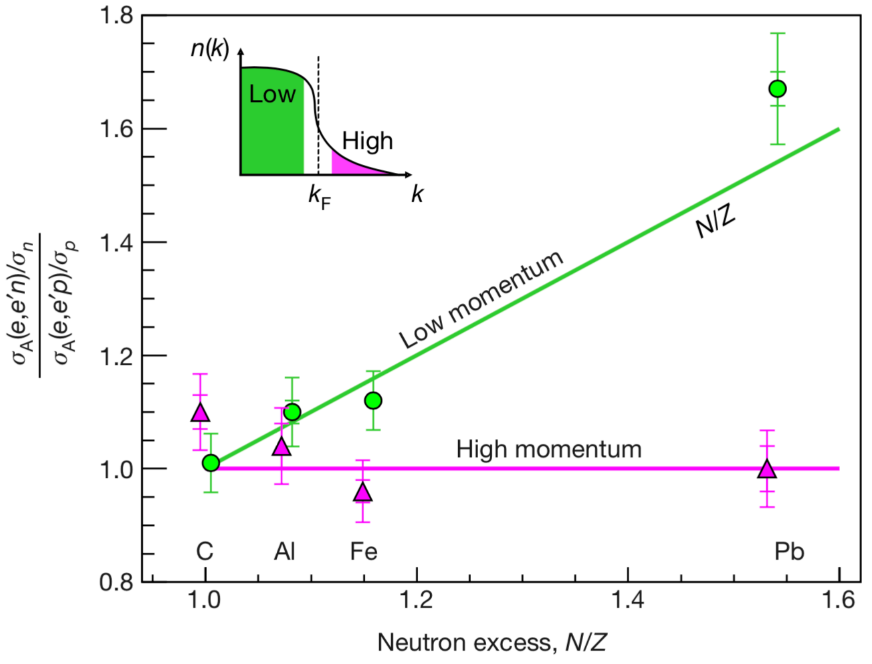
Probing 2N-SRC via (e,e'N) reactions off $^{3,4}He$ and ^{12}C

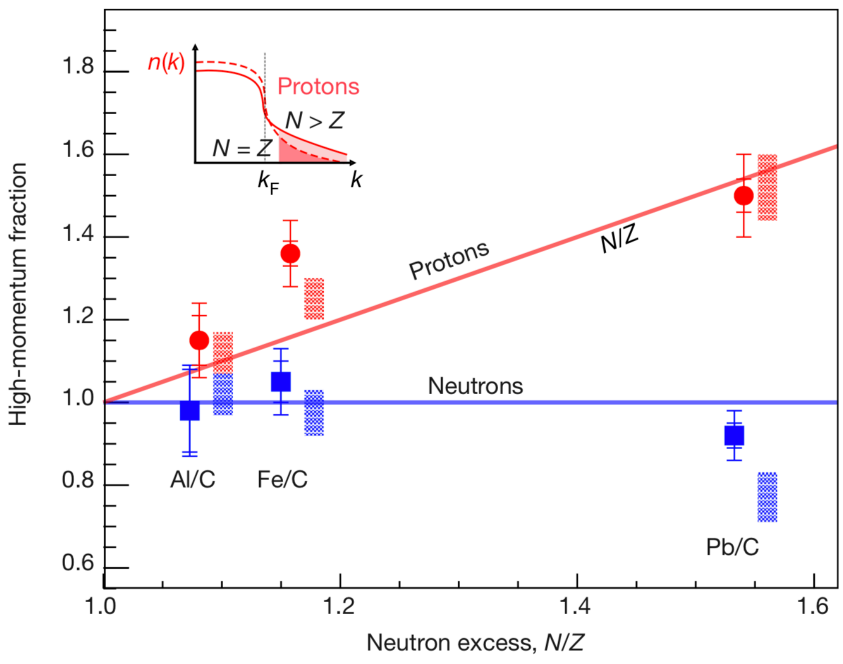
Using E2a data

Peninah Levine
Nov. 15, 2018

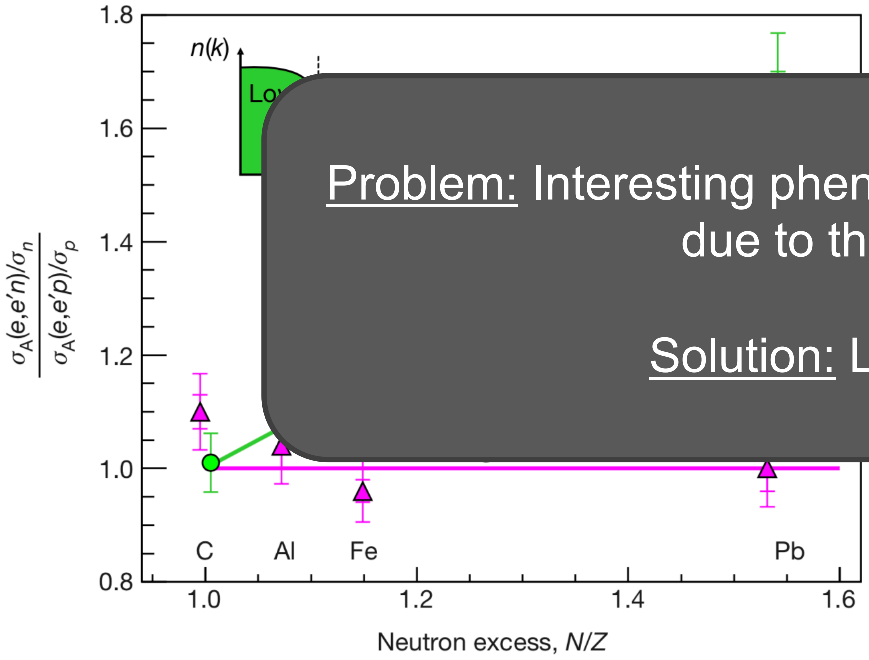
CLAS NPWG Meeting

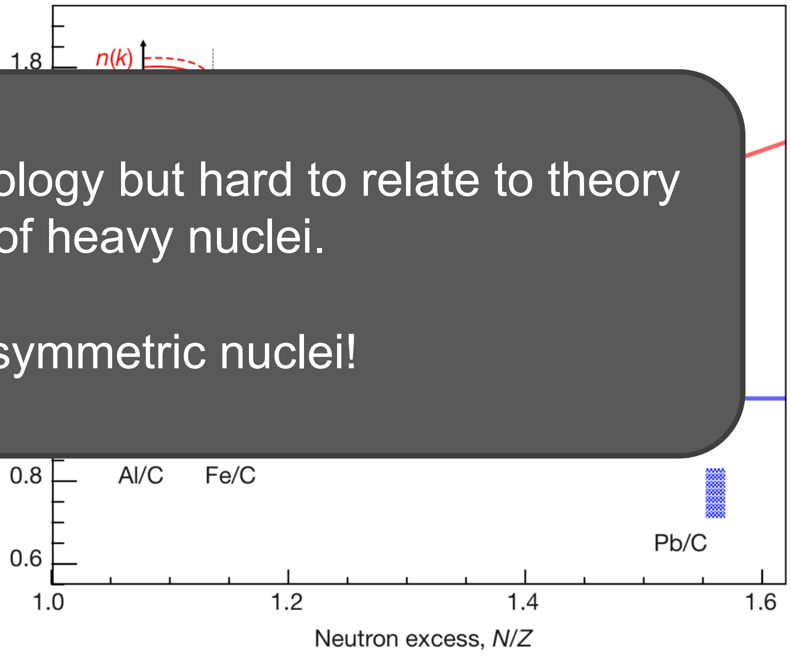
SRC in n. Rich systems





SRC in n. Rich systems

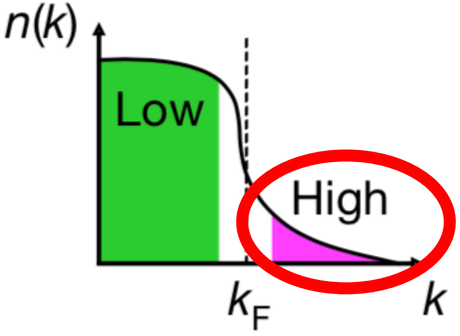




Problem: Interesting phenomenology but hard to relate to theory due to the use of heavy nuclei.

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)
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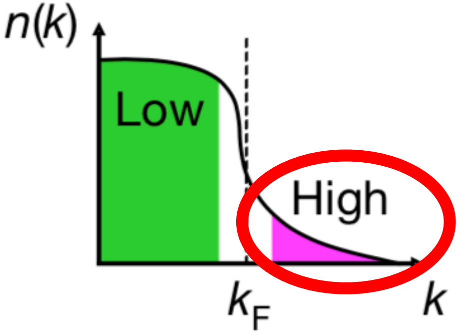

Relevant observables in 'SRC' kinematics

<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’:

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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)

^{4}He (e,e’p) / (e,e’n)

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)~~

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

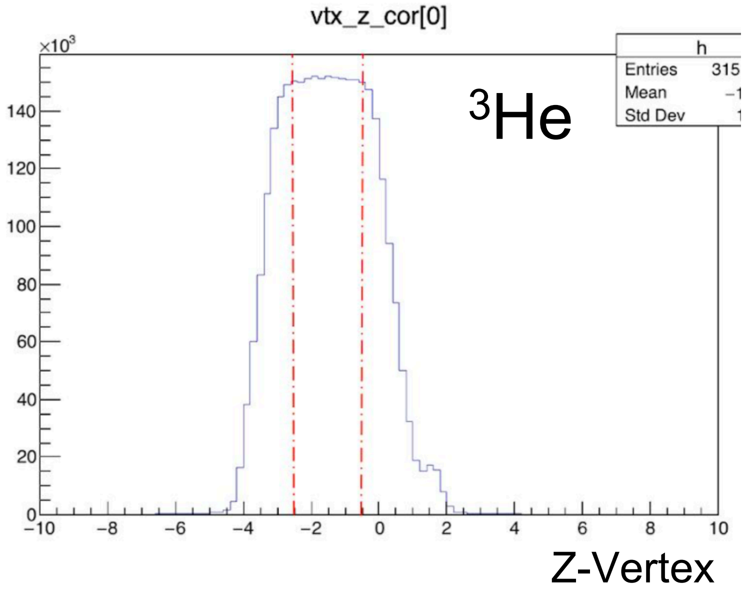
^{3}He / ^{4}He (e,e'p)

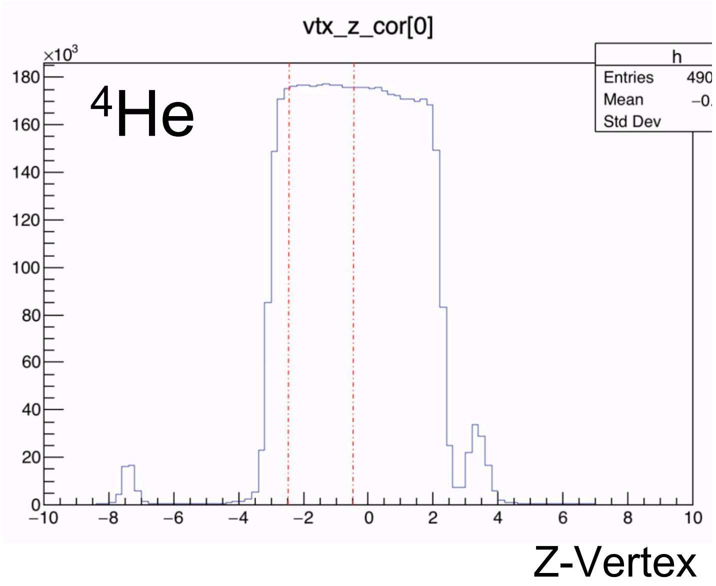
(e,e’p): Event Selection

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.

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





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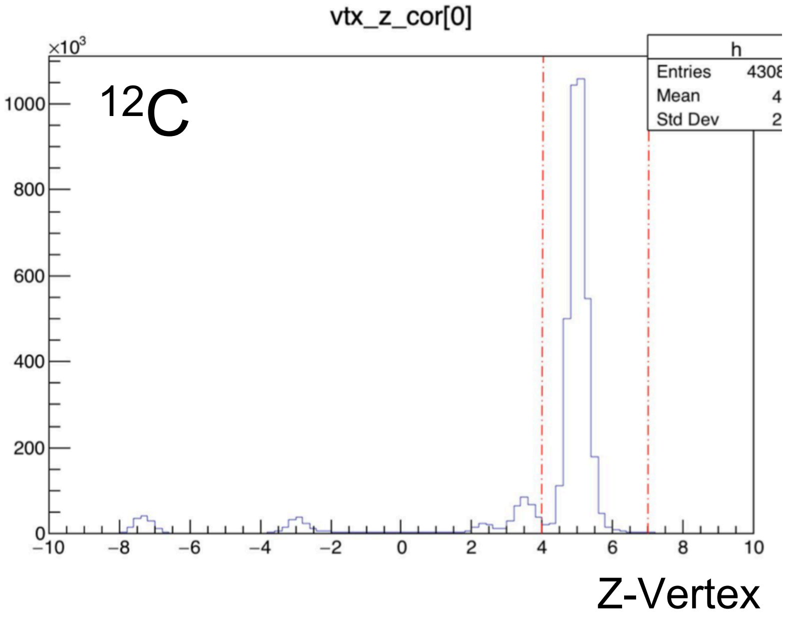

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'Standard SRC selection cuts'.
[Hen PLB, Hen Science, Cohen PRL, Duer Nature …]

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) cross-section ratio

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

A / ^{4}He (e,e'p) cross-section ratio

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

- Number of measured events

A / ^{4}He (e,e'p) cross-section ratio

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

- Number of measured events
- 1 / Simulated_Efficiency

  Only for 12C/4He; From map; Applied even-by-event

+ remove events where either ^{4}He or A map efficiency < 80%.

A / ^{4}He (e,e'p) cross-section ratio

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

- Number of measured events
- 1 / Simulated_Efficiency
  Only for 12C/4He; From map; Applied even-by-event
- Integrated luminosity

A / ^{4}He (e,e'p) cross-section ratio

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- Number of measured events
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- Number of protons in the nucleus

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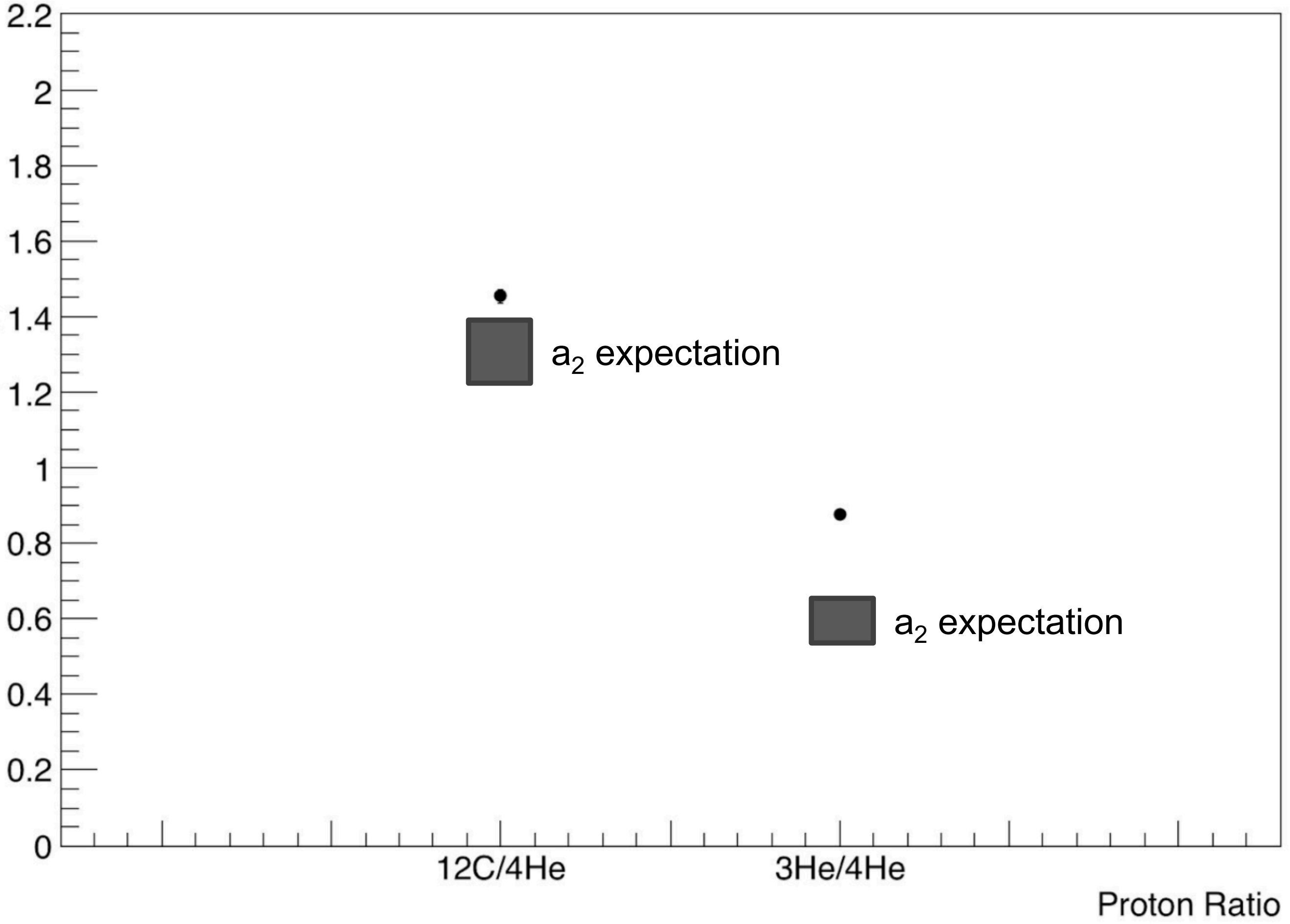
$$\frac{A(e,e'p)\cdot w / L / Z / T}{4He(e,e'p)\cdot w_{4He} / L_{4He} / Z_{He} / T_{He}}$$

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

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

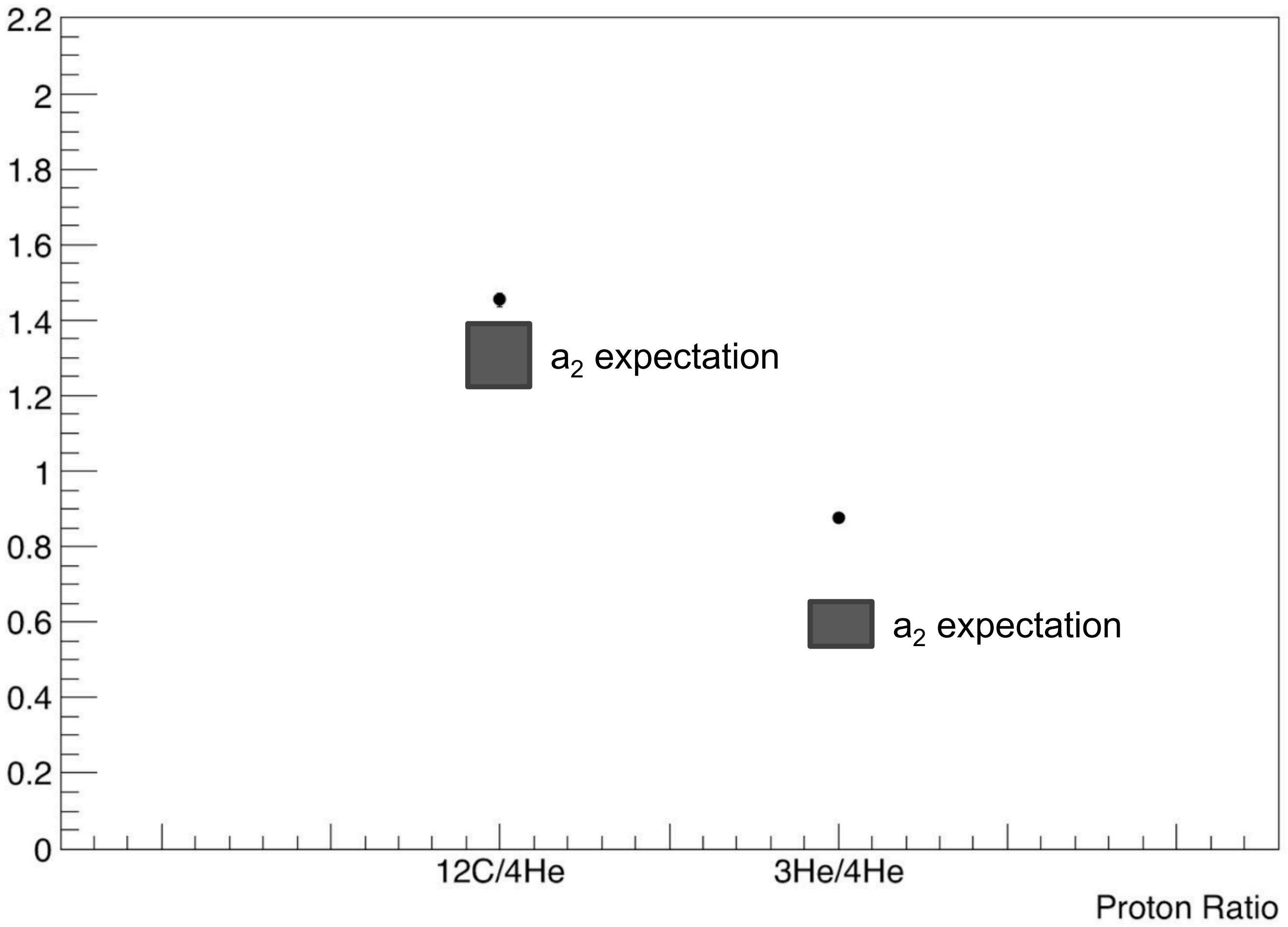


2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
a_2 expectation
a_2 expectation
12C/4He
3He/4He
Proton Ratio

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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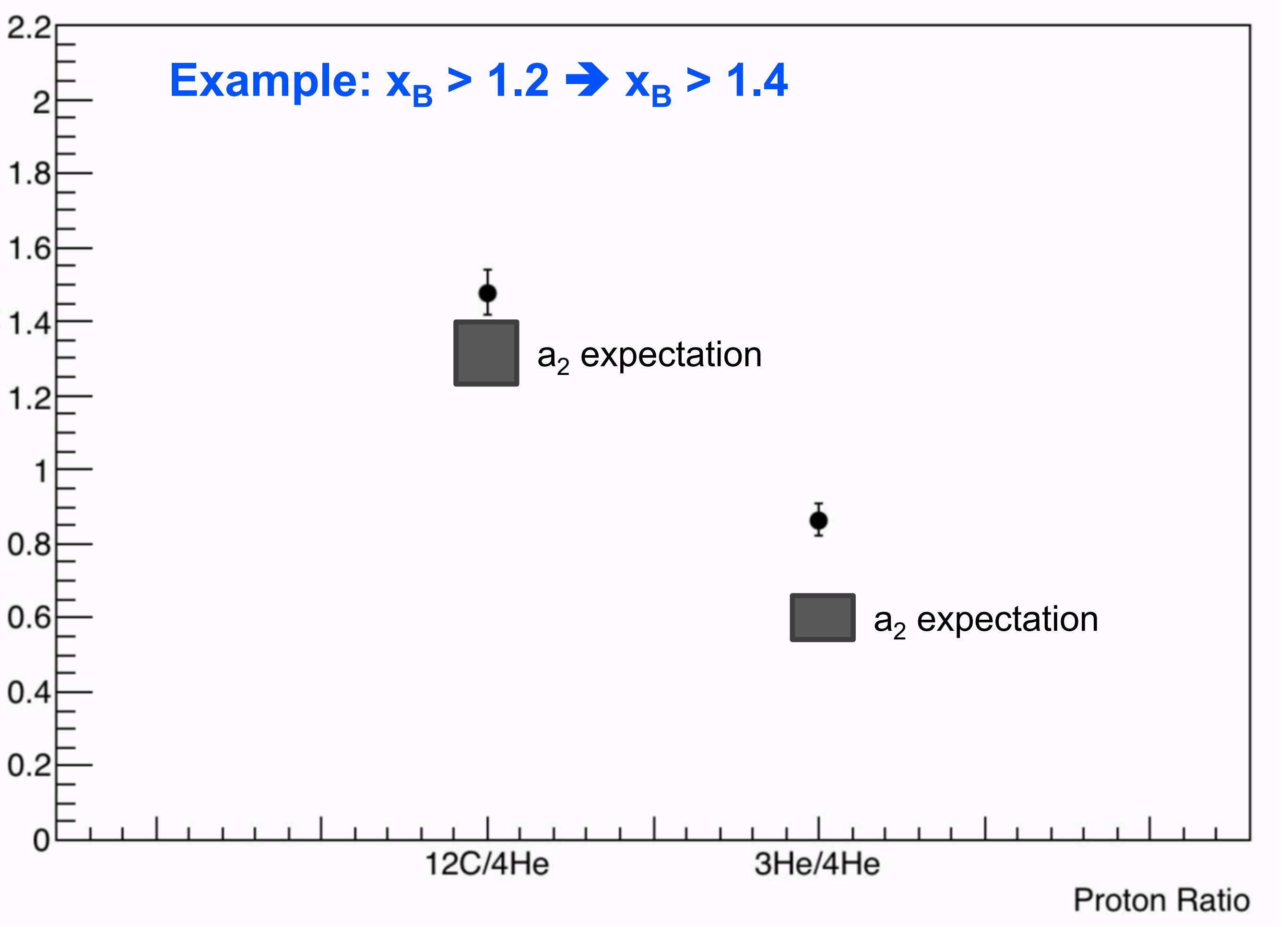
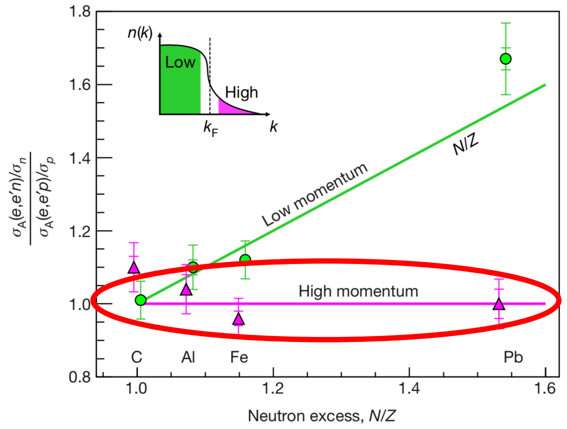
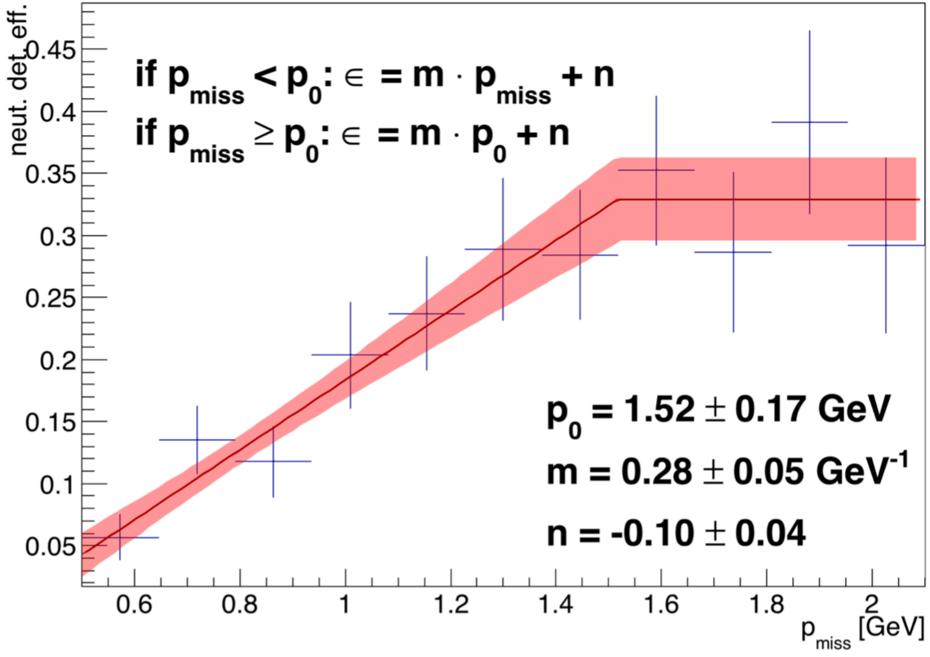


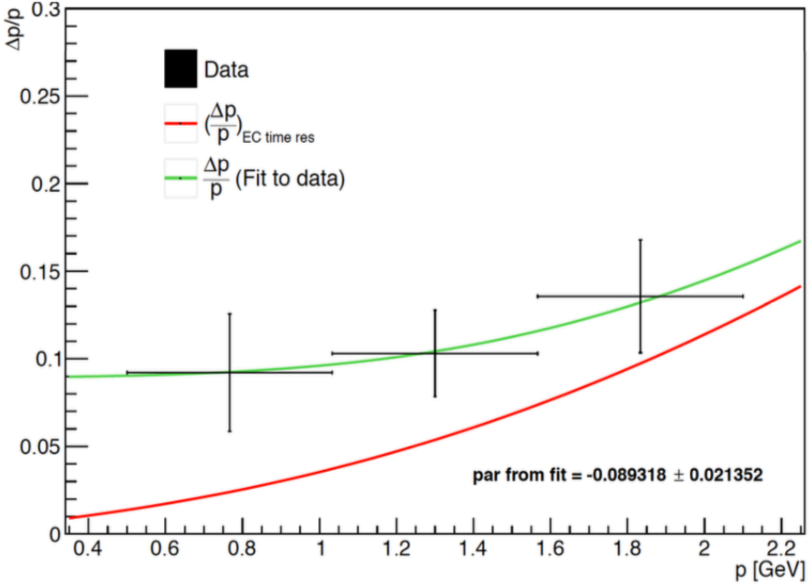
Relevant observables:

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



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

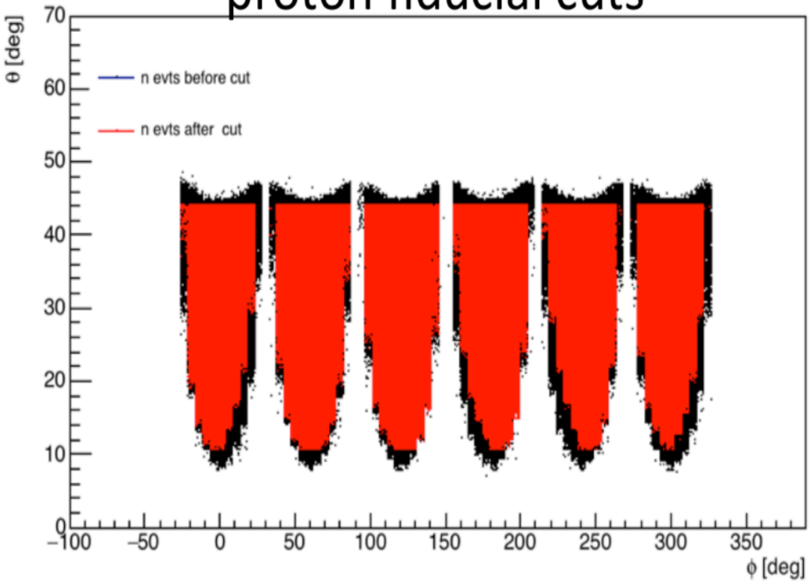




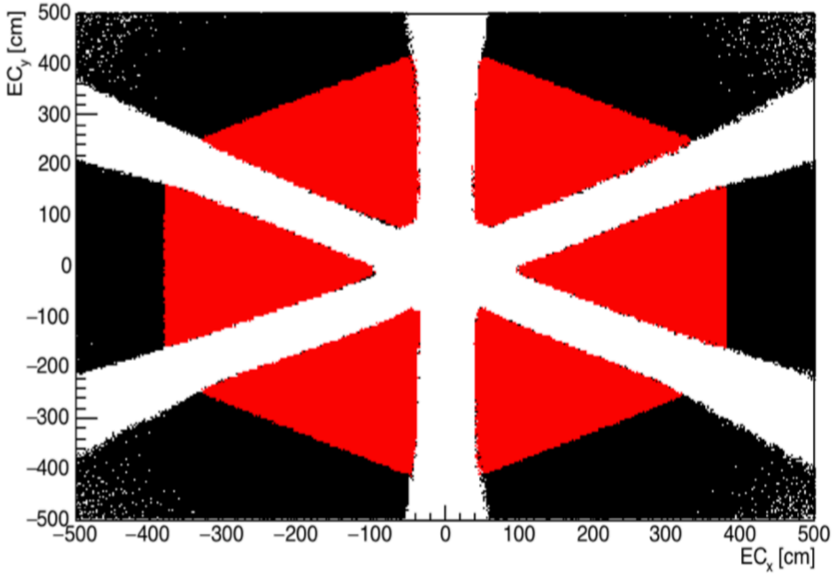
Acceptance Matching:

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

Neutrons **before** and after proton fiducial cuts



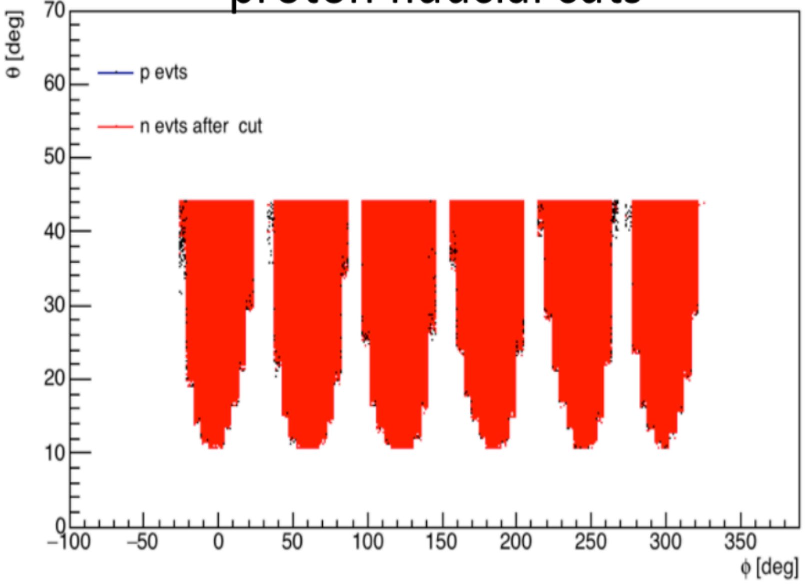
Protons **before** and after 10cm EC cut



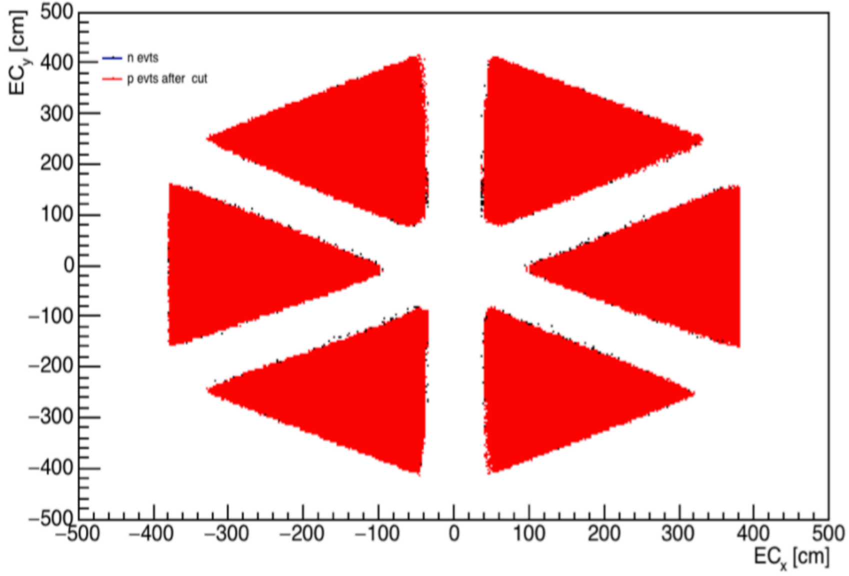
Acceptance Matching:

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

Neutrons and protons after proton fiducial cuts



Protons and neutrons after 10cm EC cut



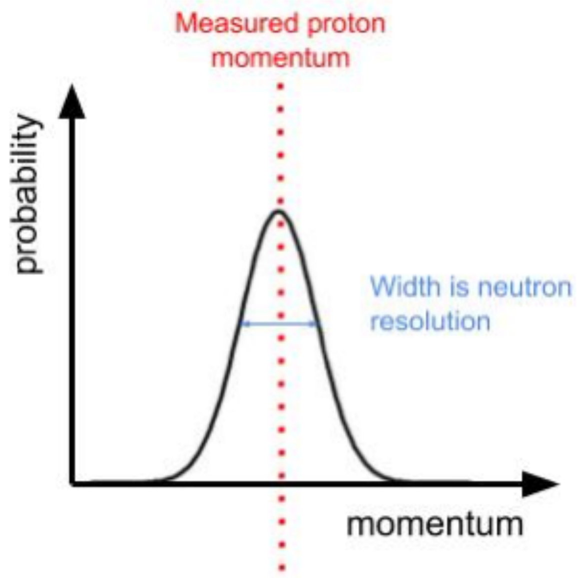
Smearing protons to simulate neutron resolution

Why

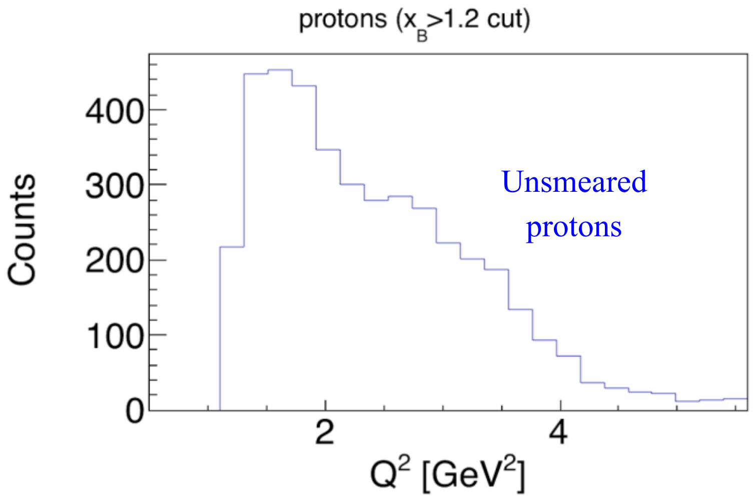
Poor neutron momentum resolut

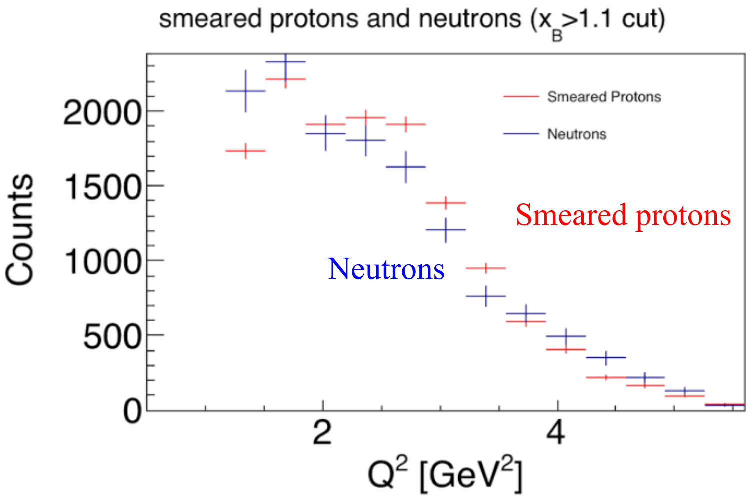
How

Smear protons by neutron mome
resolution



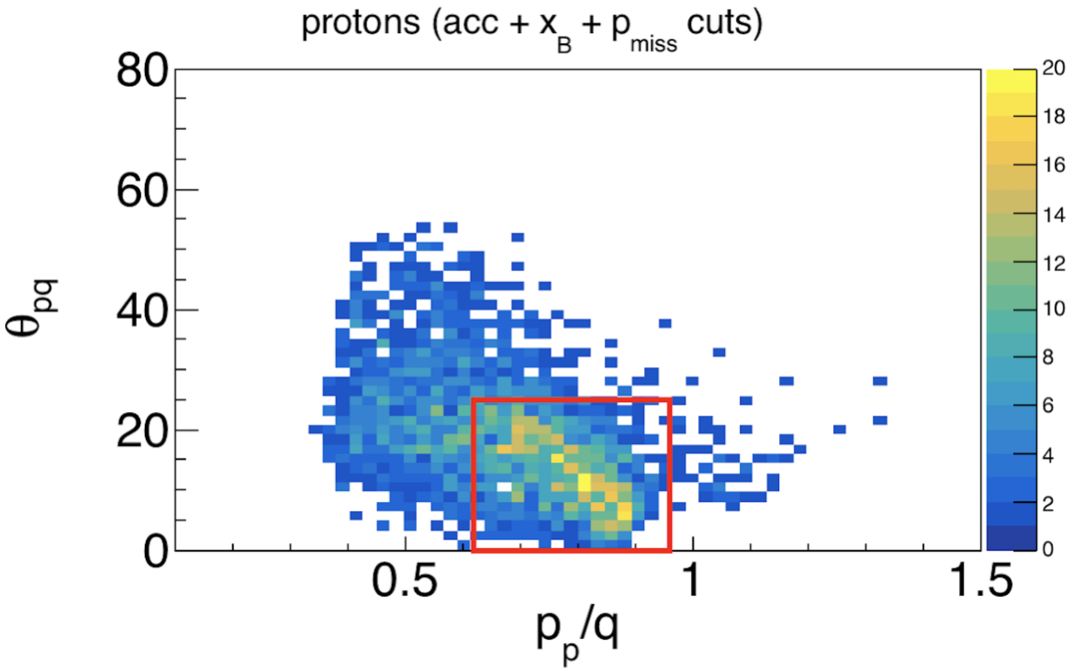
x_B cut on neutrons and smeared protons





$x_B > 1.1$

Leading nucleon cuts: θ_{pq} and p/q



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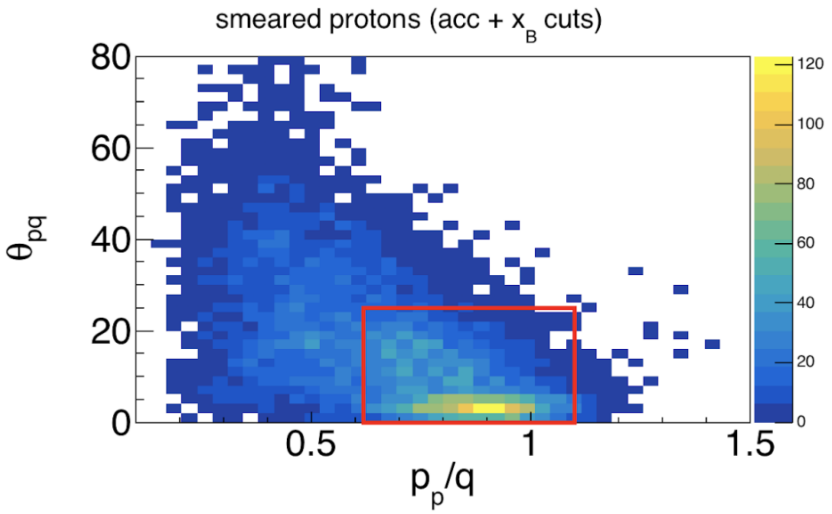
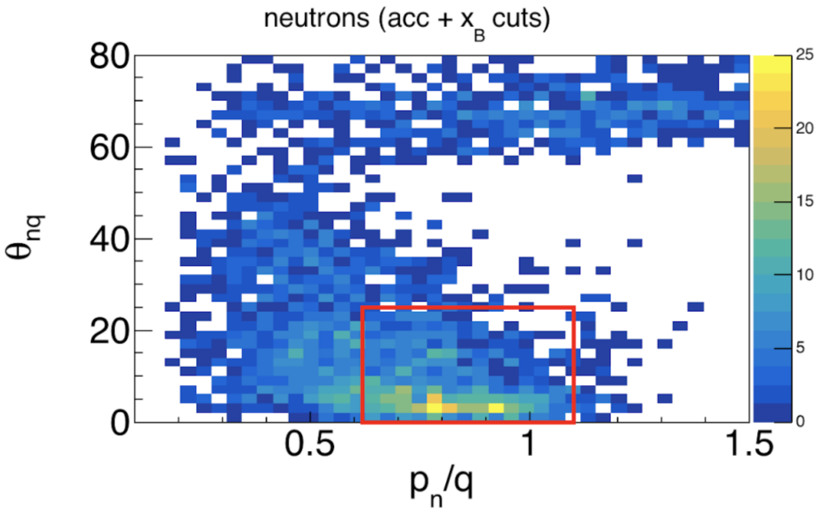




$\theta_{nq} < 25^o$

$0.62 < P_N/q < 1.1$

Summary of smeared proton and neutron cuts

$$x_B > 1.1$$

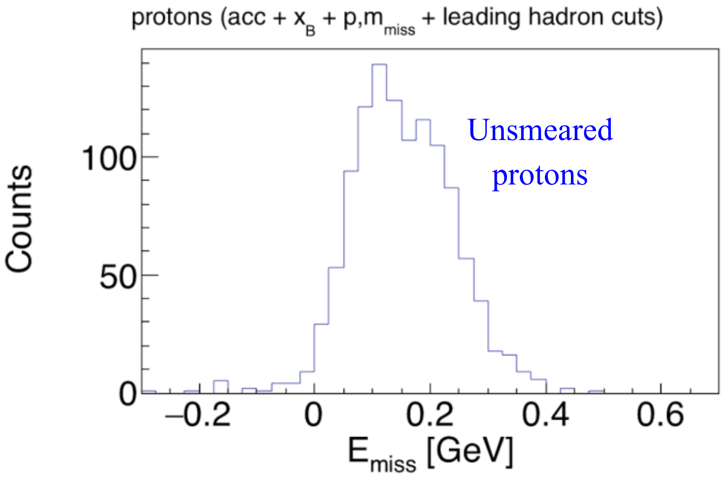
$$0^o < \theta_{pq} < 25^o$$

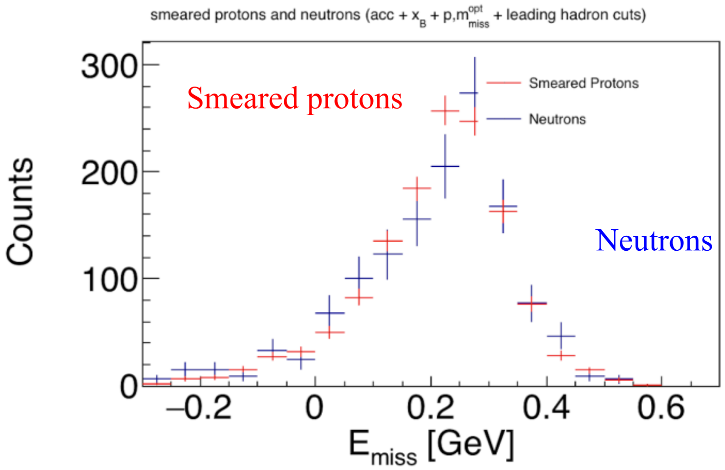
$$0.62 < \theta_{pq} < 1.10$$

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

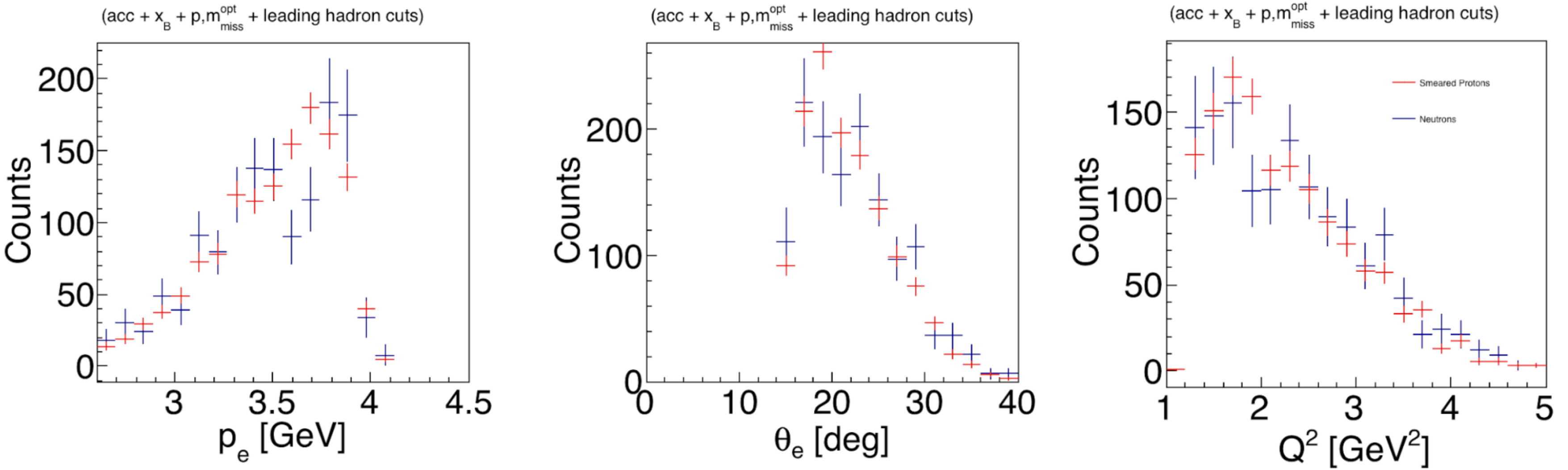
$$M_{miss} < 1.175 \ \text{GeV/c}^2$$

Checking selected cuts using E_{miss} distributions





Checking selected cuts using e⁻ kinematic variables



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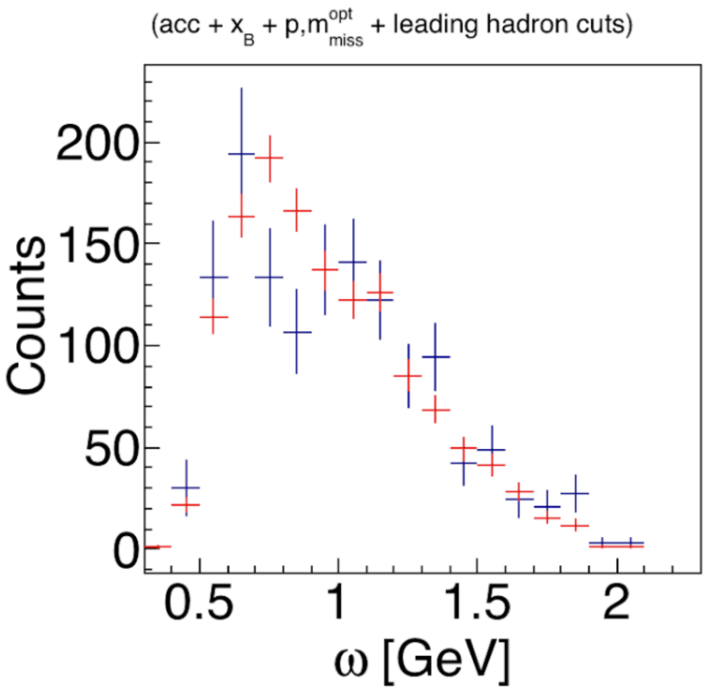
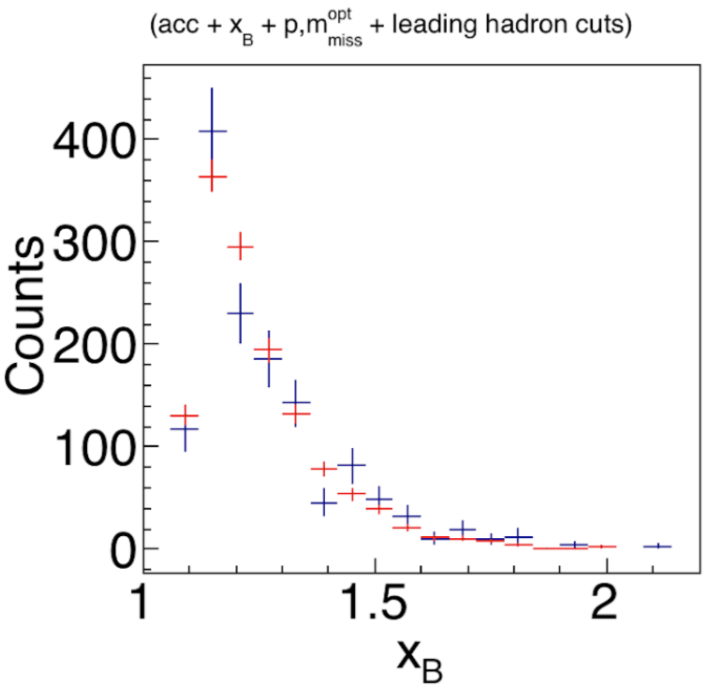
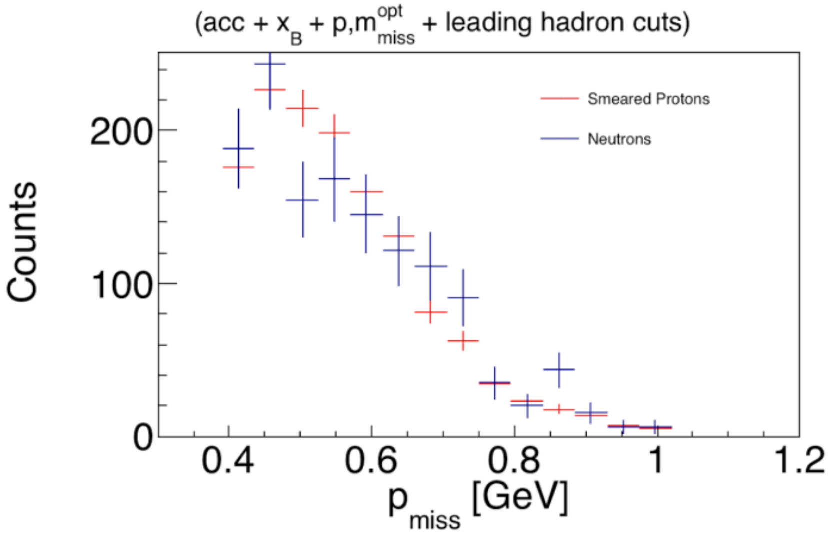
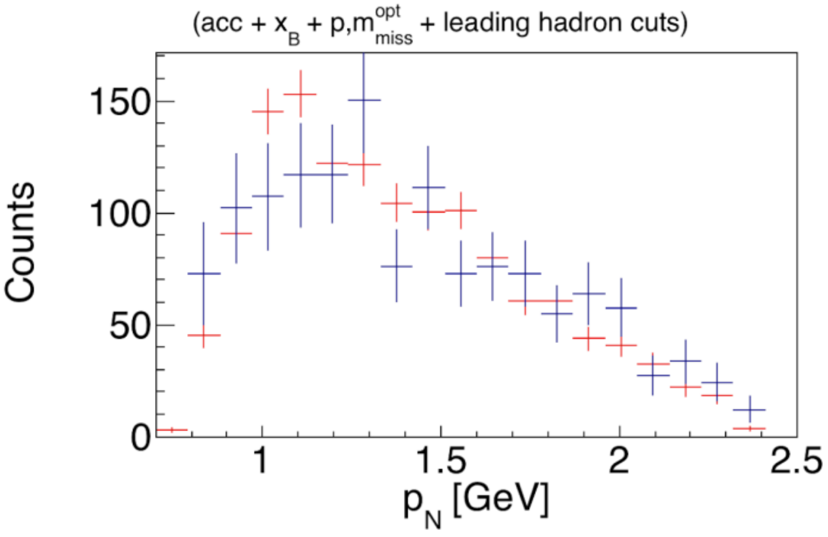




Checking selected cuts using p and n kinematic variables





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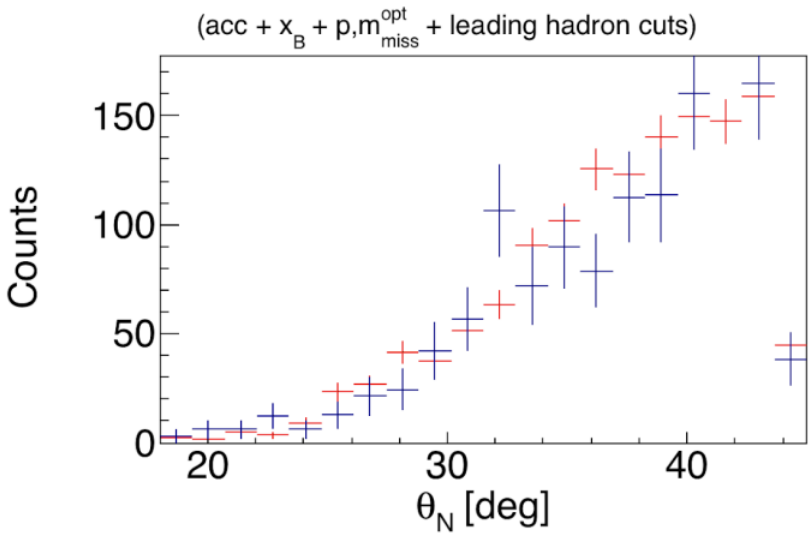
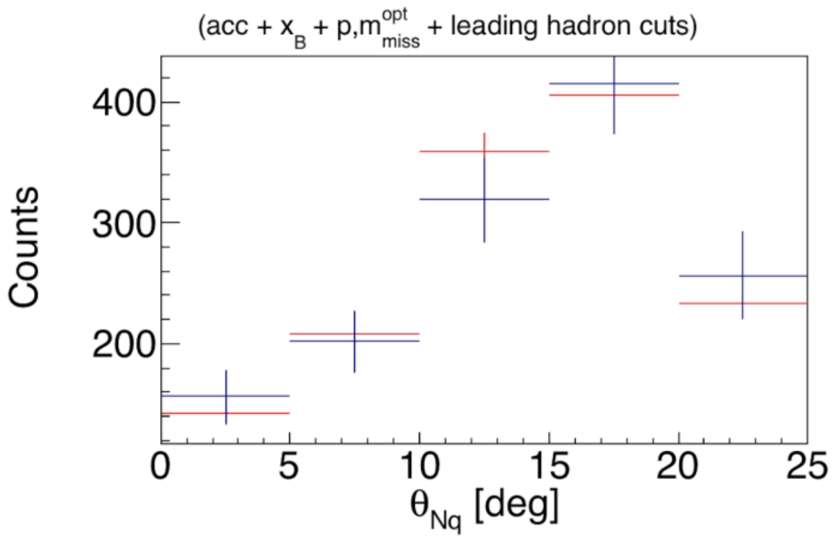




Raw counts of (e,e’p) and (e,e’n) events

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. **Will use maps.**

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.)

Back Up Slides

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

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

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

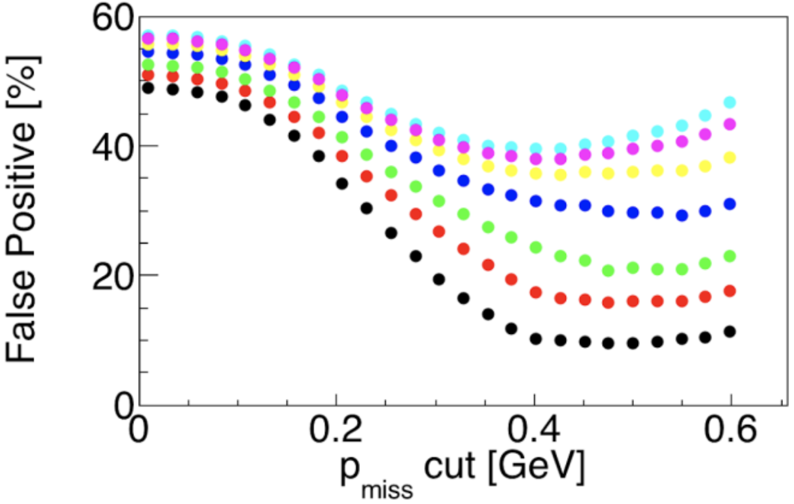
False Positives

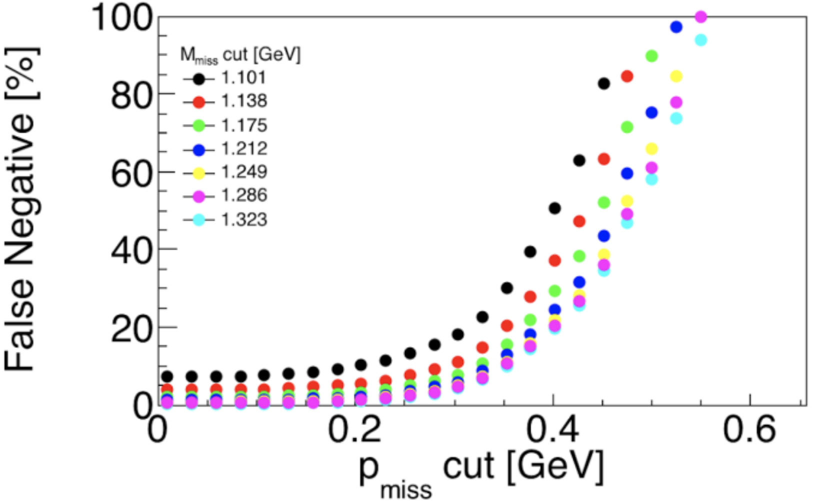
Smearing causes non-SRC events to pass the cuts.

False Negatives

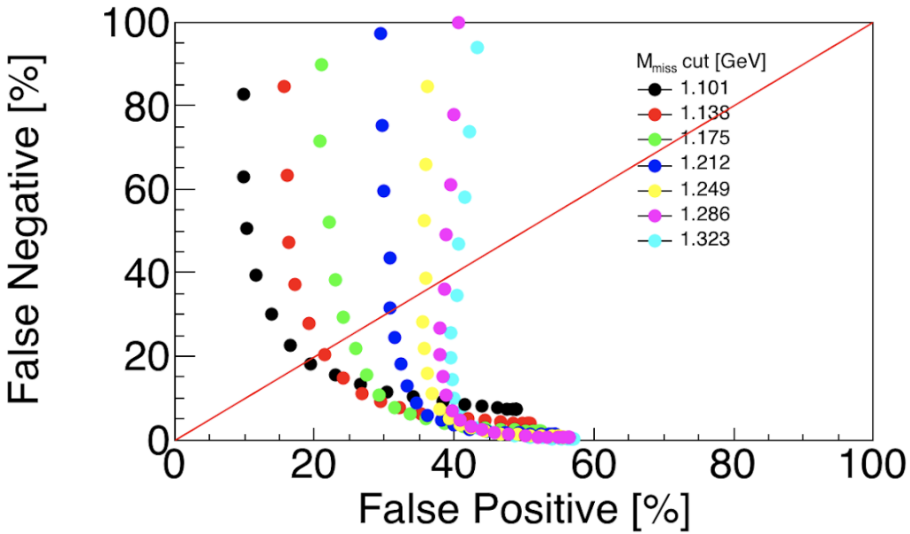
Smearing causes SRC events to fail the cuts.

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)