A few considerations about the TW calibration

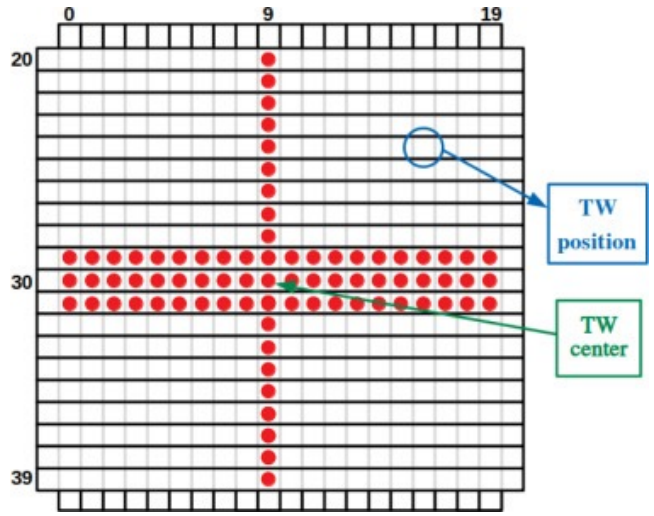
TW group

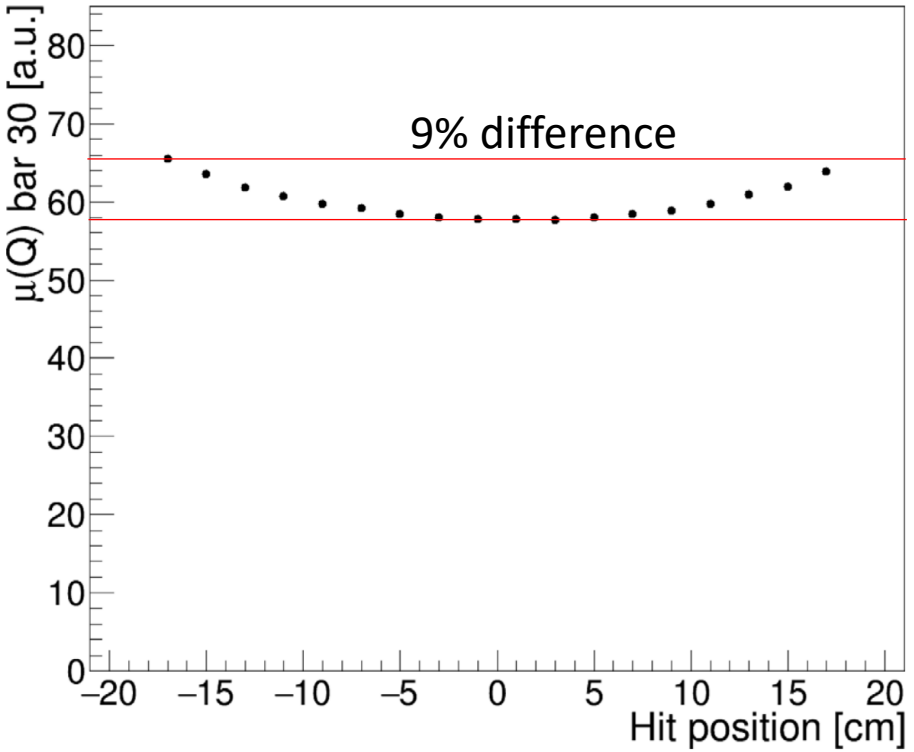
Introduction

- Calibration is essential in view of data-MC comparisons, calorimeter comparisons, etc.
- CNAO2019 and 2020: position-by-position calibration with monoenergetic beam
- CNAO2021 data (presented in Perugia, december 2022)
  - Bar-by-bar calibration
  - Fully based on SHOE
  - All bars calibrated
  - Monte-Carlo-data comparisons of CNAO 2021 for all energies
- Today: CNAO2022 data calibration. Two calibration procedures tested:
  - Bar-to-bar calibration
  - Position-to-position calibration
  - Compare them

Calibration of TW data 2019-2020

- Based on comparing expected energy with measured signal
- Collected charge in bar depends on hit position
- Calibrated al bars position-by position with mono-energetic beams without target, full scan of 20x20=400 positions (front and rear separately)
- Up to 10% difference found



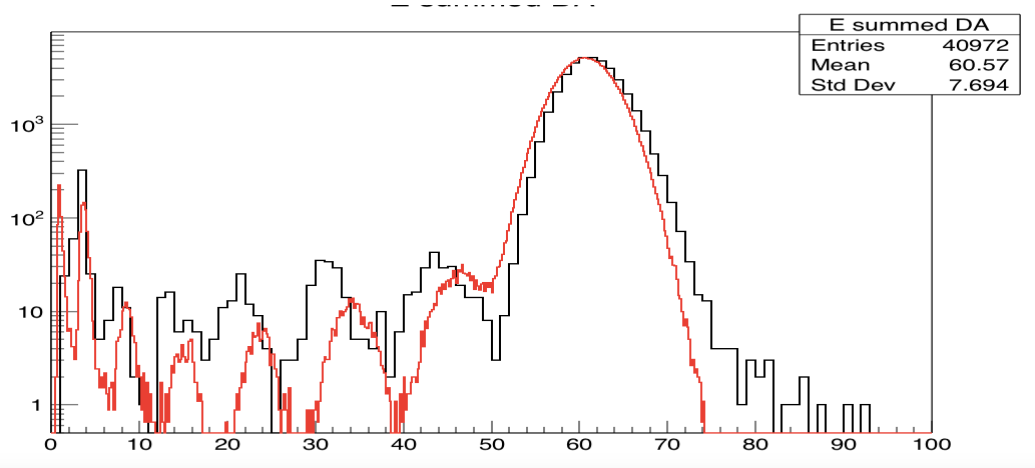


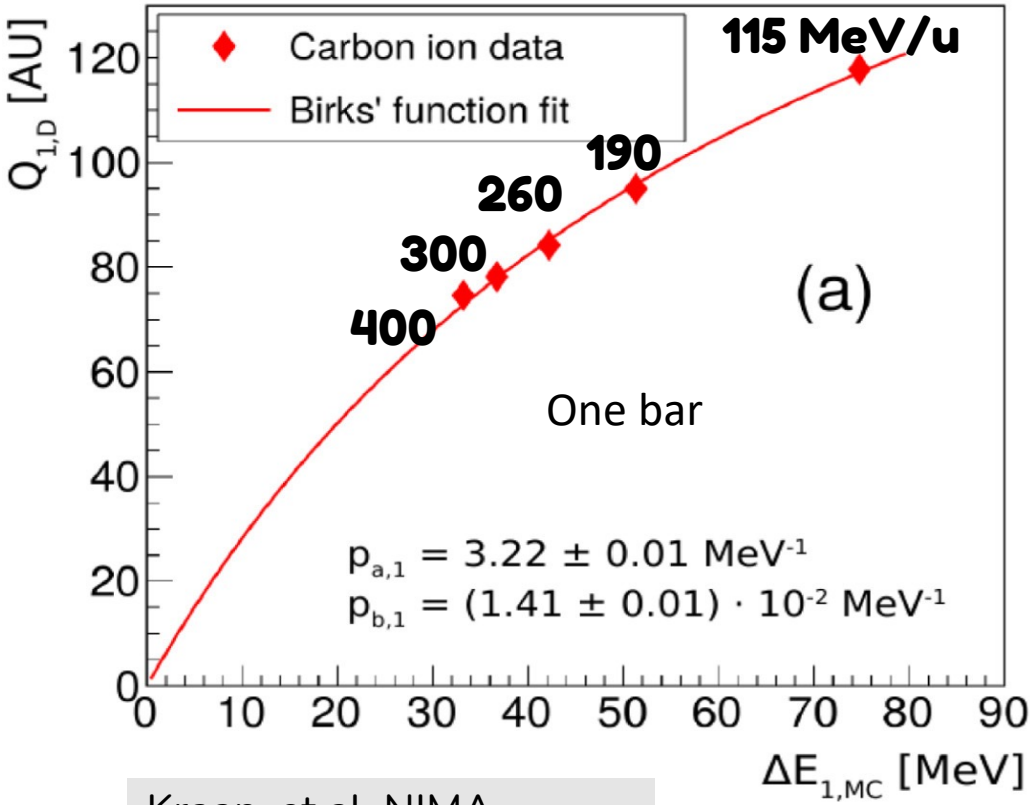
Kraan, et al, NIMA Volume 1001, 11 June 2021, 165206

CNAO

Calibration of TW data 2019-2020

- Mono-energetic beams without target, full scan of 400 positions
- Disadvantage
  - Time consuming (400 positions, various energies)
  - It is known that scintillator charge output depends on fragment charge, but no datapoints for other fragments
  - Calibrating on one site and data-taking in another doesn't work



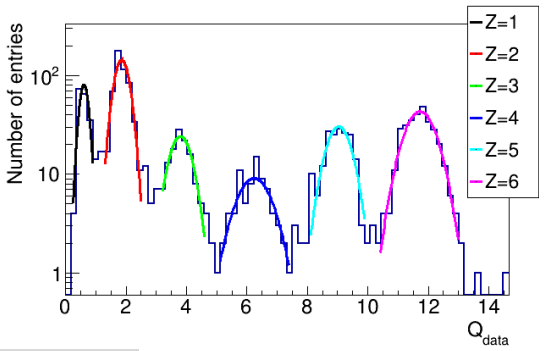


Kraan, et al, NIMA Volume 1001, 11 June 2021, 165206

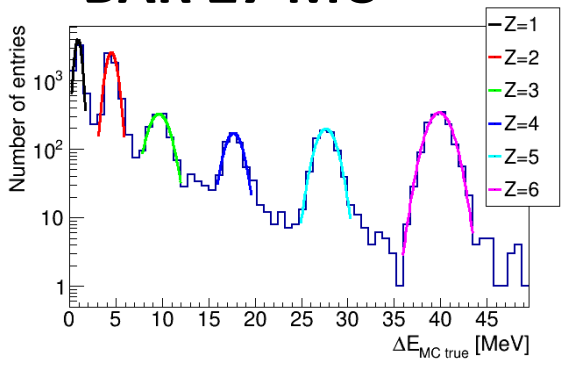
Calibration of TW: CNAO2021 data

- New strategy proposed in 2022: calibrate directly with fragments
- Repeat for all fragments (apart from protons→ **4 energies x 5 fragments=20 points**)
- Presented in Perugia 2022
- Data sample: min bias carbon on carbon target, 150, 200, 300, 400 MeV/u

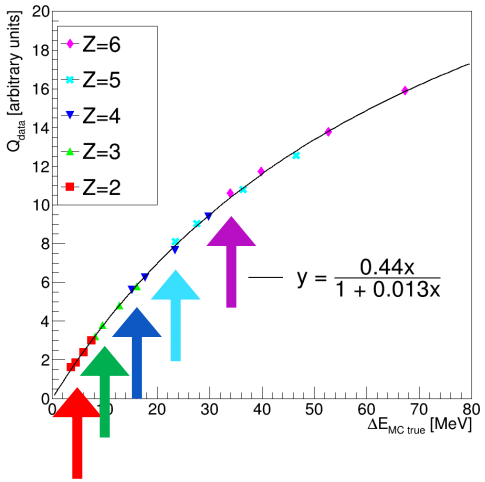
BAR 27 DATA



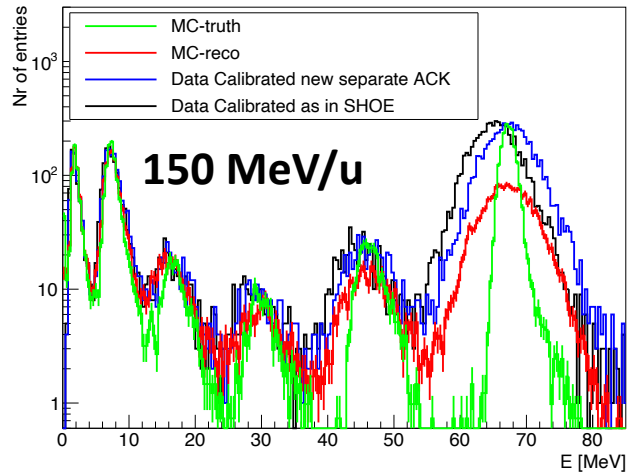
BAR 27 MC



BAR 27 Curve

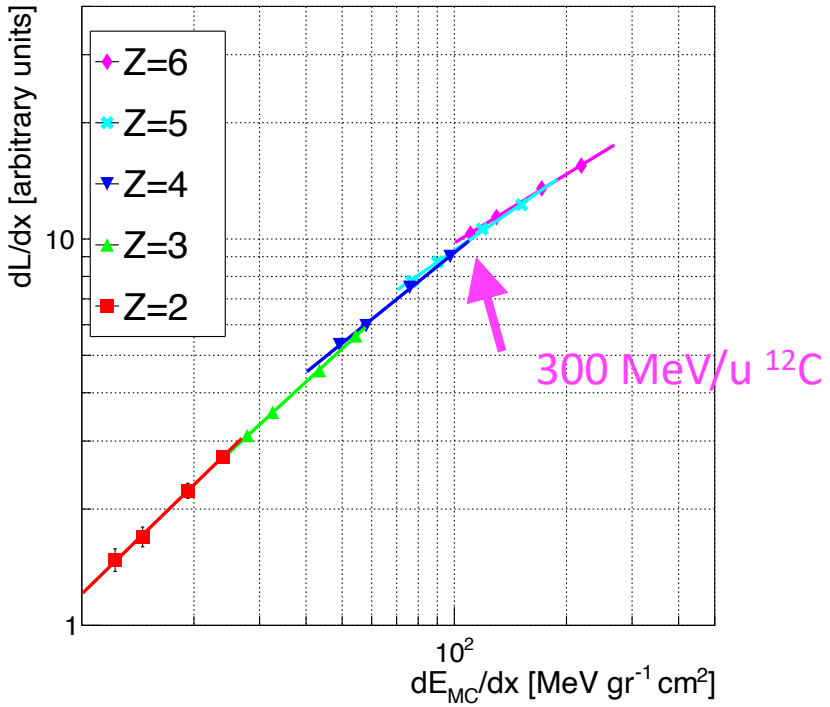


MC vs DATA (ACK cal)



- **Repeated for all bars**

CNAO2021 data allowed for comparison with literature



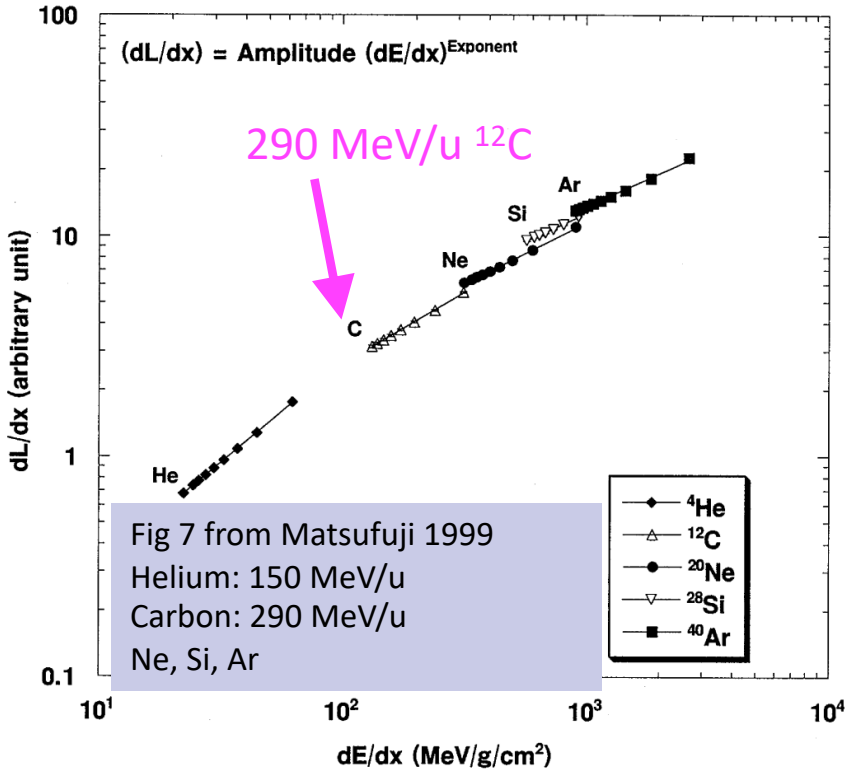
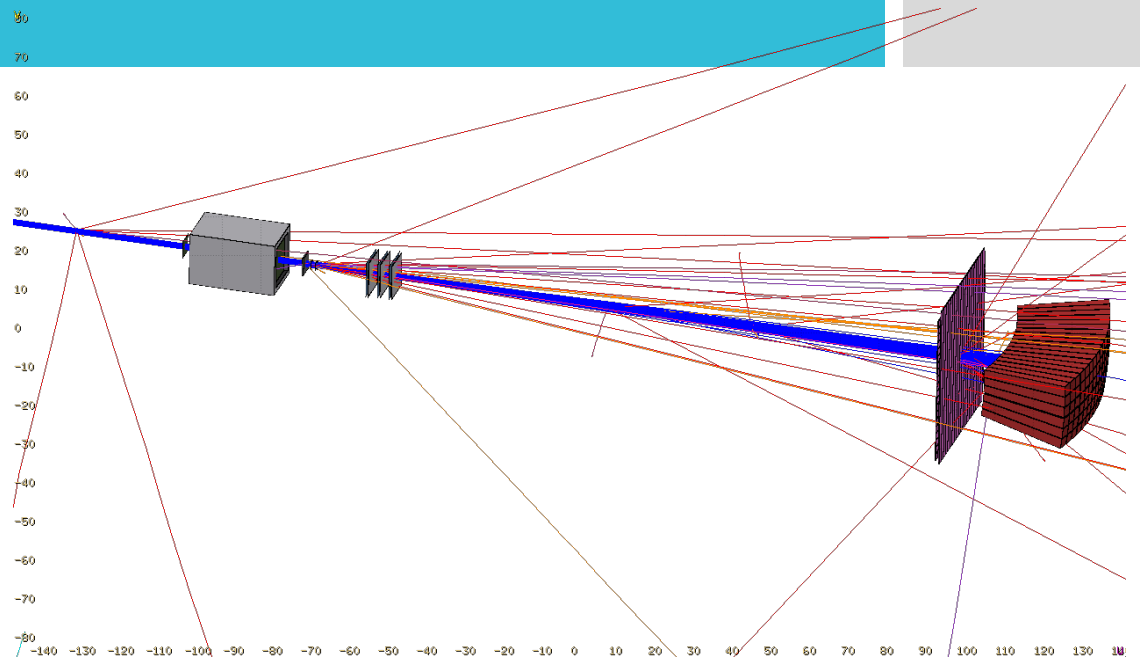


Fig 7 from Matsufuji 1999
Helium: 150 MeV/u
Carbon: 290 MeV/u
Ne, Si, Ar

- 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

CNAO2022 calibration



- **MC:** shoereg run 201: December geometry (run 201, 10^6 primaries) /gpfs_data/local/foot/Simulation/CNAO2022_MC/12C_C_200dec_shoereg.root
- **Data:** CNAO2022 december data, run 6854: 200 MeV/u carbon on carbon target, 498k primaries
- One shoe-macro to store MC true information and MC reco
- One shoe-macro to store Data information
- Thanks to Marco, Triestino, Giuseppe and Roberto Z for help with some technical issues
- Separate root macro made to analyze and get out calibration parameters
- Read these back in the shoe macro for data to get out calibrated energy values
- In the next, test bar-by-bar and pos-by-pos strategy and compare for 1 bar

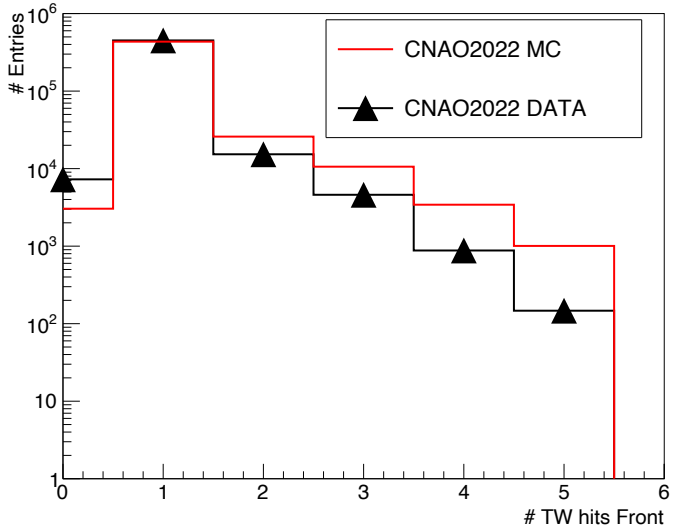
MC sample

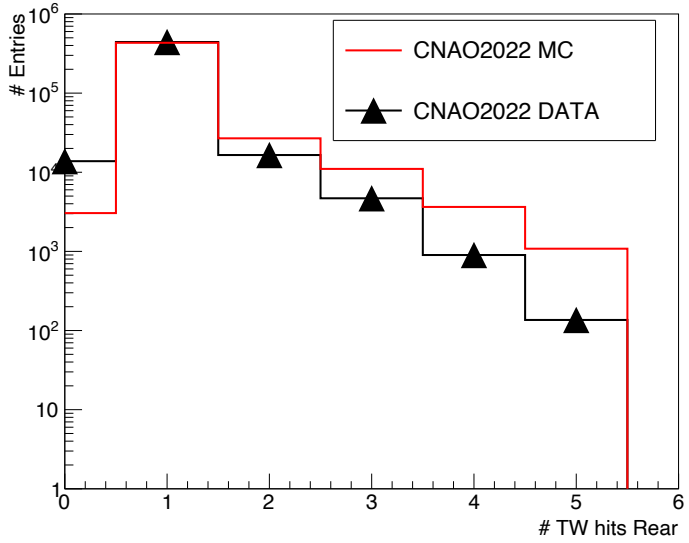
Compare Data with MC sample
- Nr reconstructed Twhits
- Bars hit

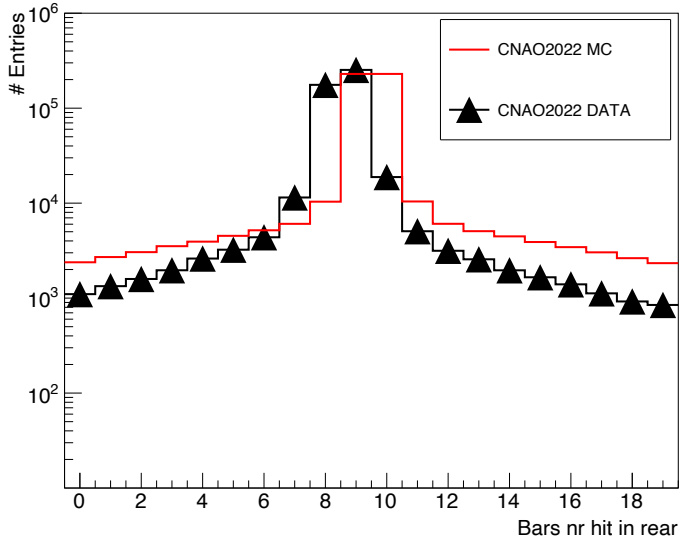
Some disagreements found

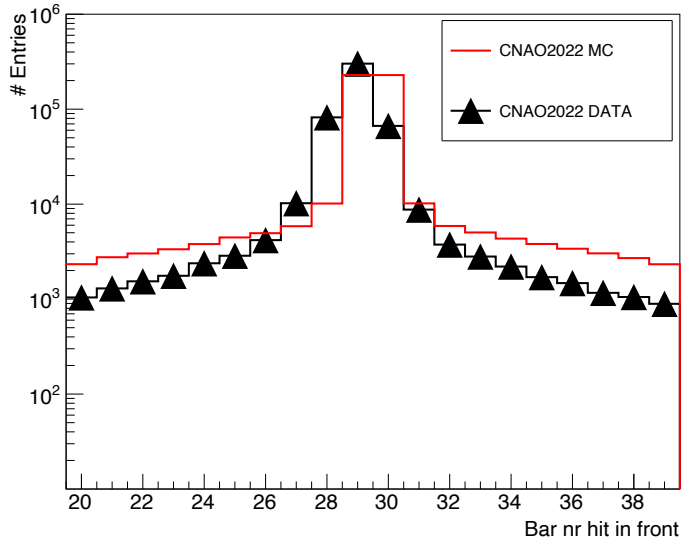
Under investigation

Most obvious difference is in beam position, which is easy to fix (see Silvia's presentation).



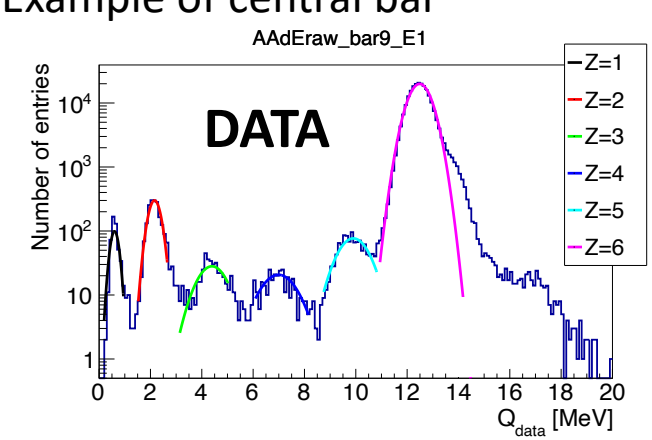


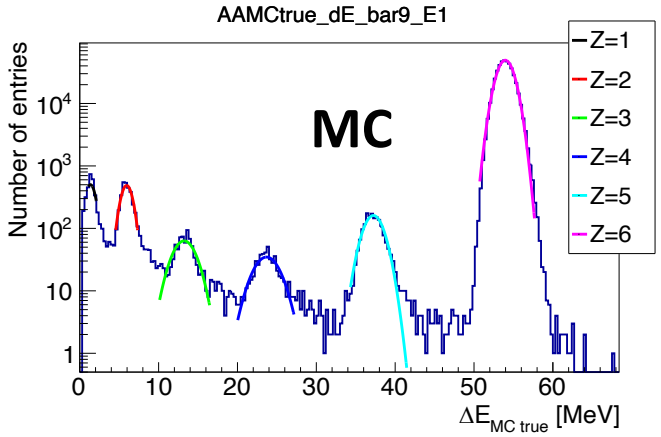


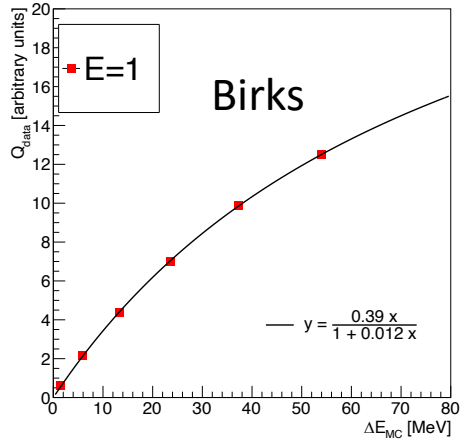


CNAO2022: bar-to-bar calibration

Example of central bar

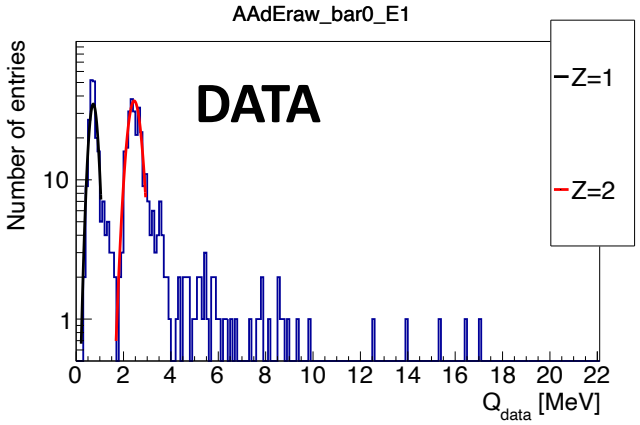


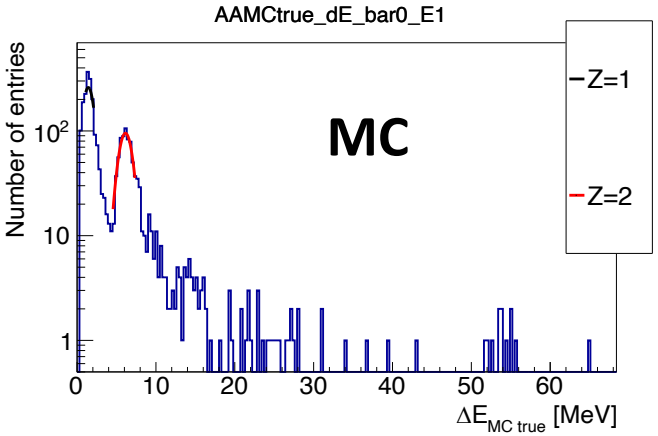


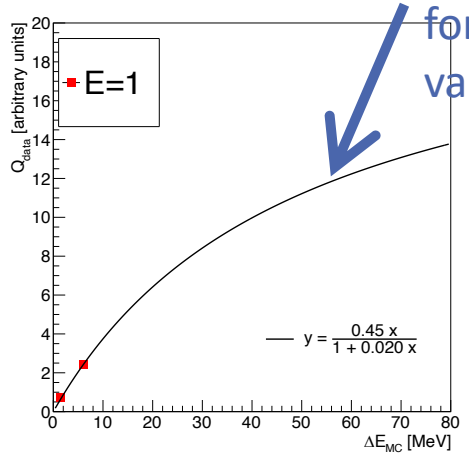


Store Birks' parameters

Example of off-central bar







Maybe better to force it to carbon value…

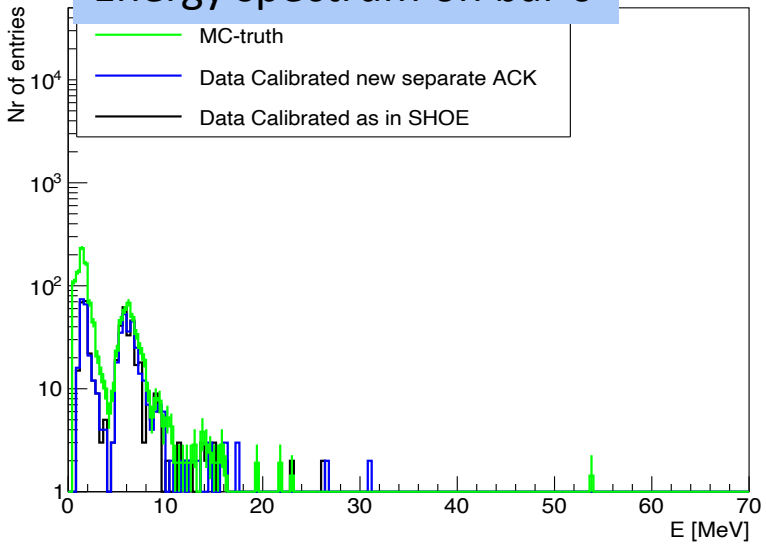
Store Birks' parameters

Repeat this for 40 bars→ Store 40 time the Birks' parameters

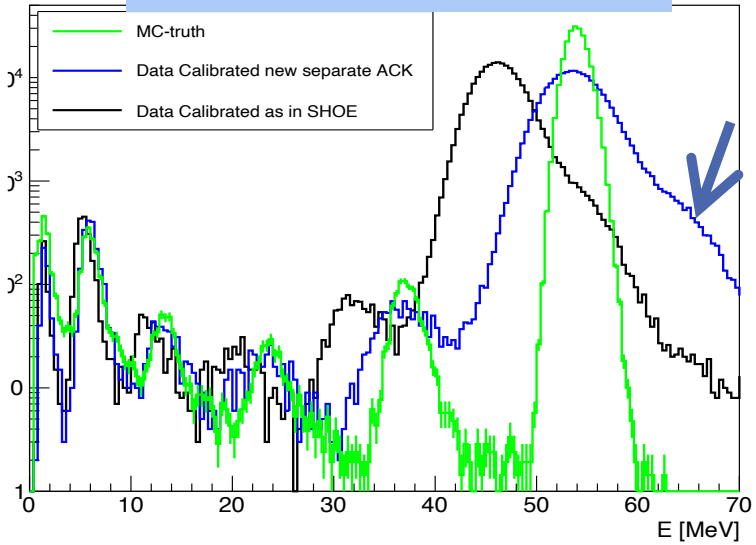
CNAO2022: bar-to-bar calibration

- Automatized but still check by eye whether reasonable
- 40 fits of N gaussians for data (decide on which peaks to fit: N=2? 3? 6?)
- 40 fits of N gaussians for MC
- 40 fits of Birks
- Read back the parameters in shoe→ a few examples of calibrated energy:

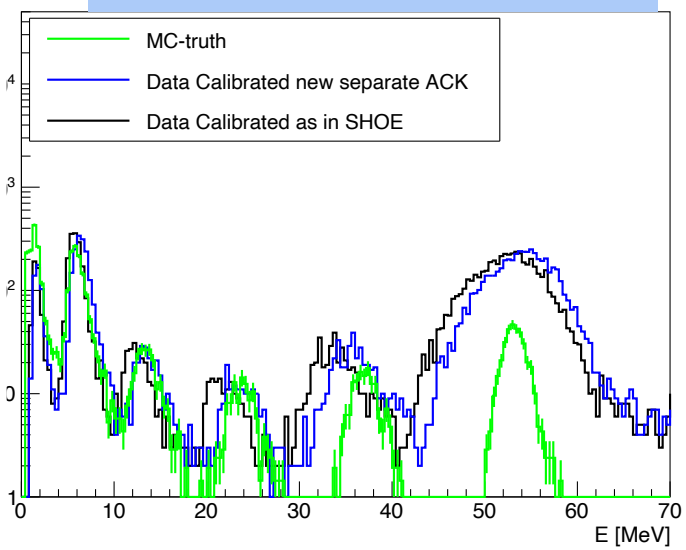
Energy spectrum on bar 0



Energy spectrum on bar 9



Energy spectrum on bar 27

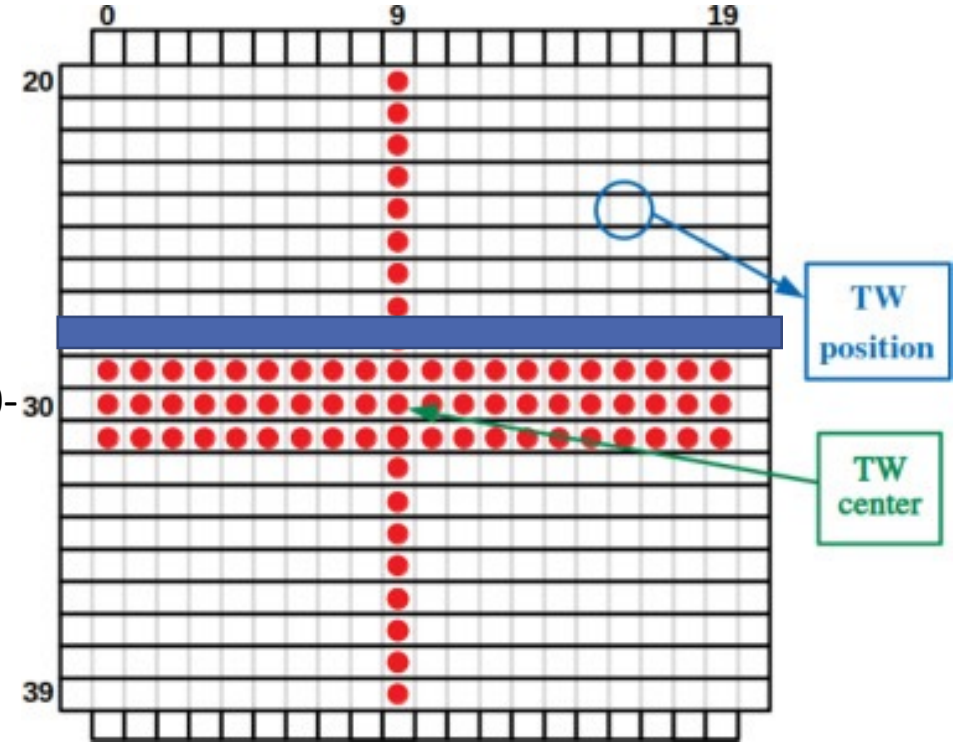


Calibration available for 40 bars. Better than what SHOE is returning at present

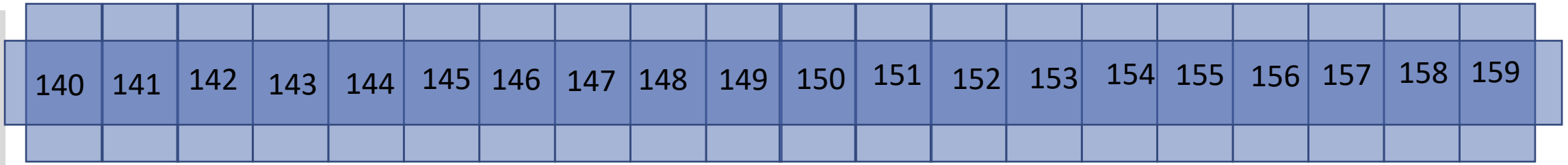
CNAO2022: pos-to-pos calibration

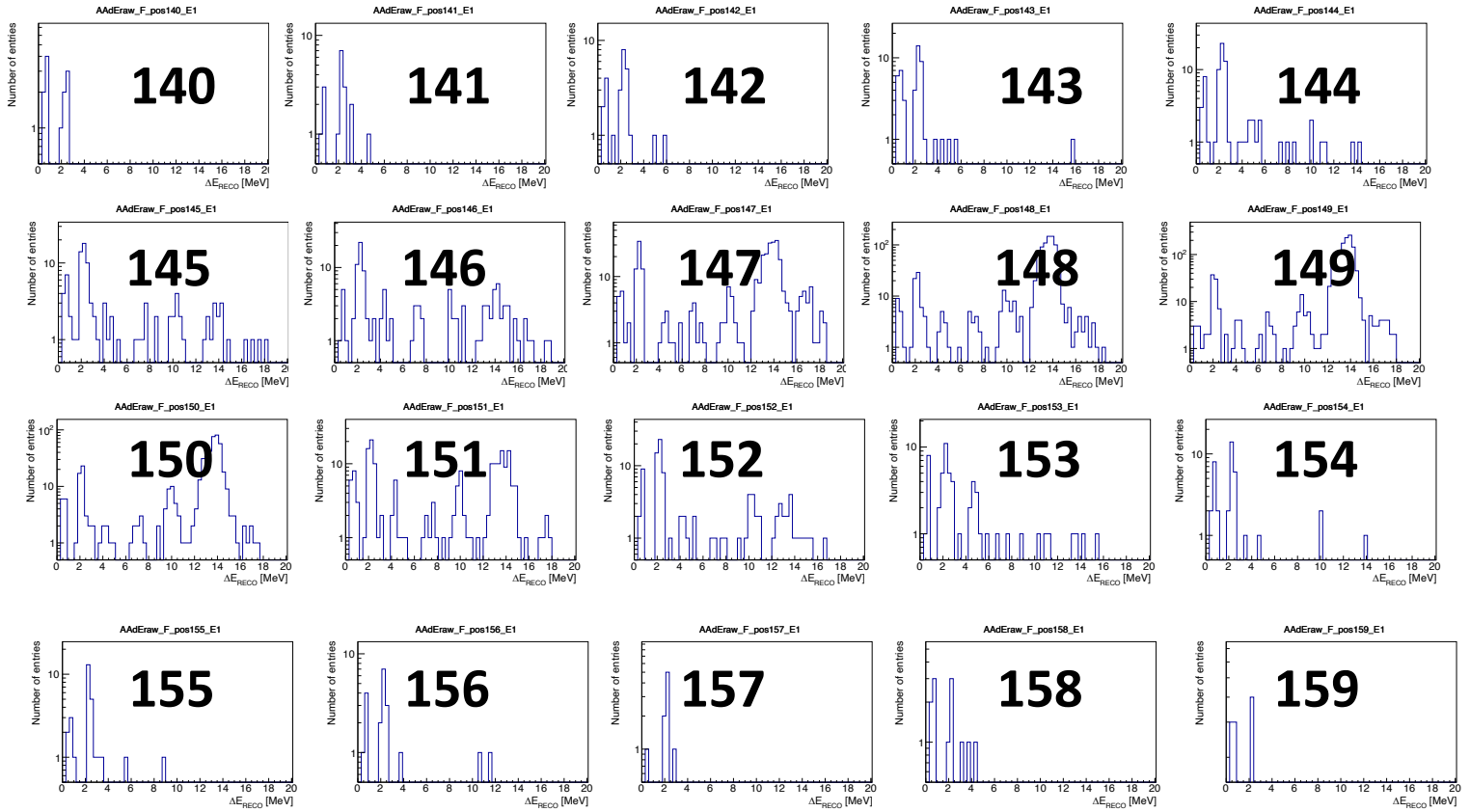
- Other strategy: calibrate position-by-position like in the past
- 1 energy only (200) --> cannot construct Birks' curve from this
- Use the fragments to construct curve
- Remember that the fragments are not monoenergetic!
- Tested on 1 bar (nr 7 front, called 27 here)

Today: bar 27 (positions 140-160)



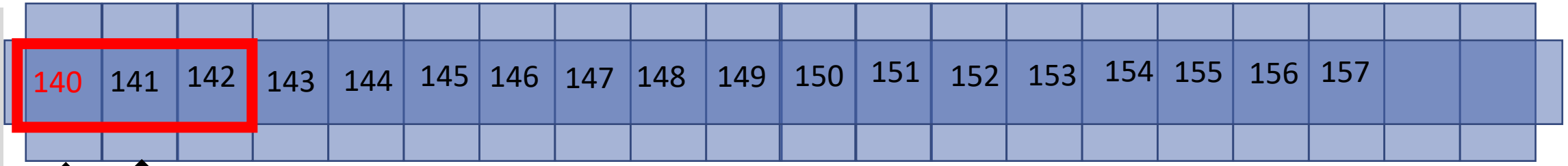
CNAO2022: pos-to-pos calibration

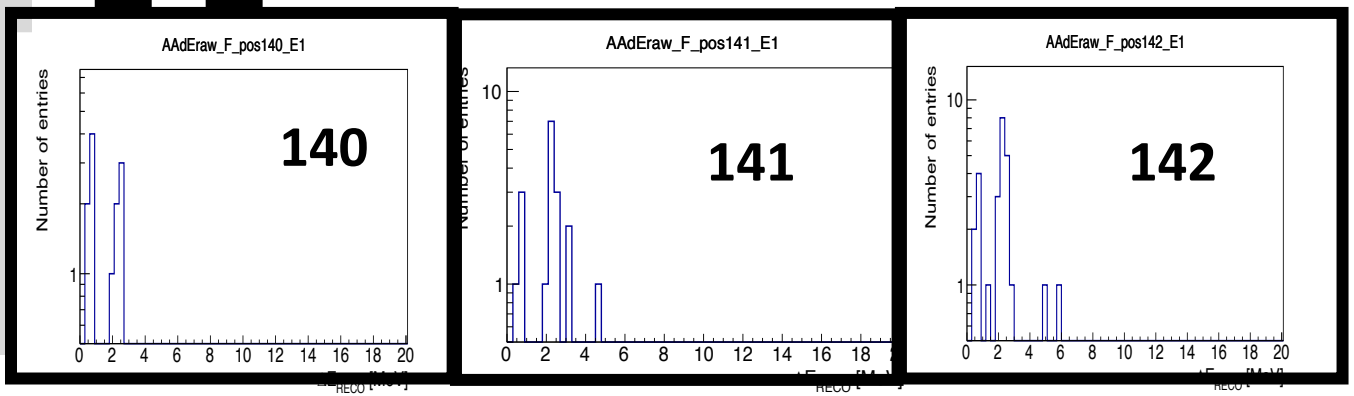




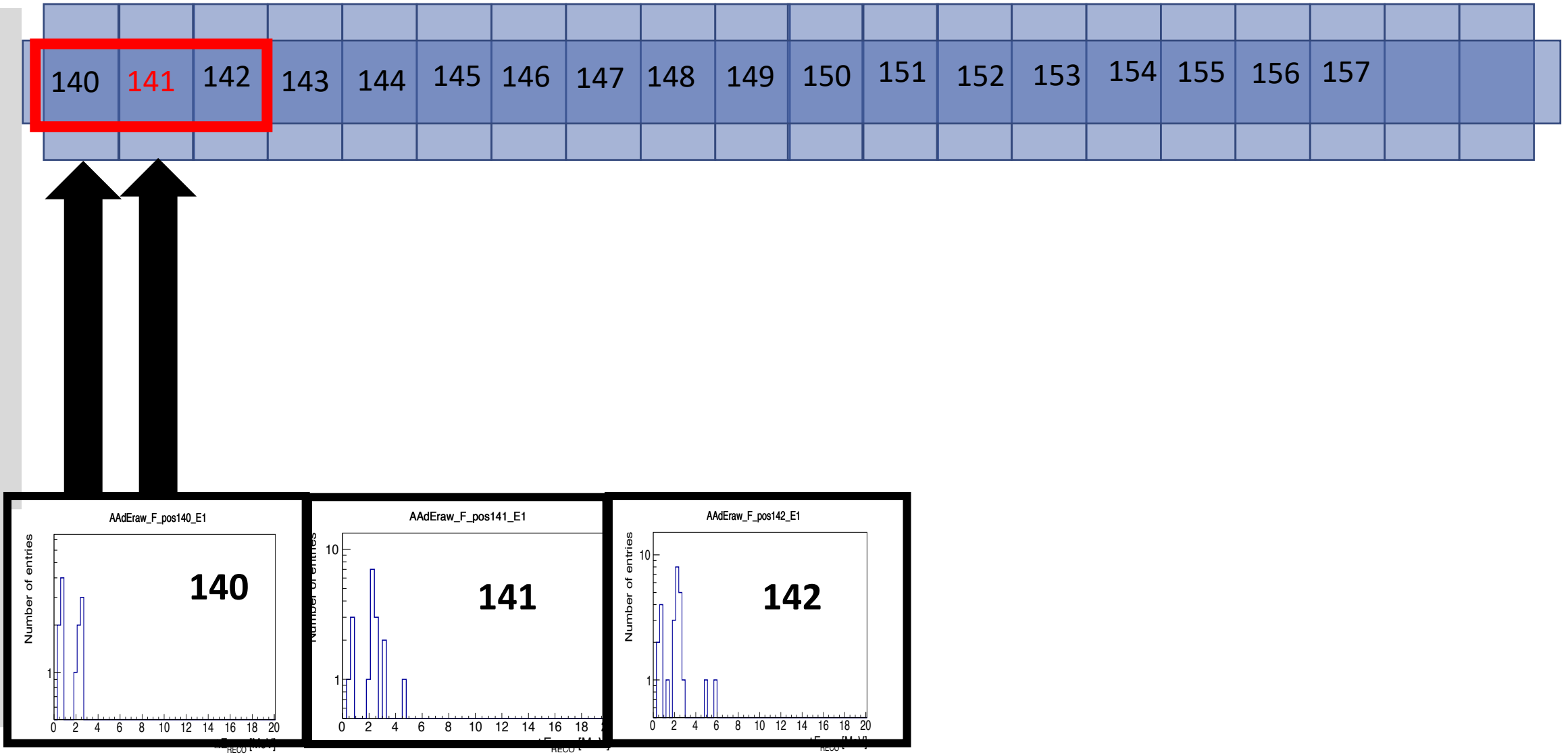
- Bar 27: **not enough statistics** at the sides (less then 10 entries)
- For more external bars even more problematic

CNAO2022: pos-to-pos calibration

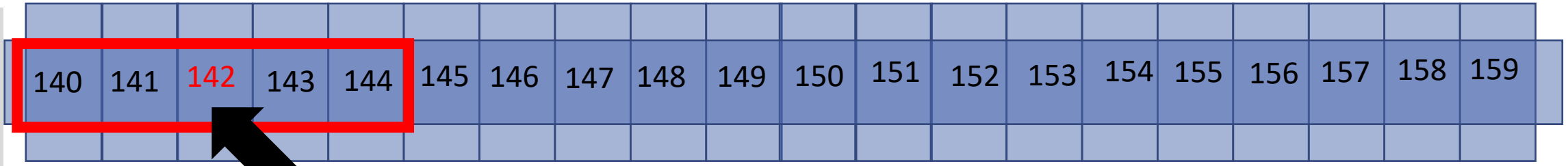


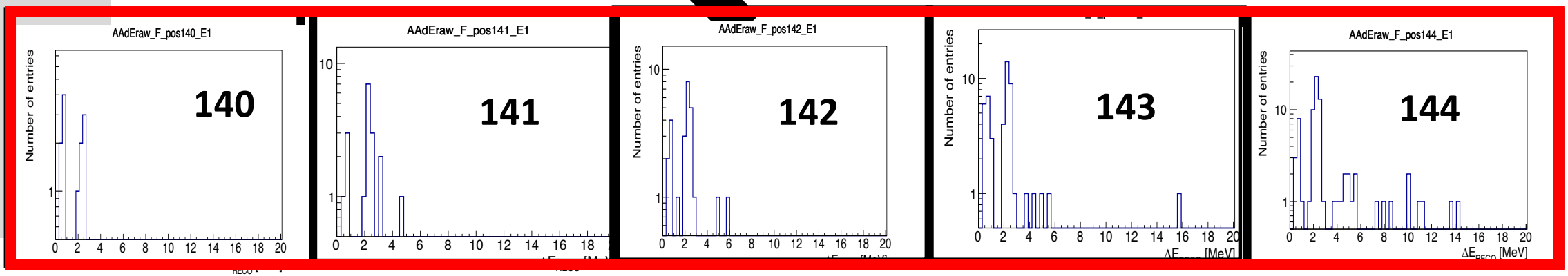


CNAO2022: pos-to-pos calibration

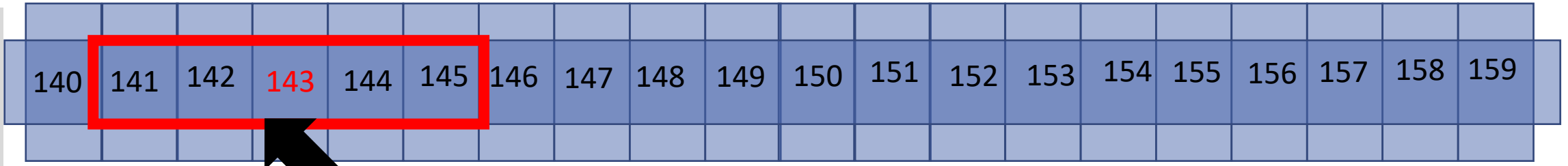


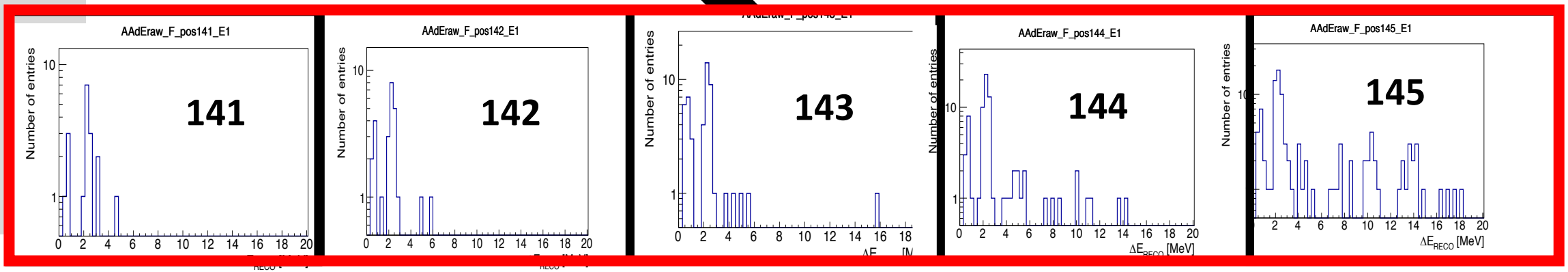
CNAO2022: pos-to-pos calibration



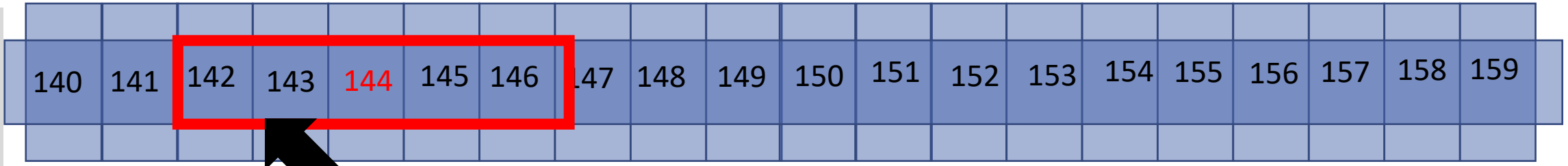


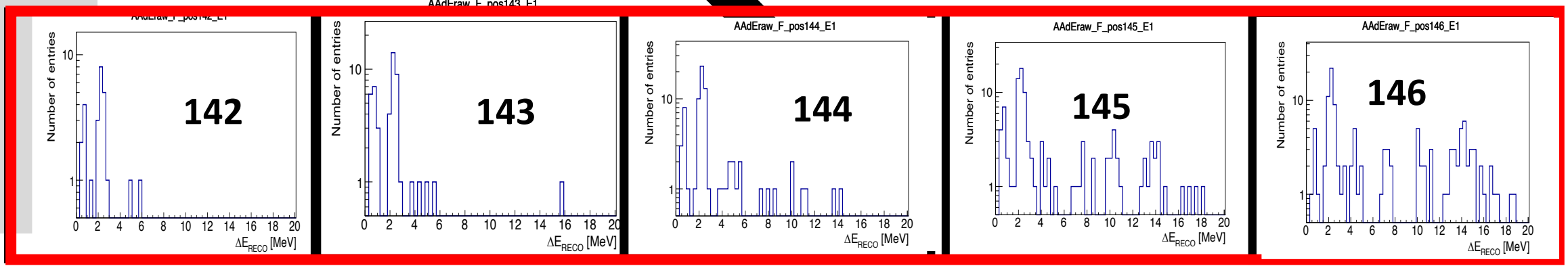
CNAO2022: pos-to-pos calibration



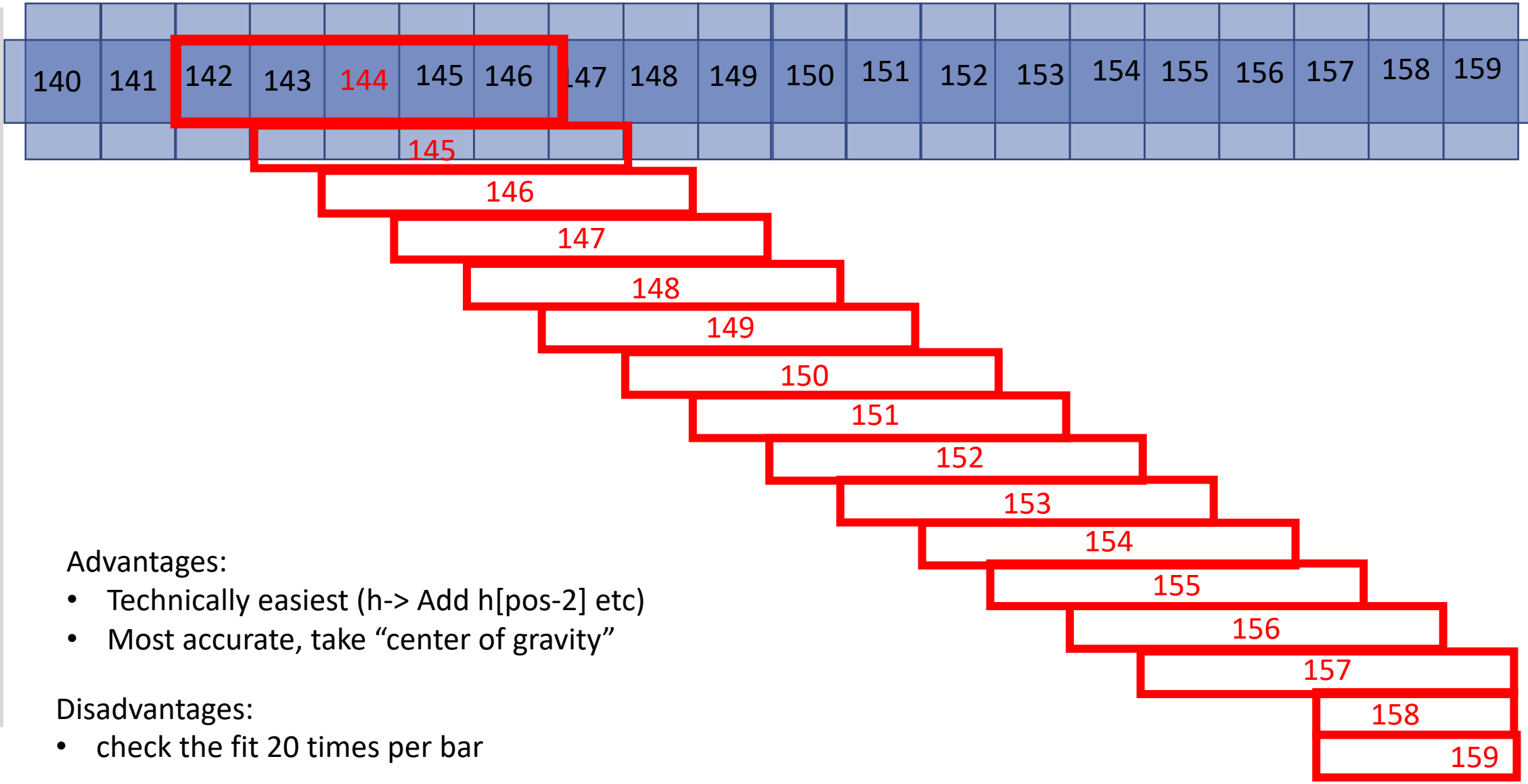


CNAO2022: pos-to-pos calibration





CNAO2022: pos-to-pos calibration



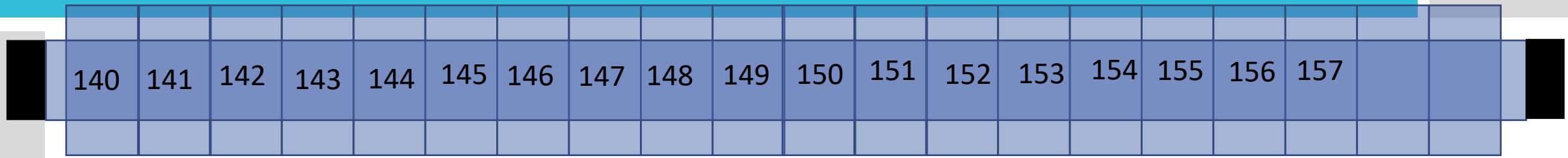
Advantages:

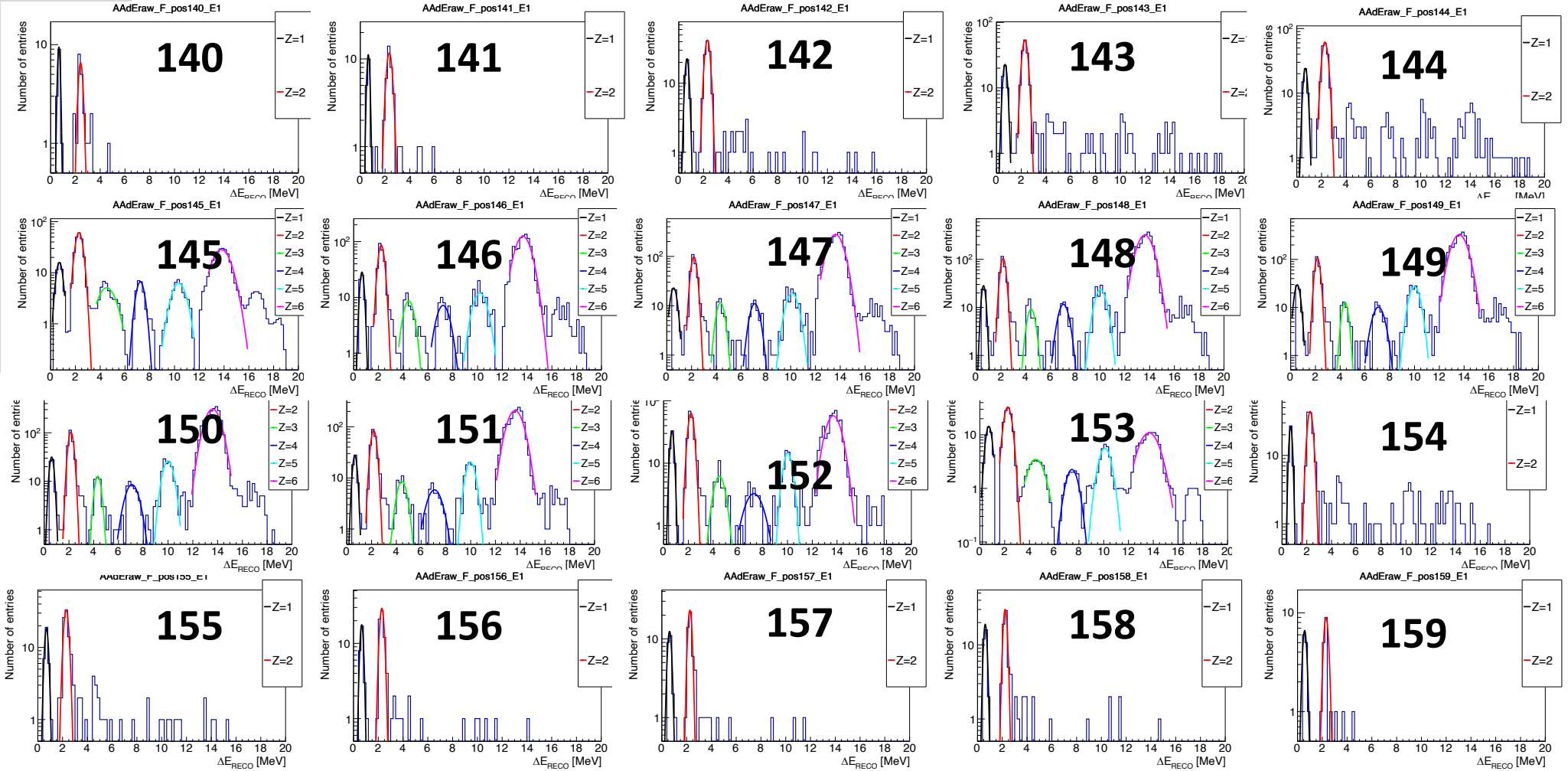
- Technically easiest (h-> Add h[pos-2] etc)
- Most accurate, take “center of gravity”

Disadvantages:

- check the fit 20 times per bar

CNAO2022: pos-to-pos calibration





DATA

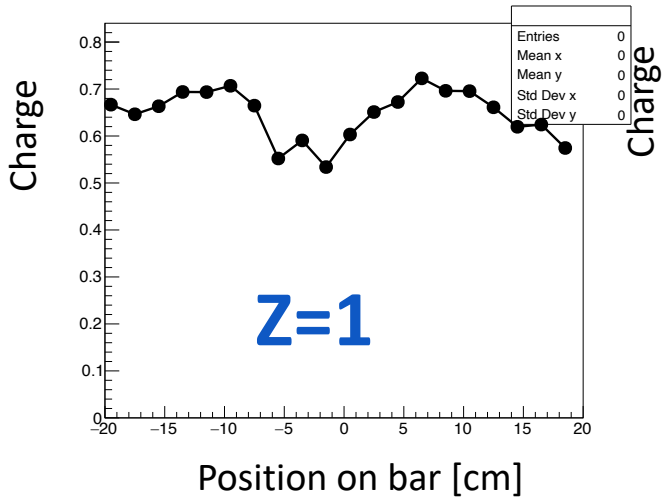
Now reasonable fits are possible

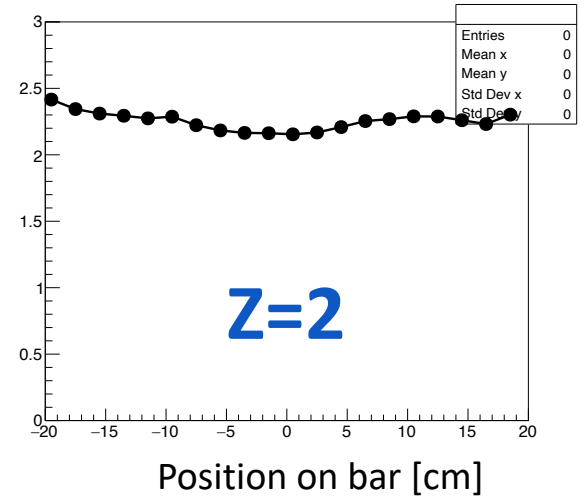
- pos 140 to 144: 2 peaks
- Pos 145 to 154: 6 peaks
- pos 155 to 159: 2 peaks

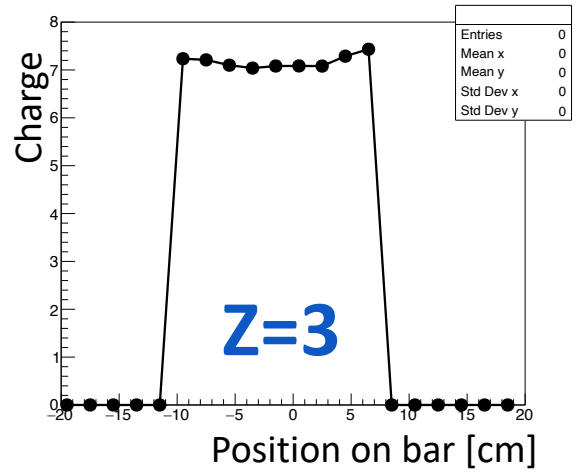
CNAO2022: pos-to-pos calibration

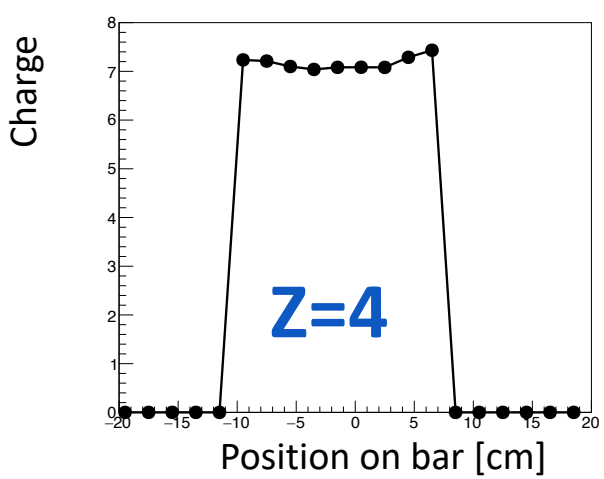
140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159

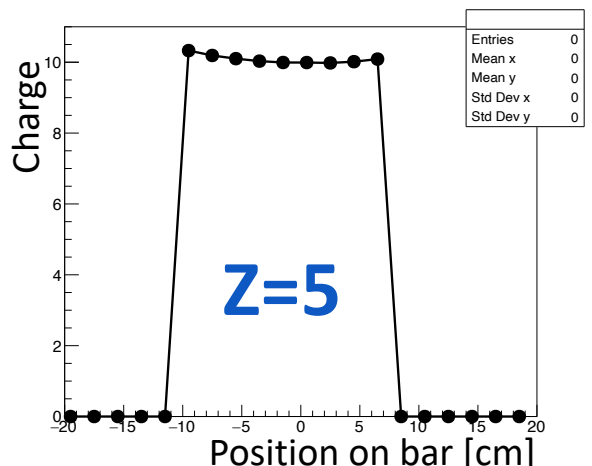
Collected charge as a function of hit position for fragments with different charge

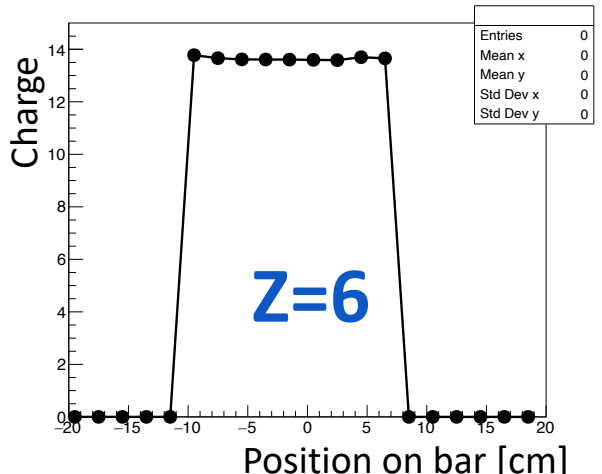






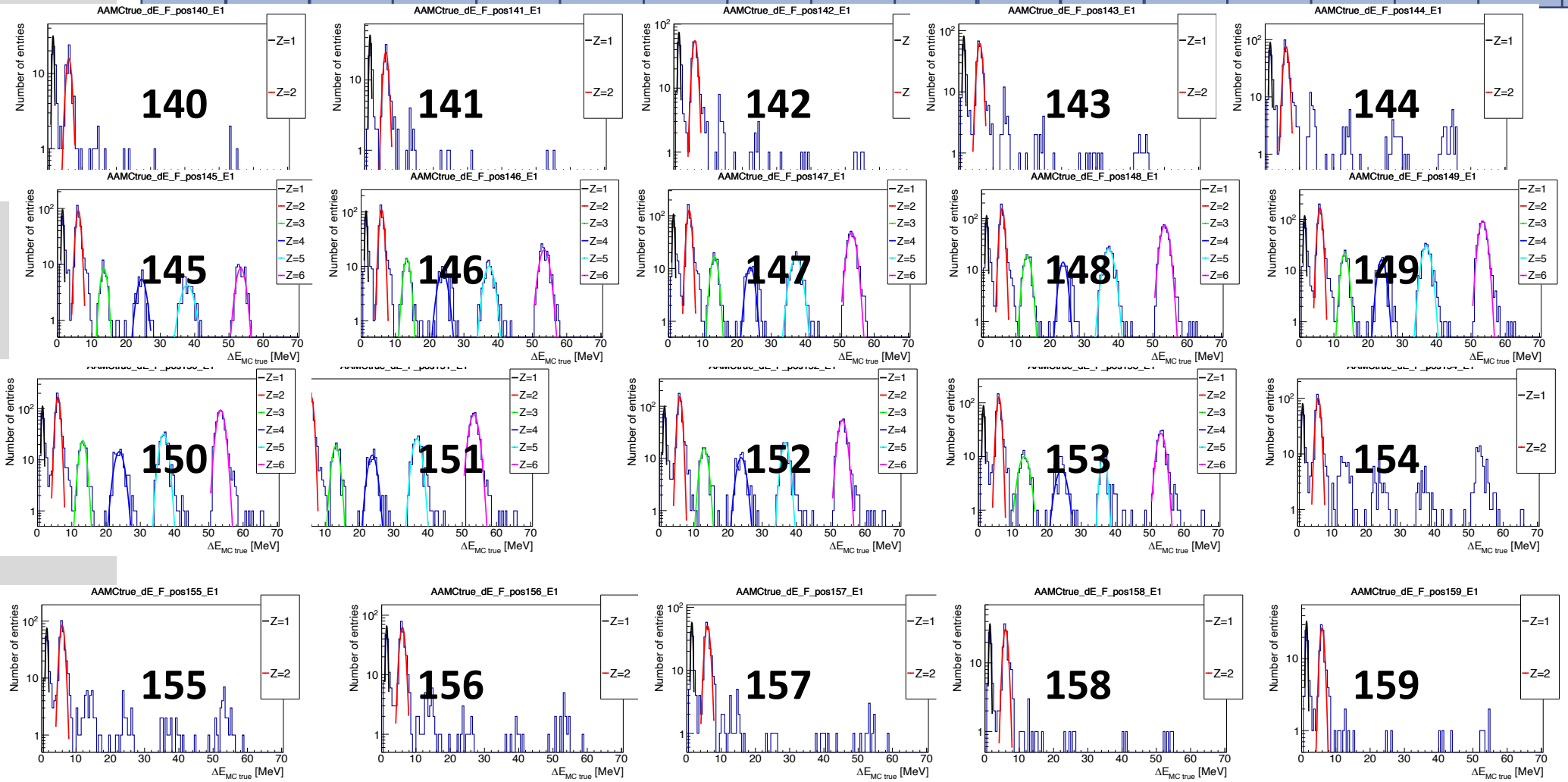




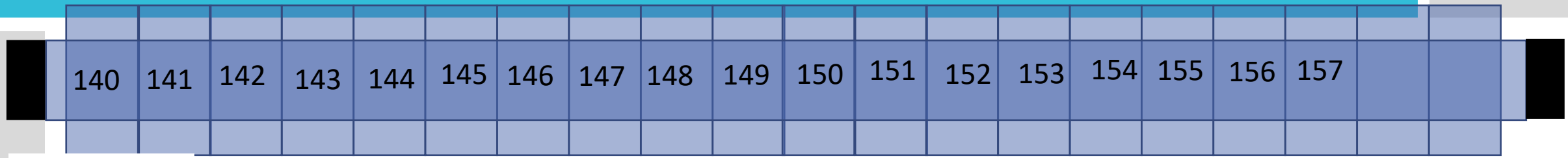


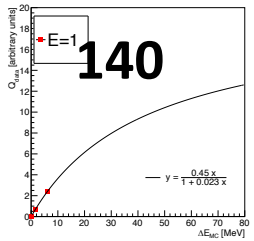
CNAO2022: pos-to-pos calibration

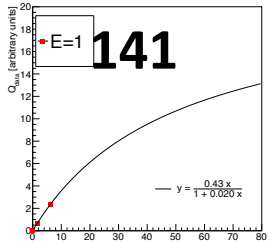
MC

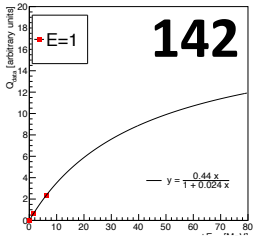


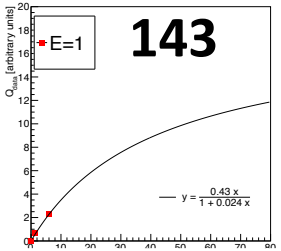
CNAO2022: pos-to-pos calibration

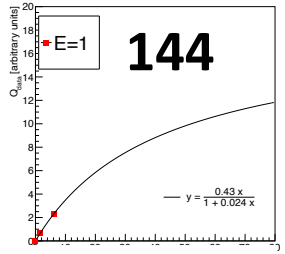


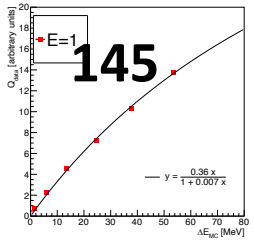


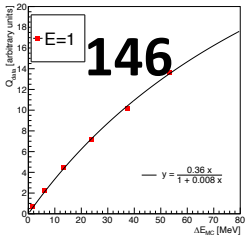


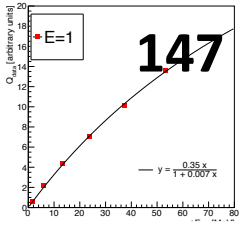


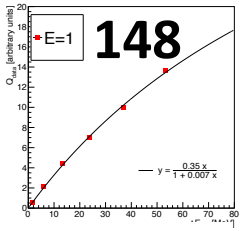


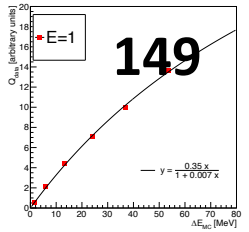


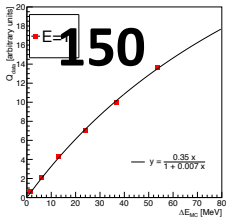


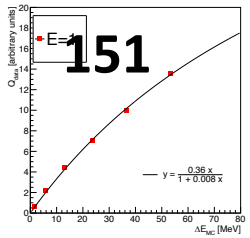


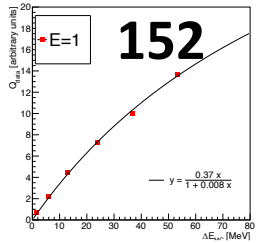


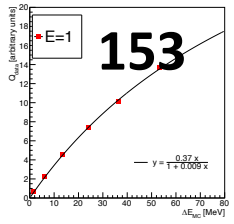


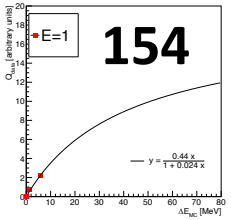


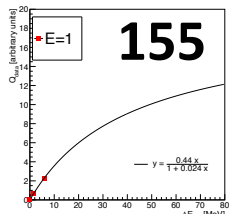


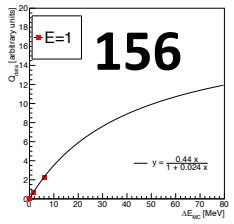


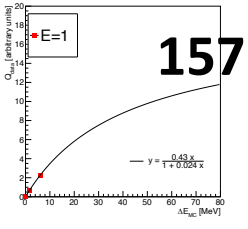


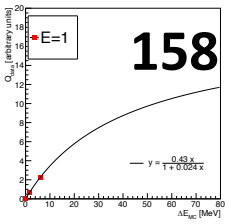


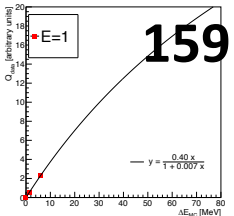












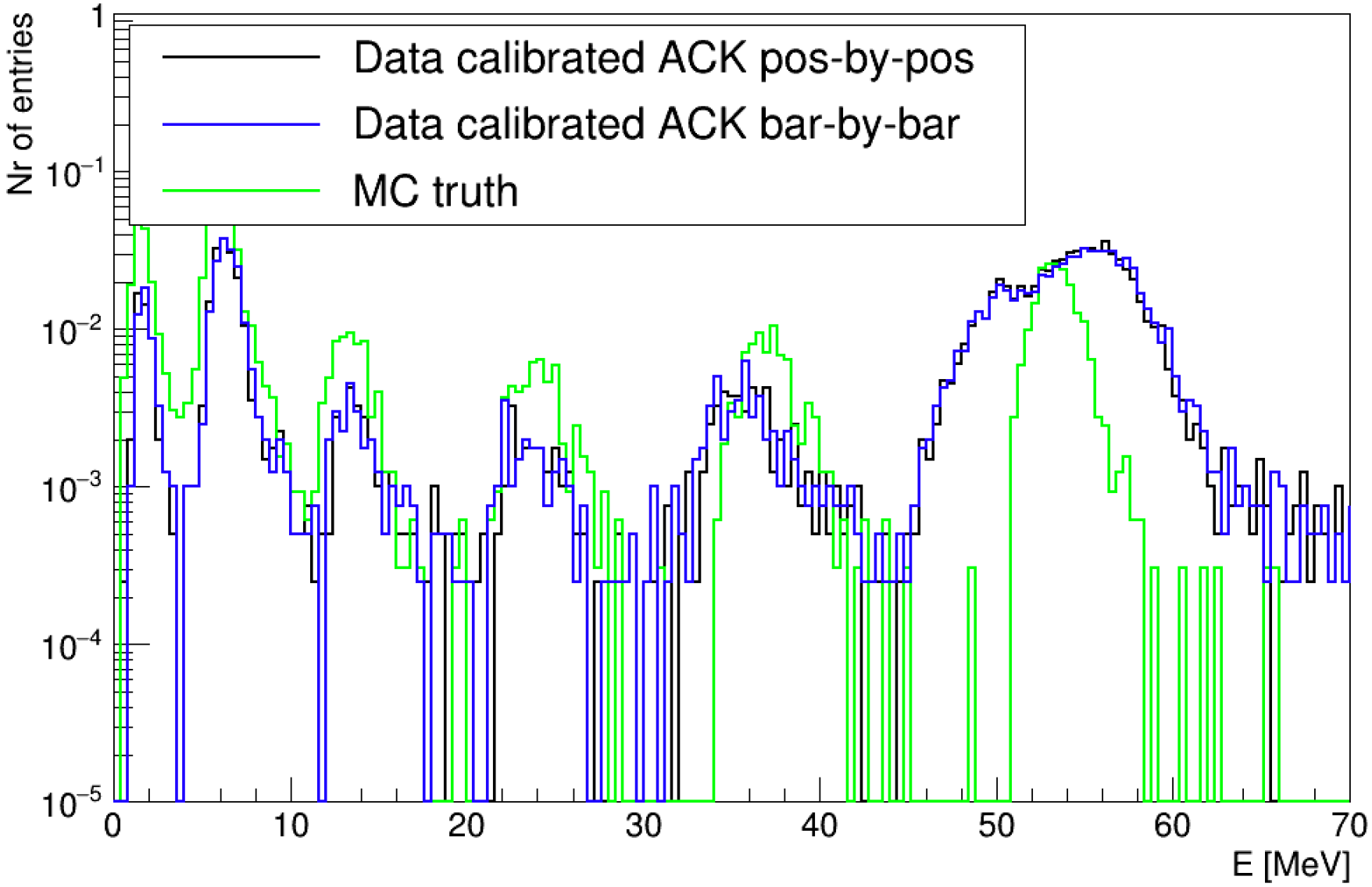
MC

20 curves for bar 27

CNAO2022: final result bar 27

Calibrated (normalized) energy spectrum compared with MC truth (use the same events for this plot!)

Results similar

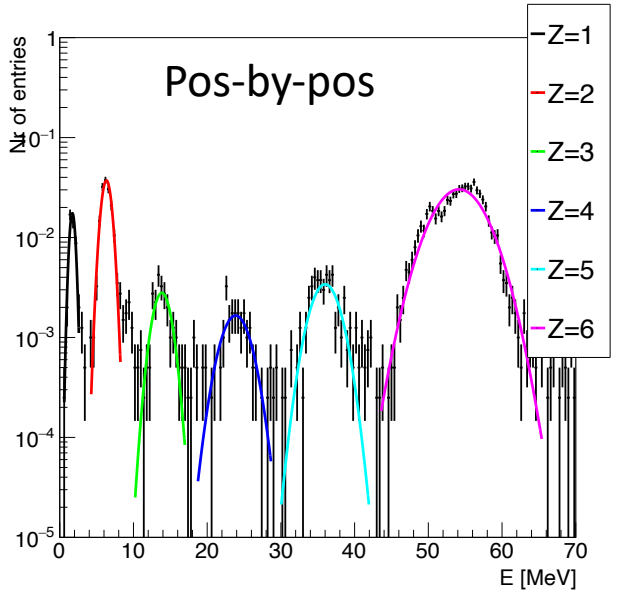


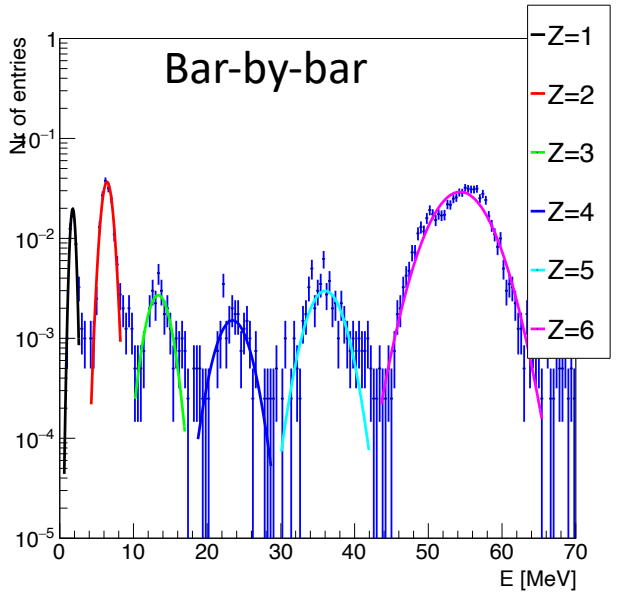
CNAO2022: compare these strategies

- How about the width of the peaks?

Z	σ bar-per-bar calibration	σ pos-per-pos calibration
1	0.33 ± 0.02	0.37 ± 0.03
2	0.67 ± 0.02	0.66 ± 0.02
3	1.43 ± 0.20	1.18 ± 0.19
4	2.00 ± 0.30	1.85 ± 0.30
5	2.19 ± 0.25	1.86 ± 0.24
6	3.42 ± 0.05	3.31 ± 0.05

- **For peaks with largest statistics and best fits: w**idth values are very similar
- **For peaks with smallest statistics and largest fit error**, position calibration gives smallest width, but compatible within errors.
- Is it worth to do 400 fits (of N gaussians)?
- Should test one more bar (more central, so more statistics) to get answer…





Conclusions

- CNAO2022: Bar-by-bar calibration ready, can already be used and is better than what is now included in shoe
- Comparison done for one bar between bar-by-bar strategy and position-by-position strategy
- Check for one more bar that widths do not substantially change