Possible measurements in a GSI2021/CNAO2021 campaign

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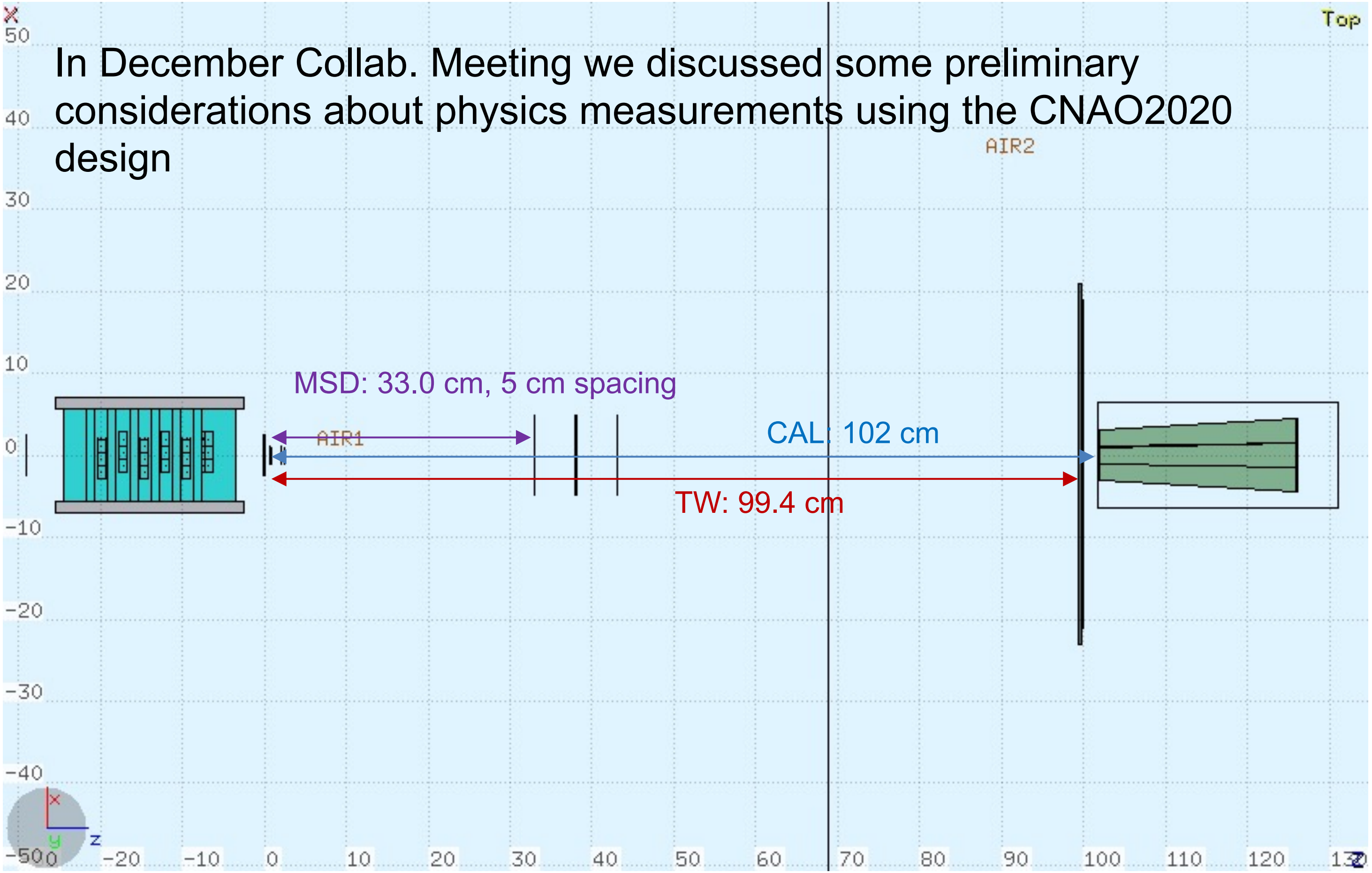
Exploiting the CNAO2020 design

In December Collab. Meeting we discussed some preliminary considerations about physics measurements using the CNAO2020 design

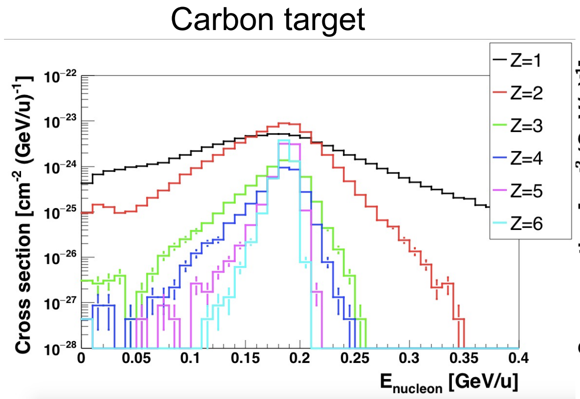


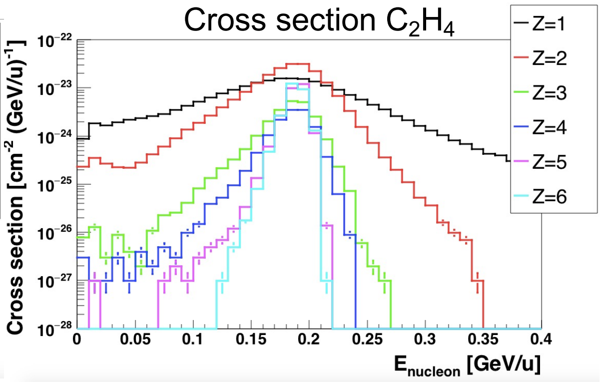
$d\sigma/E_{nucleon}$ for MC truth (fragments from target)

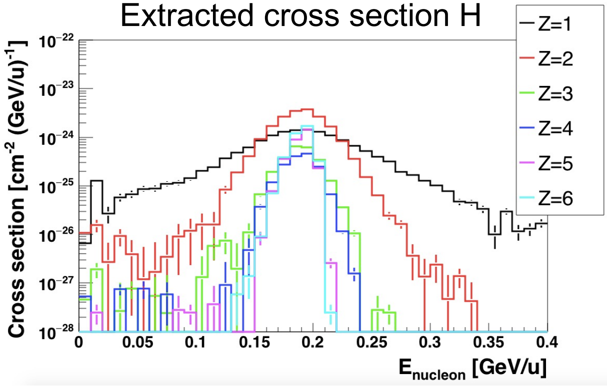
From A.C.K. talk at the FOOT Collaboration meeting 9/12/2020

C target: 5×10^6 primaries
C_2H_4 target: 10^7 primaries

Applying the appropriate factors to translate yields into cross sections:



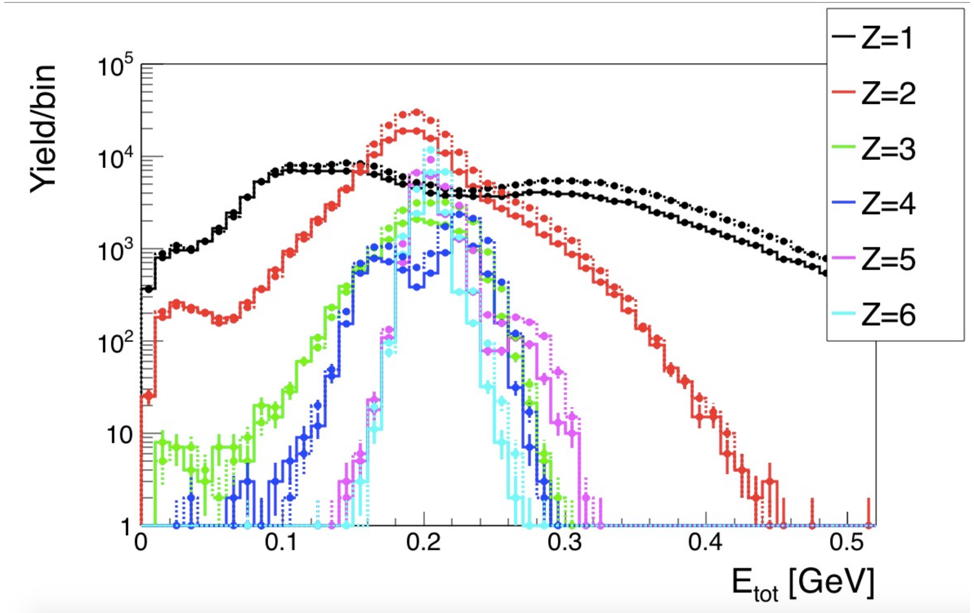




Exploiting the CNAO2020 design

Actually, the plots presented in December were obtained at the level of MC truth using the acceptance of the ToF Wall

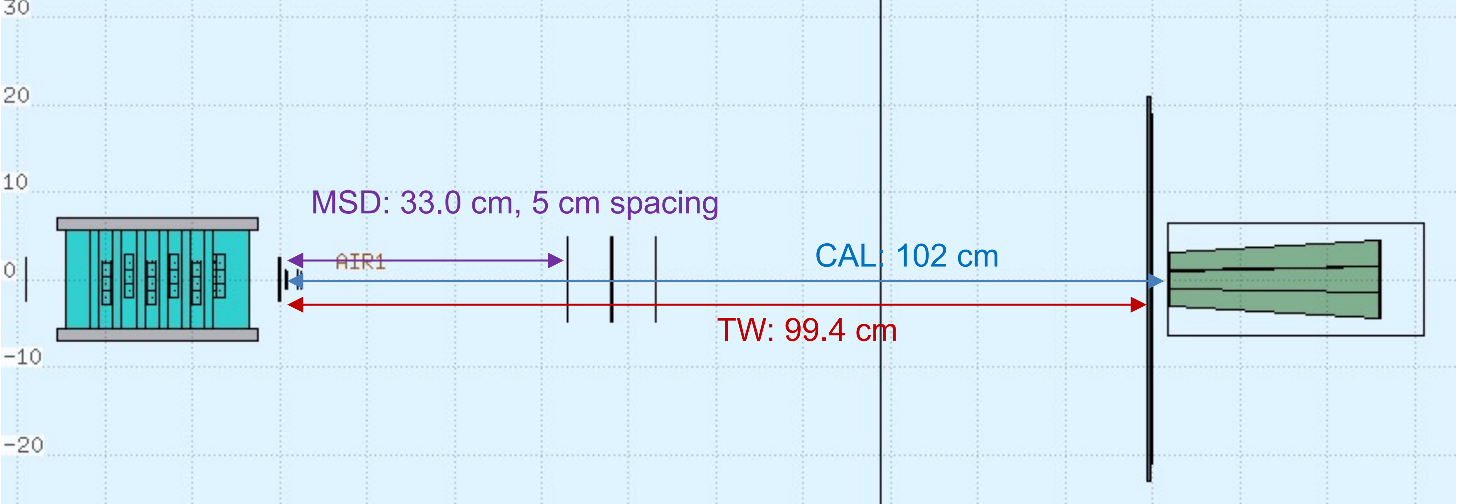
In practice, without knowing the mass, it is impossible to estimate E_{kin}



This would be the result if the "average" mass for each Z is used to calculate E_{kin}

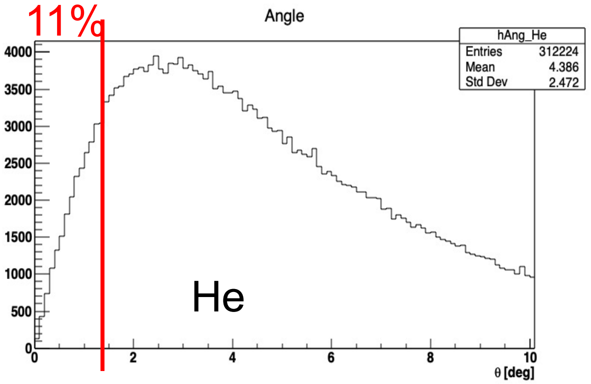
Towards a GSI/CNAO2021 campaign

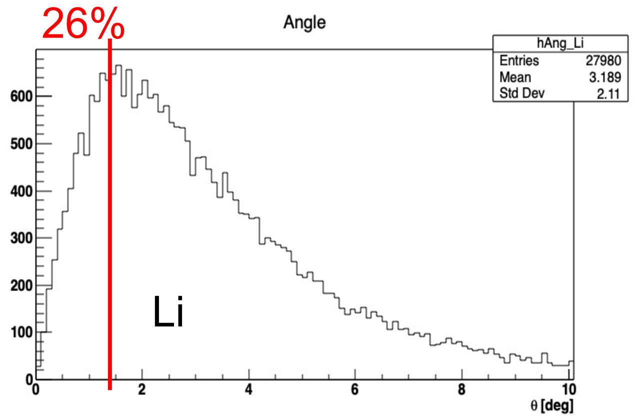
However, while waiting for the magnets, the presence of a calorimeter module gives us the chance to test the capability of A reconstruction by ToF and Calorimetric measurements



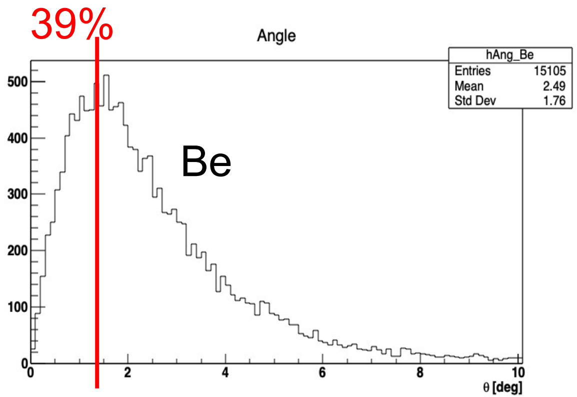
This of course can be attempted in a restricted angular: in the CNAO2020 design, the calorimeter module gives a limited angular coverage (semi-aperture ~1.7º)

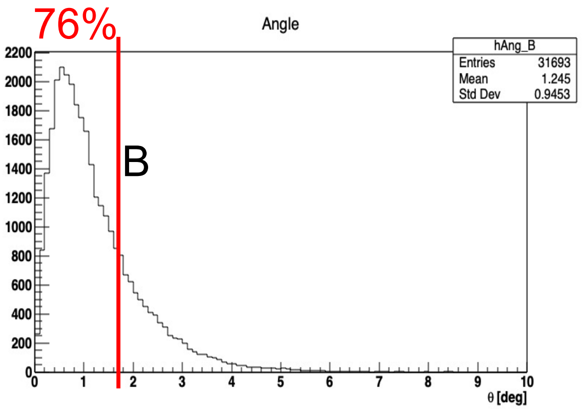
Expected angular distributions for ^{12}C @ 200 MeV/u

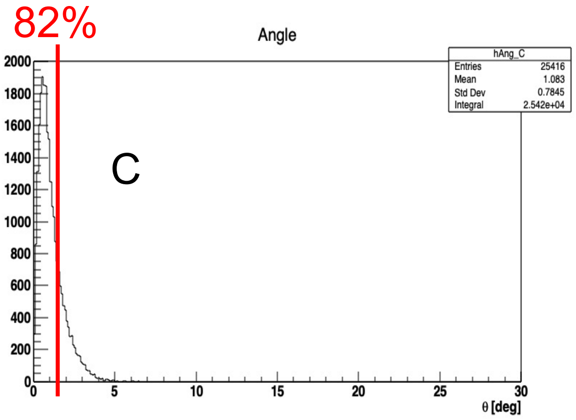




Although the fraction of ^{4}He is small, the absolute number should still be large

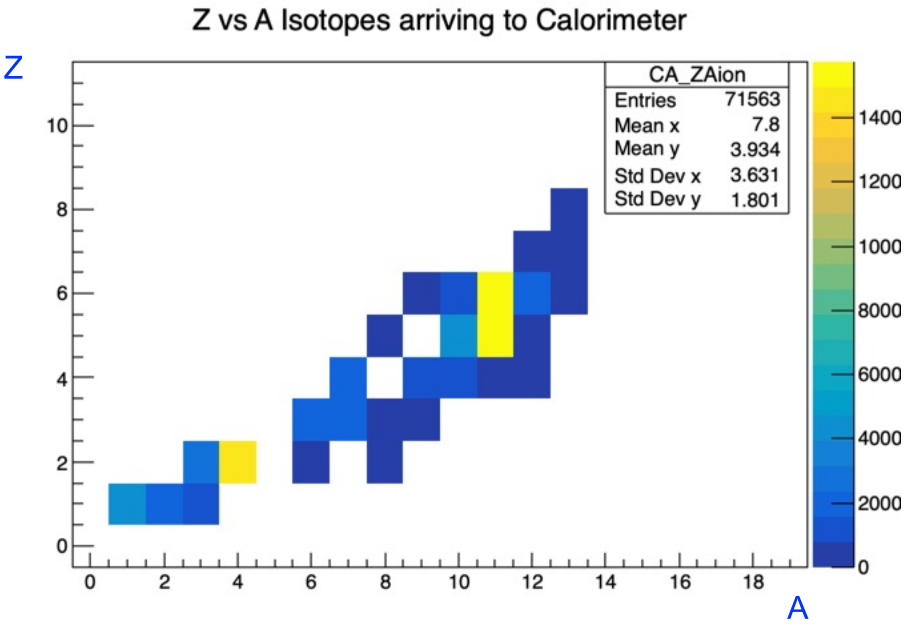


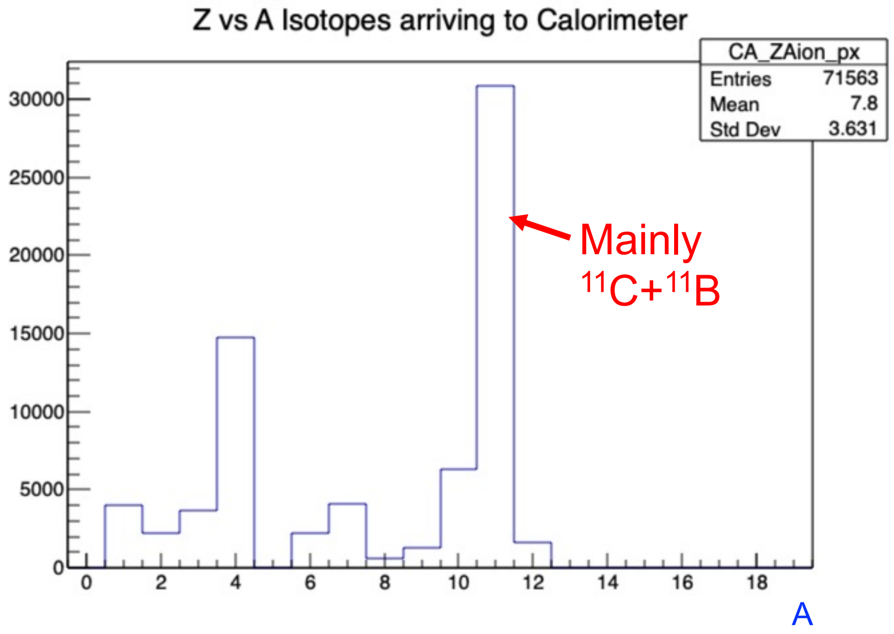




MC truth check

CNAO2020 campaign ^{12}C on C target 10^7 primaries. Events from target fragmentation with only one track arriving to Calorimeter.

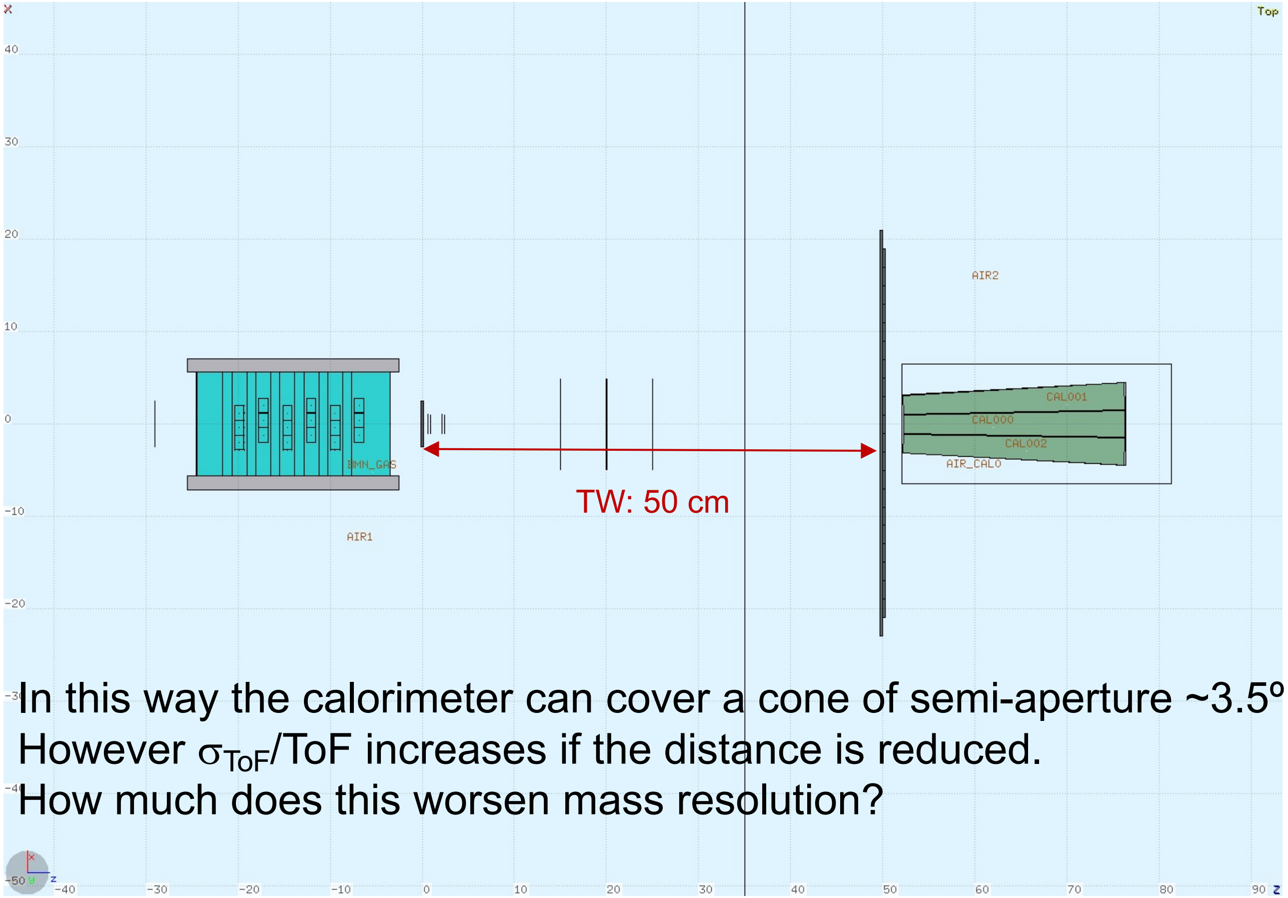




Perspectives

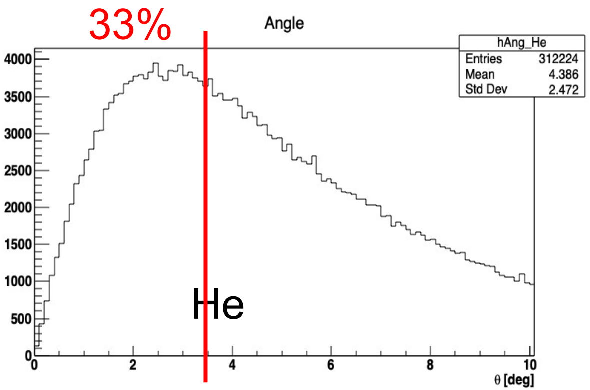
1. It is of course necessary that both ToF and calorimeter are calibrated
2. Mass number A reconstruction can be checked with the non-interacted primary beam
3. However a measurement of other isotopes can be performed
4. The acceptance of the calorimeter allows in any case to perfom a cross sections measurement at 0 degrees for different isotopes. It might be relevant

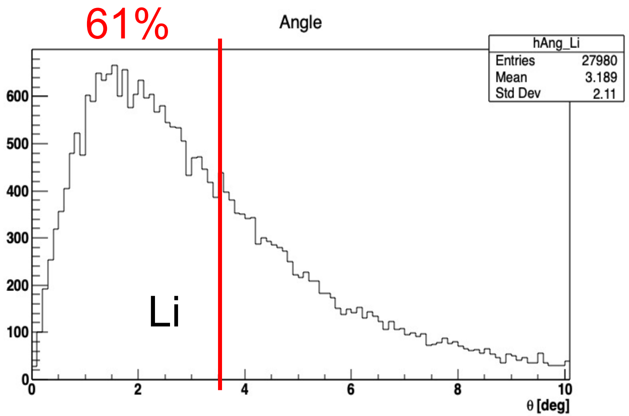
Is it convenient to conceive an increased acceptance?

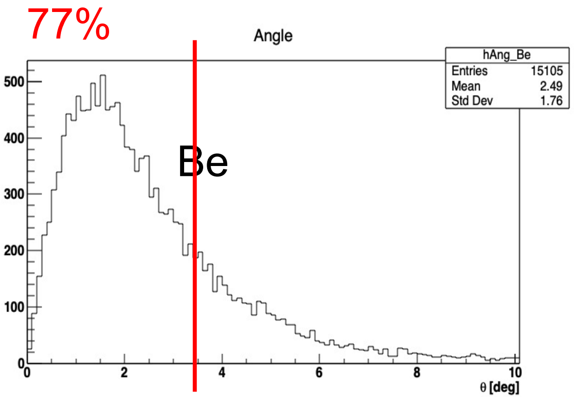


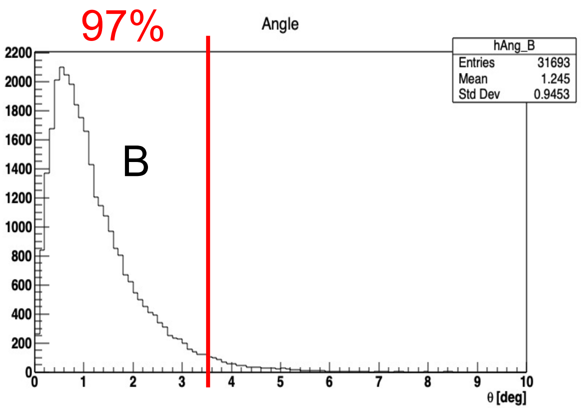
In this way the calorimeter can cover a cone of semi-aperture ~3.5º
However σ_{ToF}/ToF increases if the distance is reduced.
How much does this worsen mass resolution?

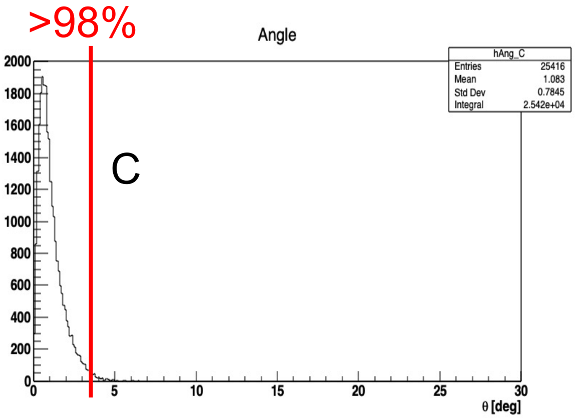
Expected angular distributions for ^{12}C @ 200 MeV/u











Analytical considerations on Mass Reconstruction

When only ToF and Calorimeter are available:

$$\boxed{m = \frac{E_k}{c^2(\gamma - 1)}}$$

$$\sigma_\beta = \frac{\sigma_{ToF}\,\beta}{ToF} \qquad \sigma_\gamma = \frac{\sigma_\beta\,\beta}{(1-\beta^2)^{3/2}} \qquad \sigma_m = \sqrt{\left(\frac{\partial m}{\partial E_k}\right)^2 \sigma_E^2 + \left(\frac{\partial m}{\partial \gamma}\right)^2 \sigma_\gamma^2} = \sqrt{\frac{\sigma_E^2}{(\gamma-1)^2} + \frac{E_k^2\sigma_\gamma^2}{(\gamma-1)^4}}$$

Example:

^{10}B @E~200 A MeV (2000 MeV), M = 9324 MeV/c^2

β = 0.565 γ =1.212

Hypothesis: σ_{ToF} ~ 70 ps σ_E/E ~ 2% → σ_E ~ 40 MeV

For L = 100 cm: ToF ~6 ns → σ_β ~ 0.0066 → σ_γ ~ 0.0066

→ σ_M ~ 350 MeV/c^2 → σ_M/M ~ 3.7%

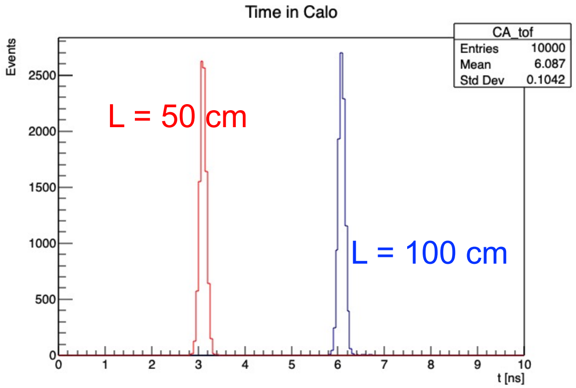
For L = 50 cm: ToF ~3 ns → σ_β ~ 0.013 → σ_γ ~ 0.013

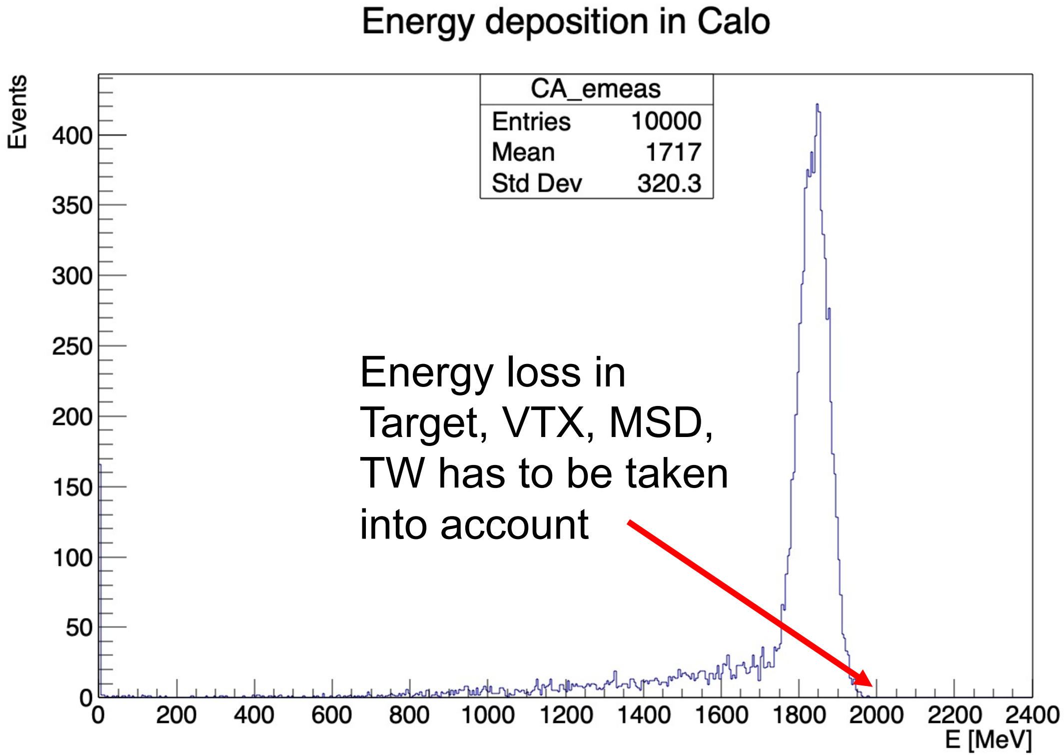
→ σ_M ~ 600 MeV/c^2 → σ_M/M ~ 6.3%

ΔM(^{11}B-^{10}B) ~ 928 MeV/c^2 → For L=50 cm can the expected mass resolution allow to distingush these 2 isotopes?

MC exercise check

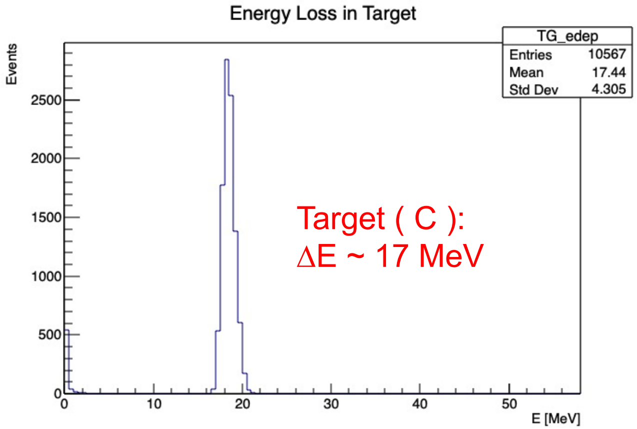
Shooting 10B @ 200 MeV/u along the beam line, assuming resolutions quoted in previous slide

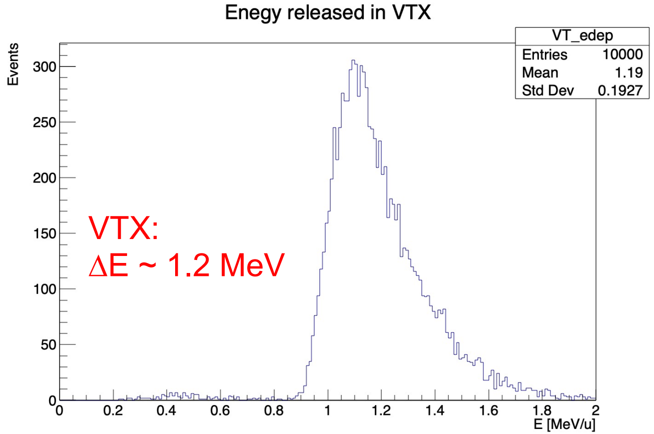


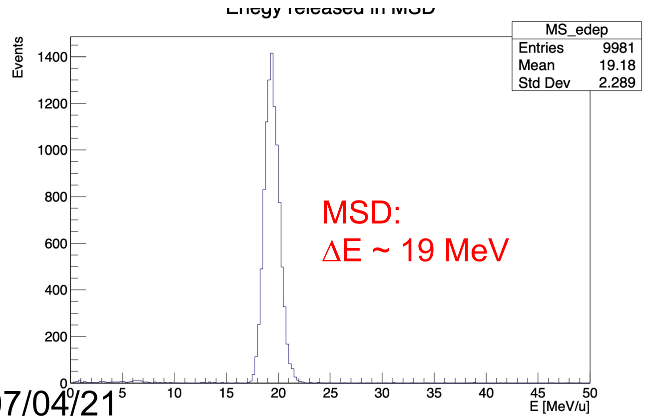


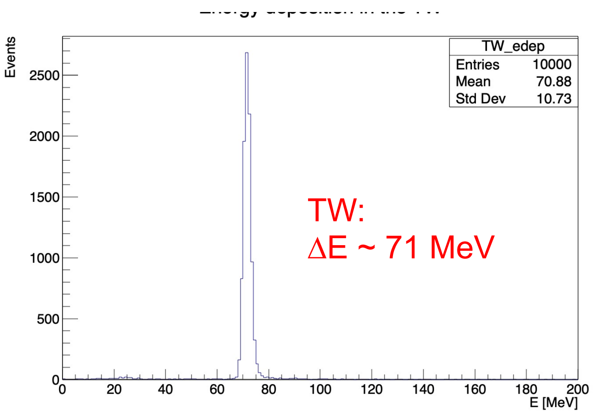
MC exercise check

Checking in MC energy loss along the path up to Calorimeter





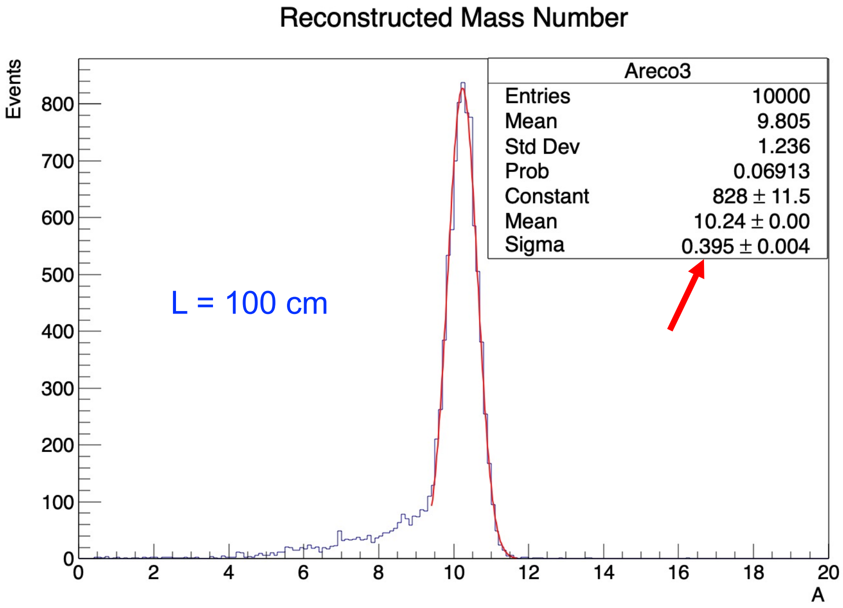


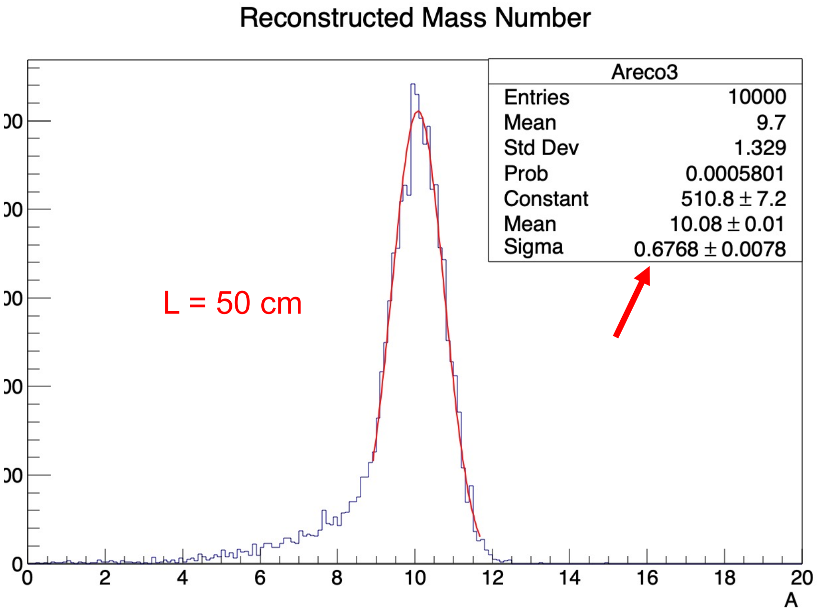


A further resolution of 3% is then applied to energy loss measurement in TW

MC exercise check

Mass Number reconstruction after compensating for energy loss in other detectors

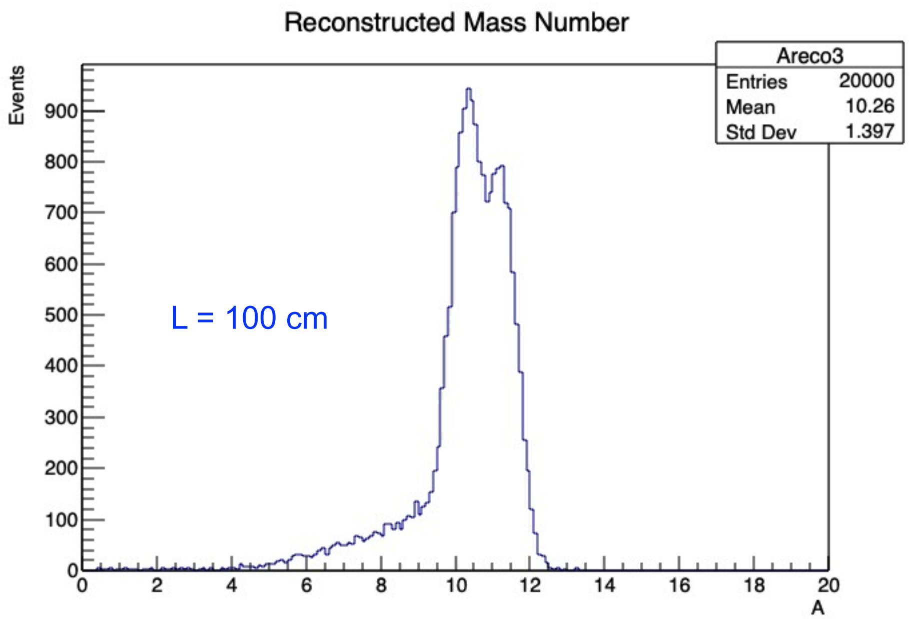


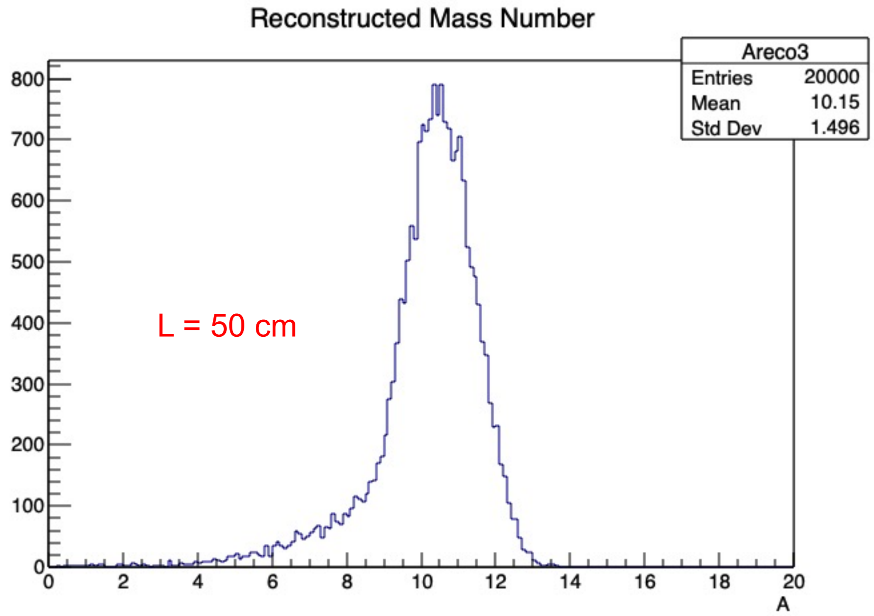


Close to expectations

MC exercise check: shooting both ^{10}B and ^{11}B

10k events of both isotopes





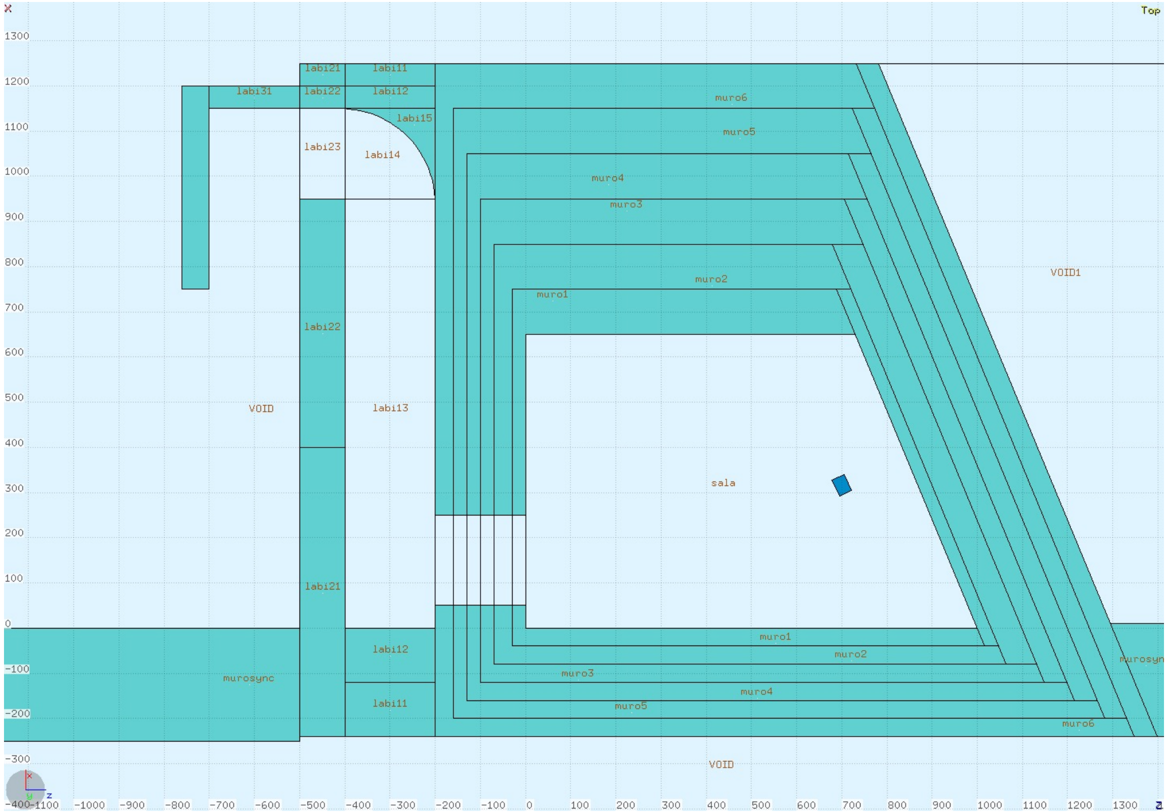
Reduction of distance does not pay off

Conclusions

1. A data taking with the calorimeter module is a good chance to test our capability of identifying A
2. For this analysis purpose is of course necessary that both ToF and calorimeter are calibrated
3. Checking A reconstruction can be done with the non-interacted primary beam
4. A measurement of other isotopes can be performed
5. The acceptance of the calorimeter allows to perfom interesting physics measurement around 0^o, such $d\sigma/dE(\theta=0^o)$ for different A *(what is the needed statistics?)*
6. The increase of acceptance by reducing the lever arm of TOF+Calo from ~100 cm to ~ 50 cm does not seem to be convenient because of the loss in A resolution
7. We plan to work to present a dedicated study of possible physics results in the next meetings using reconstruction software

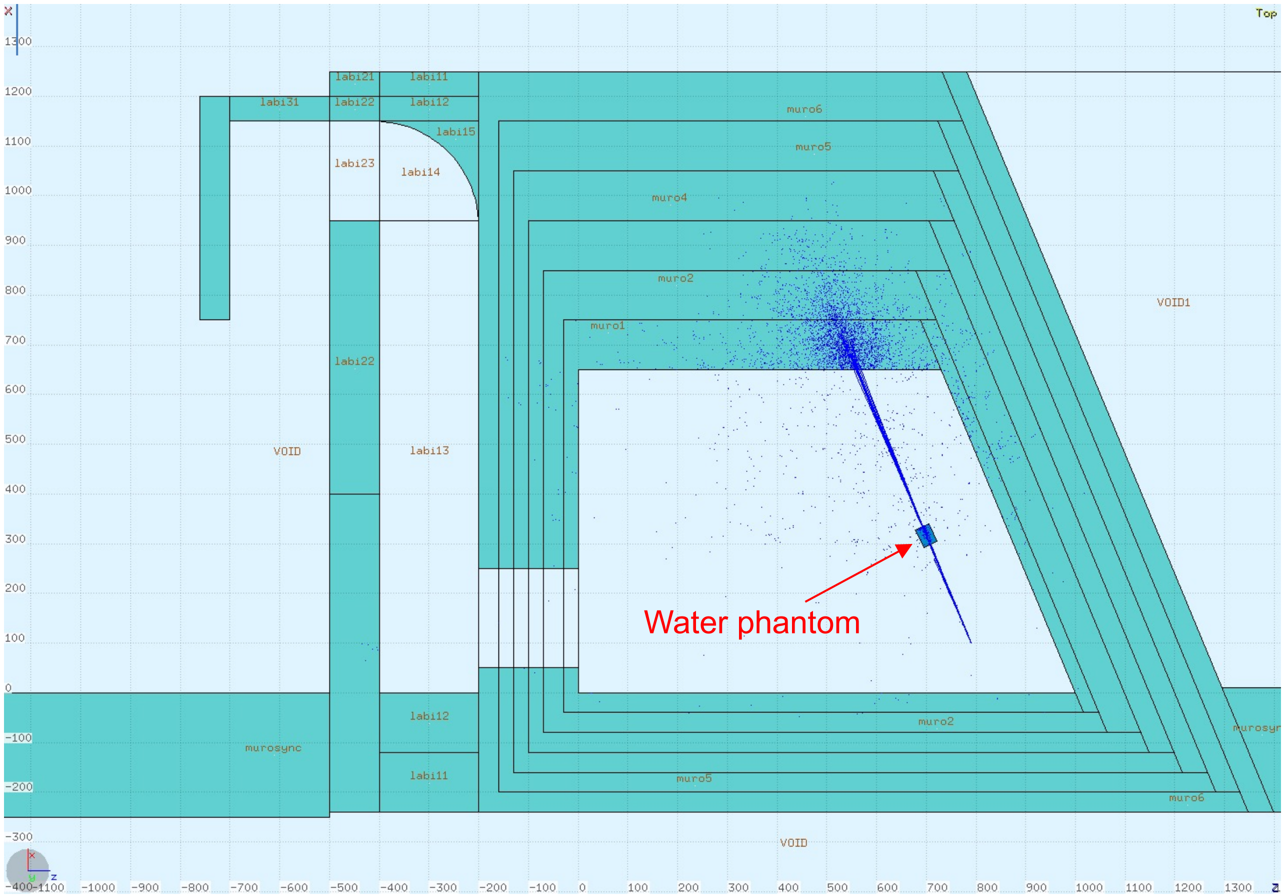
Appendix: possible improvements in the simulation

Expecially in view of runs where dedicated mesurements of neutron productions are considered, it could be important to consider the environment around the apparatus.



Example for CNAO Exp. Room.

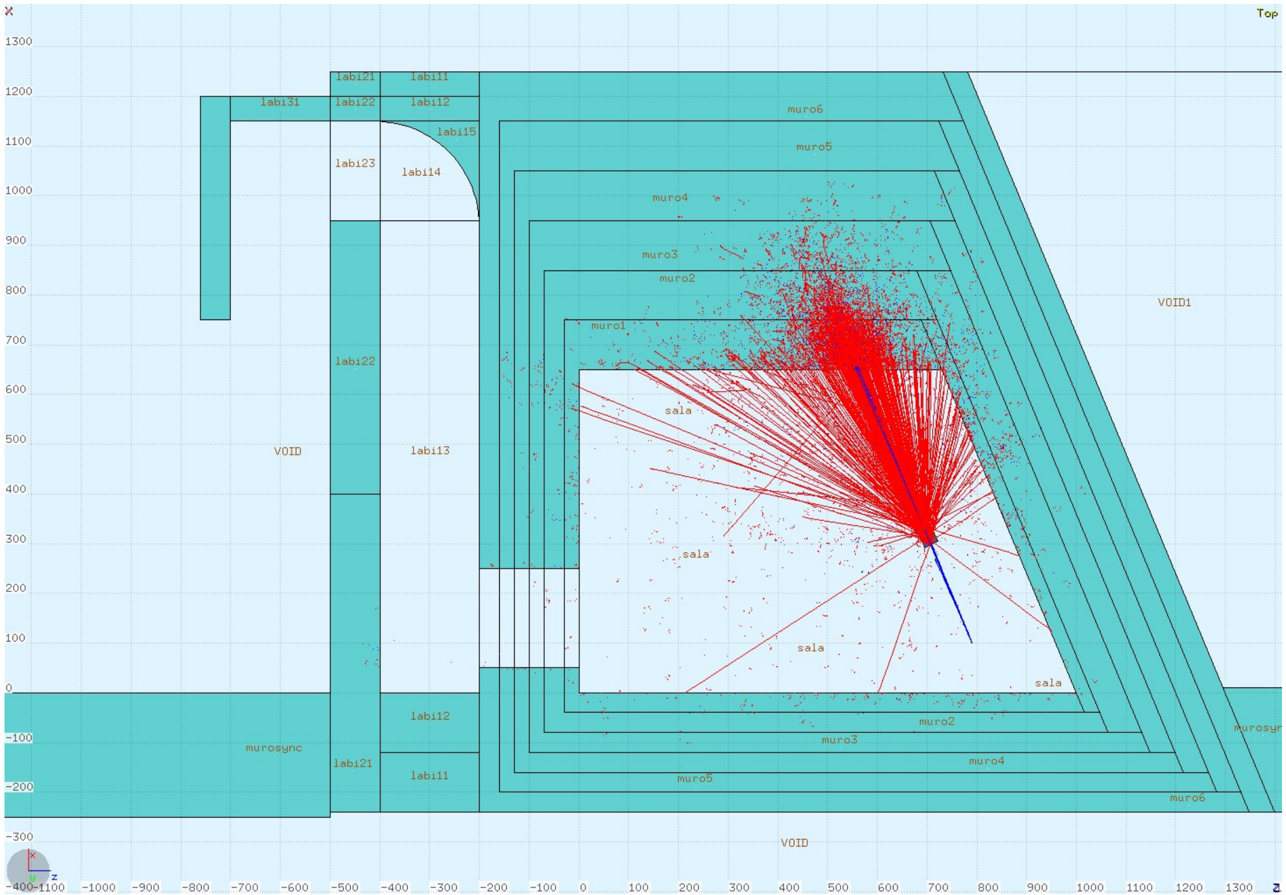
Thanks to M. Ferrarini (CNAO) and A. Embriaco



^{12}C beam 250 MeV/u

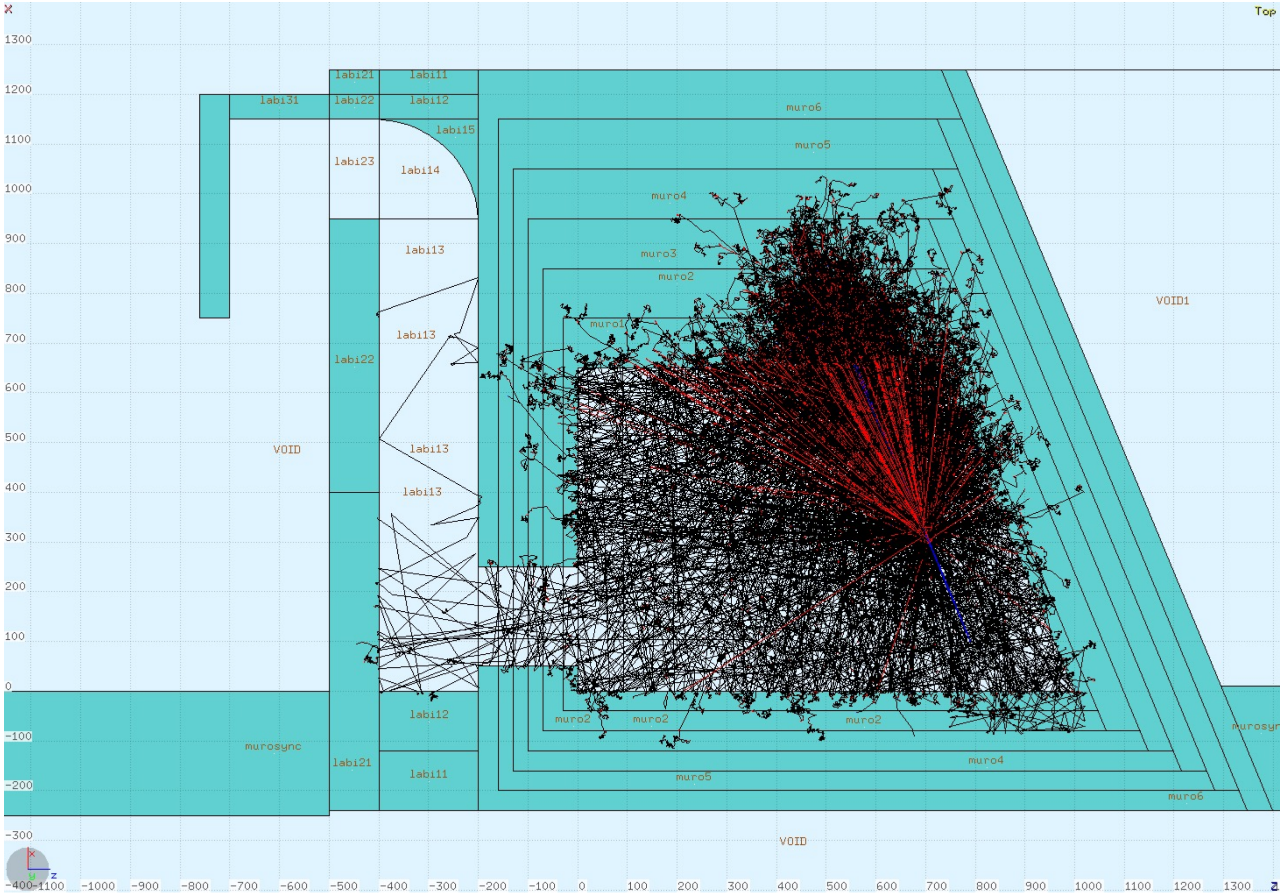
100 primary events

Blue Tracks are nuclear fragments with Z>2



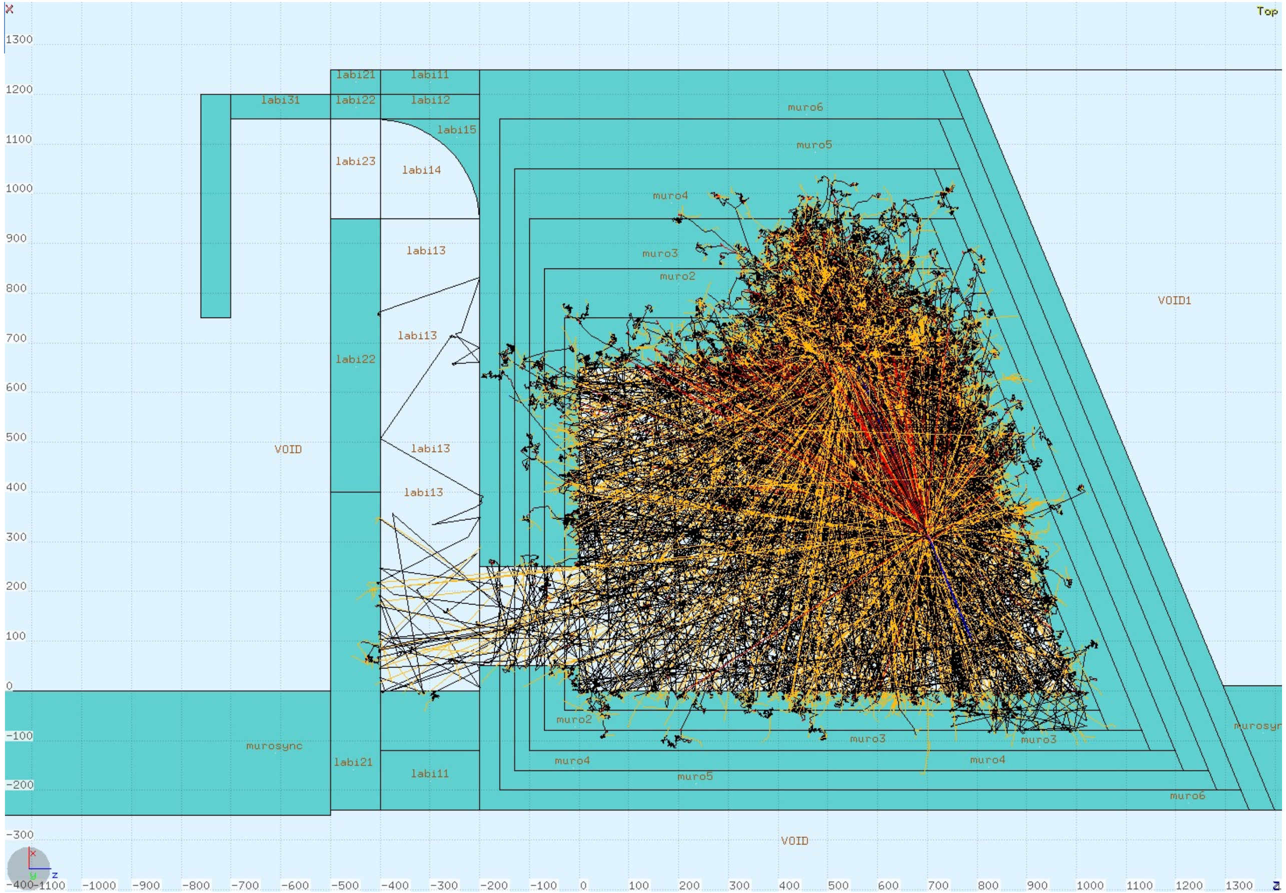
Secondary p (red)

100 primary events
^{12}C beam 250 MeV/u



Secondary p + n
(black, En threshold ~0)

100 primary events
^{12}C beam 250 MeV/u



Secondary p + n + γ (yellow)

100 primary events

^{12}C beam 250 MeV/u