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# Determination of the Relative Sign of the Higgs Boson Couplings to $W$ and $Z$ Bosons Using $WH$ Production via Vector-Boson Fusion with the ATLAS Detector

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The associated production of Higgs and  $W$  bosons via vector-boson fusion is highly sensitive to the relative sign of the Higgs boson couplings to  $W$  and  $Z$  bosons. In this Letter, two searches for this process are presented, using  $140 \text{ fb}^{-1}$  of proton-proton collision data at  $\sqrt{s} = 13 \text{ TeV}$  recorded by the ATLAS detector at the LHC. The first search targets scenarios with opposite-sign couplings of the  $W$  and  $Z$  bosons to the Higgs boson, while the second targets standard model-like scenarios with same-sign couplings. Both analyses consider Higgs boson decays into a pair of  $b$  quarks and  $W$  boson decays with an electron or muon. The data exclude the opposite-sign coupling hypothesis with a significance beyond  $5\sigma$ , and the observed (expected) upper limit set on the cross section for vector-boson fusion  $WH$  production is 9.0 (8.7) times the standard model value at 95% confidence level.

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The study of the Higgs boson's couplings to  $W$  and  $Z$  bosons offers a crucial means of testing electroweak symmetry breaking in the standard model (SM). These couplings can be parametrized in terms of the coupling modifiers  $\kappa_W$  and  $\kappa_Z$ , where values of 1 correspond to the SM expectation, or in terms of their ratio  $\lambda_{WZ} = \kappa_W/\kappa_Z$  [1]. Any deviation of  $\lambda_{WZ}$  from 1 would indicate a violation of the SM's custodial symmetry and be a clear sign of physics beyond the standard model (BSM).

By combining measurements of many Higgs boson production and decay modes, the ATLAS [2] and CMS [3] collaborations have measured  $|\lambda_{WZ}|$  to be consistent with 1 with a precision of about 6%. However, this relies primarily on decays into  $WW^*$  or  $ZZ^*$ , vector-boson fusion (VBF) production, and  $WH$  and  $ZH$  associated production, all of which scale with the squares of  $\kappa_W$  and  $\kappa_Z$ . Therefore, the relative sign of these parameters is nearly unconstrained by current measurements, and they are both assumed to be positive in the coupling combinations. Negative values of  $\lambda_{WZ}$  are predicted by various models in which the observed Higgs boson is part of an isospin multiplet larger than a doublet [4], as in the Georgi-Machacek model [5], making an experimental determination of its sign a key priority. In contrast to those processes, the VBF  $WH$  production mechanism [6] includes diagrams where the Higgs boson couples to either a  $W$  or  $Z$  boson, as shown in Fig. 1. These

diagrams interfere destructively in the SM, preserving unitarization of longitudinal gauge-boson scattering, but the interference becomes constructive for negative values of  $\lambda_{WZ}$ . This leads to an enhancement in the cross section, particularly for events with large Higgs or  $W$  boson momentum. Therefore, a measurement of this process can be used to constrain the available  $(\kappa_Z, \kappa_W)$  parameter space with either the same or opposite sign. Furthermore, the enhancement is due to tree-level interference, and therefore does not rely on assumptions regarding BSM loop contributions. Other proposals to measure the sign of  $\lambda_{WZ}$  include exploiting one-loop interference effects in  $H \rightarrow 4\ell$  decays [7], or using  $W^+W^-H$  production [8].

This Letter presents two searches for VBF  $WH$  production at the LHC, each using  $140.1 \pm 1.2 \text{ fb}^{-1}$  [9] of  $\sqrt{s} = 13 \text{ TeV}$   $pp$  collision data collected by the ATLAS detector during 2015–2018. The first search (“negative  $\lambda_{WZ}$ ”) targets BSM scenarios with a negative coupling ratio, while the second (“positive  $\lambda_{WZ}$ ”) targets SM-like production. Both analyses consider Higgs boson decays into  $b\bar{b}$

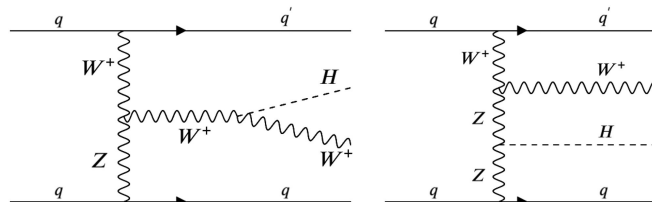


FIG. 1. Examples of leading-order Feynman diagrams for VBF  $WH$  production, where the Higgs boson interacts with either a  $W$  or  $Z$  boson. These diagrams interfere destructively if the Higgs boson couplings to  $W$  and  $Z$  have the same sign, and constructively if they have opposite sign.

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and  $W$  boson decays with an electron or muon (directly or via a  $\tau$  lepton). This leads to a final state with two  $b$  jets, two additional jets from the protons, a charged lepton, and missing transverse momentum ( $E_T^{\text{miss}}$ ) from the neutrino(s).

The ATLAS experiment [10] is a multipurpose particle detector with a forward-backward symmetric cylindrical geometry and nearly  $4\pi$  coverage in solid angle [11]. It consists of an inner detector (ID) for tracking surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadron calorimeters, and a muon spectrometer. A two-level trigger system is used to select events. The first-level trigger is implemented in hardware and uses a subset of the detector information to accept events at a rate below 100 kHz. This is followed by a software-based trigger that reduces the accepted event rate to 100 kHz on average depending on the data-taking conditions. An extensive software suite [12] is used in data simulation, in the reconstruction and analysis of real and simulated data, in detector operations, and in the trigger and data acquisition systems of the experiment.

The VBF  $WH$  process was simulated at leading-order accuracy in  $\alpha_s$  with MADGRAPH5\_AMC@NLO [13] for the matrix element calculation, interfaced to PYTHIA8 [14] for parton showering, hadronization, and multiple parton interactions. The NNPDF3.0NLO parton distribution function set [15] was used. Predictions were obtained for various values of  $\kappa_W$  and  $\kappa_Z$  using the procedure outlined in Ref. [6]. Because the Lagrangian is insensitive to an overall sign change, only positive values of  $\kappa_W$  were simulated. The largest backgrounds come from  $t\bar{t}$ ,  $W$  + jets, and  $Wt$  single-top production, with smaller contributions from  $t$ - and  $s$ -channel single-top,  $Z$  + jets,  $VV$ ,  $VH$ ,  $t\bar{t}H$ , and  $t\bar{t}V$  production ( $V = W$  or  $Z$ ). Backgrounds from  $t\bar{t}$  and single top quark production were simulated with POWHEG [16,17] interfaced to PYTHIA8. Overlap between  $Wt$  and  $t\bar{t}$  production was handled using the diagram removal scheme [18]. The  $W$  + jets and  $Z$  + jets processes were simulated with SHERPA2.2.1 [19] for the matrix element and parton showering. Different parton multiplicities were merged using the CKKW-L [20] technique. Electroweak production of  $WZ$  plus two jets was simulated at leading order with MADGRAPH5\_AMC@NLO interfaced to PYTHIA8. Other  $VV$  processes were simulated with SHERPA, version 2.2.1 for quark-initiated processes and 2.2.2 for gluon-initiated processes. Other Higgs boson processes were generated with POWHEG, with the MiNLO procedure [21] applied for quark-induced  $VH$ , and with PYTHIA8 used for parton showering. The  $t\bar{t}V$  process was simulated at NLO with MADGRAPH5\_AMC@NLO interfaced to PYTHIA8. The background arising from misidentified or nonprompt leptons is evaluated using events with inverted lepton isolation requirements. This background is seen to populate kinematic regions with low momentum objects and is found to be negligible after applying the final selection criteria that define the signal and control regions.

Events in the electron channel were selected online using a single-electron trigger [22]. In the muon channel, events where the vector sum of the offline  $E_T^{\text{miss}}$  and the muon  $p_T$  is greater than 150 GeV were selected with an  $E_T^{\text{miss}}$  trigger [23], while below this threshold a single-muon trigger [24] was used. (The trigger-level  $E_T^{\text{miss}}$  calculation does not include muons, making this vector sum a close approximation of the trigger-level  $E_T^{\text{miss}}$ .) Because of the changing beam conditions, the kinematic and isolation requirements on the trigger objects varied during the data-taking period. Electrons are reconstructed offline by matching clusters of energy deposits in the electromagnetic calorimeter to tracks in the ID, which are fitted allowing for energy loss due to bremsstrahlung [25]. Events in the electron channel must have one electron candidate with  $p_T > 27$  GeV and  $|\eta| < 2.47$  passing the ‘‘Tight’’ likelihood identification criteria and the ‘‘HighPtCaloOnly’’ isolation criteria of Ref. [25]. The electron must furthermore be matched to the primary vertex (the primary vertex is taken as the vertex with the highest sum of squared transverse momenta of associated tracks) by requiring  $|d_0|/\sigma_{d_0} < 5$  and  $|z_0 \sin(\theta)| < 0.5$  mm, where  $d_0$  is the track’s transverse impact parameter,  $\sigma_{d_0}$  is its uncertainty, and  $z_0$  is the longitudinal impact parameter. Muons are reconstructed offline by matching tracks in the ID and muon spectrometer, accounting for energy loss in the calorimeters [26]. Events in the muon channel must have one muon satisfying  $p_T > 25$  GeV (27 GeV) if an  $E_T^{\text{miss}}$  (a single-muon) trigger was used,  $|\eta| < 2.5$ , ‘‘Medium’’ quality, and ‘‘HighPtTrackOnly’’ isolation, as defined in Ref. [26]. Similarly to electrons, the track must satisfy  $|d_0|/\sigma_{d_0} < 3$  and  $|z_0 \sin(\theta)| < 0.5$  mm. In both channels, events are rejected if a second lepton is present. For this veto, the  $p_T$  requirement is lowered to 7 GeV, ‘‘Loose’’ identification and isolation requirements are applied [25,26], and the muon pseudorapidity range is widened to  $|\eta| < 2.7$ .

Jets are reconstructed from particle-flow objects [27], combined using the anti- $k_r$  [28] algorithm with a radius parameter of 0.4. Jets in the central region ( $|\eta| < 2.5$ ) must have  $p_T > 20$  GeV, while the  $p_T$  requirement is raised to 30 GeV for forward jets ( $2.5 < |\eta| < 4.5$ ). To reduce the effect of multiple collisions per bunch crossing, jets in the central (forward) region with  $p_T < 60$  GeV (120 GeV) must have a jet vertex tagger [29] score  $> 0.5$  (forward jet vertex tagger [30] score  $< 0.5$ ). Jets in the central region may be ‘‘ $b$  tagged’’, i.e., identified as containing a  $b$ -hadron decay, by combining information from sources such as secondary-vertex reconstruction, track impact parameter measurements, and decay-chain fitting. The deep-learning algorithm DL1r [31,32] is used, with a working point that has 70% efficiency for  $b$  jets from top quark decays. The rates at which charm and light-flavor jets are incorrectly tagged as  $b$  jets are around 10% and 0.3%, respectively [33,34]. In addition to the standard jet calibration [27],

TABLE I. Definition of the signal regions used in the analyses. The SRs for the positive- $\lambda_{WZ}$  analysis are orthogonal: events in  $\text{SR}_{\text{tight}}^+$  are excluded from  $\text{SR}_{\text{loose}}^+$ . The definition of the  $W$  boson system is given in the text.

Variable	Description	$\text{SR}^-$	$\text{SR}_{\text{loose}}^+$	$\text{SR}_{\text{tight}}^+$
$m_{b\bar{b}}$	Invariant mass of the two $b$ jets ( $b\bar{b}$ system).	$\in (105, 145)$ GeV	$\in (105, 145)$ GeV	$\in (105, 145)$ GeV
$\Delta R_{b\bar{b}}$	$\Delta R$ between the two $b$ jets.	$< 1.2$	$< 1.6$	$< 1.2$
$p_{\text{T}}^{b\bar{b}}$	$p_{\text{T}}$ of the $b\bar{b}$ system.	$> 250$ GeV	$> 100$ GeV	$> 180$ GeV
$m_{jj}$	Invariant mass of the VBF jets.	$\dots$	$> 600$ GeV	$> 1000$ GeV
$\Delta y_{jj}$	Rapidity separation of the VBF jets.	$> 4.4$	$> 3.0$	$> 3.0$
$m_{\text{top}}^{\text{lep}}$	Invariant mass of the $W$ and either $b$ jet that is closest to 172.7 GeV ( $m_{\text{top}}$ ).	$> 260$ GeV	$> 260$ GeV	$> 260$ GeV
$\xi_{Wb\bar{b}}$	$( y_{Wb\bar{b}} - y_{jj} /\Delta y_{jj})$ , where $y_{Wb\bar{b}}$ ( $y_{jj}$ ) is the rapidity of the $Wb\bar{b}$ (VBF-jet) system.	$< 0.3$	$< 0.3$	$< 0.3$
$\Delta\phi(Wb\bar{b}, jj)$	Azimuthal separation between the $Wb\bar{b}$ system and the VBF-jet system.	$\dots$	$\dots$	$> 2.7$
$N_{\text{jets}}^{\text{veto}}$	Number of nontagged, non-VBF jets with $p_{\text{T}} > 25$ GeV and $ \eta  < 2.5$ .	$\dots$	$\leq 1$	$= 0$

two corrections are applied to  $b$  jets to improve their energy resolution [35]. First, if any ‘‘Medium’’ [26] muons with  $p_{\text{T}} > 5$  GeV and  $|\eta| < 2.5$  are found within a cone of jet- $p_{\text{T}}$ -dependent size around the jet axis, the four-momentum of the closest muon is added to that of the jet. After this, a residual correction is applied to equalize the response to jets with leptonic or hadronic decays of heavy-flavor hadrons. The  $E_{\text{T}}^{\text{miss}}$  is calculated as the negative vector sum of the transverse momenta of all jets and leptons in the event, plus a track-based soft term accounting for other charged particles associated to the primary vertex [36].

Events must have exactly one charged lepton, exactly two  $b$ -tagged jets, and at least two nontagged jets. The two highest- $p_{\text{T}}$  nontagged jets are chosen as the VBF jets, and these are required to have a rapidity separation of  $\Delta y_{jj} > 3$ . After these requirements, approximately 430 000 background events, primarily  $t\bar{t}$ , are expected from simulation, compared to 860 signal events if  $\kappa_W = 1$  and  $\kappa_Z = -1$ , or 50 if both parameter values are 1. Selection criteria are applied to several kinematic variables to increase the signal-to-background ratio. These include the VBF jets’ invariant mass  $m_{jj}$  and rapidity separation  $\Delta y_{jj}$ , as well as the  $b$  jets’ invariant mass  $m_{b\bar{b}}$ , transverse momentum  $p_{\text{T}}^{b\bar{b}}$ , and angular separation  $\Delta R_{b\bar{b}}$ . The  $W$  boson is reconstructed by summing the four-momenta of the lepton and neutrino, where the neutrino is assumed to have  $p_{\text{T}}$  equal to the observed  $E_{\text{T}}^{\text{miss}}$  and  $\eta$  equal to that of the charged lepton. This is used to calculate the mass  $m_{\text{top}}^{\text{lep}}$  of leptonically decaying top quarks, the centrality  $\xi_{Wb\bar{b}}$ , and  $\Delta\phi(Wb\bar{b}, jj)$ , according to the definitions in Table I. Finally,  $N_{\text{jets}}^{\text{veto}}$  is defined as the number of jets with  $p_{\text{T}} > 25$  GeV and  $|\eta| < 2.5$ , which are not VBF or  $b$ -tagged jets. In the negative- $\lambda_{WZ}$  analysis, a single signal region named  $\text{SR}^-$  is used, while the positive- $\lambda_{WZ}$  analysis uses two orthogonal

regions,  $\text{SR}_{\text{loose}}^+$  and  $\text{SR}_{\text{tight}}^+$ , to enhance the sensitivity to the smaller SM signal. The selection criteria that define these regions are given in Table I; they were chosen to maximize the statistical significance, while keeping enough simulated events for robust estimation of the backgrounds and systematic uncertainties. Compared to the negative- $\lambda_{WZ}$  signal, the SM signal has lower Higgs boson  $p_{\text{T}}$ , but similar VBF jet  $p_{\text{T}}$  and additional jet activity. This motivates the higher  $p_{\text{T}}^{b\bar{b}}$  threshold in  $\text{SR}^-$ , and the requirements on  $m_{jj}$  and  $N_{\text{jets}}^{\text{veto}}$  in  $\text{SR}_{\text{loose}}^+$  and  $\text{SR}_{\text{tight}}^+$ . Distributions of the key kinematic observables used to define the signal regions are presented as Supplemental Material [37].

In order to improve the background estimation, control regions (CRs) are defined for  $t\bar{t}$ ,  $W + \text{jets}$ , and  $Wt$ , separately for the two analyses. The CRs are dominated by the targeted background and depleted of signal, while maintaining key kinematic features of the signal regions (SRs). The definitions of the CRs are given in the Appendix. For each analysis, the signal region(s) and the CRs are used together in a binned profile likelihood fit [38,39]. The number of events in each region is taken as the observable. The normalization of each of the main backgrounds is determined with an unconstrained parameter in the fit,  $k_{t\bar{t}}$ ,  $k_W$ , or  $k_{Wt}$ , while systematic uncertainties are treated as nuisance parameters with Gaussian or Poisson constraints.

Systematic uncertainties considered for the electrons and muons include those in the trigger, reconstruction, identification, and isolation efficiencies, and the energy or momentum scale and resolution [25,26]. For jets, uncertainties are considered for the energy scale and resolution [40], the vertex tagging efficiency [29,30], and the  $b$ -tagging efficiency for  $b$  jets [32],  $c$  jets [33], and light jets [34]. Uncertainties in the momenta of all objects are propagated to the  $E_{\text{T}}^{\text{miss}}$ ; additional uncertainties in the  $E_{\text{T}}^{\text{miss}}$  are considered

for the soft term [36] and for the trigger efficiency. Systematic uncertainties in the modeling of the main backgrounds are assessed by replacing the nominal Monte Carlo (MC) predictions described previously with ones from MADGRAPH5\_AMC@NLO interfaced to PYTHIA8, and, for  $t\bar{t}$  and  $Wt$ , by using HERWIG7 as an alternative parton shower algorithm. The treatment of overlap between  $t\bar{t}$  and  $Wt$  is varied by using the alternative diagram subtraction scheme [41]. These uncertainties are symmetrized. Additionally, the renormalization and factorization scales are varied by a factor of 2, and, for  $t\bar{t}$  and  $Wt$ , other parameters sensitive to initial-state radiation are also varied [42]. Because the normalization of these backgrounds is unconstrained in the likelihood fit, the systematic uncertainties affect only the relative contribution in each region. Uncertainties in the cross section and acceptance of the smaller backgrounds are also considered, but their impact on the analysis is small. For the VBF  $WH$  signal, the renormalization and factorization scales, the parton distribution function, and  $\alpha_s$  are varied [43]. In addition, an uncertainty in the modeling of additional jets in the positive- $\lambda_{WZ}$  analysis is assessed by using an alternative MC sample with up to one additional parton in the matrix element, merged using the CKKW-L technique. The total uncertainties of the signal yields in the SRs range from 11% to 27%.

Table II presents the normalization factors and background yields in each SR obtained from the fit, as well as the predicted signal and observed data yields. No significant pulls or constraints on any nuisance parameters are observed. Because the CRs are not fully pure in the targeted background, the normalization factors for these backgrounds are anticorrelated by up to 71% (for instance, a higher value of  $k_{t\bar{t}}$  would imply more  $t\bar{t}$  in the  $W + \text{jets}$  CR, and therefore a lower  $k_W$ ; see the Supplemental Material [37] for more information). This results in the total predicted yield having an uncertainty smaller than the uncertainty in some individual components. The postfit values of  $k_{t\bar{t}}$  and  $k_W$  are close to unity, indicating good modeling by the simulation. The values of  $k_{Wt}$  are significantly below 1 because the MC prediction exceeds the data in the  $Wt$  CRs. The phase space selected in this analysis is highly sensitive to the treatment of  $t\bar{t}$ - $Wt$  overlap; when using the alternative diagram subtraction scheme, a deficit of MC events is seen in the  $Wt$  CRs, and values of  $k_{Wt}$  close to 3 are obtained. The difference between the baseline MC prediction and data is therefore smaller than the difference between the two MC predictions used to estimate the systematic uncertainty. Moreover, because the  $Wt$  normalization is determined from the fit to data, the uncertainty in the measured signal strength from this source is less than 10% of the total uncertainty.

In the negative- $\lambda_{WZ}$  analysis, 70 data events are observed in  $\text{SR}^-$ , compared to an expectation of  $80.6 \pm 8.6$  assuming the SM (including  $2.93 \pm 0.35$  signal events), or  $361 \pm 46$  in the  $\kappa_W = 1, \kappa_Z = -1$  scenario. (This is less than the sum

TABLE II. Normalization factors, expected background and signal yields, and observed data yields in each signal region. The background yields are given after the fit to data, while the signal yields show both the prefit expectation and the fitted values. The VBF  $WH$  signal corresponds to the prediction with  $\kappa_W = 1, \kappa_Z = -1$  for  $\text{SR}^-$ , and  $\kappa_W = 1, \kappa_Z = 1$  for  $\text{SR}_{\text{loose}}^+$  and  $\text{SR}_{\text{tight}}^+$ . The uncertainty in the total background is smaller than the quadrature sum of individual uncertainty components because of correlations.

	Negative $\lambda_{WZ}$	Positive $\lambda_{WZ}$	
$k_{t\bar{t}}$	$0.88^{+0.30}_{-0.35}$	$0.96^{+0.21}_{-0.23}$	
$k_W$	$1.12^{+0.34}_{-0.25}$	$1.25^{+0.33}_{-0.24}$	
$k_{Wt}$	$0.32^{+0.39}_{-0.13}$	$0.31^{+0.37}_{-0.14}$	
$\mu = \sigma/\sigma_{\text{pred}}$	$-0.027^{+0.054}_{-0.057}$	$0.9^{+4.0}_{-4.3}$	
	$\text{SR}^-$	$\text{SR}_{\text{loose}}^+$	$\text{SR}_{\text{tight}}^+$
$t\bar{t}$	$42 \pm 19$	$172 \pm 35$	$15.0 \pm 5.8$
$W + \text{jets}$	$26 \pm 13$	$84 \pm 32$	$14.1 \pm 7.6$
$Wt$	$4.6 \pm 7.0$	$8 \pm 13$	$0.8 \pm 1.5$
Other background	$5.4 \pm 1.6$	$16.2 \pm 4.2$	$3.0 \pm 1.5$
Total background	$77.7 \pm 8.6$	$279 \pm 15$	$32.9 \pm 5.8$
VBF $WH$ , prefit	$285 \pm 45$	$4.15 \pm 0.56$	$2.30 \pm 0.62$
VBF $WH$ , postfit	$-8 \pm 17$	$4 \pm 17$	$2.2 \pm 9.8$
Data	70	274	37

of signal and background in Table II, due to the effect that signal contamination in the CRs would have on the background normalization factors.) Figure 2 shows confidence regions in the  $(\kappa_Z, \kappa_W)$  plane derived from the fit. These are compared with the confidence regions obtained from a combination of the ATLAS Higgs boson measurements collected in Ref. [2]. This combination assumes that all coupling modifiers other than  $\kappa_W$  and  $\kappa_Z$  are positive. The resulting fit excludes negative values of  $\kappa_W$ , primarily because of interference with the top quark in the loop decay  $H \rightarrow \gamma\gamma$ . However, a region of parameter space with negative values of  $\kappa_Z$  lies within one of the  $2\sigma$  boundaries from the previous measurements. This region is excluded by the present analysis with significance much greater than  $5\sigma$ . Thus the sign of  $\lambda_{WZ}$  is determined to be positive.

In the positive- $\lambda_{WZ}$  analysis, 274 (37) events are observed in  $\text{SR}_{\text{loose}}^+$  ( $\text{SR}_{\text{tight}}^+$ ), compared to an expected background of  $279 \pm 15$  ( $32.9 \pm 5.8$ ), and a SM signal of  $4.15 \pm 0.56$  ( $2.30 \pm 0.62$ ). The fitted value of the signal strength  $\mu = \sigma/\sigma_{\text{pred}}$  is  $0.9^{+2.3}_{-2.6}(\text{stat})^{+3.3}_{-3.4}(\text{syst}) = 0.9^{+4.0}_{-4.3}$ , indicating compatibility of the data with both the SM and background-only hypotheses. The largest systematic uncertainties come from the  $W + \text{jets}$  and  $t\bar{t}$  modeling, and the jet energy resolution. An upper limit of 9.0 is set on the signal strength at 95% confidence level (CL), compared to an expected limit of 8.7. The 95% CL limit on the cross section for SM-like

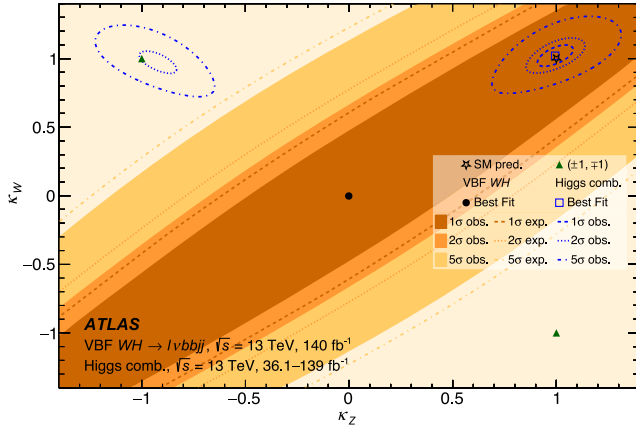


FIG. 2. Fit results in the  $(\kappa_Z, \kappa_W)$  plane, using the negative- $\lambda_{WZ}$  analysis. The results are overlaid with the confidence regions (shown in blue) from a separate fit using a combination of the Higgs boson measurements collected in Ref. [2]. This fit assumes that all Higgs boson couplings besides the ones represented are positive, and that only SM particles contribute to loop processes. Confidence regions are constructed from the log-likelihood ratio  $\Lambda_{LR} = -2 \ln(L/L_{\max})$ , where  $L_{\max}$  is the likelihood for the best-fit point, which is shown as a black dot for the VBF  $WH$  analysis or a blue dot for the Higgs combination. The  $1\sigma$ ,  $2\sigma$ , and  $5\sigma$  regions are defined by  $\Lambda_{LR}$  values smaller than 2.30, 6.18, and 28.7, respectively. The SM value is marked with a star, while green triangles mark the points with  $\kappa_Z = \pm 1$ ,  $\kappa_W = \mp 1$ .

VBF  $WH$  production times the branching ratio  $H \rightarrow b\bar{b}$  is 308 fb.

In conclusion, the VBF  $WH$  process has been studied by the ATLAS experiment, using  $140 \text{ fb}^{-1}$  of  $pp$  collision data at  $\sqrt{s} = 13 \text{ TeV}$ . Events with two  $b$  jets, a charged lepton, and two additional jets with a large rapidity gap are considered. No excess of events is observed above the SM expectation. The 95% CL upper limit set on the cross section for SM-like VBF  $WH$  production is 9.0 times the SM prediction, compared to an expected limit of 8.7. The  $W$  and  $Z$  boson couplings to the Higgs boson are determined to have the same sign, with previously unexcluded opposite-sign hypotheses now excluded with significance beyond  $5\sigma$ .

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[1] LHC Higgs Cross Section Working Group, *Handbook of LHC Higgs Cross Sections: 3. Higgs Properties*, edited by S. Heinemeyer, C. Mariotti, G. Passarino, and R. Tanaka (2013), [arXiv:1307.1347](https://arxiv.org/abs/1307.1347).

[2] ATLAS Collaboration, A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery, *Nature (London)* **607**, 52 (2022); **612**, E24 (2022).

[3] CMS Collaboration, A portrait of the Higgs boson by the CMS experiment ten years after the discovery, *Nature (London)* **607**, 60 (2022); **623**, E4 (2023).

[4] I. Low and J. Lykken, Revealing the electroweak properties of a new scalar resonance, *J. High Energy Phys.* **10** (2010) 053.

[5] H. Georgi and M. Machacek, Doubly charged Higgs bosons, *Nucl. Phys.* **B262**, 463 (1985).

[6] D. Stolarski and Y. Wu, Tree-level interference in vector boson fusion production of  $Vh$ , *Phys. Rev. D* **102**, 033006 (2020).

[7] Y. Chen, J. Lykken, M. Spiropulu, D. Stolarski, and R. Vega-Morales, Golden probe of electroweak symmetry breaking, *Phys. Rev. Lett.* **117**, 241801 (2016).

[8] C.-W. Chiang, X.-G. He, and G. Li, Measuring the ratio of  $HWW$  and  $HZZ$  couplings through  $W^+W^-H$  production, *J. High Energy Phys.* **08** (2018) 126.

[9] ATLAS Collaboration, Luminosity determination in  $pp$  collisions at  $\sqrt{s} = 13$  TeV using the ATLAS detector at the LHC, *Eur. Phys. J. C* **83**, 982 (2023).

[10] ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, *J. Instrum.* **3**, S08003 (2008).

[11] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the  $z$  axis along the beam pipe. The  $x$  axis points from the IP to the center of the LHC ring, and the  $y$  axis points upward. Polar coordinates  $(r, \phi)$  are used in the transverse plane,  $\phi$  being the azimuthal angle around the  $z$  axis. The pseudorapidity is defined in terms of the polar angle  $\theta$  as  $\eta = -\ln \tan(\theta/2)$  and is equal to rapidity  $y = 0.5 \ln[(E + p_z)/(E - p_z)]$  in the relativistic limit. Angular distance is measured in units of  $\Delta R \equiv \sqrt{(\Delta y)^2 + (\Delta \phi)^2}$ . The transverse momentum is defined as  $p_T = \sqrt{p_x^2 + p_y^2}$ .

[12] ATLAS Collaboration, The ATLAS collaboration software and firmware, Report No. ATL-SOFT-PUB-2021-001, 2021, <https://cds.cern.ch/record/2767187>.

[13] J. Alwall *et al.*, The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations, *J. High Energy Phys.* **07** (2014) 079.

[14] T. Sjöstrand *et al.*, An introduction to PYTHIA8.2, *Comput. Phys. Commun.* **191**, 159 (2015).

[15] R. D. Ball *et al.* (NNPDF Collaboration), Parton distributions for the LHC run II, *J. High Energy Phys.* **04** (2015) 040.

[16] S. Frixione, G. Ridolfi, and P. Nason, A positive-weight next-to-leading-order Monte Carlo for heavy flavour hadroproduction, *J. High Energy Phys.* **09** (2007) 126.

[17] P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms, *J. High Energy Phys.* **11** (2004) 040.

[18] S. Frixione, E. Laenen, P. Motylinski, C. White, and B. R. Webber, Single-top hadroproduction in association with a  $W$  boson, *J. High Energy Phys.* **07** (2008) 029.

[19] E. Bothmann *et al.*, Event generation with SHERPA2.2, *SciPost Phys.* **7**, 034 (2019).

[20] L. Lönnblad, Correcting the colour-dipole cascade model with fixed order matrix elements, *J. High Energy Phys.* **05** (2002) 046.

[21] G. Luisoni, P. Nason, C. Oleari, and F. Tramontano,  $HW^\pm/HZ + 0$  and 1 jet at NLO with the POWHEG BOX interfaced to GoSam and their merging within MiNLO, *J. High Energy Phys.* **10** (2013) 083.

[22] ATLAS Collaboration, Performance of electron and photon triggers in ATLAS during LHC Run 2, *Eur. Phys. J. C* **80**, 47 (2020).

[23] ATLAS Collaboration, Performance of the missing transverse momentum triggers for the ATLAS detector during Run-2 data taking, *J. High Energy Phys.* **08** (2020) 080.

[24] ATLAS Collaboration, Performance of the ATLAS muon triggers in Run 2, *J. Instrum.* **15**, P09015 (2020).

[25] ATLAS Collaboration, Electron and photon performance measurements with the ATLAS detector using

- the 2015–2017 LHC proton–proton collision data, *J. Instrum.* **14**, P12006 (2019).
- [26] ATLAS Collaboration, Muon reconstruction and identification efficiency in ATLAS using the full Run 2  $pp$  collision data set at  $\sqrt{s} = 13$  TeV, *Eur. Phys. J. C* **81**, 578 (2021).
- [27] ATLAS Collaboration, Jet reconstruction and performance using particle flow with the ATLAS detector, *Eur. Phys. J. C* **77**, 466 (2017).
- [28] M. Cacciari, G. P. Salam, and G. Soyez, The anti- $k_r$  jet clustering algorithm, *J. High Energy Phys.* **04** (2008) 063.
- [29] ATLAS Collaboration, Tagging and suppression of pileup jets with the ATLAS detector, Report No. ATLAS-CONF-2014-018, 2014, <https://cds.cern.ch/record/1700870>.
- [30] ATLAS Collaboration, Forward jet vertex tagging using the particle flow algorithm, Report No. ATL-PHYS-PUB-2019-026, 2019, <https://cds.cern.ch/record/2683100>.
- [31] ATLAS Collaboration, Optimisation and performance studies of the ATLAS  $b$ -tagging algorithms for the 2017-18 LHC run, Report No. ATL-PHYS-PUB-2017-013, 2017, <https://cds.cern.ch/record/2273281>.
- [32] ATLAS Collaboration, ATLAS  $b$ -jet identification performance and efficiency measurement with  $t\bar{t}$  events in  $pp$  collisions at  $\sqrt{s} = 13$  TeV, *Eur. Phys. J. C* **79**, 970 (2019).
- [33] ATLAS Collaboration, Measurement of the  $c$ -jet mistagging efficiency in  $t\bar{t}$  events using  $pp$  collision data at  $\sqrt{s} = 13$  TeV collected with the ATLAS detector, *Eur. Phys. J. C* **82**, 95 (2022).
- [34] ATLAS Collaboration, Calibration of the light-flavour jet mistagging efficiency of the  $b$ -tagging algorithms with  $Z +$  jets events using 139 fb $^{-1}$  of ATLAS proton–proton collision data at  $\sqrt{s} = 13$  TeV, *Eur. Phys. J. C* **83**, 728 (2023).
- [35] ATLAS Collaboration, Evidence for the  $H \rightarrow b\bar{b}$  decay with the ATLAS detector, *J. High Energy Phys.* **12** (2017) 024.
- [36] ATLAS Collaboration, Performance of missing transverse momentum reconstruction with the ATLAS detector using proton–proton collisions at  $\sqrt{s} = 13$  TeV, *Eur. Phys. J. C* **78**, 903 (2018).
- [37] See Supplemental Material at <http://link.aps.org/supplemental/10.1103/PhysRevLett.133.141801> for additional information on the analysis and results.
- [38] M. G. Kendall and A. Stuart, *The Advanced Theory of Statistics, Volume 2: Inference and Relationship* (Charles Griffin, London, 1961).
- [39] G. Cowan, K. Cranmer, E. Gross, and O. Vitells, Asymptotic formulae for likelihood-based tests of new physics, *Eur. Phys. J. C* **71**, 1554 (2011).
- [40] ATLAS Collaboration, Jet energy scale and resolution measured in proton–proton collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector, *Eur. Phys. J. C* **81**, 689 (2021).
- [41] C. D. White, S. Frixione, E. Laenen, and F. Maltoni, Isolating  $Wt$  production at the LHC, *J. High Energy Phys.* **11** (2009) 074.
- [42] ATLAS Collaboration, Study of top-quark pair modelling and uncertainties using ATLAS measurements at  $\sqrt{s} = 13$  TeV, Report No. ATL-PHYS-PUB-2020-023, 2020, <https://cds.cern.ch/record/2730443>.
- [43] J. Butterworth *et al.*, PDF4LHC recommendations for LHC Run II, *J. Phys. G* **43**, 023001 (2016).
- [44] ATLAS Collaboration, ATLAS computing acknowledgements, Report No. ATL-SOFT-PUB-2023-001, 2023, <https://cds.cern.ch/record/2869272>.

## End Matter

*Appendix*—In order to improve the background estimation, control regions (CRs) are defined for  $t\bar{t}$ ,  $W +$  jets, and  $Wt$ , separately for the two analyses. The CRs are designed to be dominated by the targeted background and depleted of signal, while maintaining

important kinematic features of the signal regions. Table III presents the definitions of the CRs for each of the two analyses. The  $t\bar{t}$  CRs use the high  $m_{b\bar{b}}$  sideband, and consider values of  $\Delta y_{jj}$  or  $m_{jj}$  that are lower than in the SRs. The  $t\bar{t}$  events with high  $m_{\text{top}}^{\text{lep}}$  often have a

TABLE III. Definitions of the control regions for  $t\bar{t}$ ,  $W +$  jets, and  $Wt$ . The  $W$  boson’s transverse momentum  $p_{\text{T}}^W$  is the vector sum of the lepton  $p_{\text{T}}$  and  $E_{\text{T}}^{\text{miss}}$ ; the  $W$  boson’s transverse mass is calculated as  $m_{\text{T}}^W = \sqrt{2E_{\text{T}}^{\text{miss}}p_{\text{T}}^{\ell}(1 - \cos\phi)}$ , where  $\phi$  is the azimuthal angle between the lepton and  $E_{\text{T}}^{\text{miss}}$ ;  $p_{\text{T}}^{j1}$  is the  $p_{\text{T}}$  of the leading VBF jet. Other variables are defined in Table I.

Variable	$t\bar{t}$ CR $^{-}$	$t\bar{t}$ CR $^{+}$	$W +$ jets CR $^{-}$	$W +$ jets CR $^{+}$	$Wt$ CR $^{-}$	$Wt$ CR $^{+}$
$m_{b\bar{b}}$	$> 145$ GeV	$> 145$ GeV	$< 70$ GeV	$< 70$ GeV	$> 145$ GeV	$> 145$ GeV
$\Delta R_{b\bar{b}}$	$< 1.2$	$< 1.2$	$< 2.23 - 0.007p_{\text{T}}^{b\bar{b}}/\text{GeV}$	$< 2.23 - 0.007p_{\text{T}}^{b\bar{b}}/\text{GeV}$	$> 1.5$	$> 1.6$
$p_{\text{T}}^{b\bar{b}}$	$> 200$ GeV	$\dots$	$\in (150, 250)$ GeV	$> 80$ GeV	$> 250$ GeV	$> 180$ GeV
$m_{\text{top}}^{\text{lep}}$	$> 260$ GeV	$> 220$ GeV	$> 275$ GeV	$> 260$ GeV	$> 320$ GeV	$> 320$ GeV
$\Delta y_{jj}$	$\in (3, 4.4)$	$> 3$	$> 3$	$> 3$	$> 3$	$> 3$
$m_{jj}$	$\dots$	$\in (400, 1000)$ GeV	$\dots$	$> 500$ GeV	$\dots$	$> 500$ GeV
$N_{\text{jets}}^{\text{veto}}$	$\dots$	$< 2$	$\dots$	$< 1$	$\dots$	$< 2$
$p_{\text{T}}^W$	$\dots$	$< 350$ GeV	$\dots$	$\dots$	$> 250$ GeV	$> 250$ GeV
$m_{\text{T}}^W$	$\dots$	$\dots$	$\dots$	$< 200$ GeV	$\dots$	$\dots$
$p_{\text{T}}^{j1}$	$\dots$	$\dots$	$> 70$ GeV	$> 70$ GeV	$< 350$ GeV	$< 350$ GeV



misidentified charm jet in place of the  $b$  jet from leptonic top quark decay; to preserve this feature, the  $t\bar{t}$  CRs maintain a minimum threshold for this variable. The  $W$  + jets CRs use a two-dimensional cut on  $\Delta R_{b\bar{b}}$  and  $p_T^{b\bar{b}}$  to find events where the  $b$  jets are too close

together to be consistent with the Higgs boson mass. The  $Wt$  CRs use high values of  $\Delta R_{b\bar{b}}$  to remove signal, and high values of  $m_{\text{top}}^{\text{lep}}$  and  $W$  boson  $p_T$  to reduce the contamination from  $t\bar{t}$  events.

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Akiyama<sup>168</sup>, N. N. Akolkar<sup>24</sup>, S. Aktas<sup>21a</sup>, K. Al Khoury<sup>41</sup>, G. L. Alberghi<sup>23b</sup>, J. Albert<sup>165</sup>, P. Albicocco<sup>53</sup>, G. L. Albouy<sup>60</sup>, S. Alderweireldt<sup>52</sup>, Z. L. Alegria<sup>121</sup>, M. Aleksa<sup>36</sup>, I. N. Aleksandrov<sup>38</sup>, C. Alexa<sup>27b</sup>, T. Alexopoulos<sup>10</sup>, F. Alfonsi<sup>23b</sup>, M. Algren<sup>56</sup>, M. Alhroob<sup>120</sup>, B. Ali<sup>132</sup>, H. M. J. Ali<sup>91</sup>, S. Ali<sup>148</sup>, S. W. Alibocus<sup>92</sup>, M. Aliev<sup>145</sup>, G. Alimonti<sup>71a</sup>, W. Alkahi<sup>55</sup>, C. Allaire<sup>66</sup>, B. M. M. Allbrooke<sup>146</sup>, J. F. Allen<sup>52</sup>, C. A. Allendes Flores<sup>137f</sup>, P. P. Allport<sup>20</sup>, A. Aloisio<sup>72a,72b</sup>, F. Alonso<sup>90</sup>, C. Alpigiani<sup>138</sup>, M. Alvarez Estevez<sup>99</sup>, A. Alvarez Fernandez<sup>100</sup>, M. Alves Cardoso<sup>56</sup>, M. G. Alviggi<sup>72a,72b</sup>, M. Aly<sup>101</sup>, Y. Amaral Coutinho<sup>83b</sup>, A. Ambler<sup>104</sup>, C. Amelung<sup>36</sup>, M. Amerl<sup>101</sup>, C. G. Ames<sup>109</sup>, D. Amidei<sup>106</sup>, S. P. Amor Dos Santos<sup>130a</sup>, K. R. Amos<sup>163</sup>, V. Ananiev<sup>125</sup>, C. Anastopoulos<sup>139</sup>, T. Andeen<sup>11</sup>, J. K. Anders<sup>36</sup>, S. Y. Andrean<sup>47a,47b</sup>, A. Andreatta<sup>71a,71b</sup>, S. Angelidakis<sup>9</sup>, A. Angerami<sup>41,d</sup>, A. V. Anisenkov<sup>37</sup>, A. Annovi<sup>74a</sup>, C. Antel<sup>56</sup>, M. T. Anthony<sup>139</sup>, E. Antipov<sup>145</sup>, M. Antonelli<sup>53</sup>, F. Anulli<sup>75a</sup>, M. Aoki<sup>84</sup>, T. Aoki<sup>153</sup>, J. A. Aparisi Pozo<sup>163</sup>, M. A. Aparo<sup>146</sup>, L. Aperio Bella<sup>48</sup>, C. Appelt<sup>18</sup>, A. Apyan<sup>26</sup>, N. Aranzabal<sup>36</sup>, S. J. Arbiol Val<sup>87</sup>, C. Arcangeletti<sup>53</sup>, A. T. H. Arce<sup>51</sup>, E. Arena<sup>92</sup>, J.-F. 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