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Search for charged Higgs bosons produced in vector boson fusion processes and decaying into vector boson pairs in proton–proton collisions at $\sqrt{s} = 13\,\text{TeV}$

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Abstract A search for charged Higgs bosons produced in vector boson fusion processes and decaying into vector bosons, using proton–proton collisions at $\sqrt{s} = 13\,\text{TeV}$ at the LHC, is reported. The data sample corresponds to an integrated luminosity of $137\,\text{fb}^{-1}$ collected with the CMS detector. Events are selected by requiring two or three electrons or muons, moderate missing transverse momentum, and two jets with a large rapidity separation and a large dijet mass. No excess of events with respect to the standard model background predictions is observed. Model independent upper limits at 95% confidence level are reported on the product of the cross section and branching fraction for vector boson fusion production of charged Higgs bosons as a function of mass, from 200 to 3000 GeV. The results are interpreted in the context of the Georgi–Machacek model.

1 Introduction

The discovery [1–3] of a Higgs boson [4–9] at the CERN LHC marks an important milestone in the exploration of the electroweak (EW) sector of the standard model (SM) of particle physics. Measurements of vector boson scattering (VBS) processes at the LHC may reveal hints for extensions of the SM. In particular, extended Higgs sectors with additional SU(2) doublets [10–13] or triplets [14–19] introduce couplings of gauge bosons to heavy neutral or charged Higgs bosons with specific signatures like singly or doubly charged Higgs boson decays to WZ boson pairs or same-sign $\text{W}^{\pm}\text{W}^{\pm}$ boson pairs, respectively.

At the LHC, interactions from VBS are characterized by the presence of two gauge bosons in association with two forward jets with a large pseudorapidity separation ($|\Delta\eta_{\text{jj}}|$) and a large dijet invariant mass (m_{jj}). An excess of events with respect to the SM predictions could indicate the presence of new resonances, such as singly or doubly charged Higgs bosons. Extended Higgs sectors with additional SU(2) isotriplet scalars give rise to charged Higgs bosons with couplings to W and Z bosons at the tree-level [19]. Specifically, the Georgi–Machacek (GM) model [18,20], with both real and complex triplets, preserves a global symmetry $\text{SU(2)}_{\text{L}} \times \text{SU(2)}_{\text{R}}$, which is broken by the Higgs vacuum expectation value to the diagonal subgroup $\text{SU(2)}_{\text{L+R}}$. Thus, the tree-level ratio of the W and Z boson masses is protected against large radiative corrections. In this model, singly (doubly) charged Higgs bosons that decay to W and Z bosons (same-sign W boson pairs) are produced via vector boson fusion (VBF).

The charged Higgs bosons $\text{H}^{\pm}$ and $\text{H}^{\pm\pm}$ in the GM model are degenerate in mass (denoted as m_{H_5}) at tree level and transform as a quintuplet under the $\text{SU(2)}_{\text{L+R}}$ symmetry. The $\text{H}^{\pm}$ and $\text{H}^{\pm\pm}$ bosons are also collectively referred to as H_5 in the context of the GM model. Production and decays of the H_5 states depend on the two parameters m_{H_5} and s_{H}, where s_{H}^2 characterizes the fraction of the W boson mass squared generated by the vacuum expectation value of the triplet fields. The H_5 states are fermiophobic and are assumed to decay to vector boson pairs with branching fraction of 100% [21]. Figure 1 shows representative Feynman diagrams for the production and decay of the charged Higgs bosons. There are additional charged Higgs bosons $\text{H}^{\pm}$ predicted in the GM model that transform as a triplet under the $\text{SU(2)}_{\text{L+R}}$ symmetry. These $\text{H}^{\pm}$ bosons have only fermionic couplings and are not considered here.

This paper presents a search for $\text{H}^{\pm}$ and $\text{H}^{\pm\pm}$ that are produced via VBF and decay to WZ and $\text{W}^{\pm}\text{W}^{\pm}$ boson pairs, respectively, using proton–proton (pp) collisions at $\sqrt{s} = 13\,\text{TeV}$. The data sample corresponds to an integrated luminosity of $137 \pm 2\,\text{fb}^{-1}$ [22–24], collected with the CMS detector [25] in three separate LHC operating periods during 2016, 2017, and 2018. The three data sets are analyzed independently, with appropriate calibrations and corrections, to account for the various LHC running conditions and the performance of the CMS detector.

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