Measurements and Simulations of *(e,e'n)/(e,e'p)* in ^{3}He for High and Low Momentum Nucleons

Erin Marshall Seroka, Holly Szumila-Vance, Axel Schmidt

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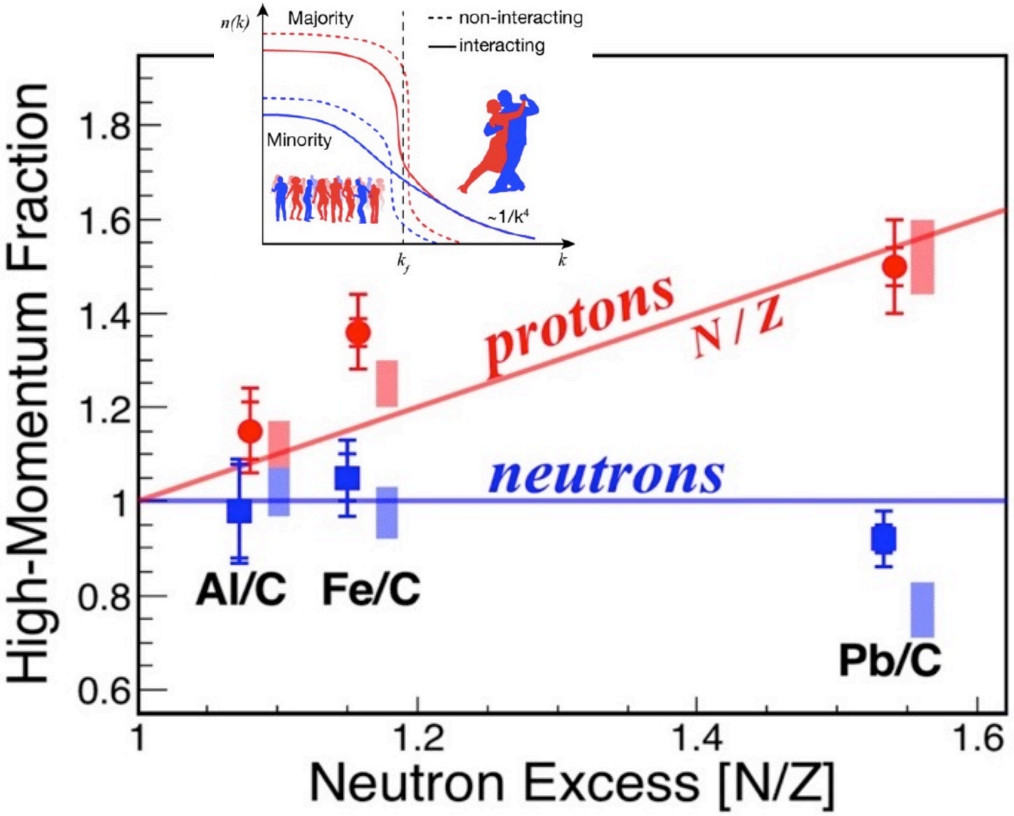
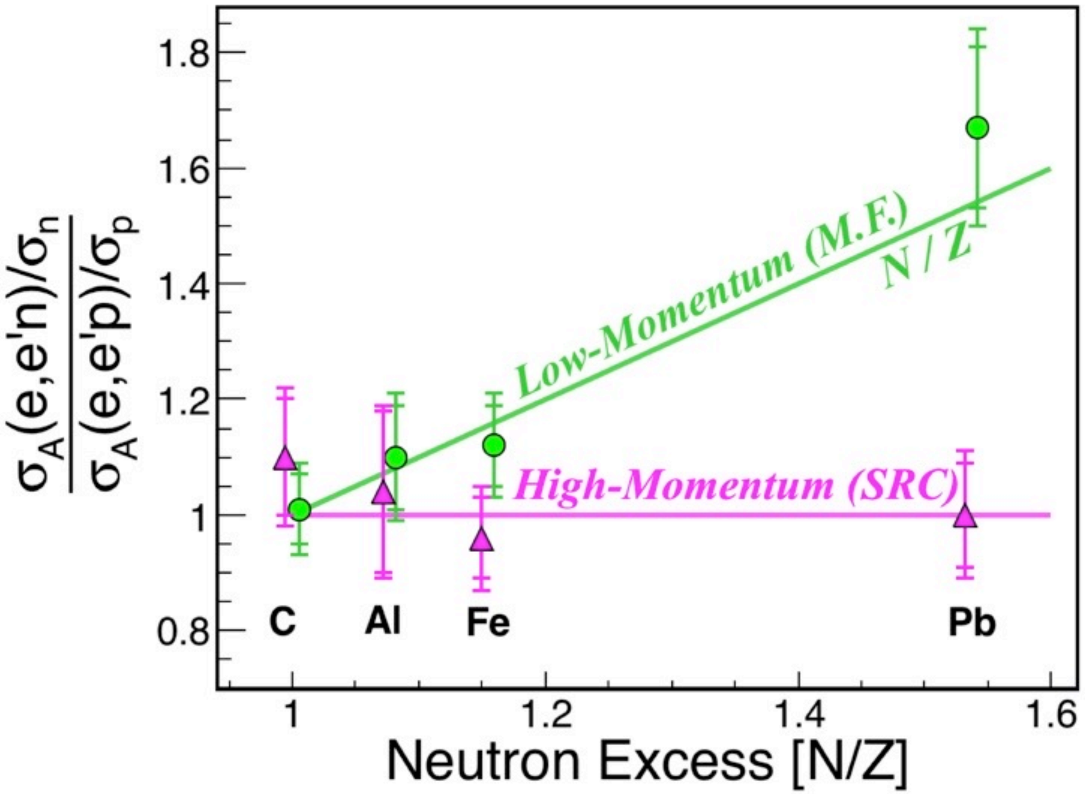
Protons "speed up" in neutron-rich nuclei

- Minority (p) moves faster than majority (n) in neutron-rich nuclei

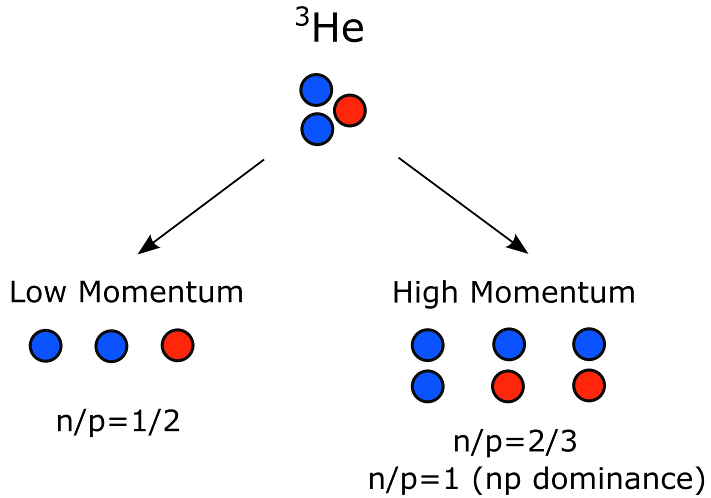


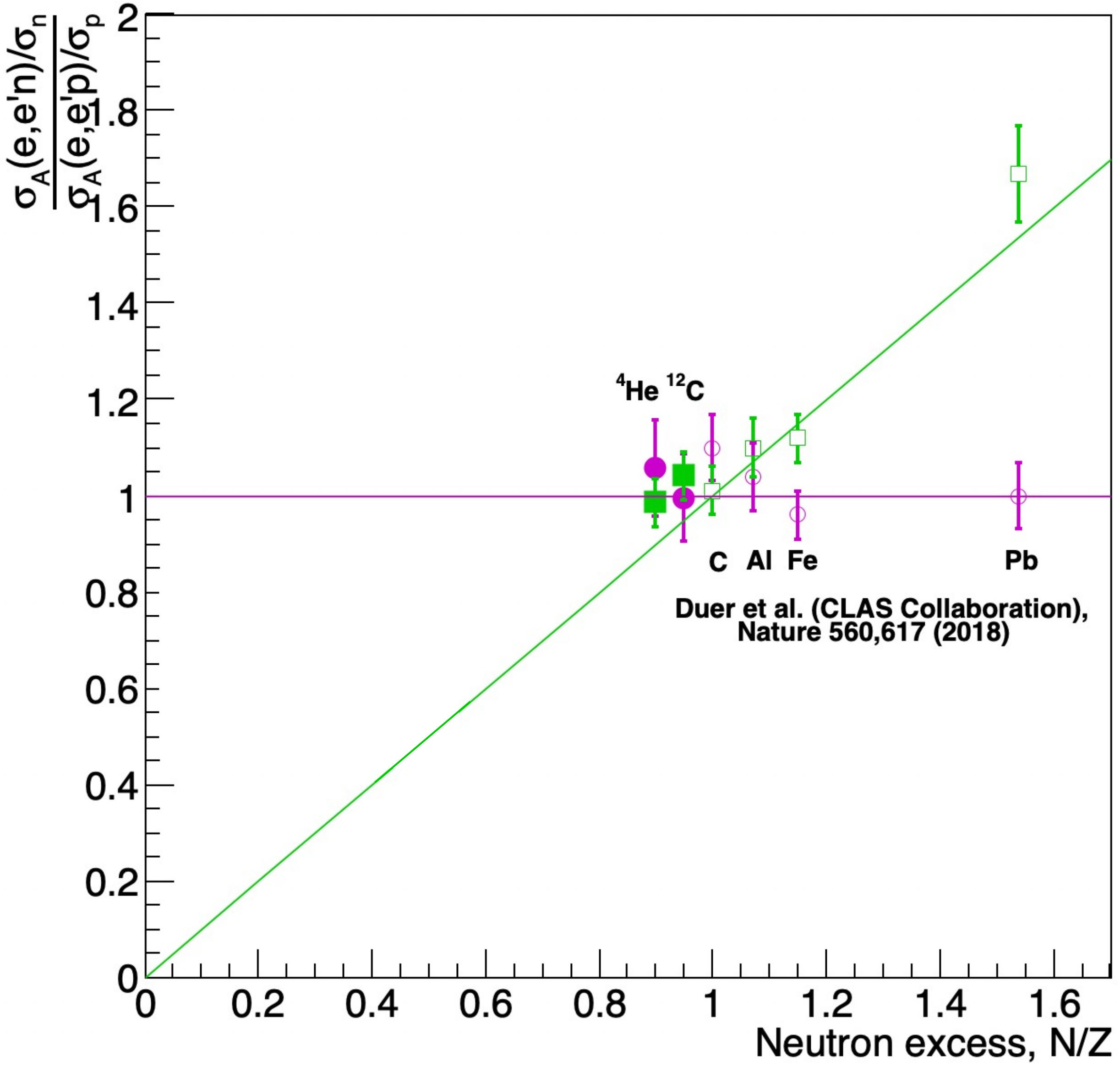


Duer et al. (CLAS Collaboration), Nature 560, 617 (2018)

Expectation

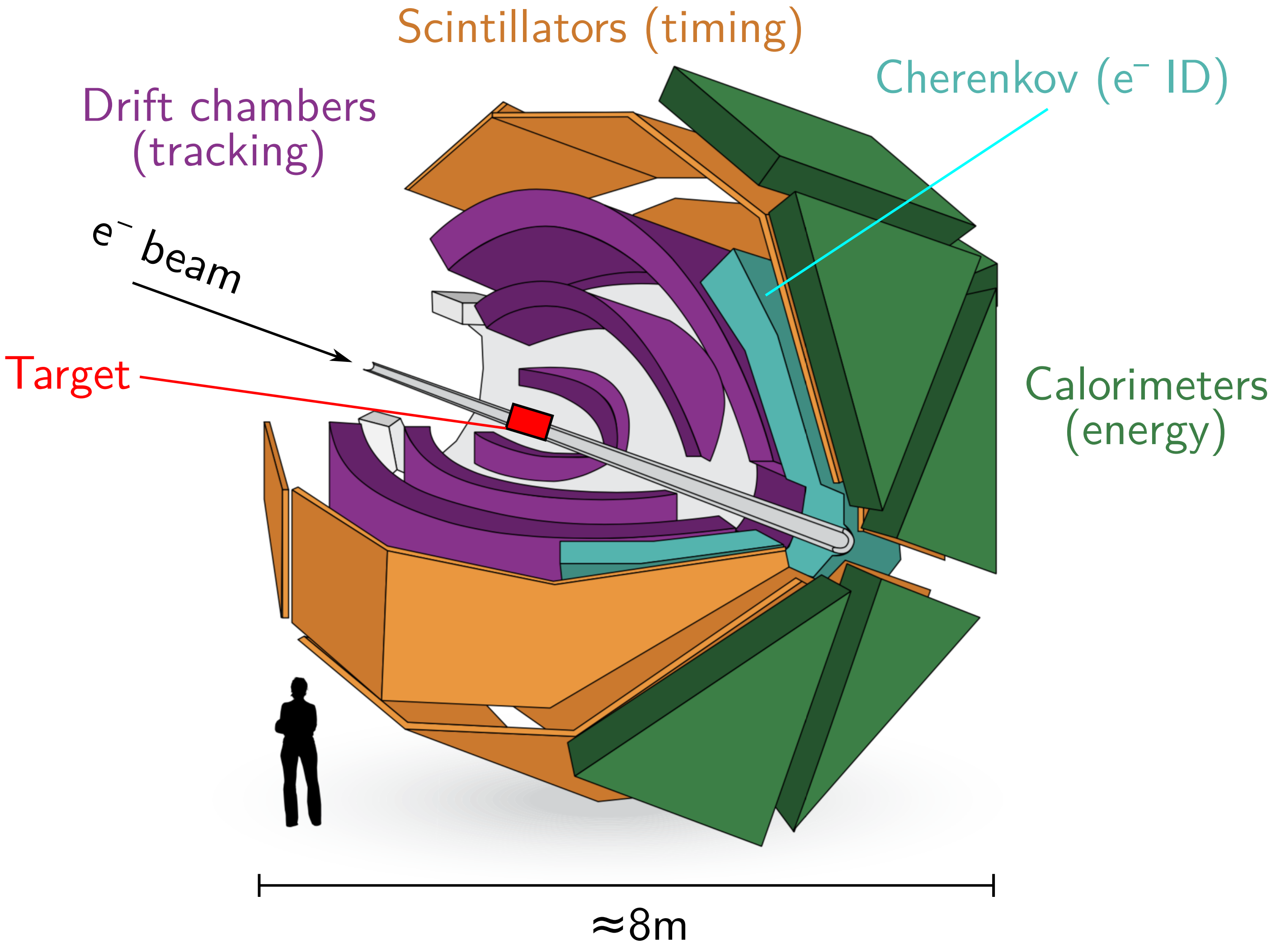
- Low momentum: 1/2
- High momentum: 1





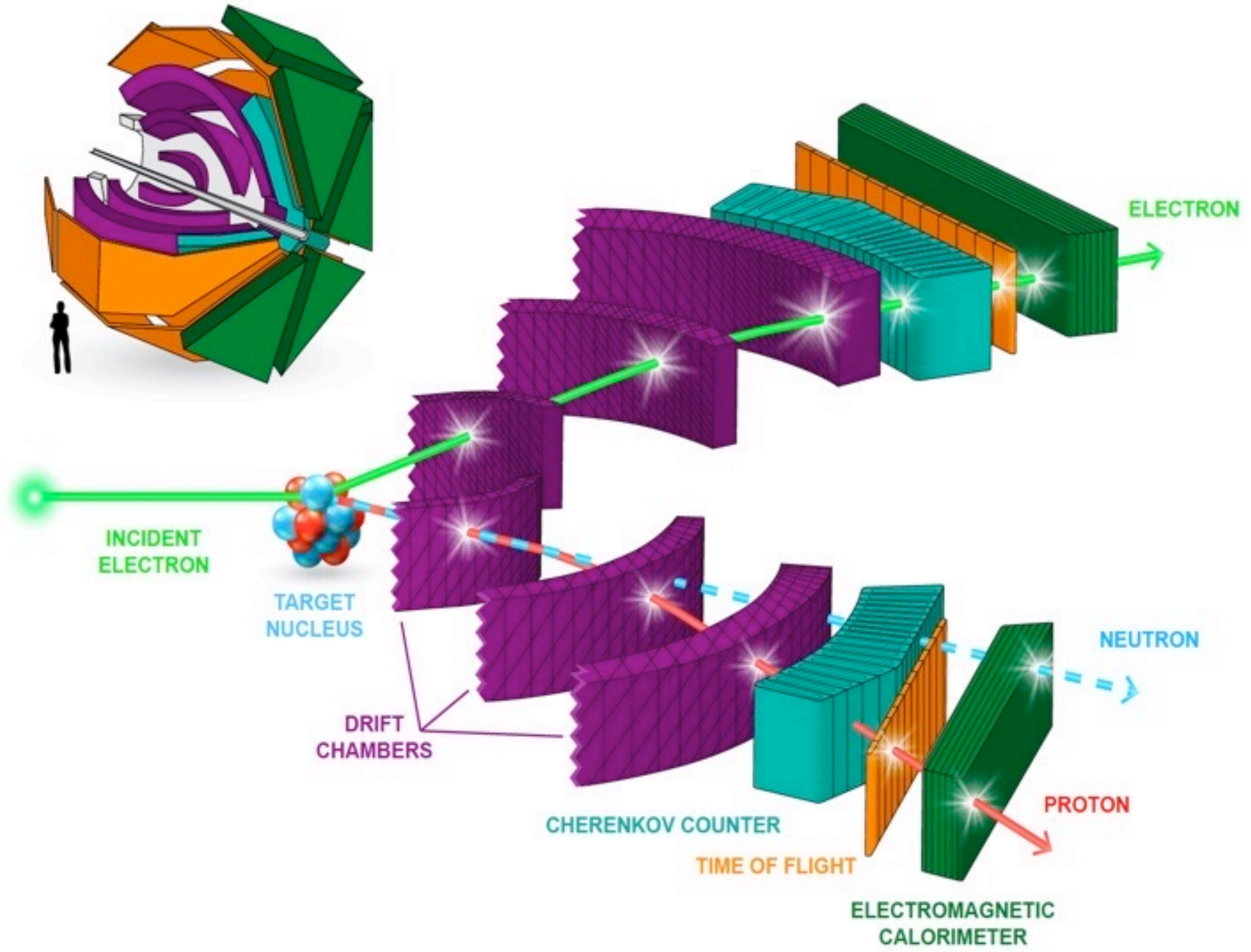
Data Mining

- CLAS6: precursor to CLAS12
- Experiment e2a (April-May 1999)
- 4.4 GeV e^- beam
- ^{3}He, ^{4}He, ^{12}C targets
- Measure $^3He(e,e'n)/^3He(e,e'p)$



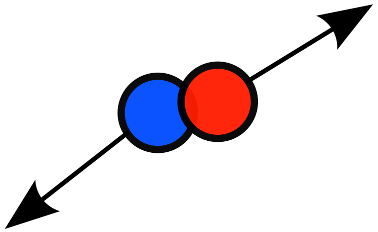
Neutron Detection in CLAS6

- Neutron knocks out proton in the EC
- Unlike proton, no DC track or TOF hit
- **Problem**: Neutrons have worse momentum resolution than protons



Source: Meytal Duer thesis (2018)

Event Selection Criteria for Protons



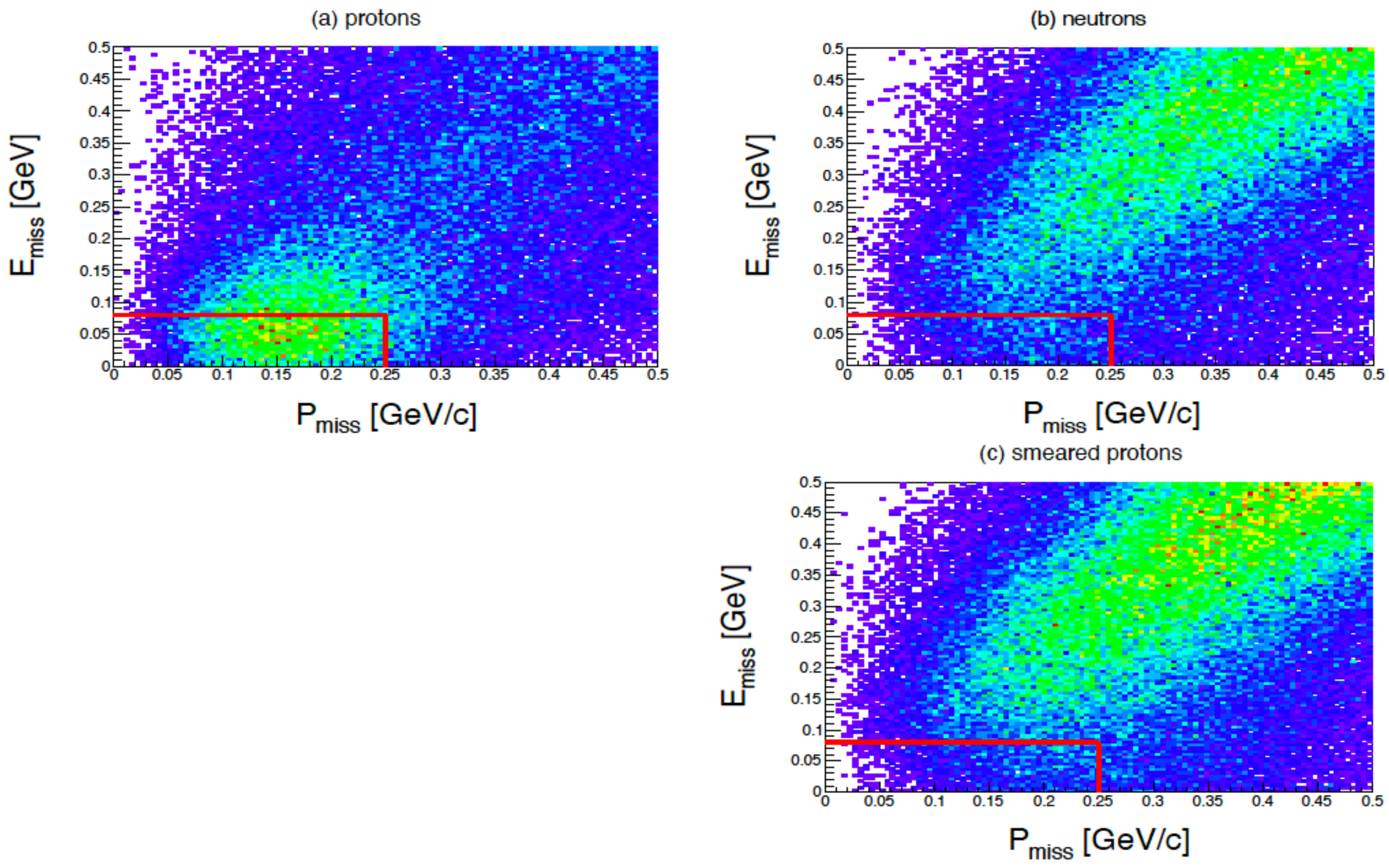
Low Momentum (MF)
$-0.05 < y < 0.2$
$0.9 < \nu < 1.6\ GeV$
$\theta_{pq} < 7\ deg$
$\boldsymbol{E_{miss} < 0.08\ GeV}$
$\boldsymbol{p_{miss} < 0.22\ GeV/c}$

High Momentum (SRC)
$x_B > 1.2$
$0.62 < \frac{\lvert p \rvert}{\lvert q \rvert} < 1.1$
$\theta_{pq} < 25\ deg$
$\boldsymbol{M_{miss} < 1.1\ GeV/c^2}$
$\boldsymbol{0.3 < p_{miss} < 1\ GeV/c}$

The p-dependent cuts developed for protons don’t work for neutrons!

Smearing the Proton Momentum

- Neutron have worse momentum resolution than protons
- Need to apply same cuts to both p and n
- **Solution**: smear proton momentum and find modified cuts!

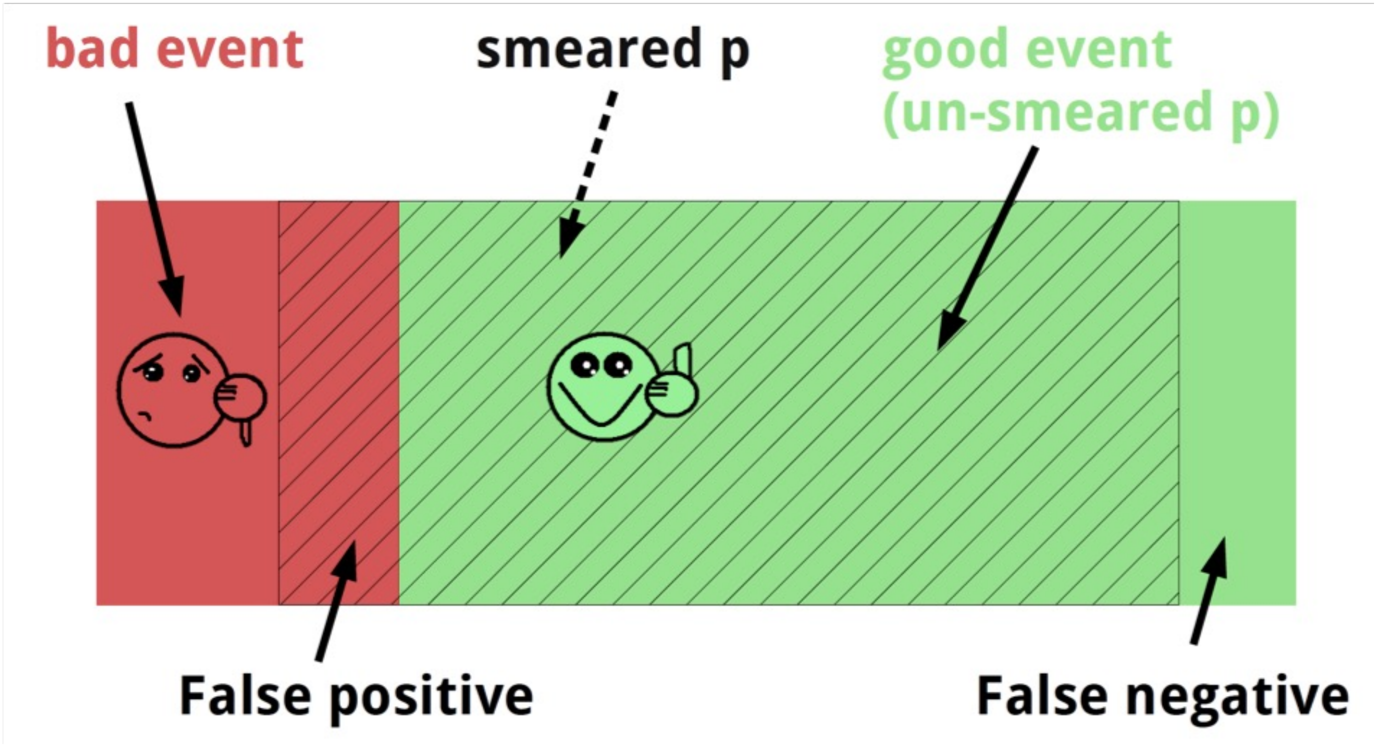


Source: Meytal Duer thesis (2018)

Finding Modified Cuts for Neutrons

Low Momentum (modified)
$E_{miss} < ?$
$p_{miss} < ?$

High Momentum (modified)
$M_{miss} < ?$
$p_{miss} > ?$



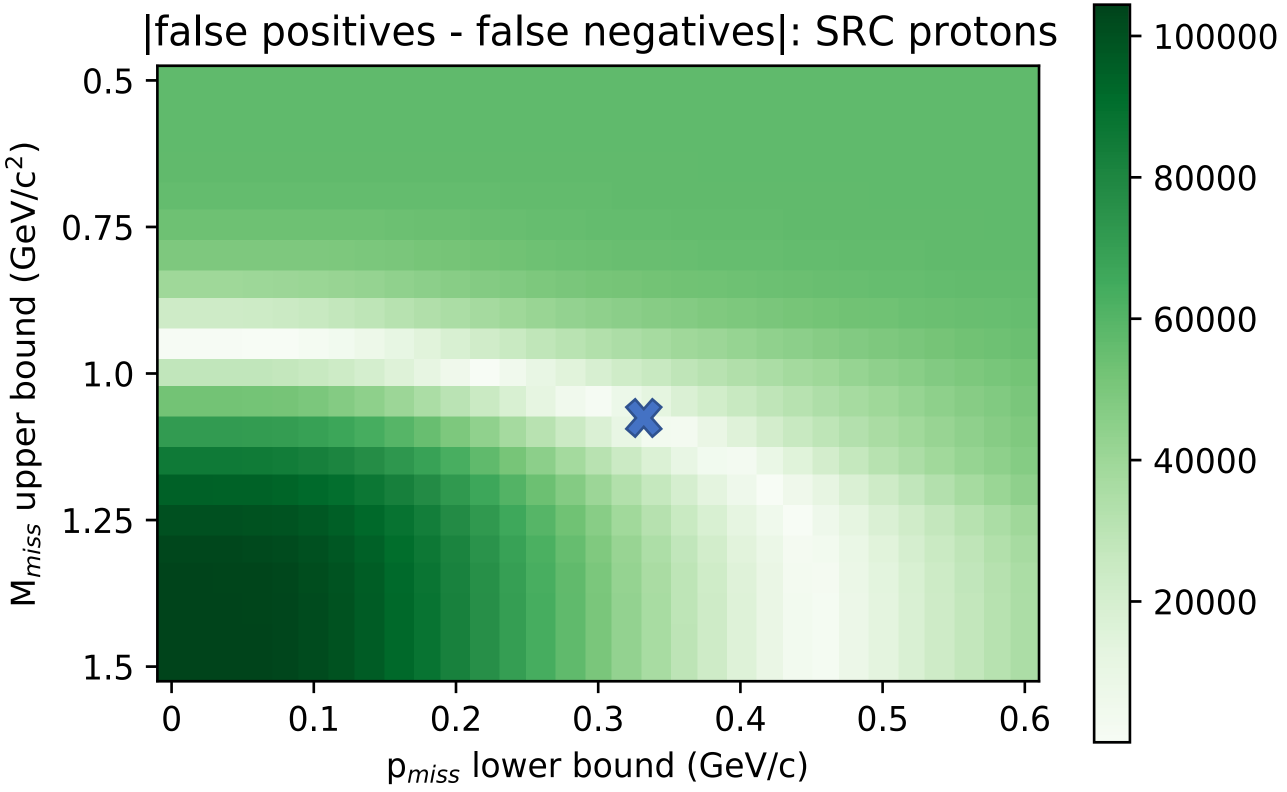
Goal: # of smeared protons passing modified cuts = # of unsmeared protons passing original cuts

Cut Optimization

- Testing potential modified cuts
- Parallel jobs on JLab iFarm

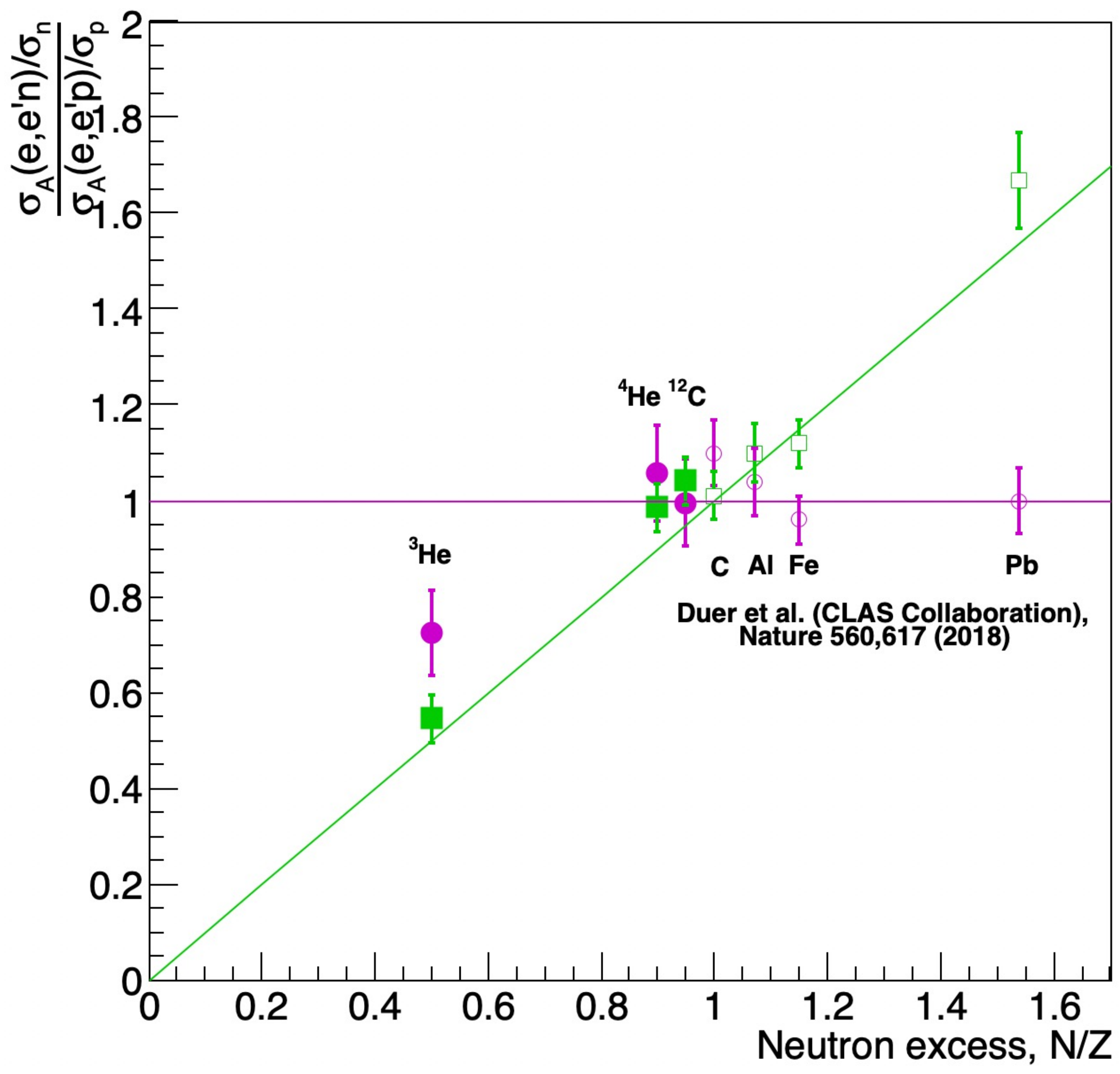
Low Momentum (modified)
$E_{miss} < 0.265\ GeV$
$p_{miss} < 0.265\ GeV/c$

High Momentum (modified)
$M_{miss} < 1.13\ GeV/c^2$
$0.32 < p_{miss} < 1\ GeV/c$



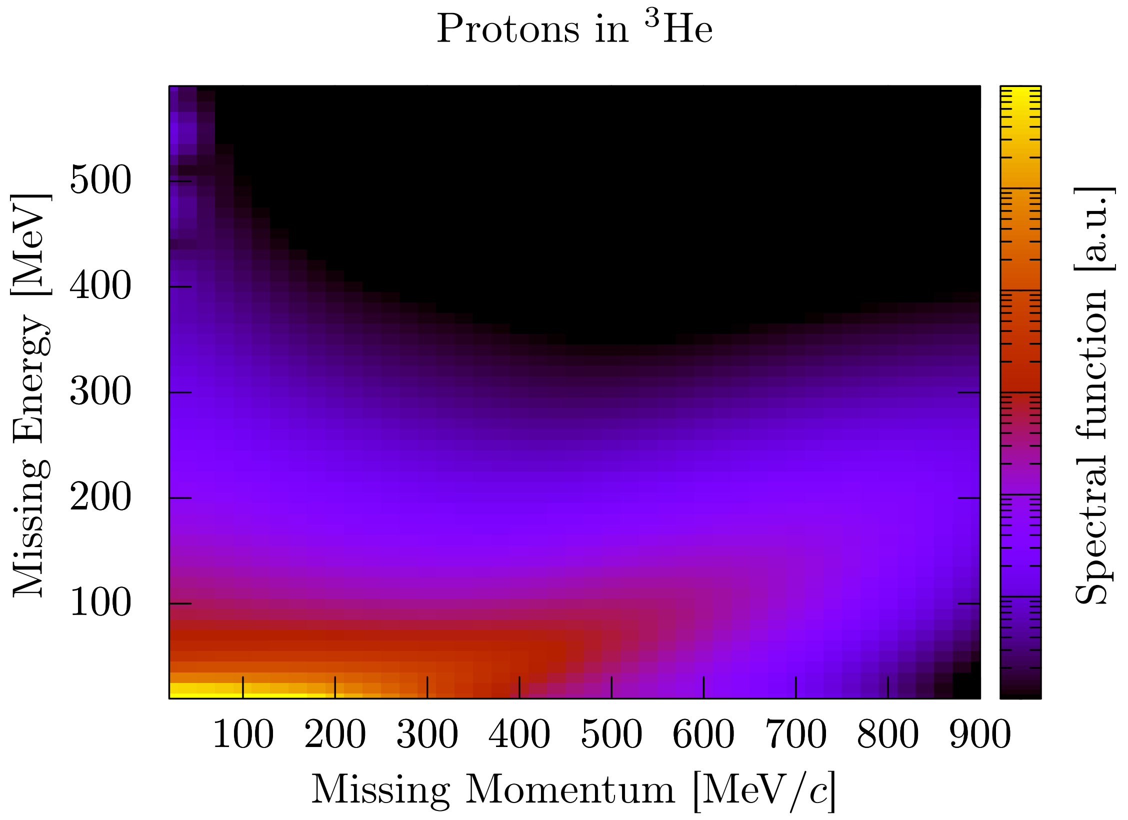
Results

- Low momentum ratio as expected
- Neutrons speed up in proton-rich nuclei
- *np* dominance less pronounced than in larger nuclei



Fast Monte Carlo Simulations

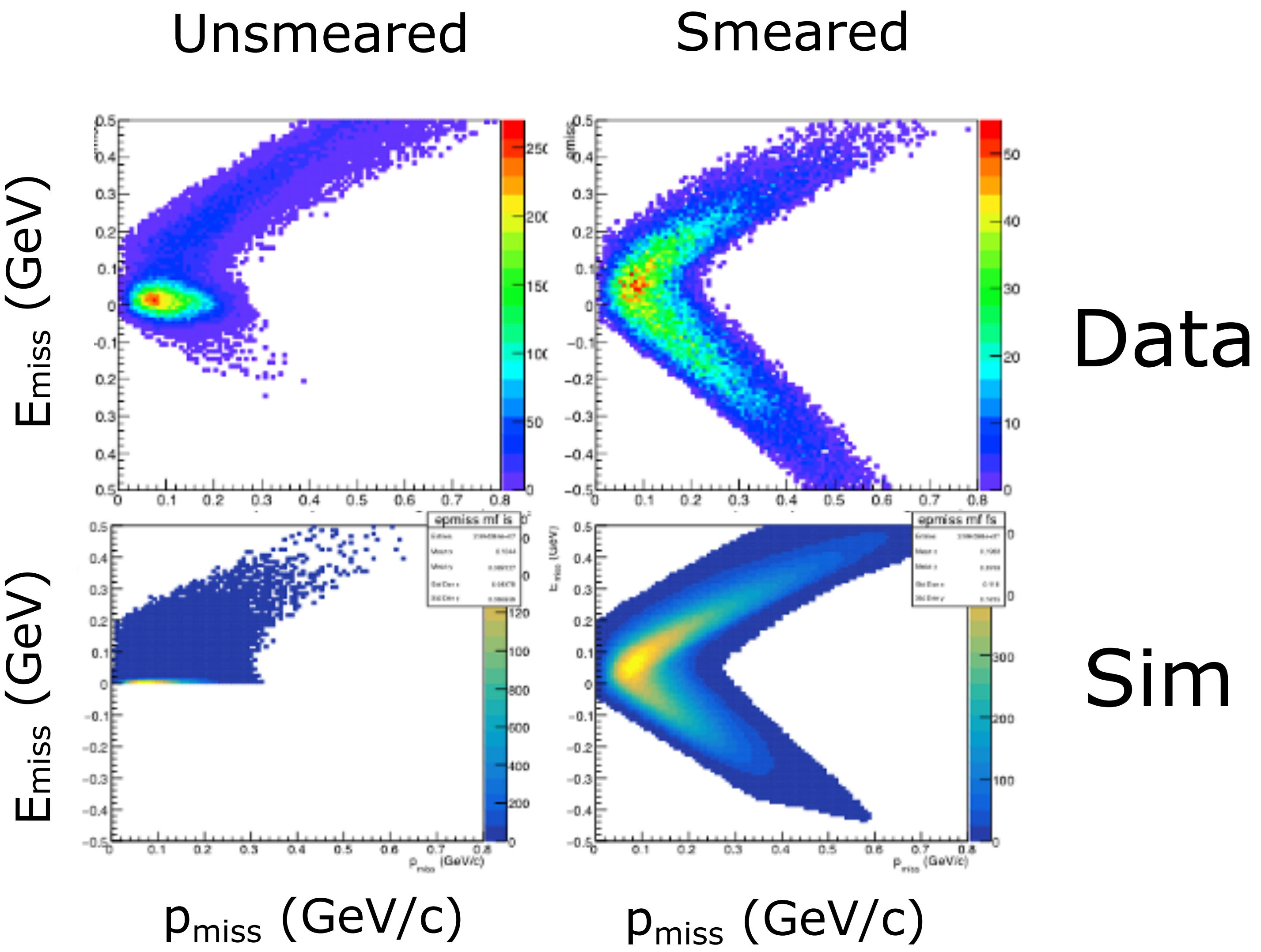
- Used 3-body spectral functions based on Fadeev equations from Ciofi degli Atti and Kaptari
- Unweighted quasielastic generator under PWIA
- Modified cuts from data also work for simulation



$$\frac{d^6\sigma}{d\Omega_e dE_e d\Omega_N dE_N} = |\vec{p}_N| E_N \sigma_{eN} S_N(E_m, \vec{p}_m)$$

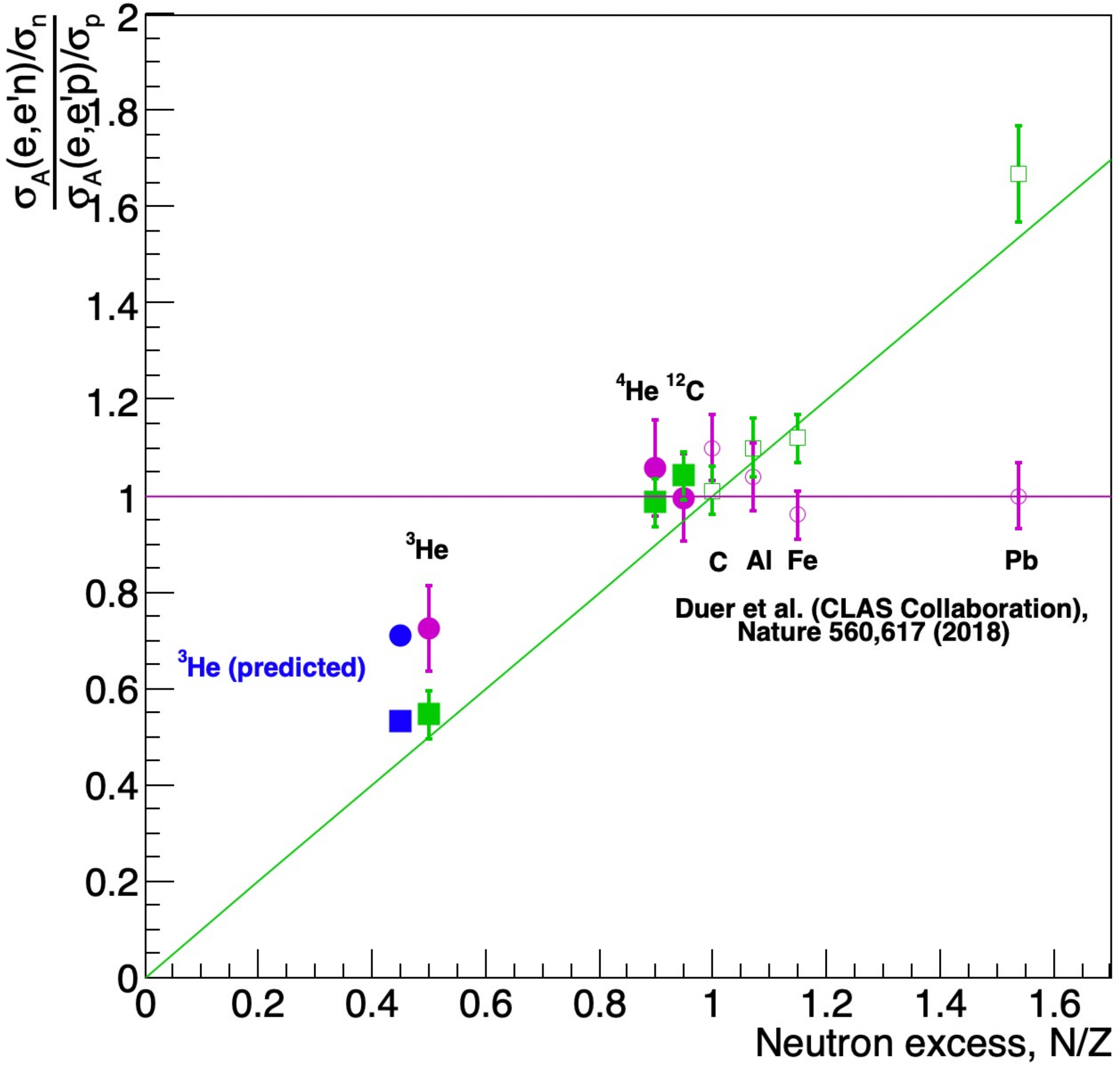
Ciofi delgi Atti and Kaptari, Phys. Rev. C 71:024005, 2005.

Data and Simulation in Agreement



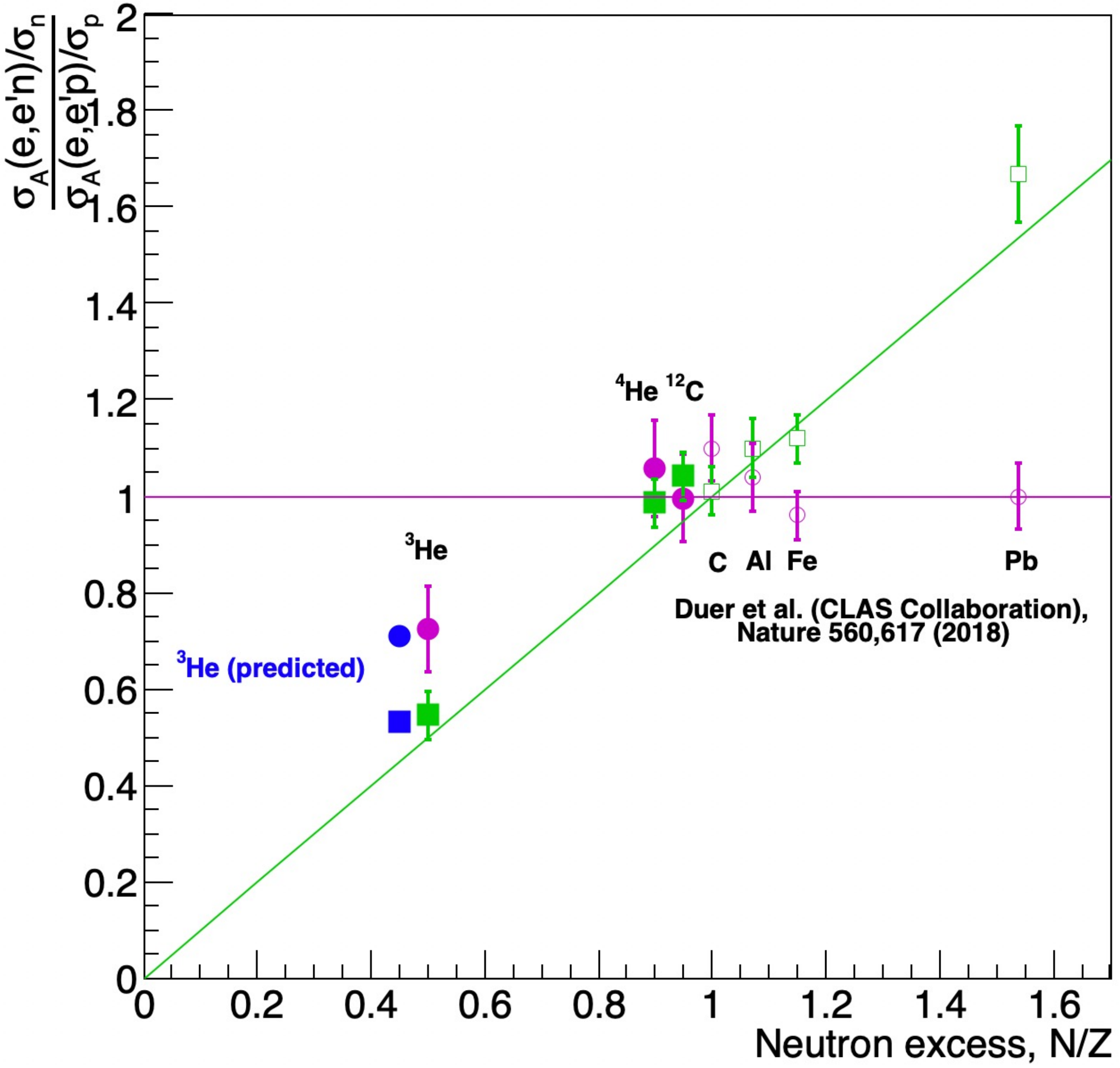
Results

- Low momentum nucleons behave as expected
- Neutrons speed up in proton-rich nuclei
- *np* dominance less pronounced than in larger nuclei
- Spectral functions good at replicating ^{3}He(e,e'n)/^{3}He(e,e'p) ratios
- Peculiarity of ^{3}He wavefunction



Open Questions

- Decouple nuclear mass from asymmetry
- 3N SRCs
- SRC Formation
- Connection to EMC effect
- Repulsive core of NN interaction

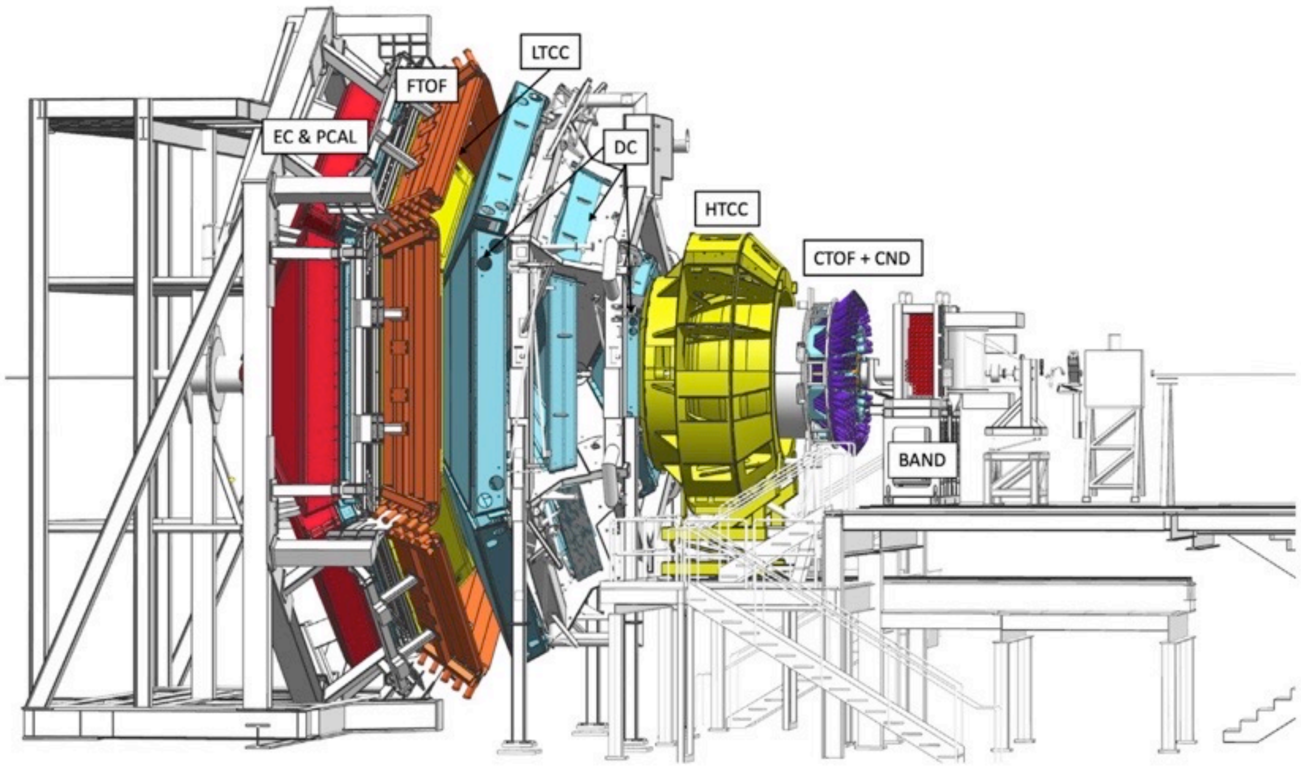


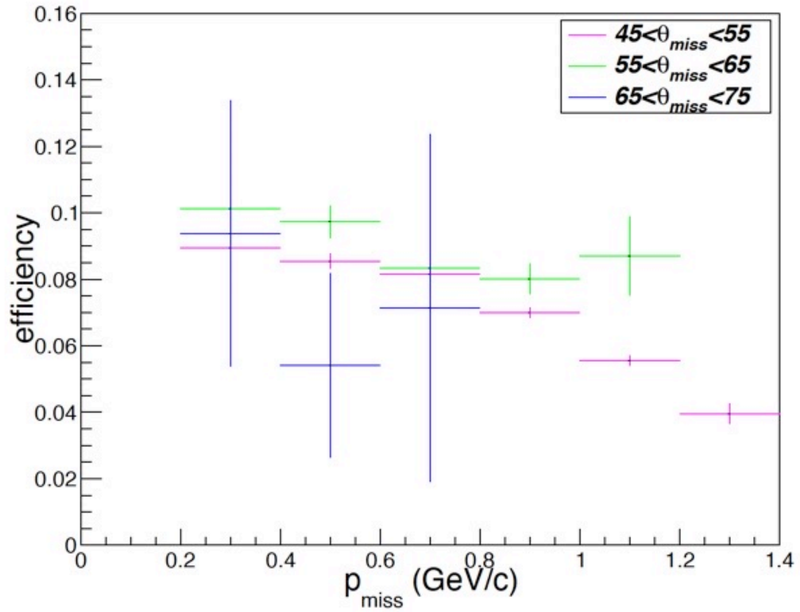
Hall B Nuclear Targets Experiment (2021-22)

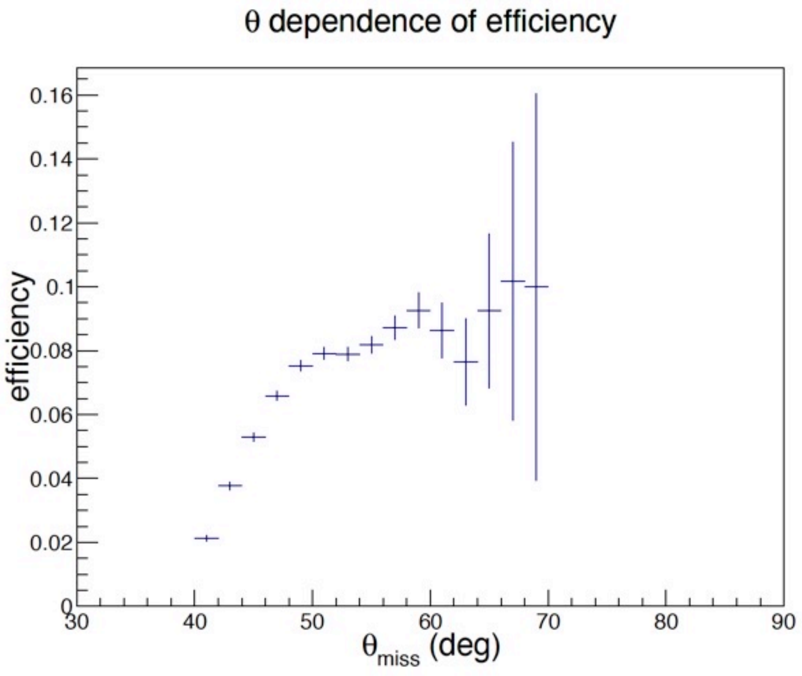
- Decouple nuclear mass from asymmetry
- 3N SRCs
- SRC Formation
- Connection to EMC effect
- Repulsive core of NN interaction

Target	A	N/Z
H	1	0
D	2	1
He	4	1
C	12	1
^{40}Ca	40	1
Ar	40	1.22
^{48}Ca	48	1.4
Sn	120	1.4

Steps towards SRCs in CLAS12







Neutron detection efficiency

- $p(e, e'\pi^+n)$ – forward neutrons
- $d(e, e'pn)$ – neutrons across polar angle range
- Measure as a function of both momentum and θ

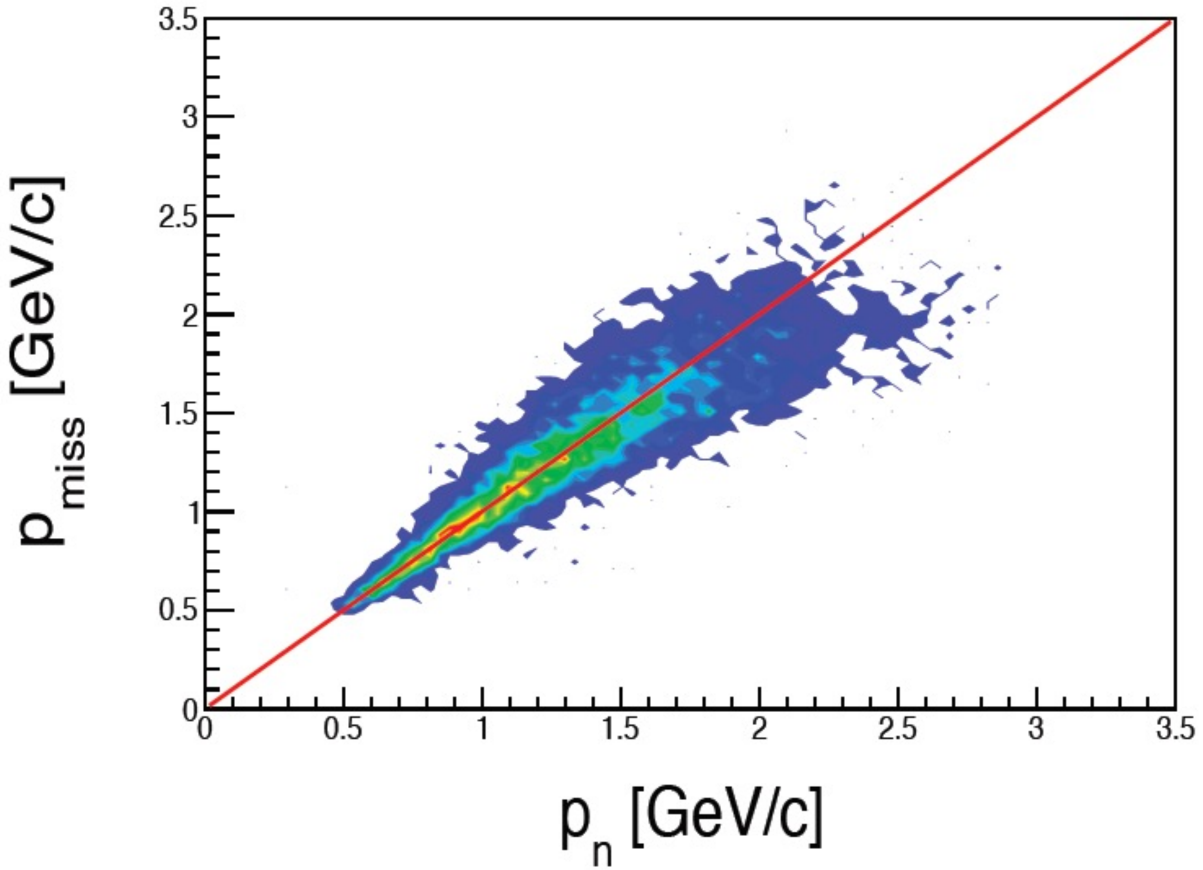
Thank You!

Questions?

Analysis: Understanding Neutrons

- $e^- + d \rightarrow e^- + p + n$
- 3He(e,e'ppn) and 3He(e,e'pp$\pi^+\pi^-$n)
- Momentum correction
- Momentum resolution
- Detection efficiency

$$n_{eff} = \frac{neutron\ detected}{neutron\ expected}$$



Source: Meytal Duer thesis (2018)

Definitions

$$P_\mu^{miss} = q_\mu + p_\mu^d - p_\mu^p$$

$$M_{miss} = \sqrt{P_\mu^{miss} P^{\mu,miss}}$$

$$\vec{p}_{miss} = \vec{p}_N - \vec{q}$$

$$E_{miss} = \omega - T_N - T_B$$

$$T_B = \omega + m_A - E_N - \sqrt{(\omega + m_A - E_N)^2 - |\vec{p}_{miss}|^2}$$

Data vs Simulation