Top quark Production and Properties at DØ

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Abstract. The latest results from the DØ Collaboration on top quark production and properties in $p\bar{p}$ collisions at a center of mass energy of 1.96 TeV are presented. The measurements were performed using approximately 1 fb$^{-1}$ of DØ data taken during Run II at the Tevatron.

1. Introduction
The discovery of the top quark by the CDF and DØ collaborations at the Fermilab Tevatron Collider in 1995 [1, 2] completed the quark sector of the three-generation structure of the standard model (SM). This quark is the heaviest known elementary particle with a mass approximately forty times larger than that of the next heaviest quark, the bottom quark. Despite the fact that the top quark has been discovered more than a decade ago it remains one of the least-studied components of the SM and the Tevatron is at present the only facility capable of producing it. Since the Yukawa coupling of the top quark is larger than that of all other quarks, the top quark would play an important role in the electroweak symmetry breaking mechanism and new physics at the electroweak scale as the Higgs boson would tend to couple to the top quark. Understanding the production and properties of the top quark is in itself a test of perturbative Quantum Chromo Dynamics.

The following sections present results for the measurement of the $t\bar{t}$ production cross section, a simultaneous measurement of $B(t \rightarrow Wb)/B(t \rightarrow Wq)$ and $\sigma(p\bar{p} \rightarrow t\bar{t})$, and the helicity of the W boson in top quark decays.

2. Measurement of the top quark pair production cross section
At a center of mass energy of 1.96 TeV top quarks are mainly produced in pairs through strong interactions in $p\bar{p}$ collisions. The top quark pair production cross section for a hard scattering process initiated by a proton-antiproton collision depends on the top quark mass ($m_t$). For $m_t = 175$ GeV the predicted SM $t\bar{t}$ production cross section is $6.7^{+1.7}_{-0.9}$ pb$^{-1}$ [3, 4]. Deviations of the measured cross section from the theoretical prediction would indicate effects beyond QCD perturbation theory including substantial non-perturbative effects, new production mechanisms or additional top quark decay modes beyond the SM. Previous [5] and new results based on approximately 1 fb$^{-1}$ are summarized in Figure 1 together with the theoretical predictions.

3. Simultaneous measurement of $B(t \rightarrow Wb)/B(t \rightarrow Wq)$ and $\sigma(p\bar{p} \rightarrow t\bar{t})$
In top quark decays any down-type quark can be produced in association with the W boson. The relative strength of these modes is governed by the CKM matrix. In the SM the ratio
This decay angle is explicitly reconstructed as shown in Figure 3. The measurement yields the charged lepton and the top quark (opposite to the $W$ used to measure the $f_{Wtb}$ physics beyond the SM. For example, a $V+A$ term in the $W$ boson coupling would increase $f_{Wtb}$, while leaving $f_{0}$ unchanged. Top quark pair events with dilepton and lepton-plus-jets events were used to measure the $W$ boson helicity by studying the distribution of the angle $\theta^*$ between the charged lepton and the top quark (opposite to the $b$ quark) in the $W$ boson rest frame. This decay angle is explicitly reconstructed as shown in Figure 3. The measurement yields $f_{+} = 0.017 \pm 0.048$ (stat) $\pm 0.047$ (syst). A bayesian confidence interval is also calculated giving $f_{+} < 0.14$ at 95% C.L.

\[ R = B(t \to Wb)/B(t \to Wq) \]

is tightly constrained assuming unitarity of the CKM matrix and exactly three quark generations to the interval 0.9980-0.9980 at 90% C.L [6]. A measurement of $R$ allows then to test these SM assumptions. At DØ a simultaneous measurement of $R$ and $\sigma(p\bar{p} \to t\bar{t})$ are performed using lepton-plus-jets events by counting the number of selected events and the number of $b$-tagged jets. Since $a$ priori there is no knowledge on the $b$-jet content of the events, a model independent cross section is obtained. The preliminary result from this simultaneous determination of $R$ and $\sigma(p\bar{p} \to t\bar{t})$ based on $1 fb^{-1}$ of DØ data is shown in Figure 2. $R$ is found to be $0.99 \pm 0.09$ (stat. + syst.) and the cross section $\sigma_{tt} = 8.1^{+0.9}_{-0.8}(stat. + syst.) \pm 0.5(lumi.)$ pb. Using a bayesian method the lower limit on $R$ is found to be 0.81 at 95% C.L.

4. Measurement of the $W$ boson helicity

In the SM top quarks decay via the $V-A$ charged current interaction into a $W$ boson and a $b$ quark. Within this framework, the fraction of $W$ bosons from top quark decays with left-handed, longitudinal and right-handed polarizations are predicted to be $f_{-} = 0.3$, $f_{0} = 0.7$ and $f_{+} = 0(10^{-4})$ respectively [7]. A measurement that departs from these values would indicate physics beyond the SM. For example, a $V+A$ term in the $Wtb$ coupling would increase $f_{+}$ but leave $f_{0}$ unchanged. Top quark pair events with dilepton and lepton-plus-jets events were used to measure the $W$ boson helicity by studying the distribution of the angle $\theta^*$ between the charged lepton and the top quark (opposite to the $b$ quark) in the $W$ boson rest frame. This decay angle is explicitly reconstructed as shown in Figure 3. The measurement yields $f_{+} = 0.017 \pm 0.048(stat) \pm 0.047(syst)$. A bayesian confidence interval is also calculated giving $f_{+} < 0.14$ at 95% C.L.
Figure 2. The 68% and 95% C.L. contours in the \((B(t \to Wb)/B(t \to Wq), \sigma_{\ell\ell})\) plane using statistical uncertainties only. The point indicates the best fit to data.

Figure 3. \(\cos \theta^*\) distribution in lepton-plus-jets (left) and dilepton events (right). The SM prediction is shown as the solid line while a model with a pure V+A interaction would result in the distribution given by the dashed line.

5. Conclusions
The Tevatron is still the only top quark factory and has entered a new era of top quark precision measurements. The experimental precision on the top quark pair production cross section results is approaching the theoretical uncertainties showing agreement among different channels and using different techniques. The current top quark programme at DØ is also exploring the territory of top quark properties and a series of new measurements are becoming available based on larger statistics samples. All measurements are in agreement with the SM expectations.

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