中国科学技术大学
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Analysis of secondary cosmic lithium、beryllium and boron with the DAMPE mission

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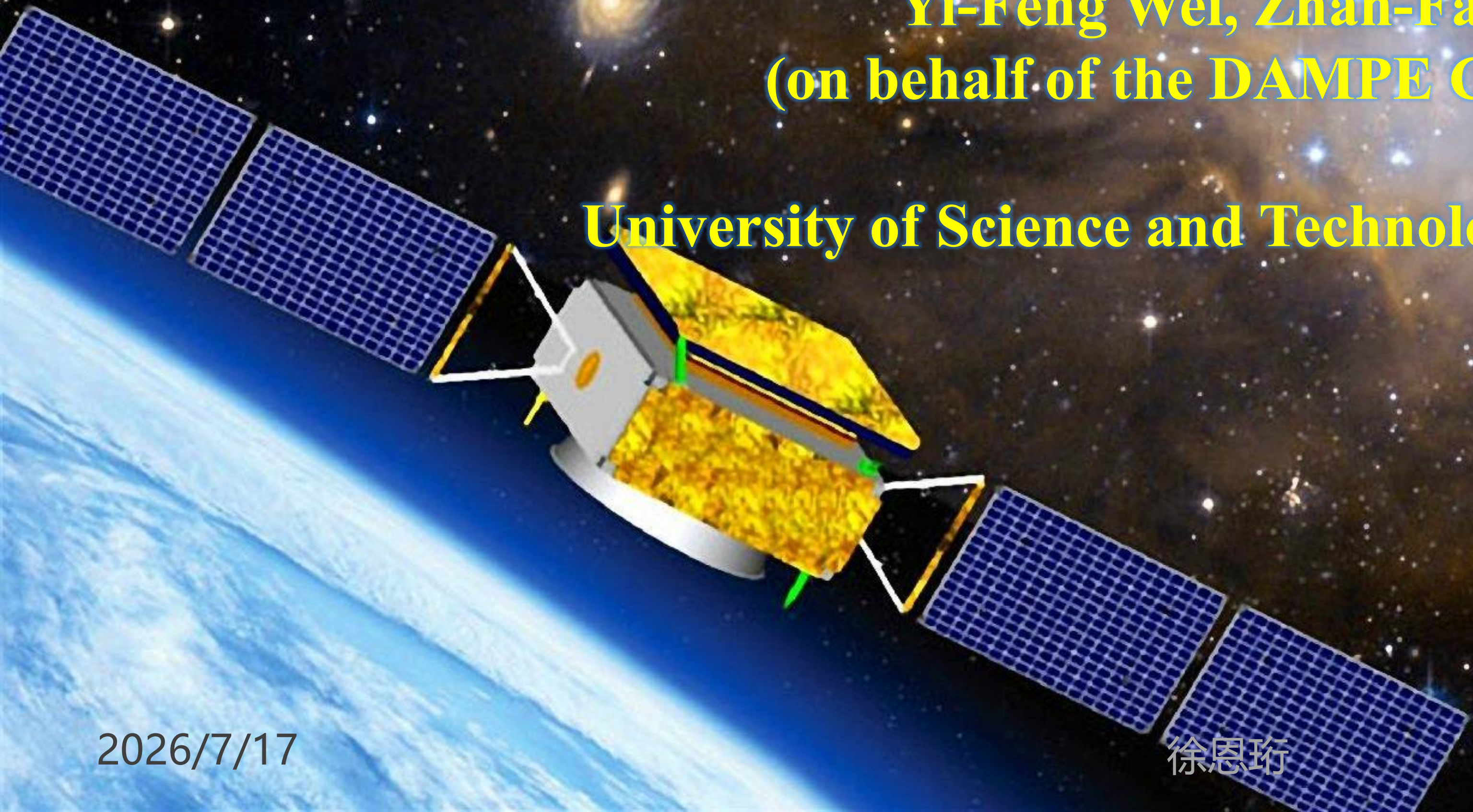
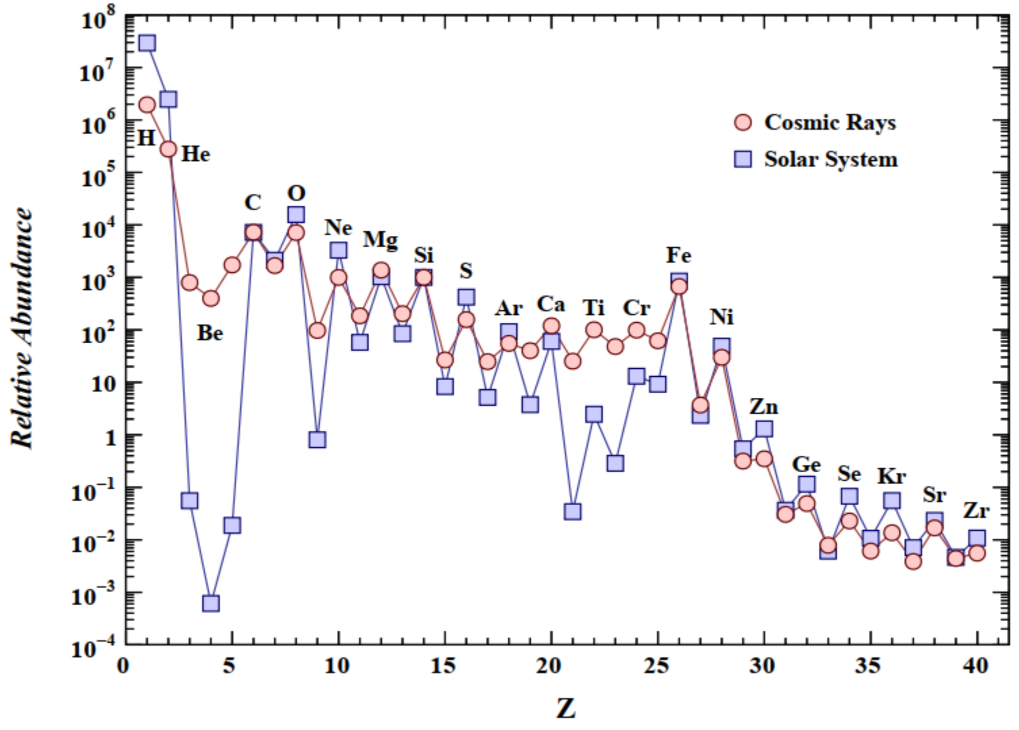
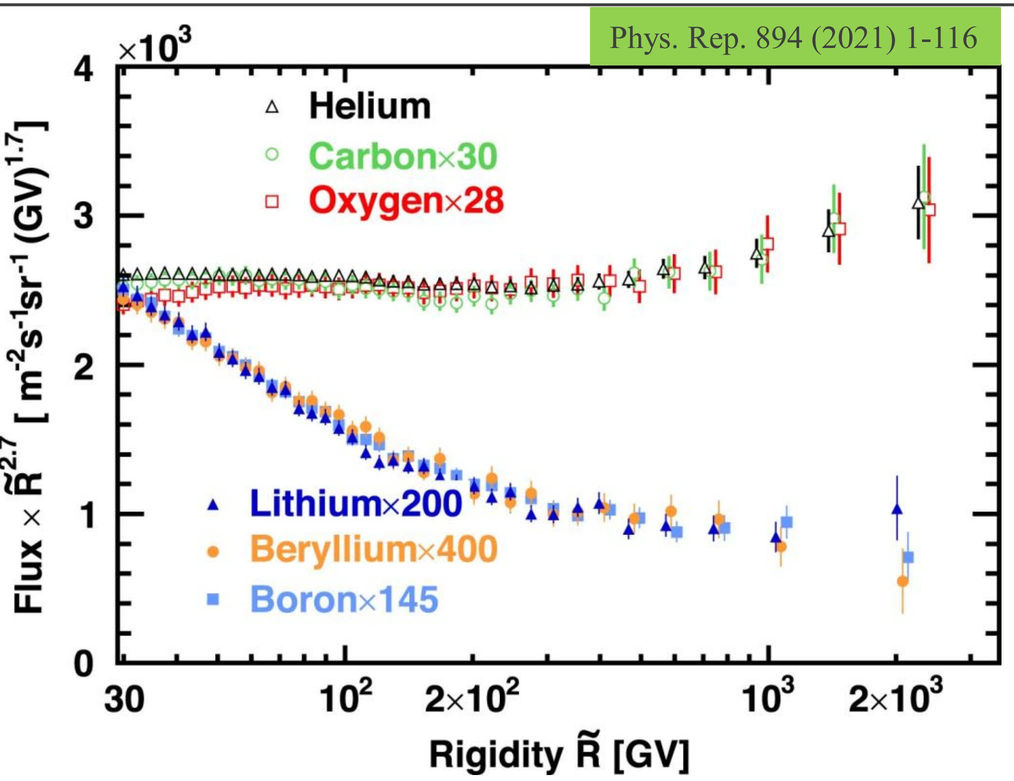


Motivation





Li, Be and B:

● Lithium, Beryllium and Boron (**secondaries**) are not produced in main stellar nucleosynthesis reactions

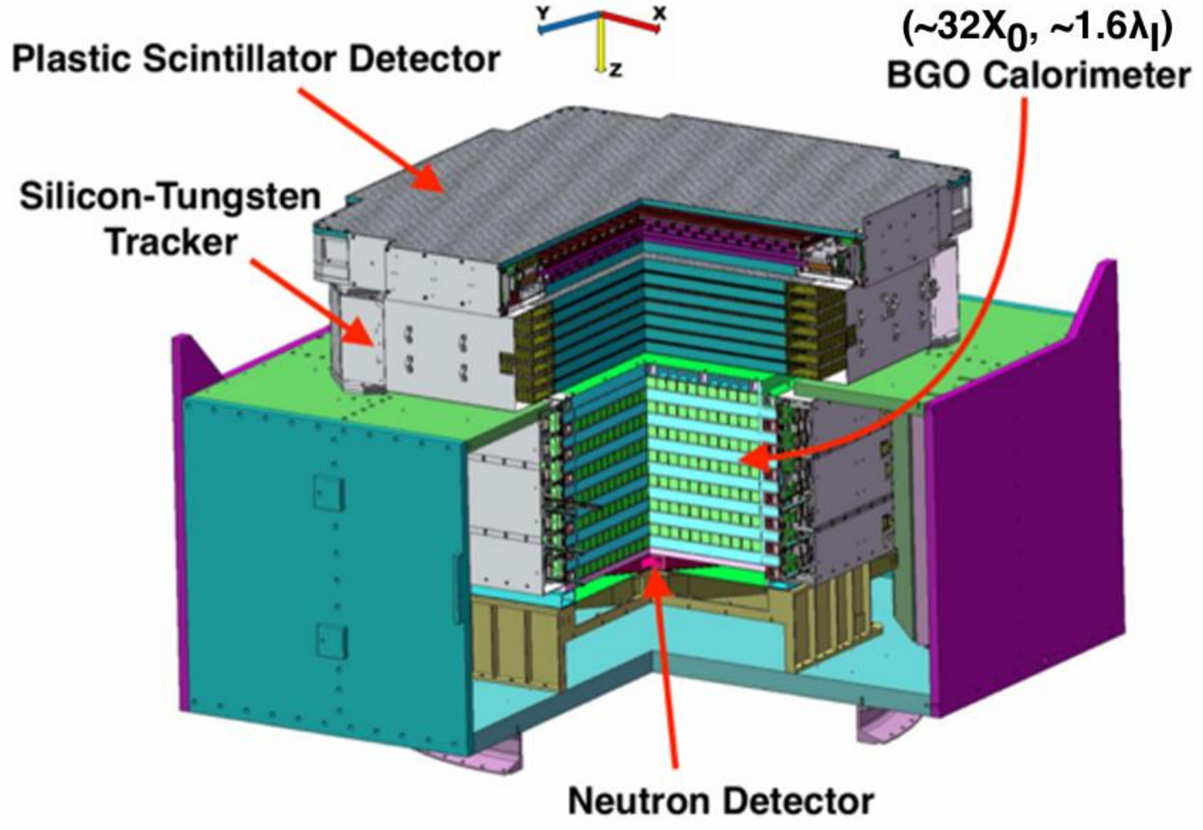
● Production: **cosmic ray spallation** with the ISM Mainly from C, O (**primaries**)

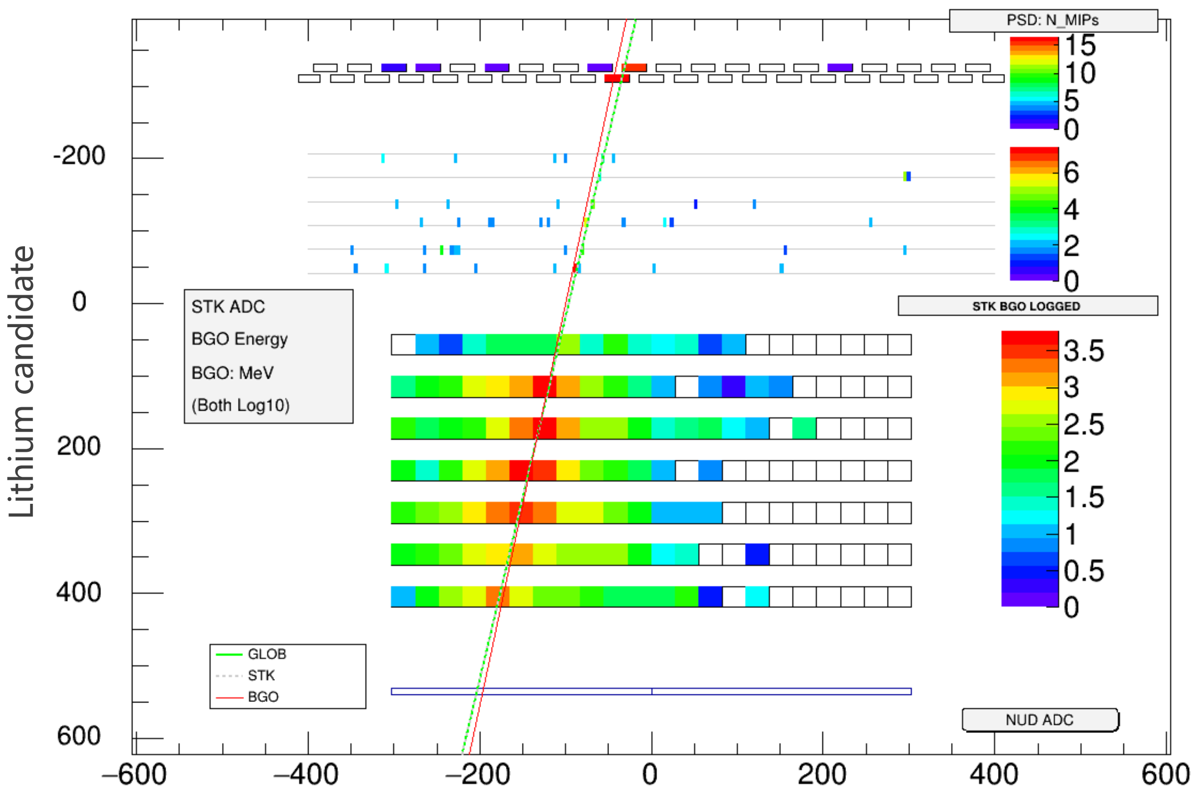
CR propagation:

● Measuring the flux of secondaries can offer insight into:

- ○ Mechanisms of CR propagation
- ○ Origin of structures in the CR nuclei spectra

Events Selection

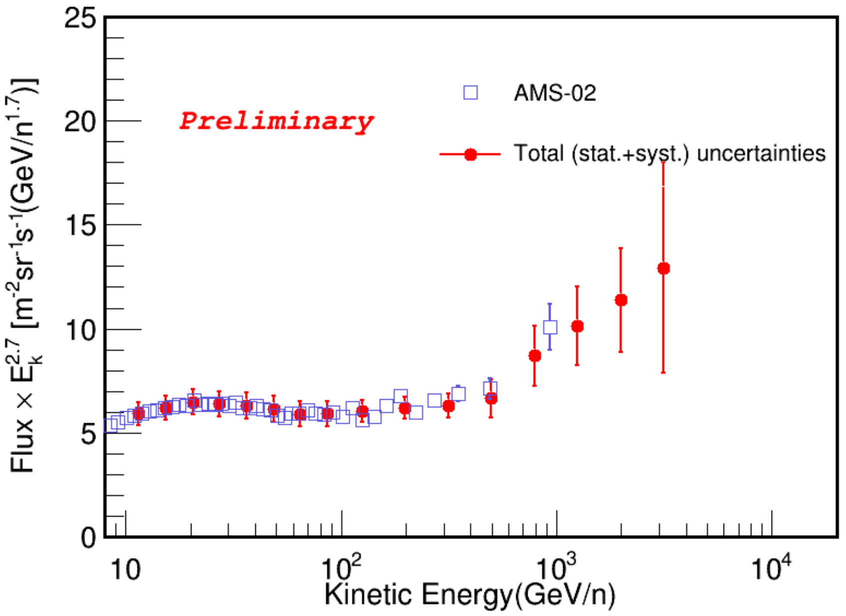




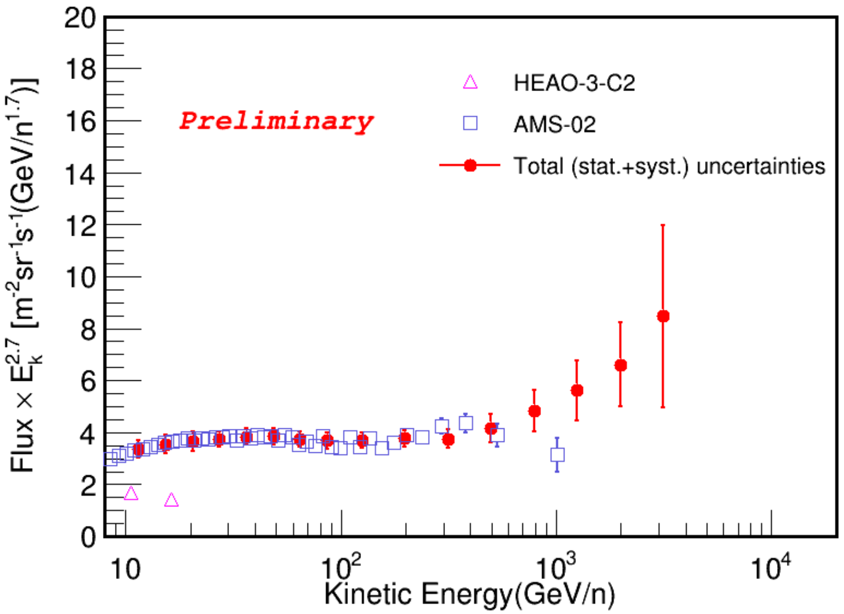
PSD : Charges measurement
STK : Particle tracker & additional charge measurement
BGO: Energy measurement

Li and Be flux

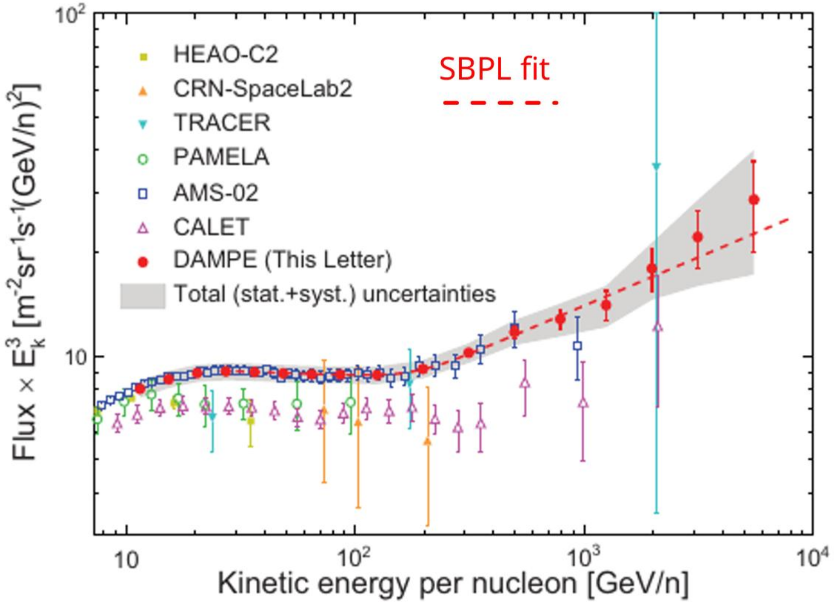
Lithium flux



Beryllium flux



Boron flux

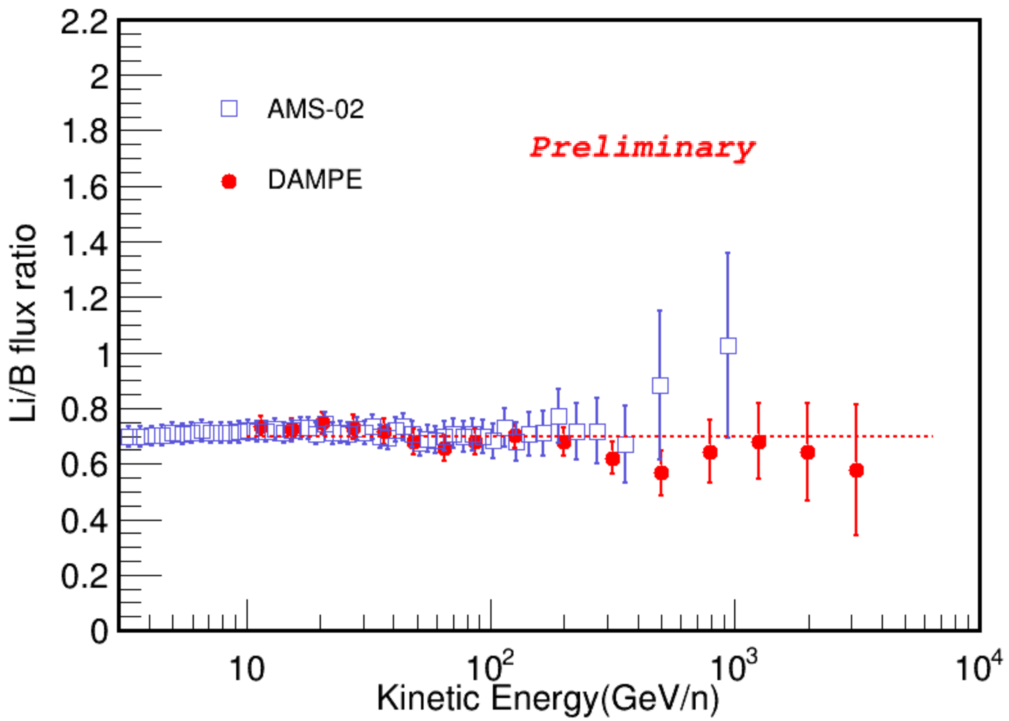


Physical Review Letters, 134 (2025), 191001

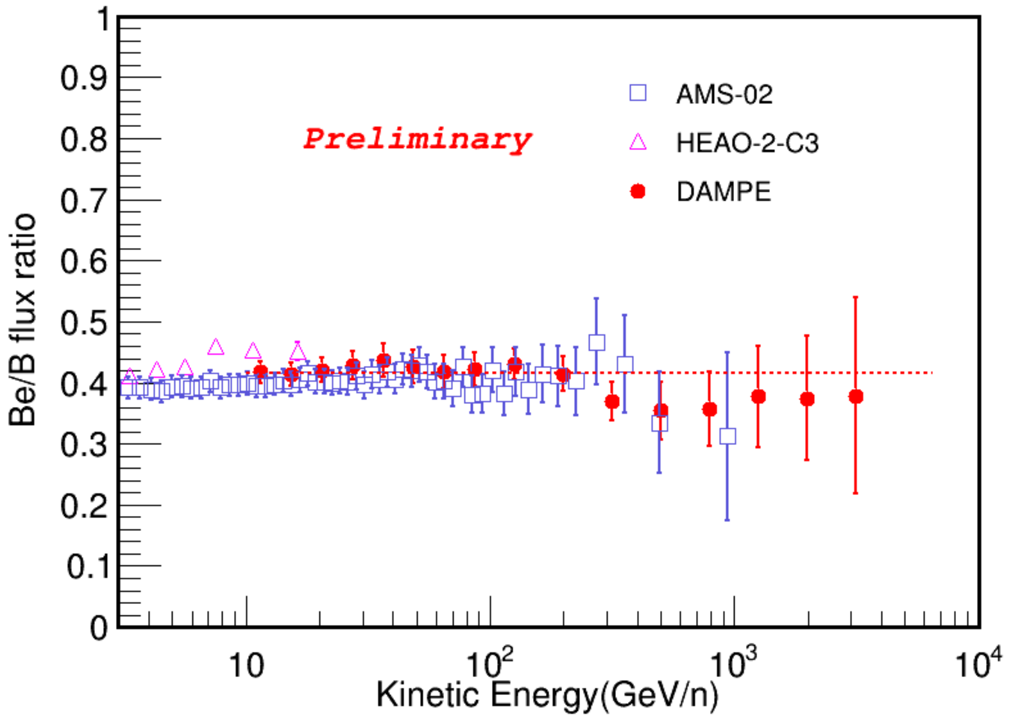
- Preliminary measurement of Li and Be from 10 GeV/n to 4.1 TeV/n

Secondary Flux ratio

Li / B



Be / B



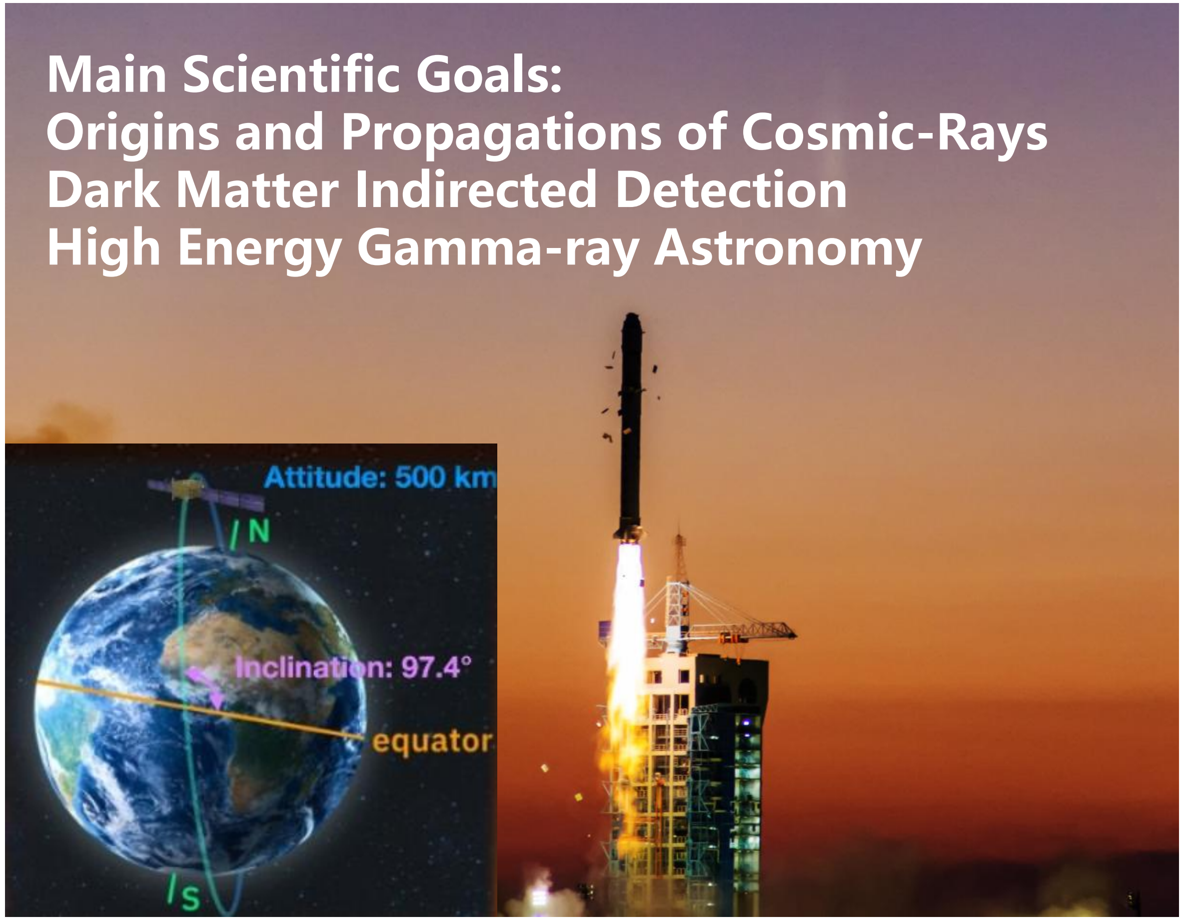
- **Preliminary measurement of Li/B and Be/B from 10 GeV/n to 4.1 TeV/n**

Thank you

Backup

DAMPE: The DArk Matter Particle Explorer

The mission



DAMPE is a space-borne high energy particle detector launched in Dec. 2015 from the Jiuquan Satellite Launch Center

International collaboration:

China

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

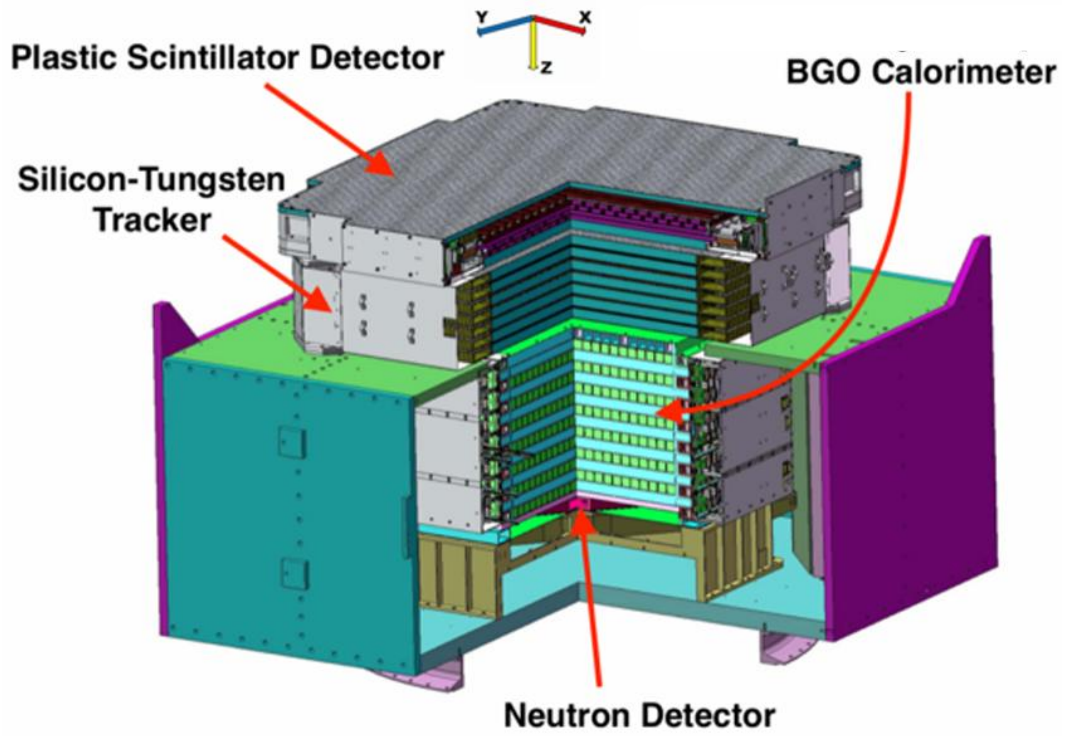
Italy

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

Switzerland

- University of Geneva

DAMPE: Detector system



Parameter	Value
Energy range (e/γ)	5 GeV to 10 TeV
Energy resolution (e/γ)	1.5% at 800 GeV
Energy range (p/ion)	20 GeV to 500 TeV
Energy resolution (p)	40% at 800 GeV
Geometric factor (e)	0.3 m^2 sr above 30GeV
Angular resolution (γ)	0.1 degree at 100 GeV
Field of view	1.0 sr

PSD: Anti-coincidence detector for gammas and charges measurement
STK: Particle tracker, photon converter & additional charge measurement
BGO: Energy measurement & particle identification via shower topology
NUD: Further particle ID from electromagnetic & hadronic showers

Astropart.Phys 95 (2017) 6–24

FLUX Measurements

Flux in *i*-th incident energy bin:

$$\phi(\mathrm{E}_i, \mathrm{E}_i + \Delta\mathrm{E}_i) = \frac{\Delta\mathrm{N}_{\mathrm{obs}}(\mathrm{E}_i, \mathrm{E}_i + \Delta\mathrm{E}_i)}{\Delta\mathrm{E}_i\ \mathrm{A}_{\mathrm{eff},i}\ \Delta\mathrm{T}_{\mathrm{exp}}}$$

Φ = Absolute differential flux ($\mathrm{m}^{-2}\mathrm{sr}^{-1}\mathrm{GeV}^{-1}\mathrm{s}^{-1}$)

$\mathrm{N}_{\mathrm{obs}}$ = Number of observed events

$\mathrm{A}_{\mathrm{eff}}$ = Effective acceptance ($\mathrm{m}^2\mathrm{sr}$)

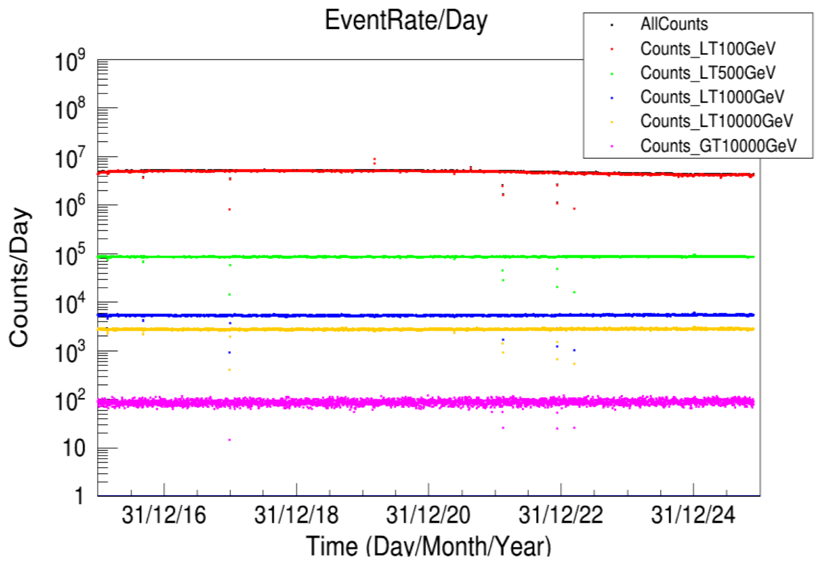
$\Delta\mathrm{T}_{\mathrm{exp}}$ = Exposure time (s)

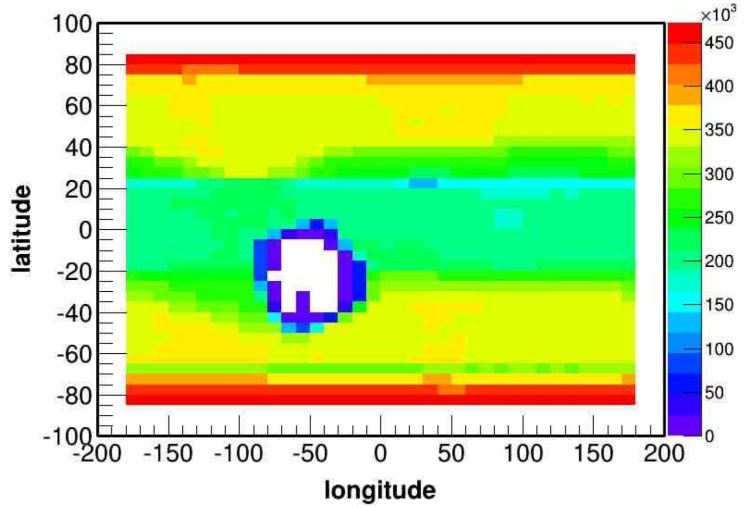
$\Delta\mathrm{E}_i$ = Energy bin

DAMPE data sample

Flight Data:

- 96 months
- Exposure time ~1.96×10^8 seconds
- Data in **South Atlantic Anomaly** region are excluded
- Data during Sep.2017 Solar Flare (20170908-20170913) are excluded





Simulation Data:

The MC samples are generated with:

- Geant4 CRMC_FTFP_BERT, version 10.5.1 (EPOSLHC/ FLUKA)

Selection Cuts

Analysis Selection

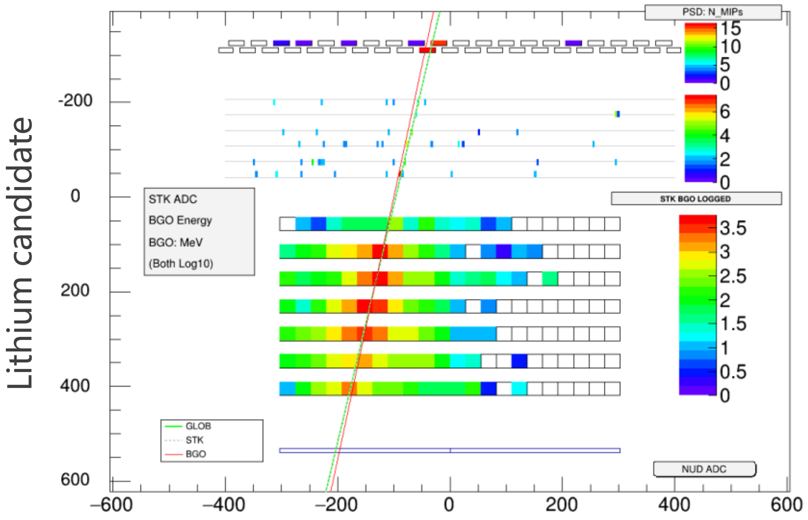
- Energy deposited in BGO: $E_{BGO} > 20$ **GeV**
- **High Energy Trigger** (HET) activation

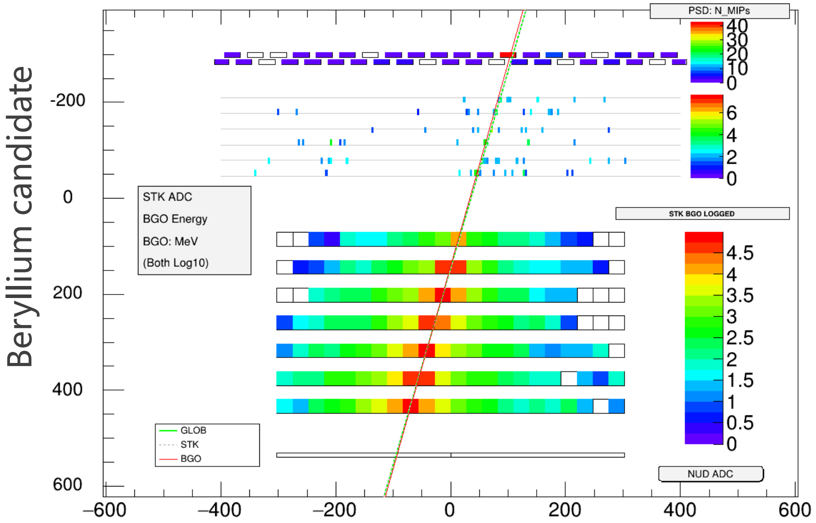
Trajectory Selection

- STK track reconstructed with the **Kalman filter** algorithm
- STK signal matches BGO and PSD.

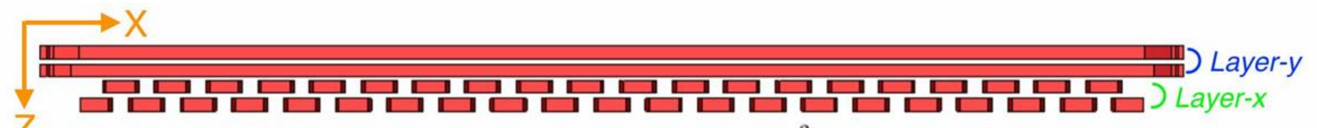
Fiducial Selection

- **Fiducial containment** of track direction in the whole detector





Charge selection

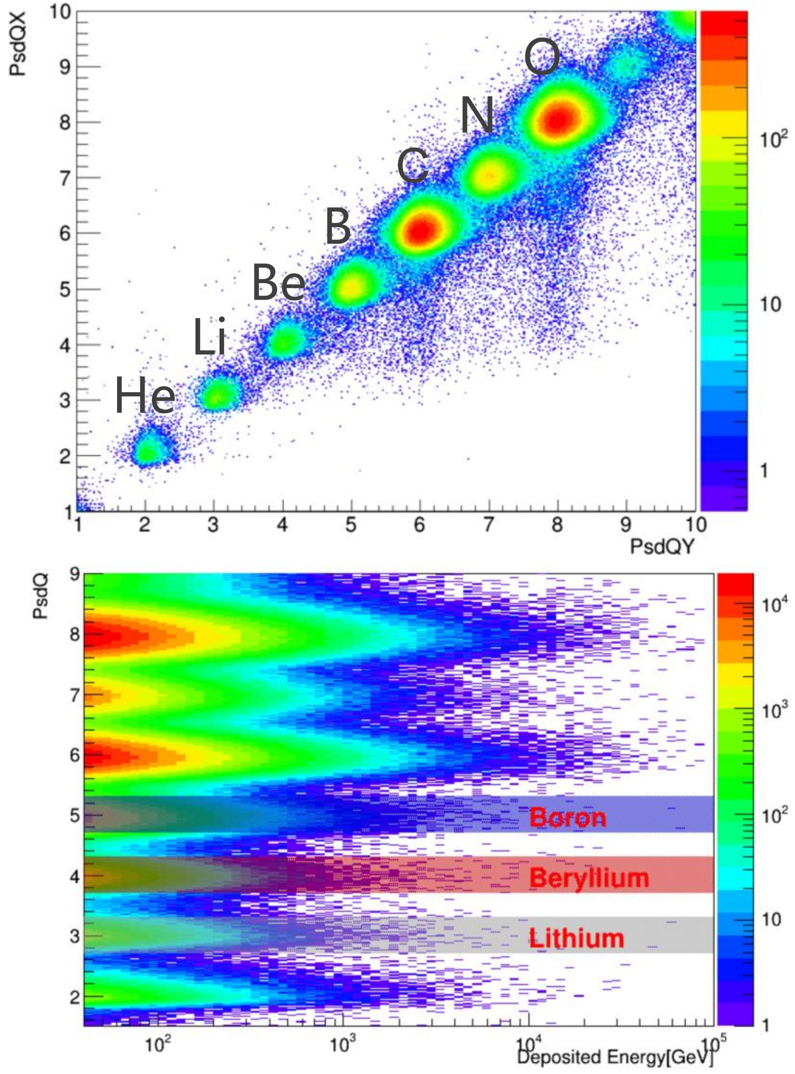


Bethe-Bloch $-\left\langle \frac{dE}{dx} \right\rangle = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e c^2 \beta^2}{I \cdot (1-\beta^2)}\right) - \beta^2\right]$

Progressing PSD charge selection:

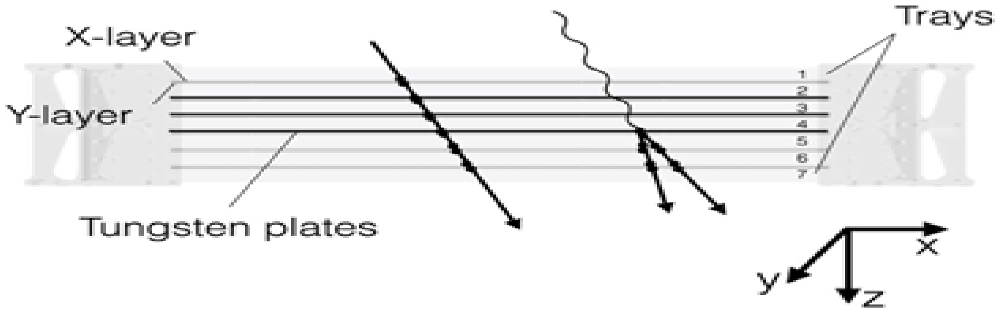
$$Q^{PSD} = \frac{\sum_i Q_i^{PSD}}{N_{Layers}}$$

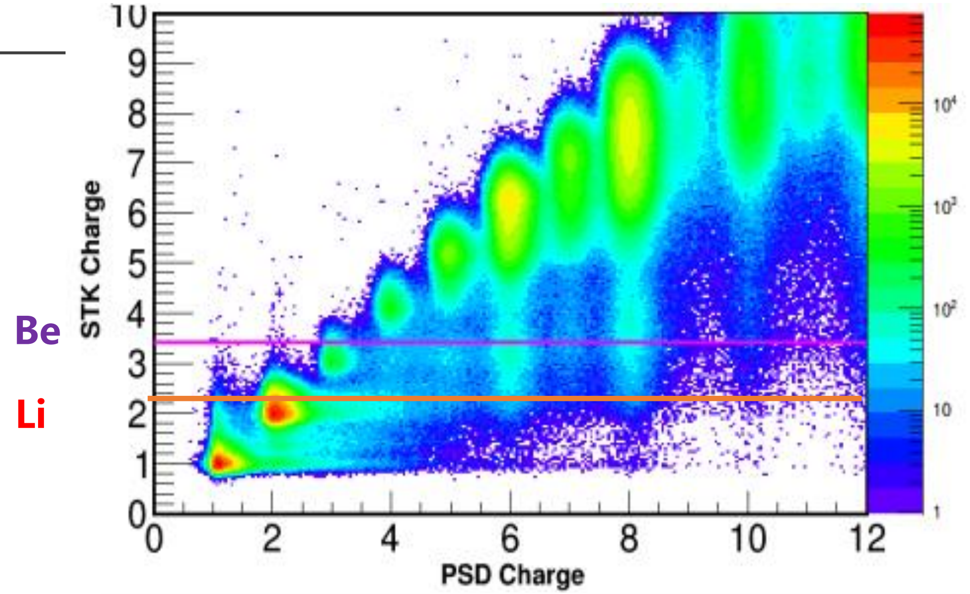
i = index of consecutive layer with charge



A good energy-independence

Charge selection

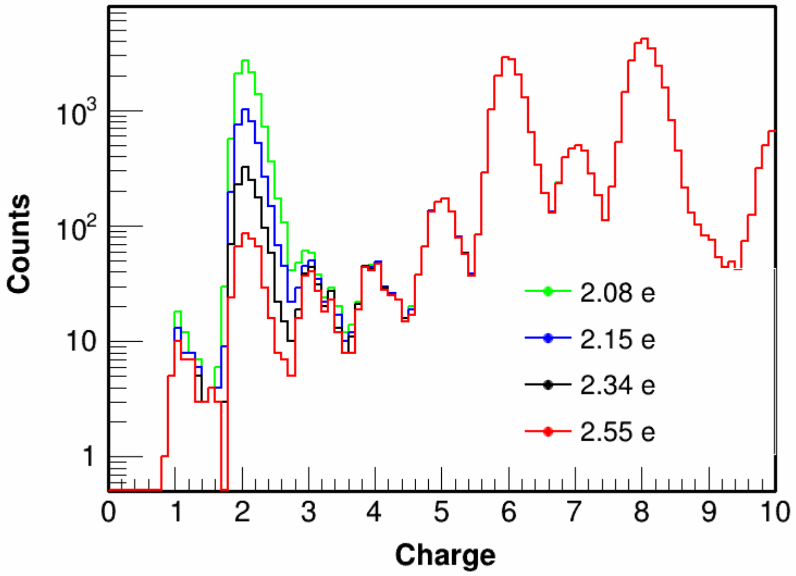




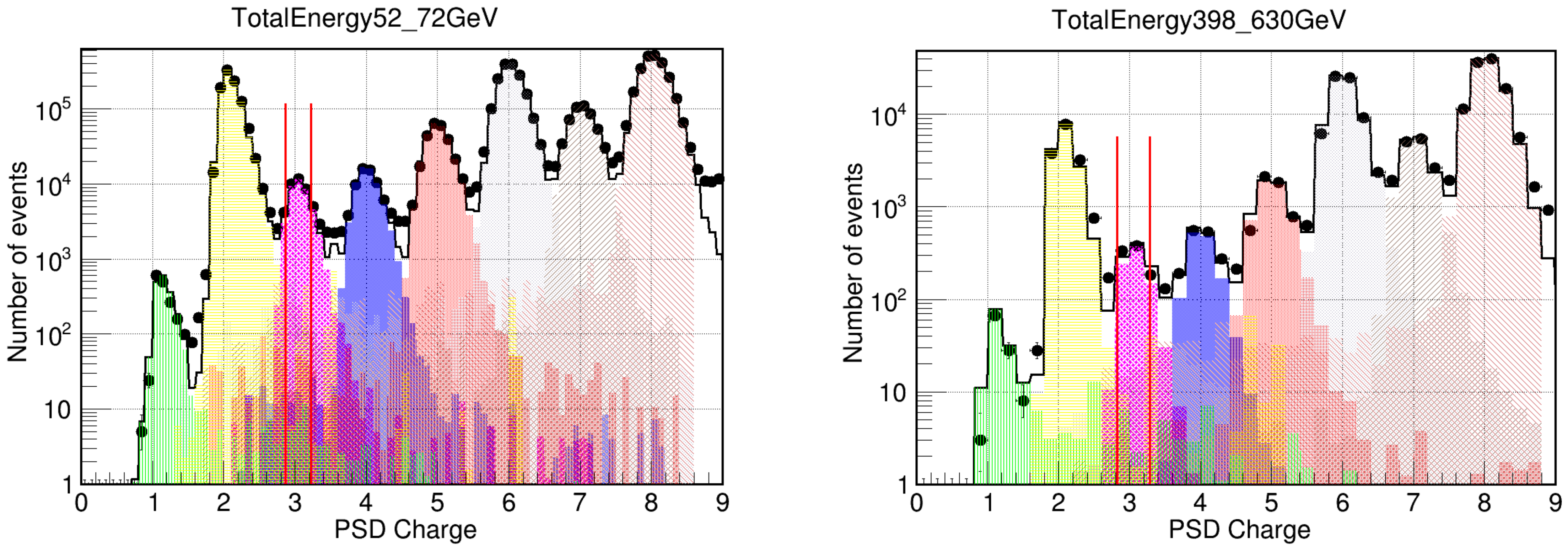
Contamination Reduction:

- Use the charge deposit in first STK plane to reduce p, He contamination.
- STK charge > 4.1 e for boron 2.1e for lithium 3.0e for berylliur 2.1e for lithium.

$$\text{STK ADC} = \frac{Adc_{x0} + Adc_{Y0}}{isX0 + isY0} > 2.1\ (3.0)e$$



Template fits



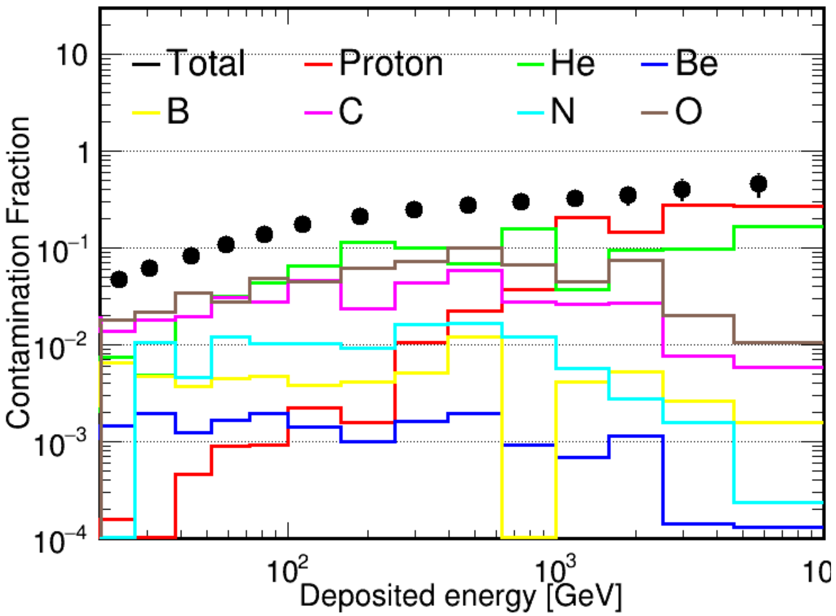
The σ define an energy–dependent PSD charge selection window.

The chosen signal windows are Q_{Li}^{PSD} = (3-2.0 · σ, 3+2.5 · σ)

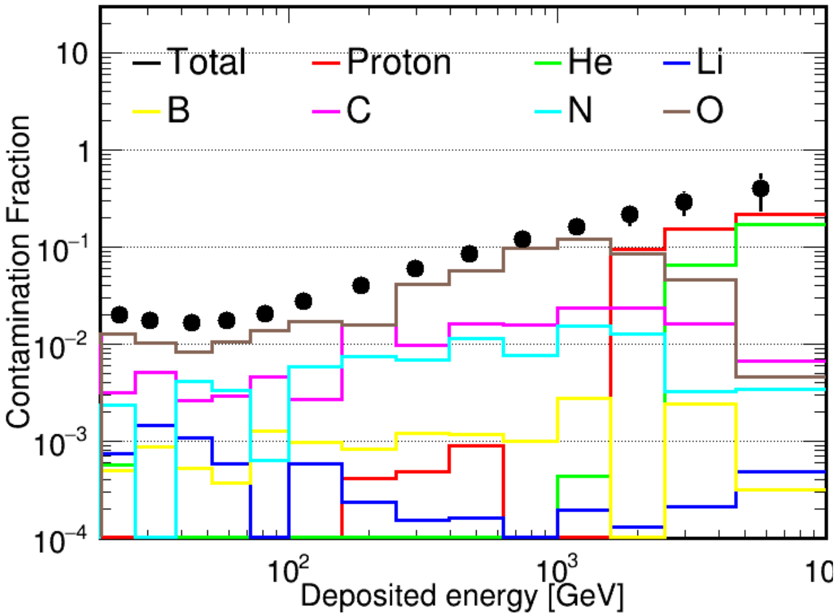
Q_{Be}^{PSD} = (4-2.0 · σ, 3+2.5 · σ)

Template fits

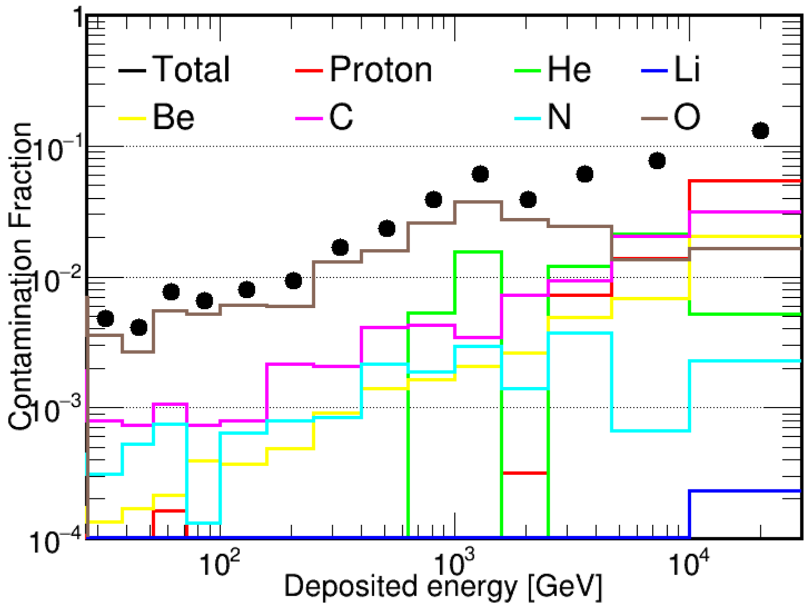
Lithium



Beryllium



Boron



Total background for lithium and beryllium analysis shown as a stack of the various components. For the lithium and beryllium sample selection, the background is well about 40%.

Unfolding and Acceptance

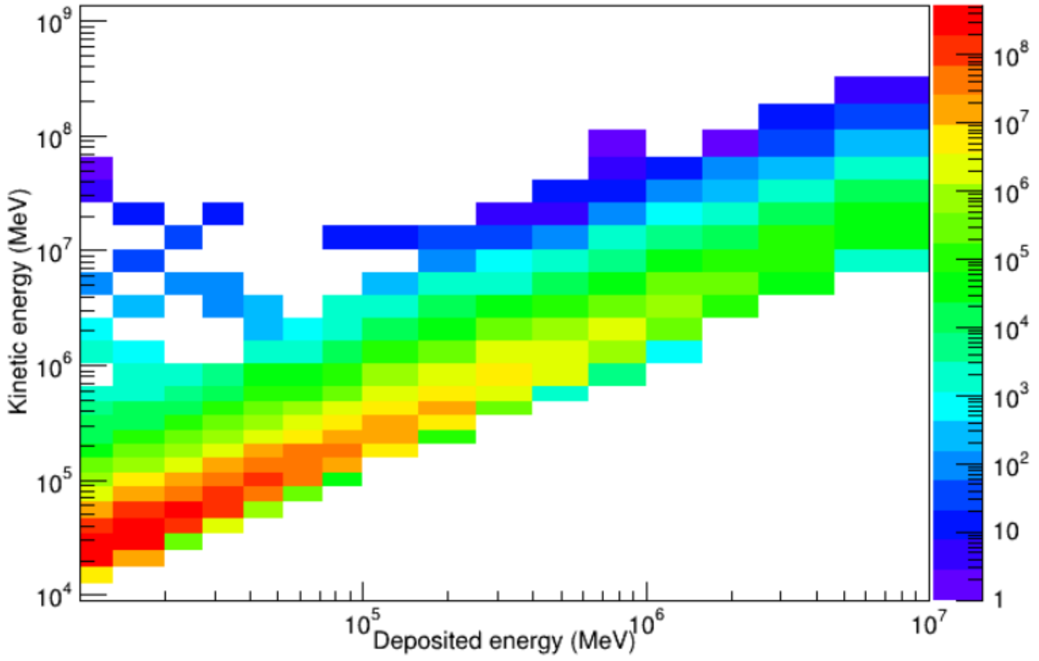
Bayesian unfolding BGO energy to kinetic energy

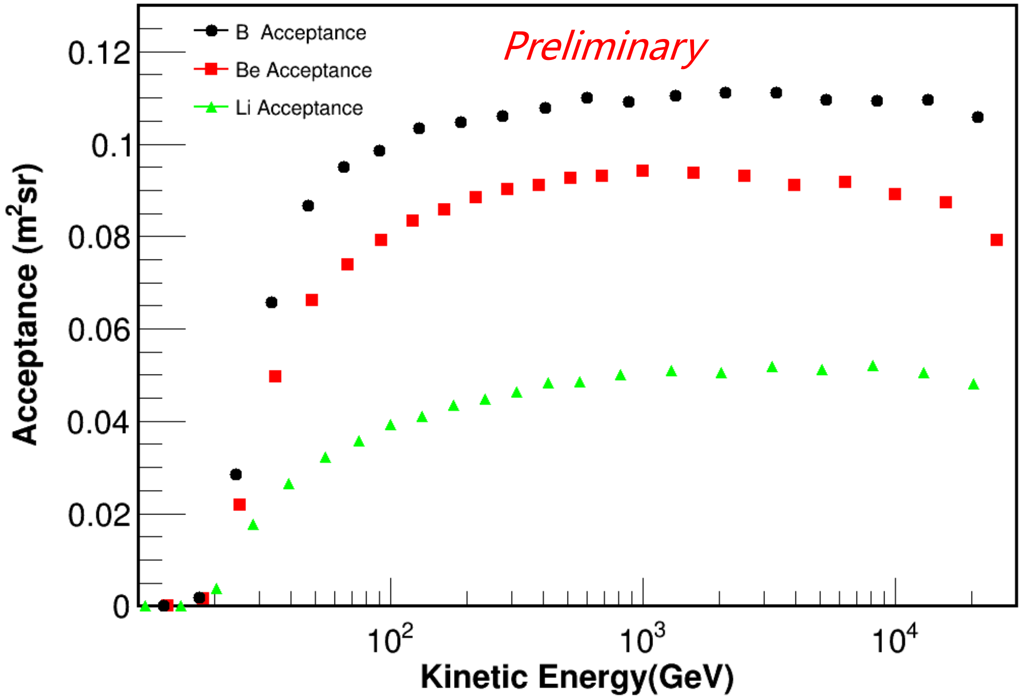
$$P(E_{true,j}|E_{meas,i}) = \frac{P(E_{meas,i}|E_{true,j})P(E_{true,j})}{\sum_k P(E_{meas,i}|E_{true,k})P(E_{true,k})}$$

$$A_i = G_{gen}\frac{N_{sel}(E_T^i)}{N_{gen}(E_T^i)}$$

Be7 : Be9 : B10=5.4 : 4.3 : 0.3

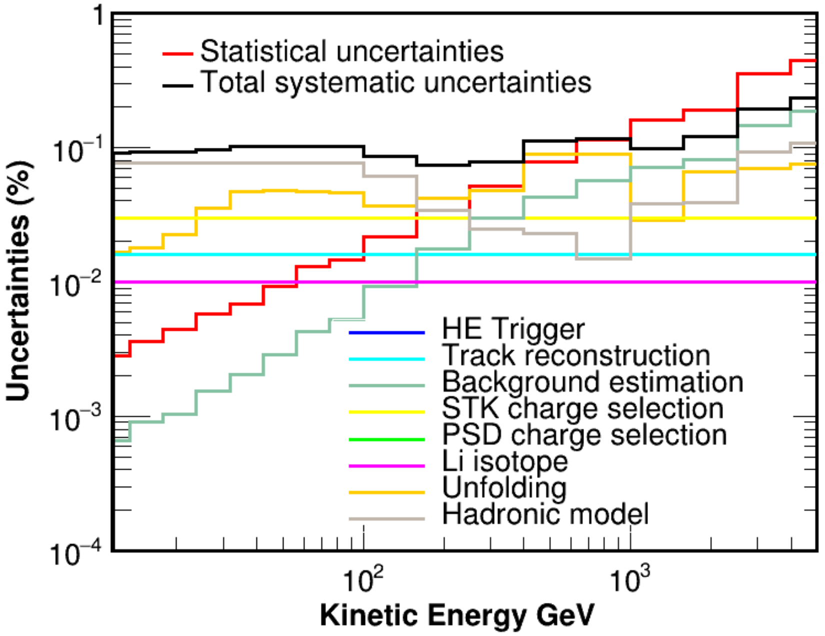
B10 : B11=3 : 7, Li6 : Li7=5 : 5



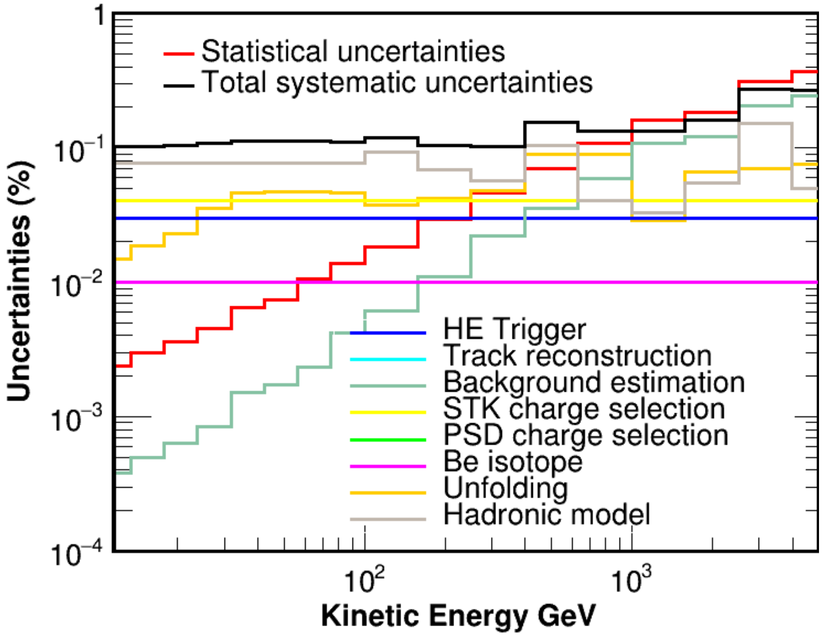


Uncertainties estimation

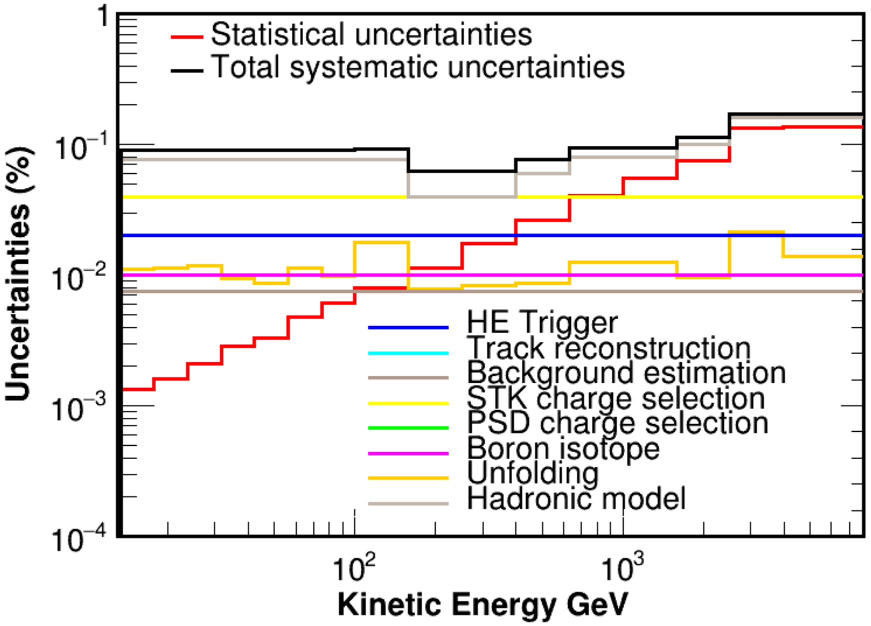
Lithium



Beryllium



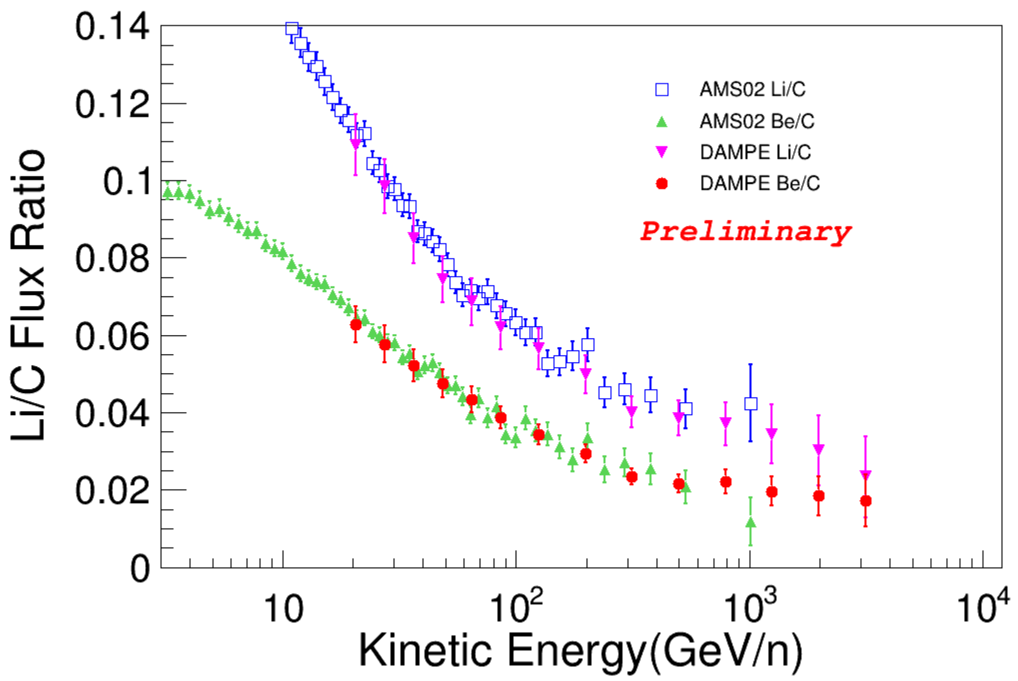
Boron



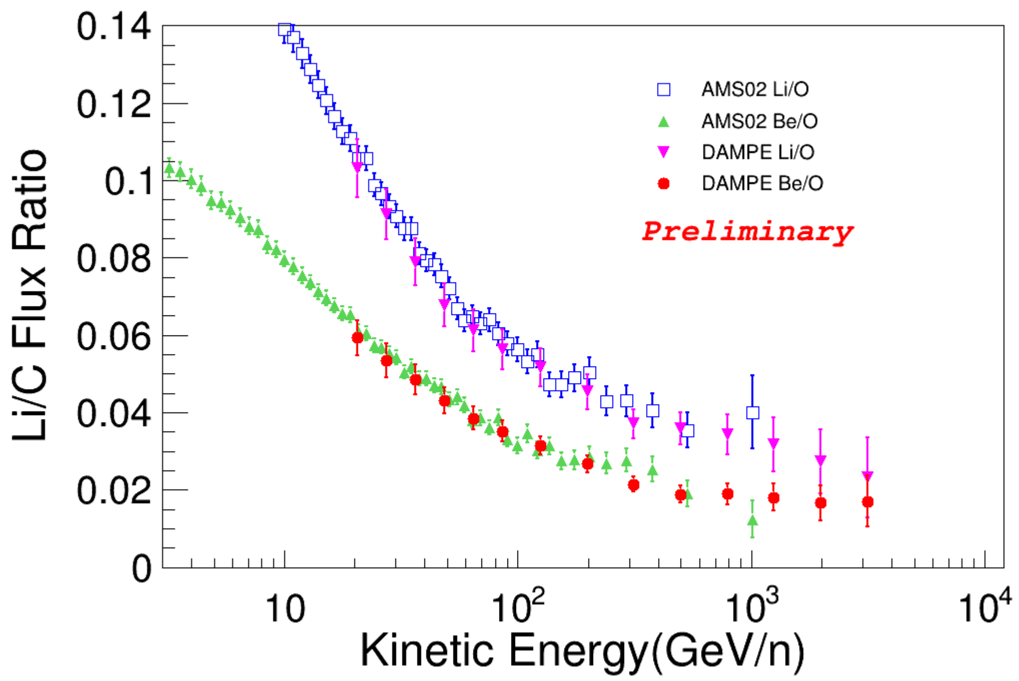
- **Statistical uncertainty dominant at higher energies**
- **Many systematical contributions evaluated**
- **Systematical contribution from hadronic model still under evaluation**

Flux ratio

Li (Be) / C



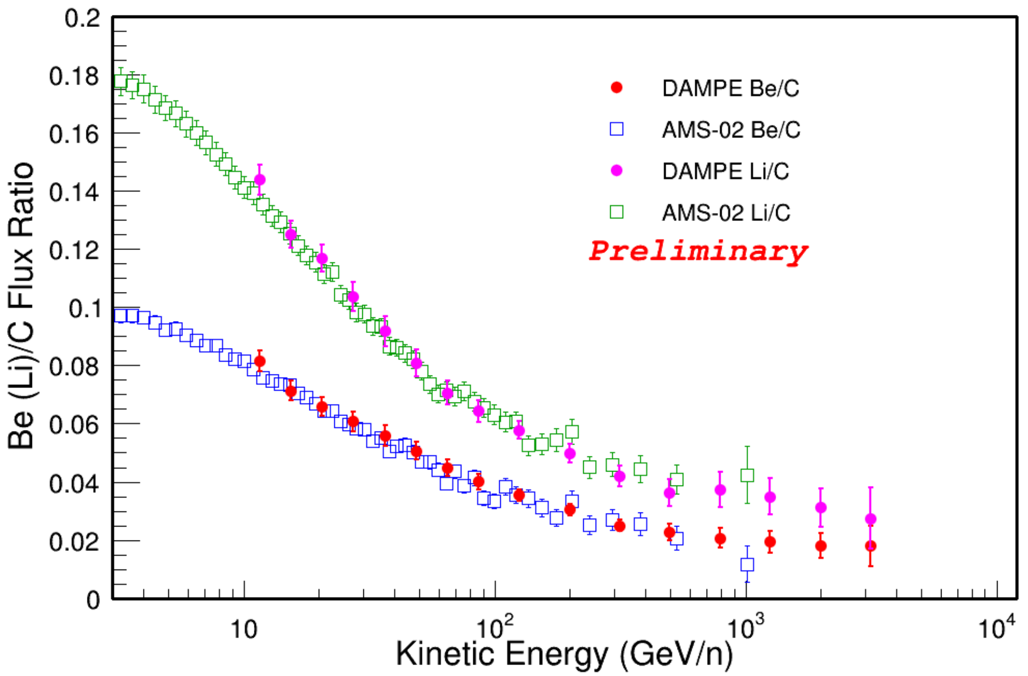
Li (Be) / O



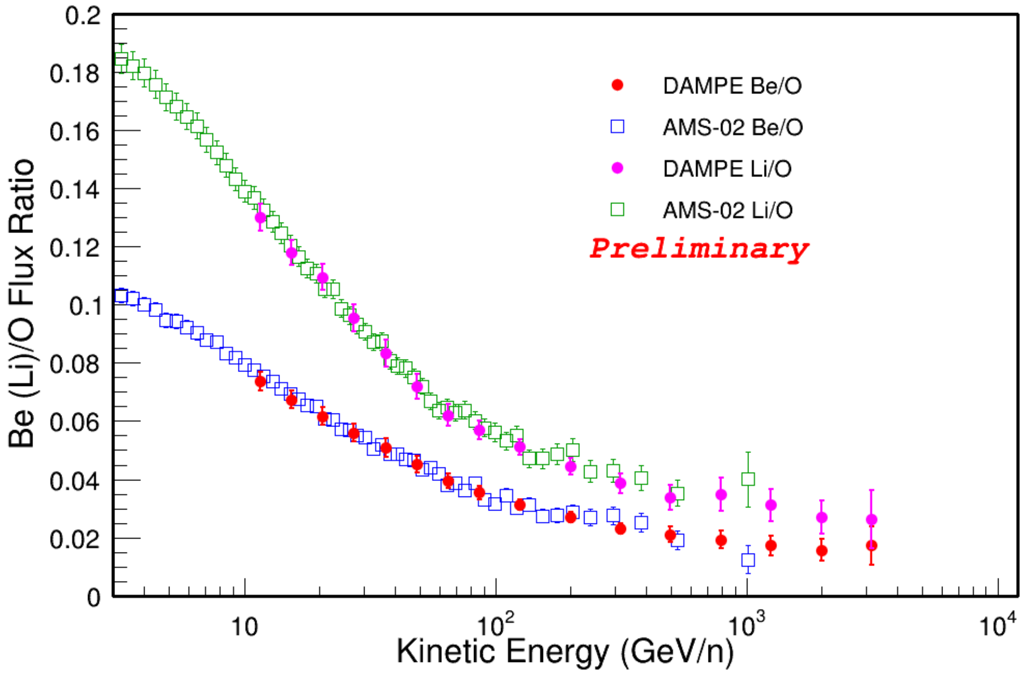
- Preliminary measurement of Li/C(O) and Be/C (O) from 16 GeV/n to 4.1 TeV/n
- Preliminary estimation of systematic uncertainty to be updated

Flux ratio

Li (Be) / C



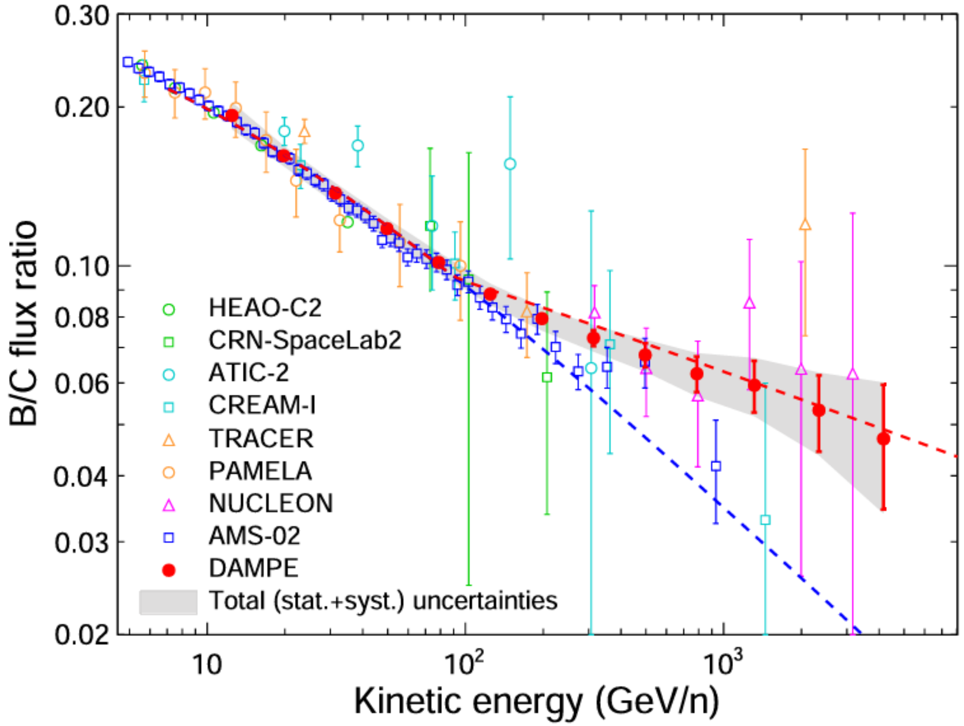
Li (Be) / O



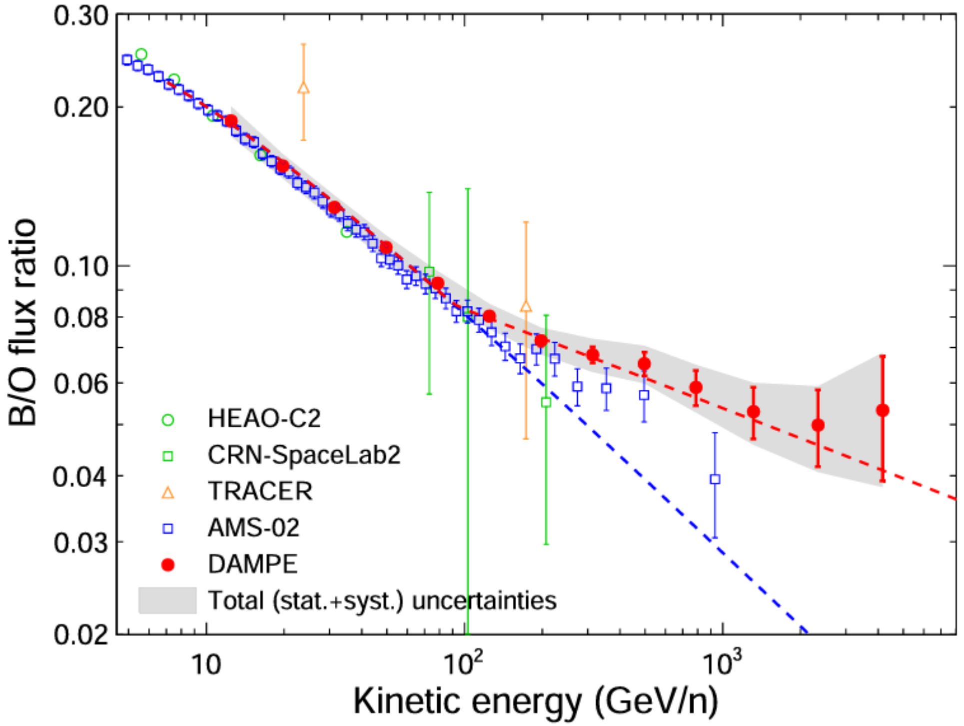
- Preliminary measurement of Li/C(O) and Be/C (O) from 10 GeV/n to 4.1 TeV/n
- Preliminary estimation of systematic uncertainty to be updated

Flux ratio

B / C



B / O



Science Bulletin, 67(2022), 21

- Measurement of B/C and B/O from 10 GeV/n to 5.6 TeV/n

Summary

- Study of secondary cosmic rays fundamental to understand propagation in the Galaxy and origin of observed structures in CR spectra

- **Lithium and Beryllium:**
  - Full sample selection and systematics evaluation
  - Preliminary spectrum in the 10 GeV/n to 4.1 (7.9) TeV/n energy range
  - Preliminary Li/ B and Be/B ratios in the 10 GeV/n to 4.1 TeV/n energy range