Measurement of the WW Production Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV

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The measurement of the W boson pair-production cross section $\sigma_{p\bar{p}\to W^+W^-}$ offers a good opportunity to test the non-Abelian structure of the standard model (SM). Furthermore, this measurement is sensitive to new phenomena since anomalous trilinear couplings [1] or the production and decay of new particles such as the Higgs boson [2] would enhance the rate of W boson pair-production. The next-to-leading order (NLO) calculations for $\sigma_{p\bar{p}\to W^+W^-}$ [3] predict a cross section of 12.0–13.5 pb at $\sqrt{s} = 1.96$ TeV.

We present a measurement of the W^+W^- production cross section in leptonic final states $p\bar{p} \to W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$ ($\ell = e, \mu$) [4,5]. We use data collected between April 2002 and March 2004 in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV of Run II of the Tevatron Collider. The integrated luminosities are $224 \pm 15\,\mathrm{pb}^{-1}$ to $252 \pm 16\,\mathrm{pb}^{-1}$ depending on the final state. The differences in the integrated luminosities for various channels are primarily due to different trigger conditions.

The components of the DØ Run II detector important to this analysis are described elsewhere [5,6]. The decay of two W bosons into electrons or muons results in three different final states $e^+e^- + X$ (ee channel), $e^\pm\mu^\mp + X$ ($e\mu$ channel), and $\mu^+\mu^- + X$ ($\mu\mu$ channel), each of which consists of two oppositely charged isolated high transverse momentum, p_T, leptons and large missing transverse energy, $\not\!\!E_T$, due to the escaping neutrinos. The selection criteria for each channel were chosen to maximize the expected signal significance, while keeping high efficiency for WW production. In the further description we mainly focus on the $\mu^+\mu^-$ decay channel.

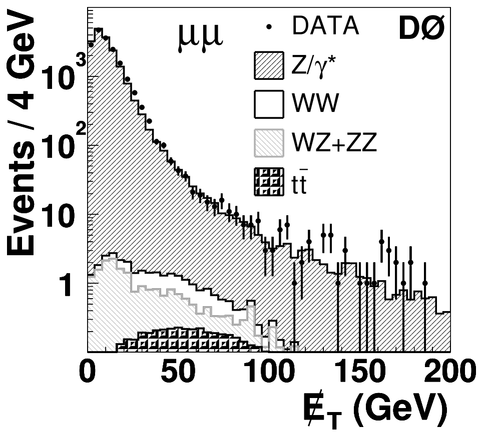

Fig. 1: Distribution of missing transverse energy in the event.

Two muons originating from the same vertex are required to be of opposite charge, and must have $p_T >$ 20 GeV for the leading lepton and $p_T > 15$ GeV for the trailing one. Figure 1 shows the good agreement between data and Monte Carlo (MC) in the $\not\!\!E_T$ distribution for the $\mu\mu$ channel after applying the lepton transverse momentum cuts. The background is largely dominated by Z/γ^* production which is suppressed by requiring the $\not\!\!E_T$ to be greater than 40 GeV. To further reduce the Z/γ^* background, only events with an invariant di-muon mass between 20 and 80 GeV are retained. Since the momentum resolution is worsening for high p_T tracks, an additional constrained fit is performed to reject events compatible with Z boson production. The opening angle between the two muons in the transverse plane is required to be $\Delta\phi_{\mu\mu} <$ 2.4. Finally, requiring $H_T < 100$ GeV removes the remaining background from $t\bar{t}$ events. Four events are observed in the $\mu\mu$ data sample after application of all selection criteria.

The efficiency for WW signal events to pass the acceptance and kinematic criteria is determined using the PYTHIA 6.2 event generator followed by a detailed GEANT-based simulation of the DØ detector. All trigger and reconstruction efficiencies are derived from the data. For the $\mu\mu$ channel, the overall detection efficiency is $(6.22 \pm 0.15)\%$. Using an NLO cross section of 13.5 pb [3], the expected number of events for the pair production of W bosons combined for all three channels is $16.6 \pm 0.1(\mathrm{stat}) \pm 0.6(\mathrm{syst}) \pm 1.1(\mathrm{lum})$ events, where the statistical error is given by the statistics of the MC sample. The total background sum is $8.1 \pm 0.6(\mathrm{stat}) \pm 0.6(\mathrm{syst}) \pm 0.5(\mathrm{lum})$ events.

Sources of systematic uncertainties that affect the WW production cross section measurement such as the trigger efficiency, electron and muon identification (ID) efficiencies, jet energy scale (JES), electron and muon momentum resolution, branching fraction $B(W \to \ell\nu)$, cross section calculation of Z/γ^* and $t\bar{t}$ events, and the determination of W+jet/γ background contributions have been studied.

The cross section for W boson pair production is estimated using a likelihood method with Poisson statistics. As a final result, the combined cross section for WW production at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV is [5]

$$\sigma_{p\bar{p}\to W^+W^-} = 13.8^{+4.3}_{-3.8}(\mathrm{stat})\ ^{+1.2}_{-0.9}(\mathrm{syst}) \pm 0.9(\mathrm{lum})\ \mathrm{pb}.$$

This value is in good agreement with the NLO calculation of 12.0–13.5 pb at $\sqrt{s} = 1.96$ TeV [3]. The probability of an upward fluctuation of the background is 2.3×10^{-7}, which corresponds to 5.2 standard deviations for a Gaussian probability distribution.

References

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