Inclusive + Semi-Inclusive Scattering EXPERIMENT

Quantitative challenges in EMC and SRC Research and Data-Mining

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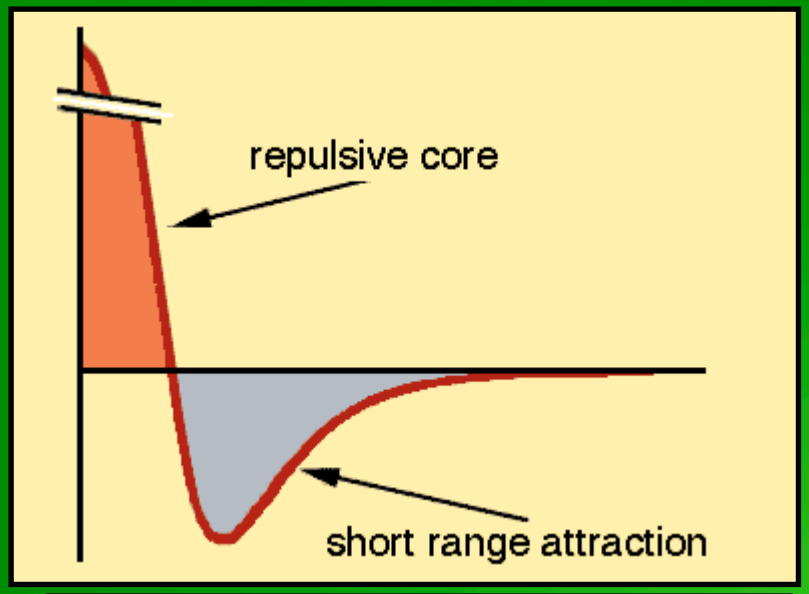
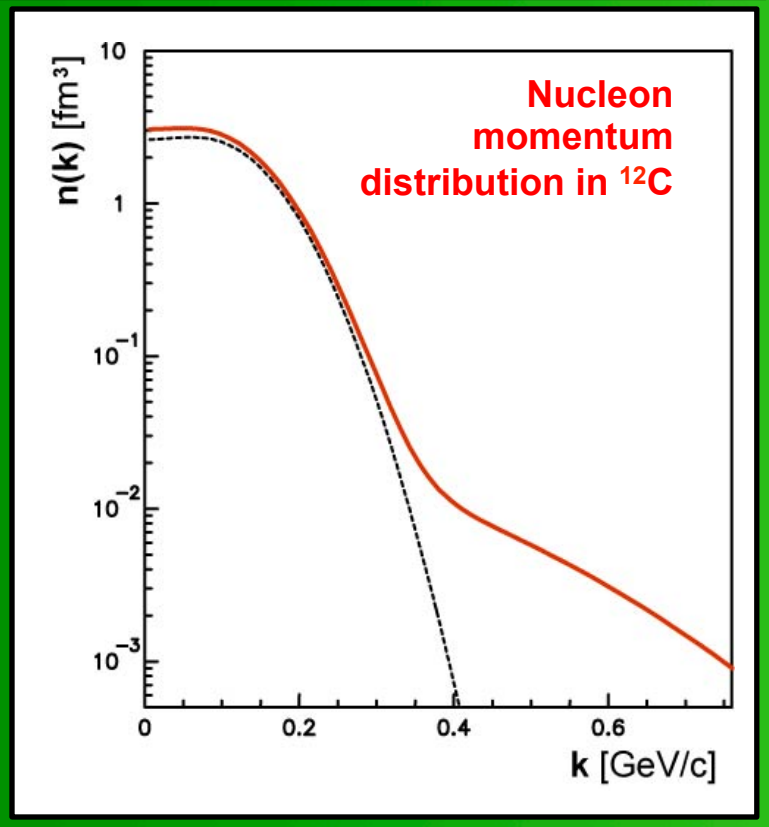
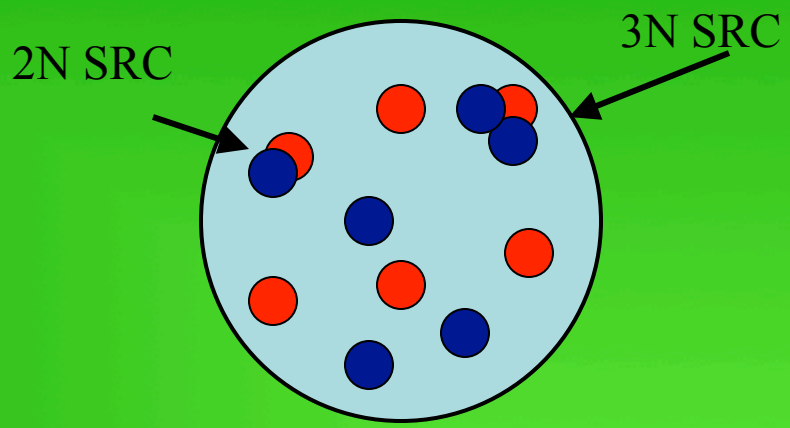
December 2, 2016

High momentum nucleons

- Short Range Correlations







High momentum tails in A(e,e'p)

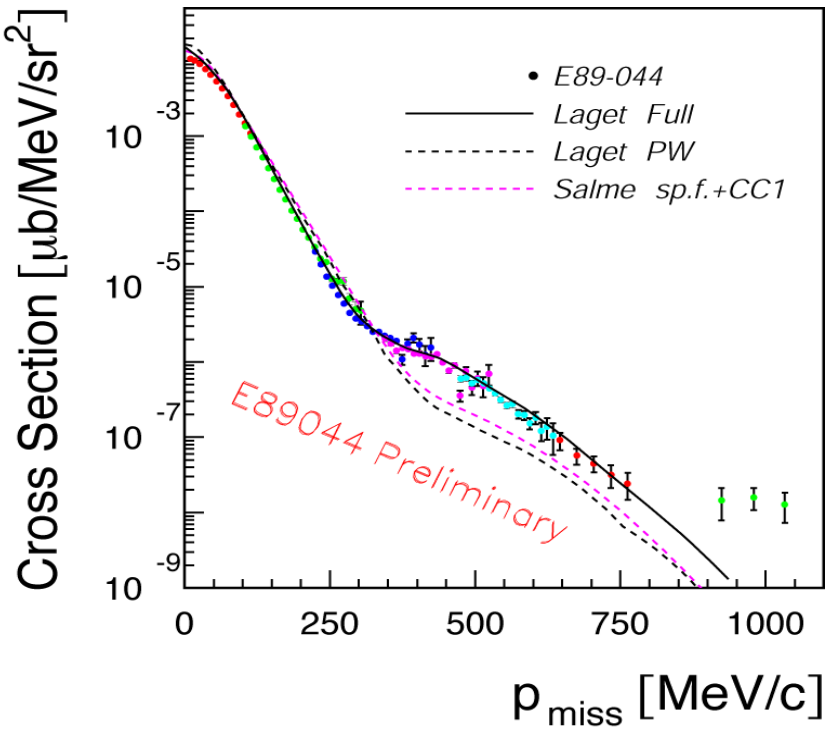
- E89-004: Measure of ^{3}He(e,e'p)d
- Measured far into high momentum tail: Cross section is ~5-10x expectation

Difficulty

- High momentum pair can come from SRC (initial state)

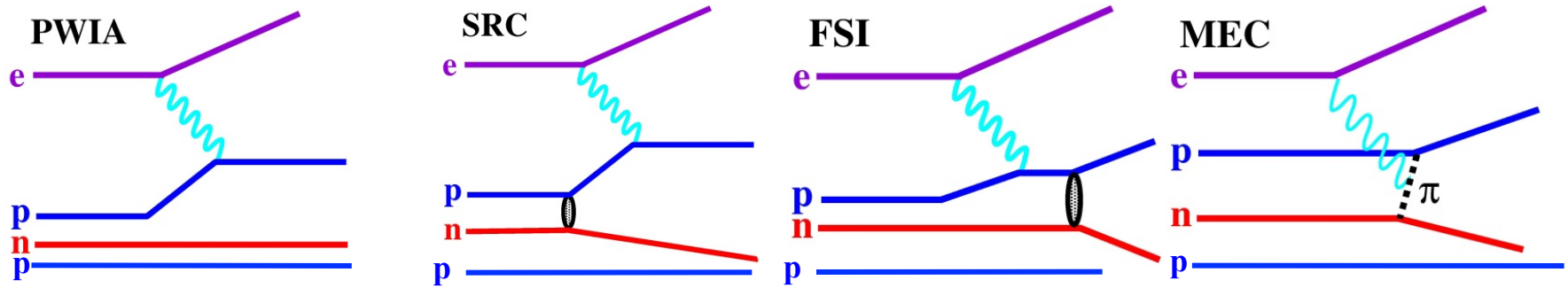
OR

- Final State Interactions (FSI) and Meson Exchange Contributions (MEC)



"slow" nucleons

"fast" nucleons



A(e,e'p)

^{2}H(e,e'p) Mainz
PRC 78 054001 (2008)

E =0.855 GeV
θ = 45°
E'=0.657 GeV
Q^2=0.33 GeV^2
x=0.88

Unfortunately: FSI, MECs overwhelm the high momentum nucleons

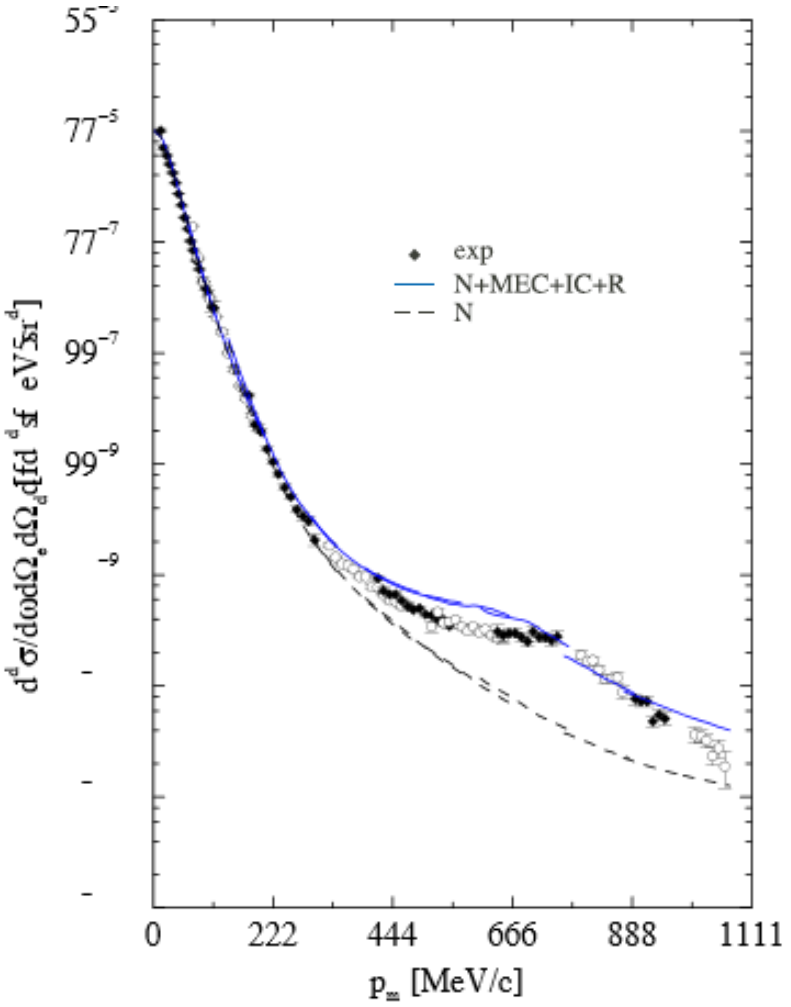


FIG. 1: The experimental D(e,e′p)n cross section as a function of missing momentum measured at MAMI for $Q^2 = 0.33$ $(\mathrm{GeV/c})^2$ [4] compared to calculations [7] with (solid curve) and without (dashed curve) MEC and IC. Both calculations include FSI. The low p_m data have been re-analyzed and used in this work to determine f_{LT} (color online).

Past A(e,e'p) experiments in Hall A

E89-003	Study of the Quasielastic $(e, e'p)$ reaction in ^{16}O at High Recoil Momentum
E89-044	Selected Studies of the ^{3}He and 4He Nuclei through ...
E97-111	Systematic Probe of Short-Range Correlations via the Reaction $^{4}\mathrm{He}(e, e'p)^{3}H$
E00-102	Testing the limits of the Single Particle Model in $^{16}\mathrm{O}(e, e'p)$
E03-104	Probing the Limits of the Standard Model of Nuclear Physics with the $^{4}\mathrm{He}(e, e'p)^{3}$H Reaction
E04-004	In-Plane Separations and High Momentum Structure in d$(e, e'p)$n
E06-007	Impulse Approximation limitations to the $(e, e'p)$ on ^{208}Pb, ...

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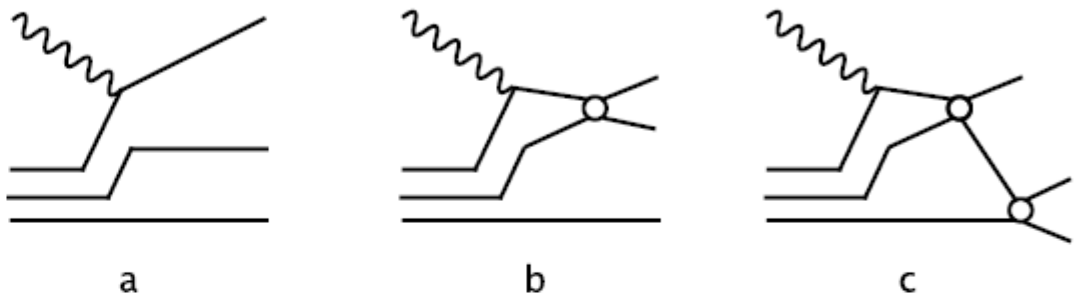

FIG. 1: Feynman diagrams for a) direct disintegration, b) rescattering, and c) rescattering with the spectator nucleon.

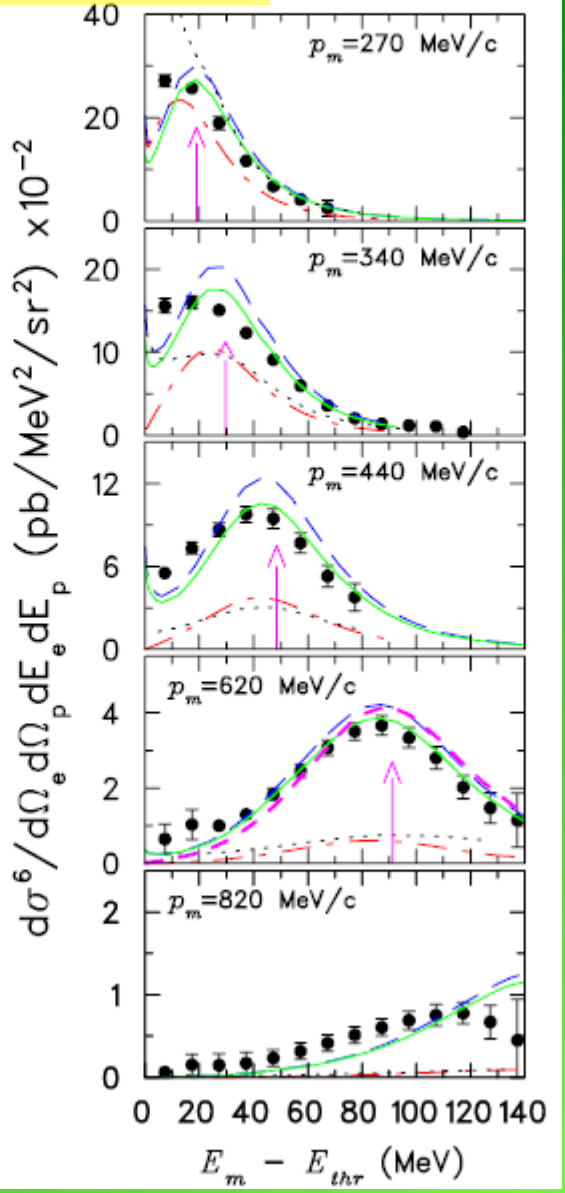

FIG. 2: (color online). Cross-section results for the ^{3}He$(e, e'p)pn$ reaction versus missing energy E_m. The vertical arrow gives the peak position expected for disintegration of correlated pairs. The dotted curve presents a PWIA calculation using Salme's spectral function and σ_{cc1} electron-proton off-shell cross section. Other curves are recent theoretical predictions of J. M. Laget [19] from the PWIA (dash dot) to PWIA + FSI (long dash) to full calculation (solid), including meson exchange current and final state interactions. In the 620 MeV/c panel, the additional short dash curve is a calculation with PWIA + FSI only within the correlated pair.

Inclusive Scattering

- Relative measurement
- Reduced FSI
- Test scaling in x and Q^2
- No direct information on isospin structure
  - Only via target isospin structure
- No direct information on momentum distribution for A>2

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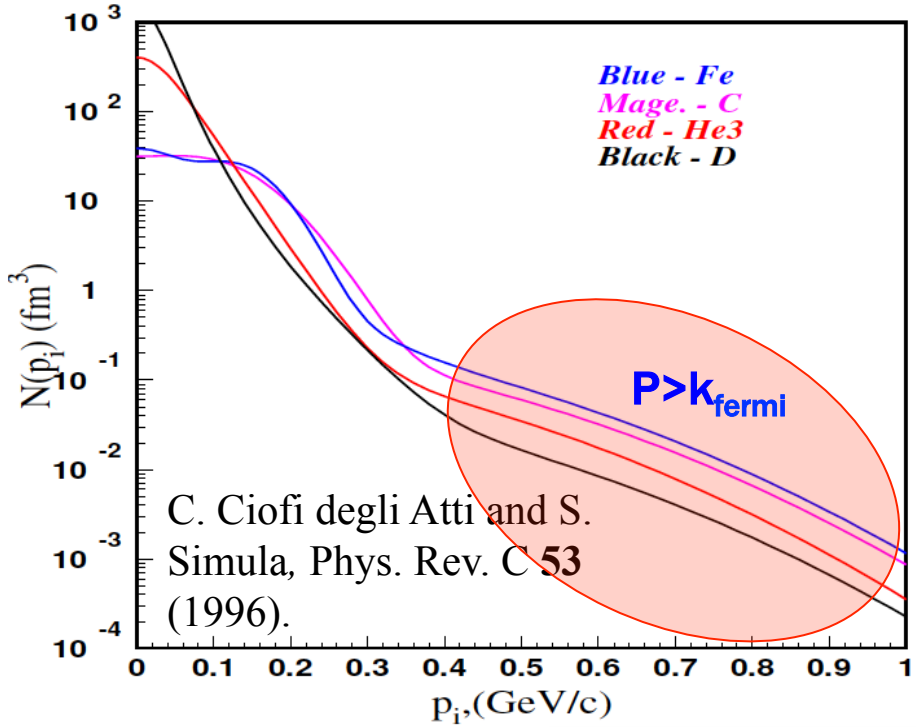

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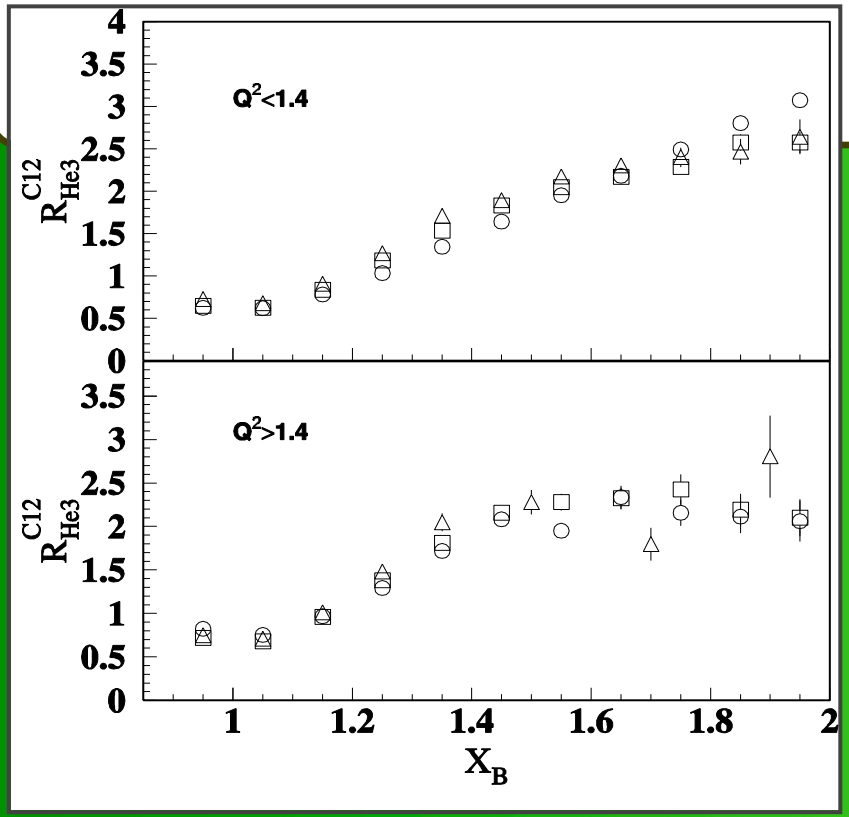
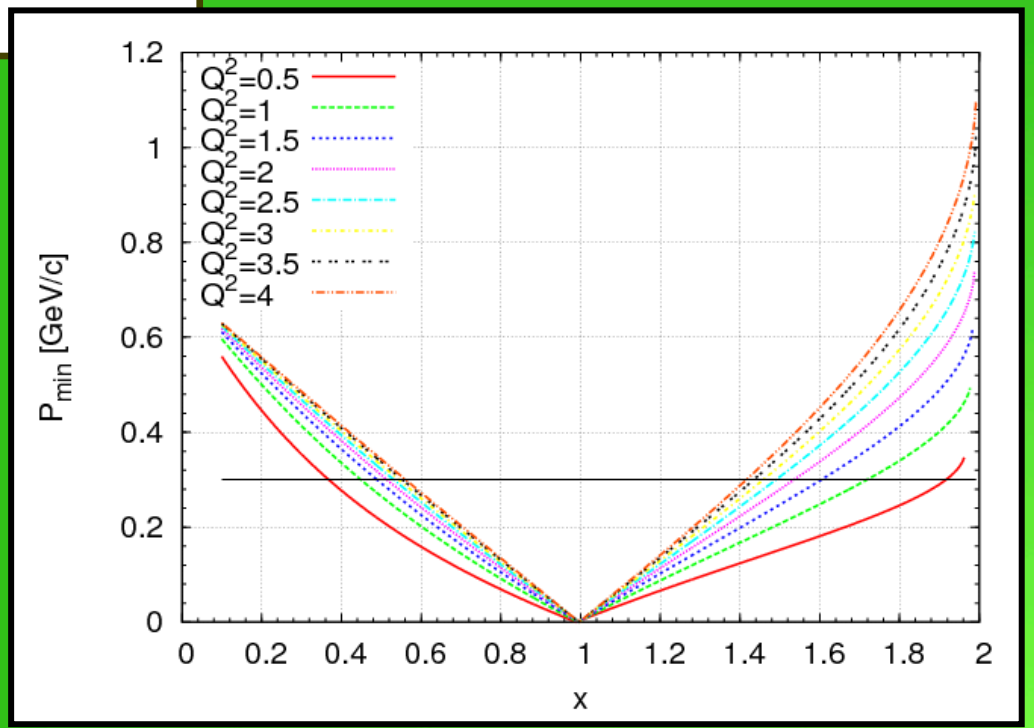
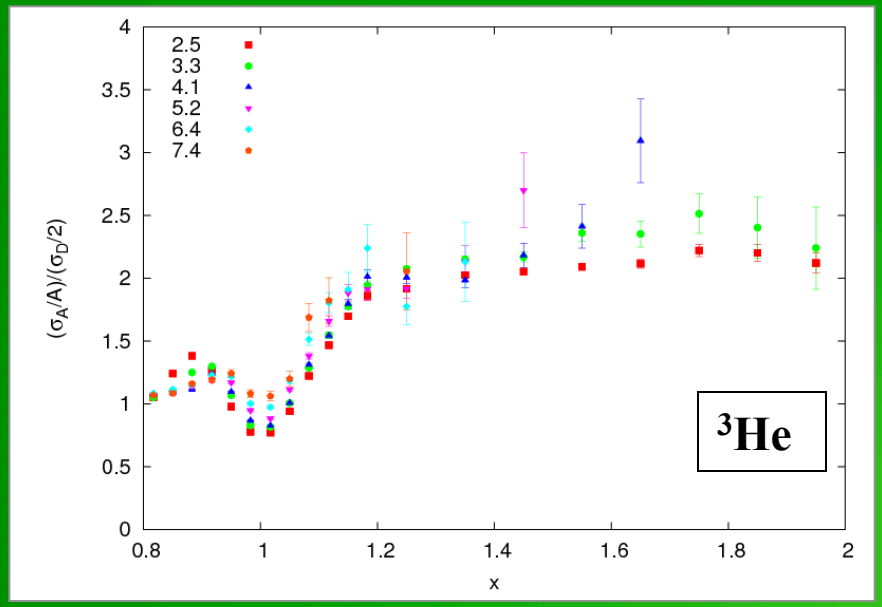
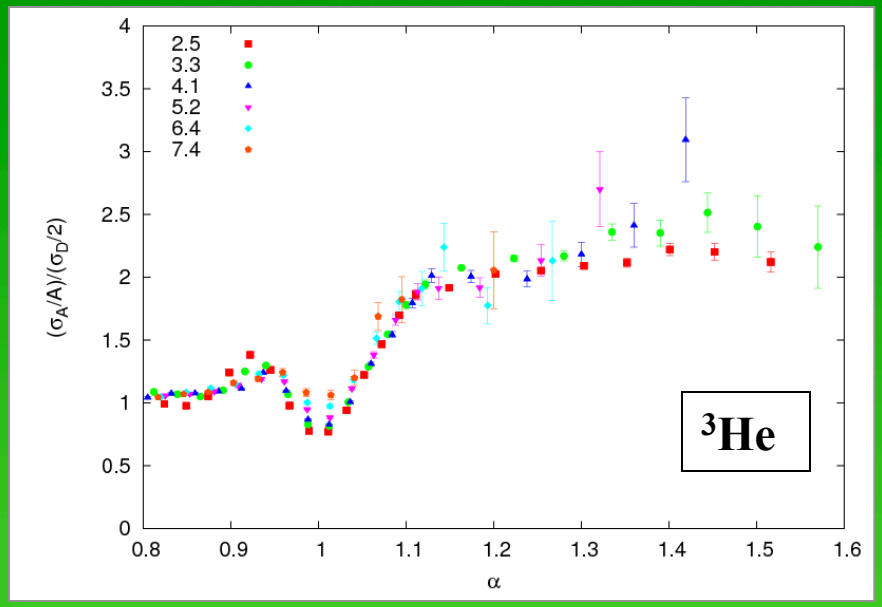


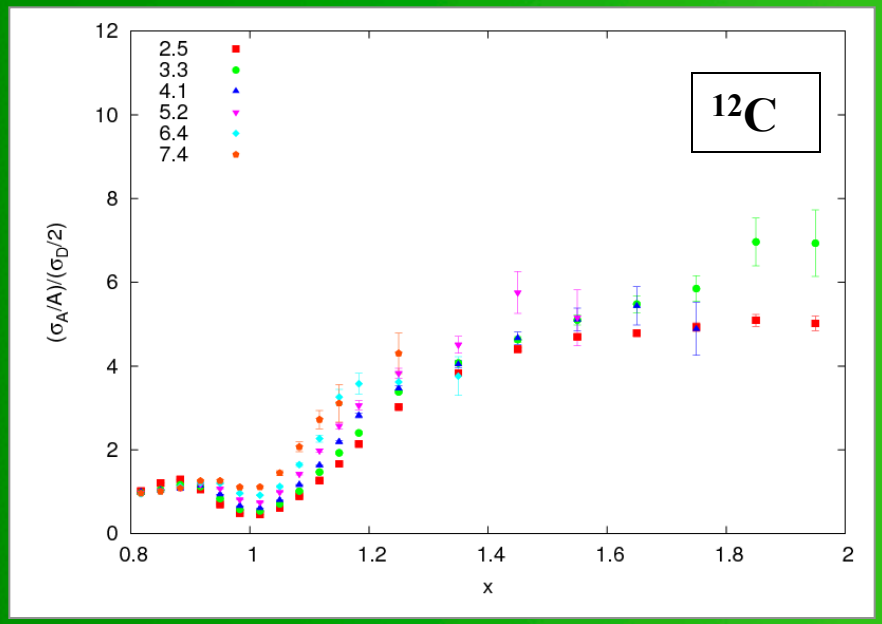


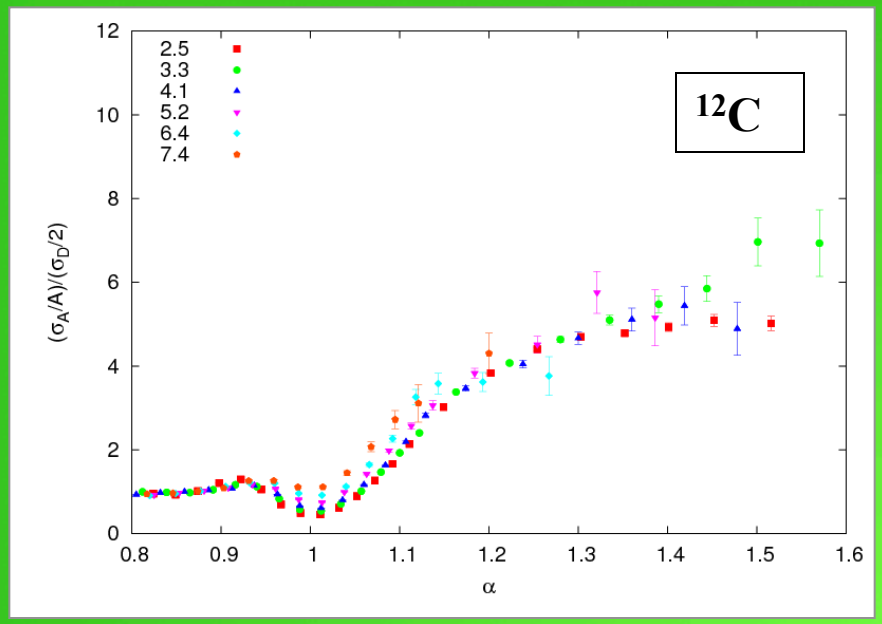
Test scaling in x and Q^2

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









Inclusive Scattering

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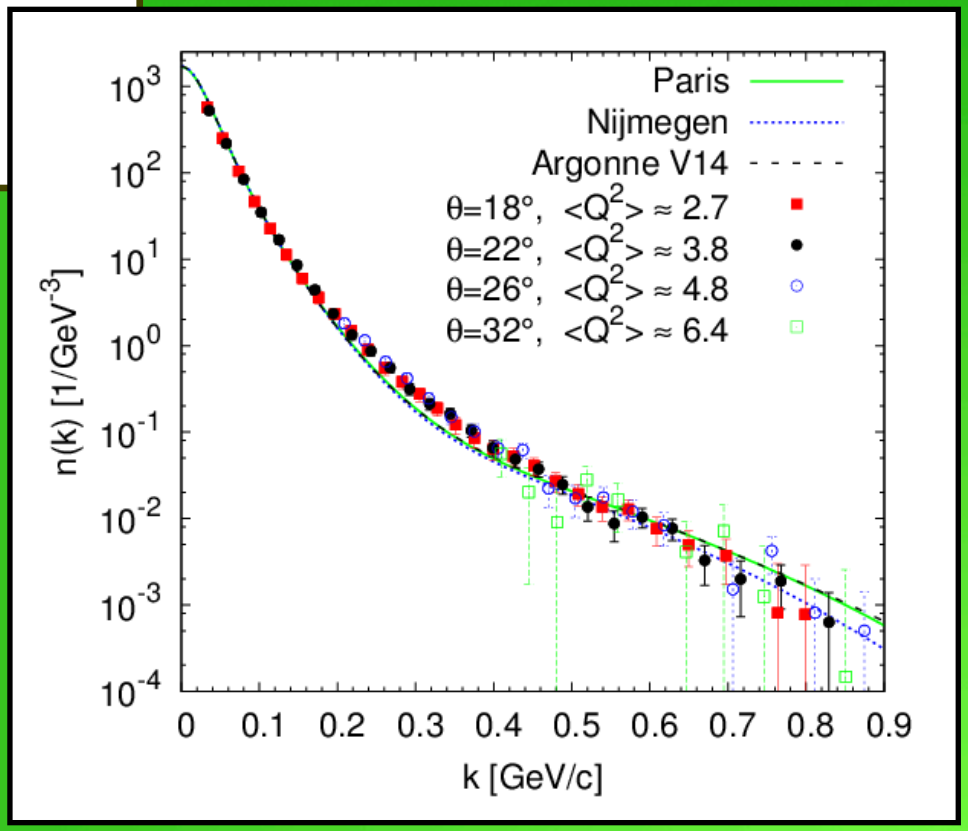
- **No direct information on momentum distribution for A>2**

$$\frac{d\sigma^{QE}}{d\Omega dE'} \propto \int d\vec{k} \int dE \sigma_{ei} S_i(k,E) \delta(Arg)$$

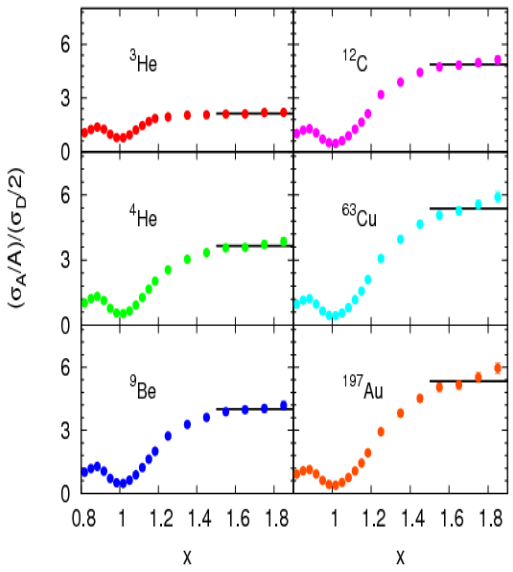
$$Arg = \nu + M_A - \sqrt{M^2 + p^2} - \sqrt{M^{*2}_{A-1} + k^2}$$

$$F(y,\mathbf{q}) = \frac{d^2\sigma}{d\Omega d\upsilon} \frac{1}{(Z\bar{\sigma}_p + N\bar{\sigma}_n)} \frac{\mathbf{q}}{\sqrt{M^2 + (y+q)^2}}$$

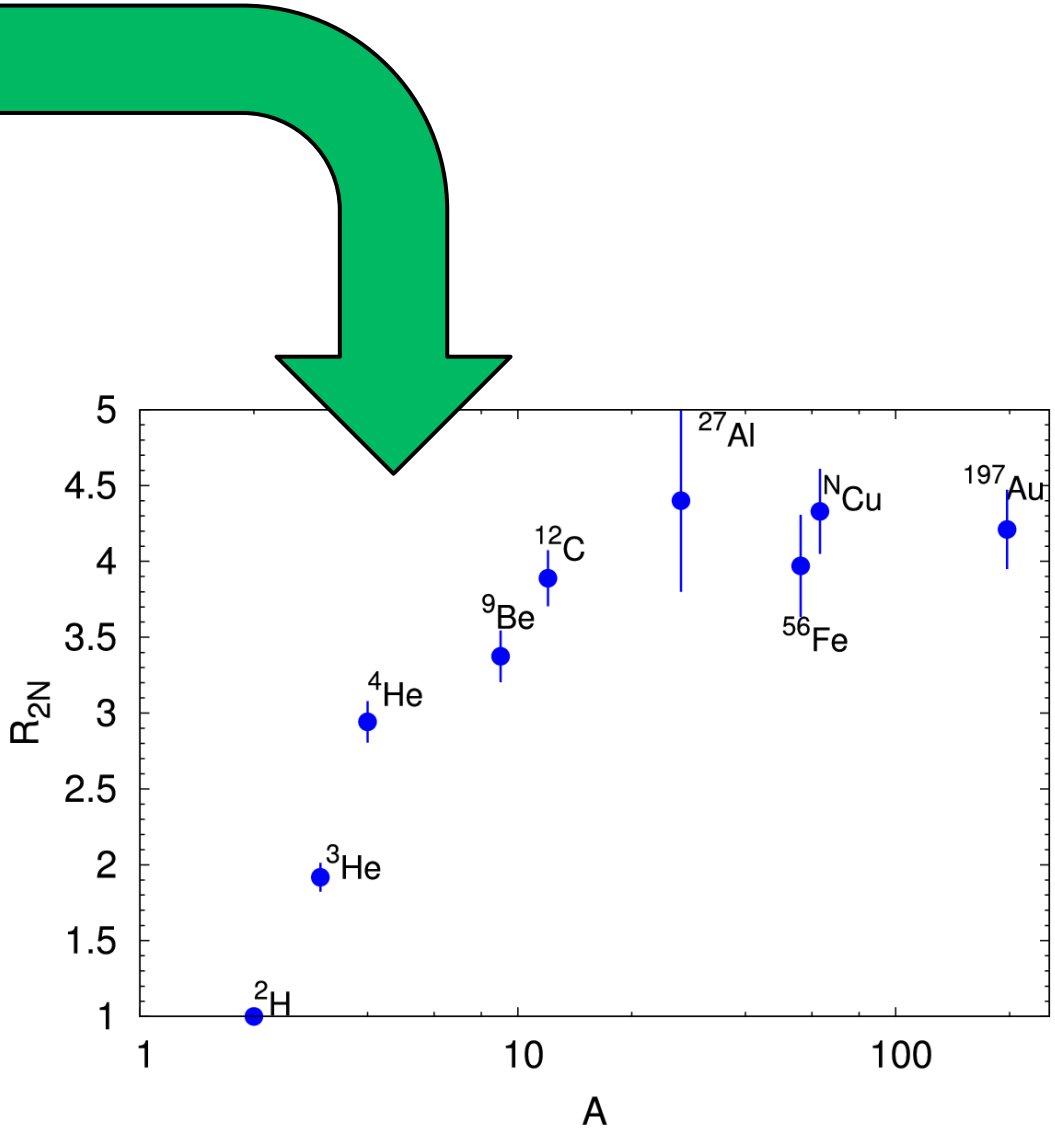
$$= 2\pi \int_{|y|}^{\infty} n(k) k dk$$



2N correlations



Have not solved the nuclear dependence



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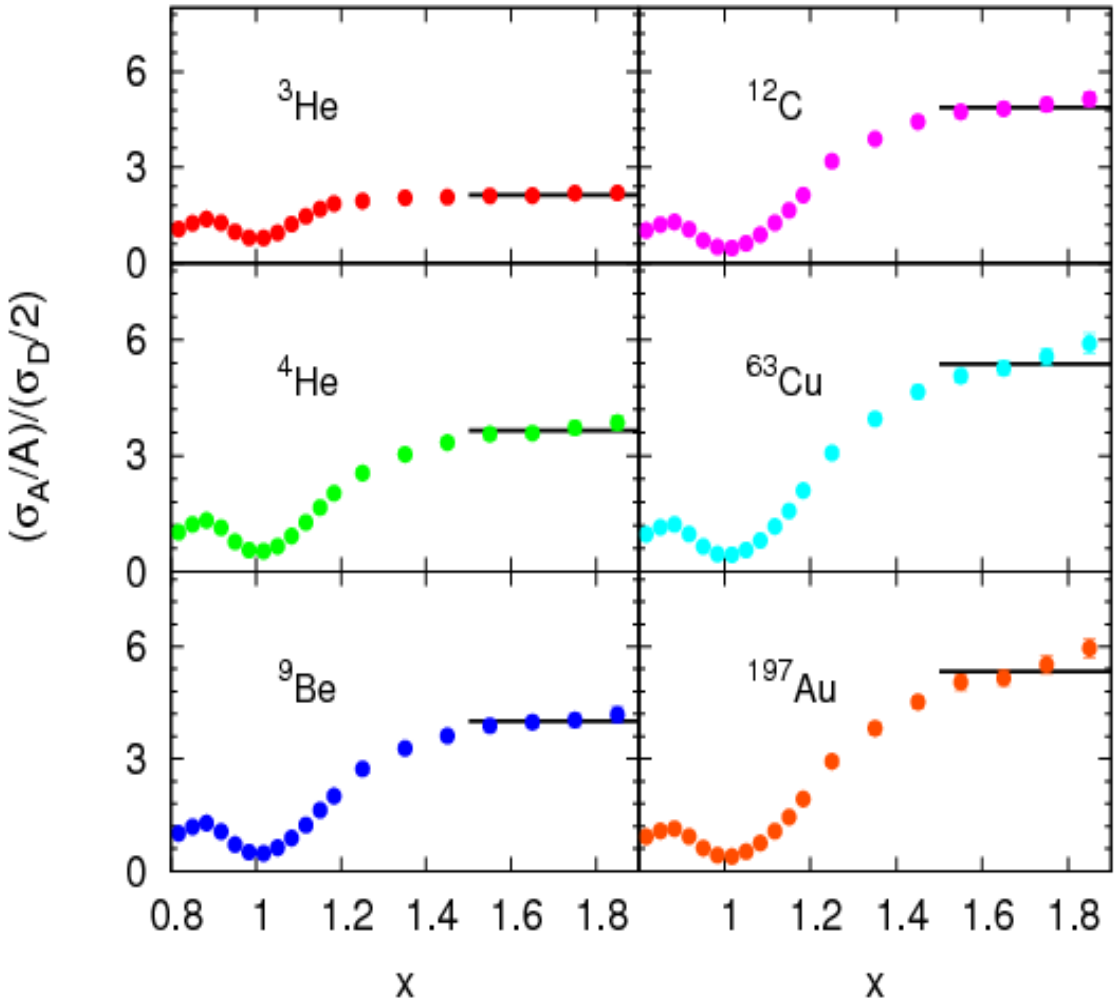
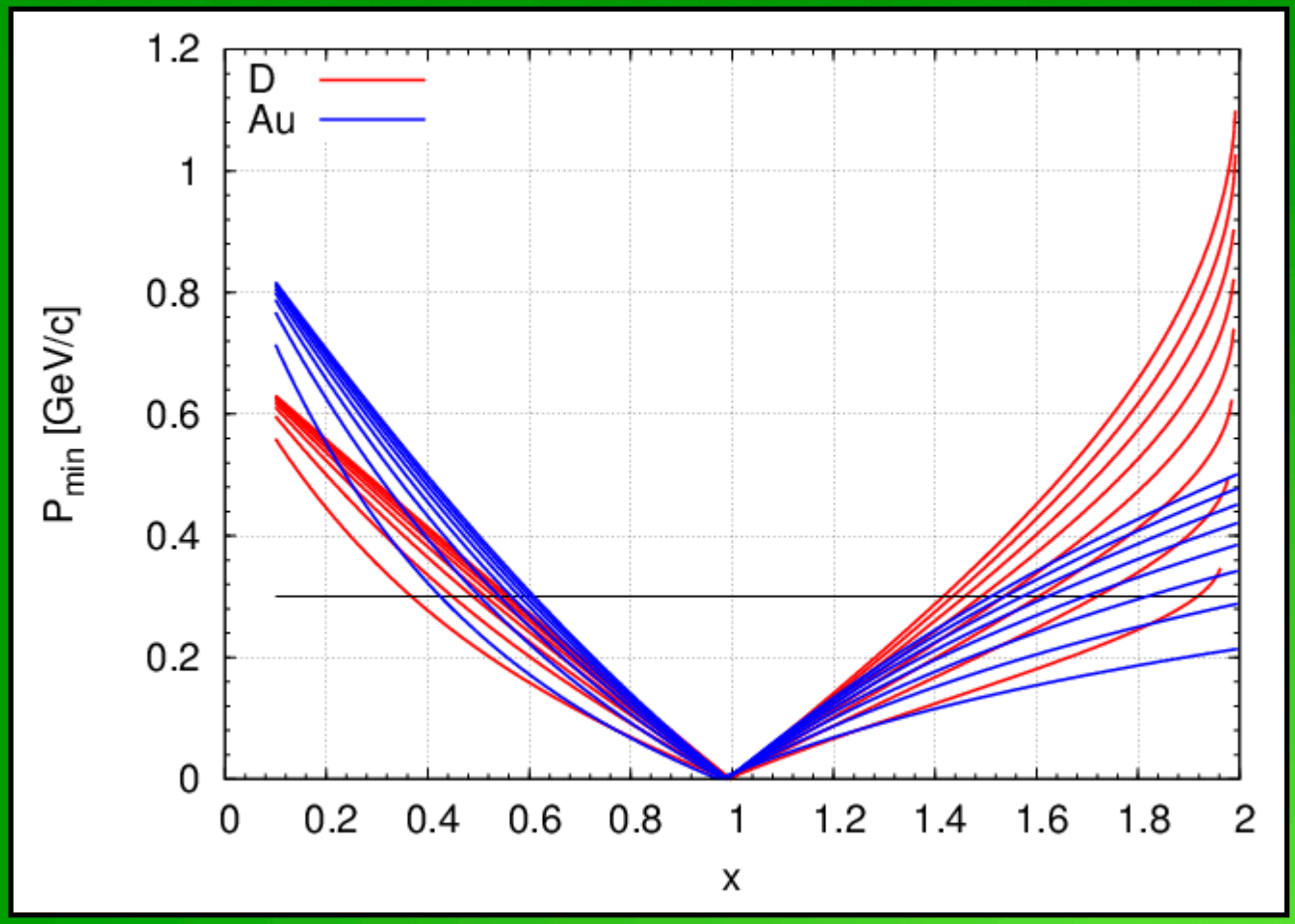
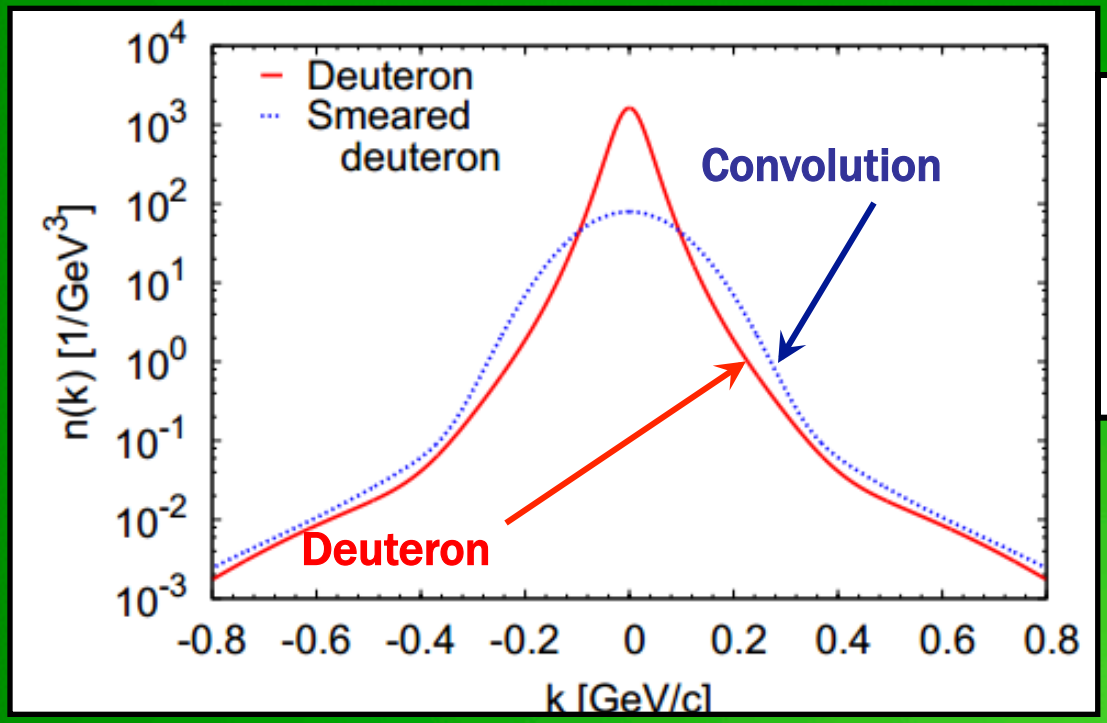


Kinematic cutoff is A-dependent



- For heavy nuclei, the minimum momentum changes → heavier recoil system requires less kinetic energy to balance the momentum of the struck nucleon
- Larger fermi momenta for A>2 → MF contribution persists for longer

$(a_2=\sigma_A/\sigma_D)$!= Relative #of SRCs



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

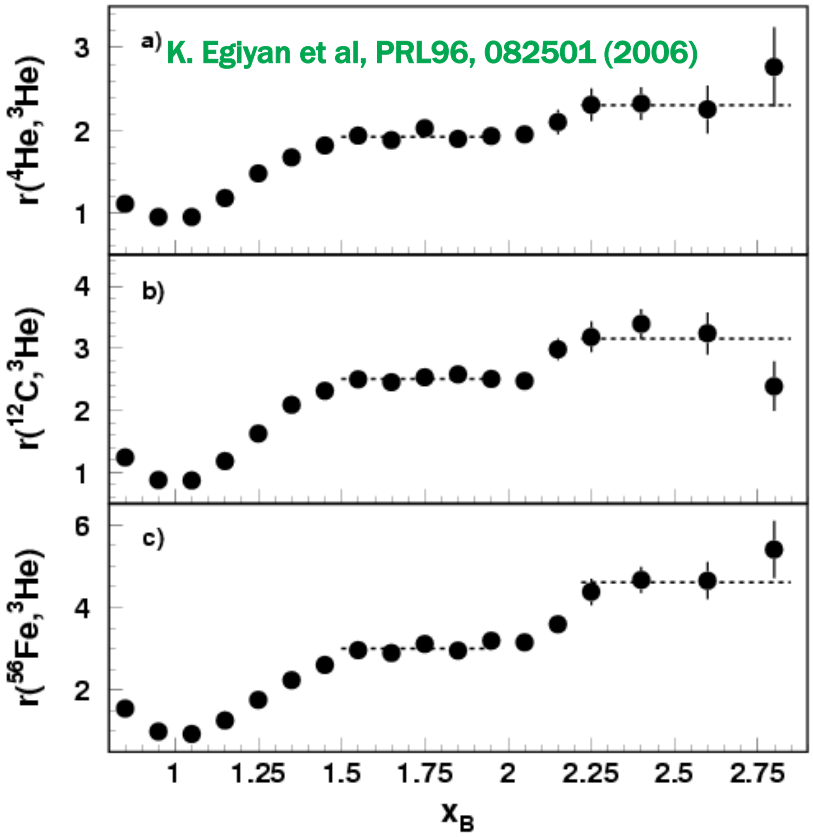
Following prescription from C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996)

	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

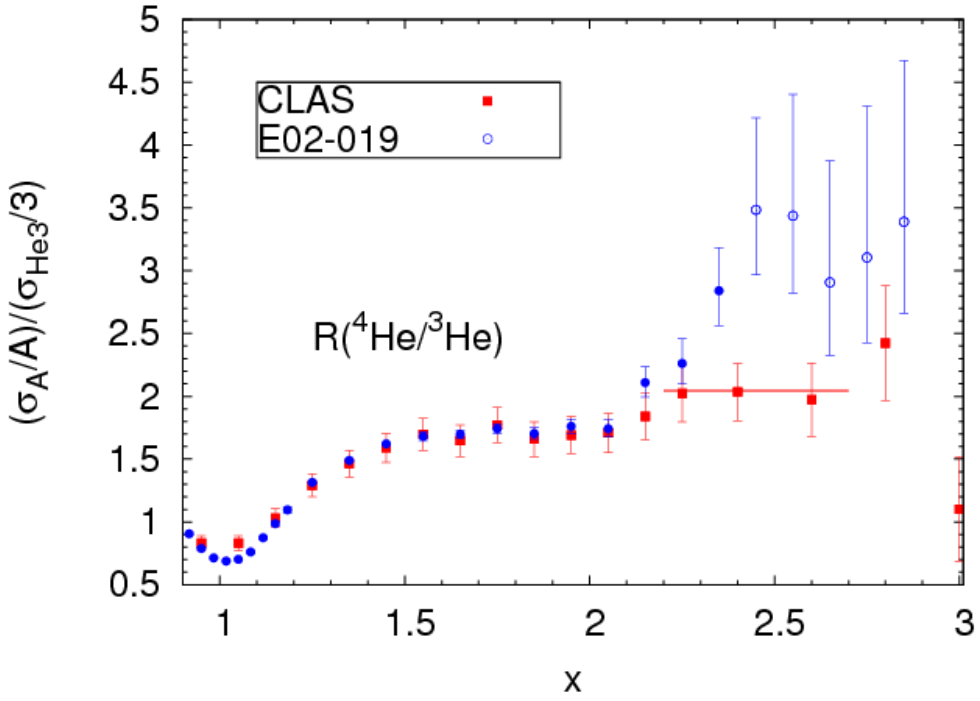
$a_2=\sigma_A/\sigma_D$ *→ relative measure of high momentum nucleons*

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

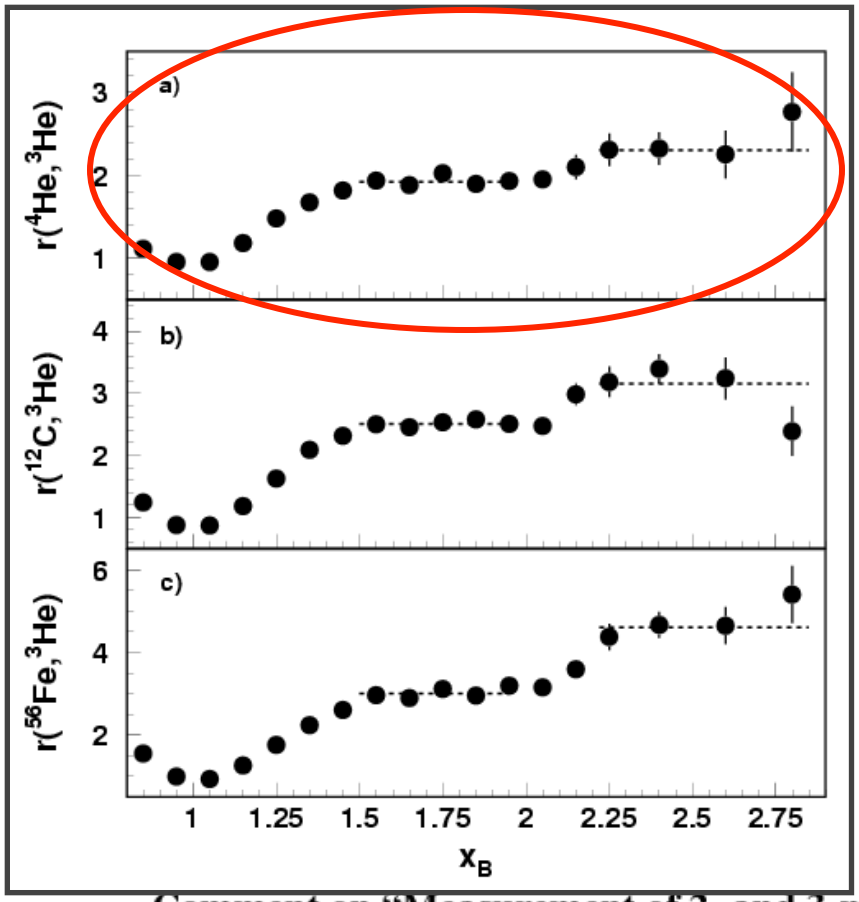
3N correlations (x>2 inclusive scattering)

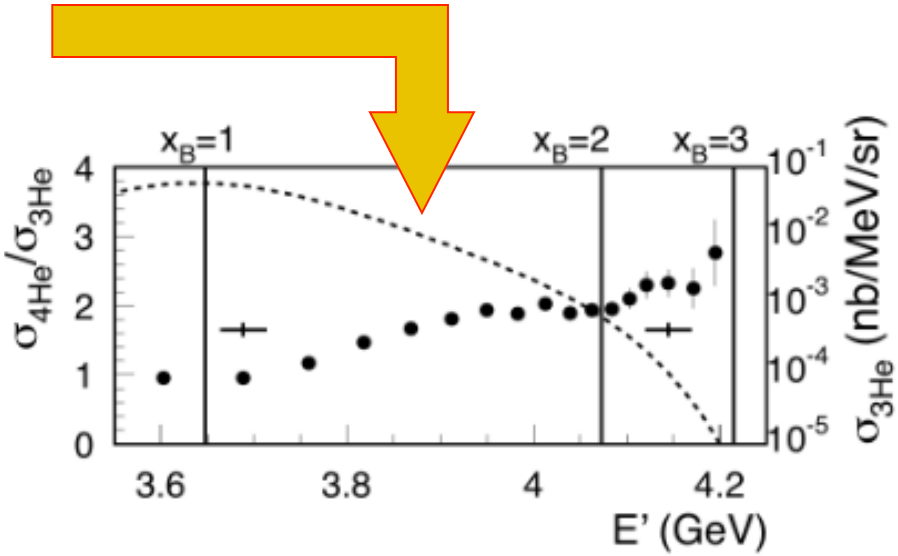


<Q²> (GeV²): *CLAS: 1.6* *E02-019: 2.7*



Have we actually seen 3N SRC in ratios?

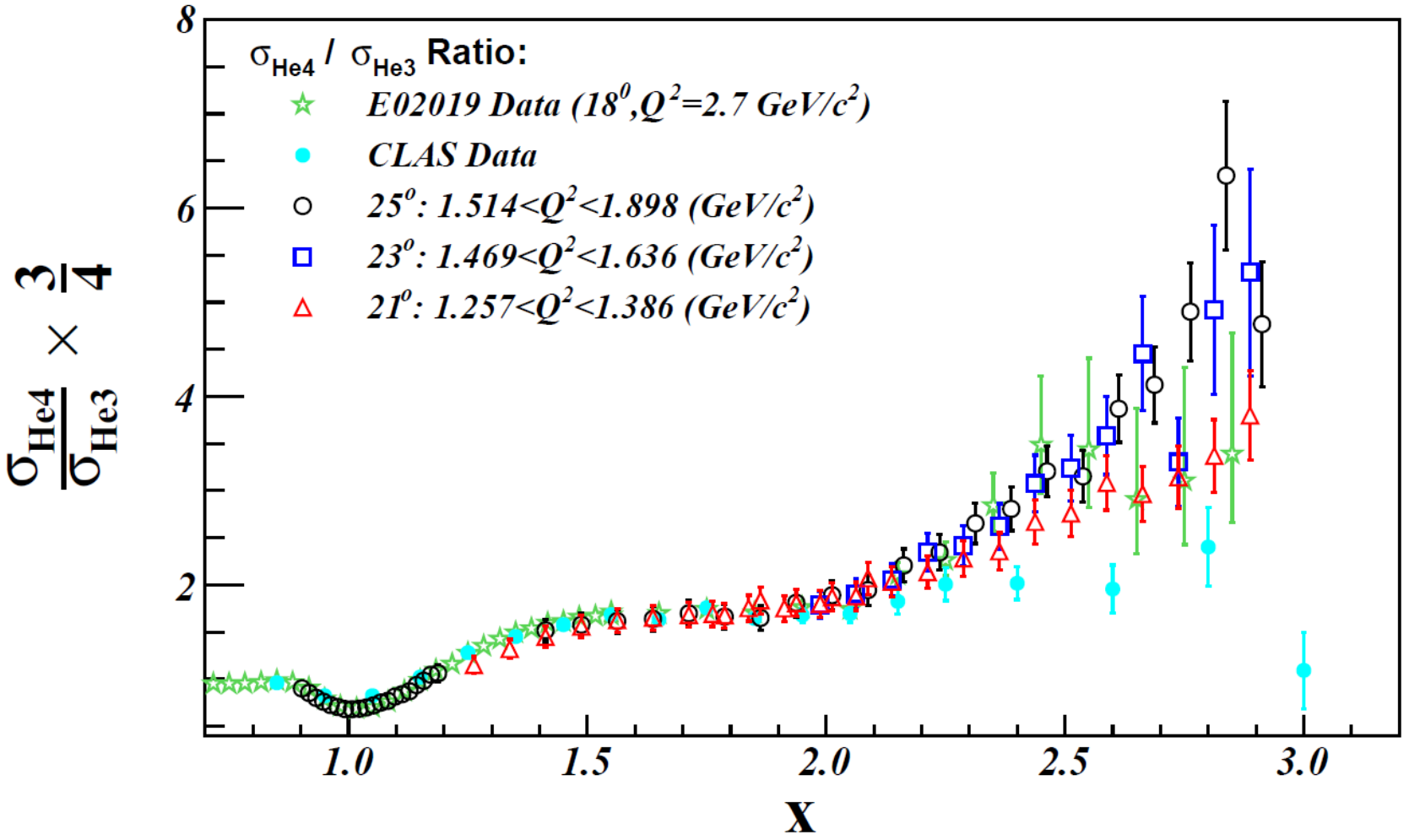


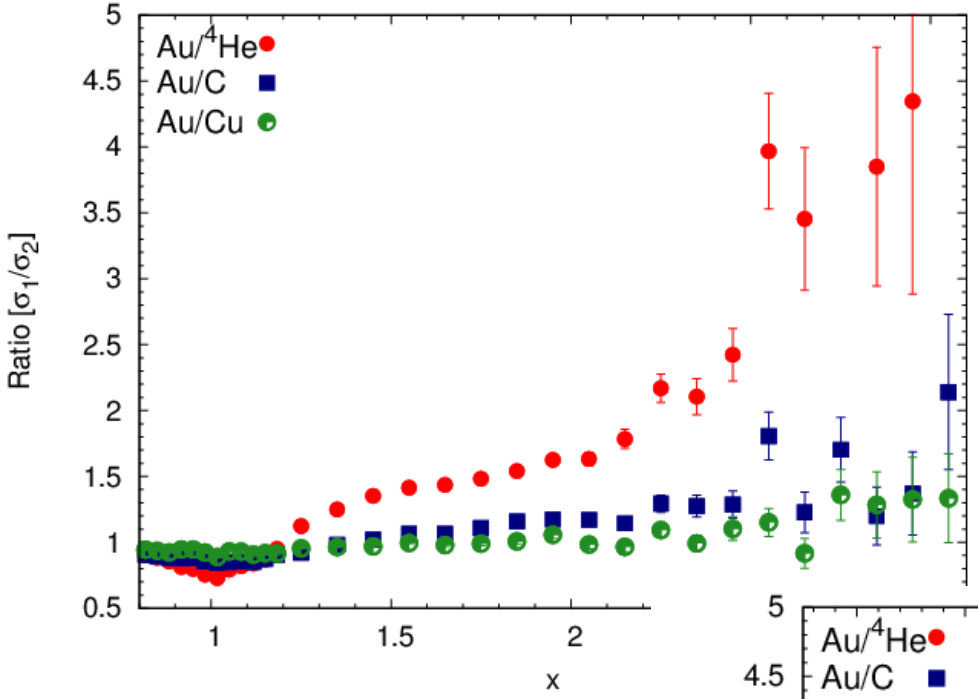


Comment on "Measurement of 2- and 3-nucleon short range correlation probabilities in nuclei"

Douglas W. Higinbotham[1] and Or Hen[2]

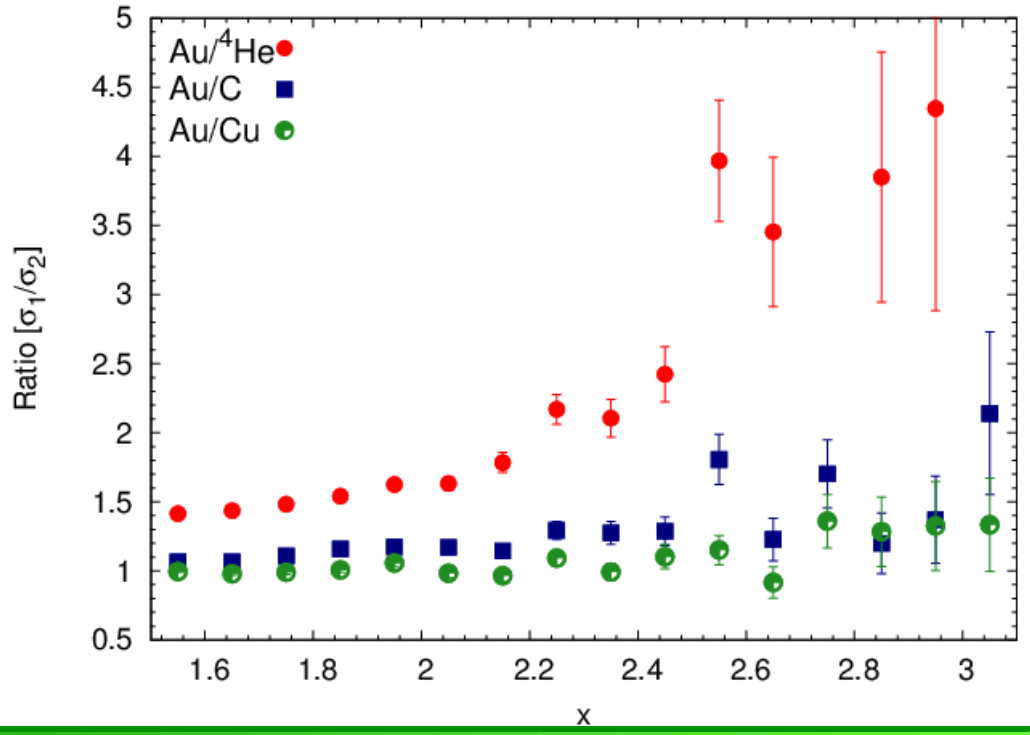
3N correlations





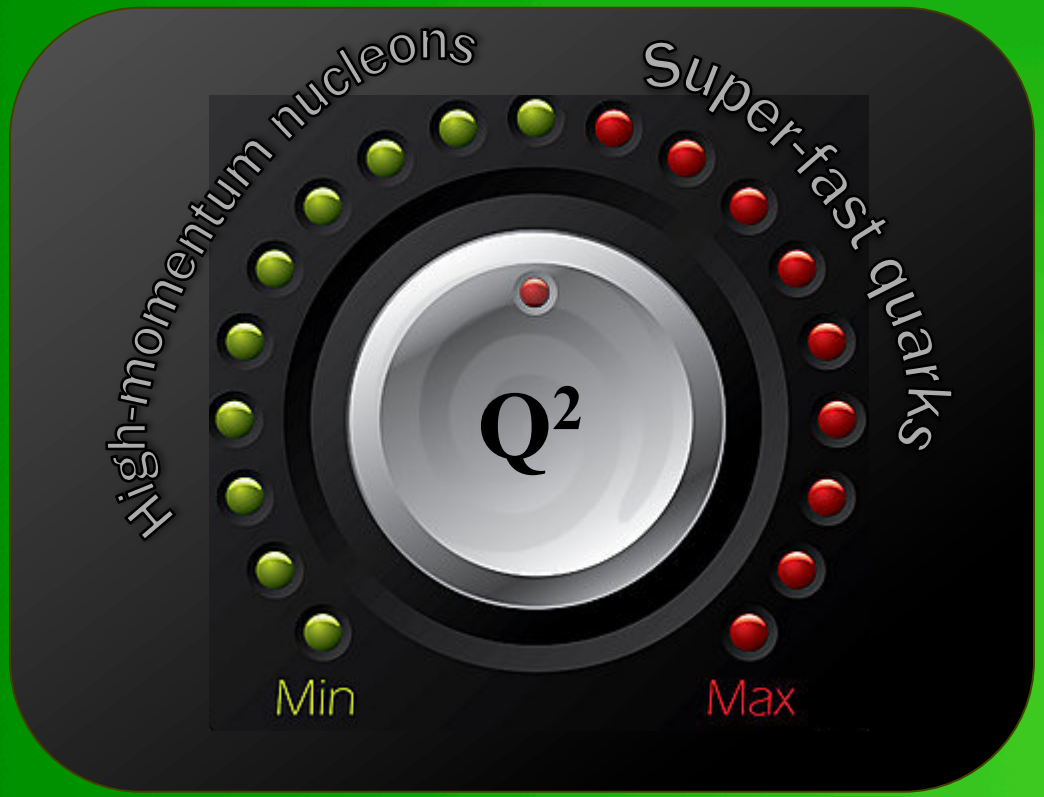
By popular demand

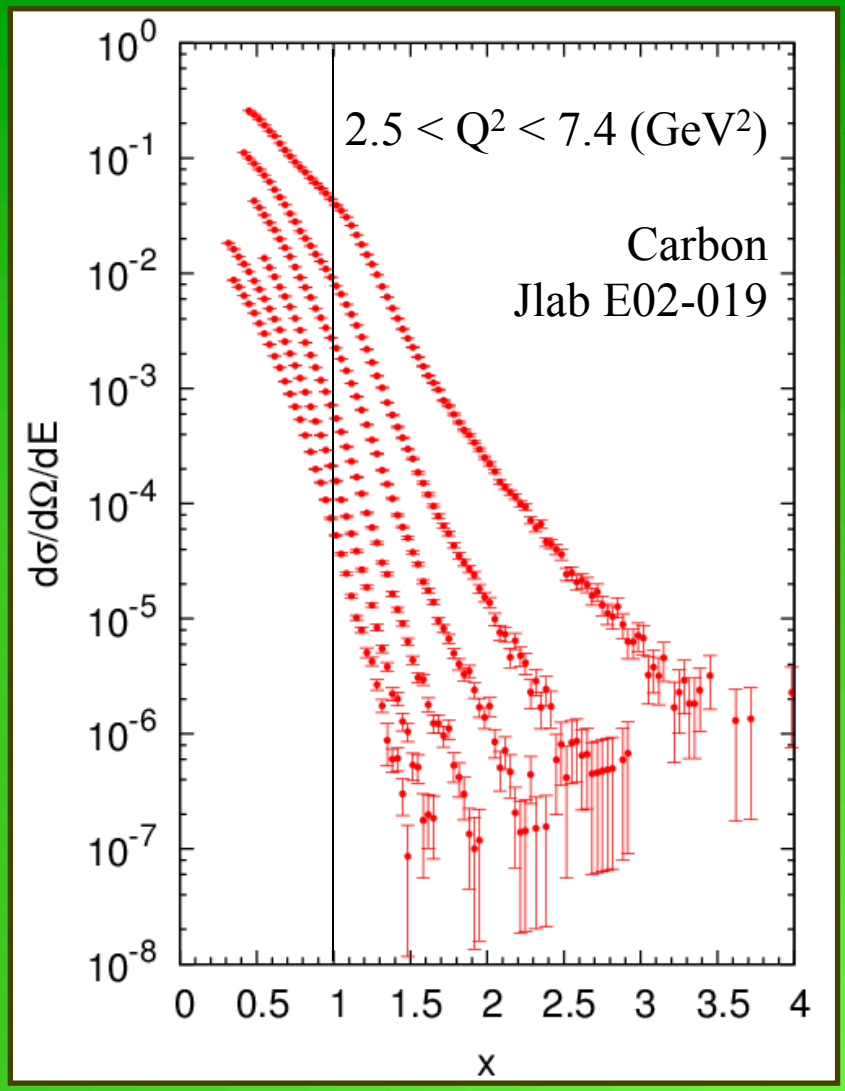
σ_{A1}/σ_{A2}



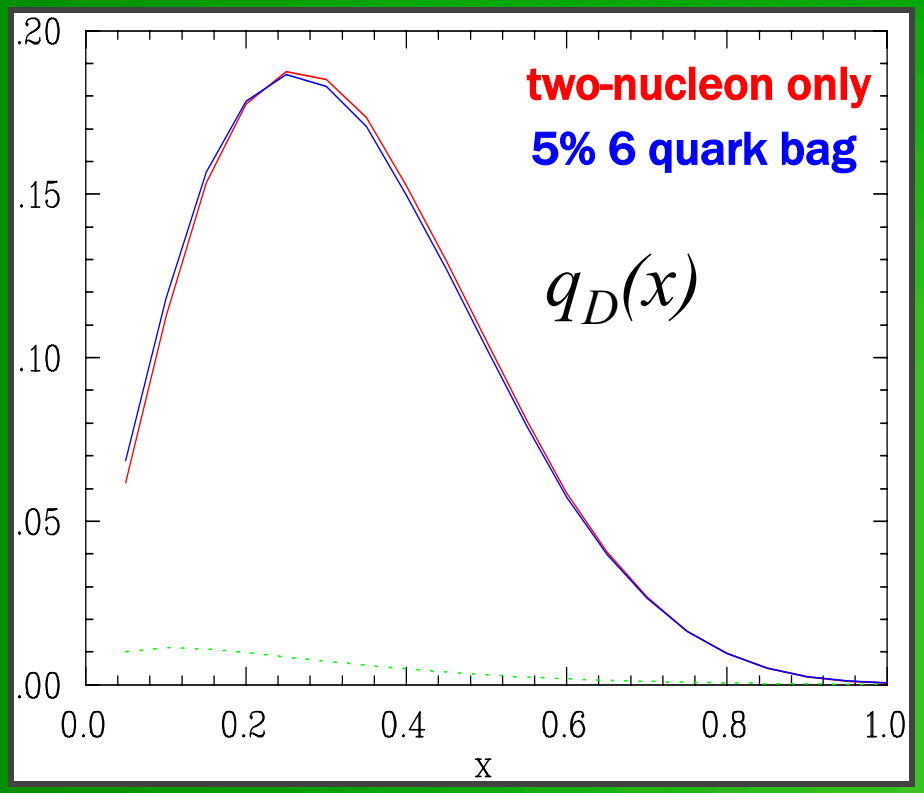
No hint of a second plateau at x>1.6 for Au/(A>=12)

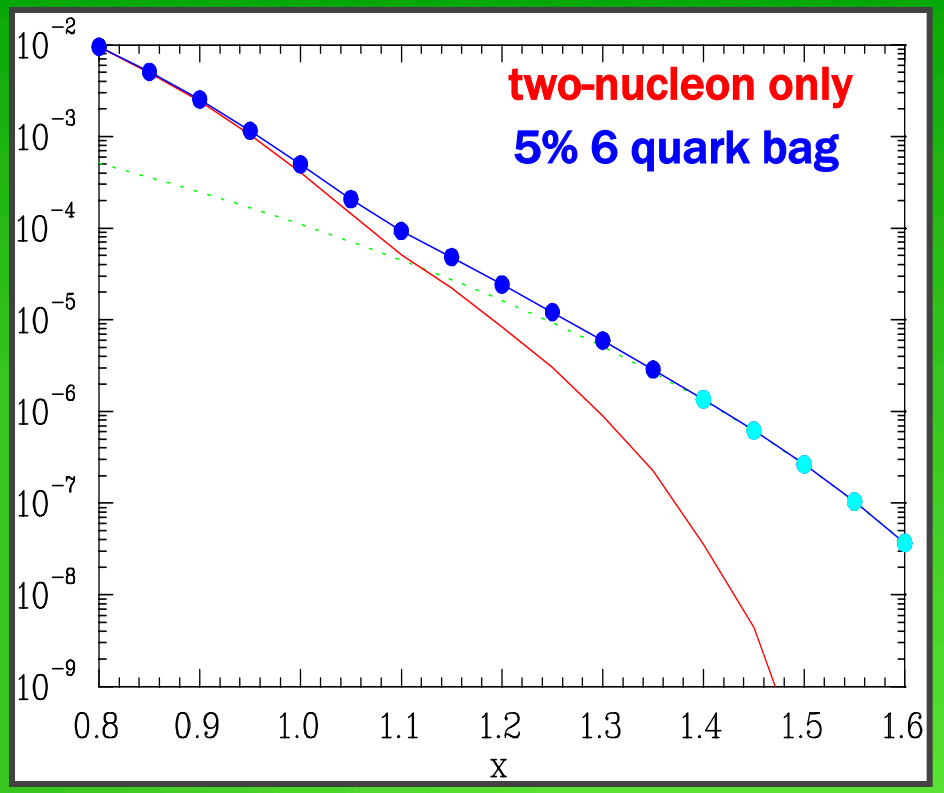
x > 1: Nuclear PDFs





Overlapping nucleons ⟶ enhancement of F_2 structure function





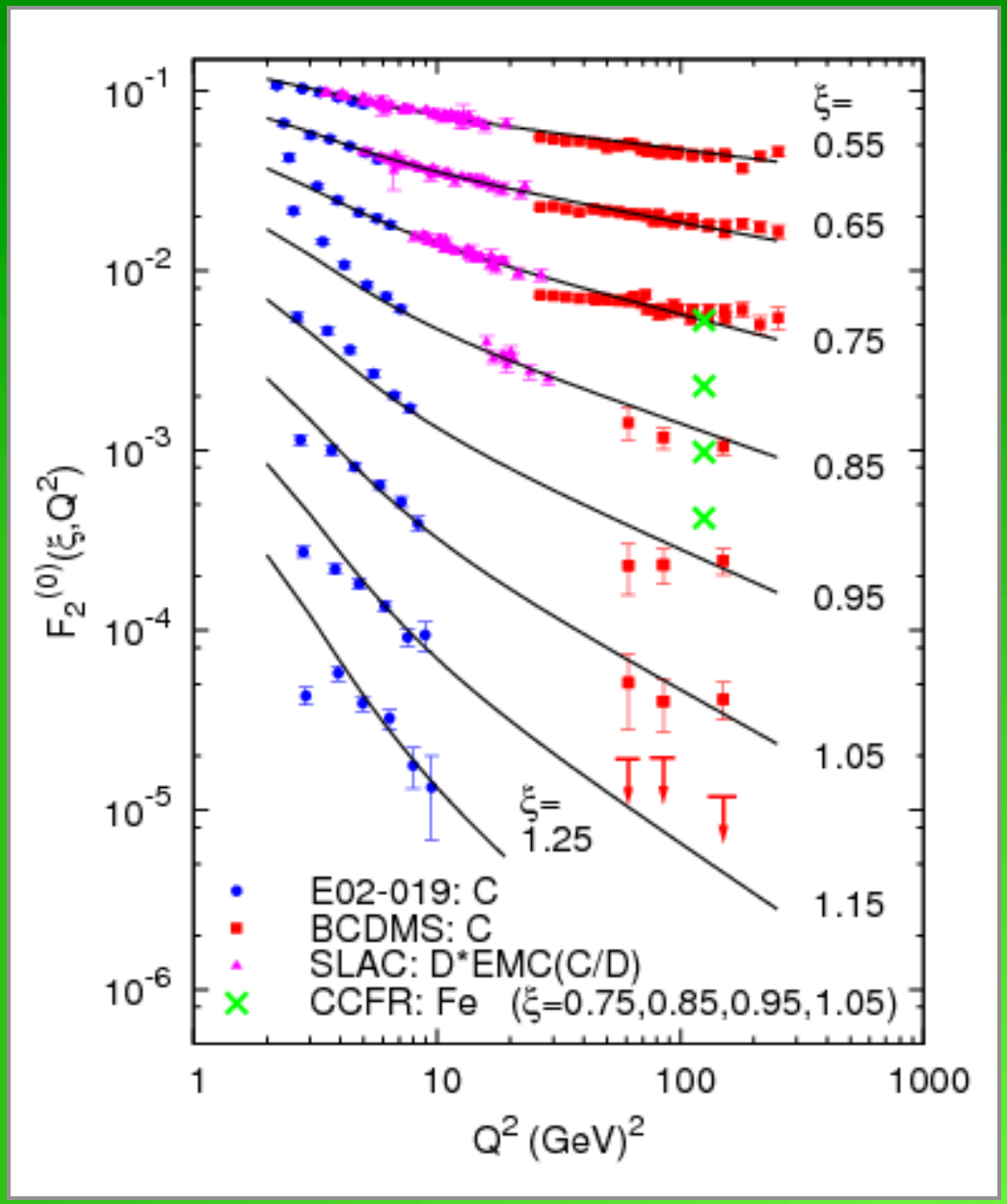
Small effect, possible contribution to EMC effect?

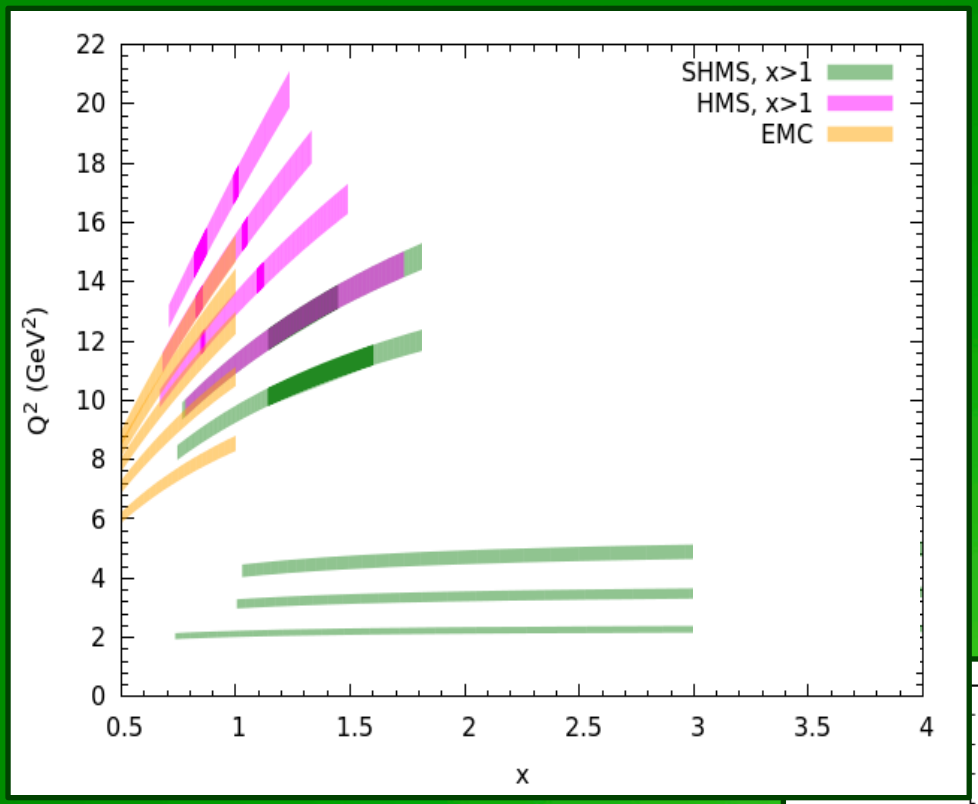
Noticeable effect at x>1

“Super-fast quarks”

- With all the tools in hand, we apply target mass corrections to the available data sets
- With the exception of low Q^2 quasielastic data – E02-019 data can be used for SFQ distributions

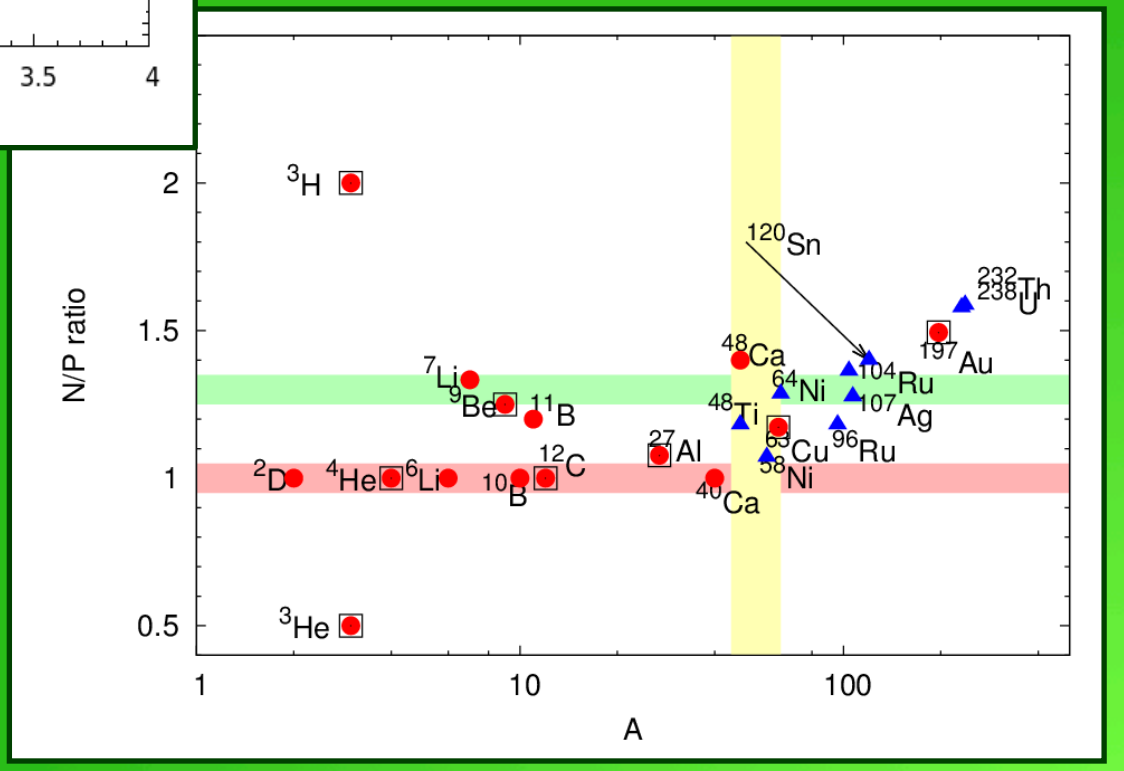
N. Fomin et al, PRL 105, 212502 (2010)





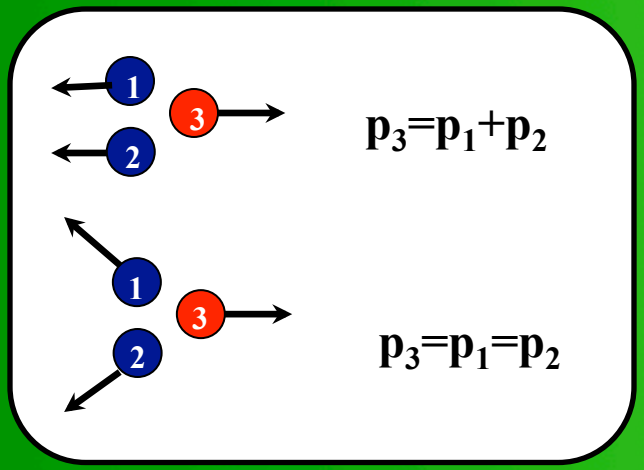
Jlab E12-06-105

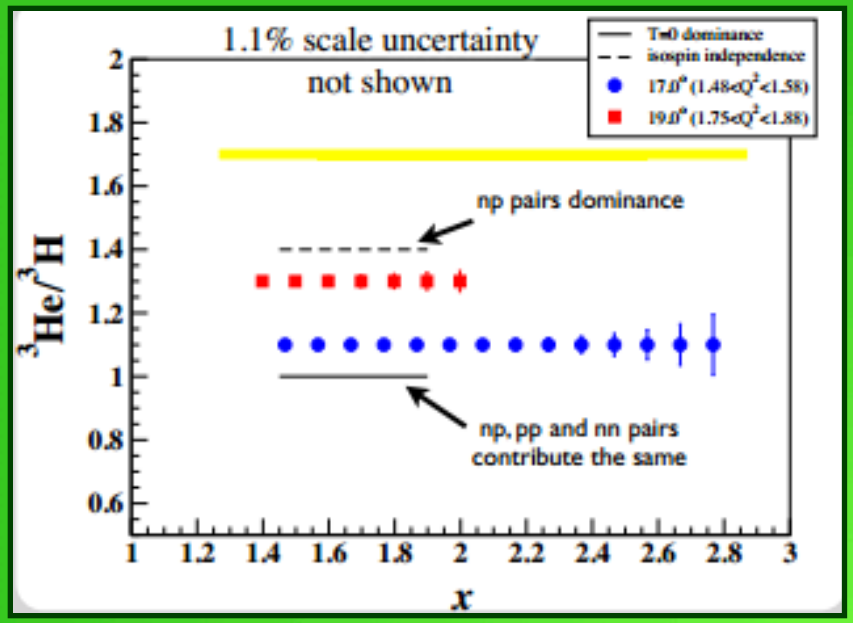
- short-range nuclear structure
  - Isospin dependence
  - A-dependence
- Super-fast quarks



Coming very soon: [Jlab E12-11-112]

- Quasielastic electron scattering with ^{3}H and ^{3}He
- Study isospin dependence of 2N and 3N correlations
- Test calculations of FSI for well-understood nuclei





Discussion/Summary

Inclusive x >1
- Extraction of a2(A,Z) for wide range of nuclei
- Extraction of light-cone momentum distribution of nuclei in 2N SRC region
- Possible Medium Modification in Quasi-Elastic Domain
- Probing polarized structure of the deuteron at x>1
- Probing superfast quarks
- Setting up studies of nuclear partonic distributions at x>1

Inclusive x >3
- Looking for the plateau in inclusive cross section ratio
- Understanding transition from 2N to 3N SRCs
- Extraction of momentum distribution in 3N SRC
- Center of mass motion effects in 3N SRCs

Semi-Inclusive Reactions

- Probing x-\alpha correlations in fast backward production off nuclei
- Probing Non-nucleonic components in nuclei in backward production of resonances
- Probing superfast quarks in jet production at LHC/EIC