THE EFFECT OF POLARIZED DIS HADRONIZATION PROCESS ON THE DETERMINATION OF POLARIZED PARTON DISTRIBUTIONS*

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We present our new determination of polarized PDFs of the nucleon at NLO accuracy performing a QCD fit on the global set of newest combined inclusive deep inelastic scattering (DIS) and the semi-inclusive polarized deep inelastic scattering (SIDIS) data. Considering SIDIS data, which comes from the hadronization of polarized DIS process, helps us to break SU(2) and SU(3) symmetry and light sea-quark decomposition happens. Our results are compared with the most precise theoretical models obtained by recent analyses.

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1. Introduction

One of the major goals of quantum chromodynamics (QCD) in the recent years has been the particular investigation of the spin structure of the nucleon. In this regard, extraction of polarized parton distribution functions (PPDFs) from polarized deep inelastic scattering experiments spread very fast [1–4]. Considering the hadronization process in the final state, semi-inclusive deep inelastic scattering experimental data have been included in the recent analysis by theoretical groups [5–7]. The extracted valence quarks PPDFs slightly differ in various analysis but the sea quarks and gluon PPDFs are more different due to datasets selection, parametrization forms of PPDFs

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and also the method of evolution and QCD analysis. We have studied the effect of different PPDFs and the spin physics on the determination of fragmentation functions in Ref. [8].

In our latest analysis, we utilized the inclusive DIS data to determine PPDFs based on Jacobi polynomials with flavor symmetric light sea distribution, *i.e.* $\delta\bar{u} = \delta\bar{d} = \delta\bar{s} = \delta s$ [4]. Now, we consider light sea-quark decomposition and focus on the effect of SIDIS data on determination of PPDFs [7], specially sea-quarks distribution separation which was not considered in our last analysis on DIS data.

This paper is organized as follows. In Sec. 2 we present QCD analysis including the relationship between polarized structure functions and asymmetry data as observables and the parametrization form of PPDFs. The fitting procedure and global χ^2 minimization for asymmetry data are discussed in Sec. 3. Finally, we present the results of our fit to the data and comparison with other models in Sec. 4.

2. NLO QCD analysis

The idea behind our global analysis is to extract the universal PPDFs entering factorized cross sections by optimizing the agreement between the measured experimental data and the corresponding theoretical calculations. This process is done through the variation of the PPDFs shapes. In our QCD analysis, we perform fit procedure on A_1 or g_1/F_1 for DIS data

$$A_1\left(x,Q^2\right) = \frac{g_1\left(x,Q^2\right)}{F_1\left(x,Q^2\right)}\left(1+\gamma^2\right) , \tag{1}$$

here $g_1(x,Q^2)$ is the polarized structure function which can be written in NLO approximation as [9]

$$g_1\left(x,Q^2\right) = \frac{1}{2}\sum_{q,\bar{q}}^{n_{\rm f}} e_q^2 \left\{\left[1+\frac{\alpha_{\rm s}}{2\pi}\delta C_q\right]\otimes\delta q\left(x,Q^2\right)+\frac{\alpha_{\rm s}}{2\pi}\,2\delta C_g\otimes\delta g\left(x,Q^2\right)\right\} , \tag{2}$$

where e_q is the charge of the quark flavor and $\{\delta q, \delta\bar{q}, \delta g\}$ are the polarized quark, anti-quark, gluon distributions and $\delta C_{q,g}$ are the corresponding Wilson coefficient functions, respectively. The unpolarized structure function $F_1(x,Q^2)$ can be obtained from experimental group calculation [7].

After the hadronization process, charged hadrons are the particle detected in semi-inclusive polarized deep inelastic experiments in addition to the scattered lepton. Thus, the asymmetry in SIDIS experiments for the production of the hadron h is

$$A_{1N}^h\left(x,z,Q^2\right) = \frac{g_{1N}^h\left(x,z,Q^2\right)}{F_{1N}^h\left(x,z,Q^2\right)} . \tag{3}$$

The SIDIS polarized structure function $g_{1N}^h(x,z,Q^2)$ has the following form in NLO approximation

$$g_{1N}^h\left(x,z,Q^2\right) = \frac{1}{2}\sum_{q,\bar{q}}^{n_\mathrm{f}} e_q^2 \Bigg\{ \Bigg[\delta q \left(1 + \otimes \frac{\alpha_\mathrm{s}(Q^2)}{2\pi}\delta C_{qq}\otimes\right) D_q^h$$
$$+\delta q \otimes \frac{\alpha_\mathrm{s}(Q^2)}{2\pi}\delta C_{gq}^{(1)} \otimes D_g^h + \delta g \otimes \frac{\alpha_\mathrm{s}(Q^2)}{2\pi}\delta C_{qg}^{(1)} \otimes D_q^h\Bigg]\left(x,z,Q^2\right)\Bigg\}\,, \tag{4}$$

where δq denotes polarized parton distributions, $\delta C_{ij}^{(1)}(x,z)$ and $C_{ij}^{(1)}(x,z)$, $i,j = q,g$ are Wilson coefficient functions. Also $D_{q,\bar{q}}^h$, D_g^h denote the corresponding fragmentation functions and n_f presents the number of active flavors which we take $n_\mathrm{f} = 3$ in the present analysis. The full form of SIDIS unpolarized structure function $F_{1N}^h(x,z,Q^2)$ is available in Ref. [5].

In our analysis, we choose an initial scale for the evolution of $Q_0^2 = 1$ GeV^2 and assume the PPDFs to have the following functional form

$$x\,\delta q = \mathcal{N}_q \eta_q x^{a_q}(1-x)^{b_q}\left(1 + c_q x^{0.5} + d_q x\right)\,, \tag{5}$$

with $\delta q = \delta u + \delta\bar{u}$, $\delta d + \delta\bar{d}$, $\delta\bar{u}$, $\delta\bar{d}$, $\delta\bar{s}$ and δg. The normalization constants $\mathcal{N}_q$ are chosen such that η_q are the first moments of $\delta q(x,Q_0^2)$, we also assume $\delta s(x,Q^2) = \delta\bar{s}(x,Q^2)$ throughout the analysis. To control the behavior of PPDFs, we have to consider some extra constraints on parameter space which are well described in Ref. [7].

Generally, PPDFs analyses use two well-known sum rules relating the first moments of PPDFs to F and D quantities which are evaluated in neutron and hyperon β-decays [7]. Since we do not focus on flavor symmetry and we have $\delta\bar{u} \neq \delta\bar{d} \neq \delta s$, we can use the following form of these two equations

$$\begin{aligned} \Delta u + \Delta\bar{u} &= 0.9275 + \Delta s + \Delta\bar{s}\,, \\ \Delta d + \Delta\bar{d} &= -0.3415 + \Delta s + \Delta\bar{s}\,, \end{aligned} \tag{6}$$

and we apply the above relations in our analysis.

3. Global χ^2 minimization

Our analysis is carried out using the QCD-PEGASUS program [10] for the evolution of distributions in N-moment space and the MINUIT package [11] for the minimization of χ^2 function

$$\chi^2 = \sum_i \left(\frac{A_{1,i}^\mathrm{exp} - A_{1,i}^\mathrm{theor}}{\Delta A_{1,i}^\mathrm{exp}}\right)^2\,, \tag{7}$$

where $A_{1,i}^{\rm exp}$, $\Delta A_{1,i}^{\rm exp}$, and $A_{1,i}^{\rm theor}$ are the experimental measured value, the experimental uncertainty and theoretical value for the $i^{\rm th}$ data point, respectively. Currently present available SIDIS data are not precise enough to determine strong coupling constant at input scale, so according to the precise scale dependent equation of $a_{\rm s} = \frac{\alpha_{\rm s}}{4\pi}$ used in PEGASUS in NLO [10], we fixed $\alpha_{\rm s}(Q_0^2) = 0.580$ which is corresponding to $\alpha_{\rm s}(M_Z^2) = 0.119$, obtained from MRST02 analysis [7]. We work in the fixed-flavor number scheme $n_{\rm f} = 3$ with massless partonic flavors. Finally, we minimize the χ^2 with 17 unknown parameters and obtained $\chi^2/{\rm d.o.f.} = 1171.571/1132 = 1.03$. The used DIS and SIDIS data and the obtained parameters are presented in Ref. [7].

4. The impact of SIDIS data in determining the polarized parton distributions

We present the polarized parton distributions and their comparison to the results from other models [1, 5, 6] at input scale $Q_0^2 = 1$ GeV^2 in Fig. 1. Examining the distributions of $x(\delta u + \delta\bar{u})$ and $x(\delta d + \delta\bar{d})$, we see that all of

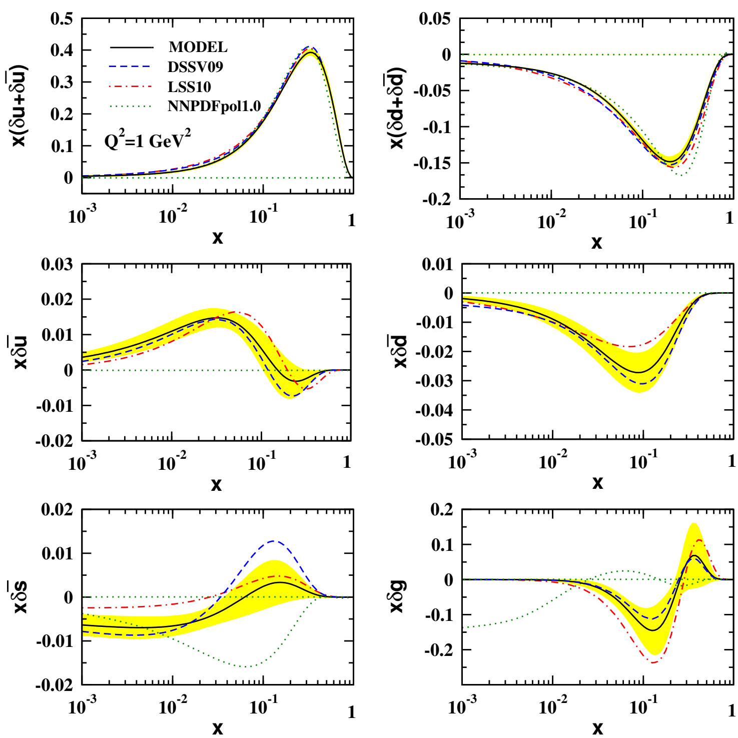

Fig. 1. The result of our analysis for quark helicity distributions at $Q_0^2 = 1$ GeV^2 in comparison with DSSV09 [6], LSS10 [5] and unbiased NNPDFpol1.0 [1].

the fits are in good agreement. The curves of $x\delta\bar{u}$ and $x\delta\bar{d}$ distributions are very close, specially our model and DSSV09. $x\delta\bar{d}$ is negative for any x in the measured x region, while $x\delta\bar{u}$ passes zero around $x = 0.1$–0.2 and becomes negative for large x for all the three models. The main difference between the presented model, LSS10 and DSSV09 sets for the strange sea-quark density $x\delta s$ is that LSS10 is less negative than others for $x < 0.03$, also both of current models and LSS10 are less positive than DSSV09 for $x > 0.03$. The other differences of the distributions come from the different number of data (we use the most and the newest ones), especially DSSV09 uses pp collision data from RHIC which can impose important effects on the determination of parton distributions in the nucleon [6]. Recently, NNPDF perform a QCD

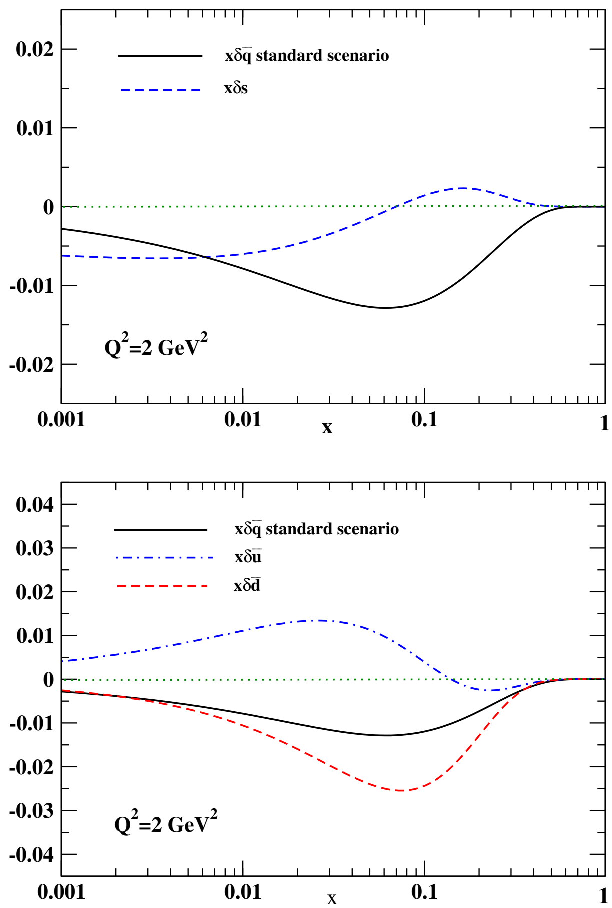

Fig. 2. The quark helicity distributions for $x\delta s$, $x\delta\bar{u}$ and $x\delta\bar{d}$ at $Q_0^2 = 2$ GeV^2 comparing to $x\delta q$ obtained from the previous standard scenario [4].

analysis on polarized inclusive DIS data [1] and, as they mentioned, they used neural networks as unbiased interpolants in their analysis. The main cause of the difference between NNPDFpol1.0 and other groups sea-quarks behavior is that NNPDF used only inclusive DIS data and they do not have sufficient information to separate the quarks and anti-quarks distributions. The NNPDFpol1.0 polarized gluon distribution is almost compatible with zero for $x > 0.01$ values, so we can conclude that the theoretical constraints on the polarized distribution also have considerable impact on the determination of gluon behavior. By considering the hadronization process of polarized DIS and employing SIDIS data, a flavor decomposition of the polarized sea quarks is obtained and the light anti-quark polarized densities $\delta\bar{u}$, $\delta\bar{d}$ and $\delta s = \bar{s}$ are determined separately, Fig. 2 shows the difference between δs, $\delta\bar{u}$ and $\delta\bar{d}$ in the current analysis comparing to $x\delta q$ obtained from the previous standard scenario [4].

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