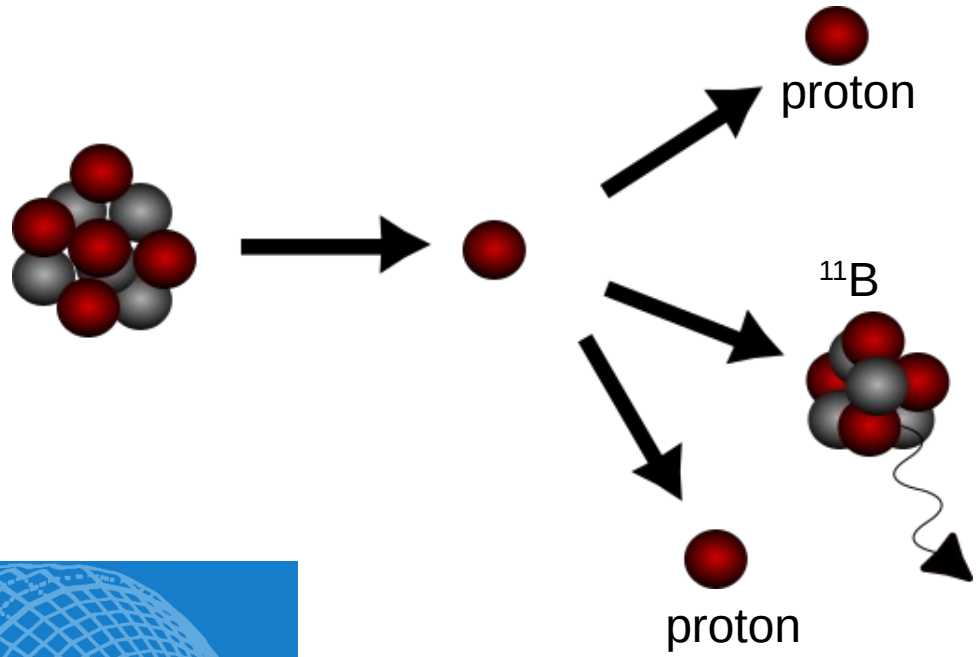
Quasi Free Scattering Analysis with Experiment S444/467 (2020)

12C(p,2p)11B reaction:

- ^{12}C beam
- proton like target

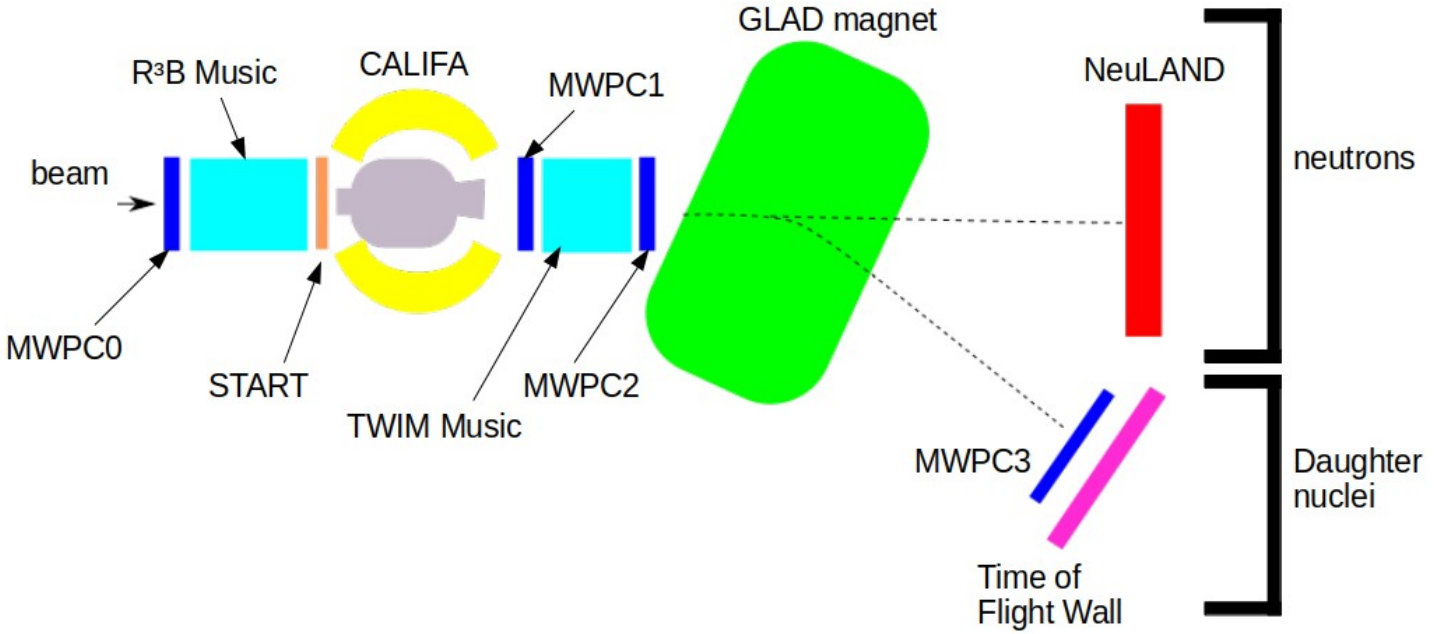
→

- 2 protons
- ^{11}B fragment (spectator)



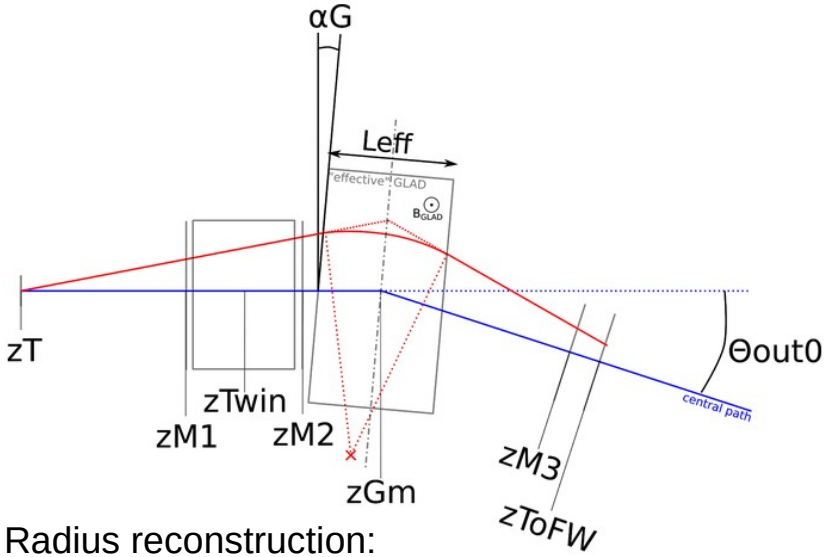
SETUP:

Beam energy: 400 AMeV
Beamtype: ^{12}C
Target: CH_2



Fragment Particle Identification

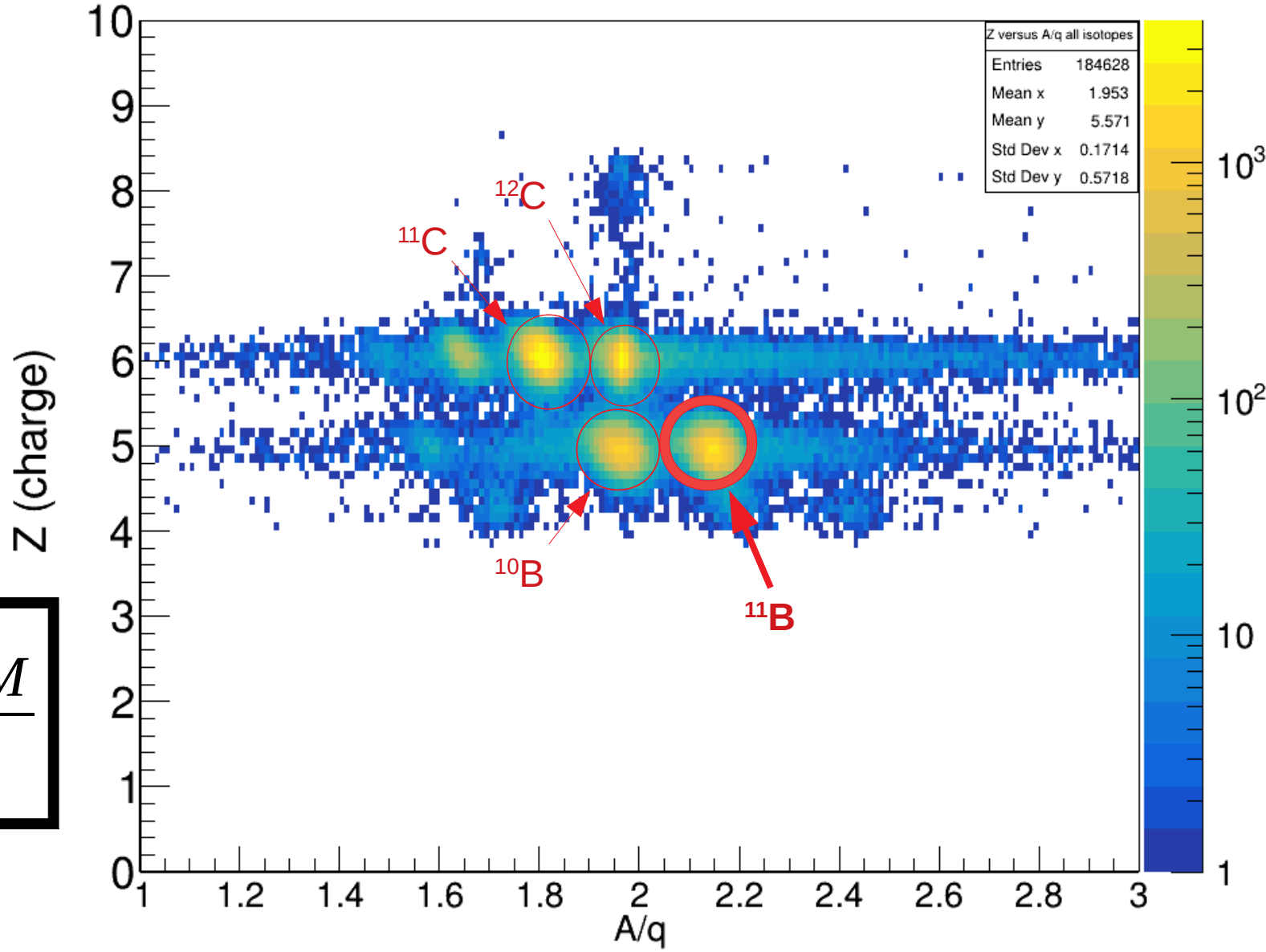
Flightpath reconstruction:



Radius reconstruction:

$$R = \frac{L_{eff}}{2\sin\left(\frac{\theta_{in} + \theta_{out}}{2}\right)}$$

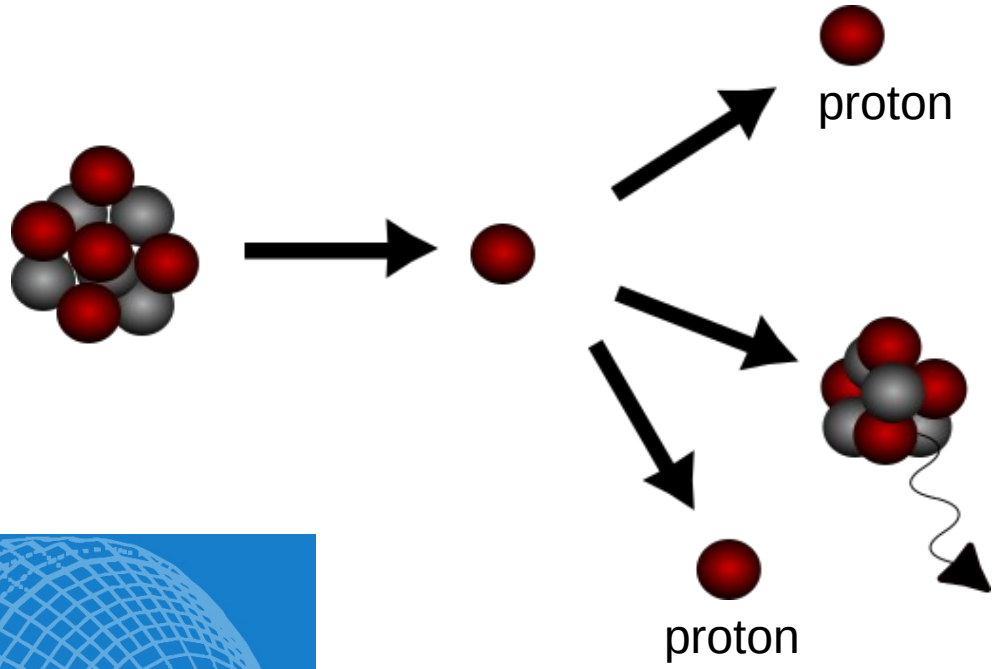
$$B * \rho = \frac{\beta * \gamma * M}{q}$$

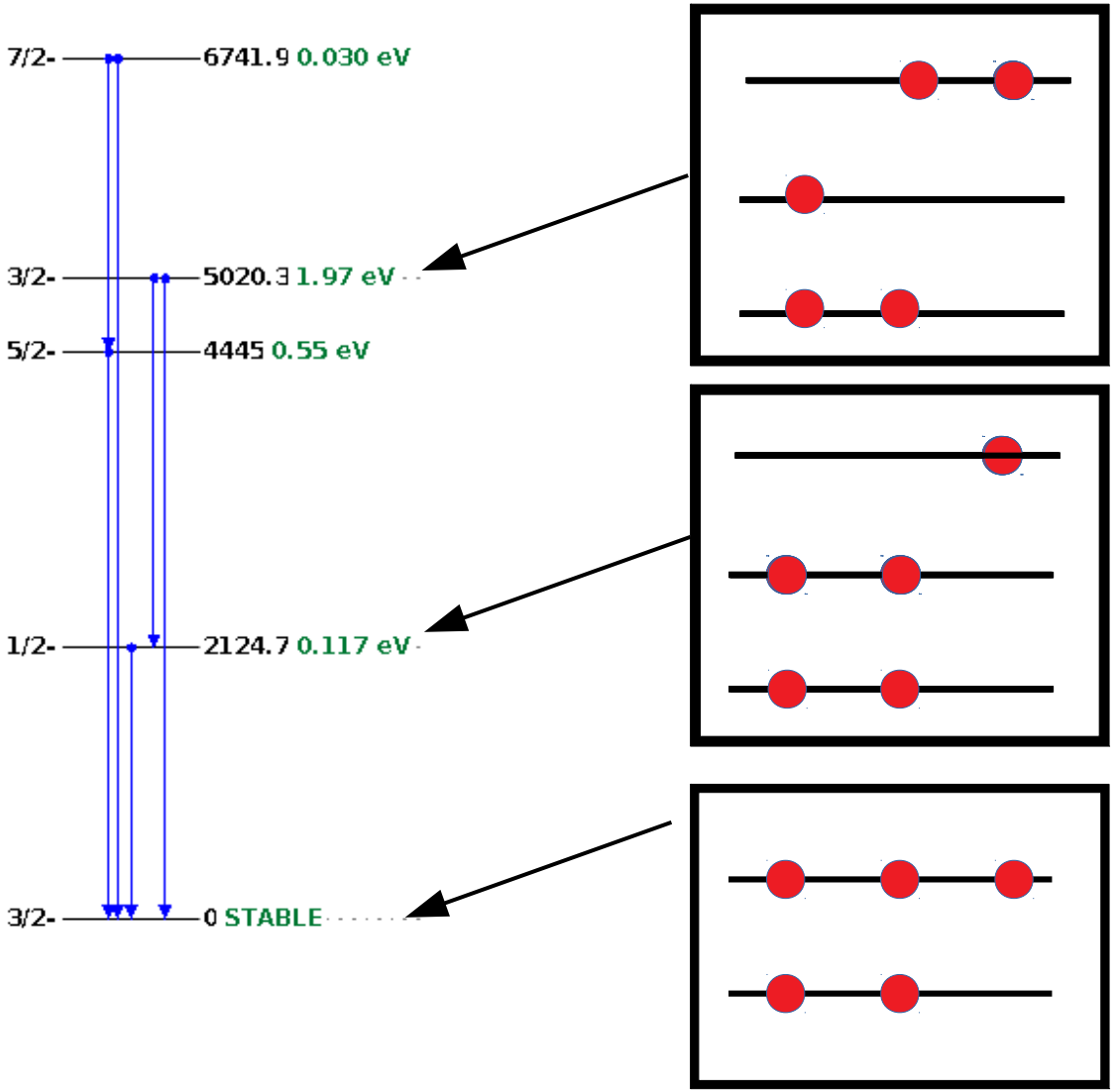


12C(p,2p)11B reaction

Two Proton Identification:

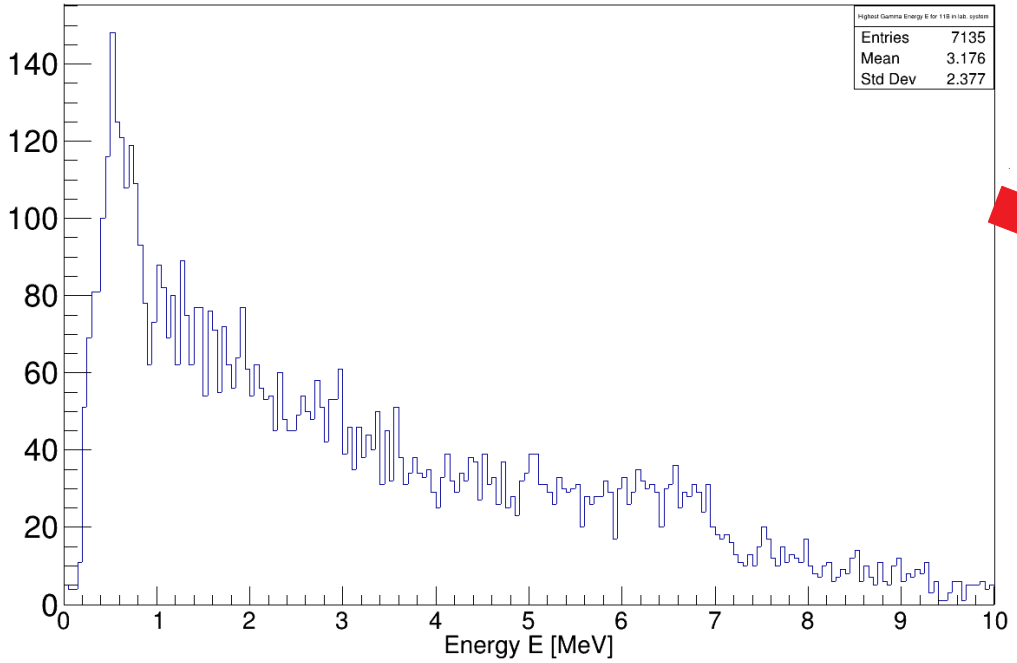
→ two hits with E_{hit} > 30 MeV





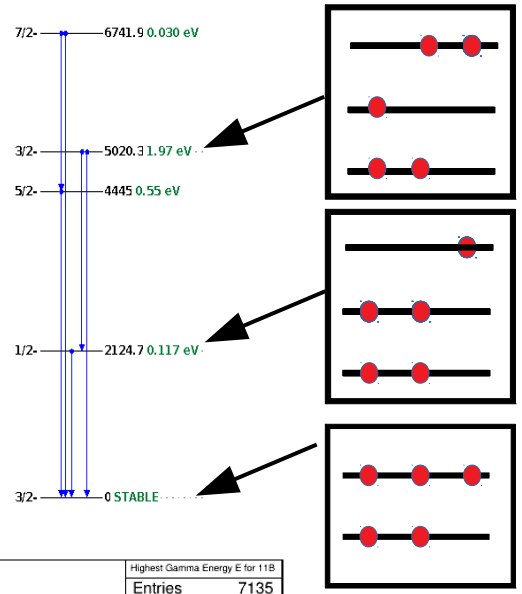
Gamma Spectrum of 11B

laboratory system

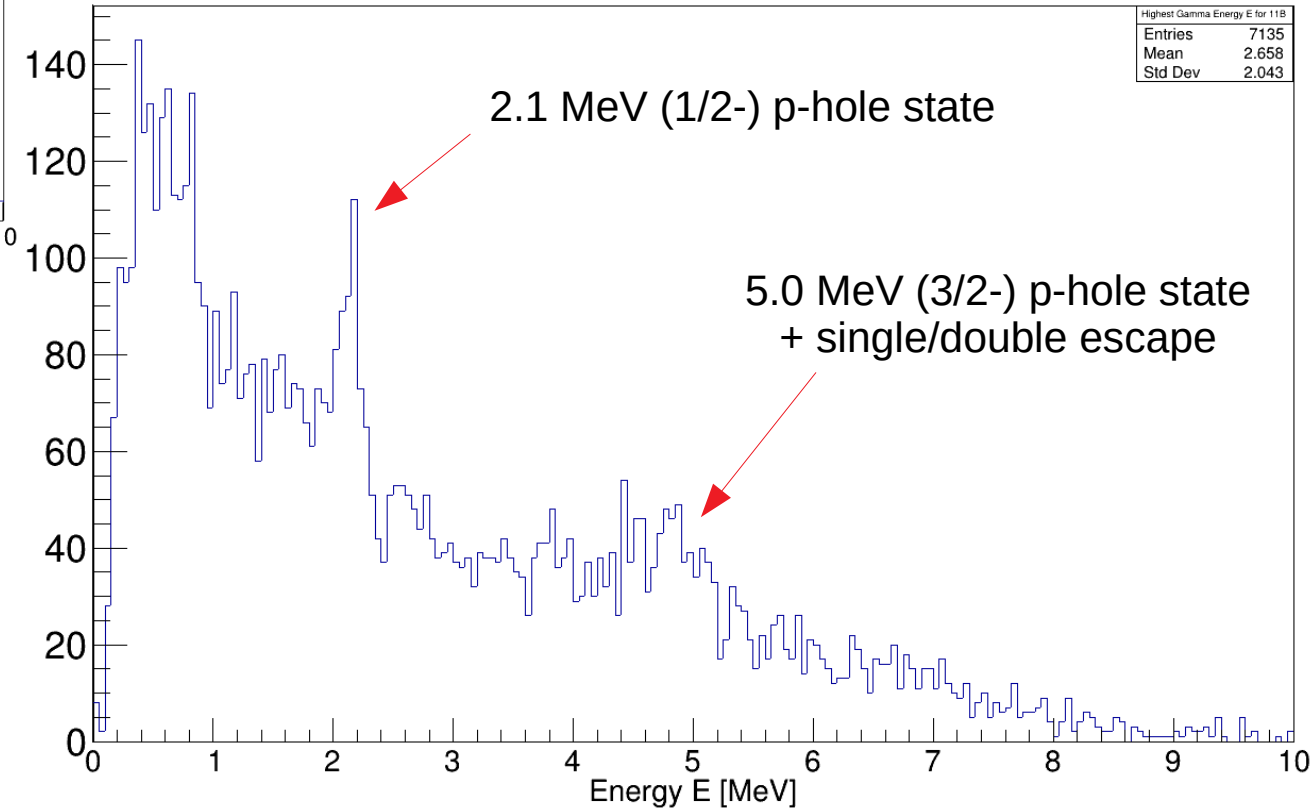


Doppler Correction:

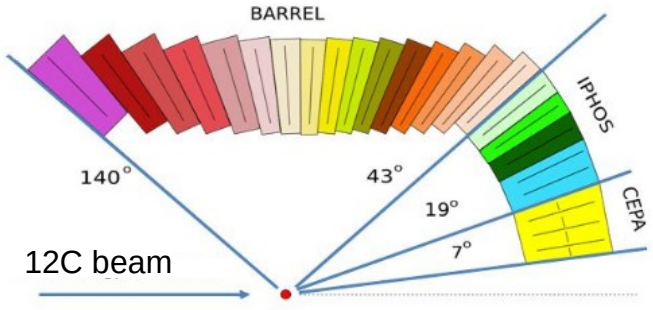
$$E_\gamma = \gamma E_{lab}\left(1-\beta\cos\left(\theta\right)\right)$$

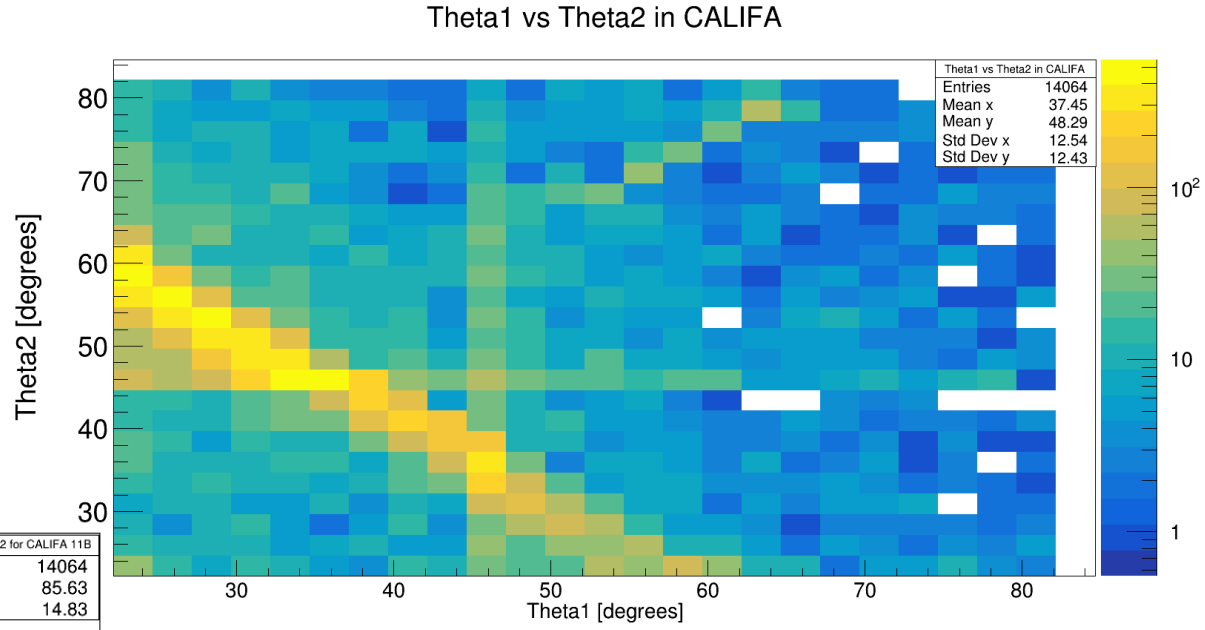


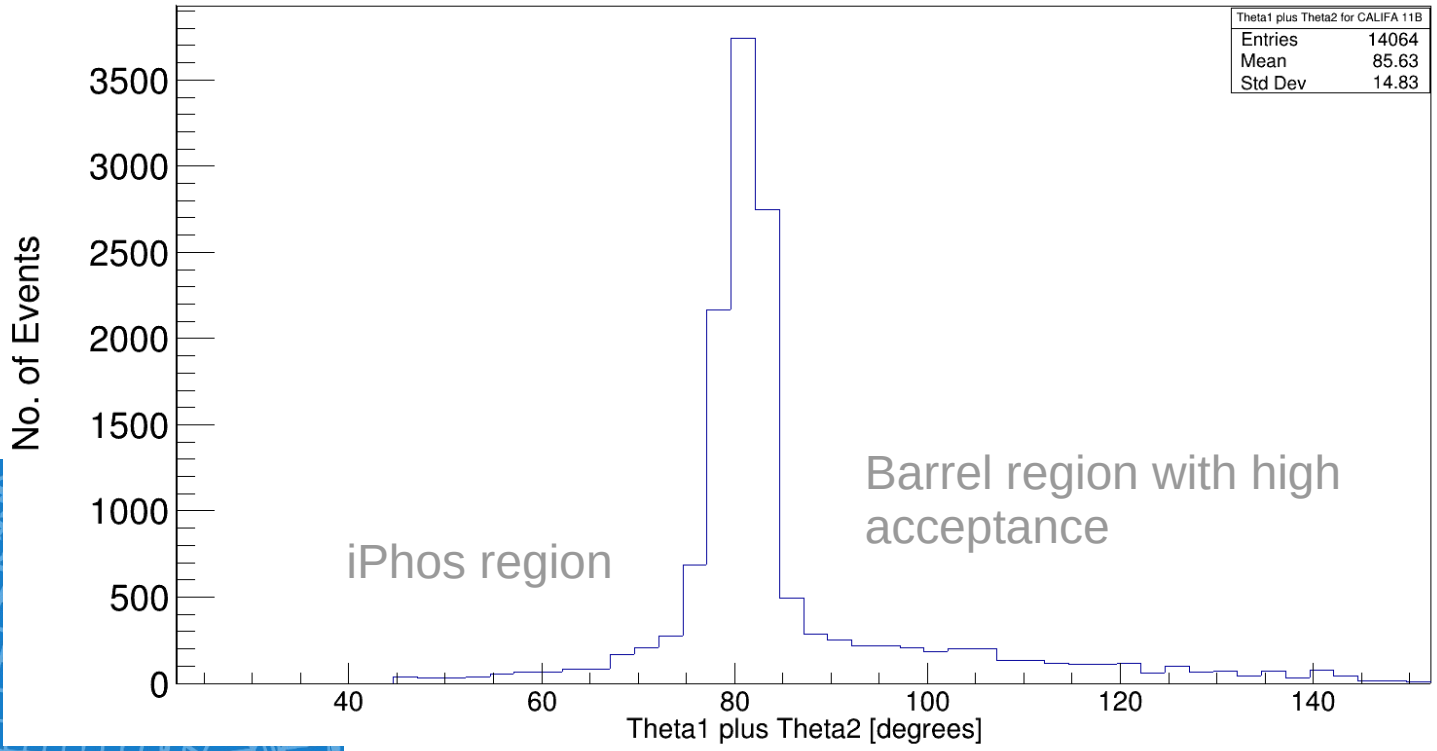
^{11}B rest frame

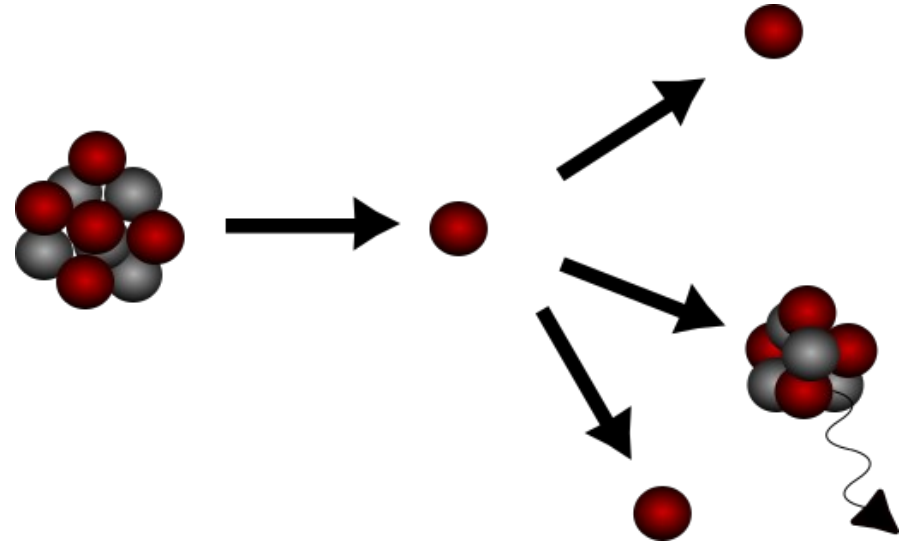


Polar Angular Distribution of protons for 12C(p,2p)11B

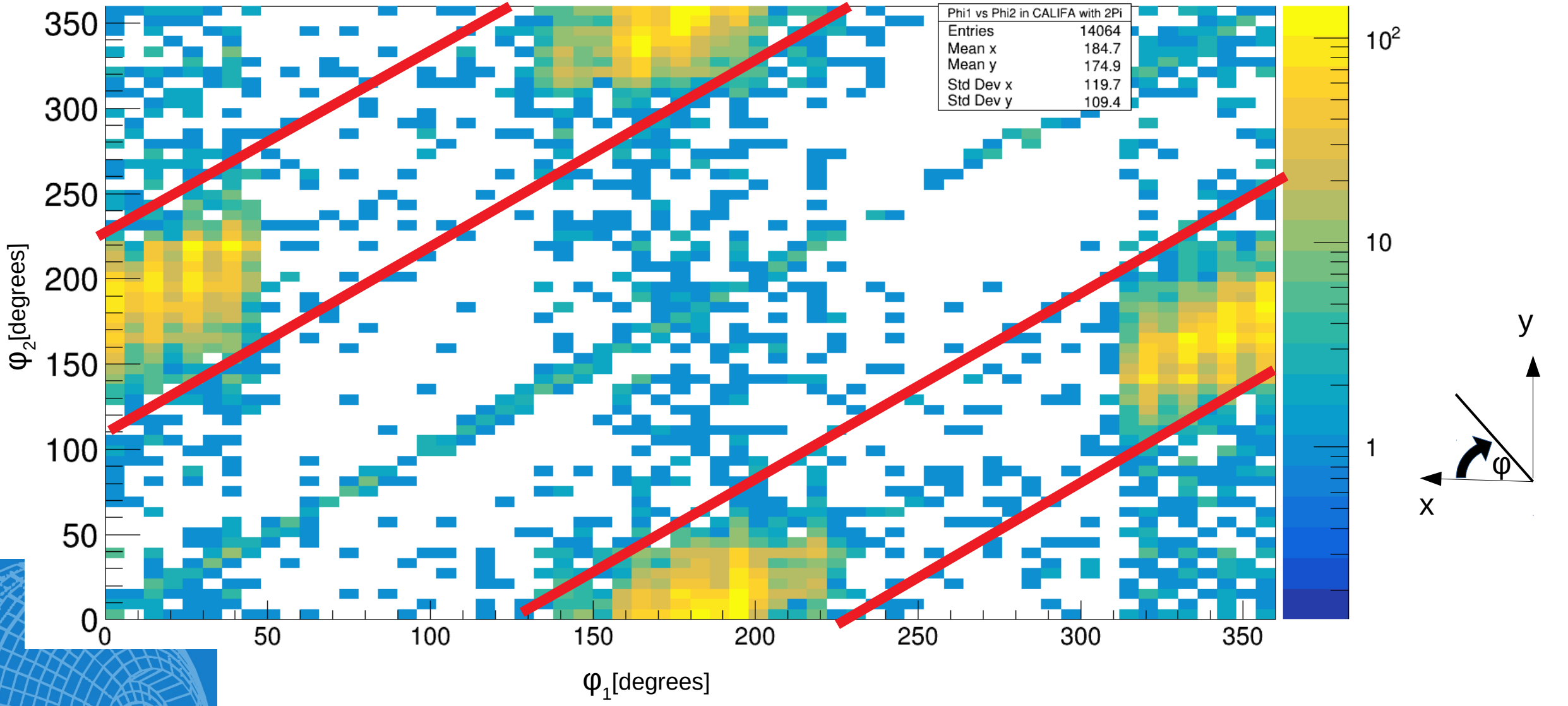








Arzimuthal Distribution of protons for 12C(p,2p)11B



Gamma Spectrum with Angular Cuts

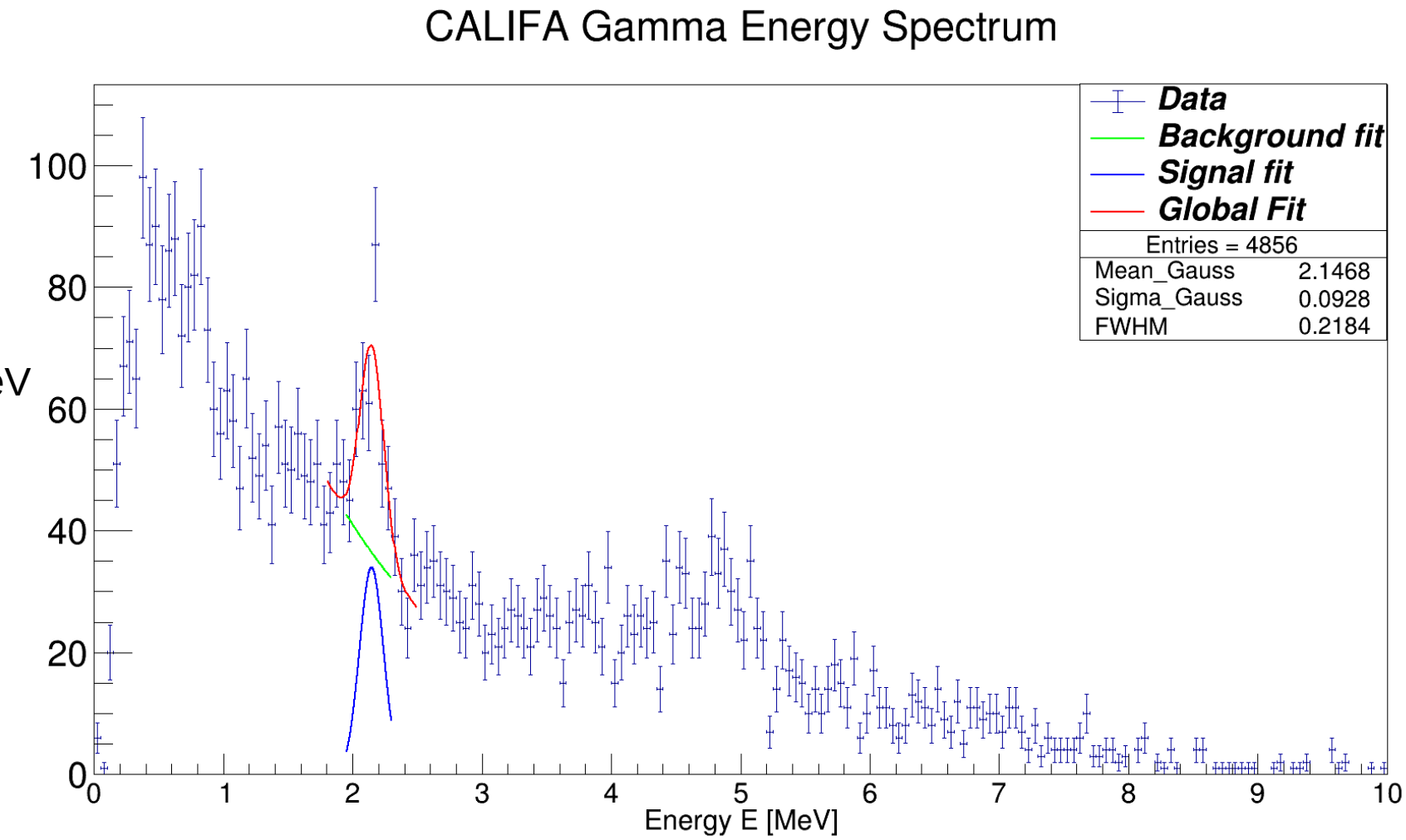
Event selection criteria for CALIFA:

→ 11B fragment identification

→ two hits (protons) with E_{hit} > 30 MeV

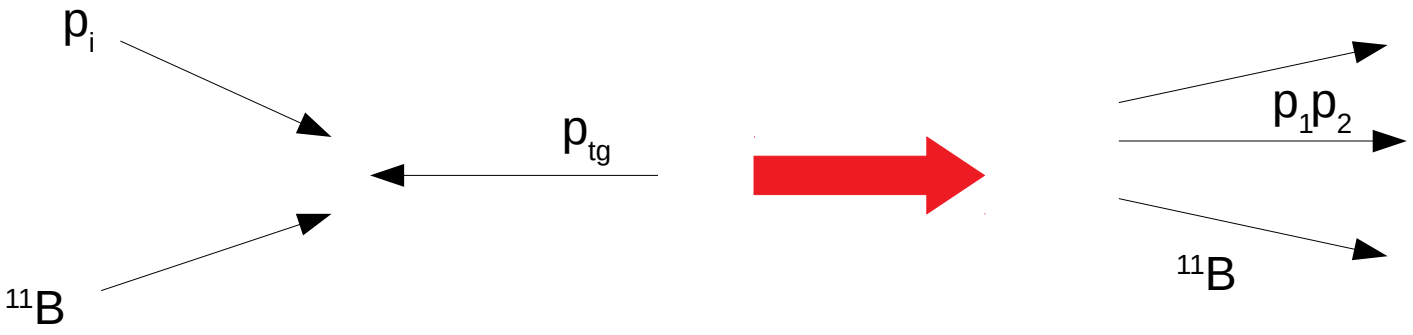
→ θ1 + θ2 < 90°

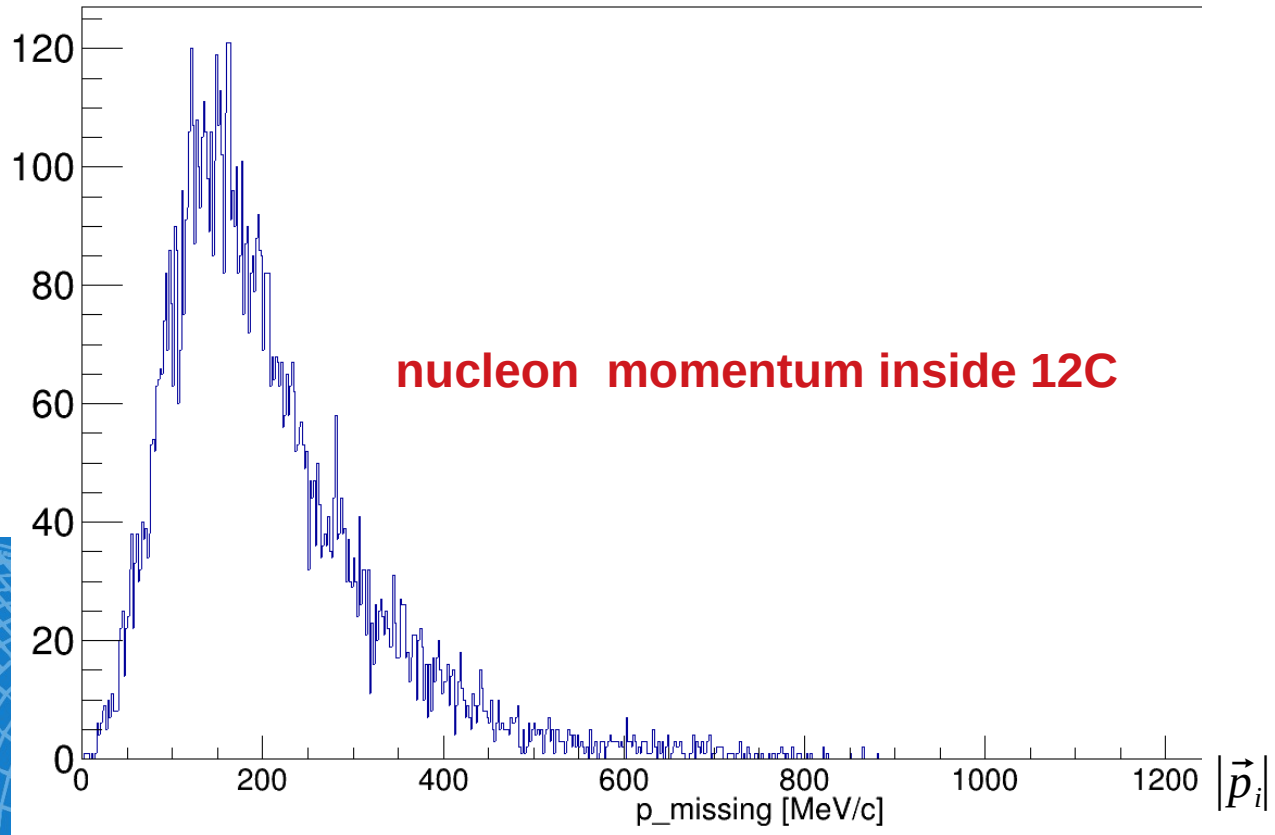
→ Δφ = 180° +- 40°



TODO: make bkg from 1 to 3 and add also plots with hit-multiplicities...

Reconstruction of Inner Momenta





nucleon momentum inside 12C

Momentum conservation relation:

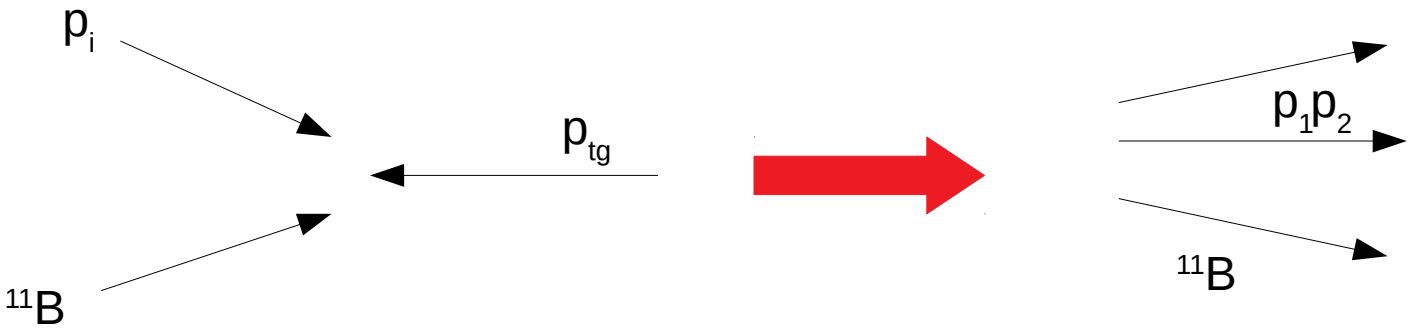
$$\boldsymbol{p}_{12\,C} + \boldsymbol{p}_{tg} = \boldsymbol{p}_1 + \boldsymbol{p}_2 + \boldsymbol{p}_{11\,B}$$

assuming QE scattering in mean field potential:

$$\boldsymbol{p}_{12\,C} = \boldsymbol{p}_i + \boldsymbol{p}_{11\,B}$$

$$\boldsymbol{p}_i \approx \boldsymbol{p}_{missing} = \boldsymbol{p}_1 + \boldsymbol{p}_2 - \boldsymbol{p}_{tg} \left(no\ ISI\,/\,FSI \right)$$

Momentum components of p_i



Momentum conservation relation:

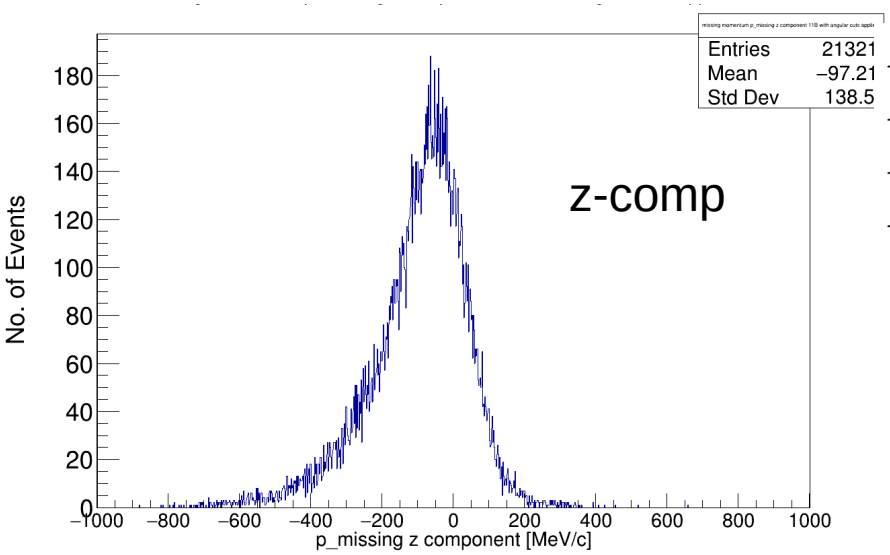
$$p_{12C} + p_{tg} = p_1 + p_2 + p_{11B}$$

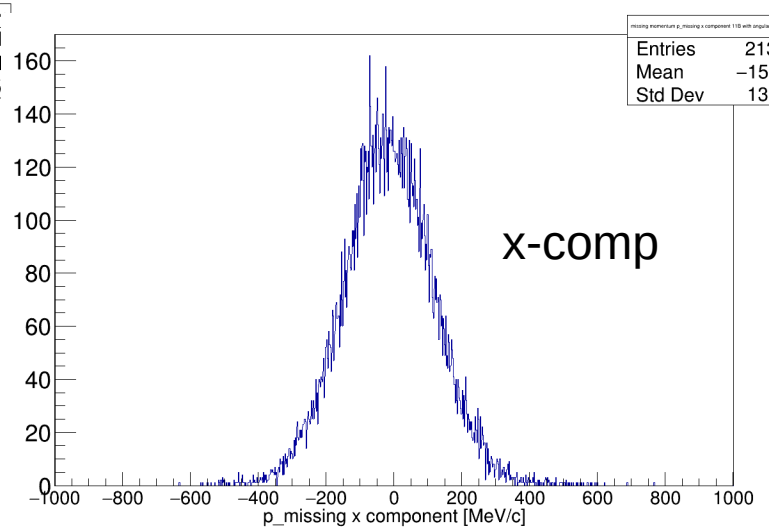
assuming QE scattering in mean field potential:

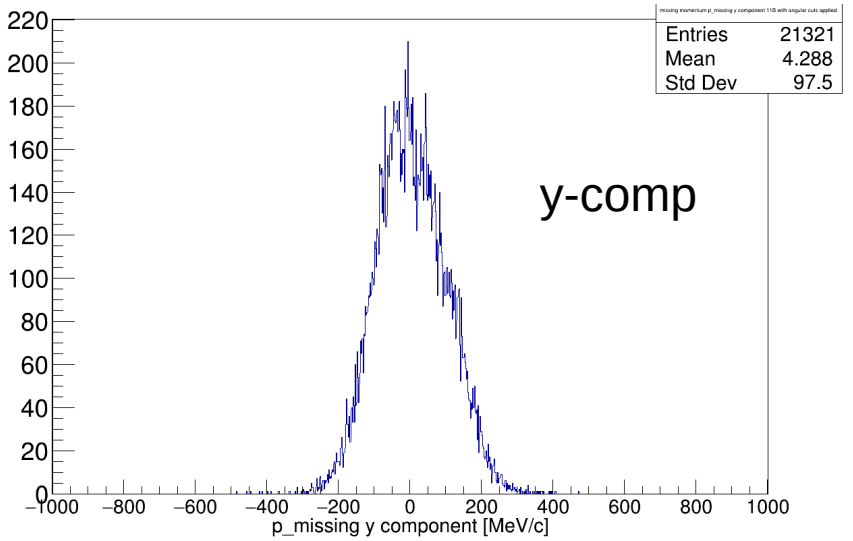
$$p_{12C} = p_i + p_{11B}$$

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

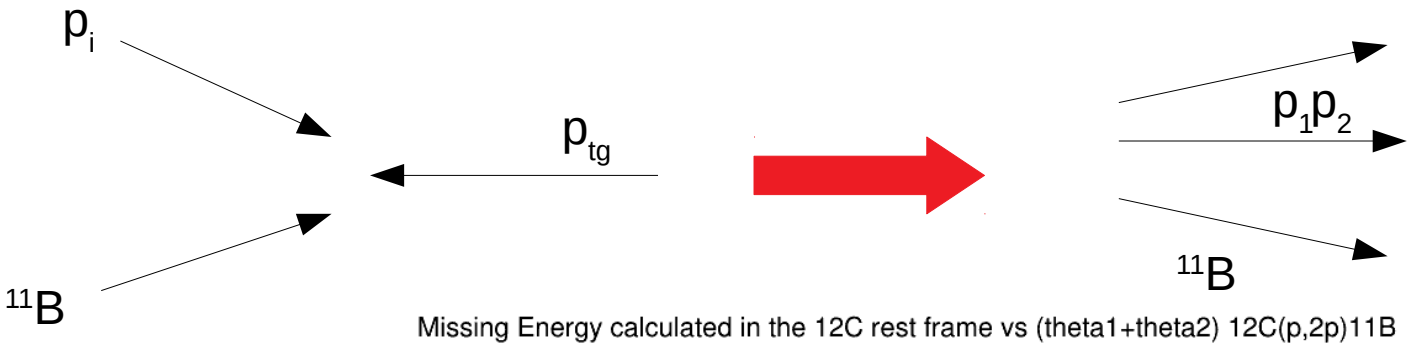
momentum-components (with angular cuts applied)







Missing Energy Distribution

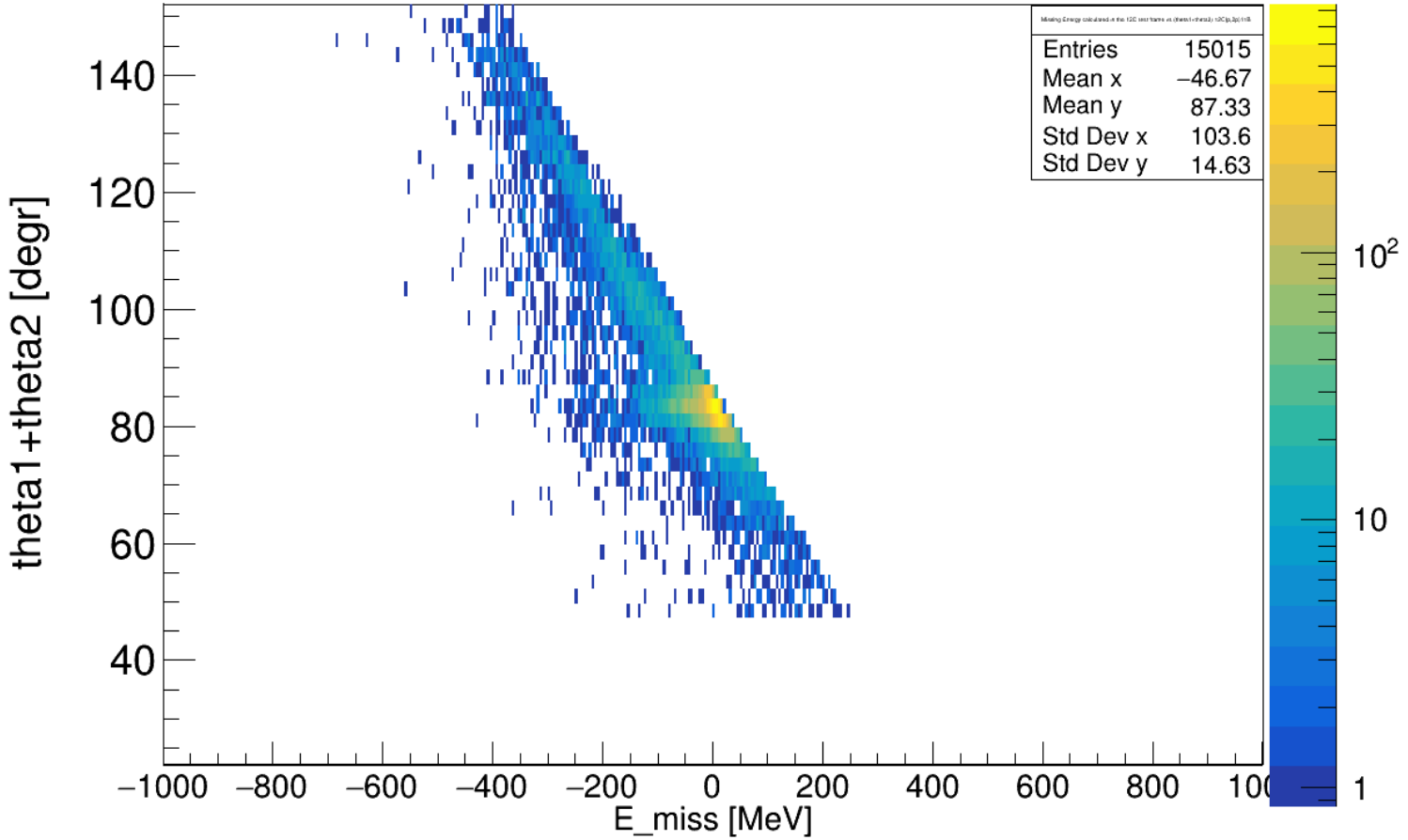


$$\boldsymbol{p_i} \approx \boldsymbol{p_{missing}} = \boldsymbol{p_1} + \boldsymbol{p_2} - \boldsymbol{p_{tg}} \left(no\ ISI / FSI \right)$$

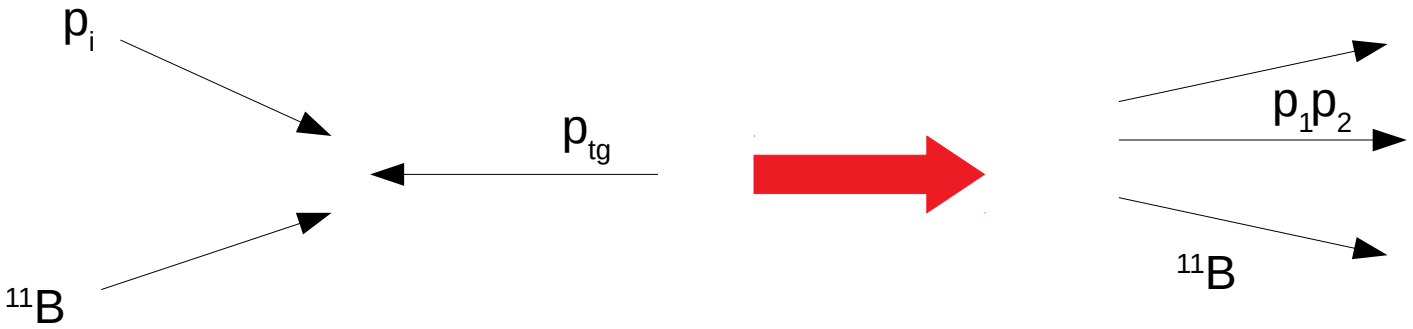
$$E_{miss} = m_p - e_{miss} \left(\approx -E_{kin} \right)$$

(where e_miss is the energy component of $\mathbf{p}_{missing}$)

Missing Energy calculated in the 12C rest frame vs (theta1+theta2) 12C(p,2p)11B

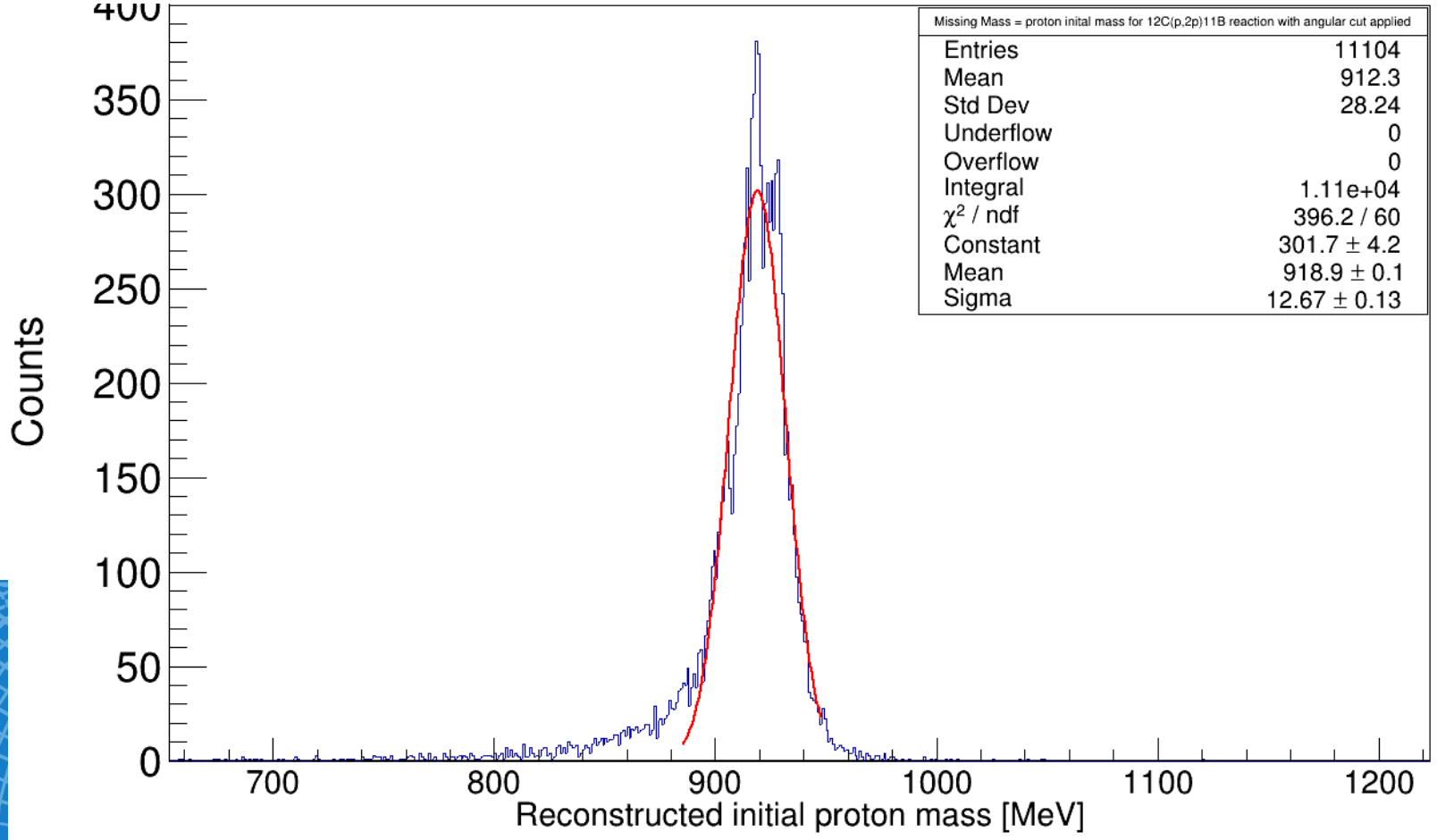


Mass reconstuction of p_i



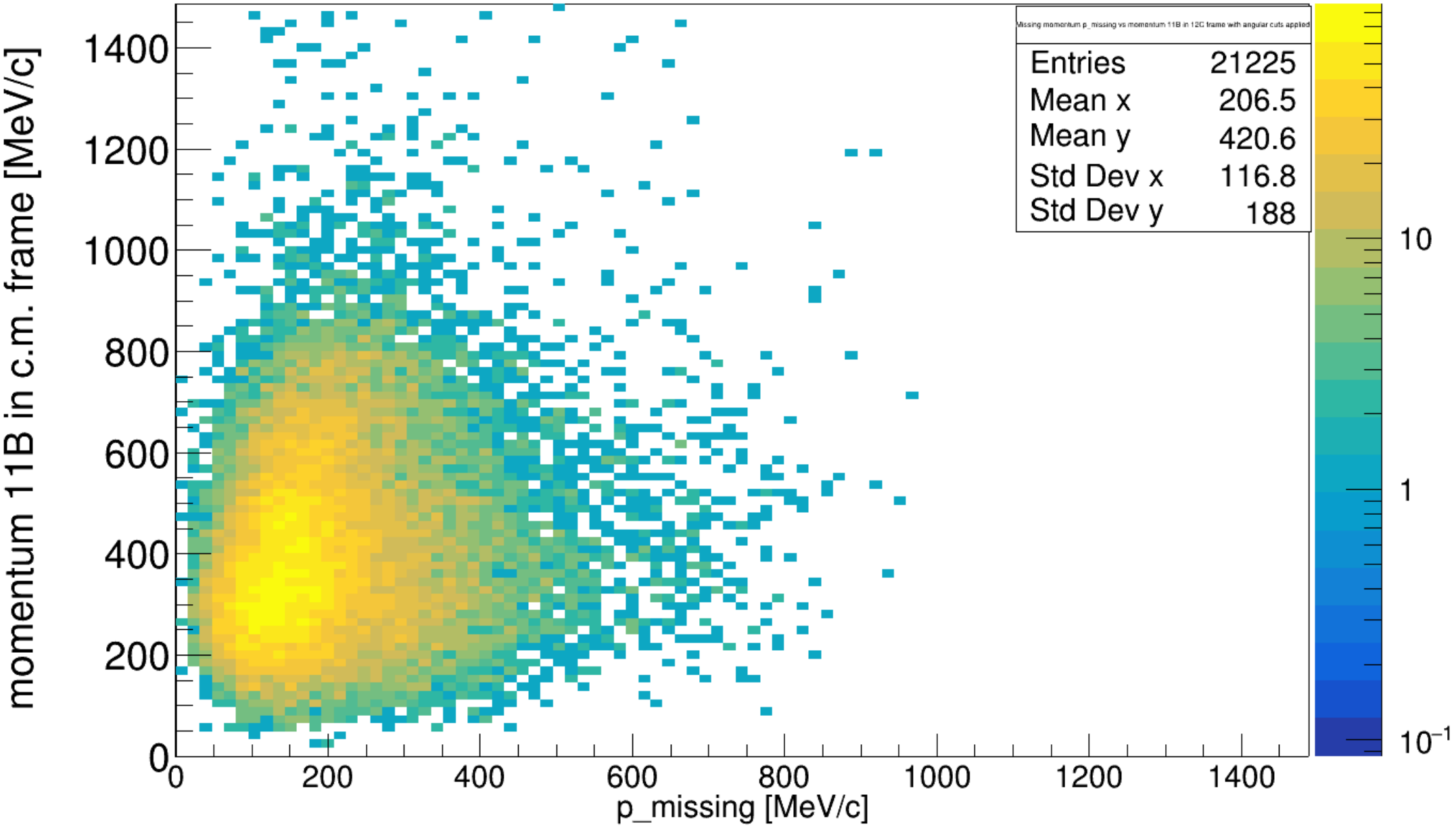
$$p_i \approx p_{missing} = p_1 + p_2 - p_{tg} \, (no\ ISI/FSI)$$

$$M_i = \sqrt{(p_1 + p_2 - p_{tg})^2}$$

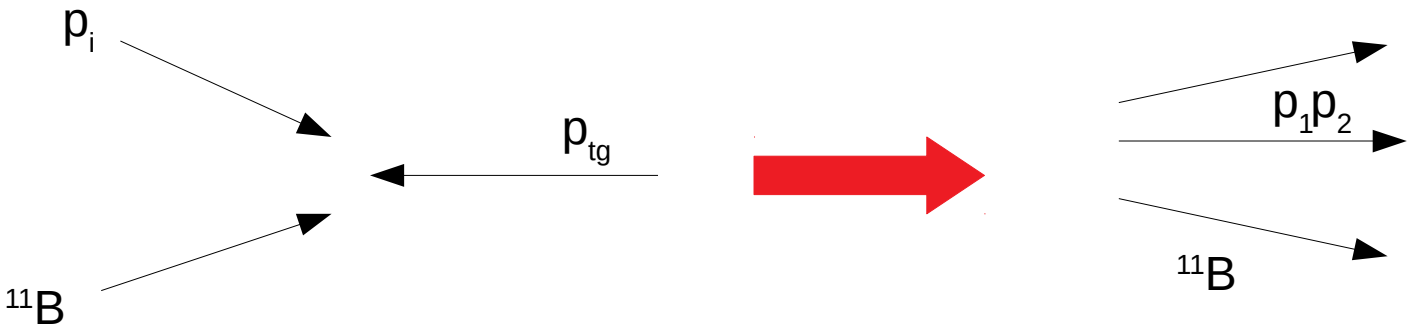


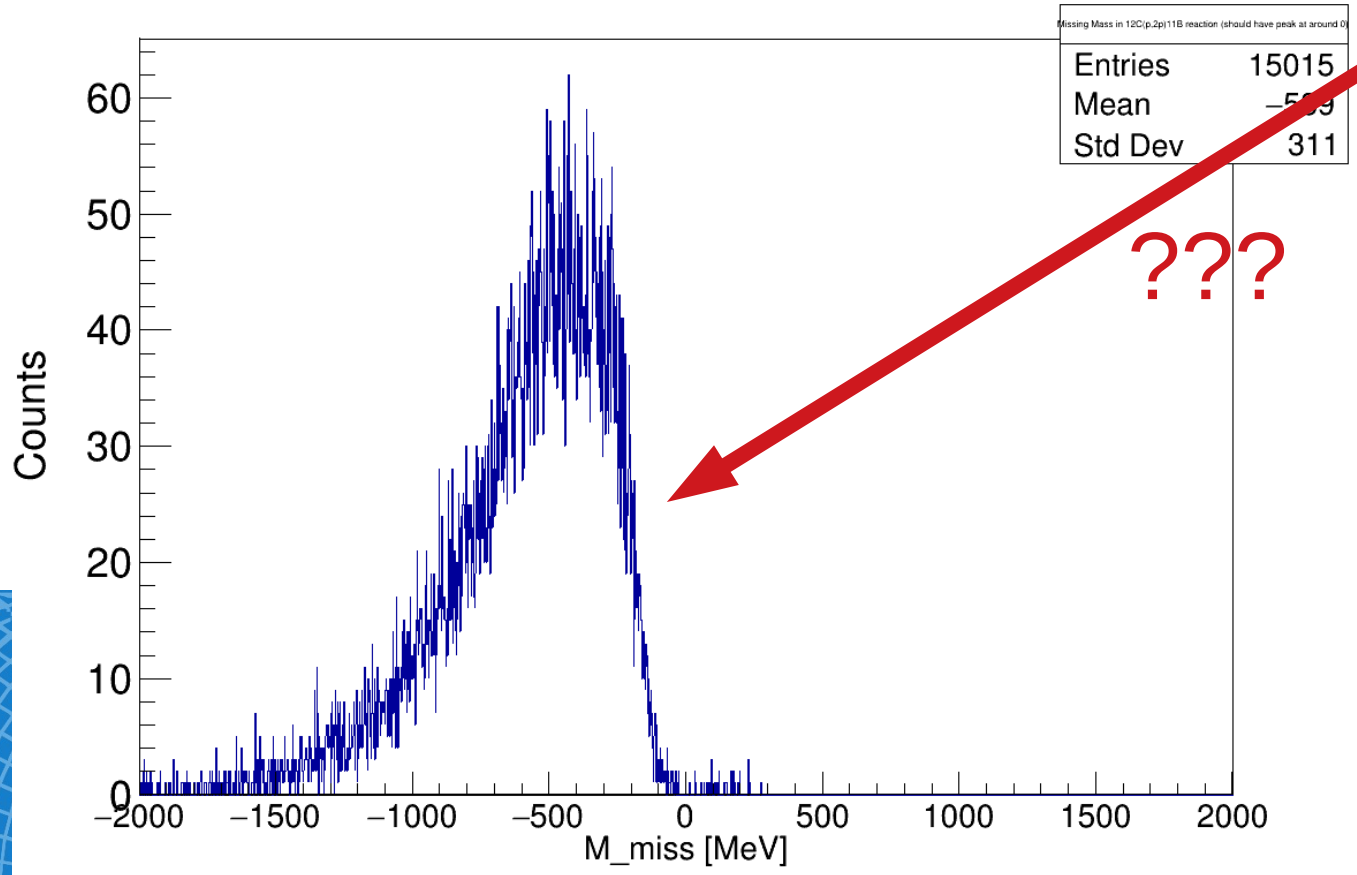
Looks ok, mean of 918 MeV is lower than expected….

Momentum p_i vs p_11B in 12C



Missing mass reconstruction





$$M_{miss} = \sqrt{(p_{12C} - p_i - p_{11B})^2}$$

should be ≈ 0

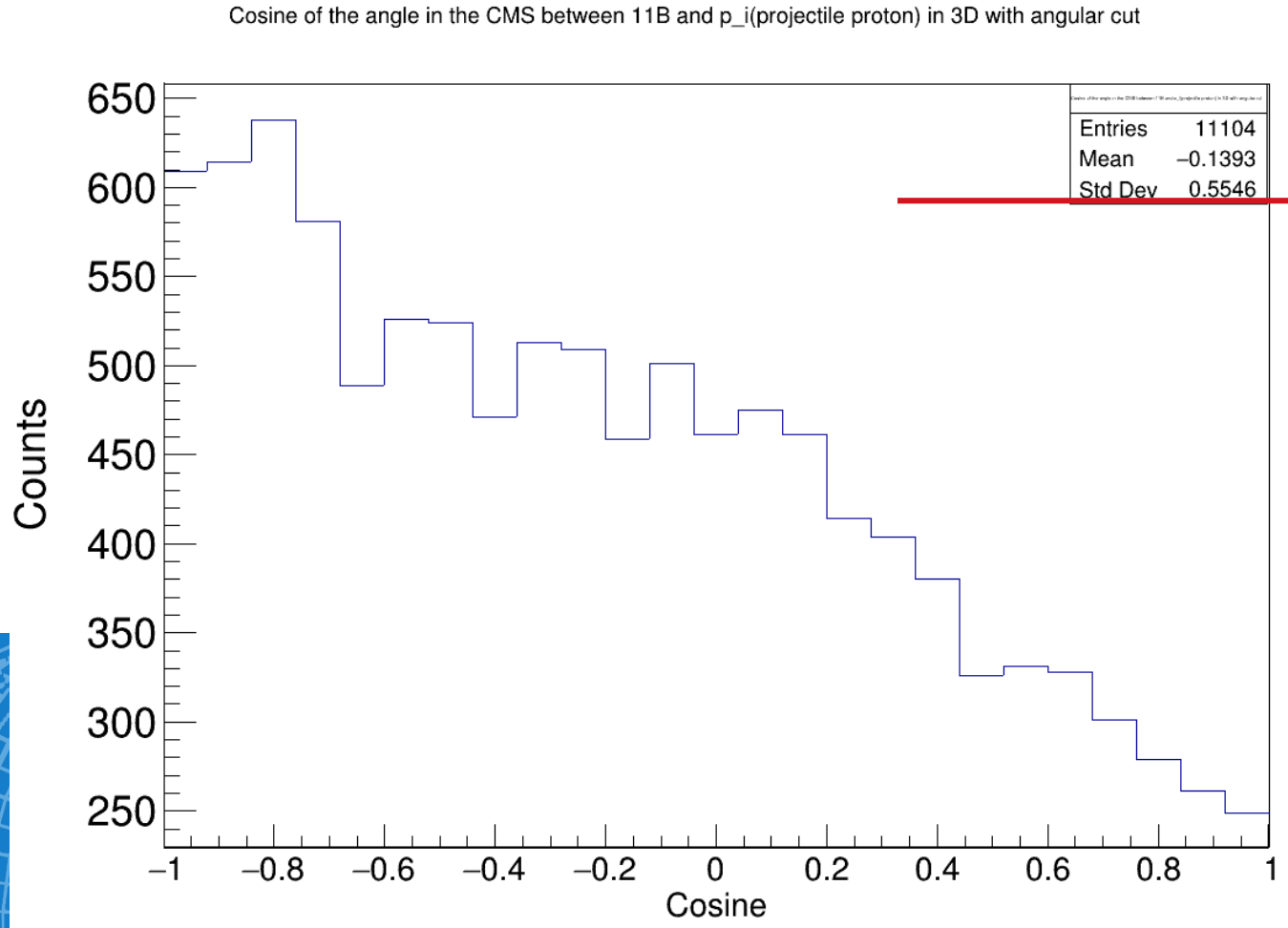
→ give better look at the 3-momentum distribution
(+- permutation at MW position??)

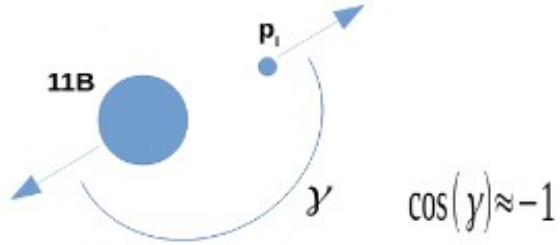
→ as the reconstruction of p_i works well it can be deduced that 11B reconstruction faulty….

Inner angular distributions

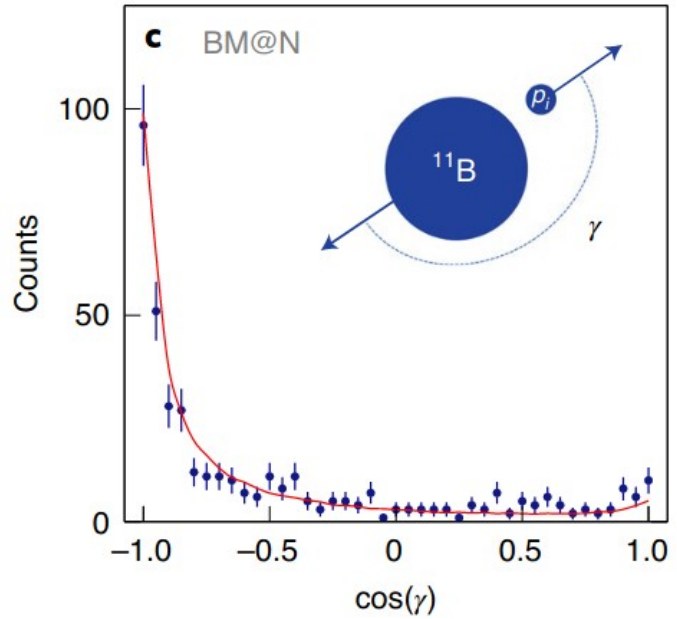
$$p_{12C} = p_i + p_{11B}$$

In 12C cms frame:





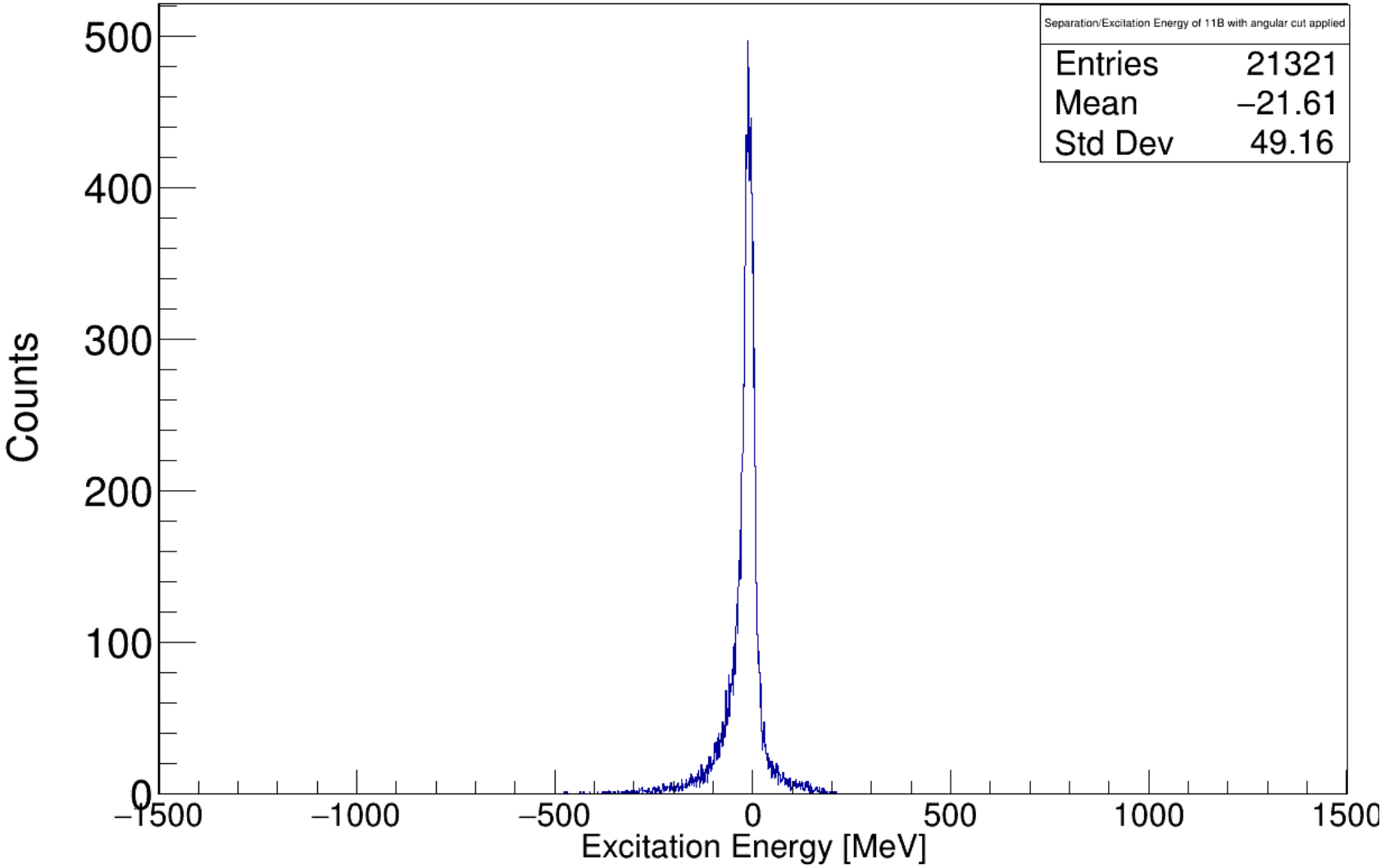
Not satisfactory….
See:
https://www.nature.com/articles/s41567-021-01193-4.pdf



Excitation Energy of 11B

$$E_{exc} = \left(\boldsymbol{P}_{12C} + \boldsymbol{p}_{tg} - \boldsymbol{p}_1 - \boldsymbol{p}_2 \right) . M - M_{11B}$$

$-\mathbf{p}_i$



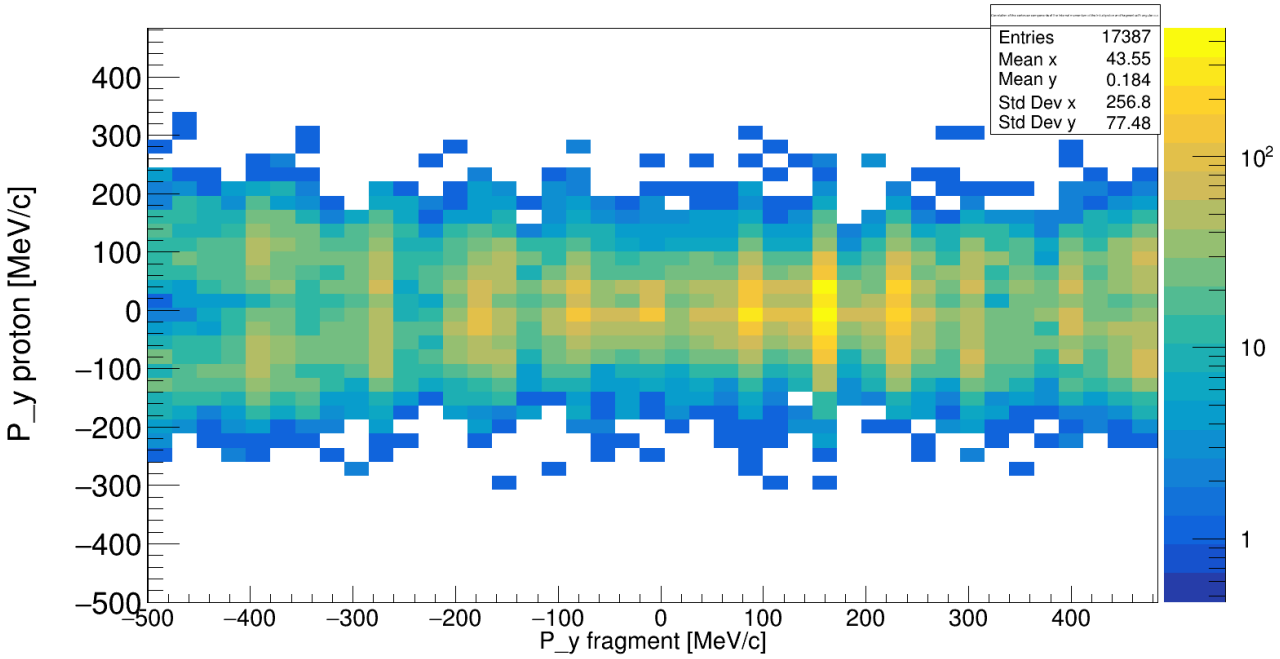
Is this formula valid?

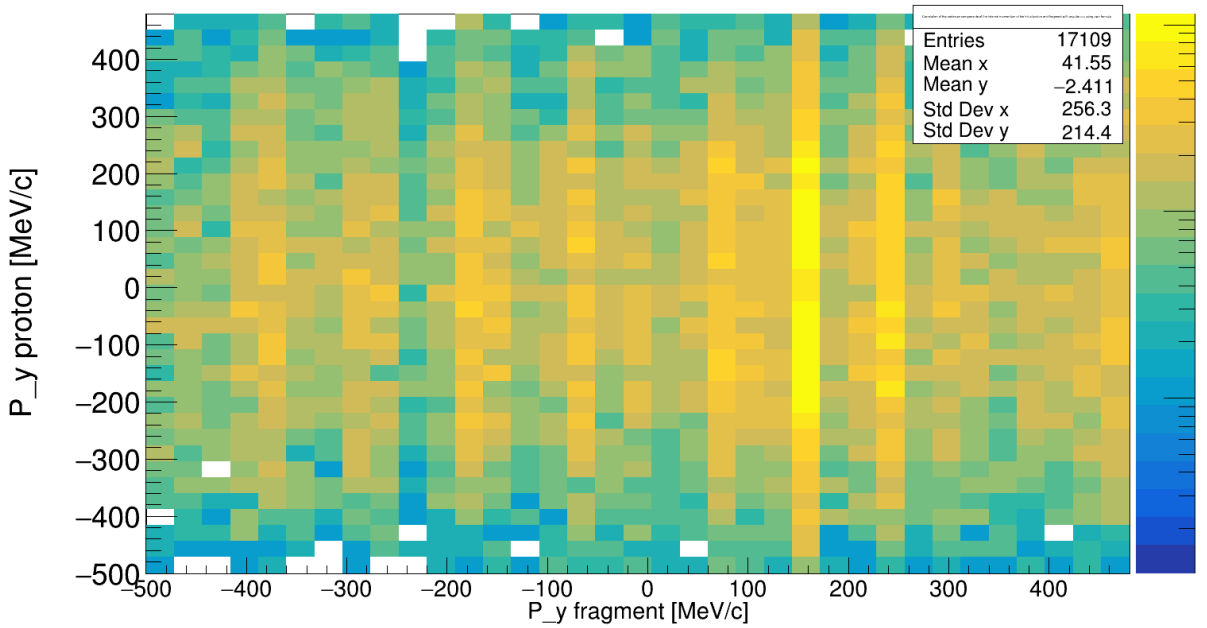
Correlation between knocked out proton and 11B

With given formula: $P_y = Q_k \times sin\theta_k sin(\varphi_k - \varphi_i),$

With my formula:

$$P_y = Q_k * \sin(\theta_k) * \sin(\phi_k) - Q_i * \sin(\theta_i) * \sin(\phi_i)$$

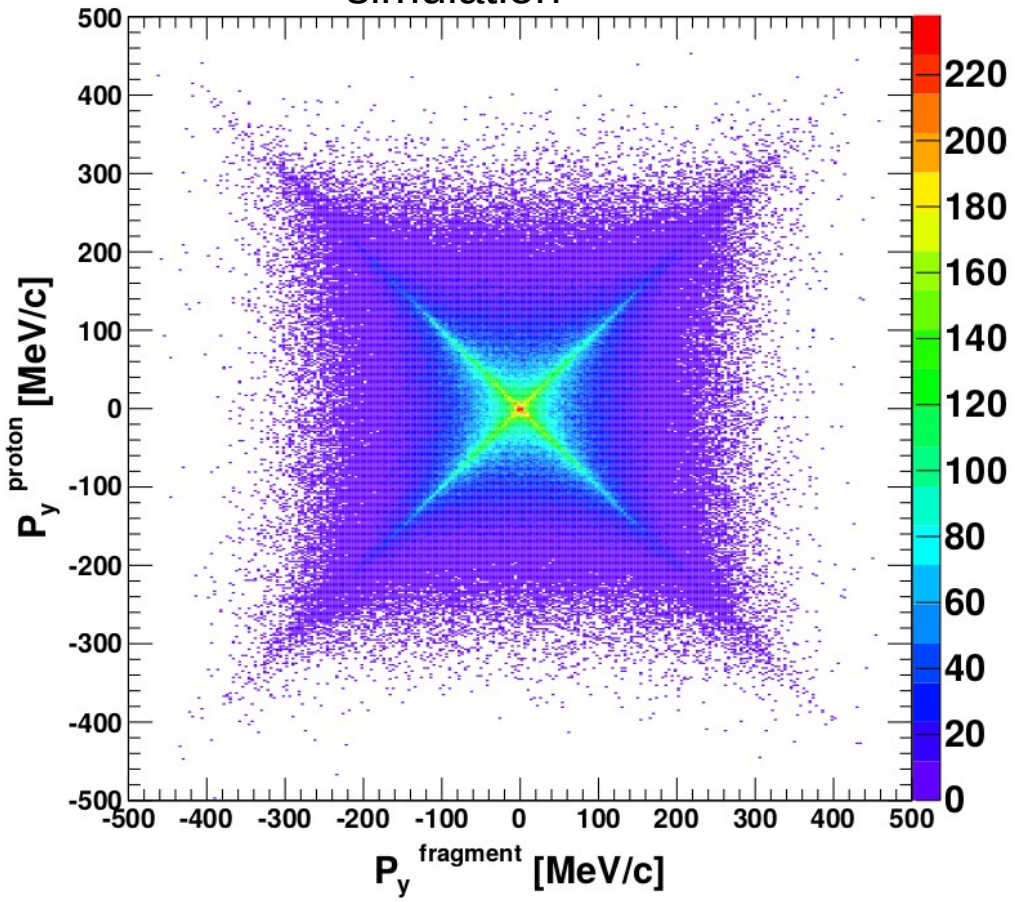




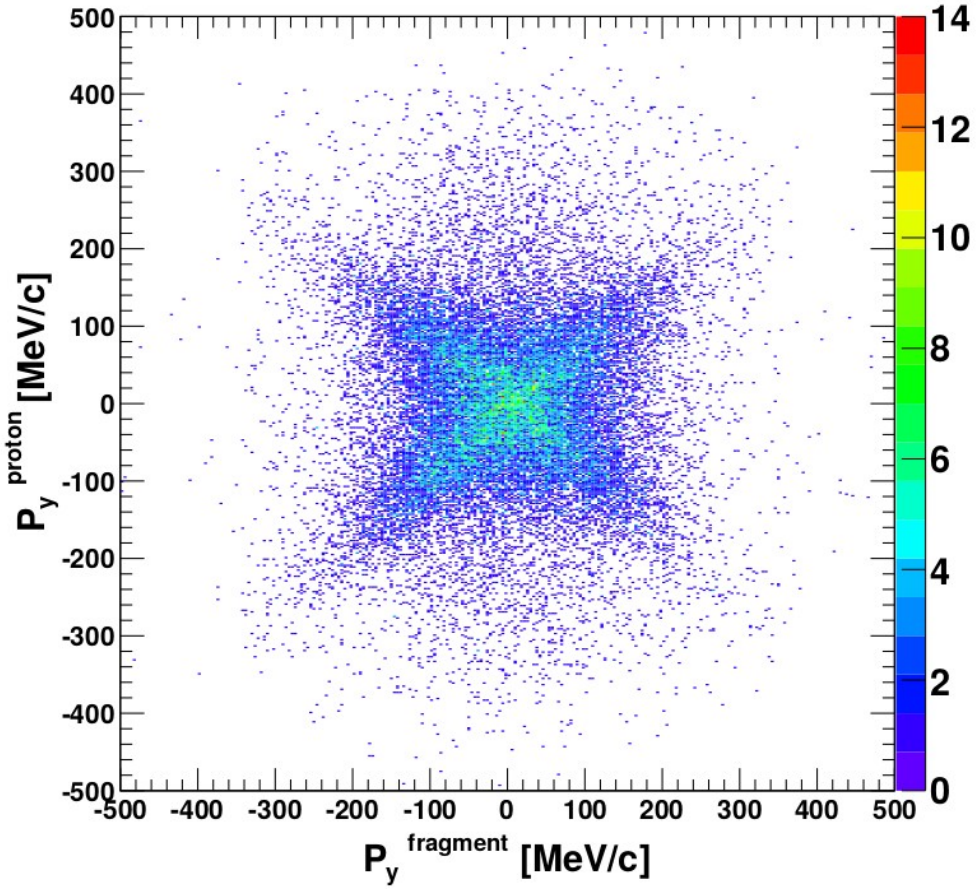
Correlation between knocked out proton and 11B

What we expect:

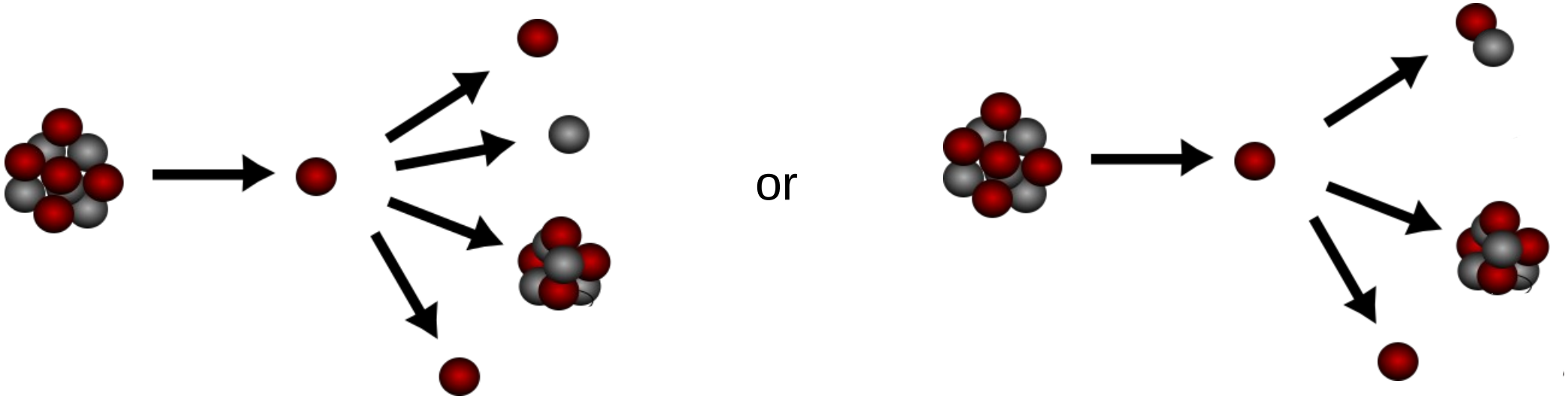
simulation



experiment

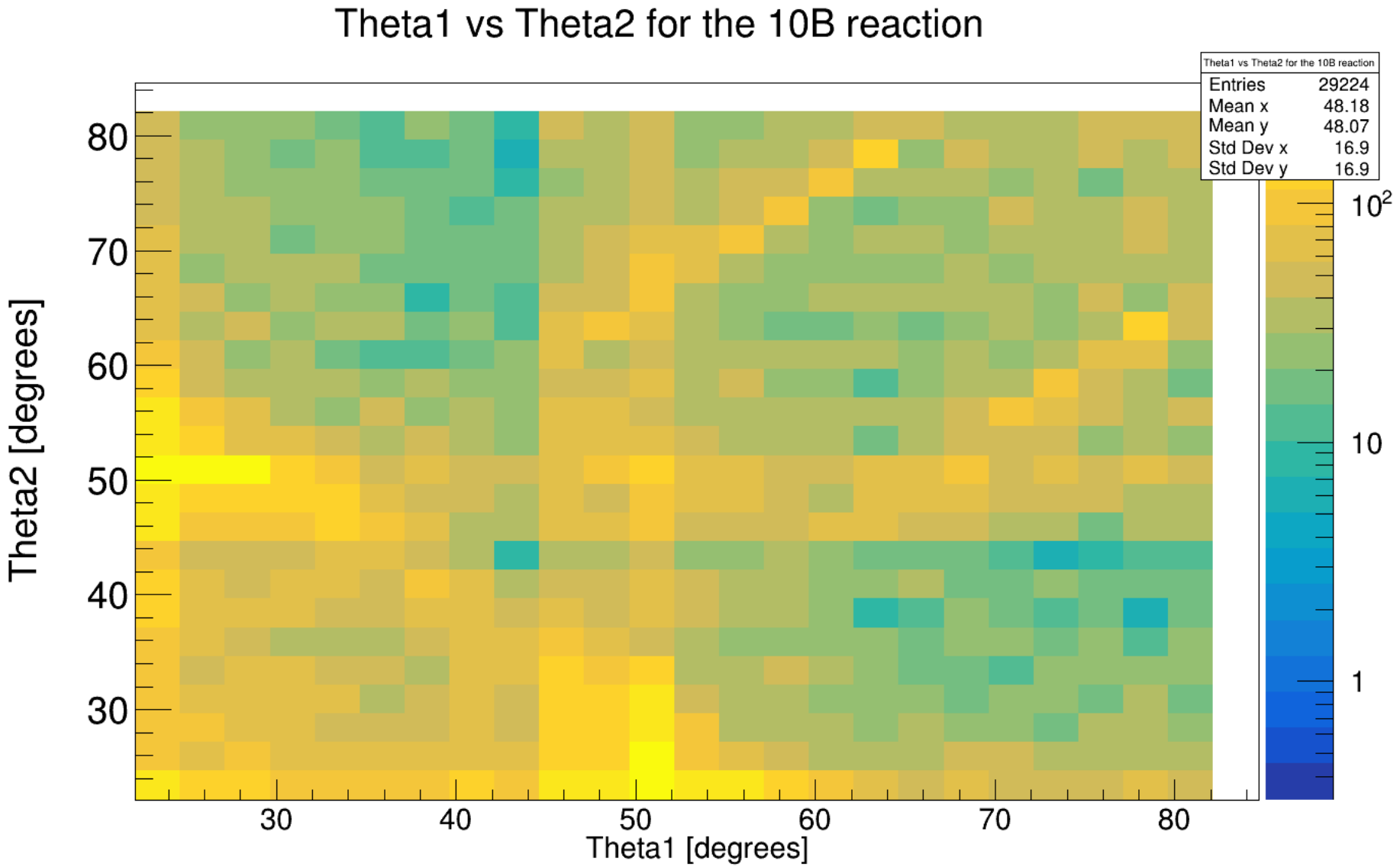


12C(p,ppn/pd)10B Reaction



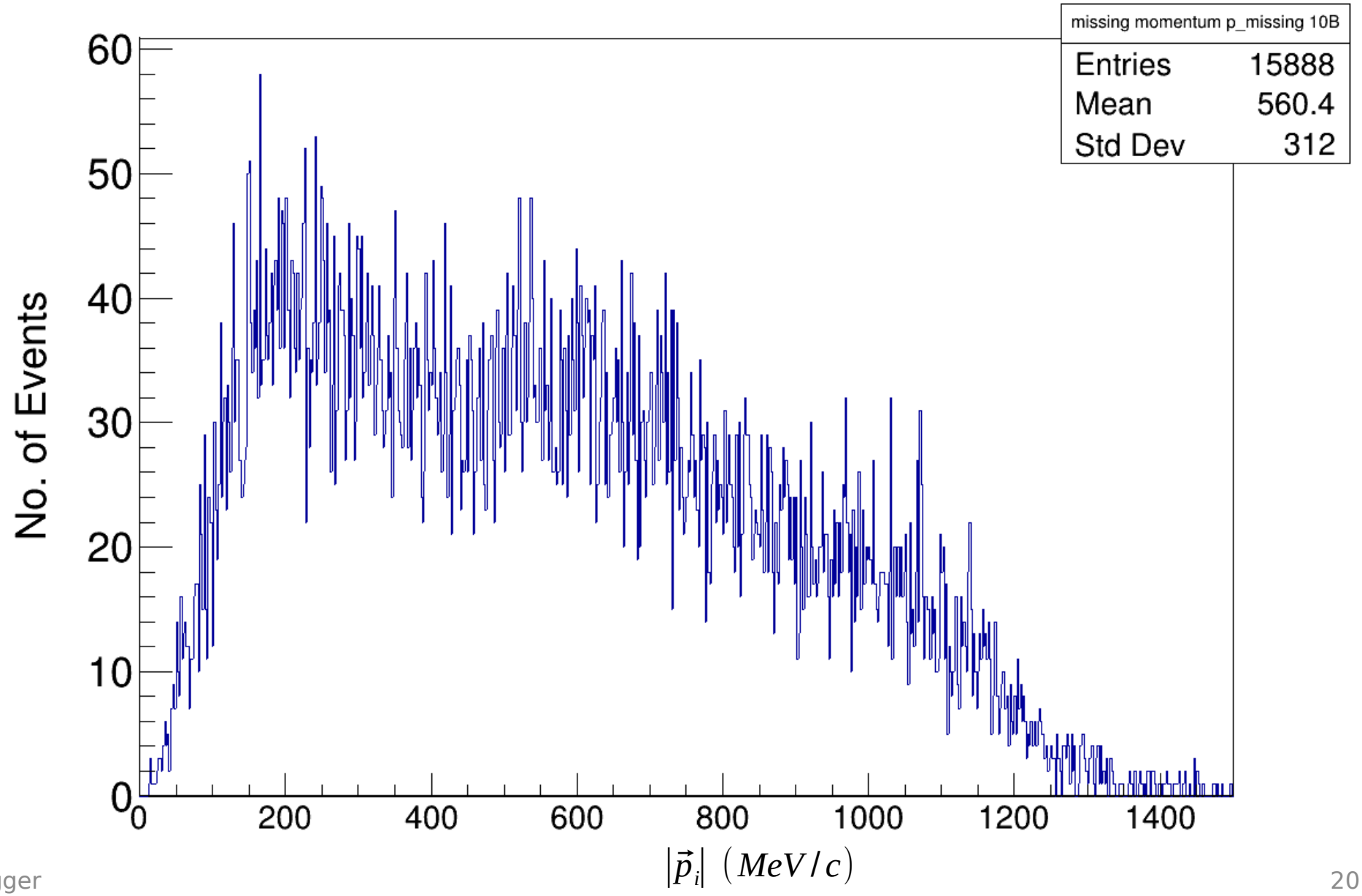
First Angular and Momentum Plots …

Without cut:



Reconstruction of inner momentum p_i

$$p_i = (p_1 + p_1 - p_{tg})$$



Neutron Mass Reconstruction

$$M^2_{missing} = (p_{12C} + p_{tg} - p_1 - p_2 - p_{10B})^2$$

before reaction

after reaction