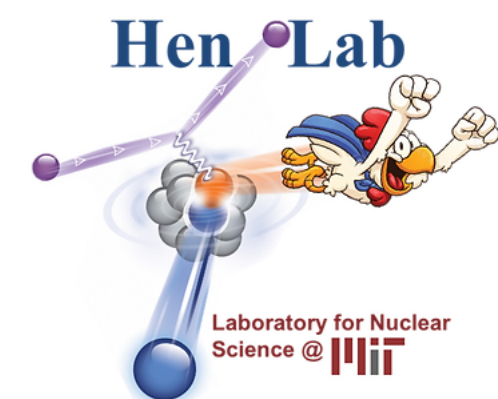


Short-Range Correlations in Exotic Nuclei

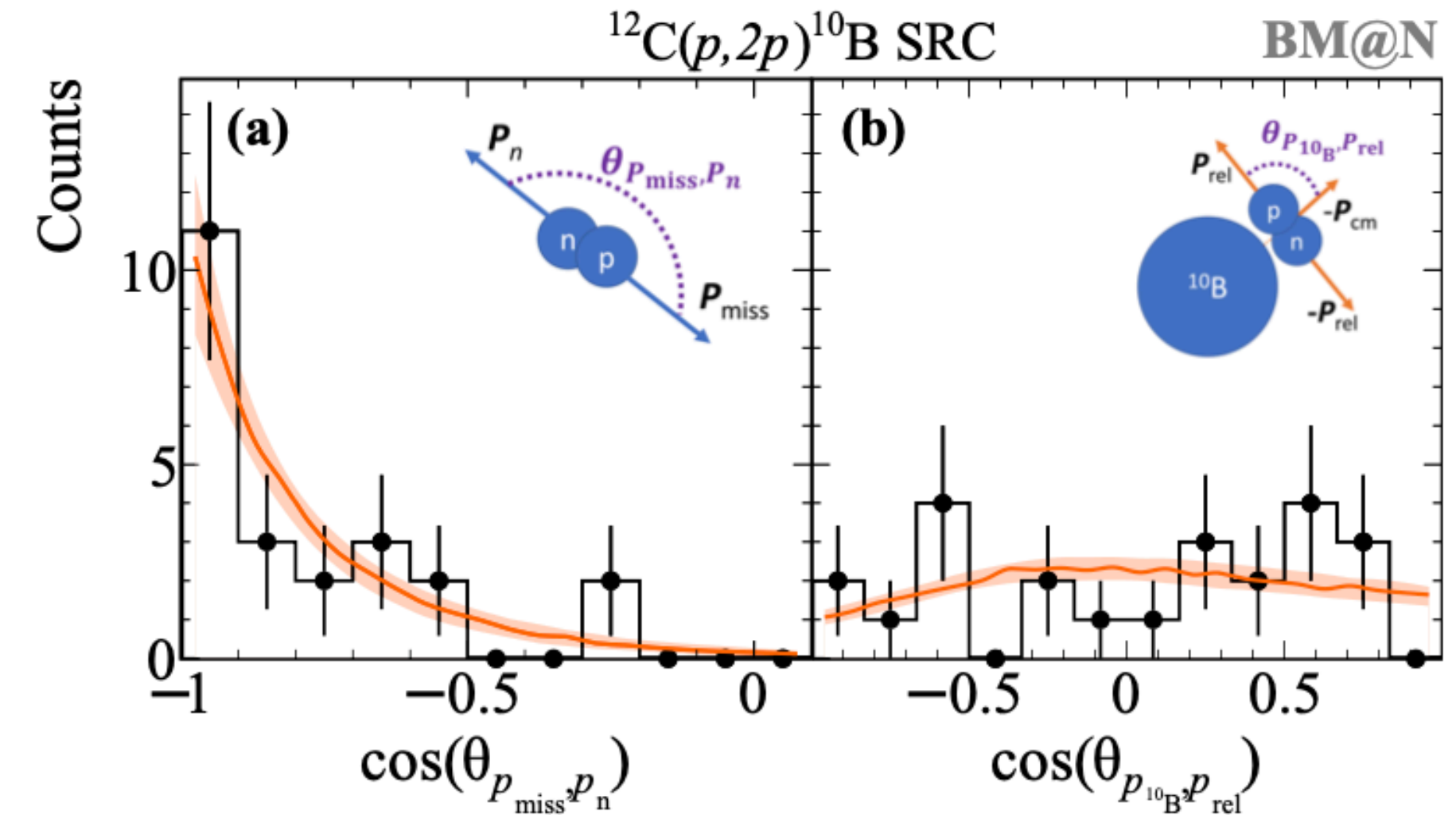
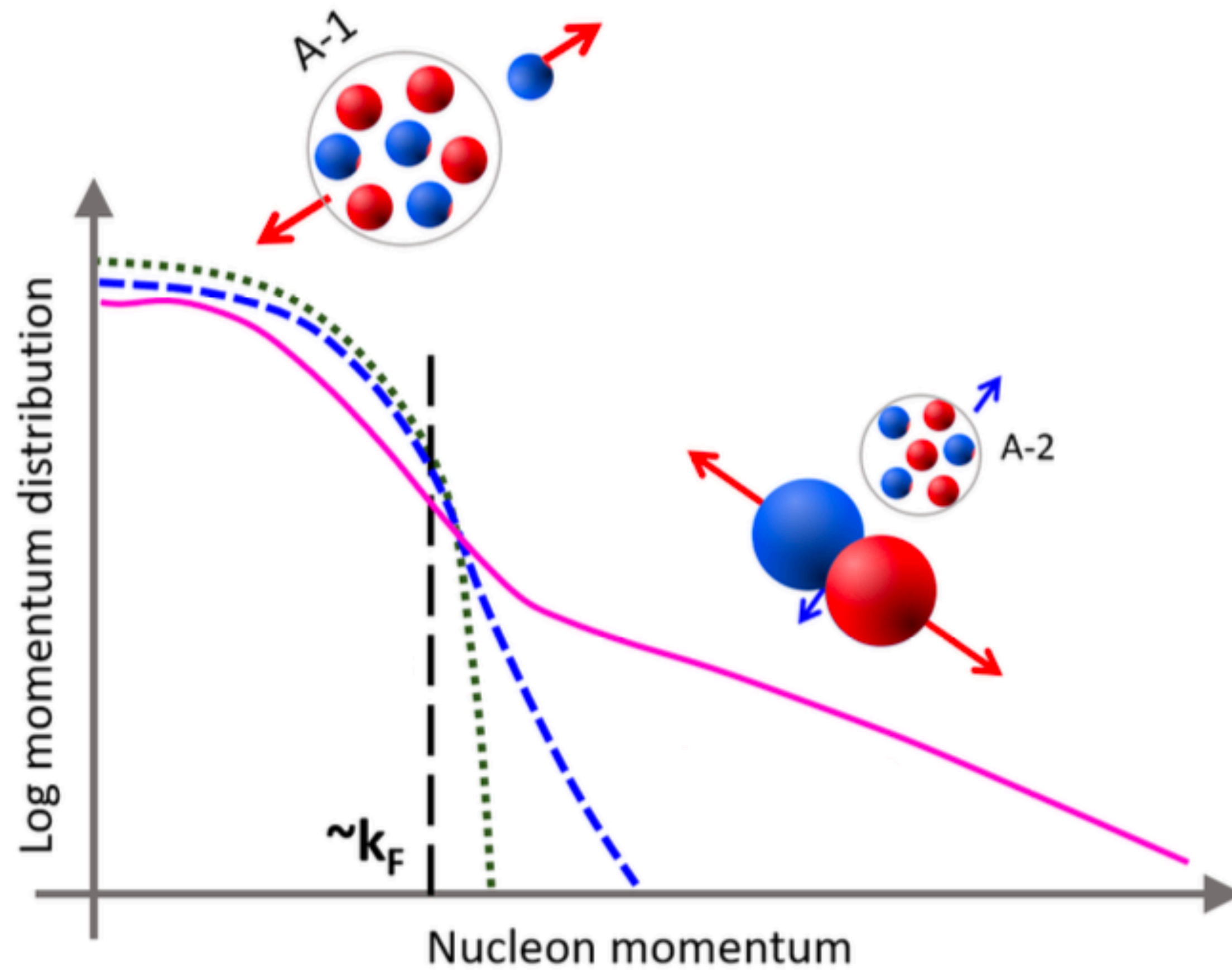
Preliminary results on SRC study in ^{16}C and ^{12}C using inverse kinematics at GSI-FAIR

Christine Qi, 08/2024



Nuclear Short-Range Correlations

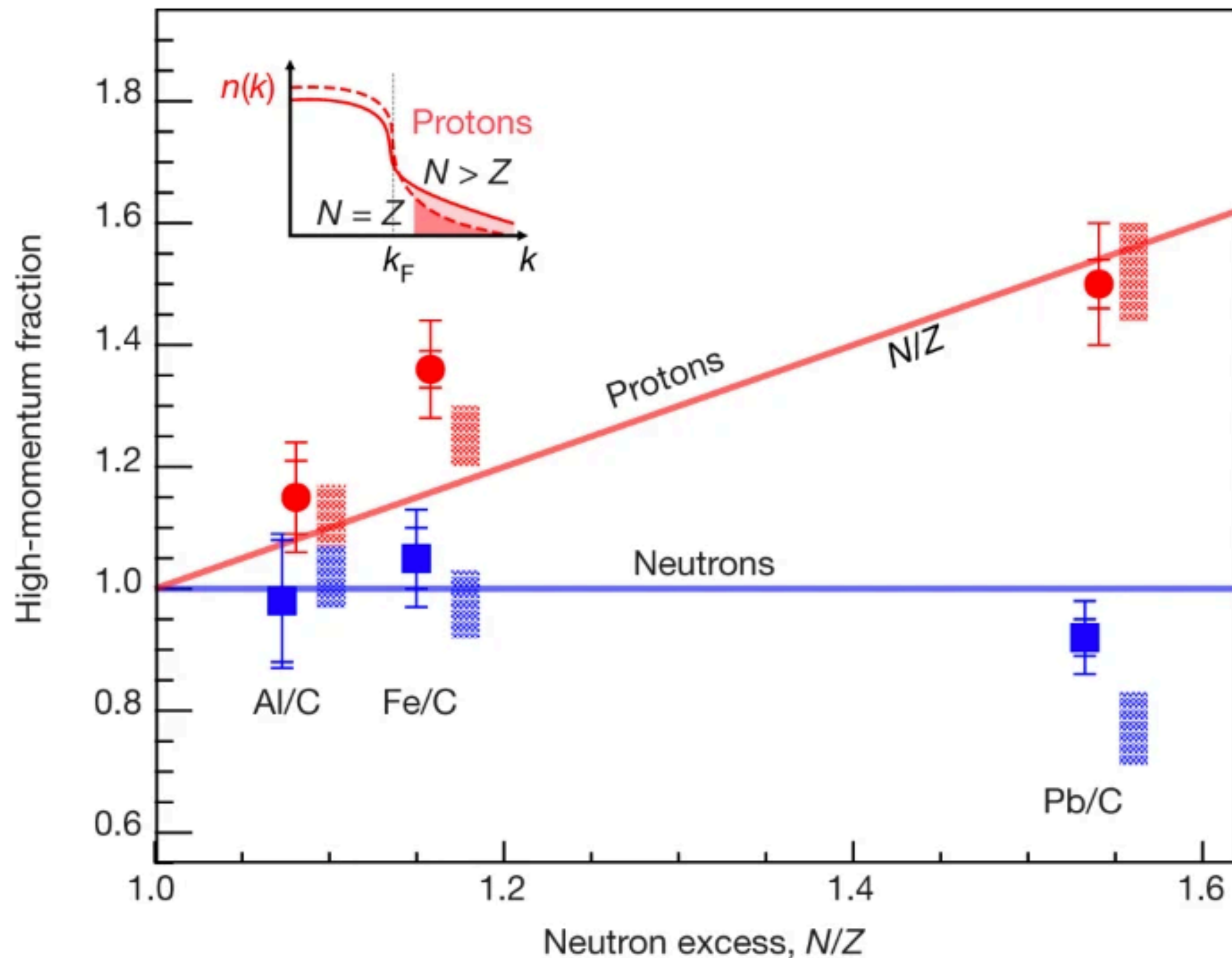
Patsyuk et al., Nat. Phys. 17, 693-699 (2021)



- Factorization into SRC and A-2 system
- Dominance of p-n over p-p SRC pairs

How excess neutrons in neutron-rich nuclei form SRC pairs?

(e,e'N) experiment



Consistent with n-p dominance of SRC pairs

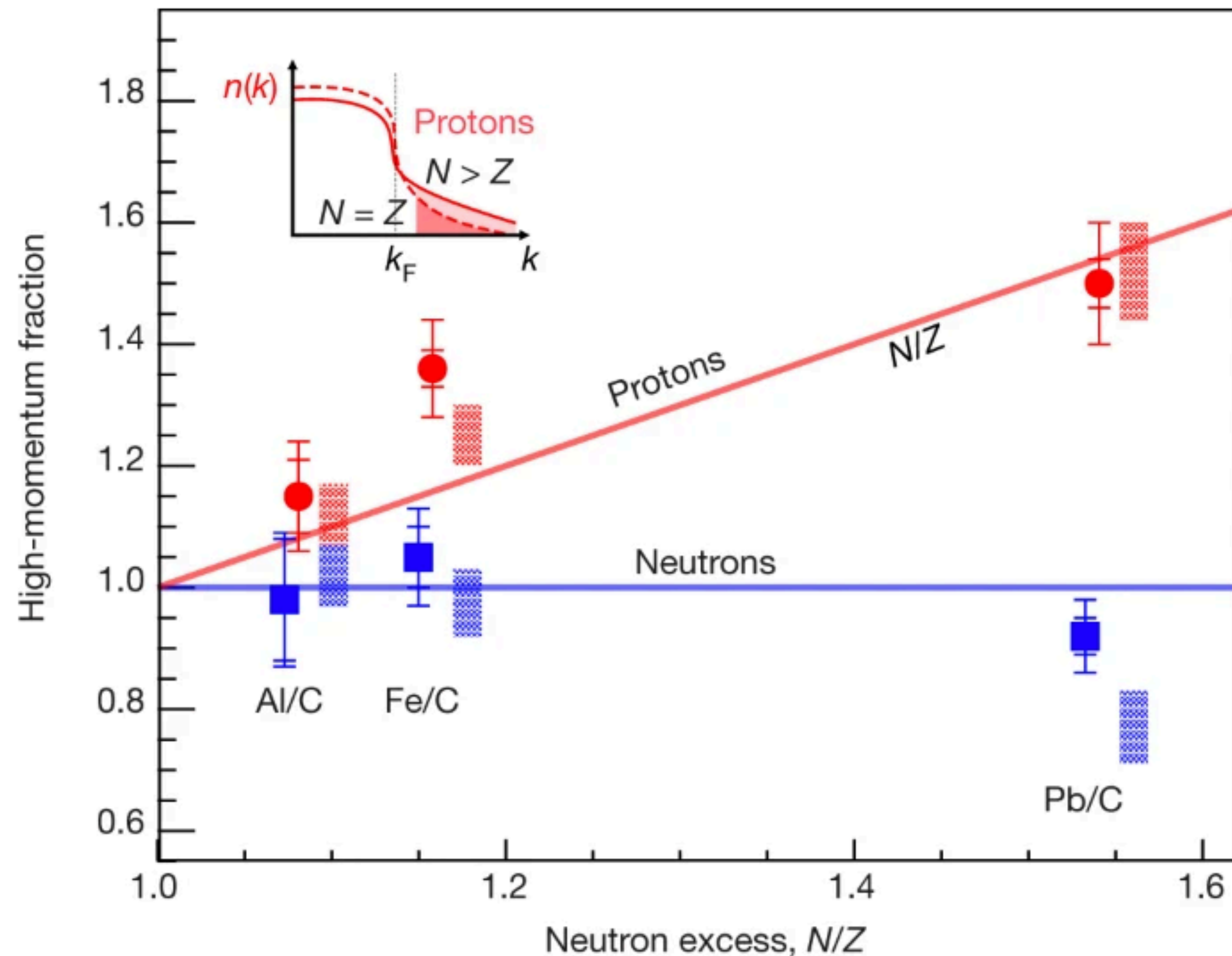
High-momentum proton fraction increased in neutron-rich nuclei

SRC fraction for neutrons saturates in asymmetric nuclei

M. Duer et al. (CLAS), Nature 2018.

Why unstable beams?

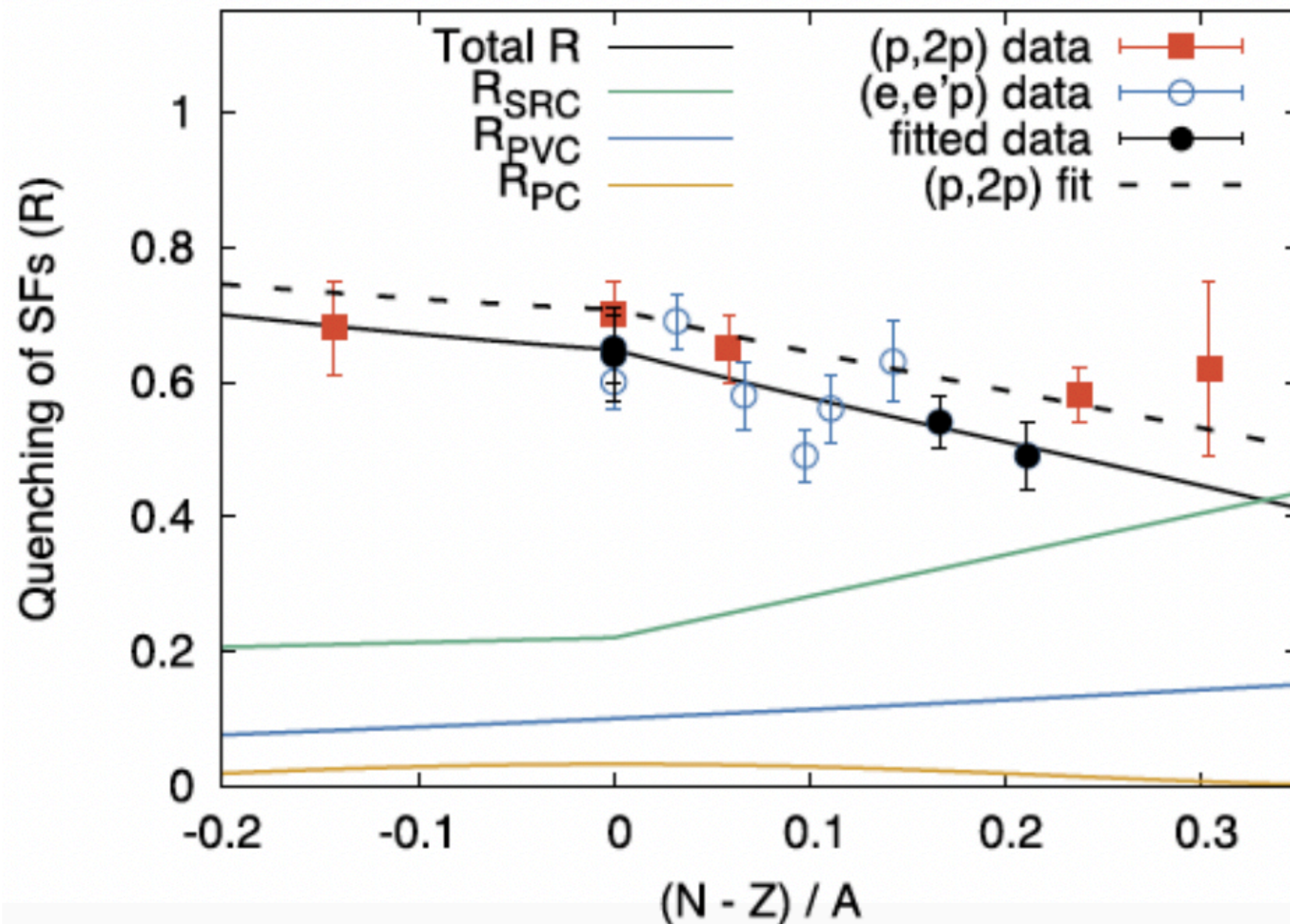
(e,e'N) experiment



- Reach large asymmetry with unstable nuclei
- Disentangle mass and N/Z dependence with nucleus along isotopic chain

M. Duer et al. (CLAS), Nature 2018.

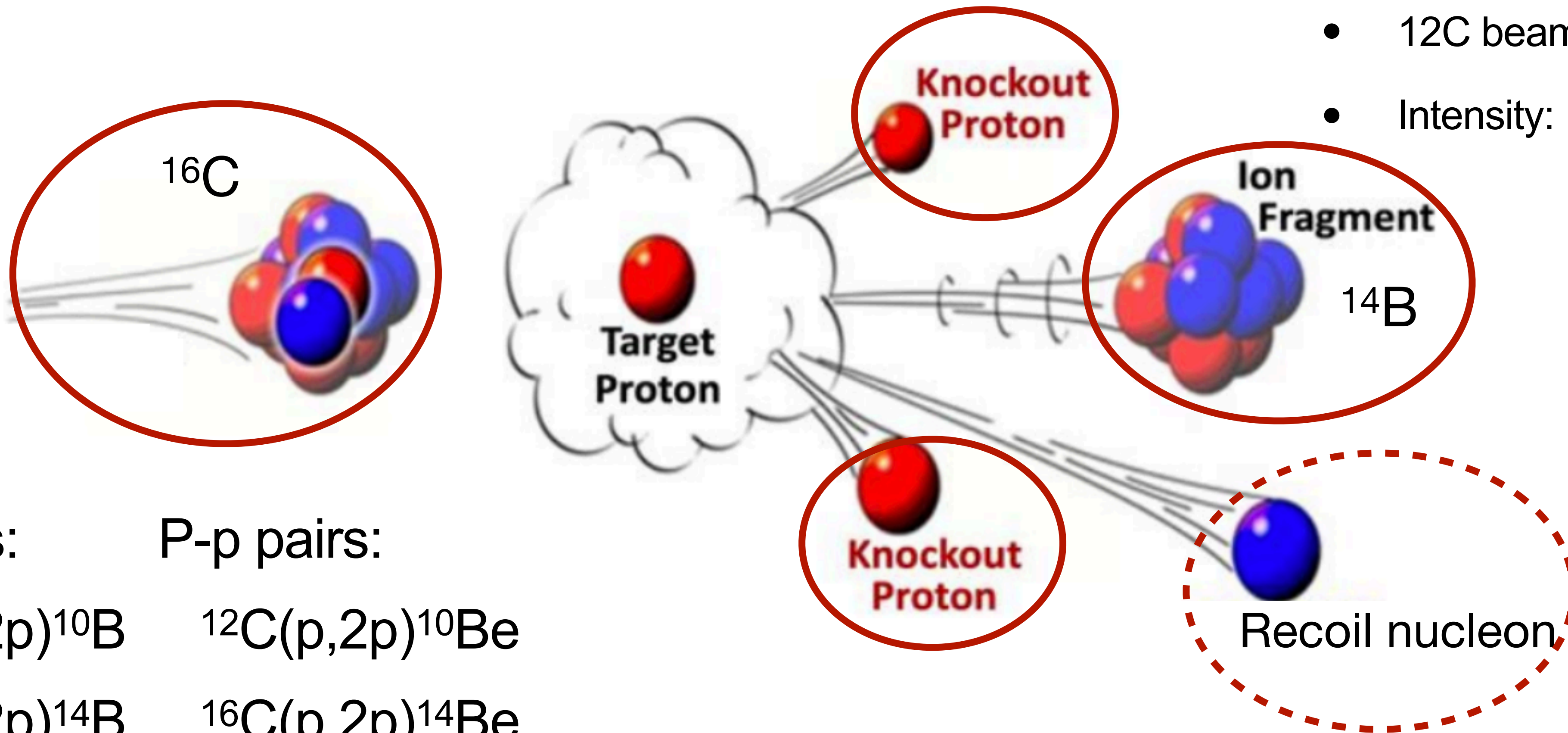
Quenching of spectroscopic factors dependency on proton-neutron asymmetry



- Phenomenological model of SRC contribution to the quenching of spectroscopic factor
- Further SRC in neutron-rich nuclei study required

Inverse kinematics at R³B: exclusive measurement of SRC break-up

- Beam information
 - 16C beam, 1.25 GeV/u
 - 12C beam, 1.25 GeV/u
 - Intensity: 1×10^5 pps



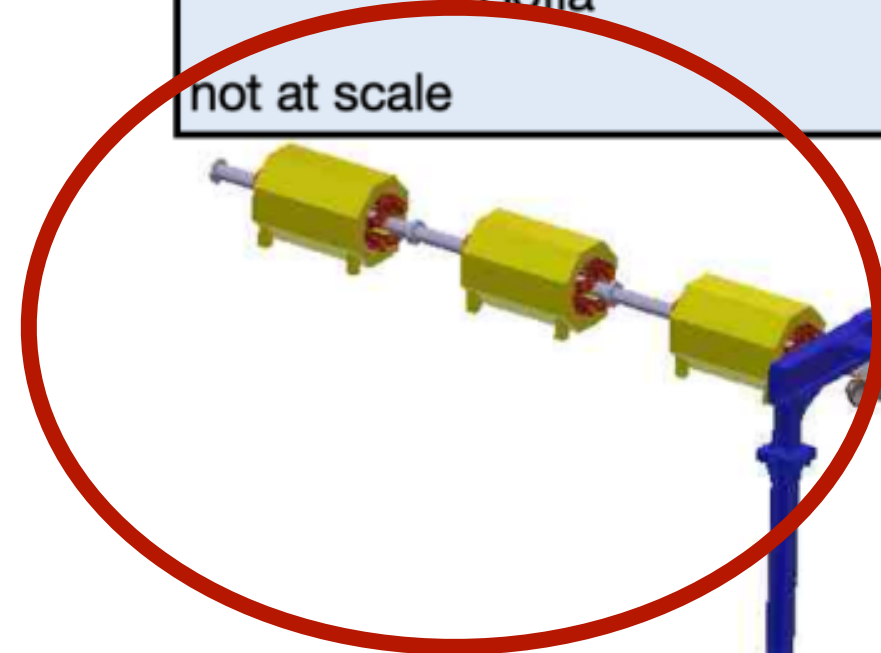
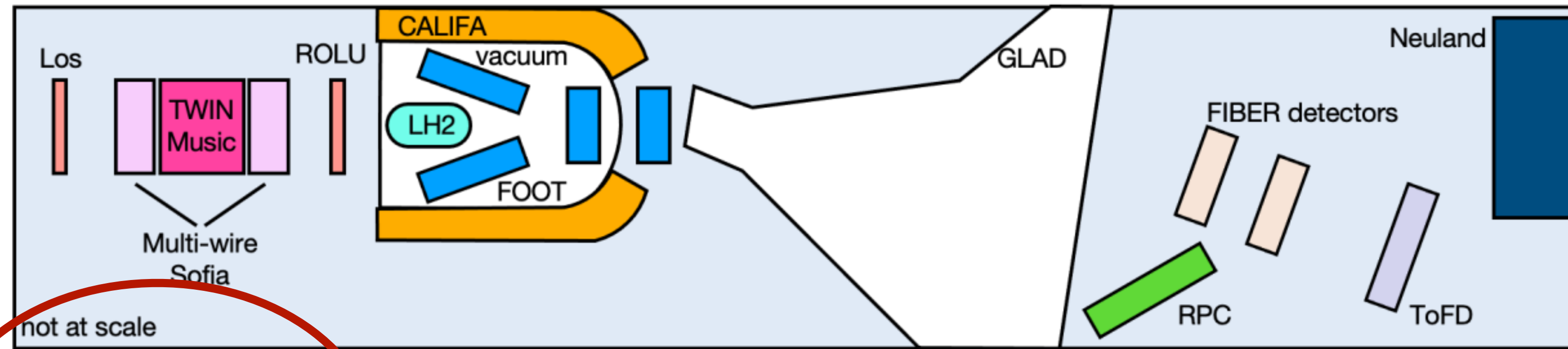
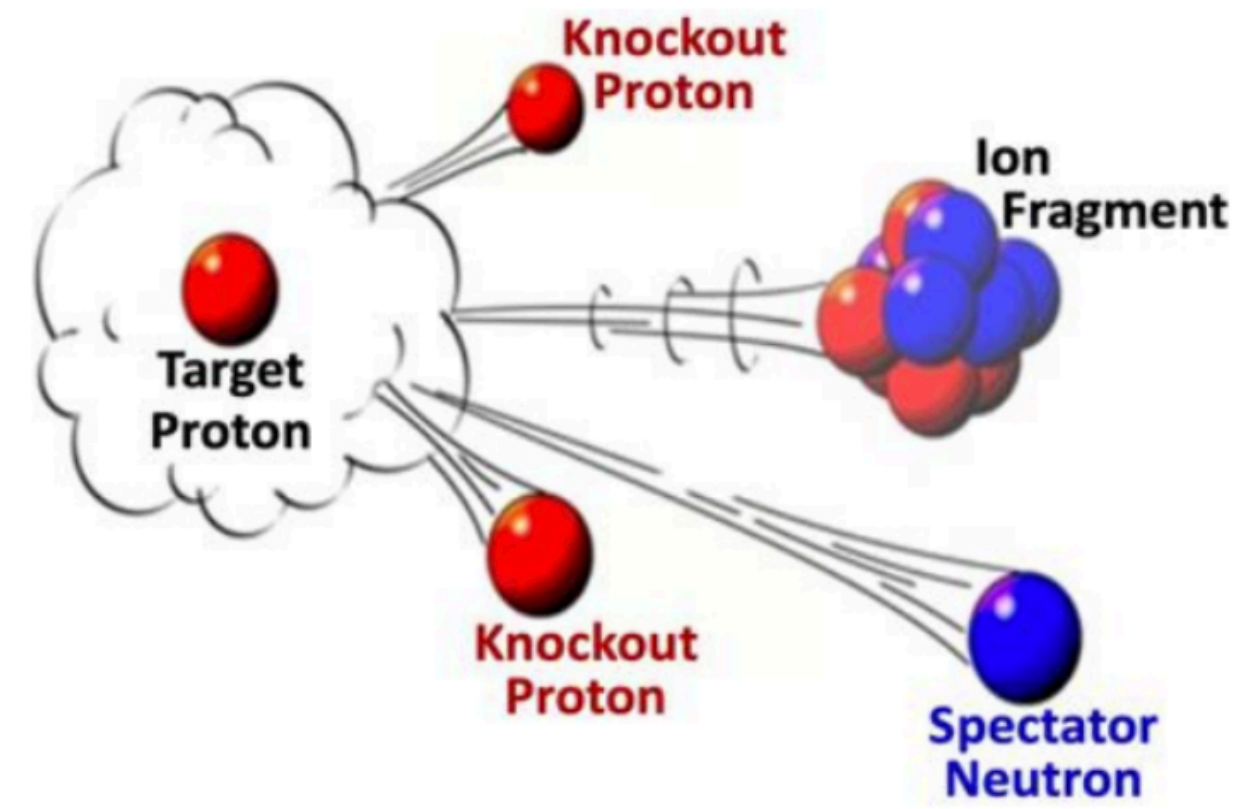
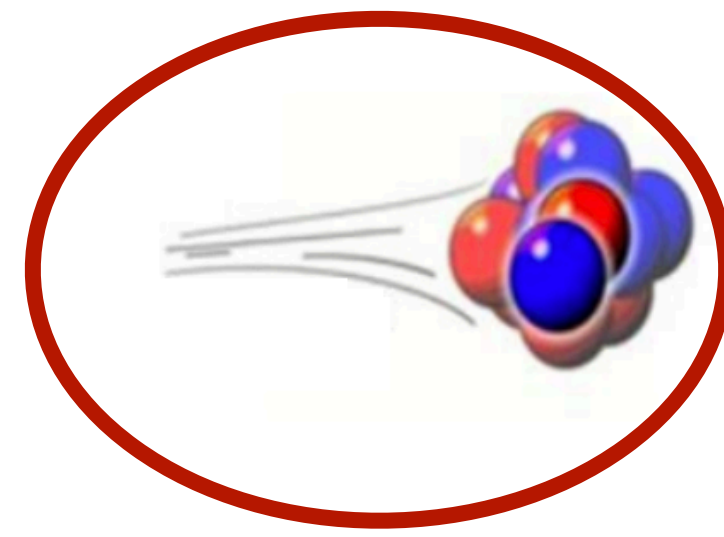
P-n pairs:



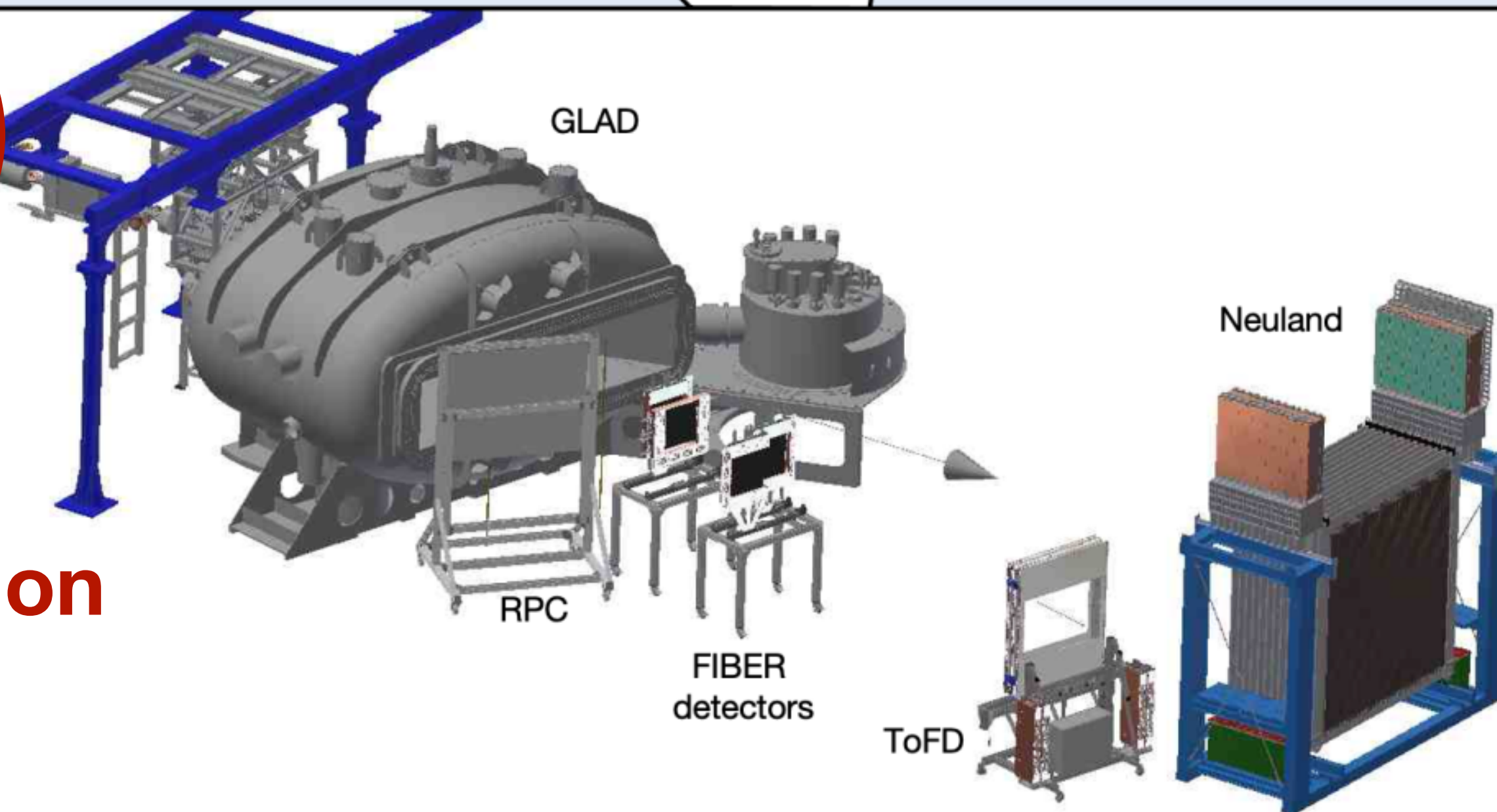
P-p pairs:



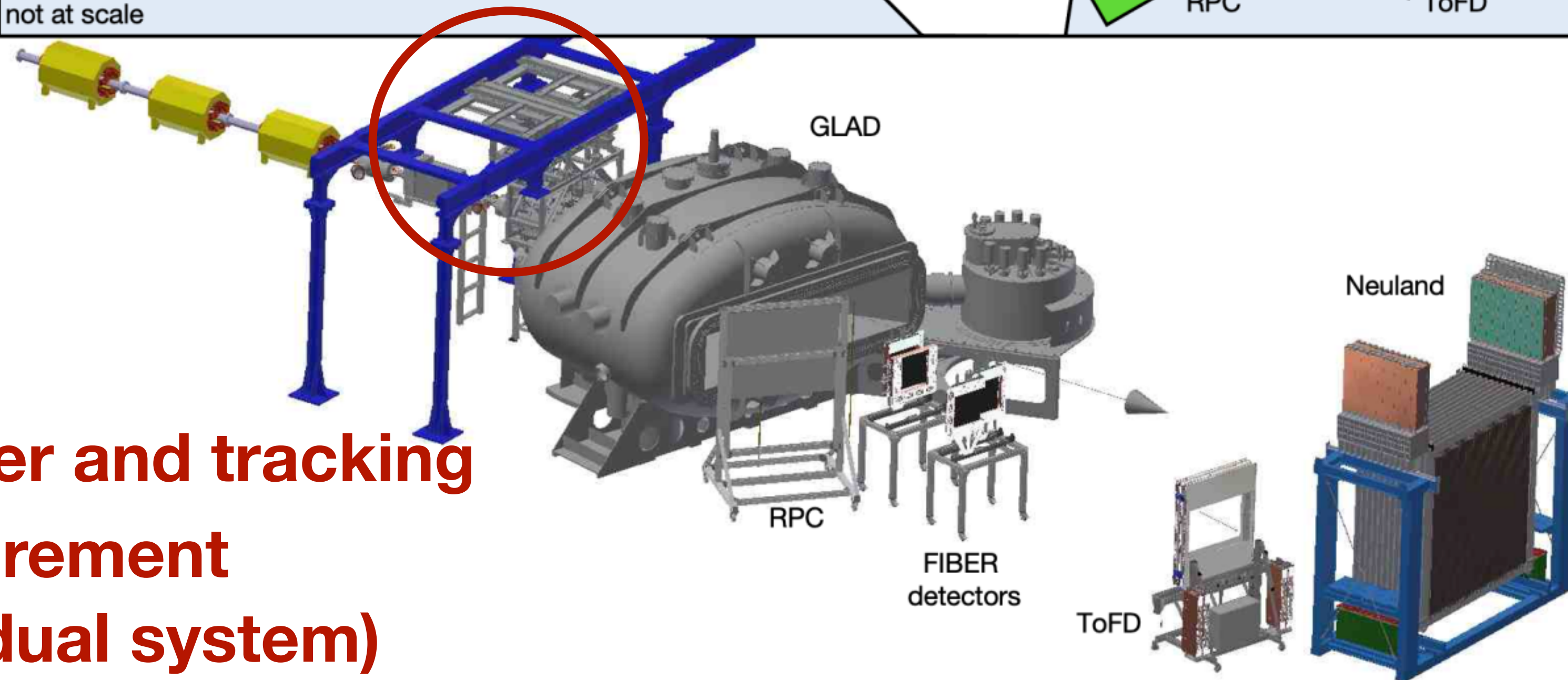
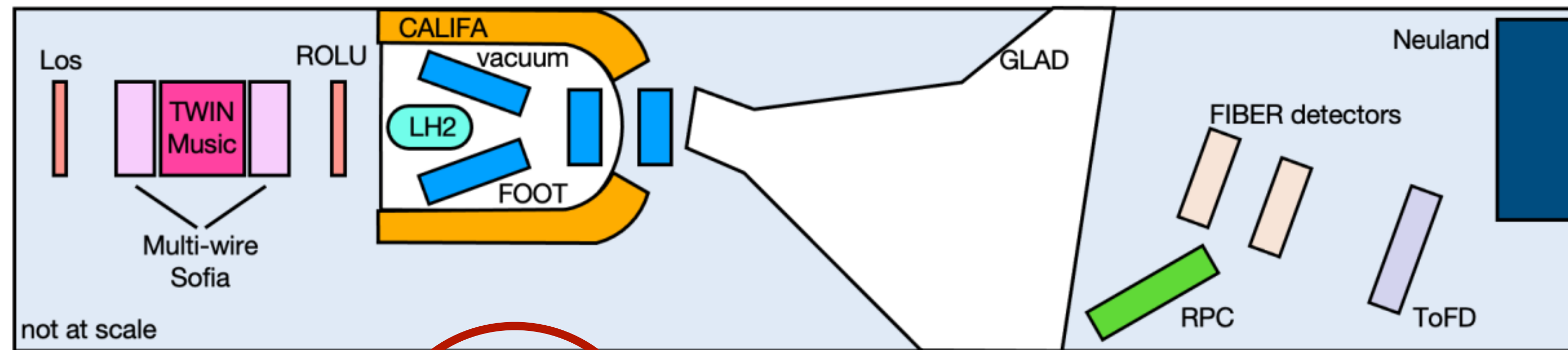
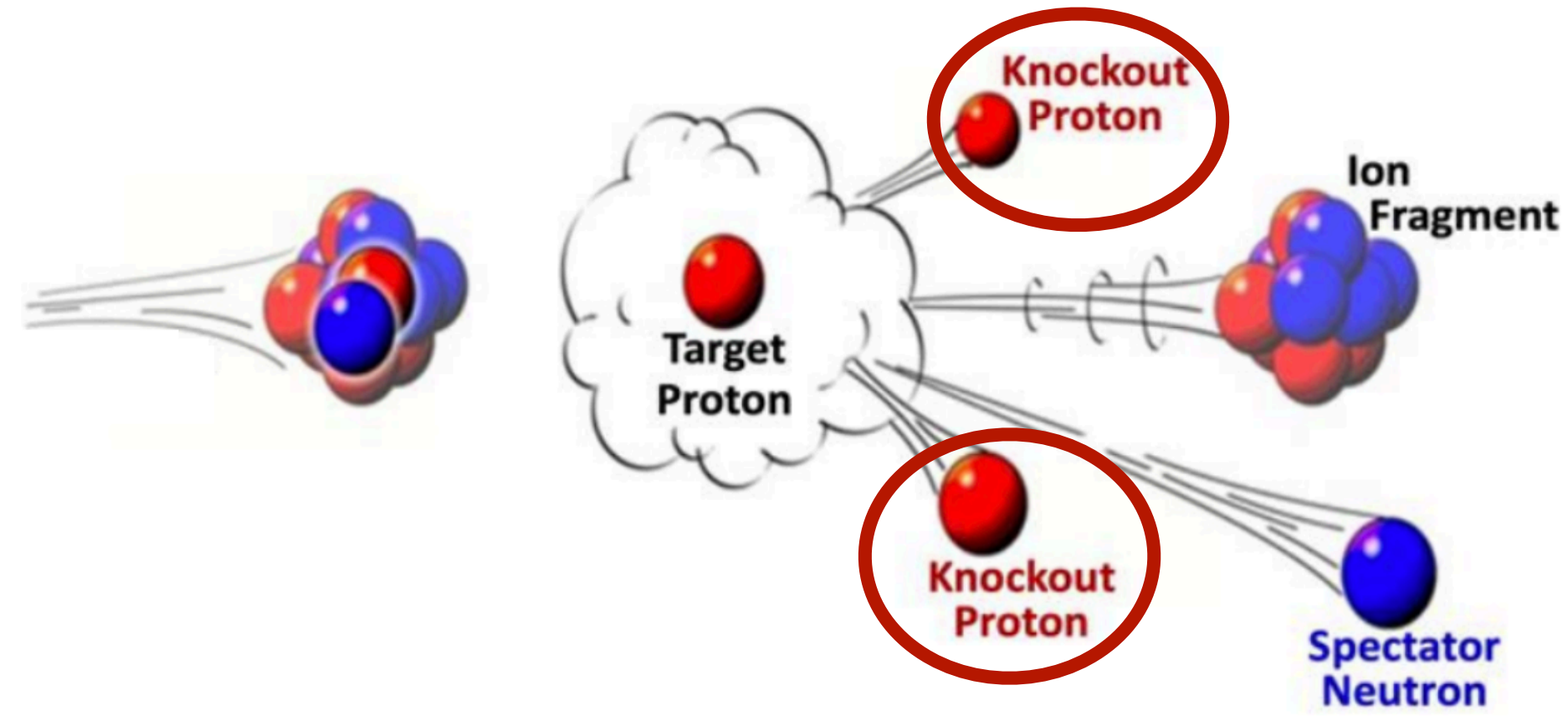
R³B Setup



Incoming beam identification
And tracking

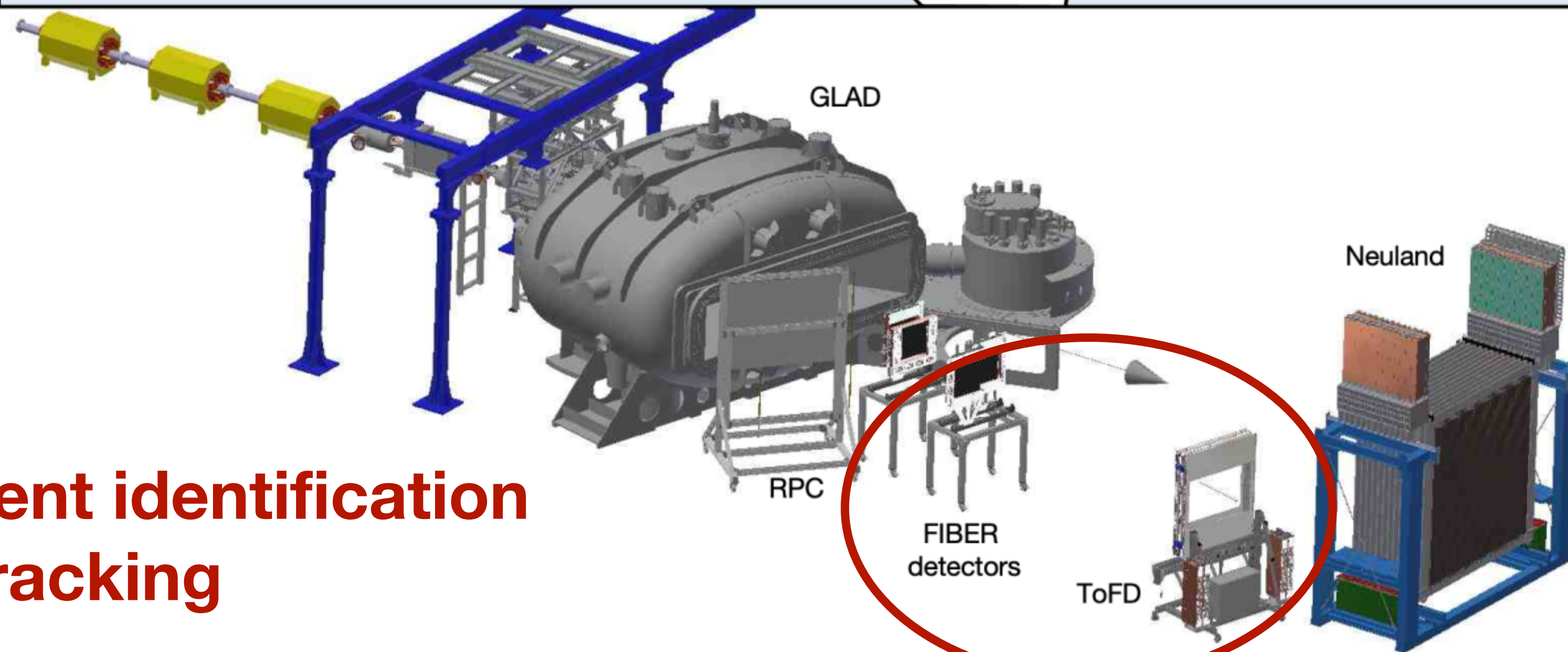
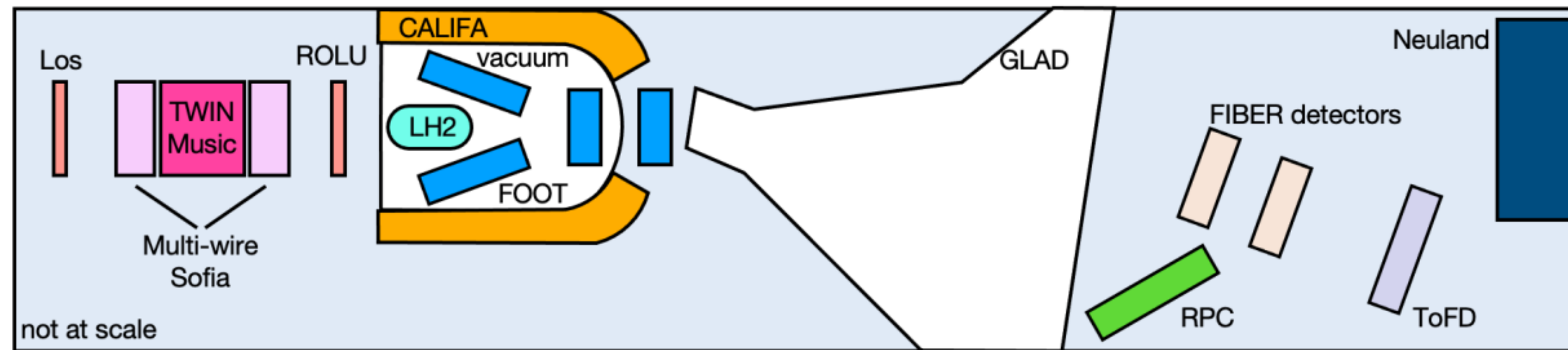
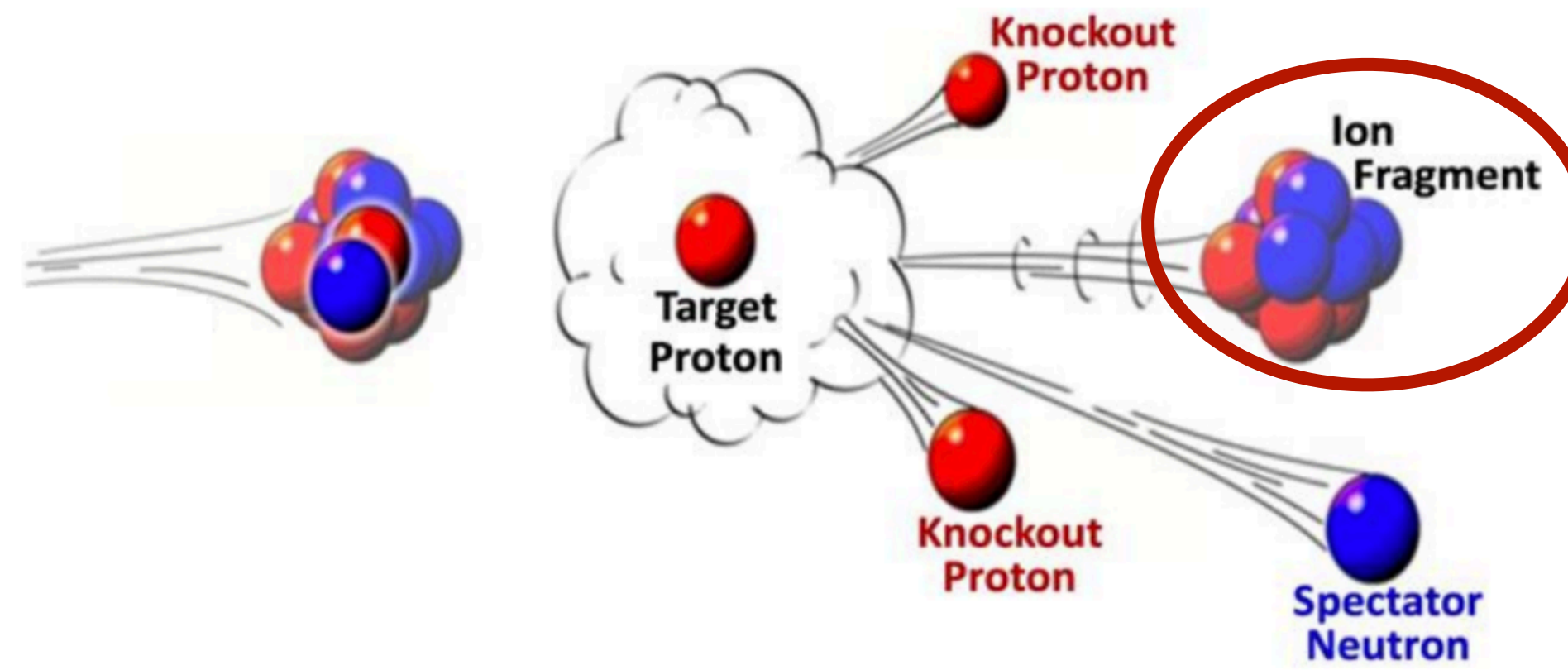


R³B Setup



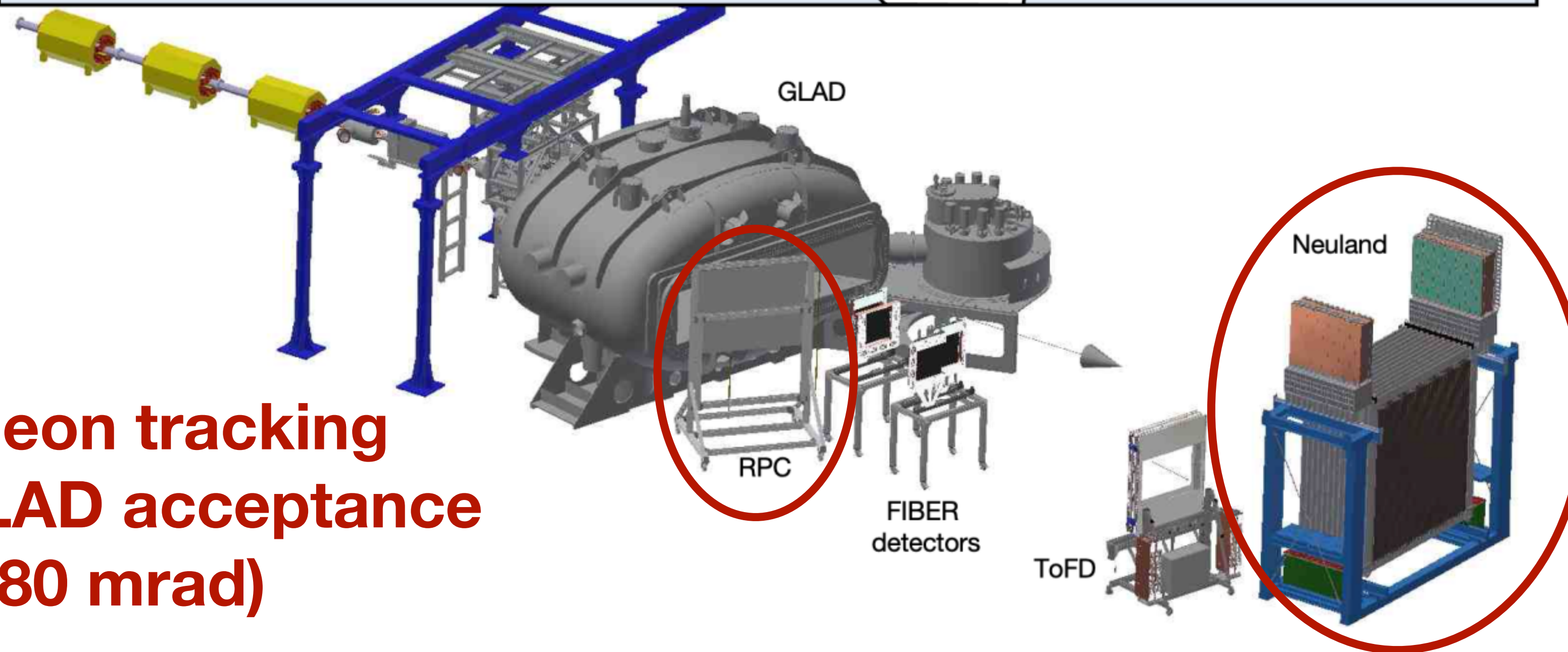
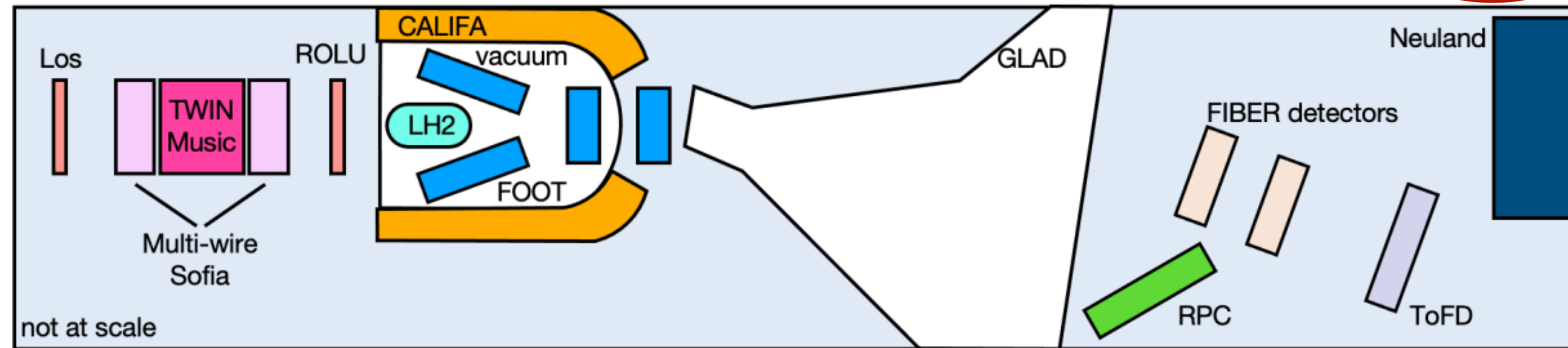
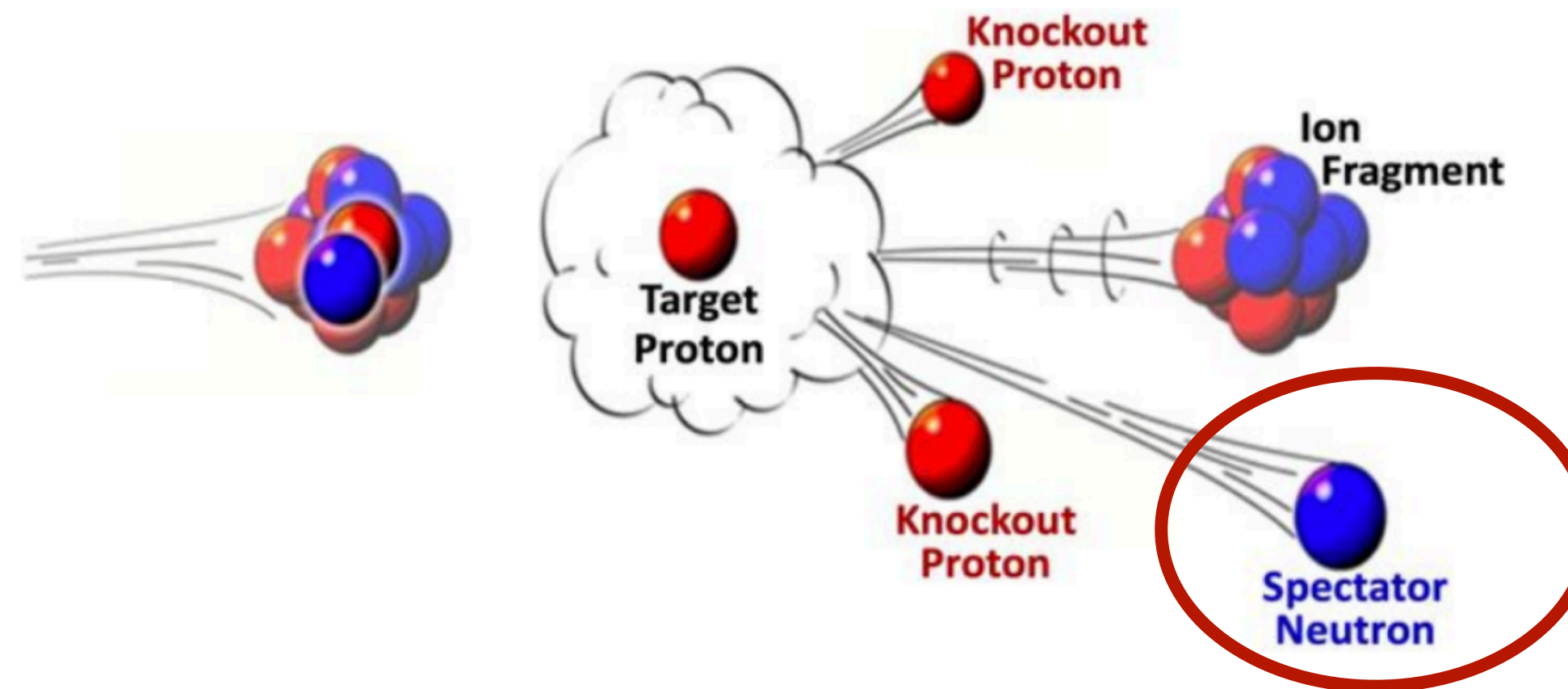
(p,2p) calorimeter and tracking
 γ measurement
(excited residual system)

R³B Setup



**Residual fragment identification
And tracking**

R³B Setup

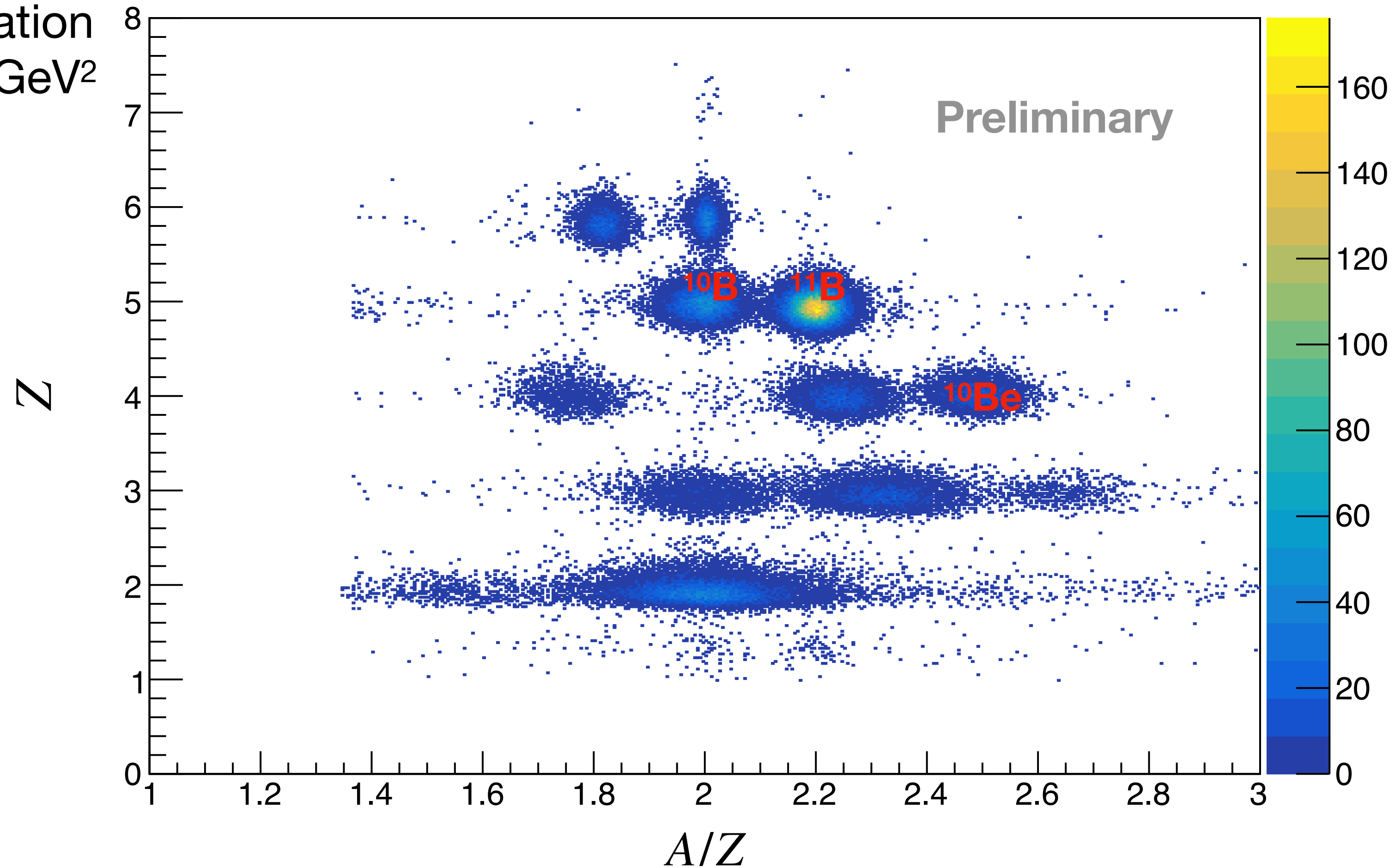


**Recoil nucleon tracking
(Limited by GLAD acceptance
range, 80 mrad)**

Residual fragment identification for ^{12}C data

(p,2p) tagging:

- Two high energy cluster identification
- $|t| > 0.8 \text{ GeV}^2$



Quasi-elastic event identification by A-1 system tagging

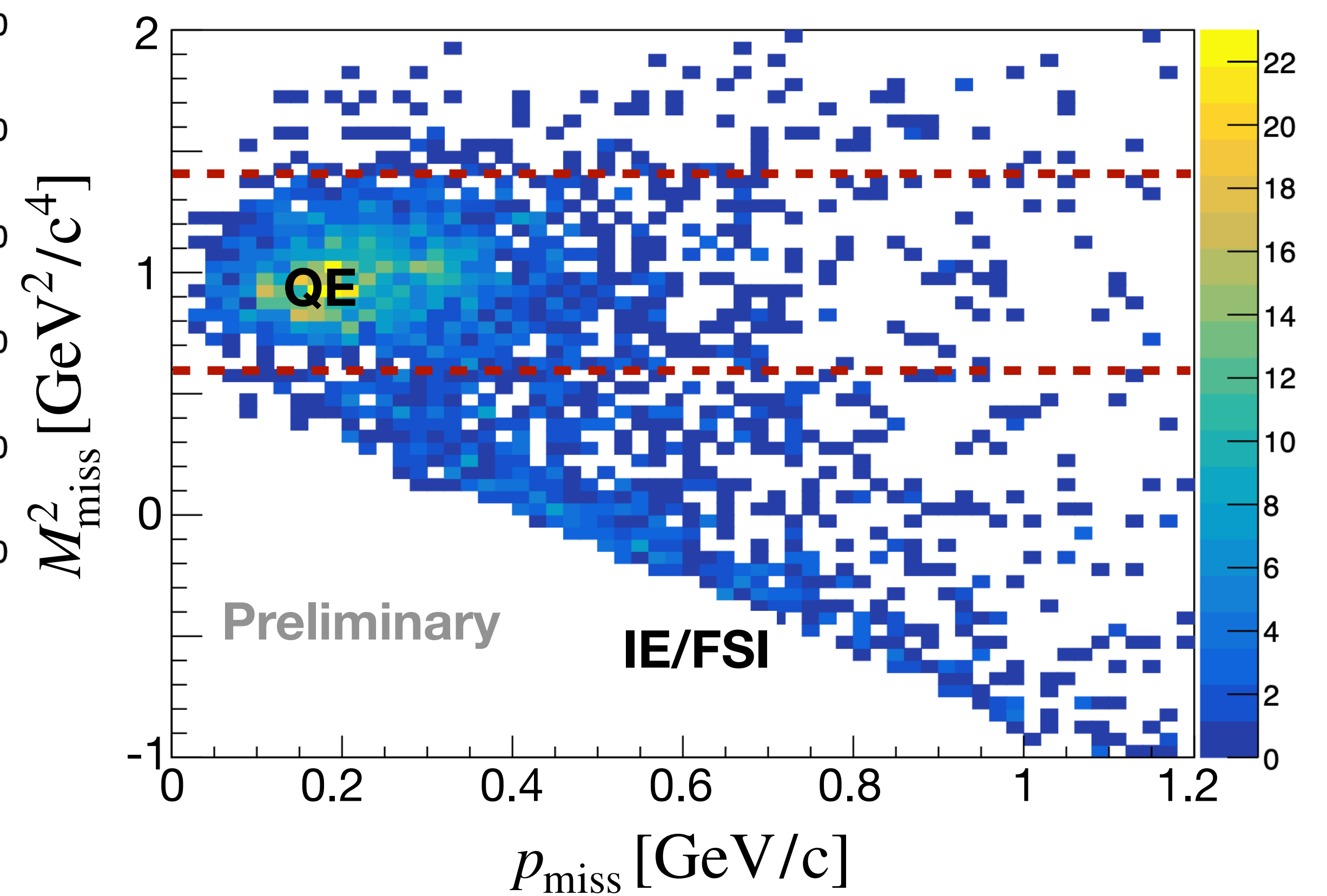
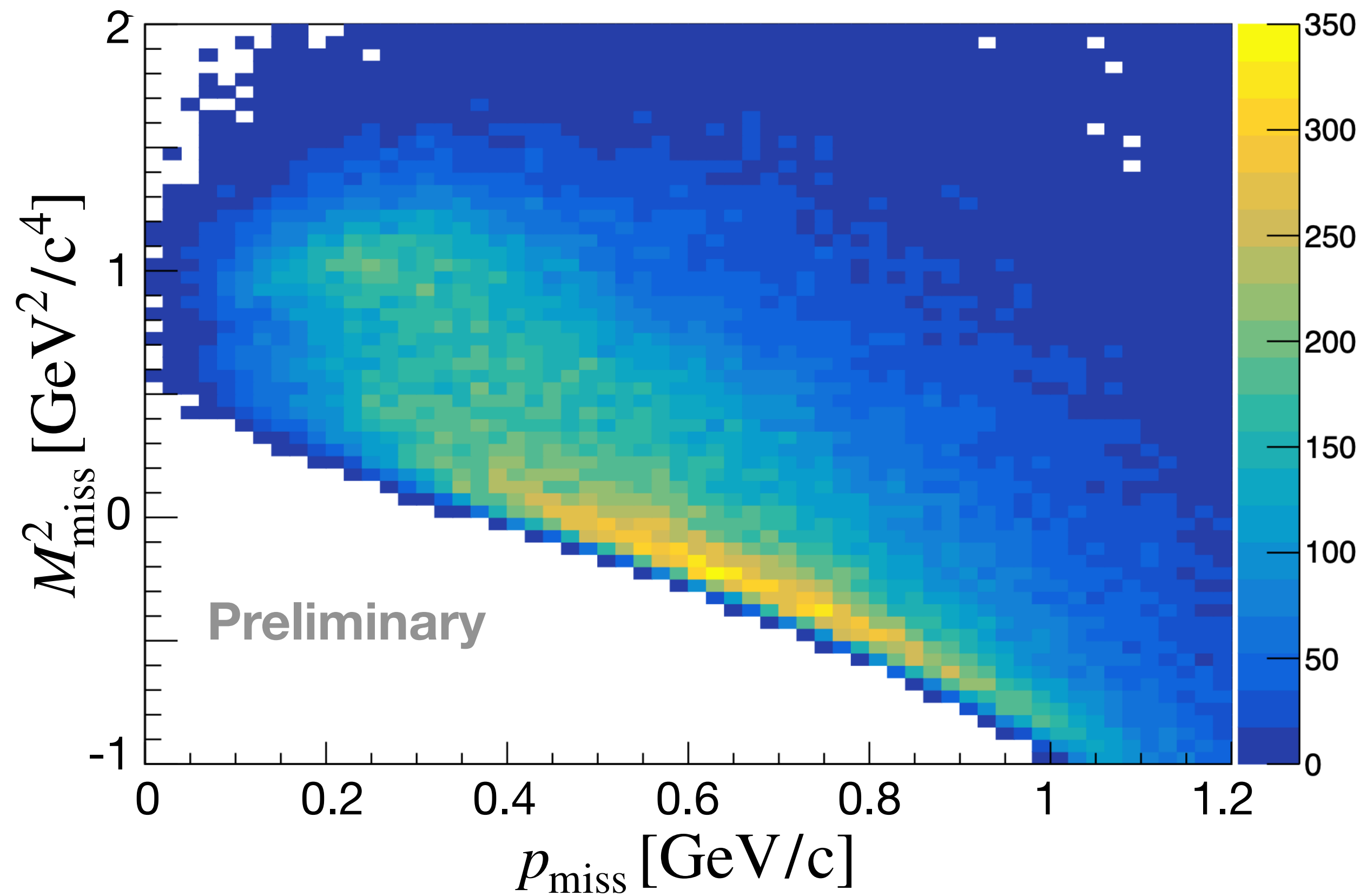
$$p_{miss} = p_3 + p_4 - p_{tg}$$

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

11B tag



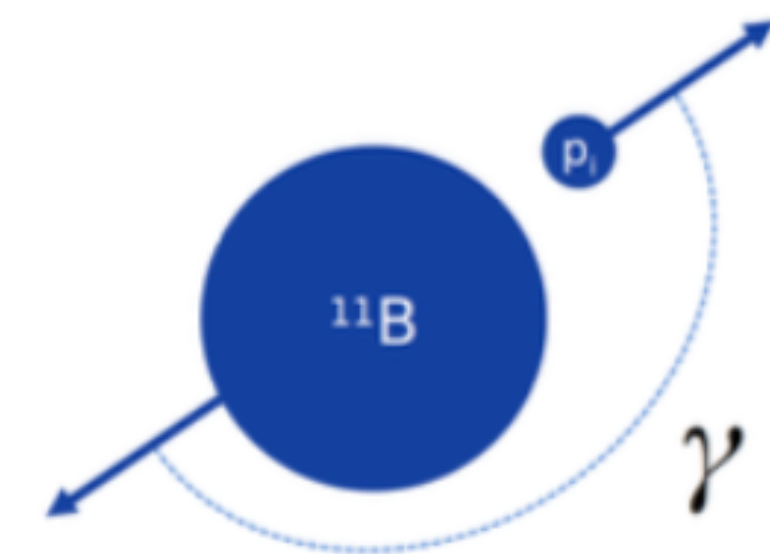
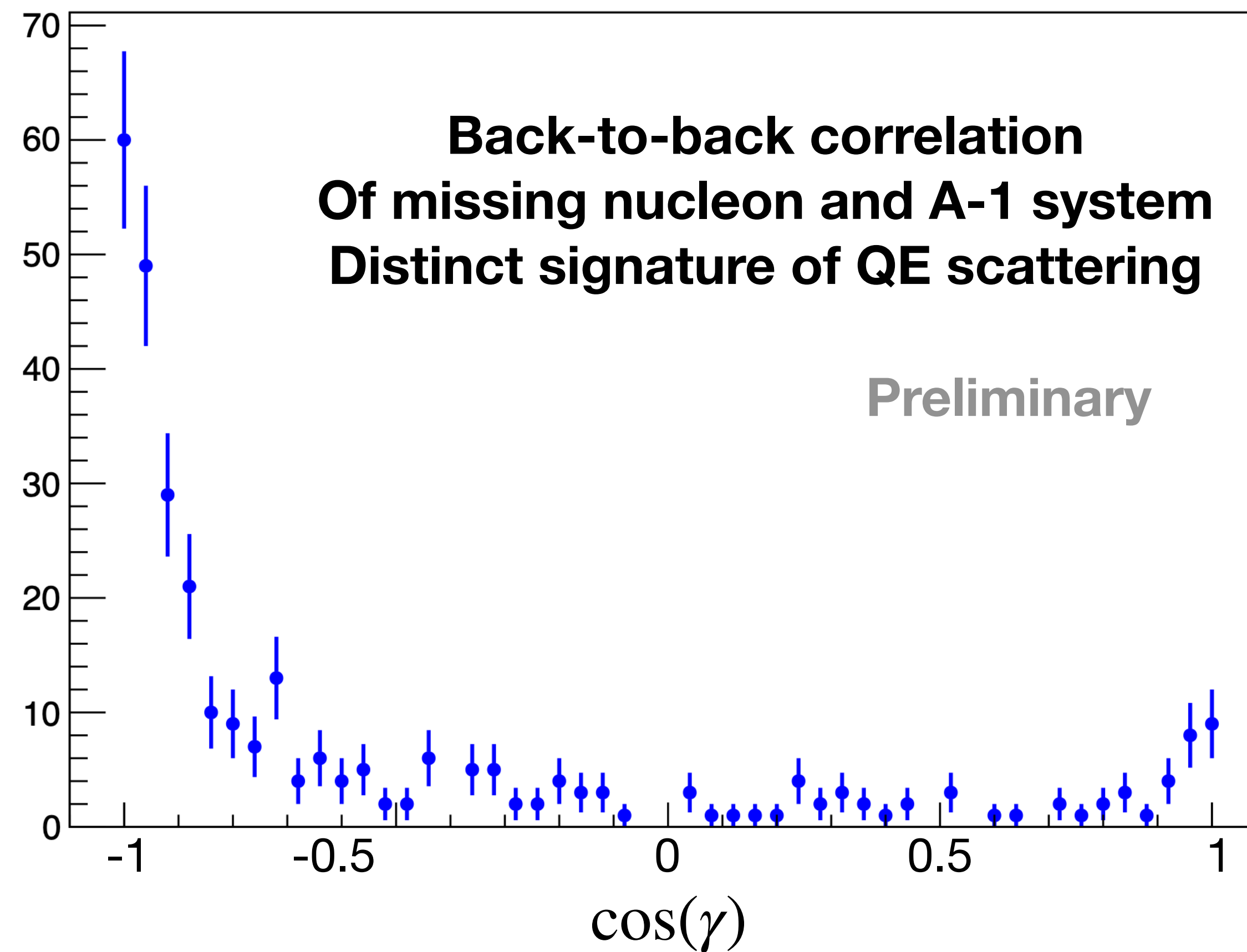
$^{12}\text{C}(p,2p)^{11}\text{B}$



Back-to-back correlation between initial proton and residual A-1 fragment system

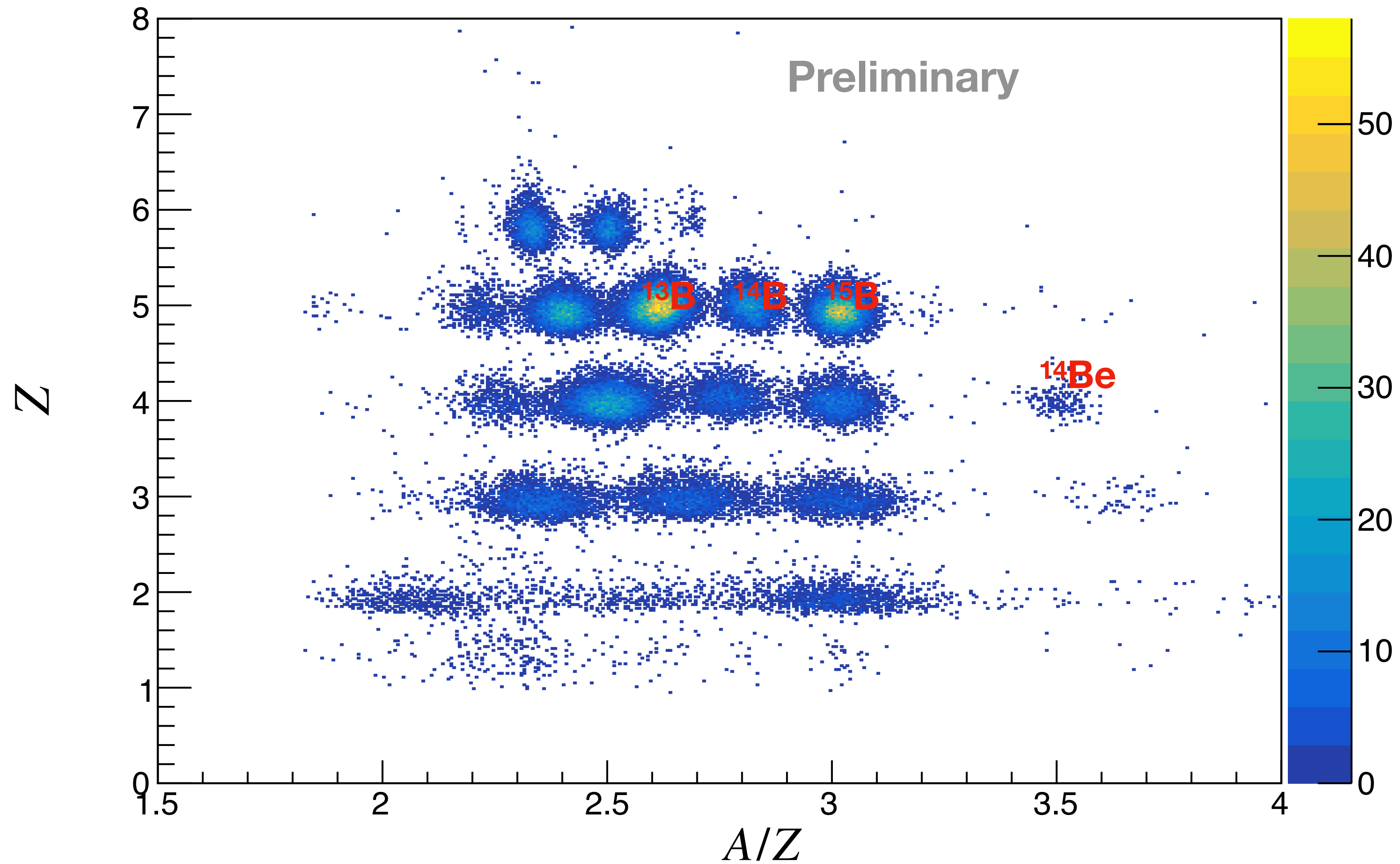
$^{12}\text{C}(p,2p)^{11}\text{B}$

(p,2p) tagging
(p,2p) missing mass squared: 0.6-1.4 GeV^2/c^4

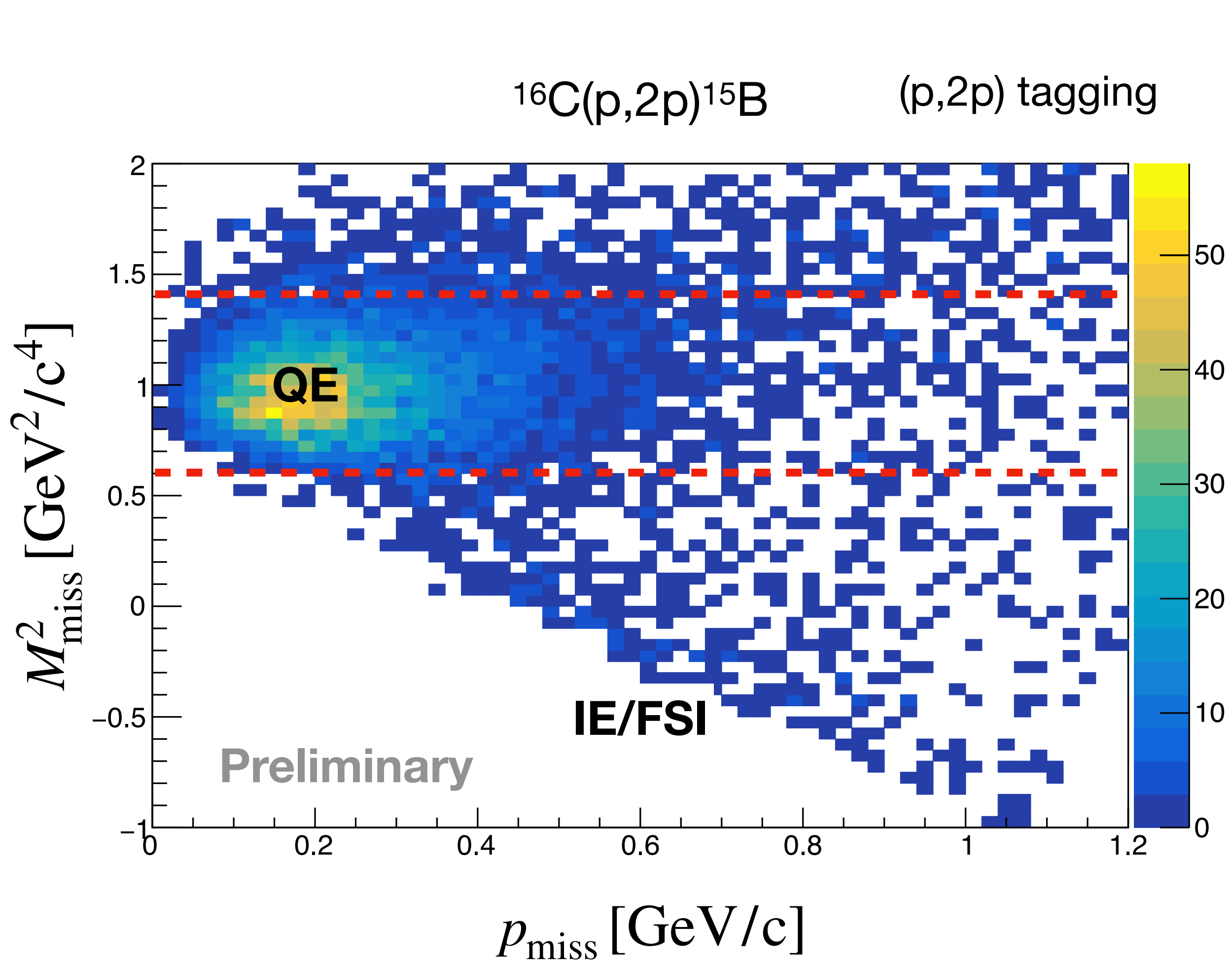


Residual fragment identification for ^{16}C data

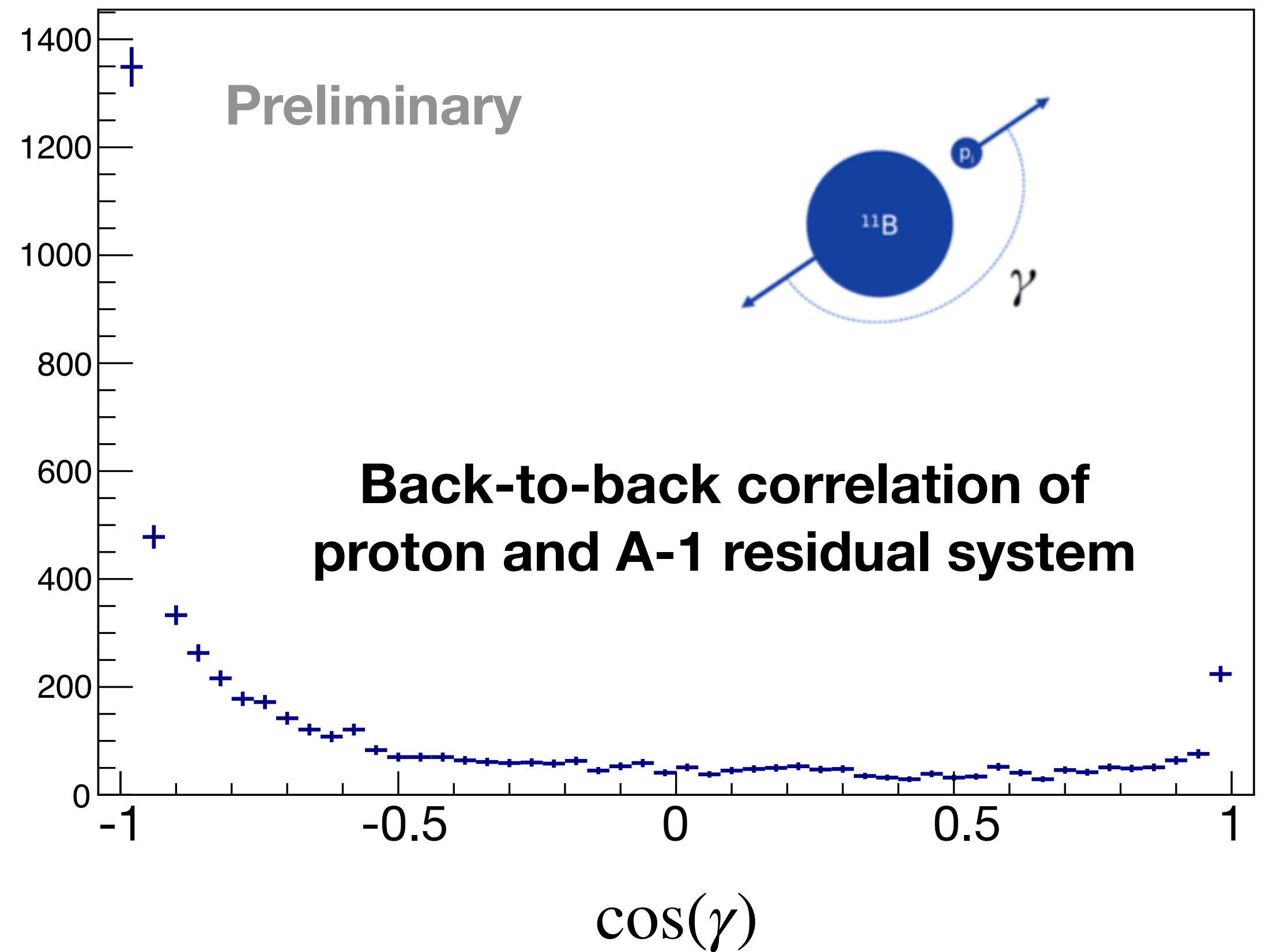
(p,2p) tagging



$^{16}\text{C}(p,2p)^{15}\text{B}$ quasi-elastic events selection



(p,2p) tagging
(p,2p) missing mass squared: 0.6-1.4 GeV^2/c^4



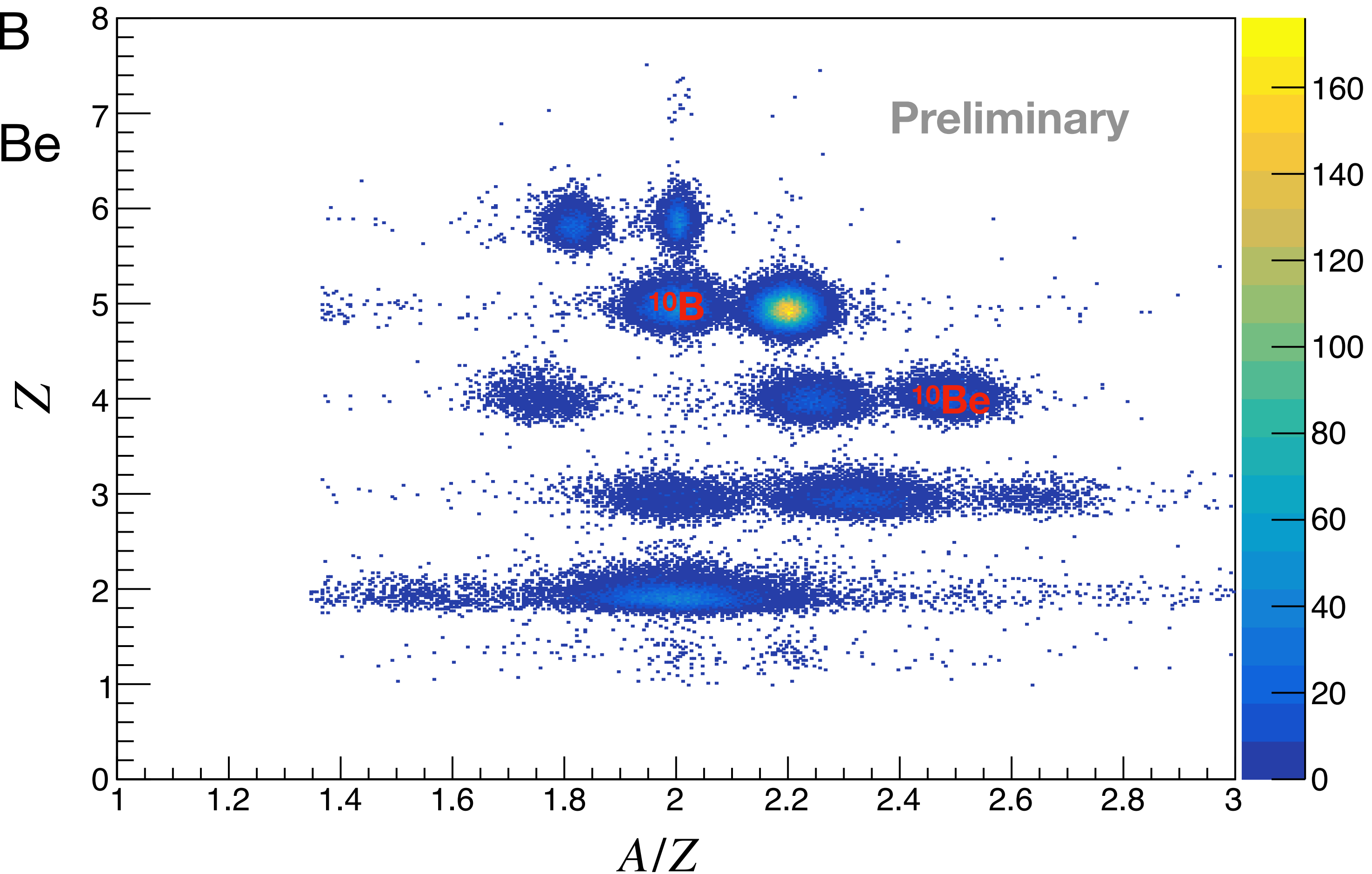
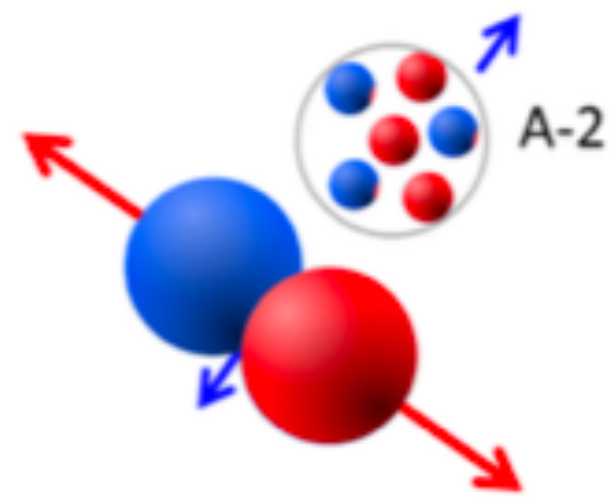
SRC identification in ^{12}C

SRC selection through A-2 system tagging

(p,2p) tagging

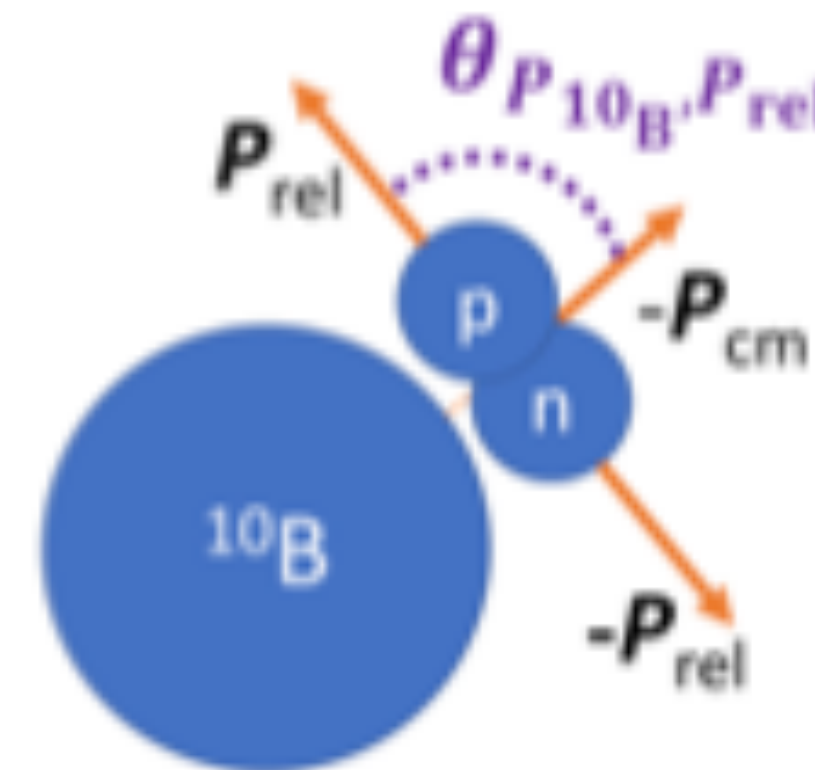
P-n pair: $^{12}\text{C}(p,2p)^{10}\text{B}$

P-p pair: $^{12}\text{C}(p,2p)^{10}\text{Be}$

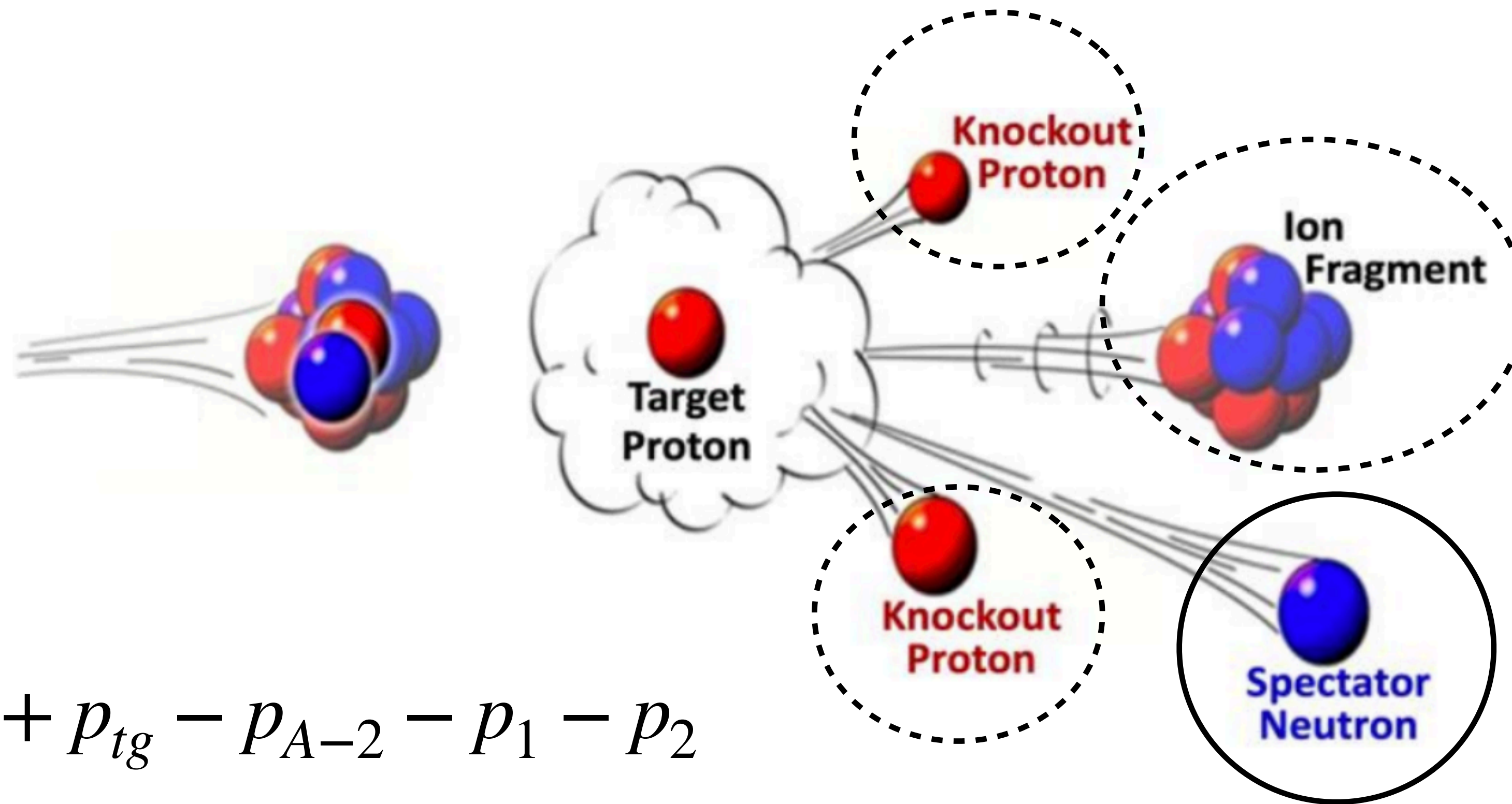


Mean-field and SRC channels for A-2 tagged events

- SRC identification through A-2 system tagging
 - e.g.: $^{12}\text{C}(p,2p)^{10}\text{B}$
- Mean-field (p,2p) with A-1 system nucleon evaporation
 - $^{12}\text{C}(p,2p)^{11}\text{B}^*$; $^{11}\text{B}^* \rightarrow ^{10}\text{B} + n$
- SRC pair
 - $^{12}\text{C}(p,2p)^{10}\text{B}$, with recoil neutron



Quasi-elastic event selection through exclusive missing mass selection

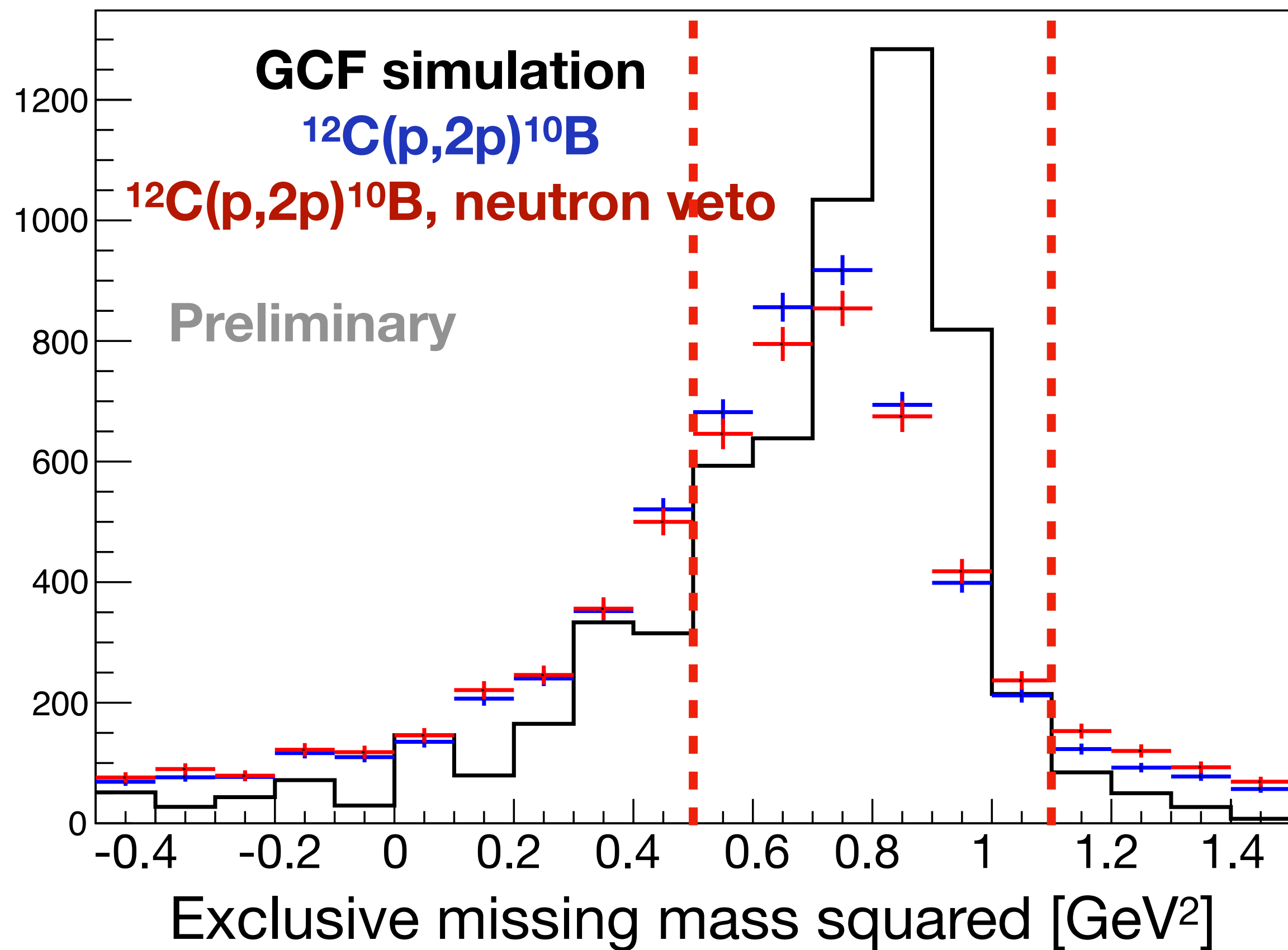


$$p_n = p_{beam} + p_{tg} - p_{A-2} - p_1 - p_2$$

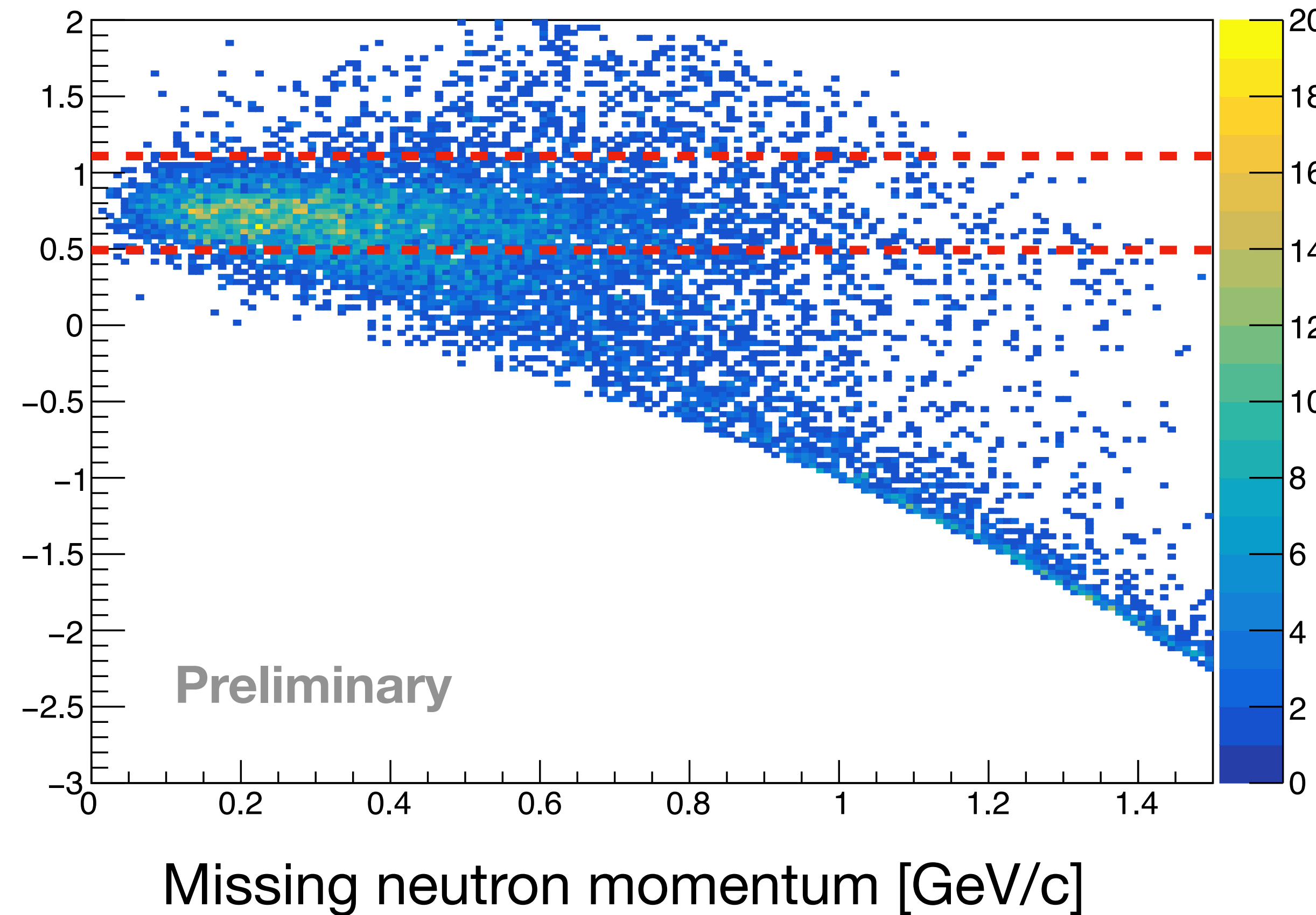
On-shell recoil nucleon mass selection

Quasi-elastic event selection through exclusive missing mass selection

(p,2p) tagging

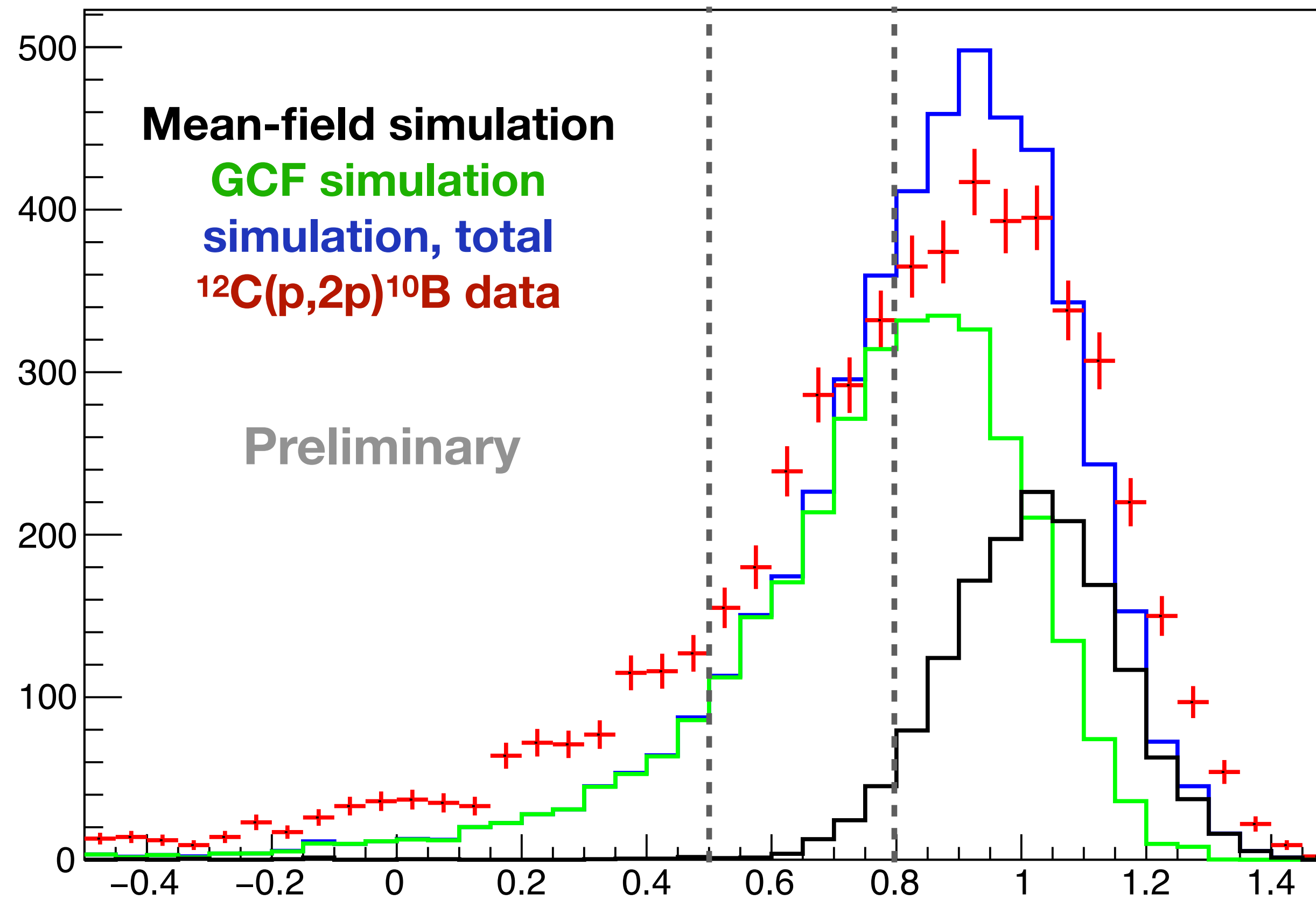


Exclusive missing mass squared [GeV^2]



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

(p,2p) selection
Exclusive missing mass
squared: 0.5 ~ 1.1 GeV^2/c^4

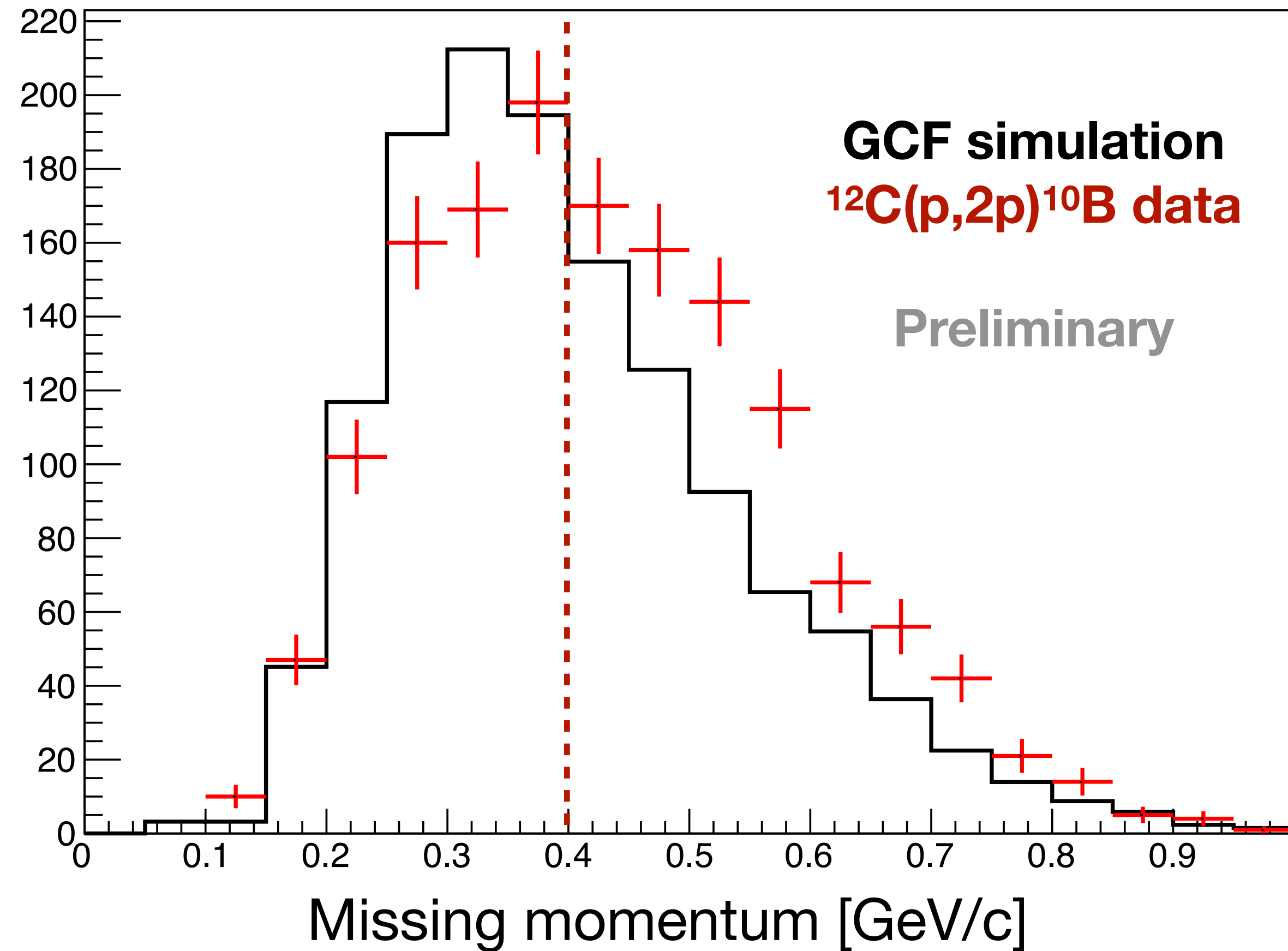


Light-cone momentum fraction α

$$\alpha = (E_{pmiss} - p_{z,pmiss})/m_N$$

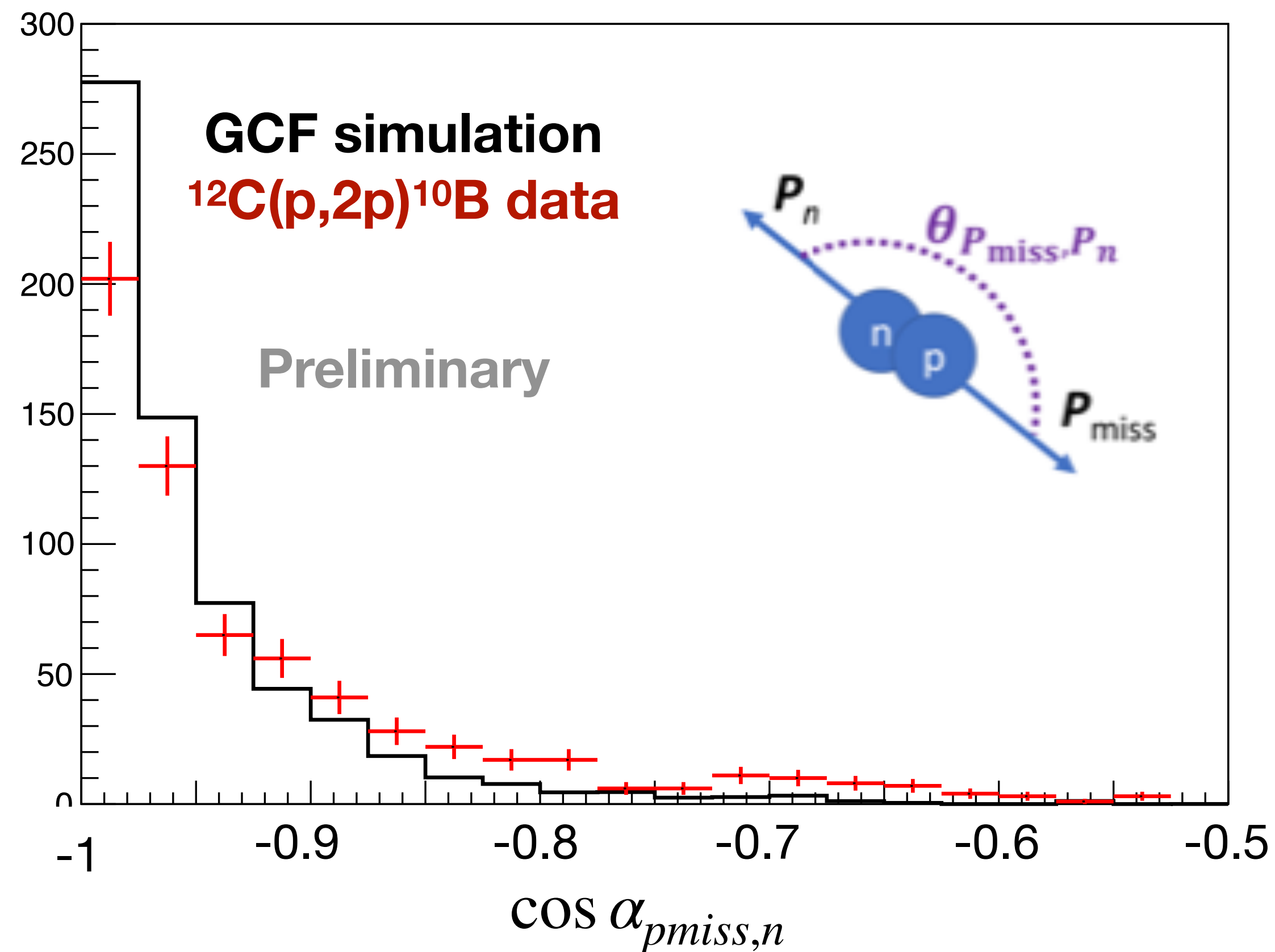
$^{12}\text{C}(p,2p)^{10}\text{B}$ SRC selection

$|t| > 0.8 \text{ GeV}^2$
Proton multiplicity 2
Exclusive missing mass squared: $0.5 \sim 1.1 \text{ GeV}^2/c^4$
LC α : 0.5-0.8



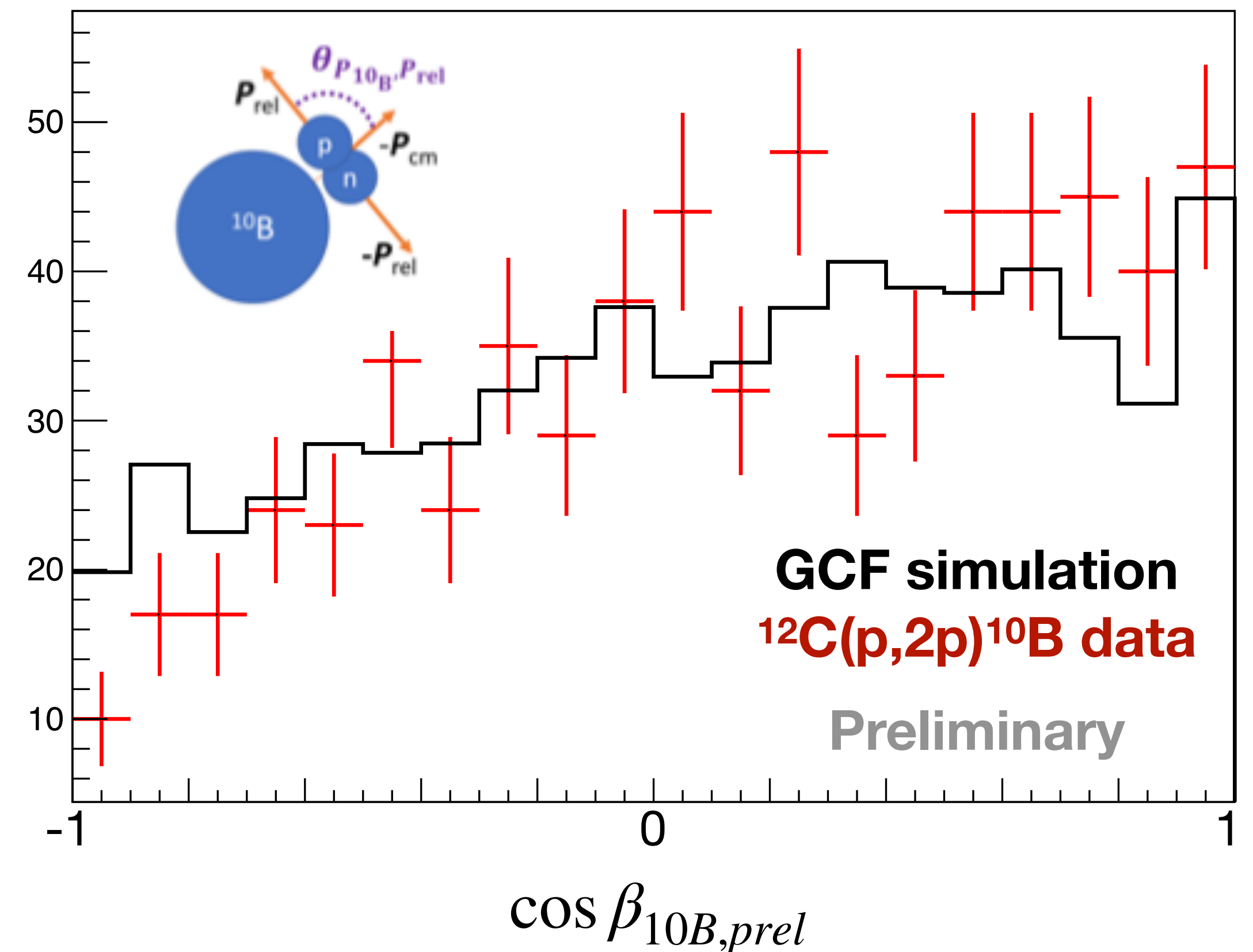
$^{12}\text{C}(p,2p)^{10}\text{B}$ identified p-n SRC pair angular correlation

Back-to-back p-n pair



Reconstructed p-n pair angle

SRC factorization from A-2 system

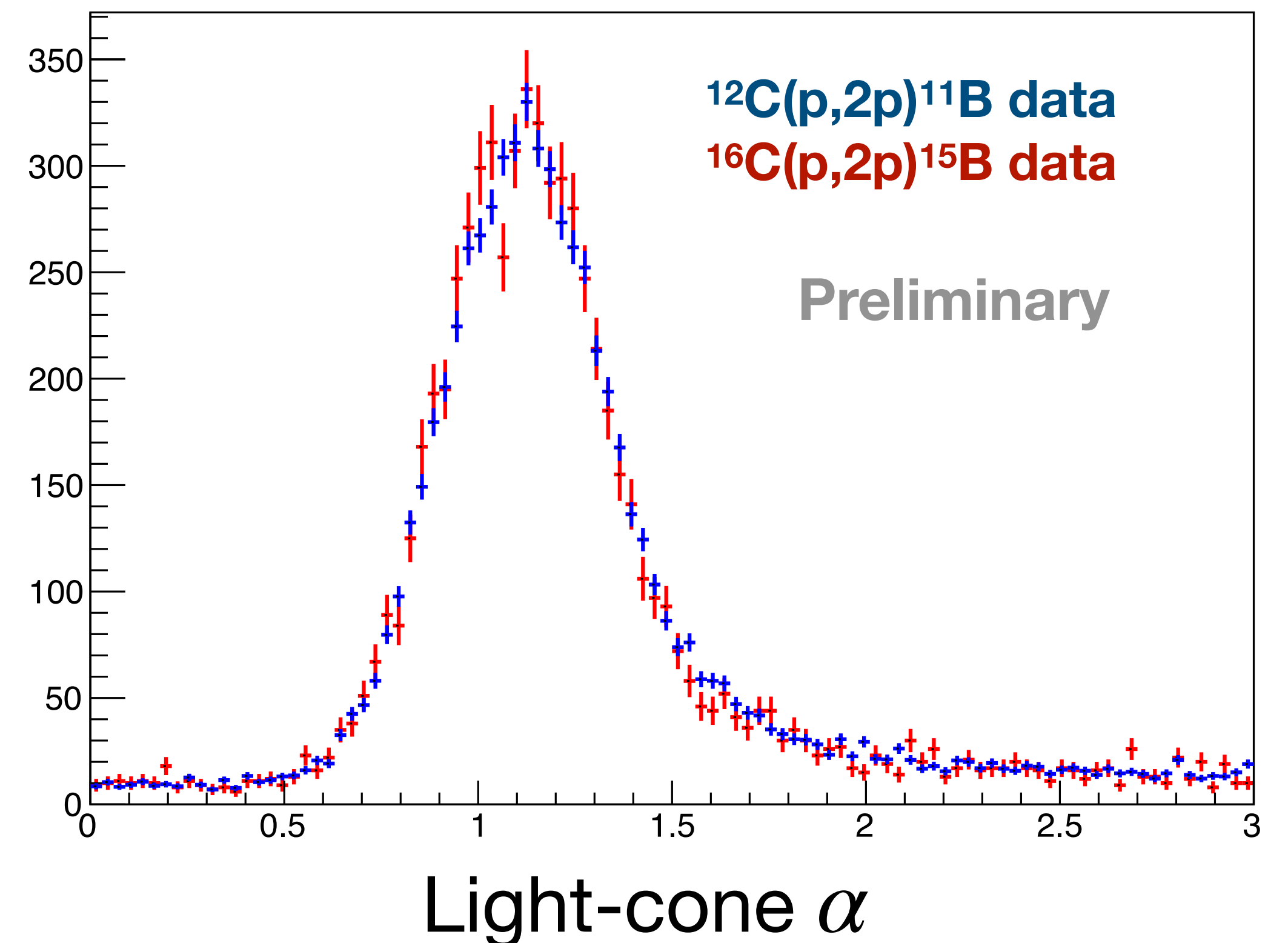
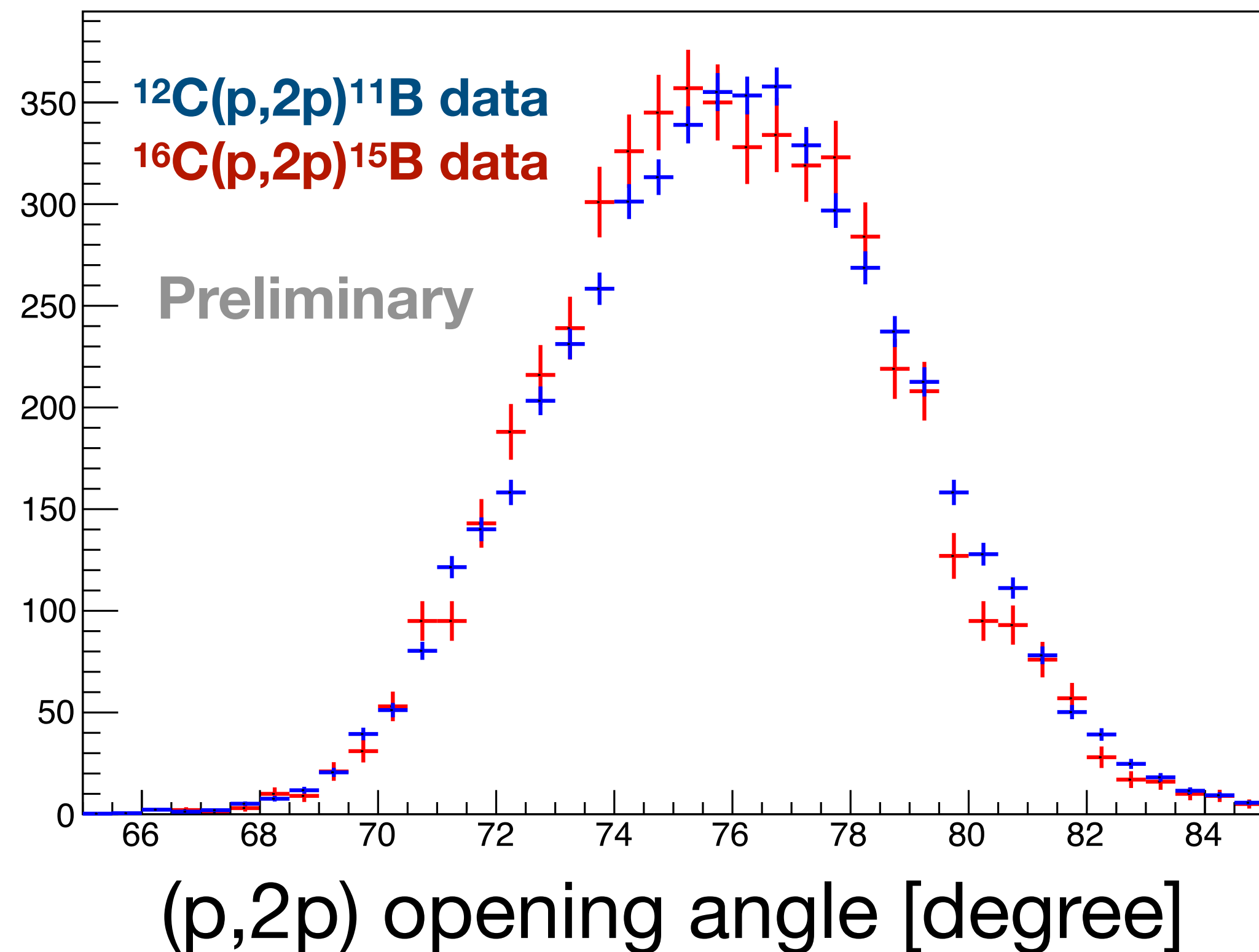


p-n pair relative momentum v. Fragment angle

^{16}C data analysis

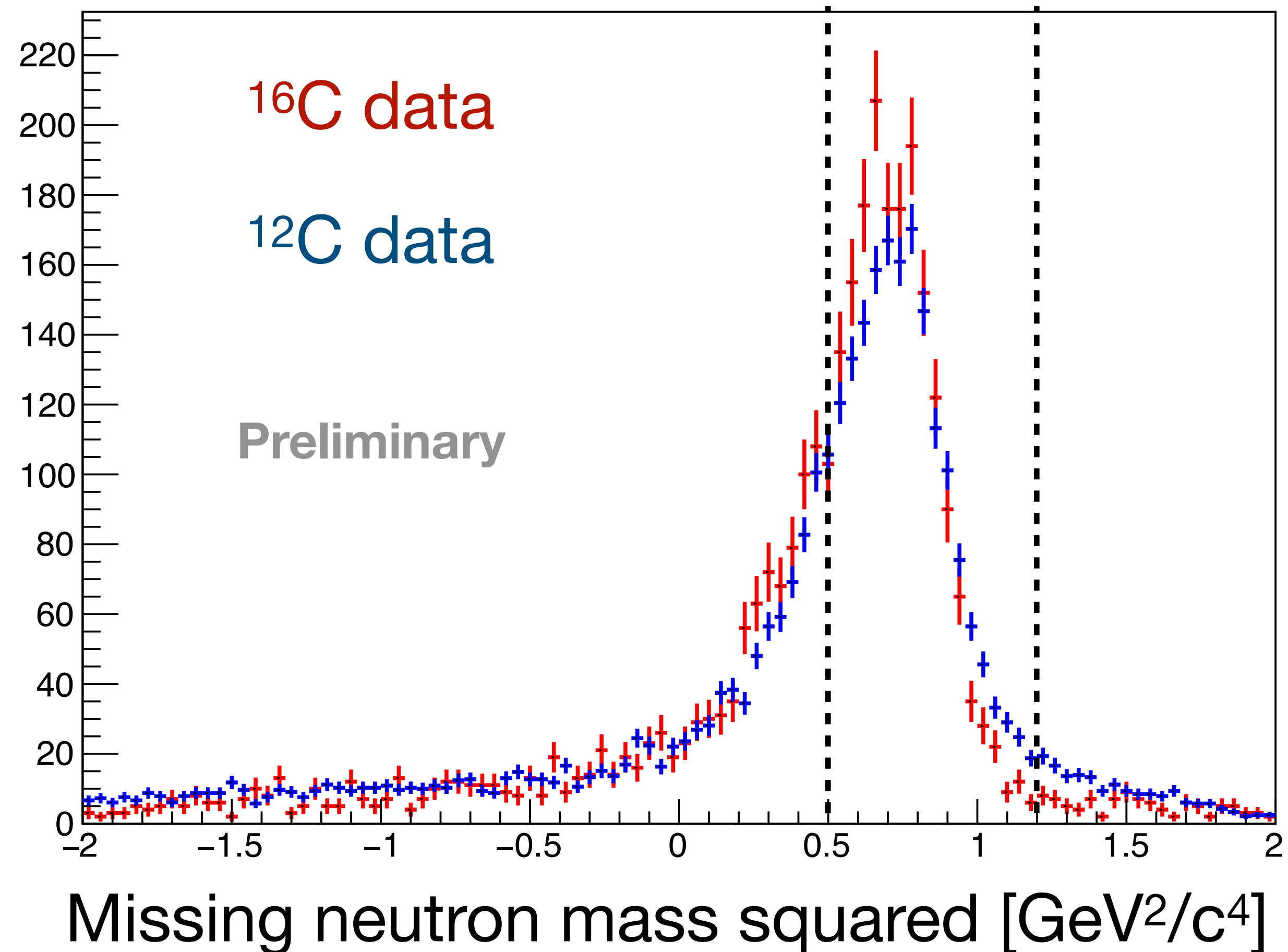
$^{12}\text{C}/^{16}\text{C}$ data with A-1 tagging show consistent kinematic distribution

(p,2p) selection
(p,2p) missing mass squared: 0.6-1.4 GeV^2/c^4



Exclusive missing mass selection with A-2 tagging

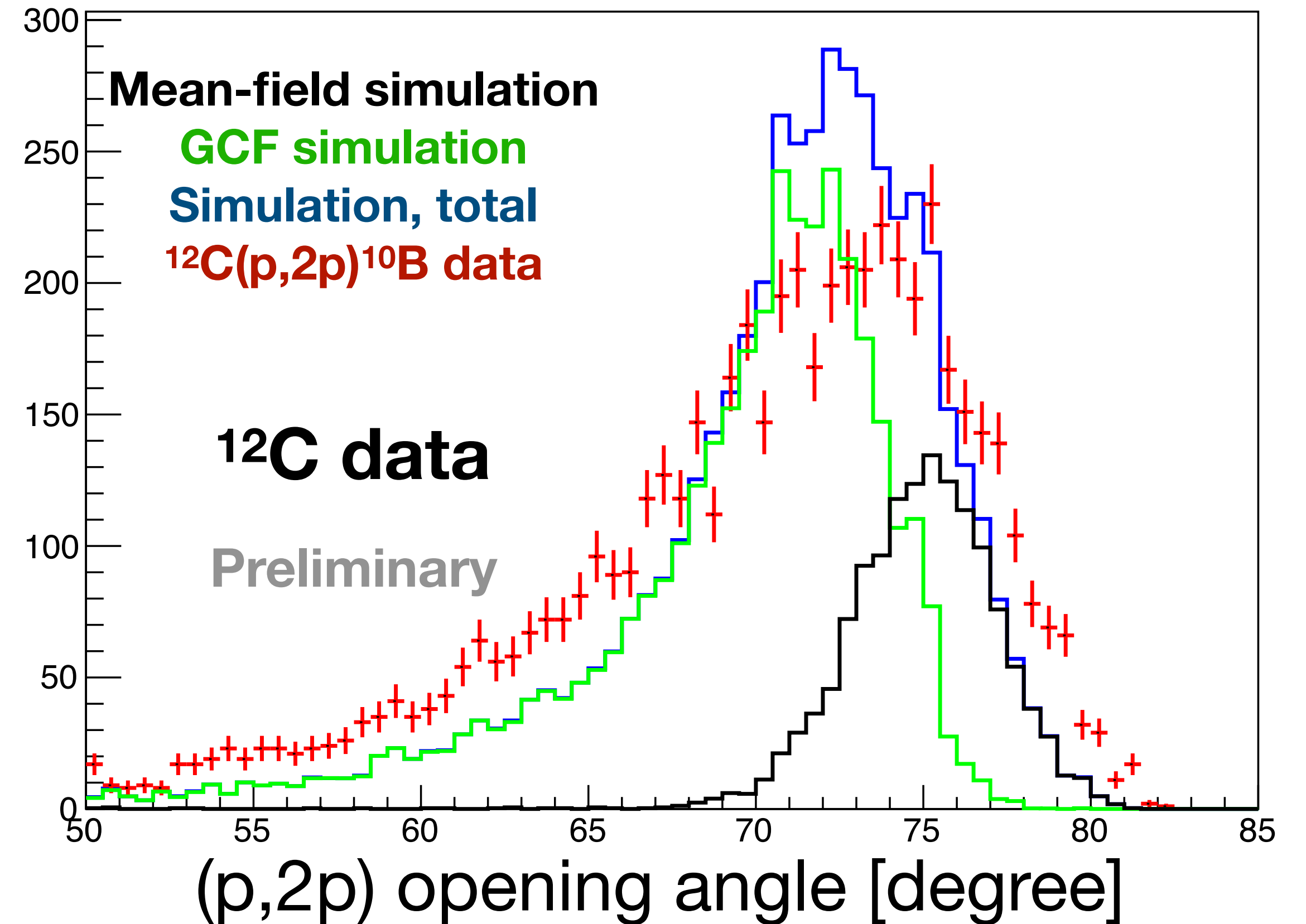
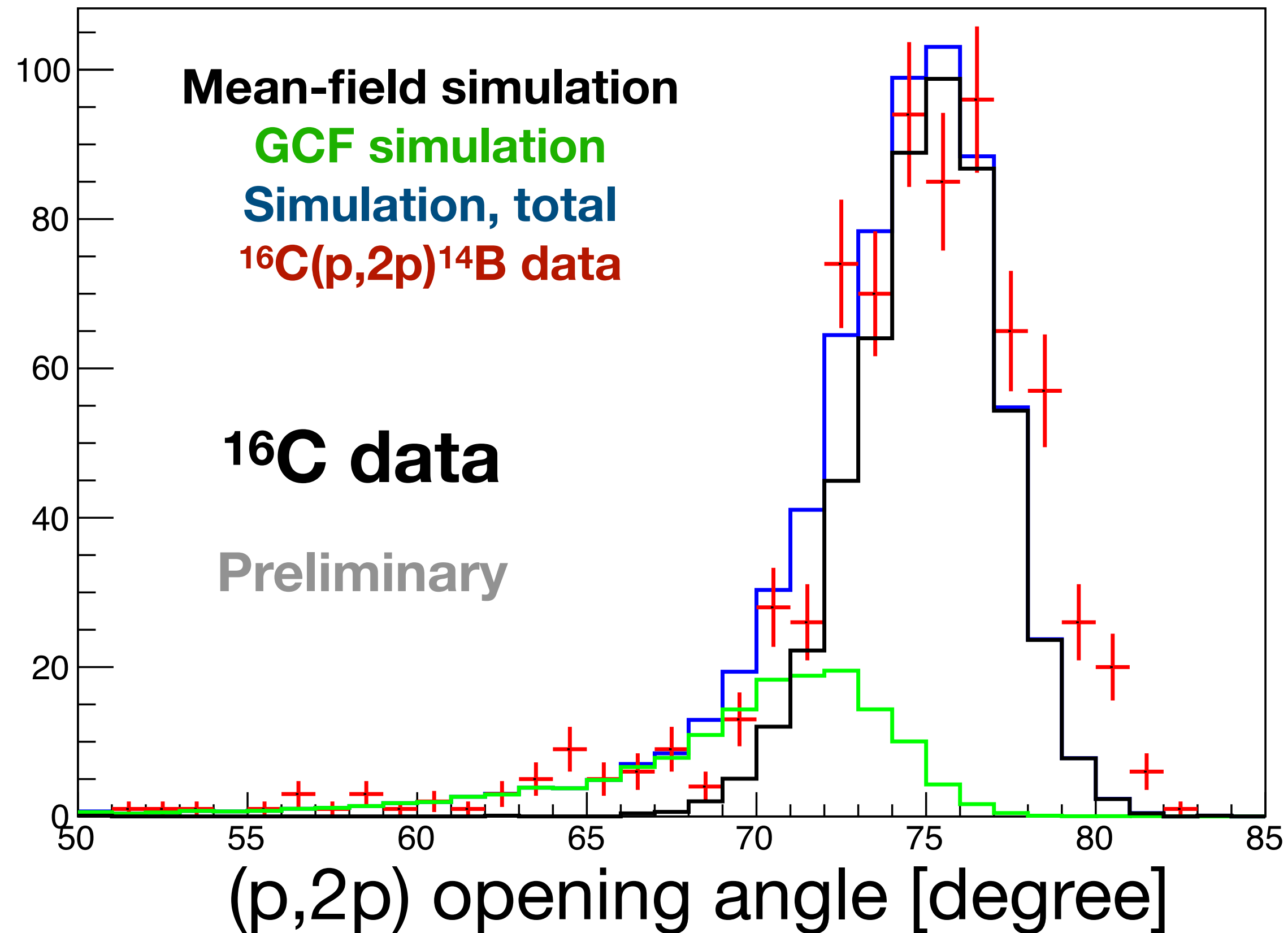
$|t| > 0.8 \text{ GeV}^2$
Proton multiplicity 2
(p,2p) missing mass squared: 0.6-1.4 GeV^2/c^4



^{16}C kinematics with A-2 tagging

**Significantly less SRC
contribution to ^{16}C kinematics
with ground ^{14}B state**

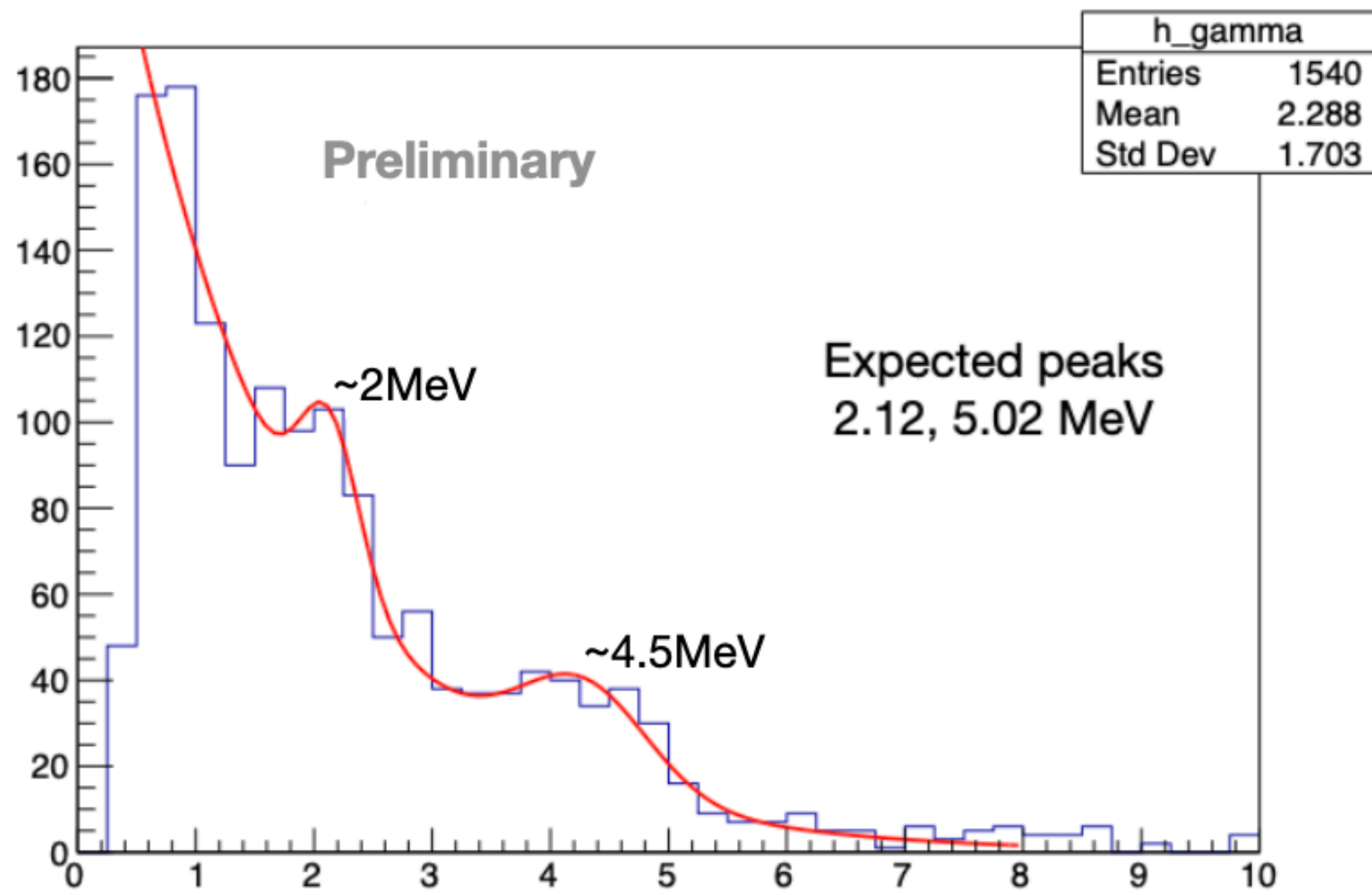
(P,2p) selection
Exclusive missing mass
squared: $0.5 \sim 1.1 \text{ GeV}^2/c^4$



Upcoming analysis

Upcoming analysis: γ spectrum associated with excited residual A-1/A-2 system

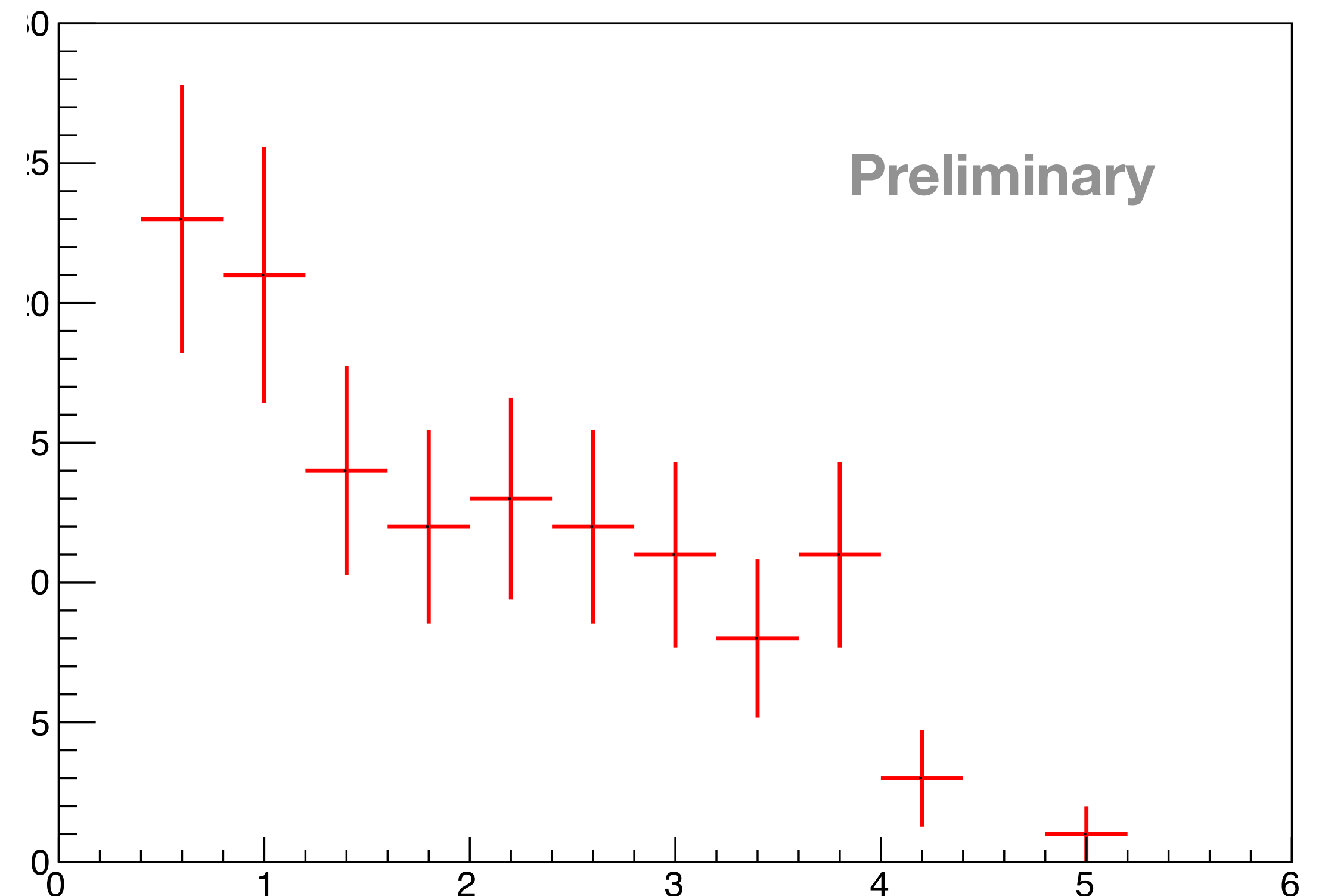
$^{12}\text{C}(p,2p)^{11}\text{B}$ with Mean-field selection



$E_{\gamma,CM}$ [MeV]

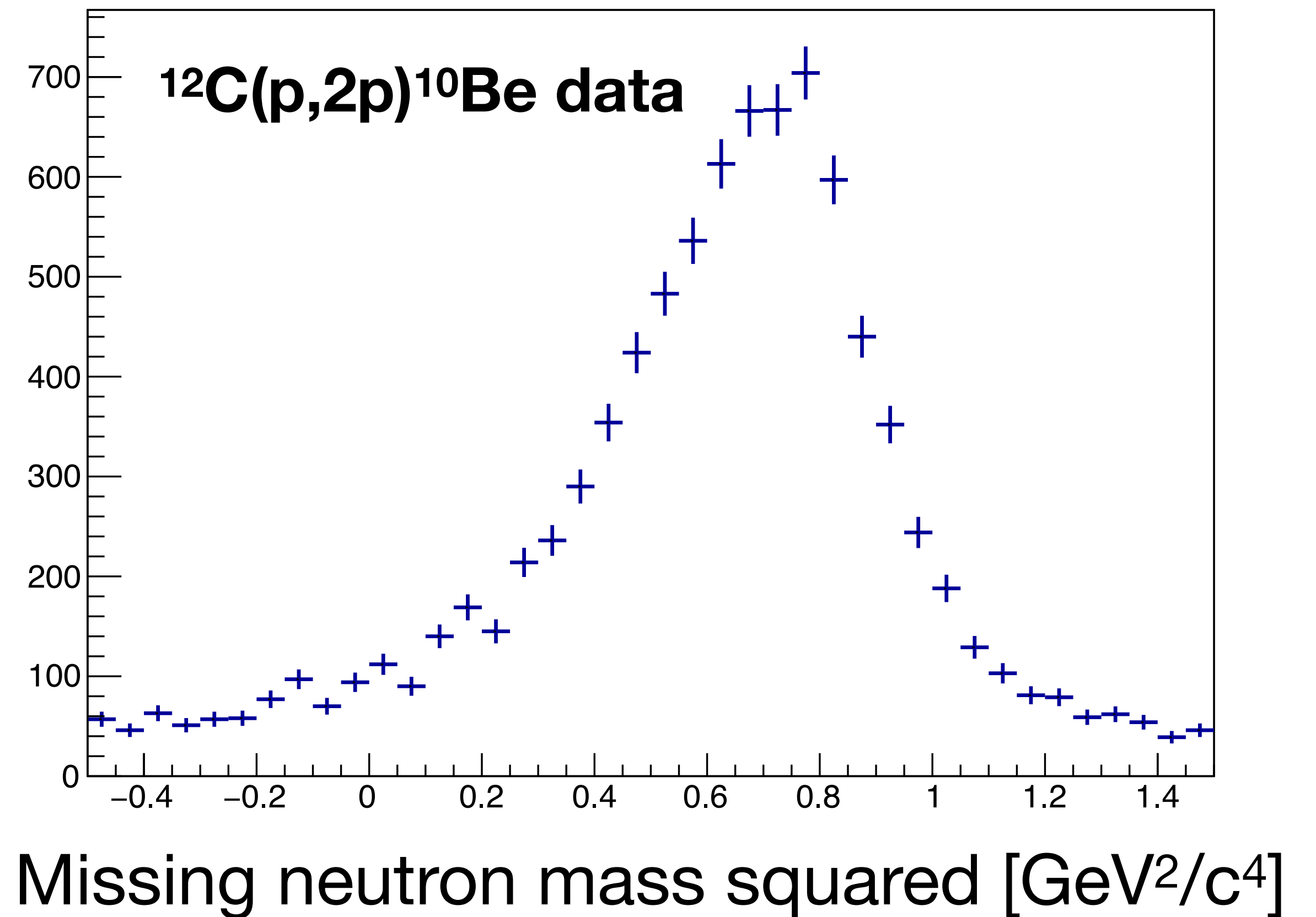
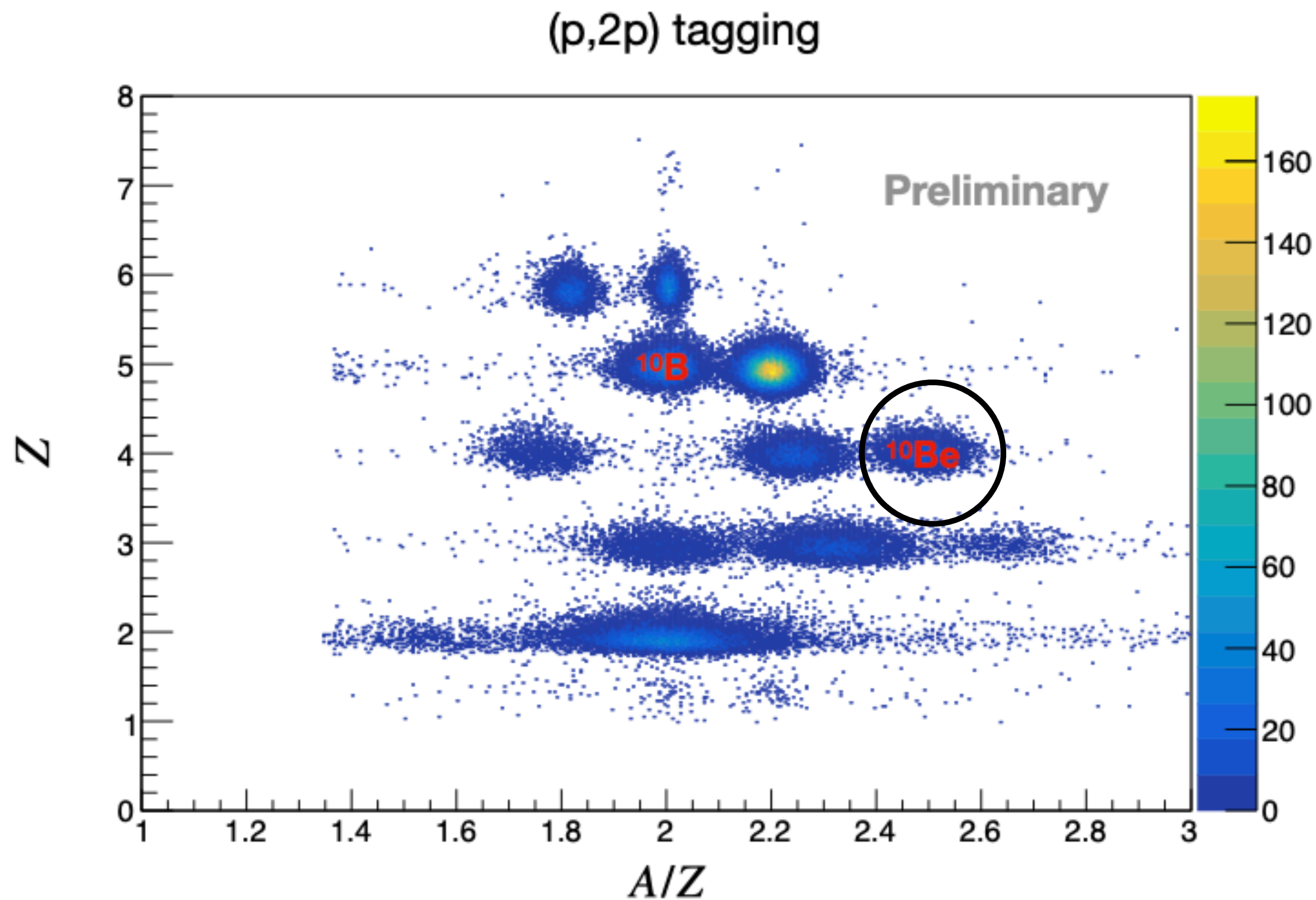
$$E_{CM} = E_{lab} \gamma \times (1 - \beta \cos \theta)$$

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



$E_{\gamma,CM}$ [MeV]

Upcoming analysis: pp SRC pair identification



Summary

- Current analysis on ^{12}C and ^{16}C
 - Quasi-elastic identification for A-1/A-2 tagged events
 - Initial identification of p-n SRC pairs in ^{12}C
 - $^{16}\text{C}(p,2p)^{14}\text{B}$ dominated by mean-field kinematics
 - Excited states of ^{14}B
- Upcoming analysis
 - Identification of p-p SRC pairs
 - Excitation energy spectrum study for A-1/A-2 system

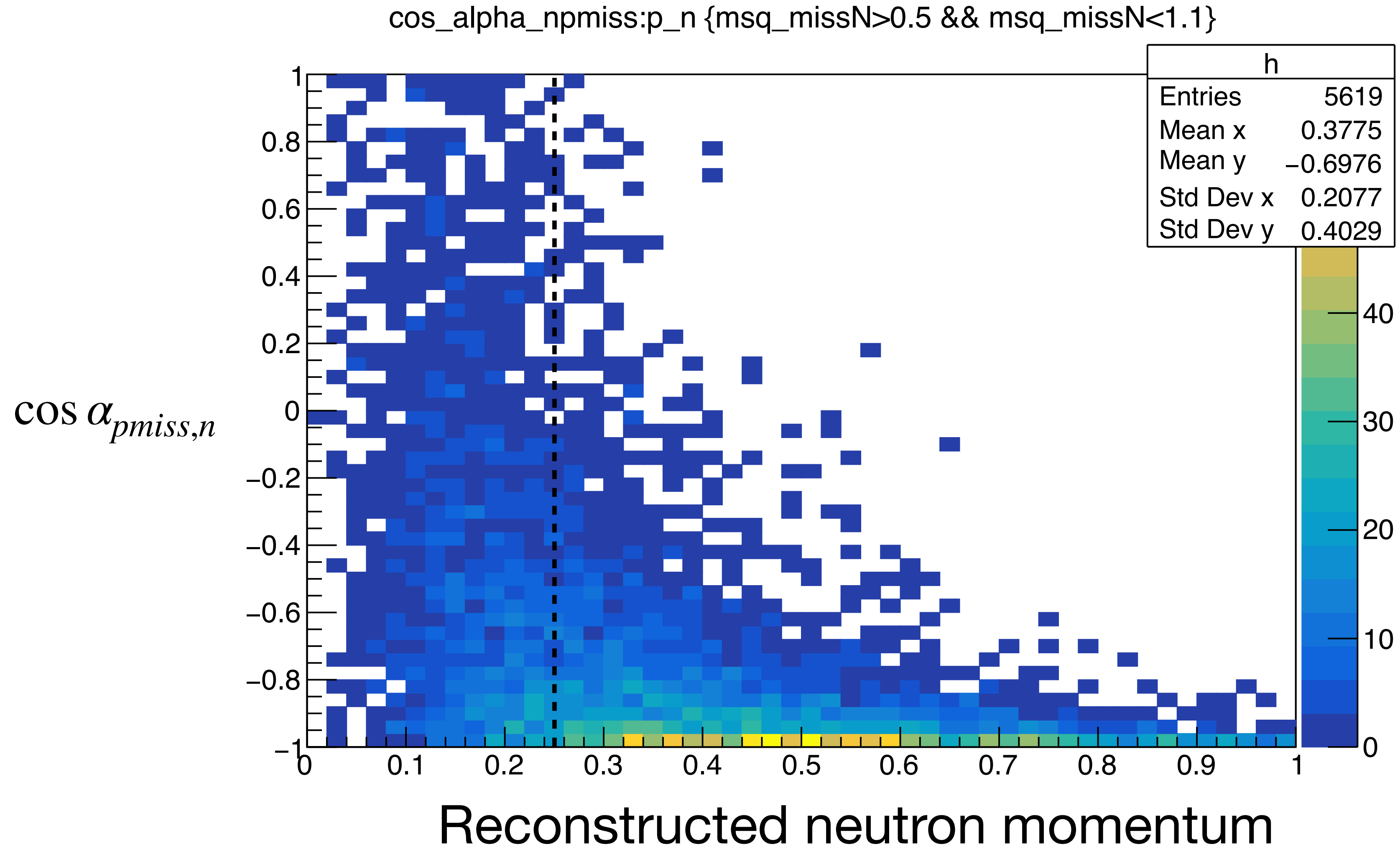
Thank you!



Credits to R3B collaboration

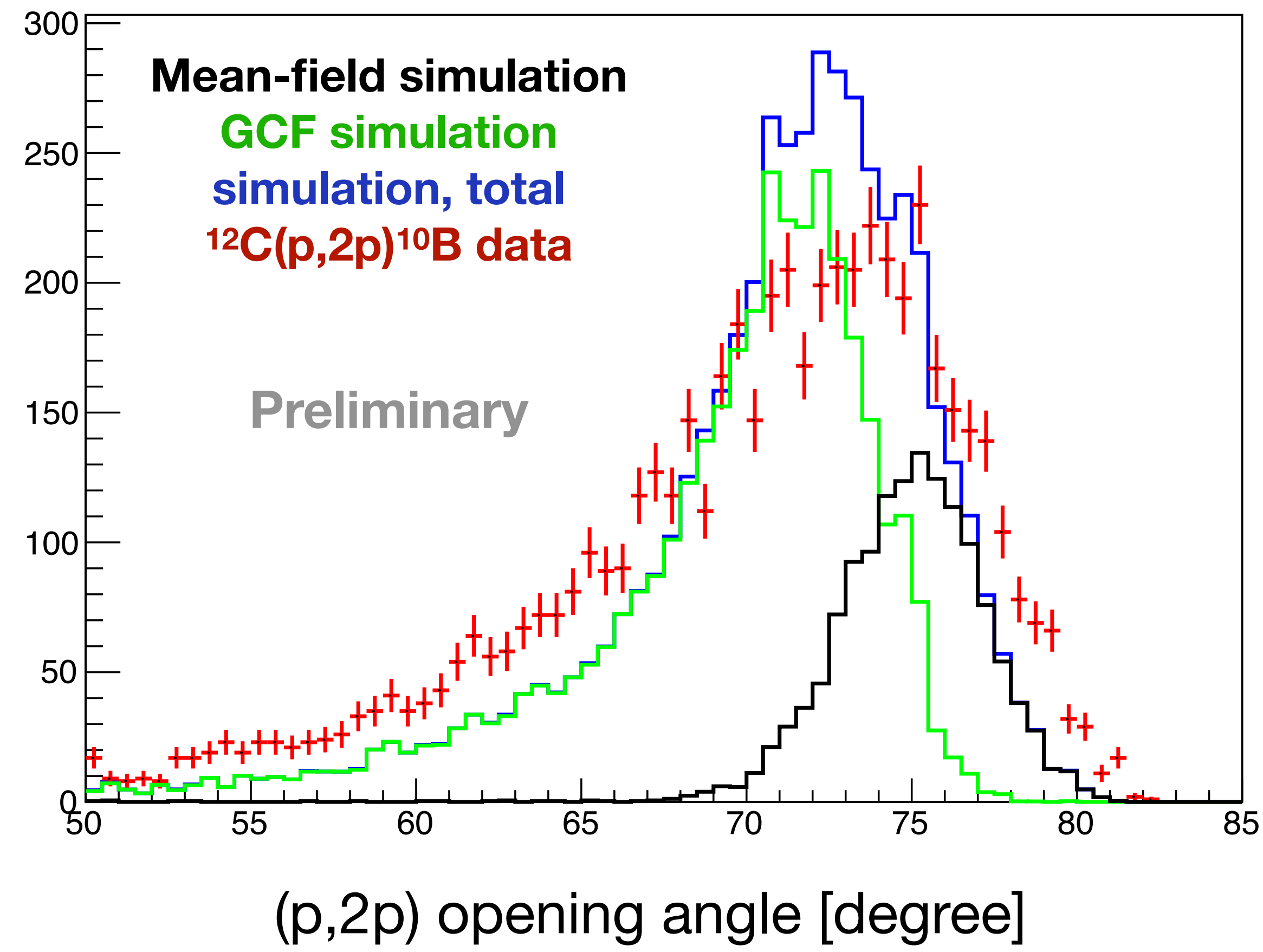
Backup slides

SRC identification



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

(p,2p) selection
Exclusive missing mass squared: $0.5 \sim 1.1 \text{ GeV}^2/c^4$



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

$|t| > 0.8 \text{ GeV}^2$

Proton multiplicity 2

Exclusive missing mass squared: $0.5 \sim 1.1 \text{ GeV}^2/c^4$

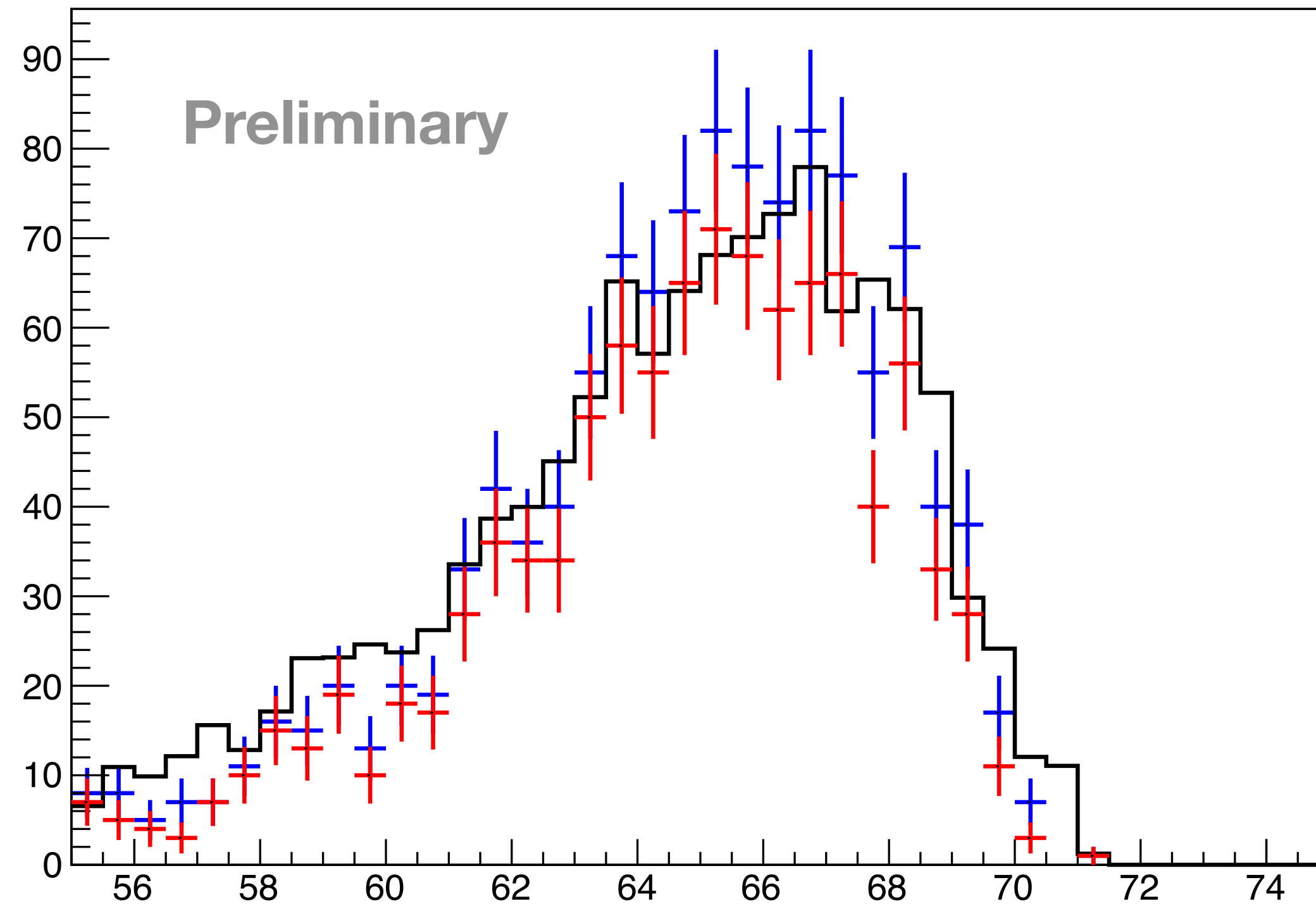
LC α : 0.5-0.8

(p,2p) missing momentum $> 400 \text{ MeV}/c$

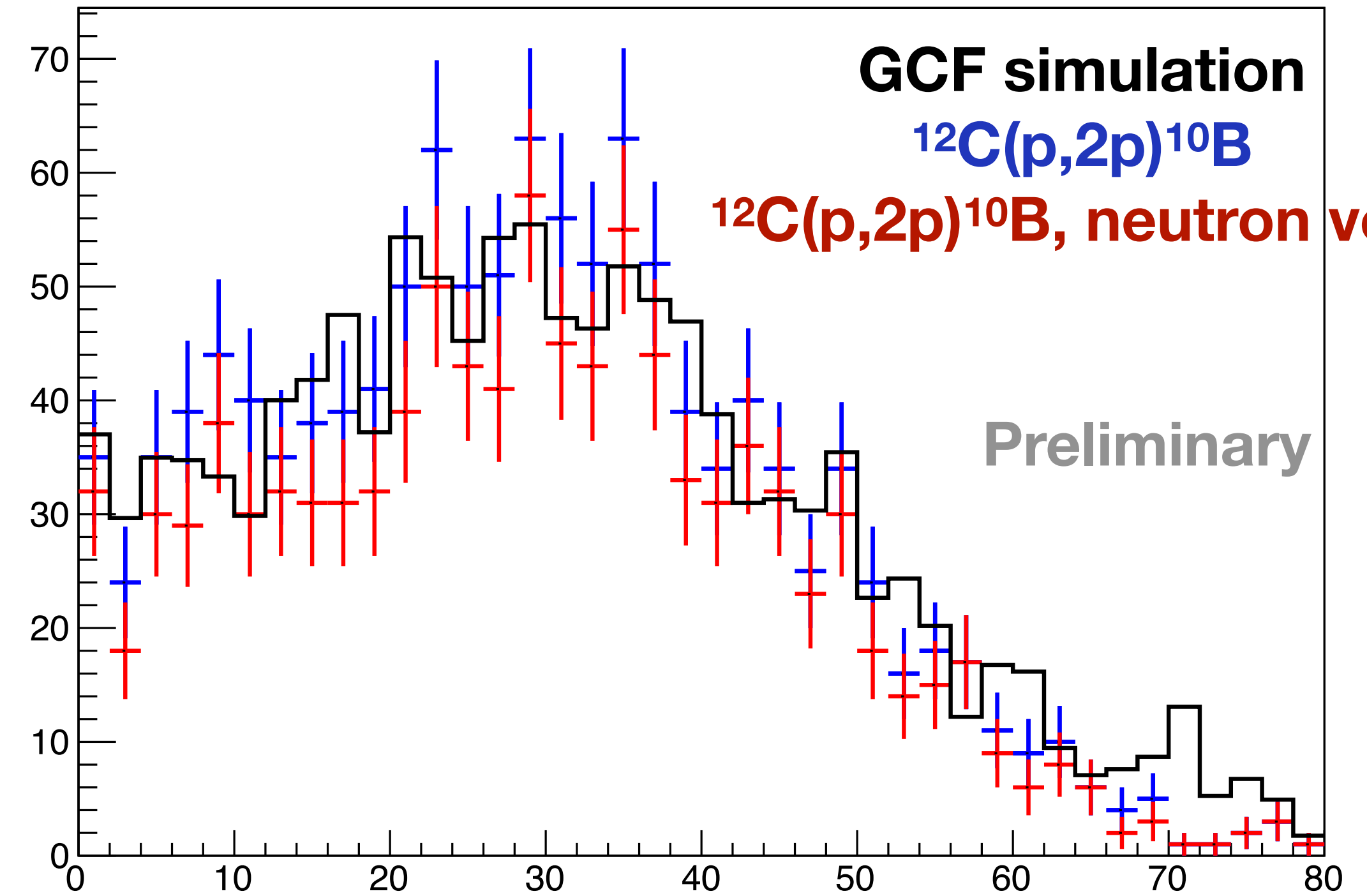
GCF simulation

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

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



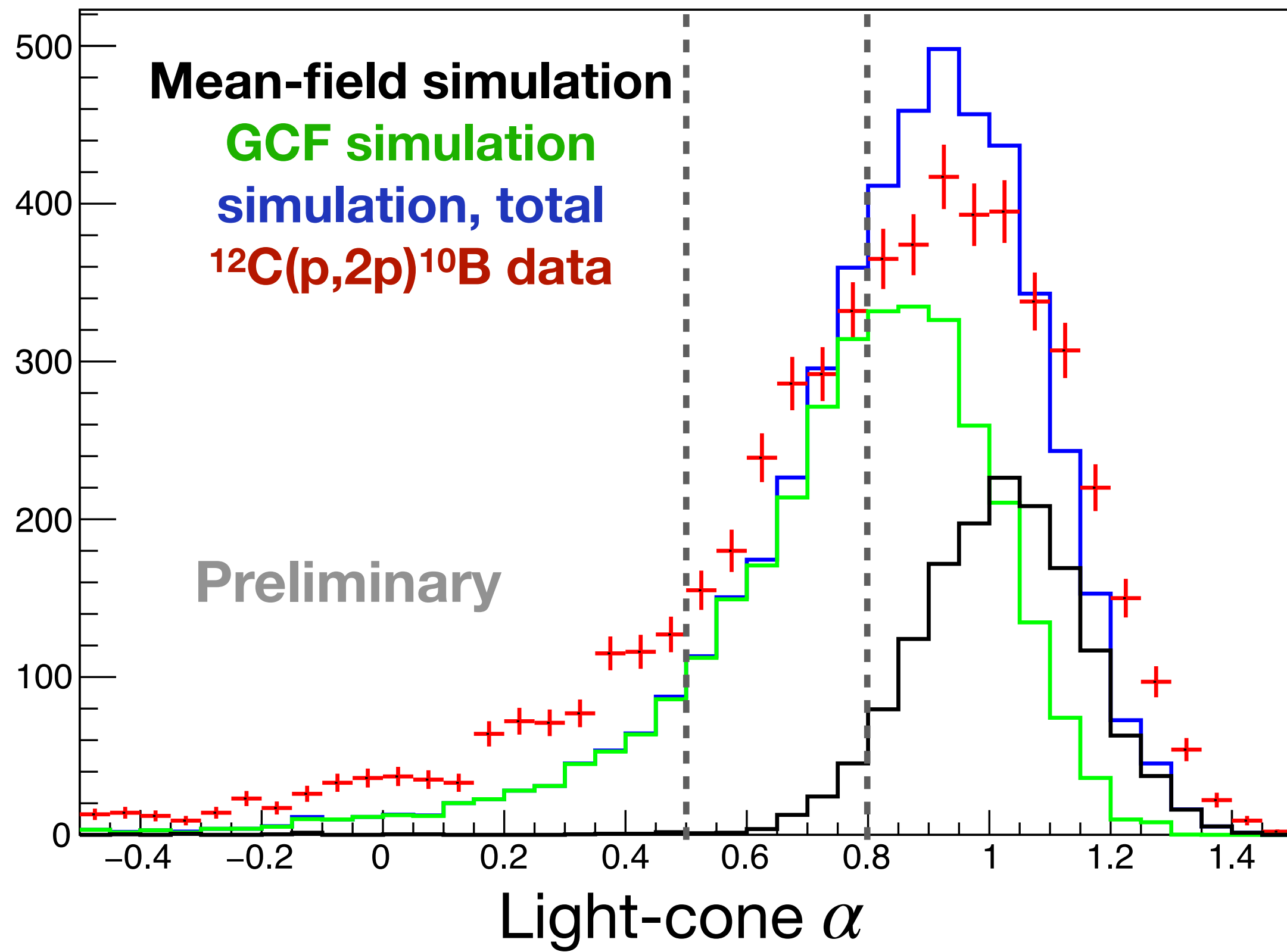
(P,2p) opening angle [degree]



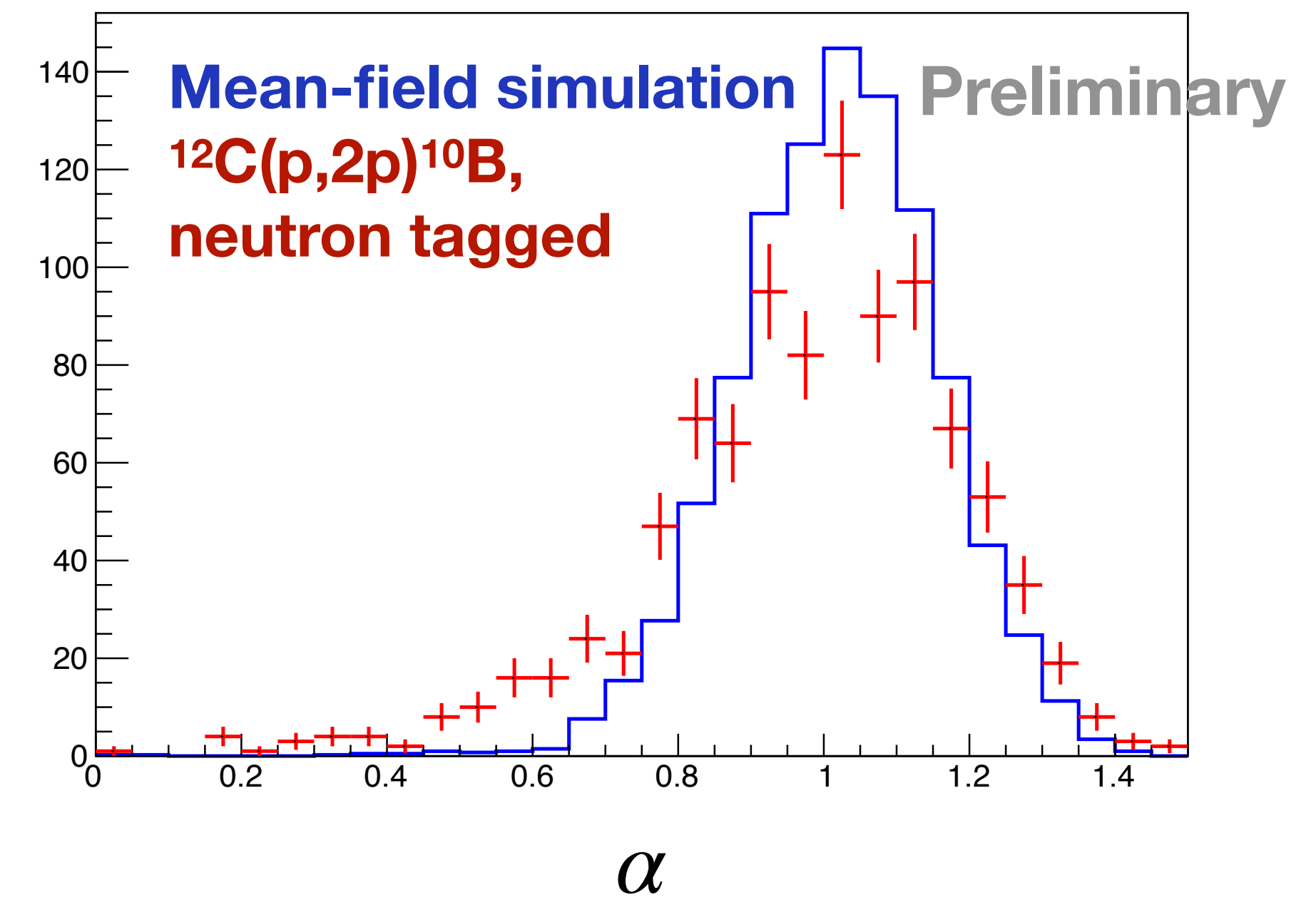
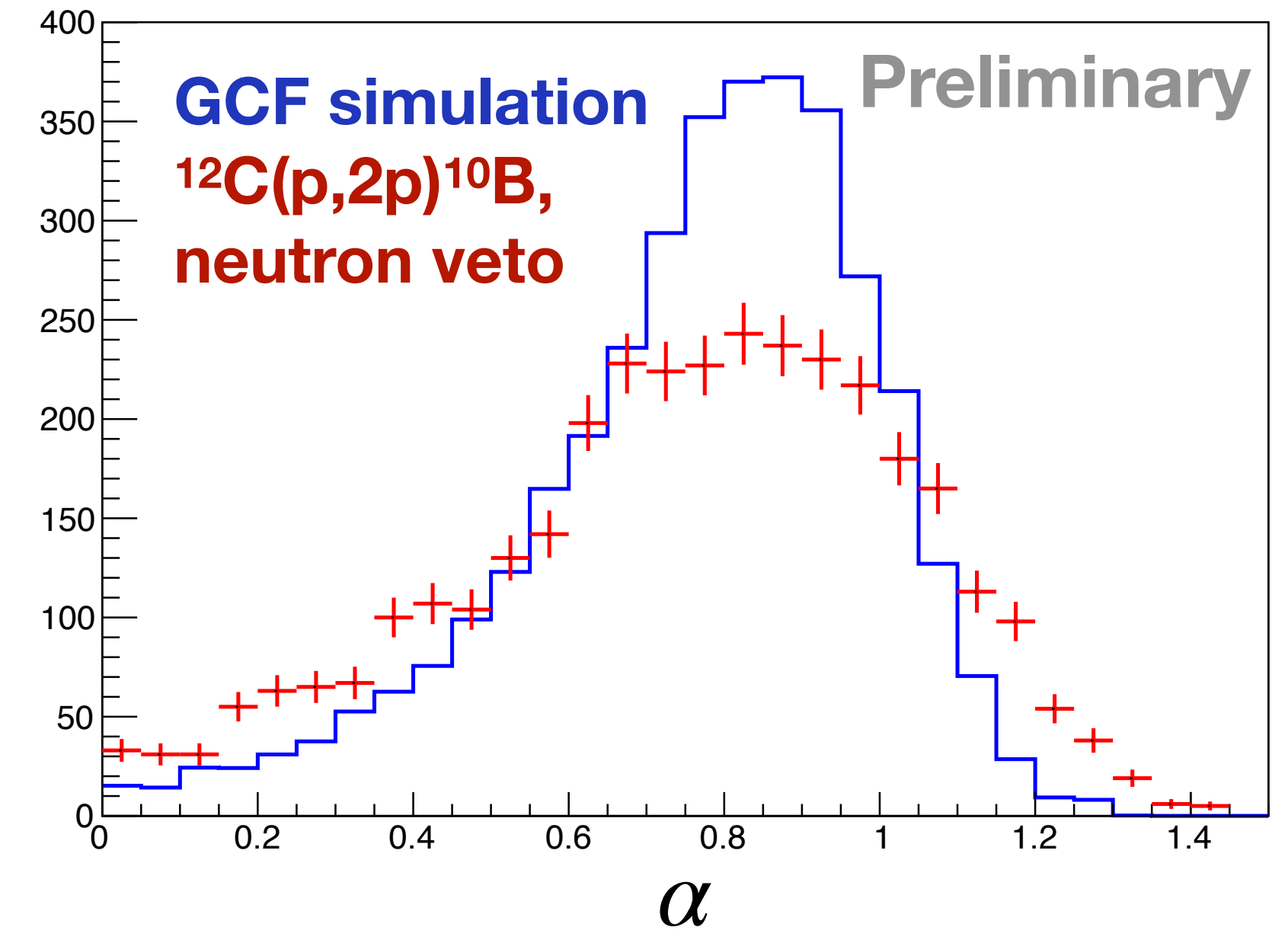
$|\Delta\phi - 180|$ [degree]

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

$|t| > 0.8 \text{ GeV}^2$
 Proton multiplicity 2
 Exclusive missing mass squared:
 $0.5 \sim 1.1 \text{ GeV}^2/c^4$

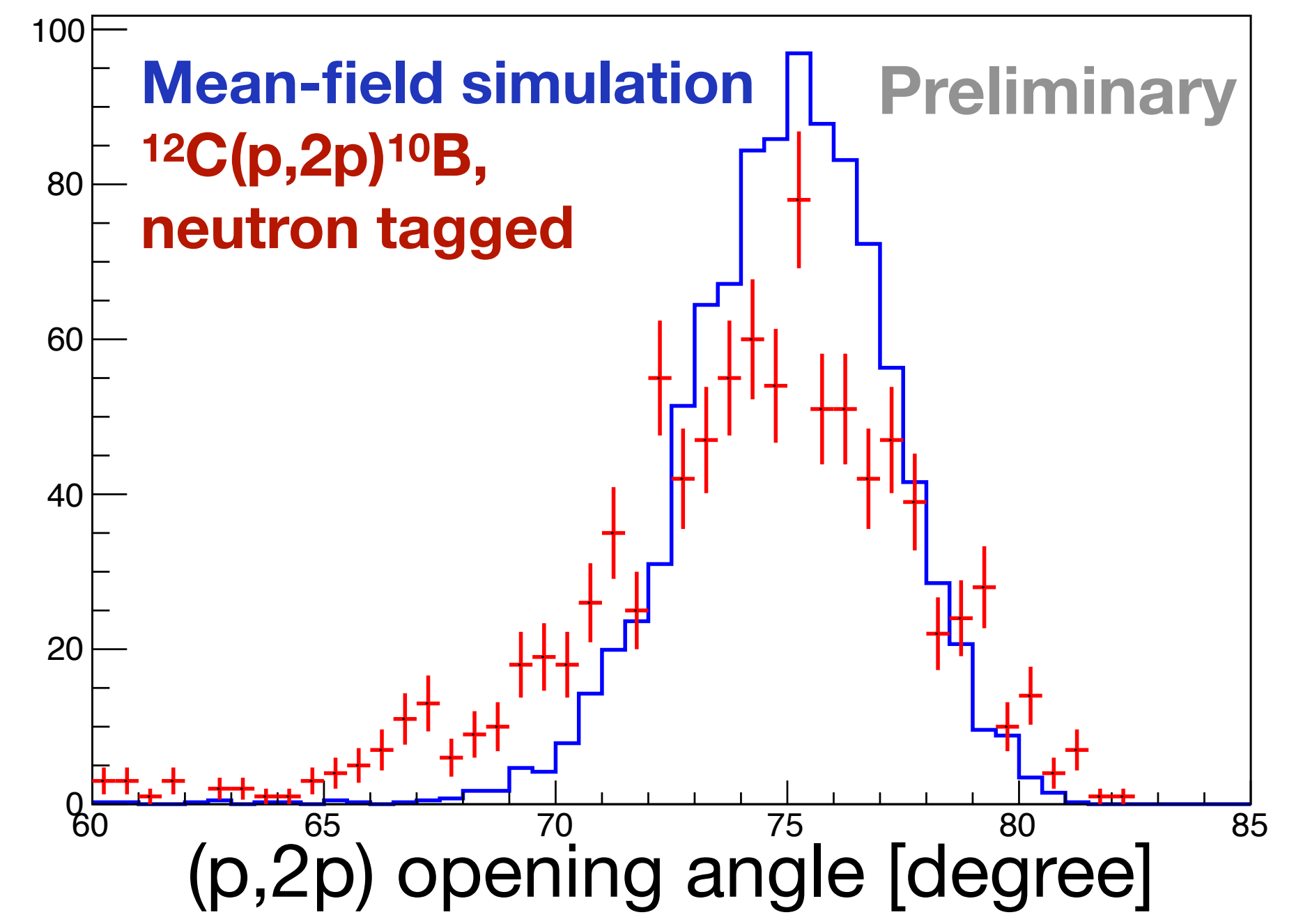
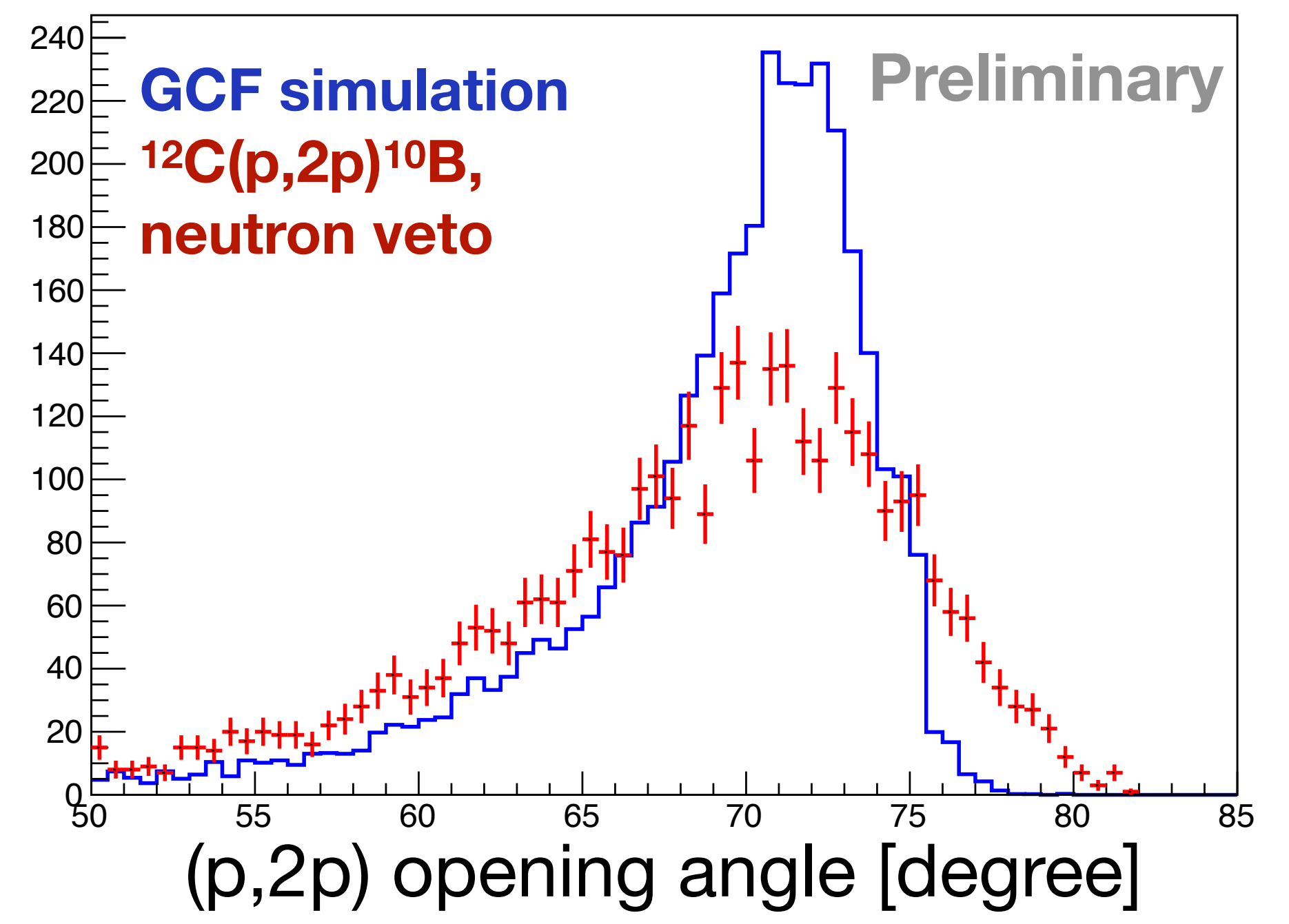
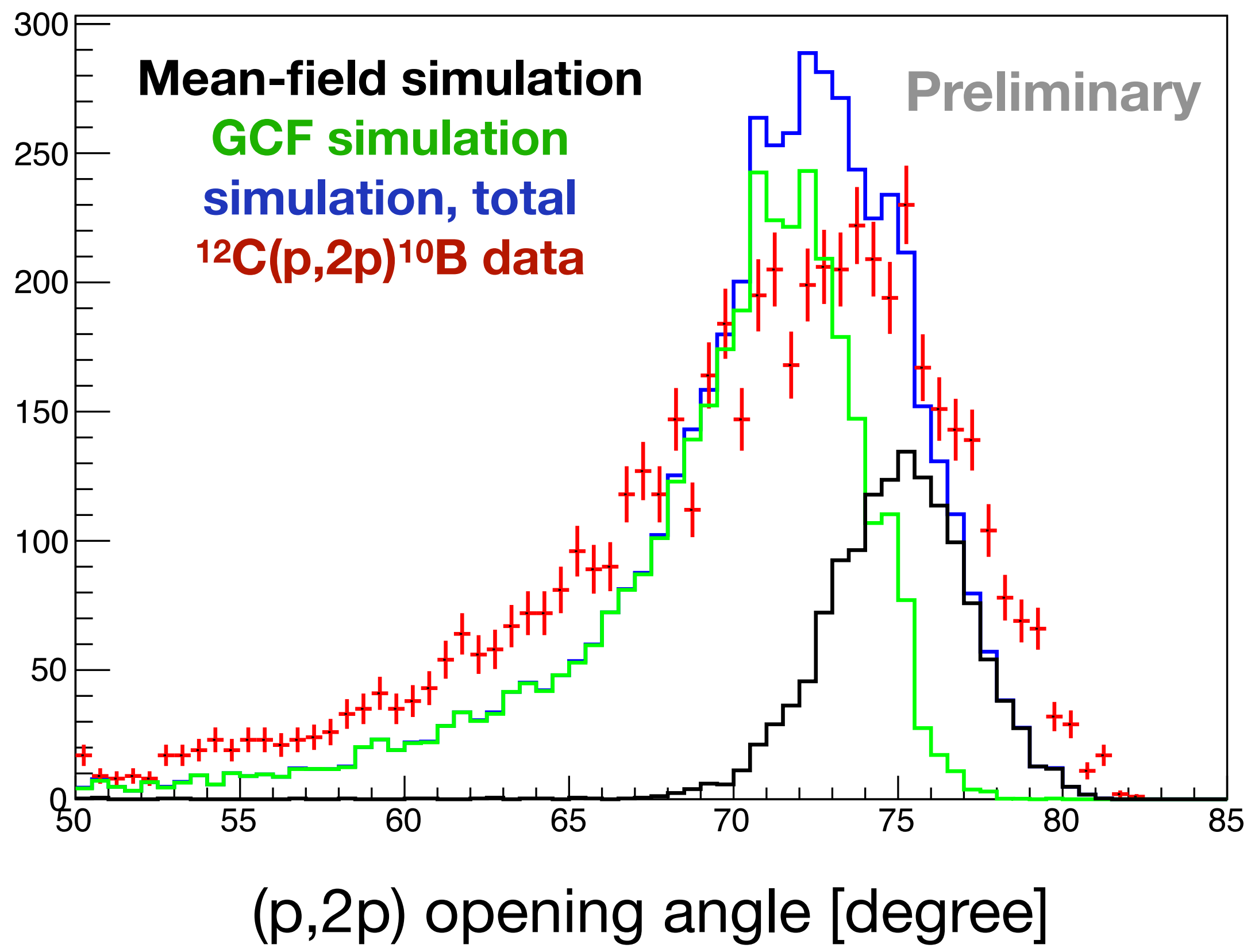


$$\alpha = (E_{pmiss} - p_{z,pmiss})/m_N$$



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

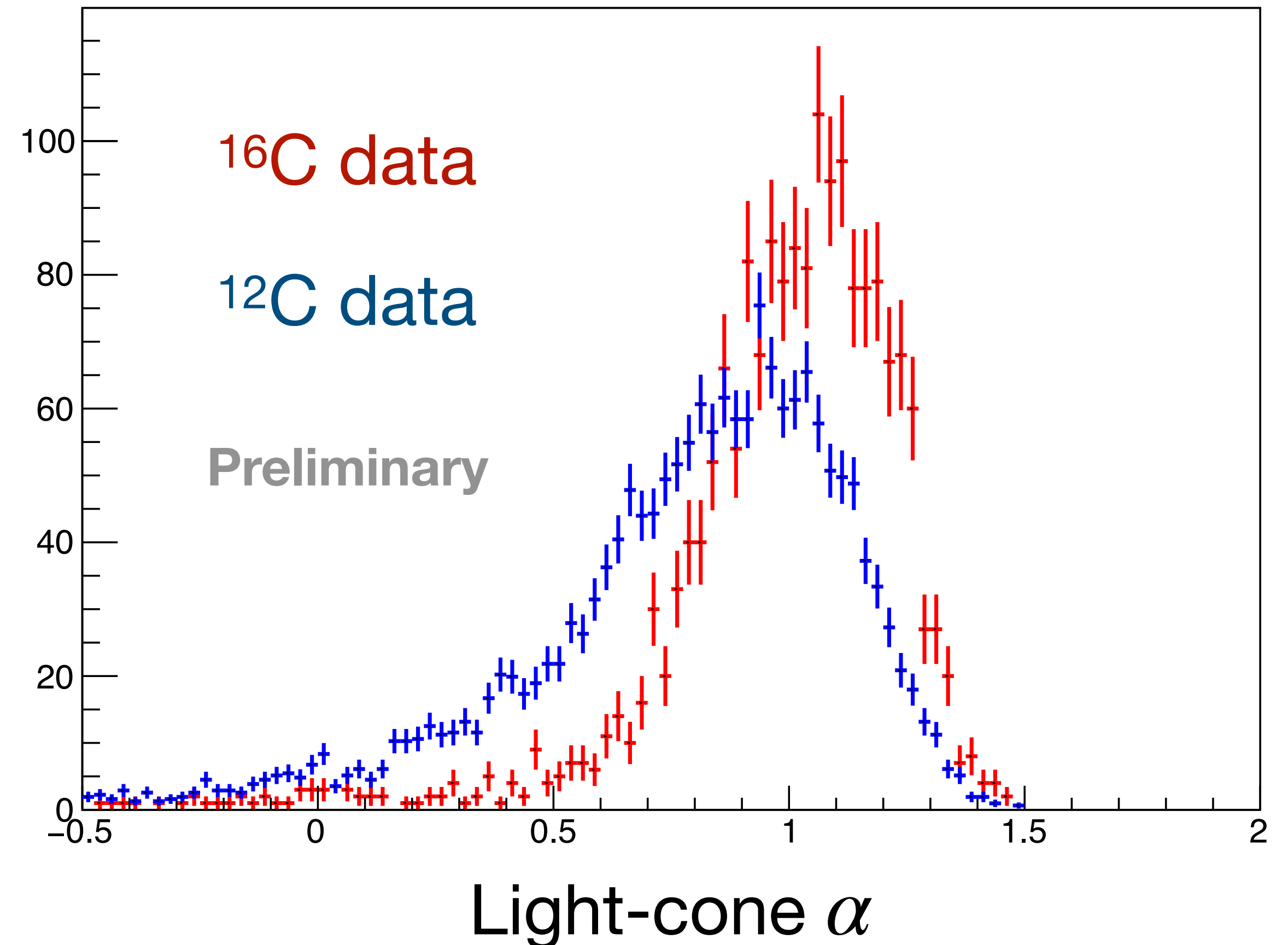
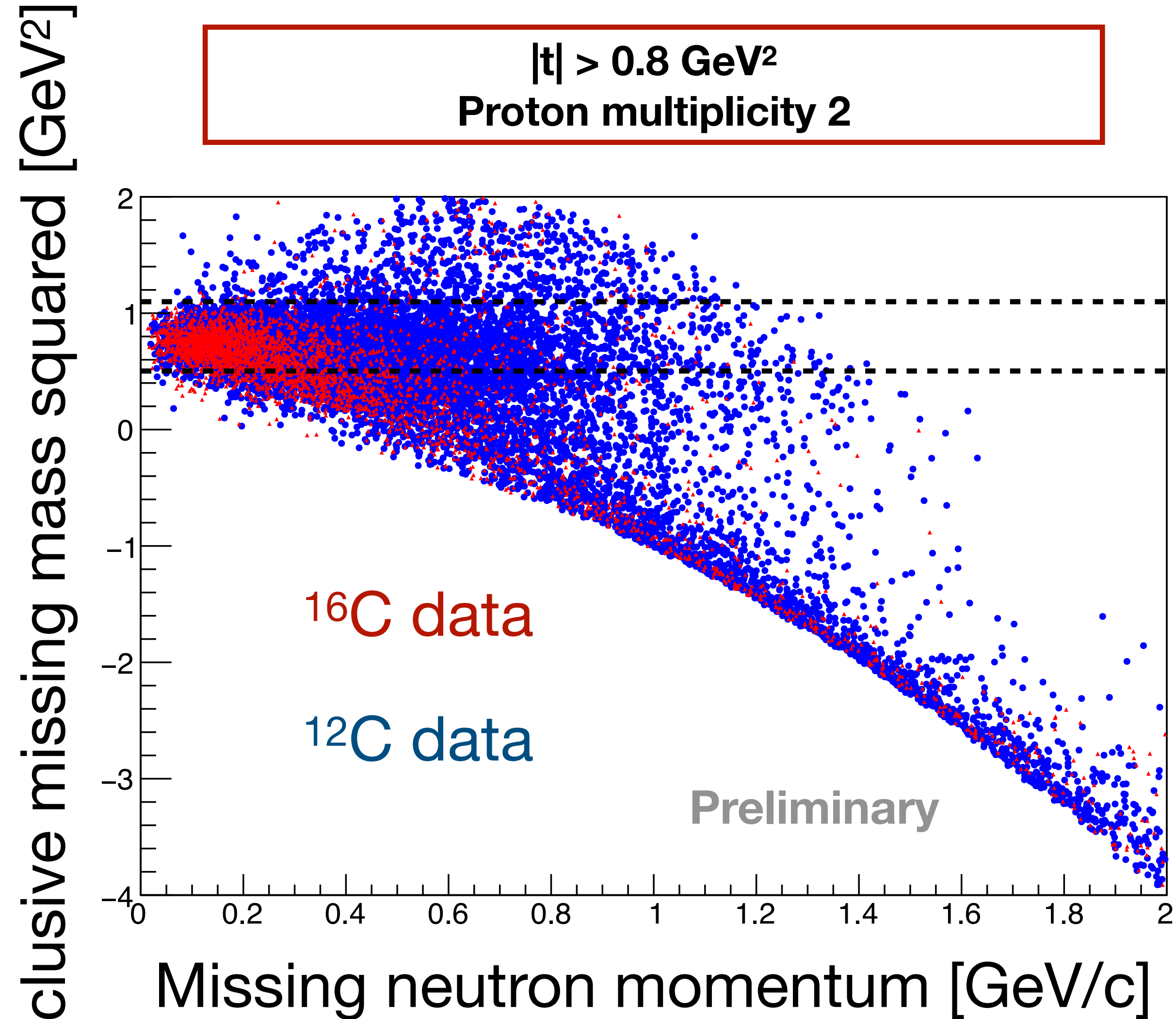
$|t| > 0.8 \text{ GeV}^2$
Proton multiplicity 2
Exclusive missing mass squared:
 $0.5 \sim 1.1 \text{ GeV}^2/c^4$



A-2 system tagging (14B/10B)

$|t| > 0.8 \text{ GeV}^2$
Proton multiplicity 2

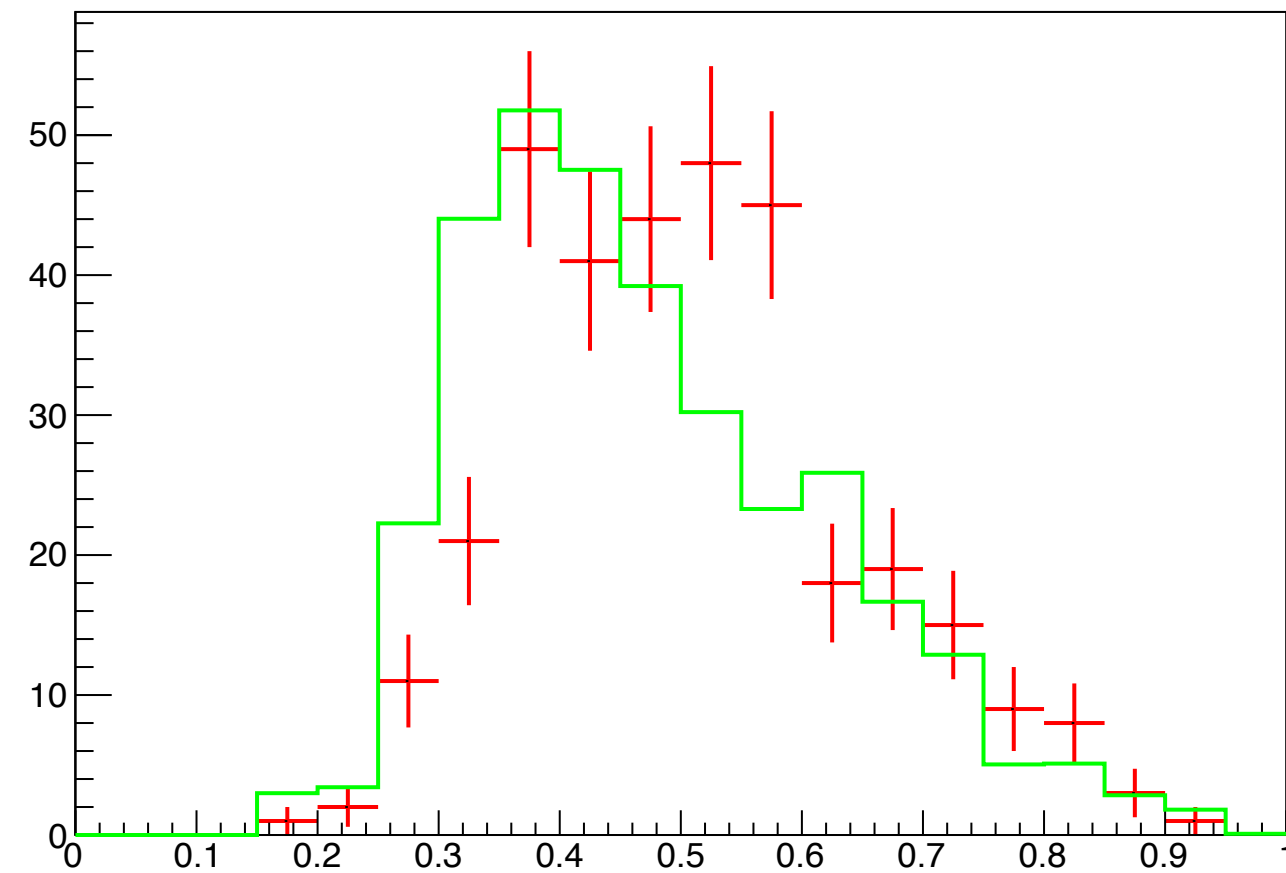
$|t| > 0.8 \text{ GeV}^2$
Proton multiplicity 2
Exclusive missing mass squared:
 $0.5 \sim 1.1 \text{ GeV}^2/c^4$



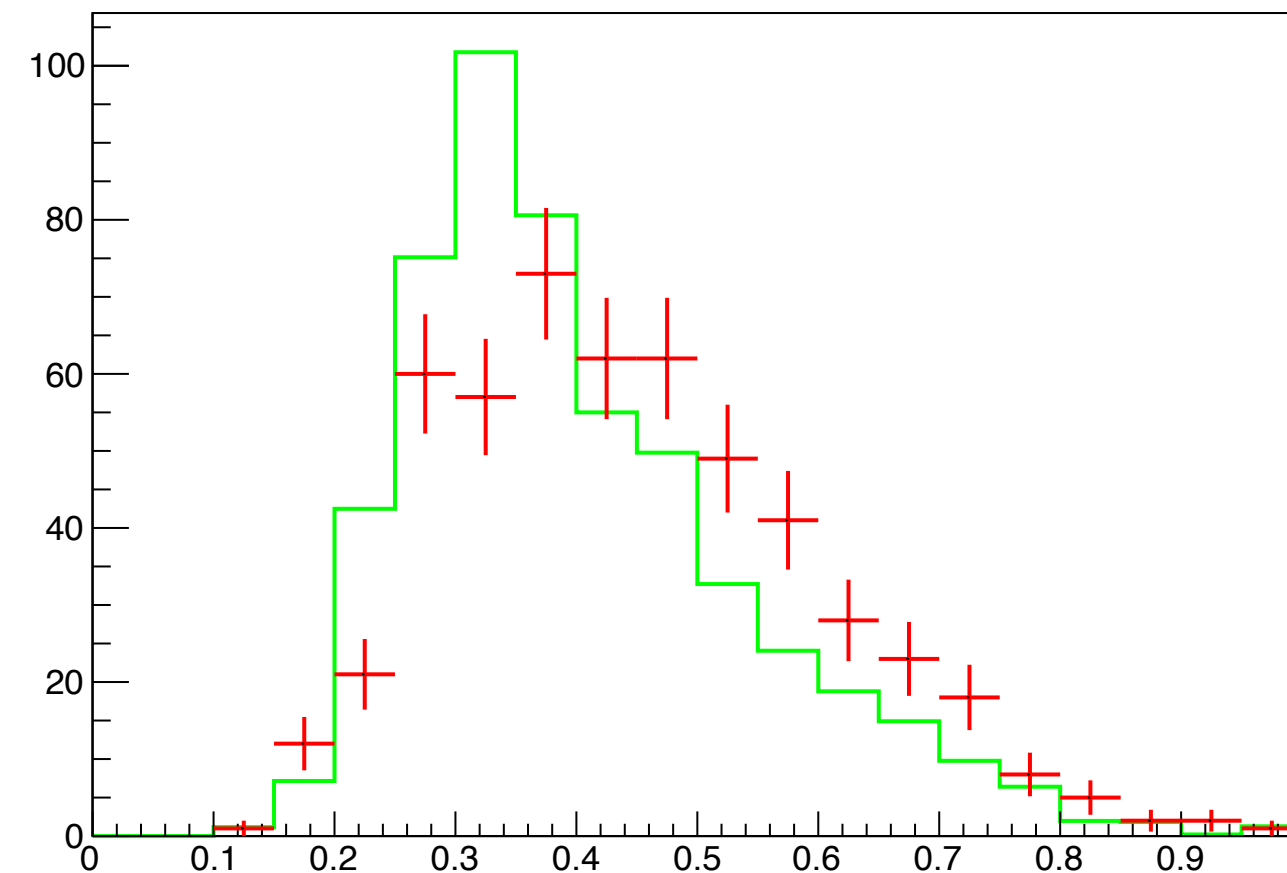
$^{12}\text{C}(p,2p)^{10}\text{B}$ SRC selection

$|t| > 0.8 \text{ GeV}^2$
Proton multiplicity 2
Exclusive missing mass squared:
 $0.5 \sim 1.1 \text{ GeV}^2/c^4$

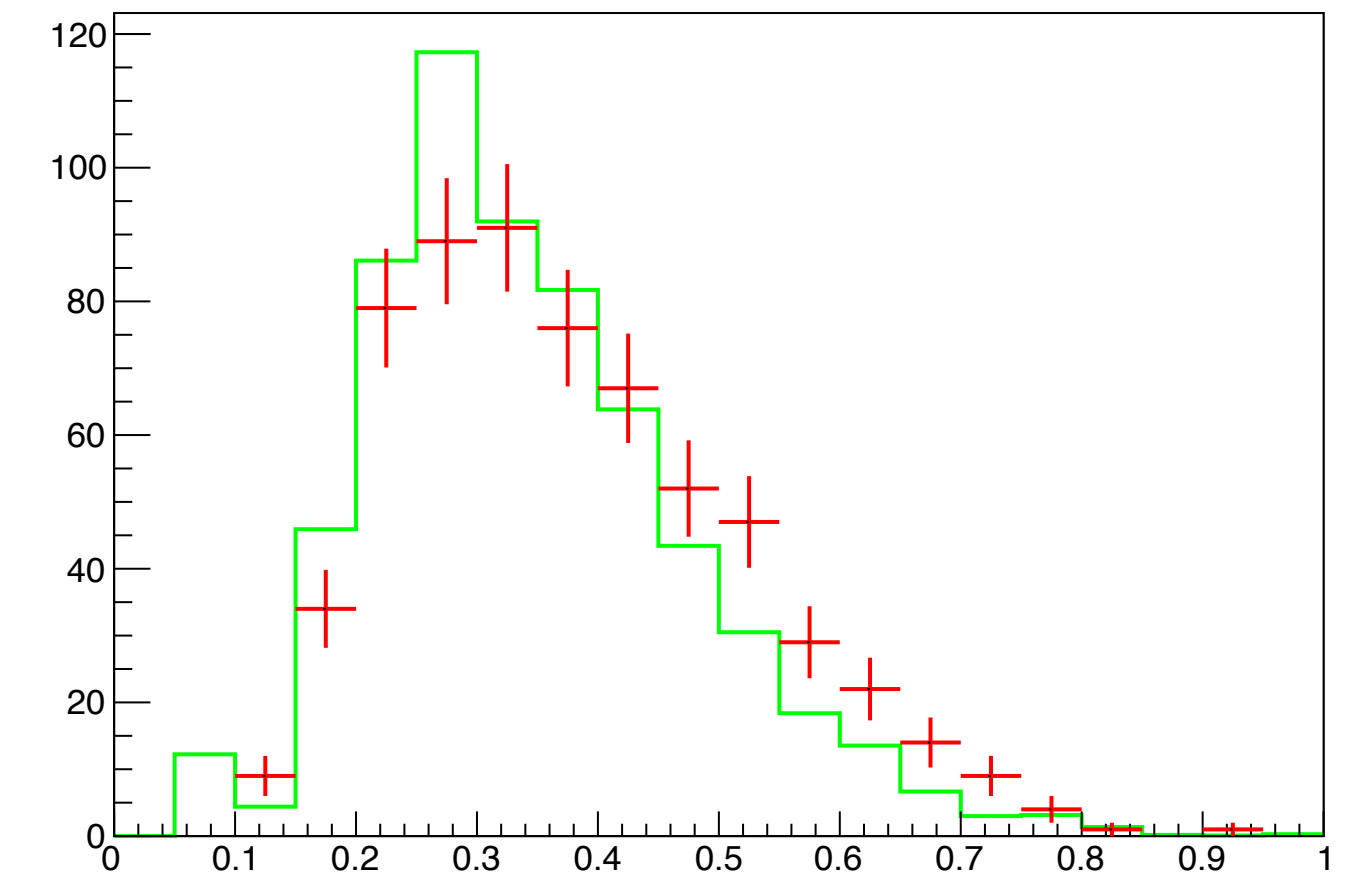
$\alpha: 0.5-0.6$



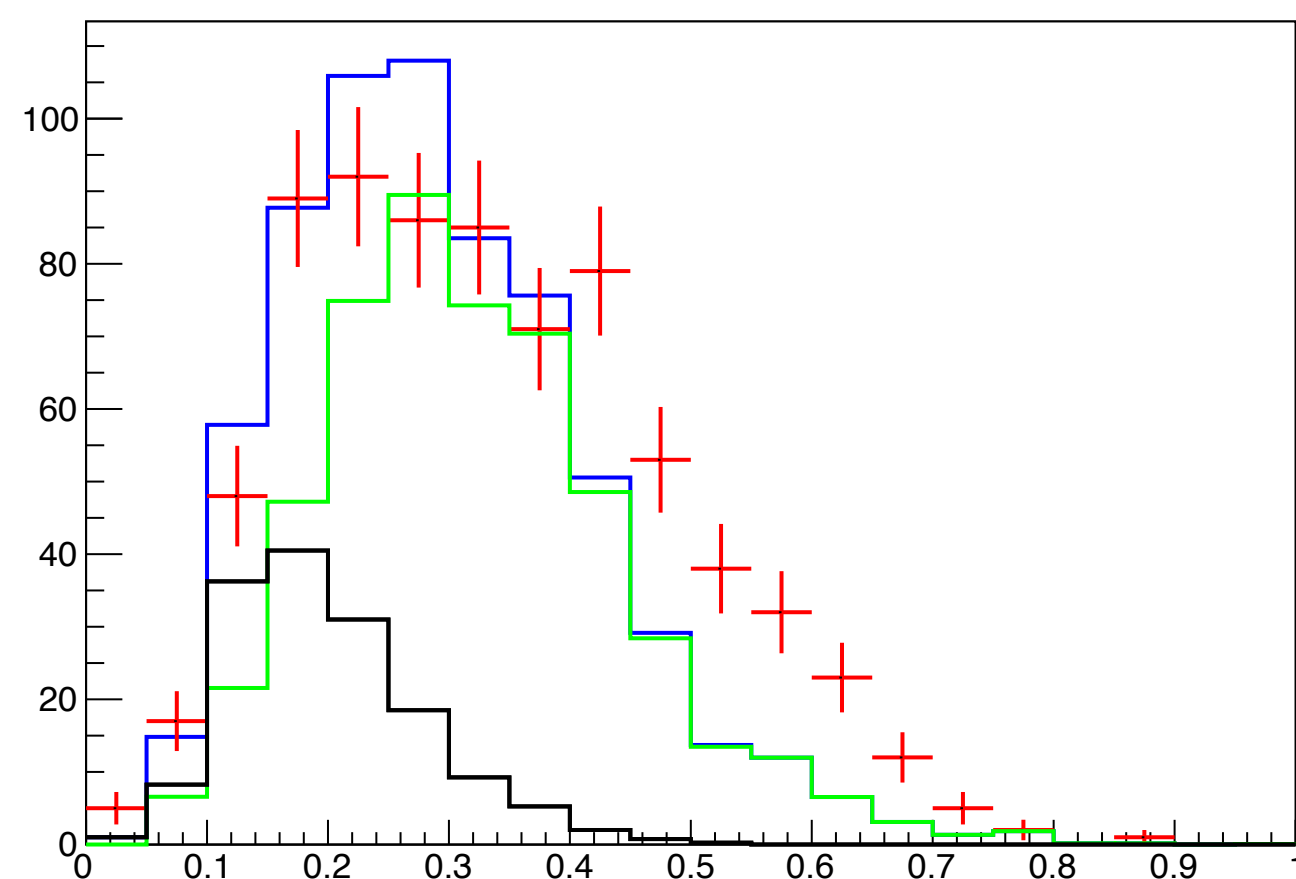
$\alpha: 0.6-0.7$



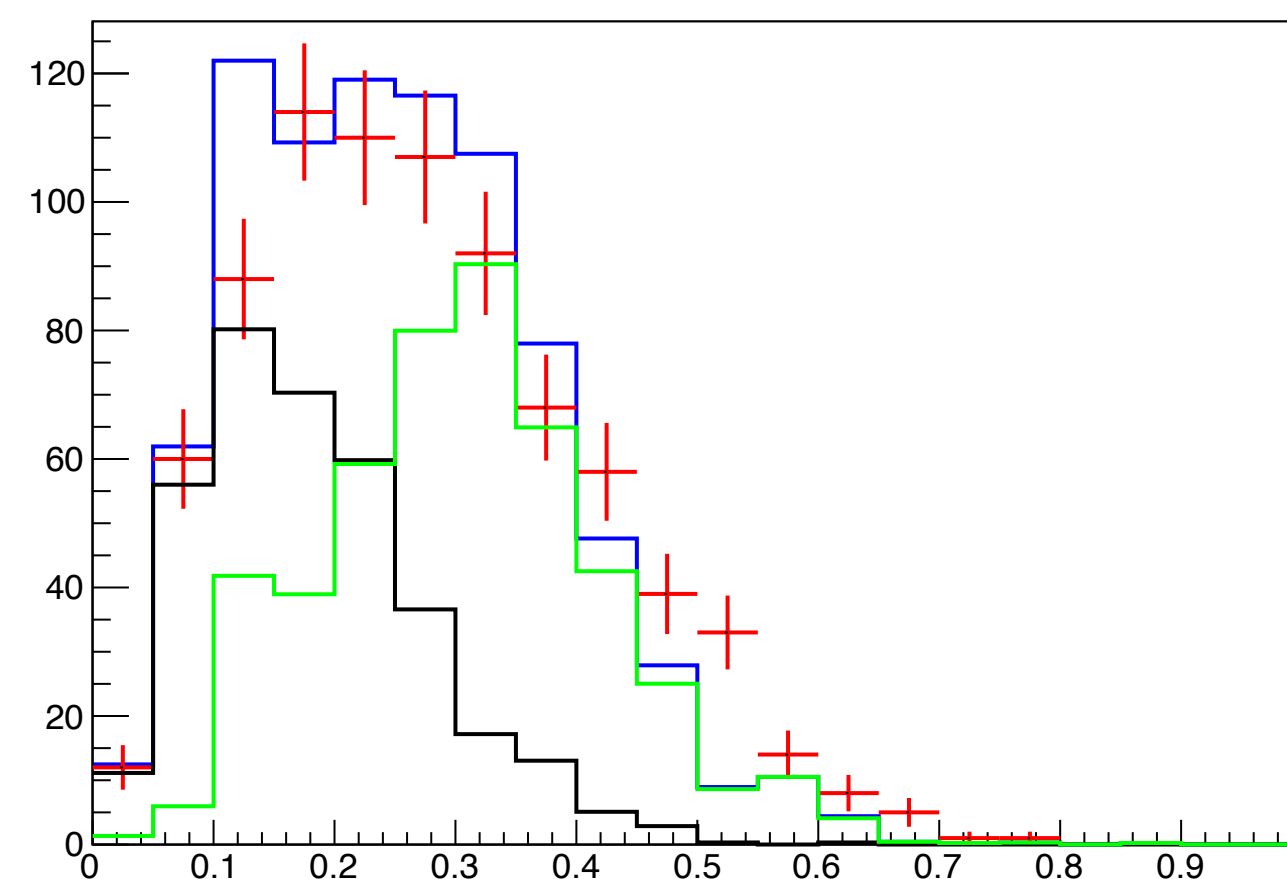
$\alpha: 0.7-0.8$



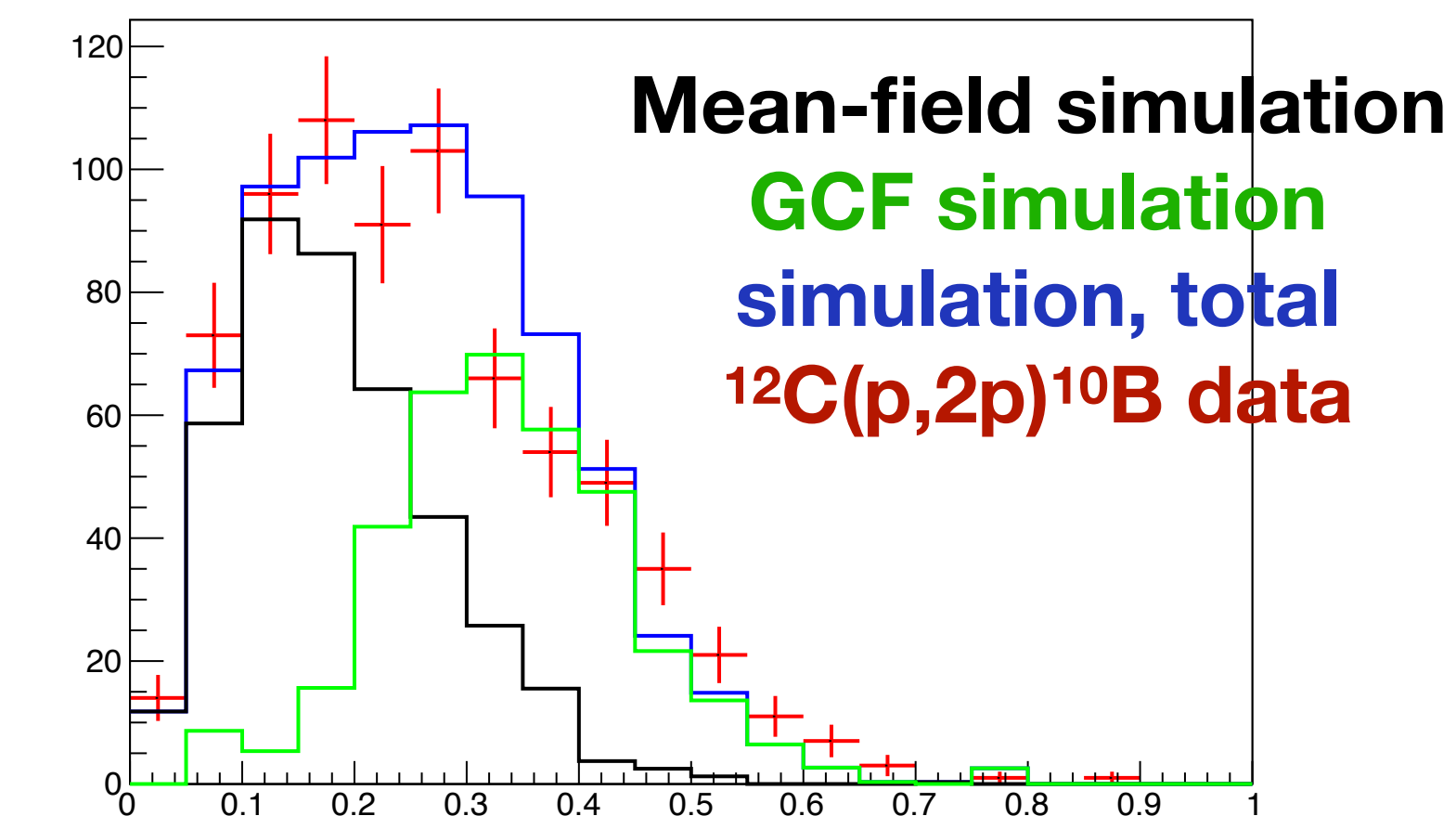
$\alpha: 0.8-0.9$



$\alpha: 0.9-1.0$

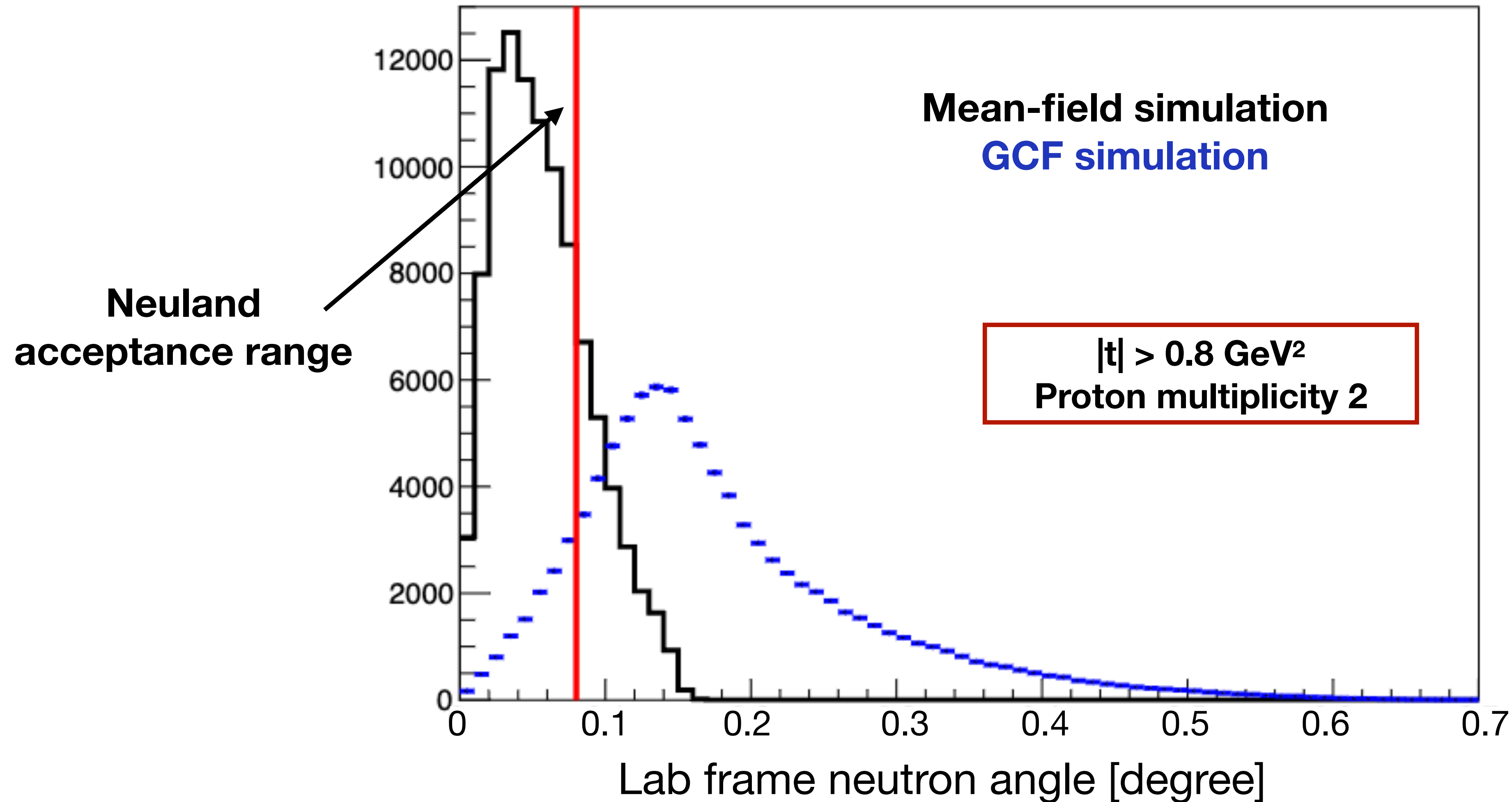


$\alpha: 1.0-1.1$



Missing momentum [GeV²/c⁴]

Neutron veto for mean-field event rejection



$^{16}\text{C}(p,2p)^{14}\text{B}$ opening angle with neutron veto dominated by mean-field contribution

