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The Compact Muon Solenoid Experiment

Conference Report

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Higgs boson production cross section and couplings in the W boson pair decay channel in pp collisions at $\sqrt{s} = 13$ TeV with the CMS detector

Ganapati Dash on behalf of the CMS Collaboration

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The production cross sections of the Standard Model Higgs boson decaying into a pair of W bosons have been measured in proton-proton collisions at a center-of-mass energy of 13 TeV. The analysis targets Higgs bosons produced through gluon-gluon fusion, vector boson fusion, and in association with a vector boson. Candidate events were selected based on the presence of at least two charged leptons and moderate missing transverse momentum, focusing on scenarios where at least one leptonically decaying W boson is originating from the Higgs boson. The results are presented as both inclusive and differential cross sections within the simplified template cross section framework, and include measurements of the Higgs boson's couplings to vector bosons and fermions. Data collected by the CMS detector from 2016 to 2018, corresponding to an integrated luminosity of $138\,\mathrm{fb}^{-1}$, were utilized for this analysis. The signal strength modifier, defined as the ratio of the observed production rate in a specific decay channel to the Standard Model expectation, was measured and found to be consistent with the Standard Model.

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Abstract. The production cross sections of the Standard Model Higgs boson decaying into a pair of W bosons have been measured in proton-proton collisions at a center-of-mass energy of 13 TeV. The analysis targets Higgs bosons produced through gluon-gluon fusion, vector boson fusion, and in association with a vector boson. Candidate events were selected based on the presence of at least two charged leptons and moderate missing transverse momentum, focusing on scenarios where at least one leptonically decaying W boson is originating from the Higgs boson. The results are presented as both inclusive and differential cross sections within the simplified template cross section framework, and include measurements of the Higgs boson's couplings to vector bosons and fermions. Data collected by the CMS detector from 2016 to 2018, corresponding to an integrated luminosity of 138 fb^{-1}, were utilized for this analysis. The signal strength modifier, defined as the ratio of the observed production rate in a specific decay channel to the Standard Model expectation, was measured and found to be consistent with the Standard Model.

1 Introduction

The Higgs boson was discovered by the ATLAS and CMS collaborations in 2012 [1–3], and since then, there has been a constant effort to measure its properties precisely. Among the Higgs boson decay channels, the decay into a pair of W bosons has the second largest branching fraction (22%) and a lower background than the b-quark decay, making it highly sensitive for measuring the Higgs boson production cross section and its couplings. This study is focused on gluon fusion, vector boson fusion (VBF), and associated production with a vector boson (VH), analyzed in final states with at least two charged leptons from either the associated vector boson or W decays, requiring at least one W boson from the Higgs boson to decay leptonically [4]. The Higgs boson properties are investigated by measuring inclusive cross sections for each production mechanism and by analyzing production cross sections in detailed phase spaces defined by the simplified template cross section (STXS) framework. Additionally, measurements of the Higgs boson couplings to fermions and vector bosons are studied.

These events used are based on datasets obtained in pp collisions at $\sqrt{s} = 13$ TeV with the CMS detector [5] at the LHC, corresponding to a total integrated luminosity of 138 fb^{-1}, with contributions of 36.3 fb^{-1}, 41.5 fb^{-1}, and 59.7 fb^{-1} from the years 2016, 2017, and 2018, respectively.

2 Event selection and categorization

Events are selected by requiring at least two high p_T charged leptons, $p_T^{miss} >$ 20GeV, and a variable number of hadronic jets with $p_T > 30$GeV. Higgs bosons produced via ggH, VBF, and VH are categorized into different-flavor (DF- $e\mu$) and same-flavor (SF- $ee/\mu\mu$) classes. VH categories with leptonically decaying vector bosons are subdivided based on the number of leptons and jets: WHSS (same sign), WH3ℓ, ZH3ℓ, and ZH4ℓ, WH $\rightarrow \ell^{\pm}\ell^{\pm}2\nu qq$, WH $\rightarrow 3\ell 3\nu$, ZH $\rightarrow 3\ell\nu qq$, and ZH $\rightarrow 4\ell 2\nu$ processes, respectively. Events with additional leptons with $p_T > 10$ GeV are excluded.

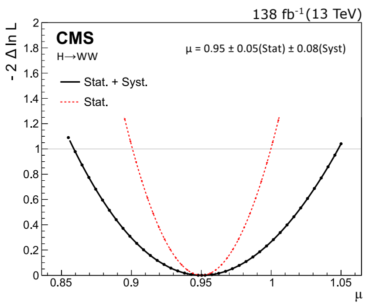
The analysis reports signal strength modifiers, STXS cross sections, and coupling modifiers via a simultaneous maximum likelihood fit across all categories, assuming a Higgs boson mass of 125.38 GeV. Results are given as signal strength modifiers μ, defined as the production cross section times the branching ratio to a W boson pair, normalized to the SM prediction. Higgs boson couplings to fermions and vector bosons are measured within the κ framework, and STXS results are reported as cross sections. Background estimates from data control samples cover non-prompt, top quark, nonresonant WW, Drell-Yan, and multiboson backgrounds.

3 Results

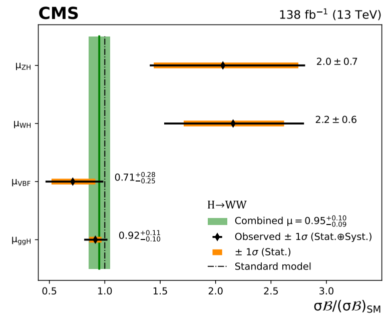
The global signal strength modifier is determined by fitting the template to data, using any of $m_{\ell\ell}$, m_T^H, p_T^H, or DNN parameters (C_{VBF} OR C_{ggH}), allowing all contributions from the Higgs boson to vary freely while keeping the relative contributions of different production modes fixed to their Standard Model (SM) predictions. The observed signal strength modifier is: $\mu = 0.95^{+0.10}_{-0.09} = 0.95 \pm 0.05\,(\mathrm{stat}) \pm 0.08\,(\mathrm{syst})$ as shown in figure 1a.

In the κ framework, coupling modifiers κ_V and κ_f scale the Higgs boson yield in the $H \rightarrow WW$ as $\sigma^i \mathcal{B}(H \rightarrow WW) = \kappa_i^2 \frac{\kappa_V^2}{\kappa_H^2} \sigma^i_{\mathrm{SM}} \mathcal{B}_{\mathrm{SM}}(H \rightarrow WW)$, where σ_i is cross section for different production modes and κ_H is the total width modifier. Here, κ_i equals κ_f for ggH, ttH, and bbH modes, and κ_V for VBF and VH modes, yielding best-fit values of $\kappa_V = 0.99 \pm 0.05$ and $\kappa_f = 0.86^{+0.14}_{-0.11}$, with large sensitivity in κ_V from the $H \rightarrow WW$ vertex.

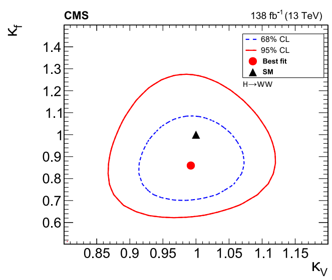
In the STXS framework, cross sections for different Higgs boson production mechanisms are measured in exclusive phase space regions (STXS bins). Each control region (CR) is subdivided to align with the STXS bin structure following the Stage 1.2 STXS framework [4]. Results are reported as signal strength modifiers and cross sections, with uncertainties separated into statistical, theoretical, and experimental components.



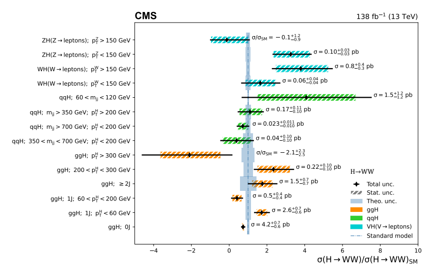
(a) Observed profile-likelihood function for μ



(b) Observed signal strength modifiers for the main SM production modes



(c) Two-dimensional likelihood profile as a function of the coupling modifiers κ_V and κ_f



(d) Observed cross sections of the H $\to$ WW process in each STXS bin, normalized to the SM expectation.

Fig. 1: Plots representing Signal strength modifiers, Higgs boson production cross section and couplings using $H \to WW$ decay modes[4].

References

1. ATLAS Collaboration: Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC. Phys. Lett. B 716, 1–29 (2012). doi:10.1016/j.physletb.2012.08.020
2. CMS Collaboration: Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC. Phys. Lett. B 716, 30–61 (2012). doi:10.1016/j.physletb.2012.08.021
3. CMS Collaboration: Observation of a New Boson with Mass Near 125 GeV in pp Collisions at $\sqrt{s} = 7$ and 8 TeV. JHEP 06,081(2013). doi:10.1007/JHEP06(2013)081
4. CMS Collaboration: Measurements of the Higgs boson production cross section and couplings in the W boson pair decay channel in proton-proton collisions at $\sqrt{s} =$ 13 TeV. Eur. Phys. J. C 83, 667 (2023). doi.org/10.1140/epjc/s10052-023-11632-6
5. CMS Collaboration: The CMS experiment at the CERN LHC. J. Instrum. 3, S08004 (2008). IOP. doi:10.1088/1748-0221/3/08/S08004