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Diffractive W/Z and Exclusive Dijet Production at CDF II

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We report preliminary single-diffractive W/Z and final exclusive dijet production results for $\bar{p}p$ collisions at $\sqrt{s} = 1.96$ TeV extracted from data collected by the CDF II detector at the Fermilab Tevatron. The results are compared with previous measurements, and the obtained exclusive dijet cross sections are used to constrain / calibrate theoretical models for exclusive Higgs boson production rates at the Large Hadron Collider.

1 Introduction

The CDF collaboration has studied several soft and hard diffraction processes in $\bar{p}p$ collisions at the Fermilab Tevatron using rapidity gaps and/or a leading antiproton as a signature for diffraction (Fig. 1). These studies have revealed regularities in the data that point to a QCD picture of diffraction as an exchange of a spin zero color singlet combination of gluons and/or quarks carrying the quantum numbers of the vacuum [1].

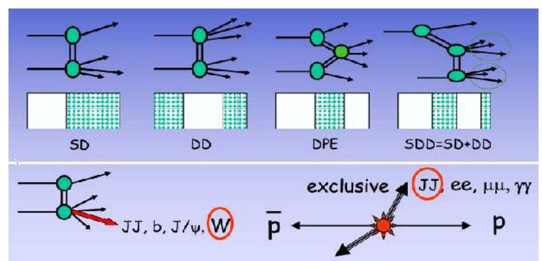

Figure 1: Diffraction at CDF.

The CDF II detector is shown schematically in Fig. 2 (from Ref. [2]). The components of the main detector [3] used in the diffractive program are the tracking system, the central, plug, and forward calorimeters (CCAL, PCAL, and FCAL), and the Čerenkov luminosity counters (CLC). In addition, the following special forward detectors are employed [2]:

- RPS (Roman Pot Spectrometer) - detects leading $\bar{p}$'s at $\sim 0.03 < \xi \equiv 1 - p_L < 0.09$,
- MPCAL (MiniPlug Calorimeters) - measure E_T and (θ, ϕ) at $\sim 3.5 < |\eta| < 5.5$, and
- BSC (Beam Shower Counters) - identify rapidity gaps at $\sim 5.5 < |\eta| < 7.5$.

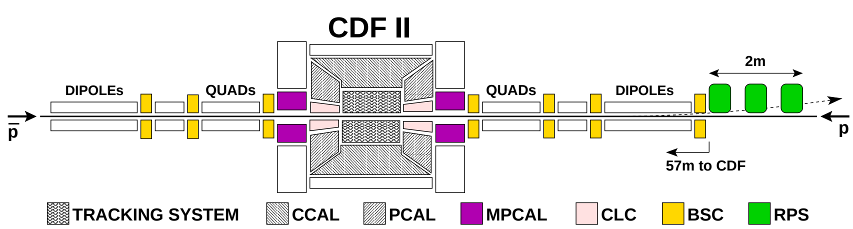

Figure 2: The CDF II detector.

*Representing the CDF Collaboration.

The result that has attracted widespread attention is the observation of a breakdown of QCD factorization in hard diffractive processes, expressed as a suppression by a factor of $\mathcal{O}(10)$ of the production cross section relative to theoretical expectations. However, of equal importance is the finding of a breakdown of Regge factorization in soft diffraction by a factor of the same magnitude [1]. Combined, these two results strongly support the hypothesis that the breakdown of factorization is due to a saturation of the probability of forming a rapidity gap by an exchange of a color-neutral construct of the underlying parton distribution function (PDF) of the proton, which is historically referred to as the *Pomeron*. Renormalizing the "gap probability" to unity over all (ξ, t) phase space corrects for the unphysical effect of overlapping difftavtive rapidity gaps and leads to agreement between theory and experiment (see [1] and references therein).

The renormalization model is further supportaed by the following soft-diffraction results obtained by CDF [1]:

- double-diffraction (central gap): same suppresion factor as in single-diffraction;
- multi-gap diffraction: double-gap to single-gap ratio non-suppressed;
- energy independence: σ_{tot}^{D} →constant as $s \to \infty$;
- Pomeron intercept and slope: they were related! [4]).

Similar results are found for hard-diffraction. In this paper we concentrate on the two most recent results of diffractive W/Z and exclusive dijet production.

2 Diffractive W/Z production

Whereas diffractive dijet production at the Tevatron has been found to be suppressed by a factor of $\mathcal{O}(10)$ relative to expectations from the DSF extracted from diffractive deep inelastic scattering (DDIS) at the DESY *ep* Collider HERA, where no suppression is expected in certain models (see e.g. [5]), dijets are mainly produced by a gg exchange while in DDIS the primary exchange is a $q\bar{q}$ pair. Dijet rates at the Tevaytron are calculated using a gluon PDF extracted from DDIS. A more direct comparison could be made by measuring the DSF in diffractive W production at the Tevatron, which is dominated by a $q\bar{q}$ exchange as in DDIS. In Run I, only the overall diffractive W fraction was measured [6]. In Run II, we measure both the W and Z diffractive fractions and aim at also measuring the DSF.

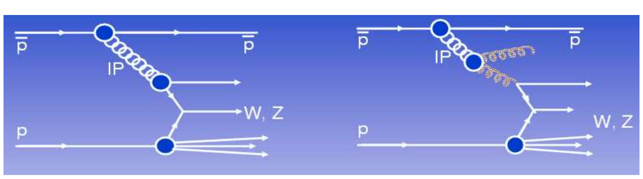

Figure 3: LO diffractive W/Z production diagrams.

Figure 3 shows schematic Fynman diagrams for diffractive W/Z production. In leading order, the W/Z is produced by a quark in the Pomeron (left), while production by a gluon (right) is suppressed by a factor of α_s and can be distinguished from quark production by an associated jet [6].

This analysis is based on events with RPS tracking from a data sample of ~ 0.6 fb^{-1}. In addition to the W/Z selection requirements (see below), we require a hit in the RPS trigger counters and a RPS reconstructed track with $0.03 < \xi < 0.1$ and $|t| < 1$. A novel feature of the analysis is the determination of the full kinematics of the $W \to e\nu/\mu\nu$ decay by obtaining the neutrino E_T^ν from the missing E_T, as usual, and η_ν from the formula $\xi^{\rm RPS} - \xi^{\rm cal} = (E_T/\sqrt{s}) \exp[-\eta_\nu]$, where $\xi^{\rm cal} = \sum_{\rm towers}(E_T/\sqrt{s}) \exp[-\eta]$.

The CDF W/Z selection requirements are $E_T^{e,\mu} > 25$ GeV, $40 < M_T^W < 120$ GeV, $66 < M^Z < 116$ GeV, and vertex z-coordinate $z_{vtx} < 60$ cm. The W mass distribution for events with $\xi^{\mathrm{CAL}} < \xi^{RPS}$ is shown in Fig. 4 along with a Gaussian fit. The obtained value of $M_W^{\mathrm{exp}} = 80.9 \pm 0.7$ GeV is in good agreement with the world average W-mass of $M_W^{\mathrm{PDG}} = 80.403 \pm 0.029$ GeV [7].

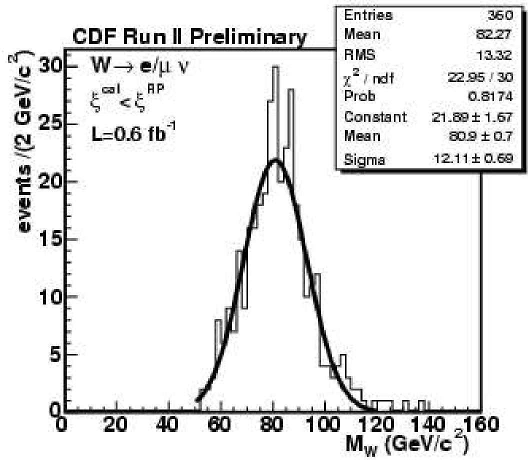

Figure 4: Histogram of the W mass from the diffractive data sample and a Gaussian fit.

Figure 5 shows the ξ^{CAL} distributions of the W/Z events satisfying different selection requirements. In the W case, the requirement of $\xi^{\mathrm{RP}} > \xi^{\mathrm{CAL}}$ is very effective in removing the overlap evemnts in the region of $\xi^{\mathrm{CAL}} < 0.1$, while a mass cut of $50 < M_W < 120$ GeV has the same effect. In the Z case, we use the ξ^{CAL} distribution of all Z events normalized to the RP-track distribution in the region of $-1 < \log \xi^{\mathrm{CAL}} < -0.4$ $(0.1 < \xi^{CAL} < 0.4)$ to obtain the ND background in the diffractive region of $\xi^{\mathrm{CAL}} < 0.1$. Accounting for the RPS acceptance $A_{\mathrm{RPS}} \approx 80$ %, the trigger counter efficiency $\epsilon_{\mathrm{RPStrig}} \approx$

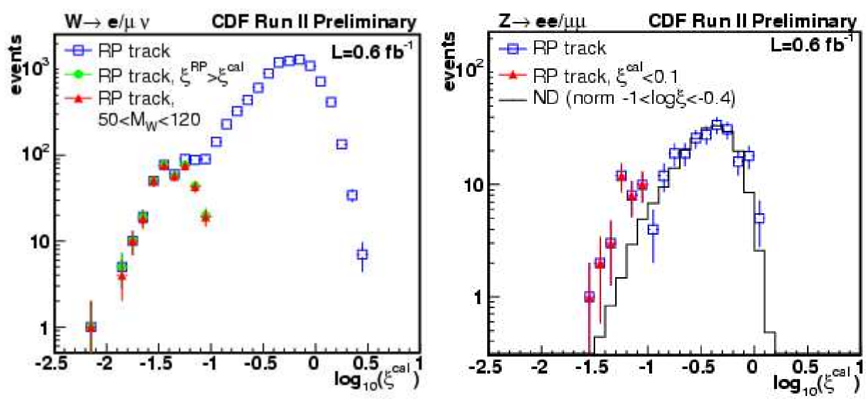

Figure 5: The ξ^{CAL} distribution for various W (left) and Z (right) event samples.

75 %, the track reconstruction efficiency $\epsilon_{\mathrm{RPStrk}} \approx 87$ %, multiplying by 2 to include production by $\bar{p}p \to W/Z + p$, and correcting the ND event number for the effect of overlaps due to multiple interactions by multiplying by the factor $f_{1-\mathrm{int}} \approx 25$ %, we obtain the diffractive fraction of W/Z events as $R_{W/Z} = 2 \cdot N_{SD}/A_{\mathrm{RPS}}/\epsilon_{\mathrm{RPStrig}}/\epsilon_{\mathrm{RPStrk}}/(N_{\mathrm{ND}} \cdot f_{1-\mathrm{int}})$:

$R_W(0.03 < \xi < 0.10,\ |t| < 0.1) = [0.97 \pm 0.05\ (\mathrm{stat}) \pm 0.11\ (\mathrm{syst})]\%$

$R_Z(0.03 < \xi < 0.10,\ |t| < 0.1) = [0.85 \pm 0.20\ (\mathrm{stat}) \pm 0.11\ (\mathrm{syst})]\%$

The R_W value is consistent with our Run I result of

$\mathit{Run\ I} : R_W(0.03 < \xi < 0.10,\ |t| < 0.1) = [0.97 \pm 0.47]$ %,

obtained from measured value of $R^W(\xi < 0.1) = [0.15 \pm 0.51\ (\mathrm{stat}) \pm 0.20\ (\mathrm{syst})]\%$ [6] multiplied by a factor of 0.85 that accounts for the reduced (ξ-t) range in Run II.

3 Exclusive dijets

Ihe process of exclusive dijet production is important for testing and/or calibrating models for exclusive Higgs production at the LHC. We have made the first observation of this process and present our main final result in Fig. 6. Details can be found in Ref. [2]. This result favors the model of Ref. [8], which is implemented in the Monte Carlo simulation ExHuME [9].

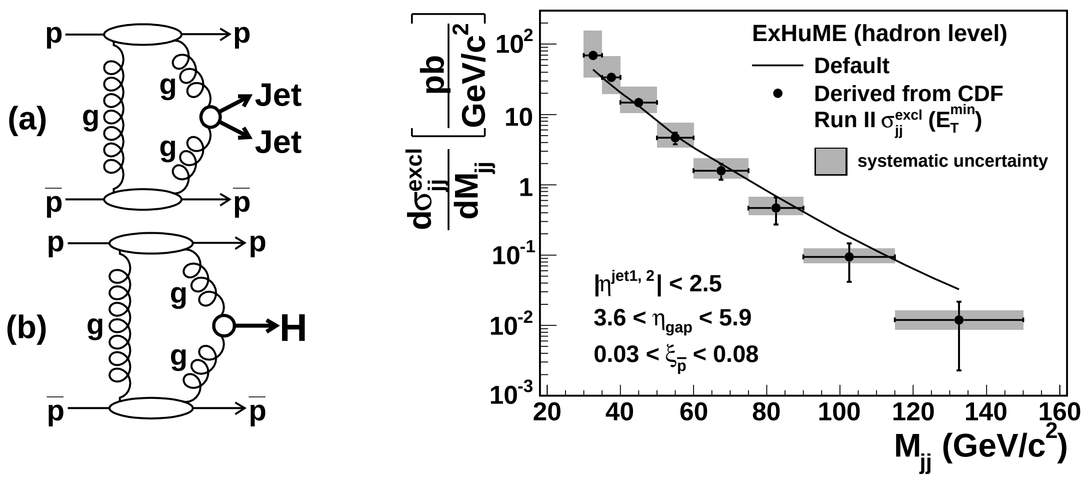

Figure 6: Diagrams for exclusive dijet (a) and Higgs (b) production, and the ExHuME [9] exclusive dijet differential cross section at the hadron level vs. dijet mass M_{jj} normalized to measured σ_{jj}^{excl} values. The solid curve is the cross section predicted by ExHuME.

References

[1] K. Goulianos, "Hadronic diffraction: where do we stand"? in *Les Rencontres de Physique de la Vallee d'Aoste: Results and Perspectives in Particle Physics, La Thuile, Italy, February 27 - March 6, 2004*, Frascati Physics Series, Special 34 Issuee, edited by Mario Greco; arXiv:hep-ph/0510035.

[2] T. Aaltonen *et al.* (CDF Collaboration), "Observation of Exclusive Dijet Production at the Fermilab Tevatron $p\bar{p}$ Collider," Phys. Rev. D **77**, 052004 (2008).

[3] D. Acosta *et al.* (CDF Collaboration), Phys. Rev. D **71**, 032001 (2005).

[4] K. Goulisnos, "*Diffraction at CDF*," in Proceedings of *12th Inte rnational Conference on Elastic and Diffractive Scattering (Blois Workshop) - Forward Physics and QCD*, DESY, Hambyrg, Germany 21-25 May 2007, arXiv:0712.3633V2[hep-ph]3 Jun 2008, pp. 137-144, `http://arxiv.org/abs/0712.3633`; ib. "*Pomeron intercept and slope: the QCD connection*, pp. 248-253.

[5] J. Collins, Factorization in Hard Diffraction, J. Phys. G **28**, 1069 (2002); arXiv:hep-ph/0107252.

[6] Abe et al. (CDF Collaboration), "Observation of Diffractive W-Boson Production at the Fermilab Tevatron,"' Phys. Rev. Lett. **78**, 2698-2703 (1997).

[7] W.-M. Yao et al., Journ. Phys. G **33**, 1 (2006) and 2007 partial update for 2008; `http:\\pdg.lbl.gov`.

[8] V. A. Khoze, A. D. Martin, and M. G. Ryskin, Eur. Phys. J. C **19**, 477 (2001) [Erratum-ibid. C **20**, 599 (2001)].

[9] J. Monk and A. Pilkington, Comput. Phys. Commun. **175**, 232 (2006); arXiv:hep-ph/0502077.