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Measurement of differential $t\bar{t}$ production cross sections for high-p_T top quarks at 13 TeV with the CMS detector

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A measurement of the production cross section for high transverse momentum top quark pairs is reported. The data set was collected during 2016 with the CMS detector at the LHC from pp collisions at 13 TeV, and corresponds to an integrated luminosity of 35.9 fb^{-1}. The measurement uses events where either both top quark candidates decay hadronically and are reconstructed as large-radius jets with $p_T > 400$ GeV, or where one top quark decays hadronically and is identified as a single large-radius jet with $p_T > 400$ GeV and the other top quark decays leptonically to a b jet, an electron or a muon, and a neutrino. The cross section is extracted differentially as a function of kinematic variables of the top quark or the top quark pair system. The results are presented at the particle level, within a region of phase space close to that of the experimental acceptance, and at the parton level, and are compared to various theoretical models. The measured differential cross sections are significantly lower in both decay channels in the phase space of interest, compared to the theory predictions, while the normalized differential cross sections are consistent between data and theory.

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1. Introduction

Being the heaviest of the known quarks, the study of the top quark and its properties provides an excellent test for the predictions of the standard model (SM). In particular, the measurement of the cross section of the top (t) anti-top ($\bar{t}$) quark pair is a crucial test for the perturbative quantum chromodynamics (QCD). This measurement also plays an important role in the discovery of new physics as the $t\bar{t}$ pair consists a background on many of these processes. The really high number of $t\bar{t}$ pairs expected in the LHC make it an ideal environment for the study of its production. Both ATLAS [1] and CMS [2] have studied the production of top quarks, but this study [3] focuses on high p_T (boosted) top quarks trying to shed light in this less studied part of the phase space.

2. Analysis strategy

This analysis uses data collected with the CMS detector during the 2016 run period and corresponding to an integrated luminosity of 35.9 fb^{-1} at a center of mass energy of 13 TeV. The channels studied are the all-jet and the lepton+jets. In the all-jet channel, both W bosons originating from the top quark ($t \rightarrow Wb$) decay hadronically into a quark (q) and and anti quark ($\bar{q}'$). This results in a final state with 6 quarks, two of which are bottom (b) quarks. In the lepton+jets channel, one of the W bosons decays into a quark anti quark pair as in the all-jets channel, while the other one decays into a charged lepton, an electron (e) or a muon (μ) and a neutrino.

For the all-jets channel, the trigger level selection requires events to contain two b-tagged large-R jets with a radius of 0.8 reconstructed with the anti-kt algorithm (AK8). In the event reconstruction, events are requested to contain no leptons and have at least two jets with a p_T grater than 400 GeV, absolute pseudorapidity (η) less than 2.4 and mass between 50 and 300 GeV. In addition, a neural network (NN) based discriminator using the jet substructure variables as inputs is used in order to discriminate between $t\bar{t}$ events and background. The selected events are splitted in two categories, the signal region (SR) where the actual measurement is performed and the control region (CR). The CR is used for the calculation of the QCD background which constitutes the main background source for this channel. Events that pass the NN selection and have two b-tagged jets with a mass between 120 and 220 GeV consist the signal region. The control region has the same requirements except that the b tagging is inverted, i.e. both jets are required to not be b-tagged. A maximum likelihood (ML) fit to the mass of the leading jet is performed in order to calculate the number of QCD events. The shape of the QCD distribution used in the fit is taken from the CR.

For the lepton+jets channel, the final state consists of a lepton, a b jet, missing Et (MET) and a top jet (t jet). At the trigger level, events that contain a single lepton and two small-R jets with a radius of 0.4 (AK4) are selected. Furthermore, events are required to have exactly one lepton, either e or μ, one or more AK4 jets that are also b-tagged and MET. These are the products of the leptonically decaying t. For the hadronically decaying top, an AK8 jet with a mass between 105 and 220 GeV that is also top tagged is required. For top tagging purposes the subjetiness variables and in particular the ratio τ_{32} is used. The selected events are divided in three categories based on the top and b tagging information. The 0t region contains no top jet, the 1t0b region has a top jet but no b jet and the 1t1b region consists of both a top and a b jet and constitutes the signal region. A simultaneous binned ML fit is performed to all three categories for signal and background

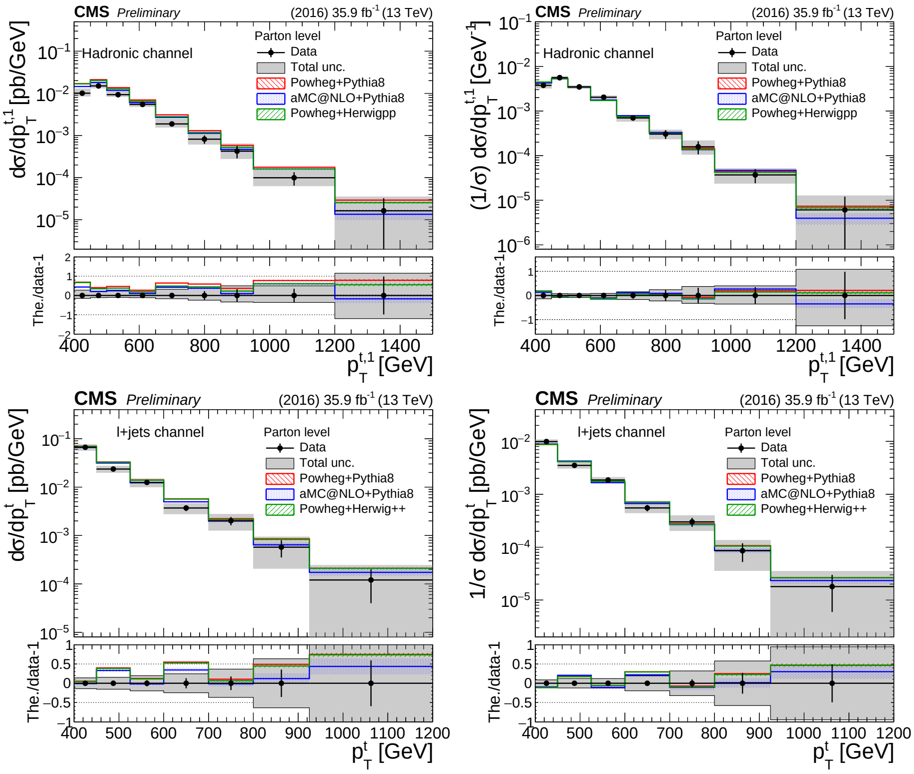

Figure 1: Absolute (left) and normalised (right) differential cross section in the parton level for the leading jet p_T of the all-jets channel (top) and for the top p_T on the lepton+jets channel (bottom). See [3].

discrimination. For both channels the final results are obtained doing unfolding, using the simple matrix inversion without regularisation method. Some selected results can be seen in Fig. 1.

3. Conclusions

The differential cross sections for the production of the $t\bar{t}$ pair have been measured for the all-jets and the lepton+jets channels. For the all-jets channel, the shapes are overall compatible with theory, but an overall shift in the order of 35% is observed between the data and the theory. For the lepton+jets, the differential distributions are generally well described by the theory, but all models over predict the absolute cross sections. In general, more data is needed in order to enhance the statistical significance of the result and investigate the severity of the discrepancy.

References

[1] ATLAS Collaboration, The ATLAS experiment at the CERN large hadron collider, JINST 3 (2008) S08003.

[2] CMS Collaboration, The CMS experiment at the CERN LHC, JINST 3 (2008) S08004

[3] CMS Collaboration, Measurement of differential $t\bar{t}$ production cross sections using top quarks at large transverse momenta in pp collisions at $\sqrt{s}$ =13 TeV, arXiv:2008.07860