Tevatron Measurements of Electroweak Boson Production

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Abstract. With a large and still increasing dataset, W and Z boson physics studies at the Tevatron $p\bar{p}$ collider are particularly useful for testing many aspects of the Standard Model. In this proceeding, we present measurements of electroweak boson properties, distributions, and charge asymmetries. We examine both solitary W and Z production as well as production in association with jets. These measurements are compared to NLO QCD predictions, are used to extract fundamental Standard Model parameters, and constrain parton distribution functions.

THE TEVATRON ACCELERATOR, CDF, AND DØ DETECTORS

The Tevatron accelerator complex located at the Fermi National Accelerator Laboratory outside Chicago, IL collides proton (p) and anti-proton ($\bar{p}$) beams at a center-of-mass energy of 1.96 TeV ($\sqrt{s} = 1.96$ TeV). Both CDF and DØ are multipurpose collider detectors located at separate beam crossing locations at the Tevatron. Details about the detectors can be found at [1, 2].

THE ELECTROWEAK BOSON ANALYSES

The electroweak sector of the Standard Model (SM) of particle physics is governed by the exchange of the W and Z bosons. A copious number of these bosons have been produced at the Tevatron: millions of W's and hundreds of thousands of Z's. With an electroweak boson sample of this size, detailed studies of their properties can shed light on some of the SM's underlying physics. This proceeding focuses on W boson results from 2009. For Z production, we review the newest 2011 results from both experiments.

DØ 's Updated $Z/\gamma^* \to e^+e^-$ Analysis

This analysis utilizes 5.0 fb^{-1} of data which is collected via a list of dilepton triggers. Final events are then selected by requiring one $E_T > 20$ GeV electron and one $E_T > 20$ GeV positron. Further details on this analysis can be found at [3]. Because the Z boson couples via both the vector (V) and axial (A) type couplings, there exists a forward-backward asymmetry defined as: $A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$, where σ_F represents the cross section of events where the decay electron has $cos(\theta^*) > 0$ in the Z center of mass frame and σ_B represents the case where the electron has $cos(\theta^*) < 0$. θ^* is the polar angle as measured in the Z frame. This forward-backward asymmetry is sensitive to the weak mixing angle (θ_W), via $sin^2(\theta_W)$. By fitting templates of different $A_{FB}(sin^2(\theta_W))$'s to dielectron data near the Z-pole (70 GeV $< M_{ee} <$ 130 GeV), we extract a measurement of $sin^2(\theta_W)$. This analysis finds $sin^2(\theta_W) = 0.2309 \pm 0.0010$, which has a precision comparable to LEP's c-quark result, and is more precise than LEP's hadronic charge result [3].

This analysis further explores the physics of the Z boson by creating an unfolded A_{FB}, which can be compared to various MC predictions. A comparison between the DØ data and two MC generators are shown in Fig. 1. By fitting simulation templates which vary the couplings ($g_A^u, g_V^u, g_A^d, g_V^d$) between Z and light quarks to the unfolded A_{FB} distribution, we extract measurements of these couplings. Table 1 shows the measured coupling parameters found in this analysis as well as the SM predicted values. As can be seen from Table 1, the coupling parameters are in good agreement with the SM prediction. It is worth noting that this measurement of the Z to light quark couplings is the most precise to date.

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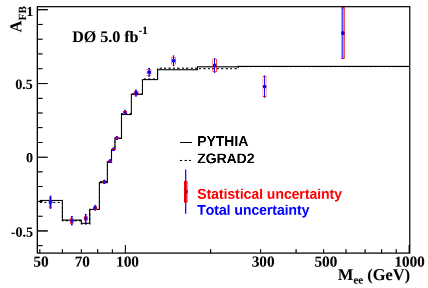

FIGURE 1. The unfolded A_{FB} as a function of dielectron mass data distribution compared to two different MC predictions.

TABLE 1. Comparison between DØś measured coupling parameters and the SM predictions.

	g_A^u	g_V^u	g_A^d	g_V^d
DØ (5.0 fb^{-1})	0.502 ± 0.040	0.208 ± 0.014	-0.495 ± 0.037	-0.379 ± 0.027
SM	0.501	0.192	-0.502	-0.347

CDF's $Z/\gamma^* + X \rightarrow e^+e^-$ Angular Coefficient Analysis

For this analysis CDF utilizes 2.1 fb^{-1} of $Z \rightarrow e^+e^-$ data which fires at least one high E_T lepton trigger, and has one $E_T > 20$ GeV electron and one $E_T > 20$ GeV positron. By comparing this data it to the expected Drell-Yan+X differential cross section as parameterized in Equation (1), CDF extracts measurements of the angular coefficients (A_0,A_2,A_3,A_4). This analysis looks at dielectron events in the Z-pole region (66 GeV < M_{ee} < 116 GeV). Further details for this analysis can be found at [4].

$$\frac{d\sigma}{dcos\theta} \propto (1 + cos^2\theta) + \frac{A_0}{2}(1 - 3cos^2\theta) + A_4 cos\theta$$
$$\frac{d\sigma}{d\phi} \propto 1 + \frac{3\pi A_3}{16} cos\phi + \frac{A_2}{4} cos2\phi \tag{1}$$

These differential cross sections include contributions from $q\bar{q} \rightarrow Z/\gamma^* + g$ (annihilation) and $qg \rightarrow Z/\gamma^* + q$ (Compton) processes. The Compton process in particular can result in Z events with large dilepton transverse momentum.

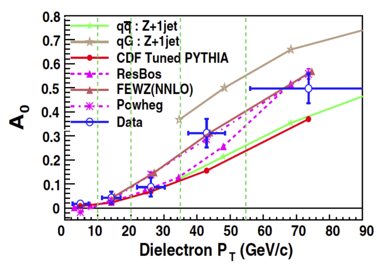

FIGURE 2. The dielectron p_T data distribution compared to several different MC predictions for coefficient parameter A_0.

As shown in Fig. 2, the data best match the prediction made by the FEWZ (NNLO) MC. Furthermore, Lan-Tung relations give concrete predictions as to the relationship between parameters A_0 and A_2. It turns out that if the gluon has spin 1, parameters A_0 and A_2 should be equal; that is $A_0 - A_2 = 0$ [4]. Violations of this prediction would be an indication of some new physics. Table 2 gives the measured values of $A_0 - A_2$ over several different dielectron p_T bins. Across every dielectron p_T bin the data is consistent with $A_0 - A_2 = 0$, which favors a spin 1 gluon hypothesis.

W Charge Asymmetry

The DØ selections look at a $W \rightarrow \mu^\pm\nu$ final state utilizing 4.9 fb^{-1} of data. The muon must fire one of a suite of single muon triggers. The muon must be matched to a central track, have $p_T > 20$ GeV, be isolated from

TABLE 2. Difference between angular coefficients A_0 and A_2 for several dielectron transverse momentum bins.

Dielectron p_T (GeV)	$A_0 - A_2$
0-10	$(0.005 \pm 0.314) \times 10^{-1}$
10-20	$(0.434 \pm 0.458) \times 10^{-1}$
20-35	$(0.341 \pm 0.706) \times 10^{-1}$
35-55	0.005 ± 0.314
> 55	0.014 ± 0.139

other activity in the detector, and satisfy scintillator timing requirements which eliminate cosmic ray backgrounds. Furthermore, selected W events must have large missing transverse energy ($\not\!\!E_T > 20$ GeV) as well as high transverse mass ($M_T^{\mu\nu} > 40$ GeV).

CDF's W selections discussed here focus on the $W \to e^{\pm}\nu$ final state using 1.0 fb^{-1} of data. Events must fire one of a combination of high E_T and large $\not\!\!E_T$ triggers. Further requirements are that there exists an isolated electron with $E_T > 25$ GeV (> 20 GeV for electrons in the end plug calorimeter). The final event selection for this analysis requires $\not\!\!E_T > 25$ GeV. Now we will discuss some details of the different individual results.

Because u-quarks carry more of the incoming proton's momentum than d-quarks, W^+ bosons tend to get boosted along the proton's direction. This bias produces a charge asymmetry with respect to the W's rapidity (y_W). Because this asymmetry is directly related to the amount of momentum carried by an incoming parton, its study can shed light on parton distribution functions (PDFs). By analyzing the $W \to e\nu$ data, CDF has attained experimental measurement uncertainties which are smaller than those included in common PDF sets. Figure 3 shows the $W \to e\nu$ charge asymmetry as a function of $|y_W|$ for the CDF results.

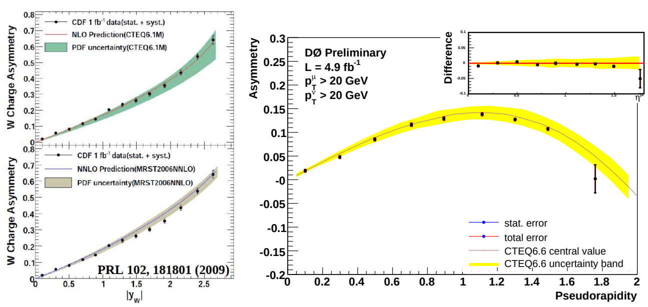

FIGURE 3. The CDF and DØ asymmetry distribution as a function of rapidity (both W and μ) for data and several PDF predictions.

The DØ experiment quotes preliminary results based on the analysis of the $W \to \mu\nu$ data. Again the experimental measurements yield uncertainties which are much smaller than those associated with common PDF sets. Figure 3 shows the W's muon charge asymmetry as a function of $|y|$ for the DØ result. In both analyses the experimental results provide valuable input to further refine PDF predictions. Additional details regarding both of these analyses can be found at [5, 6].

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