Jefferson Lab

The Thomas Jefferson National Accelerator Facility

Theory Group Preprint Series

Additional copies are available from the authors.

The Southeastern Universities Research Association (SURA) operates the Thomas Jefferson National Accelerator Facility for the United States Department of Energy under contract DE-AC05-84ER40150.

November 1999

ADP-99-47/T384

JLAB-THY-99-39

Comment on "Parton distributions, d/u, and higher twist effects at high x"

W. Melnitchouk[1,2], I.R. Afnan[3], F. Bissey[1] and A.W. Thomas[1]

[1] *Special Research Centre for the Subatomic Structure of Matter, and Department of Physics and Mathematical Physics, University of Adelaide, 5005, Australia*

[2] *Jefferson Lab, 12000 Jefferson Avenue, Newport News, VA 23606*

[3] *School of Physical Sciences, The Flinders University of South Australia, Bedford Park, S.A. 5042, Australia*

In a recent Letter Yang and Bodek [1] presented results of a new analysis of proton and deuteron structure functions in which the free neutron structure function, F_2^n, was extracted at large x. Knowledge of F_2^n is crucial for determining the neutron/proton structure function ratio, whose $x \to 1$ limit is sensitive to mechanisms of SU(6) spin-flavor symmetry breaking, and provides one of the fundamental tests of the x dependence of parton distributions in perturbative QCD.

Relating nuclear structure functions to those of free nucleons is, however, not straightforward because at large x nuclear effects become quite sizeable. In particular, omitting nuclear binding or off-shell corrections can introduce errors of up to 50% [2] in F_2^n/F_2^p already at $x \sim 0.75$. Rather than follow the conventional procedure of subtracting Fermi motion and binding effects in the deuteron via standard two-body wave functions, Yang and Bodek instead extract F_2^n by extrapolating the density dependence of the nuclear corrections to the case of the deuteron. Here we point out why this approach is likely to be misleading for light nuclei, and correctly applied predicts that the nuclear correction in the deuteron should be zero.

For heavy nuclei the nuclear EMC effect is observed to scale with the nuclear density, ρ_A [3,4]

$$\frac{R_{A_1}-1}{R_{A_2}-1}=\frac{\rho_{A_1}}{\rho_{A_2}}\ , \qquad (1)$$

where $R_A = F_2^A/F_2^d$ and $\rho_A = 3A/(4\pi R_e^3)$, with $R_e^2 = (5/3)\langle r^2\rangle$ and $\langle r^2\rangle^{1/2}$ is the nuclear r.m.s. radius. Assuming that an analog of Eq.(1) holds also for F_2^A/F_2^N ($F_2^N = F_2^p + F_2^n$) and taking $A_2 = d$ gives $F_2^d/F_2^N = 1+(R_A-1)\rho_d/(\rho_A - \rho_d\ R_A)$. The denominator is usually further approximated [3] by $\rho_A - \rho_d\ R_A \approx \rho_A - \rho_d$. Using this one can extract the free F_2^n from empirical EMC ratios and the nuclear densities. One finds then that the EMC effect in d is about 25% as large as in ^{56}Fe at $x \sim 0.7$ [1,3], and has the same x dependence.

While the correlation of EMC ratios with nuclear densities is empirical for heavy nuclei, application of Eq.(1) to light nuclei, $A < 4$, for which the EMC effect has not yet been measured, is fraught with ambiguities in defining physically meaningful nuclear densities for few body systems. Firstly, the relevant density in Eq.(1) is the nuclear matter density, while in practice ρ_A is usually calculated from the charge radius [1] — for heavy nuclei the difference is negligible, but for light nuclei it can be significant. Secondly, treating the deuteron as a system with radius $\langle r^2\rangle^{1/2} \approx 2$ fm means that one includes *both* nucleons in the average density felt by one of them, even though one nucleon obviously cannot influence its own structure. Therefore what one should consider is the probability of one nucleon overlapping with the other, which is simply the deuteron wave function at the origin. This has zero weight, however, so the only sensible definition of mean density for the deuteron is zero. Strictly speaking, the nuclear density extrapolation then predicts *no nuclear EMC effect in the deuteron.*

The size of the EMC effect in the deuteron cannot be tested directly in any inclusive deep-inelastic scattering experiment on the deuteron, as it requires knowledge of F_2^n, which itself must be extracted from deuteron data. If, on the other hand, the EMC effect scales with nuclear density even for the deuteron [1], it must also scale with ρ_A for all $A > 2$. In particular, it must predict the size of the EMC effect in 3-body nuclei. In fact, for

$A = 3$ the nuclear density extrapolation makes quite a dramatic prediction: since the 3-body nuclear densities calculated from the charge radii [3] are $\rho_{^3He} = 0.049$ fm^{-3} and $\rho_{^3H} = 0.068$ fm^{-3}, the EMC effect in ^3H is 40% larger than that in ^3He. This is to be compared with standard many-body calculations in terms of Faddeev wave functions [5] which predict $\lesssim 10\%$ difference between the EMC effects in $A = 3$ mirror nuclei, see Fig.1.

Clearly it is of interest to resolve this matter using data if at all possible. Fig. 1 shows that the $A = 3$ system presents an ideal case for such a test. A proposal to perform deep-inelastic scattering experiments from tritium targets [6] is currently being discussed at Jefferson Lab.

ACKNOWLEDGMENTS

We would like to acknowledge stimulating discussions with J. Gomez and G. Petratos concerning the nuclear corrections in $A = 3$ nuclei. This work was supported by the Australian Research Council.

REFERENCES

[1] U.K. Yang, A. Bodek, Phys. Rev. Lett. 82, 2467 (1999).

[2] W. Melnitchouk and A.W. Thomas, Phys. Lett. B 377, 11 (1996).

[3] L. Frankfurt and M. Strikman, Phys. Rep. 160, 235 (1988).

[4] D.F. Geesaman, K. Saito and A.W. Thomas, Ann. Rev. Nucl. Part. Sci. 45, 337 (1995).

[5] I.R. Afnan, F. Bissey and A.W. Thomas, in preparation.

[6] G. Petratos et al., in preparation.

FIGURES

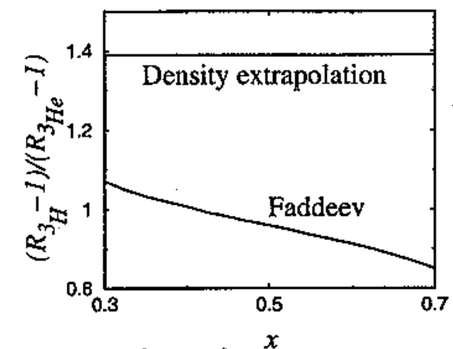

FIG. 1. Ratio of EMC effects in ^3He and ^3H using standard many body (Faddeev) wave functions, and the nuclear density extrapolation.