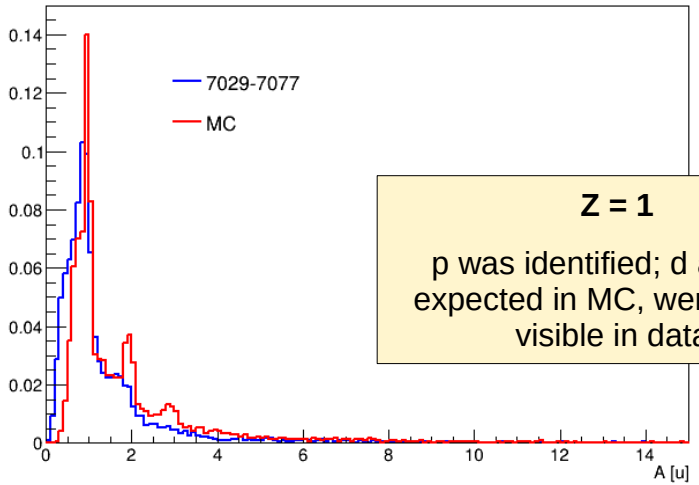
Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO


Status of mass reconstruction @ CNAO 2024

B. Spadavecchia on behalf of the Turin group

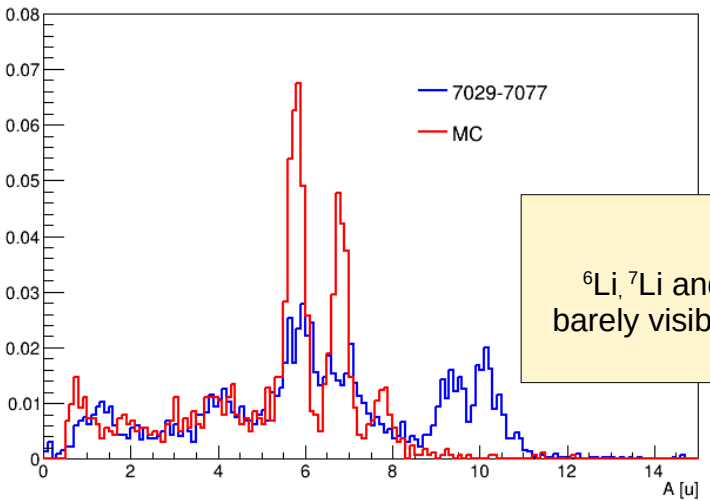
XVIII FOOT Collaboration Meeting - Riccione

Last update (MC vs runs 7029-7077)



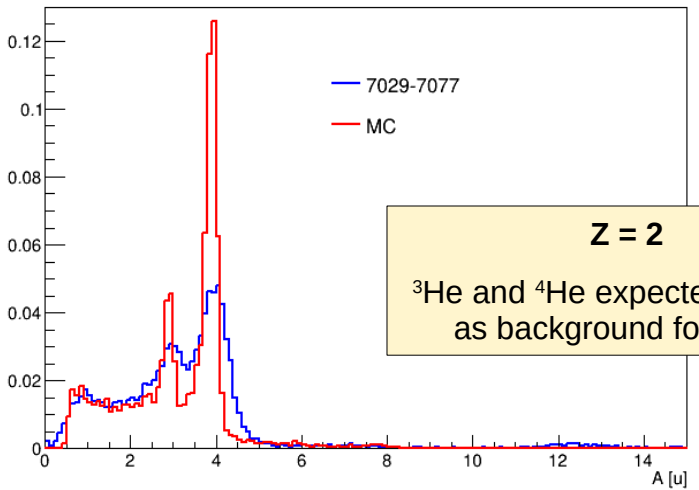
Z = 1

p was identified; d and ^{3}H, expected in MC, were barely visible in data.



Z = 3

^{6}Li, ^{7}Li and ^{8}Li expected, but barely visible + misidentification issues.



Z = 2

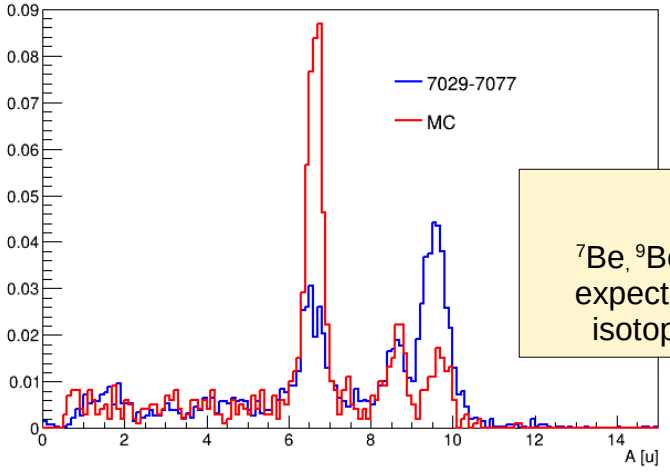
^{3}He and ^{4}He expected, as well as background for A ≈ 1.

CALO resolution was modeled according to CNAO24 calibration points and added to MC simulation.

Some problems are already visible:

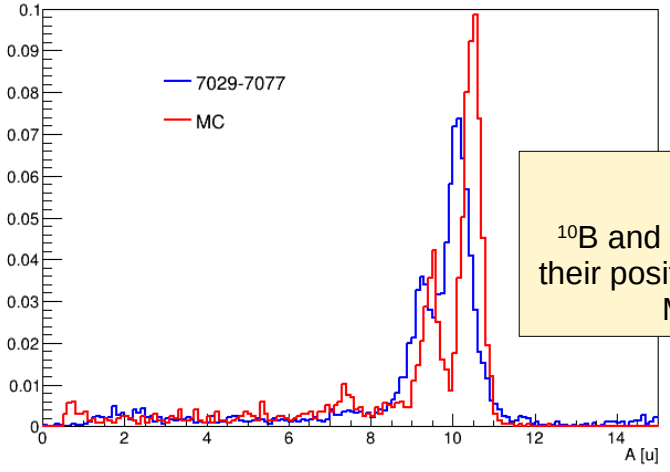
- Background due to TW-CALO mismatching / fragmentation in exp setup;
- Small shifts with respects to nominal values;
- Experimental resolution worse than expected.

Last update (MC vs runs 7029-7077)



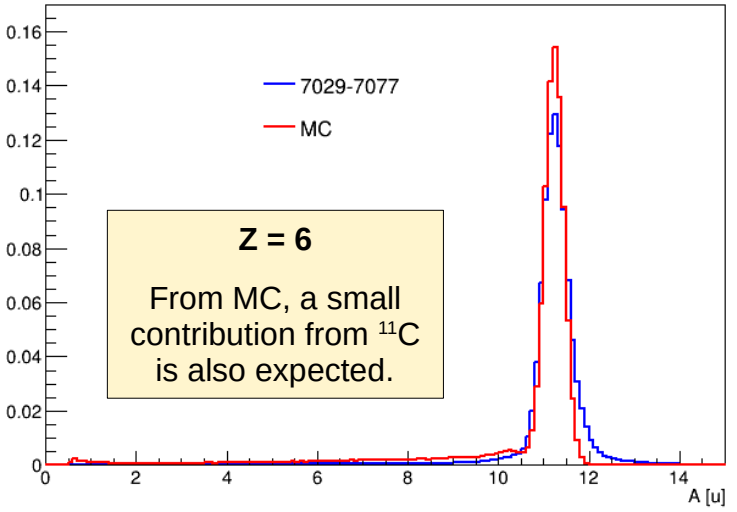
Z = 4

^{7}Be, ^{9}Be and ^{10}Be were expected with different isotopic abundance.



Z = 5

^{10}B and ^{11}B are expected, but their position is shifted between MC and data.



Z = 6

From MC, a small contribution from ^{11}C is also expected.

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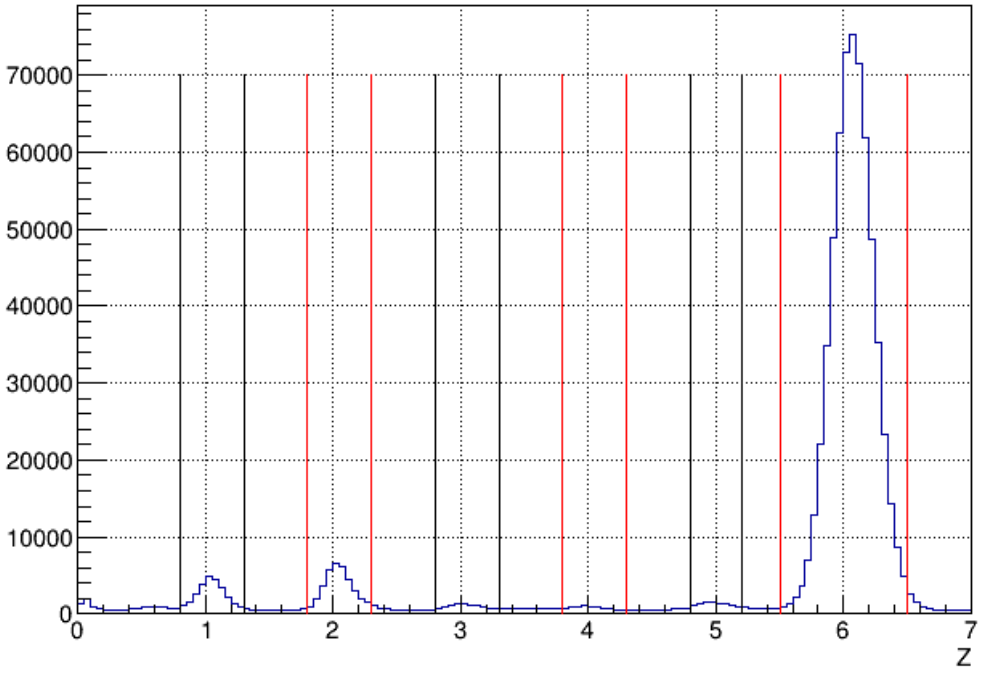
Some problems are already visible:

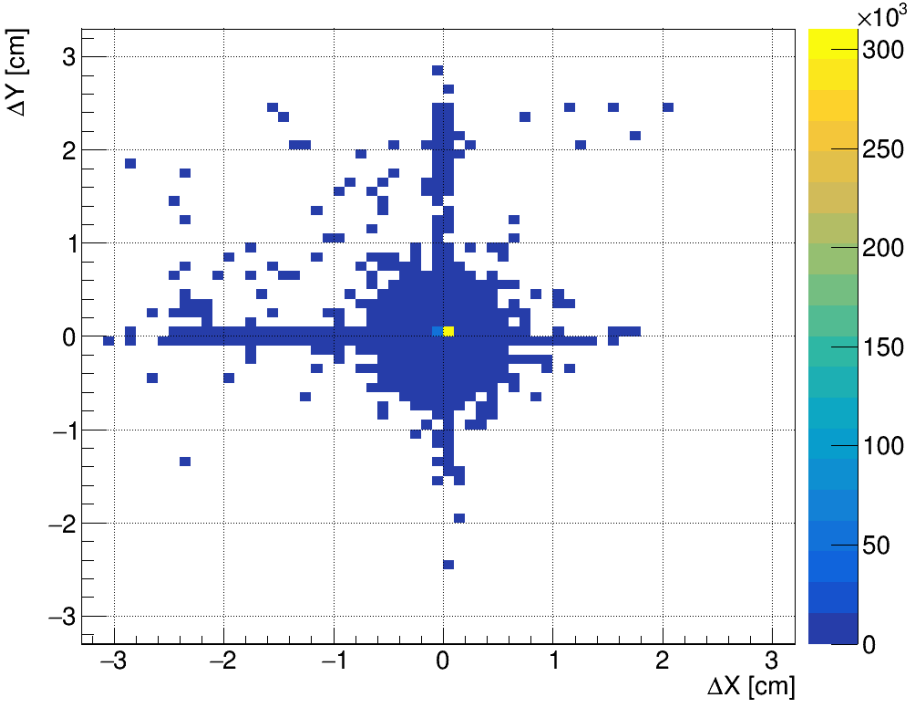
- Background due to TW-CALO mismatching / fragmentation in exp setup;
- Small shifts with respects to nominal values;
- Experimental resolution worse than expected.

Selection on Z and cluster position

Z distribution for ≃ 1.5M fragmentation events
→ thresholds on Z selection.

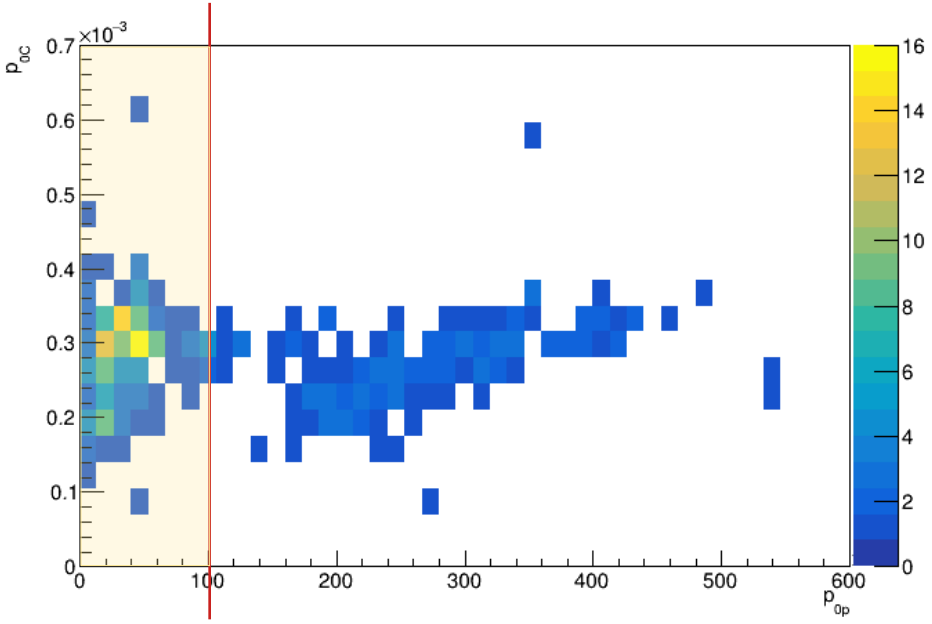


After the energy equalization, the shift in (X,Y) is < 0.1 cm for 80% of the clusters → threshold on cluster selection.

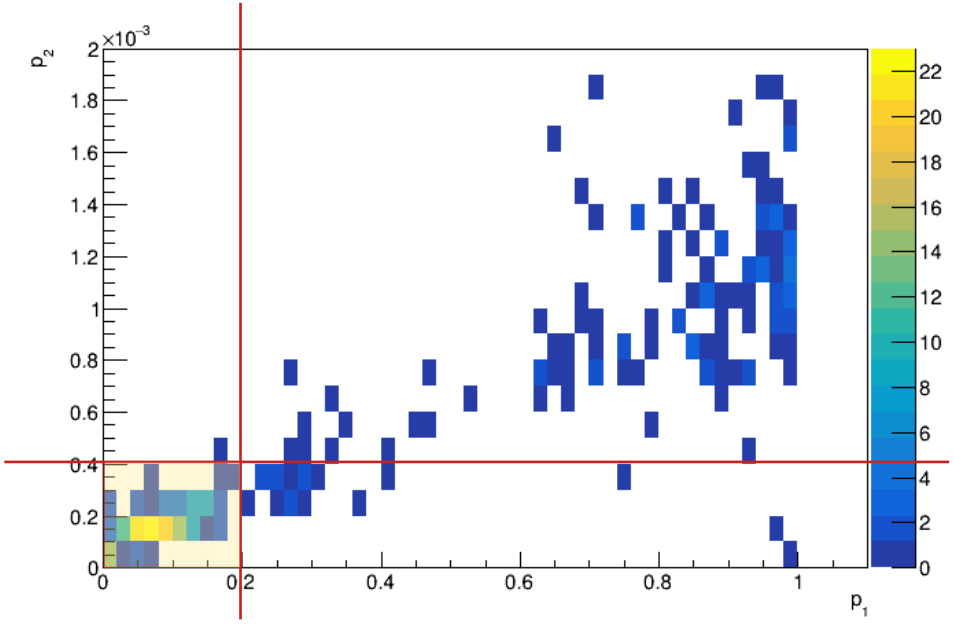


Selection on good-calibrated crystals

Best-fit MBF parameters for p have wider dispersion than for C → further selection on crystals.



p_0 for C vs p_0 for p.



p_1 vs p_2 for p.

What changed since then?

✓ TW @ CNAO2024 is now fully calibrated (thanks Marco and Pisa group) → TOF and Z are now reliable, with known efficiency in Z identification.

✓ Yun took care of TW-CALO alignment (to be perfectioned);

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✓ Yun took care of TW-CALO alignment (to be perfectioned);

✓ I have re-computed calibration parameters for p, by setting the following limits:

$$p_0\,(C) < p_0\,(p) < 0.1$$
$$p_1\,(C) < p_1\,(p) < 0.2$$
$$p_2\,(C) < p_2\,(p) < 4e\text{-}04$$

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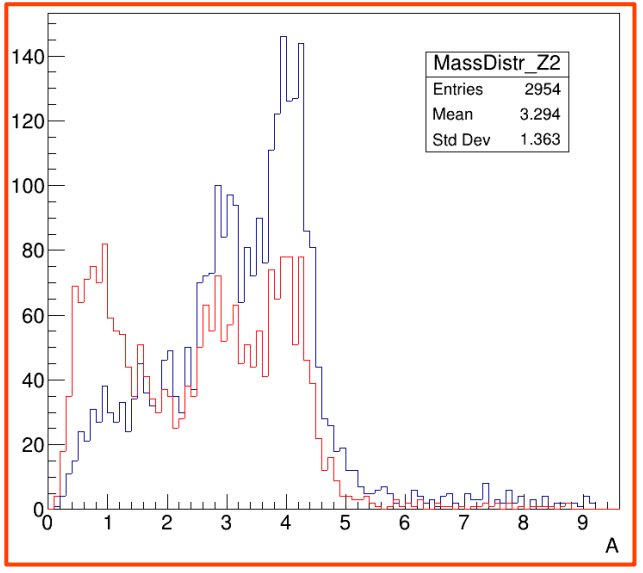
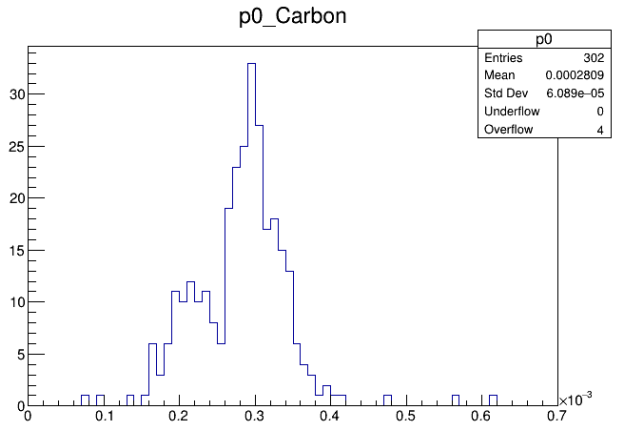
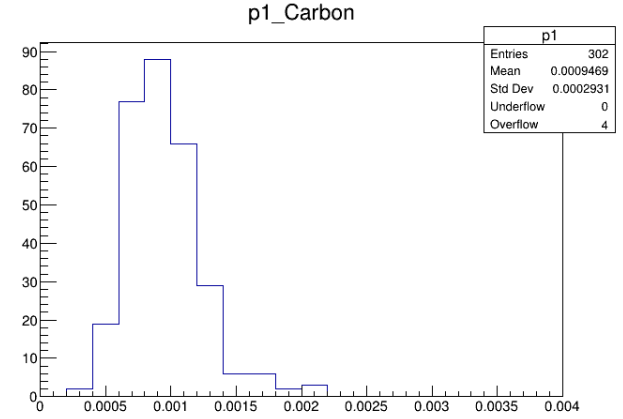


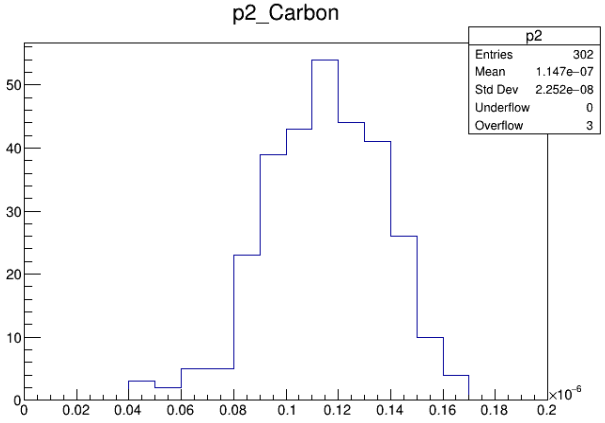
✓ New functions for calibration of CALO hits and TW-CALO matching were implemented in *shoe* → ready for the merge.

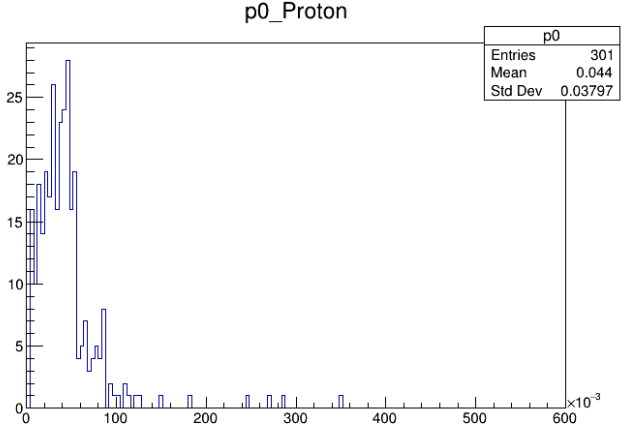
- CALO calibration is performed via power-law functions, and can be enabled in the .cfg file (validated for CNAO2024 only!);
- TW-CALO matching is done for all clusters right after computing their position (and not with one clusters at once, since it was leading to misidentification).

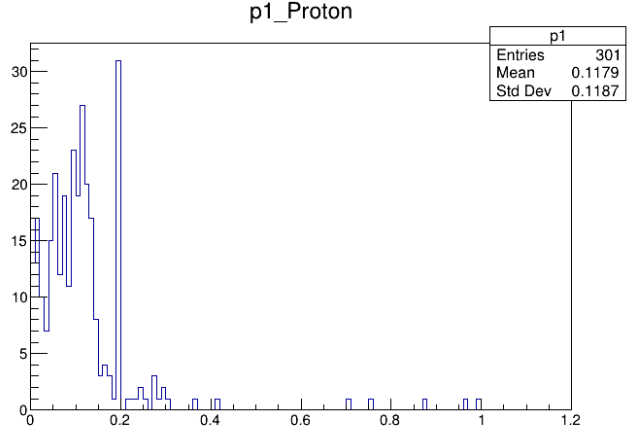
Calibration parameters distribution for p and C

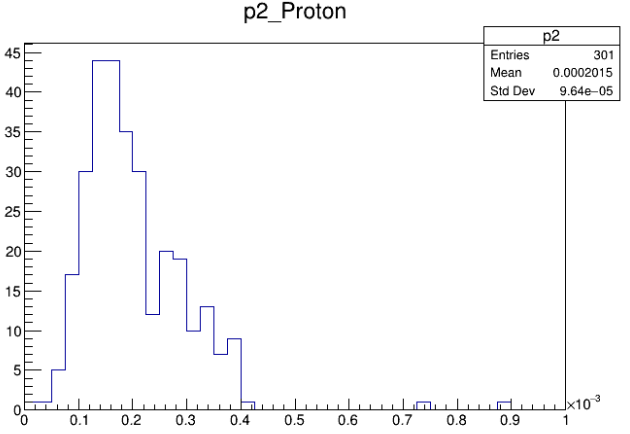












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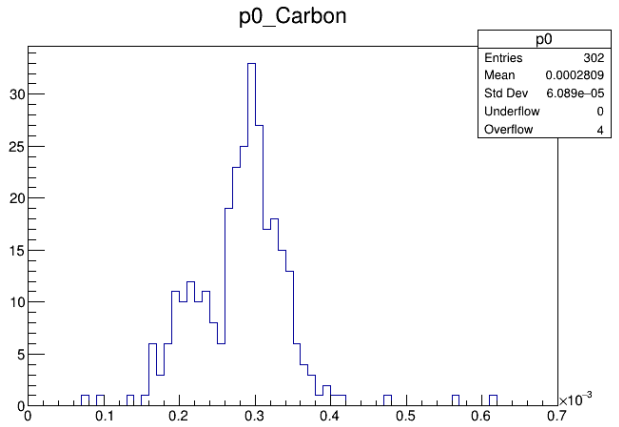
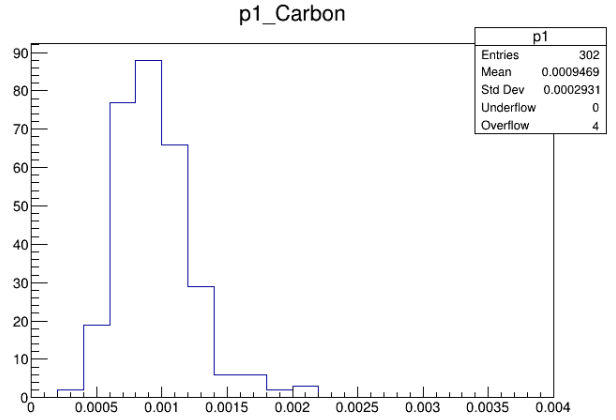
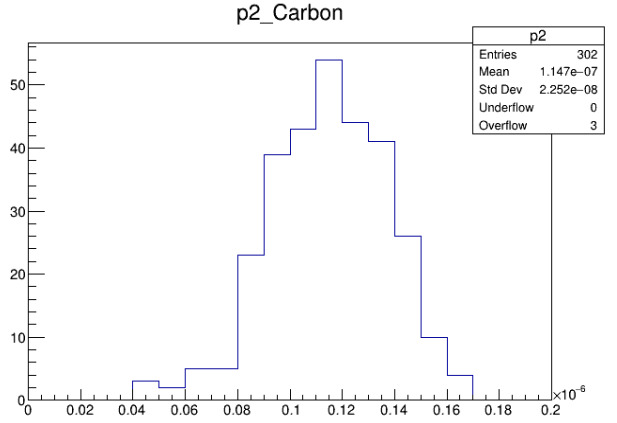
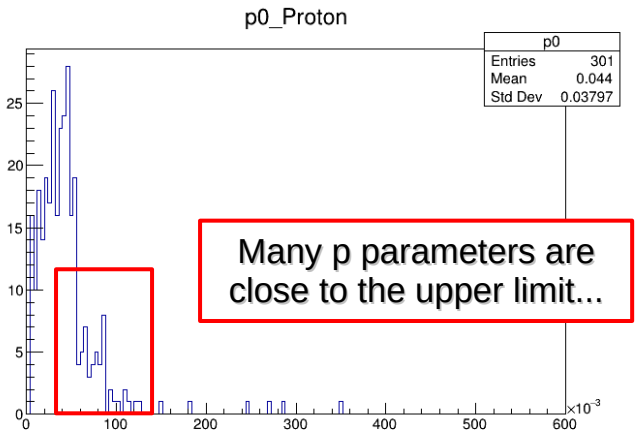
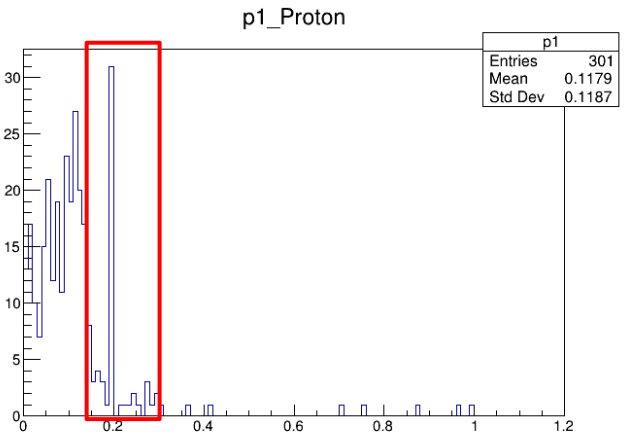


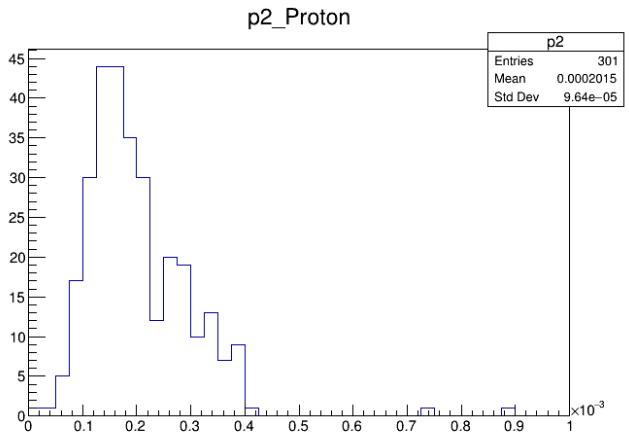




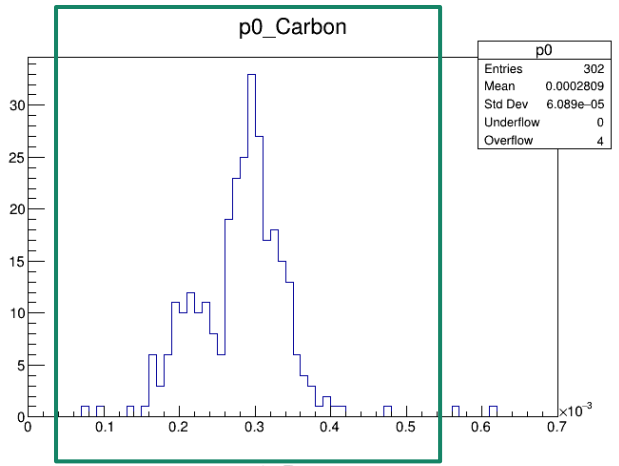


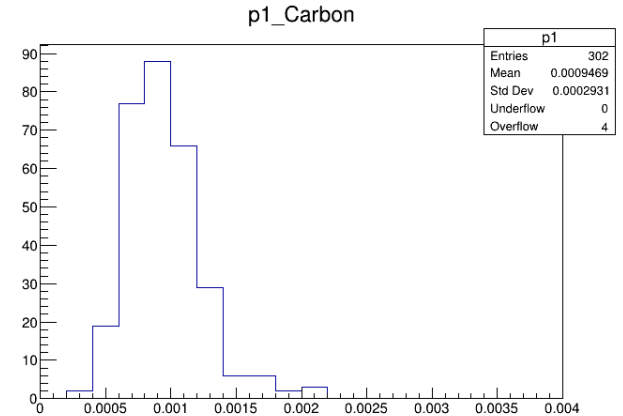
Many p parameters are close to the upper limit...

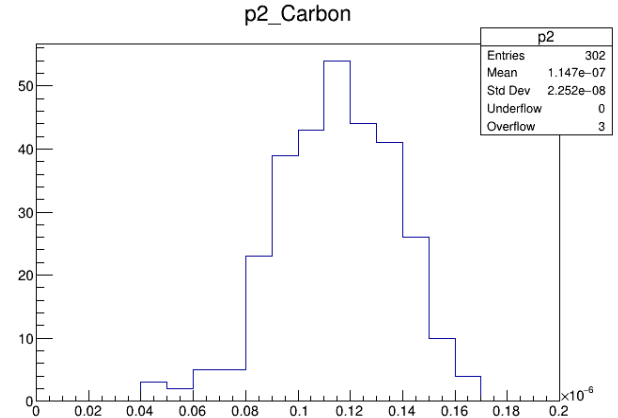


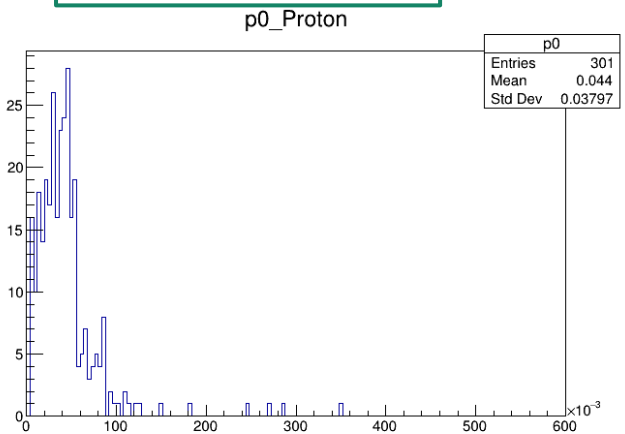


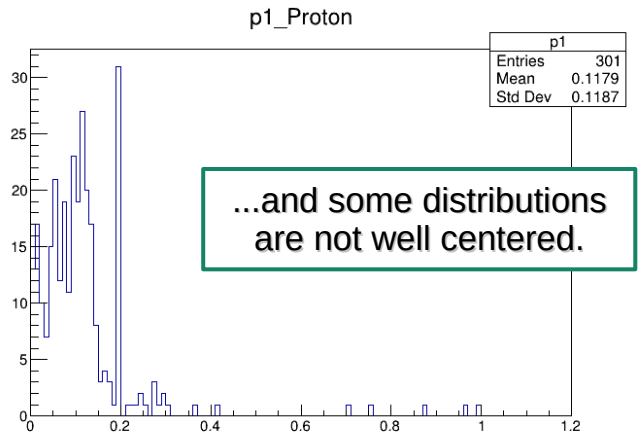
Calibration parameters distribution for p and C



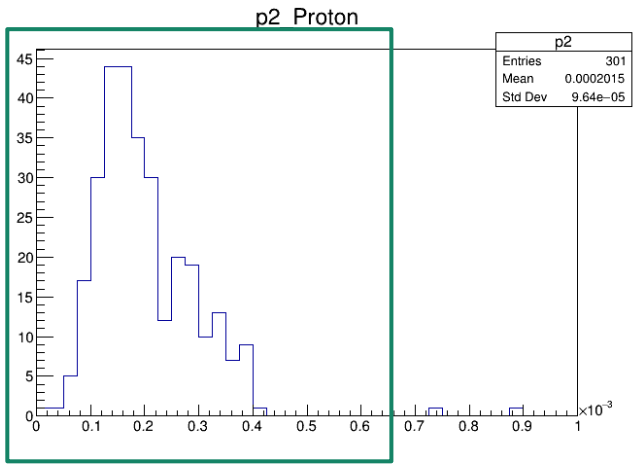




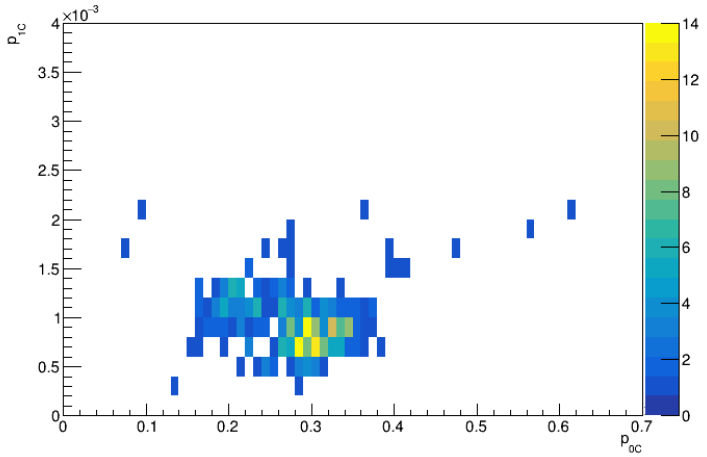


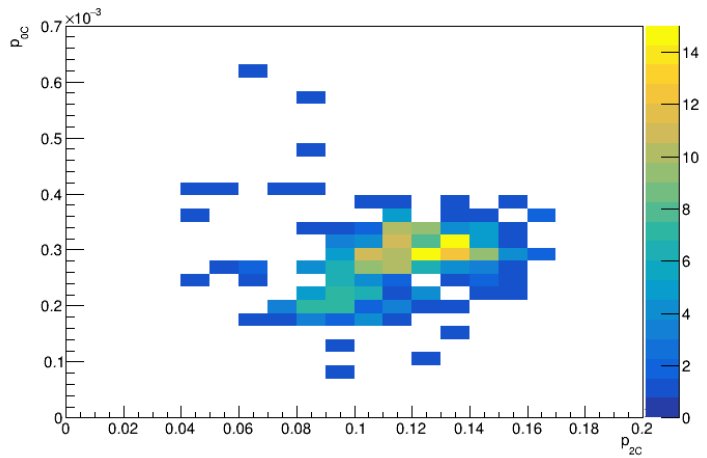


...and some distributions are not well centered.



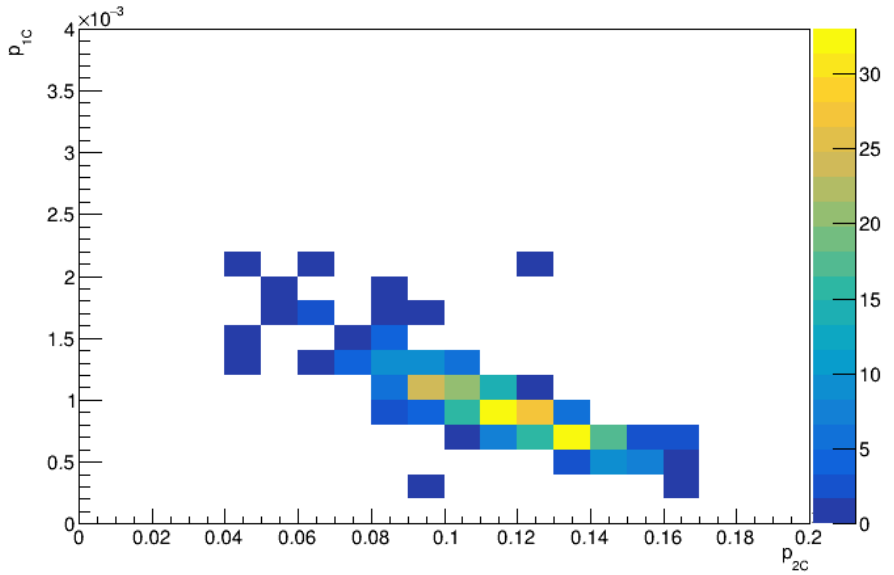
Correlation between MBF parameters





There is evidence of a correlation between parameters p_1 and p_2 in Modified Birks Function (MBF):

$$ADC(E) = \frac{p_0 x^2}{1 + p_1 x + p_2 x^2}$$



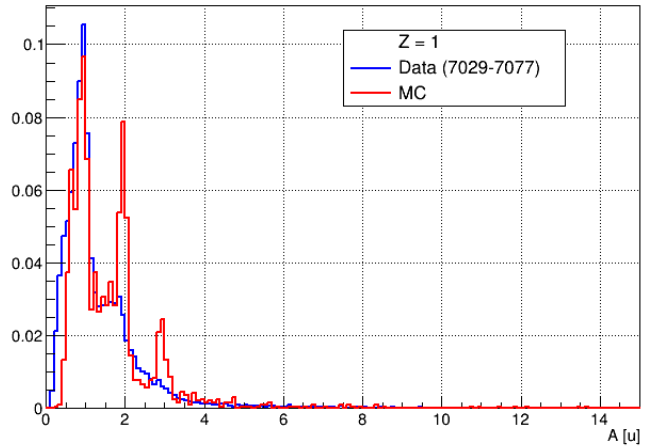
To keep in mind

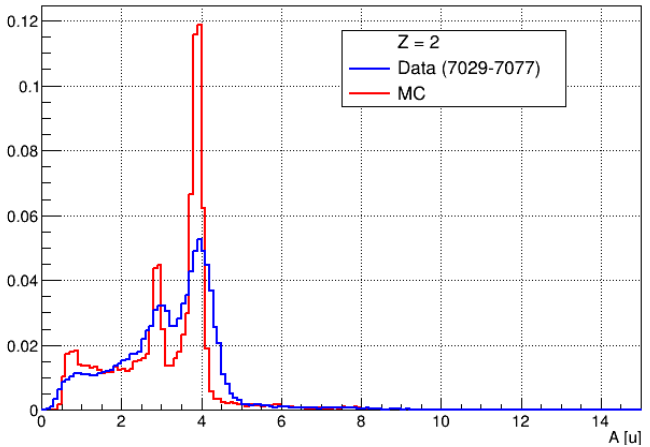
>> In the following analysis, all previous cuts will be removed

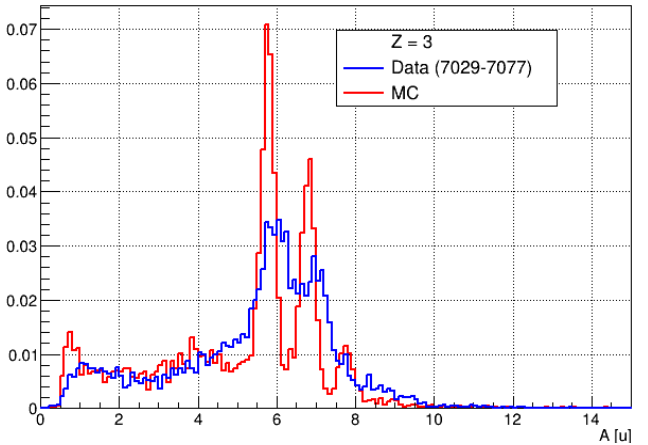
→ only non-fully calibrated clusters (19/320) are excluded.

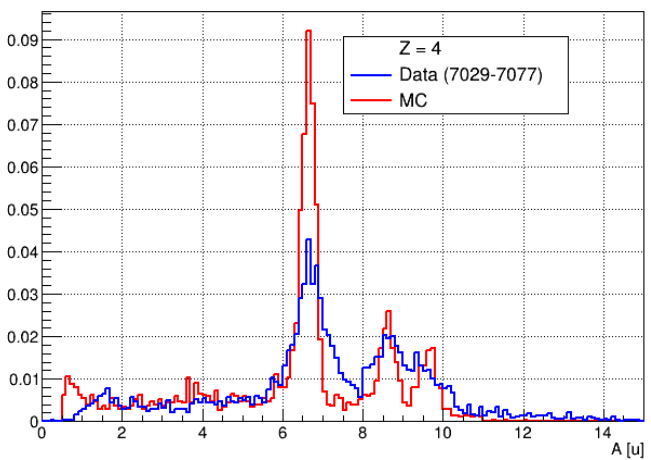
>> In all comparisons, distributions are normalized with respect to the total number of entries.

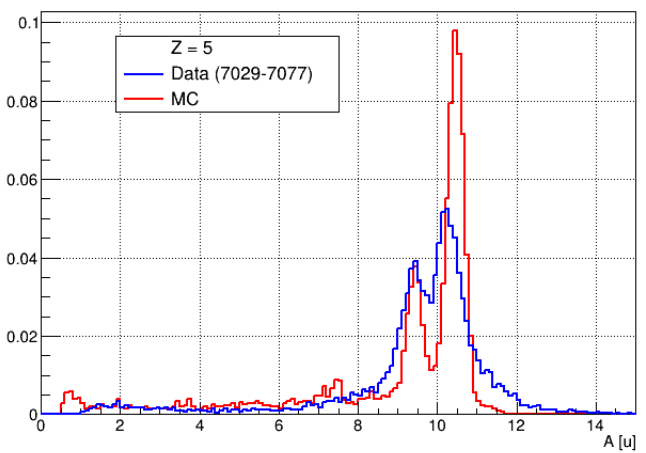
Normalized mass distributions - data vs MC

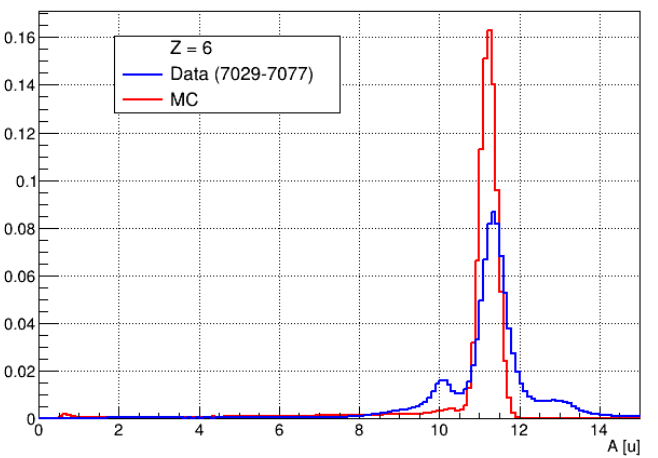




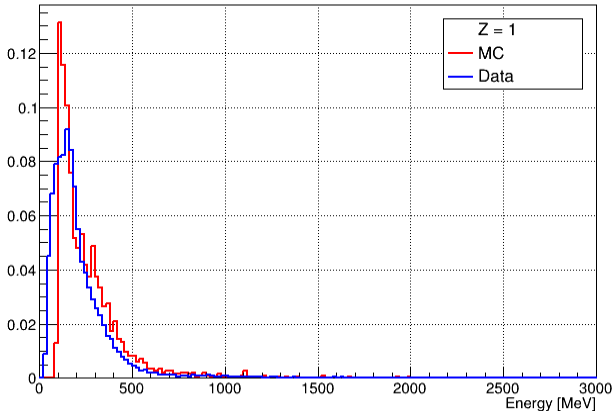


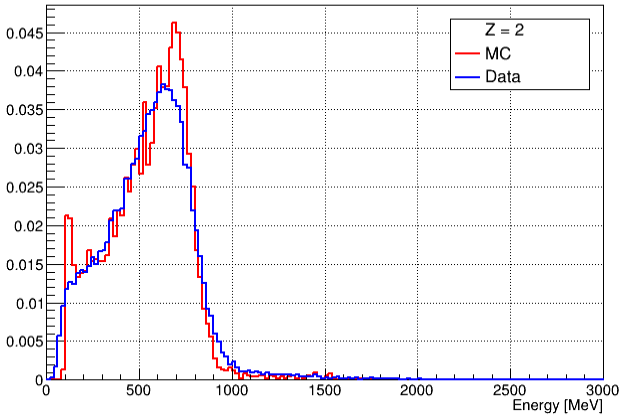


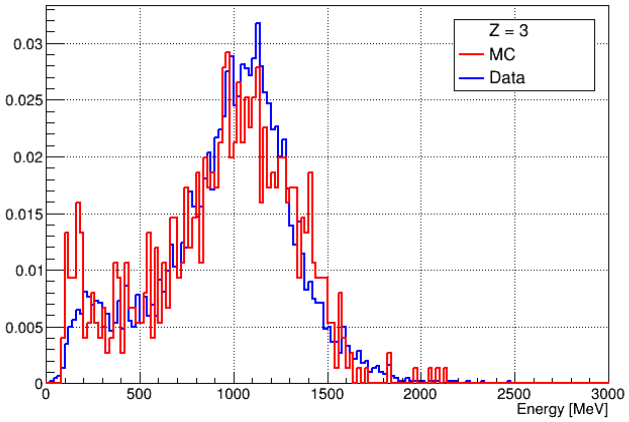


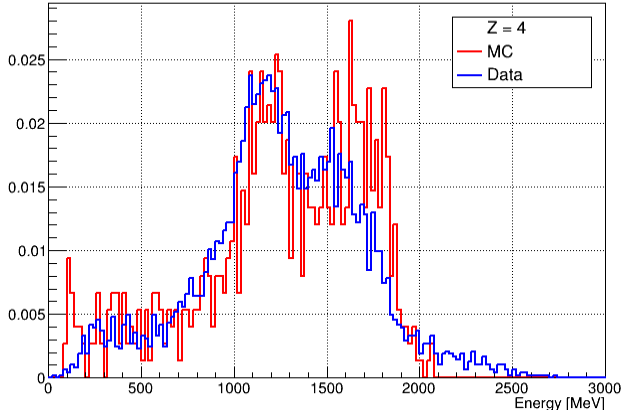


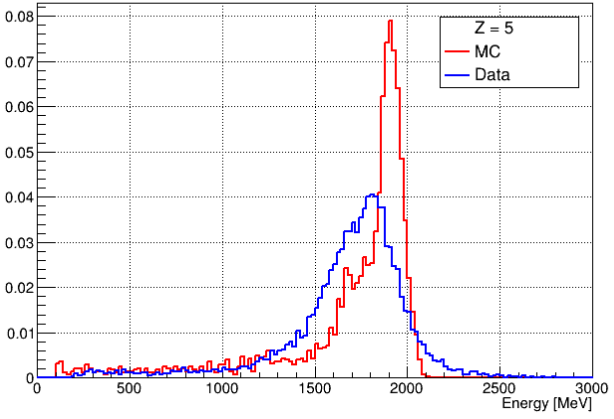
Normalized E_{kin} distributions - data vs MC

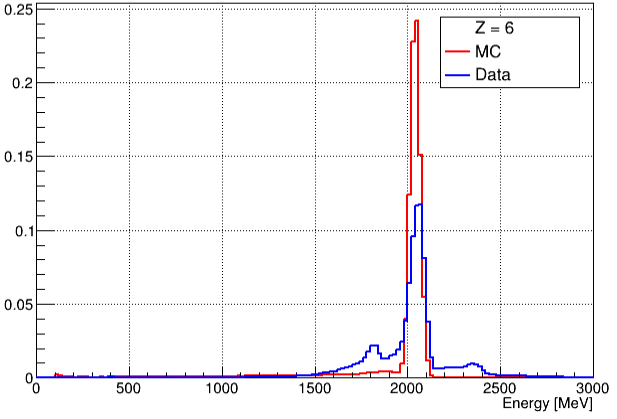




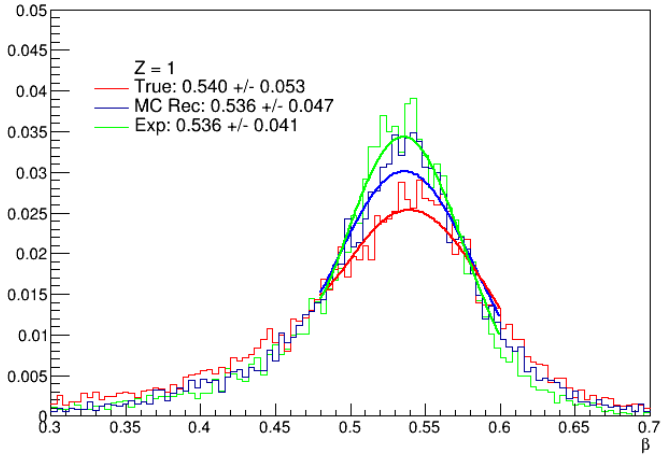


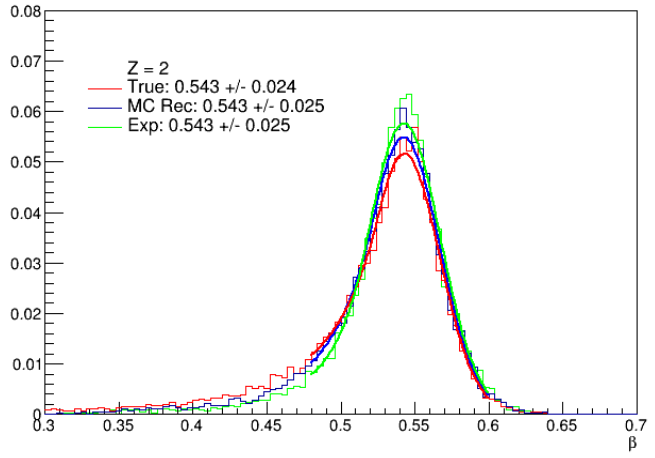


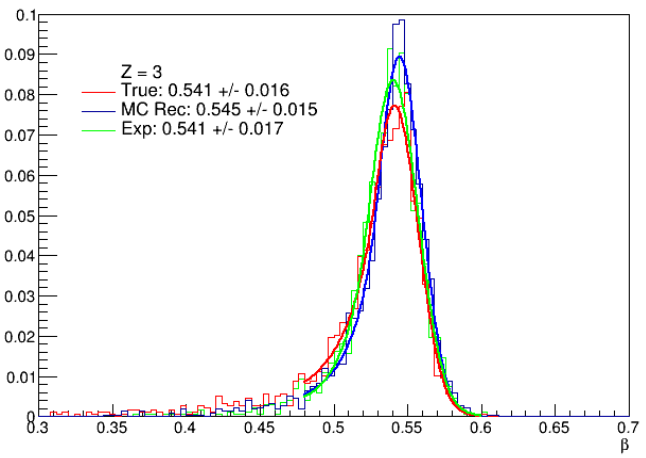


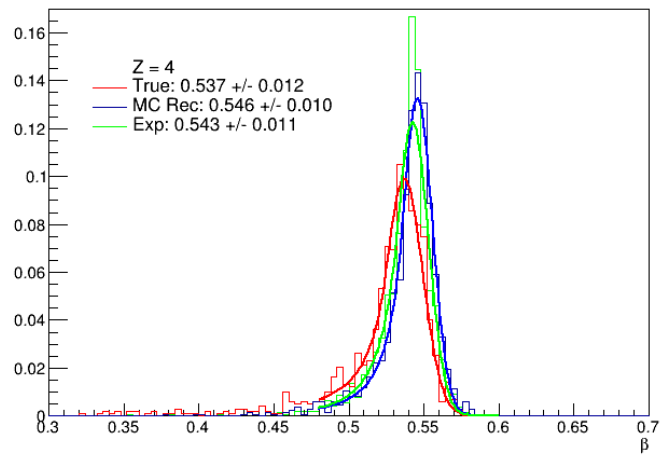


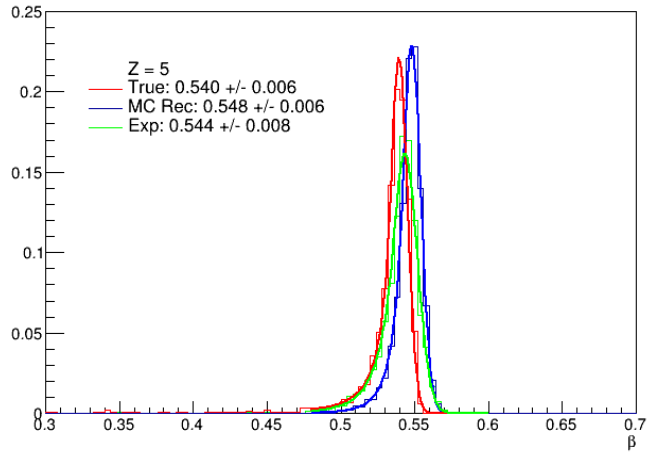
Normalized β distributions - data (7072) vs MC

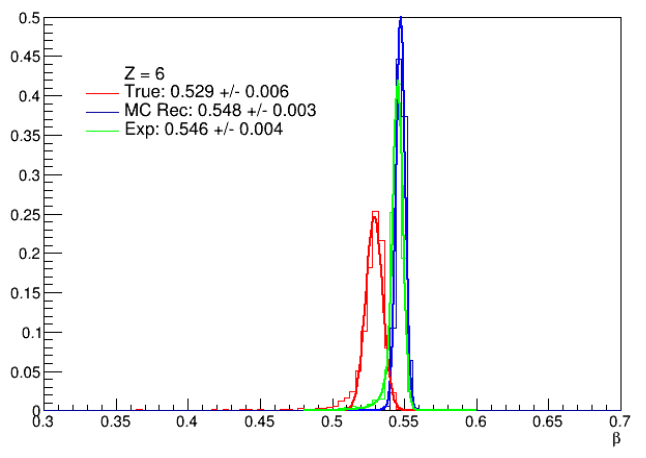




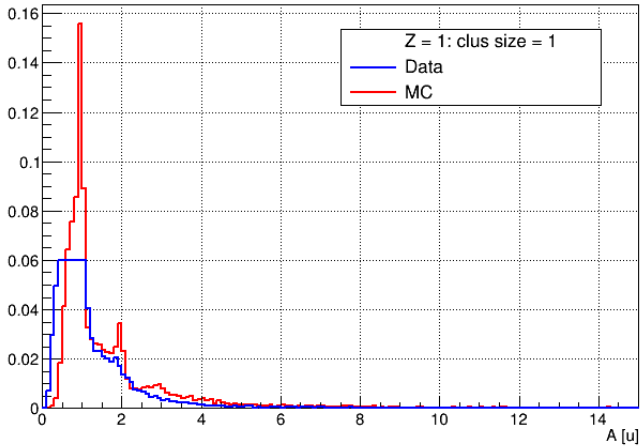


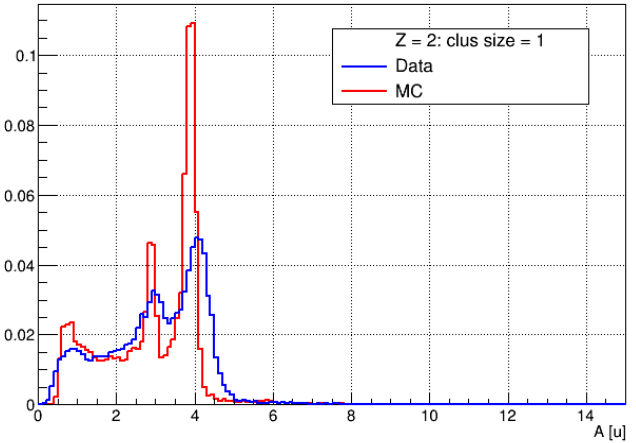


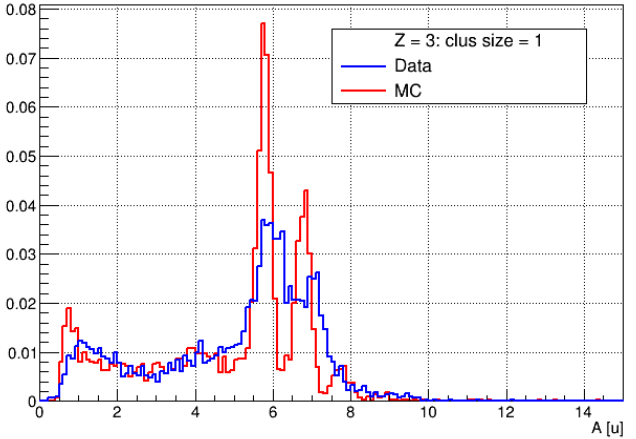


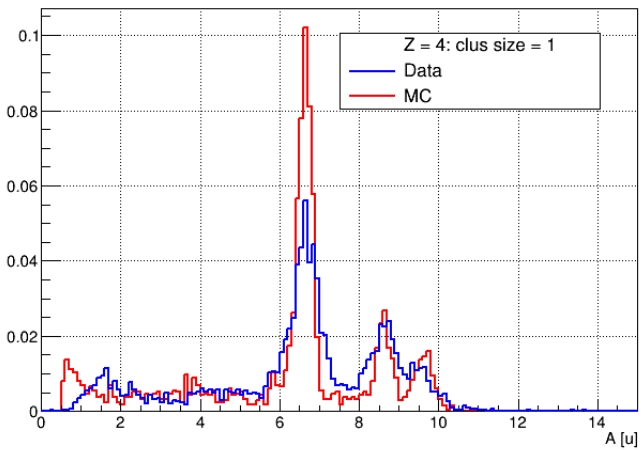


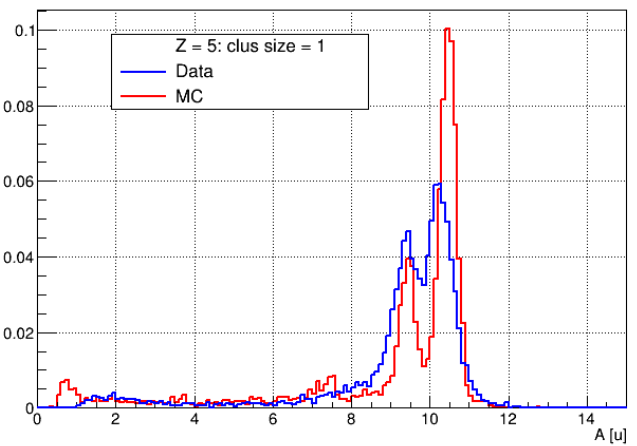
Selection: cluster size = 1

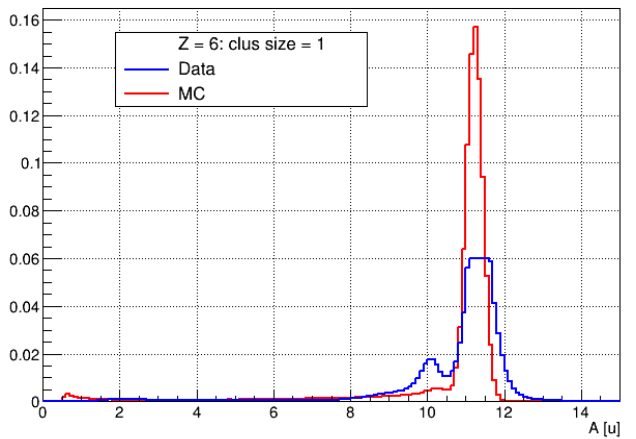




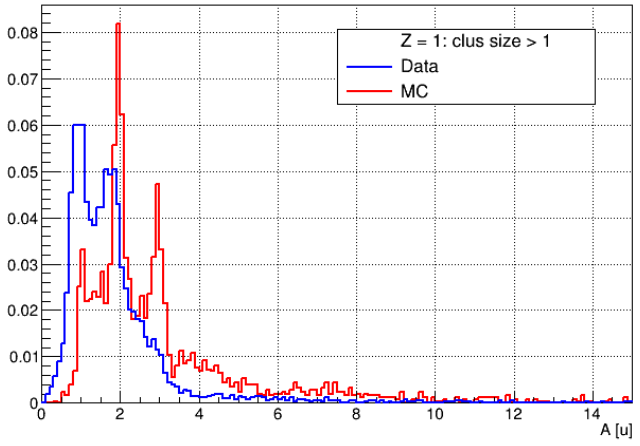


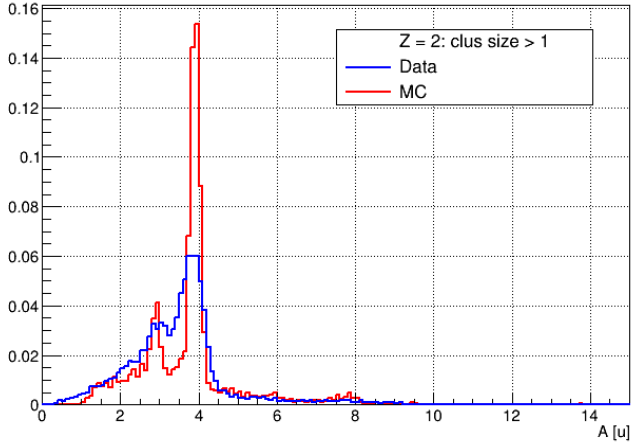


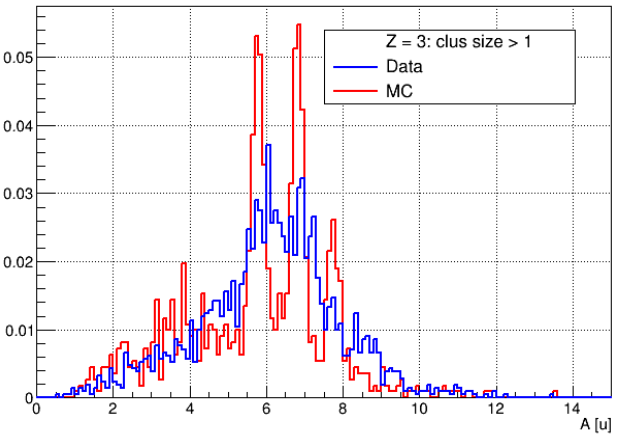


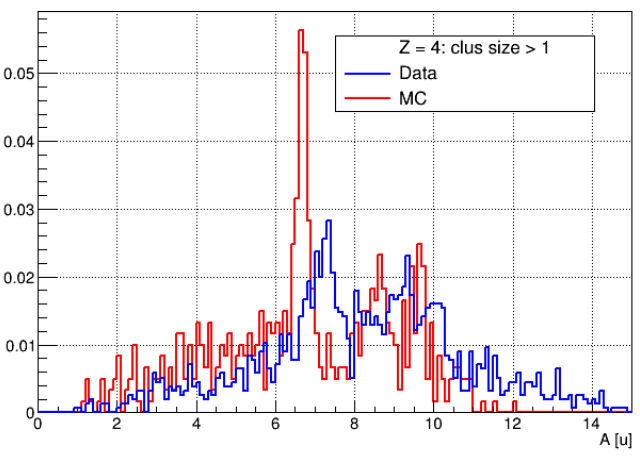


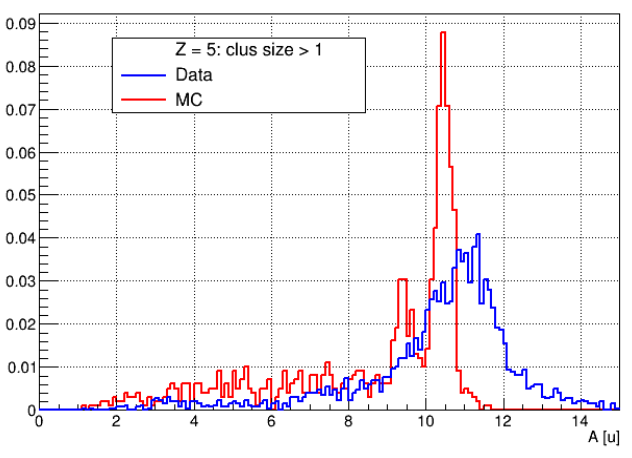
Selection: cluster size > 1

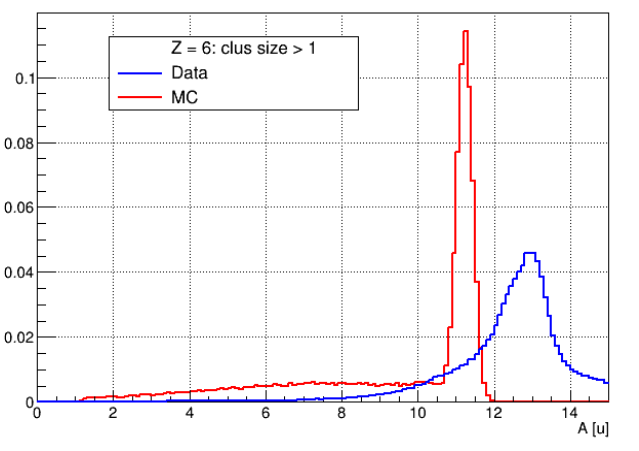




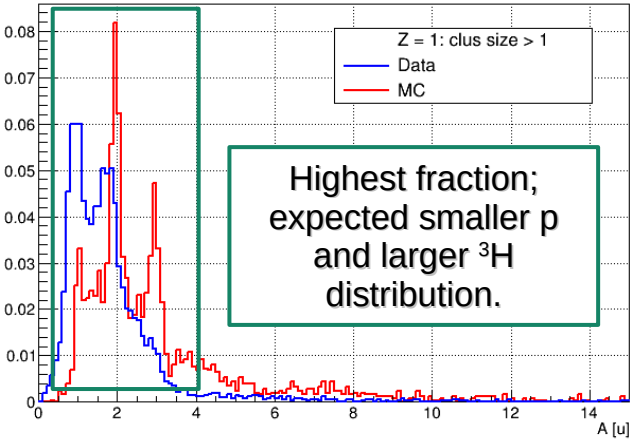




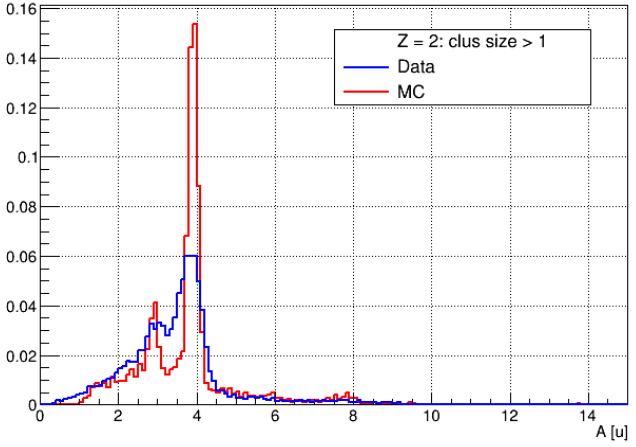


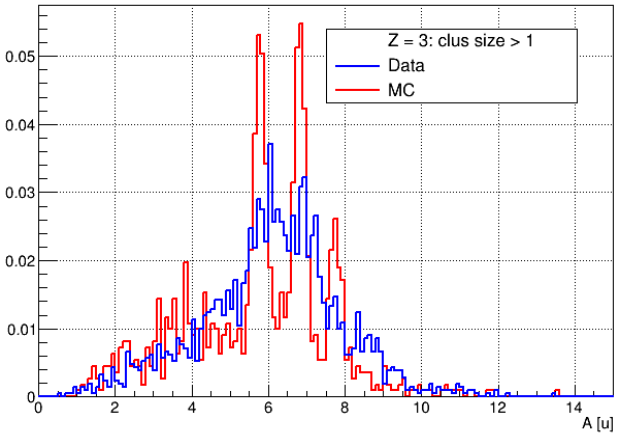


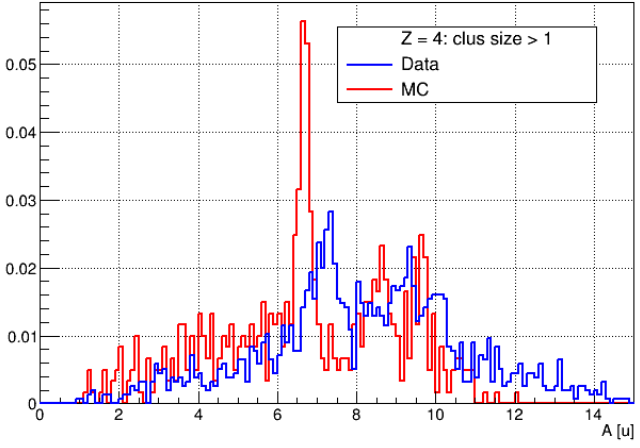
Selection: cluster size > 1

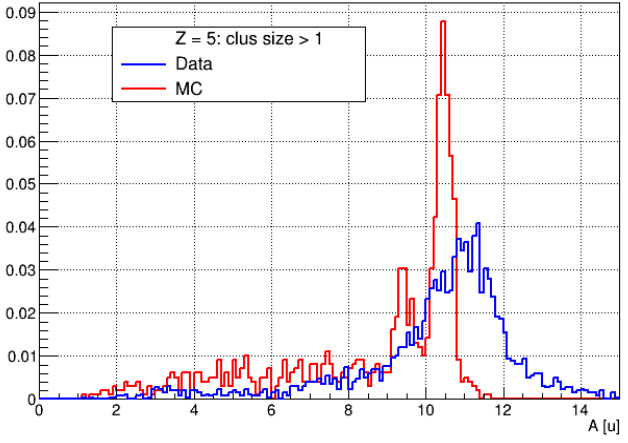


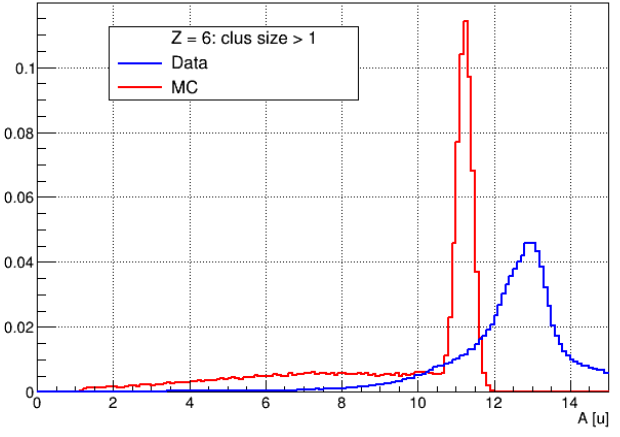
Highest fraction; expected smaller p and larger ^{3}H distribution.



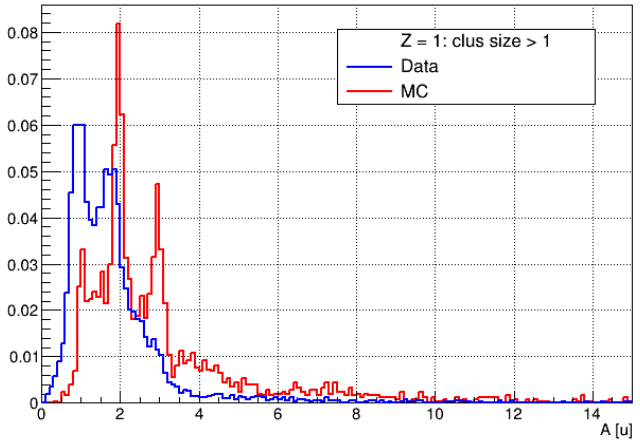


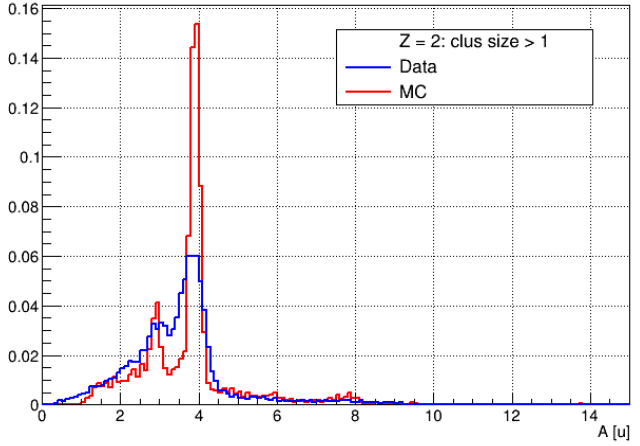


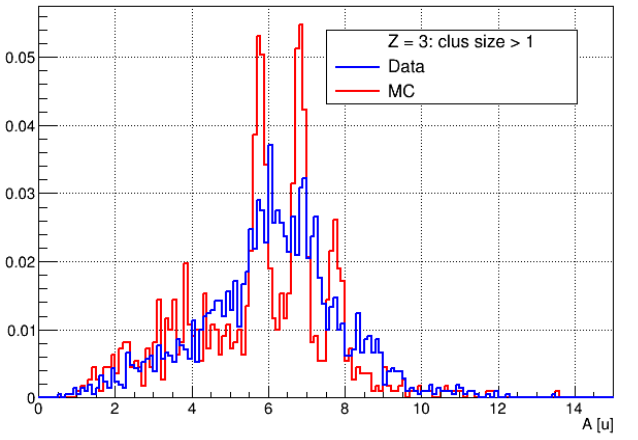


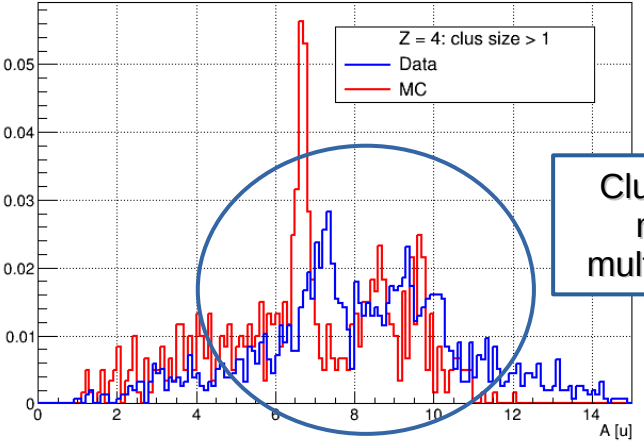


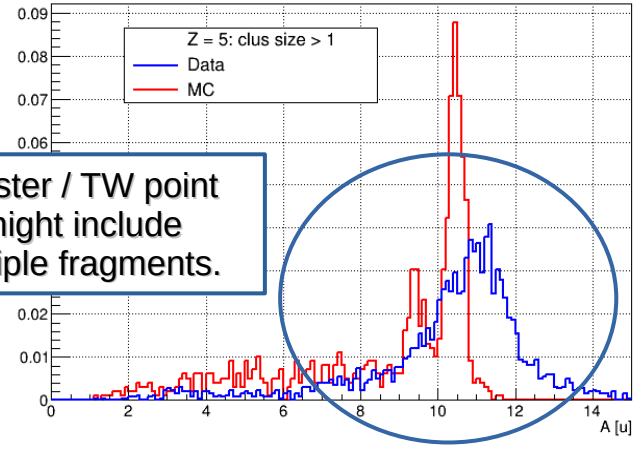
Selection: cluster size > 1

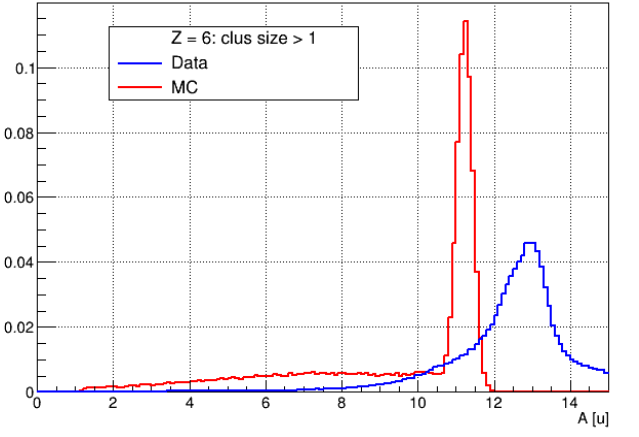






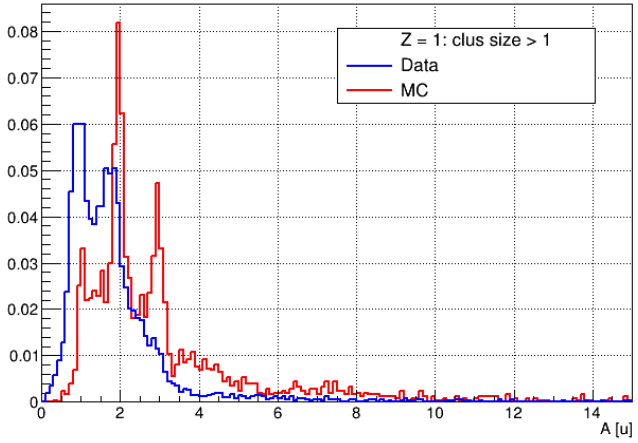


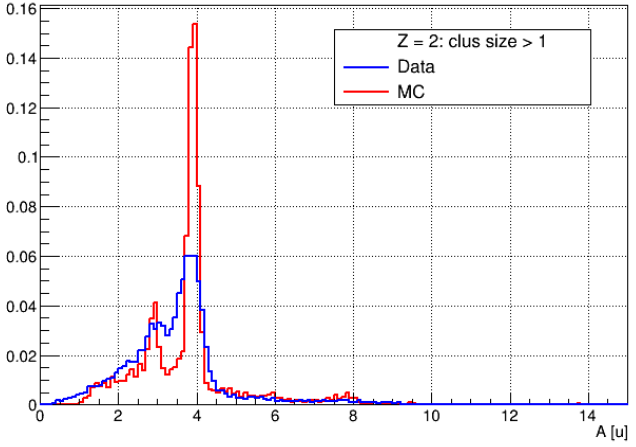


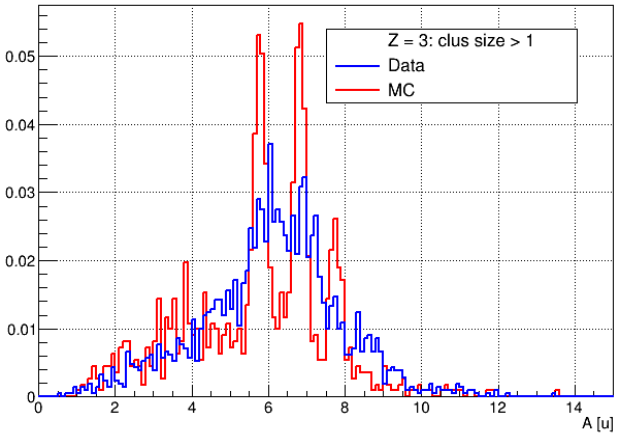


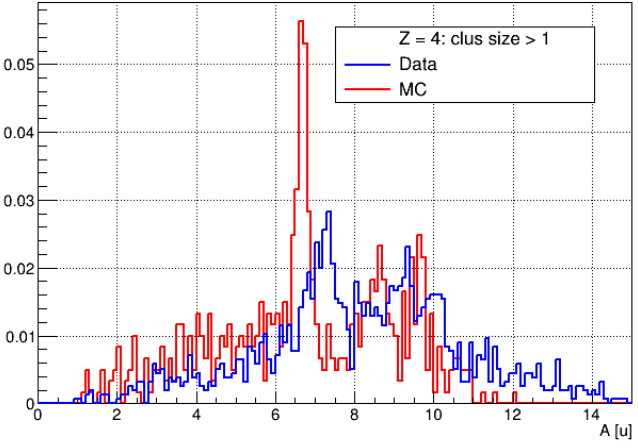
Cluster / TW point might include multiple fragments.

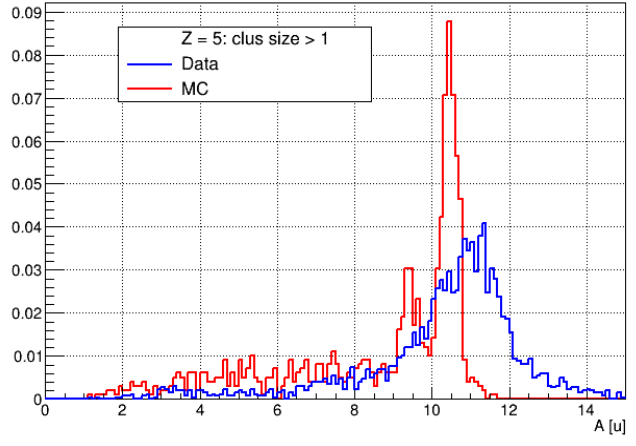
Selection: cluster size > 1

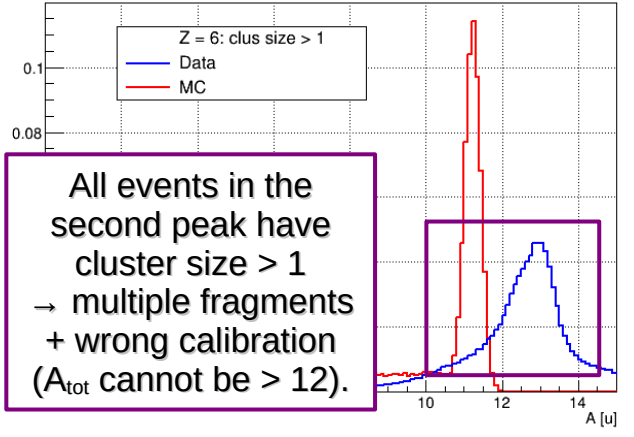






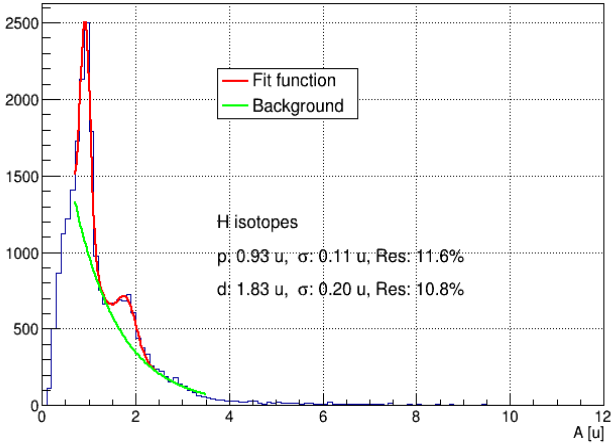


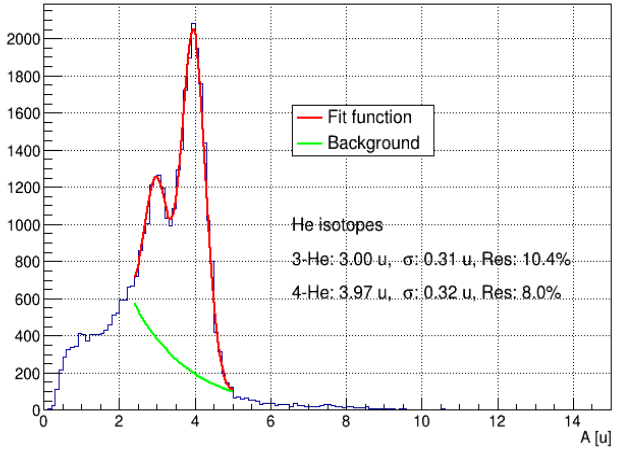


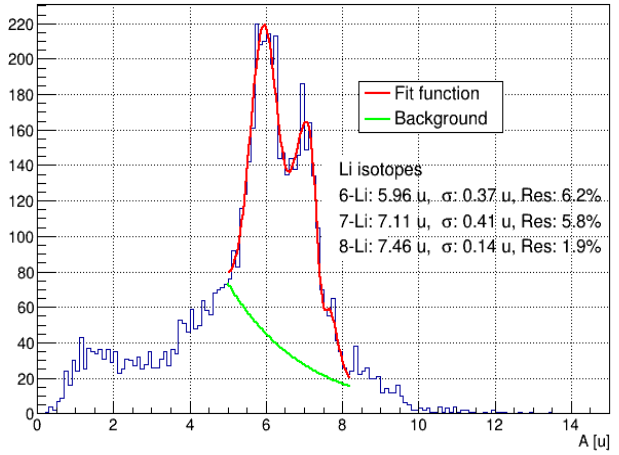


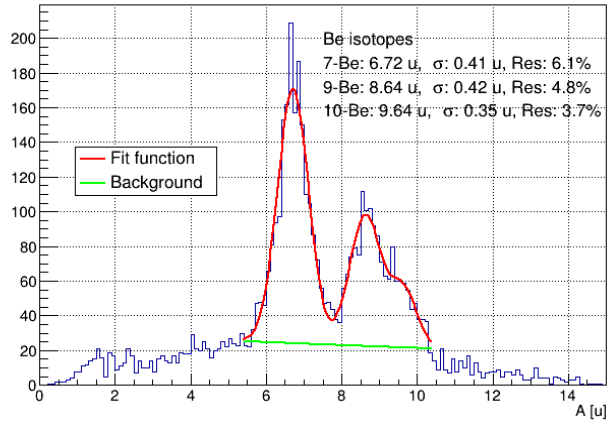
All events in the second peak have cluster size > 1
→ multiple fragments + wrong calibration (A_{tot} cannot be > 12).

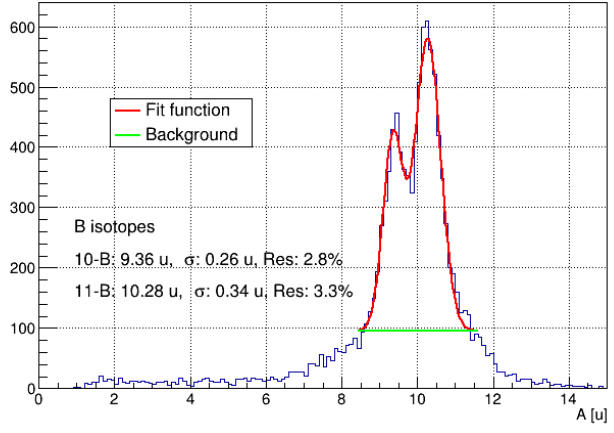
Mass peaks fitting

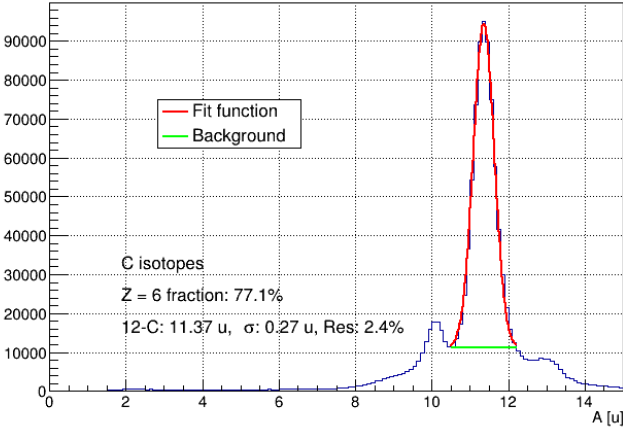




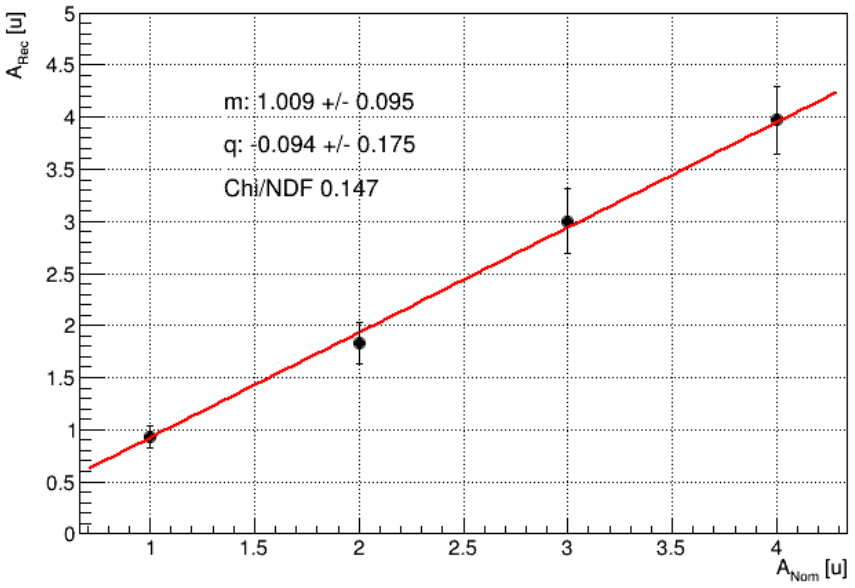








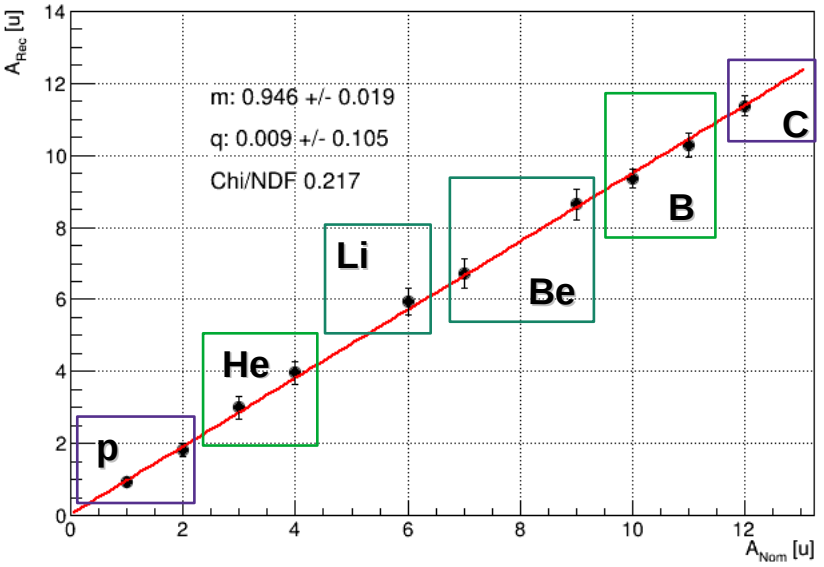
A_{rec} vs A_{nom}



For Z up to 4, A_{rec} / A_{nom} ratio is ≃ 1.

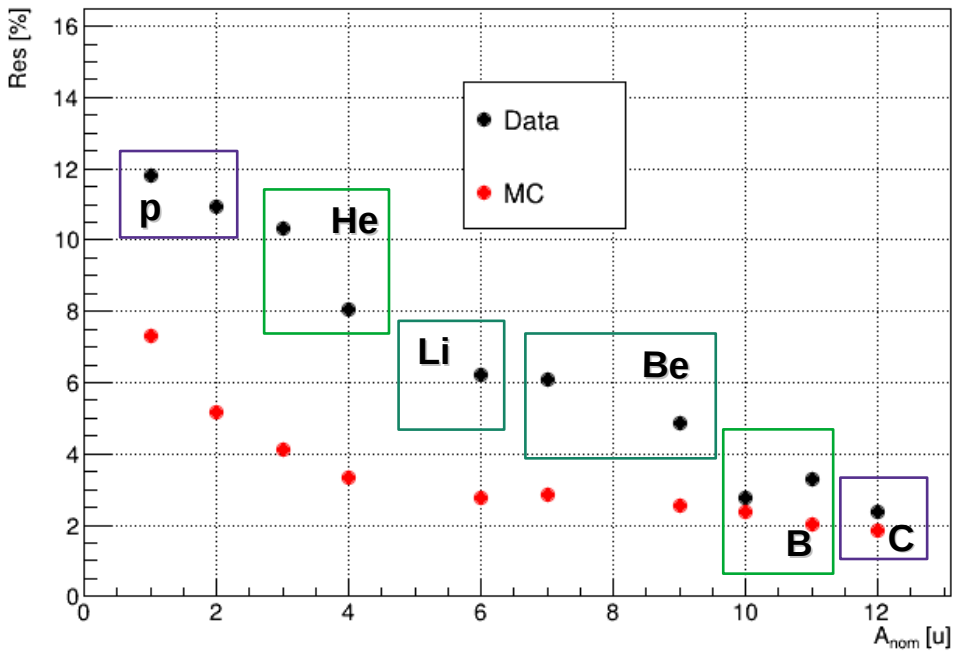
Considering peaks from Z = 1 to Z = 6, Lorentz factor overestimation leads to an underestimation in mass.

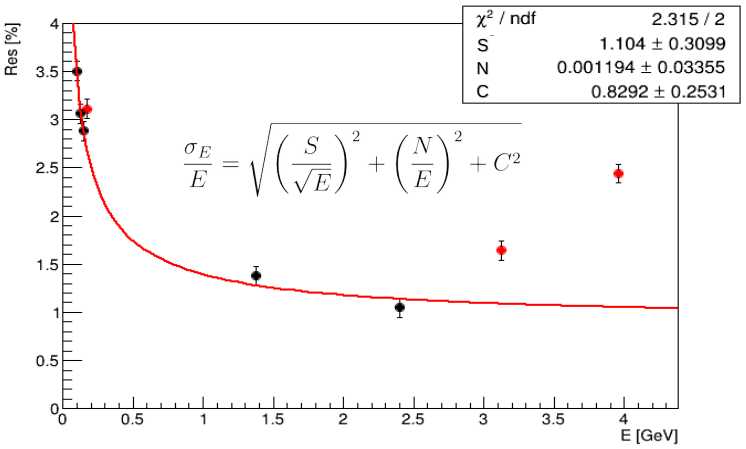
However, linear correlation still works.



Resolution vs A

Mass resolution gets closer to MC predictions with increasing A.



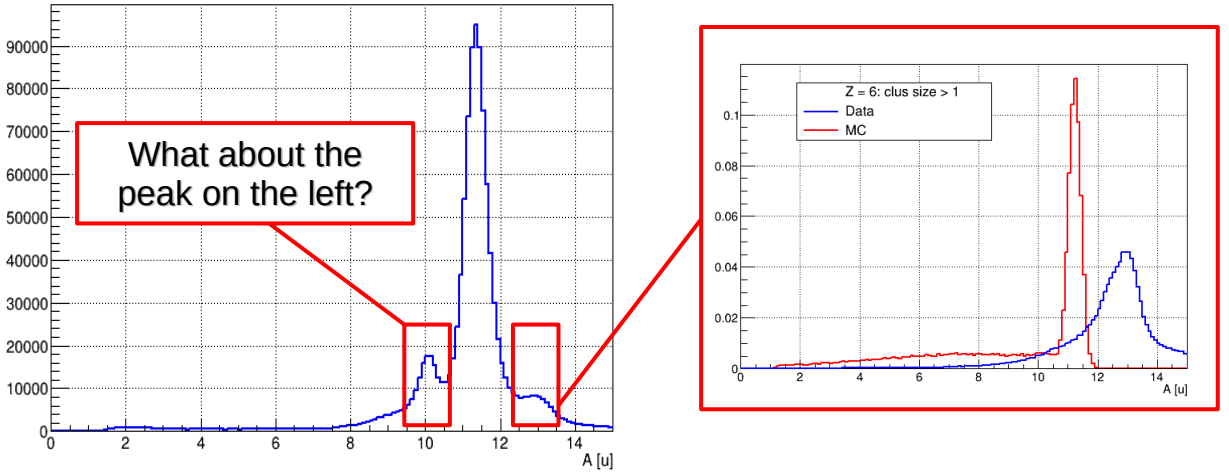


Data acquired during CNAO2024 were fitted with this usual 3-parameters function, in order to obtain a resolution vs E function

→ smearing applied to MC hits.

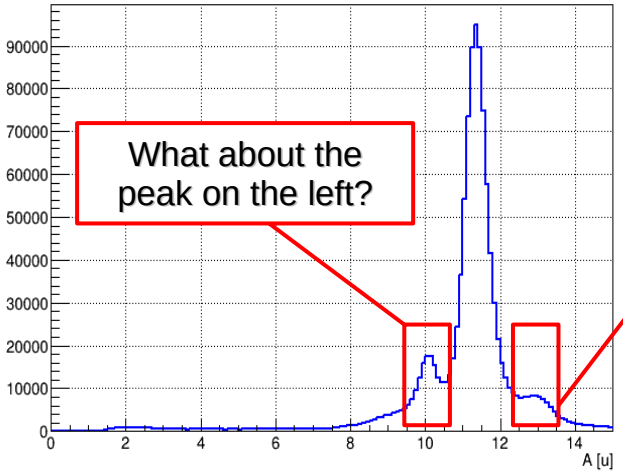
Red points were considered as “outliers”, since affected by larger systematic error due to beam sharing.

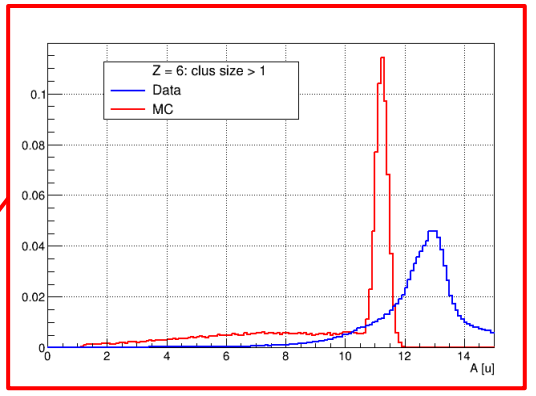
The case of C



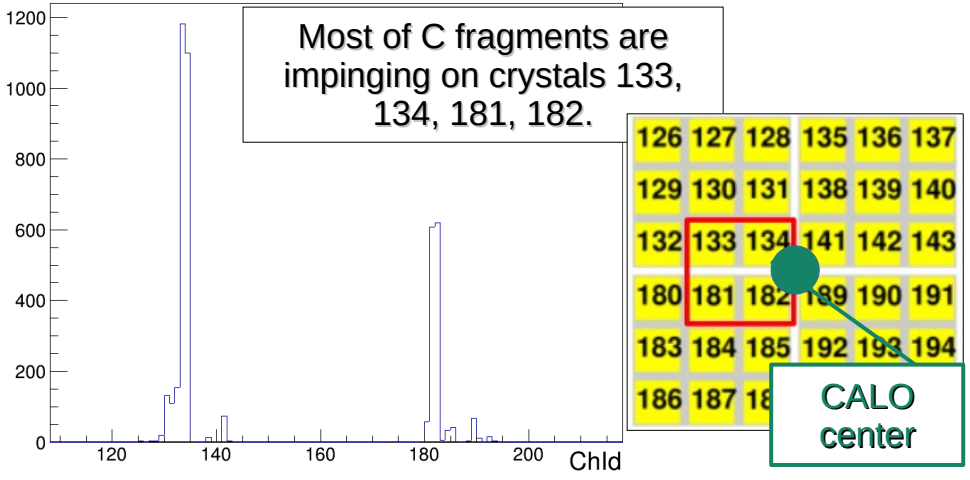
The small peak on the right is quite entirely related to events with cluster size > 1.

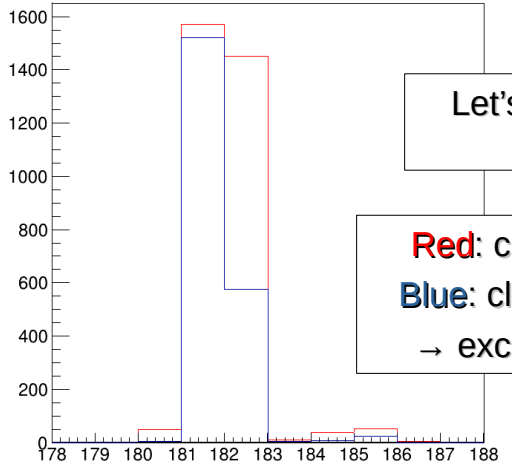
The case of C





The small peak on the right is quite entirely related to events with cluster size > 1.





Let's focus on crystals 181 and 182.

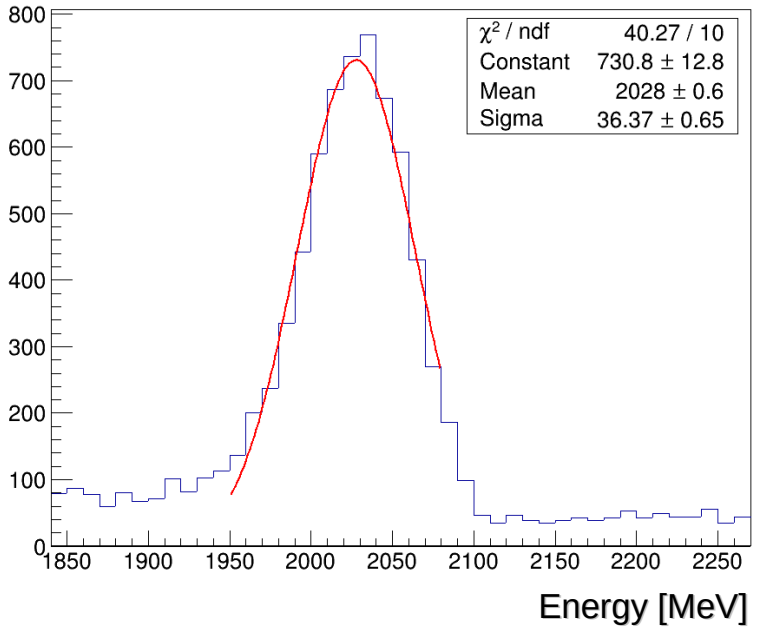
Red: clus size = 1 selection

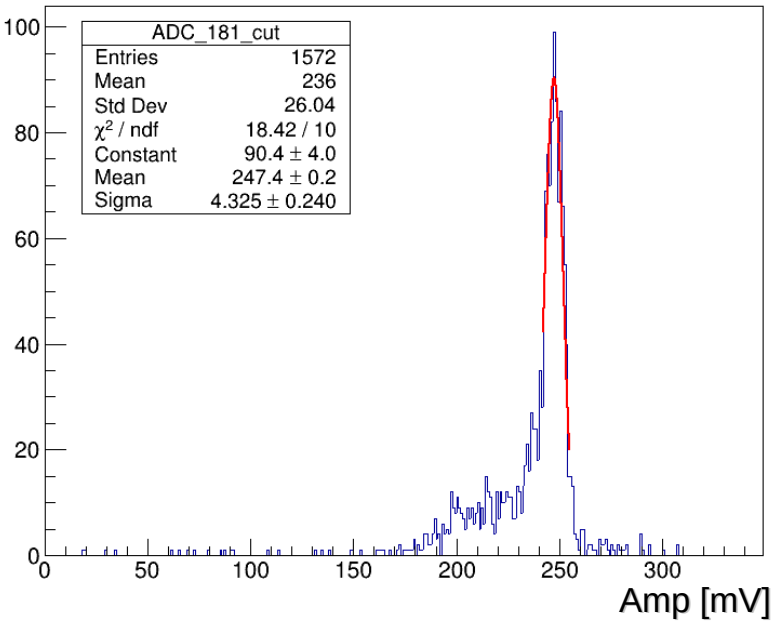
Blue: clus size = 1 + A < 10.5

→ excess of events in 181.

The case of crystal 181

The following results come from a sample of 15k events in run 7072.



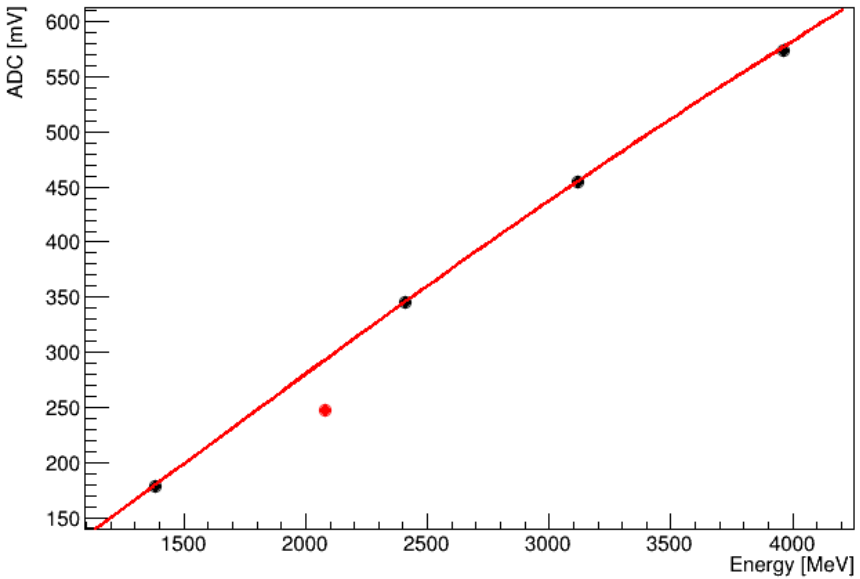


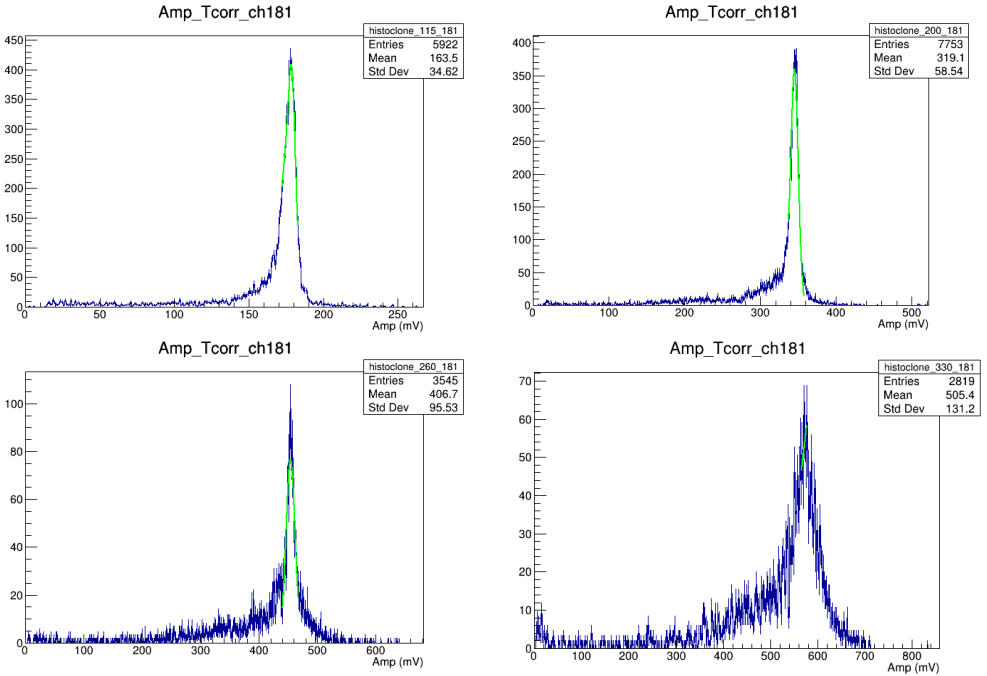
The average energy of well reconstructed ^{12}C fragments is ≃ 170 MeV/u.

Signal amplitudes in ch181, events with clus size = 1.

The case of crystal 181

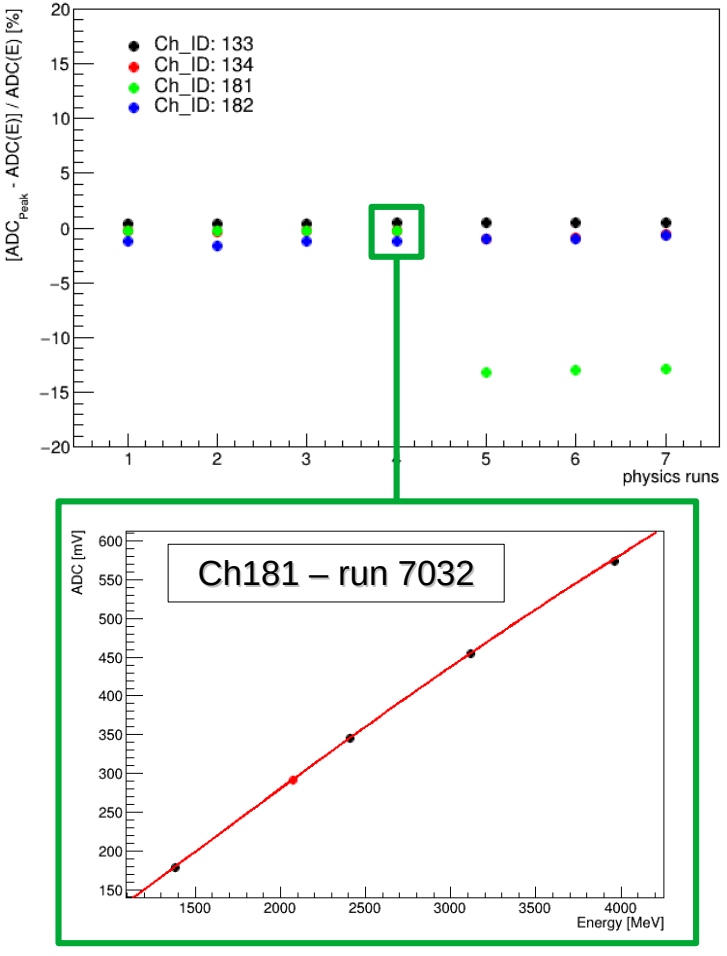
From crystal 181 calibration curve, one would expect a higher ADC response @ 170 MeV/u!





Crystal 181 is also one of the **few** ones showing good quality C calibration points from 115 to 330 MeV/u.

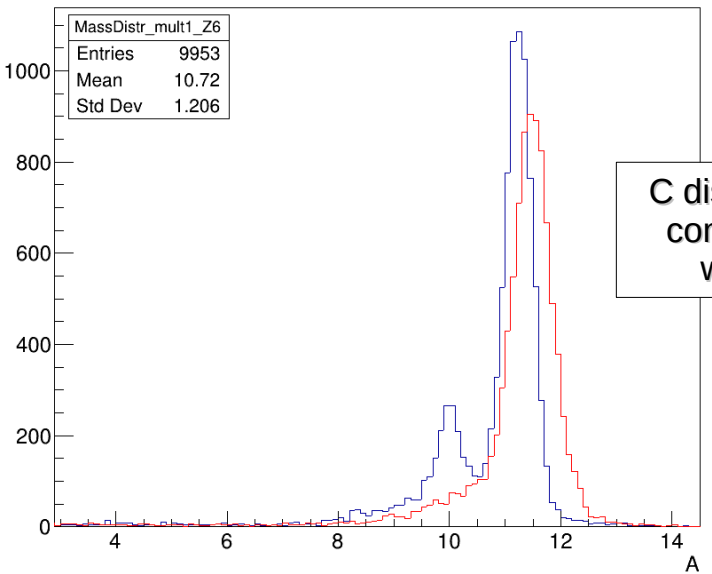
The case of crystal 181



For fragmentation runs 7029, 7030, 7031, 7032 (*18-19 Nov*) and 7072, 7076, 7077 (*19-20 Nov*) I have:

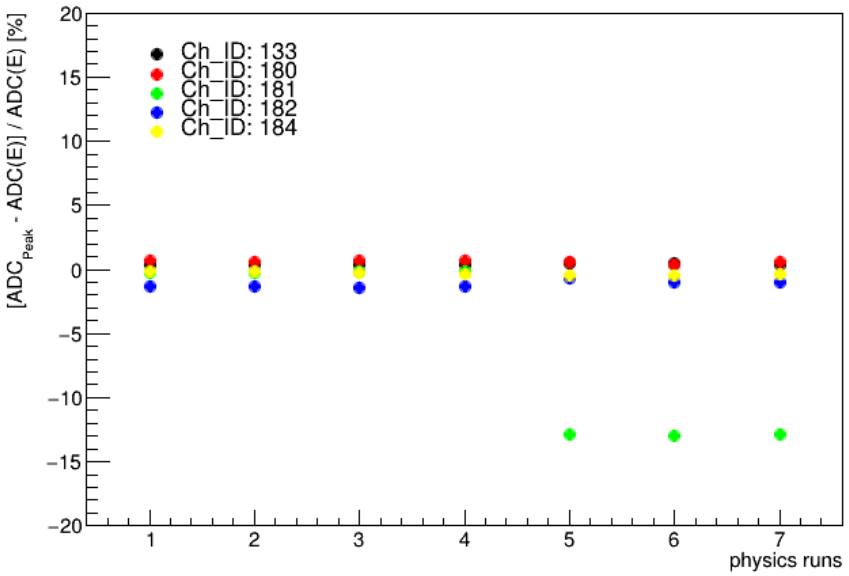
- computed the average ^{12}C energy;
- evaluated the expected signal amplitude from crystals 133, 134, 181, 182.

Deviation from expected signals is within 2% (or even 1%) in all cases, except for crystal 181 and only starting from run 7072.



C distributions for run 7032 compared with run 7072, with cluster size = 1.

The case of crystal 181



Let's include also crystals 180 and 184, which, together with crystal 133 and 182, are neighbors of crystal 181.

With the exception of 133, these channels share:

- same *module* (21 in HW numeration);
- same *WD board* (106) - but different channels;
- same channel for *LV* and *HV* supply;

In spite of this, a deviation from the expected ADC response only appears in crystal 181

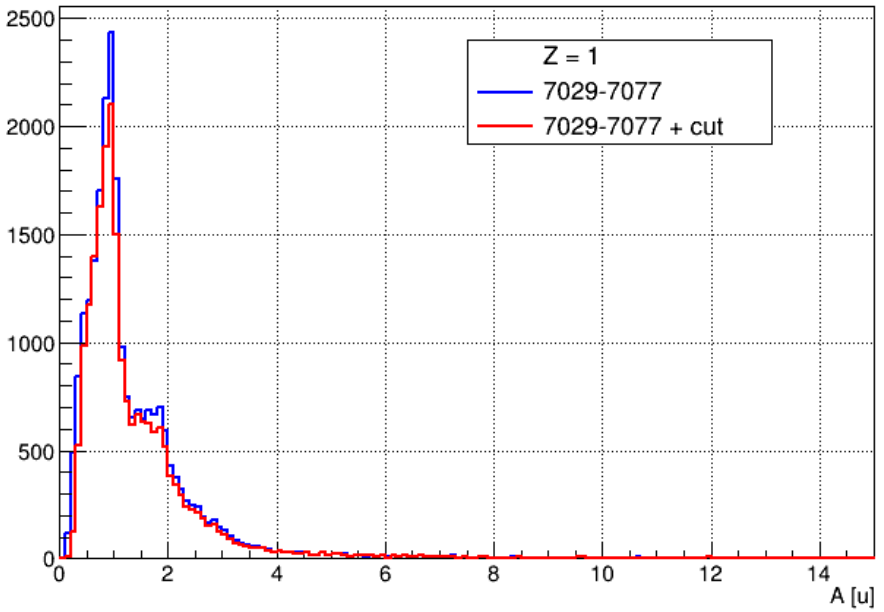
→ wrong clustering to be excluded.

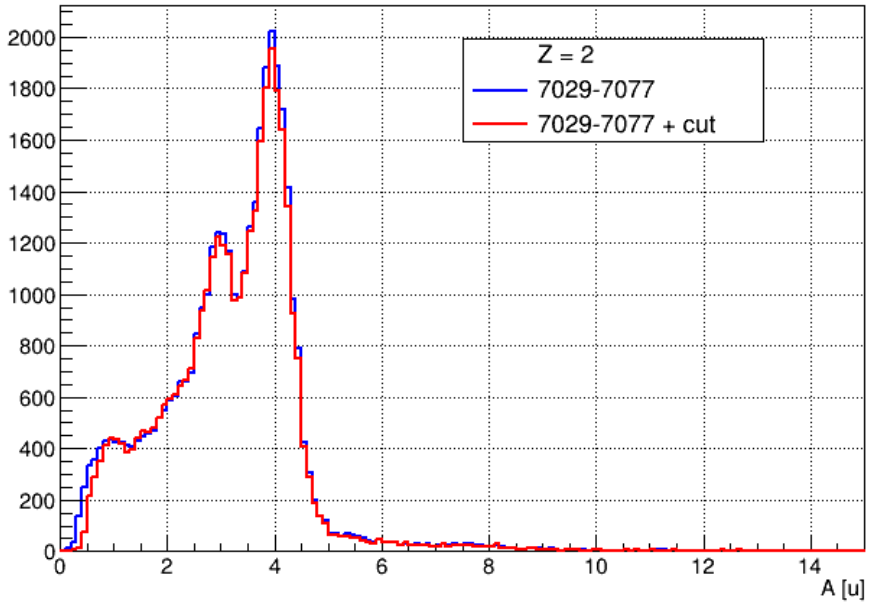
Note: after the 4th fragmentation run (7032), crystal 181 stops contributing to ^{12}C peak energy

→ expected peak response from other channel is less disperse.

Threshold cut effect on Z = 1, 2

I have tried excluding applying a threshold cut on CALO cluster hits (discarded if amp < 20 mV).





- However, small improvement in *p* peak comes at the price of a mass underestimation for *d*;
- no significative difference for Z = 2;

→ from now on, no threshold / crystals cut is considered.

Runs & clus size selection effects: Z = 1, 2

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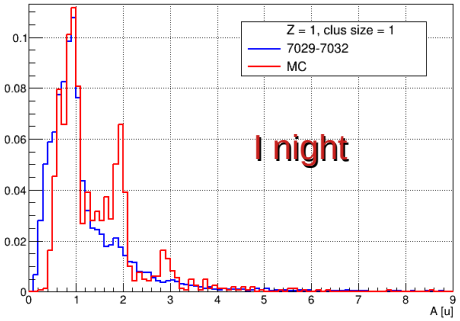
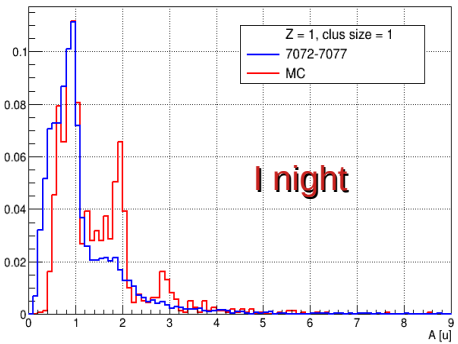
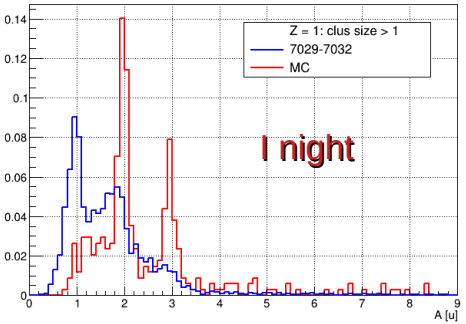
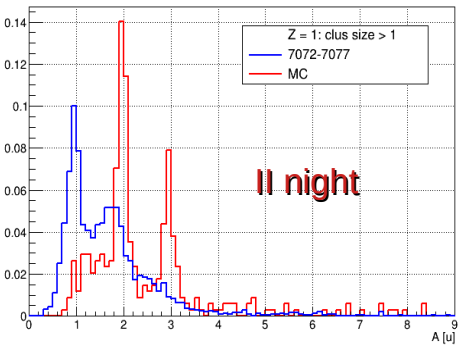
H, Clus size = 1



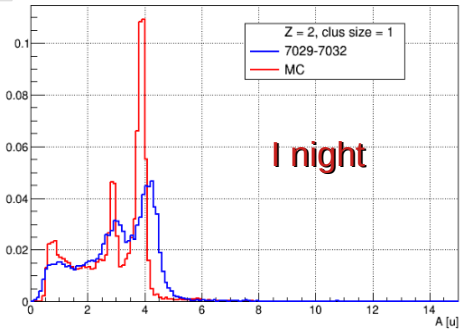


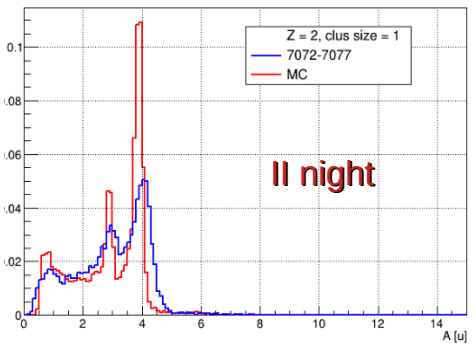
H, Clus size > 1



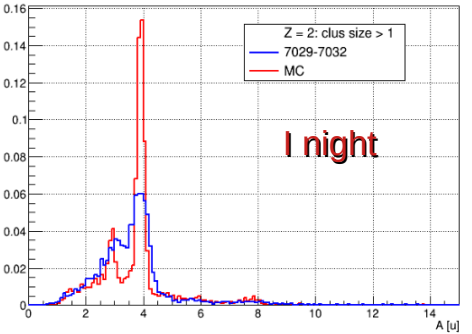


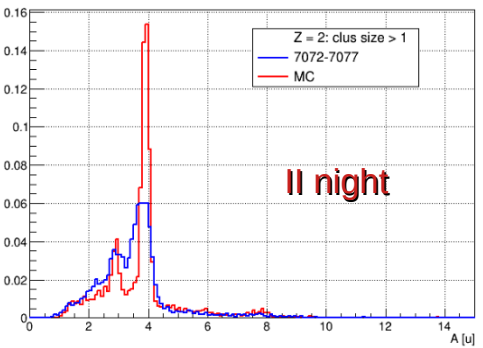
He, Clus size = 1





He, Clus size > 1





- For clus size = 1, peaks from runs 7072-77 (II night) look more centered on MC prediction;
- For Z = 2, no significant difference between clus size = 1 or > 1.

Runs & clus size selection effects: Z = 3, 4

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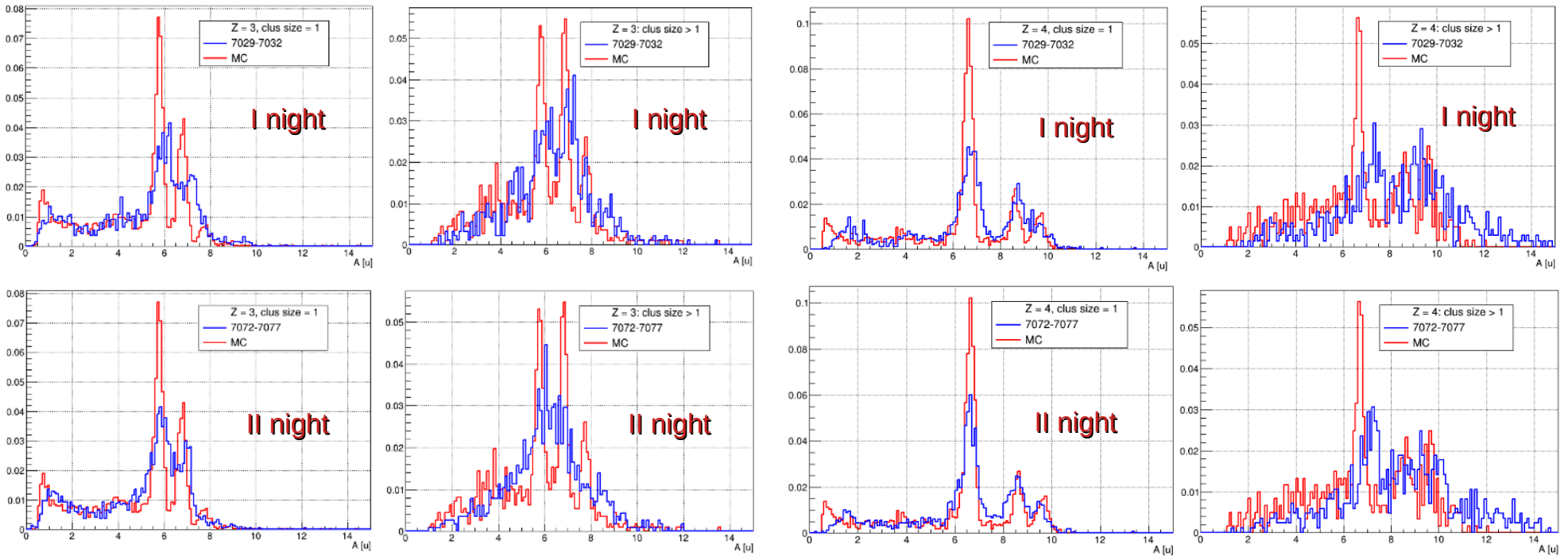
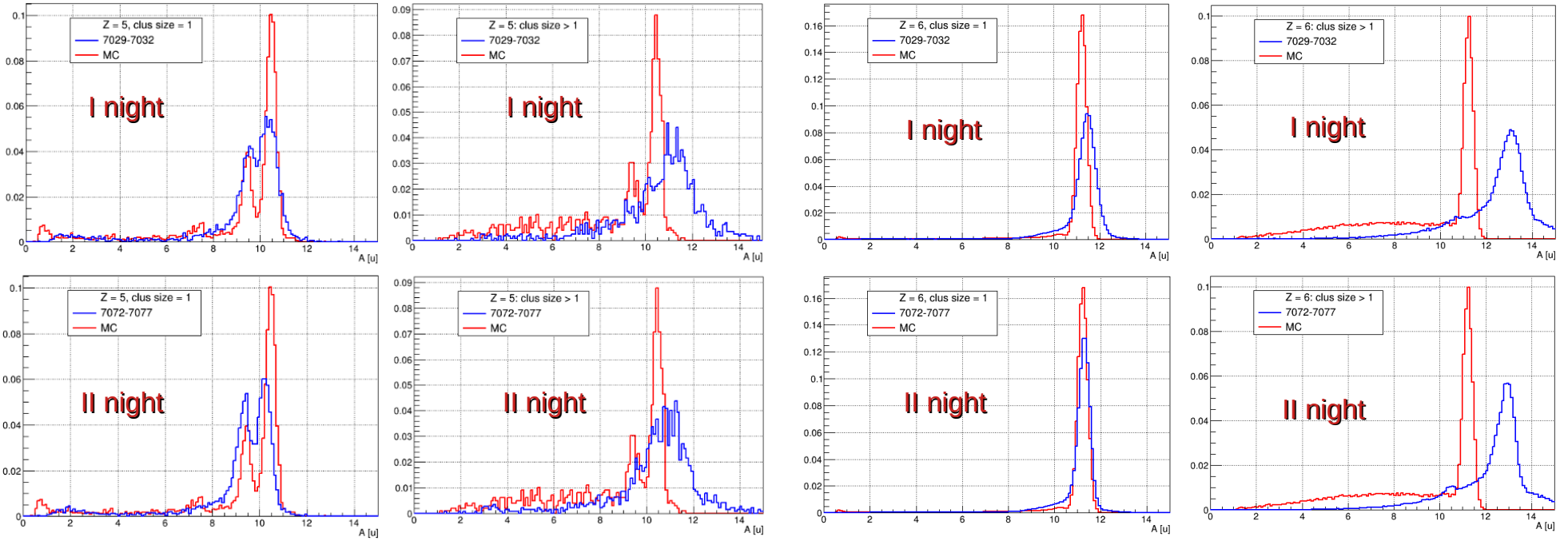
Li, Clus size = 1 | Li, Clus size > 1 | Be, Clus size = 1 | Be, Clus size > 1



- Peaks from runs 7072-77 (II night) look more centered on MC prediction;
- For clus size > 1, low statistics for Z = 3, 4.

Runs & clus size selection effects: Z = 5, 6

B, Clus size = 1 | B, Clus size > 1 | C, Clus size = 1 | C, Clus size > 1



- For B, I night peaks are more centered on MC simulation, but II night peaks have better resolution → (?)
- For Z = 6, I have excluded crystal 181; visible shift with clus size = 1→ possible calibration effect impacting on other Z via power-law parameters.

Conclusion and upcoming tasks

- There is clear evidence of response instabilities in CALO, especially in crystal 181 (crossed by ^{12}C directly)

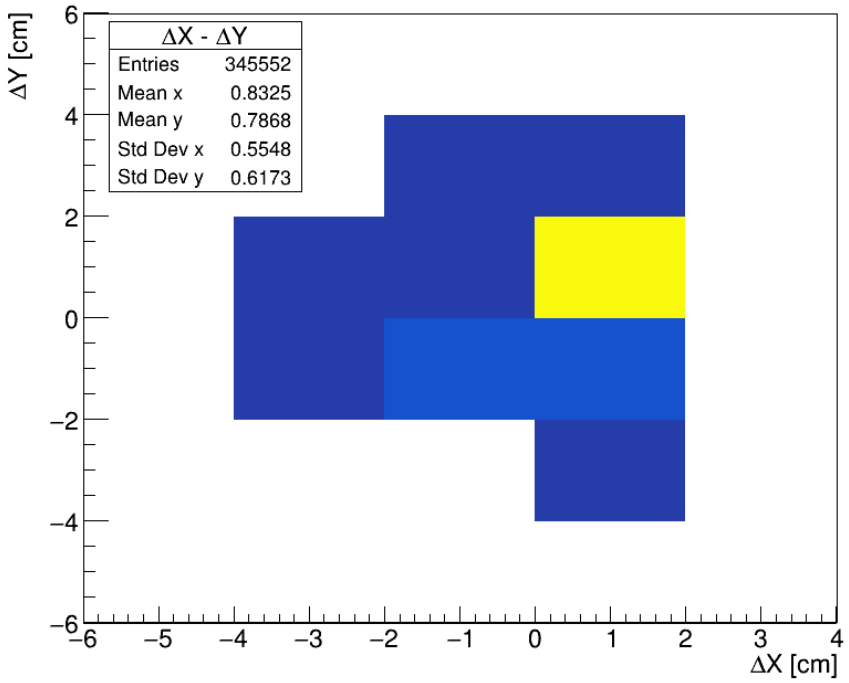
→ faulty SiPM coupling / mechanical trauma? Only possible explanation found...

- However, wrong TW-CALO matching and Z assignment were considerably reduced
  - → isotope distributions better respect MC expectancy;
  - → mass peaks from Z = 1 to Z = 6 were successfully reconstructed.

- Possible further improvements concerning TW-CALO alignment.

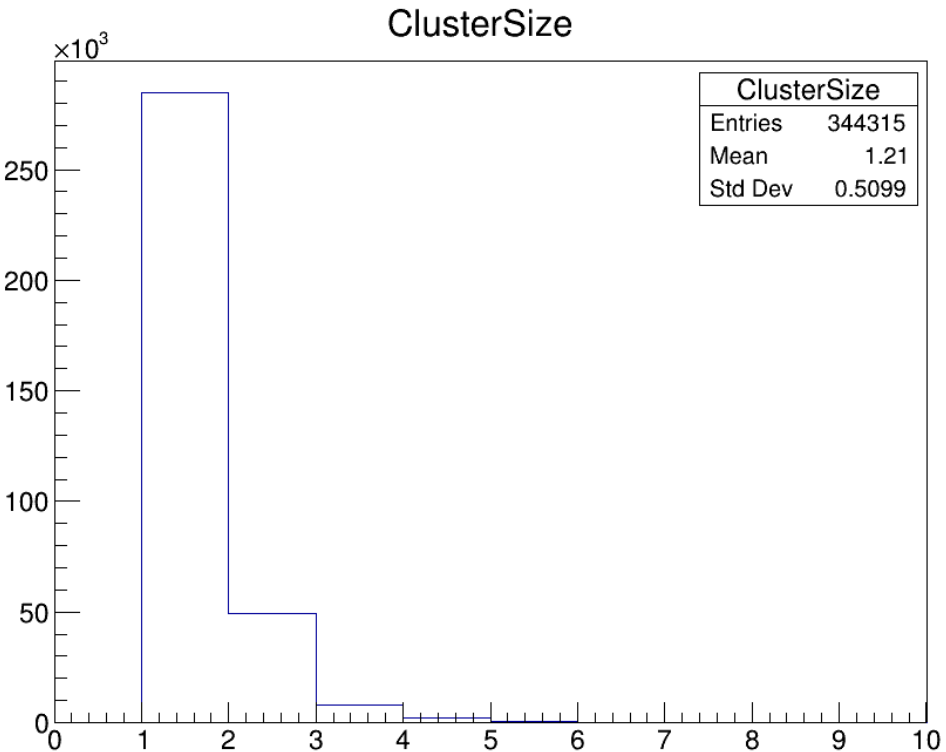
- Resolution still worse with respect to MC and not always below 5%
  - → required optimization of CALO calibration;
  - → further investigation on MBF parameters (correlation, distribution with respect to Z,…).

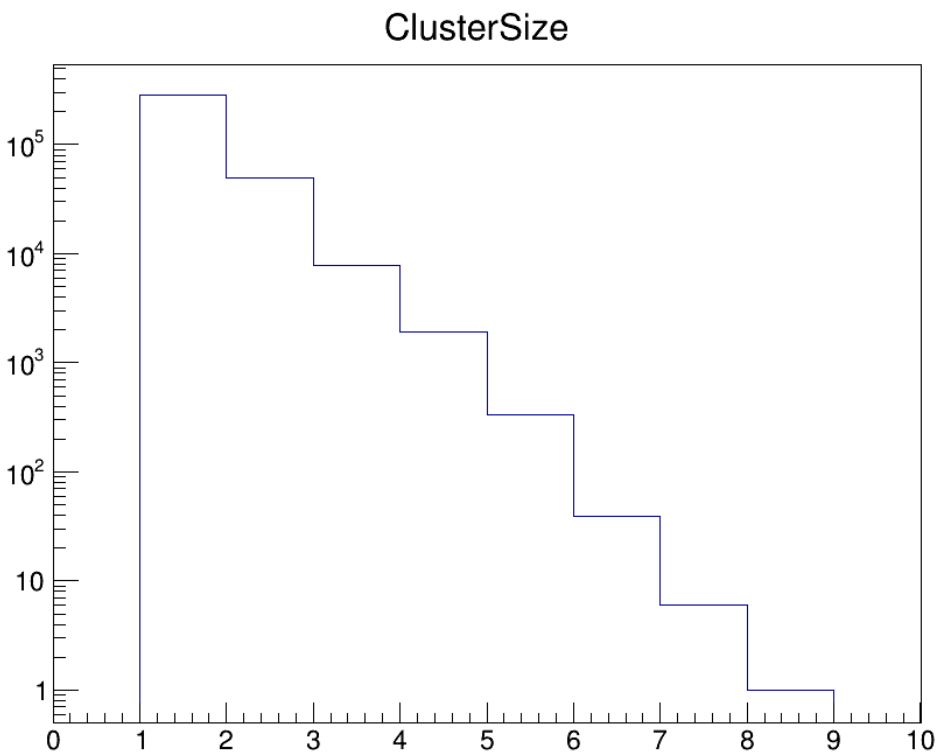
Post-calibration shifting in CALO



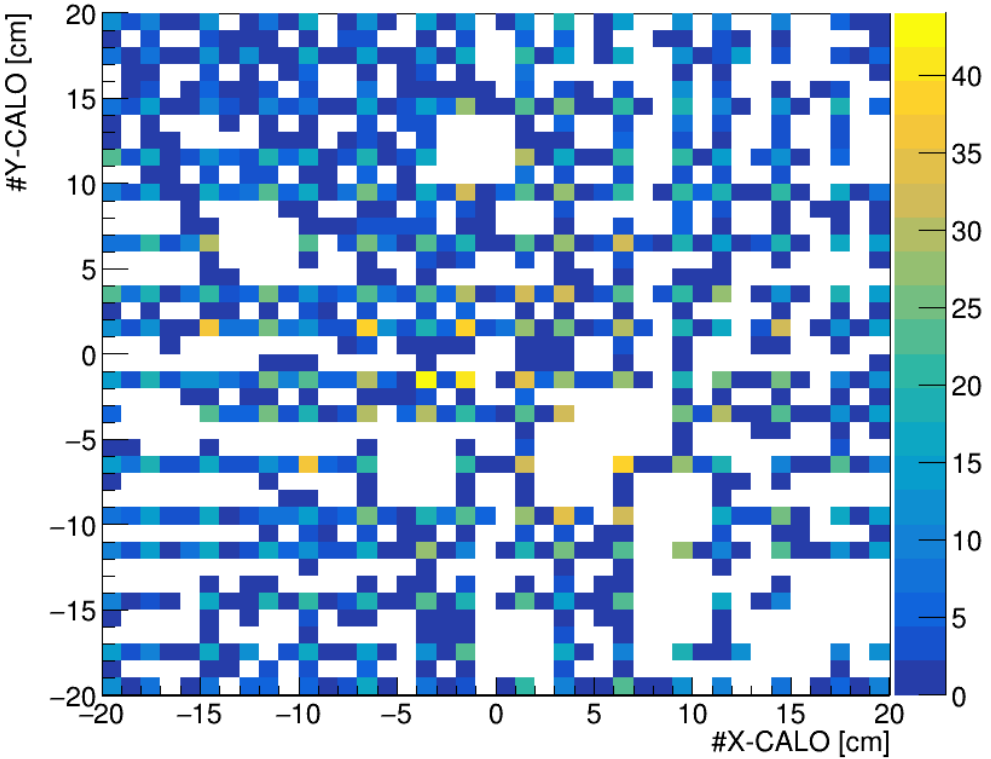
After calibrating the clusters, their position is shifted, in most cases between up to 2 cm in both axis → within CALO granularity.

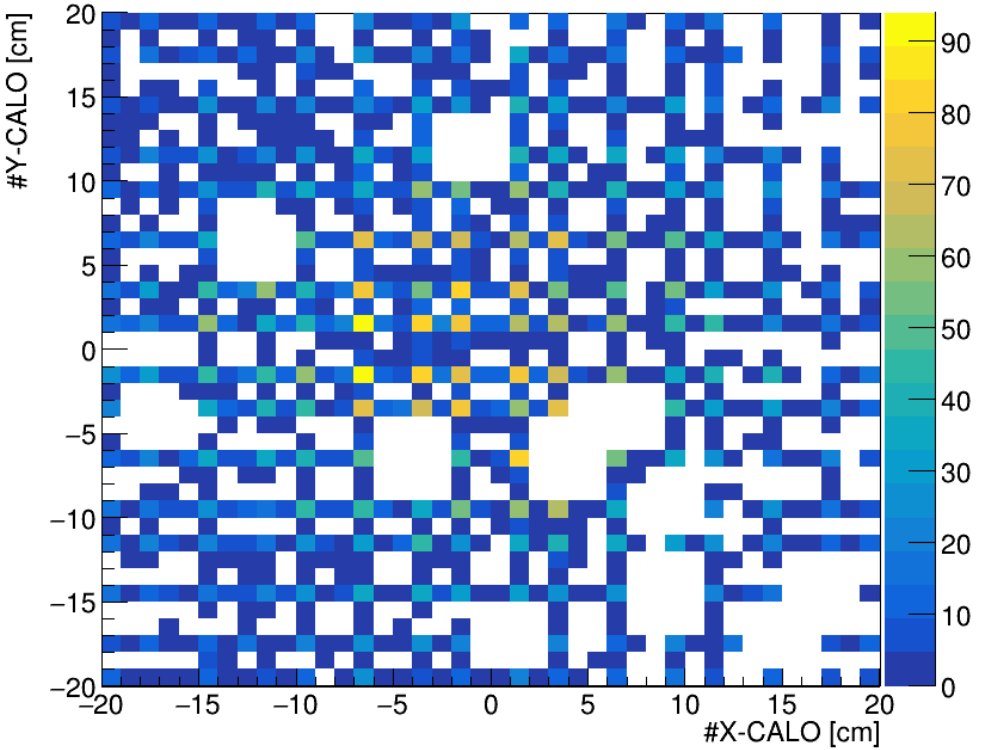
Cluster size distribution (run 7072)



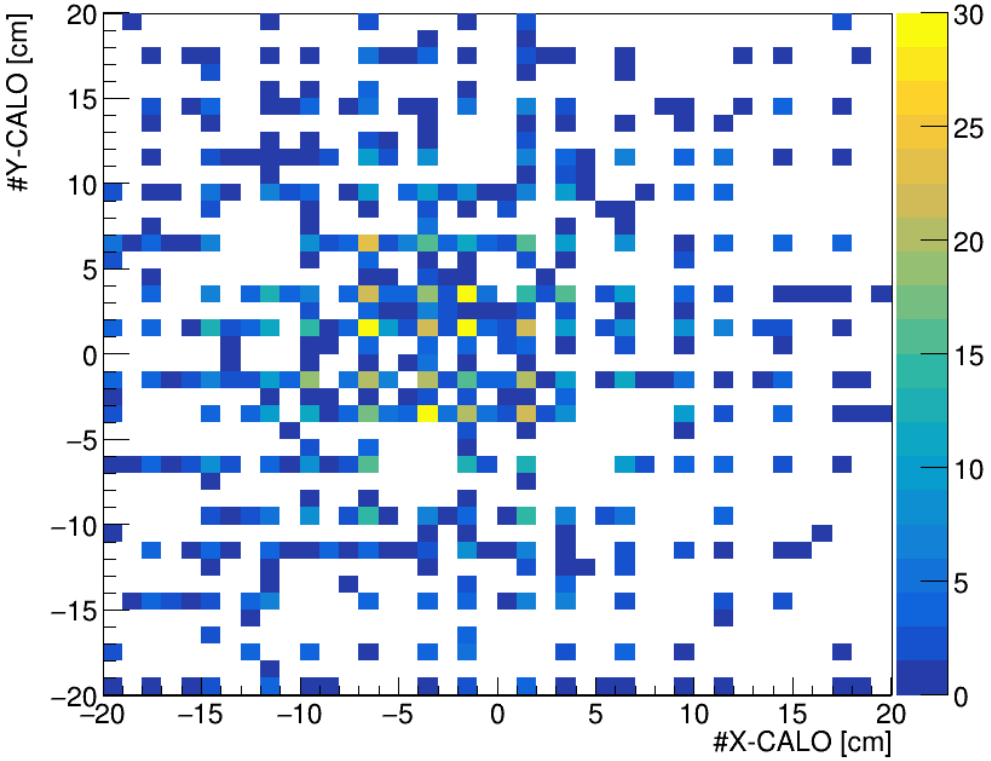


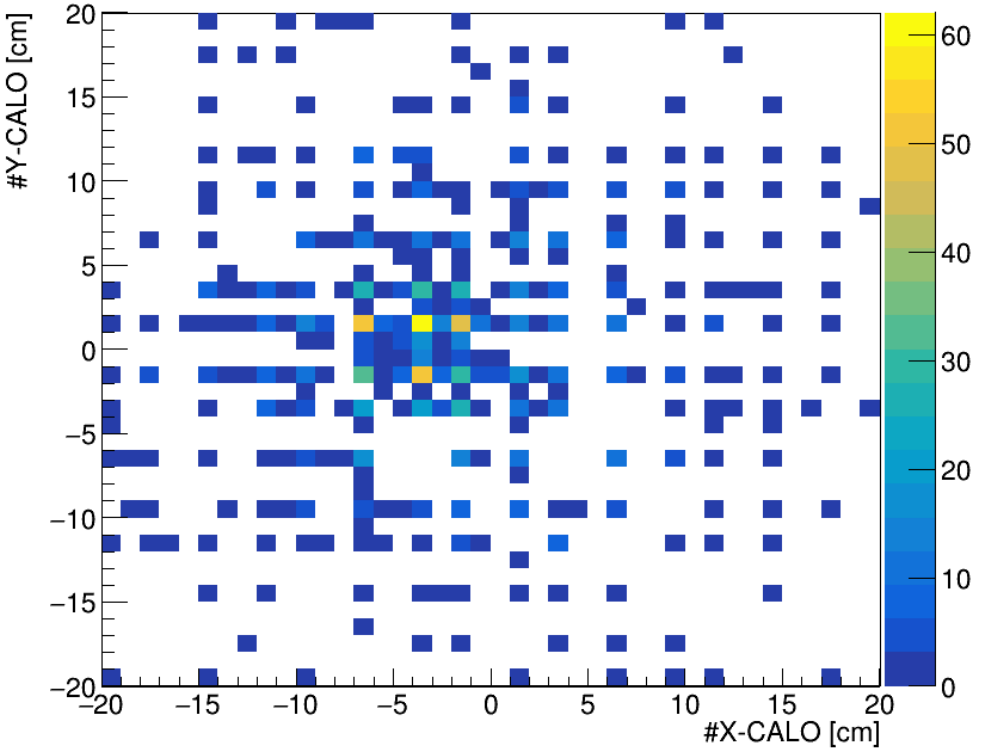
Cluster distribution (run 7072) Z = 1, 2



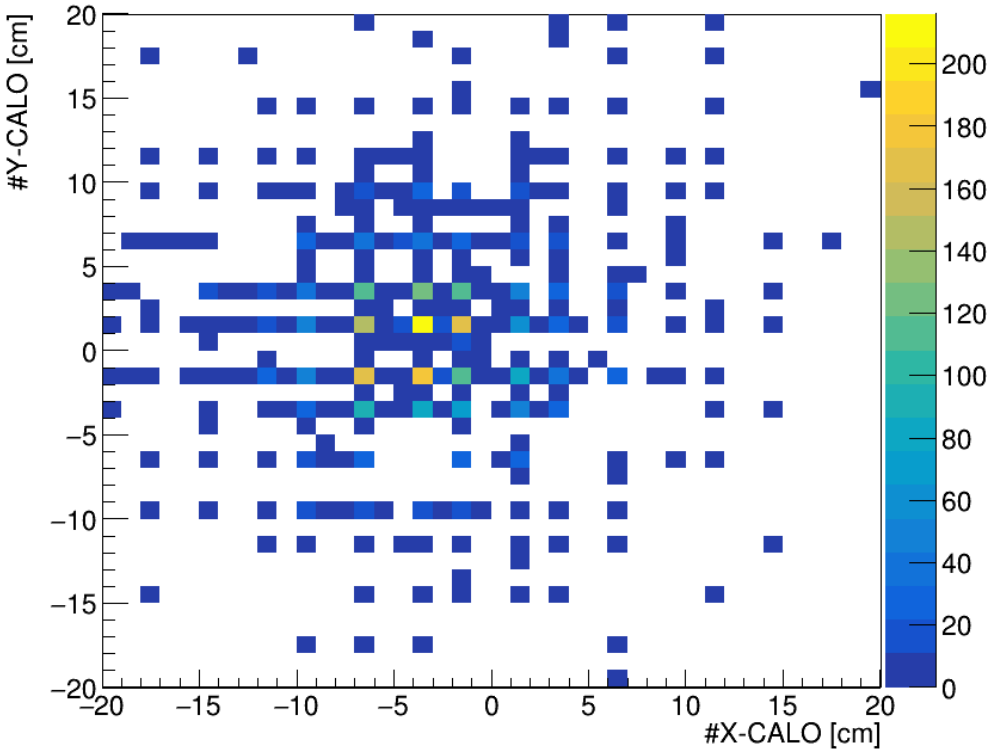


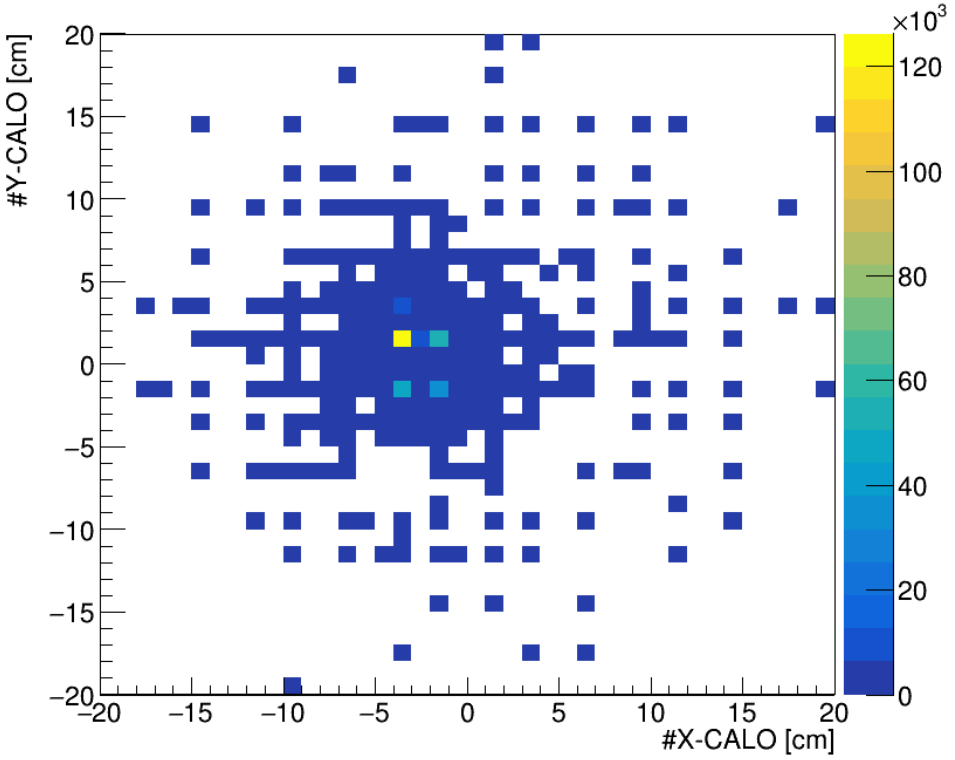
Cluster distribution (run 7072) Z = 3, 4





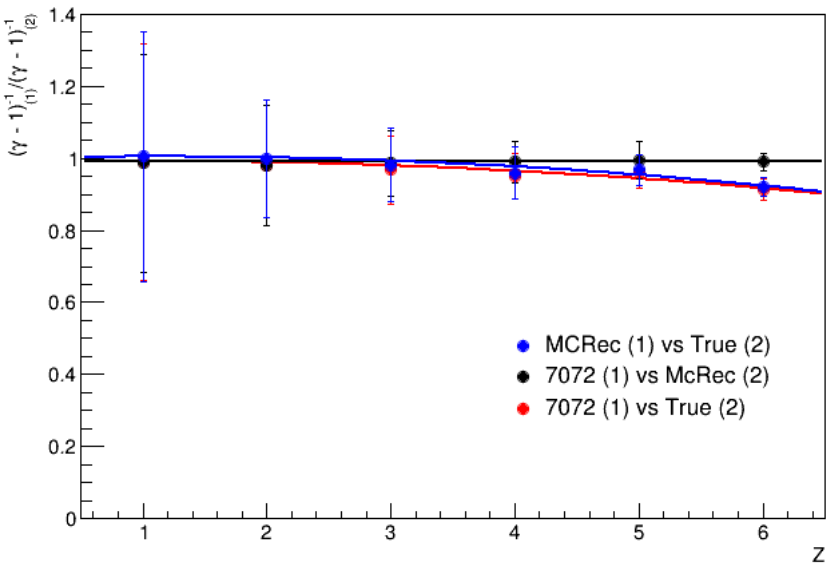
Cluster distribution (run 7072) Z = 5, 6





β effect on mass underestimation

β = L/TOF, assuming uniform fragments velocities, neglects energy losses through 3 tracking layers
→ β overestimation →$(\gamma-1)^{-1}$ underestimated up to 8-9%.



Given K = $(\gamma-1)^{-1}$, this plot shows:

- in **blue**, K_{MCRec} / K_{true}, fitted with a 2nd order function with $p_0 = 1$ (no reconstruction error in absence of e.m. losses); dependence on Z^2 is expected based on Bethe-Bloch formula;

- in **black** K_{7072} / K_{MCRec} (7072 refers to a single fragmentation run), fitted with a uniform function $y = a_0$ (systematic error is expected); results $a_0 \approx 99.0\%$

-in **red**, K_{7072} / K_{True}, fitted with a 2nd order function having $p_0 = a_0$ (only systematic error in absence of e.m. losses).

At lower Z, uncertainties on β are ~ 10 times higher than at Z = 6 → however, β is most likely the main source of underestimation of nominal mass values.