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Remark on double diffractive χ meson production

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Abstract

The double pomeron exchange contributions to the central inclusive and exclusive χ_c^0 and χ_b^0 mesons production in the Bialas–Landshoff approach are calculated. We find the model to be consistent with the preliminary CDF upper limit on double diffractive exclusive χ_c^0 production cross section.

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1. Introduction

The study of the double pomeron exchange (DPE) production processes is interesting in its own right. It is an ideal way to improve our understanding of diffractive processes and the dynamics of the pomeron exchange.

However, the great interest in such reactions is caused by the possibility of the DPE processes to be one of the main mechanisms leading to Higgs boson production [1–10] within a very clean experimental environment.

In the present Letter we are particularly interested in the exclusive and central inclusive (central inelastic) DPE production of heavy quarkonium states χ_c and χ_b [11–13], see also [14,15]. In the exclusive DPE event the central object χ is produced alone, separated from the outgoing hadrons by rapidity gaps:

$$p\bar{p} \to p + \text{gap} + \chi + \text{gap} + \bar{p}.$$

In the central inclusive DPE event an additional radiation accompanying the central object is allowed.

The basis for our considerations is the Bialas–Landshoff model for central inclusive double diffractive Higgs boson production [2]. We showed that the Bialas–Landshoff model and its exclusive extension [10] give satisfactory description of the DPE central inclusive and exclusive dijet cross sections [10,16].

In this Letter we show that the exclusive extension of the Bialas–Landshoff model is consistent with the preliminary CDF upper limit on double diffractive exclusive χ_c^0 production cross section [17].

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2. Central inclusive χ meson production

In the Bialas–Landshoff approach pomeron exchange corresponds to the exchange of a pair of non-perturbative gluons which takes place between a pair of colliding quarks [18]. Thus, the process of χ meson production is described by a sum of the four (reggeized) diagrams shown in Fig. 1 where dashed lines correspond to the non-perturbative gluons. The χ coupling is taken to be through a c-quark and b-quark loop for χ_c and χ_b, respectively.

Our calculation follows closely that of Ref. [2] where the DPE contribution to the central inclusive Higgs boson production is calculated.

First, one calculates the (non-reggeized) production amplitude in the forward direction i.e. for vanishing transverse momenta of the produced χ meson and of the final hadrons. In this case the sum of the diagrams of Fig. 1 can be approximately replaced by the s-channel discontinuity of the first one [2], shown in Fig. 2.

In the second step one introduces phenomenologically the effects of reggeization, transverse momentum dependence and the gap survival so that the full amplitude becomes:[1]

$$\mathcal{M} = \mathcal{M}_0 \left(\frac{s}{s_1}\right)^{\alpha(t_2)-1} \left(\frac{s}{s_2}\right)^{\alpha(t_1)-1} \times F(t_1) F(t_2) \exp\bigl(\beta(t_1+t_2)\bigr) S_{\mathrm{gap}}. \tag{1}$$

Here $\mathcal{M}_0$ is the amplitude in the forward scattering limit given by the diagram shown in Fig. 2. $\alpha(t) = 1 + \epsilon + \alpha' t$ is the pomeron Regge trajectory with $\epsilon \approx 0.08$, $\alpha' = 0.25\ \mathrm{GeV}^{-2}$. $s = (p_1 + p_2)^2$, $s_1 = (k_1 + P)^2$, $s_2 = (k_2 + P)^2$, $t_1 = (p_1 - k_1)^2$, $t_2 = (p_2 - k_2)^2$ where p_1, p_2, k_1, k_2 and P are defined in Fig. 2. $F(t) = \exp(\lambda t)$ is the nucleon form-factor with $\lambda = 2\ \mathrm{GeV}^{-2}$. The phenomenological factor $\exp(\beta(t_1+t_2))$ with $\beta = 1\ \mathrm{GeV}^{-2}$ takes into account the effect of the momentum transfer dependence of the non-perturbative gluon propagator given by (p^2 is the Lorentz square of the momentum carried by the non-perturbative gluon):[2]

$$D\bigl(p^2\bigr) = D_0 \exp\bigl(p^2/\tau^2\bigr), \tag{2}$$

with $\tau = 1$ GeV and $D_0 G^2 \tau = 30\ \mathrm{GeV}^{-1}$ [2] where G is the scale of the process independent non-perturbative quark gluon coupling.

The factor S_{gap} takes the gap survival effect into account i.e. the probability (S^2_{gap}) of the gaps not to be populated by secondaries produced in the soft rescattering. It is not a universal number but it depends on the initial energy and the particular final state. Theoretical predictions of the gap survival factor S^2_{gap} can be found in Ref. [19]. In our calculations, following [10,16], we take for the Tevatron (LHC) energy $S^2_{\mathrm{gap}}/(G^2/4\pi)^2 = 0.6$ (0.25).

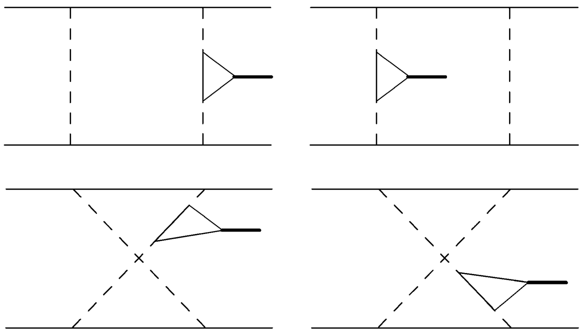

Fig. 1. Four diagrams contributing to the amplitude of the process of χ meson production by double pomeron exchange. The dashed lines represent the exchange of the non-perturbative gluons. The χ coupling is taken to be through a c-quark and b-quark loop for χ_c and χ_b, respectively.

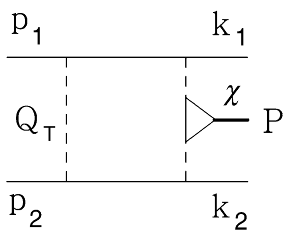

Fig. 2. Putting the inner quark lines "on-shell" is equivalent to calculating the amplitude for χ meson production by double pomeron exchange in the forward scattering limit i.e. $t_1 = t_2 = 0$.

[1] For DPE central inclusive χ_c and χ_b mesons production we can neglect the additional gap spoiling effect i.e. the Sudakov effect. It is justified by the relatively small masses of the produced mesons.

[2] As was stated in Ref. [2] there is no reason to believe that the true form of D is as simple as this. We hope it is not a serious objection to our model.