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Impact of intrinsic charm models on production of $\gamma + c-$jet differential cross section at LHC and Tevatron

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In this article, we estimate the impact of some phenomenological nonperturbative intrinsic charm quark models based on light-cone on differential cross section of $\gamma + c$-jet production in $p\bar{p}$ collision at Tevatron and pp collision at LHC. We use the non-singlet evolution technique to evolve intrinsic charm quark. This technique allows us to evolve intrinsic heavy quark distribution independently from the gluon and other PDFs.

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1. Introduction

Charm quark distribution function plays an important role in study of many processes. In the standard global analysis of parton distribution functions, charm quark distribution arises perturbatively by gluon splitting [1–3]. Nonetheless, existence of a non-perturbative intrinsic charm quark component (IC) in the nucleon is predicted by QCD [4]. Today there are many articles [5–10] related to intrinsic charm component. In the present article, we describe some phenomenological light cone models for non-perturbative intrinsic charm quark component and show the Q^2-evolution of the intrinsic charm quark distribution is controlled by non-singlet evolution equation. In Sec. 2 we investigate the impact of the various intrinsic charm models on production of $\gamma + c$-jet differential cross section in pp and $p\bar{p}$ collisions at LHC and Tevatron.

2. Intrinsic charm quark

The probability of the existence of five-quark Fock component in the wave function of the proton for the first time was presented by Brodsky *et al.* (BHPS) in 1980 [4]. According to the BHPS model, the distribution of intrinsic charm quark assumption with 1% probability for IC in the proton can be written as

$$\bar{c}(x) = c(x) = 18x^2 \left[\frac{(1-x)}{3} \left(1 + 10x + x^2\right) + 2x(1+x)\ln(x) \right]. \tag{2.1}$$

Another model to describe the proton in the light-cone was presented by Pumplin (scalar five-quark model) [11] . The probability distribution for the intrinsic quark drives directly from the Feynman diagram rules. In this model, the IC distribution contains a wave function factor F^2 to characterizes the dynamics of the bound state. Pumplin proposed two exponential and power-law forms for F^2 and presented several IC distribution. In this article we have chosen two of them as follows

$$\bar{c}(x) = c(x) = 520.517\, x^{4.611}(1-x)^{11.477}, \tag{2.2}$$

$$\bar{c}(x) = c(x) = 0.187\, x^{0.521}(1-x)^{4.194}. \tag{2.3}$$

In addition to the BHPS and scalar five-quark models, there are another models in which the nucleon fluctuates to a virtual baryon plus a meson state and often called meson-baryon models (MBMs). Here, we investigate the effects of IC from two MBM models including the confining model and effective mass model. The parametrization form for the IC distributions in the nucleon for confining model and effective mass model are given respectively by [12]

$$c(x) = 4.128\, x^{1.59}(1-x)^{6.586}, \tag{2.4a}$$

$$\bar{c}(x) = 1.77696\, x^{1.479}(1-x)^{4.624}, \tag{2.4b}$$

and

$$c(x) = 252.48\, x^{3.673}(1-x)^{10.16}, \tag{2.5a}$$

$$\bar{c}(x) \; = \; 99.84\, x^{4.153}(1-x)^{6.800}. \tag{2.5b}$$

There is a major difference between MBM and other models. As can be seen from Eqs. 2.4 and2.5 the MBM predicts the asymmetry of $c(x)$ and $\bar{c}(x)$ distributions in the proton.

If we accept the existence of IC in the proton, then the total charm quark distribution in any x and Q^2 values can be obtained by adding the intrinsic contribution (xc_{int}) to the extrinsic component (xc_{ext}) as follows

$$xc(x,Q^2) = xc_{ext}(x,Q^2) + xc_{int}(x,Q^2). \tag{2.6}$$

According to DGLAP equations [13], the evolution equation of heavy quarks presented by

$$\dot{Q}_{ext} + \dot{Q}_{int} = P_{Qg} \otimes g + P_{Qg} \otimes q + P_{QQ} \otimes Q_{ext} + P_{QQ} \otimes Q_{int}, \tag{2.7}$$

the evolution equation of heavy quarks can be separated into two independent parts [6].

$$\begin{aligned} \dot{Q}_{ext} \; &= \; P_{Qg} \otimes g + P_{Qg} \otimes q + P_{QQ} \otimes Q_{ext}. \\ \dot{Q}_{int} \; &= \; P_{QQ} \otimes Q_{int}. \end{aligned} \tag{2.8}$$

where P_{QQ} is the splitting function. So the evolution of the intrinsic charm quark distribution is controlled by non-singlet evolution equation. This technique allows us to evolve intrinsic charm quark distribution without performing a new global analysis add it to any PDFs set [14].

3. Production of photon and charm quark jet

Here we present, differential $\gamma + c-$jet cross section over the transverse momentum of the photon for the Tevatron and LHC. We choose kinematical regions particularly sensitive to the IC contribution. All cuts for the Tevatron and LHC are given in Tab 1.

Exp.	$\sqrt{s}$	photon rapidity	p_T^γ	p_T^c min	η^c
Tevatron	1.96 TeV	$\lvert y_\gamma \rvert < 1$	$30 < p_T^\gamma < 300$ GeV	15	$\lvert\eta^c\rvert < 1.5$
LHC	8 TeV	$1.52 < \lvert y_\gamma \rvert < 2.37$	$50 < p_T^\gamma < 400$ GeV	20	$\lvert\eta^c\rvert < 2.4$

Table 1: Kinematic cuts for $p\bar{p}$ and pp collider at Tevatron and LHC.

Data for the differential $\gamma + c-$jet cross section in $p\bar{p}$ collision are already available for D0 experiment at the Fermilab Tevatron [15]. As can be seen in Fig.1, data at large p_T^γ do not agree with the CTEQ66 PDFs [16], without the IC contribution. At high transverse momentum of the photon, as expected, the spectrum grows by the inclusion of the IC contribution. The BHPS model enhances the cross-section at $p_T^\gamma = 216$ GeV by a factor of 1.45. This factor for the exponential and power-law suppression model are about 1.5 and 1.3, respectively. As can be seen from Fig. 1 the MBM results are much more than the BHPS and Pumplin results by a factor of 1.9 for the confining model and 2.25 for the effective mass model at $p_T^\gamma = 216$ GeV.

A similar prediction to the Tevatron can be made for the LHC. we use the kinematical regions which presented by V. A. Bednyakov et al. [17]. Fig. 2 shows, the difference between the CTEQ66

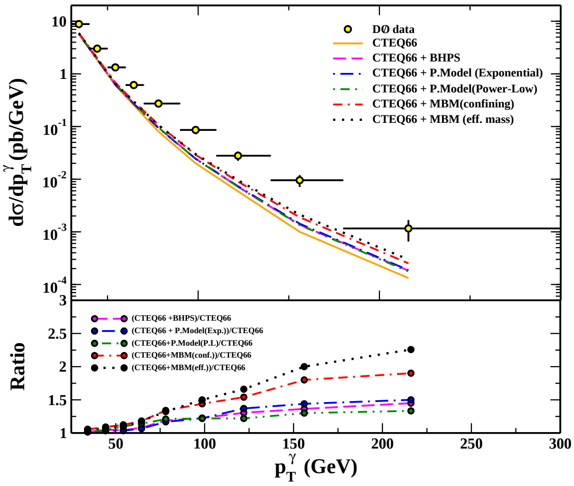

Figure 1: A comparison of D0 measurement of differential $\gamma + c$-jet cross section as a function of p_T^γ at $\sqrt{s} = 1.96$ TeV [15] with the prediction for five models of intrinsic charm: BHPS (dashed), the exponential (dashed-dotted), the power-law form (dashed-dotted-dotted), the confining (dashed-dashed-dotted) and the effective mass (dotted). The solid curve describes CTEQ66 without IC contribution. The ratio of these spectra (IC models) to the CTEQ66 are shown in the bottom panels.

result without IC and the results of five models of intrinsic charm. As can be seen from Fig. 2 the difference between the standard PDF (CTEQ66) and the results considering IC contribution are clearly visible specially at large p_T^γ. The MBM results at p_T^γ are upper than other models and increase the spectrum by a factor of 2.5 and 3.1 at $p_T^\gamma = 380$ GeV for the confining model and the effective mass model, respectively.

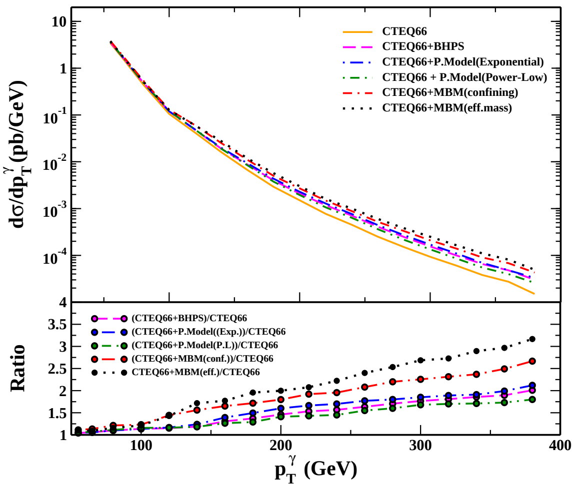

Figure 2: The differential $\gamma + c$-jet cross section in pp collisions as a function of p_T^γ at $\sqrt{s} = 8$ TeV at the LHC showing the same curves as in Fig. 1.

4. Conclusion

In this work, we have performed a comparative analysis of three IC models based on the light cones to study the role of intrinsic charm in the results of the inclusive production of $\gamma + c$-jet in hadron colliders. An aspect of our calculation is that we used a non-singlet evolution technique for evolution of IC distribution. This allows one to add IC to any PDF set without performing a new complete global analysis. The grid files for the evolution of IC in this paper are available in Ref. [18]. We found that, in the used kinematical region, the IC contribution increases the value of the cross section regardless of the chosen IC model, specially at large transverse momentum of the photon.

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