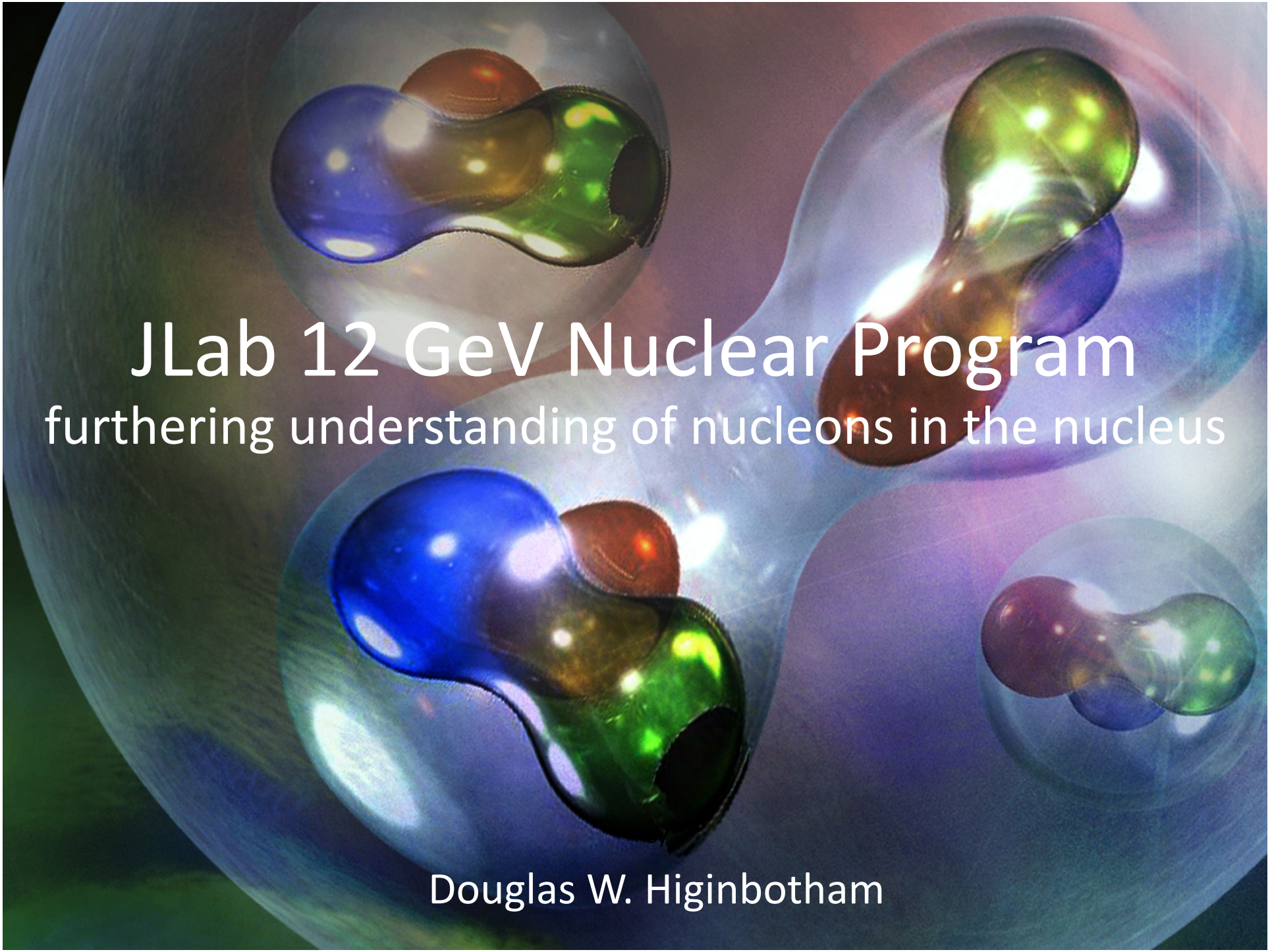


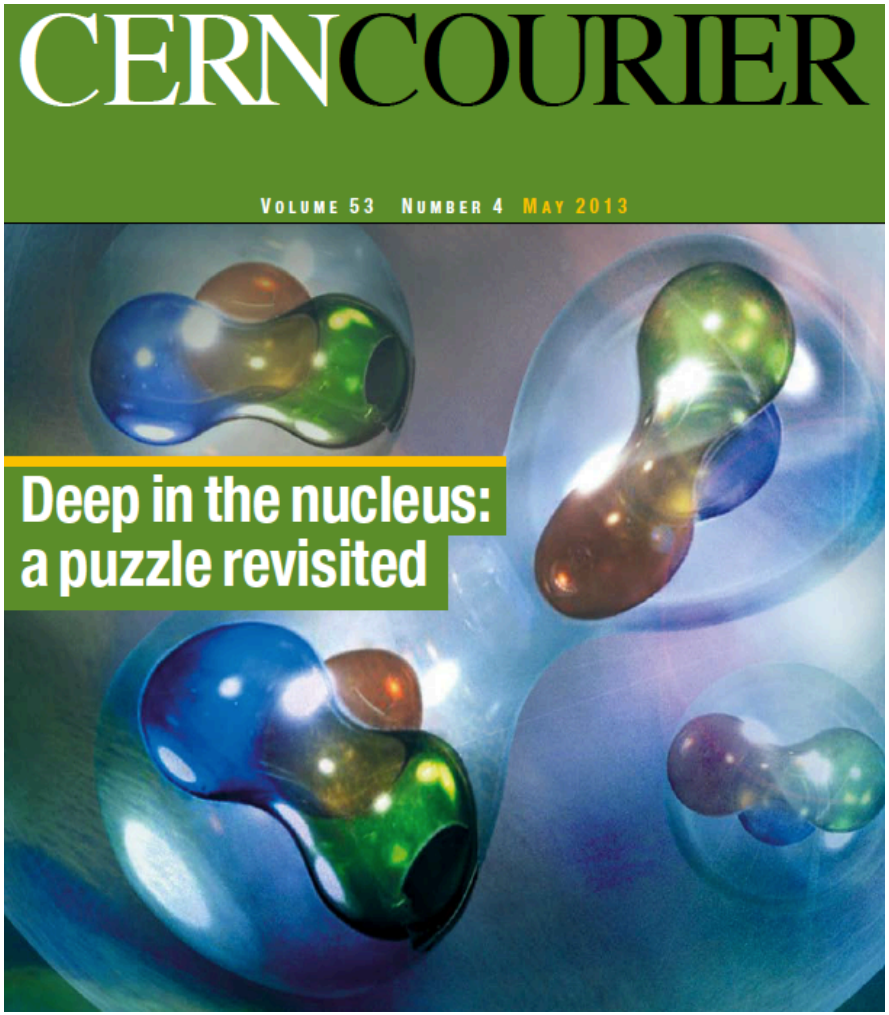
JLab 12 GeV Nuclear Program

furthering understanding of nucleons in the nucleus

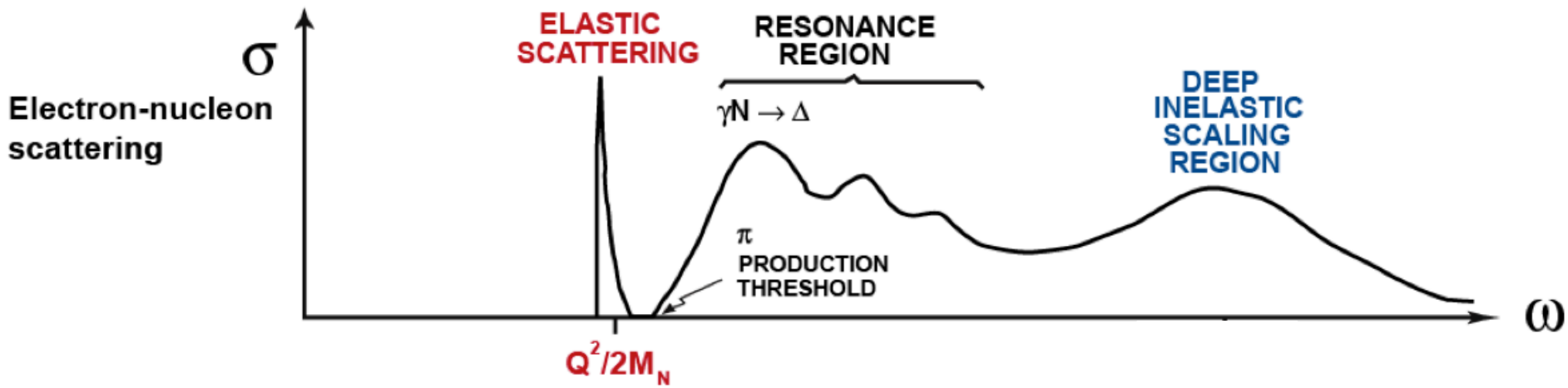
Douglas W. Higinbotham

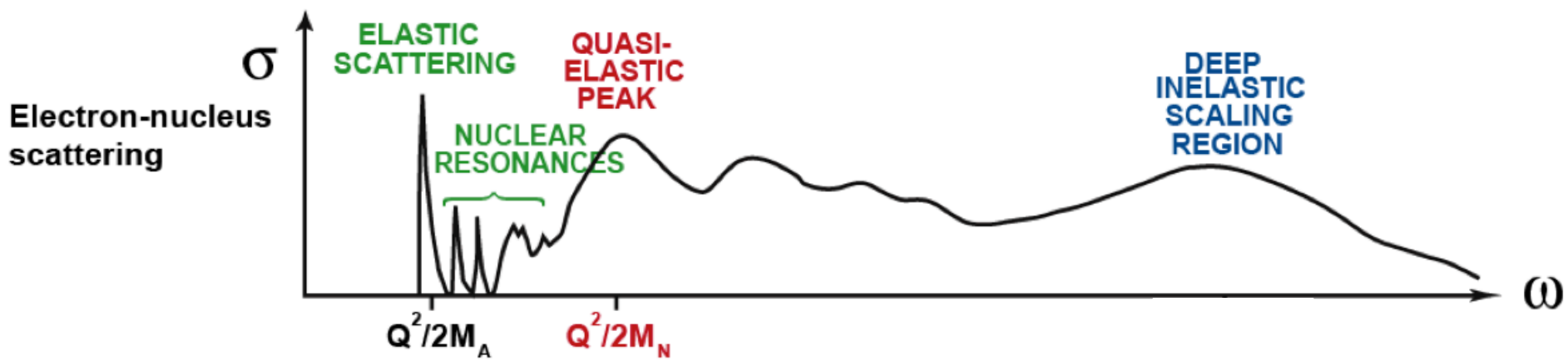
Outline

- Review of (e,e') Kinematics
- EMC Effect
  - What is it?
  - Recent developments.
- Short Range Correlations (SRC)
  - What is it?
  - Recent developments
- **SRC and EMC Together!?**
- Upcoming Experiments



Electron Scattering Regions

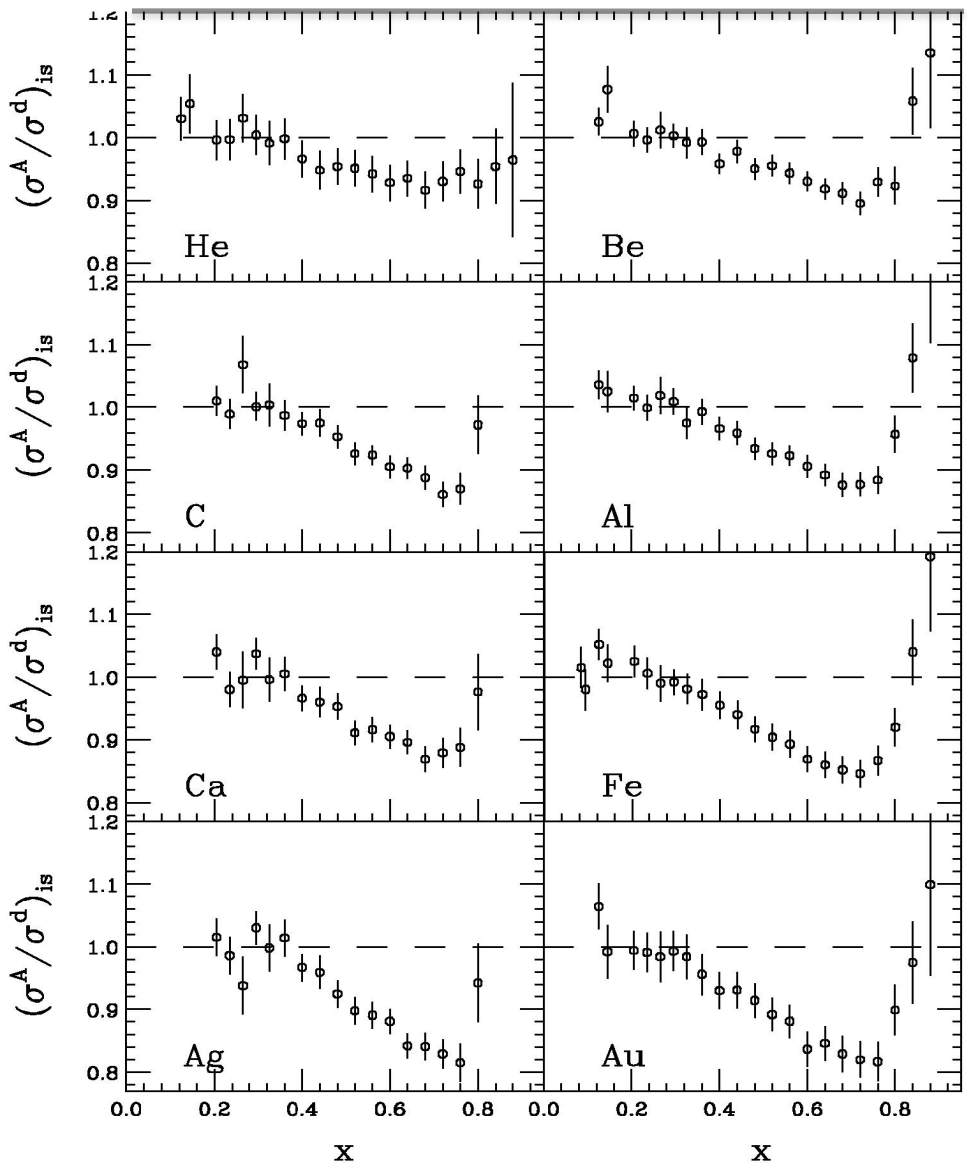




$\mathbf{x_B = Q^2/2m\omega}$ $x_B > 1$ $x_B = 1$ $x_B < 1$

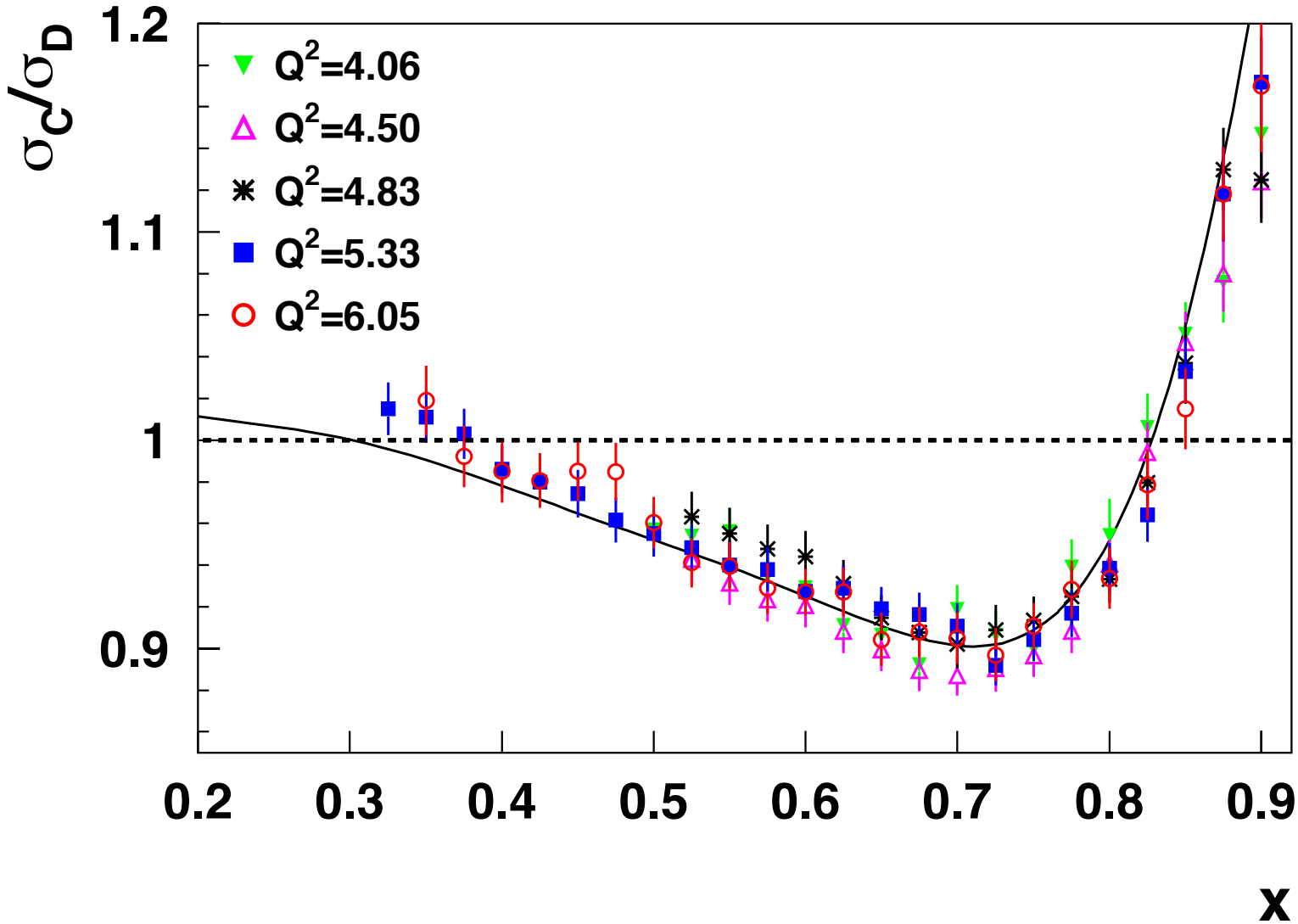
What is the EMC Effect?

- **EMC effect is simply the fact the ratio of DIS cross sections is not one**
  - J.J. Aubert et al. PLB 123 (1983) 275.
  - Simple Parton Counting Expects One
  - **MANY Explanations**
- **SLAC E139**
  - J. Gomez et al., PRD 49 (1994) 4348.
  - Precise large-x data
  - Nuclei from A=4 to 197
- **Conclusions from SLAC data**
  - Q^2-independent
  - Universal x-dependence (shape)
  - Magnitude varies with A
  - Average Nuclear Density Effect



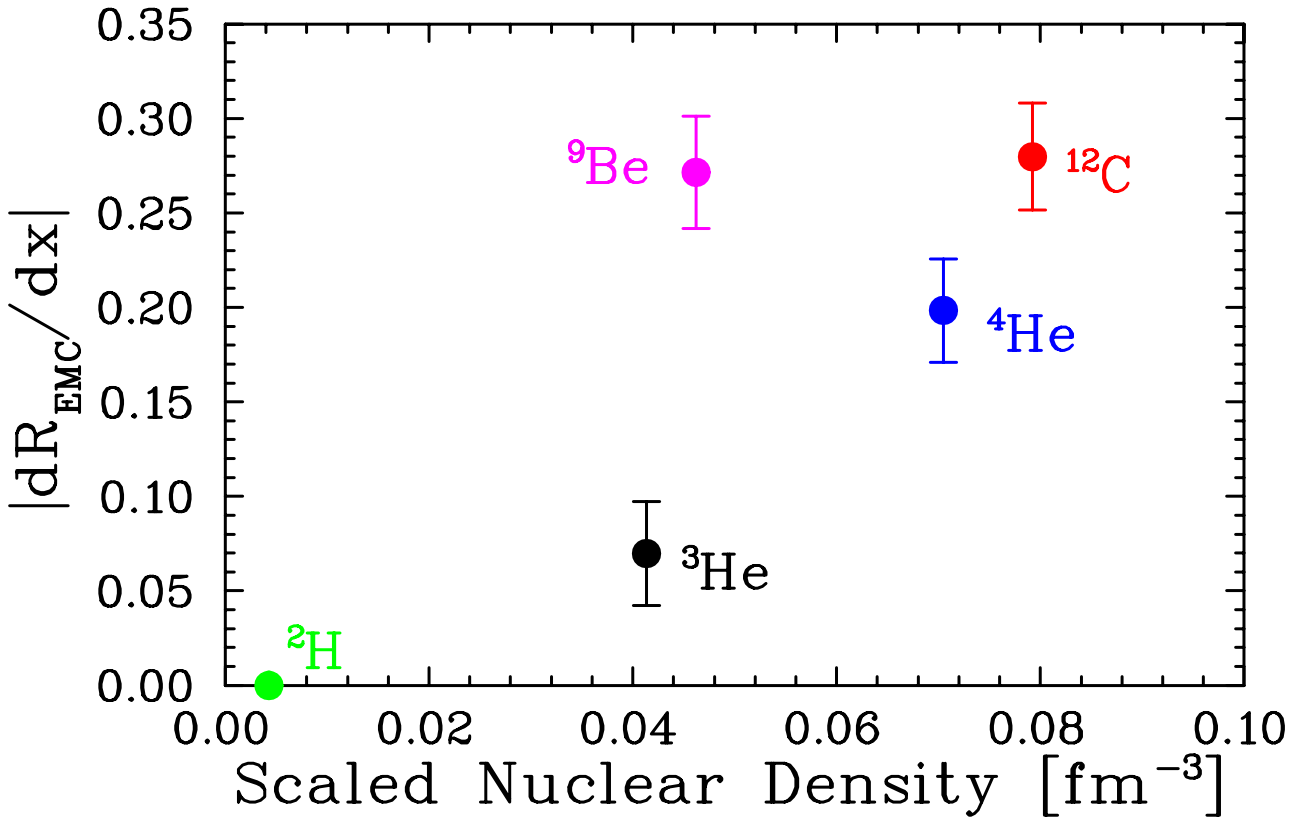
Jefferson Lab EMC Effect Data

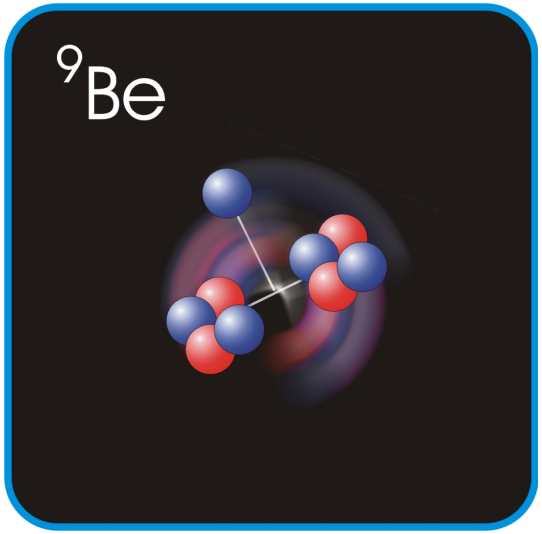
J. Seely *et al*., Phys, Rev. Lett. **103** (2009) 202301.



New Jefferson Lab EMC Effect Data

J. Seely *et al*., Phys, Rev. Lett. **103** (2009) 202301.





- Plot shows slope of ratio σ_A/σ_D at EMC region.
- EMC effect correlated with **local density** not average density.

If the EMC effect is a local density effect, then it seems reasonable to look for connections to other local density effects.

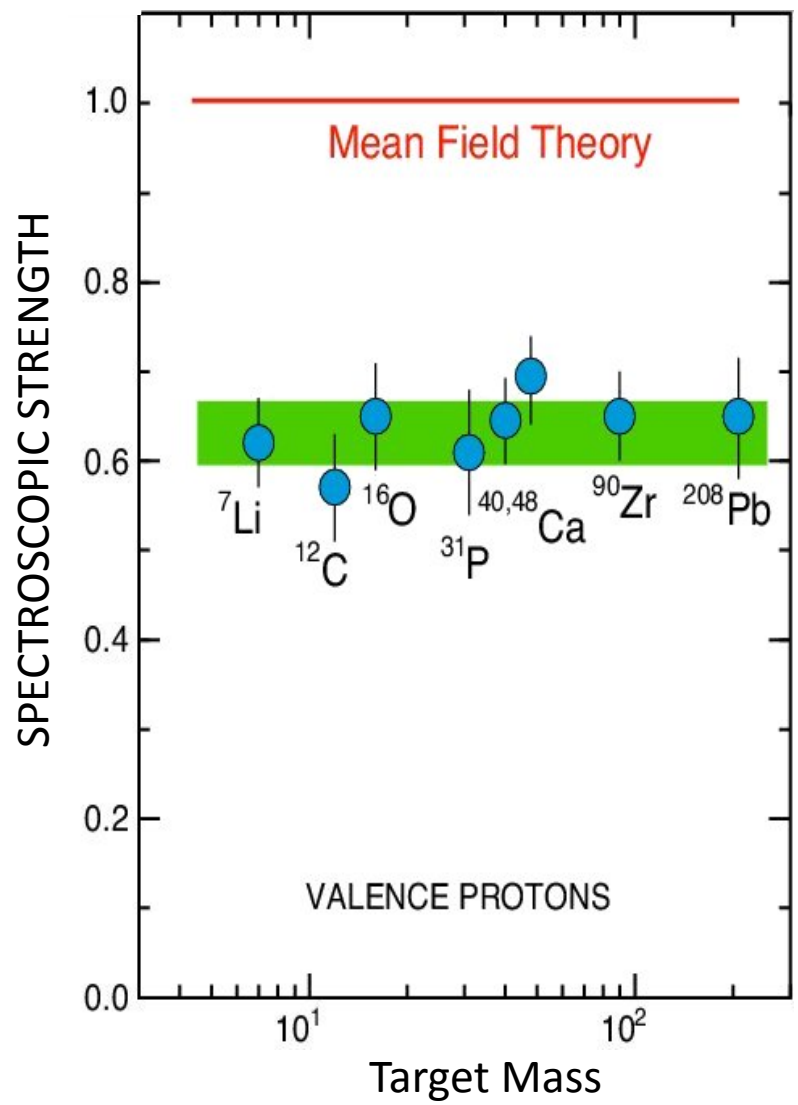
Classic (e,e'p) Results

L. Lapikas, Nucl. Phys. A553 (1993) 297.

Independent-Particle Shell-Model is based upon the assumption that each nucleon moves independently in an average potential (mean field) induced by the surrounding nucleons

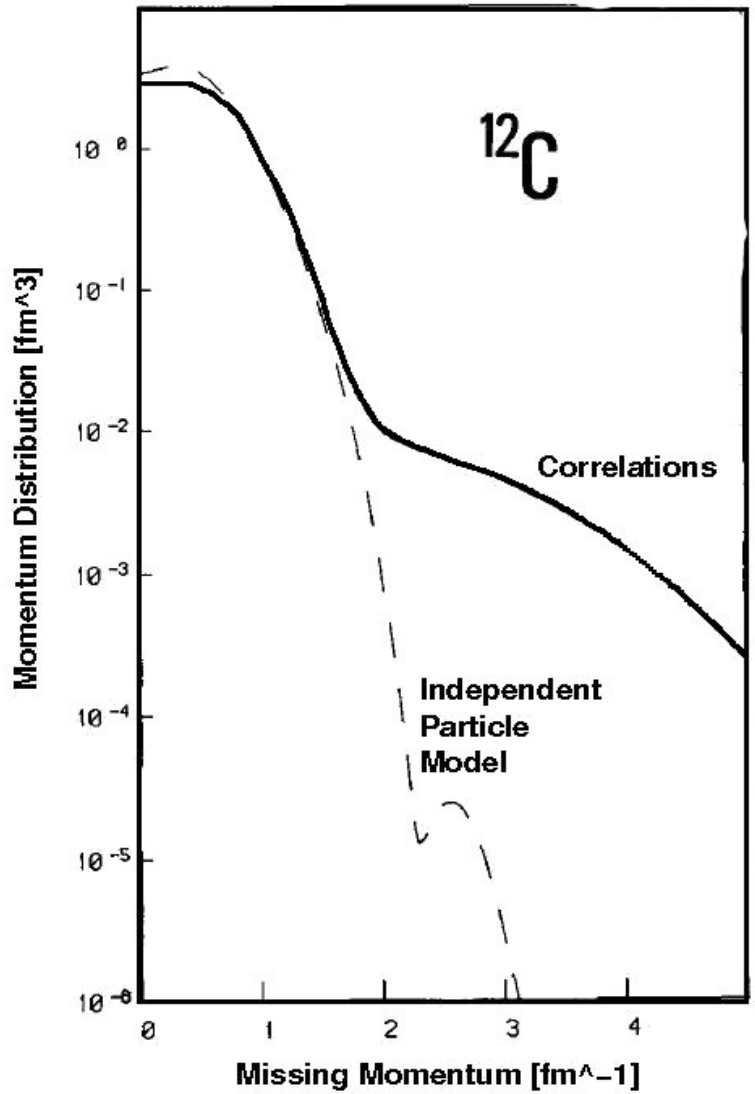
The (e,e'p) data for knockout of valence and deeply bound orbits in nuclei gives spectroscopic factors that are 60 – 70% of the mean field prediction.

Solution: Correlations Between Nucleons



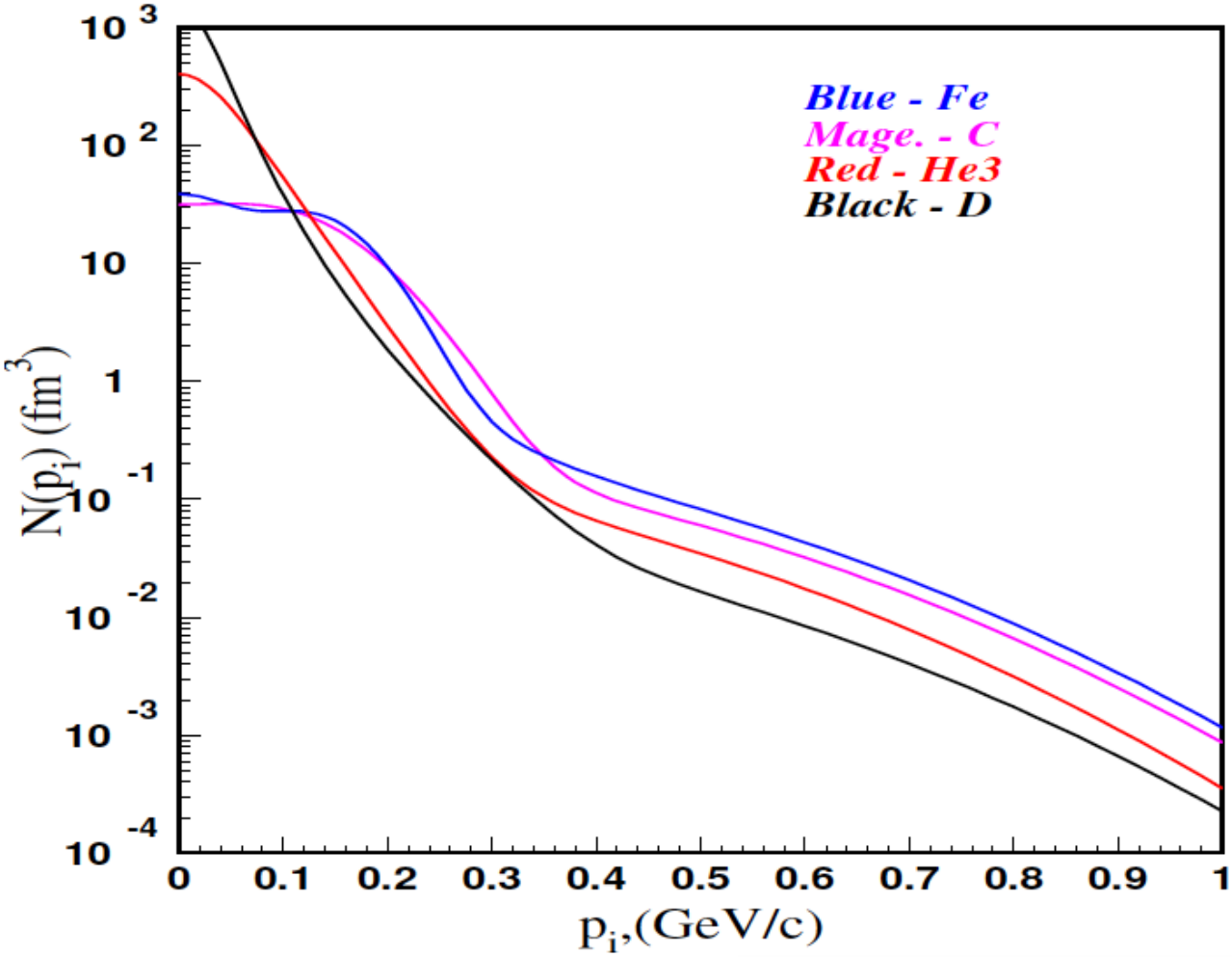
Realistic Momentum Distribution

Benhar et al., Phys. Lett. **B** 177 (1986) 135.



Momentum Distributions

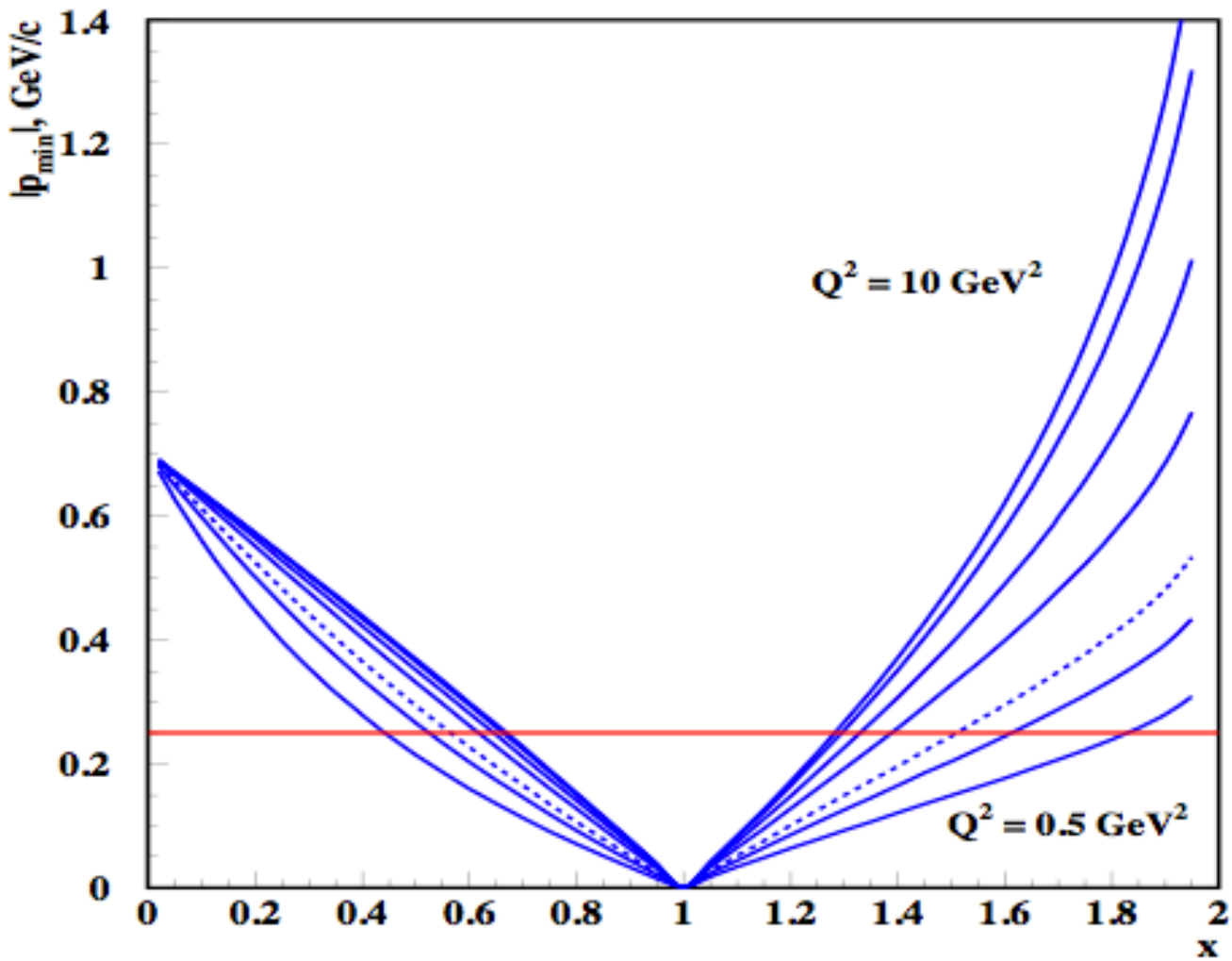
C. Ciofi degli Att and S. Simula, Phys. Rev. C **53** (1996) 1689.



At high *initial* momentums $\mathbf{n_A(p) = N * n_D(p)}$

Minimum Missing Momentum

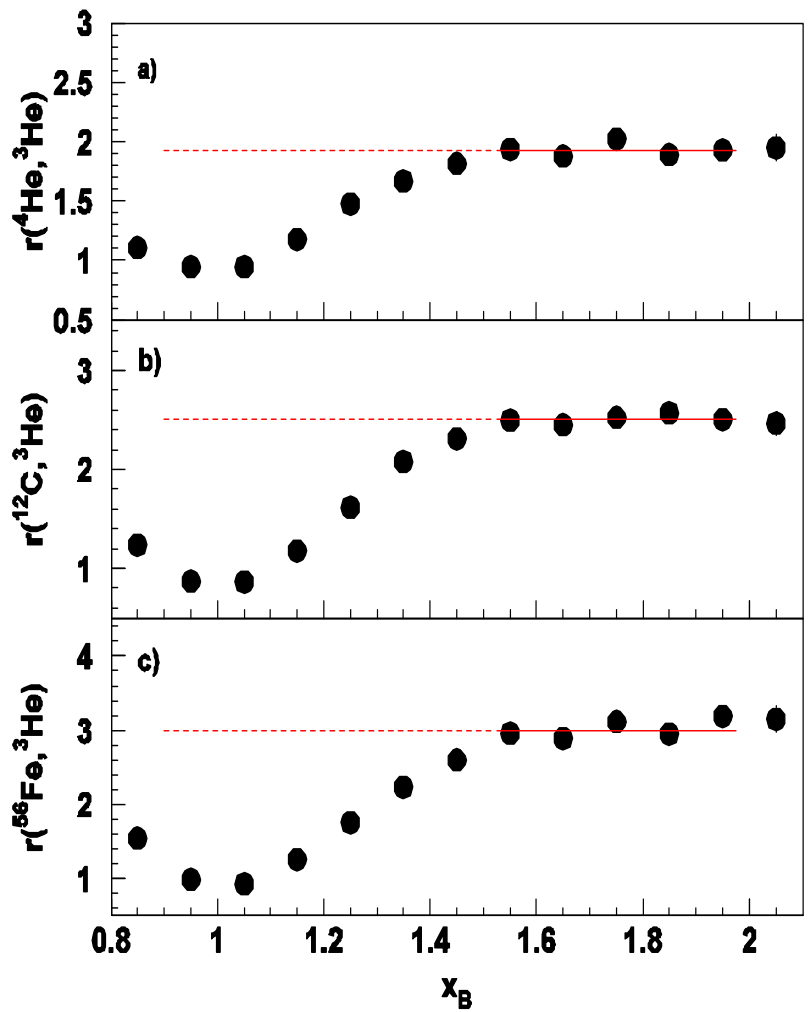
Assuming a (e,e'p) reaction, inclusive (e,e') can set limits on recoiling system's momentum.



Nuclear Scaling Plateaus from CLAS

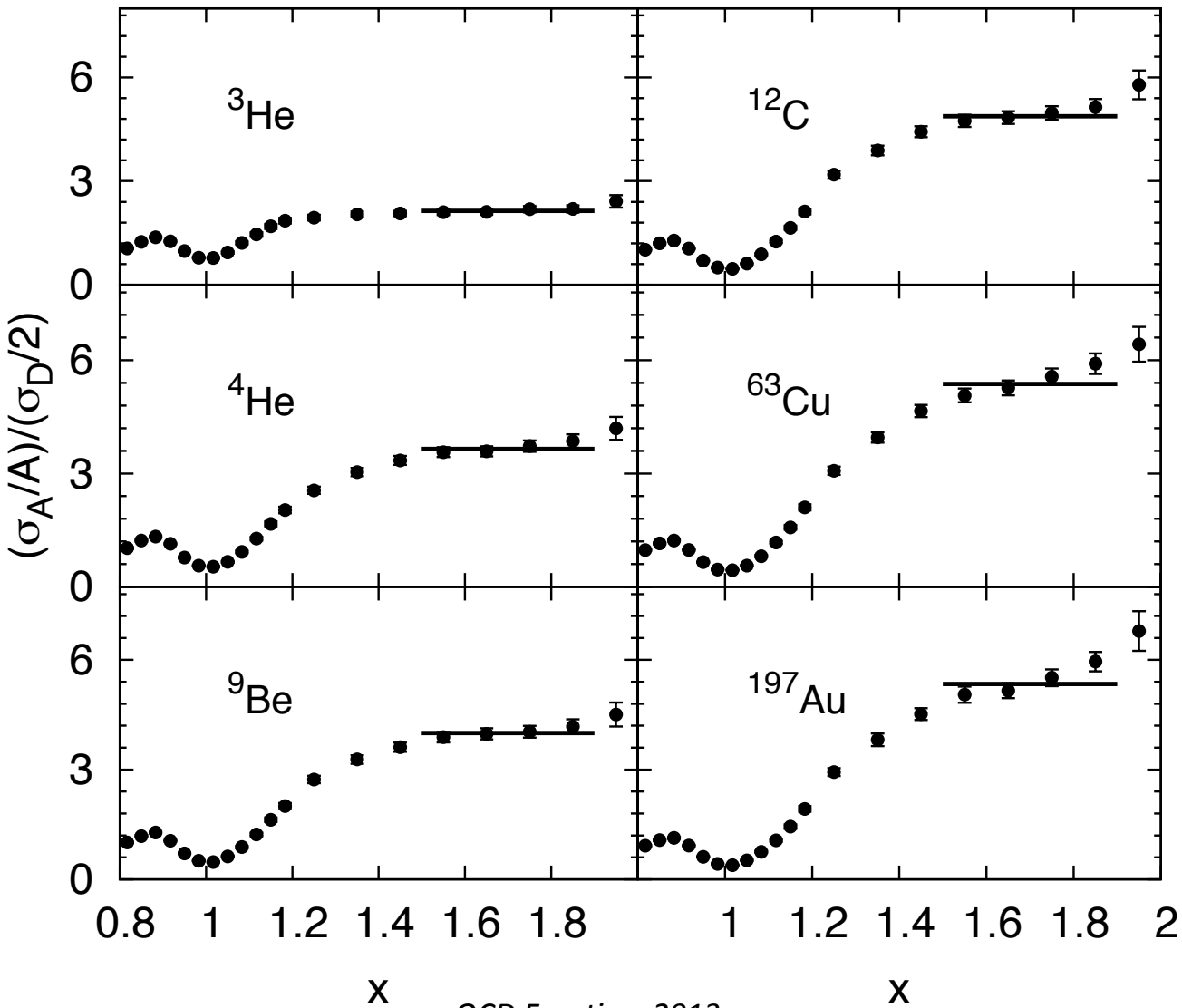
K. Sh. Egiyan *et al.,* Phys. Rev. C **68** (2003) 014313.

Originally done with SLAC data by Frankfurt et al., Phys. Rev. C **48** (1993) 2451.



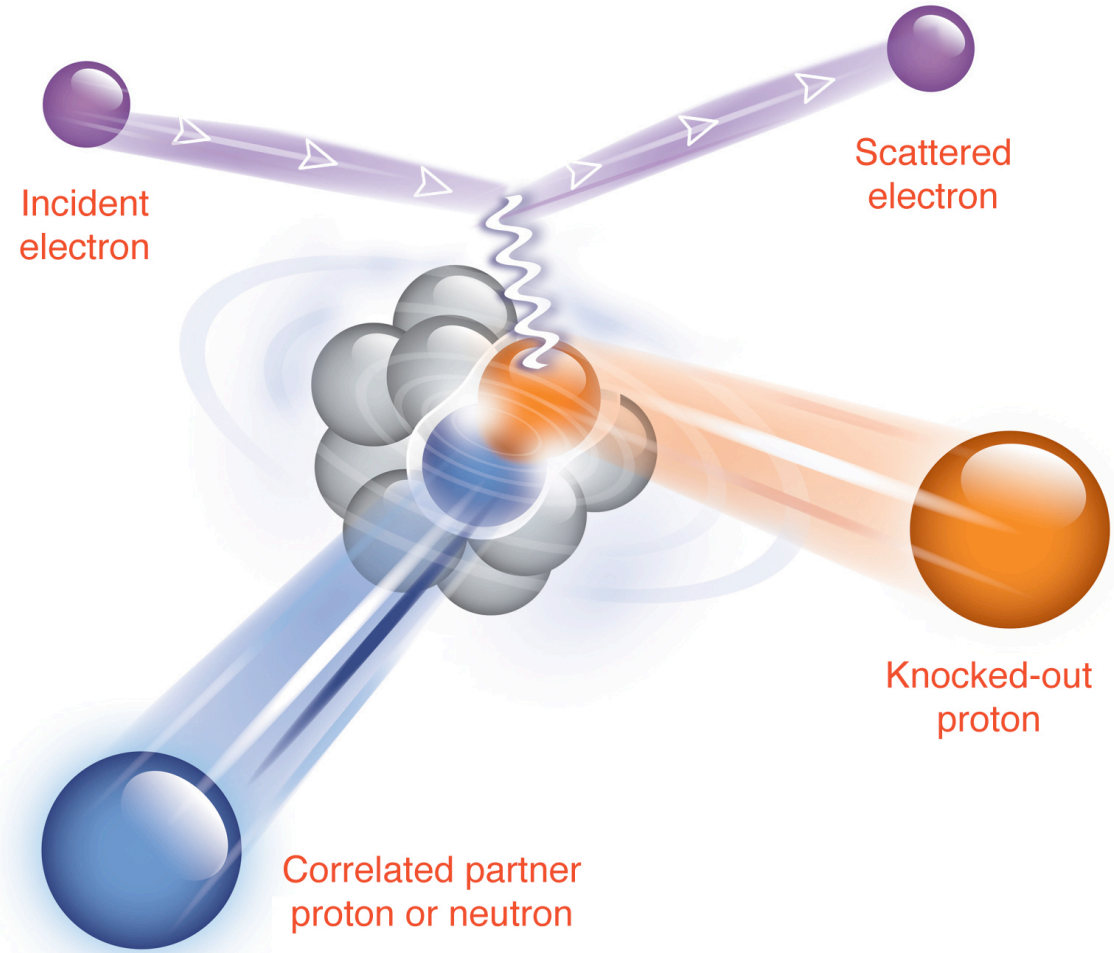
New Results From JLab Hall-C

N. Fomin et al., Phys. Rev. Lett. **108** (2012) 092502.



Coincidence (e,e'pN) Measurement

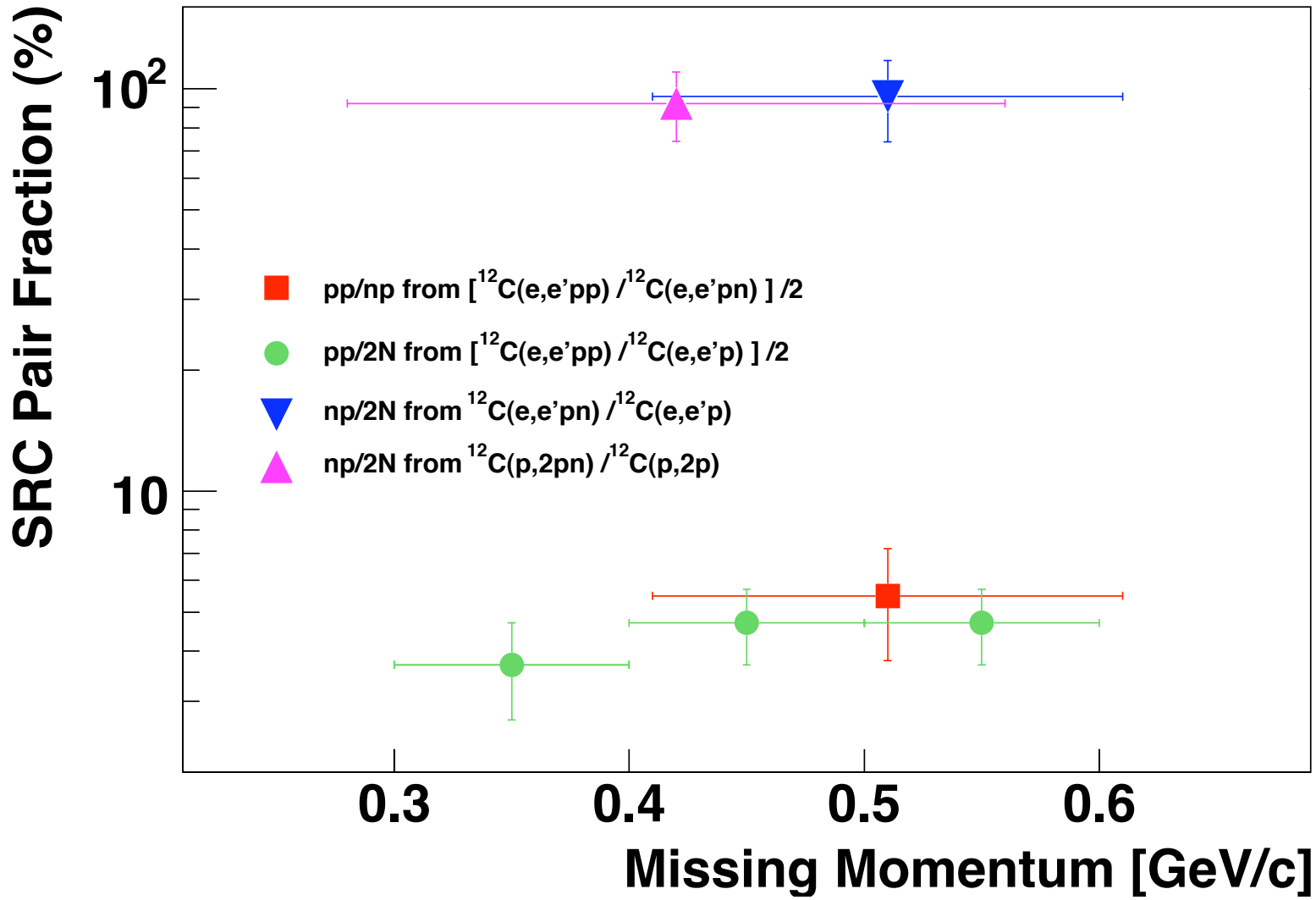
To study nucleon pairs and the fraction that contribute to momentum tail.



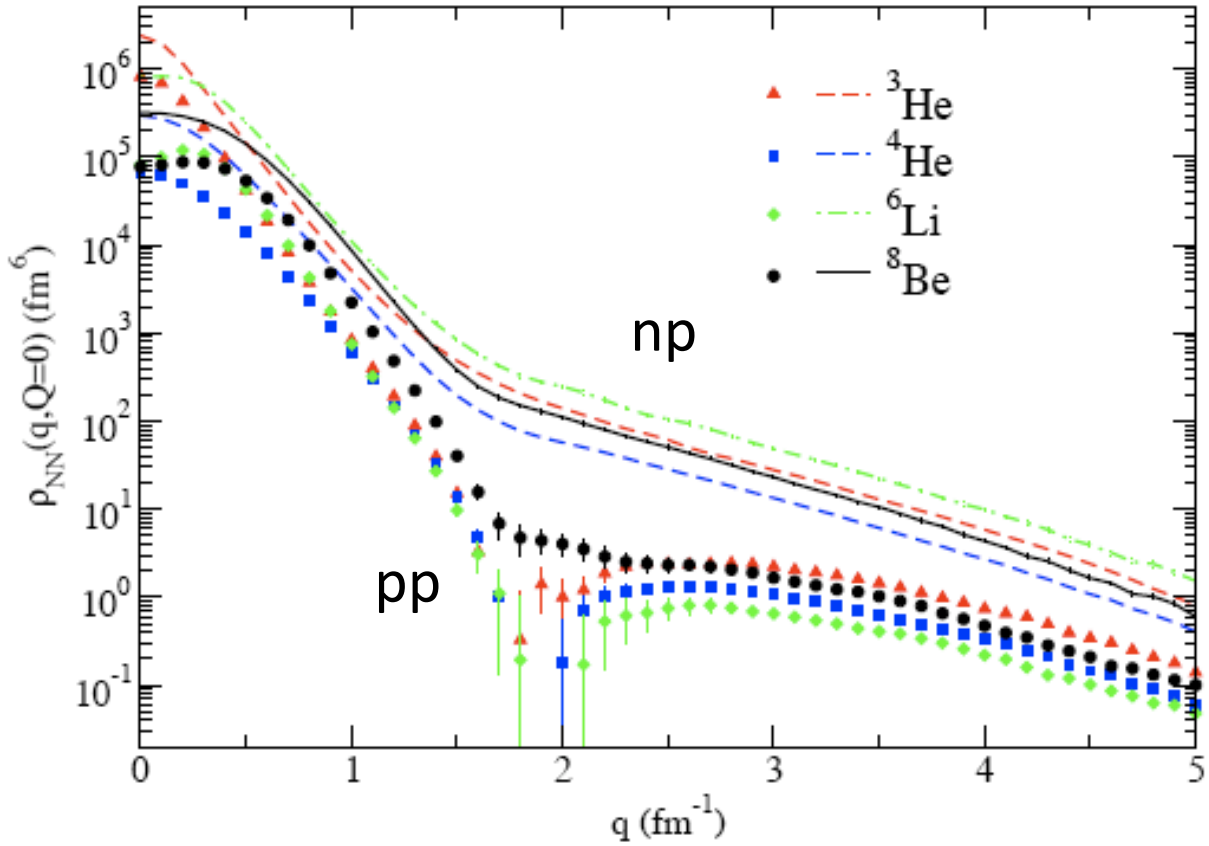
$x > 1$, $Q^2 = 1.5$ [GeV/c]^2 and missing momentum of 500 MeV/c

High p_m (e,e'p) events have recoiling neutrons.

R. Subedi *et al.*, Science **320** (2008) 1476.

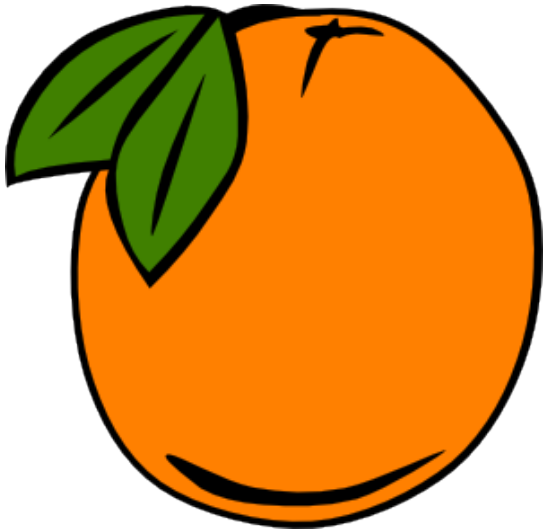


Importance of Correlations



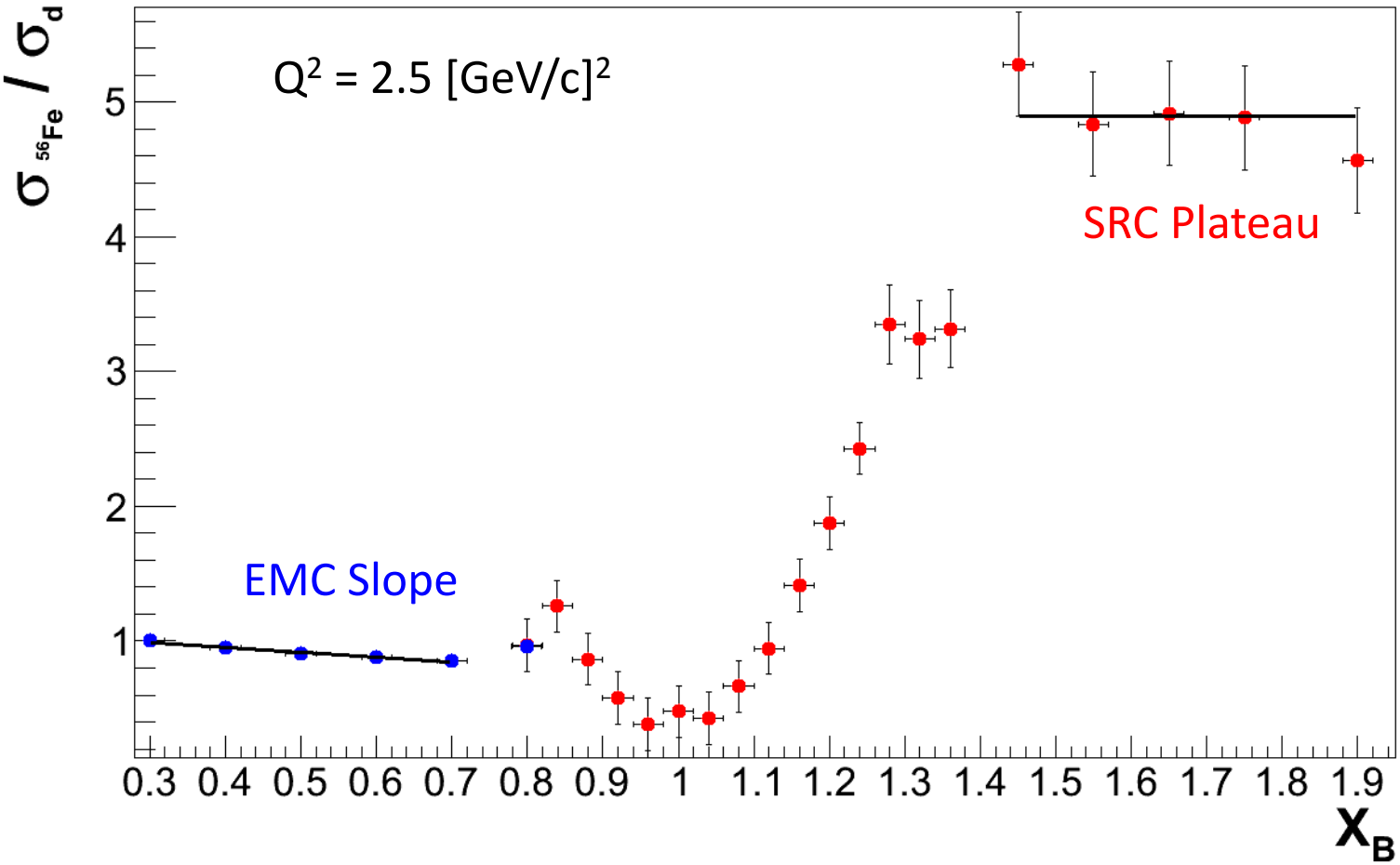
- R. Schiavilla *et al.*, Phys. Rev. Lett. 98 (2007) 132501.
- M. Sargsian *et al.*, Phys. Rev. C (2005) 044615.
- M. Alvioli *et al.*, Phys. Rev. Lett. 100 (2008) 162503.

So How These "Nuclear" Results Relate To The "Deep Inelastic" EMC Effect Results?!



Holistic View of the EMC & SRC Data

D. Higinbotham *et al.*, arXiv:1003.4497

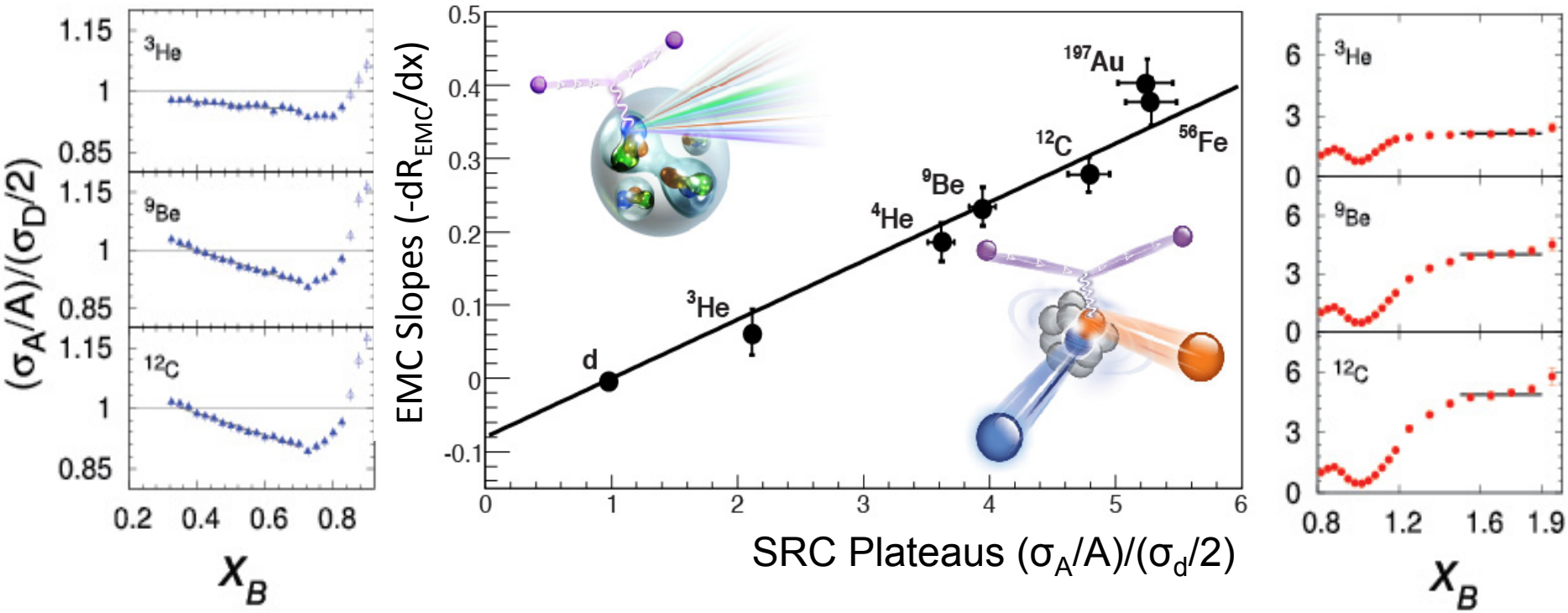


- Scaling plateaus are likely due to proton-nucleon **local density** correlations
- So could the **EMC** slopes (x_B<0.7) and **SRC plateaus** (x_B>1.5) correlated?!

Experimental SRC and EMC Correlation

L. Weinstein, E. Piasetzky, D.H., J. Gomez, O.Hen and R. Shneor, Phys. Rev. Lett. **106** (2011) 052301.

J. Arrington, A. Daniel, D. Day, N. Fomin, **D. Gaskell, P. Solvignon**, Phys. Rev. C **86** (2012) 065204

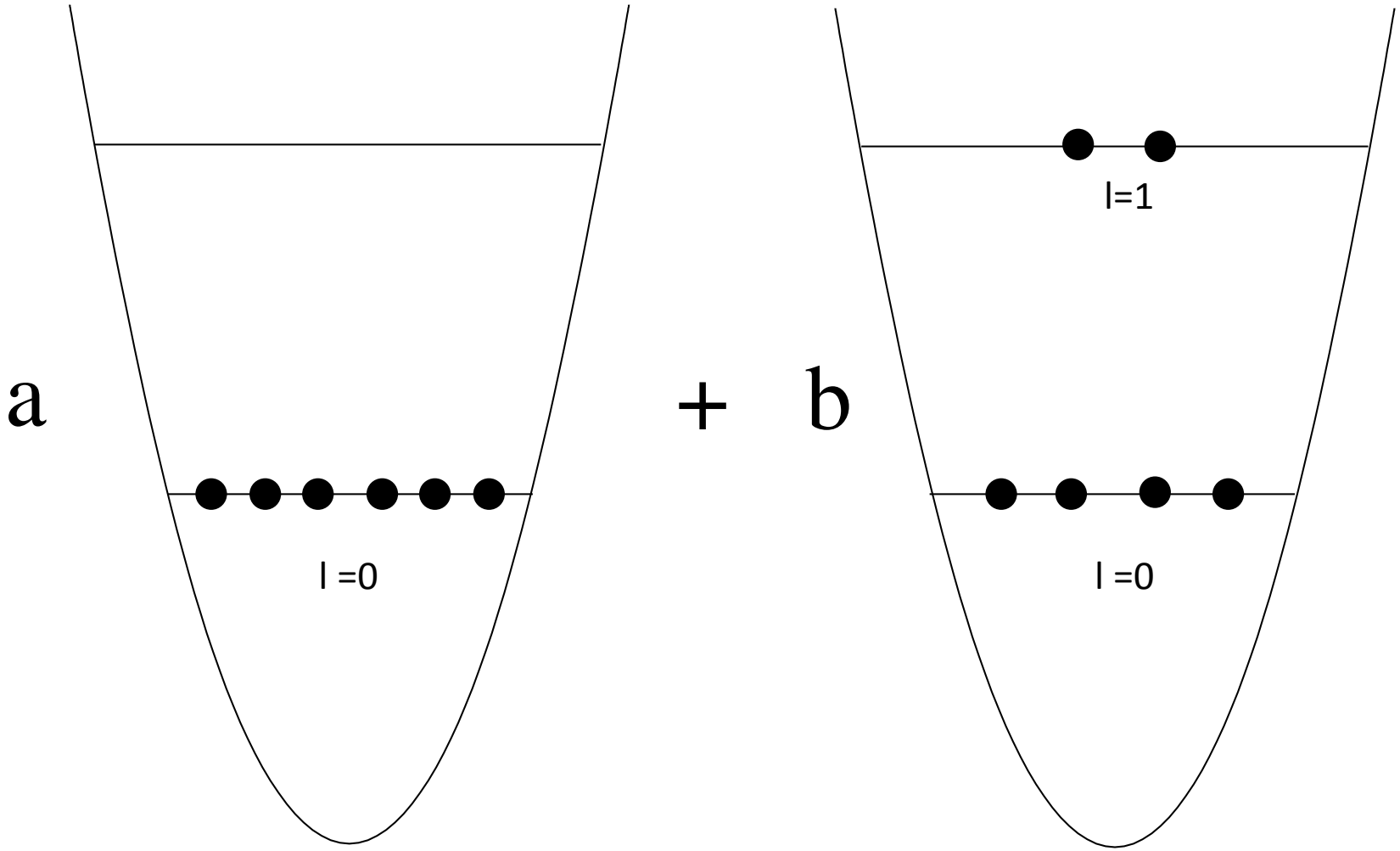


The data show that EMC effect slopes are proportional to the SRC plateaus.

An intriguing possibility suggested by this correlation is that the EMC effect and SRCs are both a consequence of the local QCD effects within the nucleus.

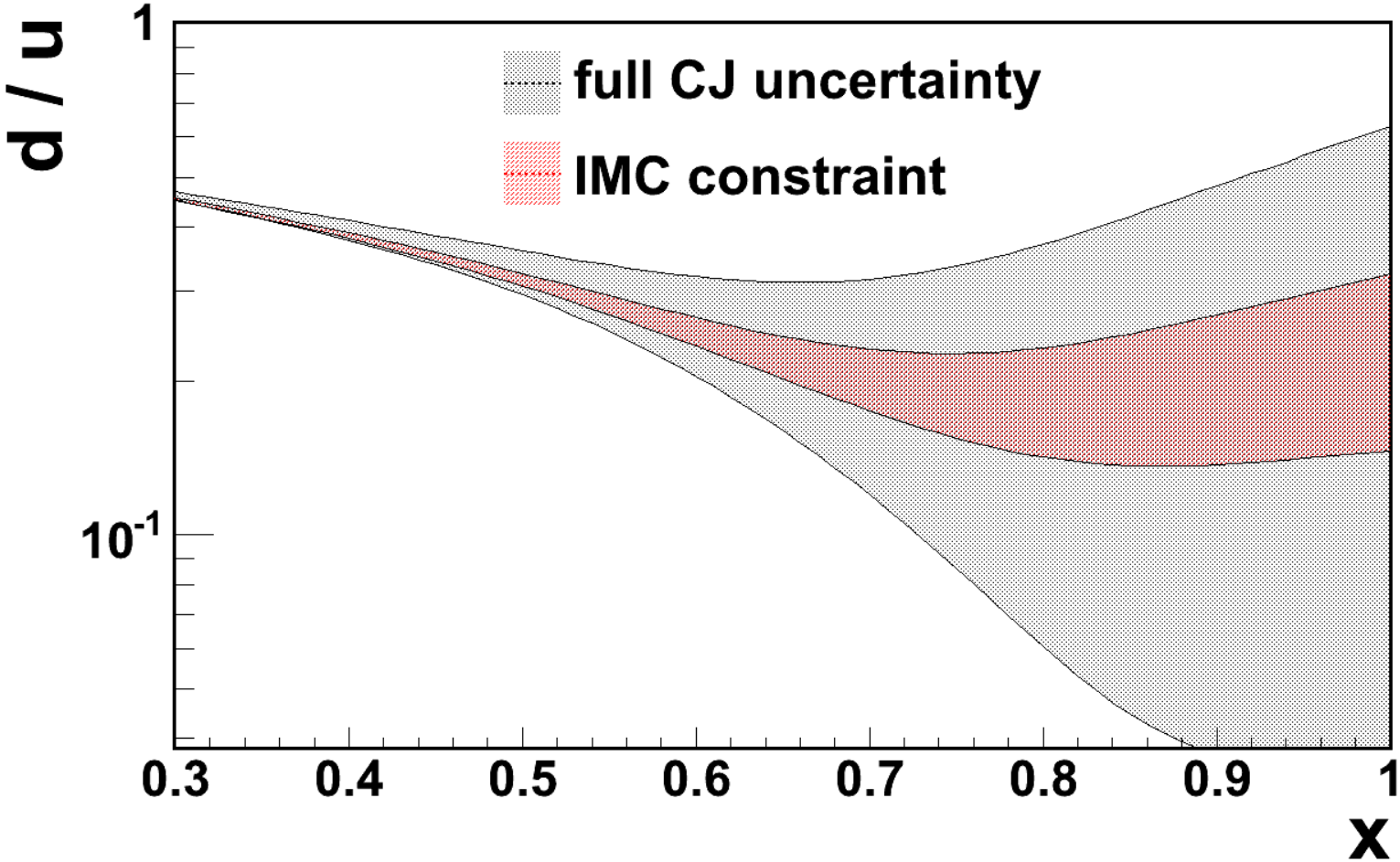
Quark State of Overlapping Nucleons?

Deuteron Has Quadripole Moment In **All** Frames Of Reference!



Using SRC & EMC to get d/u ratios

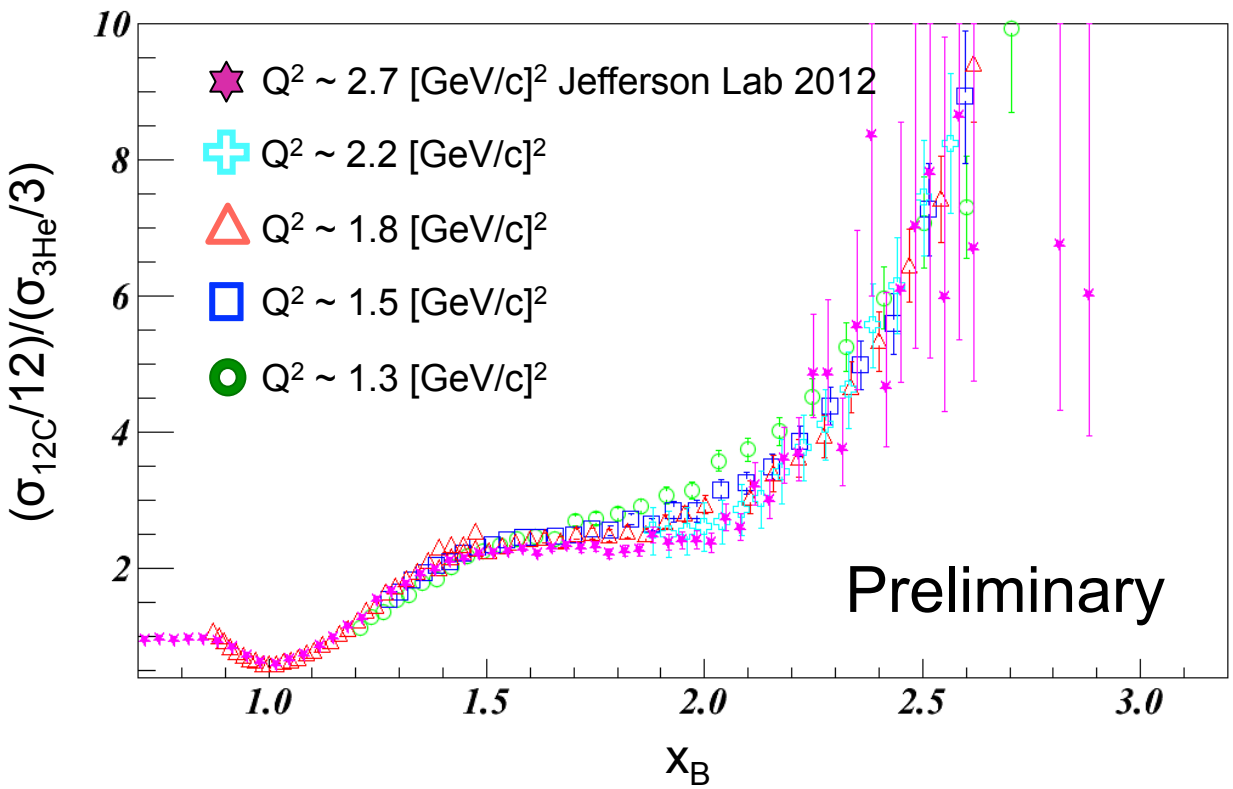
CTEQ-Jefferson Lab (CJ): A. Accardi *et al*., Phys. Rev. D **84**, 014008 (2011).
In-Medium Correction (IMC): O. Hen *et al*., Phys. Rev. D **84** (2012) 117501.



Result is between the SU(6) symmetry limit of ½ and the scalar di-quark dominance limit of 0.

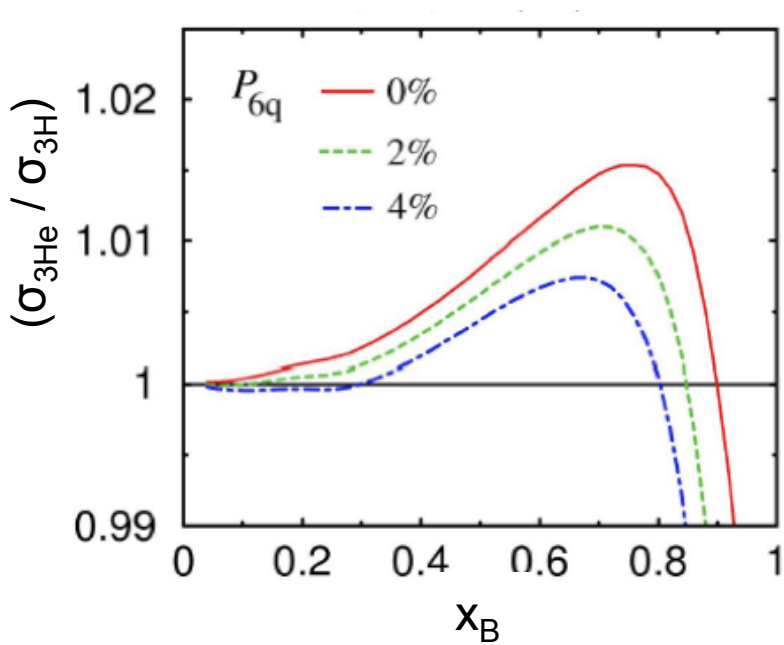
Analysis in Progress

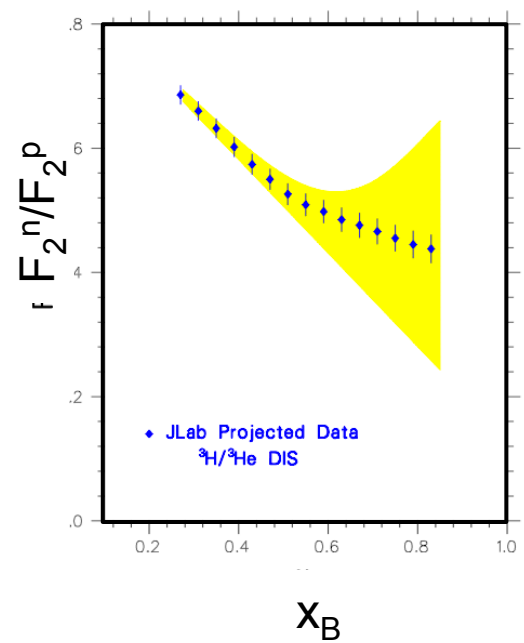
- **E07-006**: SRC 2nd Generation (e,e'pN) Triple Coincidence Experiment
  - Goal to further probe the repulsive part of the nucleon-nucleon potential with a few body, ^{4}He, target.
- **E08-014**: SRC (e,e') x_B >1 & 2 data on ^{3}He, ^{4}He, ^{40}Ca, & ^{48}Ca
  - Goal to study Q^2, x_B > 2 region, and the A/Z dependence of the SRC plateaus.



Upcoming 12GeV Experiments

- **E12-10-103 & E12-11-112** plans ^{3}He & ^{3}H (e,e') SRC & EMC Measurements
  - DIS 3He/3H is a text book u/d experiment
  - x>1 to further investigate SRC and possible link EMC effect
- **E12-10-008 & E12-06-105** plans a survey of (e,e') nuclei from light to heavy.
  - Exact list being optimized, but goal is to cover EMC x < 1 and SRC x > 1 for each nucleus
- **E12-11-002** recoil polarization in the 4He(e,e'p)3H, 2H(e,e'p)n, and 1H(e,e'p) reactions
  - Classic medium modification experiment pushed to higher precision and higher missing momentum
- **E12-11-107** will use a Large Acceptance Device (LAD) to tag recoiling nuclei
  - Goal to directly show if the cause of the EMC effect is due to SRC pairings





Summary

- New data points to EMC effect being a local density effect.
- x_B>1 nuclear scaling plateaus are likely a local density effect.
- Data shows the two effects to be correlated.
- Open Questions
  - What exactly is the high momentum tail?

    (i.e. momentum p >> p_{fermi} $n_A(p) = N * n_D(p)$ but why?)
  - Is it hadronic, partonic , or some combination both?
  - Can we use this correlation to make even more insights?
- **Many New EMC (x<1) and SRC (x>1) Experiments Coming with 12GeV Jefferson Lab, including ^{3}H & ^{3}He ratios as an early measurement.**

Tritium Target Cell Development

25cm cell machined from a single piece of Al that can be filled, sealed, and returned.