E12-10-008: Detailed Studies of the Nuclear Dependence of F_2 in Nuclei

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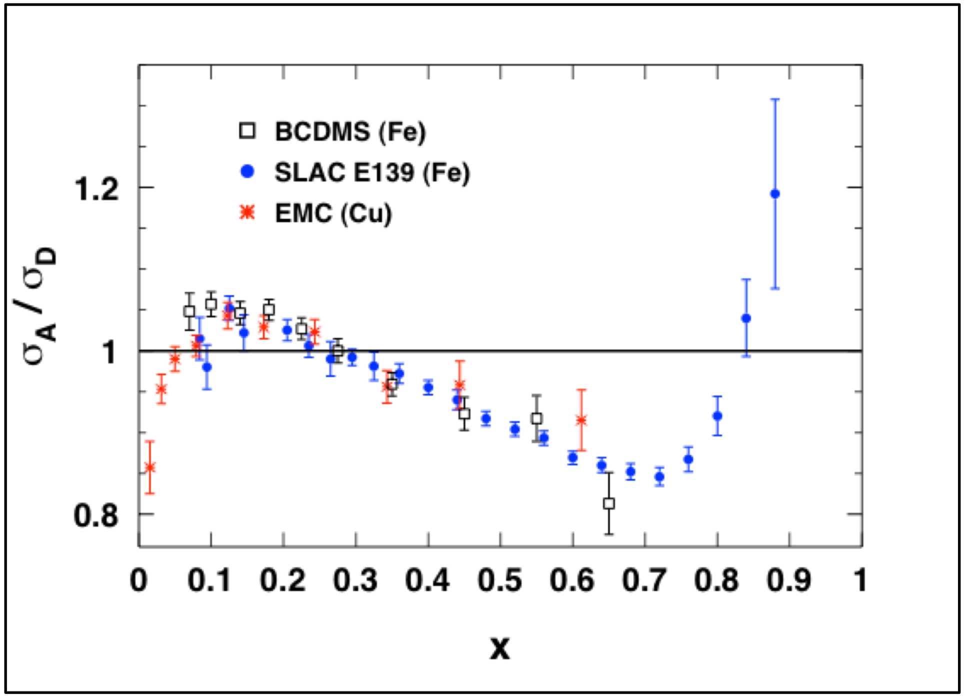
The EMC Effect



Discovered in 1983 – the EMC Effect demonstrated that quark distributions are modified in the nucleus

→ After >35 years, still no consensus on origin of this effect

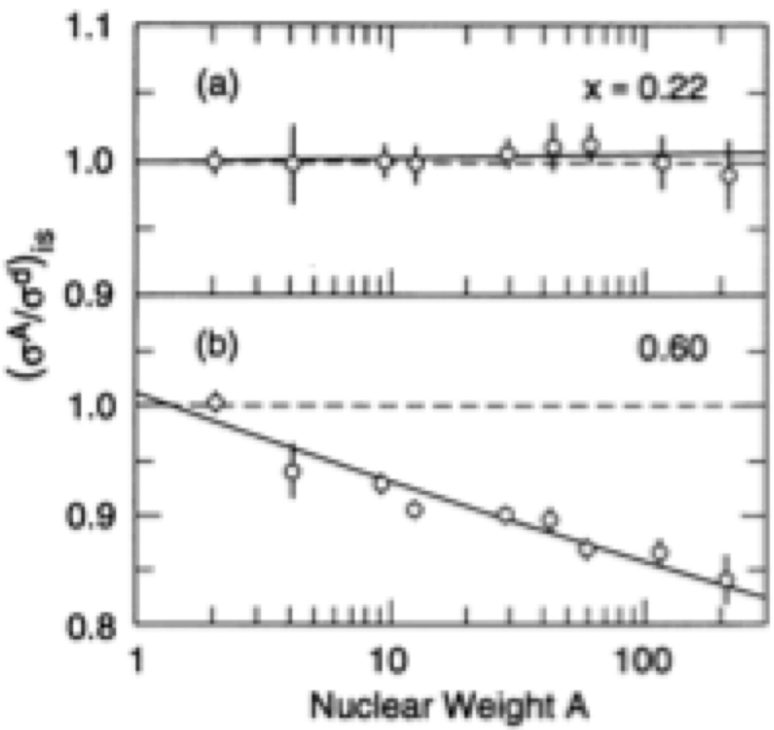
→ The EMC Effect cannot be explained in terms of "conventional" nuclear physics alone (although it does play a role)

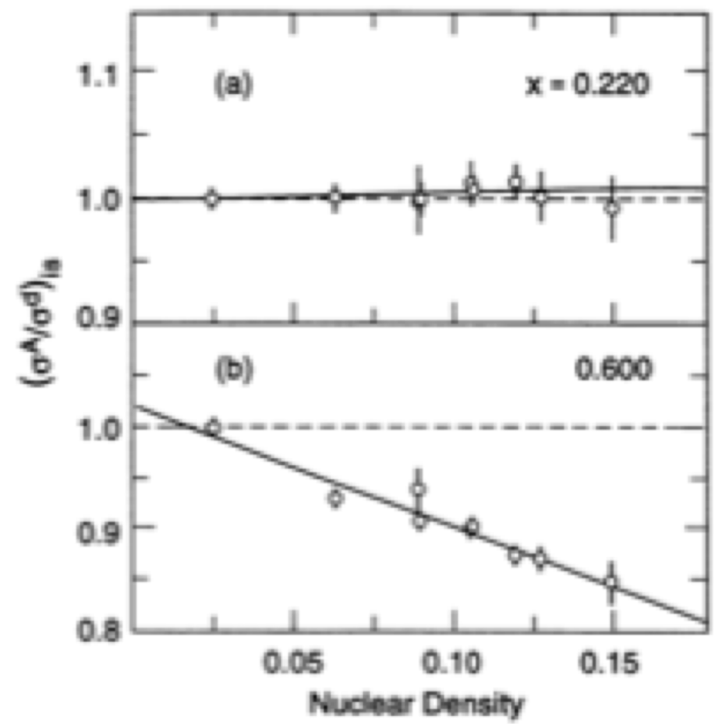
→ Ideas include nuclear pions, dynamical rescaling, multiquark clusters

→ Recently, a lot of interest in the connection between the EMC effect and Short Range Correlations

Nuclear Dependence of EMC Effect

Studying nuclear dependence of EMC Effect one way to gain insight to its origin





$\rho = 3A/4\pi R_e^3$ $R_e^2 = 5\langle r^2 \rangle/3$

$<r^2>$=RMS electron scattering radius

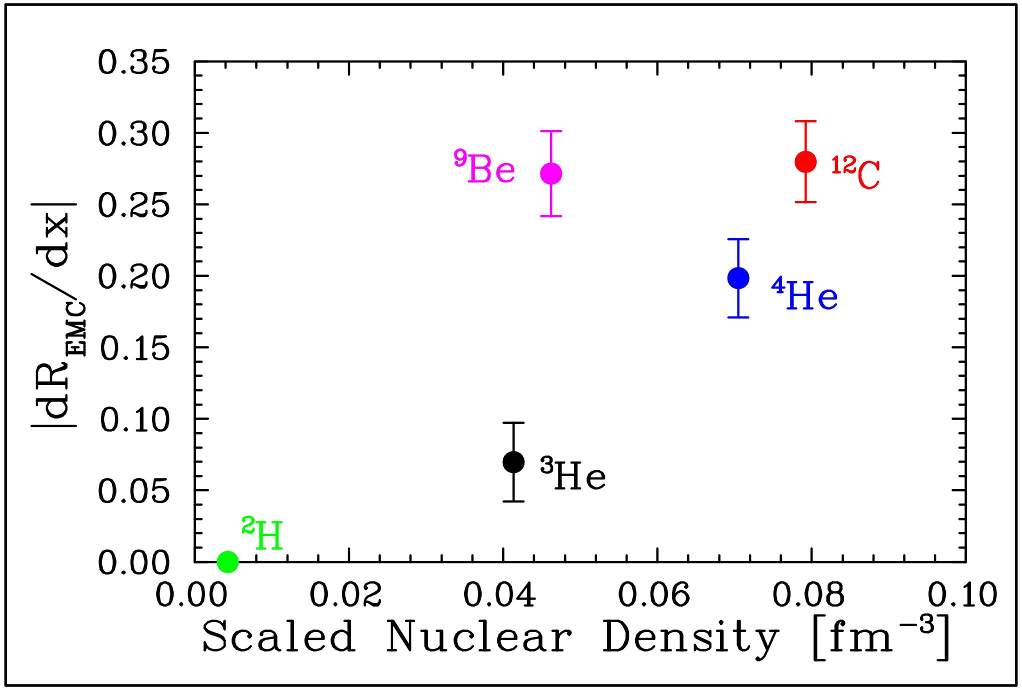
SLAC E139: *Gomez et al, PRD 49, 4348 (1992)*

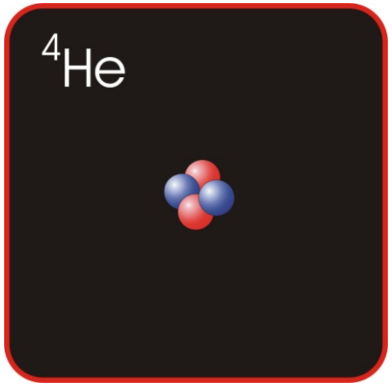
EMC Effect and Local Nuclear Density

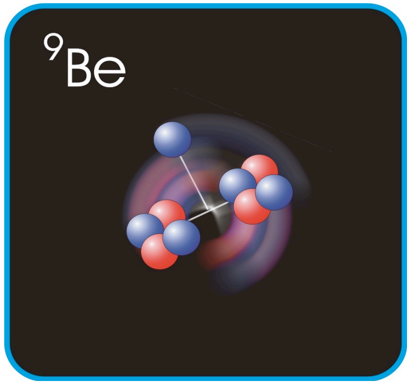
E03-103 studied nuclear dependence in light nuclei

^{9}Be has low average density
→ Large component of structure is ***2α+n***
→ Most nucleons in tight, *α*-like configurations

EMC effect driven by ***local*** rather than *average* nuclear density



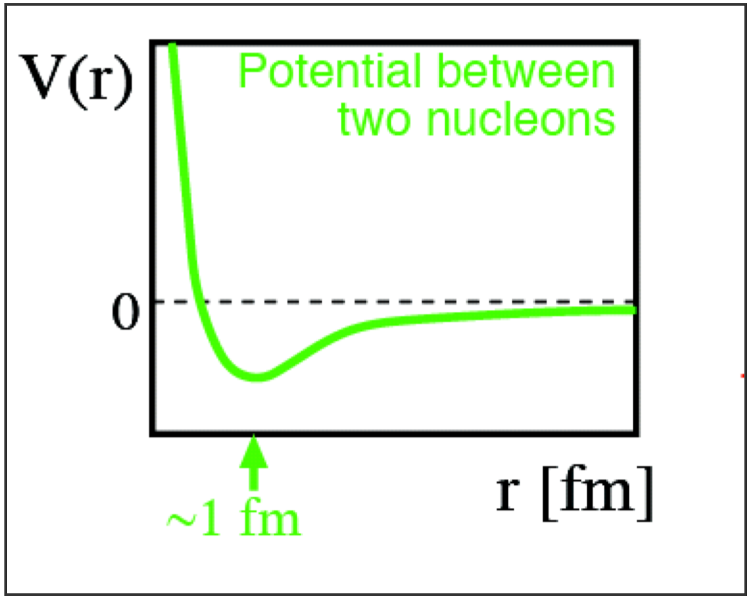


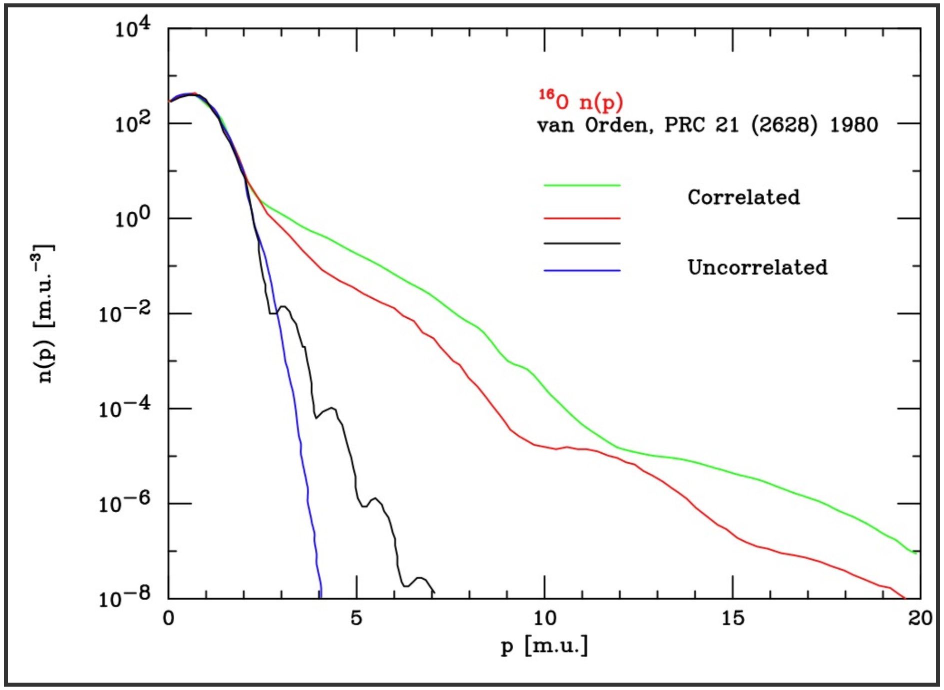


“Local density” is appealing in that it makes sense intuitively – can we make this more quantitative?

Local Density → Short Range Correlations

What drives high "local" density in the nucleus?



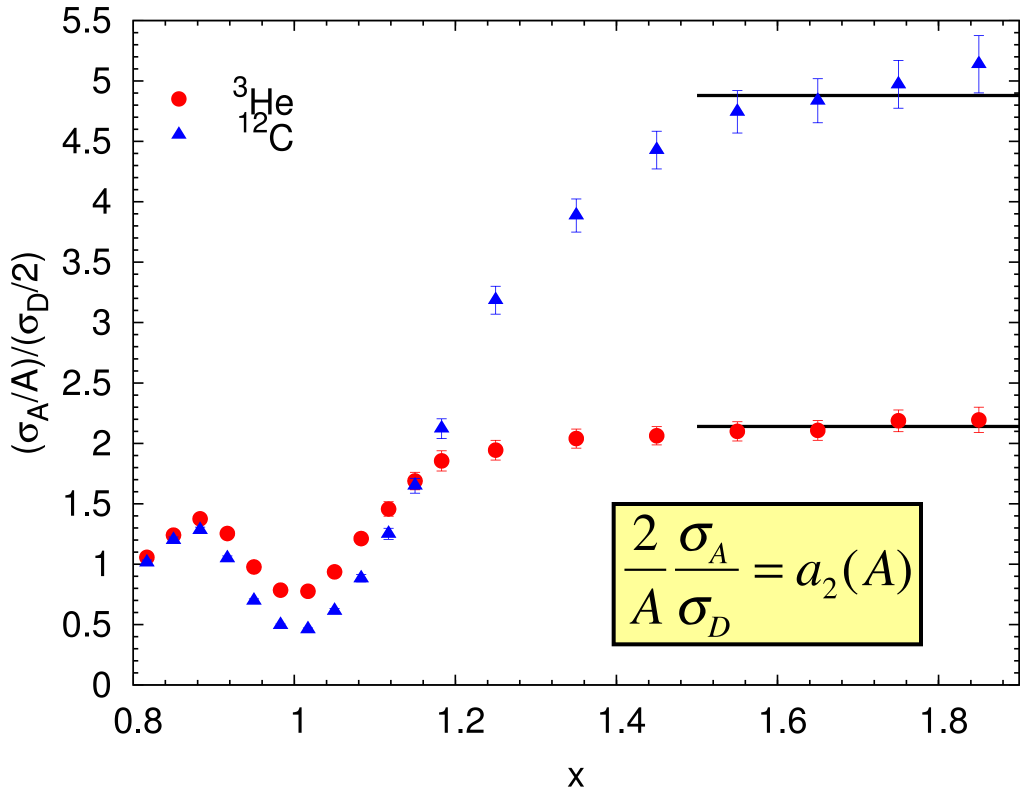


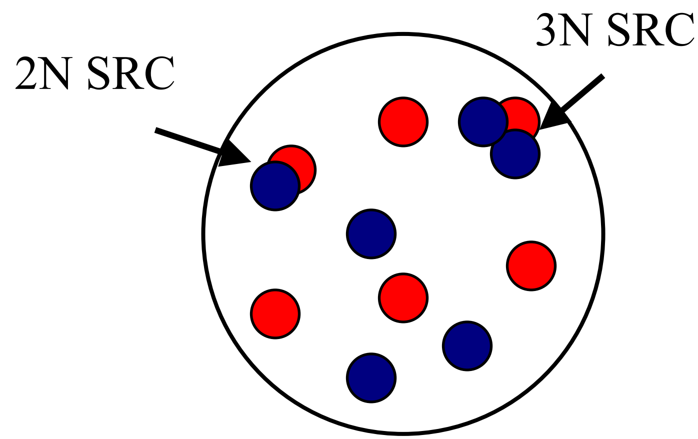
Tensor interaction and short range repulsive core lead to high momentum tail in nuclear wave function → correlated nucleons

Measuring Short Range Correlations

To measure the (relative) probability of finding a correlated pair, ratios of heavy to light nuclei are taken at ***x>1*** → QE scattering

If high momentum nucleons in nuclei come from correlated pairs, ratio of A/D should show a plateau (assumes FSIs cancel, etc.)

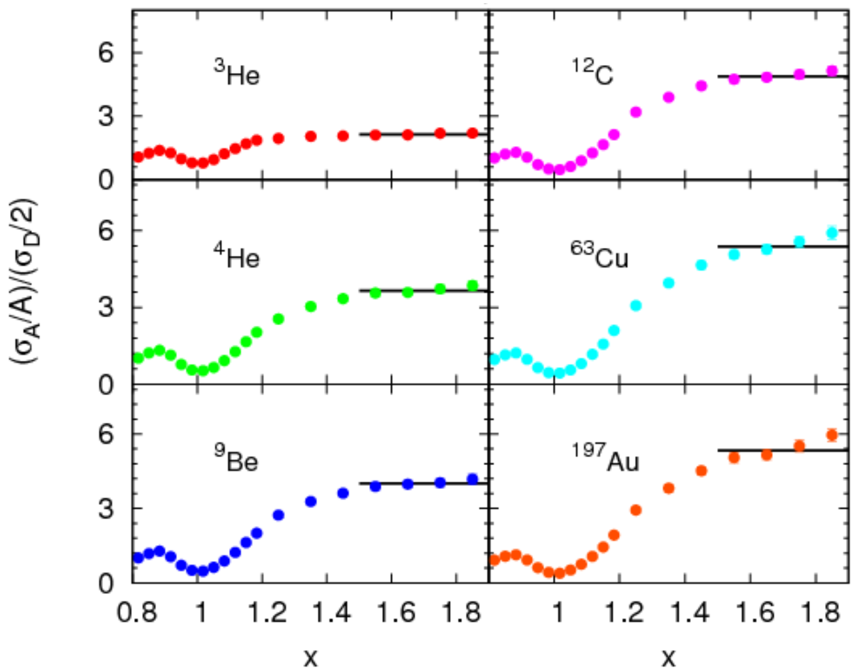




1.4<x<2 => 2 nucleon correlation

2.4<x<3 => 3 nucleon correlation

SRCs and Nuclear Density



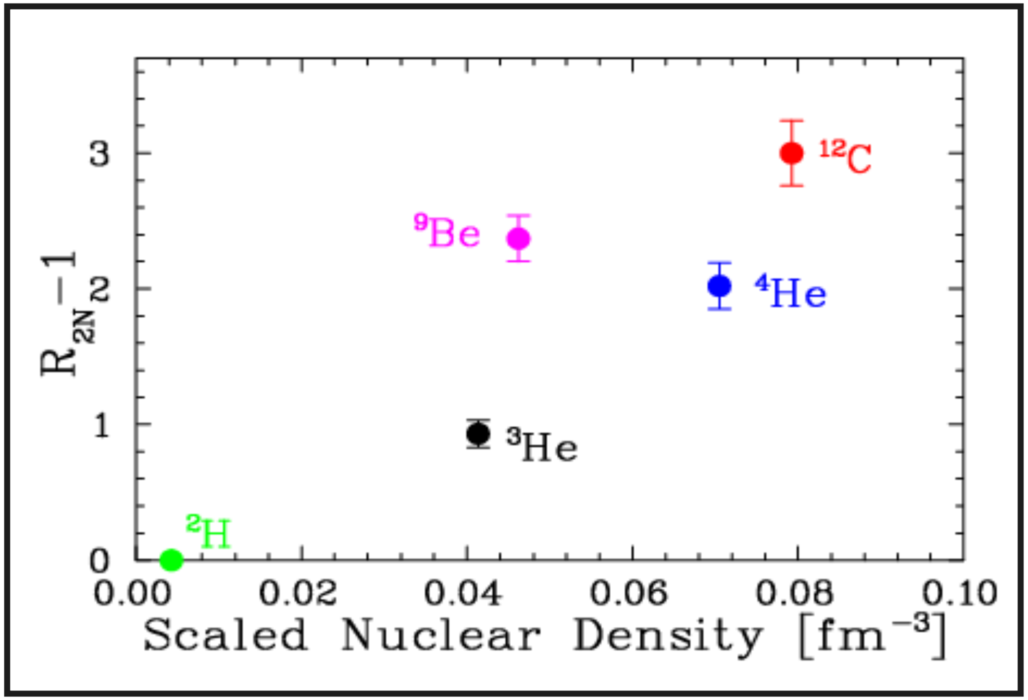
N. Fomin et al, Phys.Rev.Lett. 108 (2012) 092502

<u>Hall C data on ratios at *x>1*</u>

a_2 ratios for:

→Additional nuclei (Cu, Be, Au)

→Higher precision for targets with already existing ratios



→ Relative probability to find SRC shows similar dependence on nuclear density as EMC effect

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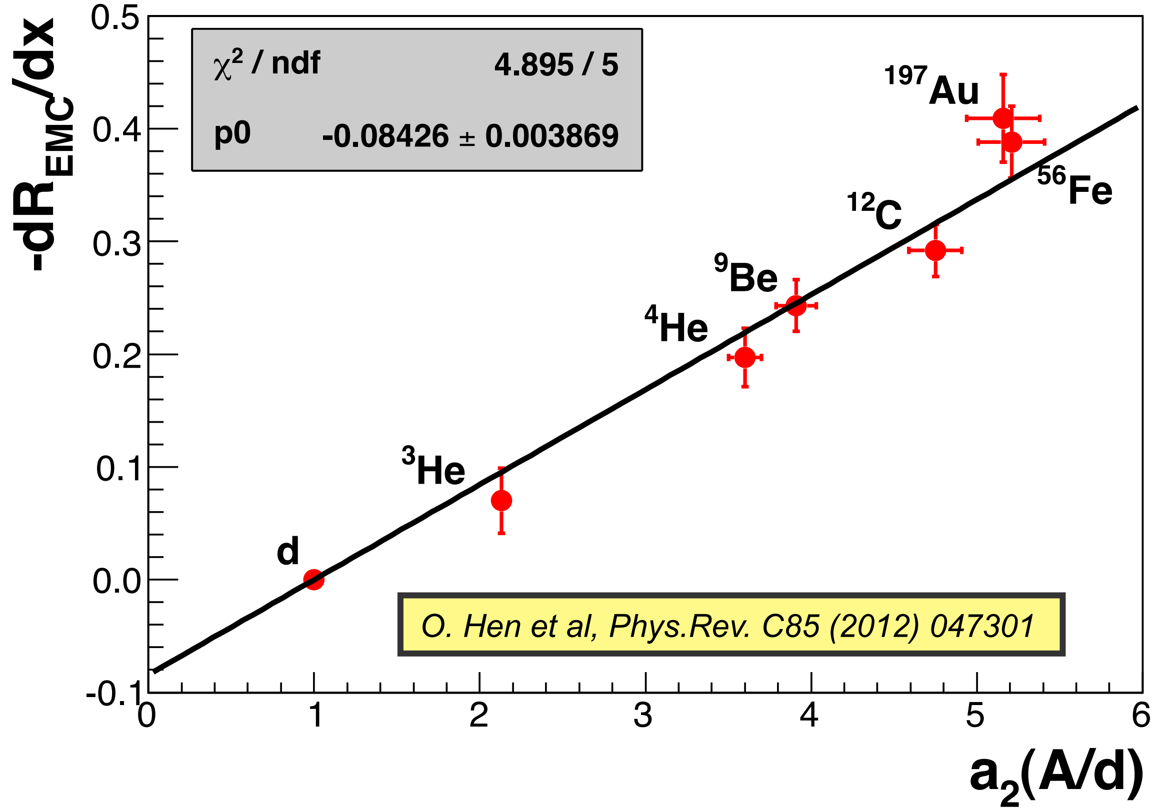
EMC Effect and SRC

Weinstein *et al* first observed linear correlation between size of EMC effect and Short Range Correlation "plateau"

Correlation <u>strengthened</u> with addition of Beryllium data



This result provides a ***quantitative*** test of level of correlation between the two effects

E12-10-008: EMC effect in light→ heavy nuclei

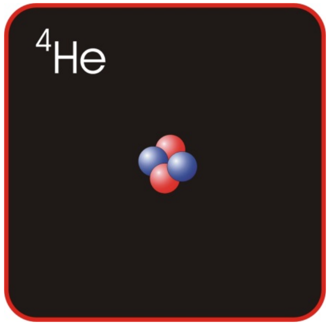
Spokespersons: J. Arrington, A. Daniel, N. Fomin, D. Gaskell

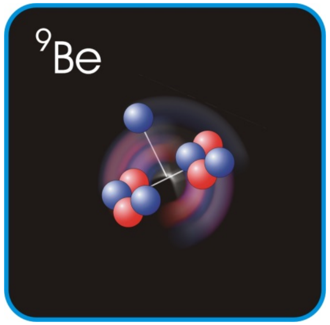
E03-103: EMC at 6 GeV

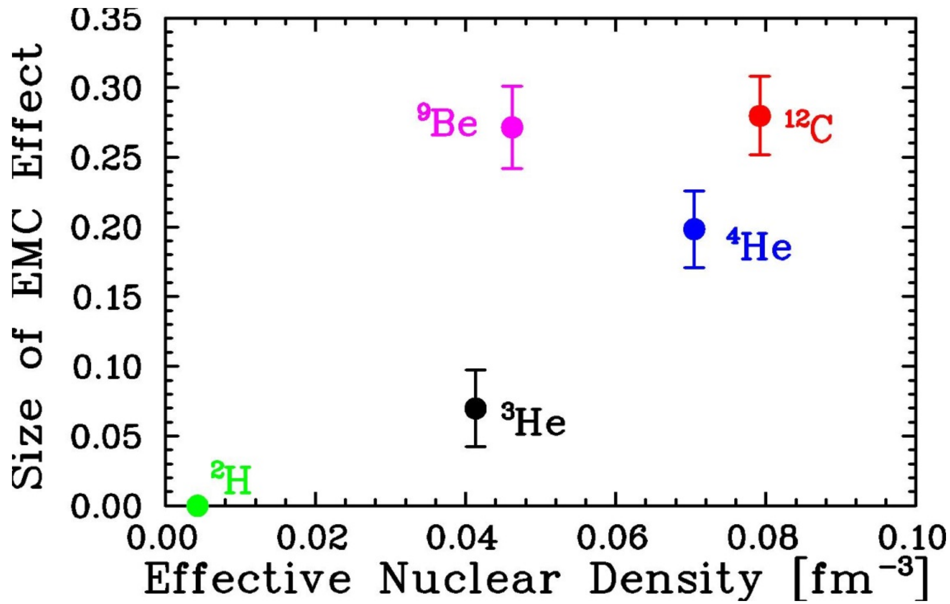
→ Focused on light nuclei

→ Large EMC effect for ^{9}Be

→ Local density/cluster effects?







J. Seely, et al., PRL 103, 202301 (2009)

E12-10-008: EMC effect at 12 GeV

→ Higher Q^2, expanded range in x (both low and high x)

→ Light nuclei includes ^{1}H, ^{2}H, ^{3}He, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, ^{12}C

→ Heavy nuclei include ^{40}Ca, ^{48}Ca and Cu and additional heavy nuclei of particular interest for EMC-SRC correlation studies

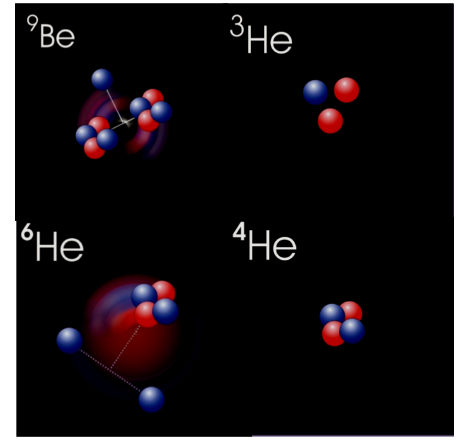
E12-10-008 (EMC effect) and E12-06-105 (x>1)

- Both experiments use wide range of nuclear targets to study impact of cluster structure, separate mass and isospin dependence on SRCs, nuclear PDFs

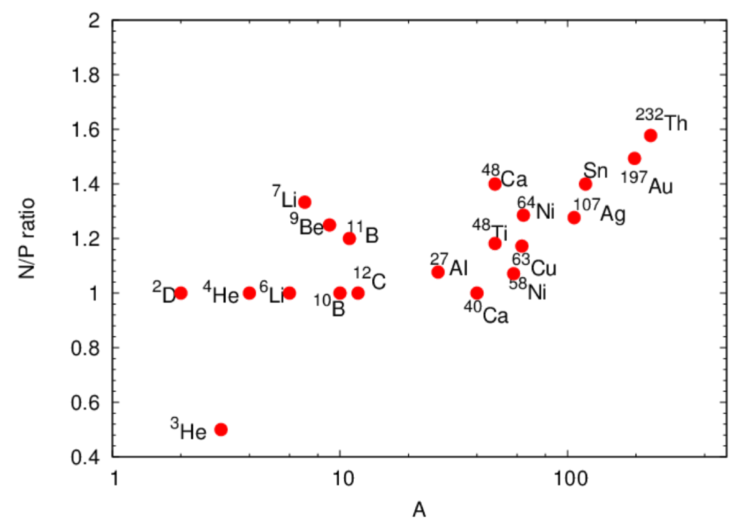
- Experiments will use a common set of targets to provide more information in the EMC-SRC connection

Light nuclei: Reliable calculations of nuclear structure (e.g. clustering)

^{1}H	^{6,7}Li
^{2}H	^{9}Be
^{3}He	^{10,11}B
^{4}He	^{12}C



^{27}Al	^{64*}Cu
^{40*,48}Ca	^{108*}Ag
^{48}Ti	^{119*}Sn
^{54}Fe	^{197*}Au
^{58,64}Ni	^{232}Th

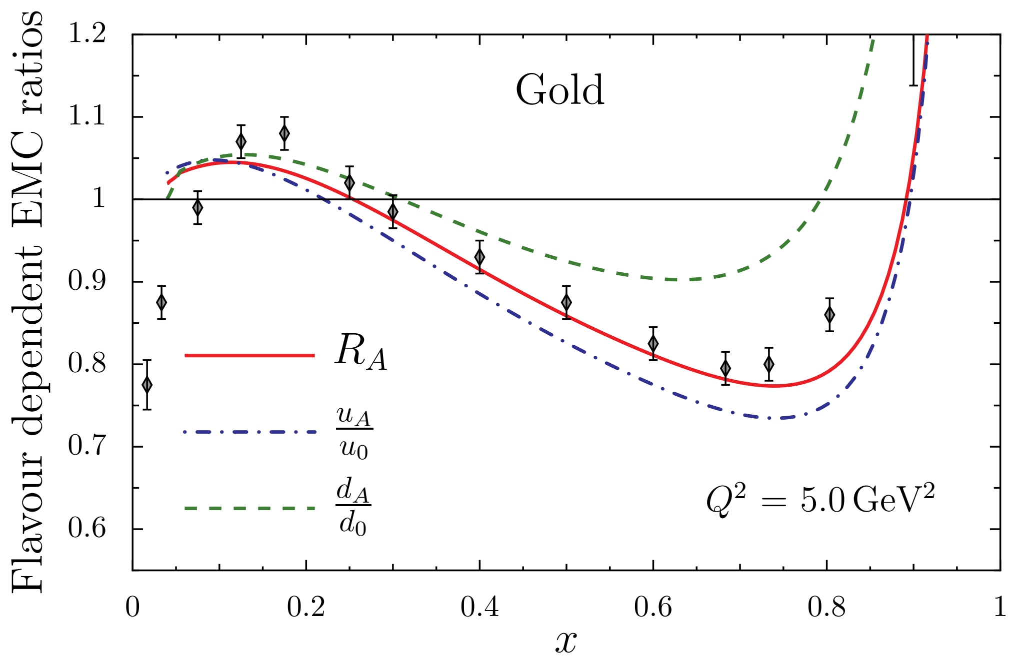


Heavier nuclei: Cover range of N/Z at ~fixed values of A

Flavor dependence and SRCs

High momentum nucleons in the nucleus come primarily from *np* pairs
→The relative probability to find a high momentum proton is larger than for neutron for *N*>*Z* nuclei

Under the assumption the EMC effect comes from "high virtuality" (high momentum) nucleons, modification of F_2 structure function driven by protons (u-quark dominates)
→ Similar flavor dependence is seen in "mean-field" calculations

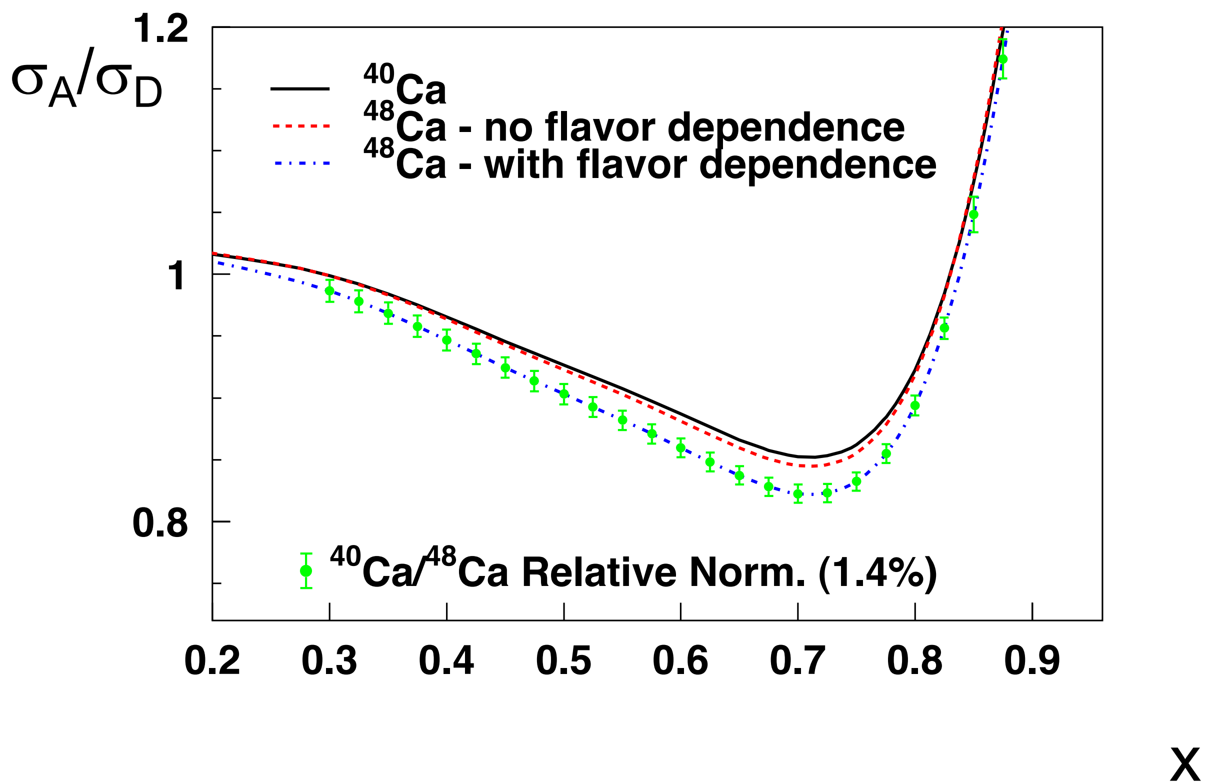


Cloët, Bentz, and Thomas, PRL 102, 252301 (2009)

Flavor dependence from ^{40}Ca and ^{48}Ca

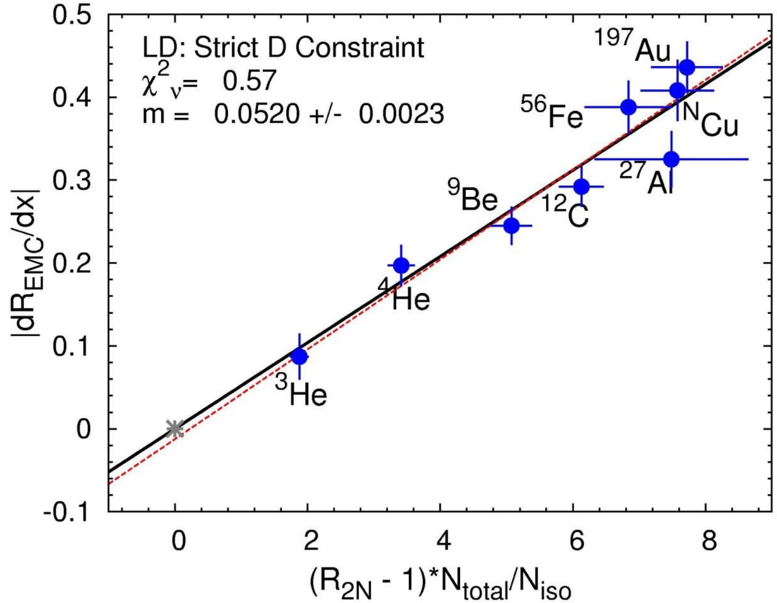
CBT model predicts a ~3% effect for ^{48}Ca at *x=0.6*
→*N/Z = 1.4*

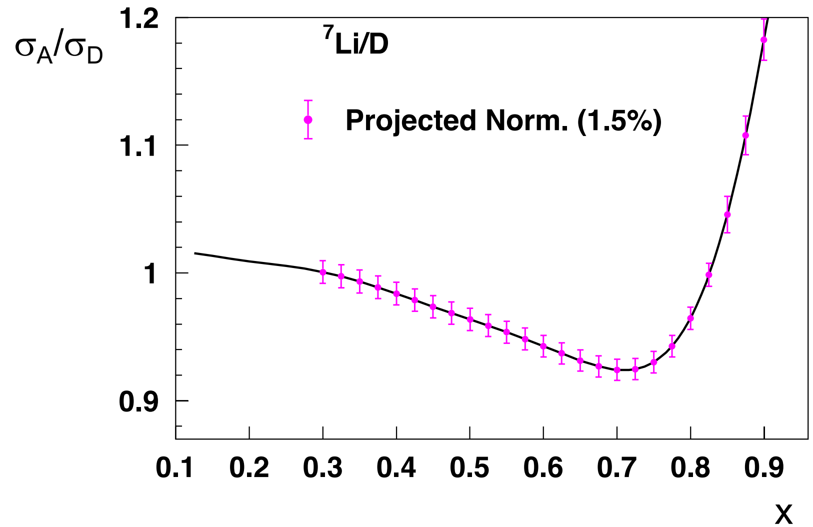
Assuming no flavor dependence, difference between ^{40}Ca and ^{48}Ca should be less than < 1% assuming SLAC E139 A-dependent parametrization

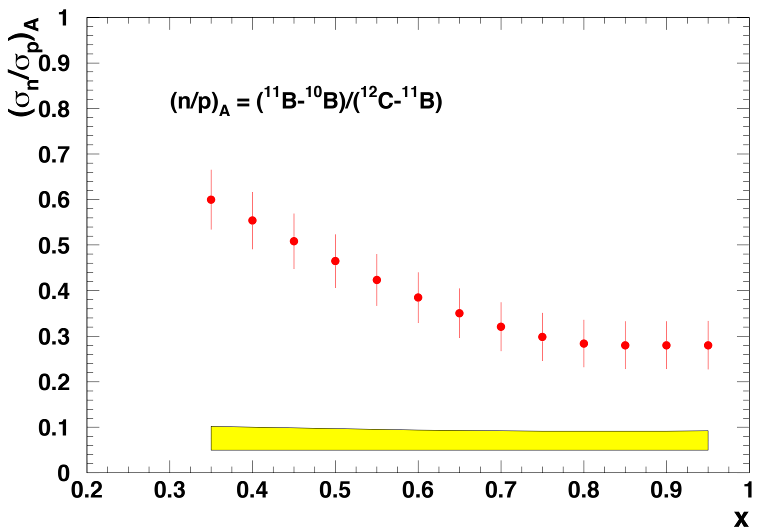


Measurement of unpolarized EMC effect in ^{40}Ca and ^{48}Ca provides some sensitivity to possible flavor dependent effect

E12-10-008: Physics Reach







<u>E12-10-008 outcomes</u>

1. EMC Ratios of a variety of previously unmeasured nuclei
2. Additional nuclei to explore the EMC-SRC correlation in more detail (when combined with E12-06-105)
3. Sensitivity to flavor dependence of EMC effect via measurements of ^{40}Ca and ^{48}Ca
4. n/p ratio in nuclei

E12-10-008: Commissioning running

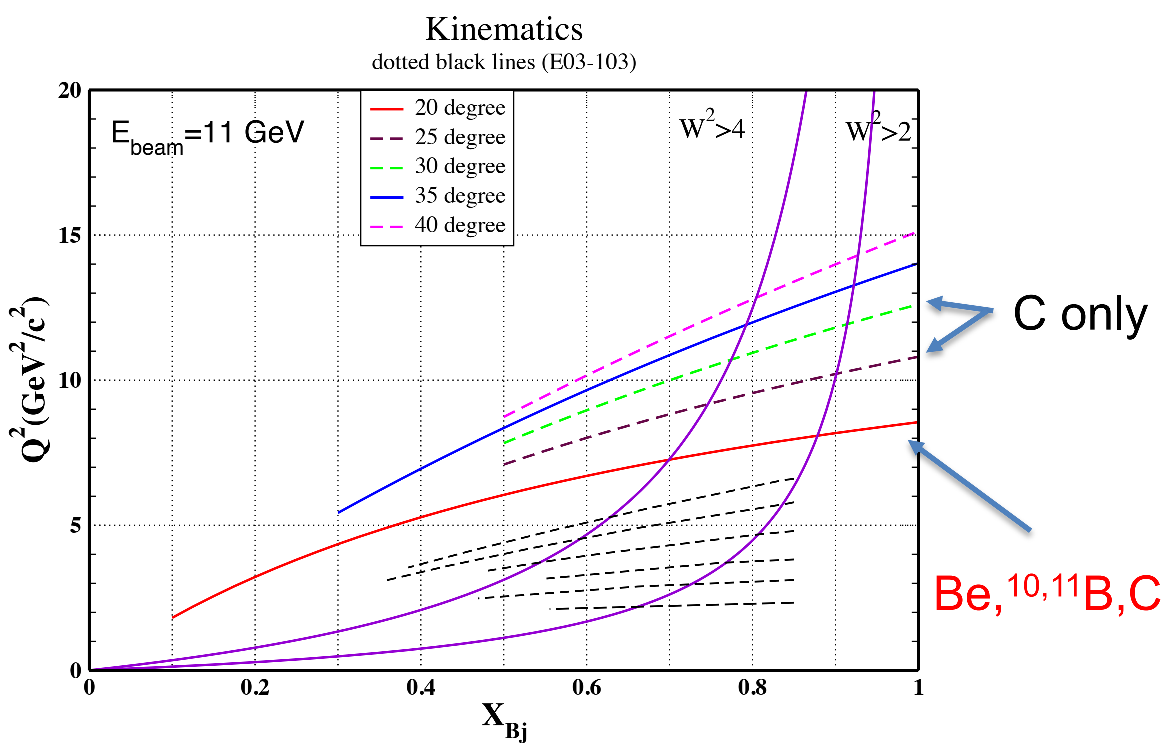
→ Ran with E12-10-002 (F_2) as part of commissioning experiment run to make some initial EMC effect measurements

→ 2 PAC days used to:

1. Measure Q^2 dependence of EMC effect over range of x to check scaling of EMC ratio → carbon target
2. Obtain data on a few light nuclei at a single Q^2/angle (^{9}Be, ^{10}B, ^{11}B, C)

<u>Targets:</u>
10 cm H, D cryotargets with Al dummy, ^{9}Be, ^{10}B4C, ^{11}B4C, C solid targets

Measurements in both SHMS and HMS



E12-10-008 Analysis Status

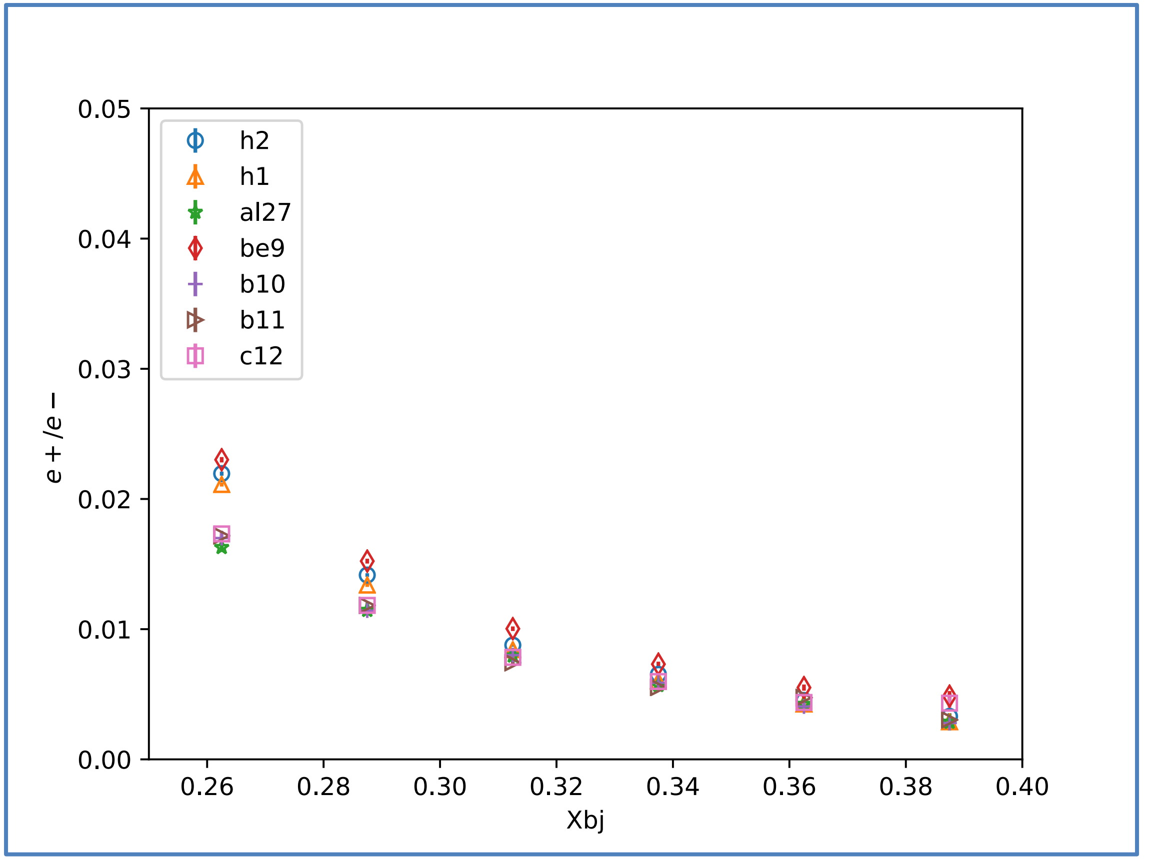
- Common analysis with E12-10-002 (F_2)
- Calibrations complete
- Working on understanding efficiencies, rate dependent effects
- Extraction of raw ratios in progress
  - No bin-centering corrections
  - Very preliminary RC corrections (if any)
- To-do list (partial)
  - Complete efficiency studies
  - Detailed data/Monte Carlos comparisons
  - Iterate RC model

Charge Symmetric Background

21 degrees

First look at charge symmetric background

→ No correction for pion contamination in e+ sample
→ At 21 deg., only took e+ data for lowest momentum setting
→ Even in the worst case (Be/LD2/LH2) background is small

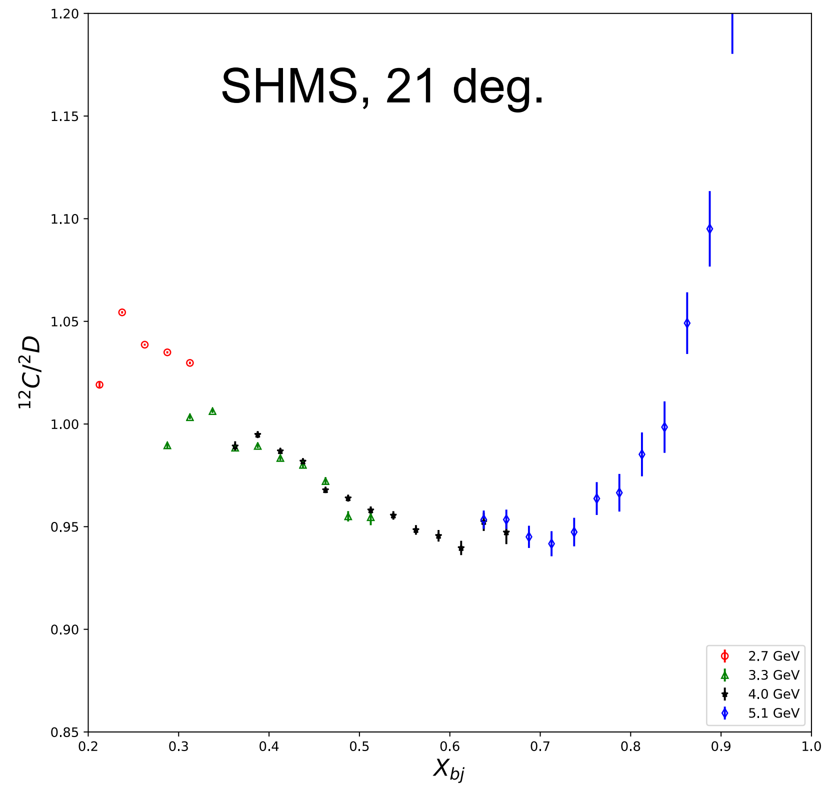


Abishek Karki

Carbon Yield Ratio

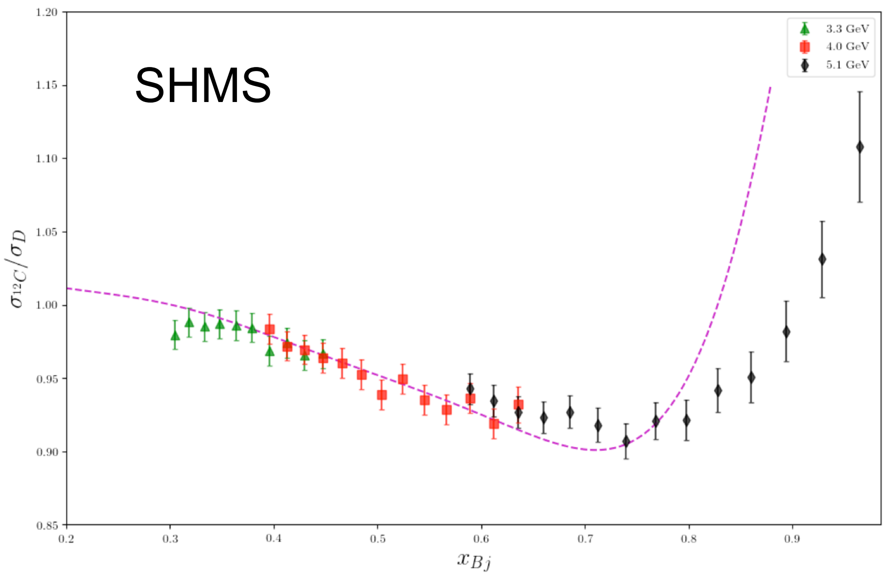
Ratio corrected for target thickness only

→ No radiative corrections, charge-symmetric background subtraction
→ Yields binned in x
→ Mis-match at overlaps likely due to resolution, acceptance differences (thin solid vs. 10 cm cryotargets)



Abishek Karki

Carbon ratios – HMS/SHMS



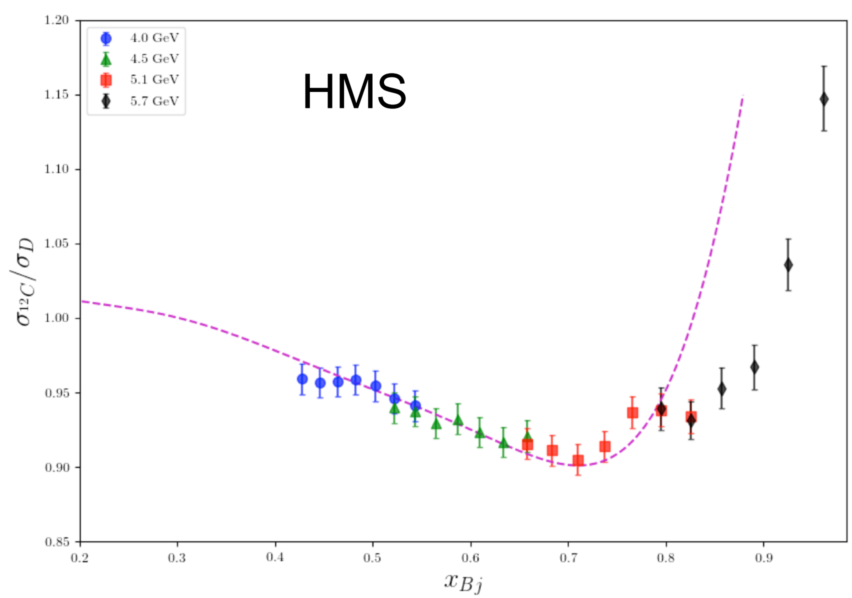
→ Raw ratios, binned in Eprime, converted to xbj

→ Preliminary RC based on Bodek F2 parametrization + EMC fit

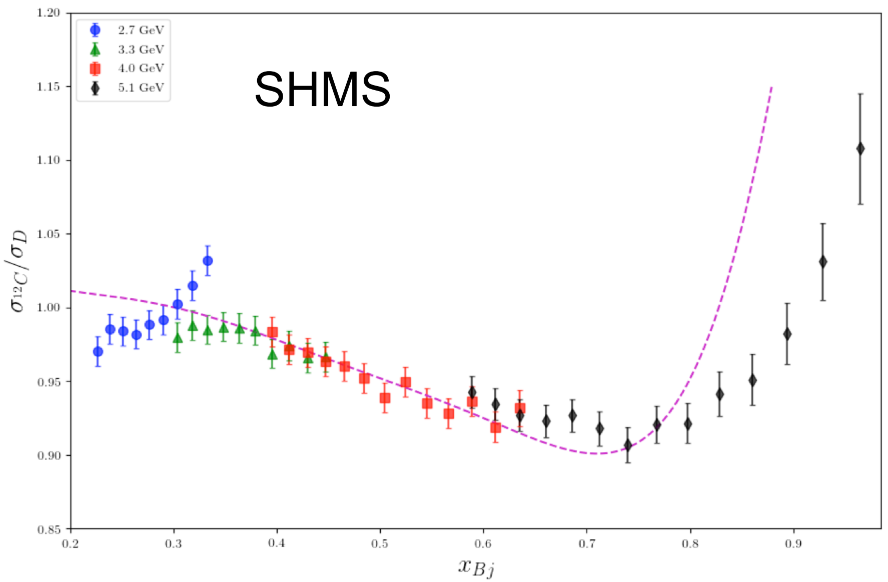
→ Note: electrons selected with calorimeter only

→ Good agreement with EMC effect parametrization up to x~0.8

→ Discrepancy at large x likely due to model, lack of bin-centering



Carbon ratios – HMS/SHMS



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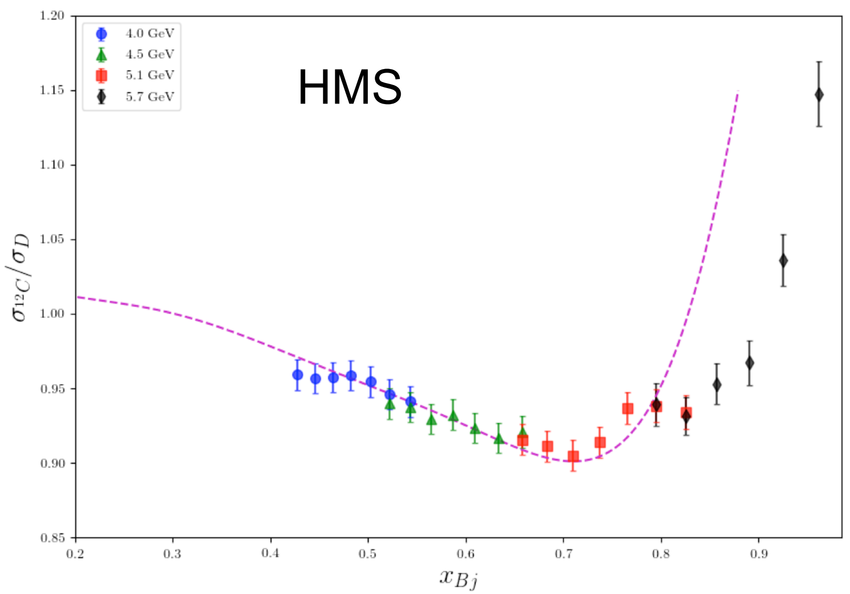


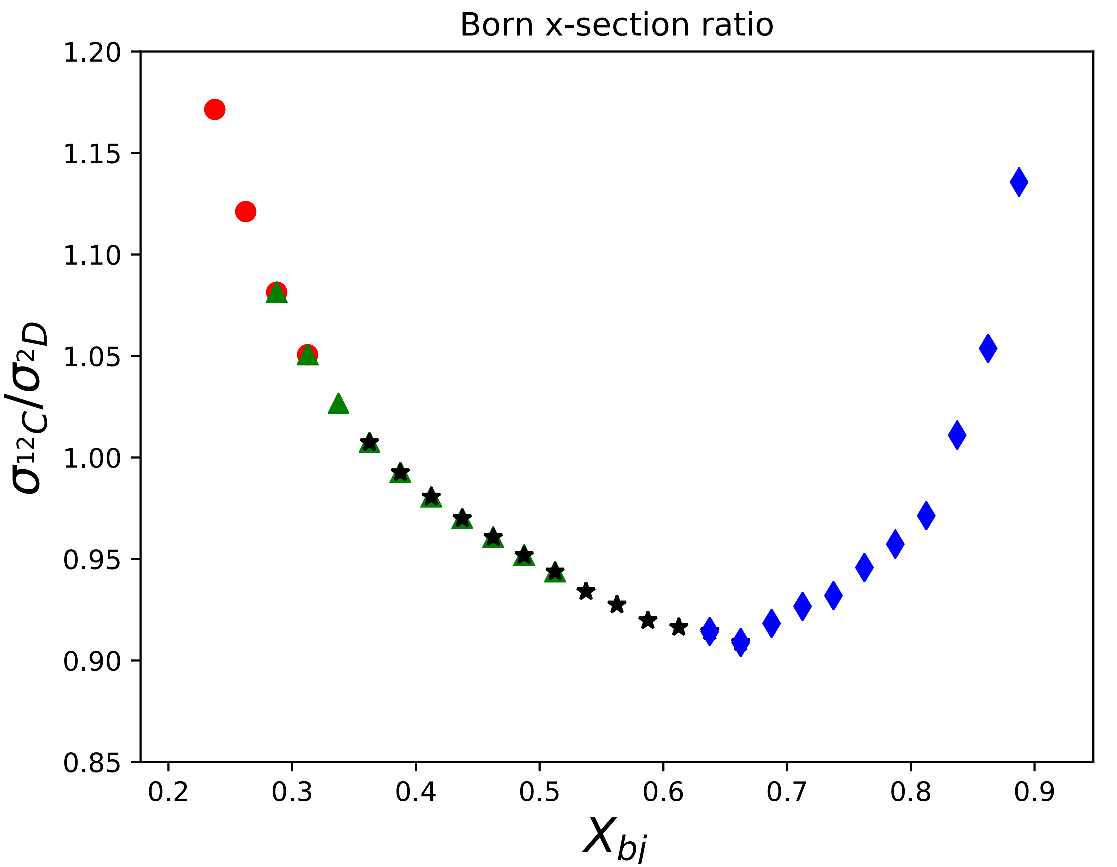
→ Good agreement with EMC effect parametrization up to x~0.8
→ Discrepancy at large x likely due to model, lack of bin-centering
→ Some issue at lowest P setting

Radiative Corrections Model

Started looking at preliminary radiative corrections using "rc-externals"

From F2 analysis, model for H, D looks pretty good

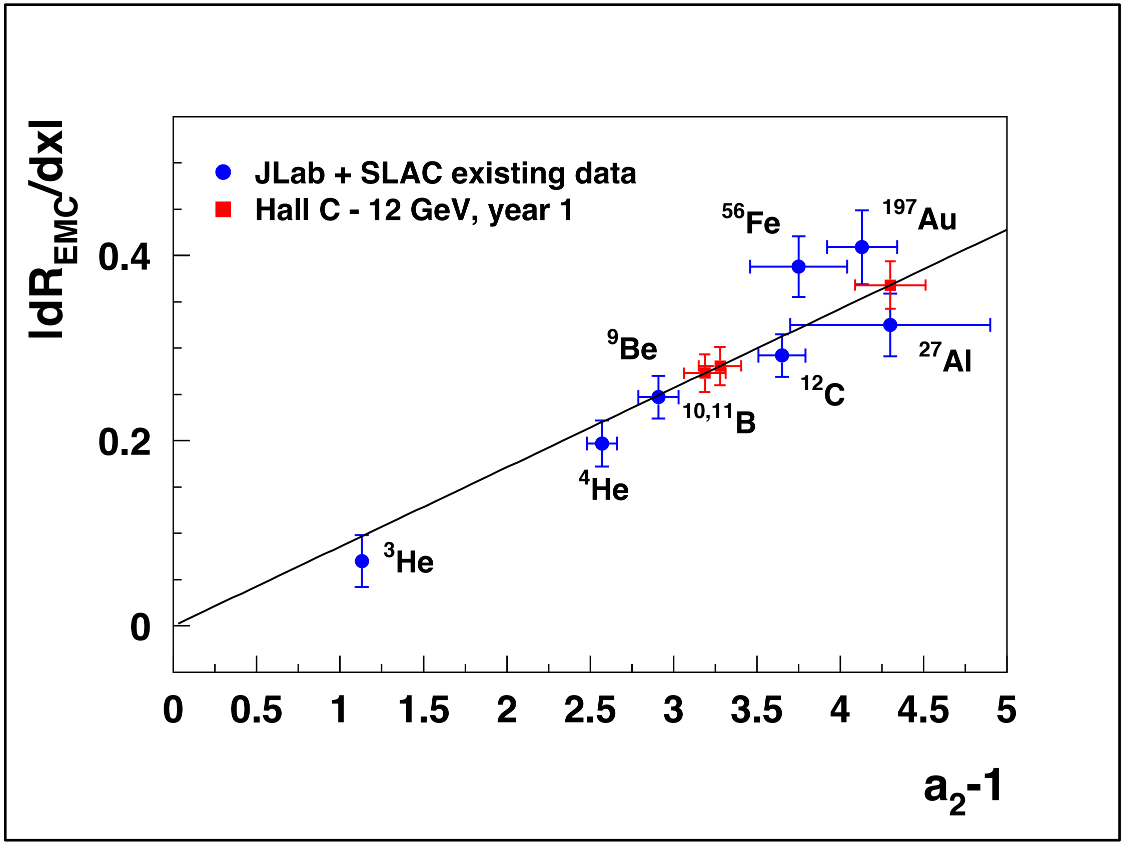
Existing model looks fine for x>0.3, but needs improvement at lower x
→ Likely moving beyond kinematic range (*W*) of original fit



E12-10-008 Commissioning Run Outcome

E12-10-008, in combination with data taken at large x, will provide:

1. EMC ratios for Be, ^{10}B, ^{11}B, C
2. a_2 ratios for same nuclei
3. New information for EMC-SRC correlation



Summary

- The EMC effect clearly demonstrates that quark distributions are modified in the nucleus
- More than 30 years after the initial discovery of the EMC effect, there is no universally accepted explanation
  - Recent JLab data combined with observation of EMC-SRC correlation has provided an intriguing clue
  - High density in local nuclear environment? Highly virtual nucleons?
- E12-10-008 (and E12-06-105) will provide new data on a several nuclei
  - Explore N/Z dependence at fixed A and A dependence at fixed N/Z
- 2018 data will provide first EMC measurements on ^{10}B and ^{11}B, initial measurements of Q^2 dependence at large x
- Analysis in progress → only in initial stages of ratio extraction