TOP QUARK AND ELECTROWEAK RESULTS FROM DZERO

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Reported are new top quark and electroweak results from the DØ experiment, which is accumulating luminosity from \( p\bar{p} \) collisions at center-of-mass energy 1.96 TeV (Run II).

1 W and Z Production

We study \( W \) and \( Z \) boson production at the Tevatron to extract a variety of physics. For instance, comparison of the branching fractions \( B(W \to \ell\nu) \), where \( \ell = e, \mu, \) or \( \tau \), tests the universality of the leptonic couplings to the weak current \( \text{I} \). The angular distribution of leptons from \( W \) boson decay provides constraints on parton distribution functions that describe the structure of the proton \( \text{II} \) and allow us to understand beyond-tree-level QCD corrections to production models \( \text{III} \). Equally importantly at this early stage in Run II, these relatively common processes allow us to benchmark the performance of our detector, trigger, and reconstruction algorithms.

Using 32 pb\(^{-1} \) of \( p\bar{p} \) collisions at \( \sqrt{s} = 1.96 \) TeV, we measured the cross section times branching ratio \( \sigma(Z + X)Br(Z \to \mu\mu) \). The selection criteria required at least two oppositely-charged muons with \( p_T \geq 15 \) GeV/c within \( |\eta| \leq 1.8 \) and \( (\Delta R)^2 = (\Delta \phi_{\mu\mu})^2 + (\Delta \eta_{\mu\mu})^2 \geq 4.0 \). At least one muon was required to be isolated in the calorimeter and the central tracker. Figure 1a shows the dimuon invariant mass distribution for the resulting 1585 muon pairs (data points) and the \( 1.5 \pm 1.0\% \) background from \( b\bar{b} \) and \( Z \to \tau\tau \) events (shaded). The histogram is the Monte Carlo. Because there was no explicit mass selection, the Drell-Yan contribution, determined using Pythia, is \( 12 \pm 1\% \). It was \( 4\% \) in the region \( 75 \leq M(\mu\mu) \leq 105 \) GeV/c\(^2 \). The result is \( \sigma(Z + X)Br(Z \to \mu\mu) = 264 \pm 7(\text{stat.}) \pm 17(\text{sys.}) \pm 26(\text{lum}'\text{y}) \) pb. The largest uncertainty, 26 pb, comes from uncertainty in the delivered luminosity.

Figure 1b shows the cross section times branching ratio for \( W \) and \( Z \) bosons in the electron and muon channels in \( p\bar{p} \) collisions as a function of center-of-mass energy including the new result...
(described above), preliminary results\cite{1,2} from Run II, and previously published results\cite{3}. Comparing the cross sections times branching ratios measured by DØ at 1.8 TeV and 1.96 TeV, we find \( \sigma_{W \rightarrow e\nu}(1960 \text{ GeV})/\sigma_{W \rightarrow e\nu}(1800 \text{ GeV}) = 1.15 \pm 0.19, \sigma_{Z \rightarrow ee}(1960 \text{ GeV})/\sigma_{Z \rightarrow ee}(1800 \text{ GeV}) = 1.20 \pm 0.19, \) and \( \sigma_{Z \rightarrow \mu\mu}(1960 \text{ GeV})/\sigma_{Z \rightarrow \mu\mu}(1800 \text{ GeV}) = 1.48 \pm 0.32 \). In the first two cases the main uncertainty is the Run II luminosity. In the case of \( Z \) to muons, the main uncertainty is in the Run I result, where we struggled with the muon acceptance. In fact, the \( Z \) boson peak in Fig. 1a indicates the success of the DØ Upgrade for Run II.

2 Search For \( Z' \rightarrow \text{Di-electrons} \)

Using 50 pb\(^{-1}\) we searched for non-SM particles that decay to lepton-antilepton pairs. We assume the couplings of the leptons to the putative particle are the same as their couplings to the \( Z \) boson and we refer to it as a \( Z' \). We triggered on events with EM clusters within the region \(|\eta| \leq 0.8\). The remaining selection criteria are designed not to remove very high \( E_T \) electrons. We simply require events with two or more isolated EM showers with \( E_T \geq 25 \text{ GeV} \) in the fiducial regions \(|\eta| \leq 1.1 \text{ or } 1.5 \leq |\eta| \leq 2.5\). Figure 2a shows the di-EM invariant mass from 80 to 800 GeV/c\(^2\). After subtracting the multijet background we observe 2817 \( Z \rightarrow ee \) and Drell-Yan events. No excess of events was observed at any mass. We set limits on the ratio of cross section for \( Z' \) production compared to the \( Z \) boson production (so that many systematic uncertainties are removed) as a function of the putative \( Z' \) mass. Figure 2b shows the 95\% C.L. limits and the (default) Pythia prediction as a function of mass. The two lines cross at 620 GeV, the 95\% C.L. mass limit.

3 Top Quark Cross Section at \( \sqrt{s} = 1.96 \text{ TeV} \)

We have measured the \( t\bar{t} \) cross section at \( \sqrt{s} = 1.96 \text{ TeV} \). Top (antitop) quarks decay to a \( W^+(-) \) boson and a (anti)b-quark and the different decay channels are “named” by the \( W \) boson decay modes and whether or not the \( b \)-quarks are tagged with either a secondary vertex or a muon. We combined the results from six decay channels: “electron plus jets”, “electron plus jets with a muon tag”, “muon plus jets” (with and without a muon tag), and the \( \mu\mu \) and \( e\mu \) “dilepton” modes.
In the “leptons plus jets” analysis we preselected a sample rich in $W$ boson decays to an electron or muon (and neutrino) by requiring an isolated lepton with $p_T \geq 20$ GeV/$c$ and at least 20 GeV of missing transverse energy (MET). We veto on events with a non-isolated muon, preserving them for the tagged-sample analysis. We bin them according to the number of jets with $E_T \geq 15$ GeV and evaluate the hadronic background in each bin. The data samples correspond to 50 (40) pb$^{-1}$ of collisions in the electron (muon) channels. We estimate that the number of hadronic background and $W+4$ or more jets events in the electron + jets (muon + jets) channel is 12.5 (11.9) and 11.9 (24.2), respectively. We observe 22 (38) events. To further distinguish the backgrounds due to hadrons and $W+\text{jets}$ from the top signal we apply topological selection criteria including, variously, the $E_T$ of the highest $E_T$ jet, the $E_T$ and pseudorapidity of the reconstructed $W$ (dijets) boson, the total hadronic $E_T$ (called $H_T$), and the aplanarity. In the electron plus jet analysis the bottom line is $2.7 \pm 0.6$ background events expected, 1.8 $t\bar{t}$ events (assuming $\sigma(t\bar{t})$ is 7 pb), and 4 candidates observed. In the muon plus jets channel, the corresponding numbers are $2.7 \pm 1.1$ background, 2.4 signal, and 4 candidates observed.

In the “lepton plus jets with muon tag” samples, we start with the preselected events described above that were vetoed because of the non-isolated muon. We further require the events have at least 3 jets with $E_T \geq 20$ GeV within $|\eta| \leq 2.0$, that there be at least 110 GeV of $H_T$, and that the events be aplanar. The bottom line is that in the electron plus jets with muon tag analysis, we expect $0.2 \pm 0.1$ background events, $0.5 \ t\bar{t}$ events (again assuming $\sigma(t\bar{t})$ is 7 pb), and we observe 2 candidates. In the muon plus jets with muon tag analysis, we expect $0.6 \pm 0.3$ background events, $0.4 \ t\bar{t}$ events, and we observe no candidates.

The data in the $\mu\mu$ and $e\mu$ “dilepton” decay channels corresponds to 43 and 33 pb$^{-1}$, respectively. In the dimuon channel we require at least two isolated muons with $p_T \geq 15$ GeV/$c$, two or more jets with $E_T \geq 20$ GeV, MET $\geq 30$ GeV (except around the Z boson mass where we require at least 40 GeV), and that the $H_T$ be at least 100 GeV. The remaining background is a combination of Z boson, Drell-Yan dimuon, and $b$-quark decays and is expected to total $0.6\pm0.3$ events. SM top, with the usual assumption for the cross section, is expected to produce $0.30\pm0.04$ events. We observe 2 candidates. In the $e\mu$ channel we require an isolated electron and muon with $p_T \geq 15$ GeV/$c$, that the muon-corrected MET be at least 10 GeV, the not-muon-corrected MET be at least 20 GeV, two or more jets with $E_T \geq 20$ GeV, and $H_T \geq 120$ GeV. The expected background of $Z \rightarrow \tau\tau$ and hadronic events is expected to result in $0.07 \pm 0.01$ candidates. SM top is expected to yield $0.5 \pm 0.1$ candidates. We observe one candidate.

When we combine the results in all six channels, a $3\sigma$ excess exists in the number of events.
observed compared to background expected. Channel-to-channel the observed distribution is consistent with SM top at the 35\% C.L., consistent with interpretation of the signal as SM $t\bar{t}$ production. The cross section is $8.4^{+4.5}_{-3.7}(\text{stat.})^{+5.3}_{-3.5}(\text{sys.}) \pm 0.8(\text{lum}'y)\text{ pb}$. This represents a 47\% increase over the cross section at 1.8 TeV.

4 Improved Top Quark Mass Measurement

We report a new measurement of the top quark mass extracted from the 125 pb$^{-1}$ sample accumulated during Run I. This measurement is an update over that which we have published previously\cite{8} from the leptons plus jets data, where the final data sample consisted of 91 events with an isolated lepton and 4 or more jets.

Some additional event selection was applied in the new analysis. The candidates were required to contain exactly 4 jets for comparison, on an event-by-event basis, with a leading-order matrix element calculation for the production and decay process. That reduced the sample to 71 events. The $W$+jets background probability was determined from VECBOS matrix elements. Selecting on background probability reduced the sample to 22 events with signal efficiency of 70\%.

A likelihood variable\cite{9} involving all of the measured features of the event was formed from the probability the event was $W$+jets background or top signal of a given mass. The probability for top signal was determined from the leading-order matrix element calculation including all 12 jet-identification permutations, all possible values of the neutrino momentum and the detector response as measured from the data. The likelihood is plotted as a function of top quark mass. The maximum value of the likelihood occurred with 12 of the 22 events determined to be signal, 10 to be background, and a top mass $M_{\text{top}} = 179.9 \pm 3.6(\text{stat.}) \pm 6.0(\text{sys.})\text{ GeV}/c^2$. The systematic uncertainty is dominated by contributions from uncertainty in the jet energy scale (5.6 GeV/c$^2$).

This technique provides great promise for Run II because of it’s statistical power (the statistical uncertainty is reduced by nearly a factor of 1.6 from the Run I result) and because the main systematic is constrained by the $W$ boson mass as determined from the dijet invariant mass combination in the signal.

5 Summary

We have reported $W$ boson, $Z$ boson, and $t\bar{t}$ cross section results. They demonstrate the upgraded DØ detector is performing nicely in Run II. We have presented an update of DØ’s Run I top mass measurement in the lepton plus jets channel. The technique provides great promise for Run II.

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