Diffractive open charm production in DIS at H1

Stefan Hengstmann[a] for the H1 collaboration

[a]Physik–Institut der Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich

The rate of diffractive open charm production in DIS at HERA probes the gluonic content of the pomeron. The measured cross section $\sigma(ep \to e(D^{*\pm}X)Y)$ is presented differentially as a function of observables exploring the dynamics of the process. The results are compared with a model based on a partonic pomeron as determined in a QCD analysis of the diffractive structure function, with perturbative QCD calculations of two gluon exchange and with a soft color interaction model.

1. Models of diffractive charm production

Large rapidity gap events observed at HERA constitute approximately 10% of the inclusive deep inelastic scattering (DIS) cross section. They are attributed dominantly to pomeron exchange. The rate of diffractive open charm production in DIS is sensitive to the gluon content of the exchange, since charm quarks are predominantly produced by the photon-gluon fusion process (PGF). Different theoretical approaches to diffractive charm production exist and are discussed below.

1.1. Resolved pomeron model

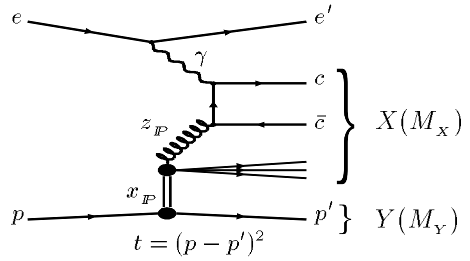

Figure 1. *Photon–gluon–fusion in the resolved pomeron process. $z_{I\!P}$ denotes the fraction of the pomeron momentum carried by the gluon.*

The resolved pomeron model [1] is a partonic interpretation of a factorisable pomeron. The calculation of the cross section factorises into the parton density of the pomeron and a pomeron flux factor, describing the probability for finding a pomeron in the proton. The pomeron flux in agreement with Regge theory is proportional to $(1/x_{I\!P})^{1+2\varepsilon}$, where ε is small. The partonic content of the pomeron can be determined by a QCD analysis of the inclusive diffractive structure function $F_2^{D(3)}$ [2]. The parameterisation of $F_2^{D(3)}$ needs to make assumptions on the pomeron parton structure at the starting scale. The cross section depends on whether the pomeron has mainly a quark or a gluon structure.
In the resolved pomeron model (see figure 1) open charm is produced by PGF, where the photon, radiated by the incoming lepton, interacts with a gluon of the pomeron, carrying a fraction $z_{I\!P}$ of the pomeron momentum. Since there is no color flow between the particles of the hard interaction and the proton, which remains intact or becomes a low mass state M_Y, a rapidity gap in the particle flow is observed for these processes.

1.2. A two gluon exchange model

In perturbative QCD diffractive open charm production can be realized by the exchange of two perturbative gluons [3–5]. Consequently the cross section for the process $\gamma^* + p \to c\bar{c} + p'$ is essentially proportional to the gluon density squared $\sigma \sim [x_{I\!P} G_p(x_{I\!P}, \mu)]^2$ of the proton. This process is implemented in the Monte Carlo generator RAPGAP [6] allowing for different parameterizations of the gluon density in the proton.

1.3. A soft color interaction model

In the soft color interaction model (SCI) [7] the $c\bar{c}$ pair is produced via PGF. With a certain probability the color structure of the partonic state is changed by low momentum parton exchanges between each pair of colored partons emerging from

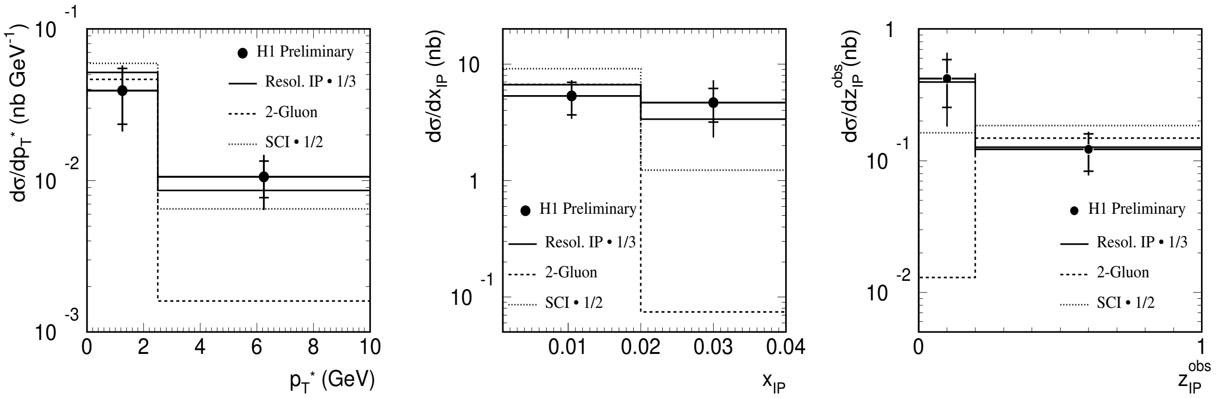

Figure 2. *Cross sections $\sigma(ep \to e(D^{*\pm}X)Y)$ as a function of p_T^*, where p_T^* denotes the transverse momentum of the D^* in the $\gamma^* p$ center of mass system, the fraction $x_{I\!P}$ of the proton momentum carried by the pomeron and $z_{I\!P}^{obs}$, which is an approximation to the momentum fraction of the pomeron carried by the gluon. The data are points with error bars (inner: statistical, outer: total) and are compared to the resolved pomeron model (solid line), the 2–gluon model (dashed line) and the SCI–model (dotted line). The resolved pomeron model is normalised by a factor of 1/3 and the SCI–model by a factor of 1/2.*

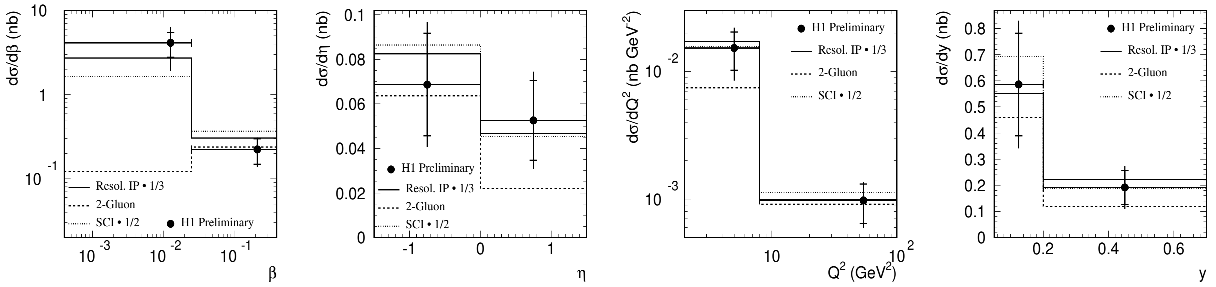

Figure 3. *Cross sections $\sigma(ep \to e(D^{*\pm}X)Y)$ as a function of β, η, Q^2 and y.*

the hard interaction, without changing the kinematics of the process. Large rapidity gap events can be produced when the soft interactions lead to a color-singlet $c\bar{c}$ system. The probability for SCI is a free parameter in this model, which has been implemented in the Monte Carlo generator AROMA 2.2 [8].

2. Cross section measurement

The analysis presented here uses a sample from the 1995–1997 H1 data corresponding to an integrated luminosity of 20.8 pb^{-1}. Charm production is identified by the reconstruction of $D^{*\pm}$ mesons in the decay chain $D^{*+} \longrightarrow D^0\pi^+ \longrightarrow K^-\pi^+\pi^+(+\ c.c.)$ with an overall branching fraction of 2.6%. Cuts on particle track quantities are applied to guarantee a reliable measurement, but limit the region of phase space in transverse momentum p_T and pseudorapidity η of the D^* to $p_T > 2$ GeV and $|\eta| < 1.5$ in the H1 laboratory frame. The measurement of the scattered positron in the main detector is used to reconstruct the DIS kinematics that is restricted to the region 2 GeV^2 $< Q^2 <$ 100 GeV^2 and $0.05 < y < 0.7$. Diffractive events are defined experimentally by the absence of any signal in detectors situated in the forward part of the H1 apparatus, which have acceptance at large pseudorapidities. This requirement restricts the mass of the dissociating system $M_Y < 1.6$ GeV and the momentum transfer to the proton $|t| < 1$ GeV^2. The rapidity gap in the outgoing parton direction is measured using the quantity η_{max}, which is the pseudorapidity of the most forward cluster in the liquid argon calorimeter with energy

$E > 300$ MeV. A cut of $\eta_{max} < 3.3$ is applied, which restricts the $x_{I\!P}$ range to be less than 0.04. The kinematic cuts listed above define the visible phase space region for which cross sections are given. The data are corrected for inefficiencies and migrations by running the full H1 detector simulation on a sample of D^* events generated with RAPGAP using the resolved pomeron process. Radiative corrections are assumed to be small and are neglected here. The number of D^* mesons extracted from a fit to the invariant mass difference distribution $\Delta m = M(K^-\pi^+\pi^+) - M(K^-\pi^+)$ is measured to be $38 \pm 10(stat.) \pm 4(syst.)$, corresponding to a diffractive cross section of $\sigma(ep \to e(D^{*\pm}X)Y) = (154 \pm 40 \pm 35)$ pb (H1 preliminary [9]), where the first error is the statistical and the second the systematic. The systematic error is dominated by the dependence of the acceptance correction on the underlying physics model of the simulation. The differential diffractive cross sections shown in figure 2 and 3 are measured using a slightly different fitting procedure, taking the limited statistics of typically 20 events in each bin into account. Applying the same procedure to the full diffractive D^* sample increases the cross section within the errors.

In figure 2 the cross section is shown as a function of the transverse momentum of the D^* in the $\gamma^* p$ center of mass system p_T^*, of $x_{I\!P}$, and of the hadronic observable $z_{I\!P}^{obs}$, which is an approximation (in the resolved pomeron picture) to the momentum fraction of the pomeron carried by the interacting gluon. $z_{I\!P}$ is given by

$$z_{I\!P} = \beta \cdot \left(1 + \frac{\hat{s}}{Q^2}\right) = \frac{M_{c\bar{c}}^2 + Q^2}{M_X^2 + Q^2},$$

where $M_{c\bar{c}}$ can be reconstructed using the scattered positron and the tagged D^* meson (see also [10]). If the partons could be observed directly, in the two gluon model $z_{I\!P} = 1$ would always hold. In figure 3 cross sections are also shown as a function of β, η, Q^2 and y.

The resolved pomeron approach reproduces well the shape of the spectra and in particular the fact that the data show a sizeable fraction of "resolved" charm production in the low $z_{I\!P}^{obs}$ region. However, the model fails in the overall normalisation by a factor of 2 to 3, depending on choices to be made for the calculation.

The two gluon model, on the other hand, does not describe the regions of higher masses M_X i.e. low $M_{c\bar{c}}/M_X$, low $z_{I\!P}^{obs}$. It is apparent – also from the p_T^* distribution – that higher order contributions such as $\gamma^* + p \to c\bar{c}g + p'$ are needed. (The discrepancy at low β reflects the behavior at high $x_{I\!P}$.) It is, however, interesting to note that the data in regions where the hadronic system X predominantly consists of the $c\bar{c}$ system alone (high $z_{I\!P}^{obs}$) are well reproduced in magnitude.

The SCI model fails in the overall normalisation by a factor of about 2 and does not reproduce well the shape of the $z_{I\!P}^{obs}$ and $x_{I\!P}$ distributions.

3. Conclusions

The dynamics of diffractive charm production have been studied. In the probed kinematic range, about 5% of the events with charm are produced diffractively, which is below the expectation based on the resolved pomeron model with parton distributions derived from the QCD analysis of inclusive diffractive DIS data. Differential cross sections have been presented, which are able to discriminate between different models. They are all well described in shape by the resolved pomeron model.

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