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Combined results of searches for standard model, four fermion standard model, and fermiophobic Higgs bosons (Moriond 2012)

This is a condensed description with plots for the analysis CMS-HIG-12-008 ⬈

Abstract

Combined results are reported from searches for the standard model Higgs boson in proton-proton collisions at $\sqrt{s}$ = 7 TeV in five Higgs boson decay modes: , bb,   , WW, and ZZ. The explored Higgs boson mass range is 110−600 GeV. The analysed data correspond to an integrated luminosity of 4.6−4.8 fb^{-1}. The expected excluded mass range in the absence of the standard model Higgs boson is 114.5−543 GeV at 95% CL. The observed results exclude the standard model Higgs boson in the mass range 127.5−600 GeV at 95% CL, and in the mass range 129−525 GeV at 99% CL. An excess of events above the expected standard model background is observed at the low end of the explored mass range making the observed limits weaker than expected in the absence of a signal. The largest excess, with a local significance of 2.8   , is observed for a Higgs boson mass hypothesis of 125 GeV. The global significance of observing an excess with a local significance greater than 2.8   anywhere in the search range 110−600 (110−145) GeV is estimated to be 0.8 (2.1   ). More data are required to ascertain the origin of this excess. For an extension of the standard model including a fourth generation of fermions (SM4), the SM4 Higgs boson is excluded in the mass range 120−600 GeV at 95% CL. In the fermiophobic Higgs boson scenario, a fermiophobic Higgs boson is excluded in the mass range 110−192 GeV at 95% CL.

Searches for a Standard Model Higgs Boson

CMS Combination

Plot	Caption
	The CL$_s$ values for the SM Higgs boson hypothesis as a function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The three horizontal lines on the CL$_s$ plot show confidence levels of 90%, 95%, and 99%, defined as (1−CL$_s$).
	The 95% CL upper limits on the signal strength parameter $\mu = $ / $_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively.
	The 95% CL upper limits on the signal strength parameter $\mu = $ / $_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass as obtained with three methods. CL$_s$ as presented in the paper (black solid points and black solid line), CL$_s$ using an asymptotic approximation (red curve), and Bayesian (blue open circles and blue dashed line). The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively, all computed for the CL$_s$

	method as presented in the paper.
	The observed local p-value p_0 as a function of the SM Higgs boson mass in the range 110−145 GeV. The global significance of the observed maximum excess (minimum local p-value) in this mass range is about 2.1 , estimated using pseudoexperiments. The dashed line on the plot shows the expected local p-values $p_0(m_H)$, should a Higgs boson with a mass m_H exist.
	The observed best-fit signal strength $\mu = / _{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the ±1 uncertainties on the μ values.

Plots showing contributions from individual decay modes

Plot	Caption
	The 95% CL observed upper limits on the signal strength parameter $\mu = / _{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the five explored Higgs boson decay modes and their combination. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL upper limits on the signal strength parameter $\mu = / _{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the five explored Higgs boson decay modes and their combination. Observed limits are shown with solid lines, while expected limits are shown with dashed lines. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL expected upper limits on the signal strength parameter $\mu = / _{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the five explored Higgs boson decay modes and their combination. The limits are obtained with the asymptotic CL_s approximation.
	The observed local p-value p_0 as a function of the SM Higgs boson mass in the range 110−145 GeV, for the five explored Higgs boson decay modes and their combination. The local p-values for individual channels and their combination are obtained with the asymptotic formula (lines); the combined local p-value is validated by generating ensembles of background-only pseudo-datasets (points). The global significance of the observed maximum excess (minimum local p-value) for the full combination in this mass range is about 2.1 , estimated using pseudoexperiments. The dashed line on the left plot shows the expected local p-values $p_0(m_H)$ for the combination, should a Higgs boson with a mass m_H exist.

Plots showing contributions from all individual search channels

Plot	Caption
	The 95% CL observed upper limits on the signal strength parameter $\mu = / _{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the eleven individual searches and their combination. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL upper limits on the signal strength parameter $\mu = / _{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the eleven individual searches and their combination. Observed limits are shown with solid lines, while expected limits are shown with dashed lines. The limits are obtained with the asymptotic CL_s approximation.

	The 95% CL expected upper limits on the signal strength parameter $\mu = \hat{\sigma}/\sigma_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the eleven individual searches and their combination. The limits are obtained with the asymptotic CL_s approximation.

Plots of the separate combinations of ZZ+$\gamma\gamma$ and bb+$\tau\tau$+WW

Plot	Caption
	The 95% CL upper limits on the signal strength parameter $\mu = \hat{\sigma}/\sigma_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the ZZ+$\gamma\gamma$ (left) and bb+$\tau\tau$+WW (right) sub-combinations. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL upper limits on the signal strength parameter $\mu = \hat{\sigma}/\sigma_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the full combination and the two sub-combinations. Observed limits are shown with solid lines, while expected limits are shown with dashed lines. The limits are obtained with the asymptotic CL_s approximation.
	The observed local p-value p_0 as a function of the SM Higgs boson mass in the range 110–145 GeV, for the full combination and the two sub-combinations. The local p-values for individual channels and their combination are obtained with the asymptotic formula (lines); the combined local p-value is validated by generating ensembles of background-only pseudo-datasets (points). The global significance of the observed maximum excess (minimum local p-value) for the full combination in this mass range is about 2.1 σ, estimated using pseudoexperiments. The dashed line on the left plot shows the expected local p-values $p_0(m_H)$ for the combination, should a Higgs boson with a mass m_H exist.
	The observed local p-value p_0 as a function of the SM Higgs boson mass in the range 110–145 GeV, for the ZZ+$\gamma\gamma$ (left) and bb+$\tau\tau$+WW (right) sub-combinations. The dashed line on the plot shows the expected local p-values $p_0(m_H)$, should a Higgs boson with a mass m_H exist.
	The observed best-fit signal strength $\hat{\mu} = \hat{\sigma}/\sigma_{SM}$ as a function of the SM Higgs boson mass in the range 110–145 GeV, for the ZZ+$\gamma\gamma$ (left) and bb+$\tau\tau$+WW (right) sub-combinations. The band in the plot corresponds to the ±1σ uncertainties on the $\hat{\mu}$ values.

Channel compatibility plots

Plot	Caption
	Values of $\hat{\mu} = \hat{\sigma}/\sigma_{SM}$ for the combination (solid vertical line) and for contributing channels (points), for a hypothesized Higgs boson mass of 119.5 GeV. The band corresponds to ±1σ uncertainties on the overall $\hat{\mu}$ value. The horizontal bars indicate ±1σ uncertainties on the $\hat{\mu}$ values for individual channels.

	Values of μ = / $_{SM}$ for the combination (solid vertical line) and for contributing channels (points), for a hypothesized Higgs boson mass of 124 GeV. The band corresponds to ±1 uncertainties on the overall μ value. The horizontal bars indicate ±1 uncertainties on the μ values for individual channels.
	Values of μ = / $_{SM}$ for the combination (solid vertical line) and for contributing channels (points), for a hypothesized Higgs boson mass of 125 GeV. The band corresponds to ±1 uncertainties on the overall μ value. The horizontal bars indicate ±1 uncertainties on the μ values for individual channels.
	Values of μ = / $_{SM}$ for the combination (solid vertical line) and for contributing channels (points), for a hypothesized Higgs boson mass of 136 GeV. The band corresponds to ±1 uncertainties on the overall μ value. The horizontal bars indicate ±1 uncertainties on the μ values for individual channels.
	Values of μ = / $_{SM}$ for the combination (solid vertical line) and for contributing channels (points), for a hypothesized Higgs boson mass of 144 GeV. The band corresponds to ±1 uncertainties on the overall μ value. The horizontal bars indicate ±1 uncertainties on the μ values for individual channels.
	Values of μ = / $_{SM}$ for the combination (solid vertical line) and for contributing channels (points), for a hypothesized Higgs boson mass of 320 GeV. The band corresponds to ±1 uncertainties on the overall μ value. The horizontal bars indicate ±1 uncertainties on the μ values for individual channels.

Exclusion limits compared to LEP, Tevatron

Plot	Caption
	The 95% CL upper limits on the signal strength parameter μ = / $_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The mass ranges first excluded by LEP and Tevatron are shown as hatched areas.
	The 95% CL upper limits on the signal strength parameter μ = / $_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The mass ranges first excluded by LEP, Tevatron and this measurement are shown as hatched areas.
	The 95% CL upper limits on the signal strength parameter μ = / $_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The mass range excluded by LEP is shown as hatched area. The observed (expected) limits from Tevatron are shown as a blue solid (dashed) line

Best fit signal strengths for individual decay modes or search channels

Plot	Caption
	Combination of the H bb searches: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	Combination of the H searches: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	Combination of the H searches: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values. *Note: the WH $\to$ $_h$ 2l, includes some contributions from WH 3W.*
	Combination of the H WW searches: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	Combination of the H ZZ searches: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
Individual H WW channels	
	H WW 2l 2ν : observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	W H 3 W 3l 3ν : observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
Individual H ZZ channels	
	H ZZ 4l: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	H ZZ 2l 2τ : observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	H ZZ 2l 2q: observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higgs boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.
	H ZZ 2l 2ν : observed best-fit signal strength $\mu = \sigma/\sigma_{SM}$ as a function of the SM Higg s boson mass. The band in the plot corresponds to the $\pm 1\sigma$ uncertainties on the μ values.

Comparison with earlier public results

Plot	Caption
	The 95% CL upper limits on the signal strength parameter $\mu = \sigma/\sigma_{SM}$ for the SM Higgs boson hypothesis as function of the Higgs boson mass, for the full CMS combination. The observed values are shown by the black solid line. The dashed black line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The observed and expected limits from the HIG-11-032, arXiv:1202.1488 paper are shown as blue solid and dashed line respectively.
	The 95% CL upper limits on the signal strength parameter $\mu = \sigma/\sigma_{SM}$ for the SM

Higgs boson hypothesis as function of the Higgs boson mass, for the CMS H search. The observed values are shown by the black solid line. The dashed black line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The observed and expected limits from the HIG-11-033, arXiv:1202.1202.1487 paper are shown as blue solid and dashed line respectively.

Searches for a Higgs Boson in the context of the SM with four fermion generations (SM4)

Plot	Caption
	The 95% CL upper limits on the signal strength parameter μ = / $_{SM4}$ for the SM4 Higgs boson hypothesis as function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively.The limits are obtained with the asymptotic CL$_s$ approximation.
	The 95% CL upper limits on the signal strength parameter μ = / $_{SM4}$ cfor the SM4 Higgs boson hypothesis as function of the Higgs boson mass, for the five explored Higgs boson decay modes and their combination. Observed limits are shown with solid lines, while expected limits are shown with dashed lines. The limits are obtained with the asymptotic CL$_s$ approximation.
	The 95% CL observed upper limits on the signal strength parameter μ = / $_{SM4}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass, for the five explored Higgs boson decay modes and their combination. The limits are obtained with the asymptotic CL$_s$ approximation.
	The 95% CL expected upper limits on the signal strength parameter μ = / $_{SM4}$ for the SM4 Higgs boson hypothesis as function of the Higgs boson mass, for the three explored Higgs boson decay modes and their combination. The limits are obtained with the asymptotic CL$_s$ approximation.
	The observed local p-value p_0 as a function of the SM4 Higgs boson mass in the range 110−145 GeV, for the five explored Higgs boson decay modes and their combination. The local p-values for individual channels and their combination are obtained with the asymptotic formula (lines); the combined local p-value is validated by generating ensembles of background-only pseudo-datasets (points). The dashed line on the left plot shows the expected local p-values $p_0(m_H)$ for the combination, should a Higgs boson with a mass m_H exist. The global p-value of the observed maximum excess (minimum local p-value) for the full combination in the mass range 110−600 GeV is about 0.5.
	The observed best-fit signal strength μ = / $_{SM4}$ as a function of the SM4 Higgs boson mass. The band in the plot corresponds to the ±1 uncertainties on the μ values.

Searches for a Fermiophobic Higgs Boson

Plot	Caption
	The 95% CL upper limits on the signal strength parameter μ = / $_{FP}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL upper limits on the signal strength parameter μ = / $_{FP}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass, for the three explored Higgs boson decay modes and their combination. Observed limits are shown with solid lines, while expected limits are shown with dashed lines. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL observed upper limits on the signal strength parameter μ = / $_{FP}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass, for the three explored Higgs boson decay modes and their combination. The limits are obtained with the asymptotic CL_s approximation.
	The 95% CL expected upper limits on the signal strength parameter μ = / $_{FP}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass, for the three explored Higgs boson decay modes and their combination. The limits are obtained with the asymptotic CL_s approximation.
	The observed local p-value p_0 as a function of the fermiophobic Higgs boson mass in the range 110−145 GeV, for the three explored Higgs boson decay modes and their combination. The local p-values for individual channels and their combination are obtained with the asymptotic formula (lines); the combined local p-value is validated by generating ensembles of background-only pseudo-datasets (points). The dashed line on the left plot shows the expected local p-values $p_0(m_H)$ for the combination, should a Higgs boson with a mass m_H exist. The global significance of the observed maximum excess (minimum local p-value) for the full combination in the mass range 110−300 GeV is about 1.1 .

| | **The observed best-fit signal strength μ = / $_{FP}$ as a function of the fermiophobic Higgs boson mass.** The band in the plot corresponds to the ±1 uncertainties on the μ values. |

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