Search for 3N-SRC

in Inclusive Electron Scattering

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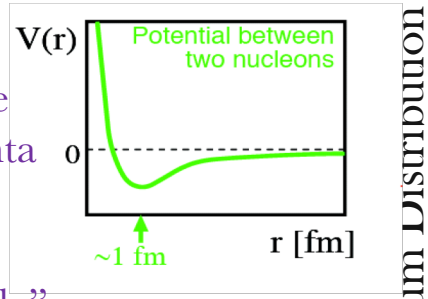
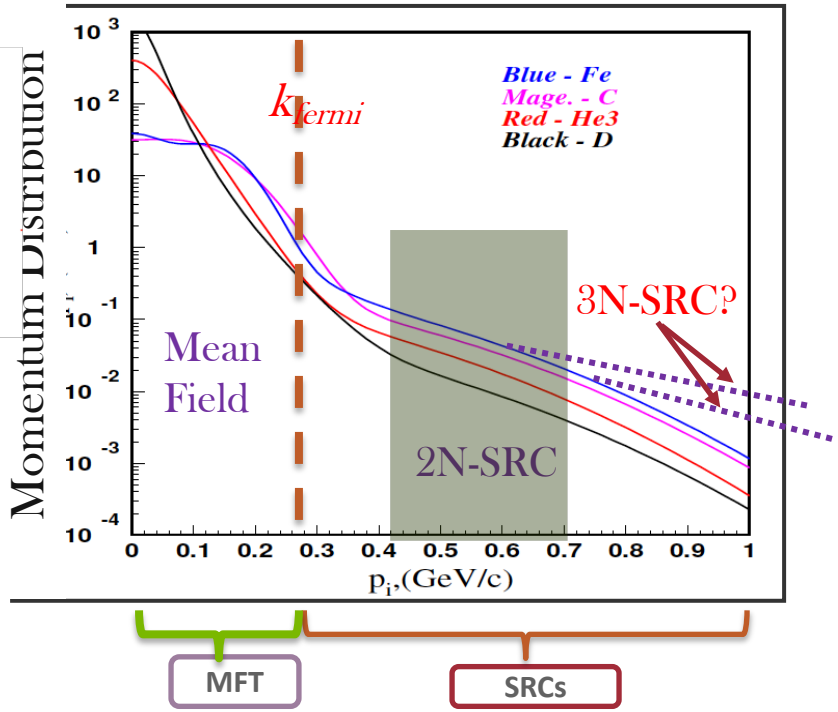
Simple Picture of 3N-SRC

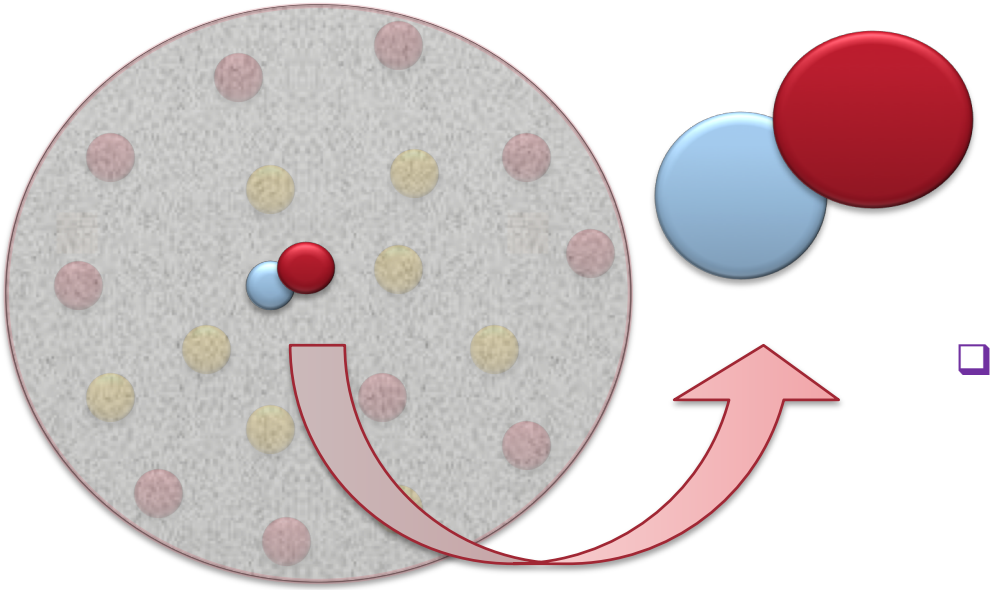
- 2N-SRC In Initial State:

- At close distance, Nucleon-Nucleon are in dynamic balance w/ relatively super-high momenta

- 2N-SRC pairs have small total momentum, and interact "weakly" w/ other nucleons





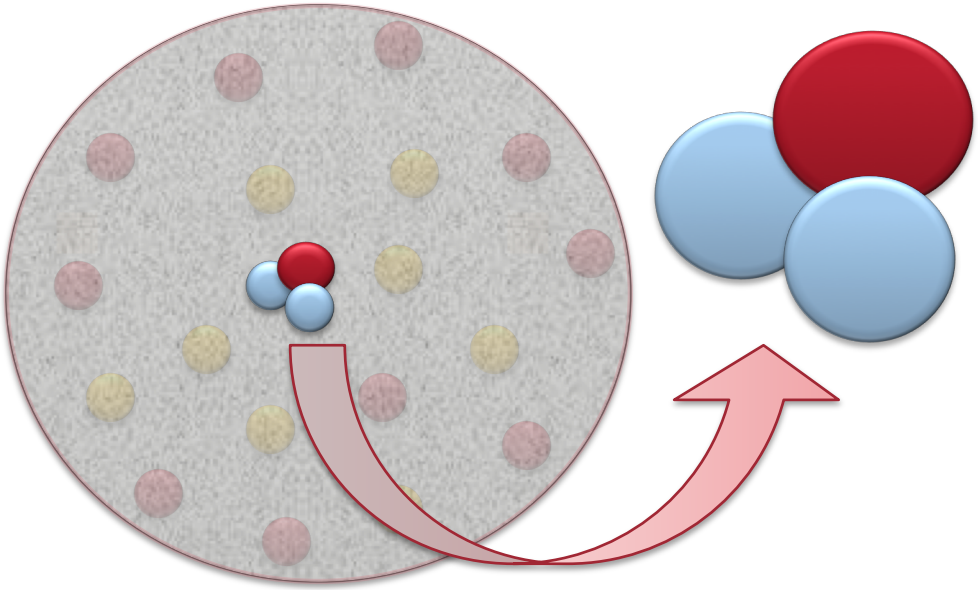


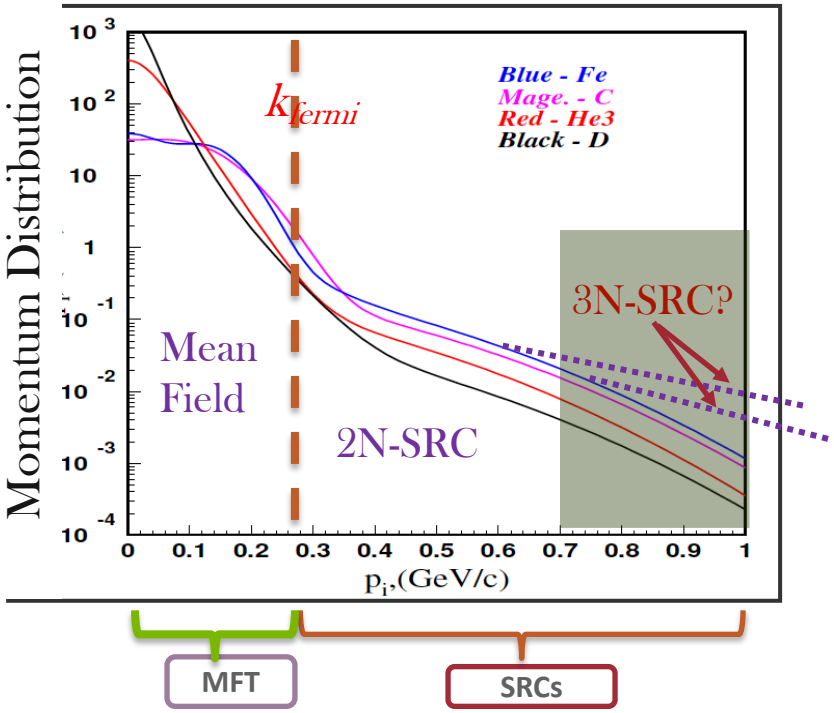
- In nuclei, the momentum distribution scale like a nucleon inside a deuteron at high-k

Simple Picture of 3N-SRC

- 3N-SRC In Initial State:

- A 2N-SRC pair can also carry high total momentum
- Form 3N-SRC when a third high-momentum nucleon balances the 2N-SRC motion
- Extend the momentum distribution to much higher-k, and another "A=3"-like scaling region could exist.



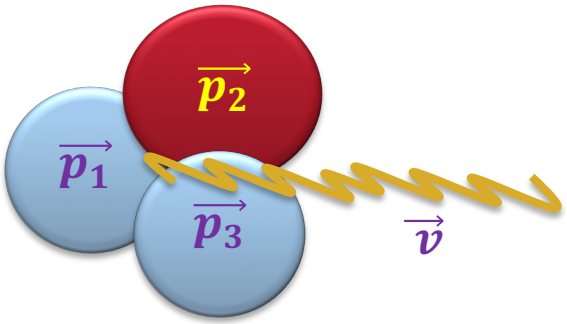


- Forming 2N-pairs is easy, no even SRC needed, but how easy to make 3N in absolute balance?
- No strong theory endorsement, but we just believe it is natural to happen

Simple Picture of 3N-SRC

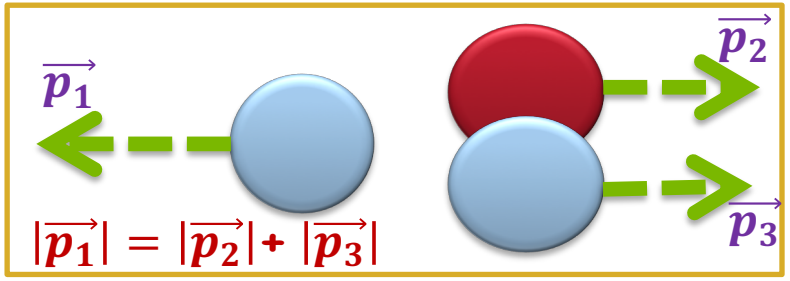
- 3N-SRC In Final State:

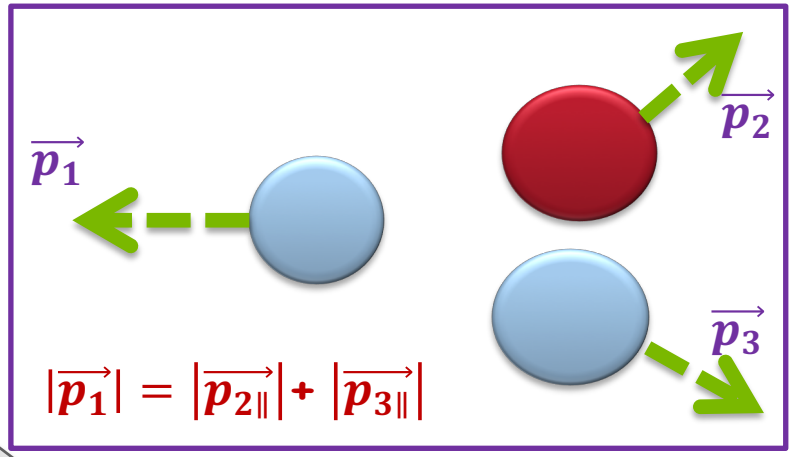
- High energy particles (γ, e, p) break up 3N-SRC

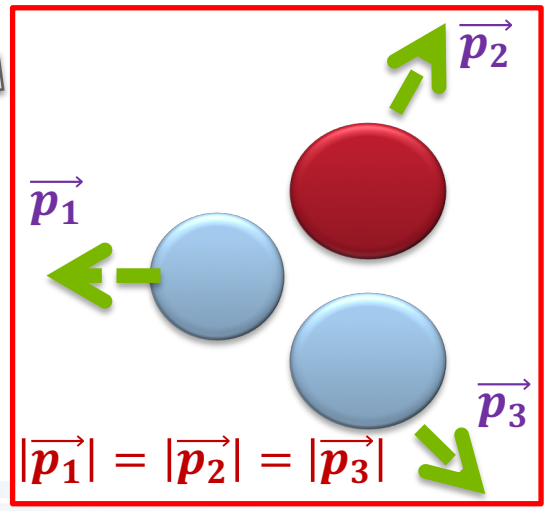


$\vec{p_1} + \vec{p_2} + \vec{p_3} \rightarrow k_F$

Center of Mass Frame







- Nucleons from 3N-SRC can go any direction in their C.M. (unlike 2N-SRC which is always back-to-back)!

- Even in C.M., individual nucleons can carry very different energy (2N-SRC has two-equal "p>k_F" nucleons)

- How easy to know nucleons from the same 3N-SRC?

Simple Picture of 3N-SRC

- Probe 3N-SRC In A(e, e')/^{3}He(e, e'):

- QE cross section in a SRC picture:

One nucleon: (x~1). Two nucleons: (1.3<x<2) (x>2)

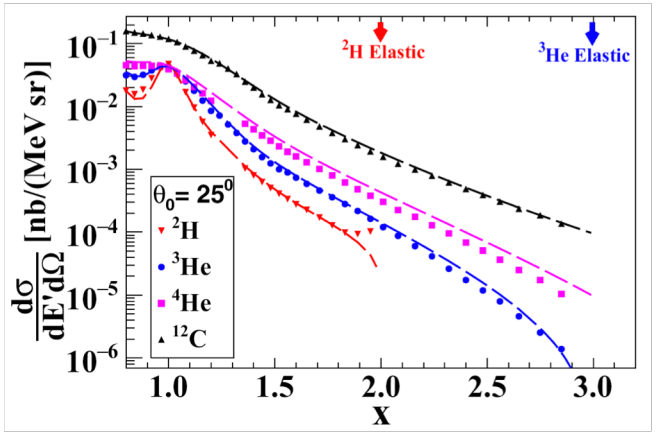
$$\sigma_A(x,Q^2) = \sum_{j=1}^{A} \frac{A}{j}\sigma_j(x,Q^2) = A\sigma_{1N}(x,Q^2) + \frac{A}{2}a_2(A)\sigma_{2N}(x,Q^2) + \frac{A}{3}a_3(A)\sigma_{3N}(x,Q^2)\ldots$$

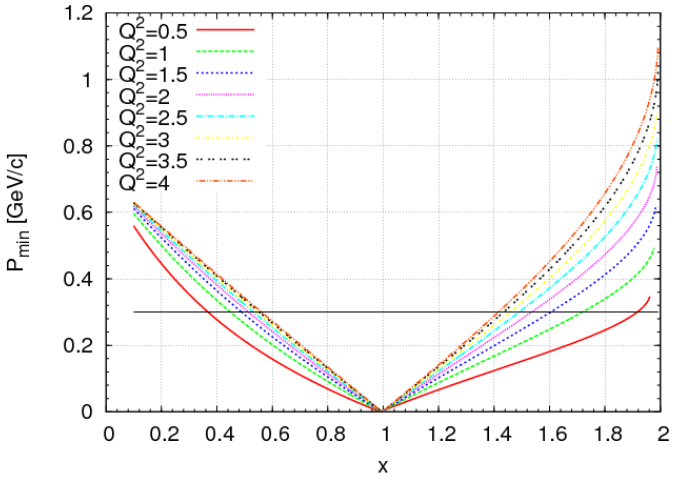
a_j (A) ---the probability of a nucleon in a jN-SRC.
σ_j (A) --- the cross section of an electron scattering on a nucleon in jN-SRC.

- QE cross sections ratios:

2N-SRC (1.3<x<2) 3N-SRC (2<x<3)

$$a_2(A,D) = \frac{2}{A}\frac{\sigma_A(x,Q^2)}{\sigma_D(x,Q^2)}, \qquad a_3(A,{}^3He) = K \cdot \frac{3\sigma_A}{A\sigma_{{}^3He}}$$

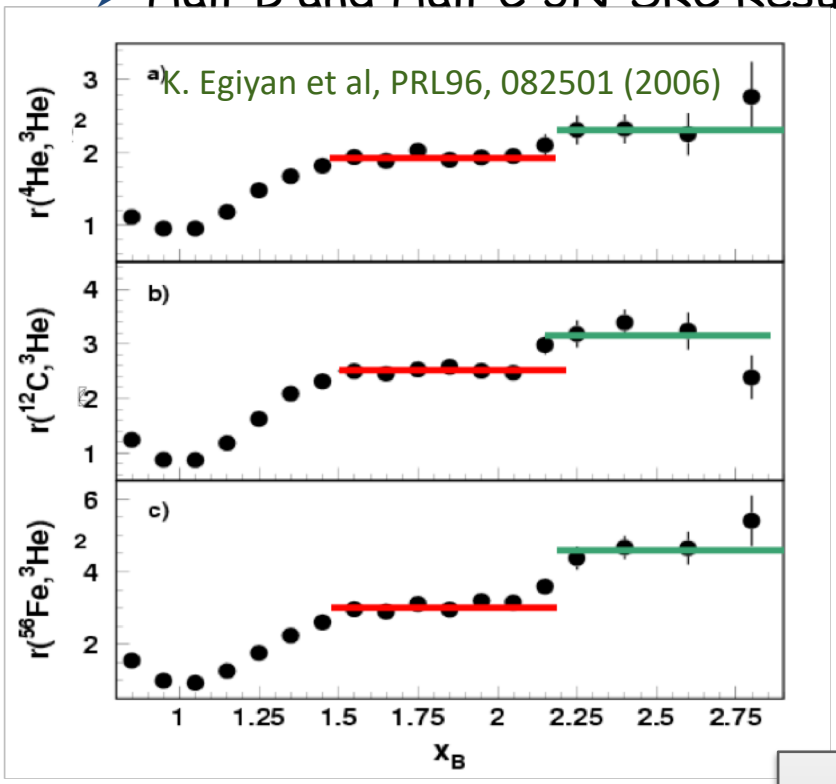




- Choose the right kinematic region:
  - 2N-SRC: Q2>1.0 GeV^2, 1.3<x<2.0
  - 3N-SRC: Q2>1.0 GeV^2, x>2.0?

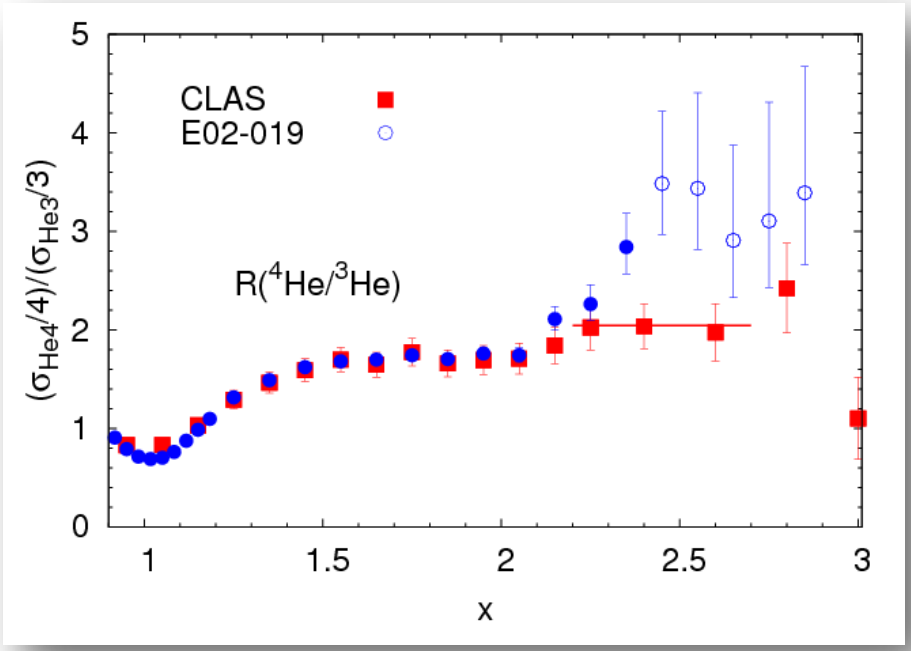
3N-SRC Results

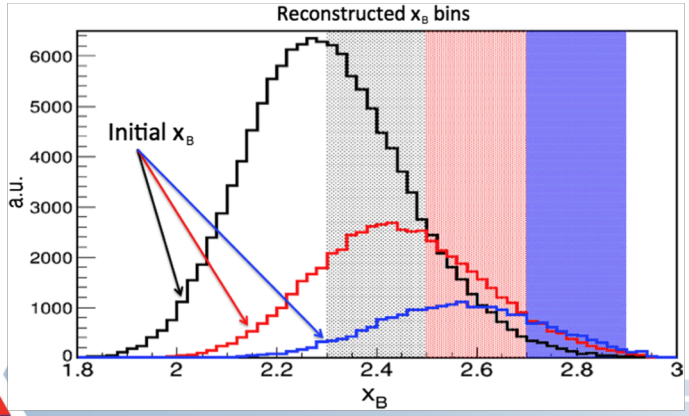
- Hall-B and Hall-C 3N-SRC Result:



K. Egiyan et al, PRL96, 082501 (2006)

N. Fomin *et al*, PRL 108,092502 (2012)





CLAS & E02-019 don't agree in the 3N-SRC region:

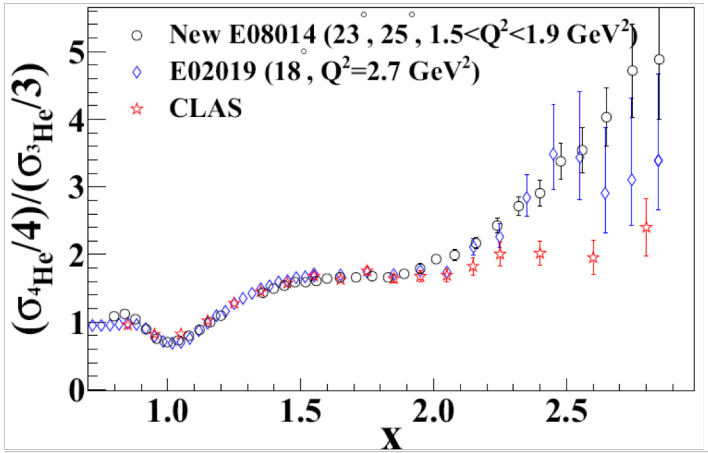
- Clear plateau seen in Hall-B result
- E02-019 doesn't have a clear plateau or different values
- CLAS: $Q^2 \approx 1.6\ GeV^2$, E02-019: $Q^2 \approx 2.7\ GeV^2$
- CLAS's plateaus were proved to be due to bin-migration

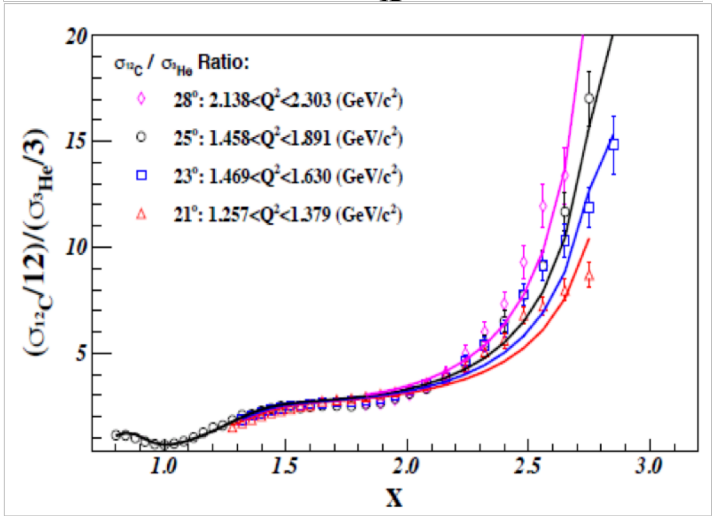
Higinbotham & Hen, PRL 114,169201 2015)

3N-SRC Results

- Hall-A 3N-SRC Result:

Z. Ye, Phys. Rev. C 97, 065204 (2018)



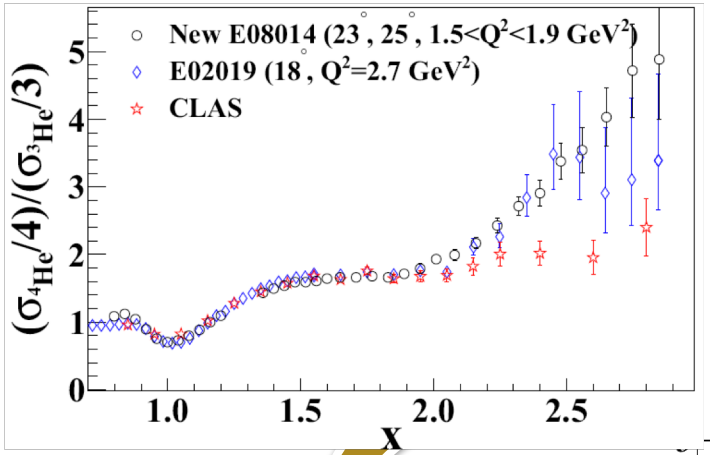


- Much higher precision than Hall-B/C
- Small Q2 values (close to Hall-B)
- Data from D2, He3, He4, C12, Ca40, Ca48
- No any indication of 3N-SRC at x>2 in both He4/He3 and C12/He3 ratios
- Also show strong Q^2 dependence at x>2

3N-SRC Results

- Hall-A 3N-SRC Result: Z. Ye, Phys. Rev. C 97, 065204 (2018)

Z. Ye, Phys. Rev. C 97, 065204 (2018)

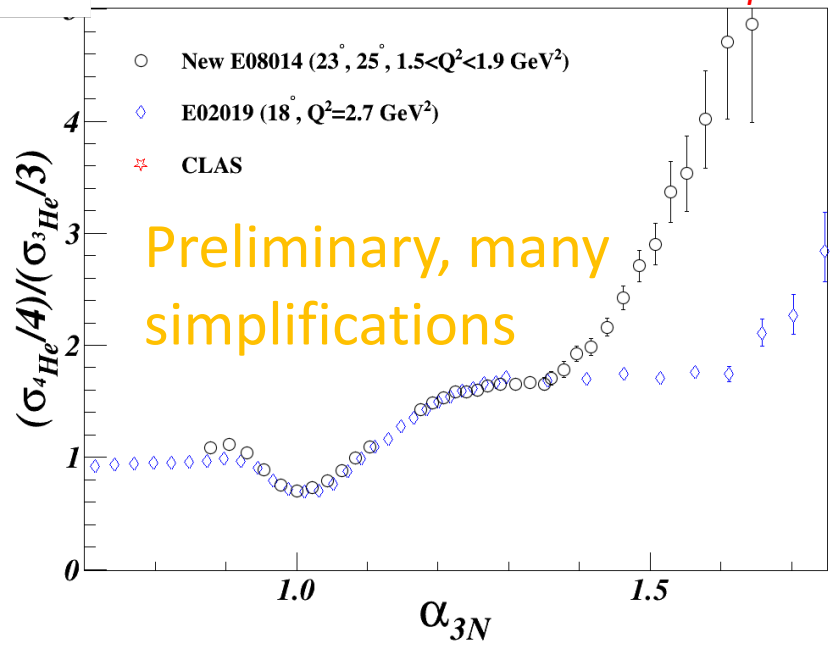


- Use a different physics quantity instead of x_B

D. Day, L. Frankfurt, M. Sargsian, M. Strikman, arXiv:1803.0762

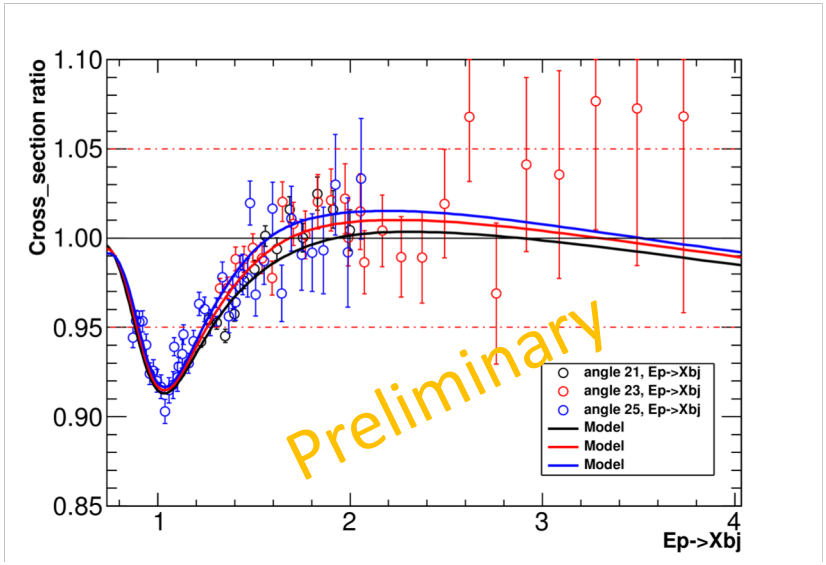
$$\alpha_{3N} = 3 - \frac{q_- + 3m_N}{2m_N}\left[1 + \frac{m_S^2 - m_N^2}{W_{3N}^2} + \sqrt{\left(1 - \frac{(m_S + m_n)^2}{W_{3N}^2}\right)\left(1 - \frac{(m_S - m_n)^2}{W_{3N}^2}\right)}\right].$$

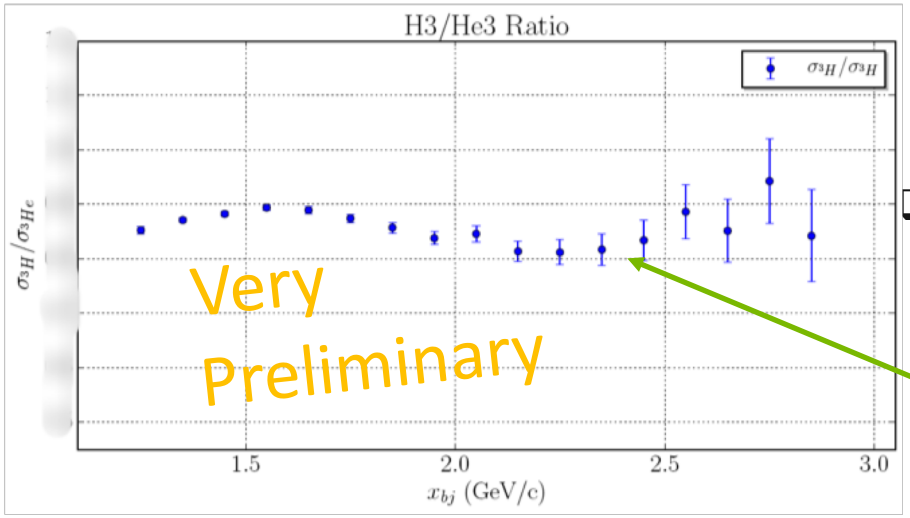
Still no plateau



3N-SRC Results

- Upcoming New 3N-SRC Results:
  - Ca48/Ca40 ratio is consistent with one in 1.3<x<3.0 (Dien's talk)
  - Because nucleons always pair with their closest neighbors to form 2N-SRC and 3N-SRC?





- For He3 and H3, ratio should be one when forming 3N-SRC, but doesn't the x-dependence tells the transition from 2N-SRC to 3N-SRC?
  - ✓ 2N-SRC+p > 2N-SRC+n?
  - ✓ Transition from 2N-SRC to 3N-SRC differ in He3 and H3?

Future Search for 3N-SRC

- What Next?

  - Forming 3N-SRC clusters are much harder than 2N-SRC clusters
  - Also very complicated to probe/reconstruct after breaking up 3N-SRC
  - No any indication of 3N-SRC from existing measurement
  - The kinematic regions where 3N-SRC exist (if it does) is also not very clear
  - (e, e') measurement at high Q^2 are so difficult (no rates!)
  - (e, e'NNN) measurement is even harder to image

Way-Out?

- Can we consider (p, p' NNN) which provides much larger cross sections?
- New observables better other than Cross-Section Ratios?

My personal question: Why 3N-SRC has to exist? The world is still happy with only 2N-SRC!