News on Nuclei:
Results on x>1 and EMC

Patricia Solvignon

Jefferson Lab

Curriculum Vitae

- **Ph.D at Temple University (2006)**

  "Measurement of the ^{3}He Spin Structure Functions in the Resonance Region: A Test of Quark-Hadron Duality on the Neutron".

- **Post-doctoral at Argonne National Lab (2006-09)**

  Analyzed parts of E03-103 (EMC) & E02-019 (x>1)

  Analysis coordinator for ROSEN07 experiments: R_A in the resonance region, TPE

  Spokeperson and contact of E08-014: 3N-SRC and isospin dependence

  Spokeperson and contact of E12-11-112: isospin dependence in 2N, 3N SRC
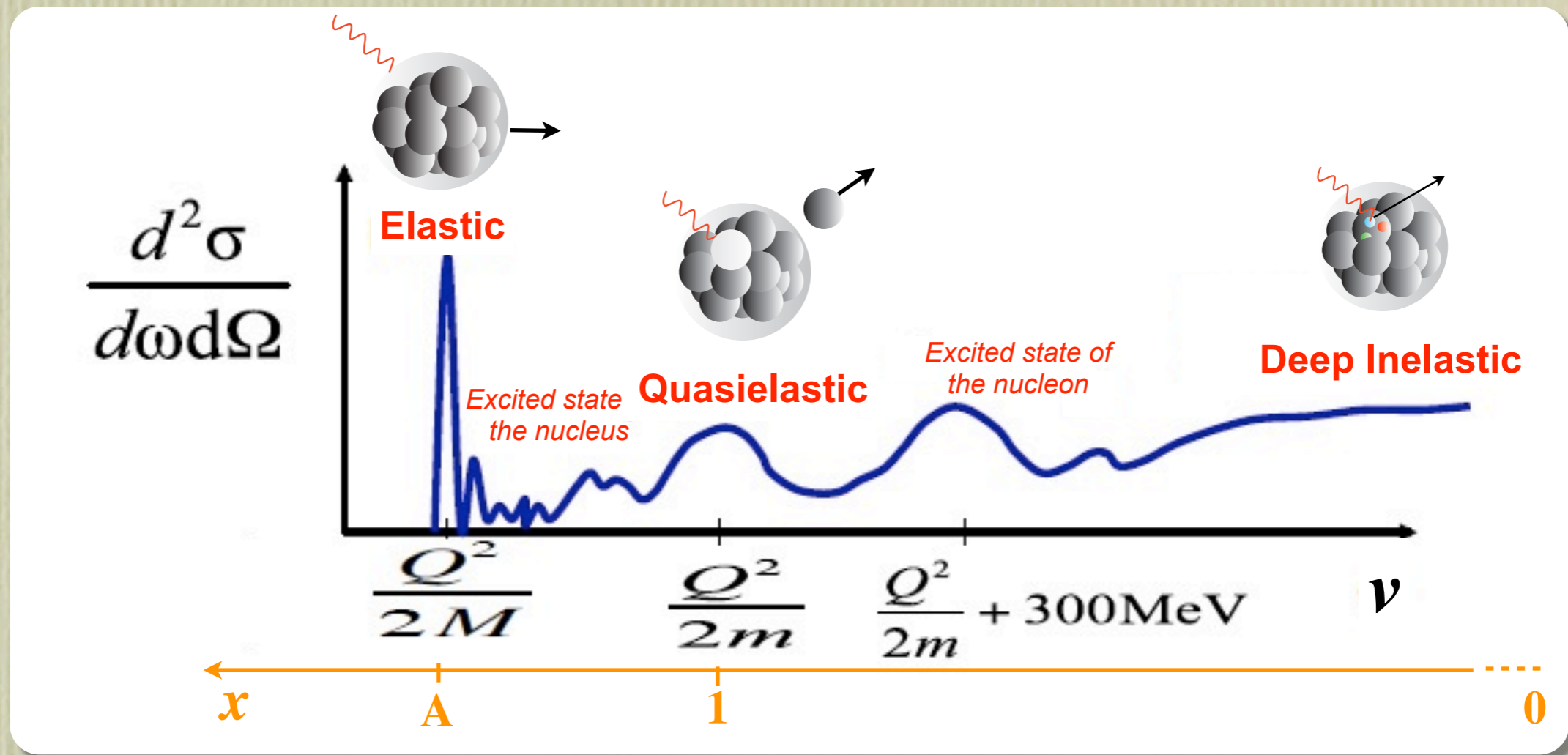
  Member of the Tritium Task Force

- **Hall C staff scientist** and **Affiliated Professor at UNH (2009-present)**

  Continuing above responsibilities

  Supporting the running of Hall C Compton and Moller polarimeters

  Responsible for the implementation of the new Polarized ^{3}He target in Hall C at 12 GeV
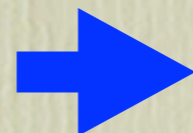
Electron Scattering

4-momentum transfer squared

$$Q^2 = -q^2 = 4EE'\sin^2\tfrac{\theta}{2}$$

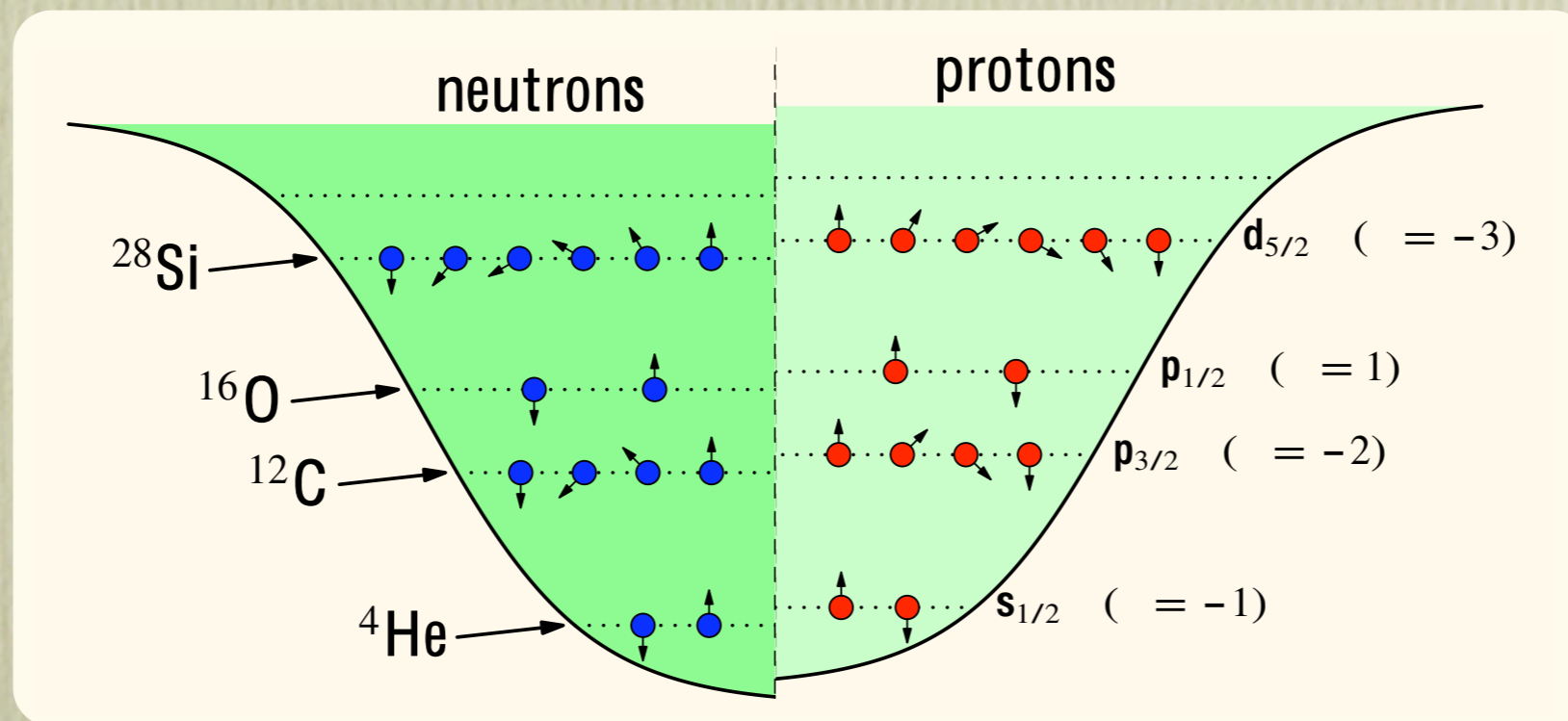Energy transfer

$$\nu = E - E'$$

Bjorken variable

$$x = \frac{Q^2}{2M\nu}$$

The Nuclear Force

Definition: nucleon-nucleon interaction

Nuclear Shell Model:

- Pauli principle $\Rightarrow$ the nucleus is not a dense system

- Nucleons far apart $\Rightarrow$ strong nucleon-nucleon interaction is reduced

- Independent motion of the nucleons in the mean field created by the rest of the nucleus


Filled shell
=
greater stability

Simple picture is extremely successful.

Limits of the Nuclear Shell Model

➡ Reconstruct initial proton binding energy (E_m), momentum (p_m)

➡ Proton (E_m, p_m) distribution modeled as sum of independent shell contributions

Mean field approximation: the probe nucleon experiences the average force created by the rest of the nucleus
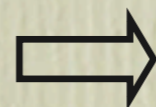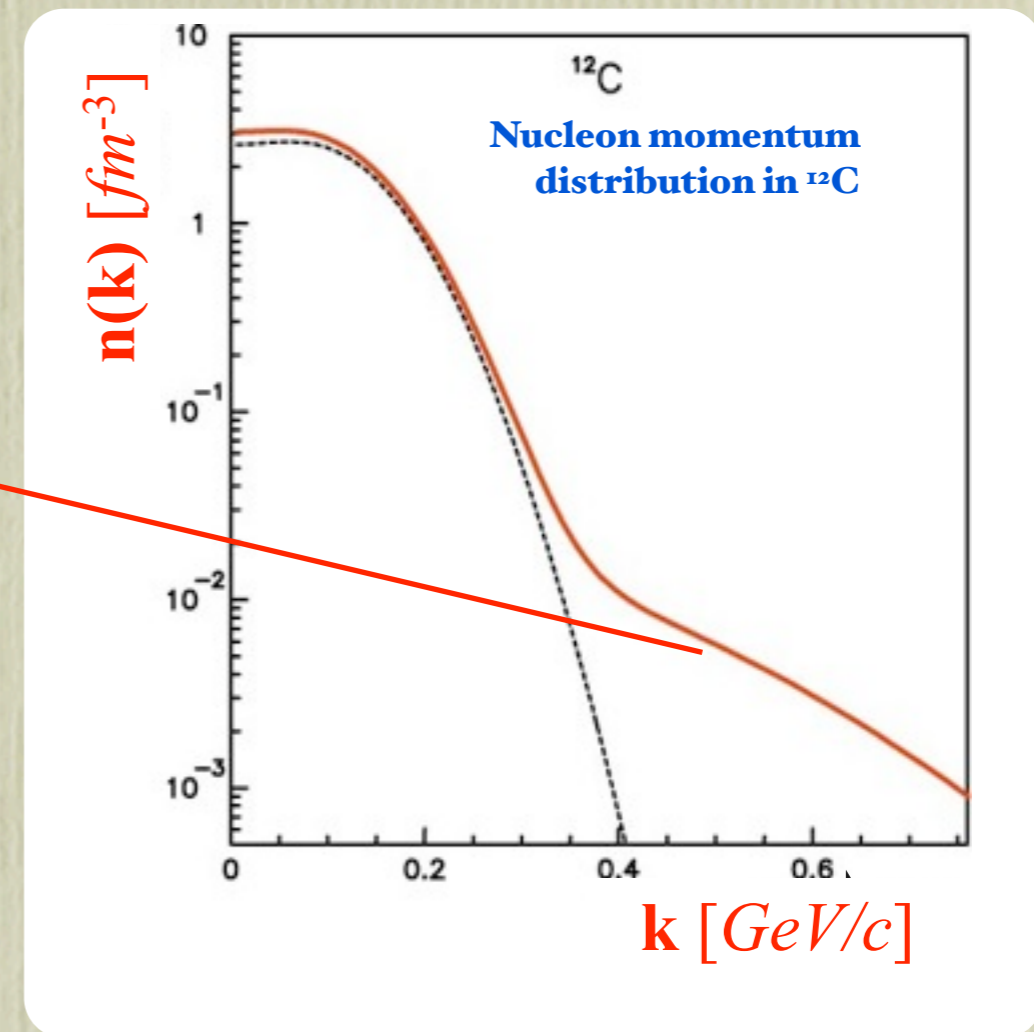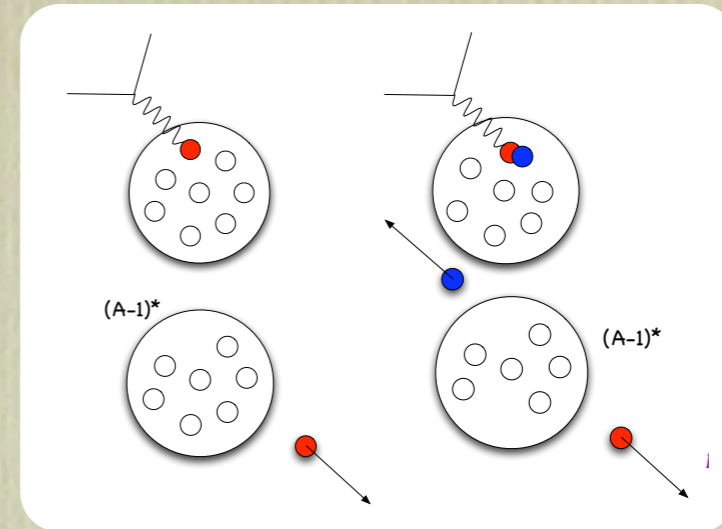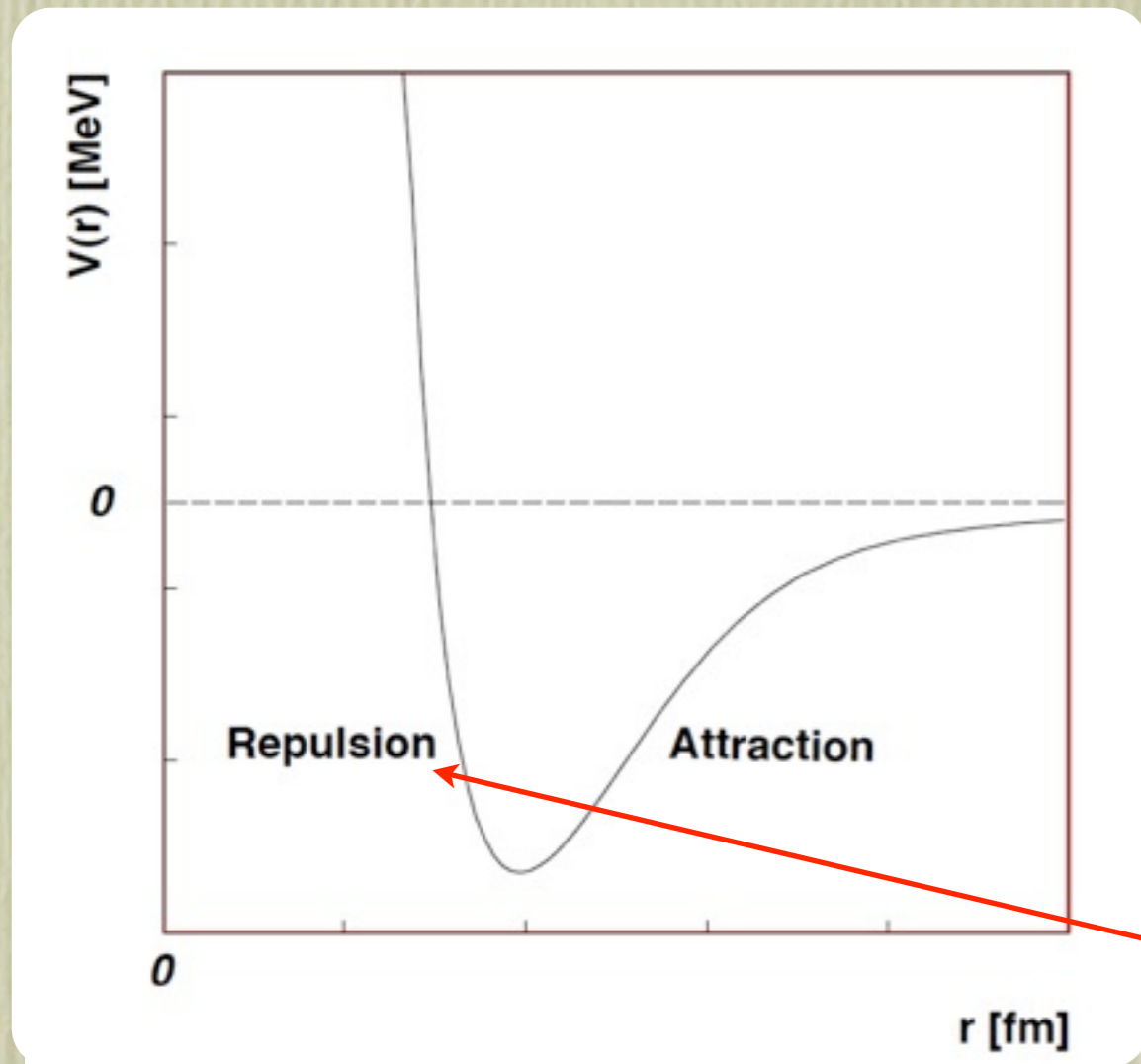
30-40% missing strength

The Nuclear Potential

Nucleon momentum distribution in ^{12}C

$n(k)$ $[fm^{-3}]$

^{12}C

k $[GeV/c]$
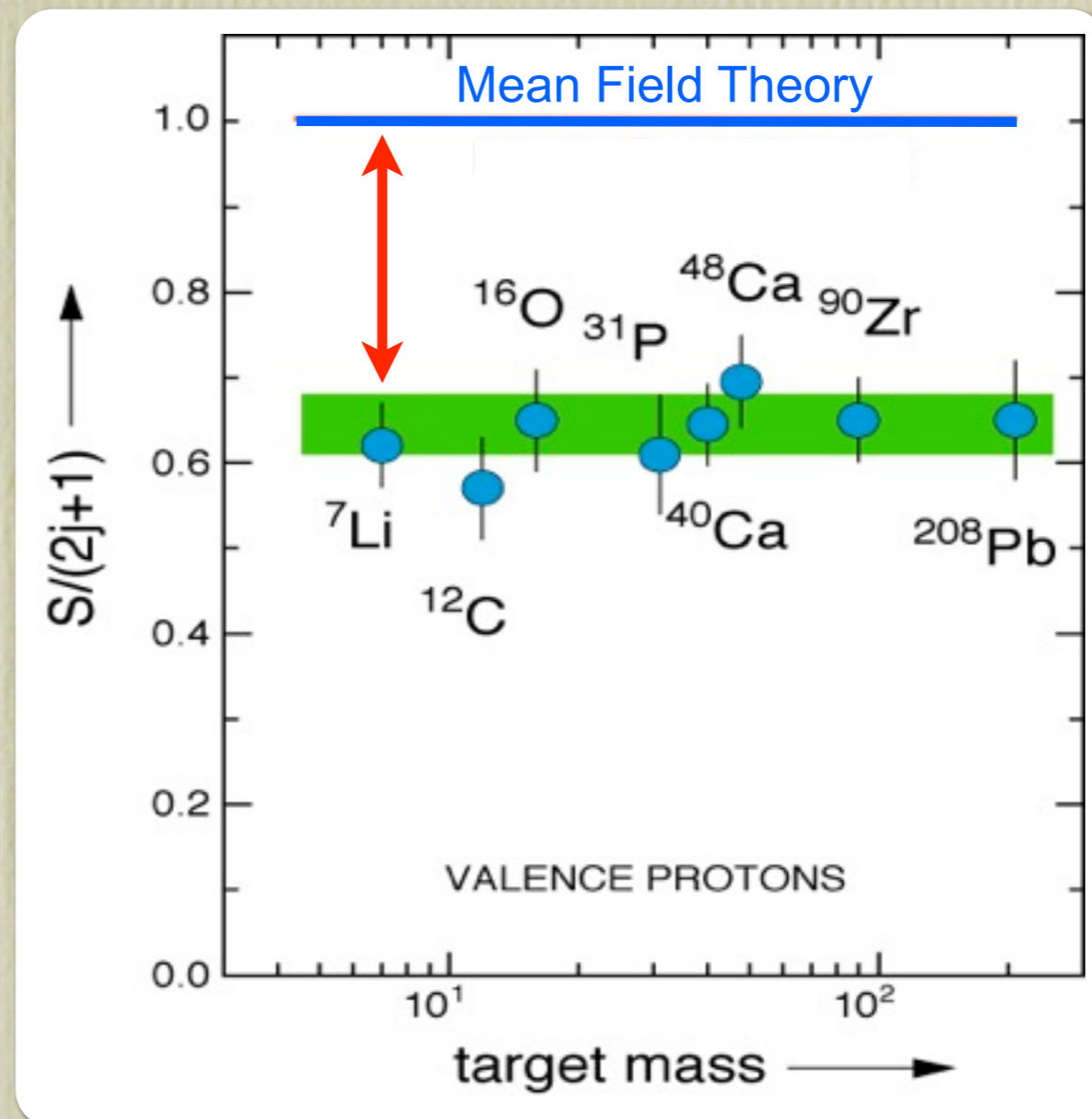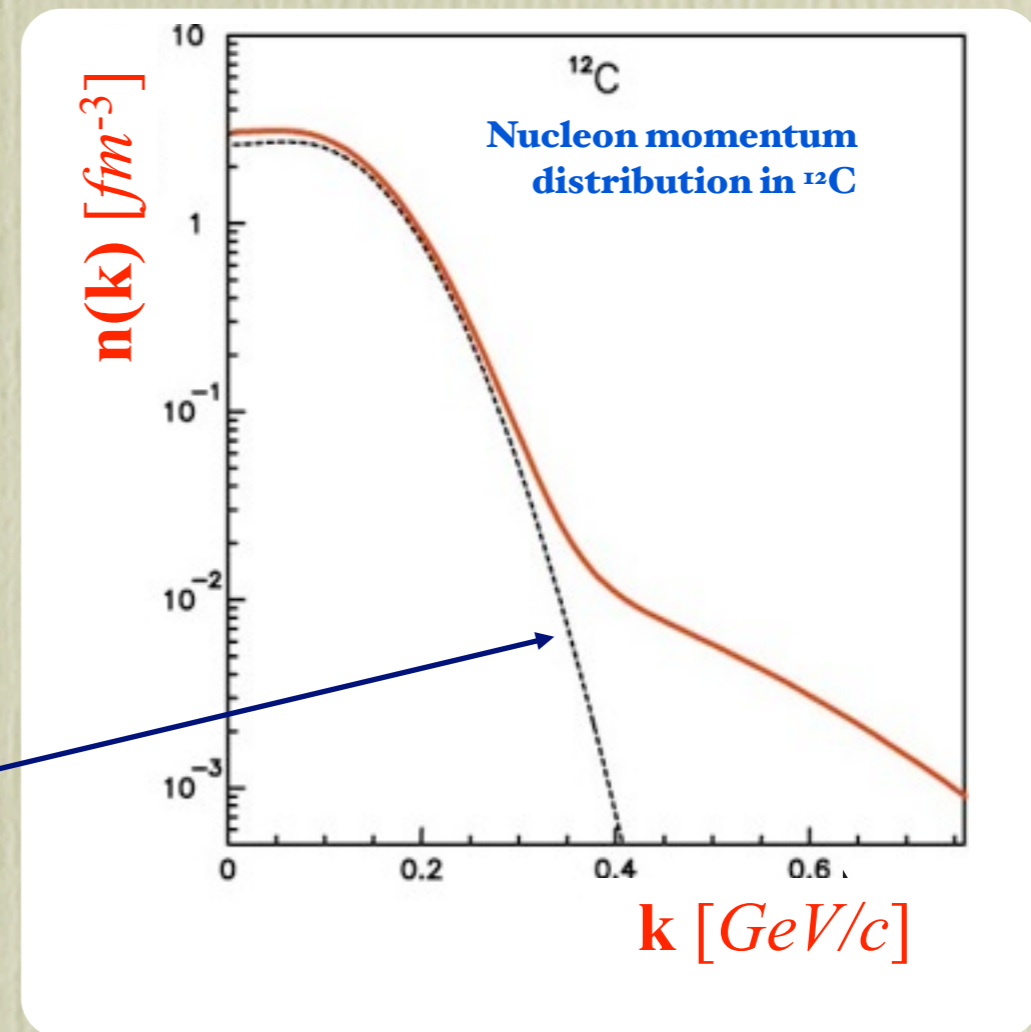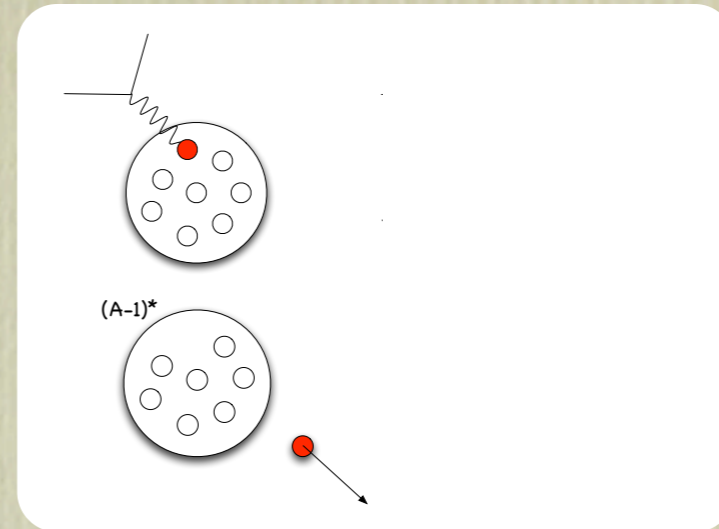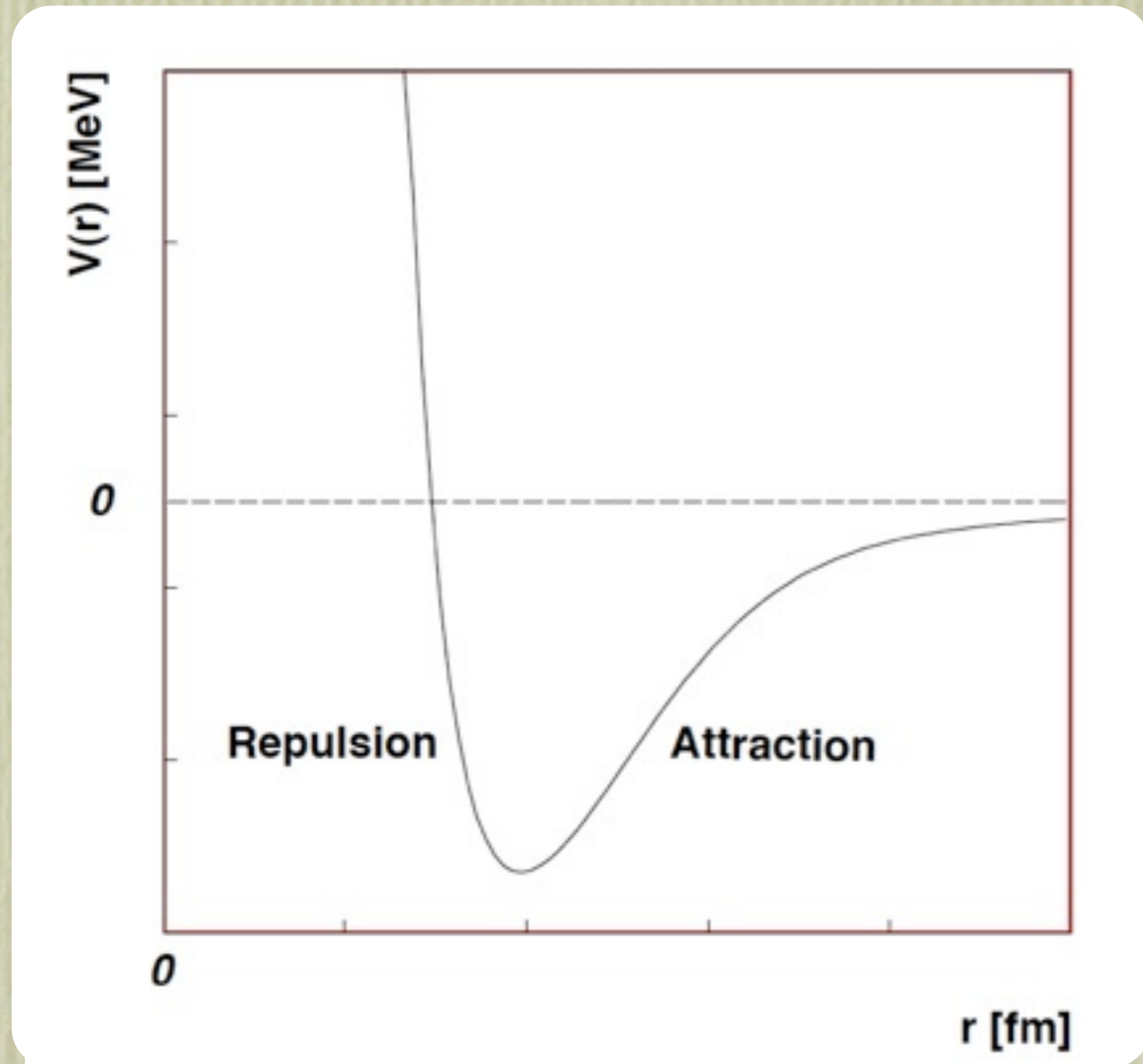
Mean field part

N-N interaction $\Rightarrow$ Hard interaction at short range

The Nuclear Potential

$$\frac{}{d\Omega d\nu} \propto \int dp \int dE \sigma_{ei} \underbrace{S_i(p,E)} O()$$
Spectral function

Repulsion   **Attraction**

$(y_{cw}) = \dfrac{\sigma^{exp}}{(Z\tilde{\sigma}_p + N\tilde{\sigma}_n)} \cdot K$

$(A-1)^*$

n(k) $[fm^{-3}]$

^{12}C

Nucleon momentum distribution in ^{12}C

k $[GeV/c]$
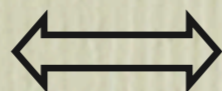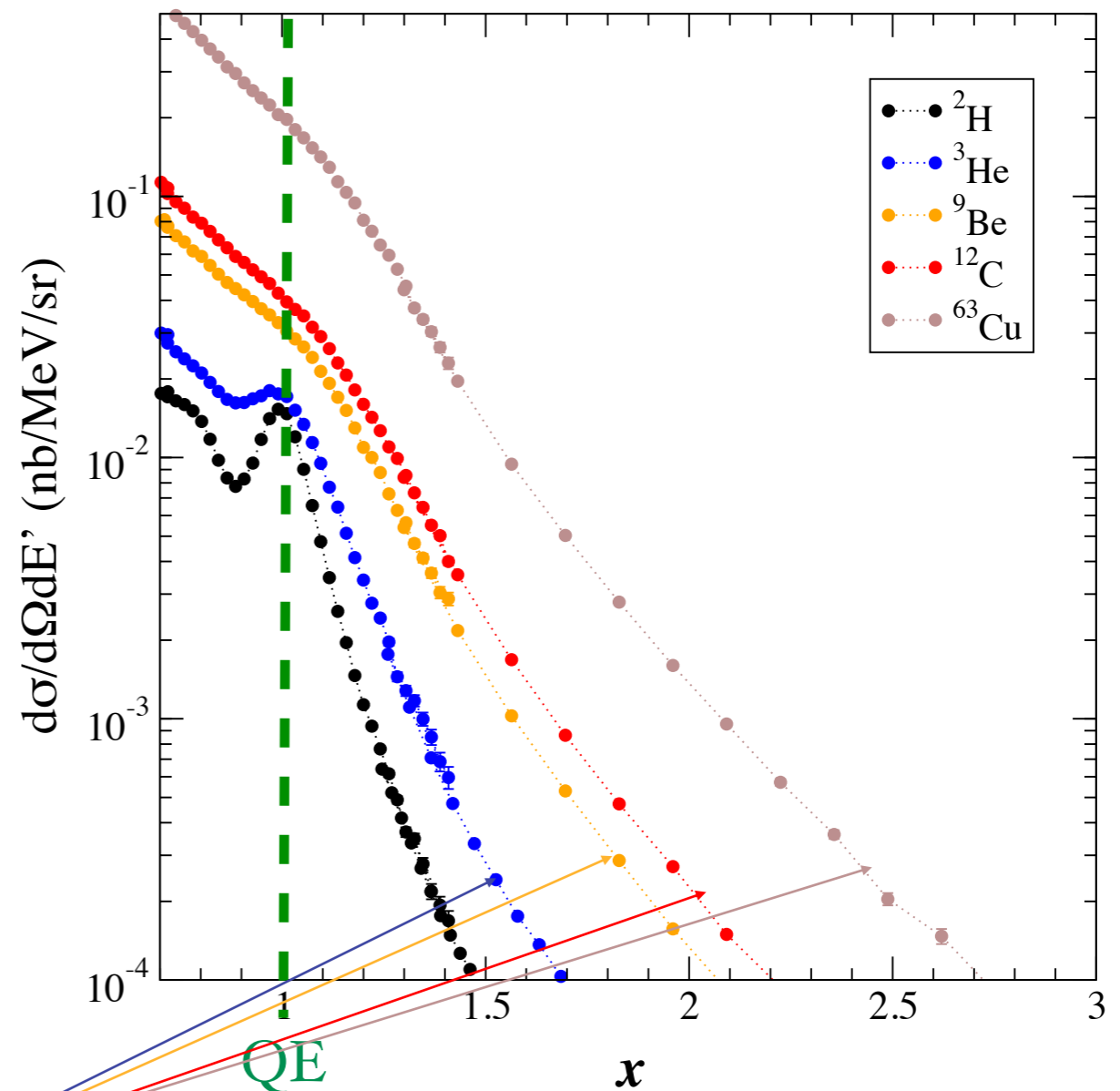
Short range/distance ⟺ **High relative momenta**

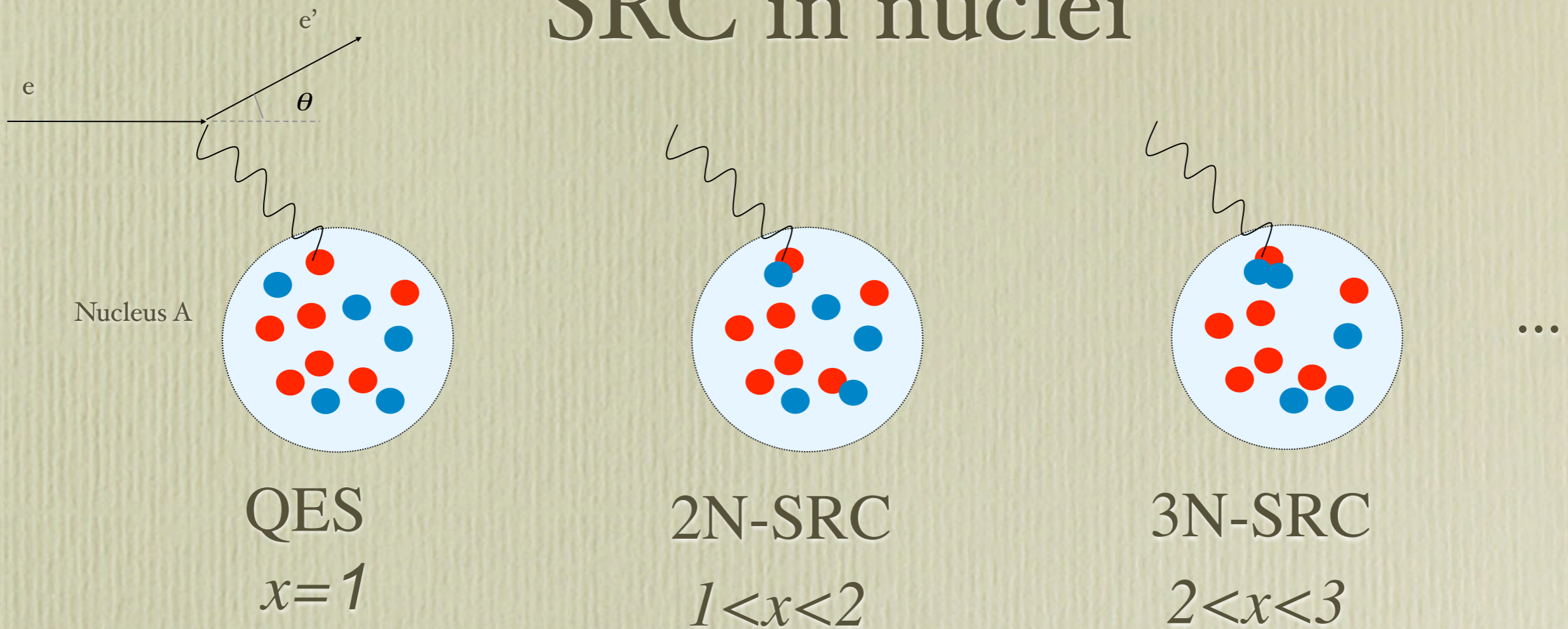# Inclusive scattering at large x

Quasi-Elastic Scattering:

- peak at x ≈ 1

- motion of the nucleon in the nucleus broadens the peak

- little strength from mean field above x=1.3

High momentum tails should yield constant ratio if seeing Short-Range Correlations (SRC)

JLab E02-019 data from N. Fomin

Legend:
- ^{2}H
- ^{3}He
- ^{9}Be
- ^{12}C
- ^{63}Cu

y-axis: $d\sigma/d\Omega dE'$ (nb/MeV/sr)

x-axis: x

QE

SRC in nuclei

QES
$x=1$

2N-SRC
$1<x<2$

3N-SRC
$2<x<3$

...

<u>Properties:</u>
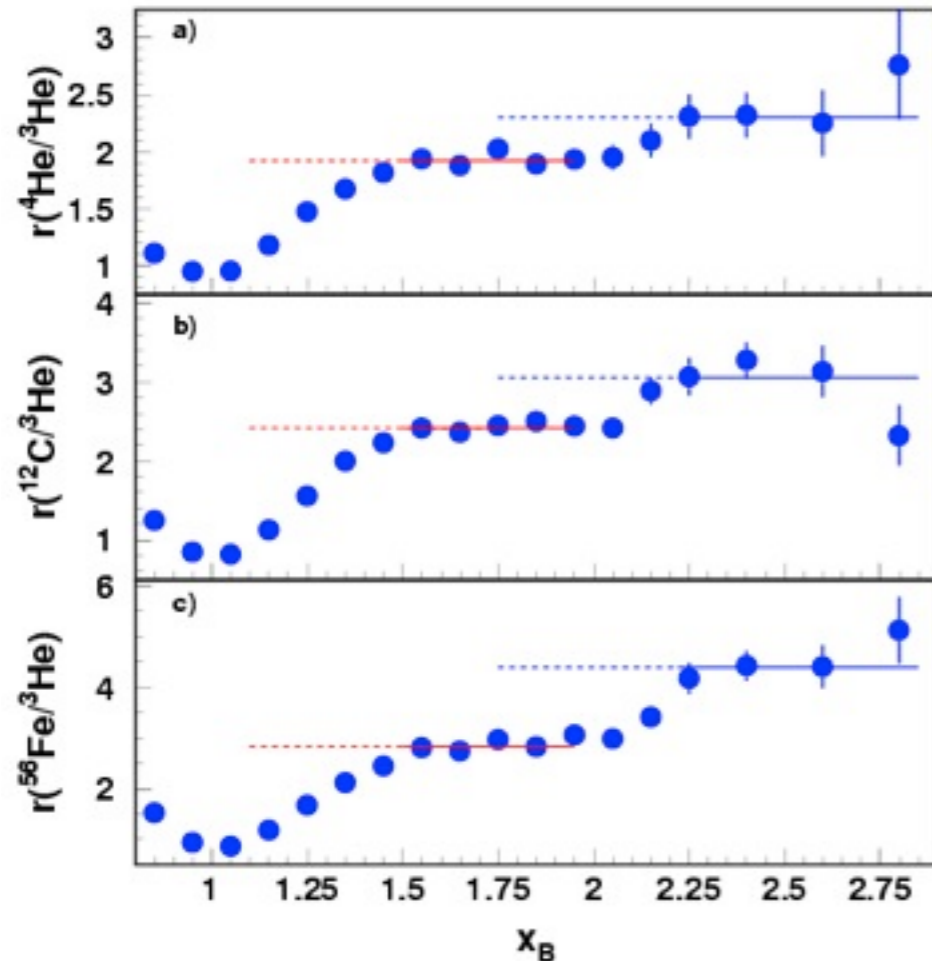
- **1N, 2N, 3N, ..., contributions at x≤1,2,3,...**

- **Isospin independence = equal probability of np, pp & nn pairs**

- **Nuclear saturation**

SRC results from JLab

Hall B

Hall C

Good agreement in the 2N-SRC region

but

potential difference in the 3N-SRC region

The EMC effect

e^-

e^-
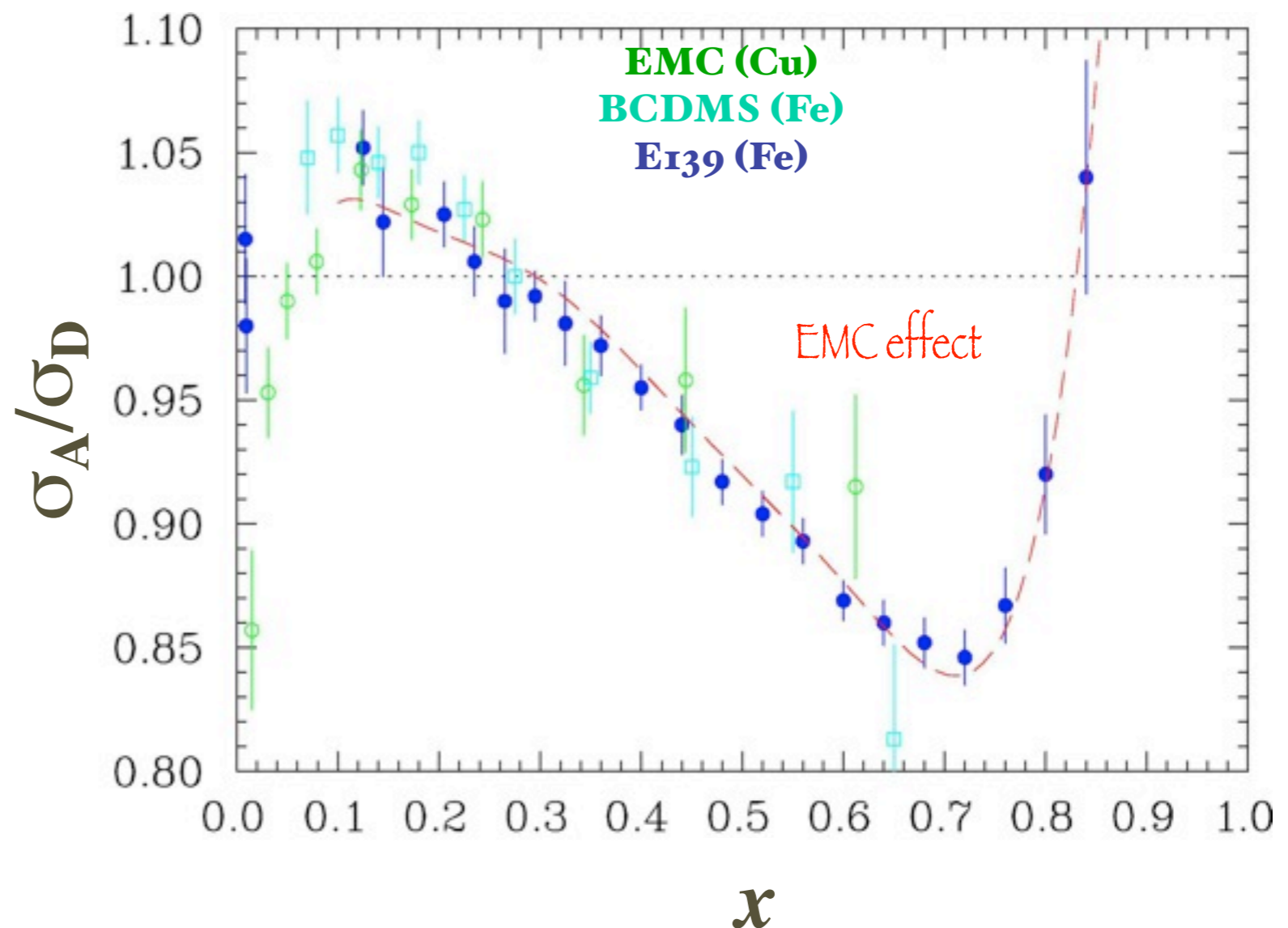θ
$\gamma*$

$\neq$ Z $\gamma*$ p + N $\gamma*$ n
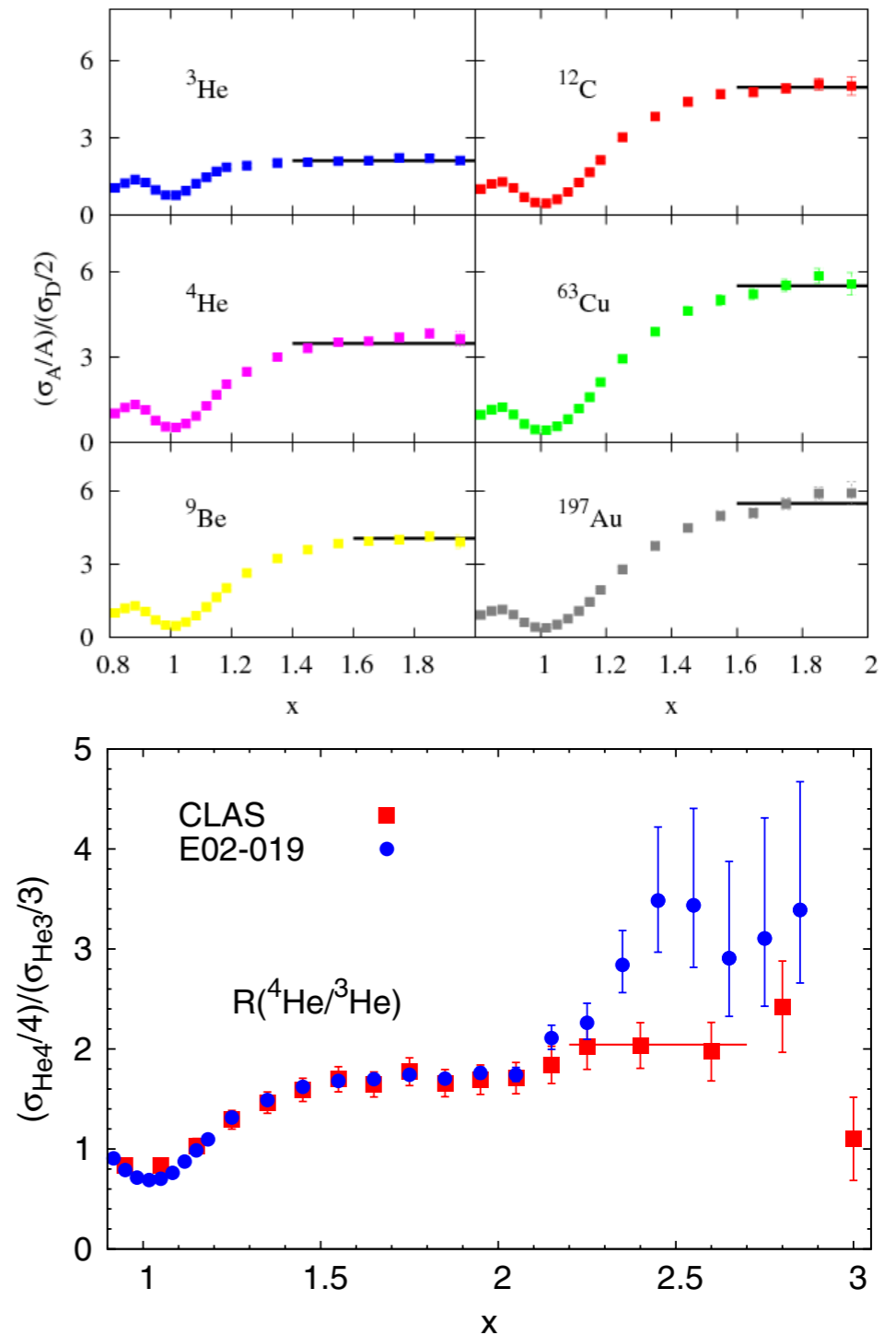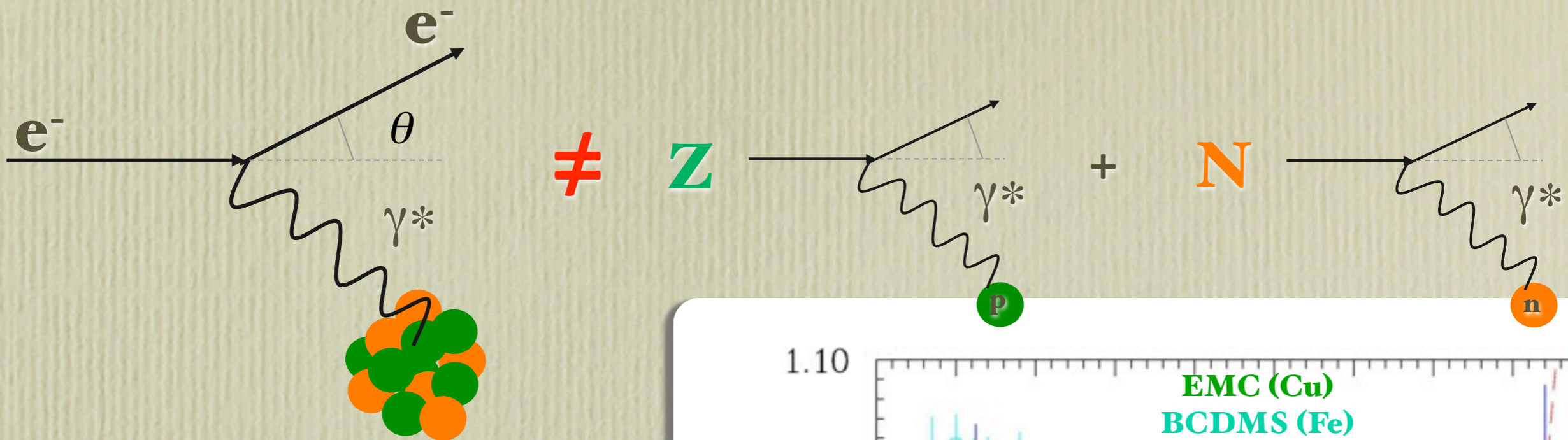
Nucleus at rest
(A nucleons = Z protons + N neutrons)

First measurement by the EMC collaboration (1983) found an excess of low-x quarks, deficit of high-x quarks in heavy nuclei

EMC (Cu)
BCDMS (Fe)
E139 (Fe)

EMC effect

σ_A/σ_D

x

Models of the EMC effect

Nucleon structure is modified in the nuclear medium
- Dynamical rescaling
- Nucleon 'swelling'
- Multiquark clusters (6q, 9q 'bags')

or

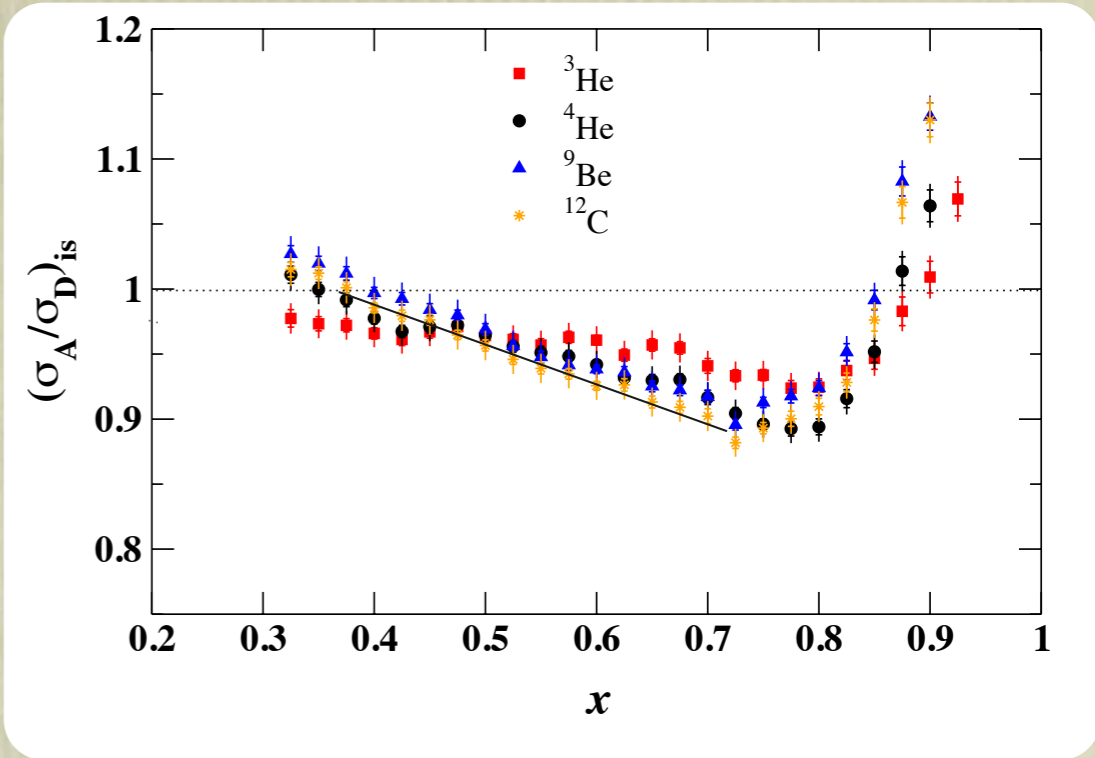**Nuclear structure is modified due to hadronic effects**
- More detailed binding calculations
  - Fermi motion + binding
  - N-N correlations
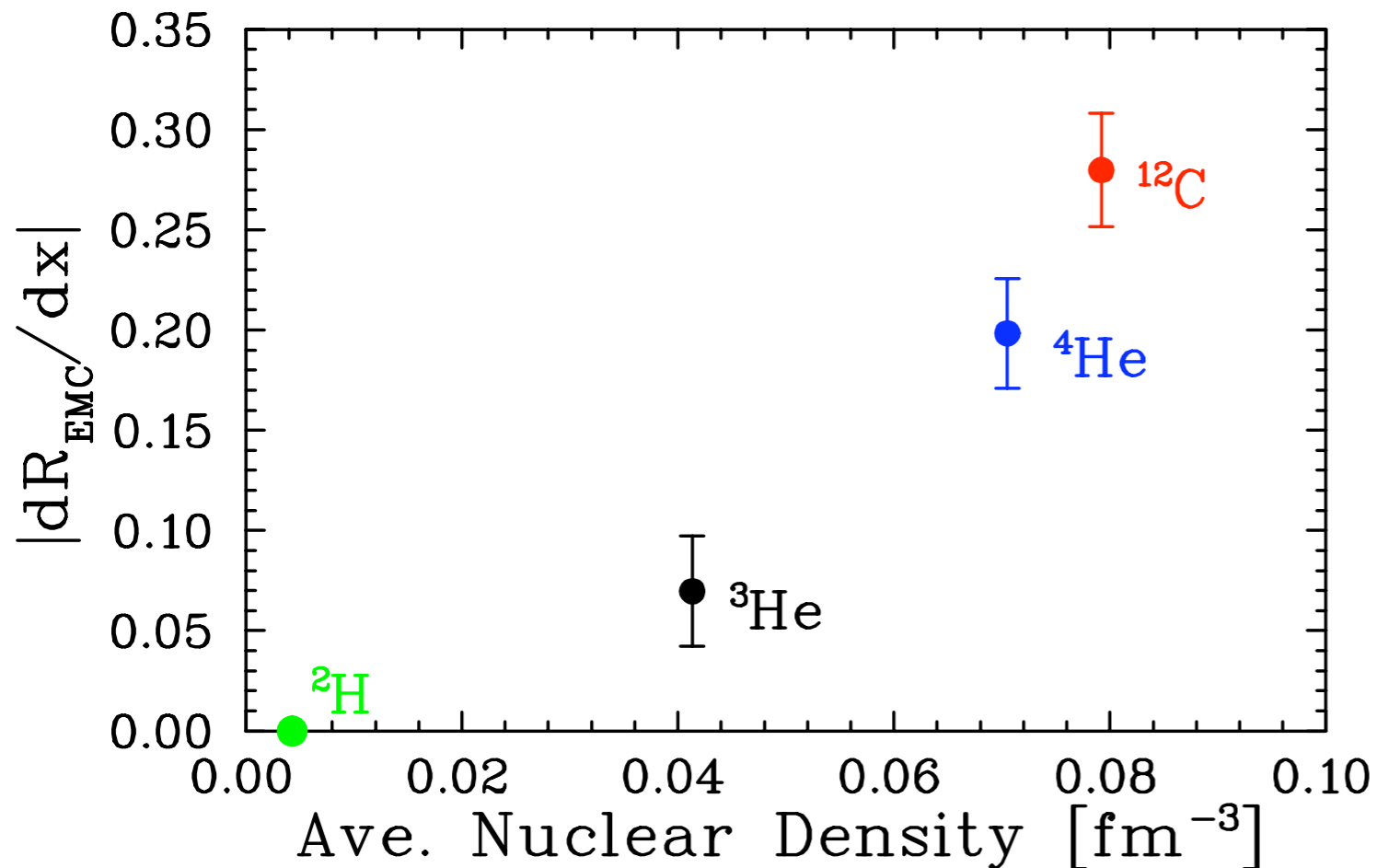- Nuclear pions

Many models but no complete, consistent picture

EMC results at JLab

HallC E03-103 results

Fit of the EMC ratio for 0.35<x<0.7 and look at A- and density dependence of the slope
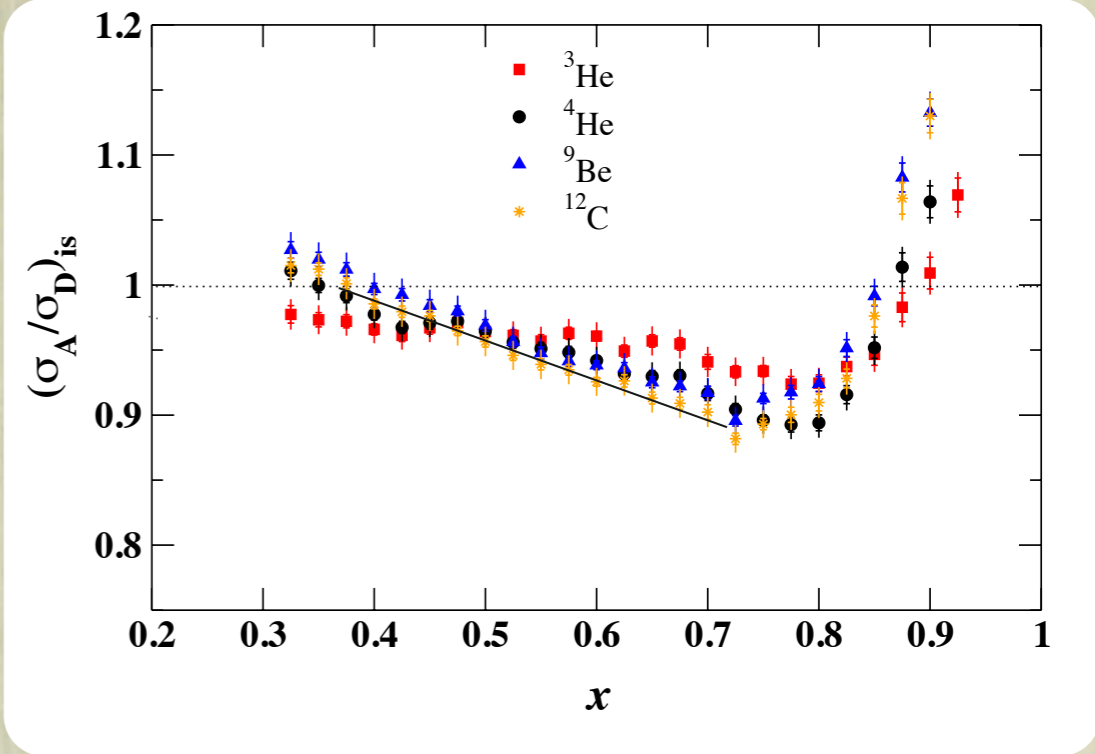

J. Seely et al, Phys. Rev. Lett. 103, 202301(2009)

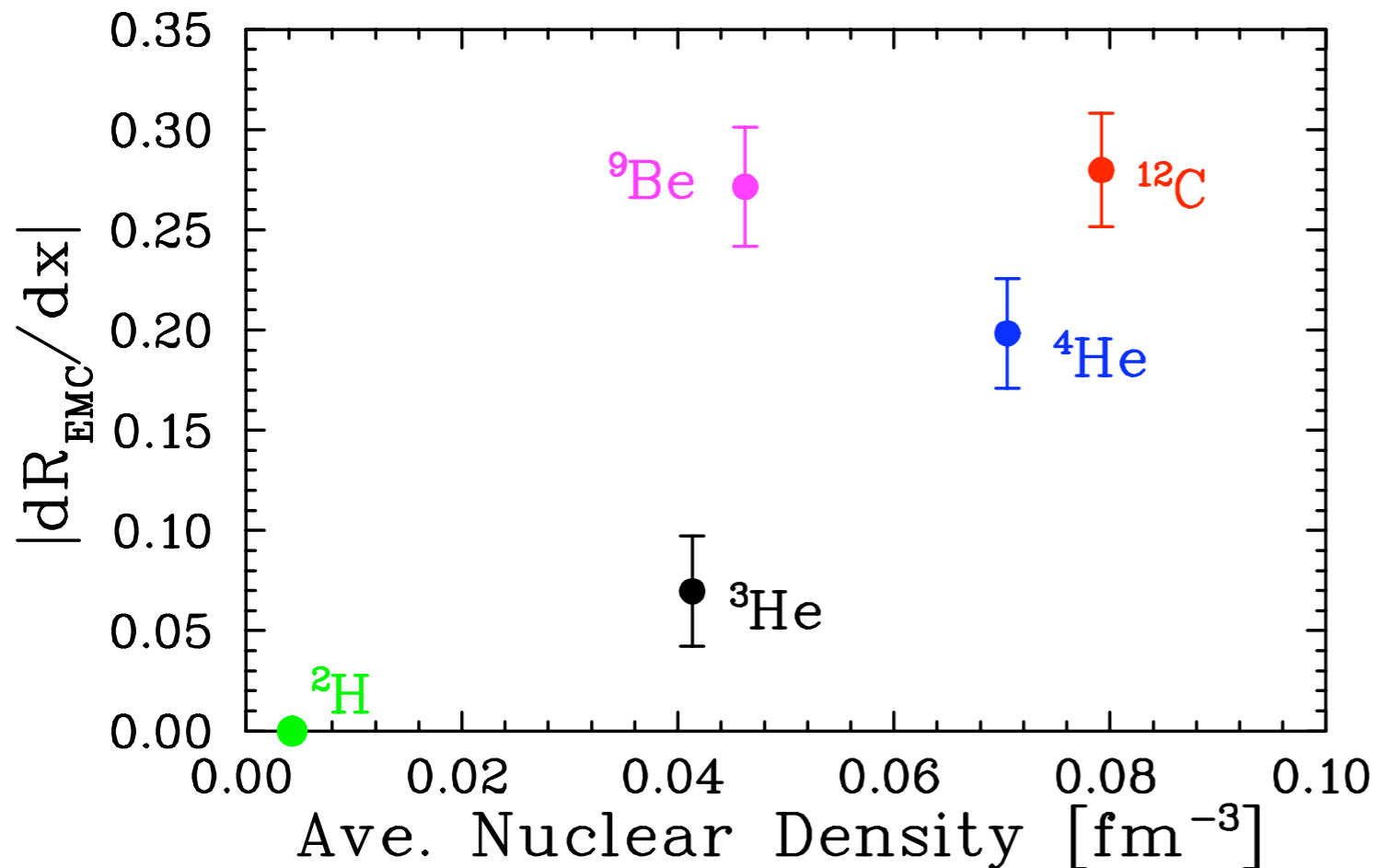**dependence on average density works well as for SLAC E139 data till ...**

EMC results at JLab

HallC E03-103 results
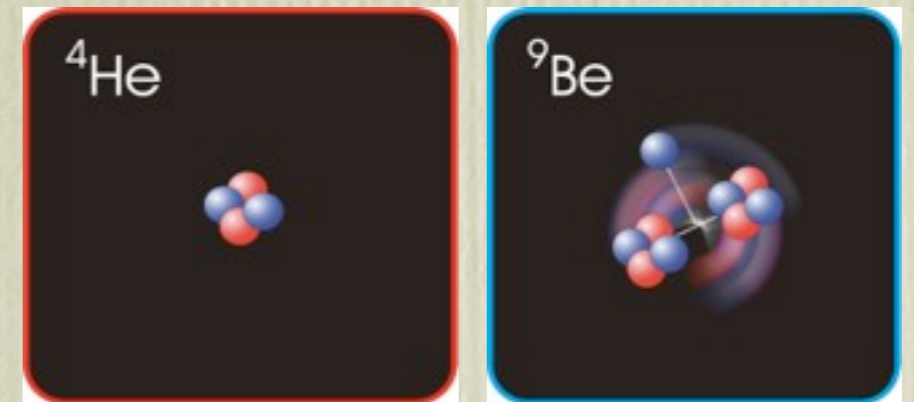
Fit of the EMC ratio for 0.35<x<0.7 and look at A- and density dependence of the slope

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

^{9}**Be has low average density, but large component of structure is 2α+n: most nucleons in tight, α-like configurations**

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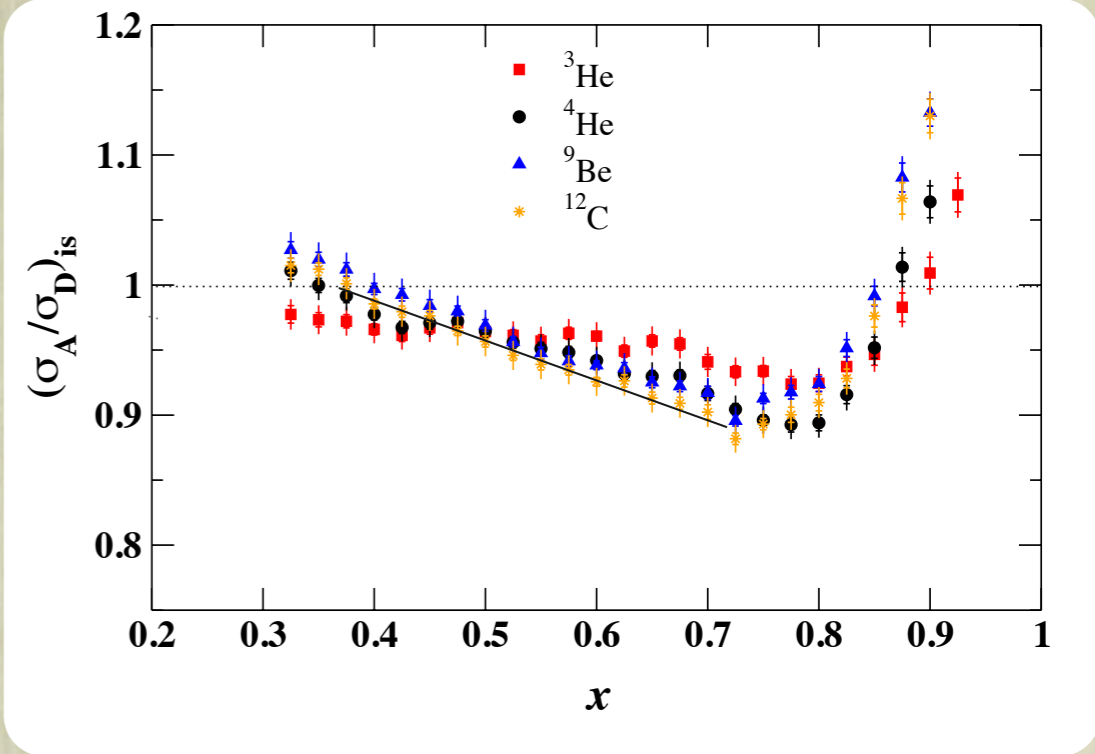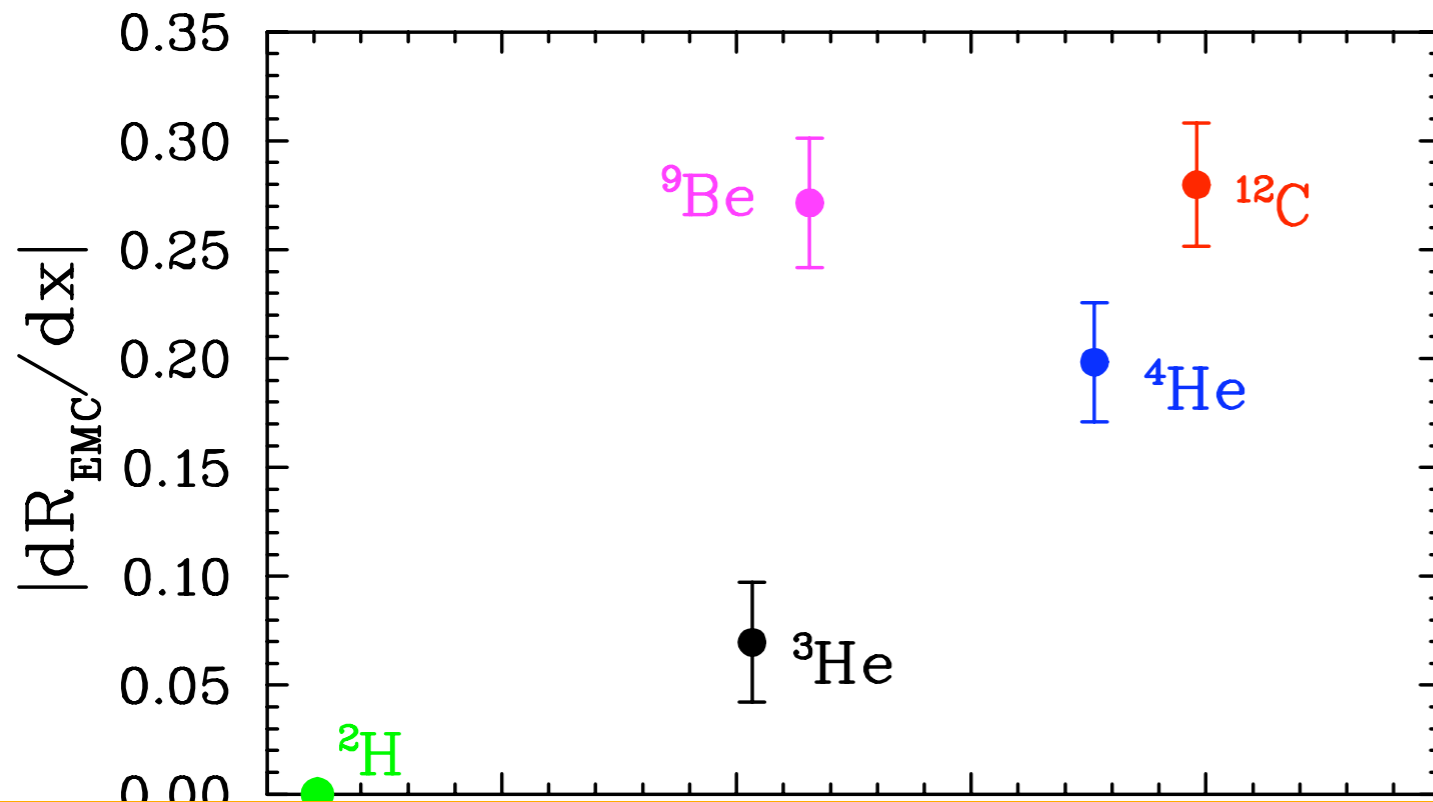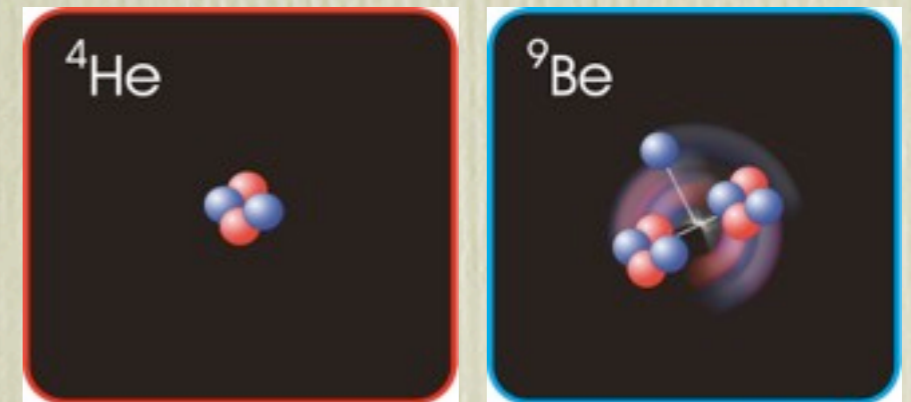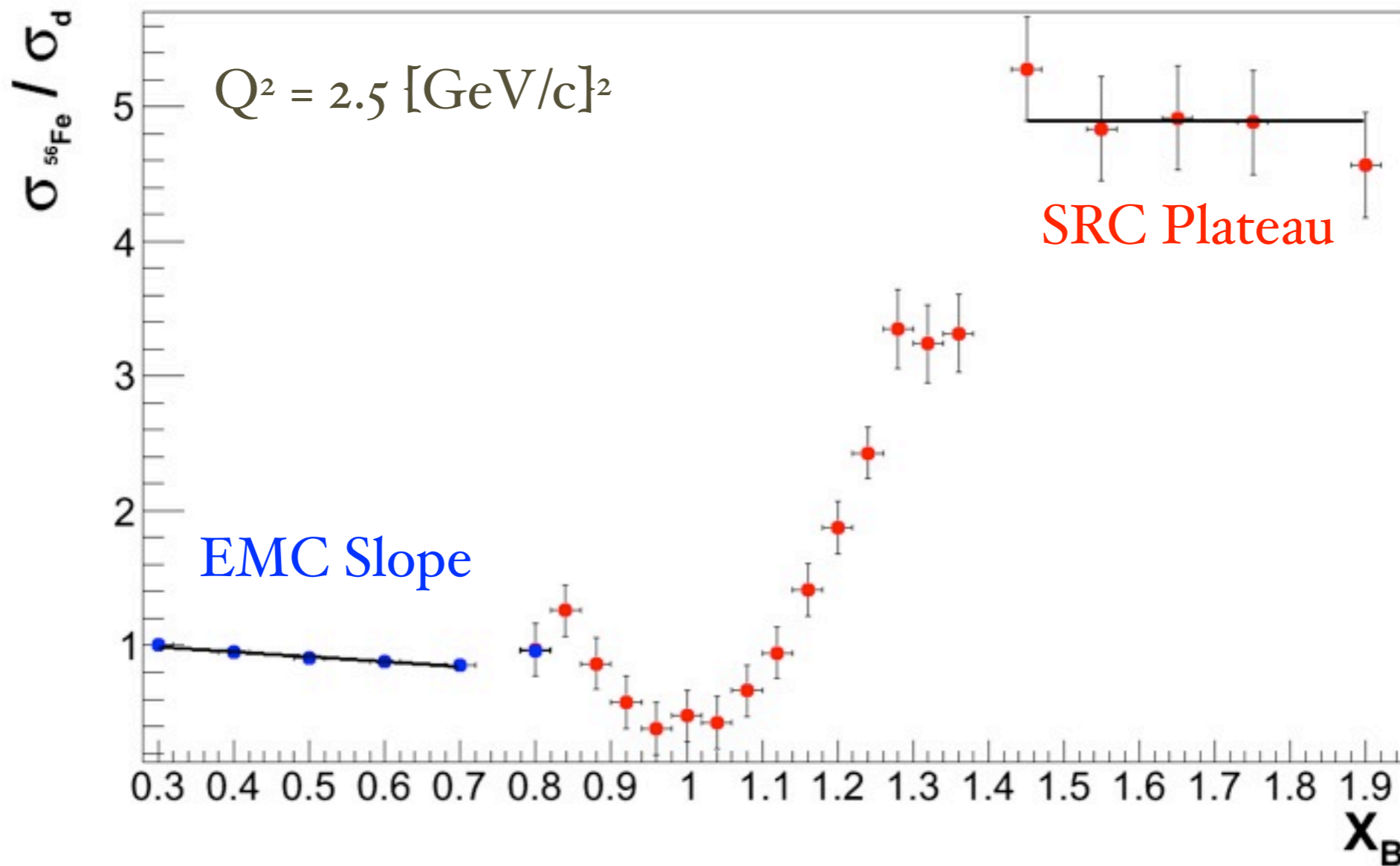
J. Seely et al, Phys. Rev. Lett. 103, 202301(2009)

^{9}Be has low average density, but large component of structure is 2α+n: most nucleons in tight, α-like configurations

New results on light nuclei suggest connection to local structure
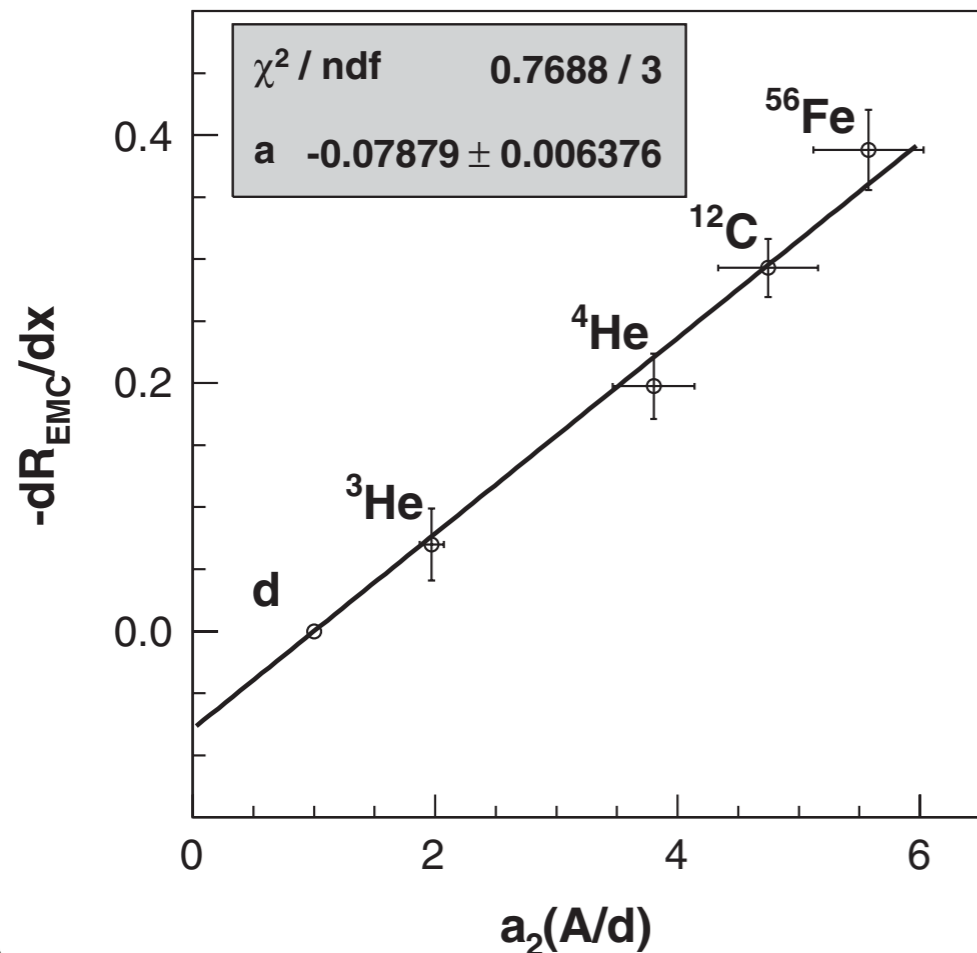
Putting everything together

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?!
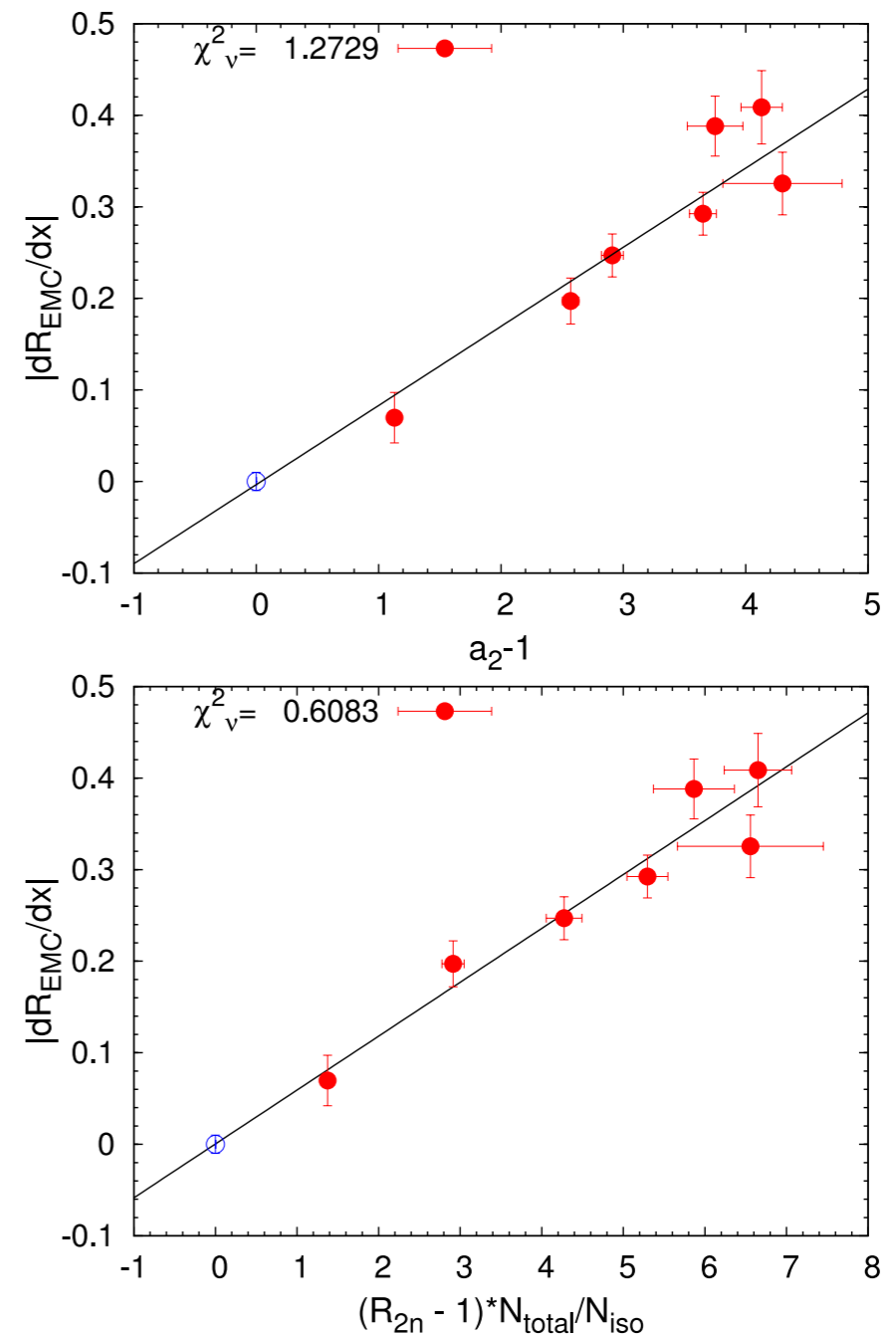
EMC slopes vs. SRC plateaux

L. B. Weinstein et al, Phys. Rev. Lett. 06, 052301(2011)

Arrington, Daniel, Day, Fomin, Gaskell and Solvignon, to be submitted to PRC

EMC data = combined Hall C E03-103 and SLAC E139

SRC data = Hall B SRC A/^{3}He with ^{3}He/d from SLAC data

Including JLab E02-019 SRC data

Jefferson Lab

Patricia Solvignon

More measurements to come at JLab 12GeV

- Hall A:

  - E12-11-112: x>1 ^{3}He/^{3}H

- Hall C:

  - E12-10-108: EMC

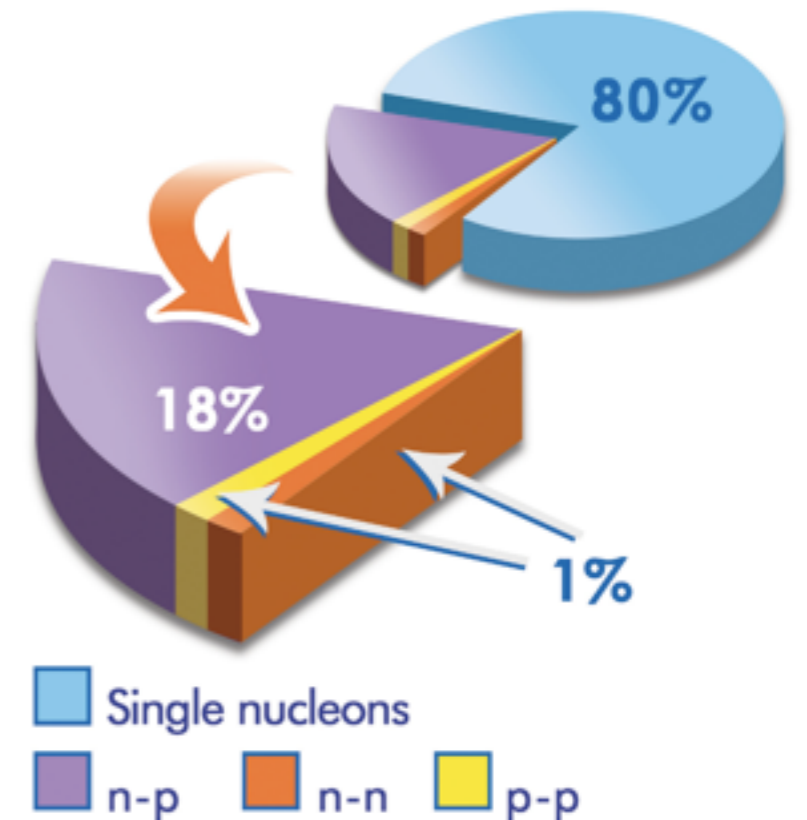 - E12-11-107: In Medium Nucleon Structure Functions, SRC and the EMC effect
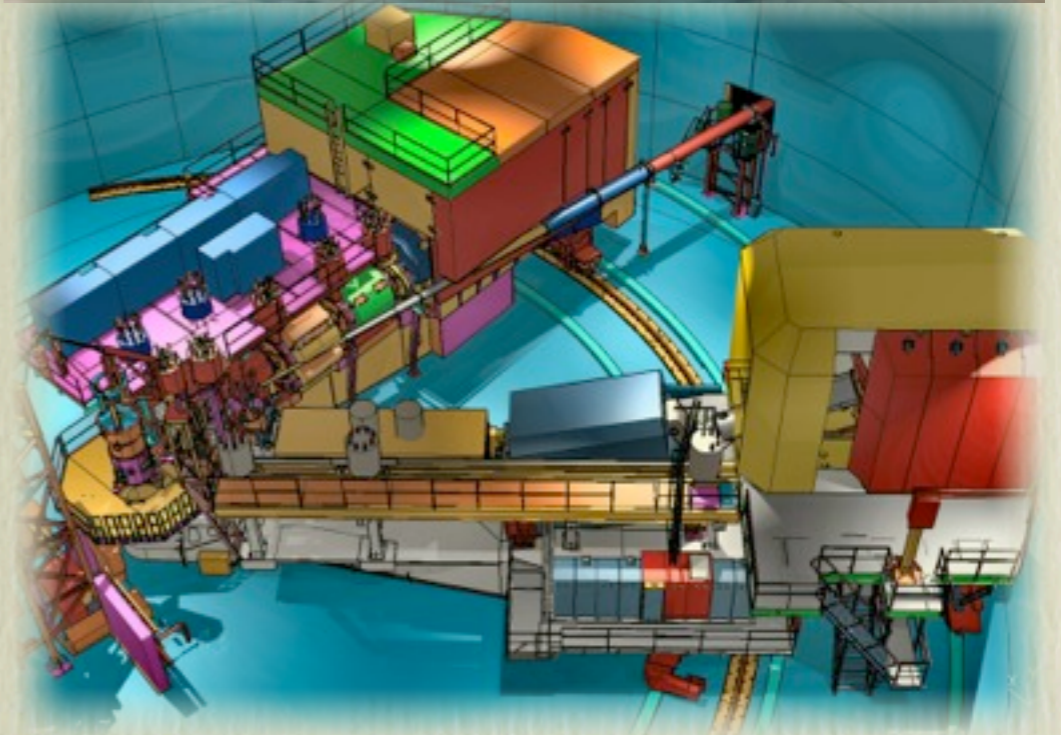
Summary

SRCs are an important component of the nuclear structure:

- ~20% of nucleons in SRC
- Very few (~1%) p-p, n-n pairs
- Limited room for other things: 3N, 4N SRCs, more exotic configurations (6q bag)

E03-103 suggests the EMC effect is sensitive to the detailed nuclear structure

Combined data shows the two reactions to be correlated and originating from local density effects. Or is it just a coincidence ?

Many experiments are planned at JLab 12 GeV to bring more insights to this question: new EMC ($x<1$) and SRC ($x>1$) experiments, including ^{3}H & ^{3}He.