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Search for the Standard Model Higgs boson produced in the decay channel $H \to ZZ \to 2l2\tau$ with CMS detector at $\sqrt{s} = 7$ TeV

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Abstract. Search for the Standard Model Higgs boson in the decay mode $H \to ZZ \to 2l2\tau$, where $l = \mu, e$, is presented based on CMS data corresponding to an integrated luminosity of 1.1 fb^{-1} at $\sqrt{s} = 7$ TeV. No evidence is found for a significant deviation from Standard Model expectations anywhere in the ZZ mass range considered in this analysis. An upper limit at 95% CL is placed on the product of the cross-section and decay branching ratio for the Higgs boson decaying with Standard Model-like couplings, which excludes cross-sections of about ten times the expected value for Higgs boson masses in the range $200 < m_{\rm H} < 400$ GeV/c^2.

Keywords. CMS, Standard Model Higgs boson.

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1. Introduction

The discovery of the signal compatible with the production of the Standard Model (SM) Higgs boson would, in particular, shed light on the mechanism of spontaneous breaking of the electroweak symmetry. The search for the SM Higgs in the $H \to ZZ \to 2l2\tau$ decay complements the search in the $H \to ZZ^{(*)} \to 4l$ channel [1] at Higgs masses above the kinematical threshold for ZZ production. The presence of four leptons in the final state provides a clean signature with small background contributions. The major sources of backgrounds are irreducible SM ZZ production, reducible SM Z and WZ production in association with jets, and $t\bar{t}$. One Z, which is called 'leading', is required to decay into $\mu\mu$ or ee pair, whereas the second Z called 'subleading', decays into $\tau\tau$ pair with four possible final states: $\tau_{\rm h}\tau_{\rm h}$, $\mu\tau_{\rm h}$, $e\tau_{\rm h}$ and $e\mu$, where $\tau_{\rm h}$ represents hadronically decaying taus. The final states $\tau\tau \to \mu\mu, ee$ are not considered since these are accounted for in the $H \to 4l$ Higgs search.

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2. Event selection

The events selected for this analysis pass triggers which require the presence of at least two muons or electrons in the event with transverse momentum $p_{\mathrm{T}} > 13(8)$ GeV for leading(subleading) muons and $p_{\mathrm{T}} > 17(8)$ GeV for electrons. A particle flow (PF) technique is used to construct electrons and muons and to reconstruct hadronically decaying taus using the 'loose' and 'medium' operating point of the hadron plus strip (HPS) algorithm [2].

Events are required to have at least one leading Z boson candidate decaying into either a pair of oppositely charged electrons or muons with p_{T} greater than 20 GeV and 10 GeV for leading and subleading leptons, respectively, and satisfy $|\eta| < 2.4$ for muons and $|\eta| < 2.5$ for electrons. Both leptons are required to be isolated with PF-combined relative isolation less than 0.25 and 0.2 for muons and electrons, respectively. The PF-combined relative isolation is defined as

$$I_{\mathrm{rel}}^{\mathrm{PF}}(\rho) = \frac{\sum \left(p_{\mathrm{T}}^{\mathrm{charged}} + \max(E_{\mathrm{T}}^{\gamma} + E_{\mathrm{T}}^{\mathrm{neutral}} - \rho\pi\Delta R^2, 0.0\right)}{P_{\mathrm{T}}^{l}}, \tag{1}$$

where $P_{\mathrm{T}}^{\mathrm{charged}}$ is the sum of charged hadron transverse momenta and E_{T}^{γ} and $E_{\mathrm{T}}^{\mathrm{neutral}}$ are the sum of the photon and neutral hadron transverse energy, respectively, in the isolation cone of $\Delta R < 0.4$ around the lepton direction. The energy density due to pileup and underlying events, ρ, is estimated on event-by-event basis using the so-called FastJet approach.

For the subleading Z boson, a tau pair is selected. Since taus decay leptonically or hadronically, if the final state contains only muons and electrons, the leptons are required to have p_{T} in excess of 10 GeV. The remaining requirements are then identical to those for the leading Z. Since τ_{h} have a much larger misidentification rate than other leptons, if one tau decays hadronically, the isolation on the electrons and muons is required to be tighter (0.15 for muons and 0.05 for electrons). The taus are required to have $p_{\mathrm{T}} > 20$ GeV, pseudorapidity $|\eta| < 2.3$, and to pass the 'loose' HPS working point requirement. If both taus decay hadronically, they are required to pass the 'medium' working point of the HPS algorithm.

A limit of 30–80 GeV is set on visible invariant mass of $Z \to \tau\tau$ to avoid the contribution of subleading $Z \to 2l$ where the muons or electrons are misidentified as τ_{h}. All possible $4l$ decay modes have been checked to avoid double counting of events from $H \to ZZ \to 2l2\tau$ and $H \to ZZ \to 4l$ production.

3. Background estimates

The estimation of the ZZ contribution is based on a comparison of the well-measured inclusive Z production cross-section. The number of expected ZZ events can be written as

$$N_{\mathrm{ZZ}}^{\mathrm{estimated}} = N_{\mathrm{Z}}^{\mathrm{obs}} \cdot \frac{\sigma_{\mathrm{ZZ}}^{\mathrm{SM}} \cdot A_{\mathrm{ZZ}}}{\sigma_{\mathrm{Z}}^{\mathrm{SM}} \cdot A_{\mathrm{Z}}}, \tag{2}$$

where N_Z^{obs} is the number of observed events via inclusive Z production, A_Z is the analysis acceptance estimated using MC simulation and scaled with measured data/MC correction factors, and A_{ZZ} is the analysis acceptance for ZZ events.

For the reducible backgrounds, the probability for jets to fake τ_h is measured using events in which the leading Z passed all selection requirements and τ_h pairs are observed, where no requirement on the τ_h isolation is applied. Additionally, the τ_h candidates are required to have the same charge. This region is dominated by $Z+$jets events with signal contamination of less than 0.1%.

To estimate the number of background events in the signal region, the measured fake rate is applied to events which pass all selection requirements, including proper charge combination of the subleading Z, but requiring the τ_h candidates to be anti-isolated. A similar procedure is applied to estimate the fake rate for electrons in the $\mu\mu\mu e$ and $ee\mu e$ final states. The results of the data-driven estimate are summarized in table 1.

Table 1. The total yield of reducible backgrounds in the signal region.

Channel	Estimated events
$ee\tau\tau$	0.084±0.004
$\mu\mu\tau\tau$	0.066±0.0004
$eee\tau$	0.24±0.07
$\mu\mu e\tau$	0.12±0.05
$ee\mu\tau$	0.07±0.04
$\mu\mu\mu\tau$	0.05±0.03
$\mu\mu e\mu$	0.12±0.09
$eee\mu$	0.06±0.05

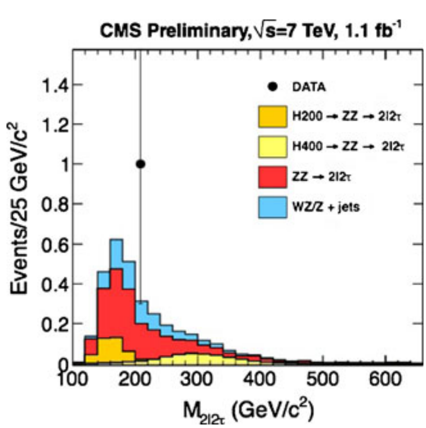

Figure 1. Four-lepton reconstructed mass summed for all $2l2\tau$ final states.

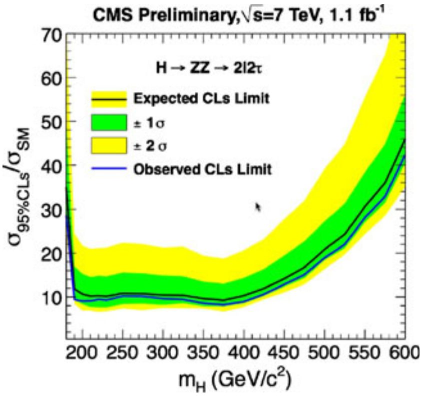

Figure 2. Expected and observed 95% CL upper limits as a function of m_{H}.

4. Results

In 1.1 fb^{-1} of data one event is observed in the eight search channels, in the $eee\tau$ state, compared to 2.5 background events expected (figure 1). The expected and observed upper limits at 95% CL are set on the cross-section ratio to the nominal SM Higgs cross-section using the modified frequentist construction CLs by taking all the sources of systematic uncertainties into account. They are presented as a function of the Higgs mass in figure 2. The upper limit on the cross-section excludes cross-sections of about ten times the expected value for Higgs masses in the range of $200 < m_{\mathrm{H}} < 400\ \mathrm{GeV/c}^2$.

References

[1] CMS Collaboration, *Search for a Standard Model Higgs boson produced in the decay channel 4l*, CMS Physics Analysis Summary CMS-PAS-HIG-11-004, 2011

[2] CMS Collaboration, *Performance of tau reconstruction algorithms in 2010 data collected with CMS*, CMS Physics Analysis Summary CMS-PAS-TAU-11-001, 2011