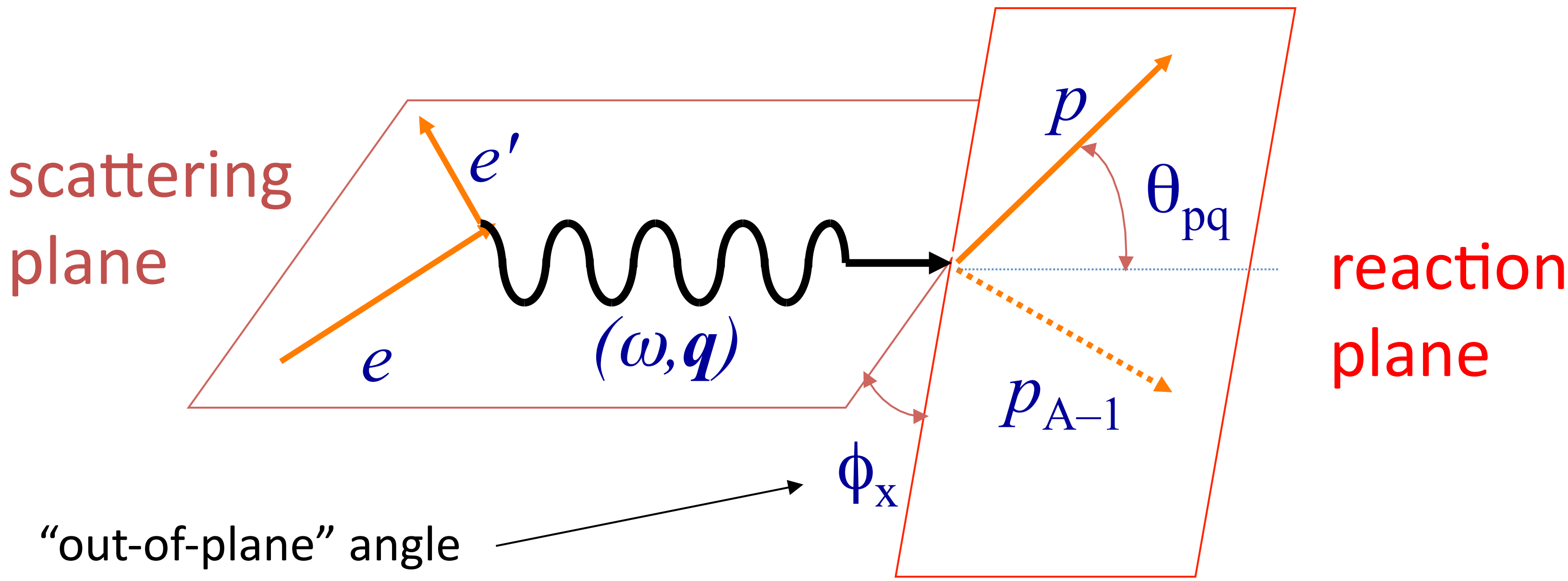
Nucleon Pairs from Light to Heavy Nuclei

by

Douglas W. Higinbotham

Quasi-Elastic Scattering Kinematics



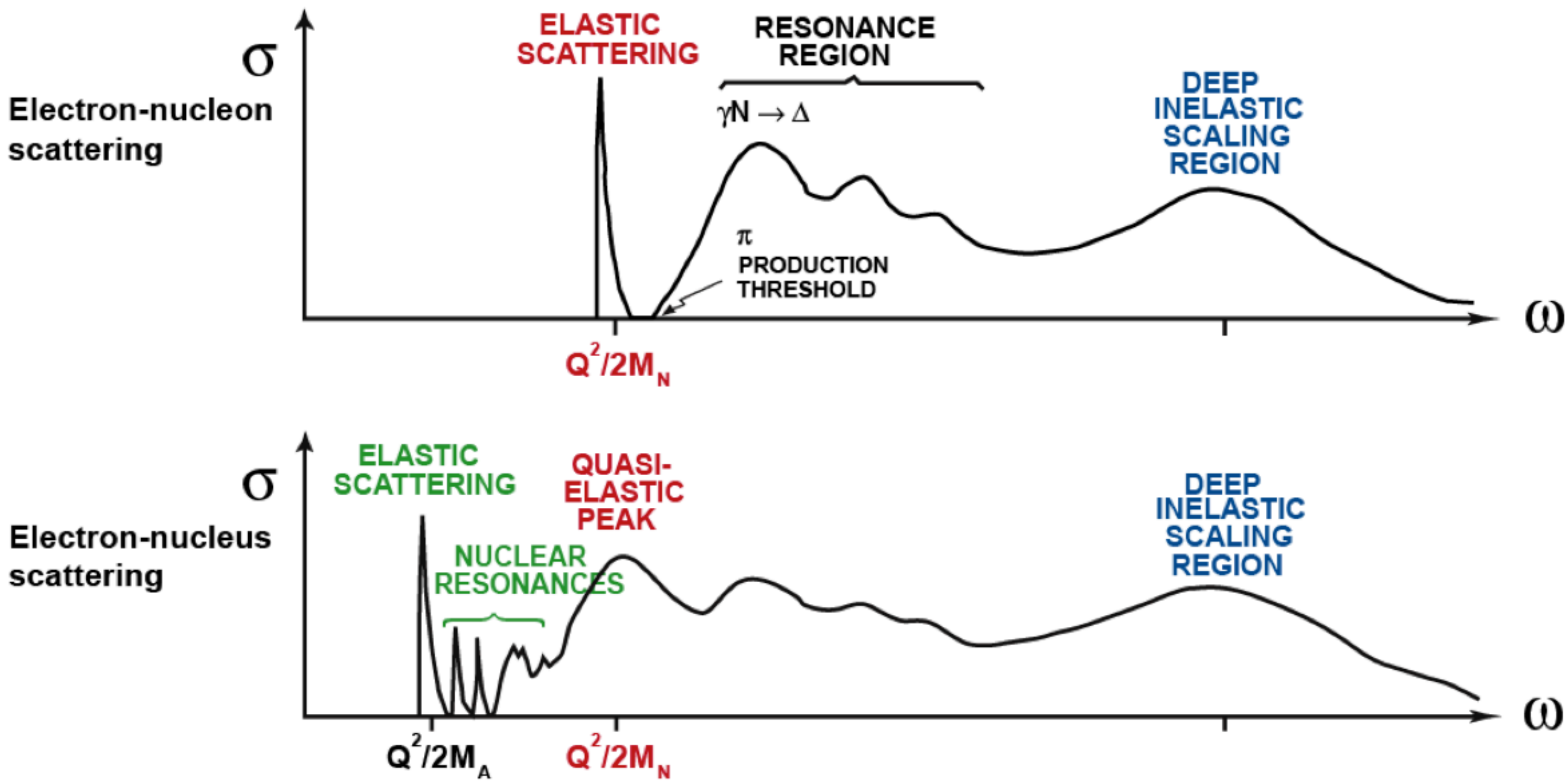
Energy transfer: $\omega = e - e'$

Four-momentum transfer: $Q^2 \equiv -q_\mu q^\mu = \boldsymbol{q}^2 - \omega^2$

Missing momentum: $\boldsymbol{p}_m = \boldsymbol{q} - \boldsymbol{p} = \boldsymbol{p}_{A-1}$

Bjorken x: $x_B = Q^2/2m\omega$ ***(just kinematics!)***

Electron Scattering from Nucleons in the Nucleus



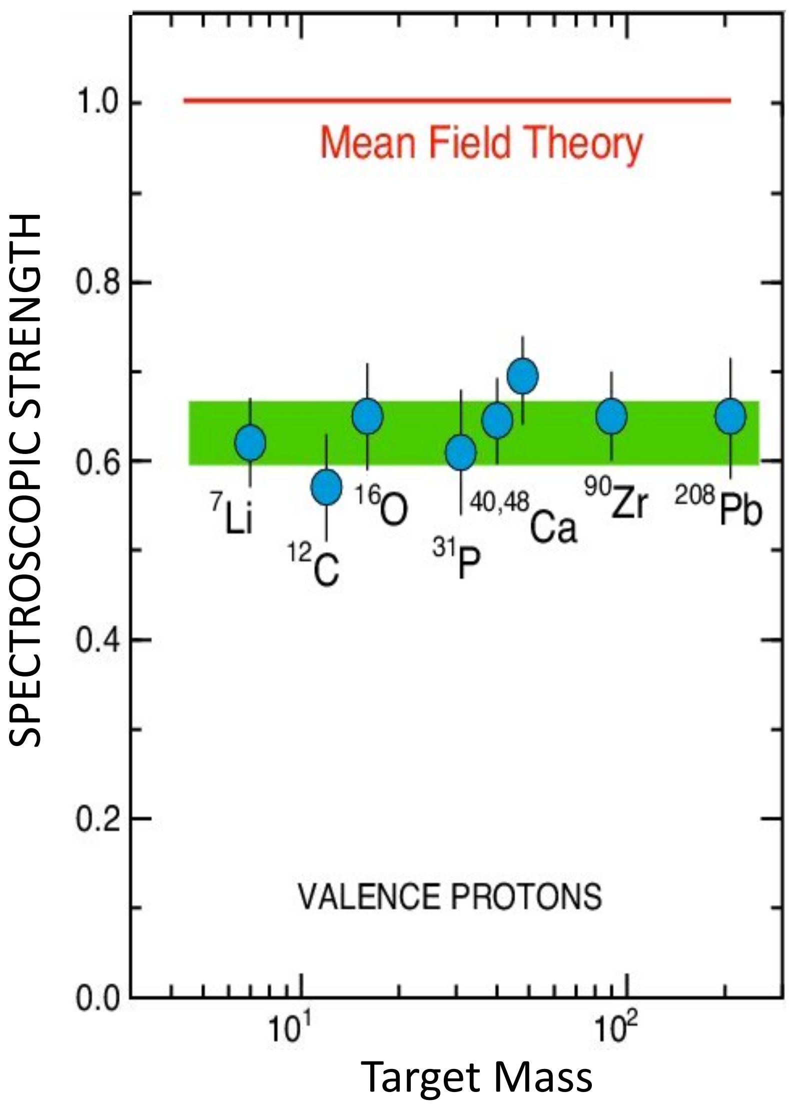
$\mathbf{x_B = Q^2/2m\omega}$ $\quad x_B > 1 \quad x_B = 1 \quad x_B < 1$

Classic (e,e'p) Results

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

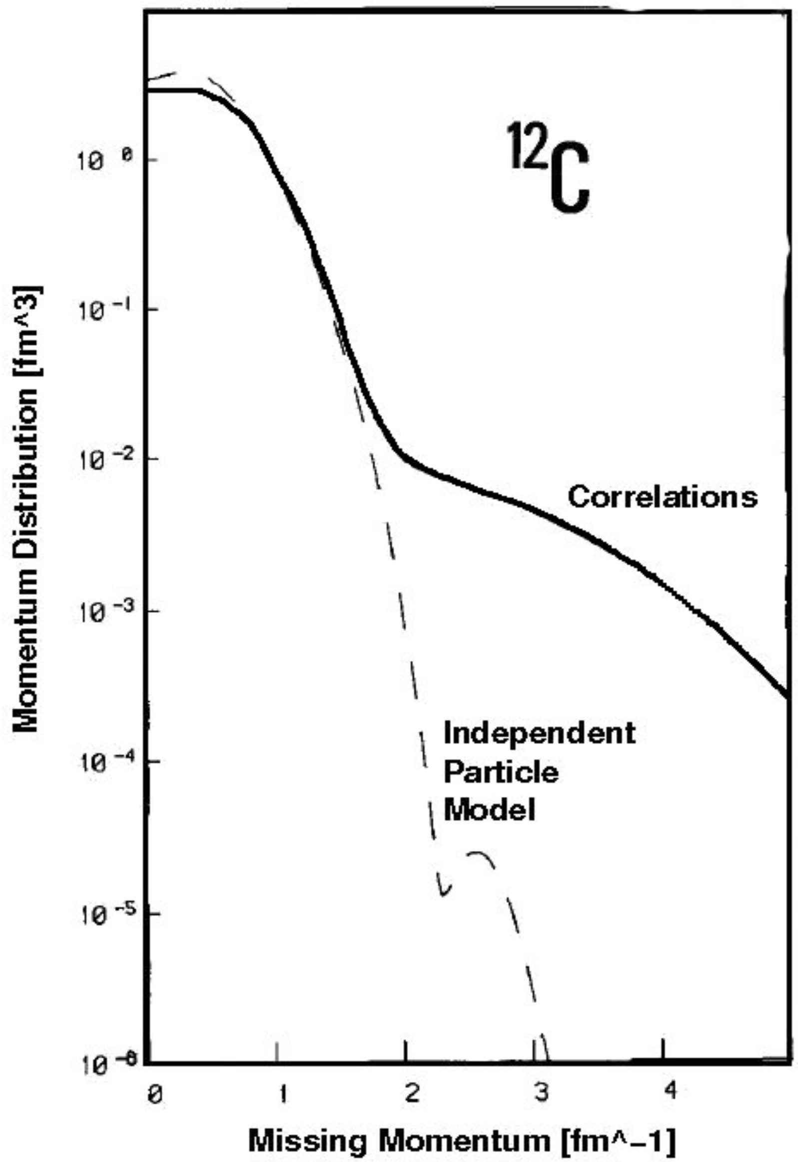
Independent-Particle Shell-Model
is based upon the assumption that
each nucleon moves independently
in an average potential (mean field)
induced by the surrounding nucleons

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.



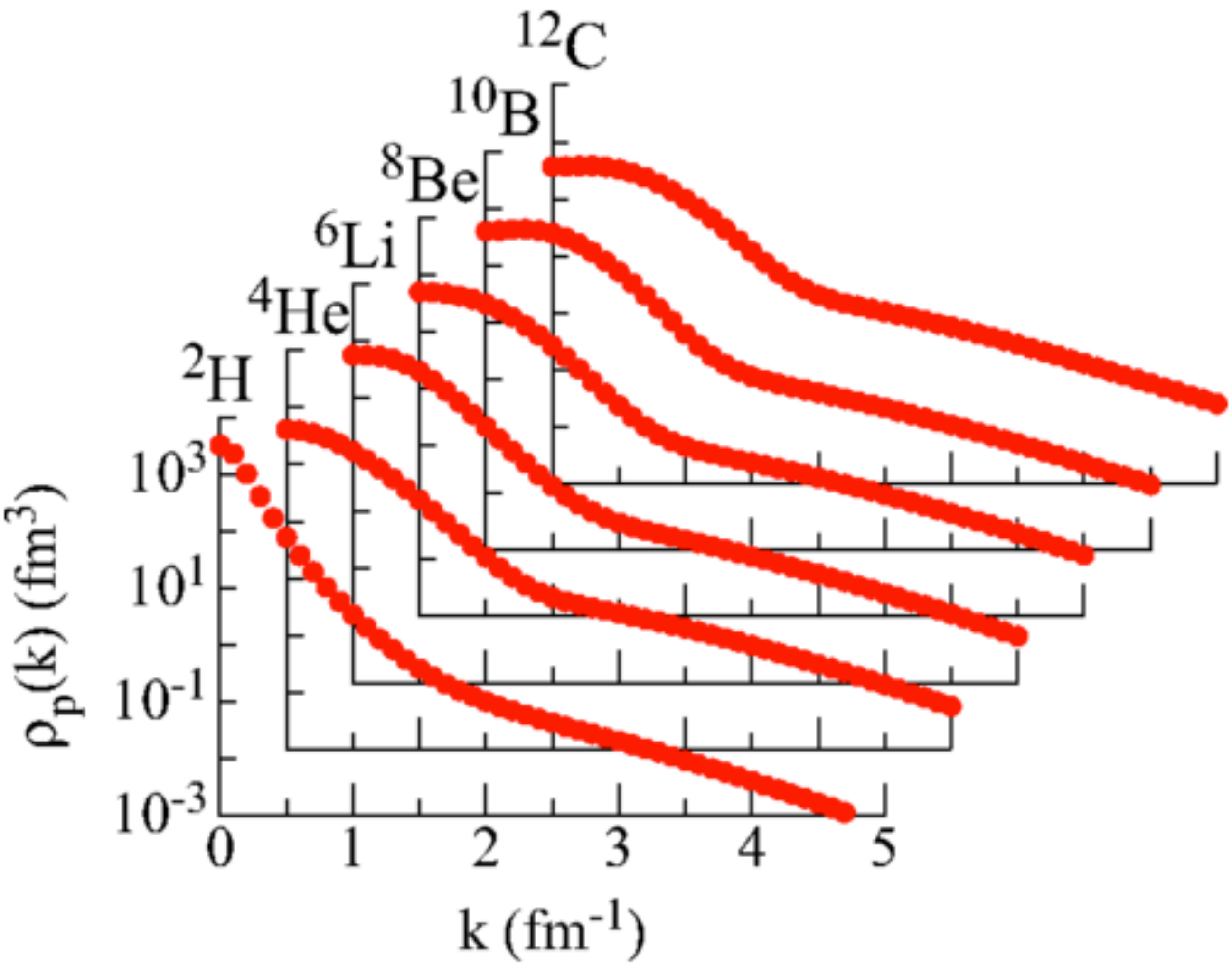
Classic Momentum Distribution

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



Modern AV18 and Urbana-X Results

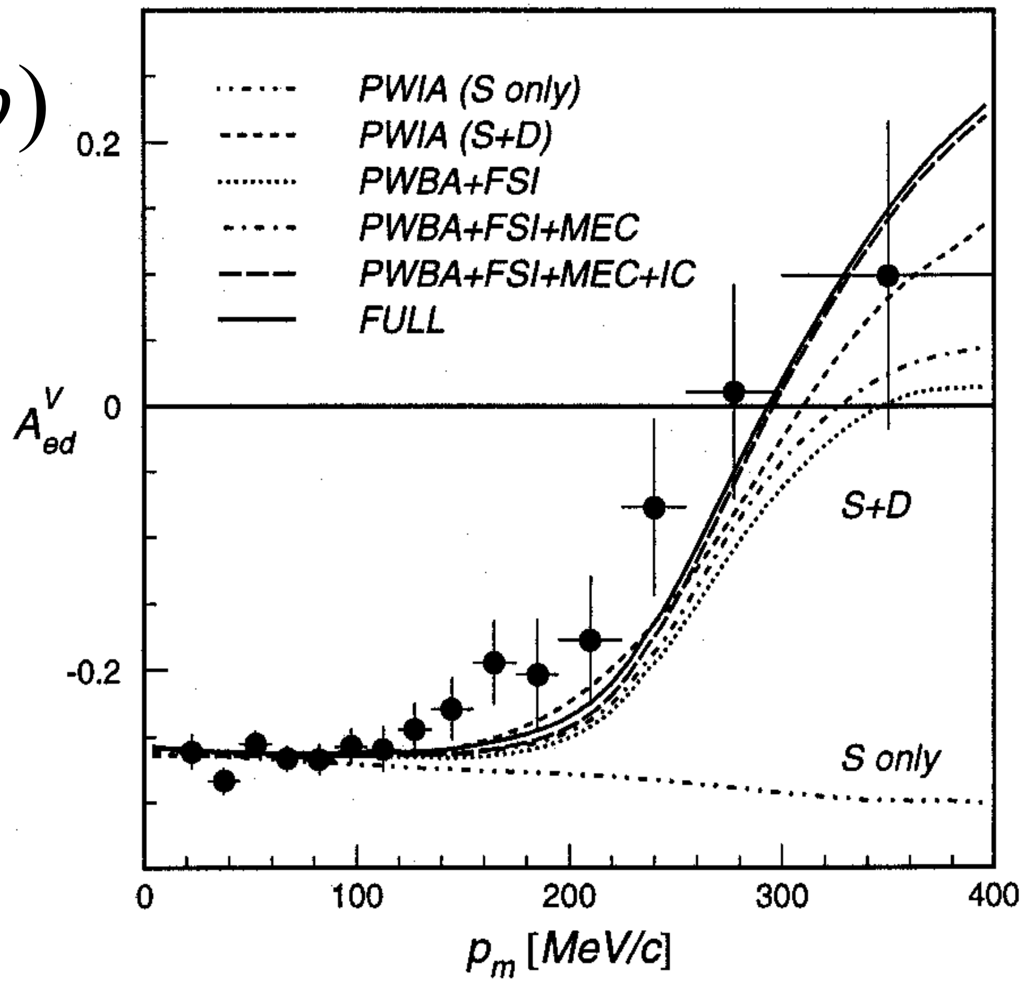
R. Wiringa, R. Schiavilla, S. Pieper, and J. Carlson, Phys. Rev. C89 (2014) 024305.



Deuteron Asymmetry Data

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

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



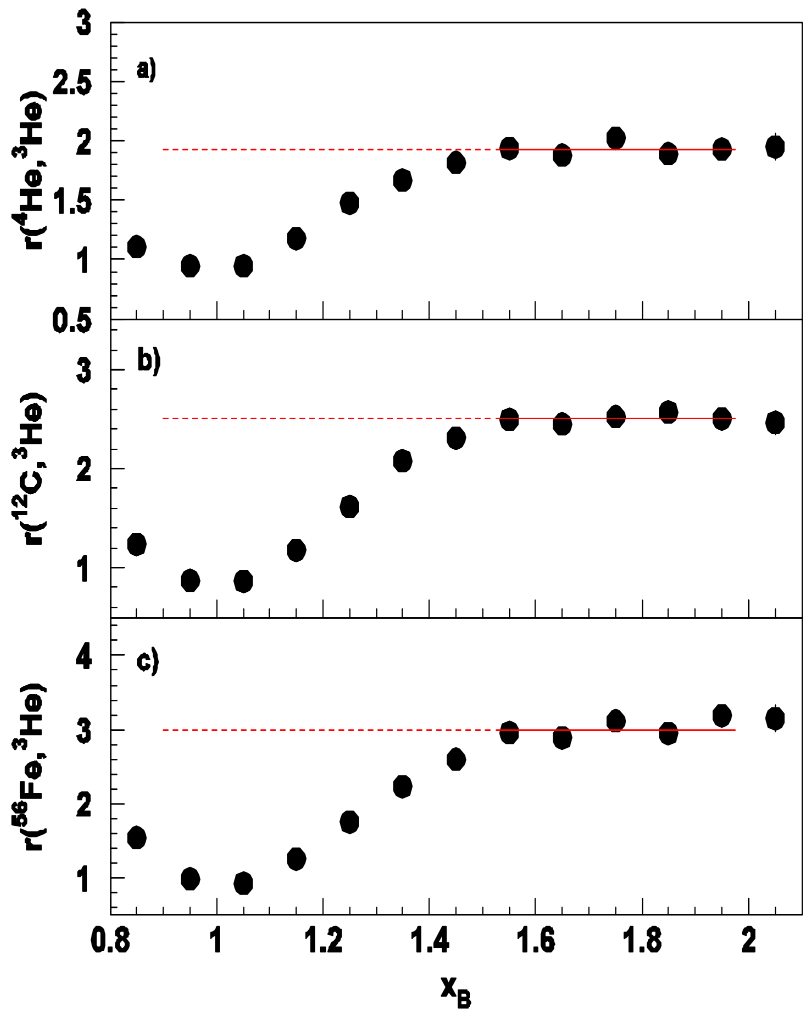
Q^2 = 0.2 GeV/c

x_B = 1

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.



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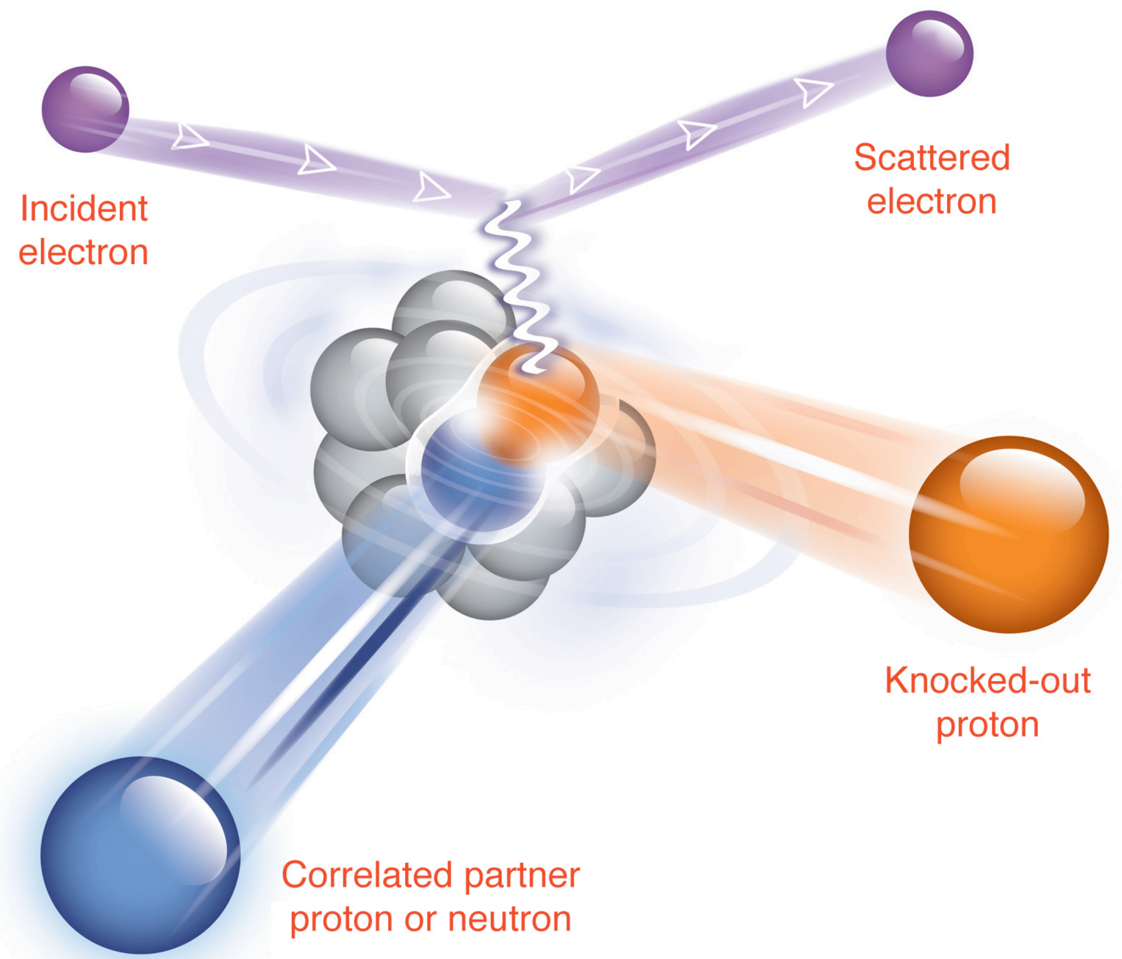
Coincidence (e,e'pN) Measurement

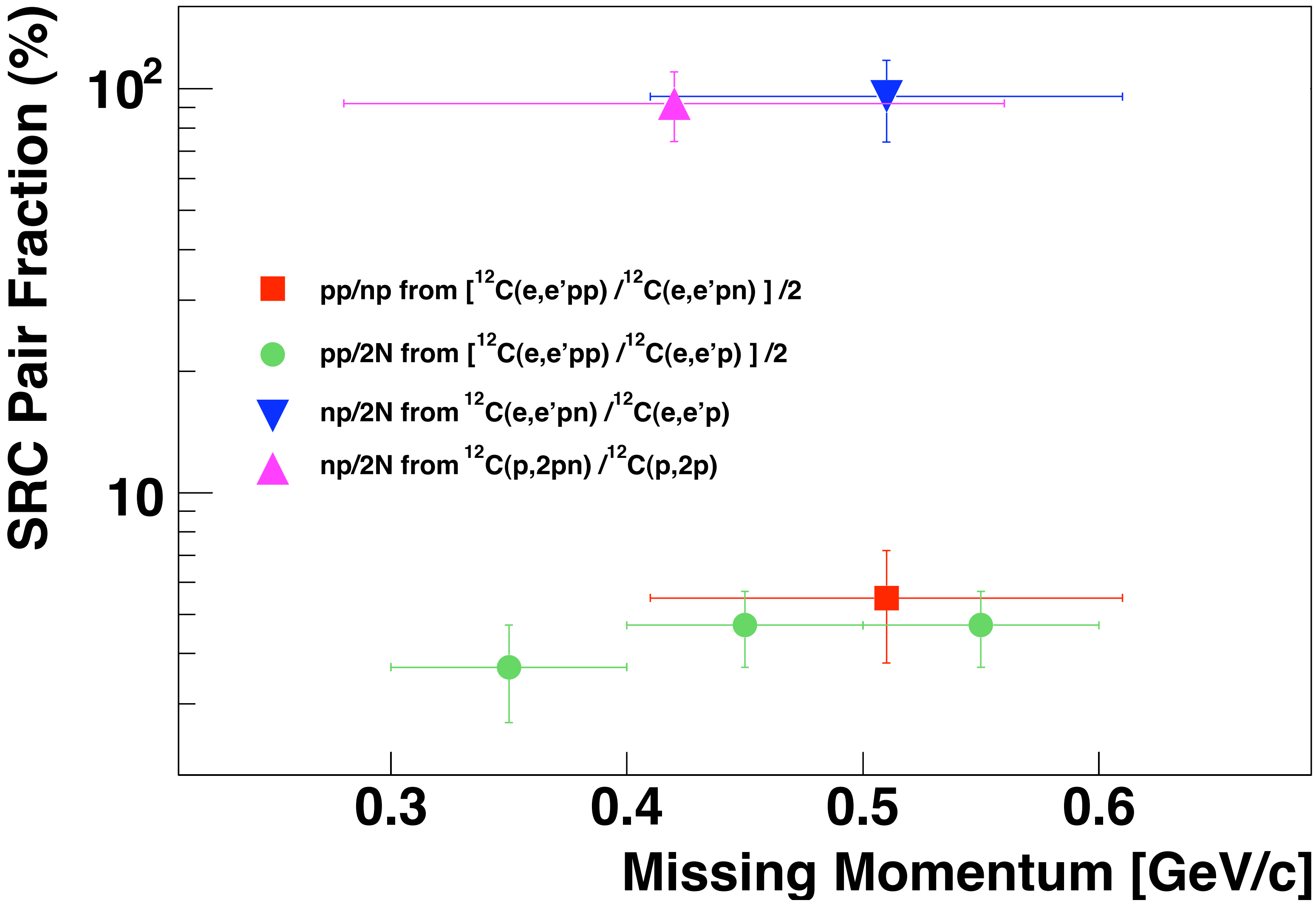
To study nucleon pairs and the fraction that contribute to momentum tail.



$x > 1$, $Q^2 = 1.5\ [GeV/c]^2$ 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.



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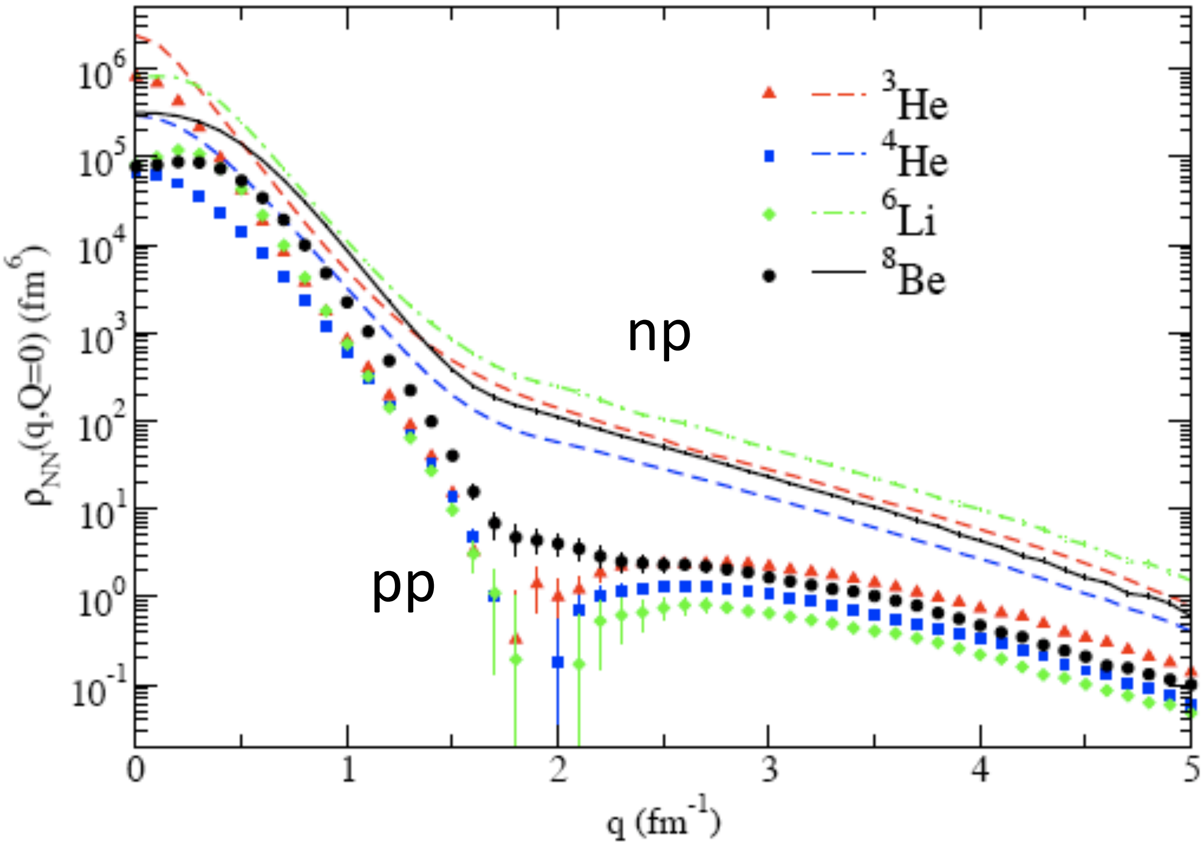
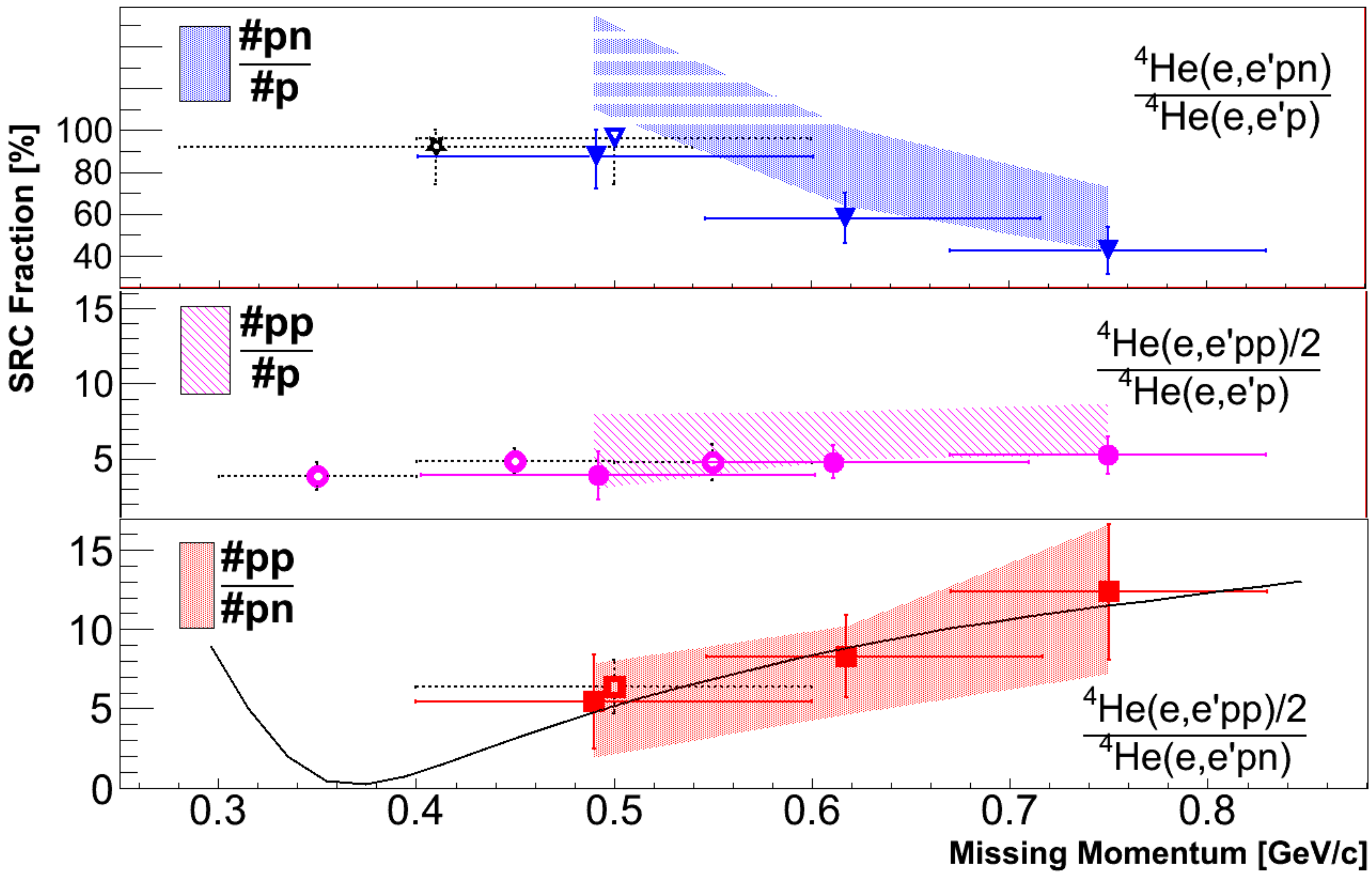
Importance of Correlations



- 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.

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

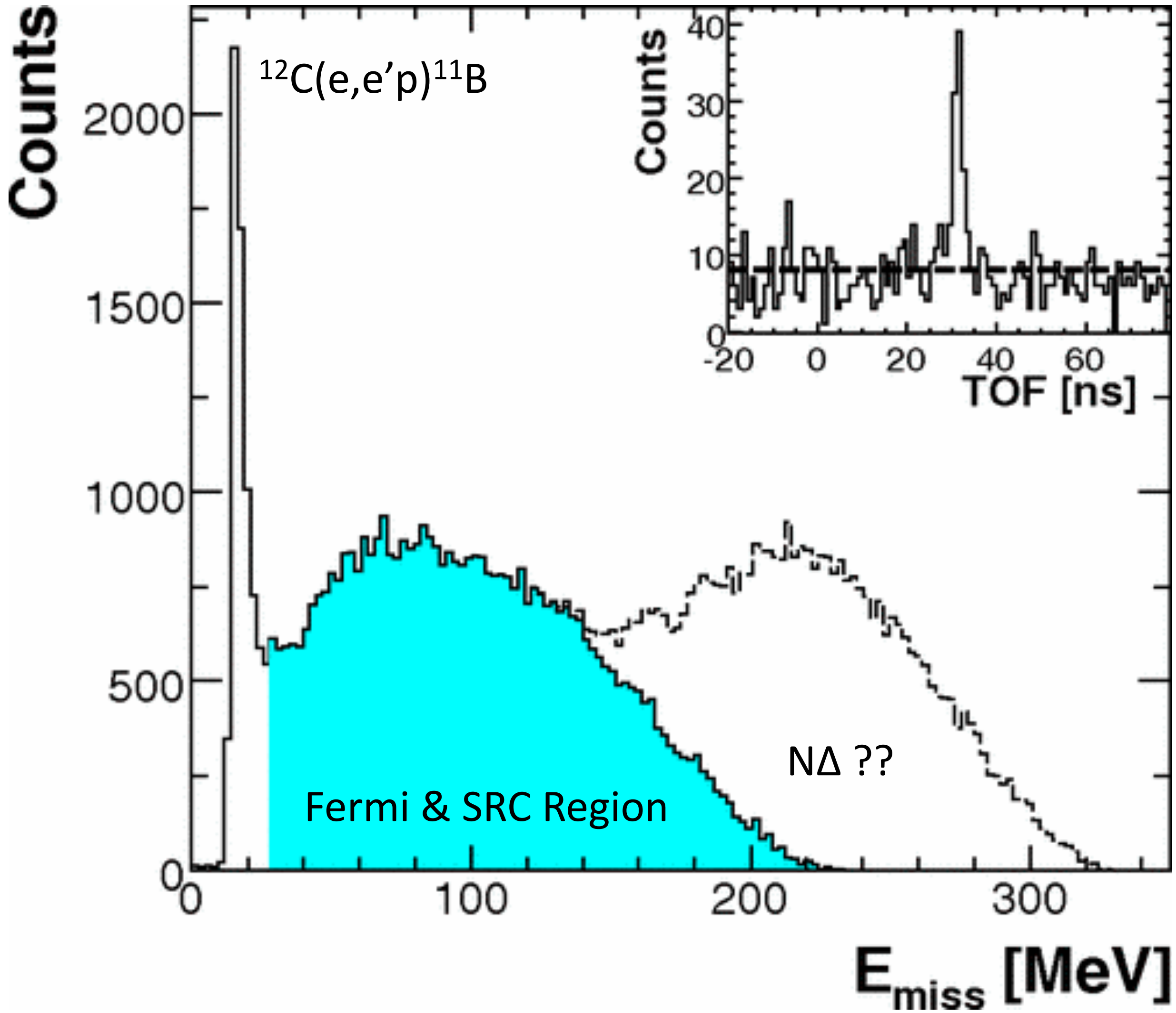
I. Korover et al., Phys. Rev. Lett. **113** (2014) 022501.

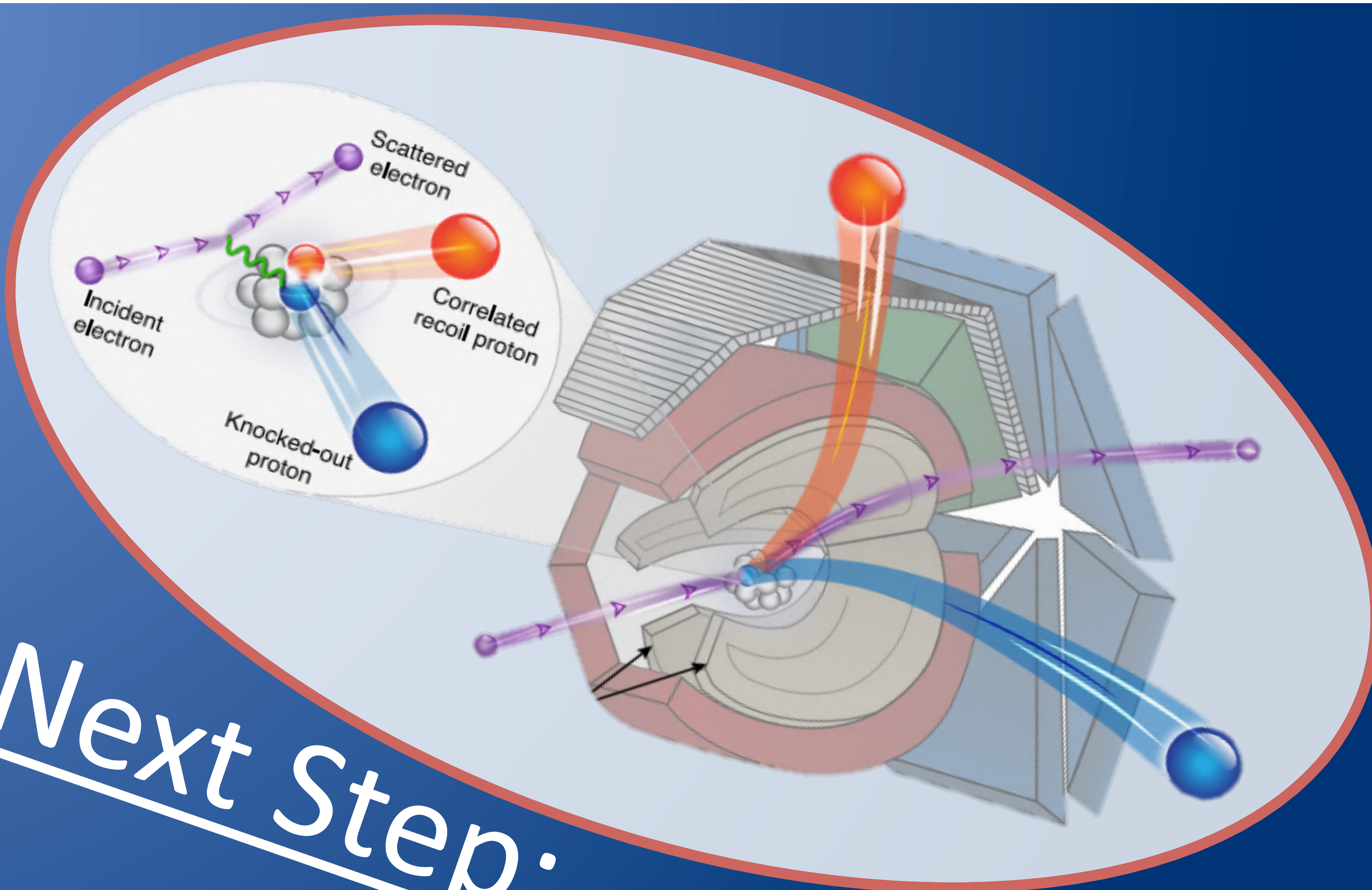


Jefferson Lab

Large E_{miss} $^{12}C(e,e'p)$ Events

R. Shneor *et al*. Phys. Rev. Lett. **99** (2007) 072501.

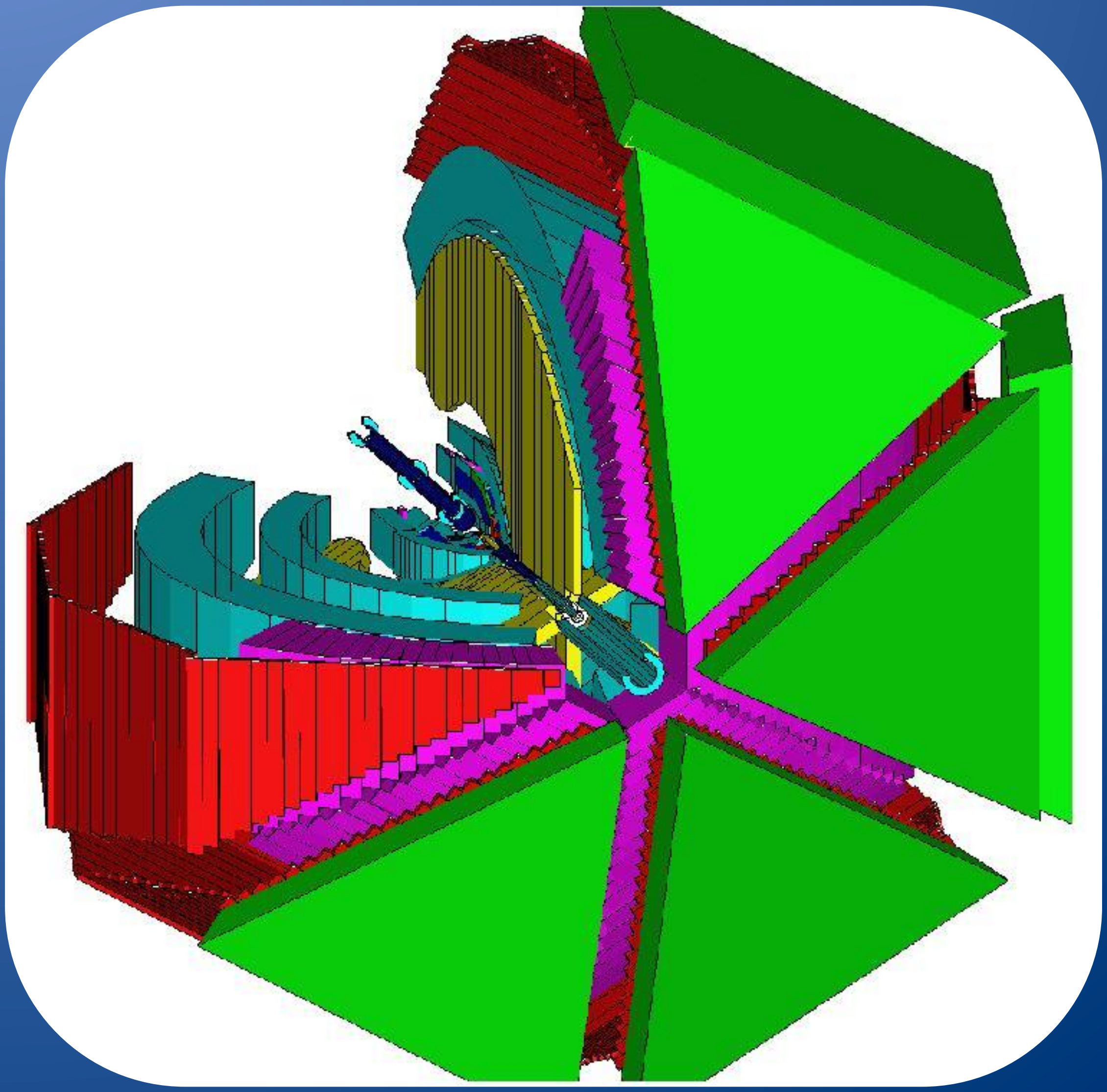




The Next Step:

Heavy Nuclei

CEBAF Large Acceptance Spectrometer
[CLAS]



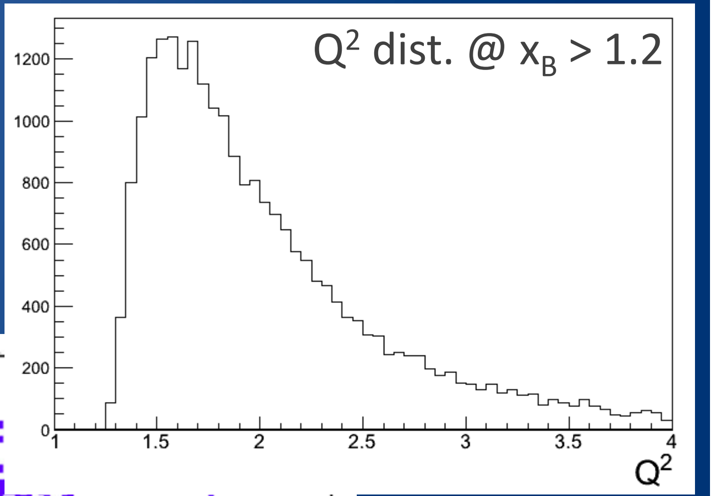
Open (e,e') trigger, Large-Acceptance, Low luminosity (~10^{34} cm^{-2} sec^{-1})

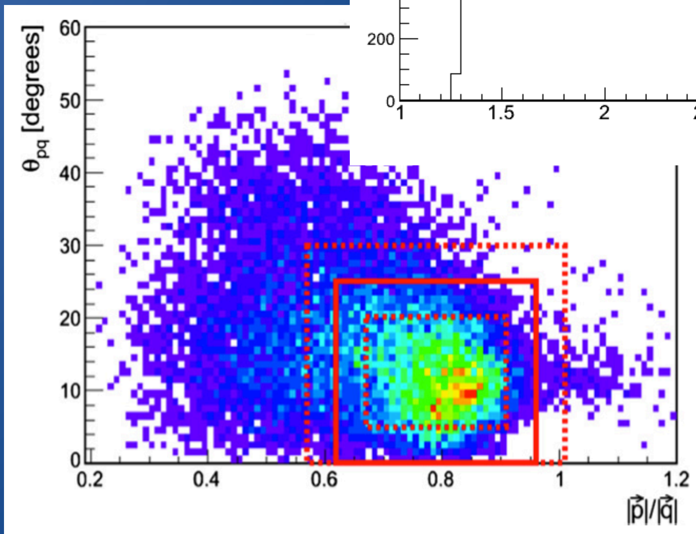
Mining CLAS Data for SRCs

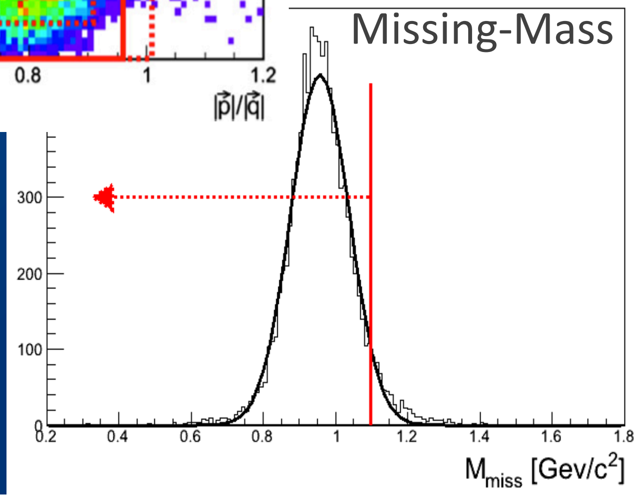
Reanalyzed existing CLAS data via a data-mining initiative

5 GeV electrons on ^{12}C, ^{27}Al, ^{56}Fe, and ^{208}Pb:

1. Cut (e,e'p) kinematics to simulate previous measurements*.
2. Look for a correlated recoil proton.



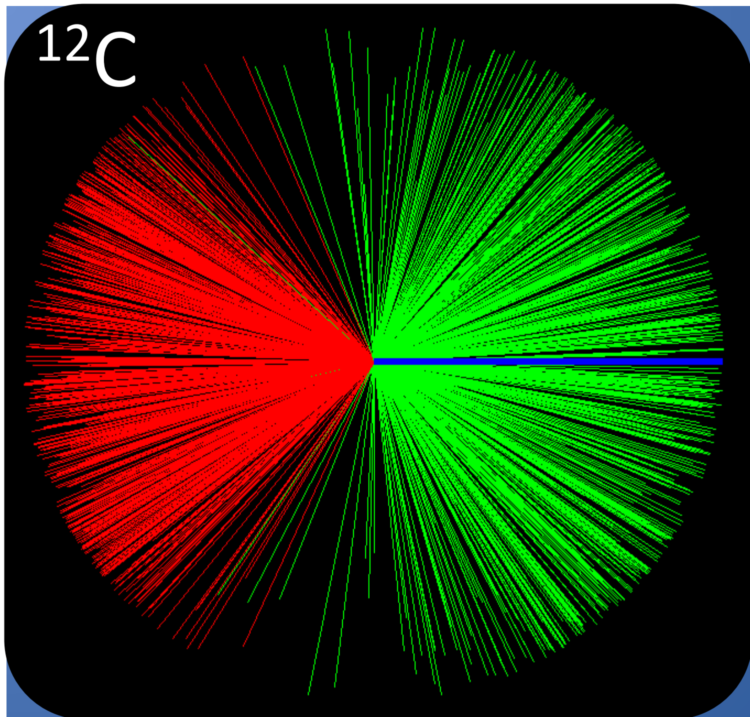


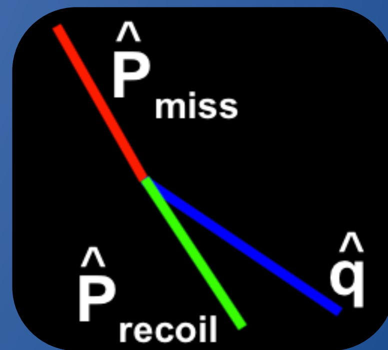


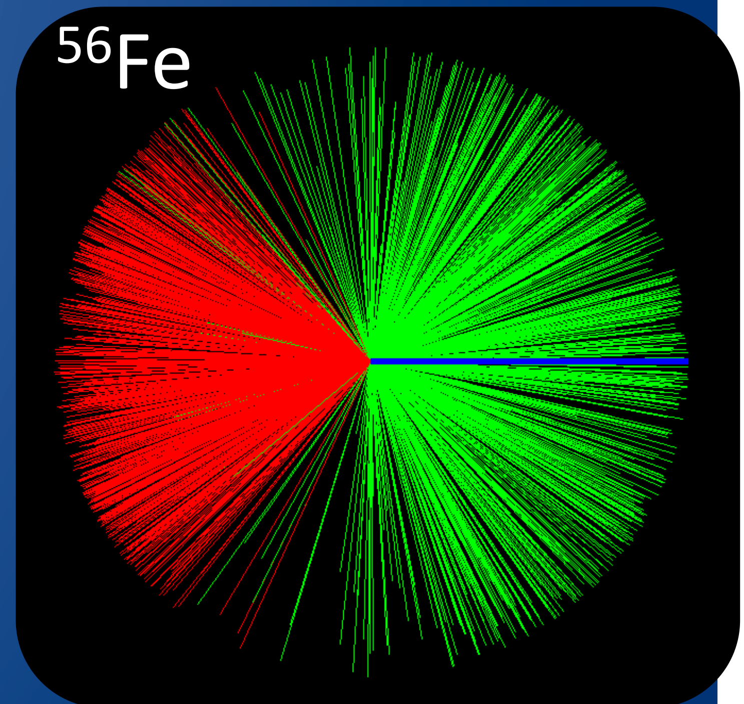
O. Hen et al. (CLAS Collaboration), Phys. Lett. B **772**, 63 (2013)

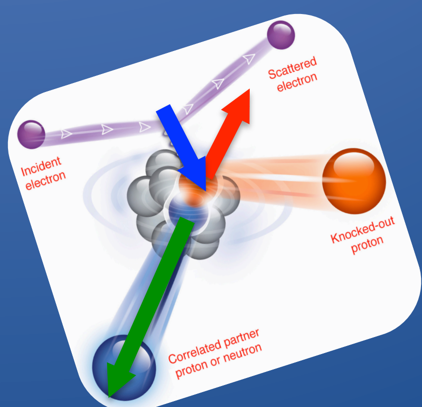
*Quasielstic knockout of high-initial-momentum protons

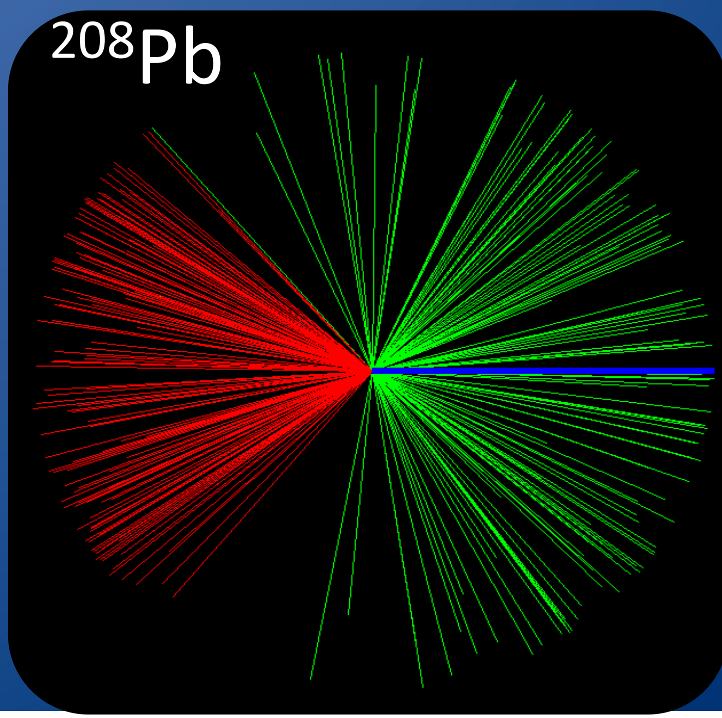
3D Reconstruction





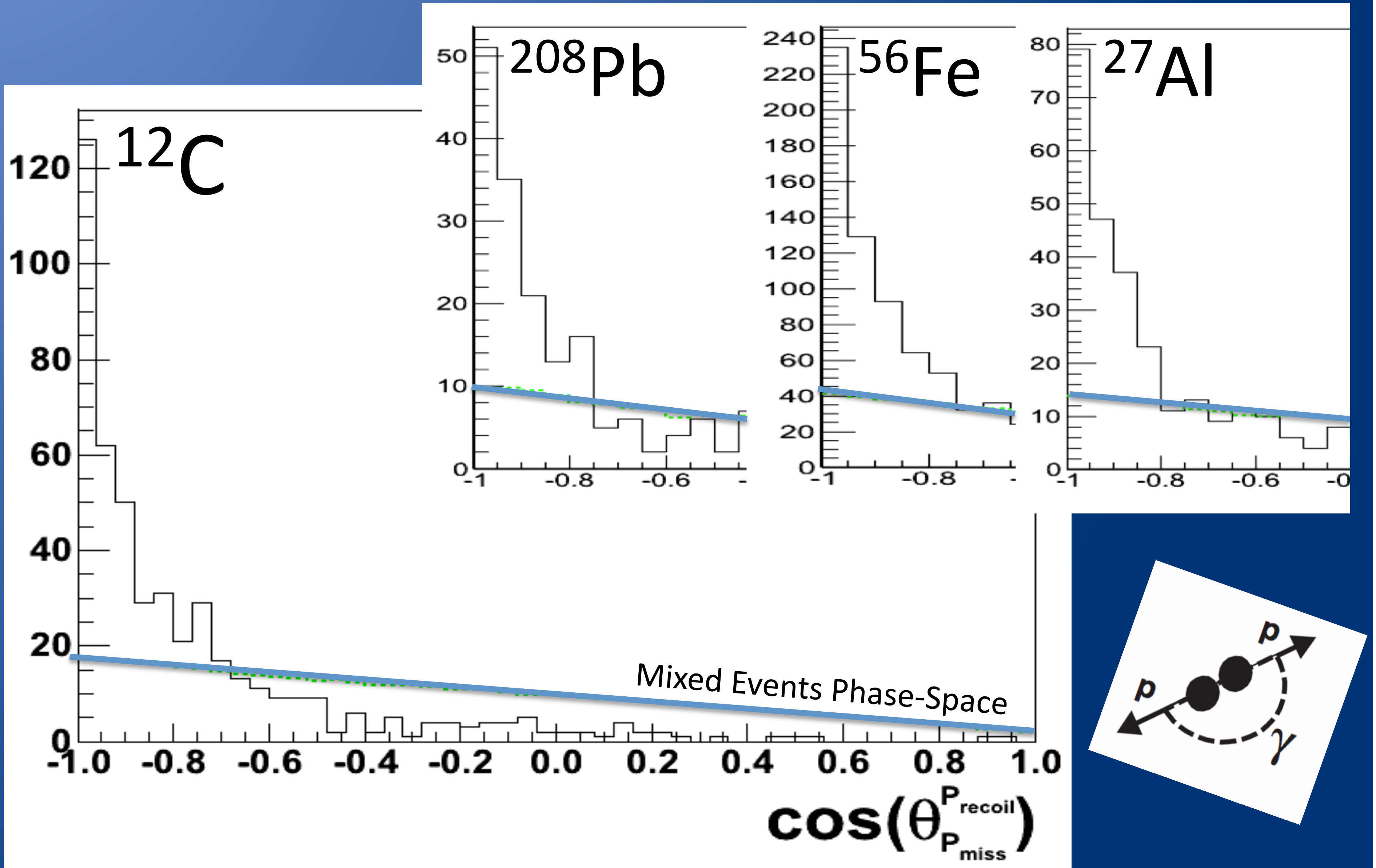




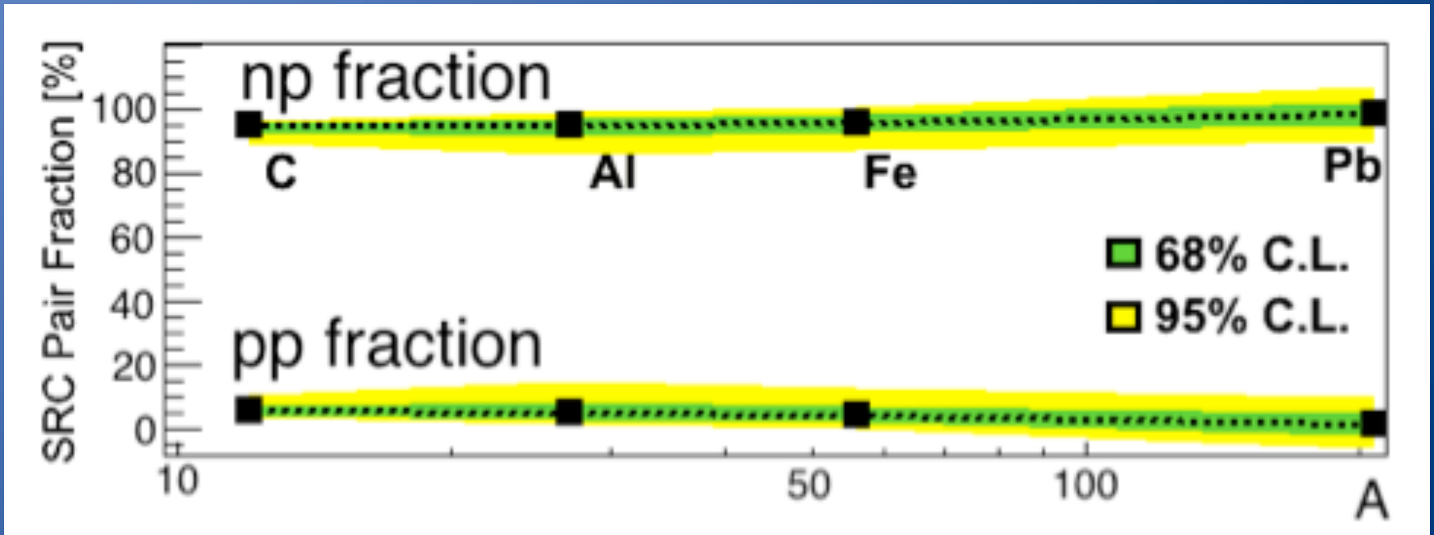


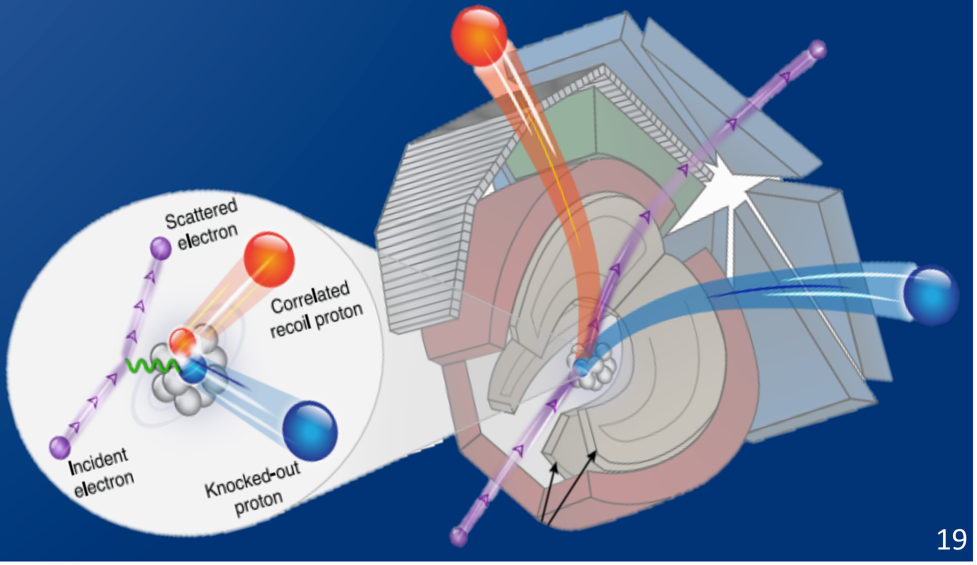
Back-to-back = pairs!

Opening angle



np-pairs also dominate SRC in *heavy (asymmetric)* nuclei

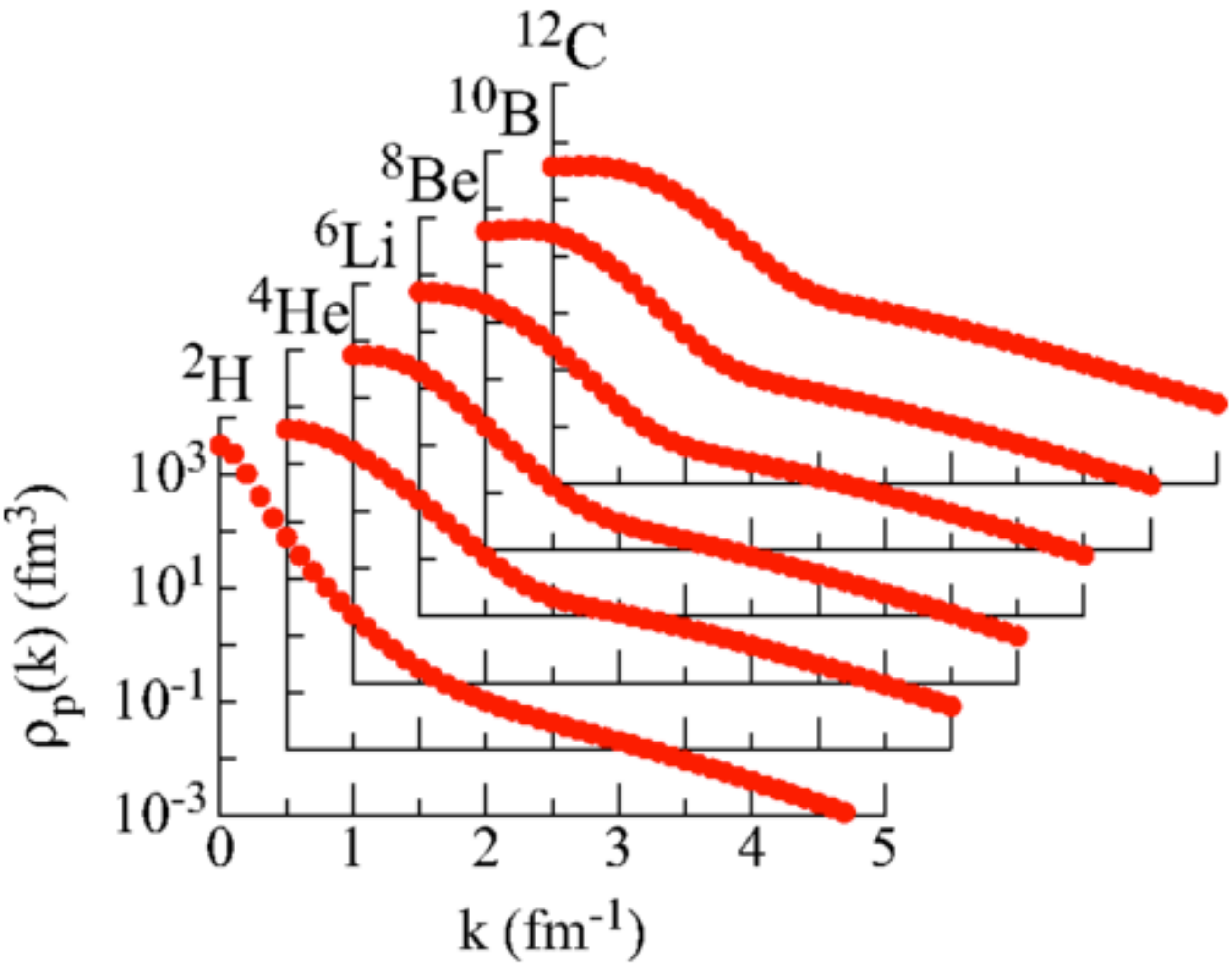




O. Hen *et al.*, Science **346** (2014) 614.

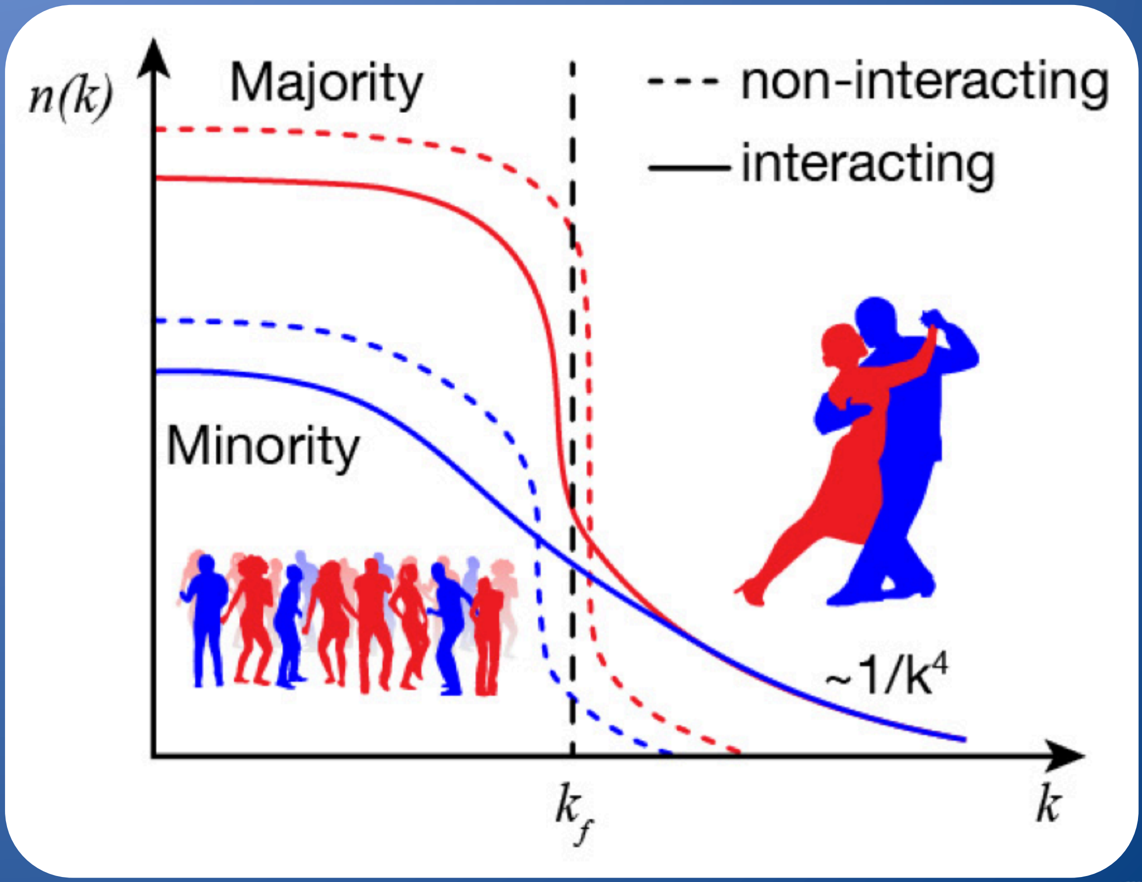
Modern AV18 and Urbana-X Results

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

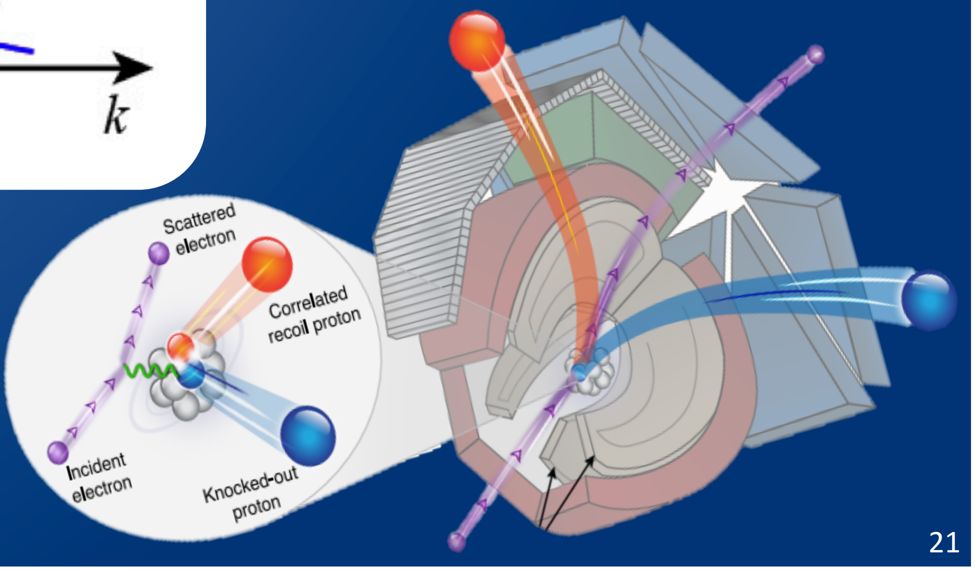


Jefferson Lab

Kinetic Energy Sharing in Asymmetric Nuclei



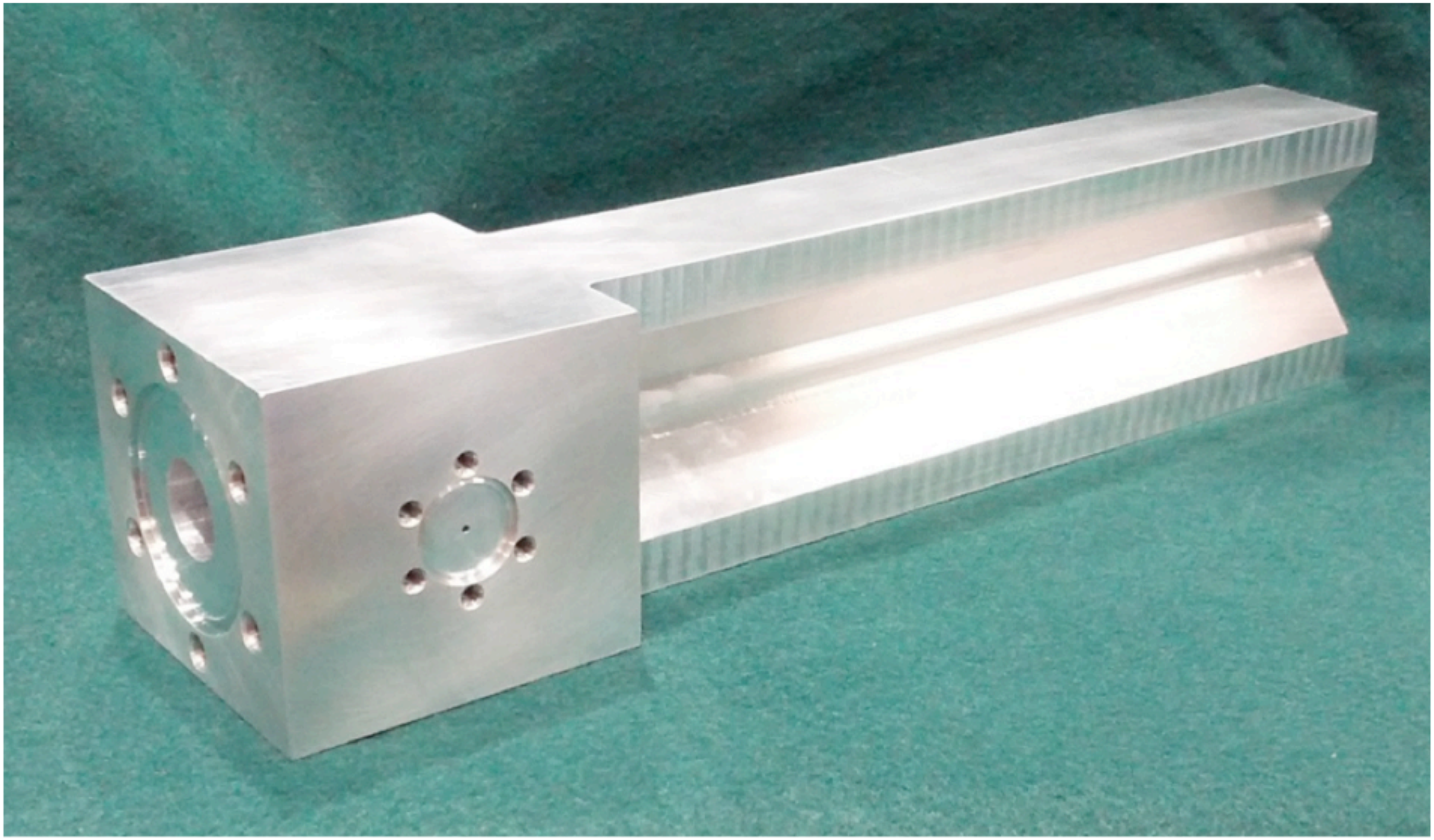
Momentum distribution of imbalanced two-component Fermi system



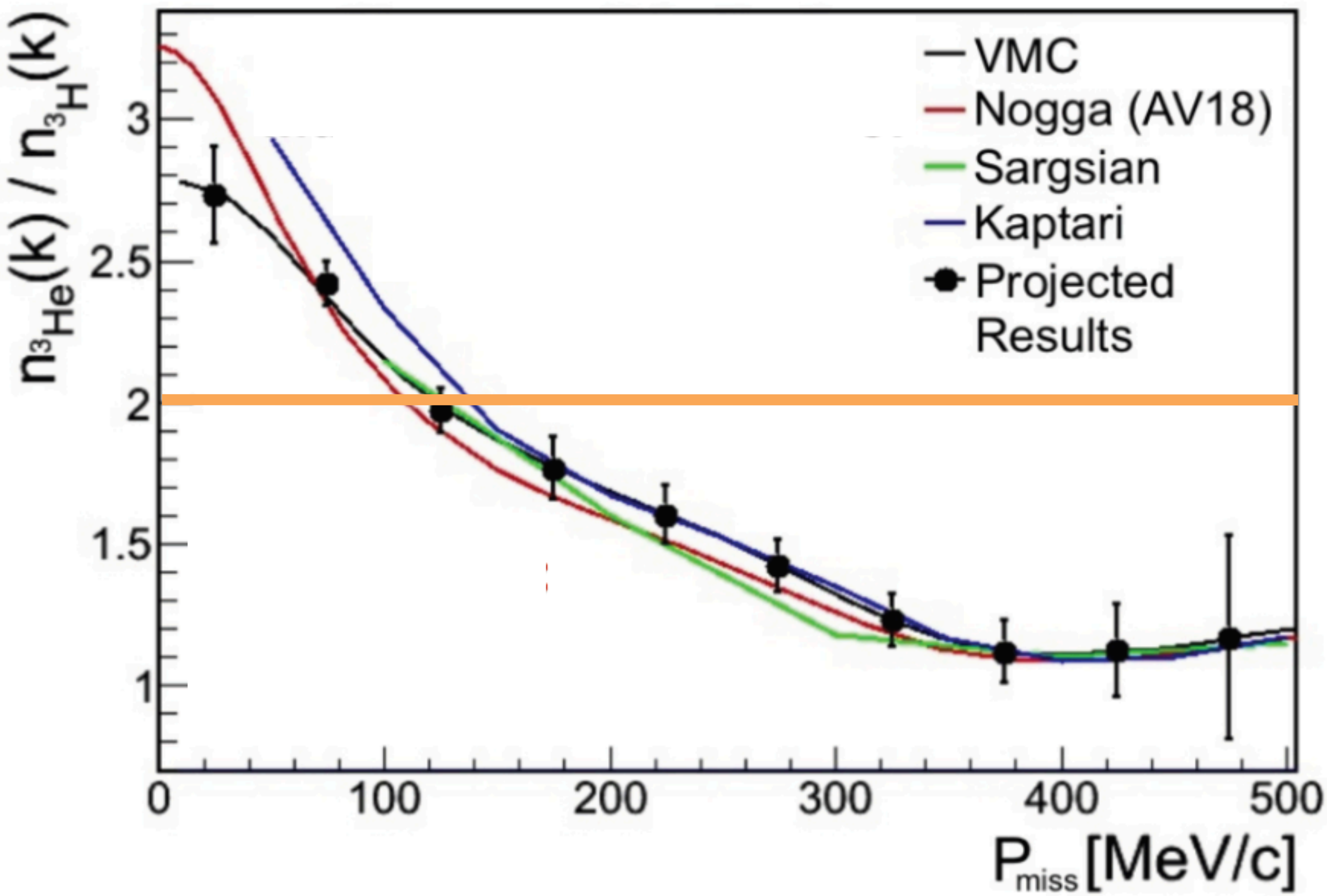
O. Hen *et al*., Science **346** (2014) 614.

Upcoming 3He/3H Experiments

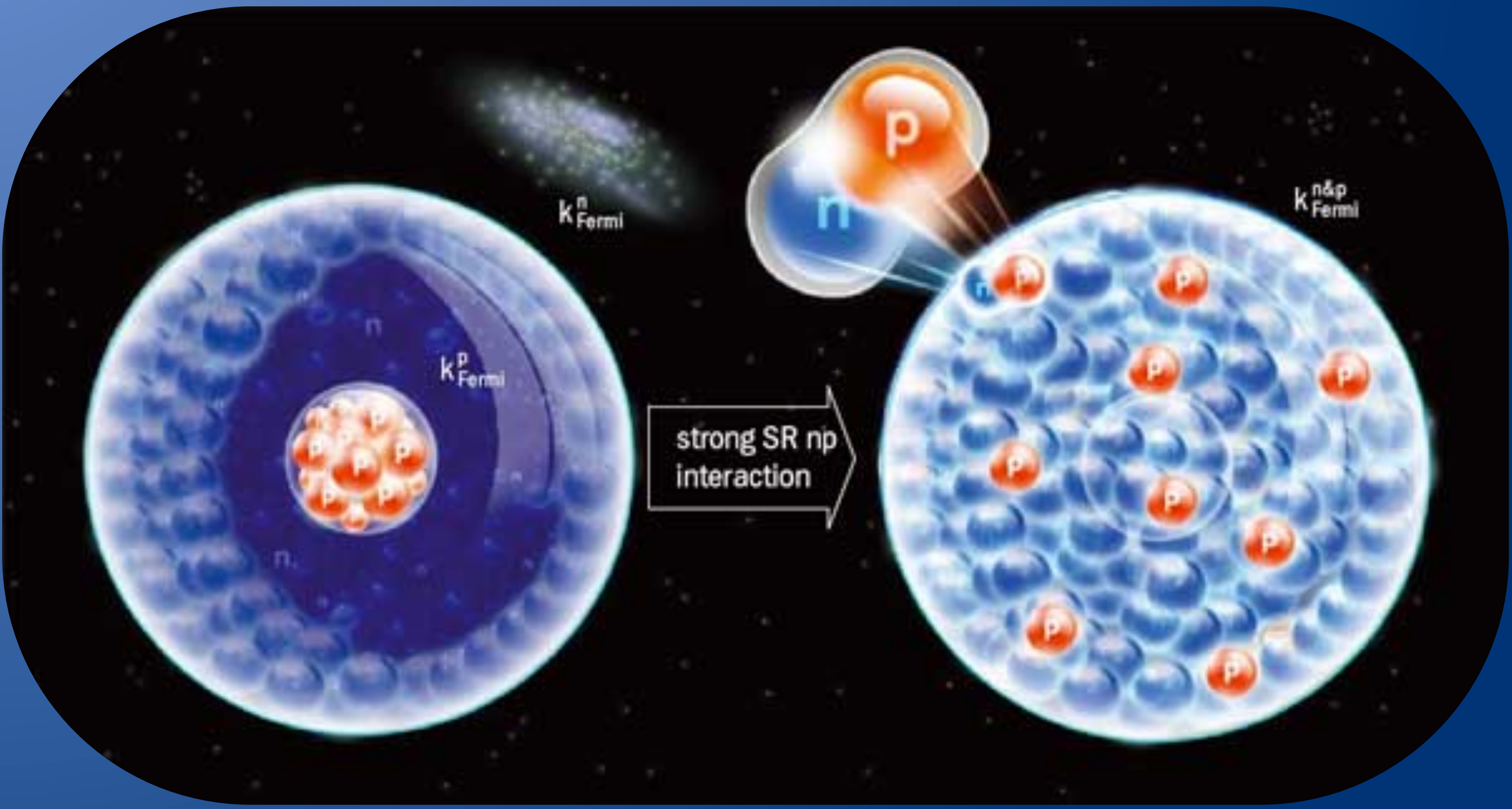
Target Designed by David Meekins



$^3He(e,e'p)/^3H(e,e'p)$ Ratio

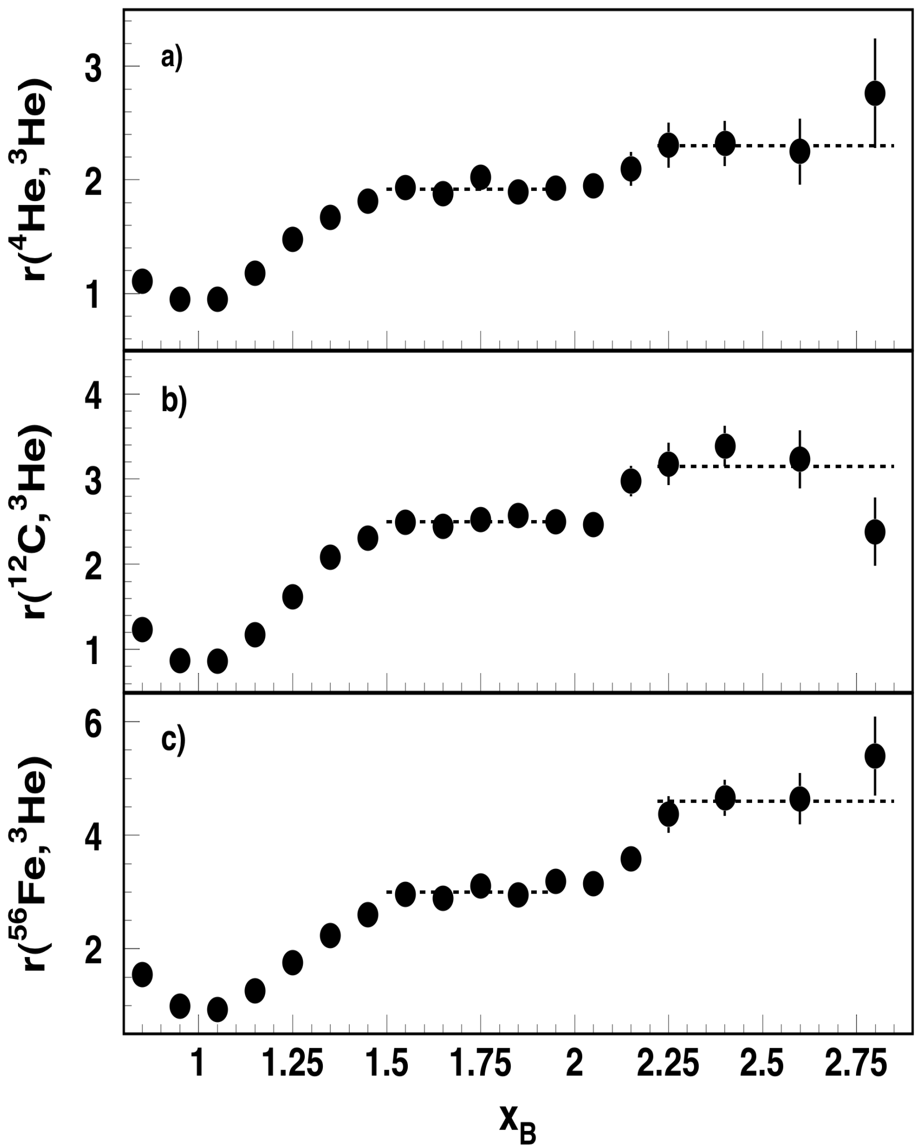


Correlations in Heavy Nuclei

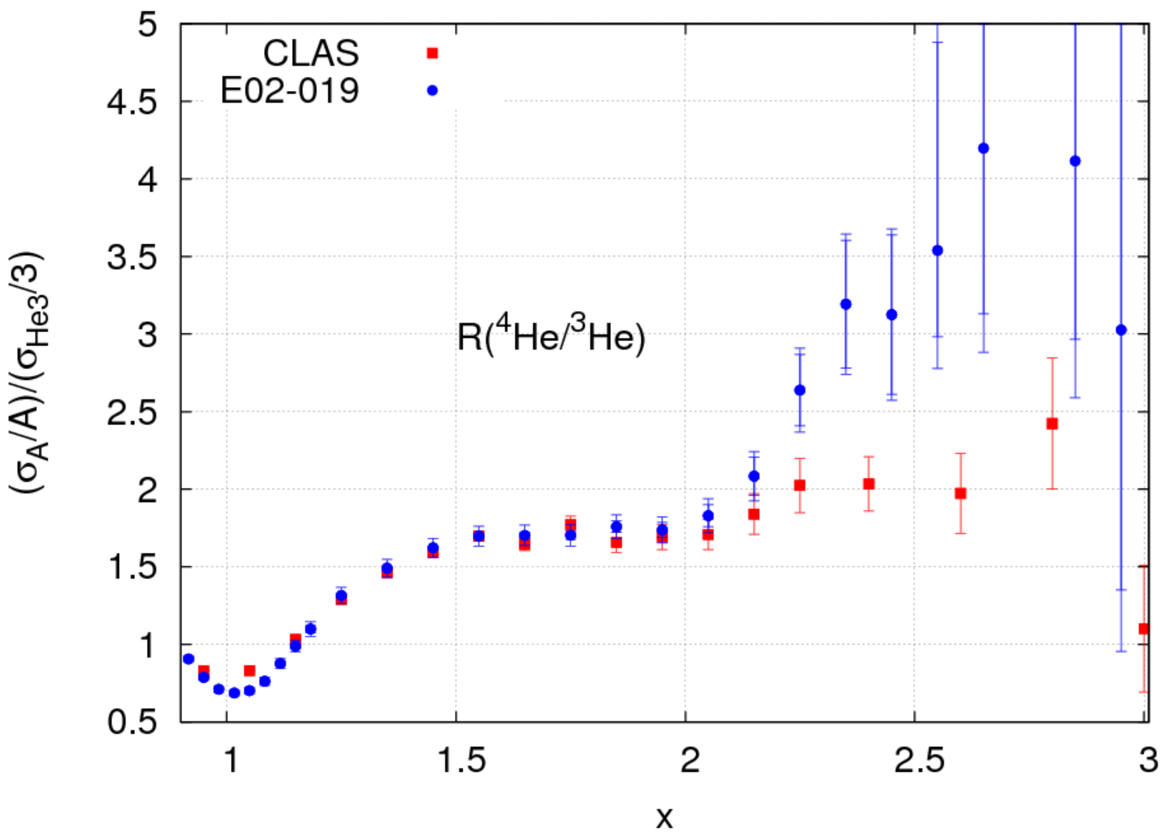


Three Nucleon Correlations

K. Sh. Egiyan *et al.*, Phys. Rev. Lett. **96** (2006) 082501.



BUT Hall B x>2 doesn't agree with Hall C

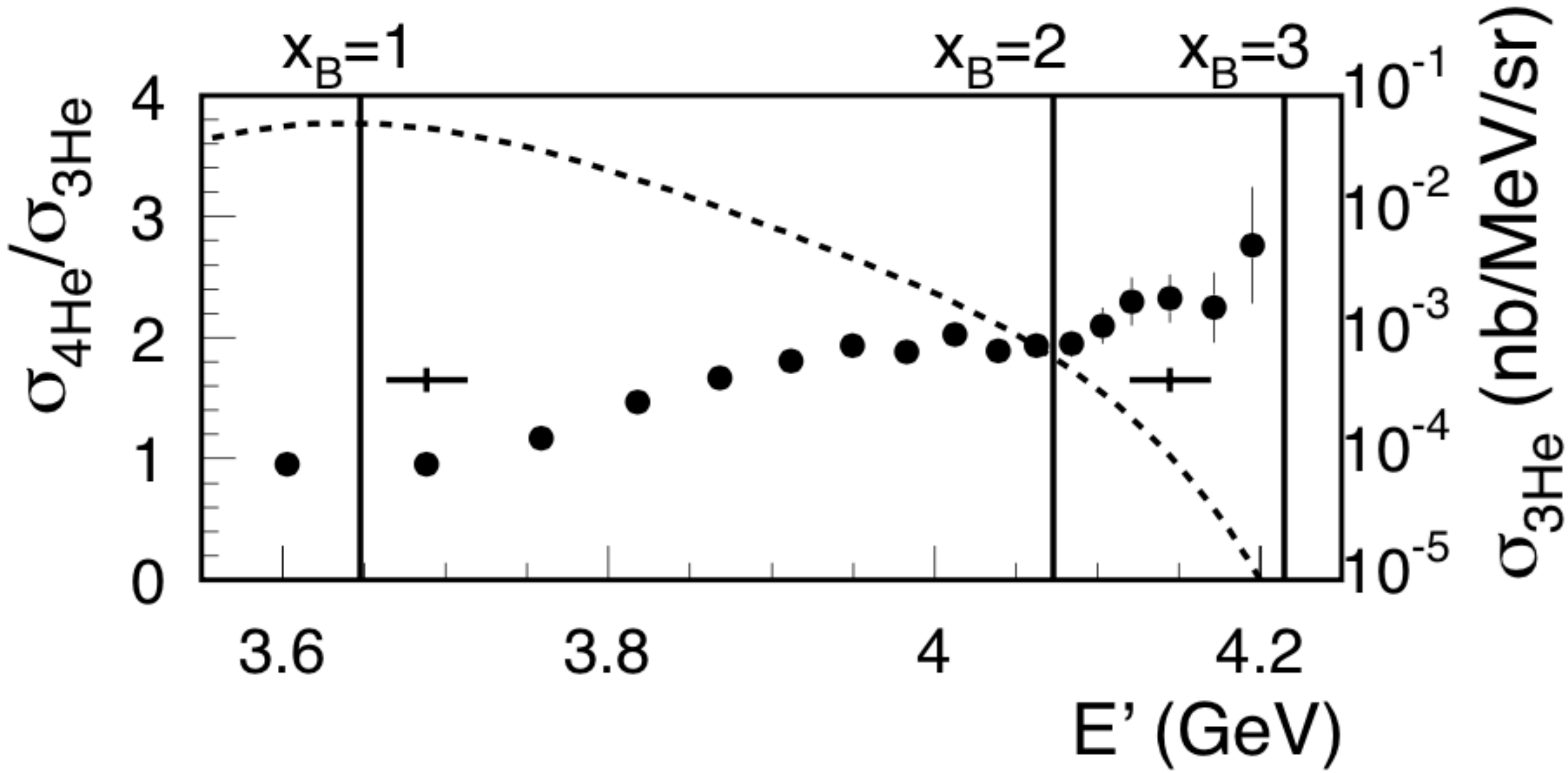


CLAS: 1.4 - 2.6 $[GeV/c]^2$
Hall C: 2.5 – 3.0 $[GeV/c]^2$

- Excellent agreement for x≤2
- Very different shape and error bars in the x>2 region
- **Time for a third measurement!**

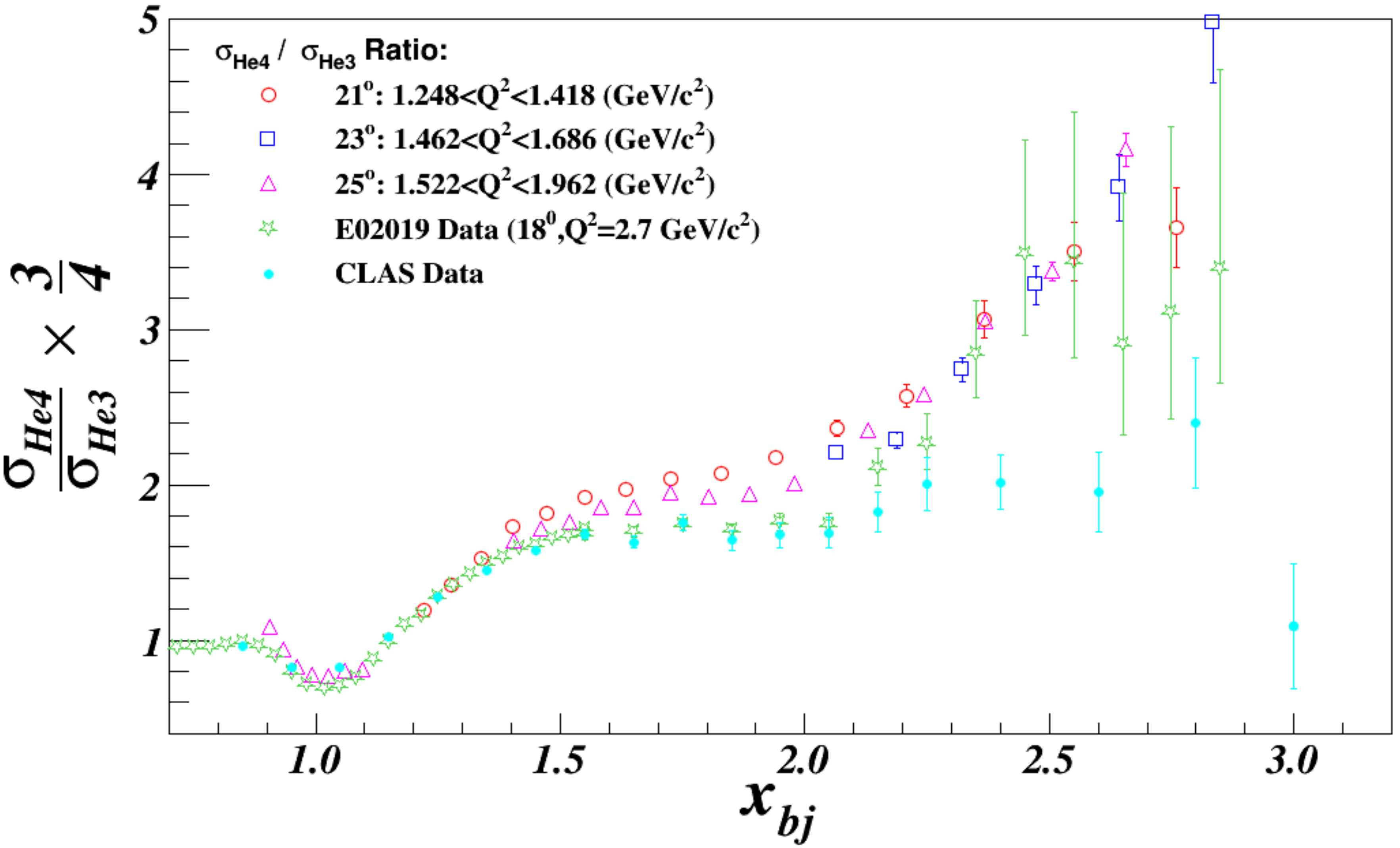
Plotting Egiyan *et al.* Results vs. E’

D. Higinbotham and O. Hen, Accepted by Phys. Rev. Lett. April 2015



Preliminary Hall A Data with B & C

Analysis by Zhihong Ye.

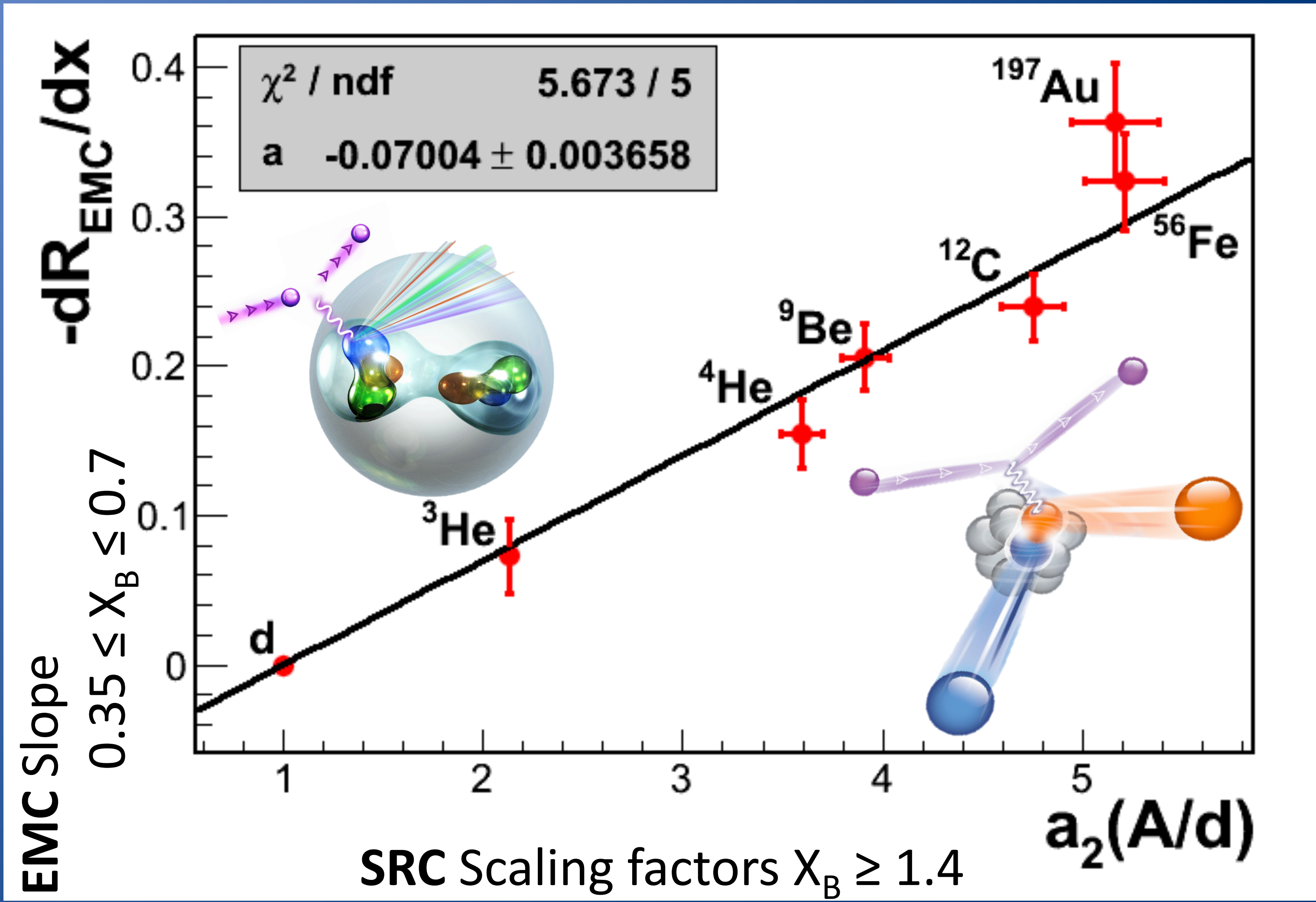


NOTE: CLAS x>2.4 errors are small compared to the Hall C x>2.4 errors.

Summary

- Independent particle model over predicts A(e,e'p)A-1 cross sections and pointed to the need for high momentum particles in the initial-state.
- BUT one cannot directly measure initial-states, so the electron community problem was how see the effect without getting dominated by reaction mechanisms (MEC, FSI, etc.)
- Many Jefferson Lab experiments, (e,e') ratios as well as (e,e'pN), have clearly shown evidence of high momentum initial-states via x>1 scaling plateaus as well as proton-neutron dominance above the Fermi momentum.
- Simple signature of three nucleon-correlations is proving elusive.
- Many New Nuclear Structure Experiments and Results Coming, including ^{3}H & ^{3}He, ^{40}Ca & ^{48}Ca and **^{40}Ar(e,e'p)**.

EMC-SRC Correlation



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