A new method to study the EMC Effect using the F_2^n structure function

H. Szumila-Vance[1], I. Cloet[2], C. Keppel[1] , N. Kalentarians[3]

[1]Thomas Jefferson National Accelerator Facility, Newport News, VA
[2]Argonne National Laboratory, Argonne, IL
[3]Virginia Union University, Richmond, VA

Abstract

The EMC effect is the go-to observable in the deep inelastic scattering regime that explains how nucleons in bound nuclei are modified compared to bound nucleons in deuterium. The free neutron structure function has recently been extracted in a systematic study of the world data and is available as part of the Jefferson Lab-CTEQ Collaboration. Here we introduce a new method to study the EMC Effect in nuclei by re-examining data from the SLAC E139 experiment and determining the magnitude of the EMC Effect using the free neutron and free proton structure functions in the denominator. From the extraction of the free neutron from world data, it is possible to examine the nuclear effects in deuterium and their contribution to our interpretation of the EMC Effect.

1 Introduction

We chose to use the SLAC E139 data set because it is the most complete published list of cross sections available. From the initial cross sections given, we converted the absolute cross section to the structure function by using the kinematics and R1990 fitting.

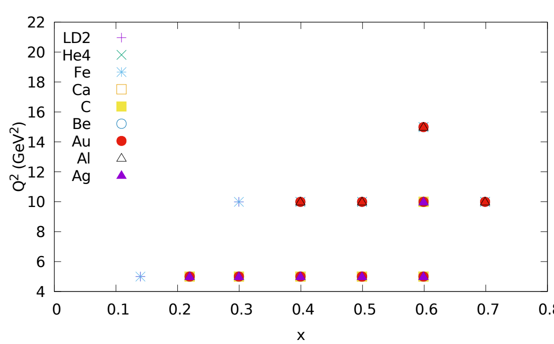

Figure 1

2 Theory predictions using nuclear matter

Ian can write something here.

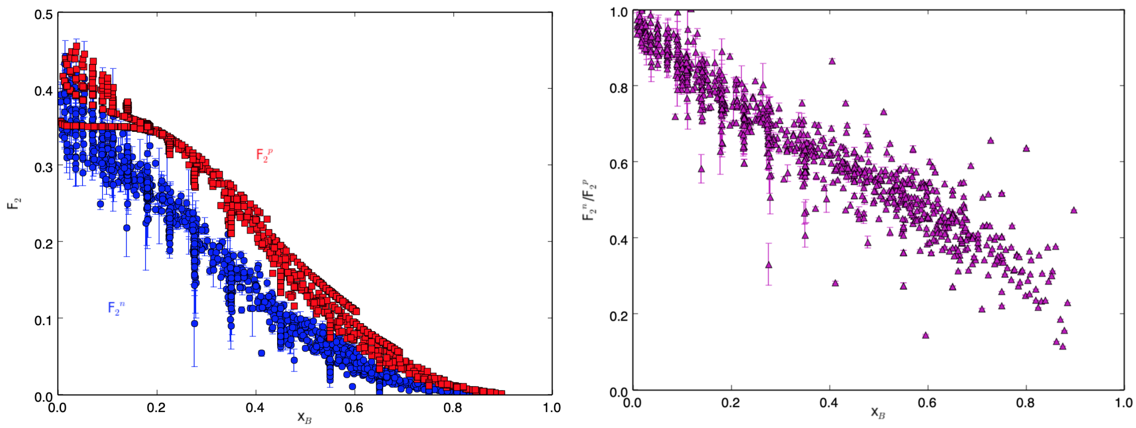

Figure 2: *Left: The extracted F_2^n from the world DIS data is shown in blue, and the F_2^p from the NMC global fit is shown in red for the same corresponding x_B and Q^2. Right: The ratio of the F_2^n / F_2^p from the left is shown as a function of x_B.*

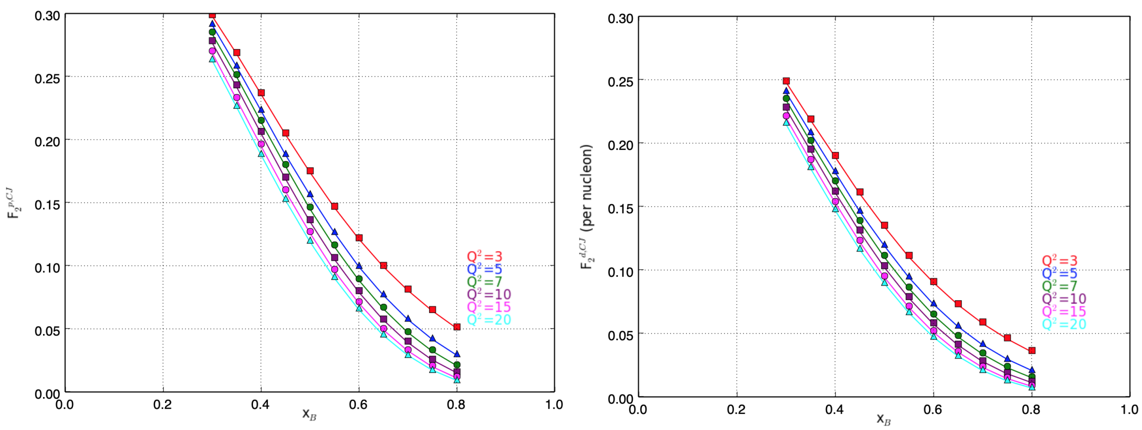

Figure 3: *Left: The proton structure function from the CJ15 fit is shown as a function of x_B for various fixed Q^2. Right: The deuteron structure function from the CJ15 fit is shown as a function of x_B for various fixed Q^2.*

3 F_2^n extraction and the CJ15 fit

We need to point to CJ and how the world data was extracted.

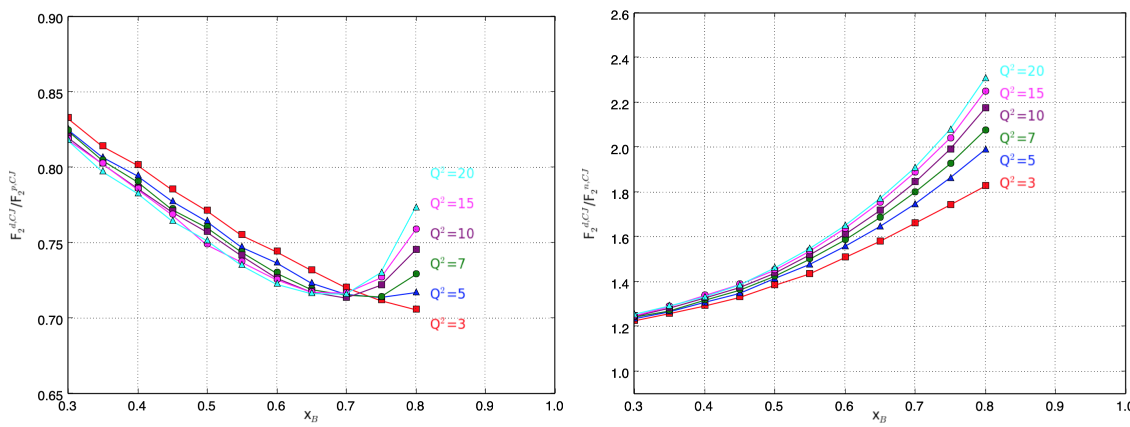

Figure 5: *Left: The deuterium structure function from the CJ15 fit is shown as a ratio to the proton structure function from CJ15 for various Q^2. Right: The deuterium structure function from the CJ15 fit is shown as a ratio to the neutron structure function from CJ15 for various Q^2.*

3.1. Q^2 dependence

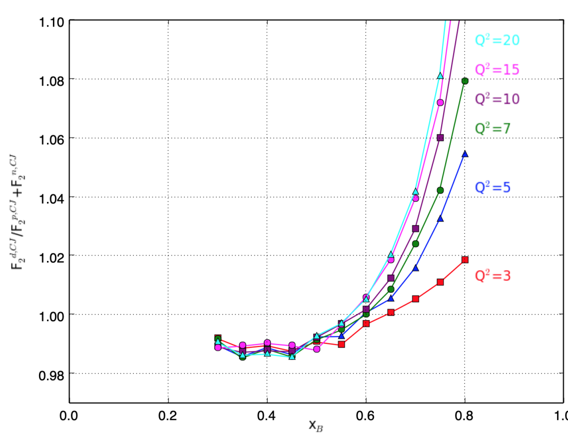

Figure 4: *The deuteron structure function divided by the sum of the free proton and free neutron structure functions from the CJ15 fit is shown for various Q^2. This ratio roughly shows the magnitude of the nuclear effects in the deuteron. The Q^2 dependence shows significant spread above $x_B = 0.6$ where the ratio begins to increase.*

4 Structure function extraction from the E139 cross sections

Discuss the input cross section, conversion to F2A and the iso-scalar correction.

$$F_2 = \frac{d^2\sigma}{d\Omega dE'} \frac{1+R}{1+\epsilon R} \frac{K\nu}{4\pi^2\alpha\Gamma(1+\nu^2/Q^2)} \tag{1}$$

$$\epsilon = (1 + 2\frac{\nu^2 + Q^2}{Q^2} tan^2 \frac{\theta}{2})^{-1} \tag{2}$$

$$K = \frac{W^2 - M^2}{2M} \tag{3}$$

$$\Gamma = \frac{\alpha K E'}{2\pi^2 Q^2 E(1-\epsilon)} \tag{4}$$

$$f_{iso}^{A} = \frac{\frac{1}{2}(1 + F_2^n / F_2^p)}{\frac{1}{A}(Z + (A-Z) F_2^n / F_2^p)} \tag{5}$$

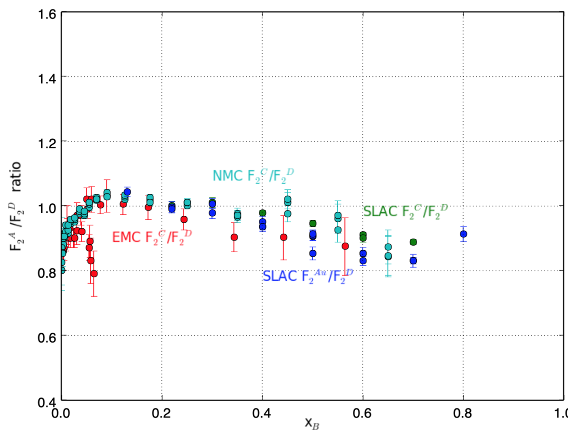

Figure 6: *The published structure function ratios per nucleon for carbon and gold are shown from SLAC, NMC, and the EMC experiments.*

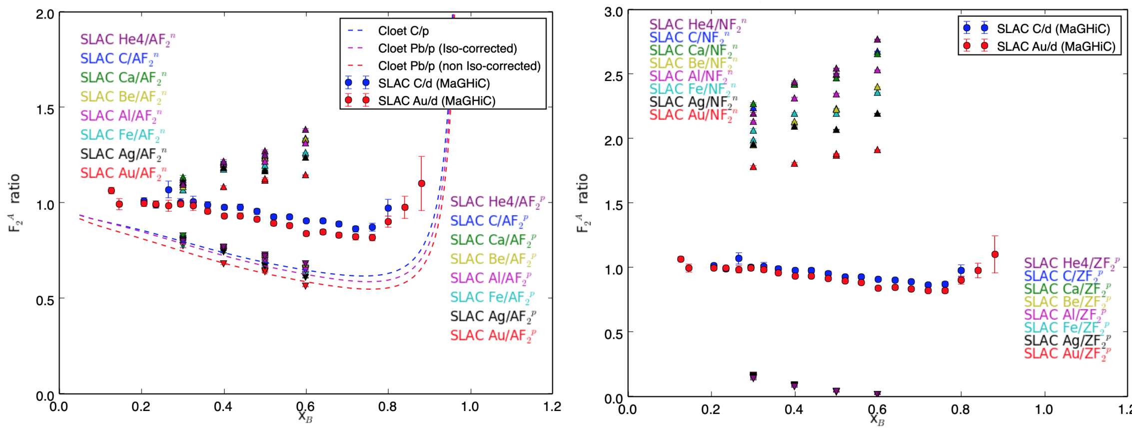

Figure 7: *Left: F_2^A calculated from the published SLAC E139 cross sections is taken as a ratio per nucleon to F_2^n and F_2^p, separately. The published EMC ratios for carbon and gold [9] are shown for reference as F_2^A/F_2^d per nucleon. Theory predictions for the F_2^A structure function per nucleon as a ratio to F_2^p are shown. Right: F_2^A calculated from the published SLAC E139 cross sections is taken as a ratio per neutron or proton and F_2^n and F_2^p, separately. The published EMC ratios for carbon and gold [9] are shown for reference.*

5 General observations

6 Deuterium nuclear effects and heavier nuclei

6.1. Deuterium

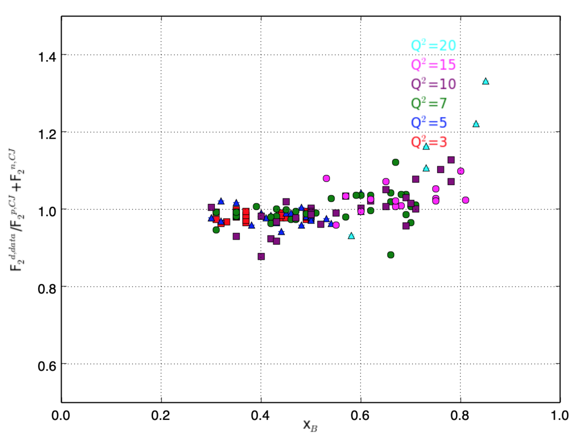

Figure 8: *The global Whitlow deuterium data from SLAC [7] is shown divided by the sum of the free proton and free neutron structure functions from the CJ15 fit.*

plots: include d/n or n/d of Whitlow+BONUS to show Q2 dependency

6.2. Heavier nuclei

Include a table of the fit slopes with errors. Do we include fits for Q2=5 only? Then do we discuss the x larger than 0.6 (higher Q2) separately as an observation?

Table 1: *Summary of linear fits to x_B.*

Nucleus	A/d slope	A/d intercept	A/(n+p) slope	A/(n+p) intercept

7 Conclusions

n and p have Q2 dependence and deuterium is not so linear.

8 Acknowledgments

The authors would like to thank Shujie Li for constructing the most complete world F_2^n data set to date and Alberto Accardi and Wally Melnitchouk for providing crucial insights and interpretations for this analysis.

References

[1] A. Accardi, L. T. Brady, W. Melnitchouk, J. F. Owens and N. Sato, Phys.Rev. D93 (2016) 114017

[2] J. Gomez *et al.*, "Measurement of the A-dependence of deep inelastic electron scattering," Phys. Rev. D **49**, 4348 (1994). doi:10.1103/PhysRevD.49.4348

[3] K. A. Griffioen *et al.*, "Measurement of the EMC Effect in the Deuteron," Phys. Rev. C **92**, no. 1, 015211 (2015) doi:10.1103/PhysRevC.92.015211 [arXiv:1506.00871 [hep-ph]].

[4] J. G. Rubin, J. Arrington, "A New Extraction of Neutron Structure Functions from Existing Inclusive DIS Data," doi: 10.1063/1.3631528 [arXiv:1101.3506v2 [nucl-ex]].

[5] L.W.Whitlow, SLAC-Report-357, Ph.D. Thesis, Stanford University, March 1990.

[6] https://www.slac.stanford.edu/exp/e139/E139.RESULTS

[7] http://www.slac.stanford.edu/exp/e140/SIGMA.D2_357

[8] Alekhin, S. I. and Kulagin, S. A. and Petti, R., "Nuclear effects in the deuteron and constraints on the d/u ratio," Phys. Rev. D **96**, no. 5, 0054005 (2017) doi:10.1103/PhysRevD.96.054005 [arXiv:1704.00204].

[9] S. Malace, D. Gaskell, D. W. Higinbotham and I. Cloet, "The Challenge of the EMC Effect: existing data and future directions," Int. J. Mod. Phys. E **23**, no. 08, 1430013 (2014) doi:10.1142/S0218301314300136 [arXiv:1405.1270 [nucl-ex]].