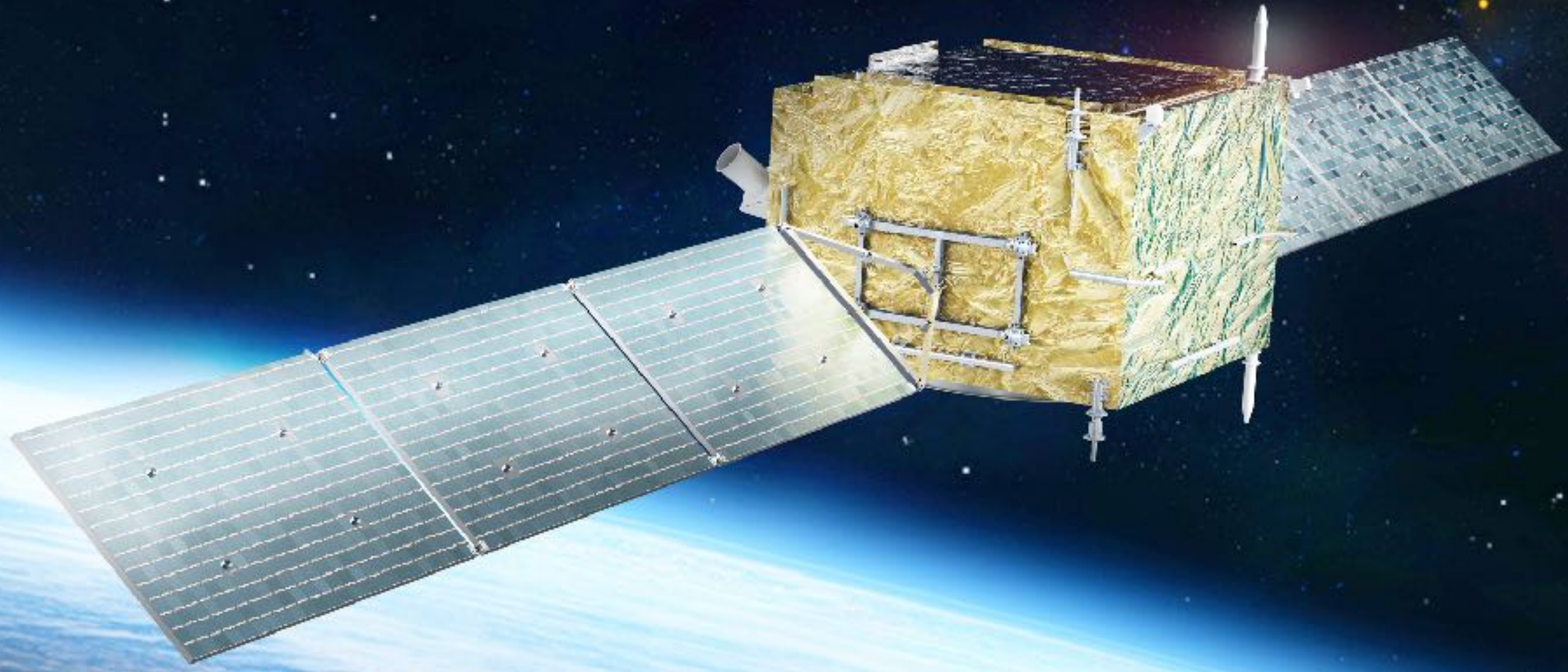
Combined analysis of CNO group with DAMPE



Pengxiong Ma* (Speaker), Wei Jiang, Ivan De Mitri and Qiang Yuan
mapx@pmo.ac.cn
Purple mountain observatory, CAS, Nanjing,China
On behalf of the DAMPE Collaboration.

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45th Scientific Assembly
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BEXCO, Busan, Korea

DAMPE collaboration

- China

  1. **Purple mountain observatory, CAS, Nanjing.**
  2. University of Science and Technology of China, Hefei.
  3. Institute of Modern Physics, CAS, Lanzhou.
  4. Institute of High Energy Physics, CAS, Beijing.
  5. National Space Science Center, CAS, Beijing.
- Italy

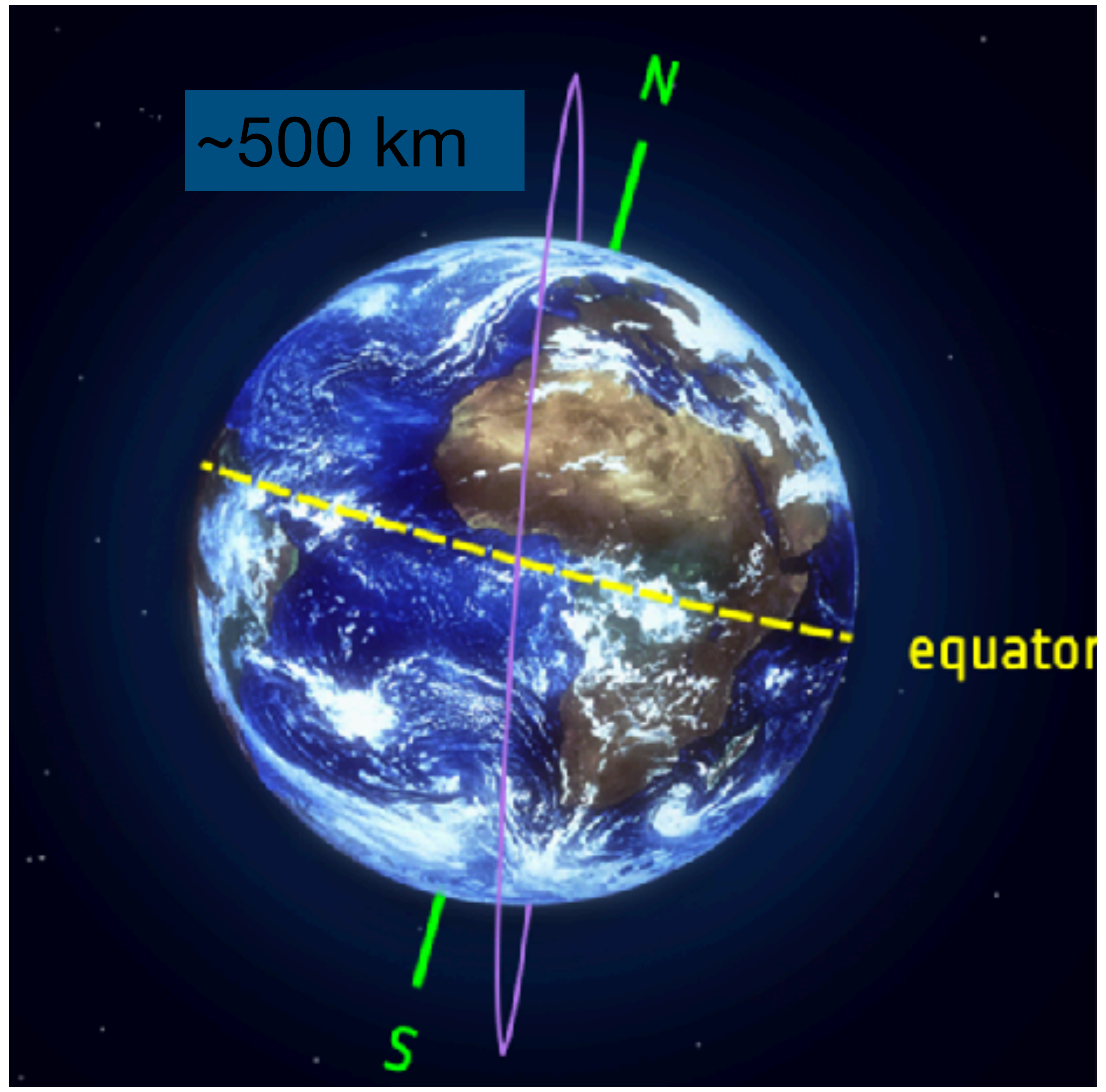
  

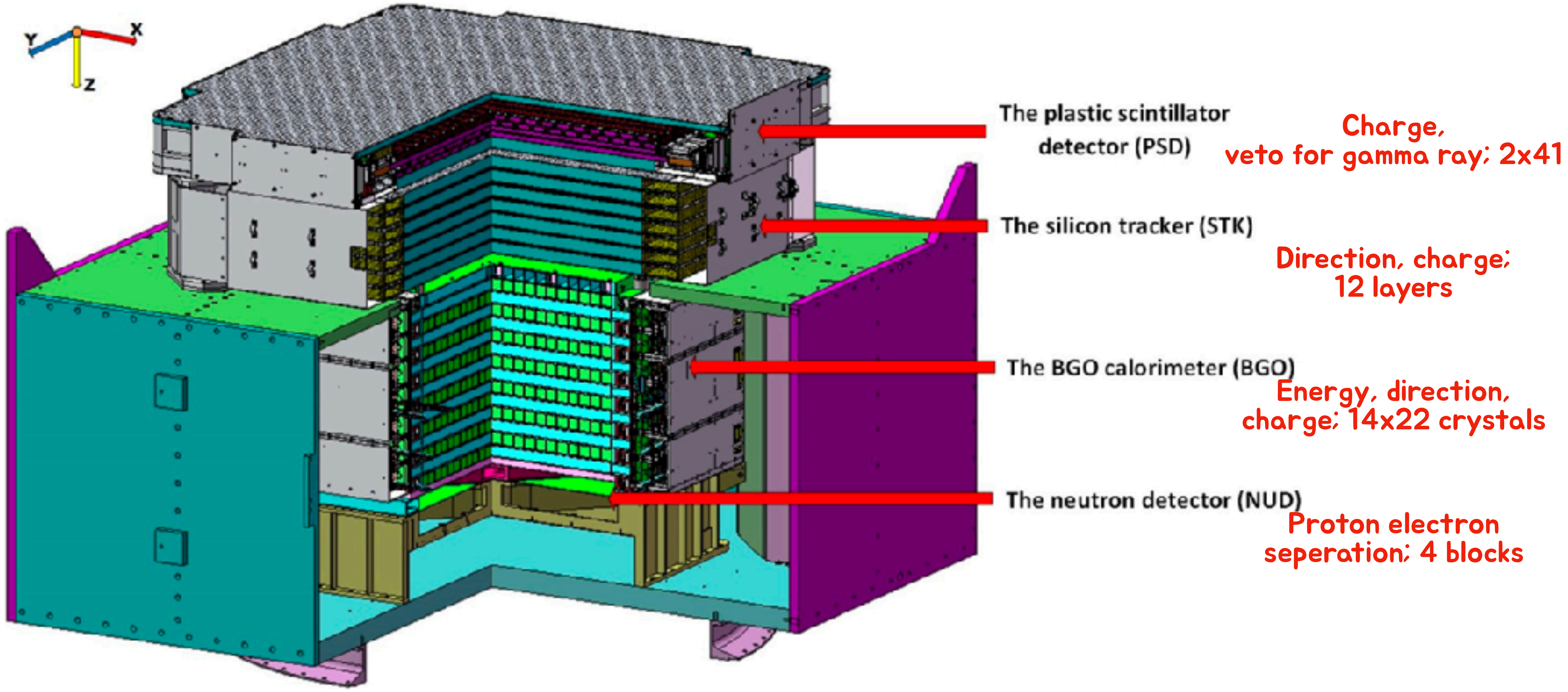
  1. INFN Perugia and University of Perugia.
  2. INFN Bari and University of Bari.
  3. INFN-LNGS and Gran Sasso Science Institute.
  4. LNFN Lecce and University of Salento.
- Switzerland

  1. University of Geneva.

DAMPE

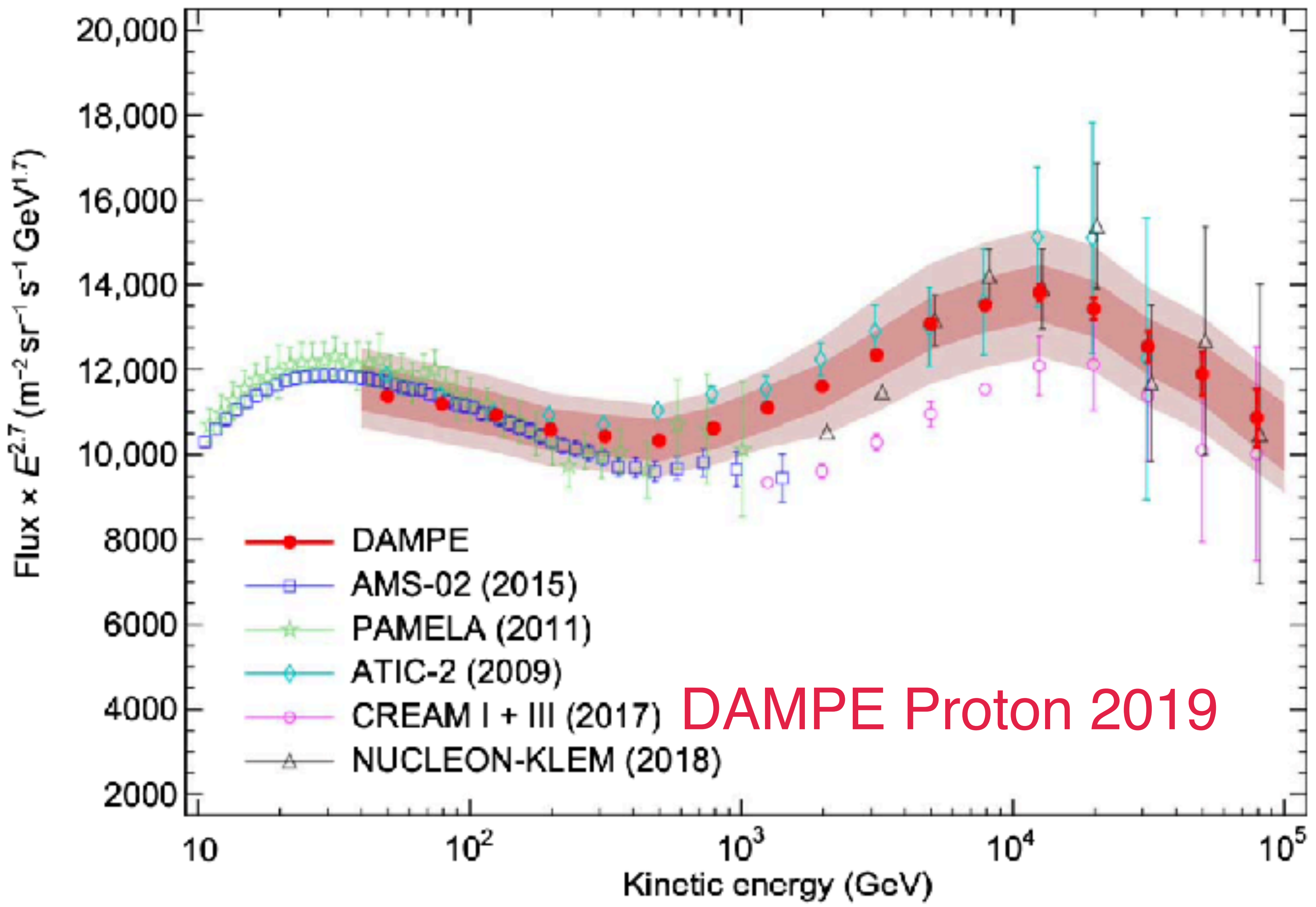


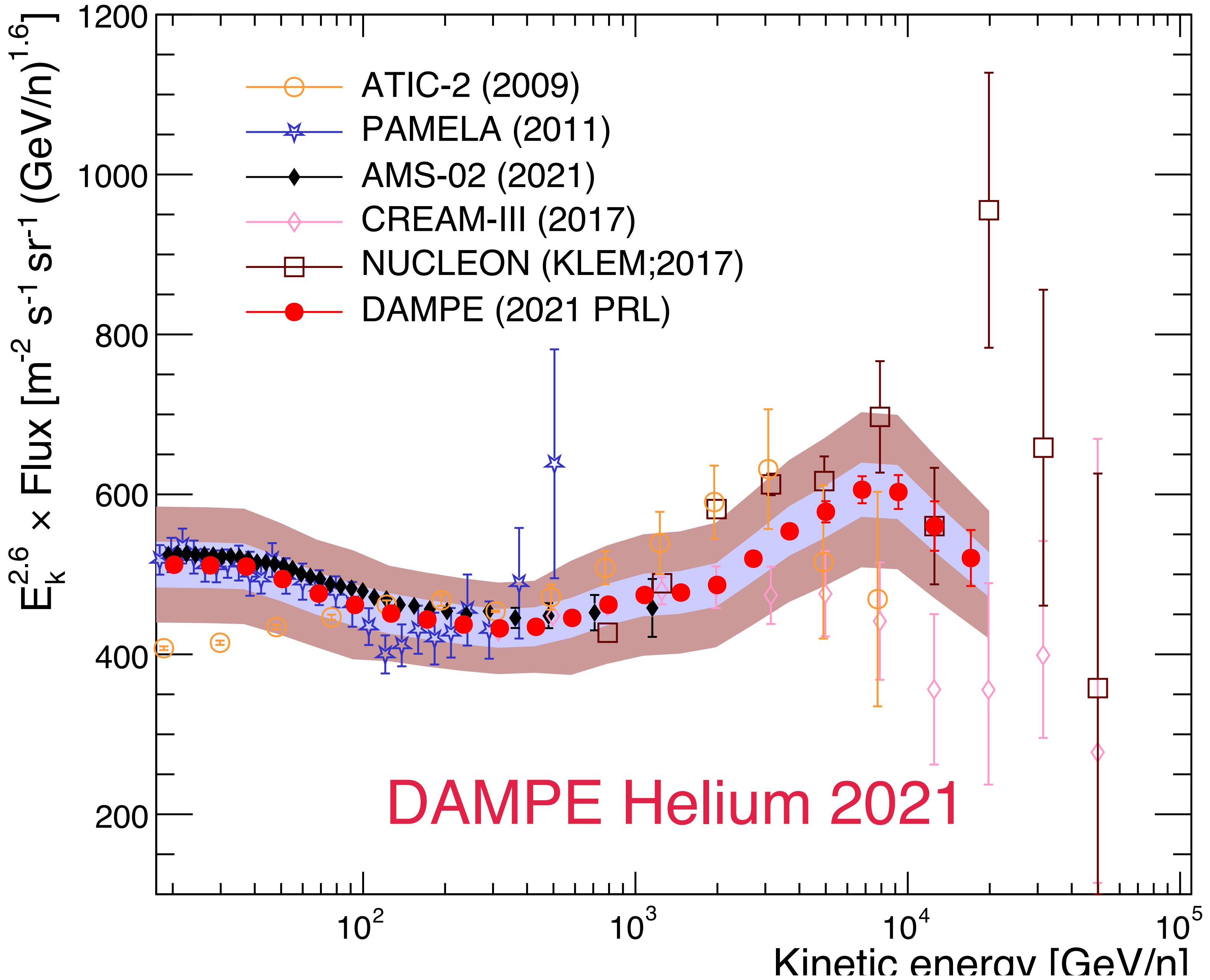


- Expected lifetime: 3 years
- Raw data: 16 GB per day.
- Orbit: sun-sync. ~500 km, ~95 minutes
- Smoothly operated since launch for more than 8 years.

✓ Four sub-detectors, 1.4 tons in total. 32 radiation length & 1.6 nuclear interaction length

What can we know more with DAMPE.

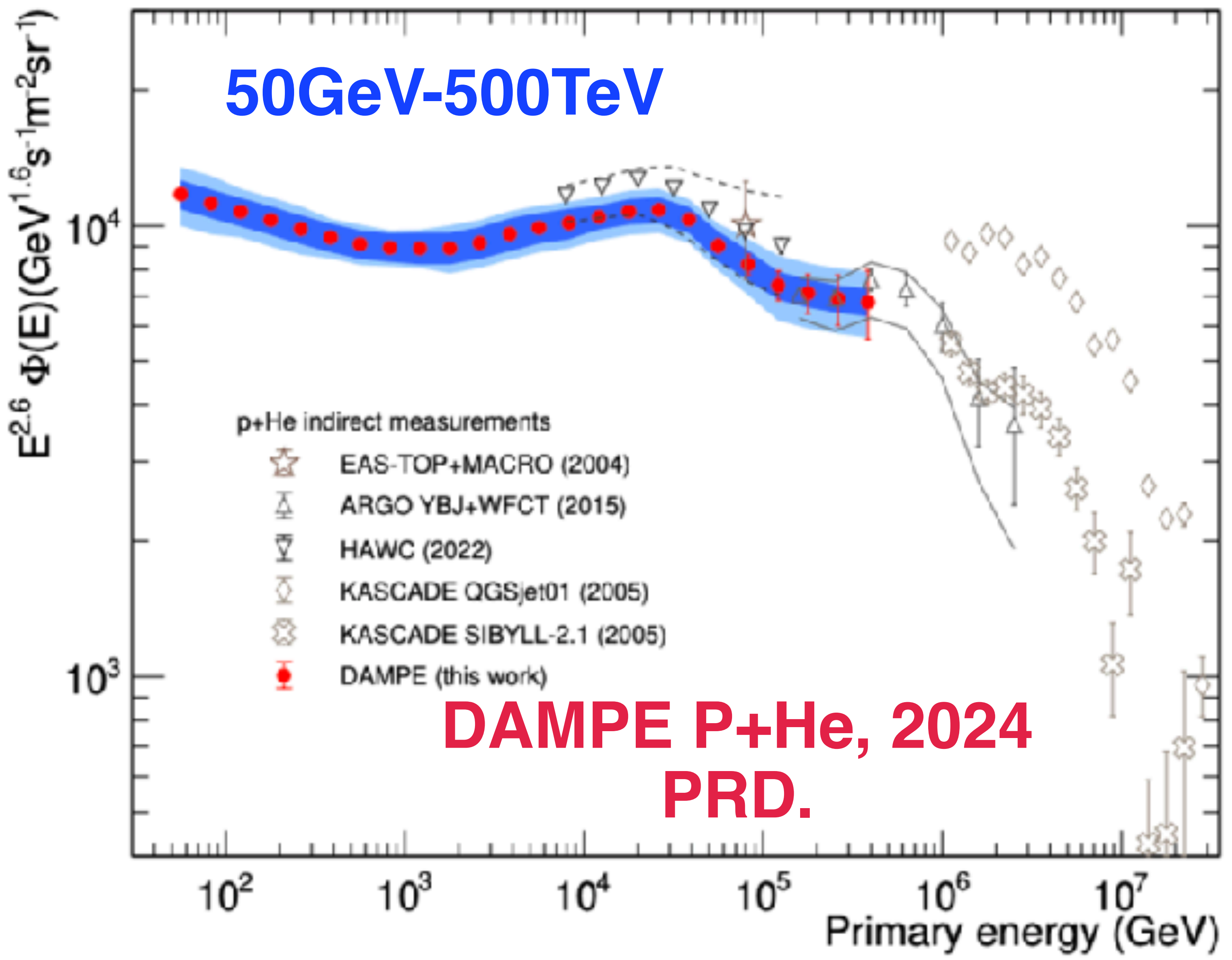




1. **There is a clear softening for proton (~14 TeV) & helium (~34 TeV) with DAMPE, which is also approved by latest measurement from CALET. <u>Noted that NUCLEON claimed to exist a knee at ~10 TV even though there was no strong evidence</u>. (Can we say/state?)**

2. **How about for other species?**

3. **Could space-based experiments reach the PeV region?**



https://link.aps.org/doi/10.1103/PhysRevD.109.L121101

Data selection

Cut 1: BgoE > 100GeV in the first 13 layers or all 14 layers and HET

Cut 2: Rule out the event taking across South Atlantic Anomaly

Cut 3: Nhits>=3 and Chi2Ndof < 5 && Maximum total ADC of track

Cut 4: Selected STK track pass through whole detector [First 13layers and second PSD plane]

Cut 4: $\Delta_{diff} < 200mm$ between BGO and STK track on the PSD

Cut 6: Downward going event E0+E1 < E2+E3

Cut 7: Maximum Eratio in one layer less than 35% of whole energy deposit

The case of standard track

(1)Maximum BGO crystal is not at the edge of each layer for all first 10 BGO layers.

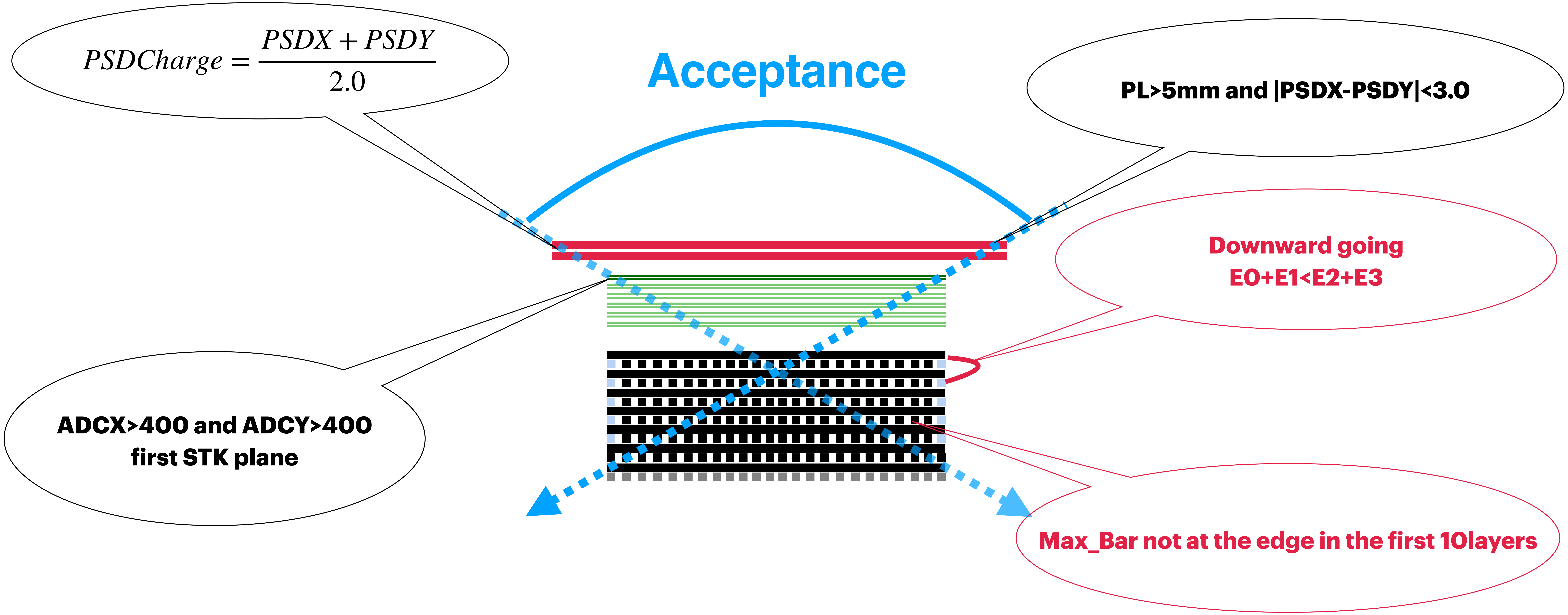
(2) Path-length should be larger than 5 mm within the passed PSD

(3) Difference between charge-x and charge-y should be less than 3.

Charge selection： Mean value of two planes: $5.5 + 0.002 \times \left(lg\frac{E_{GeV}}{10}\right)^{3.5}, 8.9 + 0.01 \times \left(lg\frac{E_{GeV}}{10}\right)^{3.5}$

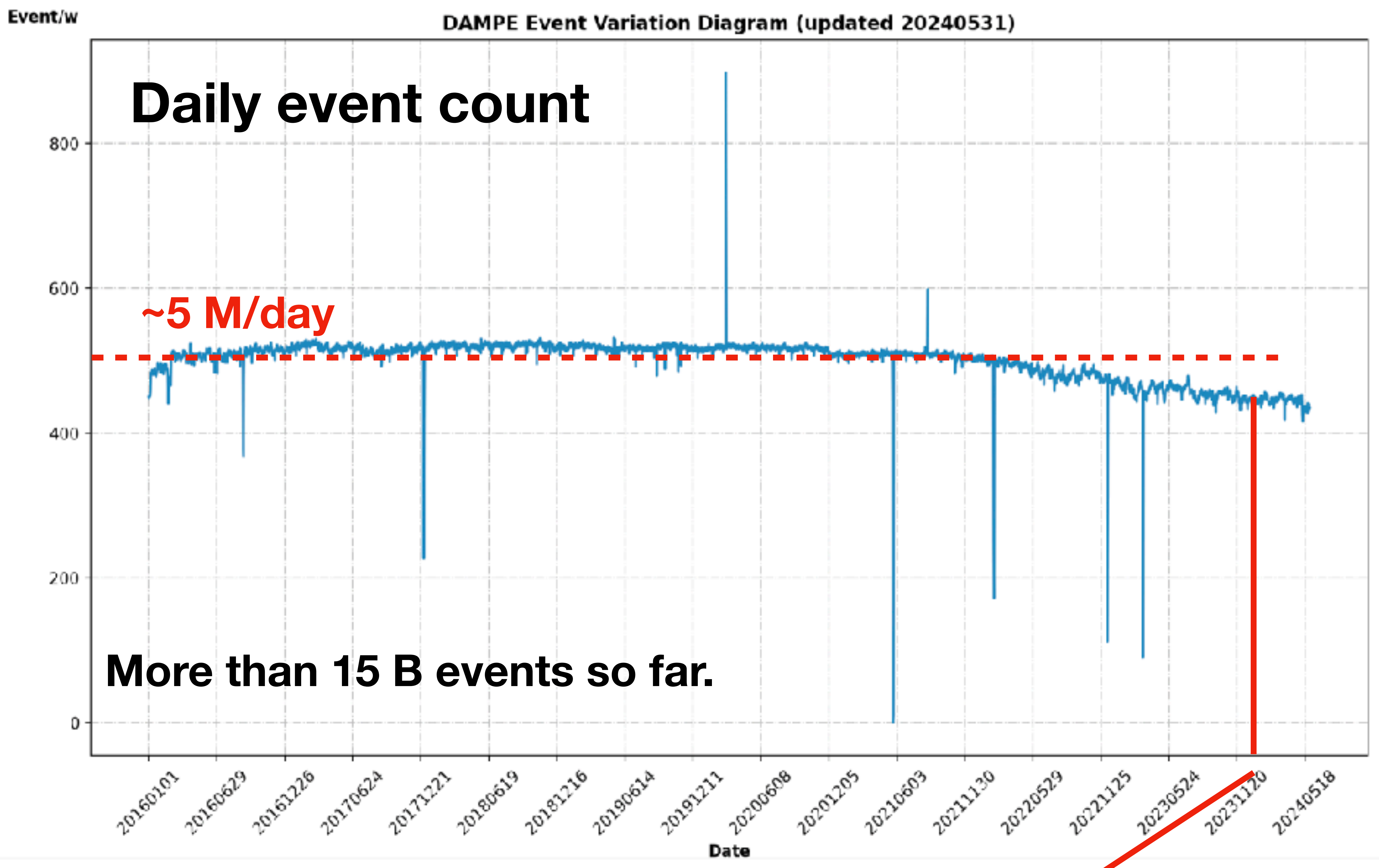
&& Both two clusters in the first STK plane have ADC larger than 400.

Sketch of an event selection



- Geometry: second PSD plane and first 13 BGO layers.
- Areas of PSD and BGO are 408.5mm*408.5mm and 280mm*280mm, respectively.

Data samples in this work

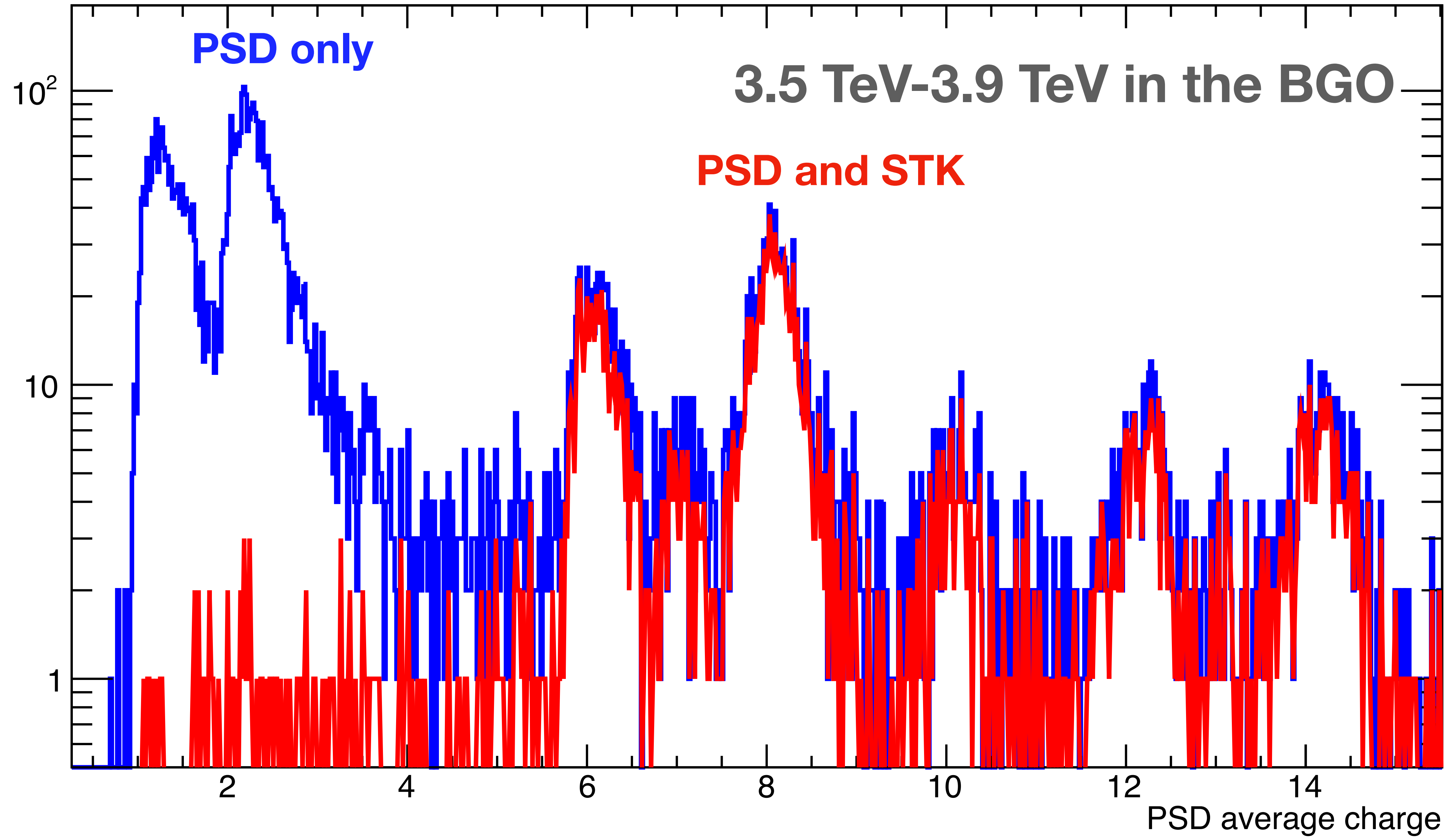


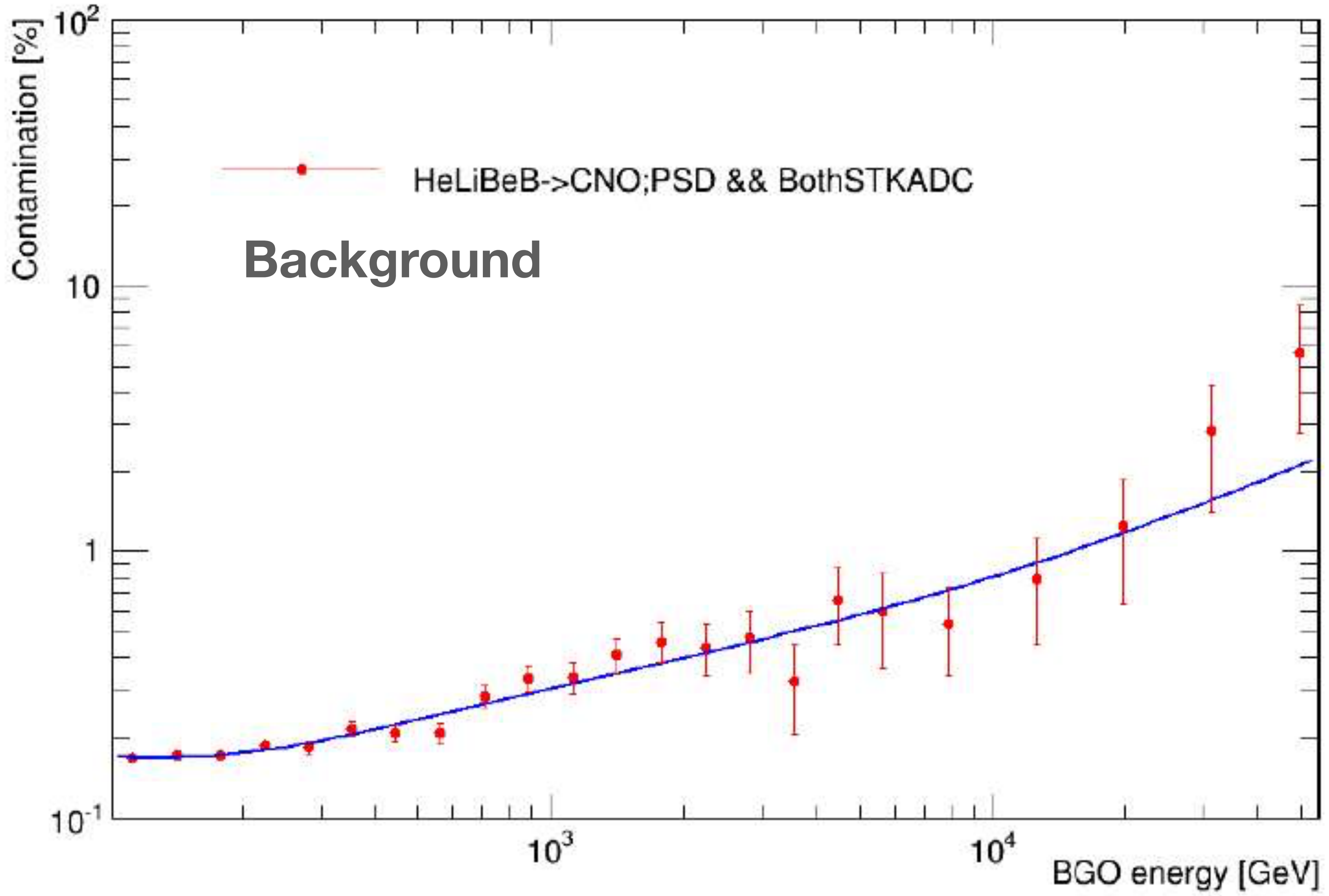
We have used the flight data from Jan.1 2016 to Dec. 31 2023.

1. MC data sets include C12, N14, N15 and O16, maximum energy can be as high as 3 PeV.
2. There are also Li, Be and B MC samples available for background estimation.
3. All MC data sets are available for both Geant4 and Fluka-based geometry, hadronic models used include FTFP_BERT, EPOS_LHC in case of Geant4, DPMJET is used in the latter case.
4. We also have beam test data from CERN taken before launch.

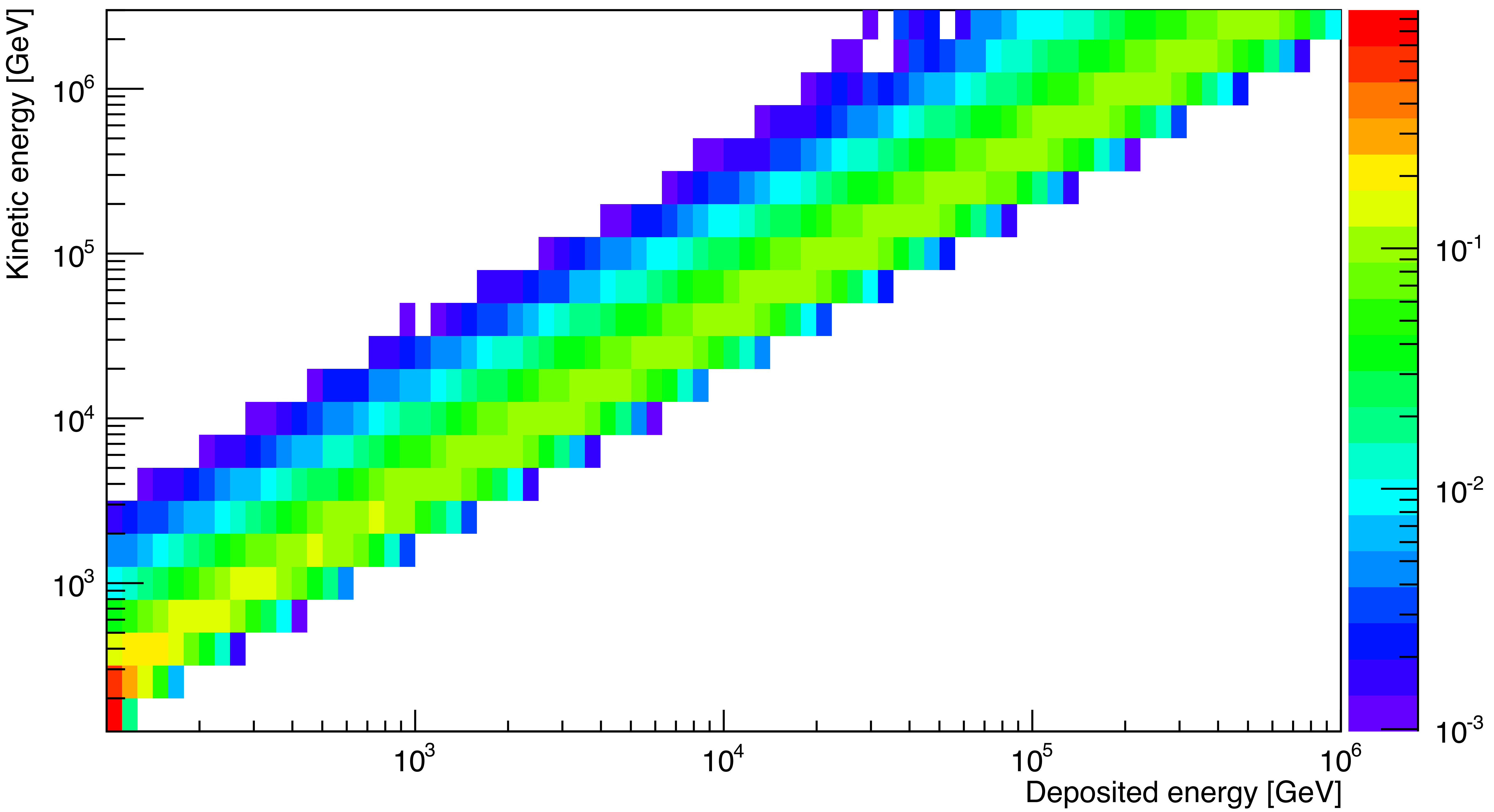
Relative abundance after pre-selection

PSD Charge distribution at 3 TeV inside of the BGO





How we obtain the flux as function of kinetic energy.



- Bayesian unfolding is applied to obtain the primary flux (G. D'Agostini et al. 1995; arXiv:1105.1160)
- Smoothing is applied during iteration to control the statistical fluctuations.
- 1000 times Poisson sampling are used to figure out the uncertainty from unfolding process.

Uncertainties during data processing

✓**Track** $$Eff_{STK\ track} = \frac{N_{STK\ track\ \&\&\ BGO\ track}}{N_{BGO\ track}}$$

✓**Trigger (HET)** $$Eff_{HET} = \frac{N_{HET\ \&\&\ LET}}{N_{LET}}$$

✓**Charge efficiency**

$$Eff_{STKY} = \frac{N_{PSD\ \&\&\ STKX\ \&\&\ STKY}}{N_{PSD\ \&\&\ STKX}}$$

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$$Eff_{PSDX} = \frac{N_{PSDX\ \&\&\ PSDY\ \&\&\ STK}}{N_{PSDY\ \&\&\ STK}}$$

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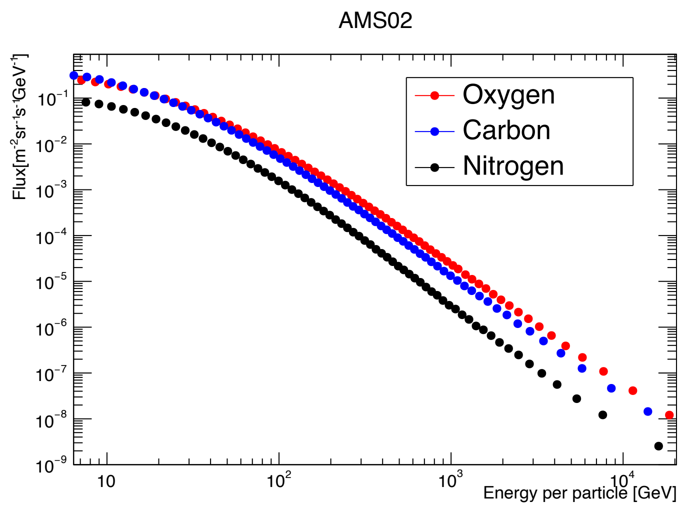
✓**Mixture ratio C:N:O**

A. Template from AMS-02 measurements

B. 1:1:1



✓**Weighting factor[-3.0, -2.3]**

Our MC data is generated with a power law index at -1.

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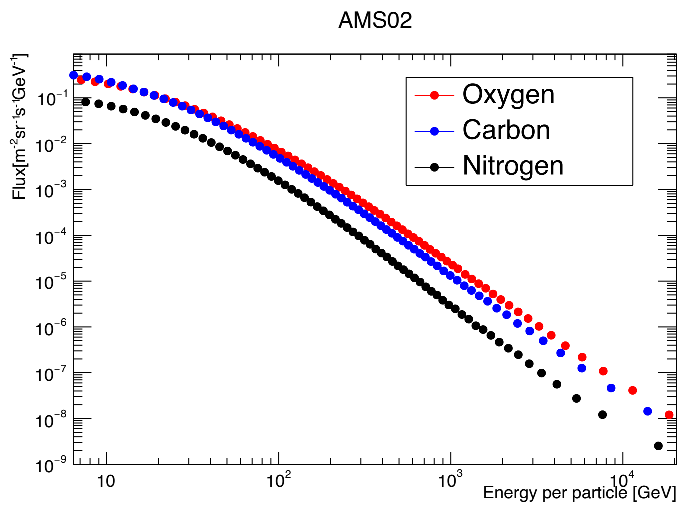

✓**Weighting factor[-3.0, -2.3]**

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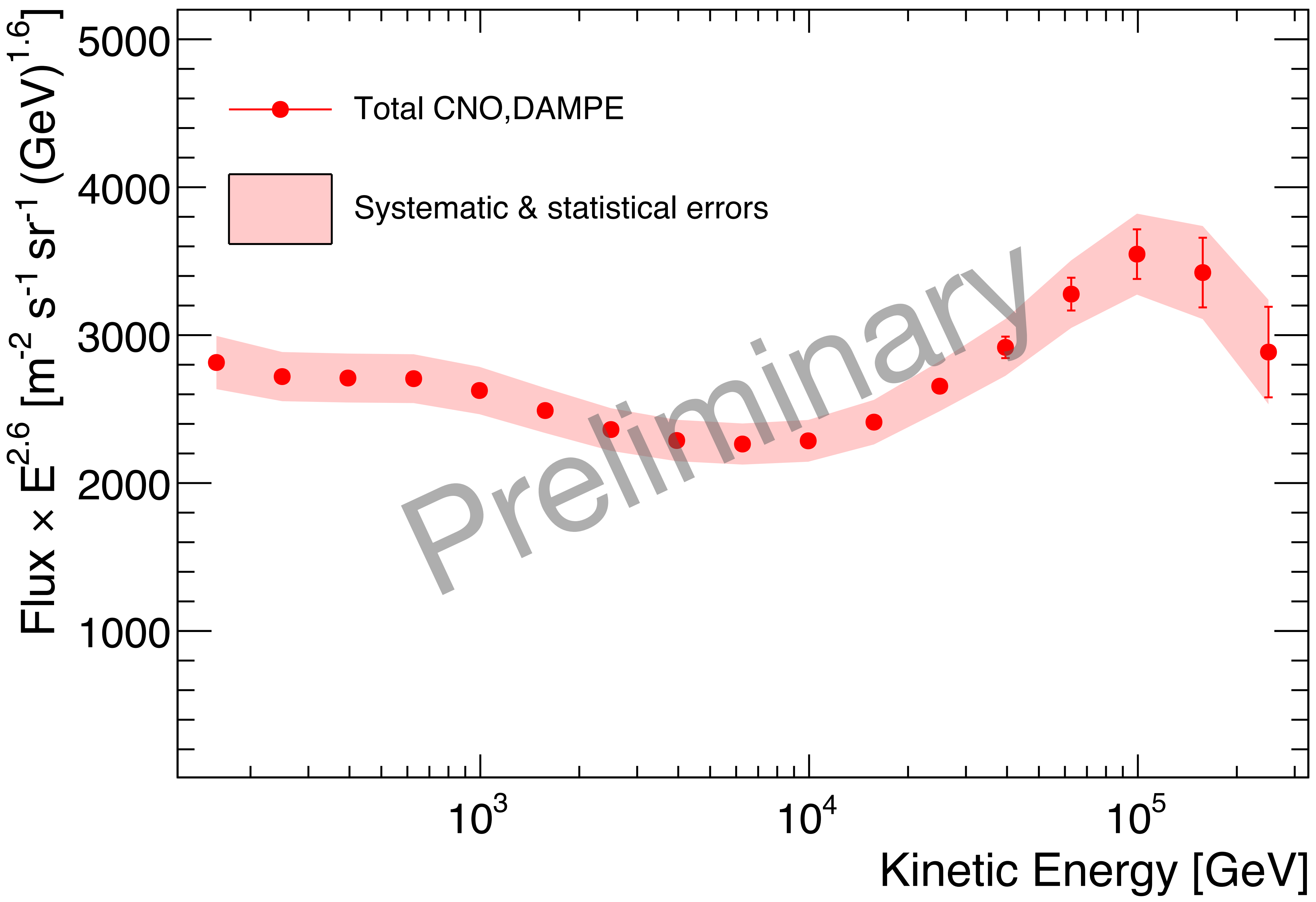
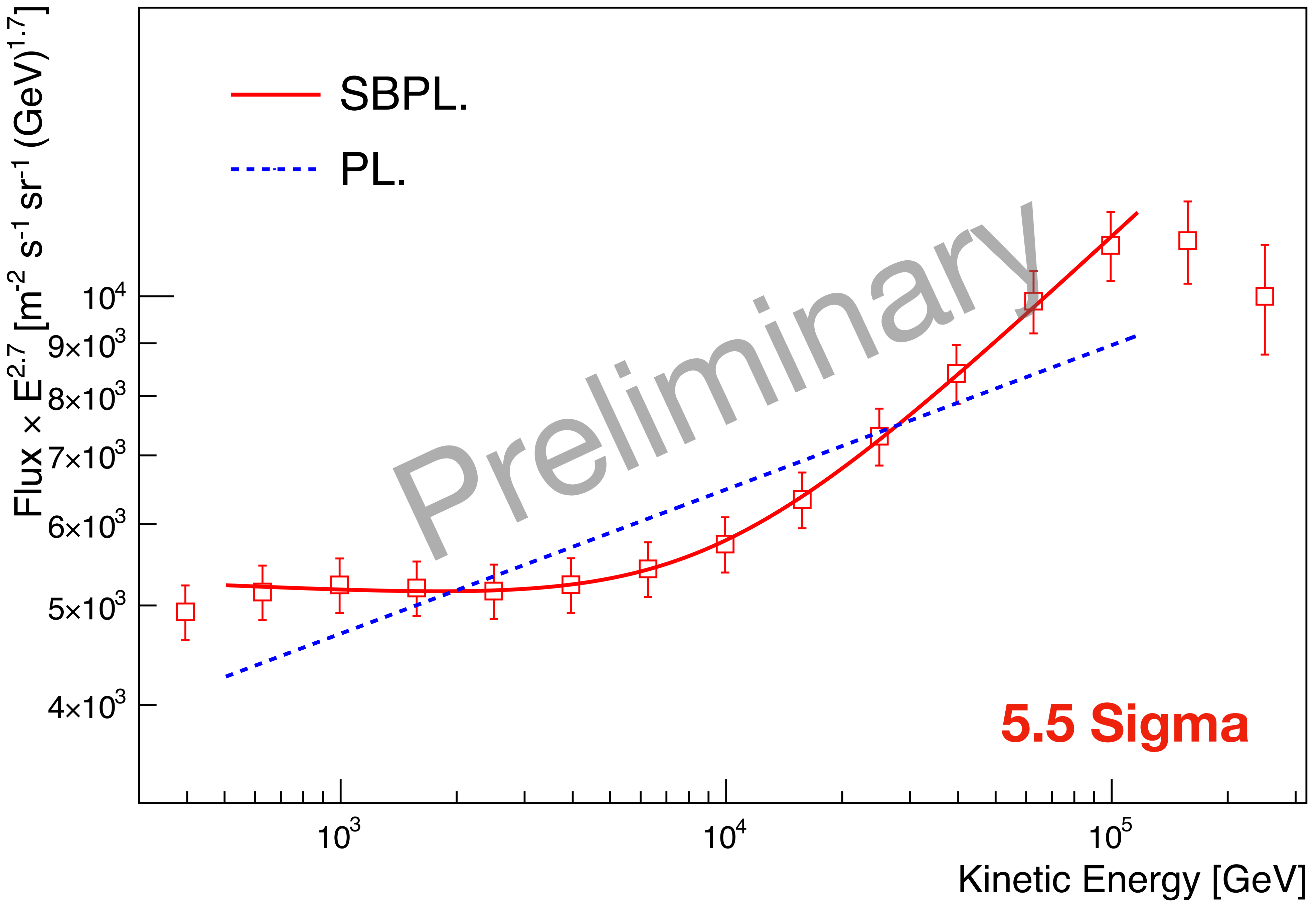
- Total analysis uncertainty is 6.1% over energies by adding all above items together quadratically.

CNO spectrum from 0.1TeV to 316 TeV





$$F = F_0 \times \left(\frac{E}{E_0}\right)^{\gamma_0} \times \left[1 + \left(\frac{E}{E_b}\right)^{\Delta\gamma \times s}\right]^{\frac{1}{s}}$$

Parameters	Hardening
Fit range	[400 GeV-110 TeV]
F_0	4.10e-5 ± 1.37e-6 [$m^2 s^{-1} sr^{-1} GeV^{-1}$]
γ_0	−2.72 ± 0.08
E_b	9.18 TeV ± 4.89 TeV
$\Delta\gamma$	0.37 ± 0.05
s	5 (fixed)

We also conducted other data processing for this measurement, all results show great consistence within this shaded band here.

Summary

- Thanks to the large acceptance and long-term smooth operation of DAMPE, we can measure the CNO combined spectrum more than 100TeV.

- Hardening at ~9 TeV with 5.5 sigma of CL. is observed in this work, which confirms again the hardening break reported by previous measurements.

- Our data shows the softening hint around 100 TeV, which will be studied in more detail in the near future.

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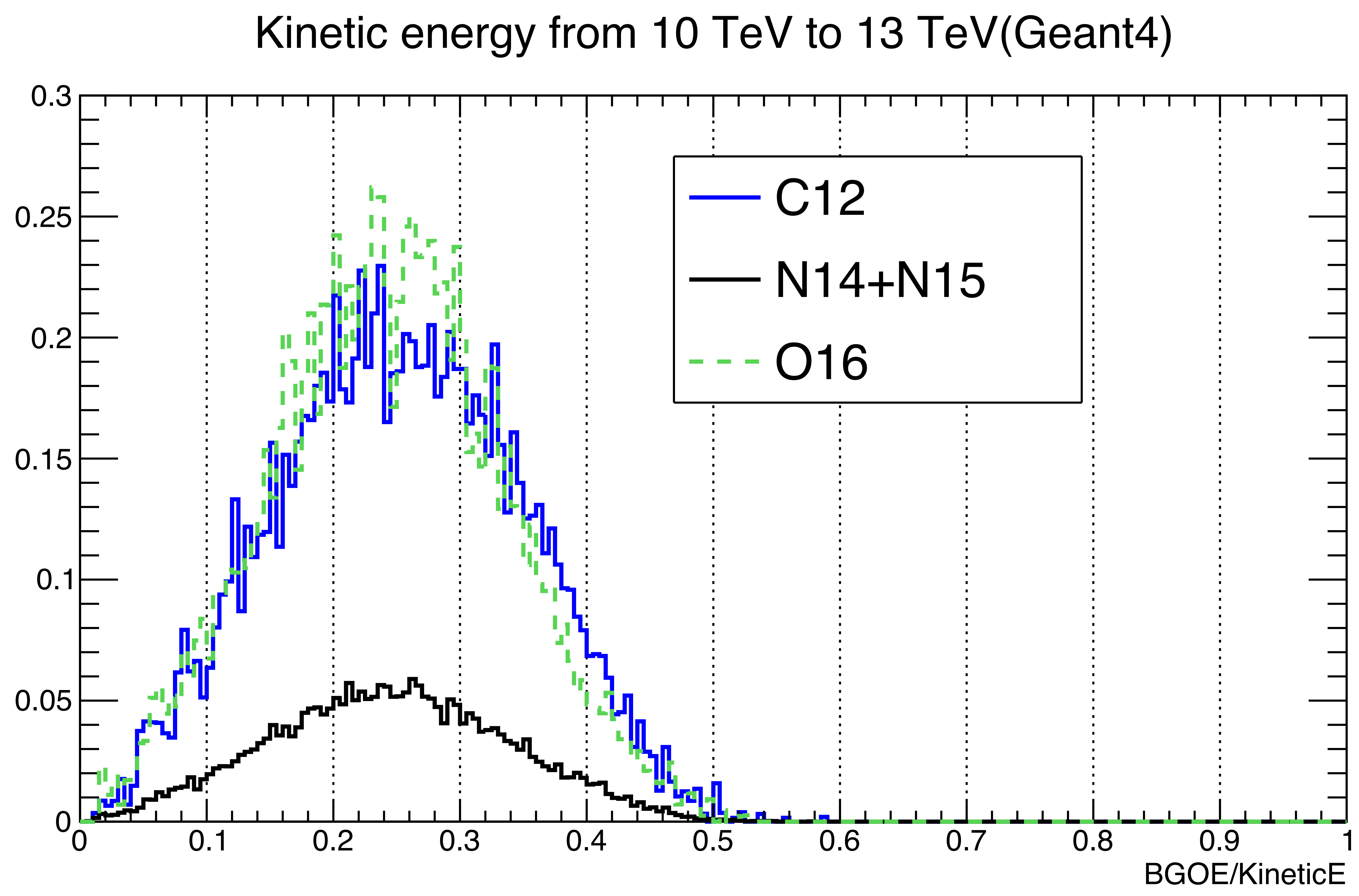
Thank you

Backup



- Those three nuclei have similar response in the BGO colorimeter.