PROCEEDINGS OF SCIENCE

Top-quark pair production cross-section measurements with the ATLAS detector

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Measurements of the inclusive and differential top-quark pair production cross sections in proton-proton collisions with the ATLAS detector at the Large Hadron Collider at center-of-mass energies of 8 TeV and 13 TeV are presented. The inclusive measurements reach high precision and are compared to the best available theoretical calculations. Differential measurements of the kinematic properties of the top-quark production are also discussed. These measurements, including results using boosted tops, probe our understanding of top-quark pair production in the TeV regime.

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1. Introduction

The large recorded luminosity of proton-proton collisions at the Large Hadron Collider (LHC) allows to perform high-precision measurements in top quark physics. In this overview, measurements of the top-quark pair ($t\bar{t}$) production cross sections at the ATLAS experiment [1] at center-of-mass energies of 8 TeV and 13 TeV are presented.

There are several important reasons to perform these measurements. First of all, they are precision tests of the Standard Model (SM) and they are sensitive to many physics models beyond the SM. In particular, the measurements of the $t\bar{t}$ differential cross sections probe the TeV scale, and therefore a new particle with large coupling to the top quark can cause a significant increase in the $t\bar{t}$ invariant mass spectrum or can modify the top p_{T} spectrum. Furthermore, the measurements can constrain parton density function (PDF) fits and the parameters of the SM Monte Carlo (MC) generators, which is important for many searches for which the $t\bar{t}$ production is a background. Last but not least, the differential cross section measurements can be used to extract the top quark pole mass.

2. $t\bar{t}$ inclusive cross sections

Precise measurements of the $t\bar{t}$ inclusive cross sections are performed in the full and the fiducial phase spaces at $\sqrt{s} = 8$ TeV [2], and $\sqrt{s} = 13$ TeV [3] using events containing exactly one isolated electron (e) and one isolated muon (μ) of opposite charges. Further selection requirements are on the missing transverse energy and on the number of jets tagged by a track-based algorithm which identifies jets containing a b-quark (b-tagged jets). The number of events with exactly one b-tagged jet and exactly two b-tagged jets is used to determine the b-tagging efficiency in data which reduces the systematic uncertainty due to the difference in the b-tagging efficiencies between data and MC. The main systematic uncertainties arise from the luminosity and LHC beam energy measurements, as well as from the modeling of the $t\bar{t}$ events. The total uncertainty is about 4% for measurements at each of the two center-of-mass energies. The result of the full phase space measurement is compared to theoretical QCD calculations at next-to-next-to-leading order (NNLO), and all measurements are found to be consistent with it.

Figure 1 summarizes the $t\bar{t}$ inclusive measurements in the full phase space as a function of the center-of-mass energy compared to the NNLO QCD prediction complemented with NNLL resummation (NNLO+NNLL QCD). The measurements from the two LHC experiments, ATLAS and CMS, and also a combination of the Tevatron measurements from proton-antiproton collisions are shown. All the existing measurements of the $t\bar{t}$ inclusive cross section are consistent with the NNLO+NNLL QCD calculation.

3. $t\bar{t}$ differential cross sections

The ATLAS experiment explores the $t\bar{t}$ differential cross sections in various decay channels and phase spaces as functions of top quark and $t\bar{t}$ system kinematic observables. Targeting the all-hadronic decay channel of the $t\bar{t}$ pair, measurements of highly boosted top quarks are performed at $\sqrt{s} = 13$ TeV [5]. The single lepton decay channel is exploited in measurements at $\sqrt{s} = 8$ TeV

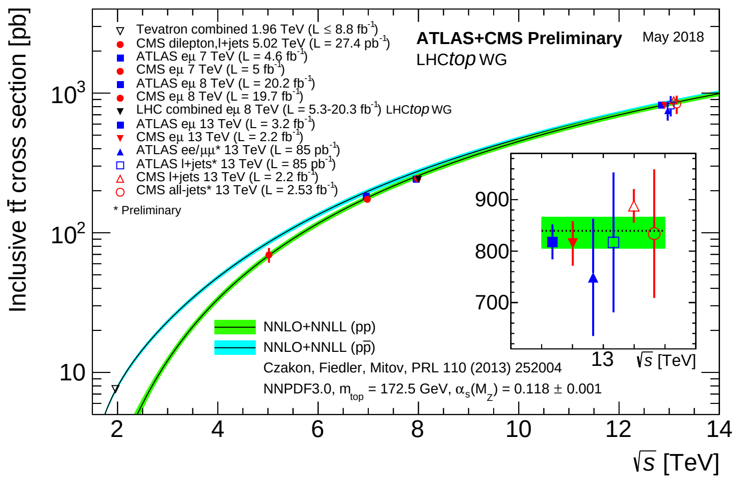

Figure 1: Summary of LHC and Tevatron measurements of the top-pair production cross-section as a function of the center-of-mass energy compared to the NNLO QCD calculation complemented with NNLL resummation (top++2.0) [4]. The theory band represents uncertainties due to the renormalization and factorization scale, parton density functions and the strong coupling. The measurements and the theory calculation assume $m_{\text{top}} = 172.5$ GeV. Measurements made at the same center-of-mass energy are slightly offset for clarity.

[6, 7] and at $\sqrt{s} = 13$ TeV [8], where both, resolved and boosted, topologies are used. Additionally, $t\bar{t}$ + jets differential cross sections are measured at $\sqrt{s} = 13$ TeV [9] using the single lepton decay channel. The dilepton decay channel is exploited in measurements at $\sqrt{s} = 8$ TeV [10] and at $\sqrt{s} = 13$ TeV [11]. All the ATLAS measurements of $t\bar{t}$ differential cross sections are consistent with the SM prediction.

As an example, Figure 2 shows the measured relative differential cross-section at particle level as a function of the transverse momentum of the hadronic top quark in the single lepton decay channel with resolved topology [8]. The measurement is compared to the predictions of next-to-leading-order (NLO) matrix-element MC generators interfaced with various parton shower (PS) MC generators with various parameters. The main uncertainties arise from signal modeling, b-tagging efficiency, and jet energy scale (JES). Statistical tests showed that the measurement is consistent with all the tested MC configurations. However, this measurement together with other $t\bar{t}$ measurements has sufficient discriminating power to allow an improvement in the choice of MC generator parameter values.

4. Summary and outlook

The ATLAS experiment has an extensive program of inclusive and differential $t\bar{t}$ cross section measurements. The total uncertainty on the $t\bar{t}$ inclusive cross section measurements is only of a few percent. The $t\bar{t}$ differential cross section measurements probe the TeV scale and their main uncertainties are due to signal modeling and JES. All the performed measurements are consistent with the SM.

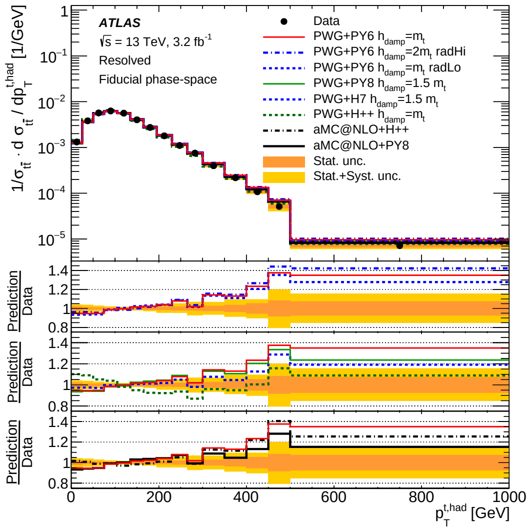

Figure 2: Fiducial phase-space relative differential cross-section as a function of the transverse momentum of the hadronic top quark in the resolved topology [8]. The yellow bands indicate the total uncertainty of the data in each bin. The Powheg+Pythia6 generator with $h_{\mathrm{damp}} = m_t$ and the CT10 PDF is used as the nominal prediction to correct for detector effects. The lower three panels show the ratio of the predictions to the data. The first panel compares the three Powheg+Pythia6 samples with different settings for additional radiation, the second panel compares the nominal Powheg+Pythia6 sample with the other Powheg samples and the third panel compares the nominal Powheg+Pythia6 sample with the MadGraph5_aMC@NLO samples.

Further $t\bar{t}$ production cross section measurements are on-going at the ATLAS experiment while there are more data delivered by the LHC. With their improved precisions, they allow to explore higher scales in the $t\bar{t}$ differential cross section measurements. Moreover, the current measurements can improve the signal modeling, and therefore a reduction of signal modeling uncertainties is expected for the future measurements.

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