EPJ Web of Conferences will be set by the publisher
DOI: will be set by the publisher

Measurement of Normalized Differential Cross Section for the $t\bar{t}$ Production in the Dilepton Channel in pp Collisions at a center-of-mass energy of 13 TeV

Dajeong Jeon[1,a] on behalf of the CMS Collaboration

[1] *University of Seoul, South Korea*

Abstract. Differential cross sections of top-quark pair production as function of the kinematic variables of leptons, b-jets and top-quarks at particle level are measured in the dilepton decay channel with proton-proton collisions at a center-of-mass energy of 13 TeV. The measurements are performed with Run II data using the CMS detector at the Large Hadron Collider.

1 Introduction

The precise measurement of the $t\bar{t}$ differential cross section can lead to a better understanding of background contributions [1] and provides a good test of perturbative QCD calculations. The normalized $t\bar{t}$ differential cross section is measured in the dilepton channel as a function of the $t\bar{t}$ system, top quark, daughter lepton and b-jet kinematic properties such as transverse momentum, rapidity, invariant mass and azimuthal decorrelation [2]. We present the measurement at particle level with final state objects defined in a theoretically safe and unambiguous way. The particle level measurements are expected to reduce the dependence on the theoretical model, so variables are mainly corrected for detector effects.

2 Differential cross section measurement

2.1 Data and simulated samples

We use $\sqrt{s} = 13$ TeV proton-proton (pp) collision data, corresponding to an integrated luminosity of $2.2 fb^{-1}$collected in 2015 with the CMS detector at the CERN LHC [3]. At least two leptons (electrons or muons) are required at trigger level. Monte Carlo (MC) simulated event samples are used to model the $t\bar{t}$ signal and the background processes. The detector response to the final state particles is simulated using `GEANT4` [4], and the events are reconstructed and analyzed with the same software used to process the data.

[a] e-mail: dajeong.jeon@cern.ch

2.2 Object and event selection

The dilepton final state of the $t\bar{t}$ decay consists of two leptons (electrons or muons), at least two jets, and missing transverse momentum from two neutrinos.

We require events with exactly two opposite-charge leptons with $M(l^{+}l^{-}) > 20$ GeV, and at least two jets, of which at least one jet identified as a b-quark jet. In addition, for the same-flavor lepton channels (ee and $\mu\mu$), additional selection criteria are applied which are designed to reject events from Drell-Yan production: $E_T^{miss} > 40$ GeV and $|M(l^{+}l^{-}) - M_Z| > 15$ GeV, where $M_Z = 91$ GeV.

2.3 Signal definition at particle level

We define the particle level top quark following the generator level prescriptions used in Ref. [5]. This approach avoids differences in the top quark definition due to possible differences in the decay history of different generators, and leads to results that are expected to be independent of the generator implementation and tuning.

The top quarks are reconstructed starting from the final state particles in $t\bar{t}$ events at generator level as summarized in Tab.1. To avoid the ambiguity from additional leptons at generator level, a distinction is made between prompt particles and particles from hadron decays.

Table 1. Summary of object definitions at the particle level

Object	Definition	Selection criteria
Prompt neutrino	neutrinos not from hadron decay	none
Dressed lepton	anti-k_T jet with a distance parameter of 0.1 using electrons, muons and photons not from hadron decay	$p_T > 20$ GeV, $\lvert\eta\rvert < 2.4$
b quark jet	anti-k_T jet with a distance parameter of 0.4 using all particles and ghost B hadrons not including any neutrinos nor particles used in dressed leptons	$p_T > 30$ GeV, $\lvert\eta\rvert < 2.4$ with ghost B hadrons

Pseudo-W bosons are reconstructed by combining a dressed lepton and a prompt neutrino. A pair of pseudo-W bosons is chosen among the possible combinations to minimize the scalar sum of invariant mass differences with respect to the W boson mass of 80.4 GeV. Similarly, the pseudo-top quarks are defined with an invariant mass requirement of 172.5 GeV. The visible phase space is defined to have a pair of pseudo-top quarks, constructed from prompt neutrinos, dressed leptons and b-quark jets. Events that are not in the visible phase space are considered as background.

2.4 Systematic uncertainties

We consider the following experimental and theoretical systematic uncertainties: Pileup contribution, lepton identification and isolation, lepton trigger efficiency scale factors, jet energy scale and jet energy resolution, b jet tagging scale factor, MC modeling, PDF, factorization and Renormalization scales, hadronization, top quark mass and background. The dominant contributions to the systematic uncertainty are due to the modeling (12%), hadronization (6%) and background estimation (6%). MC modeling uncertainties are measured using different generator such as MG5_aMC@NLO and POWHEG sample. To estimate the hadronisation uncertainties, we compare POWHEG +HERWIG++ from POWHEG +PYTHIA 8 samples.

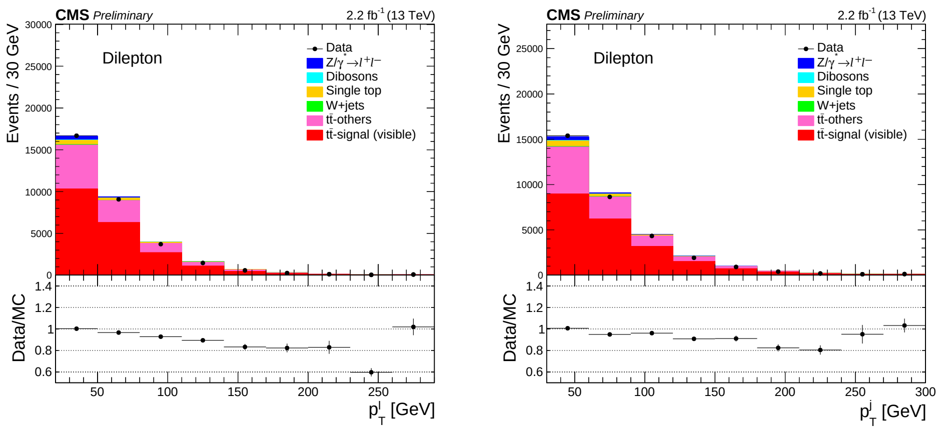

Figure 1. Reconstructed p_T^l, p_T^j distributions. All corrections described in the text are applied to the simulation.

3 Measurements of the normalized differential cross section

We measure the normalized differential $t\bar{t}$ cross section $(1/\sigma)(d\sigma/dX)$ as a function of the transverse momenta of leptons (p_T^l), jets (p_T^j), top quarks (p_T^t), and the $t\bar{t}$ system ($p_T^{t\bar{t}}$), the rapidities of the top quarks (y^t) and the $t\bar{t}$ system ($y^{t\bar{t}}$), and the invariant mass of the $t\bar{t}$ system ($M^{t\bar{t}}$). In the $t\bar{t}$ dilepton channel, the reconstruction of the neutrino and anti-neutrino is crucial in determining the top quark kinematics. Using an analytical approach [6, 7], the six unknown neutrino degrees of freedom are constrained by the two measured components of the missing transverse momentum and the assumed invariant masses of both W boson and top quark systems.

To allow for the finite resolution of the measured objects the $t\bar{t}$ system is reconstructed for 100 random variations within their simulated resolution functions, and the W boson mass is also allowed to vary over its Breit-Wigner distribution. In each trial there are up to eight solutions, and we select the solution with the minimum invariant mass of the $t\bar{t}$ system. For each trial, a weight is calculated using the expected invariant mass distribution of lepton and b quark jet pairs (M_{lb}) at particle level. The reconstructed neutrino momentum is taken from the weighted average over the trials. The final solution of the $t\bar{t}$ system is the solution with the maximum weight. The efficiency of the kinematic reconstruction is approximately 90%. Figure 1 shows the distributions of p_T^l and p_T^j.

Detector resolution and reconstruction efficiency effects are corrected by using an unfolding procedure. The method relies on a response matrix which maps the expected relation between the true and reconstructed variables. D′Agostini's method is employed to perform the unfolding [8–10].

Figures 2 show the normalized differential $t\bar{t}$ cross section as a function of $p_T^{t\bar{t}}$, $y^{t\bar{t}}$ and $M^{t\bar{t}}$ at particle level in the visible phase space. The measurements are generally found to be in agreement with the standard model predictions.

References

[1] A. Denner, S. Dittmaier, S. Kallweit, S. Pozzorini, PoS **LL2012**, 015 (2012), arXiv:1208.4053

[2] S. Choi, H.S. Lee, Phys. Rev. D **87**, 034012 (2013), arXiv:1207.1484

[3] Journal of Instrumentation **3**, S08004 (2008)

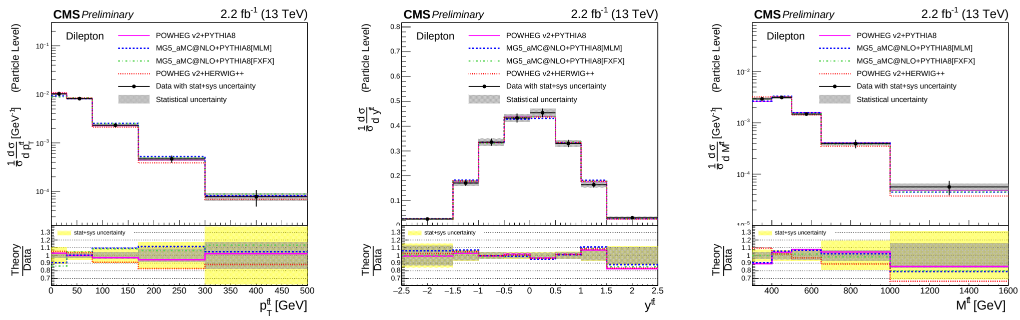

Figure 2. Normalized differential cross section as a function of $p_T^{t\bar{t}}$ (left), $y^{t\bar{t}}$ (center) and $M^{t\bar{t}}$ (right) for the top quarks or anti-quarks, measured at particle level in the visible phase space. The error bars on the data points indicate the total (combined statistical and systematic) uncertainties, while the dark shaded band shows the statistical uncertainty.

[4] J. Allison et al., IEEE Trans. Nucl. Sci. **53**, 270 (2006)

[5] CMS Physics Analysis Summary CMS-PAS-TOP-15-011 (2015), `https://cds.cern.ch/record/2110635`

[6] L. Sonnenschein, Phys. Rev. D **73**, 054015 (2006), [Erratum: Phys. Rev.D78,079902(2008)], `hep-ph/0603011`

[7] R.H. Dalitz, G.R. Goldstein, Phys. Lett. B **287**, 225 (1992)

[8] T. Adye, Tech. Rep. arXiv:1105.1160 (2011), `https://cds.cern.ch/record/1349242`

[9] G.D'Agostini., Nuclear Instruments and Methods in Physics Research A **362:487-498** (February 1995)

[10] G. D'Agostini, ArXiv (2010), `arXiv:1010.0632`