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Search for a light charged Higgs boson decaying to a W boson and a CP-odd Higgs boson in trilepton final states in pp collisions at 13 TeV with CMS

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A search for a light charged Higgs boson (H^+) decaying to a W boson and a CP-odd Higgs boson (A) using trilepton final states (electron-dimuon or trimuon) is presented. The result is based on data from pp collisions at a center of mass energy of 13 TeV, recorded by the CMS detector, corresponding to an integrated luminosity of 35.9 fb^{-1}. In this search, it is assumed that the H^+ boson is produced in decays of top quarks, and the A boson decays to two oppositely charged muons. The first upper limits are set on the combined branching fraction for the decay chain.

40th International Conference on High Energy physics - ICHEP2020
July 28 - August 6, 2020
Prague, Czech Republic (virtual meeting)

[1] On behalf of the CMS Collaboration
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PoS(ICHEP2020)095

The Higgs boson with a mass around 125 GeV was discovered in 2012 by the ATLAS and CMS Collaborations [1–3], and its observed properties have been consistent with the expectation in the standard model (SM) [4, 5]. However, there are models beyond the SM which have a different Higgs sector compared to the SM, yet are consistent with the experimental results. Two-Higgs-doublet models (2HDM) are an example of such models [6].

In 2HDM, a charged Higgs boson (H^+) and a CP-odd Higgs boson (A) are predicted. The H^+ boson can be mainly produced in top quark decays ($pp \to t\bar{t} \to b\bar{b}W^-H^+$) and decay to W and A bosons ($H^+ \to W^+A$) [7, 8]. The A boson can decay to an oppositely charged muon pair ($A \to \mu^+\mu^-$). A search is performed to investigate this production and decay mode of H^+ and A bosons. The A boson mass (m_A) hypotheses between 15 and 75 GeV and the H^+ boson mass (m_{H^+}) hypotheses between (m_A + 85 GeV) and 160 GeV are considered. The motivation behind the choice of the range of m_{H^+} values is based on the mass thresholds of ($m_A + m_W$) and ($m_t - m_b$) for the decay. For the two W bosons in the decay chain, semileptonic decay channels ($WW \to \ell\nu q\bar{q}'$, ℓ = e or μ) are targeted.

The search utilizes a data set of pp collisions at a center of mass energy of 13 TeV, corresponding to an integrated luminosity of 35.9 fb^{-1}, recorded using the CMS detector [9]. Selected events are required to contain two muons, and one electron or an additional muon. The three leptons should include at least one $\mu^+\mu^-$ pair, and the invariant mass of $\mu^+\mu^-$ pair is required to satisfy $m_{\mu\mu} > 12$ GeV and $|m_{\mu\mu} - 91.2| > 10$ GeV for all the $\mu^+\mu^-$ pairs in an event. In addition, the events are required to contain two or more jets, at least one of which is identified as originating from a b quark. The $m_{\mu\mu}$ distribution is analyzed to look for the A boson resonance. The background of the search originates mainly from $t\bar{t}$ processes that include a nonprompt lepton from B hadron decays.

No statistically significant evidence of the signal is found, and 95% confidence level (CL) upper limits are set on the product of branching fractions, $\mathcal{B}_{sig} = \mathcal{B}(t \to bH^+)\mathcal{B}(H^+ \to W^+A)\mathcal{B}(A \to \mu^+\mu^-)$. The upper limits on $\mathcal{B}_{sig}$ vary between 1.9×10^{-6} and 8.6×10^{-6} depending on the assumed m_{H^+} and m_A values, as shown in the Fig. 1.

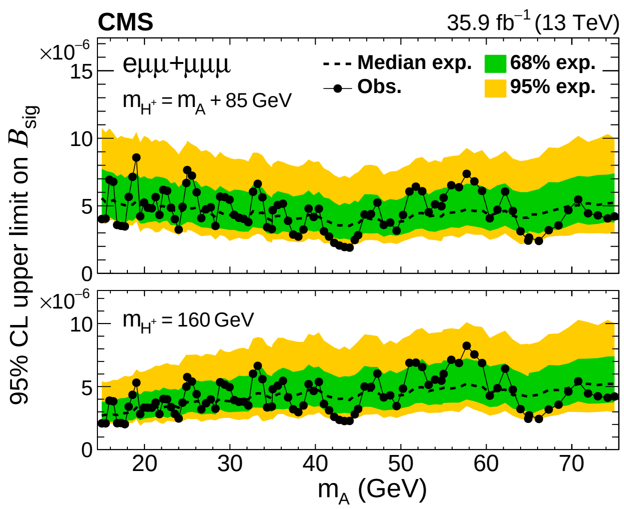

Figure 1: The upper limits at 95% CL on $\mathcal{B}_{sig} = \mathcal{B}(t \to bH^+)\mathcal{B}(H^+ \to W^+A)\mathcal{B}(A \to \mu^+\mu^-)$ [10]. In the upper (lower) panel, the m_{H^+} values are assumed to be m_A + 85 GeV (160 GeV).

This result can be used to derive upper limits on the product of branching fractions, $\mathcal{B}(\mathrm{t} \to \mathrm{bH}^+)\mathcal{B}(\mathrm{H}^+ \to \mathrm{W}^+\mathrm{A})$, at the order of 10^{-2} (10^{-3}) in the type-1 and 2 (X) 2HDM. This is more stringent than the previous results from the CDF experiment, using different decay modes of the A boson [11, 12]. This is the first search for the decay mode of the H^+ boson ($\mathrm{H}^+ \to \mathrm{W}^+\mathrm{A} \to \mathrm{W}^+\mu^+\mu^-$), and it constrains the class of models which predict a significant rate of the production and decay mode of the H^+ boson.

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