NEW TESTS FOR THE K_T−FACTORIZATION: HEAVY QUARK PRODUCTION AT HERA*

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We present calculations of the beauty photoproduction at HERA collider in the framework of the k_T-factorization approach.

1. Introduction

The beauty production at high energies is a subject of intensive study from both theoretical and experimental points of view. Recently H1 and ZEUS collaborations have reported important data [1–3] on the beauty photoproduction at HERA which refer to small values of the Bjorken variable x. These data are in a reasonable agreement with NLO QCD predictions or somewhat higher. Some disagreement is observed [3] mainly at small decay muon and/or associated jet transverse momenta. But the large excess of the first measurements over NLO QCD, reported by the H1 collaboration [4], is not confirmed.

The present note is summary of the results [5] obtained in the so-called k_T-factorization [6, 7] (or semi-hard [8, 9]) approach of QCD. We investigated a number of different photoproduction rates and make comparisons with the recent H1 and ZEUS data [1–3]. Both direct ($\gamma g \to b\bar{b}$) and resolved photon contributions ($gg \to b\bar{b}$) are taken into account. Our analysis covers also both inclusive and dijet associated b-quark production. In last case special attention is put on the $x_\gamma^{\rm obs}$ variable. In the numerical analysis we test different unintegrated gluon distributions (UGD).

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2. Basic ingredients and parameters

The main formulas for the total and differential beauty production cross sections (including the expressions for the off shell matrix elements) have been evaluated in the papers [10, 11]. Concerning the UGD in a proton, in the numerical calculations we used five different sets of them, namely the J2003 (set 1 — 3) [12], KMS [13] and KMR [14]. At present there is not the KMS UGD in a photon, therefore we do not take into account the resolved photon contribution in the case.

The visible theoretical uncertainties in our results connect with the choice of the factorization and renormalization scales. We choose $\mu_R = \mu_F = \mu = \sqrt{m_b^2 + \langle \mathbf{p}_T^2 \rangle}$, where $\langle \mathbf{p}_T^2 \rangle$ is set to the average $\mathbf{p}_T^2$ of the beauty quark and antiquark[a]. We take $m_b = 4.75$ GeV and use LO formula for $\alpha_s(\mu^2)$ with $n_f = 4$ at $\Lambda_{\rm QCD} = 200$ MeV, such that $\alpha_s(M_Z^2) = 0.1232$.

3. Inclusive $b-$photoproduction

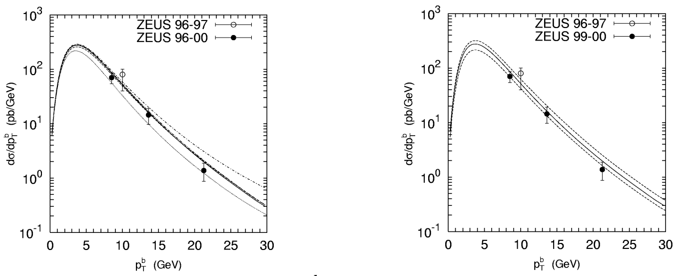

Figure 1. The cross section $d\sigma/dp_T^b$: The solid, dashed, dash-dotted, dotted and short dash-dotted curves correspond to the J2003 set 1 – 3, KMR and KMS UGDs (left panel), the curves in right panel correspond to the J2003 set 1 UGD with different scale μ^2 (see text), the exp. data are from ZEUS [1, 2].

In Fig. 1 (left panel) we show our predictions in comparison to the ZEUS data [1, 2]. One can see that overall agreement between our predictions and experimental data is a very good. We found also a some enhancement of the estimated cross sections as compared with the collinear NLO QCD calculations which lie somewhat below the measurements [1, 2]. Note that the KMR gluon distribution gives results which lie below the ZEUS data and which are very similar to the NLO QCD predictions.

[a]We use special choice $\mu^2 = \mathbf{k}_T^2$ in the case of KMS gluon, as it was originally proposed in [13].

In Fig. 1 (rigt panel) the scale dependence of the calculated cross section is investigated. Here we plot the results which correspond to the J2003 set 1 UGD with the different values of scale μ^2: $\mu^2 = m_{b\,T}^2$ (solid curve), $\mu^2 = 1/4m_{b\,T}^2$ (upper dashed curve) and $\mu^2 = 4m_{b\,T}^2$ (lower dashed curve). One can see that such scale variation changes the normalization of beauty cross section by $20 - 30\%$ approximately.

In general, we can conclude (see [5]) that the central values of cross sections calculated in the k_T-factorization formalism (with the CCFM or unified BFKL-DGLAP evolution) are larger by $30 - 40\%$ than ones calculated at NLO level of collinear QCD.

4. Dijet assosiated beauty photoproduction

Now we demonstrate how the k_T-factorization approach can be used to calculate the semi-inclusive beauty photoproduction rates. To produce muons from b-quarks in our theoretical calculations, we first convert b-quarks into B-hadrons using the Peterson fragmentation function [15] and then simulate their semileptonic decay according to the standard electroweak theory. Our default set of the fragmentation parameter is $\epsilon_b = 0.0035$. One can see that calculated cross sections (using the J2003 and KMS UGDs) agree with the H1 experimental data [3] except the low p_T^μ region ($p_T^\mu < 3$ GeV) in Fig. 2 (left panel).

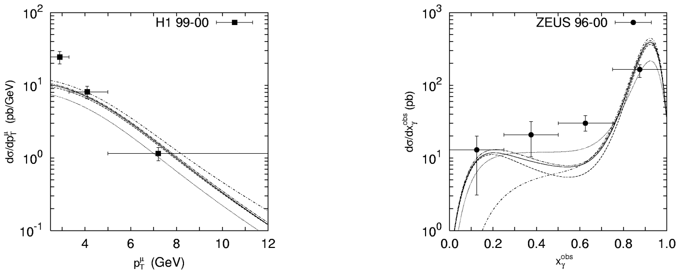

Figure 2. The cross section $d\sigma/dp_T^\mu$ for dijets with an assosiated μ from b decays (left panel): all curves are the same as in Fig. 1, the exp. data are from H1 [3]; The cross section $d\sigma/dx_\gamma^{obs}$ for dijets with an associated μ from b decays (rigt panel): all curves are the same as in Fig. 1, the exp. data are from ZEUS [2].

Note, however, that the behaviour of measured cross sections in this region is very different from each other in the H1 and ZEUS data. Our calculations give a less steep behaviour and are lower than the H1 data in the lowest momentum bin by a factor of 2.5. In contrast, a good description of the ZEUS data [2] for all values of p_T^μ is observed (see Fig. 4 in [5]).

In Figs. 9 - 12 of Ref. [5] we have show our predictions for the transverse momentum and pseudo-rapidity distributions of the $\mu-$jet and $b-$jet in comparison with the ZEUS measurement [2]. The J2003 and KMS UGDs give results which agree well with the data.

In Fig. 2 (right panel) we confront the $x_\gamma^{\rm obs}$ distributions calculated in different kinematical regions with the ZEUS data [2]. One can see that the J2003 and KMR UGDs give a reasonable description of the data but tend to slightly underestimate them at middle and low $x_\gamma^{\rm obs}$. In the case of KMS gluon this discrepancy is more significant. Therefore we can conclude that the gluon-gluon fusion contribution from resolved photon is important in description of the experimental data and that the behaviour of calculated $x_\gamma^{\rm obs}$ distributions at low values of $x_\gamma^{\rm obs}$ is strongly depends on the UGD used.

To summarise, we have shown that the k_T-factorization approach with the J2003 or KMS UGDs reproduces well the numerous HERA data on beauty production. At the same time we have obtained that the KMR formalism results in some underestimation of the cross sections. This shows the importance of a detail understanding of the non-collinear parton evolution process.

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