PROCEEDINGS OF SCIENCE

$t\bar{t}H$ measurement in final states with multileptons using data taken during the Run 2 of the LHC with CMS

Clara Ramon Alvarez (on behalf of the CMS Collaboration)[a,*]

[a] *University of Oviedo,*
Oviedo, Spain

E-mail: clara.ramon.alvarez@cern.ch

The production of the Higgs boson in association with a pair of top-antitop quarks is studied using final states with multiple leptons in proton-proton collisions collected by the CMS experiment at $\sqrt{s}$ = 13 TeV centre-of-mass energy, during the Run 2 of the LHC. Machine learning and matrix element techniques are used to enhance the sensitivity of the analysis. The measured production rates are used to determine constraints on the Yukawa coupling of the Higgs boson to the top quark.

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1. Introduction

The Higgs boson (H) was discovered by CMS [1, 2] and ATLAS [3] in 2012. In order to determine whether the observed Higgs boson is consistent with the Standard Model (SM) predictions, high-precision measurements are needed. One such property is the Yukawa coupling of the Higgs boson to fermions (y_f). In the SM y_f is proportional to the mass of the fermion, hence measuring y_t, which is the coupling of the top quark (most massive fermion) to the Higgs, is of special interest. Deviations of y_t from the SM prediction would indicate the presence of physics beyond the SM. The measurement of the Higgs boson production rate in association with a top quark pair ($t\bar{t}$H) allows a model-independent determination of the magnitude of the y_t. To determine the sign of the coupling it is also necessary to study the associated production of a Higgs boson with a single top quark (tH).

In this study, the measurement of the $t\bar{t}$H and tH production rates in final states with multiple electrons, muons and hadronically decaying taus is presented. These final states target the Higgs boson decays to WW, ZZ and $\tau\tau$. The measurement was performed using the data recorded by the CMS [5] experiment in pp collisions at $\sqrt{s}$ = 13 TeV during the Run 2 of the LHC, and corresponds to an integrated luminosity of 137 fb^{-1}.

2. Analysis Strategy

Events are classified according to the number of leptons (ℓ meaning e and μ) and taus in the final state. Ten non-overlapping categories are defined: $2\ell ss + 0\tau$, $3\ell + 0\tau$, $2\ell ss + 1\tau$, $2\ell os + 1\tau$, $1\ell + 2\tau$, $4\ell + 0\tau$, $3\ell + 1\tau$, $2\ell + 2\tau$, $1\ell + 1\tau$ and $0\ell + 2\tau$, where ss denotes same sign leptons and os denotes opposite sign leptons. In each category, events are selected with specific requirements to have a more favourable signal-to-background ratio. Requirements on the number of jets and b-tagged jets are applied in all categories depending on the expected jet and b jet multiplicity in $t\bar{t}$H events. In categories sensitive to tH the requirements on the number of jets and b-tagged jets is extended in order to target also tH events, this is done by selecting events with a jet in the forward region. In some categories additional vetoes on the invariant masses of the reconstructed lepton pairs are added to exclude background events.

The main backgrounds after imposing the selection are $t\bar{t}$Z and $t\bar{t}$W which are estimated with MC simulation and constrained using dedicated control regions. On the other hand, the most important reducible background is coming from mis-identified leptons. This background is estimated using the misidentification probability method [4]. This background is highly suppressed by using a dedicated multivariate analysis (MVA) classifier in order to select prompt muons coming from H and vector boson decays.

In order to enhance the separation of the signal processes, MVA techniques are used on top of the previous selection. In $2\ell ss + 2\tau$, $2\ell ss + 0\tau$ and $3\ell + 0\tau$, which are sensitive both to $t\bar{t}$H and tH, artificial neural networks (ANNs) are used. In other, less sensitive, channels boosted decision trees (BDTs) are used. Events are further categorized using the lepton flavour or the b-tagged jet multiplicity to increase the sensitivity. Fig. 1 shows the output nodes of the ANN on the $2\ell ss + 0\tau$ channel, which is the most sensitive one.

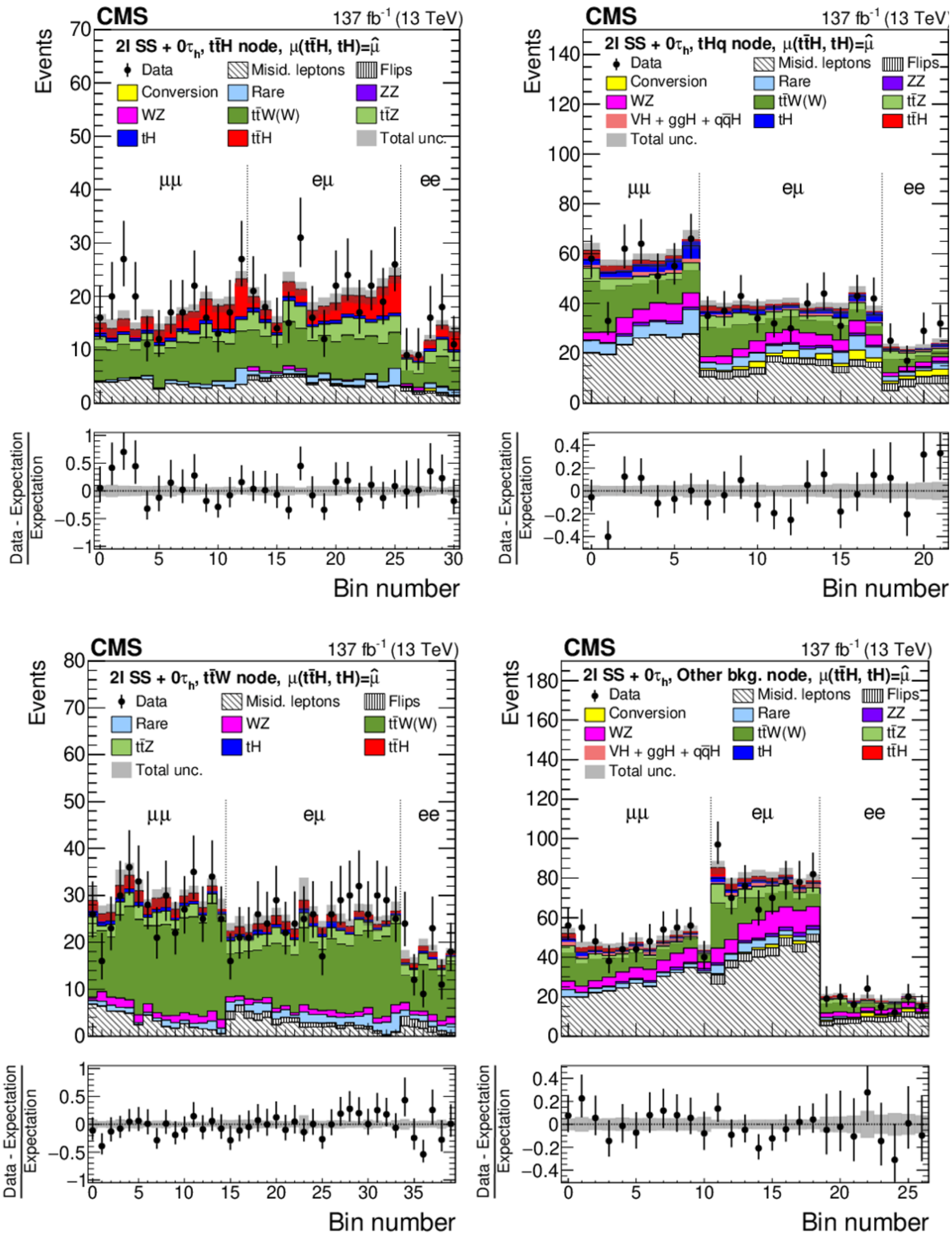

Figure 1: Output nodes of the ANN in $2\ell ss+0\tau$ category. From left to right and up to bottom node targeting: tt̄H, tH, tt̄W and the rest of backgrounds. Figures take from [6].

3. Results

A Maximum Likelihood fit is performed using as parameter of interest the signal strength. The output of the MVA in each category of each channel as well as the control regions are used as input to the fit. The production rate obtained for tt̄H production is $0.92^{+0.26}_{-0.23}$ times its SM expected value. The production rate for tH process is $5.67^{+4.1}_{-4.0}$ times its SM expected value. This result is in good agreement with the SM. This yields an observed (expected) significance for tt̄H production of 5.2

(4.7) standard deviations.
The measurement is used to constrain the coupling of the Higgs boson to the top quark. The production rates of the t$\bar{t}$H and tH processes are parametrized as a function of $\kappa_t = \frac{y_t}{y_t^{SM}}$ and $\kappa_V = \frac{y_V}{y_V^{SM}}$. The κ_t parameter is constrained, at 95% confidence level, to be within $-0.9 < \kappa_t < -0.7$ or $0.7 < \kappa_t < 1.1$ as is shown in fig. 2. The best fit is in good agreement with the SM and 95 % CL while the inverted top coupling scenario is excluded at more than 68 % CL.

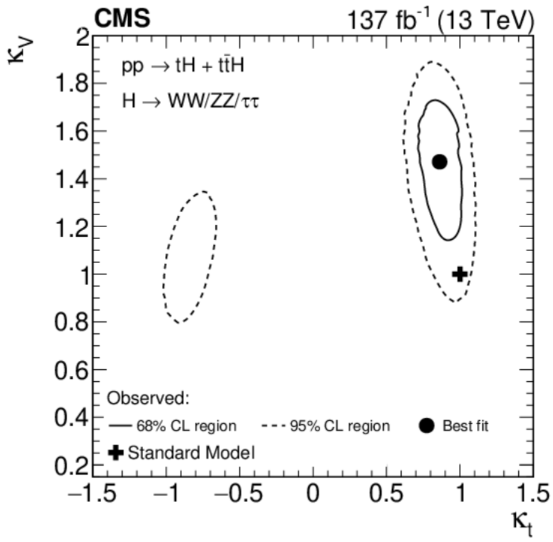

Figure 2: Variation of the likelihood function $\mathcal{L}$, as a function of κ_t and κ_V. Figure taken from [6].

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