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TOP PAIR PRODUCTION CROSS-SECTION AT THE TEVATRON

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An overview of latest top quark pair production cross-sections measured at the Tevatron is given. These measurements have been carried out in the dilepton, lepton+jets and all-jets channels with an integrated luminosity of about 1 fb^{-1}. The measurements are consistent with NNLO calculations.

Since the top quark discovery in 1995 by the CDF and DØ collaborations [1], top pair production cross-sections are one of the basic measurements to be carried out on each new data sample. During Tevatron Run I (1992-1996) an integrated luminosity of about 100 pb^{-1} at a center of mass energy of $\sqrt{s} = 1.8$ TeV allowed to measure top pair production cross-sections of $6.5^{+1.7}_{-1.4}$ pb and 5.7 ± 1.6 pb by the CDF and DØ collaborations respectively. The Tevatron Run II started in 2001 and until spring 2006 about 1 fb^{-1} of $p\bar{p}$ collisions with $\sqrt{s} = 1.96$ TeV have been produced and analyzed since. At this energy an increase of about 30% in the cross-section is expected. The most recent NNLO calculations predict a cross-section of $6.7^{+0.7}_{-0.9}$ pb [2] or 6.8 ± 0.6 pb [3] for a top mass, $m_{\text{top}} = 175$ GeV.

In the standard model (SM) $|V_{tb}| \sim 1$ leads to a branching fraction $t \rightarrow Wb$ close to 100%. With a lifetime of $\tau \sim 10^{-25}$ s top quarks decay before hadronization. Their decay channels are classified according to the decay of the W bosons produced. The *dilepton* channel accounts for about 6% of all decays, taking into account decays into ee, $\mu\mu$ and $e\mu$ and including leptonic τ decays. The l+jets channel represents about 34% of the cross-section with the leptonic τ decays included in the e+jets and μ+jets channels. Decays into *all jets* occur in 46% of the events, the remaining 14% correspond to signatures with hadronic τ decays.

Cross-section measurements are an important test of perturbative QCD at high p_T as non-SM top production, for example resonant top production, may lead to higher a cross-section than

Table 1: Summary of the observed and expected number of events in the dilepton channels used for the DØ combined dilepton cross-section measurement and the CDF $lepton + track$ measurement.

	ee	$\mu\mu$	$e\mu(\geq 2jets)$	$e\mu(1jet)$	$l + track$
$\mathcal{L}$ in fb^{-1}	1.04	1.05	1.05	1.05	1.07
N_{bkgd}	3.0 ± 0.5	3.6 ± 0.5	6.7 ± 1.2	$10.2^{+1.8}_{-1.7}$	48.2 ± 4.4
$t\bar{t}_{\text{exp}}$	9.5 ± 1.4	5.8 ± 0.5	$28.6^{+2.1}_{-2.4}$	$7.1^{+0.6}_{-0.7}$	60.5 ± 1.9
N_{obs}	16	9	32	16	129

expected. It is important to verify the consistency of different decay channels, as some non-SM models for example $t \to H^+$ or $t \to \tilde{t}$, modify the contributions in different decay channels. Non-W top decays are probed from the comparison of the *dilepton* and l+jets measurements. Top quark event selections using b-jet tagging assume a branching ratio $BR(t \to Wb) = 1$. Their consistency with kinematic methods, free of this assumption, is an important check of the SM prediction.

A cross-section is in most cases obtained from a counting experiment: $\sigma(p\bar{p} \to t\bar{t}) = (N_{\text{obs}} - N_{\text{bkgd}})/A_{\text{tot}}\mathcal{L}$. N_{bkgd}, the number of background events, estimated from Monte Carlo simulations and/or data samples, is subtracted from N_{obs}, the number of observed events meeting the selection criteria of a top-event signature. This difference is normalized by the integrated luminosity $\mathcal{L}$ and the total acceptance A_{tot}. A_{tot} includes the geometric acceptance as well as trigger efficiency and event selection efficiency and is slightly dependent on m_{top}. In all the Monte Carlo simulations $m_{\text{top}} = 175$ GeV has been used.

1 The dilepton channels

The signature of top dilepton events is two high p_T, opposite sign leptons ($p_T > 15$ GeV), some missing transverse energy ($\not{E}_T > 35$ GeV) and two or more, high p_T jets ($p_T > 20$ GeV). Physics background is due dominantly to Z/γ^*+jets events, $WW/WZ/ZZ$+jets events, and estimated from Monte Carlo simulations. Instrumental backgrounds occur due to fake isolated leptons, either as a mis-identified e or a μ in a non-reconstructed b-jet, as well as $\not{E}_T$ from detector resolution, fake jets or noise in the calorimeter. These background are estimated from data.

DØ measured the cross-section in the ee, $\mu\mu$ and $e\mu$ channels [4]. Requiring 2 *leptons* and 2 *jets* in the event selection yields to an acceptance of 8% and 5% in the ee and $\mu\mu$ channels, and 12% in the $e\mu$ channel. The acceptance in $e\mu$ channel could be further improved by an additional 3% taking in account the events with only 1 *jet* in the final state. In total 73 events are observed for 51 expected signal events and 24 expected background events. Details for each channel are given in table 1. The combined result from the three measurements is $\sigma_{t\bar{t}} = 6.8^{+1.2}_{-1.1}(\text{stat})^{+0.9}_{-0.8}(\text{syst}) \pm 0.4(\text{lumi})$ pb, with the main systematic errors being the lepton identification efficiency and the jet energy calibration.

An alternative method used by CDF loosens the lepton identification criteria for the second lepton, by requiring only an isolated track [5]. The error on this measurement has been improved through an increase of the acceptance reaching 14%, even though the signal/background (S/B) ratio is reduced to 1.3. The number of expected and observed events are also given in table 1, leading to a cross-section of $\sigma_{t\bar{t}} = 9.0 \pm 1.3(\text{stat}) \pm 0.5(\text{syst}) \pm 0.5(\text{lumi})$ pb.

DØ carried out an exclusive lepton+track analysis on a data sample with 360 pb^{-1}, explicitly vetoing a fully reconstructed second lepton to allow for a combination with the dilepton measurements and using b-jet tagging to improve the purity of the sample. An update of this measurement with 1 fb^{-1} is in progress.

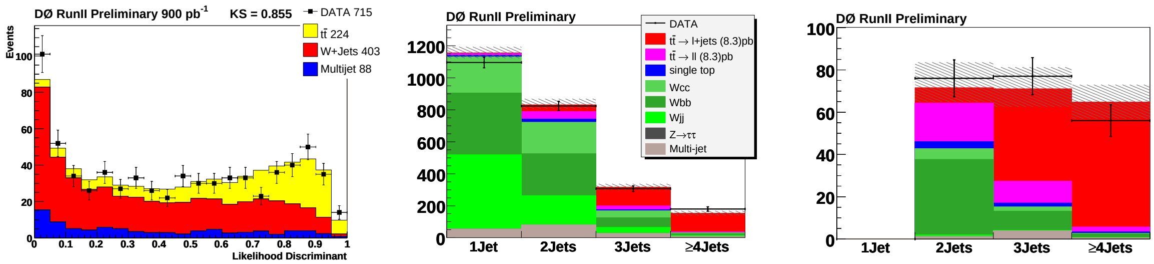

Figure 1: The Likelihood discriminant for the kinematic analysis (left) and the jet multiplicities in the 1-tag sample (middle) and 2-tag sample (right) for the b-jet tagging analysis with the DØ lepton+jets samples.

2 The lepton+jets channel

For top decays into l+jets, the signature is a high p_T lepton, large $\not\!\!E_T$ and 4 or more high p_T jets. Dominating physics background is due to W+jets events. Instrumental background is due to fake isolated leptons in multijet events. To separate the signal and background in the l+jets channels either the kinematic properties of the events are used or b-jet tagging is required.

For the first type of analysis, DØ constructs a likelihood discriminant based on six kinematic variables without a b-jet tagging requirement [6]. Its output is shown in figure 1(left) for the combined e+jets and μ+jets sample. For an integrated luminosity of $\mathcal{L} = 0.91$ fb^{-1}, 124 (100) $t\bar{t}$ events are expected in the e+jets (μ+jets) channel for 168 (235) W+jets events and 62 (27) multijet events, leading to a combined cross-section of $\sigma_{t\bar{t}} = 6.8^{+0.9}_{-0.8}$(stat)$\pm$+0.7(syst)$\pm$0.4(lumi) pb. The dominant systematic errors come from the background model, lepton identification and jet energy scale.

The complementary method [7] uses a new Neural Network (NN) based b-jet tagging algorithm. The chosen operating point has a b-jet tagging efficiency of 55% and a fake tag rate of 1%. For the same fake tag rate this represents a 15% increase in efficiency with respect to the previous b-jet tagging algorithm. The cross-section result of $\sigma_{t\bar{t}} = 8.3^{+0.6}_{-0.5}$(stat)$^{+0.9}_{-1.0}$(syst) $\pm$ 0.5(lumi) pb is a combination from the NN-output in 8 different channels, considering e and μ final states, 3-jet events, or 4 and more jet events, 1-tag or 2-tags separately. The jet-multiplicities for the combined 1-tag and 2-tags samples are shown in figure 1(middle and right respectively). Within the errors, the results are consistent between the kinematic and the b-tagging analyses.

CDF results in the l+jets channels have been presented at the previous Moriond QCD conference [8] on an integrated luminosity of $\mathcal{L} = 0.7$ fb^{-1}. For a method using only kinematic variables the result is $\sigma_{t\bar{t}} = 6.0 \pm 0.6$(stat) $\pm$ 0.9(syst) $\pm$ 0.3(lumi) pb. The analysis using b-jet tagging yields to a cross-section of $\sigma_{t\bar{t}} = 8.2 \pm 0.6$(stat) $\pm$ 0.9(syst) $\pm$ 0.5(lumi) pb.

3 All jets channel

Even though this channel has the highest branching ratio, it is largely dominated by multijet background. The preselection of $t\bar{t} \to jets$ in the inclusive CDF multijet sample [9] requires 6 to 8 jets with $p_T > 15$ GeV separated by $\Delta R > 0.5$. This preselection has a S/B ratio of 1/1300. To reduce the background a NN is used with 11 kinematic input variables. A further improvement in the S/B ratio is obtained by requiring a secondary vertex tag. The cross-section is then measured from the number of observed tags with an expectation of $n_{tag} = 0.95 \pm 0.07$ per top event determined from Monte Carlo. In total 387 signal and 846 background events have been found for $\mathcal{L} = 1.02$ fb^{-1}. The cross-section obtained is $\sigma_{t\bar{t}} = 8.3 \pm 1.0$(stat)$^{+2.0}_{-1.5}$(syst) $\pm$ 0.5(lumi) pb with the error on the jet energy calibration being the largest systematic contribution.

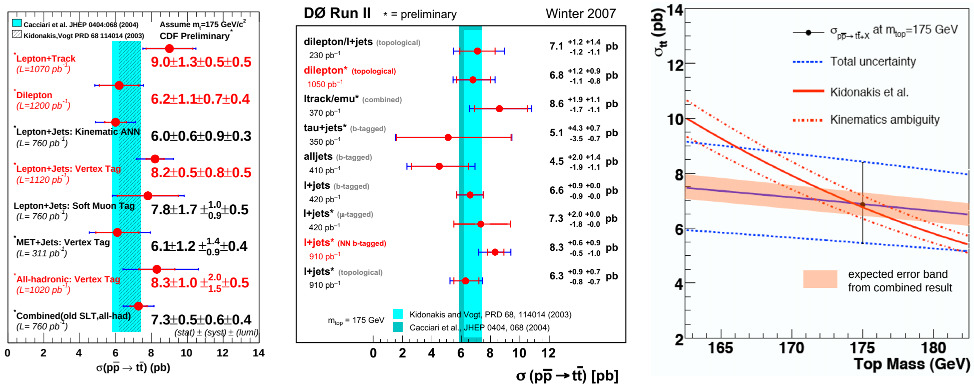

Figure 2: Top quark pair production cross-section measurements: summary of the current CDF (left) results and DØ results (middle). The right figure shows the $m_{\rm top}$ dependence of the DØ dilepton measurement.

4 Summary

Summaries of the CDF and DØ top quark pair production cross-section measurements are shown in figure 2(left and middle respectively). All the measurements are in good agreement with the NNLO-predictions. Results with an integrated luminosity of about 1 fb^{-1} are highlighted. With this luminosity the errors have been sizably reduced and reach in some of the decay channels about 15%. From a combination of all results an experimental error at the order of the theoretical error can be expected.

During the conference the question was raised if $m_{\rm top}$ could be determined from the cross-section measurements. A first answer concerning the precision that could be achieved can be interfered from figure 2(right) showing the dependence of the DØ dilepton cross-section as a function of $m_{\rm top}$. The shaded band shows the assumption of the total error for a combined result of the currently measured current cross-sections to be of the size of the theoretical error and with the same $m_{\rm top}$ dependence than the di-lepton cross-section. A determination of $m_{\rm top}$ using the current production cross-section would lead to an error on $m_{\rm top}$ of about ± 5 GeV. With the full Run II statistics an experimental error half this size looks a reasonable guess.

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