SM H→WW VH leptonic modes - Full Run 2

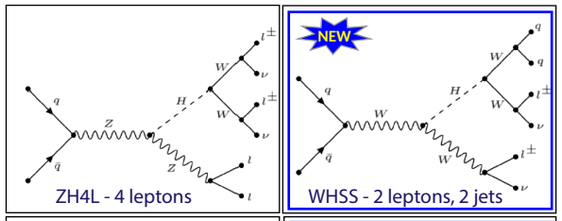
Sahithi Rudrabhatla, University of Illinois at Chicago

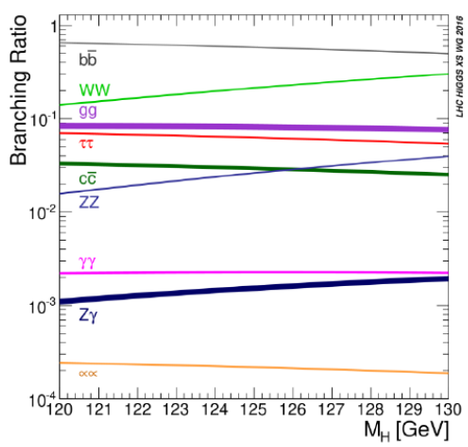
https://cds.cern.ch/record/2758367/
On behalf of the CMS Collaboration
LHCP 2021

ABSTRACT

Recent measurements of the Higgs boson production cross section in the H->WW decay channel using proton-proton collision data with CMS experiment at 13 TeV will be presented. In particular the Higgs boson production in association with leptonically decaying vector bosons is targeted, and the H->WW decays in which at least one W boson decays to leptons are considered. Results for both the inclusive production cross section and cross sections in the STXS scheme will be presented

MOTIVATION AND INTRODUCTION





Large Higgs boson branching ratio to a W boson pair and direct handle on Higgs boson coupling to vector bosons makes this decay mode interesting.

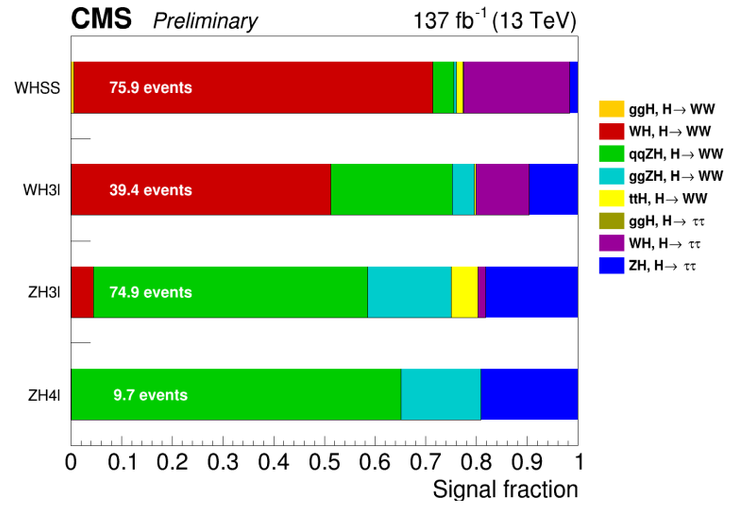
The VH leptonic production cross section is measured in the WHSS, WH3l, ZH3l, and ZH4l decay channels. The four channels are differentiated by the number of leptons and jets in the final state

Simplified Template Cross Sections (STXS)

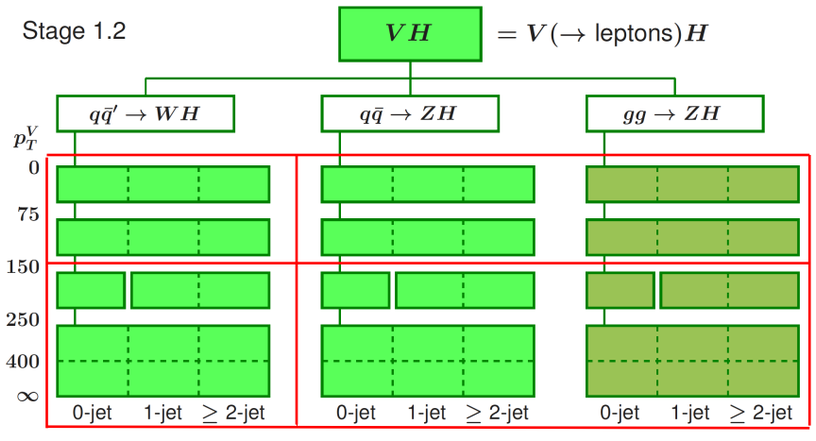
Motivation:
Maximize the sensitivity of the measurements to kinematics and minimize dependence on theoretical uncertainties.

Signal strength measurement:
Signal is divided into bins of true vector boson p_T and data is divided into bins of reconstructed p_T. Signal strengths in each true p_T bin is extracted in simultaneous fit to reconstructed p_T bins.

SIGNAL COMPOSITION



SIMPLIFIED TEMPLATE CROSS SECTIONS (STXS)



Definition of p^V_T

WHSS: $p_T^W = p_T(l_W) + p_T(\nu_W)$

$$= p_T(l_W) + E_T^{miss} - p_T(\nu_H)$$

$$p_T(\nu_H) = p_T(l_H) * \left(\frac{125}{||p_T(l_H) + p_T(jj)||} - 1\right)$$

WH3L: $p_T(l_W)$ is used as a proxy for W p_T

ZH3L, ZH4L: p_T of OSSF lepton pair is used as Z p_T; $m_{ll} \sim m_z$

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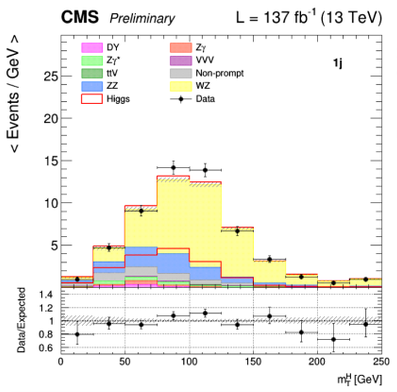
BASELINE SELECTION AND ANALYSIS STRATEGY

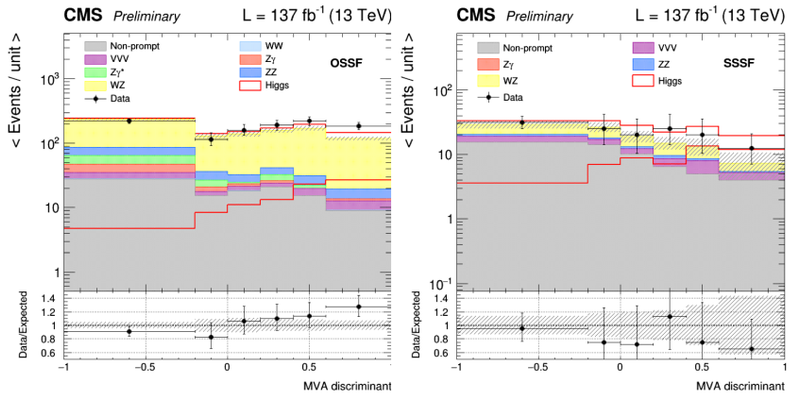
ZH3l

Backgrounds:
WZ, ZZ, Non-prompt(Z+Jets)

Fit kinematic:
m_T(/+MET,j(j)) in 1j, 2j SRs
(Higgs mass proxy)



	Preselection			
Lepton p_T (GeV)	$> 25, 20, 15$			
Fourth lepton p_T (GeV)	< 10			
$ch_{\ell\ell\ell}$	± 1			
$\min(m_{\ell\ell})$ (GeV)	> 12			
b jet veto	DeepCSV, medium WP, applied to all jets with $p_T > 20$ GeV			
$\lvert m_{\ell\ell} - m_Z \rvert$ (GeV)	< 25			
$\lvert m_{\ell\ell\ell} - m_Z \rvert$ (GeV)	> 20			
	1j SR	2j SR	1j WZ CR	2j WZ CR
Jets with $p_T > 30$ GeV	==1	≥ 2	==1	≥ 2
$\Delta\varphi(\ell p_T^{miss}, j(j))$	$< \pi/2$	$< \pi/2$	$> \pi/2$	$> \pi/2$

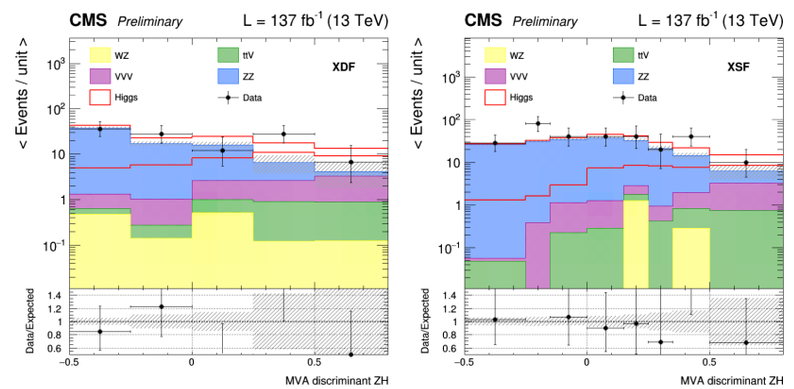


ZH4L

Backgrounds: ZZ

Fit kinematic:
BDT discriminant in XSF, XDF regions

	Preselection		
Lepton p_T (GeV)	$> 25, 15, 10, 10$		
Fifth lepton p_T (GeV)	< 10		
$ch_{\ell\ell\ell\ell}$	0		
$\min(m_{\ell\ell})$ (GeV)	< 12		
$\lvert m_{\ell\ell}^Z - m_Z \rvert$ (GeV)	< 15		
B jet veto	DeepCSV, loose WP, applied to all jets with $p_T > 20$ GeV		
	XSF SR	XDF SR	ZZ CR
X pair flavor	Same	Different	
$m_{\ell\ell\ell\ell}$ (GeV)	> 140		
$m_{\ell\ell}^X$ (GeV)	[10,60]	[10,70]	[75,105]
PUPPI p_T^{miss} (GeV)	> 35	> 20	< 35



WH3l

Backgrounds:
Non-prompt(Z+Jets,top)
WZ, ZZ, Vγ

Fit kinematic:
BDT discriminant in OSSF and SSSF regions

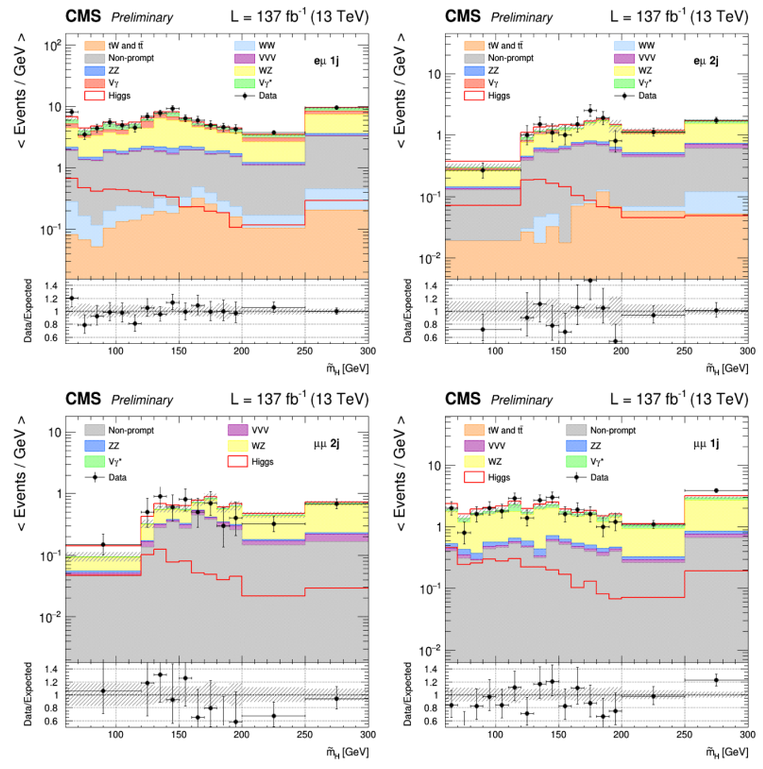
	Preselection			
Lepton p_T (GeV)	$> 25, 20, 15$			
Fourth lepton p_T (GeV)	< 10			
$ch_{\ell\ell\ell}$	± 1			
$\min(m_{\ell\ell})$ (GeV)	> 12			
Jets with $p_T > 30$ GeV	0			
B jet veto	DeepCSV, loose WP, applied to all jets with $p_T > 20$ GeV			
	OSSF SR	SSSF SR	WZ CR	Zγ CR
OSSF lepton pair	Yes	No	Yes	Yes
$\lvert m_{\ell\ell} - m_Z \rvert$ (GeV)	> 20		< 20	< 20
p_T^{miss} (GeV)	> 40		> 45	< 40
$m_{\ell\ell\ell}$ (GeV)			> 100	[80, 100]

WHSS

Backgrounds:
Non-prompt(W+Jets)
Vγ, Vγ*

Fit kinematic:
mll20_whss in all regions
(Higgs mass proxy)

	Preselection			
Lepton p_T (GeV)	$> 25, 20$			
Third lepton veto	Yes			
$m_{\ell\ell}$ (GeV)	> 12			
$\Delta\eta_{\ell\ell}$	< 2.0			
B jet veto	DeepCSV, medium WP, applied to all jets with $p_T > 20$ GeV			
p_T^{miss} (GeV)	> 30			
$\tilde{m}_H$ (GeV)	> 50			
	1j $e\mu$ SR	2j $e\mu$ SR	1j $\mu\mu$ SR	2j $\mu\mu$ SR
Jets with $p_T > 30$ GeV	==1	≥ 2	==1	≥ 2
m_{jj} (GeV)		< 100		< 100
$\lvert m_{\ell\ell} - m_Z \rvert$ (GeV)			> 15	> 15



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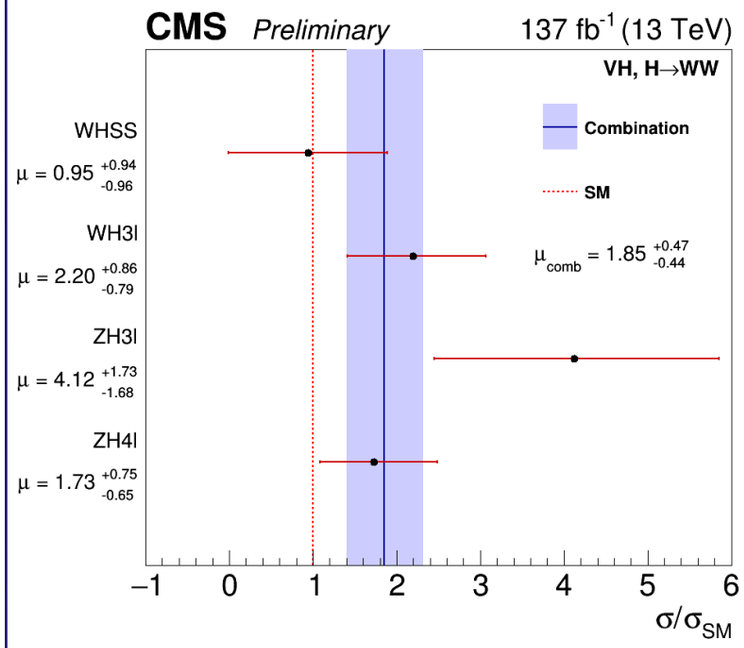
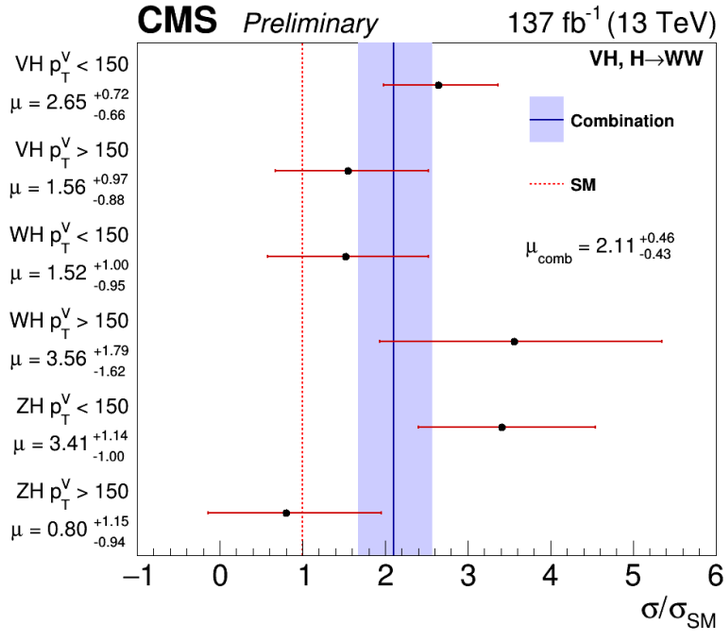
INCLUSIVE RESULTS



Category	μ	Significance
WHSS	$0.95^{+0.94}_{-0.96}$	1.0 σ (1.1 σ expected)
WH3l	$2.20^{+0.86}_{-0.79}$	3.0 σ (1.6 σ expected)
ZH3l	$4.12^{+1.73}_{-1.68}$	2.5 σ (0.6 σ expected)
ZH4l	$1.73^{+0.75}_{-0.65}$	3.1 σ (2.1 σ expected)
Combination	$1.85^{+0.47}_{-0.44}$	4.7 σ (2.8 σ expected)

(Upper) Comparison of the combined and individual signal strengths **(Lower)** The posterior signal strengths and significances for the signal strengths for each of the channels and the combination.

STXS RESULTS



	μ	Significance
$WH\ p_T^V < 150$ GeV	$1.5^{+1.0}_{-0.9}$	1.64 σ (1.24 σ expected)
$WH\ p_T^V > 150$ GeV	$3.6^{+1.8}_{-1.6}$	2.23 σ (0.83 σ expected)
$ZH\ p_T^V < 150$ GeV	$3.4^{+1.1}_{-1.0}$	4.37 σ (1.59 σ expected)
$ZH\ p_T^V > 150$ GeV	$0.8^{+1.2}_{-0.9}$	0.83 σ (1.18 σ expected)

(Upper) Comparison of the combined and individual signal strengths **(Lower)** The posterior signal strengths and significances for the signal strengths in each bin

SYSTEMATIC UNCERTAINTIES

Type	Source	Impact (%)
Theoretical	Renormalization and factorization scale	3
	Parton distribution function	2
	Parton shower, underlying event	2
Experimental	Nonprompt	9
	Sample size of simulation data	8
	Electron	3
	b tag	3
	Jet	2
	Luminosity	2
	WZ normalization	2
	$Z\gamma$ normalization	2
	ZZ normalization	1
	Muon	1

Impacts of sources of systematic uncertainty on signal strength

SUMMARY

The cross sections for Higgs boson production in association with a leptonically decaying vector boson have been measured in events where the Higgs decays to a pair of W bosons. The measurements have been performed with pp collision data sets recorded by the CMS detector at a center-of-mass energy of 13 TeV in 2016, 2017, and 2018, corresponding to a total integrated luminosity of 137 fb−1.

In addition to the inclusive measurement, the cross section for VH production was measured with respect to the transverse momentum of the associated vector boson, following the simplified template cross sections framework. The cross sections are extracted through a simultaneous template fit to kinematic distributions of the signal candidate events finely categorized to maximize the sensitivity to Higgs boson production. The observed significance of the inclusive VH production cross section is 4.7σ, while the observed significance of the VH production cross section for p^V_T < 150(> 150) is 4.7σ(1.8σ).

REFERENCES

https://cds.cern.ch/record/2758367/files/HIG-19-017-pas.pdf