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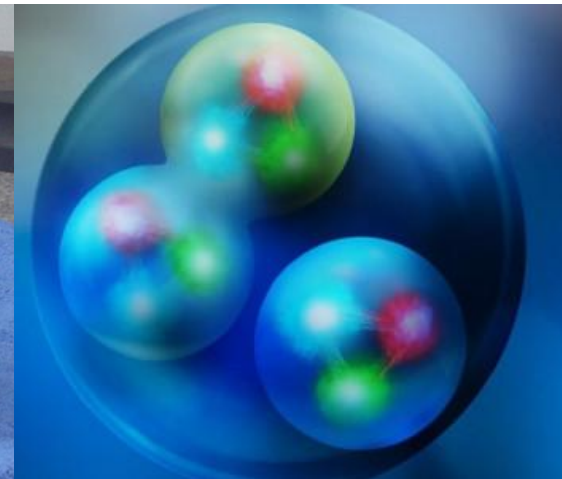
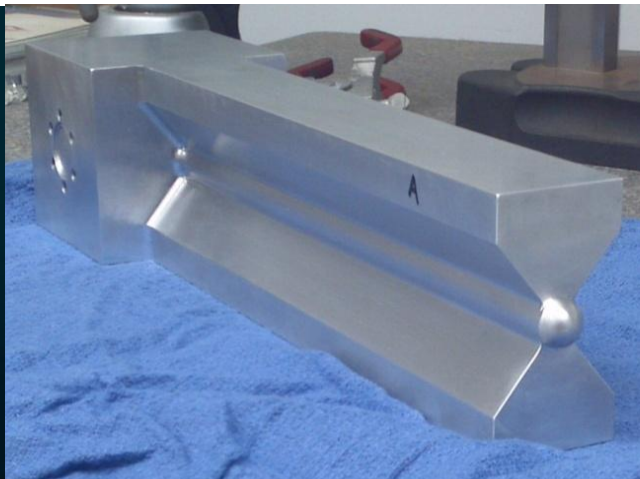
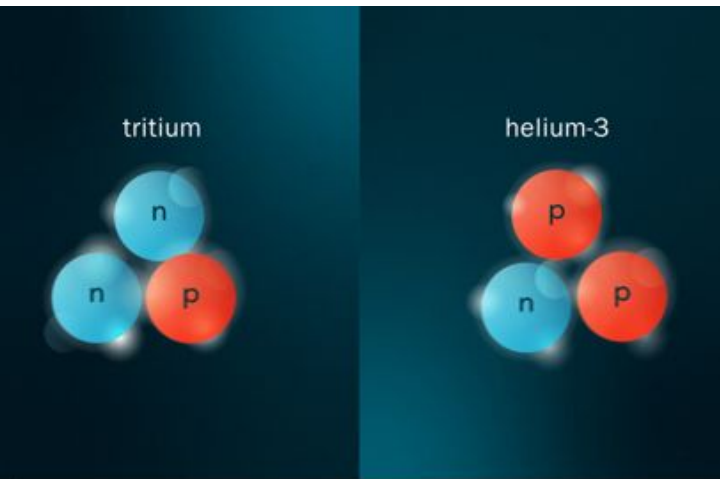
Office of Science

Scaling behaviors of Short-range Correlations in $A=3$ Systems

Shujie Li, Lawrence Berkeley National Lab

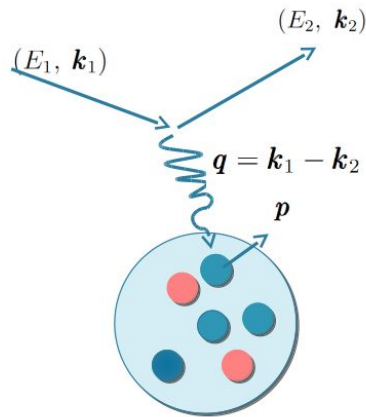
JLUO meeting

Jun 12, 2024



(e,e') x>1 data from 2018

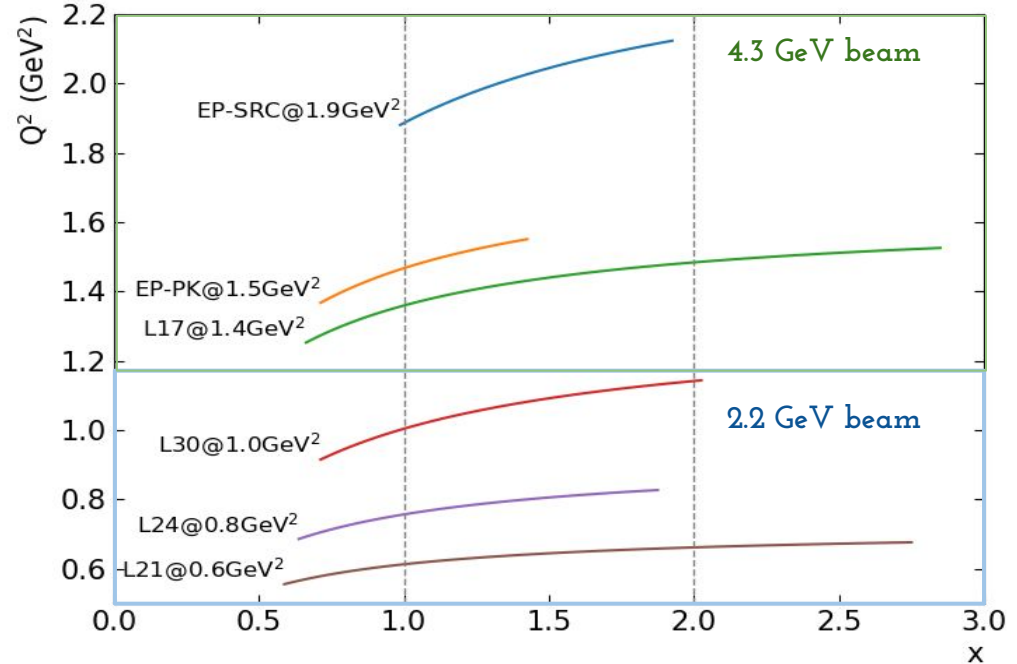
4-momentum transfer $Q^2 = -q^2$
Bjorken $x = Q^2/2m(E_1 - E_2)$



x>1: SL et al, Nature 609, 41-45 (2022)
GMn (see [Nathaly's talk](#) on Tuesday): N. Santiesteban et al, Phys.Rev.Lett. 132 (2024) 16, 162501

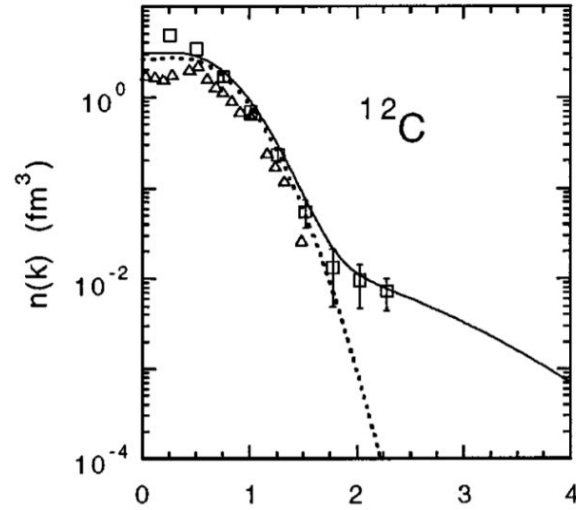
LHRS@Hall A:

Deuterium, tritium and helium-3 targets
E12-11-112 and E12-14-011



Nucleon momentum and interactions

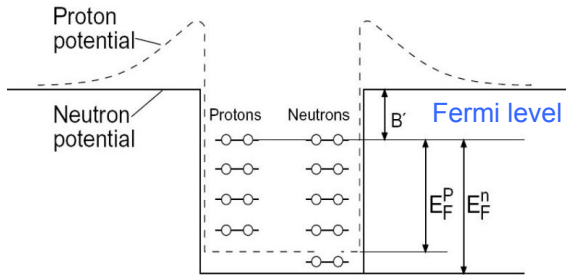
Cioffi Deali Atti. et al. PRC53. 1689 (1996)



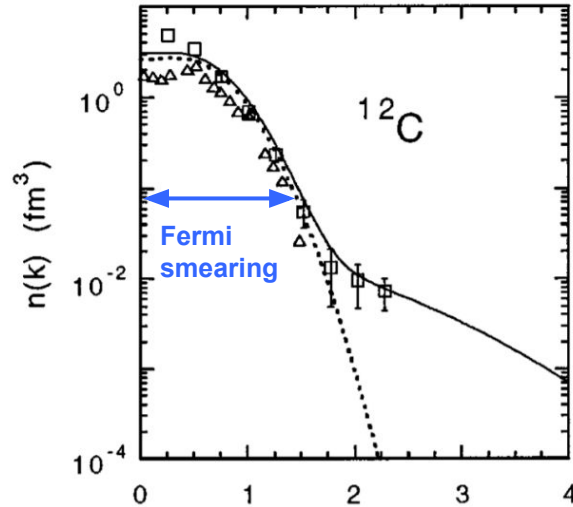
Nucleon momentum and interactions

- Independent particle shell model (“Mean field”):

nucleons move independently in an averaged potential induced by the rest of the nucleus system:



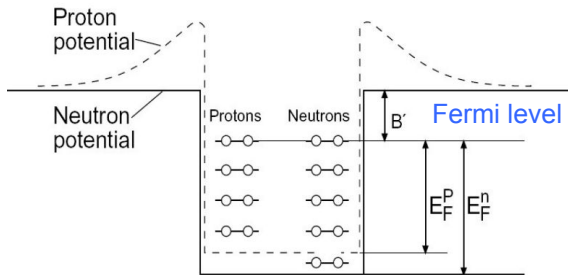
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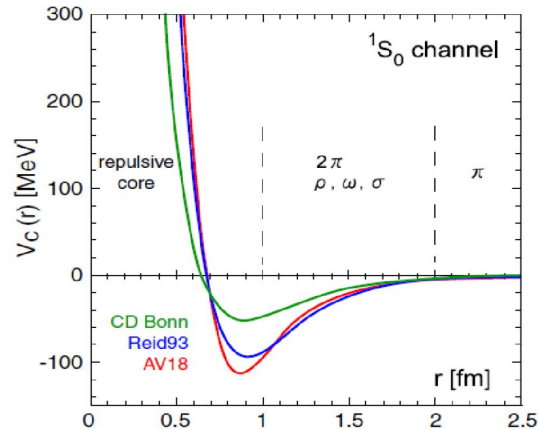
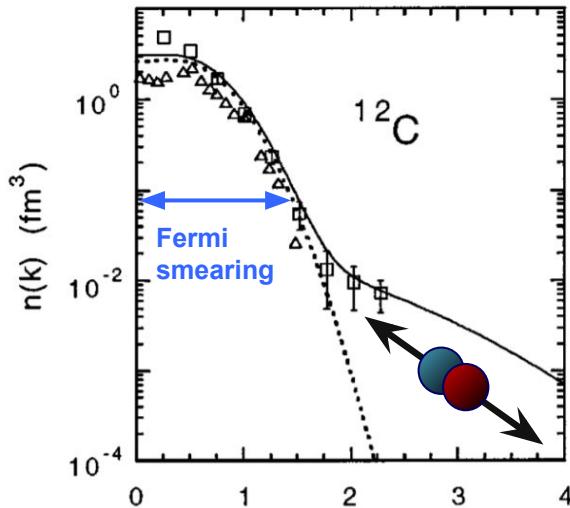
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- Nucleon-nucleon short-range correlations:**

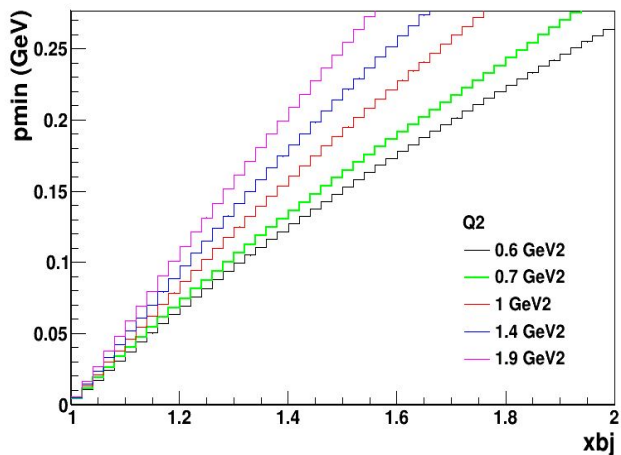
- NN pairs with large back-to-back momentum, while total $\rightarrow 0$
- T=0 deuteron-like np pair dominants due to tensor force.

Probing high momentum nucleons in (e,e')

Inclusive (e,e') scattering:

- high statistics
- background suppressed at high Q^2
- No **direct** access to initial nucleon momentum
- high x and $Q^2 \rightarrow$ high nucleon momentum

p_min: minimum momentum of the struck nucleon

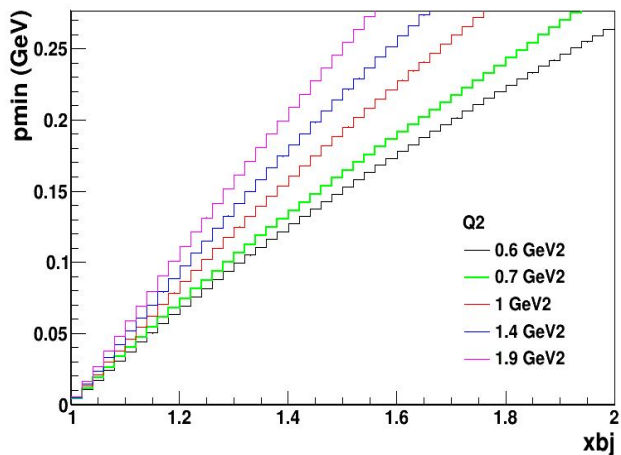


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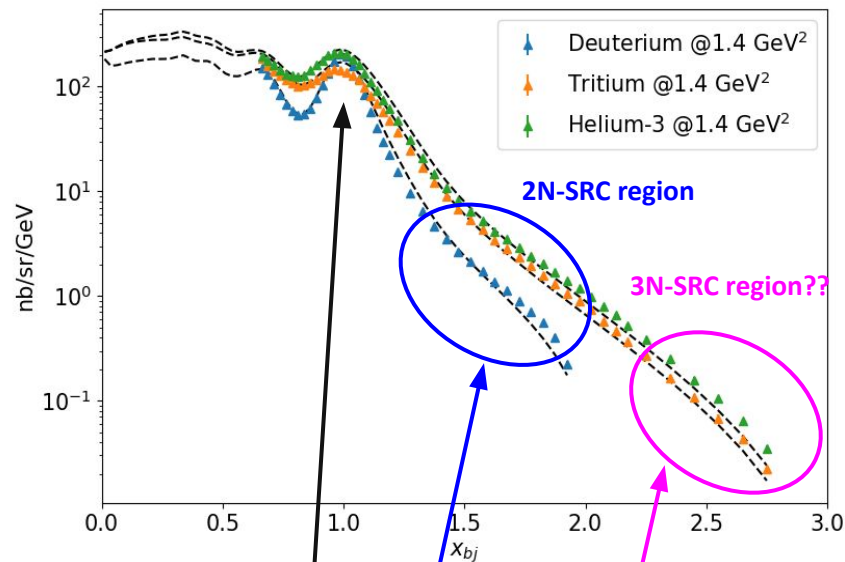
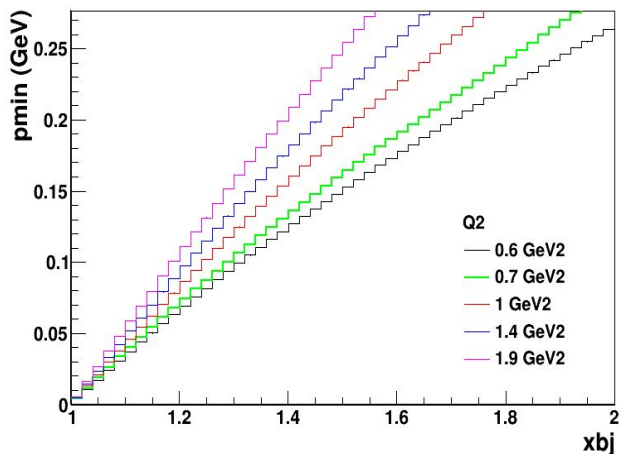


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$$\sigma_A = \sigma_{QE} + a_2(A)\sigma_2 + a_3(A)\sigma_3 + \dots$$

Vanishes quickly at $x > 1$

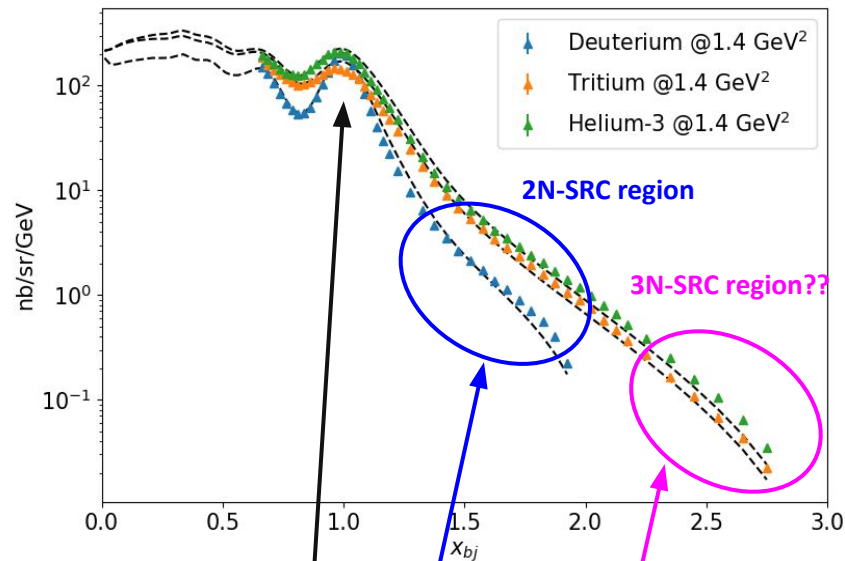
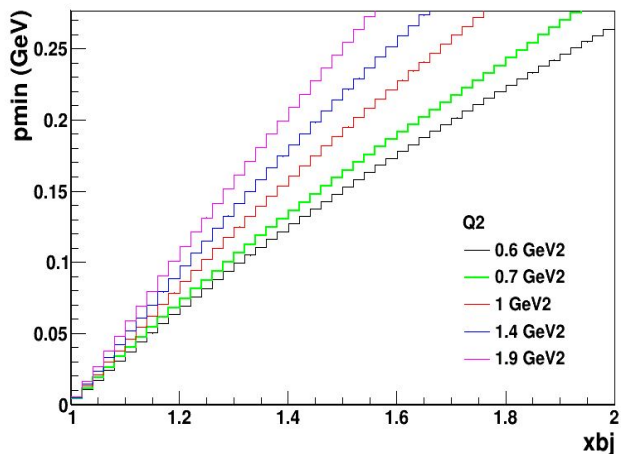
e'N contribution dominant by np pairs

Probing high momentum nucleons in (e,e')

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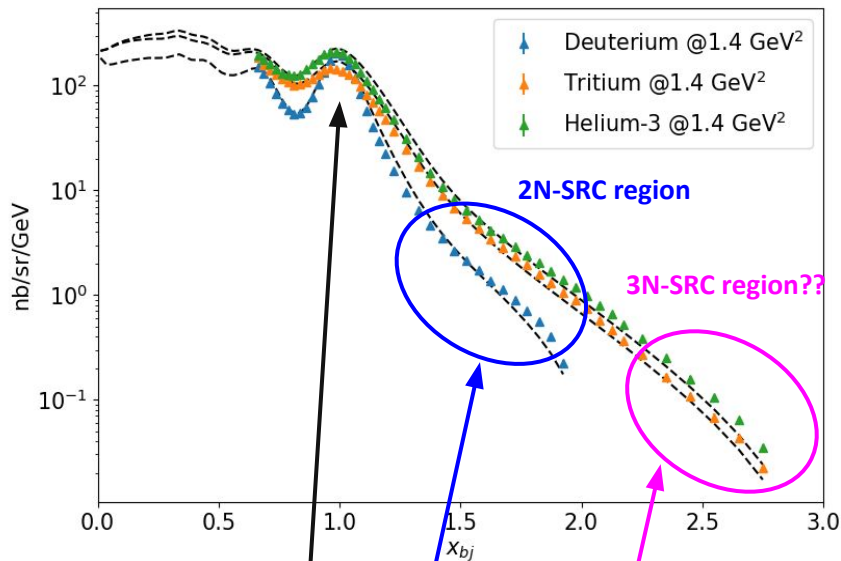
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Onset of 2N SRC scaling at $x > 1$



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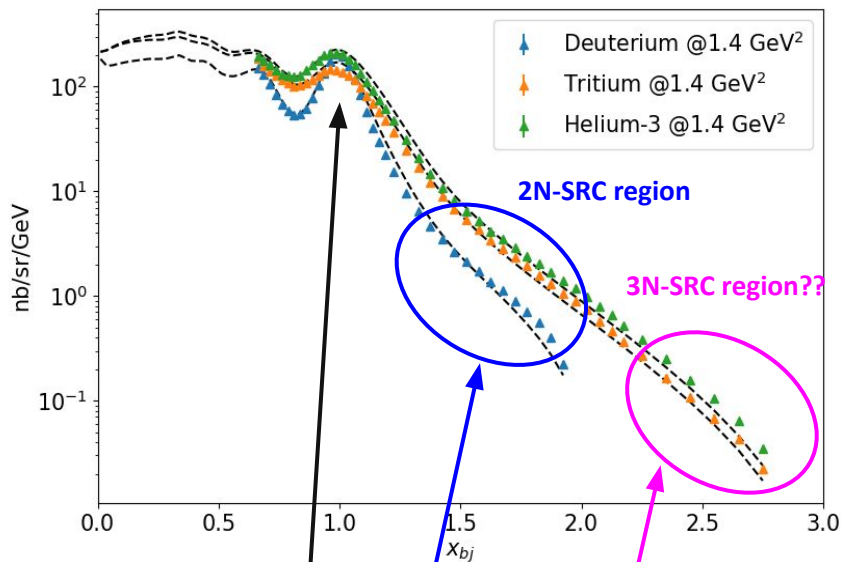
Suppression of scaling-violating behaviors:

- Meson-exchange current (MEC):
 - $1/Q^2$ suppression
- Isobar Current (IC):
 - $1/Q^2$ and $x > 1$ suppression
- Final State Interactions (FSI):
 - **exclusive:** kinematics (recoil angle etc.)
pre-selection, model-dependent corrections
 - **inclusive:** contained within the SRC pair at large Q^2



$$\frac{\sigma_A}{\sigma_{2H}} \approx \frac{a_2(A)}{a_2(^2H)} = const$$

Onset of 2N SRC scaling at $x > 1$



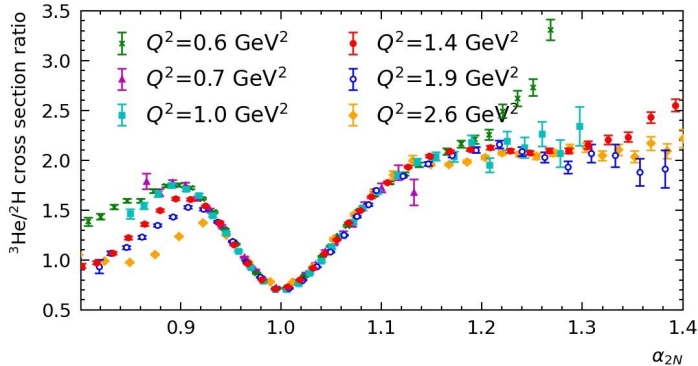
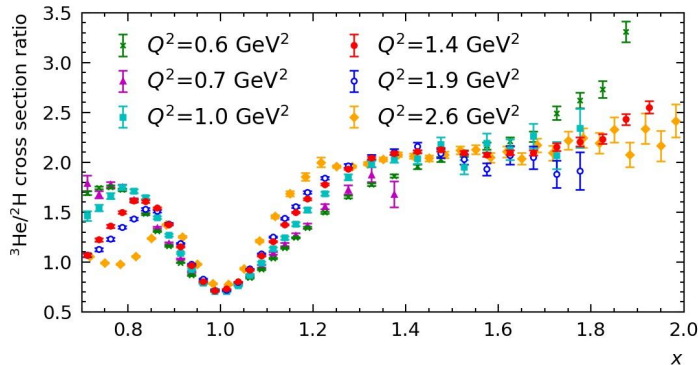
$$\sigma_A = \sigma_{QE} + a_2(A)\sigma_2 + a_3(A)\sigma_3 + \dots$$

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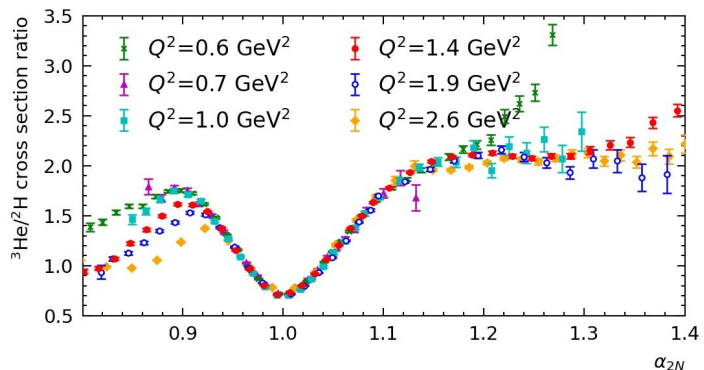
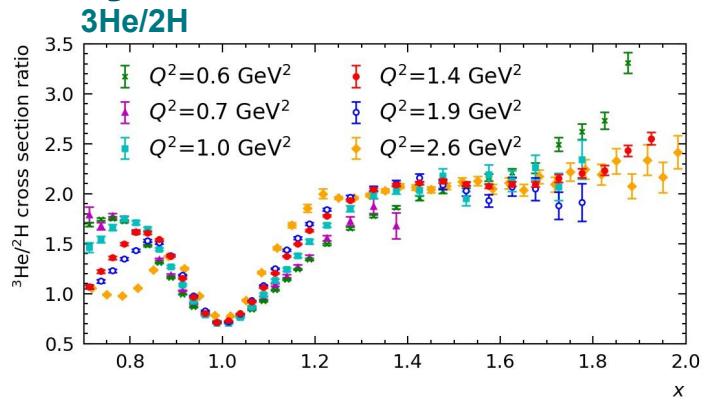


³He/²H



$$\alpha_{2N} = 2 - \frac{q_- + 2m}{2m} \frac{\sqrt{W^2 - 4m^2} + W}{W}$$

Early onset of SRC scaling

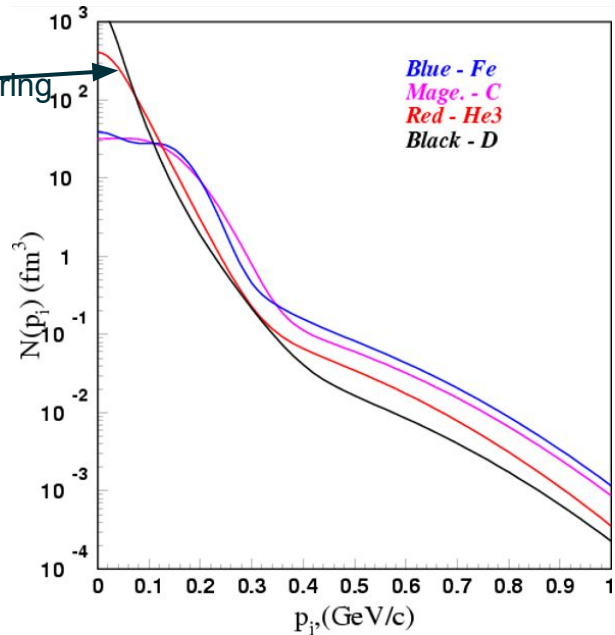


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In ${}^3\text{He}/2\text{H}$:

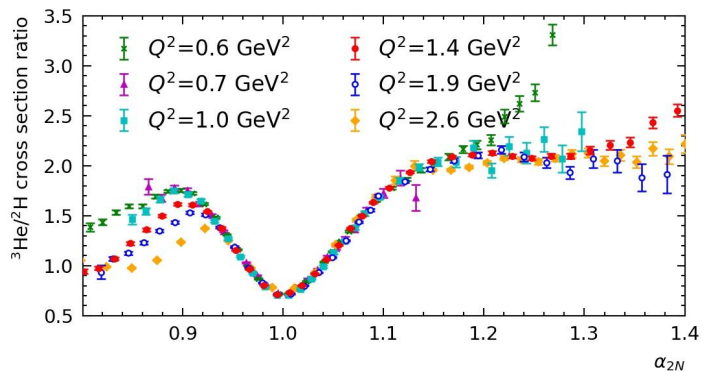
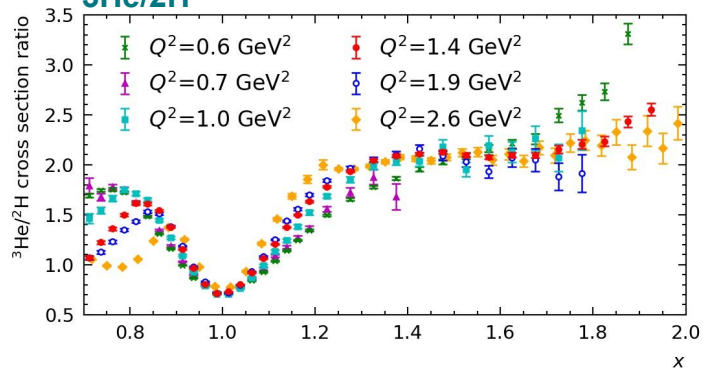
- Earlier onset in α_{2N} due to lower mean-field momenta
- Same for ${}^3\text{H}/3\text{He}$, although expect cancellation between MF contributions where it's small but not negligible
- More cancellation between FSI, CM motion \rightarrow scaling down to $Q^2 = 1 \text{ GeV}^2$
- Should be nearly complete in ratio of mirror nuclei

Narrower smearing
in light nuclei

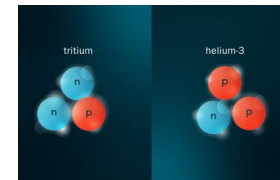


Early onset of SRC scaling

${}^3\text{He}/2\text{H}$



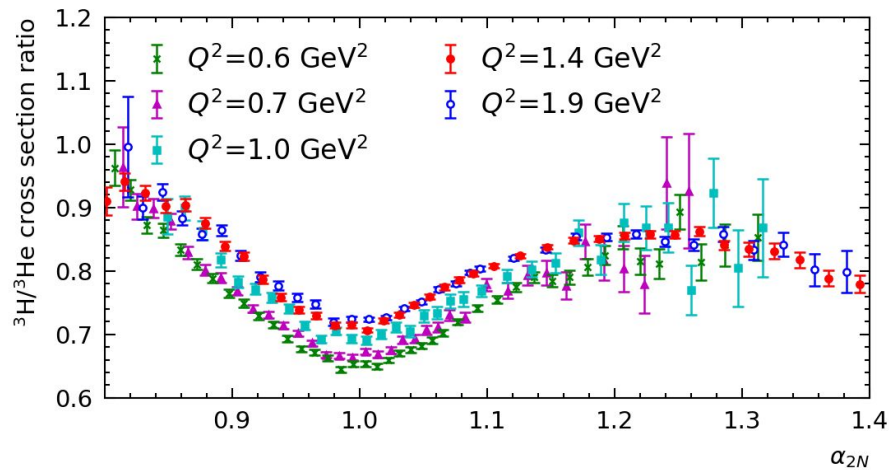
$$\alpha_{2N} = 2 - \frac{q_- + 2m}{2m} \frac{\sqrt{W^2 - 4m^2} + W}{W}$$



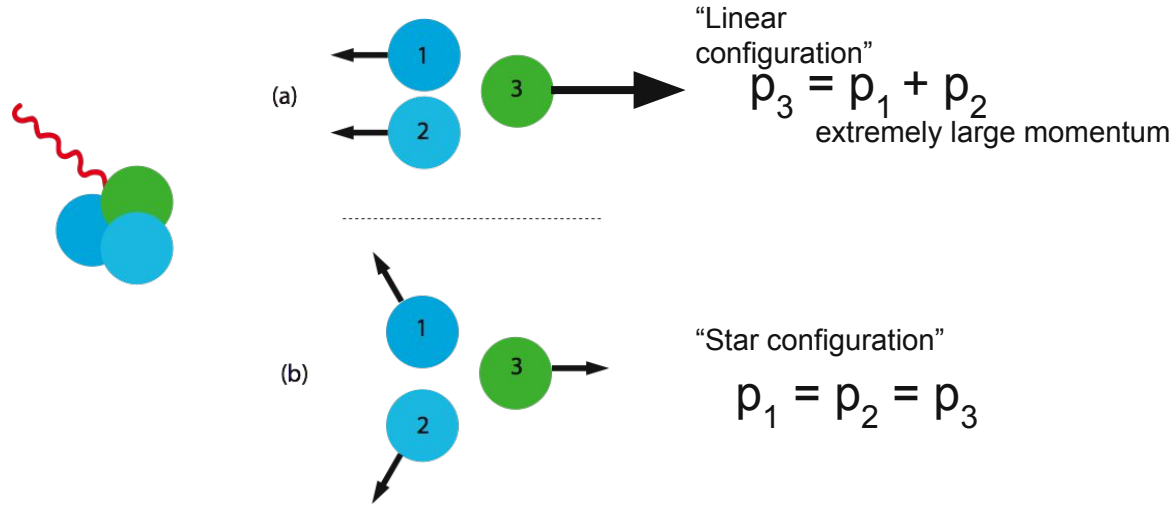
Tritium v.s. Helium-3:

- Large isospin (neutron-proton) asymmetry
- Similar separation energy: 6.26 MeV v.s. 5.49 MeV
- Small Coulomb effect: $V_{\text{eff}} = 0.66 \text{ MeV}$ v.s. 0

${}^3\text{H}/{}^3\text{He}$



Momentum-isospin correlations in $A=3$ systems



(a) yields $R(^3\text{H}/^3\text{He}) \approx \sigma_p/\sigma_n \approx 2.5$ if nucleon #3 is always the singly-occurring nucleon

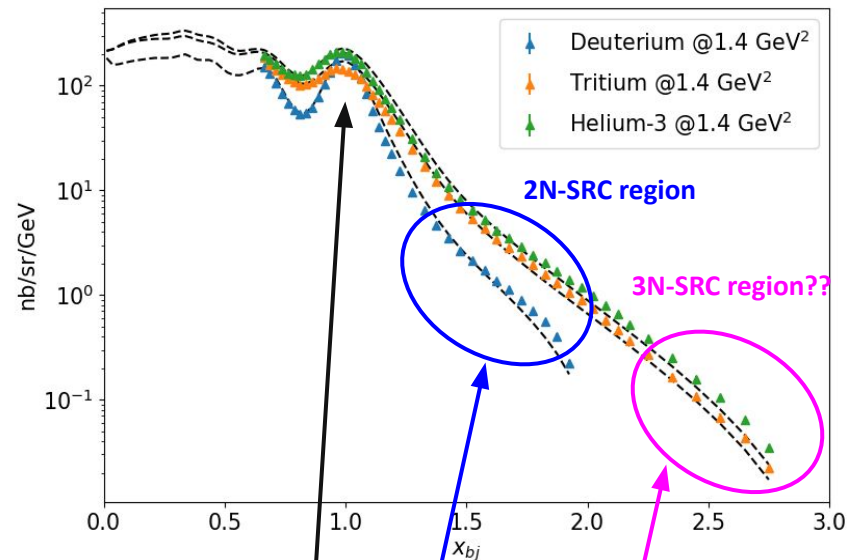
(a) yields $R(^3\text{H}/^3\text{He}) \approx \sigma_n/\sigma_p \approx 0.4$ if nucleon #3 is always the doubly-occurring nucleon

(a) yields $R(^3\text{H}/^3\text{He}) \approx 0.7$ if configuration is isospin-independent

(b) yields $R(^3\text{H}/^3\text{He}) \approx 0.7$ since all nucleons have same contribution to high-momentum component

$R \neq 0.7$ implies isospin dependence AND non-symmetric momentum sharing

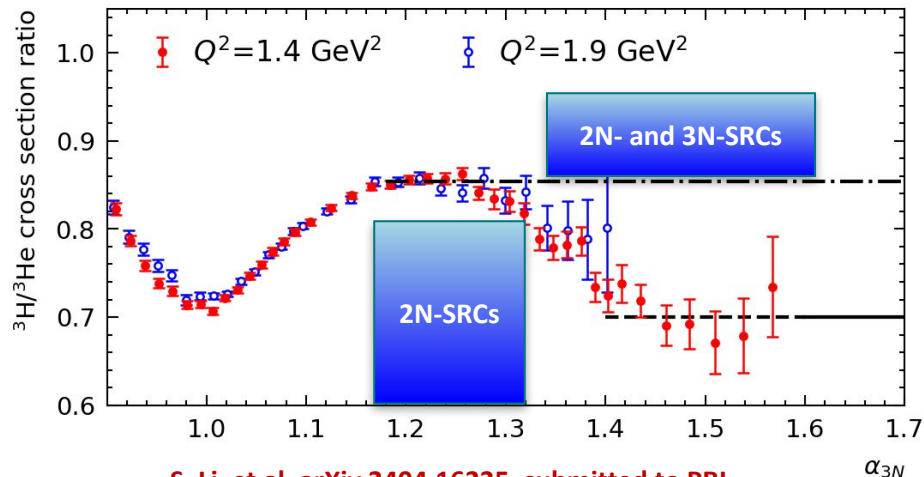
Cross Section beyond $x=2$: three-nucleon SRCs?



Beyond $x=2$ both 2N and 3N-SRCs can contribute

- $A^3\text{He}$ ratio examined for 3N-SRC dominance: plateau at $x > 2$
- No clear observation of 3N-SRCs; "need higher Q^2 values"

$^3\text{H}/^3\text{He}$ ratios show early onset of scaling in $\alpha_{3N}(x)$, and



S. Li, et al. arXiv 2404.16235, submitted to PRL

$$\sigma_A = \sigma_{QE} + a_2(A)\sigma_2 + a_3(A)\sigma_3 + \dots$$

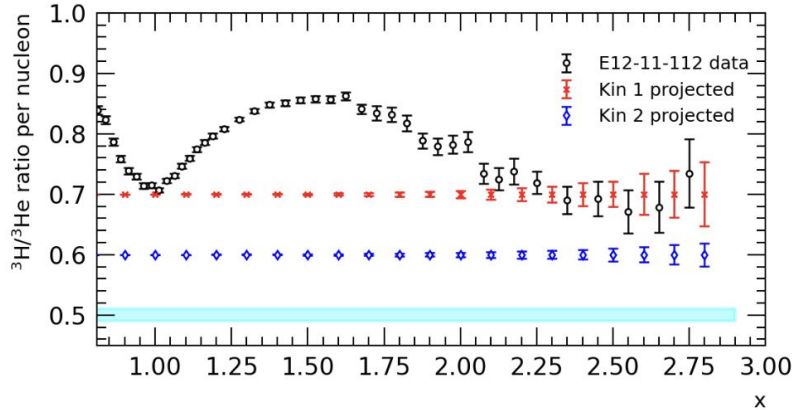
Calculations using realistic decay function predict $R=0.7$

Scaling in $A^3\text{He}$ predicted to be valid for $\alpha > 1.6$ in all nuclei*

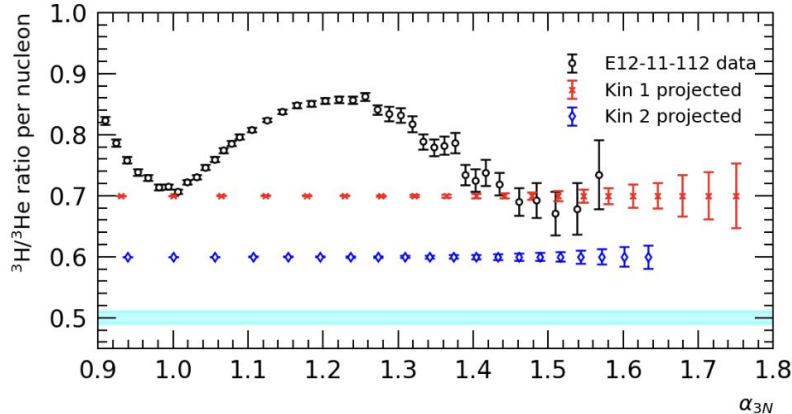
* $\alpha > 1.4$ using the same criteria for $A=3$

New PAC proposal to study 3N SRC with Tritium

PR12-24-012 projected stats



- Bring tritium target to Hall C
- 53 PAC days
- Higher momentum, smaller angle with SHMS
- higher $Q^2 \rightarrow$ larger α
- more DIS (n/p) measurements at large x , and more potentials...



Isospin structure of 3N short-range correlations and the nucleon structure functions in ${}^3\text{H}$ and ${}^3\text{He}$

A Proposal to PAC 52

May 1, 2024

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 S. Li (co-spokesperson and contact)
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Florida International University, Miami, FL

Thank you!

np/pp pair ratio v.s.A

