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# Probing 3N-SRCs with Tritium and Helium-3

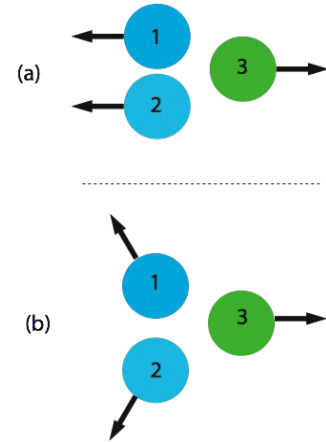
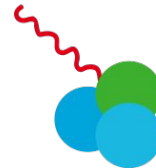
Shujie Li

SRC-EMC Workshop 2026 @ LBNL

June 11, 2026

# Probing 3N-SRCs with Tritium and Helium-3 via inclusive $(e,e')$ scattering at JLab

- Hints/surprise from existing data
  - Early onset of scaling and second plateaus
  - Momentum and isospin structure of 3N
- New Proposal
  - Same target, Hall A  $\rightarrow$  Hall C
  - higher  $Q^2$ , higher alpha
  - Designed to provide answers

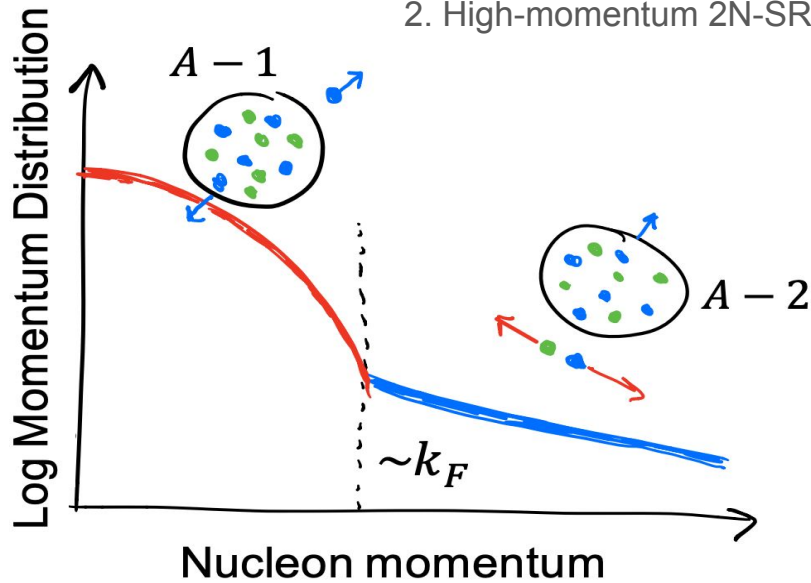


# Short-range Correlations 1, 2, 3...

Established picture:

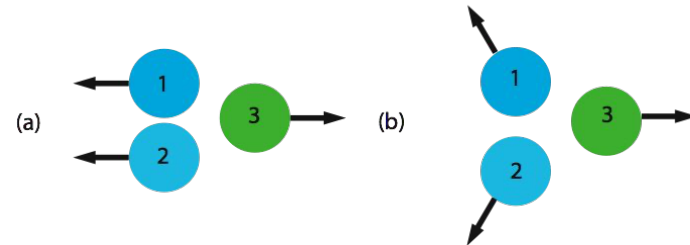
1. Mean field single nucleon

2. High-momentum 2N-SRC pairs.



Search for 3N SRC:

- Predicted to become dominant at higher momentum
- Isospin configuration?
  - ppp, nnn, ppn, nnp
- Momentum configuration?



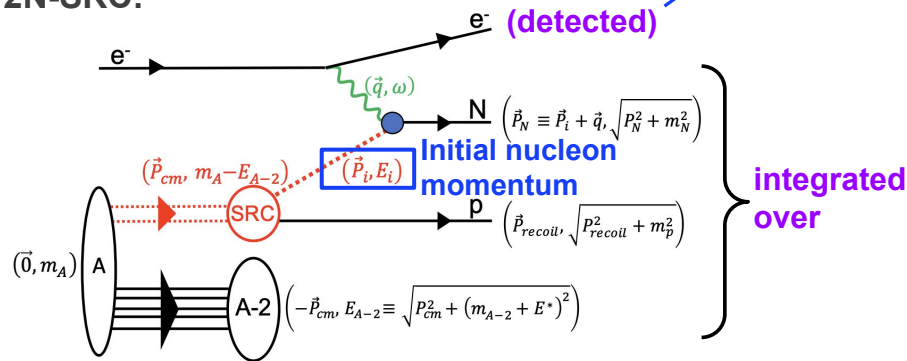
- Mechanism?

# Background: probing high momentum nucleons in (e,e')

- Electron knocks out nucleon quasi-elastically
- “Inclusive”: detect e' only, integrate over final state

Use scattered electron kinematics to select reactions involve nucleon with **high initial momentum**

2N-SRC:

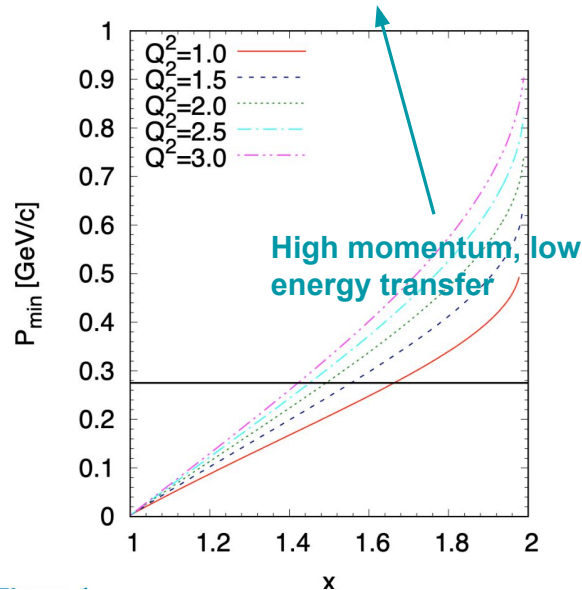


**Conventional cuts:**

Momentum transfer  $Q^2 > 1.4 \text{ GeV}^2$

Bjorken  $x > 1.4$

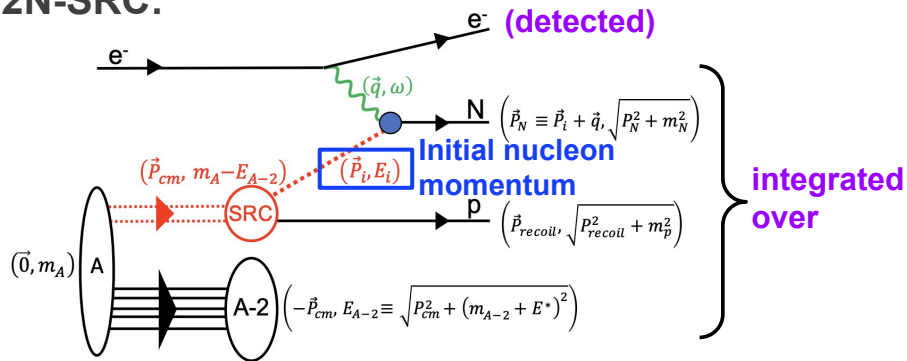
$\Rightarrow \min(p_{ini}) := p_{min} > k_F \Rightarrow 2N \text{ SRC dominant}$



# Background: probing high momentum nucleons in (e,e')

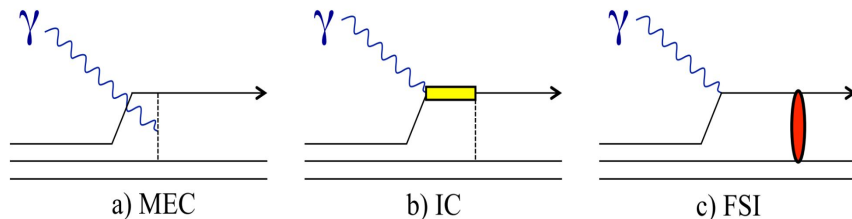
- Electron knocks out nucleon quasi-elastically
- “Inclusive”: detect e' only, integrate over final state

## 2N-SRC:



## Competing processes:

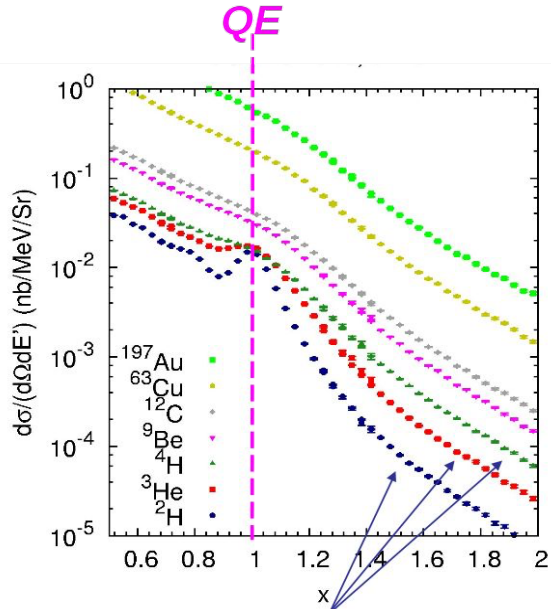
- Meson-exchange current (MEC):
  - $1/Q^2$  suppression
- Isobar Current (IC):
  - $1/Q^2$  and  $x > 1$  suppression
- Final State Interactions (FSI):
  - contained within the SRC pair at large  $Q^2$



# Background: 2N SRC Scaling

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

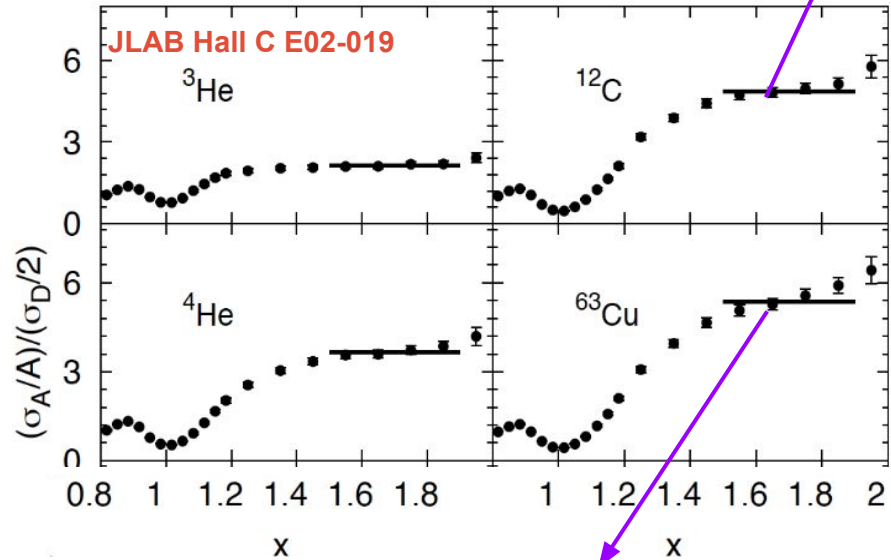
$a_2(^{12}\text{C})$  x fraction of high-momentum nucleons in deuteron  $\Rightarrow$  20% SRC pairs in  $^{12}\text{C}$



High momentum tails should yield constant ratio if SRC-dominated

N. Fomin, et al., PRL 108 (2012) 092052

## Plateaus in A/D cross section ratio



Smearred plateau due to center-of-mass motion, non-ground state configuration etc

# Background: Previous Searches for 3N-SRC Scaling

## Methods:

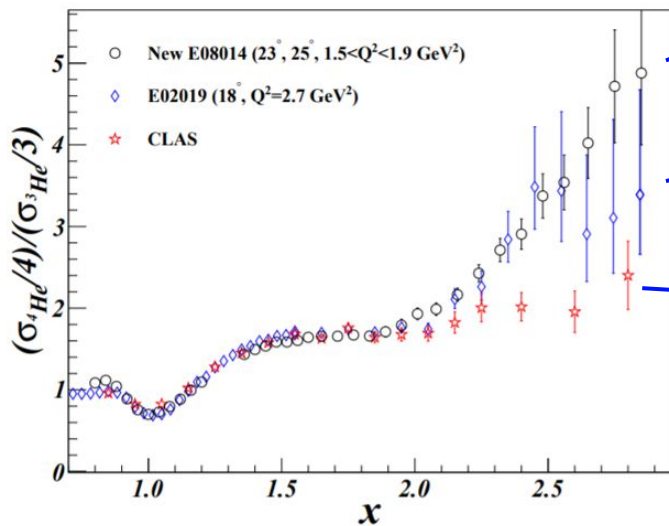
- In  $(e,e')$ , looking for  $A/{}^3\text{He}$  plateaus at  $x > 2$ , high  $Q^2$

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

- No positive signal so far (\*See Jordan and Burcu's talks for ongoing studies)
- Was suggested to go  $>5 \text{ GeV}^2$  for a clean isolation of 3N SRC

## Challenges in $A/{}^3\text{He}$ scaling search:

${}^3\text{He}$  is just one of four possible 3N configurations



No scaling observed. Theorists suggested scaling at higher  $Q^2$

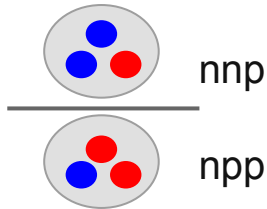
Stats too low due to high  $Q^2$

Claimed to see a plateau of scaling, but later identified as bin-migration effects.

# Our Approach: 3N SRC with A=3 Mirror Nuclei

## Tritium v.s. Helium-3:

- Clean 3N isospin structure. Can construct the isoscalar average



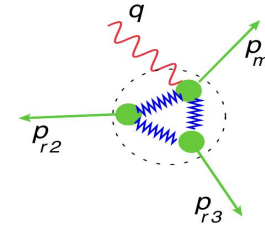
- Clean and guaranteed momentum sharing between 3 nucleons without the ambiguity from center-of-mass motions and long-range FSI.
- Nuclear effects, final-state interactions, and other competing processes cancelled in ratios
- Small Fermi motion  $\rightarrow$  mean field contribution drops fast
- Calculable\* few-body systems  $\rightarrow$  provide a clean benchmark for theory used in neutrino/nuclear reaction modeling

feasible to detect scaling at lower  $Q^2$

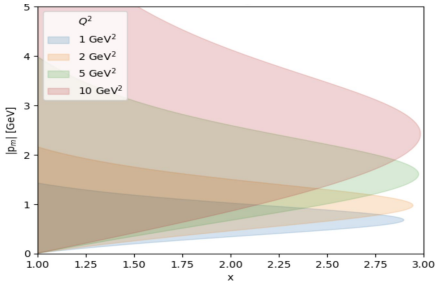
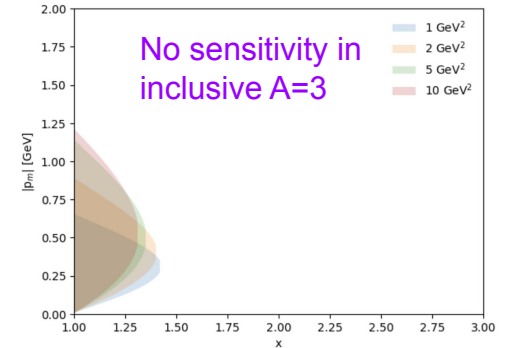
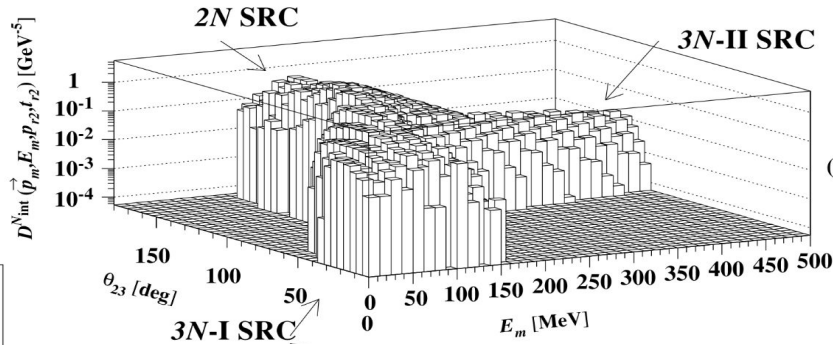
# Momentum Sharing in A=3

3He decay function from electro-disintegration  $eA \rightarrow e' + p + p + n$ :

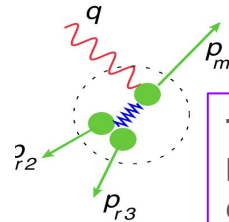
Sargsian, Abrahamyan, Strikman, Frankfurt, PRC 71, 044615 (2005)



(a) **Type II (star):** large angle between recoils, high Emiss



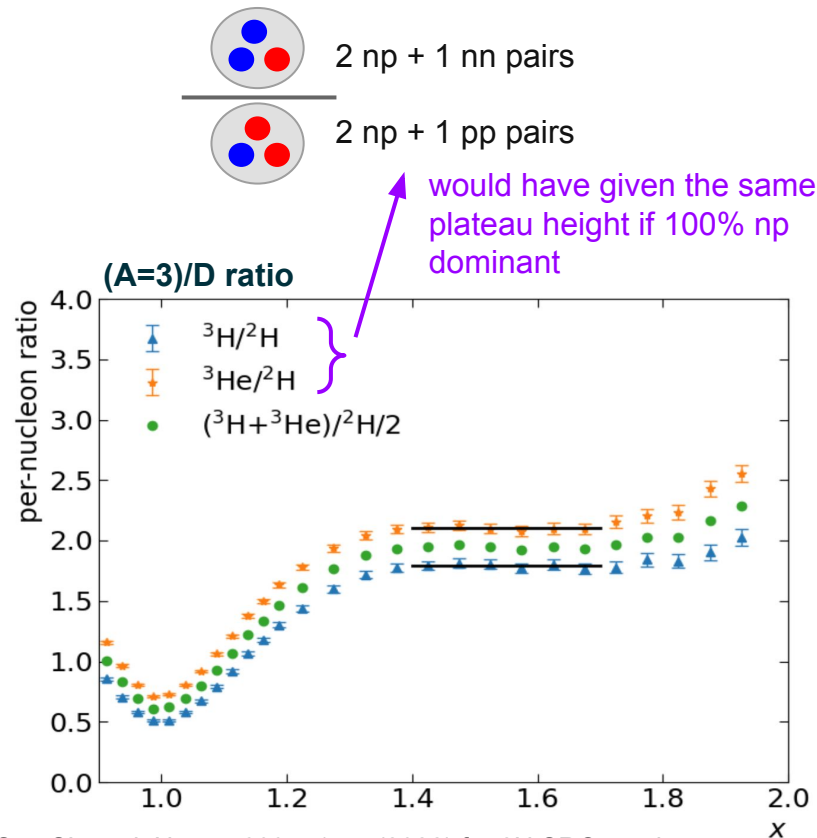
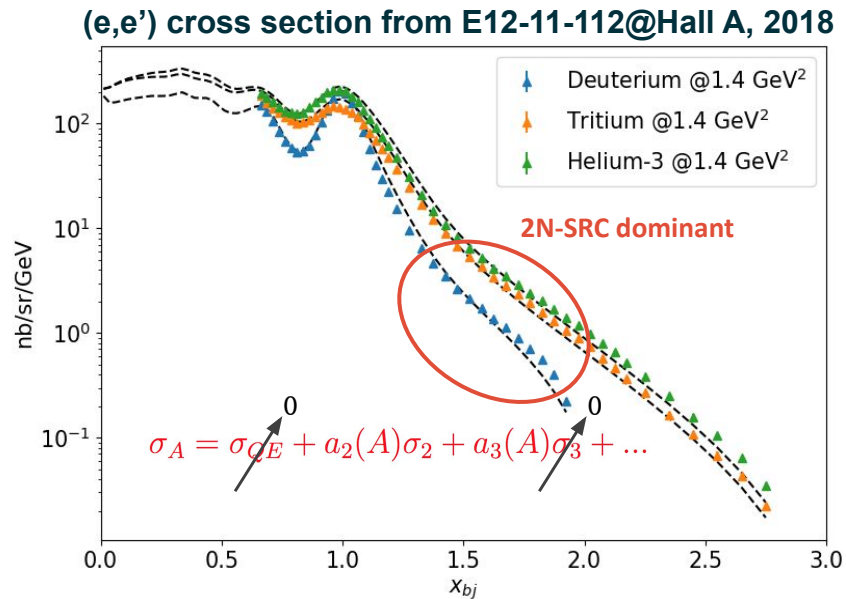
Allowed phase space in ground state A=3



**Type I (line):** small angle between recoils, small missing energy

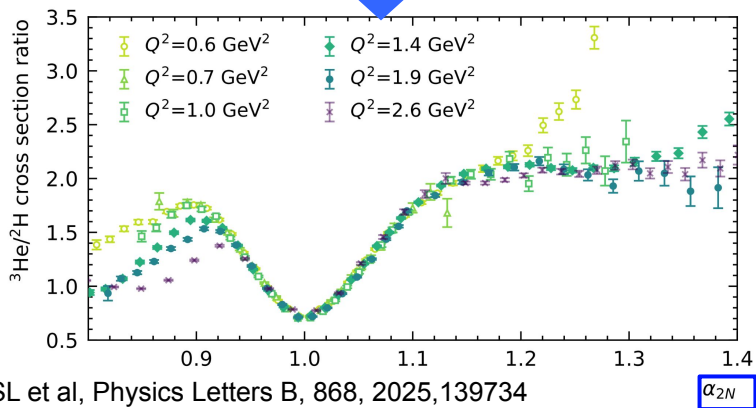
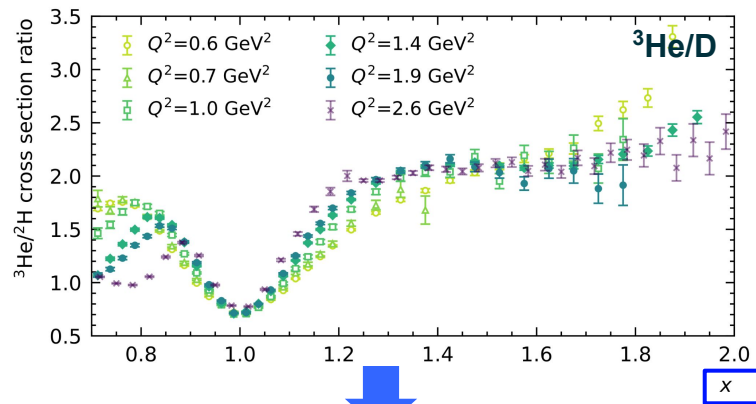
Focus of this study

# Existing Data: 2N SRC scaling in A=3



See SL et al, Nature 609, 41-45 (2022) for 2N SRC results.

# Existing Data: early onset of 2N SRC scaling in A=3

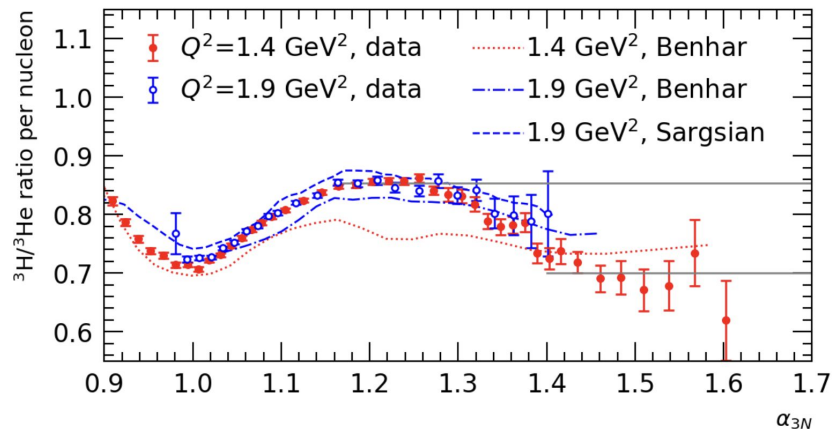


- Good agreement in 2N SRC ratio across a wide range of  $Q^2$
- Light-cone variable  $\alpha_{2N}$  described the full region of scaling better than  $x$
- Onset of 2N SRC plateaus at lower  $Q^2$ :
  - Light nuclei  $\rightarrow$  lower Fermi motion  $\rightarrow$  2N SRC dominance at lower momentum

$\Rightarrow$  Can we also expect onset of 3N SRC scaling at lower  $Q^2$ ?

# Existing Data: possible 3N SRC scaling?

SL et al, Physics Letters B, 868, 2025,139734



## What we have:

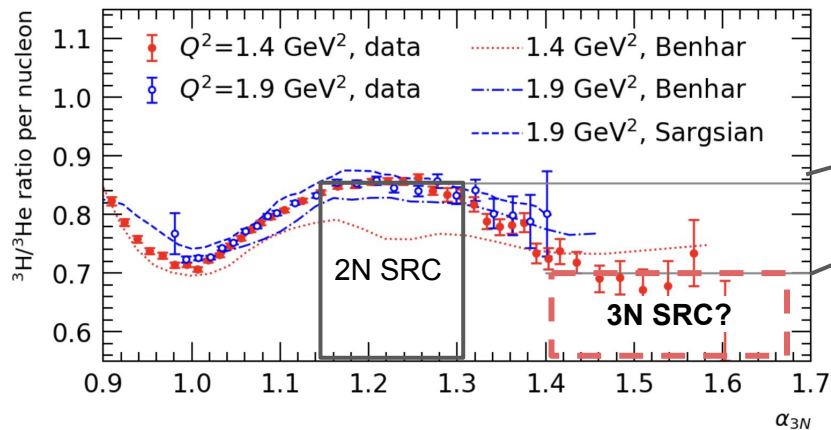
- High precision data up to alpha of 1.6
- 2N SRC scaling at lower  $Q^2$  than calculation suggested
- Possible **onset** of 3N SRC scaling

## What is missing:

- Better statistics
  - Multiple  $Q^2$  settings to confirm scaling
  - Compare with  $A=3$  calculations
- ⇒ **motivation for new proposal**

# Existing Data: possible 3N SRC scaling?

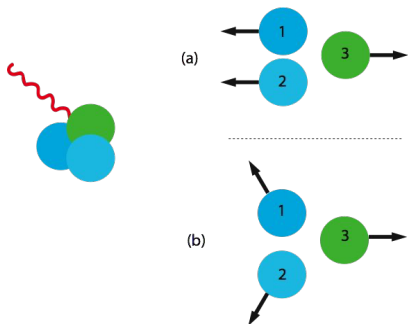
SL et al, Physics Letters B, 868, 2025,139734



2N SRC plateau at 0.84

Possible 2nd plateau at  $0.7 \sim (0.84)^2$  ?

What we learn about 3N momentum-sharing:



“Line” configuration

$$p_3 = p_1 + p_2$$

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

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

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

The ratio of 0.7 favors this

“STAR” configuration

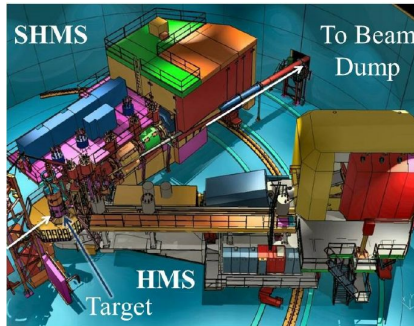
$$p_1 = p_2 = p_3 \rightarrow$$

Kinematically NOT accessible in this measurement

# New Proposal: Instrumentation

Same target cell design from the 2018 tritium program:

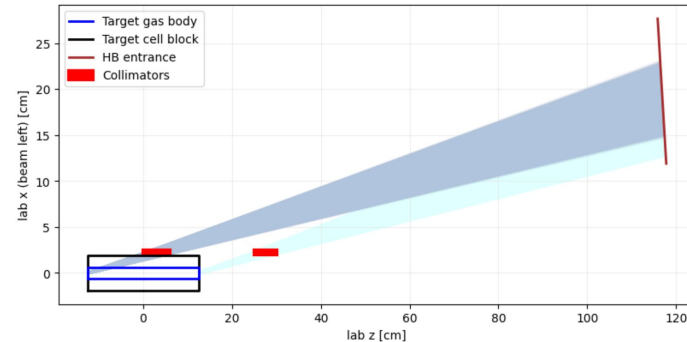
- 25cm long **sealed** Alloy cell, hold **1000 Ci** tritium
- Well-understood target properties: density fluctuation, decay etc
- Beam current < 25uA and other **safety** measures



**SHMS in standard configuration to detect scattered electrons**

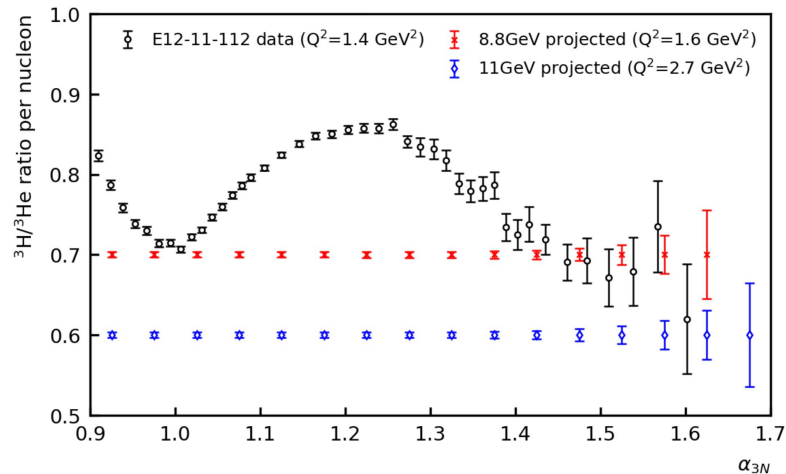
- Good momentum resolution (v.s. Hall B CLAS12)
- Higher central momentum range, smaller angle (v.s. Hall A)  
→ higher rates → can afford higher  $Q^2$
- Large momentum acceptance → one single setting to cover  $x=1$  to 3

**Dedicated Collimator (tungsten block)  
to remove endcap contamination**



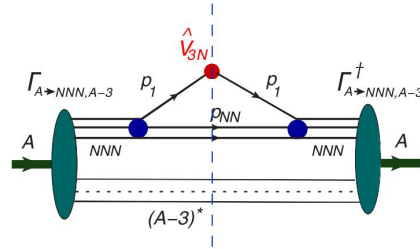
# New Proposal: Kinematics

	E12-11-112	This Proposal	
<b>Kinematics</b>	<b>L17</b>	<b>kin1</b>	<b>kin2</b>
<b>Beam Energy</b>	4.3 GeV	11 GeV	8.8 GeV
<b>Spectrometer</b>	HRS@Hall A	SHMS@Hall C	SHMS@Hall C
<b>Angle</b>	17.0	8.5	8.5
<b>Central momentum</b>	3.54 - 3.94 GeV	9.8 GeV	8.2 GeV
<b>Q<sup>2</sup></b>	1.4	2.7	1.6



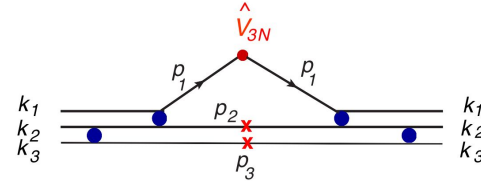
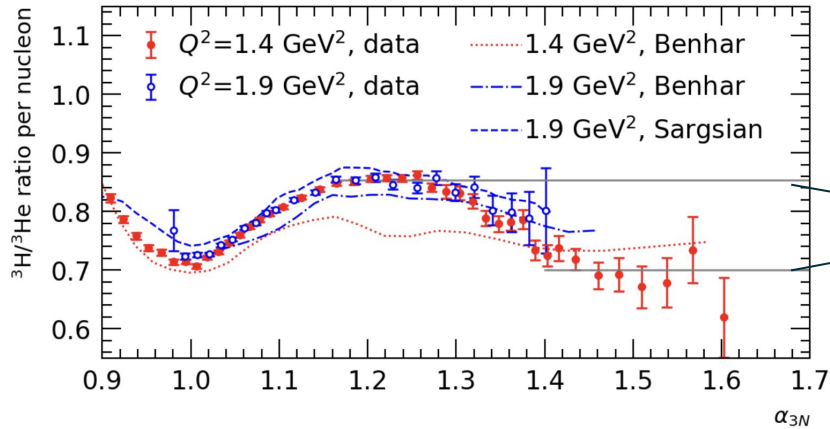
- 60 PAC days including calibrations
- <3% uncertainties up to  $\alpha=1.7$
- 2 settings to confirm the plateau, and establish scaling
- Unique chance to probe high-momentum structure in  $A=3$ , and provide constraints to calculations

# What We Talk About When We Talk About 3N SRC



## Irreducible 3N SRC:

- ❖ 3-body force?
- ❖ Involves inelastic transition?
- ❖ Extremely high momentum?
- ❖ Repulsive core?



D. Day, L. Frankfurt, M. Sargsian, and M. Strikman, PRC 107 (2023) 014319

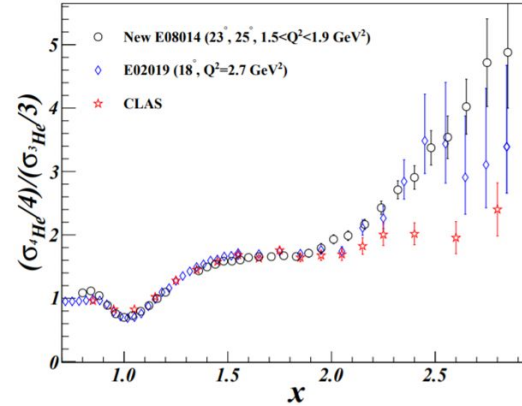
## Convolution of 2N SRCs?

$$R(^3\text{H}/^3\text{He})_{3\text{N}} \approx [R(^3\text{H}/^3\text{He})_{2\text{N}}]^2 = 0.854^2 \approx 0.7$$

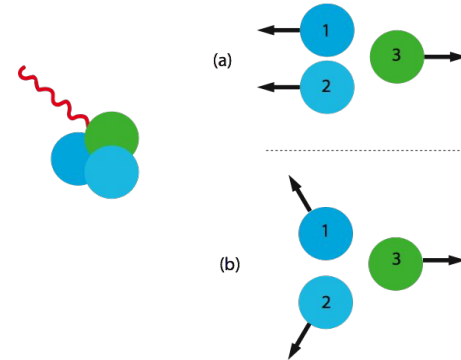
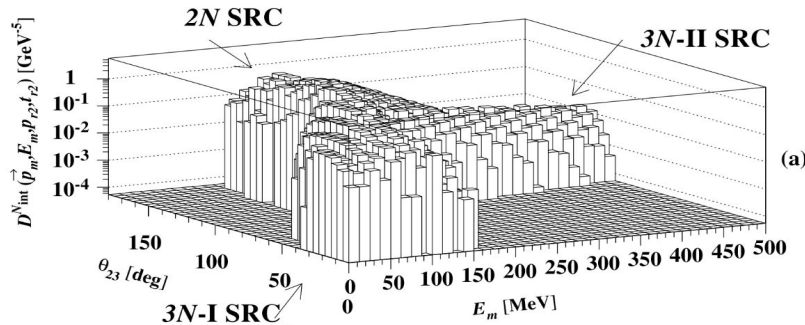
- Seems to be consistent with data
- Favors the line configuration
- Still tensor force?

# My View of 3N SRC Search

- Does it exist?
  - $x > 2$  scaling with  $A=3$  and  $A > 12$
  - Coincident detection
  -
- Universality?
  - $A/3$  ratios
- What configuration?
  - $A=3$  electrodisintegration
  - $A=3$  e,e' ratio



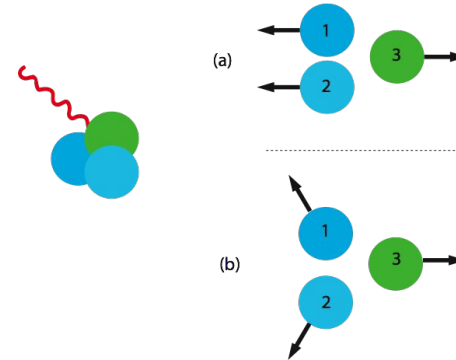
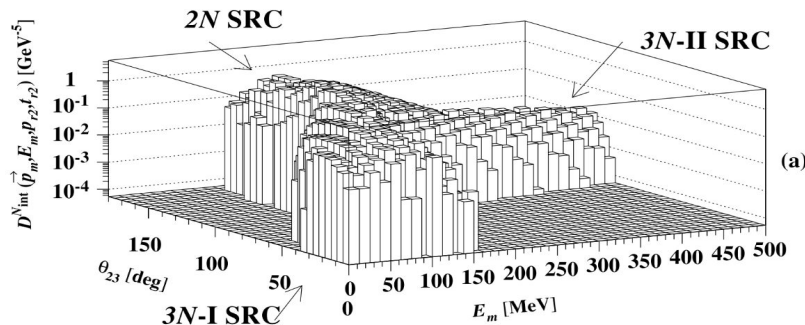
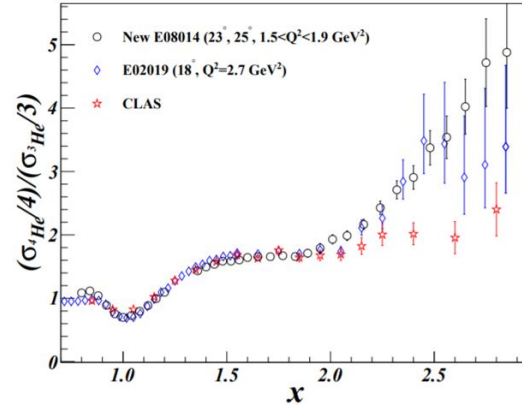
ALL needs theory support (nuclear structure, reaction theory ...)



# My View of 3N SRC Search

- Why tritium (e,e')?

- Still extreme kinematics but less expensive:
  - Lower  $Q^2$  comparing to heavier nuclei
- Provide baseline for other measurements and calculations (know your baseline)
- Mirror nuclei
  - Control scale-violation processes
  - Zero center of mass motion, two clean nnp or npp configuration → remove ambiguities in interpretation



# Path Towards Tritium SRC in Hall C

- **Proposal initially submitted to PAC52**
  - **Deferred :** (*The PAC encourages the proponents to get **theoretical support** in order to devise a clear strategy to quantify 3N-SRCs and their A-dependence ... A robust and comprehensive theoretical analysis is needed to interpret the outcome of the proposed measurement in any scenario.*)
- **Development since then**
  - Careful study of existing data (2025 PLB):
    - Early onset of scaling in  $A=3$
    - Indication of second plateaus at predicted alpha and magnitude
  - Interaction with theorists:
    - Better understanding of 2BB vs 3BB, and FSI
    - define sensitivity and phase space

# Path Towards Tritium SRC in Hall C

- ❖ **Resubmission to PAC 54 (2026 as a tritium run group):**
  - **SRC: two updated kinematic settings to**
    - Confirm the plateaus and establish scaling with higher  $Q^2$
    - Understand 3N momentum and isospin structure
  - **DIS: Parallel data-taking with HMS to**
    - Measure DIS cross sections that extends MARATHON kinematics.
    - Validate the large-x n/p, HT, ... (See John's [talk](#) on Friday)
  - **New ideas are welcome: (e,e'p), SIDIS ?**
- This measurement can ONLY happen at JLab with its high intensity electron beam and high-momentum, high-resolution spectrometers. And JLab had already great success with 2018 Tritium program.
- The 2018 tritium program is the first at JLab, and the only with high intensity beam worldwide in 40 years. We need strong community support to bring tritium back to JLab!

Thank you!