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New theoretical method of the quark helicity distributions extraction in NLO QCD

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Abstract

It is proposed the modification of the Jacobi polynomial expansion method (MJEM) which is based on the application of the truncated (available to experiment) moments instead of the full ones. The application of MJEM with respect to quark helicity distributions reconstruction from the SIDIS data is considered.

One of very important topics in the modern high energy physics is the investigation of the partonic spin structure of nucleon. In this connection, nowadays, there is a huge growth of interest to semi-inclusive DIS (SIDIS) experiments with longitudinally polarized beam and target such as HERMES [1] and COMPASS [2].

It is argued (see, for example, Ref. [3]) that to obtain the reliable distributions at relatively low average Q^2 available to the modern SIDIS experiments[1], the leading order (LO) analysis is not sufficient and next to leading order analysis (NLO) is necessary. In ref. [4] the procedure allowing the direct extraction from the SIDIS data of the first moments (truncated to the accessible for measurement x_B region) of the quark helicity distributions in NLO QCD was proposed. However, in spite of the special importance of the first moments, it is certainly very desirable to have the procedure of reconstruction in NLO QCD of the polarized densities themselves. At the same time, it is extremely difficult to extract the local in Bjorken x distributions directly, because of the double convolution product entering the NLO QCD expressions for semi-inclusive asymmetries (see [4] and references therein). Fortunately, operating just as in ref. [4], one can directly extract not only the first moments, but the Mellin moments of any required order. In turn, using the truncated moments of parton distribution functions (PDFs) and applying the modified Jacobi polynomial expansion method (MJEM) proposed in Ref. [5] one can reconstruct PDFs themselves in the entire accessible for measurement Bjorken x region.

The proposed in Ref. [5] modified Jacobi polynomial expansion method is the expansion of the PDF $F(x)$ in the series

$$F(x) \simeq F_{N_{max}}(x) = \left(\frac{x-a}{b-a}\right)^{\beta}\left(1-\frac{x-a}{b-a}\right)^{\alpha}$$
$$\times \sum_{n=0}^{N_{max}} \Theta_n^{(\alpha,\beta)}\left(\frac{x-a}{b-a}\right)\sum_{k=0}^{n} c_{nk}^{(\alpha,\beta)}\frac{1}{(b-a)^{k+1}}\sum_{l=0}^{k}\frac{k!}{l!(k-l)!}M'[l+1](-a)^{k-l}, \qquad (1)$$

[1]For example, HERMES data [1] on semi-inclusive asymmetries is obtained at $Q^2_{average} = 2.5 GeV^2$

over the Jacobi polynomials $\Theta_n^{(\alpha,\beta)}$ and the truncated to accessible for measurement x_B region $[a,b]$ moments $M'[j] \equiv M'_{[a,b]}[j] \equiv \int_a^b dx x^{j-1} F(x)$. The later is of especial importance since the full Mellin moments $M[j] \equiv \int_0^1 dx x^{j-1} F(x)$ entering the usual Jacobi polynomial expansion method (JEM) [6–9] are unavailable while the substitution in the usual JEM the truncated moments instead of the full ones leads to the strong deviation [5] of the reconstructed $F_{N_{max}}(x)$ from $F(x)$. On the contrary, all numerical tests demonstrate [5] that for the truncated region MJEM yields much better accuracy of the input parametrization reconstruction in comparison with JEM. Thus, dealing with the truncated, available to measurement, x_B region one should apply the proposed MJEM to obtain the reliable results on the local distributions.

Let us now apply MJEM to the HERMES SIDIS data on the pion production. Here we would like just to test the applicability of MJEM to the experimental data, so that, for a moment, we do not like to deal with the such poorly known objects such as $D_s^{K^\pm}$ and D_g^h fragmentation functions. From this point of view the most attractive objects are the difference asymmetries (see [4] and references therein), where the fragmentation functions are cancel out in the leading order, while in the next to leading order the difference asymmetry has only weak dependence of the difference of the favored and unfavored fragmentation functions (known with a good precision). At the same time the difference asymmetries are still not constructed[3]. So, let us apply a trick and to express the difference asymmetries

$$A_{p(d)}^{\pi^+-\pi^-} = \frac{1}{P_B P_T f D} \frac{(N_{\uparrow\downarrow}^{\pi^+} - N_{\uparrow\downarrow}^{\pi^-}) - (N_{\uparrow\uparrow}^{\pi^+} - N_{\uparrow\uparrow}^{\pi^-})}{(N_{\uparrow\downarrow}^{\pi^+} - N_{\uparrow\downarrow}^{\pi^-}) + (N_{\uparrow\uparrow}^{\pi^+} - N_{\uparrow\uparrow}^{\pi^-})} \quad (2)$$

via the standard virtual photon SIDIS asymmetries

$$A_{p(d)}^{\pi^\pm} = \frac{1}{P_B P_T f D} \frac{N_{\uparrow\downarrow}^{\pi^\pm} - N_{\uparrow\uparrow}^{\pi^\pm}}{N_{\uparrow\downarrow}^{\pi^\pm} + N_{\uparrow\uparrow}^{\pi^\pm}},$$

which were measured by HERMES [1]. Namely, the difference asymmetries, Eq. (2), can be rewritten as

$$A_{p(d)}^{\pi^+-\pi^-} = \frac{R}{R-1} A_{p(d)}^{\pi^+} - \frac{1}{R-1} A_{p(d)}^{\pi^-}, \quad (3)$$

where the ratio

$$R^{\pi^+/\pi^-} \equiv N^{\pi^+}/N^{\pi^-}, \quad N^{\pi^\pm} \equiv N_{\uparrow\downarrow}^{\pi^\pm} + N_{\uparrow\uparrow}^{\pi^\pm}$$

is taken from the unpolarized SIDIS data. This quantity is well known (much better than the fragmentation functions). We take its value from the LEPTO generator of unpolarized

[3]At present the such analysis is performed by HERMES collaboration

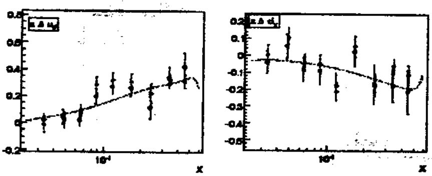

Figure 1. The results of LO reconstruction of $\Delta u_V(x)$ and $\Delta d_V(x)$. The closed circles correspond to the HERMES LO analysis [1]. The open circles correspond to direct LO extraction from the difference asymmetries constructed applying Eq. (3). The solid curves correspond to reconstruction with MJEM ($N_{max} = 4$).

events [11], which reproduces the results on this quantity obtained by EMC collaboration [12]. First, for the sake of testing, we reconstruct the local valence distributions in the leading order. The results are presented in Fig. 1. One can see that reconstructed with MJEM curve is in a good agreement with both HERMES results and with the results of direct LO extraction from the difference asymmetries constructed with the application of Eq. (3).

Thus, the proposed Eq. (3) can be successfully applied, at least for the preliminary analysis. The results of NLO reconstruction with MJEM of Δu_V and Δd_V from the difference asymmetries given by Eq. (3) are presented in Fig. 2 in comparison with the respective LO results. It is seen that the behavior of NLO and LO curves with respect to each other is in agreement with the predictions of existing parametrizations (see, for example, [10]).

Thus, all tests confirm that the proposed modification of the Jacobi polynomial expansion method, MJEM, allows to reconstruct with a high precision the quark helicity distributions in the accessible for measurement x_B region. The performed preliminary analysis of the HERMES data on the pion production gives the reliable results on the valence quark helicity distributions, which are in accordance with the leading order HERMES results as well as with the existing NLO parametrizations on these quantities. Thus, MJEM occurs successful with respect to NLO extraction of the valence PDFs. In future we also plan to apply MJEM to NLO QCD extraction of the sea and strange quark helicity distributions from the published HERMES data and expected COMPASS data on the SIDIS asymmetries with the pion and kaon production.

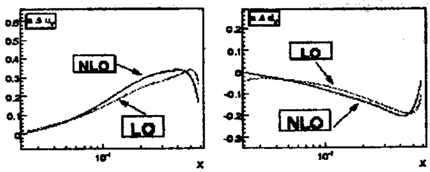

Figure 2. The results of Δu_V and Δd_V NLO reconstruction with MJEM from the HERMES data in comparison with the respective LO results.

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