Hard Diffraction at CDF

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Recently published and new preliminary results from the analyses of diffractive events selected with a central or a forward rapidity gap are summarized. New measurements of the ratio of dijet production in single diffractive and non-diffractive events obtained from the Roman Pot data are discussed.

1. INTRODUCTION

In the studies described below different techniques to identify diffractive events are used. One of them is the direct measurement of the diffractively scattered anti-proton with Roman Pots. Results obtained by those data are described in section 3. Another technique is to look for a rapidity gap in the event topology.

2. RESULTS FROM RAPIDITY GAP DATA

Rapidity gaps are large regions in pseudorapidity in which no signal above noise is measured in the detector. They are devoid of any produced particle, a clear signature for the exchange of a colorless object (see figure 1). The cen-

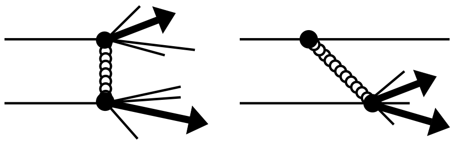

Figure 1. Dijet production with a central(left) or a forward(right) rapidity gap.

tral tracker ($|\eta| < 1.8, p_T^{track} > 300$MeV) and the central calorimeter ($|\eta| < 1.1, E_T^{tower} > 200$MeV [300MeV corrected]) of the CDF detector [1] were used to select events with a rapidity gap between two jets. The search for the forward rapidity gaps was performed with the forward calorimeter ($2.4 < |\eta| < 4.2, E^{tower} > 1.5$GeV), measuring charged and neutral particles, and the scintillator systems of the Beam-Beam Counters ($3.2 < |\eta| < 5.9$), sensitive to charged particles.

2.1. Data with a Central Rapidity Gap

In this study opposite side dijets ($\eta_1 \cdot \eta_2 < 0$) are compared to same side dijets ($\eta_1 \cdot \eta_2 > 0$). Results on the production rate and the properties of these dijets at a center of mass energy of $\sqrt{s} = 1800$GeV have been published in [2] and [3]. The ratio of dijets with a central gap to those without a gap is measured to be $R_{JGJ}(1800) = (1.13 \pm 0.16)\%$ for dijets with $E_T^{jet} > 20$ GeV. The study of these dijets at the lower center of mass energy of $\sqrt{s} = 630$GeV is also finished and published in [4]. The ratio R_{JGJ} is determined to $R_{JGJ}(630) = (2.7 \pm 0.9)\%$ for a lower jet E_T threshold of 8 GeV, so that the same η of a jet corresponds to the same x, the longitudinal momentum fraction of the interacting parton, at both values of $\sqrt{s}$ and the ratios can be compared: $R_{JGJ}(630/1800) = 2.4 \pm 0.9$. The distribution of the ratio as a function of the average η, E_T and x are measured at both energies and are found to be flat within the errors.

2.2. Data with a Forward Rapidity Gap

Already in 1997 the diffractive production rates of W bosons [5] and dijets [6] were published. From these two analyses it was derived, that the fraction of hard gluons in the pomeron is $f_g = 0.7 \pm 0.2$. Compared to HERA measurements a discrepancy of $D = 0.18 \pm 0.04$ in the momentum sum was found. This discrepancy is predicted by the concept of the renormalized flux [7].

New, preliminary results on diffractive heavy flavor production are now available, in which the same rapidity gap criterion has been applied as in the previous analyses. In both cases, the b-quark and the J/ψ production, the signal is extracted from the multiplicity bin with no forward calorimeter tower above noise and no hit in the Beam-Beam Counters. The background from non-diffractive events in this signal bin is extracted from the extrapolation of the diagonal and subtracted (figures 2 and 3). In the study

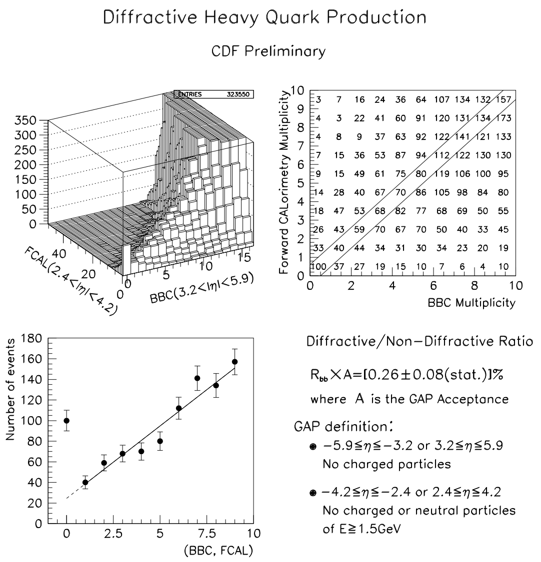

Figure 2. Diffractive b-quark production.

of diffractive b-production the diffractive events are required to contain a central($|\eta| < 1.1$) electron with $E_T > 9.5$GeV from the semi-leptonic b-decay. The ratio of diffractive to non-diffractive b-production is measured to be $R_b\left(\frac{\mathrm{SD}}{\mathrm{ND}}\right) \times \mathcal{A} = [0.26 \pm 0.08(stat)]\%$. The quoted ratio is uncorrected for the rapidity gap acceptance $\mathcal{A}(\approx 40\%)$.

In the data selection for the J/ψ production its decay into 2 muons is used. The diffractive events are required to have a central μ-pair of

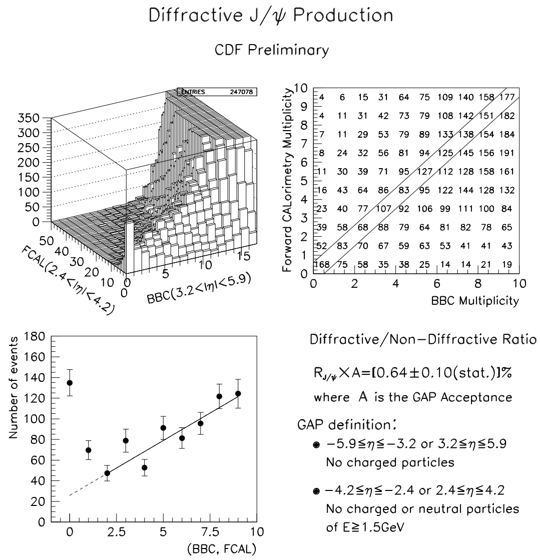

Figure 3. Diffractive J/ψ production.

$p_T > 2$GeV. Here again the ratio of diffractive to non-diffractive J/ψ production is uncorrected for the rapidity gap acceptance and evaluated to: $R_{J/\psi}\left(\frac{\mathrm{SD}}{\mathrm{ND}}\right) \times \mathcal{A} = [0.64 \pm 0.12]\%$.

3. RESULTS FROM ROMAN POT DATA

In the beginning of 1996 the CDF experiment was additionally equipped with three Roman Pot stations in the anti-proton direction and took the data of Run 1C under high and low luminosity conditions at both $\sqrt{s} = 1800$GeV and $\sqrt{s} = 630$GeV. By requiring a good reconstructed track single diffractive events were selected. The Roman Pots show a good acceptance for ξ, the longitudinal momentum fraction taken in the diffractive interaction from the scattered anti-proton, in the range of 0.04 to 0.1. In t, the squared four-momentum transfer, the Roman pot acceptance at $\sqrt{s} = 1800$GeV is good up to $|t| < 1\mathrm{GeV}^2$, extending to about $3\mathrm{GeV}^2$, whereas at $\sqrt{s} = 630$GeV the acceptance is good up to $|t| = 0.2\mathrm{GeV}^2$.

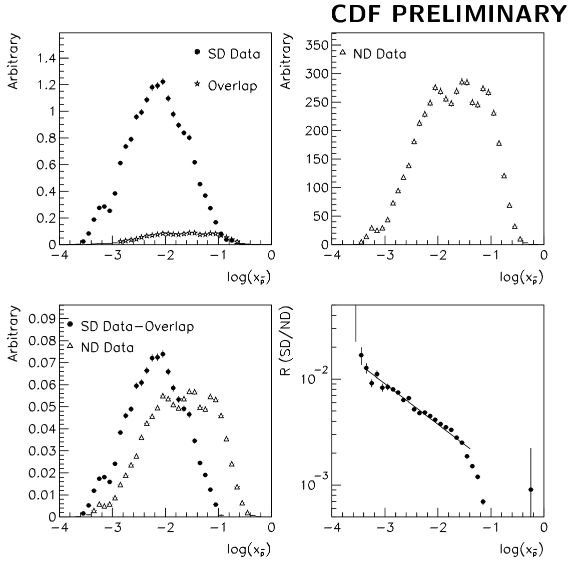

Figure 4. Distribution of $x_{\bar{p}}$ in the single diffractive dijet data and overlap background events(top left) and in the non-diffractive data(top right). Comparison of the SD and ND distributions (bottom left) and their ratio(bottom right).

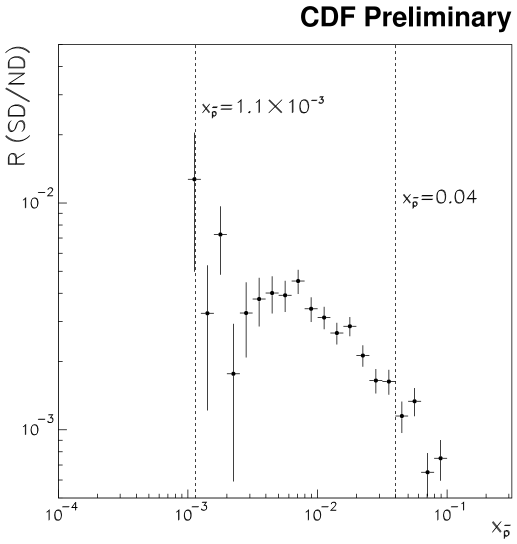

Figure 5. Ratio of single diffractive to non-diffractive dijet events as a function of $x_{\bar{p}}$ at a center of mass energy of $\sqrt{s} = 630$GeV.

In addition to the analysis of the single diffractive events a study for double pomeron exchange has been performed.

3.1. Dijets in Single Diffractive Events

In the single diffractive data we select events with two jets of $E_T \geq 7$GeV and evaluate the momentum fraction of the parton in the anti-proton, which took part in the jet production from the equation

$$x_{\bar{p}} = \frac{E_T^{jet_1} \cdot e^{-\eta_1} + E_T^{jet_2} \cdot e^{-\eta_2}}{2 \cdot p_{beam}} \quad . \tag{1}$$

The measurement of this quantity is independent of any assumption on the diffractive scattering process, since these events are only required to have a Roman Pot track. The analysis of the ratio of its distribution in single diffractive events(SD) to that in non-diffractive events(ND) is therefore completely model independent. Figure 4 illustrates the separate steps of the evaluation. The advantage of calculating a ratio is the cancelation of detector influences, like jet energy calibration or cracks in the calorimeter, because jets at the same $x_{\bar{p}}$ have similar E_T and η. In addition some uncertainties in eventual theoretical calculations will also cancel.

In figure 4 bottom right the ratio is shown for the center of mass energy of $\sqrt{s} = 1800$GeV and in figure 5 for $\sqrt{s} = 630$GeV. In both cases dijets with an $E_T \geq 7$GeV were required and the single diffractive events were taken in the range $0.04 < \xi < 0.1$ and $|t| < 1\text{GeV}^2(\sqrt{s} = 1800\text{GeV})$, $|t| < 0.2\text{GeV}^2(\sqrt{s} = 630\text{GeV})$. No Roman Pot acceptance has been applied so far, but the conclusions are not influenced by this. The left dotted line in figure 5 denotes the approximate lower limit for $x_{\bar{p}}$ given by the minimum jet E_T and detector size, whereas the right dotted line shows the upper limit determined by the smallest accepted ξ of 0.04. All events with a $x_{\bar{p}} > 0.04$ stem from events with a larger ξ up to the highest accepted value of 0.1.

The level of the ratio of diffractive to non-diffractive dijet production lays below 1% in contrast to the ratios of about 10% observed at HERA in inclusive DIS measurements. The range covered in $x_{\bar{p}}$ is quite large, it starts as low as 4.0×10^{-4} and spans over two orders of magnitude. The observed ratio can be interpreted as the diffractive structure relative to the proton structure probed in the non-diffractive case. The ratio decreases with increasing $x_{\bar{p}}$ as $1/x_{\bar{p}}^n$. This dependence is similar at both values of $\sqrt{s}$. Since the proton structure also decreases as $1/x_{\bar{p}}^r$ in this range of $x_{\bar{p}}$, the diffractive structure is expected to have a $1/x_{\bar{p}}^{(n+r)}$ behavior.

Turning now to the assumption that a pomeron was exchanged in the diffractive interaction (see fig. 1 right) the measurement of ξ by the Roman Pots makes it possible to calculate the distribution of β, the momentum fraction of the parton in the pomeron, which took part in the hard subprocess, according to the relation $\beta = x_{\bar{p}}/\xi$. To interpret the distribution of β observed in the data, it is necessary to unfold the influences from the finite detector size and the physics process dependencies. This can be achieved by dividing the data by Monte Carlo simulations generated with a flat parton distribution in the pomeron, in which all values of β are equally distributed, and which have been passed through the detector simulation and reconstruction. Studies performed with the POMPYT generator [8] of version 2.61 show the expected behavior of the diffractive structure. Using the standard parameterization of the pomeron flux a discrepancy between the measured and the predicted cross section is observed of the same magnitude as already found in the diffractive W and dijet production. The application of the renormalized pomeron flux resolves this discrepancy. With simulations also direct comparisons with predictions from the pomeron model and its parton densities as measured by the H1 Collaboration [9] can be performed.

3.2. Dijets in Double Pomeron Exchange

Candidates for a double pomeron exchange (DPE) have been selected by asking for a forward rapidity gap opposite to the Roman Pots. Compared to the already reported results [10] the study has be refined in several aspects, like jet reconstruction, but the conclusions stay the same:

- the kinematic properties of the DPE candidates are in agreement with predictions from DPE simulations,
- the rate $R(\frac{\mathrm{DPE}}{\mathrm{SD}})$ predicted by simulations become consistent with the measured rate if both pomeron fluxes are renormalized by the measured discrepancy D,
- the E_T spectrum of the leading jet in DPE, SD and ND look similar.

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