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Searches for additional Higgs bosons at CMS

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Direct searches for additional Higgs bosons at CMS are presented. The searches for heavy neutral Higgs bosons, charged Higgs bosons and light neutral Higgs bosons are performed using proton-proton collision data at $\sqrt{s} = 13$ TeV collected by the CMS detector. No significant sign of any beyond standard model Higgs boson is observed.

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1. Introduction

In 2012, both the ATLAS [1] and CMS [2, 3] Collaborations observed a new boson with a mass of approximately 125 GeV whose properties are at present compatible with those of the Higgs boson in the standard model (SM) of particle physics. However, physics beyond the SM (BSM) can also provide a Higgs boson that is compatible with the observed 125 GeV boson. The extended parameter space of several BSM models, such as generalized models containing two Higgs doublets (2HDM) [4] and the next-to-minimal supersymmetric model (NMSSM) [5, 6], give rise to a rich and interesting phenomenology, including the presence of additional Higgs bosons. Searching for additional Higgs bosons is therefore an important way to probe BSM physics and address the naturalness problem in the SM. This paper summarizes the latest results of the searches for additional Higgs Bosons in a wide mass range at CMS. The data set is the proton-proton collisions collected in 2016 with the CMS detector at the LHC, corresponding to an integrated luminosity of 35.9 fb^{-1} at a center-of-mass energy of 13 TeV.

2. Heavy neutral Higgs boson searches

For heavy neutral Higgs bosons decaying into $\tau\tau$ [7], the analysis is performed in four different $\tau\tau$ final states: $e\mu$, $e\tau_h$, $\mu\tau_h$, and $\tau_h\tau_h$, where e, μ and τ_h indicate τ lepton decays into electrons, muons and hadrons, respectively. For the search with the $b\bar{b}$ final state [8], the analysis focuses on neutral Higgs bosons A and H with masses $m_A \geq 300$ GeV that are produced in association with at least one b quark. Stringent upper limits on the cross section times branching fraction are set for Higgs bosons with masses up to 1300 GeV. The search for beyond-the-SM neutral Higgs bosons in the dimuon final state [9] is performed in the context of the minimal supersymmetric model (MSSM) for values of m_A larger than 130 GeV, assuming either the modified scenario m_h^{mod+} or the phenomenological MSSM (hMSSM) scenario. The search is sensitive to neutral Higgs bosons produced via the gluon fusion process or in association with a $b\bar{b}$ quark pair. No significant deviations from the standard model expectation are observed. The left plot in Figure 1 summarizes the observed and expected 95% CL upper limits on the MSSM parameter tanβ versus m_A in the hMSSM benchmark scenario, from different decay channels of heavy neutral Higgs.

Recently the results of a search for heavy Higgs bosons decaying to a top quark pair has been published [10]. Final states with one or two charged leptons are considered. As evident from the right plot in Figure 1, the largest deviation from the SM background is observed for a pseudoscalar Higgs boson with a mass of 400 GeV with a local significance of 3.5 $\pm$ 0.3 standard deviations. When accounting for the look-elsewhere effect, the global significance is 1.9 standard deviations.

3. Charged Higgs boson searches

Searches for a light charged Higgs boson (H^+) are performed using the 2016 35.9 fb^{-1} data set. No significant deviation above the expected background is observed. A search for H^+ decaying to a W boson and a CP-odd Higgs boson (A) in final states with $e\mu\mu$ or $\mu\mu\mu$ [11] is investigated with H^+ boson masses between 100 and 160 GeV and A boson masses between 15 and 75 GeV. Upper limits at 95% confidence level are obtained on the combined branching fraction for the decay

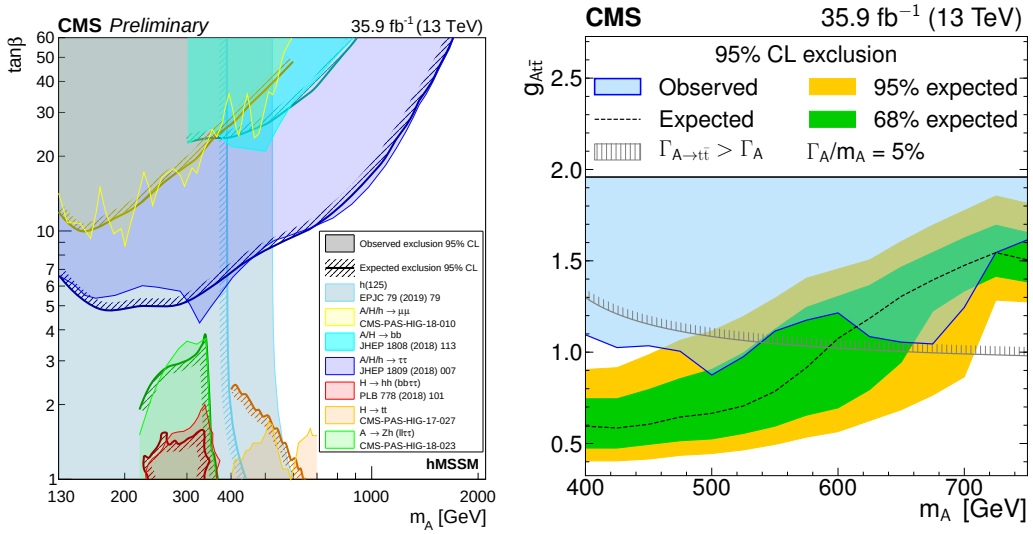

Figure 1: (Left) Observed and expected 95% CL upper limits on the MSSM parameter tanβ versus m_A in the hMSSM benchmark scenario, with the results from different decay channels of the heavy neutral Higgs [7]. (Right) Model-independent constraints on the coupling strength modifier ($g_{A\to t\bar{t}}$) as a function of the heavy pseudoscalar boson mass m_A, for relative width of 5%, from the search for heavy Higgs bosons decaying to a top quark pair [10].

chain, $t \to bH^+ \to bW^+A \to bW^+\mu^+\mu^+$, of 1.9×10^{-6} to 8.6×10^{-6}, depending on the masses of the H^+ and A bosons. These are the first limits for these decay modes of the H^+ and A bosons. For the search for $H^\pm$ in the $H^\pm \to \tau^\pm\nu_\tau$ decay mode in the hadronic final state and in final states with an electron or a muon, the observed limit on the production cross section times branching fraction to $\tau^\pm\nu_\tau$ for an $H^\pm$ in the mass range of 80 GeV to 3 TeV, including the region near the top quark mass, ranges from 6 pb at 80 GeV to 5 fb at 3 TeV [12]. For charged Higgs bosons in the range of 0.2 to 3 TeV, the combination from H^+ decaying into a top and a bottom quark-antiquark pair in the leptonic final states [13] and the fully hadronic final state [14] results in improved limits of 9.25 to 0.005 pb. Searches for charged Higgs bosons ($H^\pm$) and the doubly charged Higgs boson ($H^{\pm\pm}$), with mass up to 2000 GeV, are also performed, when measuring the electroweak production of WW, WZ, and ZZ boson pairs in association with two jets [15, 16]. The upper limits on VBF produced charged Higgs boson cross sections in the high-mass region extend the previous results at the LHC.

4. Light neutral Higgs boson searches

Searches for light pseudoscalar a_1 bosons, produced from decays of the 125 GeV Higgs boson (H), in different decay channels $H \to a_1a_1 \to 4\mu/2\mu2b/4\tau/2\mu2\tau/2b2\tau$, are performed using the 2016 35.9 fb^{-1} data set [17, 18, 19, 20, 21]. With no evidence for a signal, the observed 95% confidence level upper limit on the product of the inclusive signal cross section and the branching fraction, relative to the SM H production cross section, are set. Observed limits on $\frac{\sigma(h)}{\sigma_{SM}} \times B(h \to$

aa) for different exotic h decay searches are shown in the left plot of Figure 2 as a function of m_{a_1} for type-II 2HDM + singlet (S) model [22] with $\tan\beta = 2$.

The results of a search for a standard model-like Higgs boson in the mass range between 80 (70) and 110 GeV decaying into two photons, using the data set collected with the CMS experiment in proton-proton collisions corresponds to an integrated luminosity of 19.7 (35.9) fb^{-1} at $\sqrt{s} = 8$ (13) TeV, are presented [23]. The statistical combination of the results from the analyses of the two data sets in the common mass range between 80 and 110 GeV yields an upper limit on the product of the cross section and branching fraction, normalized to that for a standard model-like Higgs boson, ranging from 0.7 to 0.2, with two notable exceptions: one in the region around the Z boson peak, which may be due to the presence of Drell–Yan dielectron production where electrons could be misidentified as isolated photons, and a second due to an observed excess with respect to the standard model prediction, which is maximal for a mass hypothesis of 95.3 GeV with a local (global) significance of 2.8 (1.3) standard deviations. The expected and observed local p-values as a function of the mass of an additional SM-like Higgs boson, calculated with respect to the background-only hypothesis, from the analyses of the 8 and 13 TeV data, and from their combination, are shown in the right plot of Figure 2.

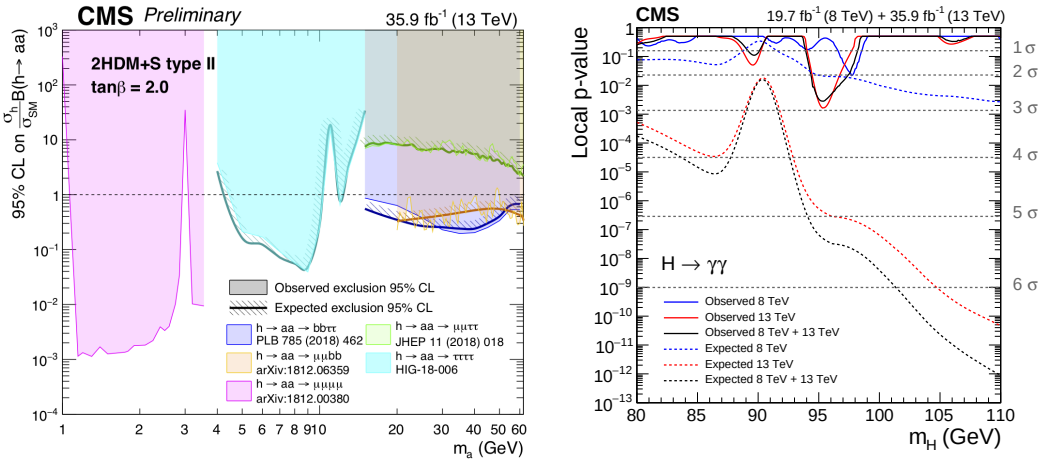

Figure 2: (Left) 95% CL on $\frac{\sigma(h)}{\sigma_{SM}} \times B(h \to aa)$ in the 2HDM + singlet (S) type-II $\tan\beta = 2$ scenario for exotic h decay searches performed with data collected at 13 TeV center-of-mass energy [24]. (Right) Expected and observed local p-values as a function of m_H for the 8 and 13 TeV data and their combination (solid curves) plotted together with the relevant expectations for an additional SM-like Higgs boson (dotted curves) [23].

5. Summary

The latest results of the searches for additional Higgs bosons, including heavy neutral Higgs bosons, charged Higgs bosons and light neutral Higgs bosons, in a wide mass range at CMS are presented. No significant sign of any beyond the standard model Higgs boson is observed.

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