Diffraction Results from CDF[1]

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ABSTRACT

We present final results by the CDF II collaboration on diffractive W and Z production, report on the status of ongoing analyses on diffractive *dijet* production and on rapidity gaps between jets, and briefly summarize results obtained on exclusive production pointing to their relevance to calibrating theoretical models used to predict exclusive Higgs-boson production at the LHC.

1 Introduction

Starting with the first $\bar{p}p$ collider data at the Tevatron in 1989, the CDF Collaboration has been carrying on a comprehensive diffractive physics program aimed at understanding the QCD mechanism of diffraction. It is presumed that in diffraction a strongly-interacting color-singlet quark/gluon combination with the quantum numbers of the vacuum (the *Pomeron*, $I\!\!P$) is exchanged [1]-[3]. The aim of diffractive studies is to decipher the parton distribution function (PDF) of $I\!\!P$ exchange. There is also a practical reason for diffractive studies. As approximately one quarter of all inelastic $\bar{p}p$ collisions at Tevatron energies are diffractive, they have a significant effect on the underlying event (UE) of hard (high transverse momentum) processes. Therefore, understanding diffraction can provide a tool for all data analyses where the UE influences trigger efficiencies and acceptance corrections. Since no radiation is expected from vacuum exchange, a large non-exponentially-suppressed pseudorapidity region devoid of particles, called a *rapidity gap* [4], is produced and can serve as an experimental signature for diffraction. Depending on the dissociation pattern, diffractive processes are classified as single-dissociation or single-diffraction (SD -with one forward gap adjacent to a surviving p or $\bar{p}$), double-dissociation or double-diffraction (DD- with one central gap), and central-dissociation or double-Pomeron exchange (CD or DPE -with two forward gaps).

In Run I, CDF studied all soft/inclusive (SD, DD, CD) and several hard (W, *dijet*, J/ψ, and b-quark) diffraction processes using the rapidity-gap signature to select diffractive events, and in some cases a Roman Pot Spectrometer (RPS) to measure the momentum of the surviving $\bar{p}$. While all Run I results were found to be self-consistent within the RENORM model [5], based on a renormalized Regge phenomenology to account for overlapping rapidity gaps, there were two striking disagreements with other experiments.

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First, depending on the model used for estimating gap acceptance/survival, the D0 Collaboration measured a larger fraction of SD to ND W events by a factor of up to ~ 3.5; and second, CDF measured a ratio of diffractive to non-diffractive (ND) structure functions that was $\sim 20\%$ greater than expectations based on HERA ep measurements. To address these issues, special forward detectors were built and commissioned in Run II. The forward detectors were also used to make a series of measurements on exclusive production of specific final states relevant to diffractive Higgs-boson production at the large Hadron Collider (LHC).

The status of the CDF analyses and final/preliminary results on diffractive and exclusive production are presented in Sec. 2, and conclusions are drawn in Sec. 3.

2 Results

In this section we present final results for W/Z production (Sec. 2.1) and preliminary results of the *dijet* (Sec. 2.2) and *gaps between jets* (Sec. 2.2.2) analyses.

2.1 Diffractive W and Z production

This analysis was fully reviewed in *DIFFRACTION 2010* [7]. Here, we present final results [8] for events in the regions of $\bar{p}$ momentum-loss fraction, ξ, within $0.01 < \xi < 0.10$, and 4-momentum-transfer squared, t, within $-1 < t < 0$ (GeV/c)^2.

Figure 2.1 shows LO diffractive W and Z production diagrams. The results are:

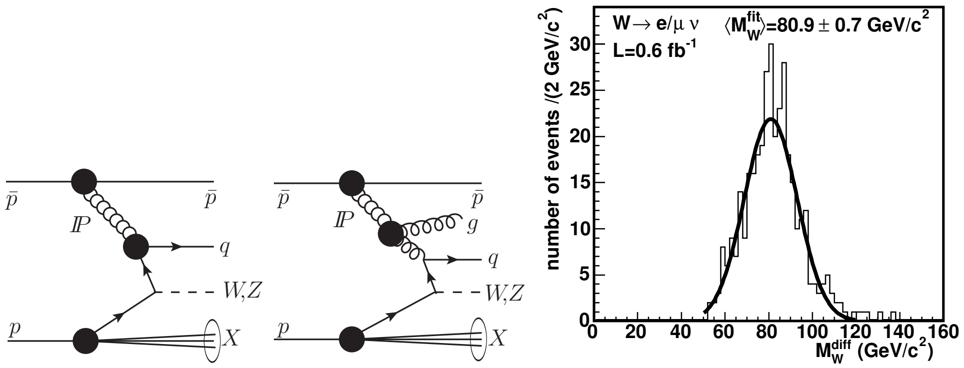

Figure 1: Diffractive W and Z production diagrams and $\mathrm{M}_W^{\mathrm{diff}}$ from diffractive W events.

- SD/ND ratios for SD events within $0.03 < \xi < 0.10$ and $-t < 0$ (GeV/c)^2:

  $\mathrm{R}_{\mathrm{W}}^{\mathrm{sd/nd}} = [1.00 \pm 0.05\,(\mathrm{stat.}) \pm 0.10(\,\mathrm{syst.})], \mathrm{R}_{\mathrm{Z}}^{\mathrm{sd/nd}} = [0.88 \pm 0.21(\,\mathrm{stat.}) \pm 0.08(\,\mathrm{syst.})]\%.$

  The $\mathrm{R}_{\mathrm{W}}^{\mathrm{sd/nd}}$ value confirms the CDF Run I rapidity-gap-based result [9].

- $\mathrm{M_W}$ is measured from fully reconstructed diffractive W events by obtaining p_z^ν for $W \to \mu/e + \nu$ from the difference between $\xi_{\bar{p}}^{\mathrm{RPS}}$ and its calorimetric value $\xi_{\bar{p}}^{\mathrm{CAL}}$:

$$\xi_{\bar{p}}^{\mathrm{CAL}} = \sum_{i=1}^{N_{\mathrm{towers}}} \frac{E_{\mathrm{T}}^i}{\sqrt{s}} e^{-\eta^i},\ \xi_{\bar{p}}^{\mathrm{RPS}} - \xi_{\bar{p}}^{\mathrm{CAL}} = \sum_{i=1}^{N_{\mathrm{towers}}} \frac{\not{E}_T^i}{\sqrt{s}} e^{-\eta^\nu},\ p_z^\nu = \not{E}_T / \tan\left[2\tan^{-1}\left(e^{-\eta^\nu}\right)\right].$$

The measured value of $\mathrm{M_W^{diff}} = 89.9 \pm 0.7$ GeV/c^2, shown in Fig. 2.1 (right), agrees with the world average of $\mathrm{M_W^{PDG}} = (80.399 \pm 0.023)$ GeV/c^2 [10].

2.2 Diffractive *dijet* production

We discuss the status of two analyses: " Measurement of the structure function in single-diffraction dijet production" and "Gaps between jets".

2.2.1 Structure function is single-diffraction *dijet* production

Substantial progress has been made in this analysis since *EDS2009* [6], but updated results have not yet been released. The main conclusions remain the same:

- the measured x_{Bj} rates confirm the factorization breakdown observed in Run I;
- In the range 10^2 (GeV/c)$^2 < Q^2 < 10^4$ (GeV/c)^2, where the inclusive E_{T} measured distribution falls by a factor of $\sim 10^4$, the ratio of the SD/ND distributions increases by only a factor of ~ 2.
- The slope parameter $b(Q^2)|_{t=0}$ of an exponential fit to t distributions near $t = 0$ shows no Q^2 dependence in the range 1 (GeV/c)$^2 < Q^2 < 10^4$ (GeV/c)^2.

These results support a picture of a composite Pomeron formed from color-singlet combinations of the underlying parton densities of the nucleon (see, e.g., [5]).

Currently, we are working on extending the measurement of the t distribution to $t \sim -4$ (GeV/c)^2 to search for a diffraction minimum.

2.2.2 Gaps between jets

An update of this analysis has been recently presented in [7]. Jet-Gap-Jet (JGJ) event rates can be used to test perturbative gap-creation models, such as the BFKL hypothesis (see, e.g., [3]). To reduce model dependence, we measure ratios of gap events to all events, $\mathrm{R_{gap}} \equiv \mathrm{N_{gap}}/\mathrm{N_{all}}$, as a function of the width of the gap and study the suppression relative to expectations between JGJ and soft DD events selected by their activity in the MiniPlugs in the η-range $3.5 < |\eta| < 5.1$. We find that the $\mathrm{R_{gap}^{jet}}$ ratios are suppressed relative to $\mathrm{R_{gap}^{DD}}$, as expected, but the suppression is independent of the width of the gap. A BFKL-model contribution to the JGJ distribution would be expected to be concentrated at high $\Delta\eta$. No excess that could be attributed to a BFKL contribution is observed.

2.3 Exclusive production

The main interest in studying diffractively produced exclusive final states is to use the results to check/calibrate QCD models of diffraction that can be applied to calculate production rates of exclusive *Higgs* production at the LHC. Final states studied include JJ (*dijet*) [11], χ_c [12], $\gamma\gamma$ [13], and J/ψ and $\psi(2s)$ [14]. The results are in good agreement with the model of [15].

3 Conclusion

We present final results by the CDF II collaboration on diffractive W and Z production and report on the status of ongoing analyses on diffractive *dijet* production and on rapidity gaps between jets.

The diffractive W/Z analysis has been completed and the results are published [8]. We find that in the range of $\bar{p}$ forward momentum loss $0.03 < \xi_{\bar{p}} < 0.10$ and for $-1 < t < 0$ (GeV/c)^2 the fraction of diffractive events in W and Z production is $\mathrm{R_W} = [1.00 \pm 0.05\,(\mathrm{stat.}) \pm 0.10(\,\mathrm{syst.})]\%$ and $\mathrm{R_Z} = [0.88 \pm 0.21(\,\mathrm{stat.}) \pm 0.08(\,\mathrm{syst.})]\%$, respectively. The R_W value is compatible with our Run I rapidity-gap based result.

In the analysis on the diffractive structure function in *dijet* production, we are working to extend the measurement of the t distribution to $t \sim -4$ (GeV/c)^2 to search for a diffraction minimum; and in the *gaps between jets* analysis, we are reanalyzing the data to obtain results in a format more suitable for comparison with theoretical predictions.

We also summarize results on exclusive production, pointing to their relevance to calibrating theoretical models used to predict exclusive *Higgs* production at the LHC.

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[4] Rapidity, $y = \frac{1}{2} \ln \frac{E+p_L}{E-p_L}$, and pseudorapidity, $\eta = -\ln \tan \frac{\theta}{2}$, where θ is the polar angle of a particle with respect to the proton beam ($+\hat{z}$ direction), are used interchangeably

for particles detected in the calorimeters, since in the kinematic range of interest in this analysis they are approximately equal.

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