Diffractive W, Z, dijet and jet-gap-jet production in CDF

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We report results on diffraction obtained by the CDF collaboration in $p\bar{p}$ collisions at the Fermilab Tevatron collider at $\sqrt{s}$ =1.96 TeV. The single-diffractive dijet production and Q^2 and t dependence of the diffractive structure function are discussed. The results on diffractive W/Z production and central gaps between very forward jets are presented.

1 Introduction

The diffractive processes became an important tool in understanding many interesting aspects of QCD such as low-x structure of the proton, behavior of QCD in high density regime. The diffractive reaction can be defined as a reaction in which no quantum numbers are exchanged between the colliding particles and/or a large, non exponentially suppressed, rapidity gap is present. The diffractive exchange is defined by the fraction ξ of the leading particle momentum carried away in the exchange, the exchanged object referred to as a "pomeron", and the four-momentum transfer-squared t.

CDF collaboration contributed extensively [1]-[9] to significant progress in understanding diffraction by studying wide variety of diffractive processes at three different center-of-mass energies: 630 GeV, 1800 GeV, Run I of Tevatron, and 1960 GeV - Run II. Some of the important results include the observation of the QCD factorization breakdown in hard single diffractive processes, discovery of large rapidity gaps between two jets, study of diffractive structure function in double pomeron exchange dijet events.

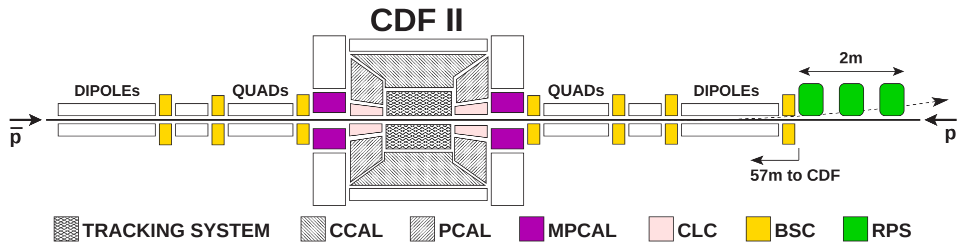

Figure 1: Schematic drawing of the CDF II detector.

The schematic layout of CDF II detector is presented in Fig. 1. The forward detectors are very important for the implementation of a diffractive program, since the identification of diffractive events requires either tagging of the leading particle or observation of a rapidity gap. The Forward Detectors include the Roman Pot fiber tracker Spectrometer (RPS) used to select events with a leading $\bar{p}$, the Beam Shower Counters (BSCs), covering the pseudorapidity range 5.5<$|\eta|$<7.5, detecting particles traveling in either direction from the interaction point along the beam-pipe, and the Miniplug Calorimeters (MP) [10] measuring energy and lateral position of electromagnetic and hadronic showers in the pseudorapidity region of 3.5<| η |<5.1.

2 Single Diffractive Dijet Production

One of the diffractive processes studied during Run I was the hard single diffraction (SD) [6]. We compared two samples of dijet events, diffractive, triggered by the presence of intact antiproton detected in the RPS, and non-diffractive (ND). By taking the ratio of SD dijet rates to ND, which in a good approximation is the ratio of the diffractive to the known proton structure function, the diffractive structure function can be extracted.

We continued our studies of the diffractive structure function in Run II. One of the major challenges in diffractive studies during Run II is the presence of multiple $p\bar{p}$ interactions, which by overlapping with the diffractive event spoil signature characteristics of those, such as rapidity gaps. The rejection of *overlaps* was done by reconstructing ξ from the calorimeter towers, and considering only ξ^{cal} <0.1, thus rejecting overlap events which have high ξ^{cal} values as a result of having more energy than just the diffractive interactions.

We extended our results from Run I by studying 310 pb^{-1} SD data sample to examine the Q^2 dependence of the structure function up to 10^4GeV^2, where Q^2 is defined as an average value of mean dijet E_T. No appreciable Q^2 dependence was observed. We also studied the t distribution in single diffractive dijet events up to Q^2 ~4500 GeV^2, and no Q^2 dependence of the shape of the t distribution was observed.

3 Diffractive W/Z Production

The diffractive W/Z production is an important process for probing the quark content of the pomeron, since to leading order, the W/Z is produced through a quark, while the gluon associated production is suppressed by a factor of α_S and can be identified by an additional jet.

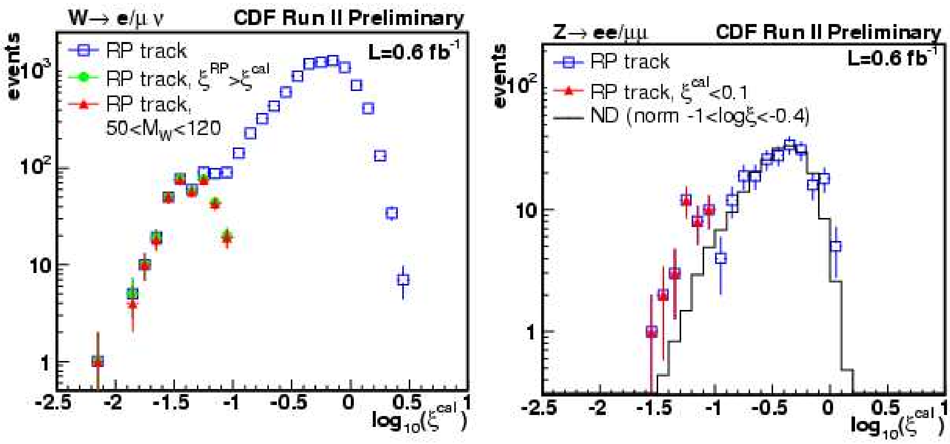

Figure 2: Calorimeter ξ distribution in W (left) and Z (right) events with a RPS track.

CDF studied diffractive W production in Run I [2] by using rapidity gap signature of the diffractive event. In Run II, we developed a method that completely reconstructs W kinematics. The events are selected by utilizing "intact leading antiproton" signature of the diffractive event. The RP spectrometer allows very precise ξ measurement, eliminating the problem of *gap survival probability.* The presence of a hit in the RPS trigger counters and a RPS reconstructed track with 0.03< ξ <0.1 and $|t|$<1 is required. The novel feature of the analysis, the determination of the full kinematics of the $W \to l\nu$ decay, is made possible by obtaining the neutrino ${E_T}^{\nu}$ from the missing E_T, $\not{E}_T$, and η_ν from the formula $\xi^{RPS} - \xi^{cal} = \frac{\not{E}_T}{\sqrt{s}} e^{-\eta_\nu}$, where ξ^{RPS} is true ξ measured in RPS and $\xi^{cal} = \sum_{i(towers)} (E_T^i/\sqrt{s}) exp(-\eta^i)$. Since we expect $\xi^{cal} < \xi^{RPS}$, we impose this requirement to remove overlap events to ensure that Ws were produced diffractively. Figures 2a,b show ξ^{cal} distributions for W and Z events with a RPS track. Figure 3 shows reconstructed W mass in diffractive W candidates. The requirements for W/Z selection are following: ${E_T}^l$ >25 GeV, 40< M_T^W <120 GeV, 66< M^Z <116 GeV, and $z-$vertex coordinate z_{vtx} < 60 cm. The fractions of diffractive W and Z events are measured to be $[0.97 \pm 0.05(stat.) \pm 0.11(syst.)]$% and $[0.85 \pm 0.20(stat.) \pm 0.11(syst.)]$% for the kinematic range 0.03< ξ <0.10 and $|t|$<1 GeV/c. The measured diffractive W fraction is consistent with the Run I CDF result when corrected for the ξ and t range.

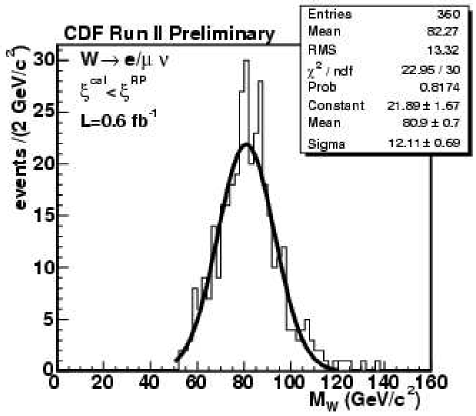

Figure 3: Reconstructed W mass in diffractive W candidate events.

4 Central Rapidity Gaps

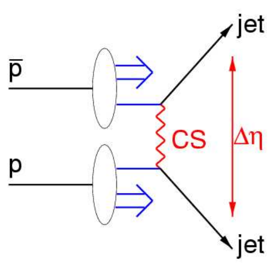

Figure 4: Schematic diagram of an event with a rapidity gap between jets produced in $p\bar{p}$ collisions.

Double diffractive (DD) dissociation is the process in which two colliding hadrons dissociate into clusters of particles (jets in case of hard DD dissociation) producing events with a large non-exponentially suppressed central pseudo-rapidity gap, see Fig. 4. Events with pseudorapidity gaps are presumed to be due to the exchange across the gap of a color singlet (CS) object, *pomeron*, with vacuum quantum numbers. The dependence of the gap fraction on the width and on the position of the center of the gap, $\Delta\eta^{gap}$ and ${\eta_c}^{gap}$, and the jet characteristics of the event are of great interest, as they allow testing different theoretical models. Measurements of DD have been performed for hard and soft diffraction processes [1],[4],[5],[8] for $p\bar{p}$ collisions at $\sqrt{s}$ =630 and 1800 GeV by the CDF collaboration. The extended rapidity coverage provided by the MP calorimeters (3.5<$|\eta|$<5.1) makes CDF II a powerful detector for hard DD studies, as it provides up to 8 units of η

between jets for jets in the MPs. Using this data sample, we select events with two jets in the MPs with E_T >2 GeV, 3.5<| η^{jet} |<5.1, and $\eta_1\eta_2$ <0. The E_T cut is designed to maximize the jet signal while minimizing the effect of energy deposited by single particles and misidentified jets. We use this data sample to study the dependence of the gap fraction on the width of the gap in "hard" and "soft" DD production. For this aspect of our analysis we use a definition of rapidity gap similar to that of our Run I study [8], where the rapidity gap variable, $\Delta\eta$, is defined as $\Delta\eta = \eta_{max} - \eta_{min}$, where η_{max} is the pseudorapidity of the particle (tower) closest to $\eta = 0$ in the proton direction and η_{min} is the pseudorapidity of the particle closest to the $\bar{p}$ direction. For events with gaps which overlap η =0 these are effectively the edges of the rapidity gap. The data sample mentioned above is used to study "hard" diffraction production, where a hard structure (jet) is present in the event. "Soft" diffractive production is analyzed by examining low luminosity data collected with a min-bias trigger. Fig. 5 shows a comparison of the gap fraction, as a function of $\Delta\eta$, between "hard" and "soft" DD production when a rapidity gap is required within -1.1< η <1.1.

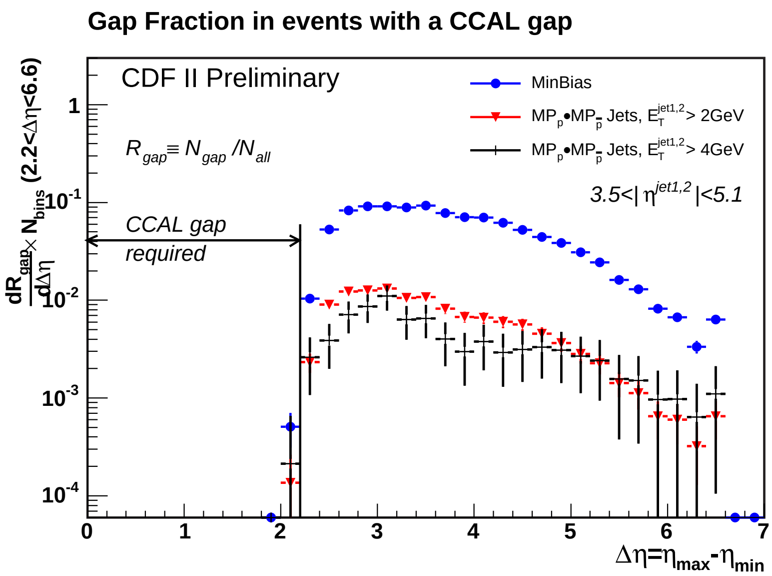

Figure 5: The distribution of the gap fraction $R_{gap} = N_{gap}/N_{all}$ vs. $\Delta\eta = \eta_{max} - \eta_{min}$ for min-bias and MiniPlug jet events of $E_T^{jet1,2}$ >2 GeV and $E_T^{jet1,2}$ >4 GeV.

This comparison is relatively free of systematic uncertainties, as detector and beam related effects cancel out. The distributions are similar in shape, demonstrating that the gap fraction decreases with increasing $\Delta\eta$ for both "hard" and "soft" DD productions.

5 Conclusions

The long running diffractive program at CDF has significantly improved our understanding of diffractive processes. The diffractive structure function and t distribution from SD dijet production have been measured. The measurement of diffractive W/Z production using RPS was found to confirm CDF Run I measurement. The study of events with a rapidity gap shows similar shape distribution for gap fraction as a function of the width of the gap for both *hard* and *soft* samples.

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