CONTROVERSIAL ISSUES IN THE POLARIZED PARTON DENSITIES: $\Delta G, \Delta S$, POSITIVITY AND HIGHER TWIST*

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We discuss some of the problems involved in determining the polarized strange quark and gluon densities, and comment on the issue of higher twist contributions.

1. The difficulties

There are two main problems compared with the unpolarized case: the small range of Q^2 implies poor determination of $\Delta G(x)$, and the absence of neutrino and antineutrino data implies poor flavour separation, and that we can only measure $\Delta q + \Delta\bar{q}$. What are the remedies?

2. Include data at lower Q^2 via higher twist (HT) terms

$$g_1^{expt} = F_1^{expt}\, A_1^{expt} \tag{1}$$

$$= \frac{F_2^{expt}}{2x(1+R^{expt})}\, A_1^{expt} \tag{2}$$

$$= g_1^{QCD} + h/Q^2 \tag{3}$$

According to LSS05 [1] and LSS06 [2] HT is essential, but BB02 [3] claims this is not so and AAC06 [4] does not include HT. As an example: comparing HERMES g_1^d data at low $Q^2 = 1GeV^2$ with COMPASS data at $6GeV^2$, Ref. [4] explains the difference as possibly due to gluonic effects, whereas Ref. [2] claims it due to HT. See Figs. 1 and 2.

*Work done in collaboration with A. V. Sidorov (Dubna)and D. B. Stamenov (Sofia)

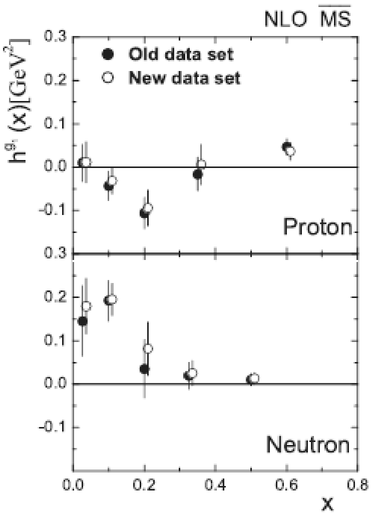

Figure 1. Higher twist $h(x)$ in g_1.

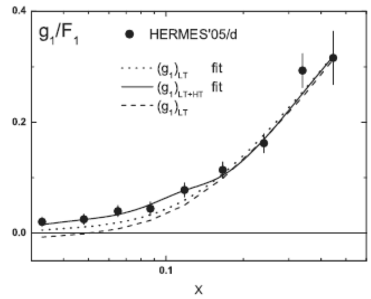

Figure 2. Effect of higher twist corrections in fitting HERMES data.

3. Impose the $SU(3)$ sum rule

Notation:

$$\Delta q \equiv \Delta q(Q^2) = \int_0^1 dx\,\Delta q(x,Q^2) \tag{4}$$

$$a_8 \equiv \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} - 2(\Delta s + \Delta\bar{s}) \tag{5}$$

$$= 3F - D = 0.585 \pm 0.025 \tag{6}$$

Leader and Stamenov [5] showed, depending on which data is used, SLAC E155 or E143, that *if* $(\Delta s + \Delta\bar{s}) \geq 0$, then

$$a_8 \leq 0.089 \pm 0.058 \quad or \quad a_8 \leq 0.197 \pm 0.068 \tag{7}$$

But analysis of hyperon decays by Ratcliffe [6] implies $a_8 = 0.585 \pm 10\%$ and a new analysis of SIDIS by deFNS06 [7] implies $a_8 = 0.585 - 8\%$ or -12% depending on the choice of fragmentation functions. These values significantly contradict the bounds in (7). We conclude that a positive value of the first moment $\Delta s + \Delta\bar{s}$ is almost impossible.
What are the experimental results on $(\Delta s + \Delta\bar{s})$? Ref. [3] has -0.148 ± 0.034, [1] -0.132 ± 0.018, [4] -0.12 ± 0.04 and [7] -0.116, whereas HERMES [8] reports $+0.056 \pm 0.066 \pm 0.018$. There appears to be incompatibility.

Is this real or is it due to underestimating the errors in the analyses or in the use of a LO analysis by HERMES? It will be very interesting to have more accurate data from SIDIS.

4. Impose positivity.

We note briefly, regarding the x-dependence of $\Delta s(x) + \Delta\bar{s}(x)$, that differences between various present analyses are due to the imposition of different positivity constraints $|\Delta q(x)| \leq |q(x)|$ i.e. use of different choices of unpolarized strange density [1]. Why do people continue to use the relatively ancient GRV [9] and not the modern versions on the market?

5. Look for reactions sensitive to ΔG.

The range of Q^2 in polarized DIS is too small to give a precise determination of ΔG. Nonetheless essentially all analyses give positive $\Delta G(x)$ with large error bands. For a more precise determination we have to look at other possibilities.

The gold plated reaction is the photon fusion reaction 'γ'$p \to c\bar{c}$ with identification of both charmed particles (open charm). (See Fig. 3.) The next best (silver plated) is picking up just one of the charmed particles. Less clean is picking up two high P_T jets.

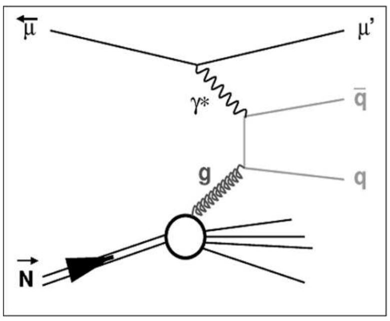

Figure 3. Feynman diagram for $c\bar{c}$ production.

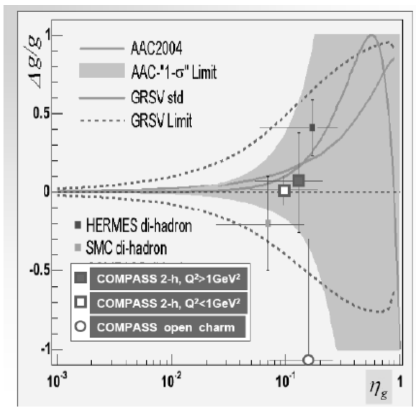

Figure 4. $\Delta G/G$ from various experiments. Curves refer to some theoretical analyses.

Old and new results are shown in Fig. 4. Errors are still large, but the situation looks intriguing. Will there be a contradiction between HERMES and COMPASS? Is there a hint that $\Delta G(x)$ changes sign?

Also intriguing are the very small values, perhaps negative, of A_{LL} in $pp \to \pi X$ [which is quadratic in $\Delta G(x)$] in the preliminary analyses of PHENIX and STAR at RHIC. There are still large errors, but it may turn out that A_{LL} will require either that gluons are unpolarized, in contradiction with almost all the DIS results, or that $\Delta G(x)$ changes sign as a function of x. Interestingly Ref. [4] has tried a fit to the DIS data with a $\Delta G(x)$ which changes sign, and which *might* fit the RHIC A_{LL} data. If $\Delta G(x) \neq 0$, a good way to study its sign is via A_{LL} in $pp \to \gamma X$, which is linear in $\Delta G(x)$.

6. Conclusion: the 'good' news.

It seems that $\Delta G(x)$ is small, so we are facing a resurrection of *A CRISIS IN THE PARTON MODEL - WHERE, OH WHERE, IS THE PROTON'S SPIN?* [10]. Recall that the small value of the proton's a_0 was explained as a cancellation between quarks and the anomalous gluon contribution

$$a_0 = \Delta\Sigma - N_f(\alpha_s/2\pi)\,\Delta G \tag{8}$$

thereby allowing $\Delta\Sigma$, the spin carried by the quarks, to be reasonably large (say ≈ 0.6) provided ΔG is big (≈ 1.7 at $Q^2 = 1GeV^2$). This wonderful escape from the 'crisis' may no longer be tenable.

Acknowledgments

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