IL NUOVO CIMENTO Vol. 33 C, N. 4 Luglio-Agosto 2010
DOI 10.1393/ncc/i2010-10677-x

Colloquia: TOP2010

Measurement of the $t\bar{t}$ cross section in the lepton-plus-jets channel in CMS

I. Villella on behalf of the CMS Collaboration

Vrije Universiteit Brussel, Inter-university Institute for High Energies
Pleinlaan 2, B-1050 Brussels, Belgium

(ricevuto il 6 Settembre 2010; approvato il 6 Settembre 2010; pubblicato online il 19 Ottobre 2010)

Summary. — The Large Hadron Collider will produce top quark pairs copiously, which will permit to perform a rich top quark physics program. We describe plans for the measurement of the top quark pair cross section in the lepton-plus-jets channel at a center-of-mass energy of 10 TeV using an integrated luminosity of about 20 inverse picobarn. The selected events contain one muon or one electron and at least four jets in the final state. We present methods to select the top quark pair events, to measure the $t\bar{t}$ cross section and to estimate the W/Z production and QCD multi-jet background in a data-driven way. The statistical and the main systematical uncertainties are also estimated.

PACS 14.65.Ha – Top quarks.

1. – Introduction

The top quark pair cross section measurement at the LHC represents a unique test of perturbative QCD predictions. This measurement also plays a central role in the understanding of new physics channels.

The top quark pair decays to two W bosons and two b-quarks: $t\bar{t} \to W^+bW^-\bar{b}$. We present the potential of CMS [1] to measure the $t\bar{t}$ cross section using simple and robust methods able to identify top quark pairs in the first data in the lepton-plus-jets channels, in which one W decays hadronically and the other W decays into a lepton and a neutrino, leading to a signature with one high-p_t lepton, four high-p_t jets including two b jets and missing transverse energy.

2. – Muon-plus-jets channel

The event selection in the muon-plus-jets channel [2,3] requires a single muon trigger, one isolated muon with $p_{t,\mu} > 20\,\text{GeV}/c$ within a pseudorapidity region $|\eta| < 2.1$ and transverse impact parameter $d_0 < 200\,\mu\text{m}$, at least four jets with $p_{t,\text{jet}} > 30\,\text{GeV}/c$ within

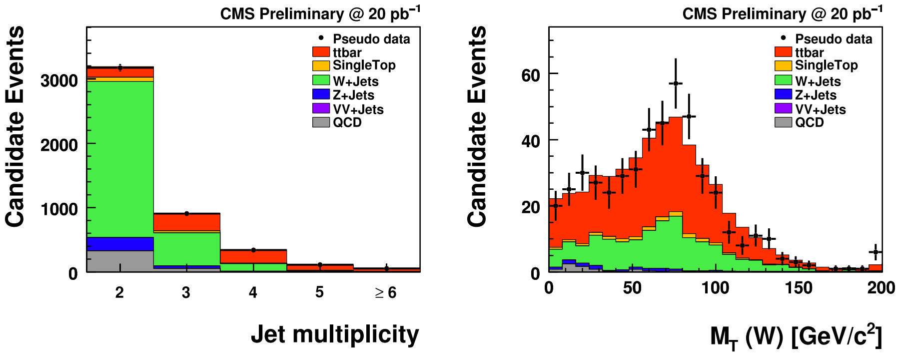

Fig. 1. – Left: expected number of events for an integrated luminosity of $20\,\text{pb}^{-1}$ as a function of jet multiplicity. Right: transverse W mass. The *pseudo data* distribution is built to mimic the data obtained with $20\,\text{pb}^{-1}$.

a pseudorapidity region $|\eta| < 2.4$. No cut on the missing transverse energy is applied. The production of W bosons in association with up to four jets, where the vector boson decays leptonically, constitutes the main background to $t\bar{t}$ events in the lepton-plus-jets channel. Other backgrounds are single top quark and Z boson production. Figure 1 shows the jet multiplicity and the transverse mass of the lepton and missing transverse energy after the final event selection. The general idea, to extract the number of $t\bar{t}$ events from data, is to build variable templates which discriminate between signal and background and to estimate the number of signal and background events. Several methods have been developed and studied:

- Binned likelihood fit to the following variables: the pseudorapidity of the lepton $\eta(\mu)$, the invariant mass of the combination of the three jets whose vectorial sum has the highest p_t, called $M3$, and $M3'(\chi^2)$ defined as the invariant mass of the hadronic leg for the jet combination provided by the χ^2-*sorting* method. In this method the χ^2 is calculated for each permutation of jets using the top quark and the W masses; the best combination of jets is selected as the one with the lowest χ^2.

- Boosted Decision Trees (BDT) are used to exploit the difference in the signal and background shapes and in the correlations of the variables. Ten kinematic and topological quantities are selected to train the BDT, using $t\bar{t}$ production as signal and $W/Z + jets$ and single top production as background. The distribution of the trained BDT classifier is applied to a set of $t\bar{t}$ production, a mix of $W/Z + jets$ and single top events, and a set of QCD events.

The contribution of QCD events with several jets and a muon which pass the selection cuts is very difficult to simulate and the process has a cross section much larger than the signal. Therefore, it has to be determined from data. Two data-driven techniques to determine the number of QCD events are discussed:

- Quadrant or ABCD method: it provides a method to estimate the number of background events in the signal region; it relies on two variables which are at most weakly correlated. Four regions are defined in the phase space given by the two variables, three of them are mostly dominated by background events and one is

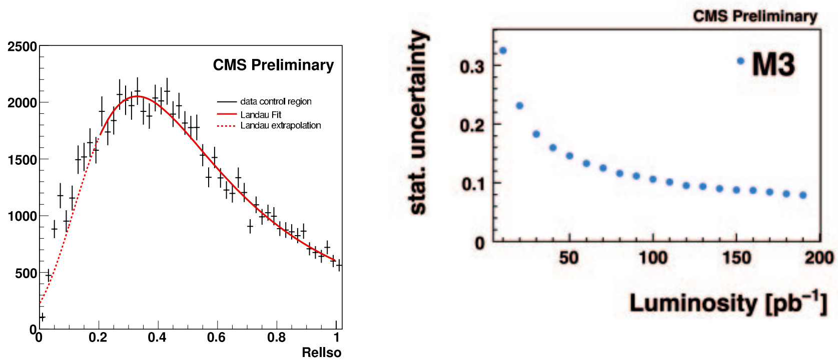

Fig. 2. – Left: fit with a Landau function to the RelIso distribution of events from a QCD dominated sample in the electron-plus-jets channel. The dashed line below 0.2 is an extrapolation. Right: expected statistical uncertainties as a function of the integrated luminosity.

dominated by signal events. The number of events in the signal region can be estimated from the number of events in the other regions.

– Extrapolation of the isolation variable: the relative isolation distribution (RelIso) is used before to apply the cut on it. The QCD events are broadly distributed while the W-like events are strongly peaked towards very small values of RelIso. These features can be exploited in order to estimate the number of QCD events in the signal region.

The uncertainty of the two methods is estimated as 50%.

3. – Electron-plus-jets channel

The event selection in the electron-plus-jets channel [4] is based on the single electron trigger, exactly one isolated electron passing some identification criteria, $E_t > 30\,\text{GeV}$, $|\eta| < 2.5$ (excluding the electrons from the transition region $1.442 < |\eta| < 1.560$), transverse impact parameter $d_0 < 200\,\mu\text{m}$, at least four jets with $p_{t,\text{jet}} > 30\,\text{GeV}/c$ within $|\eta| < 2.4$. A binned likelihood fit of the $M3$ distribution is performed in order to extract the number of events from signal and background processes. To estimate the multi-jet background in a data-driven way, the extrapolation of the electron isolation variable in the signal region is used. By lowering the electron E_t threshold and inverting all the other selection cuts, a control sample enriched in QCD events can be obtained. In fig. 2 a fit to the QCD control sample in the range of RelIso from 0.2 to 1.0 is shown. The uncertainty of the method is estimated as 50%.

4. – Measuring the top cross section

The jet energy scale, which is known to about 10% for the early data, is the most relevant source of systematic uncertainty for all the described measurements. The expected 10% uncertainty related to the integrated luminosity estimate is not included.

– Muon-plus-jets channel (binned likelihood fit): the cross section can be measured with 12–18% statistical and around 20–25% systematical uncertainty, depending on the variable employed as input of the binned likelihood ratio.

– Muon-plus-jets channel (BDT): the cross section can be measured with an expected statistical uncertainty of 8.6% and 21.7% systematical uncertainty.

– Electron-plus-jets channel: the cross section can be measured with an expected statistical uncertainty of 23% and 20% systematical uncertainty.

At the LHC the beams are currently colliding at 7 TeV center-of-mass energy. To measure the $t\bar{t}$ cross section with the same precision as at 10 TeV, approximately, twice the integrated luminosity is needed.

REFERENCES

[1] CMS Collaboration, *JINST*, **3** (2008) S08004.
[2] CMS Collaboration, *Prospects for the first Measurement of the $t\bar{t}$ Cross Section in the Muon plus Jets Channel at $\sqrt{s} = 10$ TeV with the CMS Detector*, Jul 2009 [CMS-PAS-TOP-09-003].
[3] CMS Collaboration, *Expectation for a measurement of the $t\bar{t}$ production cross section in the muon + jets final state using a multivariate technique*, Jul 2009 [CMS-PAS-TOP-09-010].
[4] CMS Collaboration, *Plans for an early measurement of the $t\bar{t}$ cross section in the electron + jets channel at $\sqrt{s} = 10$ TeV*, Jul 2009 [CMS-PAS-TOP-09-004].