A proposed measurement of 3N SRC scaling plateau in inclusive scattering in Hall C, Jefferson Lab

A Proposal to Jefferson Lab PAC 54

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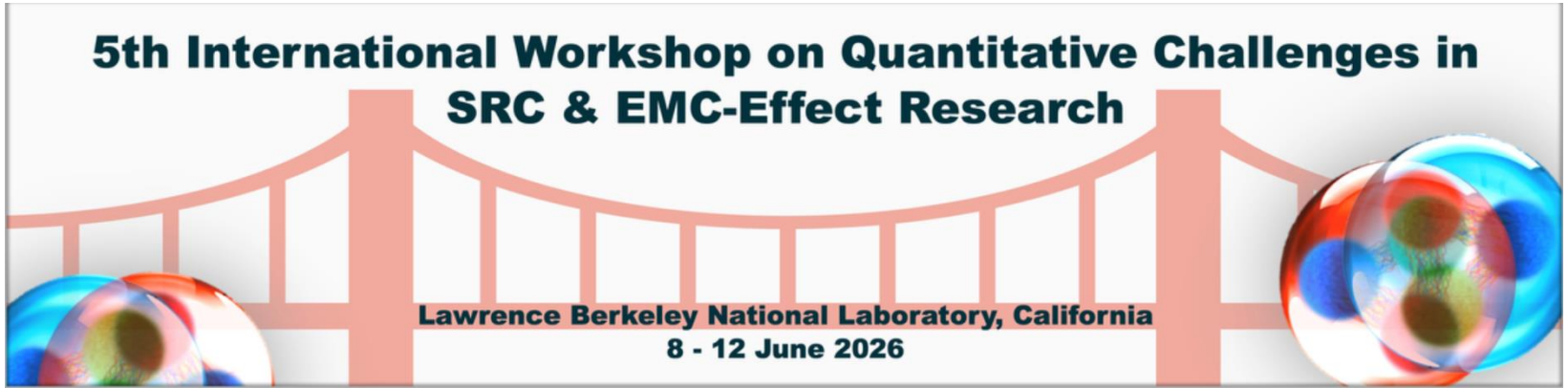
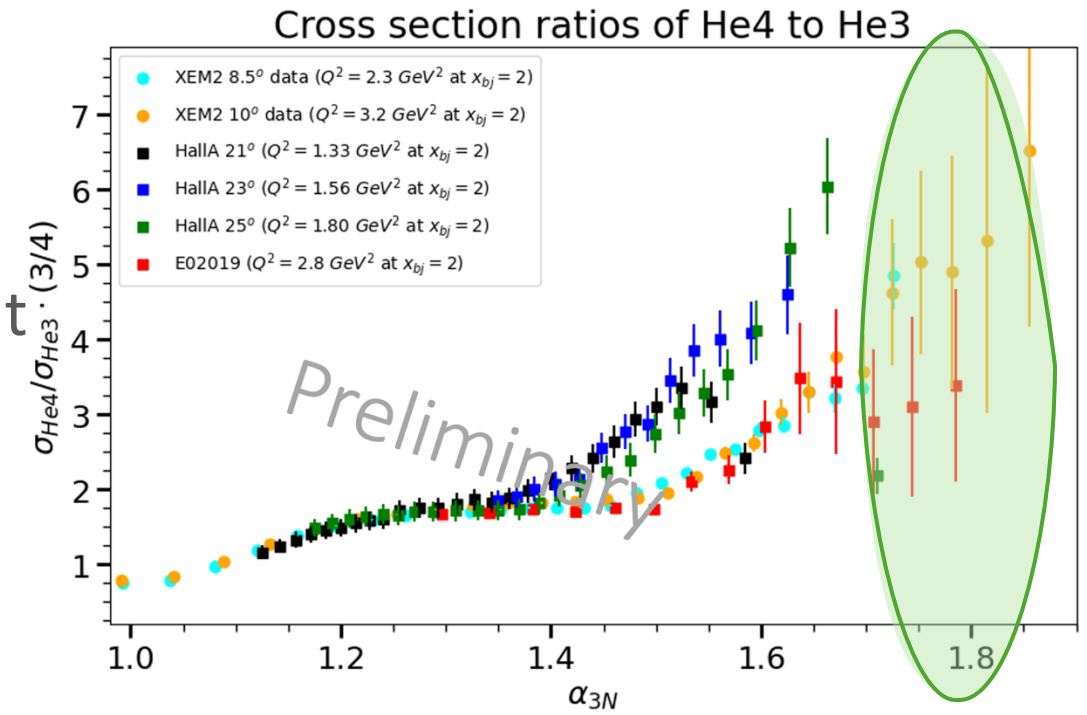


Goal: (The first) unambiguous observation of a 3N-SRC scaling plateau

- Measurement of inclusive cross-section ratios at the highest accessible Q^2 in Hall C Jefferson Lab
- Guided by recent high-precision data and theoretical predictions



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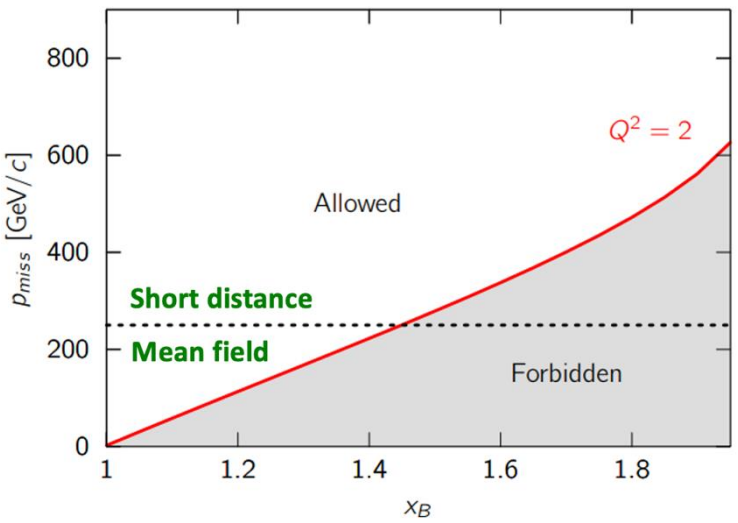
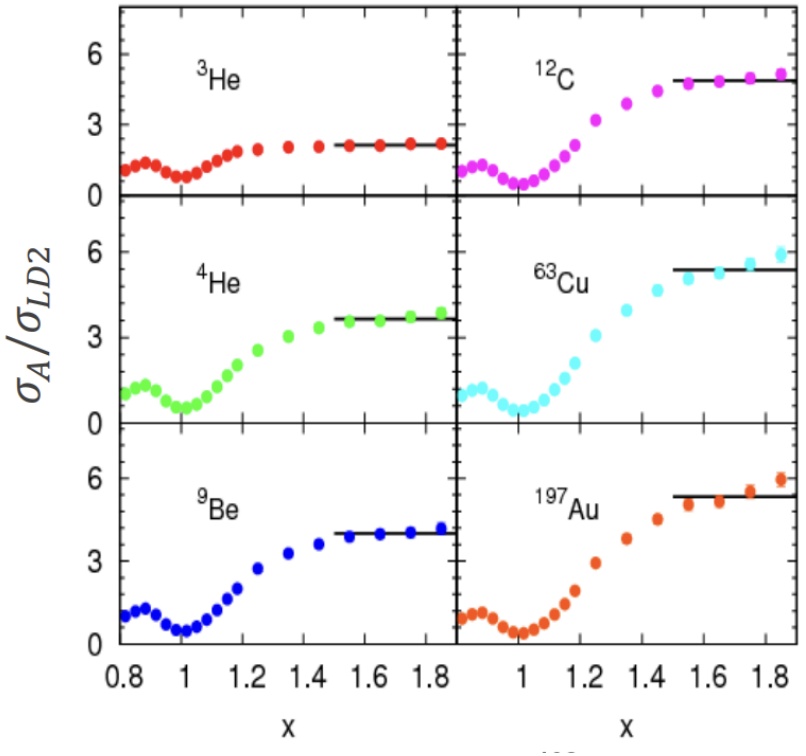
Credit: Jordan O'Kronley

Cross Section Scaling





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

At large x, mean-field region excluded, should see universal behavior from 2N-SRCs

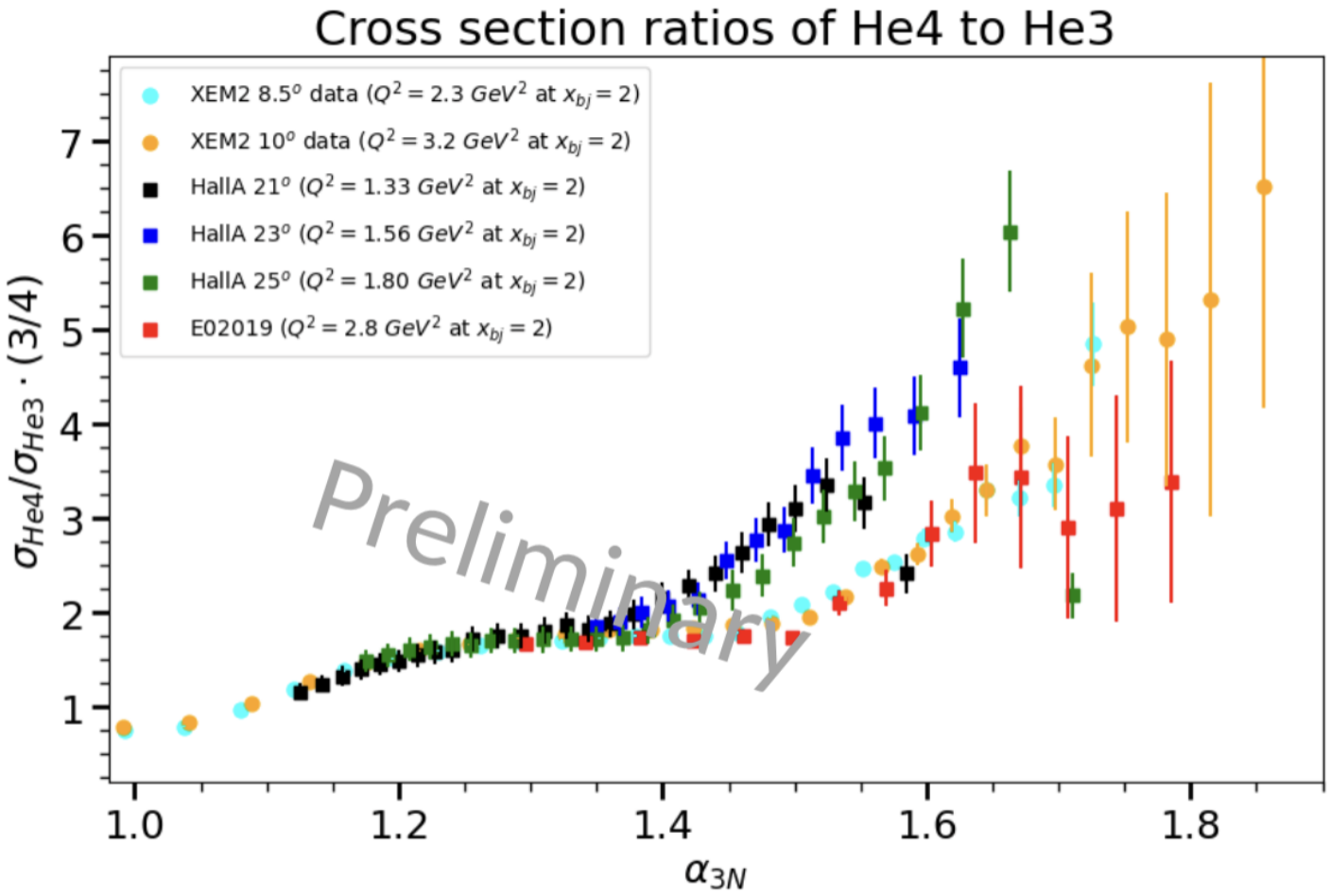
Cross section identical in all targets, A/D ratio independent of x and Q^2 (SRC CS scaling)

$$\sigma(x,Q^2) = Aa_1\sigma_1(x,Q^2) + \frac{A}{2}a_2\sigma_2(x,Q^2) + \frac{A}{3}a_3\sigma_3(x,Q^2) + \ldots$$

$$\frac{3}{A}\frac{\sigma_A(x,Q^2)}{\sigma_{^3\mathrm{He}}(x,Q^2)} = a_3(A)$$

Data in the 3N SRC region so far

Experiment	Q^2 (GeV^2)	Max α_{3N}	Targets
CLAS06 [19]	1.4	1.4	^{4}He, ^{3}He
XEM [4]	2.7	1.8	^{4}He, ^{3}He
Hall A [23]	1.5 - 1.9	1.7	^{4}He, ^{3}He
XEM2*	2.2, 3.1	1.85	^{40}Ca, ^{12}C, ^{9}Be, ^{4}He, ^{3}He



Credit: Jordan O'Kronley

Theoretical Predictions

1) Light Front

Representation of the nucleon momentum at large Q^2 values by light-cone nuclear momentum fraction carried by the struck nucleon

3N SRCs become a significant factor at $\alpha_{3N} \approx 1.6$ and are dominant starting at $\alpha_{3N} \approx 1.8$

Two successive np correlations $a_3(A,Z) \sim a_2(A,Z)^2$

Day D B, Frankfurt L L, Sargsian M M and Strikman M I 2023 Phys. Rev. C 107 014319

Frankfurt L L and Strikman M I 1981 Nucl. Phys. B181 22

2) Ab-initio

Ab-initio calculations from nuclear ground state

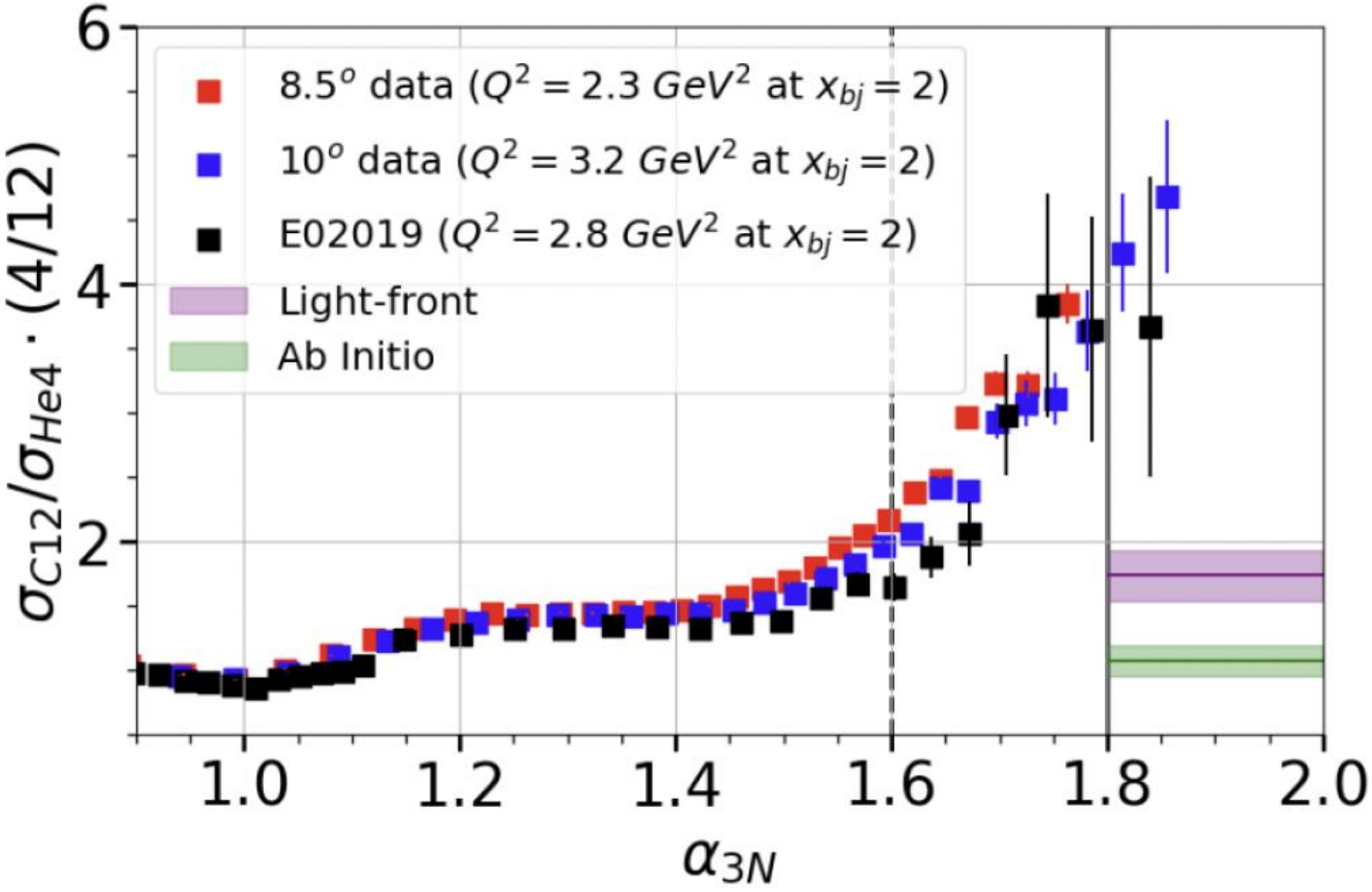
Weiss R and Gandolfi S 2023 Phys. Rev. C 10 L021301

- independent of kinematics
- three-nucleon abundances are generally independent of two-nucleon abundances

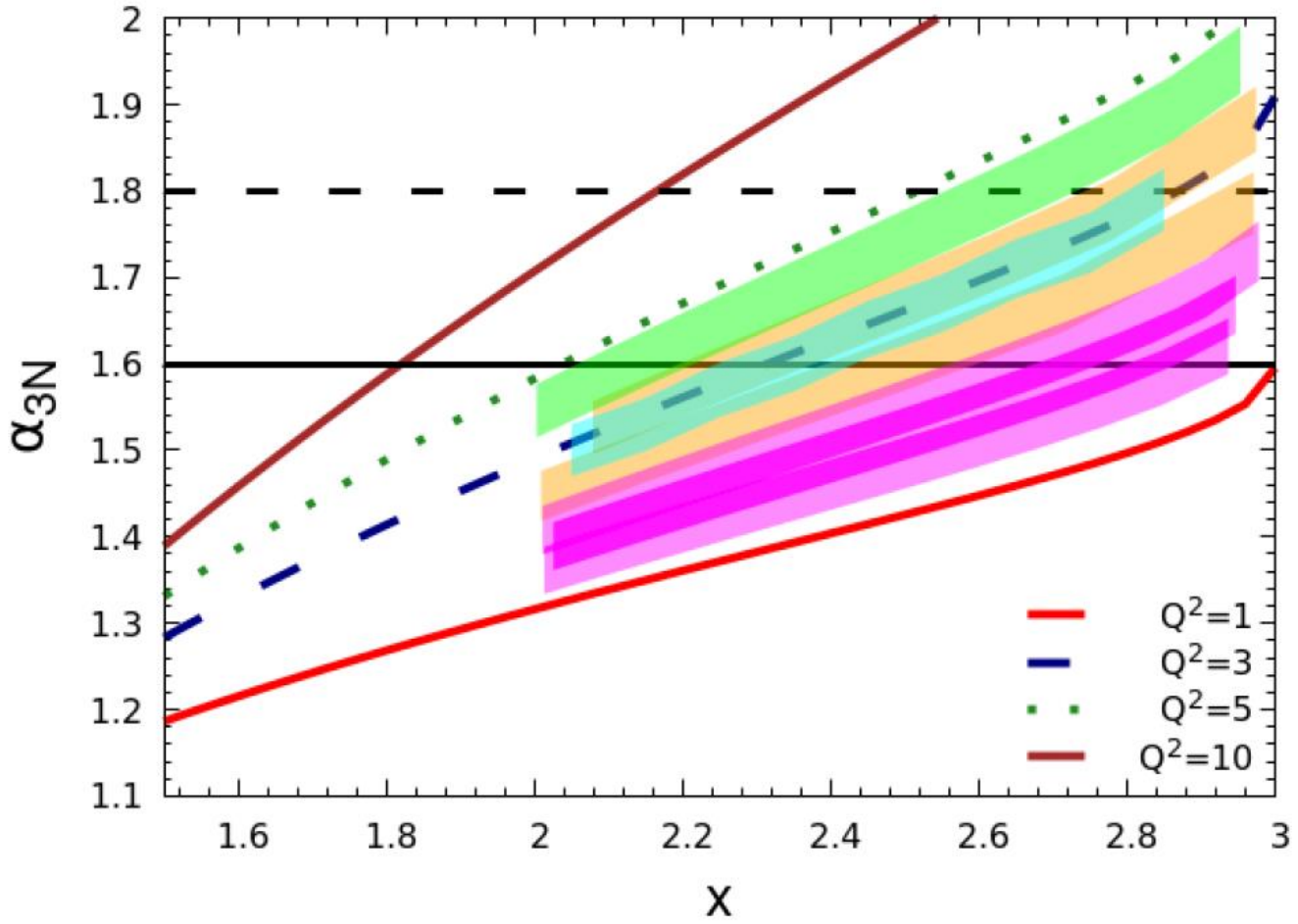
Weiss R, Bazak B and Barnea N 2015 Phys. Rev. C 92 054311

Theoretical Predictions – Comparison to Existing Data

Ratio	Ab Initio	Light-front
$^{6}Li/^{4}He$	0.82±0.1	1.06±0.2*
$^{12}C/^{4}He$	1.08±0.12	1.74 ± 0.2
$^{16}O/^{4}He$	1.11±0.16	N/A



Proposed Measurement – where do we look at?

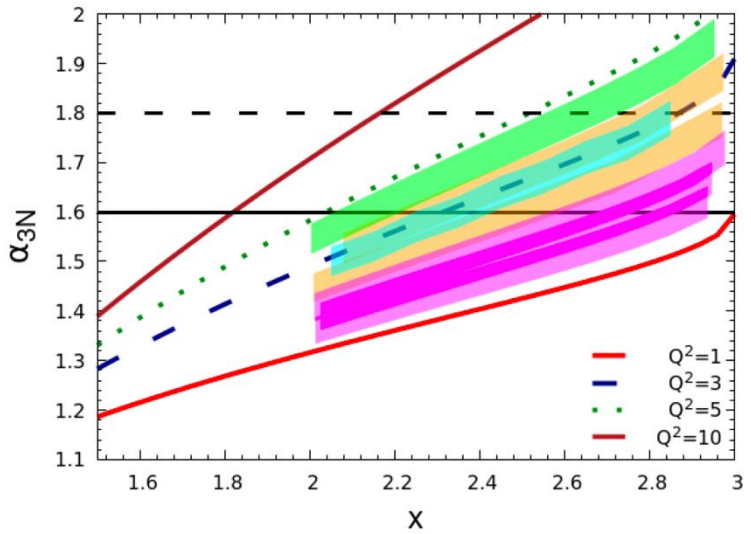


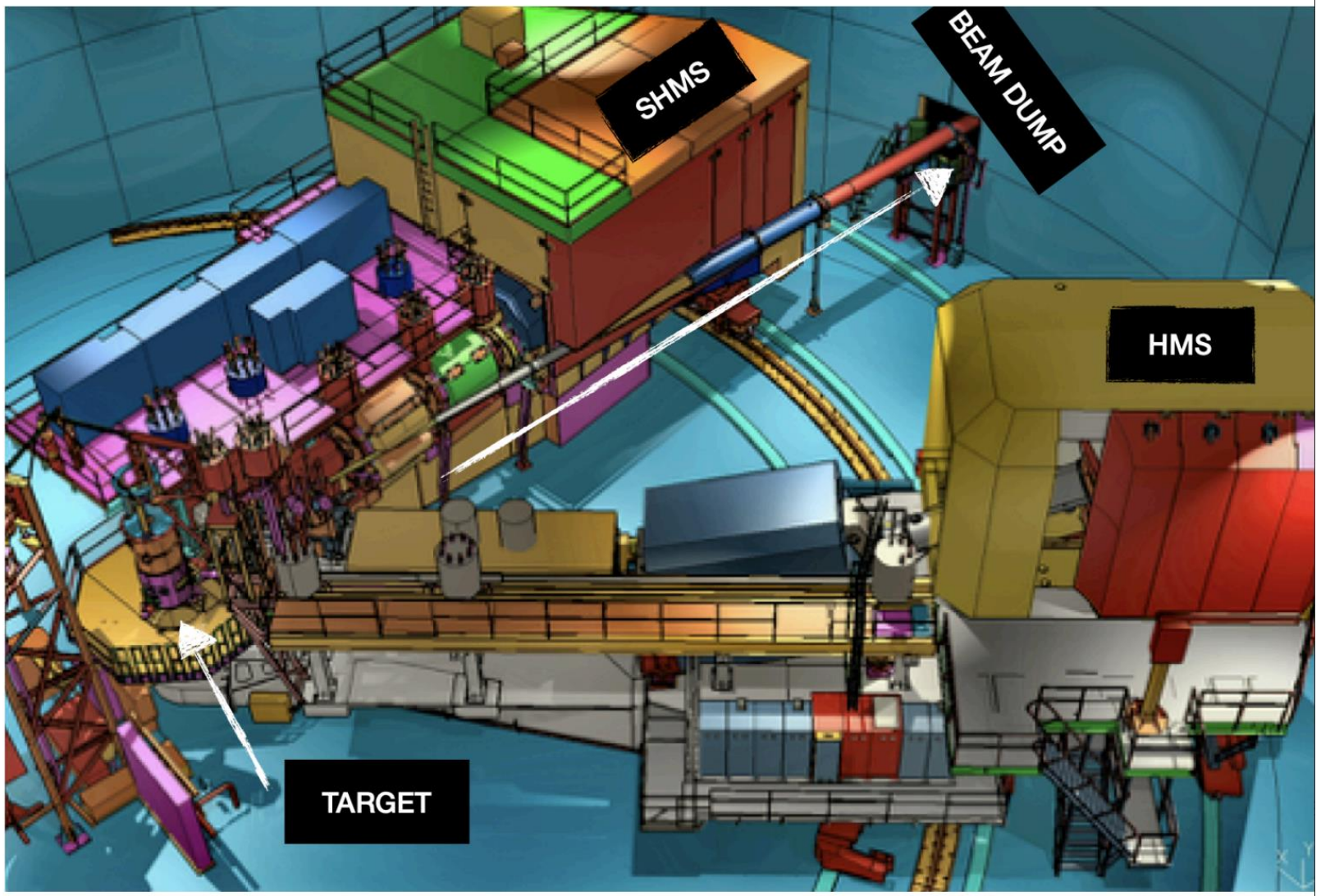
- **Hall A data**
- **Hall C 6 GeV data**
- **XEM2 data**
- **Proposed measurement**

Proposed Measurement in Hall C

Beam energy: 10.6 GeV

SHMS: 9.2 GeV, 11.5 degrees





Hall C in 12 GeV ERA

Proposed Measurement – target selection

Using ^{4}He as a “denominator” to lower systematic uncertainties

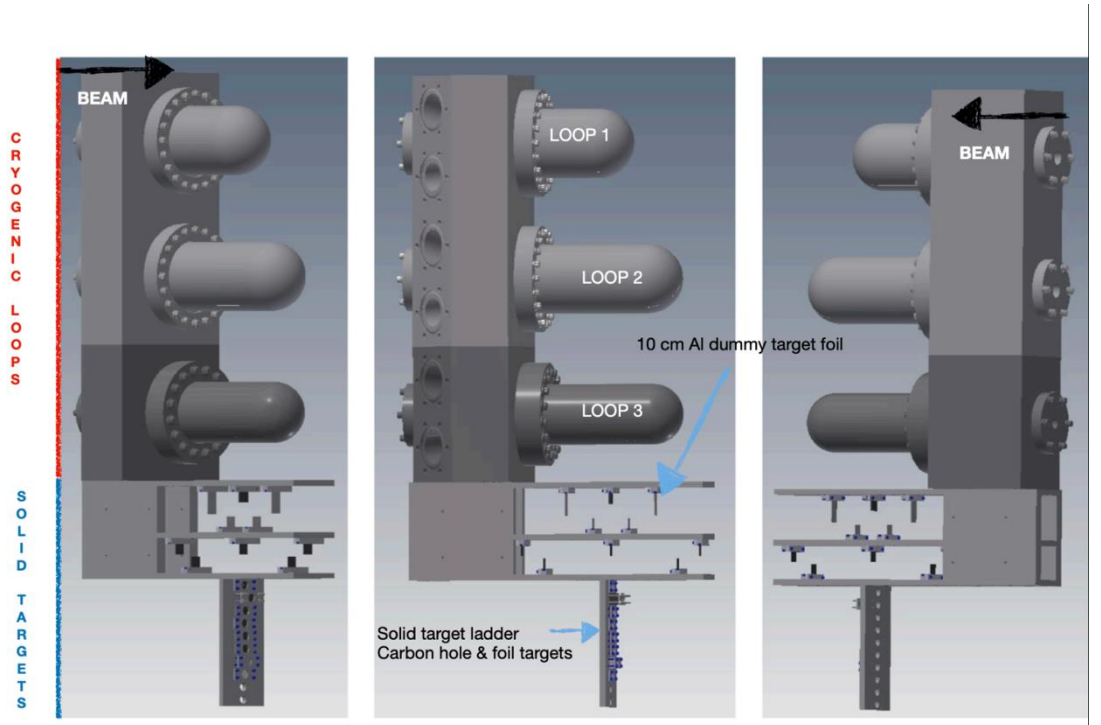
Planned to measure: $^{6}Li/^{4}He$ and $^{12}C/^{4}He$

Rapid fall-off of the ^{3}He cross section at large x

^{3}He sensitive to target related background

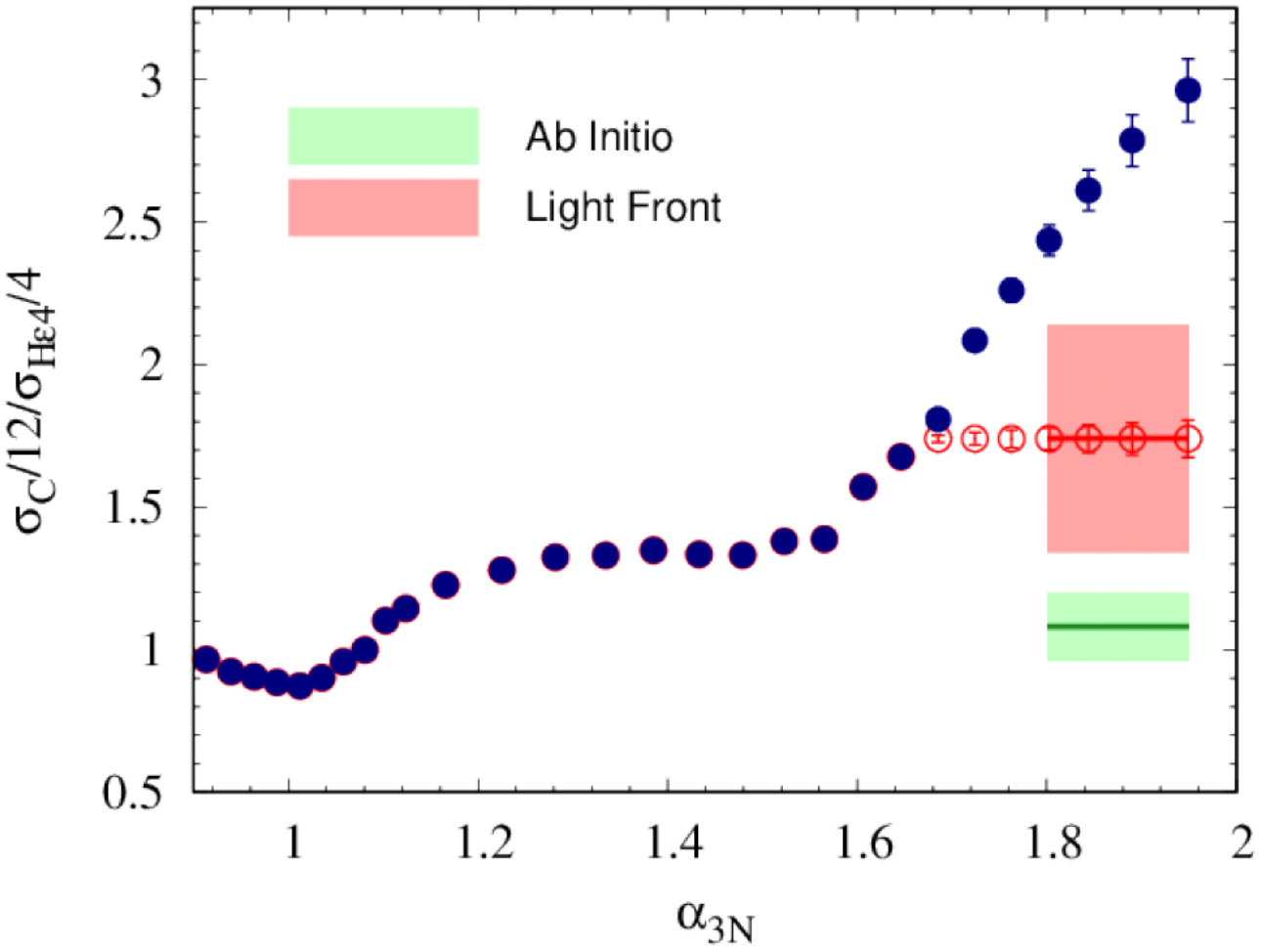
^{12}C: benchmark for comparison with existing data

^{6}Li: additional insight beyond simple scaling behavior due to clustering structure



Standard Target Configuration in Hall C

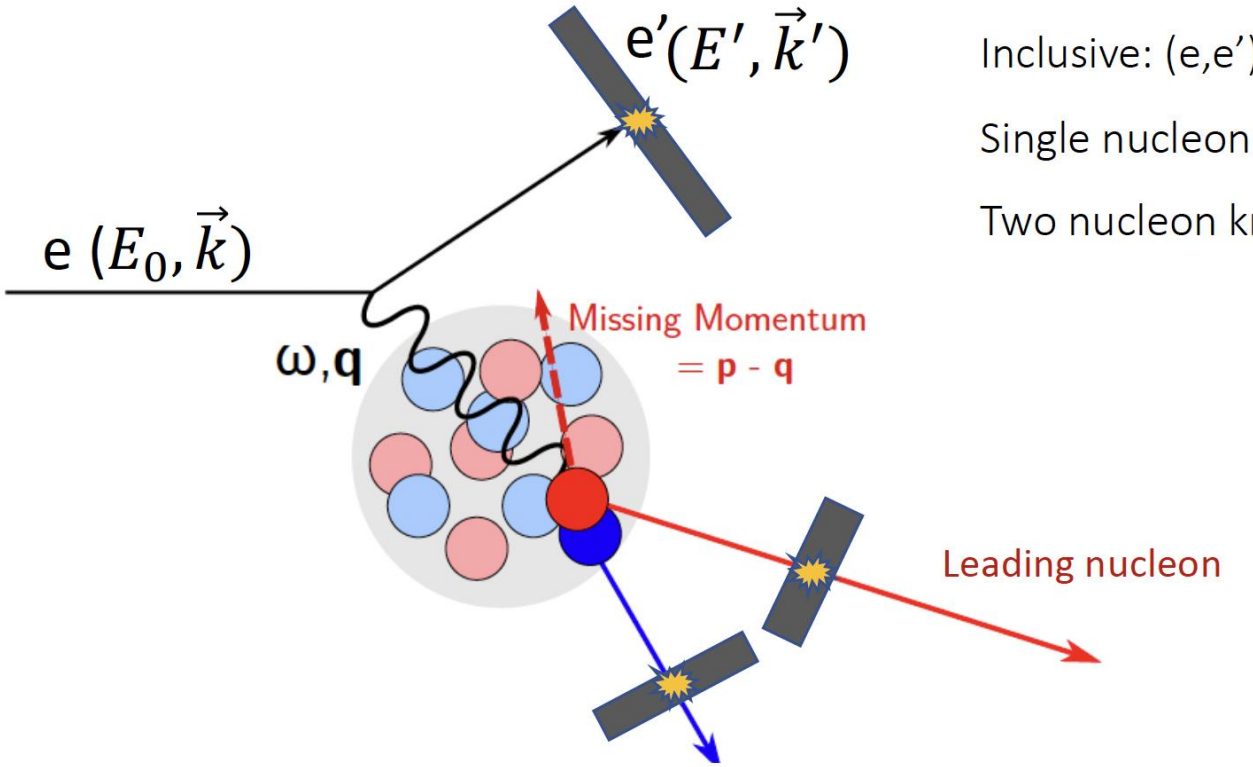
Desired Statistics



Impact

- 3N SRCs haven’t been experimentally observed
- Current data do not clearly align with theory predictions (light-front dynamics or ab initio calculations)
- A definitive measurement of the 3N-SRC scaling plateau will directly constrain these models and provide critical insight into short-range nucleon dynamics

BACK UP



Inclusive: (e,e')

Single nucleon Knockout: A(e,e'N)

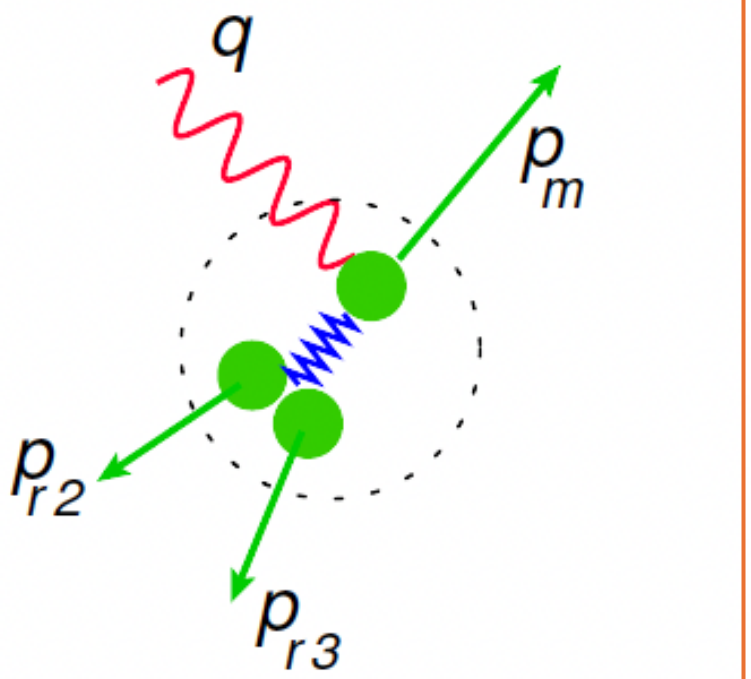
Two nucleon knock out: A(e,e'NN)

Credit: Dien Nguyen

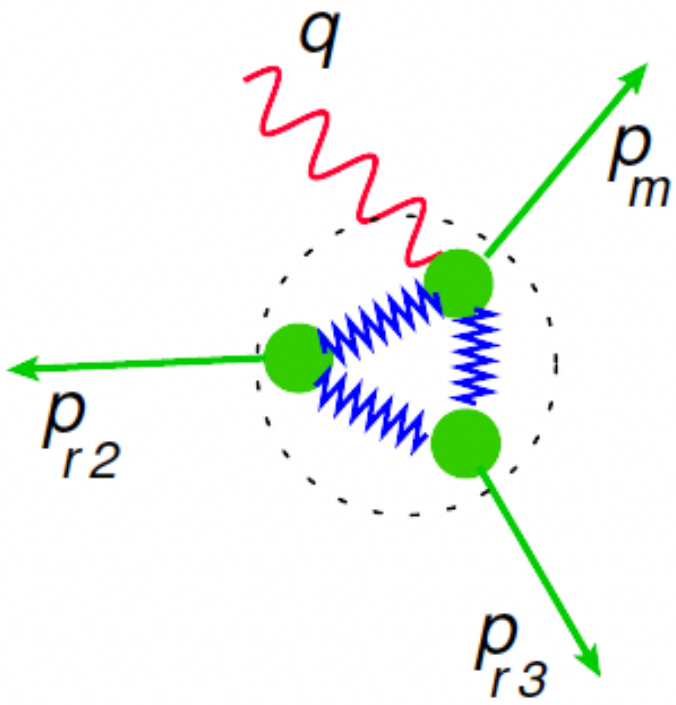
$$Q^2 = -(p_e - p'_e)^2 \qquad x_B = Q^2/2m(E - E') \qquad \vec{p}_{\text{miss}} = \vec{p}_{\text{f}} - \vec{q}$$

Quasi-elastic scattering: electron scatters elastically off an almost free nucleon

Dominating 3N SRC Configuration in Inclusive Scattering



$p_{r2}=p_{r3} \sim p_m/2$



equal momenta

D. B. Day et al, Phys. Rev. C ***107****, 014319, 2023*

Alpha 3N limit

- Informed by the onset of 2N SRC kinematics → alpha>1.3 → internal momenta of 300-350 MeV

- For 3N SRCs: p_{min} ~ 700 MeV → alpha_3N=1.6 → two high momentum spectators to belong to a 3N SRC

Systematics

Source	Scale	Point-to-Point
Trigger Eff	-	0.02%
Track Eff	0.5%	0.3%
τ_{He} (incl boiling)	1.5%**	-
τ_A	(0.5-1.0)%	-
PID cuts	-	0.2%
Ytar accep	0.5%	0.2%
Charge	0.5%	0.35%
Pion Contam.	-	N/A
Dummy sub	0.7%	0.3%
Model dependence	-	1%
Kine offsets	0.6%	0.7% (1.4% for x>1.7)
Rad Corr	0.5%	0.3%
Total	2.1 - 2.5 %	upto 2%