DØ note 5459-CONF

Measurement of the Top Quark Mass using $\sigma(\mathrm{p\bar{p}} \to \mathrm{t\bar{t}})_{\ell+\mathrm{jets}}$ and $\sigma(\mathrm{p\bar{p}} \to \mathrm{t\bar{t}})_{\ell\ell}$ with the DØ Detector at $\sqrt{s} = 1.96$ TeV in the Run II Data

The DØ Collaboration

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We extract values for the top quark mass from the comparison of the top pair production cross section measured in the l+jets and dilepton channels with two different theoretical predictions in NLO QCD, including resummations in higher orders QCD.

Supplement to: Preliminary Results for Summer 2007 Conferences

I. INTRODUCTION

The concept of a quark mass is convention-dependent. The value of the top quark mass can vary considerably for different definitions. The running top quark mass $\overline{m}_t$ defined in the $\overline{\mathrm{MS}}$ scheme at the scale m_t, for instance, is related to the pole top quark mass M_t by the following relation [1]:

$$\overline{m}_t = m_t^{\overline{\mathrm{MS}}}(m_t) = \frac{M_t}{1 + \frac{4}{3\pi}\alpha_s(M_t)} \, , \tag{1}$$

where only the QCD corrections to leading order in α_s are included. However, the corrections up to 3-loop order are already known (see also [1]). The difference between those definitions is on the order of 7 GeV at 1-loop level and of the order of 10 GeV at 3-loop level, including an estimate of the 4-loop contribution [2].

In the measurement of the top quark mass it is therefore important to know to which mass definition the measured quantity corresponds. This question becomes even more important due to the precision currently claimed for the top quark mass world average of $\Delta m_{\mathrm{top}} = 1.8$ GeV [3]. Furthermore, these results are used as input for Standard Model (SM) predictions which are worked out, for instance, using the pole mass definition of the top quark as in [4]. So it is crucial for the future to exactly understand what quantity is extracted for the world average of the top mass and thus how to translate it into a quantity that can be used as input for SM calculations.

Current measurements of the top quark mass using template (see e.g. [5]), ideogram (see e.g. [6]), or matrix element (see e.g. [7]) methods rely highly on the detailed description of the top pair production signal in Monte Carlo (MC) simulations. For example, the output top quark masses are calibrated with respect to the generated top quark masses. Since all currently used MC simulations contain only matrix elements in Leading Order (LO) Quantum Chromodynamics (QCD) [15] while higher orders are simulated by applying parton showers, the convention used for the top quark mass is in principle unknown. In LO QCD, the top quark mass is just a free parameter and it is unknown which effective scale is applied through the parton showers. Therefore, in principle, the world average of the top quark mass is extracted in a not well-defined scheme [16].

To this respect, valuable and independent information can be gained from cross section measurements (see e.g. [8]). These analyses have the advantage of being simple and not relying on the simulation of the signal except for the determination of signal detection efficiencies. Since NLO corrections in $t\bar{t}$ production will affect mostly the normalisation of the cross section rather than changing the shape of kinematic distributions, one can assume that the signal efficiencies do not change much due to this [9]. Another advantage is that we can probe the measured total cross section with inclusive theoretical predictions which thus contain QCD calculations at a much higher level of accuracy compared to what is currently implemented in exclusive Monte Carlo simulations.

In this note we compare our most precise cross section measurements in the ℓ+jets [10] and dilepton [11] channels to two different calculations of the top pair production cross section. Both are performed at NLO QCD. One calculation includes additional subleading terms, next-to-next-to-next-to-leading-logarithmic terms and some virtual terms [12]. The other includes the resummation of leading and next-to-leading soft logarithms appearing at all orders of perturbation theory [13]. These calculations represent the highest level of understanding of the $t\bar{t}$ production cross section with the best available accuracy to date. Both calculations are performed using the top quark pole mass M_t definition for renormaisation [14].

II. RESULTS

Fig. 1 shows the $t\bar{t}$ cross section as measured in the ℓ+jets channel as function of the top quark mass compared to the SM prediction of [12] (left) and [13] (right). Fig. 2 shows the $t\bar{t}$ cross section as measured in the dilepton channel as function of the top quark mass compared to the SM prediction of [12] (left) and [13] (right).

From the intersection of the measured curves with the theoretical predictions we extract the measured top quark mass. Here we assume that the measured signal detection efficiencies are not affected by the NLO and higher order corrections in the signal calculations. This is justified since the NLO contributions mostly change the normalisation rather than the shape of kinematic distributions [9]. Thus, we assume that our experimental uncertainties, which are given by the sum of the statistical uncertainty and the total systematic uncertainty on the background, are not correlated with the theoretical errors on the signal. In the following we quote them separately. [17]

We extract from the measurement of the $t\bar{t}$ cross section in the ℓ+jets channel using data samples which correspond to an integrated luminosity of 912.5 pb^{-1} in the e+jets channel and 871.3 pb^{-1} in the μ+jets channel [10]

$$M_t = 166.9 \,^{+5.9}_{-5.2} \text{ (stat+syst) } ^{+3.7}_{-3.8} \text{ (theory) GeV}$$

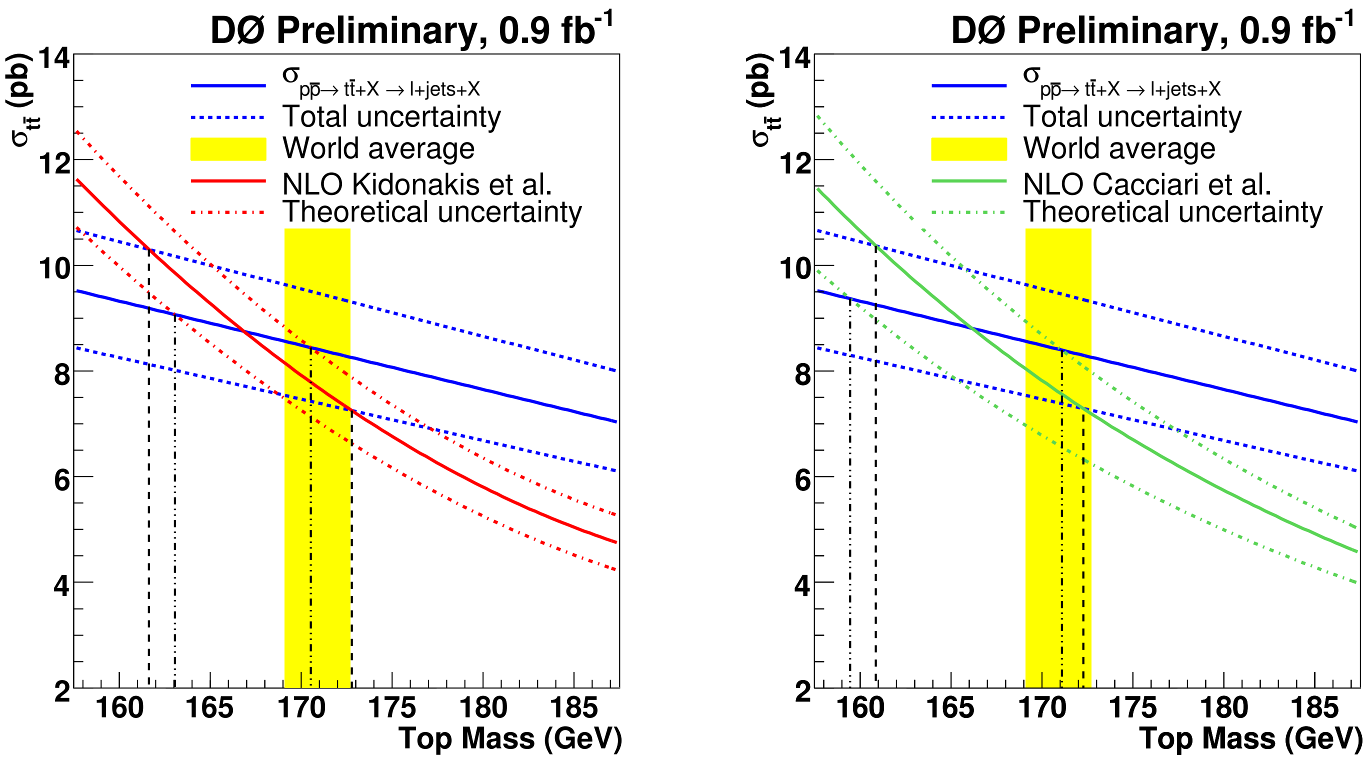

FIG. 1: The $t\bar{t}$ production cross section as measured in the $\ell + jets$ channel as function of top quark mass (blue line). The red line shows the theoretical prediction from [12] (left) and the green line the theoretical prediction from [13] (right). The yellow band indicates the current world average for the top quark mass [3].

comparing with [12] and

$$M_t = 166.1 \; ^{+6.1}_{-5.3} \; (\text{stat+syst}) \; ^{+4.9}_{-6.7} \; (\text{theory}) \; \text{GeV}$$

comparing with [13]. These values are in accordance with the respective mass measurement using the matrix element method [7]

$$m_{\text{top}} = 170.5 \; \pm 2.4 \; (\text{stat+JES}) \; \pm 1.2 \; (\text{syst}) \; \text{GeV} .$$

From the $t\bar{t}$ cross section measurement in the dilepton channel using data samples which correspond to an integrated luminosity of 1.04 fb^{-1}, 1.05 fb^{-1}, and 1.05 fb^{-1} in the e^+e^-, $e^\pm\mu^\mp$, and $\mu^+\mu^-$ channels, respectively, we derive [11]

$$M_t = 174.5 \; ^{+10.5}_{-8.2} \; (\text{stat+syst}) \; ^{+3.7}_{-3.6} \; (\text{theory}) \; \text{GeV}$$

comparing with [12] and

$$M_t = 174.1 \; ^{+9.8}_{-8.4} \; (\text{stat+syst}) \; ^{+4.2}_{-6.0} \; (\text{theory}) \; \text{GeV}$$

comparing with [13]. These values are in accordance with the respective mass measurement using the combination of the neutrino weighting and matrix weighting methods [5]

$$m_{\text{top}} = 173.7 \; \pm 5.4 \; (\text{stat}) \; \pm 3.4 \; (\text{syst}) \; \text{GeV} .$$

All values are in agreement with the current world average for the top quark mass [3]

$$m_{\text{top}} = 170.9 \; \pm 1.1 \; (\text{stat}) \; \pm 1.5 \; (\text{syst}) \; \text{GeV} .$$

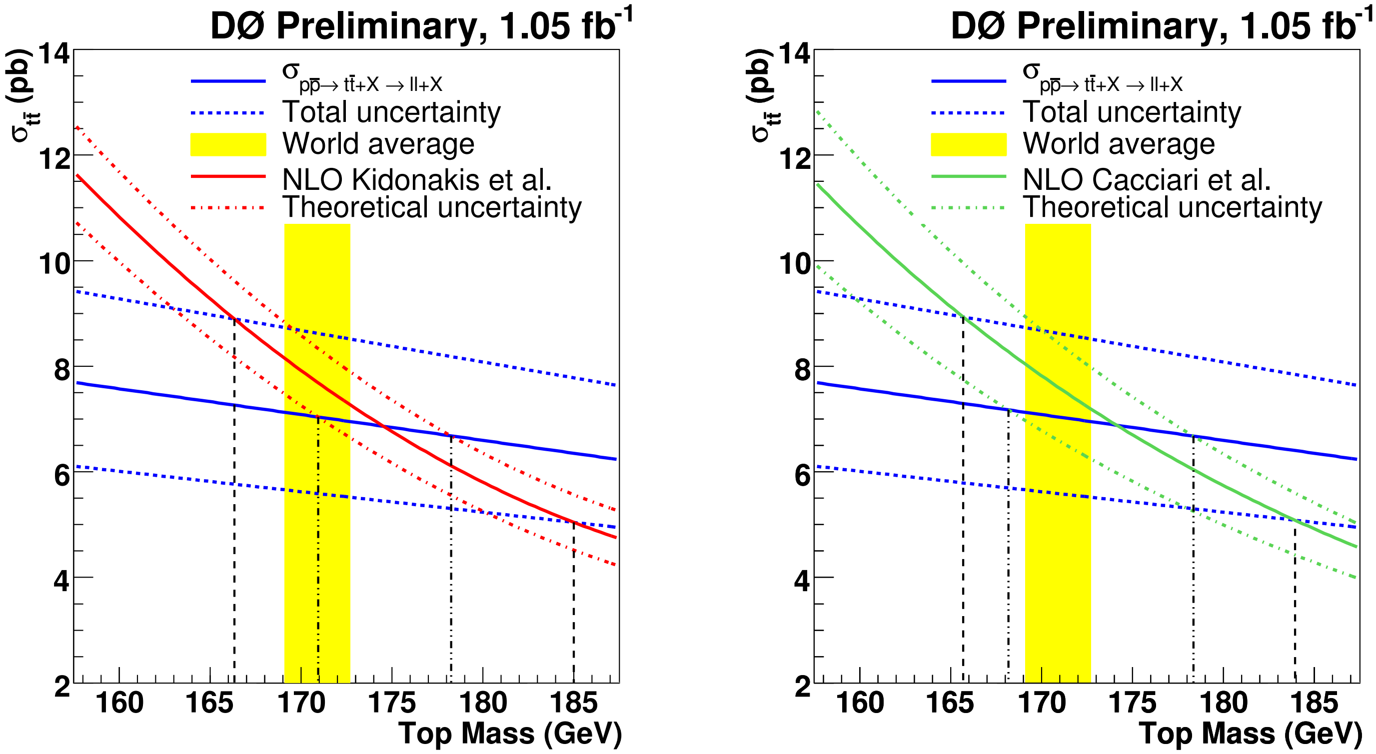

FIG. 2: The $t\bar{t}$ production cross section as measured in the dilepton channel as function of top quark mass (blue line). The red line shows the theoretical prediction from [12] (left) and the green line the theoretical prediction from [13] (right). The yellow band indicates the current world average for the top quark mass [3].

However, it has to be emphasised that the definition of the top quark mass extracted in cross section measurements is not identical to the one extracted using event kinematics as in [7], [5], and [3]. Complementary information has thus been derived with two respects; first, complementary experimental information has been used to derive a value for the top mass, and second, a different quantity for the top mass has been extracted compared to the methods using event kinematics.

III. SUMMARY

We have extracted the top quark mass comparing the top pair production cross section measured in the ℓ+jets and dilepton channels with NLO QCD calculations including higher order resummations. The results provide valuable information complementary to those derived in top quark mass measurements using kinematic information of the top pair production signal.

Acknowledgments

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[16] However, there are arguments that this scheme is close to the pole mass scheme.

[17] For a future combination of the experimental and theoretical error one would characterize the theoretical uncertainties by a band (rather than by a Gaussian since the central value is not necessarily the most probable value) and then propagating this information accordingly with e.g. a Bayesian approach.