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A. Maccari : DIFFRACTIVE HEAVY QUARK BOUND STATE PHOTOPRODUCTION

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ABSTRACT

A new approach in the framework of the photon gluon fusion model is presented in order to account for the experimetalls observed linear growth of the diffractive ψ photoproduction cross section.

Both theoretical$^{(1)}$ and experimental$^{(2)}$ effort has been devoted during the last years to the heavy quark photoproduction. Most of the experimental data involve diffractive $c\bar{c}$ production, where the $c\bar{c}$ pair carries an energy almost equal to the incoming photon's energy.

This process is well described by the photon gluon fusion model (the Bethe-Heitler process of QCD): $\gamma g \rightarrow c\bar{c}$ (Fig. 1). It correctly reproduces the magnitude and energy dependence of the total diffractive charm photoproduction cross section, once the gluon momentum distribution function and the charm quark mass (m_c = 1.5÷1.6 GeV) are extracted from experimental data.

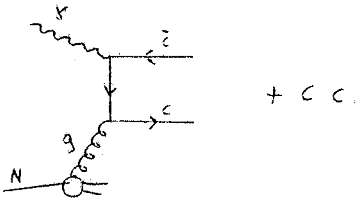

FIG. 1 - Photon-gluon fusion.

However, available calculations of diffractive ψ photoproduction fail and a constant cross section value for $E_\gamma \gtrsim 100$ GeV is predicted in open contrast with recent experimental data$^{(3)}$ in the range 100-300 GeV. The cross section above 100 GeV is characterized by a linear growth which reaches 50 nb for E_γ = 300 GeV.

In this paper we propose a new approach to reproduce this feature. The photon-gluon fusion mechanism is maintained as primary source of diffractive charmed pairs but the fraction of $c\bar{c}$ pairs which transforms in ψ's is supposed to depend explicitly on s (the center-of-mass squared energy) and M (the invariant mass of the charm quark pair).

The usual way(5) to account for diffractive ψ photoproduction is to suppose that a fixed fraction, F_ψ, of charm quark pairs produced below the open charm threshold materializes into ψ's :

$$\sigma_\psi(s) = F_\psi \int_{x_1}^{x_2} \frac{d\sigma}{dx}^{\gamma g \to c\bar{c}}(x,s)G(x)dx \tag{1}$$

where $x_1=4m_C^2/s$, $x_2=4m_D^2/s$ and $d\sigma/dx$ is the differential cross section in the nucleon momentum fraction, x, carried by the gluon, with a probability G(x). The experimental magnitude of the cross section for E 100 GeV requires a value for $F_\psi \cong 1/6$(5). This procedure, however, is correct only if the fraction of $c\bar{c}$ pairs transforming into ψ's is independent on s and x, otherwise one has to assume :

$$\sigma_\psi(s) = \int_{x_1}^{x_2} W(x,s) \frac{d\sigma}{dx}^{\gamma g \to c\bar{c}}(x,s)G(x)dx \tag{2}$$

where W(x,s) is an opportune weighting function. To obtain an expression for W(x,s) we suppose that the transition $c\bar{c}$ can be treated in the framework of the old-fashioned perturbation theory. In particular, we assume for the for the transition amplitude A :

$$A = \frac{\langle \psi | V | c\bar{c} \rangle}{E_f - E_1} \tag{3}$$

where V is the interaction potential, E_1, and E_f the energies respectively of $c\bar{c}$ and ψ.

In this model the decolorization process, which takes place through the interaction with the nucleon target, is completely ignored, i.e. it is supposed to happen with unit probability without perturbing appreciably the system.

In the γN center of mass (Fig. 2) we have :

$$E_f = (P^2+M^2)^{1/2}, \quad E_1 = (P_1^2+m_{\perp 1}^2)^{1/2}, \quad E_2 = (P_2-xP_N)^2+m_{\perp 2}^2)^{1/2}$$

$$E_i = E_1+E_2, \quad P = P_1+P_2-xP_N \tag{4}$$

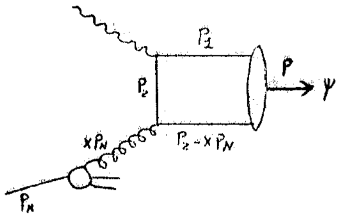

FIG. 2 - Kinematic for diffractive photoproduction.

where $m_{\perp 1}$ and $m_{\perp 2}$ are the transverse masses of the two charm quarks.

We assume now that one may to ignore the dependence of the matrix element on x and that the following approximations are valid:

$$m_{1} \cong m_C, \quad m_{2} \cong m_C, \quad P_1 \cong P_2 \cong P_N/2 . \tag{5}$$

This allows us to obtain an expression for W(x,s) depending only an unknown constant C_ψ :

$$W(x,s) = \frac{C_\psi}{(x^2 s + 2xs - 8m_C^2)^2} . \tag{6}$$

The shape of W(x,s) is characterized by a decrease as $1/x^4$ for $x \cong 4m_C^2/s$ and by a constant value for $x \cong 4m_D^2/s$. Intuitively, this behaviour can be justified, observing that, increasing x, the relative speed of the two charm quarks and the difference between invariant and ψ mass increase. Besides, the suppression experimentally observed in the ψ' production can be explained, because $x_{\psi'} \cong m_{\psi'}^2/s$ is larger than $x_\psi \cong 4m_C^2/s$ and the relative motion between the two charm quark is considerable altered.

Our model as the usual one has a free parameter C_ψ and one can immediately recognize that it predicts a linear growth of the cross section independently on the C_ψ value. We assume :

$$\sigma_\psi(s) = \int_{x_1}^{x_2} W(x,s) \, \frac{d\sigma}{dx}^{\gamma g \to c\bar{c}}(x,s) G(x) dx \tag{7}$$

and the best fit is obtained with $C_\psi = 1.75$ GeV^4 (Fig. 3, plot labelled with (2)). In the same figure the usual photon gluon fusion model prediction (with m_C=1.55 GeV and F_ψ =1/6) is also shown (plot labelled with (1)).

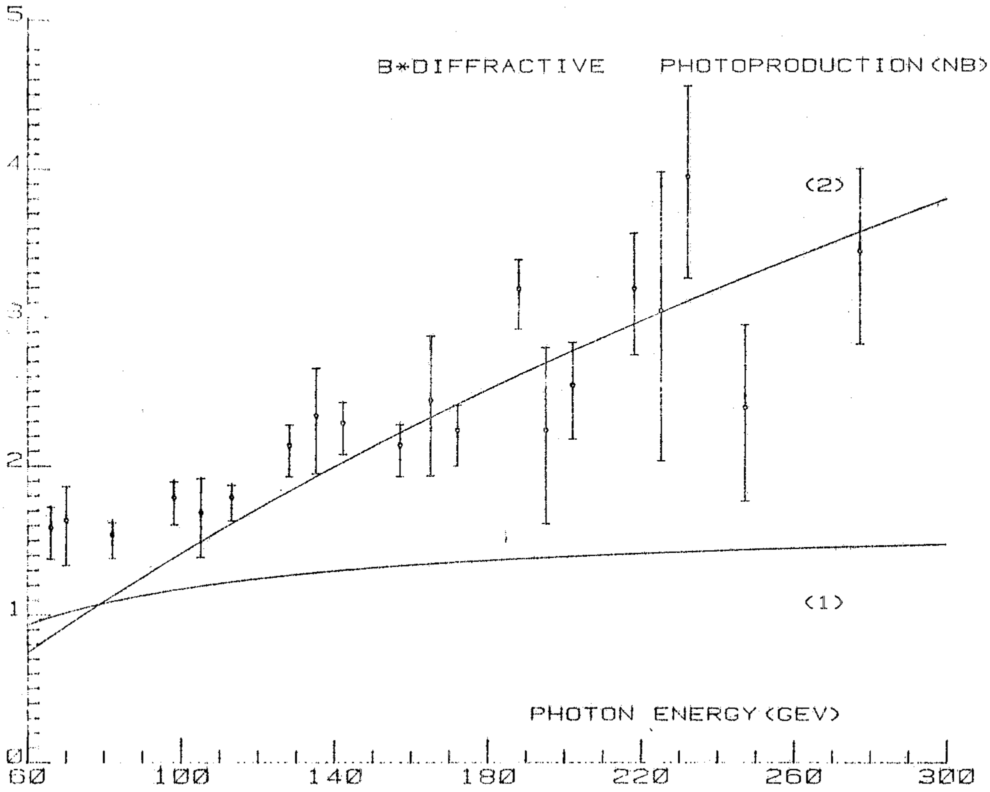

FIG. 3 - Experimental data and theoretical predictions for diffractive ψ photoproduction (R is the branching ratio into muon pairs); plot (1): photon-gluon fusion model; plot (2): the W(x,s) model; experimental data from ref.(3).

The agreement we have found allows us to conclude that the diffractive photoproduction can be explained in the framework of the photon-gluon fusion model, suitably improved with the addition of a weighting function, obtained with a very simple approach, for the transition from initial partons to hadronic final states.

REFERENCES

(1) - J.Babcock et al., Phys. Rev. D18, 162 (1978); L.M.Jones et al., Phys. Rev. D17, 759, 2332 (1978); M.A.Shifman et al., Nuclear Phys. B136, 157 (1978).

(2) - T.Nash et al., Phys. Rev. Letters 36, 1233 (1976); R.L.Anderson et al., Phys. Rev. Letters 38, 263 (1977); B.Gittelman et al., Phys. Rev. Letters 35, 1616 (1975); U.Camerini et al., Phys. Rev. Letters 35, 483 (1975).

(3) - M.Binkley et al., Phys. Rev. Letters 48, 73 (1982).

(4) - E687 Proposal: High energy photoproduction of heavy quarks and other rare phenomena, Fermilab (1981).

(5) - V.Barger et al., Phys. Letters 91B, 253 (1980).