

$^{12}\text{C}(\text{p},2\text{p})^{11}\text{B}$ Quasi Free Scattering in Inverse Kinematics at R³B

Tobias Jenegger
For the R3B Collaboration

DREB 2022

Setup Experiment S444

$^{12}\text{C}(\text{p},2\text{p})^{11}\text{B}$ reaction

Analysis

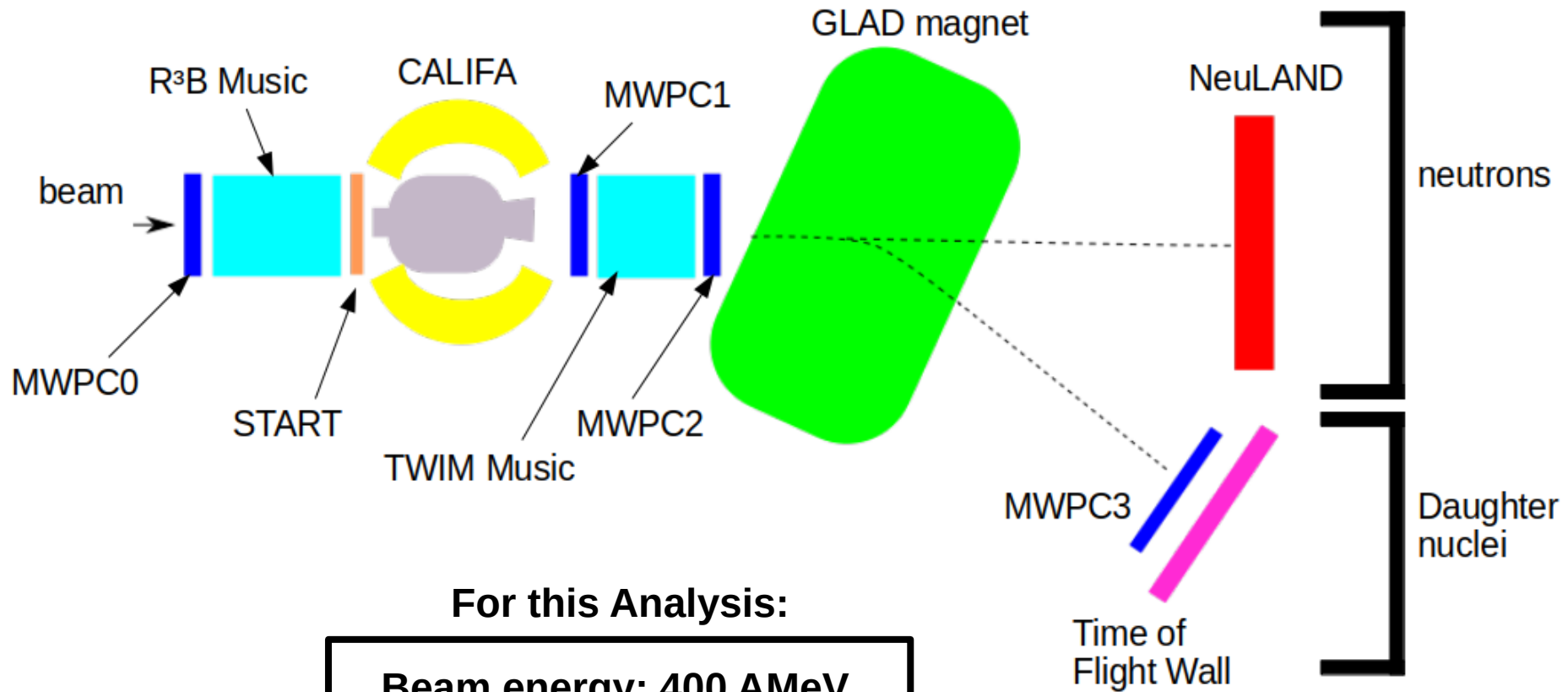
Summary & Outlook

TUM Members:
Roman Gernhäuser, Lukas Ponnath, Philipp Klenze, Tobias Jenegger



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BMBF 05P19WOFN1, 05P21WOFN1
and the FAIR Phase-0 program

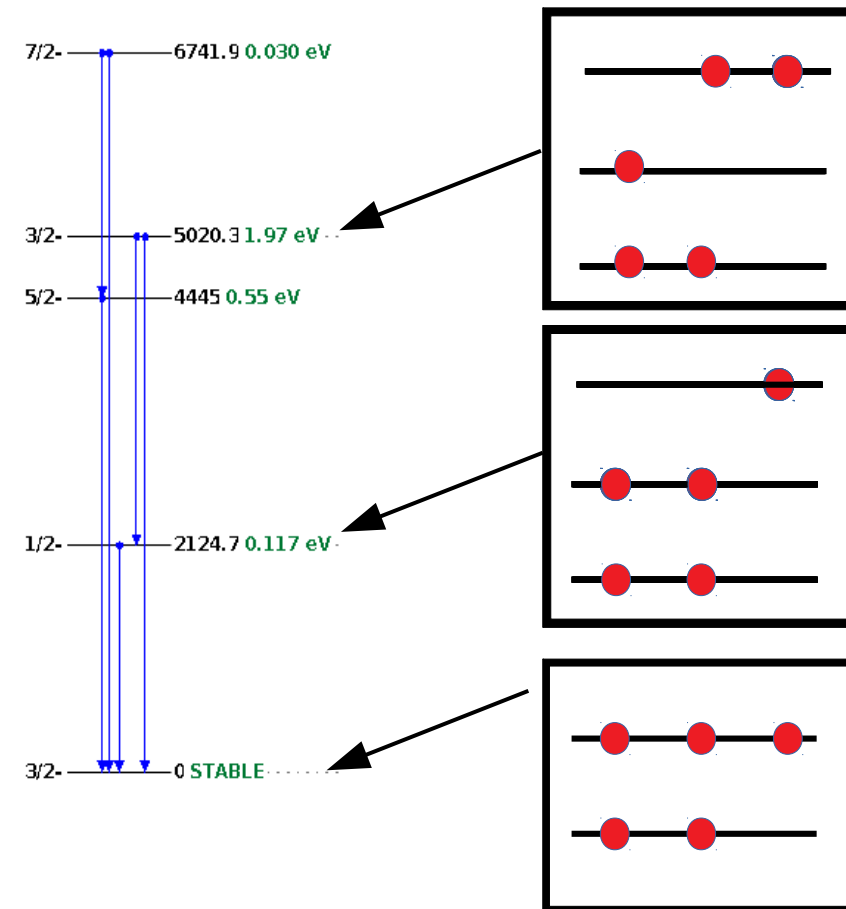
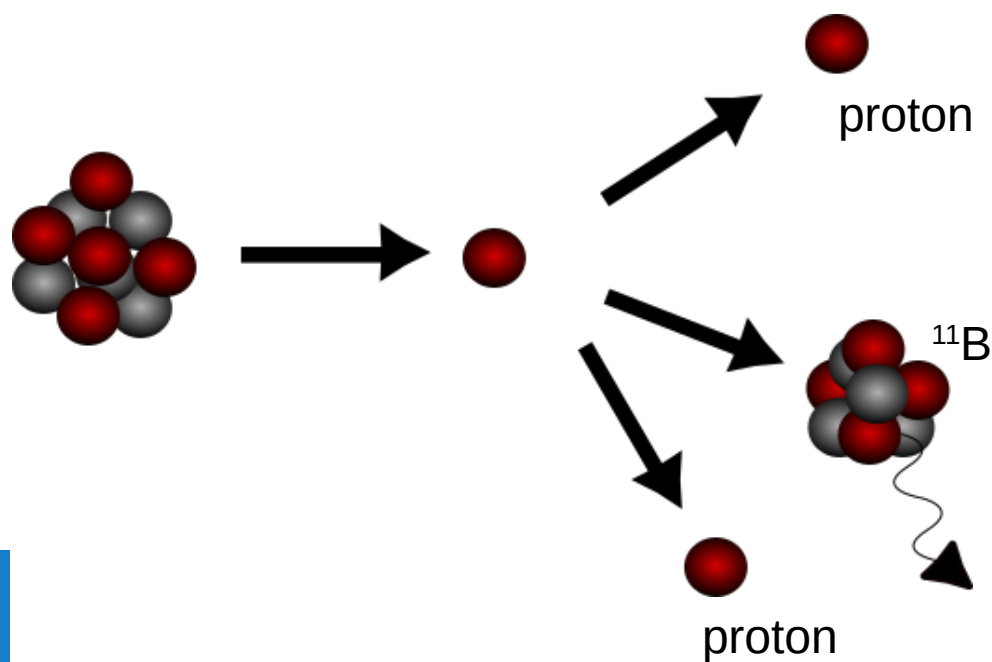
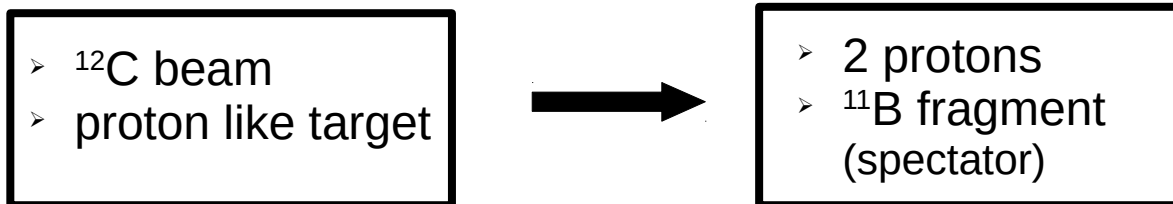
Quasi Free Scattering Analysis with Experiment S444/467 (2020)



For this Analysis:

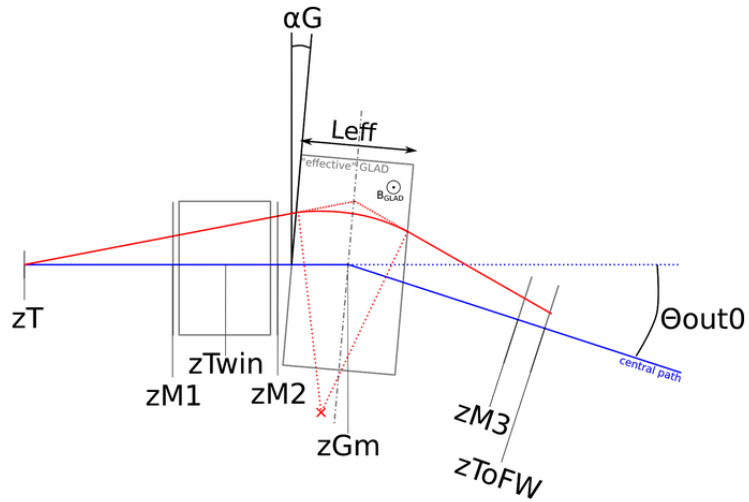
Beam energy: 400 AMeV
 Beamtype: ^{12}C
 Beamtime: 3 hours
 Intensities: 1kHz - 1MHz
 Target: CH_2 (12.29 mm)

$^{12}\text{C}(\text{p},2\text{p})^{11}\text{B}$ reaction



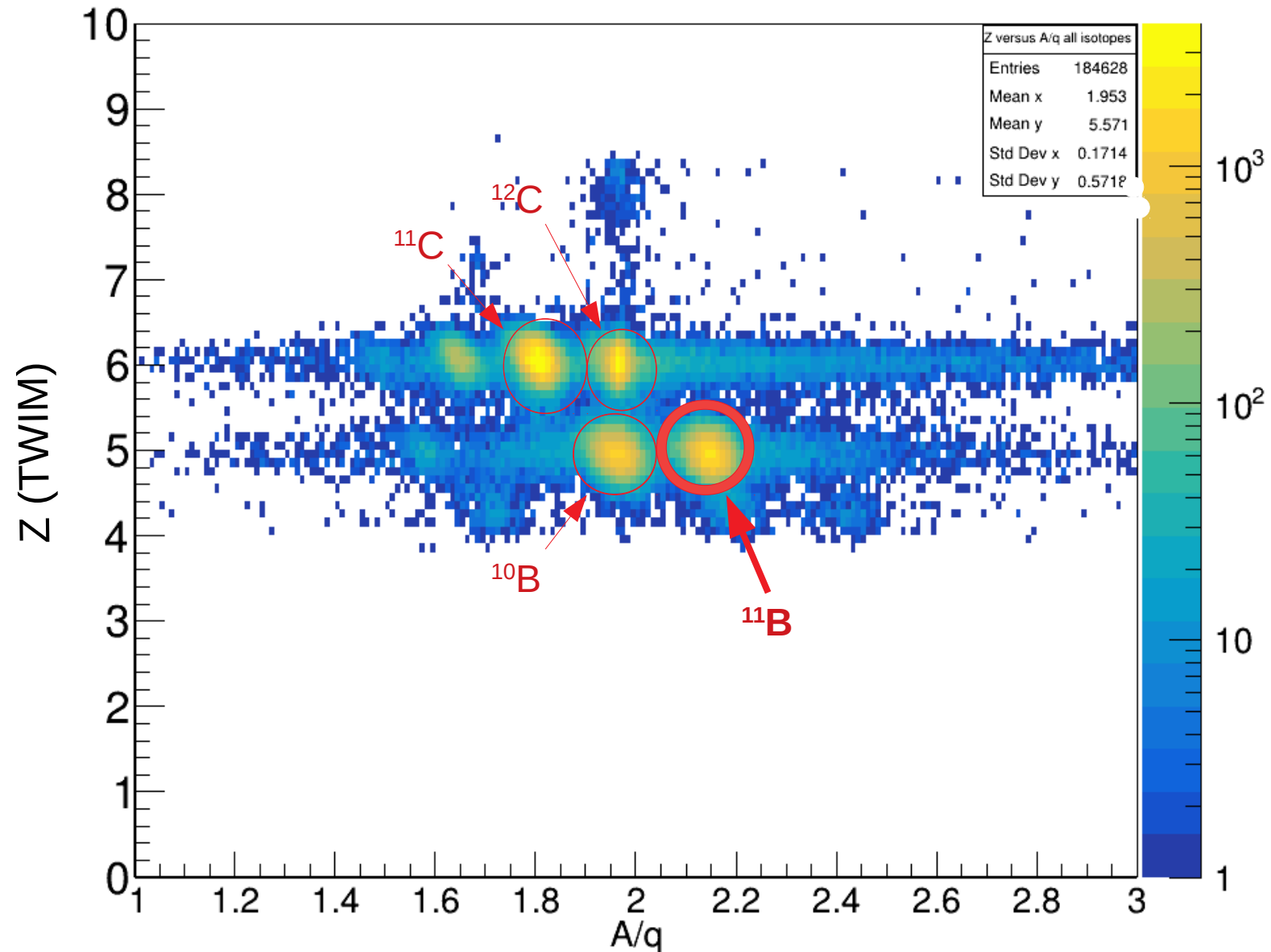
Fragment Particle Identification

- Time Measurement (START & TOFW)
- Charge Measurement (TWIM Music)
- Flightpath Reconstruction:



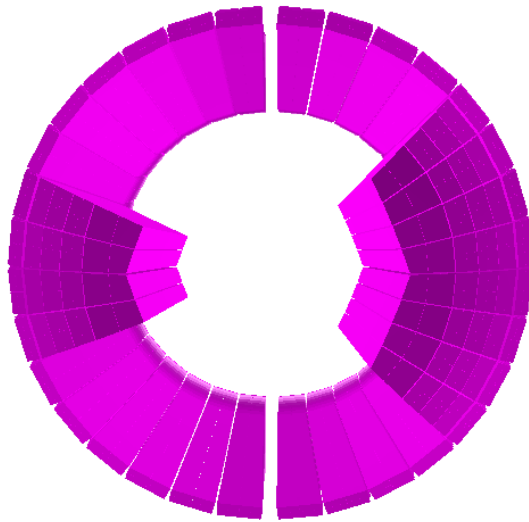
$$B * \rho = \frac{\beta * \gamma * M}{q}$$

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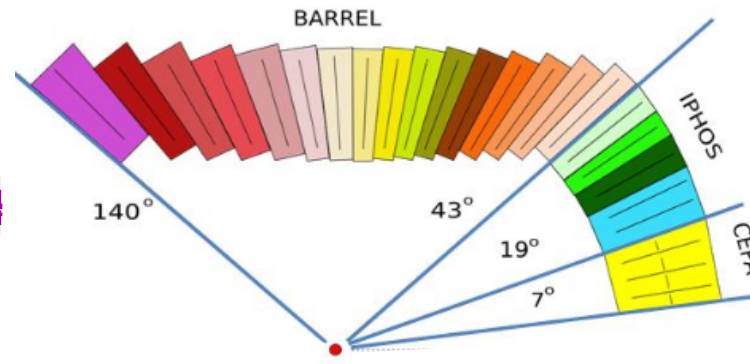


Identification of the two correlated Protons

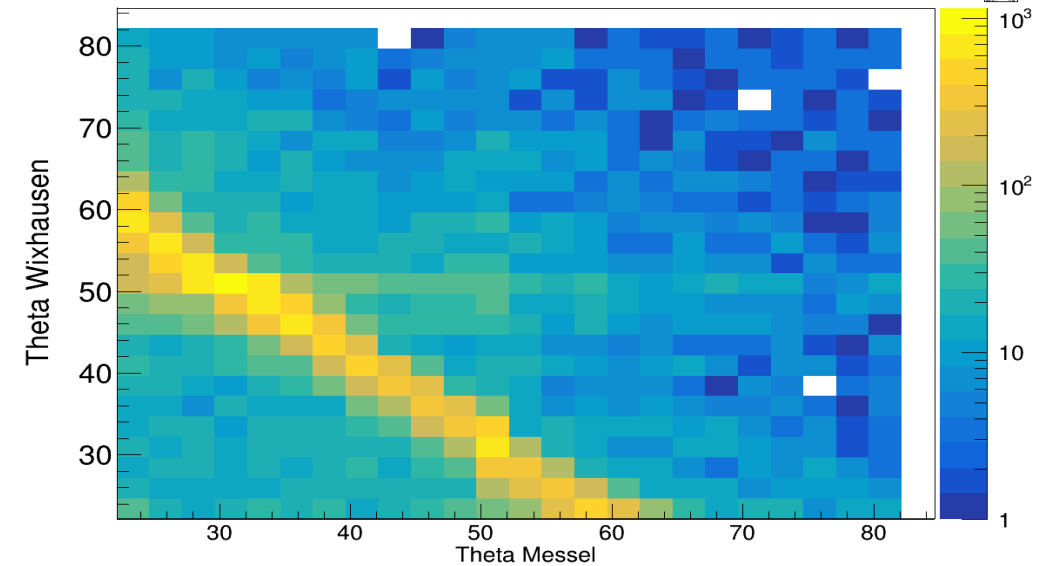
CALIFA Front View



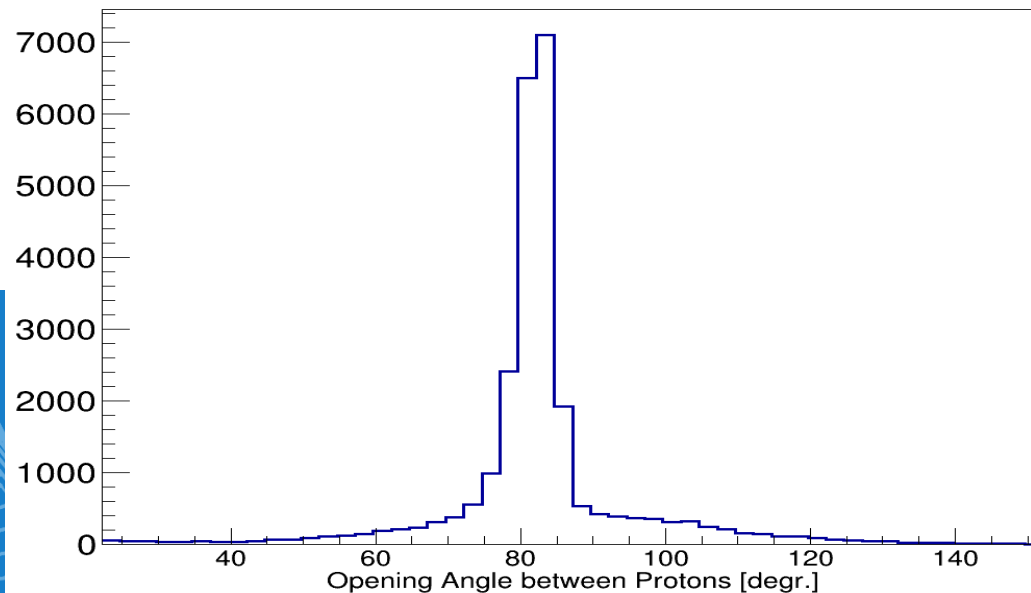
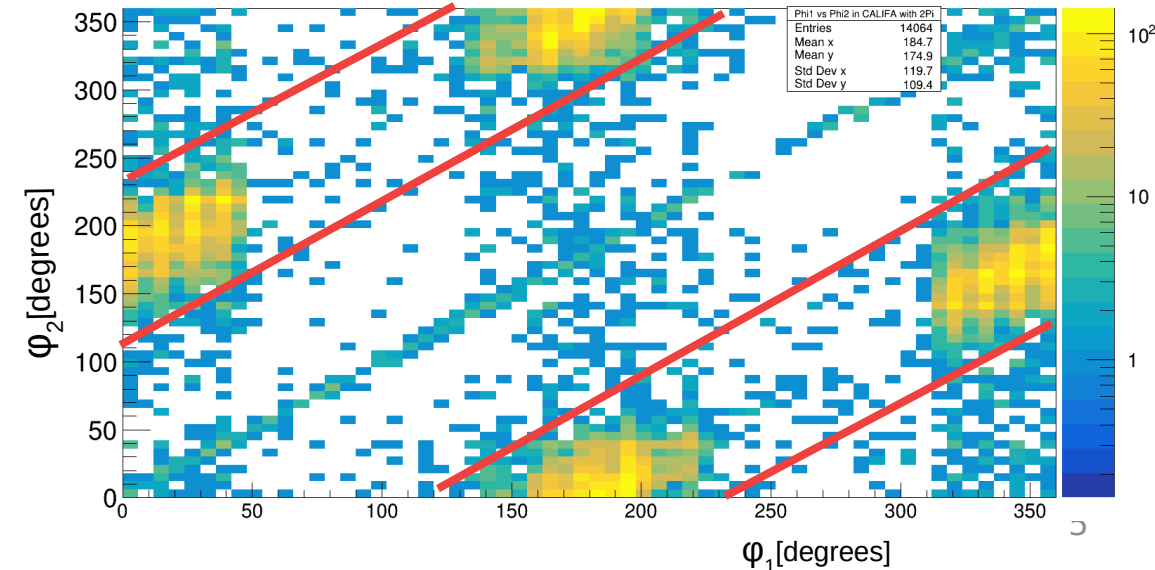
CALIFA Side View

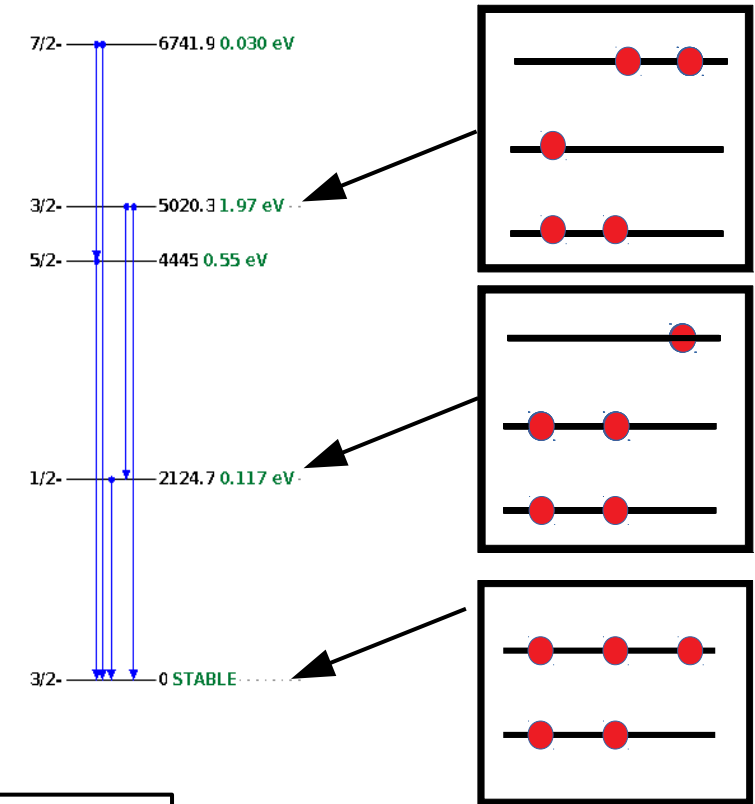
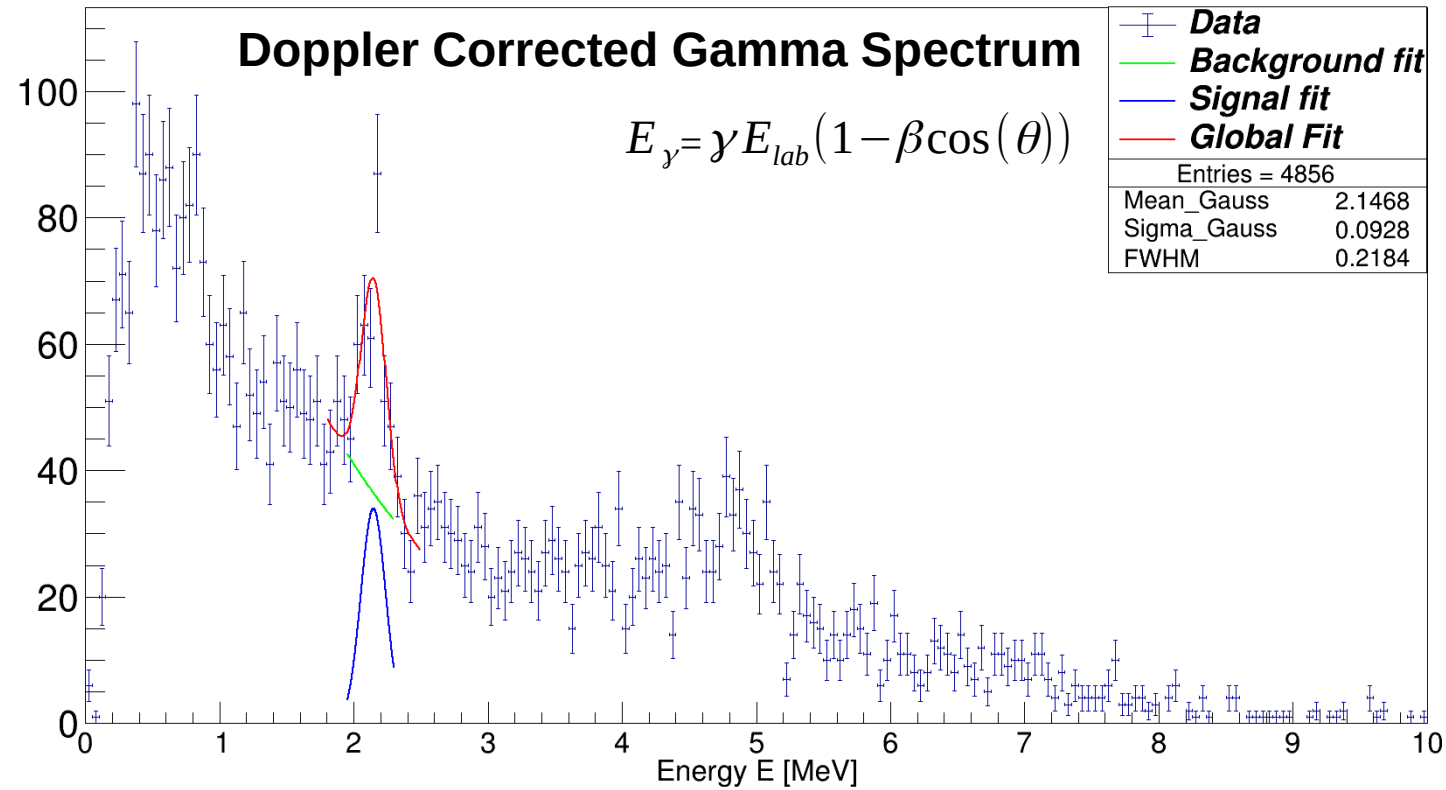


Polar Angle Protons Messel-Wixhausen



Azimuthal Angle Proton 1 vs Proton2



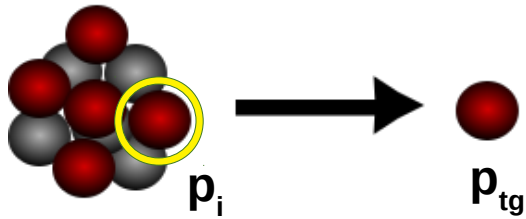


Event Selection Criteria:

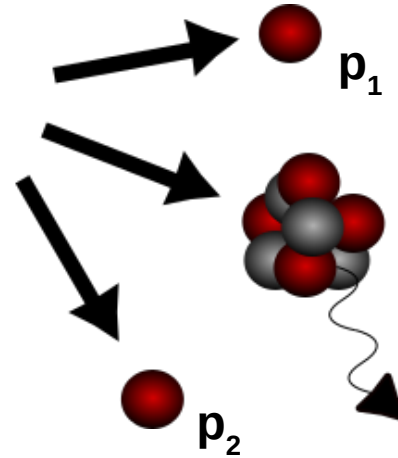
- ^{11}B fragment identification
- Two hits (protons) with $E_{\text{hit}} > 30 \text{ MeV}$
- $\theta_1 + \theta_2 < 90^\circ$
- $\Delta\varphi = 180^\circ \pm 40^\circ$

Reconstruction of Inner Momenta

Before Scattering:



After Scattering:



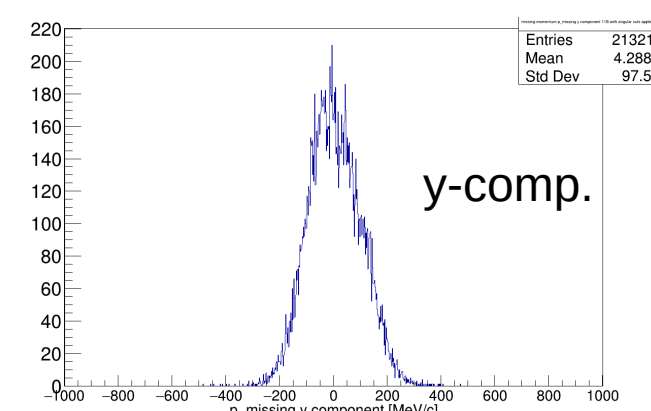
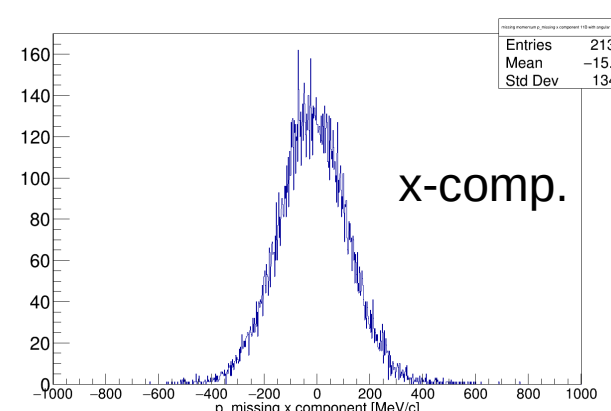
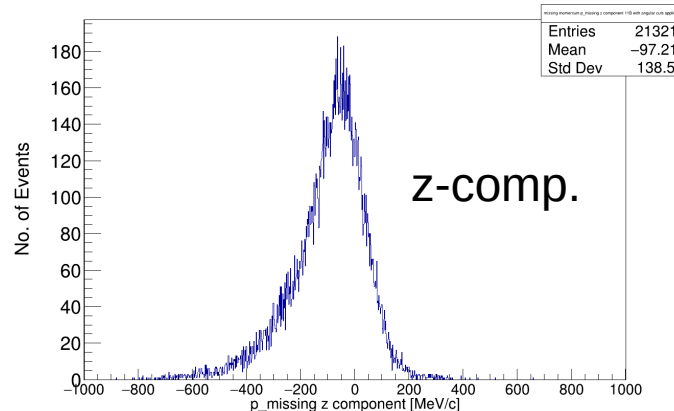
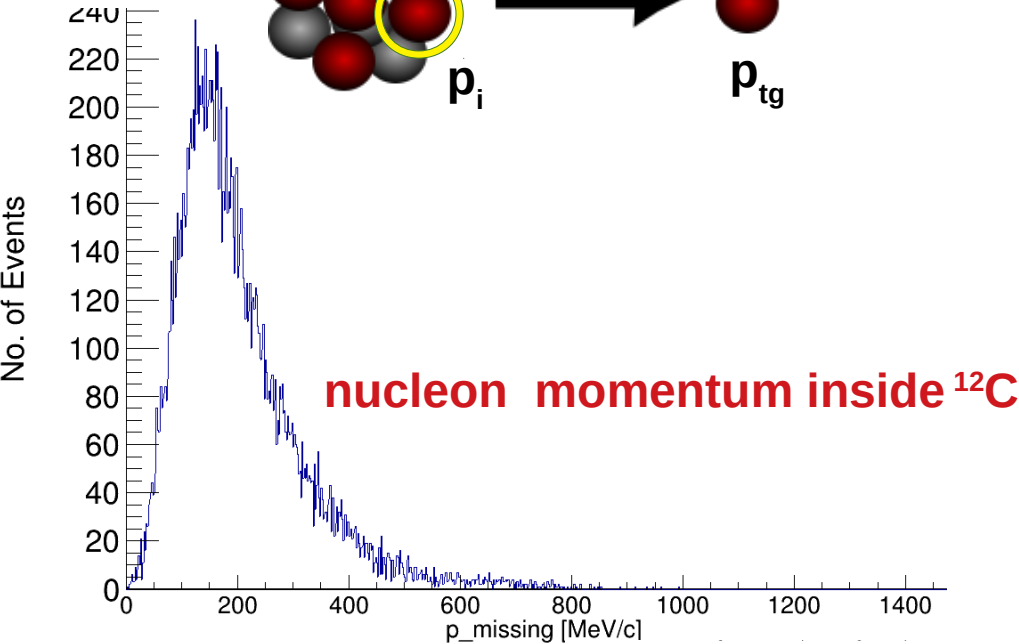
(Four-)Momentum conservation relation:

$$p_{12C} + p_{tg} = p_1 + p_2 + p_{11B}$$

assuming QE scattering in mean field potential:

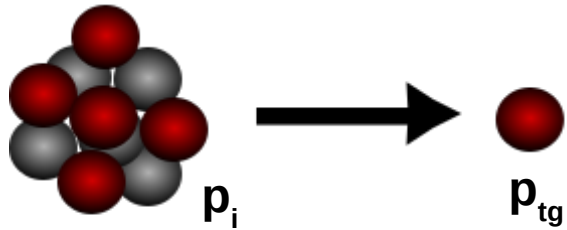
$$p_{12C} = p_i + p_{11B}$$

$$p_i \approx p_{missing} = p_1 + p_2 - p_{tg} \text{ (no ISI / FSI)}$$

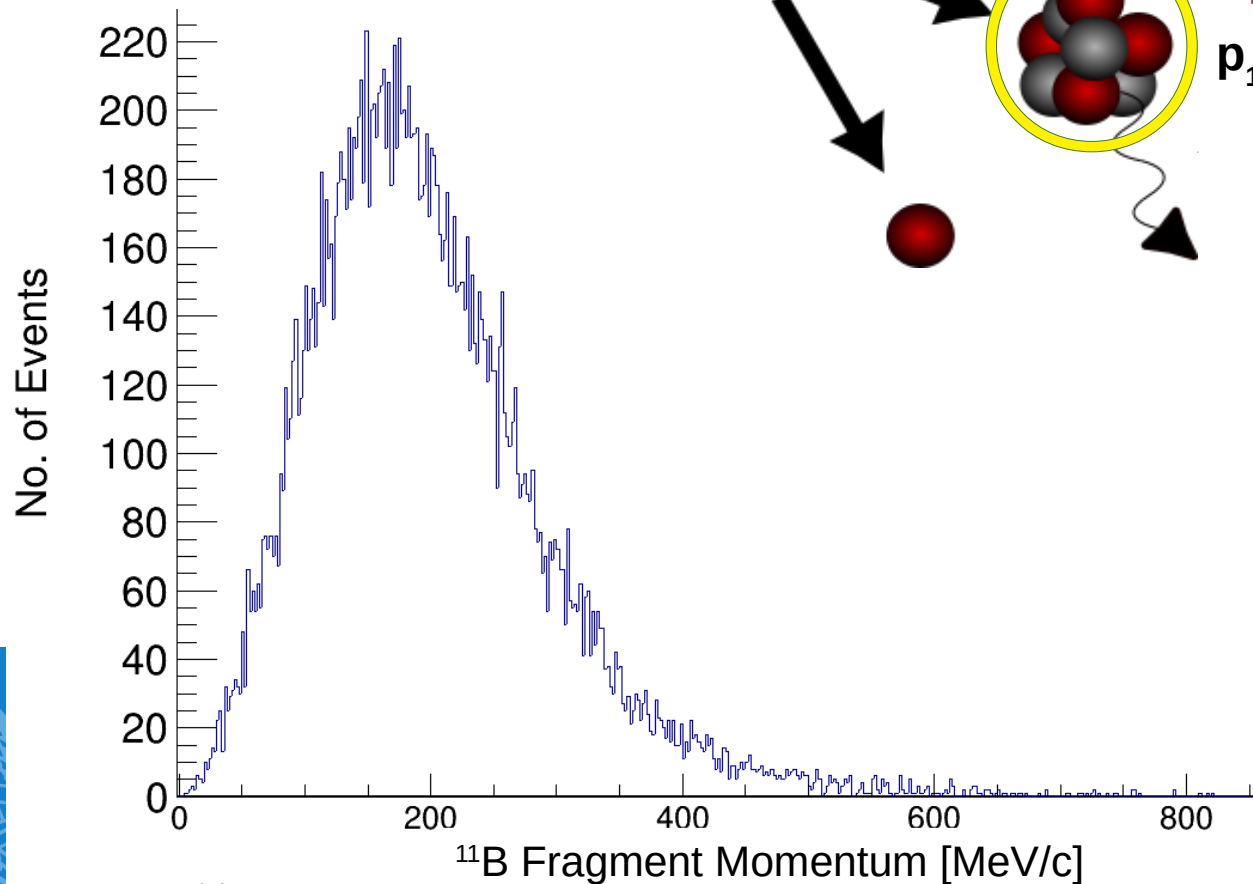
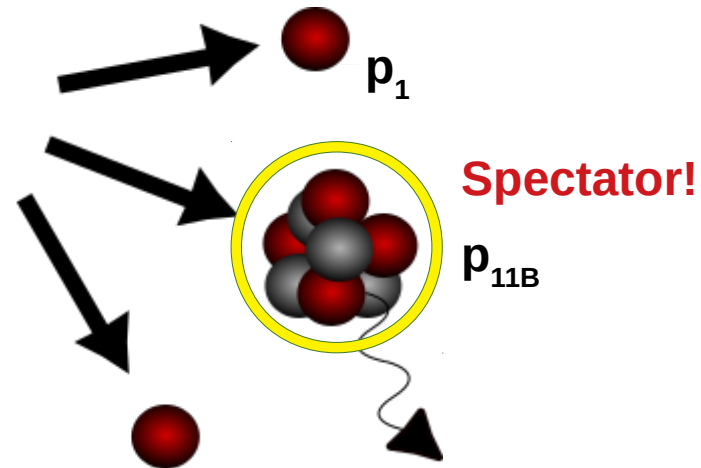


Momentum reconstruction of ^{11}B

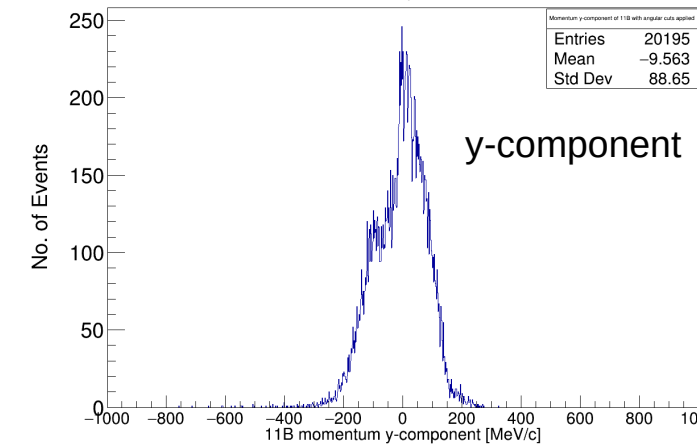
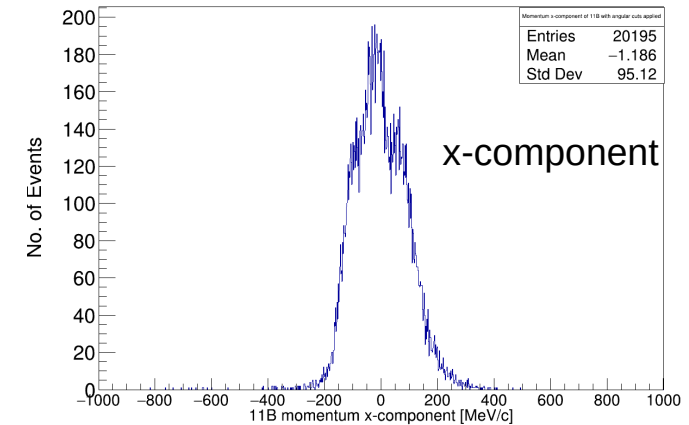
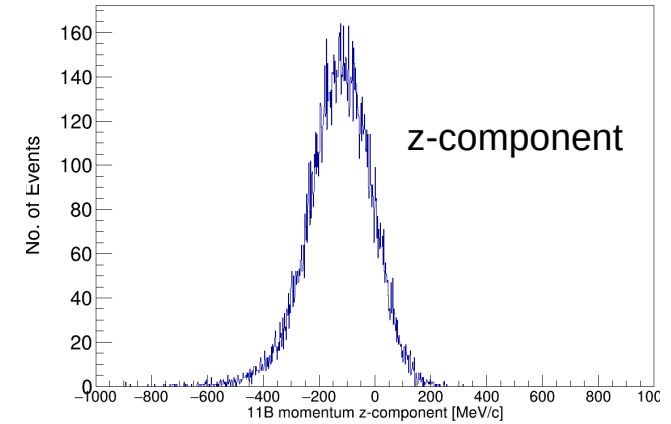
Before Scattering:



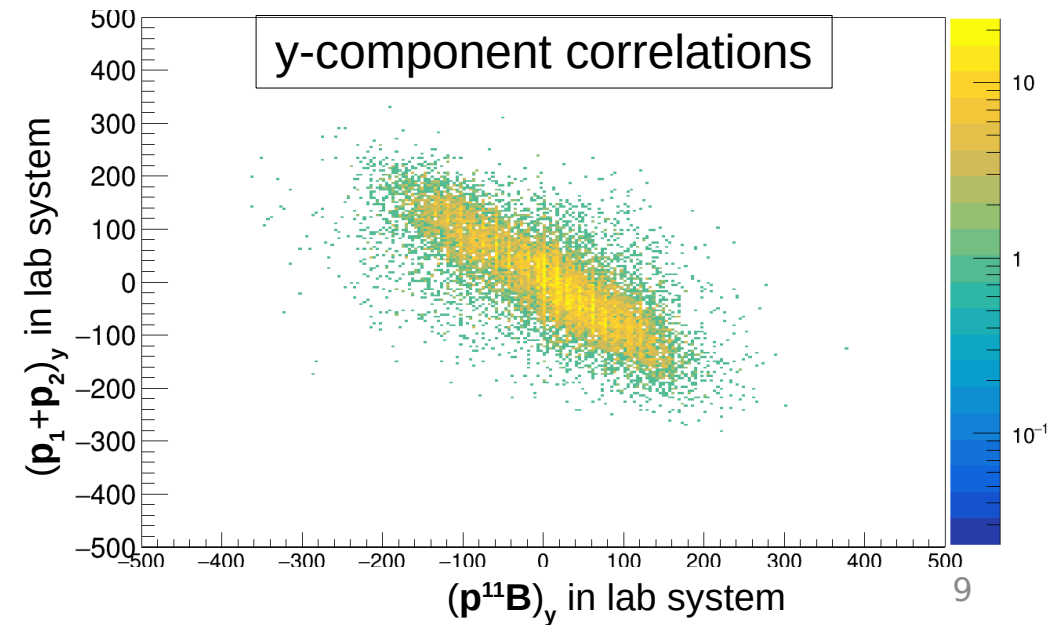
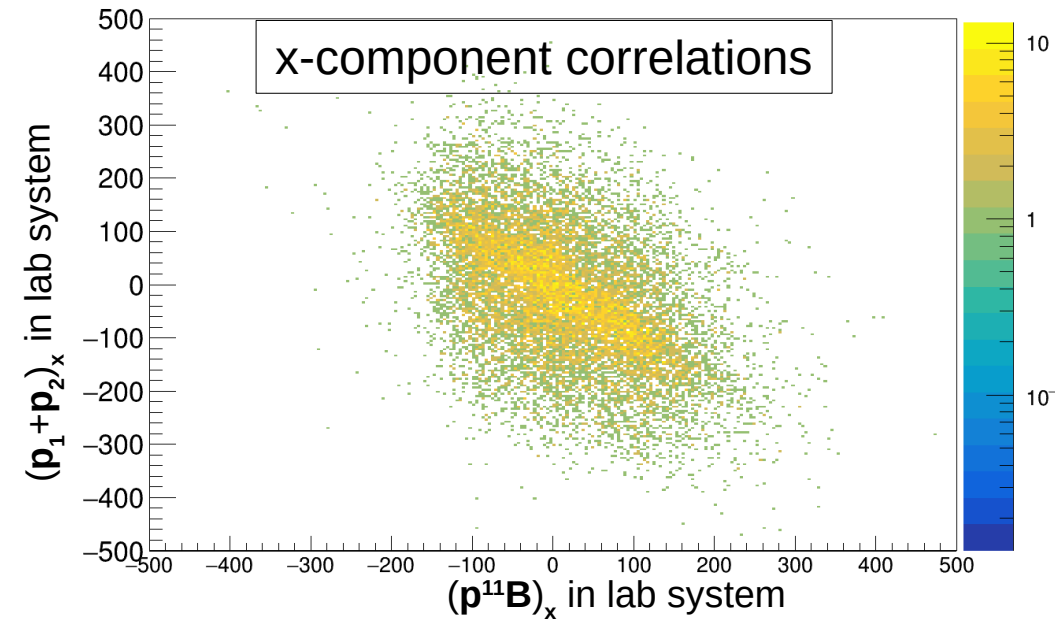
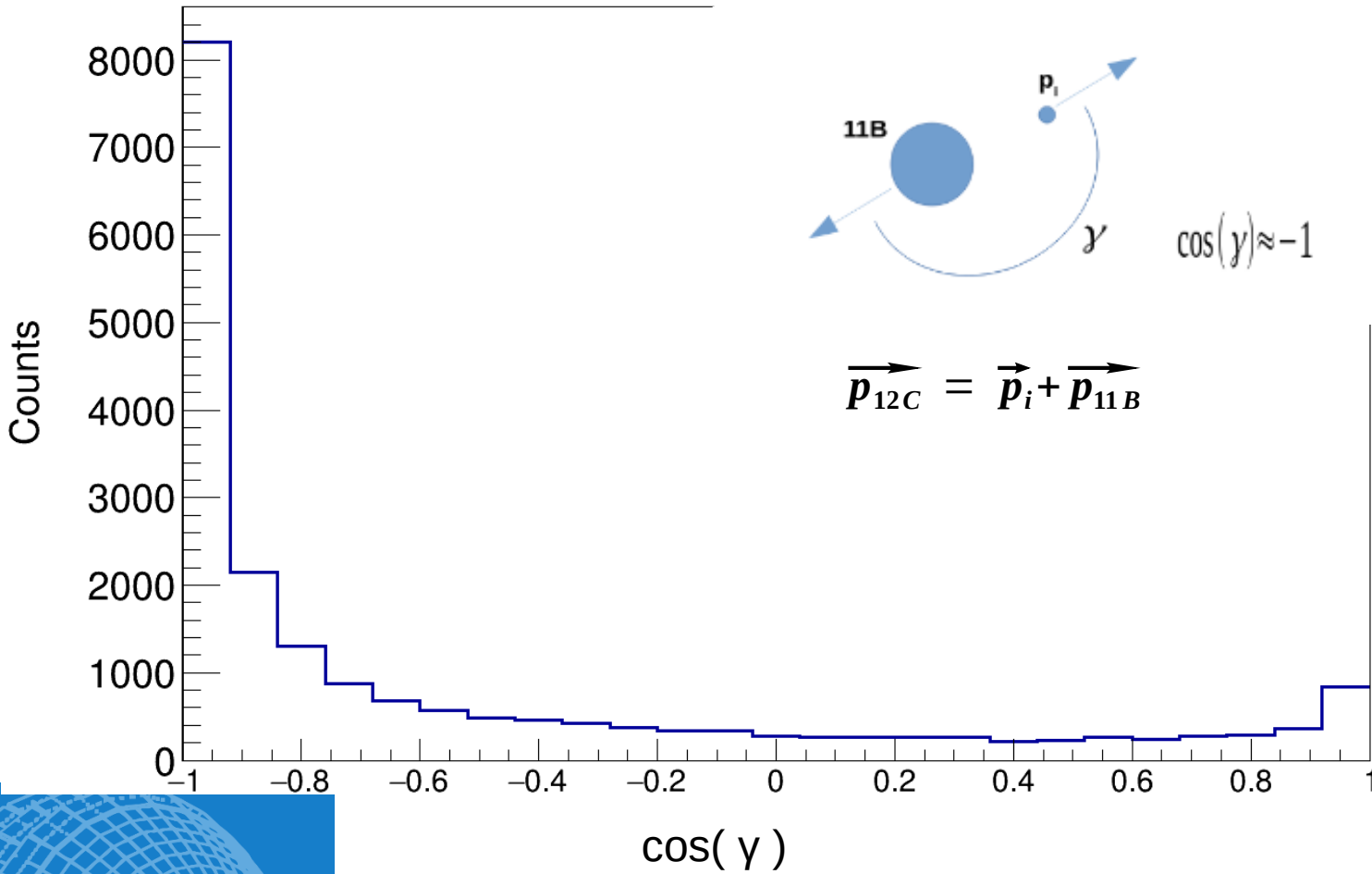
After Scattering:



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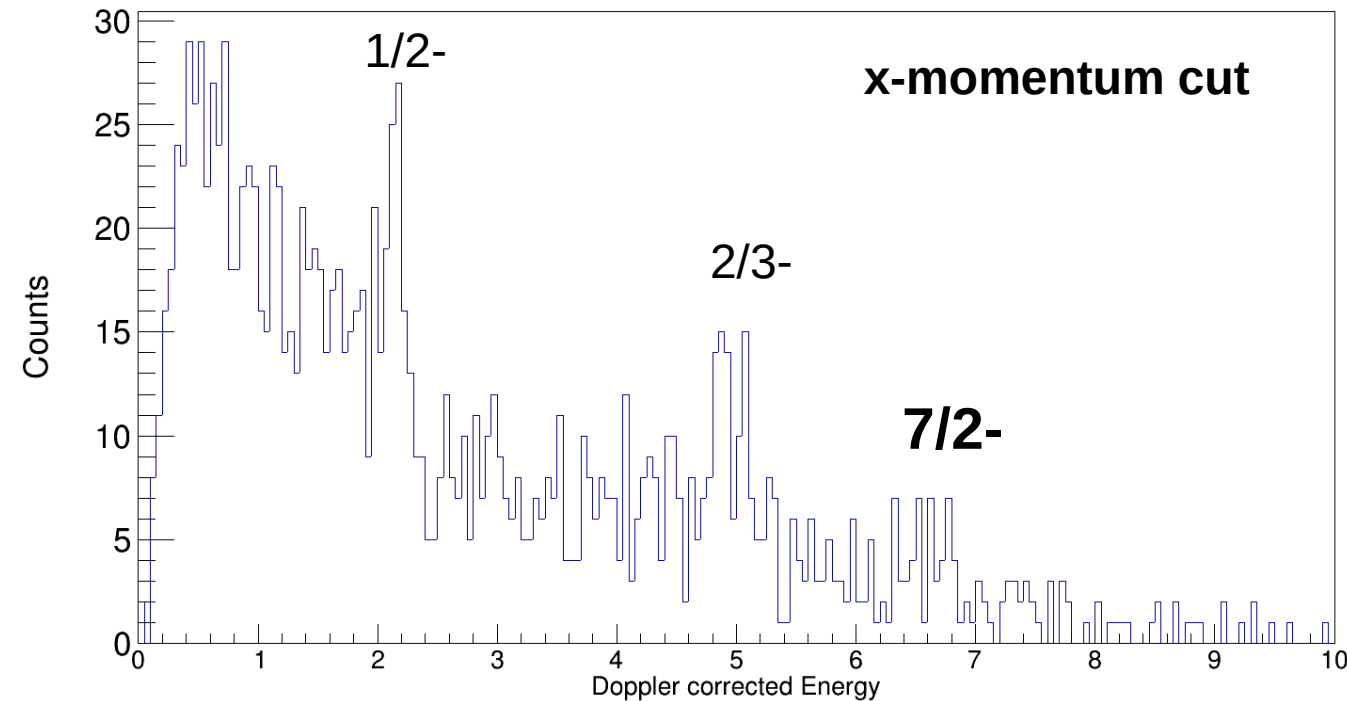


Correlations between Fragment and Proton Pair



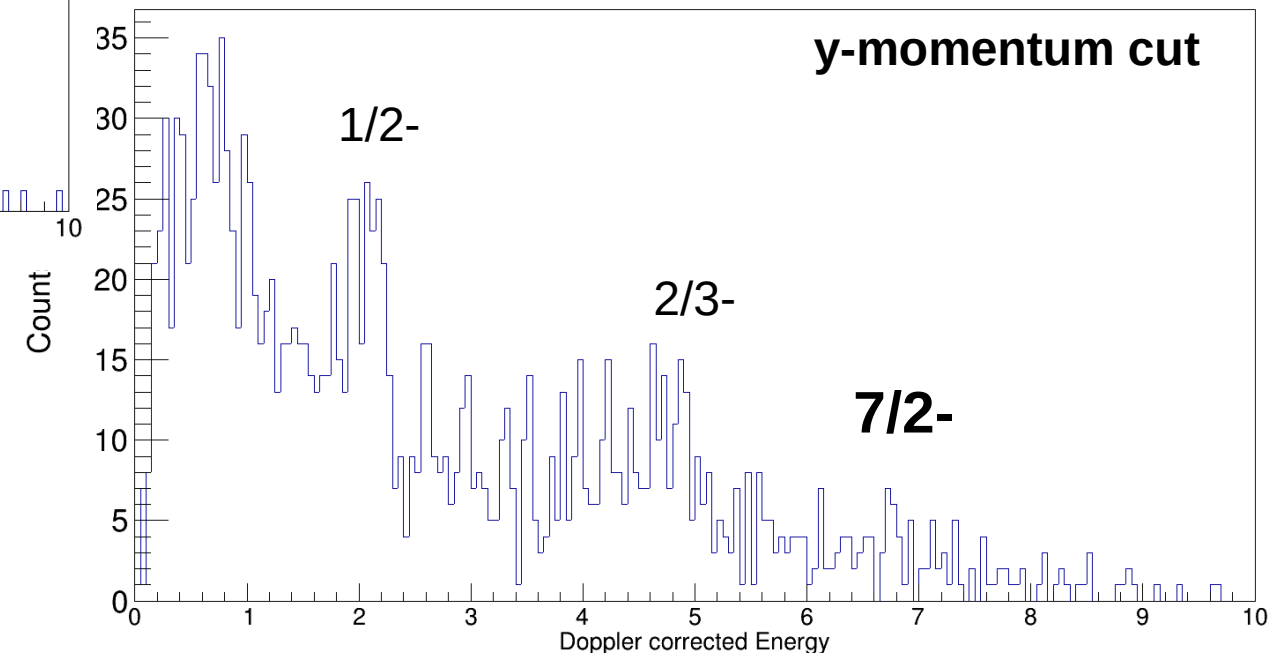
What if we cut on the events with high inner proton momentum?

Gamma spectrum (highest energy) with high $p_{11B_x} > 100 \text{ MeV/c}$ & $p_{i_x} > 100 \text{ MeV/c}$ in 12C frame

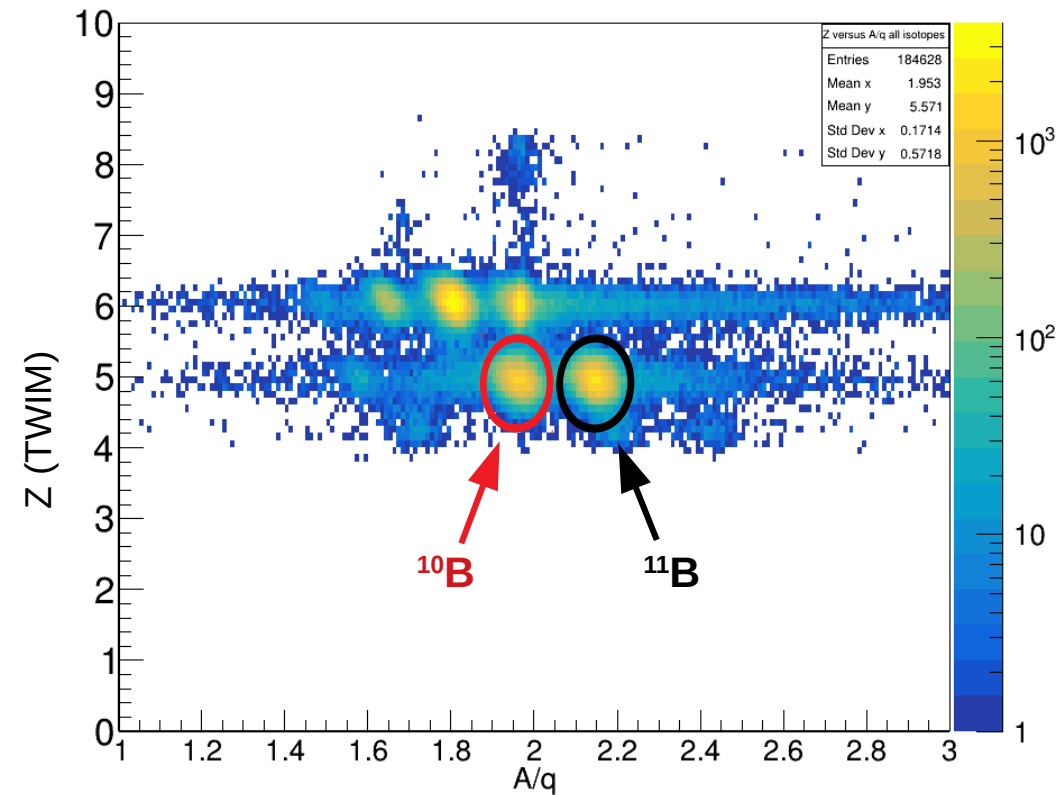
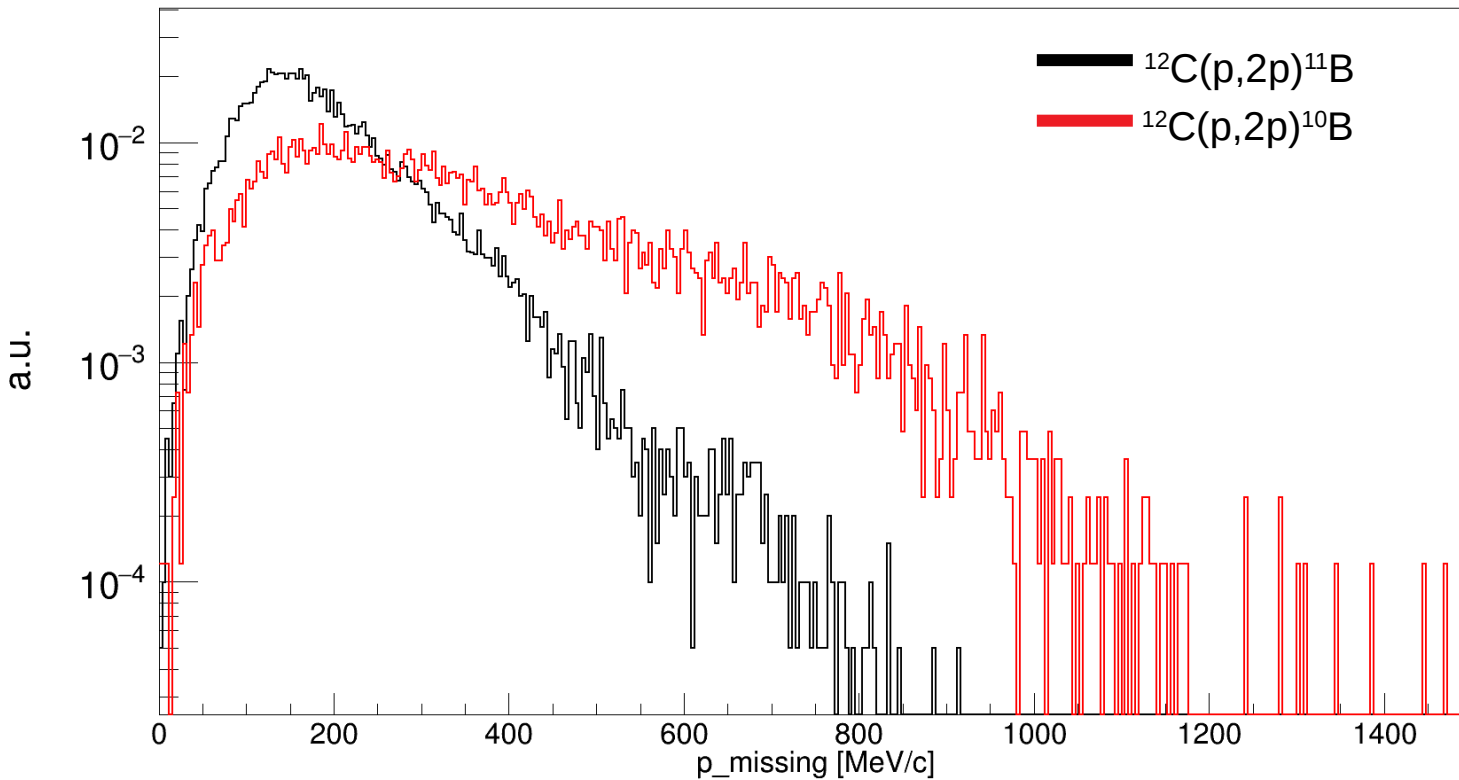


No 5/2- population (4.4 MeV)

Gamma spectrum (highest energy) with high $p_{11B_y} > 100 \text{ MeV/c}$ & $p_{i_y} > 100 \text{ MeV/c}$ in 12C frame



Momentum Reconstruction for Inclusive $^{12}\text{C}(p,2p)$

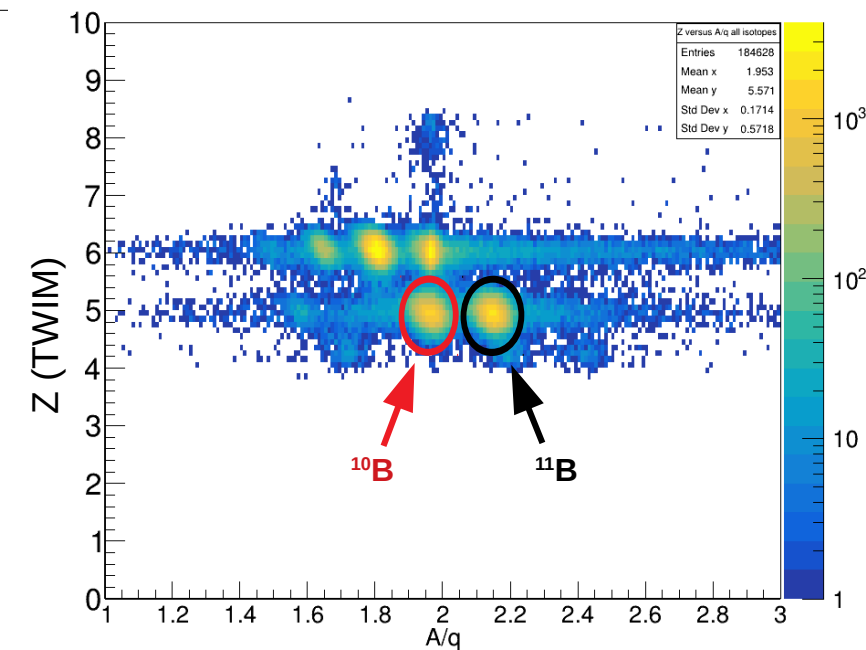
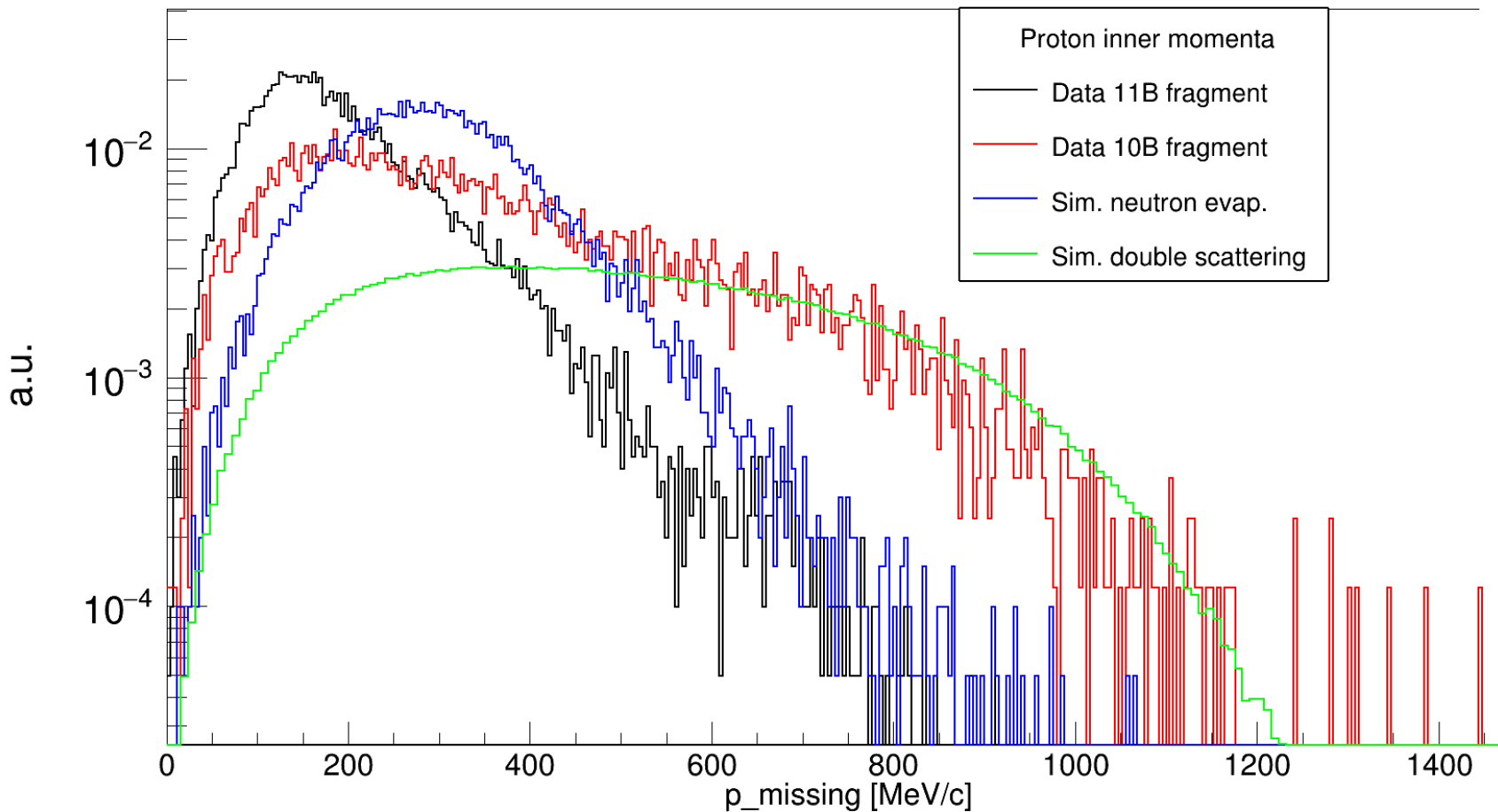


Reaction Channels for $^{12}\text{C}(p,\text{ppn})^{10}\text{B}$:

- Multiple scattering
- Neutron evaporation
- SRC breakup reactions



Momentum Reconstruction for Inclusive $^{12}\text{C}(p,2p)$



Simulation neutron evaporation: $\vec{p}_{miss\ 11B} + \vec{p}_{isotropic}^{(240\text{ MeV}/c)}$

Simulation double scattering:

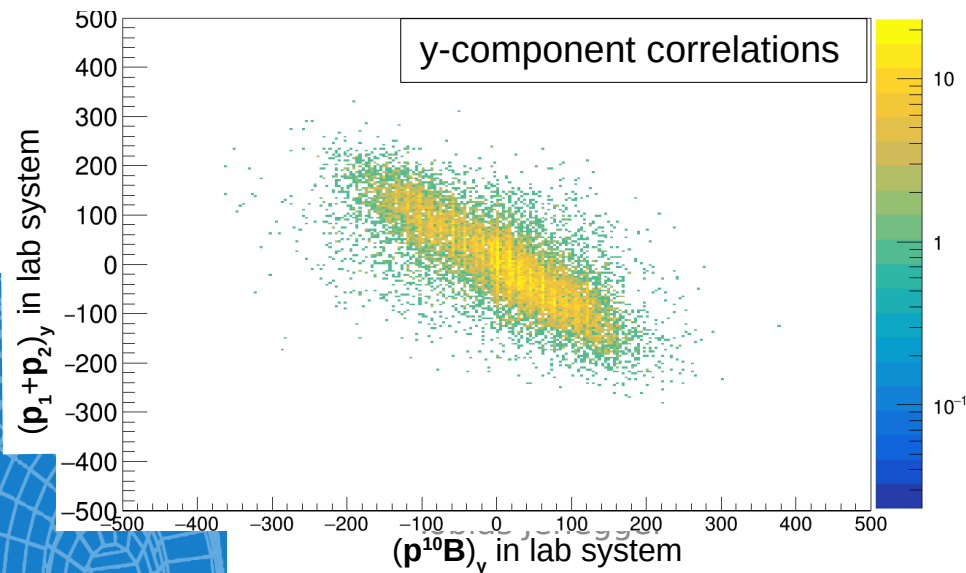
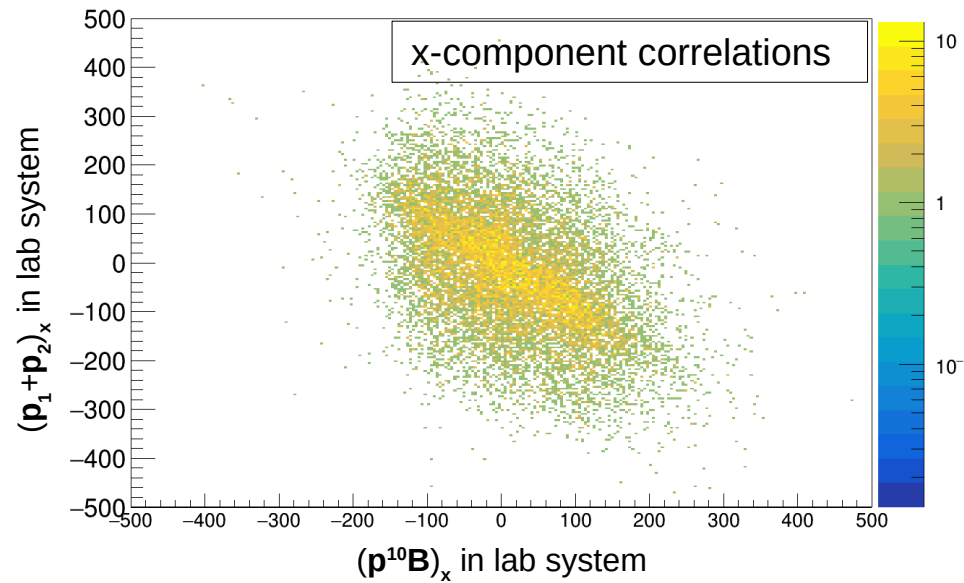
$$p \rightarrow pn \rightarrow pnp$$

or

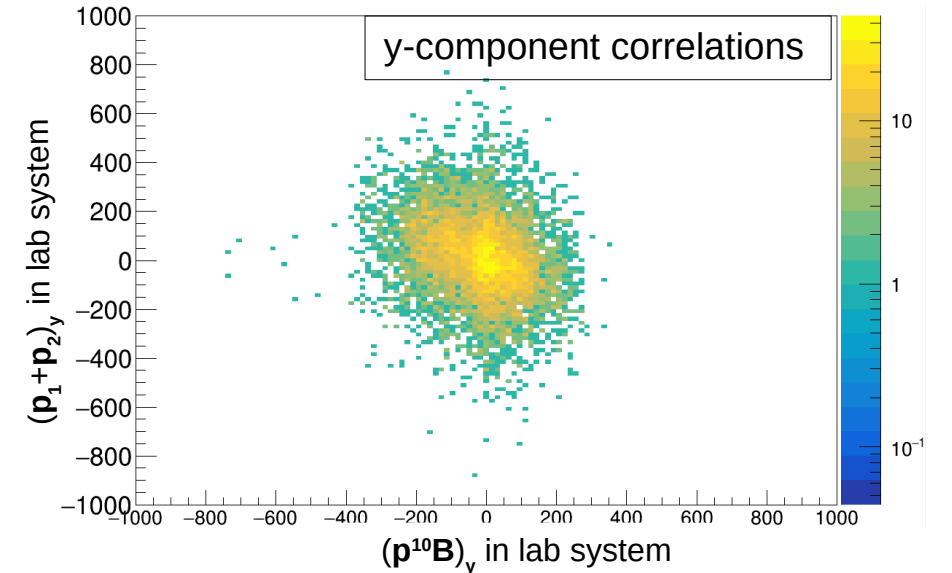
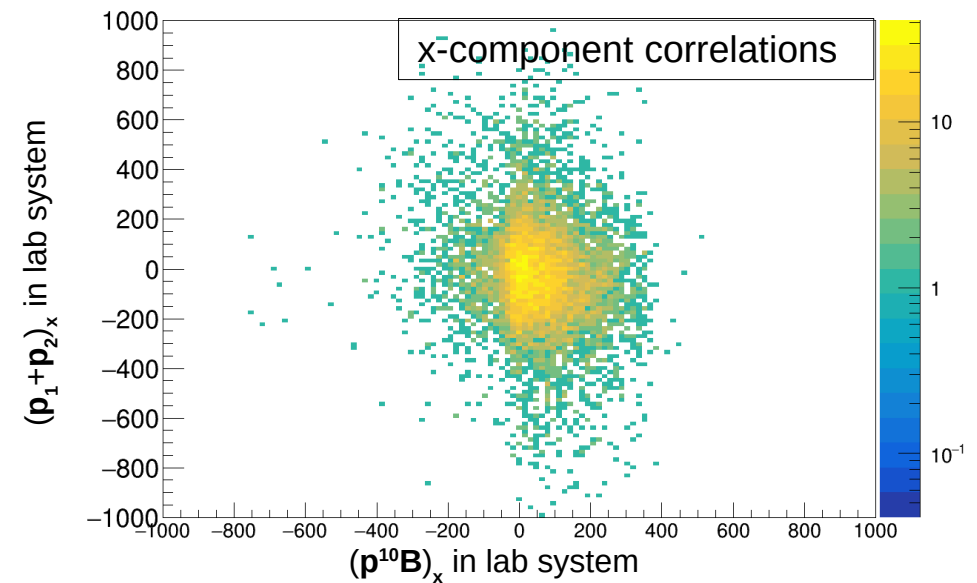
$$p \rightarrow pp \rightarrow ppn$$

Momentum Component Correlations

$^{12}\text{C}(p,2p)^{11}\text{B}$



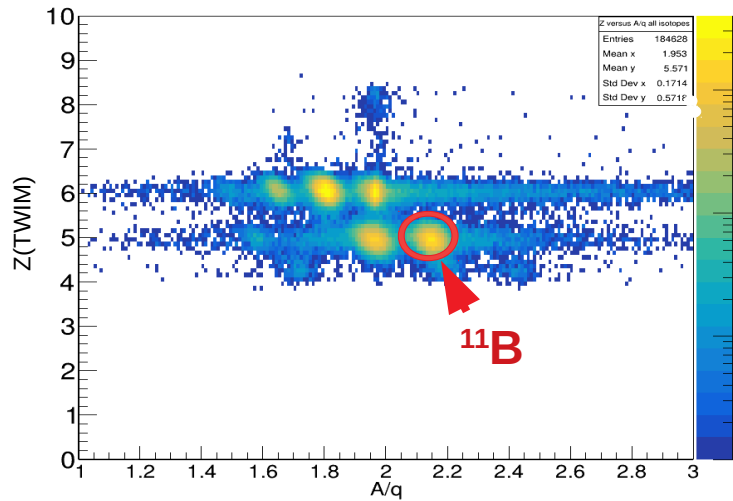
$^{12}\text{C}(p,2p)^{10}\text{B}$



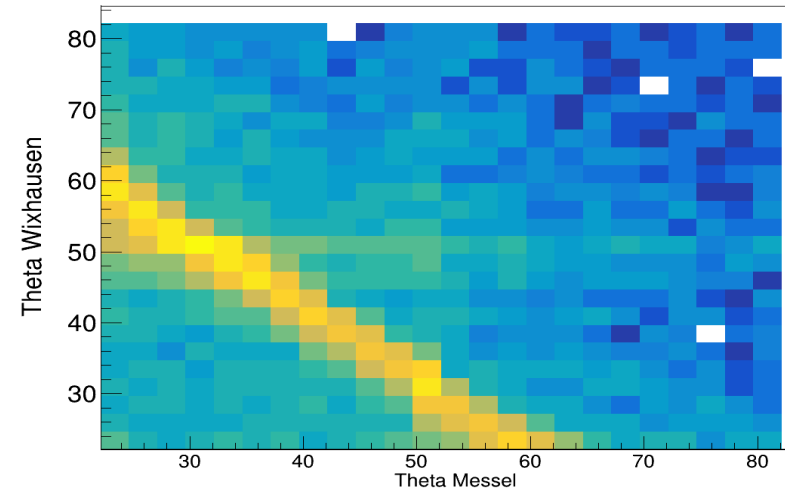
Summary

Identification of the QFS-process:

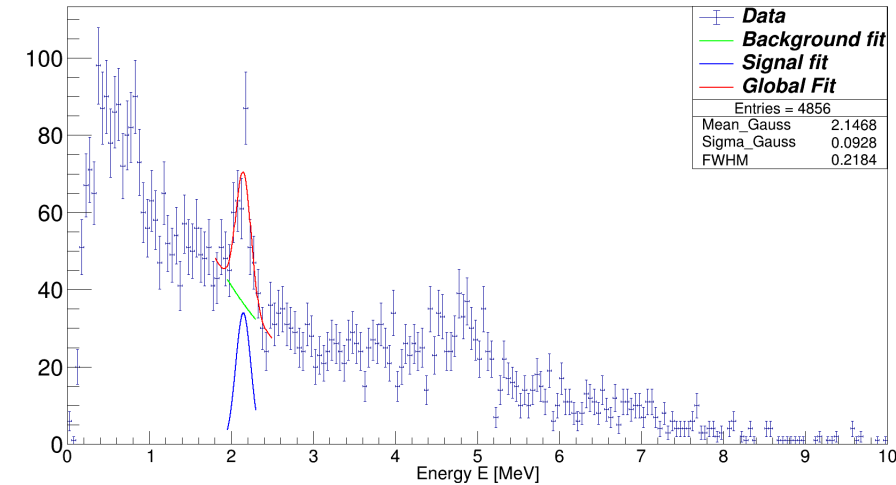
^{11}B Fragment



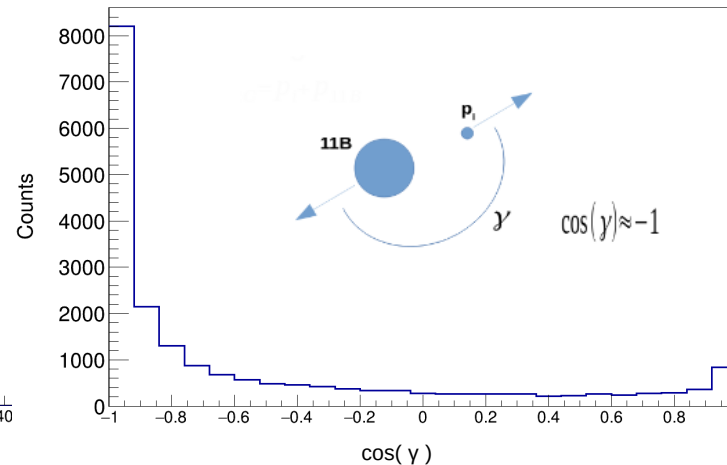
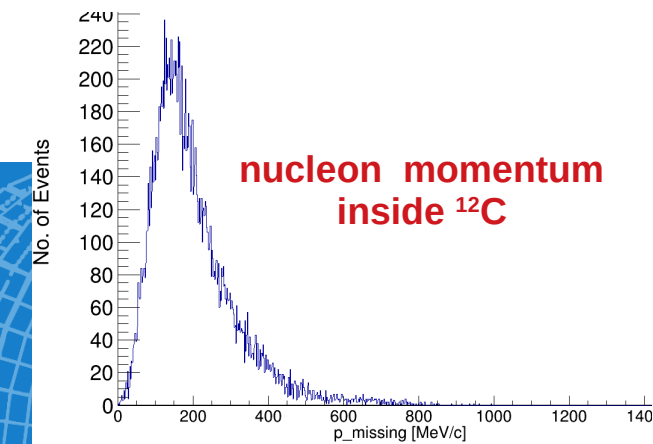
Polar Angles of two protons



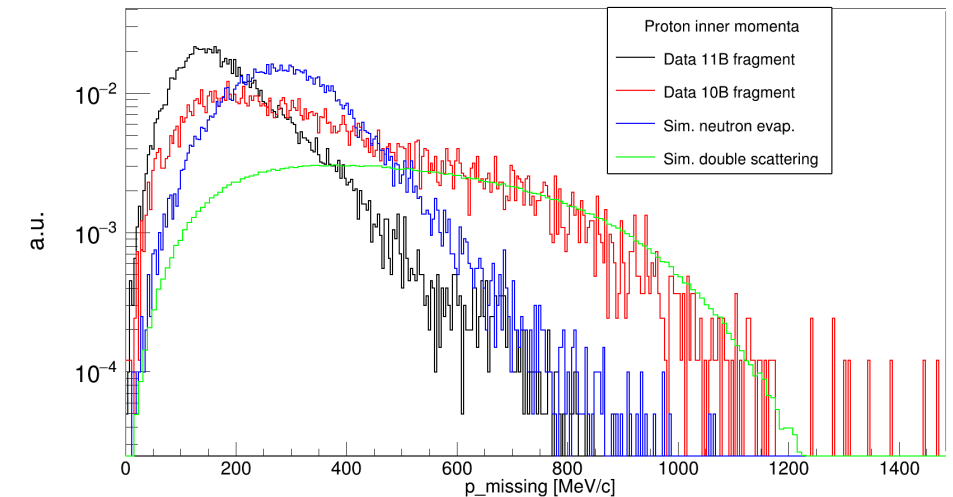
Gamma Spectrum of ^{11}B



Inner Momenta and according correlation plots:

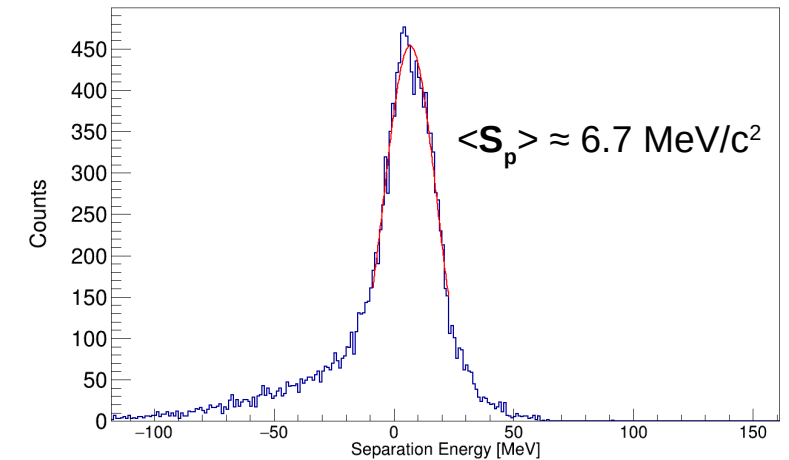


Inclusive $^{12}\text{C}(p,2p)$ Momentum Reconstruction

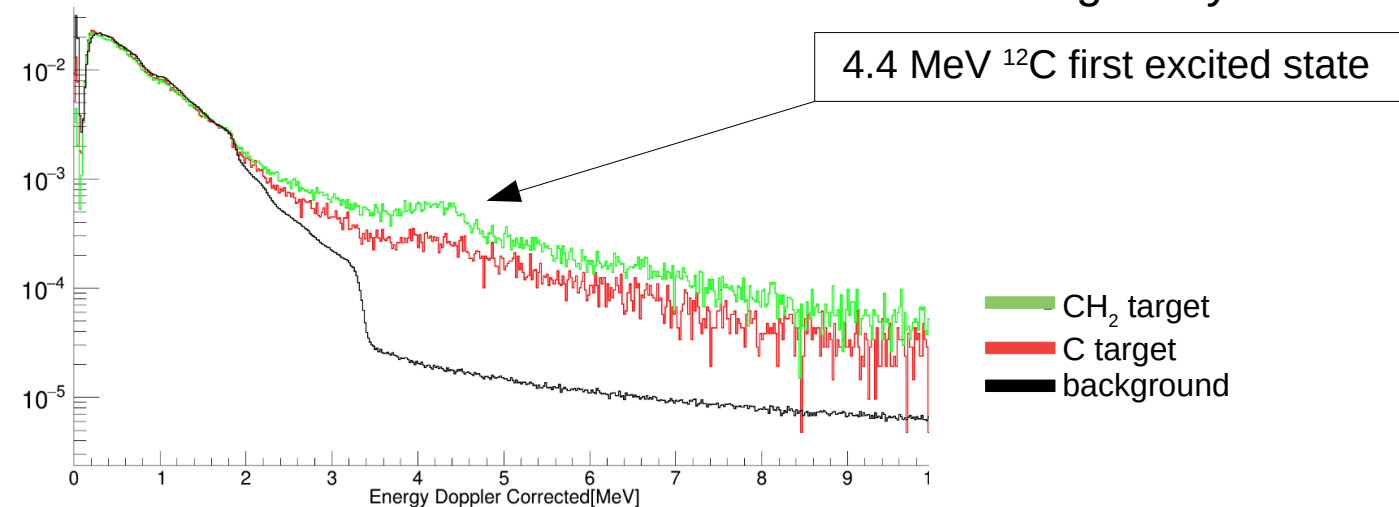


- Analyze data with other CH₂ target lengths (24.53/24 mm)
- Background subtraction with carbon target (5.4/10.86/21.98 mm)
→ Get cross section for QFS-process
- Further investigations of nuclear properties, eg. proton separation energy

$$S_p = T_{tg} - T_{p1} - T_{p2} - T_{11B} = (1 - \gamma) m_p - \gamma (T_1 + T_2) + \beta \gamma (p_{1\parallel} + p_{2\parallel}) - \frac{k^2}{2m_{11B}}$$



- S444 Commissioning Experiment can also be used for 12C – 12C inelastic scattering analysis





Thank you!



Tobias Jenegger

