

Search for the associated production of the Higgs boson with a top quark pair at the ATLAS experiment

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Summary. — The associated production of the Higgs boson with a pair of top–anti-top quarks ($t\bar{t}H$) is the only process providing the direct access to the measurement of the Yukawa coupling between the Higgs boson and the top quark. Moreover, it allows to investigate new possible scenarios of Beyond Standard Model physics. The presented results exploit the data collected by the ATLAS experiment at LHC at a center-of-mass energy of 13 TeV, during 2015 and 2016. The results and the statistical significance have been shown for different final states, sensitive to different Higgs boson decay modes, and for their combination. A special focus has been presented for the experimental techniques used for the extraction of this rare signal and the estimate of the main backgrounds. The current status of the analyses and several possible future perspectives has been discussed with a particular attention to the innovative channel at high transverse momentum.

1. – Introduction

In this document three different analyses will be presented. Each of them studies a specific decay channel of the Higgs boson: $H \rightarrow \gamma\gamma$ (with a Branching Ratio of $\sim 0.23\%$), $H \rightarrow WW/ZZ/\tau\tau$ (BR of $\sim 30\%$) and $H \rightarrow b\bar{b}$ (BR of $\sim 58\%$). All these analyses, sensitive to different kinematics and topologies, will be combined together to achieve the best sensitivity on the measurement of the signal strength of the $t\bar{t}H$ production cross-section. The signal strength is defined as the ratio between the measured cross-section and the predicted one by the Standard Model.

The importance of this measurement resides in the importance of the associated Higgs production: up to now only indirect constraints on the Top-Higgs Yukawa coupling have been possible, from the gluon-gluon fusion production, followed by $H \rightarrow \gamma\gamma$, since this process involves a top quark loop. Instead, the $t\bar{t}H$ production allows a direct access to the Top-Higgs Yukawa coupling, giving the possibility to put direct constraints on it. Moreover, the considered production mode has the highest cross-section increase as a function of the energy with respect to the other production modes.

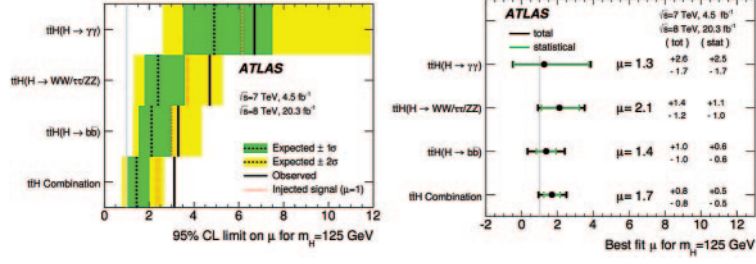


Fig. 1. – On the left, 95% CL limit (observed and expected) on the signal strength (μ) for each channel and their final combination. On the right, measured signal strength in each channel and in their combination [1].

2. – Run-1 results

Using the data collected during the Run-1, corresponding to an integrated luminosity of 4.5 fb^{-1} (7 TeV) and 20.3 fb^{-1} (8 TeV), all the channels sensitive to different final states have been combined together and the results are shown in fig. 1.

A signal strength $\mu = 1.7 \pm 0.8$ has been measured and this corresponds to an observed (expected) significance of 2.3σ (1.5σ). The observed (expected) 95% CL limit on μ is 3.1 (1.4).

3. – Run-2 $t\bar{t}H \rightarrow \gamma\gamma$ analysis

The $t\bar{t}H \rightarrow \gamma\gamma$ channel [2] is divided into two sub-channels, depending on the $t\bar{t}$ system decay: one considering one top quark decaying leptonically and a top quark decaying hadronically, the other considering both the top quarks decaying hadronically.

The leptonic selection requires two isolated photons, at least one lepton, at least two jets and at least two b -tagged jets or at least one b -tagged jet and $E_T^{\text{miss}} > 20$ GeV; and the hadronic one: two isolated photons, no leptons, at least five jets and at least one b -tagged jet.

The events selected in these two regions have been categorised and combined in a global fit in which other Higgs production processes have been considered. In fig. 2 (left), the $t\bar{t}H$ signal strength and the other processes signal strength are shown, together with the their combination using the Run-2 data (13.3 fb^{-1}). A comparison with the Run-1 result is reported as well.

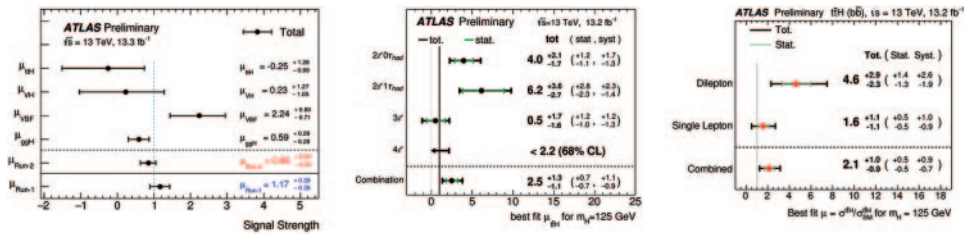


Fig. 2. – The measured signal strength for each channel and their combination, for the $t\bar{t}H \rightarrow \gamma\gamma$ (left) [2], the $t\bar{t}H \rightarrow WW/ZZ/\tau\tau$ (middle) [3] and $t\bar{t}H \rightarrow b\bar{b}$ (right) [4] using $13.3\text{--}13.2 \text{ fb}^{-1}$. The statistical and the systematic uncertainties are reported as well.

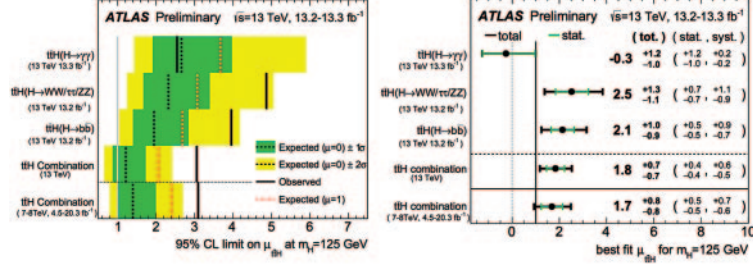


Fig. 3. – On the left, 95% CL limit (observed and expected) on the signal strength (μ) for each channel and their final combination. On the right, measured signal strength in each channel and in their combination [5].

4. – Run-2 $t\bar{t}H \rightarrow WW/ZZ/\tau\tau$ analysis

The $t\bar{t}H$ to multi-lepton final states channel [3] has used a cut-based analysis strategy and it is an extremely clean signature. Nevertheless, a big effort is focused on the extimation of non-reducible backgrounds. The analysis is divided in four sub-channels depending on the number, sign and flavour of leptons. The four different (and orthogonal) regions have been combined in a global fit, shown in fig. 2 (middle) in order to measure the single signal strengths and the combined one with the first Run-2 data (13.2 fb $^{-1}$).

5. – Run-2 $t\bar{t}H \rightarrow b\bar{b}$ analysis

The $t\bar{t}H \rightarrow b\bar{b}$ analysis [4] is characterised by a high multiplicity of control and signal regions, depending on the multiplicity of jets and b -tagged jets in the final state. The main background is the $t\bar{t}$ (with Heavy Flavour jets) process and, due to the difficulty to discriminate it from the signal process, this channel has used the MultiVariate Analysis (MVA) technique in order to increase the final sensitivity. Moreover, it is divided into two sub-channels: the single lepton (exactly one lepton, at least three jets and at least two b -tagged jets), composed by six control regions (CR) and three signal regions (SR), and the dilepton one (exactly two leptons, at least three jets and at least two b -tagged jets), with two CRs and three SRs. These have been included in a global fit to determine the signal strengths and their combination, as shown in fig. 2.

6. – Combination of all the channels and future perspectives

During the first two years of Run-2, an important result has been achieved with the combination of all the channels described in the previous sections. As shown in fig. 3, a signal strength of $\mu = 1.8 \pm 0.7$ has been measured, corresponding to an observed (expected) significance of 2.8σ (1.8σ) and the observed (expected) 95% CL limit on μ is 3.0 (2.1).

Many optimisations are ongoing in all the analyses in order to improve the final sensitivity and to reduce the modelling rising from main backgrounds (as the $t\bar{t}$). Moreover, an additional channel is being added to the $t\bar{t}H \rightarrow b\bar{b}$ analysis, sensitive to high- p_T regimes, in which innovative techniques, as the reclustering, are being used in order to reduce the combinatorial background and to exploit all the substructure characteristics of the high- p_T objects. All the analyses will provide new results with the full statistics of 2015 and 2016, corresponding to an integrated luminosity of 36.1 fb $^{-1}$, together with their final combination.

REFERENCES

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