A few considerations about the TW calibration

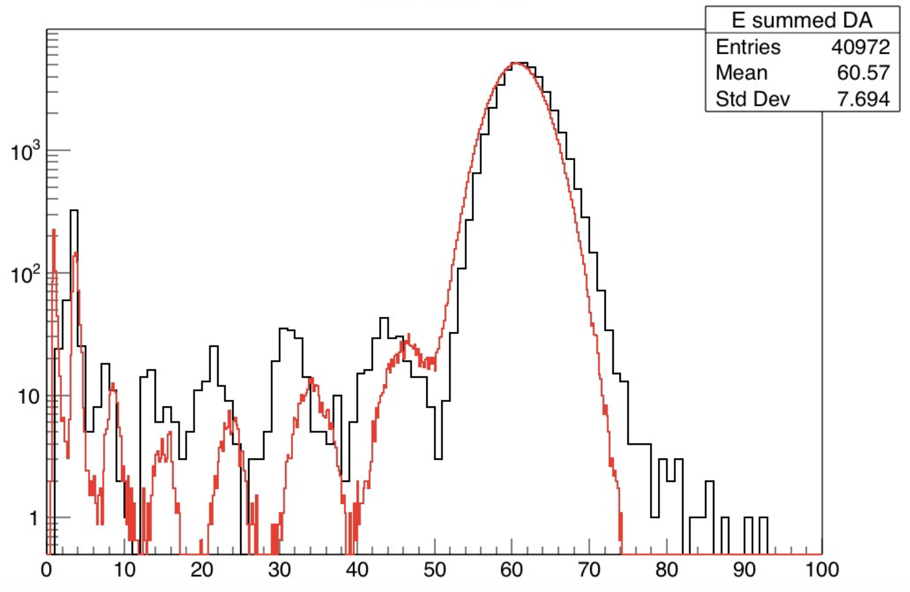
TW group

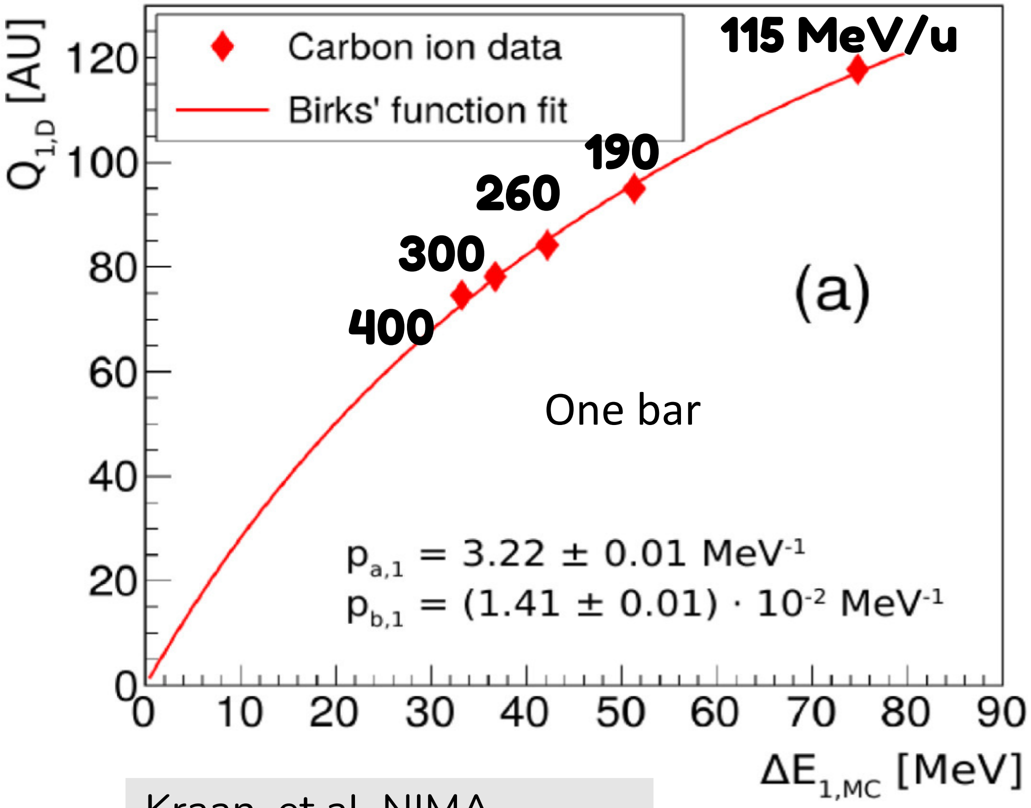
Introduction

- Calibration is essential in view of data-MC comparisons, calorimeter comparisons, etc.
- Calibration of TW allows to study in detail the material EJ230
- 2019-2020-: position-by-position calibration
- CNAO2021: See work presented in Strasbourg in May:
  - Bar-by-bar calibration
  - Based on stand-alone TW software
  - 1 bar (bar nr 27, or nr 7 of front plane in shoe)
- Today: extension
  - Fully based on SHOE (obtained decoded standalone TW data thanks code by to Giacomo)
  - All bars studied
  - Monte-Carlo-data comparisons of CNAO 2021 for all energies

Calibration of TW data 2019-2020

- Based on comparing expected energy with measured signal
- Mono-energetic beams without target, full scan of 400 positions
- Disadvantage
    - Time consuming to do in practise.
    - Calibrating on one site and data-taking in another doesn't work



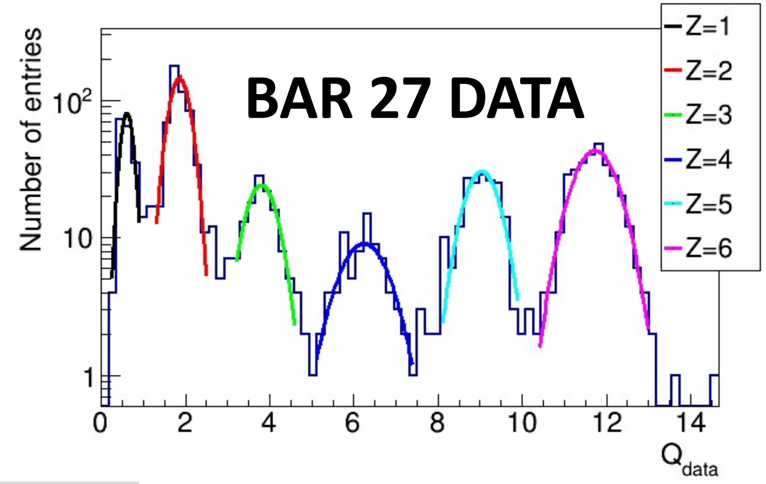


Kraan, et al, NIMA Volume 1001, 11 June 2021, 165206

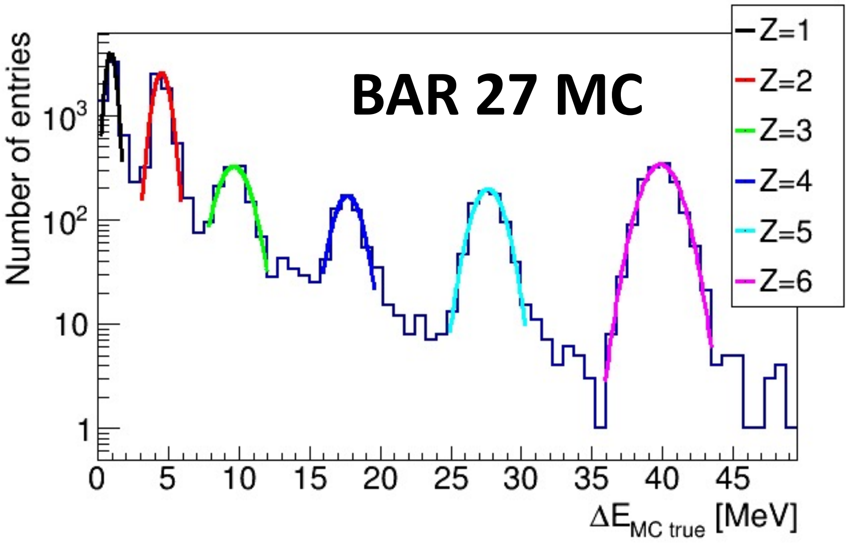
Calibration of TW: Strasbourg 2022

- New strategy proposed in May for CNAO2021 data: calibrate directly with fragments
- Repeat for all fragments (apart from protons→ 4 energies x 5 fragments=20 points)
- Example for 1 bar
- Data sample: min bias

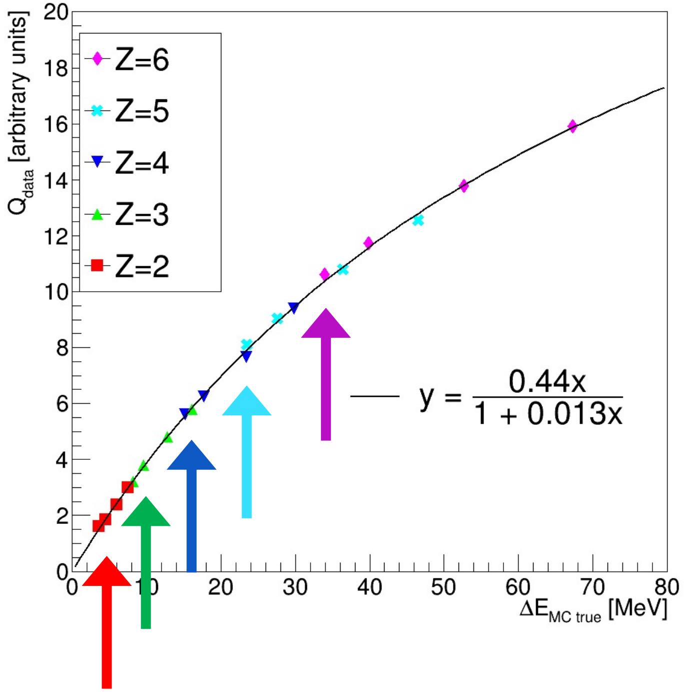
400 MeV/u carbon on carbon targetDATA



400 MeV/u carbon on carbon target



BAR 27 Curve

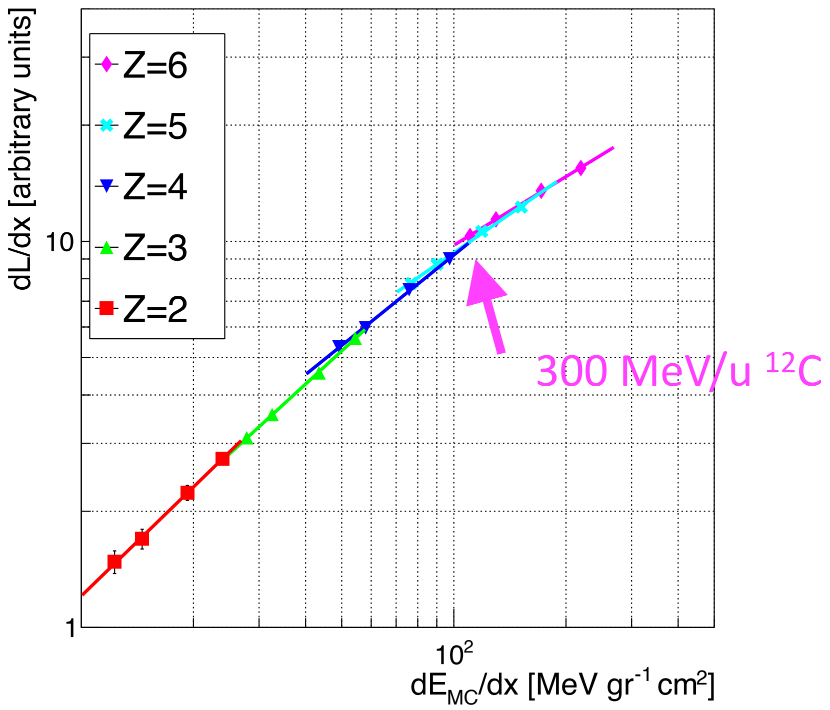


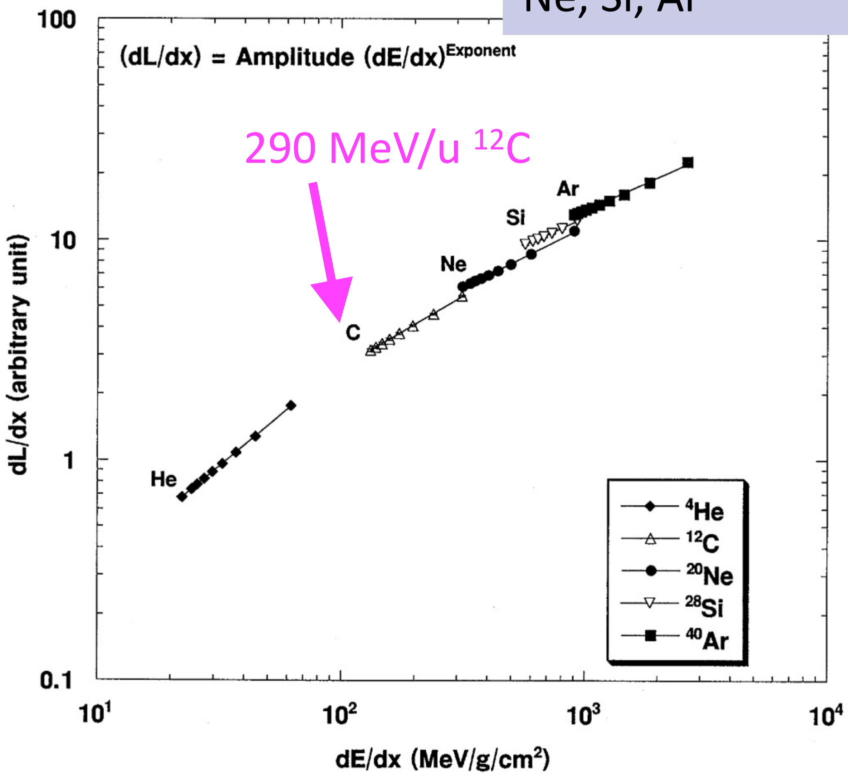
- Now repeated for all bars
- For bars with less than 6 fragments, only fitted the clearly present peaks

Before looking at FOOT calibration, tried to understand the 'group' behaviour (possible to correct?)

Does it correspond to expectations?

Fig 7 from Matsufuji 1999
Helium: 150 MeV/u
Carbon: 290 MeV/u
Ne, Si, Ar

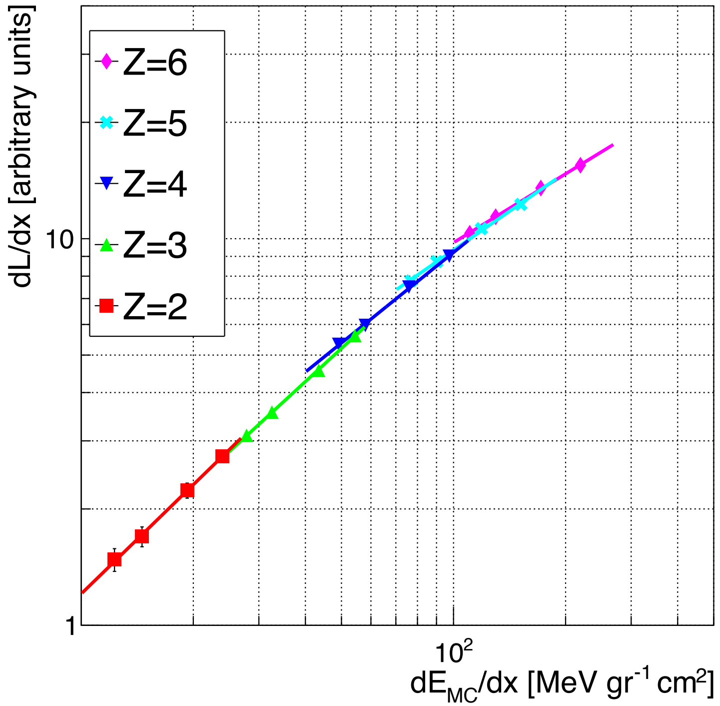


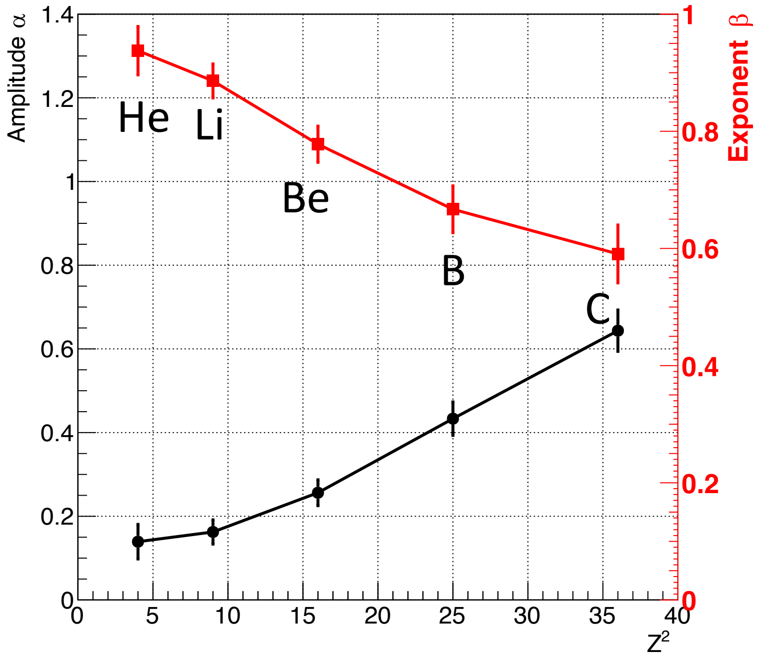


- Shape in accordance with Matsufuji et al ('grouping' seen)
- Dependence on particle species is small but present
- Our MC doesn't have Birks, light collection efficiencies, etc

- T. Ogawa, et al, Analysis of scintillation light intensity by microscopic radiation transport calculation and Fo¨rster quenching mode, PLoS ONE 13(8): e0202011, **2018**
- Matsufuji N, et al, The response of a NE102 scintillator to passing-through relativtisc heavy ions, NIM 437 **1999**, 346-353 (Data from 120 MeV to 18 GeV.)
- S Nyibule et al, Birks' scaling of the plastic light output functions for the EJ-299-33 plastic scintillator, N Nuclear Instruments and Methods in Physics Research Section A: Volume 768, **2014**, 141-145 (Data but energues from 2 to 20 MeV)
- Becchetti et al, Response of plastic scintillators detectors to heavy ions with Z<=35, E<=170 MeV, Nuclear Instruments and Methods in Physics Research Section A **1976**, 138 93-104
- Talk at IEEE By Masayori Ishikawa about quenching in plastic scintillators, partly in this energy range

Does it correspond to expectations?





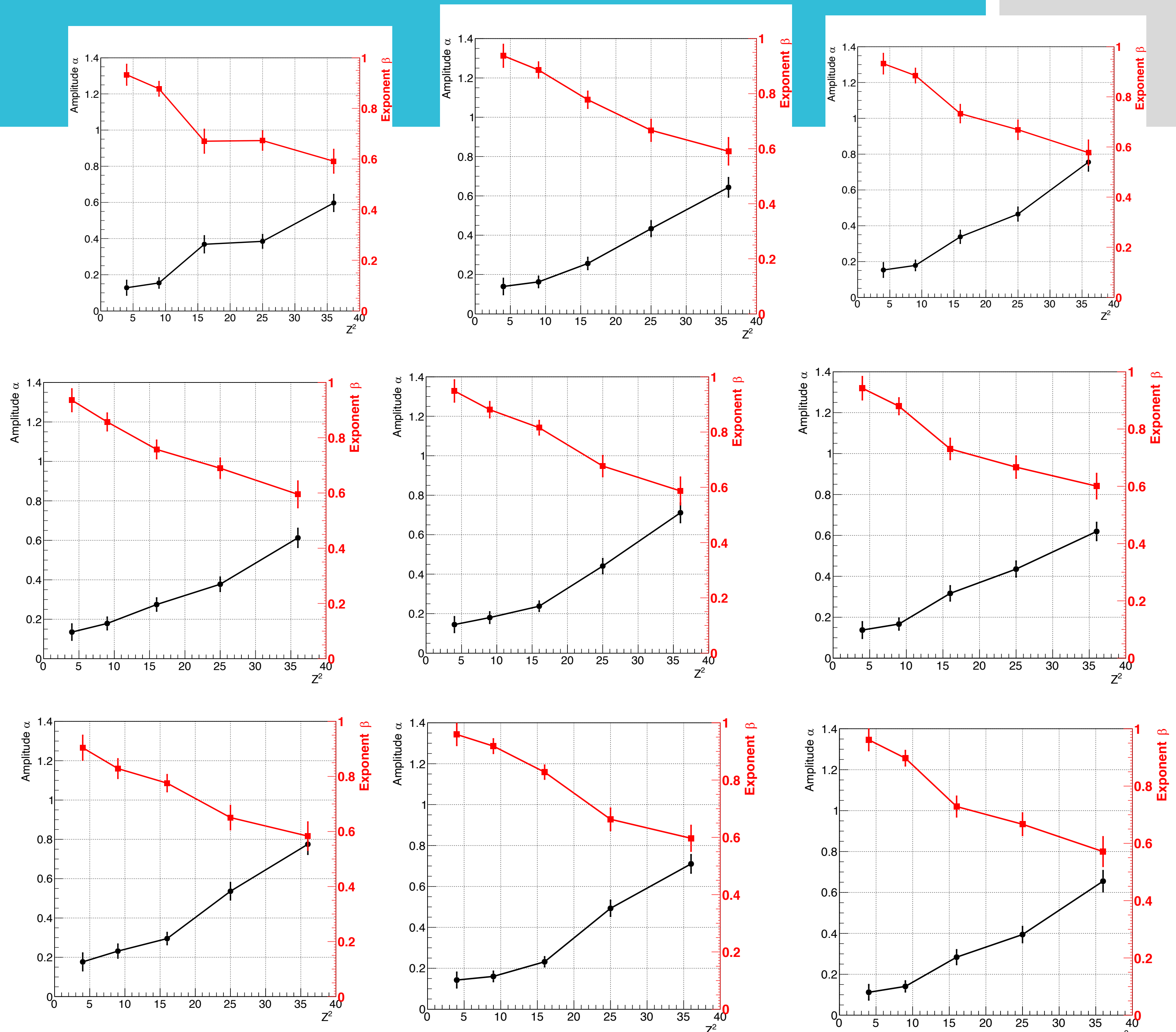
- Fit the curves with $\frac{dL}{dx} = \alpha \left[\frac{dE}{dx}\right]^{\beta}$
- Shape seems to be roughly in accordance with Matsufuji et al (see also backup slides)
- Why "grouping" in Z? Can we correct for it?
    - Quenching depends on species. Why exactly unclear…
    - Fragmentation in bar?
- Is there difference in off-even Z? Becchetti et al: "*The light output is slightly less for odd-Z ions compared to that for adjacent event-Z ions*"

Repeat for all bars

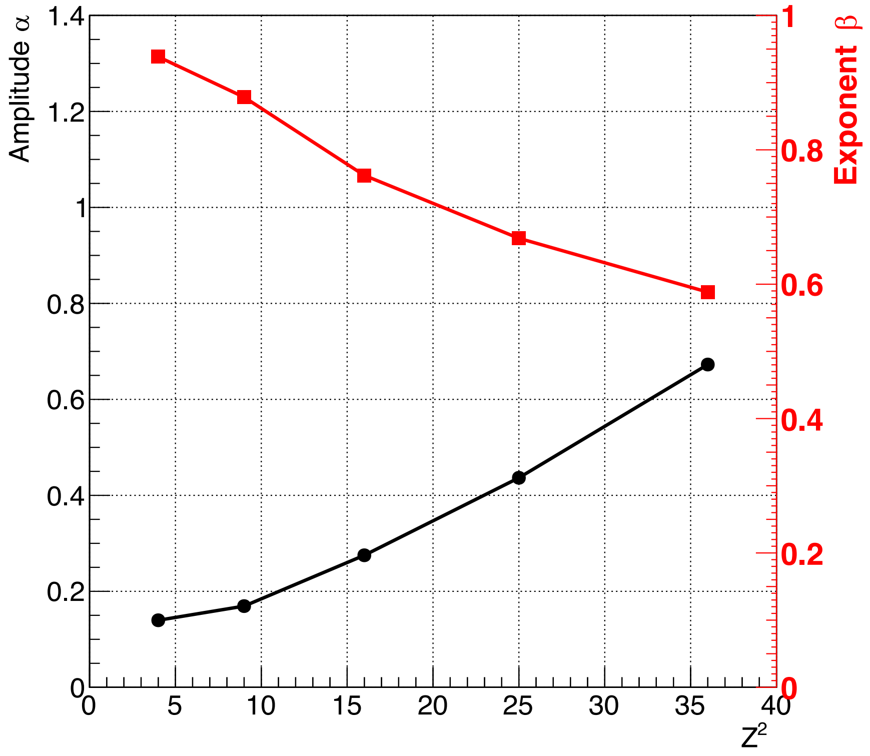
- Repeat for all bars with fragments up to Z=6

- Investigate if there is an effect for odd-even Z

→Take mean over all bars, weighted correctly with nr of entries



Repeat for all bars: odd Z effect???



Nothing special seen for odd Z

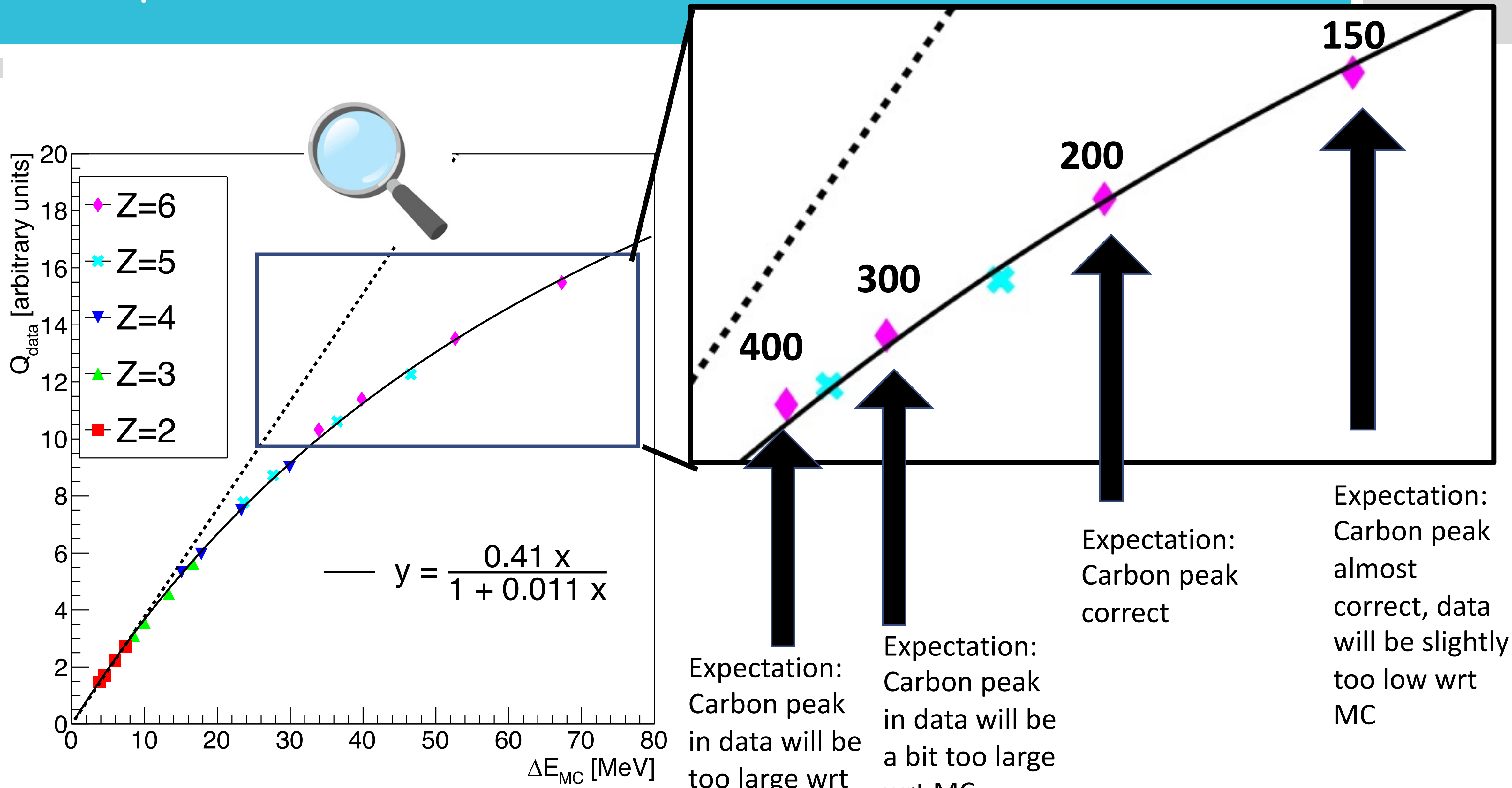
No correction

Should still investigate fragmentation

Now what about FOOT?

- Let's start with the approach in which we pretend it's all particle species independent, and we fit all data points to one curve.

Example calibration bar 27



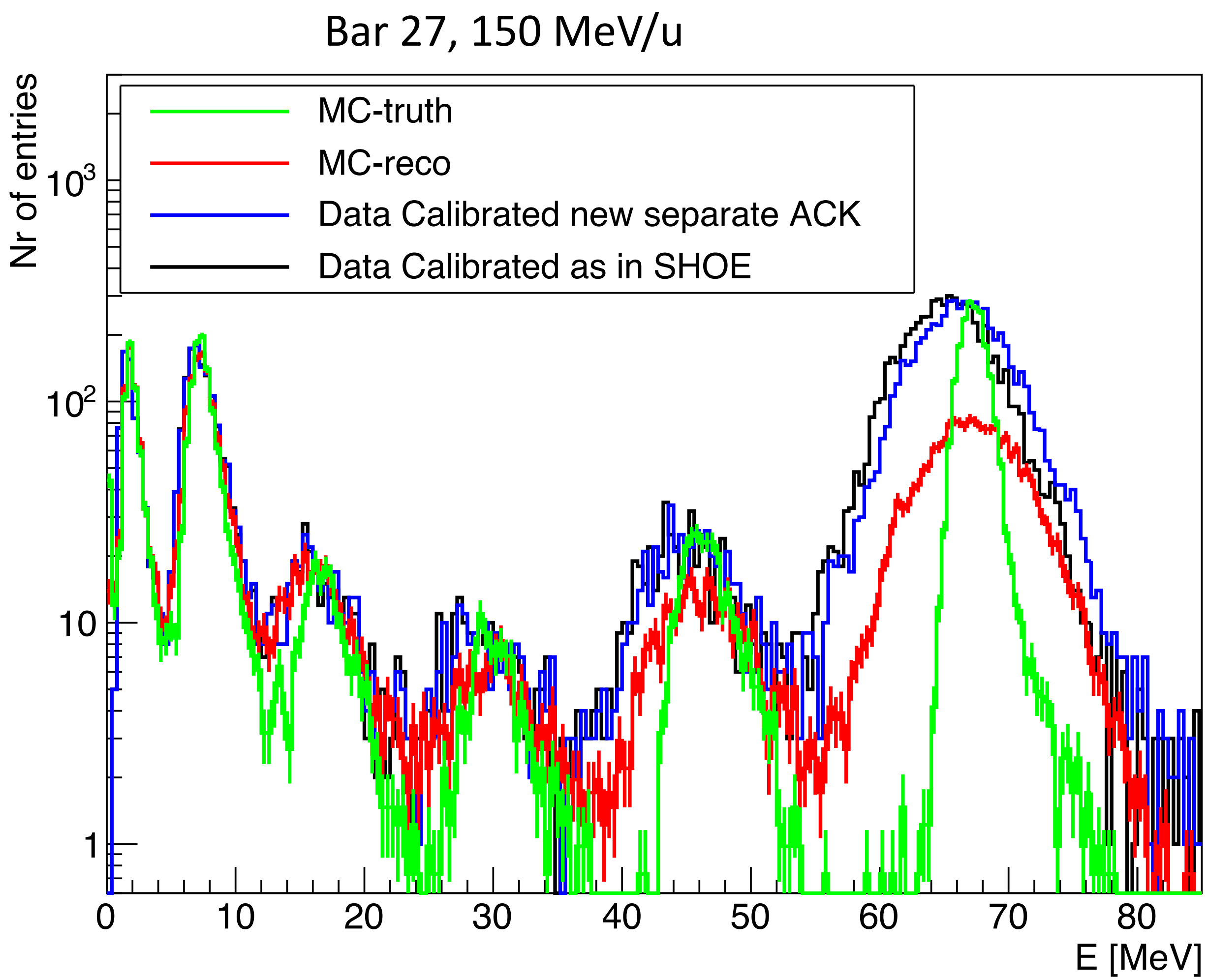
Expectation: Carbon peak in data will be too large wrt MC

Expectation: Carbon peak in data will be a bit too large wrt MC

Expectation: Carbon peak correct

Expectation: Carbon peak almost correct, data will be slightly too low wrt MC

Calibrate with single curve for all energies



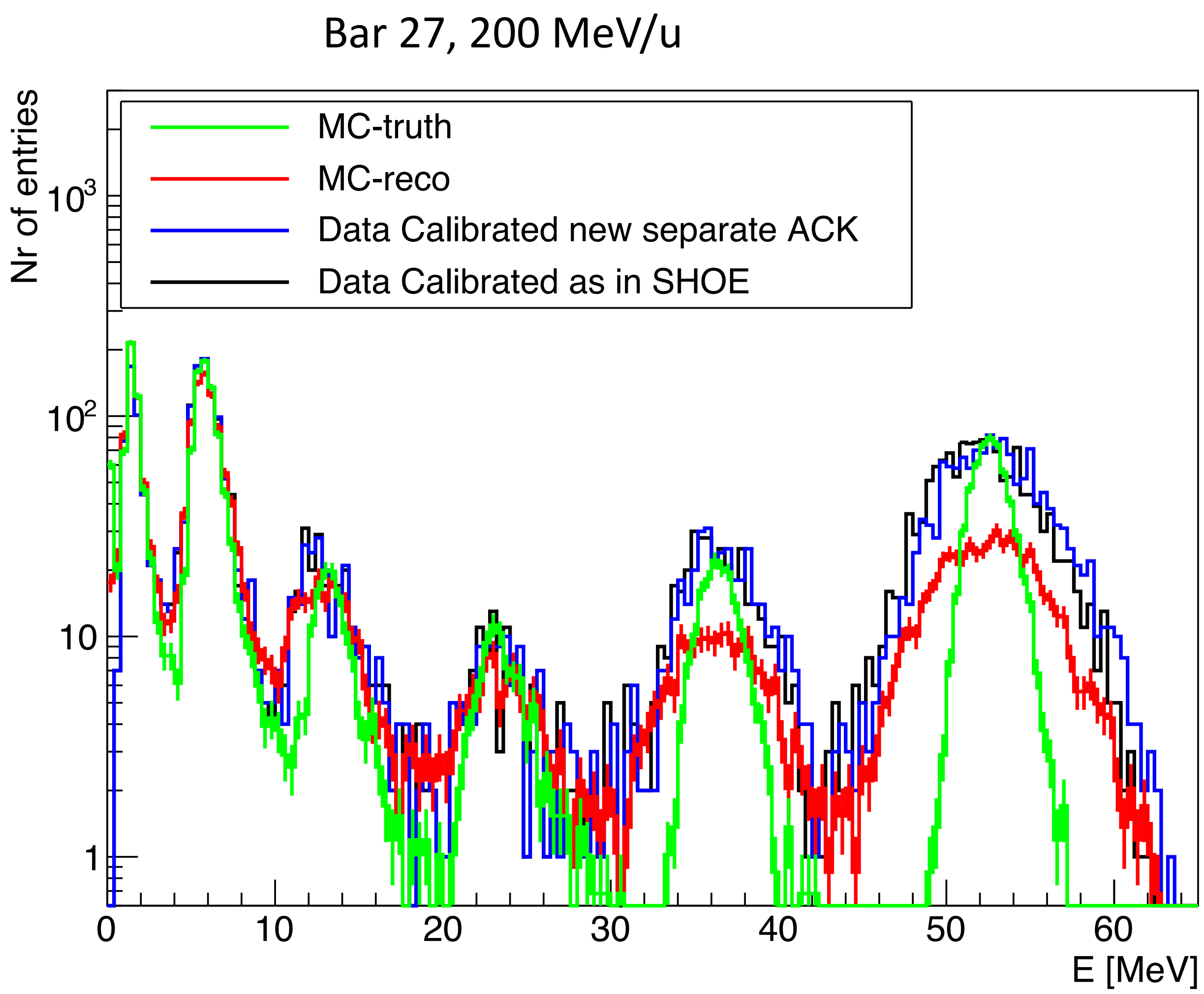
Observations from comparing red with blue

- **Position of peaks:**
  - Carbon peak: data are slightly too low wrt MC (as expected)
- **Height of peaks:**
  - Not fully correct. Normalized with nr of primaries (no efficiencies). But data are higher than expectations for Z=4,5,6

    →see slide 15 and more
- This is an example of 1 bar, but the situation is the same for the other bars

Not ideal if we want to publish plots and comparisons between MC and data!!

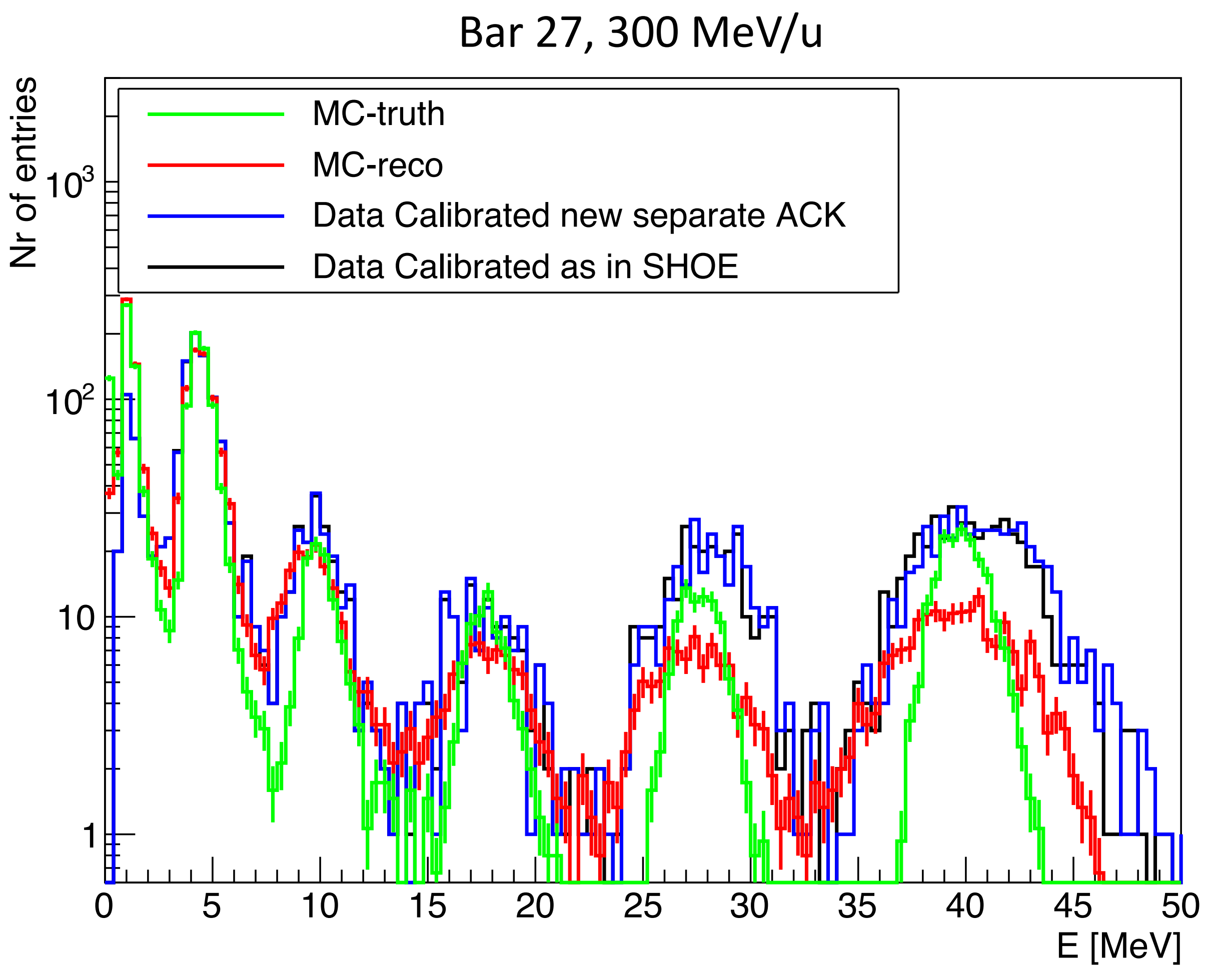
Calibrate with single curve for all energies



Observations from comparing red with blue

- **Position of peaks:**
  - ok (as expected)
- **Height of peaks:**
  - Not fully correct. Normalized with nr of primaries (no efficiencies). But data are higher than expectations for Z=4,5,6 (see slide 18)

Calibrate with single curve for all energies

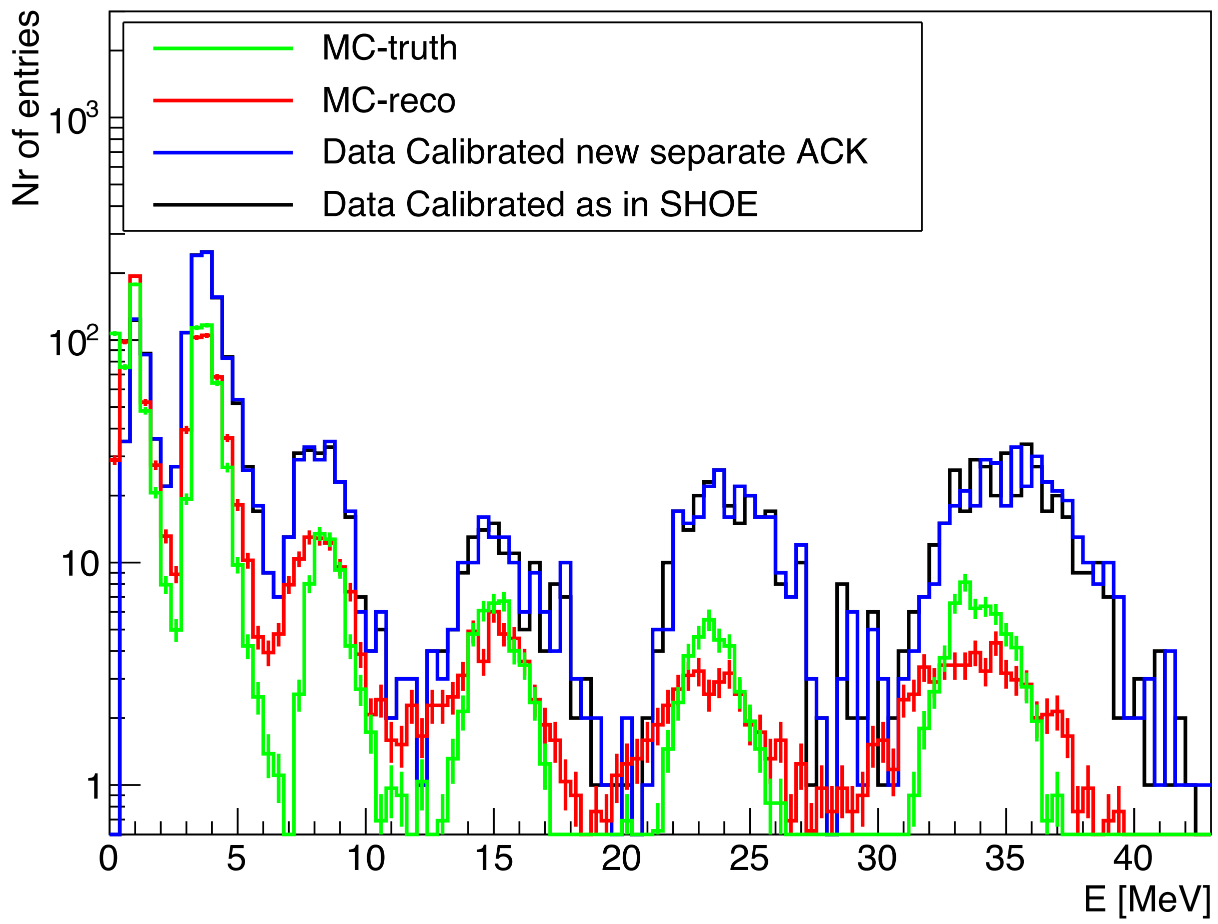


Observations from comparing red with blue

- **Position of peaks:**
  - Slightly too high wrt MC (as expected)
- **Height of peaks:**
  - Not fully correct. Normalized with nr of primaries (no efficiencies). But data are higher than expectations for Z=4,5,6 (see slide 18)

Calibrate with single curve for all energies

Bar 27, 400 MeV/u



Observations from comparing red with blue

- **Position of peaks:**
  - Too high wrt MC (as expected)
- **Height of peaks:**
  - Not fully correct. Normalized with nr of primaries (no efficiencies). But data are higher than expectations for Z=2,3,4,5,6 (see slide 18)

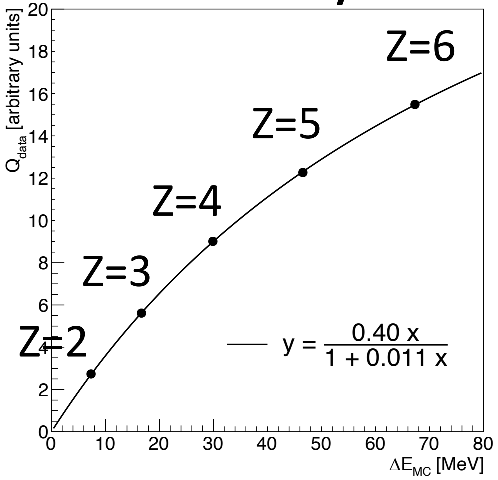
Ugly to publish!

Calibrate with single curve for all energies

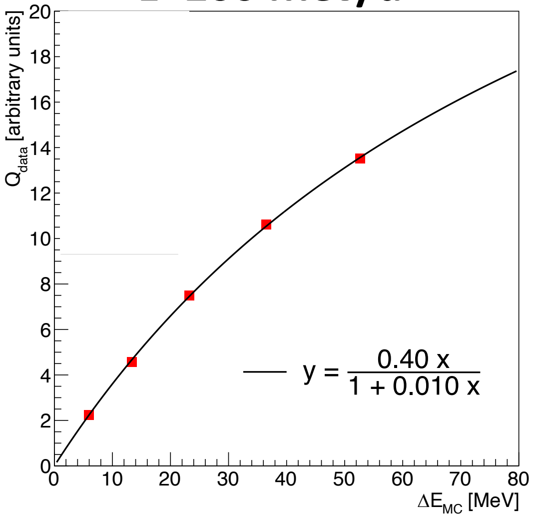
- **Fitting all species and all energies in one curve will always lead to discrepancies**!
- Will not allow FOOT to publish data-MC comparisons
- An easier and practical solution is to fit energy-by-energy.

Example for bar 27. Repeated for all bars!

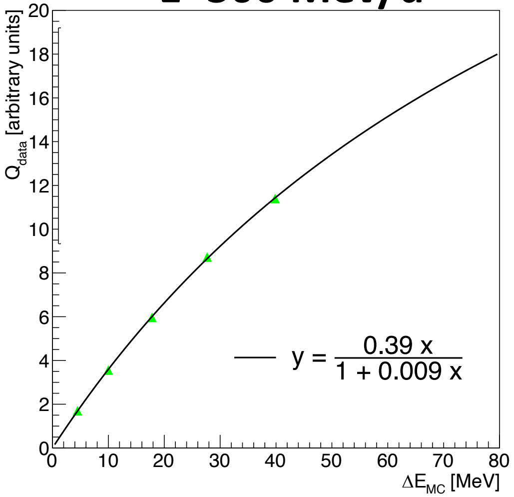
E=150 Mev/u



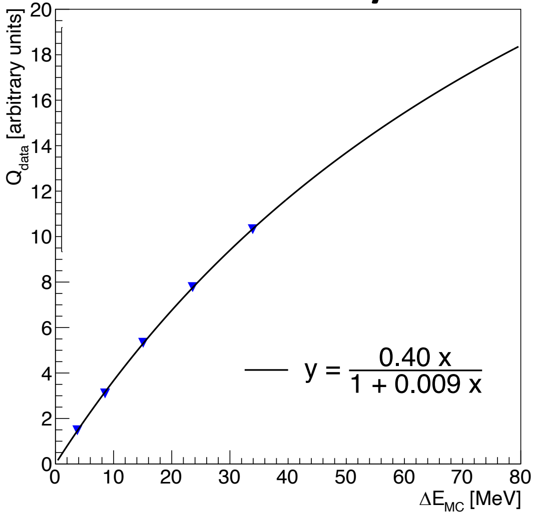
E=200 Mev/u



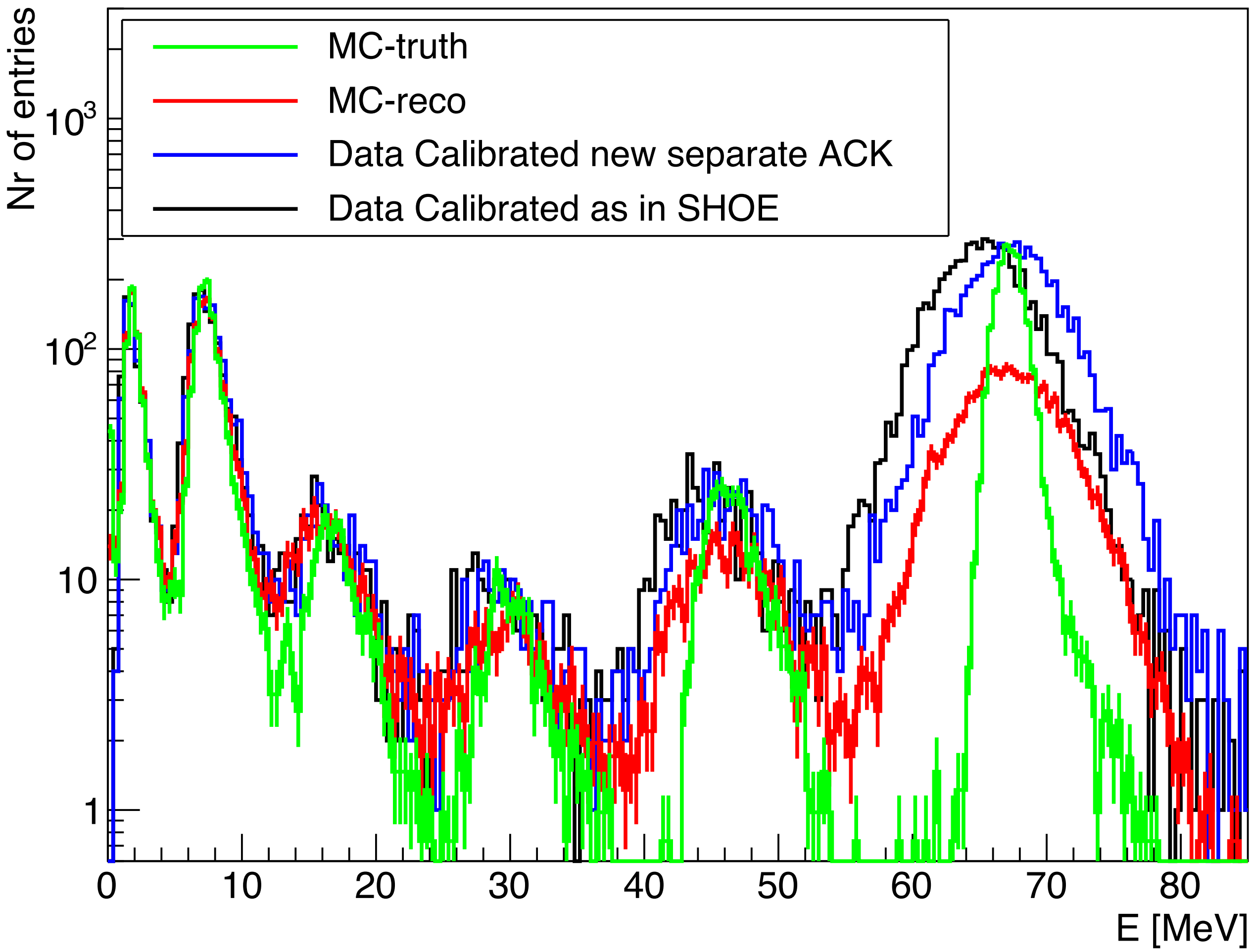
E=300 Mev/u



E=400 Mev/u



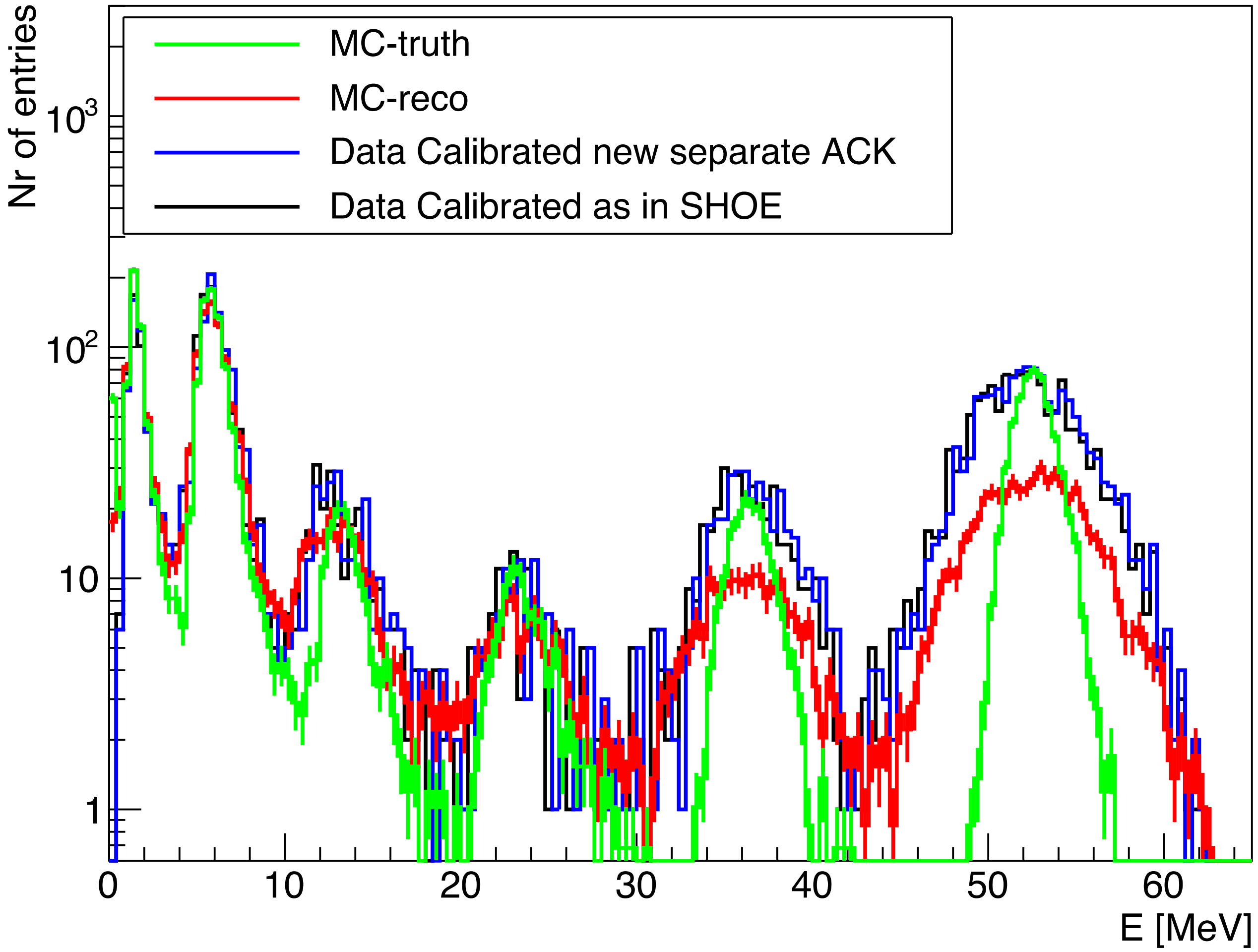
New spectrum at 150 MeV/u



Observations from comparing red with blue

- **Position of peaks:**
  - More of less ok now!
- **Height of peaks:**
  - Did not change (differences for Z>=4)
  - In MC, pure energy deposit, no effects of Birks, light collection etc
  - Cross sections?

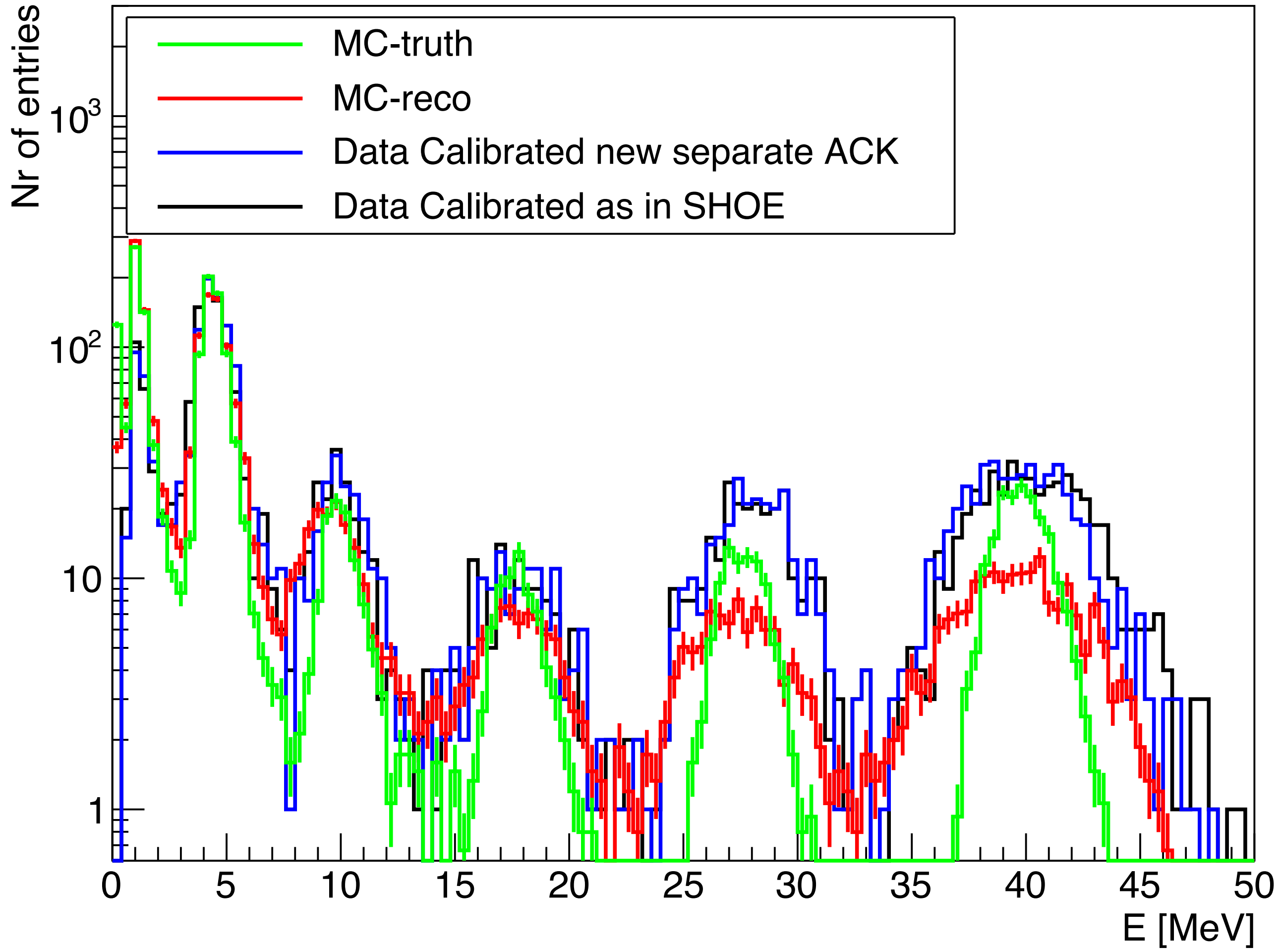
New spectrum at 200 MeV/u



Observations from comparing red with blue

- **Position of peaks:**
  - More of less ok now!
- **Height of peaks:**
  - Differences for Z>=4

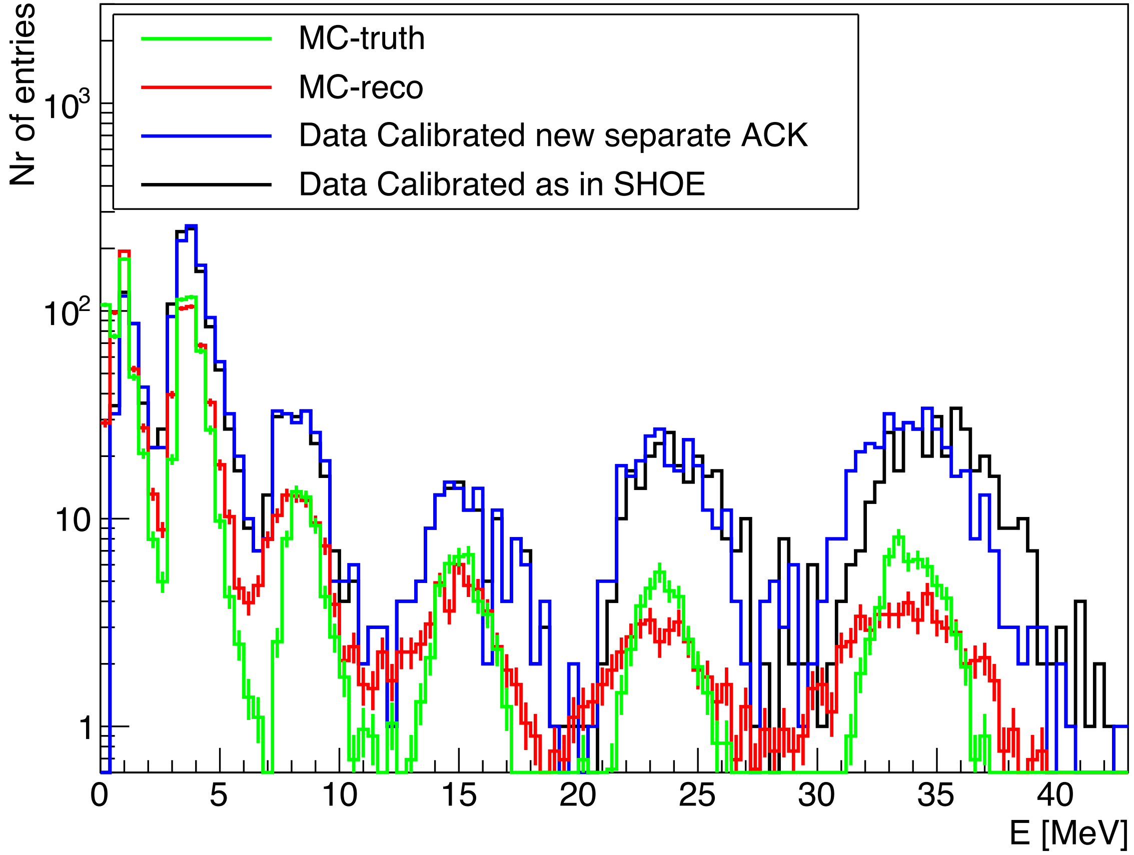
New spectrum at 300 MeV/u



Observations from comparing red with blue

- **Position of peaks:**
  - More of less ok now!
- **Height of peaks:**
  - Differences for Z>=4)

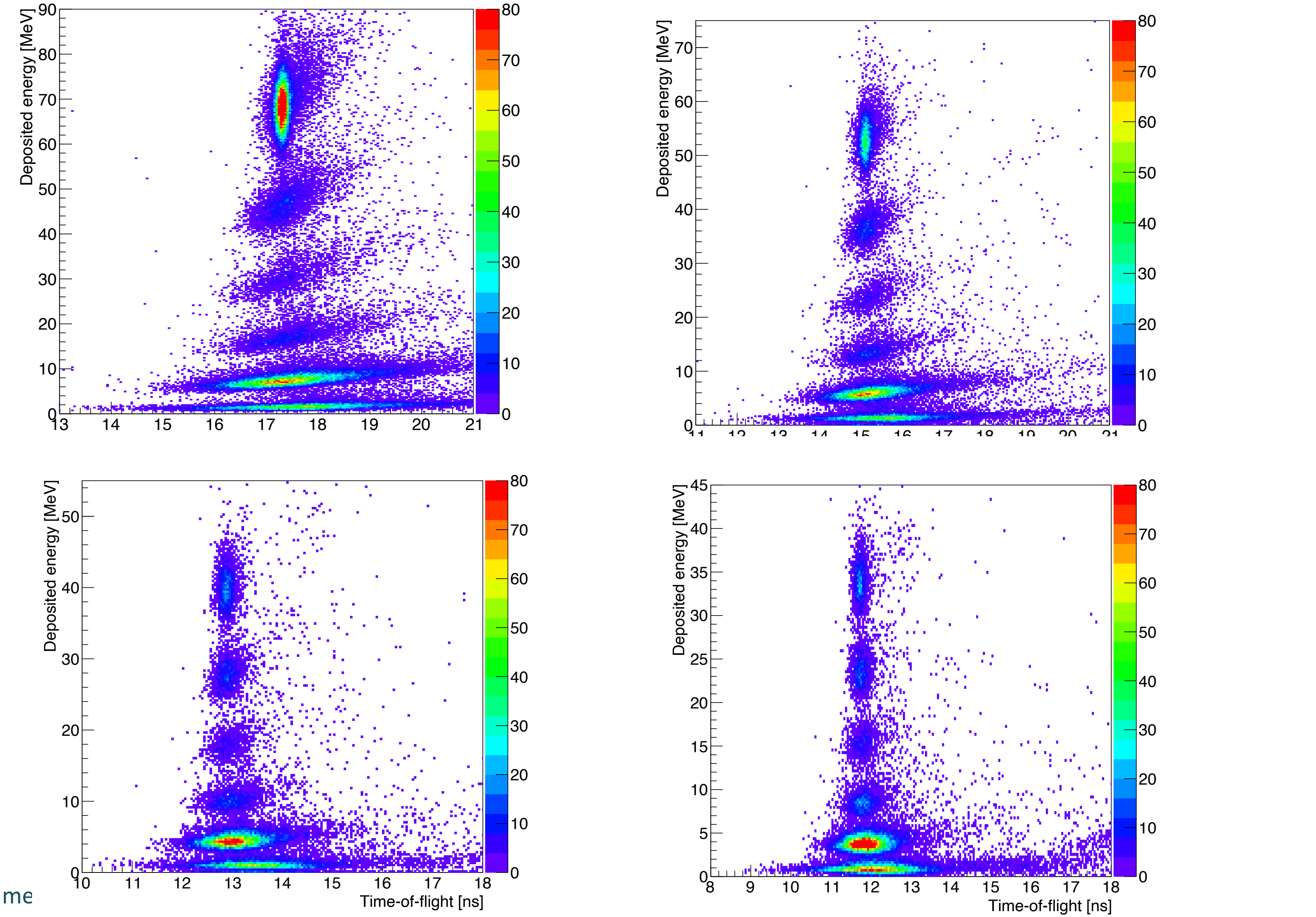
New spectrum at 400 MeV/u



Observations from comparing red with blue

- **Position of peaks:**
  - More of less ok now!
- **Height of peaks:**
  - Differences for Z>=2,3,4,5,6)

Spectrum with all bars calibrated (no central)

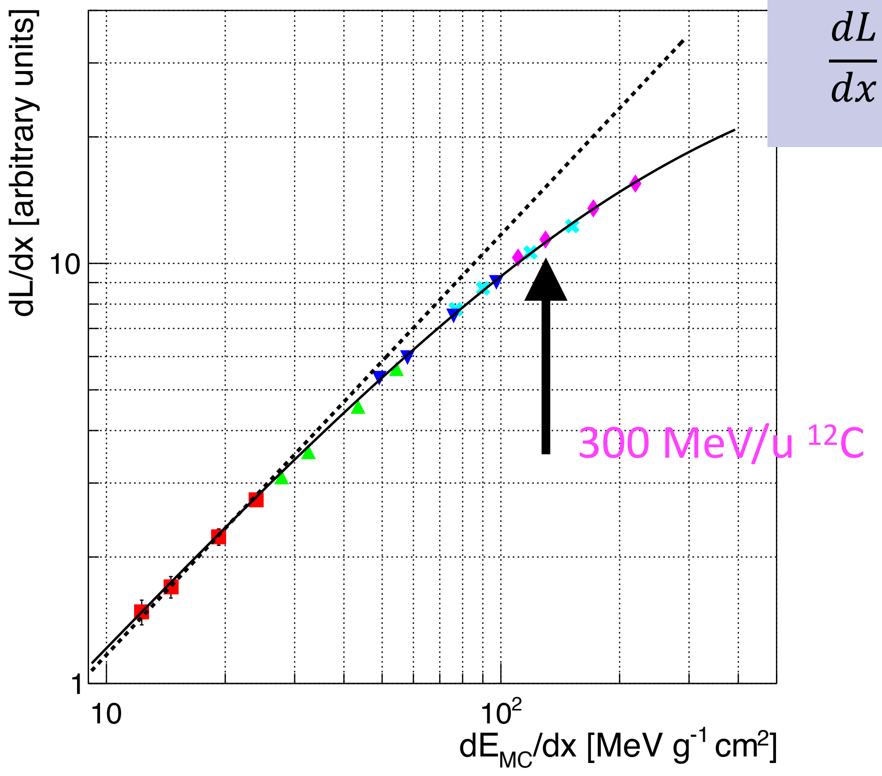


Conclusions

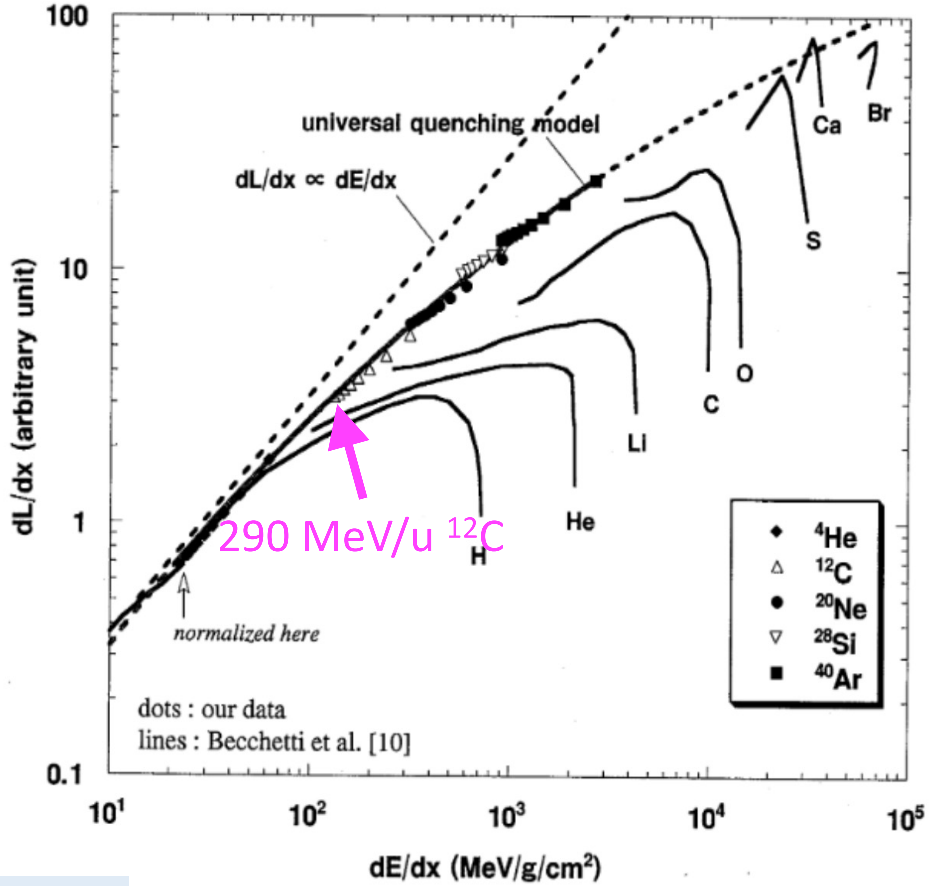
- Bar-by-bar calibration possible by directly calibrating with target
- Central bars: Z=1 up to 6 (use 2 to 6 to calibrate)
- Off-central bars: heavy fragments cannot be fitted (no statistics) so fit only the lighter fragments (and these are anyway the only ones passing)
- Differences found between data and MC in peak height,
  - Light collection efficiencies? (not present in MC)
  - wrong modelling of cross sections at larger Z
- We will calibrate new data as soon as possible

- backup

Does it correspond to expectations?



$$\frac{dL}{dx} = \frac{S\frac{dE}{dx}}{1 + kB\frac{dE}{dx}}$$



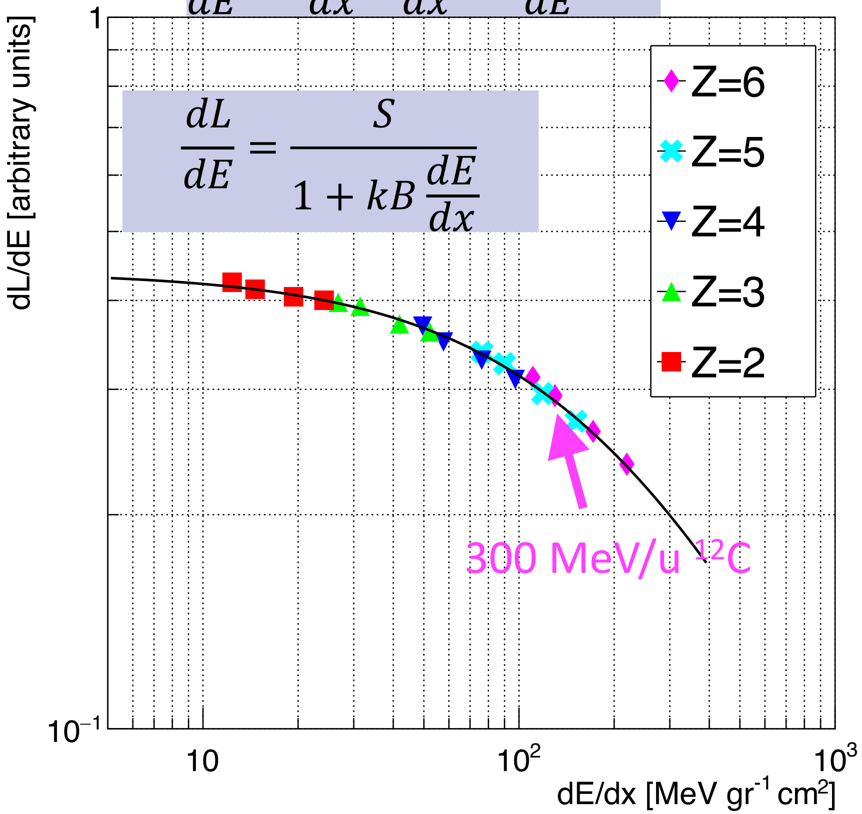
- As before but now “dL/dx”=Q/3 mm versus dE/dx
- Fit with Birk’s model
- Mostly particle species independent, but not totally

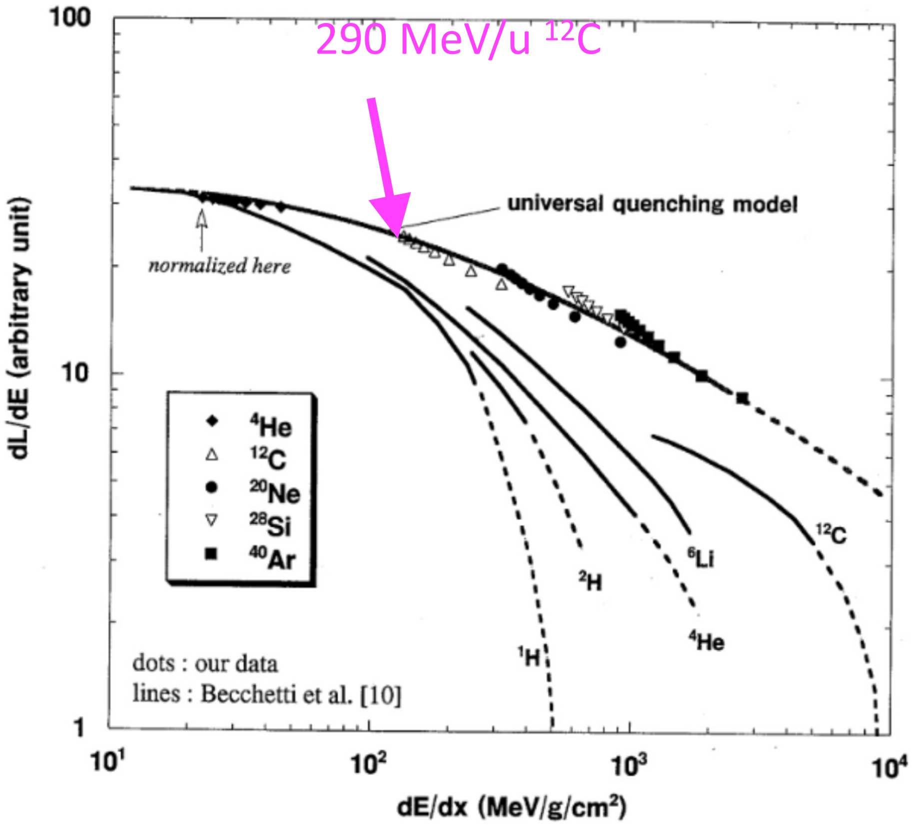
Fig 4 from Matsufuji 1999
Helium: 150 MeV/u
Carbon: 290 MeV/u
Ne, Si, Ar
Energy decreased with PMMA degrader

Does it correspond to expectations?

$$\frac{dL}{dE} = \frac{dL}{dx} / \frac{dE}{dx} \rightarrow \frac{Q}{dE}$$

$$\frac{dL}{dE} = \frac{S}{1 + kB\frac{dE}{dx}}$$





- As before but now Q/deposited energy
- Fit with Birks' model
- Our energies: mostly particle species independent, but small dependence can be seen in this plot…
- Shape seems to be in accordance with Matsufuji et al

Fig 5 from Matsufuji 1999
Helium: 150 MeV/u
Carbon: 290 MeV/u
Ne, Si, Ar