HARD DIFFRACTION AND CENTRAL DIFFRACTION IN
HADRON–HADRON AND PHOTON–HADRON COLLISIONS*

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Hadron production in single and central diffraction dissociation is studied in a model which includes soft hadron interaction as controlled by a supercritical pomeron parametrization and hard diffraction. Hard diffraction is described using leading-order QCD matrix elements together with the parton distributions for the proton, the less well known photon parton densities and a conjectured parton distribution function for the pomeron. Within this model, particle production in collisions with pomerons exhibit properties like multiple soft interactions and multiple minijets, quite similar to hadron production in non-diffractive hadronic collisions at high energies. However, important differences occur in transverse momentum jet and hadron distributions. It is shown that the model is able to describe data on single diffractive hadron production from the CERN-SPS collider and from the HERA lepton-proton collider as well as first data on central diffraction dissociation. We present also model predictions for single and central diffraction at TEVATRON.

1. Introduction

High-energy hadron production in hadron–
hadron collisions and in hadronic interactions of photons is characterized by two mechanisms: (i) minijet production and (ii) soft hadronic interactions. Whereas the minijet cross section can be estimated applying the QCD-improved parton model, soft hadron production cannot be computed directly from perturbative QCD. Most models for multiparticle production being constructed in form of Monte Carlo event generators use soft and hard mechanisms. Such models are usually called minijet models if they use minijets and a simple model for the soft component of the interaction. They are called two component Dual Parton models (DPM’s) if they use minijets and incorporate a evolved soft component which is derived from Regge theory, Gribov’s reggeon calculus (AGK) cutting rules (Ref.[4]).

Models inspired by Regge theory or the DPM describe high-mass diffractive hadron production in terms of the so-called triple-pomeron graph. According to this diffractive processes can be considered as collisions of a color neutral object, the pomeron, with hadrons, photons or other pomerons. Experimental data on diffraction support this idea showing that diffraction dissociation exhibits similar features as non-diffractive hadron production whereas the mass of the diffractively produced system corresponds to the collision energy in non-diffractive interactions (Ref.[5]). The striking similarities between diffractive and non-diffractive multiparticle production suggest that multiple soft and hard interactions may also play an important role in high-mass diffraction dissociation.

However the pomeron cannot be considered as an ordinary hadron. It is important to keep in mind that the pomeron is only a theoretical object providing an effective description of the im-
important degrees of freedom of a certain sum of Feynman diagrams in Regge limit. Pomeron-hadron or pomeron-pomeron interactions can only be discussed in the framework of collisions of other particles like hadrons or photons in terms of single, double or central diffraction dissociation.

The DPM was already successfully applied to diffractive hadron production reactions and even hard diffractive processes. In cross sections on single and central diffraction were calculated. Up to now, the minijet component in diffractive processes was described by two hadronic chains (cutting the triple-pomeron graph). Here we will argue, that for the description of diffraction dissociation producing hadronic systems with very large masses, such models are not enough. Also for high-mass diffractive hadron production we need multiple soft and multiple hard interactions.

2. The Model

2.1. The event generator Phojet

In the Phojet model, interactions of hadrons are described within the DPM in terms of reggeon (R) and pomeron (P) exchanges. The realization of the DPM with a hard and a soft component is similar to the event generator Dujet for p–p and ¯p–p collisions. In the following we briefly describe the treatment of the pomeron exchange in non-diffractive interactions since the same framework is also used for the description of particle production in diffraction dissociation.

The pomeron exchange is artificially subdivided into soft processes and processes with at least one large momentum transfer (hard processes). This allows us to use the predictive power of the QCD-improved Parton Model with lowest-order QCD matrix elements and parton density functions. Practically, soft and hard processes are distinguished by applying a transverse momentum cutoff \( p_\perp \text{cutoff} \) to the partons. Consequently, the pomeron is considered as a two-component object with the Born graph cross section for pomeron exchange given by the sum of hard and soft cross sections.

2.2. Diffractive cross section calculation

Concerning diffraction dissociation, our approach is the following.

In order to get an effective parametrization of Born graphs describing diffraction within Gribov’s reggeon calculus, we calculate the triple-, loop- and double-pomeron graphs using a renormalized pomeron intercept \( \alpha_\text{P} = 1 + \Delta_\text{P} = 1.08 \).

For example, let’s consider the Born graph cross sections for high-mass diffraction dissociation in A–B scattering (for simplicity, we omit in the following expressions the pomeron signature factors; for a discussion of the couplings etc. see [11]).

High-mass single diffraction dissociation of particle A is calculated using the triple-pomeron approximation

\[
\frac{d^2\sigma_{\text{TP},A}}{dt \, dM_D^2} = \frac{1}{16\pi} \left( g_{B,P}^0 \right)^2 g_{3,P}^0 g_{A,P}^0 \left( \frac{s}{s_0} \right)^{2\Delta_\text{P}} \times \left( \frac{s_0}{M_D^2} \right)^{\alpha_\text{P}(0)} \exp \left( b_{\text{SD}} t \right).
\]

The differential cross sections for the high-mass double diffraction dissociation reads

\[
\frac{d^3\sigma_{\text{LP}}}{dt \, dM_D^2 \, dM_{D_2}^2} = \frac{1}{16\pi} \left( g_{A,P}^0 \right)^2 g_{B,P}^0 g_{3,P}^0 \times \left( \frac{s_0}{s_1} \right)^{2\Delta_\text{P}} \left( \frac{s}{s_0} \right)^{\alpha_\text{P}(0)} \times \left( \frac{s_0}{M_D^2} \right)^{\alpha_\text{P}(0)} \exp \left( t_{\text{DD}} \right)
\]

Finally, we give the expression for central diffraction dissociation

\[
\frac{d\sigma_{\text{DP}}}{dt_1 \, ds_1 \, dt_2 \, ds_2} = \frac{1}{256\pi^2} \frac{1}{s_0} \left( g_{A,P}^0 g_{B,P}^0 g_{3,P}^0 \right)^2 \times \left( \frac{s}{s_1} \right)^{\Delta_\text{P}} \left( \frac{s}{s_2} \right)^{\Delta_\text{P}} \left( \frac{s}{s_0} \right)^{\Delta_\text{P}} \times \frac{1}{s_1 s_2} \exp \left( b_{\text{CD}} t_1 + b_{\text{CD}} t_2 \right)
\]

The experimentally observable diffractive cross sections (i.e. cross sections of rapidity gap events)
are considerably smaller than the Born graph cross section given in (1), (2) and (3). The reason for this are significant shadowing contributions which are estimated by a two-channel eikonal model [14,13]. It should be emphasized that these shadowing contributions lead to an effective pomeron flux function which is energy as well as projectile and target dependent. Hence the pomeron flux does not obey factorization within this model.

2.3. Particle production in diffraction dissociation

However, not only for cross section calculations, but also for the description of particle production, shadowing effects are important. Unitarity and AGK cutting rules predict that shadowing effects are directly connected with so-called multiple interaction contributions. In the case of diffractive multiparticle production we have to consider rescattering effects in pomeron-hadron and pomeron-pomeron interactions of enhanced graphs. Whereas it was sufficient to introduce a renormalized pomeron trajectory to calculate cross sections, one needs for the calculation of particle production a model for the physical final states which correspond to the unitarity cut of such a renormalized pomeron propagator. Following Refs. [18,19] we assume that the pomeron-pomeron coupling can be described by the formation of an intermediate hadronic system $h^*$ where the pomeron couple to. Assuming furthermore that this intermediate hadronic system has properties similar to a pion, the $n$-$m$ pomeron coupling reads [19]

$$g_{n-m} = G \prod_{i=1}^{n+m-2} g_{h \cdot p^i}$$  \hspace{1cm} (4)

with $g_{h \cdot p^i} = g_{p \cdot p^i}$ being the pomeron-pion coupling. $G$ is a scheme-dependent constant. Hence, pomeron-hadron and pomeron-pomeron scattering should exhibit features similar to pion-hadron and pion-pion scattering.

To introduce hard interactions in diffraction dissociation, the exchanged (renormalized) pomeron in pomeron–hadron and pomeron–pomeron scattering are again treated as two-component objects

$$a_{AP}(s, \vec{B}) \approx \frac{i}{2} G \left\{ 1 - \exp \left[ -\chi^\text{diff}_S - \chi^\text{diff}_H \right] \right\} \hspace{1cm} (5)$$

with the diffractive eikonal functions

$$\chi^\text{diff}_S = \frac{g_{AP}^0 g_{h \cdot p}^0 (M_D^2/s_0)^{\Delta_{p^p}}}{8\pi b_H (M_D^2)} \times \exp \left( -\frac{\vec{B}^2}{4b_H (M_D^2)} \right) \hspace{1cm} (6)$$

$$\chi^\text{diff}_H = \frac{\sigma_{\text{hard}}^A (M_D^2)}{8\pi b_{h,\text{diff}}} \exp \left( -\frac{\vec{B}^2}{4b_{h,\text{diff}}} \right). \hspace{1cm} (7)$$

In all calculations the pomeron PDFs proposed by Capella, Kaidalov, Merino, and Tran (CKMT) [20,21] with a hard gluon component are used.

![Figure 1. Single and double diffractive $p\bar{p}$ cross sections as a function of the center of mass energy $\sqrt{s}$ calculated with the model. We compare to data on single diffractive cross sections [22,23]. In addition, some experimental estimates for the cross section on double diffraction dissociation [26,27] are shown.](image)
Figure 2. The energy dependence of the central diffraction cross section. We compare the cross section as obtained from PHOJET with unitarization using a supercritical pomeron with the cross section obtained by Streng [31] without unitarization and with a critical pomeron. Both cross sections are for the same two kinematic cuts: $M_{CD} > 2 \text{GeV}/c^2$ and $c = 0.95$ and 0.97. The cross sections decrease with rising $c$.

2.4. Toy model with direct pomeron coupling

To estimate the sensitivity of the model results to non-factorizing coherent pomeron contributions as proposed in [32,33], we use optionally also a toy model with a direct pomeron-quark coupling [34]. In this case, the pomeron is treated similar to a photon having a flavor independent quark coupling $\lambda$. For definiteness, the corresponding matrix elements are given

\begin{align}
|M_{\gamma q \rightarrow q \bar{q}}|^2 &= \lambda_s \left[ 8 \frac{\hat{u}^2 - \hat{t}^2}{3 \hat{s} \hat{u}} \right] \\
|M_{\bar{p} g \rightarrow q \bar{q}}|^2 &= \lambda_s \left[ \frac{\hat{u}^2 + \hat{t}^2}{\hat{t} \hat{u}} \right] \\
|M_{\bar{p} \gamma \rightarrow q \bar{q}}|^2 &= \lambda_{em} e_q^2 \left[ 6 \frac{\hat{u}^2 + \hat{t}^2}{\hat{u} \hat{t}} \right] \\
|M_{\bar{p} \bar{p} \rightarrow q \bar{q}}|^2 &= \lambda_s \left[ 6 \frac{\hat{u}^2 + \hat{t}^2}{\hat{u} \hat{t}} \right]
\end{align}

Here, $\alpha_s$ ($\alpha_{em}$) denotes the strong (electromagnetic) coupling and $\hat{s}$, $\hat{t}$ and $\hat{u}$ are the Mandelstam variables of the partonic scattering process.

3. Comparison with data

3.1. Diffractive cross sections

First we compare single diffractive cross sections according to our model in $p-\bar{p}$ collisions to data and we present the results of the model for single and double diffractive cross sections in $\gamma-p$ collisions and for central diffraction cross sections in $p-p$ collisions. Studying diffractive cross sections is not the primary concern of this paper. Results on diffractive cross sections were already presented using the DTUJET model in Refs. [14,15] and using the present PHOJET model in Refs. [12,11], we include updated results for these cross sections here to make the present paper self-contained.

In Fig. 1 data on single diffractive cross sections [22–30] are compared with our model results. It is to be noted that the data on single diffractive cross sections at collider energies are subject to large uncertainties. Nevertheless the rise of the cross section from ISR energies to the energies of the CERN and FERMILAB colliders is less steep than expected from the Born level expression from the triple pomeron formula [31]. It is the eikonal unitarization procedure in the model, which suppresses the strong rise of the triple pomeron cross section in the full model. The same effect was also found by Capella et al. [35] and Gotsman et al. [36].

In Fig. 2 we compare as function of the energy the central diffraction cross sections in proton-proton collisions, which we obtain from PHOJET with the cross section obtained by Streng [31]. In PHOJET we use a supercritical pomeron with $\Delta_{\Phi} = 0.08$ whereas Streng [31] uses a critical Pomeron with $\Delta_{\Phi} = 0$. Note that also the double-pomeron cross section grows in Born approximation with $s$ like $\sim s^{2\Delta_{\Phi}}$. This rapid increase is damped in PHOJET by the unitarization procedure. At high energies, contributions from multiple interactions become important. The ra-
pidity gaps are filled with hadrons due to inelastic rescattering and the cross section for central diffraction gets strongly reduced. In contrast, Streng calculates only the Born term cross section. Figure 2 illustrates the differences obtained using different theoretical methods. We stress, both methods use the measured single diffractive cross sections to extract the triple-pomeron coupling.

3.2. Single diffraction in hadron-hadron collisions at collider energies

Figure 3. Mean charged particle multiplicity of the diffractively produced hadronic system with invariant mass $M$. UA–4 data [6] are compared to single and multiple interaction model predictions and data on non-diffractive $p\bar{p}$ interactions at $\sqrt{s} = M$.

There are the following experiments which have studied hadron production in single diffraction in $p\bar{p}$ collisions at the CERN–SPS–Collider:

1. The UA–4 Collaboration [37,38] measured pseudorapidity distributions of charged hadron production for different masses of the diffractive system. We have already twice compared earlier versions of the Dual Parton Model [8,9] to this data. New in the present model is hard diffraction and multiple chains in the diffractive hadron production, therefore we have again compared to this data and we find reasonable agreement (see Figs. 3 and 4). In particular we present besides the distributions according to the full model also the contribution from one pair of chains only (single interaction model). This is the rapidity distribution expected from the Born term without the contributions from hard diffraction (minijets) and multiple soft interactions, which are obtained from the unitarization method. It is evident from the data as well as from the model that multiple interactions and minijets lead to a rising rapidity plateau in pomeron–proton collisions in a similar way.

Figure 4. Pseudorapidity distribution of charged hadrons in single diffraction dissociation. UA–4 data [6] to model predictions.
as observed in hadron–hadron collisions.

2. Hard diffractive proton–antiproton interactions were investigated by the UA–8 Collaboration [39]. In this experiment the existence of a hard component of diffraction was demonstrated for the first time. Because of the importance of these findings, we compared them already in a recent paper [10] to our model and found the model to be consistent with this experiment. Therefore we will not repeat this comparison here.

Figure 5. Differential $e^–p$ cross section $d\sigma/d\eta_{\text{jet}}$ for inclusive jet production with $E_T^{\text{jet}} > 8 \text{ GeV}$ in the kinematic region $Q^2 \leq 4 \text{ GeV}^2$ and $0.2 < y < 0.85$. We compare data from the ZEUS Collaboration [40] with PHOJET results using the same trigger as used for the ZEUS data.

3.3. Single diffraction in photoproduction

Results on single photon diffraction dissociation and in particular hard single diffraction were presented by both experiments at the HERA electron–proton collider [42–44,40,45,46]. The ZEUS Collaboration [40] has presented differential and integrated jet pseudorapidity cross sections for jets with $E_T^{\text{jet}} > 8 \text{ GeV}$. The absolute normalization of these data is given. This allows one a more severe check of the model. In Figs. 6 we compare the differential jet pseudorapidity cross sections from ZEUS [40] to the model. The Monte Carlo events from PHOJET have been treated with the same cuts and trigger as used for the data. We find a reasonable agreement. We should, however, point out that the data include contributions from non-diffractive processes while the results from the model concern only diffractive events.

3.4. Central diffraction dissociation

Data on hard central diffraction in proton–antiproton collisions at 0.63 TeV have been published by Joyce et al. [41]. These data were ob-

Figure 6. The pseudorapidity distribution in central diffraction as observed by the UA–1 Collaboration [41] compared with the corresponding distribution in PHOJET without direct pomeron coupling with the UA–1 trigger applied to the Monte Carlo events (p), with a direct pomeron coupling (d) and without multiple interactions (s).
tained with the UA–1 detector at the CERN–SPS collider. The data are not easy to understand since they have been obtained with triggers demanding a pair of jets with $E_t > 3$ GeV or localized electromagnetic energy depositions larger than 1.2 GeV. This trigger accepts a cross section of 0.3 mb while we find in our model at this energy a total central diffraction cross section of approximately 0.3 mb (see Fig. 2). Thus the trigger of Joyce et al. accepts only a tiny fraction of all central diffraction events. The most remarkable features of the data are the following: The pseudorapidity distribution of the events accepted by the trigger reaches a maximum central plateau of around 5 per pseudorapidity unit, 30 percent higher than the non-diffractive minimum bias events at the full $p\bar{p}$ collision energy.

We try to understand these data in three versions of the model. (i) The full model without a direct pomeron coupling, (ii) the full model with a direct pomeron quark coupling, (iii) the model without multiple interactions and without a direct pomeron coupling. We use for the Monte Carlo events the same trigger requirements as described in [1].

In Fig. 3 the charged particle $\eta$ distribution of the three versions of the model are compared to the data. Only the full model gives a pseudorapidity maximum comparable to the data. This is easy to understand, only in the full model we have enough multiple soft chains and multiple minijets to obtain such a large particle density. In the model with direct coupling we trigger to events with one pair of direct jets, this does not give enough particle density. Similarly in the model without multiple interactions we just get one pair of soft chains together with a minijet, also in this configuration the particle density is lower than in the full model.

4. Comparing hadron production in diffractive processes to non-diffractive particle production in $p\bar{p}$ and $\gamma\gamma$ reactions

In Sections II we have already pointed out, that our model for particle production in pomeron–hadron/photon collisions and pomeron–pomeron collisions has the same structure characterized by multiple soft collisions and multiple minijets like models for hadron production in hadron–hadron collisions. Therefore, again we expect the main differences in comparison to other channels in the hard component due to the differences between the pomeron and hadron structure functions and due to the existence or nonexistence of a direct pomeron–quark coupling. We will use in all comparisons here three models for $P\bar{P}$, $P\gamma$ and $P\gamma$ collisions:

(i) our model with multiple soft and hard collisions,

(ii) in order to see the influence of the multiple soft and hard collisions a model with only one soft
Figure 8. Jet pseudorapidity distributions in non-diffractive $p$–$p$ and $\gamma$–$\gamma$ collisions compared with the jet pseudorapidity distribution in single diffraction (pomeron–$p$ scattering). The distributions were generated with PHOJET, the c.m. energy is 100 GeV in all cases, but the pseudorapidities in the collisions with pomerons given refer to the $\sqrt{s} = 2$ TeV $p$–$p$ collisions used to generate the diffractive events.

or hard collision allowed and

(iii) the full model (i) assuming in addition the existence of a direct pomeron–quark coupling according to the toy–model. We present this despite the fact that we did not find in the presently existing data any feature which could only be described with such a coupling.

The differences in the parton structure functions of protons, photons and pomerons lead to quite different energy dependences of the hard cross sections. In all processes where pomerons are involved, single diffraction and central diffraction, hard processes become important already at lower energies. For pomeron–pomeron scattering at low energy the hard cross section is about a factor 100 bigger than in $p$–$\bar{p}$ collisions. At high energies the opposite happens, the hard cross sections in all processes where pomerons are involved rise less steep with the energy than in pure hadronic or photonic processes. The reason for this is the different low-$x$ behavior of the parametrization of the structure functions used. However, nothing is known at present from experiment about the low-$x$ behavior of the pomeron structure function.

In Fig. 7 we compare jet transverse energy distributions in $p$–$p$ and $\gamma$–$\gamma$ collisions with the ones in $P$–$\bar{P}$ collisions. In the channels with pomerons we present again the distributions according to our full model, according to the model without multiple interactions and the model with a direct pomeron–quark coupling. In all non-diffractive collisions we have $\sqrt{s} = 100$ GeV and the diffractive events are generated in $\sqrt{s} = 2$ TeV collisions.

Figure 9. Average charged multiplicity as function of the c.m. energy in single diffractive collisions (pomeron–$\gamma$ collisions) according to PHOJET (points) is compared to the average charged multiplicities in non single diffractive $p\bar{p}$, $\gamma p$ and $\gamma\gamma$ collisions, also according to PHOJET (lines) and experimental data in $p\bar{p}$ collisions.
The differences in the jet transverse energy distributions between the channels are as to be expected more important than in the hadron $p_\perp$ distributions. We observe an important reduction in the jet distributions in the model without multiple interactions. The $E_\perp$ distributions in the $P-\gamma$ and $P-P$ channels extend up to the kinematic boundary. In the latter two cases as in the case of $\gamma-\gamma$ collisions the entries at large $E_\perp$ come only from direct processes.

In Fig. 8 we compare jet pseudorapidity distributions in $p-p$, $\gamma-\gamma$ and $P-P$, again, all collisions at $\sqrt{s} = 100$ GeV with the diffractive events generated in $\sqrt{s} = 2$ TeV collisions. For the jets we observe substantial differences in the shape of the pseudorapidity distributions.

In Figs. 9 we compare the average charged multiplicity in non-diffractive $p-p$, $\gamma-\gamma$ and $\gamma-p$ collisions according to the model as function of $\sqrt{s}$ with the charged multiplicity in the pomeron–$\gamma$ diffractive channel as function of the invariant mass of the diffractive system. In the same plots we compare also to data in the case of $p-p$ collisions. We find at collision energies below say 500 GeV only small differences between the channels. However, at energies above 1 TeV the model with only one pomeron exchange (one-pomeron cut) in diffraction dissociation (labeled with $s$) predicts a smaller average multiplicity than observed in hadron-hadron or photon-hadron scattering.

5. Single diffraction and central diffraction at TEVATRON

In Figs. 10 to 17 we present some cross sections calculated using PHOJET at TEVATRON energy. The distributions are mass distributions in single and central diffraction Fig. 11, jet pseudorapidity distributions in single and central diffraction as well as in non-diffractive $p-p$ collisions (ND) using $E_\perp$ thresholds of 5 and 15 GeV Fig. 11 to 13. Jet $E_\perp$ distributions Fig. 14 to 16 and the charged multiplicity as function of the diffractive mass Fig. 17. In some of the distributions we give besides the full PHOJET model also the plots for a model with a small direct pomeron coupling and for a model with only single pomeron coupling and for a model with only single soft or hard chains pairs.

Results on diffractive jet production from the two TEVATRON Collaborations are discussed in [16, 51]. one of the results obtained by the D0 Collaboration is the ratio of double–pomeron exchange (DPE) (in the present paper we use the term central diffraction (CD) instead of DPE) to non–diffractive (ND) dijet events:

$$\left( \frac{\sigma(DPE)}{\sigma(ND)} \right)_{E_\perp > 15 \text{ GeV}} \approx 10^{-6}$$

PHOJET gives the following cross sections:

- Non-diffractive (ND): $\sigma(ND) = 45.2$ mb,
- Single diffractive (SD): $\sigma(SD) = 11.2$ mb,
- Central diffraction (CD): $\sigma(CD) = 0.64$ mb.

From these cross sections together with Figs. 11 to 13 we get for this and similar ratios always for $E_\perp$ larger than 15 GeV:

$$(\text{CD})/(\text{ND}) \approx 2 \times 10^{-6},$$

$$(\text{SD})/(\text{ND}) \approx 4 \times 10^{-3},$$

$$(\text{CD})/(\text{SD}) \approx 0.5 \times 10^{-3}.$$  

Despite the fact that no experimental acceptance has been considered for these PHOJET results it is interesting to find the (CD)/(ND) ratio so close to the D0 value given above.

6. Conclusions and summary

Multiple soft and multiple hard interactions (minijets) have been introduced to describe high-mass diffractive hadron production. Comparing diffraction dissociation with the invariant mass $M$ to non-diffractive particle production at $M = \sqrt{s}$, a rise of the rapidity plateau and multiplicity is found which is similar for both hadron production processes. The model predictions agree well with data on high-mass single and central diffraction dissociation. Minimum bias hadron production in hadron-hadron, and photon-photon collisions as well as in pomeron–hadron, pomeron–photon and pomeron–pomeron collisions of the same c.m. energy is remarkably similar. To see this, one has to restrict the comparison to inelastic events and to exclude also the diffractively produced vector mesons in reactions involving photons. The only
striking differences appear in the transverse momentum distribution or distributions where the transverse momentum behavior is essential. This difference can be understood to be due to the direct photon interaction contribution and due to the photon and pomeron structure functions being considerably harder than hadronic structure functions.

Finally we would like to emphasize that measurements at TEVATRON on CD and SD would allow one to study many of the open questions: Is it possible at all to describe diffraction and hard diffraction using the triple pomeron graph? Can QCD factorization be applied to the description of hard diffraction? Does a direct pomeron–quark coupling exist? Do we have multiple soft and hard chains in diffractive particle production?

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Figure 12. Pseudorapidity distribution of jets with $E_\perp$ larger than 5 GeV and 15 GeV in central diffraction (Pom–Pom) at TEVATRON. The upper curves with the same plotting symbol are for $E_\perp = 5$ GeV, the lower curves are for $E_\perp = 15$ GeV. We plot also the distributions (d) using a small direct Pomeron coupling ($\lambda = 0.05$) and (s) in a model where only single soft or hard chains are generated.

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Figure 13. Pseudorapidity distribution of jets with $E_\perp$ larger than 5 GeV and 15 GeV in non-diffractive (ND) $p$–$p$ collisions at TEVATRON. The upper curve is for $E_\perp = 5$ GeV and the lower curve is for $E_\perp = 15$ GeV.

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Figure 14. Transverse energy distribution of jets in (one side) single diffraction (Pom–p) at TEVATRON. We plot also the distributions (d) using a small direct Pomeron coupling ($\lambda = 0.05$) and (s) in a model where only single soft or hard chains are generated.

Figure 15. Transverse energy distribution of jets in central diffraction (Pom–Pom) at TEVATRON. We plot also the distributions (d) using a small direct Pomeron coupling ($\lambda = 0.05$) and (s) in a model where only single soft or hard chains are permitted.

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Figure 16. Transverse energy distribution of jets in non-diffractive (ND) $p$–$p$ collisions at TEVATRON.

Figure 17. Charged multiplicity as function of the diffractive mass in single diffraction (Pom–$p$) and central diffraction (Pom–Pom) at TEVATRON. We plot also the distributions (s) in a model where only single soft or hard chains are considered.

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