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

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The production of the Higgs boson in association with a pair of top quarks is studied in final states with multiple leptons using proton-proton collision data 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 by discriminating signal and backgrounds. 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 discovery of the Higgs boson (H) by CMS [1] and ATLAS [2] in 2012 opened a broad new field of investigation in particle physics. Measuring the properties of that particle with high precision is of great interest. One of such properties is the coupling of the Higgs boson to fermions, the so called Yukawa coupling (y_f). In the SM it is proportional to the mass of the fermion. The top quark is the heaviest fermion known to date and its Yukawa coupling (y_t) is of order unity. 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, though, it is necessary to study the associated production of a Higgs boson with a single top quark (tH).

In this work 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 decay to WW, ZZ and $\tau\tau$. The measurement was performed using the data recorded by the CMS [3] 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

The events considered in the analysis are selected in ten non-overlapping categories using the leptonic and tau multiplicities. These categories are the following: $2\ell ss + 0\tau$, $3\ell + 0\tau$, $2\ell ss + 1\tau$, $2\ell os + 1\tau$, $1\ell + 2\tau$, $4\ell + 0\tau$, $3\ell + 1\tau$, $2\ell + 2\tau$, $1\ell + 1\tau$ and $0\ell + 2\tau$, where ss denotes same sign leptons and os denotes opposite sign leptons. In each category a specific selection is imposed to have a more favourable signal-to-background ratio. Jet multiplicity and b-tagged jet multiplicity requirements are imposed in all categories accordingly to the expected multiplicity in $t\bar{t}$H events. In categories sensitive to tH this nJets and nB-tag selection is extended to target also tH events. In some categories additional vetoes on the lepton masses are added to veto background events.

After imposing the selection the main irreducible backgrounds are $t\bar{t}$Z and $t\bar{t}$W which are estimated with MC simulation and using dedicated control regions. On the other hand, the most important reducible background is coming from mis-identified leptons. This background is estimated with data-driven methods. Using loose-to-tight methods and deriving factors in data driven control regions.

Given the low cross section of the signal process, the above mentioned selection is not enough and, in order to enhance background to signal separation, multivariate analysis techniques are used. For the purpose of separating $t\bar{t}$H and tH signal from backgrounds in $2\ell ss + 2\tau$, $2\ell ss + 0\tau$ and $3\ell + 0\tau$, ANNs are used, which allows to discriminate among the two signals and background simultaneously. In the rest of the channels BDTs are used. In fig. 1 the output nodes of the ANN on the $2\ell ss + 0\tau$ category (the most sensitive one) are shown.

3. Results

A maximum likelihood fit is performed using all categories to extract the signal strength, obtaining a production rate of $0.92^{+0.26}_{-0.23}$ times its SM expected value for the $t\bar{t}$H process and $5.67^{+4.1}_{-4.0}$

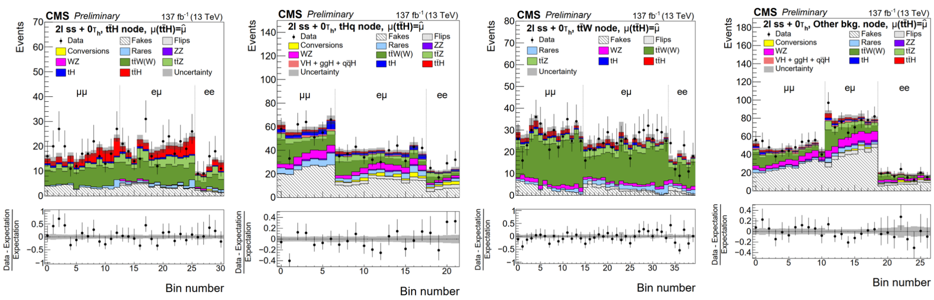

Figure 1: Output nodes of the ANN in $2\ell ss + 0\tau$ category. From left to right node targeting: t$\bar{\text{t}}$H, tH, t$\bar{\text{t}}$W and the rest of backgrounds. Figures take from [4].

for tH. Both are in good agreement with the SM. The corresponding observed (expected) significance for t$\bar{\text{t}}$H is 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$\bar{\text{t}}$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 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.

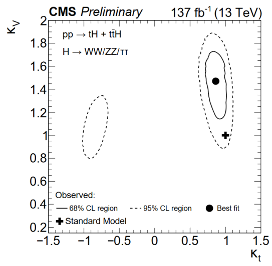

Figure 2: Variation of the likelihood function $\mathcal{L}$, as a function of κ_t and κ_V. Figure taken from [4].

References

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