Short Documentation of SRC analysis

8. Juni 2021

0.1 Setup

Beam energy: 400 AMeV
Beamtype: 12C
Target: CH2 12.29mm
Beam Time: 3 hours
Tracking detectors: MWPC 1,2,3 (just x position)
ToF measurement: START to ToFW
Charge Measurement: TWIM Music
Event selection criteria for CALIFA: two hits with E_hit > 30 MeV (laboratory system) and 10B(11B) as daughter particle (exclusive events).
No other cuts (for now).

0.2 12C(p,2p)11B analysis

The Energy and momentum conservation for this reaction can be expressed as:
$\bar{p}_{12C} + \bar{p}_{tg} = \bar{p}_1 + \bar{p}_2 + \bar{p}_{11B}$ (four momentum vectors)
Assuming QE scattering in the mean field we approximate:
$\bar{p}_{12C} = \bar{p}_i + \bar{p}_{11B}$ where $\bar{p}_i$ is the initial proton-four-momentum inside the 12C ion.
Hence we obtain:
$\bar{p}_i \approx \bar{p}_{miss} \equiv \bar{p}_1 + \bar{p}_2 - \bar{p}_{tg}$
And the missing Energy E_{miss} is defined as:
$E_{miss} \equiv m_p - e_{miss}$ (where e_{miss} is the energy component of $\bar{p}_{miss}$ in the 12C frame).

0.2.1 Plots:

The analysis of the missing momentum (components) is summarized in following plots:

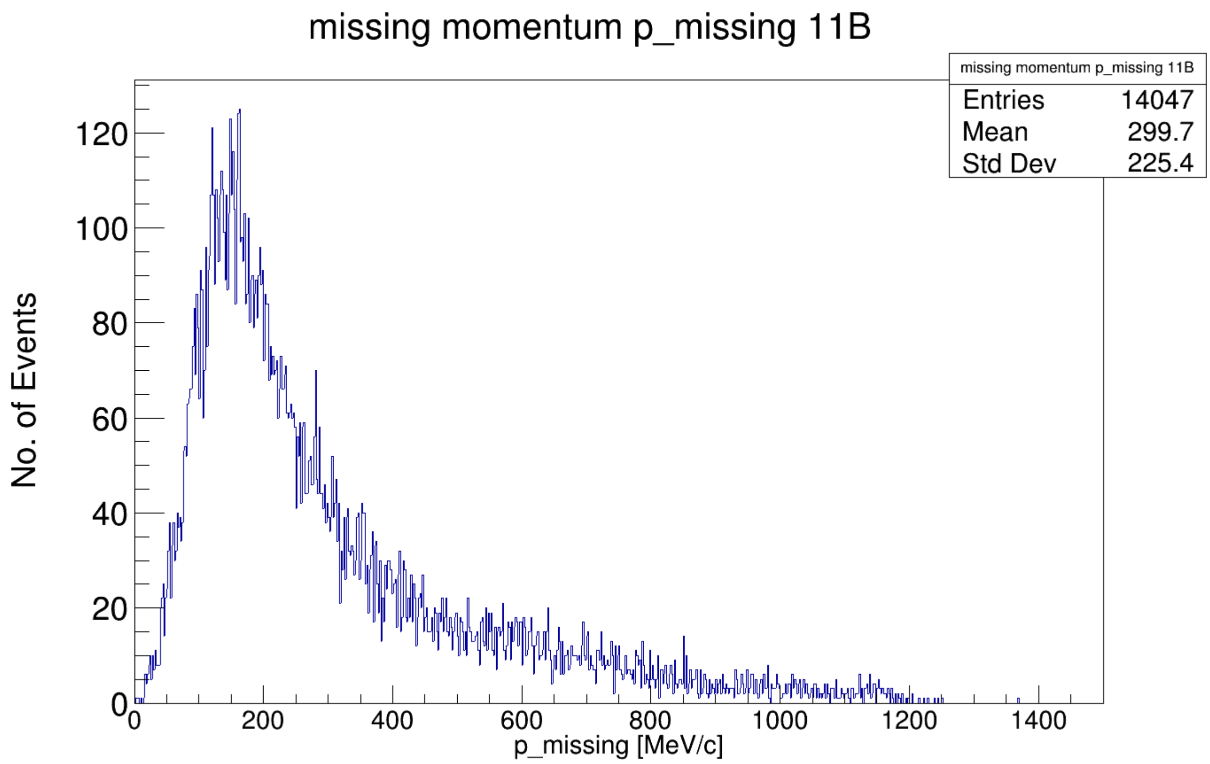


Abbildung 1: Momentum of the initial proton inside the 12C ion.

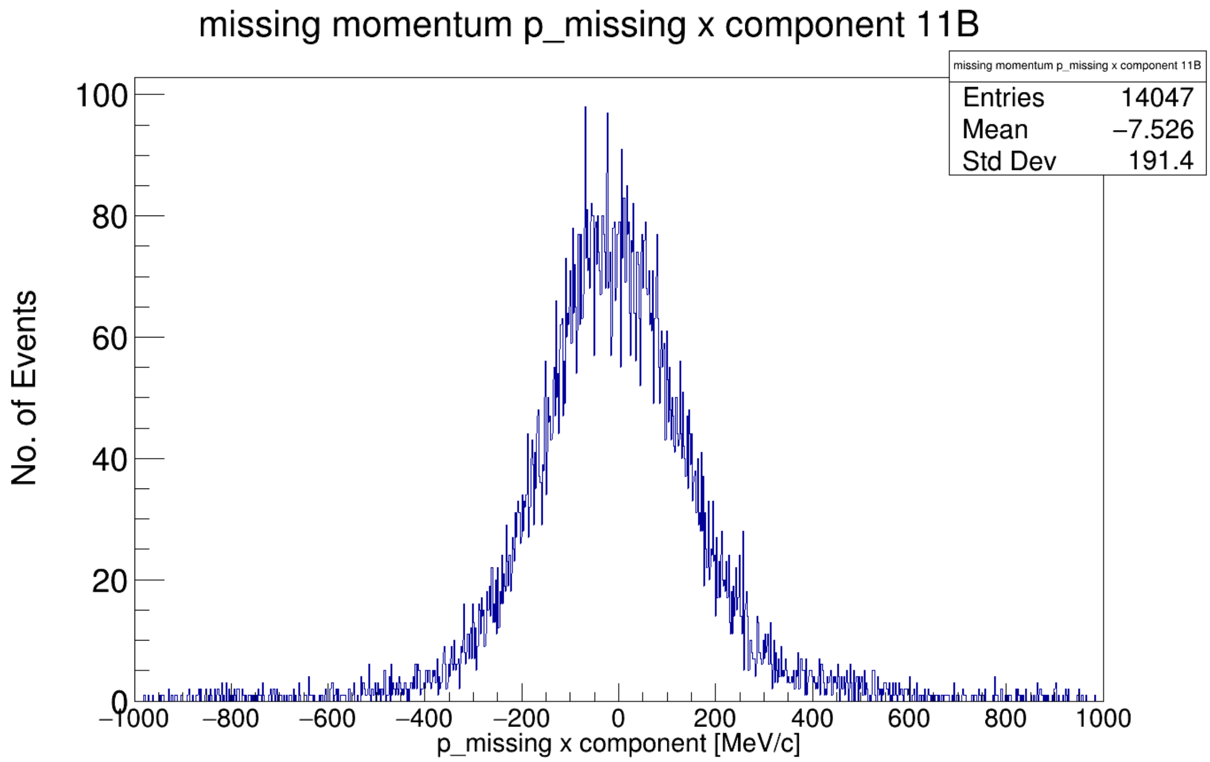


Abbildung 2: Momentum of the initial proton inside the 12C ion - x component.

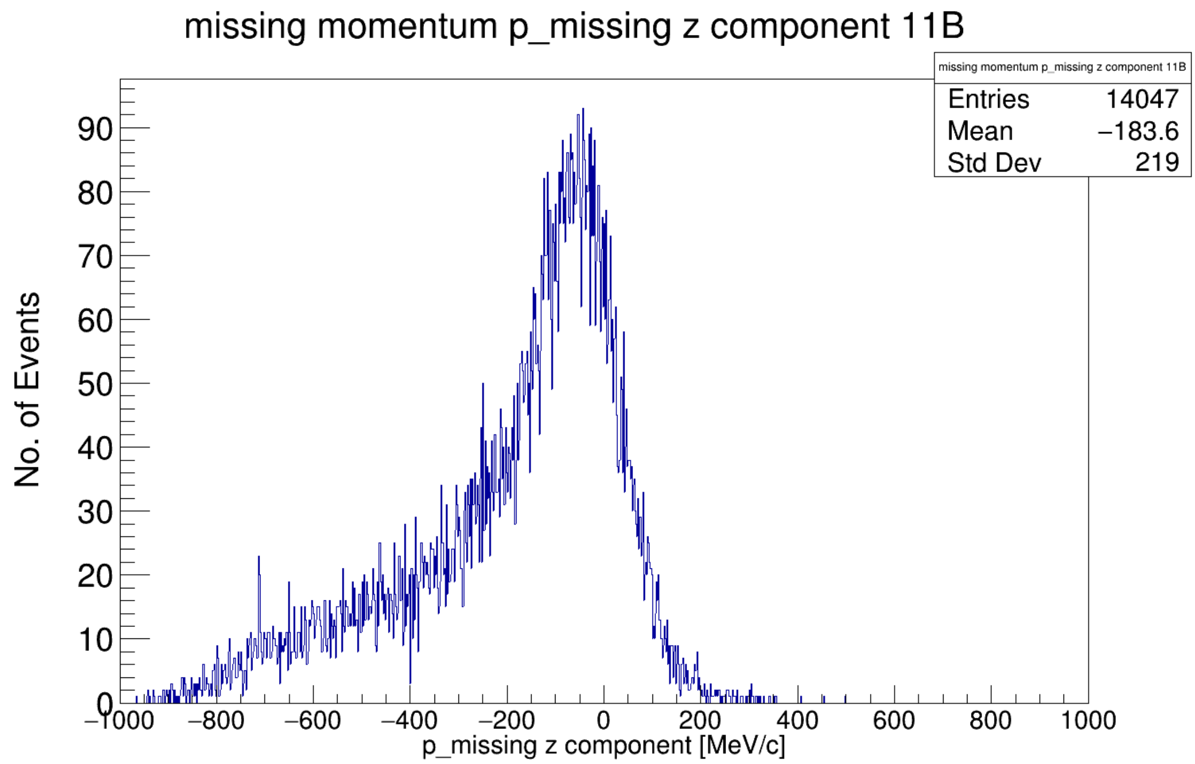


Abbildung 3: Momentum of the initial proton inside the 12C ion - z component. The shift in p_{miss_z} is associated with a strong pp cross-section scaling with c.m. energy.

The plots relating to the missing energy E_{miss} are summarized in the following plots:

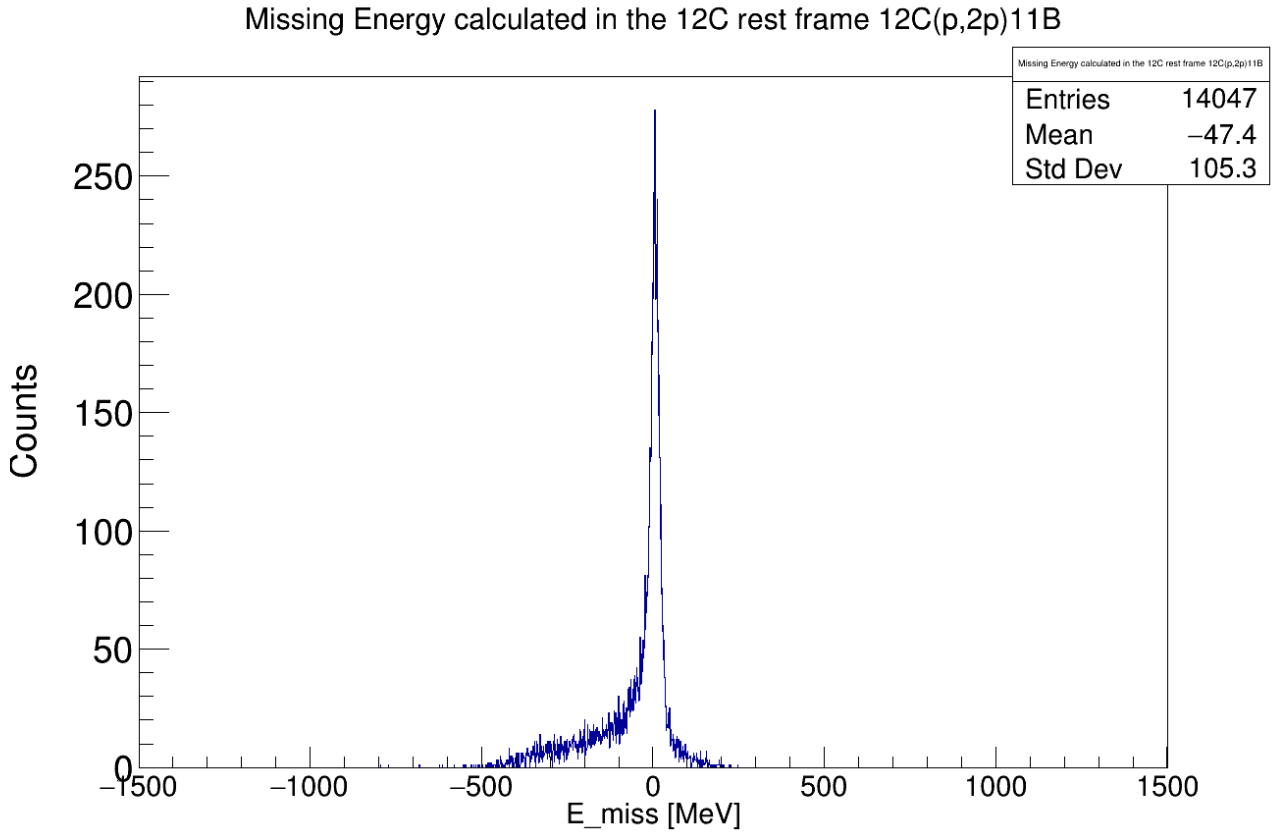


Abbildung 4: Missing energy calculated in the 12C rest frame.

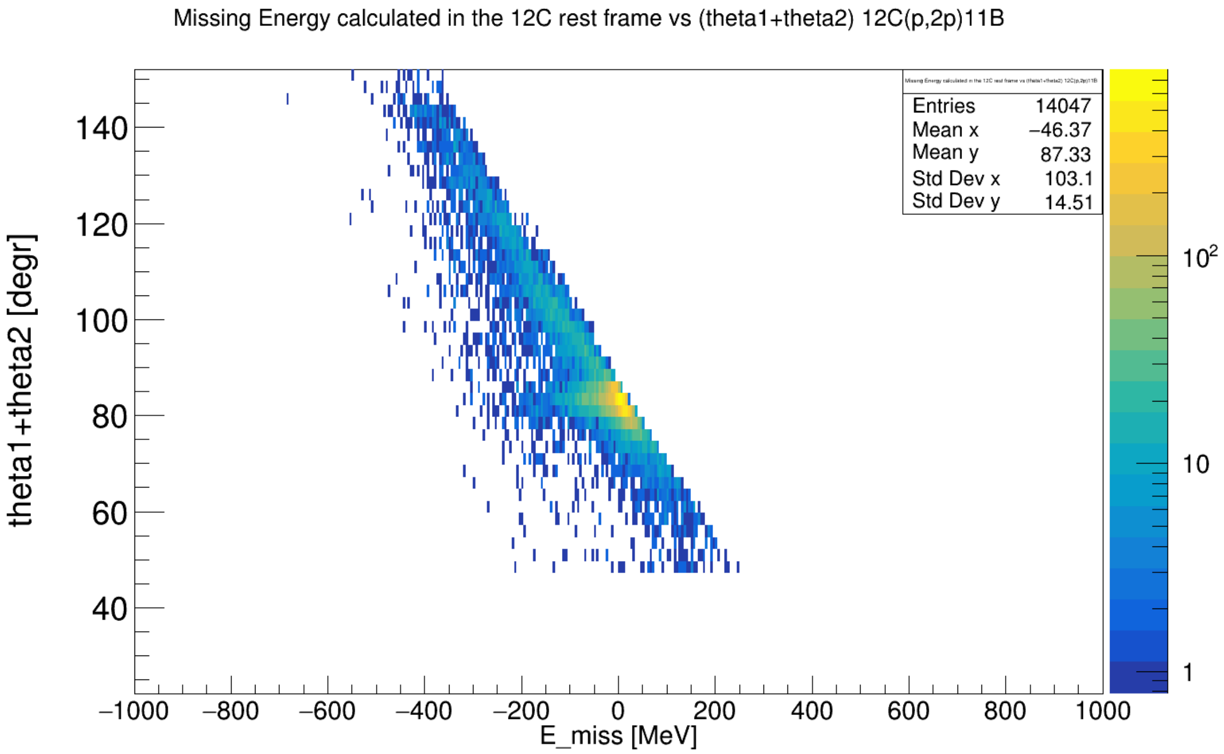


Abbildung 5: Missing energy calculated in teh 12C rest frame versus theta1 + theta2. Most of the reactions are in the QE scattering region.

The plots relating to the angular distribution of the two protons from the 12C(p,2p)11B reaction:

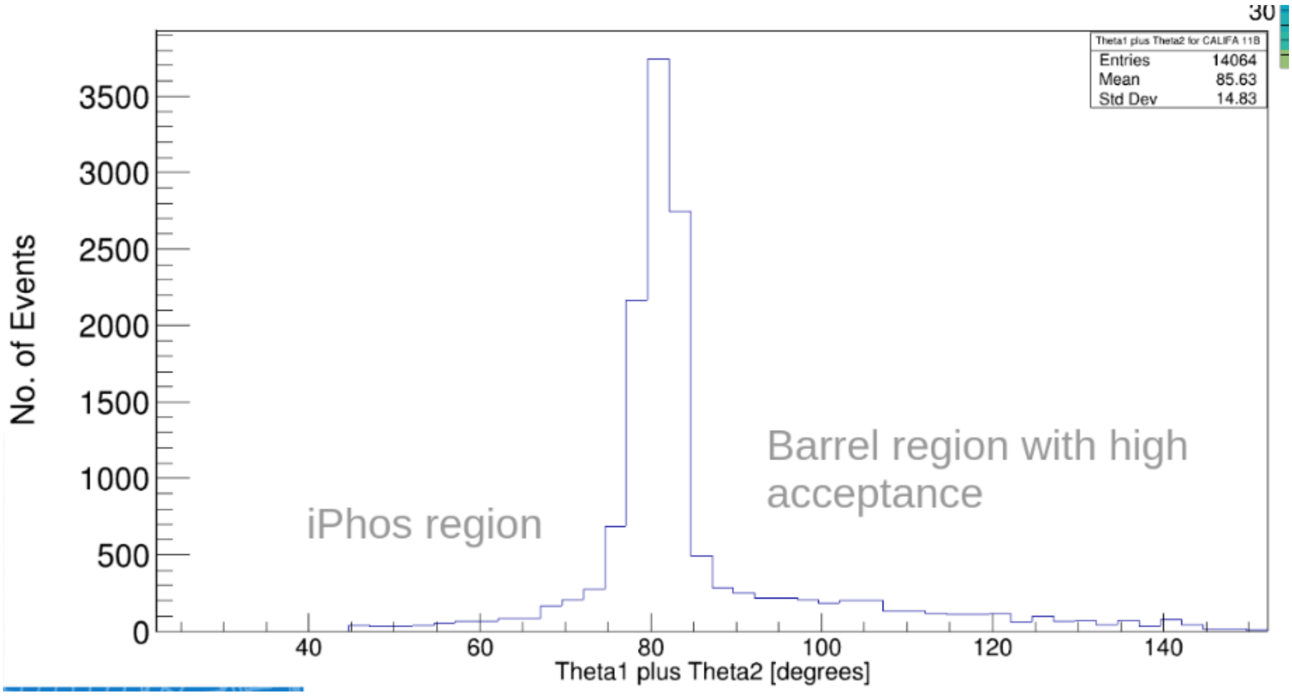


Abbildung 6: Theta1 plus theta2 for proton 1 and proton 2 distribution.

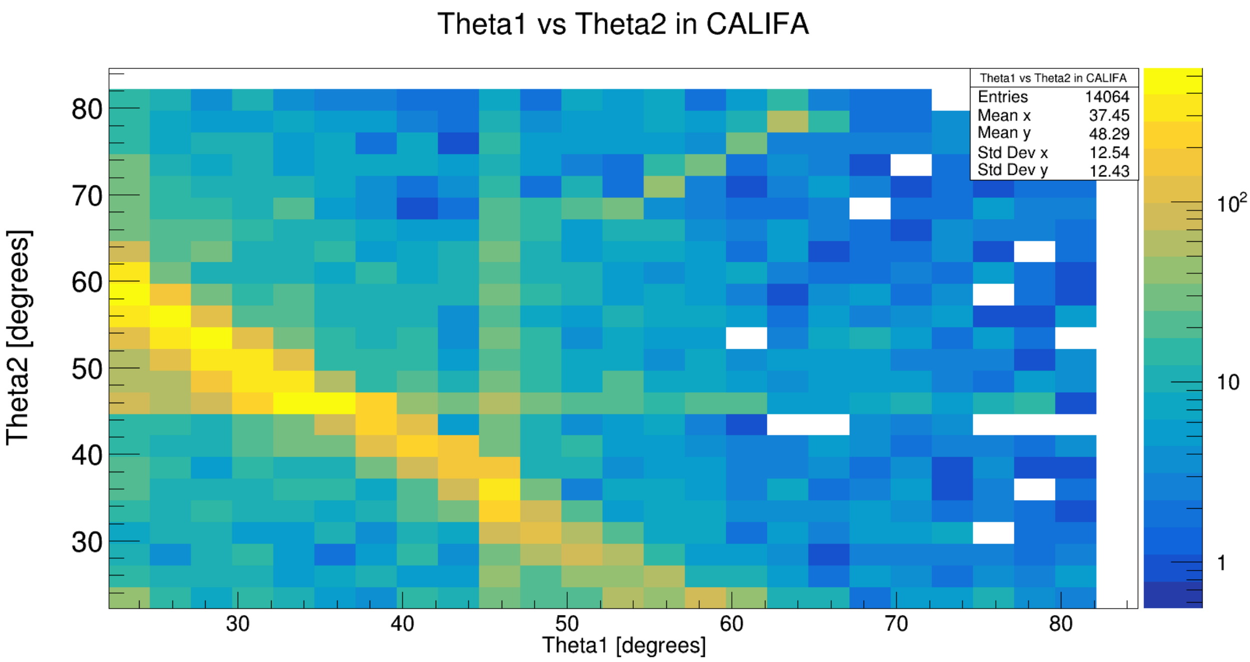


Abbildung 7: Theta1 vs theta2 for proton 1 and proton 2 where proton 1 is the one with higher kinetic energy.

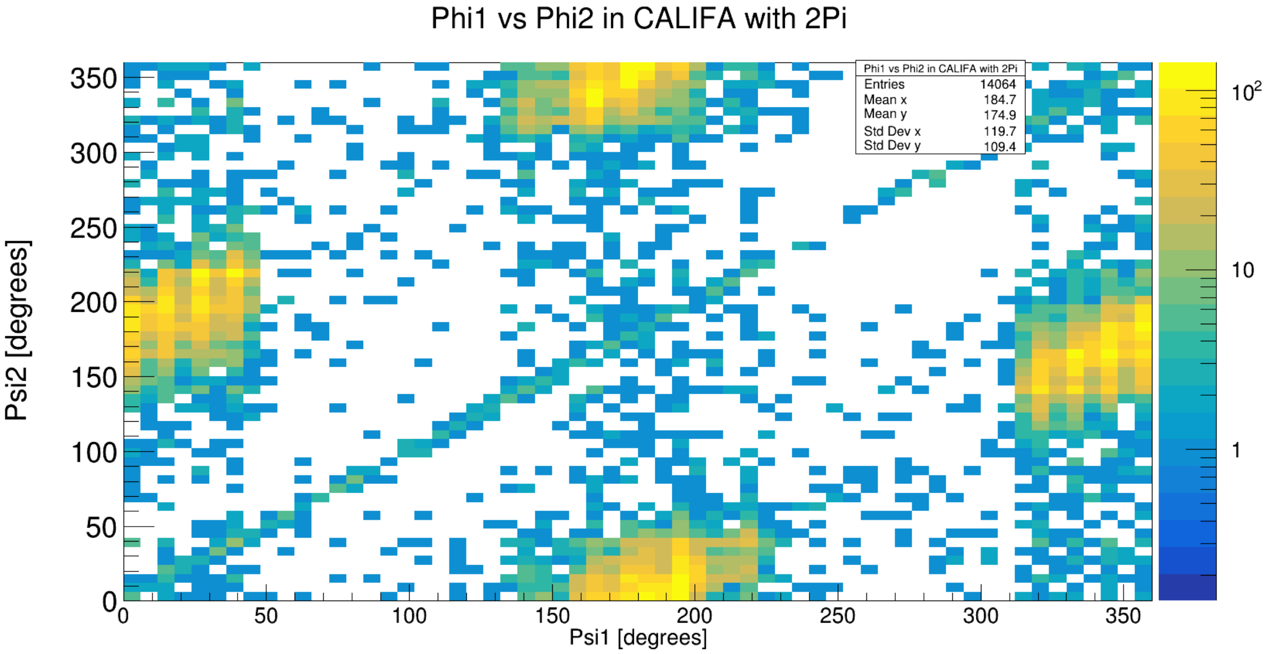


Abbildung 8: Arzimuthal angular distribution for proton 1 and proton 2.

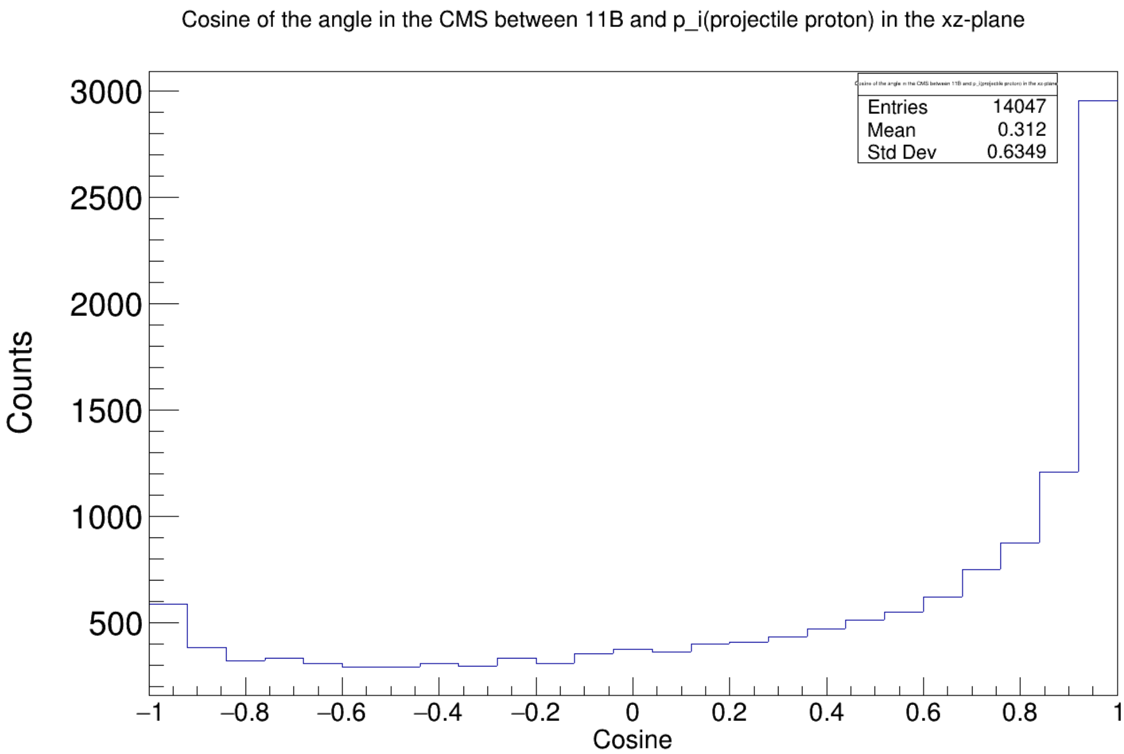


Abbildung 9: Cosine of the opening angle between the missing and fragment moment in 12C c.m. frame.

As gamma spectrum related to the 12C(p,2p)11B reaction we get:

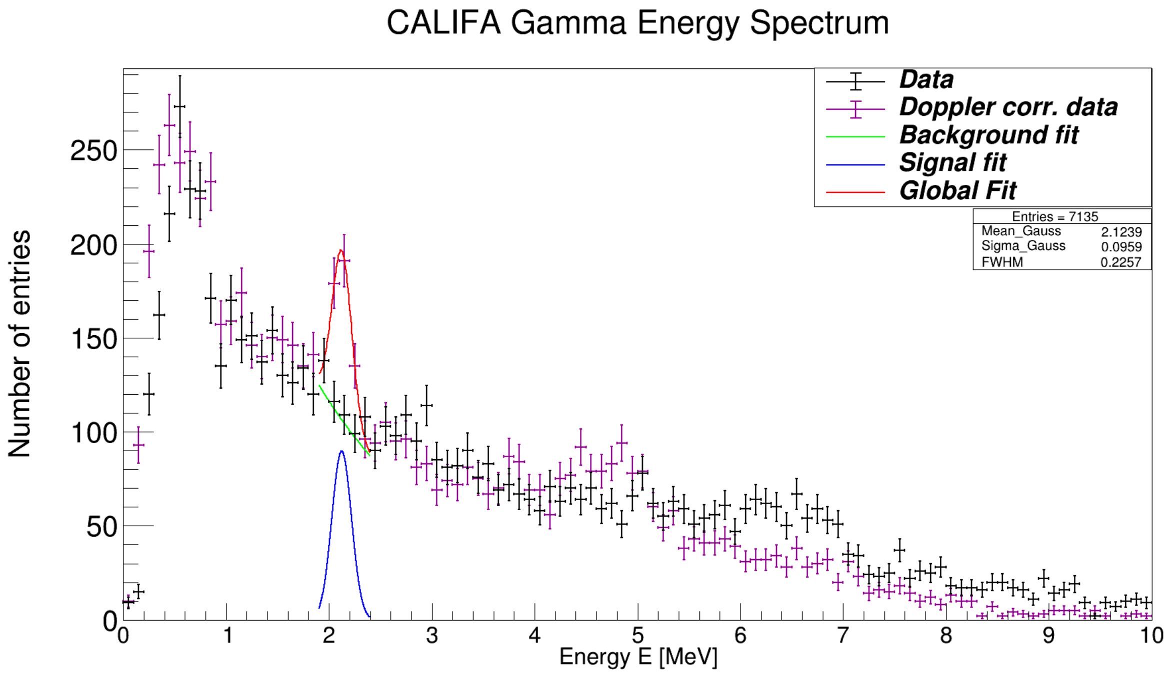


Abbildung 10: Doppler reconstructed gamma spectrum for the first excited states (with a resolution around 10%).

0.3 12C(p,2p)10B

For this reaction the missing momentum (which equals to the initial proton momentum inside the 12C ion) is same as before:
$\bar{p}_i \approx \bar{p}_{miss} \equiv \bar{p}_1 + \bar{p}_2 - \bar{p}_{tg}$
The missing nucleon mass in the entire reaction is given by:
$M^2_{miss,excl} = \left(\bar{p}_{12C} + \bar{p}_{tg} - \bar{p}_1 - \bar{p}_2 - \bar{p}_{10B}\right)^2$
The analysis of the missing momentum is summarized in following plots:

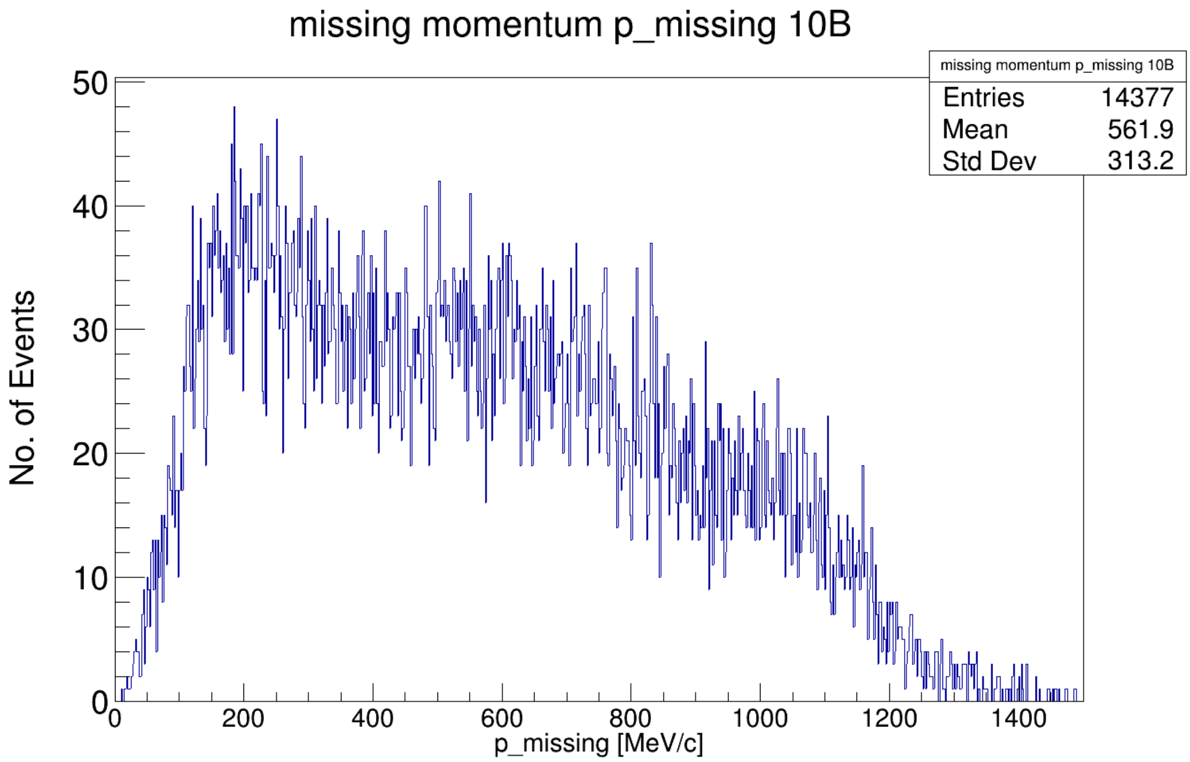


Abbildung 11: Initial proton momentum inside the 12C ion for the 12C(p,2p)10B reaction.

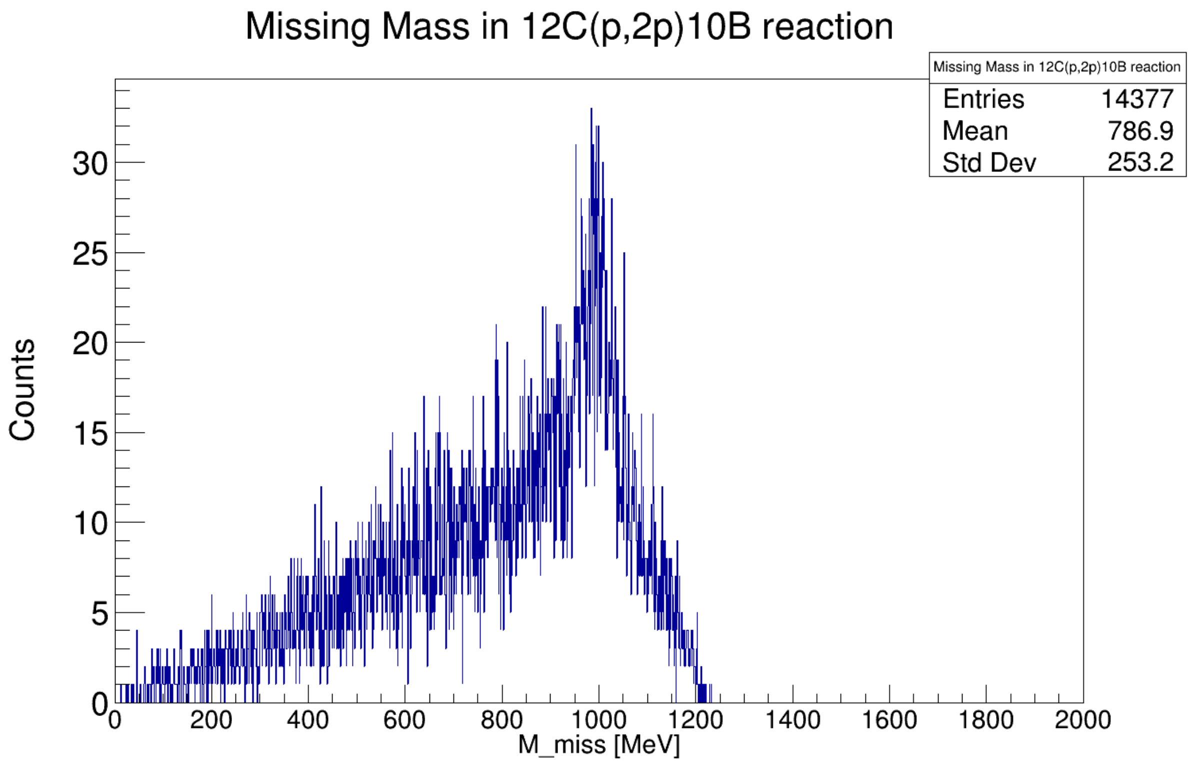


Abbildung 12: Missing mass with a peak $\approx m_N$ (where m_N is the nucleon mass).

To compare the missing momentum between the 12C(p,2p)11B and 12C(p,2p)10B reaction:

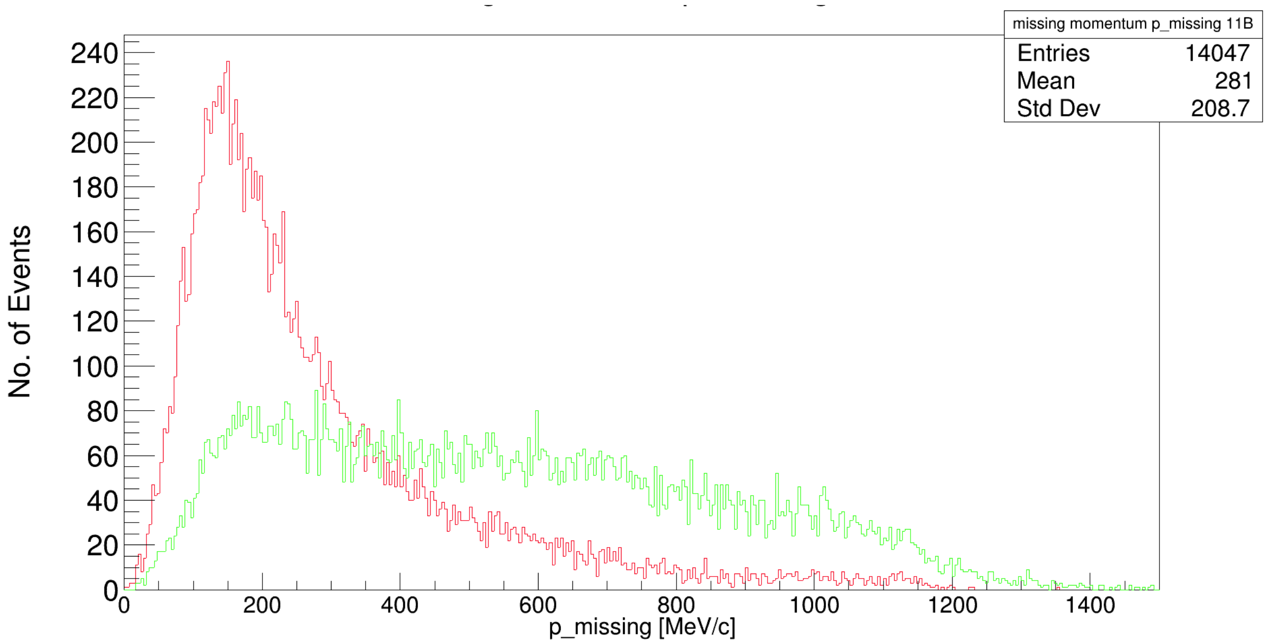


Abbildung 13: Red: missing momentum for 12C(p,2p)11B reaction. Green: missing momentum for 12C(p,2p)10B reaction.

The plots relating the angular distributions:

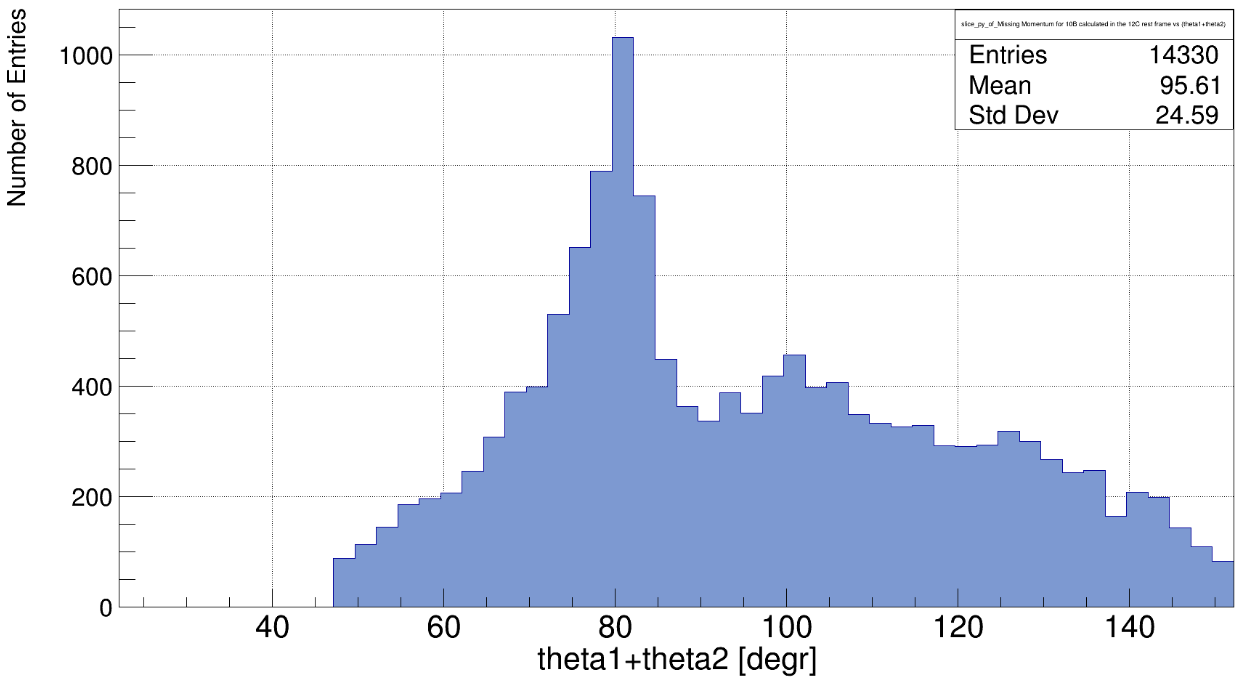


Abbildung 14: Theta1 plus theta2 for the outgoing protons (or proton and deuteron??).

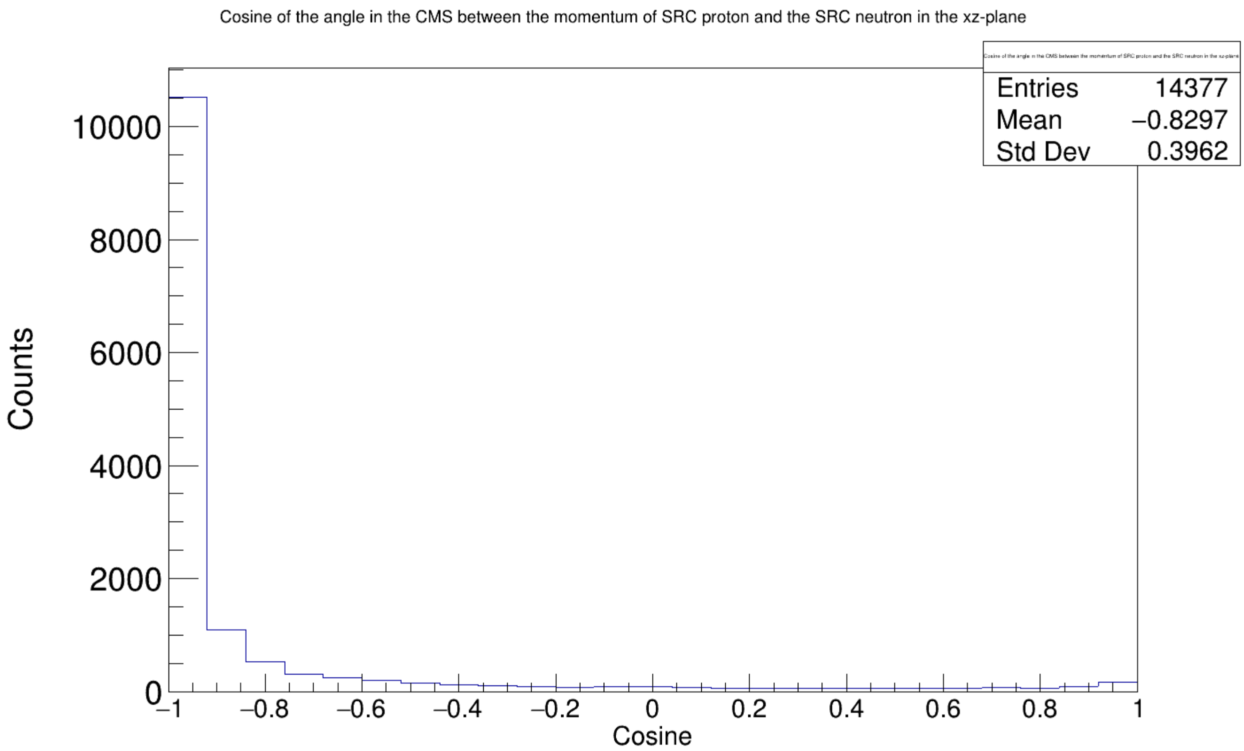


Abbildung 15: Cosine between the recoil nucleon and missing momentum.

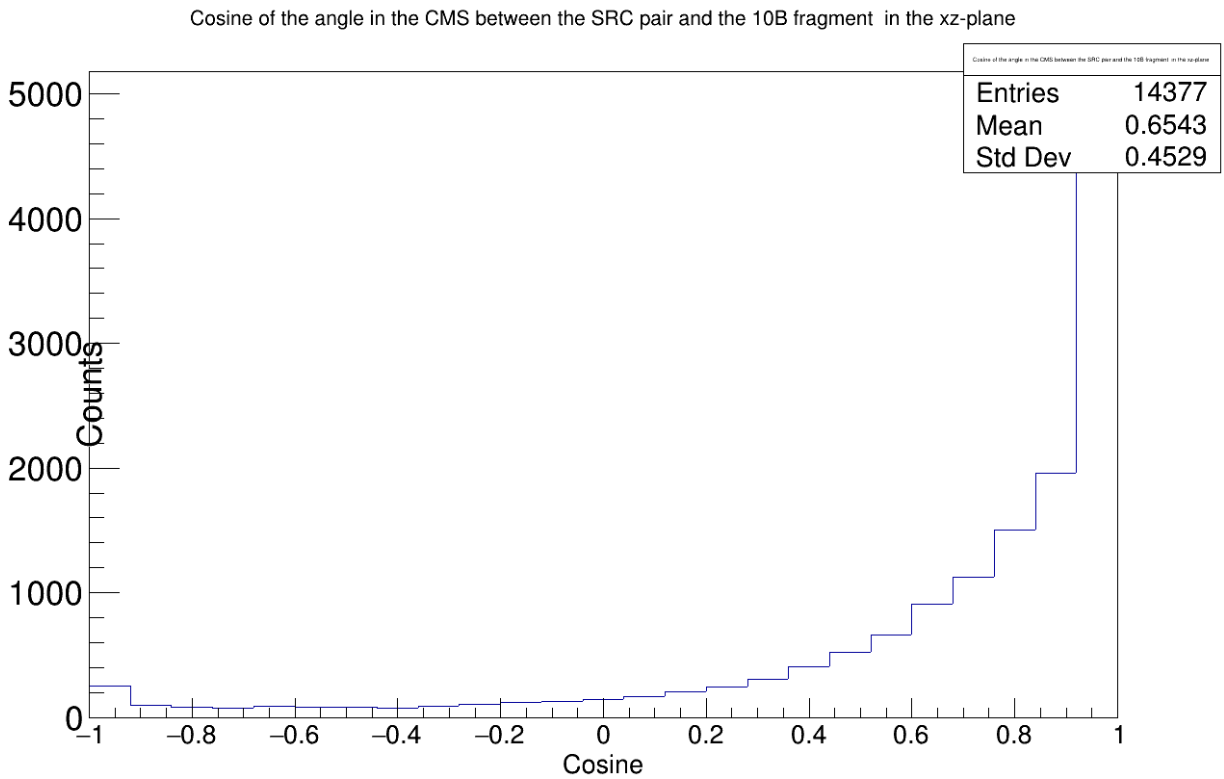
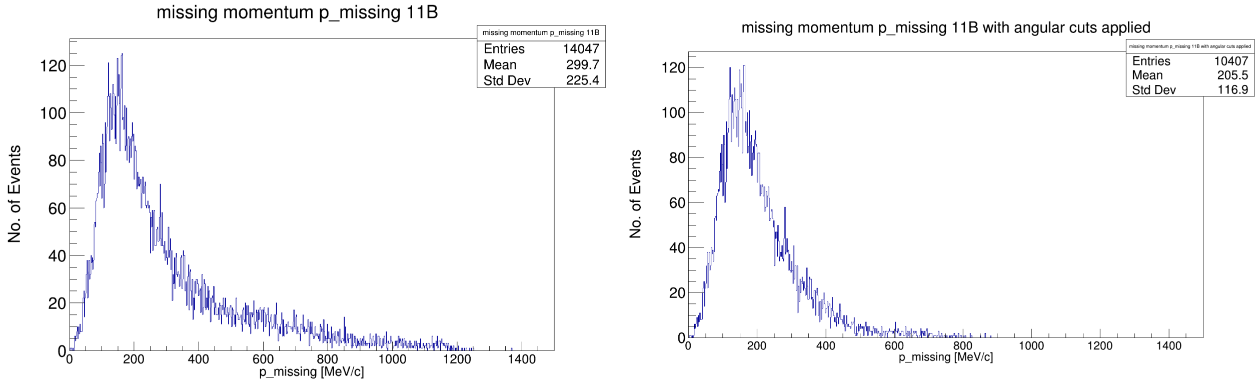


Abbildung 16: Cosine of the angle between the 10B fragment and pair relative momentum.

0.4 Now appying cuts for 12C(p,2p)11B reaction:

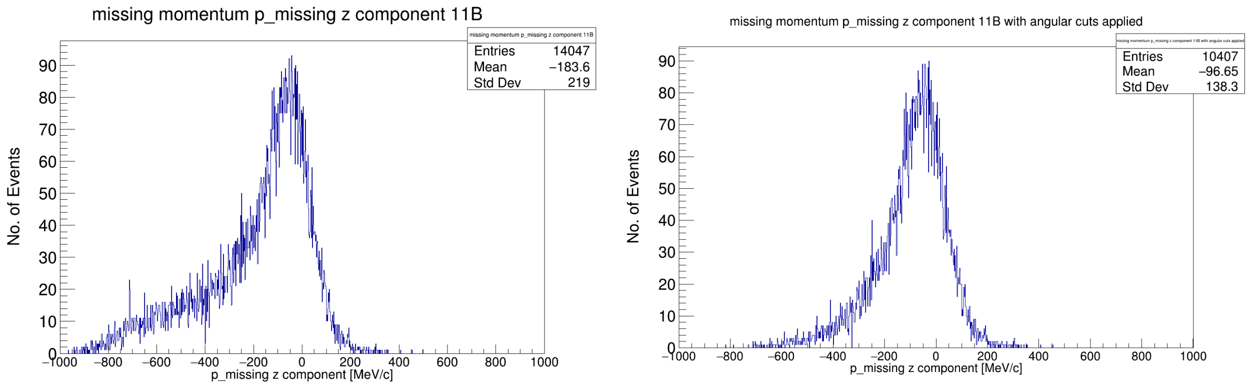
Angular cuts where applied: Theta $<$ 90 and Phi 180° $\mp$ 40°. In the following I compare plots with angular cut and without:



(a) Without cut.

(b) With angular cut.

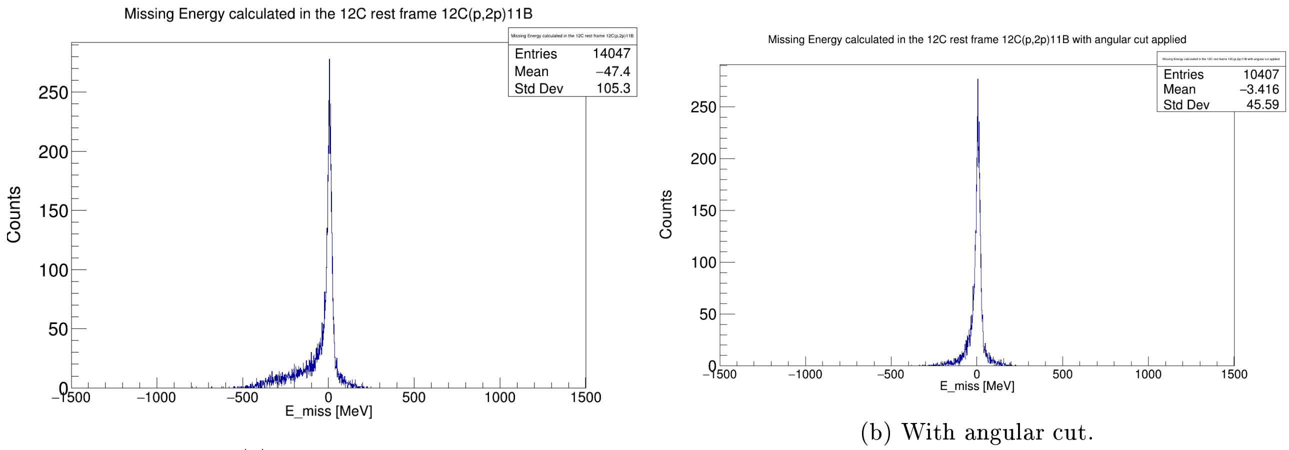
Abbildung 17: Momentum of initial proton inside the 12C ion.



(a) Without cut.

(b) With angular cut.

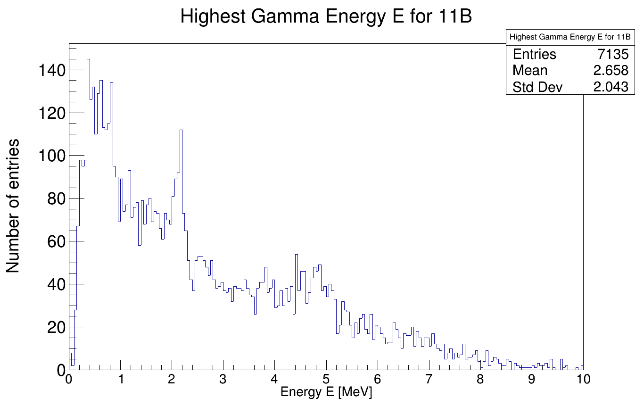
Abbildung 18: Momentum of the initial proton inside the 12C ion - z component.



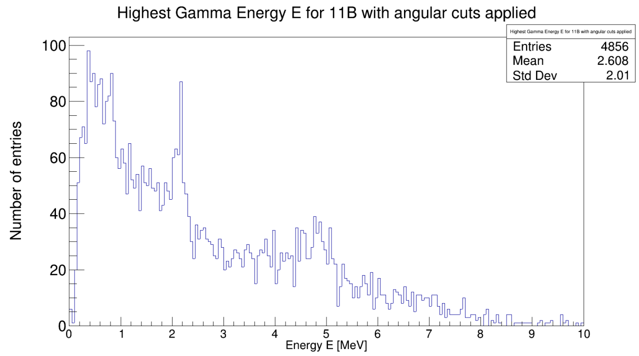
(b) With angular cut.

(a) Without cut.

Abbildung 19: Missing energy calculated in the 12C rest frame.

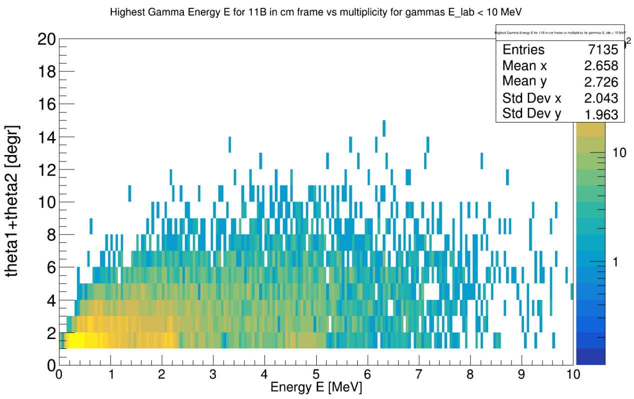


(a) Without cut.

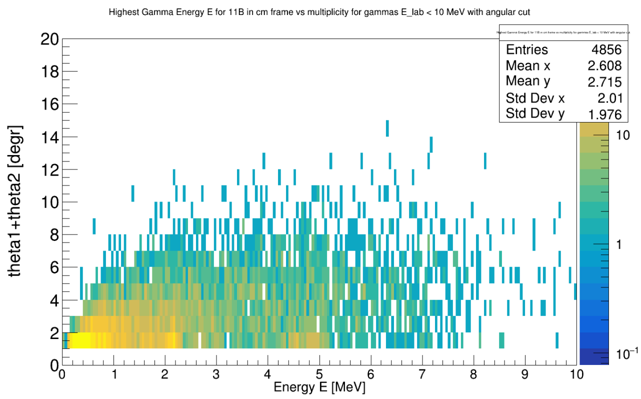


(b) With angular cut.

Abbildung 20: Doppler corrected gamma spectrum.

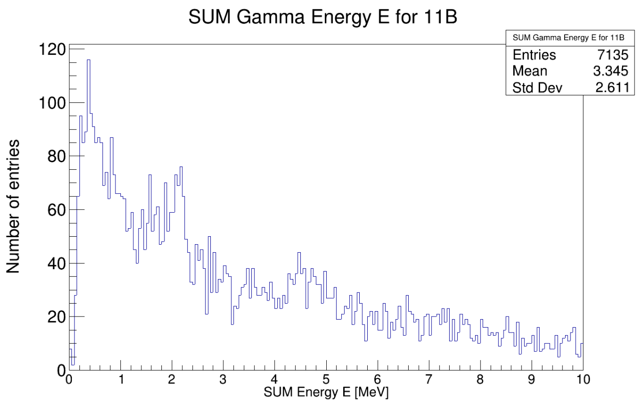


(a) Without cut.

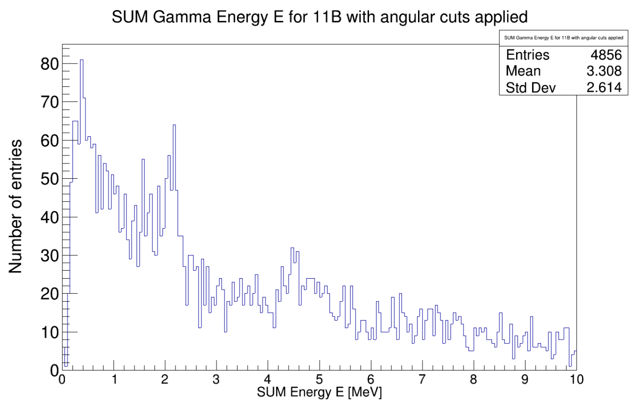


(b) With angular cut.

Abbildung 21: Doppler corrected gamma spectrum (highest energy hit) versus Multiplicity.



(a) Without cut.



(b) With angular cut.

Abbildung 22: Doppler corrected gamma spectrum summing up all the energies. The angle of the crystal with highest energy is taken for the doppler correction.This is not always true...

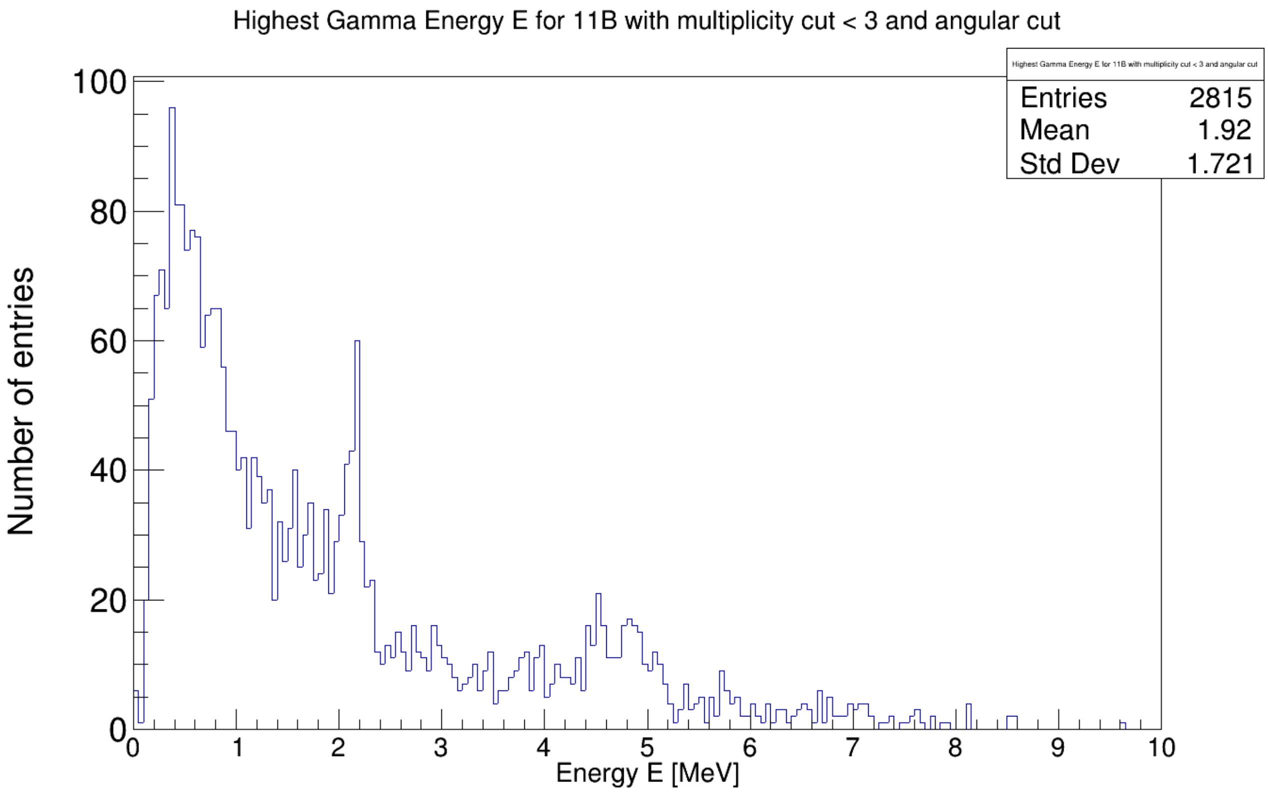
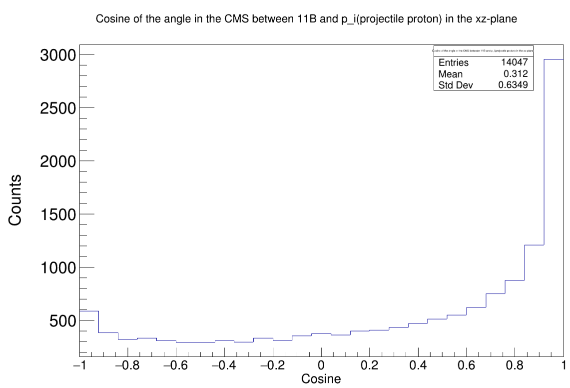
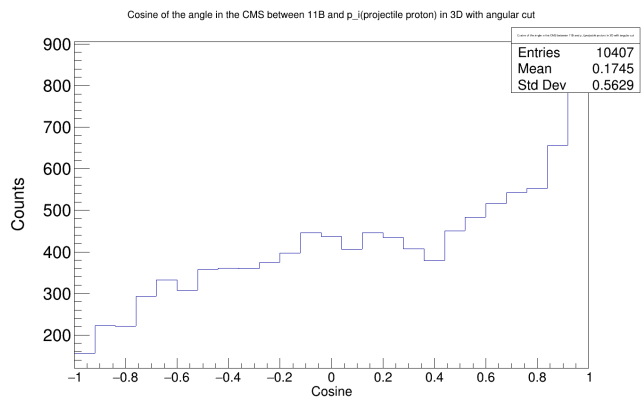


Abbildung 23: Doppler corrected gamma spectrum with angular cut and multiplicity cut (< 3).



(a) Without cut.



(b) With angular cut.

Abbildung 24: Cosine between the initial proton and the 11B in the 12C beam. For the right plot I didn't set the y-components to zero and used the angular cut.

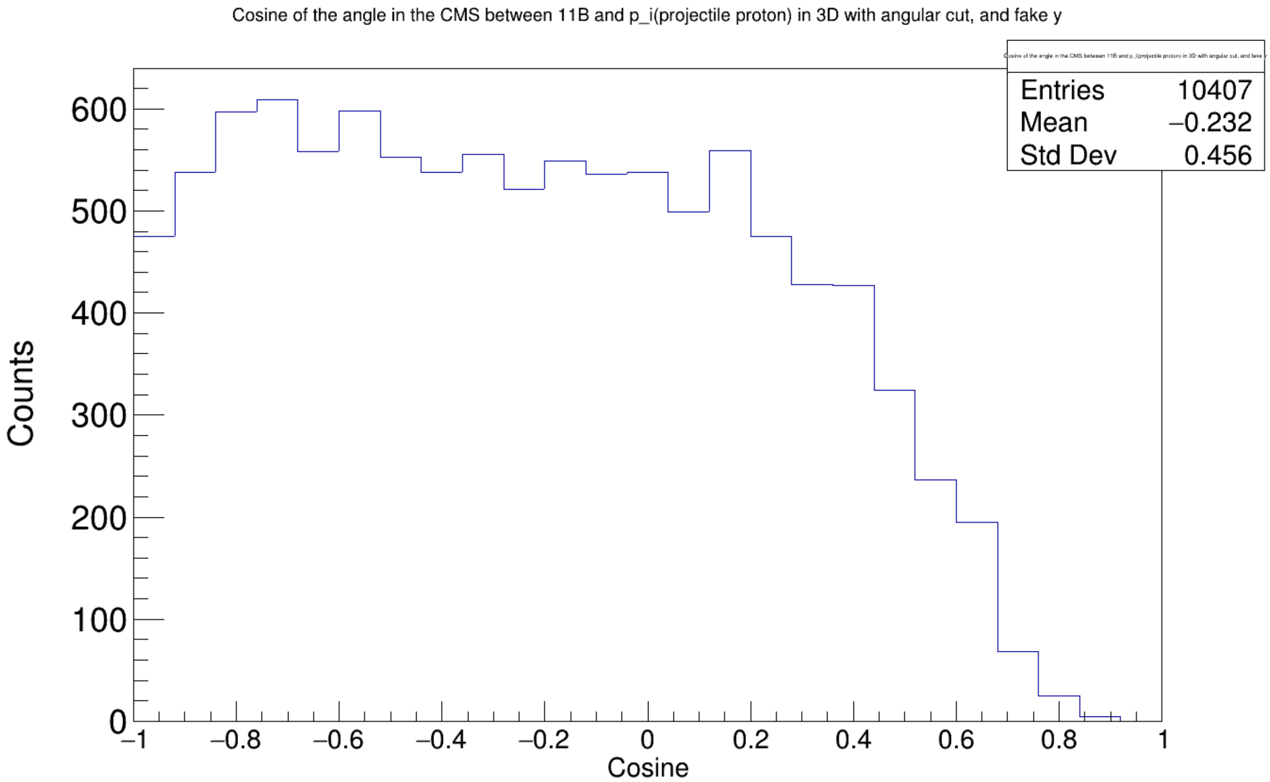


Abbildung 25: Angular cuts applied and giving 11B fragment an angular y-deflection of $\mp$ 0.03 rad.As the plots in figure 24 are not inutitive (we suppose peaking at -1, i.e. the two particles moving back to back) I set the deflection angle in y-direction of the outgoing 11B to -0.03 rad if the summed up Phi-angle in the 12C frame of the two protons is greater zero, otherwise + 0.03 rad

0.5 Additional plots for 12C(p,2p)11B reaction:

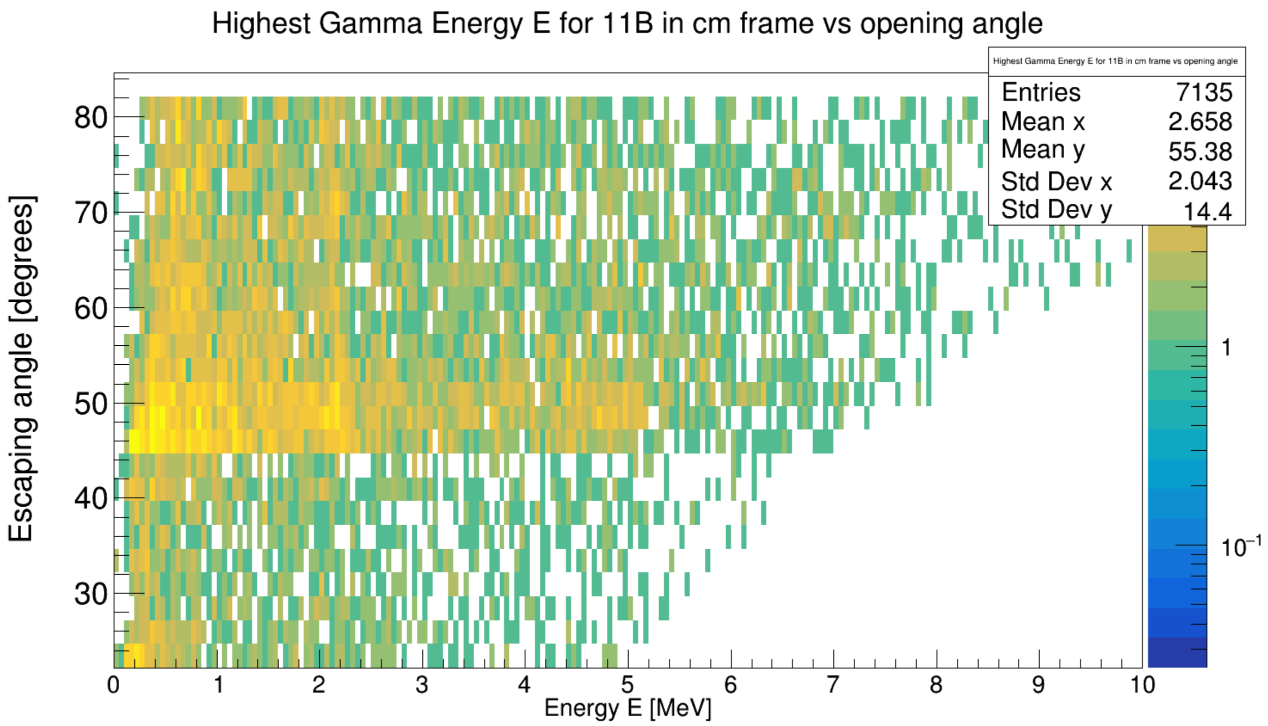


Abbildung 26: Doppler corrected gamma spectrum versus opening angle of the detected gamma. The energy is doppler corrected (cm frame). The angle is in the lab frame.

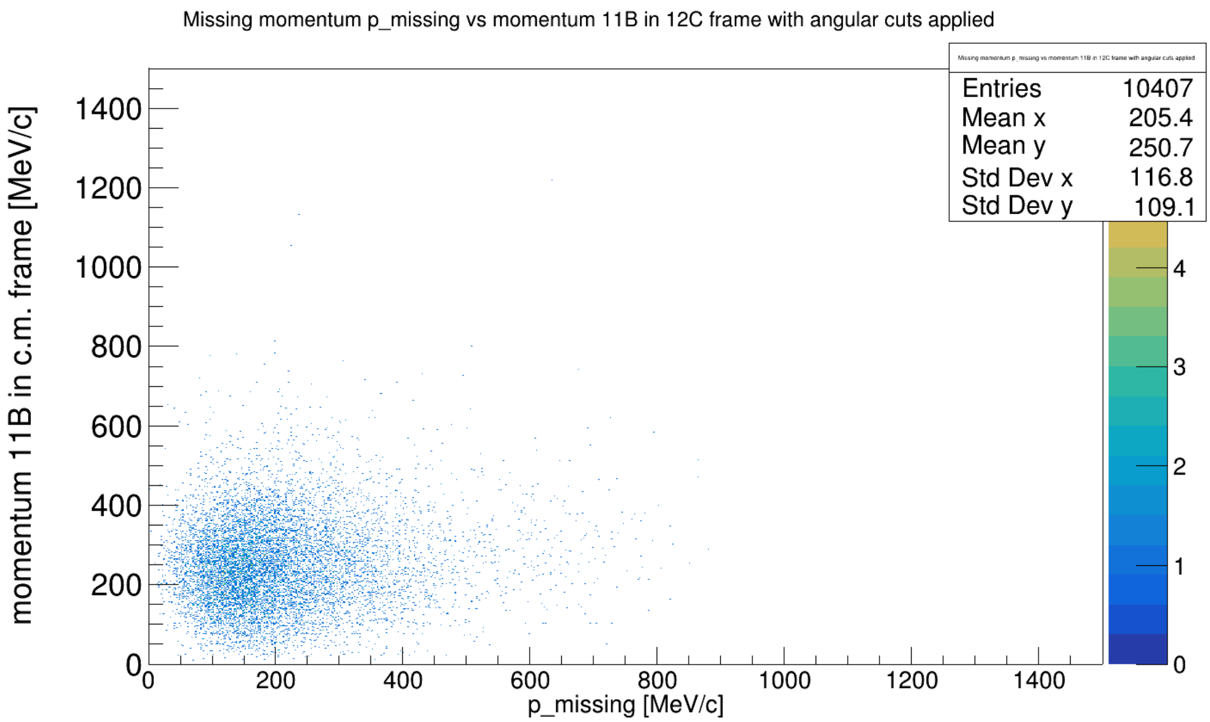


Abbildung 27: Momentum of initial proton (missing momentum) vs momentum of 11B in 12C rest frame.

0.6 Now appying cuts for 12C(p,2p)10B reaction:

For this I applied a tpat cut: spill on + sofstart + califa + neuland. This should give me all reactions where I have for sure a src pair:

0.7 To Dos and Open Questions

- plot momentum of 10B fragment versus missing momentum
- plot mandelstam variables and compare to plots from `https://www.nature.com/articles/s41567-021-01193-4`
- Analyze the plot 16 in more detail. This should actually be an uniform flat distribution (slightly shaped according to the acceptance of the detectors). It's not so the case in 16.
- the angular distribution in 9 is not as expected. We would expect back-to-back momenta in the 12C rest frame. When transforming it back to the 11B rest frame (in z-direction) instead we get the following plot:

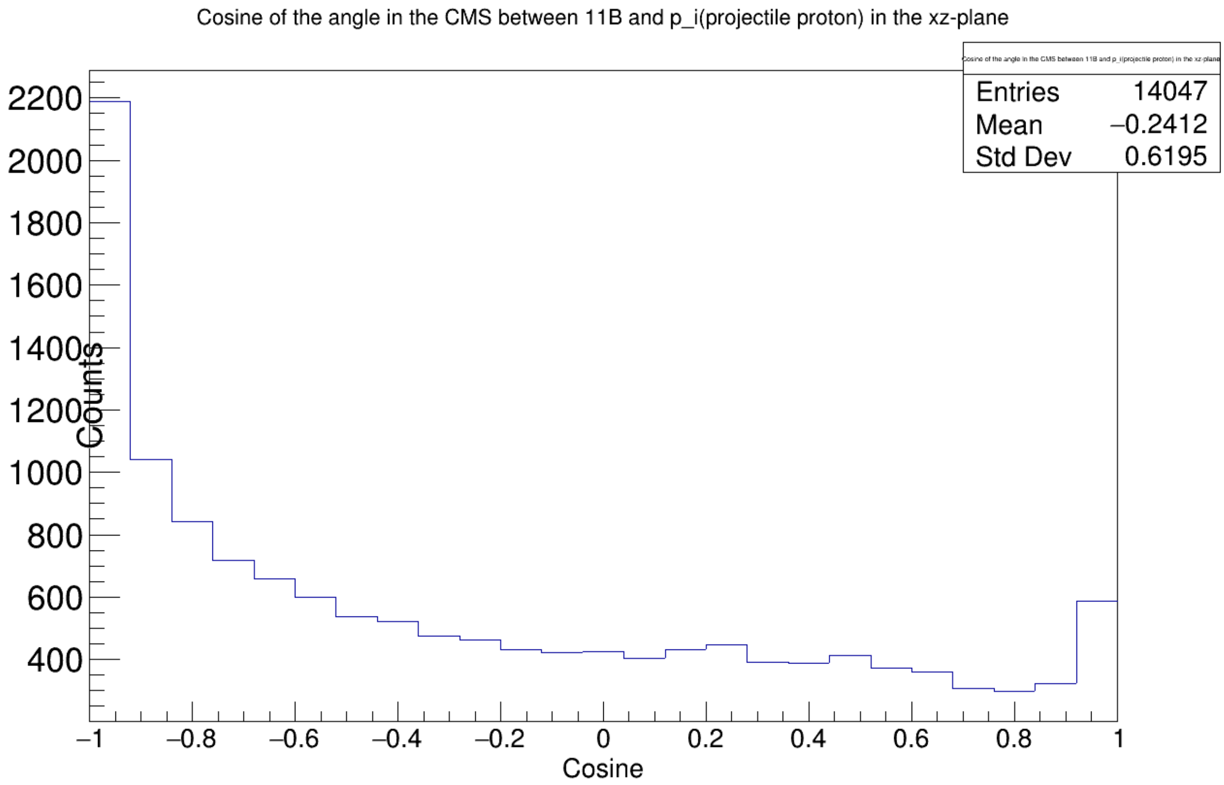


Abbildung 28: Distribution between the cosine of the opening angle between the missing and fragment momentum in the 11B rest frame (in z-direction)

As beam energy for 12C I use the value 400AMeV. It seems for me that it is set too high and attenuated down the beamline....

- the 12C(p,2p)10B reaction can come from src,(p,pd) or direct removal of neutron. In 14 we see two small peaks beyond 80 degrees. Could those be a hint for proton-deuteron scattering? Should I use a selection cut as in `https://www.nature.com/articles/s41567-021-01193-4` ($p_{miss} \geq 350MeV$). For the neutron removal, do I have to look into the NEULAND data or should I already see some excited states in the gamma spectrum?
- plot gamma spectrum for 12C(p,2p)10B.
- look at high energy runs ($750MeV$). In this configuration some of the QE scattered protons won't be stopped. What interesting info would I gain when looking at this data?
- compare all the above plots with the simulated data that can be retrieved by the QFS generator.