Polarized nucleon structure in valon framework

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I calculated hadron structure function and parton distribution function in valon framework with turns out sea quark polarization.

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1 Introduction

The most direct tool for probing the quark and gluon sub-structure of hadrons is the Polarized Deep Inelastic Scattering. In such experiments detailed information can be extracted on the shape and magnitude of the spin dependent parton distribution functions: $\delta q_f(x,Q^2)$. It is a common belief that other strongly interacting particles also exhibit similar internal structures. It seems that under certain conditions, hadrons behave as if they were composed of two or three constituents. Thus, it makes sense to decompose a nucleon into its constituent quarks, called U and D. The proton, for example, would be a composition of UUD. These constituent quarks would carry the internal quantum numbers of the nucleon. It is highly suggestive to identify the valence quark with a constituent quark. It seems to us that a constituent quark is a quasi-particle with a non trivial internal structure of its own consisting of a valence quark and a sea of $q\bar{q}$ pairs as well as gluons. Such an interpretation of a constituent quark is not new. R.C. Hwa developed a more elaborate version by introducing the so called valon model [1], (the term that we will use hereafter) and applied it to a variety of phenomena. More recently, Arash et al. [2] used the valon concept and calculated un-polarized structure function of a number of hadrons and compared the results with the experimental data and found them in good agreement. On a more theoretical front M. Lavelle and D. McMullan [3, 4] proved that one can dress a QCD lagrangian field to all orders in perturbation theory and construct a constituent quark in conformity with the color confinement. It is from this point of view that a valon is defined as a structure full object emerging from the dressing of a valence quark with gluons and $q\bar{q}$ pairs in QCD. The purpose of this paper is to investigate the polarized parton distribution functions (PPDF) and polarized hadron structure function in valon framework.

2 valon model

Each valence quark plus its associated sea quarks and gluons describe a valon in the dressing process of QCD. These valons have the quantum numbers of the valence quarks. The proton for example, has three valons named UUD. In valon model we can write the structure function of any hadron as a convolution of two parts: parton distribution in a valon , and valon distribution in nucleon.
So, in an un-polarized case we can write [5]:

$$F_2{}^h(x,Q^2)=\sum_{valon}\int_x^1 G^h_{valon}(y)\, f_2{}^{valon}(z=\frac{x}{y},Q^2)dy\,, \tag{1}$$

Where, $f_2{}^{valon}(z=\frac{x}{y},Q^2)$ is the structure function of the valon which can be calculated in perturbation QCD to certain degree of approximation.
$G^h_{valon}(y)$ Indicates the probability of finding certain valon with momentum fraction y of hadron.

3 Polarized Parton distribution function (PPDF) in valon model

In the polarized case we can write structure function of a hadron in a similar way as:

$$g1^h(x,Q^2)=\sum_{valon}\int_x^1 \delta G^h_{valon}(y) g1^{valon}(z=\frac{x}{y},Q^2)\frac{dy}{y}\,, \tag{2}$$

Where $\delta G^h_{valon}(y)$ helicity distribution of a valon and $g1^{valon}(z=\frac{x}{y},Q^2)$ is the polarized structure function of a valon. For example, At high Q^2, for a U-type valon one can write $g1^{valon}$ as follows:

$$g1^U=\frac{1}{2}(\frac{4}{9}(\delta f_{\frac{u}{U}}(z,Q^2)+\delta f_{\frac{\bar{u}}{U}}(z,Q^2))+\frac{1}{9}(\delta f_{\frac{d}{U}}(z,Q^2)+\delta f_{\frac{\bar{d}}{U}}(z,Q^2)+...))\,, \tag{3}$$

In this equation all the functions on the right-hand are polarized parton distribution in a valon and can be calculated in perturbative QCD. They evolve according to DGLAP equations.
parton distributions in the moment space obey the following equations[6]:

$$\delta q^n_{NS}(Q^2)=\{1+\frac{\alpha_s(Q^2)-\alpha_s(Q_0^2)}{2\pi}(\frac{-2}{\beta_0})(\delta P^{(1)n}_{NS}-\frac{\beta_1}{\beta_0}\delta P^{(0)n}_{qq})\}L^{\frac{-2}{\beta_0}\delta P^{(0)n}_{qq}}\,, \tag{4}$$

$$\begin{pmatrix}\delta\Sigma^n(Q^2)\\ \delta g^n(Q^2)\end{pmatrix}=\{L^{\frac{-2}{\beta_0}\delta\hat{P}^{(0)n}}+\frac{\alpha_s(Q^2)}{2\pi}\hat{U}\,L^{\frac{-2}{\beta_0}\delta\hat{P}^{(0)n}}-\frac{\alpha_s(Q_0^2)}{2\pi}L^{\frac{-2}{\beta_0}\delta\hat{P}^{(0)n}}\hat{U}\}\begin{pmatrix}1\\1\end{pmatrix}, \tag{5}$$

Then ,the proton structure function can be writen as:

$$g_1^P(Q^2)=\frac{1}{2}\sum_q e_q^2\{(1+\frac{\alpha_s}{2\pi}\delta C^q_n)(\delta q^n(Q^2)+\overline{\delta q^n}(Q^2))+\frac{\alpha_s}{2\pi}2\delta C^g_n\delta g^n(Q^2)\}\,, \tag{6}$$

Solutions of eq. (5) and (6), give ppdf in mellin space. Utilizing an inverse mellin transformation [6] we can derive ppdf of a valon in z space.
In the above equation, we choose $Q_0^2 = 1$ and $\Lambda_{QCD}^2 = 0.235 Gev^2$.

From (7) we can derive structure function for each valon as:

$$g_1^U = (1 + \frac{\alpha_s(Q^2)}{2\pi}\delta C_q^n)\frac{2}{9}\delta q^{NS} + \frac{\alpha_s(Q^2)}{2\pi}\frac{2}{3}\delta C_g^n \delta g^n, \qquad (7)$$

$$g_1^D = (1 + \frac{\alpha_s(Q^2)}{2\pi}\delta C_q^n)\frac{1}{18}\delta q^{NS} + \frac{\alpha_s(Q^2)}{2\pi}\frac{2}{3}\delta C_g^n \delta g^n \quad ,$$

We should notice that sea quark polarization in our calculation turns out to be consistent with zero in valon level. Sea quark polarization in a valon is very small, So we do not require any considerable sea contribution to the structure of proton, a fact that has already been confirmed by experiment. [7]

See the parameters of my fit for $\delta G^{U(D)}(y)$ as an example in the table [1]:

$$\delta G^{U(D)}(y) = f^{U(D)}(y) G^{U(D)} = a_j y^{b_j}(1-y)^{c_j}(1 + d_j y^{0.5} + e_j y + f_j y^2 + g_j y^3) \qquad (8)$$

$G^{U(D)}$ is valon wave function for un-polarized case [5].

Valon type	**a**	**b**	**c**	**d**	**e**	**f**	**g**
U valon	*3.462*	*0.2039*	*1.031*	*-2.233*	*2.441*	*-2.383*	*1.177*
D valon	*-0.2668*	*-0.4193*	*3.1594*	*-1.0498*	*7.3359*	*0.1266*	*-1.9494*

Table 1: fit parameters for $\delta G^{U(D)}(y)$.

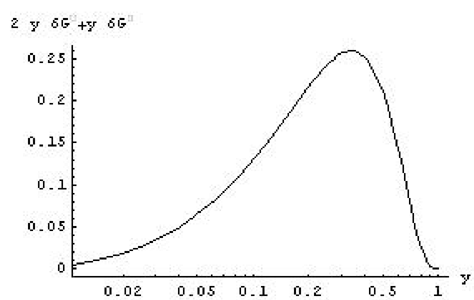

Figure1. Plot of valon helicity distributions

Also we can derive ppdf in proton and in moment space as:

$$\delta u_v(n,Q^2) = 2\delta q_{NS}^n(Q^2)\delta G^{U(n)},$$

$$\delta d_v(n,Q^2) = \delta q_{NS}^n(Q^2)\delta G^{D(n)} \quad , \qquad (9)$$

$$\delta g(n,Q^2) = \delta g^n(Q^2)(2\delta G^{U(n)} + \delta G^{D(n)}),$$

With an inverse mellin transformation we can derive ppdf in proton and in x-space too (See PPDF in valon frame work in Figure 2 below)

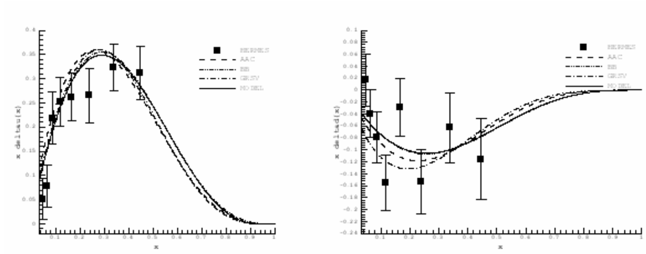

Figure2. Plot of valence distribution function in proton for $Q^2 = 2.5Gev^2$.
Compare results with other theoretical models

After calculating of PPDF, one can derive structure function of proton.(See the result in Figure 3 below)

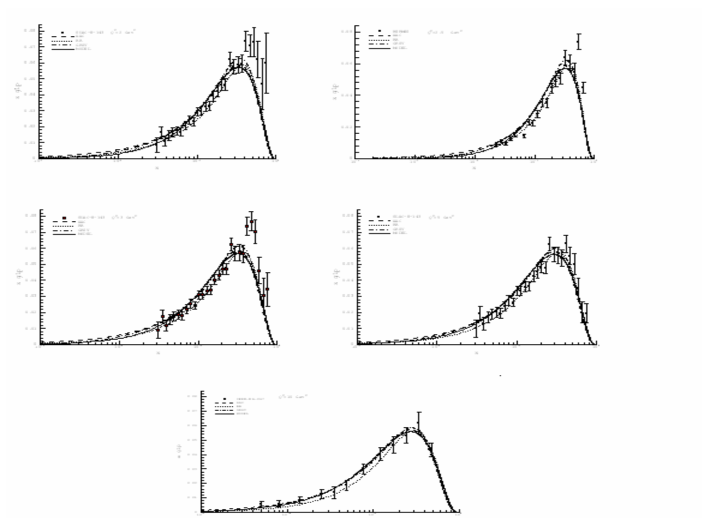

Figure3. Plot of proton structure functions

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