

Reaction Measurements $^{12}\text{C} + ^{12}\text{C}$

Experiment S444 (2020)



Tobias Jenegger

R³B Collaboration Meeting 2024

S444/S467 - Detector Setup

$^{12}\text{C} + ^{12}\text{C}$ Reaction Channels

Reaction Cross Section Measurement

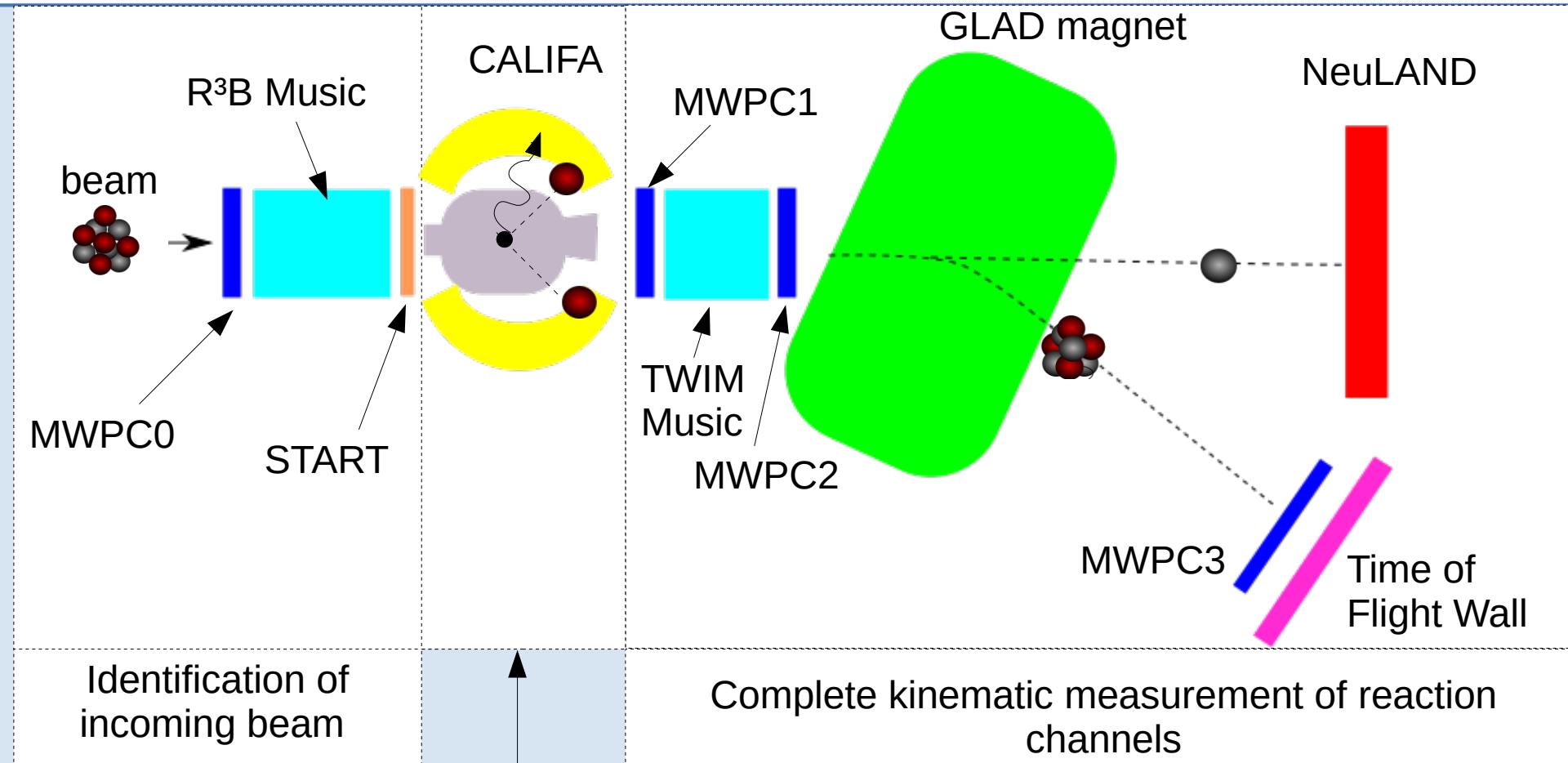
Summary & Outlook

Roman Gernhäuser, Lukas Ponnath, Philipp Klenze, Tobias Jenegger

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S444 Commissioning Experiment 2020

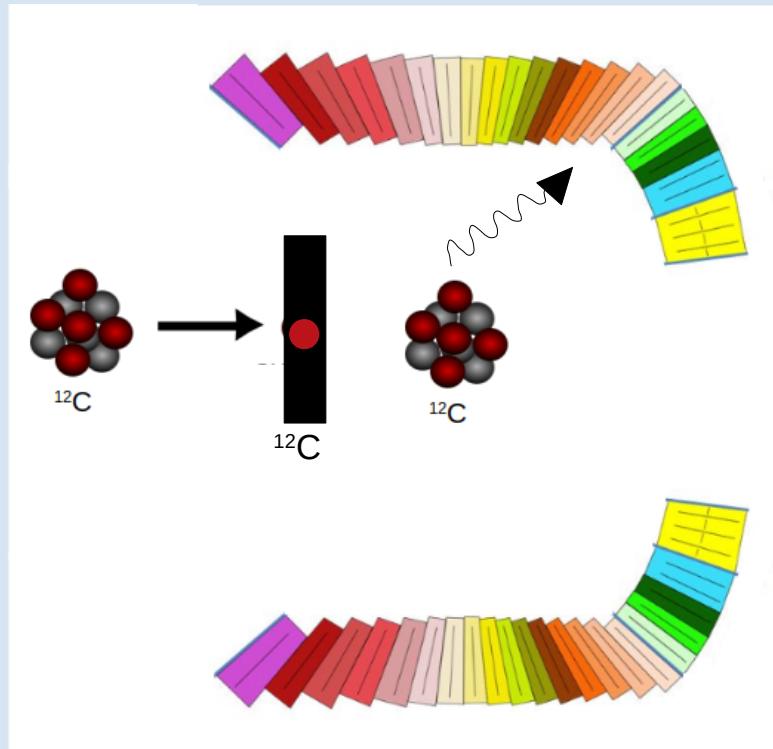
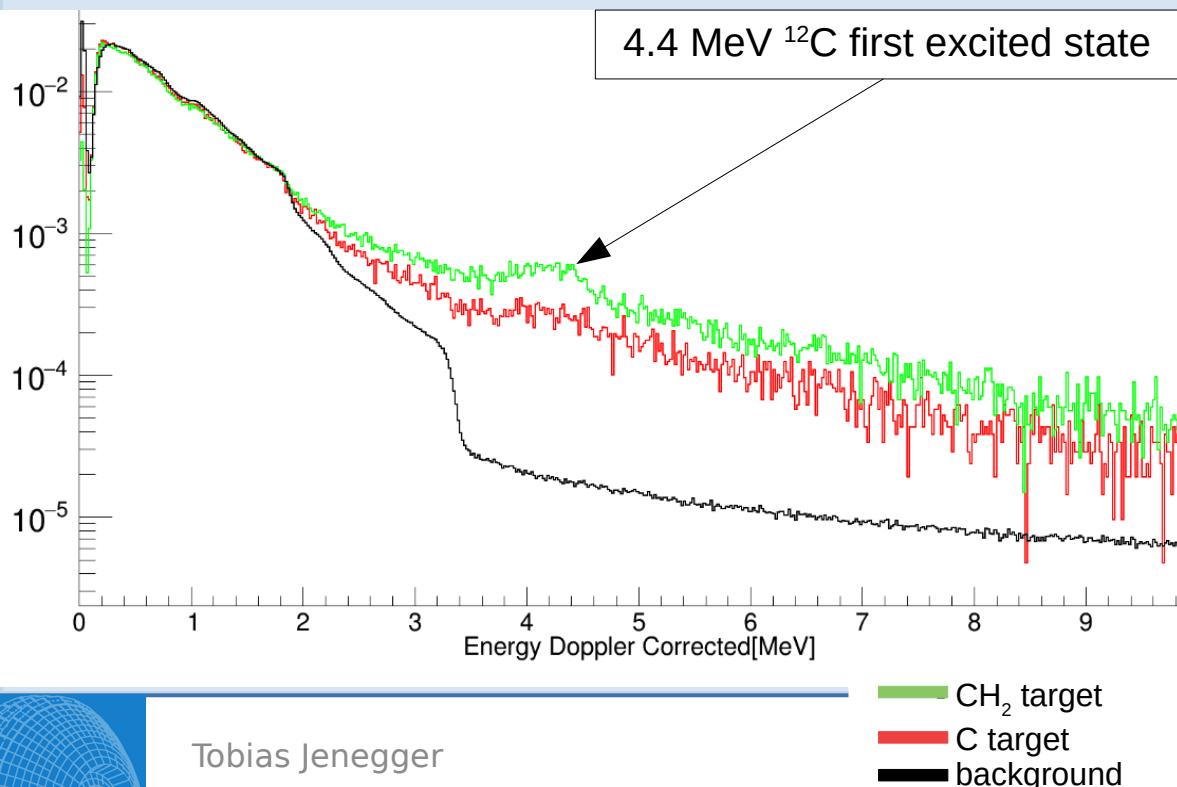


Beam energy:
400/550/650/800 AMeV
Projectile: ¹²C
Target: C and CH₂

Reaction Processes $^{12}\text{C} + ^{12}\text{C}$

Contributions to the total reaction cross section:

$$\sigma_R = \sigma_{inel} + \sigma_I$$

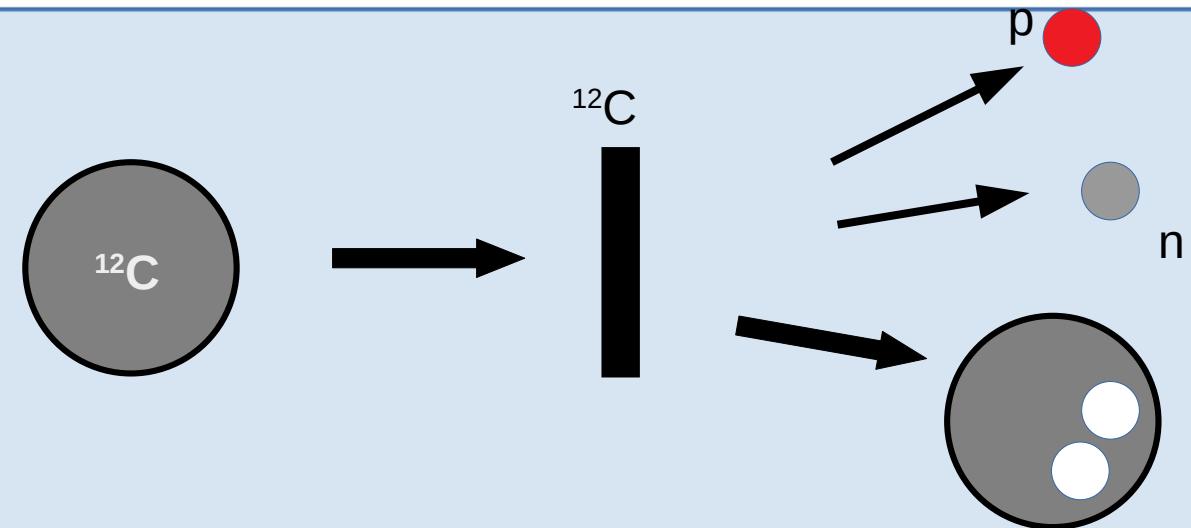
 σ_{inel} Projectile is excited to bound state. No nucleon is removedis small at high beam energies &
suppressed due to Pauli blocking

Reaction Processes $^{12}\text{C} + ^{12}\text{C}$ Interaction Cross Section σ_I

Projectile changes its identity.
At least one nucleon is removed.

charge changing pure neutron removal

$$\sigma_I = \boxed{\sigma_{\Delta Z}} + \boxed{\sigma_{\Delta Z \Delta N}} + \boxed{\sigma_{\Delta N}}$$



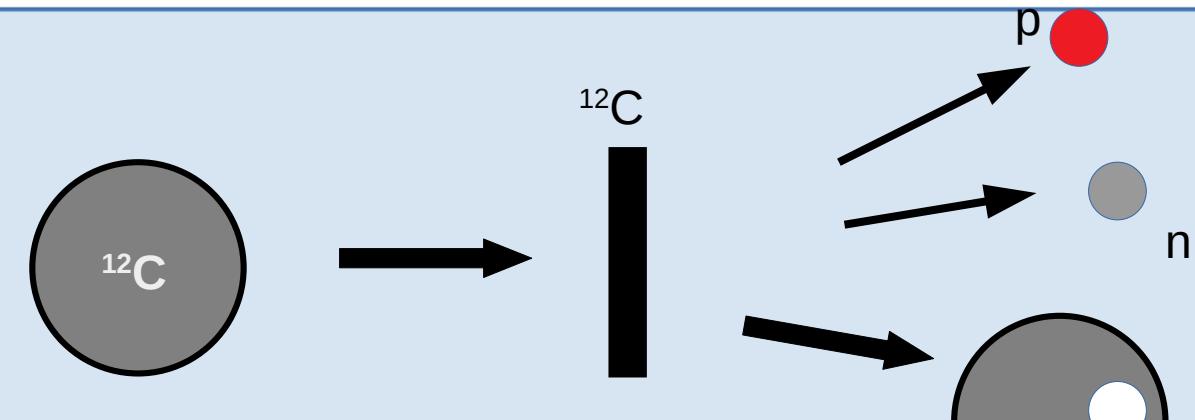
$$\sigma_{\Delta N}: Z_i = Z_f \quad N_i \neq N_f$$

$$\sigma_{\Delta Z \Delta N}: Z_i \neq Z_f \quad N_i \neq N_f$$

$$\sigma_{\Delta Z}: Z_i \neq Z_f \quad N_i = N_f$$

Reaction Processes $^{12}\text{C} + ^{12}\text{C}$ Interaction Cross Section σ_I

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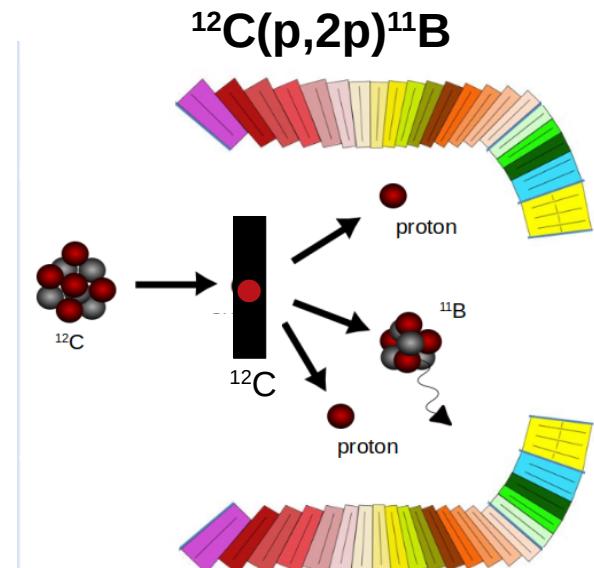
$$\sigma_{\Delta N}: Z_i = Z_f, N_i \neq N_f$$

$$\sigma_{\Delta Z \Delta N}: Z_i \neq Z_f, N_i \neq N_f$$

$$\sigma_{\Delta Z}: Z_i \neq Z_f, N_i = N_f$$

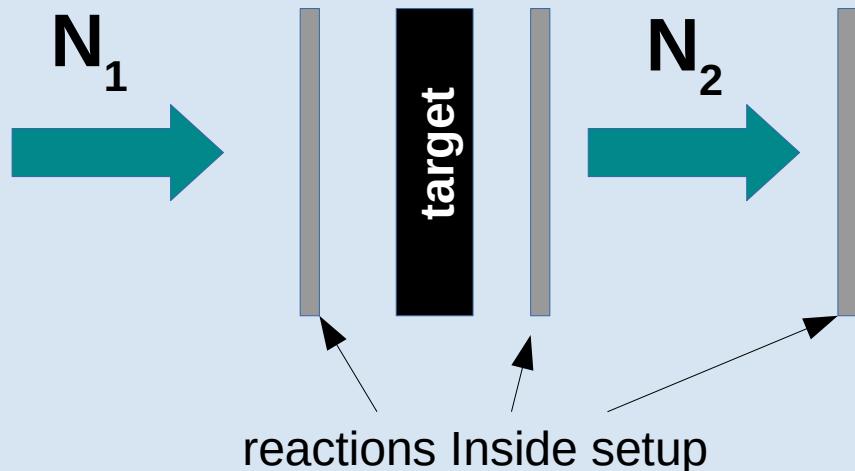
Access to quasi-free scattering ($p,2p$) reactions with CALIFA

- Two body scattering can be approximated by the identical process for free particles
- Qfs- reactions give access to single particle properties inside nucleus



Reaction Cross Section Measurement $^{12}\text{C} + ^{12}\text{C}$

clean incoming ions:



unreacted/survived ions:

Transmission method:

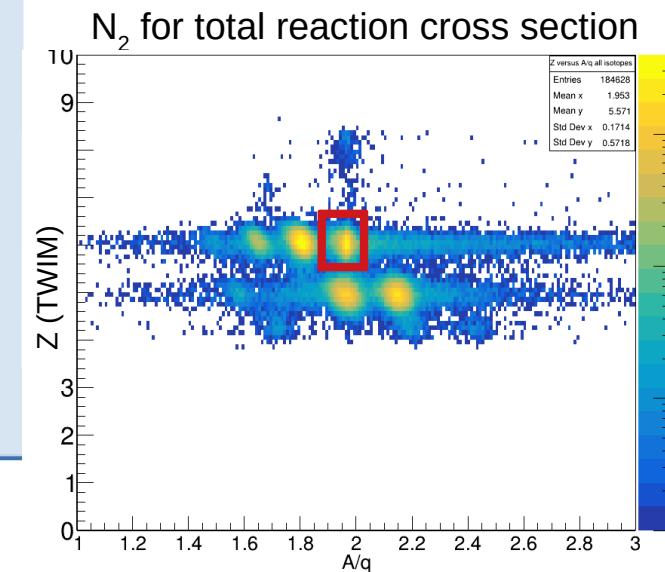
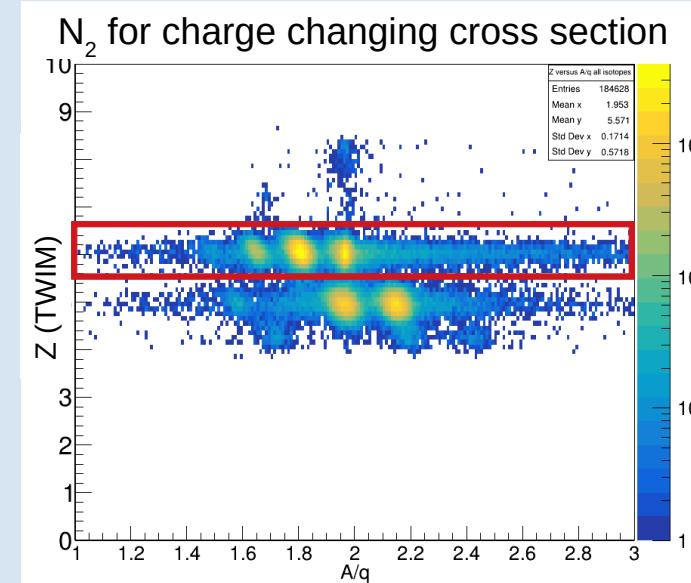
$$N_2 = N_1 e^{-N_t \sigma}$$

$$N_t: \frac{\text{\#scattering centers}}{\text{volume}}$$

Correct for reactions inside exp. setup

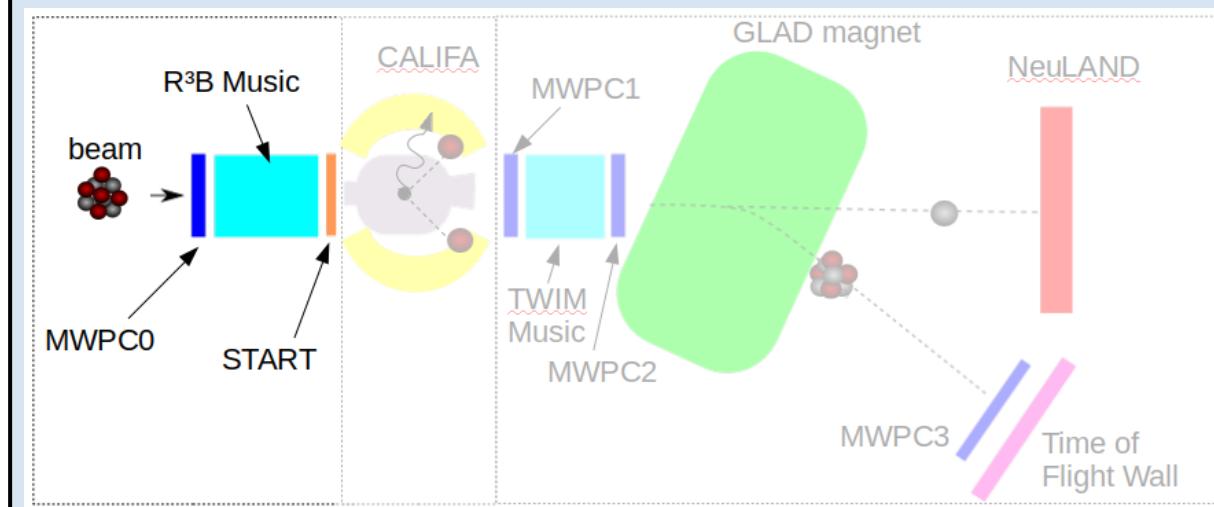
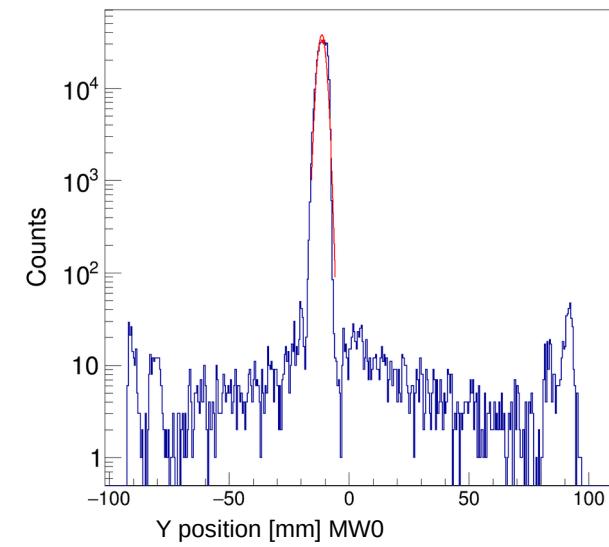
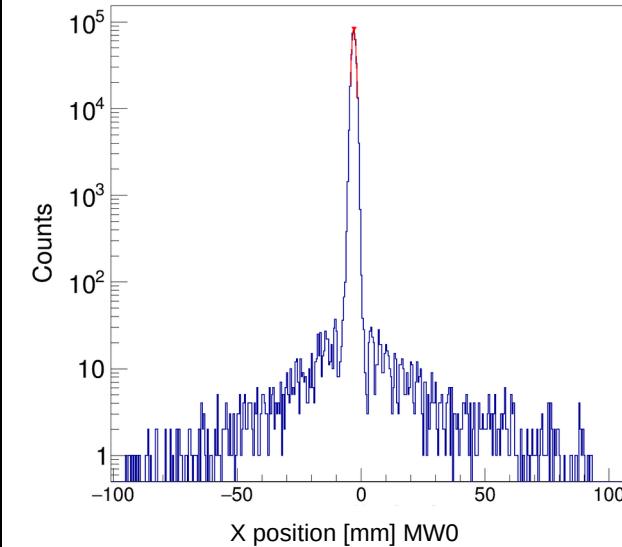
$$N_2 = \left(\frac{N_2^E}{N_1^E} \right) N_1 e^{-N_t \sigma}$$

$$\sigma = - \frac{1}{N_t} \ln \left(\frac{N_2 / N_1}{N_2^E / N_1^E} \right)$$

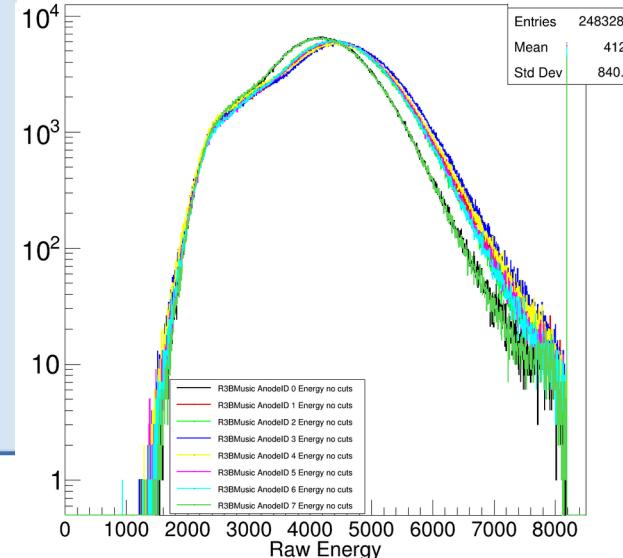


Identification of the Incoming Ions

one σ cut on x-y MW0 position

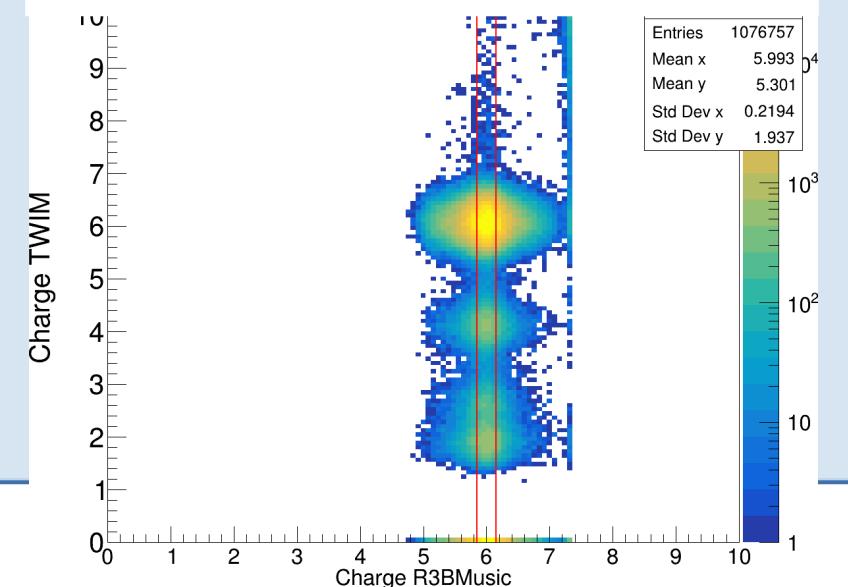


Raw ADC R3BMusic

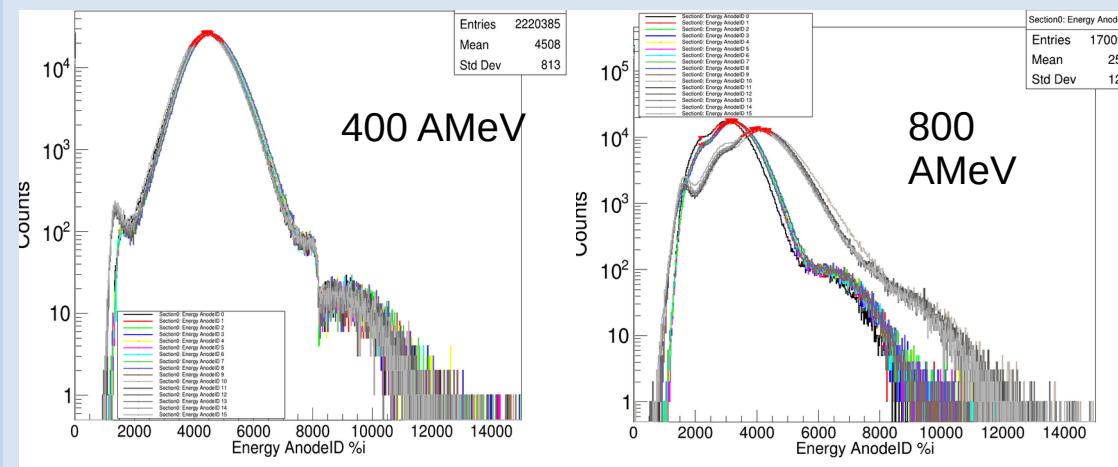


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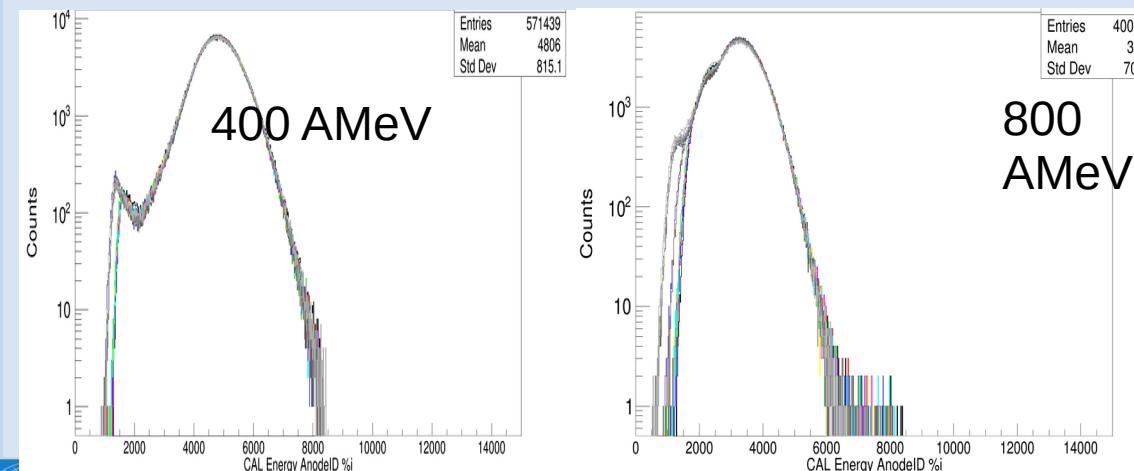
R3BMusic cut one σ



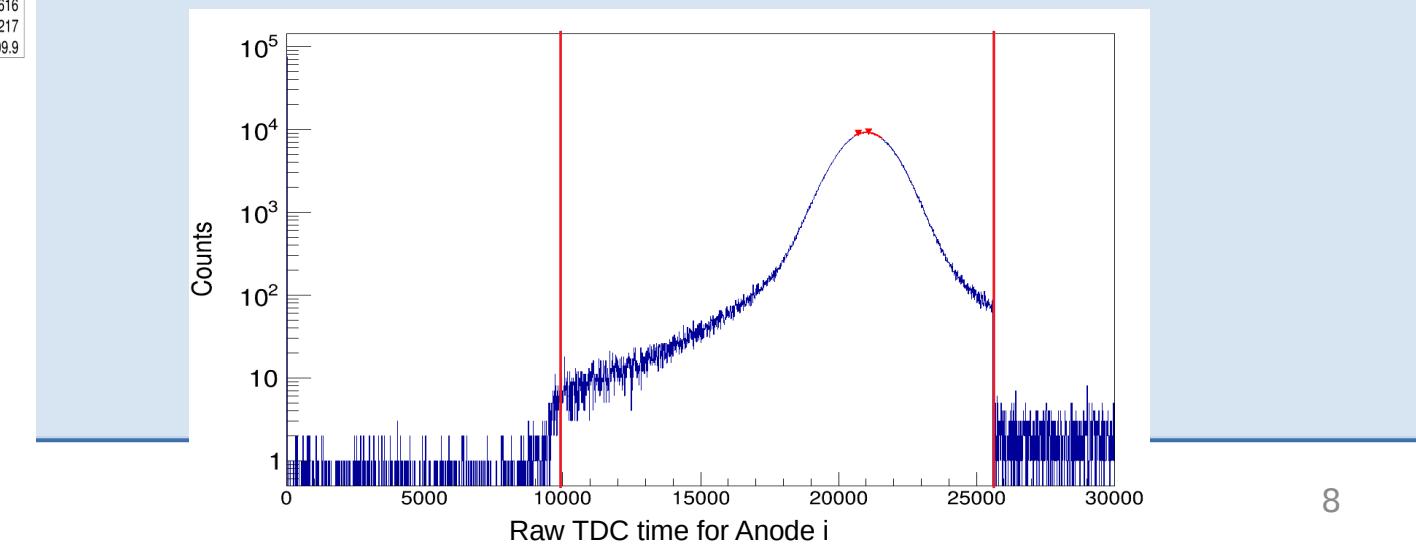
Charge Measurement in TWIM Music



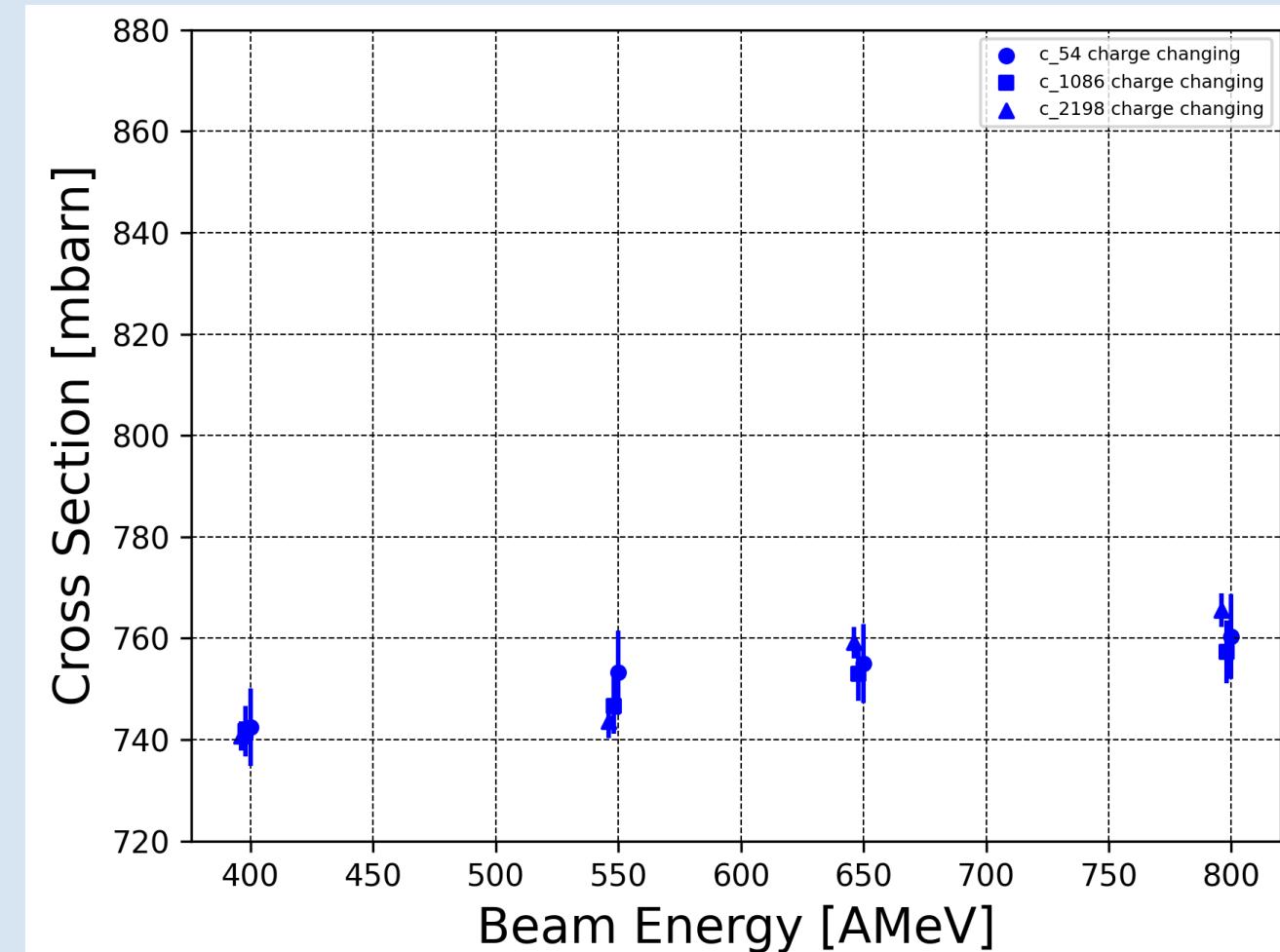
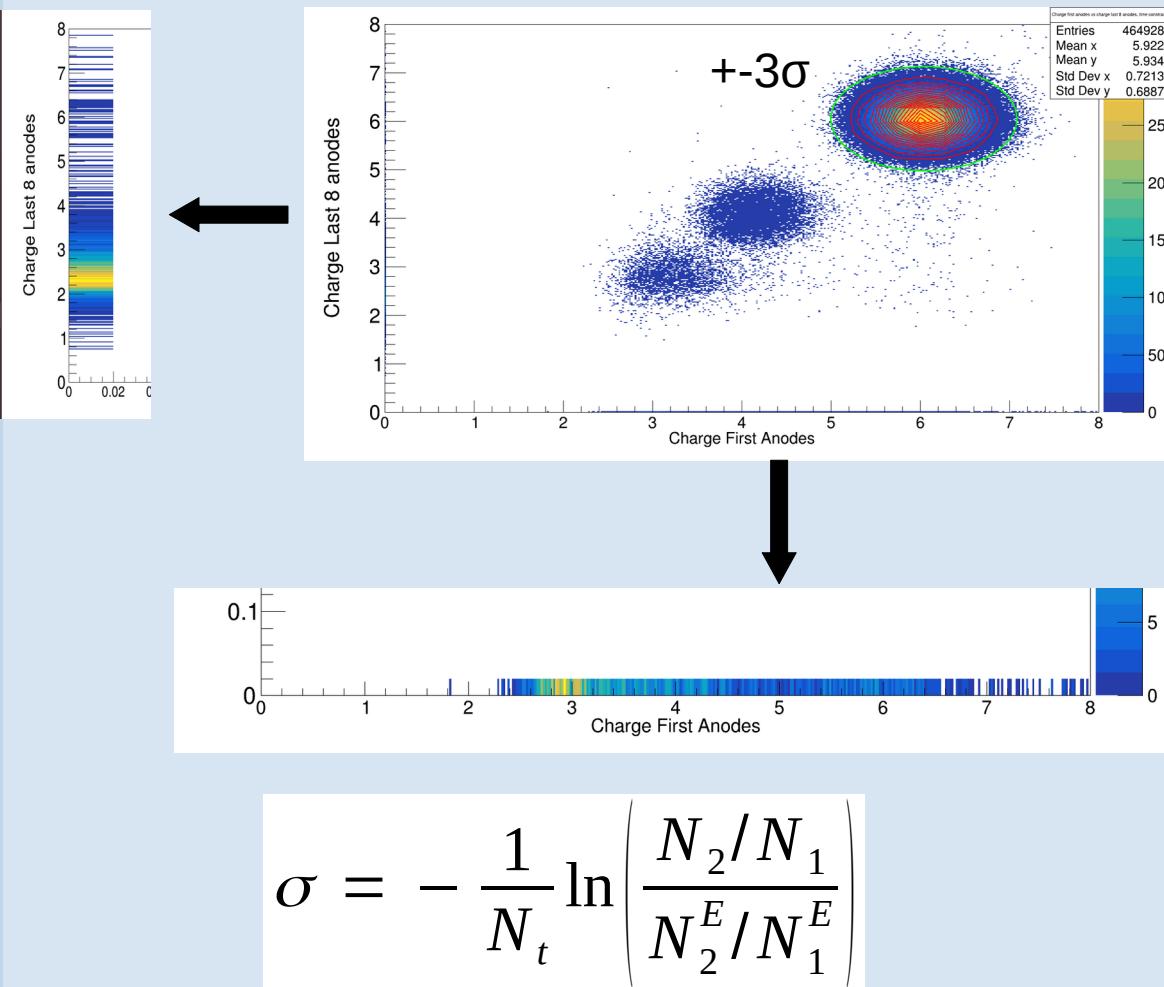
1. Calibrate Energies (using ref. anode)
2. Get Mean time for each anode
3. Multihit-algorithm:
 - a) Loop over all hits in all anodes
 - b) If hittime < 10000 or >25500, discard hit *
 - c) If anodes have multiple hits, select the one hit which is closer to the mean anode time
 - d) upstream/downstream energy is calculated by calculating the mean value of the selected hits in the upstream anodes (1-8) /downstream anodes (9-16)



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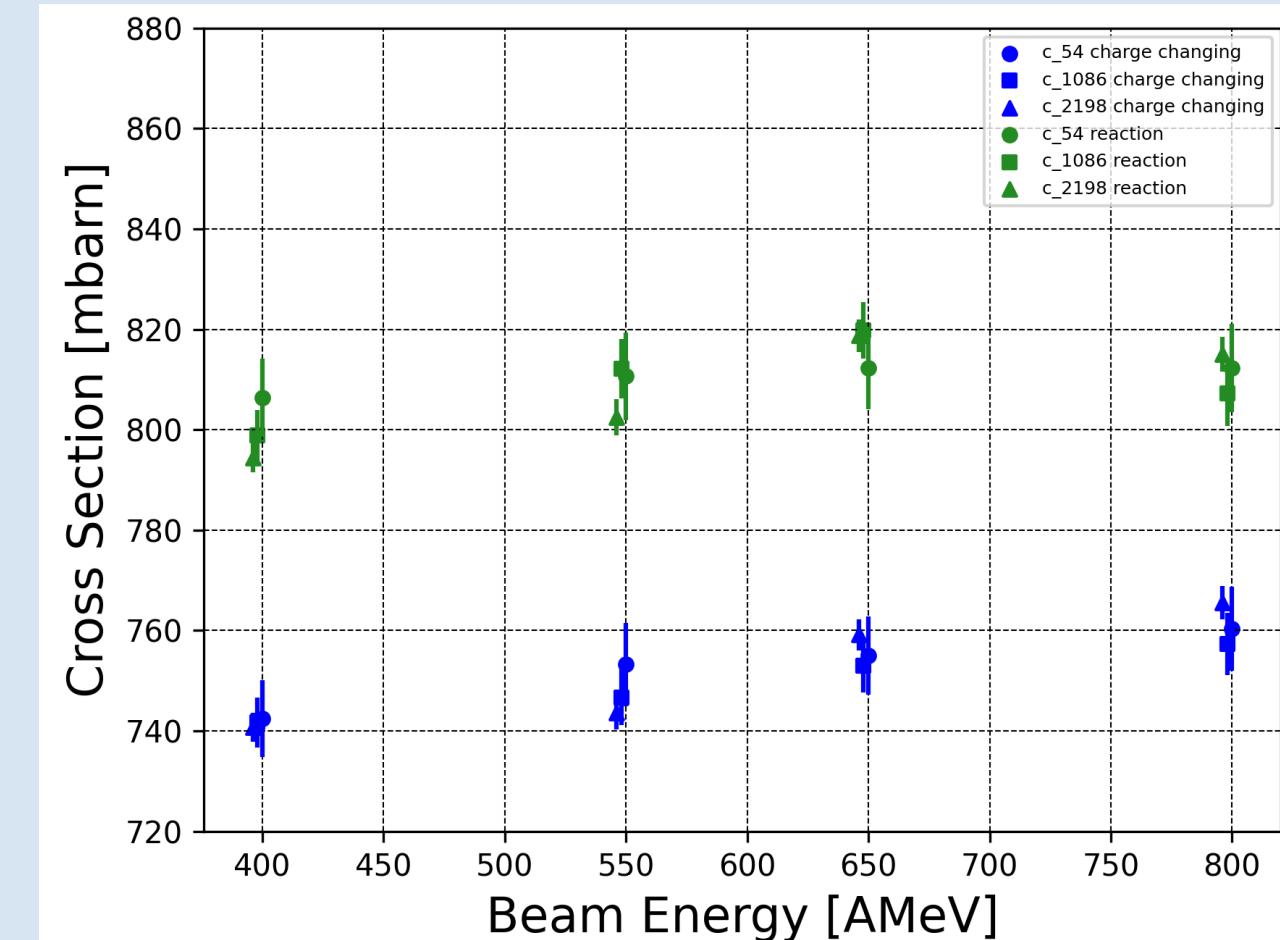
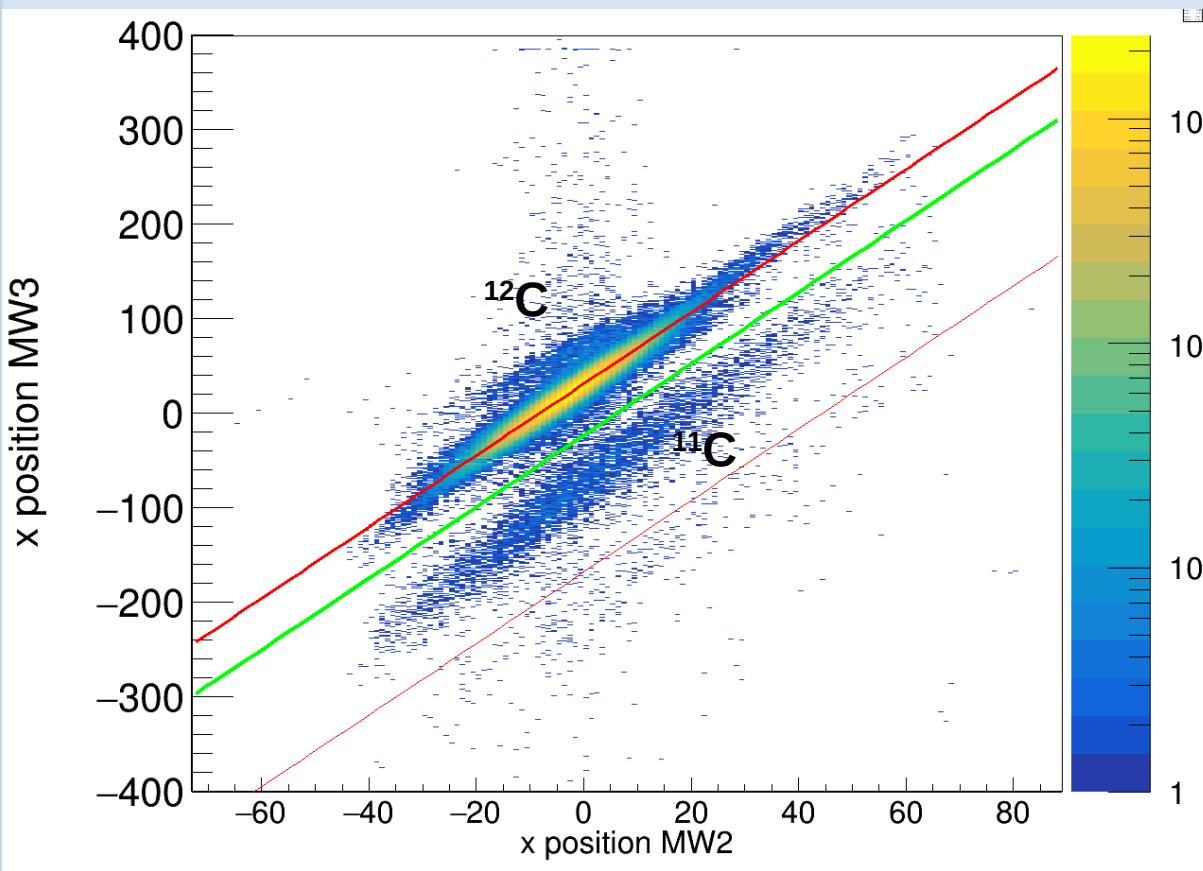
Charge Changing Cross Section



where N_2 = carbon isotopes detected in TWIM

12C/11C disentanglement

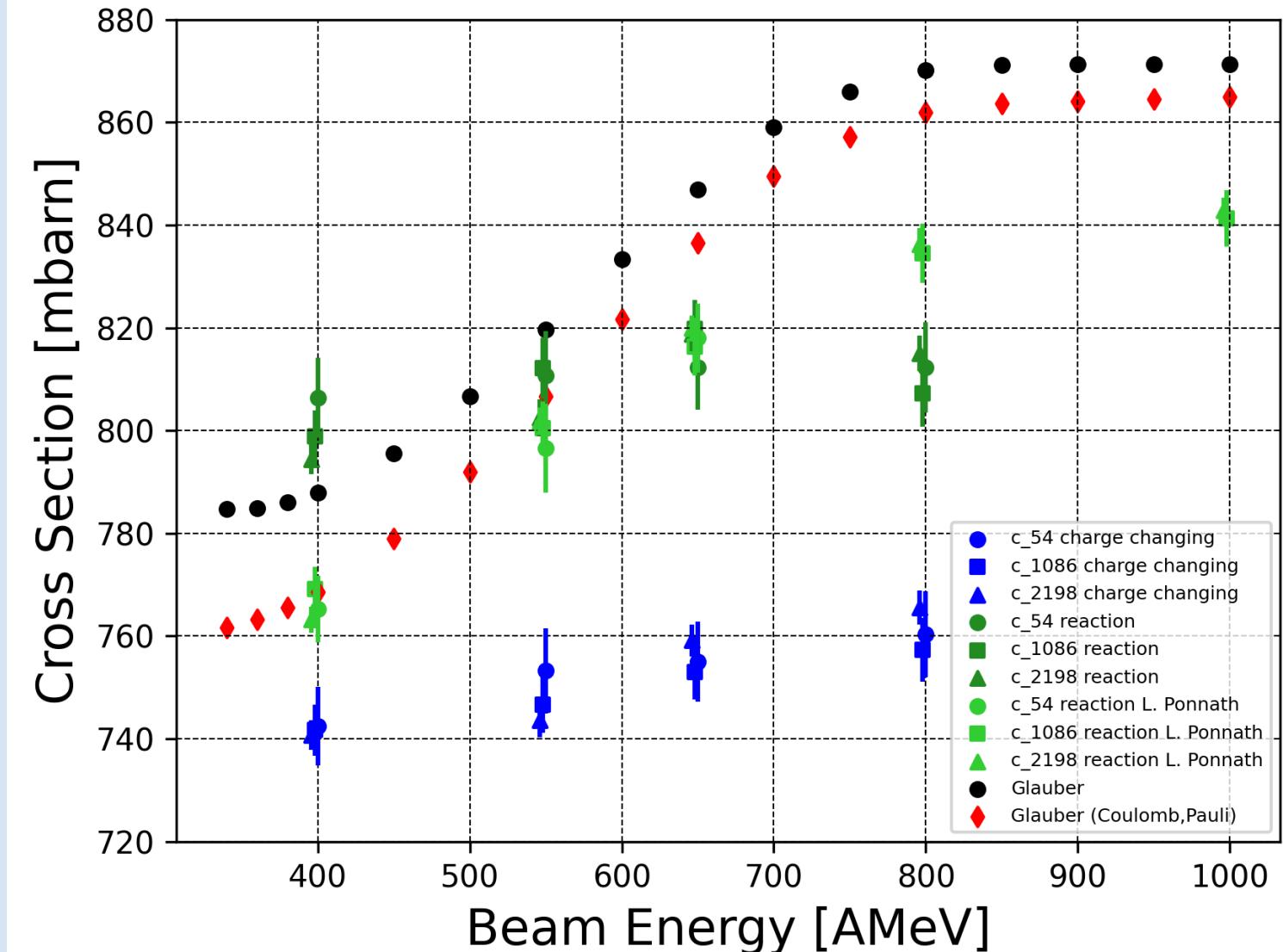
Use R³B Setup as Mass Spectrometer:



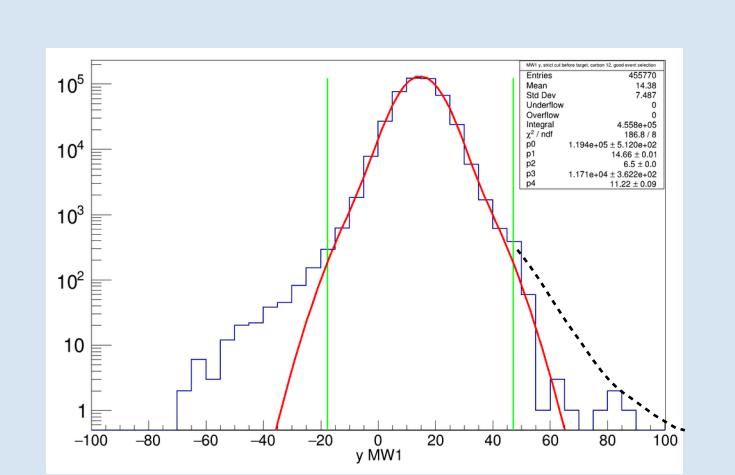
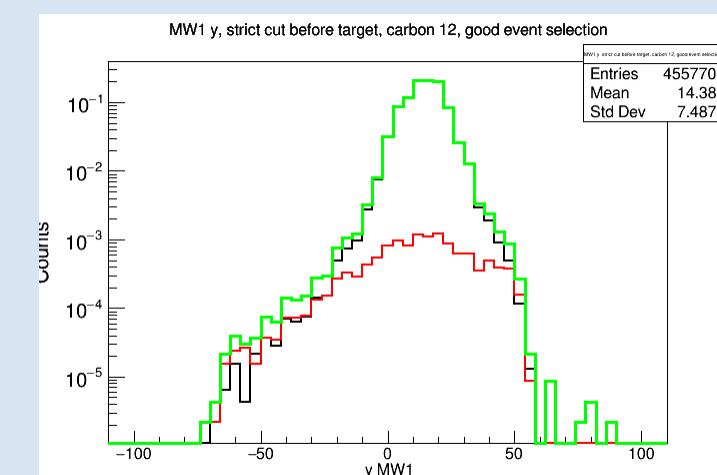
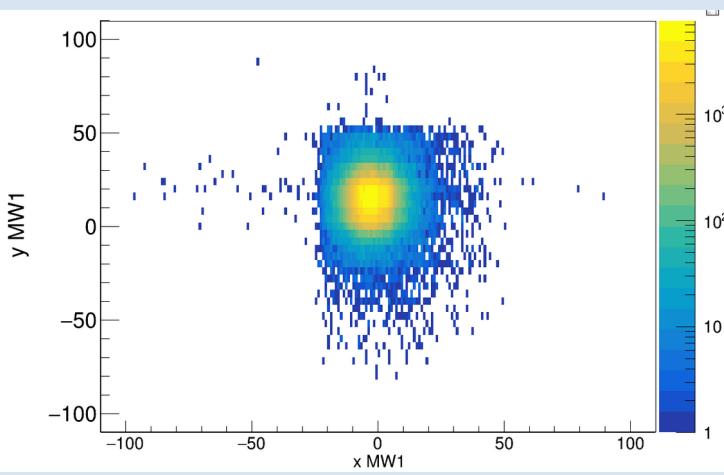
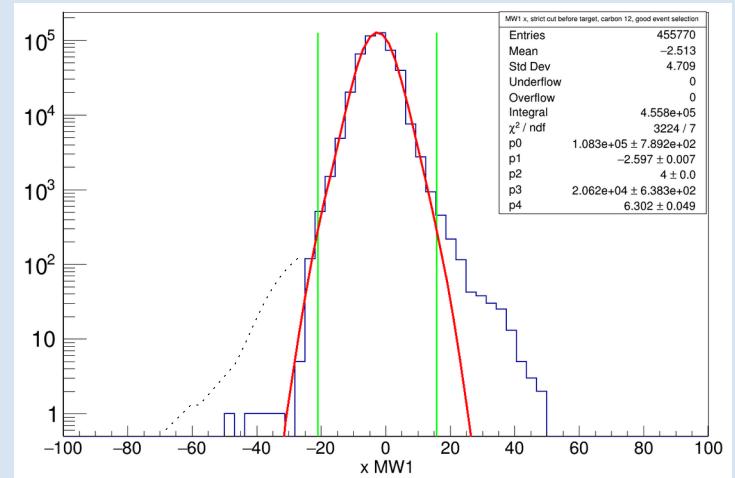
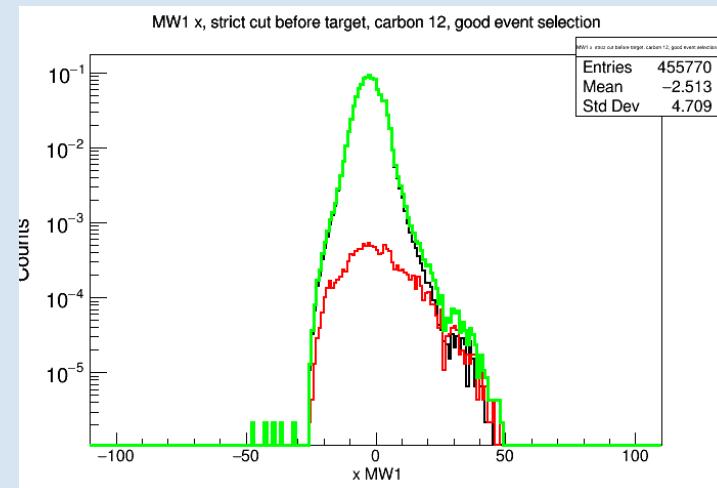
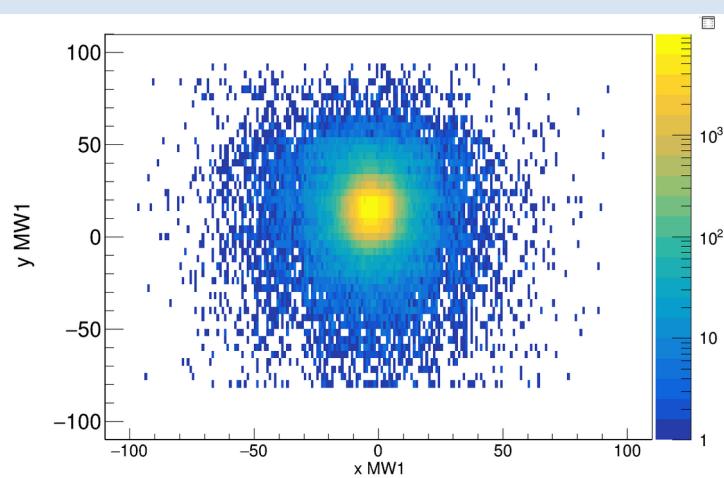
$$N_2 = N_{carbon} \cdot \frac{N_{^{12}C}}{N_{^{11}C} + N_{^{12}C}}$$

σ , measured in this analysis seems to be almost constant for a broad energy range

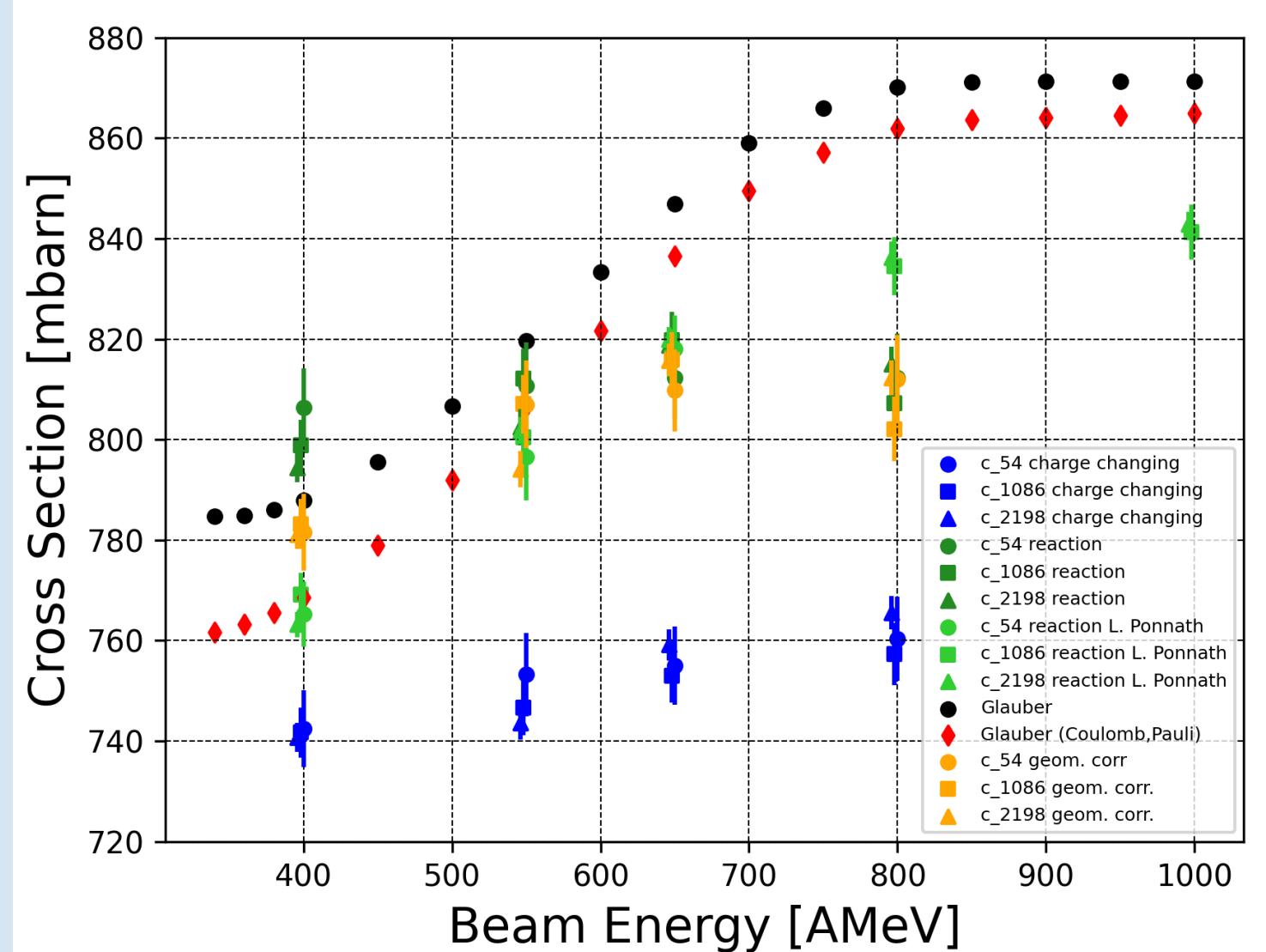
Did we miss out something?



TWIM Geometric Acceptance - Correction



Preliminary Results & Outlook





Thank you!

CALIFA @ Technical University of Munich (TUM)

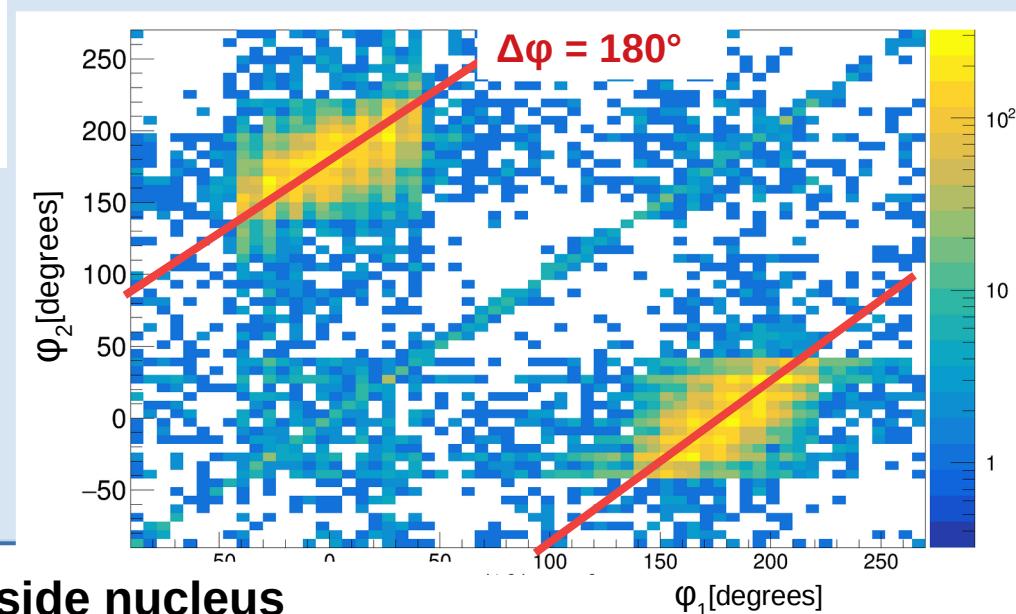
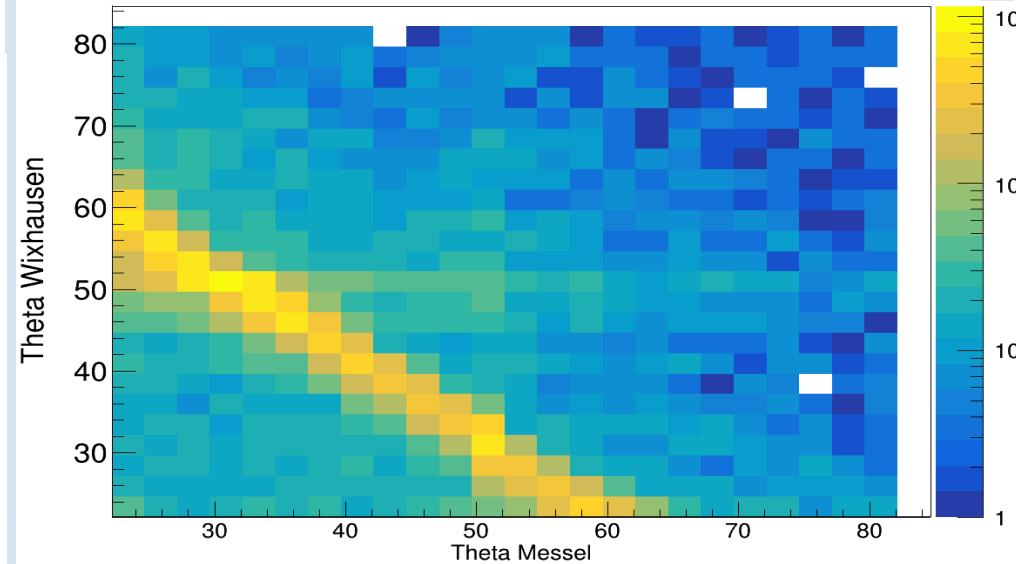
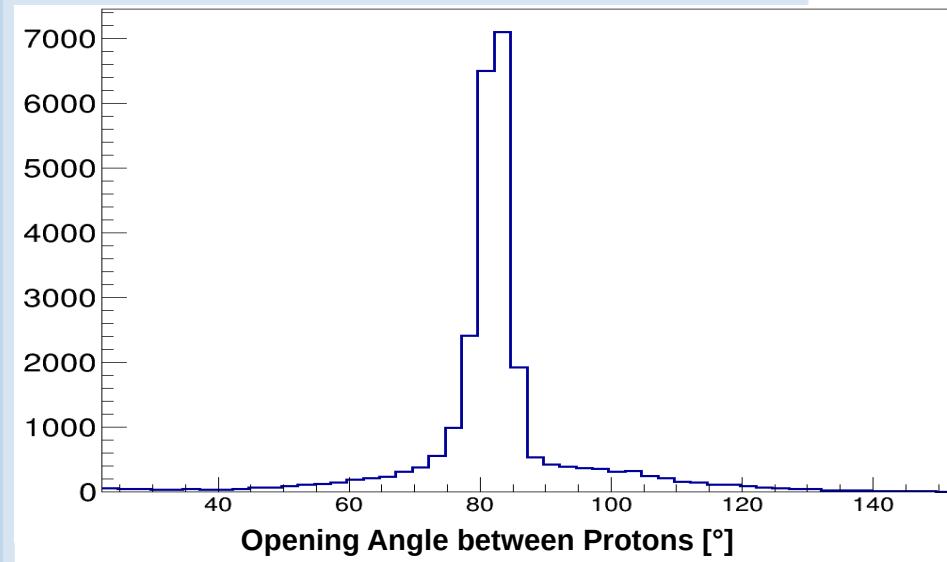
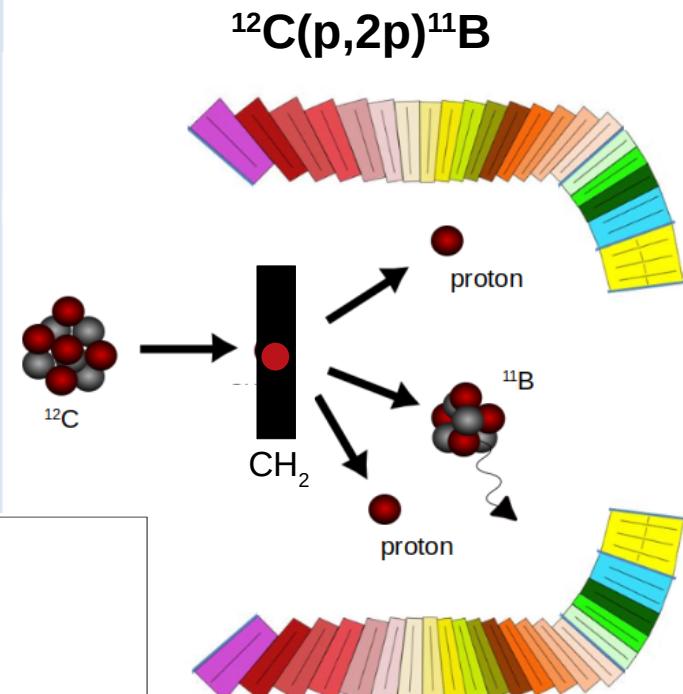
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BACKUP

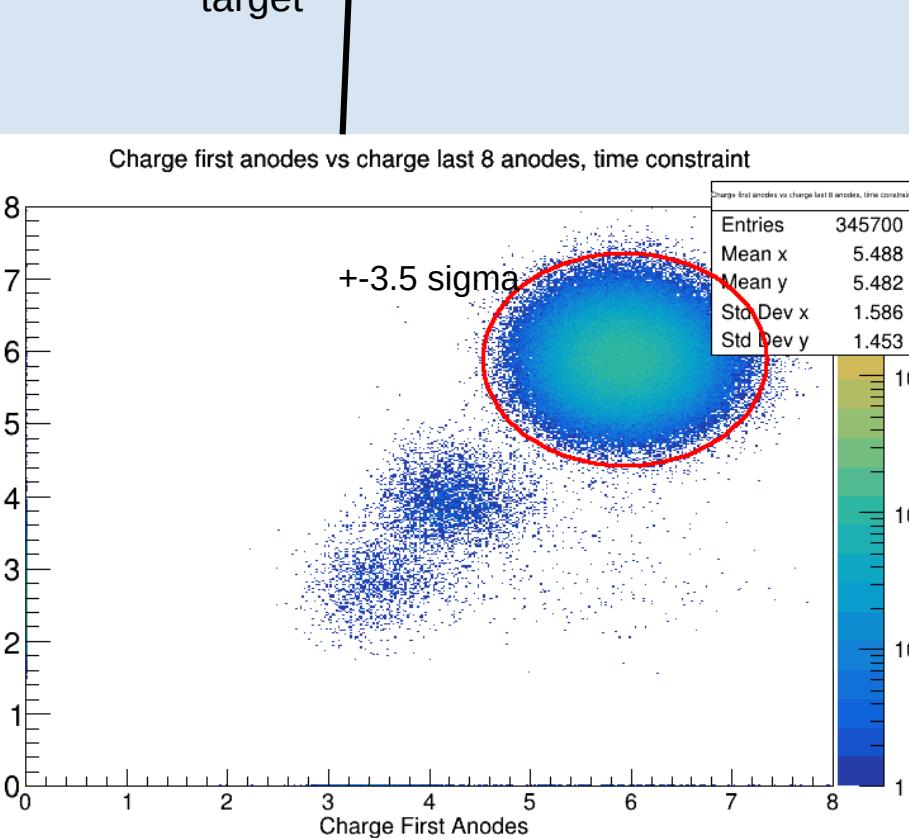
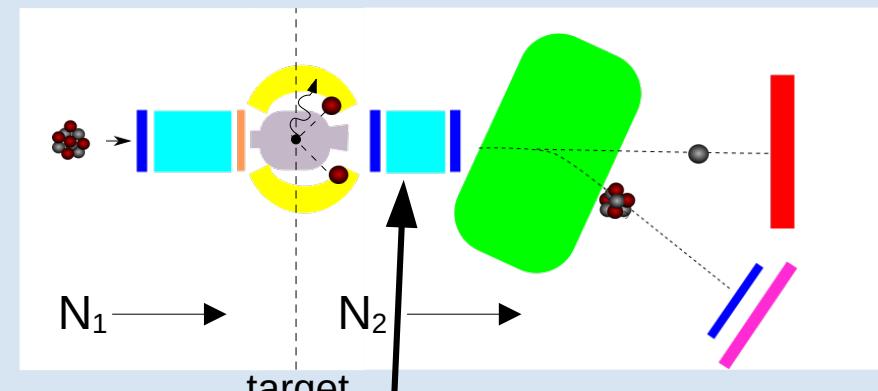
Assumption:

- Two body scattering can be approximated by the identical process for free particles
- ^{11}B acts only as spectator

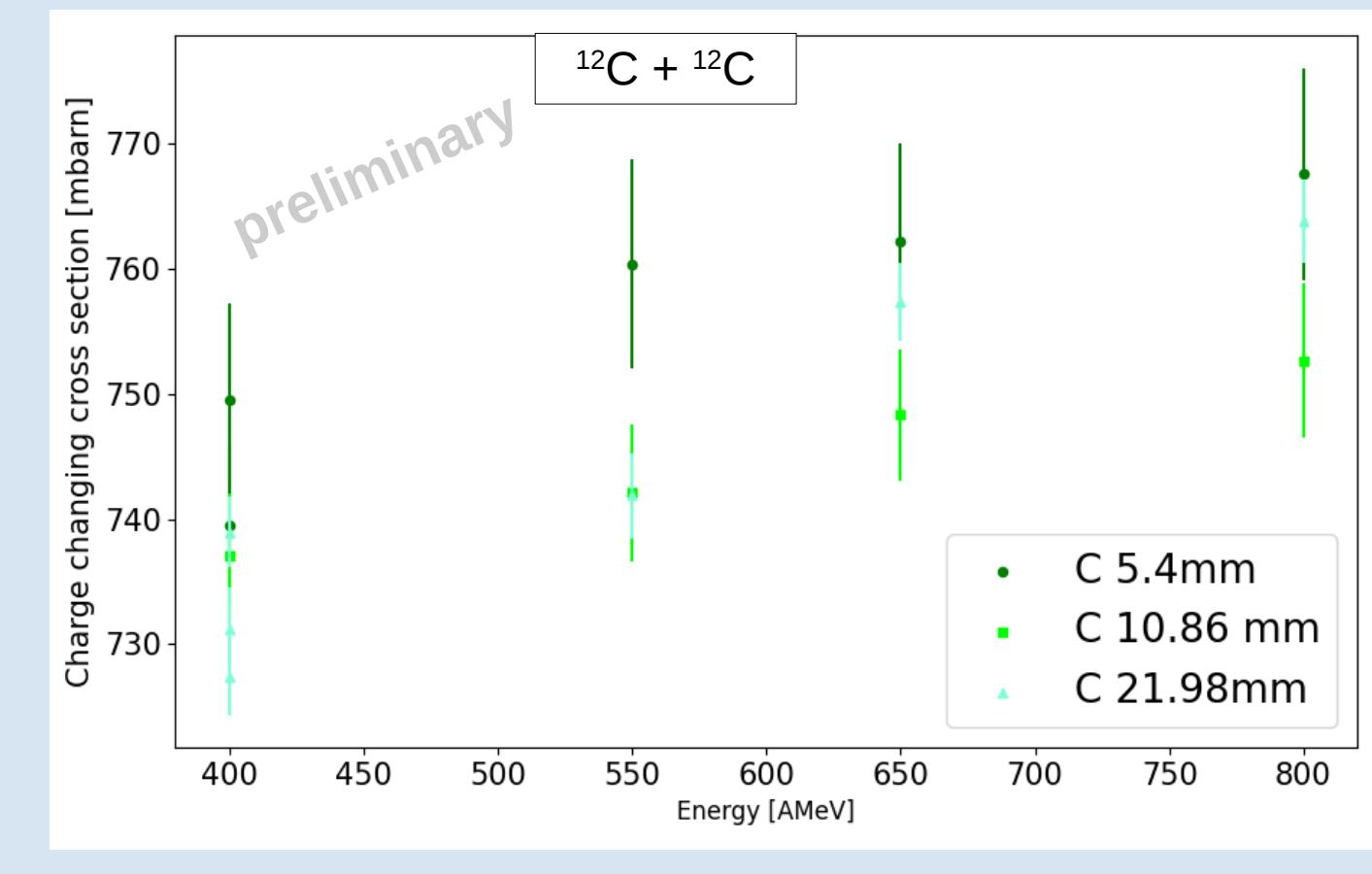


Qfs- reactions give access to single particle properties inside nucleus

Charge Changing Cross Section $^{12}\text{C} + ^{12}\text{C}$

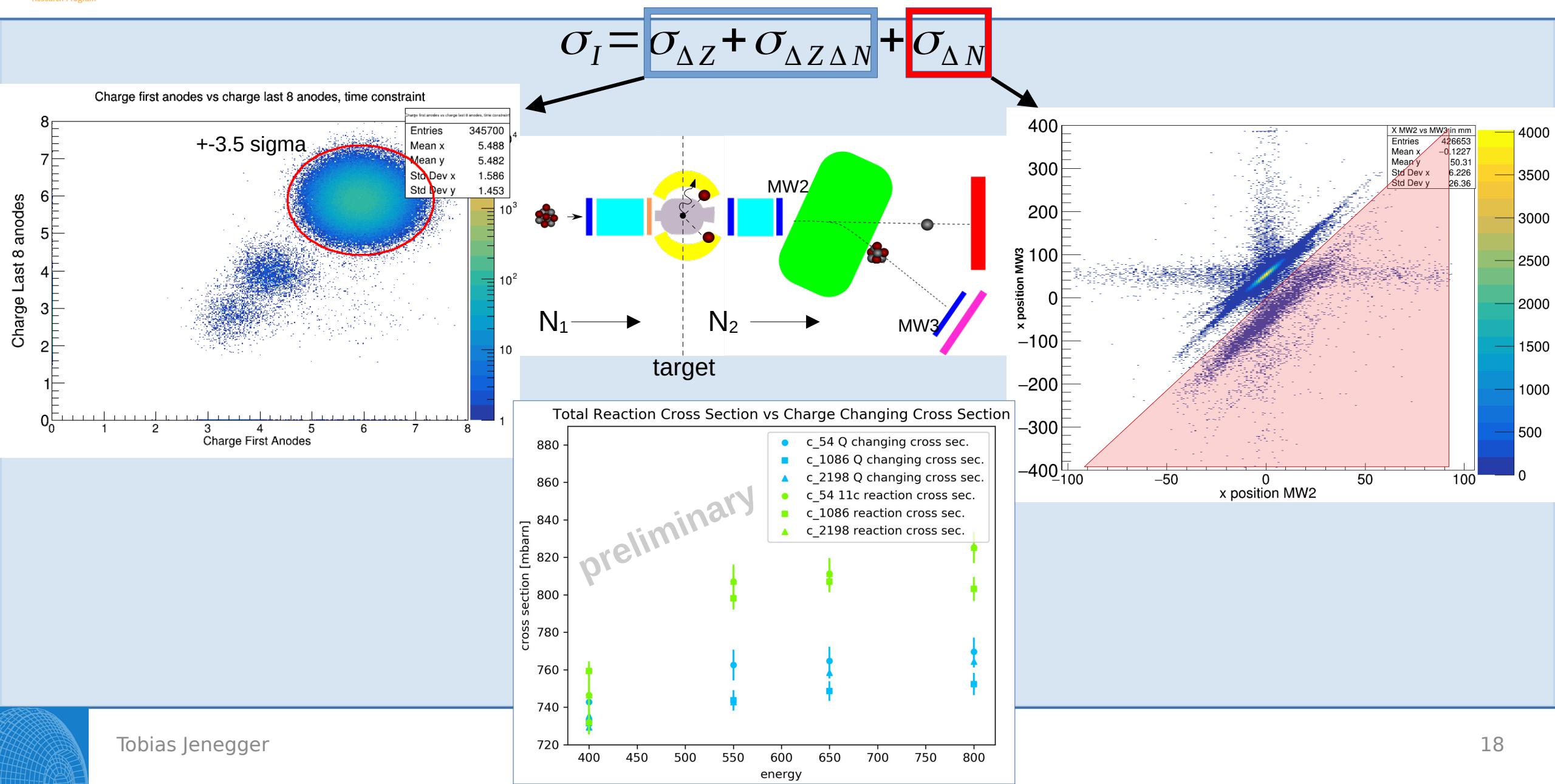


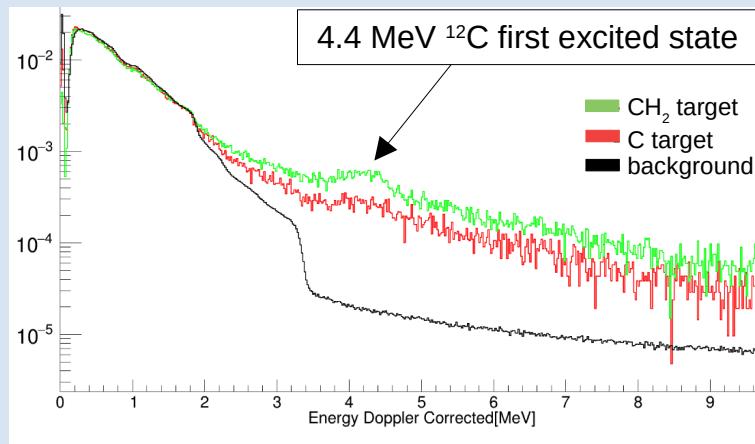
$$\sigma_{CC} = \sigma_{\Delta Z} + \sigma_{\Delta Z \Delta N}$$



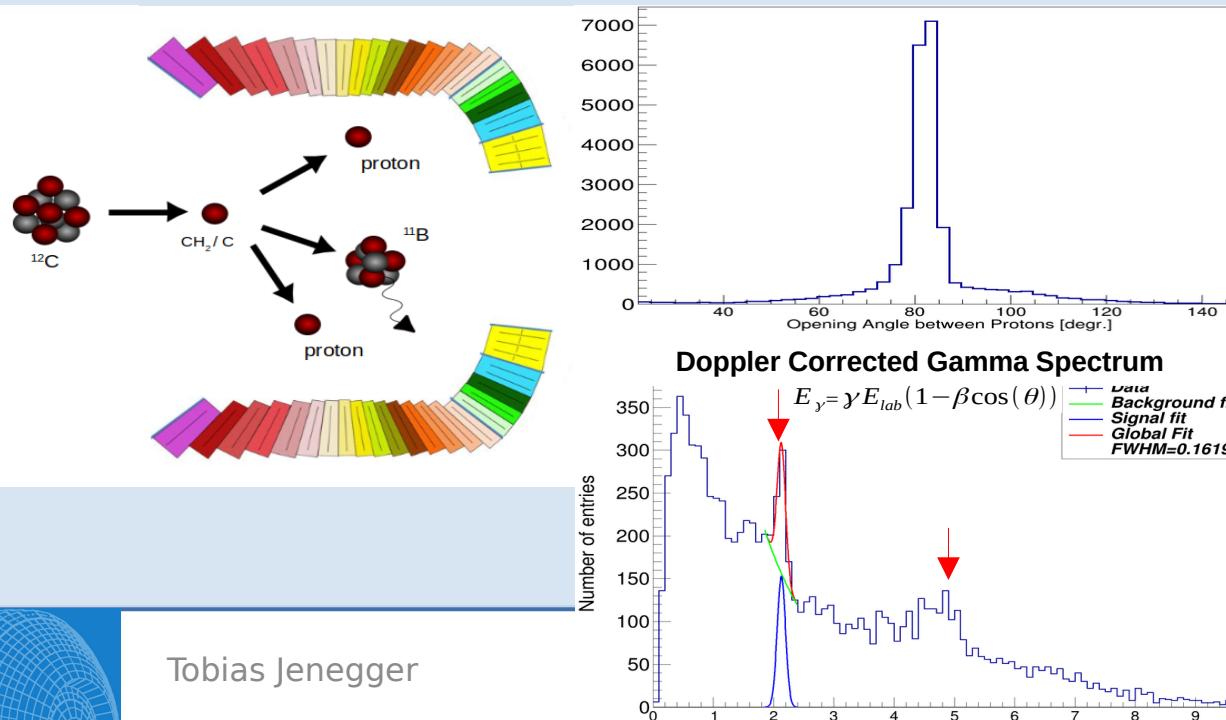
*statistical error-bars only

Total Reaction Cross Section $^{12}\text{C} + ^{12}\text{C}$

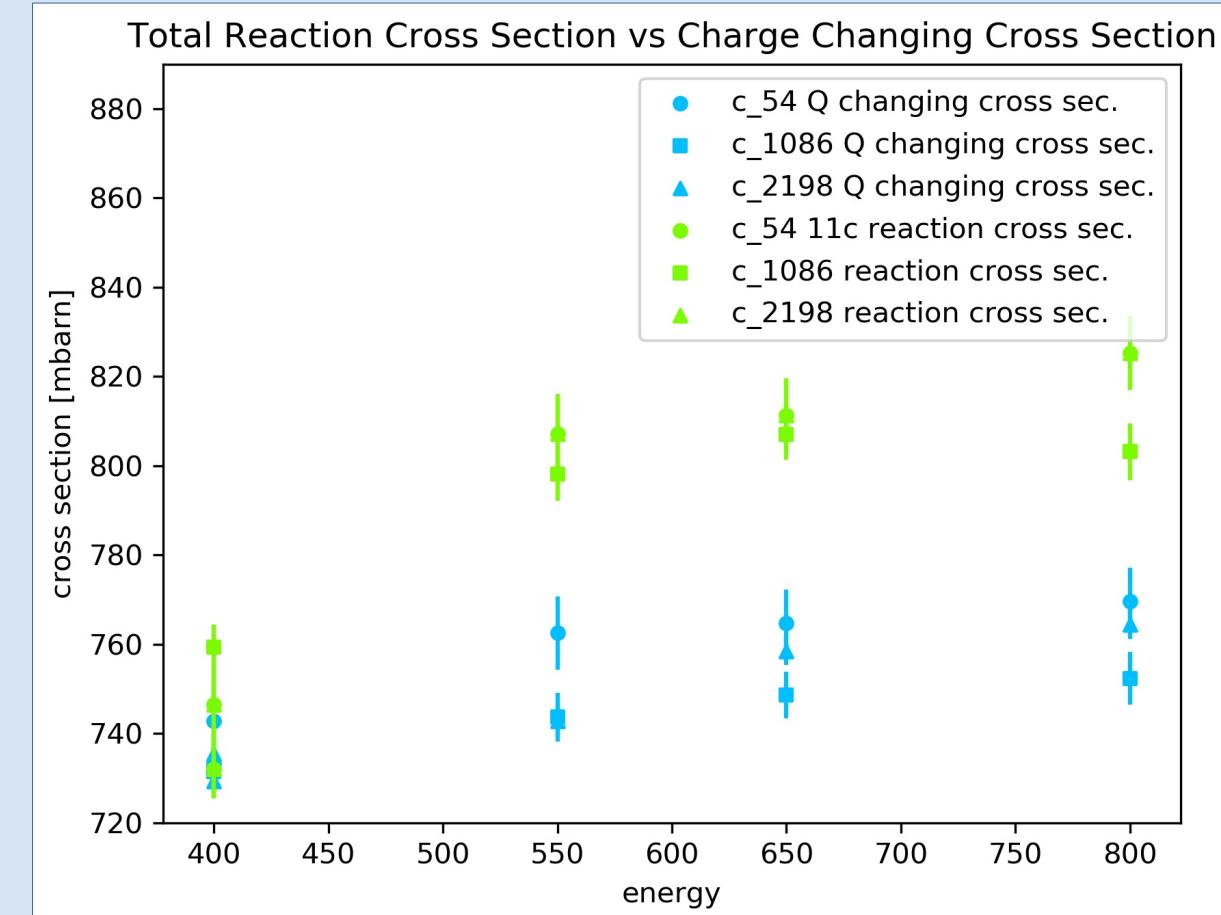




Quasi-free scattering $^{12}\text{C}(\text{p},\text{p})^{11}\text{B}$ reaction



$$\sigma_R = \sigma_{\text{inel}} + \sigma_I$$





Thank you!

CALIFA @ Technical University of Munich (TUM)

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BACKUP

Incoming Ions – Event Selection

Strict cuts in front of the target:

