Update on the New Measurement of the EMC Ratio in Lighter Nuclei

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Hall C Winter Collaboration

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Outline

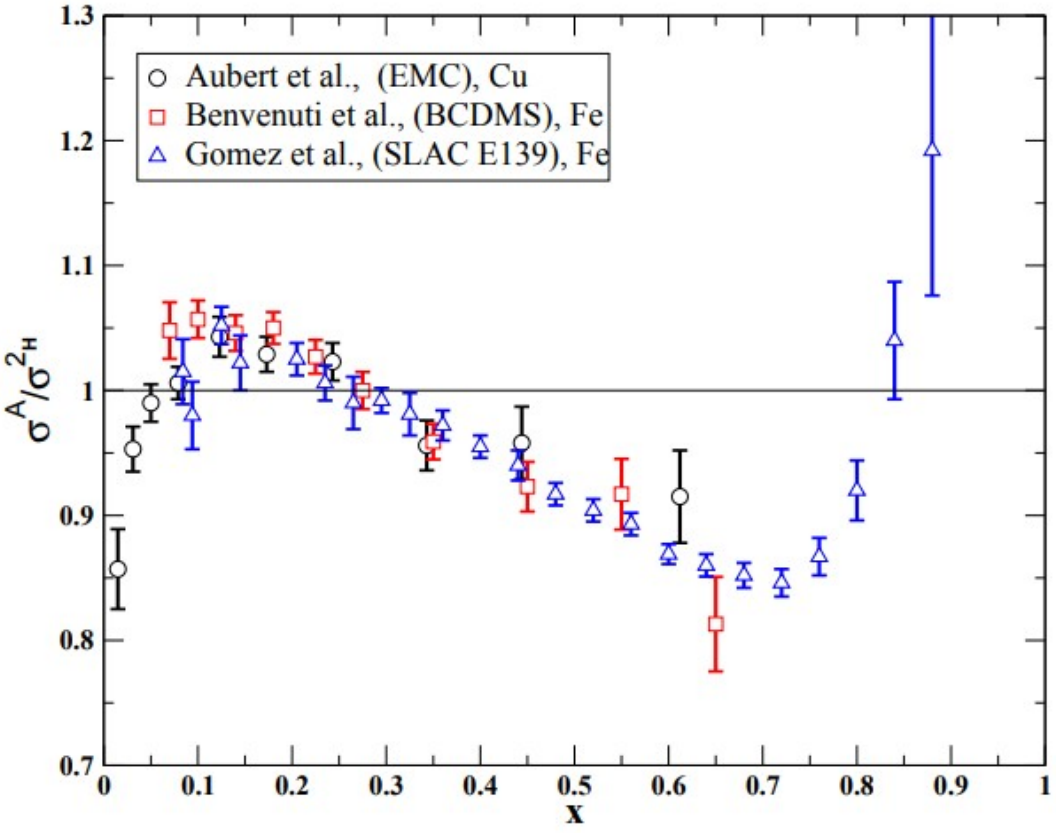
- The EMC Effect
- Experiment E12-10-008 at Hall C (Upcoming run Plans)
- Current Analysis Status
- Summary

The EMC Effect

- DIS from atomic Nuclei is not simple sum of scattering from it's constituent nucleons

  i.e $F_2^A(x) \neq ZF_2^p(x) + NF_2^n(x)$

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



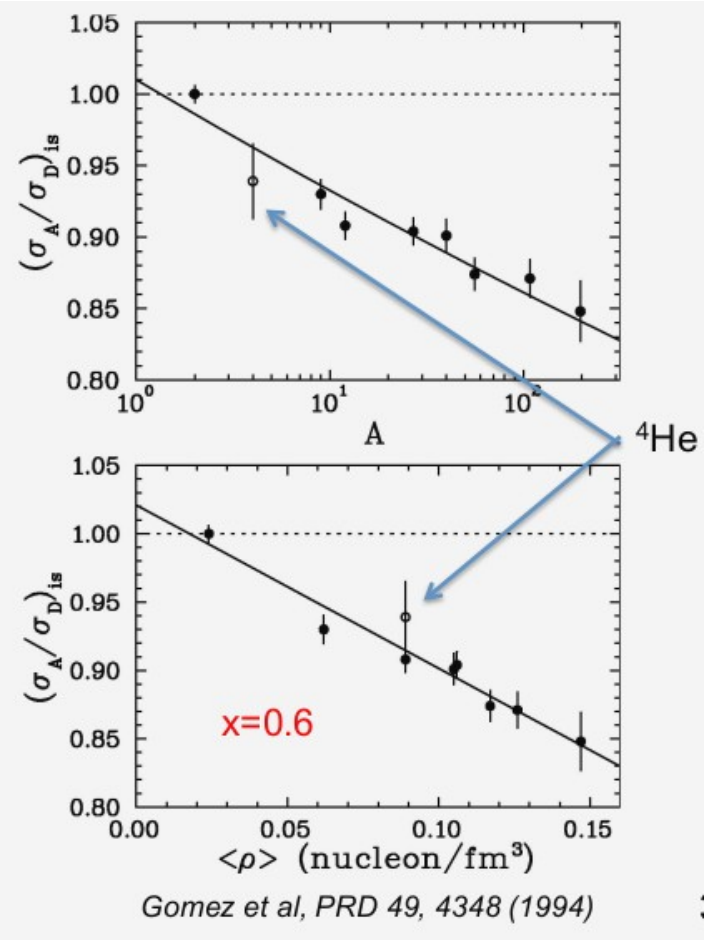
More than 36+ years yet no generally accepted explanation of the EMC effect

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



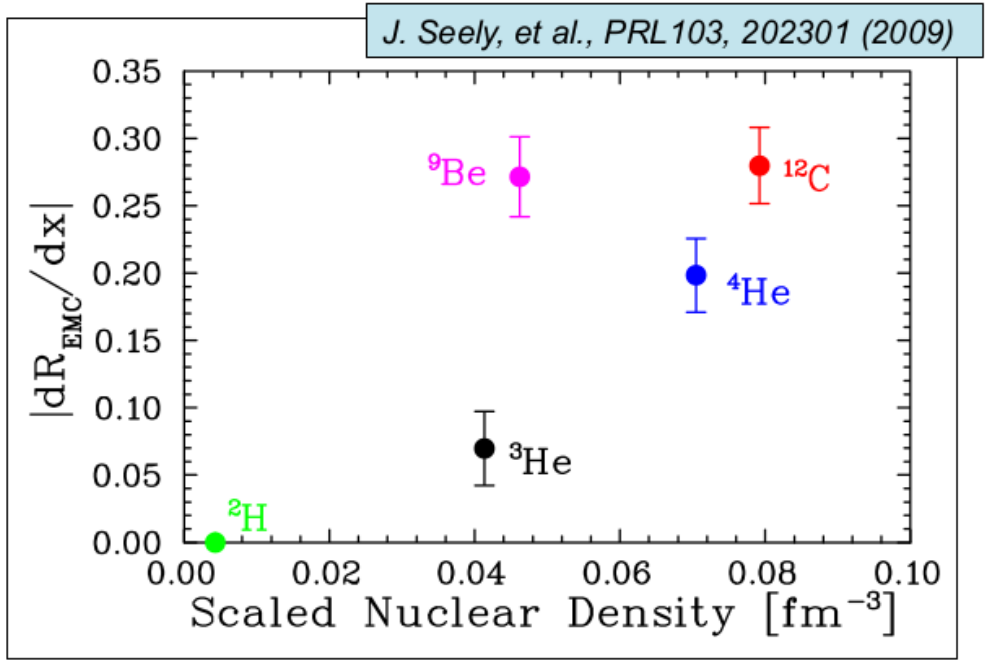
Motivation

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** 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



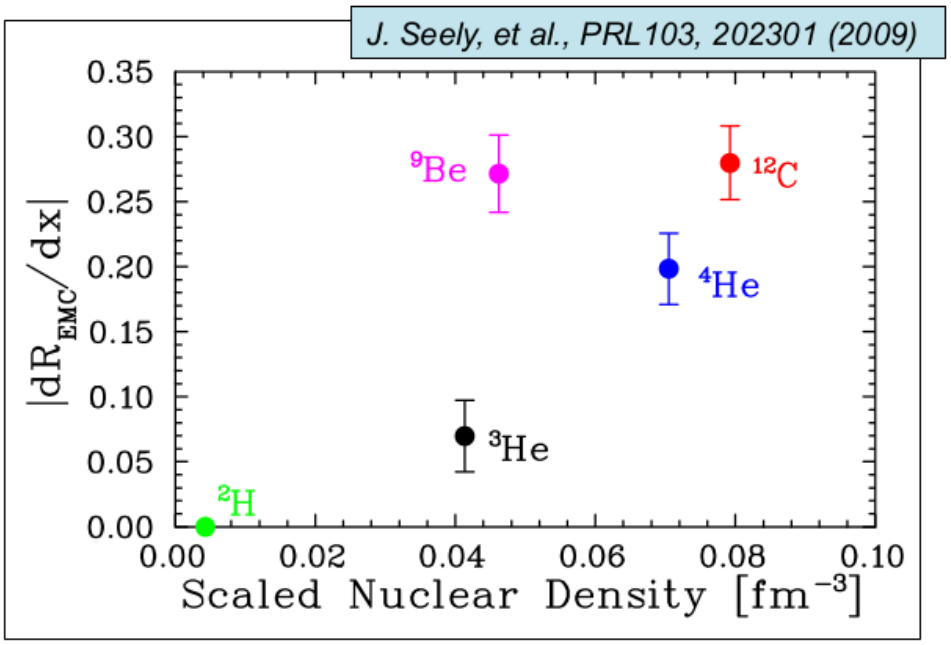
- Plot shows slope of ratio σ_A/σ_D at EMC region

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

Motivation

Jlab E03-103:

- **Suggest that EMC Effect 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.

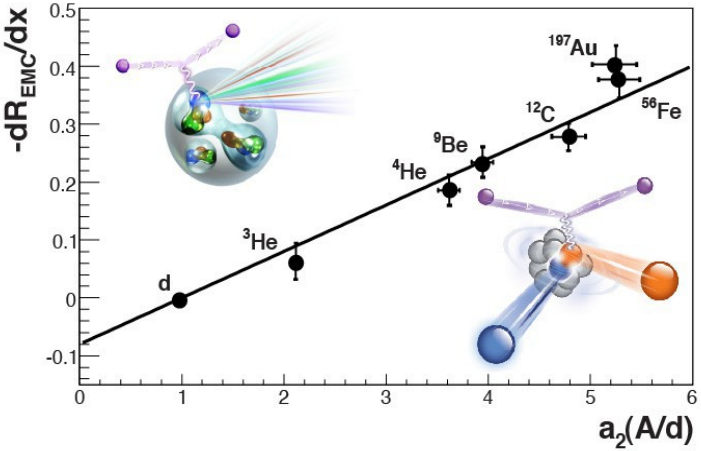
Nucleons are in high local densities of alpha cluster

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

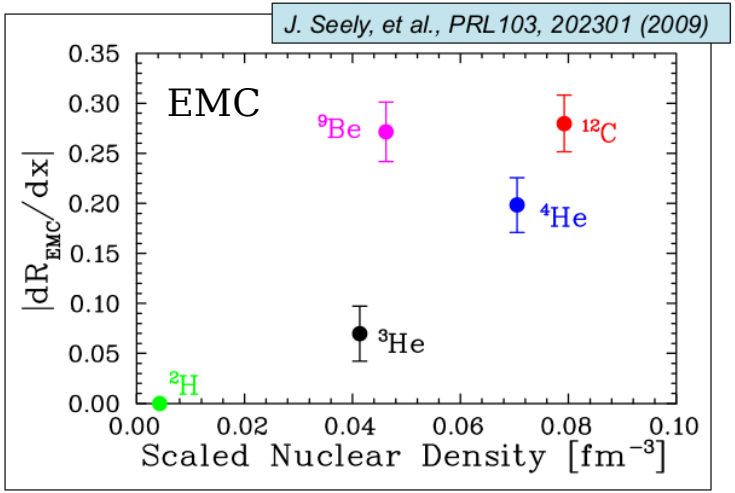
Motivation: SRC & EMC correlation

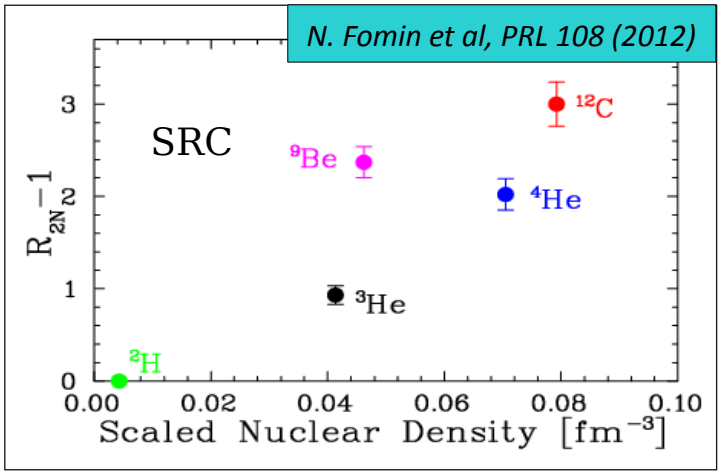
If the EMC effect is a local density effect, then it seems reasonable to look for connections to other local density effects

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



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. Formin, D. Gaskell, Solvignon, PRC 86, 065204 (2012)
O. Hen, et al, PRC 84, 047301 (2012)
L. Weinstein, et al, PRL, 106, 052301 (2011)

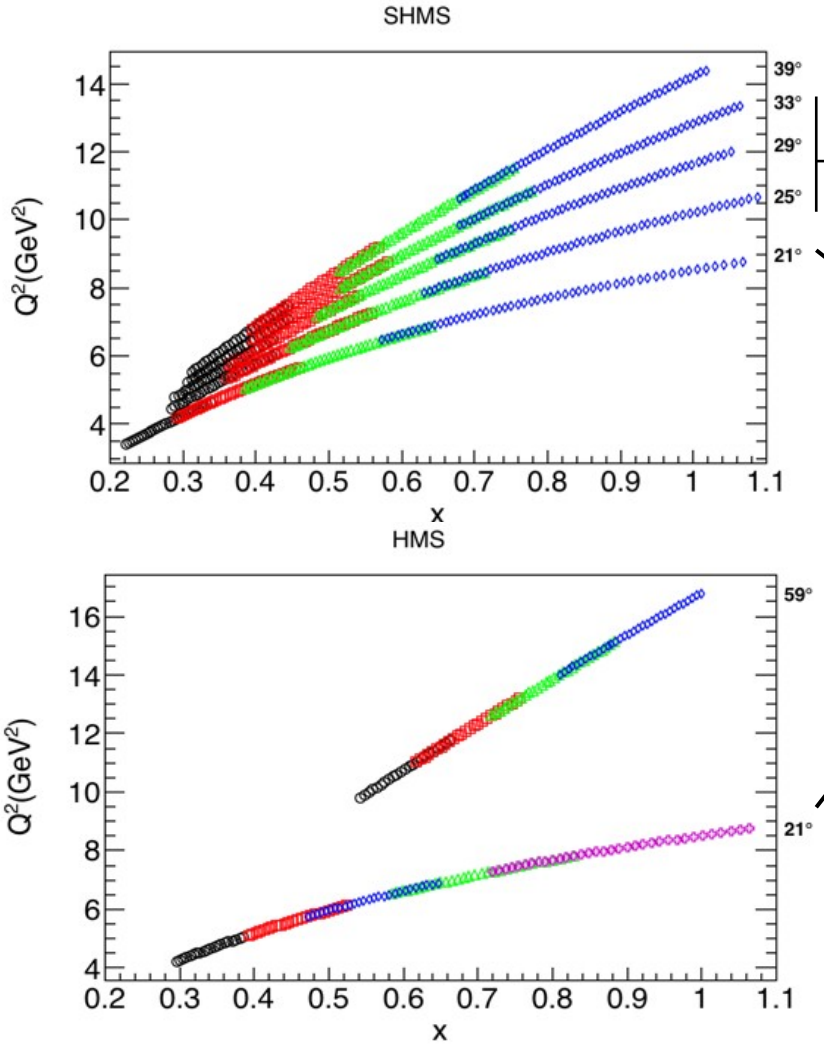
Overview of the experiment (E12-10-008)

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, $^{10,11}B$ (*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 Q2-dependence of the EMC ratios

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

Kinematic Coverage: Phase - I



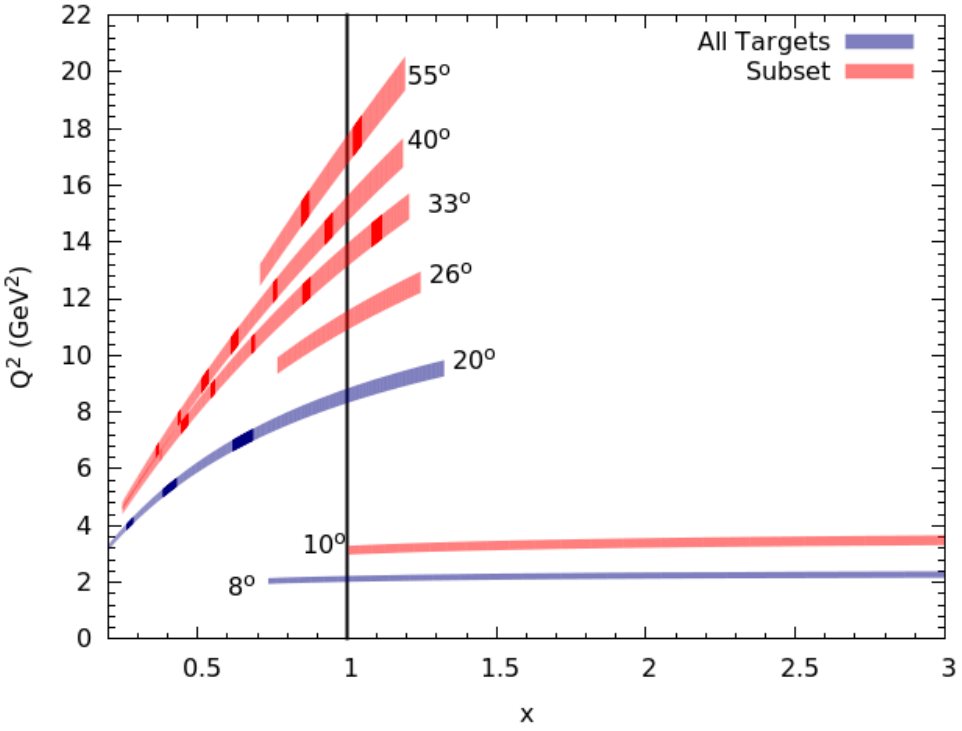
Data at large angle will provide Q^2 dependence study

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

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

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

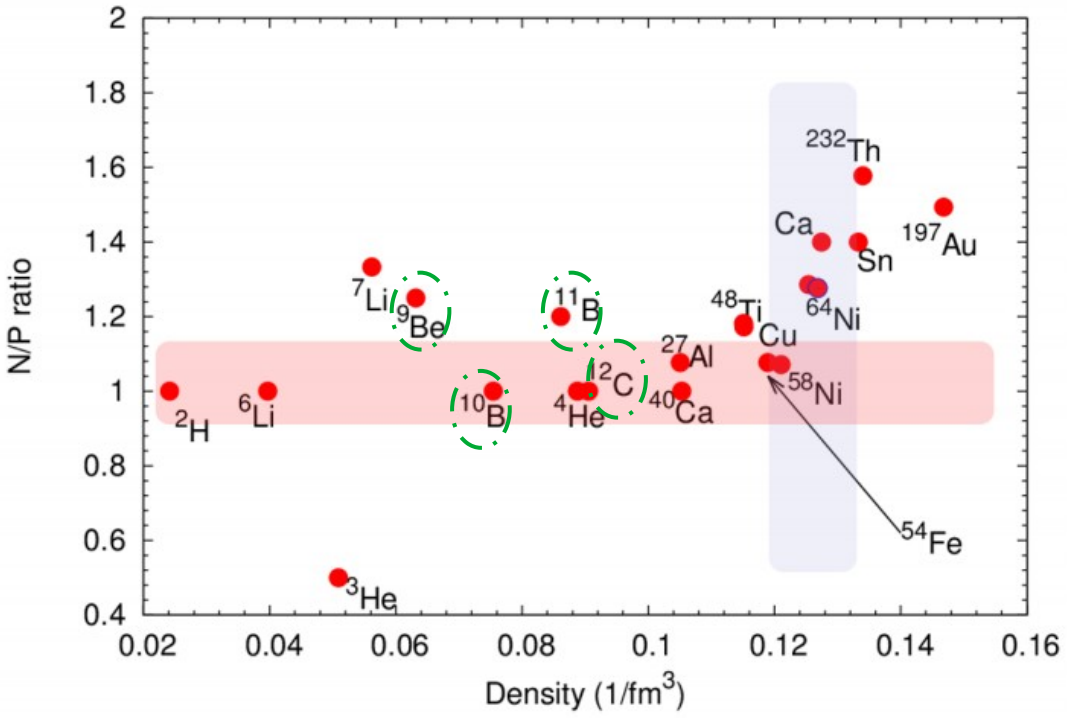
- Runs concurrently with E12-06-105 (x>1)
- Covers a range of angles (20 - 55) degree
- HMS: 20^0 - 55^0, 1.4 - 6.4 GeV/c
- SHMS: 8^0 - 33^0 , 1.4 - 10.6 GeV/c
- Beam Energy ≈ 11 GeV
- HMS and SHMS run in parallel
- 23 PAC days for Phase I and Phase II
  - 2 days completed spring 2018 (Phase I)



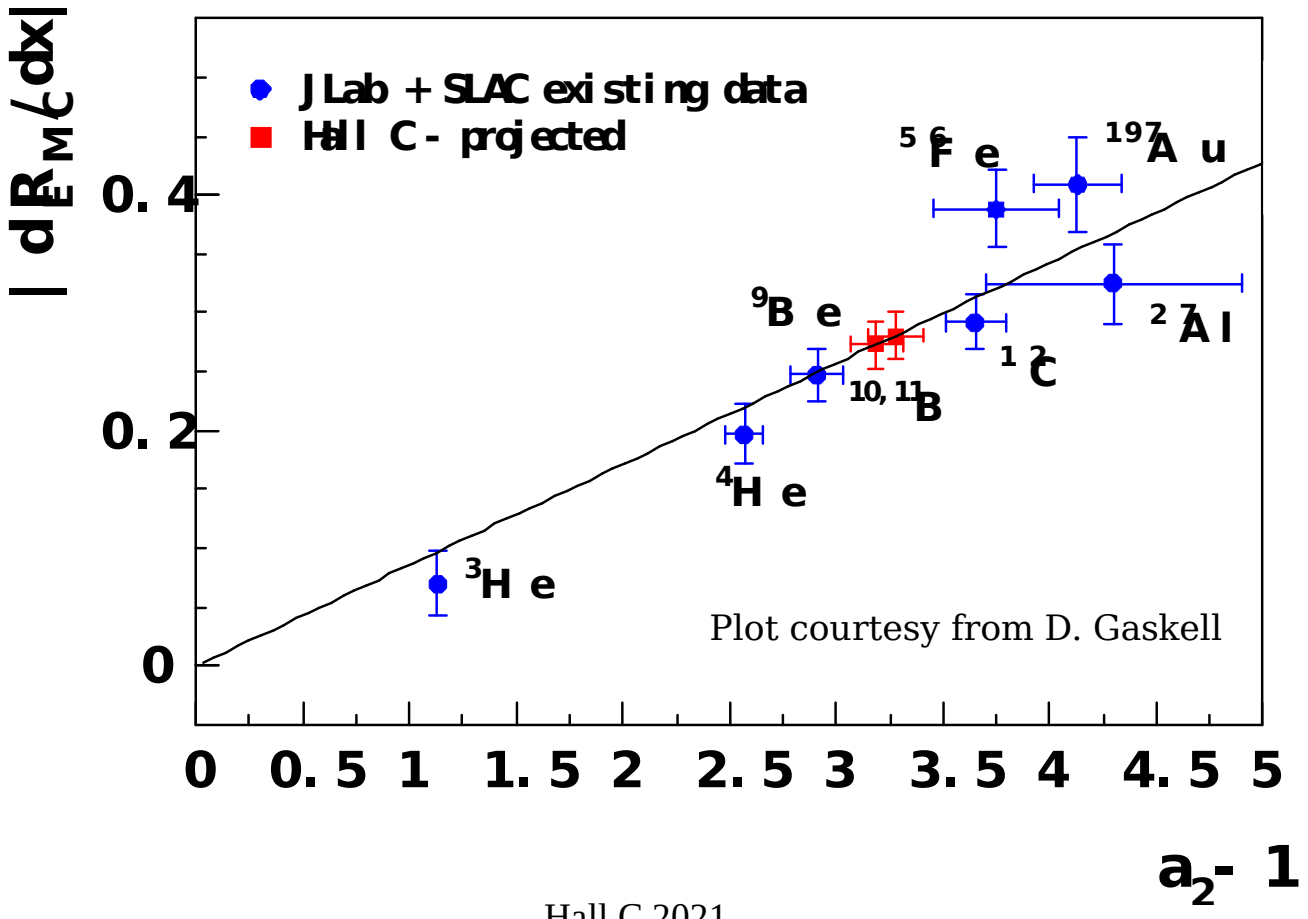
- Plot shows kinematics coverage for EMC and x>1.
- The lower x represent the EMC effect data

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



Outcome: E12-10-008 Phase I



Analysis Status

- Detector calibration complete.
- Extraction of experimental efficiencies mostly complete
  - Still working on dead time (See Casey Talk)
- Understanding the SHMS Acceptance is ongoing
  - Currently, fixing the x-beam offset and z-target offset
- Detailed Data/Monte-Carlo comparison is ongoing
- Extraction of EMC ratios are in progress

Analysis Status: x-section extraction by MC Ratio

We simulate Monte – Carlo(MC) 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

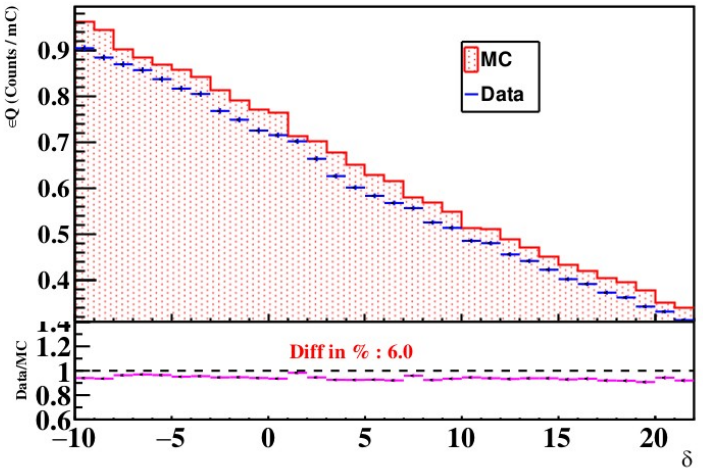
$$d\sigma/d\Omega dE' = \sigma^{model} * [Y(E',\theta)/Y_{MC}(E',\theta)]$$

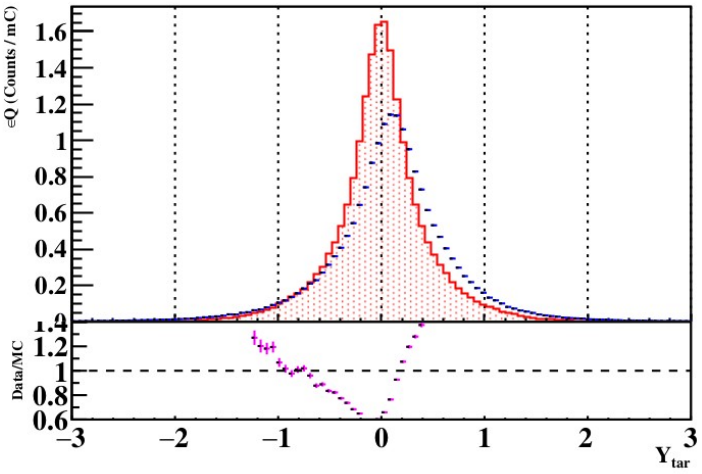
Y_{MC} = Monte-Carlo Yield
Y = Data Yield
L = Luminosity
σ = Model x-section
A = Acceptance

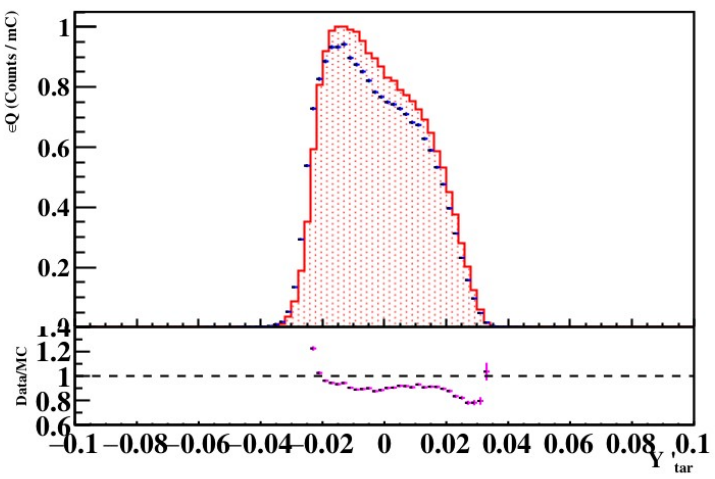
Analysis Status: Data to MC

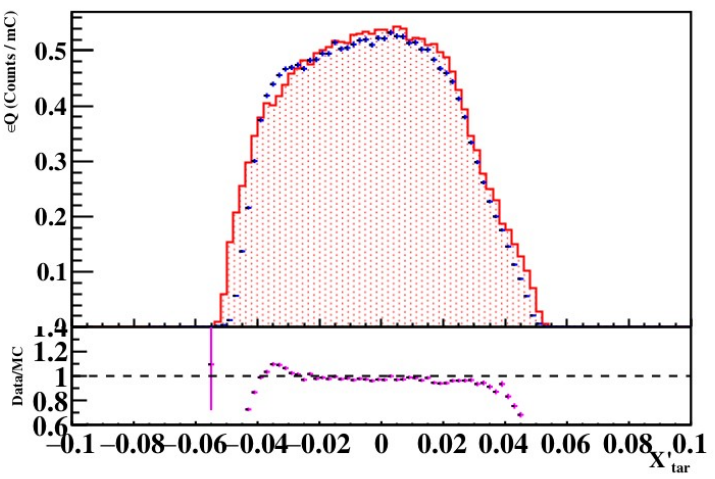
- 10.6 GeV beam energy
- ^{12}C at 2.7 GeV, 21^0
- Delta, ytar, yptar, xptar
- Integral difference ~ 6%
- Data Ytar resolution not so well

SHMS



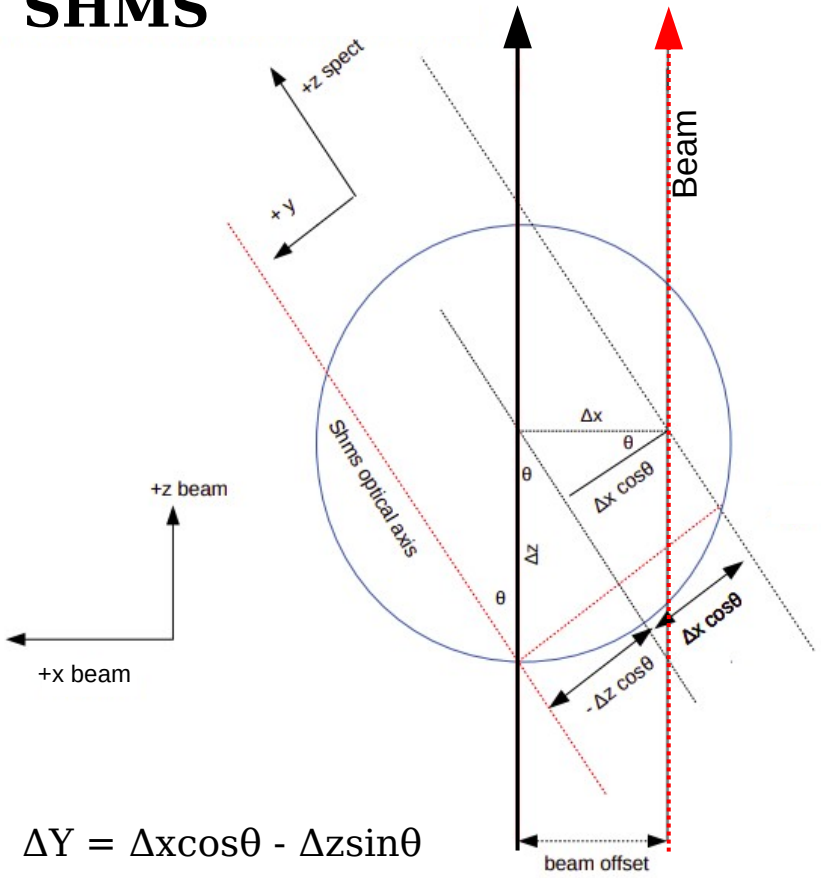






Analysis Status: x-beam offset & z-target offset

SHMS



$\Delta Y = \Delta x \cos\theta - \Delta z \sin\theta$

The relationship between the target z position which is the position of the target relative to pivot, beam x position and the reconstructed target quantities Y-tar,

$$\Delta Y = \Delta x \cos\theta - \Delta z \sin\theta$$

Here,

θ = spectrometer angle

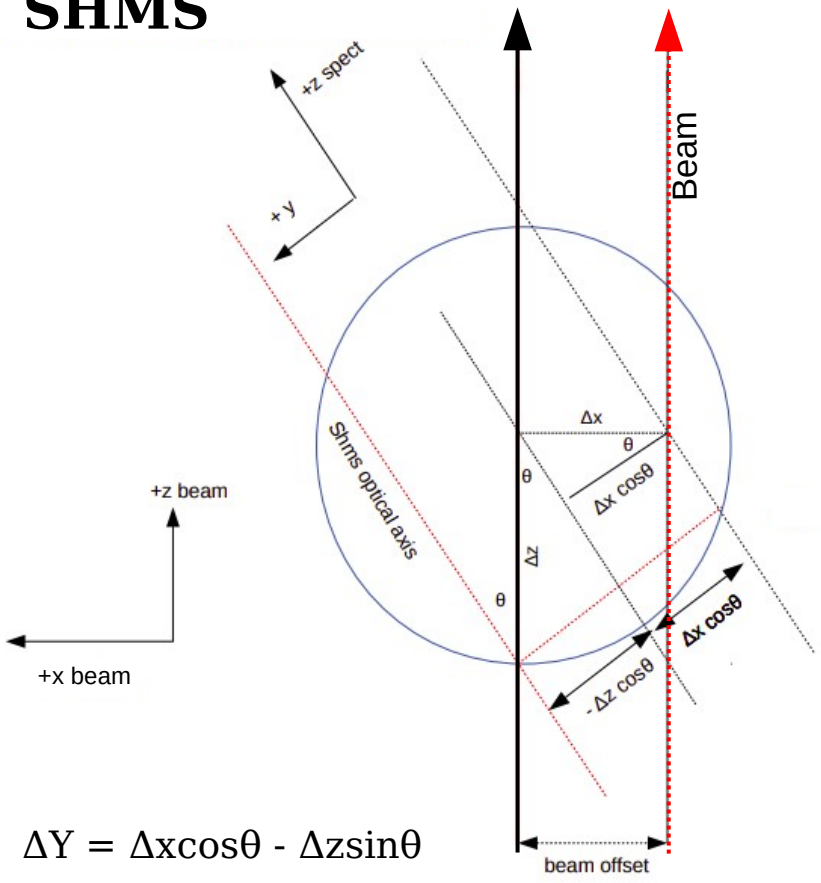
ΔY = in plane offset of the target relative to the spectrometer

Δx = in plane beam position offset relative to pivot

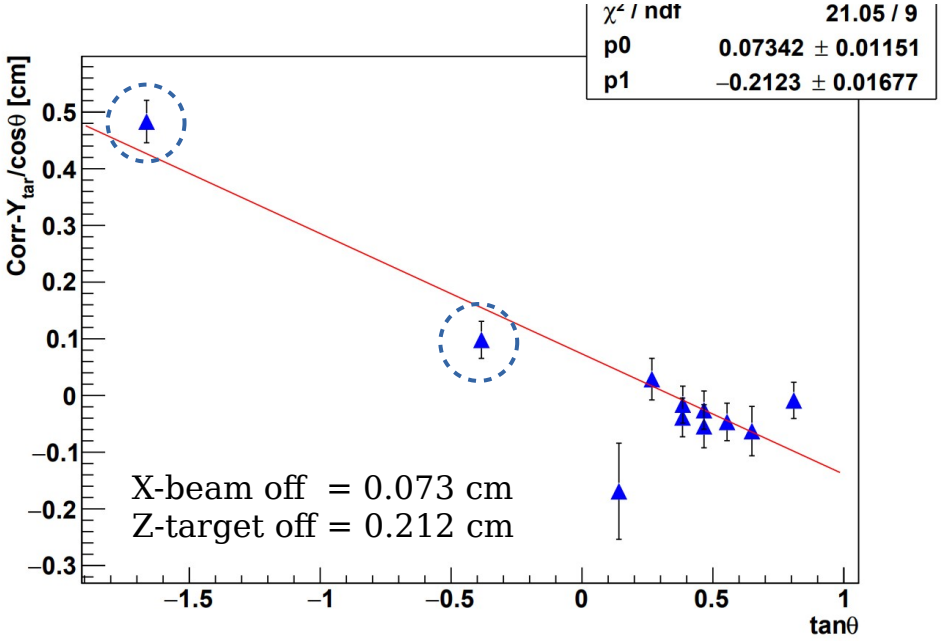
$$\Delta Y/\cos\theta = \Delta x - \Delta z \tan\theta$$

Analysis Status: x-beam offset & z-target offset

SHMS



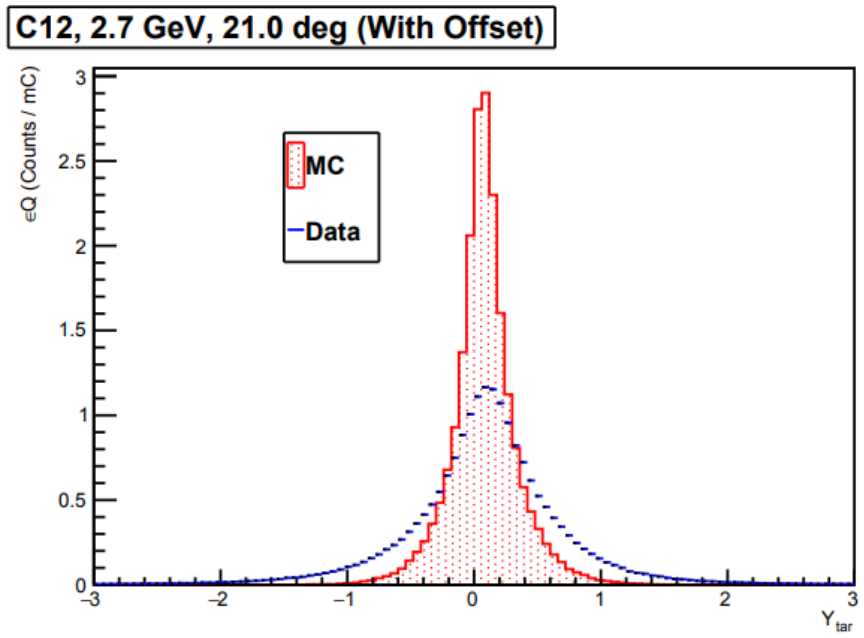
$\Delta Y = \Delta x \cos\theta - \Delta z \sin\theta$

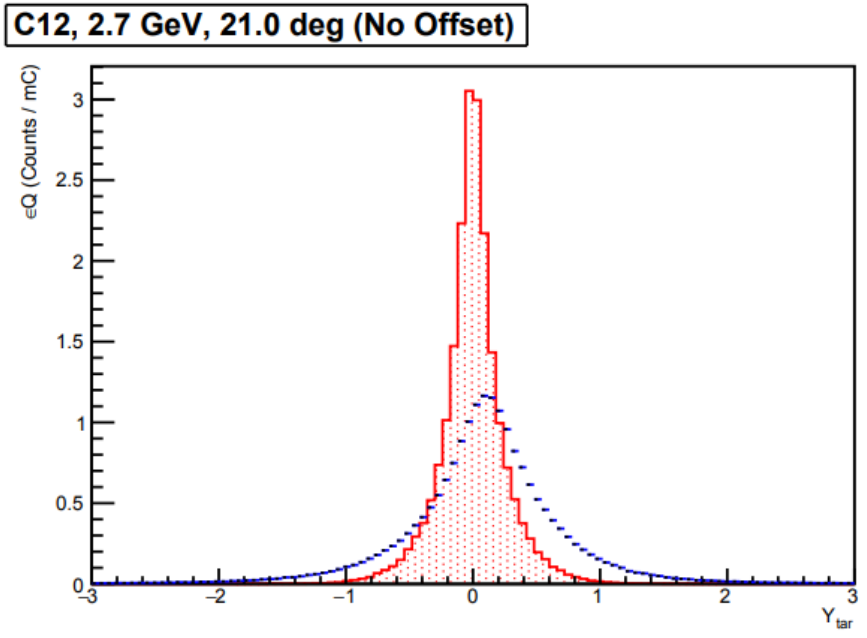


- Corr-Ytar is reconstructed Ytar obtained from carbon target from both spectrometer after correcting for mispointing and bpms.
- Mispointing was determined by survey at various spectrometer angles.

Analysis Status: x-beam offset & z-target offset

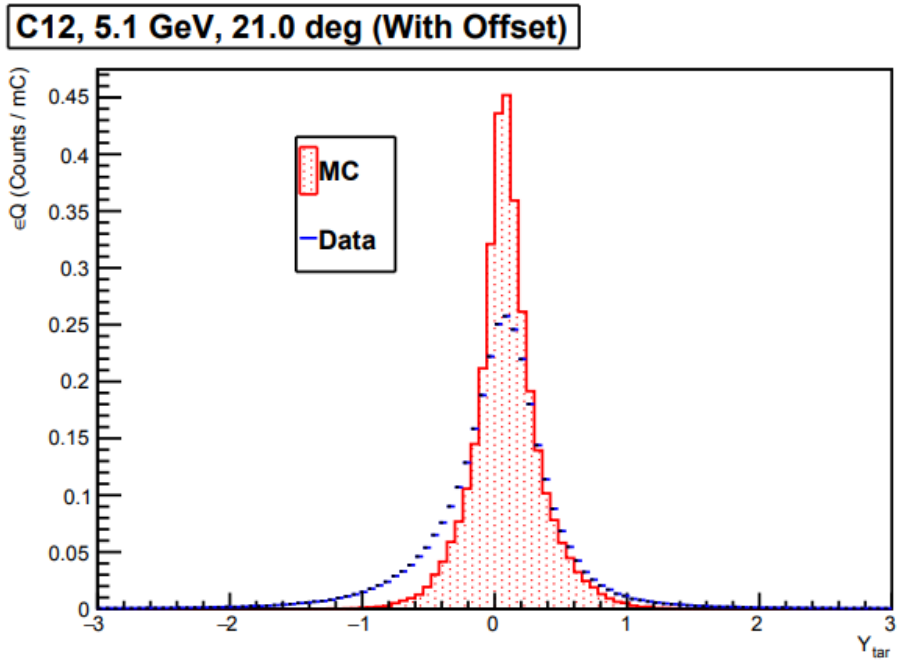
SHMS

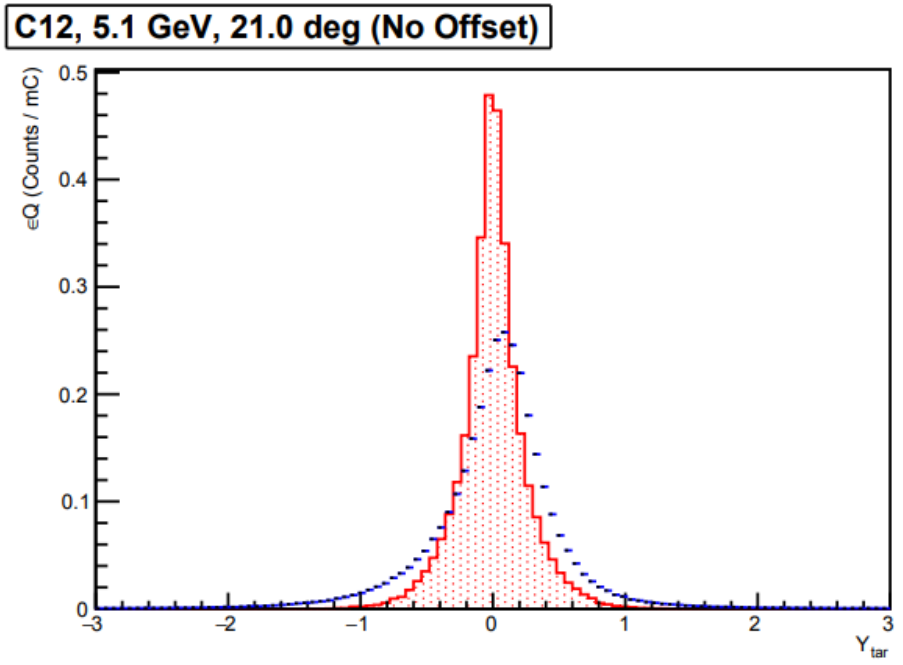




Analysis Status: x-beam offset & z-target offset

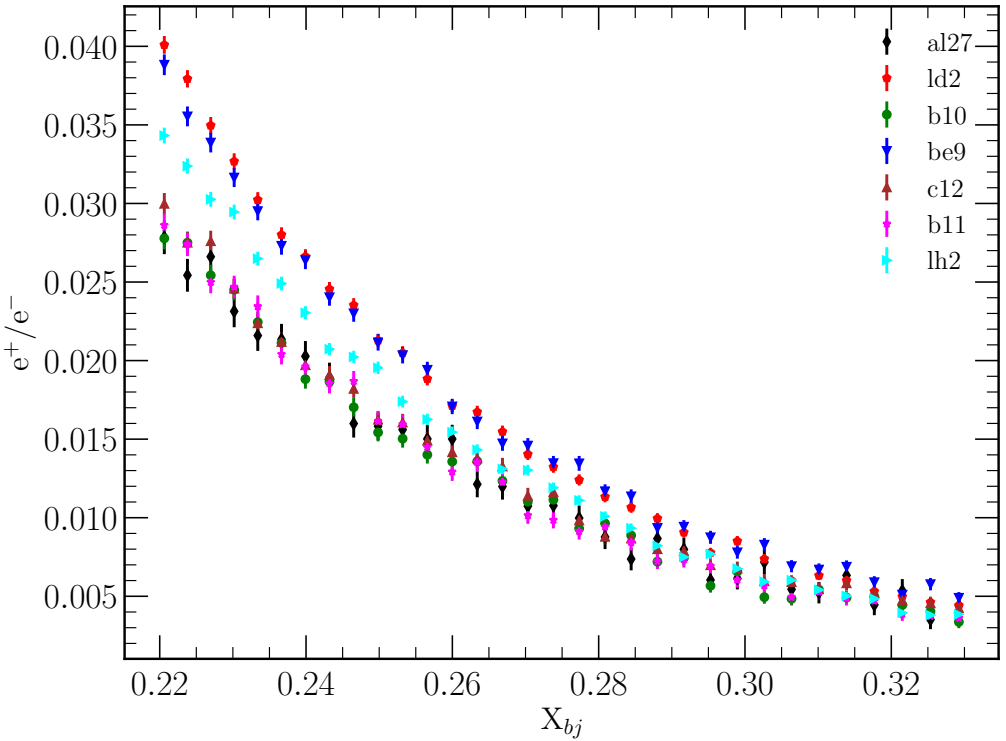
SHMS





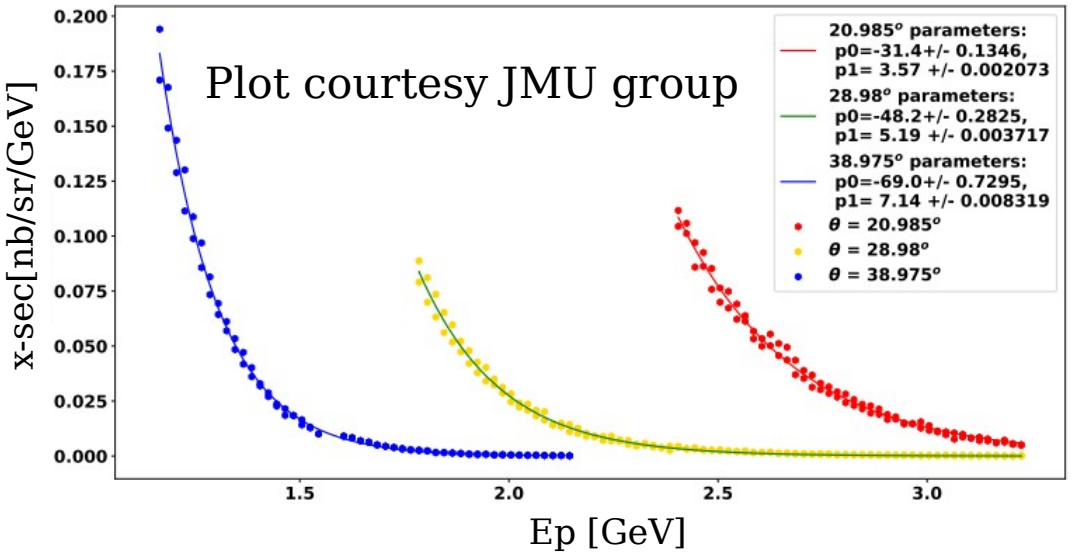
Analysis Status: Background Correction
Charge Symmetric Background (CSB)

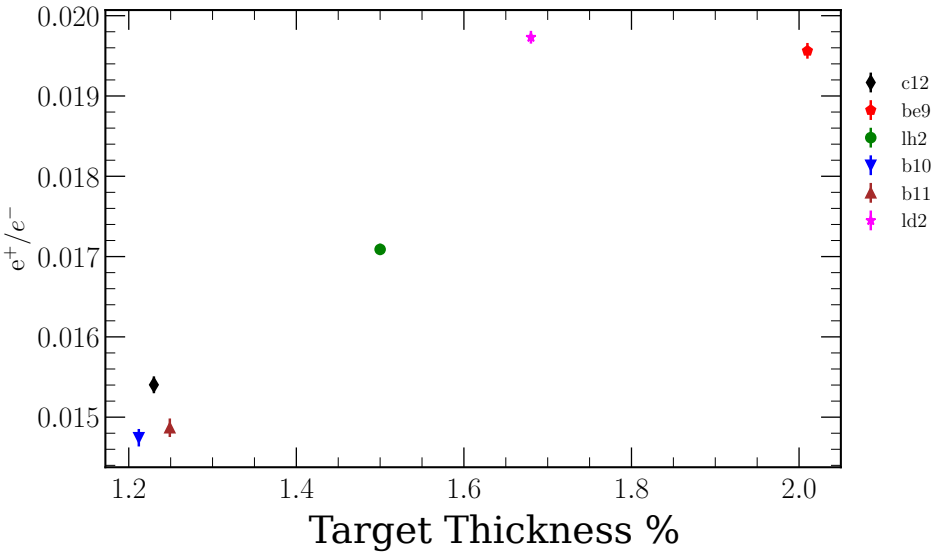
- # of $e^-_{detected}$ = # of $e^-_{primary}$ + # of $e^-_{background}$
- Equal # of e+ and e- are produced
- Allows to estimate the no of secondary background e- by running the spectrometer with +ve polarity
- Data were taken at the kinematics setting where CSB was large.
- Positron data are subjected to the same cuts as electron data
- JMU group extracted positron x-section for H, D (See Bill's Talk)



- Plot shows CSB as a function of x for 21^0

Analysis Status:Charge symmetric background (CSB)

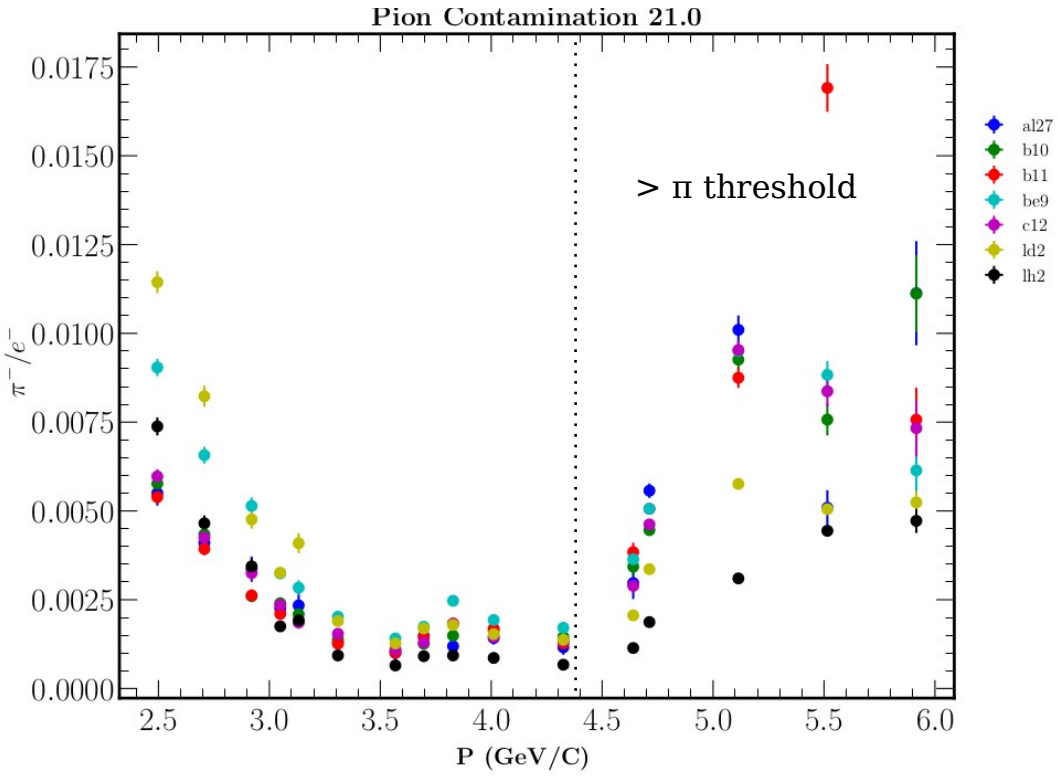




Since we also need nuclear target we can use radiation length dependence and JMU Model for other angles where we didn't take carbon data.

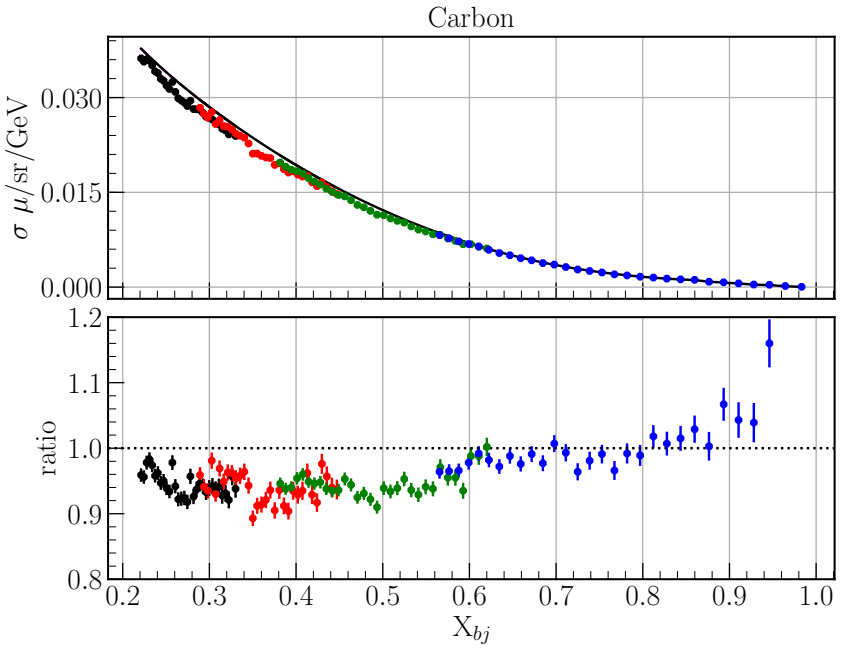
Analysis Status: Background Correction
Pion Contamination

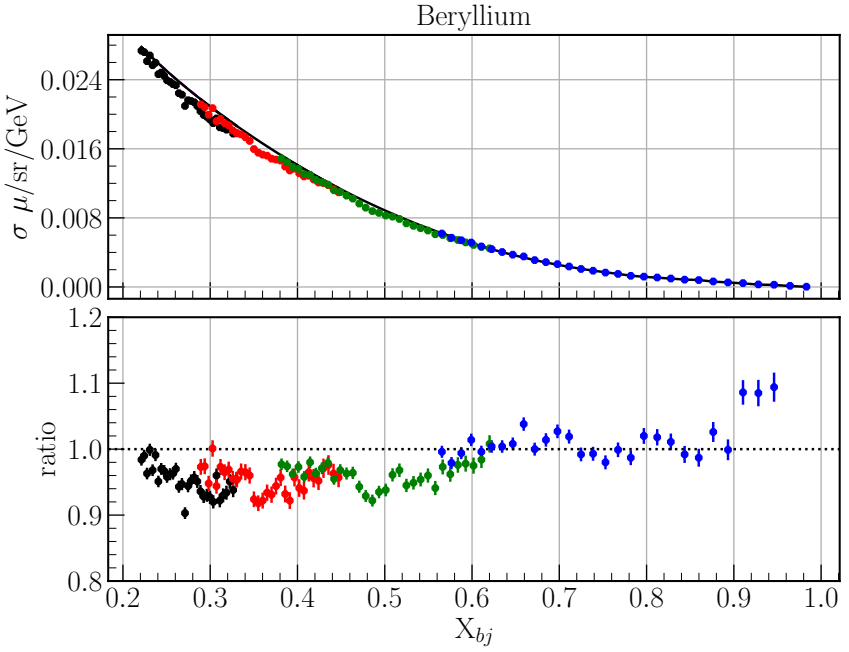
- Shows a nice drop in pion contamination as momentum increase
- Pion contamination is very small
- Increased in pion contamination after 4.5 GeV is due to fact pion threshold for Cherenkov is 4.4 GeV
- Abel (F2) also looked into this and our result matches to great extend (see Bill's talk)



- Plot shows pions to the sum of pions and electrons as a function of SHMS momentum for 21^0

Analysis Status:x-section extracted from Solid Target SHMS





- We used Arie Bodek's fit to proton and deuterium inelastic structure functions, and then a separate fit to the EMC effect in nuclei
- For radiative correction, we use QE model (F1F209 from Peter Bosted and Vahe Mamyan). In the x-region of interest, this model agrees pretty well with F1F220 (Eric Christy) .
- For Final analysis we will use generalized model that uses F1F220 for inelastic and an improved y-scaling (See Casey Talk)

Analysis Status:x-section extracted from Solid Target SHMS

x-sec from Boron Target

Note:

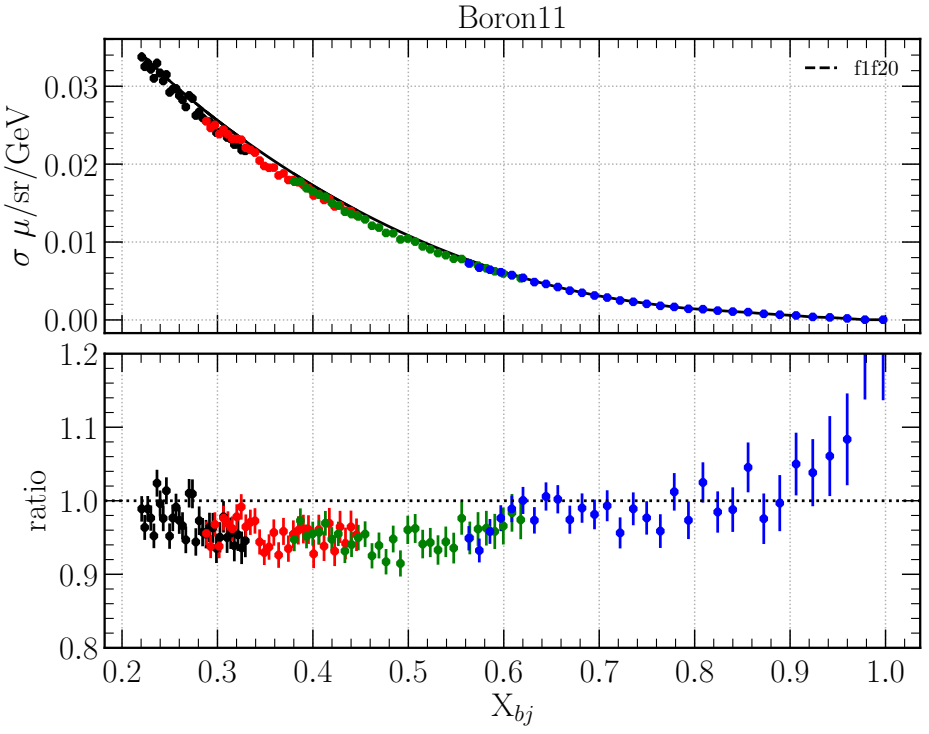
- B4C targets were used while taking data
- Need to subtract the carbon contribution

  So little more involved
- Also, 10B and 11B are not 100% isotopically

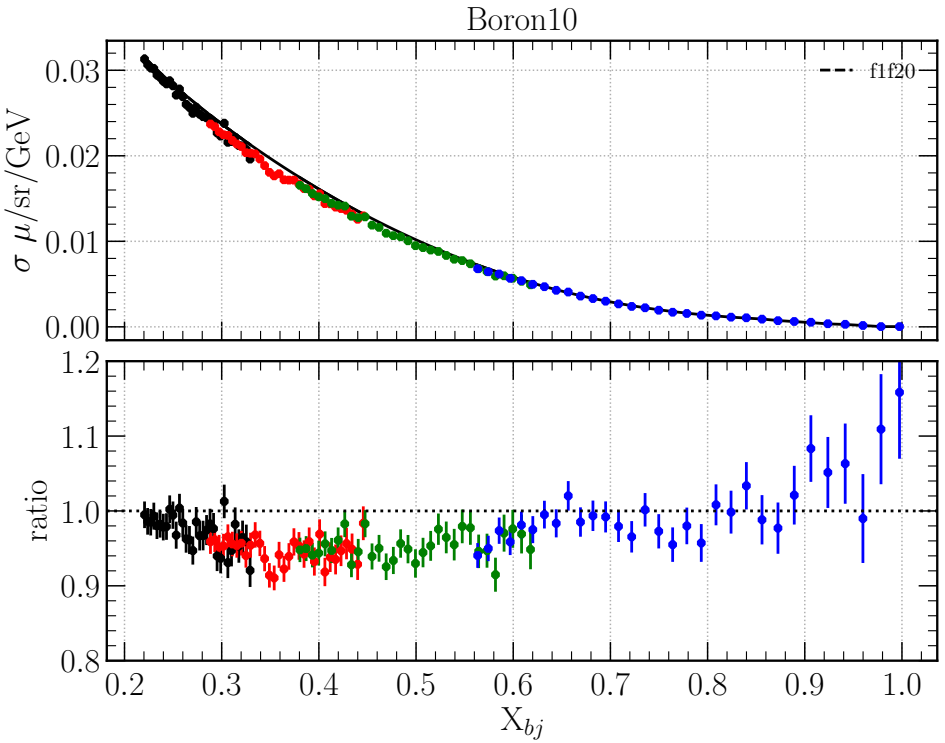
  pure they are listed to be “at least 95%”

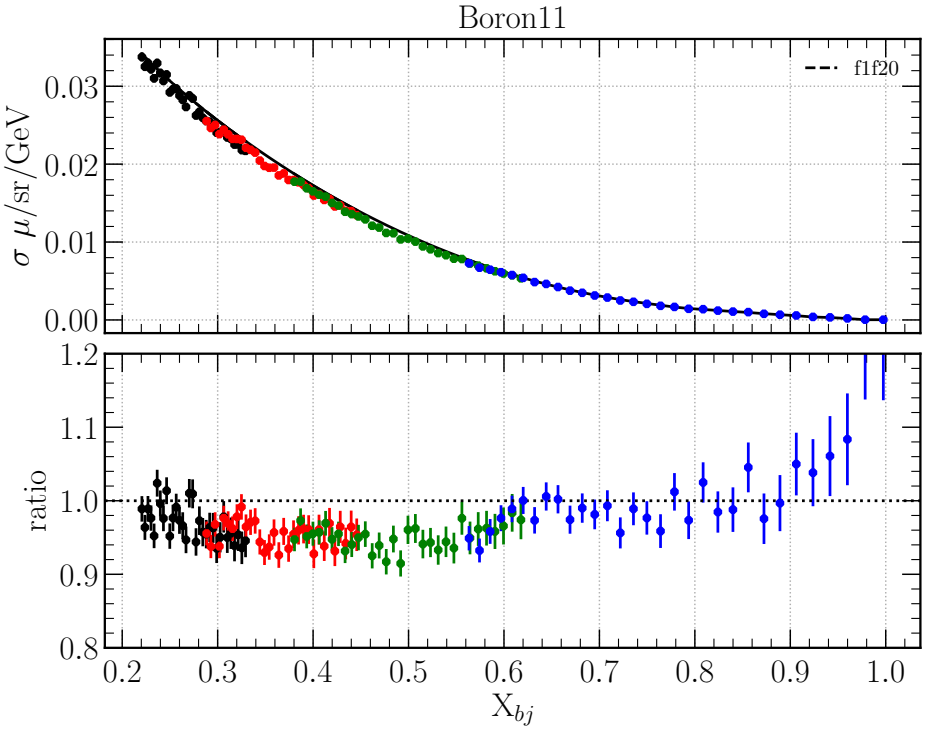
  pure), So there will be small extra

  uncertainty



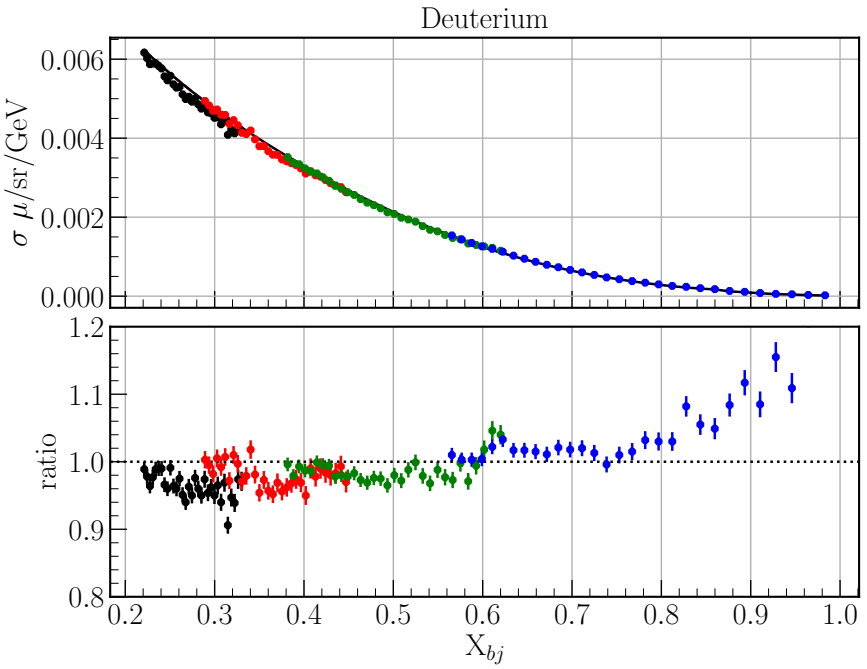
Analysis Status:x-section extracted from Solid Target SHMS

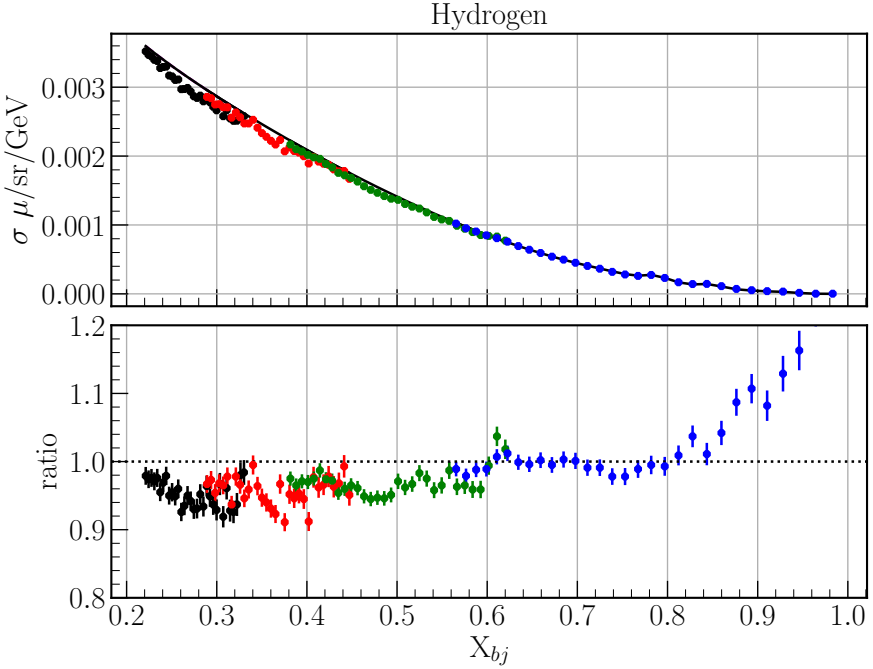




Analysis Status:x-section extracted from Cryo Target

SHMS

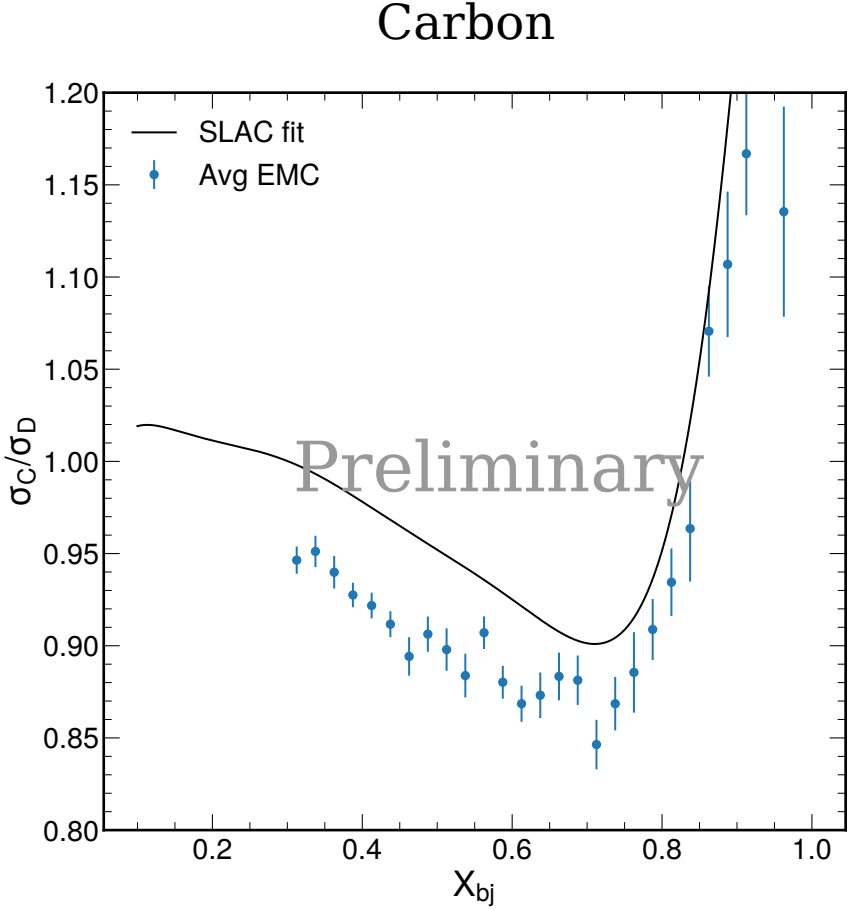




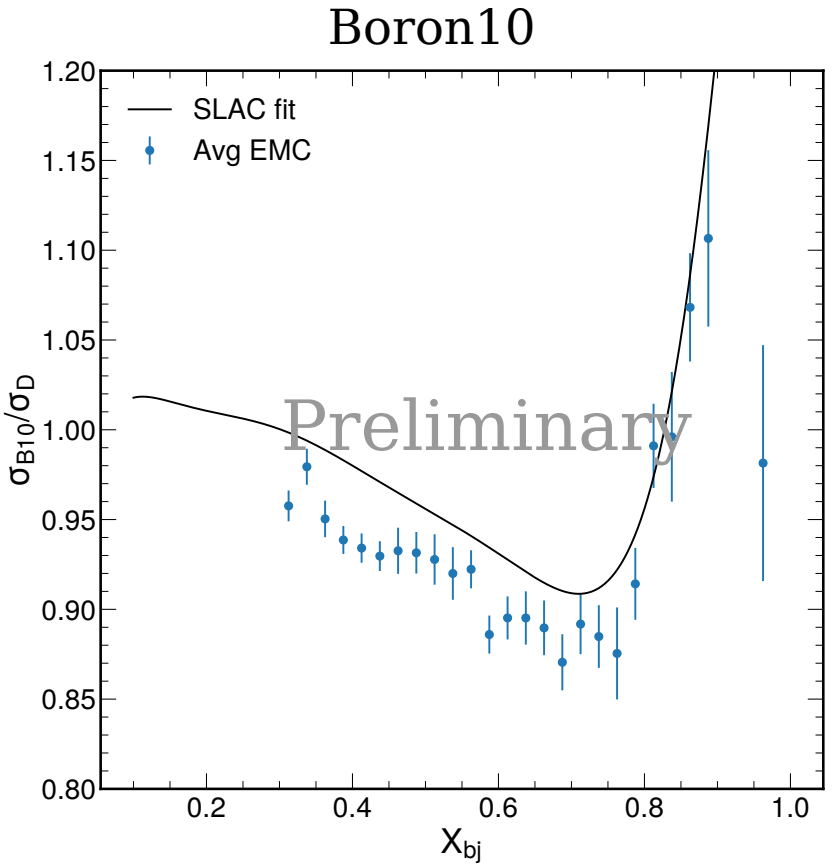
Analysis Status: EMC Ratio at 21⁰

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

- Preliminary EMC ratio
- Shape is roughly as expected
- Some normalization issue is under investigation(~ 3%)
- No Pion contamination correction



Analysis Status: EMC Ratio at 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)

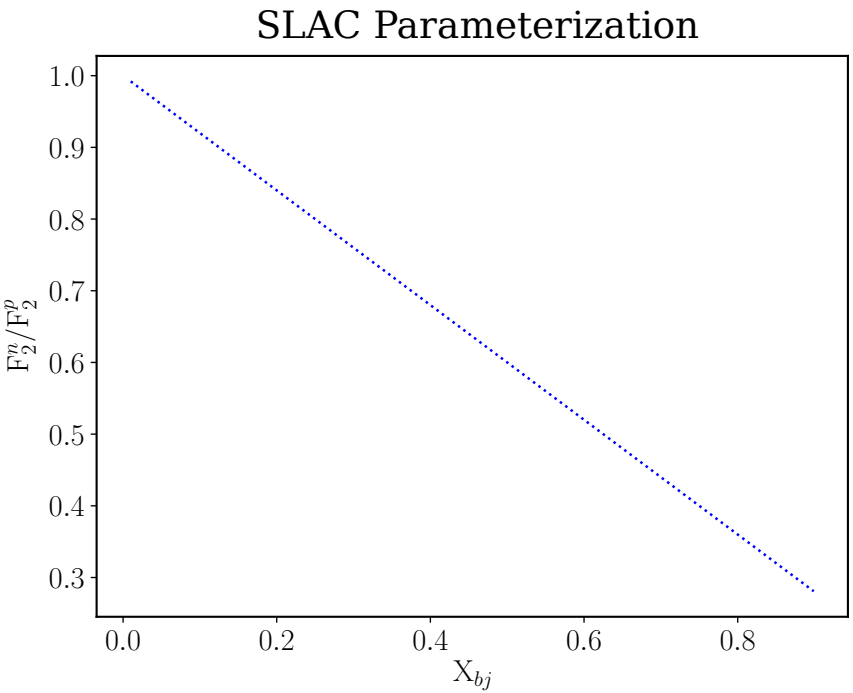
- Needs to correct for excess of neutrons or protons. The multiplicative correction factor is,

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

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

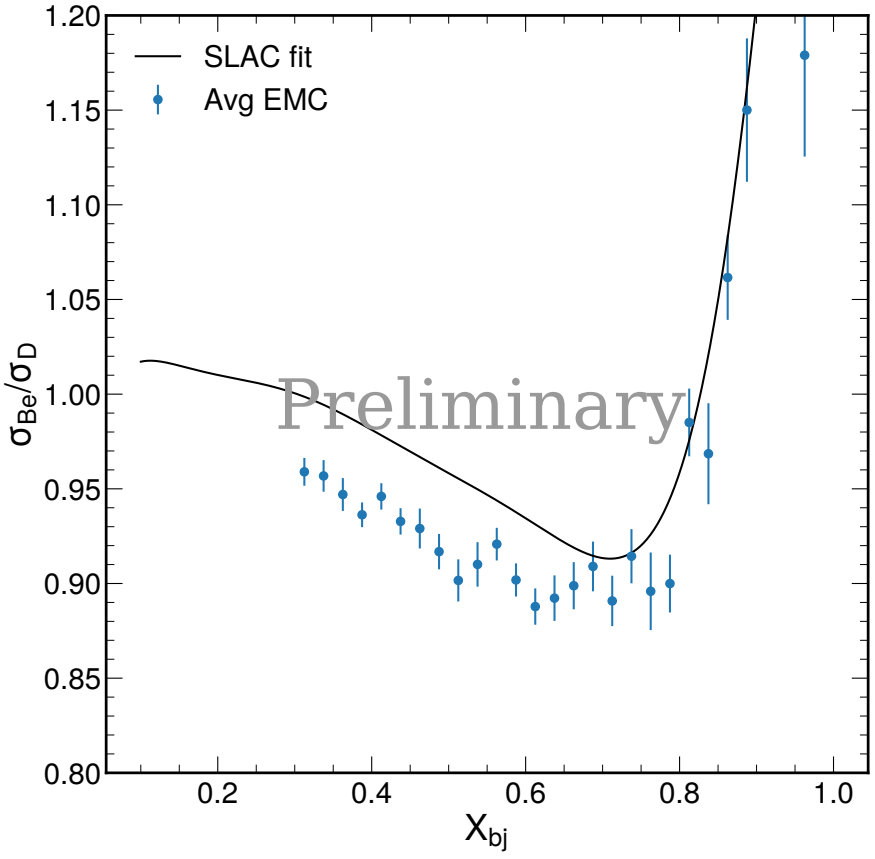
- Currently using SLAC Parameterization:

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

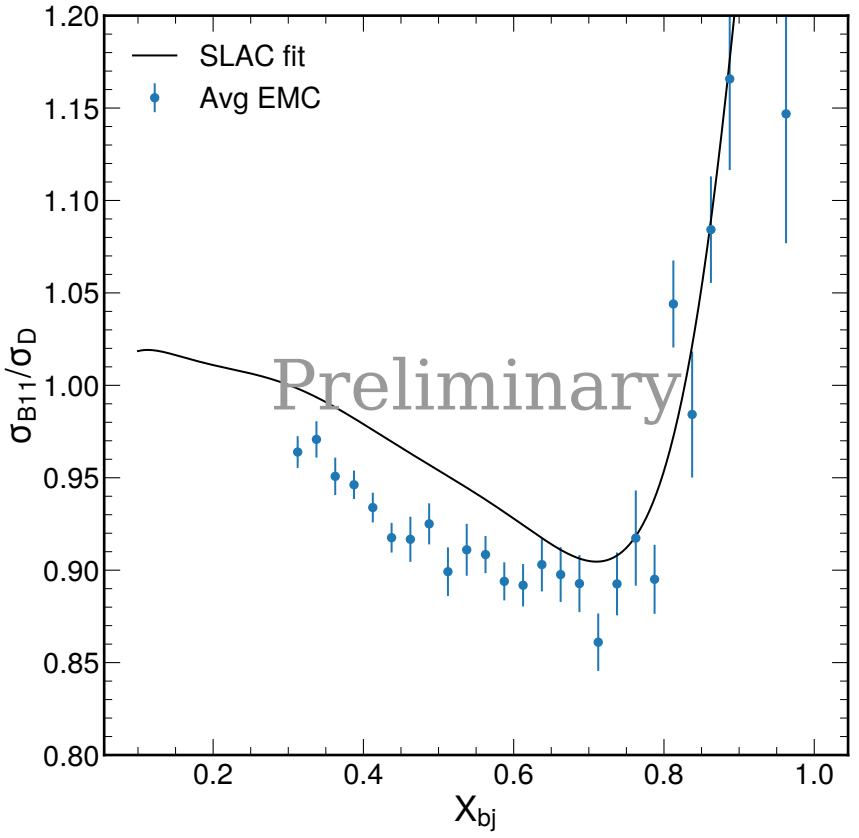


Analysis Status: EMC Ratio at 21⁰

Beryllium



Boron 11



To do:

- At low momentum, dead time and BCM needs to be looked out
- Acceptance corrections need to be worked out
- Study the z-target offset for other solid and cryo-targets
- Need to implement the pion contamination corrections
- Need to include Coloumb corrections
- Extract Carbon EMC ratio at larger angle.
- Cross check with some existing Analysis

Summary

- Experiment E12-10-008 (EMC) and E12-06-105 (x>1) will provides a new data on several nuclei to map out the SRC/EMC connections
- First EMC measurements on ^{10}B and ^{11}B
- Preliminary EMC ratios for Solid target was shown
- Preliminary ratios extraction show some global normalization issue
- Ratios extraction from HMS is ongoing
- Final results coming soon

Thank you