Analysis of B/C ratio and nuclei energy spectra

NASA GSFC / CRESST-UMBC

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February 4, 2020

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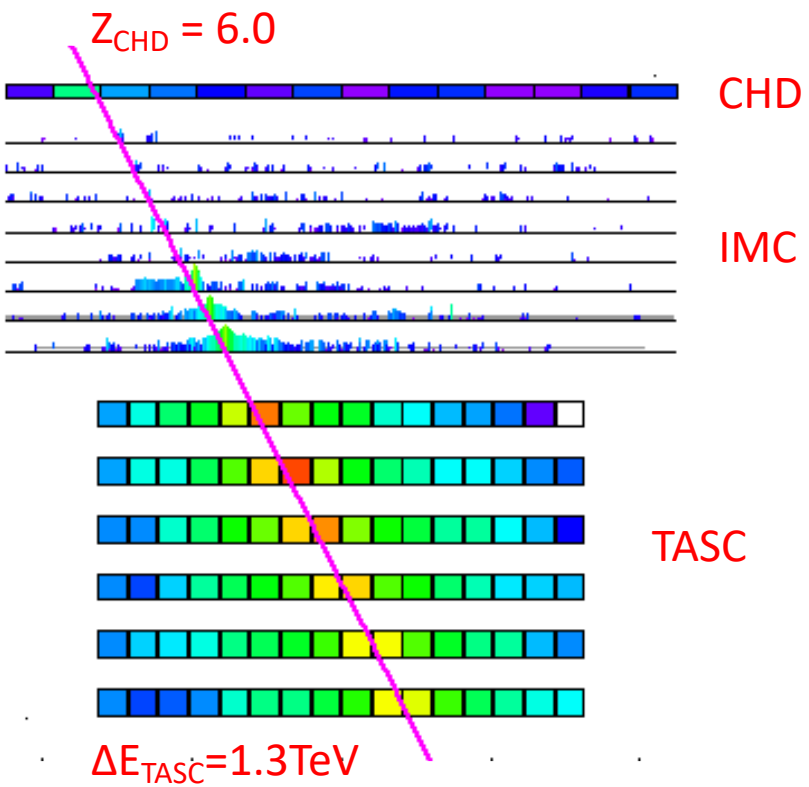
Contents

- B/C ratio
- Carbon spectra
  - Energy scale
  - Trigger efficiency
  - Direct pair production
- Heavy nuclei spectra
  - Ne, Mg, Si, S, Ca and Fe

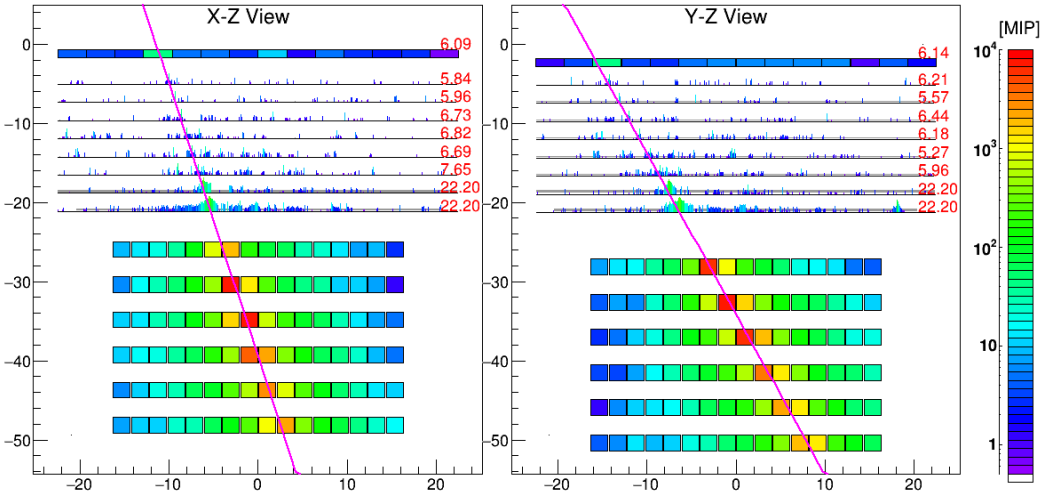
Analysis Procedure of Nuclei

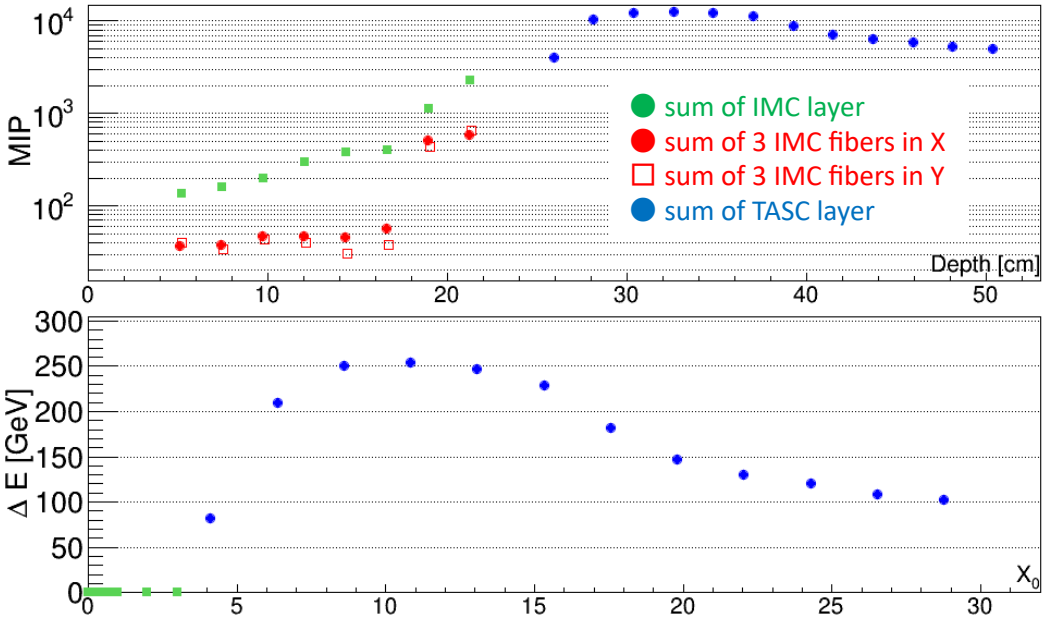
- HE trigger
  - 151013 – 190731 (1389 days)
  - FOV cut (for analysis of B/C)
- Offline Shower Trigger
  - $N_{IMC\text{-}7X+8X} > 50MIP$ & $N_{IMC\text{-}7Y+8Y} > 50MIP$ & $N_{TASC\text{-}X1} > 100MIP$
- Tracking by UH track with Geom.B
- Charge consistency with CHD and IMC
  - $Z_{CHD\text{-}Y} < 1.10\ Z_{CHD\text{-}X}$ & $Z_{CHD\text{-}Y} > 1/1.10\ Z_{CHD\text{-}X}$
  - $Z_{IMC12} < 1.15\ Z_{CHD}$ & $Z_{CHD} > 1/1.15\ Z_{IMC12}$
  - $Z_{IMC34} < 1.15\ Z_{CHD}$ & $Z_{CHD} > 1/1.15\ Z_{IMC34}$
- Track width selection
- Charge selection
  - $|Z_{CHD}\text{-}Z| < 0.4$
- Energy unfolding
- Flux calculation

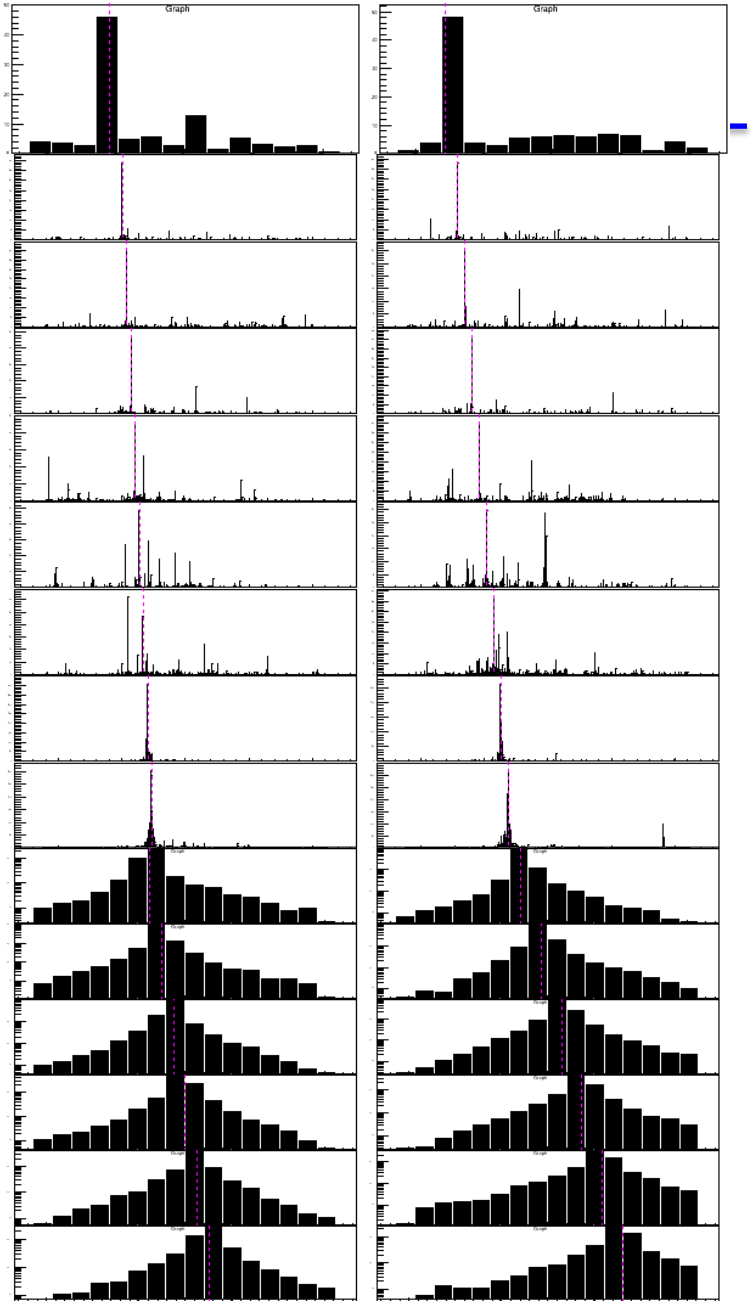


Carbon event from flight data

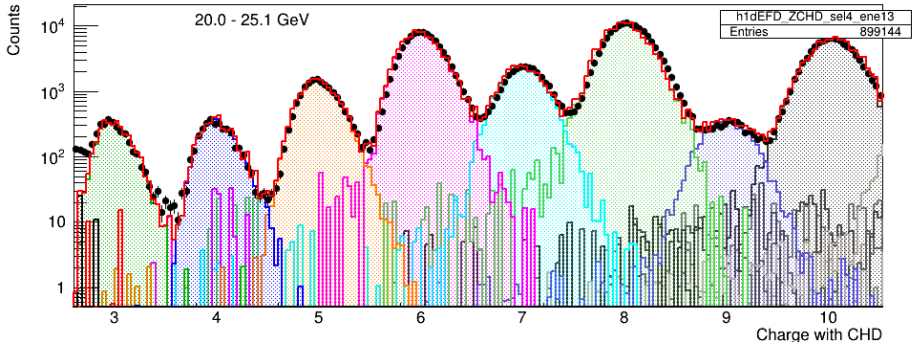
yymmddHH=16111319
MDTime 1163099894
EventID: 040210
ΔE=2062.6GeV

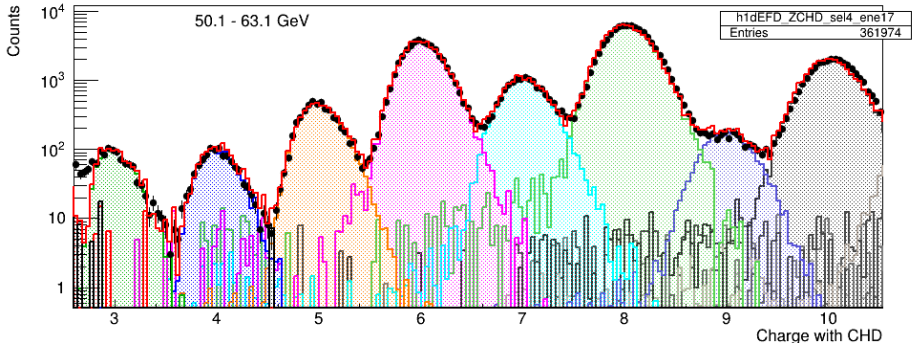


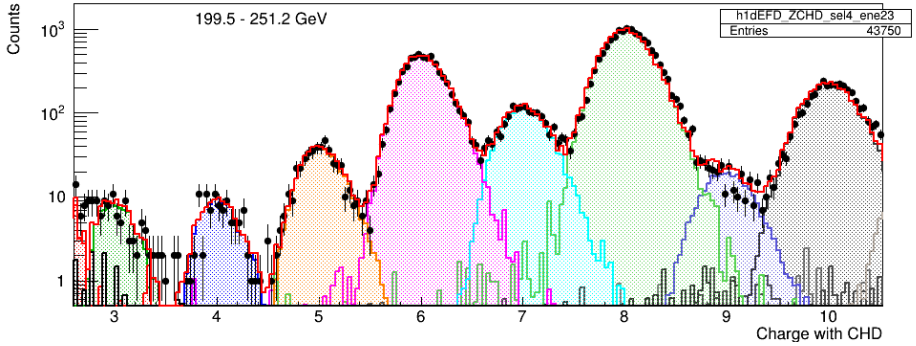


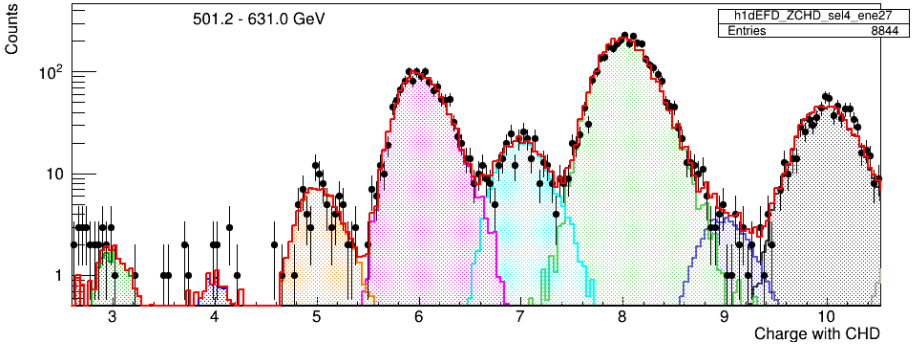


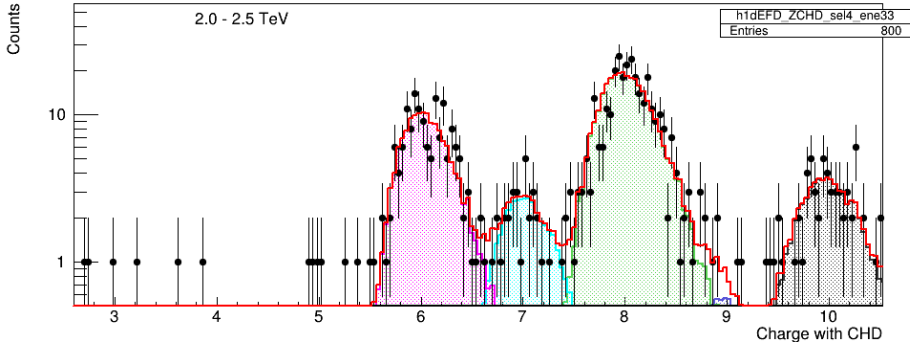
CHD Charge – EPICS –

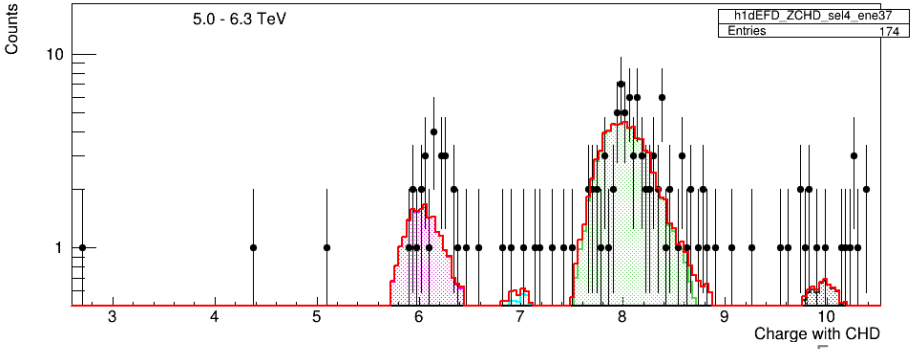




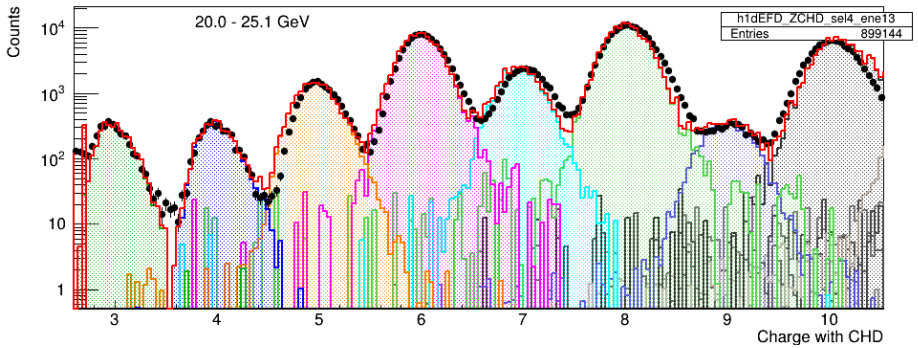


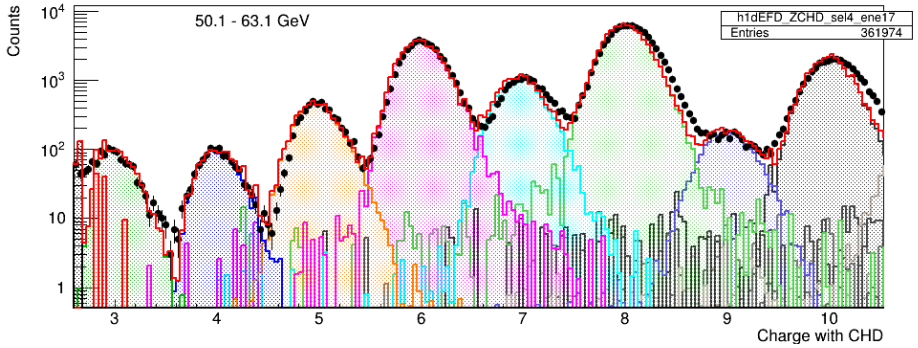


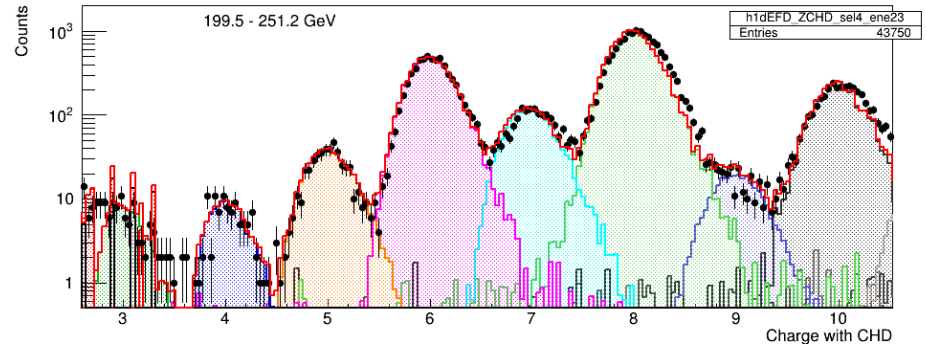


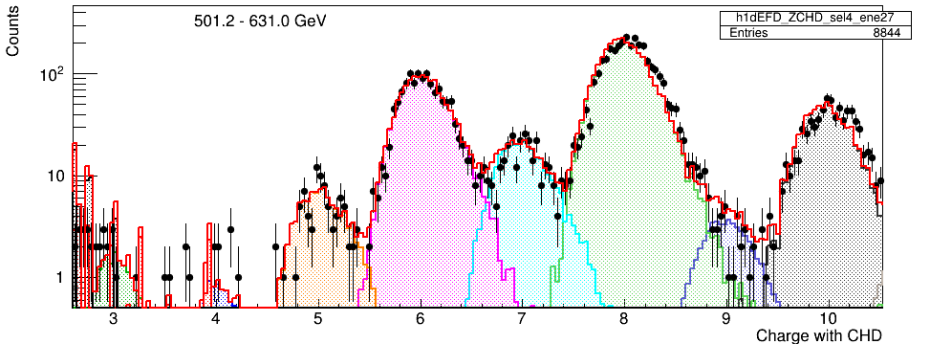


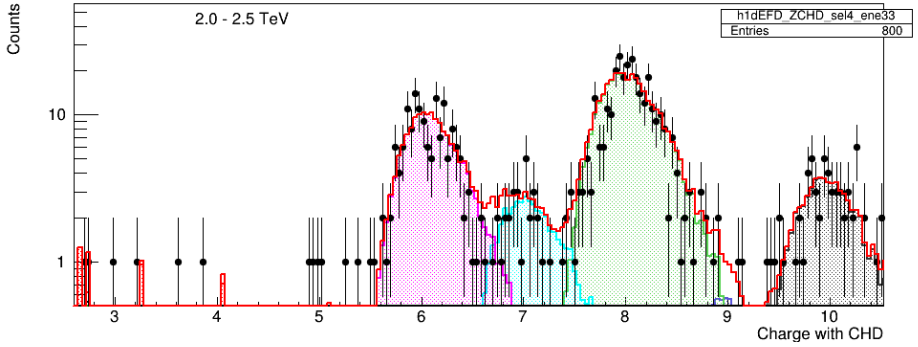
CHD Charge – FLUKA –

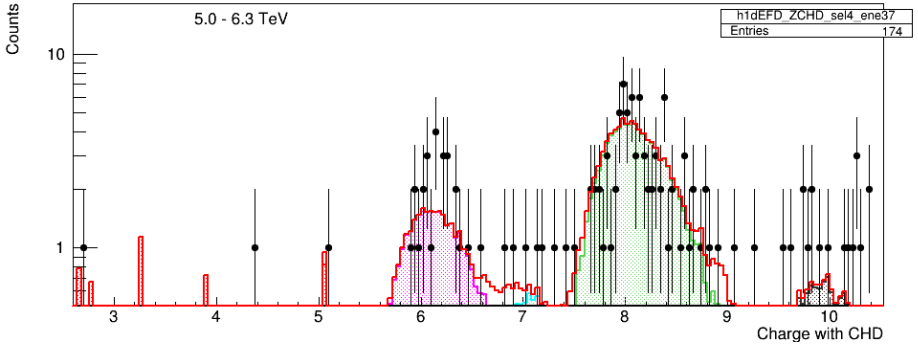










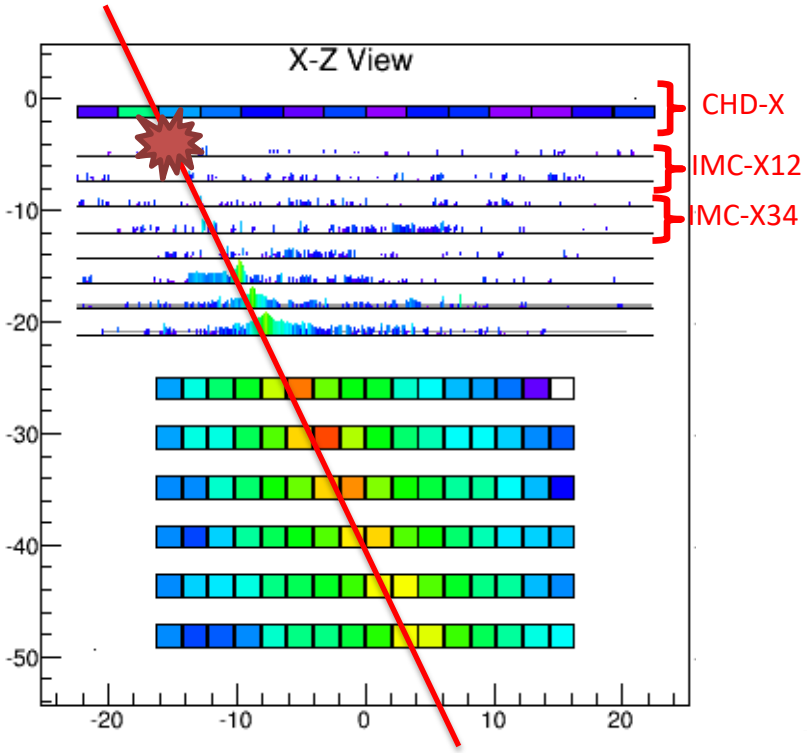


Event selection: charge-consistency in CHD and IMC

- **Charge identification**
  - Z_CHD = (ZCHDX + ZCHDY)/2
  - Z_IMC : truncated mean of upper 4 layers

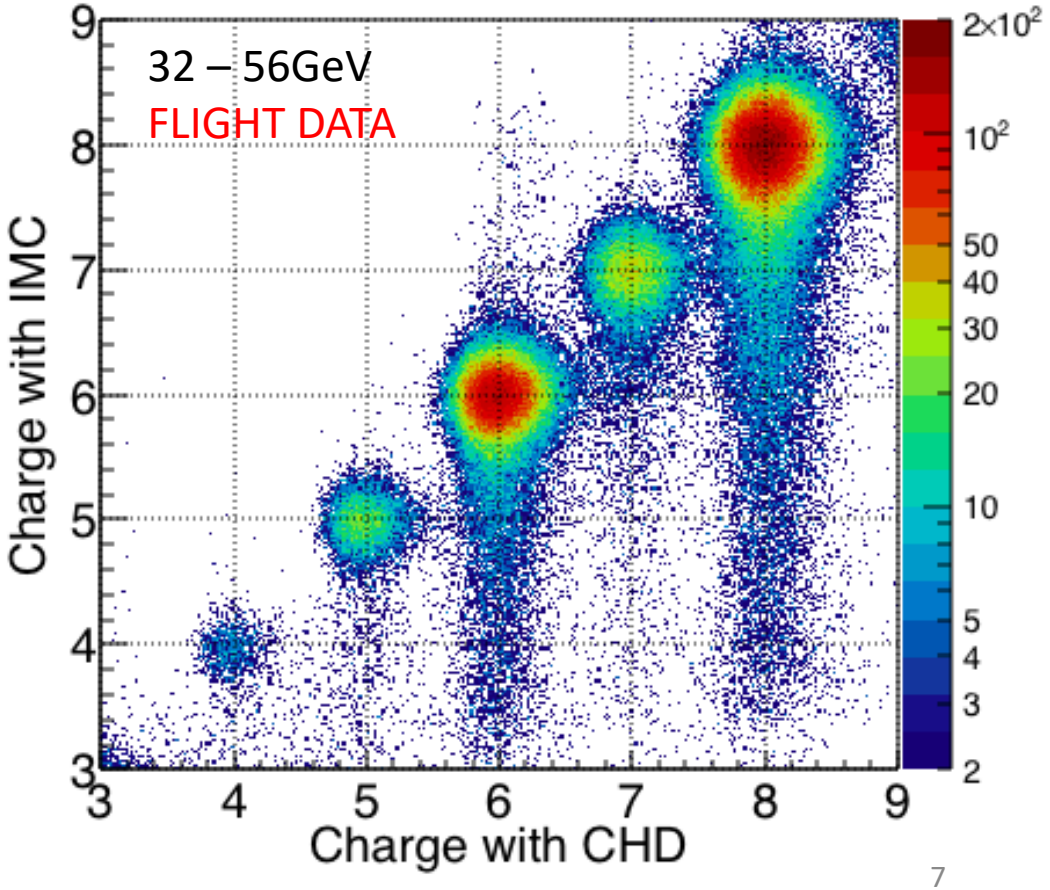
$$Z_{\mathrm{IMC12}} = \frac{1}{2}\left(\sum_{i=1}^{4} Z_{\mathrm{IMCi}} - Z_{\mathrm{IMCi_{MAX}}} - Z_{\mathrm{IMCi_{MIN}}}\right)$$

- **Background source**
  - mis-reconstructed events
  - interacted events in CHD or upper IMC layers



Pre-selection

- HE trigger
- Tracking + geometrical condition
- Z-consistency with CHD-X and CHD-Y



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- Background source
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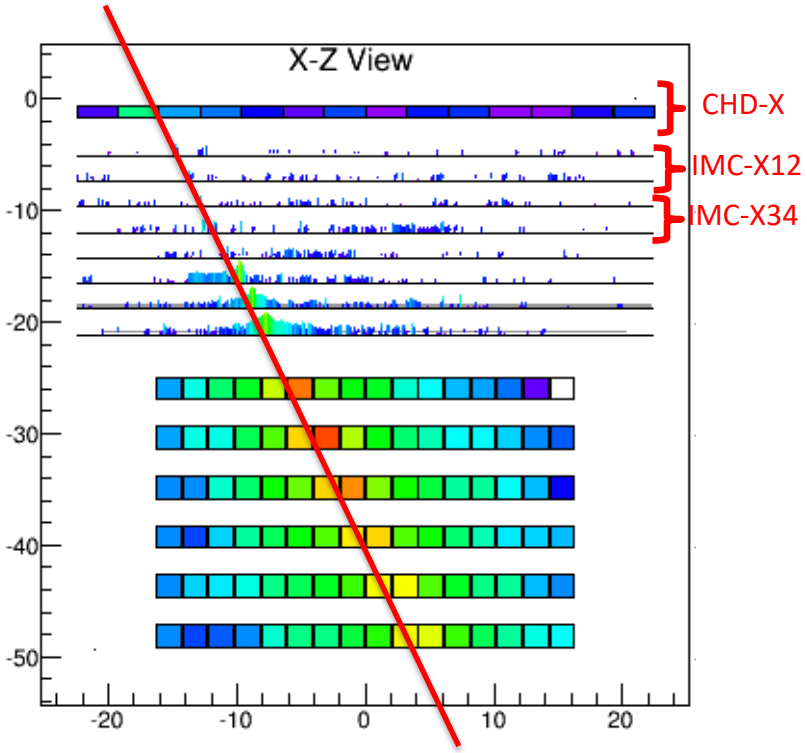
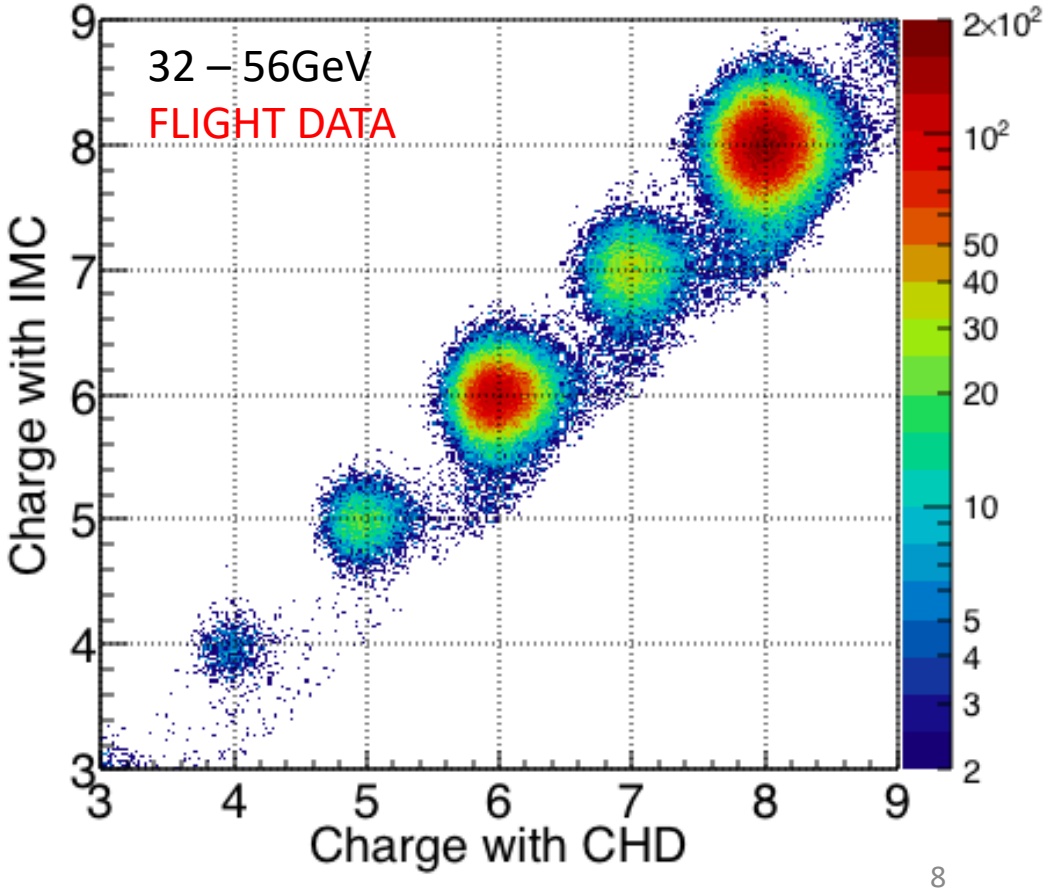
  - interacted events in CHD or upper IMC layers



Pre-selection

- HE trigger
- Tracking + geometrical condition
- Z-consistency with CHD-X and CHD-Y
- Z-consistency with IMC12 and IMC34

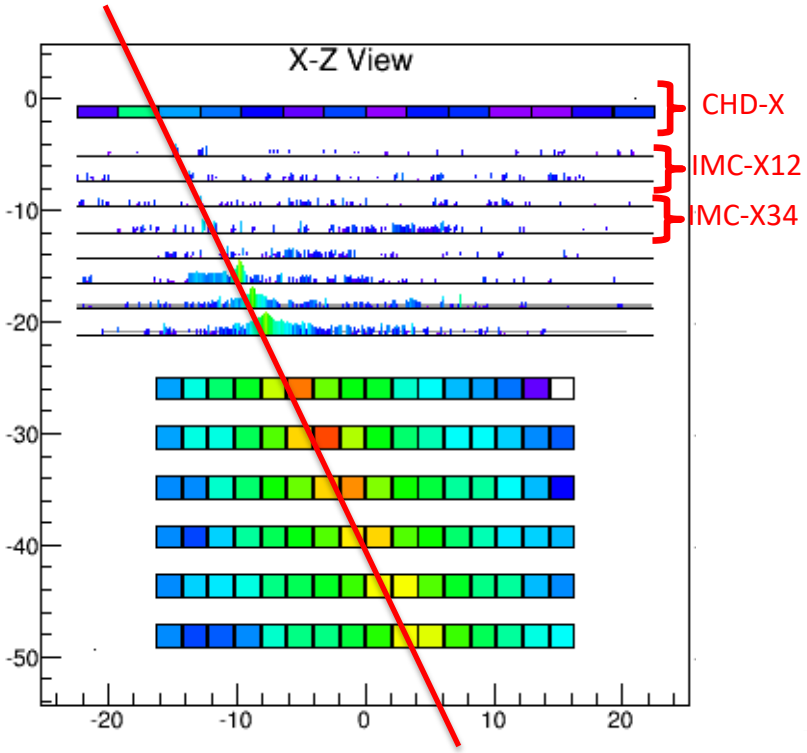


Event selection: track width in IMC

- Charge identification
  - Z_CHD = (ZCHDX + ZCHDY)/2
  - Z_IMC : truncated mean of upper 4 layers

$$Z_{\mathrm{IMC12}} = \frac{1}{2}\left(\sum_{i=1}^{4} Z_{\mathrm{IMCi}} - Z_{\mathrm{IMCi_{MAX}}} - Z_{\mathrm{IMCi_{MIN}}}\right)$$

- Background source
  - mis-reconstructed events
  - interacted events in CHD or upper IMC layers

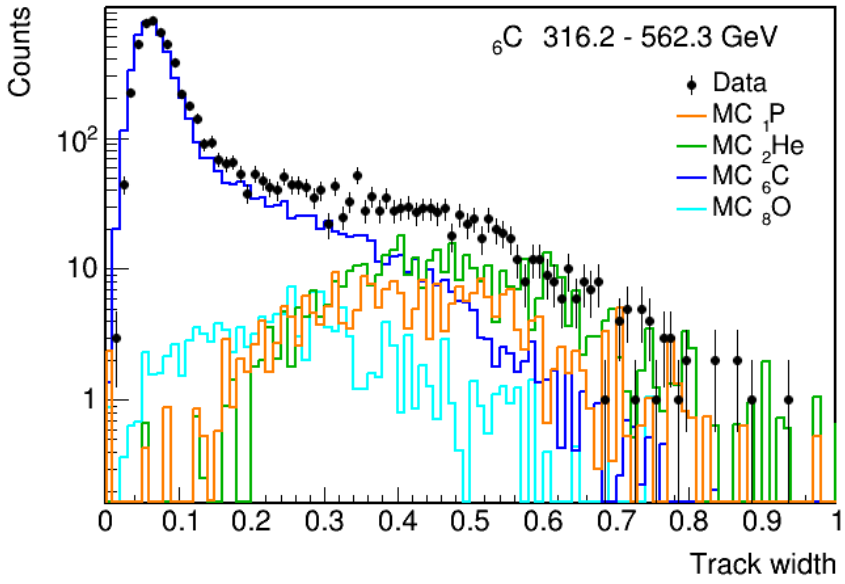


Pre-selection

- HE trigger
- Tracking + geometrical condition
- Z-consistency with CHD-X and CHD-Y
- Z-consistency with IMC12 and IMC34
- Track width selection

$$B_{\mathrm{IMCi}} = \left(\sum_{j=-k}^{k} N_{\mathrm{IMCi,j}} - \sum_{j=-1}^{1} N_{\mathrm{IMCi,j}}\right)\frac{1}{Z^2_{\mathrm{IMCi}}}$$

Sum of 7 SciFis Sum of 3 SciFis

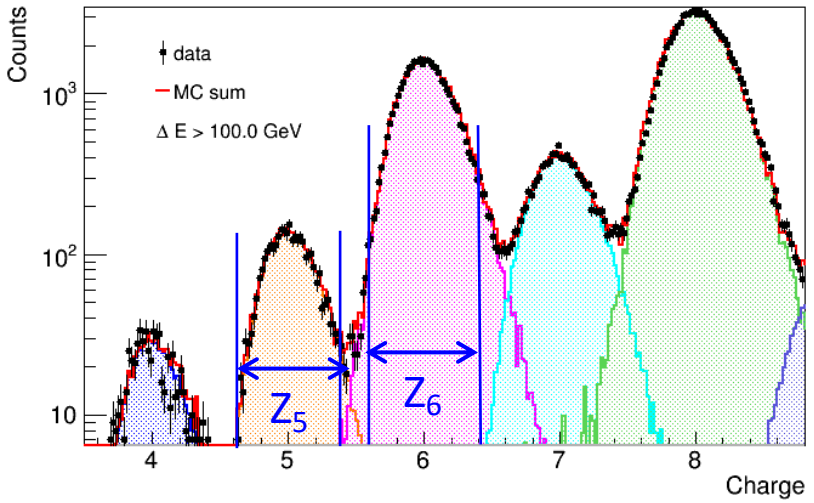


Charge identification and Background estimation

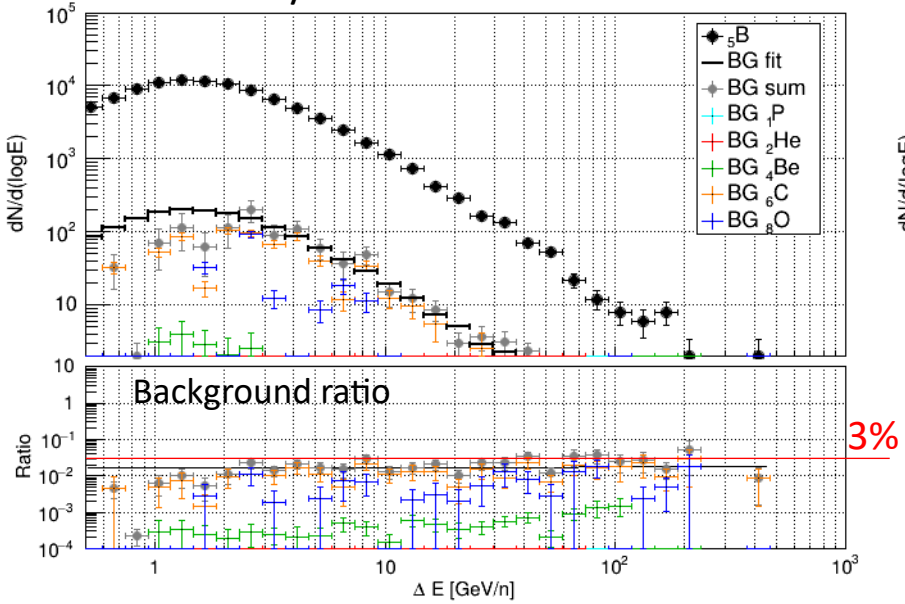
- Particle charge is identified with CHD
- Background is estimated by means of MC

MC data:
- EPICS v9.21 (Cosmos8.01)
- DPMJET-III

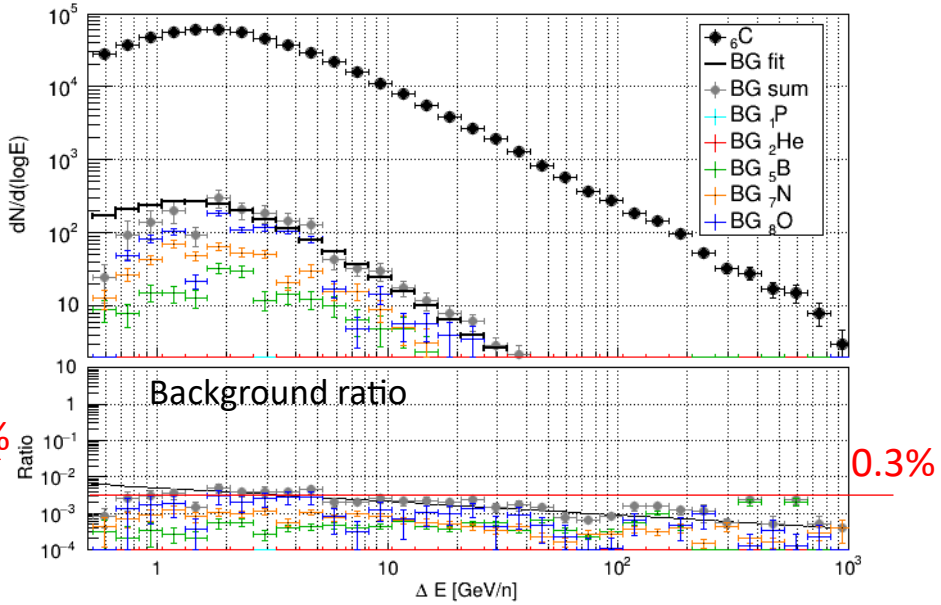
Consider quenching, noise and etc.
Apply the same selection with flight data.



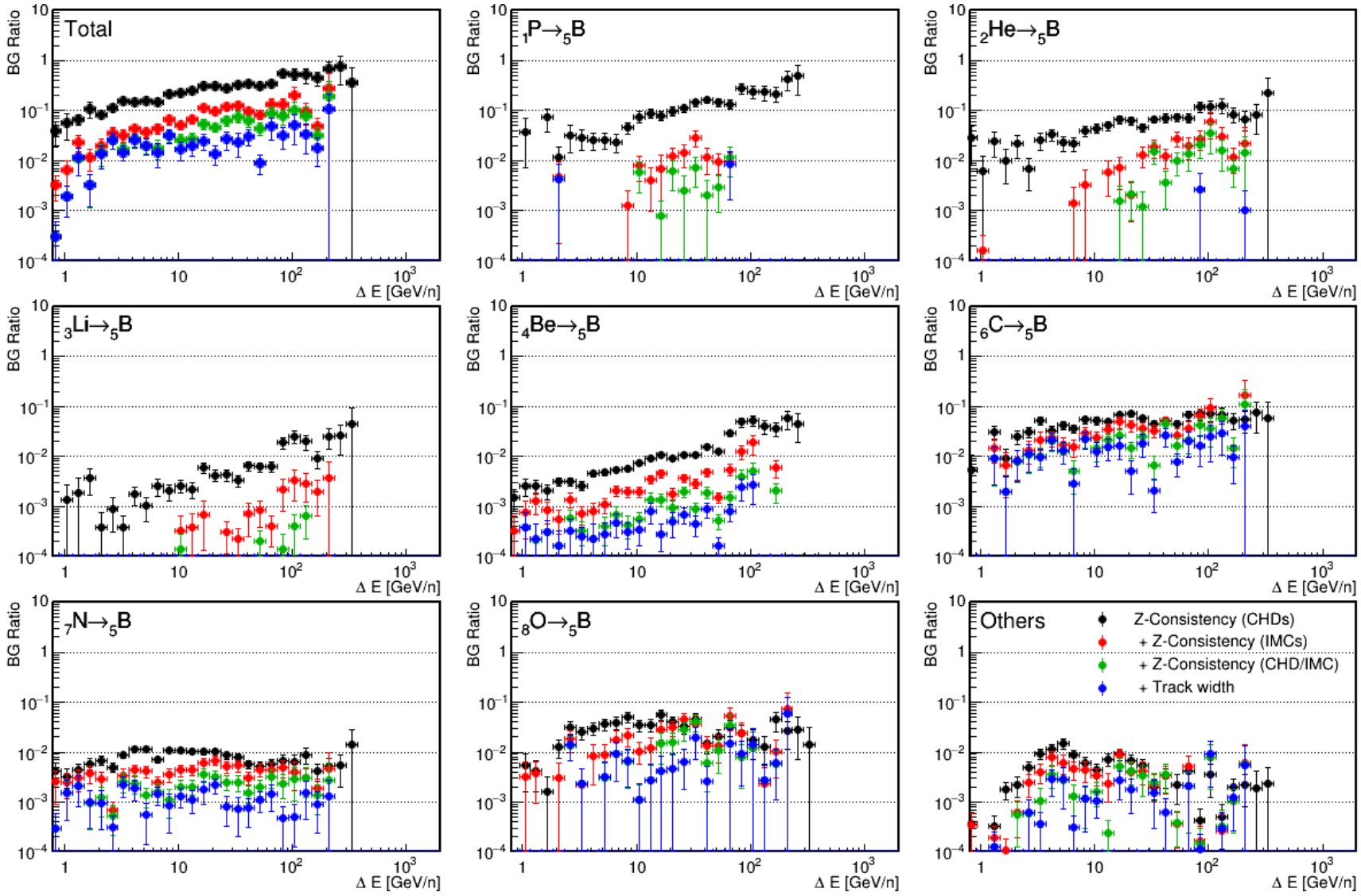
dN/dE and BG for Boron



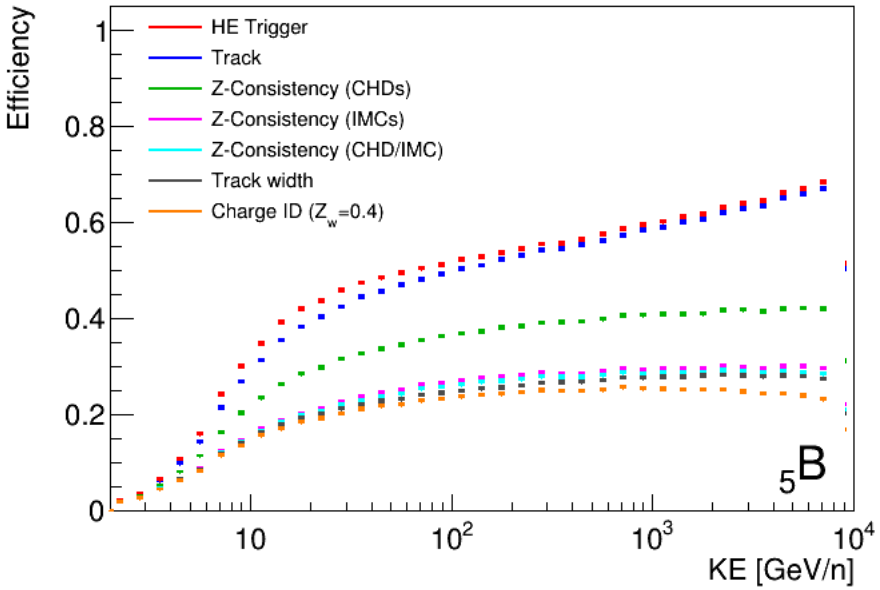
dN/dE and BG for Carbon

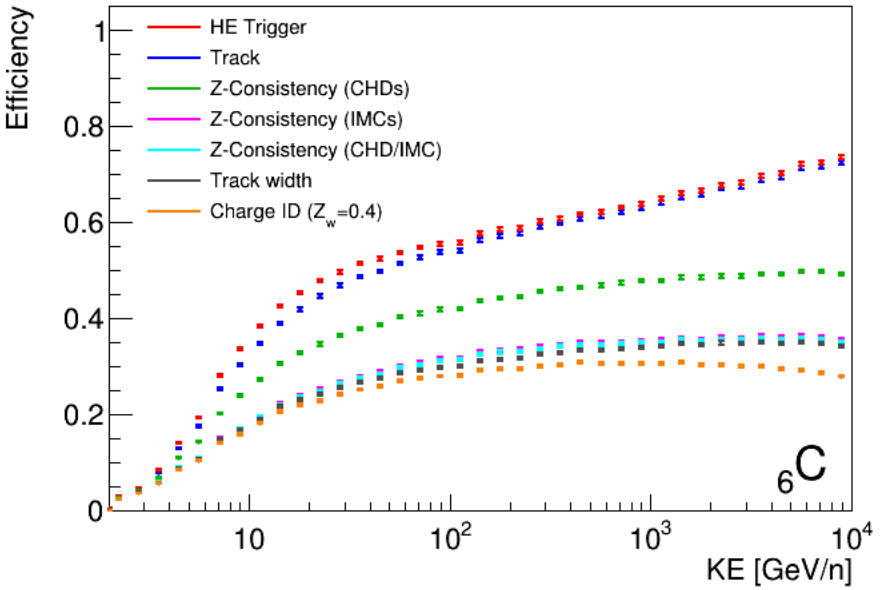


Background components for Boron



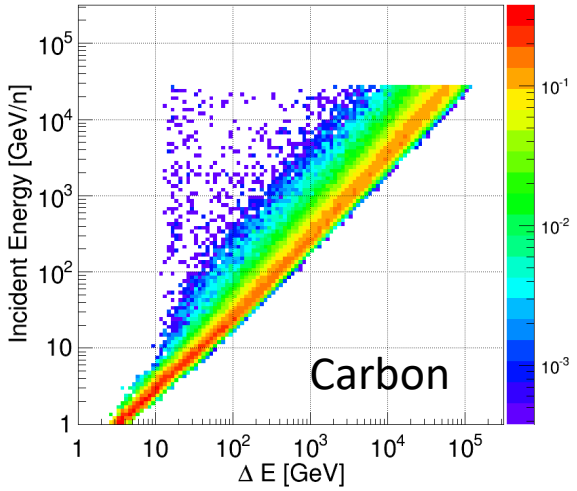
Efficiency

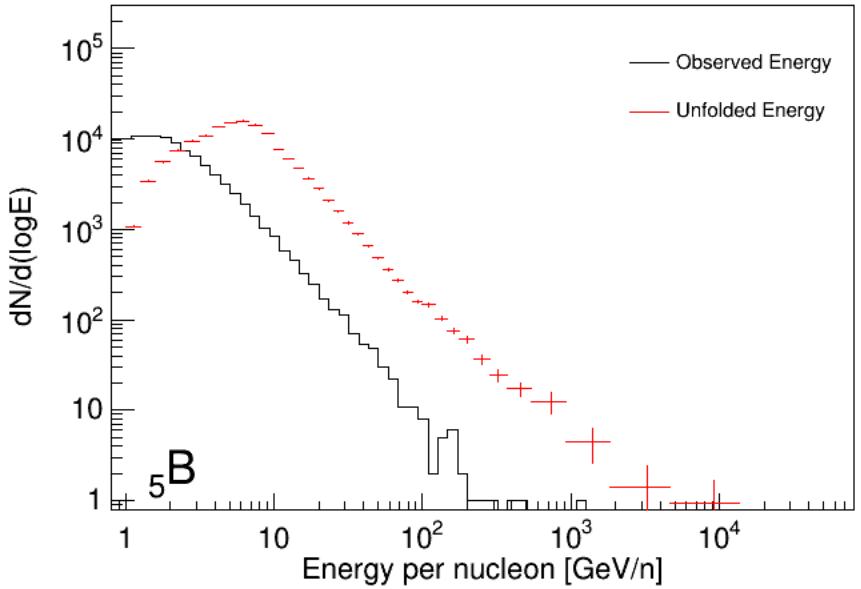

Efficiency
HE Trigger
Track
Z-Consistency (CHDs)
Z-Consistency (IMCs)
Z-Consistency (CHD/IMC)
Track width
Charge ID (Z_w=0.4)
$_5$B
KE [GeV/n]

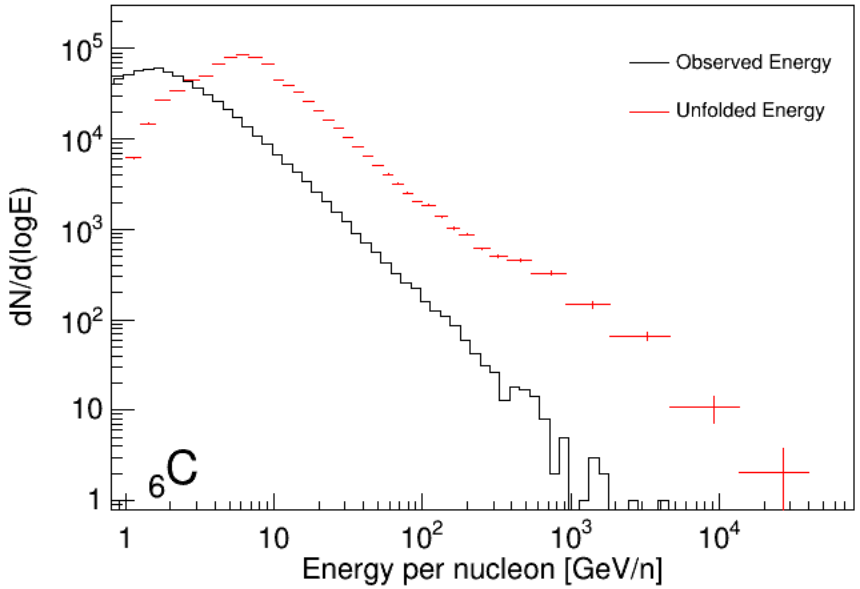

Efficiency
HE Trigger
Track
Z-Consistency (CHDs)
Z-Consistency (IMCs)
Z-Consistency (CHD/IMC)
Track width
Charge ID (Z_w=0.4)
$_6$C
KE [GeV/n]

Energy unfolding

- Iterative Bayesian unfolding
  - Initial assuming spectra: f(E)=A x $E^{-2.60}$
    A is normalized by charge distribution in CHD
  - Response function:
    ΔE [GeV] vs E_0 [GeV/n]
  - 2 iterations

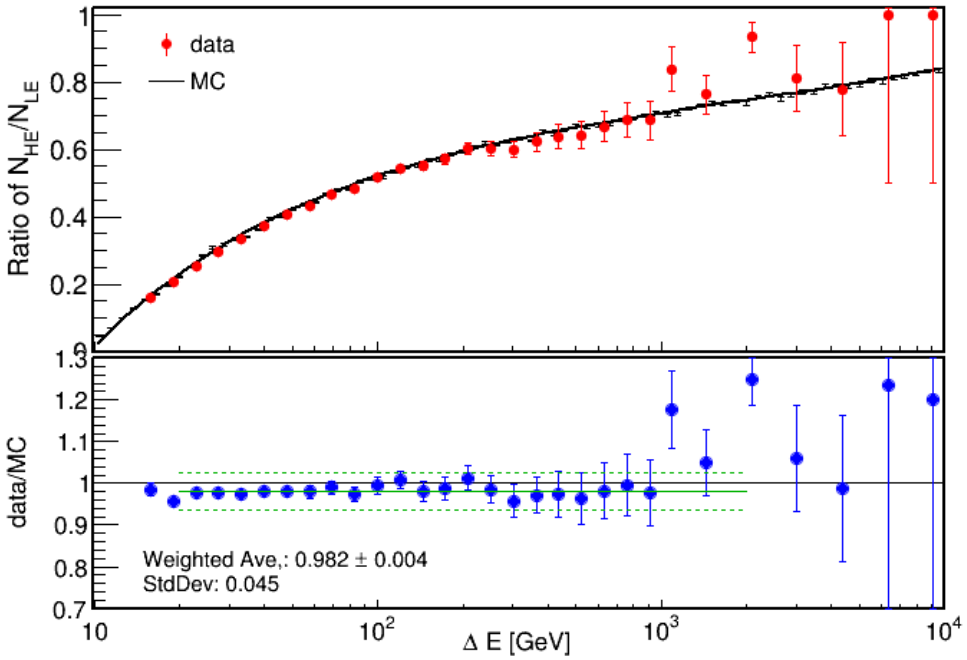






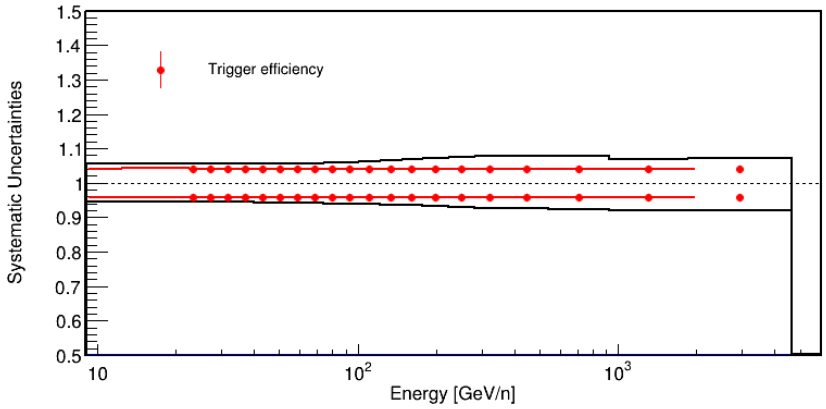
Systematic uncertainty: Trigger efficiency

$N_{LE\&HE}$ / N_{LE} for Carbon

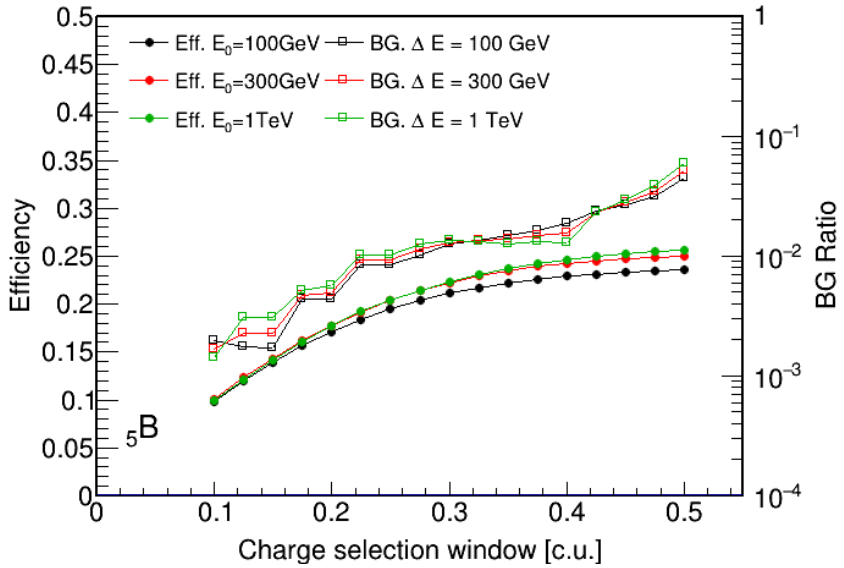


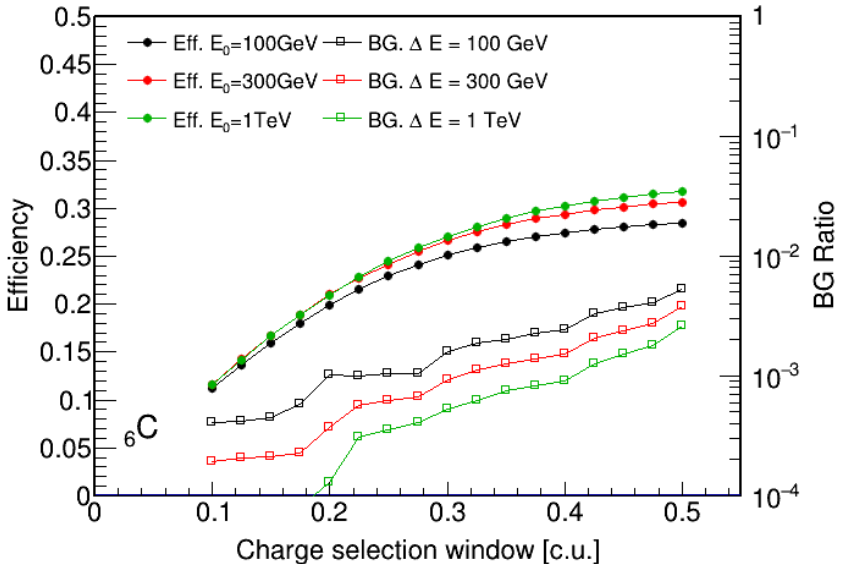
For Boron, same value with carbon is used.

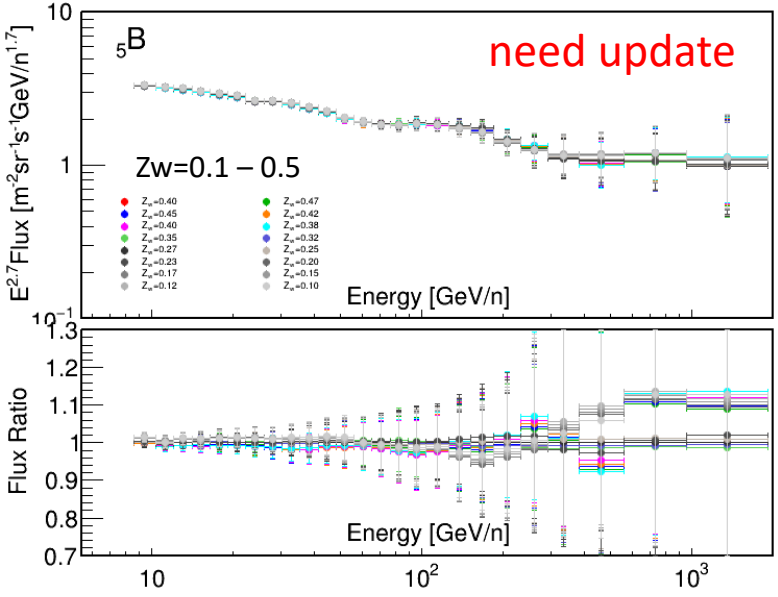
Systematic uncertainty of B/C

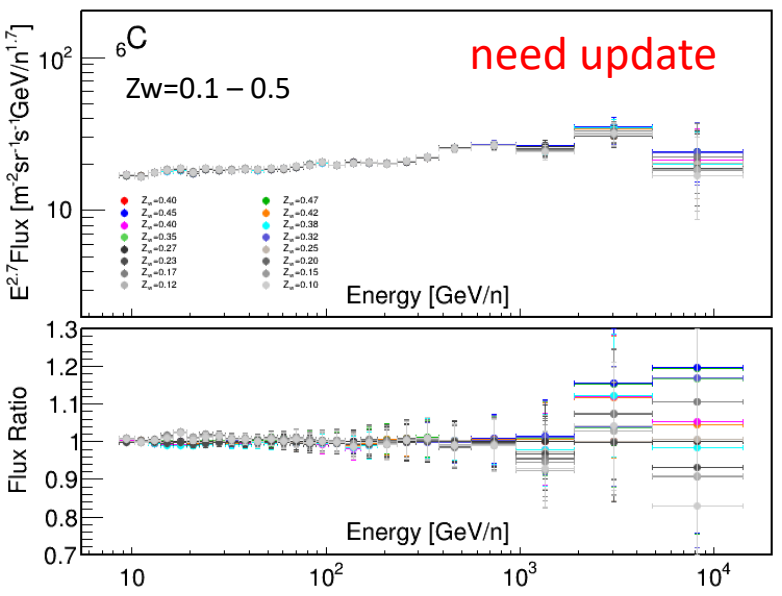


Systematic uncertainty: Charge selection





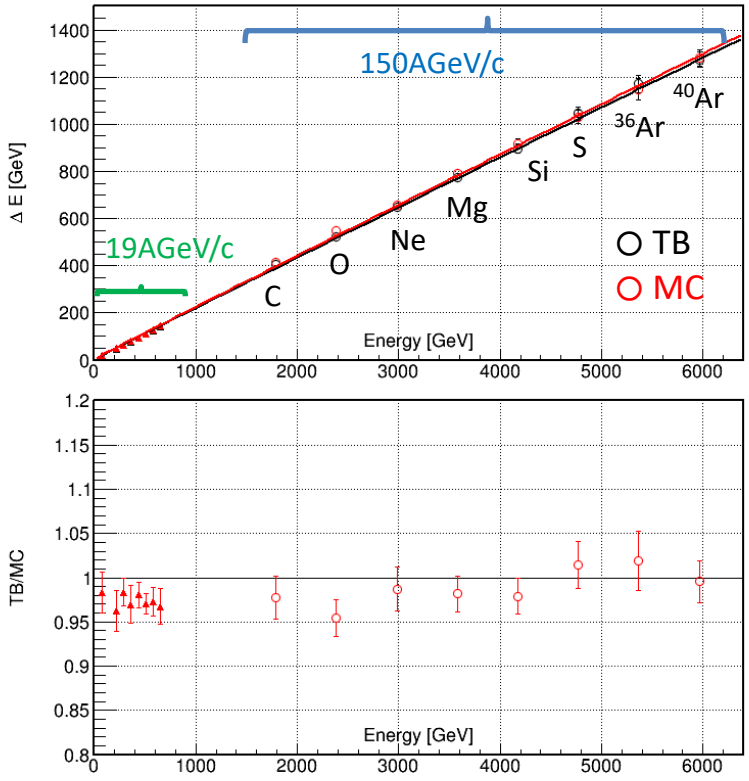


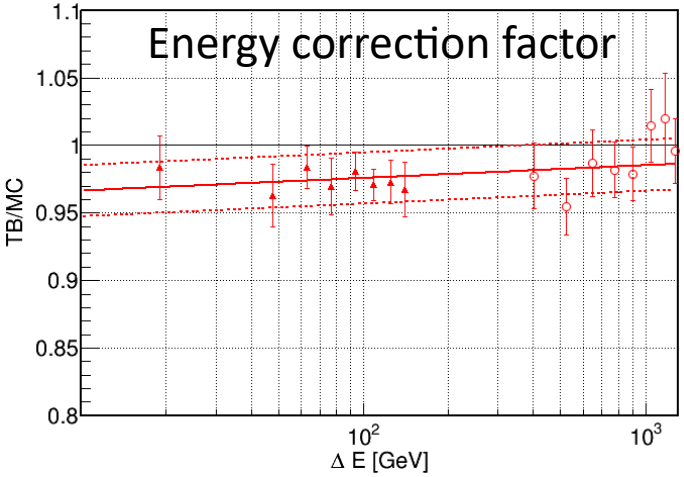


Systematic uncertainty: Energy scale

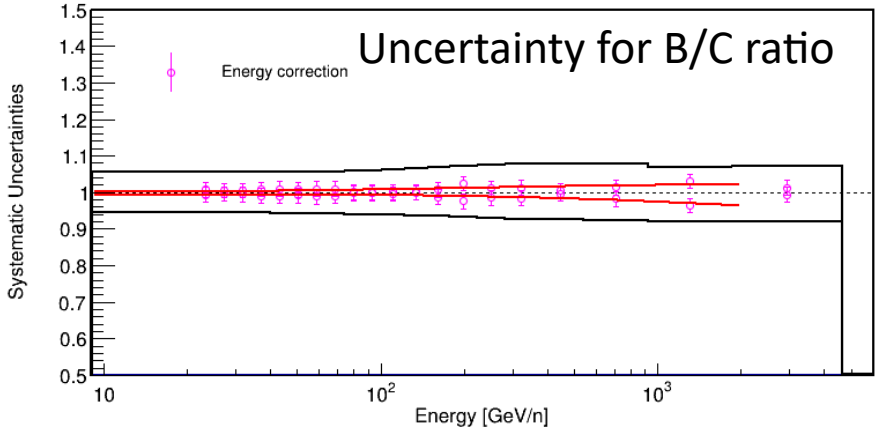
Results of CERN 2015 beam test

Deposit energy vs incident energy

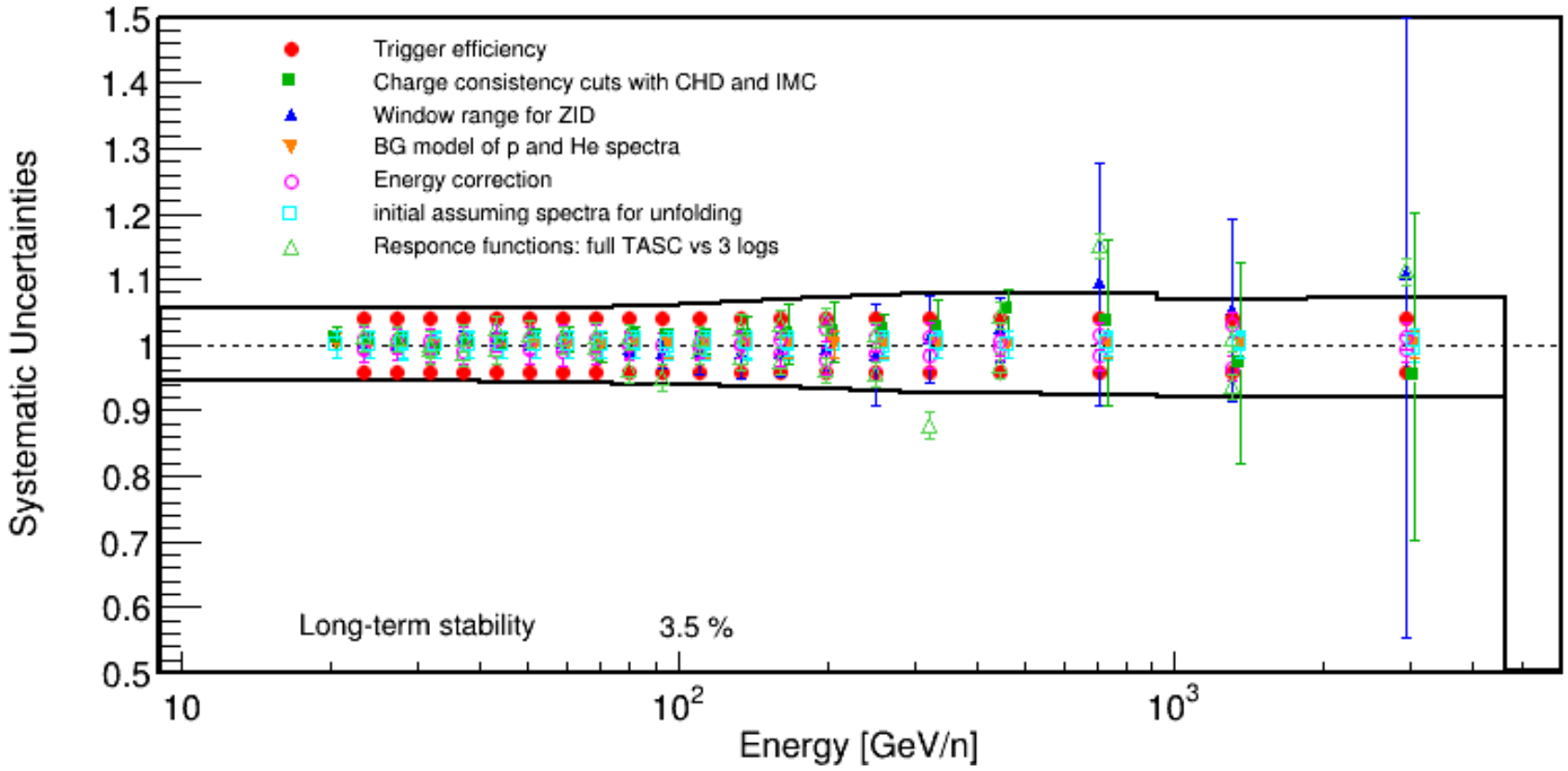




- Apply the correction to flight data analysis
- Error of energy correction is considered

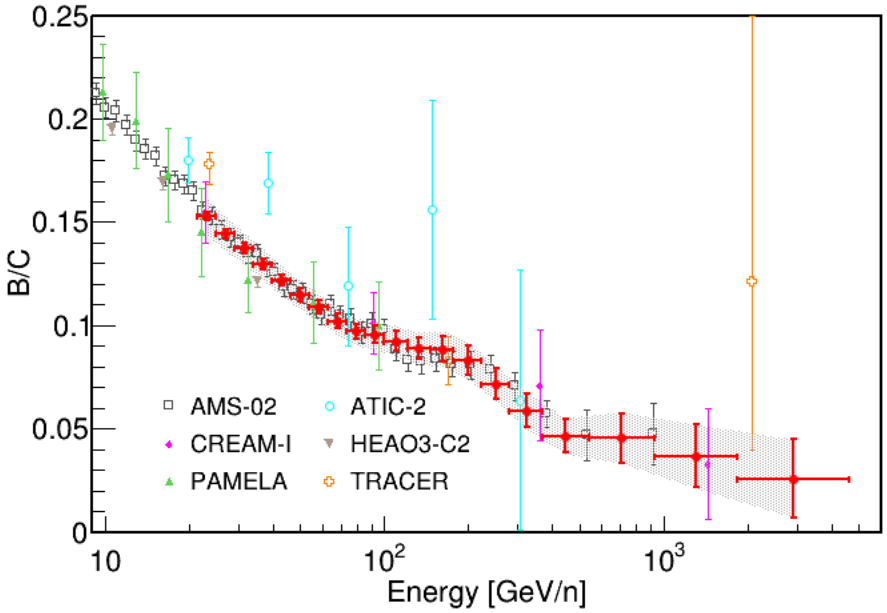


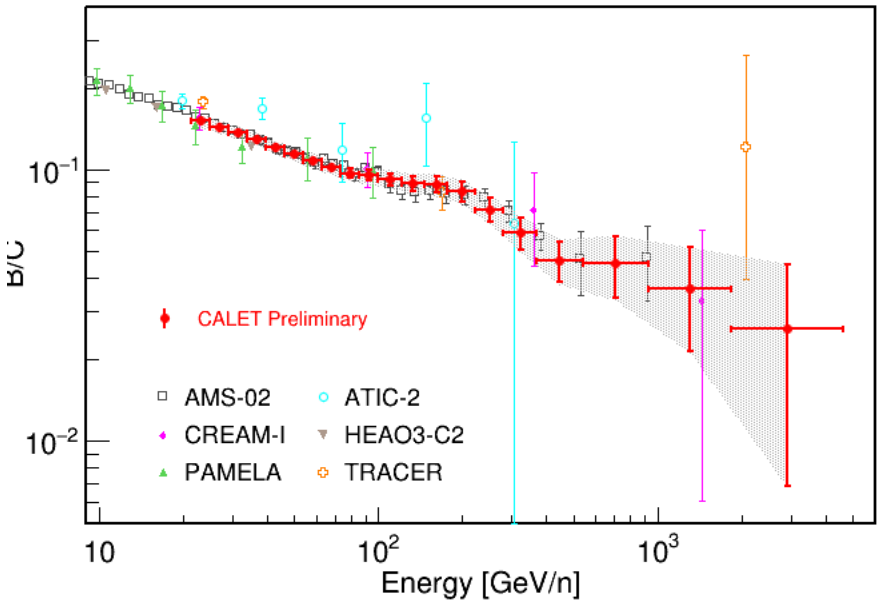
Systematic uncertainties for B/C ratio



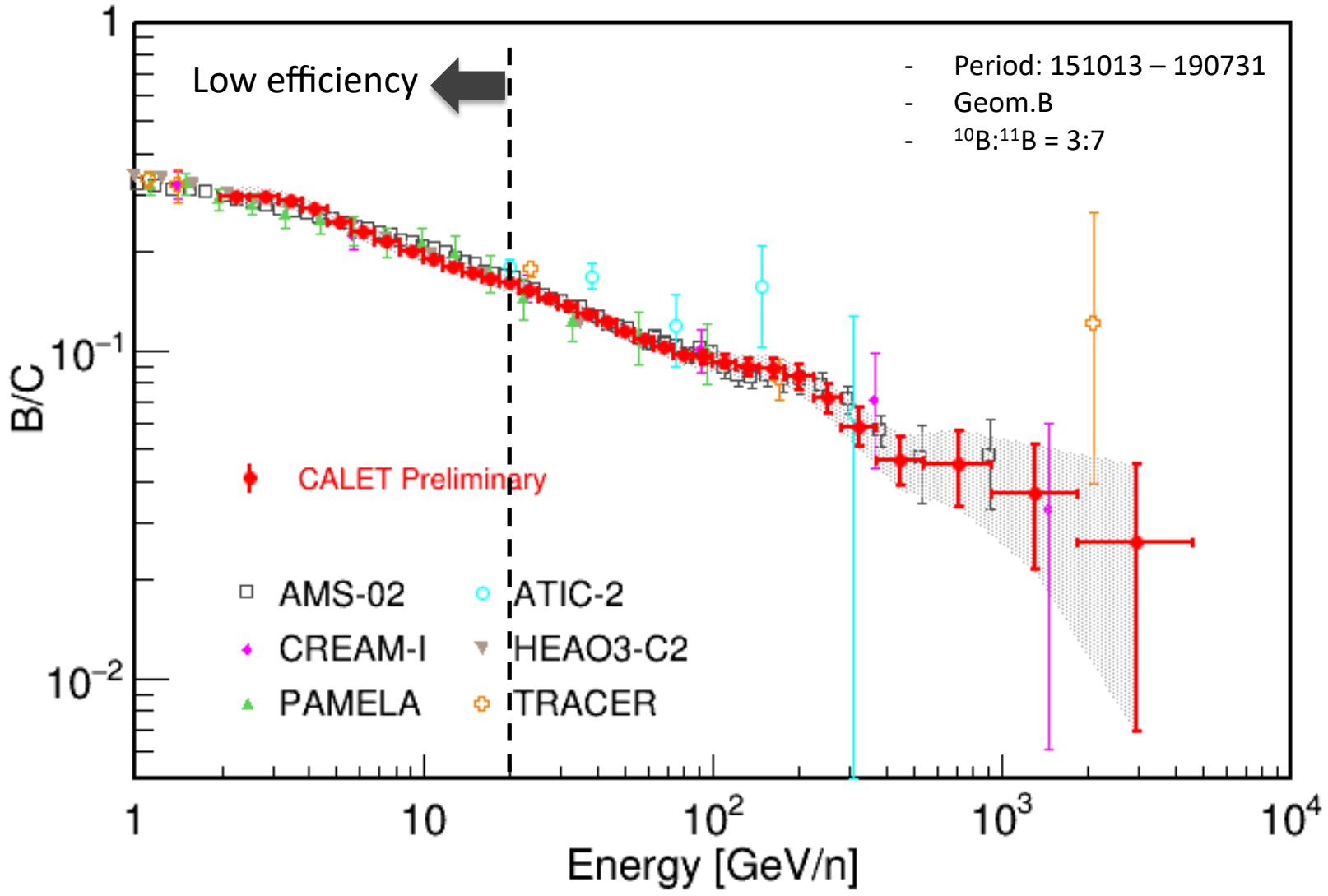
Boron-to-carbon ratio

- Period: 151013 – 190731
- Geom.B
- ^{10}B:^{11}B = 3:7

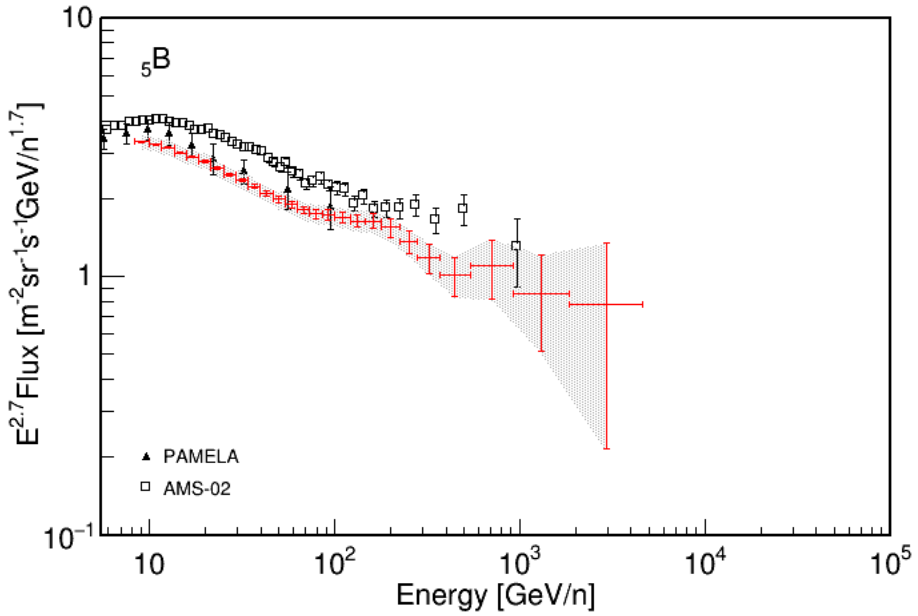


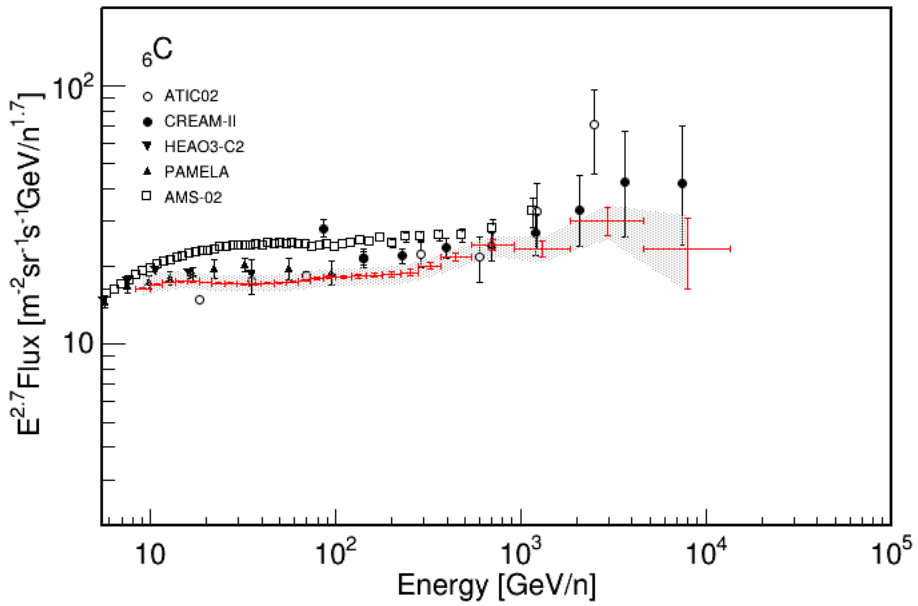


B/C ratio


Low efficiency
- Period: 151013 – 190731
- Geom.B
- ^{10}B:^{11}B = 3:7
CALET Preliminary
AMS-02
CREAM-I
PAMELA
ATIC-2
HEAO3-C2
TRACER
B/C
Energy [GeV/n]
1
10^{-1}
10^{-2}
1
10
10^2
10^3
10^4

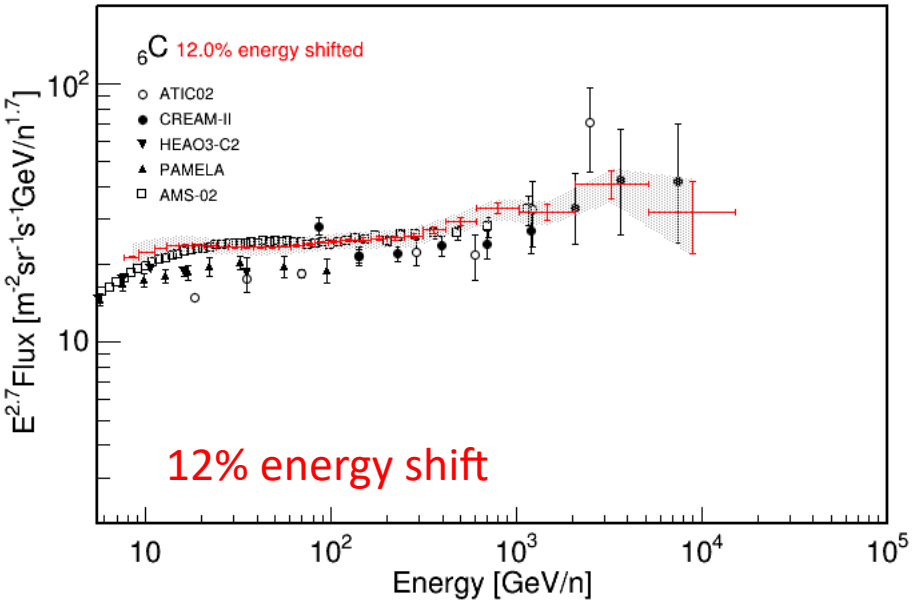
Boron and Carbon spectra





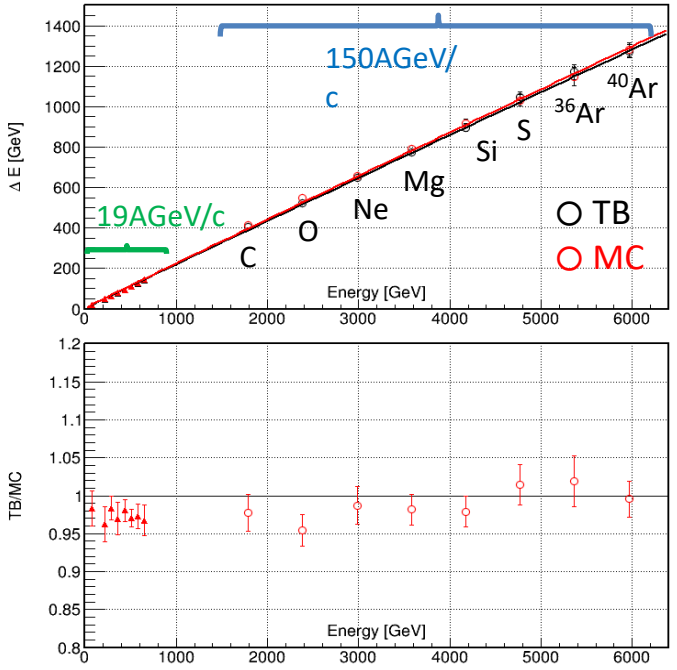
Compare to AMS-02

- Energy correction?



Results of CERN 2015 beam test

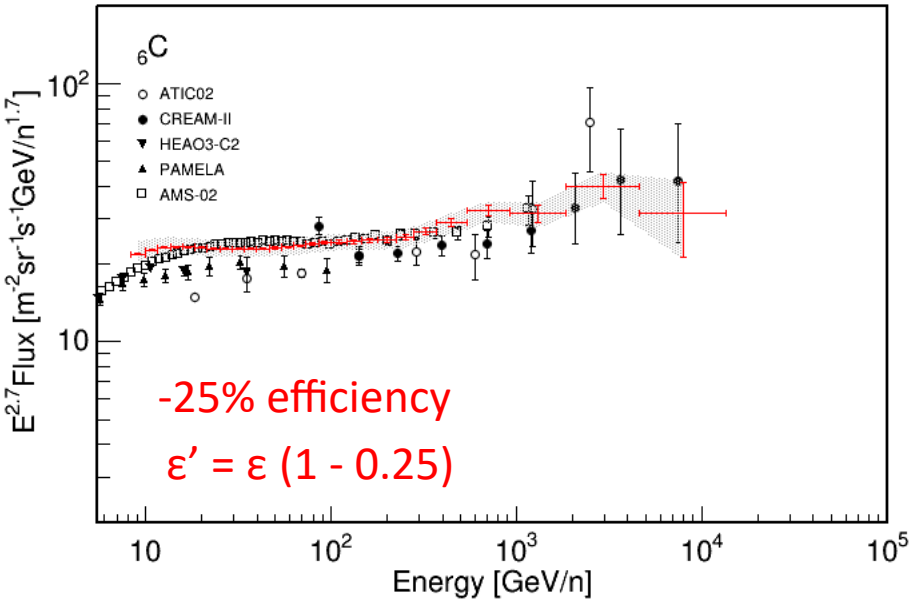
Deposit energy vs incident energy



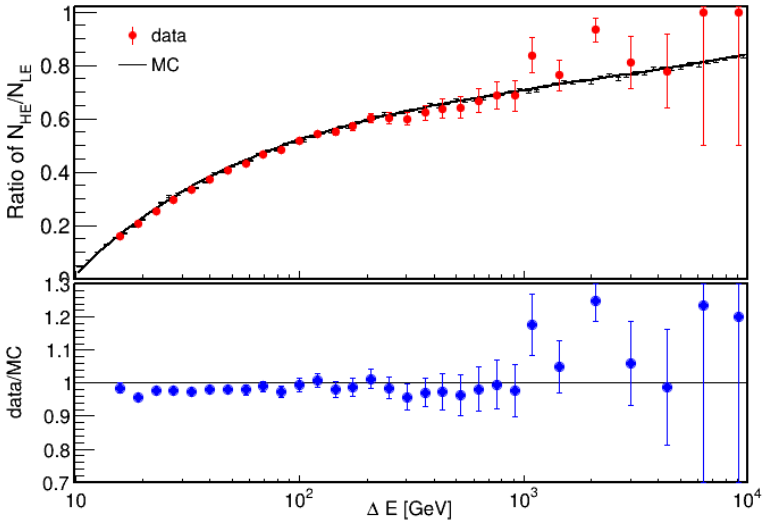
CERN 2015 beam test: ~a few %

Compare to AMS-02

- Efficiency correction?



$N_{LE\&HE}$ / N_{LE} for Carbon



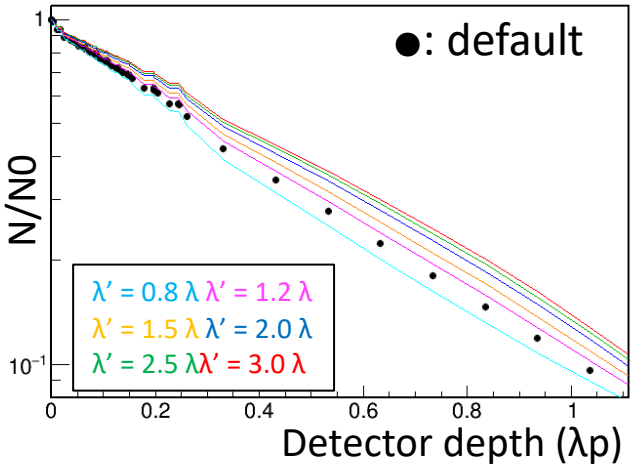
X-axis is deposit energy in TASC, not primary energy
Does this study really confirm the absolute efficiency?

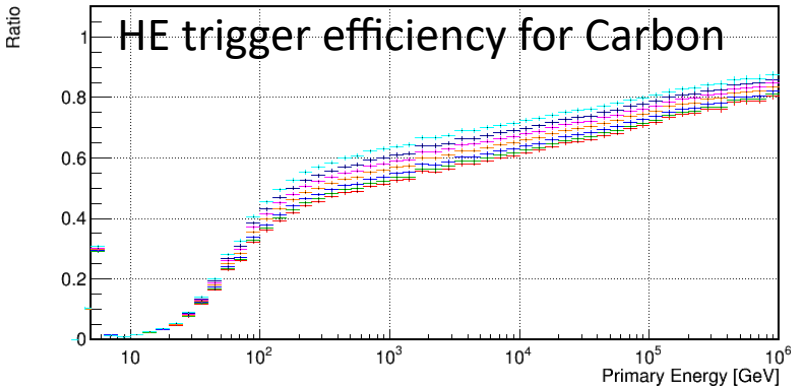
Trigger efficiency and cross-section

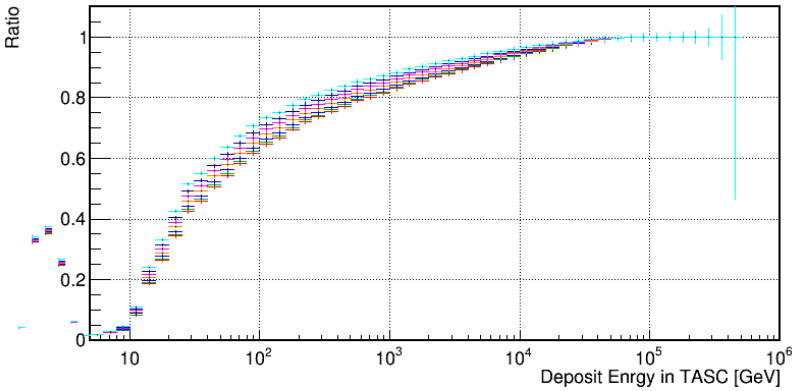
Trigger efficiency is depending on the cross-section.
To study the difference of the cross-section in MC,
MC events are reweighted by the interaction point

$w = \exp(-t/\lambda) / \exp(-t/\lambda')$,

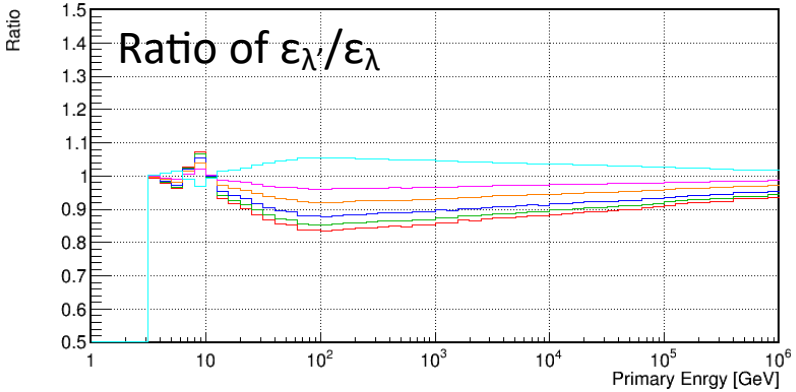
- t: depth of 1st interaction point (MC true info)
- λ: interaction length
- λ' : modified interaction length

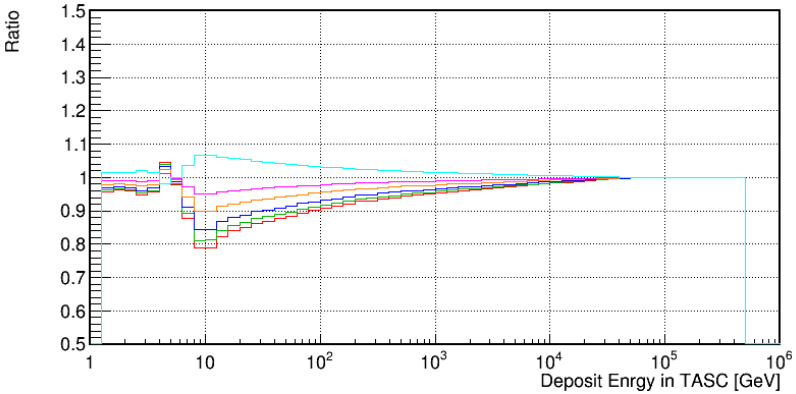




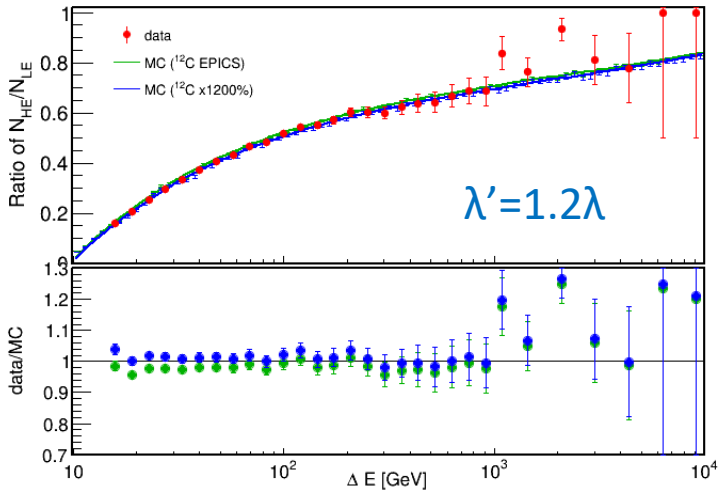


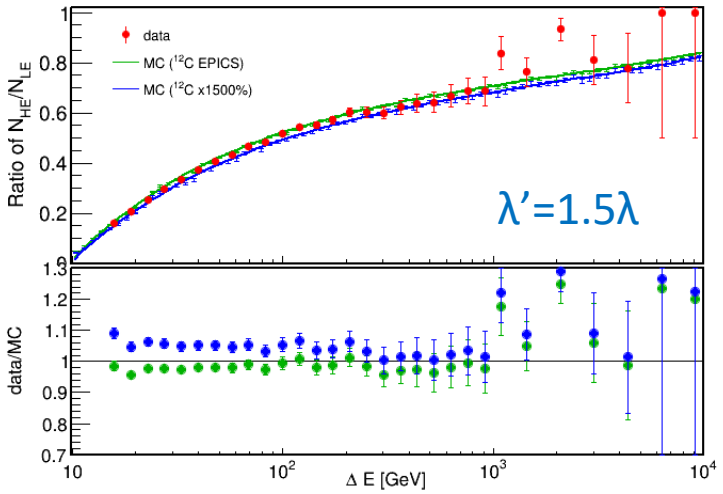
λ' = 0.8 λ
λ' = 1.2 λ
λ' = 1.5 λ
λ' = 2.0 λ
λ' = 2.5 λ
λ' = 3.0 λ

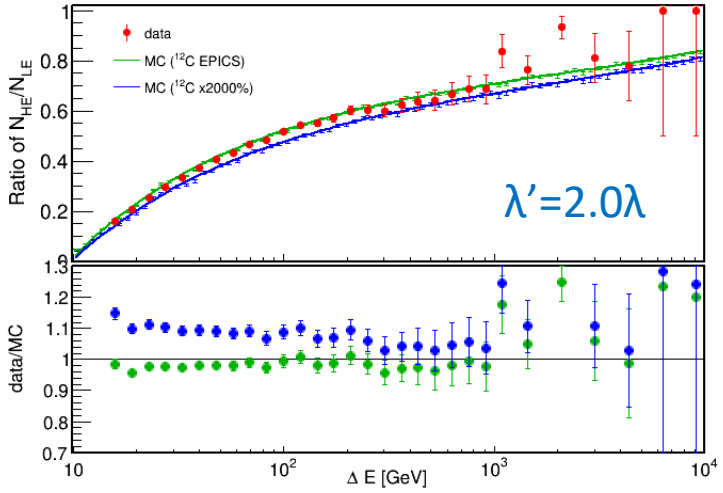


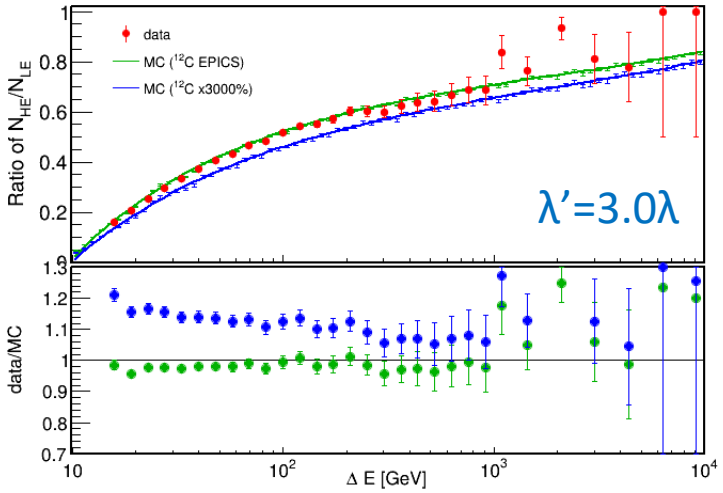


Trigger efficiency with LE triggered events







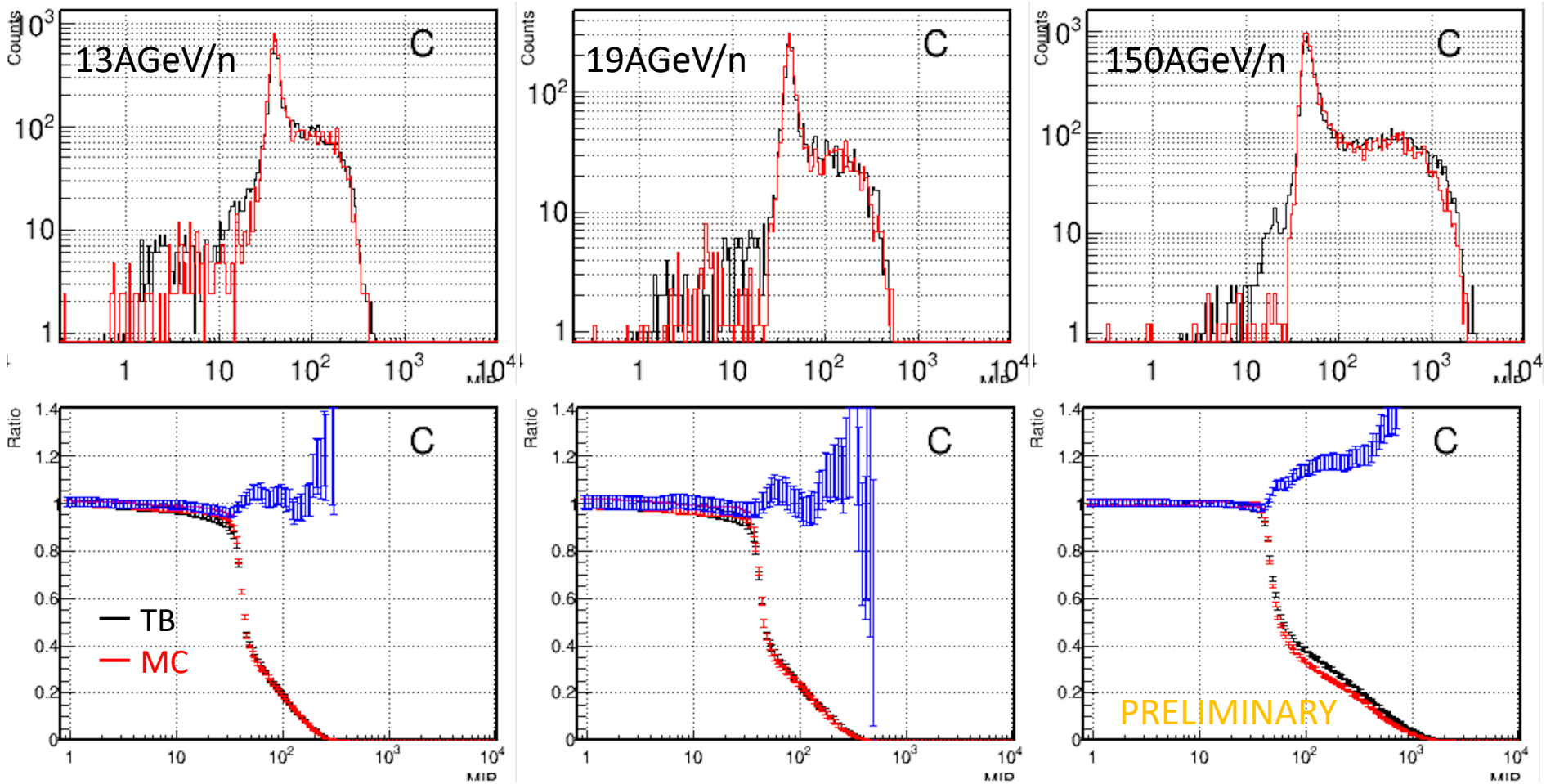


λ'>1.5λ is inconsistent with flight data.
Adjusting cross-section cannot explain the difference from AMS-02

Trigger efficiency with beam test

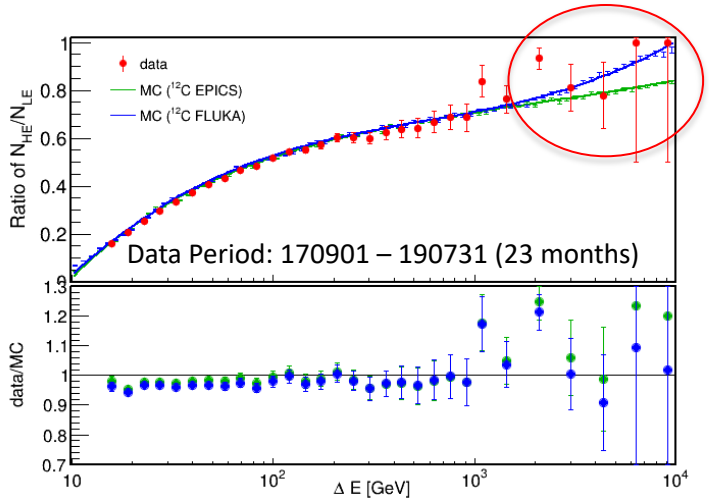
Data of 13, 19 GeV/n are required the charge consistency of IC-tracker and CHD
Data of 150 GeV/n is used only charge with CHD

➡ Contaminant events remain for 150 AGeV/n?

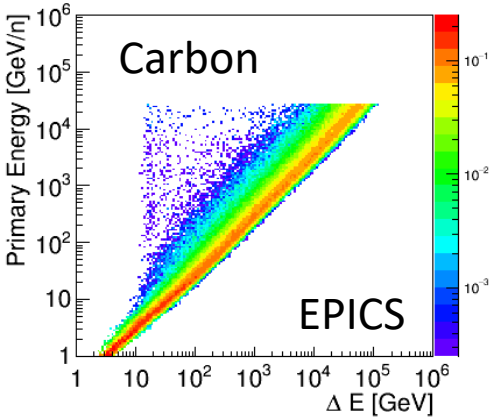


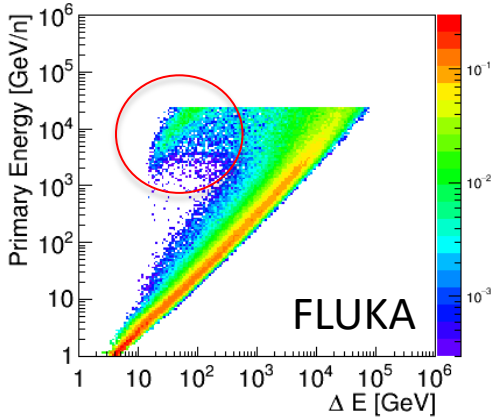
Difference of EPICS and FLUKA

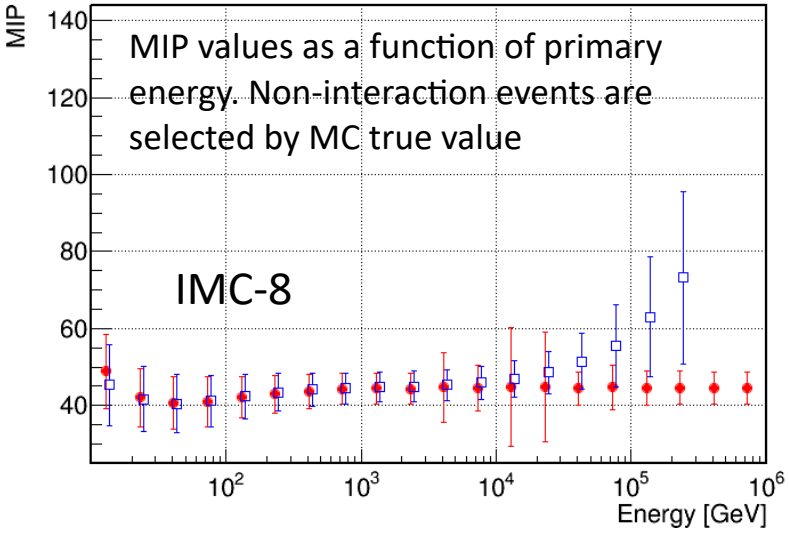
Efficiency of Fluka increase?

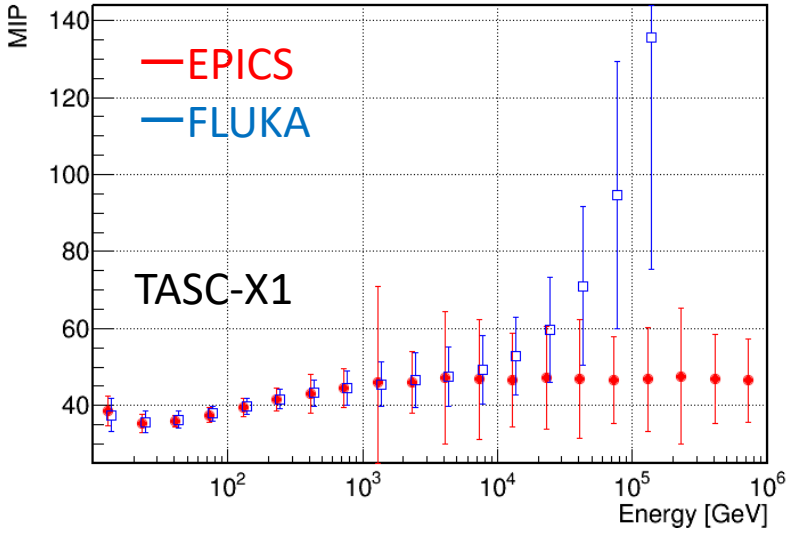


Events do not make large shower, but are triggered.



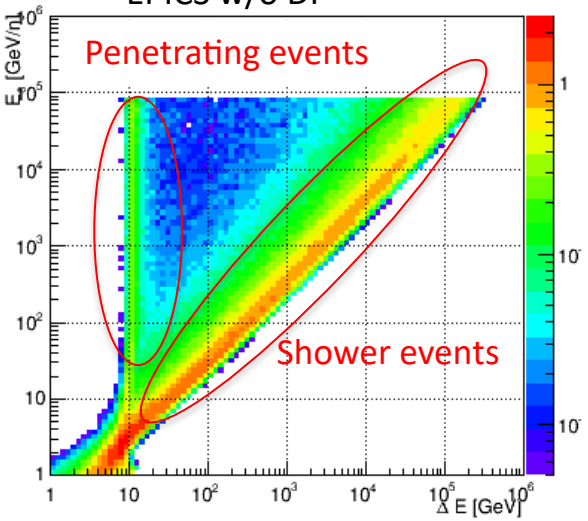




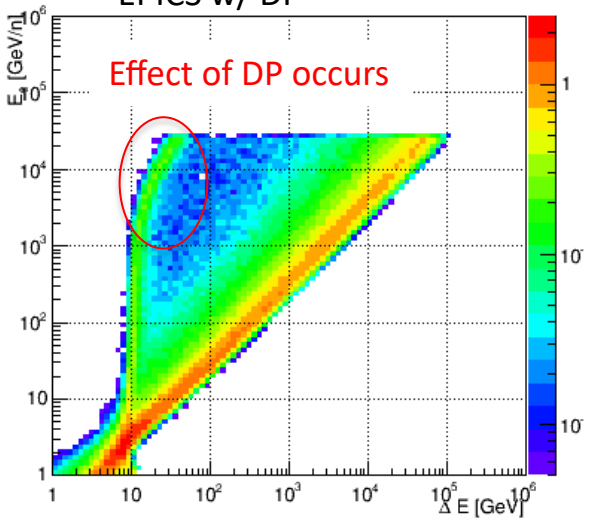


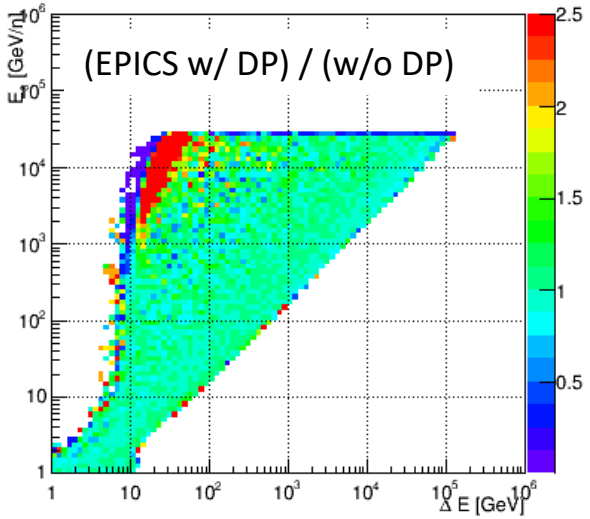
Primary energy vs observed energy in TASC

EPICS w/o DP

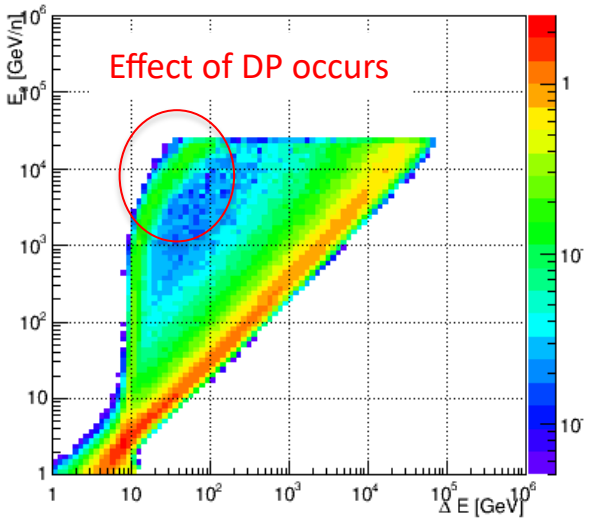


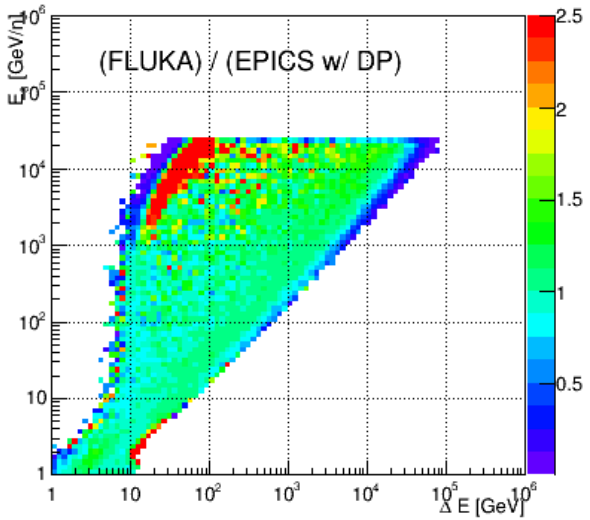
EPICS w/ DP





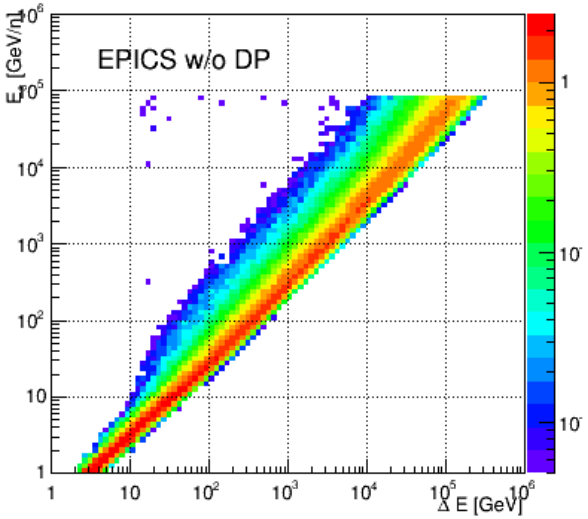
FLUKA

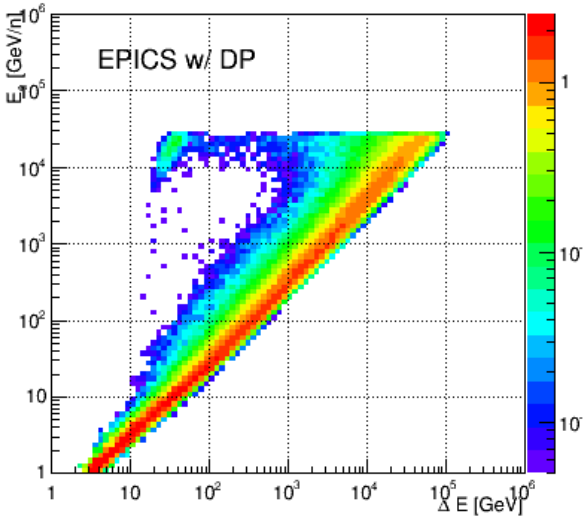


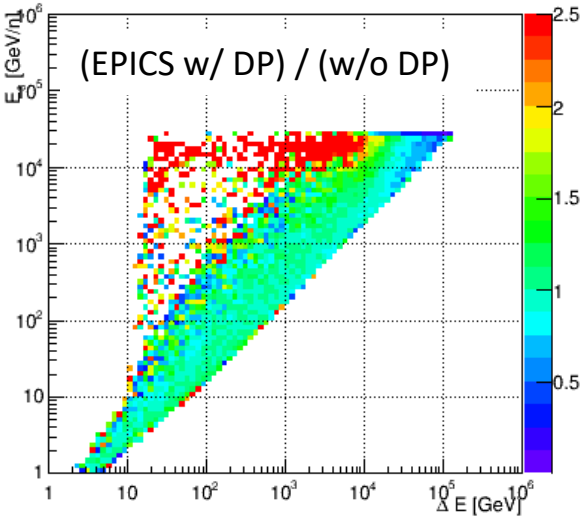


- Carbon
- LE trigger
  (all events)

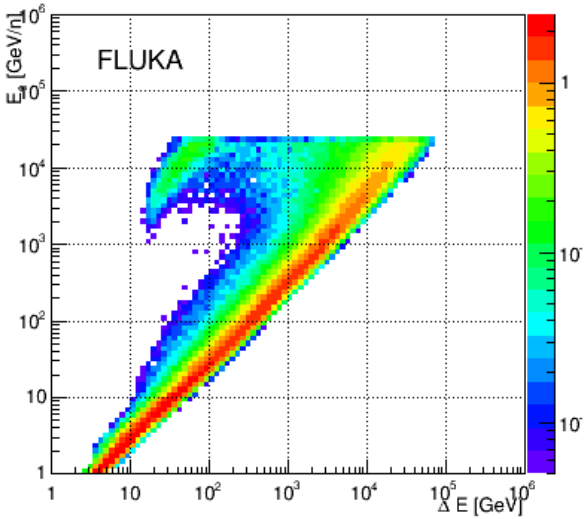
Primary energy vs observed energy in TASC

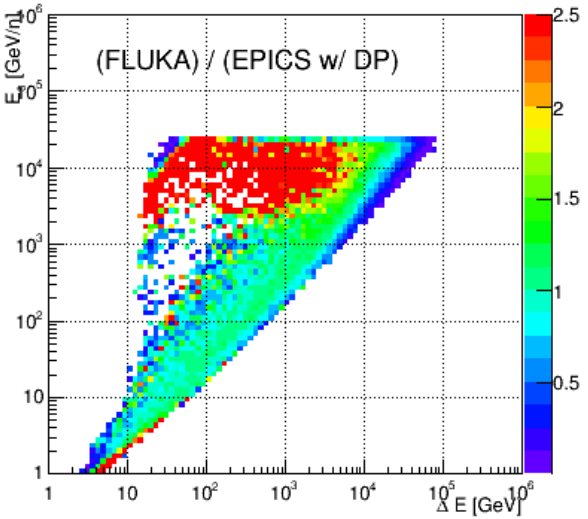






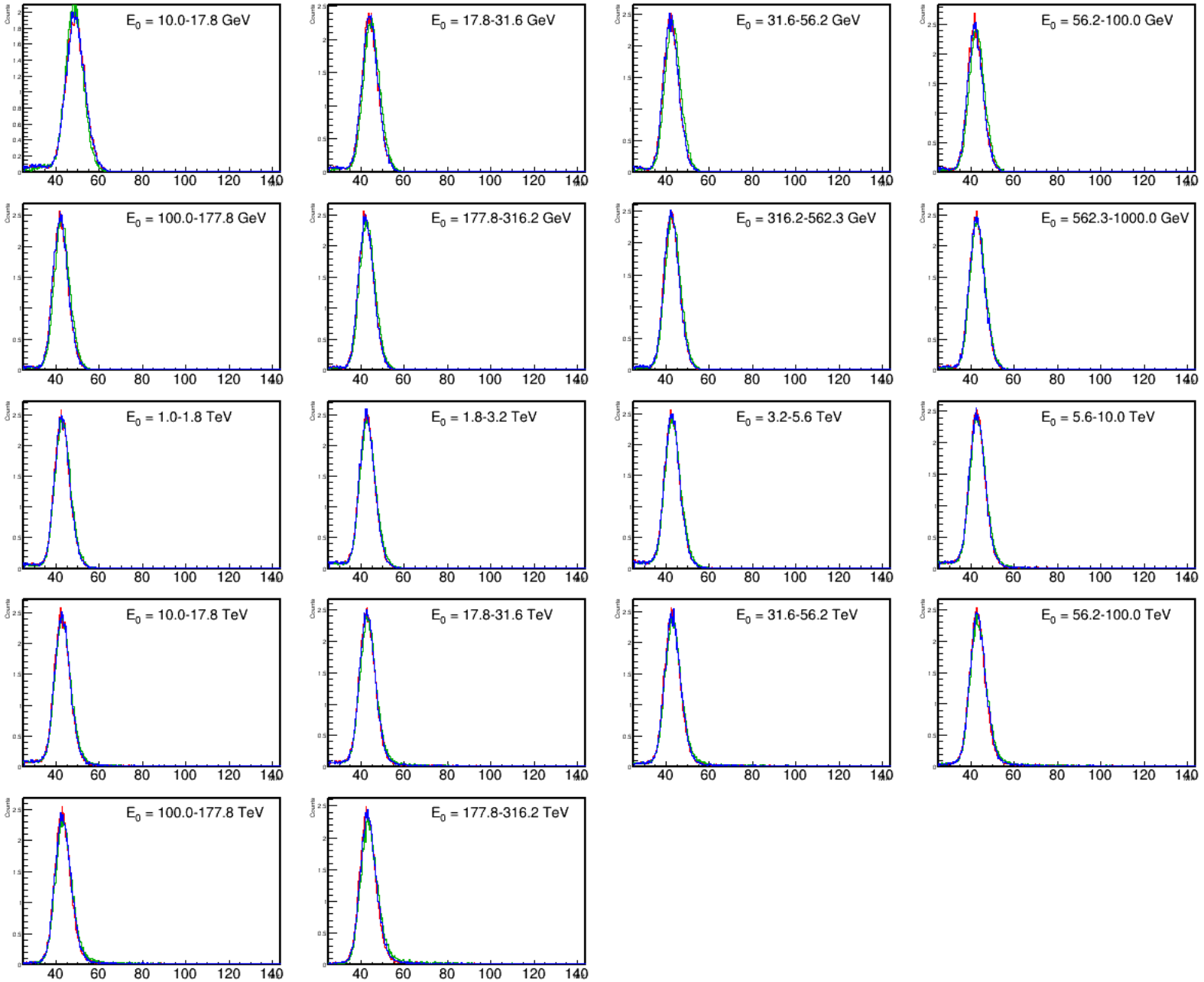
- Carbon
- HE trigger





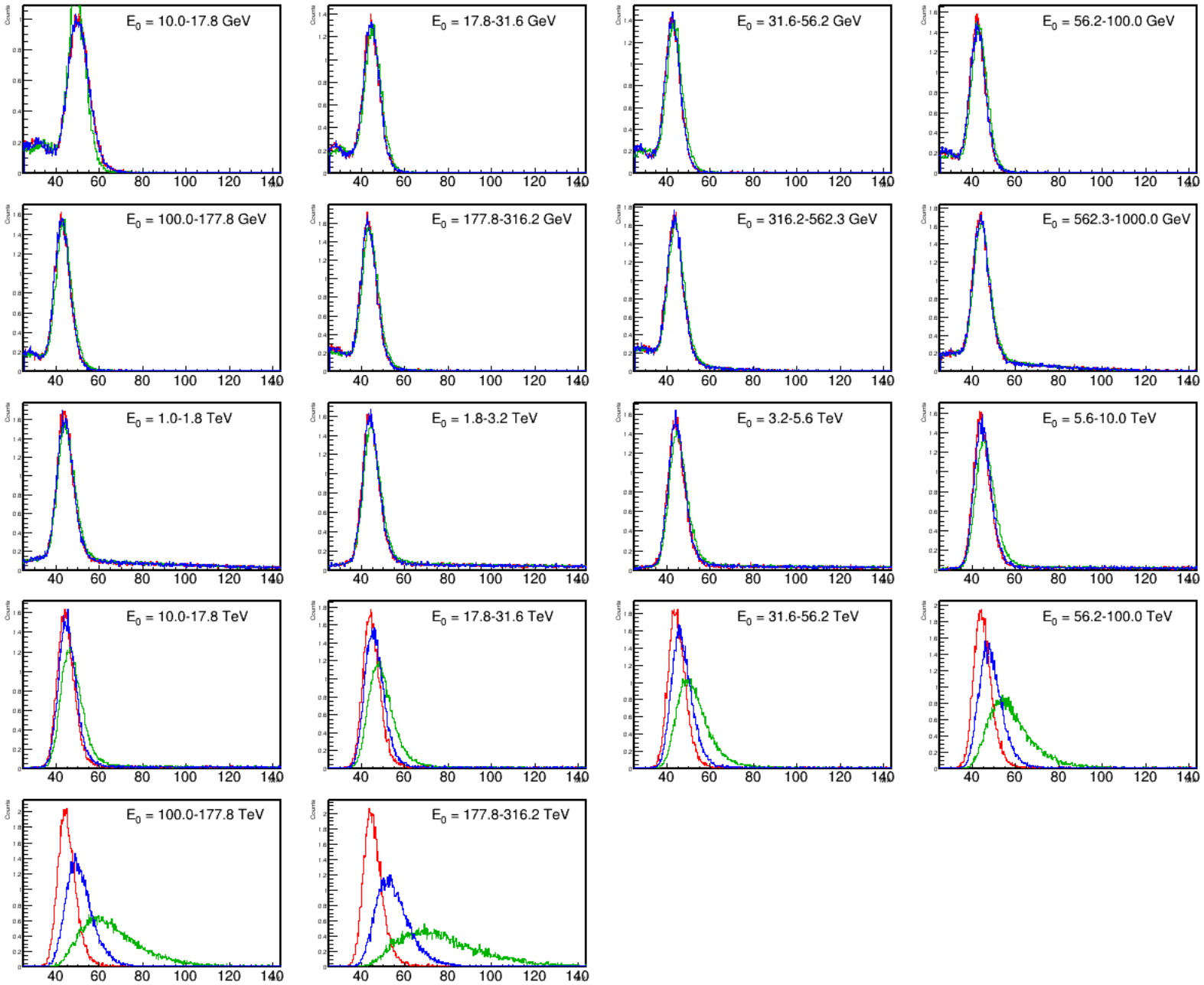
IMC 1st layer all carbon events

— EPICS w/o DP — EPICS w/ DP — FLUKA



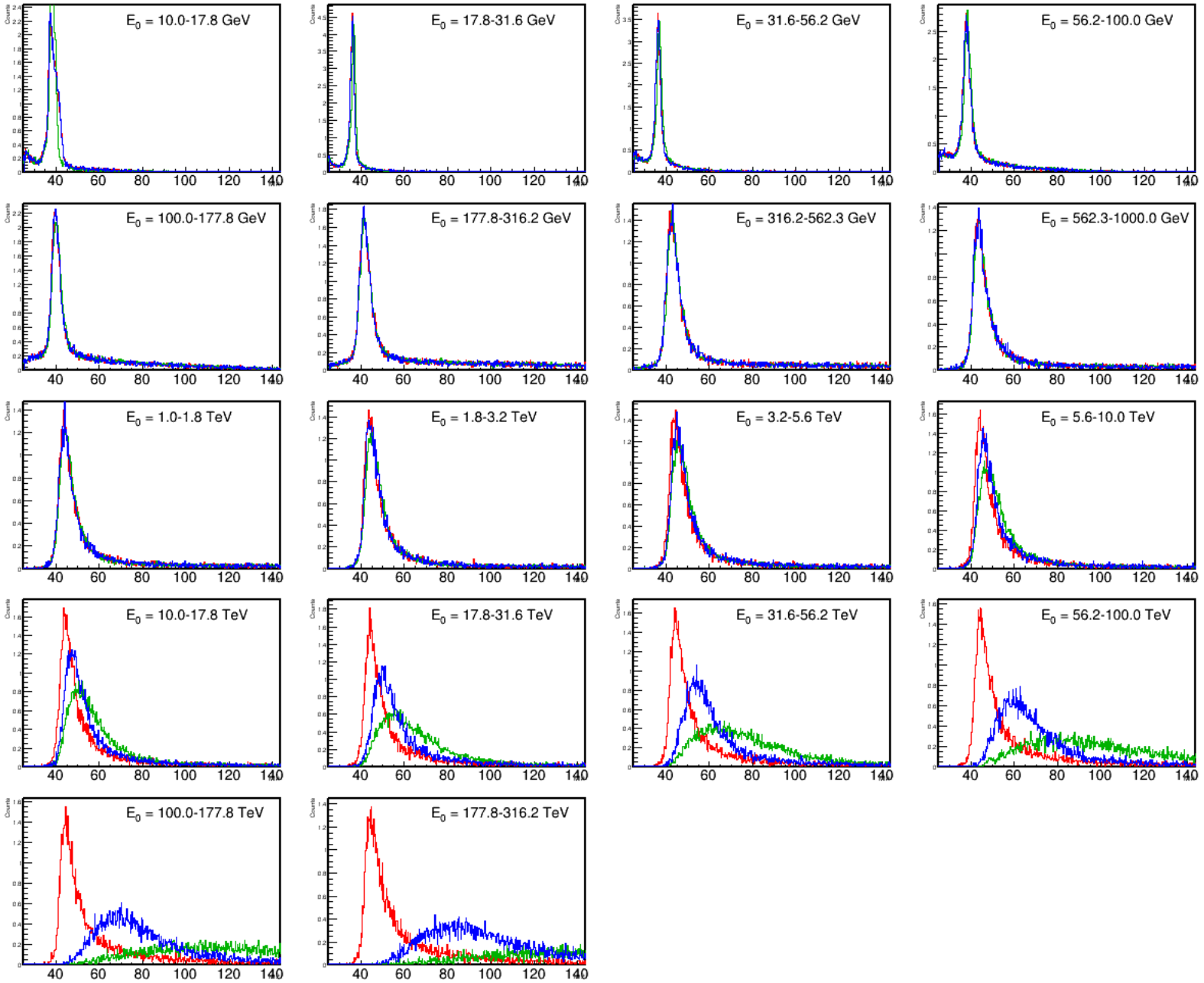
IMC 8th layer all carbon events

— EPICS w/o DP — EPICS w/ DP — FLUKA



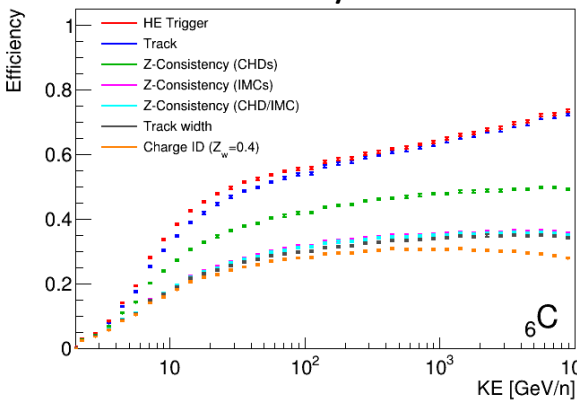
TASC X1 all carbon events

— EPICS w/o DP — EPICS w/ DP — FLUKA

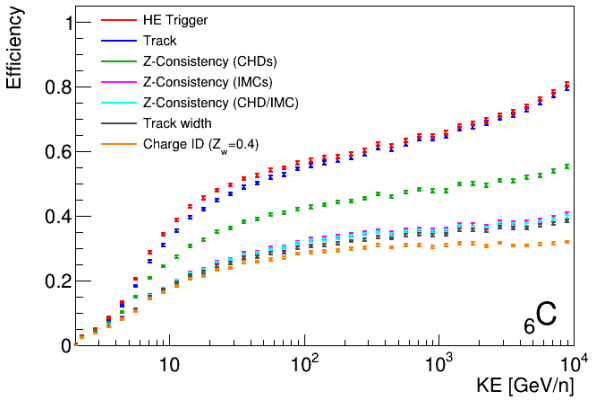


Efficiencies

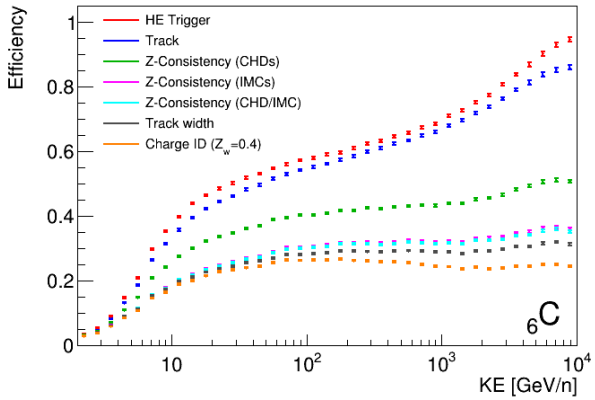
EPICS w/o DP



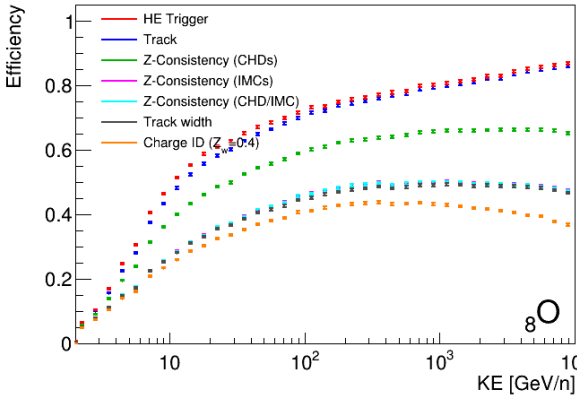
EPICS w DP



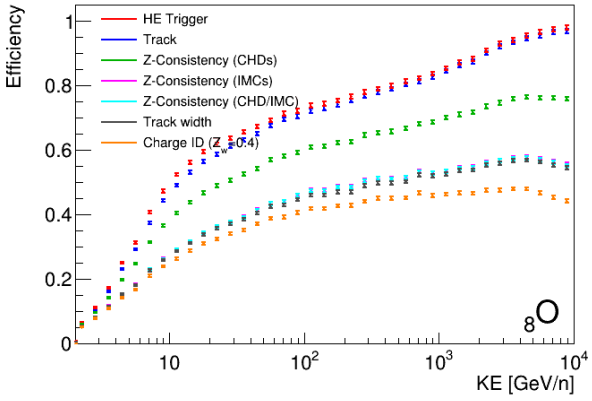
FLUKA



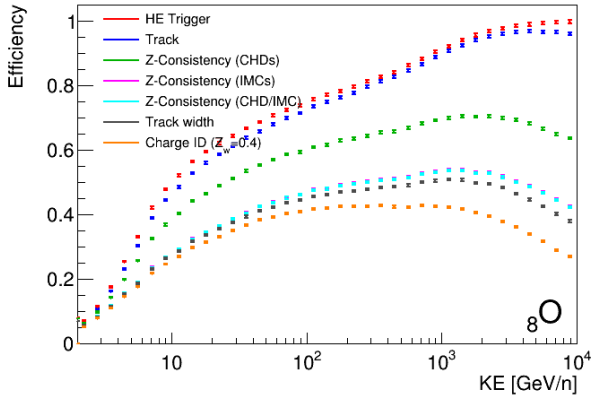
EPICS w/o DP



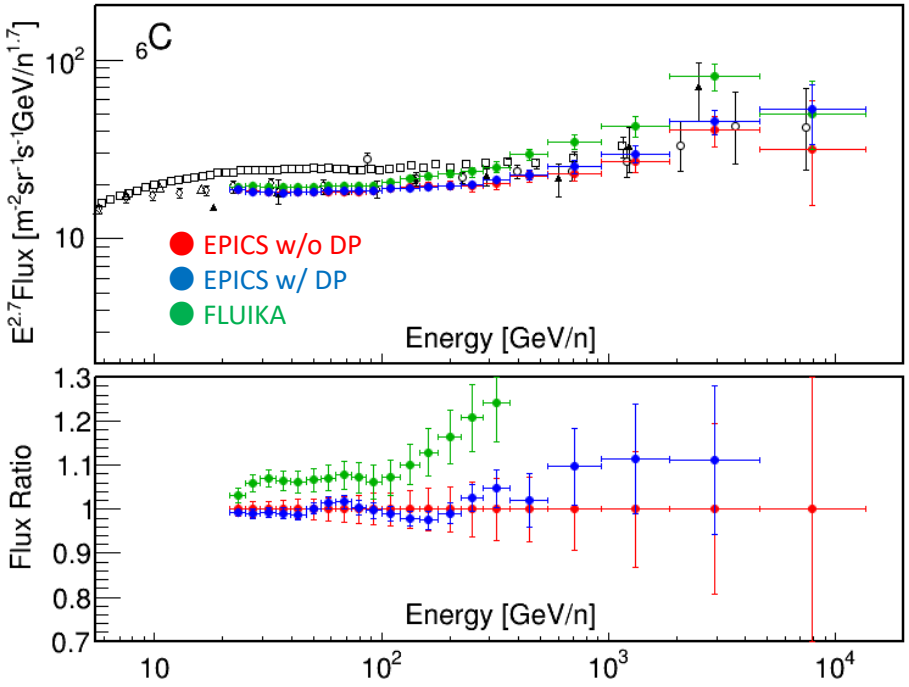
EPICS w DP

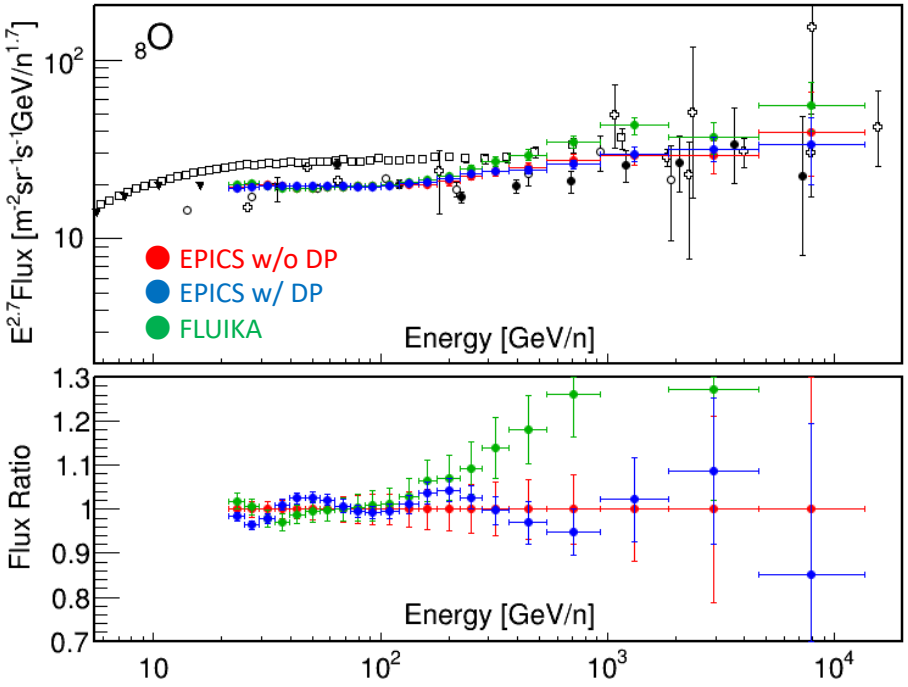


FLUKA



Difference of Carbon and Oxygen spectra





Analysis of Heavy Nuclei Spectra (Z>8)

■ Difference of heavy nuclei analysis from light nuclei analysis

- Charge consistency cut with IMC does not applied because IMC signal is saturated (Z>~12)

  (track width selection is used because it does not related with the saturation)

- Shower event selection with TASC is applied because the HE trigger efficiency is ~100% due to the large dE/dx

Shower event selection:

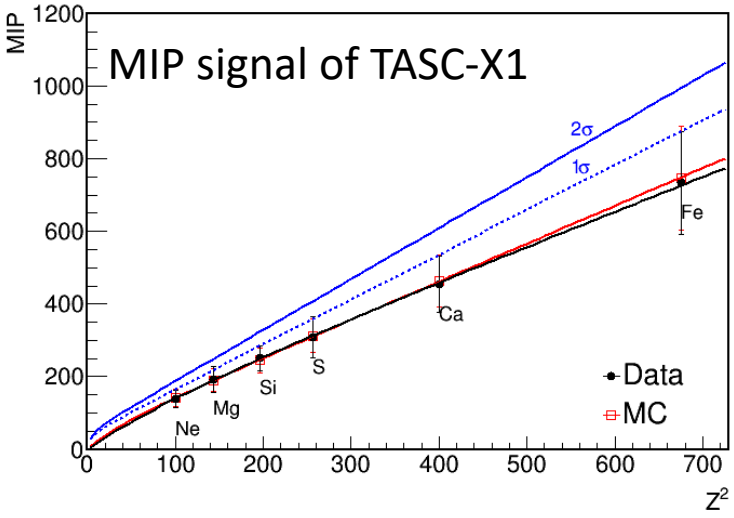
N_{TASCX1} > Nt(Z)

or N_{TASCY1} > Nt(Z)

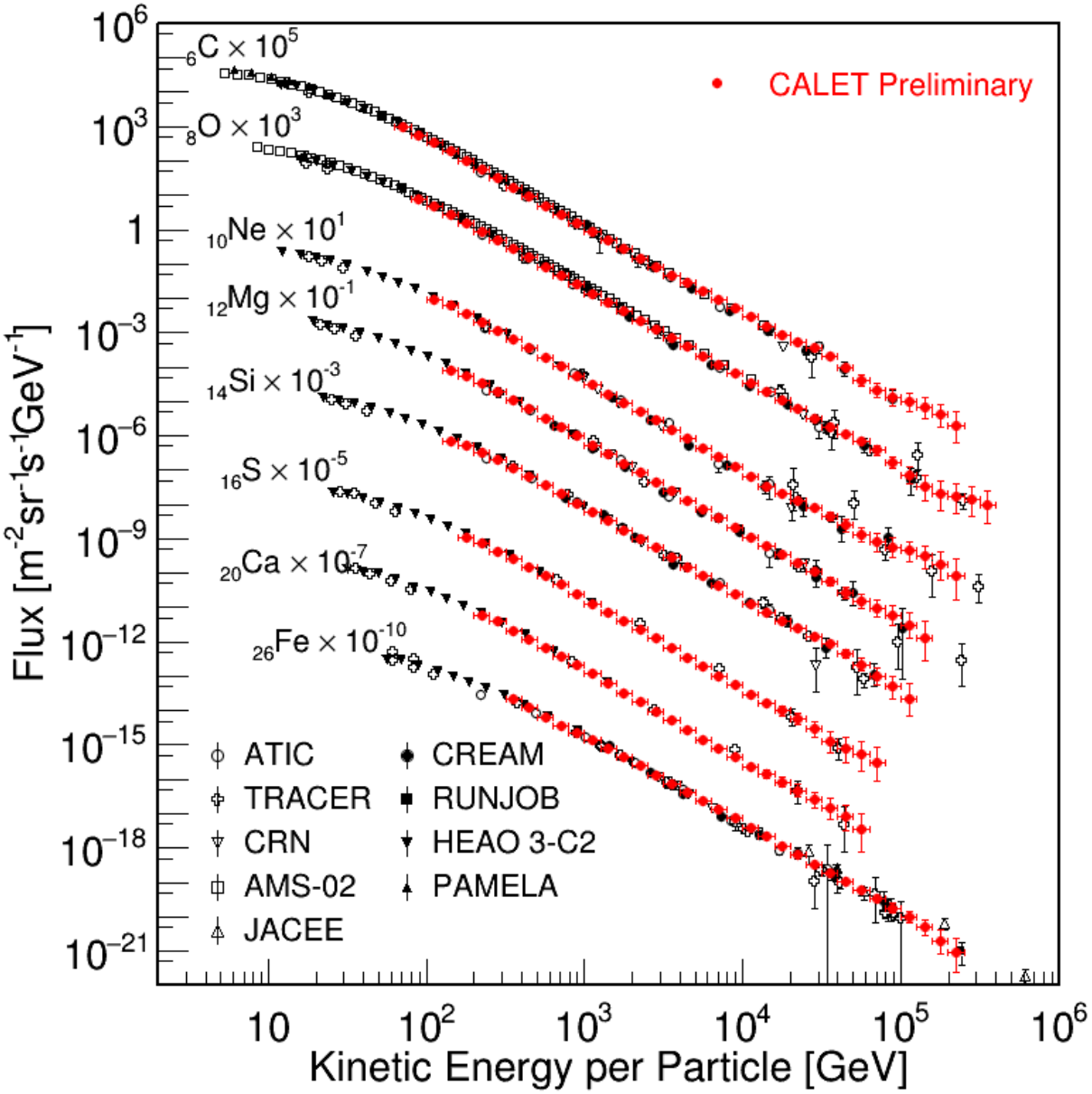
or N_{TASCX2} > Nt(Z)

or N_{TASCY2} > Nt(Z)

Nt(Z) is 2σ from the MIP peak of Z

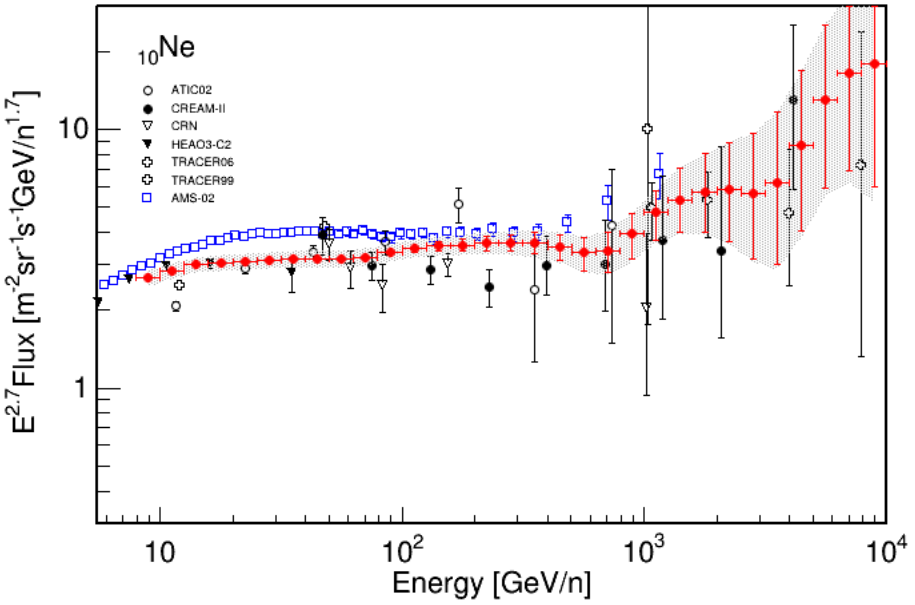


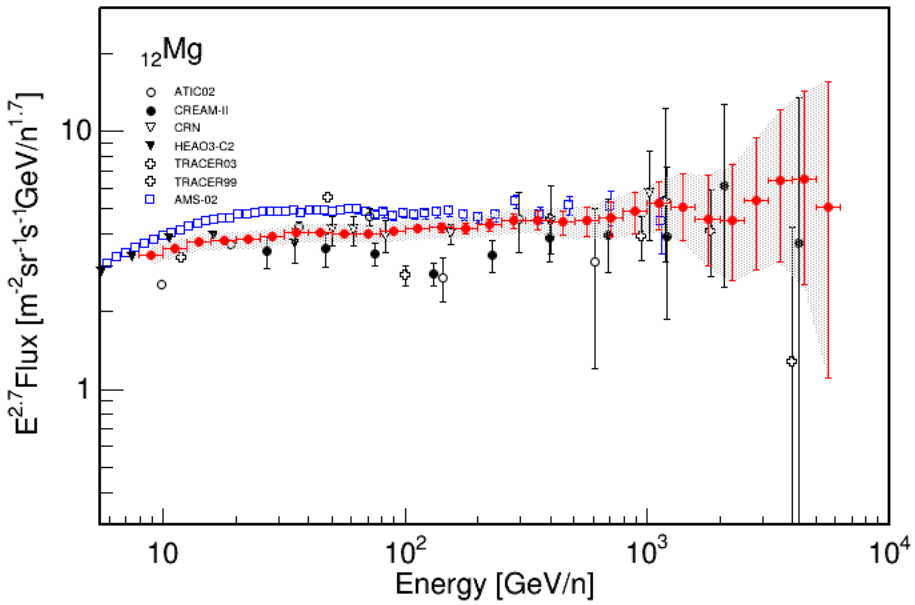
Heavy nuclei spectra

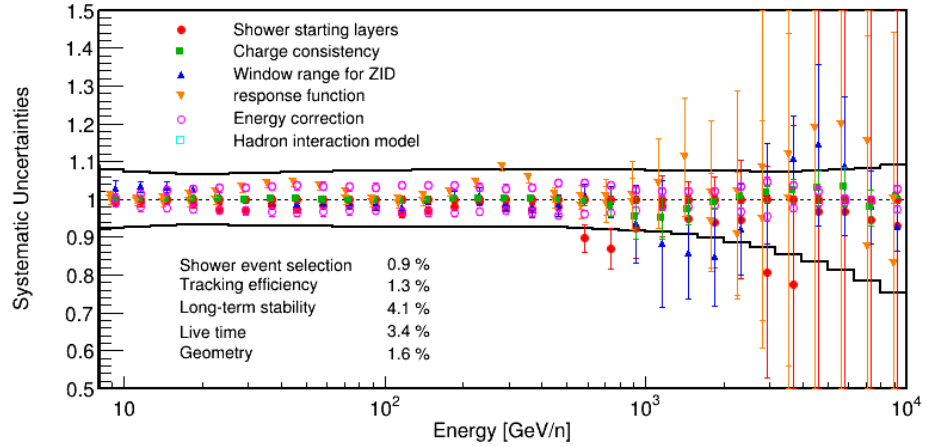


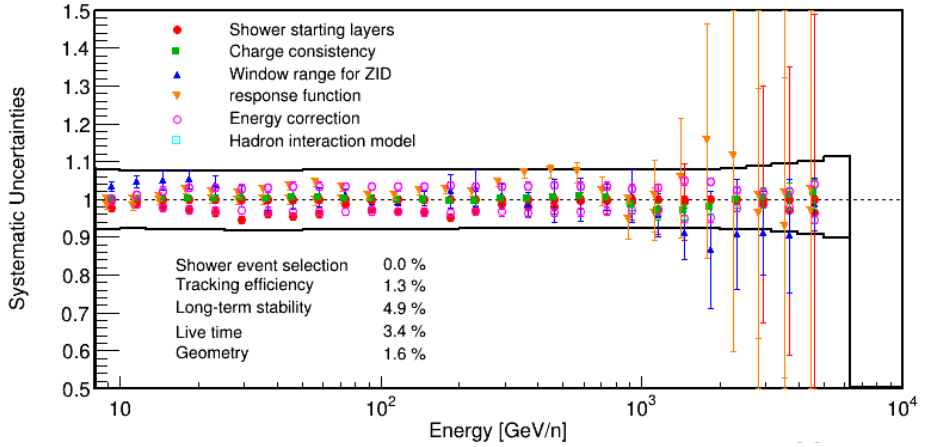
Period: 151013 – 190731
1389 days

Neon and Magnesium spectra

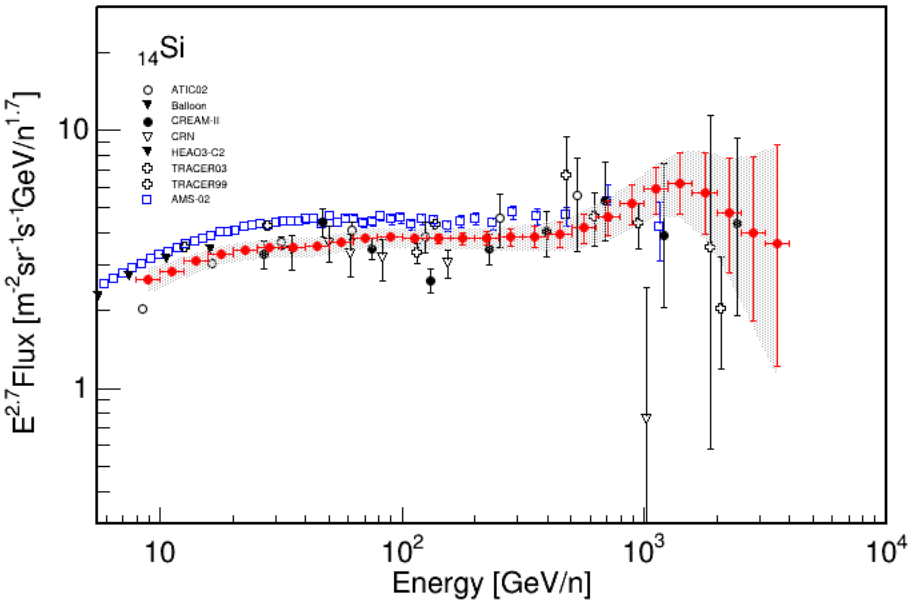


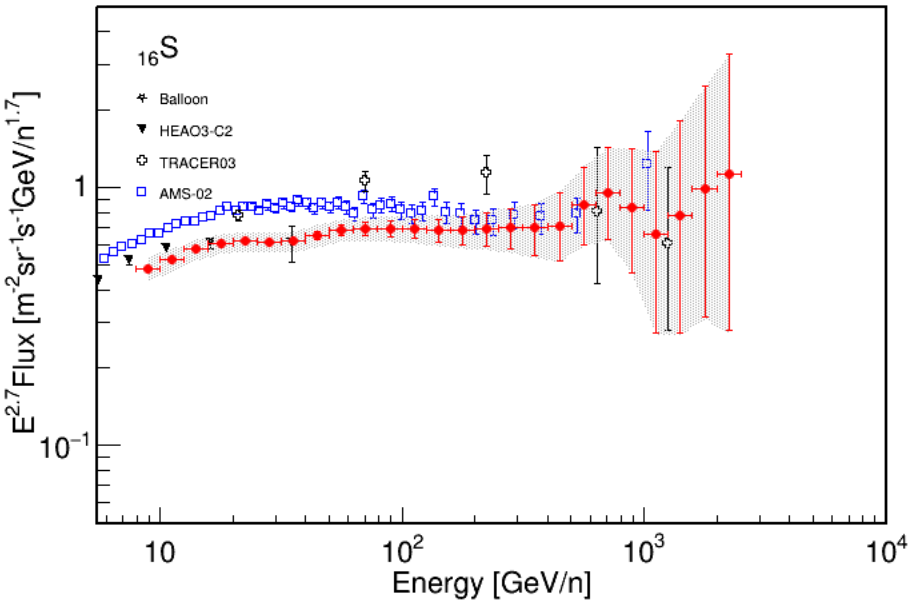


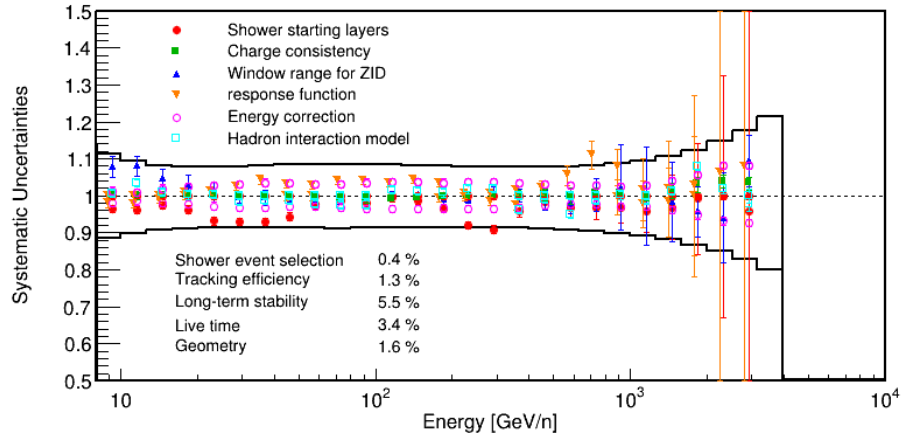


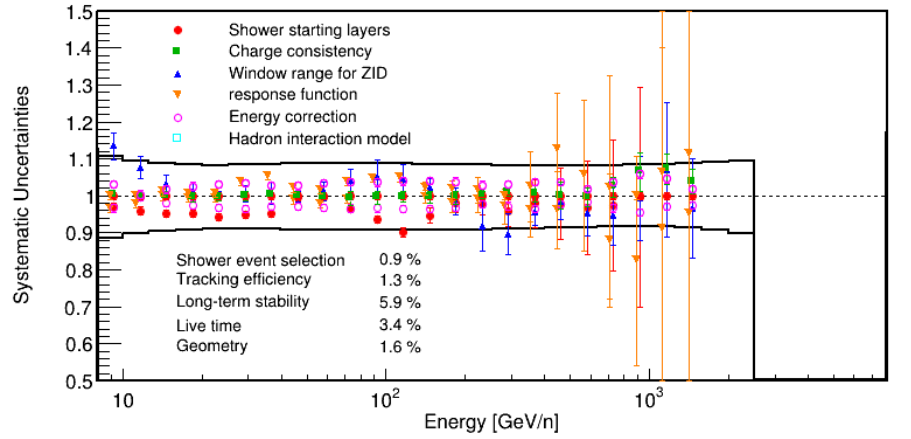


Silicon and Sulfur spectra

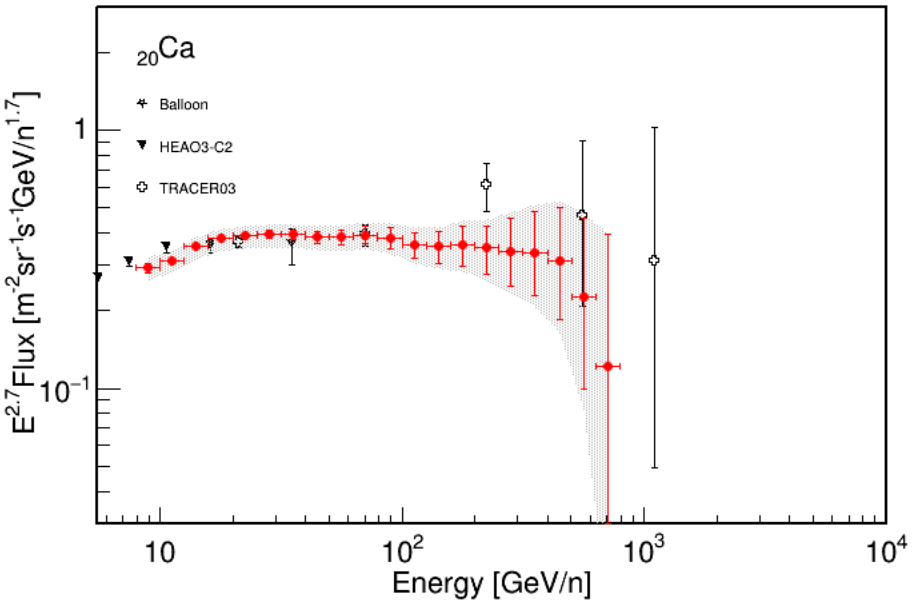


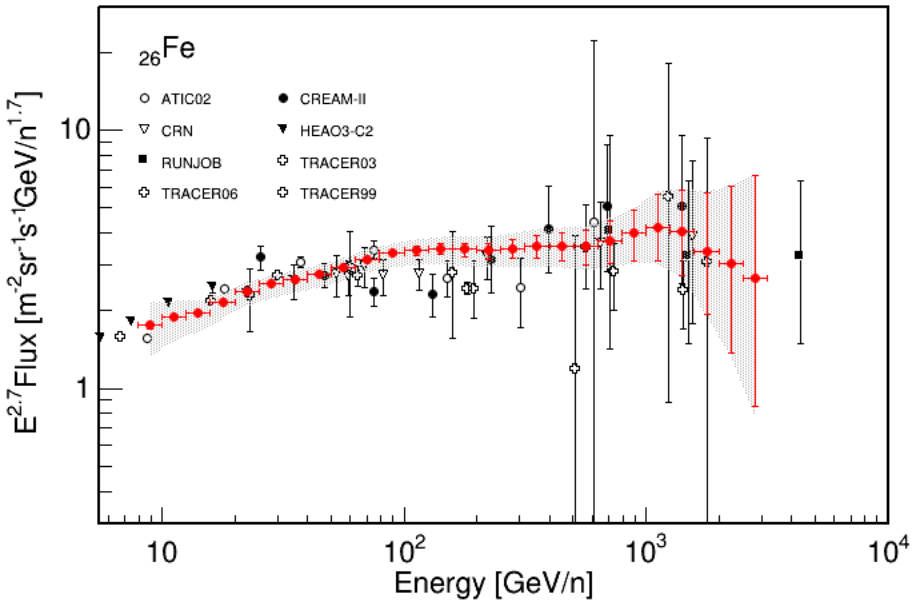


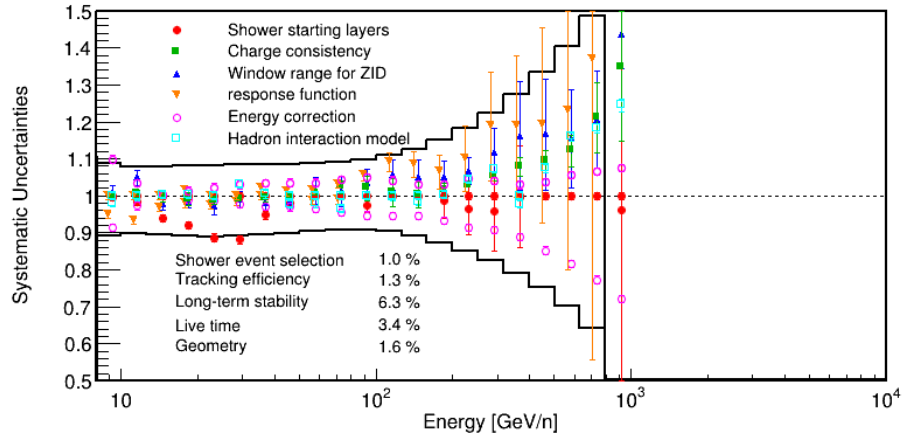


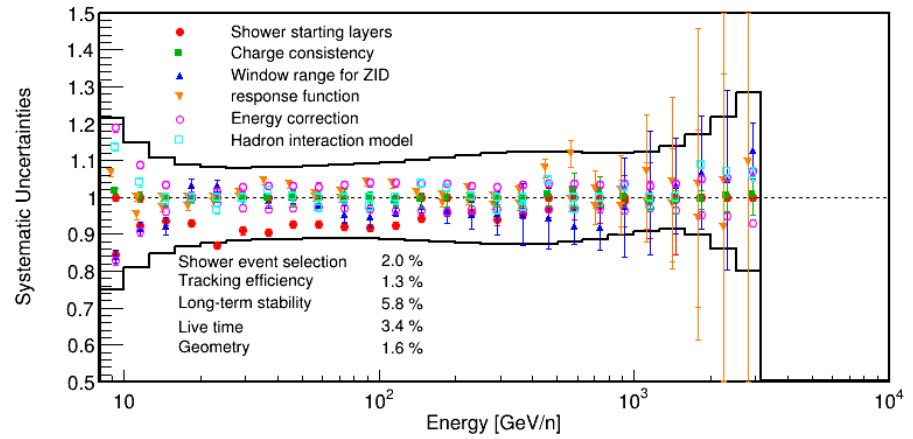


Calcium and Iron spectra









Conclusion

- B/C ratio is obtained from 1389 days of operation from 20 GeV/n to 5 TeV/n
  - Spectral index will be studied
- Carbon and Oxygen spectra are obtained
  - FLUKA spectrum is harder than EPICS -> check efficiency
- Difference from AMS-02 for nuclei spectra:
  - Although 12% energy correction or 25% efficiency correction are required, they are unlikely
- Nuclei spectra are obtained over 100TeV