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STRUCTURE FUNCTION F_L: PQCD AND K_T-FACTORIZATION VERSUS EXPERIMENTAL DATA AT FIXED W

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The structure function F_L results, obtained in the k_T-factorization and collinear approaches, are compared with recent H1 experimental data at fixed W values.

The longitudinal structure function (SF) $F_L(x,Q^2)$ is a very sensitive QCD characteristic and is directly connected to the gluon content of the proton. It is equal to zero in the parton model with spin$-1/2$ partons and has got nonzero values in the framework of perturbative Quantum Chromodynamics.

The experimental extraction of F_L data requires a rather cumbersome procedure, especially at small values of x (see [1], for example). Recently, however, there have been presented new precise preliminary H1 data [2], which have probed the small-x region $10^{-5} \leq x \leq 10^{-2}$.

In the present talk we show the analysis [3] of these data based on the standard perturbative QCD formulas and on the so called k_T-factorization approach [4]. The perturbative QCD approach is called hereafter as collinear approximation and applied at LO and NLO levels using GRV parameterizations for partion densities. The corresponding coefficient functions are taken from the papers [5].

1. The unintegrated gluon distribution $\Phi_g(x,k_\perp^2)$ (f_g is the (integrated) gluon distribution in the proton multiplied by x and $k_\perp$ is the transverse part of the gluon 4-momentum k^μ)

$$f_g(x,Q^2) \; = \; \int^{Q^2} dk_\perp^2 \, \Phi_g(x,k_\perp^2) \qquad (\text{hereafter} \;\; k^2 = -k_\perp^2) \tag{1}$$

is the basic dynamical quantity in the k_T-factorization approach. It satisfies the BFKL equation.

Then, in the k_T-factorization the SF $F_{2,L}(x,Q^2)$ are driven at small x primarily by gluons and are related in the following way to $\Phi_g(x,k_\perp^2)$:

$$F_{2,L}(x,Q^2) \; = \; \int_x^1 \frac{dz}{z} \int^{Q^2} dk_\perp^2 \sum_{i=u,d,s,c} e_i^2 \cdot \hat{C}^g_{2,L}(x/z,Q^2,m_i^2,k_\perp^2) \; \Phi_g(z,k_\perp^2), \tag{2}$$

where e_i^2 are charge squares of active quarks.

The functions $\hat{C}^g_{2,L}(x, Q^2, m_i^2, k_\perp^2)$ can be regarded as SF of the off-shell gluons with virtuality $k_\perp^2$ (hereafter we call them *hard structure functions* by analogy with similar relations between cross-sections and hard cross-sections). They are described by the sum of the quark box (and crossed box) diagram contribution to the photon-gluon interaction (see, for example, Fig. 1 in [6]).

Notice that the $k_\perp^2$-integral in Eqs. (1) and (2) can be divergent at lower limit, at least for some parameterizations of $\Phi_g(x, k_\perp^2)$. To overcome the problem we change the low Q^2 asymptotics of the QCD coupling constant within hard structure functions. We apply the "freezing" procedure [7], which contains the shift $Q^2 \to Q^2 + M^2$, where M is an additional scale, which strongly modifies the infrared α_s properties. For massless produced quarks, ρ-meson mass m_ρ is usually taken as the M value, i.e. $M = m_\rho$. In the case of massive quarks with mass m_i, the $M = 2m_i$ value is usually used.

2. So, the purpose of [3] was to describe new preliminary H1 experimental data $F_L(x, Q^2)$ using our calculations of the hard SF $\hat{C}^g_{2,L}(x, Q^2, m^2, k_\perp^2)$ given in our previous study [6] and infrared modifications of $\alpha_s(Q^2)$, explained above. For $\Phi(x, k_\perp^2, Q_0^2)$ we use the Blumlein's parametrization (JB) [8].

The JB form depends strongly on the Pomeron intercept value. In different models the Pomeron intercept has different values. So, in our calculations we apply the H1 parameterization $\Delta(Q^2)$ [9], which are in good agreement with perturbative QCD.

We calculate the SF F_L as the sum of two types of contributions: the charm quark one F_L^c and the light quark one F_L^l:

$$F_L \;=\; F_L^l + F_L^c \tag{3}$$

For the F_L^l part we use the massless limit of hard SF (see [6]). We always use $f = 4$ in our fits, because our results depend very weakly on the exact f value.

In Fig. 1 we show the SF F_L with "frozen" coupling constant as a function of Q^2 for fixed W in comparison with H1 experimental data [2]. The k_T-factorization results lie between the collinear ones, that demonstrates clearly the particular resummation of high-order collinear contributions at small x values in the k_T-factorization approach.

We also see exellent agreement between the experimental data and collinear approach at NLO approximation. The NLO corrections are large and negative and decrease the F_L value by an approximate factor of 2 at $Q^2 < 10$ GeV^2.

Our k_T-factorization results are in good agreement with the data for large and small parts of the Q^2 range. We have, however, some disagreement between the data and theoretical predictions at $Q^2 \sim 3$ GeV^2. The disagreement exists in both cases: for collinear QCD approach at the LO approximation and for k_T-factorization. Comparing these results with Fig. 4 of Lobodzinska's talk in Ref. [2] we conclude that the disagreement comes from the usage of the LO approximation.

A rough estimation of the NLO corrections in the k_T-factorization approach can be done in the following way. Consider firstly the BFKL approach. A popular resummation of the NLO corrections is done in [10], which demonstrates: the basic effect of the NLO corrections is the strong rise of the α_s argument from Q^2 to $Q^2_{eff} = K \cdot Q^2$, where $K = 127$, i.e. $K >> 1$.

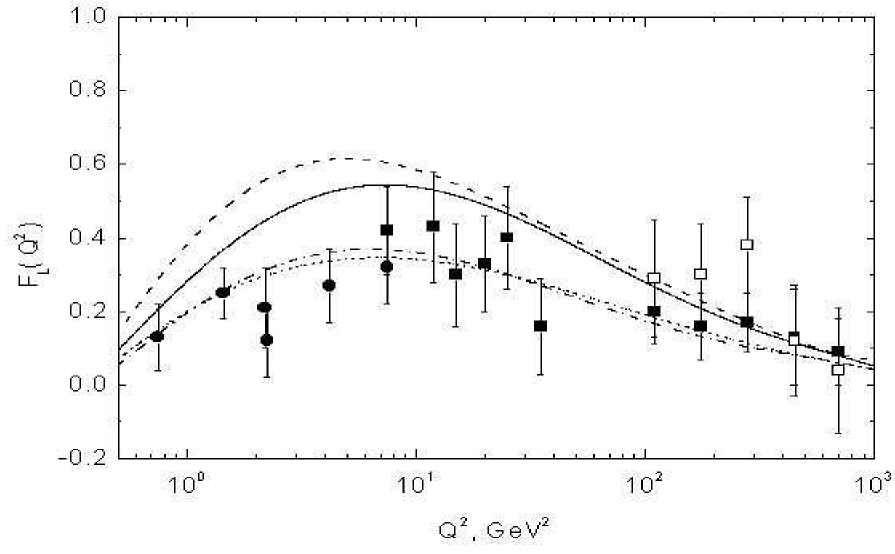

Figure 1. Q^2 dependence of $F_L(x, Q^2)$ (at fixed $W = 276$ GeV). The experimental points are from [2]. Solid curve is the result of the k_T-factorization approach, dashed, dash-dotted and dotted curves - the results of the collinear LO, NLO and LO with $\mu^2 = 127Q^2$ calculations, respectively.

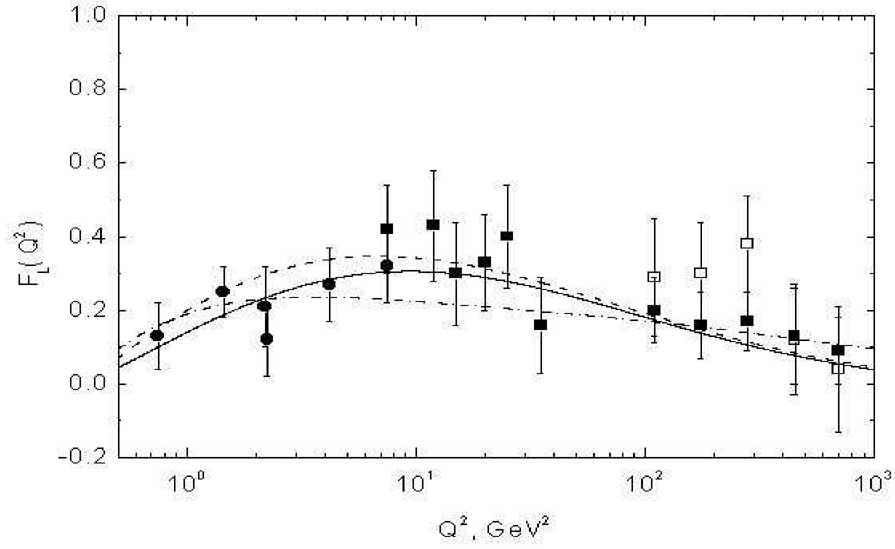

Figure 2. Q^2 dependence of $F_L(x, Q^2)$ (at fixed $W = 276$ GeV). The experimental points are as in Fig. 1. Solid curve is the result of the k_T-factorization approach at $\mu^2 = 127Q^2$, dashed curve - the collinear LO calculations at $\mu^2 = 127Q^2$, dash-dotted curve - from the R_{world}-parametrization.

The use of the effective argument Q^2_{eff} in the DGLAP approach at LO approximation leads to results which are very close to the ones obtained in the case of NLO approximation: see the dot-dashed and dotted curves in Fig. 1. Thus, we hope that the effective argument represents the basic effect of the NLO corrections also in the framework of the k_T-factorization, which in some sense lies between the DGLAP and BFKL approaches.

The results obtained in the k_T-factorization and collinear approaches based on Q^2_{eff} argument are presented in Fig. 2. There is very good agreement between the experimental data and both theoretical approaches.

Moreover, we also present in Fig.2 the F_L results based on the R_{world}-parameterization for the $R = \sigma_L/\sigma_T$ ratio (see [11]) (because $F_L = F_2 R/(1+R)$), and the F_2 parameterization from our previous paper [6]. The results are in good agreement with other theoretical predictions as well as with experimental data.

3. *Resume.* In the framework of k_T-factorization and perturbative QCD at LO and NLO approximations we have analyzed recent H1 preliminary data [2].

We have found very good agreement between the experimental data and collinear NLO results. The LO collinear and k_T-factorization results show a disagreement with the data [2] in the range $2 < Q^2 < 10$ GeV^2. It was argued that the disagreement comes from the absence of the NLO corrections. We modeled the NLO corrections in the k_T-factorization approach by choosing large effective argument of the strong coupling constant. The effective corrections significantly improve the agreement with the H1 data under consideration.

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