

Glueon Polarization and Higher Twist Effects

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We examine the influence of the recent CLAS and COMPASS experiments on our understanding of higher twist (HT) effects and the gluon polarization, and show how EIC could discriminate between negative and positive gluon polarizations. We comment on the issue of HT and the recent DSSV analysis.

1 Higher Twist (HT) Effects

CLAS [1] has presented very accurate data on g_1^p and g_1^d at low Q^2 ($1 - 4 \text{ GeV}^2$) and $0.1 \leq x \leq 0.6$, yielding an improvement in the determination of HT effects in $g_1(x)$. Compared to the HT values obtained in the LSS'05 analysis [2], the uncertainties in the HT values at each x are significantly reduced by the CLAS data, as seen in Fig. 1. (For details see [3], where 7 x -bins were used. Results in the present paper are based on an extraction of the HT terms in 5 x -bins.)

Long ago we observed empirically that we could fit the the ratio $\frac{g_1}{F_1}$ without any higher twist terms. If we split g_1 and F_1 into leading and higher twist pieces

$$g_1 = g_1^{LT} + g_1^{HT} \quad F_1 = F_1^{LT} + F_1^{HT}$$

then, approximately,

$$\frac{g_1}{F_1} \approx \frac{g_1^{LT}}{F_1^{LT}} \left[1 + \frac{g_1^{HT}}{g_1^{LT}} - \frac{F_1^{HT}}{F_1^{LT}} \right]$$

Figure 1: Higher twist terms for protons and neutrons.

Thus our observation requires a cancellation between g_1^{HT}/g_1^{LT} and F_1^{HT}/F_1^{LT} . Fig. 2, based on our recent results on g_1 [3] and the unpolarized results of [4], demonstrates the validity of this for $x \geq 0.15$, but clearly indicates that ignoring HT terms in the ratio $\frac{g_1}{F_1}$ below $x = 0.15$, as was done in the recent DSSV analysis [5], is incorrect.

*Supported by RFBR Grants 06-02-16215 and 08-01-00686

COMPASS [6] has presented data on $g_1^d(x)$ at large Q^2 and very small x ($0.004 \leq x \leq 0.02$), the *only* precise data at such small x . Their influence on the HT terms is negligible (see the talk of Sidorov at the XII Workshop on High Energy Spin Physics, Dubna, 2007 [7]), but they significantly effect the extraction of the polarized gluon density.

2 The polarized gluon density

There are three ways to access $\Delta G(x)$:

(i) via polarized DIS: we parametrize the polarized quark and gluon densities and fit data on $g_1(x, Q^2)$. The main role of the gluon is in the *evolution* with Q^2 , but the range of Q^2 is very limited, so the determination of $\Delta G(x)$ is imprecise. For a long time various analyses seemed to indicate that $\Delta G(x)$ was a positive function of x , as seen in Fig. 3 .

For reasons that we do not understand, with the inclusion of recent data, we get equally good fits with positive, negative and sign-changing $\Delta G(x)$, provided we include higher twist terms. The latter are particularly demanded by the CLAS data. Note that the COMPASS analysis finds acceptable negative $\Delta G(x)$ fits, but has some peculiarities, which suggest it is not very physical. They do *not* include HT terms! We fail to find negative $\Delta G(x)$ fits *without* HT terms!

In Fig. 4 we show the three LSS'06 versions of $\Delta G(x)$. In Fig. 5 we compare LSS'06 and COMPASS results for positive and negative $\Delta G(x)$.

It is seen that while the first moments are about the same, the shapes of $\Delta G(x)$ are considerably different for the positive case.

(ii) Another approach to $\Delta G(x)$ is via $c\bar{c}$ production in SIDIS. This is based on the very reasonable assumption that there is no intrinsic charm in the nucleon, so the production involves $\gamma - gluon$ fusion. Ideally, to be absolutely sure of the mechanism, one would like to detect both charmed particles. In practice this is not possible and one relies on single charm production at a reasonably large transverse momentum, or on jet production. In Fig. 6 we see that the $\Delta G(x)/G(x)$ extracted by COMPASS from their data is perfectly compatible with the three different LSS'06 parametrizations of $\Delta G(x)$ divided by the MRST'02 version of the unpolarized gluon density $G(x)$.

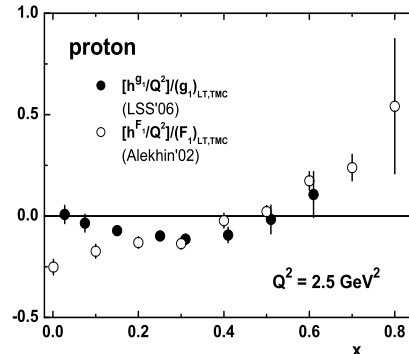


Figure 2: Comparison of HT terms in g_1 and F_1 .

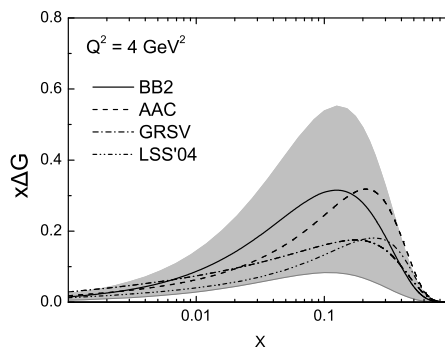


Figure 3: Results of various analyses for ΔG .

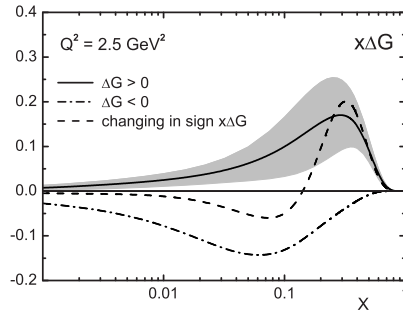


Figure 4: The three different LSS'06 parametrizations of ΔG .

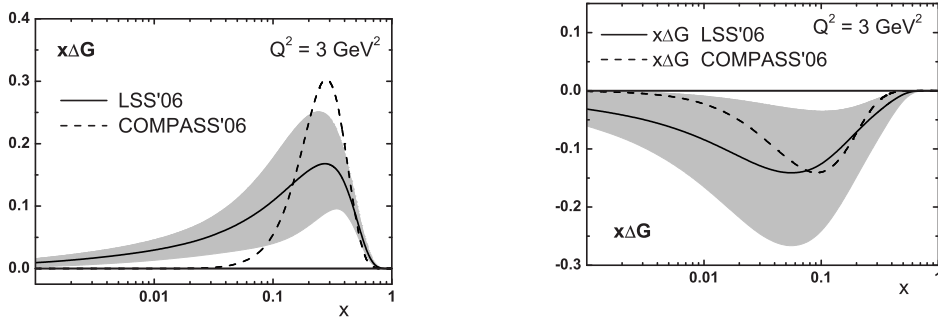


Figure 5: Comparison of LSS'06 and COMPASS for positive and negative ΔG .

(iii) One can also study $\Delta G(x)$ via its role in single particle production in polarized proton-proton collisions, especially at RHIC. We have not yet tested the LSS'06 densities by this method.

3 EIC and the sign of the polarized gluon density

It seems clear that present day data cannot distinguish between the three scenarios for $\Delta G(x)$. A clean distinction, at least between the positive and negative cases, would be possible in an EIC type collider which could access values of Q^2 in the region of 1000 GeV^2 . Fig. 7 shows $g_1(x)$ for protons, calculated using the LSS'06 positive and negative $\Delta G(x)$,

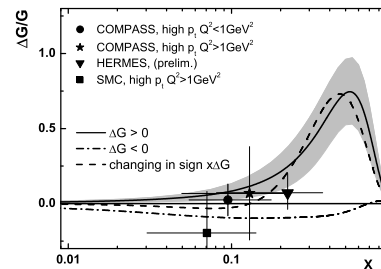


Figure 6: Comparison of the COMPASS results for $\Delta G/G$ with the three LSS'06 versions of ΔG divided by the MRST'02 G .

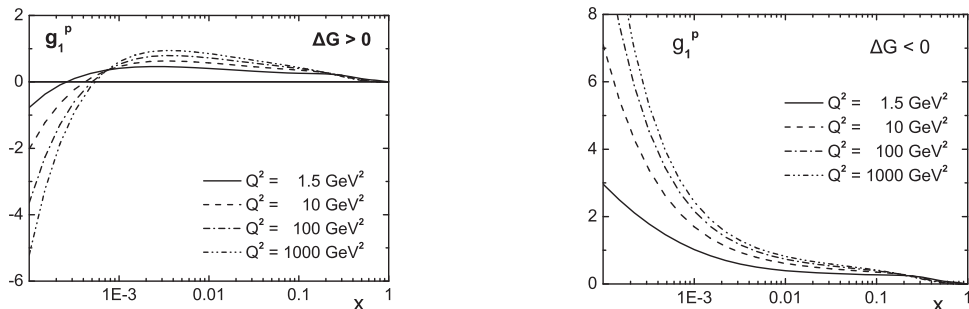


Figure 7: $g_1(x, Q^2)$ at different Q^2 calculated using the LSS'06 positive and negative ΔG .

for $1 \leq Q^2 \leq 1000 \text{ GeV}^2$. There is a dramatic difference at small x .

4 Conclusions

- The very accurate low Q^2 CLAS data significantly reduce the errors on the HT terms.
- Surprisingly, the increase in available data seems to increase the freedom in the functional form of $\Delta G(x)$.
- Positive, negative and sign-changing forms for $\Delta G(x)$ seem to be allowed with excellent χ^2 values, provided HT terms are included.
- Measurements of $g_1(x)$ at small x and large Q^2 at EIC could settle the question of the sign of $\Delta G(x)$.

References

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