Measurements of total and differential top-production cross sections with the CMS experiment

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Precise measurements of the top quark pair production cross section at 7 TeV, performed using CMS data collected in 2011, are presented. The total cross section is measured in the lepton+jets, dilepton and fully hadronic channels, including the tau-dilepton mode. The results are combined and confronted with precise theory calculations. An indirect constraint on the top quark mass through its relation to the cross section is also obtained. Various differential cross sections are measured as well and compared with theoretical models. Further results include measurements of single top production cross section.

1 Introduction

Measurements of the top quark pair production cross section in proton-proton collisions at the LHC provide important tests for understanding the top quark production mechanism, studying perturbative QCD and can also be used in new physics searches. At the LHC the top pairs are mostly produced through gluon-gluon fusion and the different final states result from the combinatorics of the W boson decays, since the top quark decays mostly in the $t \to Wb$ channel. The $t\bar{t}$ decay channels comprise therefore fully-hadronic (46%), lepton+jets (45%) and dileptonic (9%) final states. Recent CMS [1] measurements have been carried out in all these decay channels where the most precise measurement is obtained in the lepton+jets channel [2]. Inclusive and differential cross section measurements have been performed, both for top pair and single top production [3]. The results of these measurements will be shown and discussed.

2 Inclusive cross section measurements

The cleanest channel and the most suitable one for precise measurements of the $t\bar{t}$ production cross section is the lepton+jets channel. The analysis is performed by selecting different categories of events according to the jet multiplicity and the number of b-tagged jets. The cross section is then extracted with a fit to a simple and robust variable, the mass of the secondary vertex of the jets. The fit takes into account not only the normalisation of the background processes but also how it can be affected by the different systematic uncertainties such as jet energy scale, b-tag or mistag efficiencies, the contamination from initial/final state radiation (ISR/FSR) and the factorisation and renormalization scales used to model the signal and some of the backgrounds (i.e. Q^2 scale). The relative uncertainty in the measurement of the $t\bar{t}$ cross section is ≈7% and it is dominated by the uncertainty in modeling of the signal component and by the measurement of the luminosity.

In the remaining channels the $t\bar{t}$ production cross section has been carried out through counting experiment for the dilepton channel, while in the fully hadronic channel a fit to the distribution of the reconstructed top mass with a kinematic fit was used. Overall the results in these channels are compatible with the theoretical predictions but their uncertainties are larger with respect to the measurement in the lepton+jets channel due to systematic effects such as jet energy scale or background estimations.

Fig. 1 summarises the results obtained in the different channels and the final combination. The total uncertainty attained by each experiment has now surpassed the theoretical uncertainty at approx. NNLO.

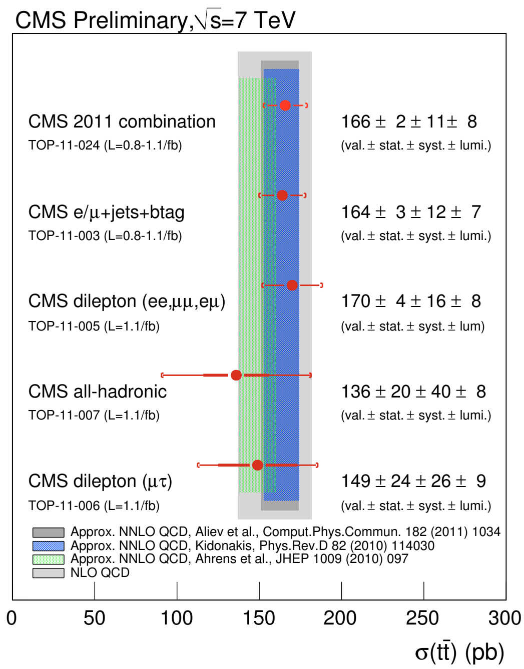

Figure 1: Summary of CMS measurements and their combination overlaid with three theory predictions.

3 Differential cross section measurements

With the large statistics sample acquired in 2011 the inclusive measurements where expanded to measure differential cross sections. Differential measurements were carried out in the lepton+jets and dilepton channels after the reconstruction of the $t\bar{t}$ kinematics, unfolded to parton level. The differential cross section is measured after background subtraction and unfolding the observed value. Overall there is a very good agreement between the unfolded data and the simulation within the uncertainty of the measurement. One distribution of particular interest is $p_T^{t\bar{t}}$ and it is shown in Figure 2 (left).

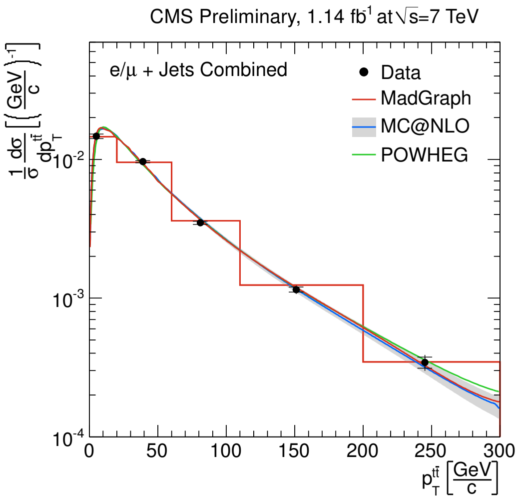

Figure 2: p_T of the $t\bar{t}$ system in the lepton+jets channel. The measurements are compared to predictions from MadGraph, POWHEG, and MC@NLO Monte Carlo generators.

4 Top quark mass extraction from the cross section

The top quark mass has also been extracted by comparing the measured inclusive $t\bar{t}$ production cross section to fully inclusive calculations at high-order QCD that involve an unambiguous definition of m_t. This extraction provides an important test of the mass scheme as applied in simulations and gives complementary information, with different sensitivity to theoretical and experimental uncertainties than the direct measurements of m_t, which rely on the kinematic details of the mass reconstruction.

Three different approaches to calculate the higher-order corrections to the next-to-leading order (NLO) calculations of top quark pair production have been used [4, 5, 6], where the cross section of $t\bar{t}$ production is obtained by a combination of measurements in the dilepton channel. Data are compared with different approximate NNLO predictions in Fig. 3. The uncertainty on the theoretical predictions includes the variation of the scales, parton luminosity and the variation of the $\alpha_S(M_Z)$ in the PDF.

5 Single top production

Single top quarks can be produced through the s and t-channels and in association with a W boson. The dominant production mode is the t-channel and its final state consists of one central isolated lepton accompanied by E_T^{miss}, a b-jet and a forward high p_T recoiling jet. The most recent results use a fit to the pseudo-rapidity of the recoil jet to extract the production of single

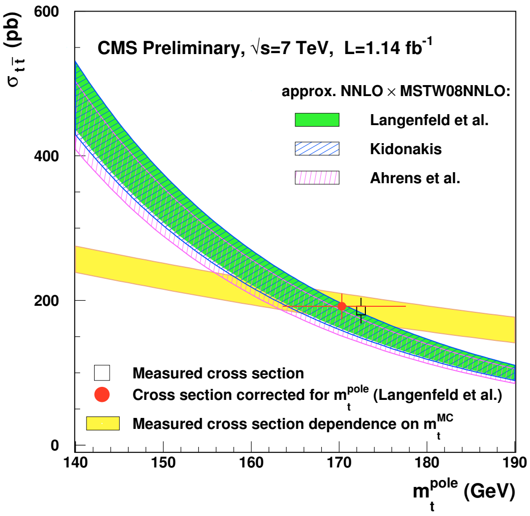

Figure 3: The cross section (open square) of $t\bar{t}$ production in the dilepton channel. The closed circle represents the measured cross section corrected for the m_t^{pole} dependence at the determined value of m_t^{pole} using three different calculations. The dependence of the measured cross section on m_t^{MC} is shown as a light shaded band. Different approximate NNLO predictions are shown as differently hatched bands. The uncertainty on the theoretical predictions includes the variation of the scales, parton luminosity and the variation of the $\alpha_S(M_Z)$ in the PDF.

top in the t-channel [7]. The cross section measurement gives $\sigma(t) = 70.2 \pm 11.5(stat. + syst.) + \pm 3.4(lumi.)$ pb, where the most important source of uncertainty is due to the Jet Energy Scale.

6 Conclusions

Inclusive and differential top quark production cross section measurements with the CMS experiment has been presented. In particular for the differential cross section measurement and for the mass extraction from the cross section, data have been compared with different theoretical predictions and they have been found to agree with the predictions within the theoretical uncertainties.

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