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HIGH TWIST CONTRIBUTION TO THE LONGITUDINAL STRUCTURE FUNCTION F_L AT HIGH X

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Abstract

Alekhin S.I. High twist contribution to the longitudinal structure function F_L at high x: IHEP Preprint 99-3. – Protvino, 1999. – p. 13, figs. 5, tables 5, refs.: 21.

We perform the NLO QCD fit to the combined SLAC-BCDMS-NMC DIS data at high x. The model independent x-shape of high twist contribution to structure function F_L is extracted. The twist-4 contribution is found to be in a qualitative agreement with the predictions of infrared renormalon model. The twist-6 contribution exhibits a weak trend to negative values, although as a whole it is compatible with zero within the errors.

Аннотация

Алехин С.И. Вклад высших твистов в структурную функцию F_L при больших x: Препринт ИФВЭ 99-3. – Протвино, 1999. – 13 с., 5 рис., 5 табл., библиогр.: 21.

В работе проведен совместный фит данных SLAC-BCDMS-NMC в рамках NLO QCD. Получена модельно независимая оценка x-зависимости вклада высших твистов в структурную функцию F_L. Оценка вклада операторов твиста 4 находится в качественном согласии с предсказаниями модели инфракрасного ренормалона. Вклад операторов твиста 6 смещен в отрицательные значения, хотя в целом и совместим с нулем в пределах экспериментальных ошибок.

Introduction

It is well known that on the basis of the operator product expansion the deep inelastic scattering (DIS) cross sections can be split into the leading twist (LT) and the higher twist (HT) contributions. By the moment the LT contribution had been fairly understood from both the theoretical and experimental points of view. The HT contribution is not so well explored. The theoretical investigations of the HT contribution meet with difficulties because in the region where it is most important, the perturbative QCD calculations cannot be applied. There are only semi-qualitative phenomenological models for the calculation of HT contribution. These models are often based on the phenomenological considerations and contain adjusted parameters, which are to be determined from experimental data. Unfortunately, the relevant experimental data, especially on the longitudinal structure function F_L, are sparse, come from different experiments and therefore are difficult to interpret. There are estimations of the twist-4 contribution to structure function F_2 [1,2,3], obtained from combined fits to SLAC-BCDMS and SLAC-BCDMS-NMC data [4,5,6]. Estimations of the HT contribution to F_3 were obtained in Refs. [7,8] from the fit to CCFR data [9]. These estimations are model independent, i.e. do not imply any x-dependence of HT and, hence, a phenomenological formula can be easily fitted to them. As to the experimental data on HT contribution to F_L, they are available only from the QCD motivated fits to the world data on the structure function $R = \sigma_L/\sigma_T$. The first fit of this kind was presented in Ref. [10] and was recently renewed in Ref. [11] with inclusion of the new data from experiments SLAC-E-143 and SLAC-E-140X. The world data on R were also analyzed using a QCD based model with account of HT contribution [12]. Since some models predict the HT contribution to structure function F_L, the comparison of those models with data requires extraction of the HT contribution to F_L from the data on HT contribution to R and F_2. This causes problems with interpolation between the data points and error propagation. In addition, the HT contributions to R, obtained in all these fits are model dependent, i.e. a priori suppose a certain x-dependence of HT.

1. Extraction of the HT contribution to F_L

In this paper we present the results of DIS data analysis aimed to obtain the estimation of the model independent HT contribution to F_L. The work is the continuation of our previous study [3], where the estimation of the HT contribution to F_2 has been obtained. Our consideration is limited by the region of $x > 0.3$, where the non-singlet approximation is valid. A data cut $x < 0.75$ was made to minimize influence of nuclear effects in deuterium. In the beginning the ansatz used in this work is essentially the same as in Ref. [3]. We fitted the data within the NLO QCD approximation with inclusion of target mass correction (TMC) [13] and twist-4 contribution in a factorized form:

$$F_2^{(p,d),HT}(x,Q) = F_2^{(p,d),TMC}(x,Q)\left[1 + \frac{h_2^{(p,d)}(x)}{Q^2}\right],$$

$$F_2^{(p,d),TMC}(x,Q) = \frac{x^2}{\tau^{3/2}}\frac{F_2^{(p,d),LT}(\xi,Q)}{\xi^2} + 6\frac{M^2}{Q^2}\frac{x^3}{\tau^2}\int_\xi^1 dz\frac{F_2^{(p,d),LT}(z,Q)}{z^2},$$

where $F_2^{(p,d),LT}(x,Q)$ are the LT terms,

$$\xi = \frac{2x}{1+\sqrt{\tau}}, \qquad \tau = 1 + \frac{4M^2x^2}{Q^2},$$

M is nucleon mass, x and Q^2 are regular lepton scattering variables. The LT structure functions of proton and neutron were parametrized at the initial value of $Q_0^2 = 9$ GeV^2 as follows:

$$F_2^p(x,Q_0) = A_p x^{a_p}(1-x)^{b_p}\frac{2}{N_p}$$

$$F_2^n(x,Q_0) = A_n x^{a_n}(1-x)^{b_n}\frac{1}{N_n}.$$

Here the conventional normalization factors N_p and N_n are

$$N_{p,n} = \int_0^1 dx x^{a_{p,n}-1}(1-x)^{b_{p,n}}.$$

These distributions were evolved in the NLO QCD approximation within the modified minimal subtraction ($\overline{\text{MS}}$) factorization/renormalization scheme. The functions $h_2^{(p,d)}(x)$ were parametrized in the model independent way: Their values at $x = 0.3, 0.4, 0, 5, 0.6, 0.7, 0.8$ were fitted, between these points the functions were linearly interpolated.

As compared to Ref. [3], we the added the NMC data [6] to the analysis (30 points on proton and 30 points on deuterium targets). The number of data for each experiment

and target are given in Table 1. We accounted for point-to-point correlations of data due to systematic errors analogously to our previous papers [3,8,14]. The systematic errors were convoluted into a covariance matrix

$$C_{ij} = \delta_{ij}\sigma_i\sigma_j + f_i f_j(\vec{s}_i^K \cdot \vec{s}_j^K),$$

where vectors $\vec{s}_i^K$ contain the systematic errors; index K runs through the data subsets, which are uncorrelated between each other; i and j run through the data points of these data subsets. A minimized functional has the form

$$\chi^2 = \sum_{K,i,j} (f_i/\xi_K - y_i)E_{ij}(f_j/\xi_K - y_j),$$

where $E_{i,j}$ is the inverse of $C_{i,j}$. Dimension of $\vec{s}_i^K$ differs for various data sets, the particular numbers for each experiment are given in Table 1. The factors ξ_K were introduced to allow for the renormalization of some data sets. In our analysis these factors were released for the old SLAC experiments in view of possible normalization errors discussed in Ref. [15]. As for the E-140, BCDMS, and NMC data subsets, we fixed these factors at 1 and accounted for their published normalization errors in the general covariance matrix.

Table 1. The number of data points (NDP) and the number of independent systematic errors (NSE) for the analyzed data sets.

Experiment	NDP(proton)	NDP(deuterium)	NSE
BCDMS	223	162	9
E-49A	47	47	3
E-49B	109	102	3
E-61	6	6	3
E-87	90	90	3
E-89A	66	59	3
E-89B	70	59	3
E-139	–	16	3
E-140	–	31	4
NMC	30	30	13
TOTAL	641	602	47

At the first stage of the analysis we reduced all the F_2 data, including the BCDMS and NMC ones, to the common value of R [10]. The results of the fit within this ansatz are given in Table 2, column 2. For comparison we also give the results of the analogous fit from Ref. [3], which was performed without the NMC data, in column 1. Addition of the NMC data increased the value of $\alpha_s(M_Z)$, but within one standard deviation. As a whole, the figures from column 2 are compatible with the results of earlier analysis [3].

Table 2. The results of the fits with the factorized parametrization of HT. The parameters ξ describe the renormalization of old SLAC data; $h^{p,d}_{2,(3,4,5,6,7,8)}$ are the fitted values of HT contribution at $x = 0.3, 0.4, 0.5, 0.6, 0.7, 0.8$. For the description of the columns see the text.

	1	2
A_p	0.516 ± 0.022	0.514 ± 0.021
a_p	0.765 ± 0.028	0.766 ± 0.028
b_p	3.692 ± 0.032	3.690 ± 0.032
A_n	4.8 ± 4.1	4.8 ± 3.9
a_n	0.118 ± 0.097	0.119 ± 0.095
b_n	3.51 ± 0.11	3.51 ± 0.11
$\alpha_s(M_Z)$	0.1180 ± 0.0017	0.1187 ± 0.0016
$h^p_{2,3}$	-0.120 ± 0.017	-0.122 ± 0.017
$h^p_{2,4}$	-0.046 ± 0.025	-0.054 ± 0.025
$h^p_{2,5}$	0.059 ± 0.043	0.043 ± 0.042
$h^p_{2,6}$	0.392 ± 0.076	0.363 ± 0.074
$h^p_{2,7}$	0.82 ± 0.13	0.77 ± 0.12
$h^p_{2,8}$	1.54 ± 0.25	1.47 ± 0.24
$h^d_{2,3}$	-0.123 ± 0.018	-0.125 ± 0.018
$h^d_{2,4}$	-0.003 ± 0.026	-0.012 ± 0.025
$h^d_{2,5}$	0.162 ± 0.043	0.145 ± 0.042
$h^d_{2,6}$	0.439 ± 0.076	0.410 ± 0.073
$h^d_{2,7}$	0.79 ± 0.12	0.75 ± 0.11
$h^d_{2,8}$	1.87 ± 0.26	1.81 ± 0.25
$\xi_{p,49A}$	1.016 ± 0.018	1.016 ± 0.016
$\xi_{d,49A}$	1.006 ± 0.017	1.008 ± 0.015
$\xi_{p,49B}$	1.028 ± 0.018	1.028 ± 0.015
$\xi_{d,49B}$	1.012 ± 0.017	1.013 ± 0.015
$\xi_{p,61}$	1.021 ± 0.021	1.021 ± 0.019
$\xi_{d,61}$	1.004 ± 0.019	1.006 ± 0.018
$\xi_{p,87}$	1.025 ± 0.017	1.025 ± 0.015
$\xi_{d,87}$	1.012 ± 0.017	1.013 ± 0.015
$\xi_{p,89A}$	1.028 ± 0.021	1.029 ± 0.019
$\xi_{d,89A}$	1.004 ± 0.021	1.006 ± 0.019
$\xi_{p,89B}$	1.022 ± 0.017	1.021 ± 0.015
$\xi_{d,89B}$	1.007 ± 0.017	1.008 ± 0.015
$\xi_{d,139}$	1.009 ± 0.017	1.010 ± 0.015
χ^2/NDP	1178.9/1183	1258.4/1243

The next step of our analysis was to change the form of HT contribution from the factorized to an additive one:

$$F_2^{(p,d),HT}(x,Q) = F_2^{(p,d),TMC}(x,Q) + H_2^{(p,d)}(x)\frac{1\ \mathrm{GeV}^2}{Q^2},$$

where $H_2^{(p,d)}(x)$ are parametrized in the model independent form analogously to $h_2^{(p,d)}(x)$. We preferred switching to this form because for the factorized parametrization the HT term contains a latent log factor and twist-6 contribution, originating from $F_2^{LT}(x,Q)$ and target mass corrections, respectively. In addition, this form is more convenient for comparison with some models predictions. The results of the fit with additive HT parametrization are given in column 1 of Table 3 and in Fig. 1. For comparison we also give the value of $F_2^{TMC}(x,Q)\cdot h_2(x)$ for the fit from column 2 of Table 2 with the factorized form of HT, calculated at $Q^2 = 2.5$ GeV^2. One can see that the switching of the form leads to a small decrease of HT terms at high x. Besides, their errors became smaller, meanwhile the errors of other parameters increased. We connect this effect with the fact that the additive HT form is not so constrained as the factorized one. It can also signal that the data are sensitive to deviation of the anomalous dimensions of twist-4 operators off zero (see in this connection Ref. [16]). However, as it can be concluded from Fig. 1, the statistical significance of this deviation is poor and more data at high x should be included in the analysis to clarify this point.

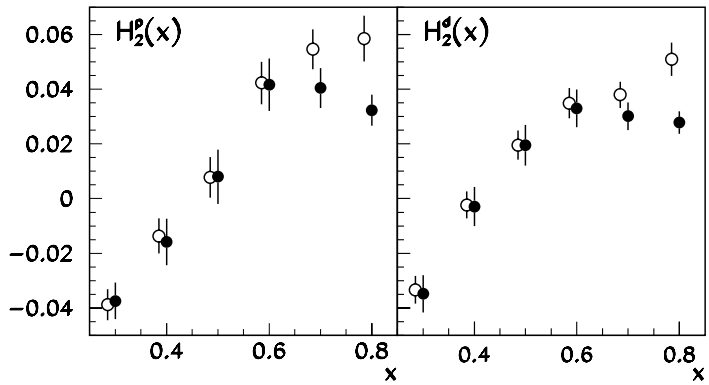

Fig. 1. The results of fits with different forms of HT contribution (full circles - additive, empty circles - factorized). For a better view the points are shifted to the left/right along the x-axis.

To extract F_L we the replaced the data on F_2 by the data on differential cross sections and fitted them using the formula

$$\frac{d^2\sigma}{dxdy} = \frac{4\pi\alpha^2(s-M^2)}{Q^4}\Big[\Big(1-y-\frac{(Mxy)^2}{Q^2}\Big)F_2^{HT}(x,Q)+$$
$$+\Big(1-2\frac{m_l^2}{Q^2}\Big)\frac{y^2}{2}\Big(F_2^{HT}(x,Q)-F_L^{HT}(x,Q)\Big)\Big],$$

where s is total c.m.s. energy, m_l is scattered lepton mass and y is lepton scattering variable. With the test purposes we first performed the fit with F_L form motivated by R_{1990} parametrization [10]:

$$F_L^{(p,d),HT}(x,Q) = F_2^{(p,d),HT}(x,Q)\Big[1-\frac{1+4M^2x^2/Q^2}{1+R(x,Q)}\Big],$$

Table 3. The results of the fits with additive parametrization of HT. The parameters ξ describe the renormalization of old SLAC data; $H^{p,d}_{2,(3,4,5,6,7,8)}$ and $H^{p,d}_{L,(3,4,5,6,7,8)}$ are the fitted values of HT contribution at $x = 0.3, 0.4, 0.5, 0.6, 0.7, 0.8$. For the description of the columns see the text.

	1	2	3
A_p	0.478 ± 0.021	0.485 ± 0.023	0.486 ± 0.022
a_p	0.830 ± 0.034	0.816 ± 0.037	0.817 ± 0.035
b_p	3.798 ± 0.043	3.791 ± 0.047	3.792 ± 0.045
A_n	4.8 ± 4.5	4.8 ± 4.8	4.7 ± 4.7
a_n	0.12 ± 0.11	0.12 ± 0.13	0.12 ± 0.12
b_n	3.58 ± 0.14	3.59 ± 0.15	3.58 ± 0.14
$\alpha_s(M_Z)$	0.1190 ± 0.0021	0.1170 ± 0.0021	0.1170 ± 0.0021
$H^p_{2,3}$	-0.0374 ± 0.0067	-0.0303 ± 0.0068	-0.0273 ± 0.0067
$H^p_{2,4}$	-0.0159 ± 0.0085	-0.0031 ± 0.0084	-0.0059 ± 0.0082
$H^p_{2,5}$	0.0080 ± 0.0099	0.0176 ± 0.0096	0.0189 ± 0.0095
$H^p_{2,6}$	0.0416 ± 0.0096	0.0497 ± 0.0095	0.0494 ± 0.0092
$H^p_{2,7}$	0.0404 ± 0.0073	0.0529 ± 0.0077	0.0501 ± 0.0073
$H^p_{2,8}$	0.0323 ± 0.0057	0.0376 ± 0.0081	0.0400 ± 0.0070
$H^d_{2,3}$	-0.0348 ± 0.0068	-0.0205 ± 0.0066	-0.0221 ± 0.0065
$H^d_{2,4}$	-0.0029 ± 0.0071	0.0057 ± 0.0069	0.0067 ± 0.0068
$H^d_{2,5}$	0.0195 ± 0.0074	0.0274 ± 0.0071	0.0269 ± 0.0070
$H^d_{2,6}$	0.0330 ± 0.0069	0.0381 ± 0.0068	0.0380 ± 0.0067
$H^d_{2,7}$	0.0301 ± 0.0050	0.0363 ± 0.0051	0.0372 ± 0.0050
$H^d_{2,8}$	0.0278 ± 0.0041	0.0354 ± 0.0061	0.0341 ± 0.0053
$H^p_{L,3}$	–	0.045 ± 0.027	–
$H^p_{L,4}$	–	0.036 ± 0.024	–
$H^p_{L,5}$	–	-0.009 ± 0.023	–
$H^p_{L,6}$	–	-0.012 ± 0.017	–
$H^p_{L,7}$	–	0.020 ± 0.013	–
$H^p_{L,8}$	–	0.004 ± 0.019	–
$H^d_{L,3}$	–	0.106 ± 0.016	0.095 ± 0.014
$H^d_{L,4}$	–	0.044 ± 0.013	0.049 ± 0.012
$H^d_{L,5}$	–	0.0343 ± 0.0089	0.031 ± 0.0087
$H^d_{L,6}$	–	0.009 ± 0.010	0.0068 ± 0.0094
$H^d_{L,7}$	–	0.0161 ± 0.0078	0.0195 ± 0.0069
$H^d_{L,8}$	–	0.021 ± 0.018	0.016 ± 0.013
$\xi_{p,49A}$	1.013 ± 0.016	1.017 ± 0.016	1.017 ± 0.016
$\xi_{d,49A}$	1.005 ± 0.015	1.007 ± 0.015	1.009 ± 0.015
$\xi_{p,49B}$	1.023 ± 0.015	1.039 ± 0.016	1.031 ± 0.015
$\xi_{d,49B}$	1.010 ± 0.015	1.011 ± 0.015	1.014 ± 0.015
$\xi_{p,61}$	1.017 ± 0.019	1.026 ± 0.019	1.028 ± 0.019
$\xi_{d,61}$	1.004 ± 0.018	1.018 ± 0.018	1.018 ± 0.018
$\xi_{p,87}$	1.019 ± 0.015	1.029 ± 0.016	1.025 ± 0.015
$\xi_{d,87}$	1.008 ± 0.015	1.007 ± 0.015	1.011 ± 0.015
$\xi_{p,89A}$	1.029 ± 0.019	1.057 ± 0.023	1.041 ± 0.020
$\xi_{d,89A}$	1.005 ± 0.019	1.011 ± 0.020	1.011 ± 0.020
$\xi_{p,89B}$	1.016 ± 0.015	1.024 ± 0.016	1.021 ± 0.015
$\xi_{d,89B}$	1.003 ± 0.015	1.004 ± 0.015	1.007 ± 0.015
$\xi_{d,139}$	1.010 ± 0.015	1.012 ± 0.015	1.014 ± 0.015
χ^2/NDP	1274.3/1223	1248.0/1243	1255.6/1243

$$R(x,Q) = \frac{b_1}{2\ln(Q/0.2)}\left[1 + \frac{12Q^2}{Q^2+1}\cdot\frac{0.125^2}{0.125^2+x^2}\right] + b_2\frac{1\ \mathrm{GeV}^2}{Q^2} + b_3\frac{1\ \mathrm{GeV}^4}{Q^4+0.3^2}$$

with a fitted parameters $b_{1,2,3}$. This parametrization comprises the term with log Q-behaviour, which mimic the LT contribution, and the HT terms with power Q-behaviour.

The resulting values of the parameters $b_1 = 0.100 \pm 0.042$, $b_3 = 0.46 \pm 0.11$, $b_3 = -0.14 \pm 0.18$ are in agreement with the values obtained in Ref. [10] ($b_1 = 0.064$, $b_3 = 0.57$, $b_3 = -0.35$). In our fit the twist-6 contribution to $R(x, Q)$ is compatible with zero. We can note in this connection that the correlations between the parameters are large (see Table 4) and, as a consequence, the data used in the fit have a limited potential both in separation of the twist-4/twist-6 and log/power contributions to R.

Table 4. Correlation coefficients for the parameters of the fit motivated by R_{1990} parametrization.

	b_1	b_2	b_3
b_1	1.	-0.61	0.38
b_2	-0.61	1.	-0.87
b_3	0.38	-0.87	1.

To achieve more precise determination of the HT contribution to F_L one can substitute for the LT contribution a perturbative QCD formula instead of a phenomenological log term. The leading order QCD gives for the nonsinglet case [17]:

$$F_L^{(p,d),LT}(x, Q) = \frac{\alpha_s(Q)}{2\pi}\frac{8}{3}x^2 \int_x^1 \frac{dz}{z^3} F_2^{(p,d),LT}(z, Q).$$

We performed the fit using the QCD expression for F_L with account of TMC

$$F_L^{(p,d),TMC}(x, Q) = F_L^{(p,d),LT}(x, Q) + \frac{x^2}{\tau^{3/2}}\frac{F_2^{(p,d),LT}(\xi, Q)}{\xi^2}(1-\tau) +$$

$$+\frac{M^2}{Q^2}\frac{x^3}{\tau^2}(6-2\tau)\int_\xi^1 dz \frac{F_2^{(p,d),LT}(z, Q)}{z^2}$$

and the additive form of HT contribution to F_L, i.e.

$$F_L^{(p,d),HT}(x, Q) = F_L^{(p,d),TMC}(x, Q) + H_L^{(p,d)}(x)\frac{1\ \mathrm{GeV}^2}{Q^2},$$

where $H_L^{(p,d)}(x)$ is parametrized in the model independent form analogously to $H_2^{(p,d)}(x)$ and $h_2^{(p,d)}(x)$. The results of this fit are given in column 2 of Table 3 and in Fig. 2. One can see that with the model independent parametrization of HT contribution to F_L the renormalization factors for the old SLAC data increased noticeably. We remind in this connection that in the source paper [15] these data were renormalized using the data of the dedicated SLAC-E-140 experiment. Since the latter did not reported a data on proton target, renormalization of the proton data was performed using bridging through the SLAC-E-49B data. There is no possibility to conclusively choose between our renormalization scheme and the one used in Ref. [15]. More proton data are necessary to adjust the old SLAC results. As to the deuterium data, their normalization factors do not practically deviate from 1. The errors of $H_L^d(x)$, due to the SLAC-E-140 deuterium data, are significantly smaller than for $H_L^p(x)$. In view of large errors of the latter, the

HT contributions to F_L for proton and deuterium are compatible within the errors and we performed one more fit imposing the constraint $H_L^p(x) = H_L^d(x)$. The results of this fit are given in column 3 of Table 3 and in Fig. 2. One can see that χ^2 obtained in this fit is practically equal to the value of χ^2, obtained in the fit without constraints, minus the number of additional parameters. Comparison with Fig. 1 shows that if F_L is fitted, the HT contribution to F_2 slightly growth. The value of strong coupling constant is insensitive to the constraint imposing. Their value

$$\alpha_s(M_Z) = 0.1170 \pm 0.0021(\text{stat} + \text{syst}),$$

correspond to

$$\Lambda^{(3)}_{\overline{MS}} = 337 \pm 29(\text{stat} + \text{syst})\ \text{MeV},$$

obtained at $Q^2 = 2$ GeV^2 with the help of relation

$$\alpha_s(Q) = \frac{2\pi}{\beta_0 \ln(Q/\Lambda)}\Big[1 - \frac{2\pi}{\beta_0 \beta}\frac{\ln(2\ln(Q/\Lambda)}{\ln(Q/\Lambda)}\Big],$$

where

$$\beta_0 = 11 - \frac{2}{3}n_f, \qquad \beta = \frac{2\pi\beta_0}{51 - \frac{19}{3}n_f}$$

and $n_f = 3$.

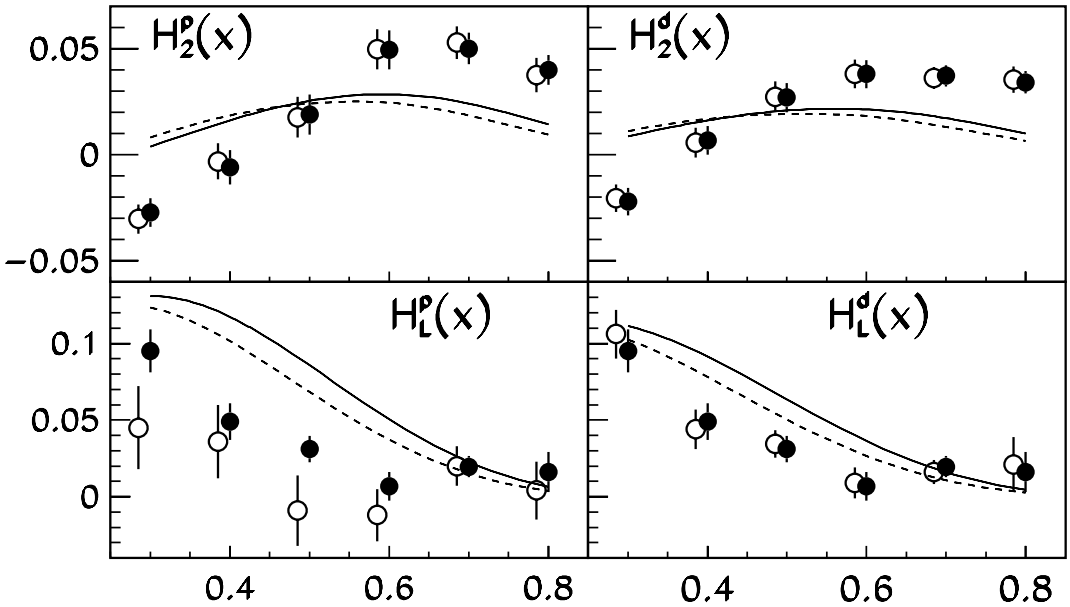

Fig. 2. The values of $H_2(x)$ and $H_L(x)$ from the fits with model independent form of HT contribution to F_L (empty circles – the unconstrainted fit, full circles – the fit with constraint $H_L^d(x) = H_L^p(x)$). For a better view the points are shifted to the left/right along the x-axis. The curves are predictions of the IRR model for $Q^2 = 2$ GeV$^2, n_f = 3$ (full lines) and $Q^2 = 9$ GeV$^2, n_f = 4$ (dashed lines).

We checked how much the analyzed data are sensitive to the twist-6 contribution to F_L. For this purpose we fitted the data with $F_L(x,Q)$ expressed as

$$F_L^{(p,d),HT}(x,Q) = F_L^{(p,d),TMC}(x,Q) + H_L(x)\frac{1\ \mathrm{GeV}^2}{Q^2} + H_L^{(4)}(x)\frac{1\ \mathrm{GeV}^4}{Q^4},$$

where functions $H_L^{(4)}(x)$ and $H_L(x)$ were the same for proton and deuterium and parametrized in the model independent way. The resulting behaviour of $H_L^{(4)}(x)$ is given in Fig. 3. One can observe a trend to negative values at highest x, but with a poor statistical significance. The χ^2 decrease in this fit is about 25 (remind that standard deviation of χ^2 is $\sqrt{2\cdot\mathrm{NDF}}$, i.e. about 40 in our analysis). These results are in correspondence with the estimates of twist-6 contribution to $R(x,Q)$ given above – the fitted twist-6 contribution to F_L is at the level of one standard deviation off zero. In our study we did not completely accounted TMC correction of the order $O(M^4/Q^4)$ and then, in a rigorous treatment, $H_L^{(4)}$ does not correspond to the pure dynamical twist-6 effects. Meanwhile, the contribution of omitted terms to $H_L^{(4)}$ estimated using a formula from Ref. [13] does not exceed 0.001 in our region of x and, hence, can be neglected.

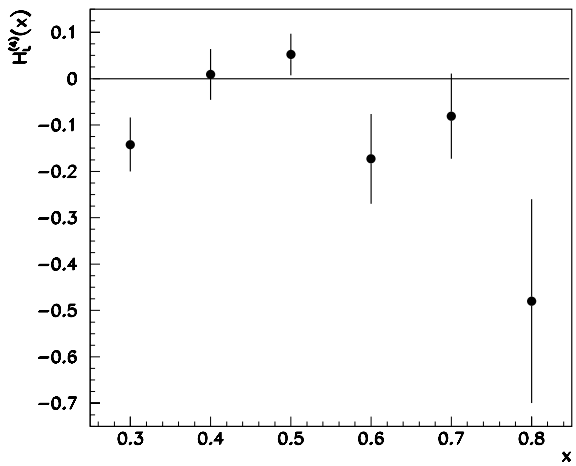

Fig. 3. The dependence of twist-6 contribution to F_L on x.

2. Comparison with other parametrizations

For comparison with other parametrizations, we calculated deuterium $R(x,Q)$ using the relation

$$R^{d,HT}(x,Q) = \frac{F_2^{d,HT}(x,Q)}{F_2^{d,HT}(x,Q) - F_L^{d,HT}(x,Q)}\left[1 + \frac{4M^2x^2}{Q^2}\right] - 1$$

and the parameters values from column 3 of Table 3. The obtained values of R are given in Fig. 4 together with the R_{1990} [10] and R_{1998} [11] parametrizations. In average all the three parametrizations coincide within errors, although our curves lie higher at the edges of x-region and lower in the middle.

The same tendency is valid for HT+TMC contribution to R, evaluated as a difference between $R^{d,HT}(x,Q)$ and $R^{d,LT}(x,Q)$, where

$$R^{d,LT}(x,Q) = \frac{F_L^{d,LT}(x,Q)}{F_2^{d,LT}(x,Q) - F_L^{d,LT}(x,Q)}.$$

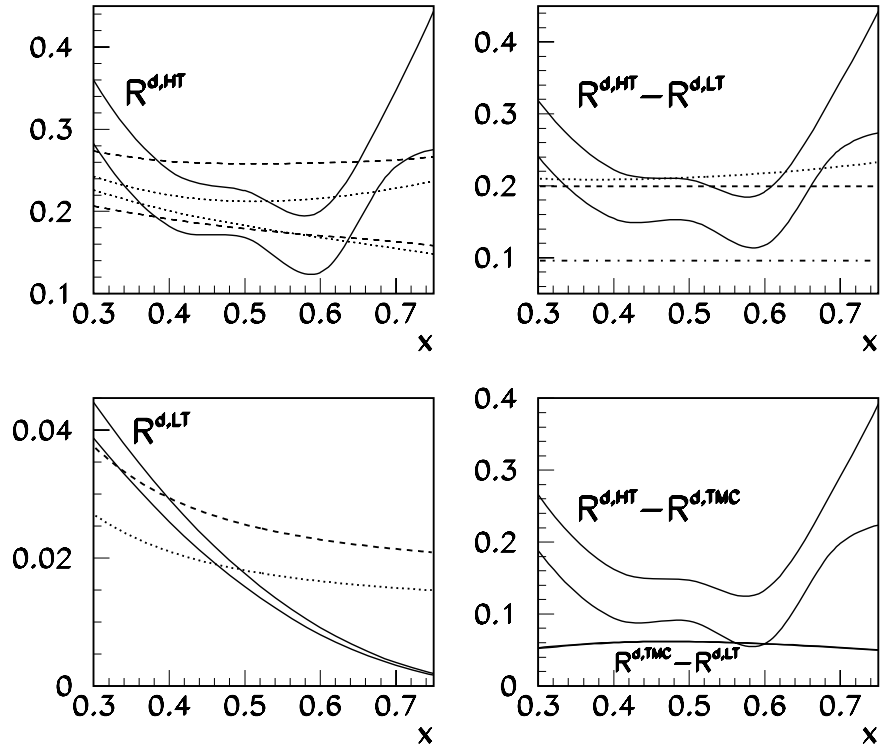

Fig. 4. One standard deviation bands for various contributions to our parametrization of $R^{d,HT}(x,Q)$ (full lines). Dashed lines correspond to the R_{1990} parametrization, dotted – to the R_{1998} one, dashed-dotted – to the BRY one [12]. All curves are given for $Q^2 = 2$ GeV^2. Our value of R is obtained as a spline interpolation between the points $x = 0.3, 0.4, 0.5, 0.6, 0.7, 0.8$.

This contribution is given in Fig. 4 together with the power parts for variants b) of the R_{1990} and R_{1998} parametrizations. Since error bands are not available for the latter, only the central values are pictured. Relative difference between log parts of the R_{1990} and R_{1998} parametrizations and our $R^{d,LT}(x,Q)$ is very large at highest x, although absolute difference is not significant due to smallness of these terms. In Fig. 4 we give the bands for TMC contribution to R, calculated as $R^{d,TMC} - R^{d,LT}$, where

$$R^{d,TMC}(x,Q) = \frac{F_2^{d,TMC}(x,Q)}{F_2^{d,TMC}(x,Q) - F_L^{d,TMC}(x,Q)}\left[1 + \frac{4M^2x^2}{Q^2}\right] - 1,$$

and the HT contribution, calculated as $R^{d,HT} - R^{d,TMC}$. (Lower and upper bands for the TMC contribution are practically indistinguishable.) It is seen that the TMC contribution is also significantly smaller at large x than the HT one, so the latter is dominating in this region. Meanwhile we should note in this connection that, as it has been observed in Ref. [7,18], account of NNLO QCD can diminish the value of HT contribution. This effect can be seen in Fig. 4, where we give a power part of R parametrization [12], obtained with a partial account of NNLO.

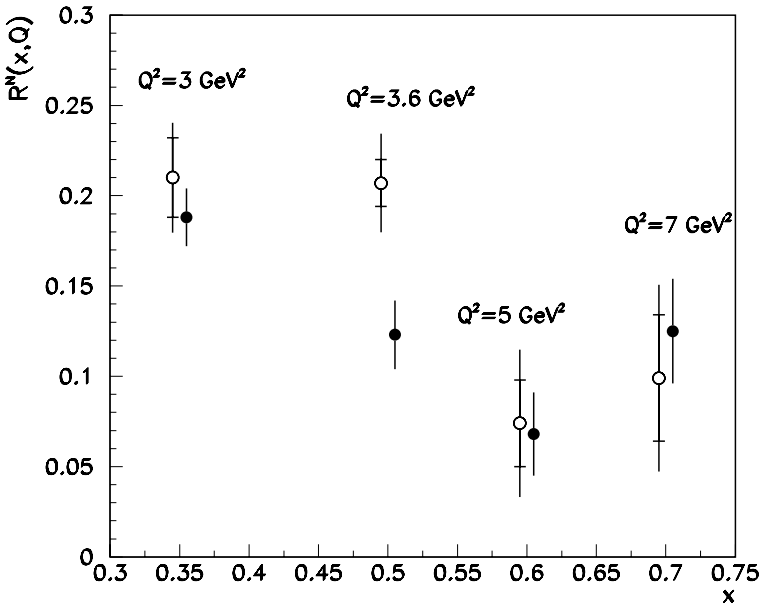

Fig. 5. The E140X data on nucleon $R(x,Q)$ (empty circles). Inner bars correspond to statistic errors, total bars – statistic and systematic ones combined in quadrature. Also are given the calculations of deuterium $R(x,Q)$ performed on our parametrization (full circles). For a better view the points are shifted to the left/right along the x-axis.

In Fig. 5 the data of SLAC-E140X experiment on nucleon $R(x,Q)$ [19], which were not included in our fit, are compared with $R^D(x,Q)$, calculated at the parameters values from column 3 of Table 3. One can observe a good agreement of the data and our parametrization. We also compared the results of the model independent analysis with predictions of an infrared renormalon model (IRR) [20]. In this model the HT x-dependence is connected with the LT x-dependence. In particular, for the nonsinglet case the twist-4 contribution is expressed as

$$H_{2,L}^{(p,d)}(x) = A_2' \int_x^1 dz C_{2,L}(z) F_2^{(p,d),LT}(x/z,Q),$$

$$C_2(z) = -\frac{4}{(1-z)_+} + 2(2+z+6z^2) - 9\delta(1-z) - \delta'(1-z),$$

$$C_L(z) = 8z^2 - 4\delta(1-z),$$

$$A_2' = -\frac{2C_F}{\beta_0}[\Lambda_R]^2 e^{-C},$$

where $C_F = 4/3$, $C = -5/3$. The normalization factor Λ_R can be considered as a fitted parameter, or, in other approach, set equal to the value of Λ_{QCD}. In Fig. 2 we give the IRR model predictions at $\Lambda_R = \Lambda_{\overline{MS}}^{(3)} = 337$ MeV, as obtained in our analysis. Parameters of LT structure functions were taken from column 2 of Table 3. One can see that the model qualitatively describes the $H_L(x)$ data. This in agreement with the curves given in Fig. 6 of Ref. [21] (remind that our value of Λ is about 1.3 times larger than one used

in Ref. [21] to calculate these curves). At the same time there is evident discrepancy between the model and the $H_2(x)$ data. In this connection we should note that $H_2(x)$ is strongly correlated with other parameters, and, in particular, with $\alpha_s(M_Z)$. In Table 5 we give a global correlation coefficients ρ_m, calculated as

$$\rho_m = \sqrt{1 - 1/e_{mm}/c_{mm}},$$

where c_{mn} is parameters error matrix, e_{mn} is its inverse and indices m, n run through the fitted parameters. The global coefficients characterize the extent of correlation of a parameter with all other parameters. (In the case of two parameters fit $\rho_1 = \rho_2$ and equal to the correlation coefficient between these parameters). From Table 5 one can see that H_L is almost uncorrelated with $\alpha_s(M_Z)$ and is correlated with other parameters less than H_2. This fact can be readily understood qualitatively. The total value of R^{HT} is defined from the y-dependence of cross sections and is weakly correlated with α_s. Then, the correlation of H_L with α_s can arise only due to the dependence of LT contribution on α_s. Since the LT contribution is small comparing with the HT one (see Fig. 4), this dependence does not cause significant correlations of the HT contribution and α_s. Due to the lower values of ρ, H_L is more stable in respect with the change of ansatz and input of fit. The shift of α_s towards higher values would not affect H_L, but can decrease H_2.

Table 5. The correlation coefficients for HT parameters and $\alpha_s(M_Z)$. Figures in parenthesis are the global correlation coefficients for HT parameters.

x	$H_2^p(x)$	$H_2^d(x)$	$H_L(x)$
0.3	-0.507(0.914)	-0.707(0.964)	-0.029(0.868)
0.4	-0.847(0.955)	-0.910(0.976)	0.122(0.852)
0.5	-0.909(0.968)	-0.944(0.987)	0.244(0.870)
0.6	-0.905(0.971)	-0.917(0.977)	0.222(0.866)
0.7	-0.871(0.972)	-0.901(0.980)	0.072(0.894)
0.8	-0.460(0.868)	-0.429(0.875)	0.156(0.870)

3. Conclusion

Thus, we have performed the NLO QCD fit to the combined SLAC-BCDMS-NMC DIS data at high x. The model independent x-shape of high twist contribution to structure function F_L is extracted. The twist-4 contribution is found to be in a qualitative agreement with the predictions of the infrared renormalon model. The twist-6 contribution exhibits a weak trend to negative values, although, as a whole is compatible with zero within the errors.

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