New Results on Three-Nucleon Short-Range Correlations

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Abstract:

- Calculation of High-Energy Nuclear Processes.

- Applying to Two-Nucleon SRC Studies

- Probing Three-Nucleon SRCs: new results

I. Calculation of High Energy Nuclear Processes

Emergence of High Energy Dynamics

- Short Range Nucleon Correlations(SRCs) are important feature of Nuclear Dynamics

- Transition from hadronic to quark-gluon degrees of freedom in cold-nuclei "should happen" through SRCs

- 3N SRCs are essential for high density cold dense nuclear matter relevant to Neutron Star dynamics in the core

- Internal momenta relevant to SRCs $p \sim M_N$ - Relativistic

- Such states are probed in high energy processes: high energy approximations can be applied in description of SRC dynamics

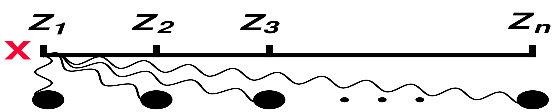
High Energy Approximations:

- High Energy: $|\vec{q}| = q_3 \gg p \sim M_N$ QE/DIS $Q^2 \geq few \ \mathrm{GeV}^2$

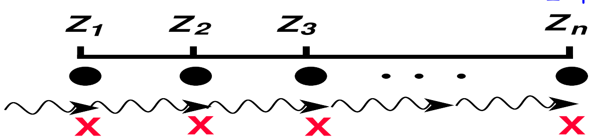
- Emergence of the small parameter

$$\frac{q_-}{q_+} = \frac{q_0 - q_3}{q_0 + q_3} \ll 1 \qquad \mathcal{O}(\frac{q_-}{q_+})$$

- Emergence of the light- front dynamics $\tau = t - z \sim \frac{1}{q_+} \to 0$



(a)



(b)

- non relativistic case: due to Galilean relativity observer X can probe all n-nucleons at the same time $\Psi(z_1, z_2, z_3, \cdots, z_n, t)$

- relativistic case: observer X probes all n-nucleons at different n times $\Psi(z_1, t_1; z_2, t_2; z_3, t_3 \cdots ; z_n, t_n)$

- observer riding the light-front X probes all n-nucleons at same light-cone time: $\Psi_{LF}(\mathcal{Z}_1, \mathcal{Z}_2, \mathcal{Z}_3, \cdots, \mathcal{Z}_n, \tau)$

$$\tau = t_1 - z_1 = t_2 - z_2 = \cdots = t_n - z_n \qquad \mathcal{Z}_i = t_i + z_i$$

Light-Front wave function of the Nucleus

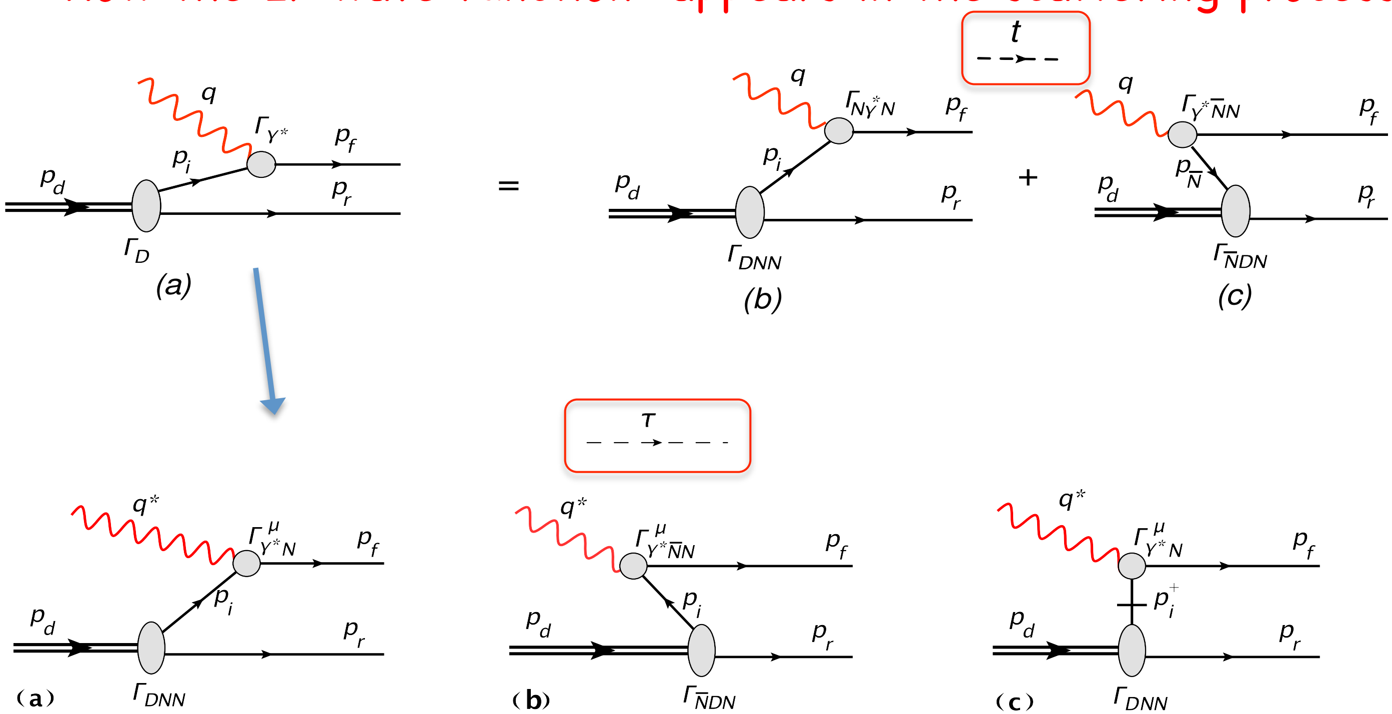
$$\Psi_{LF}(\mathcal{Z}_1, \mathcal{Z}_2, \mathcal{Z}_3, \cdots, \mathcal{Z}_n, \tau)$$

- in the momentum space

$$\Psi_{LF}(\alpha_1, p_{1\perp}; \alpha_2, p_{2\perp}; \alpha_3, p_{3\perp}; \cdots, \alpha_n, p_{n\perp})$$

$$\alpha_i = \frac{p_{i-}}{p_{A-}/A}$$

- How the LF wave function appears in the scattering process



$$(b) \sim (c)$$

$$(b) = 0$$

Frank Vera, M.S. ArXiV 2018

From Schroedinger Equation -> Feynman Diagrams-> Light-Front Wave Function

Schroedinger eq. → Lipmann-Schwinger Eq.

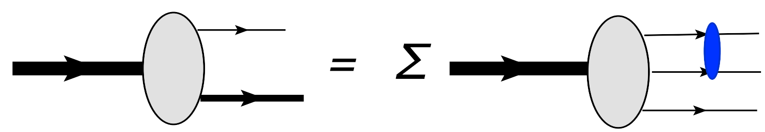
$$\left[-\sum_i \frac{\nabla_i^2}{2m} + \frac{1}{2}\sum_{i,j} V(x_i - x_j)\right]\psi(x_1,\cdots,x_A) = E\psi(x_1,\cdots,x_A)$$

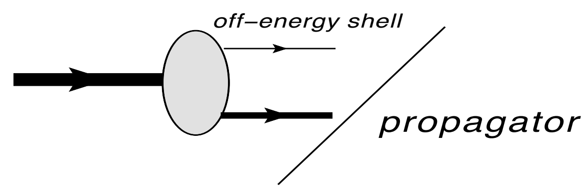
$$\left(\sum_i \frac{k_i^2}{2m} - E_b\right)\Phi(k_1,\cdots,k_A) = -\frac{1}{2}\sum_{i,j}\int U(q)\,\Phi(k_1,\cdots,k_i-q,\cdots k_j+q,\cdots,k_A)d^3q$$

Lipmann-Schwinger Eq → t- ordered diagrammatic method

$$\left(\sum_i \frac{k_i^2}{2m} - E_b\right)\Phi(k_1,\cdots,k_A) = -\frac{1}{2}\sum_{i,j}\int U(q)\,\Phi(k_1,\cdots,k_i-q,\cdots k_j+q,\cdots,k_A)d^3q$$

$$\Phi(k_1,\cdots k_A) = \frac{1}{\sum \frac{k_i^2}{2m} - E_b}\Gamma_{A\to N,A-1}$$

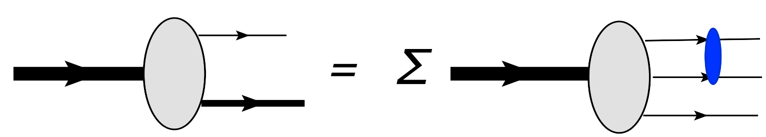


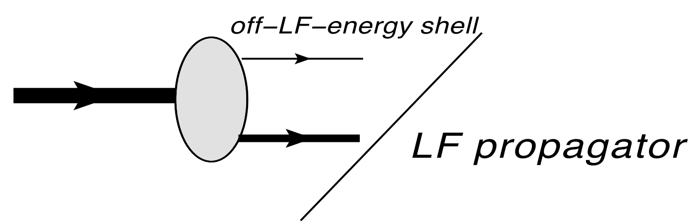


Weinberg Eq → $\mathcal{T}$ - ordered diagrammatic method

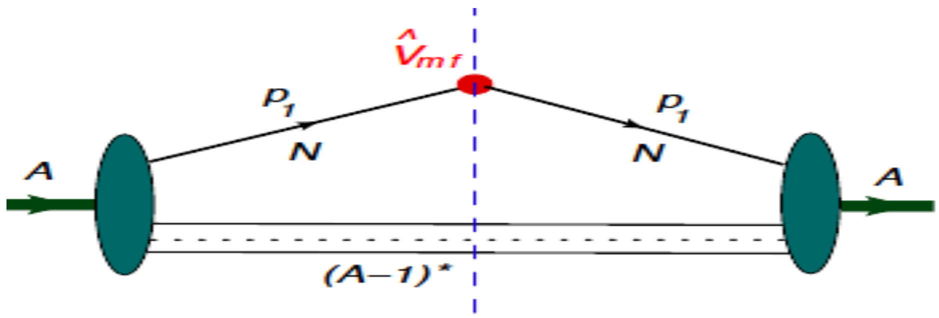
$$\left(\sum \frac{k_{i\perp}^2 + m^2}{\alpha_i} - M_A^2\right)\Phi_{LF}(k_1,\cdots k_A) = \frac{1}{2}\sum_{i,j}\int U_{LF}(q)\Phi_{LF}(k_1,\cdots k_A)\prod \frac{d\alpha_i}{\alpha_i}d^2k_{i\perp}$$

$$\Phi_{LF}(k_1,\cdots k_A) = \frac{1}{\sum \frac{k_{i\perp}^2 + m^2}{\alpha_i} - M_A^2}\Gamma_{A\to N,A-1}$$





Spectral Function Calculations



$$S_A^{MF} = -Im\int \chi_A^\dagger \Gamma^\dagger_{A,N,A-1}\frac{\not{p}_1+m}{p_1^2-m^2+i\varepsilon}\hat{V}^{MF}\frac{\not{p}_1+m}{p_1^2-m^2+i\times\varepsilon}\left[\frac{G_{A-1}(p_{A-1})}{p_{A-1}^2-M_{A-1}^2+i\varepsilon}\right]^{on}\Gamma_{A,N,A-1}\chi_A\frac{d^4p_{A-1}}{i(2\pi)^4}$$

$$\hat{V}^{MF} = ia^\dagger(p_1,s_1)\delta^3(p_1+p_{A-1})\delta(E_m-E_\alpha)a(p_1,s_1)$$

$$\psi_{N/A}(p_1,s_1,s_A,E_\alpha) = \frac{\bar{u}(p_1,s_1)\Psi^\dagger_{A-1}(p_{A-1},s_{A-1},E_\alpha)\Gamma_{A,N,A-1}\chi_A}{(M_{A-1}^2-p_{A-1}^2)\sqrt{(2\pi)^3 2E_{A-1}}}$$

$$S_A^{MF}(p_1,E_m) = \sum_\alpha\sum_{s_1,s_{A-1}} \mid \psi_{N/A}(p_1,s_1,s_A,E_\alpha)\mid^2 \delta(E_m-E_\alpha)$$

Emergence of Short-Range Correlations

- Back to Lipmann-Schwinger Equation

$$\left(\sum_i \frac{k_i^2}{2m} - E_b\right) \Phi(k_1, \cdots, k_A) = -\frac{1}{2}\sum_{i,j} \int U(q)\, \Phi(k_1, \cdots, k_i - q, \cdots k_j + q, \cdots, k_A) d^3q$$

- Assume: system is dilute

- Assume: $U_{NN}(q) \sim \frac{1}{q^n}$ with $n > 1$

- then the k dependence of the wave function for $k^2/2m_N \gg |E_B|$

$$\Phi^{(1)}(k_1, \cdots, k_c, \cdots, -k_c, \cdots, k_A) \approx \frac{U_{NN}(k_c)}{k_c^2} F_A(k_1, \cdots' \cdots', \cdots, k_A)$$

$$\Phi^{(2)}(\cdots k_c, \cdots) \sim \frac{1}{k_c^{2+n}} \int \frac{1}{q^n} dq$$

- For large k_c $\Phi^{(2)}(k_c) \ll \Phi^{(1)}(k_c)$

Amado, 1976

Frankfurt, Strikman 1981

- The same is true for relativistic equations as:
  Bethe-Salpetter or Weinberg Light Cone Equations

- From $\Phi^{(1)}(k_1, \cdots, k_c, \cdots, -k_c, \cdots, k_A) \approx \frac{U_{NN}(k_c)}{k_c^2} F_A(k_1, \cdots' \cdots', \cdots, k_A)$ follows

$$\text{for large } k > k_{Fermi}$$

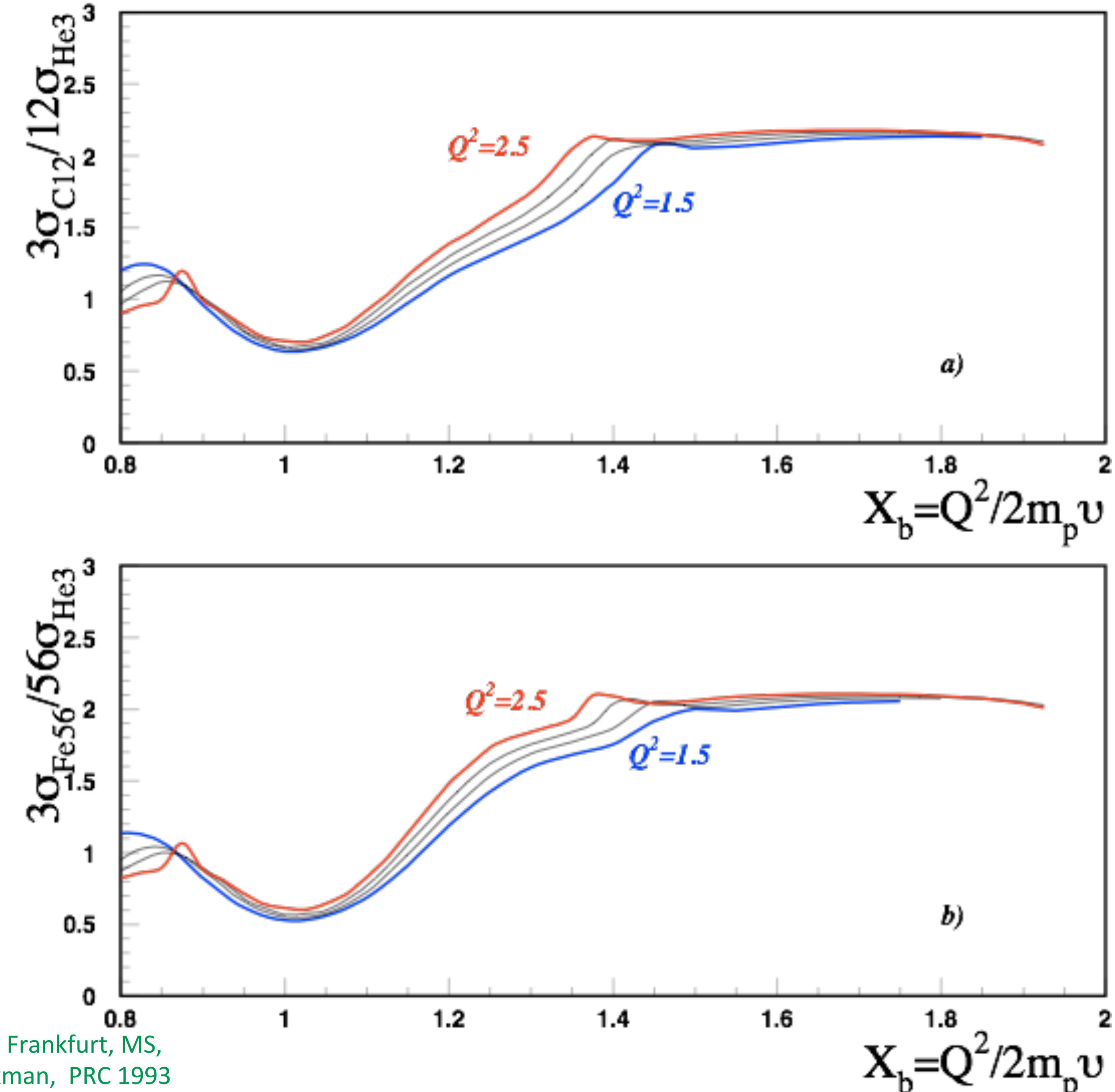
$$n_A(k) \approx a_{NN}(A) n_{NN}(k)$$

Frankfurt, Strikman Phys. Rep, 1988
Day,Frankfurt, Strikman, MS, Phys. Rev. C 1993

- Experimental observations

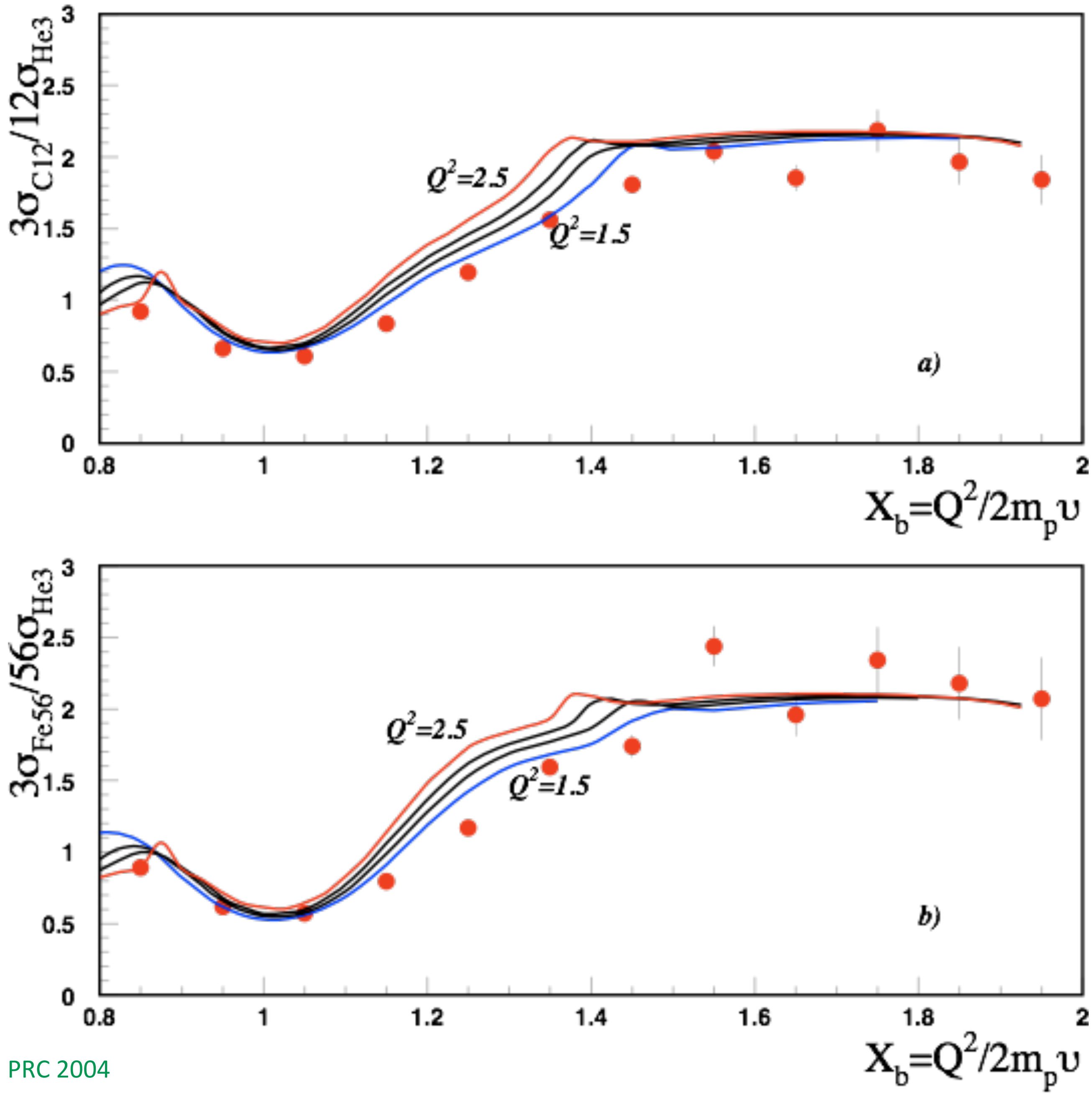
Egiyan et al, 2002,2006
Fomin et al, 2011

$A(e,e')$

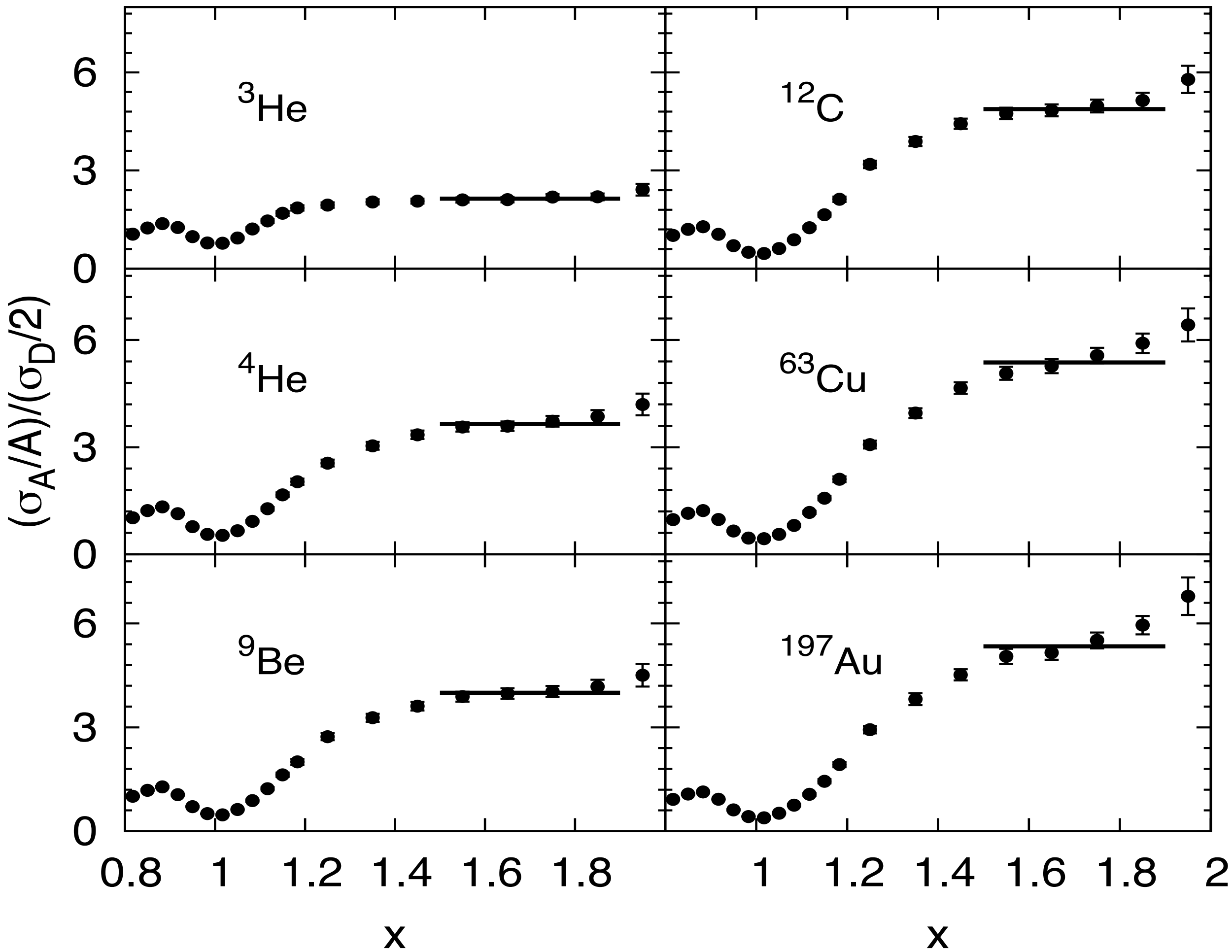


Day, Frankfurt, MS,
Strikman, PRC 1993

$A(e,e')$

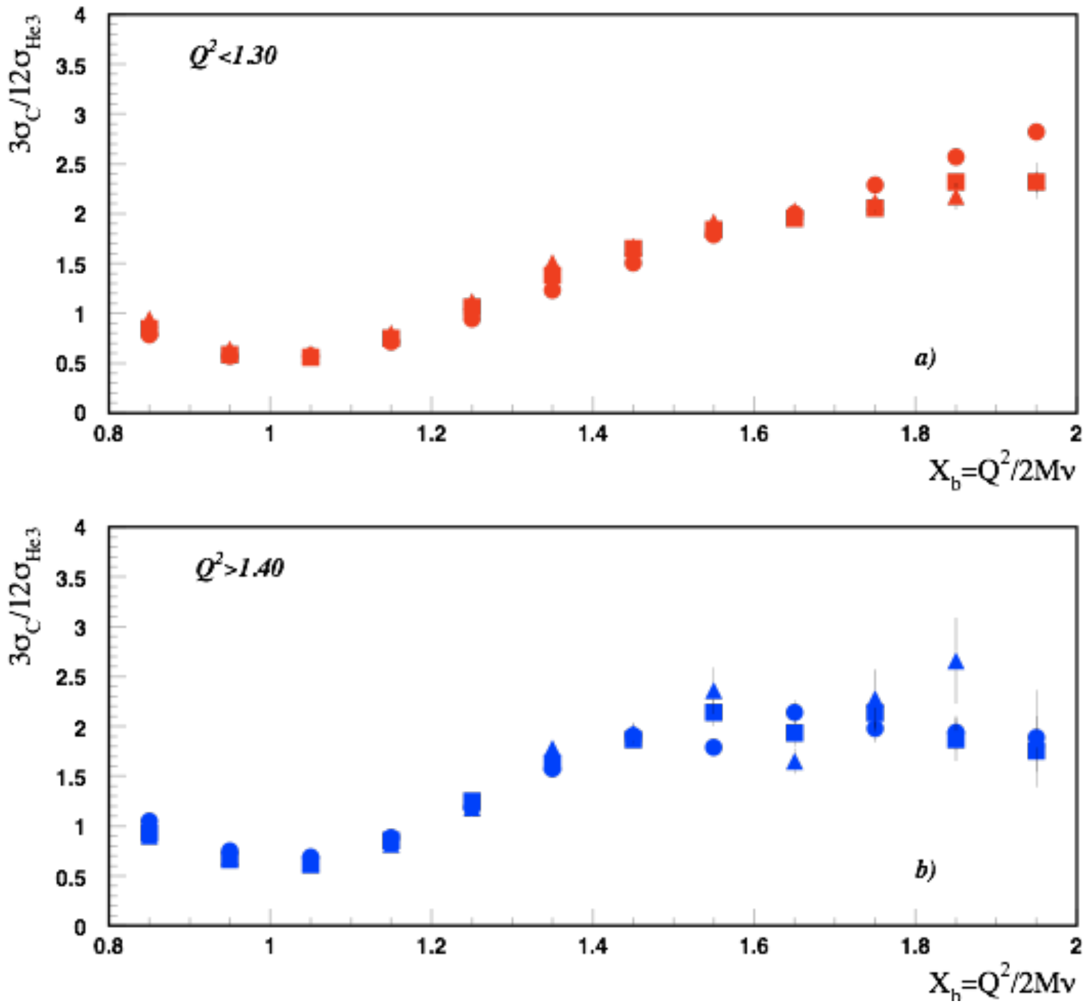


Egiyan, et al PRC 2004



Fomin et al PRL 2011

A(e,e')



$3\sigma_C/12\sigma_{He3}$
Q²<1.30
a)
$X_b=Q^2/2M\nu$
$3\sigma_C/12\sigma_{He3}$
Q²>1.40
b)
$X_b=Q^2/2M\nu$

Meaning of the scaling values

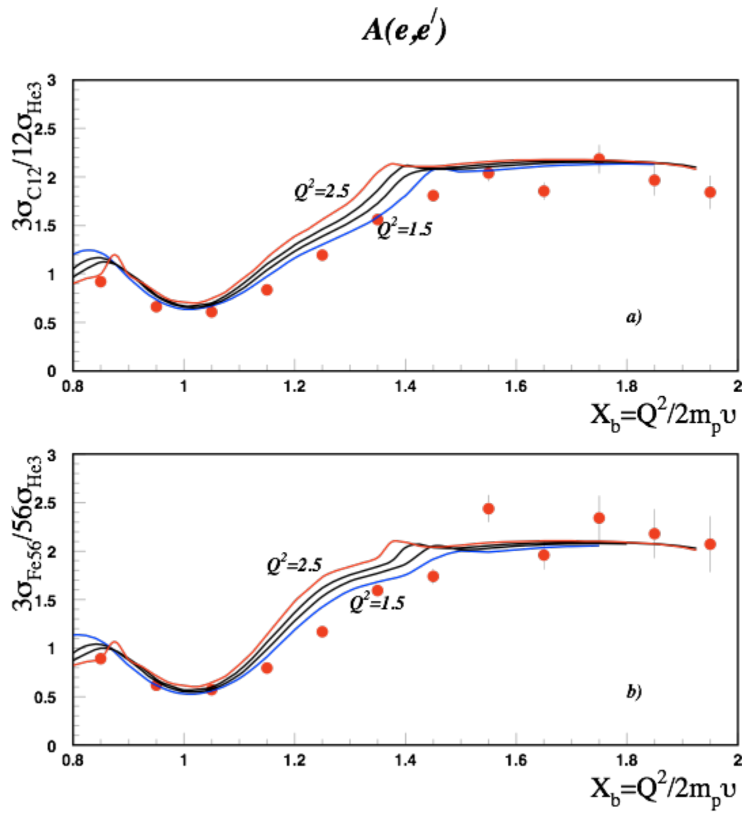
Day, Frankfurt, MS, Strikman, PRC 1993

Frankfurt, MS, Strikman, IJMP A 2008

Fomin et al PRL 2011

$$R = \frac{A_2\sigma[A_1(e,e')X]}{A_1\sigma[A_2(e,e')X]}$$

$$\text{For } 1 < x < 2 \;\; R \approx \frac{a_2(A_1)}{a_2(A_2)}$$



Egiyan, et al PRL 2006, PRC 2004

meaning of
x value

a2's as relative probability of 2N SRCs

Table 1: The results for $a_2(A, y)$

A	y	This Work	Frankfurt et al	Egiyan et al	Famin et al
^{3}He	0.33	2.07±0.08	1.7±0.3		2.13±0.04
^{4}He	0	3.51±0.03	3.3±0.5	3.38±0.2	3.60±0.10
^{9}Be	0.11	3.92±0.03			3.91±0.12
^{12}C	0	4.19±0.02	5.0±0.5	4.32±0.4	4.75±0.16
^{27}Al	0.037	4.50±0.12	5.3±0.6		
^{56}Fe	0.071	4.95±0.07	5.6±0.9	4.99±0.5	
^{64}Cu	0.094	5.02±0.04			5.21±0.20
^{197}Au	0.198	4.56±0.03	4.8±0.7		5.16±0.22

2. Dominance of the (pn) component of SRC

for large $k > k_{Fermi}$

$$n_A(k) \approx a_{NN}(A) n_{NN}(k)$$

$$P_{pn/pX} = 0.92^{+0.08}_{-0.18}$$

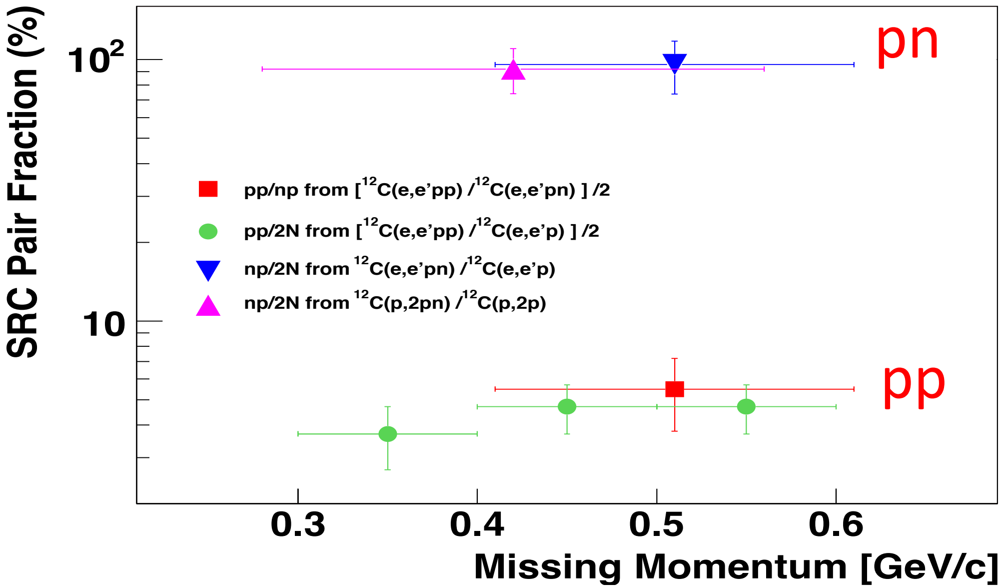
Theoretical analysis of BNL Data

$$\frac{P_{pp}}{P_{pn}} \leq \frac{1}{2}(1 - P_{pn/pX}) = 0.04^{+0.09}_{-0.04}.$$

E. Piasetzky, MS, L. Frankfurt,
M. Strikman,J.Watson PRL , 2006

$$P_{pp/pn} = 0.056 \pm 0.018$$

Direct Measurement at JLab R.Subdei, et al Science , 2008



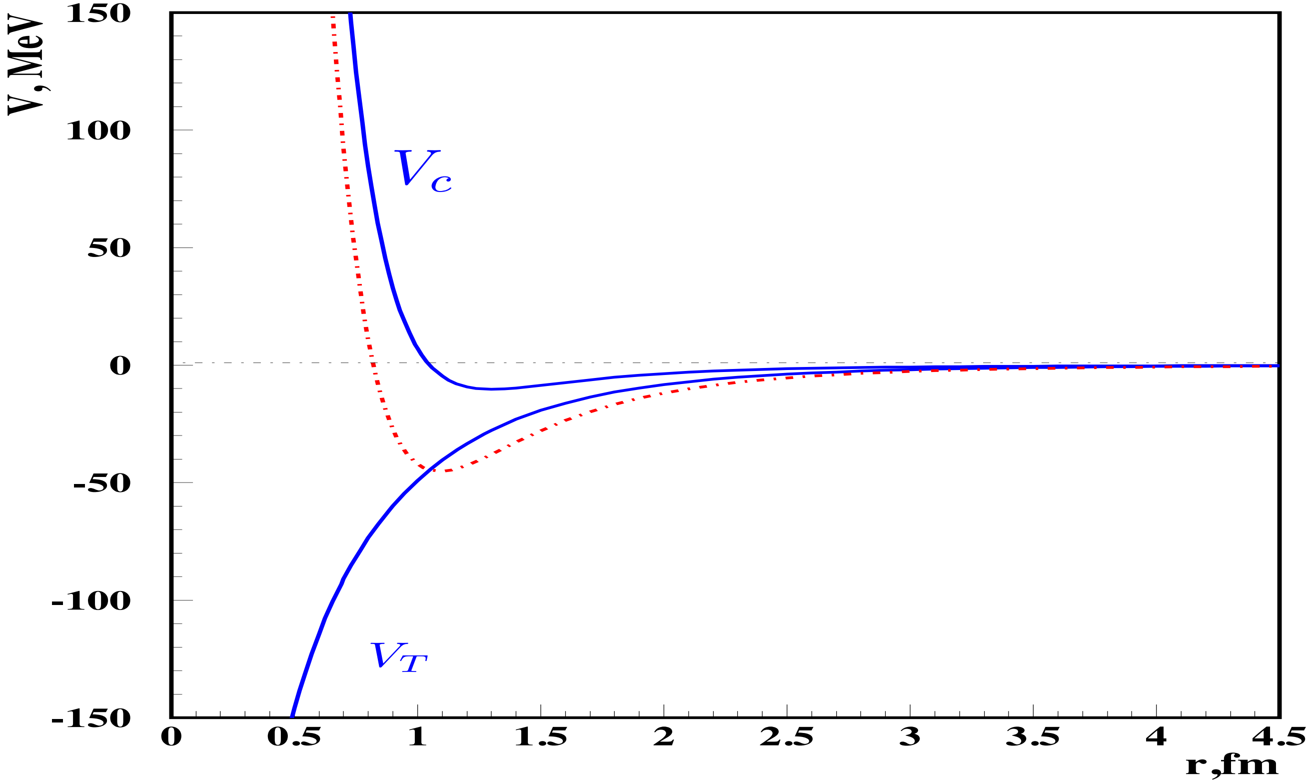
Factor of 20

Expected 4
(Wigner counting)

Theoretical Interpretation

$$\phi_A^{(1)}(k_1, \cdots, k_i = p, \cdots, k_j \approx -p, \cdots, k_A) \sim \frac{V_{NN}(p)}{p^2} f(k_1, \cdots{}' \cdots{}' \cdots \quad)$$

$$n_A(k) \approx a_{NN}(A) n_{NN}(k)$$



Explanation lies in the dominance of the tensor part in the NN interaction

$$V_{NN}(r) \approx V_c(r) + V_t(r) \cdot S_{12}(r) + V_{LS} \cdot \vec{L}\vec{S}$$

$$S_{12} = 3(\sigma_1 \cdot \hat{r})(\sigma_2 \cdot \hat{r}) - \sigma_1 \sigma_2$$

$$S_{12}|pp\rangle = 0$$

$$S_{12}|nn\rangle = 0$$

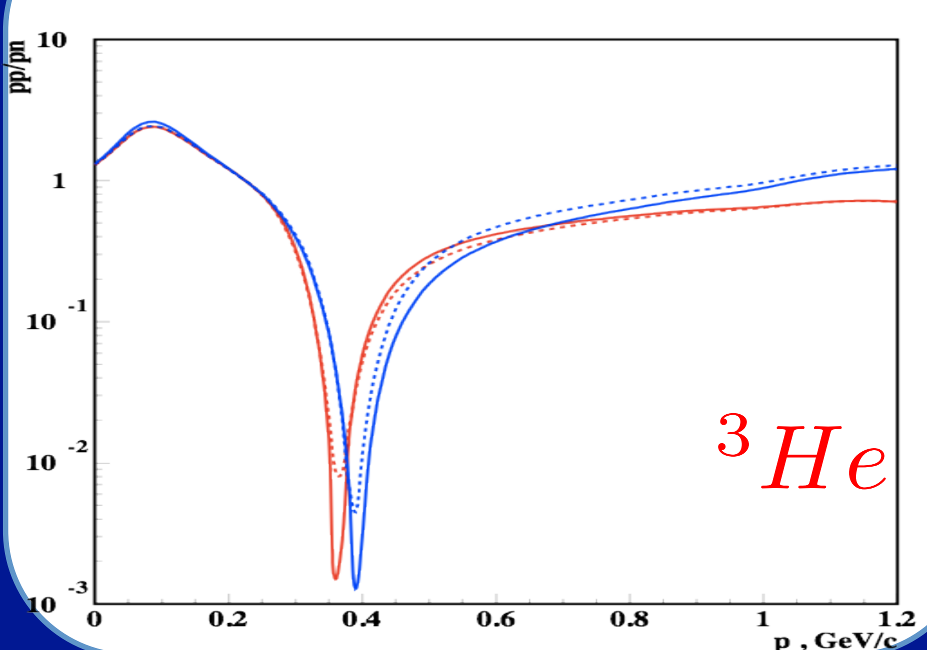
$$S_{12}|pn\rangle = 0$$

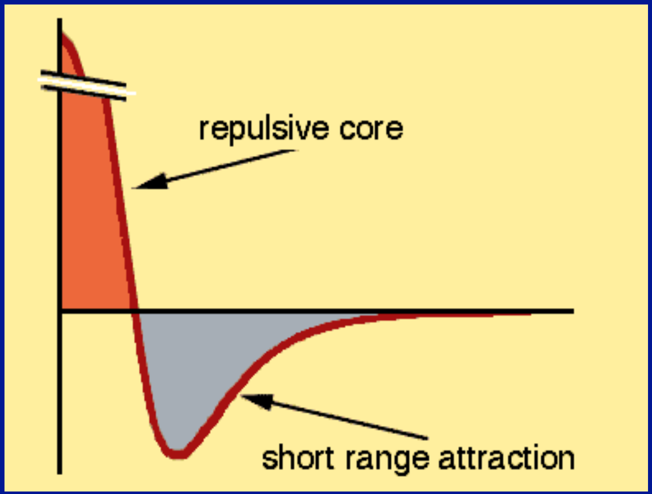
Isospin 1 states

$$S_{12}|pn\rangle \neq 0$$

Isospin 0 states

M.S, Abrahamyan, Frankfurt,Strikman PRC,2005





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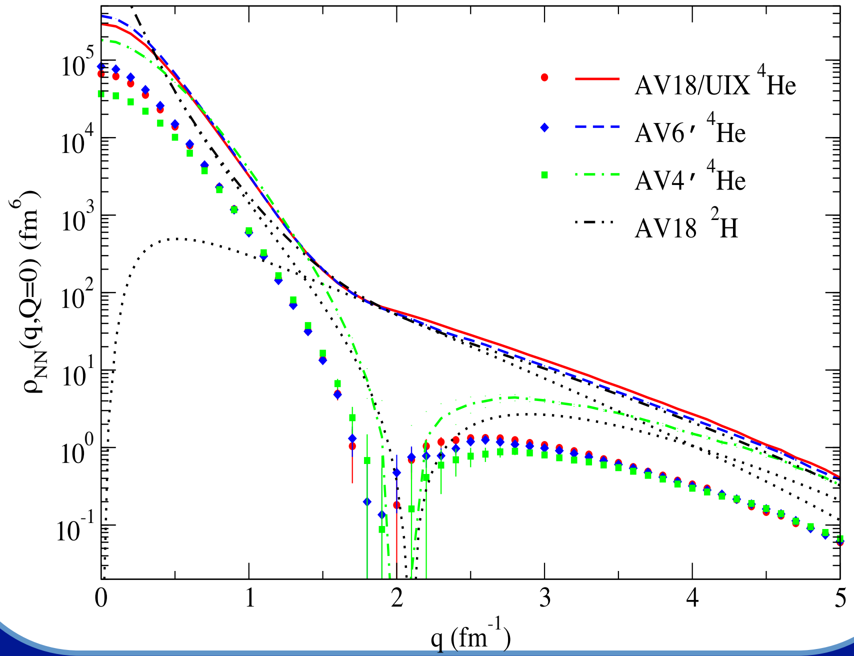
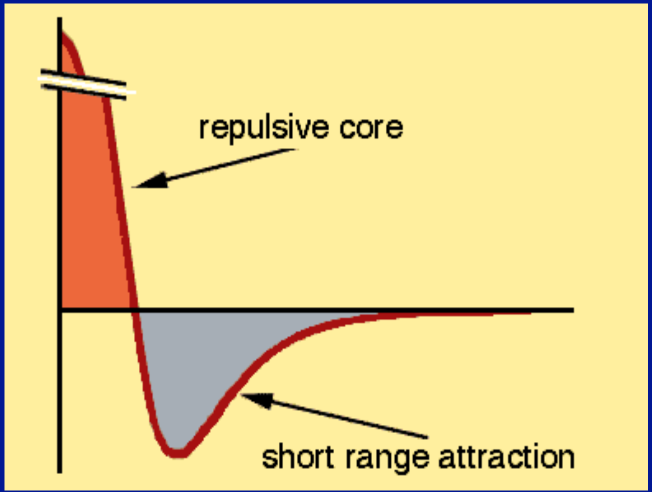
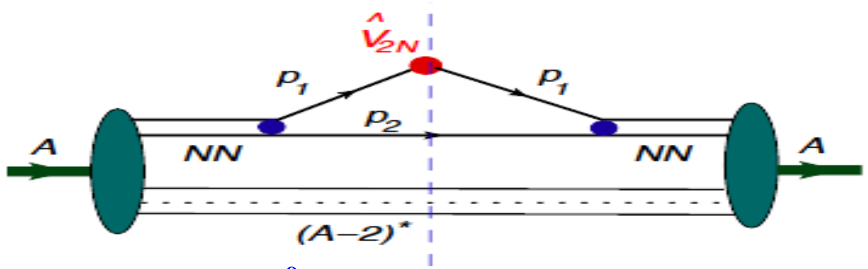
Sciavilla, Wiringa, Pieper, Carlson PRL,2007





2N SRC model



$$P^N_{A,2N}(\alpha_1, p_{1,\perp}, \tilde{M}^2_N) = \sum_{s_2, s_{NN}, s_{A-2}} \int \chi^\dagger_A \Gamma^\dagger_{A\to NN,A-2} \chi_{A-2}(p_{A-2}, s_{A-2})$$
$$\times \frac{\chi_{NN}(p_{NN}, s_{NN})\chi^\dagger_{NN}(p_{NN}, s_{NN})}{p^2_{NN} - M^2_{NN}} \Gamma^\dagger_{NN\to NN} \frac{u(p_1, s_1)u(p_2, s_2)}{p^2_1 - M^2_N}$$
$$\times \left[2\alpha_1^2 \delta(\alpha_1 + \alpha_2 + \alpha_{A-2} - A)\delta^2(p_{1,\perp} + p_{2,\perp} + p_{A-2,\perp})\delta(\tilde{M}^2_N - \tilde{M}^{(2N),2}_N)\right] \frac{\bar{u}(p_1, s_1)\bar{u}(p_2, s_2)}{p^2_1 - M^2_N}$$
$$\times \Gamma_{NN\to NN} \frac{\chi_{NN}(p_{NN}, s_{NN})\chi^\dagger_{NN}(p_{NN}, s_{NN})}{p^2_{NN} - M^2_{NN}} \chi^\dagger_{A-2}(p_{A-2}, s_{A-2})\Gamma_{A,NN,A-2}\chi_A$$
$$\times \frac{d\alpha_2}{\alpha_2} \frac{d^2p_{2,\perp}}{2(2\pi)^3} \frac{d\alpha_{A-2}}{\alpha_{A-2}} \frac{d^2p_{A-2,\perp}}{2(2\pi)^3}. \qquad (1)$$

O. Artiles & M.S. Phys. Rev. C 2016

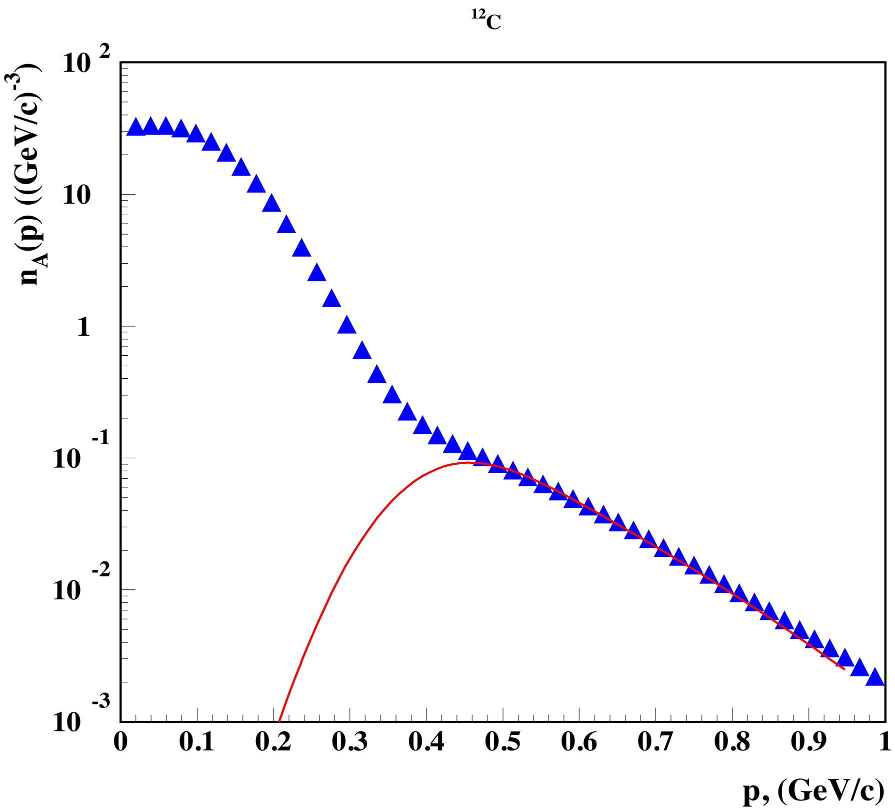
$$\rho_A(\alpha_N, p_{N,\perp}) = \int P_A(\alpha_N, p_{N,\perp}, \tilde{M}^2_N)\tfrac{1}{2} d\tilde{M}^2_N$$

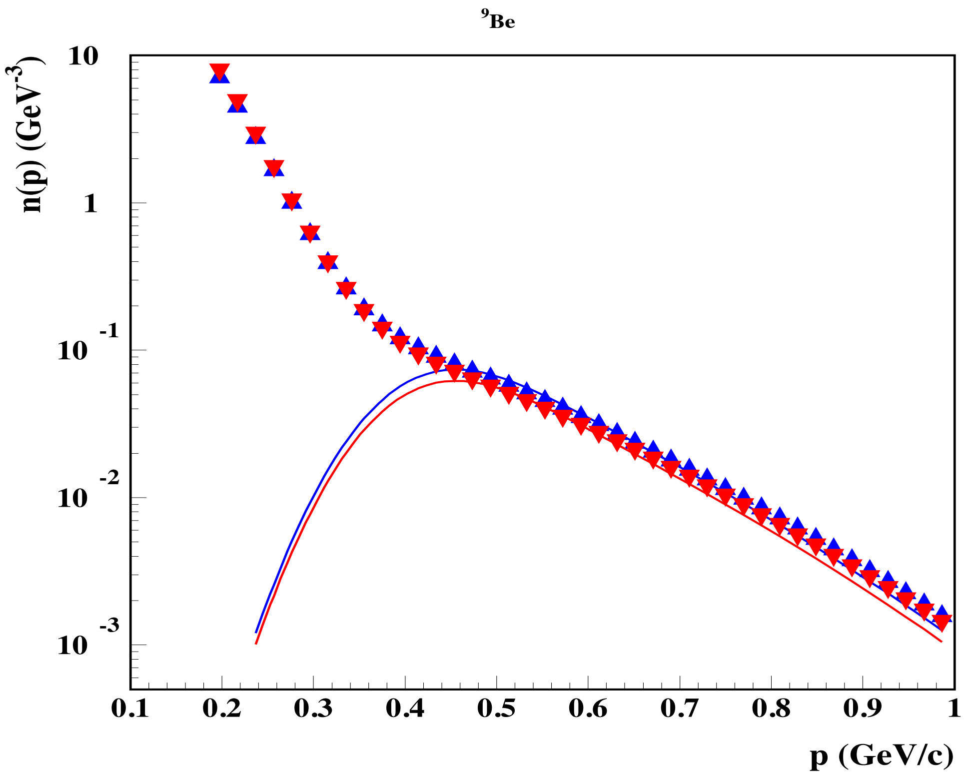
$$\psi^{LF}_{pn}(\alpha, p_\perp) \approx C\psi^{LF}_d(\alpha, p_\perp)$$

$$\psi^{s_{NN}}_{2N}(\beta_1, k_{1,\perp}, s_1, s_2) = -\frac{1}{\sqrt{2(2\pi)^3}} \frac{\bar{u}(p_1,s_1)\bar{u}(p_2,s_2)\Gamma_{NN\to NN}\cdot\chi_{NN}(p_{NN},s_{NN})}{\frac{1}{2}[M^2_{NN} - 4(M^2_N + k^2_1)]}$$

$$\psi_{CM}(\alpha_{NN}, k_{NN,\perp}) = -\frac{1}{\sqrt{\frac{A-2}{2}}} \frac{1}{\sqrt{2(2\pi)^3}} \frac{\chi^\dagger_{NN}(p_{NN},s_{NN})\chi^\dagger_{A-2}(p_{A-2},s_{A-2})\Gamma_{A\to NN,A-2}\chi^{s_A}_A}{\frac{2}{A}\left[M^2_A - s_{NN,A-2}(k_{CM})\right]}$$

2N SRC model Non Relativistic Approximation





2N SRCs:

Proper Variables of 2N SRC are

- the Light Front Momentum Fraction: $\alpha = \frac{p_N^+}{p_{NN}^+}$
- transverse momentum: $p_\perp$

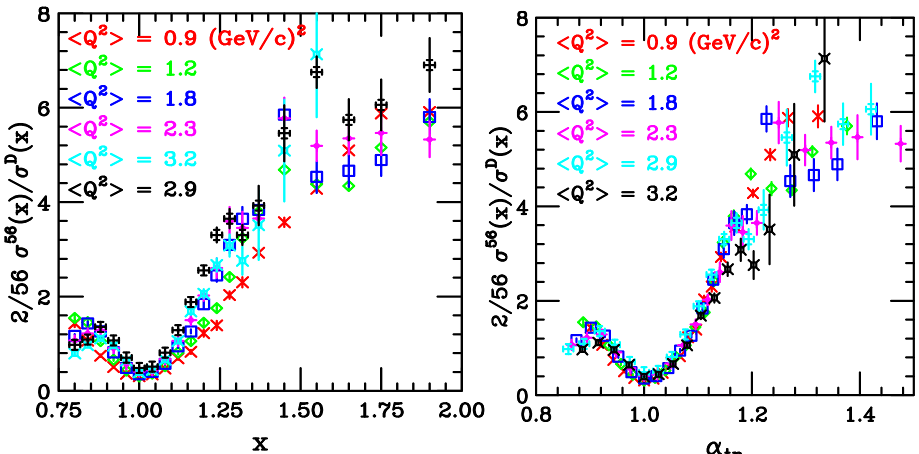
Back to inclusive A(e,e')X scattering

$$\sigma_{eA} = \sum \sigma_{eN} \cdot \rho_A(\alpha) \quad \text{where} \quad \rho_A(\alpha) = \int \rho_A(\alpha, p_\perp) d^2 p_\perp$$

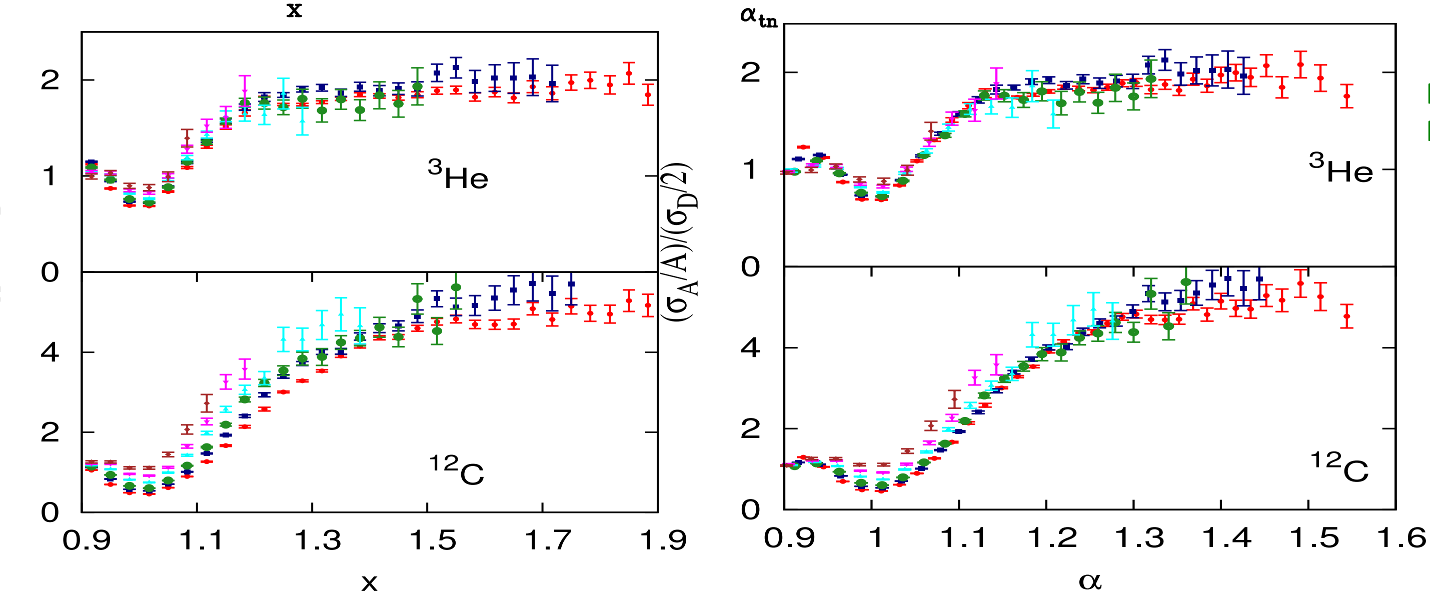
$$1.3 \le \alpha_{2N} \le 1.5$$

$$\alpha_{2N} = 2 - \frac{q_- + 2m_N}{2m_N}\left(1 + \frac{\sqrt{W_{2N}^2 - 4m_N^2}}{W_{2N}}\right)$$

$$\alpha\,\big|_{Q^2\to\infty} \to x$$
$$\alpha\,\big|_{x\to 1} \to 1$$



J.Arrington, D.Higinbotham
G.Rosner, M.S. Prog. PNP 2012

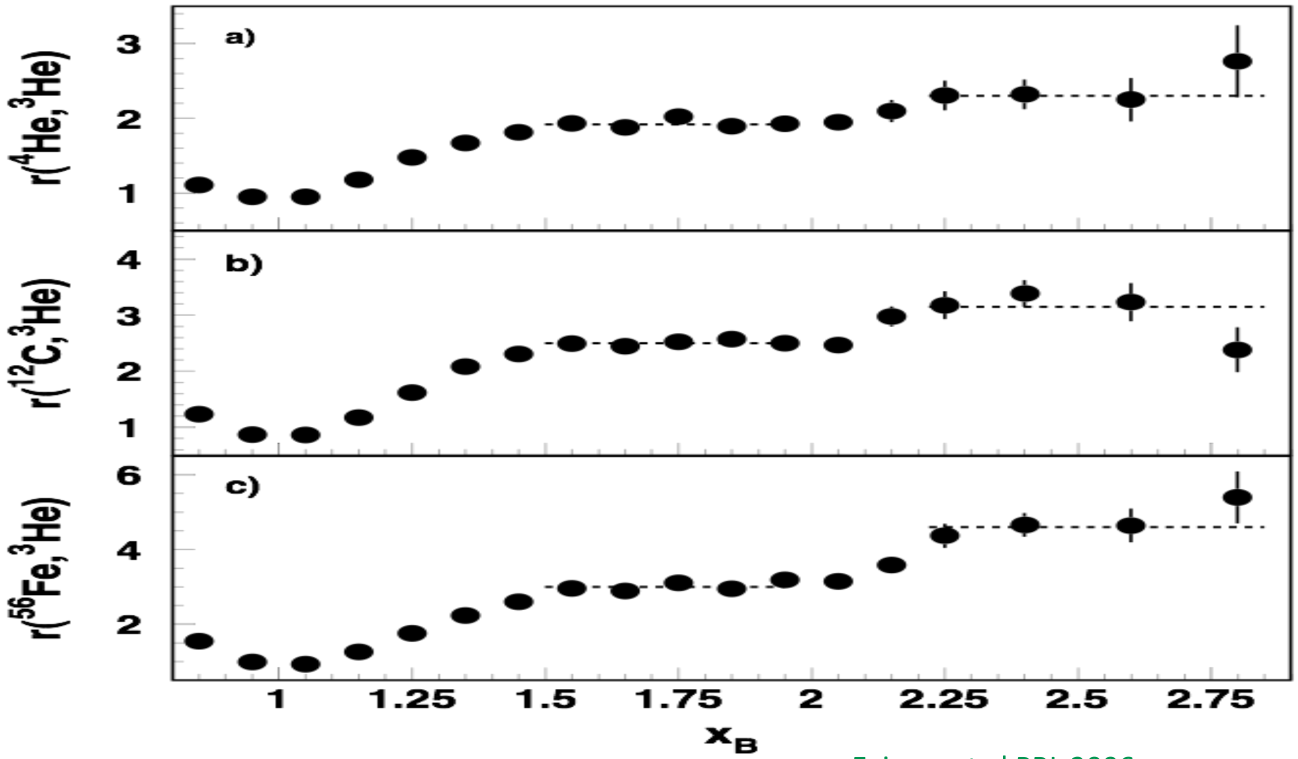


N.Fomin, D.Higinbotham
M.S., P.Sovignon ARNPS, 2017

Towards Three Nucleon Short Range Correlations

Looking for the Plateau in Inclusive Cross Section Ratios x>2

For $1 < x < 2$ $R \approx \frac{a_2(A_1)}{a_2(A_2)}$ For $2 < x < 3$ $R \approx \frac{a_3(A_1)}{a_3(A_2)}$



Egiyan, et al PRL 2006

Three Nucleon Short Range Correlations

Z. Ye, at al, 2017

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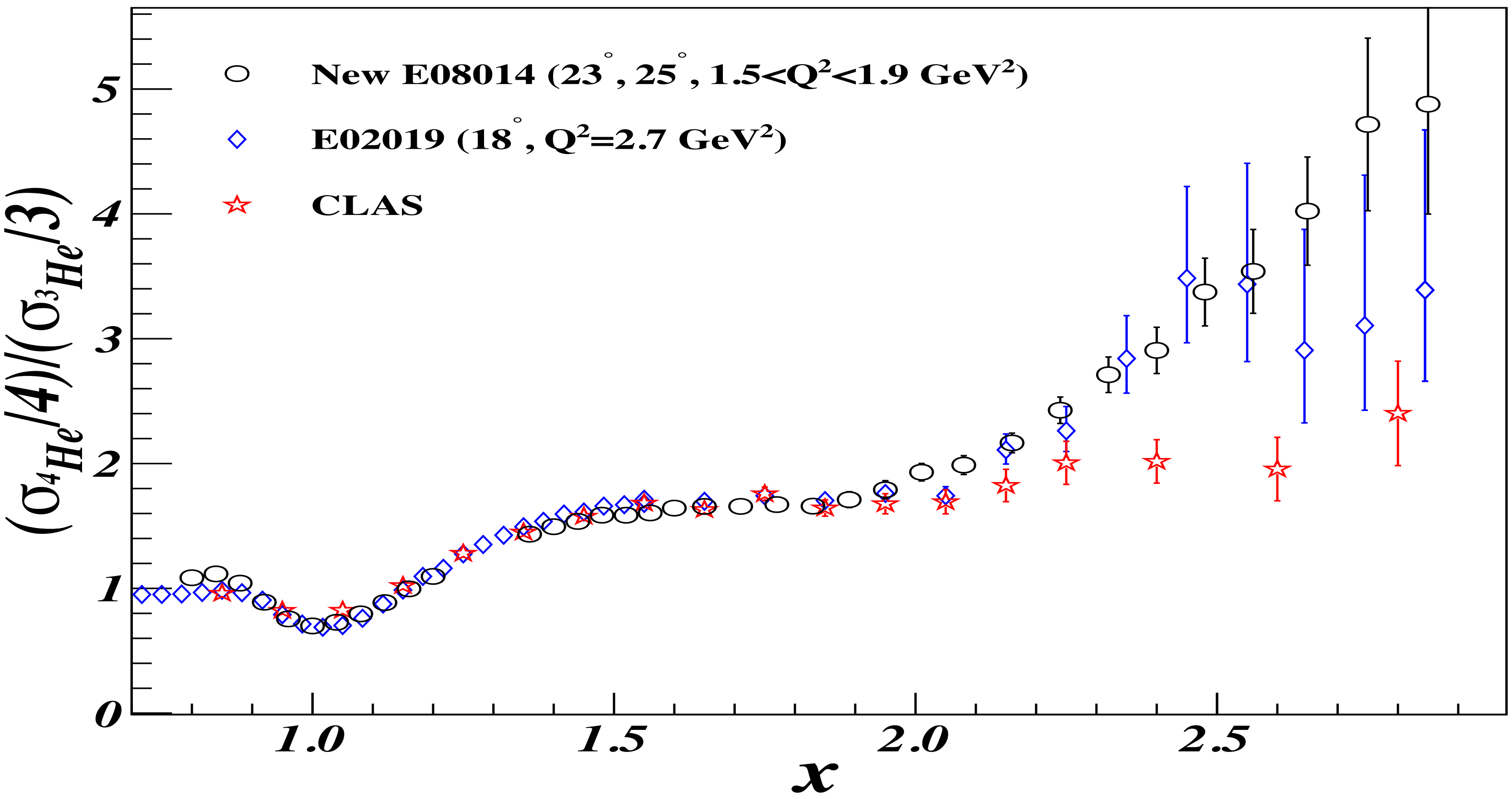

Egiyan, et al PRL 2006

Egiyan, et al PRC 2004

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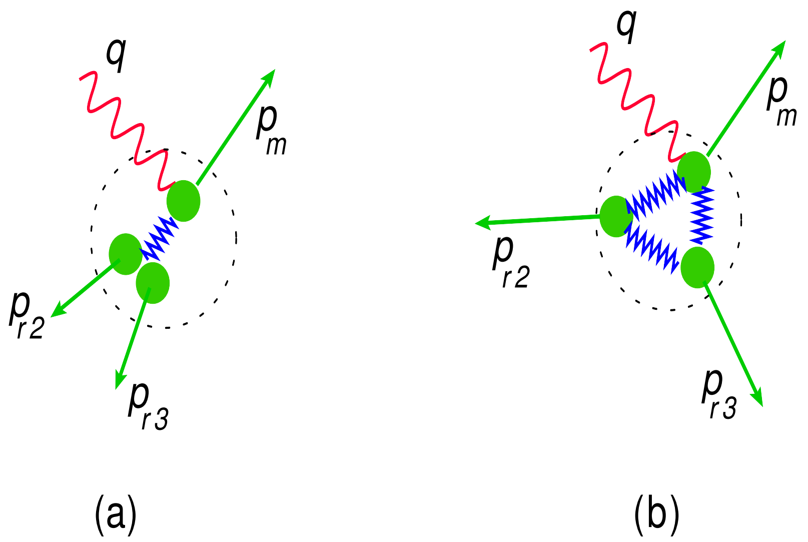
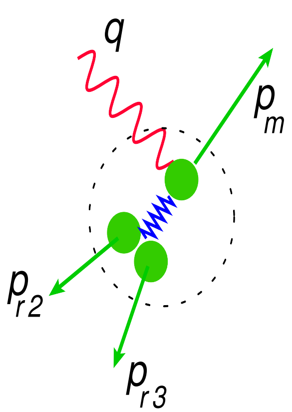


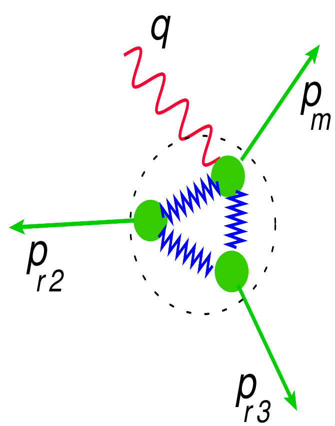
3N SRCs in Inclusive A(e,e')X Reactions

Day, Frankfurt, M.S. Strikman ,ArXiv 2018

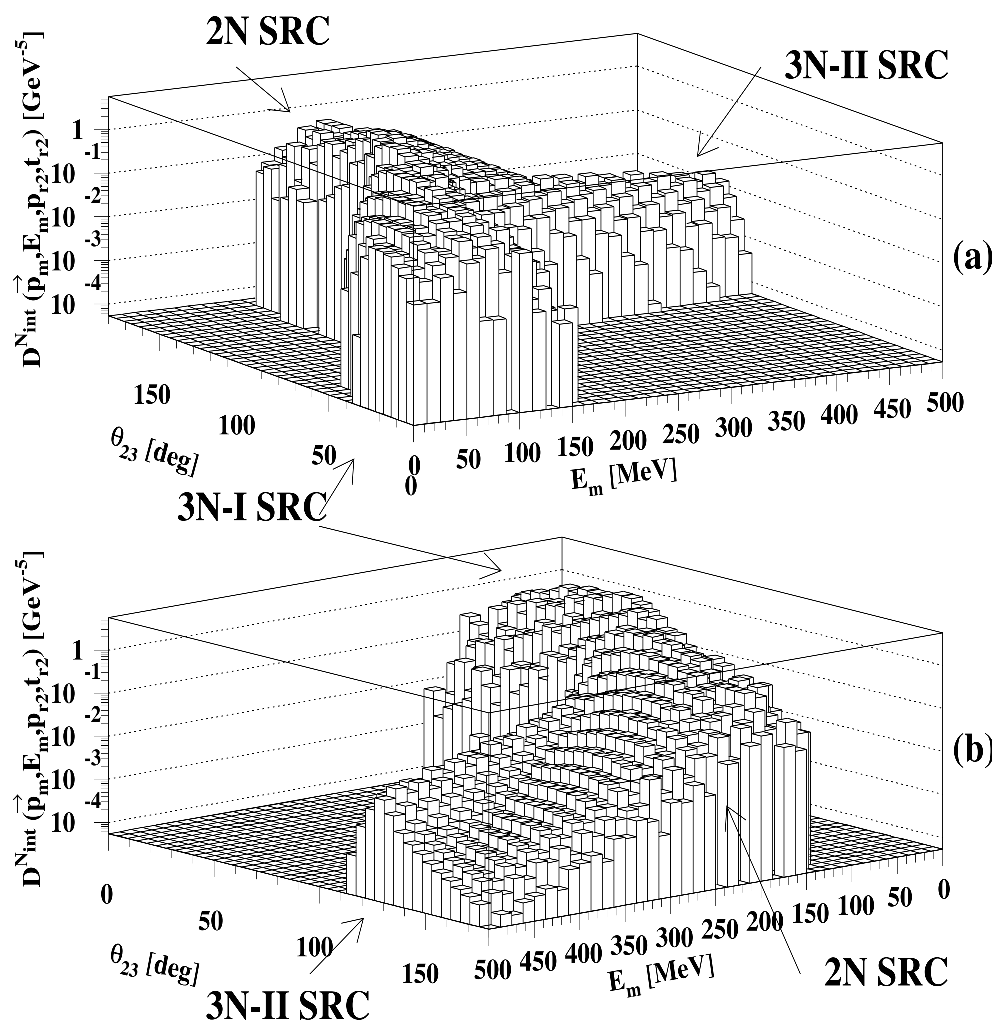
$$\sigma_{eA} = \sum \sigma_{eN} \cdot \rho_A(\alpha) \quad \text{where} \quad \rho_A(\alpha) = \int \rho_A(\alpha, p_\perp) d^2 p_\perp$$



(a)



(b)



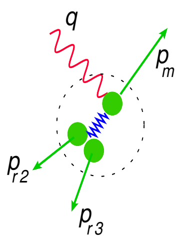
M.S. Abrahamyan, Frankfurt, Strikman ,Phys. Rev. C 2005

3N SRC model $\sigma_{eA} = \sum \sigma_{eN} \cdot \rho_A(\alpha)$ where $\rho_A(\alpha) = \int \rho_A(\alpha, p_\perp) d^2 p_\perp$

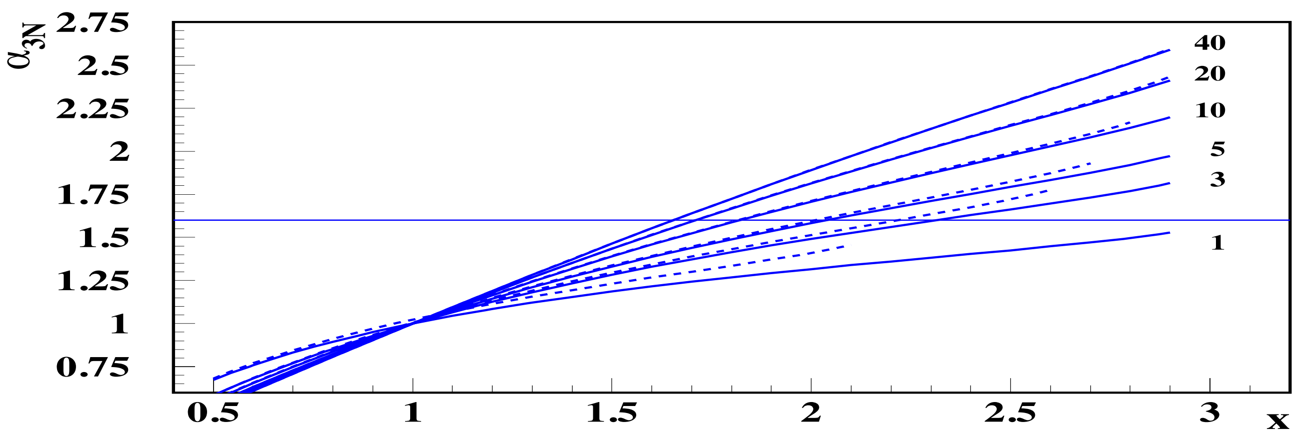
$$1.6 \leq \alpha_{3N} < 3$$

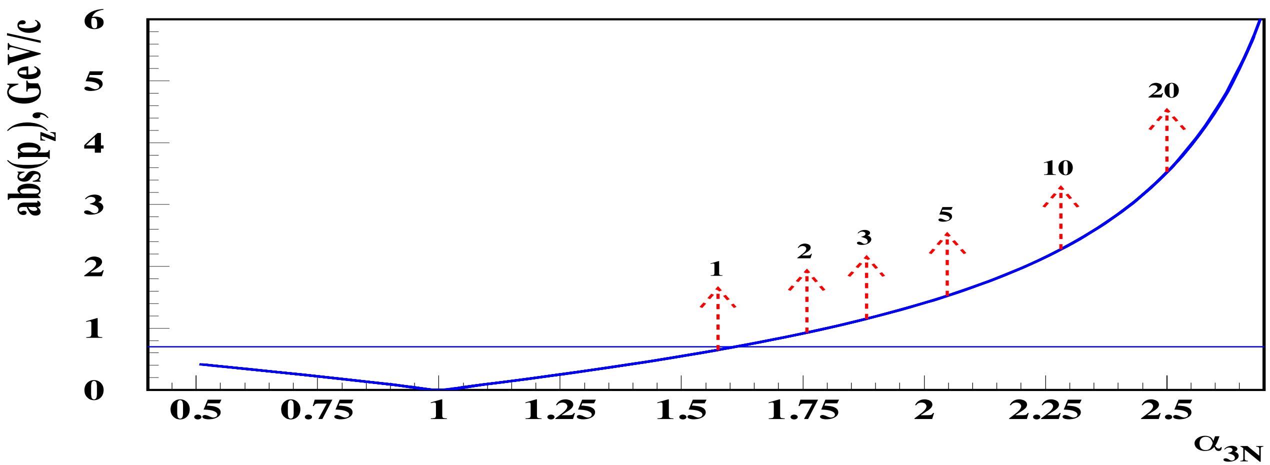
$$q + 3m_N = p_f + p_s$$

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



(a)





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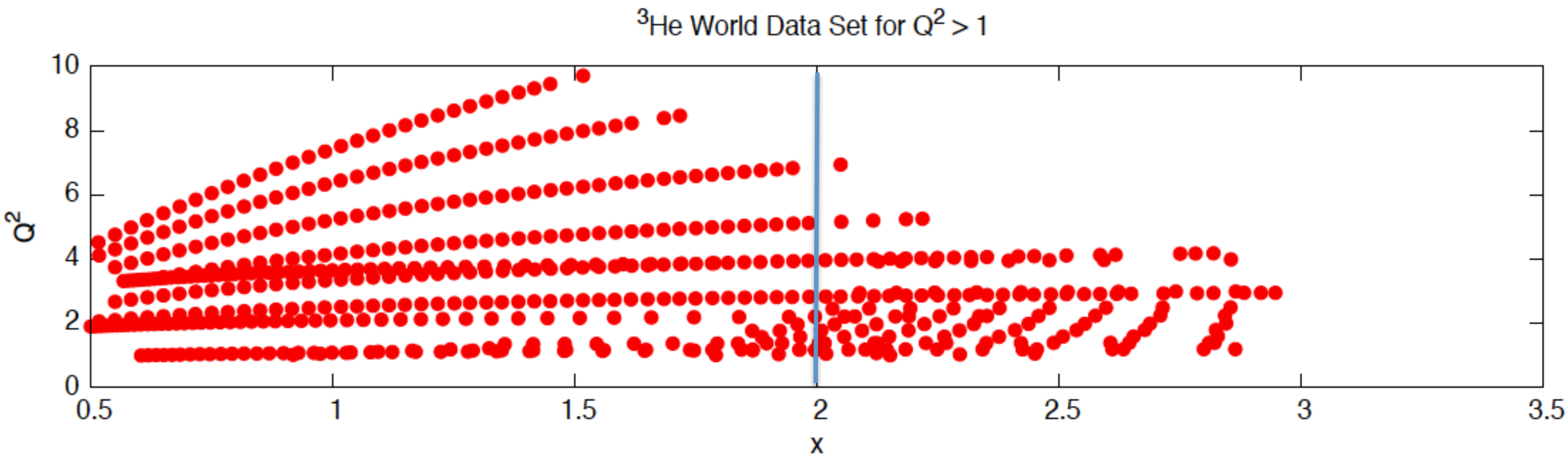
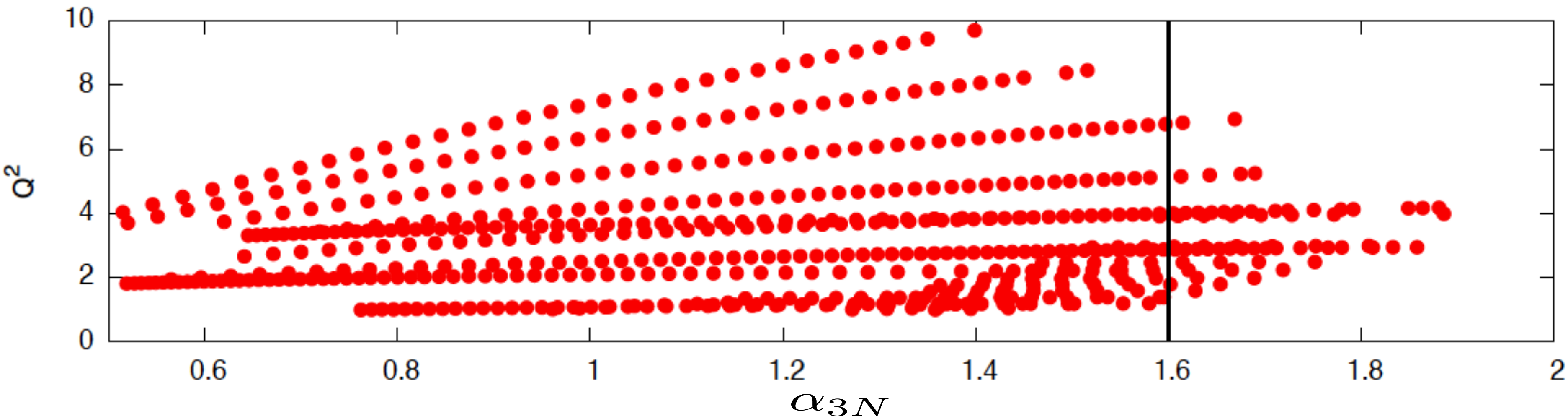
Donal Day, 2018

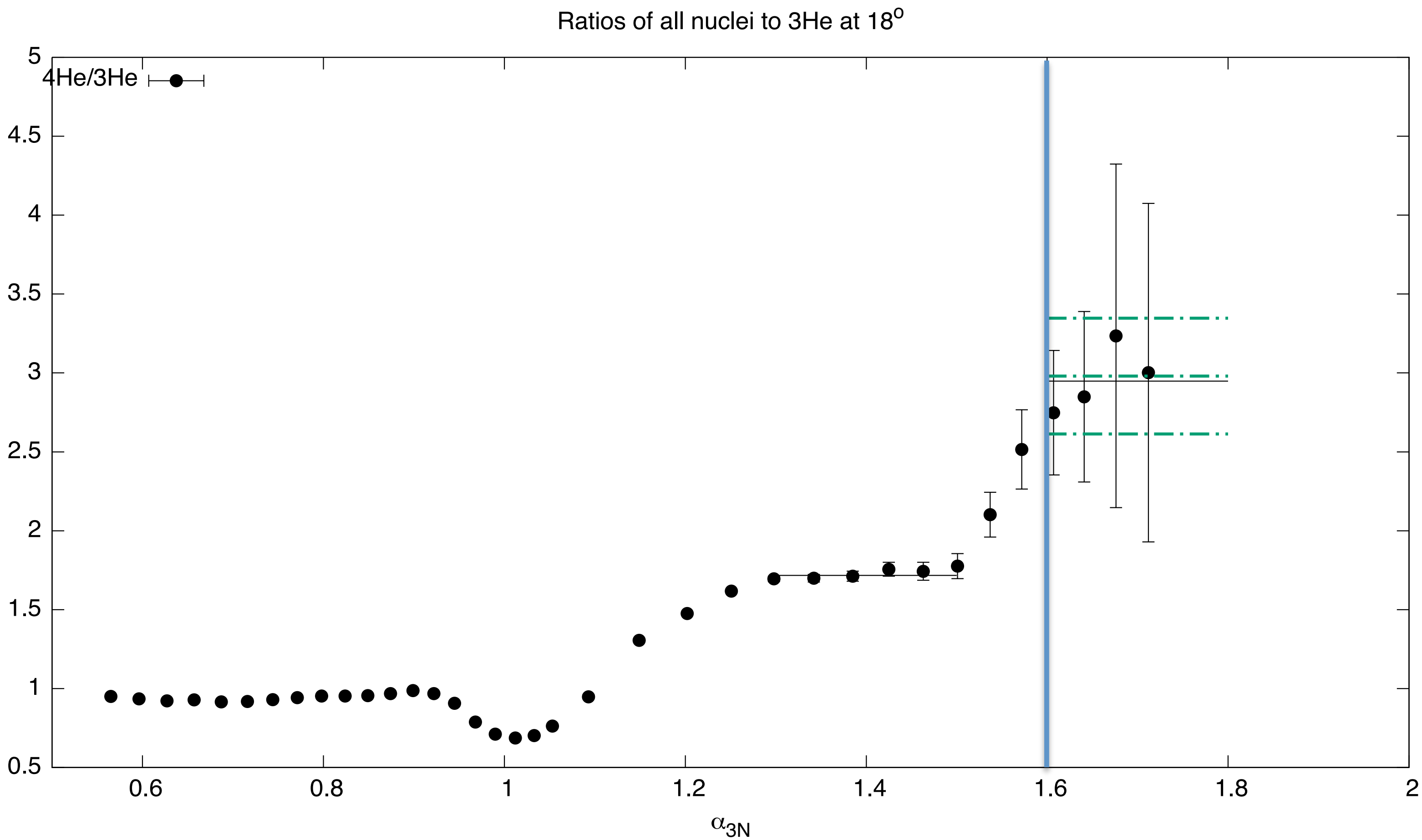




3N SRCs

$$\sigma_{eA} = \sum \sigma_{eN} \cdot \rho_A(\alpha) \quad \text{where} \quad \rho_A(\alpha) = \int \rho_A(\alpha, p_\perp) d^2 p_\perp$$

$$1.6 \le \alpha_{3N} < 3$$



JLab - E02019 - Data

3N SRC model $\sigma_{eA} = \sum \sigma_{eN} \cdot \rho_A(\alpha)$ where $\rho_A(\alpha) = \int \rho_A(\alpha, p_\perp) d^2 p_\perp$

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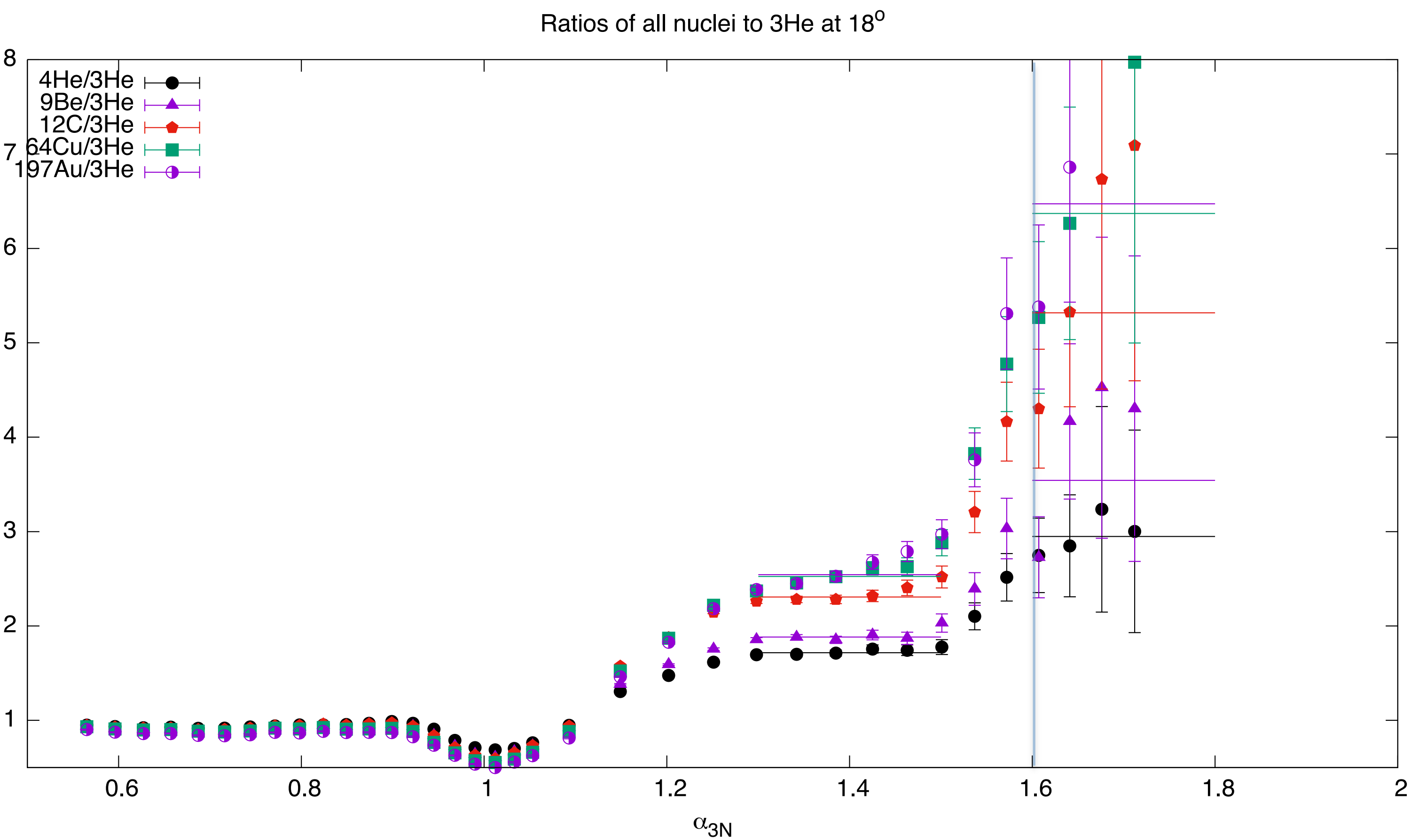
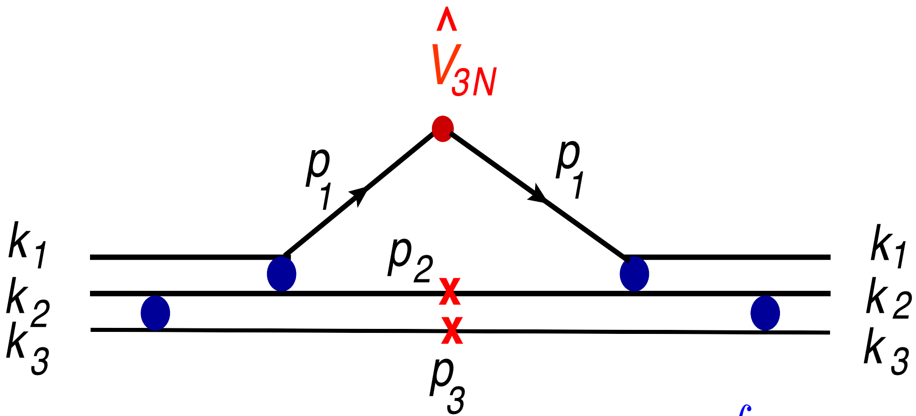


JLab - E02019 - Data

3N SRC: Light-Cone Momentum Fraction Distribution

A.Freese, M.S., M.Strikman, Eur. Phys. J 2015

O. Artiles M.S. Phys. Rev. C 2016



$$P^N_{A,3N}(\alpha_1, p_{1,\perp}, s_1, \tilde{M}_N) = \sum_{s_2,s_3,s_{2'},\tilde{s}_{2'}} \int \bar{u}(k_1)\bar{u}(k_2)\bar{u}(k_3)\Gamma^\dagger_{NN\to NN}\frac{u(p_{2'},\tilde{s}_{2'})\bar{u}(p_{2'},\tilde{s}_{2'})}{p^2_{2'} - M^2_N}$$

$$\times \Gamma^\dagger_{NN\to NN}\frac{u(p_1,s_1)}{p_1^2 - M_N^2}u(p_2,s_2)\left[2\alpha_1^2\delta(\alpha_1+\alpha_2+\alpha_3-3)\delta^2(p_{1\perp}+p_{2\perp}+p_{3\perp})\delta(\tilde{M}^2_N - M^{3N,2}_N)\right]$$

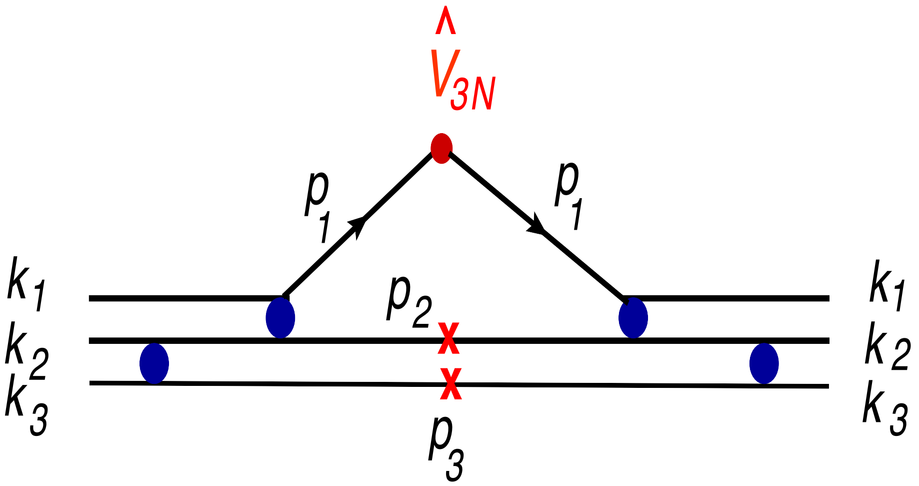
$$\times \bar{u}(p_2,s_2)\frac{\bar{u}(p_1,s_1)}{p_1^2-M_N^2}\Gamma_{NN\to NN}\frac{u(p_{2'},s_{2'})\bar{u}(p_{2'},s_{2'})}{p^2_{2'}-M^2_N}u(p_3,s_3)\bar{u}(p_3,s_3)\Gamma^\dagger_{NN\to NN}u(k_1)u(k_2)u(k_3)$$

$$\times \frac{d\alpha_2}{\alpha_2}\frac{d^2p_{2\perp}}{2(2\pi)^3}\frac{d\alpha_3}{\alpha_3}\frac{d^2p_{3\perp}}{2(2\pi)^3}, \quad (1)$$

$$P^N_{A,3N}(\alpha_1, p_{1,\perp}, \tilde{M}_N) = \int \frac{3-\alpha_3}{2(2-\alpha_3)^2}\rho_{NN}(\beta_3, p_{3\perp})\rho_{NN}(\beta_1,\tilde{k}_{1\perp})2\delta(\alpha_1+\alpha_2+\alpha_3-3)$$

$$\delta^2(p_{1\perp}+p_{2\perp}+p_{3\perp})\delta(\tilde{M}^2_N - M^{3N,2}_N)d\alpha_2 d^2p_{2\perp}d\alpha_3 d^2p_{3\perp}, \quad (1)$$

3N SRC: Light-Cone Momentum Fraction Distribution



$$\rho_{3N}(\alpha_1) = \int \frac{1}{4}\left[\frac{3-\alpha_3}{(2-\alpha_3)^3}\rho_{pn}\left(\alpha_3, p_{3\perp}\right)\rho_{pn}\left(\frac{2\alpha_2}{3-\alpha_3}, p_{2\perp}+\frac{\alpha_1}{3-\alpha_3}p_{3\perp}\right)+\right.$$

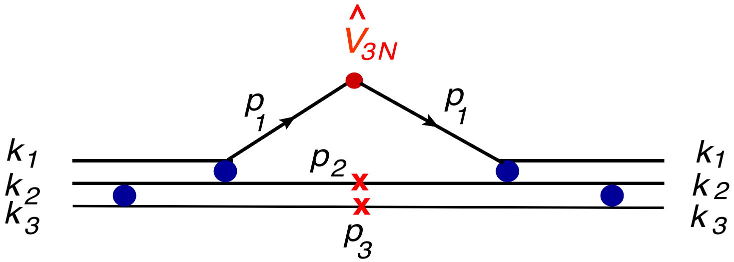
$$\left.\frac{3-\alpha_2}{(2-\alpha_2)^3}\rho_{pn}\left(\alpha_2, p_{2\perp}\right)\rho_{pn}\left(\frac{2\alpha_3}{3-\alpha_2}, p_{3\perp}+\frac{\alpha_1}{3-\alpha_2}p_{2\perp}\right)\right]\delta(\sum_{i=1}^{3}\alpha_i - 3)$$

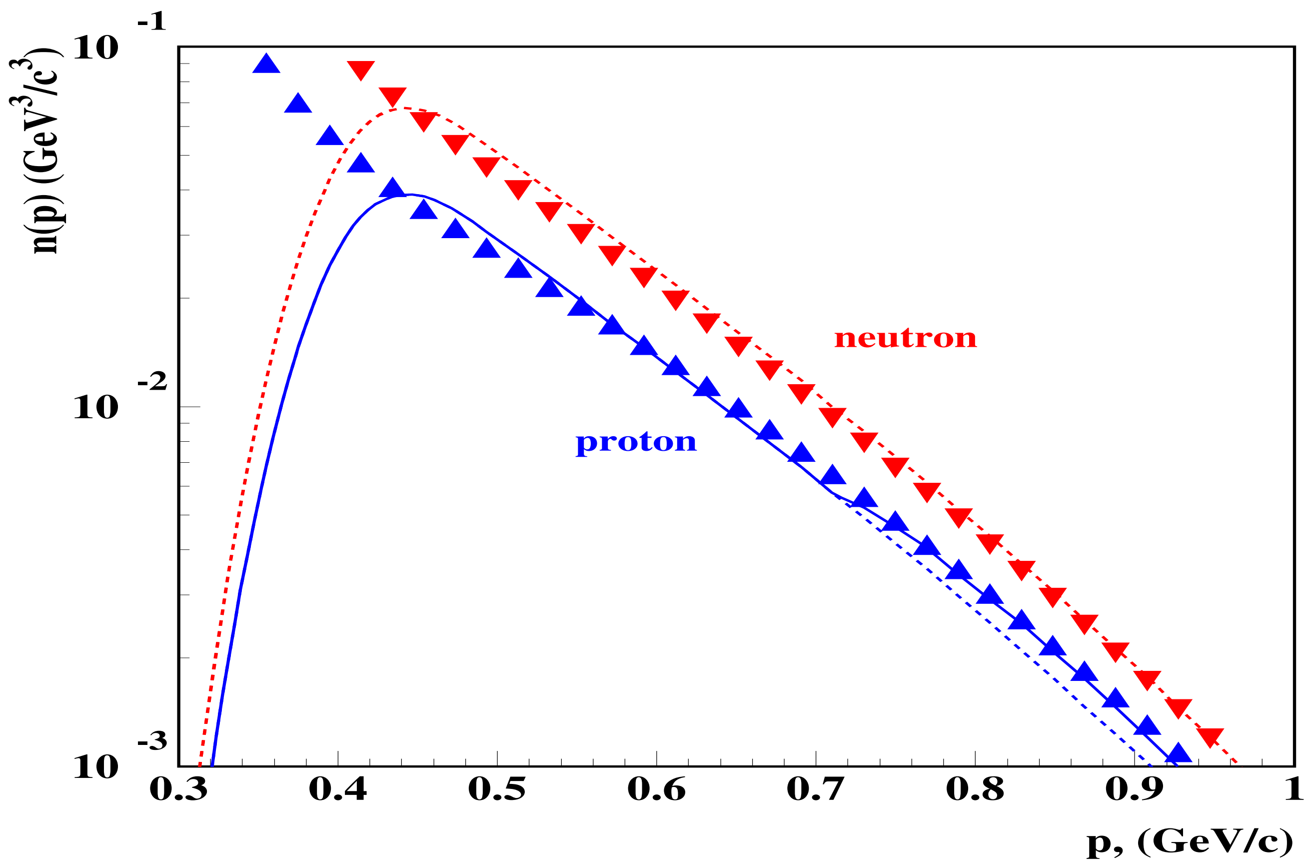
$$d\alpha_2 d^2p_{2\perp} d\alpha_3 d^2p_{3\perp}, \qquad (1)$$

$$\rho_{pn}(\alpha, p_\perp) \approx a_2(A)\rho_d(\alpha, p_\perp)$$

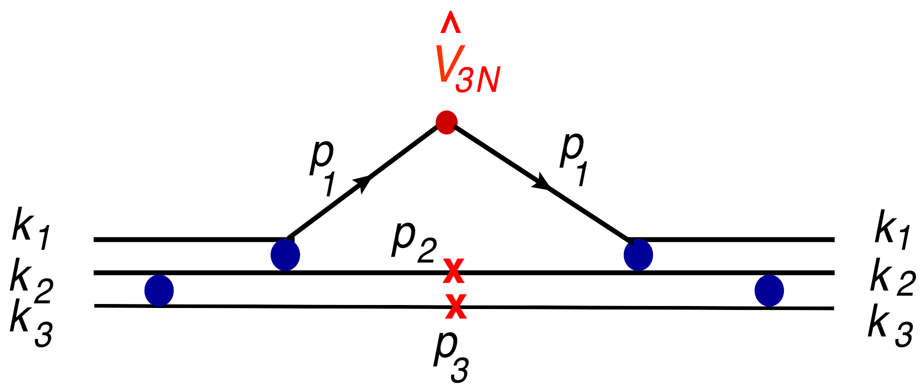
3N SRC: Light-Cone Momentum Fraction Distribution

O. Artiles M.S. Phys. Rev. C 2016





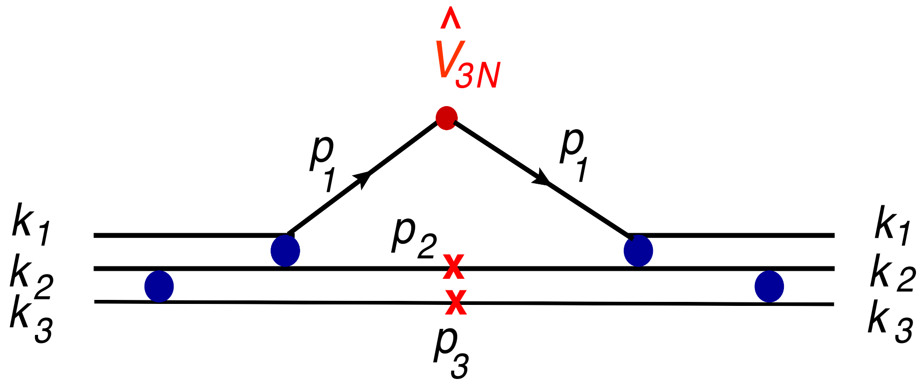
3N SRC: Light-Cone Momentum Fraction Distribution



- $\rho_{3N} \sim a_2(A,z)^2$
- ppp and nnn strongly suppressed compared with ppn or pnn
- pp/nn recoil state is suppressed compared with pn

$$R_3(A,Z) = \frac{9}{8}\frac{(\sigma_{ep}+\sigma_{en})/2}{(2\sigma_{ep}+\sigma_{en})/3}\left(\frac{a_2(A,Z)}{a_2(^3He)}\right)^2 = \frac{9}{8}\frac{(\sigma_{ep}+\sigma_{en})/2}{(2\sigma_{ep}+\sigma_{en})/3} R_2^2(A,Z),$$

3N SRC: Light-Cone Momentum Fraction Distribution



- $\rho_{3N} \sim a_2(A,z)^2$

- For A(e,e') X reactions: $\sigma_{eA} = \sum_N \sigma_{eN}\rho_{3N}(\alpha_{3N})$

- Defining: $R_3(A,Z) = \frac{3\sigma_{eA}}{A\sigma_{e^3He}}|_{\alpha_{3N}\geq\alpha^0_{3N}}$

- We predict:

$$R_3(A,Z) = \frac{9}{8}\frac{(\sigma_{ep}+\sigma_{en})/2}{(2\sigma_{ep}+\sigma_{en})/3}\left(\frac{a_2(A,Z)}{a_2(^3He)}\right)^2 = \frac{9}{8}\frac{(\sigma_{ep}+\sigma_{en})/2}{(2\sigma_{ep}+\sigma_{en})/3}R_2^2(A,Z),$$

- Where: $R_2(A,Z) = \frac{3\sigma_{eA}}{A\sigma_{e^3He}}|_{1.3\leq\alpha_{3N}\leq 1.5}$ where: $\alpha_{3N} \approx \alpha_{2N}$

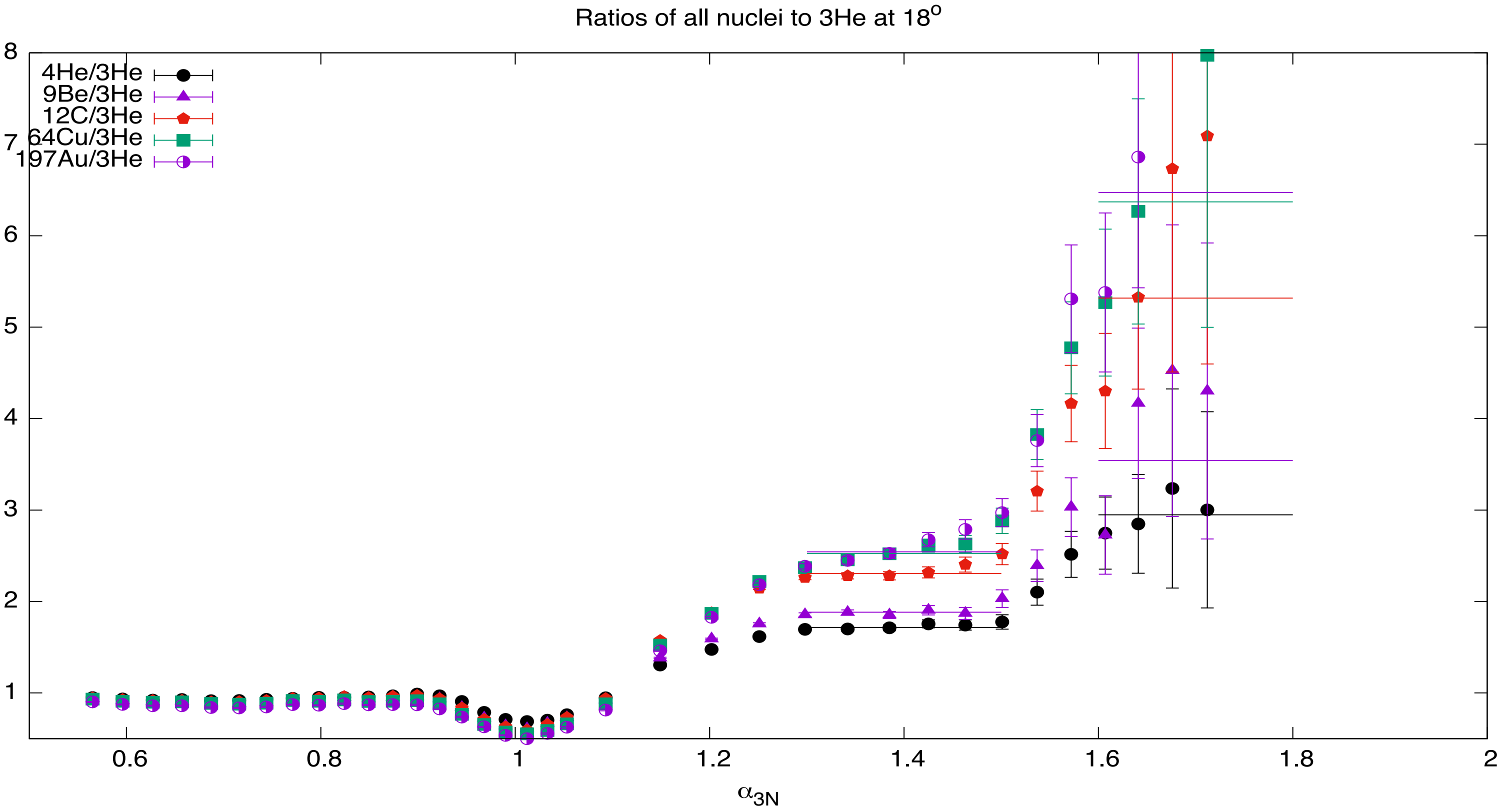
3N SRC model

$$R_2 = \frac{3\sigma_{eA}(\alpha_{3N})}{A\sigma_{3A}(\alpha_{3N})} \quad 1.3 \leq \alpha_{3N} \leq 1.5$$

$$1.6 \leq \alpha_{3N} < 3$$

$$R_3 = \frac{3\sigma_{eA}(\alpha_{3N})}{A\sigma_{3A}(\alpha_{3N})} \quad 1.6 \leq \alpha_{3N} \leq 1.8$$

$$R_3(A,Z) \approx R_2(A,Z)^2$$



3N SRC model

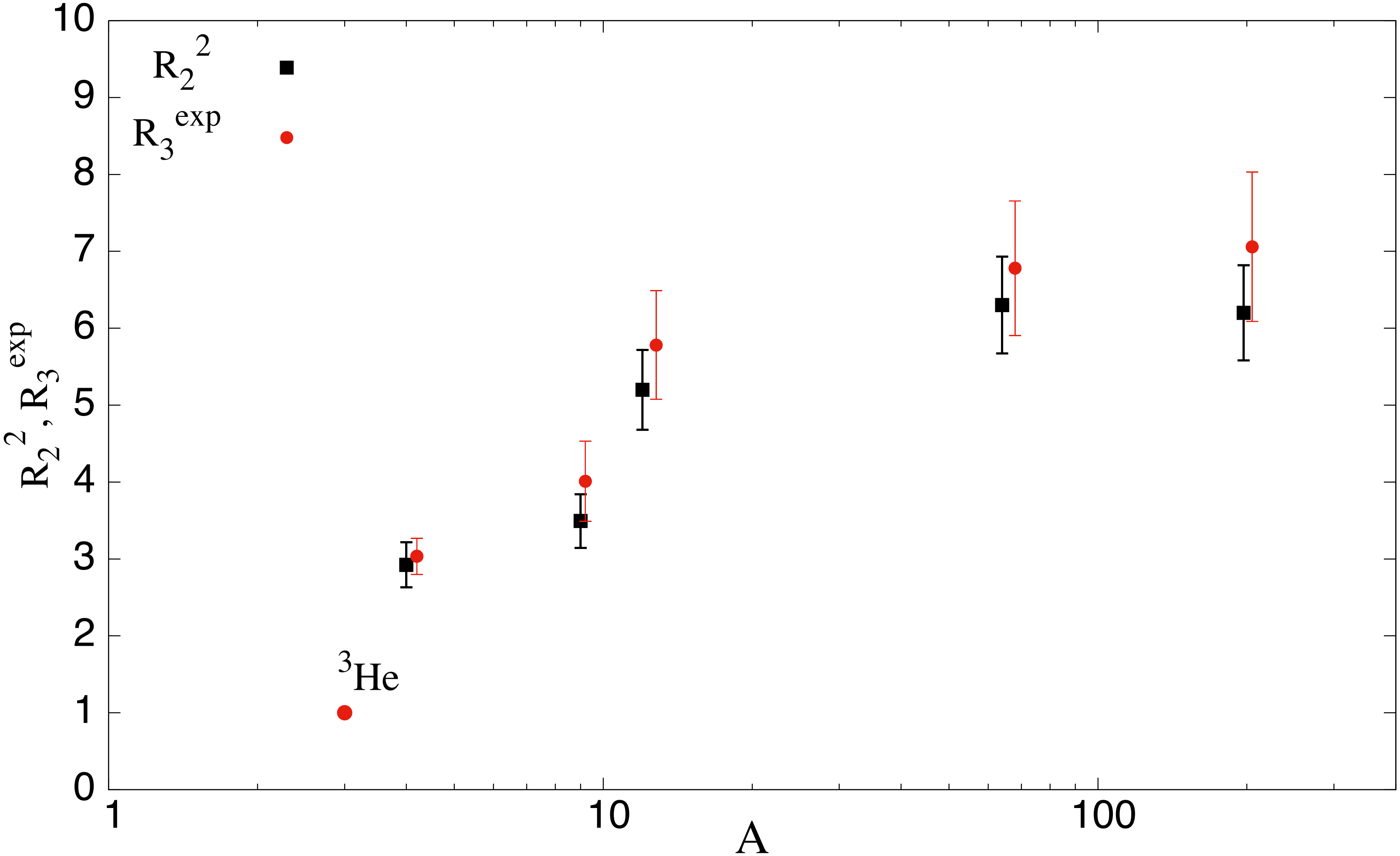
$$R_2 = \frac{3\sigma_{eA}(\alpha_{3N})}{A\sigma_{3A}(\alpha_{3N})} \quad 1.3 \leq \alpha_{3N} \leq 1.5$$

$$R_3 = \frac{3\sigma_{eA}(\alpha_{3N})}{A\sigma_{3A}(\alpha_{3N})} \quad 1.6 \leq \alpha_{3N} \leq 1.8$$

$$1.6 \leq \alpha_{3N} < 3$$

$$R_3(A) = R_2(A)^2$$

D.Day, L.Frankfurt,M.S, M.Strikman
ArXiv 2018



3N SRC model

Defining: $a_3(A,Z) = \frac{3}{A}\frac{\sigma_{eA}}{(\sigma_{e^3He}+\sigma_{e^3H})/2}$

One relates: $a_3(A,Z) = \frac{(2\sigma_{ep}+\sigma_{en})/3}{(\sigma_{ep}+\sigma_{en})/2} R_3(A,Z)$

A	a_2	R_2	R_2^{exp}	R_2^2	R_3^{exp}	a_3
3	2.14 ± 0.04	NA	NA	NA	NA	1
4	3.66 ± 0.07	1.71 ± 0.026	1.722 ± 0.013	2.924 ± 0.29	3.034 ± 0.23	4.55 ± 0.35
9	4.00 ± 0.08	1.84 ± 0.027	1.878 ± 0.018	3.38 ± 0.38	4.01 ± 0.52	6.0 ± 0.78
12	4.88 ± 0.10	2.28 ± 0.027	2.301 ± 0.021	5.2 ± 0.5	5.78 ± 0.71	8.7 ± 1.1
27	5.30 ± 0.60	NA	NA	NA	NA	NA
56	4.75 ± 0.29	NA	NA	NA	NA	NA
64	5.37 ± 0.11	2.51 ± 0.027	2.502 ± 0.024	6.3 ± 0.63	6.780 ± 0.875	10.2 ± 1.3
197	5.34 ± 0.11	2.46 ± 0.028	2.532 ± 0.026	6.05 ± 0.6	7.059 ± 0.970	10.6 ± 1.5

D.Day, L.Frankfurt,M.S, M.Strikman
ArXiv 2018

3N SRC Summary & Outlook

- Proper variable for studies of 2N and 3N SRS are Light-Cone momentum fractions: α_{2N}, α_{3N}

- In 2N SRC region: $\alpha_{2N} \approx \alpha_{3N}$, so α_{3N} is good for all region

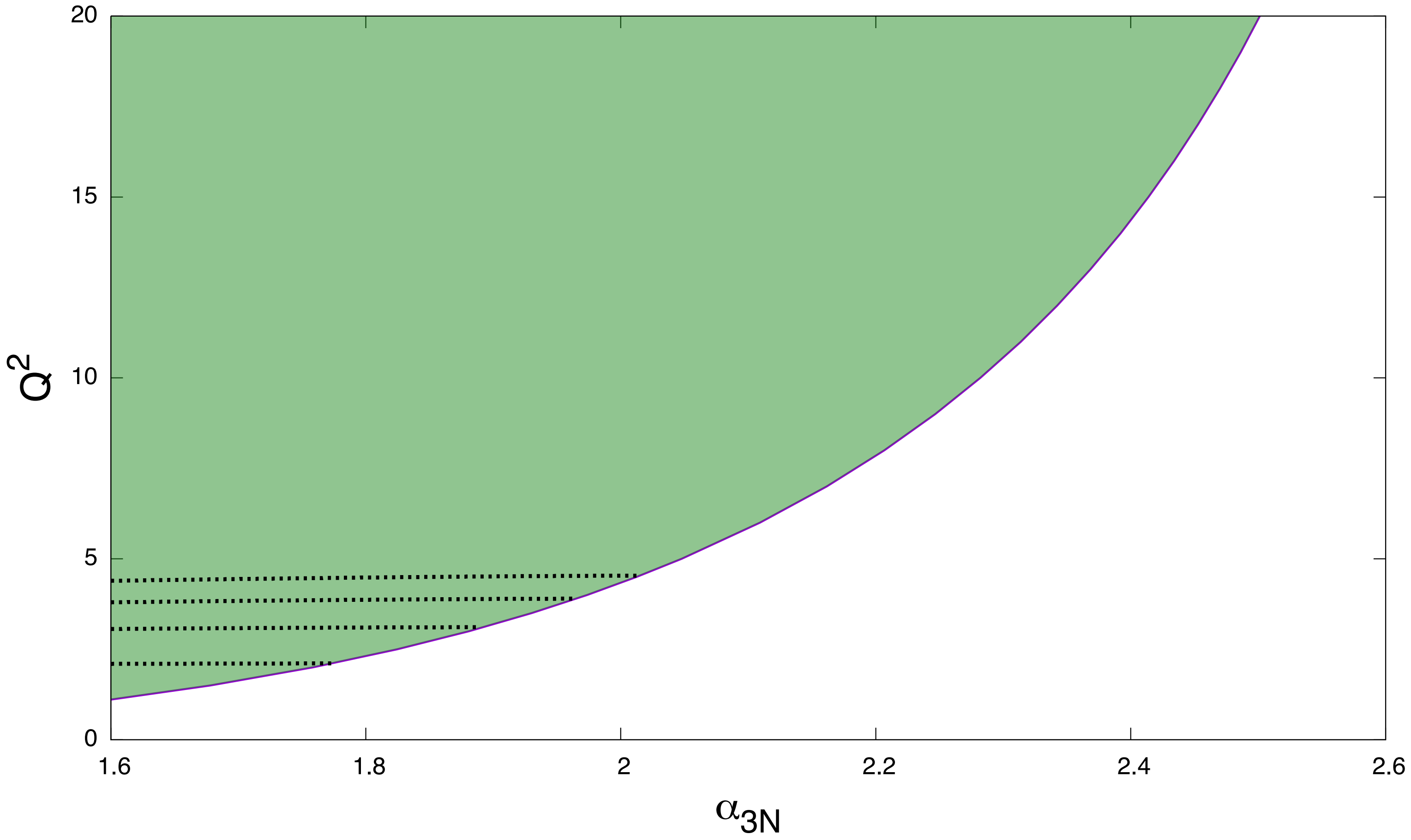
- It seems we observed first signatures of 3N SRCs in the form of the "scaling"

- Existing data in agreement with the prediction of: $R_3(A,Z) \approx R_2(A,Z)^2$

- Unambiguous verification will require larger Q2 data to cover larger α_{3N} region

- Reaching Q2 > 5 GeV2 will allow to reach: $\alpha_{3N} > 2$

3N SRC Outlook



For finite Q2 - 2N SRCs