PROCEEDINGS OF SCIENCE

Search for Higgs Pair Production in $bb\tau\tau$ Channel at 8TeV Center of Mass Energy by the ATLAS Detector at the LHC

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On behalf of the ATLAS Collaboration

We present the result of Higgs boson pair production and subsequent decay into the $bb\tau\tau$ channel in pp collision at centre-of-mass energy of 8 TeV using the ATLAS detector at the LHC. This analysis is based on the full 2012 data corresponding to a total luminosity of 20.3 fb^{-1}. We have explored resonant and non-resonant production of Higgs pair in the final state where one τ decays leptonically and the other hadronically. The observed upper limit at 95% CL on the cross-section σ $(gg \to hh)$ is found to be 1.6 pb for non-resonant production. For resonant production the observed limit ranges between 4.2 pb for $m_H = 260$ GeV and 0.46 pb for $m_H = 1000$ GeV. H is the heavy scalar, which decays to two Standard-Model-like Higgs, h.

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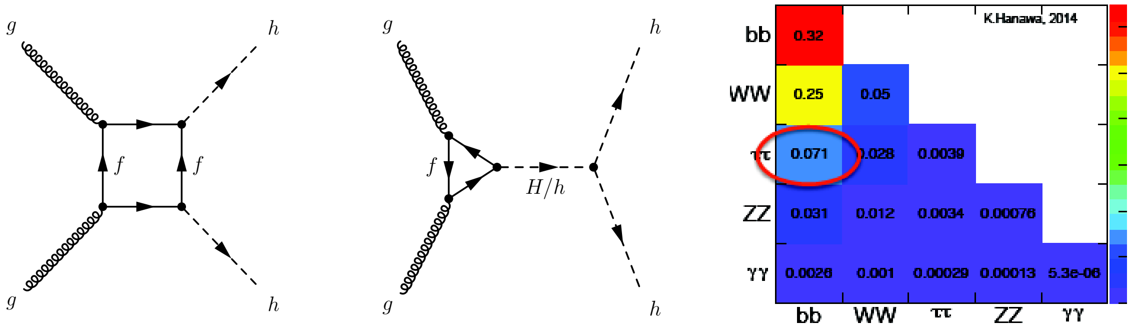
1. Introduction

After the discovery of the Higgs boson in 2012, The Higgs self-coupling is one of the most important properties to understand in electroweak symmetry breaking (EWSB). In the Standard Model (SM), Higgs pair production cross section is too small to be observed with current LHC data, but several beyond-SM (BSM) processes can enhance the production cross section significantly.



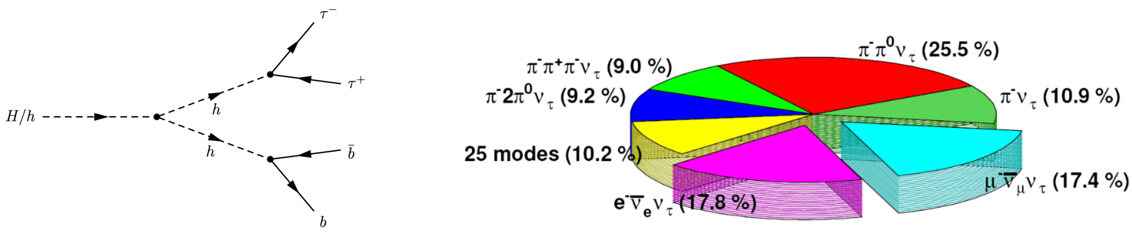
(a) (b) (c)

Figure 1: Higgs pair production : (a) Box diagram (b) Triangle diagram, (c) Branching ratios of different di-Higgs decay.

We present a search for resonant and non-resonant productions of di-Higgs in the $bb\tau\tau$ channel at 8 TeV centre-of-mass energy by the ATLAS detector [1] at the LHC, based on the 20.3 fb^{-1} data collected during 2012 [2]. The BSM heavy scalar is denoted by H and h is the lightest scalar whose properties are nearly identical to those of the Higgs boson in the SM.

2. Motivation

The $bb\tau\tau$ channel has the third largest BR among all the decay modes of di-Higgs. We have one lepton in the final state, so it is clean compared to $bbbb$. This analysis is constrained on the "lephad" final state of the τ pair, where one τ decays to e/μ and other τ decays hadronically (τ_h).



(a) (b)

Figure 2: (a) Higgs pair decay to $bb\tau\tau$. (b) Tau lepton can decay to e, μ and also to hadrons. One-prong decay of τ has one charged particle and three-prong decays consist of three charged particles in the final state.

3. Signal Simulation

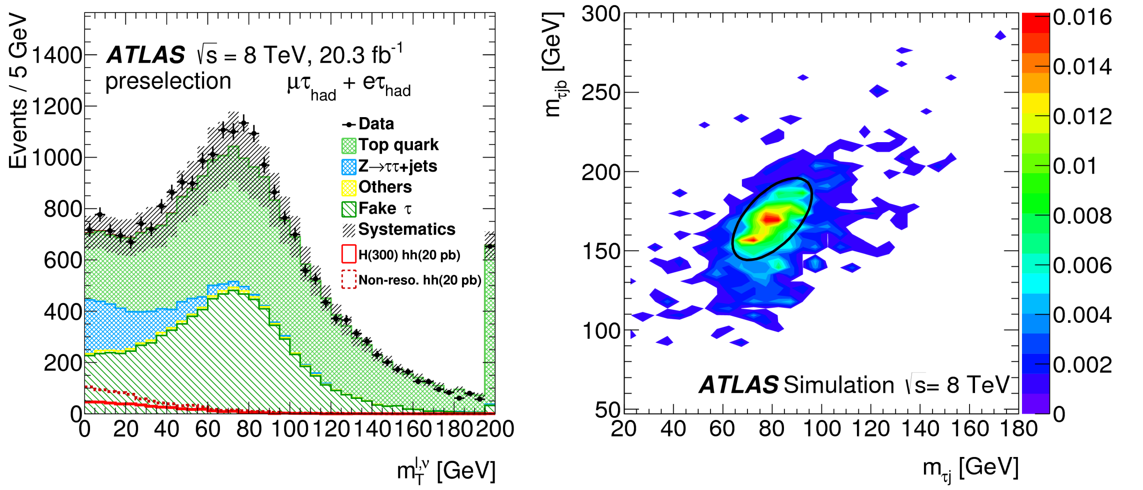
For non-resonant production Madgraph5 [3] is used to generate a SM di-Higgs pair. For the resonant samples, a heavy scalar is generated by Madgraph5 with masses between 260 and 1000 GeV. The decay of the heavy scalar into two SM-like Higgs bosons, parton showering and hadronisation are simulated using Pythia8 [4].

4. Object and Event Selection

The μ are selected with $p_T > 10$ GeV and $|\eta| < 2.5$. The e are required to have $p_T > 15$ GeV and $|\eta| < 1.37$, $1.52 < |\eta| < 2.47$. Electrons in the gap and crack regions are excluded from the analysis. The τ_hs should have the $p_T > 20$ GeV and $|\eta| < 2.5$ and jet $p_T > 10$ GeV and $|\eta| < 4.5$. To remove the overlap between different selected objects, the muons are selected first, followed by electrons from the other overlapped objects, then the hadronic τs. Finally, jets are selected from all the objects left over. Data are recorded using a trigger that accepts events containing with at least one lepton with $p_T > 24$ GeV. The triggered events are required to have exactly one lepton (e or μ) with $p_T > 26$ GeV and exactly one oppositely charged τ_h with $p_T > 20$ GeV. These selected events should also have at least two b-tag jets in the final state.

5. Signal Selection

Events in the signal region are chosen so that the transverse mass of the lepton and the E_T^{miss} system $m_T(l,\nu) = \sqrt{(2p_T^{lep}E_T^{miss}(1-\cos\Delta\phi))}$ is less than 60 GeV.



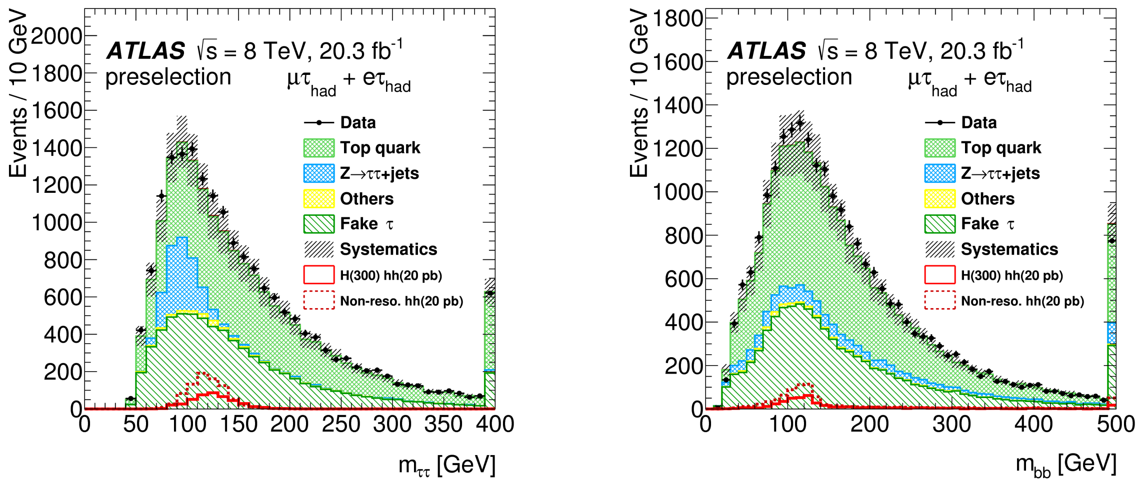
(a) (b)

Figure 3: (a) Transverse mass $m_T(l,\nu)$ of lepton and the E_T^{miss} system. (b) Large contribution from $tt \rightarrow l\nu qqbb$, where one jet is misidentified as τ_h. To reduce this W and t candidates are reconstructed from a combination of $\tau_h + j$ and $\tau_h + j + b$ respectively. Events consistent with tt (ellipse) are rejected [5].

The invariant mass of the di-τ system (MMC) in the signal region is required to be between 100 and 150 GeV. The invariant mass of the pair of the b-jets must be between 90 and 160 GeV.

6. Background Estimation

The main sources of background are fake $\tau_{\rm h}$, tt, single t and $Z \to \tau\tau$. Events with a jet misidentified as $\tau_{\rm h}$, including background from QCD multijets, W/Z+jets, tt are estimated from data using "fake factor", a ratio of "medium" to "loose" taus that do not satisfy the medium identification criteria. The $p_{\rm T}$-dependent fake factors are measured in data control regions separately for $\tau_{\rm h}$ with 1 and 3 tracks for W/Z+jets, multijets and top backgrounds. This fake factor is applied to events passing signal selection, but with a loose-but-not-medium-ID tau. The tt and diboson events with a real lepton and $\tau_{\rm h}$ are estimated from simulation. The $Z \to \tau\tau$ contribution is estimated by selecting $Z \to \mu\mu$ events in data with simulated taus "embedded" in place of the muons.



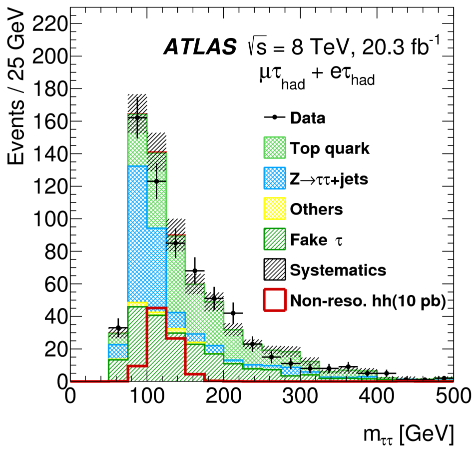
(a) (b)

Figure 4: Kinematic distributions after the preselection: (a) invariant mass of $\tau\tau$ reconstructed with MMC and (b) mass of the bb system. Background is also estimated from SM Higgs boson production but that is too small to be visible. As illustrations, expected signal distributions for a Higgs boson pair production cross section of 20 pb are overlaid for both nonresonant and resonant Higgs boson pair production. A mass of $m_H = 300$ GeV is assumed for the resonant production. The last bin in all distributions contains overflow [5].

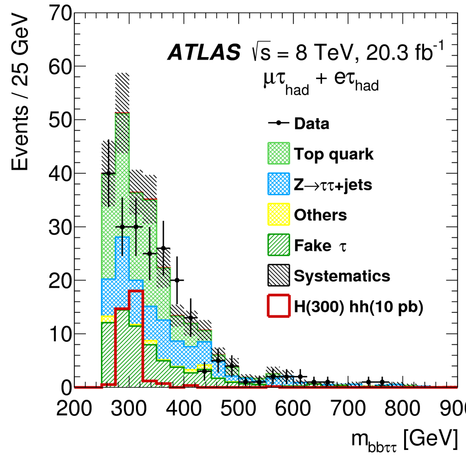
7. Result

The final discriminants $m_{\tau\tau}$ and $m_{bb\tau\tau}$ are used for non-resonant and resonant production respectively. For resonant production, m_{bb} and $m_{\tau\tau}$ are constrained to the SM Higgs mass in order to improve the resolution of $m_{bb\tau\tau}$.

The observed upper limit at 95% confidence level on the cross-section $\sigma\ (gg \to hh)$ is found to be 1.6 pb for non-resonant production. The observed limit around $m_H = 300$ GeV is lower than the expected limit due to the deficit in the $m_{bb\tau\tau}$ distribution. At high mass, the limits are correlated since a single bin is used for $m_{bb\tau\tau} = 400$ GeV. The decrease in the limit with increasing mass of the di-Higgs system reflects the selection efficiency for the signal.



(a)



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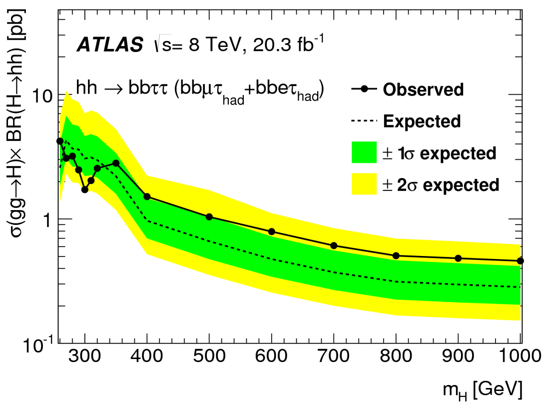

(c)

Figure 5: Final discriminant (a) $m_{\tau\tau}$ for non-resonant and (b) $m_{bb\tau\tau}$ for resonant production of a Higgs pair. (c) Upper limit on the cross section of resonant production of di-Higgs [5].

References

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[2] ATLAS Collaboration. *Searches for Higgs boson pair production in the $hh \to bb\tau\tau, \gamma\gamma WW^*, \gamma\gamma bb, bbbb$ channels with the ATLAS detector*. Phys. Rev. D 92, 092004 (2015).

[3] J. Alwall et al. *MadGraph 5: going beyond*. JHEP 1106 (2011) 128.

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