Table of Contents

Evidence for a particle decaying to W^+W^- in the fully leptonic final state in a standard model Higgs boson search in pp collisions at the LHC

This is a condensed description with plots for the analysis CMS-HIG-12-042

Abstract

An update of a previous search for the standard model Higgs boson decaying to W^+W^- in pp collisions at $\sqrt{s}$ = 8 TeV is reported. The event sample corresponds to an integrated luminosity of 12.1 ± 0.5 fb^{-1}, collected by the CMS detector at the LHC in 2012. The 2011 results obtained at $\sqrt{s}$ = 7 TeV for an integrated luminosity of 4.9 fb^{-1} are added to the present analysis. The W^+W^- candidates are selected in events with two oppositely charged leptons and large missing transverse momentum. An excess of events is observed above background which is consistent with the expectations from a standard model Higgs boson of mass 125 GeV and has a statistical significance of 3.1 standard deviations for this mass. This result provides evidence for a Higgs-like particle decaying to W^+W^-. No other excess of events is observed over the full accessible mass range. Additional standard model Higgs-like bosons are excluded in the mass range 128-600 GeV at 95 % confidence level.

Main Results

A search has been made for a Higgs boson decaying in a pair of W bosons in the CMS detector at $\sqrt{s}$ = 8 Tev. Events are classified according the exclusive jet multiplicity: 0, 1 and 2. The analysis of events with 0, 1 jets is optimized for gg H WW, while the one for events with 2 jets is optimized for Vector Boson Fusion (VBF) qq H WW. The events are further separated in same-flavor and different-flavor final states in each jet multiplicity. The main backgrounds (W^+W^-, top, Drell Yan, W+jets) are estimated with data-driven techniques. The uncertainty on the background normalization represent the largest source of systematics of the analysis, together with the theoretical uncertainties on the Higgs cross section.

A cut and count analysis is performed, optimized for each mass point in all jet multiplicity categories. The same-flavor final states have limited sensitivity to the signal and introduce a large systematic uncertainty due to the larger fake missing ET background in events with high pile-up. A 2D shape analysis of the di-leplon invariant and transverse masses for the different-flavor final state in the 0-jet and 1-jet categories which increase the sensitivity to the standard model Higgs boson is performed and combined with the cut and count analysis in the same-flavor final state in the 0-jet and 1-jet categories and the VBF category.

The search discussed here is performed over the mass range 110--600 GeV, and the data sample corresponds to 12.1fb-1 of integrated luminosity collected in 2012 at a center-of-mass energy of 8 TeV. Finally, the 7 TeV data sample is added to the analysis to obtain the combined 2011 and 2012 results. An excess of events is observed above background which is consistent with the expectations from a standard model Higgs boson of mass 125 GeV, corresponding to:

- Observed (expected) significance for mH = 125 GeV in terms of standad deviations ==> 3.1 (4.1)
- best fit value of the signal strengh for mH = 125 GeV ==> 0.74 +/- 0.25

No other excess of events is observed over the full accessible mass range. Additional standard model Higgs-like bosons are excluded in the mass range 128-600 GeV at 95 % confidence level.

PAS Figures

pdf, png, eps	Distributions of the azimuthal angle difference between two selected leptons in the 0-jet category in the different flavor final state, for data, for the main backgrounds, and for a SM Higgs boson signal with mH = 125 GeV. The standard WW selection is applied.
pdf, png, eps	Distributions of the azimuthal angle difference between two selected leptons in the 1-jet category in the different flavor final state, for data, for the main backgrounds, and for a SM Higgs boson signal with mH = 125 GeV. The standard WW selection is applied.
pdf, png, eps	Distributions of the dilepton mass of the two selected leptons in the 0-jet category in the different flavor final state, for data, for the main backgrounds, and for a SM Higgs boson signal with mH = 125 GeV. The standard WW selection is applied.
	Distributions of the dilepton mass of the two selected leptons in the 1-jet category in the different flavor final state, for data, for the main backgrounds, and for a SM Higgs boson signal with mH = 125 GeV. The standard WW selection is applied.

pdf, png, eps	
pdf, png, eps	Distributions of the azimuthal angle difference between two selected leptons in the 0-jet category, in the different-flavor final state for a mH = 125 GeV SM Higgs boson and for the main backgrounds. The cut-based HWW selection, except for the requirement on the azimuthal angle itself, is applied.
pdf, png, eps	Distributions of the azimuthal angle difference between two selected leptons in the 1-jet category, in the different-flavor final state for a mH = 125 GeV SM Higgs boson and for the main backgrounds. The cut-based HWW selection, except for the requirement on the azimuthal angle itself, is applied.
	Distributions of dilepton mass in the 0-jet category, in the different-flavor final state for a mH = 125 GeV SM Higgs boson and for the main backgrounds. The cut-based HWW selection, except for the requirement on the dilepton mass itself, is applied.

pdf, png, eps	
pdf, png, eps	Distributions of dilepton mass in the 1-jet category, in the different-flavor final state for a mH = 125 GeV SM Higgs boson and for the main backgrounds. The cut-based HWW selection, except for the requirement on the dilepton mass itself, is applied.
pdf, png, eps	Distributions of the transverse mass in the 0-jet category, in the different-flavor final state for a mH = 125 GeV SM Higgs boson and for the main backgrounds. The cut-based HWW selection, except for the requirement on the transverse mass itself, is applied.
	Distributions of the transverse mass in the 1-jet category, in the different-flavor final state for a mH = 125 GeV SM Higgs boson and for the main backgrounds. The cut-based HWW selection, except for the requirement on the transverse mass itself, is applied.

pdf, png, eps	
pdf, png, eps	Two-dimensional distribution in the 0-jet bin for the mH = 125 GeV Higgs signal hypothesis.
pdf, png, eps	Two-dimensional distribution in the 0-jet bin for the mH = 200 GeV Higgs signal hypothesis.
	Two-dimensional distribution in the 0-jet bin for the background processes.

pdf, png, eps	
pdf, png, eps	Two-dimensional distribution in the 0-jet bin for the data.
pdf, png, eps	Two-dimensional distribution in the 1-jet bin for the mH = 125 GeV Higgs signal hypothesis.
	Two-dimensional distribution in the 1-jet bin for the mH = 200 GeV Higgs signal hypothesis.

pdf, png, eps	
pdf, png, eps	Two-dimensional distribution in the 1-jet bin for the background processes.
pdf, png, eps	Two-dimensional distribution in the 1-jet bin for the data.
	Two-dimensional distribution, shown in a smaller range, in the 0-jet bin of data minus background after the CLs fit for the mH = 125 GeV Higgs signal hypothesis.

pdf, png, eps	
pdf, png, eps	Two-dimensional distribution, shown in a smaller range, in the 1-jet bin of data minus background after the CLs fit for the mH = 125 GeV Higgs signal hypothesis.
pdf, png, eps	One-dimensional unrolled bin distribution used in the two-dimensional m_T-m_{ll} analysis in the 0-jet bin after the CLs fit for the mH = 125 GeV Higgs signal hypothesis.
	One-dimensional unrolled bin distribution used in the two-dimensional m_T-m_{ll} analysis in the 0-jet bin after the CLs fit for the mH = 125 GeV Higgs signal hypothesis in a smaller range, i.e. for the bottom 2D 4-bin x 4-bin distributions.

pdf, png, eps	
pdf, png, eps	Projection of m_T-m_{ll} for the more signal-like region $m_{ll} < 50$ GeV in the 0-jet bin after the CLs fit for the mH = 125 GeV Higgs signal hypothesis.
pdf, png, eps	One-dimensional unrolled bin distribution used in the two-dimensional m_T-m_{ll} analysis in the 1-jet bin after the CLs fit for the mH = 125 GeV Higgs signal hypothesis.
	One-dimensional unrolled bin distribution used in the two-dimensional m_T-m_{ll} analysis in the 1-jet bin after the CLs fit for the mH = 125 GeV Higgs signal hypothesis in a smaller range, i.e. for the bottom 2D 4-bin x 4-bin distributions.

pdf, png, eps	
pdf, png, eps	Projection of m_T-m_{ll} for the more signal-like region $m_{ll} < 50$ GeV in the 1-jet bin after the CLs fit for the mH = 125 GeV Higgs signal hypothesis.
pdf, png, eps	Expected and observed 95% CL upper limits on the cross section times branching fraction, relative to the SM Higgs expectation, for the cut-based approach using the 8 TeV data only. The expected limits in the presence of the Higgs with mH = 125 GeV and its associated uncertainty are also shown.
	Expected and observed 95% CL upper limits on the cross section times branching fraction, relative to the SM Higgs expectation, for the shape-based approach using the 8 TeV data only. For the shape-based approach, we combine the analysis in the different-flavor final state in the 0-jet and 1-jet categories with the cut-based analysis in all other categories. The expected limits in the presence of the Higgs with mH = 125 GeV and its associated uncertainty are also shown.

pdf, png, eps	
pdf, png, eps	Expected and observed 95% CL upper limits on the cross section times branching fraction, relative to the SM Higgs expectation, for the combined 8 TeV shape-based analysis together with the analysis performed at 7 TeV. The expected limits in the presence of the Higgs with mH = 125 GeV and its associated uncertainty are also shown.
pdf, png, eps	A comparison of the expected limits for different analyses at 8 TeV for low Higgs mass hypotheses.
	The best fit value of the signal strengh (mu) for the combined 7+8 TeV analysis.

pdf, png, eps	
pdf, png, eps	The observed and expected significances under the mH = 125 GeV Higgs signal hypothesis and for each Higgs mass hypothesis for the combined 7+8 TeV analysis in a limited mass range.
pdf, png, eps	Confidence intervals in the (mu, mH) plane for the different-flavor final states combining the 0-jet and 1-jet categories for the shape analysis at 8 TeV. The solid and dashed lines indicate the 68% and 95% CL contours, respectively.
	dilepton mass in W+G* selected events.

pdf, png, eps	

PAS Tables

Observed number of events and background estimates for an integrated luminosity of 12.1 ± 0.5 fb^{-1} after applying the WW selection requirements.

	data	tot bkg.	WW	ttbar+tw
0-jet bin	4450	4233 ± 220	3146 ± 192	417 ± 45
1-jet bin	3053	2899 ± 152	976 ± 111	1369 ± 56
2-jet bin	3148	3229 ± 137	473 ± 21	1865 ± 100
	Wjets	**WZ+ZZ**	**dyll**	**WZ+gamma***
0-jet bin	334 ± 91	118.1 ± 7.1	128 ± 21	89 ± 22
1-jet bin	288 ± 83	88.6 ± 5.3	131 ± 28	46 ± 12
2-jet bin	220 ± 58	51.2 ± 3.5	579 ± 70	41.3 ± 3.9

Observed number of events, background estimates and signal predictions for an integrated luminosity of 12.1 ± 0.5 fb^{-1} after applying the Hww cut-based selection requirements. The combined statistical, experimental, and theoretical systematic uncertainties are reported. The dyll process includes the dimuon, dielectron and ditau final state.

				0-jet category e μ final state				
120	34.0± 7.3	162 ± 16	5.3± 0.5	8.6± 2.0	38 ± 14	23.1± 8.8	237 ± 23	285
125	58 ± 12	203 ± 19	6.6± 0.6	11.0± 2.5	44 ± 16	25.6± 9.5	291 ± 27	349
130	86 ± 18	226 ± 21	7.1± 0.7	12.2± 2.8	47 ± 17	27 ± 10	319 ± 29	388
160	238 ± 51	125 ± 12	3.7± 0.4	13.1± 3.1	5.9± 2.7	2.6± 1.5	160 ± 13	197
200	95 ± 21	204 ± 19	6.3± 0.6	28.9± 6.4	7.7± 3.5	1.3± 0.9	278 ± 21	309
400	40 ± 11	133 ± 15	6.2± 0.7	50 ± 11	7.6± 3.3	3.5± 2.1	200 ± 19	198
600	6.6± 2.3	42.2± 4.8	2.5± 0.3	16.5± 3.8	4.4± 2.0	2.4± 1.8	67.9±	64

							6.7	
				0-jet category ee/μμ final state				
120	20.8± 4.5	108 ± 10	48 ± 14	3.9± 1.1	24.5± 9.3	5.8± 2.5	191 ± 20	209
125	37.0± 8.0	140 ± 13	59 ± 18	5.2± 1.3	30 ± 11	6.7± 2.8	241 ± 25	266
130	57 ± 12	162 ± 15	67 ± 20	6.2± 1.5	30 ± 11	7.7± 3.1	273 ± 28	295
160	209 ± 45	107 ± 10	17.6± 7.4	7.0± 1.7	5.2± 2.7	1.2± 0.7	138 ± 13	161
200	77 ± 17	177 ± 16	19.6± 4.2	21.9± 4.9	9.0± 4.1	1.8± 0.9	230 ± 18	249
400	34.0± 9.2	117 ± 13	34 ± 16	40.1± 8.7	4.4± 2.4	34 ± 11	230 ± 25	180
600	5.7± 2.0	38.2± 4.4	4.8± 0.4	11.6± 2.7	1.8± 1.3	5.0± 2.1	61.3± 5.7	61
				1-jet category eμ final state				
120	14.9± 4.3	38.9± 6.4	5.3± 0.6	40.3± 3.0	19.1± 7.4	7.1± 3.4	111 ± 11	123
125	27.3± 8.0	47.9± 7.8	6.5± 0.7	49.5± 3.3	22.4± 8.6	7.1± 3.4	134 ± 13	160
130	40 ± 12	53.9± 8.8	7.3± 0.8	55.2± 3.6	24.5± 9.4	7.1± 3.4	148 ± 14	182
160	131 ± 37	44.4± 7.0	5.3± 0.7	51.8± 3.5	9.0± 3.9	0.6± 0.4	111.1± 8.8	145
200	58 ± 15	80 ± 13	6.8± 0.8	114.6± 6.5	16.1± 6.5	0.4± 0.3	238 ± 16	276
400	29.4± 8.1	81 ± 13	7.9± 1.2	129.0± 7.1	16.8± 6.6	0.6± 0.5	235 ± 16	226
600	6.9± 1.8	30.0± 4.8	3.1± 0.4	40.3± 3.0	8.4± 3.5	0.0± 0.0	81.8± 6.6	74
				1-jet category ee/μμ final state				
120	6.5± 1.9	19.2± 3.2	11.5± 3.0	20.6± 2.0	6.1± 2.6	2.0± 1.2	59.5± 5.6	77
125	11.8± 3.4	24.8± 4.1	13.1± 3.5	26.7± 2.3	6.5± 2.8	2.0± 1.2	73.0± 6.6	92
130	18.2± 5.4	28.0± 4.6	15.6± 4.2	30.0± 2.5	7.8± 3.3	1.7± 1.1	83.1± 7.6	115
160	76 ± 22	28.9± 4.6	9.3± 2.8	31.0± 2.4	7.7± 3.6	0.3± 0.4	77.2± 6.9	89
200	35.4± 9.4	52.9± 8.4	16.8± 3.7	74.5± 4.6	8.0± 3.8	0.0± 0.0	152 ± 11	166
400	21.0± 5.8	45.0± 7.1	18.0± 8.4	77.5± 4.7	9.5± 4.3	14.5± 5.2	165 ± 14	128
600	4.4± 1.2	15.7± 2.5	2.8± 0.3	19.3± 1.6	1.8± 1.2	3.5± 1.6	43.0± 3.6	41
				2-jet category eμ final state				
120	1.7± 0.2	0.8± 0.5	0.1± 0.0	0.9± 0.3	0.3± 0.2	0.1± 0.1	2.2± 0.6	2
125	2.8± 0.4	0.9± 0.5	0.1± 0.0	1.5± 0.5	0.3± 0.2	0.1± 0.1	2.9± 0.8	2
130	4.4± 0.6	1.3± 0.7	0.1± 0.0	1.6± 0.5	0.3± 0.2	0.1± 0.1	3.4± 0.9	4
160	11.7± 1.5	1.2± 0.6	0.0± 0.0	1.5± 0.5	0.0± 0.0	0.1± 0.1	2.9± 0.8	4
200	9.3± 1.2	2.5± 1.2	1.7± 1.6	4.6± 1.3	0.3± 0.4	0.0± 0.0	9.1± 2.4	8

Observed number of events, background estimates and signalpredictions for an integrated luminosity of 12.

400	3.9± 0.5	3.5± 2.2	1.7± 1.6	4.6± 1.3	0.0± 0.0	0.0± 0.0	9.8± 3.0	7
600	1.4± 0.2	1.6± 1.0	0.0± 0.0	1.9± 0.8	0.3± 0.2	0.0± 0.0	3.7± 1.3	3
				2-jet category ee/μμ final state				
120	1.0± 0.1	0.5± 0.3	3.2± 1.5	0.7± 0.2	0.8± 0.5	0.1± 0.1	5.2± 1.7	9
125	1.5± 0.2	0.5± 0.3	4.4± 1.3	0.7± 0.2	0.8± 0.5	0.1± 0.1	6.5± 1.5	11
130	2.3± 0.3	0.5± 0.3	4.8± 1.6	0.8± 0.2	0.8± 0.5	0.1± 0.1	7.0± 1.7	11
160	7.4± 1.0	0.5± 0.3	3.8± 3.8	0.9± 0.3	0.1± 0.1	0.0± 0.0	5.2± 3.8	5
200	4.9± 0.6	1.5± 0.7	4.4± 3.0	2.0± 0.5	0.5± 0.4	0.0± 0.0	8.3± 3.2	9
400	2.7± 0.4	1.4± 0.9	0.1± 0.0	3.6± 1.1	0.2± 0.4	0.0± 0.0	5.3± 1.4	8
600	1.1± 0.1	0.5± 0.4	0.0± 0.0	1.4± 0.6	0.1± 0.1	0.0± 0.0	2.0± 0.7	2

Expected and observed significance and best fit value of / SM for a SM Higgs with a mass of 125

	8 TeV cut-based	8 TeV shape-based	7+8 TeV shape-based
Expected and observed significance	2.4/1.7	3.7/2.9	4.1/3.1
best fit value	0.80 ± 0.45	0.77 ± 0.28	0.74 ± 0.25

Selections definition

WW selection

The following cuts constitute what in the paper is called **WW selection**

Selection [units]	ee,μμ	eμ
pT^{max} [GeV/c]	20	20
pT^{min} [GeV/c]	10	10
third lepton veto	applied	applied
opposite-sign requirement	applied	applied
mll [GeV/c^2]	12	12
projected MET [GeV] (**)	45 (*)	20
Z mass veto	applied	---
Δ (ll-jet^{max}) [dg.]	165 (*)	---
top veto	applied	applied
pT^{ll} [GeV/c]	45	45

(*) For Higgs search in 0 and 1 jet categories no cut is applied in Δ (ll-jet^{max}) and the projected MET cut in ee,μμ channel is set to 20 GeV. Additionally a dedicated multivariate selection combining missing transverse momentum, kinematic and topological variables, is used to reject Drell-Yan events and maximize the surviving signal yield. DYMVA variable has to be greater than 0.88 for 0 jet bin and above 0.84 for the 1 jet bin.

(**) For the VBF selection, Particle Flow MET is used.

Higgs selection

The following cuts constitute what in the paper is called **Higgs selection** for the cut and count analysis for all jet categories. However for the 2-jet category, the mT cut is relaxed to be mT > 30 GeV/c^2.

mH	pT^{max}	pT^{min}	mll	Δ ll	mT
[GeV/c^2]	[GeV/c]	[GeV/c]	[GeV/c^2]	dg.	[GeV/c^2]
120	20	10	40	115	[80,120]

125	23	10	43	100	[80,213]
130	25	10	45	90	[80,125]
160	30	25	50	60	[90,160]
200	40	25	90	100	[120,200]
250	55	25	150	140	[120,250]
300	70	25	200	175	[120,300]
400	90	25	300	175	[120,400]

For the 2D shape analysis in addition to the W^+W^- preselection, a loose set of requirements are applied. mT must be greater than 80 GeV and smaller than 280 (600) GeV for mH hypotheses smaller or equal than 250 GeV (greater than 250 GeV), while mll must be smaller than 200 (600) GeV for mH hypotheses smaller or equal than 250 GeV (greater than 250 GeV). Finally, pl,max is required to be larger than 50 GeV for mH hypotheses greater than 250 GeV.

Study on W+g* background

- Selection: select two opposite-sign low dilepton mass muons and one addition lepton, either electron or muon

```
pt1/2/3 > 20/10/3 GeV
 | q1+q2+q3 |  = 1
event no btagged (exclude top background)
mT(lepton-MET) > 25 GeV && mT(lepton from W-MET) > 45 GeV  (exclude fake background)
m_mu+mu- <12 GeV (signal region)
 | m_mu+mu- - 3.1 |  > 0.1 GeV (exclude J/Psi decays)
```

- Systematics uncertainties:
    - compare yields for 0 < m_mu+mu- < 2 && 2 < m_mu+mu- < 12, and 3mu vs. 2mue channels
    - covers the possible difference between the observed and expected mass shape in the g* component
    - covers the possible difference between electrons and muons

- Overall k-factor: 1.6 +/- 0.3

process	data	W+g*	background	scale factor
0<mll<12 lll	319	178.6	32.0	1.60 +/- 0.10
0<mll<2 mme	153	105.8	9.4	1.36 +/- 0.12
2<mll<12 mme	65	25.2	12.5	2.08 +/- 0.32
0<mll<2 mmm	68	32.1	4.5	1.98 +/- 0.26
2<mll<12 mmm	33	15.4	5.7	1.77 +/- 0.37

Other Figures

	Expected and observed 95% CL upper limits on the cross section times branching fraction, relative to the SM Higgs expectation, for the shape-based approach using the 8 TeV data only. For the shape-based approach, we combine the analysis in the different-flavor final state in the 0-jet and 1-jet categories with the cut-based analysis in all other categories. The mH = 125 GeV Higgs signal hypothesis is being considered as a background.

pdf, png, eps	

This topic: CMSPublic > Hig12042TWiki
Topic revision: r23 - 2013-10-03 - GuillelmoCeballos