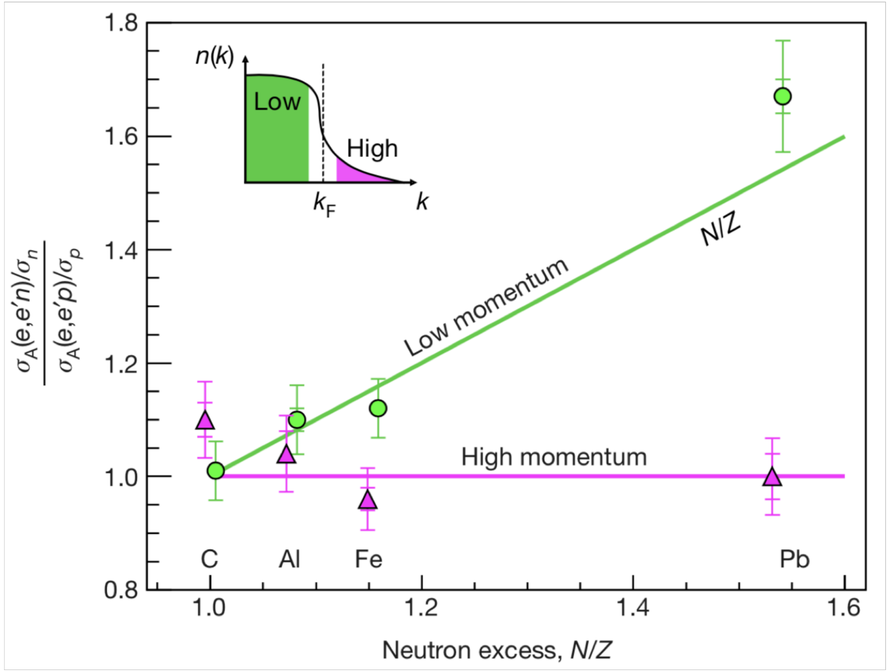
Probing 2N-SRC via (e,e'N) reactions off $^{3,4}He$ (^{12}C)

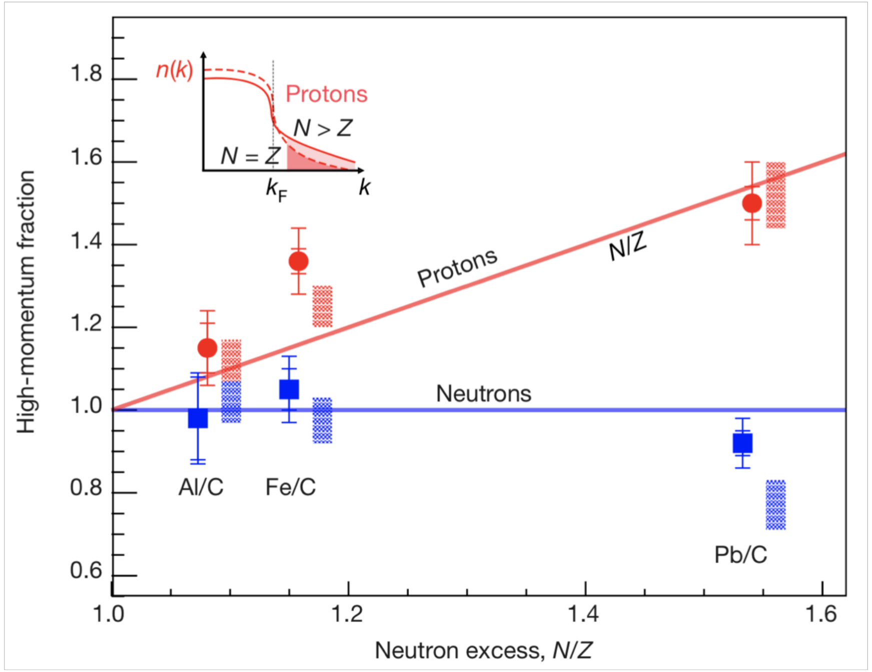
Using e2a data

Peninah Levine
March 7, 2019

SRC NPWG

SRC in n. Rich systems





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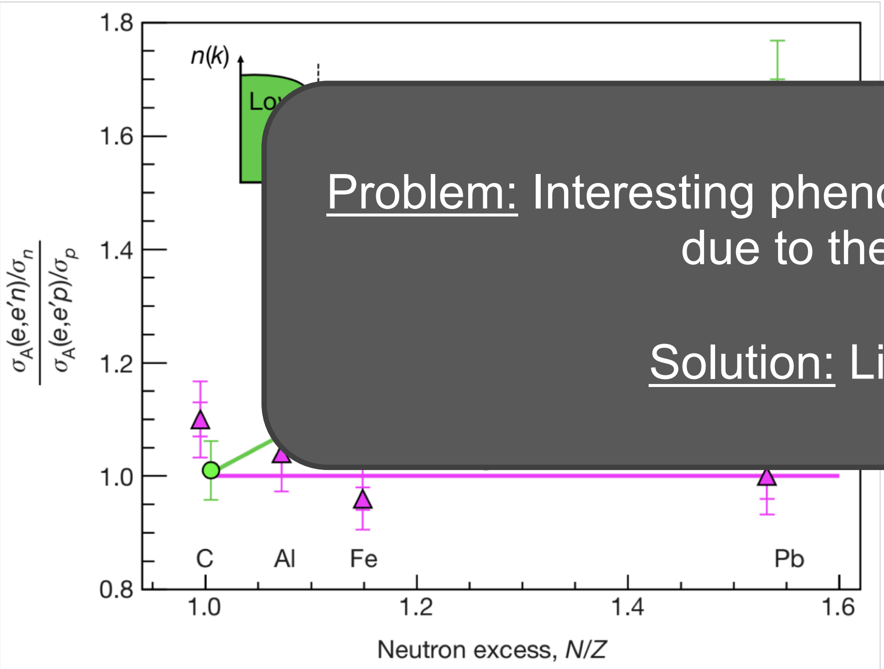
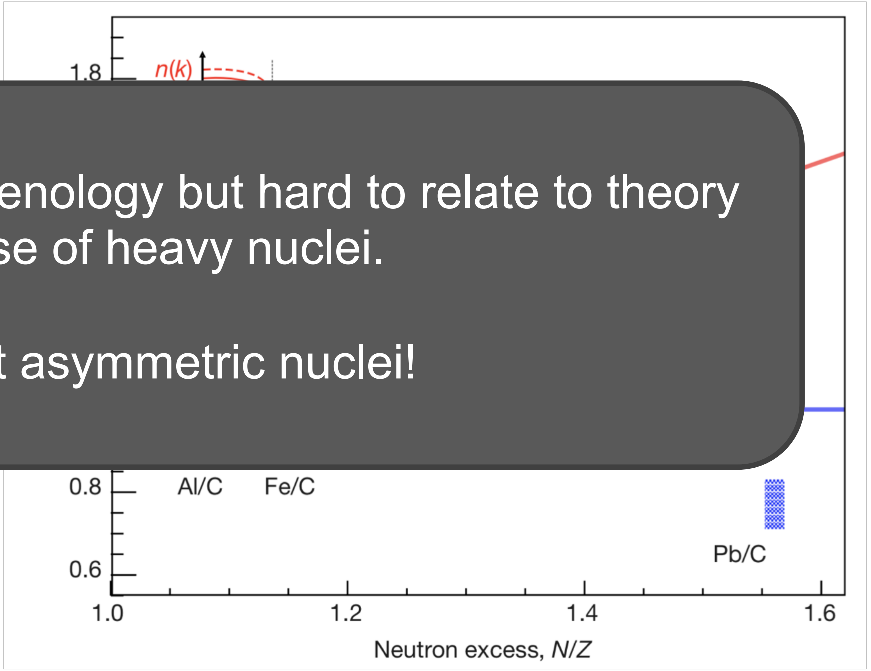
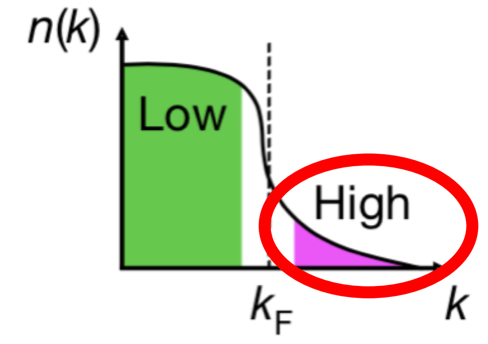




Problem: Interesting phenomenology but hard to relate to theory due to the use of heavy nuclei.

Solution: Light asymmetric nuclei!

Relevant observables in 'SRC' kinematics

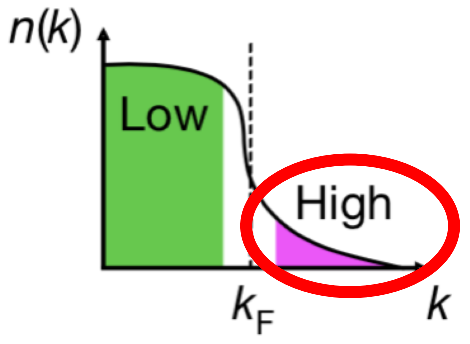


<u>Benchmark in 'SRC Kinematics':</u>

^{12}C / ^{4}He (e,e'p)
^{12}C / ^{4}He (e,e'n)

^{12}C (e,e'p) / (e,e'n)
^{4}He (e,e'p) / (e,e'n)

Relevant observables in ‘SRC’ kinematics



<u>Benchmark in ‘SRC Kinematics’:</u>

^{12}C / ^{4}He (e,e’p)
^{12}C / ^{4}He (e,e’n)

Should equal $a_2(^{12}C/^{4}He)$
Should equal each other

^{12}C (e,e’p) / (e,e’n)
^{4}He (e,e’p) / (e,e’n)

Should equal $\sigma_{e\text{-}n}$ / $\sigma_{e\text{-}p}$

Relevant observables:

Benchmark in ‘SRC Kinematics’:

^{12}C / ^{4}He (e,e’p)
^{12}C / ^{4}He (e,e’n)

^{12}C (e,e’p) / (e,e’n)
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Physics:

^{3}He / ^{4}He (e,e’p)
^{3}He / ^{4}He (e,e’n)

^{3}He(e,e’p) / ^{3}He(e,e’n)

TODAY:

Benchmark in 'SRC Kinematics':

^{12}C / ^{4}He (e,e'p)
~~^{12}C / ^{4}He (e,e'n)~~

^{12}C (e,e'p) / (e,e'n)
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^{12}C / ^{4}He (e,e'p)

^{3}He / ^{4}He (e,e'p)

(e,e'p): Event Selection

Nucleus
e^- fiducial cuts
$x_B > 1.2$
$\theta_{pq} < 25^o$
$\frac{p}{q} > 0.62$
$\frac{p}{q} < 0.96$
$P_{miss} > 0.3$
$P_{miss} < 1$
Proton fiducial cuts
(^{12}C) $v_z > 4\ cm$
(^{12}C) $v_z < 7\ cm$
(He) $v_z > -2.5\ cm$
(He) $v_z < -0.5\ cm$

Fiducial + Z-Vertex cuts.

(e,e'p): Event Selection

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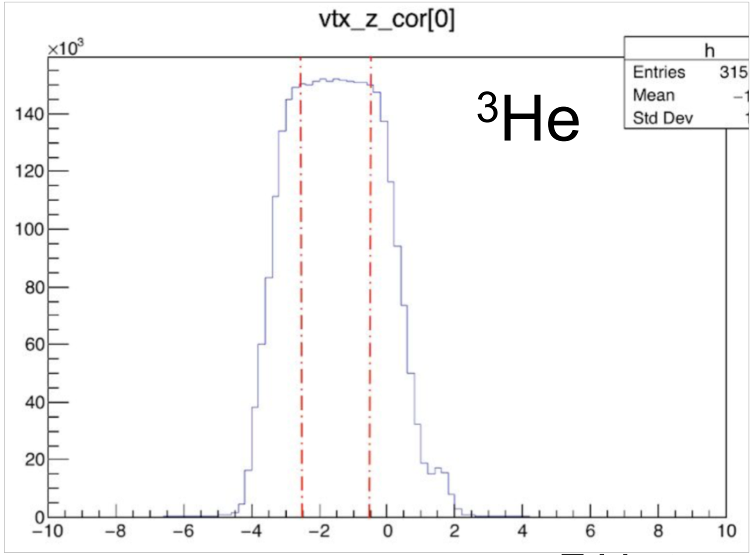
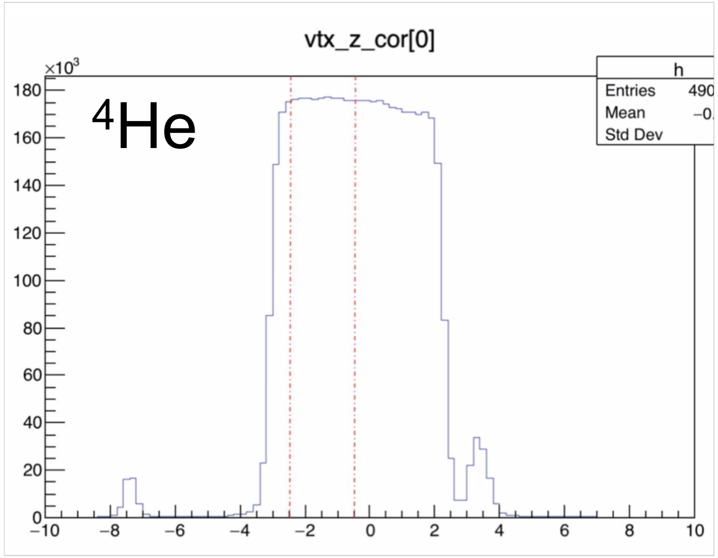
Fiducial + Z-Vertex cuts.

Note: same cut on 3He and 4He target to match acceptances for 3He/4He ratio.



Z-Vertex



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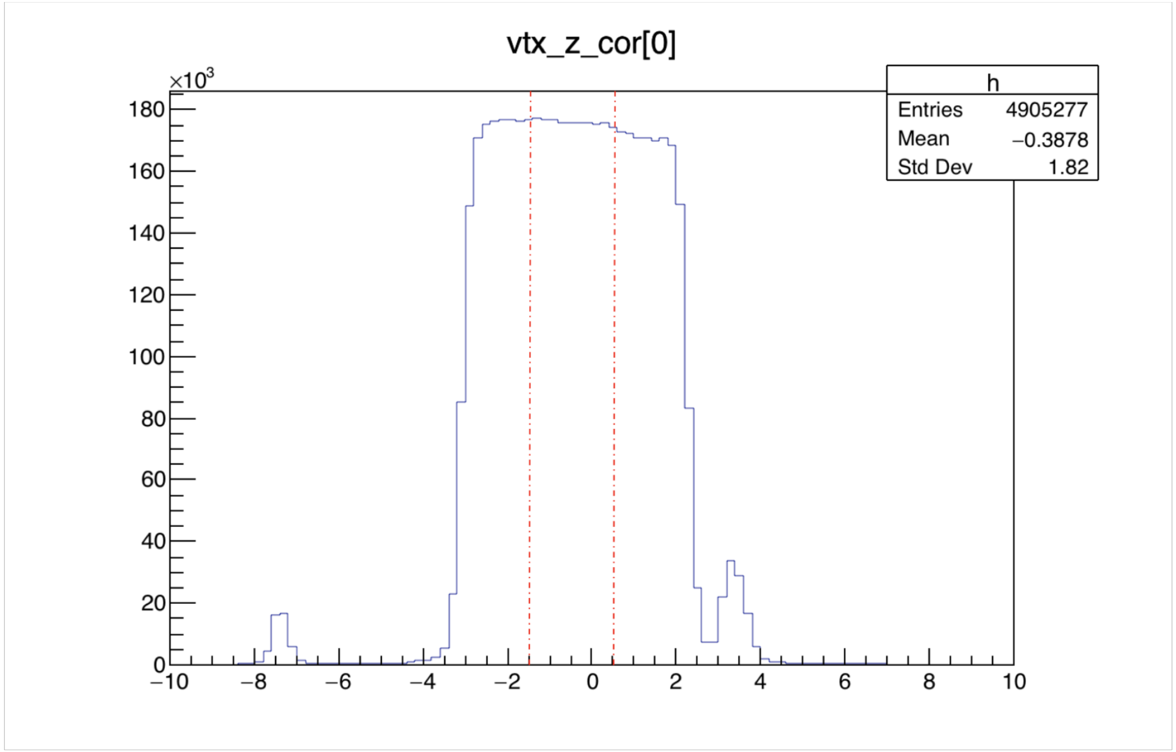
(He) $v_z < -0.5\ cm$
(^{4}He; C ratio) $v_z > 0.5\ cm$
(^{4}He; C ratio) $v_z > -1.5\ cm$

Note: use different vertex cuts for ^{4}He and ^{12}C, optimized to include most statistics



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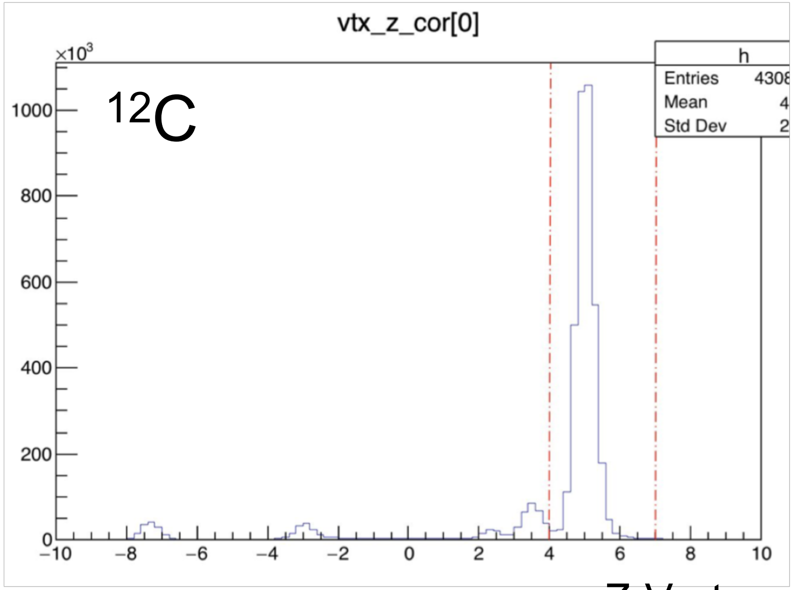
(e,e'p): Event Selection

Fiducial + Z-Vertex cuts.

Note: same cut on 3He and 4He target to match acceptances.



Z-Vertex

(e,e'p): Event Selection

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(^{4}He; C ratio) $v_z > 0.5\ cm$
(^{4}He; C ratio) $v_z > -1.5\ cm$

'Standard SRC selection cuts'.
[Hen PLB, Hen Science, Cohen PRL, Duer Nature …]

Kinematical distributions studied and will be included in the report.

Nucleus	^{3}He	^{4}He	^{12}C
e^- fiducial cuts	3151792	4905277	4308325
$x_B > 1.2$	16593	28831	25640
$\theta_{pq} < 25^o$	16593	28831	25640
$\frac{p}{q} > 0.62$	11511	17469	13850
$\frac{p}{q} < 0.96$	10526	16849	13474
$P_{miss} > 0.3$	4426	8617	7000
$P_{miss} < 1$	4407	8581	6942
Proton fiducial cuts	4143	8122	6655
(^{12}C) $v_z > 4\ cm$	--	--	5602
(^{12}C) $v_z < 7\ cm$	--	--	5600
(He) $v_z > -2.5\ cm$	3023	7179	--
(He) $v_z < -0.5\ cm$	1962	2969	--

Good (e,e'p) Statistics

A / ^{4}He (e,e'p)

$$\frac{A(e,e'p)\cdot w/L/A/T}{4He(e,e'p)\cdot w_{4He}/L_{4He}/A_{He}/T_{He}}$$

- Number of measured events
- 1 / Simulated_Efficiency
  Only for 12C/4He; From map; Applied event-by-event
- Integrated luminosity
- Number of nucleons
- Nuclear Transparency (^{3}He: 0.82; ^{4}He: 0.75; ^{12}C: 0.53)

A / ^{4}He (e,e'p)

$$\frac{A(e,e'p) \cdot w / L / A / T}{4He(e,e'p) \cdot w_{4He} / L_{4He} / A_{He} / T_{He}}$$

- Number of measured events
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- Number of nucleons
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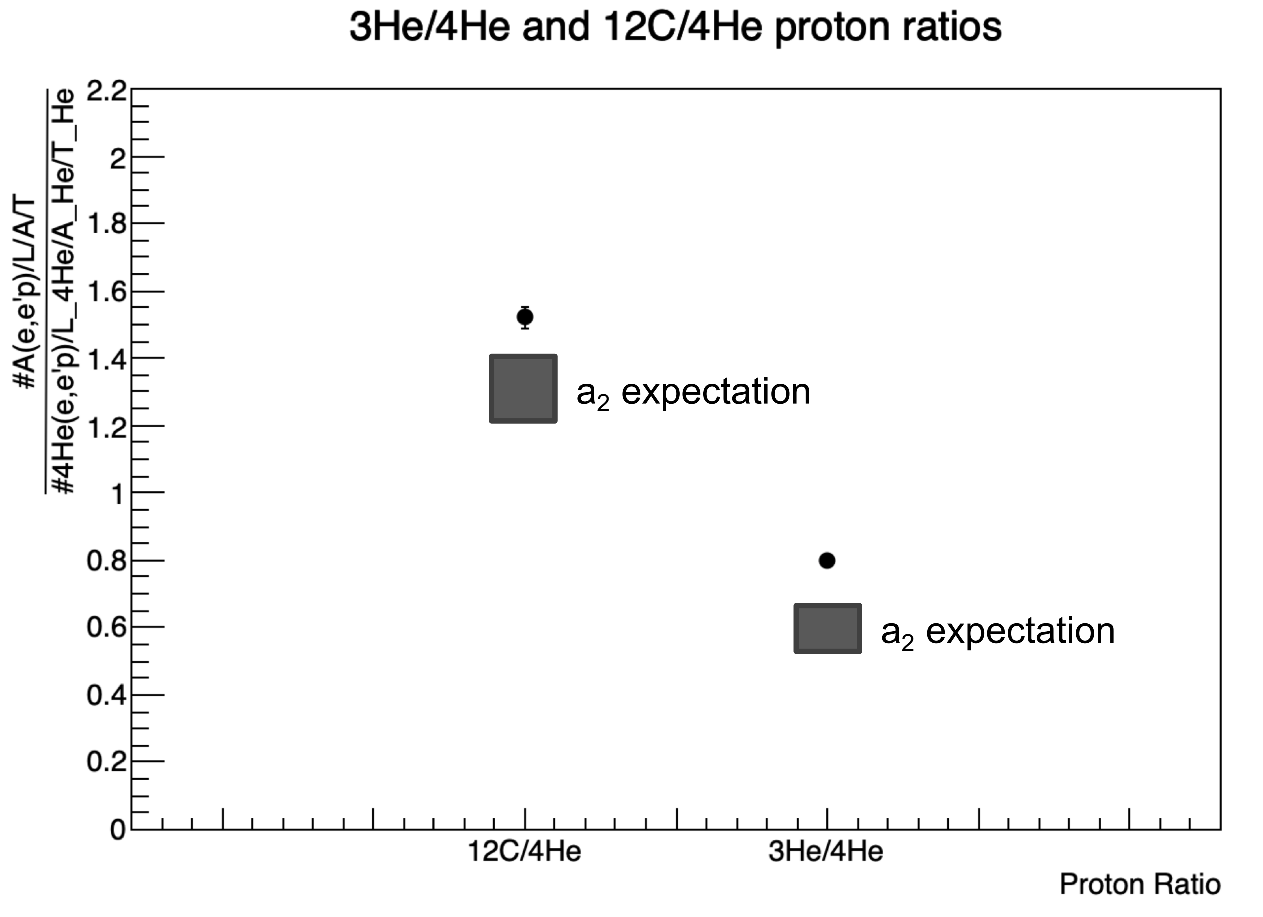
+ remove events where either ^{4}He or ^{12}C map efficiency < 80%.

A / ^{4}He (e,e'p)

Stat. uncertainties only

<u>Sys. Uncertainties:</u>

- luminosity (~2%)
- Transparency
- Cut sensitivity
- P_{miss} (in)dependence



A / ^{4}He (e,e'p)

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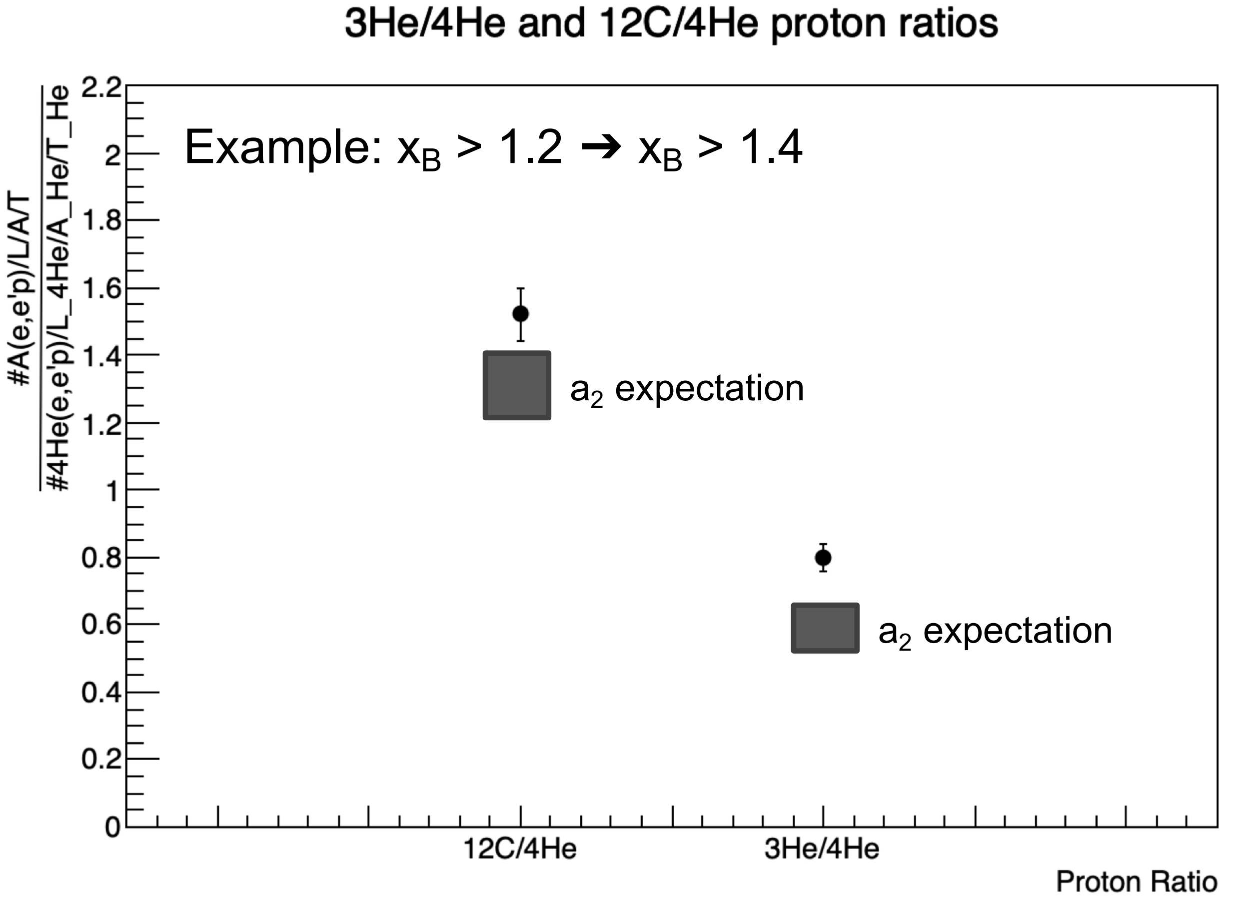
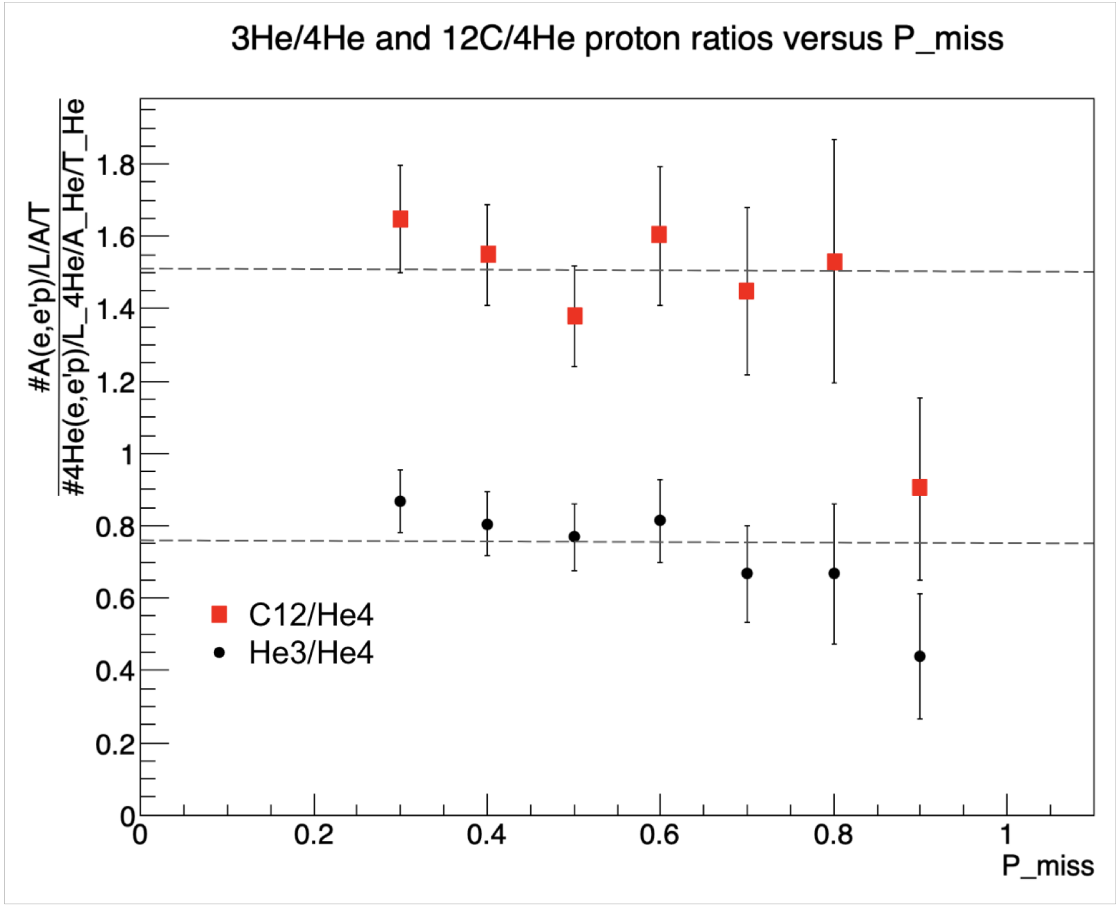
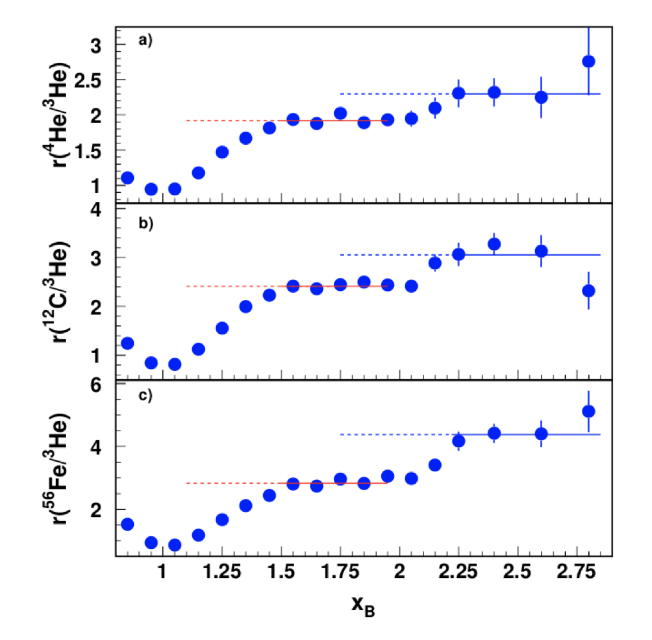
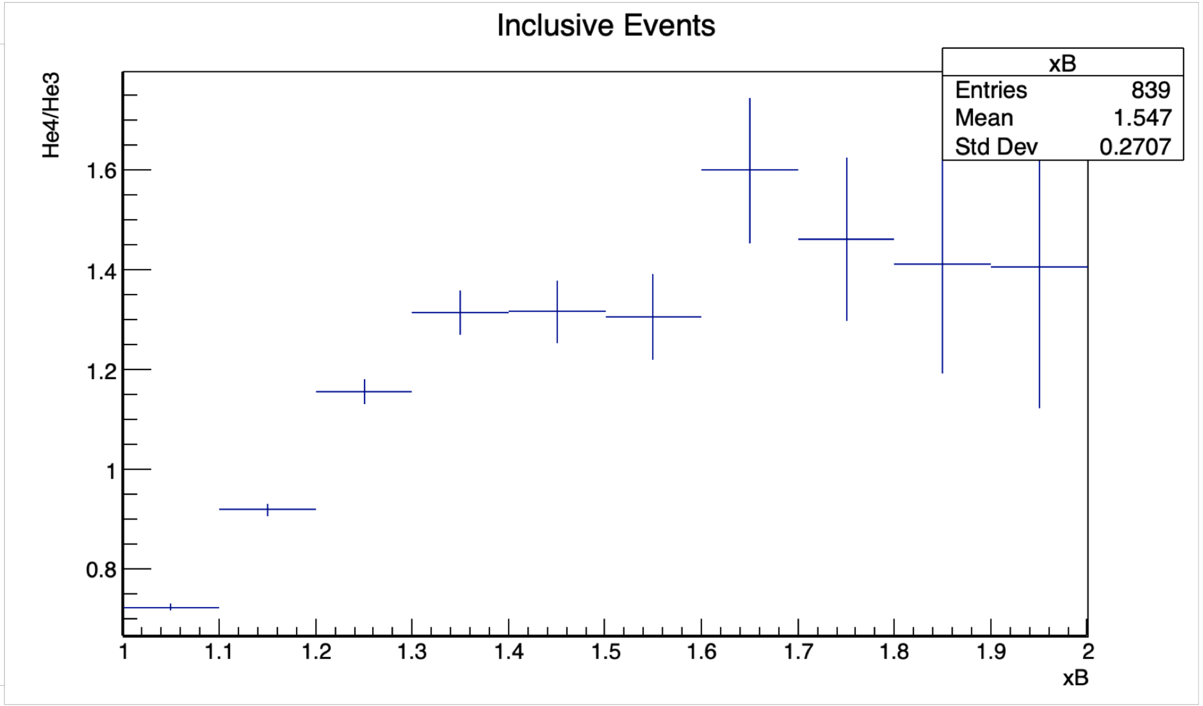


P_miss dependence



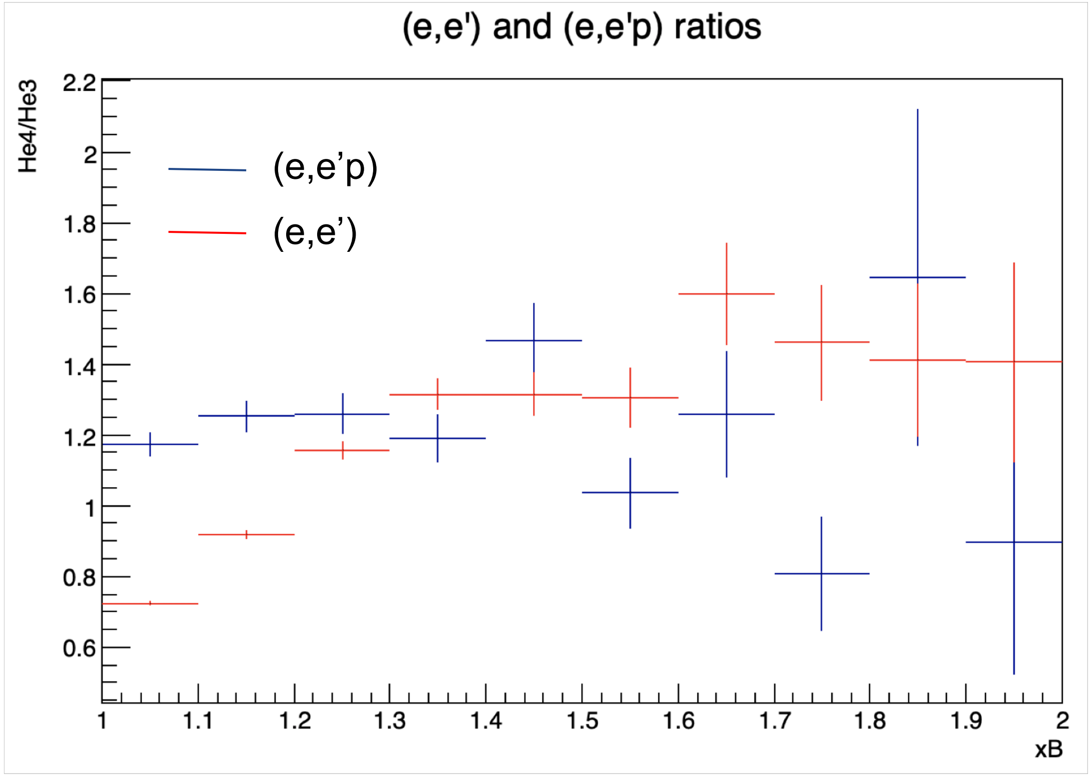
Comparing to Egiyan





Source: Egiyan. “Study of Short Range Correlations in A(e,e’) Reactions at 1 < xB < 3.” 2006.

He3/He4 xB Dependence

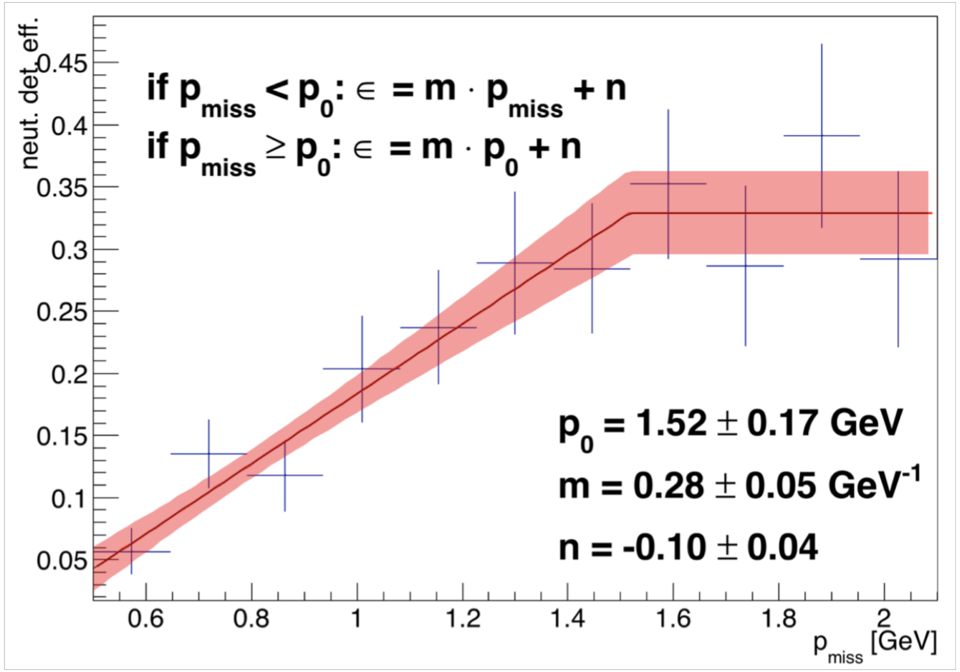


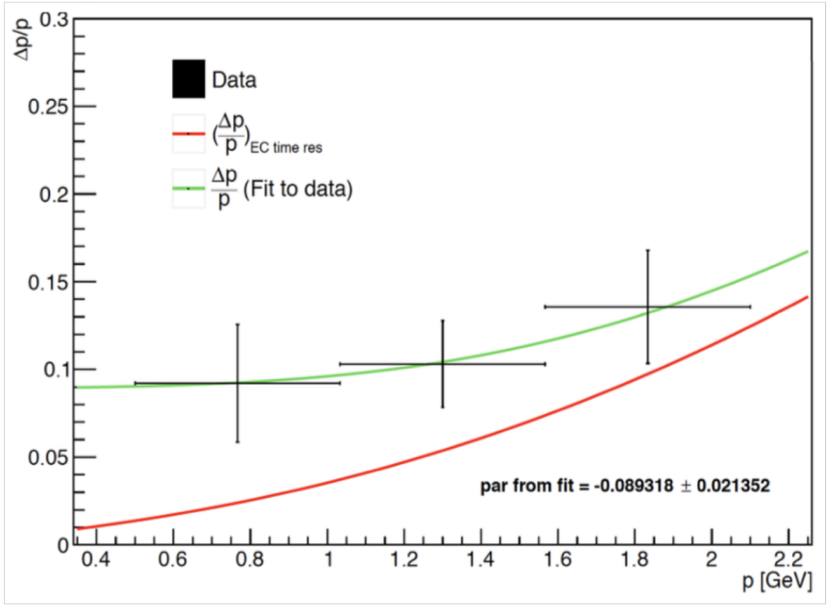
Relevant observables:

^{12}C (e,e’p) / (e,e’n)

^{4}He (e,e’p) / (e,e’n)

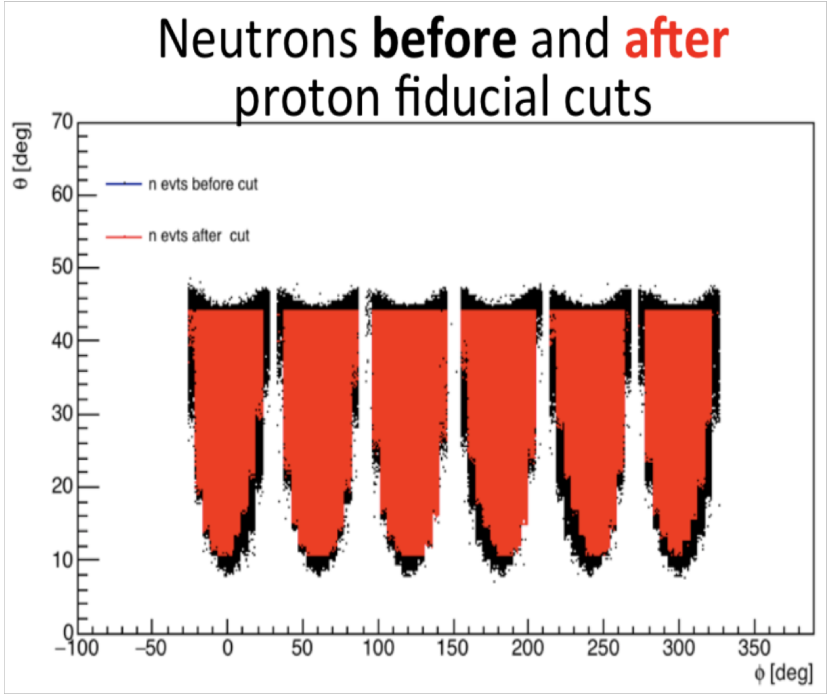
Neutrons: Detection efficiency & momentum reco. Resolution
[Follow Duer Nature 2018; Details in the report]

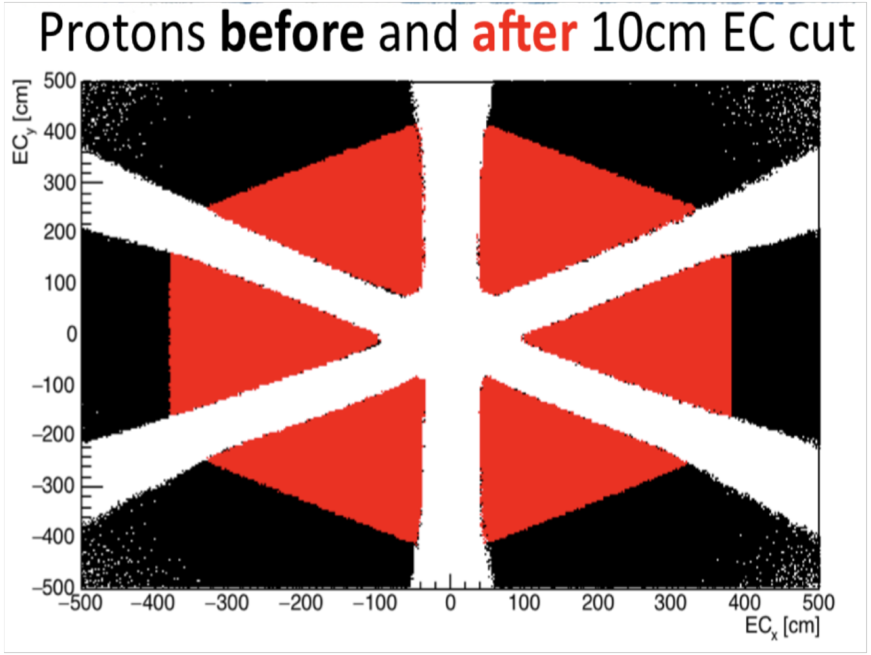




Acceptance Matching:

p-fiducials on neutrons; n-fiducials on protons.





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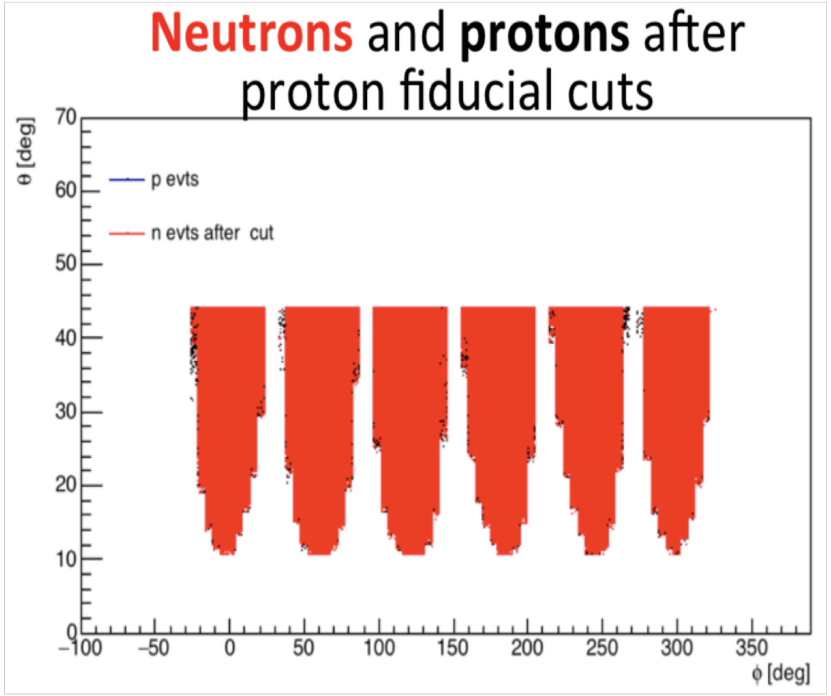
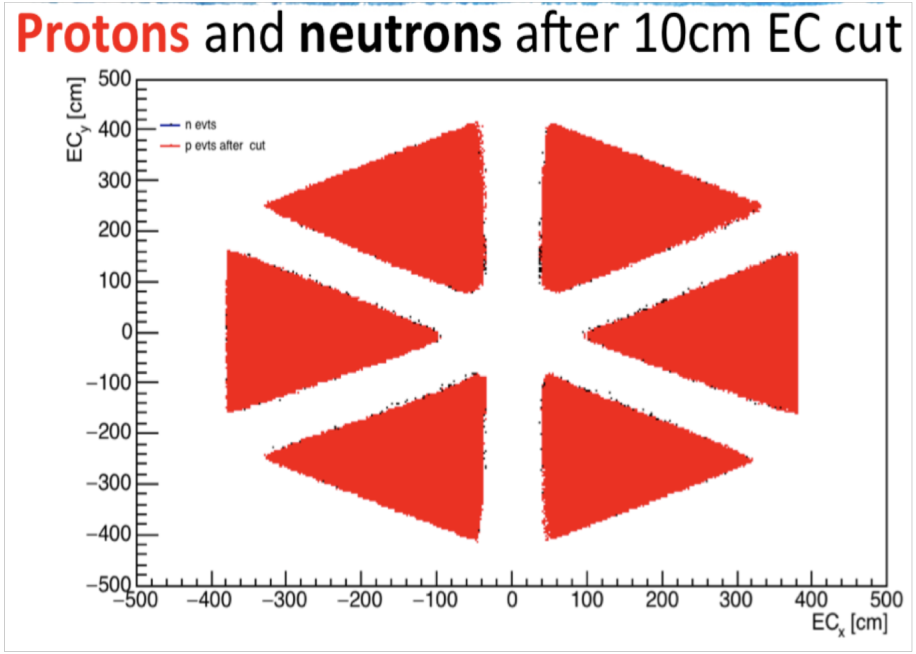




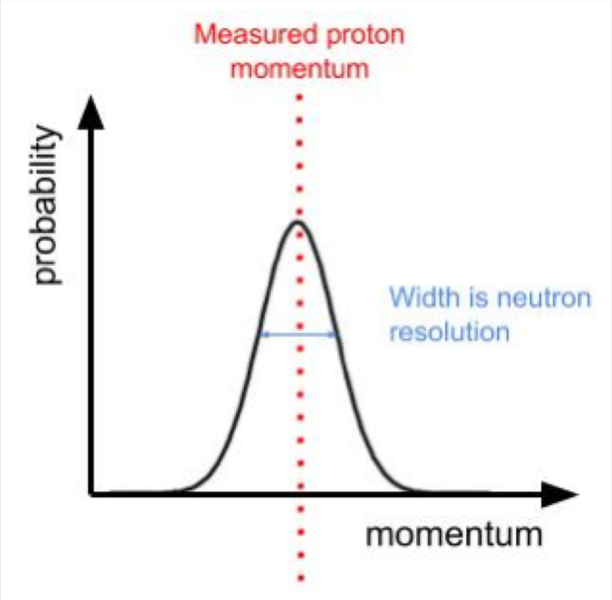
Smearing protons to simulate neutron resolution

Why

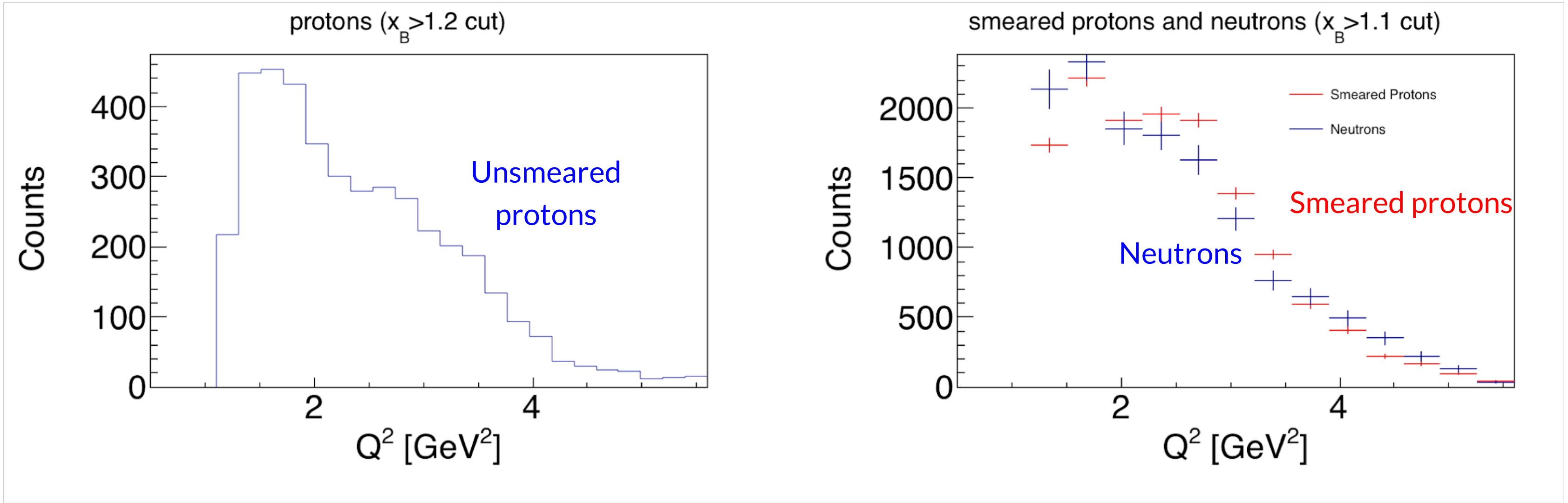
Poor neutron momentum resolution

How

Smear protons by neutron momentum resolution

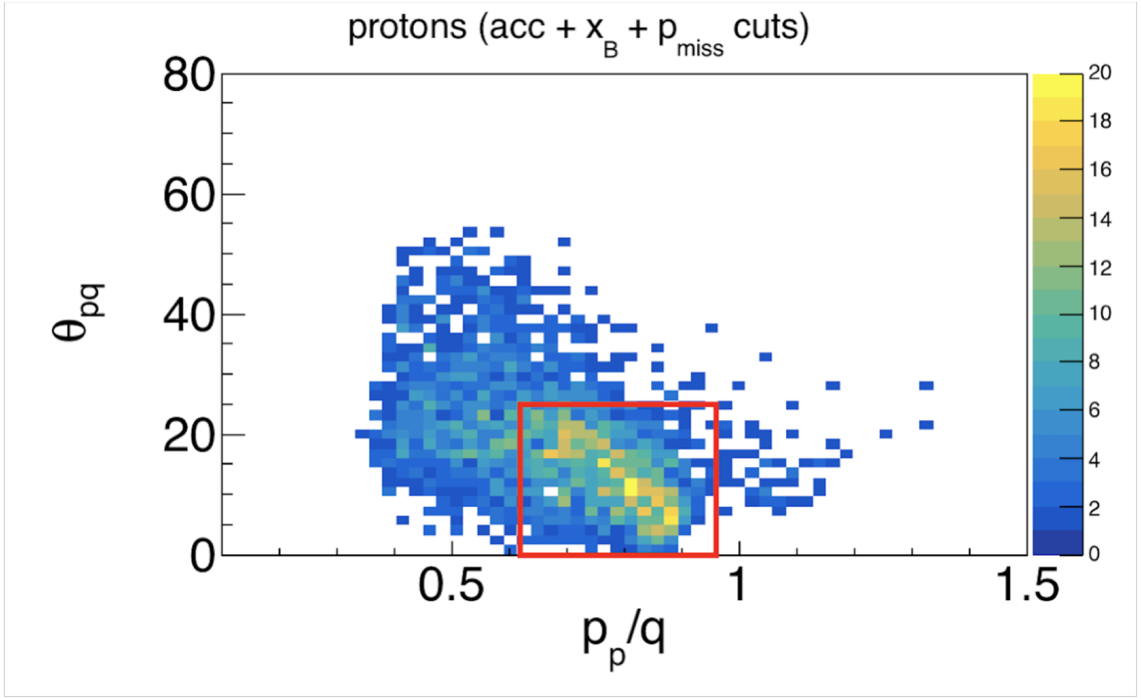


x_B cut on neutrons and smeared protons



$x_B > 1.1$

Leading nucleon cuts: θ_{pq} and p/q



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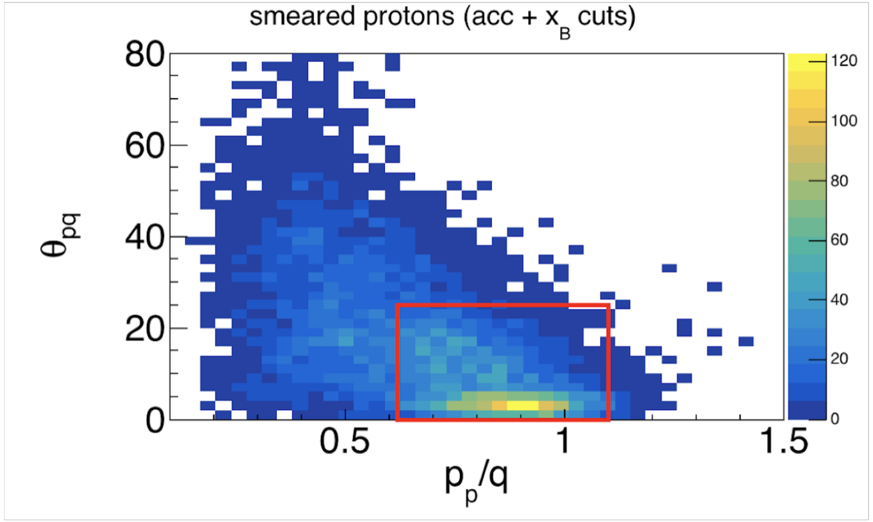
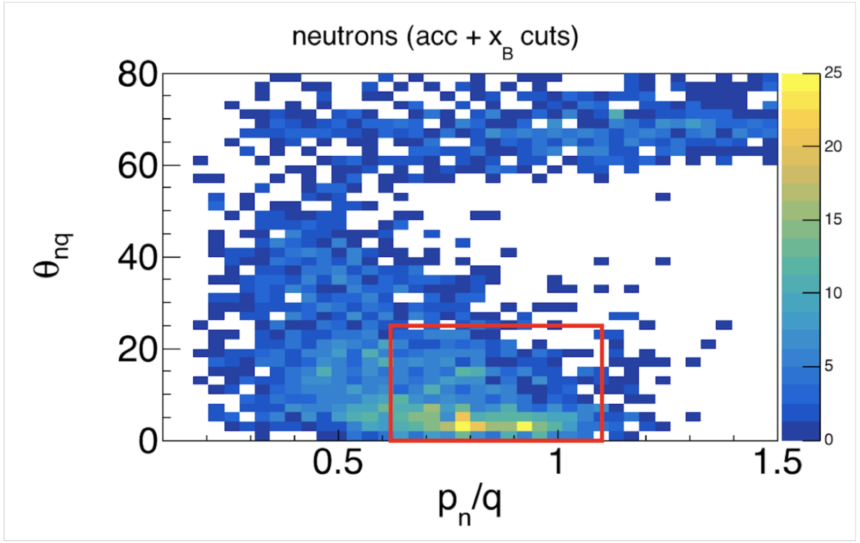




$\theta_{nq} < 25°$

$0.62 < P_N/q < 1.1$

Summary of smeared proton and neutron cuts

$x_B > 1.1$

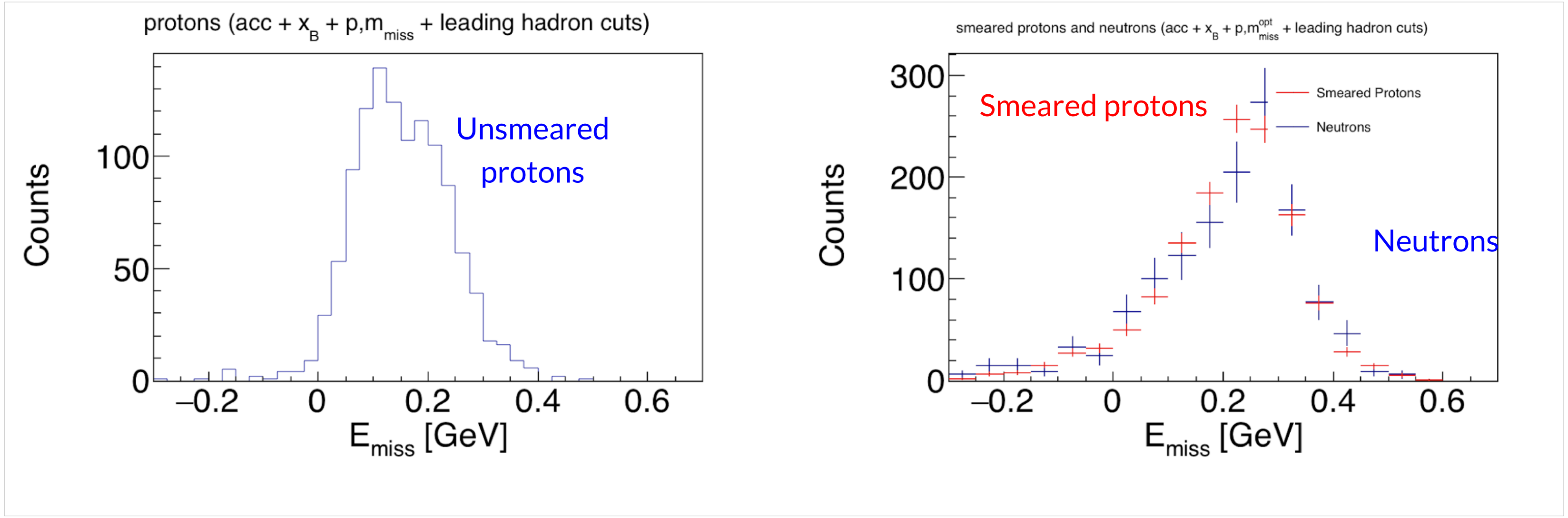
$0^{o} < \theta_{pq} < 25^{o}$

$0.62 < \theta_{pq} < 1.10$

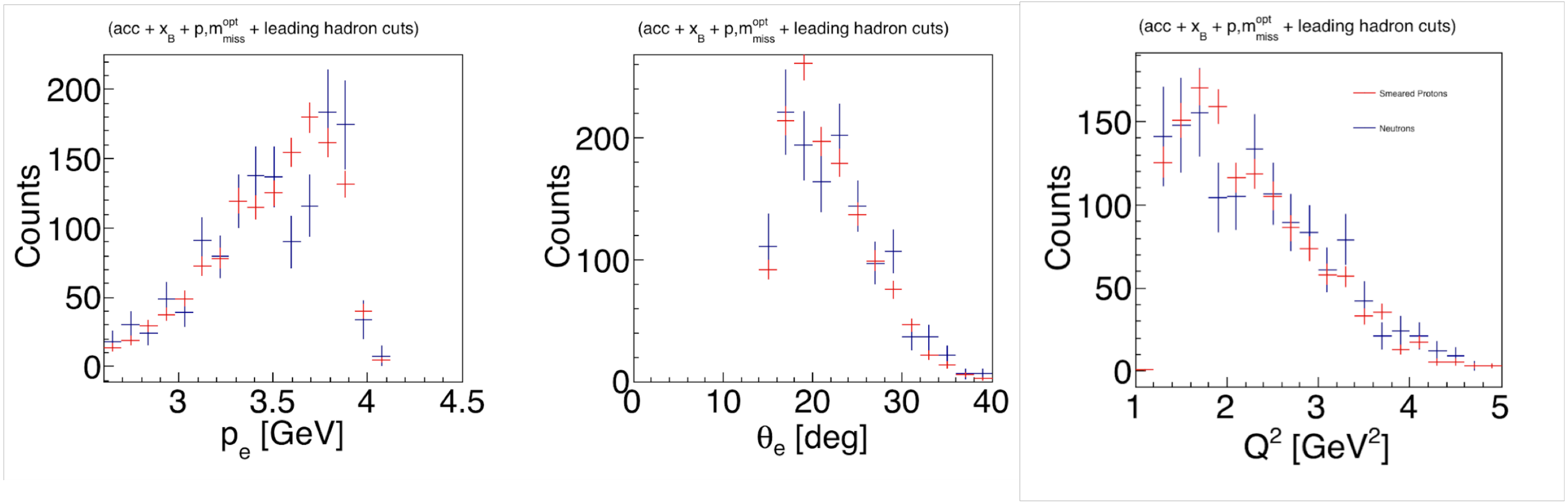
$0.402 < P_{miss} < 1.000$ GeV/c

$M_{miss} < 1.175$ GeV/c^2

Checking selected cuts using E_{miss} distributions



Checking selected cuts using e⁻ kinematic variables



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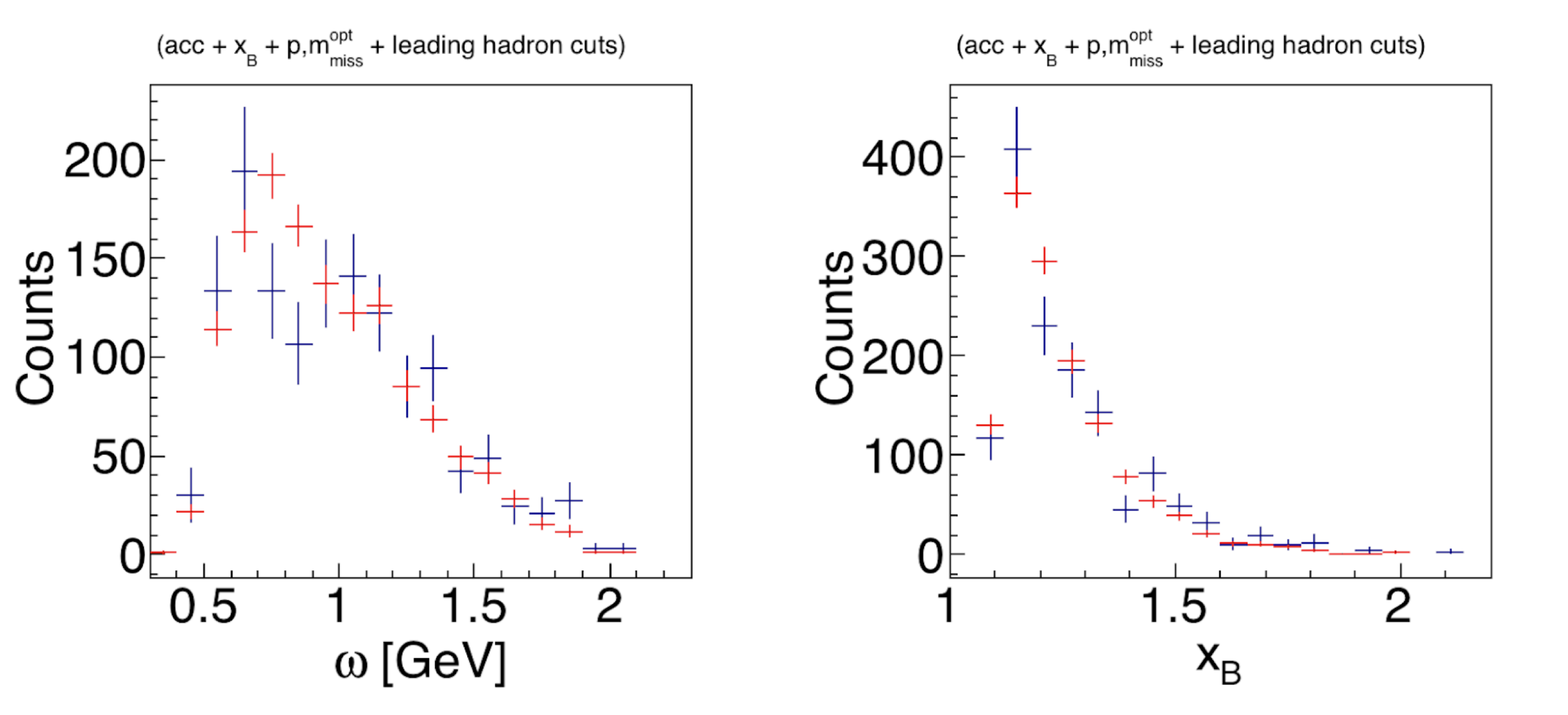
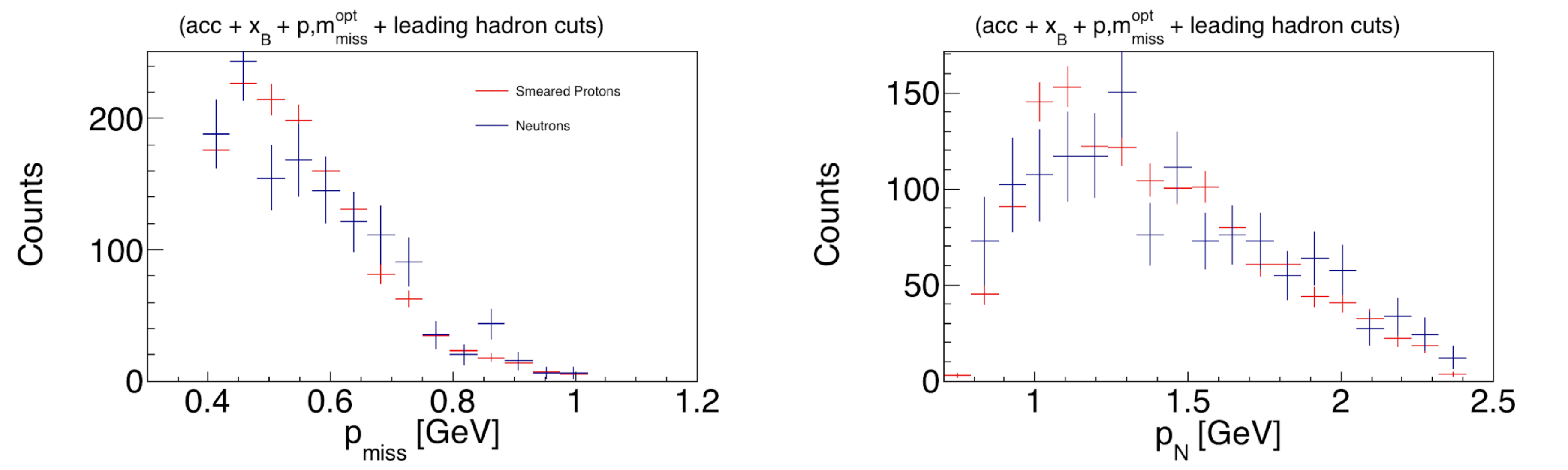


Checking selected cuts using p and n kinematic variables



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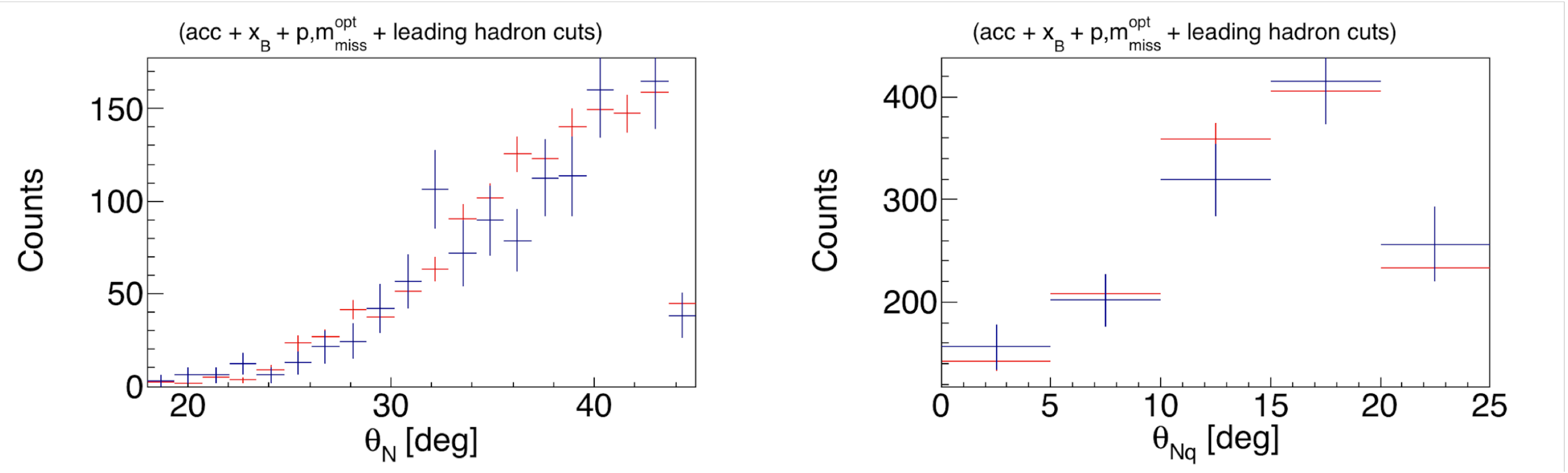


Raw counts of (e,e'p) and (e,e'n) events

Nucleus	#(e,e'p) [Statistical Uncertainty]	#(e,e'n) [Statistical Uncertainty]	Statistical Uncertainty (#(e,e'p)/Z)/(#(e,e'n)/N)
^{3}He	377 [5.2%]	62 [12.7%]	13.7%
^{4}He	948 [3.2%]	230 [6.6%]	7.3%
^{12}C	709 [3.8%]	171 [7.6%]	8.5%

Weighting the raw counts by detection efficiency

Protons

Simulate detector and count generated versus reconstructed events. Currently **assumed 50%. Will use map next.**

Neutrons

Based on neutron momentum.

A(e,e’p)/A(e,e’n) ratios

Nucleus	(#(e,e'p)/Z/$sigma_{ep}$) / (#(e,e'n)/N/$sigma_{en}$)
^{4}He	1.05 ± 0.2
^{12}C	1.00 ± 0.2

Sources of uncertainty

Statistical: Inversely related to the square root of the sample size.

Cut Sensitivity: Effect that a slight change in cuts would have on the end distribution.

Detection Efficiency: Accuracy with which the detector can detect nucleon events.

Cut sensitivity

Cut	Sensitivity Range	Change in p/n ratio
$x_B > 1.1$	± 0.05	5.2%
$0^o < \theta_{pq} < 25^o$	$\pm 5^o$	0.1%
$0.62 < p/q < 1.1$	± 0.05	
$0.402 < P_{miss} < 1$ GeV/c	± 0.025 GeV/c	4.9%
$M_{miss} < 1.175$ GeV/c^2	± 0.025 GeV/c^2	10.6%
Total Uncertainty		16.32%

What's next

- A/^{4}He (e,e'n)

- Systematics

(Double check acceptance maps, fiducials etc.)

$^3He/^4He$ (e,e'p) and (e,e'n) ratios - raw p, n counts

Nucleus	n-relevant p [Statistical Uncertainty]	all p [Statistical Uncertainty]
^3He	377 [5.2%]	5781 [1.3%]
^4He	948 [3.2%]	16804 [0.8%]
^{12}C	709 [3.8%]	11928 [0.9%]

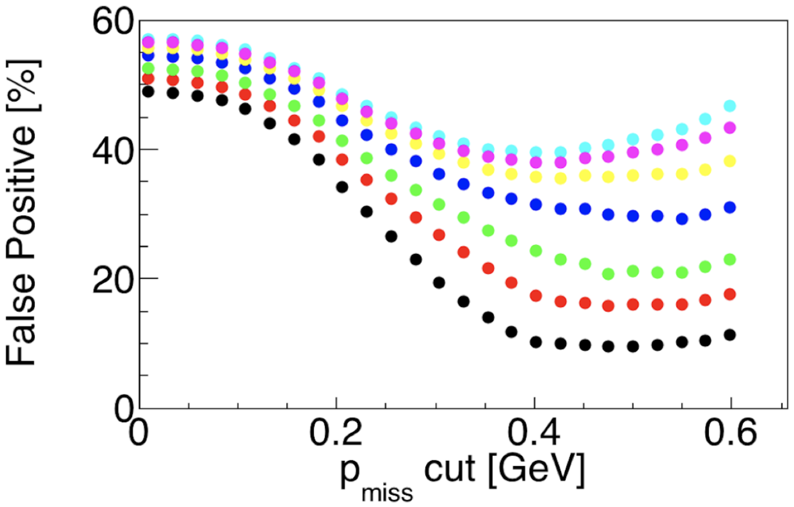
Back Up Slides

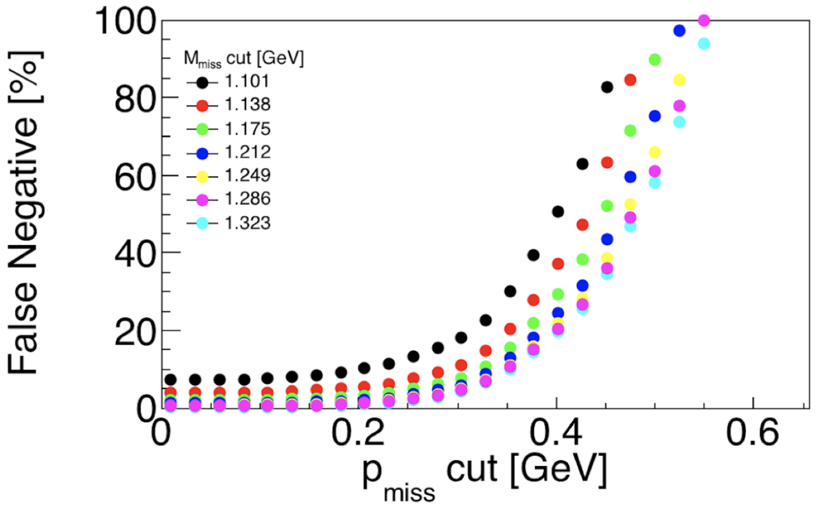
Defining false positives, negatives to optimize M_{miss}, P_{miss} cuts

False Positives — Smearing causes non-SRC events to pass the cuts.

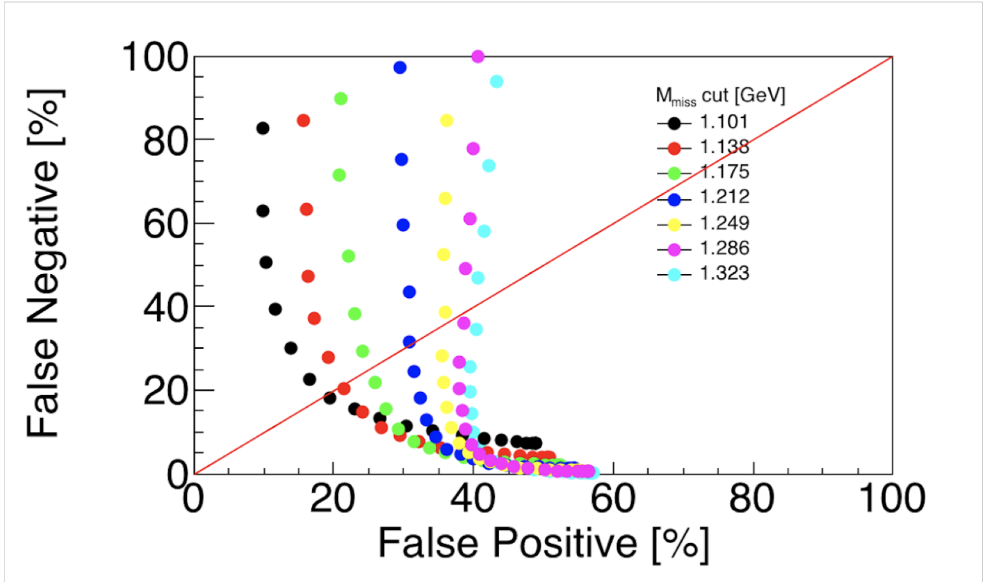
False Negatives — Smearing causes SRC events to fail the cuts.

P_{miss} and M_{miss} cuts using false positives, negatives





P_{miss} and M_{miss} cuts using false positives, negatives



$0.402 < P_{miss} < 1.000$ GeV/c

$M_{miss} < 1.175$ GeV/c^2

(adopted from Meytal's report)