Study of Higgs-gauge boson anomalous couplings through $e^- e^+ \rightarrow W^- W^+ H$ at ILC

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Abstract: In this work, Higgs couplings with gauge bosons is probed through $e^- e^+ \rightarrow W^- W^+ H$ in an effective Lagrangian framework. An ILC of 500 GeV center of mass energy with possible beam polarization is considered for this purpose. The reach of ILC with integrated luminosity of 300 $fb^{-1}$ in the determination of both the CP-conserving and CP-violating parameters are obtained. Sensitivity of the probe of each of these couplings on the presence of other couplings is investigated. The most influential couplings parameters are $\bar c_W = -\bar c_B$. Other parameters of significant effect are $\bar c_{HW}$ and $\bar c_{HB}$ among the CP-conserving ones, and $\tilde c_{HW}$ and $\tilde c_{HB}$ among the CP-violating ones. CP-violating parameter, $\tilde c_\gamma$, seems to have very little influence on the process considered. Detailed study of the angular distributions have presented a way to disentangle the effect of some of these couplings.
1 Introduction

The discovery of the new resonance of mass around 125 GeV by the ATLAS and the CMS collaborations at LHC [1–13] provides a gateway to the investigations of dynamics of elementary particles. The discovery has unambiguously established the role of Higgs mechanism in the electroweak symmetry breaking (EWSB). All properties of the new particle measured so far are consistent with that of the Standard Higgs boson. Thus, one may be tempted to conclude that for all practical purposes, the newly found particle is like that of the SM Higgs boson, and new physics effects are decoupled as far as the Higgs sector is concerned. At the same time, it is well known that there are difficulties associated with the Higgs sector of the SM that need to be addressed. The main difficulty is the hierarchy problem associated with the quadratically diverging quantum corrections to the mass of the Higgs boson when computed in the SM. There is no remedy to this difficulty within the SM, and for a Higgs boson of mass 125 GeV, the new physics effects should show up within the TeV range to cure this malady. Assuming that the new physics effects are expected to appear only indirectly in the Higgs sector, it is natural to consider these effects through effective couplings of the Higgs bosons, with itself as well as with the gauge bosons and heavy fermions. Precise measurement of these couplings is very essential to establish the true nature of the EWSB mechanism. While LHC is capable of probing some of these couplings, especially the Higgs couplings with the gauge bosons and top quark, one may need to rely on cleaner machine like the International Linear Collider (ILC) [14–16] for the required precision. Another aspect that is very important to investigate is the CP properties of the couplings of the Higgs boson. Although the measurements so far indicate a CP even Higgs boson, it is not ruled out that the Higgs sector does not involve any CP-violation. One may remember that, one of the compelling reasons to look beyond the SM is the large CP violation necessary to understand the baryon asymmetry of the universe. There had been many studies on the CP properties of the Higgs boson in the past [17]. More recently there had been studies on CP properties of the Higgs interaction with the top quark [18], investigating the influence of a CP-mixed Higgs boson on the Yukawa couplings. Within an effective Lagrangian, the effect of new physics could be studied in the various couplings...
through the quantum corrections they acquire. Such an effective Lagrangian basically en-
codes the new physics effects in higher dimensional operators with anomalous couplings.
The study of Higgs sector through an effective Lagrangian goes back to Refs.[19–31]. More
recently, the Lagrangian including complete set of dimension-6 operators is studied by Refs.
[32–35]. For some of the recent references discussing the constraints on the anomalous cou-
plings within different approaches, please see Refs. [36–49]. Ref. [47] studied the H+V,
where V= Z, W, associated production at LHC and TeVatron to discuss the bounds ob-
tainable from the global fit to the presently available data, whereas Ref. [48] has discussed
the constraint on the parameters coming from LHC results as well as other precision data
from LEP, SLC and TeVatron. Experimental studies on the Higgs couplings at LHC are
presented in, for example, Refs. [50, 51]. The measurement of trilinear Higgs couplings
is best done through the process $e^+e^- \rightarrow ZHH$ [52–59, 61–63]. At the same time, this
process also depends on the Higgs-Gauge boson couplings, $ZZH$ and $ZZHH$, which will
affect the determination of the $HHH$ coupling. Another process that could probe the
$HHH$ couplings is $e^+e^- \rightarrow \nu\bar{\nu}HH$ following the WW fusion [56–59], which is also affected
by the $WWH$ and $WWHH$ couplings. In a recent study [60], we investigated the effect of
$VVH$ coupling, where $V = Z, W$, in the extraction of the $HHH$ coupling, and found that
a precise knowledge of the $WWH$ and $ZZH$ couplings is necessary to derive information
regarding the trilinear couplings.

The process, $e^+e^- \rightarrow W^-W^+H$ is well suited to study the Higgs to gauge boson
couplings [52–59, 61–63]. At the same time, this process also depends on the trilinear
Gauge boson couplings like $WW\gamma$, which can contaminate the effects of Higgs to gauge
boson couplings. In this report we will focus our attention on this process in some detail
within the framework of the effective Lagrangian. One goal of this study is to investigate
CP violation in Higgs sector through Higgs to gauge bosons couplings, and to understand
the significance of other couplings in their measurement.

The report is presented in the following way. In Section 2 the effective Lagrangian will
be presented, with the currently available constraint on the parameters. In Section 3 the
process under consideration will be presented, with details. In Section 4 the results will be
summarized.

2 General Setup

Refs. [27–30, 34, 47, 67] present the most general effective Lagrangian with dimension-
6 operators involving the Higgs bosons. Part of this Lagrangian relevant to the process
$e^+e^- \rightarrow W^-W^+H$ considered in this report is given by
\[
\mathcal{L}_{\text{Higgs}}^{\text{CPC}} = \frac{\bar{c}_H}{2v}\partial^\mu (\Phi^\dagger \Phi) \partial_\mu (\Phi^\dagger \Phi) + \frac{\bar{c}_v}{v^2} \lambda (\Phi^\dagger \Phi)^3 + \frac{\bar{c}_W}{m_W^2} g^2 \Phi^\dagger \Phi B_{\mu \nu} B^{\mu \nu} \\
+ \frac{\bar{c}_{HW}}{2m_W^2} i g (D^\mu \Phi^\dagger \sigma_k D^{\nu} \Phi) W^k_{\mu \nu} + \frac{\bar{c}_{HB}}{2m_W^2} i g' (D^\mu \Phi^\dagger D^\nu \Phi) B_{\mu \nu} \\
+ \frac{\bar{c}_W}{2m_W^2} i g (\Phi^\dagger \sigma_k \overleftrightarrow{D}^\mu \Phi) D^\mu W^k_{\mu} + \frac{\bar{c}_B}{2m_W^2} i g' (\Phi^\dagger \overleftrightarrow{D}^\mu \Phi) \partial^\nu B_{\mu \nu},
\]

\[
\mathcal{L}_{\text{CPV}}^{\text{CPC}} = i g \frac{\bar{c}_{HW}}{m_W^2} D^\mu \Phi^\dagger T_{2k} D^{\nu} \Phi \bar{W}^k_{\mu \nu} + i g' \frac{\bar{c}_{HB}}{m_W^2} D^\mu \Phi^\dagger D^\nu \Phi \bar{B}_{\mu \nu} \\
+ \frac{g^2}{2m_W^2} \epsilon_{ijk} W^i_{\mu \nu} W^\nu_{\rho \sigma} \bar{W}^{\rho \sigma k}
\]

where the dual field strength tensor are defined as \(\bar{B}_{\mu \nu} = \frac{1}{2} \epsilon_{\mu \nu \rho \sigma} B^{\rho \sigma}, \quad \bar{W}^k_{\mu \nu} = \frac{1}{2} \epsilon_{\mu \nu \rho \sigma} W^{\rho \sigma k}\) and \(\Phi^\dagger \overleftrightarrow{D}^\mu \Phi = \Phi^\dagger D^\mu \Phi - D^\mu \Phi^\dagger \Phi, \quad D^\mu\) being the appropriate covariant derivative operator, and \(\Phi\), the usual Higgs doublet in the SM. Also, \(W^k_{\mu \nu}\) and \(B_{\mu \nu}\) are the field tensors corresponding to the \(SU(2)_L\) and \(U(1)_Y\) of the SM gauge groups, respectively, with gauge couplings \(g\) and \(g'\), in that order. \(\sigma_k\) are the Pauli matrices, and \(\lambda\) is the usual (SM) quadratic coupling constant of the Higgs field. The above Lagrangian, leads to the following CP-conserving \((\mathcal{L}_{hV}^{\text{CPC}})\), and CP-violating \((\mathcal{L}_{hV}^{\text{CPV}})\) parts in the unitary gauge and mass basis [67].
with CP-violating couplings. These anomalous coefficients $\bar{c}_T$, $\bar{c}_{HW}$, $\bar{c}_{HB}$, $\bar{c}_\gamma$ are expected to be of the order

$$\bar{c}_T \sim \mathcal{O}\left(\frac{g_{NP}^2 v^2}{M^2}\right) \quad \text{and} \quad \bar{c}_{HW}, \bar{c}_{HB}, \bar{c}_\gamma \sim \mathcal{O}\left(\frac{g_{NP}^2 M_W^2}{16\pi^2 M^2}\right),$$

(2.5)



Table 1. Physical couplings in Eq. 2.2-2.4 are given in terms of the effective couplings in Eq. 2.1.

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where $g_{NP}$ denotes the generic coupling of the new physics, and $M$ is the new physics scale. This indicates that these couplings can be significantly large for strongly coupled physics. In contrast the coefficients of the operators such as $\bar{c}_W$ and $\bar{c}_B$ are given by

$$\bar{c}_B, \bar{c}_W \sim \mathcal{O}\left(\frac{m_W^2}{M^2}\right),$$

(2.6)

and therefore expected to be relatively suppressed or enhanced according to the ratio $g/g_{NP}$. Coming to the experimental bounds, electroweak precision data put the following constraints [32],

$$\bar{c}_T(m_Z) \in [-1.5, 2.2] \times 10^{-3} \quad \text{and} \quad (\bar{c}_W(m_Z) + \bar{c}_B(m_Z)) \in [-1.4, 1.9] \times 10^{-3}$$

(2.7)

This means, we can safely ignore the effect of $\bar{c}_T$ in our analysis. On the other hand, $\bar{c}_W$ and $\bar{c}_B$ are not independently constrained, leaving possibility of having large values with cancellation between them as per the above constraint. $\bar{c}_W$ itself, along with $\bar{c}_{HW}$ and $\bar{c}_{HB}$ is constrained from LHC observations on associated production of Higgs along with W in Ref. [47]. Consideration of the Higgs associated production along with W, ATLAS
and CMS along with D0 put a limit of $\bar{c}_W \in [-0.03, 0.01]$, when all other parameters are set to zero. A global fit using various information from ATLAS and CMS, including signal-strength information constrains the region in $\bar{c}_W - \bar{c}_{HW}$ plane, leading to a slightly more relaxed limit on $\bar{c}_W$, and a limit of about $\bar{c}_{HW} \in [-0.1, 0.06]$. The limit on $\bar{c}_{HB}$ estimated using a global fit in Ref. [47] is about $\bar{c}_{HB} \in [-0.05, 0.05]$ with a one parameter fit. The CP-violating couplings are largely unconstrained so far.

The purpose of this study is to understand how to exploit a precision machine like the ILC to investigate suitable process so as to derive information regarding these couplings. In the next section we shall explain the process of interest in the present case, and discuss the details to understand the influence of one or more of the couplings mentioned above.

3 Analyses of the process considered

The Feynman diagrams corresponding to the process $e^- e^+ \rightarrow W^- W^+ H$ in the SM are given in Fig.1. This process is basically influenced by Higgs to charged gauge bosons as well as neutral gauge bosons couplings like $WWH$, $ZZH$, $WW\gamma$ and $WWZ$, apart from the fermionic couplings, which are taken to be the standard couplings in our study.

![Feynman diagrams](image)

**Figure 1.** Feynman diagrams contributing to the process $e^- e^+ \rightarrow W^- W^+ H$ in the SM.

The effective Lagrangian, 2.1, apart from allowing the existing Higgs and gauge boson couplings non-standard, introduces new couplings which are absent in the SM. In a specific
model such effects appear at higher orders with new particle present in the loops. When
the masses of such particles are taken to be large, the effect of such quantum correction
be considered in terms of changed couplings. Such effective couplings arising in the
present analysis are presented in Table 1. Our numerical analyses are carried out using
MADGRAPH [65], with the Effective Lagrangian implemented through Feynrules [66, 67].
in deriving these limits are also indicated in these figures. Clearly, precise knowledge of the CP-conserving parameters $c_W$, $c_{HW}$ and $c_{HB}$ are required to obtain reasonably robust estimate of the CP-violating parameters. Among the CP-violating couplings, $c_{HW}$ affects the cross section most significantly, and the limits derivable on the other parameters are sensitive to their presence. The effect of the $c_{\gamma}$ is much smaller than the other couplings in finding the sensitivity of $c_{HW}$, and therefore not presented.

**Figure 3.** Cross section against $\tilde{c}_{HW}$ in the presence of selected CP-conserving (left) and CP-violating (right) couplings. The black solid line corresponds to the case when only $\tilde{c}_{HW}$ is present. The center of mass energy is assumed to be $\sqrt{s} = 500$ GeV. In each case, all other parameters are set to zero. The yellow band indicates the $3\sigma$ limit of the SM cross section, with an integrated luminosity of $300$ $fb^{-1}$.

**Figure 4.** Cross section against $\tilde{c}_{HB}$ in the presence of selected CP-conserving (left) and CP-violating (right) couplings. The black solid line corresponds to the case when only $\tilde{c}_{HB}$ is present. The center of mass energy is assumed to be $\sqrt{s} = 500$ GeV. In each case, all other parameters are set to zero. The yellow band indicates the $3\sigma$ limit of the SM cross section, with an integrated luminosity of $300$ $fb^{-1}$.
Figure 5. Cross section against $\tilde{c}_\gamma$ in the presence of selected CP-conserving (left) and CP-violating (right) couplings. The black solid line corresponds to the case when only $\tilde{c}_\gamma$ is present. The center of mass energy is assumed to be $\sqrt{s} = 500$ GeV. In each case, all other parameters are set to zero. The yellow band indicates the $3\sigma$ limit of the SM cross section, with an integrated luminosity of $300$ fb$^{-1}$.

The correlation between the $\tilde{c}_{HW}$ and $\tilde{c}_{HB}$ are presented in Fig. 6, where the yellow band shows the present limits derived from the LHC results on associated production of Higgs boson with the $W$ boson [47]. In the absence of any other parameter, the allowed region in the $\tilde{c}_{HW} - \tilde{c}_{HB}$ plane is restricted to a narrow band (red). This band is not affected much by the presence of $\tilde{c}_W$, if it is positive (green band). On the other hand, if $\tilde{c}_W$ is negative, within the present bounds, it can significantly affect the allowed region (blue band) in the $\tilde{c}_{HW} - \tilde{c}_{HB}$ plane. The presence of CP-violating parameters are found to be insignificant here.

It is essential to know the behavior of various kinematic distributions, and how the anomalous couplings parameters influence these, in order to derive any useful and reliable information from the experimental results. This is so, even in cases where the fitting to obtain the reach of the parameters is done with the total number of events, as the reconstruction of events and the reduction of the background depend crucially on the kinematic distributions of the decay products. In the following we shall present some illustrative cases of distributions at the production level, to understand the effect of different couplings on these. The changes in the kinematic distributions at the production level will also be carried over to the distributions of their decay products. Presently we would like to be content with the analysis at the production level, considering the limited scope of this work. As mentioned earlier we shall focus on an ILC running at a center of mass energy of 500 GeV for our study.

We first consider in Fig. 7, the normalized $\cos \theta_H$ distributions of the Higgs boson for the SM case, as well as different cases with anomalous couplings (both CP-conserving and violating) as indicated in the figure, while all other parameters are set to zero. The normalized distributions provide clear information on the shape of the distribution, bringing
**Figure 6.** The ellipses correspond to regions in the \(\bar{c}_{HB} - \bar{c}_{HW}\) plane with the total cross section is within the 3\(\sigma\) limit of SM cross section (red), and cross sections with \(\bar{c}_W = -0.03\) (blue) and \(\bar{c}_W = +0.01\) (green). An integrated luminosity of 300 \(fb^{-1}\) is considered, and the center of mass energy is taken as 500 GeV. The yellow and grey bands correspond to the present limits of \(\bar{c}_{HW}\) and \(\bar{c}_{HB}\), respectively.

**Figure 7.** Distribution of the \(\cos \theta_H\) for different anomalous couplings, with unpolarized (left) and polarized with \(P_{e^-} = -80\%\), \(P_{e^+} = +20\%\) (right) beams. A center of mass energy of 500 GeV is assumed. Color coding in the right figure is the same as that in the left figure.

Out the qualitative difference between different cases considered. Advantage of beam polarization is evident (figure on the right) when compared to the corresponding unpolarized (figure on the left) case. Presence of \(\bar{c}_{HW}\) alone (red solid) changes the distribution so that the cross section has an enhancement in the central region with a corresponding reduction in the axial region, when compared to the SM case (black solid). This effect is nullified when considered together with non-zero values of \(c_W\) (cyan solid). Similarly, negative value of \(c_W\) in the absence of other couplings shows (light brown dashed) deviation in the
distribution compared to the SM case, which is nullified by the presence of $\tilde{c}_{HW}$ (cyan dashed). The effect of $\tilde{c}_{HB}$ and $\tilde{c}_{\gamma}$ are not significant with or without the presence of other parameters.

Fig. 8 (left) presents the normalized $\cos \theta_W$ distribution. The negative value of $c_W$ changes the nature of the distribution drastically (dashed light brown) compared to the SM case (black solid). Other coupling combinations do not have significant effect, except again for $\tilde{c}_{HW}$. Fig. 8 (right) shows the normalized $\cos \theta_{WH}$ distribution, where $\theta_{WH}$ is the angle between $H$ and $W^-$. Here $\tilde{c}_{HW}$ has significant effect, which is not affected by the presence of $\tilde{c}_W$. On the other hand, the presence of negative $\tilde{c}_W$ alone has the opposite effect. As in the other two angular distributions, $\tilde{c}_{HB}$ and $\tilde{c}_{\gamma}$ have insignificant effect. Considering these three angular distributions together might allow us to distinguish different scenarios. For example, if $\tilde{c}_{HW}$ alone is present, we may expect significant effect in $\cos \theta_H$ and $\cos \theta_{WH}$ distributions, whereas $\cos \theta_W$ distribution remains more or less unaffected. Along with $\tilde{c}_{HW}$, if $\tilde{c}_W$ was present (either positive or negative), the effect in $\cos \theta_H$ is nullified, whereas the effect would remain in $\cos \theta_{WH}$. The change in $\cos \theta_W$, as shown in Fig. 8 (left) indicates the presence of negative value of $\tilde{c}_W$ with or without the presence of other couplings. Table 2 summarizes the cases that could be distinguished.

We also note that apart from the case of $\cos \theta_H$, the beam polarization does not change the qualitative picture. At the same time, the picture is clearer in the case of polarized beams compared to the case of unpolarized beams. Fig. 8 suggests that the Forward-Backward asymmetry is a quantitative estimator of the presence of anomalous couplings. The percentage of deviation from the SM case for the cases of considered set of parameters at fixed center-of-mass energy of 500 GeV without and with polarized beams are given in Table 3, where the asymmetry is defined as

$$A_{FB} = \left[ \frac{\sum_{\cos \theta = -1}^{0} \frac{d\sigma}{d\cos \theta} \Delta \cos \theta - \sum_{\cos \theta = 0}^{1} \frac{d\sigma}{d\cos \theta} \Delta \cos \theta}{\sum_{\cos \theta = -1}^{0} \frac{d\sigma}{d\cos \theta} \Delta \cos \theta + \sum_{\cos \theta = 0}^{1} \frac{d\sigma}{d\cos \theta} \Delta \cos \theta} \right]$$

(3.1)
Table 2. Presence (yes) or absence (no) of deviations that could be expected in case of different scenarios with combinations of $\tilde{c}_W$ and $\tilde{c}_{HW}$ realized from Fig. 7, 8.

| Couplings                        | $\cos \theta_H$ | $\cos \theta_W$ | $\cos \theta_{HW}$ |
|----------------------------------|------------------|------------------|---------------------|
| $\tilde{c}_{HW}$ alone           | yes              | no               | yes                 |
| $\tilde{c}_W$ (positive) alone   | no               | no               | no                  |
| $\tilde{c}_W$ (negative) alone   | yes              | yes              | yes                 |
| $\tilde{c}_{HW}$ and $\tilde{c}_W$ (positive) | no              | no               | yes                 |
| $\tilde{c}_{HW}$ and $\tilde{c}_W$ (negative) | no              | yes              | yes                 |

Table 3. Observed Forward-Backward asymmetry and its deviation from the SM in the angular distribution at center of mass energy of 500 GeV.

| $\tilde{c}_{HW}$ | $\tilde{c}_W = -\tilde{c}_B$ | $\Delta A_{FB}(\cos \theta_{W-H})\%$ |
|------------------|-----------------------------|-------------------------------------|
| $\Delta A_{FB}$  | $A_{FB}^{\text{Ano.}} - A_{FB}^{\text{SM}}$ | $A_{FB}^{\text{SM}} \times 100$ |
| $\Delta A_{FB}^{\text{SM}}$ | 0.3117 | 0.3164 |

Finally, we consider the normalized invariant mass distributions of $W^-W^+$ and $WH$. The Fig. 9 presents the sensitivity of invariant mass distribution to the anomalous couplings parameters for the same set of parameters as in the inset of Fig. 7. The combinations of the parameters affected are similar to the case of $\cos \theta_{HW}$. This can thus provides an additional tool to distinguish these scenarios. Again, the use of polarized beams marginally improve the situation.

4 Summary and Conclusions

The discovery of the Higgs boson by the ATLAS and the CMS collaborations at LHC, has confirmed the Higgs mechanism as the way to have EWSB, providing masses to the fundamental particles. The properties of the Higgs boson measured by LHC so far are consistent with the expectations of the SM. It is expected that the LHC would measure the mass, spin and parity of this particle along with the standard decay widths somewhat precisely. On the other hand, details of the couplings like the trilinear and quartic self-
couplings as well as the couplings with the gauge bosons are not expected to be measured precisely. At the same time, precise knowledge of these couplings are very important in reconstructing the EWSB mechanism. A precision machine like the International Linear Collider (ILC) is expected to help in precise measurement of these couplings. In this report the process \( e^-e^+ \rightarrow W^-W^+H \), which is basically associated with the Higgs to gauge bosons couplings namely \( WWH \), \( WW\gamma \) and \( ZZH \), is considered. The reach of an ILC at \( \sqrt{s} = 500 \) GeV with an integrated luminosity of 300 \( fb^{-1} \) in probing different relevant parameter of the corresponding effective Lagrangian are presented. The influence of the presence of other couplings in the probe of each of the couplings are studied. In general it is observed that the CP-violating coupling \( \tilde{c}_\gamma \) has very small effect on almost all of the observables considered. Study of the \( \tilde{c}_{HW} - \tilde{c}_{HB} \) plane shows that the allowed region can be narrowed to a very small band. While this band is unaffected by the presence of \( \tilde{c}_W > 0 \), the effect is significant if \( \tilde{c}_W < 0 \). Considering the angular distributions of the Higgs boson (\( \cos \theta_H \)), the \( W \) boson (\( \cos \theta_W \)) and the distributions of the angle between \( W \) and \( H \), (\( \cos \theta_{WH} \)) has proved to provide a handle in distinguishing the presence of different combinations of \( \tilde{c}_W \) and \( \tilde{c}_{HW} \). All other parameters have indistinguishable effect on these distributions. The invariant mass distributions of \( WW \) pair as well as \( WH \) pair are also sensitive to some combinations of the above parameters. A quantitative estimate of the Forward-Backward asymmetry corresponding to the angle between \( W \) and \( H \) show that large deviations of up to 50% is possible for moderate values of the couplings. In all cases, suitably chosen beam polarization is found to be advantageous, as illustrated with an 80% left polarized electron beam and 20% right polarized positron beam. The study has shown that \( WWH \) production at ILC is useful in detecting the anomalous couplings in Higgs-gauge boson interactions. Detailed analysis involving standard kinematic distributions could be used to distinguish different scenarios involving the couplings. While the numerical study need to be improved with more realistic collider and detector information, as well as

\[ \frac{1}{\sigma} \left( \frac{d\sigma}{dM_{WW}} \right) \]

\[ \Delta M_{WW} \]

\[ M_{WW} - M_{H} \] [GeV]

\[ \sqrt{s} = 500 \text{ GeV} \]

Figure 9. The invariant mass distribution of \( W^-W^+ \) (left) and \( WH \) (right), for different anomalous coupling values. A center of mass energy of 500 GeV is assumed. The color coding is same as in Fig 7.
study of the background processes, we hope to have conveyed the importance of the process in determining and disentangling the effects of anomalous Higgs-gauge boson couplings.

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