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

Experiment S444 (2020)

Tobias Jenegger

R³B Collaboration Meeting 2024

S444/S467 - Detector Setup

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

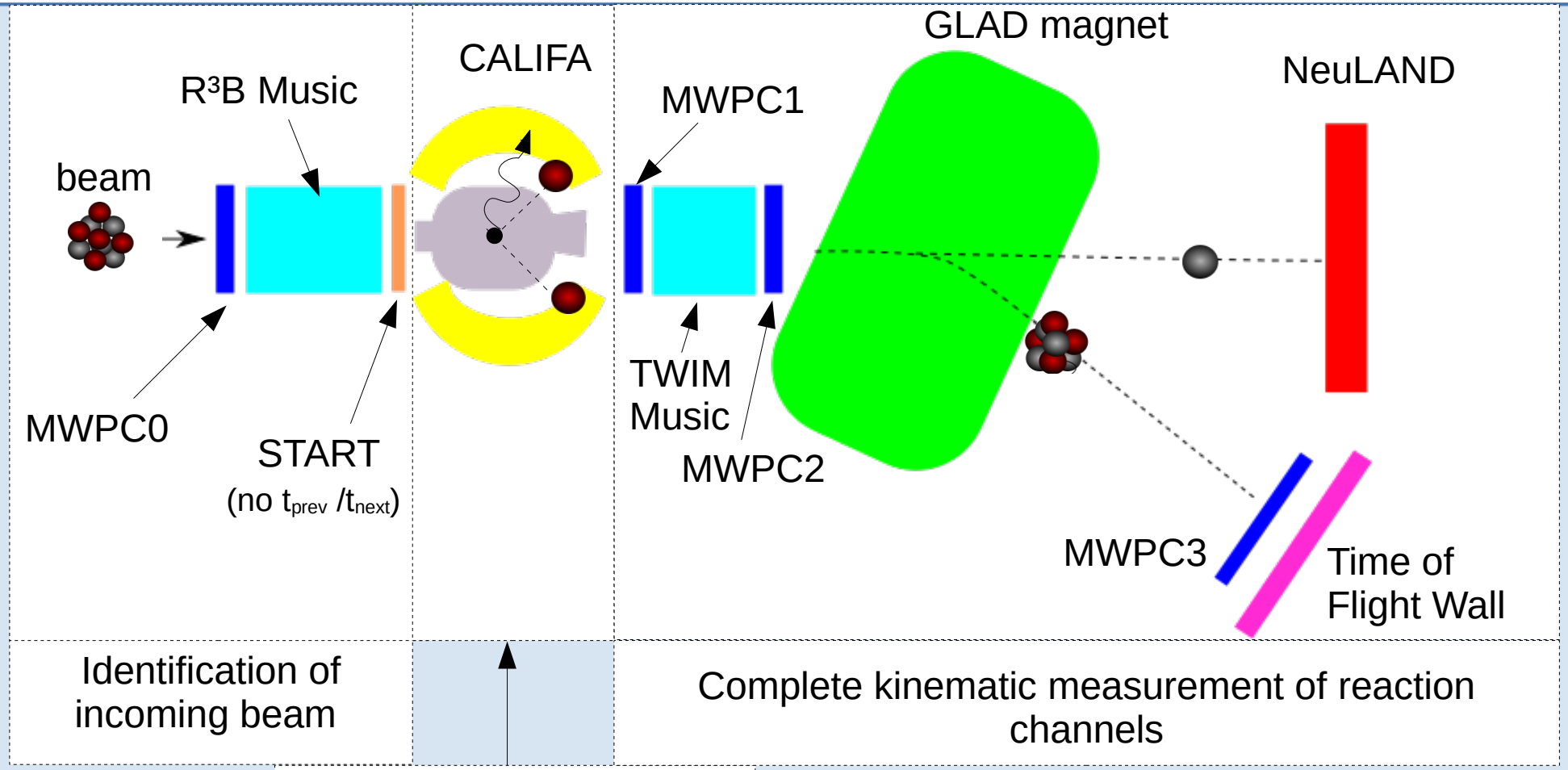
Reaction Cross Section Measurement

Summary & Outlook

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2094 – 390783311,
BMBF 05P19WOFN1, 05P21WOFN1
and the FAIR Phase-0 program

Roman Gernhäuser,Lukas Ponnath,Philipp Klenze,Tobias Jenegger

S444 Commissioning Experiment 2020



Beam energy:
400/550/650/800 AMeV

Projectile: ^{12}C

Target: C and CH_2

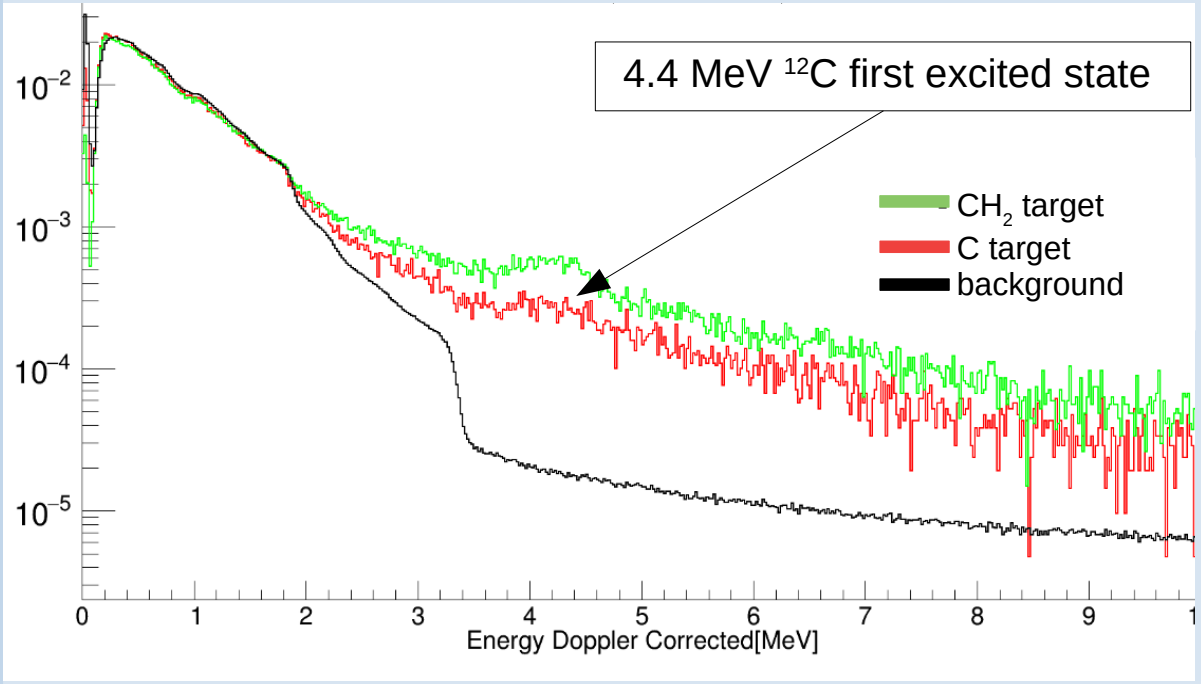
Reaction Processes $^{12}C + ^{12}C$

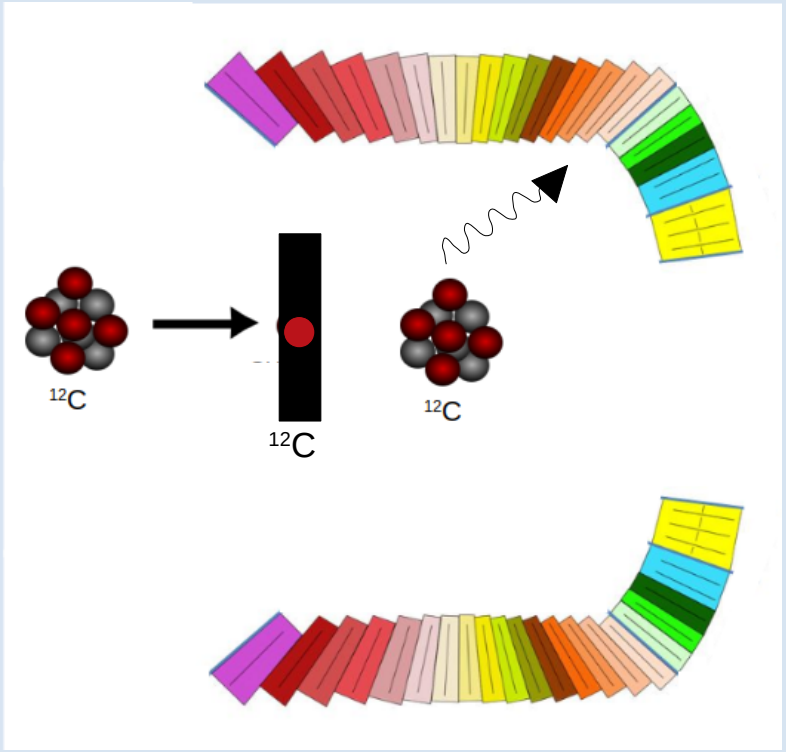
Contributions to the total reaction cross section:

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

σ_{inel} Projectile is excited to bound state. No nucleon is removed

is small at high beam energies &
suppressed due to Pauli blocking





Precise efficiency study of 4.4 MeV ^{12}C excited state (AmBe source) on CALIFA done by Philipp Klenze

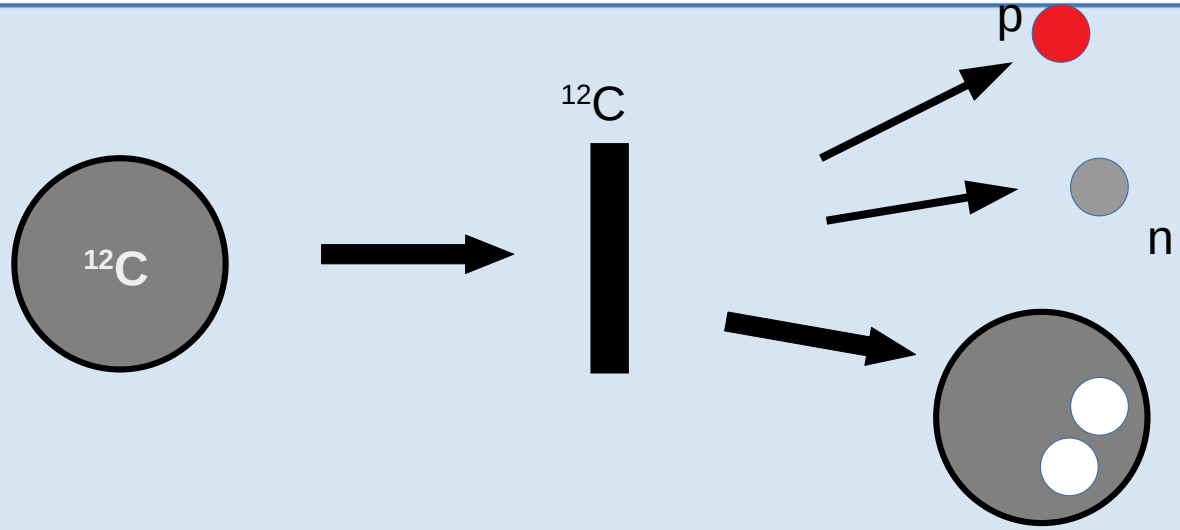
Reaction Processes $^{12}C + ^{12}C$

Interaction Cross Section σ_I

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

charge changing pure neutron removal

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



$\tilde{\sigma}_{\Delta Z}$	$Z_i \neq Z_f$	$N_i = N_f$	charge changing
$\tilde{\sigma}_{\Delta Z \Delta N}$	$Z_i \neq Z_f$	$N_i \neq N_f$	charge changing
$\tilde{\sigma}_{\Delta N}$	$Z_i = Z_f$	$N_i \neq N_f$	pure neutron removal
$\tilde{\sigma}_0$	$Z_i = Z_f$	$N_i = N_f$	

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

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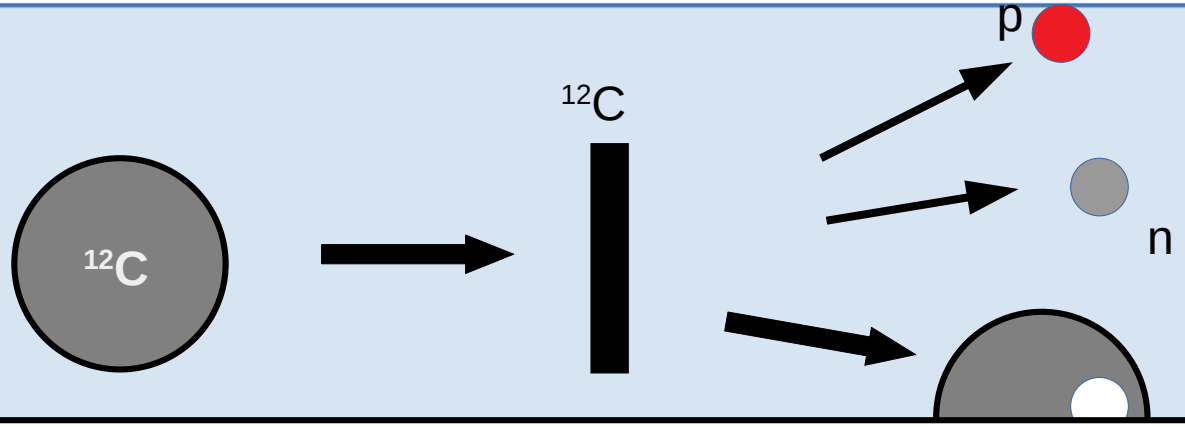
$\tilde{\sigma}_0$	$Z_i = Z_f$	$N_i = N_f$

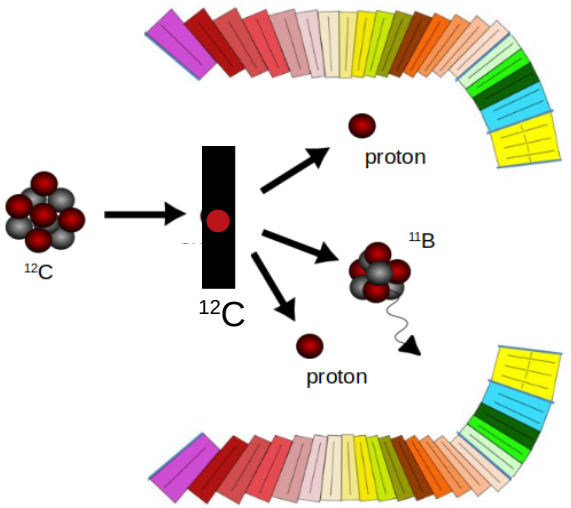


In case of proton like target (LH_2, CH_2):

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

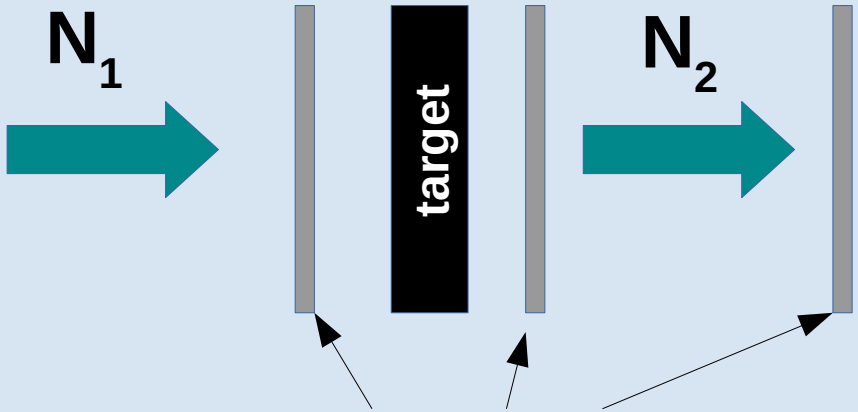
- Two body scattering can be approximated by the identical process for free particles
- Qfs- reactions give access to single particle properties inside nucleus

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



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

clean incoming ions: **unreacted/survived ions:**



Transmission method:

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

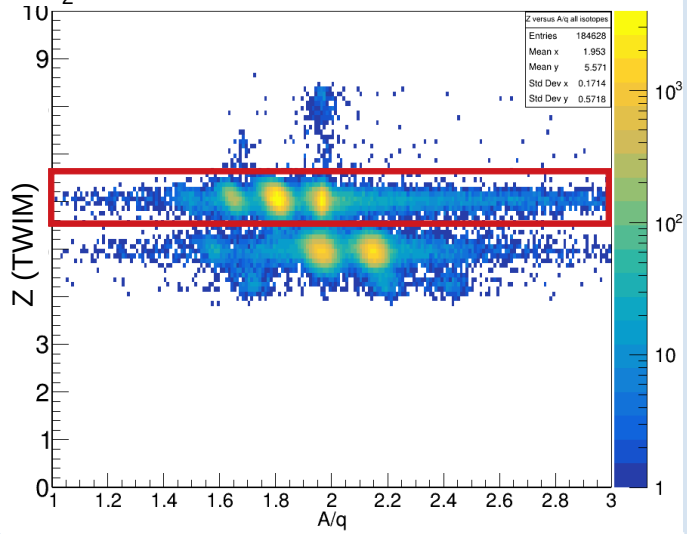
N_t: $\frac{\#\text{scattering centers}}{\text{volume}}$

Correct for reactions inside exp. setup

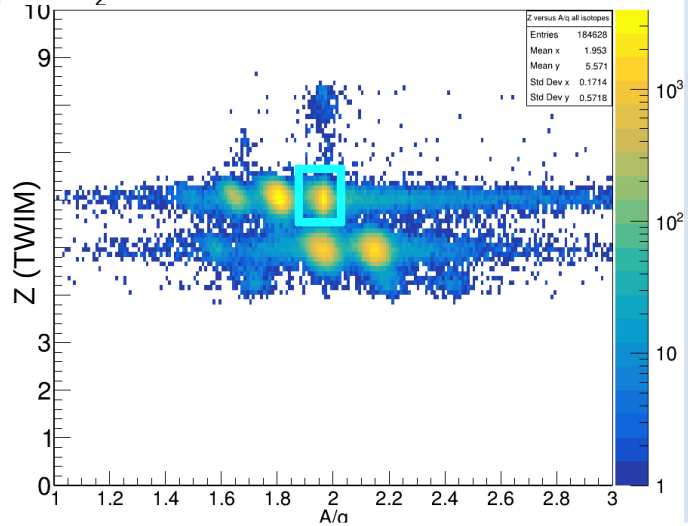
$$N_2 = \left(\frac{N_2^E}{N_1^E}\right) N_1 e^{-N_t \sigma}$$

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

N_2 for charge changing cross section



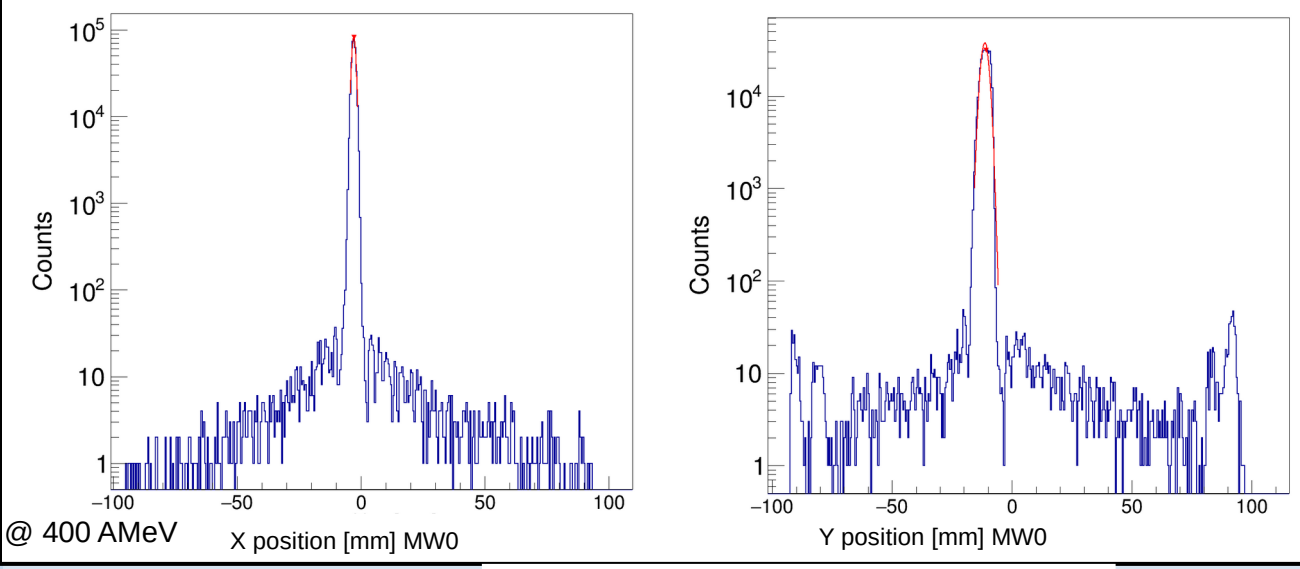
N_2 for total reaction cross section

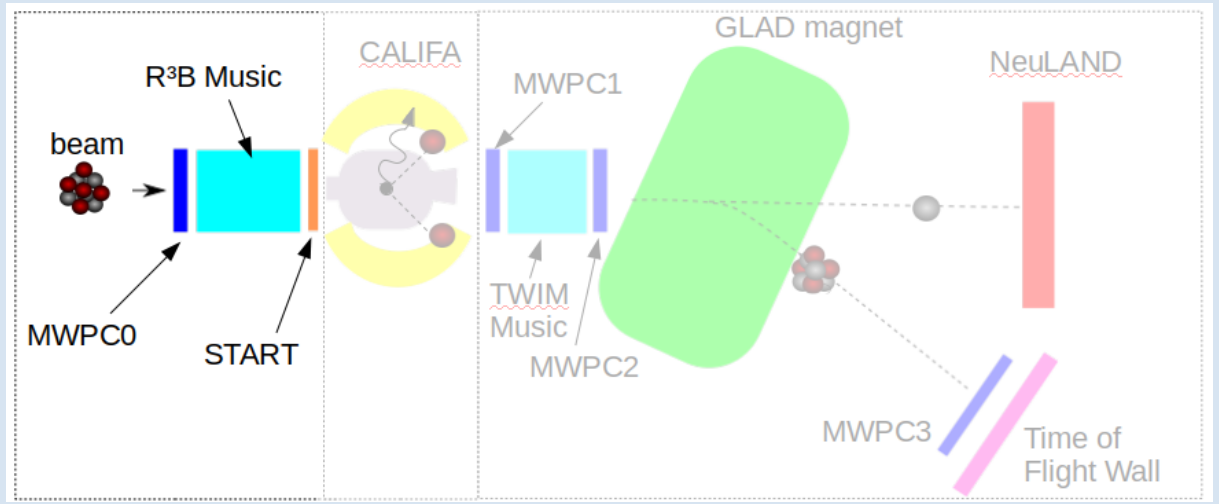


*Min. bias downscaled

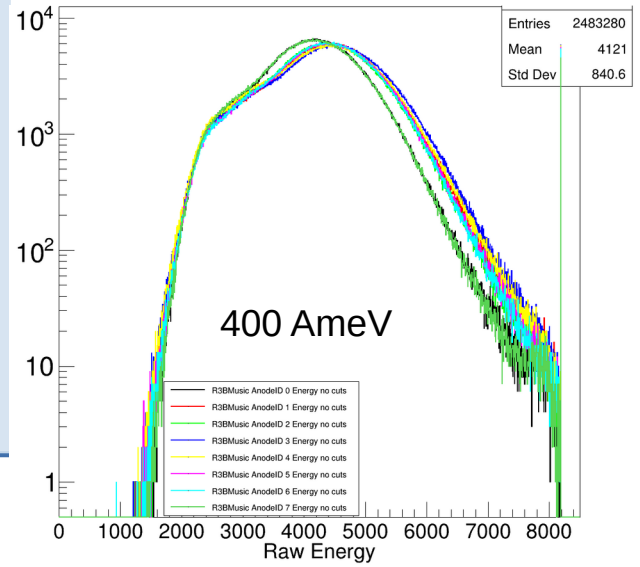
Identification of the Incoming Ions

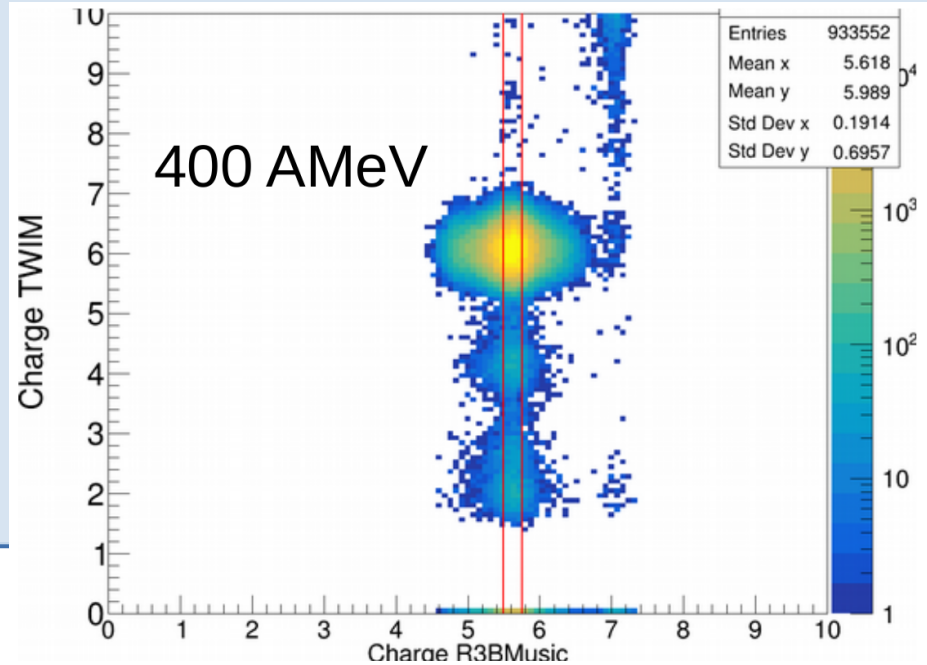
one σ cut on x-y MW0 position



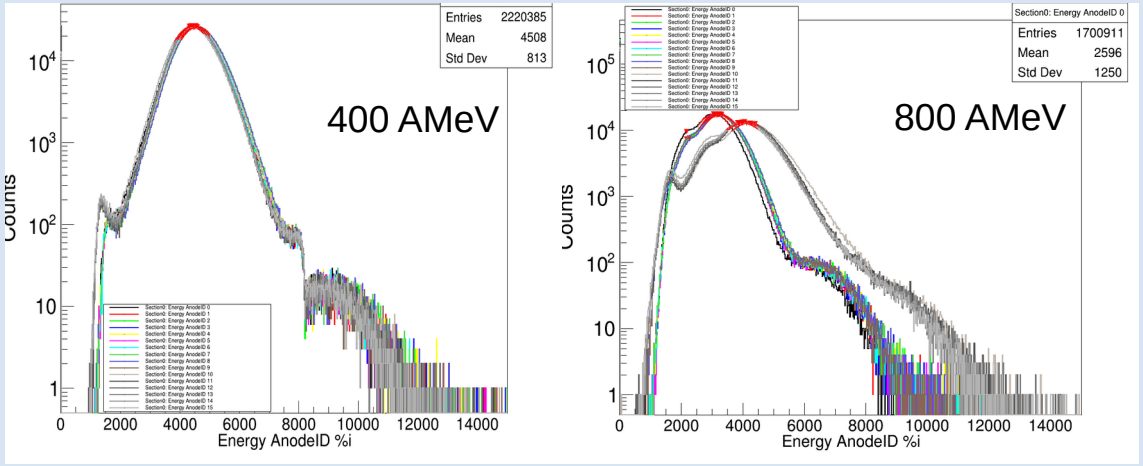


Raw ADC R3BMusic

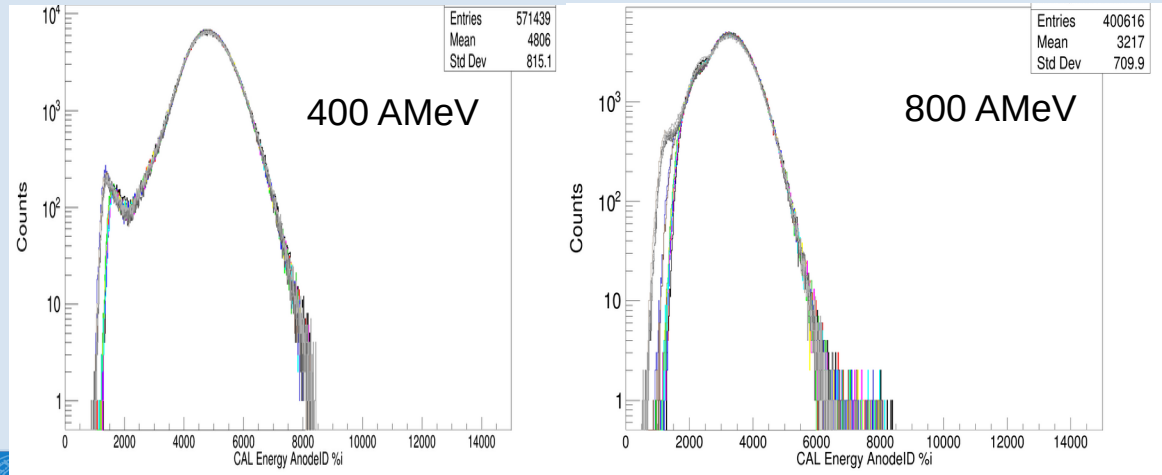




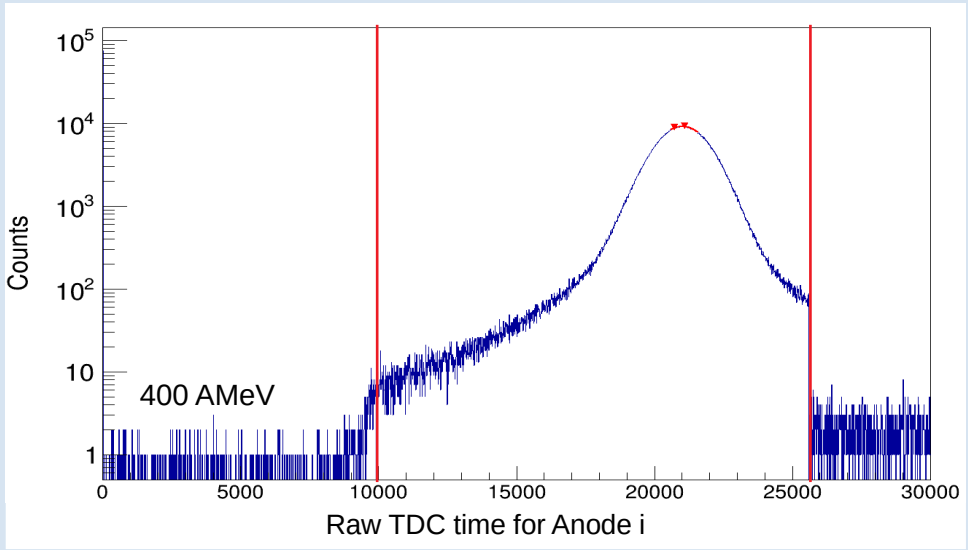
Charge Measurement in TWIM Music



calibration

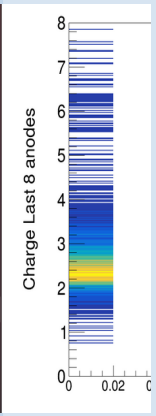


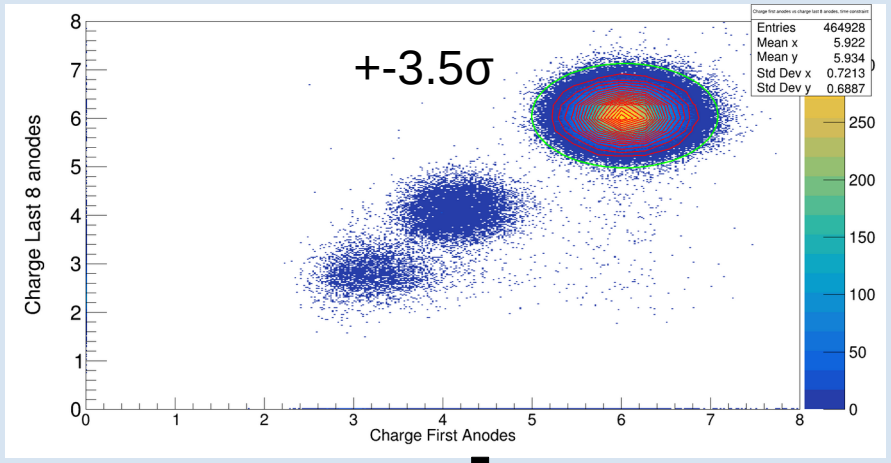
1. Calibrate Energies (using ref. anode)
2. Look at raw tdc time of each anode, discart anode hit if below 10000 or above 25500 raw tdc channel
3. For events with multiple hits in one anode: select hit which is the closest to the mean raw tdc time

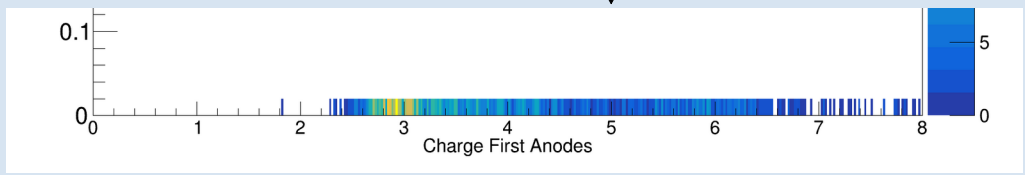


Multi hit events (with/without target)
→ 400 AmeV: 3.4/3.7 %
→ 550 AmeV: 0.5/0.6%
→ 650 AmeV: 0.5/0.5%
→ 800 AmeV: 17/19%

Charge Changing Cross Section

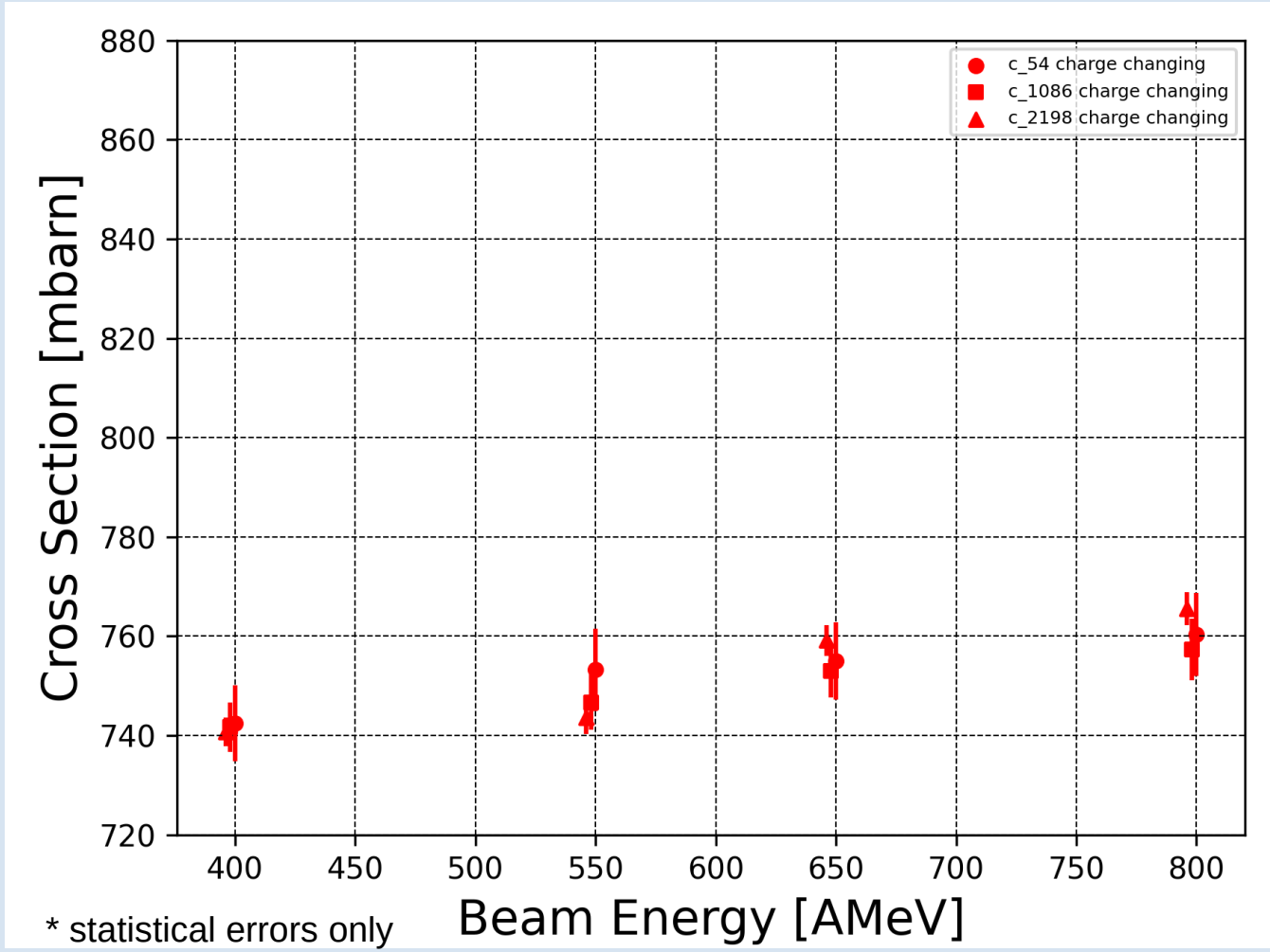






$$\sigma = -\frac{1}{N_t}\ln\left(\frac{N_2/N_1}{N_2^E/N_1^E}\right)$$

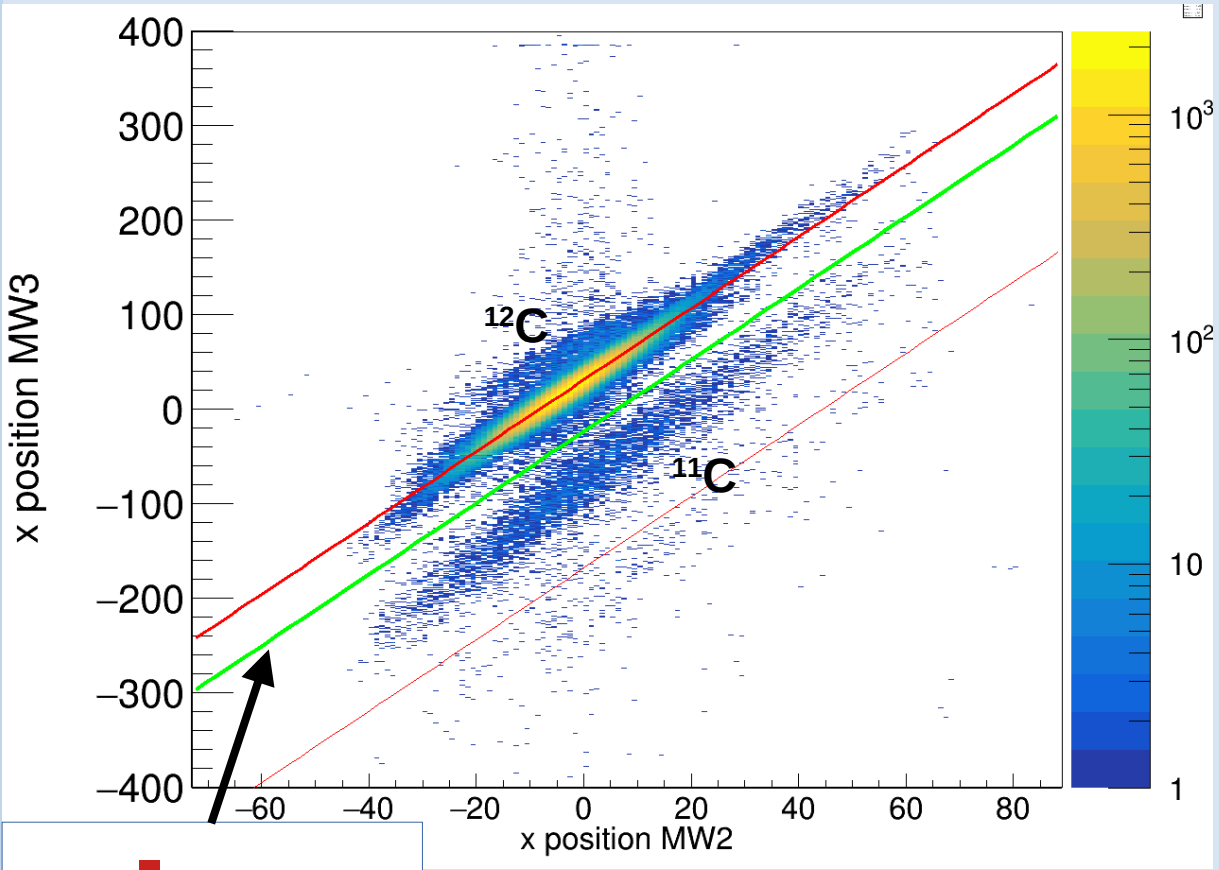
where N_2 = carbon isotopes detected in TWIM

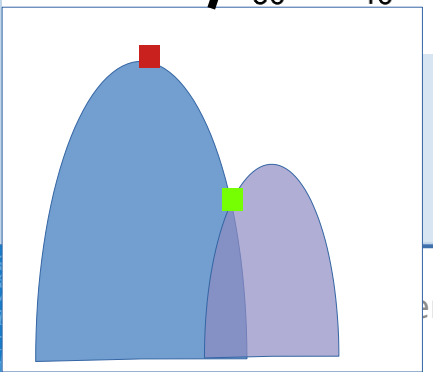


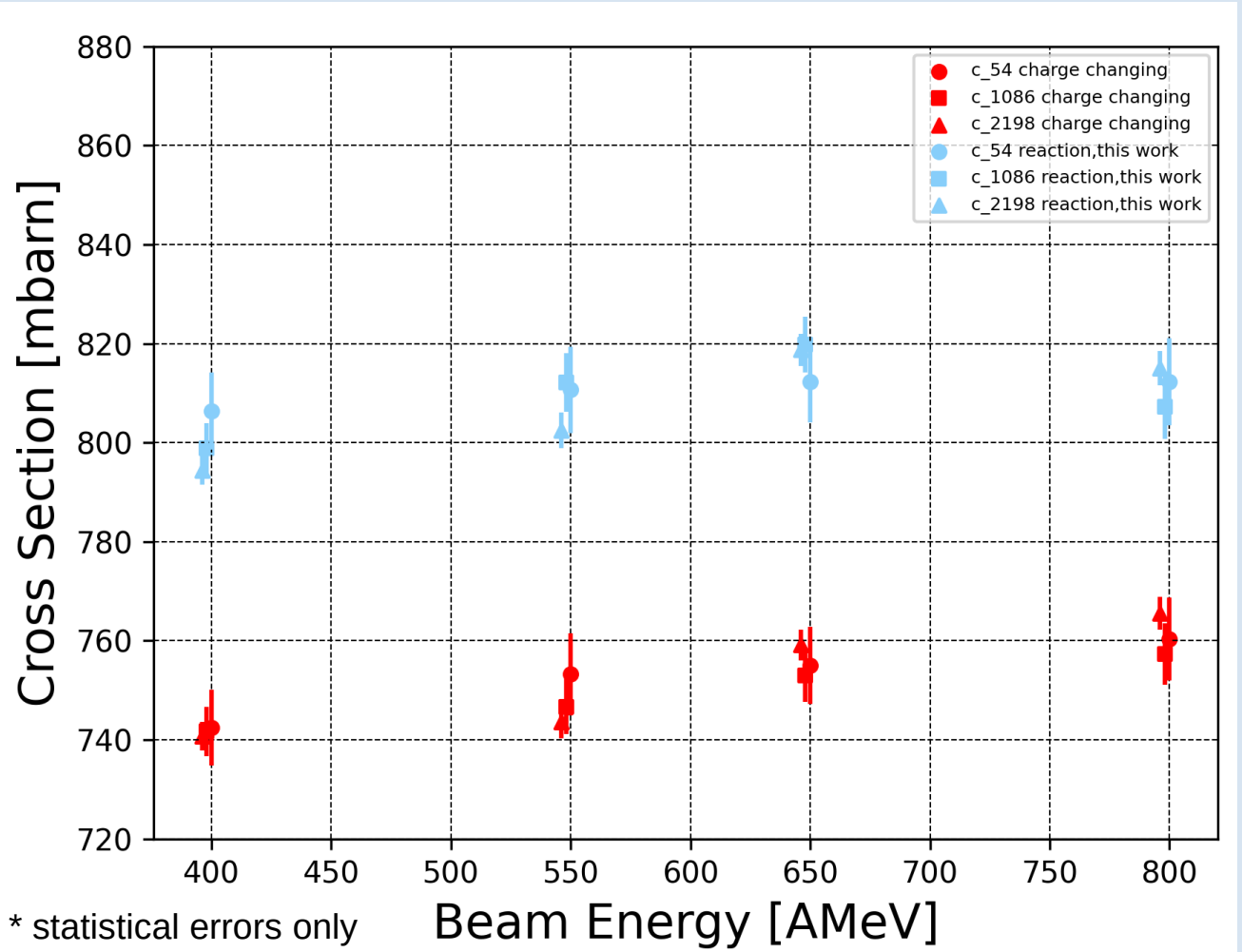
* statistical errors only

$^{12}C/^{11}C$ disentanglement

Use R^{3}B Setup as Mass Spectrometer:







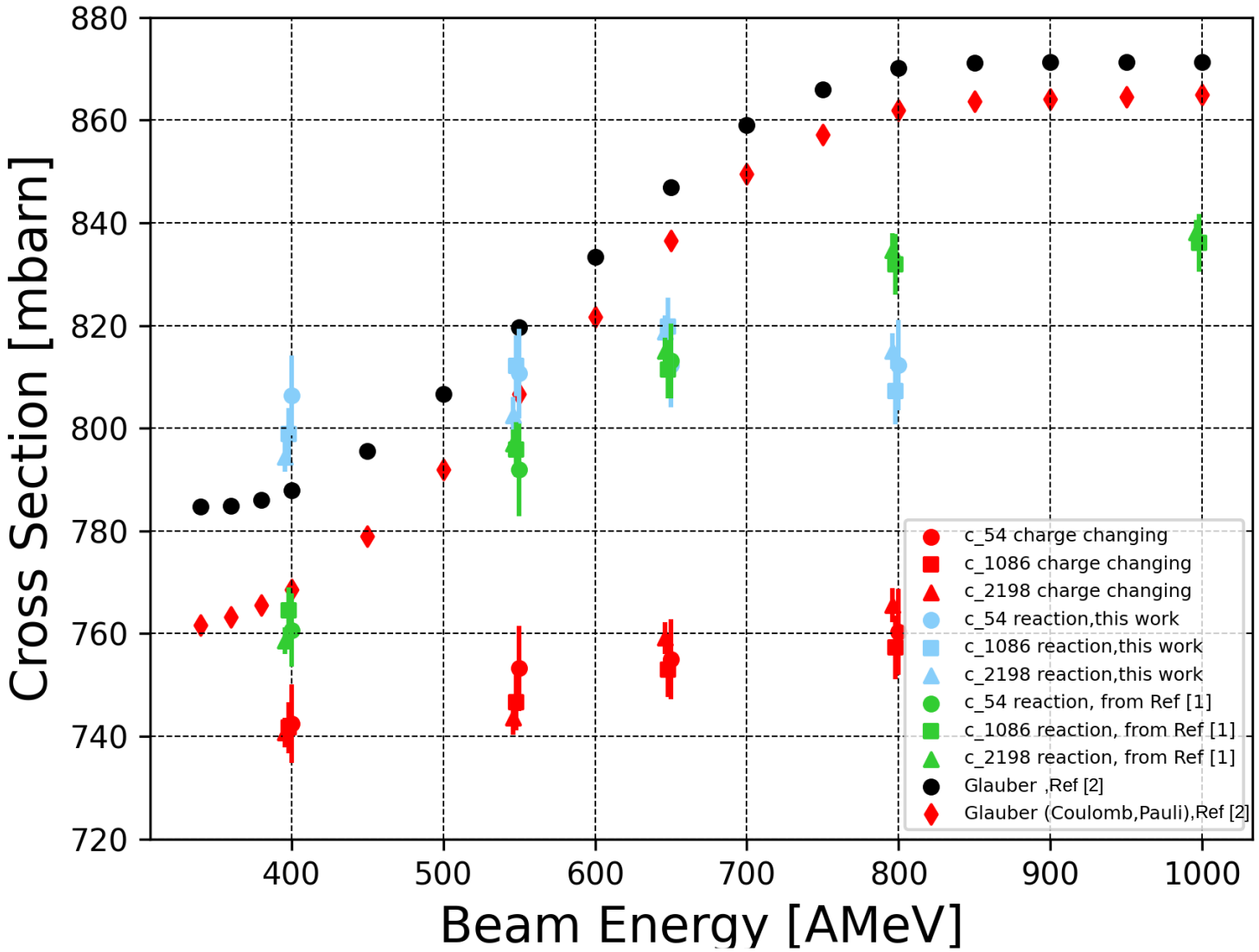
* statistical errors only

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

Reaction Cross Section Measurement

σ_I measured in this analyis seems to be almost constant for a broad energy range

Did we miss out something?

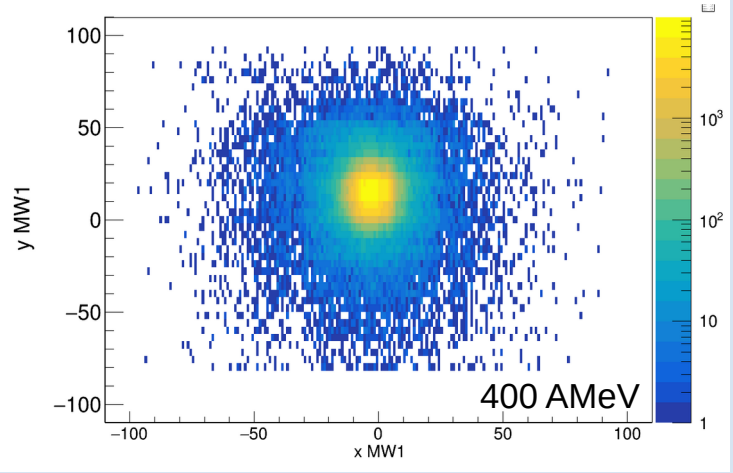


[1] L.Ponnath et al., “Measurement of nuclear interaction cross sections towards neutron-skin thickness determination”,Physics Letters B, Vol 855, August 2024

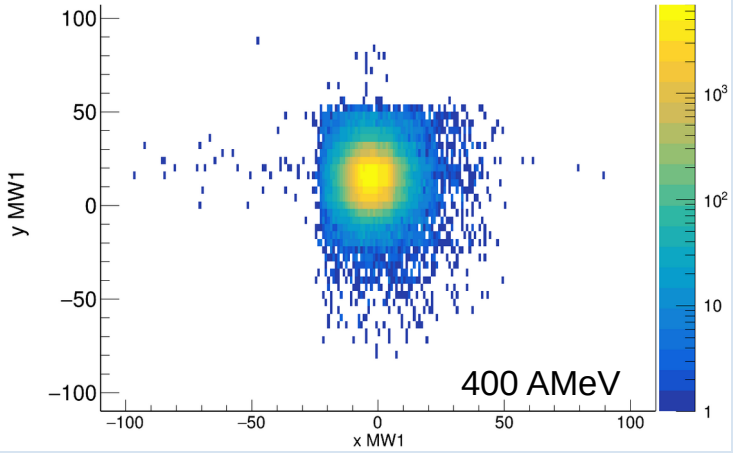
[2] E. Teixeira, T. Aumann, C. Bertulani, and B. Carlson, “Nuclear fragmentation reactions as a probe of neutron skins in nuclei,” The European Physical Journal A, vol. 58, no. 10, pp. 1–16, 2022

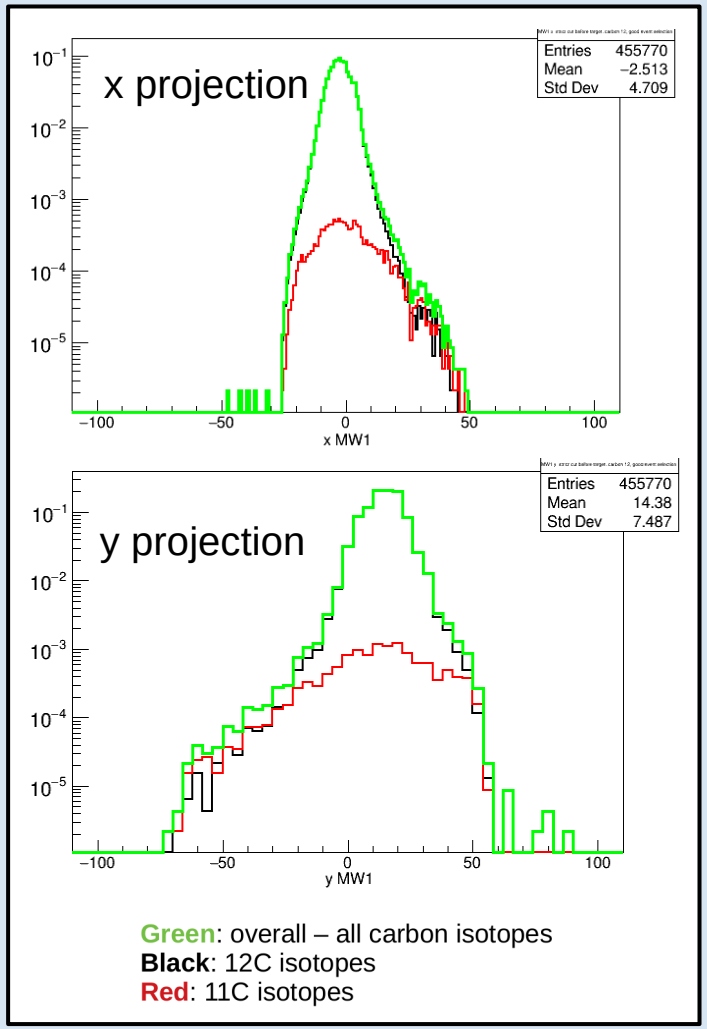
TWIM Geometric Acceptance - Correction

MW1 xy-distribution no cut after target

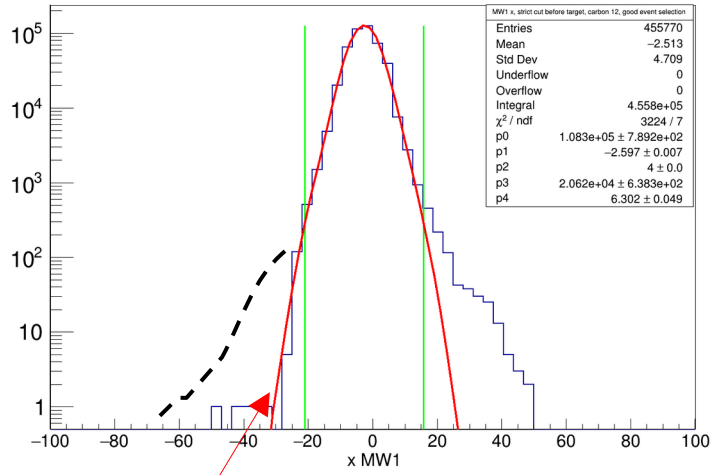


With cut TWIM charge = 6

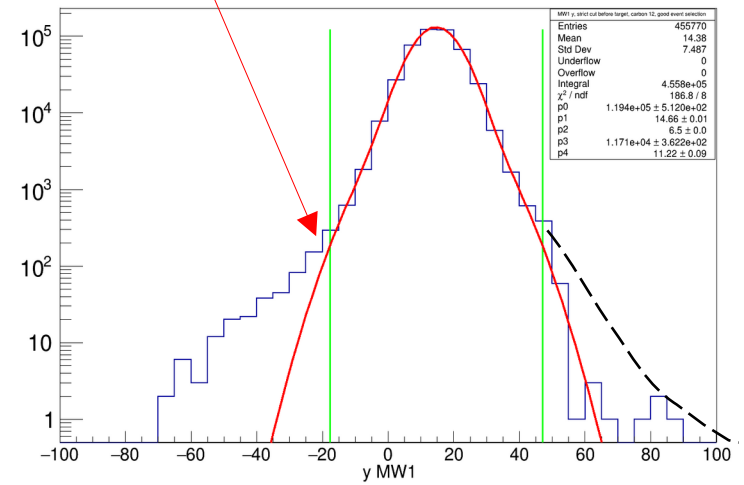




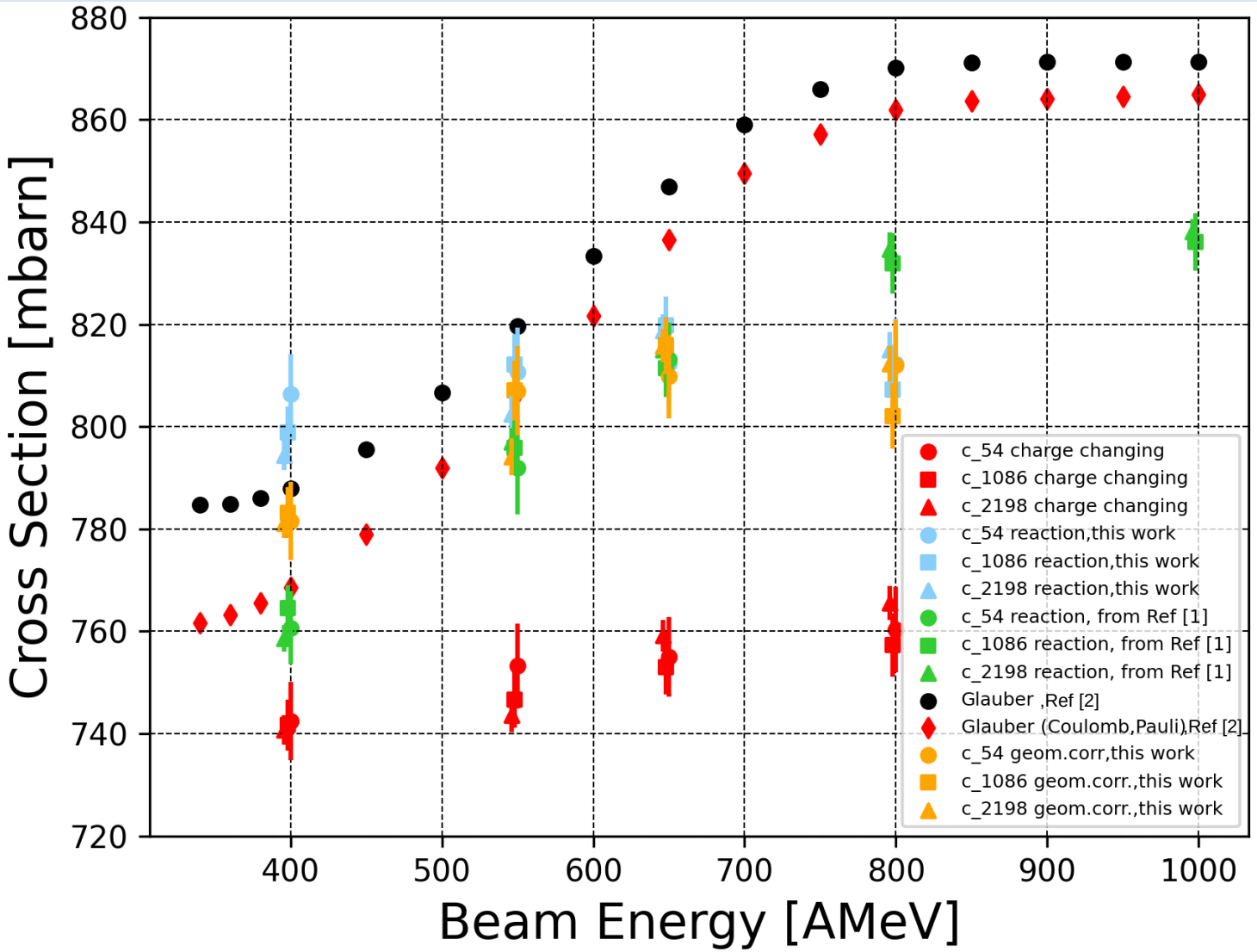
Reconstruction of ^{12}C



double gaussian function fit



Preliminary Results & Outlook



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Thank you!

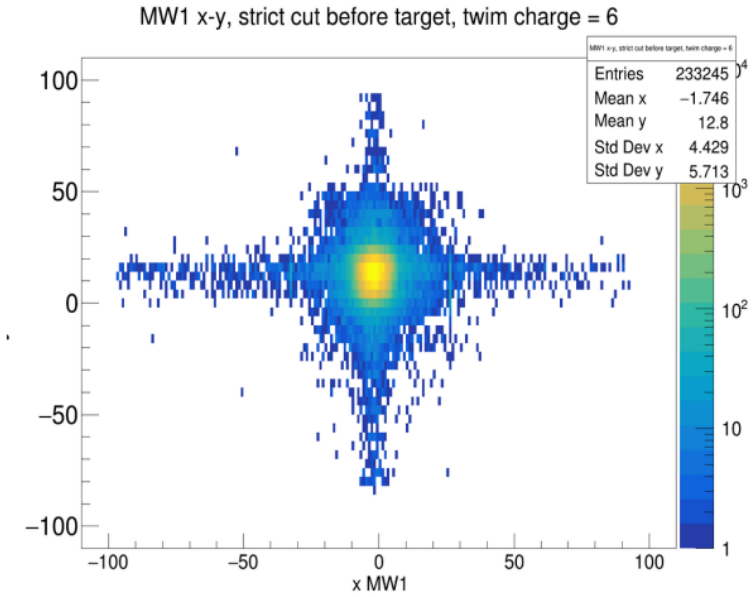
CALIFA @ Technical University of Munich (TUM)

Roman Gernhäuser, Lukas Ponnath, Philipp Klenze, Tobias Jenegger

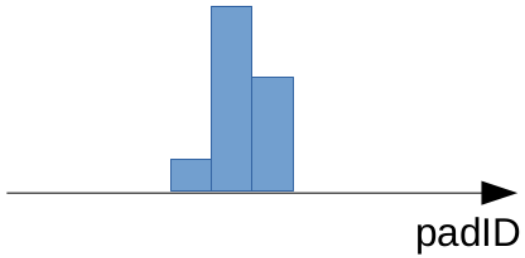
GEFÖRDERT VOM

BACKUP

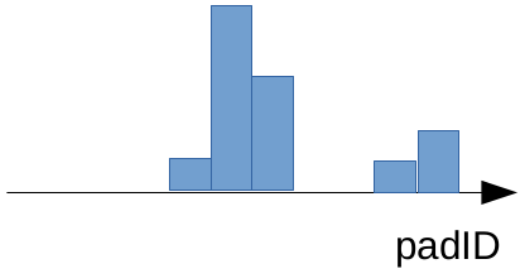
First Step: remove horizontal/vertical lines



To do this, I only select events with contiguous hits in MW1 mapped level:



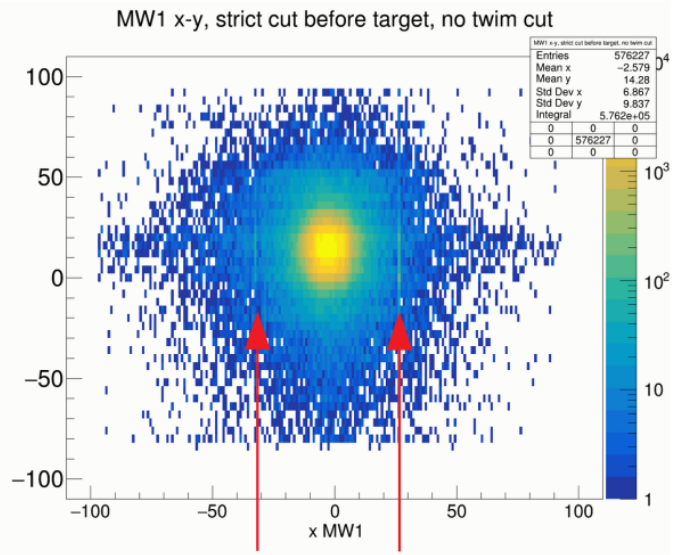
Event ok



Event not ok

MWPC – treatment II

Second Step: remove noisy pads (24 & 43)

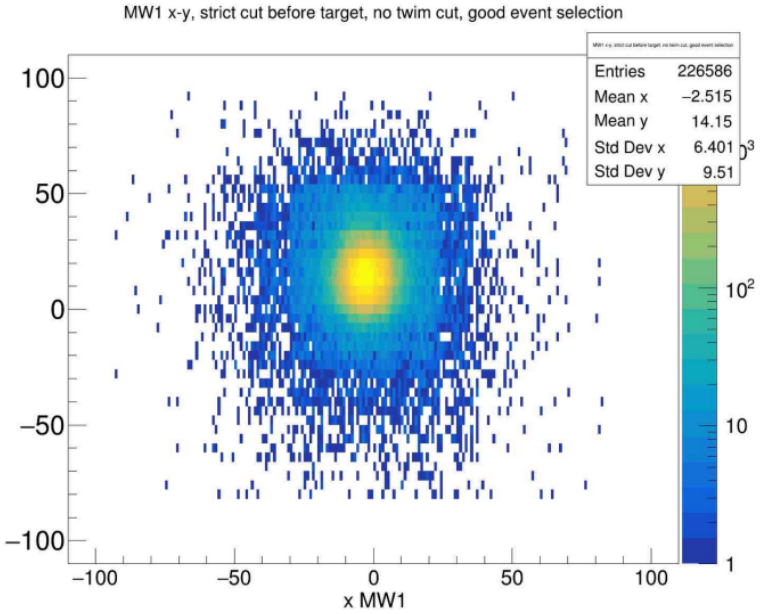


Set condition:

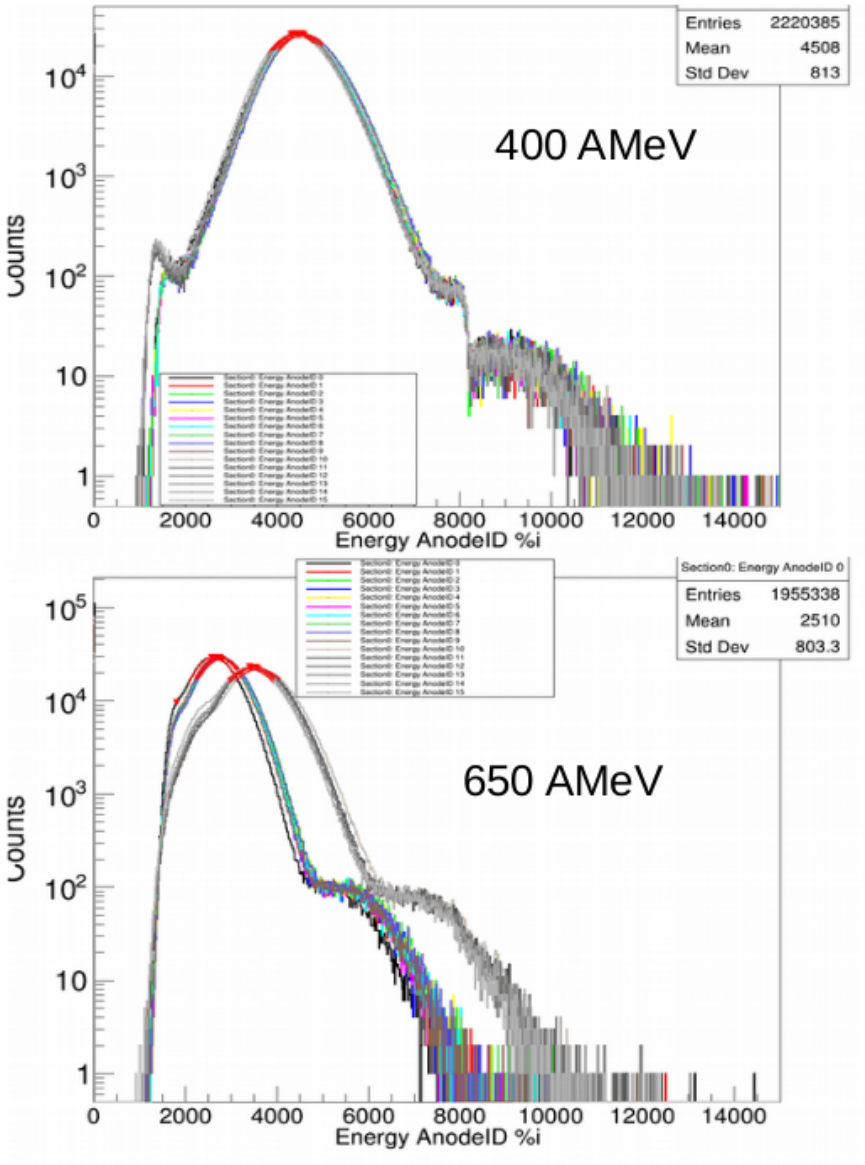
If pad with max_charge = 24 | 43

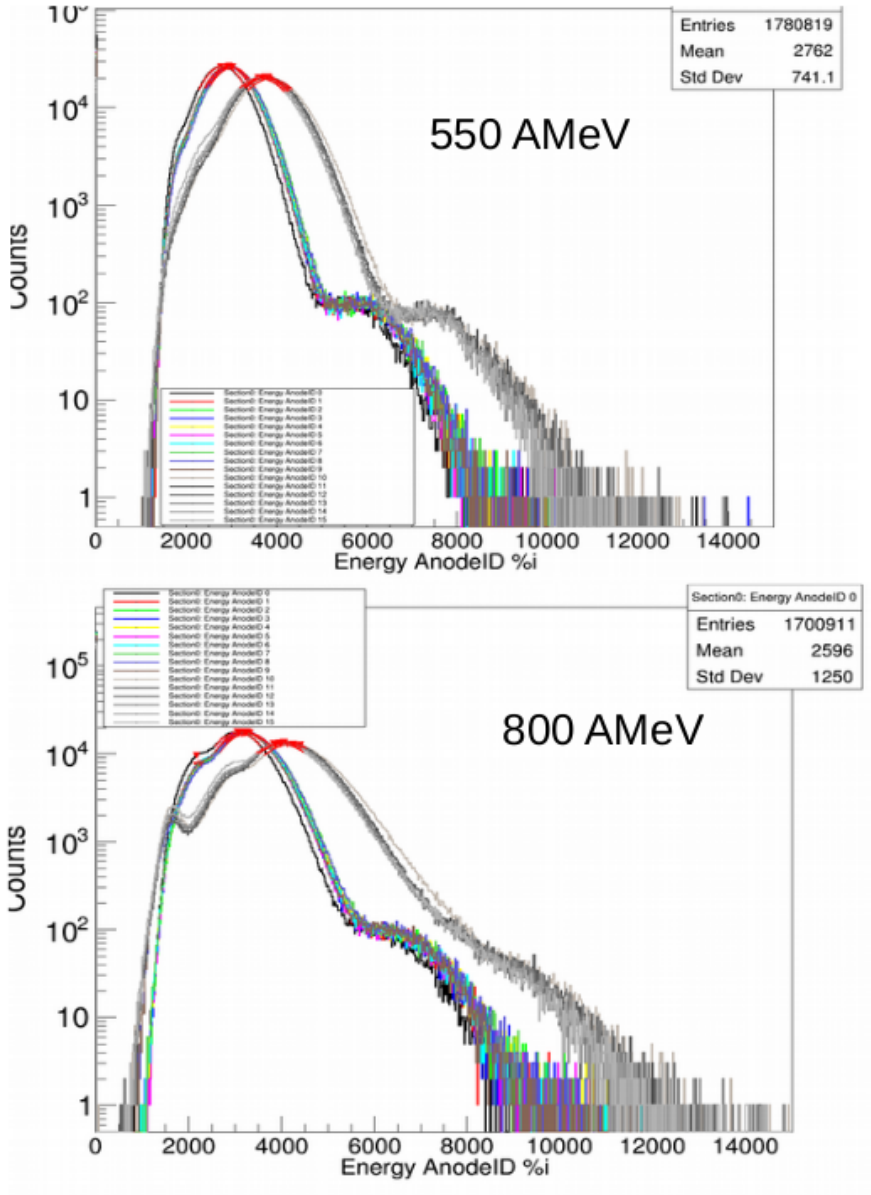
→ they need at least one neighbor pad that was also fired

after:

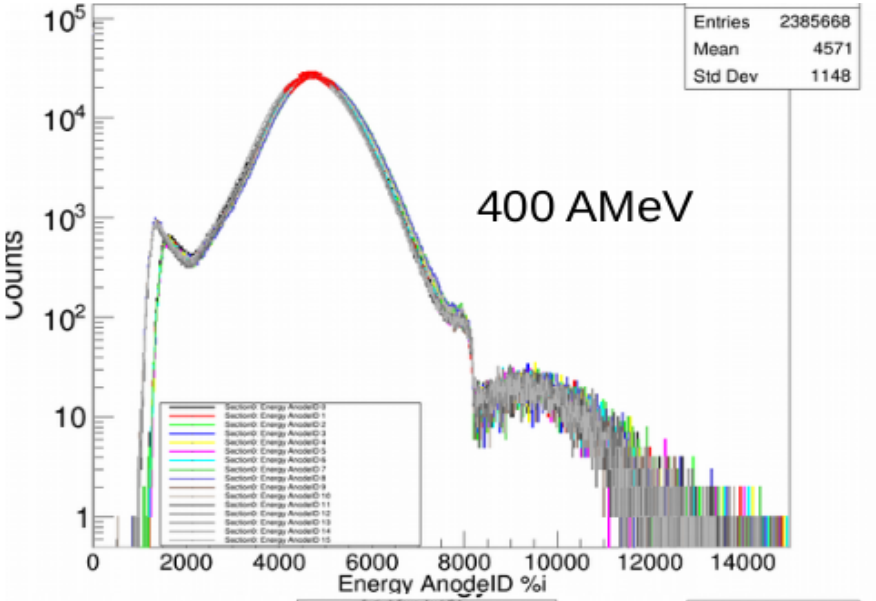


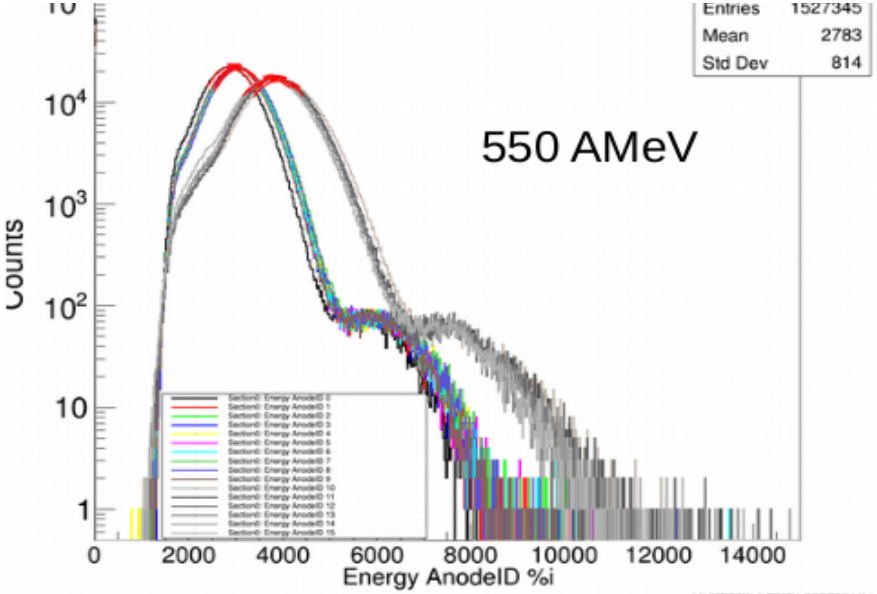
TWIM Mapped Energy – Anodes – Empty Runs

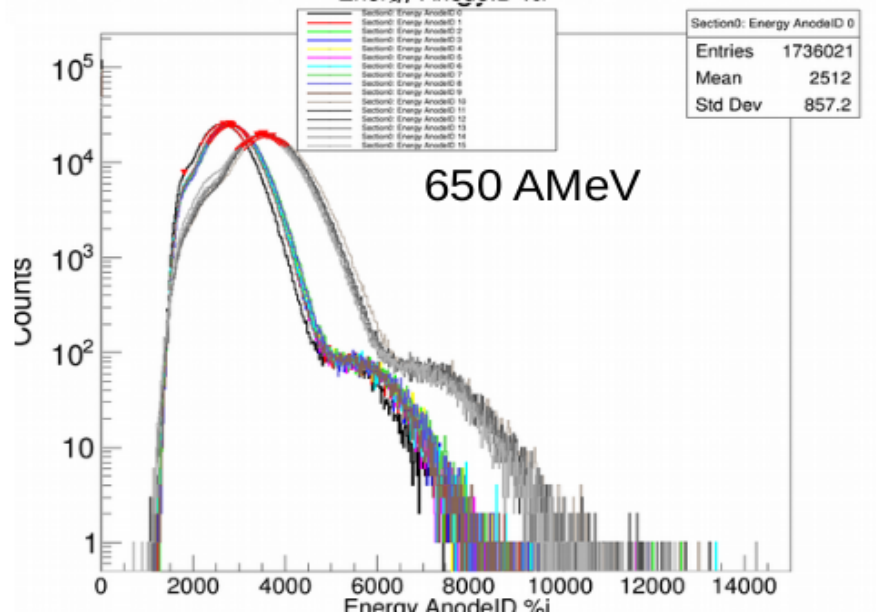


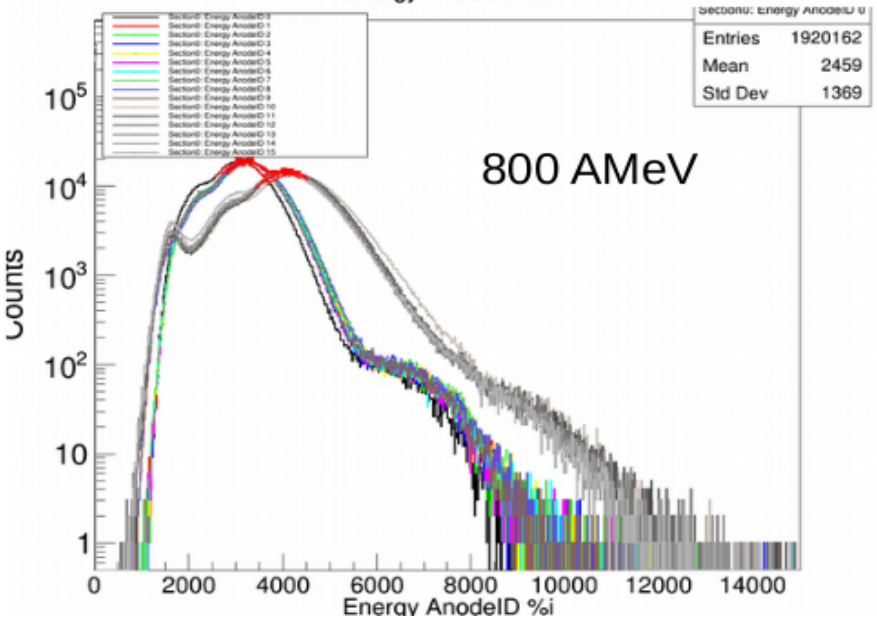


TWIM Mapped Energy – Anodes – Target Runs

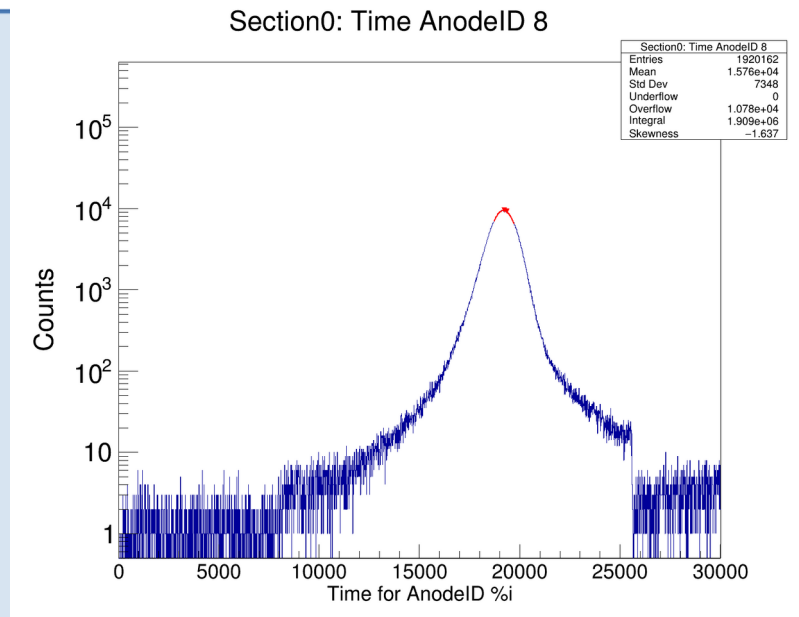


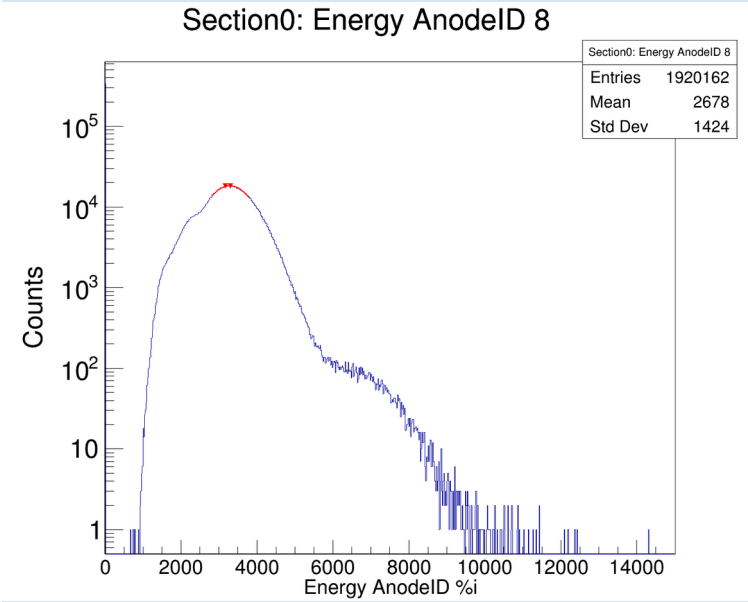


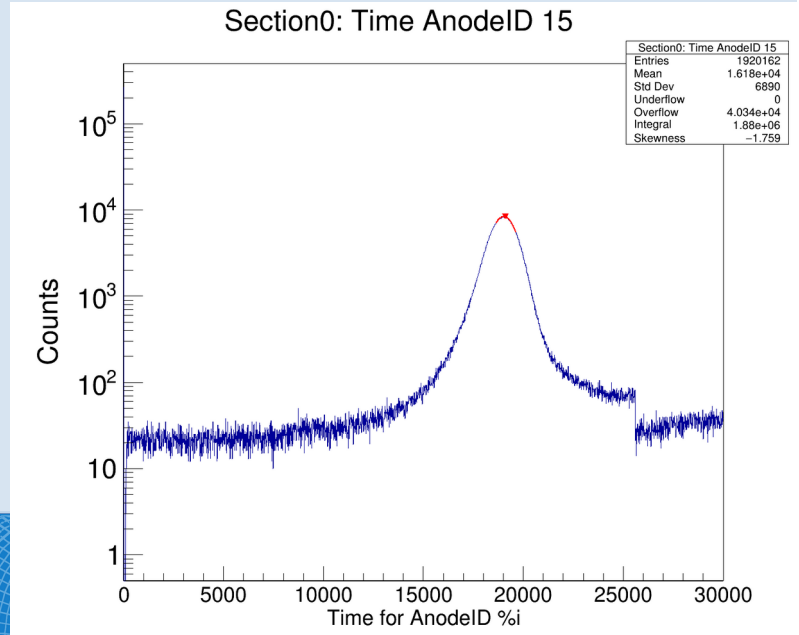


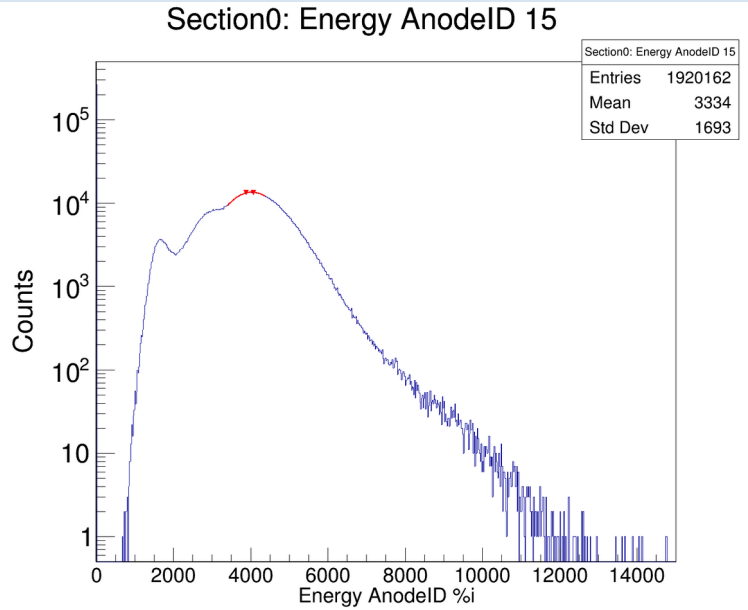


TDC time in TWIM Music for the 800 AmeV runs









Anodes 0-9 same time and energy distribution

Anodes 10-15 same time and energy distribution. Bump at low raw energy values and spread time distributions

TODO: correlation plot time - energy

Elog Entries during 800 AmeV Runs

https://elog.gsi.de/land/s444_s467/493

Message: stopping, entering cave

Right before starting with the 800 AmeV runs

https://elog.gsi.de/land/s444_s467/507

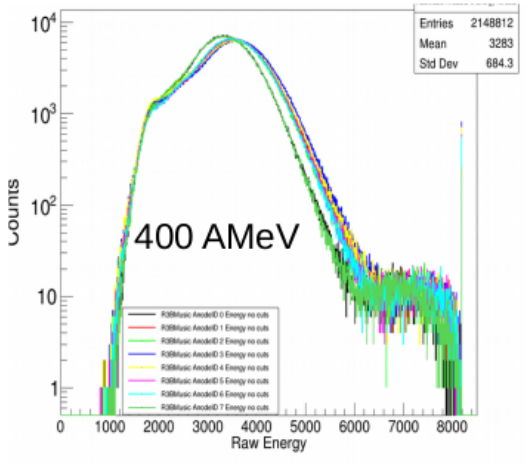
Today we again have very strong intensity fluctuations as we had seen them until Wednesday.
From 2 pm to 6 pm we had up to a factor of 100 differences after 6 pm we were down to smaller fluctuations up to 10 ranging from 200k to 20k
but most of the spills are about 100k.
Nothing to improve as accelerator people do not know the reasons.

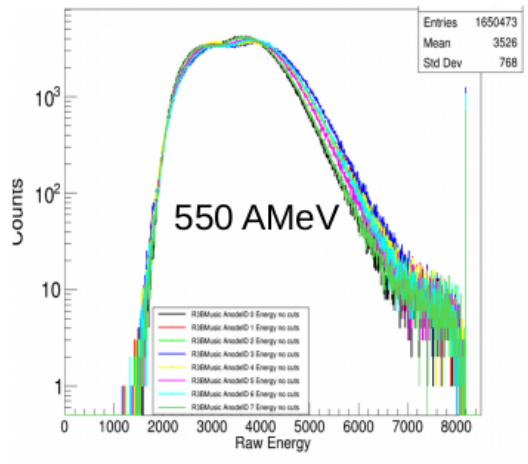
https://elog.gsi.de/land/s444_s467/544

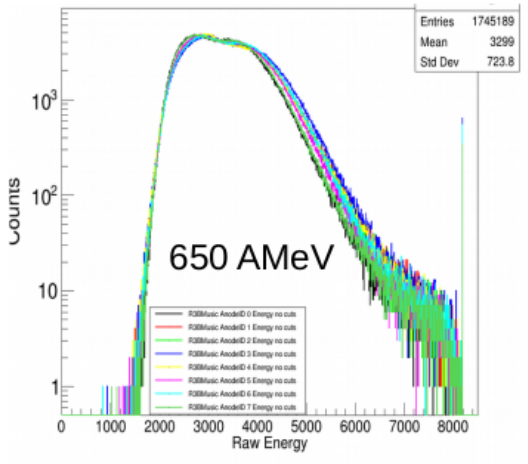
TwinMusic gain of last 6 channels reduced by about 25%
They had increased for the 800 MeV/u-Run and go back to the same gain as all the others channels

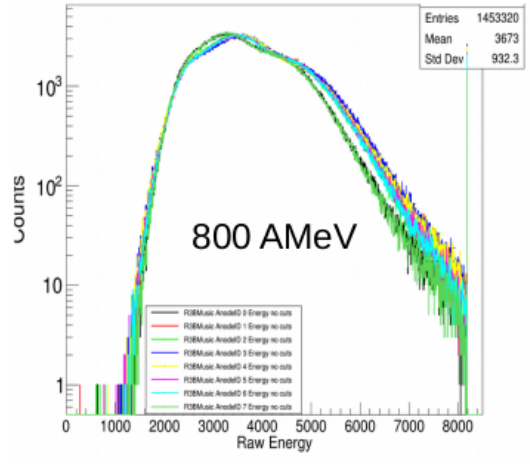
R3BMusic Mapped Raw Data - Energy

Empty Runs

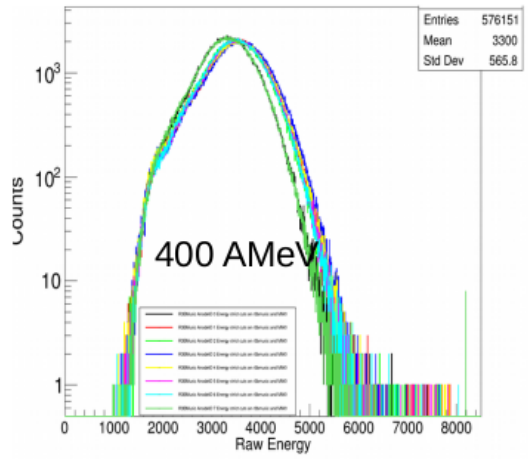


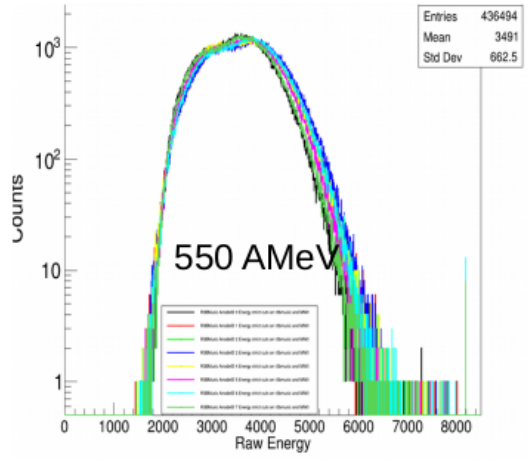


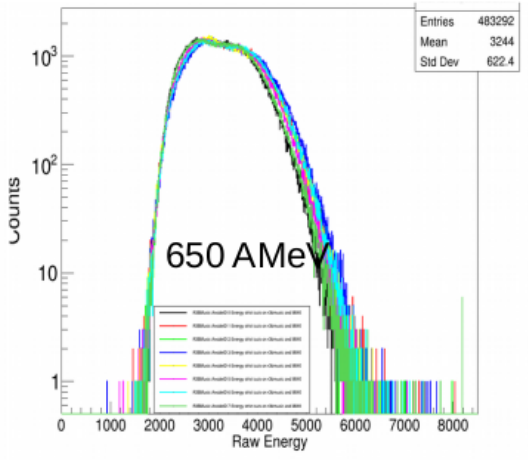


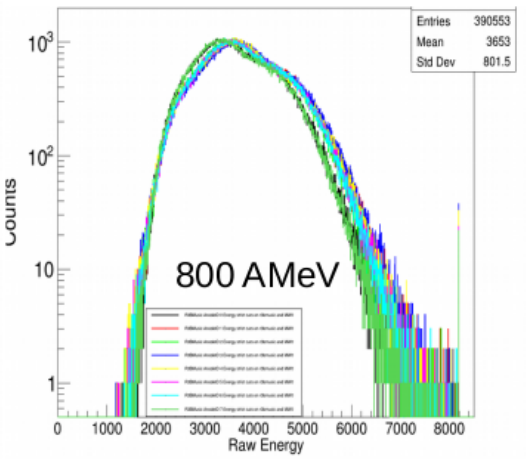


With strict cut on mw0 x-y and r3bmusic



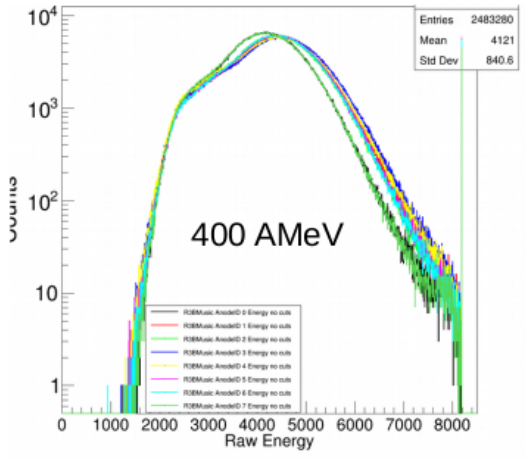


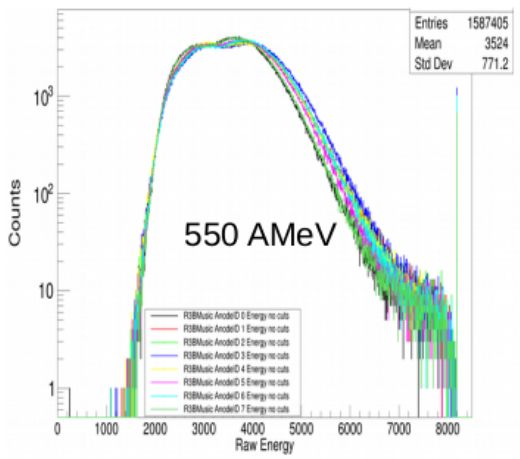


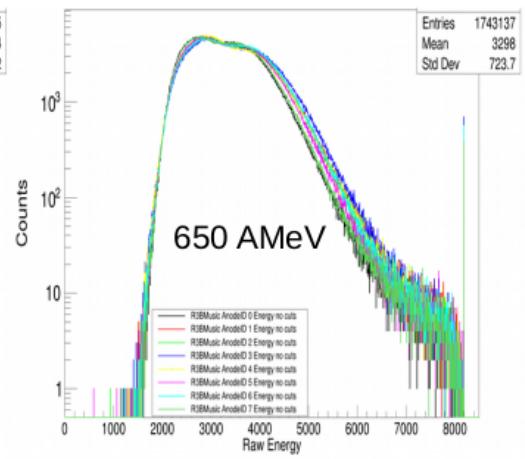


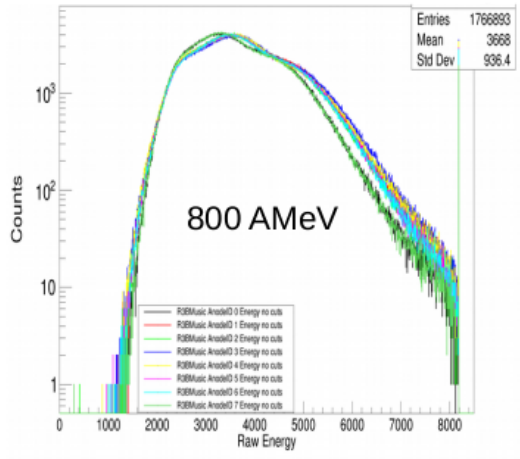
R3BMusic Mapped Raw Data - Energy

Target Runs









With strict cut on mw0 x-y and r3bmusic