Precise Measurement of Nuclear Dependence of Structure Functions in Light Nuclei

(JLab expt E03-103 ; Spokepersons: John Arrington and Dave Gaskell)

For the E03-103 collaboration

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Hall C user’s meeting 01.05.05
Outline

• Introduction
• JLAB experiment E03-103
• Work in progress
• Summary
The EMC Effect

- Energy scale of DIS interactions (GeV).
  Energy scale of nuclear processes (MeV) → result doesn’t depend on nuclear target.
  (not true!!!)

- Measurements of $\frac{F_2^A}{F_2^D}$ (EMC, SLAC, BCDMS) have demonstrated modification of quark distributions in nuclei.

![Figure 1: $(\sigma_F/\sigma_D)$ ratios as a function of $x$ from EMC (hollow circles), SLAC (solid circles), and BCDMS (squares). The data have been averaged over $Q^2$ and corrected for neutron excess.](image)
The EMC Effect

- The nuclear EMC effect shows that quark distribution is different in nuclear systems.

- Magnitude depends on $A$ but shape more or less same.

- Several models, but valid only in certain kinematical regions.

Figure 1: $(\sigma_{Fe}/\sigma_{H})$ ratios as a function of $x$ from EMC (hollow circles), SLAC (solid circles), and BCDMS (squares). The data have been averaged over $Q^2$ and corrected for neutron excess.
The EMC Effect

- EMC effect has been measured for many targets and over a large kinematic range.

Extensive measurements on heavy targets
SLAC E139
The EMC Effect

- Ratios can be parameterized as \( \log(A) \) or linear density dependence

- \(^4\text{He}/\text{D} \) is more sensitive, but uncertainty is large for existing data and consistent with both parameterizations

- Addition of \(^3\text{He} \) data will impose new constraints on the parameterization
The EMC Effect

- For heavy nuclei, the magnitude of the EMC effect varies with $A$ but the shape is more or less the same.

- Observed $x$ dependence in $^4\text{He}$ is consistent, but uncertainties are large.

- Recent predictions indicate that size and magnitude may be different for light nuclei

(point of maximum suppression and crossover of ratio at large $x$)
Inclusive electron scattering from cryo targets $^1$H, $^2$H, $^3$He, $^4$He and solid targets Al, C, Be, Cu, Au over a broad range of kinematics.

Precise measurement on $^4$He, over SLAC E139.

First measurement of EMC effect on $^3$He for $x > 0.4$

Test models of the EMC effect in “exact” few-body calculations.

Guidance for calculations of nuclear effects in deuterium.

Information on the neutron structure function.
<table>
<thead>
<tr>
<th>Source</th>
<th>Absolute Uncertainty</th>
<th>Relative Uncertainty</th>
<th>$\delta \sigma / \sigma (%)$</th>
<th>$\delta R / R (%)$ point-to-point</th>
<th>$\delta R / R (%)$ scale</th>
<th>$\delta R / R (%)$ Statistical</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMS Momentum</td>
<td>&lt;0.1%</td>
<td>0.01%</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beam Energy</td>
<td>&lt;0.1%</td>
<td>&lt;0.02%</td>
<td>0.2</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.5mr</td>
<td>0.2mr</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>$t_D$</td>
<td>0.5%</td>
<td></td>
<td>0.5</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>$t_{He}$</td>
<td>1.0%</td>
<td></td>
<td>1.0</td>
<td>-</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Charge</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.5</td>
<td>0.42</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Target Boiling</td>
<td>&lt;1.0%</td>
<td>0.5%</td>
<td>&lt;1.0</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Endcap Subtraction</td>
<td>&lt;1.0%</td>
<td>0.2%</td>
<td>&lt;1.0</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Acceptance</td>
<td>1.0-2.0%</td>
<td>0.2%</td>
<td>1.0-2.0</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Radiative Corrections</td>
<td>2.0%</td>
<td>0.5%</td>
<td>2.0</td>
<td>0.3</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Detector Efficiency</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.5</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Deadtime Correction</td>
<td>&lt;0.5%</td>
<td>0.2%</td>
<td>&lt;0.5</td>
<td>0.1</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.7-3.3</strong></td>
<td><strong>0.7%</strong></td>
<td><strong>1.3</strong></td>
<td><strong>0.5-0.7</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>E139</strong></td>
<td><strong>3.3-3.7</strong></td>
<td><strong>1.6%</strong></td>
<td><strong>2.2</strong></td>
<td><strong>1.0-2.2</strong></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4: Systematic uncertainties in the ratio $\sigma_{He}/\sigma_{2H}$, compared to E139 uncertainties (for $^4$He).
Experiment
E03-103 @ JLAB

- Ran last summer and fall along with E02-019 at HALL C of Jlab with 5.77 GeV beam energy.
- Increased beam current (due to improvement in target cooling system) allowed for extensive background and elastic studies.
- Data on
  Cryo targets $^3\text{He}$, $^4\text{He}$, LD$_2$, LH$_2$
  Solid targets Al, C, Be, Cu ,Au
  at 18, 22, 26, 32, 40 and 50 degrees
EMC effect at large $x$

- For $x>0.6$, E03-103 data at $W<4$ GeV (resonance region)

- Recent data from JLab suggest that even in the resonance region inclusive cross sections scale.

- Hall C data (E89-008) taken at 4 GeV, sees no apparent deviation (at the 10% level) from scaling for $W^2>2$ GeV$^2$ (for $Q^2 > 3$ GeV$^2$)
Analysis

Cerenkov efficiency correction

<table>
<thead>
<tr>
<th>$\delta$ (%)</th>
<th>cerEff</th>
</tr>
</thead>
<tbody>
<tr>
<td>-8</td>
<td>0.88</td>
</tr>
<tr>
<td>-4</td>
<td>0.9</td>
</tr>
<tr>
<td>0</td>
<td>0.92</td>
</tr>
<tr>
<td>4</td>
<td>0.94</td>
</tr>
<tr>
<td>8</td>
<td>0.96</td>
</tr>
<tr>
<td>12</td>
<td>0.98</td>
</tr>
<tr>
<td>16</td>
<td>0.99</td>
</tr>
<tr>
<td>20</td>
<td>1.02</td>
</tr>
</tbody>
</table>

Energy (GeV):

- 0.89 GeV
- 1.69 GeV
- 2.97 GeV
- 3.50 GeV
- 4.43 GeV
Analysis

Cerenkov efficiency correction

![Graph showing Cerenkov efficiency correction](image-url)
Analysis
Luminosity scan

\[
\chi^2 / \text{ndf} = 2.475 / 4 \\
\text{Prob} = 0.6491 \\
p_0 = 1 \pm 0.003981 \\
p_1 = 2.188e-06 \pm 6.953e-05
\]

\[
\chi^2 / \text{ndf} = 3.081 / 4 \\
\text{Prob} = 0.5443 \\
p_0 = 1 \pm 0.00376 \\
p_1 = -0.0003102 \pm 6.404e-05
\]

Jason
Analysis

Acceptance correction: multiple scattering

Nadia
External radiative corrections are different for the dummy target than for the cryotarget walls.

\[ R_{ext} = \frac{R_d}{R_{cryo}} \]

Dave
Comparison:

Carbon 1.14 GeV, 40 Degree

Cross section (mbarn/GeV.Str)

Eprime(GeV)
Analysis
Preliminary ratios: - Carbon

includes 1.5% point-to-point systematic uncertainty
3% normalization uncertainty (target thickness, radiative and bin centering corrections)

Jason
Analysis
Preliminary ratios:-He4

Jason
To do

- Acceptance corrections at low momentum need to be worked out
- Need to iterate input model for bin centering and radiative corrections
- Need to study variation of beam position, beam angle
- Need to include Coulomb corrections
Summary

• Study of the EMC effect in light nuclei will help us to distinguish between models and impose new constraints

• E03-103 will increase the precision of $^4$He ratios, and will be the first precise measurement for $^3$He at $x>0.4$

• E03-103 data at $W<4$ GeV and $x>0.6$ (resonance region) allows to study EMC effect at large $x$

• Analysis well underway and data processing almost complete
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