Recent Electroweak Results from the Tevatron

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Abstract. I present the recent electroweak measurements related to single W, Z boson and diboson productions from the CDF and DØ experiments at the Fermilab Tevatron collider.

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INTRODUCTION

W and Z bosons are mainly produced via quark-antiquark annihilations at the Fermilab Tevatron collider. Precision measurements with these gauge bosons provide us with high precision tests of the Standard Model (SM) as well as indirect search for possible new physics beyond the SM.

W BOSON PROPERTIES

Precision measurement of W boson mass ($M_W$). In the SM, $M_W$ can be calculated using the electromagnetic coupling constant $\alpha$, the Fermi constant $G_F$ and the weak mixing angle $\sin^2\theta_W$. It also receives quantum radiative corrections that depend on the top quark mass and the SM Higgs boson mass. A precise measurement of $M_W$ thus can be used to make constraints on the Higgs mass. To make the equal contribution to the Higgs mass uncertainty, we need to have $\Delta M_W \approx 0.006 \times \Delta M_{top}$. With the current world average value of $\Delta M_{top} = 1.3$ GeV and $\Delta M_W = 0.025$ GeV, $\Delta M_W$ is the limiting factor for the Higgs mass constraint.

At the Tevatron, $M_W$ is extracted from a template fit to the transverse mass ($M_T$), lepton transverse momentum ($p_T^\ell$) and missing transverse energy ($E_T^m$) distributions in $W \rightarrow \ell\nu (\ell = e, \mu)$ events. The template distributions are generated using a parameterized Monte Carlo (MC) simulation program. This program uses the state-of-the-art W and Z MC event generator and simulates the complex detector acceptance and response effects. The parameters used in the simulation are mainly determined using the $Z \rightarrow \ell\ell$ events. The uncertainties on these detector smearing parameters and theoretical calculations (including QCD and electroweak corrections and also the parton distribution functions (PDFs)) are propagated to the uncertainty on the measurement of $M_W$.

Using 1 fb$^{-1}$ of Run II data [1], the DØ collaboration measured $M_W = 80.401 \pm 0.021$(stat) $\pm 0.038$(syst) = $80.401 \pm 0.043$ GeV, the most precise measurement from

1 For the CDF and DØ Collaborations
FIGURE 1. The $M_T$ and $p_T$ distributions for data and MC simulation with backgrounds added (top), and the difference between data and MC divided by the data uncertainty ($\chi$) for each bin (bottom).

one single experiment to date. Figure 1 shows the data and MC comparison for $M_T$ and $p_T$ distributions.

Many of the systematic uncertainties in these measurements are limited by the size of the control samples (mainly $Z \rightarrow \ell\ell$ events) used to understand the detector and physics effects. These uncertainties can be improved with an analysis of the larger datasets in hand. CDF has begun analyzing a data sample with $\mathcal{L} = 2.3$ fb$^{-1}$ [2] and found the statistical uncertainty is 16 (15) MeV for muon (electron) channel and the uncertainty due to the lepton energy scale is 12 (20) MeV for muon (electron) channel. We expect to get the ultimate combined Tevatron measurement with an uncertainty of 15 MeV.

$W$ boson production charge asymmetry. At the Tevatron, $W^+$ ($W^-$) bosons are produced primarily by the annihilation of $u$ ($d$) quarks in the proton with $\bar{d}$ ($\bar{u}$) quarks in the antiproton. Due to the fact that $u$ quarks in the proton on average carry more momentum than $d$ quarks, $W^+$ ($W^-$) boson tends to move along the proton (antiproton) direction, and thus results in an asymmetry in the $W$ boson rapidity distribution between $W^+$ and $W^-$ boson production. This asymmetry is sensitive to the PDFs which describes the fraction of momentum carried by each parton ($x$) in the proton.

Since we can not measure the longitudinal momentum of the neutrino in $W \rightarrow \ell\nu$ decays, the $W$ charge asymmetry is traditionally measured as a function of the decay lepton pseudorapidity ($\eta$). The DØ collaboration analyzed 0.75 fb$^{-1}$ of data in electron channel and measured electron charge asymmetry for events with $E_T^e > 25$ GeV, $p_T^\nu > 25$ GeV and electron $|\eta| < 3.2$ [3]. The asymmetry is also measured in two electron $E_T$ bins to probe partons in different $x$ regions. The detector effects corrected charge asymmetry is compared to a NLO perturbative QCD calculation with CTEQ6.6 and MRST04 PDF sets. The measured charge asymmetries tend to be lower than the theoretical predictions for high rapidity electrons.

In a recent analysis using 1 fb$^{-1}$ of data by the CDF collaboration [4], the $W$ boson charge asymmetry is measured directly for the first time. The longitudinal momentum of the neutrino is estimated on an event-by-event basis using the $W$ boson mass constraint. The measured asymmetry is found to have good agreement with the predictions of a
DIBOSON PRODUCTION

The diboson production at the Tevatron is sensitive to the couplings between gauge bosons. These triple gauge couplings (TGCs) are a direct consequence of the non-Abelian group structure of the SM. Understanding diboson production is also critical for Higgs searches where dibosons are a major source of backgrounds in several important channels. The diboson measurements at the Tevatron often involve measurements of the overall production cross section and TGCs. The diboson processes with one charged boson in the final state are discussed here. The general Lorentz invariant effective Lagrangian describing diboson production at the Tevatron is sensitive to the couplings between gauge bosons. These triple gauge couplings (TGCs) are a direct consequence of the non-global PDFs fits and reduce the uncertainty on the future W boson mass measurements.

WW → ℓνℓν. Both CDF and DØ Collaborations select WW events with two high \( p_T \) leptons and large \( E_T \). Using 1 fb\(^{-1} \) of data [5], DØ observed 22(ee), 64(eµ) and 14(µµ) candidates. These numbers are consistent with the SM predictions of 23.5 ± 1.9(ee), 68.6 ± 3.9(eµ) and 10.8 ± 0.6(µµ) events. The measured cross section is 11.5 ± 2.1(stat+syst) ± 0.7(lumi) pb, which is consistent with the SM prediction of 12.4 ± 0.8 pb. A similar measurement by CDF used 3.6 fb\(^{-1} \) of data [6]. This measurement makes use of matrix element (ME) based likelihood ratios. Event kinematics are used to assign an event-by-event probability \( P \) based on leading-order ME cross section calculation for the WW process and for the major background processes such as WW, Wγ and W+jet. The background fractions are estimated using the \textsc{geant} MC simulation, while the signal fraction is extracted using a likelihood fit to the \( LR_{WW} \) distribution. \( LR_{WW} \) is defined as \( P_{WW}/(P_{WW} + \sum_i k_i P_i) \) with \( k_i \) as the relative fraction of each background source, \( P_{WW} \) and \( P_i \) represent the event probability for WW and each background process respectively. The measured cross section is 12.1 ± 0.9(stat)\( ^{+1.6}_{-1.4}\) (syst) pb, which is again consistent with the SM prediction. DØ also used the leading and trailing lepton \( p_T \) s to set limits on aTGCs assuming \( Λ = 2 \) TeV. The results are \(-0.14 < Δg_1^2 < 0.30, -0.54 < Δκ_γ < 0.83 \) and \( 0.14 < λ_0 = λ_γ < 0.19 \) under the SU(2)\(_L\) × U(1)\(_γ\)-conserving constraints, and \(-0.12 < Δκ_Z = Δκ_γ < 0.35 \), with the same \( λ_γ \) limits as above, under the WWγ = WWZ constraints.
**WW/WZ → ℓνjj.** The DØ Collaboration recently reported the first evidence of \(WW/WZ \rightarrow ℓνjj\) process at the hadron collider [7]. The signatures are one high \(p_T\) lepton, large \(E_T\) and two high \(p_T\) jets. The background arises mainly due to \(W/Z+\) jets, QCD multijet, and \(t\bar{t}\) events. A multivariate classifier (Random Forest) is used to separate the signal from backgrounds. The signal and background contents are determined by fitting the signal and background random forest templates to the data. The measured cross section is \(20.2 ± 2.5\) (stat) \(± 1.2\) (syst) \(± 1.2\) (lumi) \(\text{pb}\), consistent with the SM prediction of \(16.1 ± 0.9\) \(\text{pb}\). The dijet \(M_{jj}\) spectrum is used to set aTGCs limits assuming \(Λ = 2\) TeV: \(-0.12 < \Delta g_1^Z < 0.19\), \(-0.44 < \Delta κ\gamma < 0.55\) and \(-0.10 < λ_{Z,γ} < 0.11\) under the \(SU(2)_L \times U(1)_Y\)-conserving constraints, and \(-0.16 < Δκ_{Z,γ} < 0.23\) and \(-0.11 < λ_{Z,γ} < 0.11\), under the \(WWγ = WWZ\) constraints.

**WZ → jjℓℓ.** The CDF Collaboration also reported a search for anomalous WZ production at the Tevatron using the two charged leptons, two jets final state [8]. Three bins in dilepton \(p_T\) are used: \(105 − 140\) GeV (control region), \(140 − 210\) GeV (medium region) and \(> 210\) GeV (high region). Events in the control region are mainly used to validate data modeling and determine backgrounds. The dijet mass \(M_{jj}\) for the medium and high regions are used to set limits on the cross section and aTGCs. The 95% CL upper limit on the cross section is found to be \(234\) fb and \(135\) fb using events in the medium and high region respectively. Under the \(WWγ = WWZ\) constraints, the limits on the aTGCs are \(-0.20 < Δg_1^Z < 0.29\), \(-1.01 < Δκ\gamma < 1.27\) and \(-0.16 < λ_{Z,γ} < 0.17\) assuming \(Λ = 2\) TeV, and \(-0.22 < Δg_1^Z < 0.32\), \(-1.09 < Δκ\gamma < 1.40\) and \(-0.18 < λ_{Z,γ} < 0.18\) assuming \(Λ = 1.5\) TeV.

**CONCLUSIONS**

With the increasingly large datasets, both CDF and DØ continue to improve our understanding of electroweak production at the hadron collider.

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