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HEAVY QUARK PHOTOPRODUCTION FROM k_{t}-FACTORISATION*

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The k_t-factorisation approach to production of heavy quarks at HERA and at LEP is shortly reviewed.

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1. Introduction

HERA and LEP data for inclusive beauty production show some excess of the measured cross section over the theoretical expectations based on the NLO collinear calculations in QCD. While the excess is not statistically meaningful for the HERA data on $ep \to ebX$, the discrepancy is larger than 3σ for the case of beauty production at LEP. This fact stimulated investigations of the process $e^+e^- \to e^+e^-\gamma\gamma \to b\bar{b}X$ (with almost real photons in the intermediate state) in the k_{t}-factorisation approach to high energy processes in QCD. In this framework distributions of parton transverse momenta in a hadron or in the photon are explicitly taken into account and parameterised using unintegrated parton distribution functions (UPDFs). In this talk the status of unintegrated partons in the photon and their applications to description of heavy quark production is shortly reviewed.

2. Formalism

Unintegrated gluon distribution in the photon was modeled in a few different ways. The first construction was based on the CCFM evolution equation of the gluons [1,2]. The equation takes into account the coherence

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of QCD radiation by the angular ordering of emitted partons and incorporates in both the DGLAP and the BFKL resummations. An alternative construction was performed using the Kimber–Martin–Ryskin (KMR) approach [3] which allows to determine the unintegrated parton distributions from the collinear ones. Finally the unintegrated gluon in the photon was determined [4] from a saturation model for two photon-collisions [5]. Similar methods were used before to obtain unintegrated partons in the proton.

In the $k_{\rm t}$-factorisation framework there exist the same three basic heavy quark production mechanisms in two photon collisions as in the collinear case. Thus, there is a direct (D) single resolved (1R) and double resolved contributions (2R), depending on the number of intermediate partons between the photons and the produced quarks. Let me consider the expression that defines the 2R contribution in the $k_{\rm t}$-factorisation framework as an example,

$$\sigma_{2{\rm R}}^{kf}(s) = \sum_{i,j} \int \frac{dx_1}{x_1}\frac{dx_2}{x_2}\frac{d^2\boldsymbol{k}_1}{\pi k_1^2}\frac{d^2\boldsymbol{k}_2}{\pi k_2^2} f_i(x_1,k_1^2) f_j(x_2,k_2^2) \hat{\sigma}_{ij}^{kf}(\boldsymbol{k}_1,\boldsymbol{k}_2,x_1 x_2 s) \tag{1}$$

with $f_i(x_1,k_1^2)$ being the UPDF evaluated at the longitudinal momentum fraction x_1, parton virtuality k_1^2, and s is the invariant mass squared of the photon-photon pair. The partonic cross section $\hat{\sigma}_{ij}^{kf}$ for the heavy quark pair production should be evaluated for non-zero virtualities of the partons. The off-shell effects are important mostly for gluons and the quark contribution may be evaluated using the standard collinear approximation.

3. Results

Estimates were performed in the k_t factorisation framework of the cross sections for production of charmed and beautiful quarks in ep ($\gamma^* p$) and e^+e^- ($\gamma\gamma$) (see Fig. 1). For charm production the theoretical estimates agree with the data quite well. It is true not only for the total cross sections but also for the charmed structure function $F_2^c(x,Q^2)$ data at HERA and for the $\gamma\gamma$ energy dependence of charm production at LEP. In addition, also the transverse momentum and the rapidity distribution of D^* produced at LEP is well described.

Beauty production at HERA is underestimated in the $k_{\rm t}$-factorisation framework by a factor of 1.5–2. The error bars of the data are too large, however, to claim an inconsistency. Let me note that inclusion of effects of gluon transverse momentum enhances the resolved photon cross section by a factor of about three. Still, this contribution remains much smaller than the direct photon contribution which is only moderately enhanced. Interestingly enough, the results from the k_t-factorisation (at the leading order) are rather similar to ones based on the NLO collinear calculations.

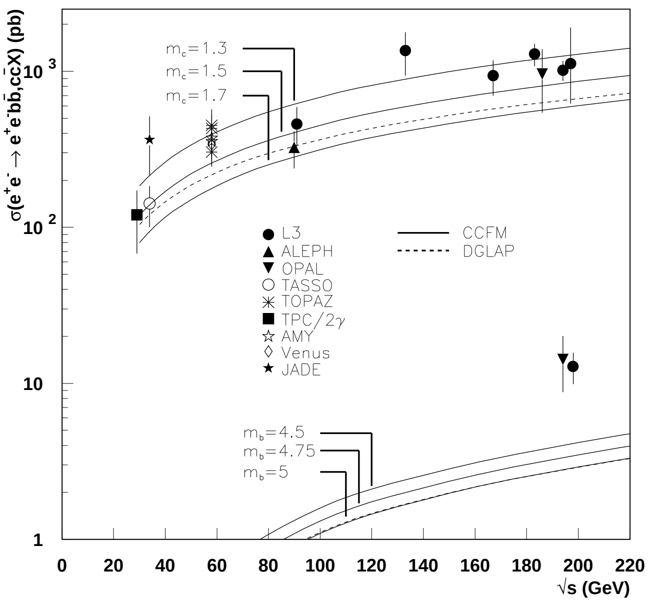

Fig. 1. Cross sections for charm and beauty production in e^+e^- collisions [2].

Cross sections for beautiful quark production in LEP2 conditions were also obtained. The k_t-factorisation with the CCFM gluon in the photon gives slightly larger results than the NLO collinear approximation. The theoretical estimate of $\sigma(e^+e^- \to e^+e^-b\bar{b}X) \simeq 3.5 \pm 0.5$ pb is still much smaller than the L3 result of $12.8 \pm 1.7 \pm 2.3$ pb, see Fig. 1.

4. Conclusions

The $k_{\rm t}$-factorisation approach was applied to heavy quark photo-production in $\gamma^{(*)}p$ and $\gamma\gamma$ collisions. Total and differential cross sections for charm production are well understood both in γp and in $\gamma\gamma$ processes. Excessive beauty production at LEP2 remains a puzzle also in the $k_{\rm t}$-factorisation framework.

REFERENCES

[1] A. Gawron, J. Kwieciński, *Acta Phys. Pol. B* **34**, 133 (2003).
[2] M. Hansson, H. Jung, L. Jonsson, `hep-ph/0402019`.
[3] M.A. Kimber, A.D. Martin, M.G. Ryskin, *Phys. Rev.* **D63**, 114027 (2001).
[4] L. Motyka, N. Timneanu, *Eur. Phys. J.* **C27**, 73 (2003).
[5] N. Timneanu, J. Kwieciński, L. Motyka, *Eur. Phys. J.* **C23**, 513 (2002).
[6] A.V. Lipatov, N.P. Zotov, *Eur. Phys. J.* **C41**, 163 (2005).