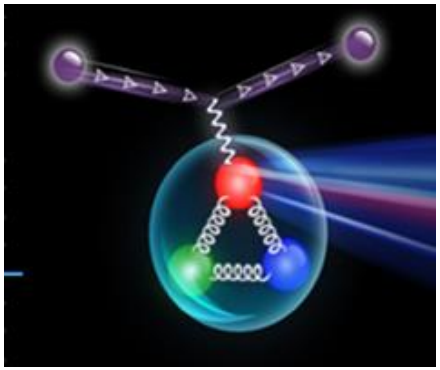
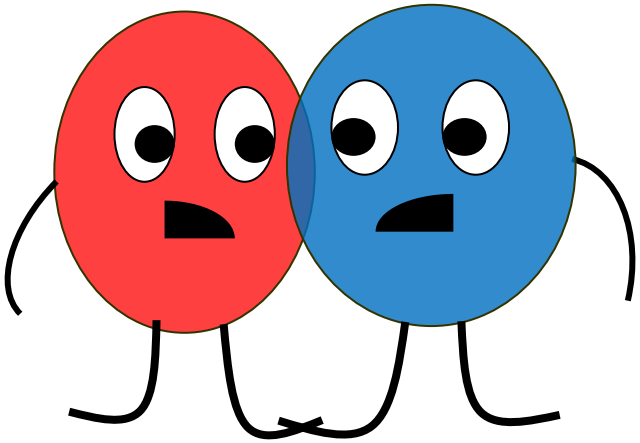
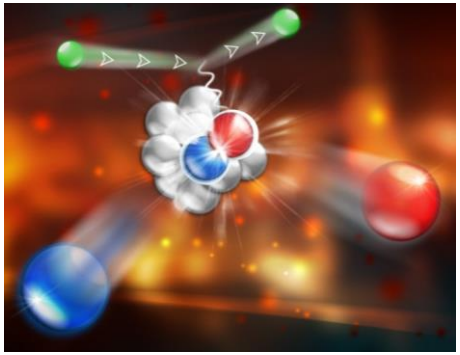
Inclusive Data Overview

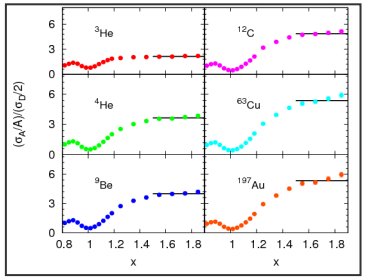


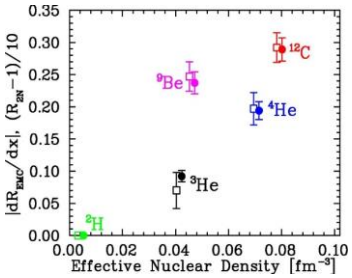


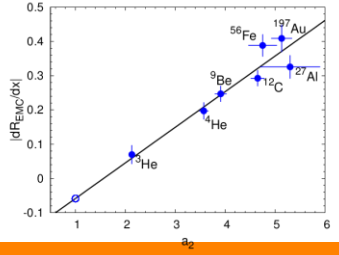


Nadia Fomin

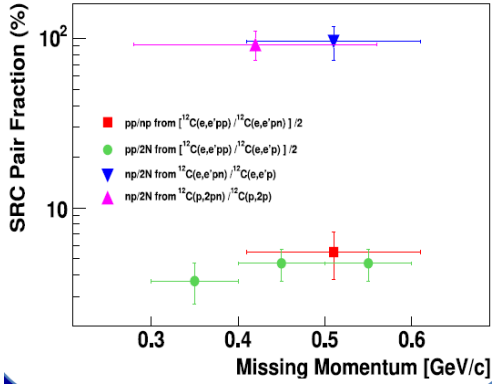
What have we learned from Jlab's 6GeV era?

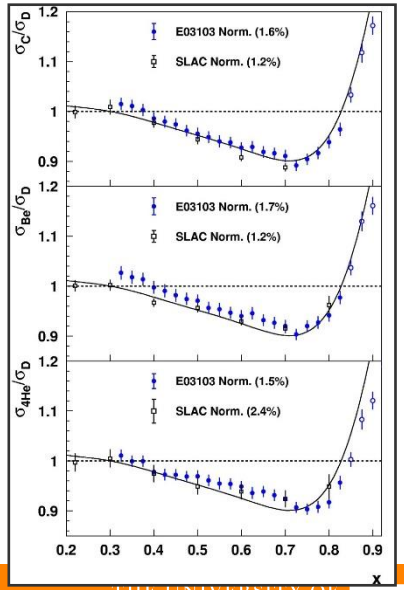






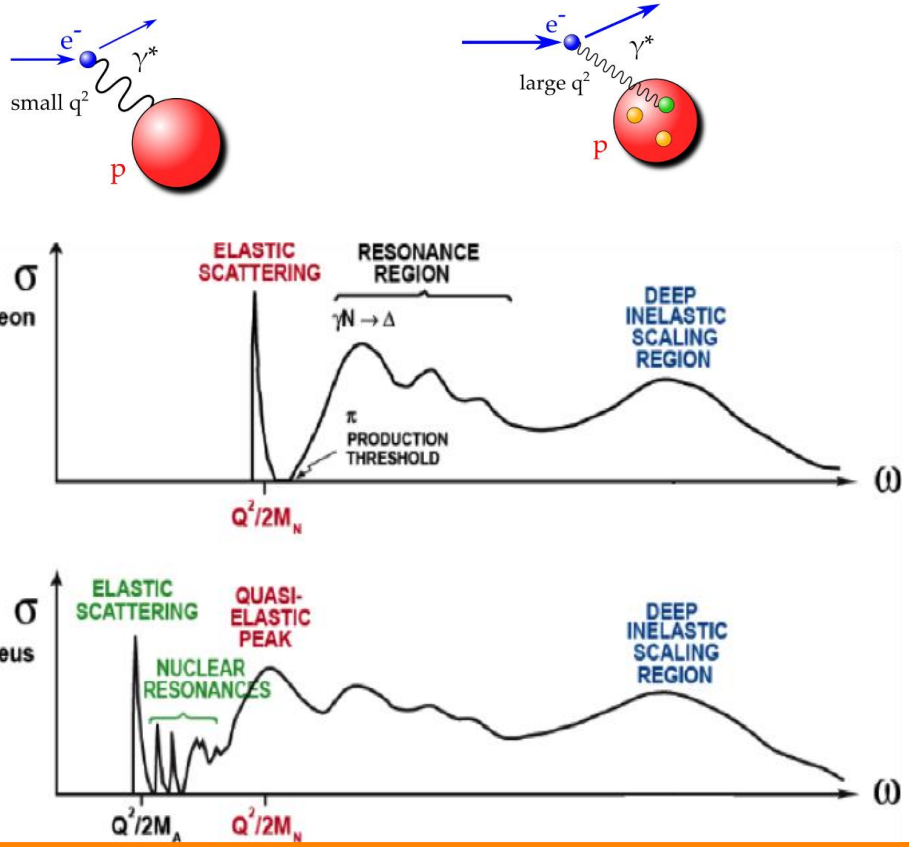
- Scaling of x>1 cross sections relative to the deuteron
  --implies high momentum tail is a result of short-range correlations
- NP dominance of short-range pairs --tensor interaction
- No trivial (A or density) dependence for SRC behavior or EMC effect
  --from high-precision light nuclei data
- Suggestive correlation between EMC effect and SRC plateaus





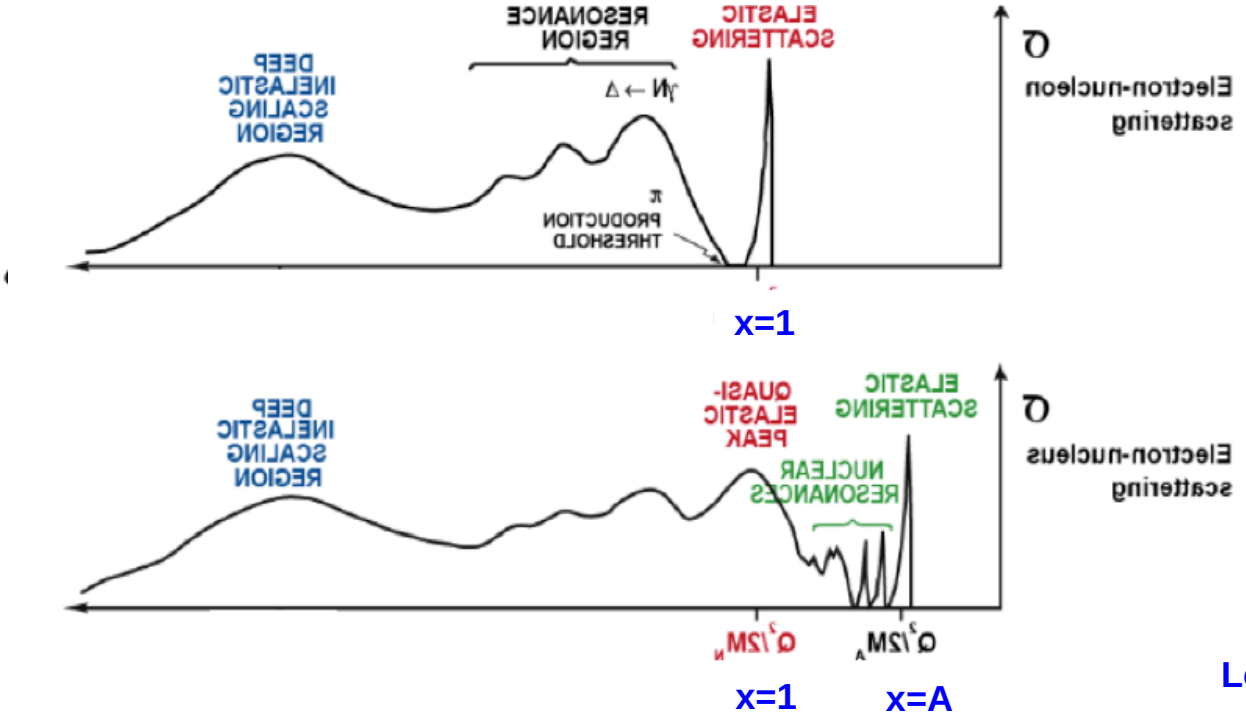
THE END

Choosing an Appropriate Microscope



$$\lambda \approx \frac{1}{\vec{q}}$$

Choosing an Appropriate Microscope



Log-ish(x_{Bj})

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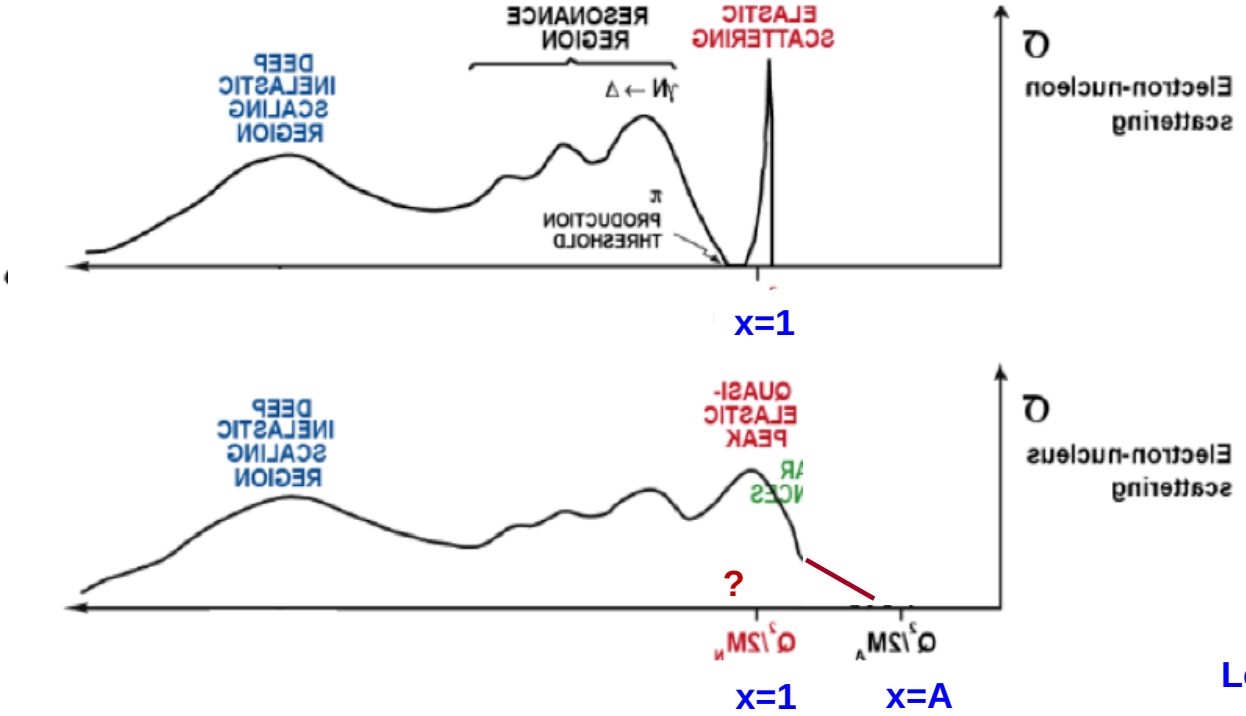
1<x<2 is combination of 2-body and 1*-body contributions; 3+ body effect assumed to be small (*=Fermi-smeared)

Choosing an Appropriate Microscope



Log-ish(x_{Bj})

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High momentum tails in A(e,e'p)

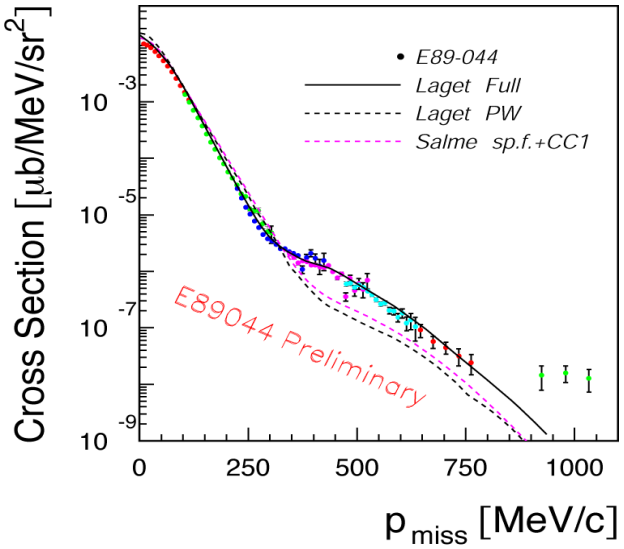
- E89-004: Measure of ^{3}He(e,e'p)d
- Measured far into high momentum tail: Cross section is ~5-10x expectation

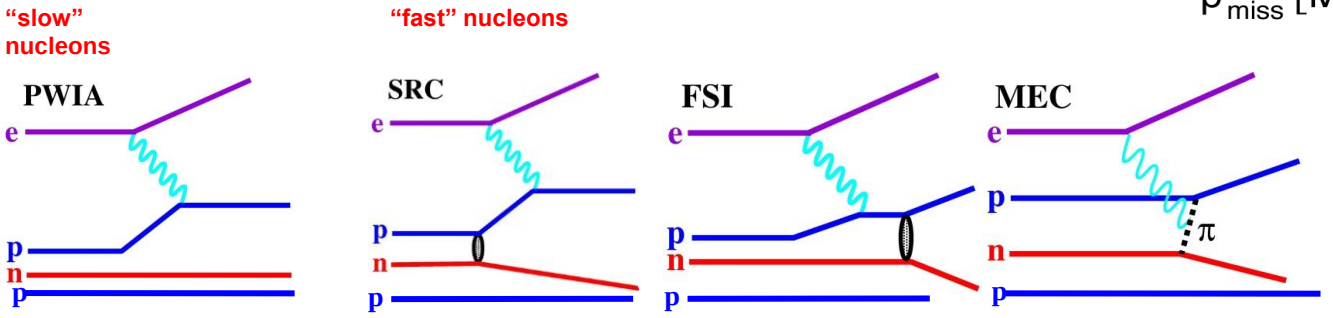
Difficulty

- High momentum pair can come from SRC (initial state)

OR

- Final State Interactions (FSI) and Meson Exchange Contributions (MEC)





A(e,e’p)

^{2}H(e,e’p) Mainz
PRC 78 054001 (2008)

E =0.855 GeV
θ = 45^o
E’=0.657 GeV
Q^2=0.33 GeV^2
x=0.88

Unfortunately: FSI, MECs overwhelm the high momentum nucleons

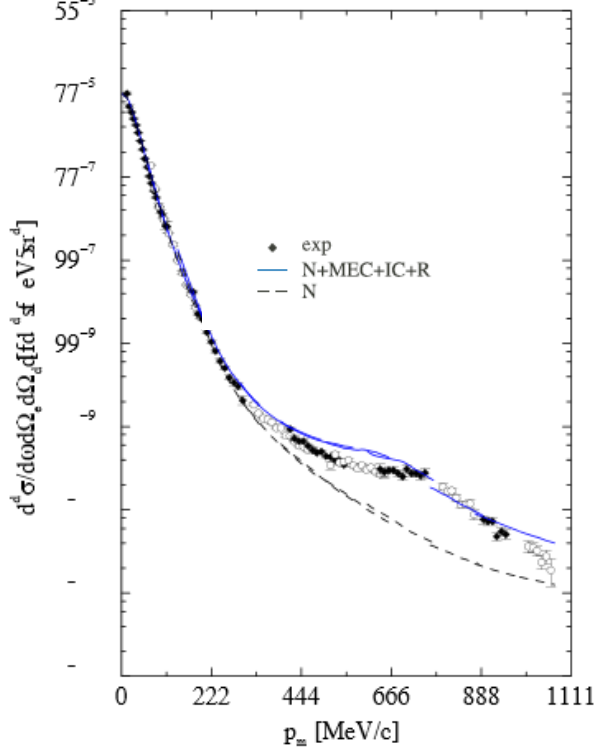


FIG. 1: The experimental D(e,e′p)n cross section as a function of missing momentum measured at MAMI for $Q^2 = 0.33$ (GeV/c)^2 [4] compared to calculations [7] with (solid curve) and without (dashed curve) MEC and IC. Both calculations include FSI. The low p_m data have been re-analyzed and used in this work to determine f_{LT} (color online).

Inclusive Scattering

- Relative measurement
- Reduced FSI
- Test scaling in x and Q^2
- No direct information on isospin structure
  - Only via target isospin structure
- No direct information on momentum distribution for A>2

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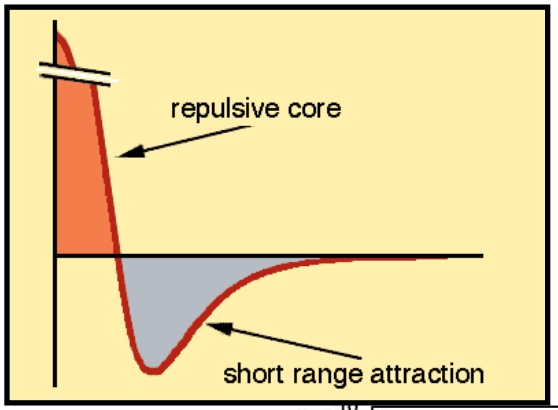
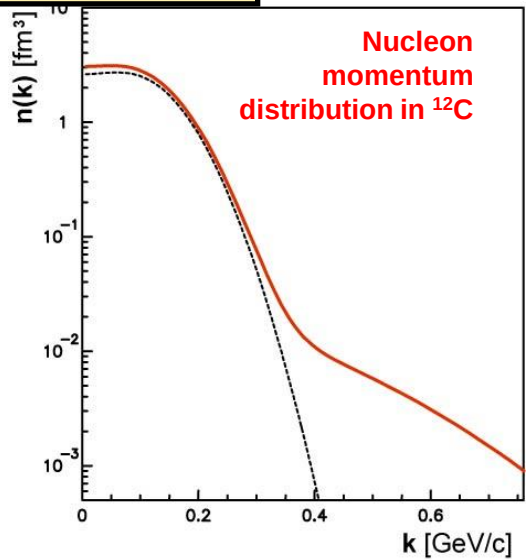
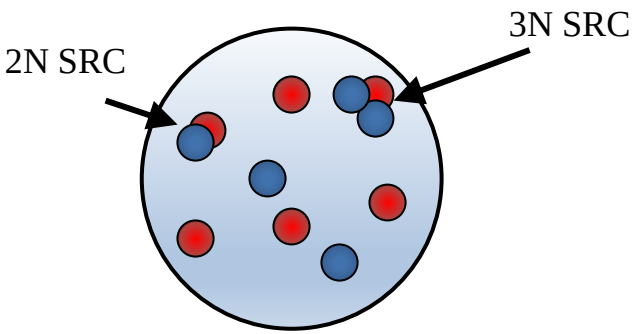
High momentum nucleons

- Short Range Correlations







Try inclusive scattering!
Select kinematics such that the initial nucleon momentum $> k_f$

High momentum nucleons - Short Range Correlations

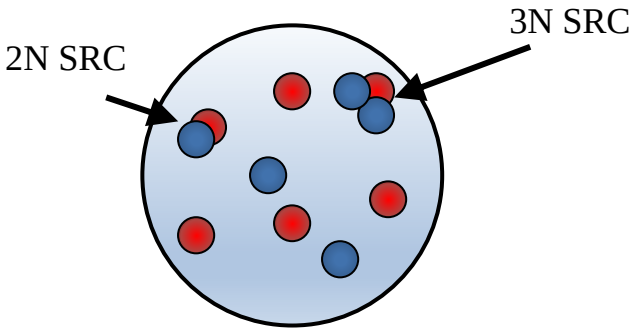
$$\frac{d\sigma^{QE}}{d\Omega dE'} \propto \int d\vec{k} \int dE \sigma_{ei} S_i(k,E) \delta(Arg)$$

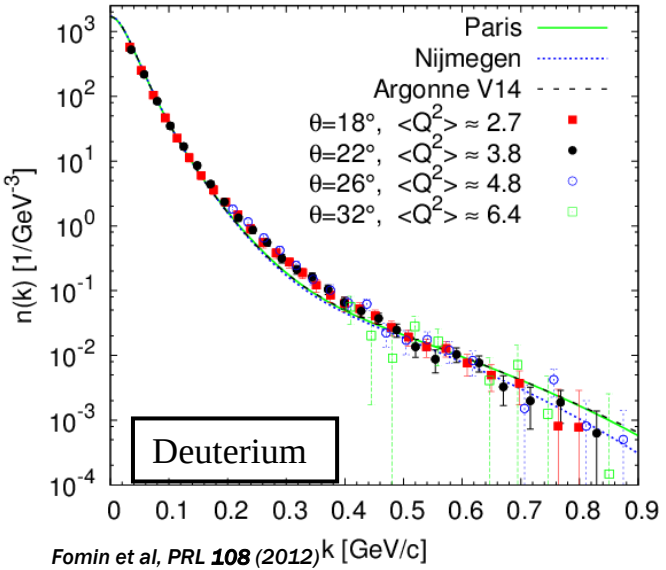
$$Arg = \nu + M_A - \sqrt{M^2 + p^2} - \sqrt{M^{*2}_{A-1} + k^2}$$

$$F(y,\mathbf{q}) = \frac{d^2\sigma}{d\Omega d\upsilon} \frac{1}{(Z\overline{\sigma}_p + N\overline{\sigma}_n)} \frac{\mathbf{q}}{\sqrt{M^2 + (y+q)^2}}$$

$$= 2\pi \int_1^\infty n(k) k dk$$

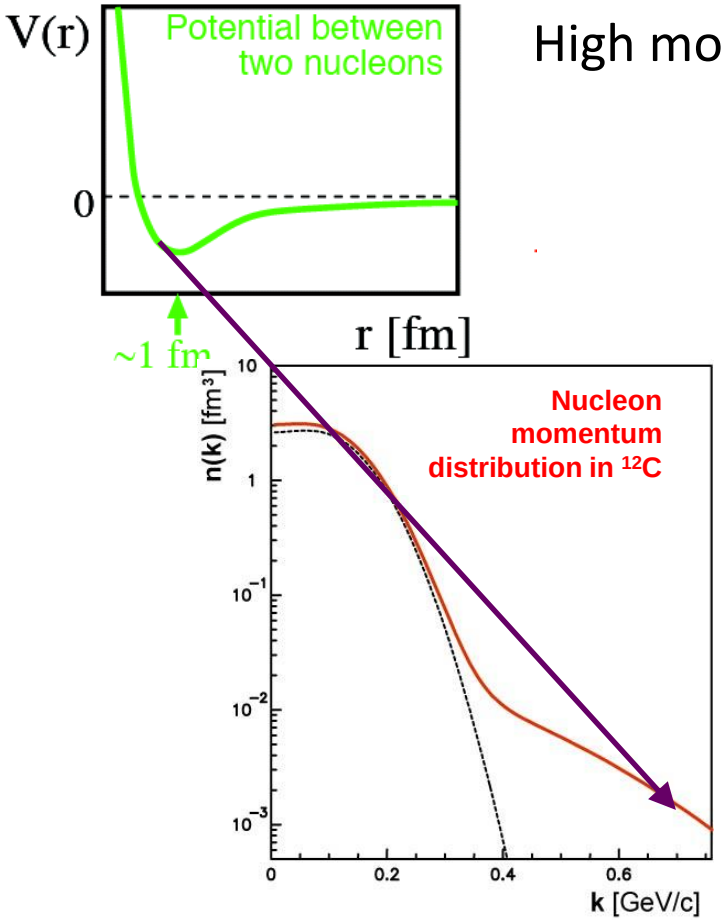
Ok for A=2

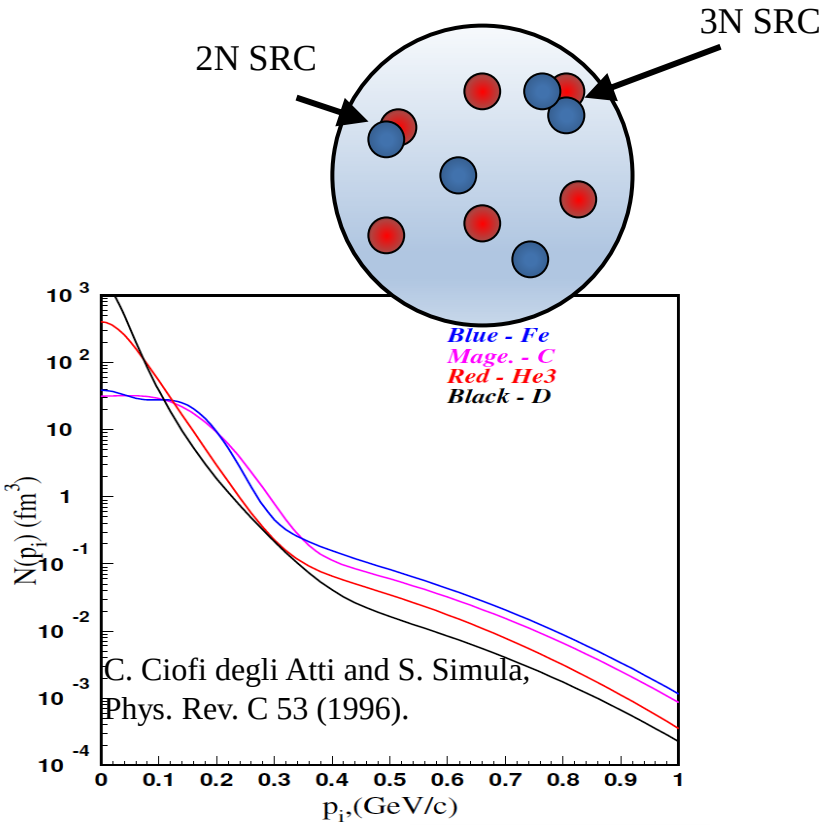




*Fomin et al, PRL **108** (2012)*

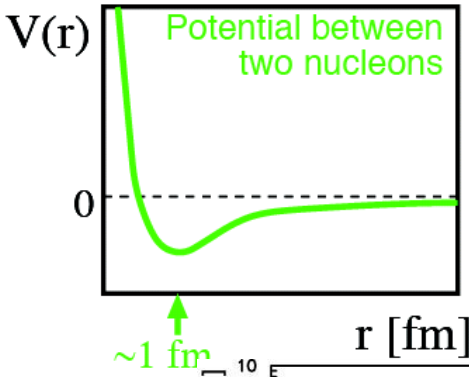
High momentum nucleons - Short Range Correlations

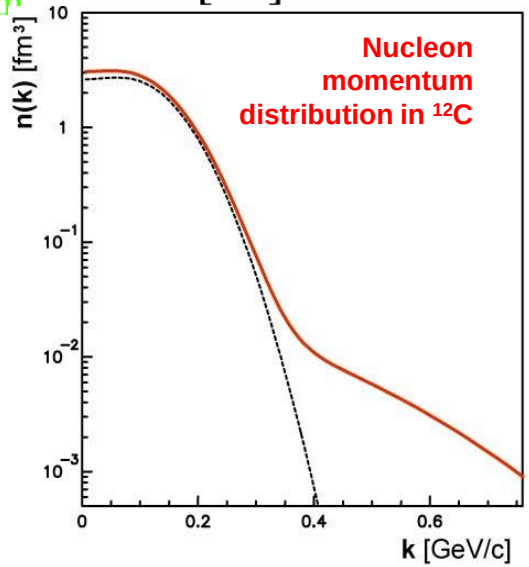


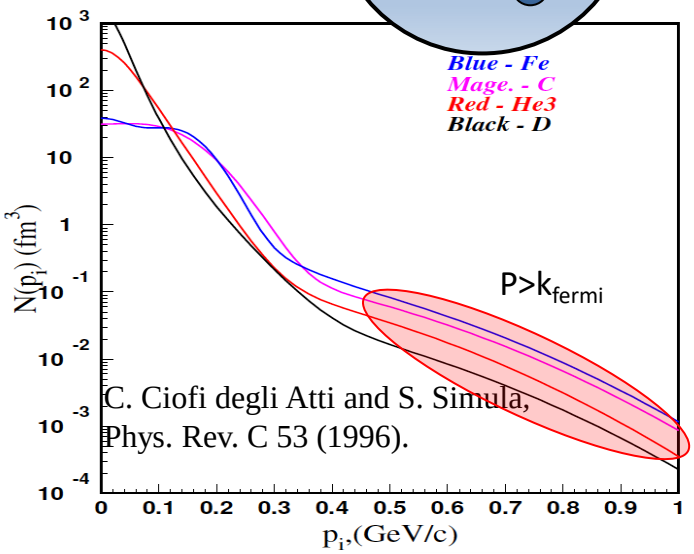


C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996).

High momentum nucleons - Short Range Correlations







C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996).

Short Range Correlations

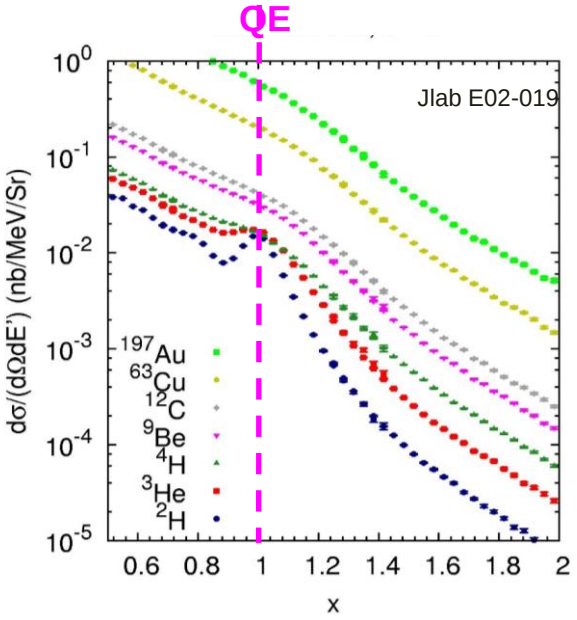
$$\frac{2}{A}\frac{\sigma_A}{\sigma_D} = a_2(A)$$

- To experimentally probe SRCs, must be in the high-momentum region (x>1)
- To measure the relative probability of finding a correlation, ratios of heavy to light nuclei are taken
- In the high momentum region, FSIs are thought to be confined to the SRCs and therefore, cancel in the cross section ratios

$$\sigma(x, Q^2) = \sum_{j=1}^{A} A\frac{1}{j} a_j(A)\sigma_j(x, Q^2)$$

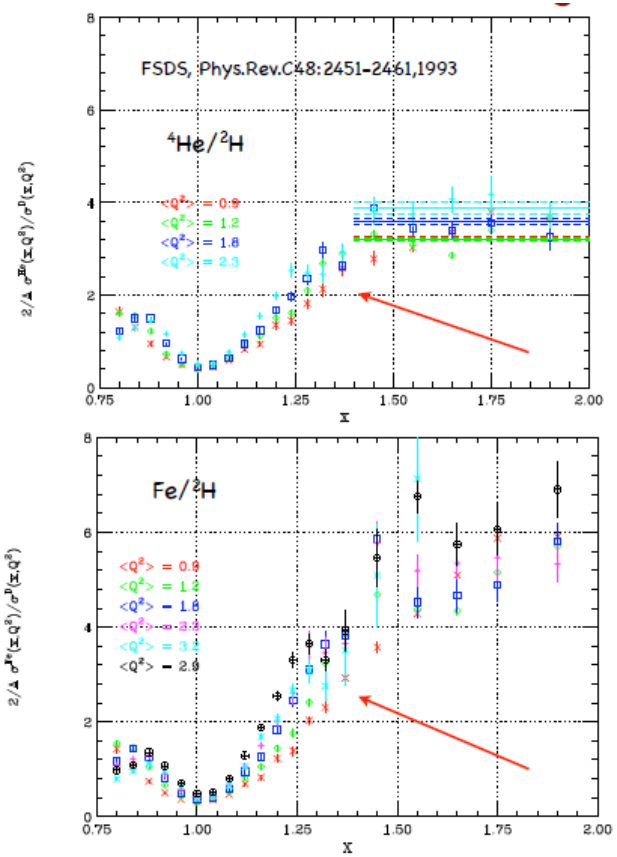
$$= \frac{A}{2} a_2(A)\sigma_2(x, Q^2) +$$

$$\frac{A}{3} a_3(A)\sigma_3(x, Q^2) + ...$$



1.4<x<2 => 2 nucleon correlation

20th Century Data



- Moderate Q^2 data from SLAC
- Originally analyzed in the *y*-scaling picture

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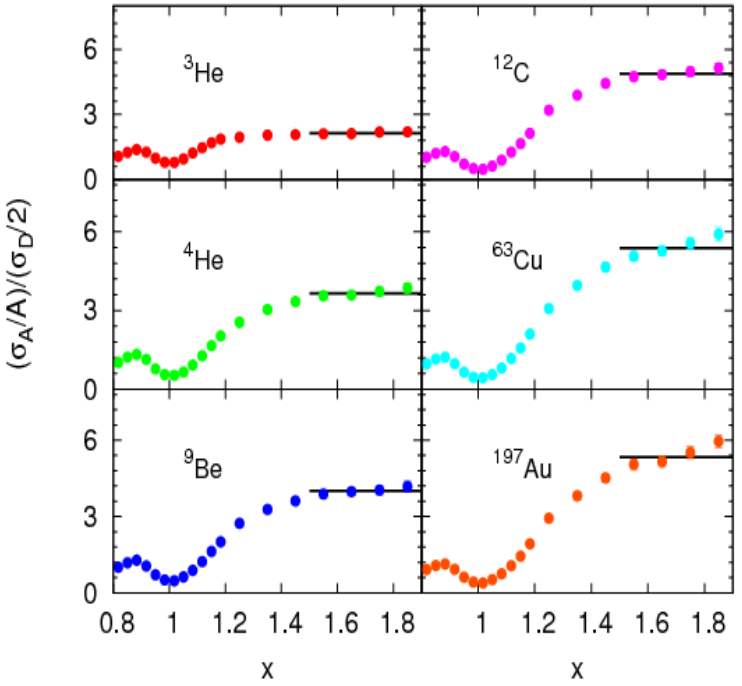
$$\frac{A}{3} a_3(A)\sigma_3(x, Q^2) + ...$$

Jlab E02-019: 2N correlations in A/D ratios (early 21st century)

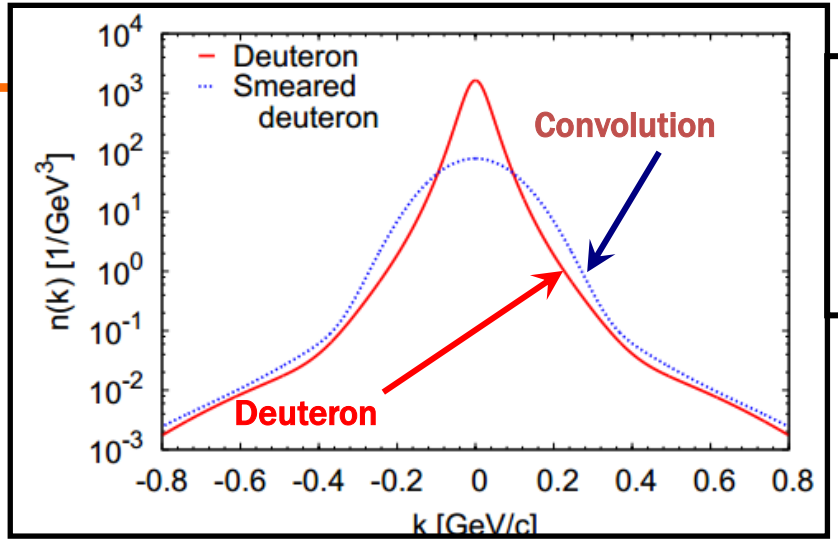
A	θ_e=18°
^{3}He	2.14±0.04
^{4}He	3.66±0.07
Be	4.00±0.08
C	4.88±0.10
Cu	5.37±0.11
Au	5.34±0.11
$\langle Q^2 \rangle$	2.7 GeV^2
x_{min}	1.5

<Q^2>=2.7 GeV^2



*Fomin et al, PRL **108** (2012) Jlab E02-019*

Note: ($a_2=\sigma_A/\sigma_D$)!= Relative #of SRCs



$n_D^{CONV}(k)$ is the convolution of $n_D(k)$ with the CM motion of correlated pairs in iron

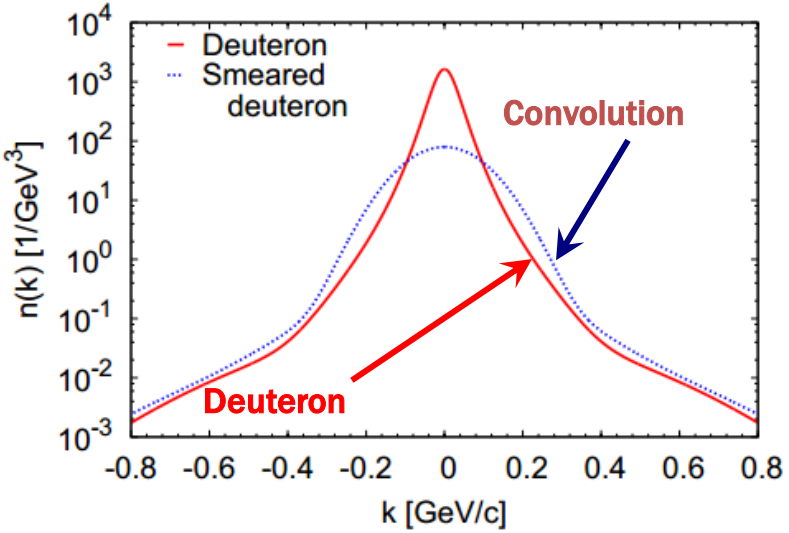
Following prescription from C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996)

	E02-019	SLAC	CLAS	R_{2N}-ALL	a_2-ALL
^{3}He	1.93±0.10	1.8±0.3	–	1.92±0.09	2.13±0.04
^{4}He	3.02±0.17	2.8±0.4	2.80±0.28	2.94±0.14	3.57±0.09
Be	3.37±0.17	–	–	3.37±0.17	3.91±0.12
C	4.00±0.24	4.2±0.5	3.50±0.35	3.89±0.18	4.65±0.14
Al	–	4.4±0.6	–	4.40±0.60	5.30±0.60
Fe	–	4.3±0.8	3.90±0.37	3.97±0.34	4.75±0.29
Cu	4.33±0.28	–	–	4.33±0.28	5.21±0.20
Au	4.26±0.29	4.0±0.6	–	4.21±0.26	5.13±0.21

$a_2=\sigma_A/\sigma_D$ *→ relative measure of high momentum nucleons*

R_{2n} *→ relative measure of correlated pairs*

NOTE: $a_2 = \frac{\sigma_A}{\sigma_D}$! =RELATIVE #OF SRCS



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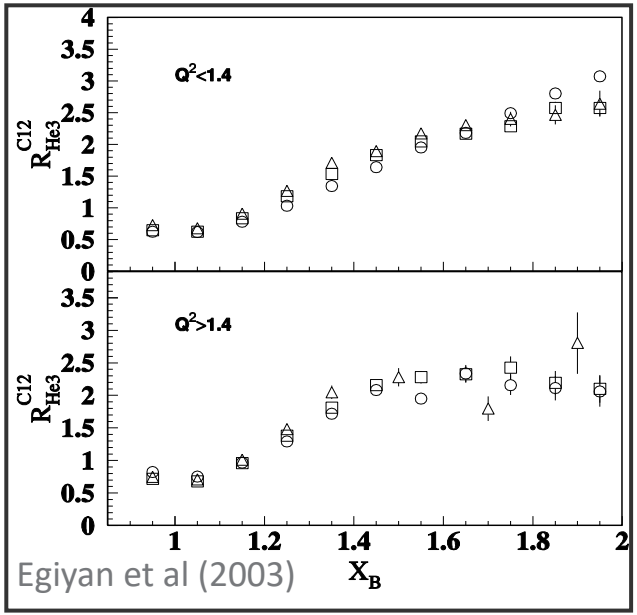
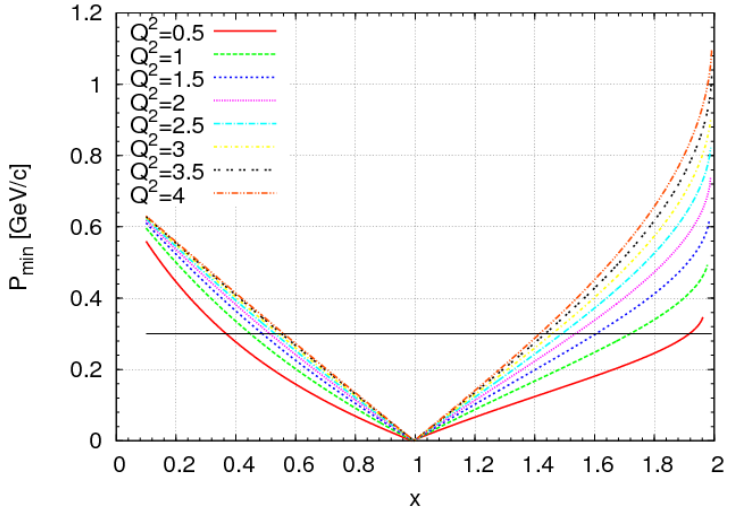


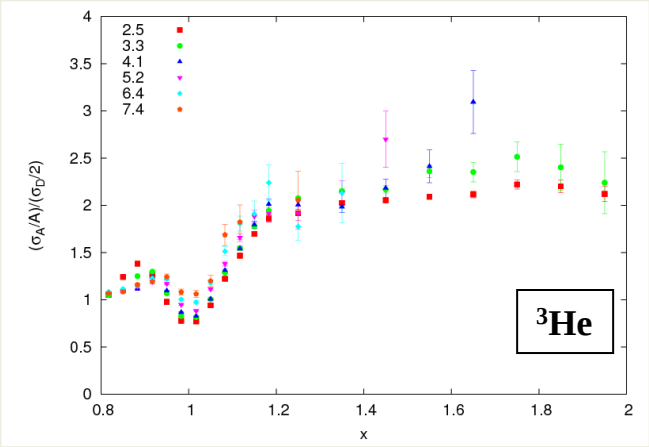
Egiyan et al (2003)

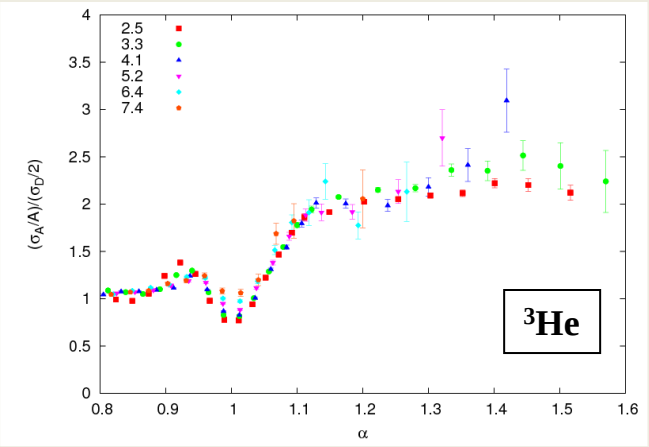


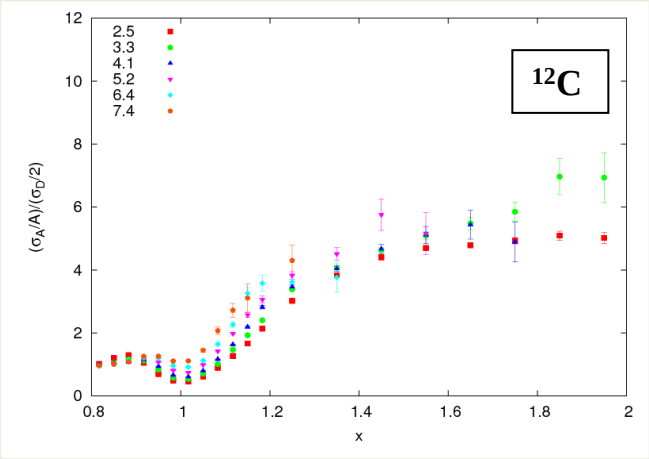
Calculation for A=2

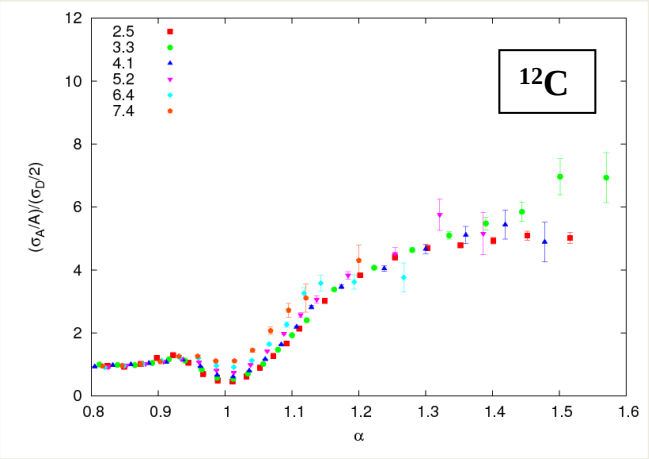
Test scaling in x and Q^2

$$\alpha = 2 - \frac{q^- + 2M}{2M}\left(1 + \frac{\sqrt{W^2 - 4M^2}}{W}\right)$$

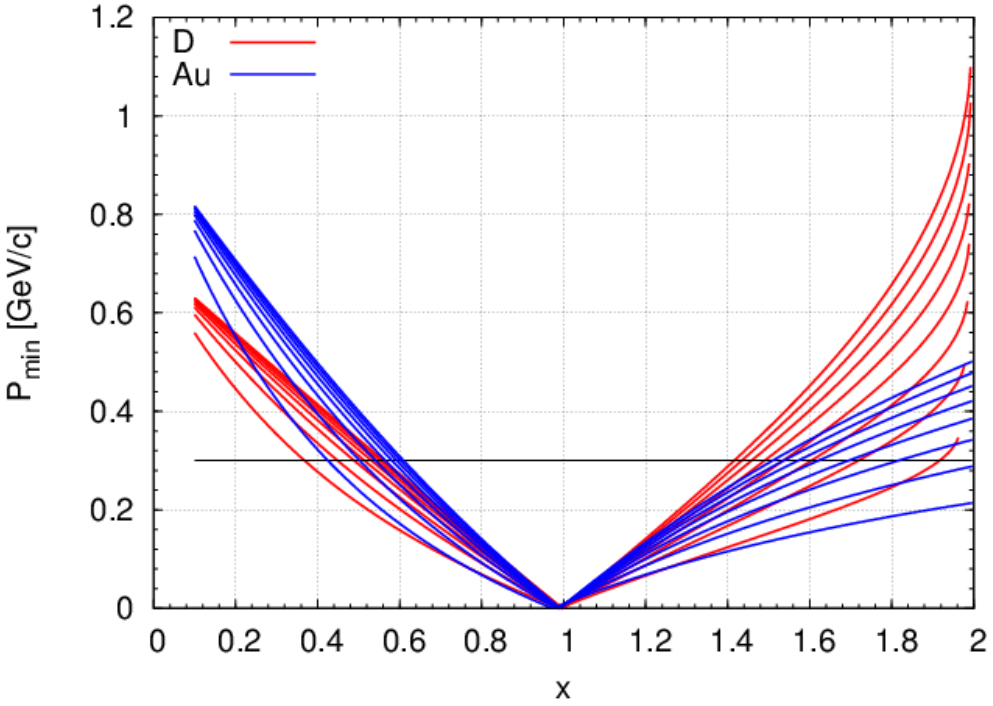








Kinematic cutoff is A-dependent

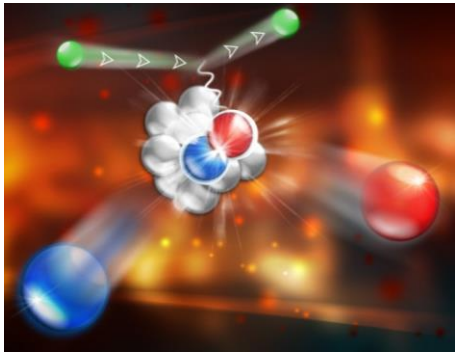


- For heavy nuclei, the minimum momentum changes → heavier recoil system requires less kinetic energy to balance the momentum of the struck nucleon
- Larger fermi momenta for A>2 → MF contribution persists for longer
- Imperfect plateau, but the picture still holds

2N knockout experiments establish NP dominance

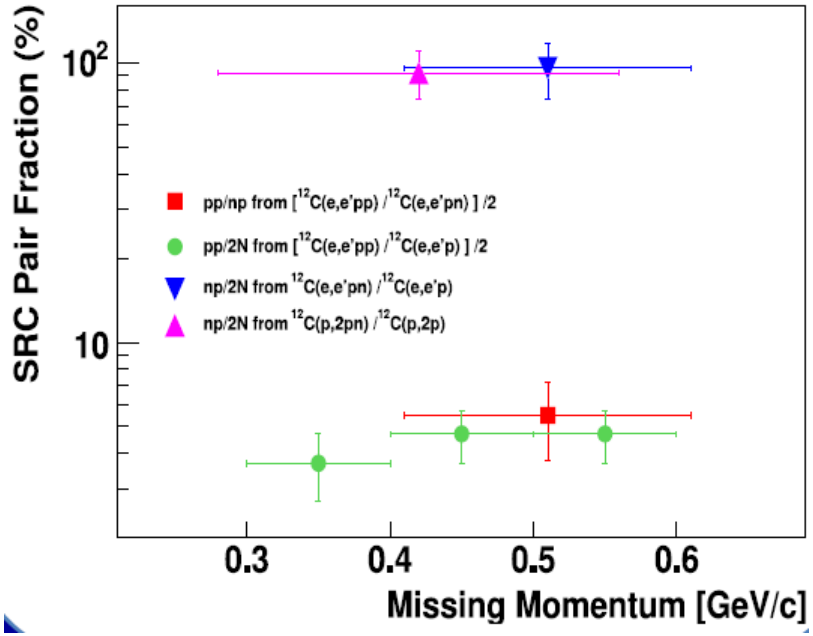
- Knockout high-initial-momentum proton, look for correlated nucleon partner.
- For $300 < P_{miss} < 600$ MeV/c all nucleons are part of 2N-SRC pairs: 90% np, 5% pp (nn)

R. Subedi et al., Science 320, 1476 (2008)



R. Shneor et al., PRL 99, 072501 (2007)

2N knockout experiments establish NP dominance



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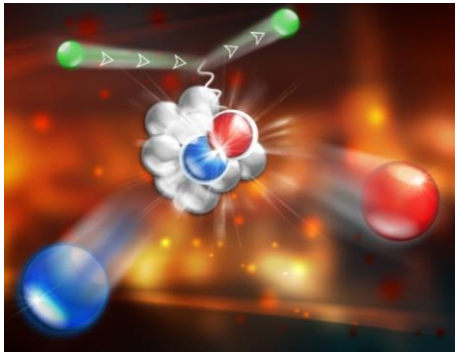
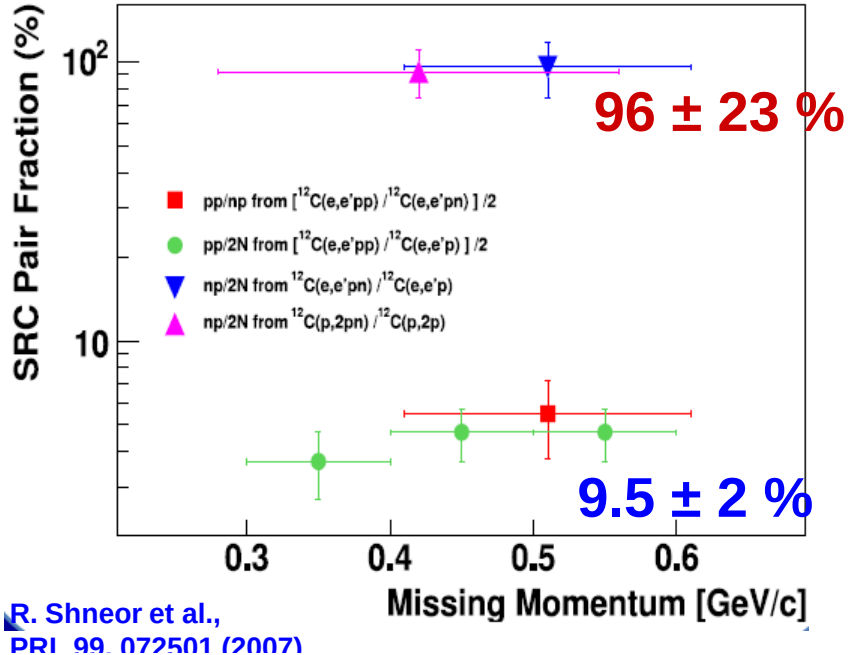


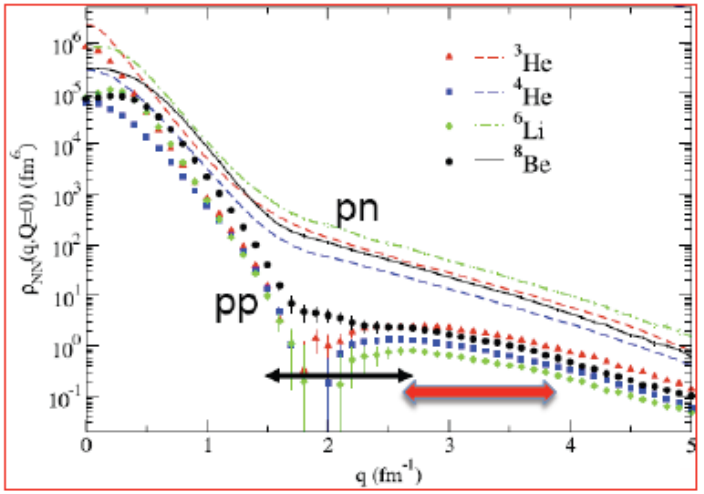
R. Shneor et al., PRL 99, 072501 (2007)

Relevant for interpretation of inclusive data

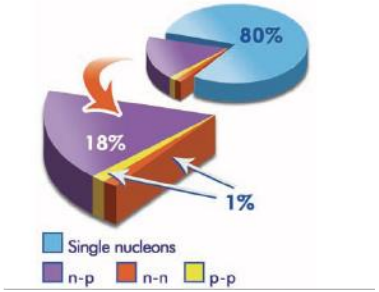
NP dominance



R. Shneor et al., PRL 99, 072501 (2007)



R. Schiavilla, R. B. Wiringa, S. C. Pieper, J. Carlson, Phys. Rev. Lett. **98** (2007) 132501



also

→ Ciofi and Alvioli PRL 100, 162503 (2008)

→Sargsian, Abrahamyan, Strikman, Frankfurt PR C71 044615 (2005)

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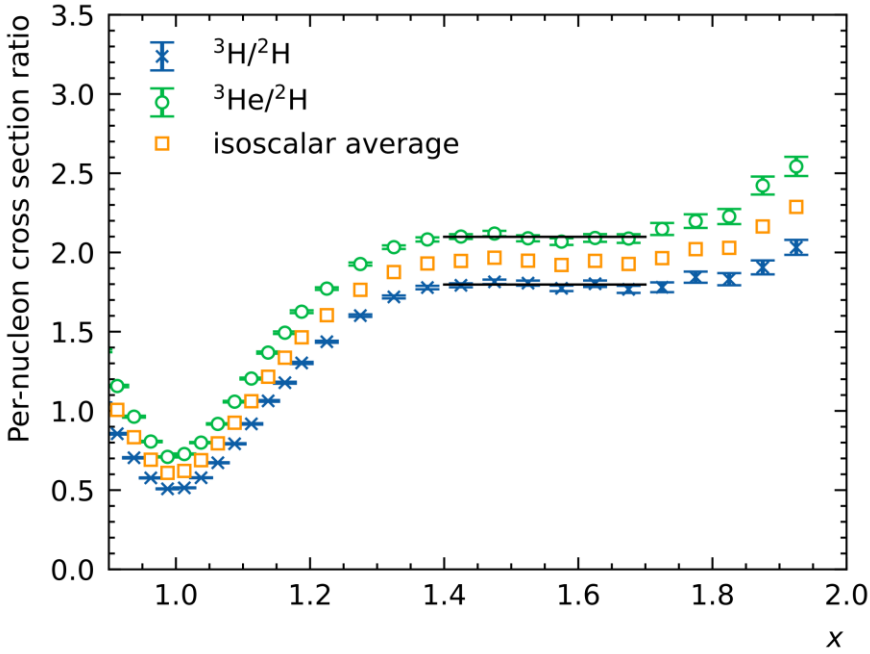
Article | Published: 31 August 2022

Revealing the short-range structure of the mirror nuclei ^{3}H and ^{3}He

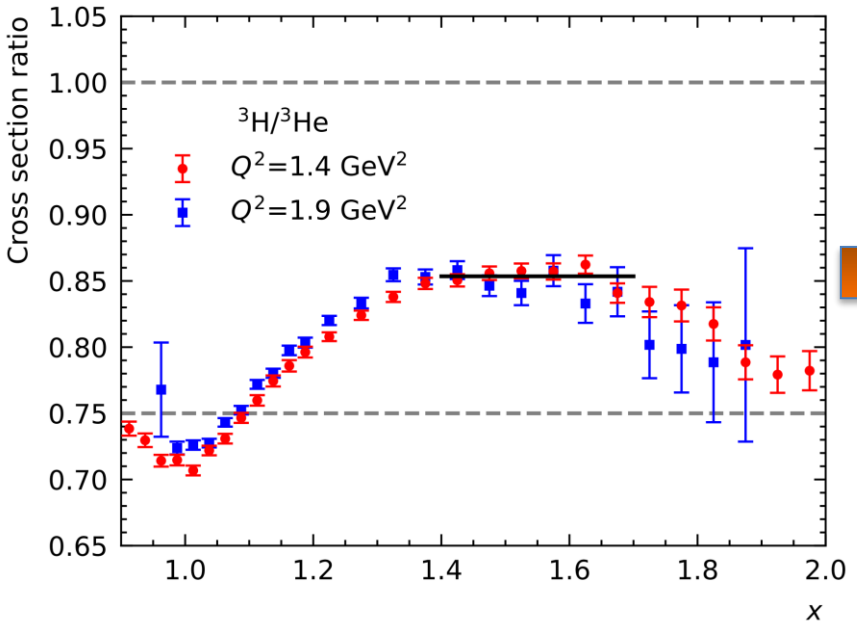
S. Li, R. Cruz-Torres, N. Santiesteban, Z. H. Ye, D. Abrams, S. Alsalmi, D. Androic, K. Aniol, J. Arring

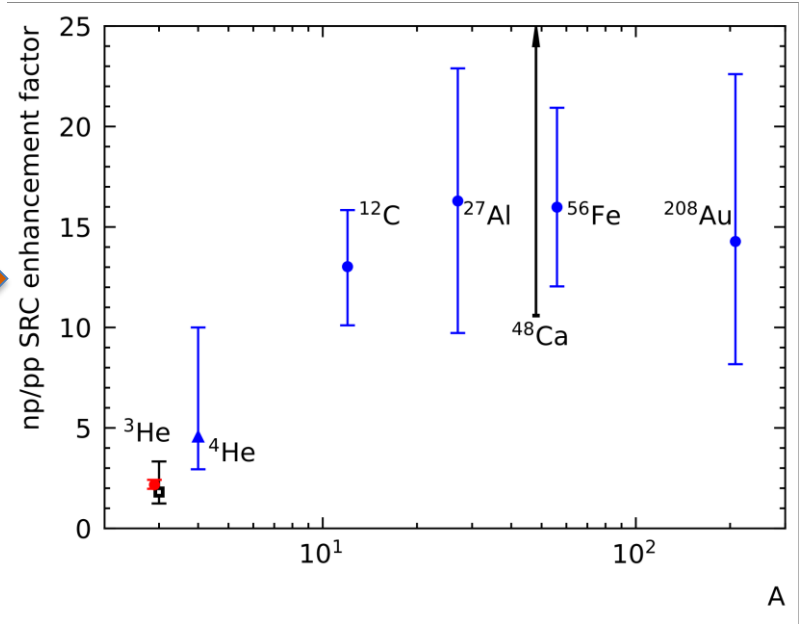


Inclusive measurement on A=3 nuclei

S. Li, et al., Nature 609, 41 (2022)

Where are we now? Publishing Nature Papers



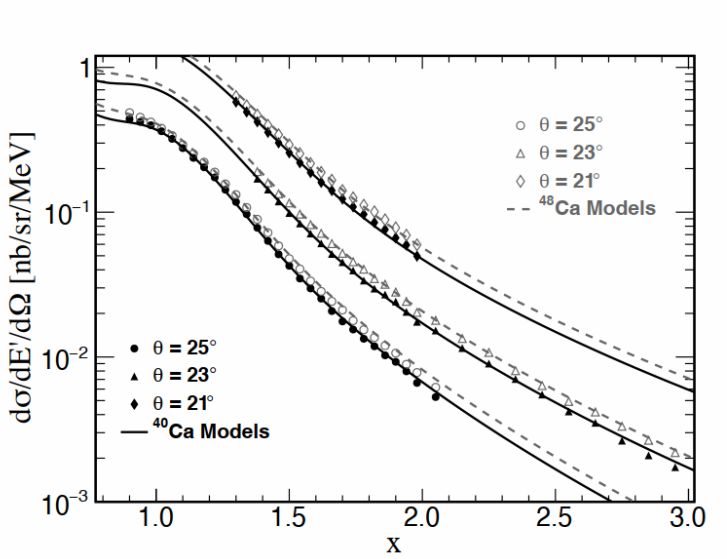


Inclusive measurement on A=3 nuclei

S. Li, et al., Nature 609, 41 (2022)

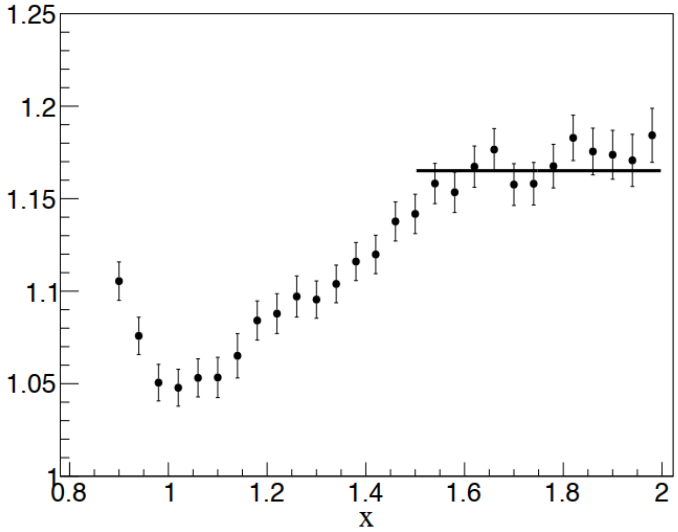
Inclusive Ca48/Ca40 Ratios

Absolute (e,e') cross-sections



More SRC pairs in ^{48}Ca!

$$\frac{\sigma(^{48}Ca)}{\sigma(40Ca)}$$



Courtesy Dien Nguyen

Potentially in tension with upcoming results (see Justin's afternoon talk)

E12-10-008: J. Arrington, A Daniel, NF, D. Gaskell:
Detailed Studies of the nuclear dependence of F_2 in light nuclei

E12-06-105: J. Arrington, D. Day, NF, P. Solvignon:
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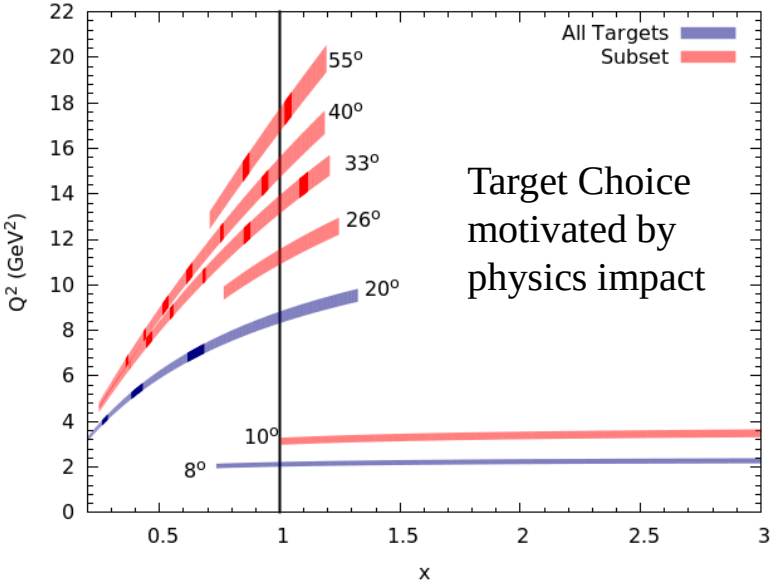
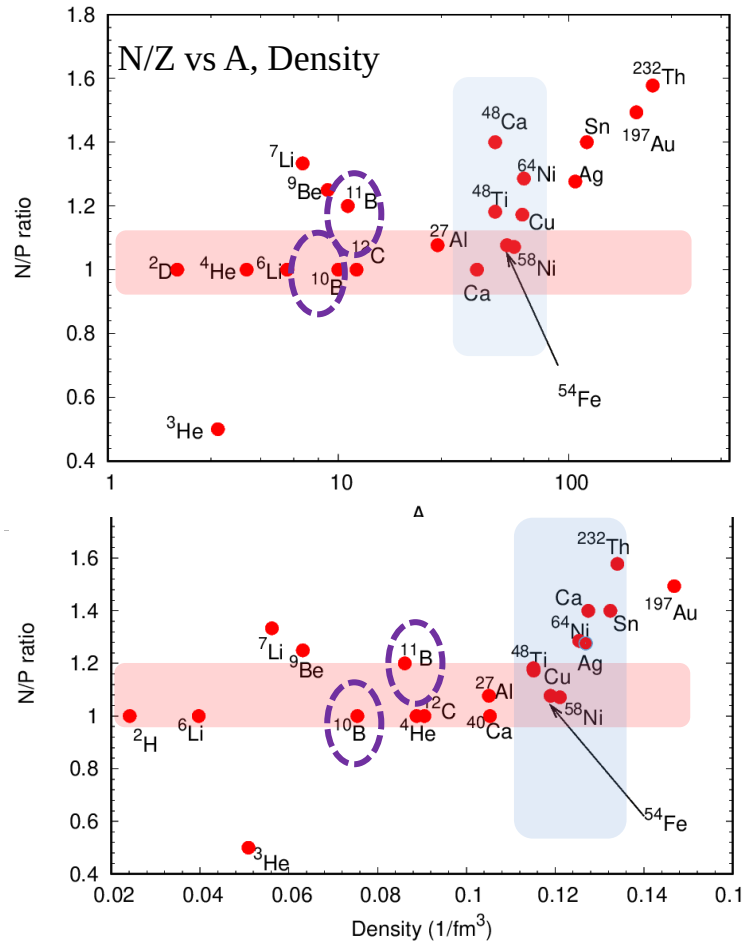
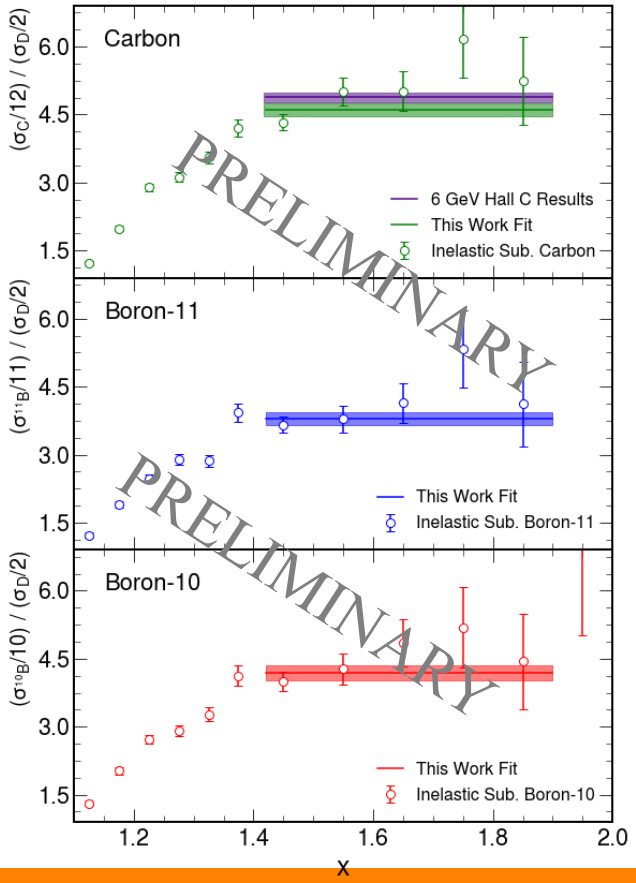
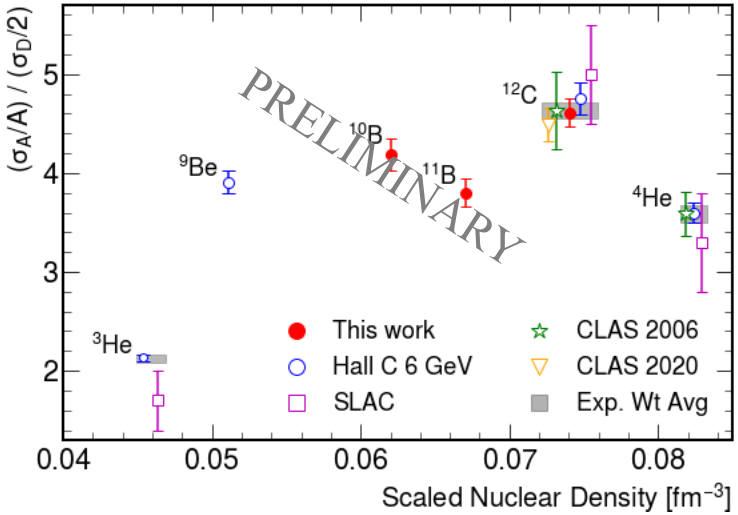




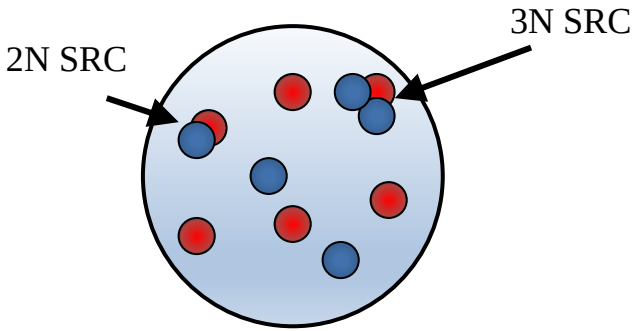
Preparing 2N SRC publication as well





Analysis by Casey Morean (UTK)

More nucleons in a correlation



$1.4 < x < 2$ => 2 nucleon correlation

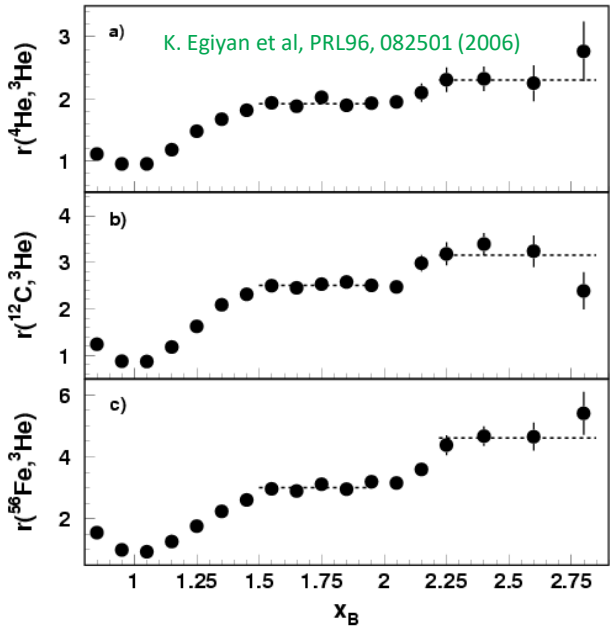
$2.4 < x < 3$ => 3 nucleon correlation

$$\sigma(x, Q^2) = \sum_{j=1}^{A} A \frac{1}{j} a_j(A)\sigma_j(x, Q^2)$$

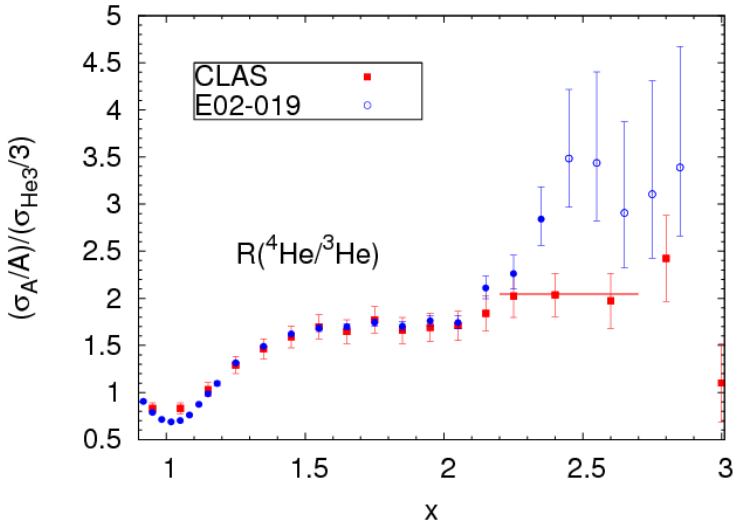
$$= \frac{A}{2} a_2(A)\sigma_2(x, Q^2) +$$

$$\frac{A}{3} a_3(A)\sigma_3(x, Q^2) + ...$$

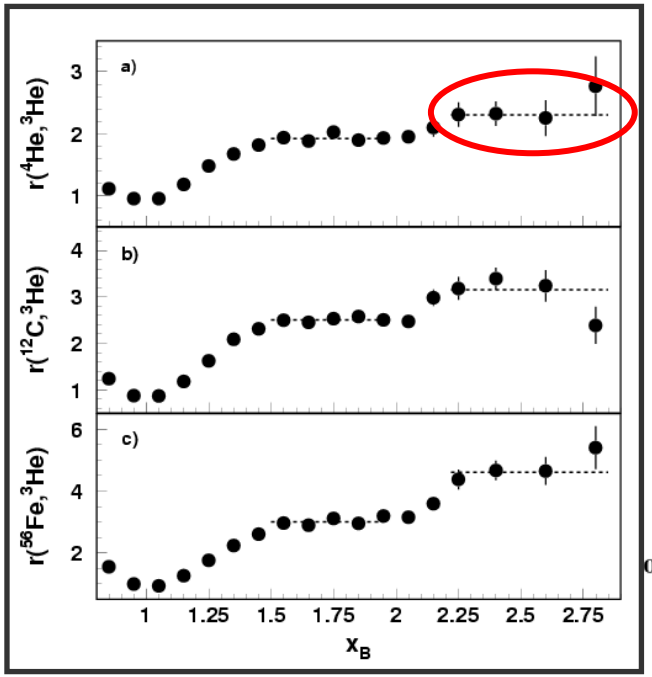
3N correlations (x>2 inclusive scattering)

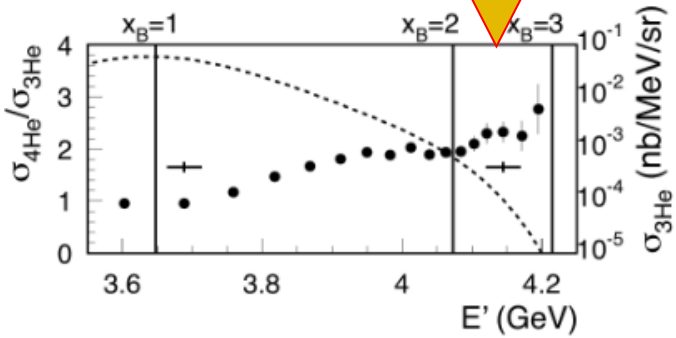


<Q²> (GeV²): *CLAS: 1.6* *E02-019: 2.7*



Have we actually seen 3N SRC in ratios?



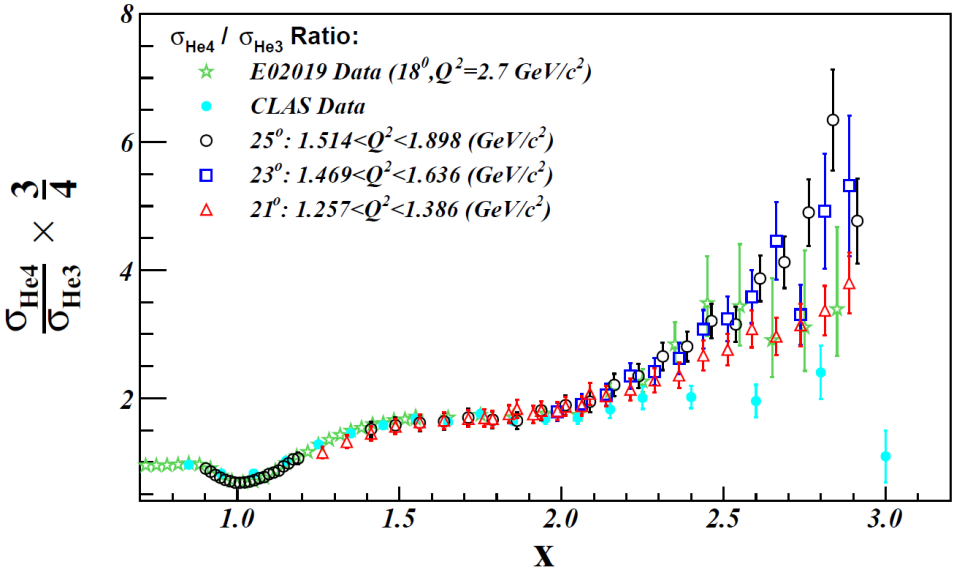


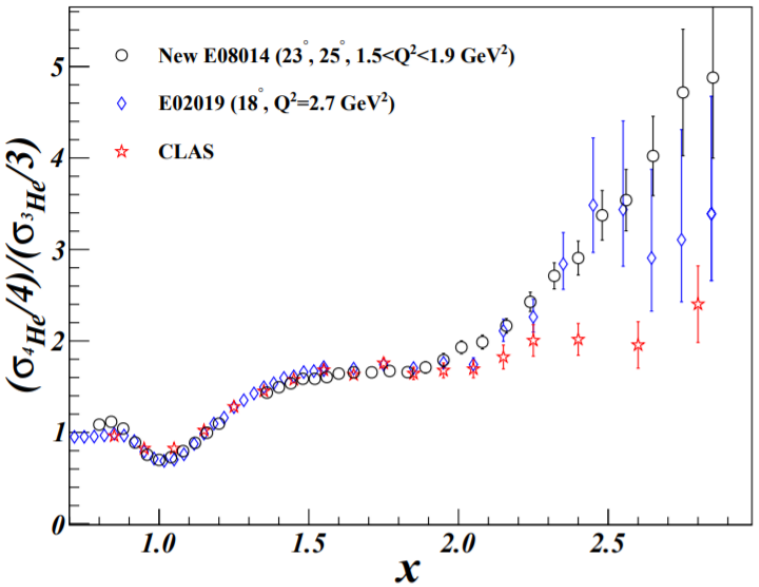
omment on "Measurement of 2- and 3-nucleon short range correlation probabilities in nuclei"

Douglas W. Higinbotham[1] and Or Hen[2]

[1]*Jefferson Lab, Newport News, VA 23606, USA*
[2]*Tel Aviv University, Tel Aviv, Israel*

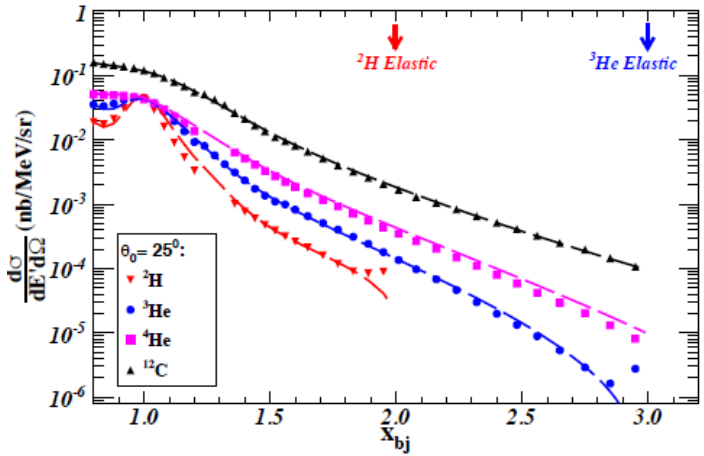
3N correlations - still looking

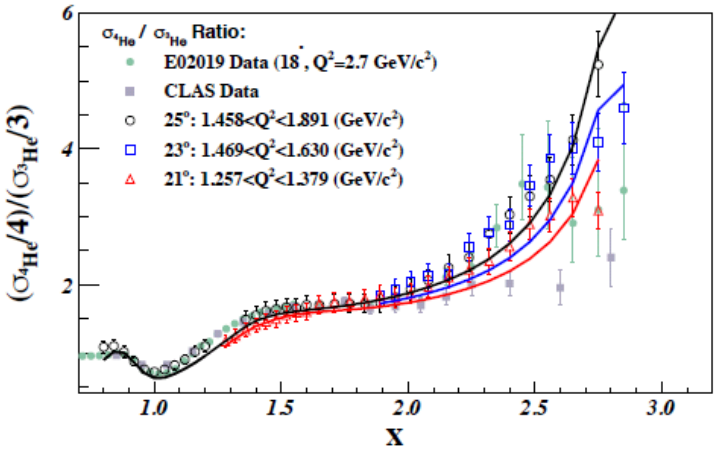


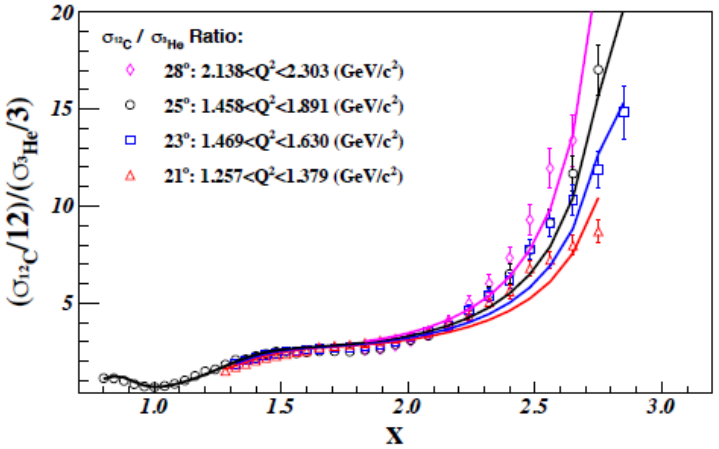


Z. Ye et al, PRC 97 (2018) 6

Can we see a second plateau?





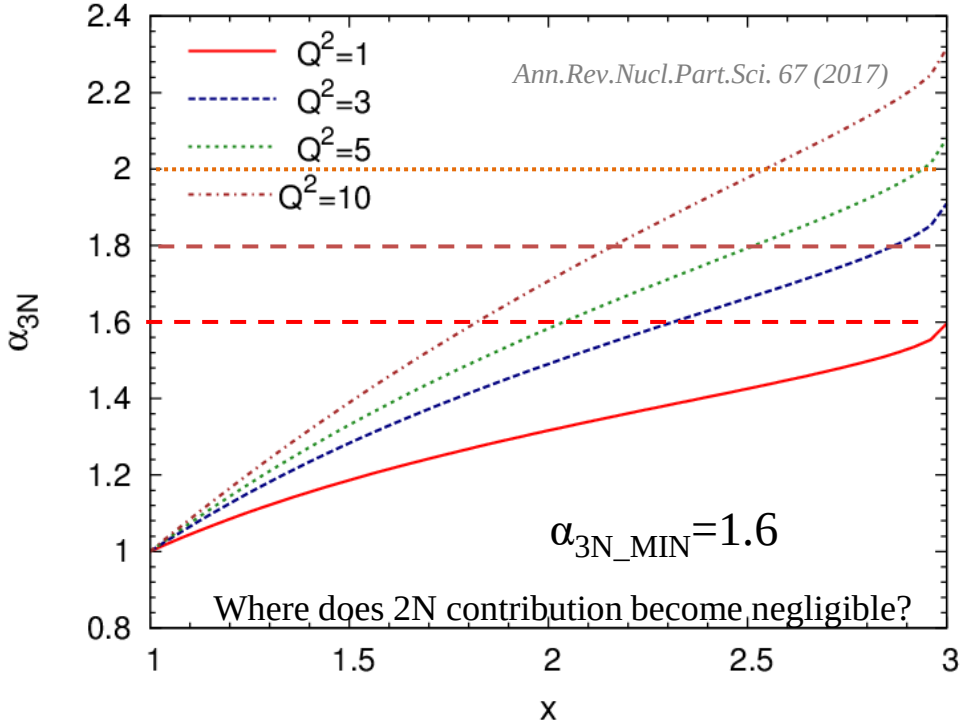


Deuteron: smeared SRC similar to 2H (A/D is ~flat) until x>1.8

3He: cross section of stationary 3N-SRC begins to fall off closer to x=2.6. Sets in EARLIER at high Q^2

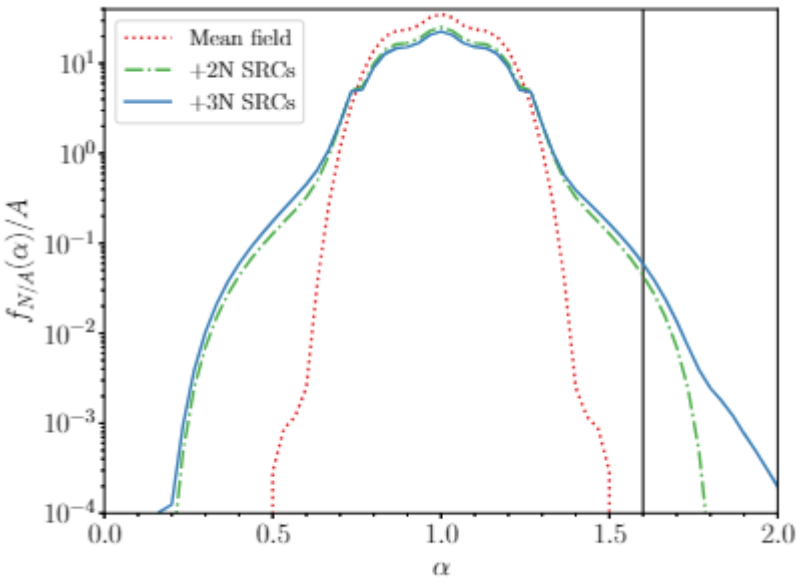

I WAS TOLD THERE WOULD BE
3N SRC PLATEAUS
imgflip.com

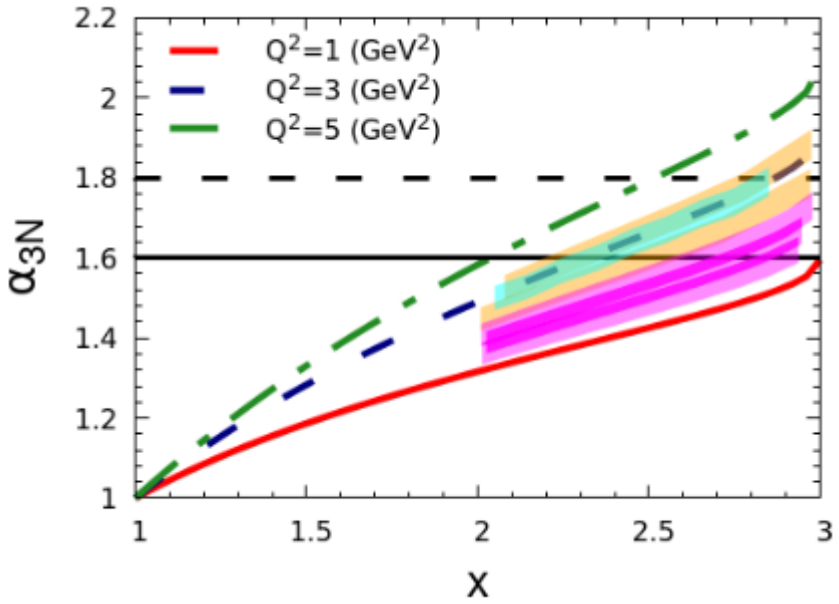
3N correlations – are we there yet?



α_i represents the light-cone momentum fraction of 3N SRCs carried by the correlated nucleon *i*

We were so close at 6 GeV in Hall C





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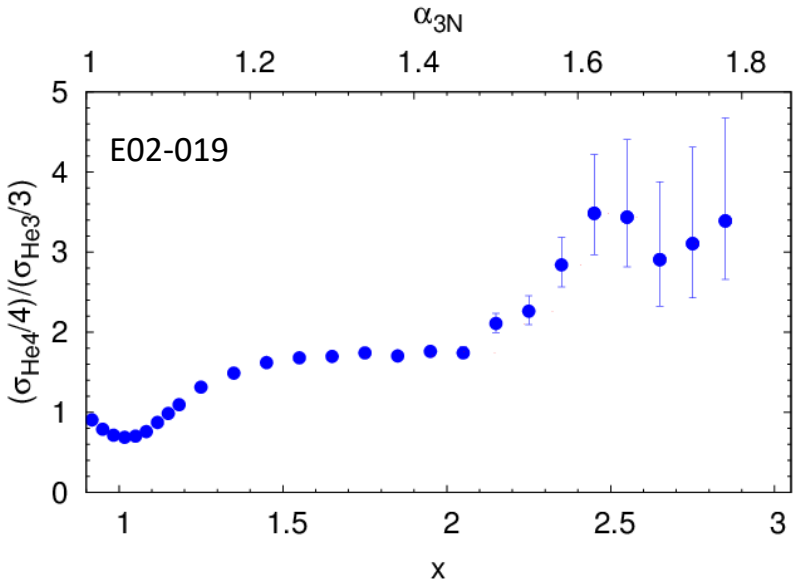

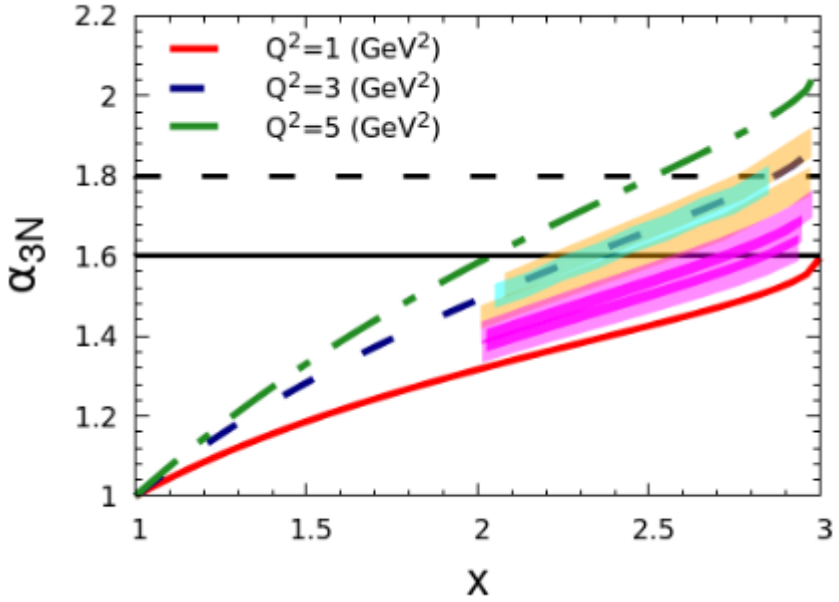

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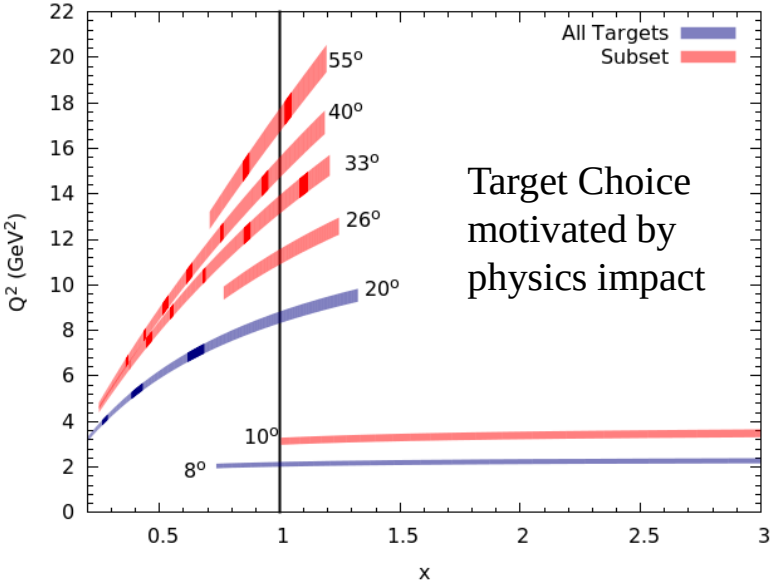
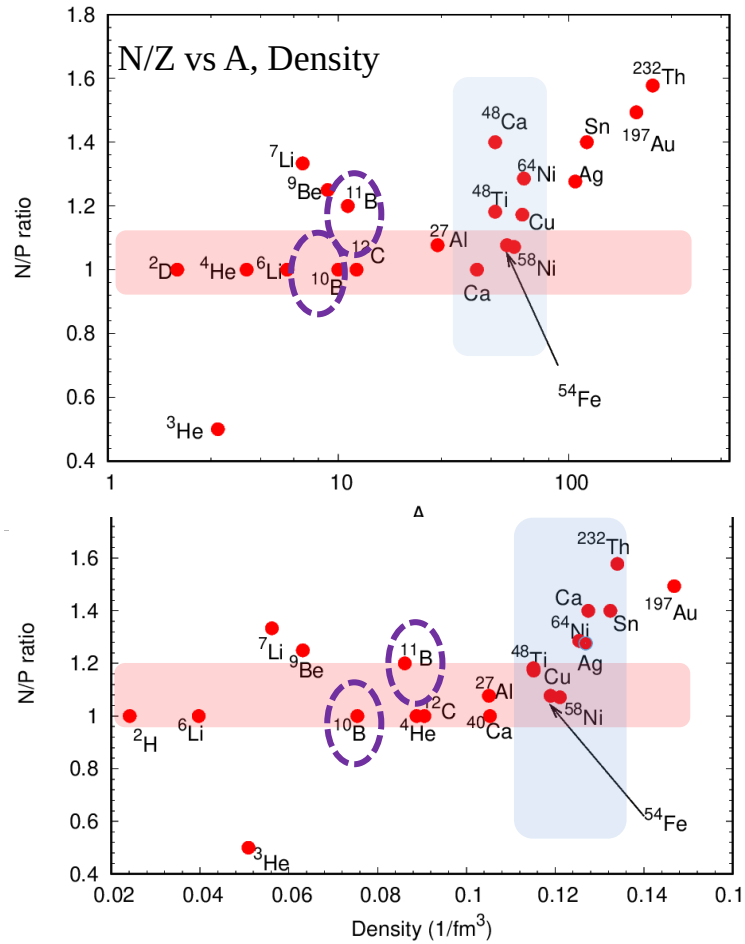
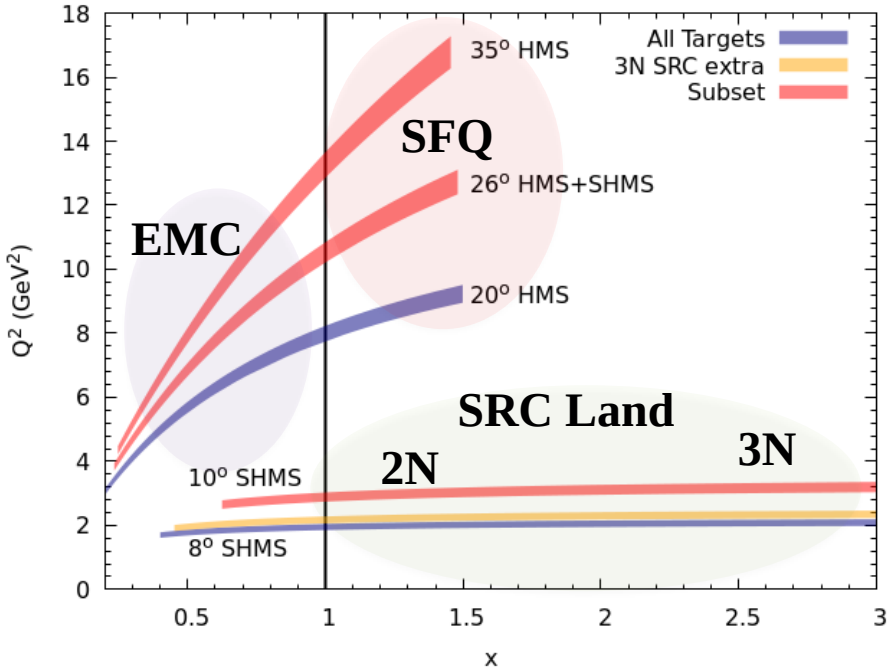


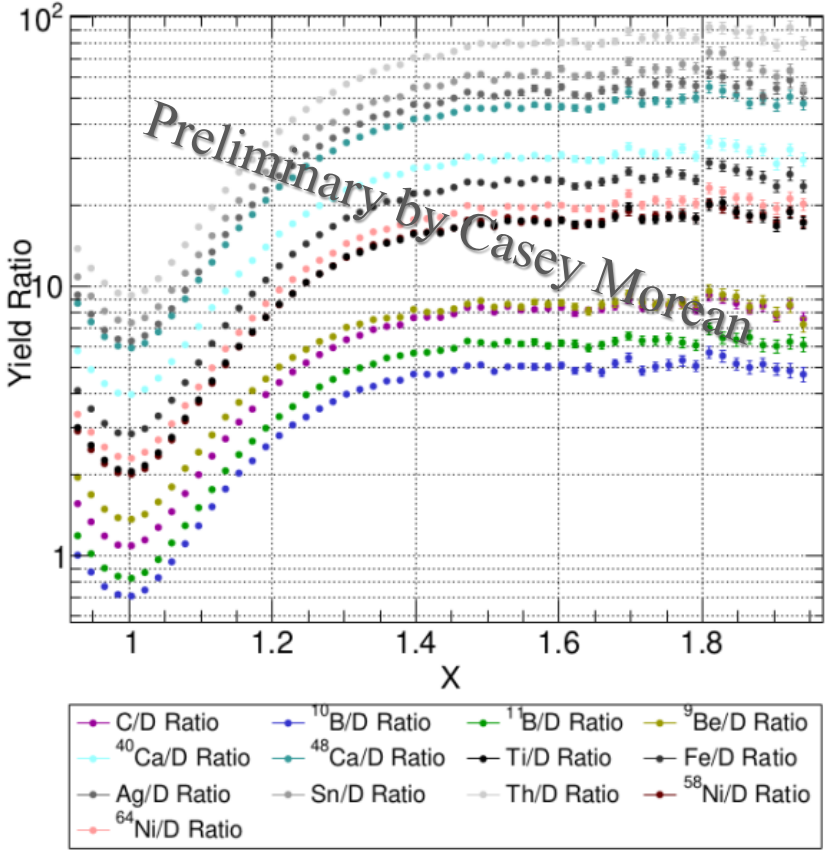


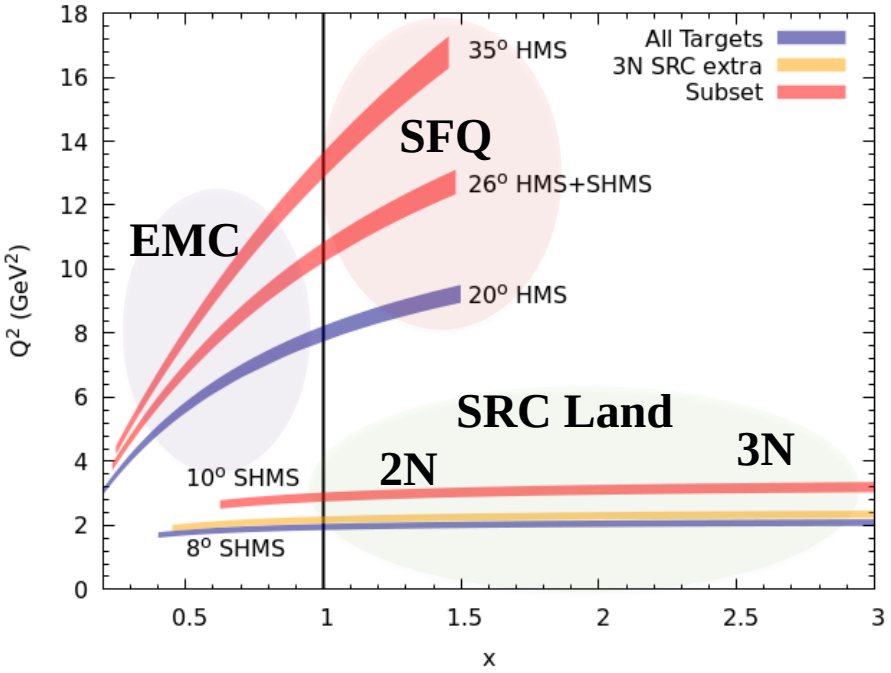
XEM2: Data taking completed

Ladder 1	Ladder 2
Hydrogen/He3	Hydrogen /He3
Deuterium/He4	Deuterium/He4
Dummy	Dummy
Optics	Optics
Carbon hole	Carbon hole
12C	12C
40Ca	6Li*
48Ca	7Li*
10B	10B
11B	11B
9Be	9Be
54Fe	Al
58Ni	Cu
64Ni	Au
Ag	1 mm
Sn	1 mm
232Thorium	1 mm
Titanium	Thicker carbon?



XEM2: 2N correlations in A/D ratios





Summary

- Studies of SRCs continue at Jlab in the 12 GeV era with inclusive Scattering
- First observation of 3N SRC existence is yet to come
- New results in the next few years!
- This work was supported by DOE Award DE-SC0013615