DIBOSON CROSS SECTIONS AT $\sqrt{s}$=1.96 TeV

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A brief survey of the results on diboson production at the Tevatron is presented. Measured cross sections for $W\gamma$, $Z\gamma$, WW, and limits on WZ/ZZ are summarized.

1 Introduction

Diboson production gives information about the structure of the Standard Model (SM) electroweak interaction. By studying the production of vector boson pairs, one may determine whether the interaction is behaving as the $SU(2)_L \otimes U(1)_Y$ gauge symmetry in the SM, or whether the structure of the theory is entirely different. There is no mechanism which alters the vector boson couplings within the SM. Any deviation is a sign of new physics. In all cases the presence of anomalous couplings manifests itself in an increase in the cross section for pairs of vector bosons. Thus measurement of the diboson production cross sections is a test of the theory.

In these proceedings, a brief summary of the current results from the Tevatron Run II is presented. Where possible, the main kinematic and fiducial requirements imposed by the CDF and DØ experiments are detailed, and references to the more detailed publications provided [a].

2 Wγ

Anomalous coupling at the WWγ vertex leads to not only a higher cross section, but also an excess of high transverse energy (E_T) photons. The $W\gamma$ cross section is measured with respect

[a] A detailed description of the two Tevatron experiments is beyond the scope of these proceedings, however the interested reader is referred to [1] and [2].

to a lepton-photon separation requirement and a threshold on the E_T of the photon. This avoids a divergences in the theoretical calculation where the photon is colinear with the lepton, and where the photon is very low E_T. CDF and DØ both use a lepton-photon separation cut of $\Delta\mathcal{R} > 0.7$. CDF and DØ use different photon E_T thresholds, so the results are not directly comparable. The dominant background for both experiments is W+jet production where the jet mimics a photon.

The kinematic and fiducial requirements for the CDF and DØ $W\gamma$ analyses are summarized in Table 1. CDF measures the cross section $\sigma(p\overline{p} \rightarrow W\gamma+X)$ with $E_T^\gamma > 7$ GeV and $\Delta R_{\ell\gamma} > 0.7$ is to be 18.3 ± 3.1 pb (stat. and syst. combined), in good agreement with the SM value of 19.3 ± 1.4 pb. This analysis has been published [3]. DØ measures the cross section $\sigma(p\overline{p} \rightarrow$

Table 1: Summary of CDF and DØ Fiducial and Kinematic Requirements for $W\gamma$. Estimated SM and background events are included, along with observed candidates.

	CDF		DØ	
Channel:	$e\nu\gamma$	$\mu\nu\gamma$	$e\nu\gamma$	$\mu\nu\gamma$
η^ℓ	2.6	1.0	1.1	2.0
p_T^ℓ	25	20	25	20
$\not{E}_T$	25	20	25	20
η^γ	1.0	1.0	1.1	1.1
p_T^γ	7	7	8	8
M_T	30< M_T <120	30< M_T <120	$M_T > 40$	0
Lumi. (pb^{-1})	202	192	162	134
Background	67.3±18.1	47.3±7.6	60.8± 4.5	71.3± 5.2
Expected (SM)	126.8±5.8	95.2±4.9	59.5± 5.4	94.0±7.4
Candidates	195	128	112	161

$W\gamma + X)$ with $E_T^\gamma > 8$ GeV and $\Delta\mathcal{R}_{\ell\gamma} > 0.7$ is to be 14.8 ±2.1 pb (stat. and syst. combined), in good agreement with the SM value of 16.0 ± 0.4 pb.

DØ uses the E_T^γ distribution to set limits on anomalous vector boson couplings. The one-dimensional limits on the anomalous coupling parameters are: $-0.88 < \Delta\kappa_\gamma < 0.96$ and $-0.20 < \lambda_\gamma < 0.20$. This is a preliminary result from DØ [4].

3 Zγ

In the SM, the Z and the photon do not directly couple to each other at leading order. Anomalous couplings would manifest as an excess of events at high photon E_T and an increase in the cross section. As with $W\gamma$, the $Z\gamma$ cross section is measured with respect to a lepton-photon separation requirement and a threshold on the E_T of the photon. Both experiments have made cuts consistent with their $W\gamma$ analyses for the photon E_T threshold, and the lepton photon separation requirement. The only significant background is Z+jet production where the jet mimics a photon.

The selection criteria for the CDF and DØ $Z\gamma$ analyses are summarized in Table 2. CDF measures the cross section $\sigma(p\overline{p} \rightarrow Z\gamma+X)$ with $E_T^\gamma > 7$ GeV and $\Delta\mathcal{R}_{\ell\gamma} > 0.7$ to be 4.6 ±0.6 pb, in good agreement with the SM value of 4.5±0.3 pb. This analysis has been published in [3]. DØ measures the cross section $\sigma(p\overline{p} \rightarrow Z\gamma+X$ with $E_T^\gamma > 8$ GeV and $\Delta\mathcal{R}_{\ell\gamma} > 0.7$ to be 4.2 ±0.5 pb, in good agreement with the SM value of 3.9±0.2 pb.

DØ uses the photon E_T spectrum to set limits on anomalous couplings. The 95% C.L. limits are $|h^Z_{10,30}| < 0.23$, $|h^Z_{20,40}| < 0.020$, $|h^\gamma_{10,30}| < 0.23$, and $|h^\gamma_{20,40}| < 0.019$ (for a form factor scale

Table 2: Summary of CDF and DØ Fiducial and Kinematic Requirements for $Z\gamma$. Estimated SM and background events are included, along with observed candidates.

	CDF		DØ	
Channel:	$ee\gamma$	$\mu\mu\gamma$	$ee\gamma$	$\mu\mu\gamma$
η^{ℓ}	2.6	1.0	1.1 (2.5)	2.0
p_T^{ℓ}	25	20	25	15
η^{γ}	1.0	1.0	1.1	1.1
p_T^{γ}	7	7	8	8
$M_{\ell\ell}$	40< $M_{\ell\ell}$ <130	40< $M_{\ell\ell}$ <130	30< $M_{\ell\ell}$	30< $M_{\ell\ell}$
Lumi. (pb^{-1})	202	192	320	290
Background	2.8±0.9	2.1±0.6	23.6±2.3	22.4±3.0
Expected (SM)	31.3±1.6	33.6±1.5	95.3±4.9	126.0±7.8
Candidates	36	35	138	152

of $\Lambda = 1\ TeV$. The limits on $|h^{Z}_{20,40}|$ and $|h^{\gamma}_{20,40}|$ represent the most stringent limits on these couplings to date. This analysis has been submitted for publication [5].

4 WW

The WW final state has couplings to both the photon and the Z. Anomalous coupings in W-pair production are heavily constrained by studies performed at LEP. However, WW is a favored decay channel for the Higgs boson, and additional production at high center of mass energy could give evidence for other non-SM heavy resonances.

WW production has several physics backgrounds from other lepton pair production. Drell-Yan production, WZ production, ZZ production, and even top quark pairs all have channels in which at least two leptons can be produced, and thus must be addressed for the purpose of identifying true WW events. In both analyses presented here, cuts have optimized to reduce these backgrounds.

4.1 CDF WW Results

Similar cuts to those described in the previous analyses for identifying leptons from W decays are used to identify W-pairs. Leptons (e, μ) are required to be identified within the fiducial coverage ($|\eta| < 2.0$ for electrons,$|\eta| < 1.0$ for muons). The leptons are required to be $p_T >$ 20 GeV/c. The event $\not{E}_T$ is required to be greater than 25 GeV. The significance of the $\not{E}_T$ is required to be greater than 3, and a veto is imposed on events that have jets above 15 GeV within $|\eta|$ <2.5, to reduce contamination from top quark events. CDF identifies a total of 17 candidates (6 in the ee, 5 in the eμ and 6 in the $\mu\mu$ channels respectively), and using a luminosity of 184 pb^{-1} measures a cross section of $14.6^{+5.8}_{-5.1}(stat.)^{+1.8}_{-3.0}(syst.)\pm$ 0.6 pb, in good agreement with the SM value of 12.4 ± 0.8 pb. This analysis has been submitted for publication [6].

4.2 DØ WW Results

Similar cuts to those described in the previous analyses for identifying leptons from W decays are used to identify W-pairs. Leptons (e, μ) are required to be identified within the fiducial coverage ($|\eta| < 3.0$ for electrons,$|\eta| < 2.0$ for muons). The leptons are required to be at p_T >20 GeV/c for the lead lepton and p_T >15 GeV/c for the trailing lepton. The event $\not{E}_T$ is required to be greater than 30 GeV in the di-electron channel, 20 GeV in the e-μ channel, and 40 GeV in the di-muon channel. The scaled $\not\!\!E_T$ is required to be greater than 15 in the di-electron and e-μ channel. A cut is imposed on the sum of the E_T of jets within $|\eta| < 2.5$ and E_T >20, for the di-electron and e-μ channels at 50 GeV, and for the di-muon channel at 100 GeV to limit contamination from top quark events. DØ identifies a total of 25 candidates (6 in the ee, 15 in the eμ and 4 in the $\mu\mu$ channels), and using a luminosity of approximately 230 pb^{-1} measures a cross section of $13.8^{+4.3}_{-3.8}(stat.)^{+1.2}_{-0.9}(syst.)\pm$ 0.9 pb, in good agreement with the SM value of 12.4 $\pm$ 0.8 pb. This analysis has been accepted for publication [7].

5 CDF WZ/ZZ Results

CDF combines a search for WZ and ZZ together in a number of different topologies, and sets a cross section limit. Two leptons (ee, $\mu\mu$) are required to resolve the invariant mass for the Z boson (required to be within the range 76 GeV< $M_{\ell\ell}$ <106 GeV). Then three separate event topologies were considered: two leptons plus $\not\!\!E_T$, three leptons plus $\not\!\!E_T$ and four leptons. The only topology with candidate events was two leptons plus $\not\!\!E_T$. Three candidate events(two di-electron, one dimuon) remain after all selection cuts. Using a luminosity of 184 pb^{-1} CDF proceeded to set a cross section limit of $\sigma(p\overline{p} \rightarrow ZW/ZZ) < 15.2$ pb. This analysis has been submitted for publication [8].

6 DØ WZ Results

DØ performed a search for WZ events in the three leptons plus $\not\!\!E_T$ channel exclusively. Two of the leptons were required to reconstruct to the Z mass range (for di-eletrons $71\ GeV < M_{\ell\ell} < 111\ GeV$ and for di-muons 51 GeV< $M_{\ell\ell}$ <131 GeV). Three candidates were observed (two tri-muon, and 1 tri-electron). Using approximately 290 pb^{-1} of luminosity DØ sets a cross section limit of $\sigma(p\overline{p} \rightarrow ZW/ZZ) < 13.3$ pb. Using these three candidates, DØ sets limits on anomalous WZ couplings. The one-dimensional limits are: $-0.53 < \lambda_Z < 0.56$, $-0.57 < \Delta g_1^Z < 0.76$, and $-2.0 < \Delta\kappa_Z < 2.4$. This is a preliminary result from DØ [9].

References

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4. At the time of the presentation, this result was preliminary. It has since been finalized (with no change) and accepted for publication. DØ Collaboration, V. Abazov *et al.*, hep-ex/0503018, accepted by *Phys. Rev.* D Rapid Communications.
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