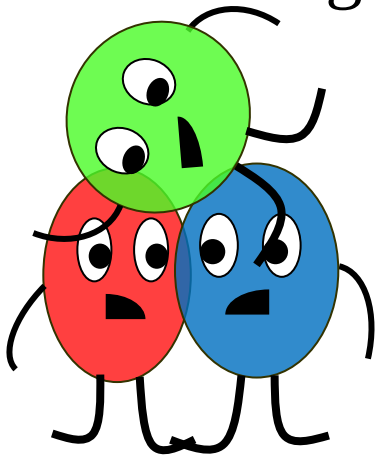
# Continuing the search for 3N SRCS (maybe)



Science at the Luminosity Frontier:
Jefferson Lab at 22 GeV

Nadia Fomin

This work was supported by U.S. Department of Energy under award number: DE-SC0013615

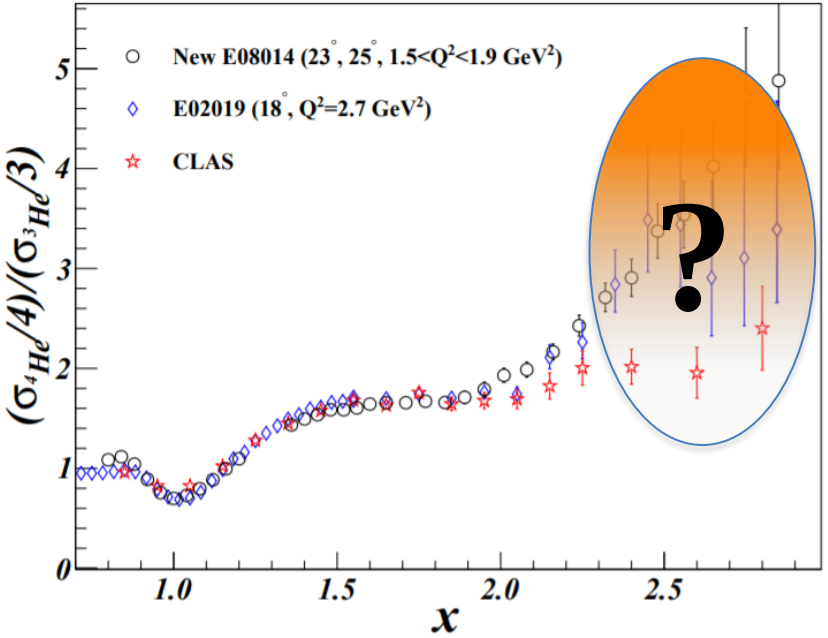


THE UNIVERSITY OF TENNESSEE KNOXVILLE

# Status of 3N SRC searches

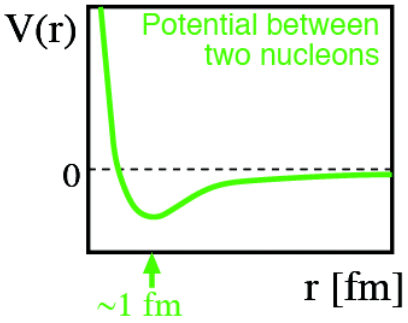
**No observation of a 3N SRC plateau**

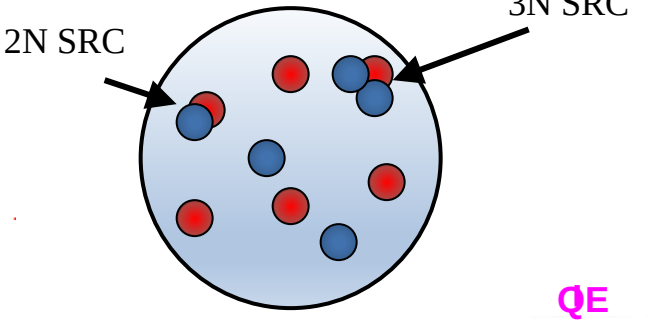
- 2N Plateaus observed in many measurements – well understood and well studied
- Several previous measurements provided inconclusive results

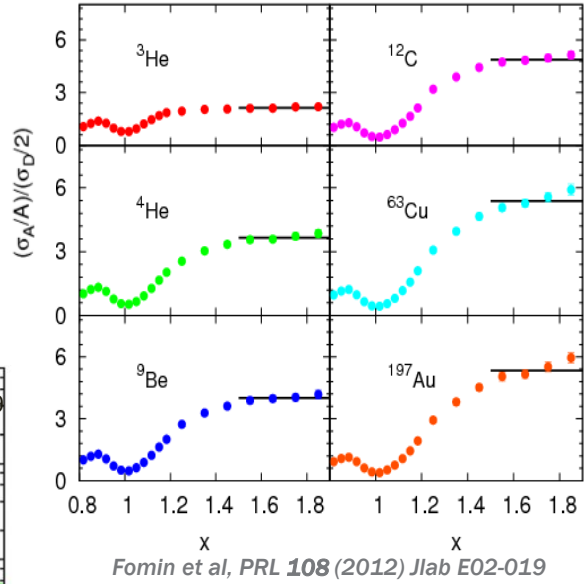



*Z. Ye et al, PRC 97 (2018) 6*

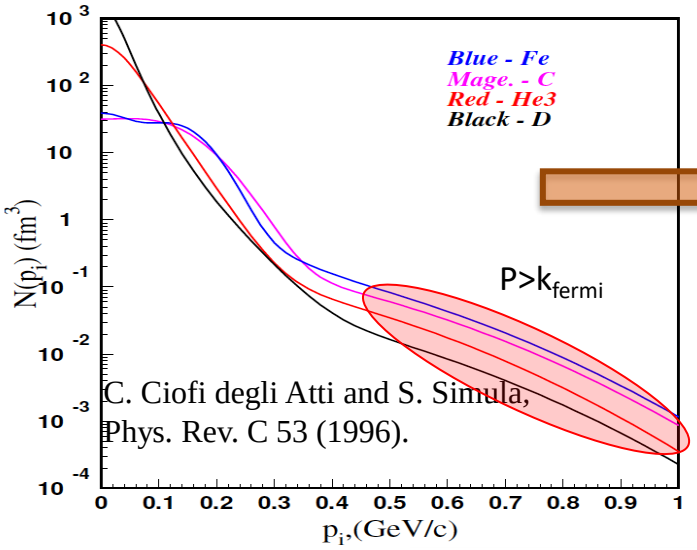
# Background: 2N SRCs studies via inclusive scattering



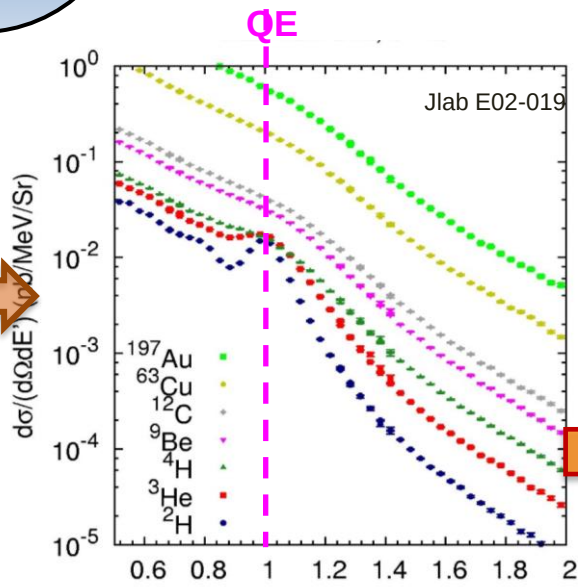




Fomin et al, PRL **108** (2012) Jlab E02-019



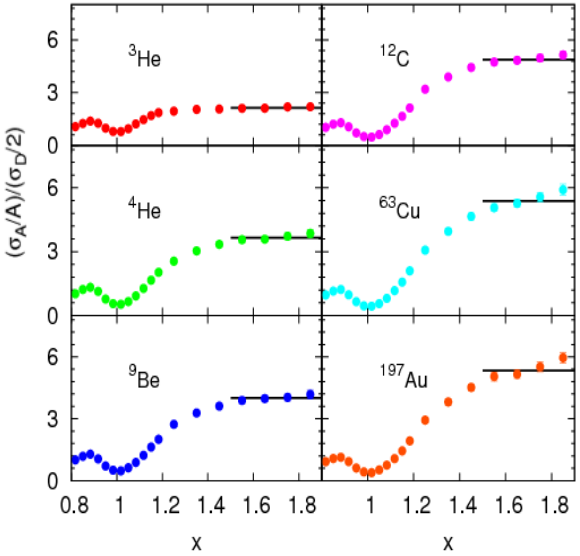

C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996).



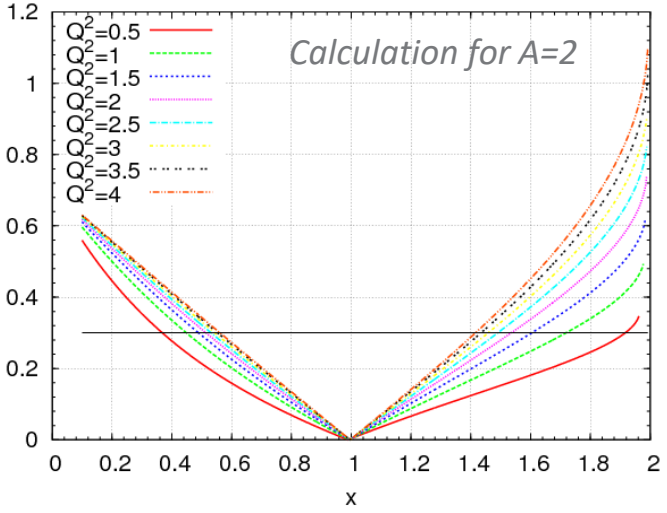

**1.4<x<2 => 2 nucleon correlation**

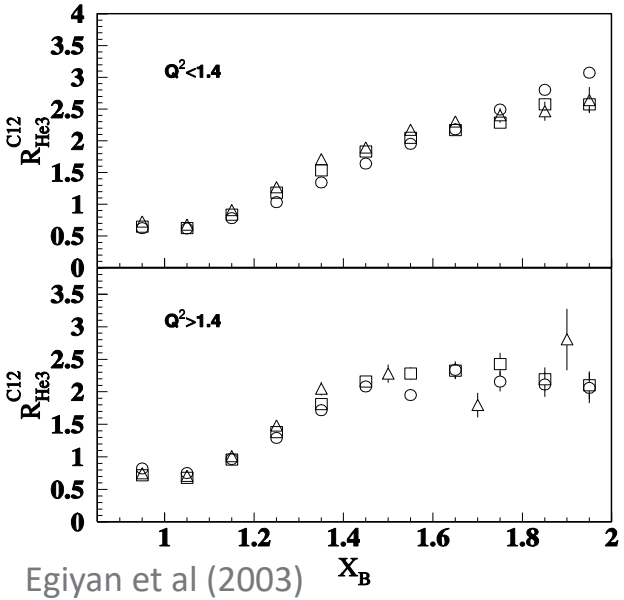
# $Q^2$ threshold for 2N SRC Observation

$\langle Q^2 \rangle \sim 2.7\ GeV^2$



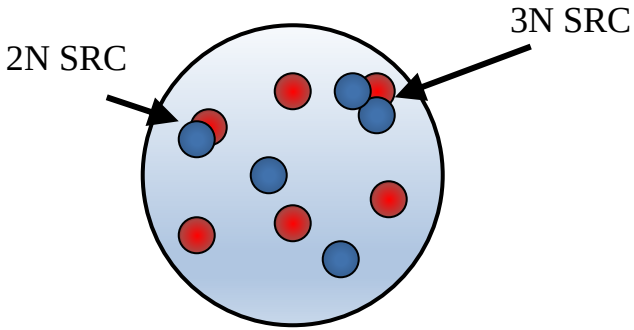

*Fomin et al, PRL **108** (2012) Jlab E02-019*




Egiyan et al (2003)

# More nucleons in a correlation




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

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

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

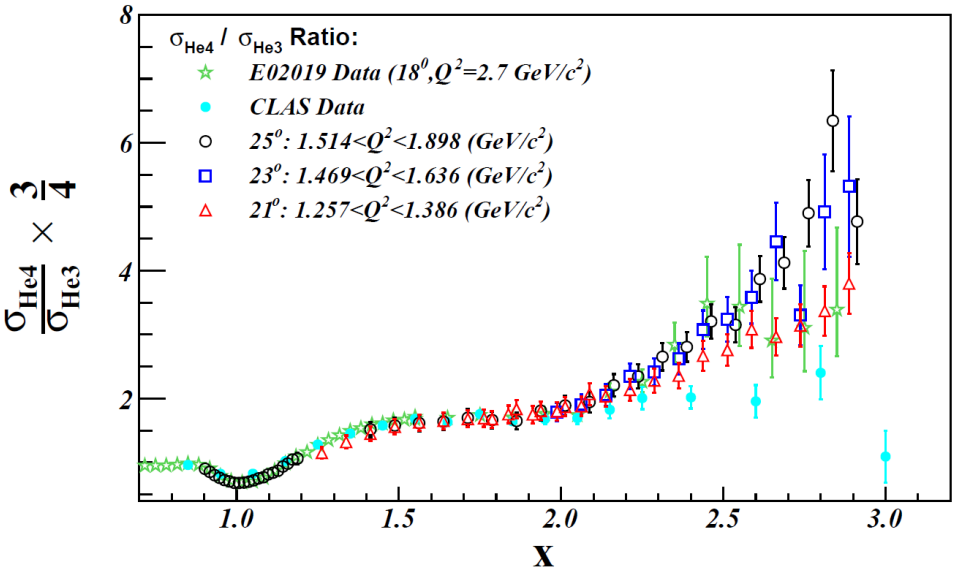
$$= \frac{A}{2} a_2(A)\sigma_2(x, Q^2) +$$

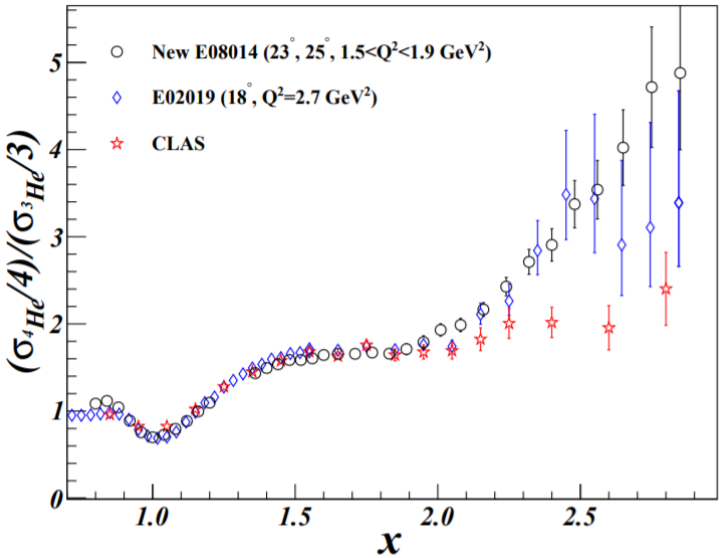
$$\frac{A}{3} a_3(A)\sigma_3(x, Q^2) + ....$$

**Go to x>2 to see a second, 3N SRC plateau in $\frac{\sigma_A}{\sigma_{3He}}$**

# Inclusive 3N SRC data so far

| Experiment | $Q^2$ range ($GeV^2$) | Note |
|---|---|---|
| E02019 | ~2.7 | XEM (6 GeV) |
| E08014 | 1.3-1.9 | Hall A 6 GeV |
| CLAS | 1.6 (ave) | Resolution Limited |

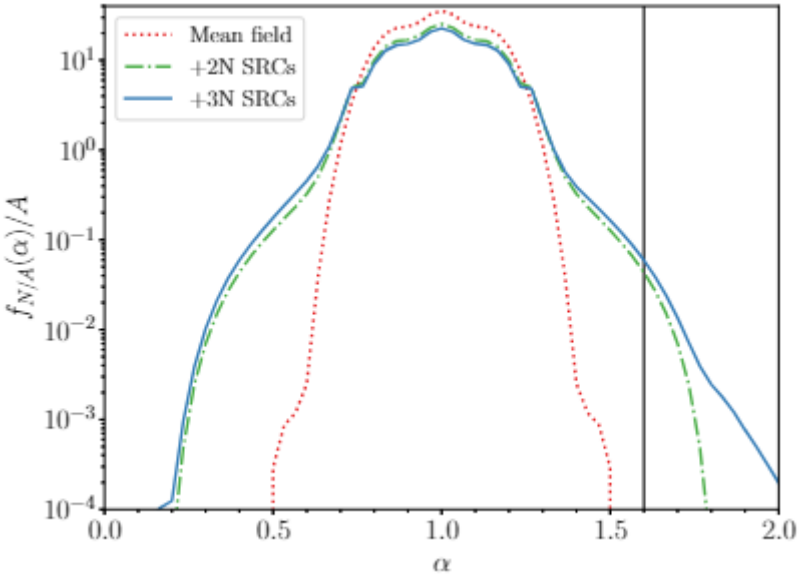


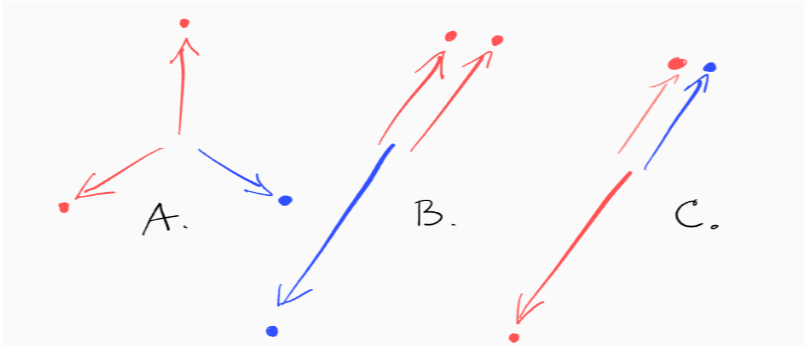



# Onset of 3N Dominance

*Light cone momentum fraction in a 3N system*

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



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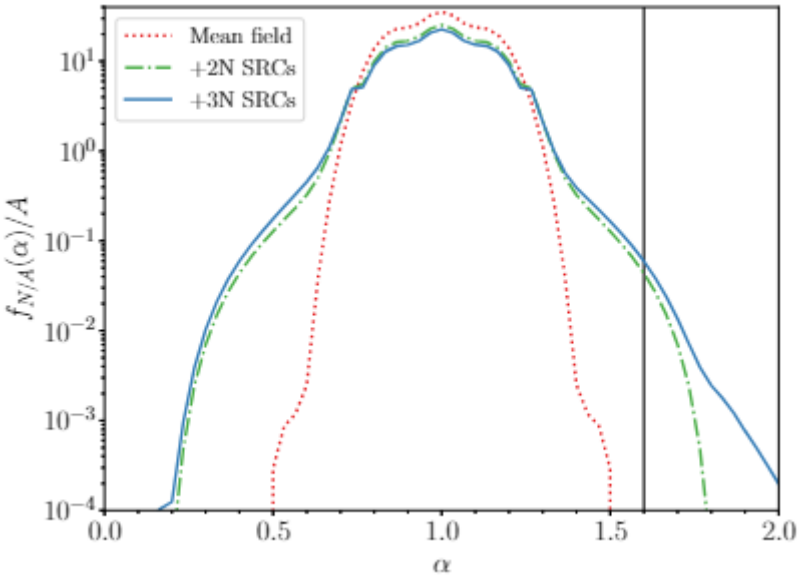
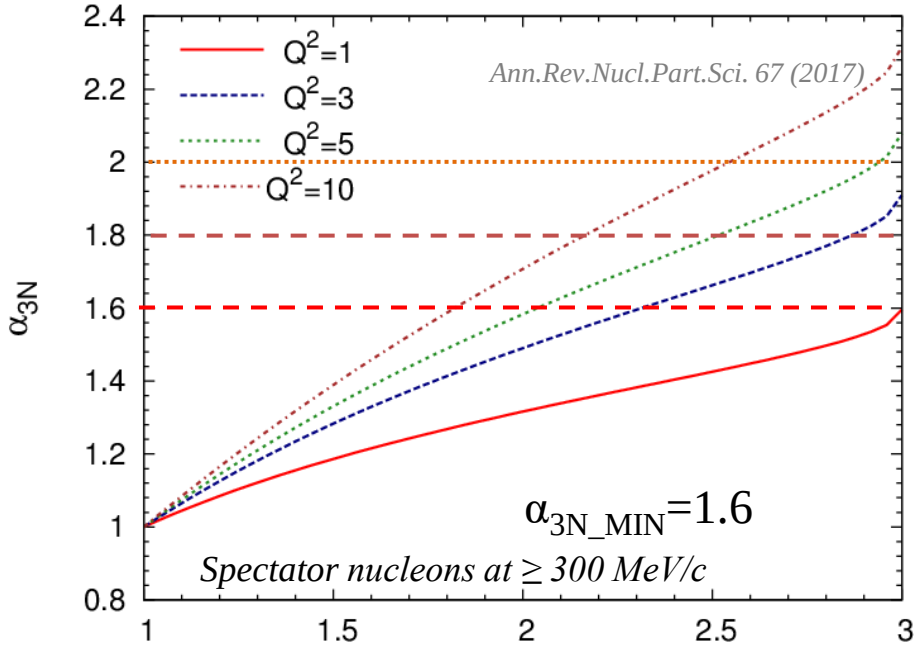
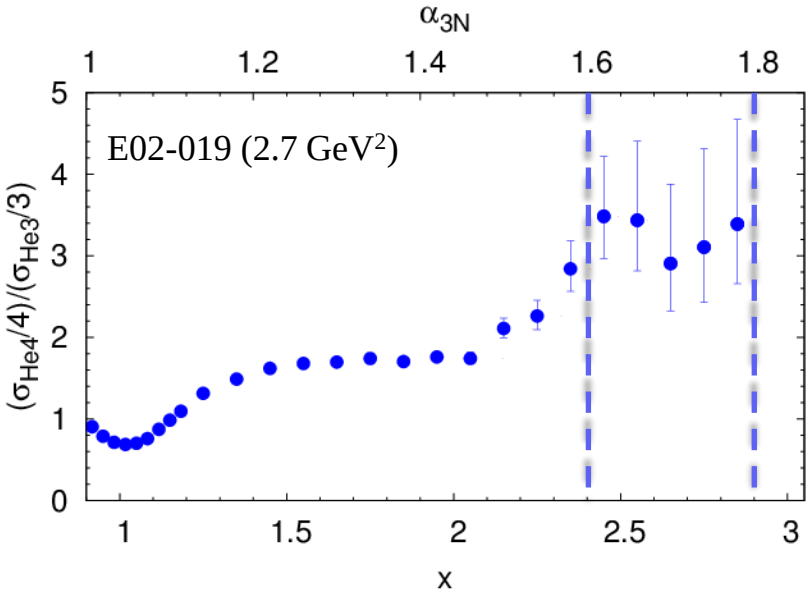
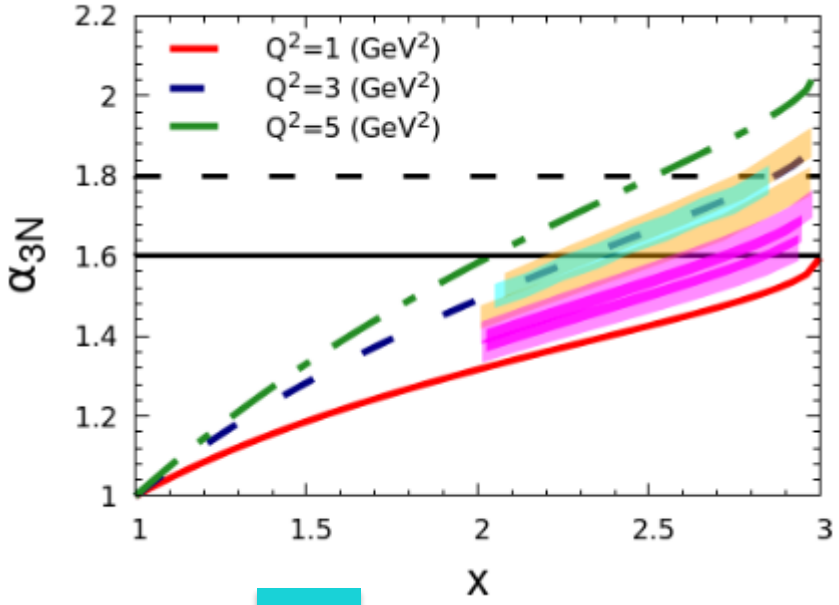


# Hall C XEM data from 6 GeV



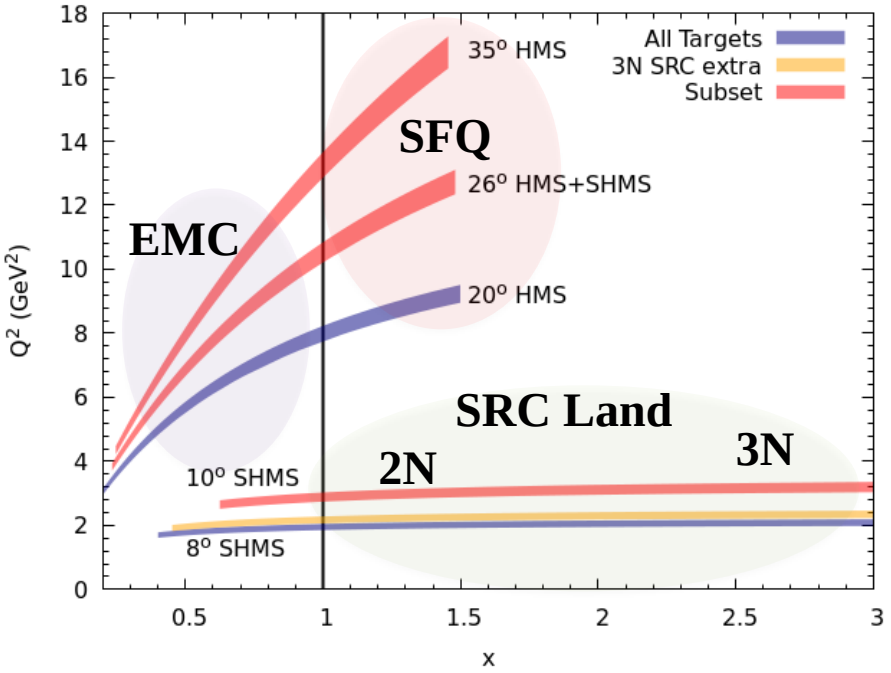




**6 GeV XEM**

**12 GeV XEM2 (Under Analysis)**

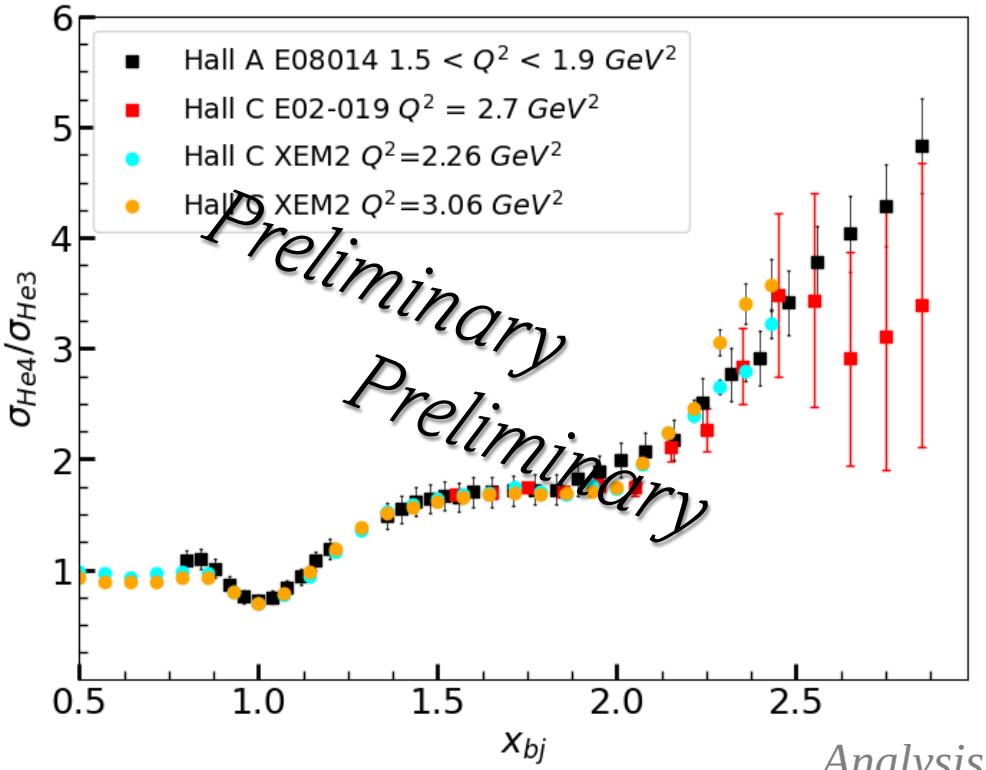
**Hall A at 6 GeV**

# E12-06-105 (XEM2): 3N SRC Data Under Analysis




| $\theta_{SHMS}$ | $Q^2$ at x=2.5 ($GeV^2$) |
|---|---|
| 8.5 | 2.3 |
| 10 | 3.2 |
| 11, 12* | 3.8, 4.4 *(test kinematics)* |

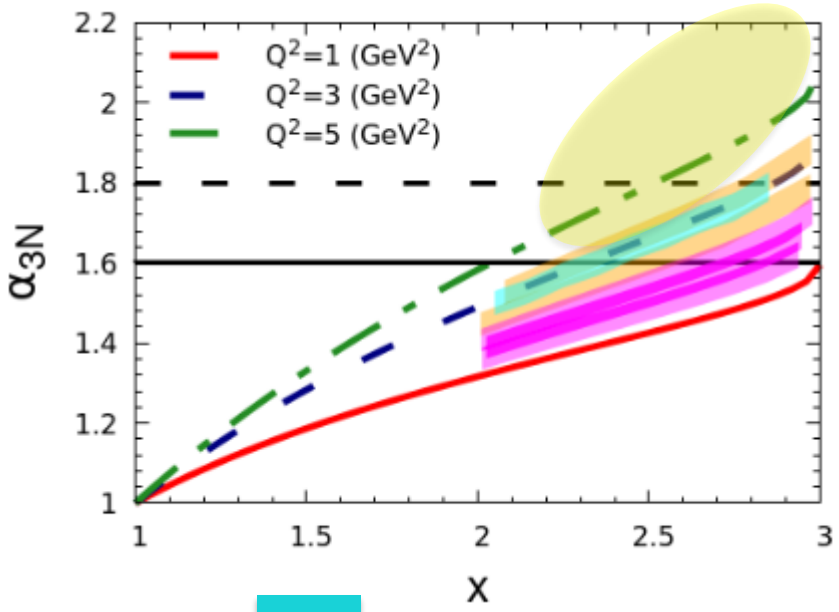
# E12-06-105: 3N SRC Data Under Analysis




- Data in 1.6 < α < 1.8 region are not at necessary precision
- Possible $Q^2$ dependence in the ratio observed at x>2.2

*Analysis by Jordan O'Kronley*

# Why don’t you just go to higher $Q^2$?

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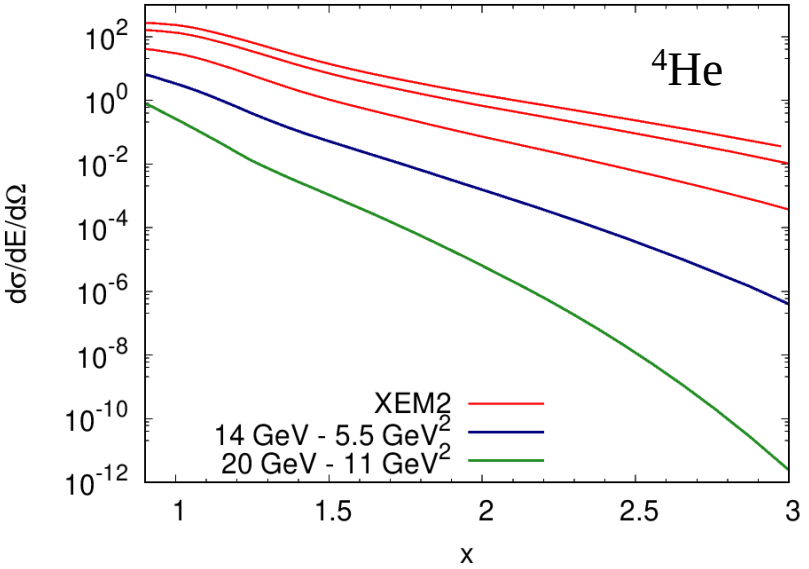
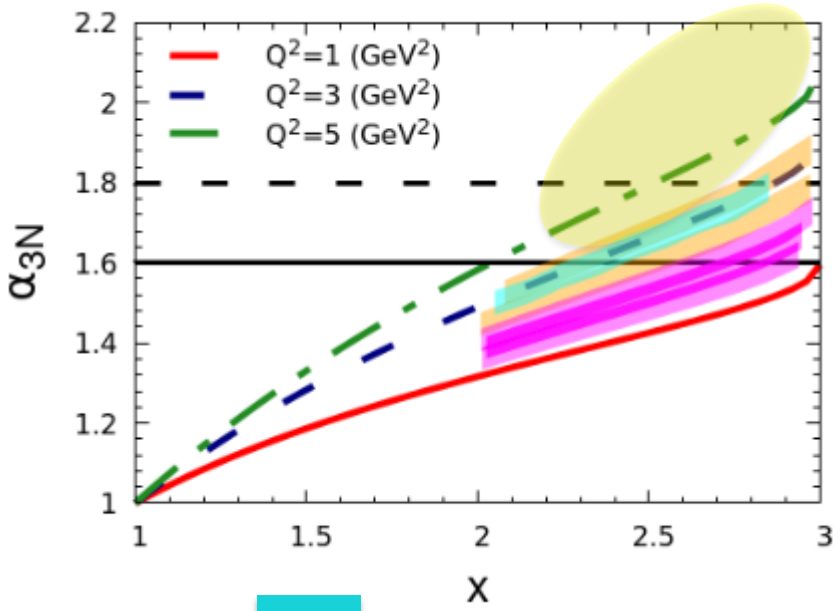


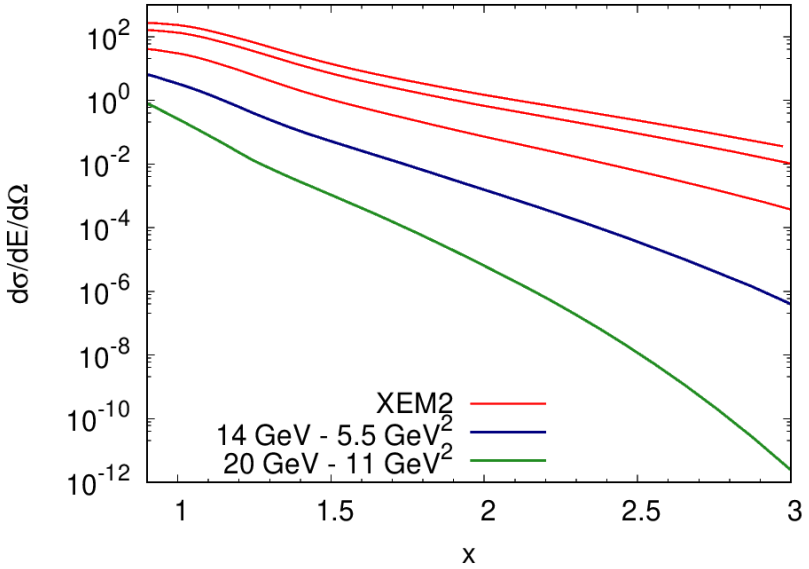



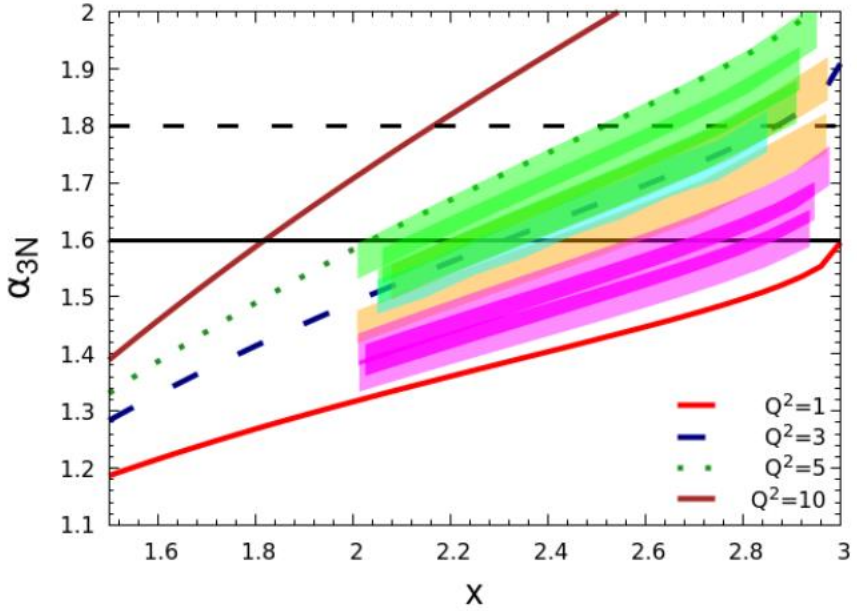

**6 GeV XEM**

**12 GeV XEM2 (Under Analysis)**

**Hall A at 6 GeV**

# E12-06-105: 3N SRC Data Under Analysis



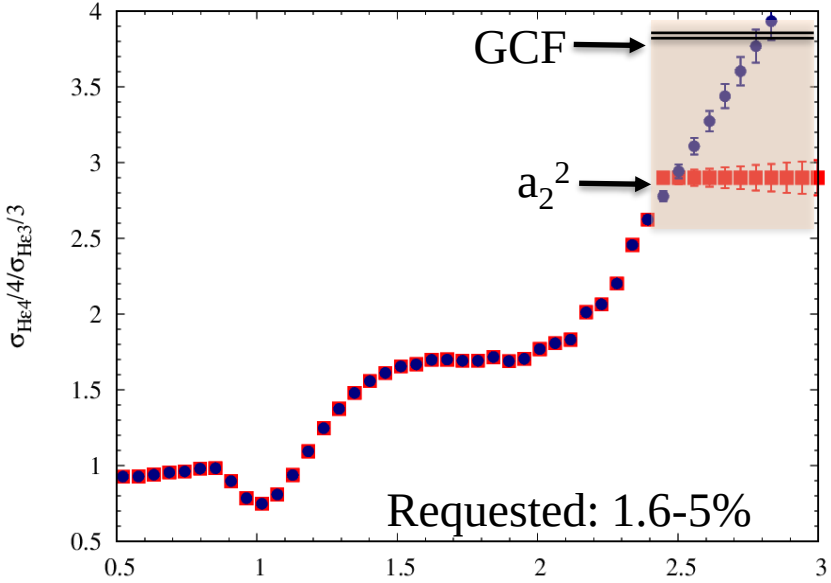

**Proposed Kinematics (10,11,12)**

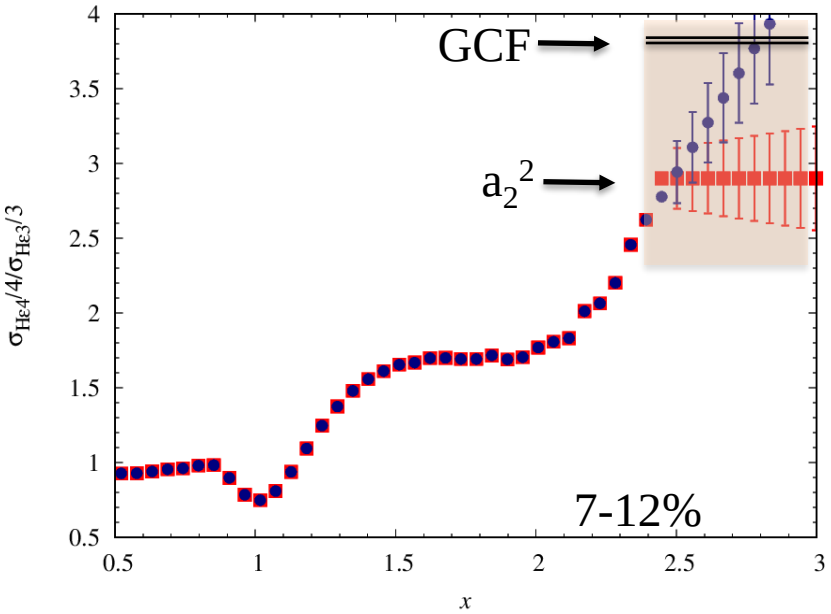
**XEM2 (Under analysis: 8.5, 10)**

**Hall A at 6 GeV**

# How much data do you really need?

$$\frac{\sigma_{4He}/4}{\sigma_{3He}/3}$$




- Statistics focused on $2.5 < x < 3.0$ kinematic range
  The high statistics goal is driven by the prediction from Misak Sargsian of $a_3 \sim (a_2)^2$
  - For 4He/3He ratio, $a_3 \sim 2.9$
- Projections don't show fluctuations in the data

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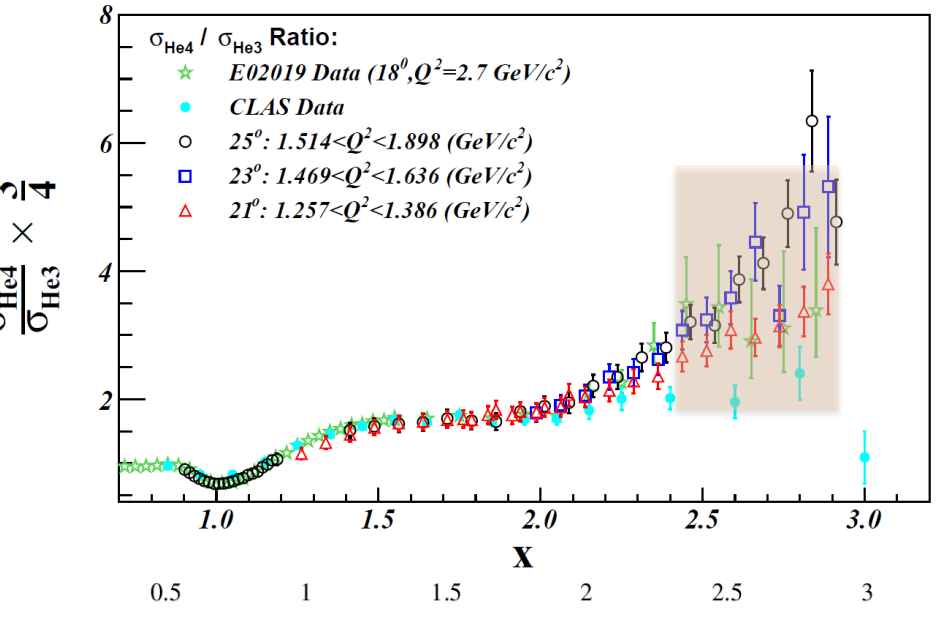


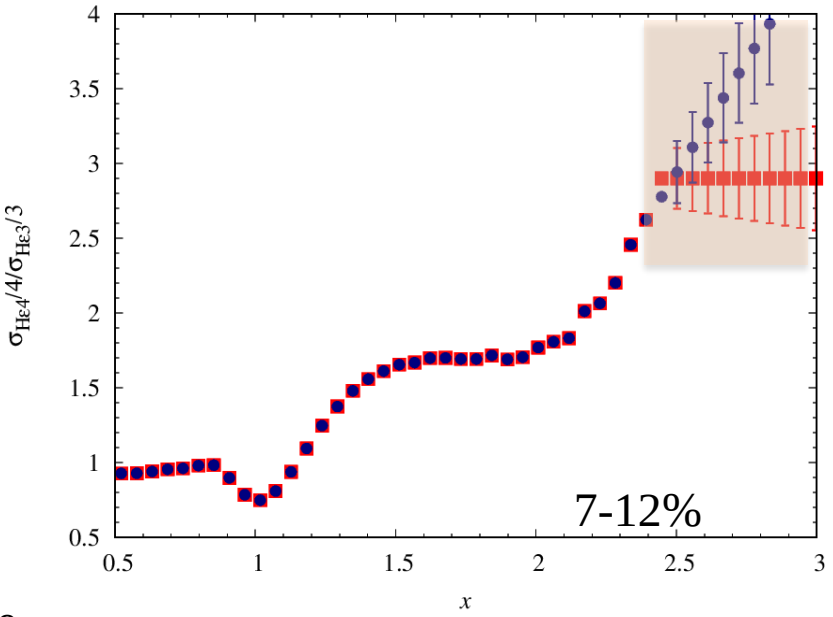


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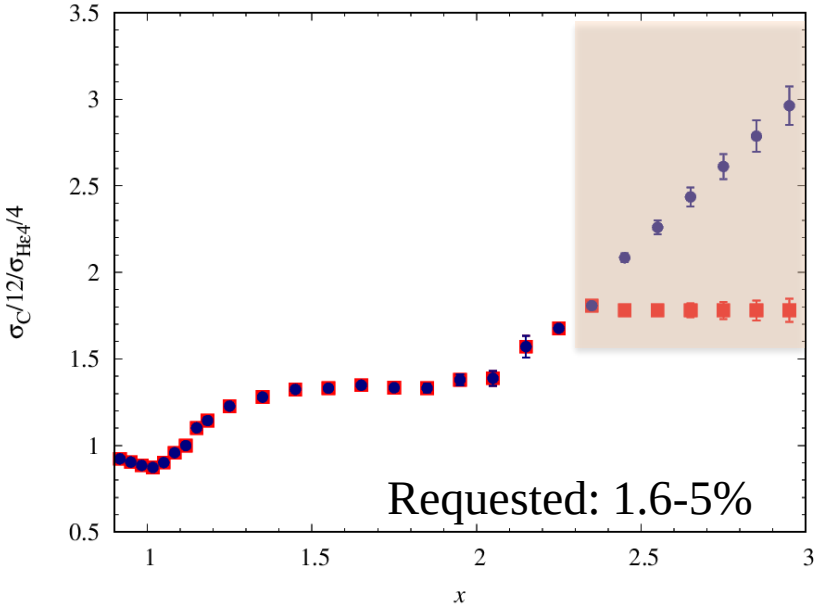
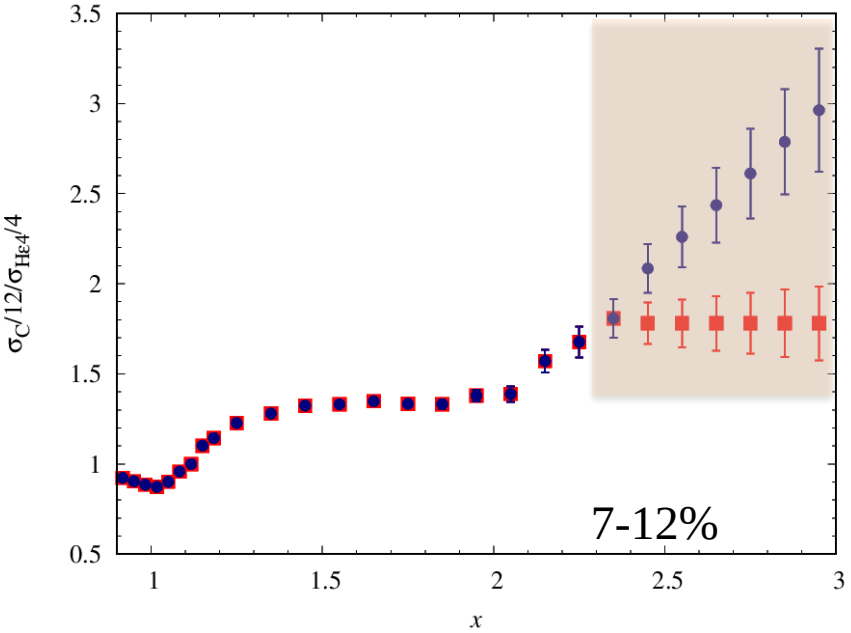
# How much data do you really need?

$$\frac{\sigma_C/12}{\sigma_{4He}/4}$$

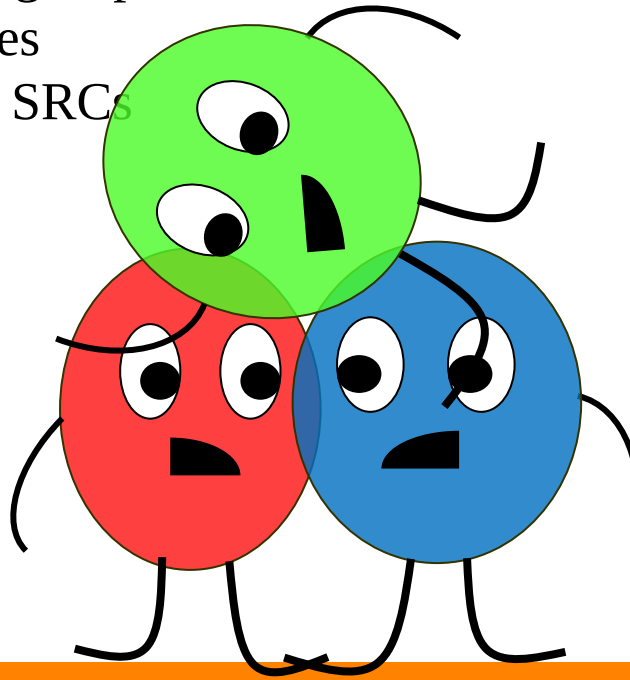



- Statistics focused on 2.5 < x < 3.0 kinematic range
  The high statistics goal is driven by the prediction from Misak Sargsian of $a_3 \sim (a_2)$
- Projections don't show fluctuations in the data

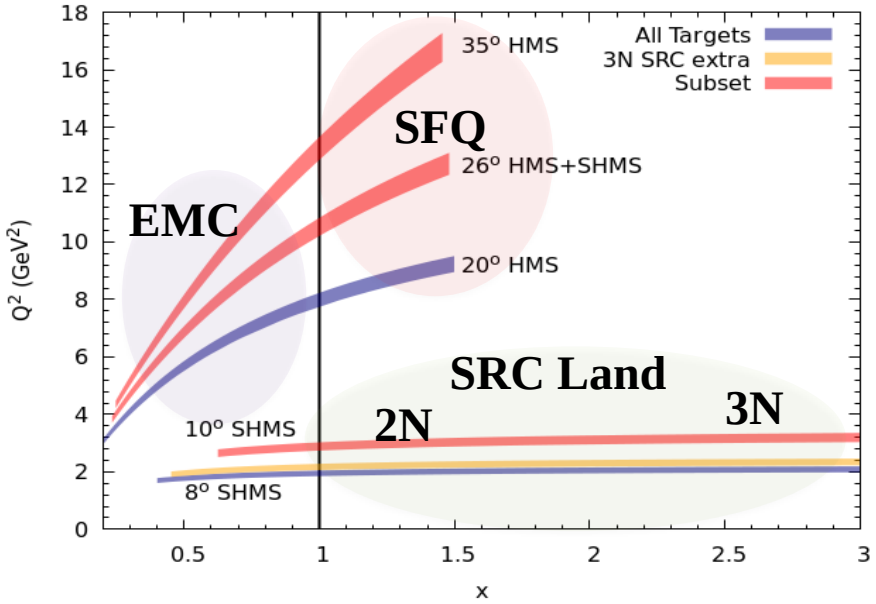
# Summary

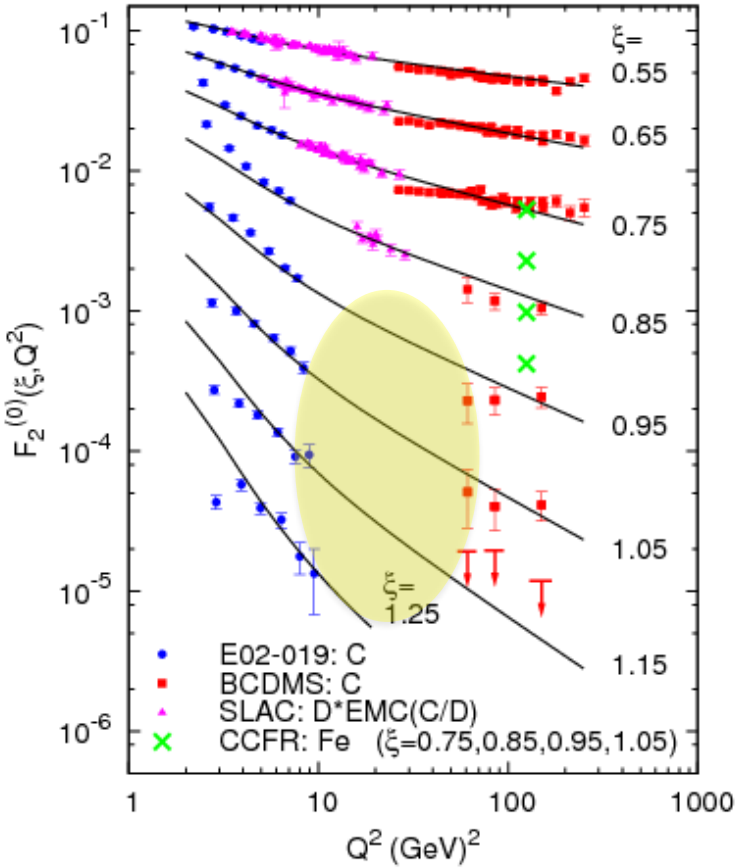
- No clear advantage to 22 GeV for Quasielastic Scattering Experiments
  - Vital to capitalize on the 11 GeV era for SRC studies
  - Next few years are the last chance to search for 3N SRCs
    - Need a dedicated experiment
      - ***CAN reach necessary kinematics!***
    - Need additional support from theory
      - Misak is our only champion



# Other fun things at x>1 at high $Q^2$

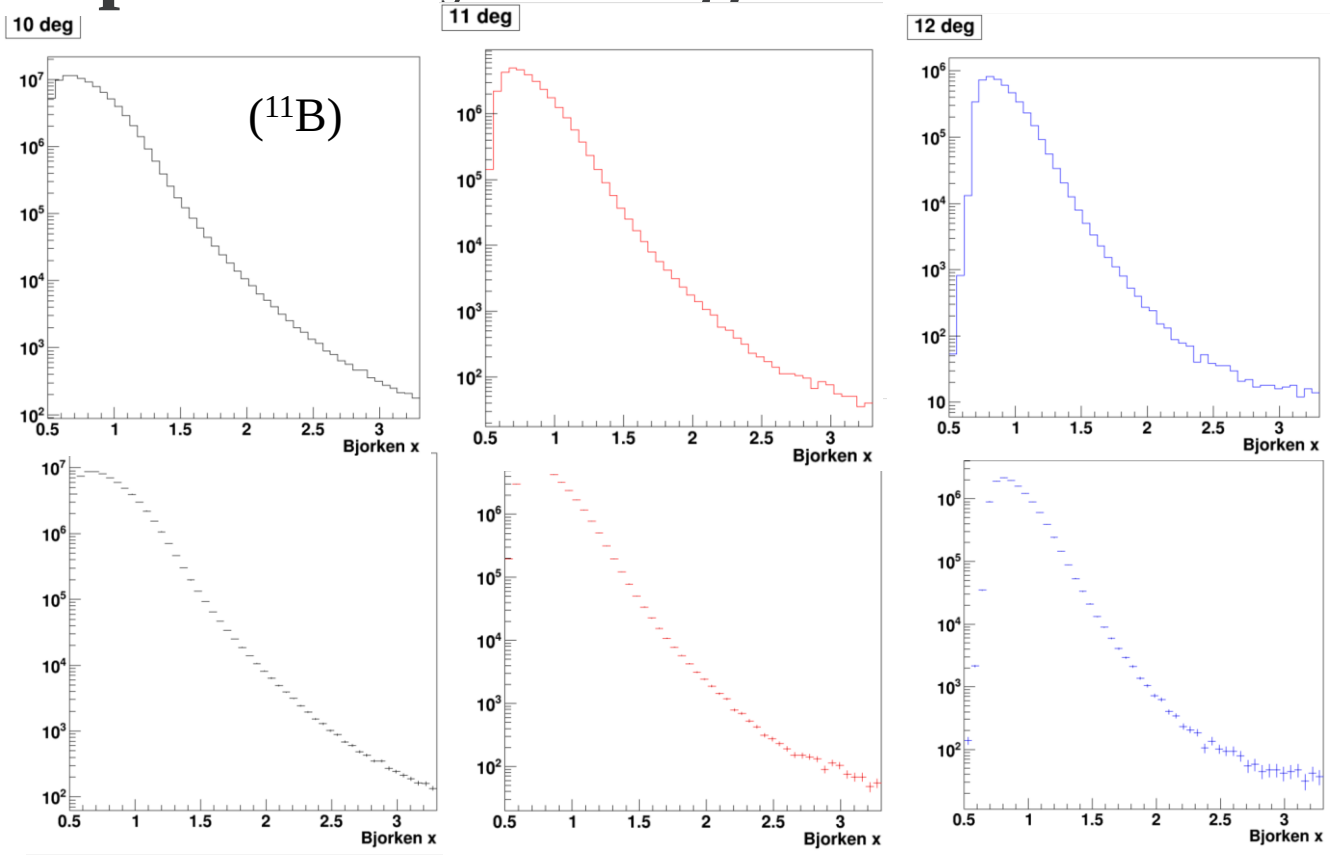
*See J. Arrington's talk later*




*N. Fomin et al, PRL 105, 212502 (2010)*

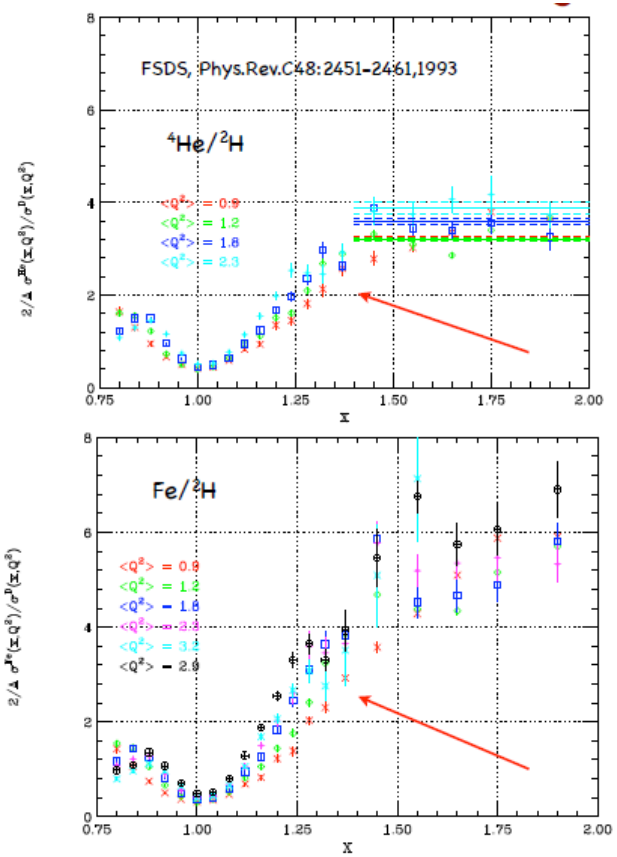
# Exponentially Falling Cross Section




- Rates in the 2.5<x<3.0 region known from XEM2 for 10 degrees
- Relative scaling based on $^{11}$B data for higher angles

# BACKUPS

# 20th Century Data



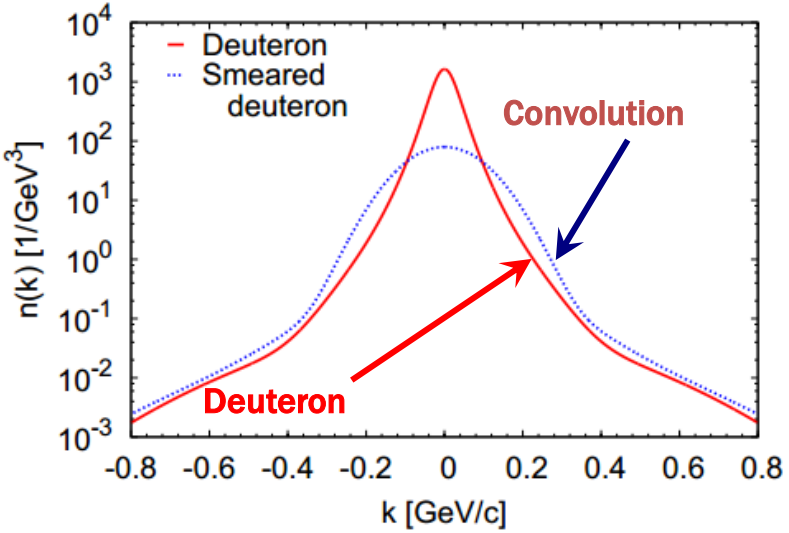

- Moderate $Q^2$ data from SLAC
- Originally analyzed in the *y*-scaling picture

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

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

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

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




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

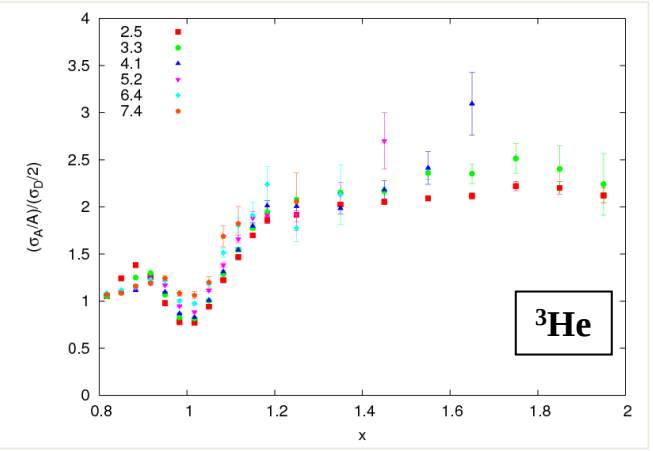
*Following prescription from C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996)*

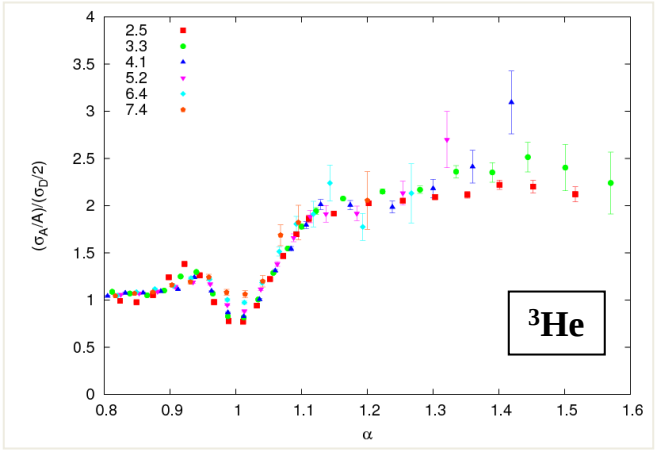
$a_2 = \sigma_A/\sigma_D$ → *relative measure of high momentum nucleons*

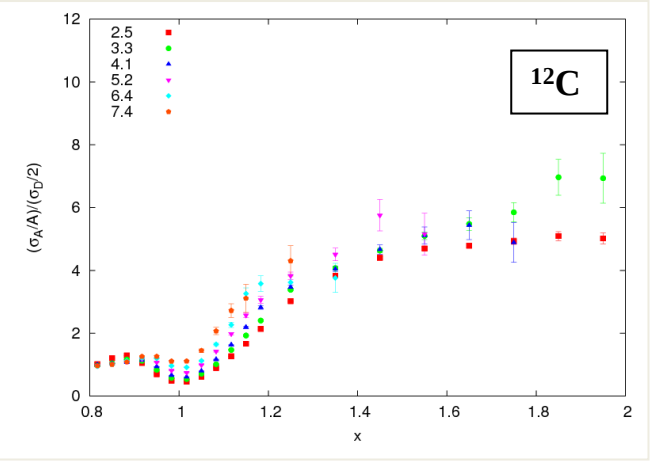
$R_{2n}$ → *relative measure of correlated pairs*

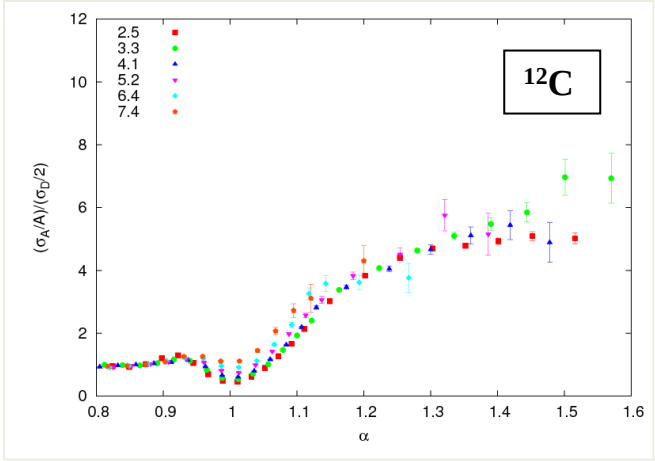
| | E02-019 | SLAC | CLAS | $R_{2N}$-ALL | $a_2$-ALL |
|---|---|---|---|---|---|
| $^3$He | 1.93±0.10 | 1.8±0.3 | – | 1.92±0.09 | 2.13±0.04 |
| $^4$He | 3.02±0.17 | 2.8±0.4 | 2.80±0.28 | 2.94±0.14 | 3.57±0.09 |
| Be | 3.37±0.17 | – | – | 3.37±0.17 | 3.91±0.12 |
| C | 4.00±0.24 | 4.2±0.5 | 3.50±0.35 | 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 |

# Test scaling in x and $Q^2$



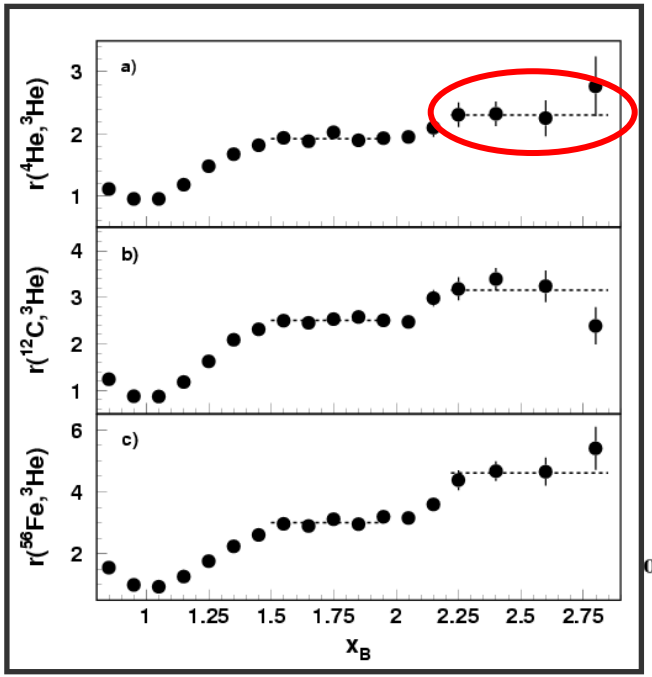



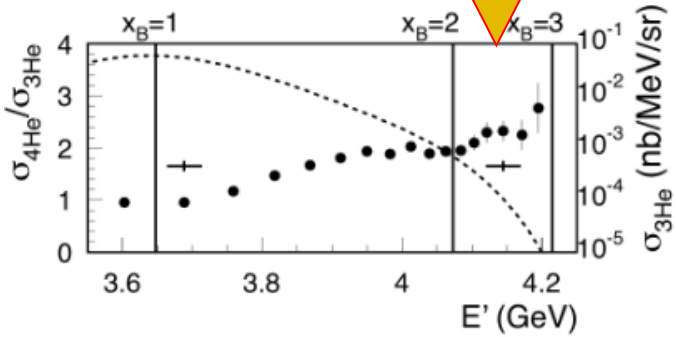




$$\alpha = 2 - \frac{q^- + 2M}{2M}\left(1 + \frac{\sqrt{W^2 - 4M^2}}{W}\right)$$

Phys. Rev. C **48**, 2451(1993)

# 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*