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Top Quark Mass Extraction from $t\bar{t}$ Cross Section Measurements

The DØ Collaboration
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We extract the top quark mass using $t\bar{t}$ cross section measurements in the l+jets and the combined l+jets, dilepton and lepton+tau channels using two different theoretical predictions in higher-order QCD including soft gluon resummations.

Preliminary Results for Summer 2008 Conferences

I. INTRODUCTION

The value of quark masses is renormalization-scheme dependent. Thus it is important to extract this parameter using a well-defined renormalization scheme. Direct top quark mass measurements compare measured distributions to distributions simulated by leading-order Monte Carlo (MC) generators as a function of the top quark mass. The input mass for these MC generators is not in a well-defined renormalization scheme leading to an uncertainty in its definition. Here we extract the top quark mass using top pair production cross section measurements. We compare them to fully inclusive theoretical calculations in higher-order QCD including soft gluon resummations. They represent the most complete calculations available. They are computed out using the pole mass definition for the top quark which is thus the parameter extracted here.

We use two $t\bar{t}$ cross section measurements. One is in the l+jets channel and is currently the world's most precise measurement [1]. The other one is a combination of the l+jets [2], dilepton [3] and lepton+tau [4] channels as described in [5]. The measurement from Ref. [1] uses two complementary techniques – a counting experiment using b-tagging and a likelihood analysis based on kinematic information. The counting measurement has a smaller top mass dependence than the likelihood measurement. The measurement from Ref. [5] is dominated by the ℓ+jets measurement which is largely based on counting b-tagged events. Thus the two measurements show a different dependence on the top quark mass. We confront these measurements with a next-to-leading order (NLO) QCD calculation including a complete soft-gluon resummation in next-to-leading log (NLL) [6] and with a calculation that includes all next-to-next-to-leading logarithms (NNLL) that are relevant in next-to-next-to-leading order (NNLO) QCD [7]. The latter is not a full NNLO calculation but contains all logarithms in NNLL and only constant terms are missing. We call it therefore NNLO$_{\text{approx}}$. In contrast to [7] the calculation of [8] doesn't include all logarithms in NNLL that are relevant for NNLO. Therefore here we have replaced it by the more complete calculation of [7]. The parton density function is CTEQ6.6 in both cases [9]. This is different from [1] where CTEQ6M was used.

The $t\bar{t}$ cross sections in theory and experiment are shown in Fig. 1 for the l+jets channel (left) and for the combined l+jets, dilepton and lepton+tau channels (right).

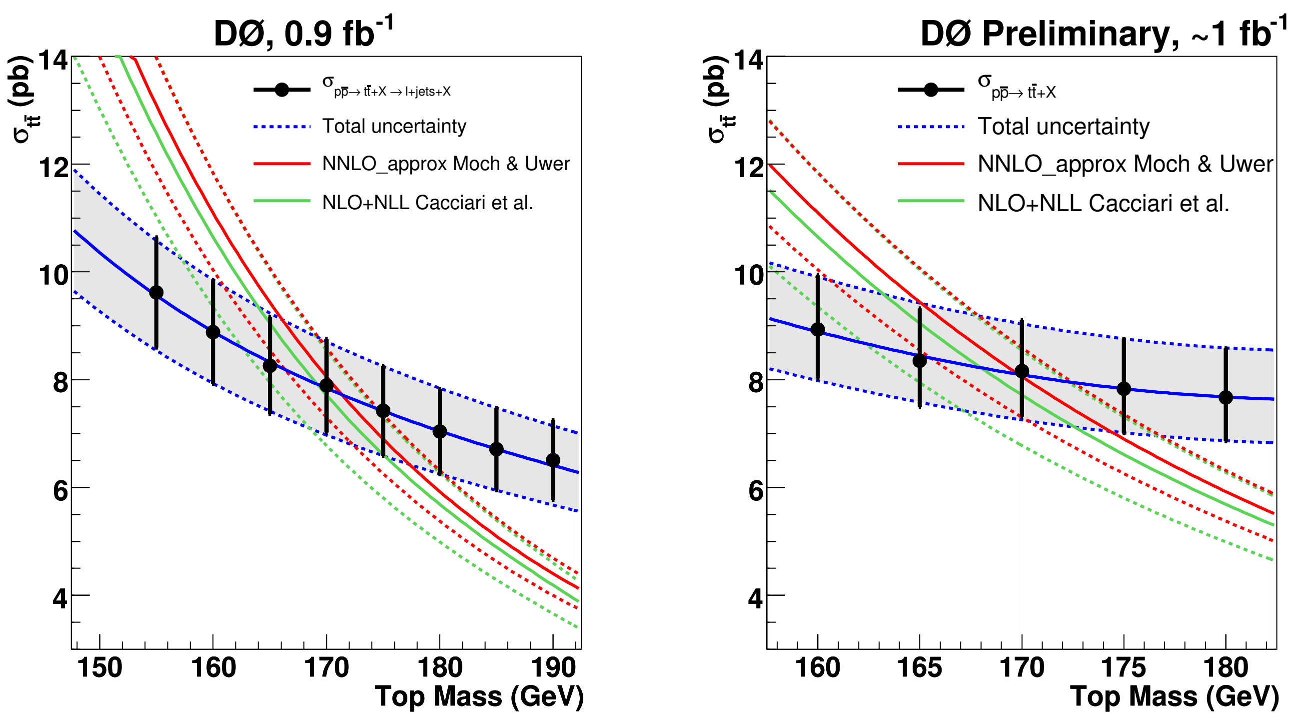

FIG. 1: Top pair production cross section measured in the l+jets channel [1] (left) and the combined l+jets, dilepton and lepton+tau channels [5] (right) as a function of the top quark mass (blue). This is compared to a NLO+NLL calculation [6] (green) and a calculation that includes all NNLL terms relevant for NNLO [7] (red).

II. EXTRACTION METHOD

The method to extract the top quark mass is exactly the same as in [1]. The experimental cross section as a function of the top mass was fitted using a third-order polynomial in the top quark mass. For the theoretical cross sections we used parameterizations given by third-order [6] or fourth-order polynomial in the top quark mass [7], respectively.

Using these parameterizations, likelihoods are defined as a function of the top pair cross section and the top mass. To represent the experimental cross section we use a Gaussian likelihood function centered on the measured value. The rms is taken equal to the total experimental uncertainty. This is justified because our dominating systematical uncertainties are derived from comparisons between data and Monte Carlo calculations that are supposed to be Gaussian. The theoretical uncertainties are dominated by the parton density function (pdf) uncertainty and the uncertainty due to variation of the factorization and renormalization scale. The pdf uncertainties are represented by a Gaussian likelihood function with rms equal to the uncertainties given in [6] and [7]. The scale uncertainty is represented by a likelihood function that is constant within the uncertainty ranges given in [6] and [7] and zero elsewhere. These two likelihood functions are convoluted. Finally, the theory and measurement likelihoods are multiplied to obtain the joint likelihood as shown in Fig. 2 for the two different measurements and the two different theoretical calculations.

The joint likelihood is integrated over the cross section to get a likelihood function that depends only on the top mass. The extracted top mass is then given by the minimum of the likelihood function. By integrating the likelihood function over the top mass the 68% CL is calculated. In case of the l+jets, dilepton and lepton+tau combined cross section an additional uncertainty of 1 GeV was assigned to the parameterization of the cross section as a function of the top mass to account for the fact that measured values are in the range of [160,180] GeV while the likelihood integration is performed in the range of [150,185] GeV.

III. RESULTS

The extracted top mass values are summarized in Tab. 1. The extracted top mass in the l+jets channel using the NLO+NLL calculation [6] is different from the value derived in the publication [1] for two reasons. First, in the publication a combination of the theoretical calculations of [6] and [8] was used. Second, here we use the newest PDF CTEQ6.6 instead of CTEQ6M as used in [1]. All extracted top quark masses are in agreement with the world average value of 172.6 ± 1.4 GeV [10].

$t\bar{t}$ cross section measurement	M_t [GeV], NLO+NLL [6]	M_t [GeV], NNLO$_{\text{approx}}$ [7]
l+jets [1]	$169.1\ ^{+6.6}_{-6.5}$	$171.2\ ^{+6.5}_{-6.2}$
l+jets, dilepton and lepton+tau [5]	$167.8\ ^{+5.7}_{-5.7}$	$169.6\ ^{+5.4}_{-5.5}$

TABLE 1: Extracted top mass values for two different cross section measurements using two different theoretical predictions.

Acknowledgments

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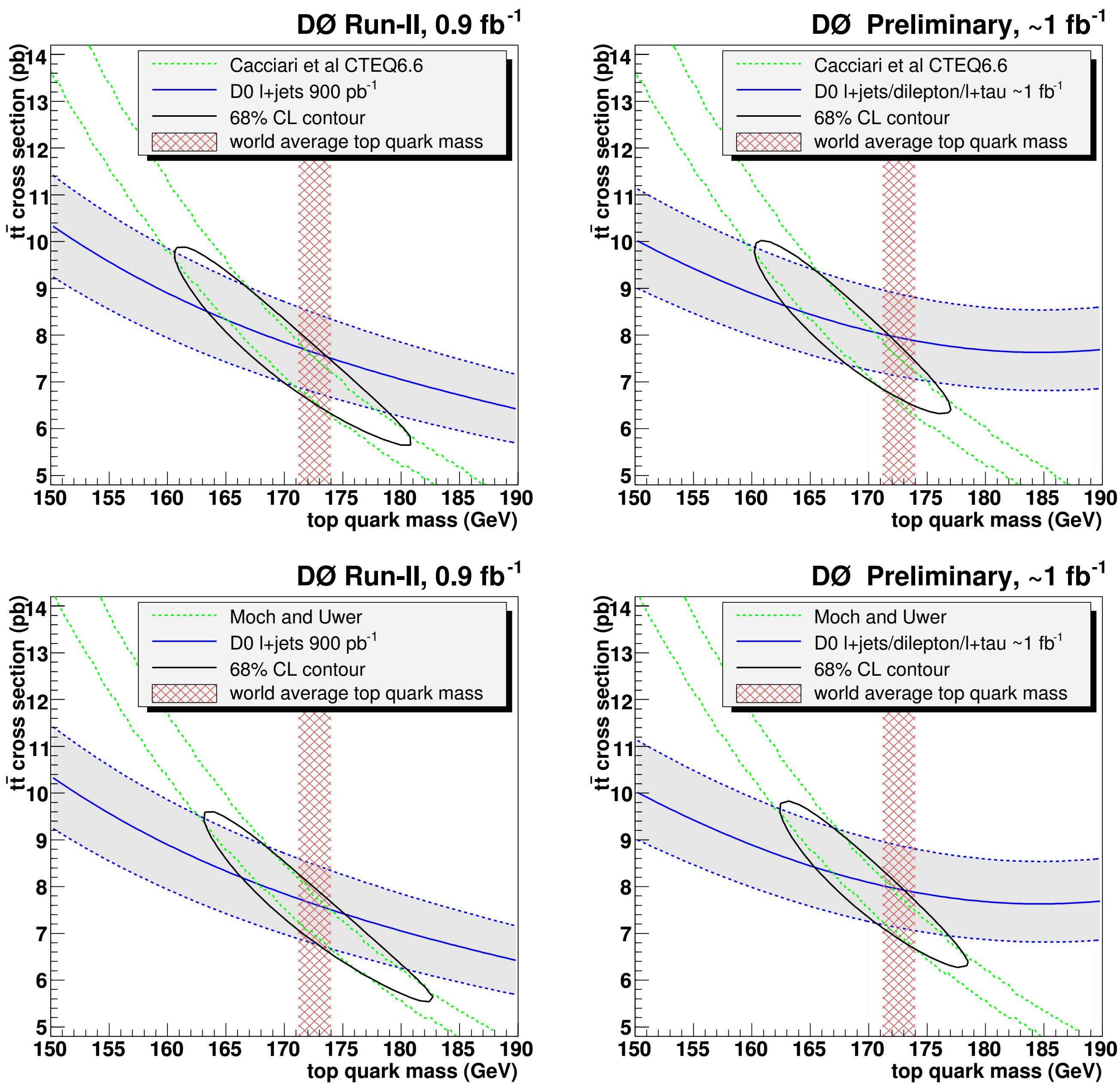

FIG. 2: Top pair production cross section measured in the l+jets channel [1] (left) and the combined l+jets, dilepton and lepton+tau channels [5] (right) as a function of the top quark mass. This is compared to a NLO+NLL calculation [6] (upper) and a calculation that includes all NNLL terms relevant for NNLO [7] (lower). The joint likelihoods are shown as well.

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[4] (DØ Collaboration), DØ note 5451-CONF.

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