Measurement of top quark pair differential cross-sections in the dilepton channel in pp collisions at $\sqrt{s} = 7$ and $8\,\mathrm{TeV}$ with ATLAS

KENTARO KAWADE

Nagoya University, JAPAN

KI LIE

University of Illinois at Urbana-Champaign, United States

ON BEHALF OF THE ATLAS COLLABORATION

Measurements of normalized differential cross-sections of top quark pair ($t\bar{t}$) production are presented as a function of the mass, the transverse momentum and the rapidity of the $t\bar{t}$ system in proton-proton collisions at center-of-mass energies of $\sqrt{s} = 7$ TeV and 8 TeV. The dataset corresponds to an integrated luminosity of 4.6 fb^{-1} at 7 TeV and 20.2 fb^{-1} at 8 TeV, recorded with the ATLAS detector at the Large Hadron Collider. Events with top quark pair signatures are selected in the dilepton final state, requiring exactly two charged leptons and at least two jets with at least one of the jets identified as likely to contain a b-hadron. The measured distributions are corrected for detector effects and selection efficiency to cross-sections at the parton level. The differential cross-sections are compared with different Monte Carlo generators and theoretical calculations of $t\bar{t}$ production. The results are consistent with the majority of predictions in a wide kinematic range.

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1   Introduction

The top quark is the most massive elementary particle in the Standard Model (SM). The production of top quarks at the Large Hadron Collider (LHC) is dominated by pair production of top and antitop quarks ($t\bar{t}$) via the strong interaction, and thus measurements of these distributions provide a means of testing the SM prediction at the TeV scale. Since new phenomena beyond the SM can modify the kinematic properties of the $t\bar{t}$ system, and $t\bar{t}$ events are the dominant background to many searches for new physics, more accurate and detailed knowledge of top quark pair production is an essential component of the wide-ranging LHC physics program.

In this paper, the measurements of normalized differential top quark pair production cross-sections are presented as a function of the mass ($m_{t\bar{t}}$), the transverse momentum ($p_{T,t\bar{t}}$) and the rapidity ($y_{t\bar{t}}$) of the $t\bar{t}$ system in proton-proton collisions at center-of-mass energies of $\sqrt{s} = 7\,\mathrm{TeV}$ and $8\,\mathrm{TeV}$. The data-set corresponds to an integrated luminosity of $4.6\,\mathrm{fb}^{-1}$ at $7\,\mathrm{TeV}$ and $20.2\,\mathrm{fb}^{-1}$ at $8\,\mathrm{TeV}$, recorded with the ATLAS detector [1] at the LHC.

2   Analysis

Events with top quark pair signatures are selected in the dilepton final state, in which both W bosons from top quarks decay leptonically, requiring exactly two charged leptons and at least two jets where at least one of them identified as likely to contain a b-hadron. In the $8\,\mathrm{TeV}$ measurement, only the $e\mu$ channel is considered, while in the $7\,\mathrm{TeV}$ analysis, where the integrated luminosity is smaller, events containing same-flavor electron or muon pairs (the ee and $\mu\mu$ channels) are also selected to maximize the size of the available data-set.

An approximate four-momentum of the $t\bar{t}$ system is reconstructed from two leptons, two jets, and missing transverse momentum. Only leptons passing good quality criteria and the two jets with highest probability to contain a b-hadron are considered. Figure 1 shows the reconstructed $p_{T,t\bar{t}}$ distributions together with the MC predictions at $7\,\mathrm{TeV}$ and $8\,\mathrm{TeV}$. Overall there is good agreement between data and prediction.

After subtraction of the estimated backgrounds, the measured distributions are corrected for detector effects and selection efficiency to cross-sections at the parton level by employing iterative Bayesian technique, with the migration matrix determined using the $t\bar{t}$ MC simulations with POWHEG+PYTHIA. Figure 2 presents the migration matrices of $p_{T,t\bar{t}}$ for both $7\,\mathrm{TeV}$ and $8\,\mathrm{TeV}$ in the $e\mu$ channel. The matrix element M_{ij} represents the probability for an event generated at parton level in bin i to be reconstructed in bin j, so the elements of each row add up to unity.

The uncertainties from the signal modeling and detector modeling, which affect the estimation of the detector response and the signal reconstruction efficiency, are
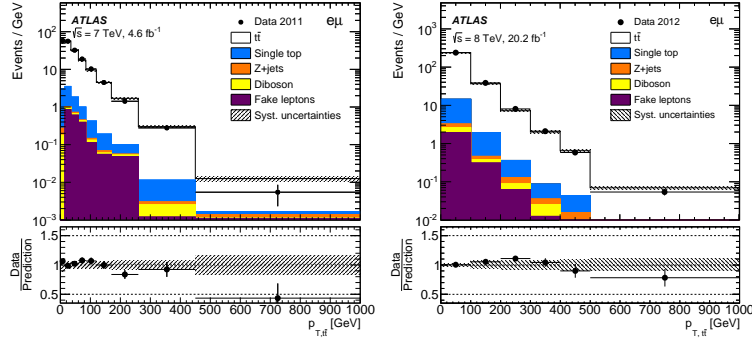
Figure 1: The reconstructed distributions of $p_{T,t\bar{t}}$ of the $t\bar{t}$ system obtained from the $\sqrt{s} = 7$ and $8\,\mathrm{TeV}$ data compared with the total signal and background predictions, in the $e\mu$ channels [2]. The bottom panel shows the ratio of data to prediction. The error band includes all systematic uncertainties except $t\bar{t}$ modeling uncertainties.
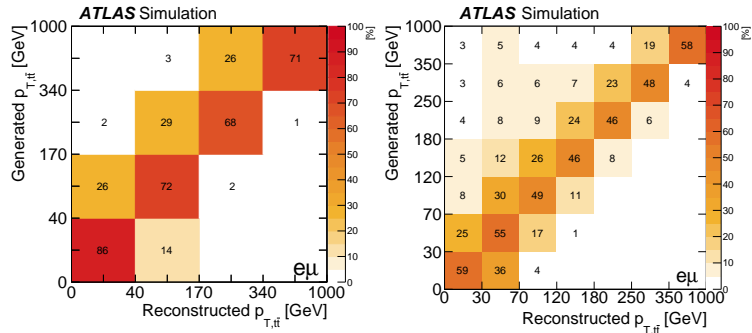

Figure 2: The migration matrix of $p_{T,t\bar{t}}$ represented in probability for $7\,\mathrm{TeV}$ (left) and $8\,\mathrm{TeV}$ (right) in the $e\mu$ channel, obtained from $t\bar{t}$ simulation with the POWHEG+PYTHIA generator [2]. Elements in each row add up to unity.

estimated by repeating the full analysis procedure with each systematic sample. The uncertainties from the signal modeling and the jet energy scale calibration are dominant for $m_{t\bar{t}}$ and $p_{T,t\bar{t}}$ measurements, while the uncertainty due to PDF is dominant for $y_{t\bar{t}}$ measurement. The uncertainty due to the background estimation is based on both data and MC simulation and mainly visible in higher $m_{t\bar{t}}$ and $p_{T,t\bar{t}}$ regions.

3   Results and discussion

Figures 3 and 4 show the comparison of the measured normalized distributions of $m_{t\bar{t}}$, $p_{T,t\bar{t}}$, and $|y_{t\bar{t}}|$ to the predictions from different MC generators for $\sqrt{s} = = 7$ and $8\,\mathrm{TeV}$, respectively. The data are also compared to the MC generator with different

PDF sets at as shown in figure 5, and the higher order theoretical predictions [3, 4] as shown in figure 6.
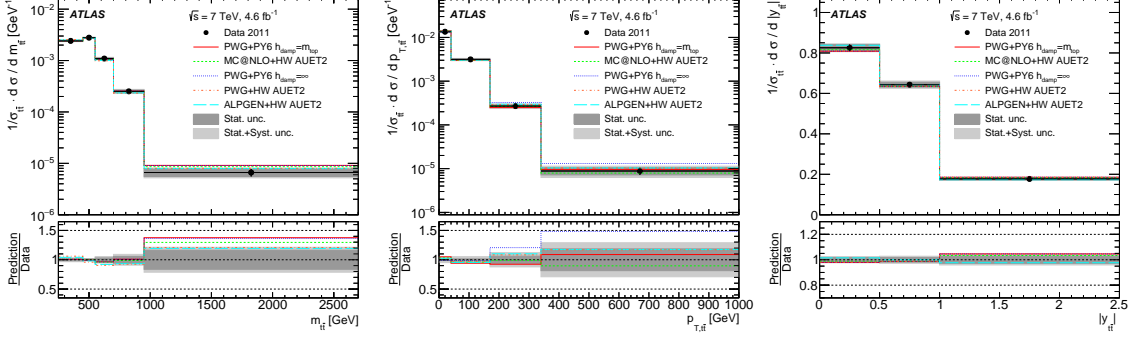

Figure 3: Normalized $t\bar{t}$ differential cross-sections as a function of $m_{t\bar{t}}$, $p_{T,t\bar{t}}$ and $|y_{t\bar{t}}|$ at $\sqrt{s} = 7$ TeV together with the MC predictions [2]. The bottom panel shows the ratio of prediction to data.
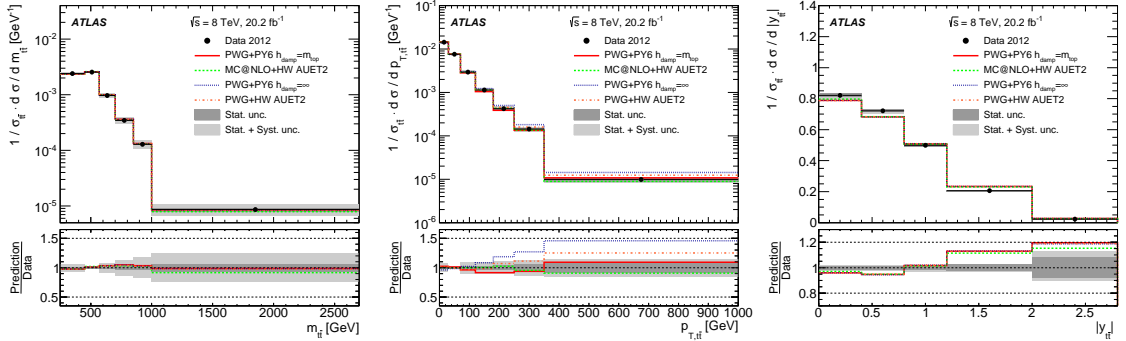

Figure 4: Normalized $t\bar{t}$ differential cross-sections as a function of $m_{t\bar{t}}$, $p_{T,t\bar{t}}$ and $|y_{t\bar{t}}|$ at $\sqrt{s} = 8$ TeV together with the MC predictions [2]. The bottom panel shows the ratio of prediction to data.

Most of the NLO generators agree with the experimental results in wide kinematic ranges of the distributions. The $m_{t\bar{t}}$ spectrum is well described by most of the NLO generators at both 7 TeV and 8 TeV, except for POWHEG+PYTHIA in the highest bin in the 7 TeV analysis. For $p_{T,t\bar{t}}$, agreement with POWHEG+PYTHIA with $h_{damp} = \inf$ is particularly bad due to a harder $p_{T,t\bar{t}}$ spectrum than data at both 7 TeV and 8 TeV. Better agreement is obtained from POWHEG+PYTHIA with $h_{damp} = m_t$. In both the 7 TeV and 8 TeV analysis, MC@NLO+HERWIG describes the $p_{T,t\bar{t}}$ spectrum well. For $|y_{t\bar{t}}|$, all the generators show fair agreement with data in the 7 TeV analysis, while at 8 TeV, none of the generators provides an adequate description of $|y_{t\bar{t}}|$. This
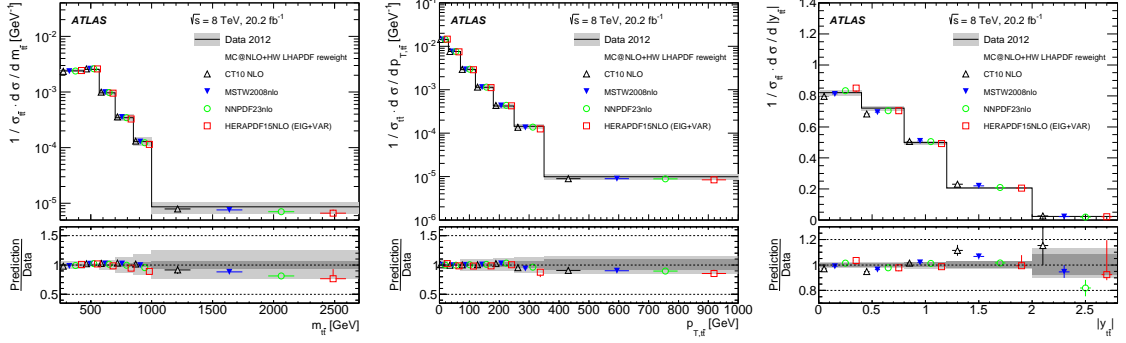
Figure 5: Normalized $t\bar{t}$ differential cross-sections compared with the prediction from MC@NLO with different PDF sets [2].
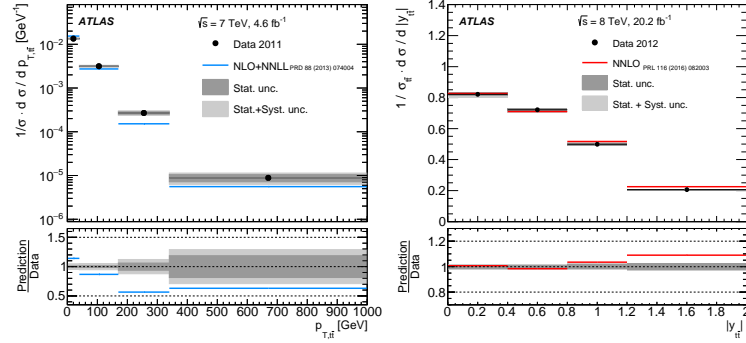

Figure 6: Comparisons with NLO+NNLL prediction at 7 TeV (left) and NNLO+NNLL prediction at 8 TeV (right) [2].

difference in the level of agreement is due to the improved statistical precision and finer binning in $|y_{t\bar{t}}|$ for the 8 TeV analysis. More details of this work are described in Ref. [2].

References

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