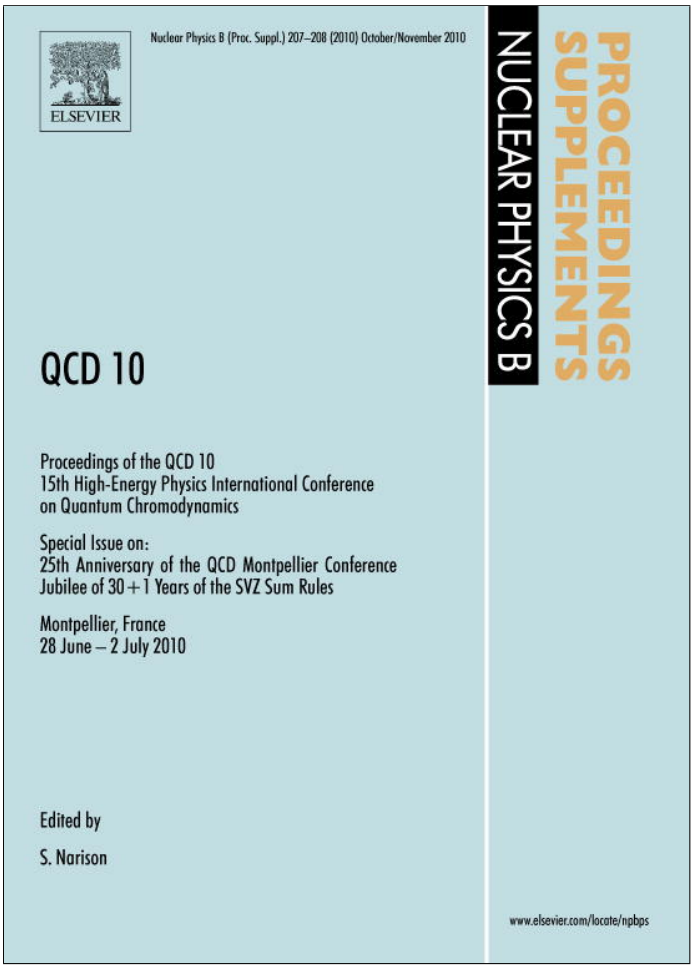

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Gluon Spin Contribution to The Nucleon Spin

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Abstract

We have calculated $\delta g/g$ in the nucleon at all measured kinematics. The smallness of $\delta g/g$ in the measured kinematics should not be interpreted as the the gluon contribution to the nucleon spin is small. In fact the first moment of gluon polarization in the nucleon, $\Delta g(Q^2)$ can be sizable.

Keywords: Nucleon Spin, Gluon polarization, valon Model

1. Introduction

The spin of nucleon can be decomposed in terms of its quarks, $\Delta\Sigma$, gluons, Δg and the overall angular momentum of quarks and gluons, $L_{q,g}$ contributions. Thus, one can write the following sum rule for a nucleon:

$$\frac{1}{2} = frac12\Delta\Sigma + \Delta g + L_{q,g} \quad (1)$$

where $\Delta\Sigma$ is the quarks and anti-quarks contribution to the nucleon spin,Δg is the gluon contribution and,$L_{q,g}$ represents the orbital angular momentum of the partons. In deep inelastic scattering, gluon spin content of the nucleon is calculated from Q^2 dependence of the polarized structure function g_1. Experimentally, one can use photon-gluon fusion, $\gamma^* g \rightarrow q\bar{q}$ process. COMPASS Collaboration have utilized this method and found a rather small value for $\frac{\Delta g}{g} = 0.024 \pm 0.080 \pm 0.057$ [1]. The smallness of $\frac{\Delta g}{g}$ cannot by itself rule out a large value for the first moment, Δg of gluon polarization.
The total quark spin contribution, $\Delta\Sigma$ is fairly well determined and amounts to a value around 0.4. In contrast to $\Delta\Sigma$, knowledge about gluon polarization is limited. The existing and the emerging data on $\frac{\delta g(x,Q^2)}{g(x,Q^2)}$ cannot rule out the negative and/or zero polarization for the gluon, including a possible sign change. In this talk we use the so-called *valon* model to determine the gluon polarization in the polarized proton.

2. Description of The Model

Deep inelastic scattering reveals that the nucleon has a complicated internal structure. Other strongly interacting particles also exhibit similar structure. 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, consisting of a valence quark and a host of $q\bar{q}$ pairs and gluons. 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 valon concept was first developed by R. C. hwa [2] and in refs. [3] [4] [5] it was utilized to calculate unpolarized structure functions of a number of hadrons. This representation is also used to calculate the polarized structure of nucleon. The details can be found in [6]and [7].
We have worked in $\overline{MS}$ scheme with $\Lambda_{QCD} = 0.22$ GeV and $Q_0^2 = 0.283\ GeV^2$. The polarized and unpolarized structure of a valon is calculated in the framework of Next-to-Leading order in QCD. The polarized (unpolarized) structure function of the nucleon is obtained by the convolution of the valon structure with the valon distribution in the hosting nucleon:

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

where $\delta G^h_{valon}(y)$ is the helicity distribution of the valon in the hosting hadron and $g_1^{valon}(\frac{x}{y}, Q^2)$ is the polarized

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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. [6] for the polarized structure function, but in order to arrive at a consistent conclusion on $\frac{\Delta G}{G}$, we re-analyze the unpolarized case. The initial densities for both polarized and unpolarized densities of the partons in a valon are taken to be as follows,

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

The above initial densities mean 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.

Figure (1) shows the polarized structure function of proton, xg_1^p, obtained from the model, along with the available data from various experiments. It is important to note that our analysis does not rely on any kind of data fitting. The structure of a valon obtained simply from QCD processes via DGLAP evolution. Here we want to

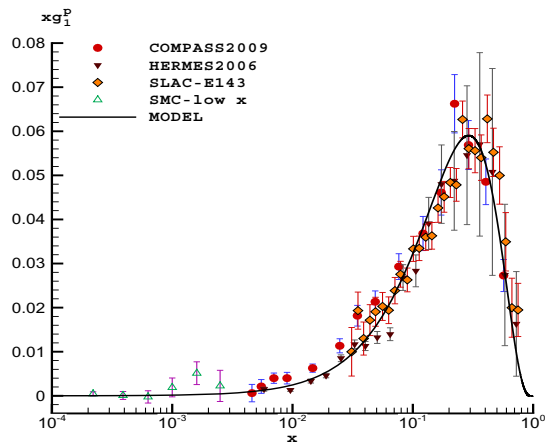

Figure 1: polarized structure function of proton , xg_1^p, as a function of x at $Q^2 = 5GeV^2$. The data points are from refs.[12-17].

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

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

where $\mathbf{L} \equiv \alpha_s(Q^2)/\alpha_s(Q_0^2)$, and $\delta\hat{P}^{(0)n}$ is 2×2 singlet matrix of splitting functions, given by

$$\delta\hat{P}^{(0)n} = \begin{pmatrix} \delta P_{qq}^{(0)n} & 2f\delta P_{qg}^{(0)n} \\ \delta P_{gq}^{(0)n} & \delta P_{gg}^{(0)n} \end{pmatrix}, \tag{5}$$

$\delta P_{lm}^{(0)n}$ are the nth moments of the polarized splitting functions and $\mathbf{U}$ 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 Ref.[6]. 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 (2) the first moments of the polarized partons are shown. In our model it turns out that the sea quark polarizations are consistent with zero. Although we have started with

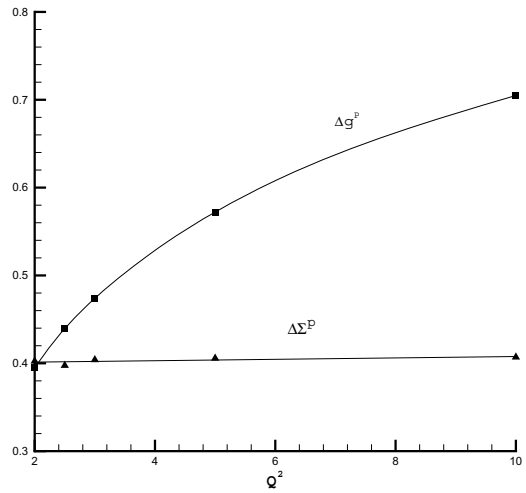

Figure 2: First moment of polarized quark, $\Delta\Sigma$, and gluon, ΔG, in proton as a function of Q^2

$\Delta g = 0$ 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 $\delta\gamma_{qg}^{(0)1}$. The positivity of the anomalous dimension 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 from quarks 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 the sum rule in Equation (1) it requires that the orbital angular momentum component to be negative and decreasing as Q^2 increases [7].

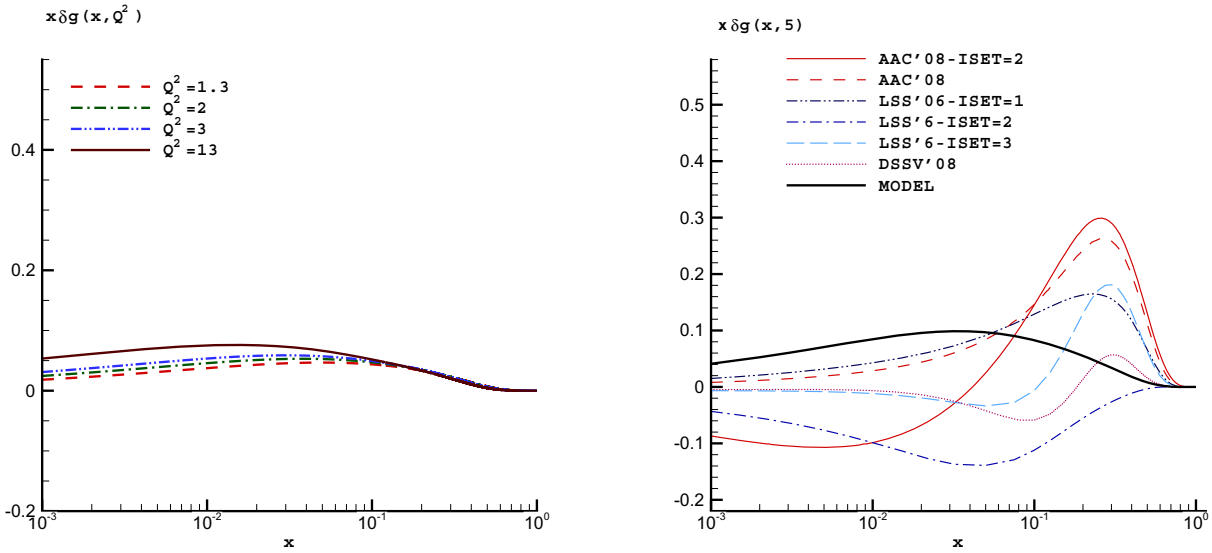

Figure 3: *Top*: $x\delta g(x, Q^2)$ at some values of Q^2. *Bottom*: comparison with other global fits at 5 GeV^2.

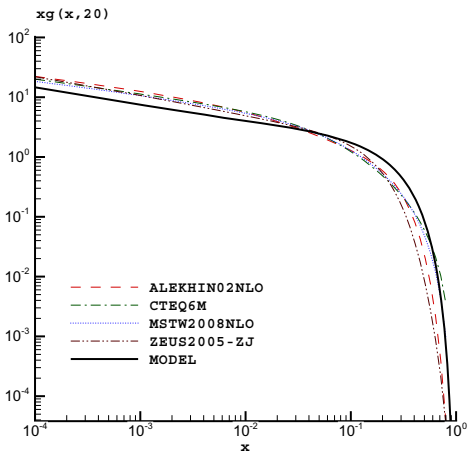

Figure 4: The model result for the unpolarized gluon distribution, $xg(x)$, at $Q^2 = 20GeV^2$. Also shown the results of the global fittings.

Figures (1) demonstrate that the model can accommodate the experimental data on structure functions fairly accurately. The calculated polarized gluon distributions, $x\delta g(x, Q^2)$, are shown in figure (3) as a function of x for several values of Q^2. We have also shown the results at $Q^2 = 5\ GeV^2$ and compared it with the global fits. The unpolarized gluon distribution is shown in figure (4)along with those obtained from various global fits. having obtained the polarized and unpolarized gluon distributions in proton, it is now straight forward to calculate the ratio $\frac{\Delta g(x)}{g(x)}$. The details can be found in [8].

In figure (5) we present the results for $\frac{\Delta g(x)}{g(x)}$ 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^2s at which the data are measured. Apparently, HERMES high p_T (2000) and COMPASS open charm data disagree with our results and with the other most recent measurements. However, these two data points are the least accurate one with very large error bars. Our results are in good agreement with the remaining experimental points, including the very recent one from HERMES [9] and COMPASS [10].

3. conclusion

We calculated gluon polarization in a polarized proton in the valon representation of hadrons and compared it with the existing data, including the most recent one from HERMES collaboration [9]. 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 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 $\delta g(x, Q^2)$ is positive and increases with Q^2. The growth of $\delta g(x, Q^2)$ in part is compensated by a negative and large orbital angular momentum, $L_{q,g}$. Although, we have not calcu-

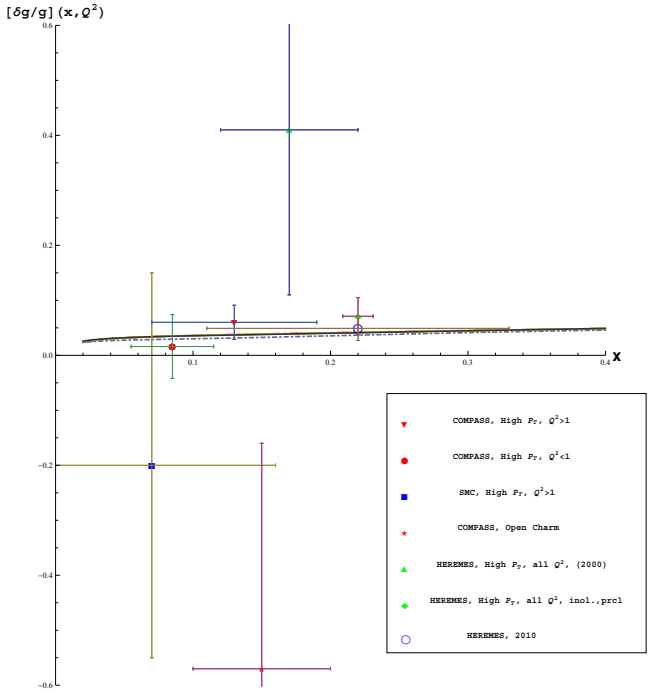

Figure 5: The ratio $\frac{\delta g(x,Q^2)}{g(x,Q^2)}$ calculated in the valon model and compared with the exist experimental data. The apparent wide band in the figure are actually seven closely packed curves corresponding to the seven values of Q^2s at which the data are measured.

lated L_q and L_g individually, but the overall $L_{q,g}$ is given in [7].

References

[1] E.S. Ageev,*et al.,* Phys. Lett. **B 633**:25-32, 2006, hep-ex/0511028.

[2] R. C. Hwa, phys. Rev. D **22**, 759 (1980).

[3] F. Arash and A. N. Khorramian, Phys. Rev. **C 67** (2003) 045201.

[4] F. Arash Phys. Lett. **B 557** (2003) 38.

[5] F. Arash Phys. Rev. **D 679** (2004)054024.

[6] F. Arash and F. Taghavi-Shahri, JHEP **0707**:071,2007.

[7] F. Arash and F. Taghavi-Shahri, Phys. Lett. **B 668**:193-196, 2008.

[8] A. Shahveh, F. taghavi-Shahri, anf F. Arash, Phys. Lett. **B 691**:32-36, 2010.

[9] HERMES Coll., A. Airapetian, *et al.,* arXiv: 1002.3921 [hep-ex].

[10] COMPASS Collaboration, M. Alekseev *et al.,* Phys. Lett. **B 680**:217-224,2009