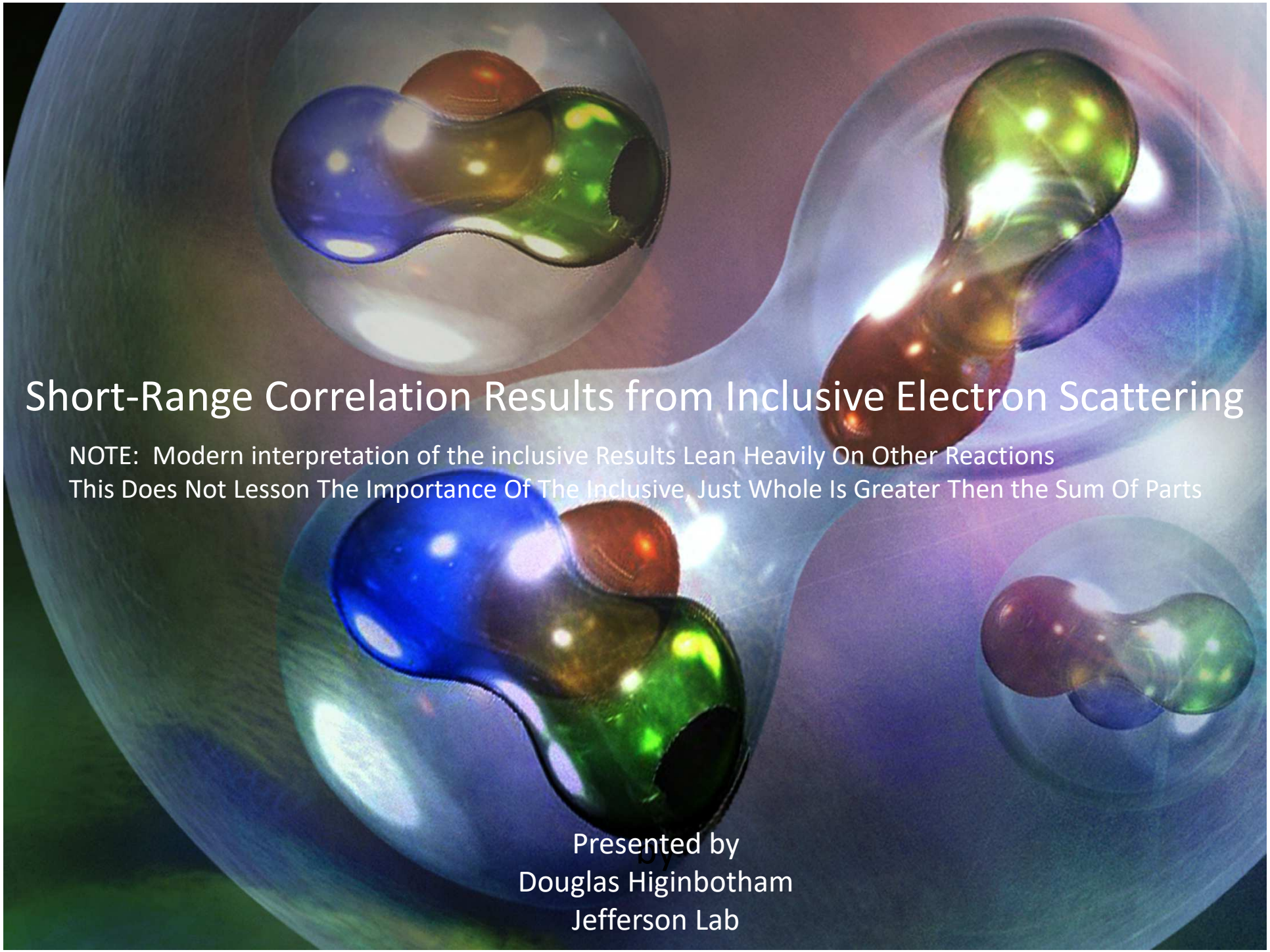


Short-Range Correlation Results from Inclusive Electron Scattering

NOTE: Modern interpretation of the inclusive Results Lean Heavily On Other Reactions
This Does Not Lesson The Importance Of The Inclusive, Just Whole Is Greater Then the Sum Of Parts

Presented by
Douglas Higinbotham
Jefferson Lab

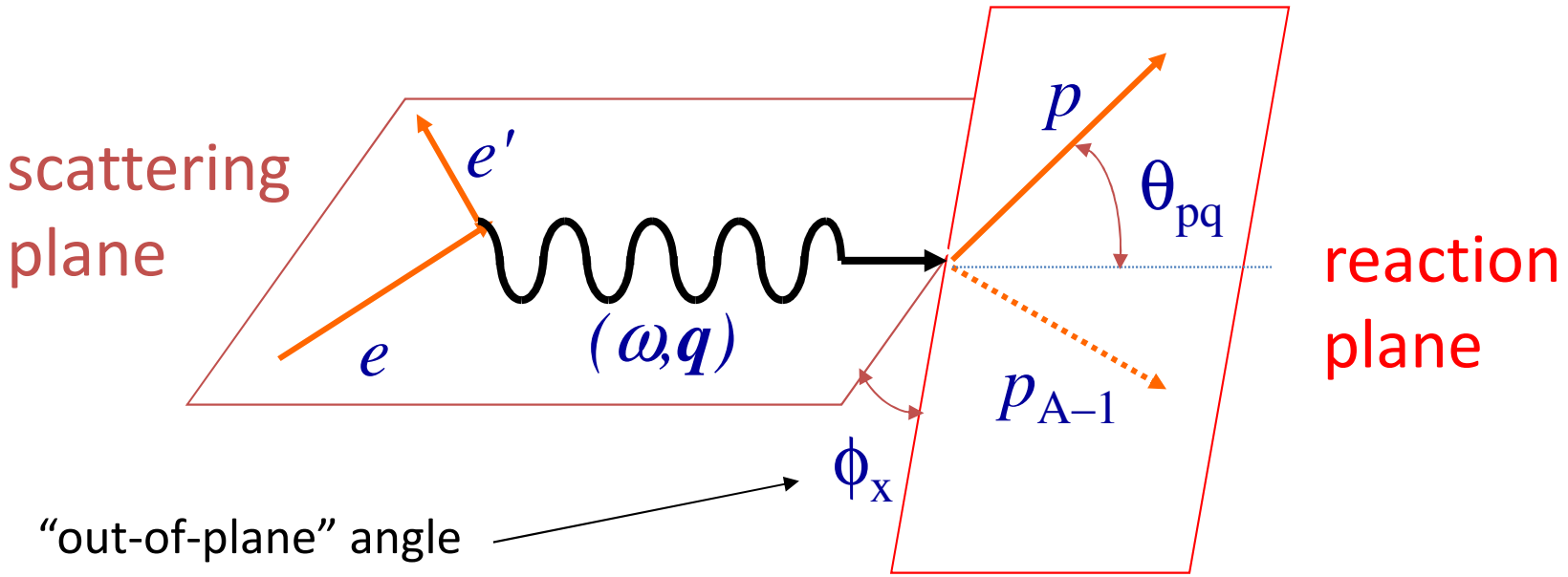
Important Acknowledgement:

Several key people who have been working on this topic that couldn't make it to this meeting and sent me slides and/or had useful discussions with me:

Dr. Burcu Duran
Prof. Nadia Fomin
Dr. Shujie Li
Dr. Dien Nguyen
Dr. Dave Gaskell
Dr. John Arrington
and almost Dr. Casey Morean

My apologies to anyone I forgot to list!

(e,e'p) Electron Scattering Kinematics



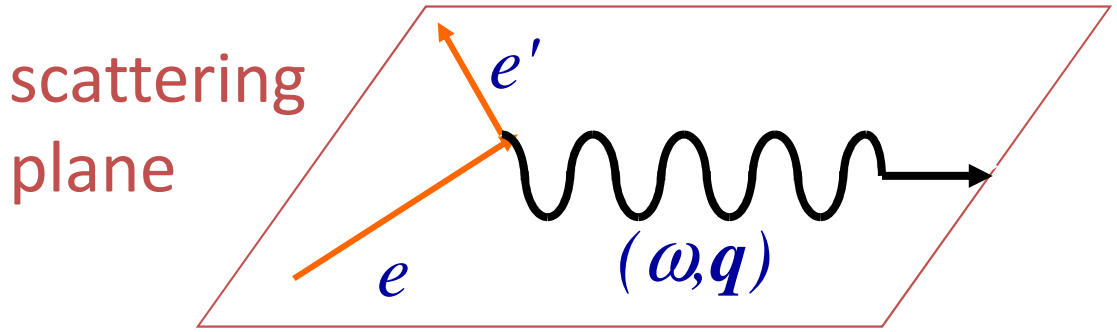
Four-momentum transfer: $Q^2 \equiv -q_\mu q^\mu = \boldsymbol{q}^2 - \omega^2$

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

Energy Transfer: ω = e – e'

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

(e,e’) Electron Scattering Kinematics

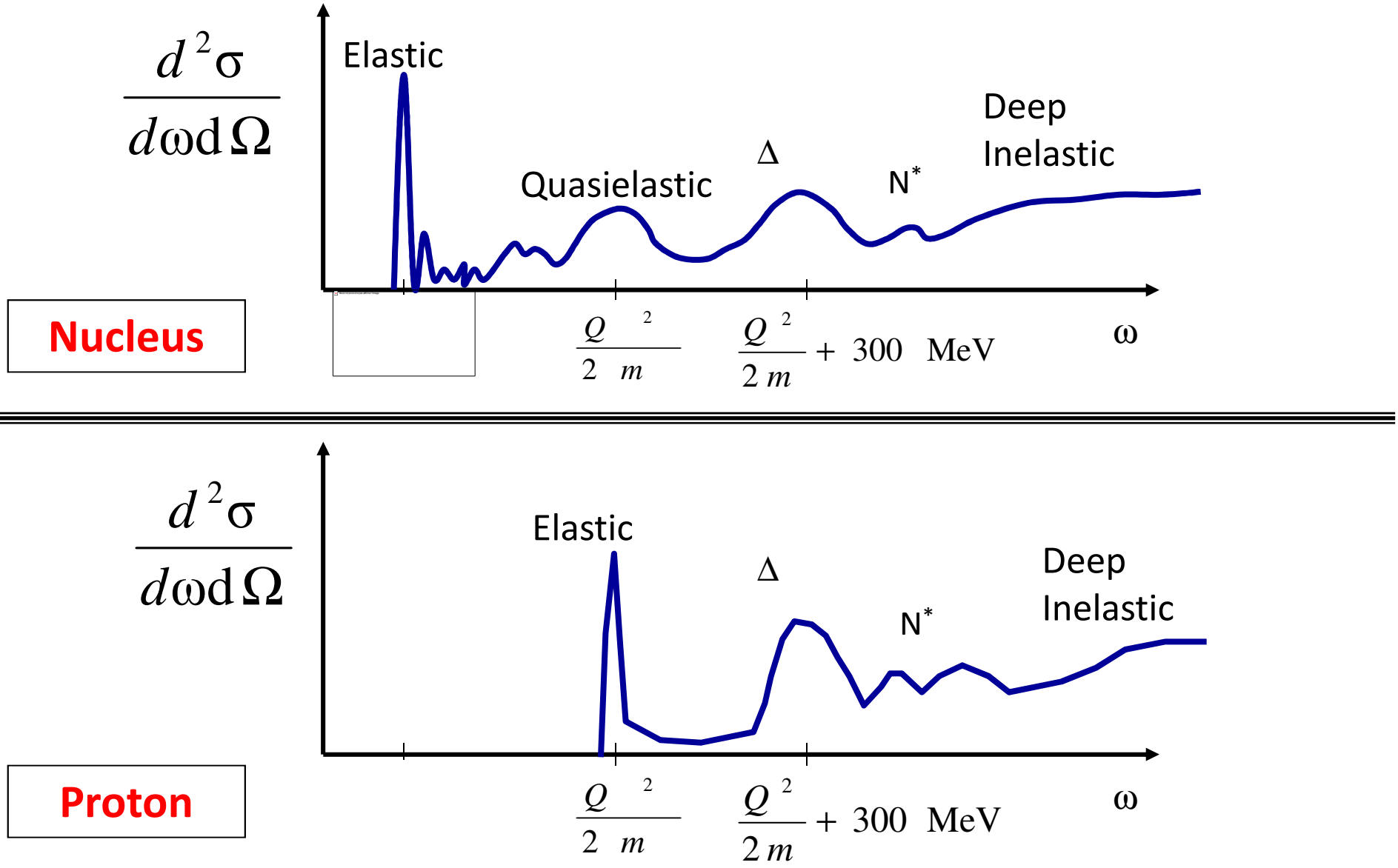


Four-momentum transfer: $Q^2 \equiv -q_\mu q^\mu = \boldsymbol{q}^2 - \omega^2$

Energy Transfer: ω = e – e’

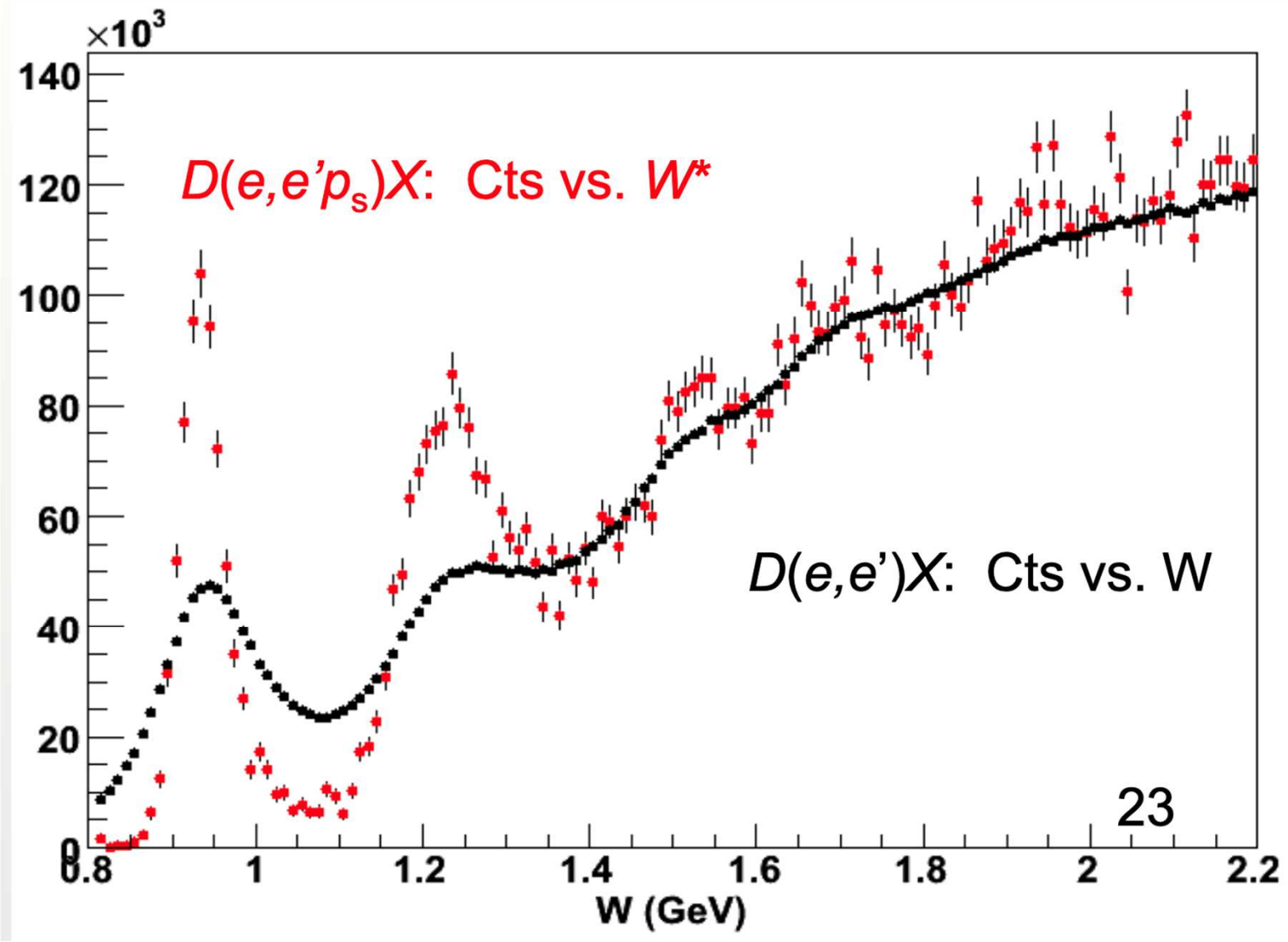
Bjorken x: $x_B = Q^2/2m\omega$ ***(determined by kinematics)***

A(e,e') at Fixed Q^2 vs. ω



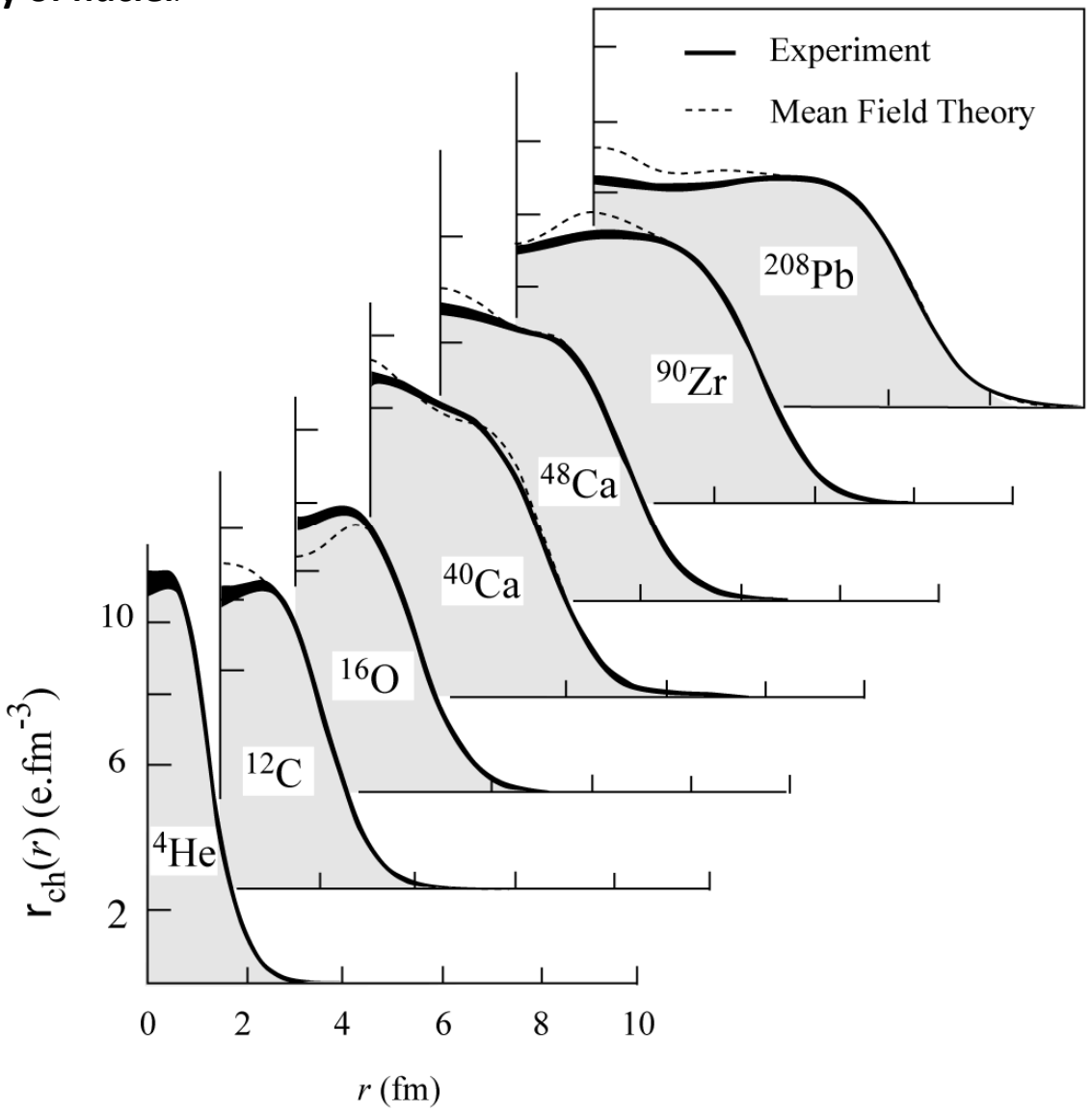
Real Electron Scattering Data

Data from the BONUS Experiment in CLAS / Hall B at Jefferson Lab



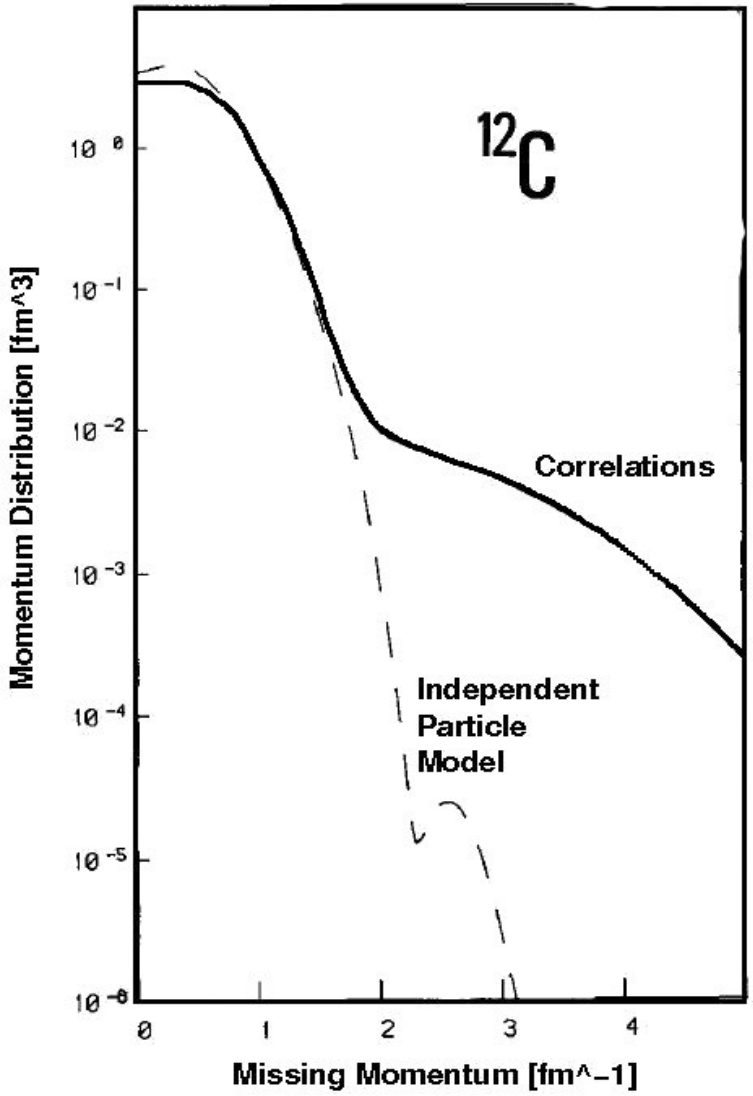
Nuclear Charge Distributions

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



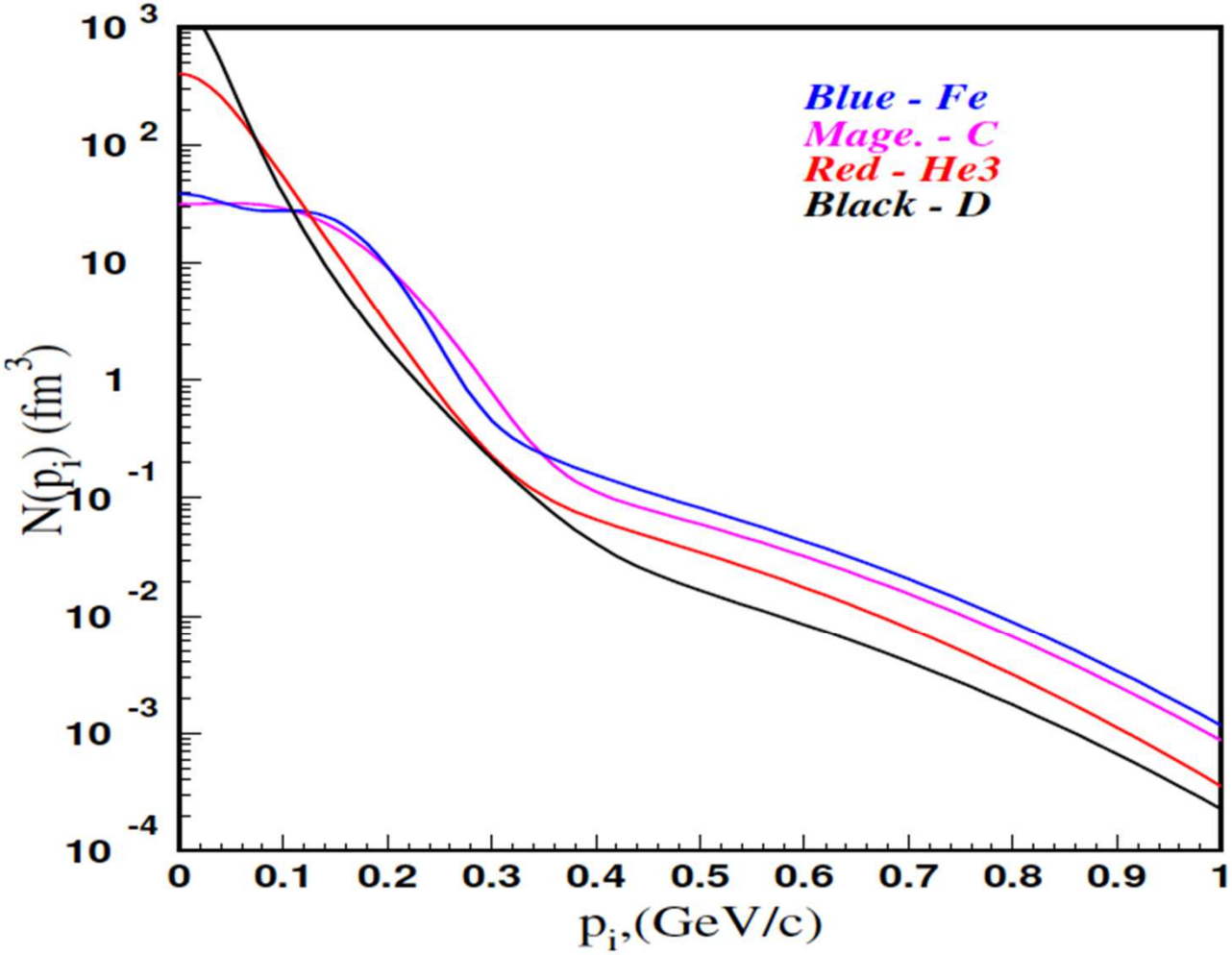
Realistic Momentum Distribution

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



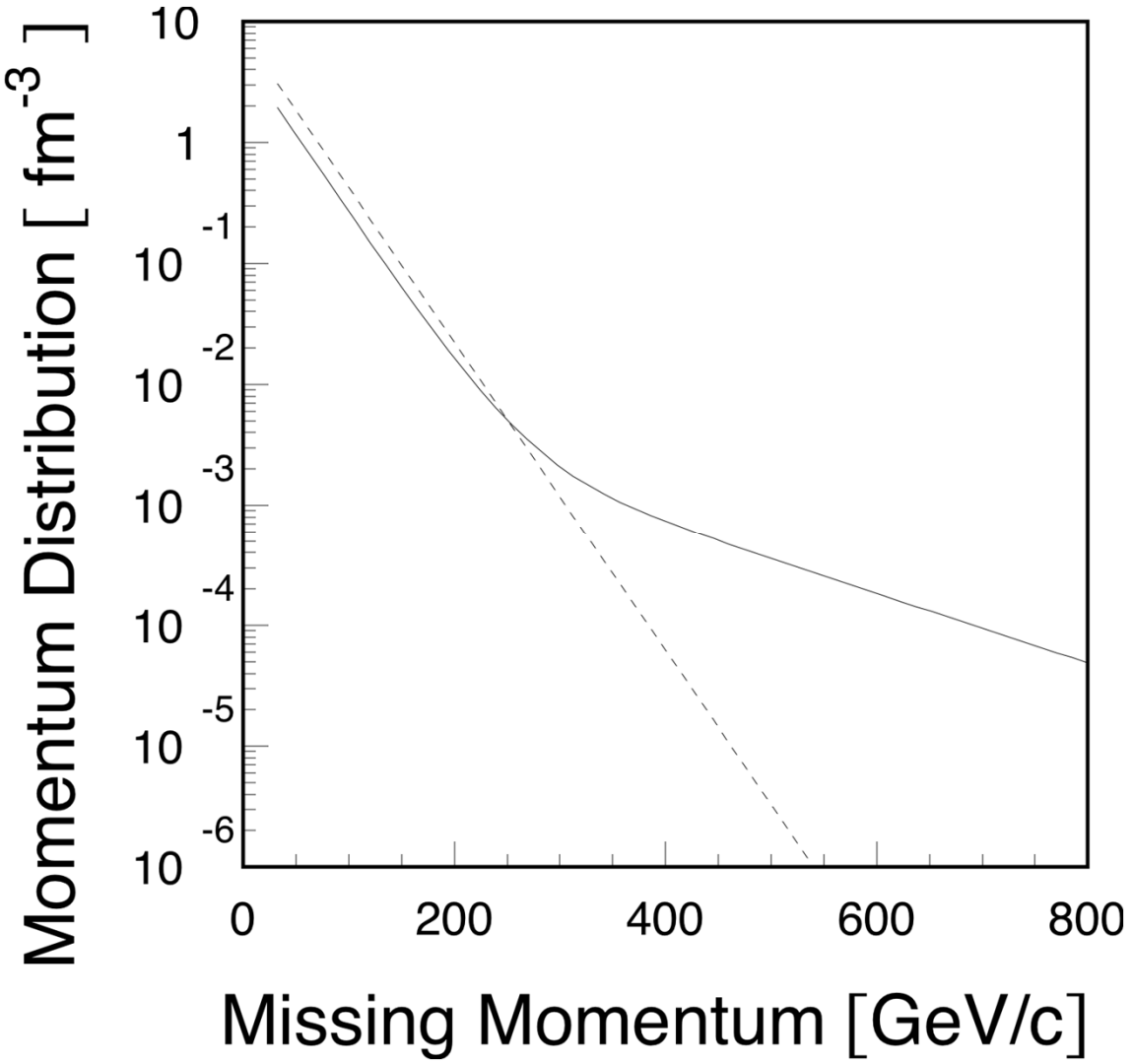
Momentum Distributions

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



At high initial momentums $\mathbf{n_A(p) = a_{2n}\, n_D(p)}$

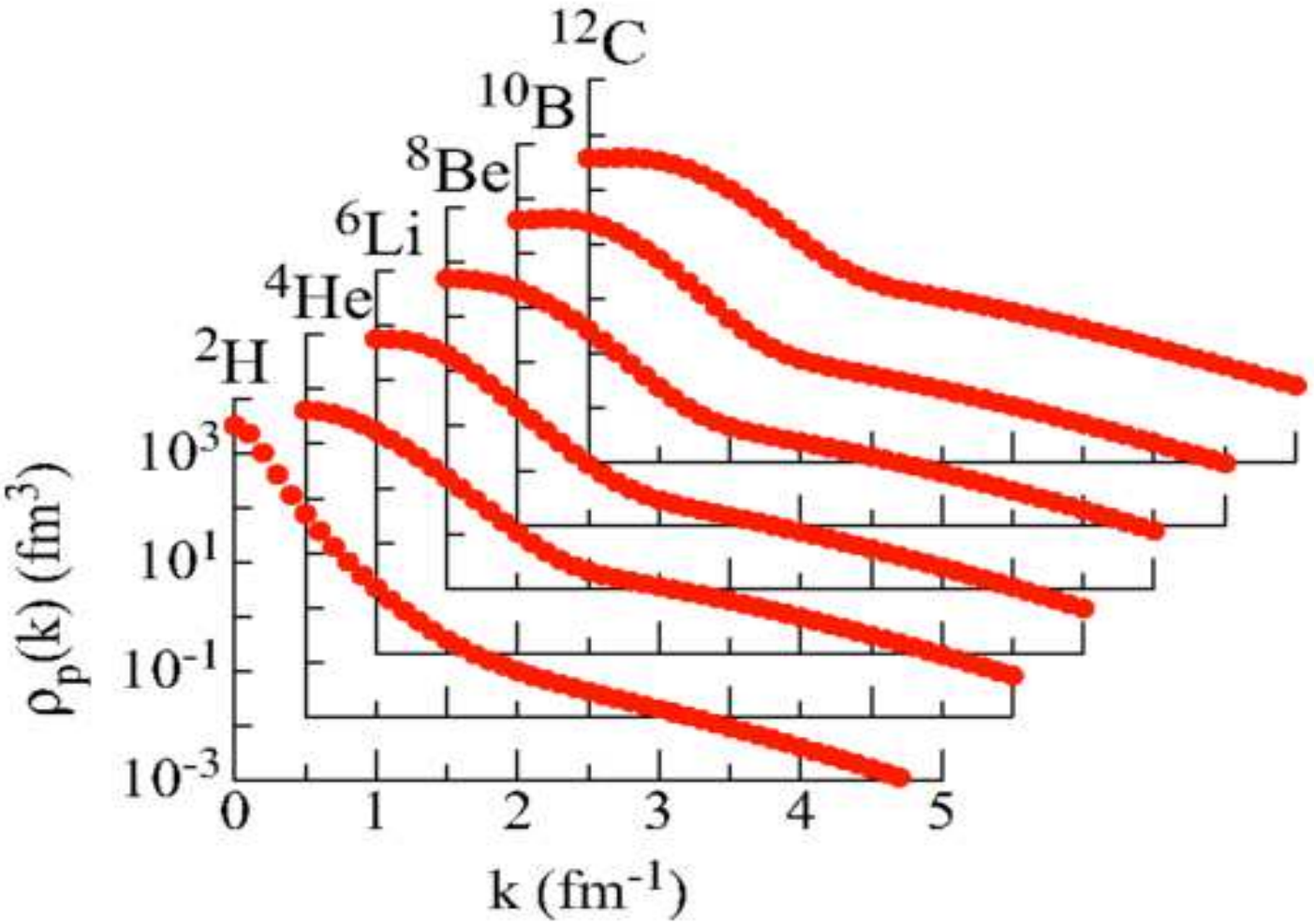
A Toy Model Momentum Distribution



By Uncertainty Principle High Momentum Region Dominated by Short Distance Phenomena

Modern AV18 and Urbana-X Results

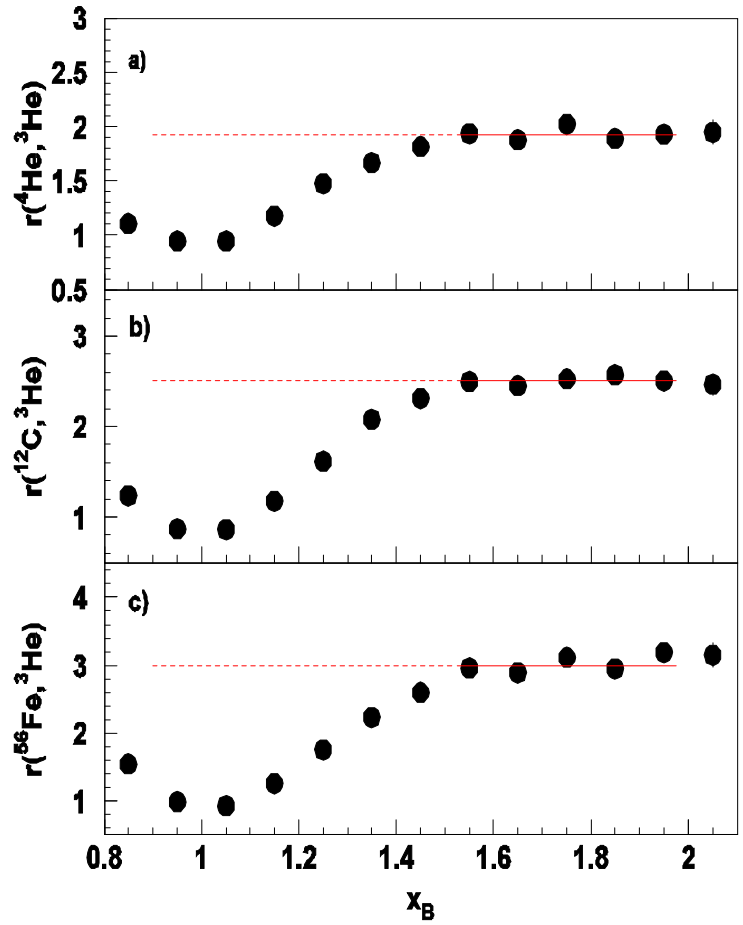
R. Wiringa, R. Schiavilla, S. Pieper, and J. Carlson, Phys. Rev. C89 (2014) 024305.



Example of Nuclear Scaling Plateaus

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

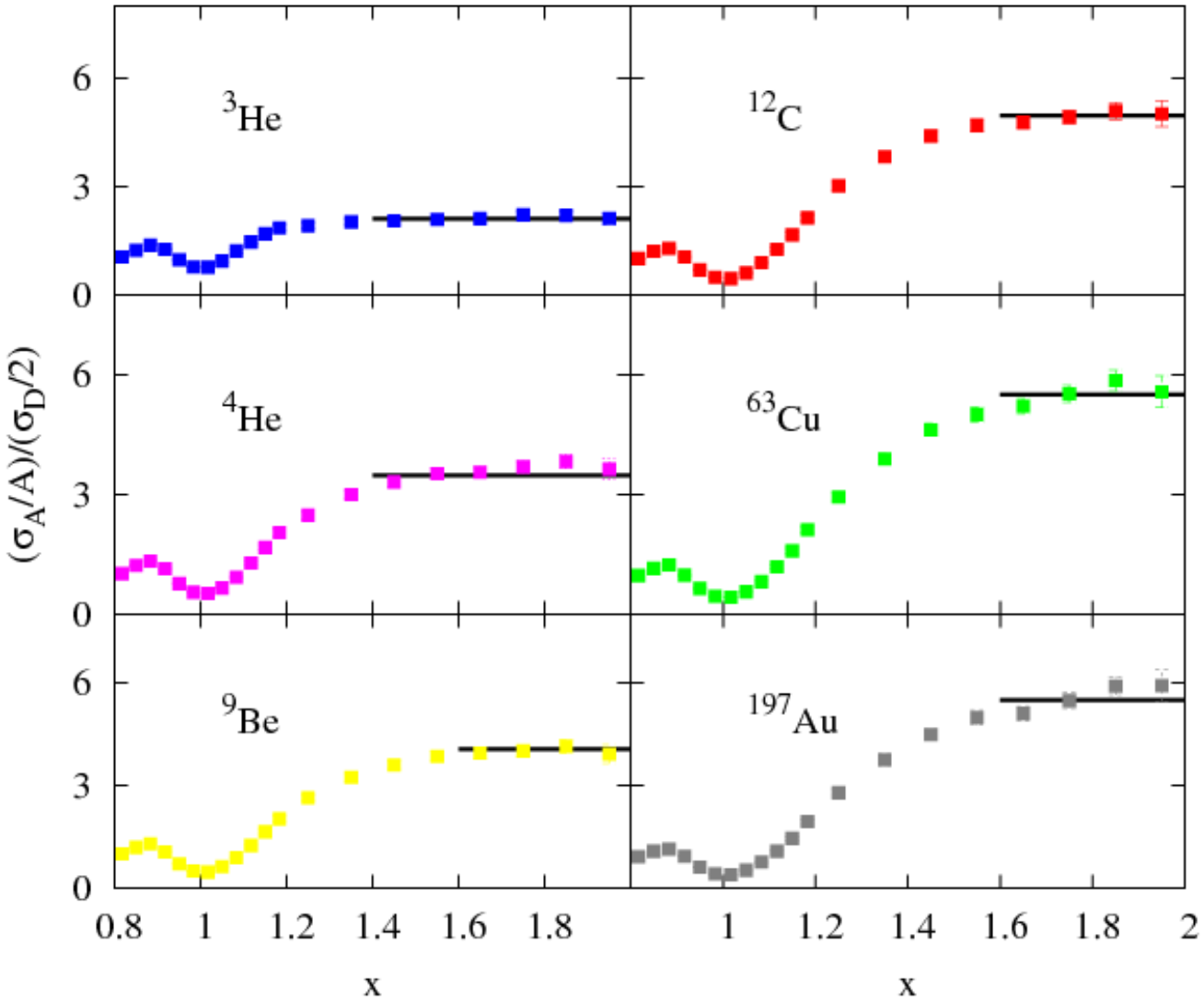
Originally done with SLAC data by D.B. Day *et al.*, Phys. Rev. C 48 (1993) 2451-2461.



These two papers are highlighted as [Physical Review C 50th Anniversary Milestones]

6 GeV Jlab Results From Hall-C

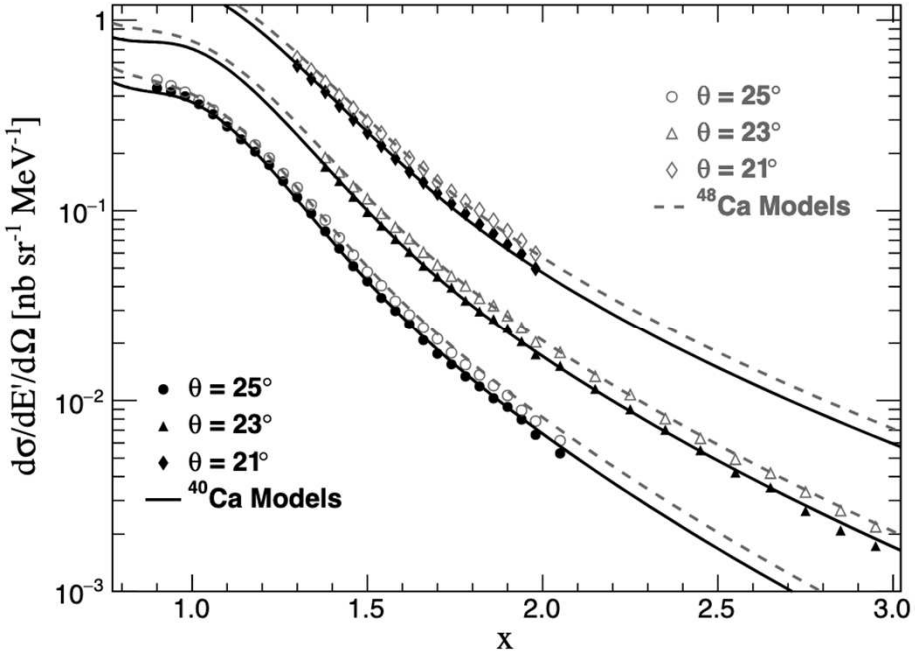
N. Fomin *et. al,* Phys. Rev. Lett. 108 (2012) 092502.

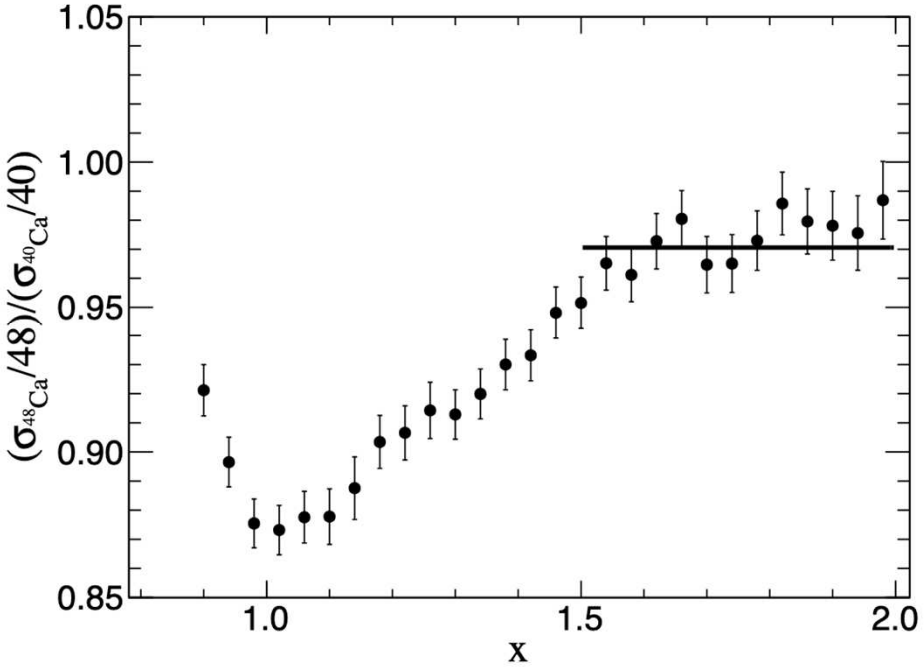


Q^2=2.5 [GeV/c]^2

Measurement of ^{40}Ca and ^{48}Ca

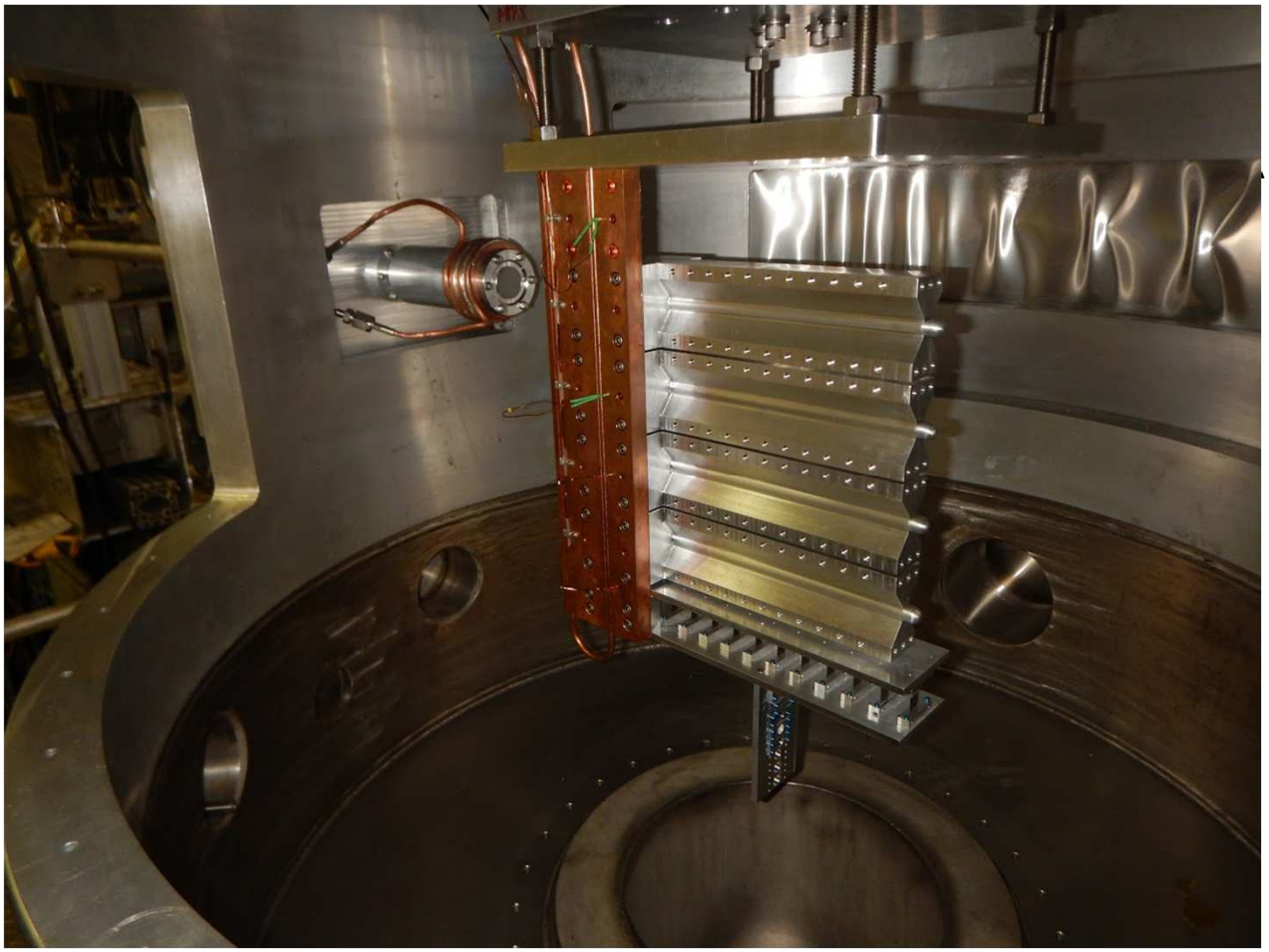
D. Nguyen et al., *Phys.Rev.C* 102 (2020) 064004

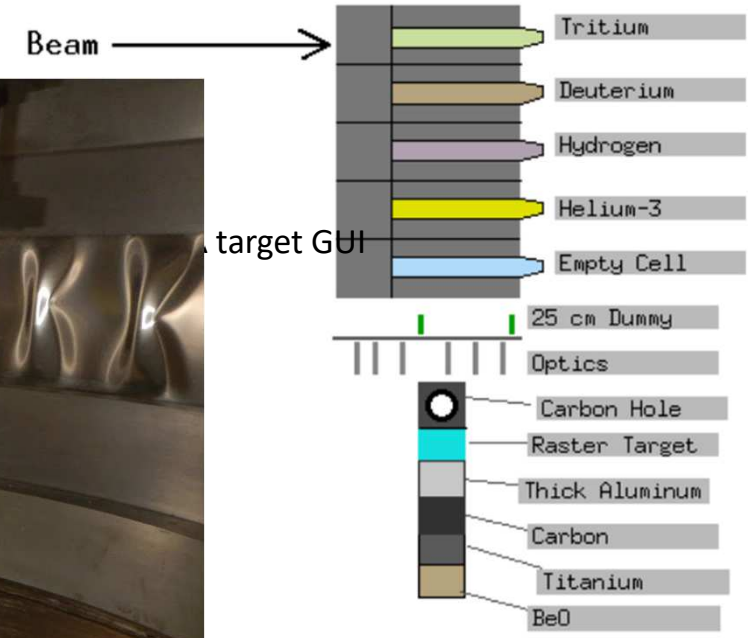




NOTE: It was noted in this work that of the 3H/3He ratio would be 0.75 for isospin independence and 1 for np dominance.

Hall A Tritium Gas Target System

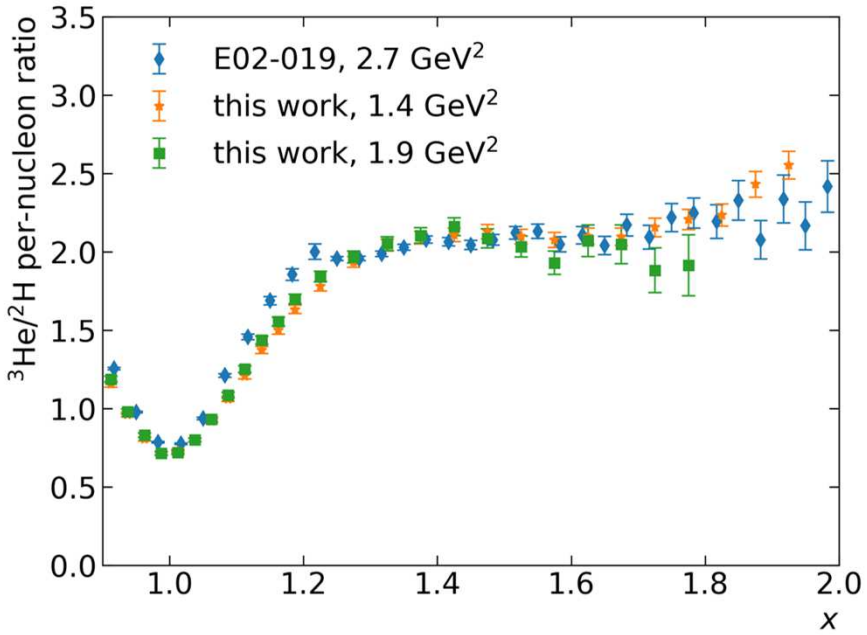


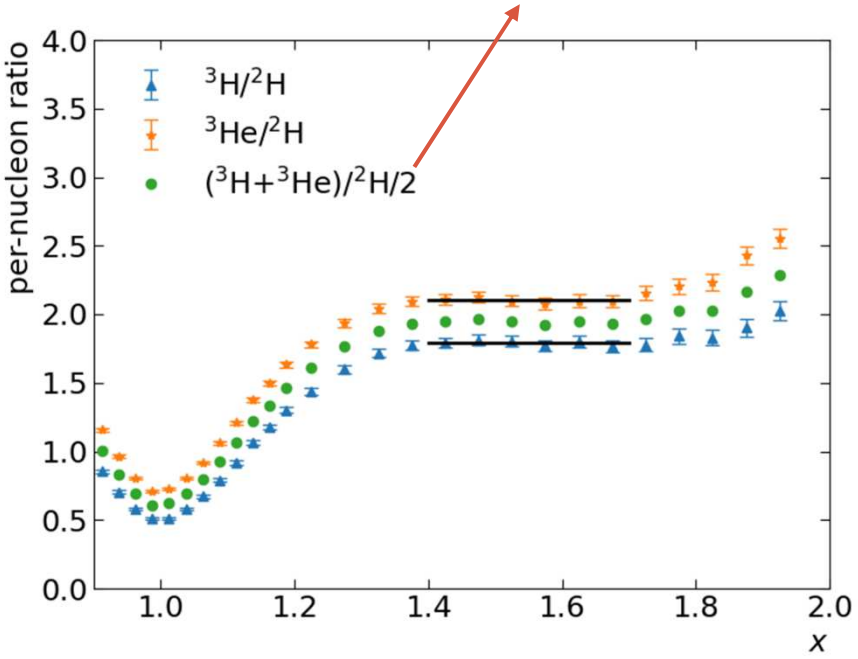


Plateaus in A/D ratios

Yield ratio to cancel systematic uncertainties!

will be combined with MARATHON EMC results to study EMC-SRC relation





E02-019 data from N. Fomin *et. al,* Phys. Rev. Lett. 108 (2012) 092502.

16

Extract np/pp SRC Fraction From 3H/3He Ratio

S. Li *et al.,* Nature **609** (2022) 41–45.

$$\frac{\sigma_{^3H}}{\sigma_{^3He}} = \frac{N_{np}\sigma_{np} + N_{pp}\sigma_{nn}}{N_{np}\sigma_{np} + N_{pp}\sigma_{pp}}$$

Offshell elastic xsection (de Forest "cc1")

$\sigma_{np} = \sigma_{ep} + \sigma_{en}, \sigma_{pp} = 2\sigma_{ep}$

number of pp to np pairs ratio （Assume the same in tritium and helium-3)

$R_{pp/np} = N_{pp}/N_{np}$

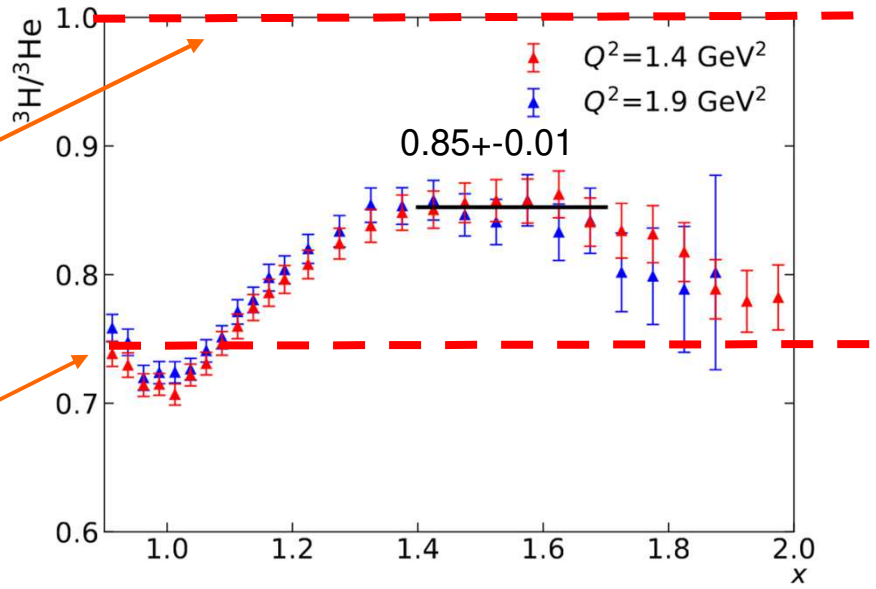
$$\frac{\sigma_{^3H}}{\sigma_{^3He}} = \frac{1 + \sigma_{p/n} + 2R_{pp/np}}{1 + \sigma_{p/n}(1 + 2R_{pp/np})}$$

if np dominance:

$R_{pp/np} = 0 \rightarrow \frac{\sigma_{^3H}}{\sigma_{^3He}} = 1$

if no isospin preference:

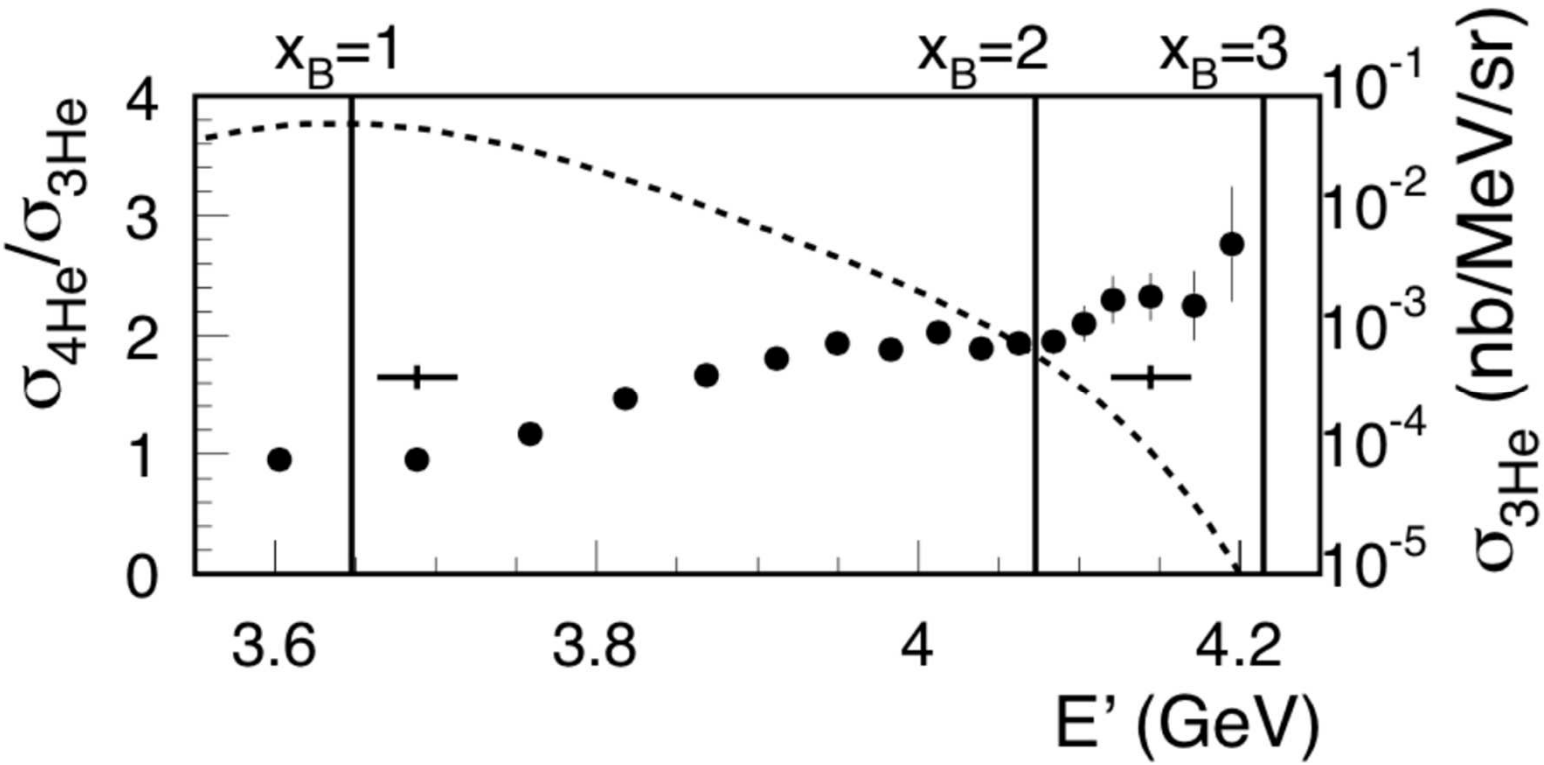
$R_{pp/np} = 0.5, \sigma_{p/n} = 2.55 \rightarrow \frac{\sigma_{^3H}}{\sigma_{^3He}} = 0.75$ ing



This result implies a complex structure in the high-momentum wavefunction of 3H & 3He.

Three Nucleon Correlations (not yet)

DH and Or Hen, Phys. Rev. Lett. 114 (2015) 16, 169201.



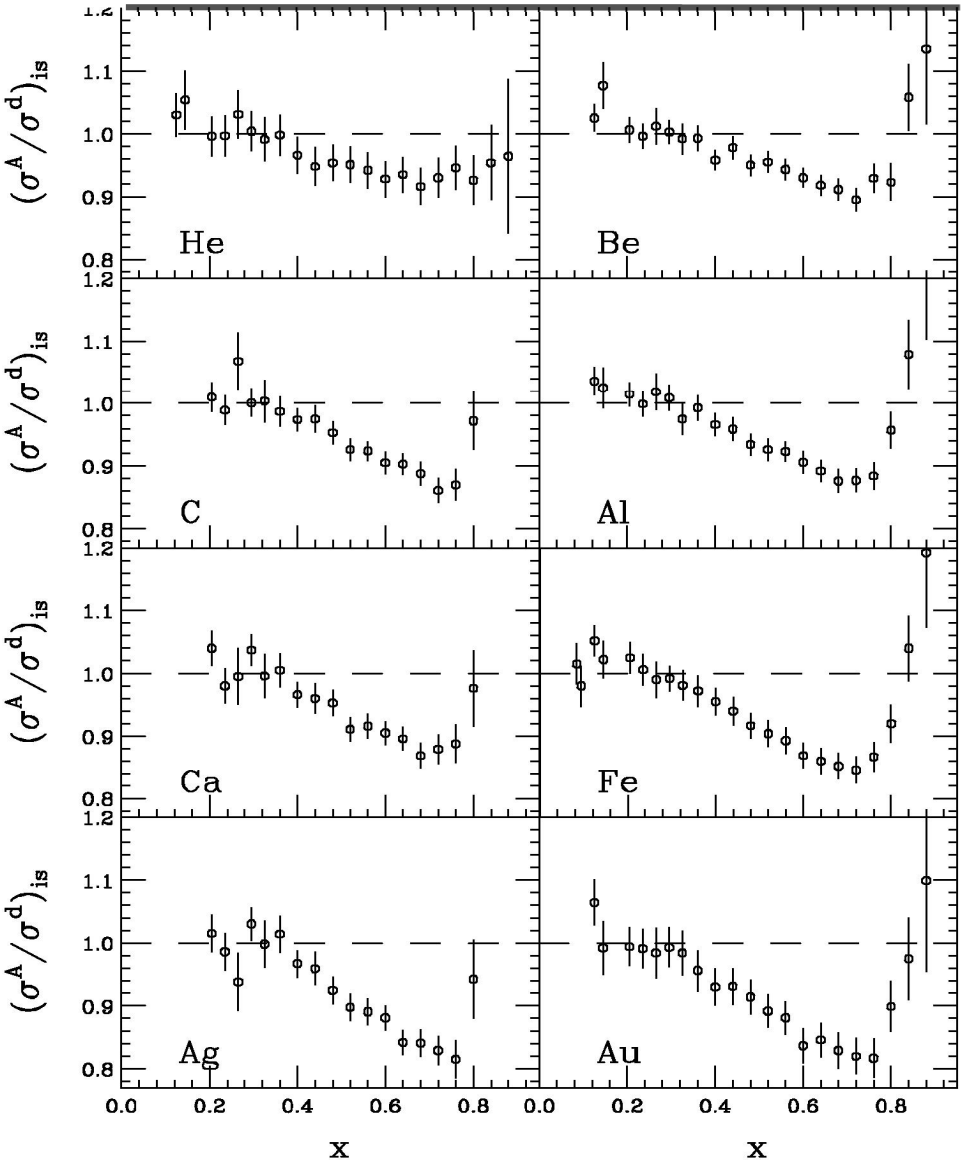
New High Q2, x>2 data being taken in Hall C right now.

Donal B. Day, Leonid L. Frankfurt, **Misak M. Sargsian, Mark I. Strikman**, Phys.Rev.C 107 (2023) 014319
Shows we should use alpha 3N instead of x_B and predicts the new data should see 3N plateaus.


And now for something completely different

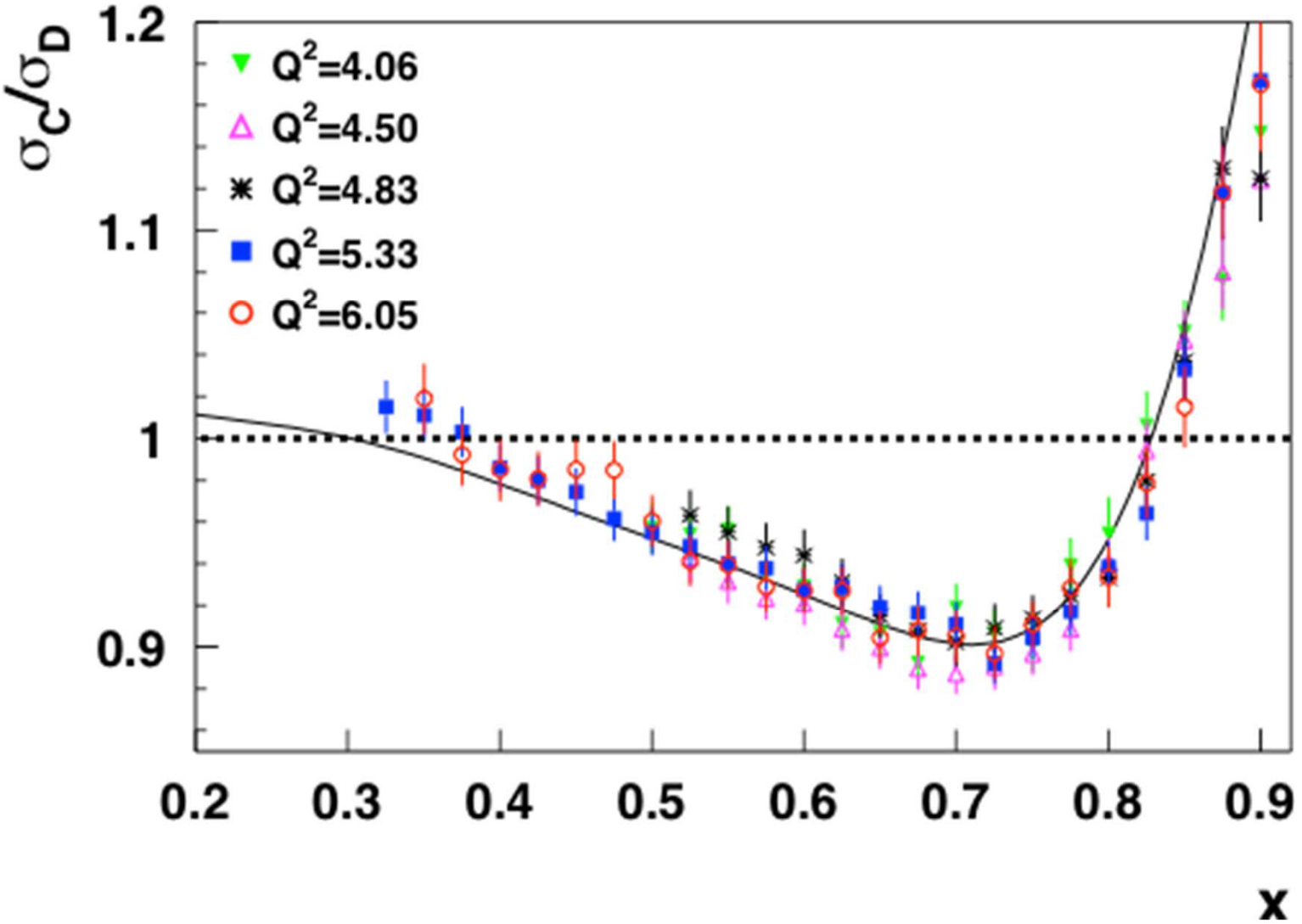
The EMC Effect

- **EMC effect is simply the fact the ratio of DIS *inclusive* 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



New Jefferson Lab EMC Effect Data

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



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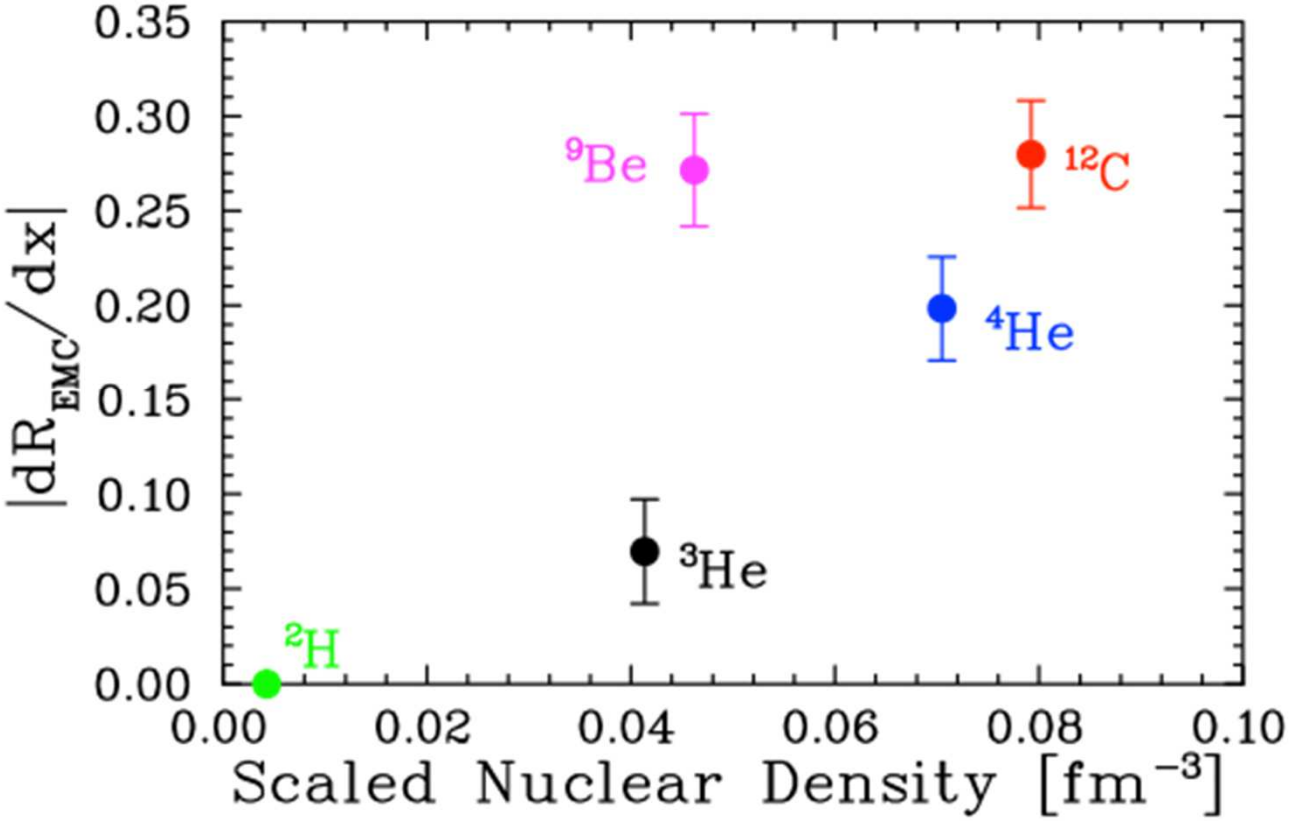
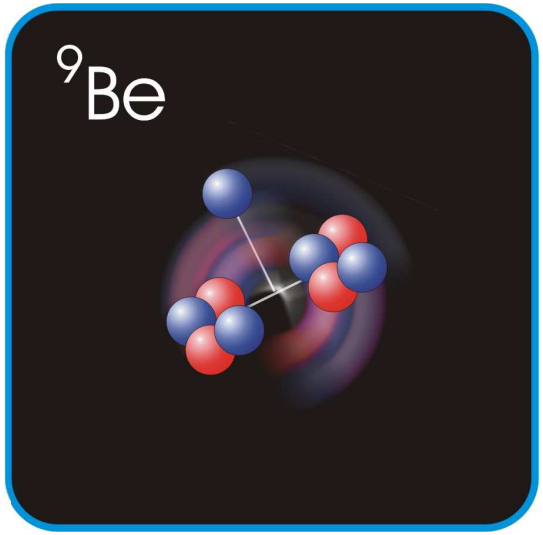
J. Seely *et al.*, Phys, Rev. Lett. **103** (2009) 202301.

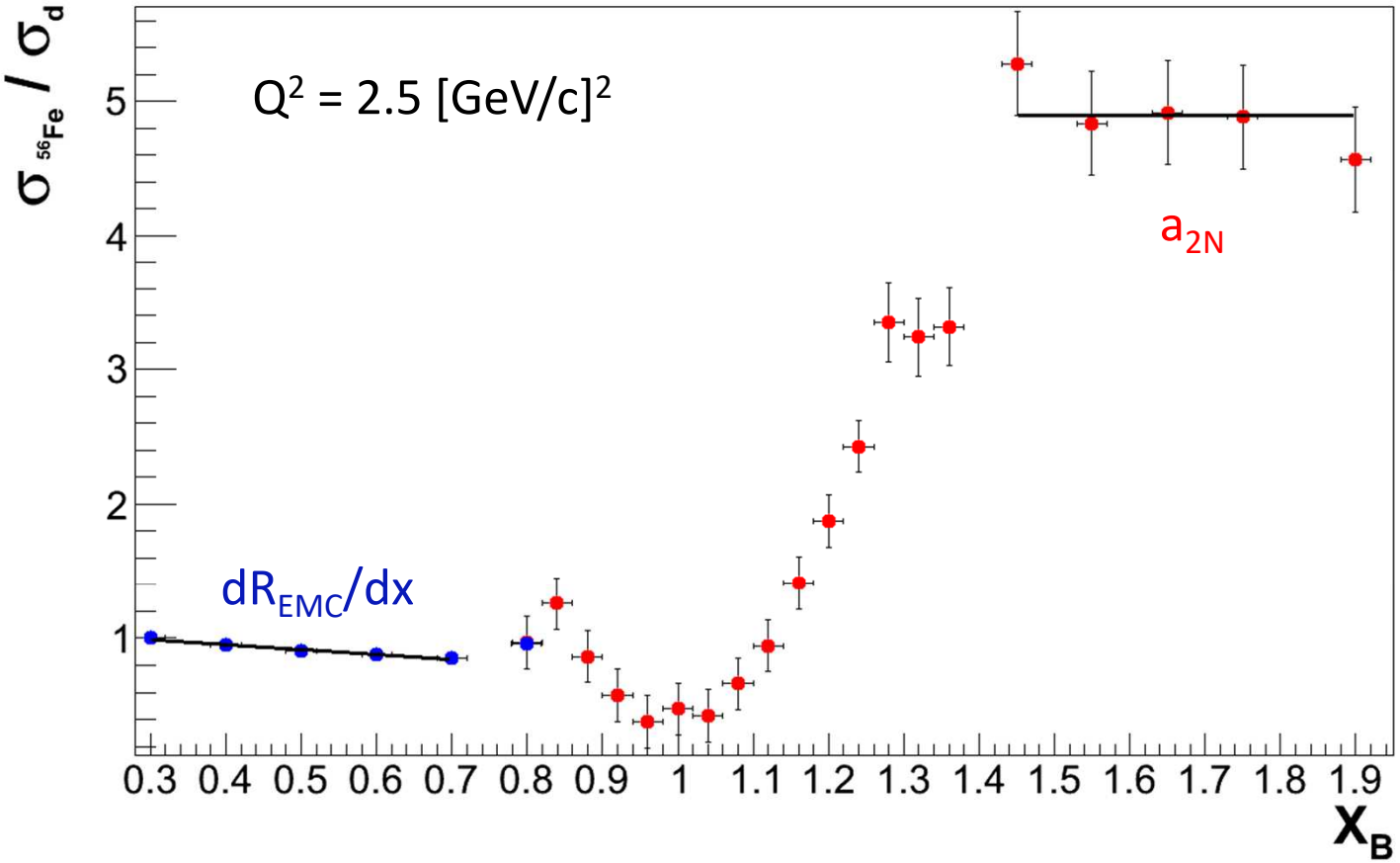




- Plot shows slope of ratio σ_A/σ_D at EMC region.
- EMC effect correlated with **local density** not average density.

Holistic View of the EMC & SRC Data

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



- Scaling plateaus (a_{2N}) are due to proton-nucleon **local density** correlations

  R. Subedi *et al.*, Science **320** (2008) 1476-1478.

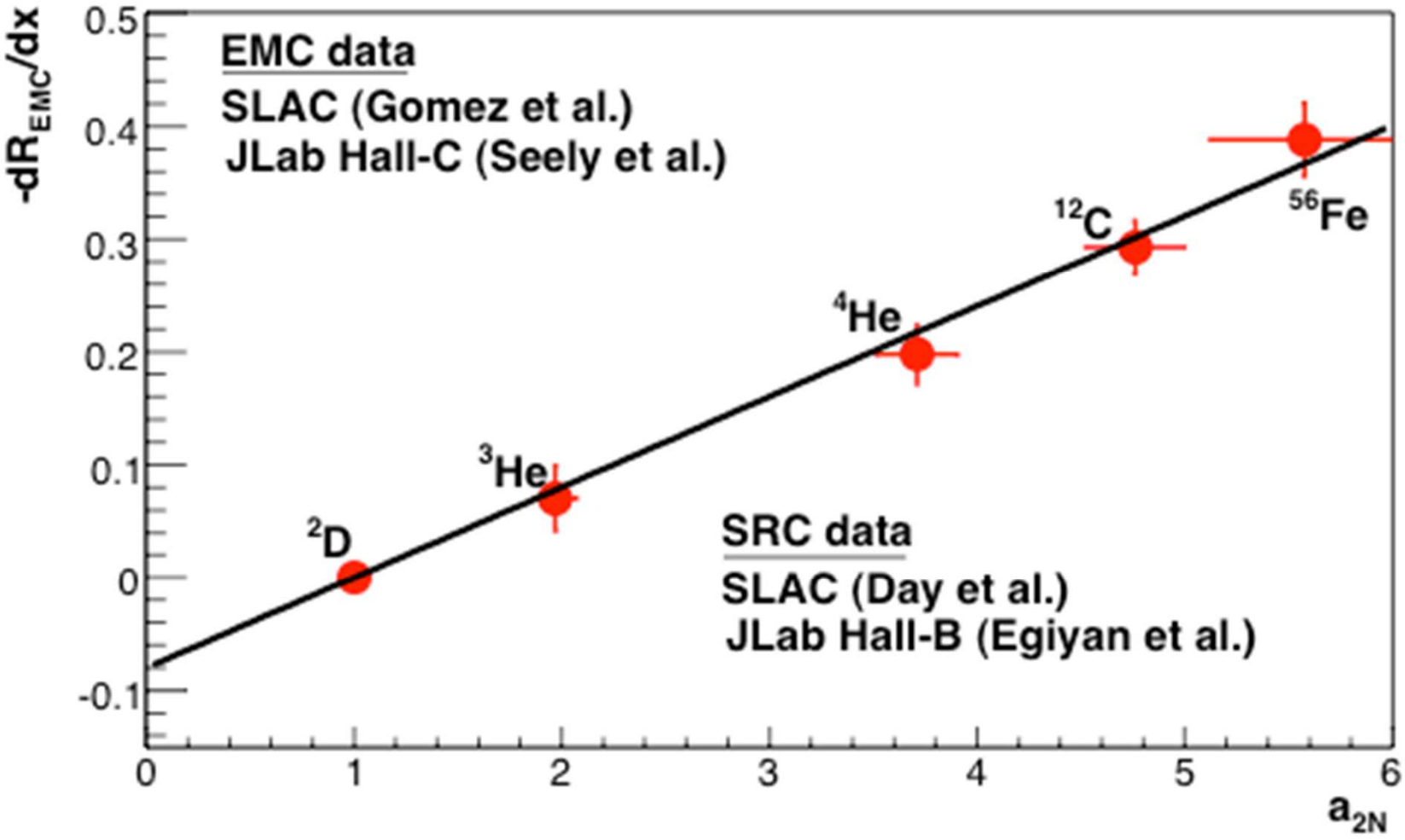
- So are the EMC slopes (x_B<0.7) and a_{2N} (x_B>1.5) correlated?!

But "Nuclear" $x_B > 1$ Results Having Nothing To Do With "Deep Inelastic" $x_B < 1$ EMC Effect Results; that would be like comparing ducks and beavers!!

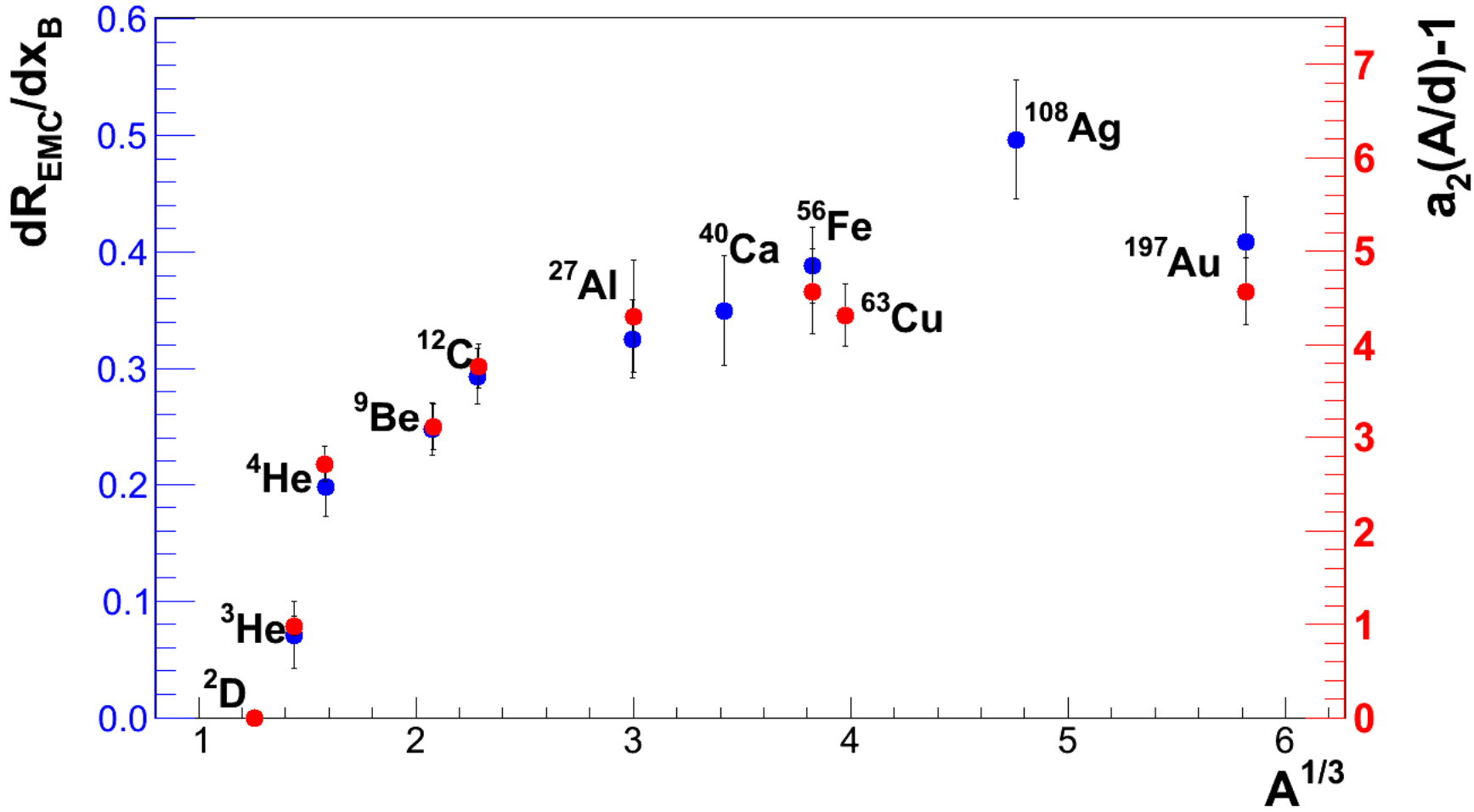
"When the explore returned from Australia, the good people of England, having seen all the animals in the world, demanded to know if it was a duck or a beaver. They were asking the wrong question!"
– Rolf G. Winter, Introduction to Quantum Physics

SRC and EMC Correlation

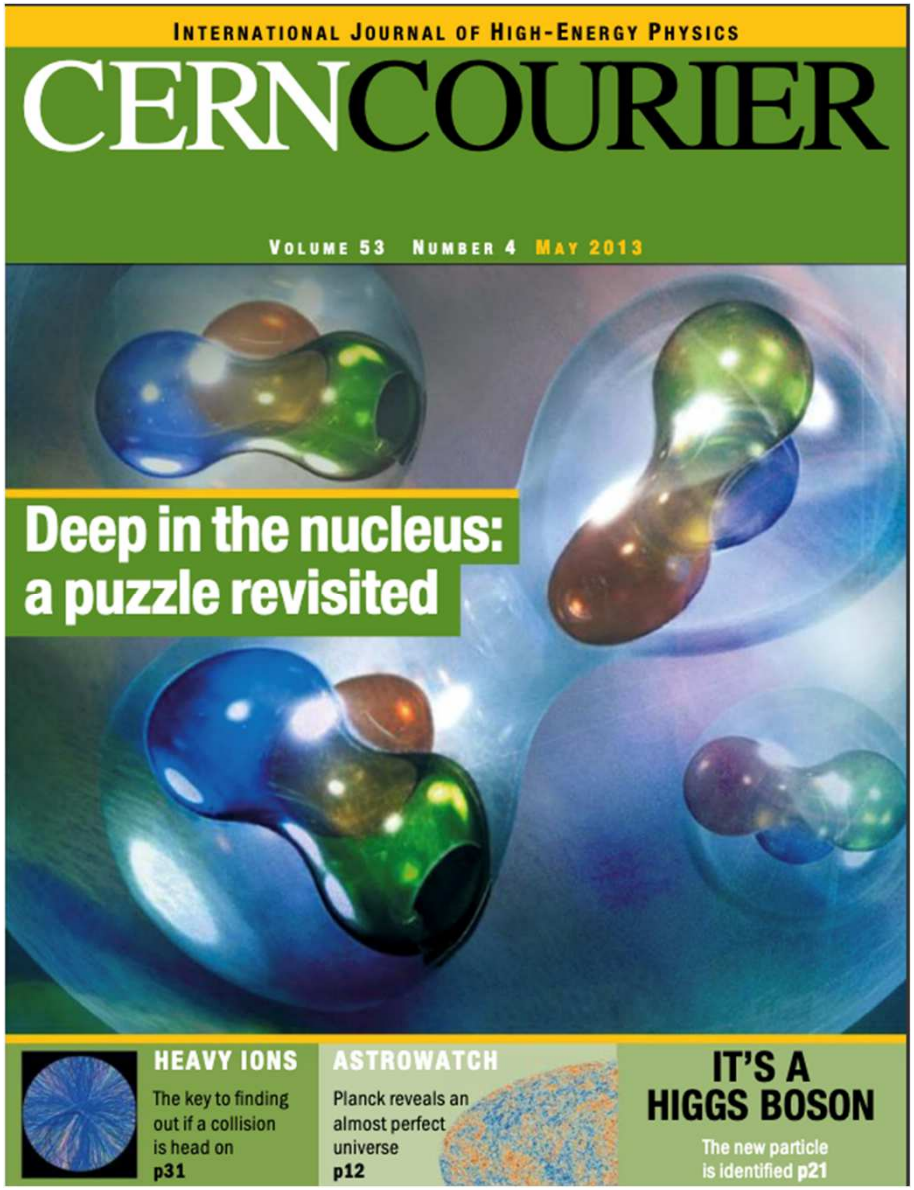
L. Weinstein *et al.*, Phys. Rev. Lett. **106** (2011) 052301.



EMC Slopes & SRC Plateaus

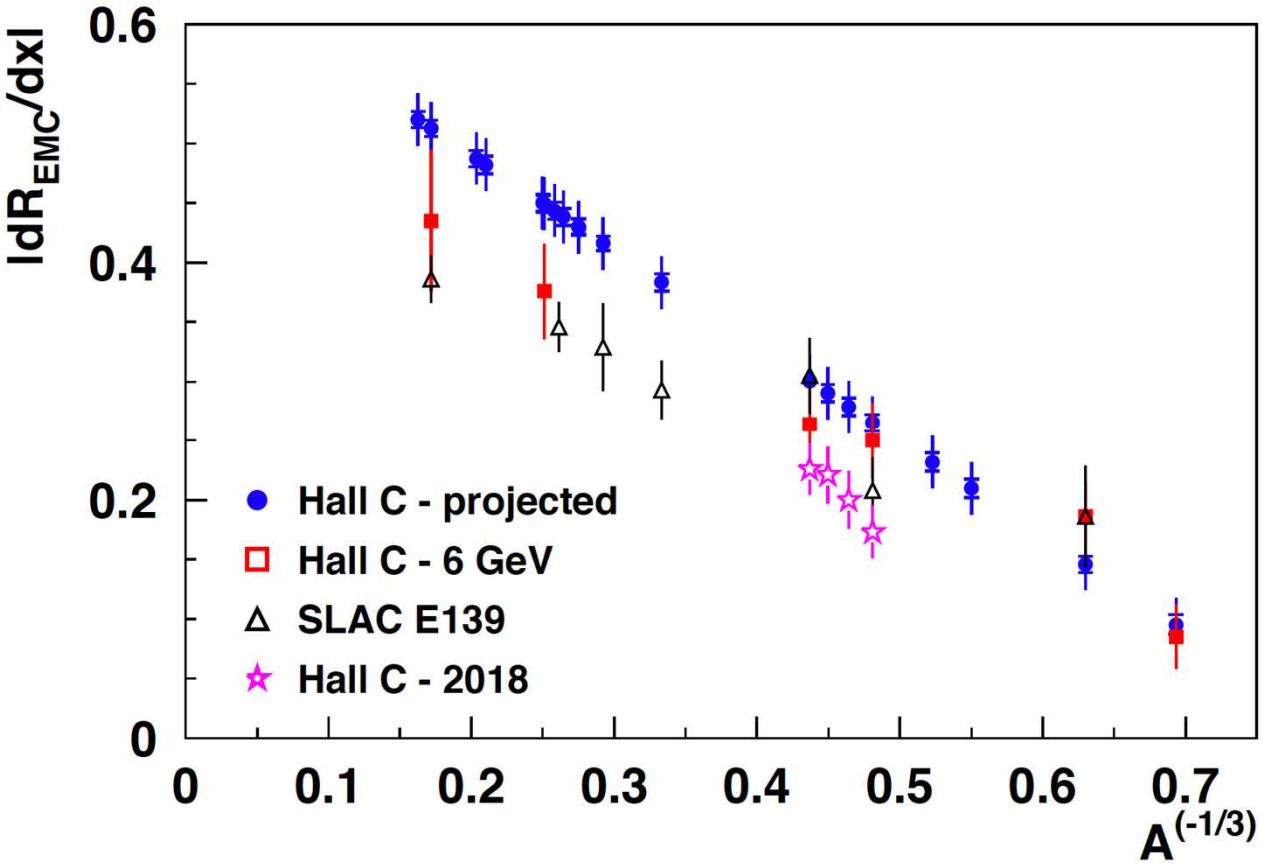


The EMC effect still puzzles after 30 years (***now 40 years***)
DH, Gerald A Miller, Or Hen, and Klaus Rith, CERN Cour. 53N4 (2013), 24



More Data Being Taken Right Now!

EMC, E12-10-008 and x>1, E12-06-105)



With thanks to Dave Meekins for his new solid target ladder!

Summary

- Inclusive Election Scattering Data Having Provided Both Valuable Insights As Well As Amazing Puzzles
- As I Think Will Become Very Clear, True Insight Comes From Making Use Of Multiple Reactions To Truly Gain Insights Into The Nucleus
- New Inclusive EMC (x<1) and SRC (x>1) Experiments Running RIGHT NOW with 12GeV Jefferson Lab
- In the future, we 2nd generation ^{3}H & ^{3}He with CLAS12
- Looking to further future (discussions on Thursday):
  - **Upgrade the dump in Hall A and/or C to 2 MW instead of 1 MW**
  - Upgrade the energy reach of JLab to 22 GeV (*circa 2040*)

So the good experimentalists and theorists finally agreed it wasn't just protons and a neutrons. It was a nucleus!