PROCEEDINGS OF SCIENCE

Top associated Higgs boson production channel $\mathbf{ttH \rightarrow 2\ell + 1\tau_{had}}$ at $\sqrt{s} = 13$ TeV with the ATLAS experiment

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Abstract

The production of the Higgs boson in association with the top quarks allows a direct measurement of the Yukawa coupling as a key parameter of the Standard Model. A search for such process in multilepton final states mainly targeting the decays $\mathrm{H} \rightarrow \mathrm{WW}^*$, $\tau\tau$, and ZZ^* is performed using 13.2 fb^{-1} of data recorded by the ATLAS detector in 2015 and 2016 at a center of mass energy $\sqrt{s} = 13$ TeV.

An overview of the final state with two same-charge light leptons (e or μ) and one hadronically-decaying τ is described in more detail. The best-fit value of the ratio of observed and Standard Model cross sections for the combined multilepton final states is 2.5 ± 0.7 (stat.) $^{+1.1}_{-0.9}$ (syst.), which is consistent with the Standard Model expectation.

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1. Introduction

Higgs boson [1, 2] production in association with a pair of top quarks ($t\bar{t}H$) allows a direct measurement of the Yukawa coupling and can be determined from the cross section of the tree-level process $gg/qq \rightarrow t\bar{t}H$, which is otherwise accessible indirectly through loop effects in gluon-gluon fusion production process.

The search of $t\bar{t}H$ production is performed in multilepton final states [3] targeting the decays $H \rightarrow WW^*$, $\tau\tau$, and ZZ^* using 13.2 fb^{-1} of data recorded by the ATLAS detector [4] in 2015 and 2016 at a center of mass energy $\sqrt{s} = 13$ TeV. The final state with two same-charge light leptons (e or μ) and one hadronically-decaying τ lepton ($2\ell 1\tau_{\mathrm{had}}$) is described.

2. Event selection

In the $2\ell 1\tau_{\mathrm{had}}$ category the events are classified by the number of leptons and τ_{had} candidate. After the object selection as explained in more detail in Ref [3], events are required to include exactly two light leptons (tightly identified and isolated) with same-charge and exactly one τ_{had} candidate of opposite charge to the light leptons. The leading lepton must have $p_T > 25$ GeV, and the sub-leading lepton must satisfy $p_T > 15$ GeV. In order to suppress the $Z \rightarrow e^+e^-$ events with a misreconstructed charge, events with dielectron invariant mass within 10 GeV around Z mass are vetoed. Events must have ≥ 4 jets, of which ≥ 1 must be b-tagged. The primarily contribution from different Higgs boson decay modes in $2\ell 1\tau_{\mathrm{had}}$ signal region (SR) is shown in Table 1.

3. Background estimation

The main backgrounds are categorized into two, irreducible and reducible. Irreducible backgrounds include $t\bar{t}V$ and diboson production and are estimated from Monte Carlo (MC) simulation. These backgrounds and the $t\bar{t}H$ signal produced same-charge prompt leptons with the fraction of events with fake τ_{had} candidates as large as 50% in the SR. A scale factor (SF) of 1.52 ± 0.14 is determined, by selecting events with opposite charge light lepton pairs and one τ_{had} candidate that passes a loose but fails the nominal selection, to correct the yields with fake τ_{had} candidates predicted by MC in such processes. The uncertainty on the SF is determined from statistical uncertainties and MC generator and process dependence.

Reducible (fake) backgrounds, mainly production of a top quark pair $t\bar{t}$, contain non-prompt leptons and fake τ_{had} candidates and are estimated using two-dimensional side-band data-driven method. The side-band control regions (CR) are constructed by requiring an anti-tight lepton and low jet multiplicity using two or three jets and at least one b-tagged jet.

The non-prompt lepton in the SR is estimated using an anti-tight/tight lepton transfer factors derived from the low jet multiplicity regions and applied to the CR with one anti-tight lepton. Due to low number of selected events in the CR's, a single overall transfer factor is derived combining both e or μ. The irreducible backgrounds are subtracted from CR's when computing the transfer factor. The background events with charge misreconstructed electrons is subtracted as well.

Table 1: Fraction of the expected $t\bar{t}H$ signal from different Higgs boson decay modes in $2\ell 1\tau_{\mathrm{had}}$ category [3].

	Higgs decay mode			
	$\tau\tau$	WW^*	ZZ^*	Other
$2\ell 1\tau_{\mathrm{had}}$	51%	46%	2%	1%

The MC truth studies show that the fraction of true and fake τ_{had} candidates in events with non-prompt leptons are similar in all the CR's, the fake τ_{had} component of the non-prompt lepton background in the SR is automatically accounted for in this method. The dominant systematic uncertainty of 76% on the non-prompt lepton background estimate in the SR is due to the limited number of events in CR's.

4. Results

The expected background, $t\bar{t}H$ signal, and observed data yields in the SR are shown in Table 2. The best-fit value of $t\bar{t}H$ signal strength $\mu_{t\bar{t}H}$ is obtained using a maximum likelihood fit to the data yields, which are treated as distinct Poisson terms in the likelihood function. The best-fit value of $\mu_{t\bar{t}H}$ for each individual final state and the combination of all the final states are shown in Fig. 1.

Figure 1 also show the jet, and b-tagged jet multiplicity, the lepton flavor composition, and the number of τ_{had} tracks of the selected events in $2\ell 1\tau_{\mathrm{had}}$ SR. An event display of one of the observed data event in the SR is illustrated in Fig. 2

Table 2: Expected and observed yields in the SR. Uncertainties shown are due to the systematics effects and MC statistics [3].

	$2\ell 1\tau_{\mathrm{had}}$
$t\bar{t}W$	0.8 ± 0.4
$t\bar{t}(Z/\gamma^*)$	1.6 ± 0.4
Diboson	0.20 ± 0.15
Non-prompt leptons	1.3 ± 1.2
Charge misreconstruction	0.24 ± 0.03
Rare	0.63 ± 0.15
Total background	4.8 ± 1.4
$t\bar{t}H$ (SM)	1.43 ± 0.31
Data	14

5. Conclusion

A search for $t\bar{t}H$ production in multilepton final states is performed using 13.2 fb^{-1} of proton-proton collision data recorded by the ATLAS detector in 2015 and 2016 at a center of mass energy $\sqrt{s} = 13$ TeV. The best-fit result of the ratio $\mu_{t\bar{t}H} = \sigma_{t\bar{t}H,\mathrm{Obs}}/\sigma_{t\bar{t}H,\mathrm{SM}}$ for the combined multilepton final states is 2.5 ± 0.7 (stat.) $^{+1.1}_{-0.9}$ (syst.), which is consistent with the Standard Model expectation.

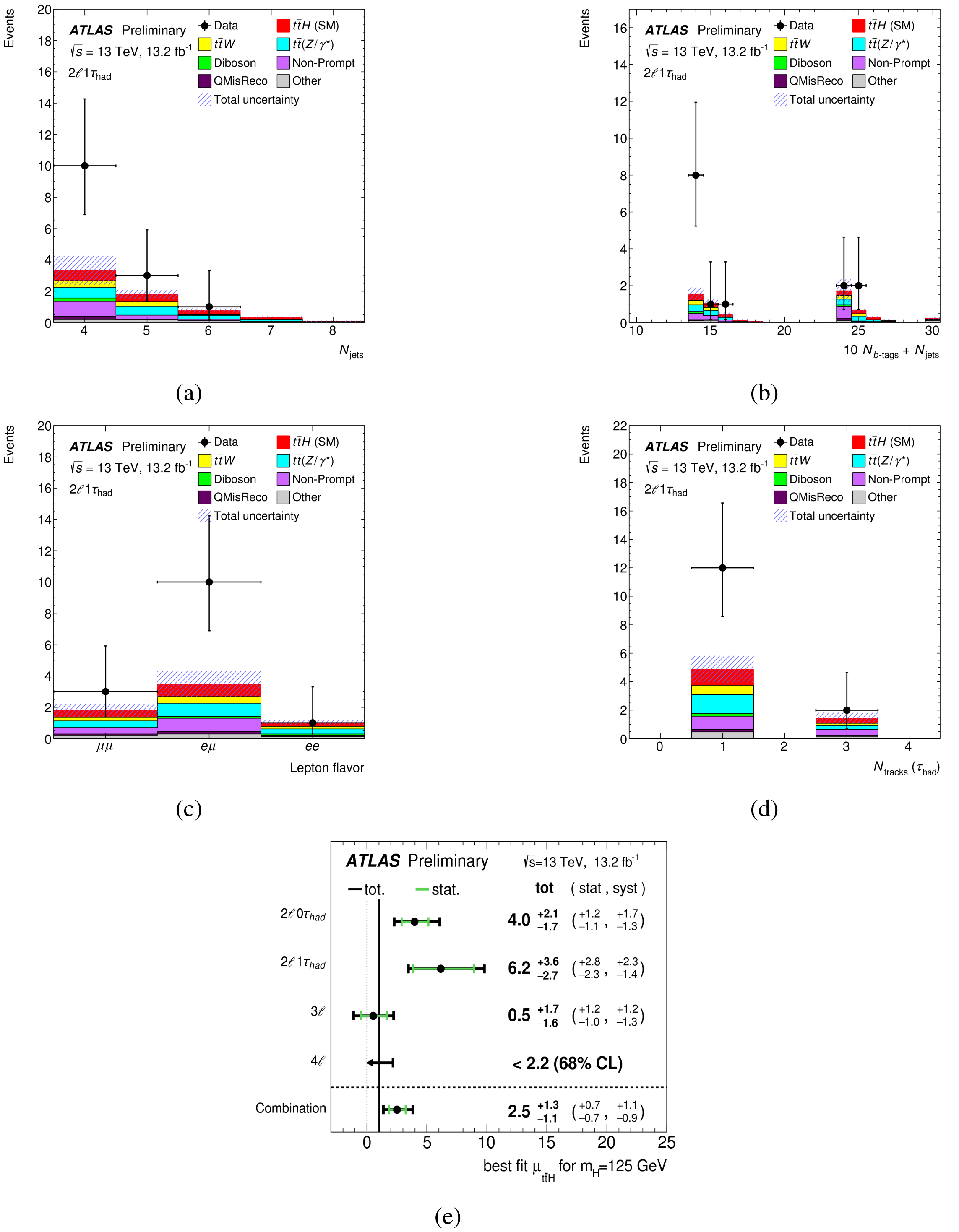

Figure 1: Characteristics of selected events in the SR: (a) number of jets; (b) 10× the number of b-tagged jets plus the total number of jets; (c) lepton flavor composition; (d) number of τ_{had} tracks. The background expectation is pre-fit (using initial values of the background systematic uncertainty nuisance parameters) and the signal is set to one to the Standard Model (SM) expectation. The hatched region shows the total uncertainty on the background plus the SM signal prediction in each bin. (e) The best-fit value of the signal strength $\mu_{t\bar{t}H}$ of all the multilepton final states and combined. The SM prediction is $\mu_{t\bar{t}H} = 1$ [3].

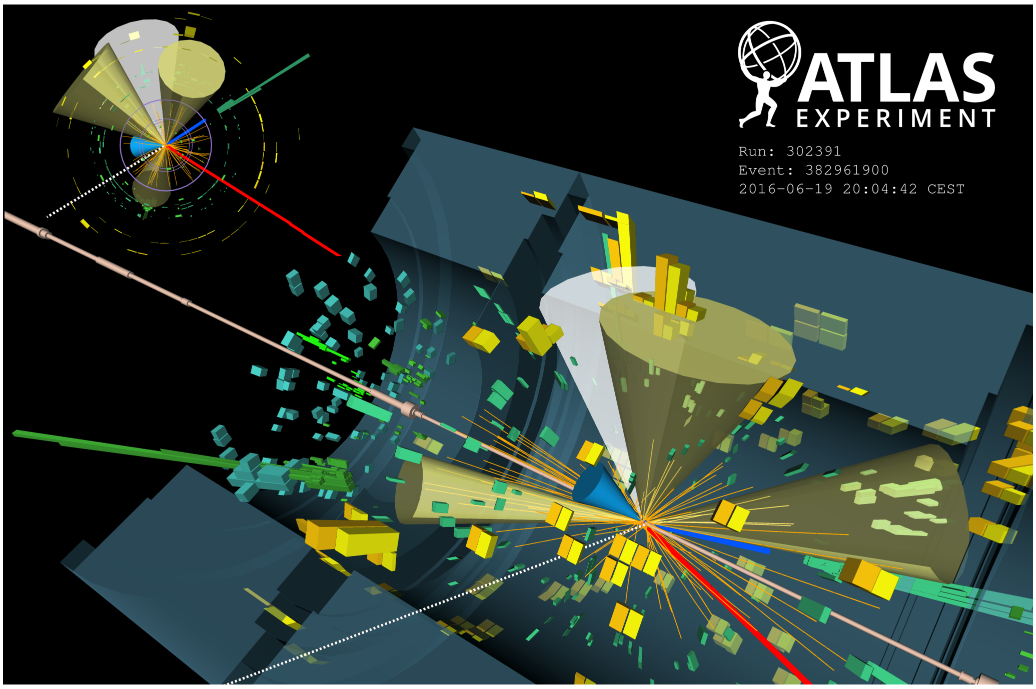

Figure 2: Event display of one of the candidate event in $2\ell 1\tau_{\text{had}}$. The blue track is the selected electron; the red track is the selected muon; the white cone is the τ_{had} candidate; the three yellow cones are the selected jets and azure cone is the selected b-tagged jet. The green and yellow bars indicate the energy deposits in the electromagnetic and hadronic calorimeters [3].

References

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