Comment on "Parton Distributions, d/u, and Higher Twist Effects at High x"

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. Relating nuclear structure functions to those of free nucleons is, however, not straightforward because at large x nuclear effects become quite sizable. 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 using "a model proposed by Frankfurt and Strikman [3], in which all binding effects in the deuteron and heavy nuclear targets are assumed to scale with the nuclear density" [1]. Here we point out why this approach is ill-defined for light nuclei and why it introduces a large theoretical bias into the extraction of F_2^n at large x.

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

$$\frac{R_{A_1} - 1}{R_{A_2} - 1} = \frac{\rho_{A_1}}{\rho_{A_2}}. \tag{1}$$

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 rms radius. Assuming that an analog of Eq. (1) holds also for F_2^A/F_2^N ($F_2^N = F_2^p + F_2^n$), Frankfurt and Strikman [3] derive $F_2^d/F_2^N \approx 1 + (R_A - 1)\rho_d/(\rho_A - \rho_d)$, from which the free F_2^n is then extracted [1].

While the correlation of EMC ratios with nuclear densities is empirical for heavy nuclei, application of Eq. (1) to light nuclei, $A < 4$, is fraught with ambiguities in defining physically meaningful nuclear densities for few body nuclei. 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 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*.

In Ref. [3] Frankfurt and Strikman argue that for heavy nuclei the average potential energy is proportional to the average nuclear density, and hence for x below 0.5–0.6 the nuclear EMC effect should scale with average nuclear density. If one applies the idea from heavy nuclei to the deuteron, one finds that the EMC effect in d is $(F_2^d/F_2^N - 1) = 0.25\ (F_2^{Fe}/F_2^d - 1)$. For light nuclei ($A = 2, 3$), however, no justification for this assumption is provided, and for $x \gtrsim 0.6$, where nuclear Fermi motion effects become large, Frankfurt and Strikman caution that this estimate is only a qualitative one [3].

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, as assumed in [1,3], it must also scale with ρ_A for all $A > 2$. In particular, it must predict the size of the EMC effect in three-body nuclei. In fact, for $A = 3$ the nuclear density extrapolation makes quite a dramatic prediction: since the three-body nuclear densities calculated from the charge radii are $\rho_{^3\mathrm{He}} = 0.049$ fm^{-3} and $\rho_{^3\mathrm{H}} = 0.068$ fm^{-3}, the EMC effect in ^{3}H is 40% larger than that in ^{3}He. This is to be compared with standard many-body calculations in terms of Faddeev wave functions which predict a $\lesssim$10% difference between the EMC effects in $A = 3$ mirror nuclei. A proposal to perform deep-inelastic scattering experiments from ^{3}He and ^{3}H targets is currently being discussed at Jefferson Lab [4].

The point is that one would never think of using a density extrapolation to extract the neutron's electromagnetic form factors from quasielastic scattering on the deuteron or ^{3}He, for example, and there is no reason to believe this method is any more reasonable for structure functions.

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