W and Z physics at TeVatron

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Abstract. Electroweak measurements performed by CDF and DØ are reported, corresponding to data collected at the center-of-mass energy of 1.96 TeV with approximately a luminosity of 200 pb^{-1}. We present measurements of W and Z cross sections and decay asymmetries, recent results in diboson physics with new limits on anomalous couplings, preliminary results on the direct determination of the W width, and preliminary studies for the W mass measurement.

Keywords: W boson, Z boson, CDF, DØ, Standard Model, gauge-bosons couplings, W width
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INTRODUCTION

Exploring the Electroweak sector of the Standard model (SM) is one of the main goals of the Tevatron experiments. The large number of W bosons and the possibility to explore the high mass Z/γ^* are exceptional opportunities at hadron colliders.

W and Z cross section measurements are key milestones in the understanding and calibration of the detectors. Studies of boson decay asymmetries have unique sensitivities to constrain the parton distribution functions in the proton and antiproton. The diboson production processes based on clean and well understood signatures are robust tests of the SM and allow an exploration beyond the SM scenarios. Finally the measurement of the W mass combined with the top mass measurement is central to constraining the SM Higgs mass.

SINGLE BOSON PRODUCTION

Cross Section in the Leptonic Modes

Due to a large QCD background, decay channels involving quarks are difficult to measure. Therefore W and Z bosons are identified through their leptonic decays. They are characterized by a lepton with a high transverse energy E_T and large transverse missing energy $\not{E}_T$ (for W) and two high transverse energy leptons (for Z).

One of the most interesting new results of Run 2 is the cross section measurement of Z production in the $Z \rightarrow \tau^+\tau^-$decay channel. The τ reconstruction, very challenging at hadron colliders, is a nice benchmark for all analyses including τ's such as searches for Supersymmetry.

The channel $Z \rightarrow \tau^+\tau^-$is studied by CDF in a mode with one τ decaying leptonically to an electron and the other decaying to hadrons. One or three charged tracks with π^0's are selected in a 10° cone pointing toward a narrow calorimeter energy cluster. The combined mass of the tracks and π^0's are required to be less than 1.8 GeV/c^2. The results [1] together with a previous measurement [1] in the $W \rightarrow \tau\nu$ channel are presented in Table 1. Figure 1 shows the combined invariant mass of electron, hadronic τ candidate and $\not{E}_T$ for final selected Z $\rightarrow \tau_e\tau_h$ events.

DØhas performed a measurement in the channel $Z \rightarrow \tau^{\,+}\tau^-$using a Neural Network (NN) technique. One τ is required to decay to $\mu\nu_\mu\nu_\tau$ and the other to hadrons+ν_τ or $e\nu_e\nu_\tau$. The result [2] is given in Table 1. Figure 1 shows the NN output distributions for data, background and signal Monte Carlo. The background is estimated from like charge (LS) sample. Signal is reconstructed from opposite charge (OS) sample.

TABLE 1. W and Z boson cross sections in τ channel.

	$\mathcal{L}$ **pb^{-1}**	σ**.Br pb**
CDF		
$W \rightarrow \tau\nu$	72	$2620 \pm 70_{stat} \pm 210_{syst} \pm 160_{lum}$
$Z \rightarrow \tau^+\tau^-$	349	$265 \pm 20_{stat} \pm 21_{syst} \pm 15_{lum}$
DØ		
$Z \rightarrow \tau^+\tau^-$	226	$237 \pm 15_{stat} \pm 18_{syst} \pm 15_{lum}$

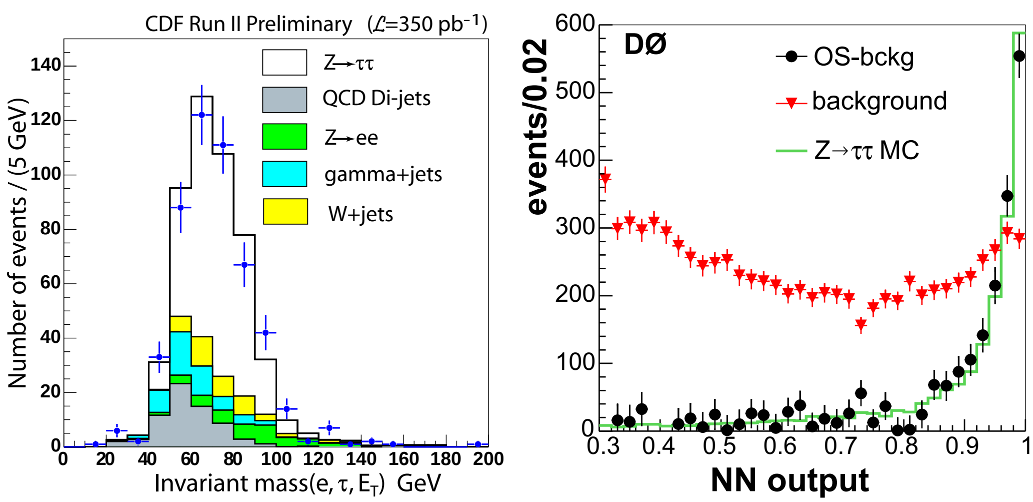

FIGURE 1. On the left : CDF Invariant mass of four-momenta of electron, hadronic tau candidate and missing transverse energy in the selected Z $\rightarrow \tau_e\tau_h$ events. On the right: DØ NN output for data (background subtracted), background and $Z \rightarrow \tau^+\tau^-$Monte Carlo simulation.

The cross sections in the electron and muon decay channels [3] are reported in Fig. 2 for W and Z production . The main contribution to the systematic uncertainty ($\sim 6\%$)

comes from the luminosity measurement. The PDF uncertainties are $\sim 2\%$ and are estimated using the eigenvector basis sets for CTEQ6M [4]. The contribution from lepton identification is between 1% and 2%. This uncertainty is expected to be reduced with more statistics in the future. The same figure 2 reports the cross sections in the τ channel for W and Z production. The $p\bar{p}$ inclusive production cross sections of W and Z bosons are in good agreement with NNLO theoretical calculation [5].

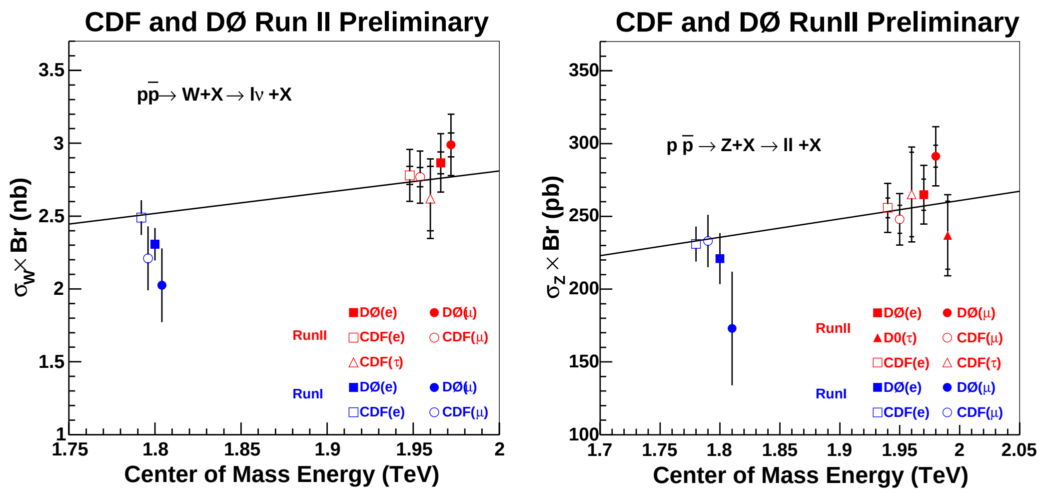

FIGURE 2. $\sigma \times B(p\bar{p} \to W \to l\nu)$ (left) and $\sigma \times B(p\bar{p} \to Z \to l^+l^-)$ (right) ,cross sections measured by CDF and DØ along with theoretical predictions.

The largest uncertainty on the cross section measurements comes from the uncertainty on the luminosity measurements. This uncertainty cancels when determining the ratio of the W boson to Z boson production cross sections.

CDF reports results on the ratio R of W and Z cross sections for combined e and μ decay channels, and for the μ decay channel only, with a luminosity of 72 pb^{-1} and 200 pb^{-1} respectively. R = $10.92 \pm 0.15_{stat} \pm 0.14_{syst}$ for the combined channels and R = $11.02 \pm 0.18_{stat}{}^{+0.17}_{-0.14 syst}$ for the μ channel. DØ reports a measurement of R = $10.82 \pm 0.16_{stat} \pm 0.28_{syst}$ in the e channel with a luminosity of 177 pb^{-1}.

The lepton universality tests in W leptonic decays can be deduced from the ratio of the electroweak couplings g_μ/g_e and g_τ/g_e. In this ratio, significant systematic uncertainties cancel. The results are: $g_\mu/g_e = 0.998 \pm 0.012$ and $g_\tau/g_e = 0.99 \pm 0.04$ [9].

Indirect W Boson Width Determination

Using the measured value B($Z \to l^+l^-$)[1] at LEP and a theoretical calculation of the ratio of W to Z production cross sections [7], CDF extracts the leptonic branching ratio B($W \to l\nu$) = (10.89 ± 0.202) % for the combined e and μ channels and

[1] B($Z \to l^+l^-$) = 0.033658 ± 0.000023.

B($W \rightarrow \mu\nu$) = ($11.01 \pm 0.18_{stat}{}^{+0.17}_{-0.14 syst}$) % for the μ channel. From the theoretical value of the leptonic partial width, $\Gamma(W \rightarrow l\nu)$ [2] [6], CDF extracts the total width of the W boson as reported in Table 2.

TABLE 2. Indirect W width measurements from CDF and the world average value.

Channel	$\mathcal{L}$ **pb**$^{-1}$	Γ**(W) MeV**
W $\rightarrow e\nu$ + W $\rightarrow \mu\nu$	72	2079 ± 41
W $\rightarrow \mu\nu$	194	2056 ± 44
World average *		2124 ± 41

* The current world average does not contain the CDF values

The indirect width measurements show good agreement with the current world average with a competitive uncertainty.

Direct W Width Measurement

DØhas performed a direct measurement of the W width in the electron decay channel. The measurement uses an integrated luminosity of 177.3 pb^{-1}. The width is determined by normalizing the predicted signal and background transverse mass distributions to 75,285 W $\rightarrow e\nu$ candidates in the transverse mass region 50 GeV/c^2 < M_T < 100 GeV/c^2. The predicted shape is then fitted to 625 candidates in the tail region 100 GeV/c^2 < M_T <200 GeV/c^2 which is the most sensitive to the W width. Figure 3 shows the transverse mass distribution and the good agreement between the data and simulation. The W width is determined to be $\Gamma_W = 2011 \pm 93(stat) \pm 107(syst)$ MeV. Figure 3 also gives a comparison of this measurement to previously published direct measurements [8].

W Charge Asymmetry

A measurement of the forward-backward W charge asymmetry is sensitive to the ratio of the *u* and *d* quark components of the parton distribution functions. W bosons at the Tevatron are produced predominantly through annihilation of valence quarks. A W^+ tends to be boosted in the proton direction since *u* quarks carry on average a higher fraction of the proton momentum, while a W^- is boosted in the anti-proton direction. The non-zero forward-backward asymmetry is defined as:

$$A(y_W) = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W}$$

[2] $\Gamma(W \rightarrow l\nu) = (226.4 \pm 0.3)$ MeV.

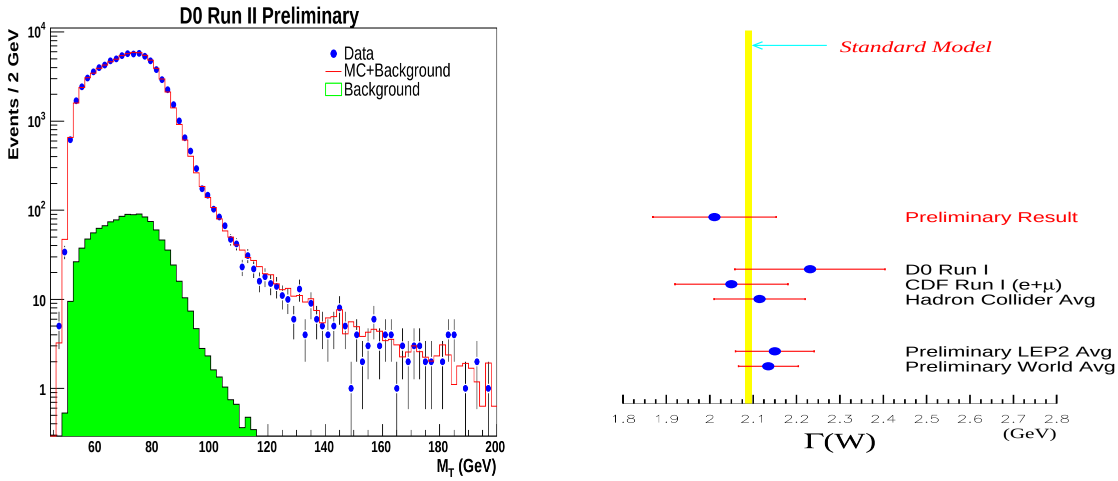

FIGURE 3. On the left : Comparison of DØ to Monte Carlo for the transverse mass shape. The direct W width result is extracted from high transverse mass tail in the range 100 GeV < M_T < 200 GeV. On the right : Comparison of the DØ result quoted as “Preliminary Result” with previously published direct measurements of W width. The shaded vertical strip indicates the predicted W width value from SM.

where y_W is the rapidity of the W boson and $d\sigma(W^{\pm})/dy_W$ is the differential cross section for W^+ or W^- boson production. However, y_W cannot be determined directly due to the unmeasured p_Z of the neutrino and CDF measures instead:

$$A(\eta_e) = \frac{d\sigma(e^+)/d\eta_e - d\sigma(e^-)/d\eta_e}{d\sigma(e^+)/d\eta_e + d\sigma(e^-)/d\eta_e}$$

where η_e is the electron pseudorapidity. Therefore the observed asymmetry is a convolution of the charge asymmetry itself and the SM V-A couplings describing the $W \to e\nu$ decays. Figure 4 shows the CDF result in the electron channel up to a pseudorapidity of $|\eta| \leq 2.5$ with a luminosity of 170 pb^{-1} [10]. It shows that binning data in two transverse energy (E_T) bins increases the sensitivity to PDFs. The predictions using the latest CTEQ and MRST PDFs are overlaid. This measurement will provide important new input for the next generation of PDFs.

Forward Backward Asymmetry in the Z/γ^* Drell Yan Production

The vector and axial-vector couplings of the quarks and leptons to the Z-boson in the process $q\bar{q} \to Z/\gamma^* \to l^+l^-$ give rise to an asymmetry in the polar angle of the lepton momentum relative to the incoming quark momentum in the rest frame of the lepton pair. The forward-backward asymmetry A_{FB} is defined as:

$$A_{FB} = \frac{N^F - N^B}{N^F + N^B}$$

where N^F is the number of forward events and N^B is the number of backward events.

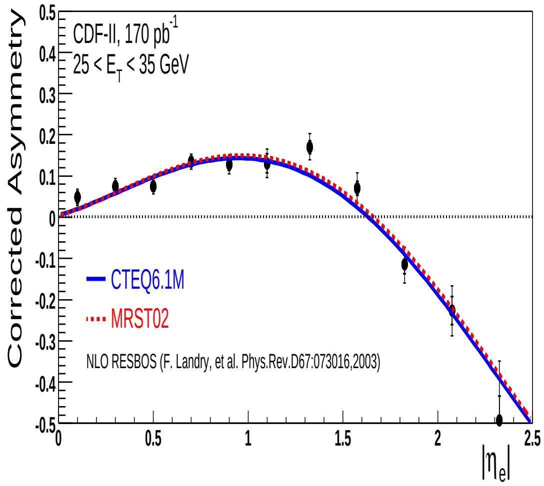

FIGURE 4. Measure of W charged asymmetry at CDF, corrected for the effects of charge misidentification and background). Left: 25 GeV < E_T < 35 GeV bin range. Right: 35 GeV < E_T < 45 GeV bin range.

A_{FB} is a direct probe of the relative strengths of the coupling constants between the Z boson and the quarks. The invariant-mass dependence of A_{FB} is also sensitive to *u* and *d* quarks separately. Moreover, as the Tevatron allows measurement of the forward-backward asymmetry at partonic center-of-mass energies above the center-of-mass energy of LEP II, this measurement can constrain the properties of any additional non-SM amplitudes from new neutral gauge bosons or large extra dimensions.

The A_{FB} distribution is shown on Figure 5 for CDF and DØmeasurements [11]. At the Z-pole the asymmetry is dominated by the couplings of the Z boson and arises from the interference of the vector and axial components of its coupling. At large invariant mass the asymmetry is ≈ 0.6, dominated by Z/γ^* interference and almost independent of invariant mass. The results are compared to theoretical prediction from PYTHIA and ZGRAD [12].

DI-BOSON PRODUCTION

Vector boson pair production provides sensitive ground for direct tests of the trilinear gauge couplings (TGC). The SM of electroweak interactions makes predictions for the couplings between gauge bosons due to the non-abelian gauge symmetry of $SU(2)_L \otimes U(1)_Y$. These self-interactions are described by the trilinear gauge boson WWγ, WWZ, Z$\gamma\gamma$, and ZZγ couplings and the quartic couplings. Deviations from SM values would indicate the presence of new physical phenomena.

In this chapter are described recent results from CDF and DØ including preliminary results from searches for anomalous couplings in WW/WZ/Wγ and Zγ.

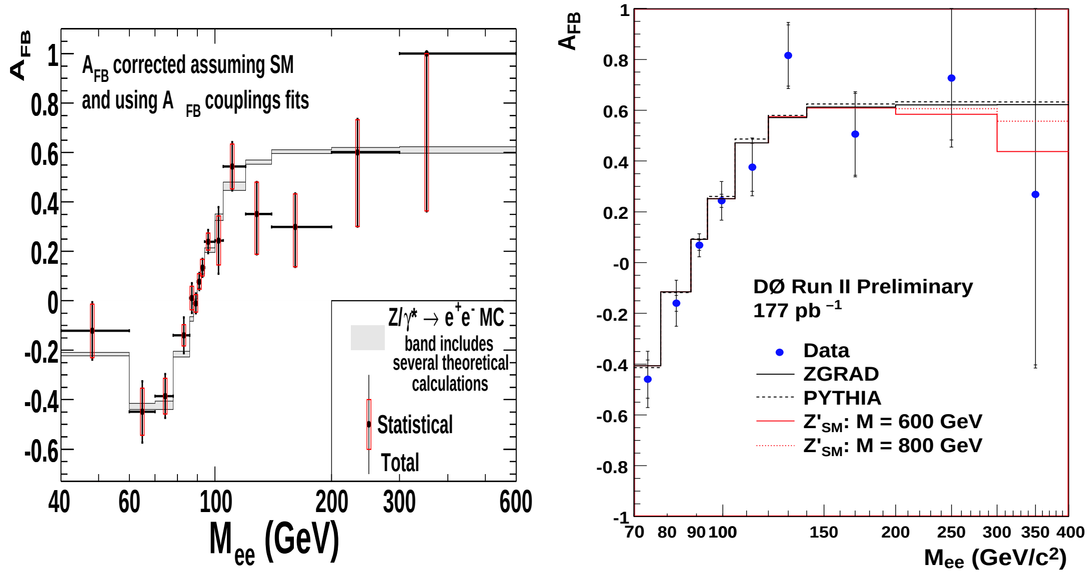

FIGURE 5. Forward-backward asymmetry vs. dielectron invariant mass and theoretical predictions based on PYTHIA and ZGRAD. The correction is calculated within the SM frame and used the derived A_{FB}^{phys} from the Z-quark coupling values. On the left : CDF and on the right : DØ measurement.

W Pair Production Study

The measurement of the W boson pair-production cross section is sensitive to new phenomena since anomalous trilinear couplings [14] or the production and decay of new particles such as the Higgs boson would enhance the rate of W boson pair-production. The next-to-leading order (NLO) calculations for $\sigma(p\bar{p} \to W^+W^-)$ [15] predict a cross section of 12.0-13.5 pb at $\sqrt{s}$ =1.96 TeV.

CDF and DØhave performed the measurement in the dilepton decay channel (e^+e^-, $\mu^+\mu^-$ and $e^\pm\mu^\mp$). The signature is two isolated and opposite charged high P_T leptons and missing transverse energy. The W boson pair-production cross section, $\sigma_{p\bar{p}\to WW}$, measured by CDF [16] and DØ[17], is reported in Table 3. Both measurements are in good agreement with the NLO calculation.

TABLE 3. WW pair-production cross section.

	$\mathcal{L}$ **pb**$^{-1}$	$\sigma(p\bar{p} \to WW)$ **pb**
CDF	184	$14.6^{+5.8}_{-5.1}(stat)^{+1.8}_{-3.0}(sys) \pm 0.9(lum)$
DØ	240 *	$13.8^{+4.3}_{-3.8}(stat)^{+1.2}_{-0.9}(sys) \pm 0.9(lum)$

* mean value for 252 in e^+e^-, 235 in $e^\pm\mu^\mp$ and 224 in $\mu^+\mu^-$ chnnels respectively

WZ Production Study

The WZ production cross section is sensitive only to the WWZ trilinear coupling and not to the WWγ coupling, while the WW production cross section is sensitive to both couplings. Furthemore, as the WZ production process is unavailable at e^+e^- colliders, the Tevatron provides an unique opportunity for measurement of the WWZ couplings.

Excursions of the WWZ interactions from the SM can be described by an effective Lagrangian with parameters g_1^Z, λ_Z, and κ_Z[13]. The SM values of these dimensionnless couplings are: g_1^Z= κ_Z=1 and λ_Z=0.

DØhas performed a search for WZ production with "trilepton" final states $l\nu l\,'l'$ (l and l'= e or μ). The background is strongly suppressed by requiring three isolated high P_T charged leptons and large $\not\!\!E_T$. Three candidates were found in a sample of 300 pb^{-1} with an expected background of 0.71 ± 0.08 events. Following a maximum likelihood technique described in refs.[18], DØobtains: $\sigma_{WZ} = 4.5^{+3.8}_{-2.6}$ pb [19] in good agreement with the expected SM value [20]. Assuming no signal the 95% C.L. upper limit is $\sigma_{WZ} < 13.3$ pb.

Limits on anomalous WWZ couplings can be extracted as σ_{WZ} is consistent with the SM model. Table 4 lists one-dimensional 95% C.L. limits on λ_Z, Δg_1^Z(= g_1^Z- 1) and $\Delta\kappa_Z$(= κ_Z-1) with a scaling form factor Λ = 1 TeV or Λ = 1.5 TeV [3].

TABLE 4. One-dimensional 95% C.L. intervals on λ_Z, Δg_1^Z, and $\Delta\kappa_Z$. The assumption $\Delta g_1^Z = \Delta\kappa_Z$ is equivalent to that used by LEP II in Ref. [21].

Condition	**Λ = 1 TeV**	**Λ = 1.5 TeV**
$\Delta g_1^Z = \Delta\kappa_Z = 0$	$-0.53 < \lambda_Z < 0.56$	$-0.48 < \lambda_Z < 0.48$
$\lambda_Z = \Delta\kappa_Z = 0$	$-0.57 < \Delta g_1^Z < 0.76$	$-0.49 < \Delta g_1^Z < 0.66$
$\lambda_Z = 0$	$-0.49 < \Delta g_1^Z = \Delta\kappa_Z < 0.66$	$-0.43 < \Delta g_1^Z = \Delta\kappa_Z < 0.57$
$\lambda_Z = \Delta g_1^Z = 0$	$-2.0 < \Delta\kappa_Z < 2.4$	- *

* The 95% C.L. limit exceeded the bounds from S-matrix unitarity

Figure 6 shows two-dimensional 95% contour limits for Λ = 1.5 teV with the assumption of $SU(2)_L \otimes U(1)_Y$ gauge invariance relating the couplings [21].

CDF has performed a search for WZ and ZZ production using the three decay modes WZ $\rightarrow lll'\nu$, ZZ $\rightarrow ll\nu\nu$, and ZZ $\rightarrow lll'l'$ where l and l' are electrons or muons. In a data sample corresponding to an integrated luminosity of 194 pb^{-1} a 95% C.L. upper limit on the sum of the production cross sections for $p\bar{p} \rightarrow$ ZZ and $p\bar{p} \rightarrow$ ZW is measured to be 15.2 pb [22], consistent with the SM prediction of 5.0 $\pm$0.4 pb [23].

The WW/WZ production has been studied by CDF recently. One W boson is decaying to lepton + neutrino and the other boson (W or Z) decays to 2 jets. While the branching ratio is higher than in the "all leptonic" mode the background is much more higher. The dominant background, W + 2 jets, is constrained by fitting the dijet mass sidebands in

[3] The couplings must be modified as form factor with a scale Λ to avoid unitarity violation; $\lambda_V(\hat{s}) = \frac{\lambda_V}{(1+\hat{s}/\Lambda^2)^2}$ and $\Delta\kappa_V(\hat{s}) = \frac{\Delta\kappa_V}{(1+\hat{S}/\Lambda^2)^2}$ where V = Z or γ.

the dijets mass distribution. As no signal is detected a 95% C. L. upper limit on the production cross section is set to 40 pb with a luminosity of 194 pb^{-1}. The limits on anomalous couplings obtained assuming equal coupling for γ and Z and with $\Lambda = 1.5$ TeV are: -0.42 < $\Delta\kappa$ < 0.58 and -0.32 < λ <0.35 (Figure 6).

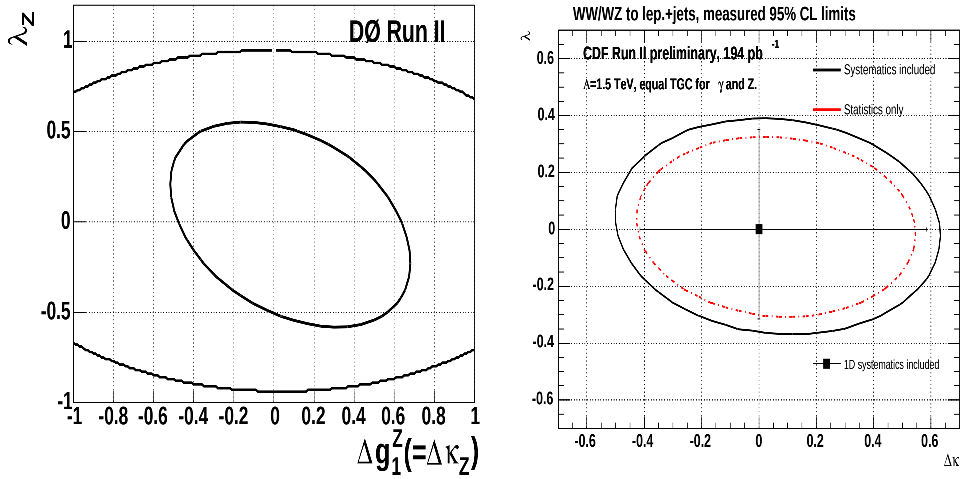

FIGURE 6. On the left : DØ Two-dimensional coupling limits (inner contour) on λ_Z vs. Δg_1^Z at 95% C.L. for Λ = 1.5 TeV. The outer contour is the limit from S-matrix unitarity. On the right : CDF Two-dimensional coupling limits from WW/WZ production study with Λ = 1.5 TeV and equal trilinear gauge couplings.

Wγ and Zγ Production Study

CDF and DØhave tested the SM prediction for Wγ and Zγ production. The selection is performed by requiring leptonic decays (e or μ) and one isolated photon with transverse energy E_T > 7 GeV for CDF and E_T > 8 GeV for DØ. The data have been collected with an integrated luminosity of 200 pb^{-1} for CDF and 162 pb^{-1} (Wγ production) and 300 pb^{-1} (Zγ production) for DØ. Kinematics cuts are applied in two dimensional planes (lν, γ) vs (lν) for Wγ and (ll, γ) vs (ll) for Zγ to cope with the irreducible background coming from the initial state radiation (ISR) and final state radiation (FSR). The FSR contribution is minimized by requiring the dilepton mass and the three-body mass to exceed 65 GeV/c^2 and 100 GeV/c^2 respectively. Figure 7 shows the distributions for Wγ production from CDF and for Zγ production from DØ.

The cross sections measured by CDF [25] and DØ[26] [27] are reported in Table 5. The results are in good agreement with the SM calculations [24].

As the Wγ cross section is in agreement with the SM expectation of 16.0± 0.4 pb, DØdeduced upper limits at the 95% C.L. from the photon energy spectrum which are $-0.88 < \Delta\kappa_\gamma < 0.96$ and $-0.20 < \lambda_\gamma < 0.20$ (see Figure 8). These limits represent the most stringent constraints on anomalous WWγ couplings obtained by direct observation of Wγ production.

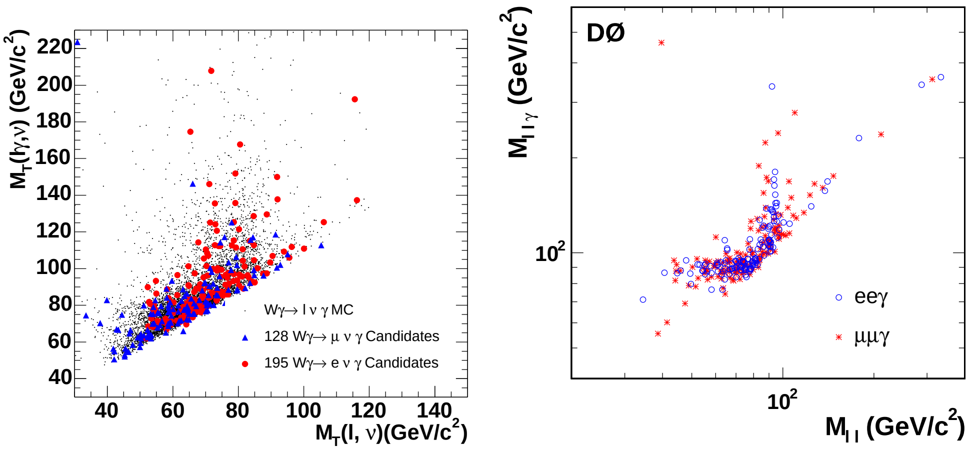

FIGURE 7. On the left : CDF : lepton+neutrino+photon *vs.* lepton+neutrino transverse mass of Wγ candidate events. On the right DØ : dilepton+photon *vs.* dilepton mass of Zγ candidates events.

TABLE 5. Wγ and Zγ cross sections measured by CDF and DØḂoth experiments quote cross section integral with their acceptance.

	E_T^γ **GeV**	$\mathcal{L}$ **pb**$^{-1}$	σ **pb (Experiment)**	σ **pb (Theory)**
CDF				
Wγ	>7	200	18.1 ± 3.1	19.3 ± 1.4
Zγ	>7	200	4.6 ± 0.6	4.5 ± 0.3
DØ				
Wγ	>8	162	$14.8 \pm 1.6_{stat} \pm 1.0_{syst} \pm 1.0_{lum}$	16.0 ± 0.4
Zγ	>8	300	$4.2 \pm 0.4_{stat+sys} \pm 0.3_{lum}$	$3.9^{+0.1}_{-0.2}$

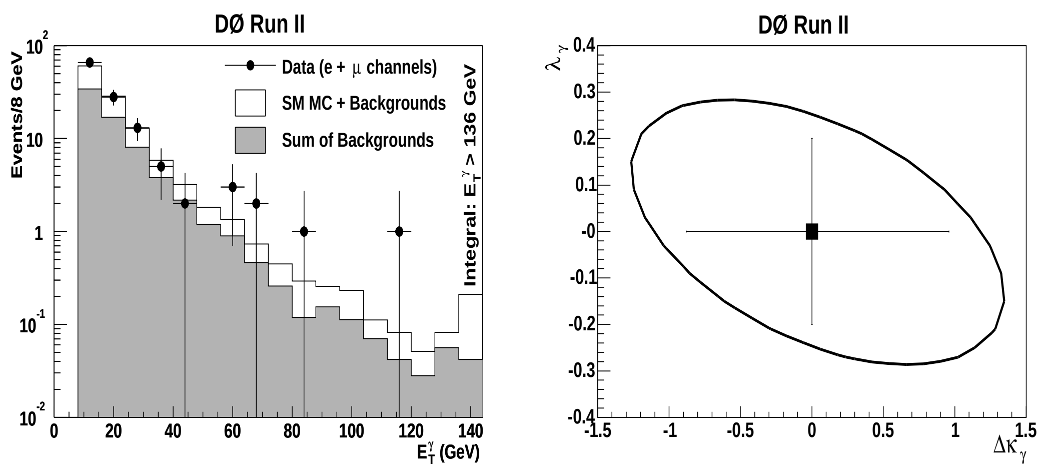

FIGURE 8. DØ : The photon E_T spectrum (on the left) for the Wγ candidates with M_T(W,γ) > 90 GeV/c^2. The points with error bars are the data and the open histogram is the sum of the SM Monte Carlo prediction and background estimate. On the right: limits on the WWγ TGC $\Delta\kappa_\gamma$ and λ_γ. The points indicate the SM value with the error bars showing the 95% C.L. intervals in one dimension. The ellipse represents the two-dimensional 95% C.L. exclusion contour.

In the SM the TGC of the Z boson to the photon are zero: photons do not interact with Z bosons at lowest order. It is clear that evidence of such an interaction would indicate new physics [28]. Following the SM the photon in dilepton plus photon final state, $l^+l^-\gamma$, can be emitted through ISR or FSR processes and its transverse energy, E_T^γ, distribution falls rapidly. On the contrary, anomalous ZZγ and Z$\gamma\gamma$ TGC can cause production with high E_T^γ and can increase the $l^+l^-\gamma$ cross section compared to SM prediction. The formalism to describe the anomalous production [29] assumes only that the ZVγ (V=Z or γ) couplings are Lorentz and gauge-invariant. The most general ZVγ coupling is parametrized by two CP-violating (h_1^V and h_2^V) and two CP-conserving (h_3^V and h_4^V) complex coupling parameters. [4]

DØhas extracted limits on anomalous couplings. The limits on real and imaginary parts of the CP-conserving and CP-violating couplings are shown in Table 6. The two-dimensional limit contours on individual CP-conserving couplings are shown in Figure 9.

TABLE 6. Summary of the 95% C.L. limits on the anomalous couplings. Limits are set allowing only the real or the imaginary part of one coupling to vary. Limits on CP-conserving and CP-violating parameters has been found nearly identical as the real and imaginary parts of all couplings.

Coupling	Λ = 750 GeV	Λ = 1TeV
$\lvert\Re(h^Z_{10,30}\rvert$, $\lvert\Im(h^Z_{10,30}\rvert$	0.24	0.23
$\lvert\Re(h^Z_{20,40}\rvert$, $\lvert\Im(h^Z_{20,40}\rvert$	0.027	0.020
$\lvert\Re(h^\gamma_{10,30}\rvert$, $\lvert\Im(h^\gamma_{10,30}\rvert$	0.29	0.23
$\lvert\Re(h^\gamma_{20,40}\rvert$, $\lvert\Im(h^\gamma_{20,40}\rvert$	0.030	0.019

These limits are more restrictive than previous results already published [30]. The limits on h_{20}^V and h_{40}^V are even more restrictive than the combined results of the four LEP experiments [31].

W MASS MEASUREMENT

The W mass, combined with a precise measurement of the top quark mass (m_t), constrains the mass of the Higgs boson. The uncertainty on the W mass at LEP [32] is 42 MeV while it is 59 MeV at Tevatron [8].

CDF and DØCollaborations are currently analyzing Run 2 data in the leptonic (*e* or μ) decay chanels. CDF has reported an estimate of the W boson mass uncertainty to be 76 MeV in a blind analysis [5] with a luminosity of 200 pb^{-1}.

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[4] To prevent unitarity violation at high energies a form factor is used with a form factor scale Λ: $h_i^V = h_{i0}^V/(1+\hat{s}/\Lambda^2)^{n_i}$ (i = 1,...4) where $\sqrt{\hat{s}}$ is the parton center-of-mass energy. The form factor powers $n_1 = n_3 = 3$ and $n_2 = n_4 = 4$ are set according [29]

[5] The W boson mass fi t results are currently blinded with a constant offset which will be removed when further cross checks have been completed

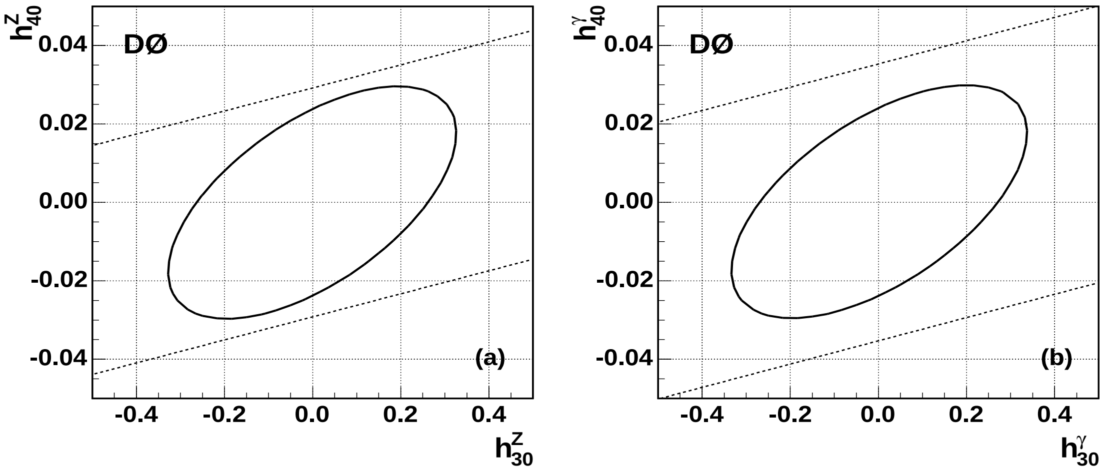

FIGURE 9. DØ : The 95% two-dimensional exclusion limits for CP-conserving ZZγ (a) and Z$\gamma\gamma$ (b) couplings for Λ = 1TeV. The unitarity constraints are shown in dashed lines.

The dominant errors in the transverse mass M_T [6] fit method is coming from the lepton energy scale, the lepton energy resolution, the hadronic recoil scale and the hadronic energy resolution. The quarkonium resonance decays J/$\Psi \rightarrow \mu\mu$ and Υ(1S) $\rightarrow \mu\mu$ are used to set the momentum scale while the energy scale of the electromagnetic calorimeter is determined by using the ratio of calorimeter energy to track momentum of electrons (E/p method).

The total uncertainty from the production model (parton distribution functions effect, P_{T_W} modelling, higher-order QED corrections) is ≈ 30 MeV. The main uncertainies are summarized in Table 7.

TABLE 7. Uncertainty on the W mass measurement using $\approx$ 200 pb^{-1} of Run 2 CDF data. The CDF Run 1b uncertainties are shown for comparison.

Uncertainty	**Electrons (Run 1b) MeV**	**Muons (Run 1b) MeV**
Production and Decay Model	30 (30)	30 (30)
Lepton Energy Scale and Resolution	70 (80)	30 (87)
Recoil Scale and Resolution	50 (37)	50 (35)
Backgrounds	20 (5)	20 (25)
Statistics	45 (65)	50 (100)
Total	105 (110)	85 (140)

The transverse mass distributions both for data and simulation is shown in Figure 10. The overall uncertainty is 76 MeV.

[6] $M_T = \sqrt{2p^l_T p^\nu_T(1-\cos(\Delta\phi))}$ where p^T_l is the transverse momentum of the lepton e or μ, p^ν_T is the transverse momentum of the ν equal to the transverse missing energy $\not{E}_T$and $\Delta\phi$ is the azimuthal angle between the lepton and the ν ($\not{E}_T$) directions.

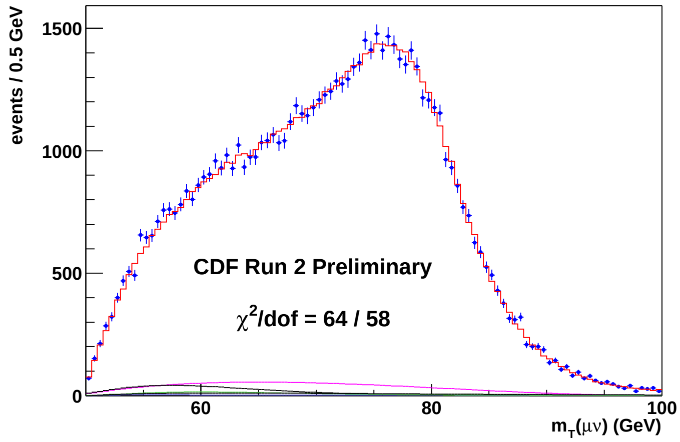

FIGURE 10. CDF: The M_T distribution in W boson decay to muon. The points represent the data, the full lines the simulation with background added. The W boson mass is obtained from a fi t in the 60-90 GeVc^2 M_T range.

CONCLUSION

The W and Z physics at the Tevatron is already a success with a mean sensitivity of 200 pb^{-1}. Around 5 times more data are recorded and beeing analyzed. CDF and DØ have measured the inclusive W and Z cross sections in all three leptonic decay channels showing a good agreement with NNLO calculations. More particularly they have shown that physics with τ leptons is very promising even if challenging at hadrons colliders.

CDF has extracted competitive measurements on lepton universality and on indirect determination of the W width. DØhas performed a direct measurement of the W width in electron channel with an improved uncertainty compared to Run 1. The W charge asymmetry measurements will help to constrain the uncertainties of parton distribution functions. Direct measurements of vector boson pair production processes and trilinear gauge boson couplings have been conducted by the CDF and DØCollaborations. New stringent limits has been put on the anomalous couplings which for some of them are better than LEP limits. For the first time the WWZ cross section production has been measured.

CDF has determined the uncertainty on the W boson mass to be 76 MeV which is lower than its Run 1 uncertainty of 79 MeV. With the additional data to come, Run 2 promises the world's highest precision measurement with an anticipated uncertainty of 30 Mev for 2 fb^{-1}.

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