New Measurement of the EMC Effect In $^3$He and $^4$He

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DIS 06
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\[
\frac{\sigma_{A}}{\sigma_{2}} = \frac{F_{2}^{A}}{F_{2}^{2}}
\]
The EMC effect has been with us for over 20 years.

Much experimental and theoretical effort has been devoted to understanding the details.
EMC (hollow circles)  
SLAC (solid circles)  
BCDMS (hollow squares)  

NUCLEAR BINDING  
FERMI MOTION  
EXCESS PIONS  

\( \frac{\sigma_{Fe}}{\sigma_D} \) vs. \( x \)
The EMC effect has been with us for over 20 years.

much experimental and theoretical effort has been devoted to understanding the details of the effect.

most of effort has been focused on heavy targets (C, Fe, Au...)

There is a dearth of data for light targets.

$^4\text{He}$ – well studied by SLAC, but need more precision

$^3\text{He}$ – low x studied at HERMES, no data for $x>0.4$

$^3\text{H}$ – no data
\(^4\text{He}\)

Anomously tightly bound
well studied at SLAC: need more precision
$^3\text{He}$

low $x$ data from HERMES, but no data for $x>0.4$
Jefferson Lab
Jefferson Lab
6 GeV electron accelerator
Newport News, VA
HMS: QQQD spectrometer

6 mStr acceptance

+/- 8% momentum bite
E03-103: EMC effect in light nuclei

Measurement of inclusive electron scattering cross section from H, \(^2\)H, \(^3\)He, \(^4\)He, B, C, Cu, Au

5.67 GeV electron beam

Single-arm measurement in HMS
Kinematic Coverage:

Data taken at six angles

main EMC extraction done using large angle (highest $Q^2$) data.

other angles will provide detailed $Q^2$ dependence study.
coverage for $x > 1$
E03-103 kinematics not very DIS – need to be able to compare to other measurements...need a scaling variable that scales over larger $Q^2$ range.

$$\xi = \frac{2x}{1 + \sqrt{1 + 4m^2x^2/Q^2}}$$

$\xi \rightarrow x$ in the Björken limit
\( \xi \) scaling

Structure functions show scaling in \( \xi \) below
\( W^2 = 4 \text{ GeV}^2, Q^2 = 4 \text{ GeV}^2 \)
\( \xi \) Scaling in E03-103 (\(^2\text{H}\))

\[ W^2 = 2 \, \text{GeV}^2 \text{ at } \xi \sim 0.8 \text{ quasieastic peak suppressed for highest } Q^2 \text{ settings.} \]
ξ Scaling in E03-103 ($^{12}$C)
The dependence of $F_2$ ratio ($Q^2$ at $x=0.6$)

- $W^2 = 2 \text{ GeV}^2$
- $W^2 = 4 \text{ GeV}^2$

Data from:
- E03-103, 2.0 (GeV/c)$^2$
- E03-103, 3.9 (GeV/c)$^2$
- E03-103, 4.5 (GeV/c)$^2$
- E03-103, 5.0 (GeV/c)$^2$
- J. Gomez et al., 1994 (SLAC)
EMC effect in $^{12}\text{C}$
EMC effect in $^4$He

\begin{itemize}
  \item E03-103, average
  \item J. Gomez et al., 1994(SLAC)
\end{itemize}
EMC effect in $^4\text{He}$ as large as in $^{12}\text{C}$
Neutron Excess:

Currently using SLAC Parameterization:

\[
\frac{\sigma^A}{\sigma^D} / \left( \frac{\sigma^A}{\sigma^D} \right)_{is} = \frac{\left( Z + N \frac{F_{2n}^n}{F_{2p}^p} \right)}{0.5A \left( 1 + \frac{F_{2n}^n}{F_{2p}^p} \right)}
\]

F2n/F2p = 1 – 0.8x

Data were taken on H and \(^2\)H at all settings in order to determine F2n/F2p for our kinematics (in progress)
EMC effect in $^3$He
Systematics:

<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>0.1</td>
</tr>
<tr>
<td>$t_D$</td>
<td>0.5%</td>
<td></td>
<td>0.5</td>
<td>-</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>$t_{He}$</td>
<td>1.0%</td>
<td></td>
<td>1.0</td>
<td>-</td>
<td>1.0</td>
<td>1.0</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>0.2</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>0.3</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>0.1</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>0.4</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>0.2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>2.7-3.3</td>
<td>0.7%</td>
<td>1.3</td>
<td>0.5-0.7</td>
</tr>
<tr>
<td>E139</td>
<td></td>
<td></td>
<td>3.3-3.7</td>
<td>1.6%</td>
<td>2.2</td>
<td>1.0-2.2</td>
</tr>
</tbody>
</table>

Table 4: Systematic uncertainties in the ratio $\sigma_{He}/\sigma_{H}$, compared to E139 uncertainties (for $^4$He).

**Measurement limited by systematic error**

**target thickness**

**charge normalization**
Conclusions:

E03-103 has made a precision measurement of the EMC effect in $^3$He and $^4$He.

Improved precision
EMC effect in $^4$He is as large as the effect in $^{12}$C.

First ever measurement on $^3$He at $x>0.4$.

Work is currently underway on radiative corrections model, and neutron excess correction.

Final results coming soon.