WHERE NEXT IN POLARIZED LEPTOPRODUCTION?

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Abstract

I will summarize the implications of the EMC polarized structure function $g_1(x,Q^2)$ under three headings: (1) the integrand, (2) what insights future high-energy beams may bring, and (3) the integral.

The Integrand

The dramatic claims that the net spin polarization of the proton is not carried by quarks ("the integral" — see later) has caused many to infer, erroneously, that the potential of polarized proton beams is reduced. This is utterly wrong. The EMC data[1] confirm old SLAC data[2] in that for $x \gtrsim 0.2$ there is large polarization in the proton. Indeed it is consistent with the prediction, made 15 years ago,[3] that the polarization maximizes as $x \to 1$ and predicts that neutron polarization will also be large in this limit.

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I show Fig. 1 to restore a bit of history. I believe that this was the first prediction that $A^p(x \to 1) = A^n(x \to 1) \to 1$ and hence that there would be non-trivial and interesting neutron polarizations. Indeed, in the experimental proposals and the early data[4] these curves used to be cited, but as the data accumulated and continued to agree with the prediction, the curves and reference became unpersons.

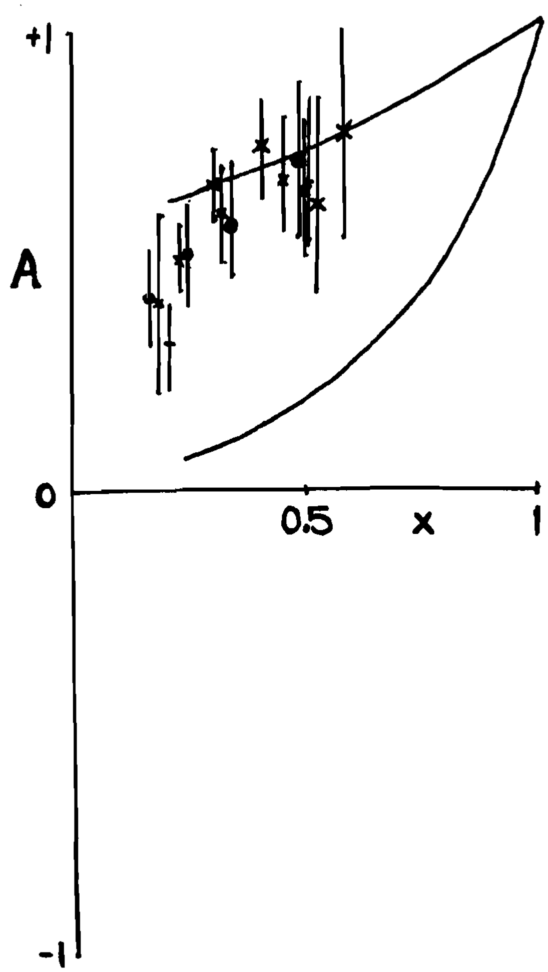

Fig. 1. Proton (upper curve) and neutron asymmetries predicted in Ref. 3. ⧫ EMC ⫯ E130 ⧫ E80 data for $x > 0.2$.

As the model dealt only with valence quarks, I cut the curves off for $x < 0.2$ (which, in light of the modern controversy, may have been foresight!). Carlitz and Kaur[5], and others, have extended this by including effects of the sea, which dilutes the asymmetry as $x \to 0$. The message of the EMC data may be that the sea, at $x \gtrsim 0.05$, is polarized "against the stream" and thereby dilutes the A^p even more. This shortfall will also occur for the neutron and cause $A^n << 0$ at $x \simeq 0.1$. These qualitative features are general (if $A^{n,p} \to 1$ as $x \to 1$); the fine details will be model dependent.

Thus, I regard the future with optimism. For protons we know there are large quark polarizations — so exploit them. For neutrons we expect big polarizations with interesting sign changes if $A^n(x=1) \to 1$. This latter is, to me, a most exciting test. The original motivations for this prediction are now outdated, but the correlation with $u(x)/d(x)$ in unpolarized and Δ-N physics remains. The modern picture is that these are all controlled by chromomagnetic effects — "one gluon exchange". If a positive asymmetry is seen for the neutron for $x \gtrsim 0.5$, then this will be a nice confirmation that we understand essential quark-gluon dynamics and fuse such disparate phenomena as deep-inelastic unpolarized and polarized data and low-energy Δ-N mass differences[10] (without recourse to Skyrmions).

Although I would not strongly defend my 1973 prediction of the approach to $x = 1$ maximization, its neutron curve may be of use to experimentalists in setting their sights. It would imply that the turn-on of A^n is rather delayed in x, being only 0.2 when $x \simeq 0.6$. More modern predictions, based on these ideas, tend to have A^n turn on sooner. So if you could measure a non-zero $A^n(x > 0.5)$ under the unfavorable conditions of Fig. 1, then you're likely to be in business. Conversely, if $A^n(x > 0.5)$ is less than that, then the whole idea of $A^n = A^p(x \to 1)$ is probably in trouble.

The Future of $g_1(x,Q^2)$

Vernon Hughes showed us[6] that, within errors, $A^p(x)$ appears to scale. But $g_1(x,Q^2) = A(x)\, F_1(x,Q^2)$ where $F_1(x,Q^2)$ is measured in unpolarized experiments. This presence of $F_1(x,Q^2)$ influences the polarized $g_1(x,Q^2)$ and sum rule inferences. Insofar as there are suggestions that[7]

$F_1(x) \sim x^{-1/2}$, then $g_1(x \to 0)$ may have more strength than has been assumed when evaluating the EMC integral. Thus, unpolarized data on $F_1(x \to 0)$ at HERA may be interesting. Whether one uses EMC or BCDMS data on F_1 to deduce g_1 can also be important, as noted in Ref. 8; so agreement on unpolarized structure functions is needed.

If $A(x)$ scales, then $g_1(x,Q^2)$ will increase with Q^2 for $x < 0.2$, and so the impotence in the present data may be transitory. So extending the reach in Q^2 by exploiting a high-energy μ beam at FNAL is important. Another interesting possibility, mentioned long ago[9] and emphasized here by Ioffe, is that as $Q^2 \to 0$, $g_1(x,Q^2)$ could become negative. Thus small Q^2, and ideally $Q^2 = 0$ and the Drell-Hearn-Gerasimov sum rule, are important. Extending the reach in $x \to 0$ at fixed Q^2 can help establish, or destroy, our confidence in extrapolation inherent in testing sum rules.

Finally, note that low-energy experiments at CEBAF can probe the role of resonances in contributing to these spin-dependent sum rules. Interesting Q^2 dependence in these helicity dependences have been predicted and qualitatively confirmed in some cases.

The Integral

Insofar as one wants to probe the net spin carried by quarks and antiquarks is concerned, the proton target is not ideal. As Roberts and I have noted,[8] there is an unfavorable cancellation between I_p and g_A/g_V:

$$I_p \simeq \frac{1}{10}\frac{g_A}{g_V} + \frac{1}{9}(\Delta S_Z).$$

This, combined with the 1/9 factor, causes the net spin polarization ΔS_Z to be a rather sensitive function of any errors in I_p. Ioffe has criticized the diffractive extrapolation of Ref. 8; however, even with the same extrapolation as used by EMC, we found[8] that inconsistencies in F+D and use of the BCDMS values for $F_1(x)$ can cause further uncertainties in the inferred ΔS of the order of 20% on top of the ±30% already admitted by EMC. Thus while it is possible that ΔS_Z is small, it is also possible that it is 50%. This is still an interesting number, but fewer textbooks would need to be rewritten than if it were zero percent.

To know this better, we recommend use of deuterium. While this will yield data on A^n, with errors arising from the p-n separation, it also yields directly information on $g_1^{p+n}(x)$, with smaller errors. The interesting feature here is that this combination is a rather direct probe of the net spin in that the effect of g_A/g_v is minimized:

$$I_{p+n} \simeq \frac{1}{30}\frac{g_A}{g_v} + \frac{2}{9}\left(\Delta S_Z\right).$$

In the parton model (with no QCD corrections), one can see this intuitively since

$$I_{p+n} = \frac{5}{9}(\Delta u+\Delta d+\Delta s) - \frac{1}{3}(\Delta s).$$

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