AIP | Proceedings

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Citation: AIP Conference Proceedings **1350**, 309 (2011); doi: 10.1063/1.3601428

View online: http://dx.doi.org/10.1063/1.3601428

View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1350?ver=pdfcov

Published by the AIP Publishing

Gluon Contribution To The Nucleon Spin

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Abstract. Gluon polarization in Nucleon is evaluated in the *valon* representation of hadrons. It is shown that although $\delta g/g$ is small at the currently measured kinematics, it does not imply that the gluon contribution to the nucleon spin is small. In fact the first moment of gluon polarization in the nucleon, $\Delta g(Q^2)$, is sizable. We also notice that the majority of Δg is concentrated at around $x = 0.08$.

Keywords: Polarized structure functions, Orbital angular momentum, gluon polarization
PACS: 13.60Hb, 13.88.+e

INTRODUCTION

Spin content of the nucleon is an ongoing debate. It can be decomposed in terms of quarks, $\Delta\Sigma$, gluons, Δg and the overall angular momentum of quarks and gluons, $L_{q,g}$ in the nucleon. Thus, one can write the following sum rule:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta g + L_{q,g} \tag{1}$$

The quark contribution to the nucleon spin is fairly measured with high precision and theoretically calculated to be around 0.4. Gluon content of the polarized nucleon is not separately measured and there is no experimental information on the orbital angular momentum part. The emerging data on $\delta g/g$, suggest that $\Delta g(x,Q^2)$ is rather small. In fact, the measured data can be fit with positive, zero and negative $\Delta g(x,Q^2)$, including a possible sign change. The situation seems to be far from clarity.

In deep inelastic scattering the polarized gluon in nucleon is obtained from Q^2 dependence of the polarized structure function g_1. Experimentally, it can be accessed by a number of methods, among them is the photon-gluon fusion, $\gamma^* g \to q\bar{q}$ process. Utilizing this method, COMPASS Coll. has found that $\frac{\Delta g}{g} = 0.024 \pm 0.080 \pm 0.057$ [1].

The aim of this paper is to show that the smallness of $\frac{\Delta g}{g}$ cannot by itself rule out a large value for the first moment, Δg, of gluon polarization.

DESCRIPTION OF THE MODEL

Deep inelastic scattering reveals that the nucleon is a complicated object. However, under certain conditions, hadrons behave as consisting of three (or two) constituents. Therefore, it seems to make sense to decompose a nucleon into three constituent quarks called U and D. We identify them as *valons*. A valon has its own internal structure.

DIFFRACTION 2010
AIP Conf. Proc. 1350, 309-312 (2011); doi: 10.1063/1.3601428

The structure of a valon emerges from the dressing of a valence quark with $q\bar{q}$ pairs and gluons in perturbative QCD. We take the view that when a nucleon is probed with high Q^2 it is the internal structure of the valon that is resolved. The parton content of a valon is calculated in the next-to-leading order in QCD for the unpolarized [2, 3] and the polarized [4, 5] cases. The polarized structure function of the nucleon is obtained by the convolution of the valon structure with the valon distribution in the hosting nucleon:

$$g_1^h(x,Q^2) = \sum_{valon} \int_x^1 \frac{dy}{y} \delta G^h_{valon}(y) g_1^{valon}(\frac{x}{y},Q^2) \tag{2}$$

here $\delta G^h_{valon}(y)$ is the helicity distribution of the valon in the hosting hadron and $g_1^{valon}(\frac{x}{y},Q^2)$ is the polarized structure function of the valon. A similar relation can also be written for the unpolarized structure function, F_2. We maintain the results of Ref. [4] for the polarized structure function, but re-analyze the unpolarized case in order to arrive at a consistent conclusion on $\frac{\Delta G}{G}$. The initial densities for both polarized and unpolarized densities of the partons in a valon are taken to be

$$\begin{pmatrix} \delta q(Q_0^2) \\ \delta g(Q_0^2) \end{pmatrix} = \begin{pmatrix} q(Q_0^2) \\ g(Q_0^2) \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \tag{3}$$

These initial densities imply that if Q^2 is small enough, at some point we may identify $g_1^{valon}(\frac{x}{y},Q^2)$ and $f_2^{valon}(\frac{x}{y},Q^2)$ as $\delta(z-1)$, for the reason that we cannot resolve its internal structure at such Q^2 value. Here $f_2^{valon}(\frac{x}{y},Q^2)$ is the unpolarized structure function of the valon. The model reproduces an accurate description of all available data of the polarized structure function, xg_1 for proton and deuteron and can be found in [4]. Here we want to calculate the polarized and the unpolarized gluon distributions and hence, the ratio $\frac{\Delta G}{G}$. The gluon is a component of singlet sector of the evolution kernel. Their moments are given as

$$\begin{pmatrix} \delta M_S(n,Q^2) \\ \delta M_G(n,Q^2) \end{pmatrix} = \left\{ \mathbf{L}^{-(\frac{2}{\beta_0})\delta\hat{P}^{(0)n}} + \frac{\alpha_s(Q^2)}{2\pi}\hat{\mathbf{U}}\mathbf{L}^{-(\frac{2}{\beta_0})\delta\hat{P}^{(0)n}} - \frac{\alpha_s(Q_0^2)}{2\pi} L^{-(\frac{2}{\beta_0})\delta\hat{P}^{(0)n}}\hat{\mathbf{U}} \right\} \begin{pmatrix} 1 \\ 0 \end{pmatrix} \tag{4}$$

$\delta P_{lm}^{(0)n}$ are the n^{th} moments of the polarized splitting functions and **U** accounts for the 2-loop contributions as an extension to the leading order. Now it is straightforward to calculate the moments of polarized partons inside a valon at any Q^2 value. They are given in [4]. The densities are obtained by an usual inverse Mellin transformation. To obtain the polarized parton distributions in a hadron, one needs to convolute the results with the valon distribution in the hadron. In Figure 1 the first moments of the polarized partons are shown. In our model it turns out that for all flavors of sea quark Δq_{sea} is consistent with zero. Although we have started with $\Delta g = 0$ at the starting scale, it grows with increasing Q^2. This behavior of gluon polarization can be related to the positive sign of the pertinent anomalous dimension $\delta\gamma_{qg}^{(0)1}$. It dictates that the polarized quark preferably radiates a gluon with helicity parallel to the quark polarization. Since the net quark spin in a valon is positive, it follows that perturbatively radiated gluons must have $\Delta g > 0$. We also note that the growth rate of δG is especially fast at low Q^2. In order to satisfy

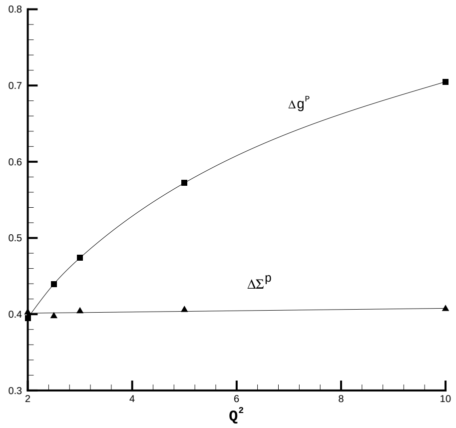

FIGURE 1. First moment of polarized quark, $\Delta\Sigma$, and gluon, ΔG, in proton as a function of Q^2

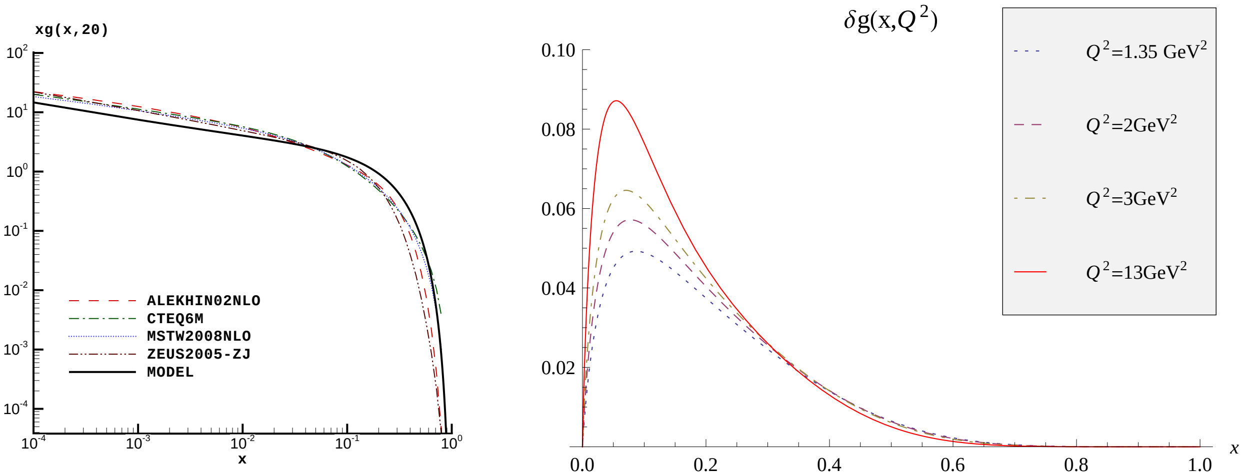

FIGURE 2. *left*: Unpolarized gluon distribution, $xg(x,Q^2)$, in the proton at several Q^2 and comparison with global fits. *Right*: Model results for he polarized gluon distribution, $\delta g(x,Q^2)$.

the sum rule in Equation (1) it requires that the orbital angular momentum component to be negative and decreasing as Q^2 increases [5]. The unpolarized, $g(x,Q^2)$ and the polarized gluon distributions, $x\delta g(x,Q^2)$, are shown in Figure 2 as a function of x for several values of Q^2. Having determined $g(x,Q^2)$ and $\delta g(x,Q^2)$ in proton, to calculate the ratio $\frac{\Delta g(x)}{g(x)}$ is straightforward. The details can be found in [6]. In Figure 3 we show $\frac{\Delta g(x)}{g(x)}$ at each value of Q^2 that experimental measurements are available. This allows us to make a meaningful comparison of our results with the experimental data. The apparent wide band in the Figure is actually seven closely packed curves corresponding to the seven individual values of Q^2's at which the data are taken. Our results are in good agreement with the experimental points, including the very recent one from HERMES

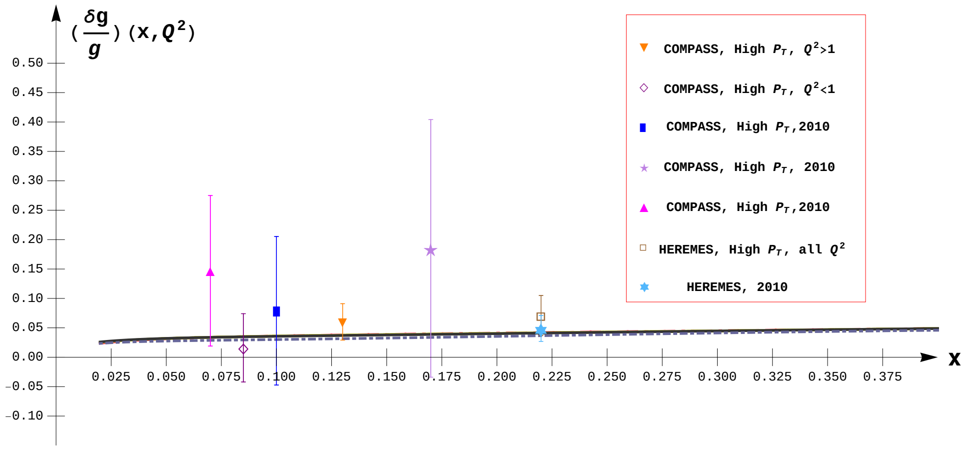

FIGURE 3. The ratio $\frac{\delta g(x,Q^2)}{g(x,Q^2)}$ calculated in the valon model and compared with the exist experimental data. The apparent wide band in the Figure are actually seven closely packed curves corresponding to the seven values of Q^2s at which the data are measured.

[7] and COMPASS [8].

CONCLUSION

We have calculated gluon polarization in a polarized proton in the valon representation of hadrons and compared it with the existing data, including the most recent ones from HERMES collaboration [7]. Since the experimental data are obtained at different Q^2 values, the calculations are also carried out at the corresponding Q^2, individually. It is evident from the results that the polarized valon model of the nucleon not only agrees with the existing data on g_1, but also provides a clear resolution for the spin problem. We maintain the view that $x\delta g(x,Q^2)$ is positive and increases with Q^2. The growth of $x\delta g(x,Q^2)$ in part is compensated by a negative and large orbital angular momentum, $L_{q,g}$. Although, we have not calculated L_q and L_g individually, but the overall $L_{q,g}$ is given in [5].

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