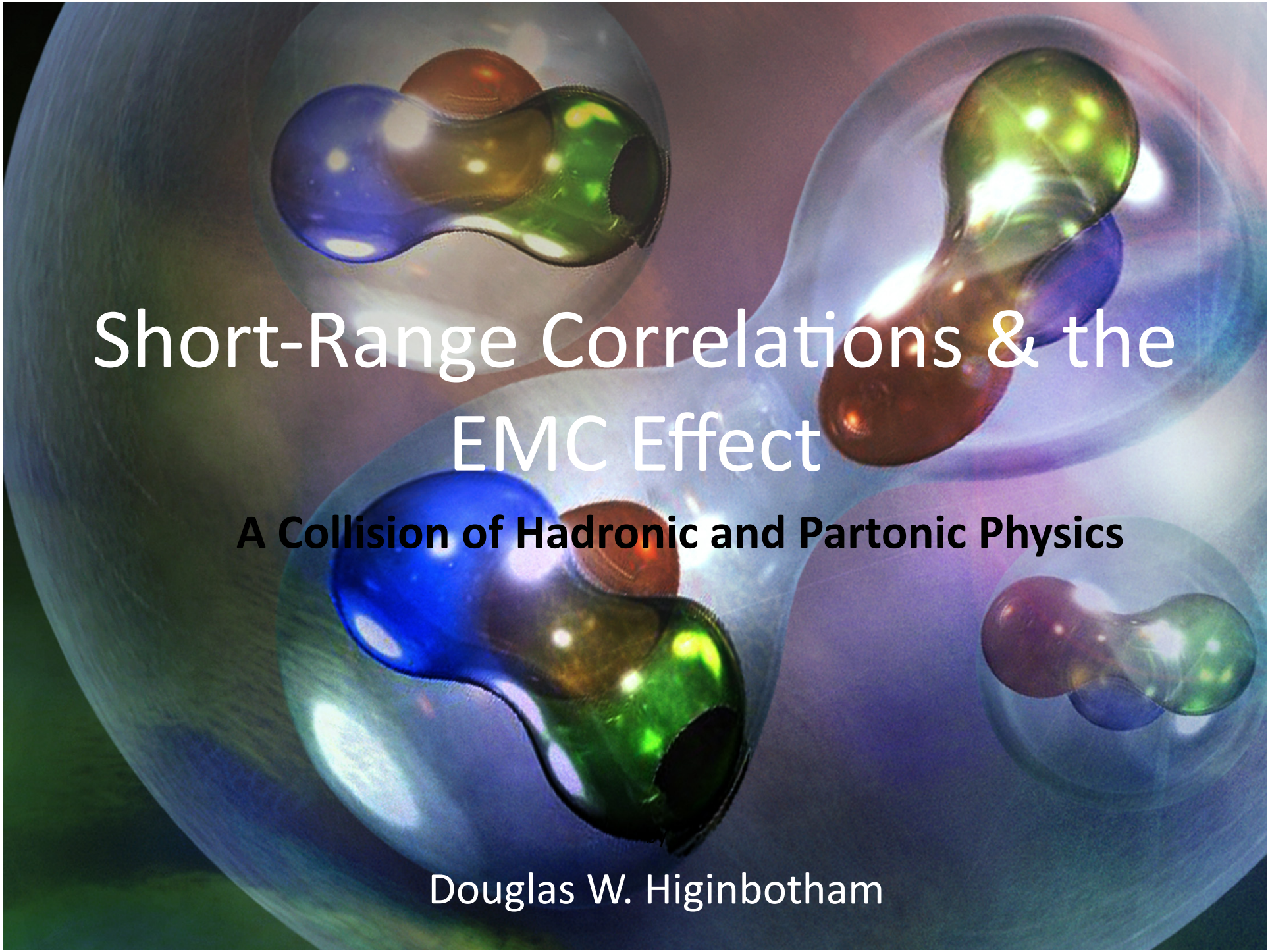
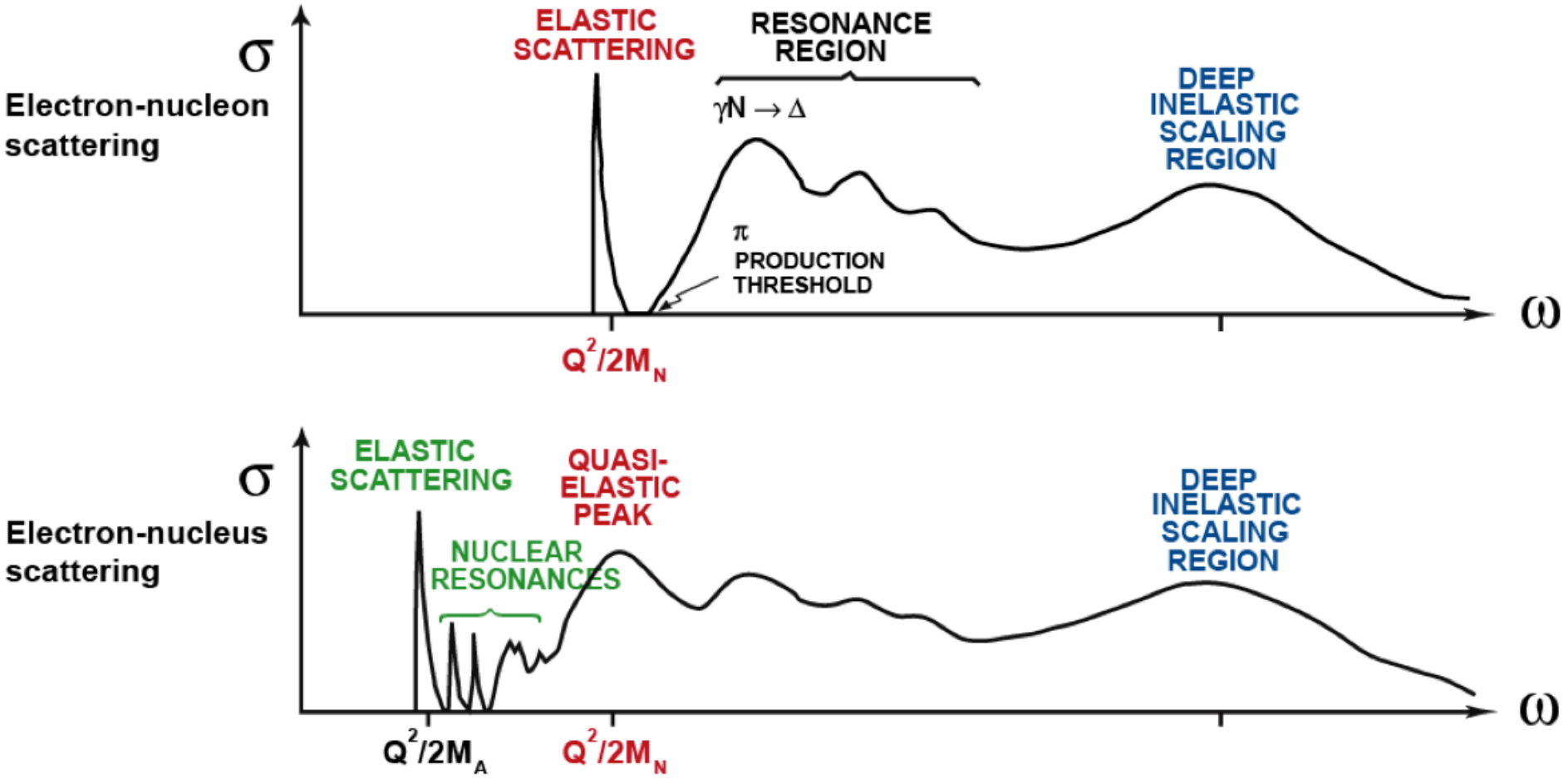


Short-Range Correlations & the EMC Effect

A Collision of Hadronic and Partonic Physics

Douglas W. Higinbotham

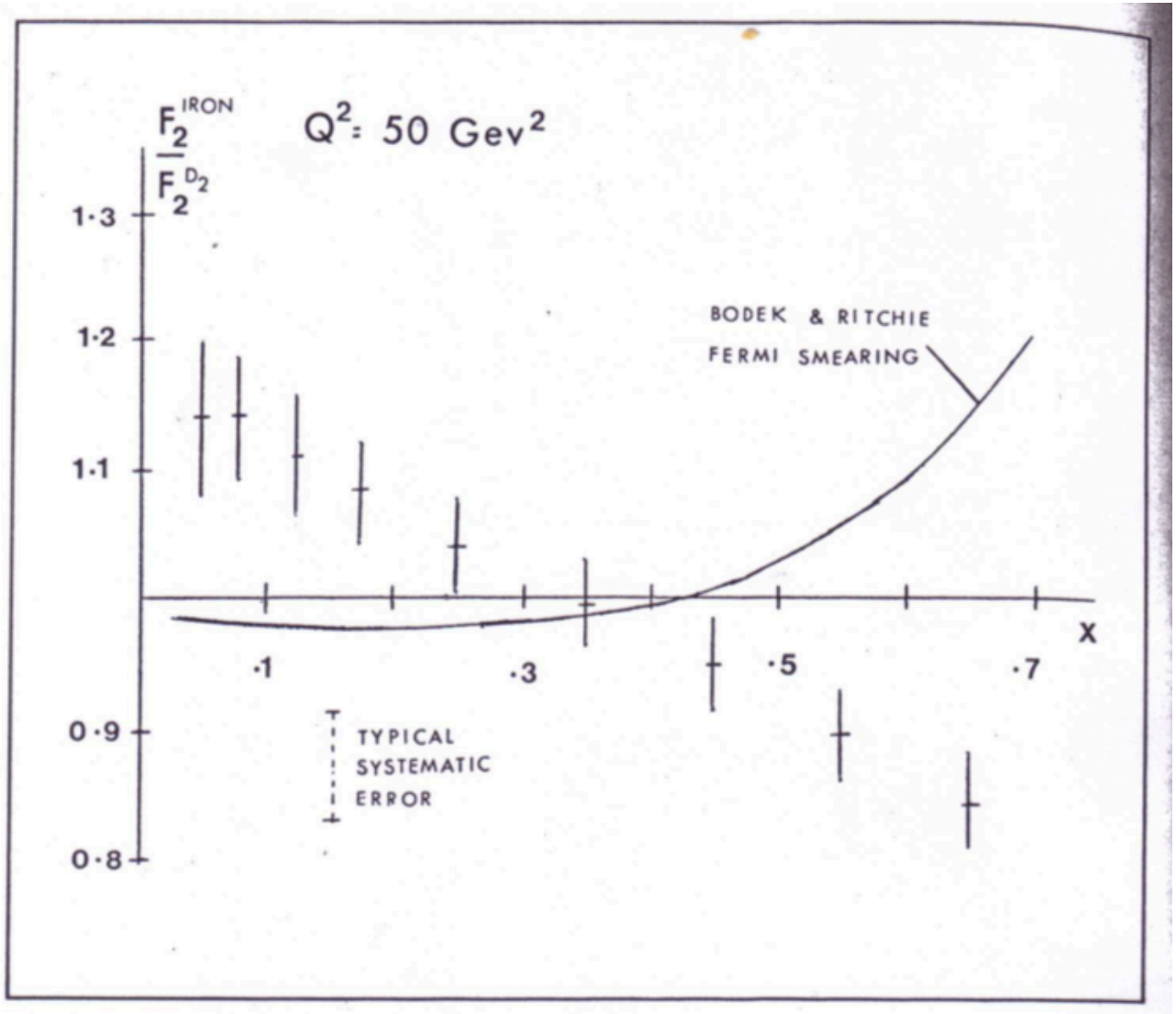
Electron Scattering from Nucleons in the Nucleus



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

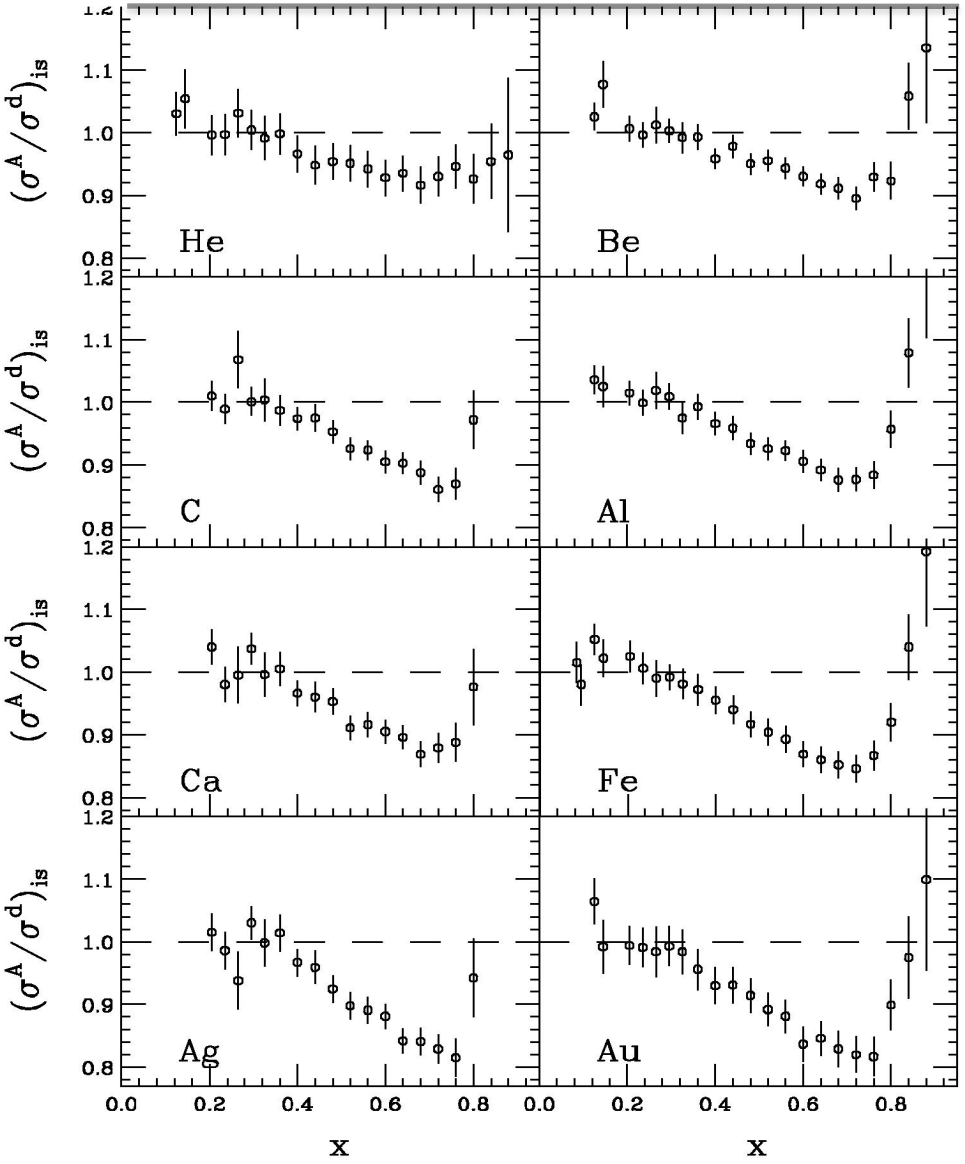
What is the EMC effect?

CERN Courier, Nov. 1982 (shown) and then J.J. Aubert *et al.*,Phys. Lett. B **123** (1983) 275.



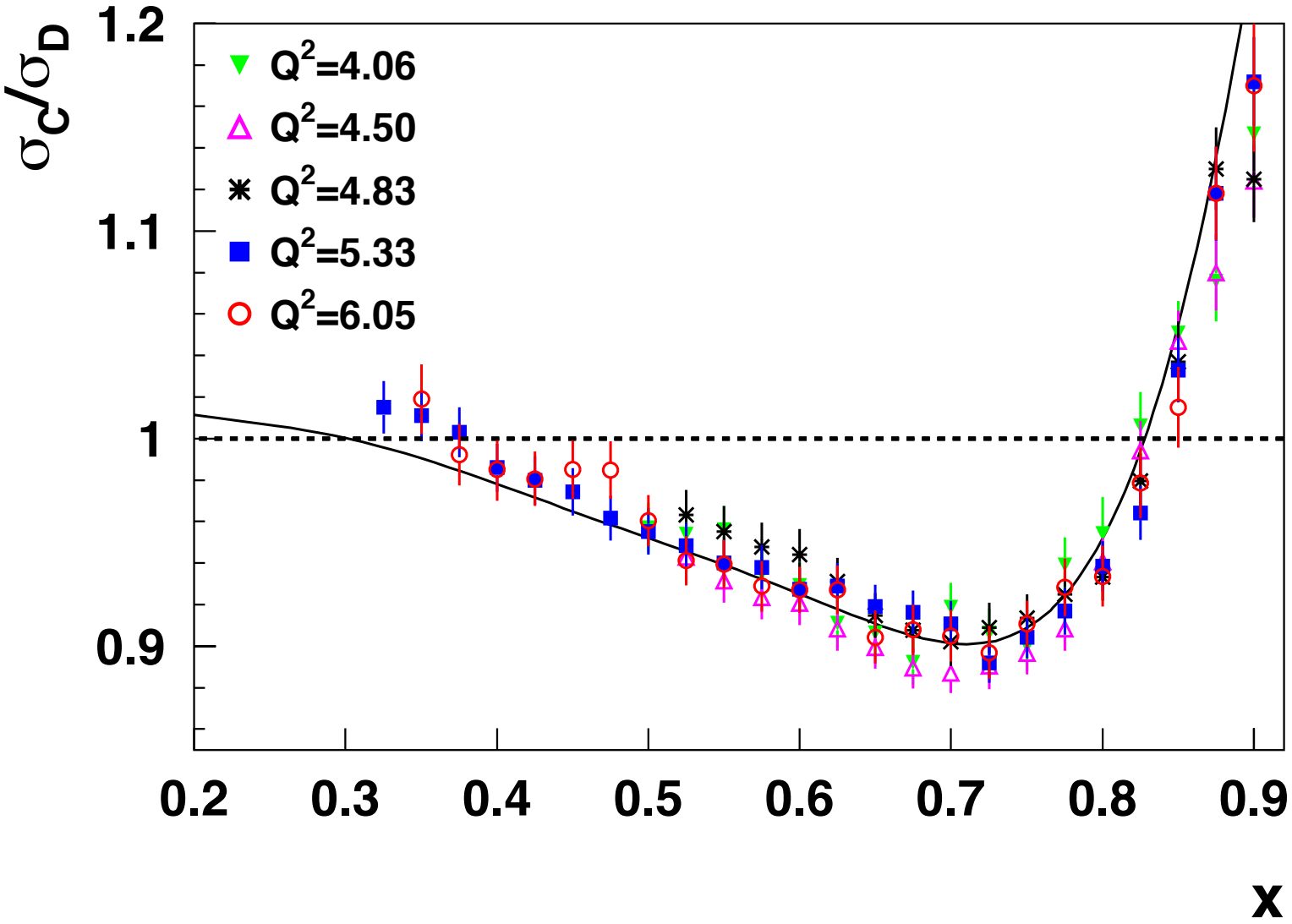
Effect Reproduced Many Times

- **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



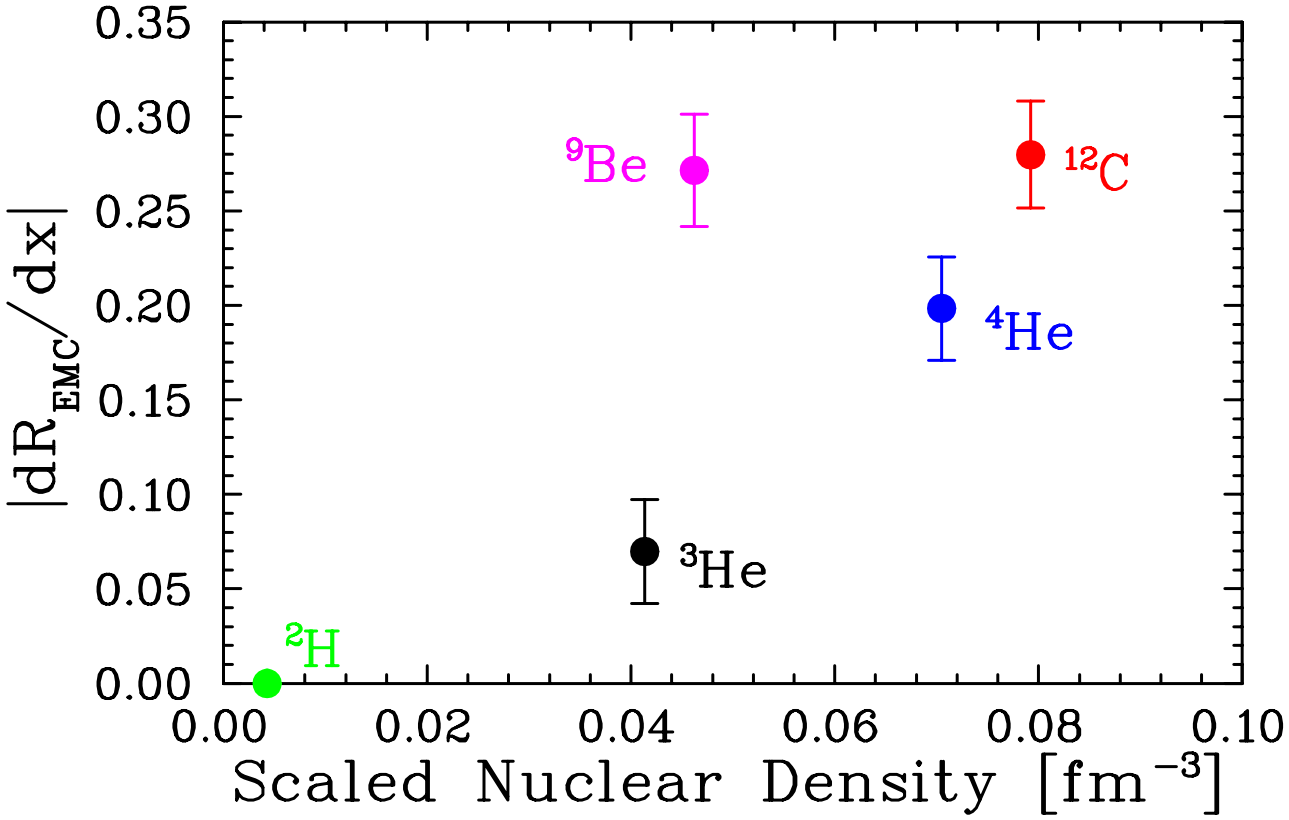
Jefferson Lab EMC Effect Data

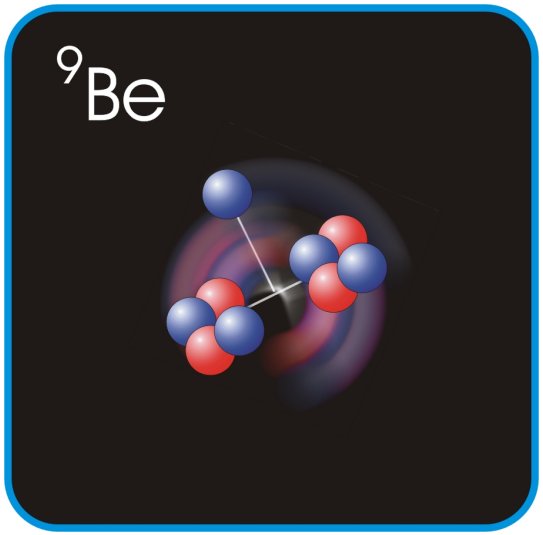
J. Seely *et al.*, Phys, Rev. Lett. **103** (2009) 202301.



New Jefferson Lab EMC Effect Data

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



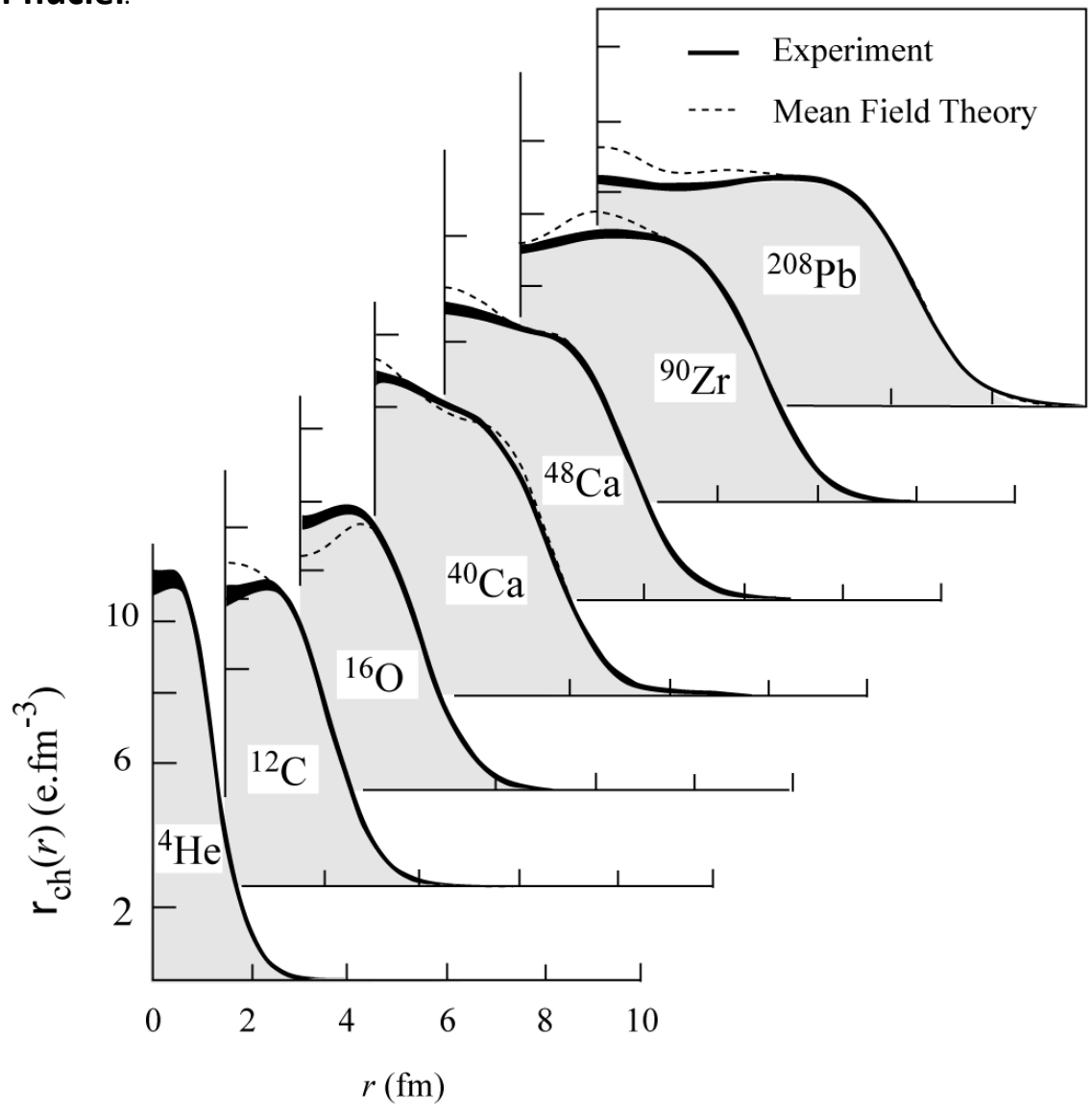


- Plot shows slope of ratio σ_A/σ_D at EMC region.
- EMC effect correlated with **local density** not average density.

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

Nuclear Charge Distributions

In '70s large data set was acquired on elastic electron scattering (mainly at Saclay) over large Q^2-range and for variety of nuclei.



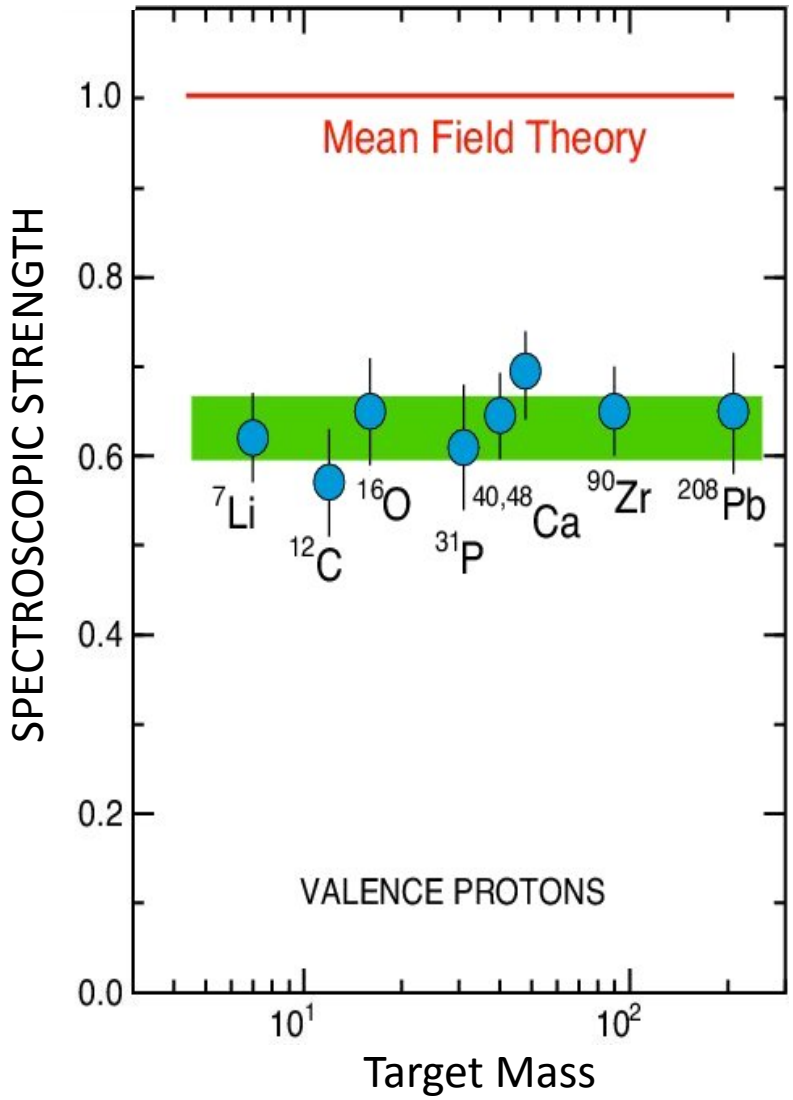
Classic (e,e'p) Results

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

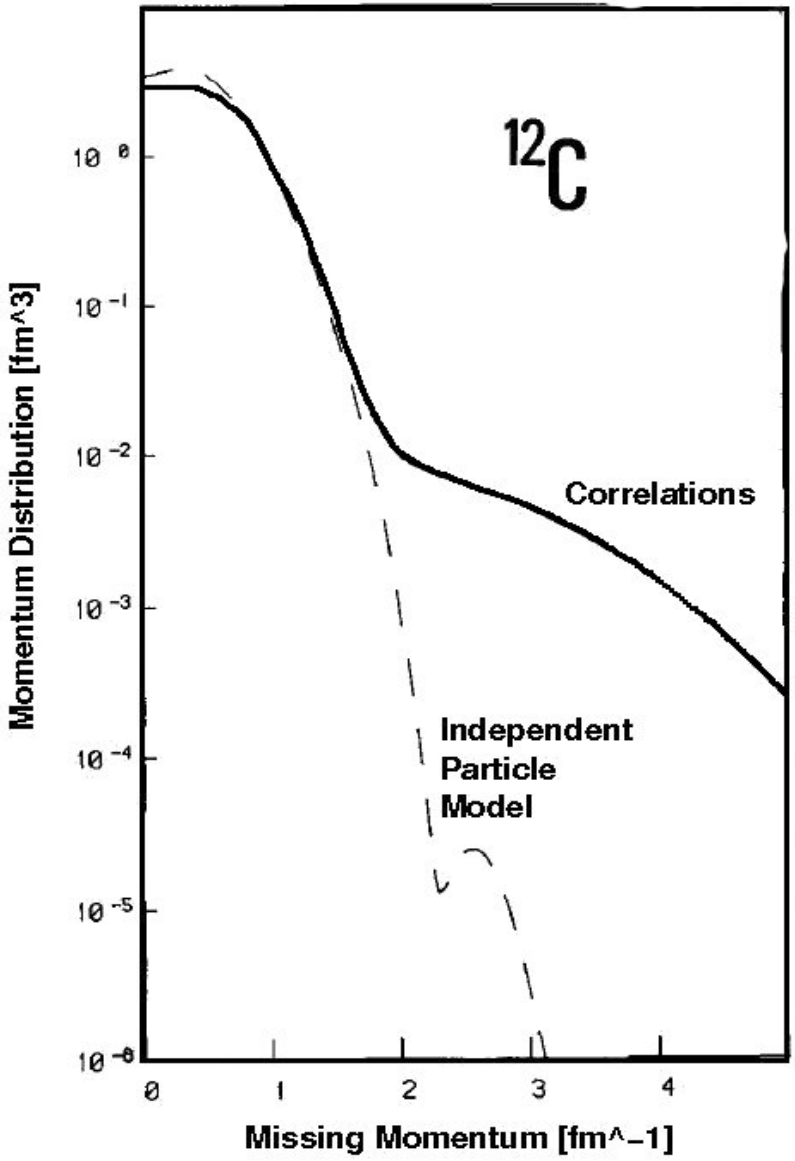
The (e,e'p) data for knockout of valence and deeply bound orbits in nuclei gives spectroscopic factors that are 60 – 70% of the mean field prediction.

Solution: Correlations Between Nucleons



Realistic Momentum Distribution

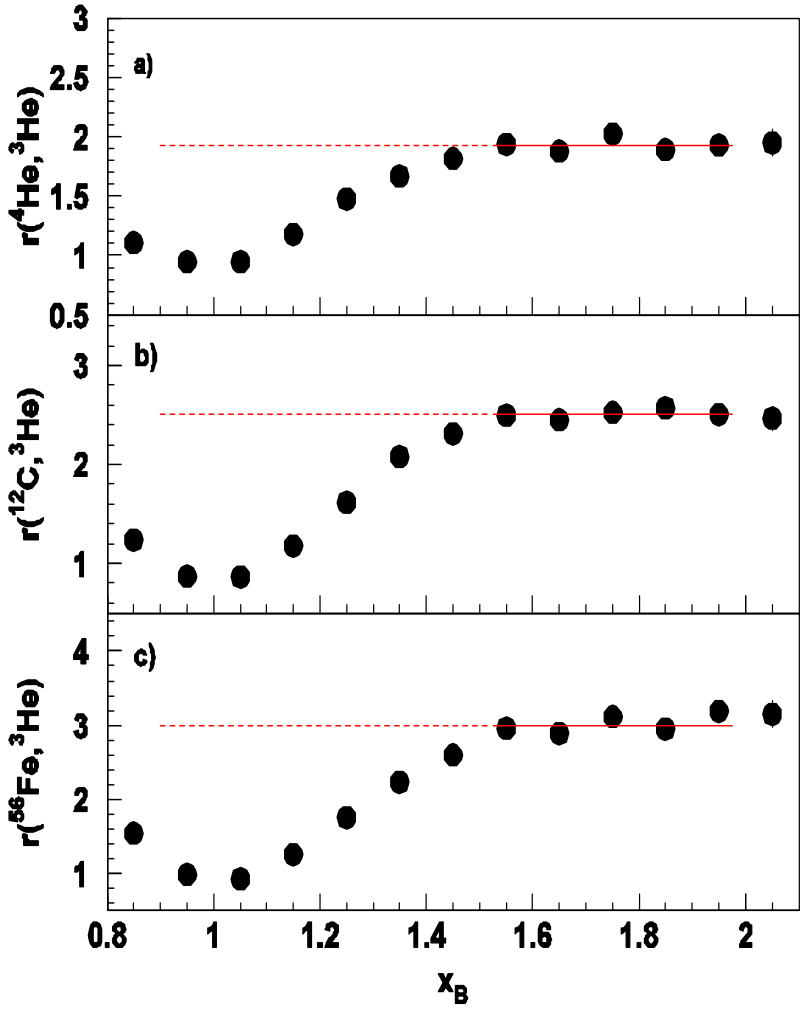
Benhar et al., Phys. Lett. **B** 177 (1986) 135.



Nuclear Scaling Plateaus from CLAS

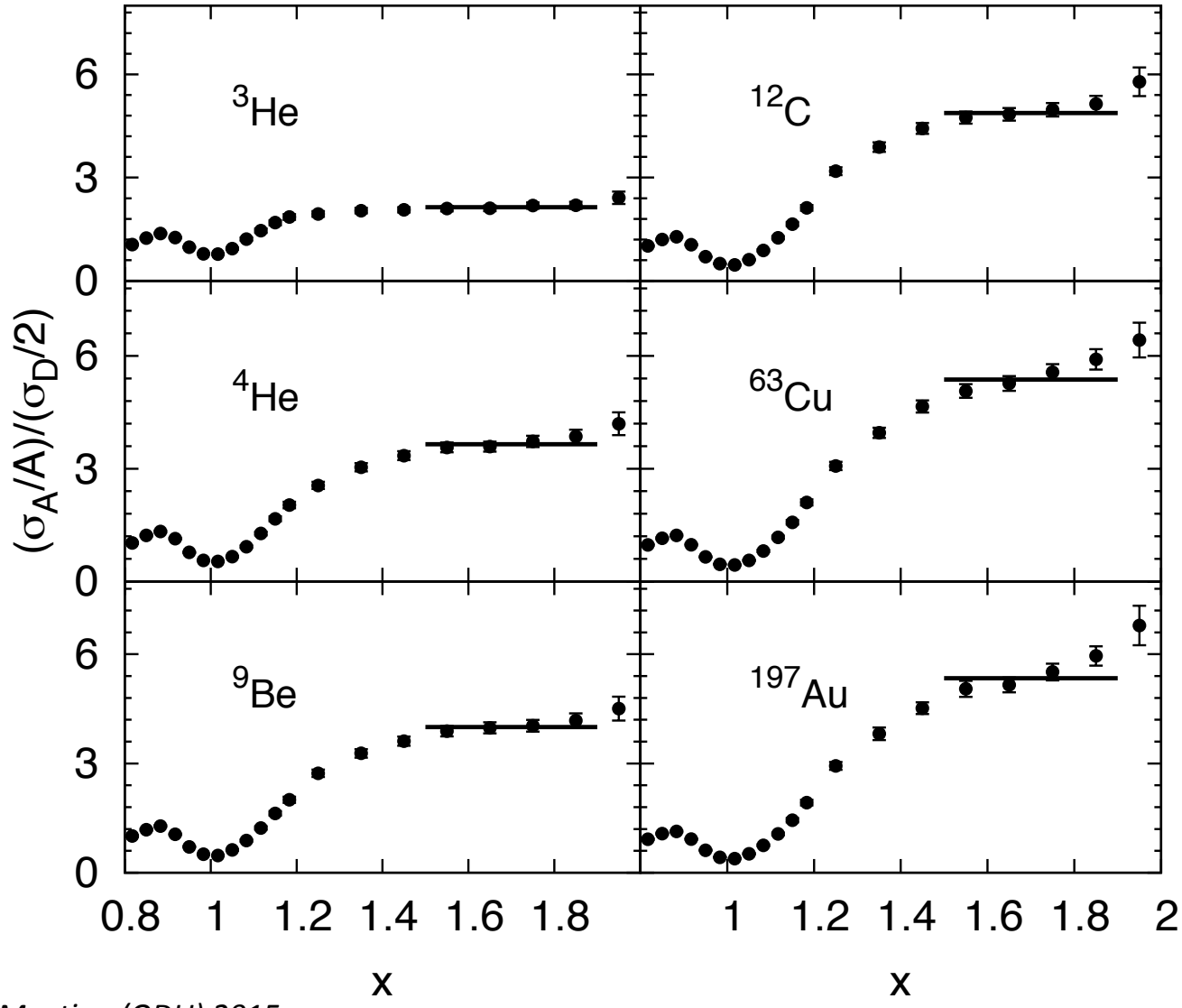
K. Sh. Egiyan *et al.,* Phys. Rev. C **68** (2003) 014313.

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



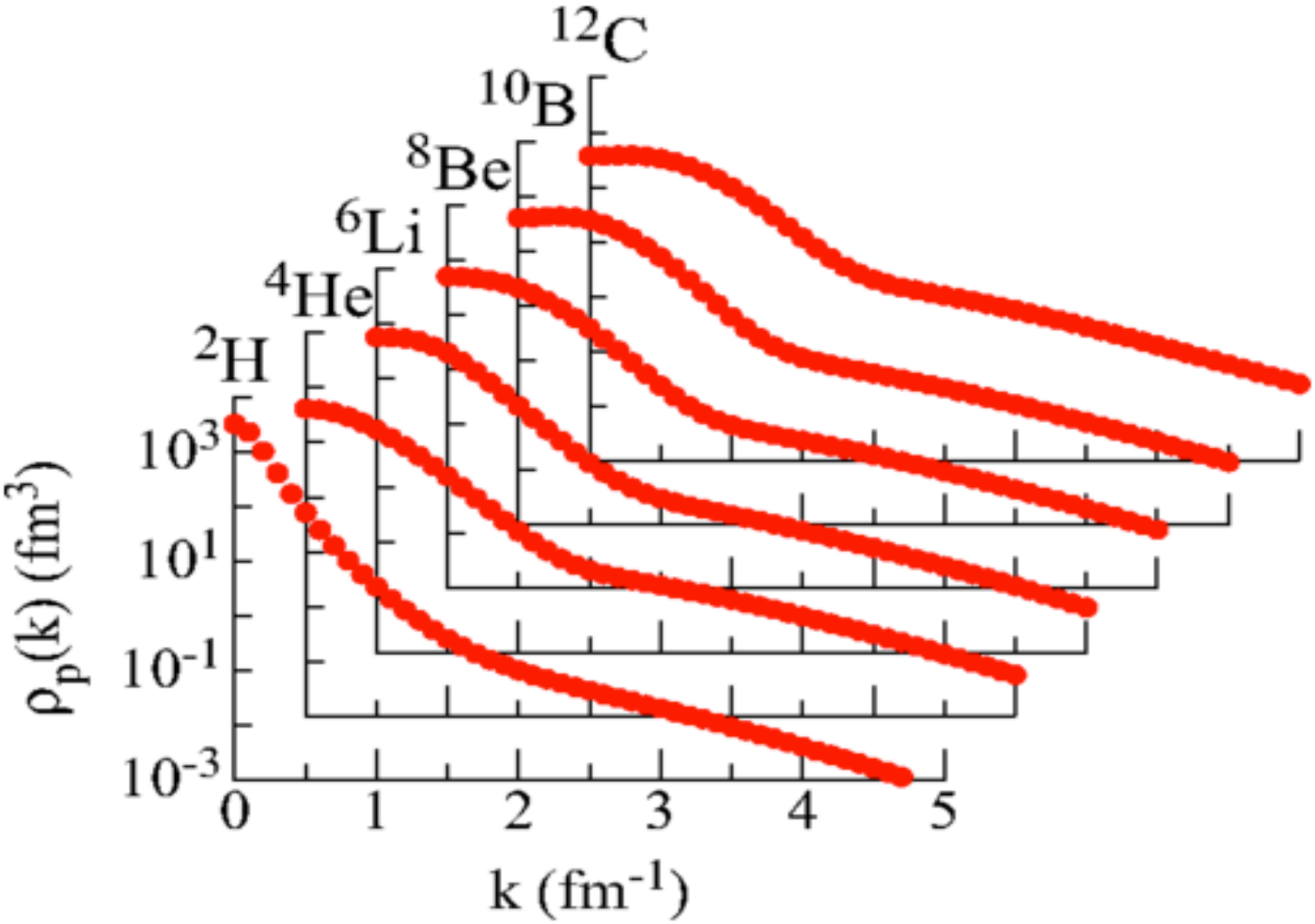
New Results From JLab Hall-C

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



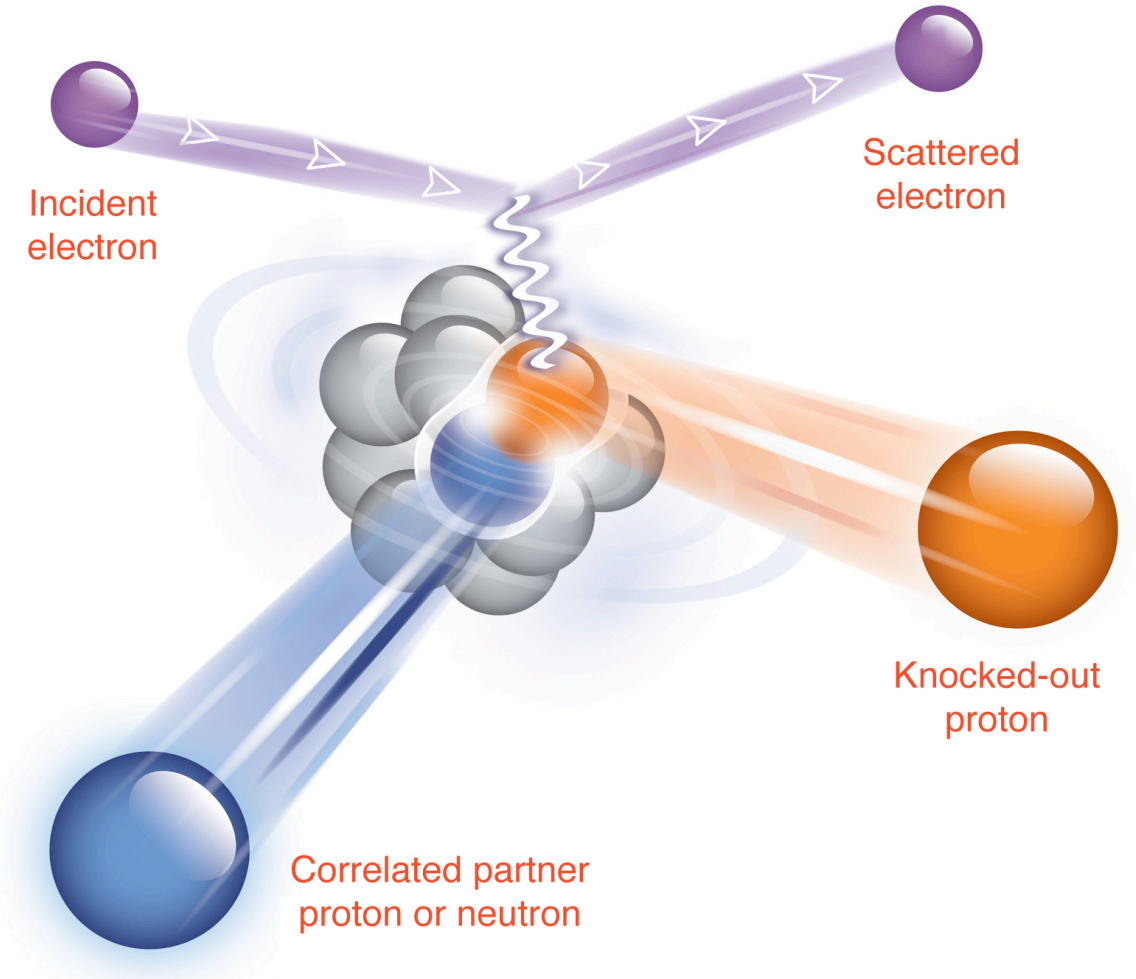
Modern AV18 and Urbana-X Results

R. Wiringa, R. Schiavilla, S. Pieper, and J. Carlson, Phys. Rev. C89 (2014) 024305.



Coincidence (e,e'pN) Measurement

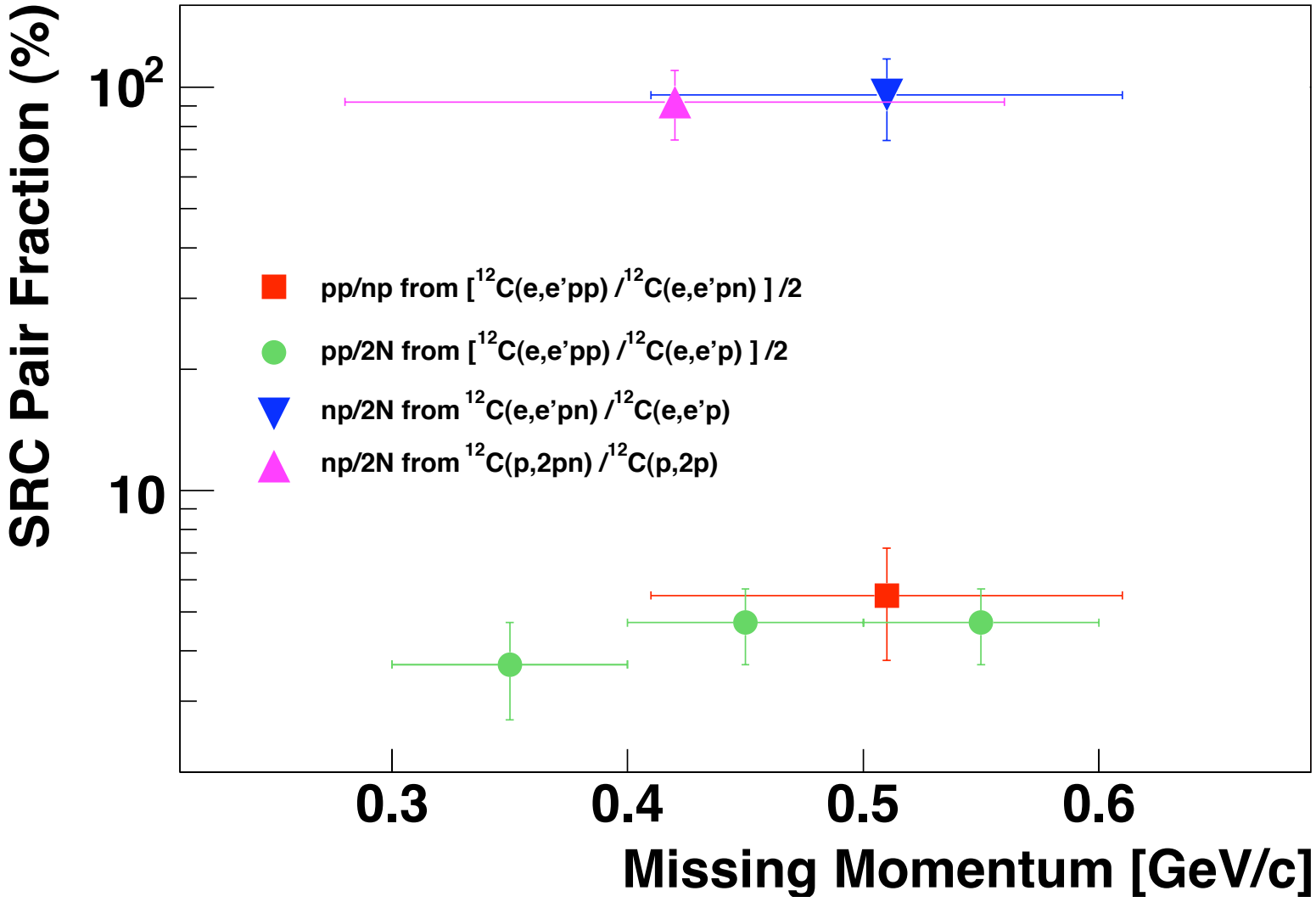
To study nucleon pairs and the fraction that contribute to momentum tail.



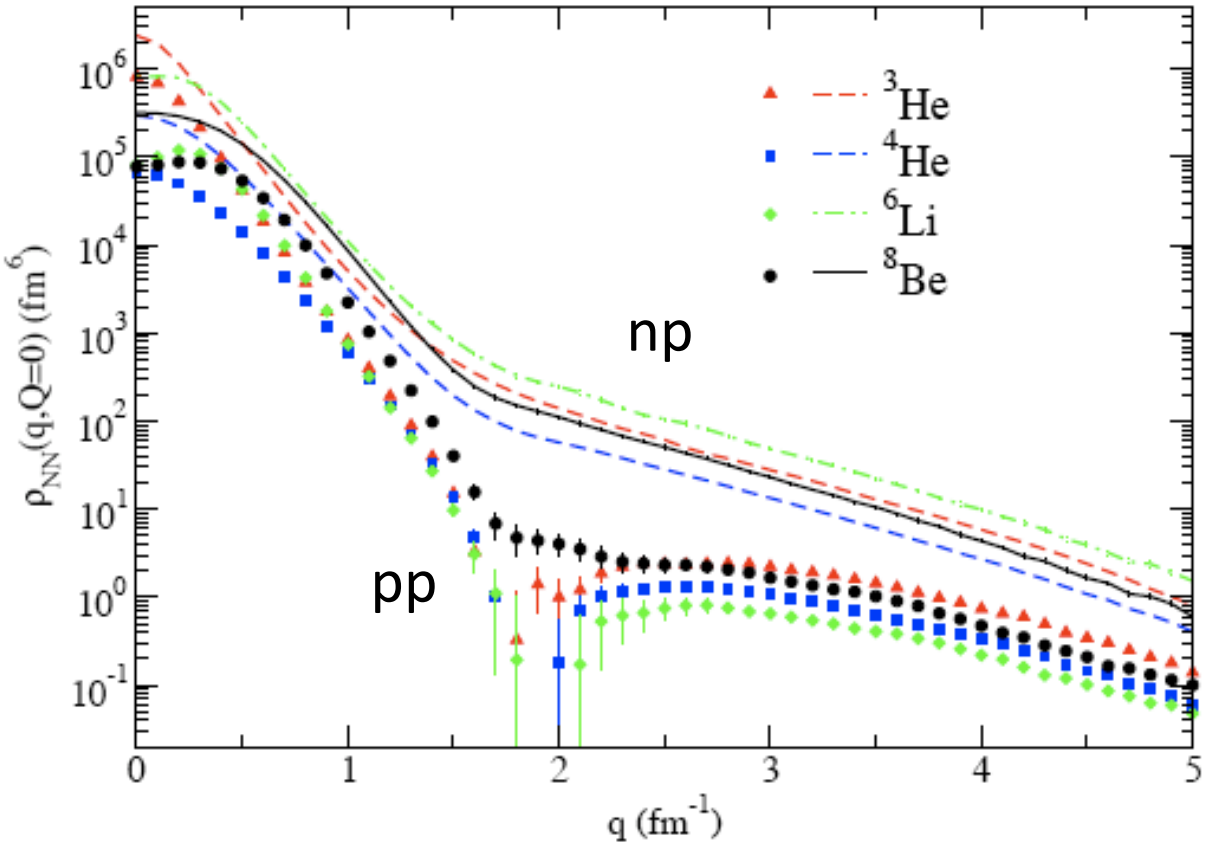
$x > 1$, $Q^2 = 1.5$ [GeV/c]^2 and missing momentum of 500 MeV/c

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

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



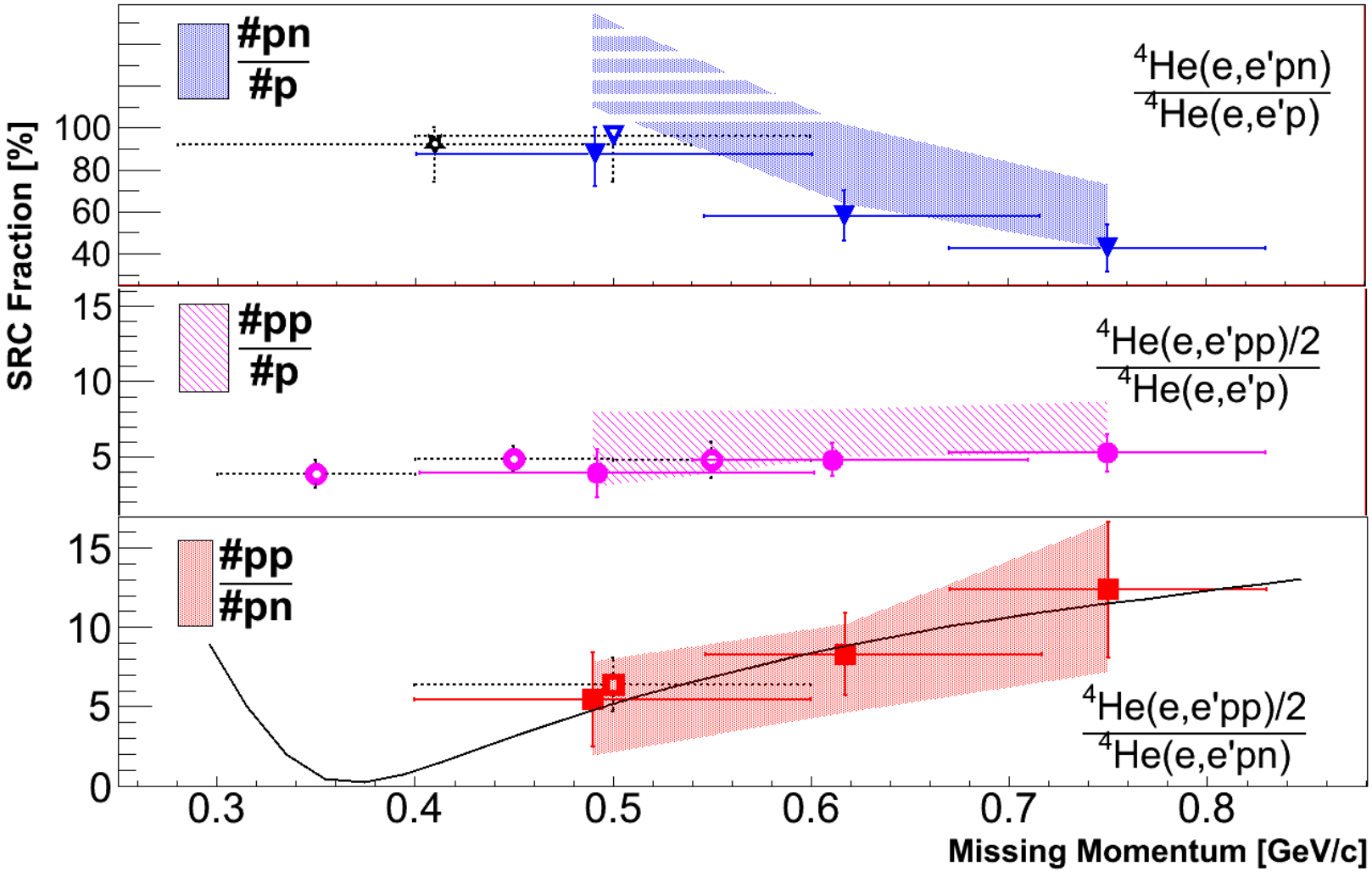
Importance of Correlations



- 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.

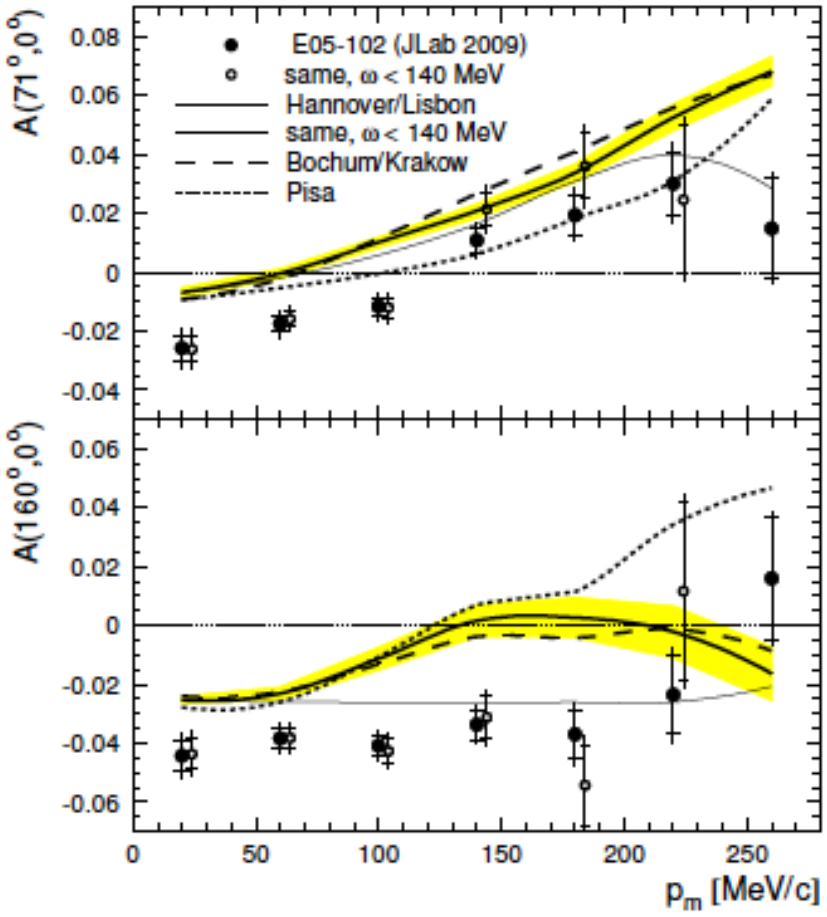
2nd Generation ^{4}He(e,e'pN) Results

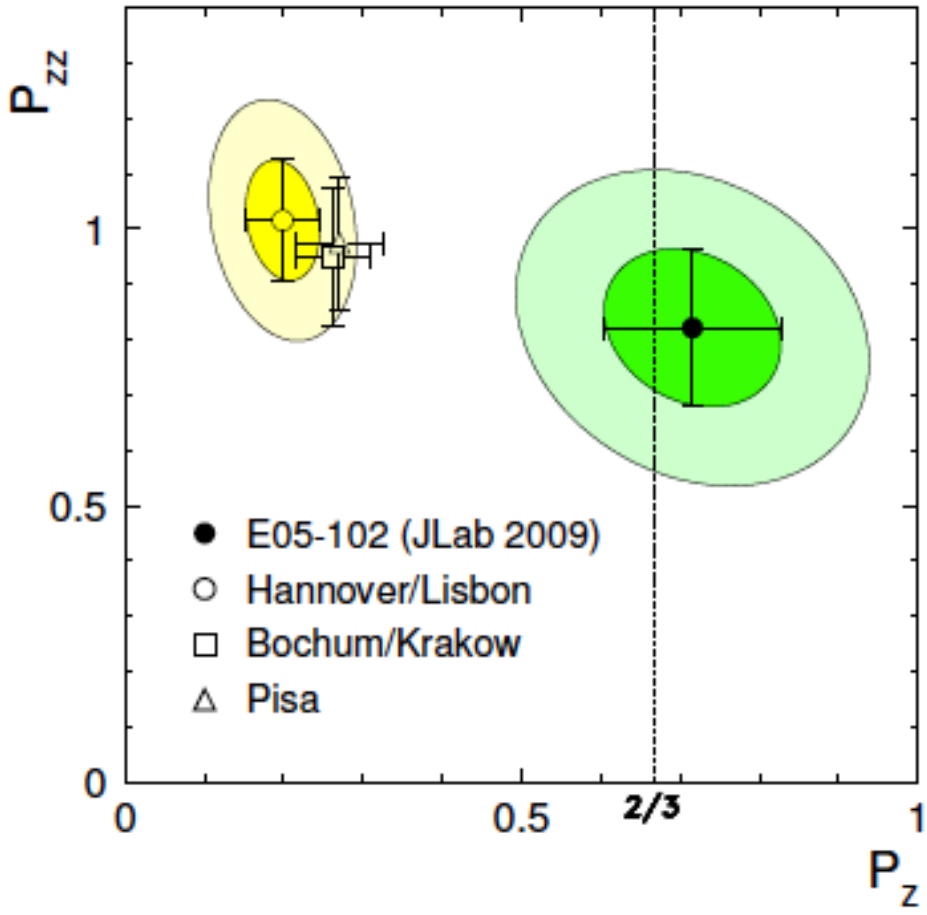
I. Korover *et al.*, Phys. Rev. Lett. **113** (2014) 022501.



Polarized ^{3}He(e,e'd)p Results

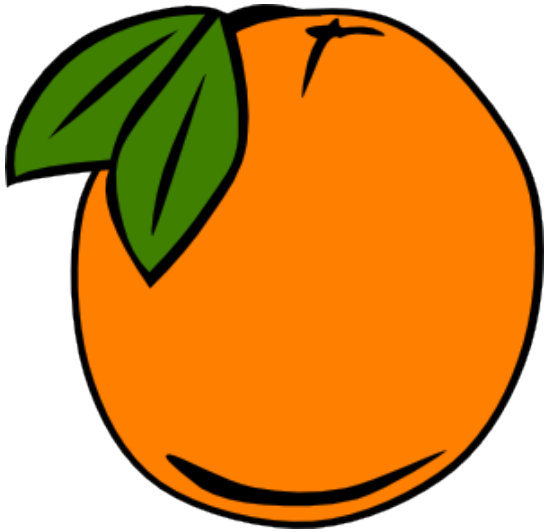
M. Mihovilovič *et al.*, Phys. Rev. Lett. **113** (2014)232505.





Data point to large vector polarization of the deuteron, not predicted by any of the models.

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

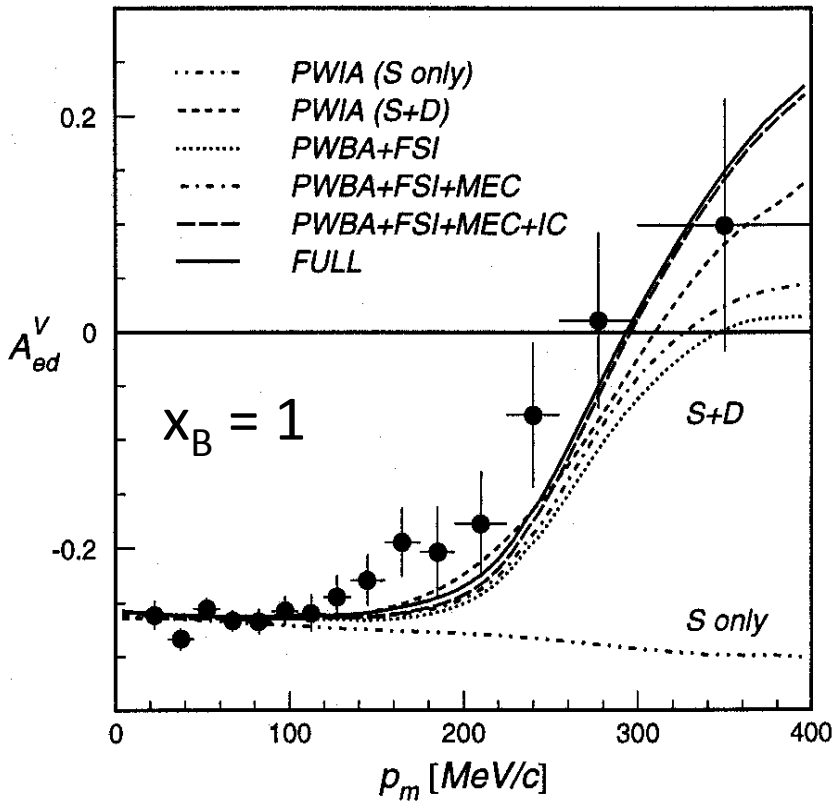


Nucleons in the Deuteron

I. Passchier *et al*., Phys. Rev. Lett. **88** (2002)102302.

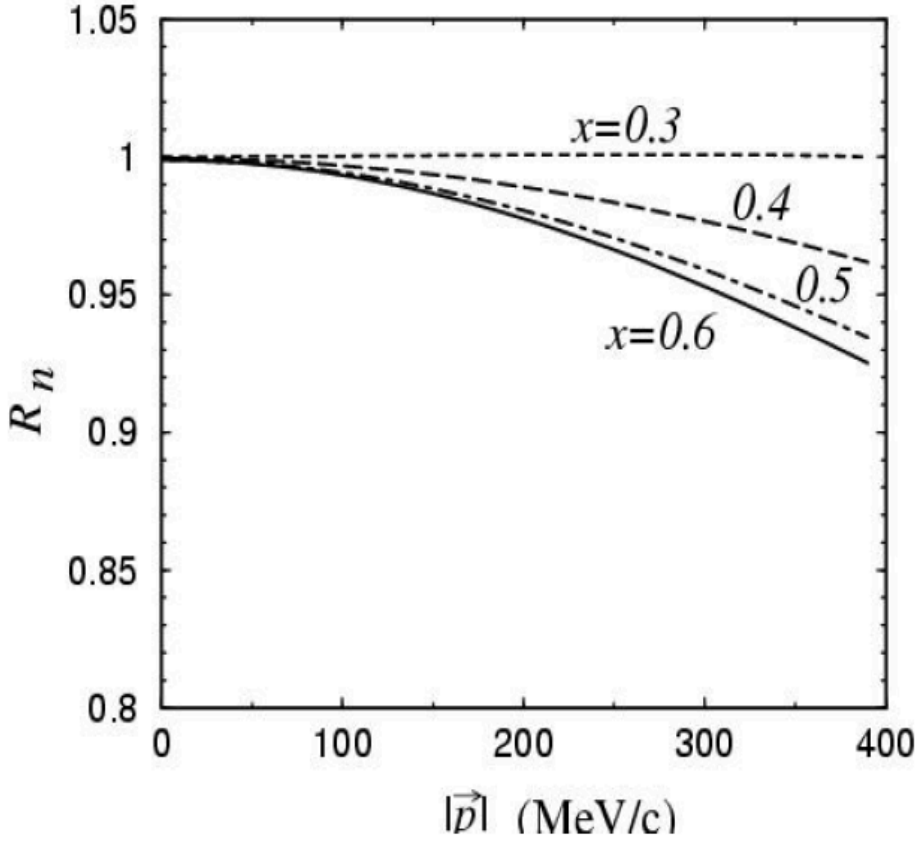
In both QE and DIS, one goes to low P_m to extract quasi-free properties on nucleons in nucleus.

$$^2\vec{\mathrm{H}}(\vec{e},e'p)n$$



Quasi-Elastic

Ratio of bound to free F2n
(see Slava's talk, calculation from Wally)

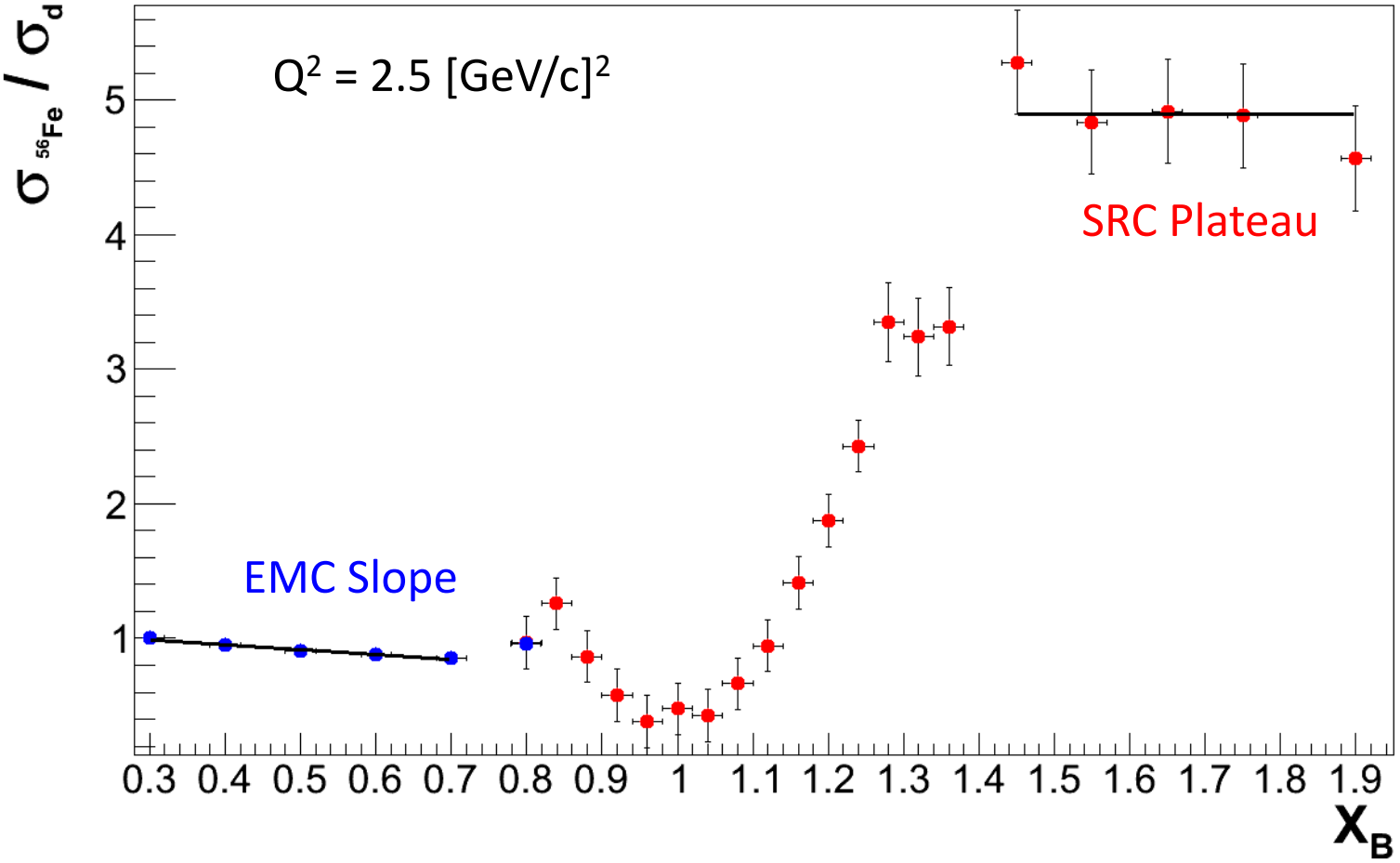


Deep Inelastic

Jefferson Lab

Holistic View of the EMC & SRC Data

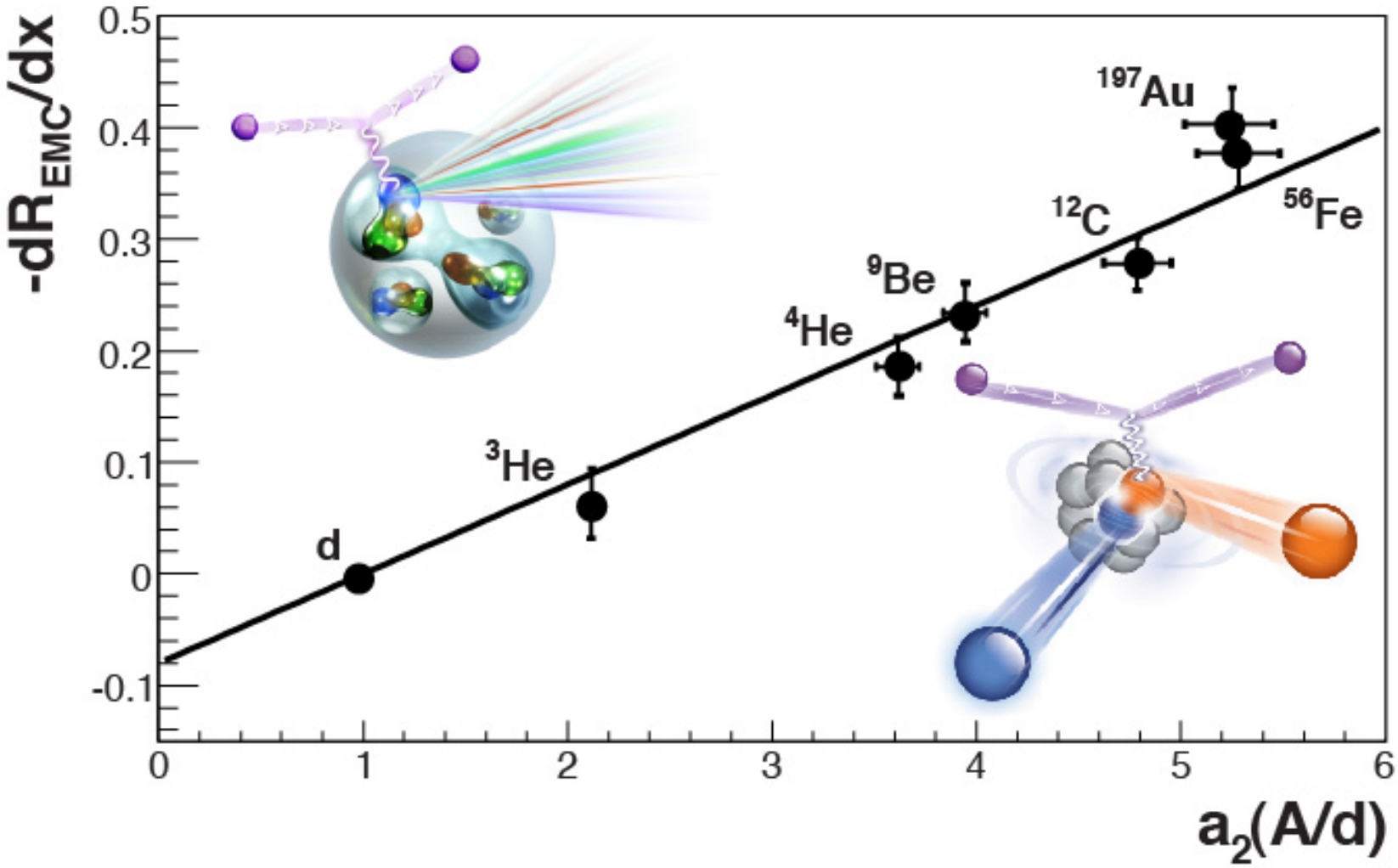
D. Higinbotham *et al.*, arXiv:1003.4497



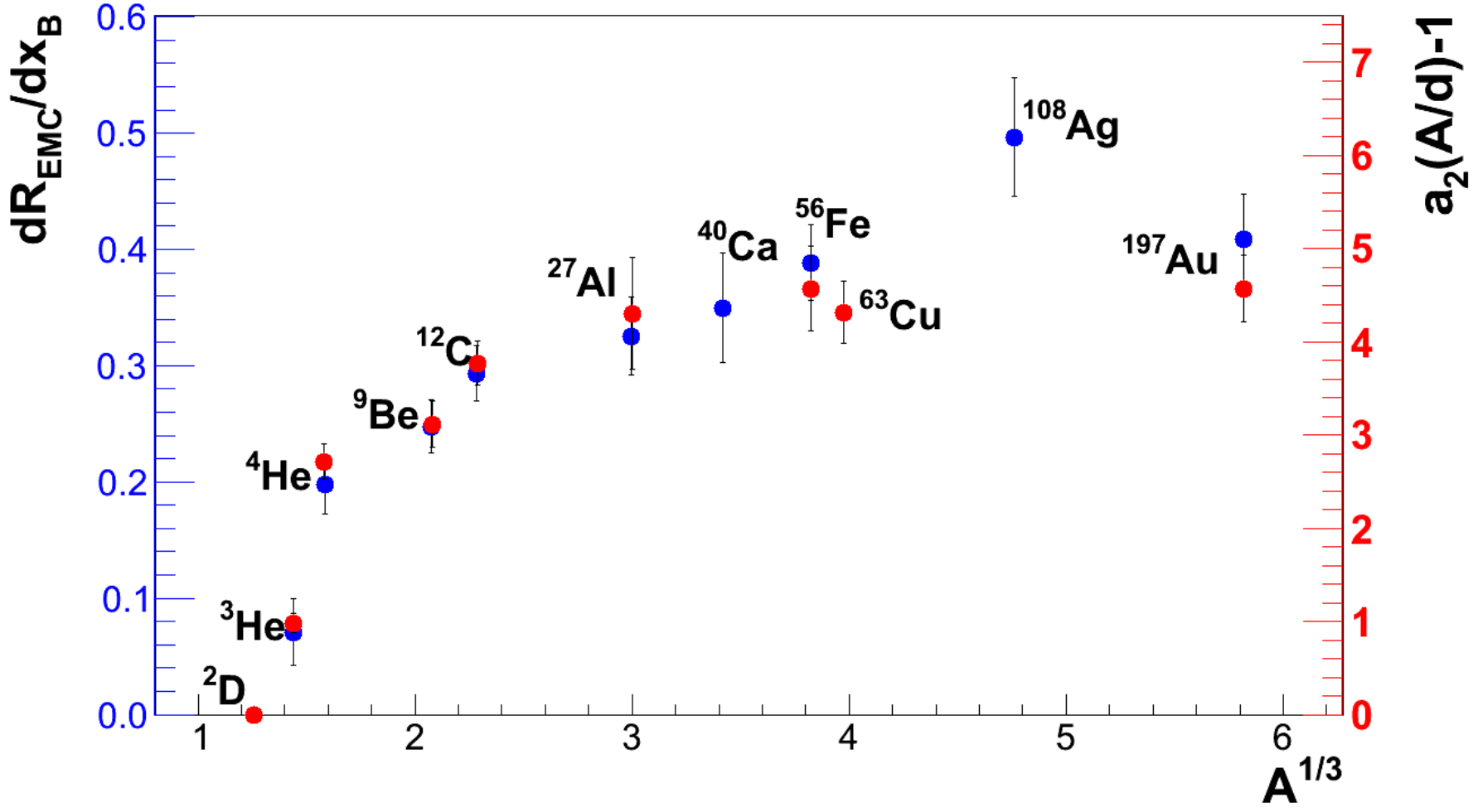
- Scaling plateaus are likely due to proton-nucleon **local density** correlations
- So could the **EMC** slopes (x_B<0.7) and **SRC plateaus** (x_B>1.5) correlated?!

SRC and EMC Correlation

L. Weinstein *et al.*, Phys. Rev. Lett. **106** (2011) 052301.

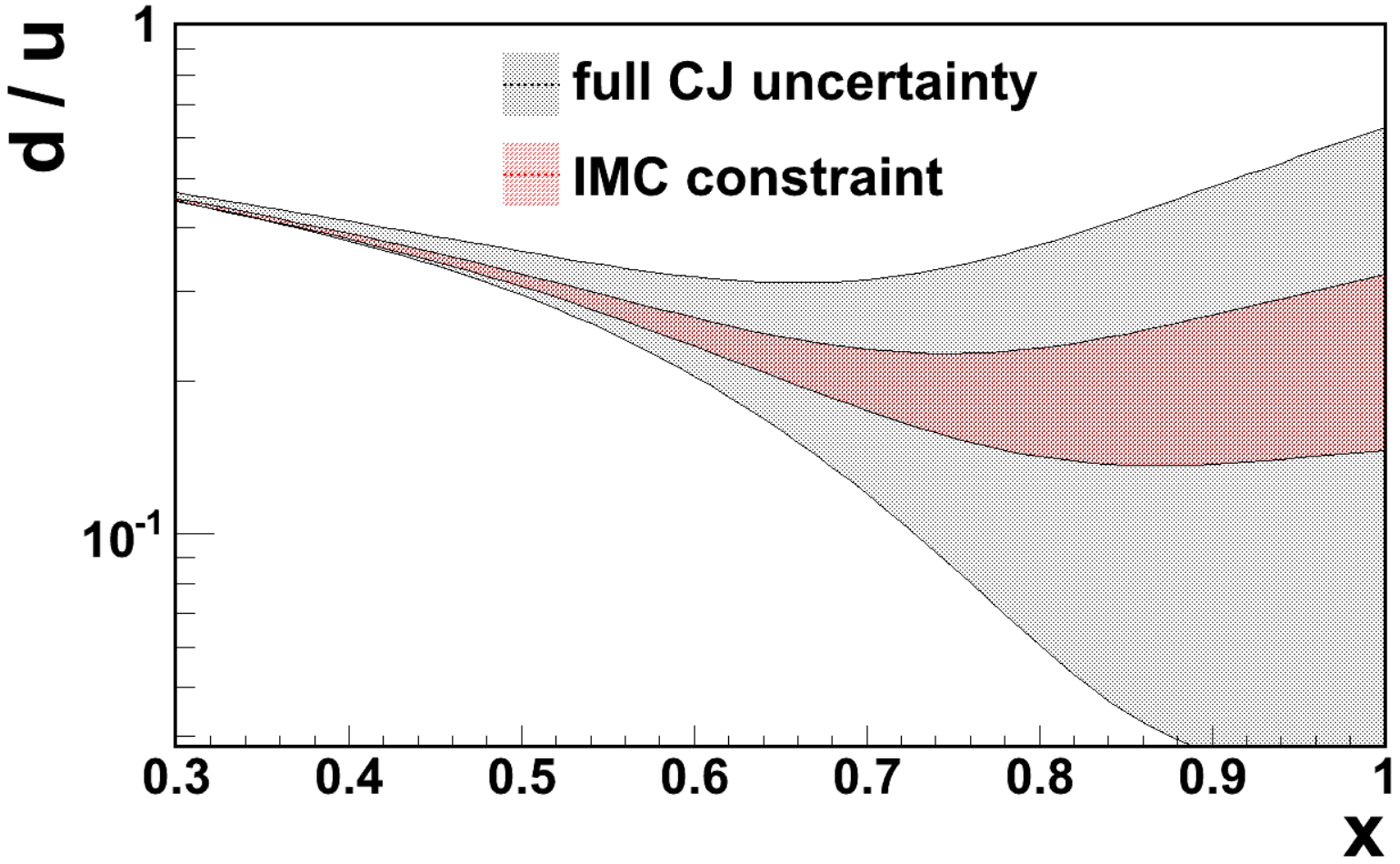


EMC Slopes & SRC Plateaus



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.



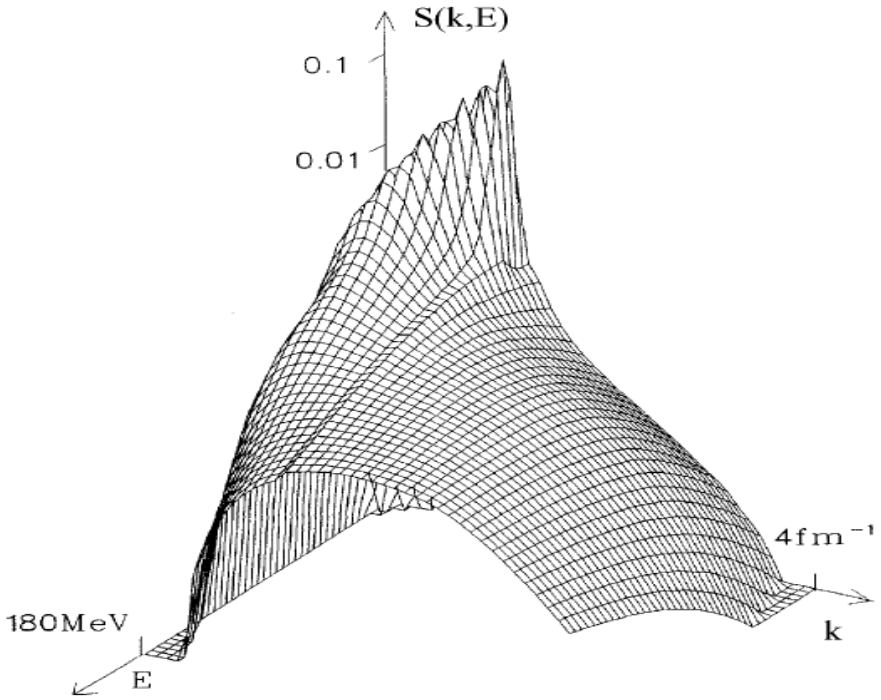
Result is between the SU(6) symmetry limit of ½ and the scalar di-quark dominance limit of 0.

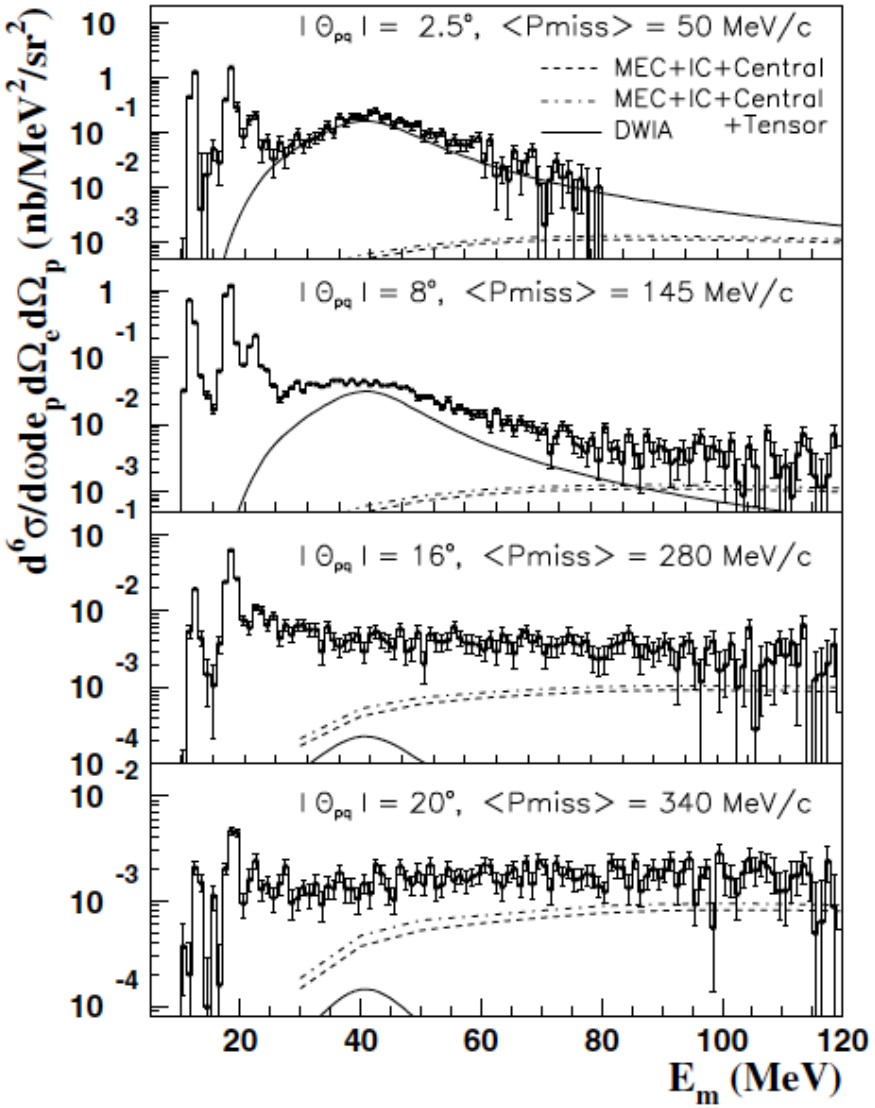
Future Measurements

Collaboration with Neutrino Community

E12-14-012: Measurement of the Spectral Function of ^{40}Ar with the (e,e'p) reaction

- Precision neutrino experiments now require detailed understanding of nuclear structure and reaction mechanisms.
- Nice example of nuclear physics subfields coming together.
- Shown are Jefferson Lab ^{16}O(e,e'p) results from N. Liyanage *et al.*, Phys.Rev.Lett. 86 (2001) 5670.

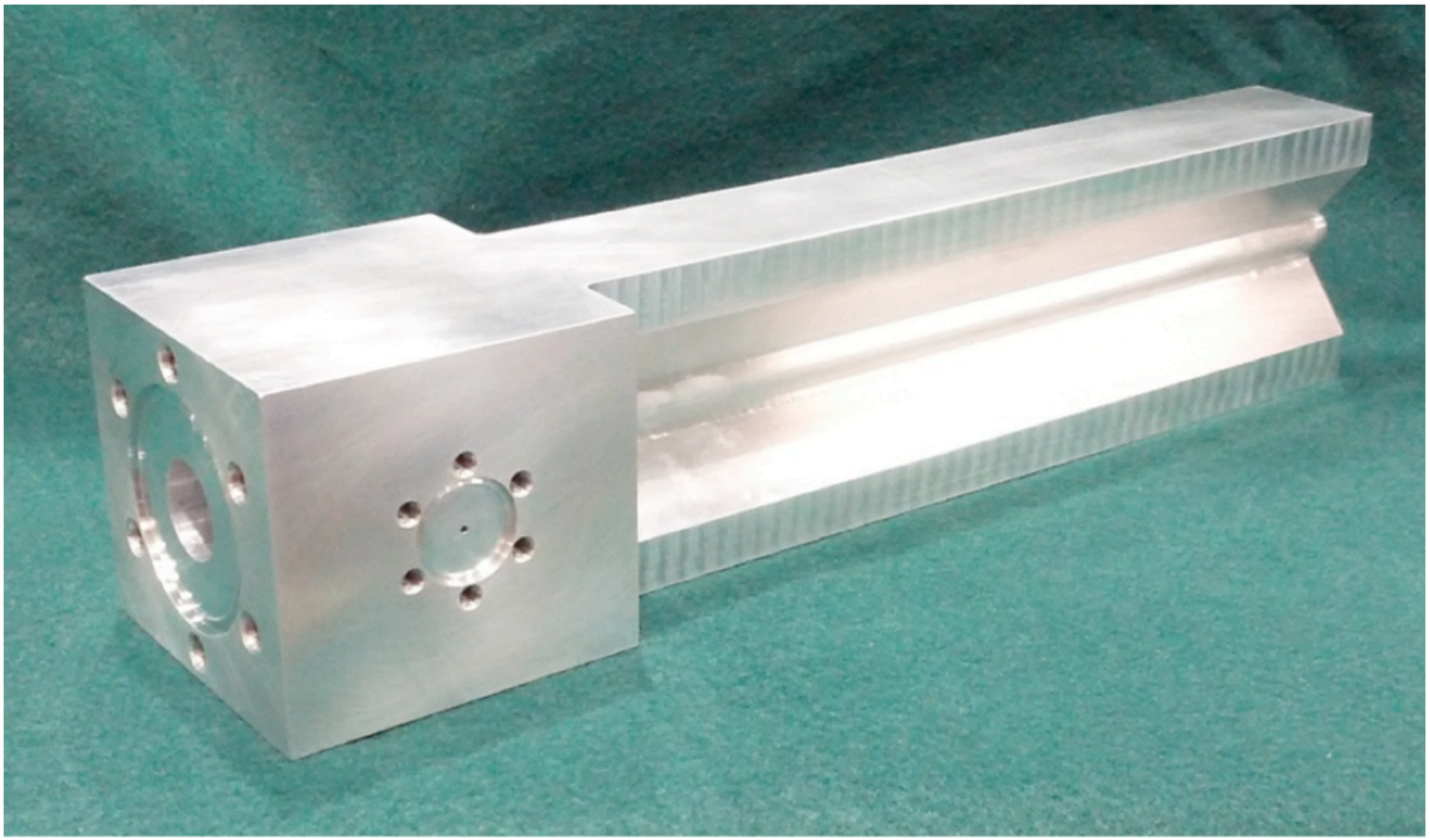




Jefferson Lab

Triton (^{3}He & ^{3}H) Measurements

E12-10-103: Marathon u/d ratios from 3He(e,e')/3H(e,e') DIS measurements
E12-11-112: x>1 measurements of correlations
E12-14-001: elastic scattering measurement to better determine the charge radius
E12-14-012: (e,e'p) momentum distribution measurements

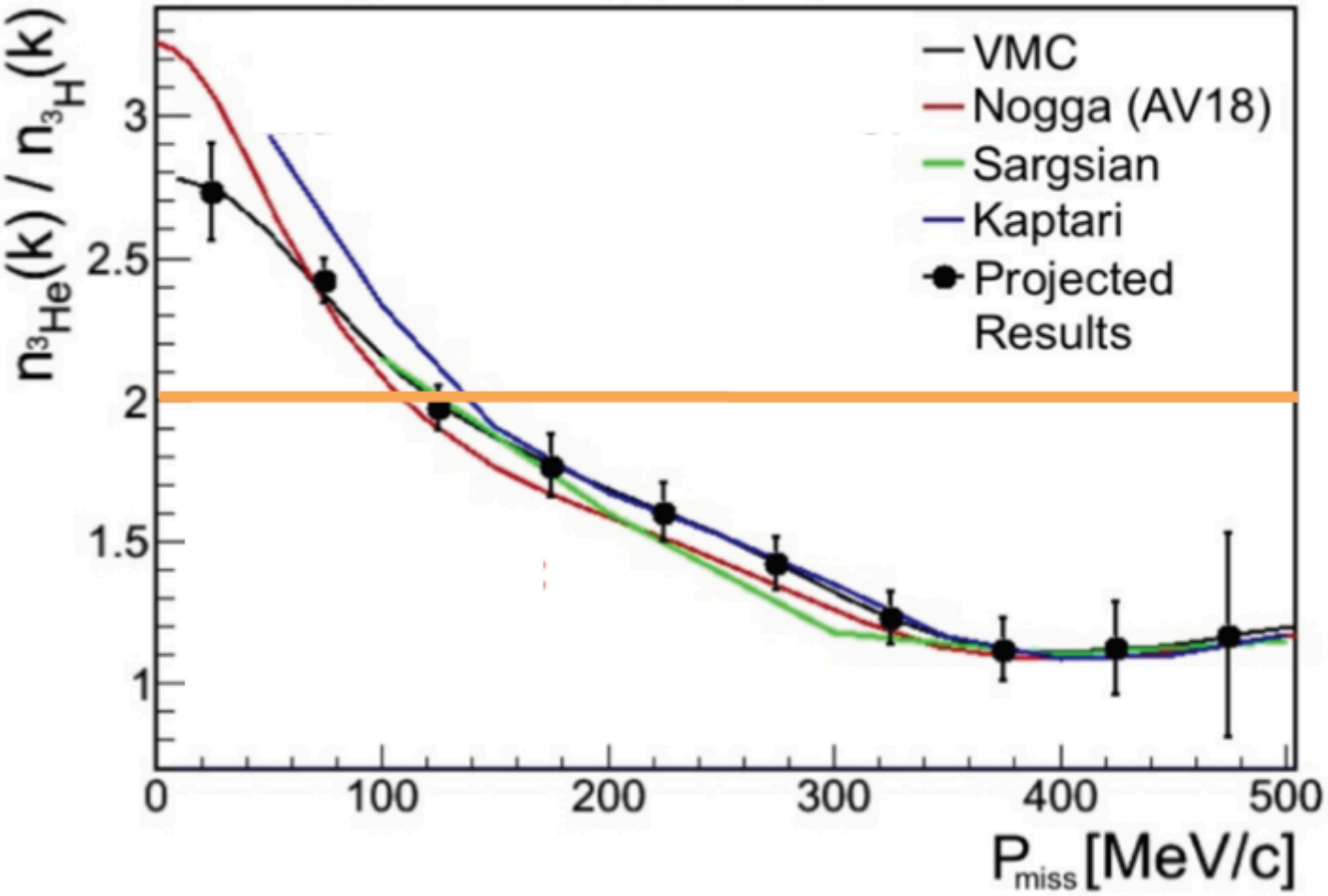


Relatively small amount of tritium (~1kC) in a cell machined from single block of Al.

^{3}He(e,e'p)/^{3}H(e,e'p) Is Two, Isn't It?!

E12-14-011: Proton and Neutron Momentum Distributions in A = 3 Asymmetric Nuclei

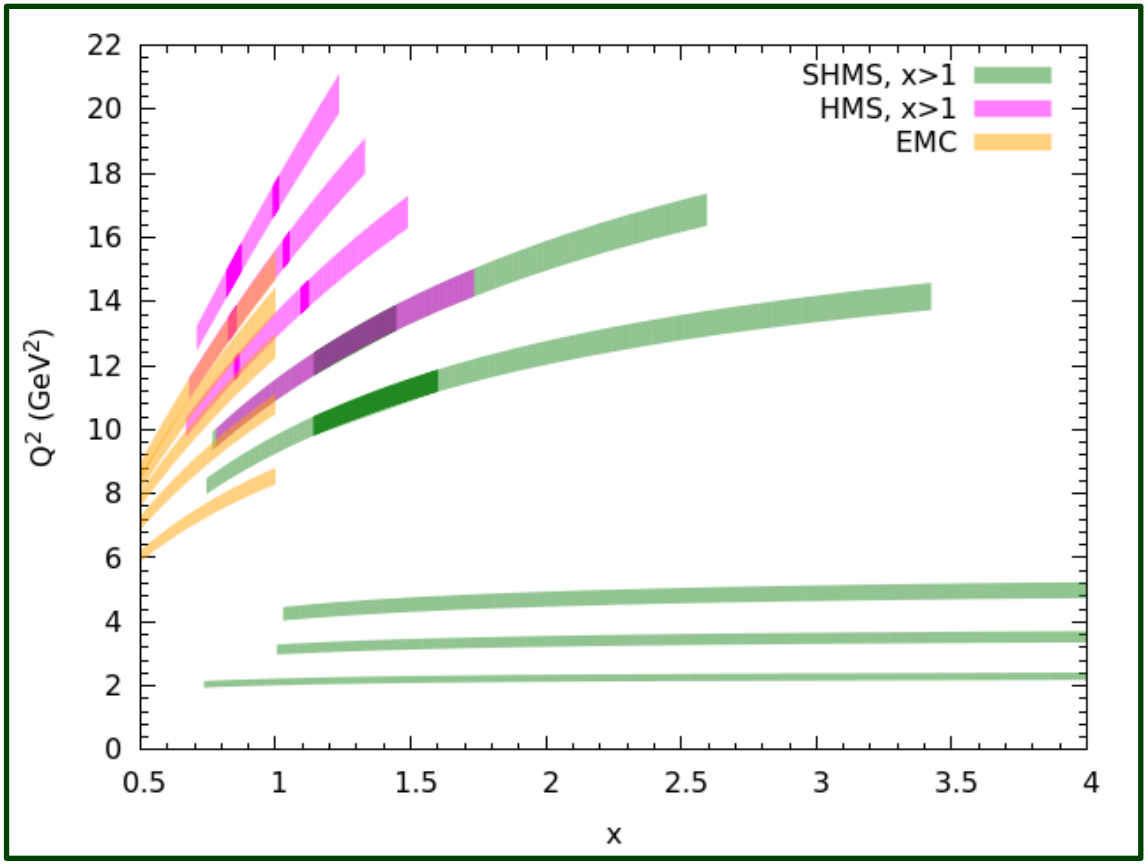
arXiv:1409.1717



Systematic Study of x>1 Region

E12-06-105: Inclusive Scattering from Nuclei at x > 1 in quasi-elastic & deeply inelastic regimes.

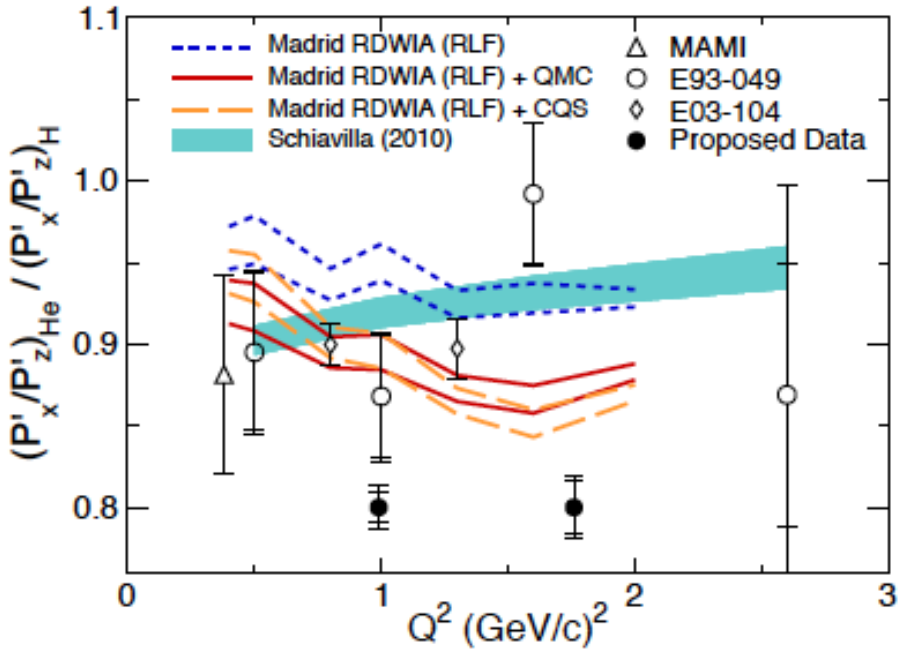
E12-11-112: Precision measurement of the isospin dependence in 2N & 3N SRC regions.

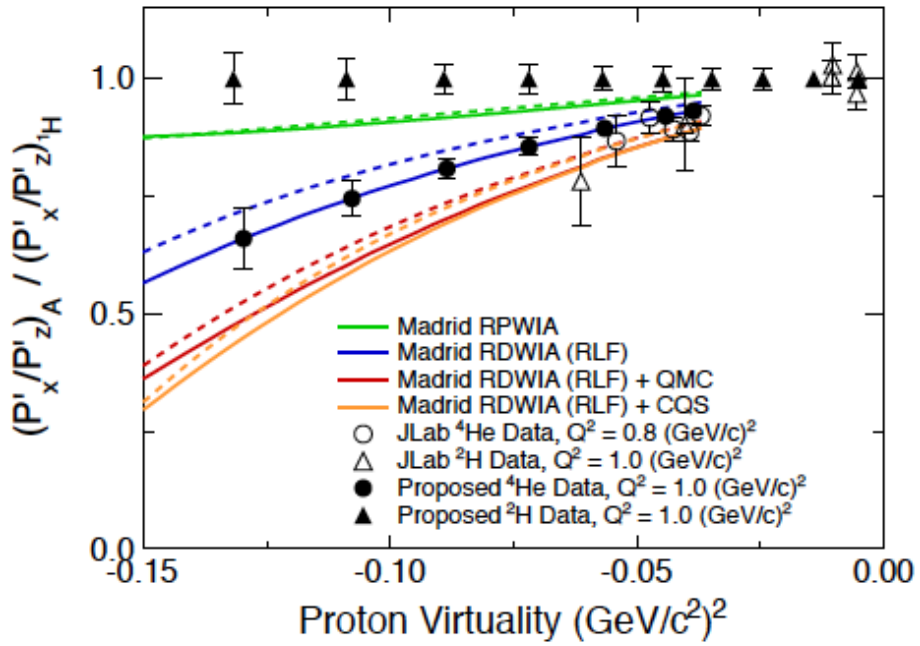


- Measure wide range of kinematics
- Measure with many targets: e.g. D2, H3, He3, He4, Be, C, Cu, Au
- Shown above is the kinematic reach of the Hall C E12-06-105 measurements

Search for Medium Modified Form Factors

E12-11-002: Recoil Polarization Measurements of ^{4}He(e,e'p)^{3}H, D(e,e'p)n, and H(e,e'p)

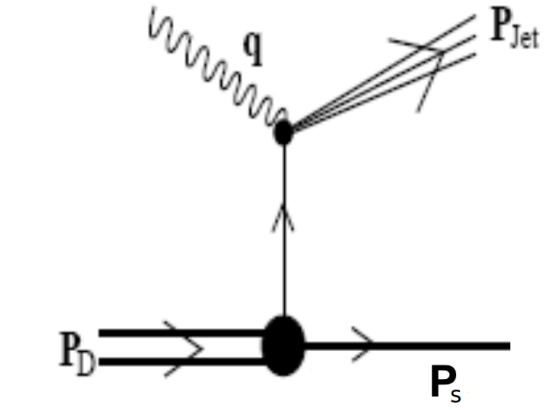


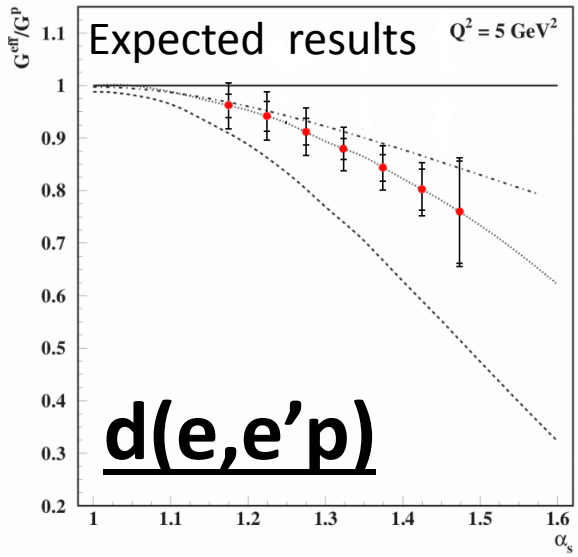


- Upcoming measurements will push the precision and reach of the these measurements and now include deuterium.

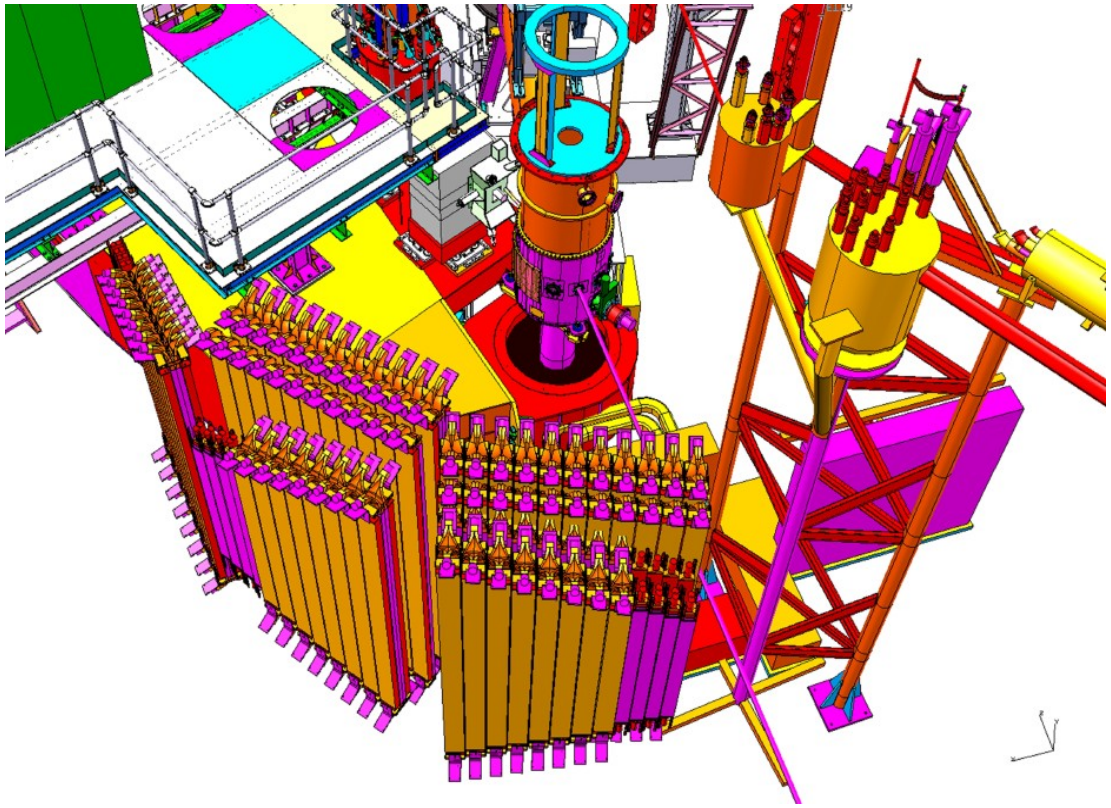
In-Medium Structure Functions

E12-11-107: In Medium Nucleon Structure Functions, SRC, and the EMC effect





Large Acceptance Detector for Jefferson Lab Hall C



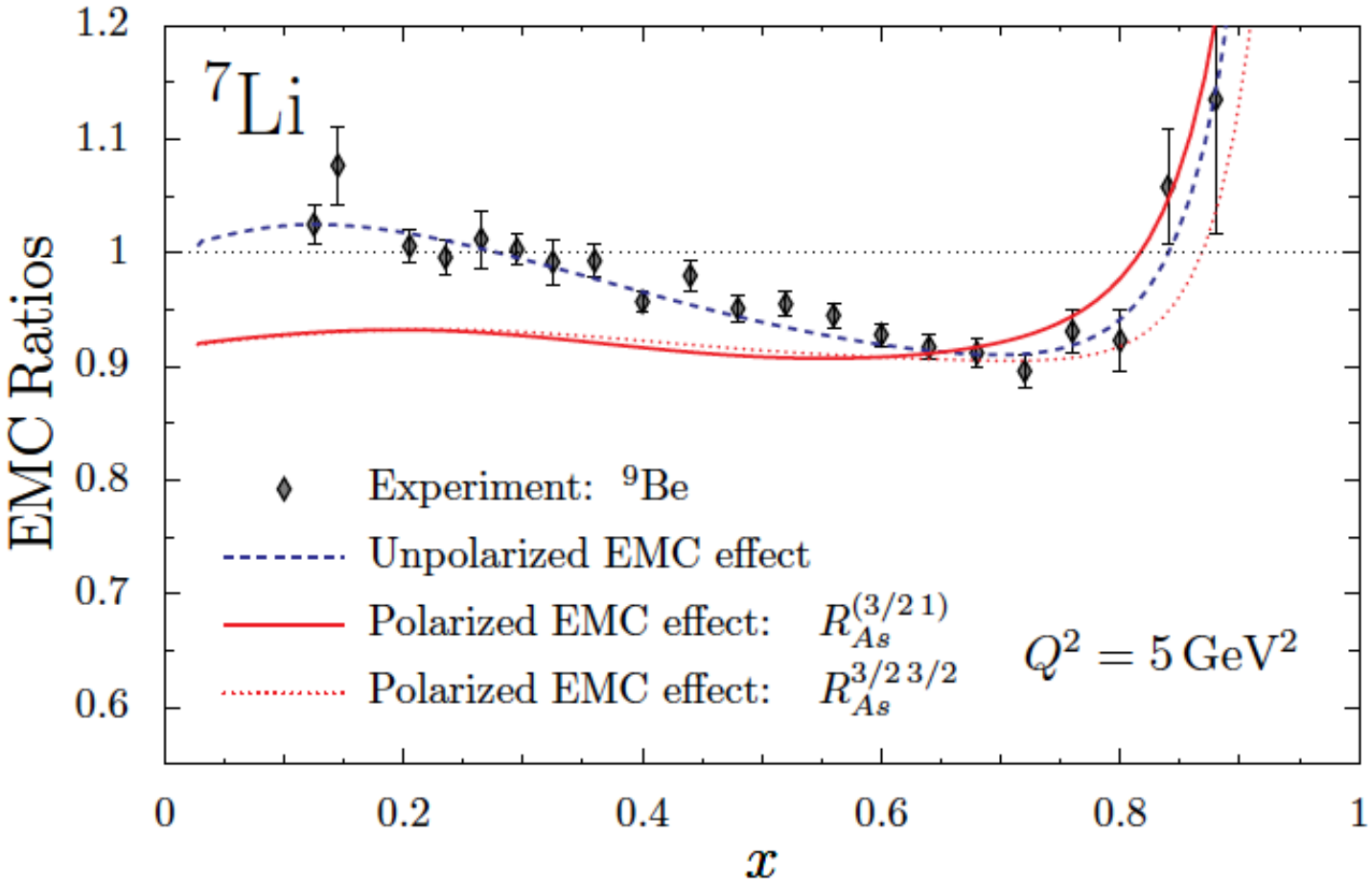
Spectator Tagging with Bonus, E12-06-113: The Structure of the Free Neutron at Large x.

In the future these measurements can be done with an EIC over to low .

(see talks by C. Weiss and C. Hyde)

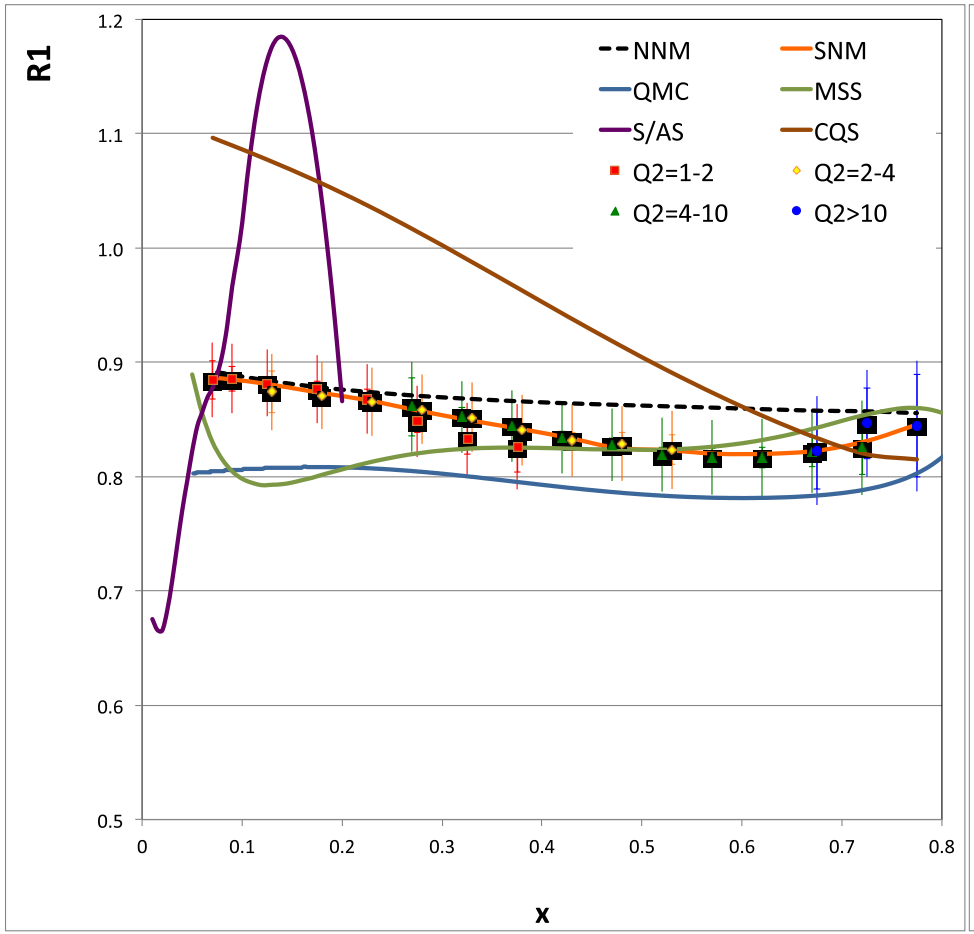
Polarized EMC Effect

I. C. Cloet, W. Bentz and A. W. Thomas, Phys.Lett.B **642** (2006) 210-217.

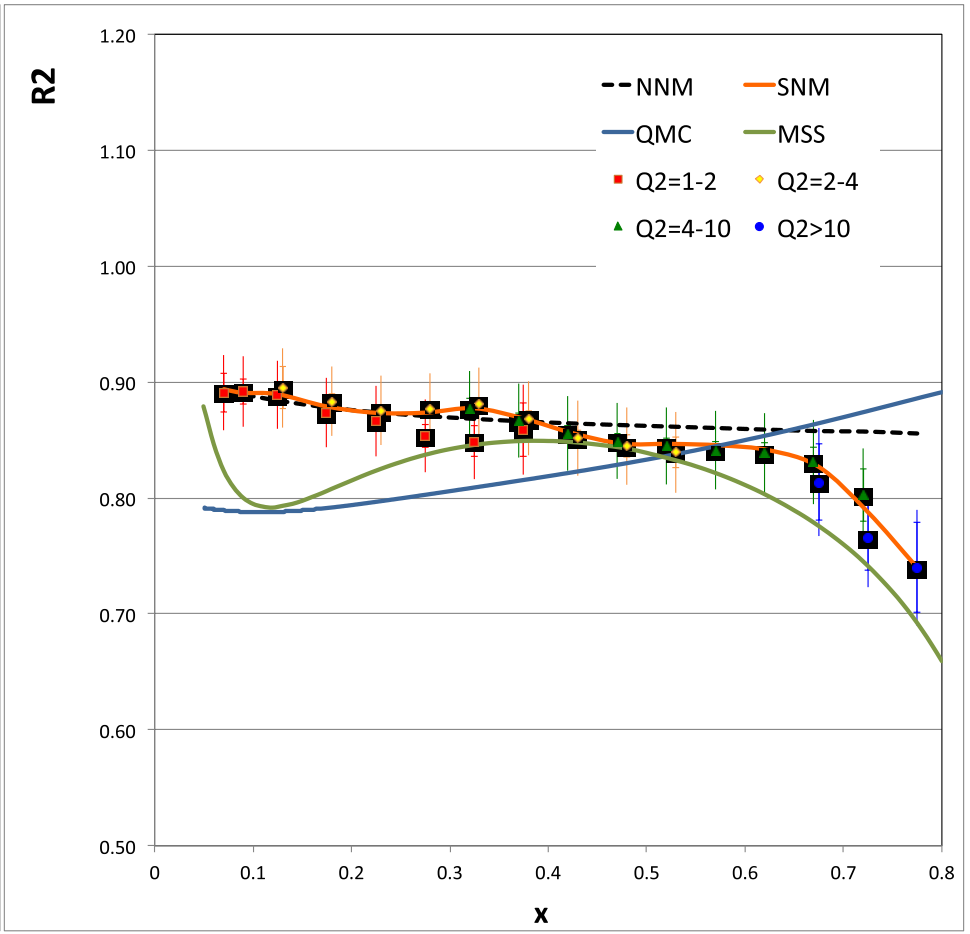


Polarized EMC = Every Model Cannot

E12-14-001: The EMC Effect in Spin Structure Functions



$\Delta\sigma$ Ratio



$A_{||}$ Ratio

Collider SRC-EMC Physics

- Spectator Tagging Cross Sections & Asymmetries
  - $D(e,e'p_{recoil})X$ (DIS on neutron)
  - $^3He(e,e'd_{recoil})X$ (DIS on proton)
- Low t' (low missing momentum) allows for on-shell extractions (*see Kijun Park's talk*)
- Mapping the entire t' recoil will allow for understanding the entire system from on-shell to extremely off-shell.
- Many other reactions to investigate!

Summary

- Many new results showing the effect of high initial-state momentums (both theory and experiment).
- New DIS data points to EMC effect being a local density effect.
- These two effects seem to be strongly correlated.
- Open Questions
  - What exactly is the high momentum tail (hadronic and/or partonic)?
  - Can we use of the EMC-SRC connection to make new insights?
  - Can we finally solve the 31 year old EMC effect puzzle?!
- Many New EMC ($x<1$) and SRC ($x>1$) Experiments Coming with 12GeV Jefferson Lab, including ^{3}H & ^{3}He.
- Revisiting topics such as importance of correlations in dense nuclear mater via efforts such as the CLAS data mining project.

Changing Picture Of Nuclear Matter

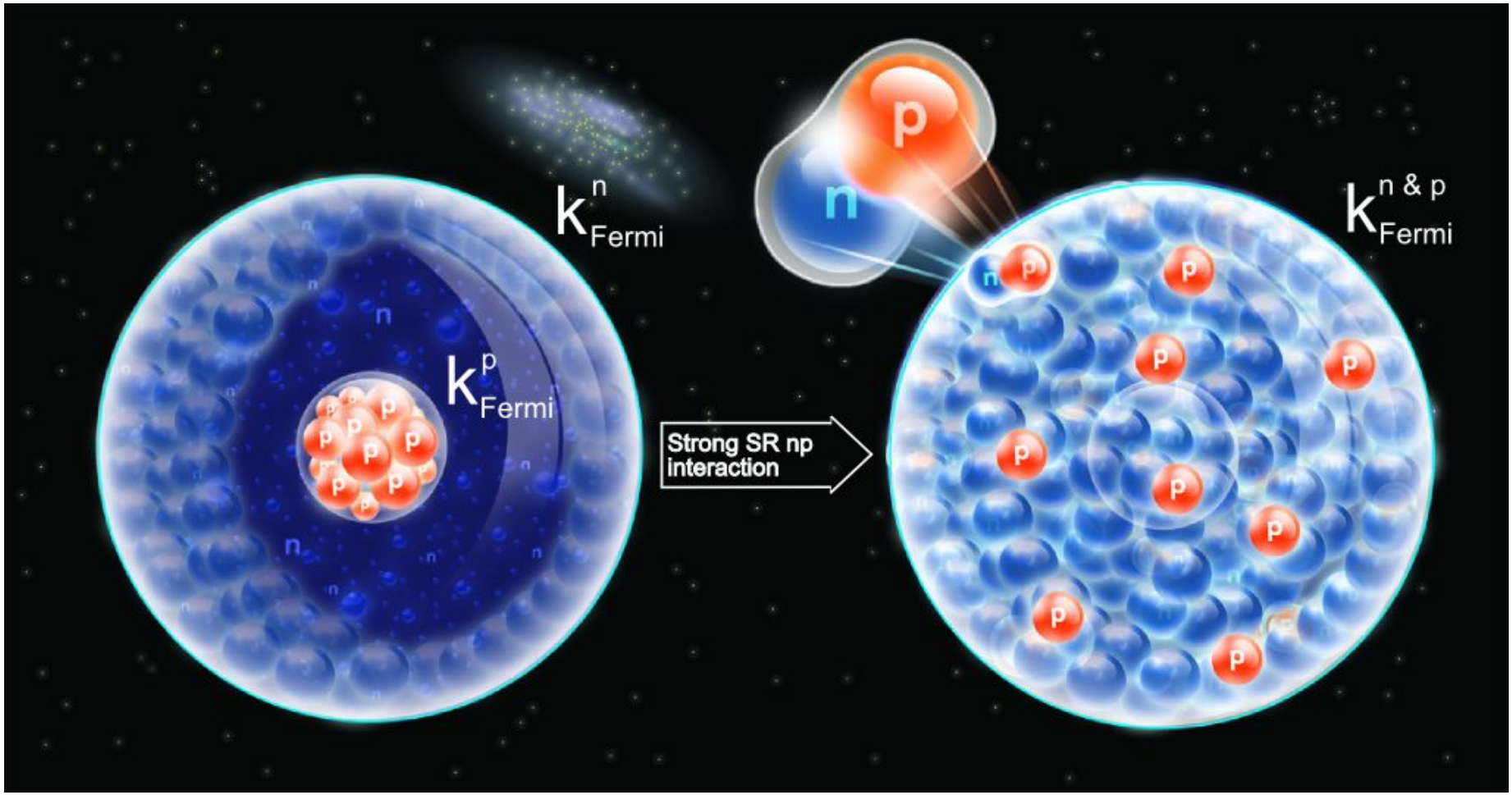


Image from CERN Courier **49N1** (2009) 22-24.