PsdQ_{X0} + PsdQ_{X1}}{2}$$



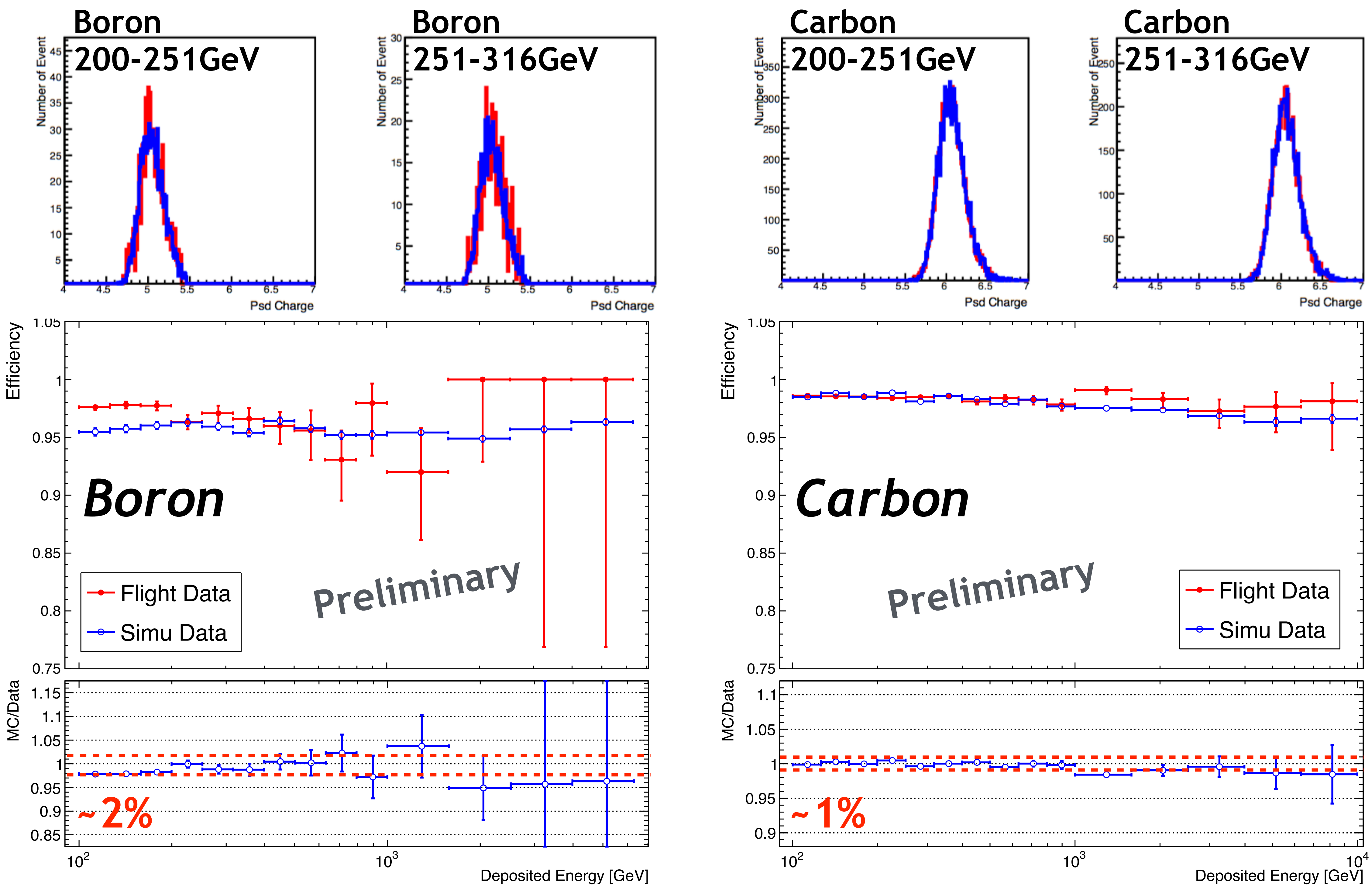
Carbon sample

Brobon sample

PSD Charge Efficiency

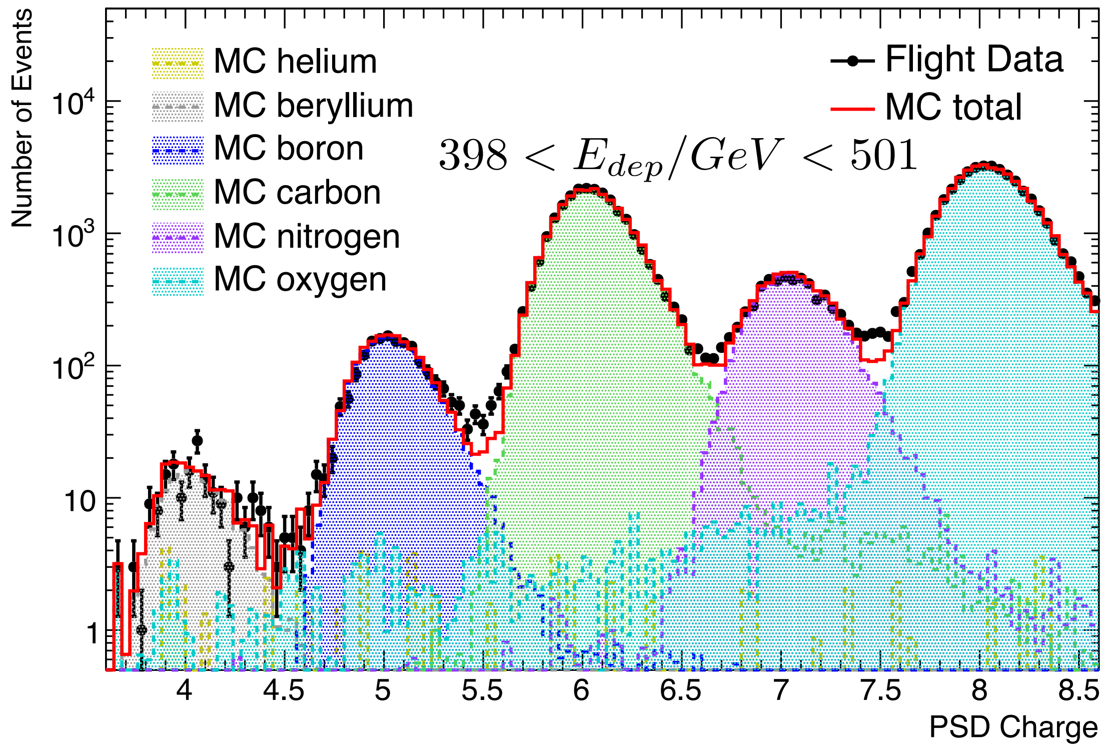
$$PsdQ_{com} = \frac{\sum_0^k PsdQ_i}{k}, \ k \leqslant 3$$

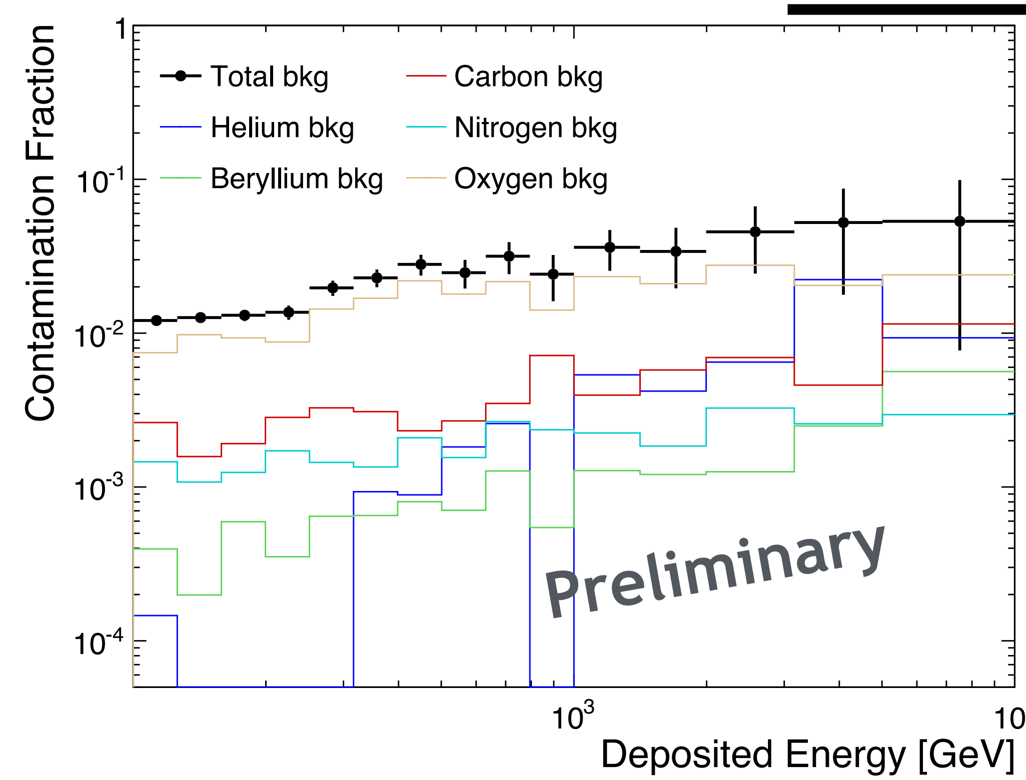
***A specific sample is selected for charge validation of MC simulation**



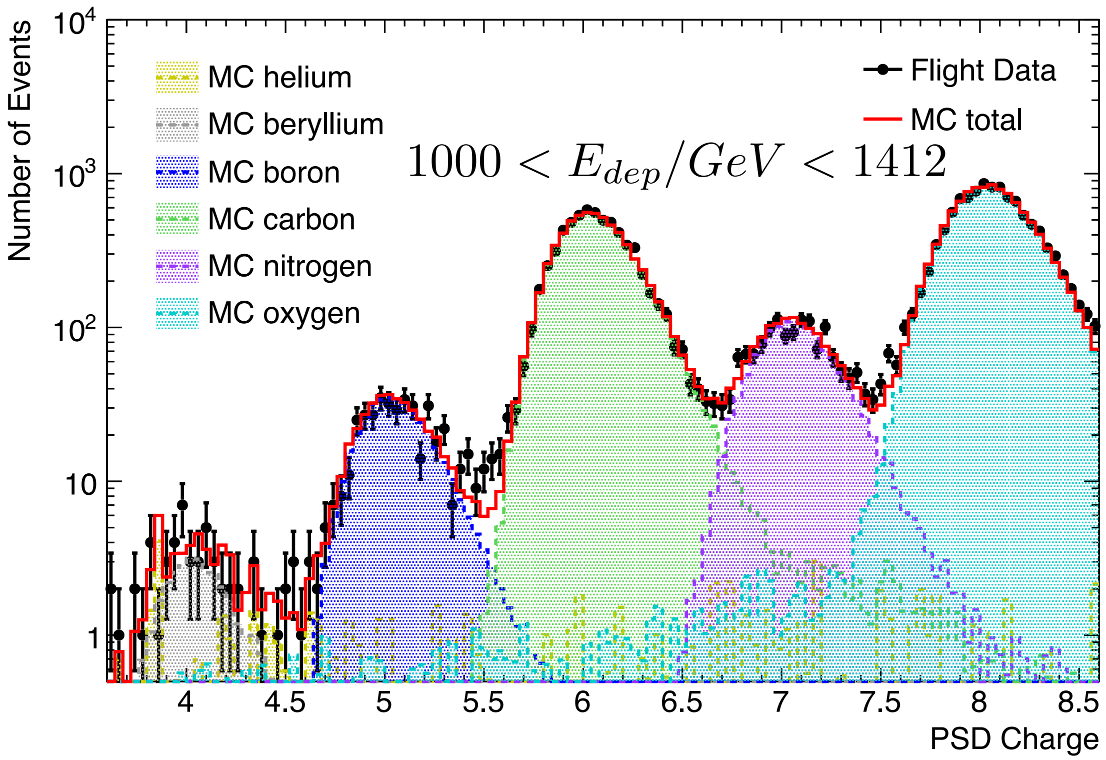
Background Estimation

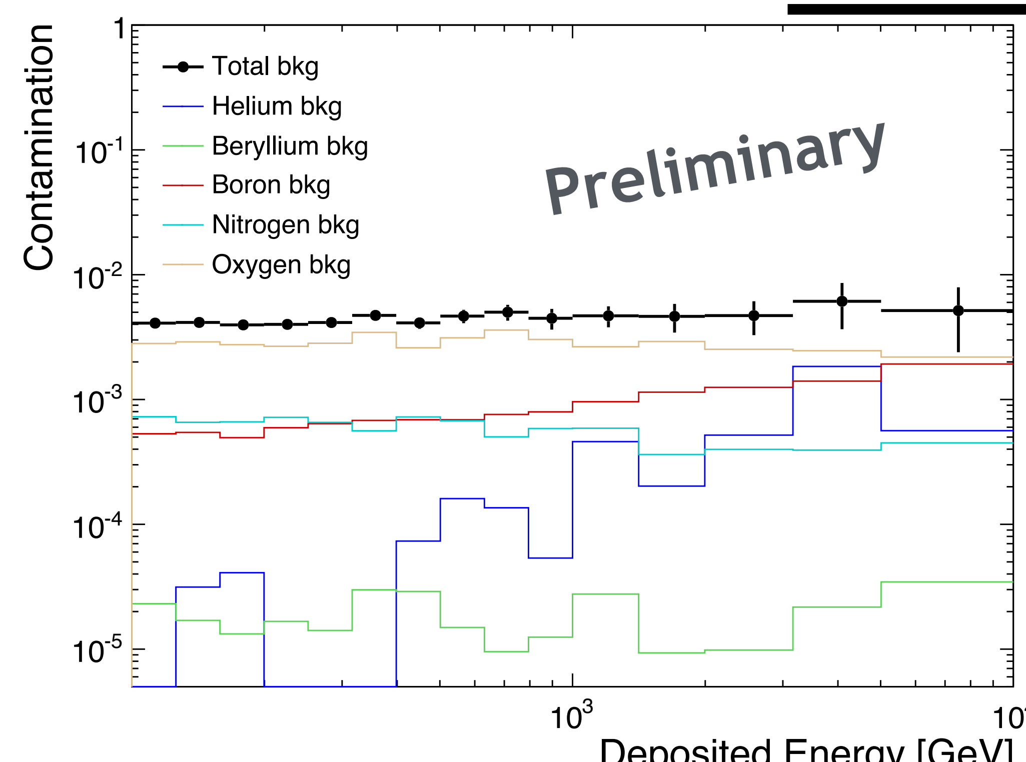
Contamination estimation for boron and carbon





Boron





Carbon

Energy Unfolding

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

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

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

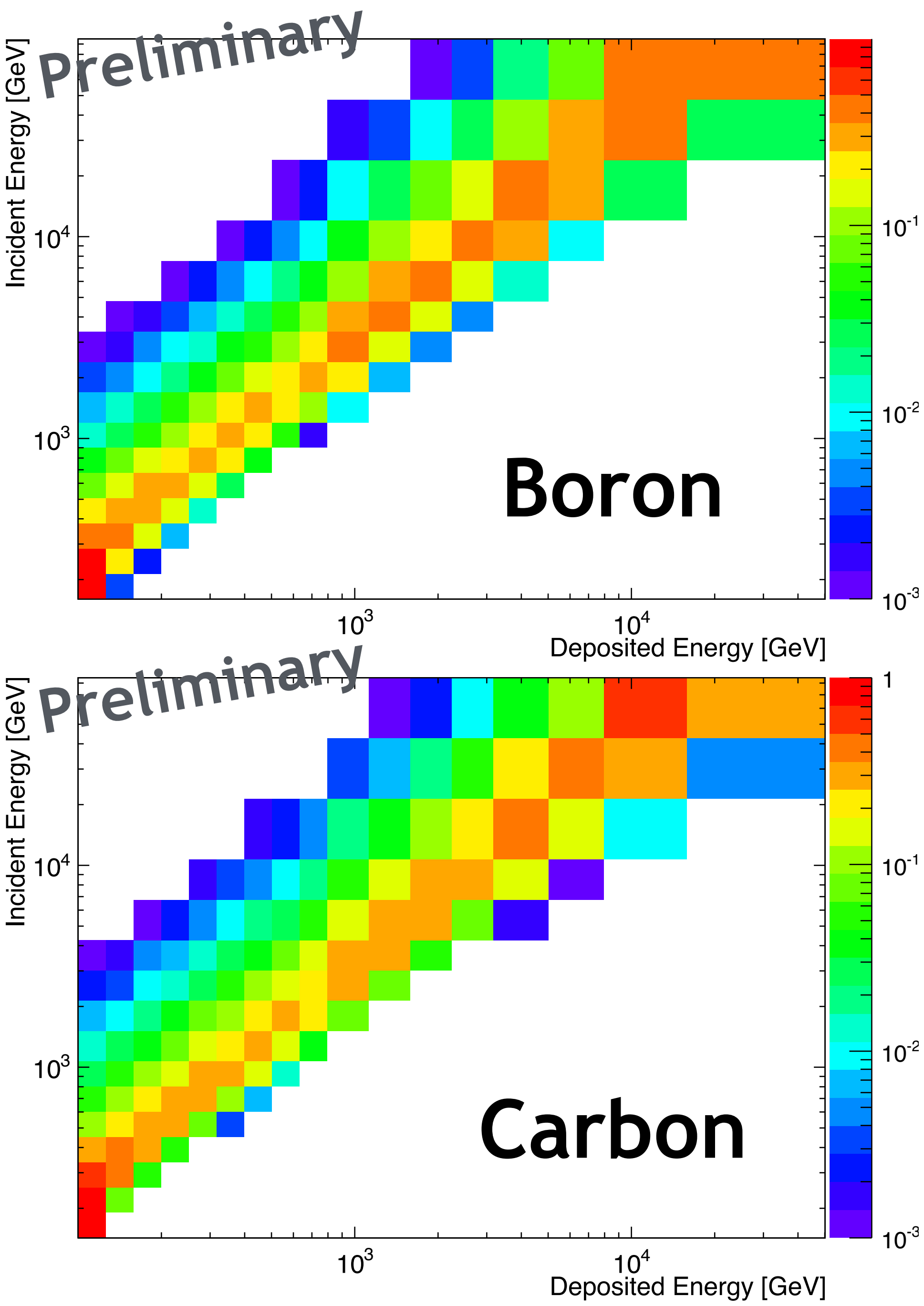
N_i : **Unfolded event number**

M_j: **Measured event number**

β_j : **Background**

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

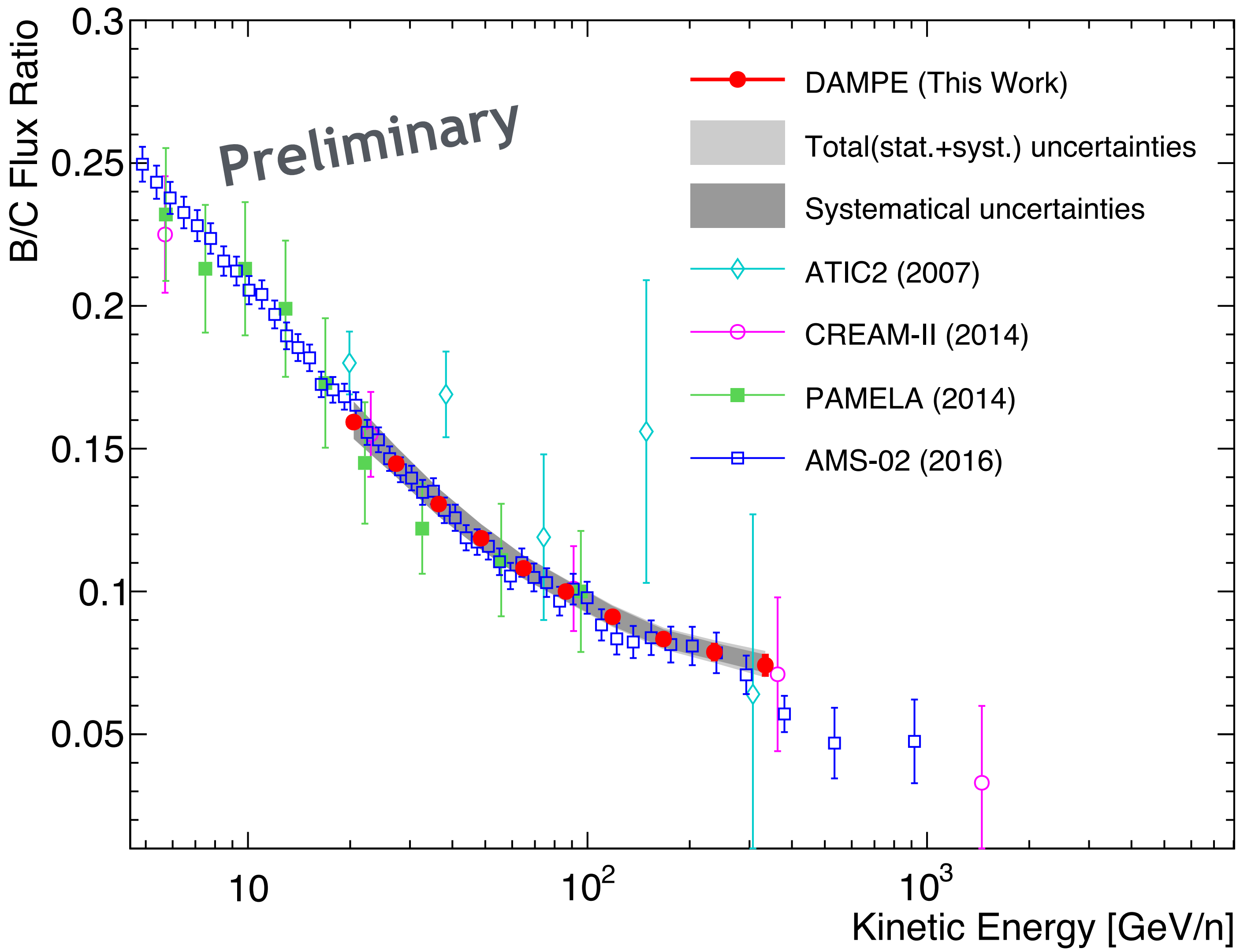
$\hat{N}_i$: **Prior ($E^{-2.7}$)**



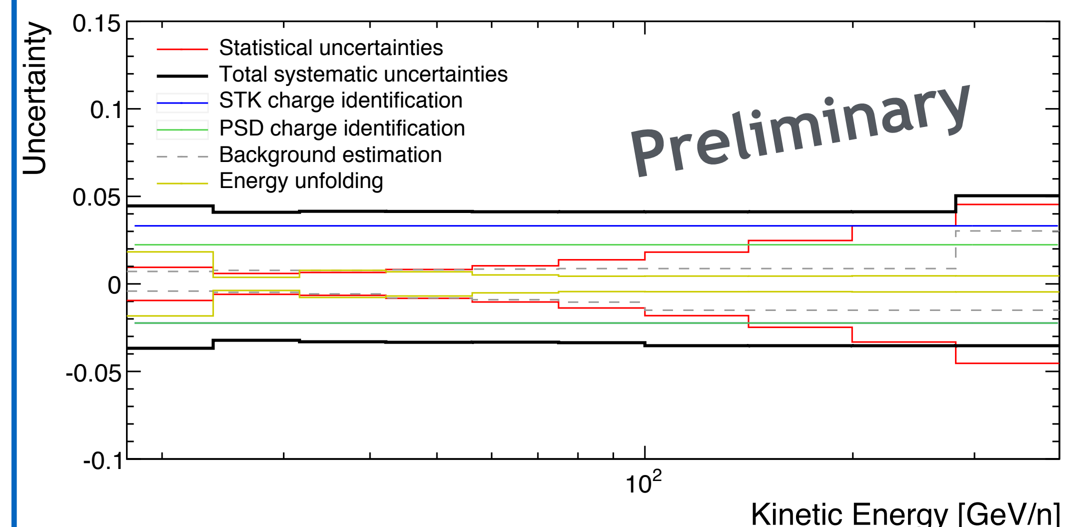
Boron to Carbon Flux Ratio

Flux in *i*-th incident energy bin:

$$\Phi(E_i, E_i + \Delta E_i) = \frac{\Delta N_i}{\Delta E_i \; A_{\mathrm{eff},i} \; \Delta T}$$



Uncertainties



- Preliminary result of B/C flux ratio from 20GeV/n to 400GeV/n has been obtained.
- DAMPE measurement is well consistent with PAMELA and AMS-02 within uncertainties

* The uncertainty from hadronic model is not included in current analysis

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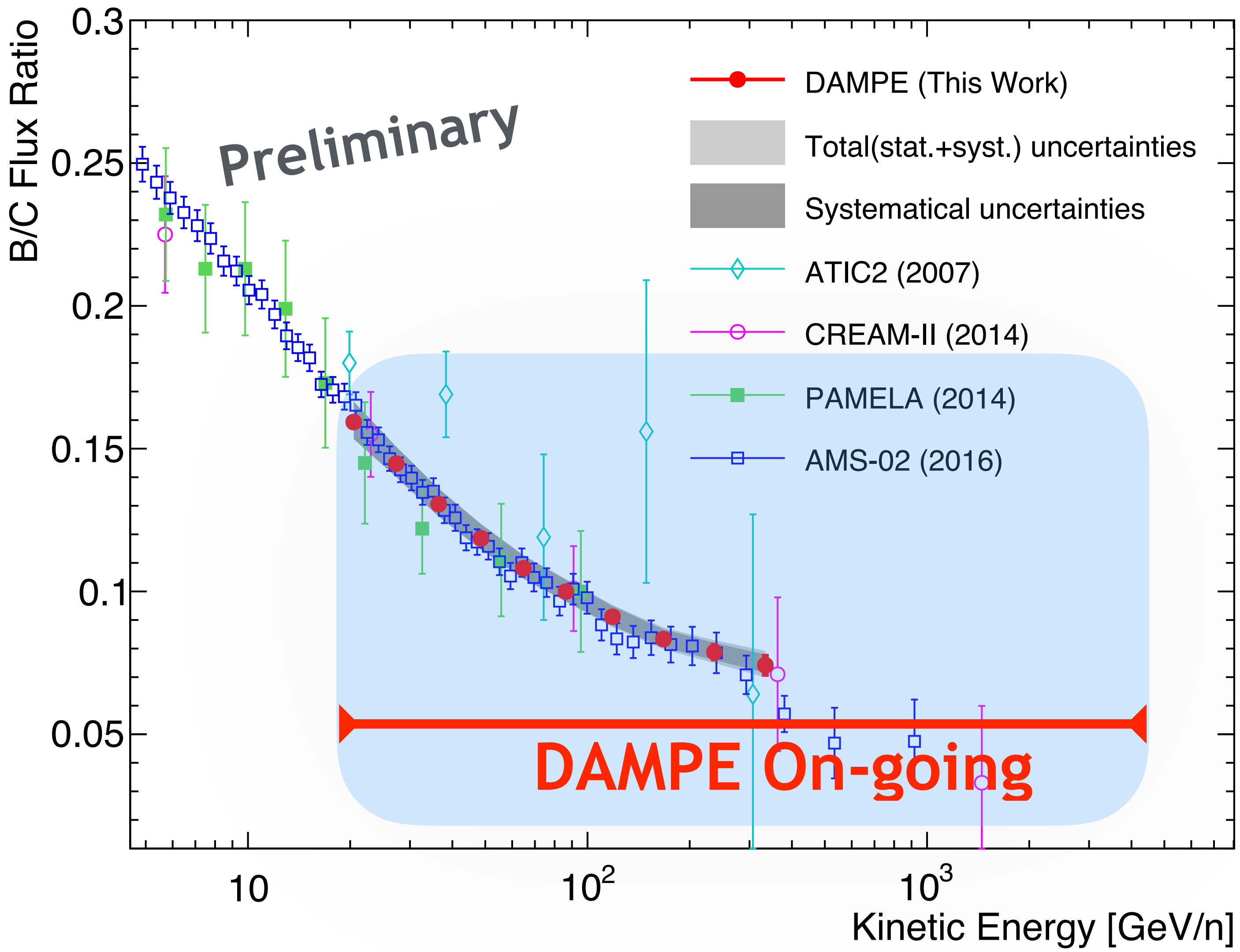

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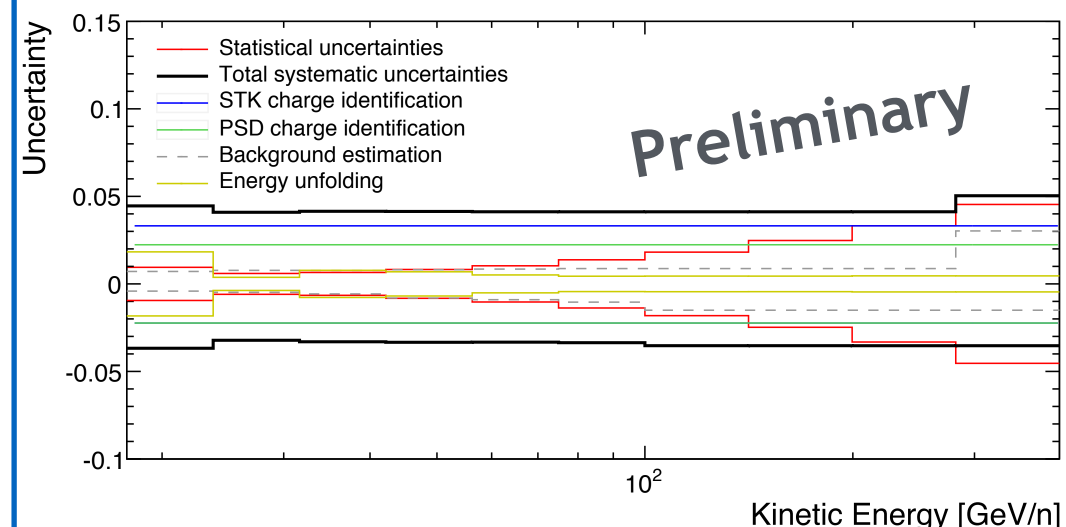

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*** The analysis of B/C flux ratio up to few TeV/n is on-going**

Conclusions

- **Since Launched at Dec. 17, 2015, DAMPE ("Wukong") has been operated for more than five and a half years**
- **Five years of on-orbit data with live time of 1.1977446×10^8 seconds are analysed for the boron to carbon flux ratio**
- **The preliminary measurement of B/C flux ratio from 20 GeV/n to 400 GeV/n is reported**
- **The B/C flux ratio of DAMPE is well consistent with previous space measurements (i.e. PAMELA and AMS-02)**
- **More studies are in processing, the B/C flux ratio measurement will be extended up to few TeV/n in the near future.**

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Thanks for your attentions!