IL NUOVO CIMENTO **42 C** (2019) 169
DOI 10.1393/ncc/i2019-19169-7

COLLOQUIA: IFAE 2018

Measurements of top-quark pair differential cross-sections using the ATLAS detector at LHC

F. LA RUFFA(1)(2)

(1) *INFN, Gruppo Collegato di Cosenza - Arcavacata di Rende (CS), Italy*
(2) *Dipartimento di Fisica, Università della Calabria - Arcavacata di Rende (CS), Italy*

received 31 January 2019

Summary. — The measurements of cross-sections of the top-quark pair production provide an ideal way to perform stringent tests of the predictions of the perturbative Quantum Chromodynamics. In addition, they are sensitive to the parton distribution functions of the proton. This contribution shows the measurements in the semi-leptonic channel, using the data sample collected by the ATLAS experiment at the Large Hadron Collider during Run-2 at a centre-of-mass energy of 13 TeV, either by applying an inclusive selection or by using an exclusive selection as a function of the multiplicity of the hadronic jets. The measurements cover a wide kinematic region reaching the boosted regime, in which the values of the transverse momentum of the top quark are greater than 400 GeV. The results are compared with the most recent theoretical predictions.

1. – Introduction

Testing the validity of the Standard Model (SM) in the high-energy regime at the Large Hadron Collider (LHC) [1] is one of the main purposes of the ATLAS [2] experiment. The top quark plays a crucial role in the SM, and so in the ATLAS physics programme, due to its peculiar properties: it is the most massive fundamental particle currently known and it is the only quark which can be studied before hadronisation. The top-quark pair is produced mainly by gluon fusion ($\sim 90\%$) and quark-antiquark annihilation at LHC and its cross-section ($\sim 800\,\text{pb}$ at a center-of-mass energy $\sqrt{s} = 13\,\text{TeV}$) is one of the largest among the SM processes investigated by the ATLAS experiment. Almost every top quark decays into a W boson and a b quark, so it is possible to have three different final states taking into account the decays of the W boson in a lepton-neutrino or a quark-antiquark pair: the hadronic, the semileptonic and the dilepetonic channel. Given the large value of the integrated luminosity collected by the ATLAS experiment during Run-2 data taking, as well as the availability of recent calculations at the next-to-next-to-leading order (NNLO) in perturbative QCD of the top-quark pair production [3],

very stringent tests of the QCD predictions could be performed by using the $t\bar{t}$ differential cross-section measurements. In addition, the $t\bar{t}$ differential cross-section measurements are very sensitive to the parton distribution functions (PDFs) of the proton and, in particular, of the gluon; this allows to put constraints on the PDFs and to improve the knowledge of the structure of the proton. Moreover, the tuning of the Monte Carlo (MC) generators could benefit from precise measurements of the $t\bar{t}$ cross-sections. Finally, $t\bar{t}$ production cross-sections are involved in many Beyond Standard Model (BSM) scenarios and they are important to investigate possible deviations from the SM predictions.

2. – $t\bar{t}$ differential cross-sections

The differential cross-section of the top-quark pair production has been measured using the ATLAS detector for all the three decay channels.

2˙1. *$t\bar{t}$ differential cross-sections in the dileptonic and in the hadronic channels.* – Recent measurements have been published for the dilepton channel [4] and the hadronic channel [5]. The dileptonic channel has the lowest branching ratio ($\sim 10\%$) among the different decay channels of the top-quark pair, but it is the purest in terms of ratio between signal and background and it is the less affected concerning the systematic uncertainties. On the opposite side, the hadronic channel is the one with the largest branching ratio ($\sim 45\%$), but it is significantly affected by the systematic uncertainties. The current measurement in this decay channel is available in the boosted regime, in which the decay products of the top-quark pair are mearged into two large-R jets. In fact, if the top quark is produced with a large value of the transverse momentum p_T, the decay products will be very boosted and they will be within $\Delta R \sim 2m/p_T$. For the top-quark case, $\Delta R = 1.0$ for $m_t = 173\,\text{GeV}$ and $p_T > 300\,\text{GeV}$.

2˙2. *$t\bar{t}$ differential cross-sections in the semileptonic channel.* – The semileptonic decay channel of the top-quark pair, characterised by the presence of one of the W bosons decaying into a lepton-neutrino pair and the other one into a quark-pair, allows to reduce the statistical uncertainty with respect to the dileptonic channel, and the systematic uncertainties, compared to the hadronic channel. The branching ratio of this channel is $\sim 45\%$. Recently, the ATLAS Collaboration published the diffential cross-section measurement of the top-quark pair production in the semileptonic channel [6]. In this analysis, two selections have been applied in order to enhance the efficiency on the overall spectrum of the transverse momentum p_T of the top quark, one targeting the resolved regime and one specific for the boosted topology. The measurement is performed in a fiducial phase space in order to reduce the uncertainty related to the extrapolation in regions not covered by the ATLAS detector. The different differential distributions are compared with several NLO predictions. In fig. 1 the differential cross-section measurements are shown as a function of the transverse momentum of the hadronic top quark in the resolved topology and in the boosted topology. In general, the MC predictions tend to overestimate the data in the high-p_T region.

A futher analysis has been performed in order to test whether the modelling of the differential cross-sections of the $t\bar{t}$ production could be dependent on the additional jets [7]. The selection applied in this analysis is the same as the resolved topology of the inclusive measurement as a function of the jet multiplicity. This analysis allowed to investigate the top p_T mismodelling and it has been found that most of the slope is related to the 4-jet exclusive region. In fig. 2 the results of the differential $t\bar{t}$ cross-section as a function of the

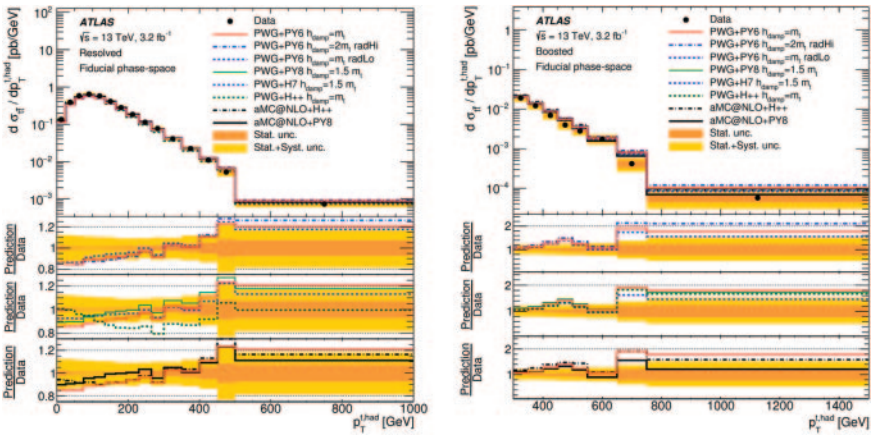

Fig. 1. – Fiducial phase-space absolute differential cross-sections as a function of the transverse momentum of the hadronic top quark in the resolved topology (on the left) and in the boosted topology (on the right) with $\sqrt{s} = 13\,\text{TeV}$, compared with the Standard Model predictions obtained with different MC generators. The yellow bands indicate the total uncertainty of the data in each bin. The lower three panels show the ratio of the predictions to data.

transverse momentum of the $t\bar{t}$ system $p_T^{t\bar{t}}$ for several jet multiplicity regions are shown. In general, good agreement is observed in the 4- and 5-jet regions while there is some tension in the 6-jet inclusive region. This was not observed in the measurement inclusive in the number of jets [6] because different configurations are dominant at different values of $p_T^{t\bar{t}}$. Since the mis-modelling is observed in regions of p_T in which the cross-section in that configuration is subdominant, it could not be observed in the previous measurement.

3. – Conclusions

The measurements of $t\bar{t}$ differential cross-section using the ATLAS detector at LHC have been presented, in particular the results in the ℓ+jets channel. These measurements can be used for the tuning of the new MC generators.

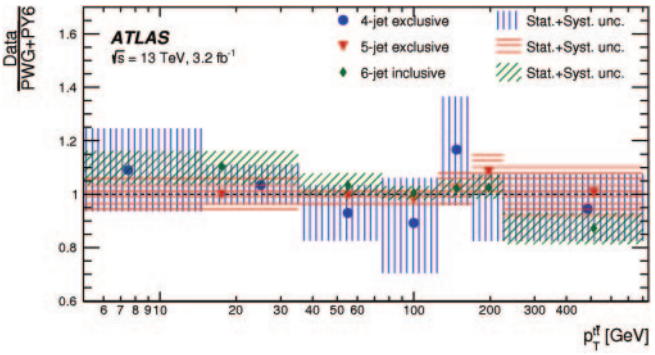

Fig. 2. – Normalised ratio of data to the nominal predictions as a function of the transverse momentum of the $t\bar{t}$ system $p_T^{t\bar{t}}$ in the 4-jet exclusive, 5-jet exclusive and 6-jet inclusive configurations.

REFERENCES

[1] Evans L. and Bryant P., *JINST*, **3** (2008) S08001.
[2] ATLAS Collaboration, *JINST*, **3** (2008) S08003.
[3] Czakon M., Heymes D. and Mitov A., *Phys. Rev. Lett.*, **116** (2016) 082003.
[4] ATLAS Collaboration, *Eur. Phys. J.*, **77** (2017) 299.
[5] ATLAS Collaboration, arXiv:1801.02052 (2018).
[6] ATLAS Collaboration, *JHEP*, **11** (2017) 191.
[7] ATLAS Collaboration, arXiv:1802.06572 (2018).