EMC Effect in Lighter Nuclei at 11 GeV

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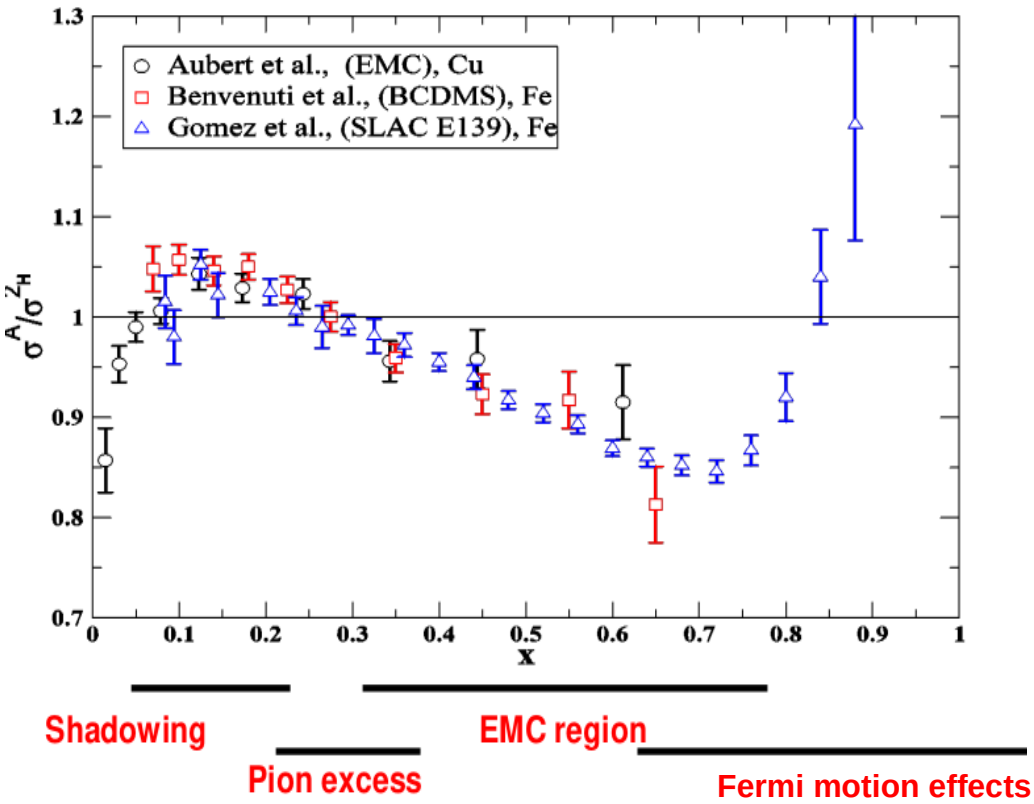
Outline

- Introduction
- Experiment E12-10-008 at Hall C
- Analysis Status
- Summary

Introduction

- DIS measures structure functions $F_2(x)$
- Energy scales of probe >> Nuclear binding
  - Expected $F_2^A(x) \approx ZF_2^p(x) + NF_2^n(x)$
- Nuclear dependence of structure function: **EMC Effect**
- **Quarks in nuclei behave differently than the quarks in free nucleon**
- Extensive measurements on heavy targets
- Different kinematic regions understood in terms of different process



Introduction

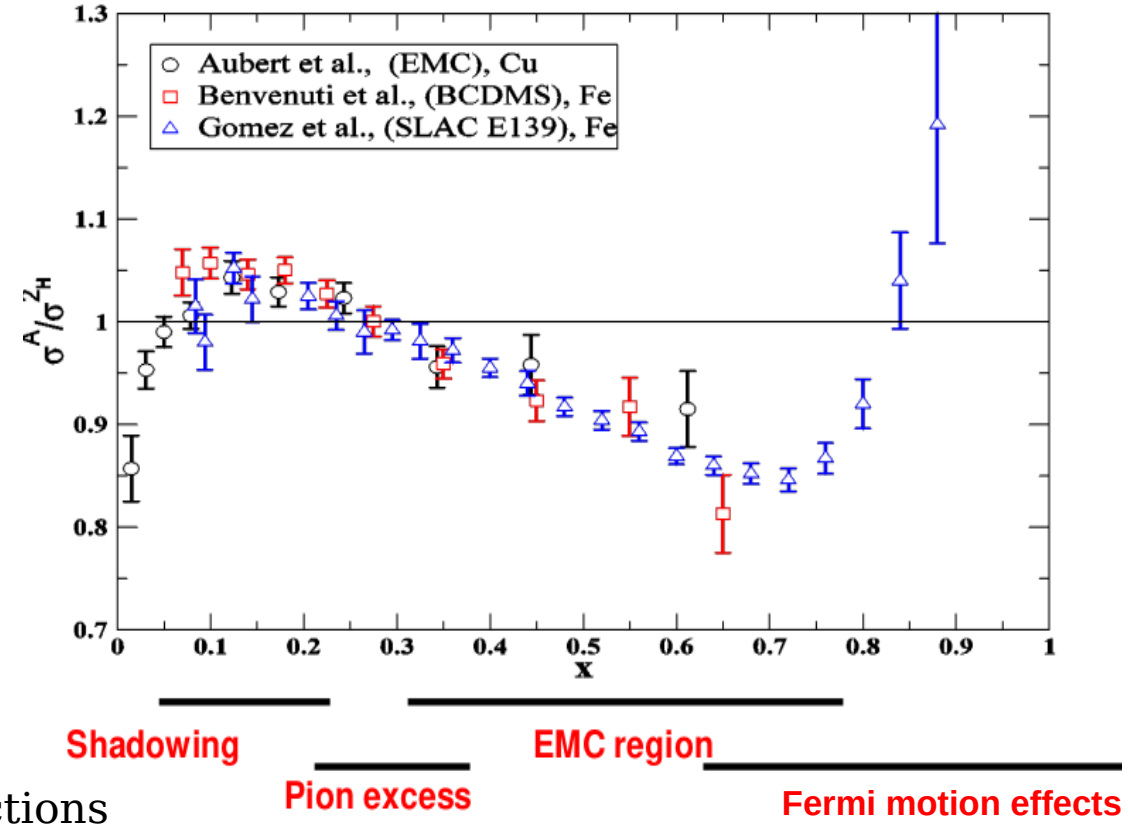
Conventional nuclear physics models

- Fermi smearing
- Binding energy
- Nuclear pions

Exotic models

- Multi-quarks clusters (6q, 9q) bags
- Dynamical rescaling
- Modification of nucleon structure

Several models. Some only valid in certain regions. Some inconsistent with other reactions



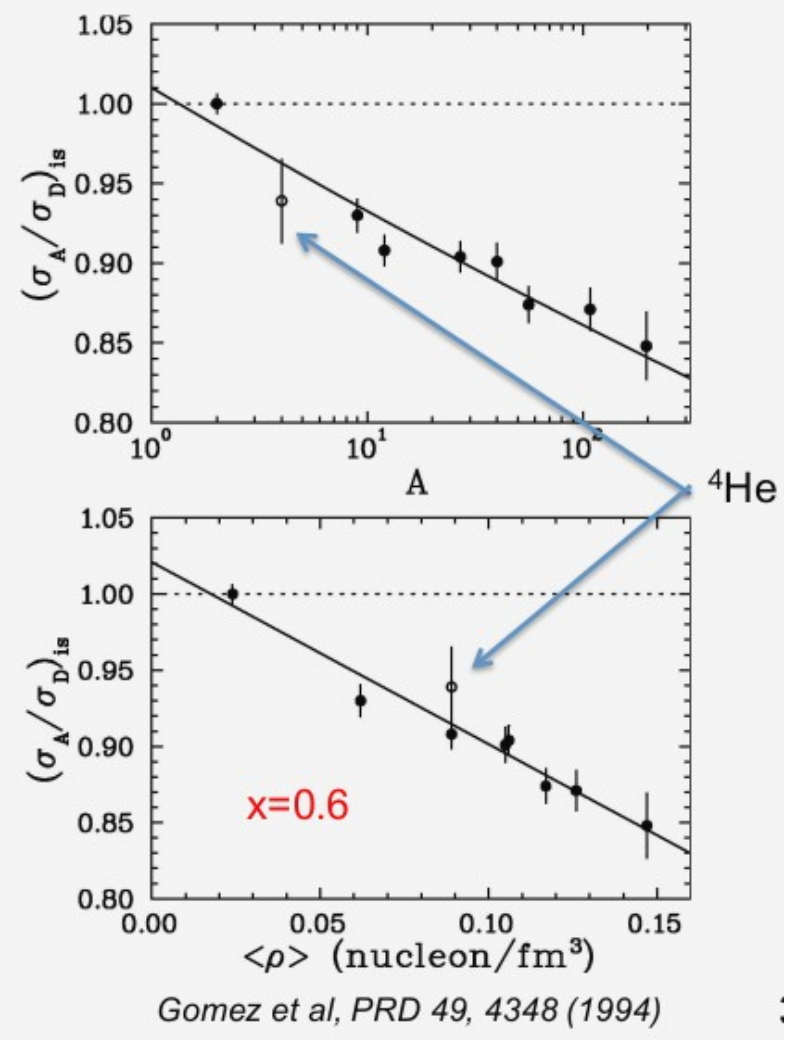
EMC effect has been with us more than 36 + years yet its origin in still unknown

Motivation

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
  - Magnitude varies with A
    - 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

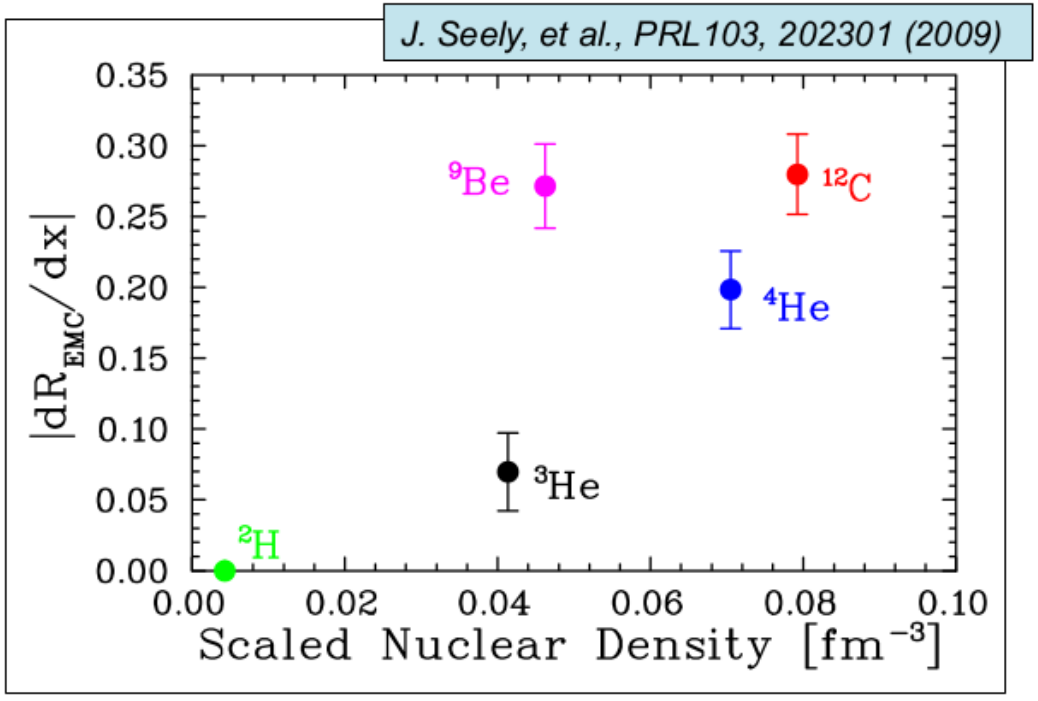


Motivation

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



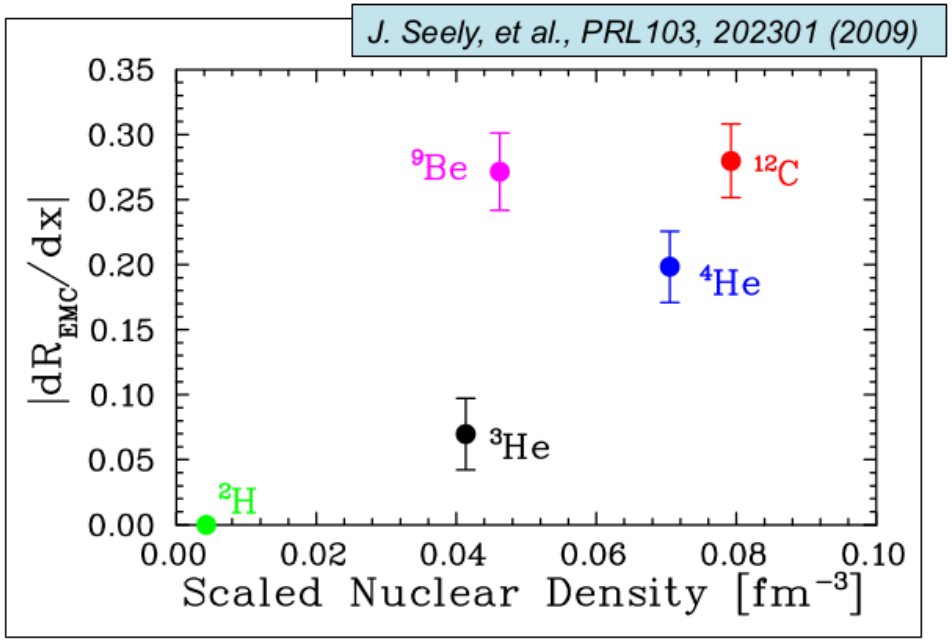
- ^{4}He matches better with C data and SLAC parameterizations
- Avg nuclear density of ^{4}He and C are similar
- Also ^{9}Be data matches better with C data. However avg nuclear density of Be<<C

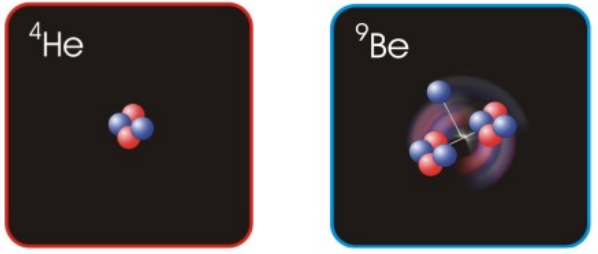
Both A- and ρ-dependent fits fail to describe these light nuclei

Motivation

Results from JLab suggest that EMC Effect does not scale with average nuclear density and hints that the effect may be driven by local environment

- One possible explanation could be even though Avg Nuclear density of Be is relatively low most nucleons are in high local densities of alpha cluster





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

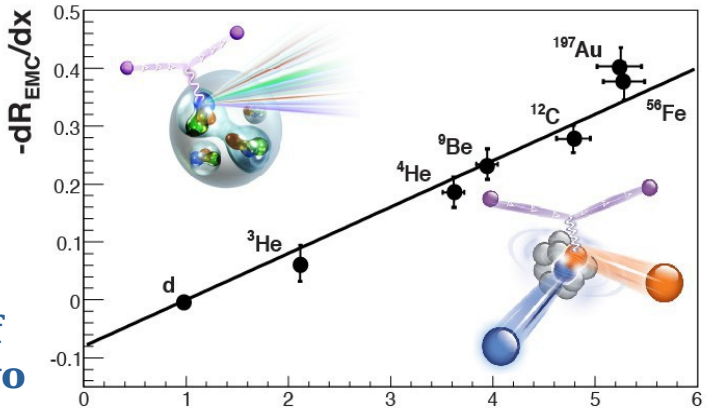
Motivation

SRC and EMC correlation

If the EMC effect is a local density effect, then it seems reasonable to look for connections to other local density effects

- EMC-SRC connection became more intriguing with the addition of Be SRC data
  - Both display similar Nuclear dependence on nuclear density

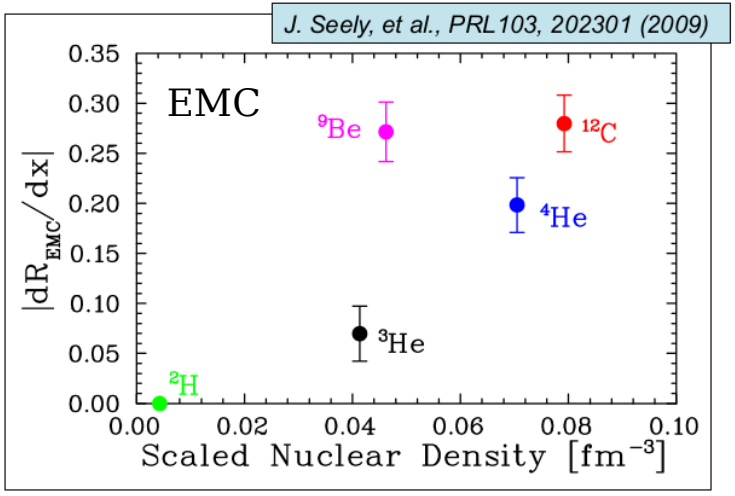
This result provides a quantitative test of level of correlation between the two effects



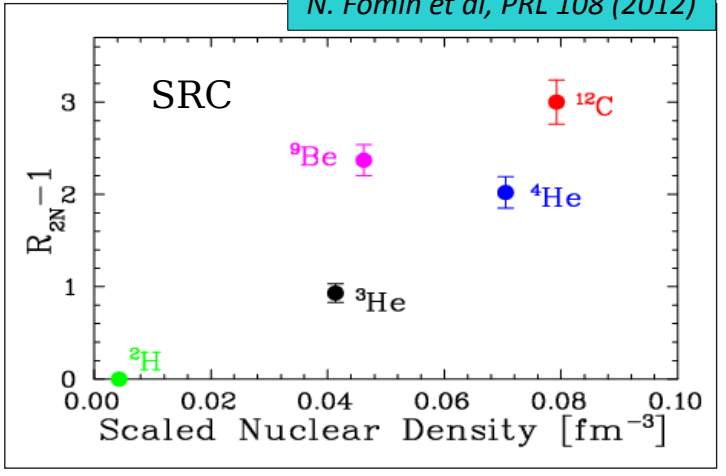
N. Fomin, et al., PRL 108, 092052 (2012)
J. Arrington, A. Daniel, D. Day, N.Fomin, D. Gaskell, P. Solvignon, PRC 86, 065204 (2012)
O. Hen, et al, PRC 85, 047301 (2012)
L. Weinstein, et al., PRL 106, 052301 (2011)

HallA/C 2020

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



N. Fomin et al, PRL 108 (2012)

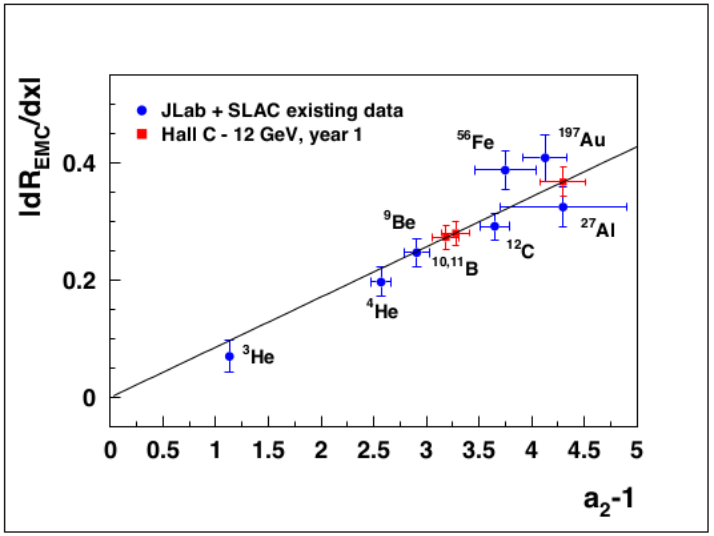


Motivation

SRC and EMC correlation

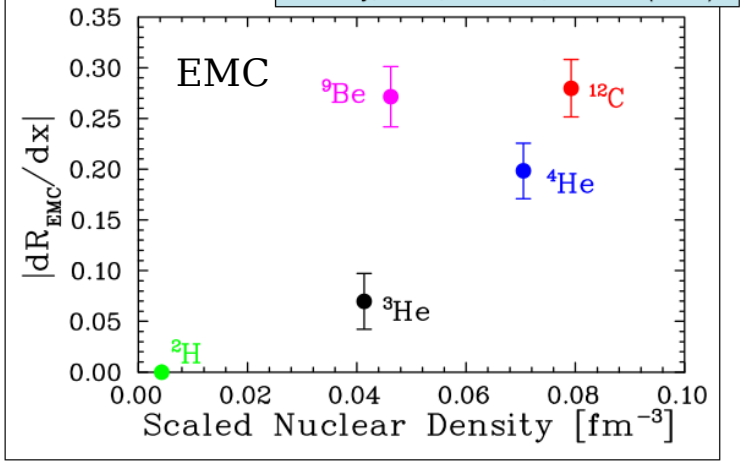
If the EMC effect is a local density effect, then it seems reasonable to look for connections to other local density effects

E12-10-008: Outcomes

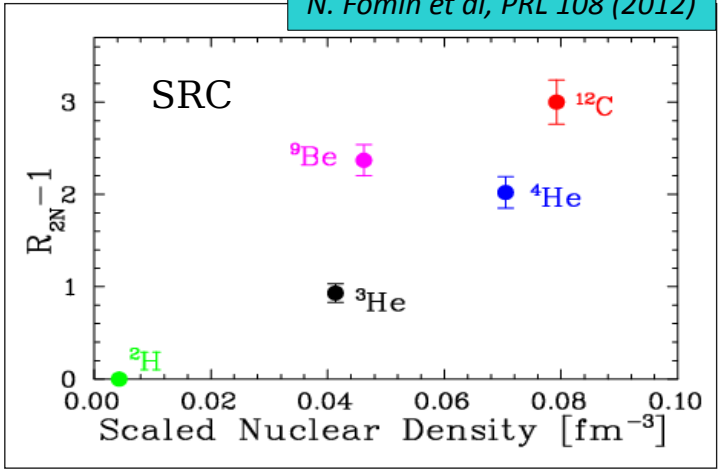


Plot from D. Gaskell

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



N. Fomin et al, PRL 108 (2012)

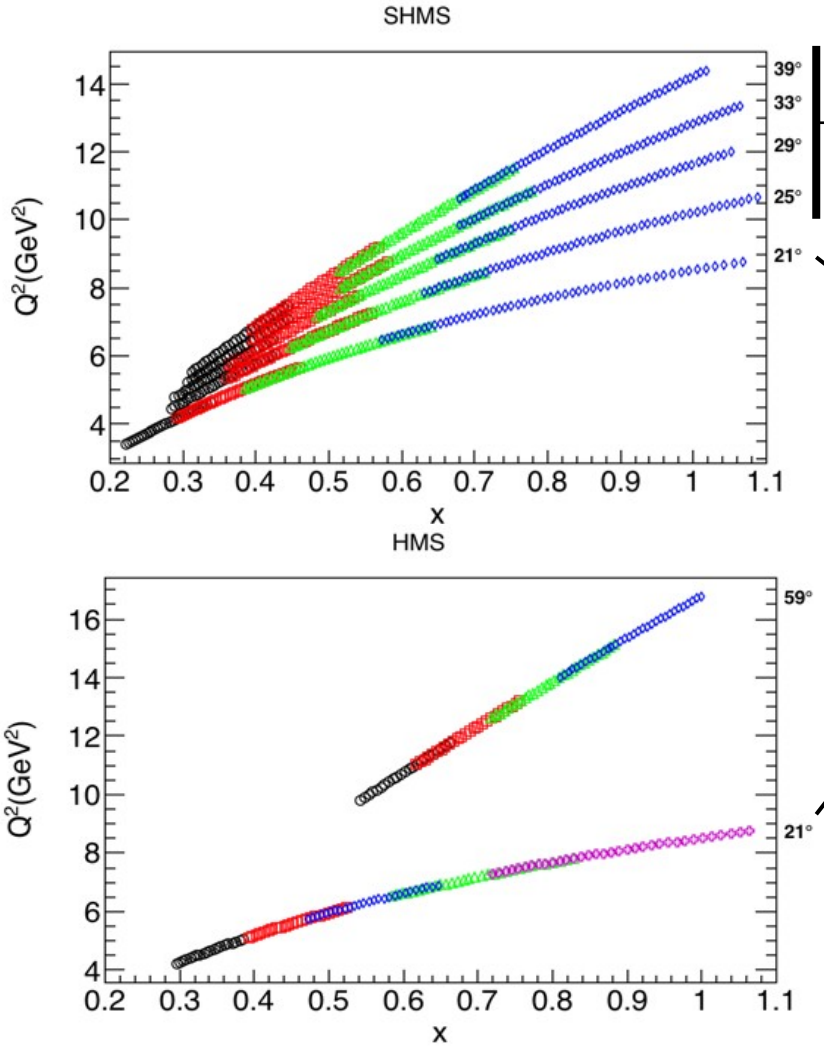


Overview of the experiment(E12-10-008) Phase - I

- 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 tragets: H, ^{2}H
  - Solid targets: Be, C, Al, ^{10,11}B (Al for cell wall subtraction)
- Single-arm measurement
- Unpolarized 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 detailed Q2-dependence of the EMC ratios

First Measurement of EMC effect in ^{10,11}B

Kinematic Coverage Phase - I



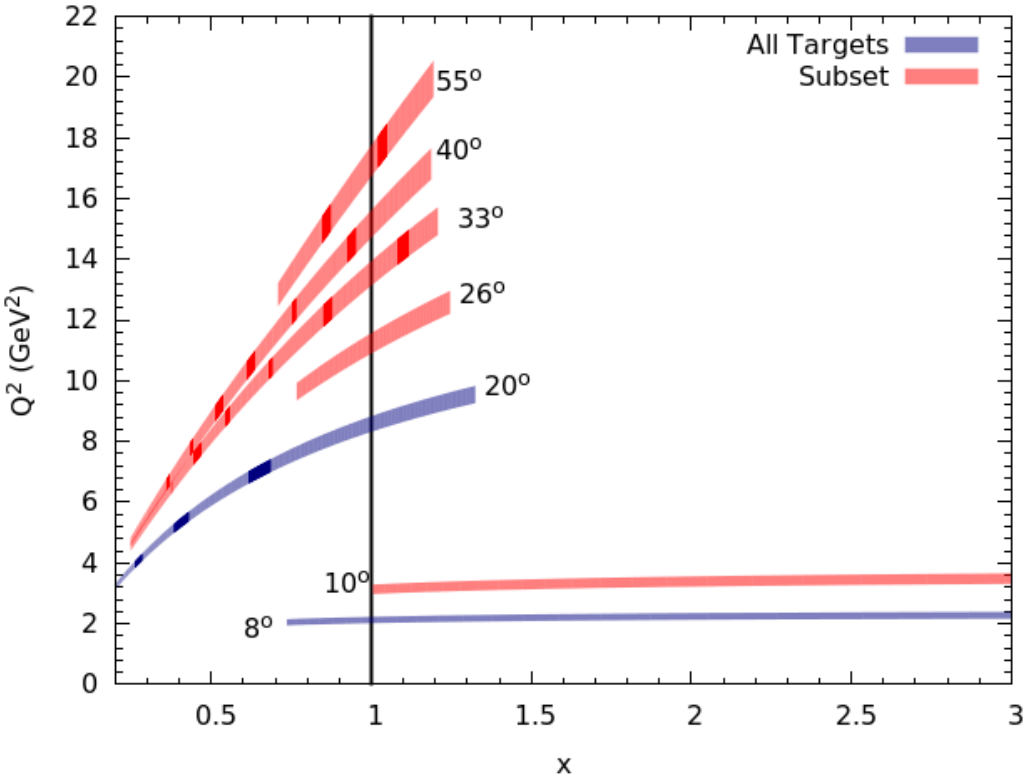
These angles will provide detailed Q^2 dependence study

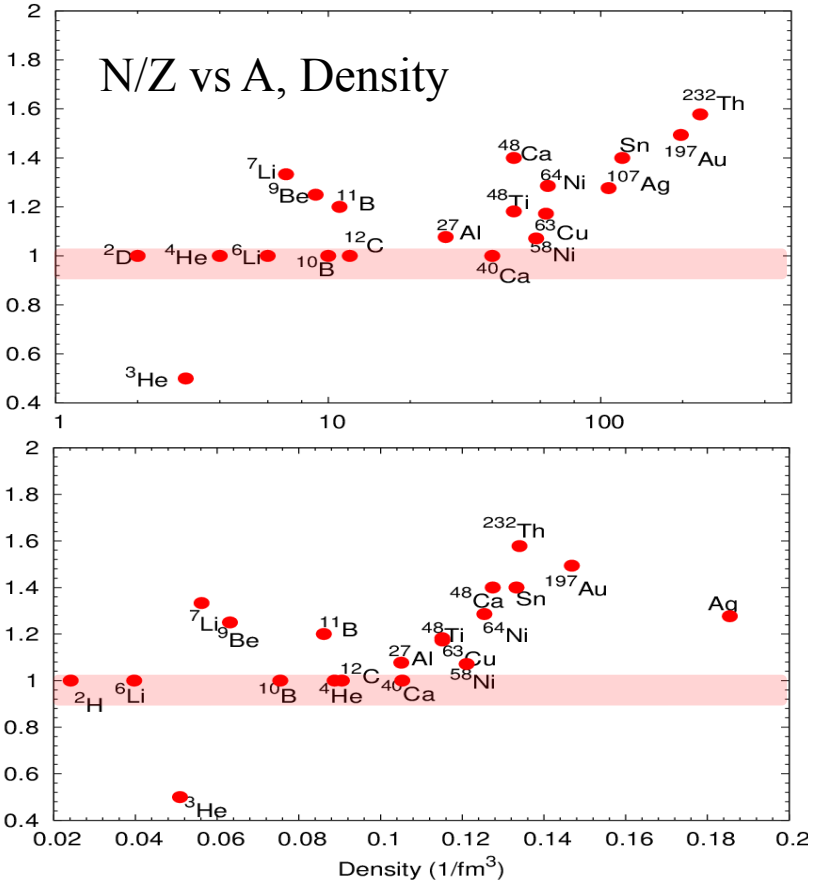
Main EMC ratios extraction is done using data at angle 21^0

Data were taking using both spectrometer

Detailed Studies of the nuclear dependence of F2 in light nuclei [E12-10-008: J. Arrington, A. Daniel, N. Fomin, D. Gaskell]

Target Choice motivated by physics impact





Coming soon* in Hall C

Analysis Status

- Detector calibration complete
- Extraction of experimental efficiencies complete
- Currently trying to understand the SHMS Acceptance
- Detailed Data/Monte-Carlo comparison is ongoing
- Extraction of EMC ratios are in progress

Analysis Status

Cross-section extraction by Monte-Carlo Ratio Method

We simulate Monte- Carlo data using a cross-section model to obtain:

$$Y_{MC}(E',\theta) = L * \sigma^{model} * (\Delta E,\Delta\Omega)* A_{MC}(E',\theta)$$

Taking ratio to data and assuming that $A_{MC} = A$, yields

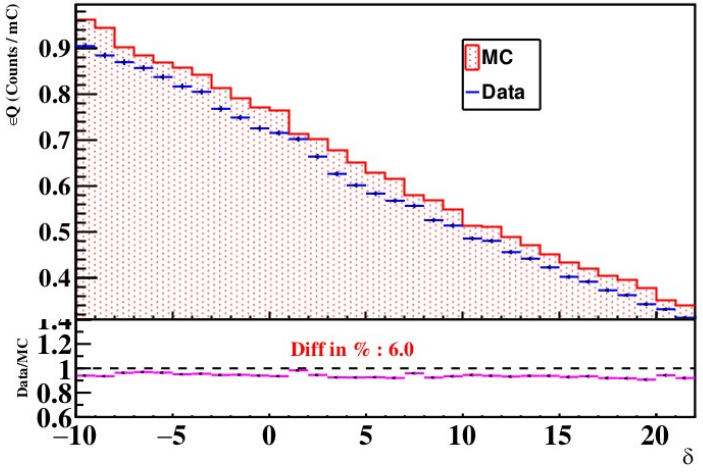
$$d\sigma/d\Omega dE' = \sigma^{model} * [Y(E',\theta)/Y_{MC}(E',\theta)]$$

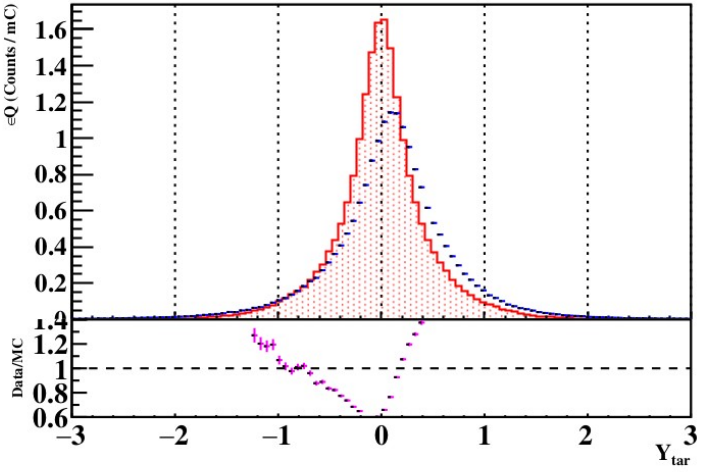
Analysis Status

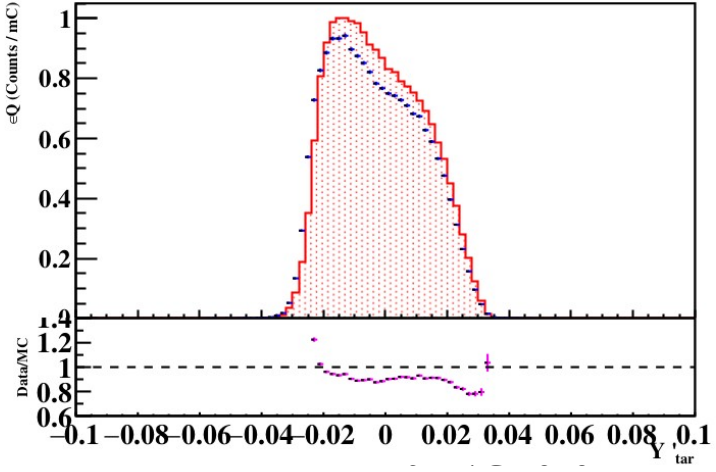
SHMS

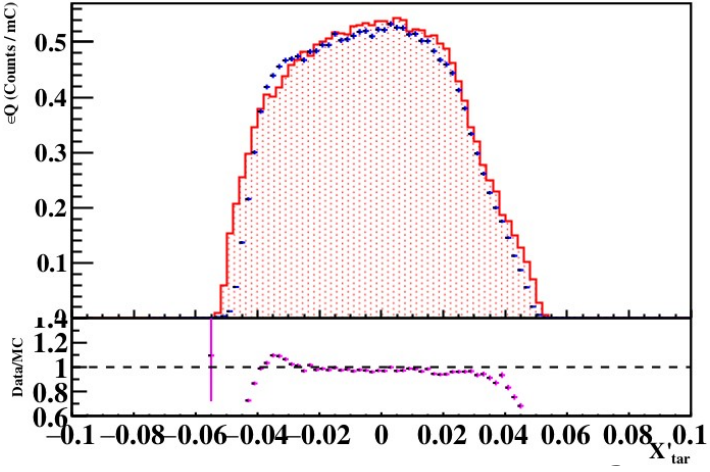
Data to MC

- 10.6 GeV beam energy
- ^{12}C at 2.7 GeV, 21^0
- Delta, ytar, yptar, xptar
- Integral difference ~ 6%
- Data Ytar resolution not so well
- Offset in ytar peak (ongoing)









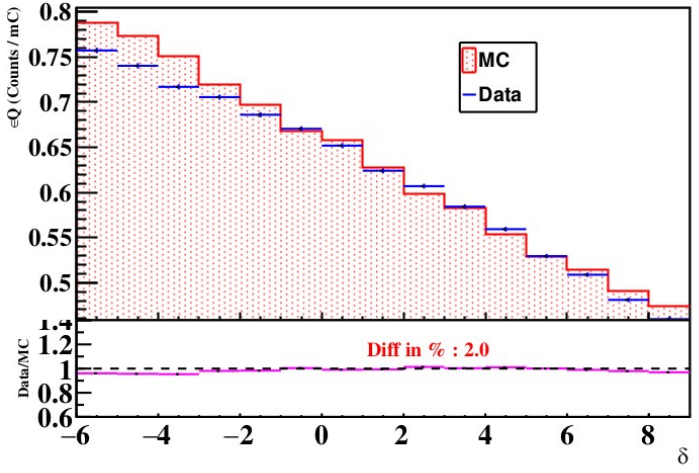
Analysis Status

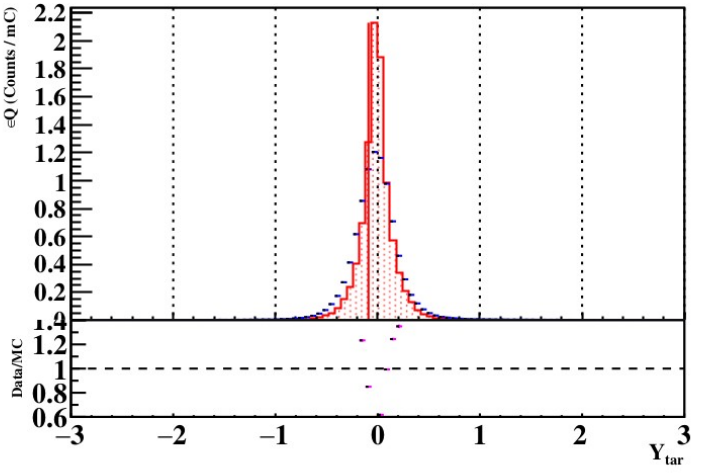
HMS

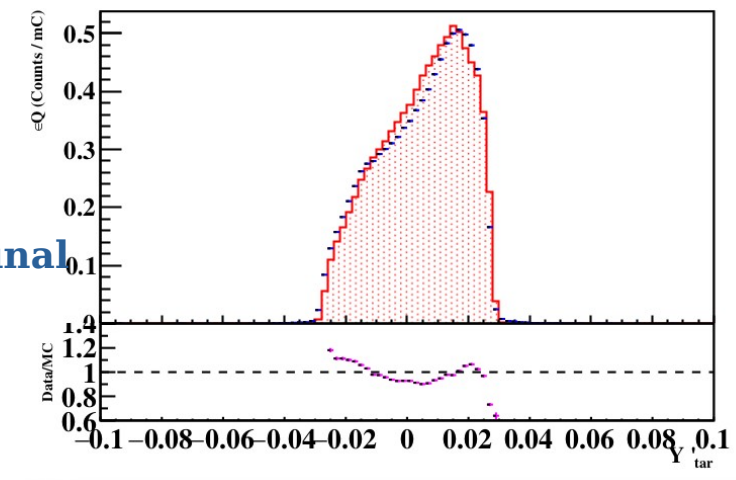
Data to MC

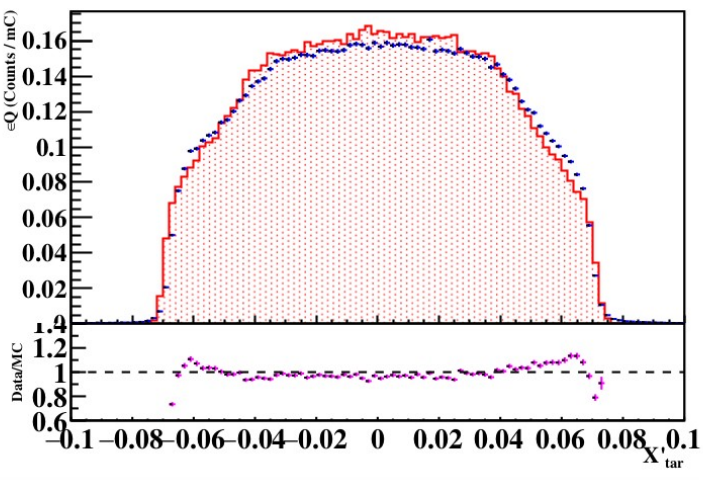
- 10.6 GeV beam energy
- ^{12}C at 4.0 GeV, 21^0
- Delta, ytar, yptar, xptar
- Integral difference ~ 2%
- Data Ytar resolution not so well

We took data in HMS and SHMS at same kinematics to cross-check the SHMS results as well as for the final results we will add data from HMS





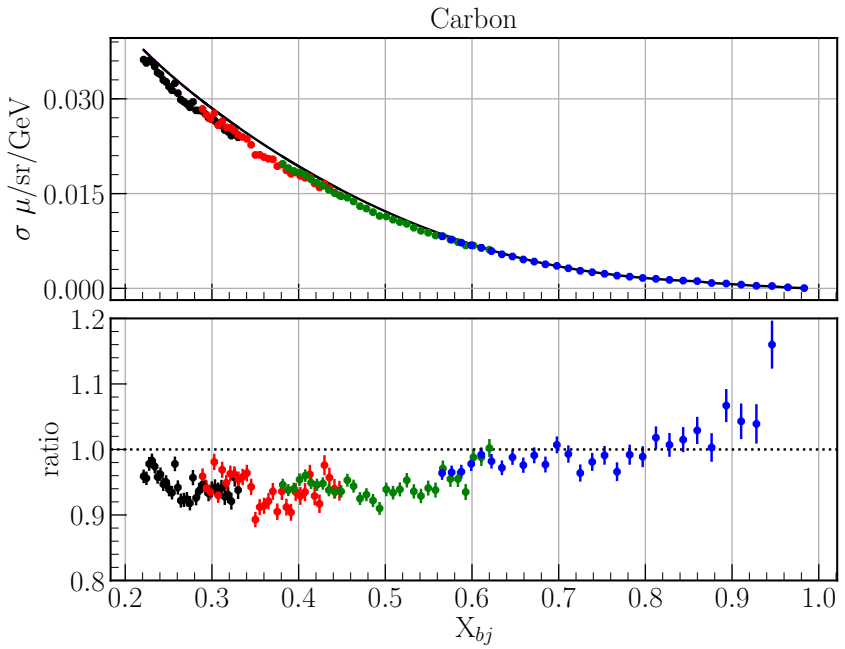


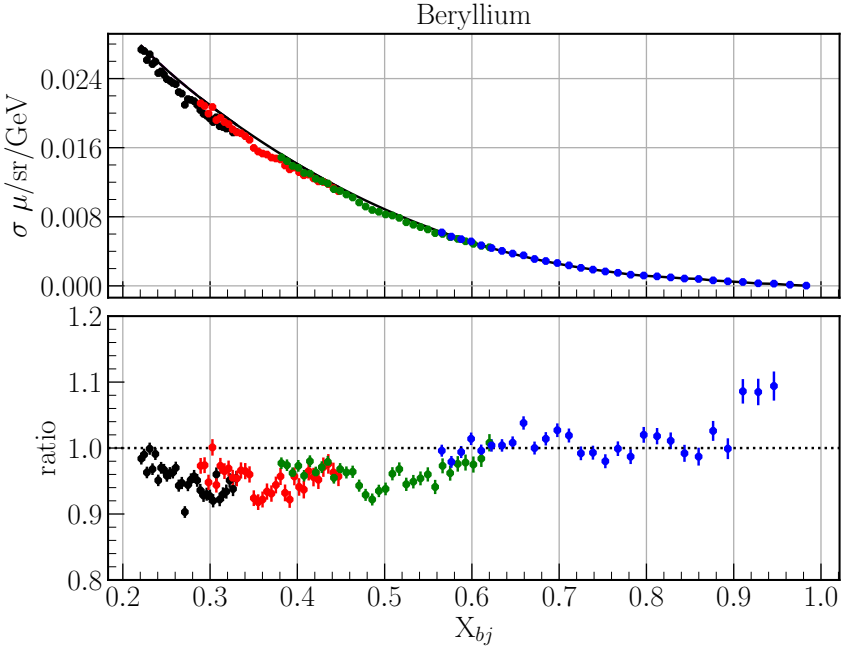


Analysis Status

SHMS

Cross-section extracted from solid target



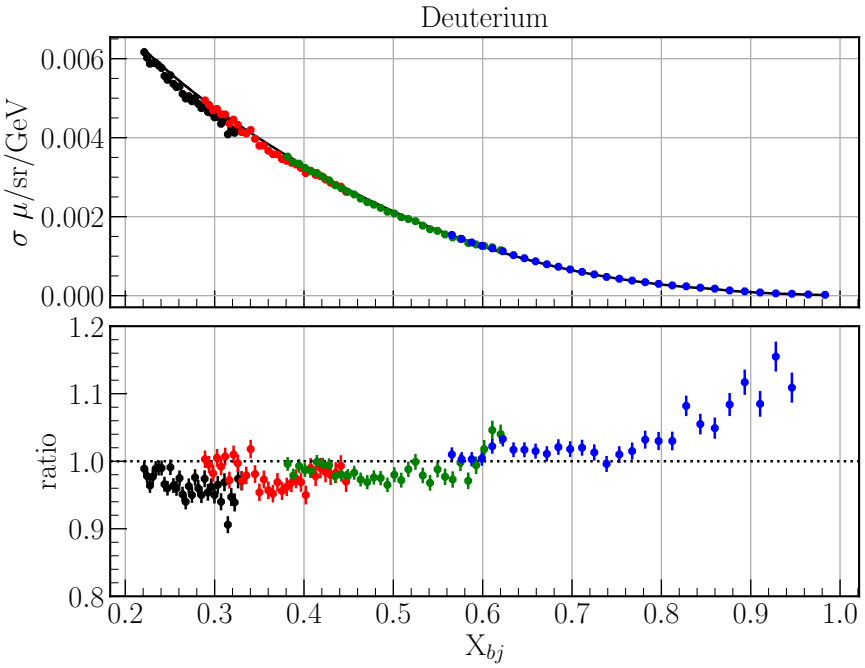


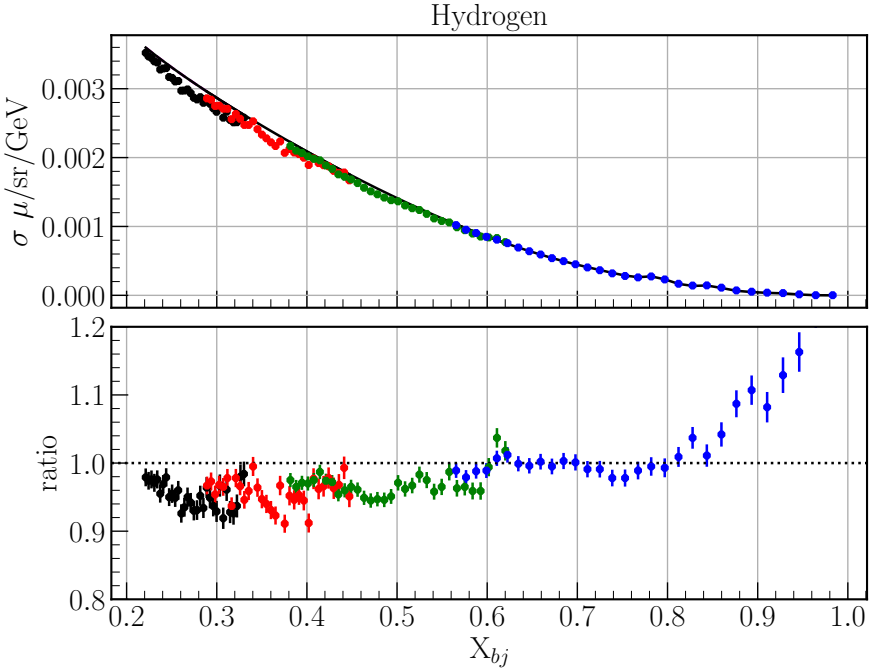
We used Arie Bodek's fit to proton and deuterium inelastic structure functions, and then a separate fit to the EMC effect in nuclei

Analysis Status

SHMS

Cross-section extracted from cryo-target





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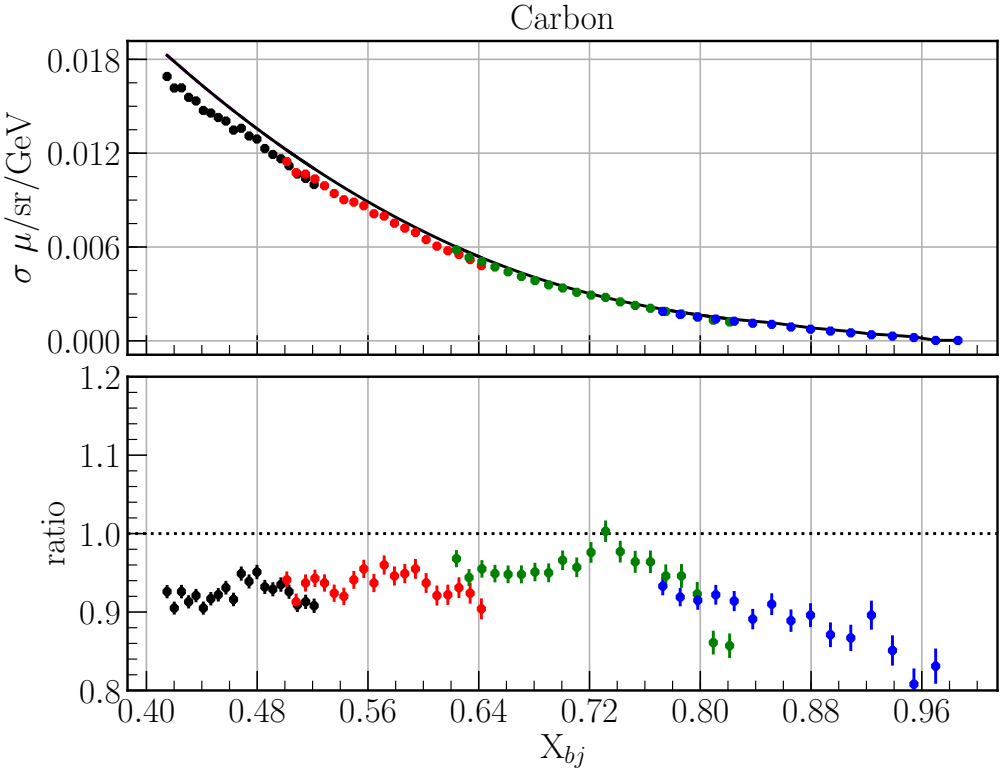
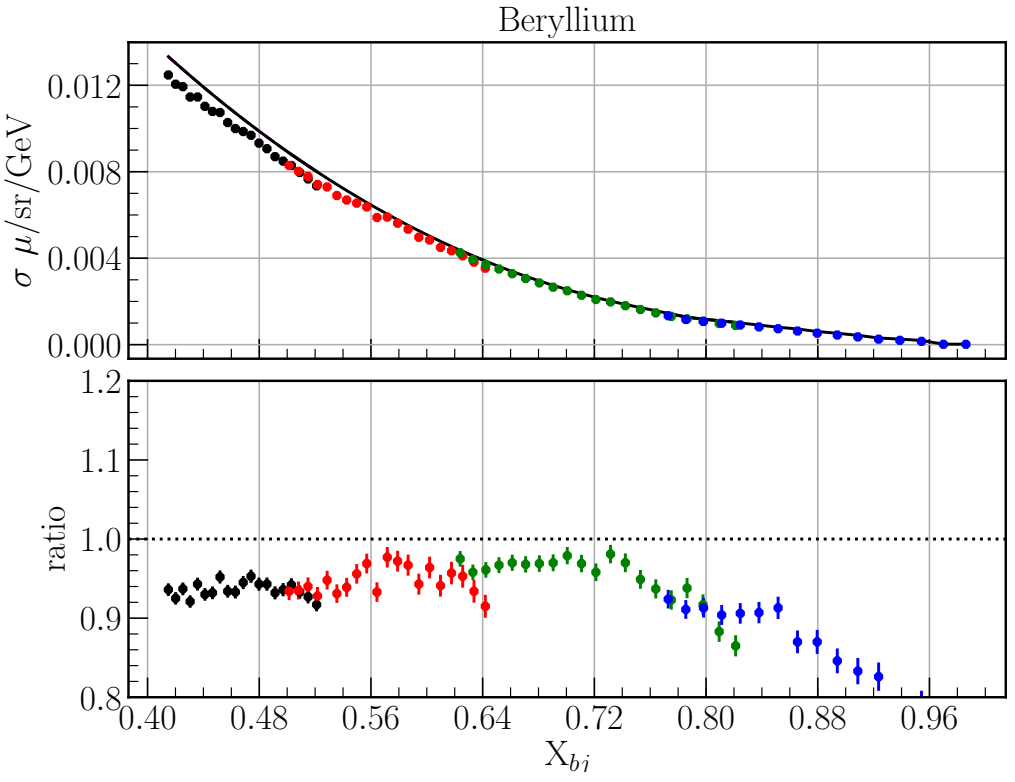
Analysis Status

HMS

Cross-section extracted from solid target

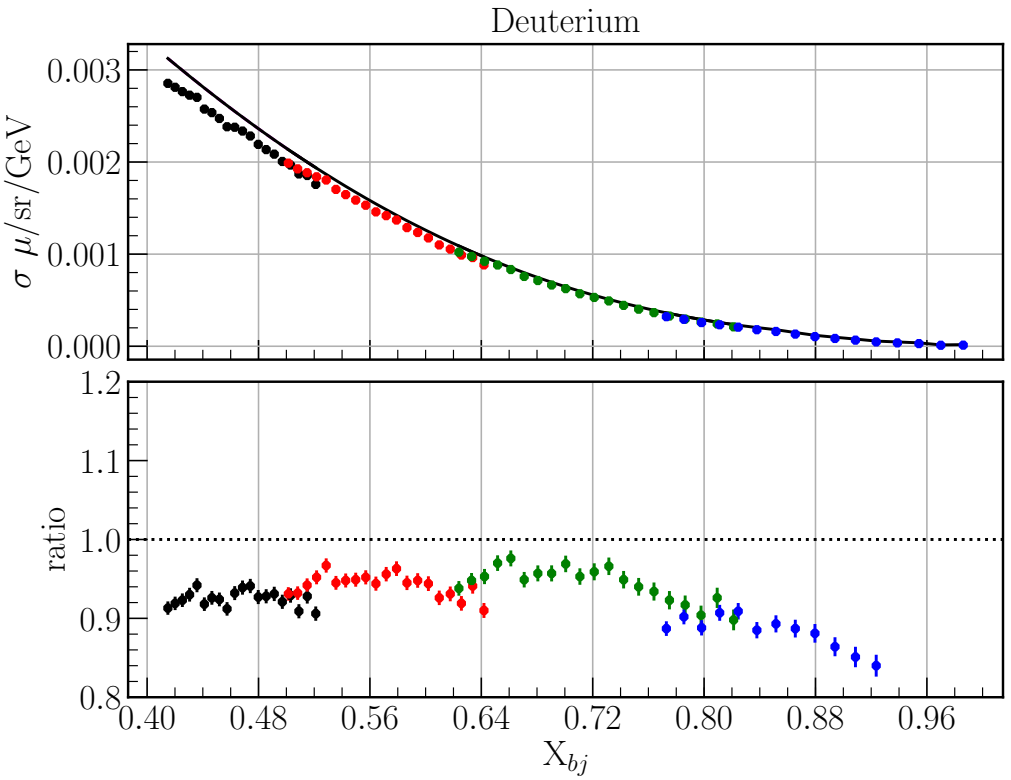


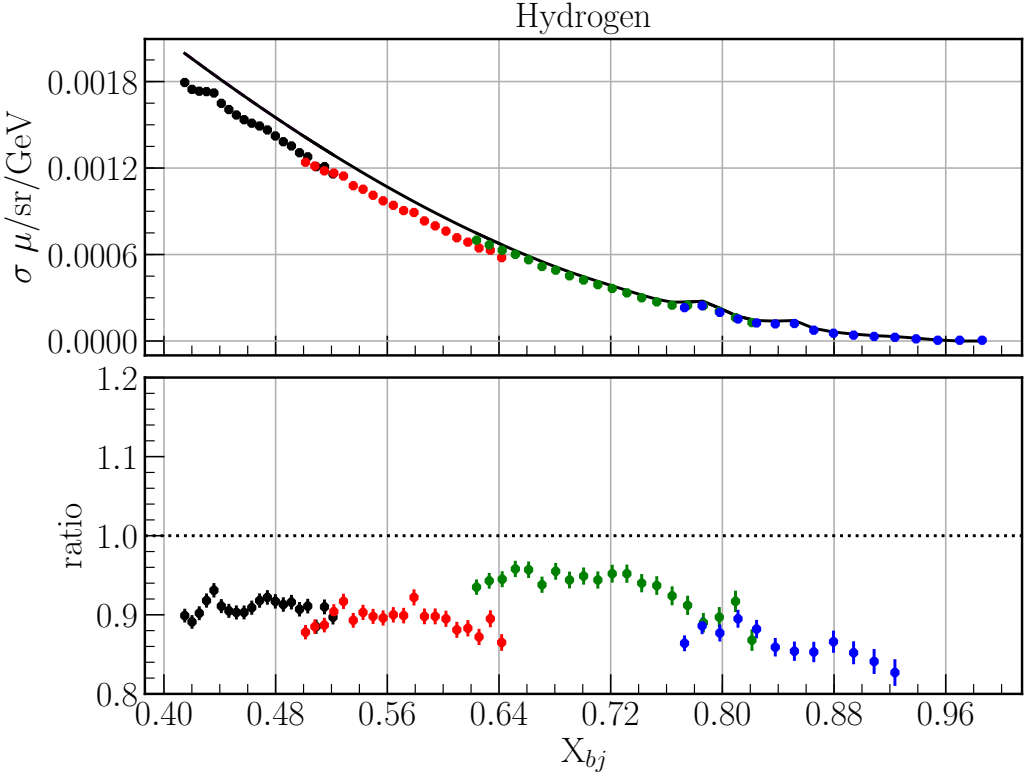


Analysis Status

HMS

Cross-section extracted from cryo- target



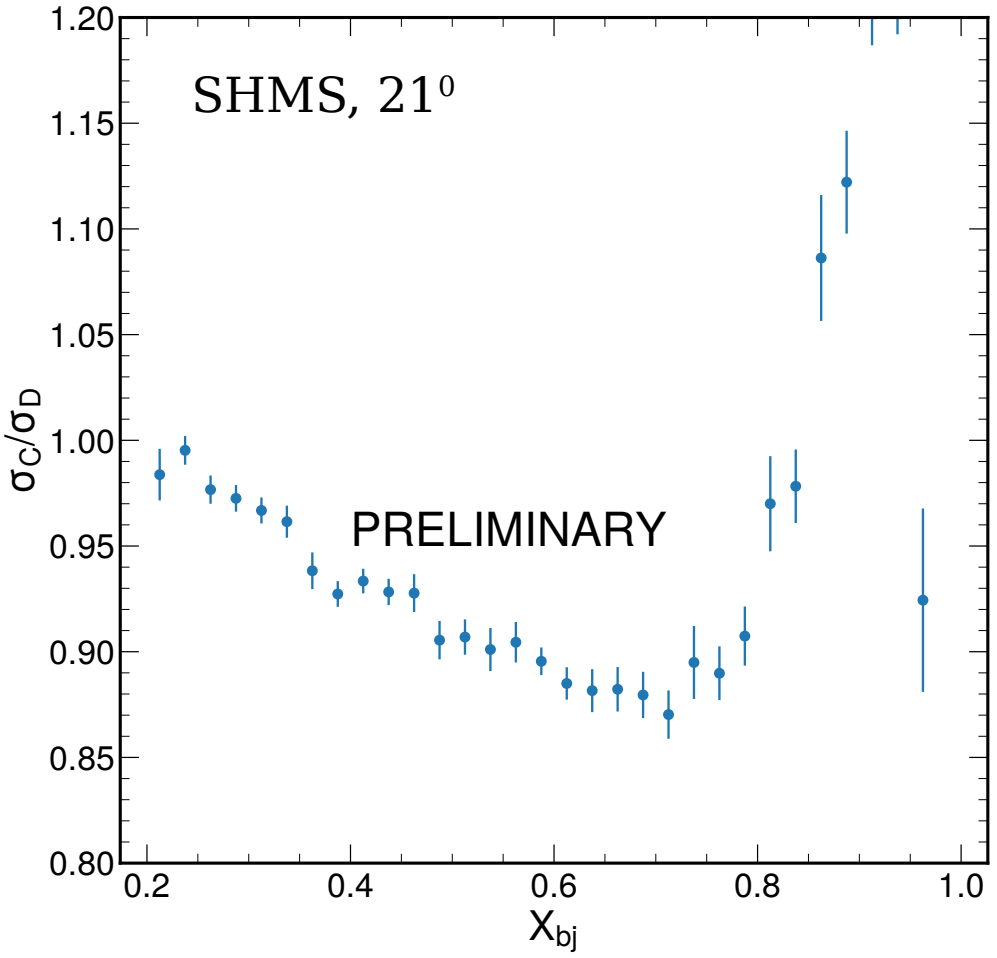


Analysis Status

$\frac{\sigma_A / A}{\sigma_D / 2}$ is plotted vs xbj

- Preliminary EMC ratio
- Carbon shape is roughly as expected
- There appears to be some issue with normalization that is under investigation

EMC ratio



Future Work

- Check more closely for few anomalies
- Work on radiative corrections model for Boron isotopes
- Extract EMC ratio for other targets

Summary

- Experiment E12-10-008 will provides a new data on several nuclei
- First EMC measurements on ^{10}B and ^{11}B
- Preliminary EMC ratio for Carbon was shown
- Final results coming soon

Thank you

Backup Slide

Neutron Excess: $$\left(\frac{\sigma^A}{\sigma^D}\right) \Big/ \left(\frac{\sigma^A}{\sigma^D}\right)_{is} = \frac{\left(Z + N\frac{F_2^n}{F_2^p}\right)}{0.5A\left(1 + \frac{F_2^n}{F_2^p}\right)}$$

Currently using SLAC Parameterization:

$F_2^n/F_2^p = 1 - 0.8x$