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Electroweak physics with CDF

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Abstract. The CDF experiment at the Tevatron has used $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV to perform electroweak physics measurements. A program of *precision* electroweak tests of the SM started measuring W and Z boson cross sections using different leptonic final states, evaluating dielectron Forward-Backward Asymmetry A_{FB} and di-boson cross section production.

PACS. 13.38.Be Decays of W bosons – 13.38.Dg Decays of Z bosons

1 Introduction

The Collider Detector at Fermilab (CDF) is a general purpose detector located in one of the interaction regions at the Tevatron collider. $p\bar{p}$ collisions at the Tevatron reach an energy in the center of mass of $\sqrt{s} = 1.96$ TeV. We are reporting here the electroweak physics measurements performed using the first physics-quality data of RunII taken from March 2002 to January 2003.

2 W and Z cross sections

W and Z bosons are produced by $q\bar{q}$ annihilation. Due to the large QCD background, decay channels of bosons involving quarks are difficult to identify; therefore W and Z bosons are identified through their leptonic decays.

2.1 Measuring W cross section

The signature for a leptonic W boson decay is a high momentum isolated lepton with missing transverse energy accounting for the undetected neutrino.

$W \to e\nu$ candidates are collected with a trigger selecting high-E_T central electron candidates; after requiring one tight electron with $E_T > 25$ GeV matched to a track with $P_T > 10$ GeV/c and missing transverse energy $\not{E}_T > 25$ GeV, 38628 events are left in data. The transverse mass distribution of the candidate events is reported in Fig. 1. Background from QCD dijets is estimated from data assuming that its distribution is flat with respect to the missing transverse energy. Background contamination from other electroweak processes like $W \to \mu\nu$, $Z \to ee$ and $W \to \tau\nu$ is estimated from MC events after a detailed simulation through our detector.

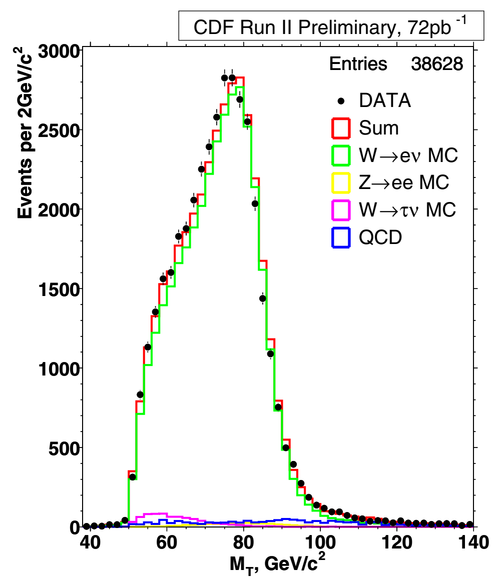

Fig. 1. Transverse Mass distribution of $W \to e\nu$ events collected by the CDF experiment

$W \to \mu\nu$ candidates are collected by a high-P_T muon trigger. After requiring an isolated muon with $P_T > 20$ GeV/c and $\not{E}_T > 20$ GeV, 21599 W candidates remain. The main background contamination comes from $Z \to \mu\mu$, $W \to \tau\nu$, cosmic rays and dijet QCD events.

Specific triggers for selecting a sample enriched with τ events decaying into hadrons have been designed for RunII [1]. Events with $\not{E}_T > 25$ GeV and with the topology of the τ decaying hadronically are selected at trigger level. $W \to e\nu$ events are explicitly removed. 2345 events pass the selection with an estimated background mainly from QCD of 612 ± 61 events. Using the removed $W \to e\nu$ events collected in the same data sample, the ratio of the

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Table 1. Yields of W boson events in the different leptonic decay channels with the measured $\sigma \times BR(W \to \ell\nu)$ ($\mathcal{L} = 72pb^{-1}$). Quoted uncertainties are respectively for statistics, systematics and luminosity.

Channel	Events	Bkg. (%)	$\sigma \times BR(W \to \ell\nu)$ (nb)
$e\nu_e$	38625	6	$2.64 \pm 0.02 \pm 0.09 \pm 0.16$
$\mu\nu_\mu$	21599	11	$2.64 \pm 0.02 \pm 0.12 \pm 0.16$
$\tau\nu_\tau$	2345	26	$2.62 \pm 0.07 \pm 0.21 \pm 0.16$
$e\nu_e$, $\mu\nu_\mu$	combined		$2.640 \pm 0.012 \pm 0.093 \pm 0.158$

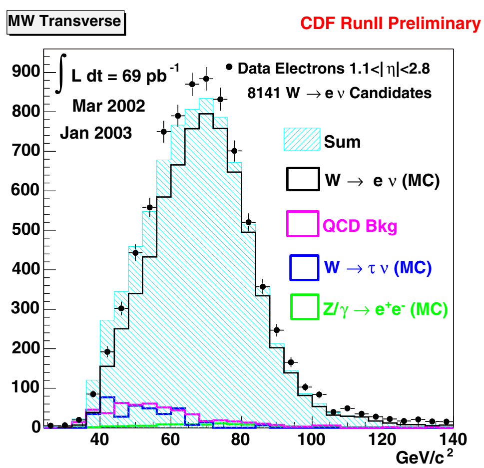

Fig. 2. Transverse Mass distribution of $W \to e\nu$ with electrons detected by forward calorimeters($|\eta| > 1$)

electroweak coupling constant has been measured:

$$g_\tau / g_e = 0.99 \pm 0.04(\text{stat.}) \pm 0.07(\text{syst.}), \qquad (1)$$

consistent with SM expectations.

Estimating the acceptance of the selection in the different decay channels, the production cross section times branching ratio is measured and reported in Table 1.

The measured values are in agreement with the predicted theoretical values [2] (NNLO) of 2.731 ± 0.002 nb.

2.1.1 Extending detector acceptance

A substantial part of the RunII upgrade was devoted to extend the pseudorapidity coverage of lepton identification [3].

$W \to e\nu$ candidates are selected using a trigger looking for an electromagnetic cluster in the plug calorimeter that covers the pseudorapidity region $1 < |\eta| < 3.6$. Events are selected with $\not{E}_T > 20$ GeV, $E_T > 20$ GeV and matching the cluster with a track. As pseudorapidity increases, the acceptance of the Central Outer Tracker [6] gets smaller; it is therefore necessary to perform tracking with the silicon detectors [7,8]. Transverse mass of $W \to e\nu$ candidates is shown in Fig. 2. $W \to \mu\nu$ candidates are identified with the upgraded muon detection system up to $\eta = 1.5$ [4]; the transverse mass of the candidates is shown in Fig. 3.

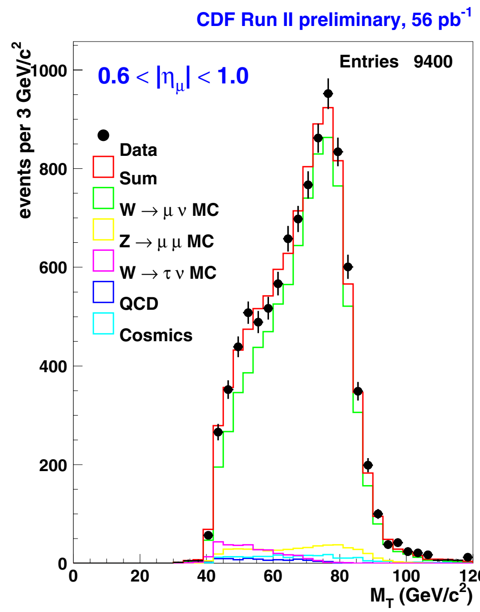

Fig. 3. Transverse Mass distribution of $W \to \mu\nu$ with muons identified for $0.6 < \eta < 1.0$

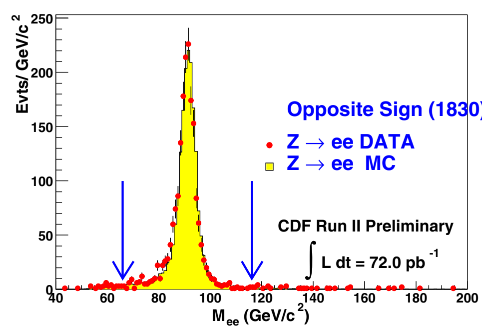

Fig. 4. Dielectron invariant mass distribution of $Z \to e^+e^-$ candidates

2.2 Measuring Z cross section

$Z/\gamma^\star \to \ell\ell$ events are selected requesting two central high-P_T isolated leptons with opposite charge. $Z/\gamma^\star \to ee$ events are required to have two central electrons with oppsite charge and with $E_T > 25$ GeV and $P_T > 10$ GeV/c. The invariant mass is required to be between 66 and 116 GeV/c^2. The total yield of candidates is 1830 with an estimated background of 10 ± 5 events. The invariant mass of the dielectron pair is reported in Fig. 4.

The $Z/\gamma^\star \to \mu\mu$ candidates are selected requiring one isolated central muon with $P_T > 20$ GeV/c and a second isolated high-P_T track passing minimum ionizing energy requirements. The production cross section times branching fraction has been measured; the values are reported in Table 2 and are in agreement with the predicted Z boson production (NNLO) 250.5 ± 3.8 pb [5] .

$Z \to \tau^+\tau^-$ candidates are selected requiring one τ identified from its electronic decay and the other one from its hadronic decay. To increase the purity we require $M_T(e, \not{E}_T) \leq 25\,\text{GeV}/c^2$ and $P_T(e, \not{E}_T) \geq 25$ GeV/c. The invariant mass is reported in Fig. 5.

Table 2. Yields of events in the different leptonic decay channels of Z boson with the measured $sigma \times BR(Z \to \ell\ell)$ ($\mathcal{L} = 72pb^{-1}$). Quoted uncertainties are for statistics, systematics, and luminosity

Channel	Events	Bkg. (%)	$\sigma \times BR(Z \to \ell^+\ell^-)$ (pb).
e^+e^-	1830	0.6	$267 \pm 6 \pm 15 \pm 16$
$\mu^+\mu^-$	1631	0.9	$246 \pm 6 \pm 12 \pm 15$
e^+e^-, $\mu^+\mu^-$	combined		$251.5 \pm 4.3 \pm 10.6 \pm 15.1$

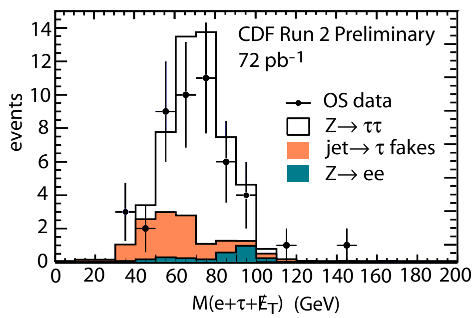

Fig. 5. Invariant Mass distribution of $Z \to \tau\tau$ candidates

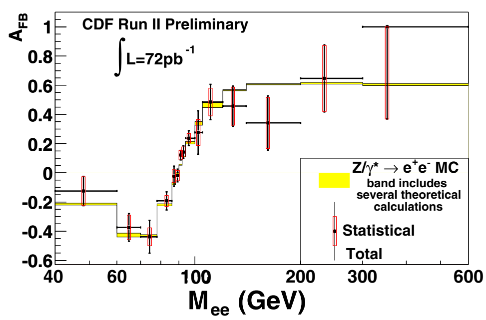

Fig. 6. Forward Backward asymmetry for dielectron pairs compared with theoretical predictions

3 Precision electroweak measurements

3.1 Dielectron forward backward asymmetry

With dielectron pairs created by the Drell-Yan process it is possible to measure the Forward Backward asymmetry (A_{FB}). A_{FB} is a probe of the strength of the vector and axial-vector couplings. What is unique at the Tevatron experiments is the possibility to probe A_{FB} not only at the Z-pole but up to a range of M_{ee} of 600 GeV/c^2 as shown in Fig. 6.

3.2 Diboson production

Electroweak interaction allow bosons to self-interact. Therefore direct production of $W\gamma$ and $Z\gamma$ is searched for. These processes probe anomalous couplings increasing therefore the sensitivity to physics beyond the Standard Model. $W\gamma$ and $Z\gamma$ events are searched for starting from the samples described in the previous section. Additionally a high energy photon with $E_T > 7$ GeV is required

Table 3. Yield of events in the e and μ decay channel of direct $W\gamma$ production ($\mathcal{L} = 72pb^{-1}$). Quoted uncertainties are for statistics, systematics, and luminosity

Channel	Events	Bkg. (%)	$\sigma \times BR(W\gamma \to \ell\nu\gamma)$ (pb)
e	43	33	$17.2 \pm 3.8 \pm 2.8 \pm 1.0$
μ	38	29	$19.8 \pm 4.5 \pm 2.4 \pm 1.2$

Table 4. Yields of events in the e and μ decay channel of direct $Z\gamma$ production ($\mathcal{L} = 72pb^{-1}$). Quoted uncertainties are for statistics, systematics and luminosity.

Channel	Events	Bkg. (%)	$\sigma \times BR(Z\gamma \to \ell^-\ell^+\gamma)$ (pb)
e	11	4.6	$5.5 \pm 1.7 \pm 0.6 \pm 0.3$
μ	14	4.0	$6.0 \pm 1.6 \pm 0.7 \pm 0.4$

with $\Delta R_{(\gamma,\ell)} \geq 0.7$. The yield of $W\gamma$ and $Z\gamma$ events are reported in Table 3 and Table 4. The predicted production cross sections are 18.7 ± 1.3 pb and 5.4 ± 0.4 pb.

WW candidates are searched in the dilepton decay channel $WW \to \ell\ell'\nu\nu'(\ell = e, \mu)$. Candidate events are selected requiring two high-P_T isolated leptons with opposite charge and $\not{E}_T > 25$ GeV. Additional requirements reject $t\bar{t}$ dilepton and Z bosons candidates. Combining the ee, $\mu\mu$ and $e\mu$ channels 2 events are observed with an estimated background of 1.53 ± 0.64 and 2.79 ± 0.62 signal events expected.

4 Conclusions

Electroweak measurements have been performed using the first *physics quality* data collected by the CDF experiment. W and Z production cross section values, dielectron forward backward asymmetry and diboson production have been established showing a substantial agreement with SM predictions. These latter measurements are statistically limited; larger data samples have been collected and are ready to be analyzed allowing a larger precision in electroweak measurements.

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