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Gluon Spin Contribution to The Nucleon Spin

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Abstract

We have calculated δg/g in the nucleon at all measured kinematics. The smallness of δg/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, Δg(Q2) can be sizable.

Keywords: Nucleon Spin, Gluon polarization, valon Model

1. Introduction

The spin of nucleon can be decomposed in terms of its quarks, ΔΣ, gluons, Δg and the overall angular momentum of quarks and gluons, Lqg contributions. Thus, one can write the following sum rule for a nucleon:

\[
\frac{1}{2} = \frac{\Delta \Sigma + \Delta g + L_{qg}}{Q^2}
\]

where ΔΣ is the quarks and anti-quarks contribution to the nucleon spin, Δg is the gluon contribution and Lqg represents the orbital angular momentum of the partons. In deep inelastic scattering, gluon spin content of the nucleon is calculated from Q2 dependence of the polarized structure function g1. Experimentally, one can use photon-gluon fusion, γ* → q̅q process. COMPASS Collaboration have utilized this method and found a rather small value for Δg/Q 2 = 0.024 ± 0.080 ± 0.057 [1].

The smallness of Δg/Q 2 cannot by itself rule out a large value for the first moment, Δg of gluon polarization. The total quark spin contribution, ΔΣ is fairly well determined and amounts to a value around 0.4. In contrast to ΔΣ, knowledge about gluon polarization is limited. The existing and the emerging data on δg(x,Q2)/g(x,Q2) 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 q̅q pairs and gluons. The structure of a valon emerges from the dressing of a valence quark with q̅q pairs and gluons in perturbative QCD. We take the view that when a nucleon is probed with high Q2 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 MMS scheme with ΛQCD = 0.22 GeV and Q0 2 = 0.283 GeV2. 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:

\[
g^h(x,Q^2) = \sum_{\text{valon}} \int_0^x dy \frac{\delta C_{\text{valon}}^h(y)}{y} g^1_{\text{valon}}(\frac{x}{y},Q^2)
\]
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 \( \frac{dG}{dQ^2} \), 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,

\[
\begin{pmatrix}
\delta q(Q_0^2) \\
\delta g(Q_0^2)
\end{pmatrix} =
\begin{pmatrix}
q(Q_0^2) \\
g(Q_0^2)
\end{pmatrix} =
\begin{pmatrix}
1 \\
0
\end{pmatrix}
\]

The above initial densities mean that if \( Q^2 \) is small enough, at some point we may identify the parton momentum component to be negative and decreasing as \( Q^2 \) increases [7].

We also note that the growth rate of \( \Delta g \) 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].

\[ \Delta g = 0 \] 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 \( \gamma_{qq}^{(0)} \). 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 \( \delta G \) 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].
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 straightforward 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 $Q^2$ 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 $\frac{\delta g(x, Q^2)}{\delta(x, Q^2)}$ 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 $Q^2$s at which the data are measured.

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

References