PROCEEDINGS OF SCIENCE

Measurement of Normalized Differential Cross Section for the $t\bar{t}$ Production in the Dilepton Channel in pp Collisions at $\sqrt{s}$=13 TeV

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on behalf of the CMS Collaboration

Differential cross sections of top-quark pair production are measured in the dilepton decay channel with proton-proton collisions at a center-of-mass energy of 13 TeV. The measurement is performed with Run II data using the CMS detector at the Large Hadron Collider. In this analysis, we measure the differential cross sections with respect to the kinematic variables of top-quarks at particle level.

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1. Introduction

Normalized differential cross sections for top quark pair production are measured in the dilepton (electron or muon) decay channel (shown in Figure 1) in proton-proton collisions at a center-of-mass energy of 13 TeV using CMS experiment [1]. The measurement is performed at particle level with final state objects defined in a theoretically safe and unambiguous way. The particle level measurements are made to minimise MC modeling dependence, so variables are corrected mainly for detector effects.

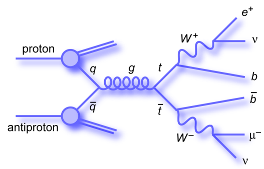

Figure 1: Feynman diagram of top-quark pair production decaying to lepton pairs.

2. Data samples

The measurement is made with Run II data recorded in 2015 by CMS detector corresponding to an integrated luminosity of 2.2 fb^{-1}. We used double lepton (electron or muon) triggered data samples and simulation data samples which are generated by POWHEG, MG5_aMC@NLO and MADGRAPH, showered with either PYTHIA8 or HERWIG++. The simulation includes $t\bar{t}$+jets, Z/γ^*+jets, W+jets, single top quark production and diboson (WW,ZZ,WZ) processes.

3. Signal definition

We define the particle level top quark following the generator level prescriptions detailed in Table1.

Table 1: Summary of object definitions at the particle level

Object	Definition	Selection criteria
Prompt neutrino	neutrinos not stemming from hadron decays	none
Dressed lepton	anti-kt jet with a distance parameter of 0.1 using electrons, muons and photons not stemming from hadron decays	$p_T > 20$ GeV, $\|\eta\| < 2.4$
b quark jet	anti-kt 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, $\|\eta\| < 2.4$ 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 minimise 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 by combining a pseudo-W boson and a b quark jet, 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.

4. Event selection

We apply following objects and event selections to filter signal events from data.

- **Electron** : $p_T > 20$ GeV, $|\eta|$ <2.4, electron medium Id tag
- **Muon** : $p_T > 20$ GeV, $|\eta|$ <2.4, muon tight Id tag
- **Jet** :$p_T > 30$ GeV, $|\eta|$ <2.4, loose jet Id tag
- Opposite signed two leptons ($ee/\mu\mu/e\mu$) $M_{ll} > 20$ GeV, where M_{ll} is invariant mass of lepton pair
- Z mass veto ($|M_{ll} - 91| < 15$ GeV) for $ee/\mu\mu$
- Missing transverse energy $\not{E}_T > 40$ GeV for $ee/\mu\mu$, 2 jets, 1 b-tagged jet

5. Top reconstruction

The top quarks are determined from the four momenta of all final-state objects by means of an algebraic kinematic reconstruction method. We impose constraints such as the balance of p_T of the two neutrinos, the W boson and the top quark mass and effects of detector resolution are accounted. The $t\bar{t}$ system is reconstructed for 100 different random variations within their simulated resolution functions and varying the W boson mass. In each trial, the minimum invariant mass of the $t\bar{t}$ system are selected. For each trial, a weight is calculated using the expected invariant mass distribution of lepton and b jet pairs at particle level. The reconstructed neutrino momentum is taken from the weighted average over the trials.

6. Normalized differential cross section measurement

Normalized differential $t\bar{t}$ cross sections at particle level in visible phase space are measured as a function of kinematic variables of top quark and $t\bar{t}$ system, as follows:

$$\frac{1}{\sigma}\frac{d\sigma}{dX} \qquad (1)$$

The correction for detector efficiencies, acceptances, and migrations is done using a D'Agostini unfolding method[3] . σ is the total cross section. X represents a variable such as top p_T, top rapidity, $p_T^{t\bar{t}}$, $t\bar{t}$ rapidity, $t\bar{t}$ mass, and $\Delta\phi_{t\bar{t}}$.

7. Results

The normalized differential cross sections at particle level are measured as a function of the top p_T, top rapidity, $p_T^{t\bar{t}}$, $t\bar{t}$ rapidity, $t\bar{t}$ mass, and $\Delta\phi_{t\bar{t}}$. The results are summarized in Figure 2.

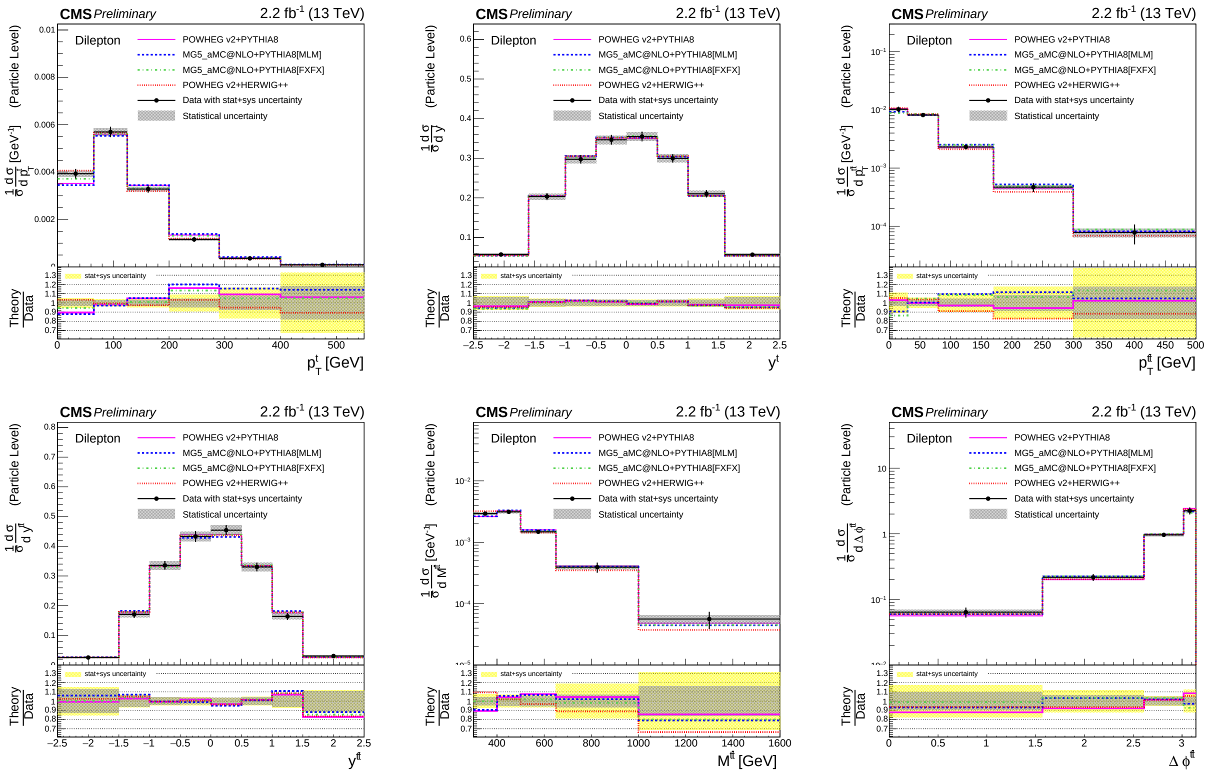

Figure 2: The error bars on data Indicate total (combined statistical and systematic) uncertainties, while the dark shaded band shows the statistical uncertainty. The measurements are compared to predictions From POWHEG v2 + PYTHIA8, MG5_aMC@NLO+ PYTHIA8[FXFX], MG5_aMC@NLO + PYTHIA8[MLM], and POWHEG v2 + HERWIG++.

8. Conclusions

Normalized differential cross sections of top quark pair production in the dilepton decay channel are measured at particle level in the visible phase space with respect to the top p_T, top rapidity, $p_T^{t\bar{t}}$, $t\bar{t}$ rapidity, $t\bar{t}$ mass, and $\Delta\phi_{t\bar{t}}$. The measured differential cross sections are found to be in agreement with the standard model predictions, being the top quark p_T distribution the only one observed to be in mild tension with the NLO predictions. More details can be found in [2].

References

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

[2] CMS Collaboration, "Measurement of particle level differential $t\bar{t}$ cross sections in the dilepton channel at $\sqrt{s}$ = 13 TeV", CMS-PAS-TOP-16-007 (2015)

[3] G.D'Agostini., "A multidimensional unfolding method based on Bayes", Nuclear Instruments and Methods in Physics Research A 362:487-498 (February 1995)