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THE ROLE OF HIGHER TWISTS IN DETERMINING POLARIZED PARTON DENSITIES

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Different methods to extract the polarized parton densities from the world polarized DIS data are considered. The higher twist corrections $h^N(x)/Q^2$ to the spin dependent proton and neutron g_1 structure functions are found to be non-negligible and important in the QCD analysis of the present experimental data. Their role in determining the polarized parton densities in the framework of the different approaches is discussed.

1 Introduction

One of the peculiarities of the polarized DIS is that a lot of the present data are at low $Q^2 : Q^2 \sim 1 - 5\ GeV^2$. For that reason, to confront correctly the QCD predictions to the experimental data and to determine the polarized parton densities a special attention should be paid to the non-perturbative higher twist (powers in $1/Q^2$) corrections to the nucleon structure functions. The size of higher twist corrections (HT) to the spin structure function g_1 and their role in determining the polarized parton densities in the nucleon using different approaches of QCD fits to the data are discussed in this talk. It is also considered how the results are influenced by the recent JLab Hall A [1] and preliminary HERMES [2] data.

2 QCD fits to the data and the role of higher twists

Up to now, two approaches have been mainly used to extract the polarized parton densities (PPD) from the world polarized DIS data. According to the first [3,4] the leading twist LO/NLO QCD expressions for the structure functions g_1^N and F_1^N have been used in order to confront the data on $A_1(\approx g_1/F_1)$ and g_1/F_1. We have shown [5] that in this case the extracted from the world data "effective" HT corrections $h^{A_1}(x)$ to A_1

$$A_1(x,Q^2) = (1+\gamma^2)\frac{g_1(x,Q^2)_{\rm LT}}{F_1(x,Q^2)_{\rm LT}} + \frac{h^{A_1}(x)}{Q^2} \tag{1}$$

are negligible and consistent with zero within the errors, $h^{A_1}(x) \approx 0$. This result has been confirmed independently in [3]. The results on the HT corrections to A_1

including in the world data set [6] the recent JLab/Hall A [1] and HERMES [2] data on g_1/F_1 for neutron and deuteron, respectively, are presented in [7]. It was shown that, due to the much more precise JLab/Hall A and HERMES new data, the HT corrections $h^{A_1}(x)$ to A_1 for the neutron and deuteron targets are much better determined now at large x and better consistent with zero in this kinematic region. What follows from these results is that the higher twist corrections to g_1 and F_1 compensate each other in the ratio g_1/F_1 and the PPD extracted this way are less sensitive to higher twist effects.

According to the second approach [8,9], g_1/F_1 and A_1 data have been fitted using phenomenological parametrizations of the experimental data for the unpolarized structure function $F_2(x, Q^2)$ and the ratio $R(x, Q^2)$ of F_2 and F_1 (F_1 has been replaced by the usually extracted from unpolarized DIS experiments F_2 and R). Note that such a procedure is equivalent to a fit to $(g_1)_{exp}$, but it is more precise than the fit to the g_1 data themselves actually presented by the experimental groups. The point is that most of the experimental data on g_1 have been extracted from the A_1 and g_1/F_1 data using the additional assumption that the ratio g_1/F_1 does not depend on Q^2. Also, different experimental groups have used *different* parametrizations for F_2 and R.

If the second approach is applied to the data, the "effective higher twist" contribution $h^{A_1}(x)/Q^2$ to $A_1(g_1/F_1)$ is found [3] to be sizeable and important in the fit [the HT corrections to g_1 cannot be compensated because the HT corrections to $F_1(F_2$ and $R)$ are absorbed by the phenomenological parametrizations of the data on F_2 and R]. Therefore, to extract correctly the polarized parton densities from the g_1 data, the HT corrections to g_1 have to be taken into account. Note that a QCD fit to the data in this case, keeping in $g_1(x, Q^2)_{QCD}$ only the leading-twist expression (as it was done in [8,9]), leads to some "effective" parton densities which involve in themselves the HT effects and therefore, are not quite correct.

Keeping in mind the discussion above we have analyzed the world data [6] on inclusive polarized DIS taking into account the higher twist corrections to the nucleon structure function $g_1^N(x, Q^2)$. In our fit to the data we have used the following expressions for g_1/F_1 and A_1:

$$\left[\frac{g_1^N(x,Q^2)}{F_1^N(x,Q^2)}\right]_{exp} \Leftrightarrow \frac{g_1^N(x,Q^2)_{\rm LT} + h^N(x)/Q^2}{F_2^N(x,Q^2)_{exp}} 2x \frac{[1+R(x,Q^2)_{exp}]}{(1+\gamma^2)} ,$$

$$A_1^N(x,Q^2)_{exp} \Leftrightarrow \frac{g_1^N(x,Q^2)_{\rm LT} + h^N(x)/Q^2}{F_2^N(x,Q^2)_{exp}} 2x[1+R(x,Q^2)_{exp}] , \qquad (2)$$

where $g_1^N(x, Q^2)_{\rm LT}$ is given by the leading twist QCD expression including the target mass corrections (N=p, n, d). The dynamical HT corrections $h^N(x)$ in (2) are included and extracted in a *model independent way*. In our analysis their Q^2 dependence is neglected. It is small and the accuracy of the present data does not allow to determine it. For the unpolarized structure functions $F_2^N(x, Q^2)_{exp}$ and $R(x, Q^2)_{exp}$ we have used the NMC parametrization [10] and the SLAC parametrization $\rm R_{1998}$ [11], respectively. The details of our analysis are given in [12].

We have found that the fit to the data is significantly improved when the higher twist corrections to g_1 are included in the analysis, especially in the LO QCD case. The best LO and NLO fits correspond to $\chi^2_{\rm DF,LO} = 0.89$ and to $\chi^2_{\rm DF,NLO} = 0.86$,

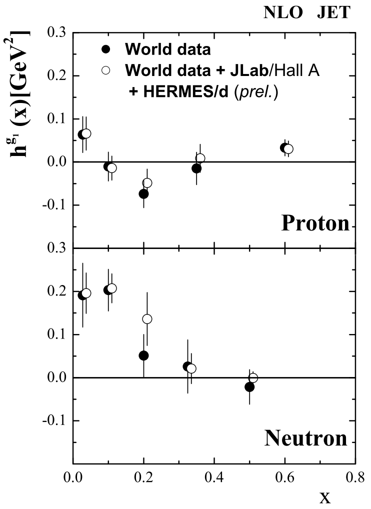

Figure 1. Higher twist corrections to the proton and neutron g_1 structure functions extracted from the data on g_1 in the NLO QCD approximation for $g_1(x,Q^2)_{\rm LT}$.

while in the case of LO and NLO fits when HT are not included, $\chi^2_{\rm DF,LO} = 1.36$ and $\chi^2_{\rm DF,NLO} = 1.22$, respectively.

We have also found that the size of the HT corrections to g_1 is *not* negligible and their shape depends on the target (see Fig. 1). In Fig. 1 our results on the HT corrections to g_1 (open circles) including in the world data set the recent JLab/Hall A [1] and HERMES [2] data are also presented. As seen from Fig. 1, the higher twist corrections to the neutron spin structure functions in the large x region are much better determined now. It was also shown [12] that the NLO QCD polarized PD($g_1^{\rm LT}$ + HT) determined from the data on g_1, including higher twist effects, are in good agreement with the polarized PD($g_1^{\rm NLO}/F_1^{\rm NLO}$) found earlier from our analysis [4] of the data on g_1/F_1 and A_1 using for the structure functions g_1 and F_1 only their *leading* twist expressions in NLO QCD. This observation confirms once more that the higher twist corrections to g_1/F_1 and A_1 are negligible, so that in the analysis of g_1/F_1 and A_1 data it is enough to account only for the leading twist of the structure functions g_1 and F_1.

Using the values of the HT corrections $h(x)$ to the proton and neutron structure functions g_1 (open circles in Fig. 1) we obtain for their first moments in the experimental region: $h_1^p = \int_{0.005}^{0.75} h^p(x)dx \approx (0.007 \pm 0.010)$ GeV^2 and $h_1^n = \int_{0.015}^{0.60} h^n(x)dx \approx (0.048 \pm 0.007)$ GeV^2. These values are in agreement with the instanton model predictions [13].

3 Conclusion

We have found that the QCD fit to the present data on the nucleon spin-structure function $g_1(x,Q^2)$ is essentially improved, especially in the LO case, when the higher twist corrections to g_1 are included in the analysis. The size of their contribution to g_1 has been extracted from the data in model independent way and found to be non-negligible. It was shown that in order to extract correctly the polarized parton densities from g_1 data, the higher twist corrections to g_1 have to be taken into account in the analysis. While, in the fit to g_1/F_1 and $A_1(\approx g_1/F_1)$ data it is enough to account only for the leading twist contributions to the structure functions g_1 and F_1 because the higher twists corrections to g_1 and F_1 compensate each other in the ratio $g1/F1$. Further investigations on the role of higher twist effects in semi-inclusive DIS processes would be important for the correct determination and flavor separation of the valence and light sea quark parton densities.

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References

1. JLab/Hall A Coll., X. Zheng *et al.*, Phys. Rev. Lett. **92** (2004) 012004.
2. C. Weiskopf, DESY, Thesis 02-043, 2002.
3. M. Glück. E. Reya, M. Stratmann, and W. Vogelsang, Phys. Rev. **D63** (2001) 094005.
4. E. Leader, A.V. Sidorov, and D.B. Stamenov, Eur. Phys. J. **C23** (2002) 479.
5. E. Leader, A.V. Sidorov, and D.B. Stamenov, in *Particle Physics at the Start of the New Millennium*, edited by A.I. Studenikin, World Scientific, Singapore, May 2001, p. 76. (*Proceedings of the 9th Lomonosov Conference on Elementary Particle Physics, Moscow, Russia, 20-26 Sep 1999*).
6. EMC, J. Ashman *et al.*, Phys. Lett. **B206** (1988) 364; SLAC E142 Coll., P.L. Anthony *et al.*, Phys. Rev. **D54** (1996) 6620; SLAC/E154 Coll., K. Abe *et al.*, Phys. Rev. Lett. **79** (1997) 26; SMC, B. Adeva *et al.*, Phys. Rev. **D58** (1998) 112001; HERMES, K. Ackerstaff *et al.*, Phys. Lett. **B404** (1997) 383; *ibid* **B442** (1998) 484; SLAC E143 Coll., K. Abe *et al.*, Phys. Rev. **D58** (1998) 112003; SLAC/E155 Coll., P.L. Anthony *et al.*, Phys. Lett. **B463** (1999) 339, *ibid* **B493** (2000) 19.
7. E. Leader, A. V. Sidorov, and D. B. Stamenov, in Deep Inelastic Scattering DIS2003, edited by V.Rim and L.Lipatov, PNPI RAS, 2003, pp. 790-794, e-Print Archive hep-ph/0309048.
8. SMC, B. Adeva *et al.*, Phys. Rev. **D58** (1998) 112002.
9. J. Blumlein and H. Bottcher, Nucl. Phys. **B636** (2002) 225.
10. NMC Coll., M. Arneodo *et al.*, Phys. Lett. **B364** (1995) 107.
11. E143 Coll., K. Abe *et al.*, Phys. Lett. **B452** (1999) 194.
12. E. Leader, A.V. Sidorov, and D.B. Stamenov, Phys. Rev. **D67** (2003) 074017.
13. N.Y. Lee, K. Goeke, and C. Weiss, Phys. Rev. **D65** (2002) 054008.