Mass reconstruction @ CNAO2024 via TW-CALO matching

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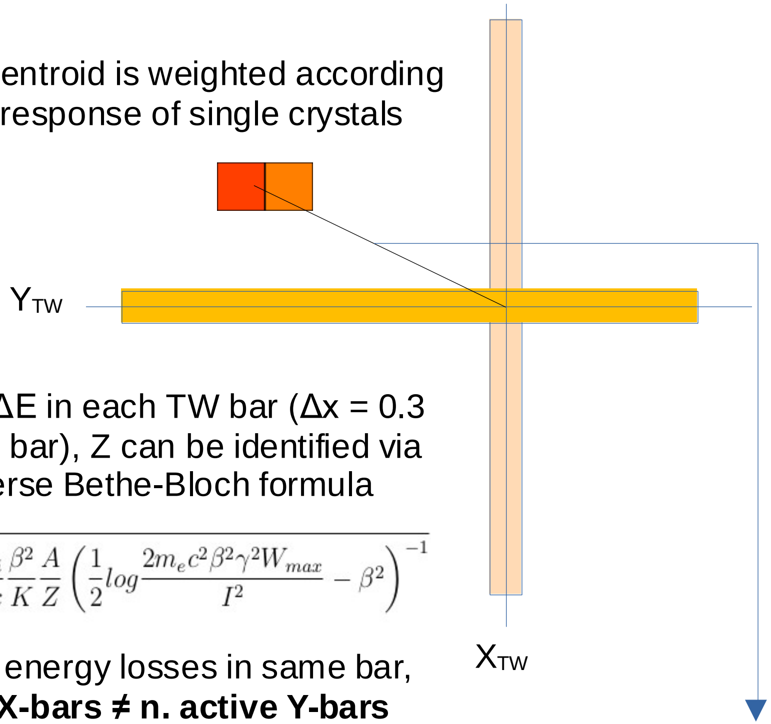
TW-CALO mass reconstruction

Cluster centroid is weighted according to the response of single crystals



Given ΔE in each TW bar (Δx = 0.3 cm per bar), Z can be identified via inverse Bethe-Bloch formula

$$Z_i = \sqrt{\frac{\Delta E_i}{\rho \Delta x}\frac{\beta^2}{K}\frac{A}{Z}\left(\frac{1}{2}log\frac{2m_e c^2\beta^2\gamma^2 W_{max}}{I^2} - \beta^2\right)^{-1}}$$

If multiple energy losses in same bar, **n. active X-bars ≠ n. active Y-bars** → Z is assigned by the layer with most hits.

Two TW hits (bars on) form a TW-point >> TOF, Z and $(X,Y)_{TW}$ coordinates are assigned.

$$A[u] = \frac{E_{kin}[MeV]}{f(\gamma - 1)c^2} \qquad f = \frac{0.931494\, MeV}{u * c^2}$$

E_{kin} = cluster → GetEnergy();

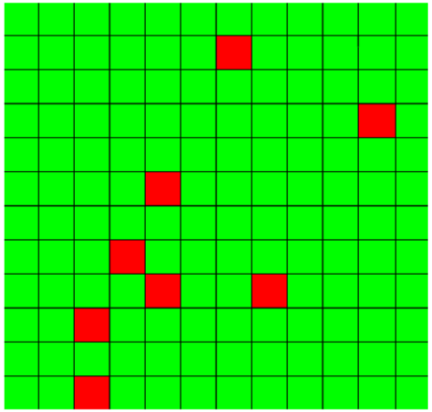
γ is obtained from β = L /TOF, where:
- L is the TG-TW point distance;
- TOF = $TOF_{TW\text{-}SC}$ – $TOF_{SC\text{-}TG}$

TW point and CALO cluster are matched according to minimum distance criterion.

Calibration status @ CNAO2024

- 4x4 central CALO modules were calibrated (aside from some non-responding crystals);

- CNAO2024 calibration for TW not available
→ Z and TOF were accessed directly from TW hits
→ ΔE_i = hit_i → GetEnergyLoss() >> Z_i = ΔE_i / (0.3cm);
TOF = hit_X → GetToF().



CNAO2023 calibration for TW is ready: why not using CNAO2023 data?

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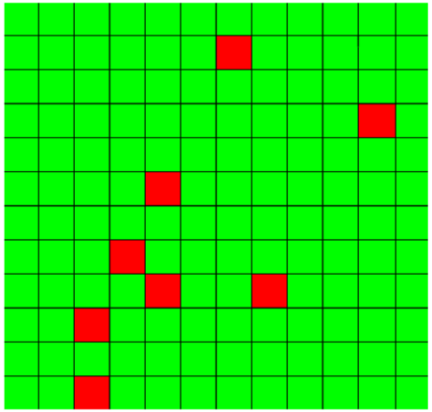

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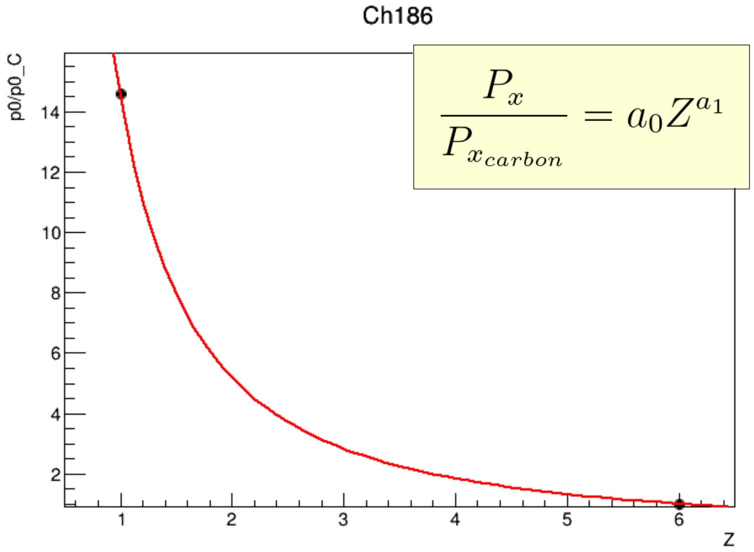


Each calibrated crystal @ CNAO2024 has three parameters (p_0, p_1, p_2) for E_{kin} (ADC) reconstruction with p and C.

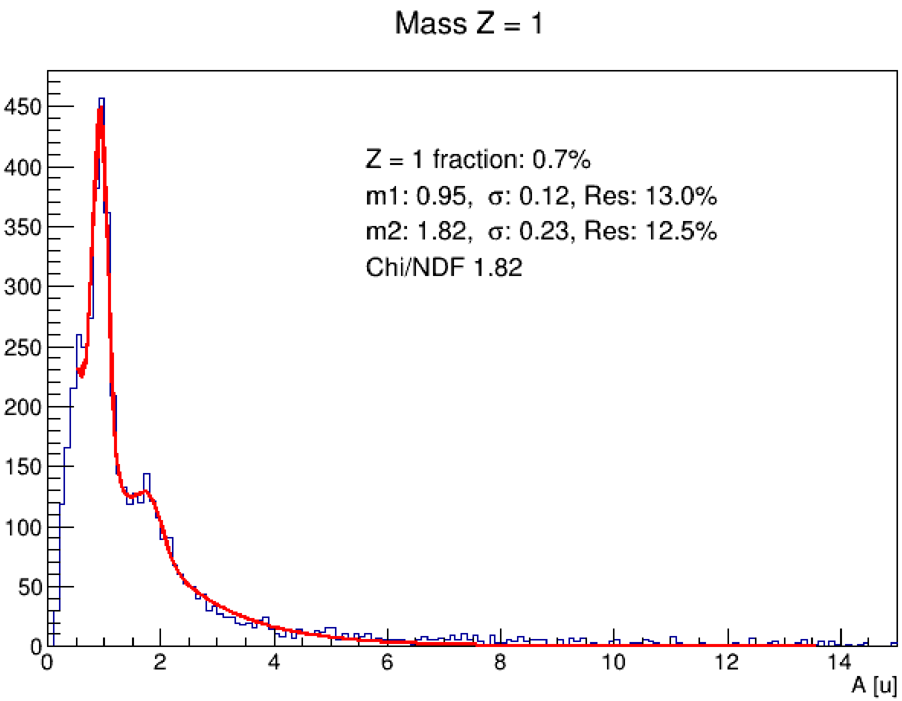
$p_i(Z) / p_i(Z = 6)$ (i = 1,2,3) vs Z, fitted with a power-law function
→ two parameters $(a_0, a_1)_i$ should give $E_{kin}(Z)$ reconstruction.

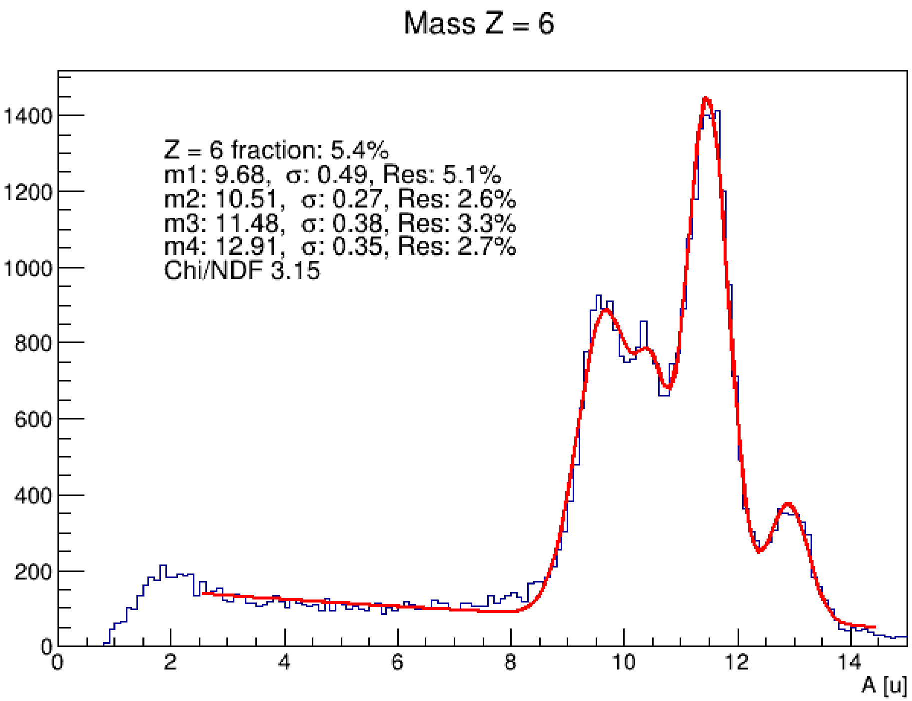
Does this method work? CNAO2023 campaign cannot provide this info (calibration done with C only).

In addition to this, it's possible that $(a_0, a_1)_i$ depend on work conditions (different between 2023 and 2024).

Mass reconstruction @ CNAO2024

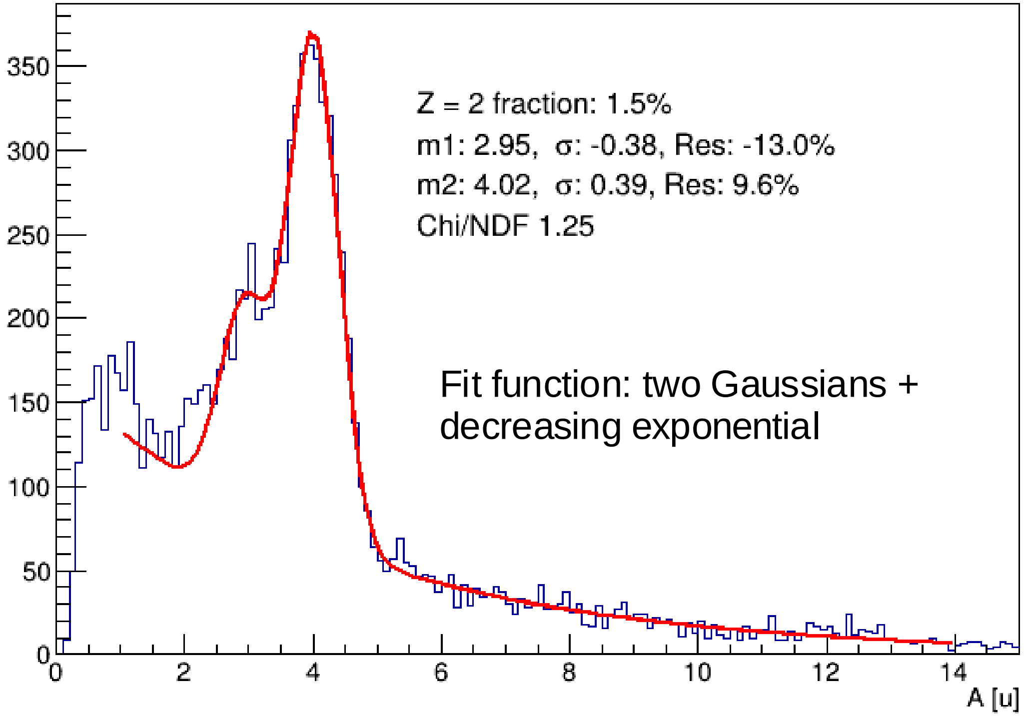
These p and C distributions were obtained from the same dataset; for these ion species, the calibration was direct and the nominal energy was reconstructed with better than 1% precision.





He mass reconstruction @ CNAO2024

He (Z = 2) mass reconstruction on runs 7072-77 (≈ 800k events) gives the following result:



Note that there was no direct calibration with He! Parameters were obtained via power-law function from calibration with p and C ions.

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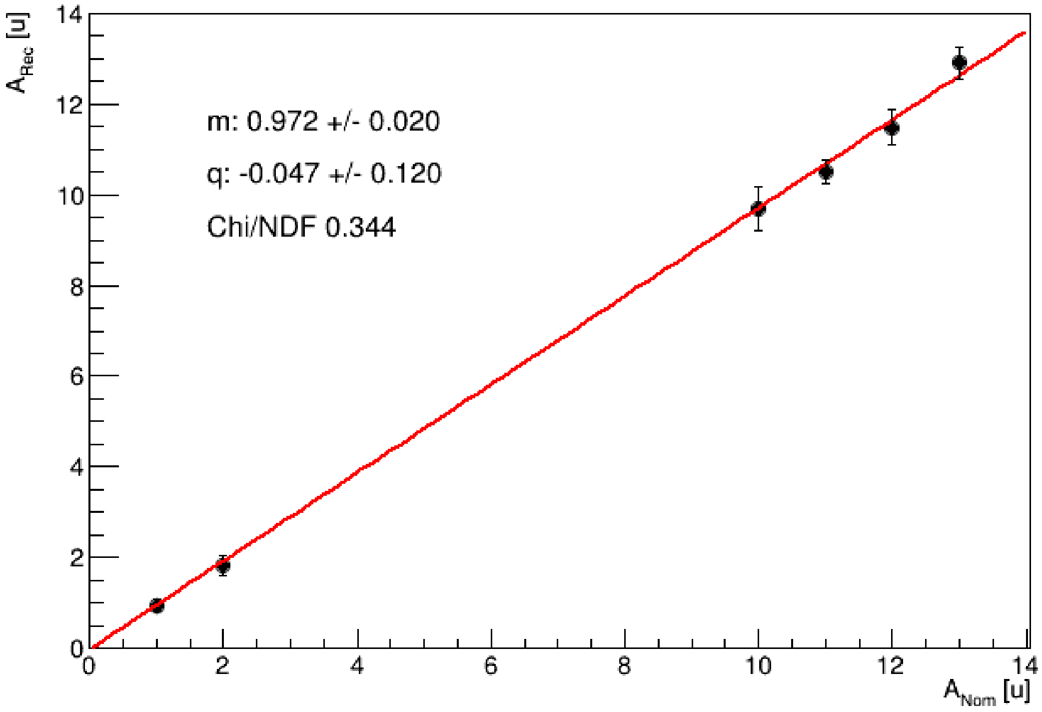


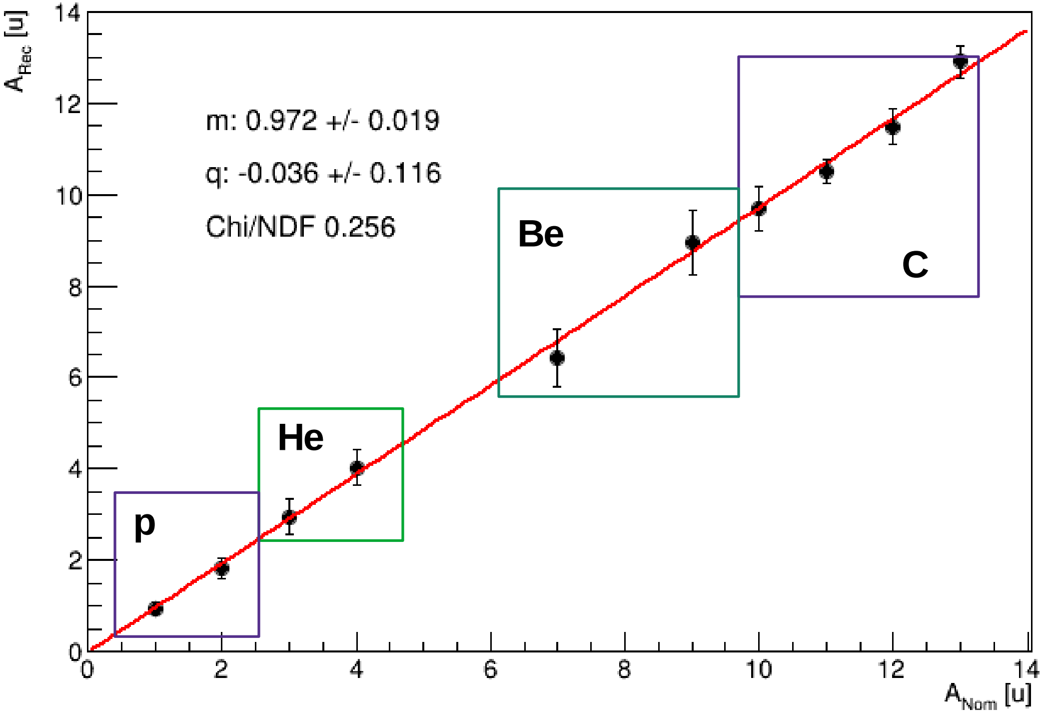
Without tracking system and pending Z misidentification issues, mass peaks reconstructed via *direct calibration*

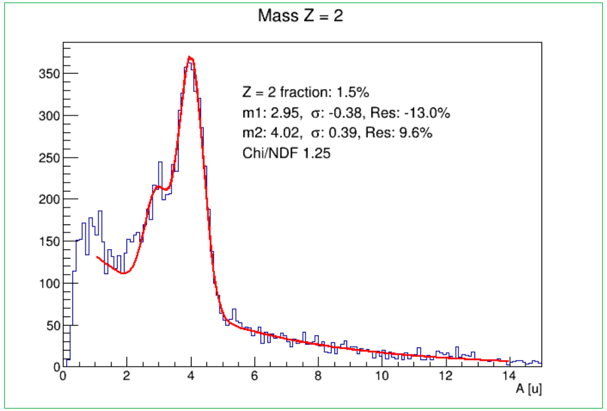
- differ from nominal values by < 3%
- offset compatible with 0.

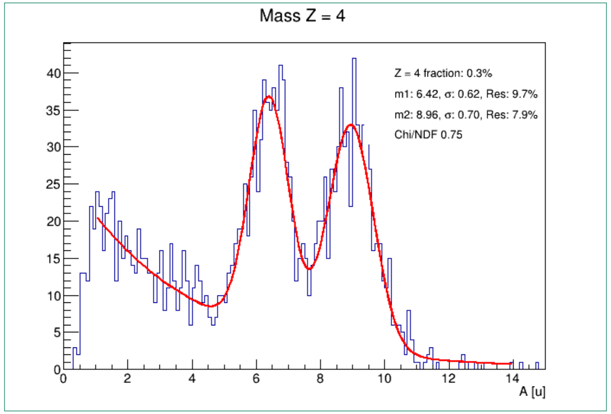
What happens if we consider mass peaks from other ion species? (obtained via power-law functions for the Z dependence of calibration parameters)

Mass reconstruction @ CNAO2024

A linear relationship is found between reconstructed and nominal mass peaks, and the offset is given by the same correction factor *m* obtained from p and C only.







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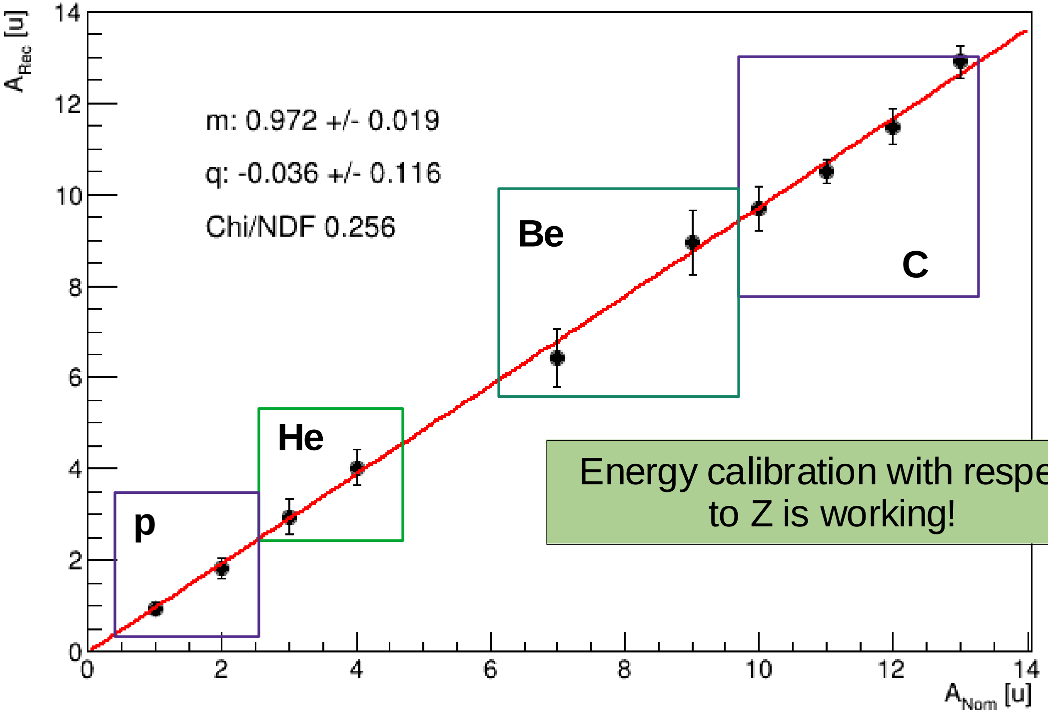
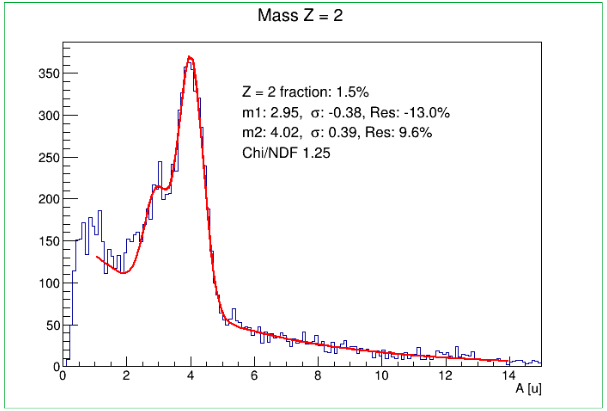
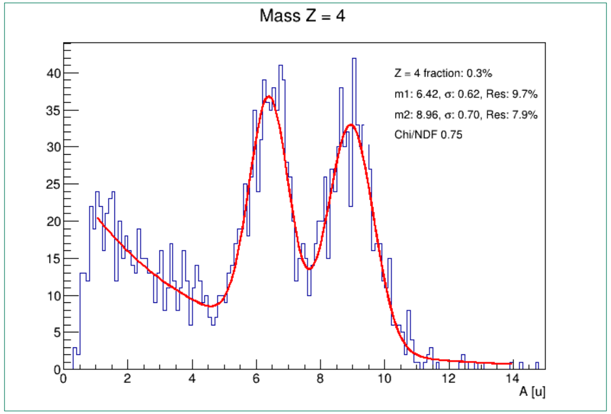
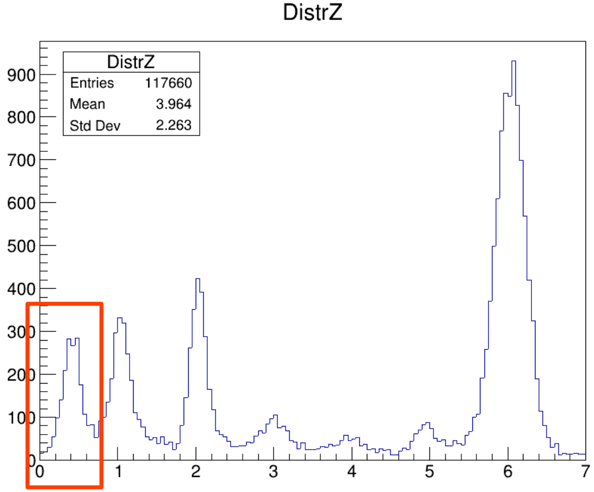


Energy calibration with respect to Z is working!





Pending issues and possible improvements



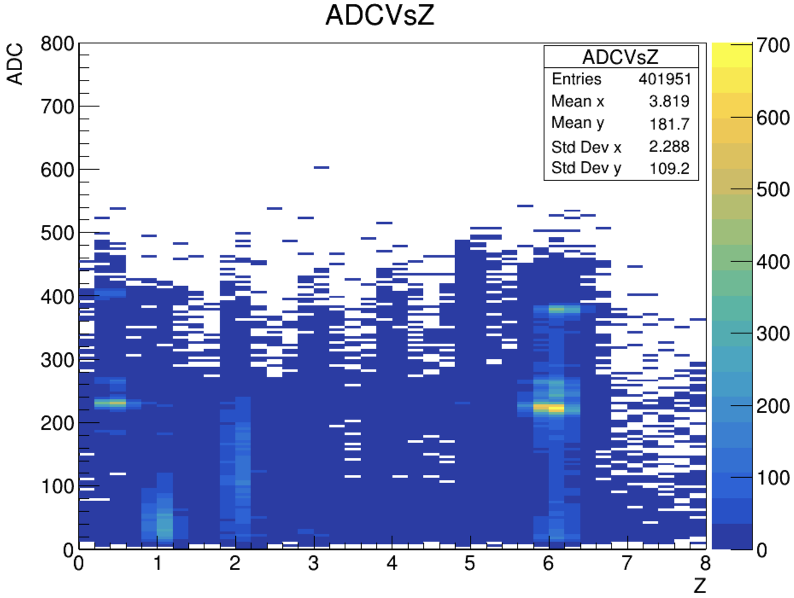
In order to select fragments with a specific Z, a threshold based on this charge distribution was set.

However, there is a charge peak between 0 and 1

We tried to plot raw signal values (ADC) vs identified Z.

Is there a connection between Z = 0 and Z = 6 (mostly primaries)?

Try to preserve only TW-hits with X ≠ -1, 1 and Y ≠ -1, 1.



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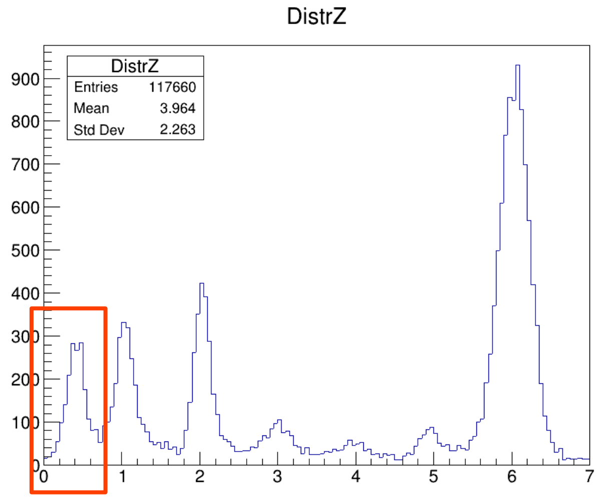

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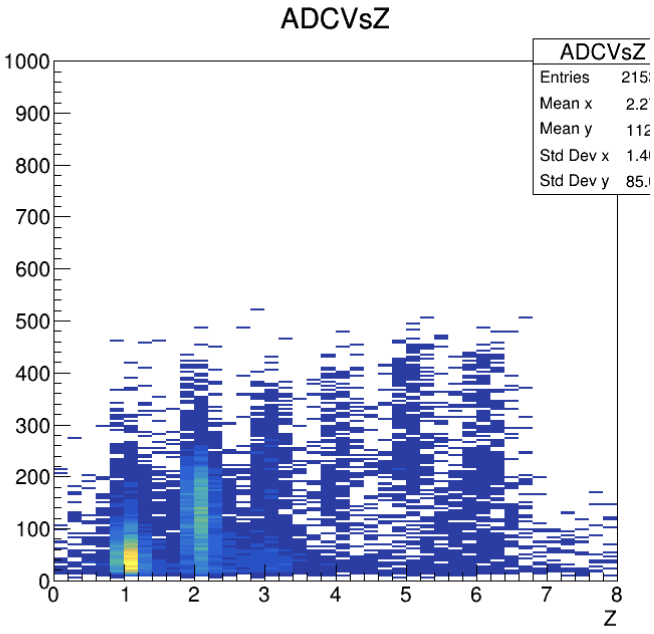
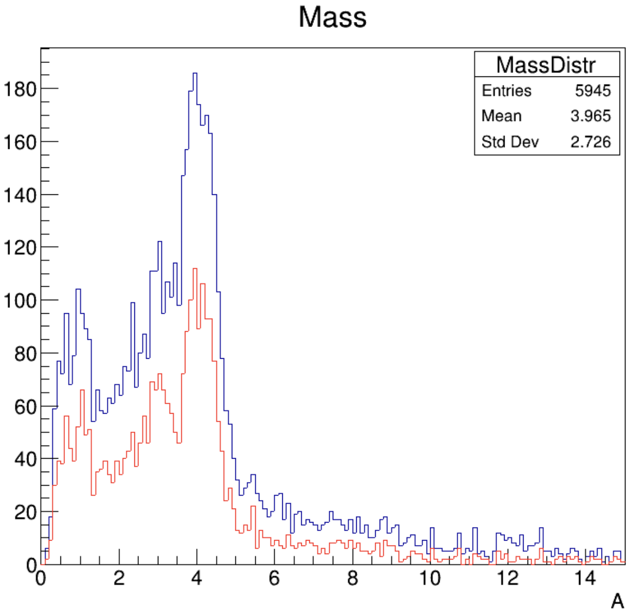
Now most events have Z = 1, 2,
and column in Z = 0 almost disappeared
>> improved resolution in He spectrum!





Pending issues and possible improvements

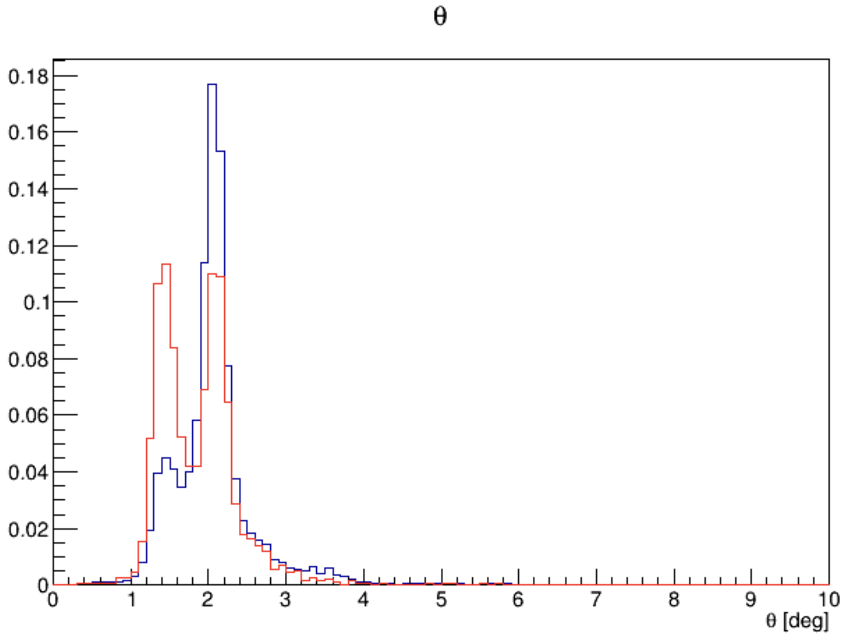
Fragments angular distribution.

Blue: distribution in θ (angle between track and z axis) for Z = 6
Red: fragments with mass in [0.6 12Ccenter , 1.4 12Ccenter]

12C is the main contribution to the peak on the left

potential fragment vs primary beam discrimination

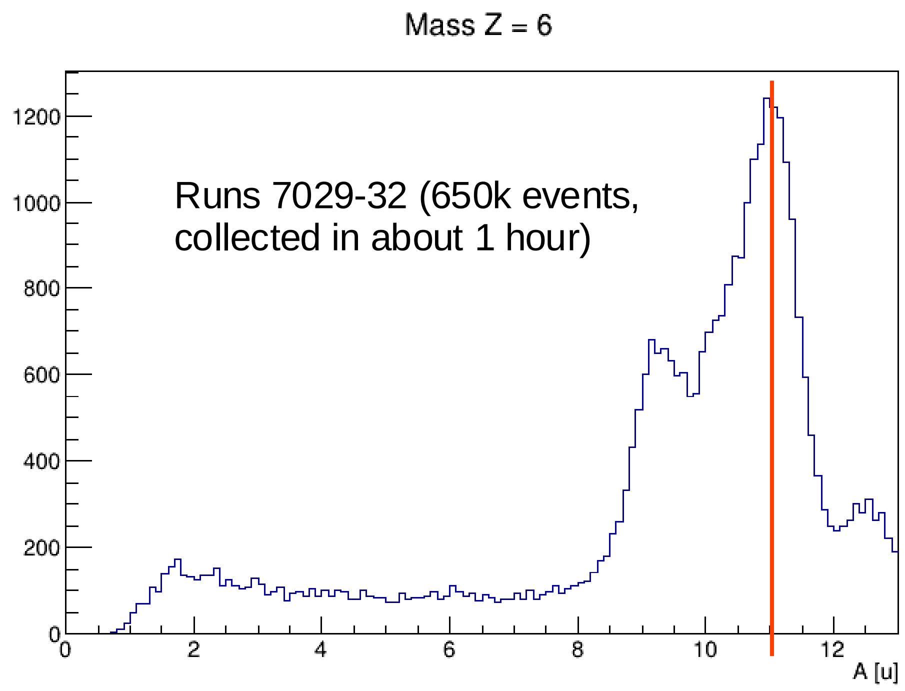
12C (beam) expected to be centered in 0
→ possible explanation: some geometry parameter is wrongly computed.

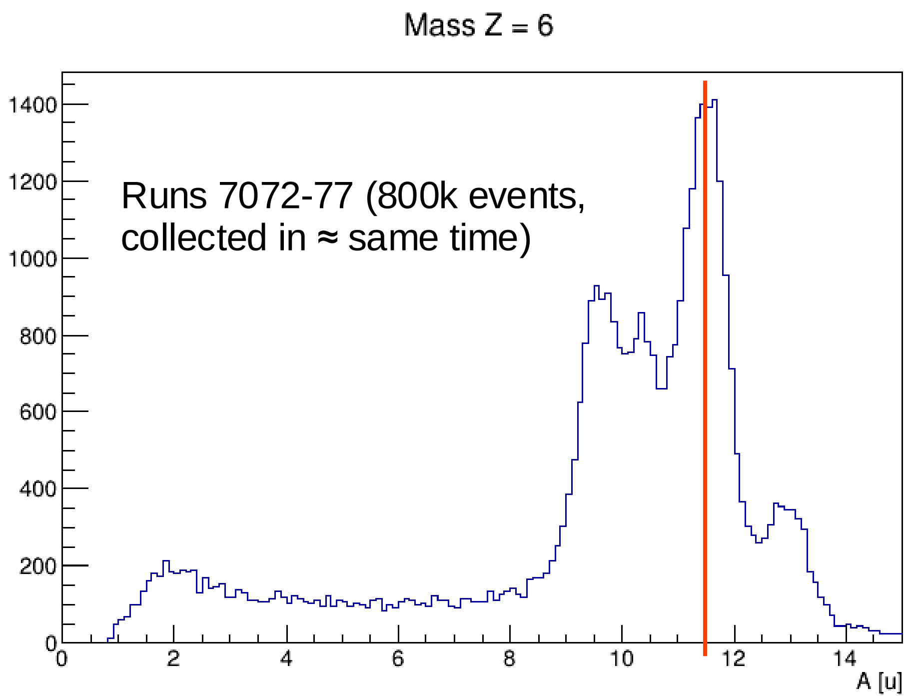


(normalization with respect to the n. of entries)

Pending issues and possible improvements

Carbon distribution obtained from a different set of fragmentation runs
→ mass resolution is worse than the previous case and peaks are shifted.





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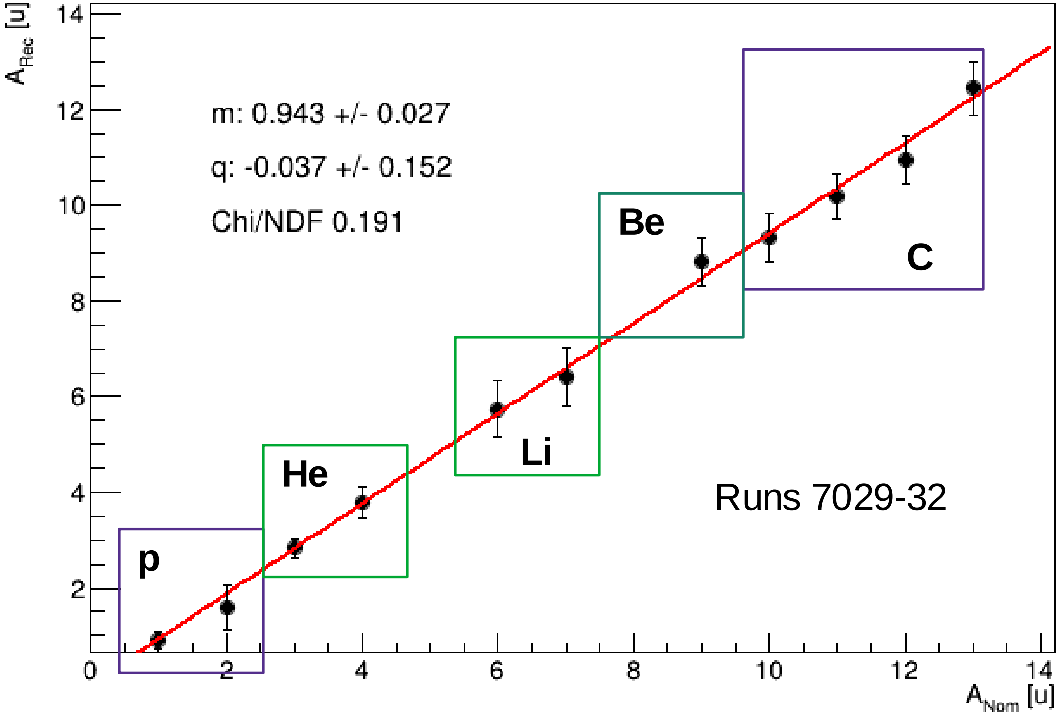
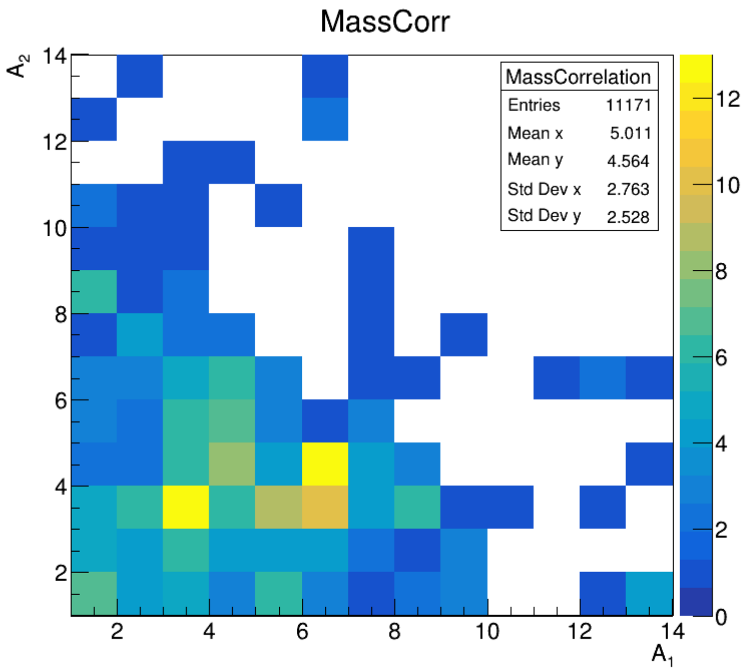
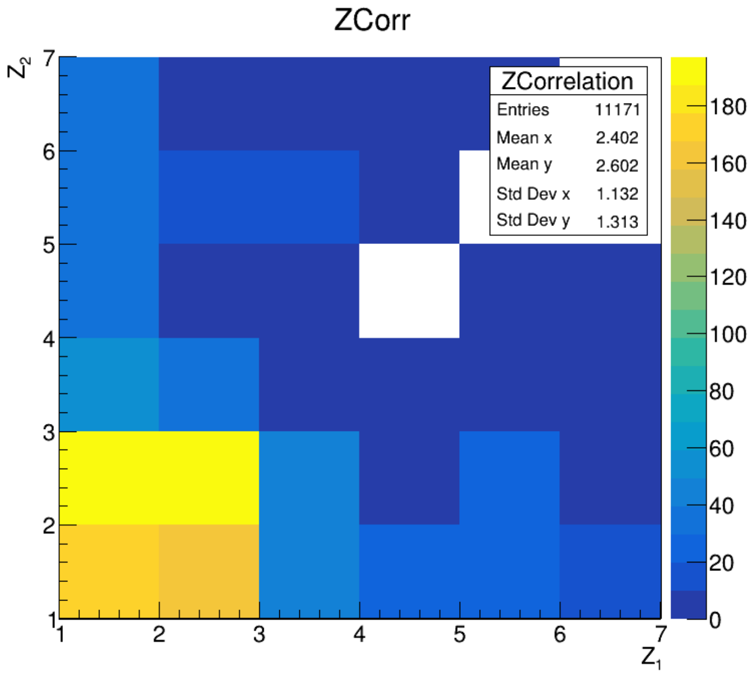


Different runs → different correction factor; however, mass peaks from Z = 2 to Z = 5 are consistent with mass peaks for Z = 1, 6
>> power-law conversion function still works!

Temperature variations between different physics runs and within the same physics run might be not negligible.

Pending issues and possible improvements





In most cases, total A and Z should be 12 and 6 respectively
→ for events with 2 clusters, we were looking for $Z_1 - Z_2$ and $A_1 - A_2$ correlations.

Many events have A = 0 (possibly, the acceptance from calibrated CALO area is too low) or Z = 0 (possible charge misidentification).

Conclusions

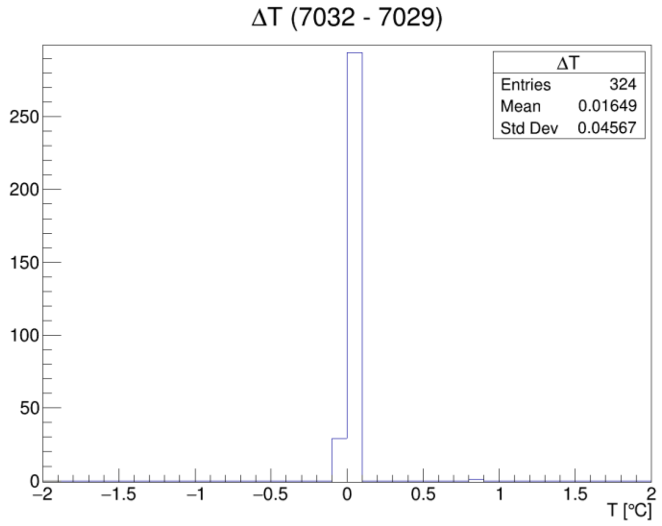
Clustering algorithm and TW-CALO matching are working properly, however:

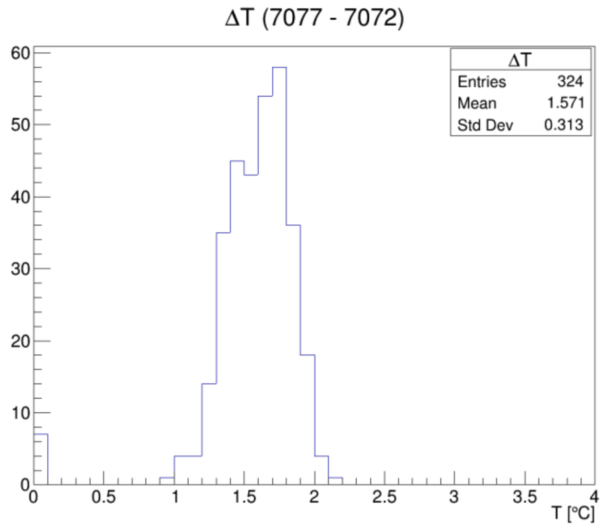
- clear dependence from CALO stability (T correction still to be applied);
- CALO calibration @CNAO2024 still to be completed (16/36 modules used for this analysis);
- Z assumed from the most-hit layer → possible misidentification;
- approximated fragments trajectory (tracking system not available for analysis) + energy loss in air neglected;

Upcoming steps for mass reconstruction:

- complete calibration for border modules → larger acceptance in order to best study A and Z correlations;

- T correction to be implemented in analysis framework → impact on mass reconstruction to be assessed.





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In spite of all these limitations, mass distributions were obtained from Z = 1 to Z = 6, and the discrepancy between nominal and reconstructed mass peaks can be modeled by a linear correction factor of ~ 3%.

- the systematic error on the mass is independent of Z
- p, C Energies are directly calibrated

can the error come from L? or from the 2023 TW calibration (instead of 2024)?