EMC Ratio in Lighter Nuclei

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Joint Hall A & C Summer Collaboration

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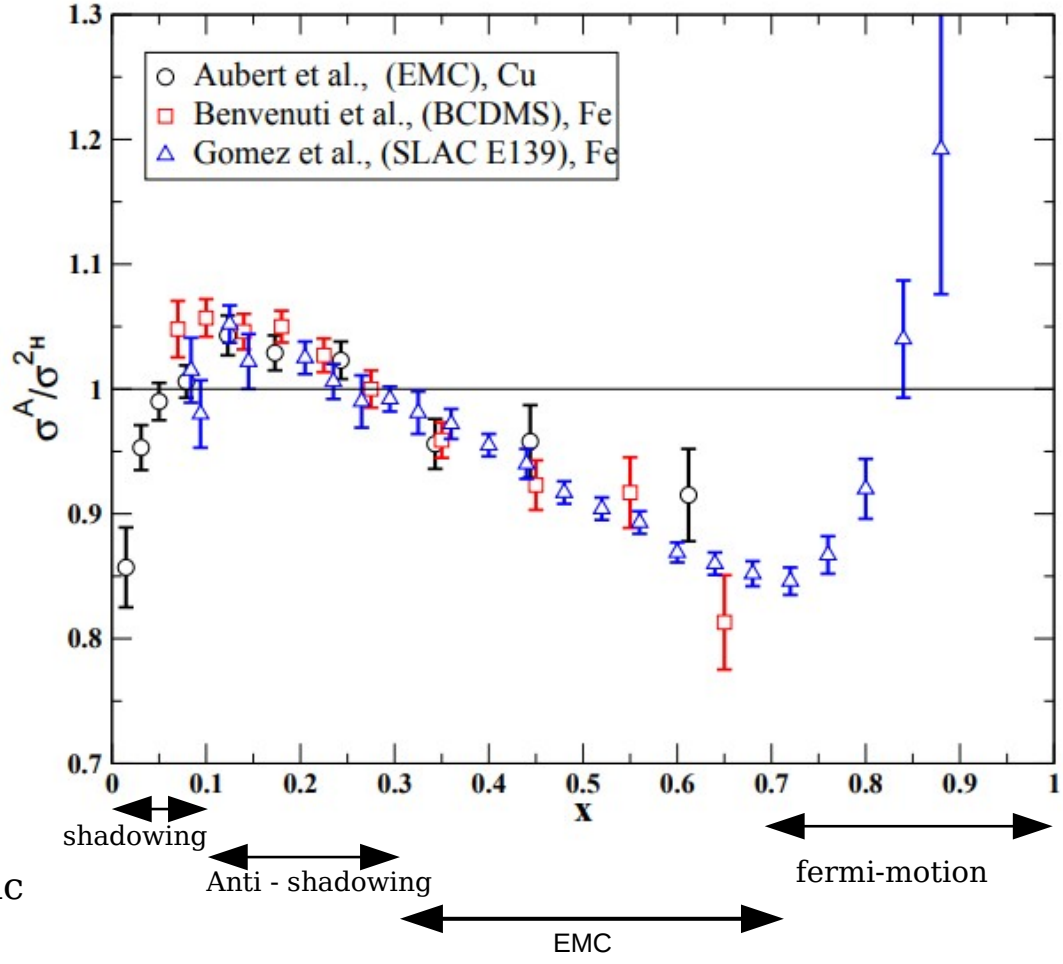
Outline

- The EMC Effect
- Experiment E12-10-008 at Hall C (Upcoming run Plans)
- Analysis Status
- Summary

The EMC Effect

- **EMC Effect : Quarks distributions are modified inside nuclei**
- Different kinematic regions understood in terms of different process
- Conventional nuclear physics models
  - Fermi smearing
  - Binding energy
  - Nuclear pions access
- Exotic models
  - Multi-quarks clusters (6q, 9q) bags
  - Dynamical rescaling
  - Modification of nucleon structure
- Several models, but valid only in certain kinematic regions



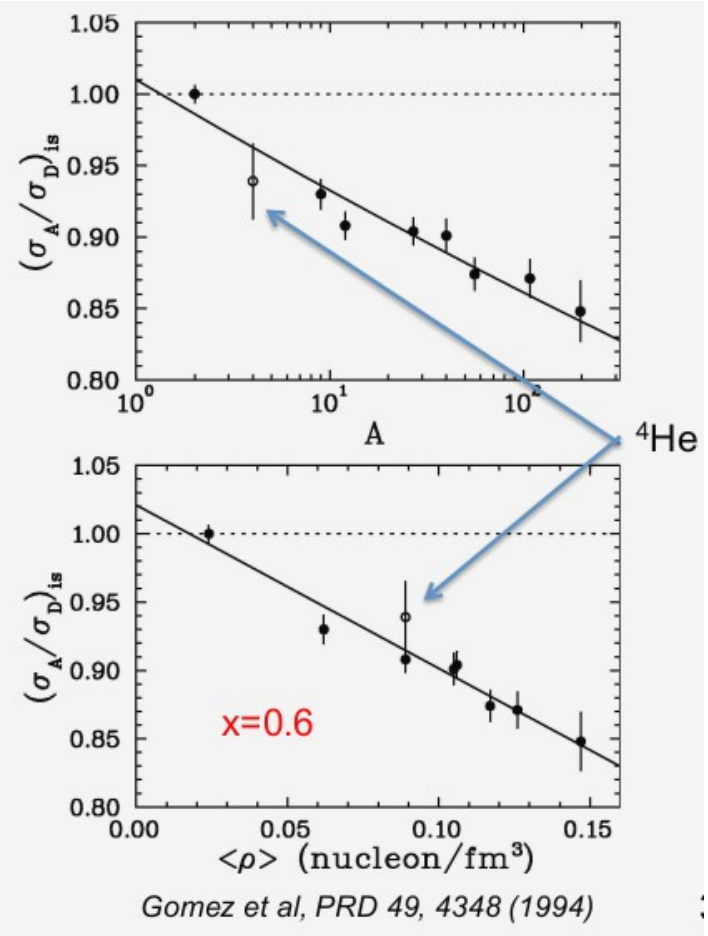
More than 36+ Years, STILL ….

The EMC Effect: Representative data

SLAC E139 studied the *Nuclear dependence of the EMC effect at fixed x

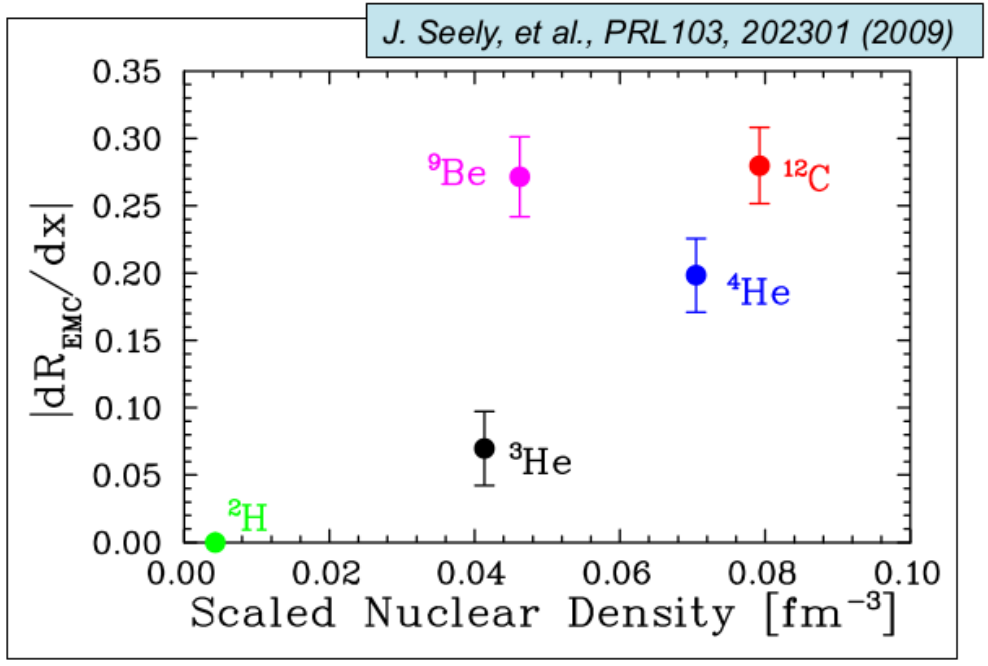
- **SLAC E139**
  - Most precise large x-data
  - Nuclei from A = 4 to 197
- **Conclusions from SLAC E139**
  - Q^2-independent
  - Universal x-dependence for all A
  - A-dependent magnitude
    - Scales with A ($\sim A^{1/3}$)
    - Scales with average density

***Nuclear dependence** is interesting as it helps to provide more information to test models



Motivation: Jlab E03-103

- Measured σ_A/σ_D for ^{3}He, ^{4}He, Be, C
  - ^{3}He, ^{4}He, C EMC effect scales well with density
  - **Be** does not fit the trend
- **^{4}He & C** data matches the trend observed in SLAC experiment.
  - Avg nuclear density of **^{4}He** and **C** are similar
- **^{9}Be** emc slope matches better with **C** data.
  - Avg nuclear density of Be<<C



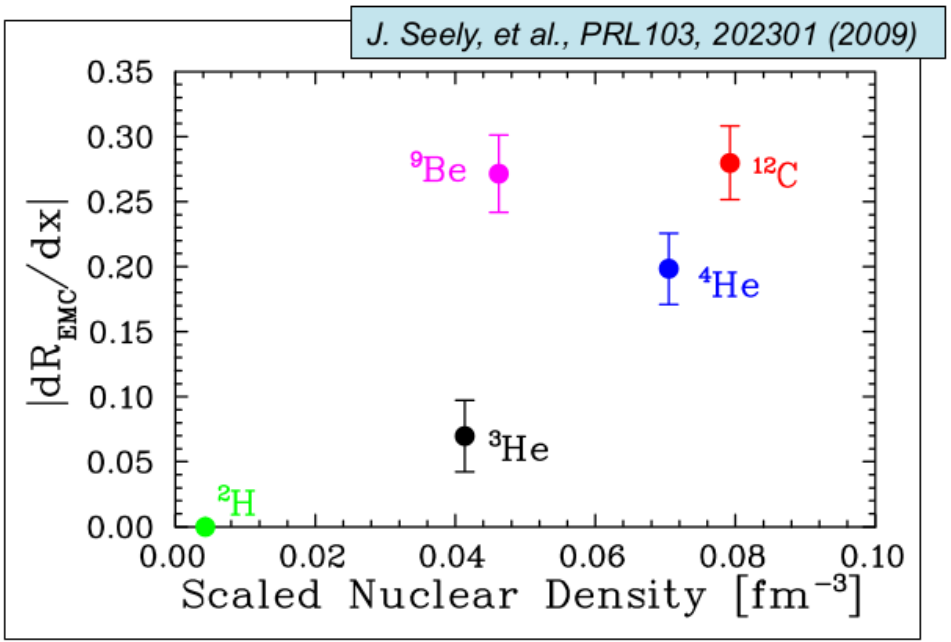
- Plot shows slope of ratio σ_A/σ_D at EMC region

Both A- and ρ- dependent fits fail to describe these light nuclei

Motivation

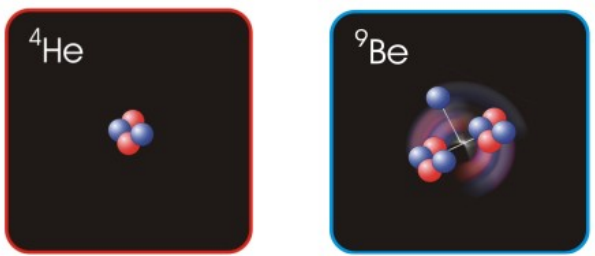
Jlab E03-103:

- **Suggest that EMC Effect in light Nuclei does not scale with average nuclear density**
- **Hints that the effect may be driven by local environment**



One could explain if one considers that the nuclear structure of Be to be that of cluster of two alpha particles with an extra neutron.

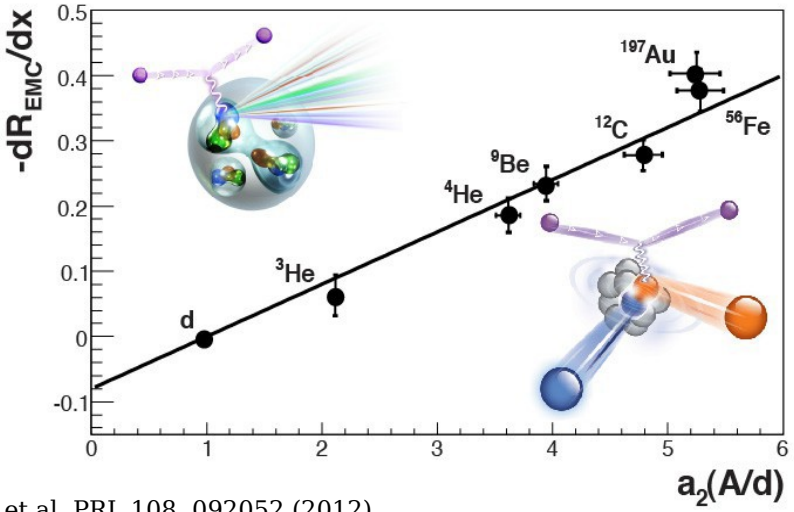
Nucleons are in high local densities of alpha cluster



^{9}Be: large components of structure is 2α+n

Motivation: SRC & EMC correlation

- Connections to other local density effects
- EMC-SRC connection became more intriguing with the addition of Be SRC data from JLab
  - Both effects display similar dependence on nuclear density
  - Quantitative test of correlations requires additional light nuclei



N. Fomin, et al, PRL 108, 092052 (2012)
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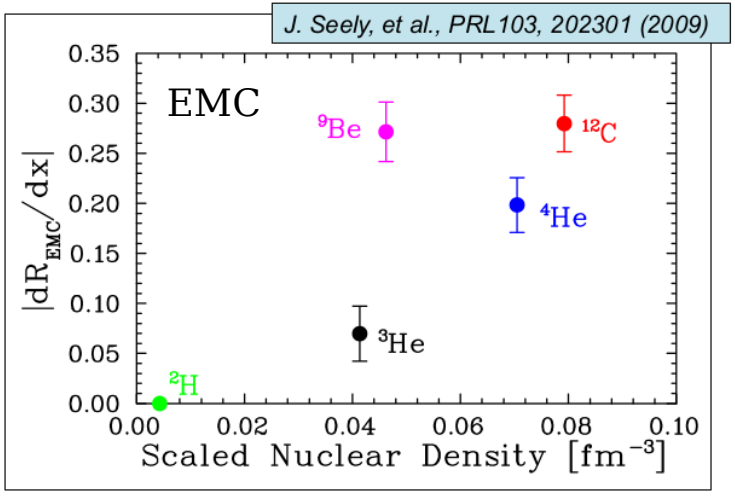
L. Weinstein, et al, PRL, 106, 052301 (2011)

J. Seely, et al., PRL103, 202301 (2009)



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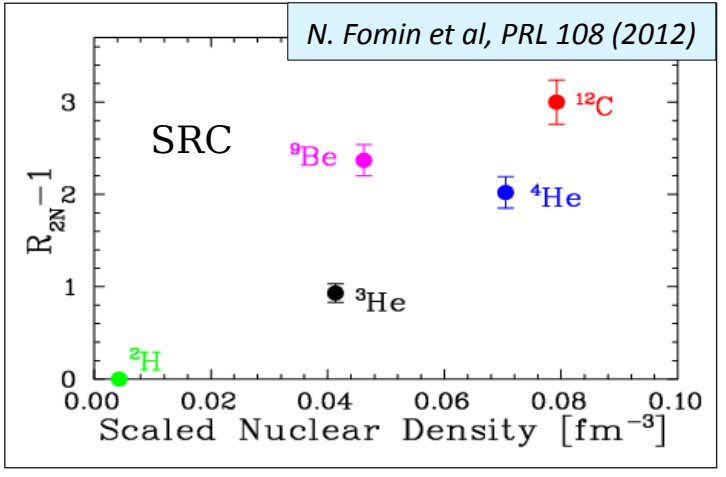

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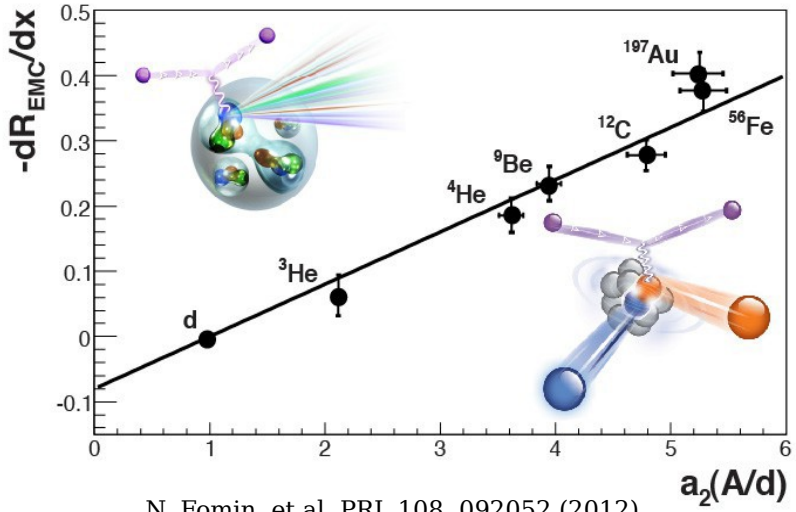

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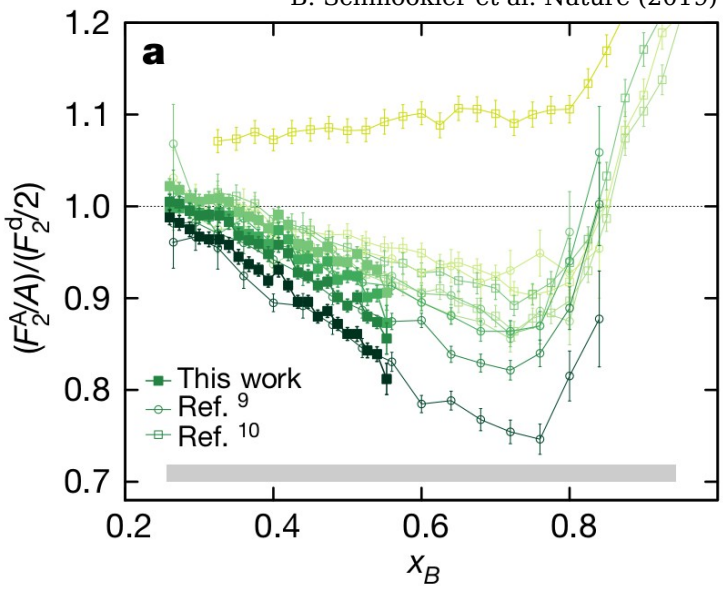
Proposed universal modification function

B. Schmookler et al. Nature (2019)



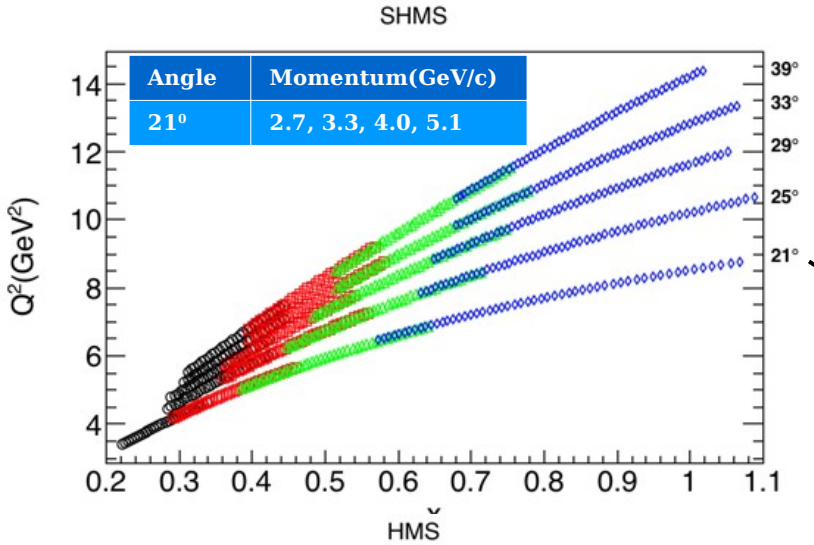
Motivation: E12-10-008

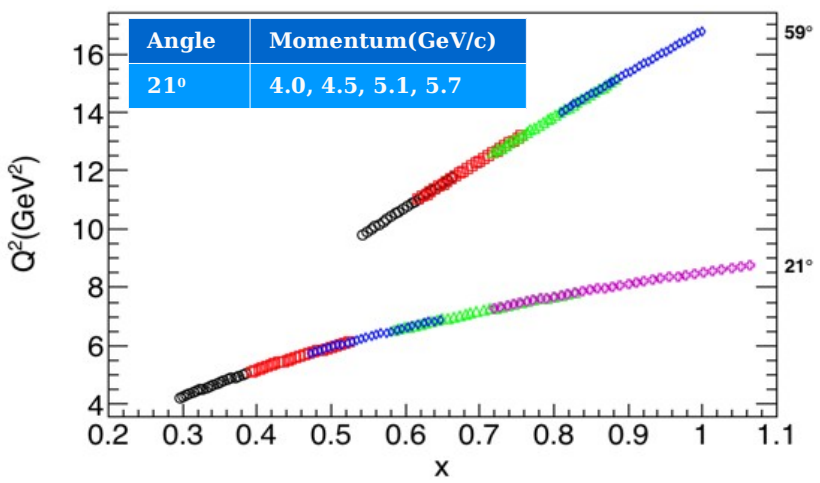
- Pushed to higher Q^2, expand range in x (both high and low)
- Investigate the influence of local environment on the observed nuclear dependence with additional light nuclei.
- To map out the SRC/EMC connection for the additional light nuclei.

Overview of the experiment (E12-10-008)
Phase - I

- Ran during spring 2018 concurrently with E12-10-002 (F_2) as a part of commissioning experiment in HallC
- Measurement of inclusive electron scattering cross section from lighter Nuclei
  - Cryo targets: H, ^{2}H
  - Solid targets: Be, C, *Al, ^{10,11}B (**First Measurement of EMC effect in ^{10,11}B**)
    (*Al for cell wall subtraction)
- Single-arm measurement
- Un-polarized electron beam energy 10.6 GeV
- Data were taken at a single (Q^2) /angle (21^0)
  - Additional data on C were taken at larger angle to investigate Q^2-dependence of the EMC ratio

Kinematic Coverage: Phase - I





NOTE: These are also kinematic points for F2 experiment

Data at large angle will provide Q^2 dependence study

Main EMC ratio extraction is done using data at angle 21° **using both spectrometer**

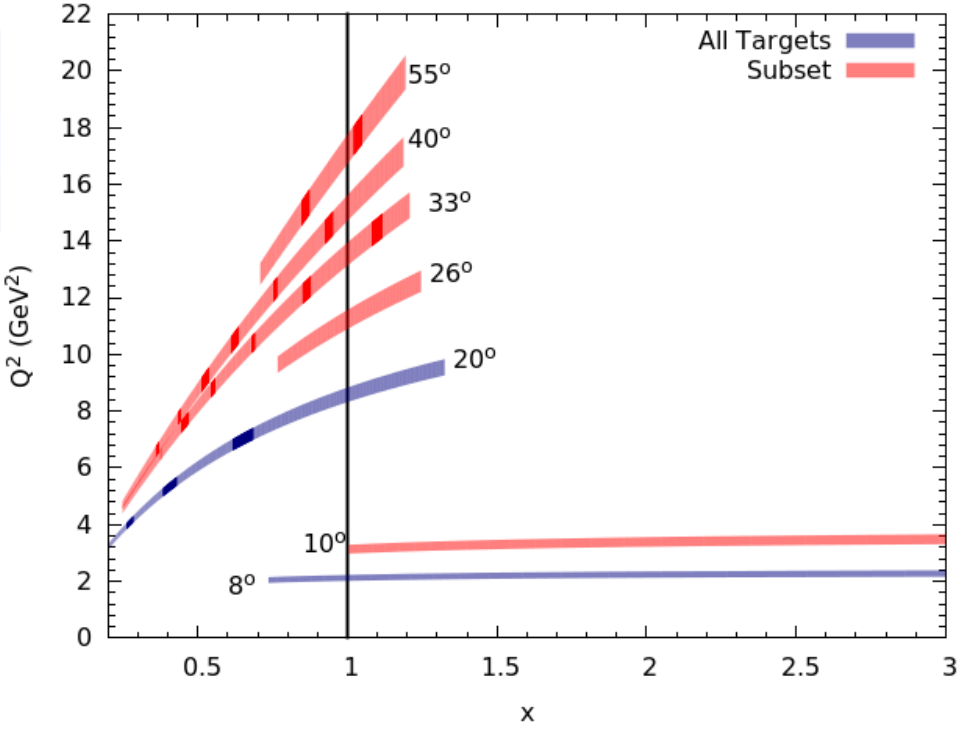
Data were taken with both arms:

- **At same Kinematics to cross-check the SHMS results**
- **For the final results we will add data from HMS**

Future Measurement: E12-10-008 Phase – II Kinematic Overview

Spectrometer	Angle	Momentum(GeV/c)	Beam Energy (GeV)
SHMS	8 - 33	1.4 – 10.6	11
HMS	20 - 55	1.4 - 6.4	11

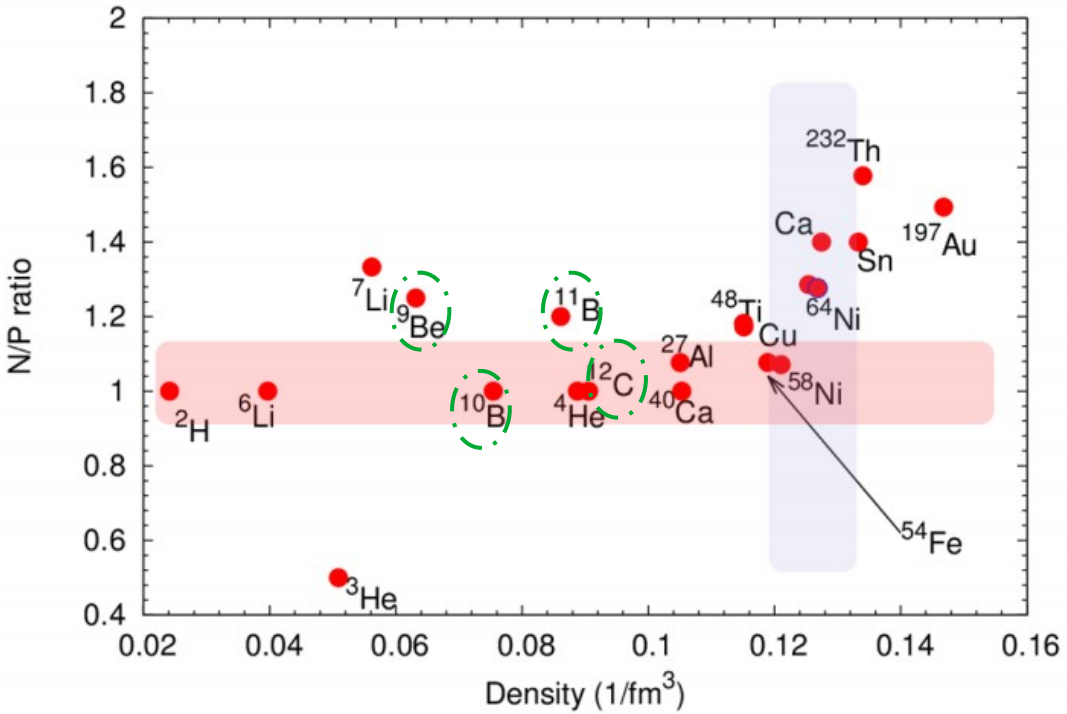
- Runs concurrently with E12-06-105 (x>1)
- Covers range of angles
- HMS and SHMS run in parallel
- 23 PAC days for Phase I and Phase II
  - 2 days completed spring 2018 (Phase I)



- Plot shows kinematics coverage for EMC and x>1.
- The lower x represent the EMC effect data

Future Measurement: E12-10-008 Phase – II Kinematic Overview

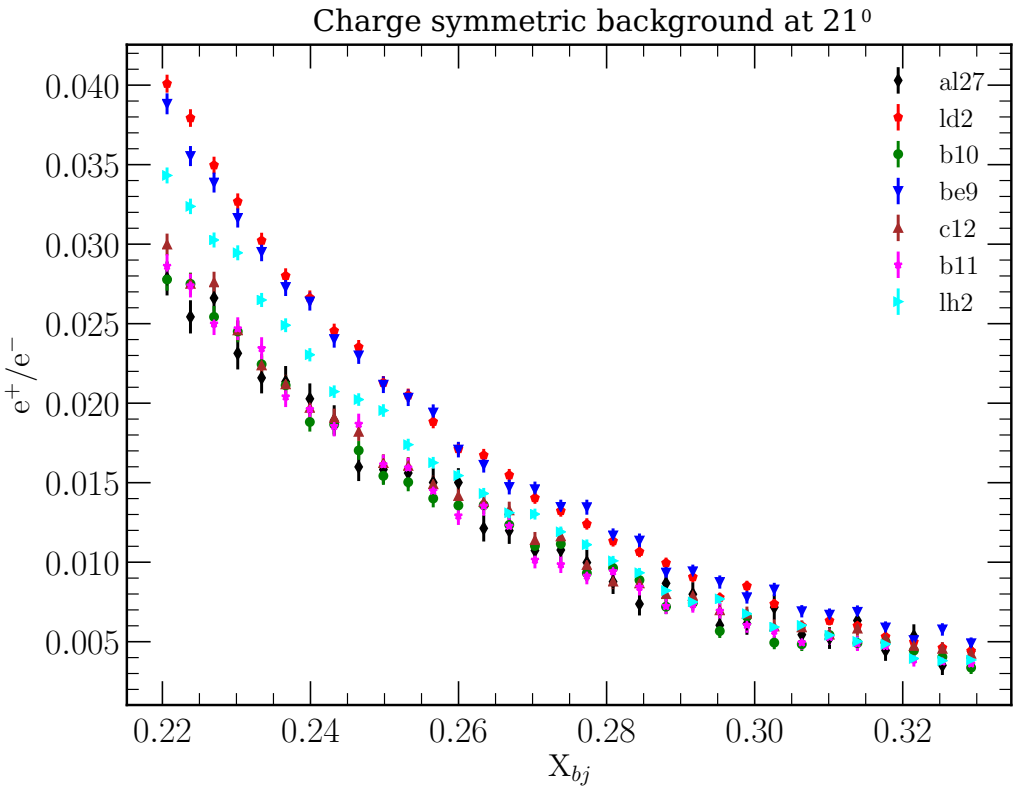
- Target Choice motivated by physics impact
  - To study A dependence at fixed N/Z
  - To study N/Z dependence at fixed A
- Focus on target ratios
  - Light nuclei: cluster structure (Reliable calculation of nuclear structure)
  - Heavier nuclei: vary N/Z
- Large range of nuclei will test the proposed universal modification function of SRC-EMC correlation



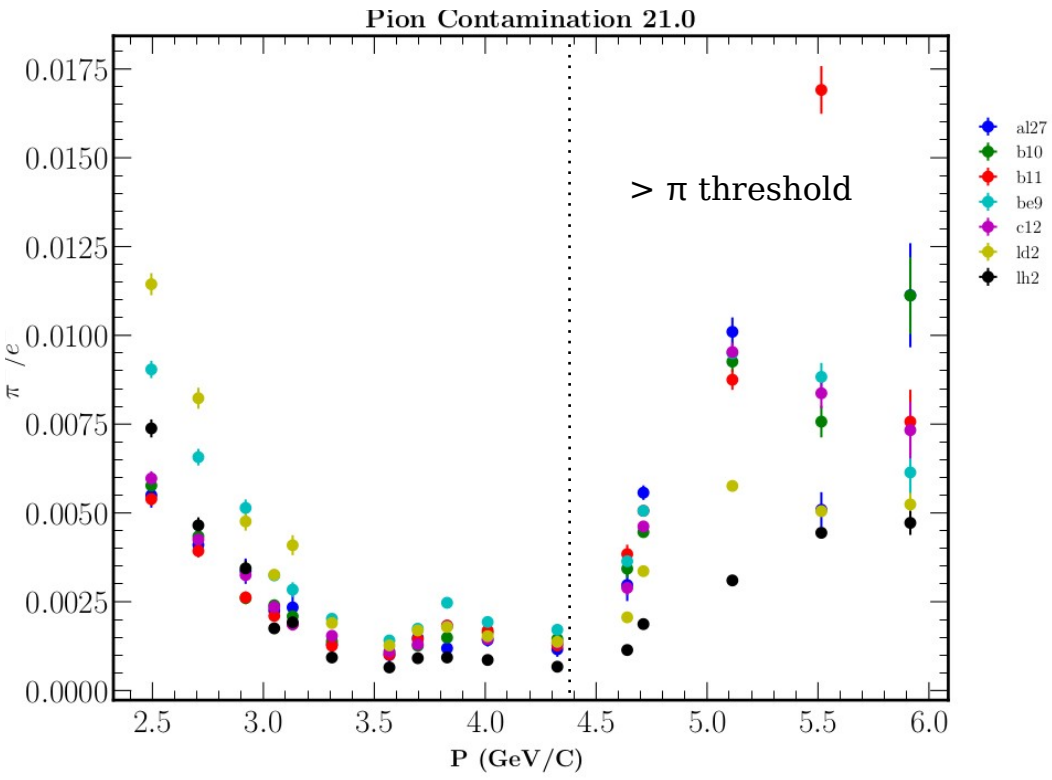
Analysis Status

- Detector calibration complete.
- Extraction of experimental efficiencies mostly complete
- Understanding the SHMS Acceptance is ongoing
- Background Correction is complete.
- Trying to understand Normalization issue in EMC ratio
  - Double check target thickness
  - SHMS and HMS comparisons
- Quantifying systematic uncertainties are in progress
- Iterating the x-section model to extract the radiative corrections ongoing

Analysis Status: Background Correction



- Plot shows CSB as a function of x for 21⁰



- Plot shows pions to the sum of pions and electrons as a function of SHMS momentum for 21⁰

Analysis Status: Isoscalar correction

- Proton and neutron have different x-sections, x-sections for nuclei with z ≠A/2 will significantly differ from that of nuclei with z =A/2 (Isoscalar)

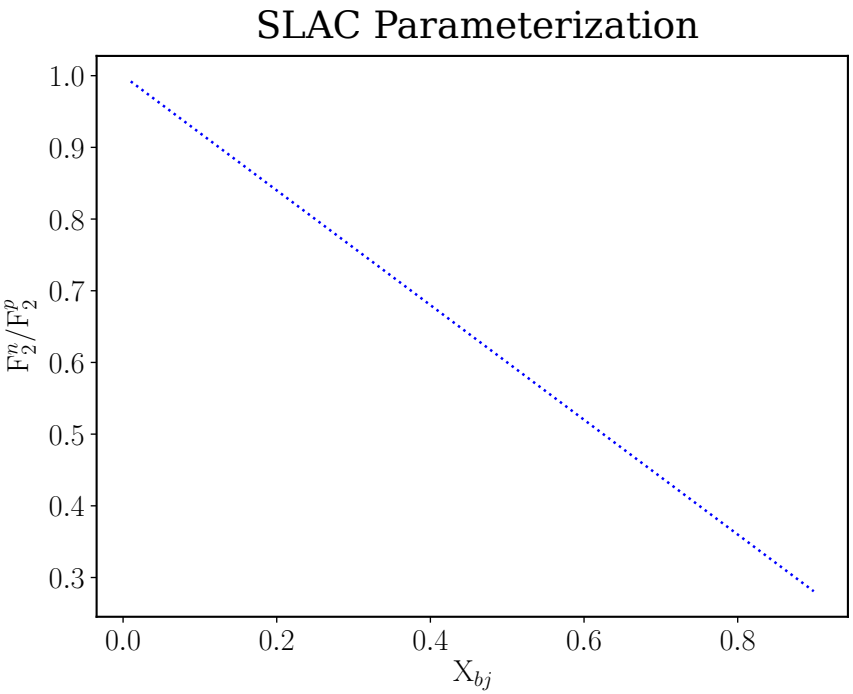
- Needs to correct for excess of neutrons or protons. The multiplicative correction factor is,

$$f_{iso}^{A} = \frac{\frac{1}{2}\left(1 + F_2^n/F_2^p\right)}{\frac{1}{A}\left(Z + (A-Z)F_2^n/F_2^p\right)}$$

- Since there is no free neutron target, extraction of F_2^n/F_2^p is always model-dependent

- **Currently using SLAC Parameterization:**

$F_2^n/F_2^p = 1 - 0.8 * X_{Bj}$



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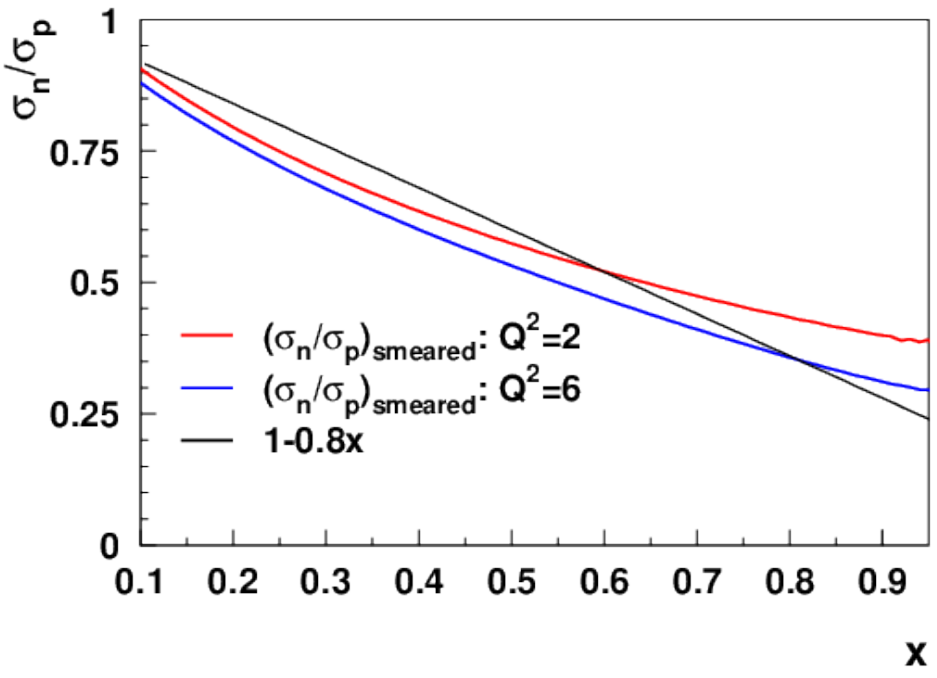
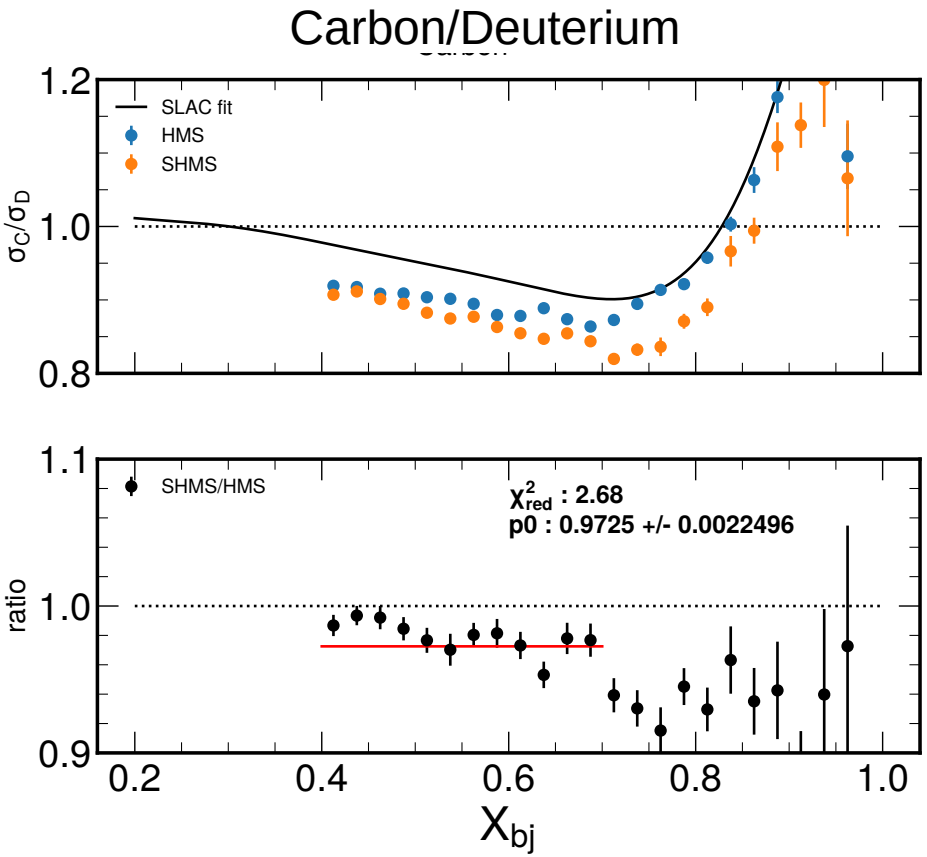
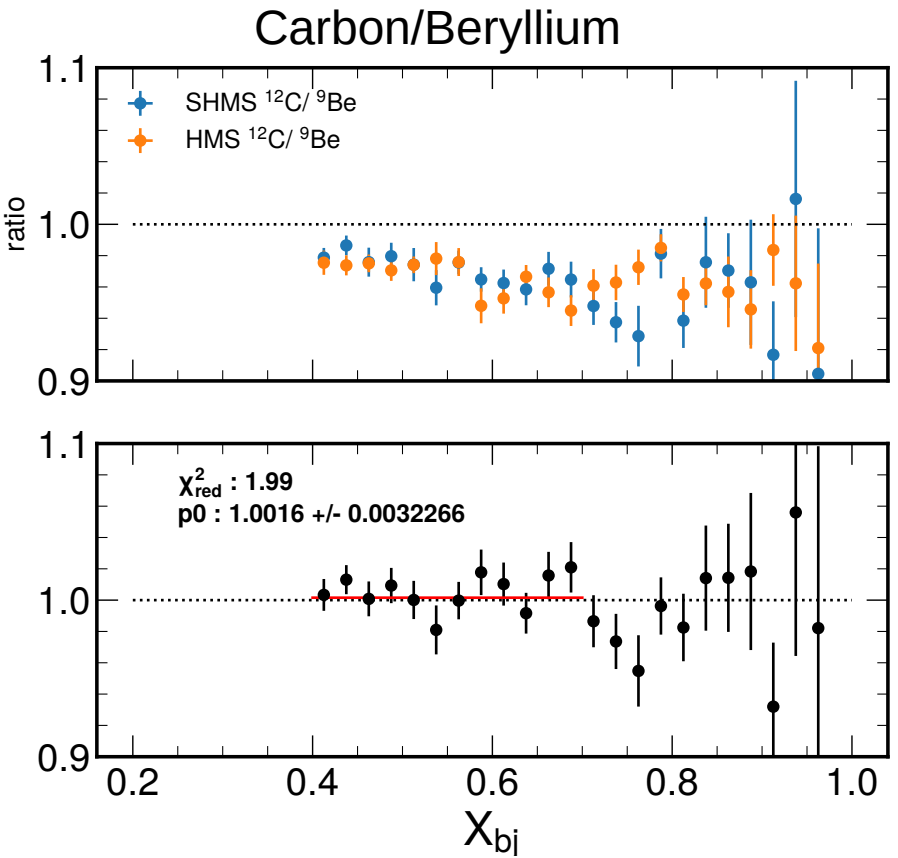


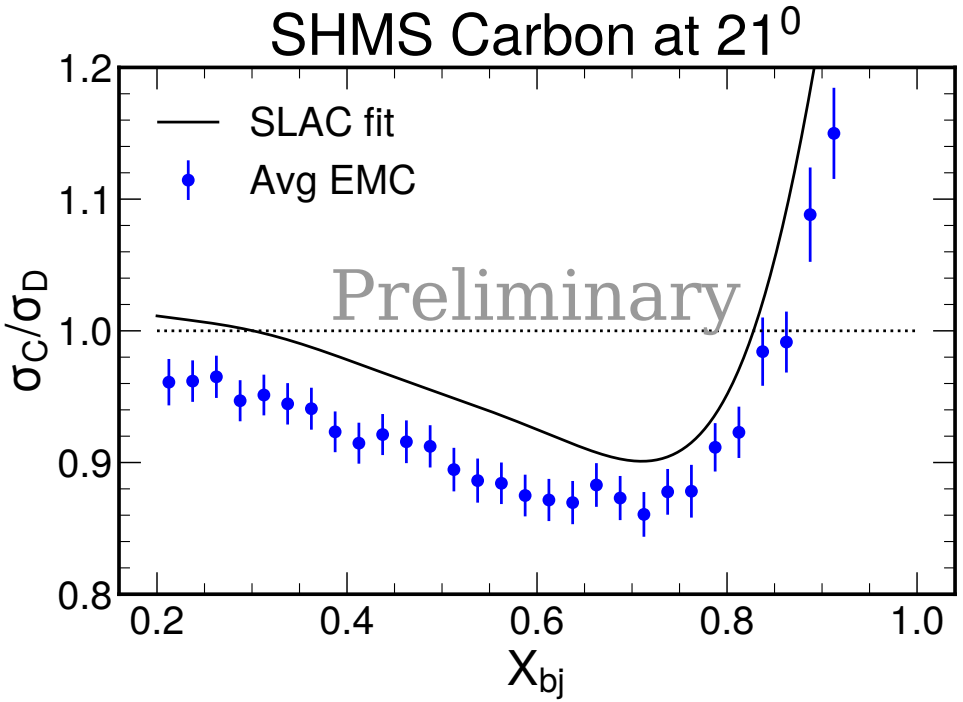
Analysis Status: Comparison HMS & SHMS at 21⁰



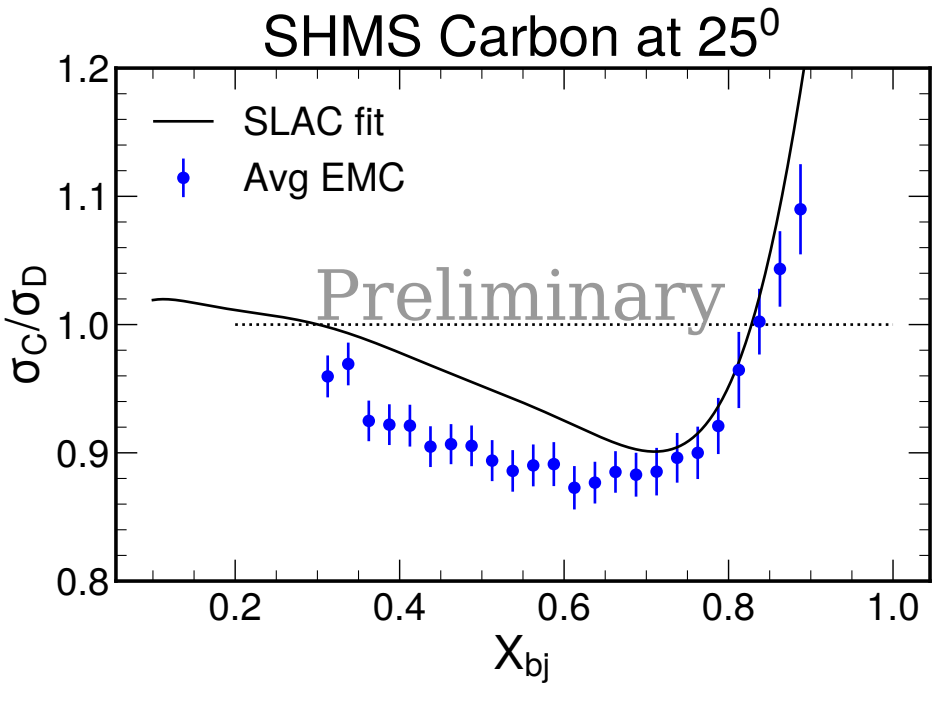


Is this due to extended target acceptance ?

Analysis Status: EMC ratio Q^2 independent

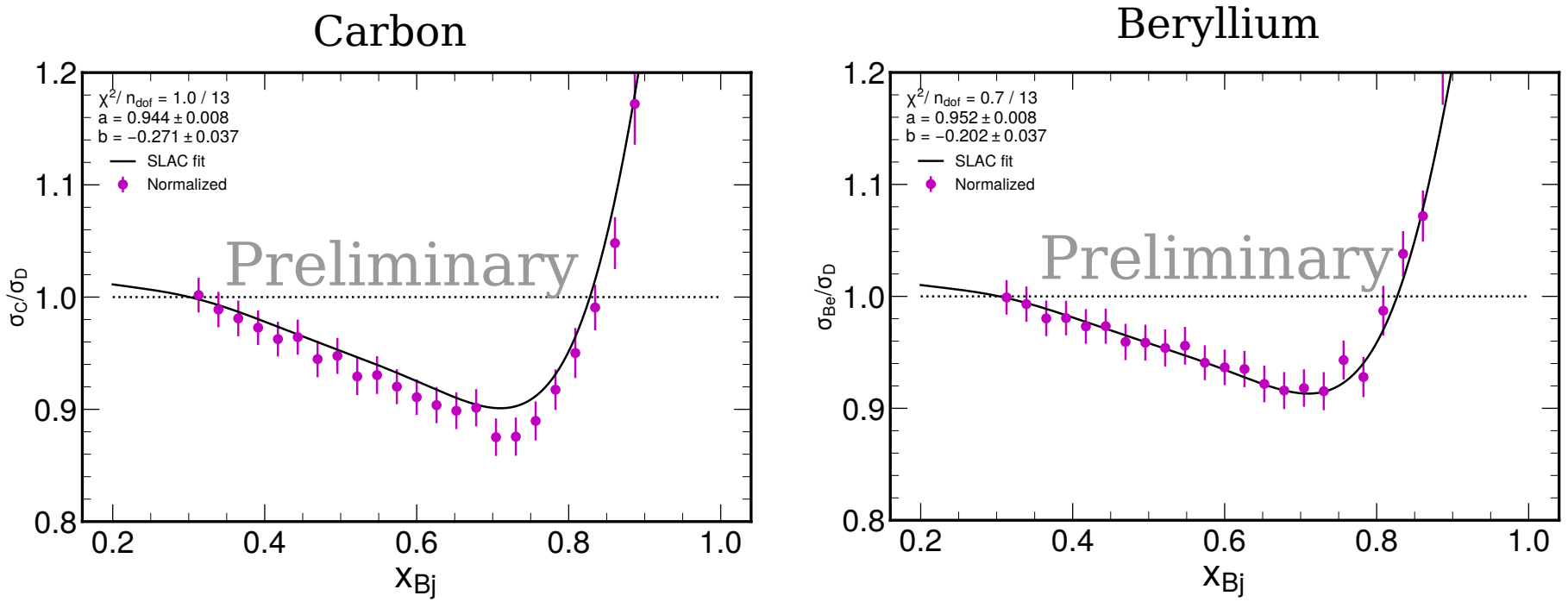


$3.39 < Q^2 < 8.25$



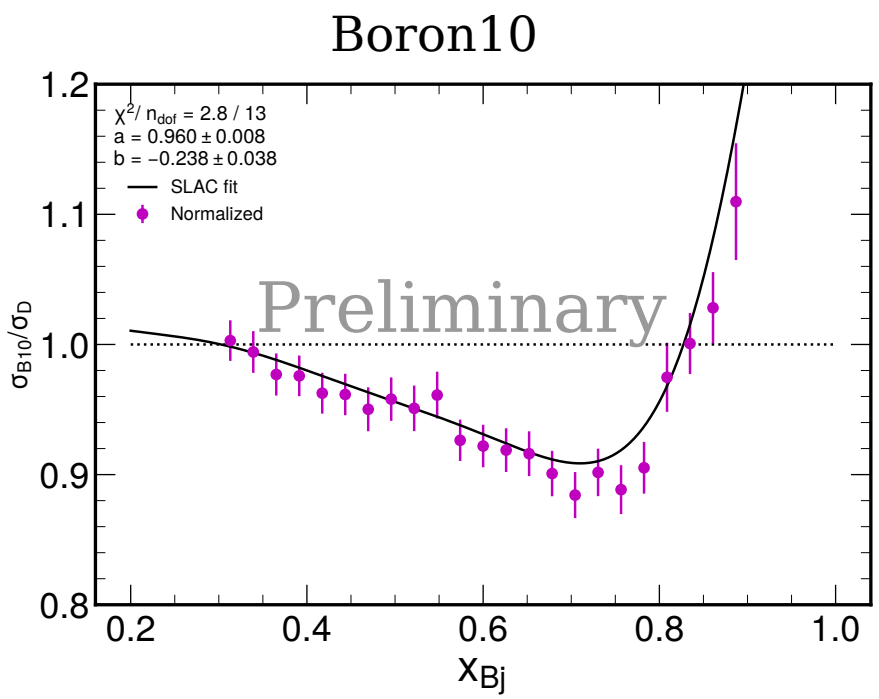
$4.41 < Q^2 < 9.91$

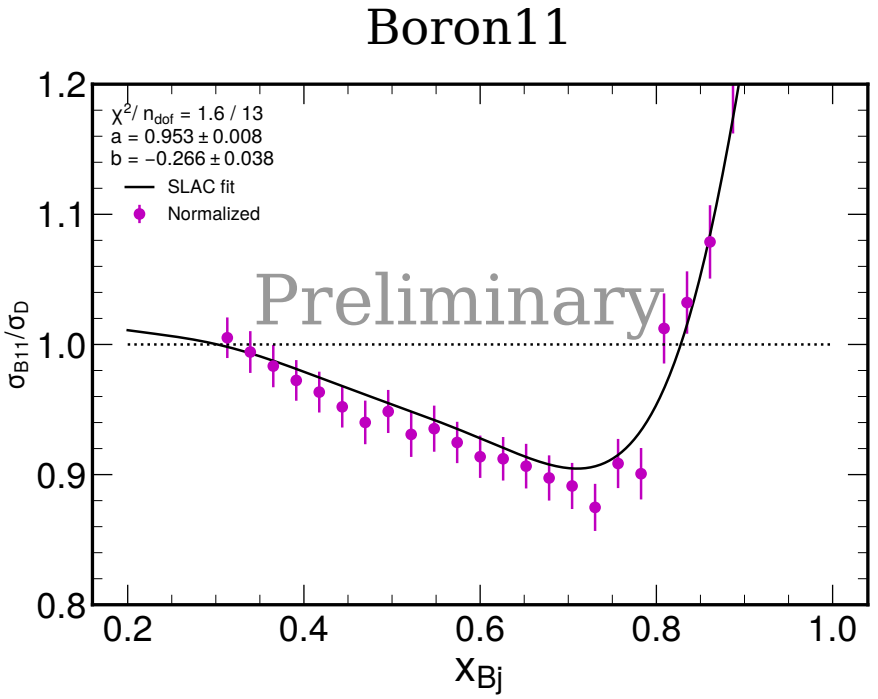
Analysis Status: Normalized EMC Ratio at 21^0



- Systematic normalization issues on the order of ~4% that we are still trying to understand
- Conservative point-to-point systematic uncertainty about ~ 1.5 % is added. Final result will have small systematic uncertainty.

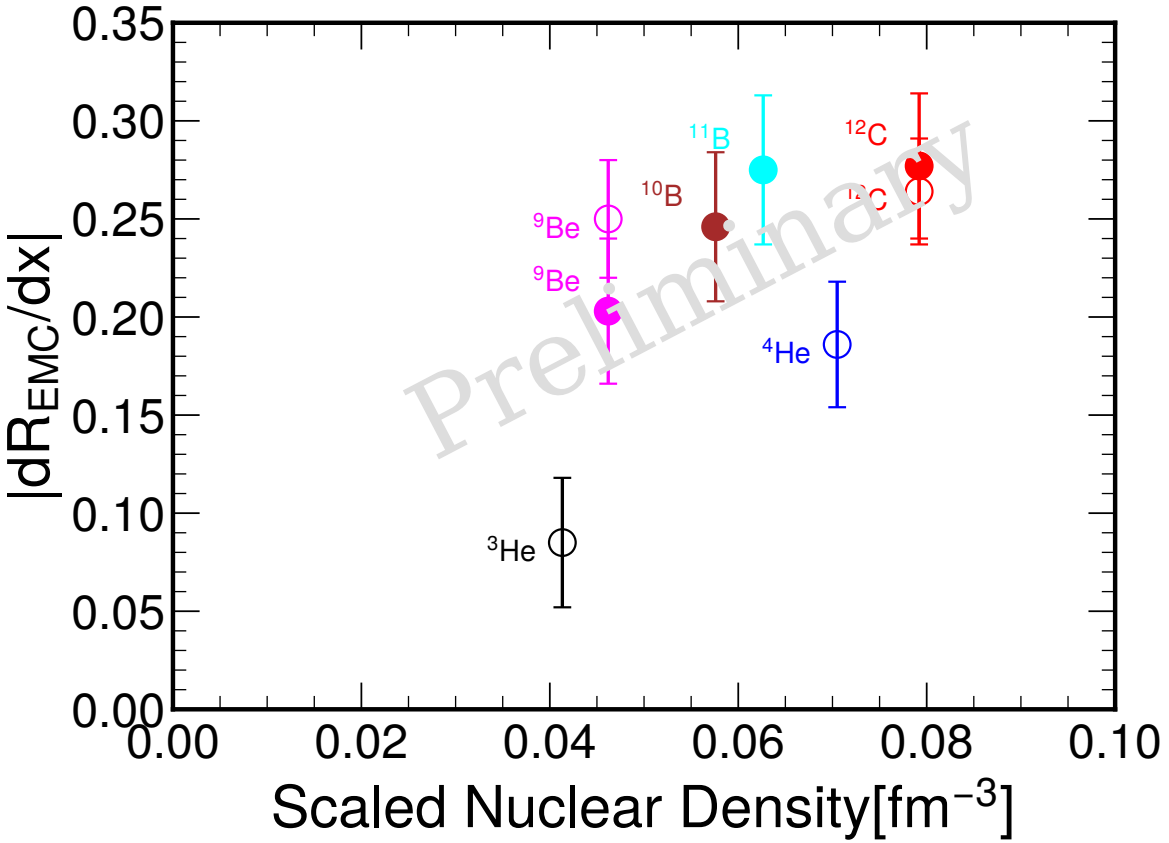
Analysis Status: Normalized EMC Ratio at 21^0





- Systematic normalization issues on the order of ~4% that we are still trying to understand
- Conservative point-to-point systematic uncertainty about ~ 1.5 % is added. Final result will have small systematic uncertainty.
- ^{10}B and ^{11}B are not 100% isotopically pure (~ 95%)

Analysis Status: EMC Ratio at 21^{0}



○ 6 GeV result

● 12 GeV result

- ^{10}B and ^{11}B doesn't seem to scale with average density

Summary

- Experiment E12-10-008 (EMC) and E12-06-105 (x>1) will provide a new data on several nuclei to map out the SRC/EMC connections
- First EMC measurements on ^{10}B and ^{11}B
- Preliminary EMC ratio for four Nuclear target from SHMS at 21^{0} is shown
- Preliminary ratio extraction show some global normalization issue (SHMS)
- Preliminary EMC effect in ^{10}B and ^{11}B doesn’t seem to scale with average density
- Final results coming soon

Thank you