Neutral Higgs Bosons, Searches for

CONTENTS:

MASS LIMITS FOR NEUTRAL HIGGS BOSONS IN SUPERSYMMETRIC MODELS

The minimal supersymmetric model has two complex doublets of Higgs bosons. The resulting physical states are two scalars [H_1^0 and H_2^0, where we define $m_{H_1^0} < m_{H_2^0}$], a pseudoscalar (A^0), and a charged Higgs pair ($H^\pm$). H_1^0 and H_2^0 are also called h and H in the literature. There are two free parameters in the Higgs sector which can be chosen to be m_{A^0} and $\tan\beta = v_2/v_1$, the ratio of vacuum expectation values of the two Higgs doublets. Tree-level Higgs masses are constrained by the model to be $m_{H_1^0} \leq m_Z$, $m_{H_2^0} \geq m_Z$, $m_{A^0} \geq m_{H_1^0}$, and $m_{H^\pm} \geq m_W$. However, as described in the review on "Status of Higgs Boson Physics" in this Volume these relations are violated by radiative corrections.

The observed signal at about 125 GeV, see section "H^0", can be interpreted as one of the neutral Higgs bosons of supersymmetric models. Unless otherwise noted, we identify the lighter scalar H_1^0 with the Higgs discovered at 125 GeV at the LHC (AAD 12AI, CHATRCHYAN 12N).

Unless otherwise noted, the experiments in e^+e^- collisions search for the processes $e^+e^- \rightarrow H_1^0 Z^0$ in the channels used for the Standard Model Higgs searches and $e^+e^- \rightarrow H_1^0 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$. Unless otherwise stated, the following results assume no invisible H_1^0 or A^0 decays. Unless otherwise noted, the results are given in the m_h^{max} scenario, CARENA 13.

In $p\overline{p}$ and pp collisions the experiments search for a variety of processes, as explicitly specified for each entry. Limits on the A^0 mass arise from these direct searches, as well as from the relations valid in the minimal supersymmetric model between m_{A^0} and $m_{H_1^0}$. As discussed in the review on "Status of Higgs Boson Physics" in this Volume, these relations depend, via potentially large radiative corrections, on the mass of the

t quark and on the supersymmetric parameters, in particular those of the stop sector. These indirect limits are weaker for larger t and $\widetilde{t}$ masses. To include the radiative corrections to the Higgs masses, unless otherwise stated, the listed papers use theoretical predictions incorporating two-loop corrections, and the results are given for the m_h^{mod+} benchmark scenario, see CARENA 13.

Mass Limits for heavy neutral Higgs bosons (H_2^0, A^0) in the MSSM

The limits rely on $pp \to H_2^0/A^0 \to \tau^+\tau^-$ and assume that H_2^0 and A^0 are (sufficiently) mass degenerate. The limits depend on tanβ.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
$>$ 377	95	[1] AABOUD	18G	ATLS	tan$\beta = 10$ GeV
> 863	95	[1] AABOUD	18G	ATLS	tan$\beta = 20$ GeV
>1157	95	[1] AABOUD	18G	ATLS	tan$\beta = 30$ GeV
$>$1328	95	[1] AABOUD	18G	ATLS	tan$\beta = 40$ GeV
$>$1483	95	[1] AABOUD	18G	ATLS	tan$\beta = 50$ GeV
>1613	95	[1] AABOUD	18G	ATLS	tan$\beta = 60$ GeV
> 389	95	[2] SIRUNYAN	18CX	CMS	tan$\beta = 10$ GeV
$>$ 832	95	[2] SIRUNYAN	18CX	CMS	tan$\beta = 20$ GeV
$>$1148	95	[2] SIRUNYAN	18CX	CMS	tan$\beta = 30$ GeV
>1341	95	[2] SIRUNYAN	18CX	CMS	tan$\beta = 40$ GeV
>1496	95	[2] SIRUNYAN	18CX	CMS	tan$\beta = 50$ GeV
>1613	95	[2] SIRUNYAN	18CX	CMS	tan$\beta = 60$ GeV

• • • We do not use the following data for averages, fits, limits, etc. • • •

		[3] AAD	20	ATLS	H^0 properties
		[4] AAD	20C	ATLS	$H_2^0 \to H^0 H^0$
		[5] SIRUNYAN	19CR	CMS	$H_2^0/A^0 \to \mu^+\mu^-$
		[6] SIRUNYAN	18A	CMS	$H_2^0 \to H^0 H^0$
		[7] SIRUNYAN	18BP	CMS	$pp \to H_2^0/A^0 + b + X$, $H_2^0/A^0 \to b\overline{b}$
		[8] AABOUD	16AA	ATLS	$A^0 \to \tau^+\tau^-$
		[9] KHACHATRY...	16A	CMS	$H_{1,2}^0/A^0 \to \mu^+\mu^-$
		[10] KHACHATRY...	16P	CMS	$H_2^0 \to H^0 H^0$, $A^0 \to Z H^0$
		[11] KHACHATRY...	15AY	CMS	$pp \to H_{1,2}^0/A^0 + b + X$, $H_{1,2}^0/A^0 \to b\overline{b}$
		[12] AAD	14AW	ATLS	$pp \to H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \to \tau\tau$
		[13] KHACHATRY...	14M	CMS	$pp \to H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \to \tau\tau$
		[14] AAD	13O	ATLS	$pp \to H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \to \tau^+\tau^-$, $\mu^+\mu^-$
		[15] AAIJ	13T	LHCB	$pp \to H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \to \tau^+\tau^-$

		[16] CHATRCHYAN	13AG	CMS	$pp \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[17] AALTONEN	12AQ	TEVA	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[18] AALTONEN	12X	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[19] ABAZOV	12G	D0	$p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[20] CHATRCHYAN	12K	CMS	$pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[21] ABAZOV	11K	D0	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[22] ABAZOV	11W	D0	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[23] AALTONEN	09AR	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
$>$ 90.4		[24] ABDALLAH	08B	DLPH	$E_{cm} \le 209$ GeV
$>$ 93.4	95	[25] SCHAEL	06B	LEP	$E_{cm} \le 209$ GeV
		[26] ACOSTA	05Q	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + X$
$>$ 85.0	95	[27,28] ABBIENDI	04M	OPAL	$E_{cm} \le 209$ GeV
		[29] ABBIENDI	03G	OPAL	$H^0_1 \to A^0 A^0$
$>$ 86.5	95	[27,30] ACHARD	02H	L3	$E_{cm} \le 209$ GeV, $\tan\beta > 0.4$
		[31] AKEROYD	02	RVUE	
$>$ 90.1	95	[27,32] HEISTER	02	ALEP	$E_{cm} \le 209$ GeV, $\tan\beta > 0.5$

[1] AABOUD 18G search for production of $H^0_2/A^0 \to \tau^+\tau^-$ by gluon fusion and b-associated prodution in 36.1 fb^{-1} of pp collisions at $E_{cm} = 13$ TeV. See their Fig. 10 for excluded regions in the $m_{A^0}-\tan\beta$ plane in several MSSM scenarios.

[2] SIRUNYAN 18CX search for production of $H^0_{1,2}/A^0 \to \tau^+\tau^-$ by gluon fusion and b-associated prodution in 35.9 fb^{-1} of pp collisions at $E_{cm} = 13$ TeV. See their Fig. 9 for excluded regions in the $m_{A^0}-\tan(\beta)$ plane in several MSSM scenarios.

[3] AAD 20 combine measurements on H^0 production and decay using data taken in years 2015–2017 (up to 79.8 fb^{-1}) of pp collisions at $E_{cm} = 13$ TeV. See their Fig. 19 for excluded region in the hMSSM parameter space.

[4] AAD 20C combine searches for a scalar resonance decaying to $H^0 H^0$ in 36.1 fb^{-1} of pp collisions at $E_{cm} = 13$ TeV from AABOUD 19A, AABOUD 19O, AABOUD 18CQ, AABOUD 19T, AABOUD 18CW, and AABOUD 18BU. See their Fig. 7(b) for the excluded region in the hMSSM parameter space.

[5] SIRUNYAN 19CR search for production of H^0_2/A^0 in gluon fusion and in association with a $b\overline{b}$ pair, decaying to $\mu^+\mu^-$ in 35.9 fb^{-1} of pp collisions at $E_{cm} = 13$ TeV. See their Fig. 5 for the excluded region in the MSSM parameter space in the $m_h^{\text{mod}+}$ and hMSSM scenarios.

[6] SIRUNYAN 18A search for production of a scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}\tau^+\tau^-$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 5 (lower) for excluded regions in the m_{A^0} − tanβ plane in the hMSSM scenario.

[7] SIRUNYAN 18BP search for production of $H^0_2/A^0 \rightarrow b\overline{b}$ by b-associated prodution in 35.7 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 6 for the limits on cross section times branching ratio for $m_{H^0_2}$, m_{A^0} = 0.3–1.3 TeV, and Fig. 7 for excluded regions in the m_{A^0}− tan(β) plane in several MSSM scenarios.

[8] AABOUD 16AA search for production of a Higgs boson in gluon fusion and in association with a $b\overline{b}$ pair followed by the decay $A^0 \rightarrow \tau^+\tau^-$ in 3.2 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 5(a, b) for limits on cross section times branching ratio for m_{A^0} = 200–1200 GeV, and Fig. 5(c, d) for the excluded region in the MSSM parameter space in the $m_h^{\text{mod}+}$ and hMSSM scenarios.

[9] KHACHATRYAN 16A search for production of a Higgs boson in gluon fusion and in association with a $b\overline{b}$ pair followed by the decay $H^0_{1,2}/A^0 \rightarrow \mu^+\mu^-$ in 5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 19.3 fb^{-1} at E_{cm} = 8 TeV. See their Fig. 7 for the excluded region in the MSSM parameter space in the $m_h^{\text{mod}+}$ benchmark scenario and Fig. 9 for limits on cross section times branching ratio.

[10] KHACHATRYAN 16P search for gluon fusion production of an H^0_2 decaying to $H^0 H^0 \rightarrow b\overline{b}\tau^+\tau^-$ and an A^0 decaying to $Z H^0 \rightarrow \ell^+\ell^-\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 12 for excluded region in the tanβ − cos($\beta - \alpha$) plane for $m_{H^0_2} = m_{A^0}$ = 300 GeV.

[11] KHACHATRYAN 15AY search for production of a Higgs boson in association with a b quark in the decay $H^0_{1,2}/A^0 \rightarrow b\overline{b}$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV and combine with CHATRCHYAN 13AG 7 TeV data. See their Fig. 6 for the limits on cross section times branching ratio for m_{A^0} = 100–900 GeV and Figs. 7–9 for the excluded region in the MSSM parameter space in various benchmark scenarios.

[12] AAD 14AW search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 19.5–20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 11 for the limits on cross section times branching ratio and their Figs. 9 and 10 for the excluded region in the MSSM parameter space. For m_{A^0} = 140 GeV, the region tanβ > 5.4 is excluded at 95% CL in the m_h^{max} scenario.

[13] KHACHATRYAN 14M search for production of a Higgs boson in gluon fusion and in association with a b quark followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 4.9 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 19.7 fb^{-1} at E_{cm} = 8 TeV. See their Figs. 7 and 8 for one- and two-dimensional limits on cross section times branching ratio and their Figs. 5 and 6 for the excluded region in the MSSM parameter space. For m_{A^0} = 140 GeV, the region tanβ > 3.8 is excluded at 95% CL in the m_h^{max} scenario.

[14] AAD 13O search for production of a Higgs boson in the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ and $\mu^+\mu^-$ with 4.7–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 6 for the excluded region in the MSSM parameter space and their Fig. 7 for the limits on cross section times branching ratio. For m_{A^0} = 110–170 GeV, tan$\beta \gtrsim$ 10 is excluded, and for tanβ = 50, m_{A^0} below 470 GeV is excluded at 95% CL in the m_h^{max} scenario.

[15] AAIJ 13T search for production of a Higgs boson in the forward region in the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 1.0 fb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 2 for the limits on cross section times branching ratio and the excluded region in the MSSM parameter space.

[16] CHATRCHYAN 13AG search for production of a Higgs boson in association with a b quark in the decay $H^0_{1,2}/A^0 \rightarrow b\overline{b}$ in 2.7–4.8 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV. See their Fig. 6 for the excluded region in the MSSM parameter space and Fig. 5 for the limits on cross section times branching ratio. For m_{A^0} = 90–350 GeV, upper bounds on tanβ of 18–42 at 95% CL are obtained in the $m_h^{\rm max}$ scenario with $\mu = +200$ GeV.

[17] AALTONEN 12AQ combine AALTONEN 12X and ABAZOV 11K. See their Table I and Fig. 1 for the limit on cross section times branching ratio and Fig. 2 for the excluded region in the MSSM parameter space.

[18] AALTONEN 12X search for associated production of a Higgs boson and a b quark in the decay $H^0_{1,2}/A^0 \rightarrow b\overline{b}$, with 2.6 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. See their Table III and Fig. 15 for the limit on cross section times branching ratio and Figs. 17, 18 for the excluded region in the MSSM parameter space.

[19] ABAZOV 12G search for production of a Higgs boson in the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ with 7.3 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV and combine with ABAZOV 11W and ABAZOV 11K. See their Figs. 4, 5, and 6 for the excluded region in the MSSM parameter space. For m_{A^0} = 90–180 GeV, tan$\beta \gtrsim$ 30 is excluded at 95% CL. in the $m_h^{\rm max}$ scenario.

[20] CHATRCHYAN 12K search for production of a Higgs boson in the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ with 4.6 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV. See their Fig. 3 and Table 4 for the excluded region in the MSSM parameter space. For m_{A^0} = 160 GeV, the region tanβ > 7.1 is excluded at 95% CL in the $m_h^{\rm max}$ scenario. Superseded by KHACHATRYAN 14M.

[21] ABAZOV 11K search for associated production of a Higgs boson and a b quark, followed by the decay $H^0_{1,2}/A^0 \rightarrow b\overline{b}$, in 5.2 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. See their Fig. 5/Table 2 for the limit on cross section times branching ratio and Fig. 6 for the excluded region in the MSSM parameter space for $\mu = -200$ GeV.

[22] ABAZOV 11W search for associated production of a Higgs boson and a b quark, followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau\tau$, in 7.3 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. See their Fig. 2 for the limit on cross section times branching ratio and for the excluded region in the MSSM parameter space.

[23] AALTONEN 09AR search for Higgs bosons decaying to $\tau^+\tau^-$ in two doublet models in 1.8 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. See their Fig. 2 for the limit on $\sigma \cdot$ B($H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$) for different Higgs masses, and see their Fig. 3 for the excluded region in the MSSM parameter space.

[24] ABDALLAH 08B give limits in eight CP-conserving benchmark scenarios and some CP-violating scenarios. See paper for excluded regions for each scenario. Supersedes ABDALLAH 04.

[25] SCHAEL 06B make a combined analysis of the LEP data. The quoted limit is for the $m_h^{\rm max}$ scenario with m_t = 174.3 GeV. In the CP-violating CPX scenario no lower bound on $m_{H^0_1}$ can be set at 95% CL. See paper for excluded regions in various scenarios. See Figs. 2–6 and Tabs. 14–21 for limits on $\sigma(Z H^0)\cdot$ B($H^0 \rightarrow b\overline{b}, \tau^+\tau^-$) and $\sigma(H^0_1 H^0_2)\cdot$ B($H^0_1,H^0_2 \rightarrow b\overline{b},\tau^+\tau^-$).

[26] ACOSTA 05Q search for $H^0_{1,2}/A^0$ production in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.8 TeV with $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$. At m_{A^0} = 100 GeV, the obtained cross section upper limit is above theoretical expectation.

[27] Search for $e^+e^- \rightarrow H^0_1 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$, and $e^+e^- \rightarrow H^0_1 Z$. Universal scalar mass of 1 TeV, SU(2) gaugino mass of 200 GeV, and $\mu = -200$

GeV are assumed, and two-loop radiative corrections incorporated. The limits hold for m_t=175 GeV, and for the m_h^{max} scenario.

[28] ABBIENDI 04M exclude 0.7 < tanβ < 1.9, assuming m_t = 174.3 GeV. Limits for other MSSM benchmark scenarios, as well as for *CP* violating cases, are also given.

[29] ABBIENDI 03G search for $e^+e^- \rightarrow H_1^0 Z$ followed by $H_1^0 \rightarrow A^0 A^0$, $A^0 \rightarrow c\overline{c}$, gg, or $\tau^+\tau^-$. In the no-mixing scenario, the region $m_{H_1^0}$ = 45-85 GeV and m_{A^0} = 2-9.5 GeV is excluded at 95% CL.

[30] ACHARD 02H also search for the final state $H_1^0 Z \rightarrow 2A^0 q\overline{q}$, $A^0 \rightarrow q\overline{q}$. In addition, the MSSM parameter set in the "large-μ" and "no-mixing" scenarios are examined.

[31] AKEROYD 02 examine the possibility of a light A^0 with tanβ <1. Electroweak measurements are found to be inconsistent with such a scenario.

[32] HEISTER 02 excludes the range 0.7 <tanβ < 2.3. A wider range is excluded with different stop mixing assumptions. Updates BARATE 01C.

Mass Limits for H_1^0 (Higgs Boson) in Supersymmetric Models

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>89.7		[1] ABDALLAH	08B	DLPH	$E_{cm} \leq$ 209 GeV
>92.8	95	[2] SCHAEL	06B	LEP	$E_{cm} \leq$ 209 GeV
>84.5	95	[3,4] ABBIENDI	04M	OPAL	$E_{cm} \leq$ 209 GeV
>86.0	95	[3,5] ACHARD	02H	L3	$E_{cm} \leq$ 209 GeV, tanβ > 0.4
>89.8	95	[3,6] HEISTER	02	ALEP	$E_{cm} \leq$ 209 GeV, tanβ > 0.5
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[7] AALTONEN	12AQ	TEVA	$p\overline{p} \rightarrow H_{1,2}^0/A^0 + b + X$, $H_{1,2}^0/A^0 \rightarrow b\overline{b}$

[1] ABDALLAH 08B give limits in eight *CP*-conserving benchmark scenarios and some *CP*-violating scenarios. See paper for excluded regions for each scenario. Supersedes ABDALLAH 04.

[2] SCHAEL 06B make a combined analysis of the LEP data. The quoted limit is for the m_h^{max} scenario with m_t = 174.3 GeV. In the *CP*-violating CPX scenario no lower bound on $m_{H_1^0}$ can be set at 95% CL. See paper for excluded regions in various scenarios. See Figs. 2–6 and Tabs. 14–21 for limits on $\sigma(Z H^0)\cdot$ B($H^0 \rightarrow b\overline{b}, \tau^+\tau^-$) and $\sigma(H_1^0 H_2^0)\cdot$ B($H_1^0,H_2^0 \rightarrow b\overline{b},\tau^+\tau^-$).

[3] Search for $e^+e^- \rightarrow H_1^0 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$, and $e^+e^- \rightarrow H_1^0 Z$. Universal scalar mass of 1 TeV, SU(2) gaugino mass of 200 GeV, and $\mu = -200$ GeV are assumed, and two-loop radiative corrections incorporated. The limits hold for m_t=175 GeV, and for the m_h^{max} scenario.

[4] ABBIENDI 04M exclude 0.7 < tanβ < 1.9, assuming m_t = 174.3 GeV. Limits for other MSSM benchmark scenarios, as well as for *CP* violating cases, are also given.

[5] ACHARD 02H also search for the final state $H_1^0 Z \rightarrow 2A^0 q\overline{q}$, $A^0 \rightarrow q\overline{q}$. In addition, the MSSM parameter set in the "large-μ" and "no-mixing" scenarios are examined.

[6] HEISTER 02 excludes the range 0.7 <tanβ < 2.3. A wider range is excluded with different stop mixing assumptions. Updates BARATE 01C.

[7] AALTONEN 12AQ combine AALTONEN 12X and ABAZOV 11K. See their Table I and Fig. 1 for the limit on cross section times branching ratio and Fig. 2 for the excluded region in the MSSM parameter space.

MASS LIMITS FOR NEUTRAL HIGGS BOSONS IN EXTENDED HIGGS MODELS

This Section covers models which do not fit into either the Standard Model or its simplest minimal Supersymmetric extension (MSSM), leading to anomalous production rates, or nonstandard final states and branching ratios. In particular, this Section covers limits which may apply to generic two-Higgs-doublet models (2HDM), or to special regions of the MSSM parameter space where decays to invisible particles or to photon pairs are dominant (see the review on "Status of Higgs Boson Physics"). Concerning the mass limits for H^0 and A^0 listed below, see the footnotes or the comment lines for details on the nature of the models to which the limits apply.

The observed signal at about 125 GeV, see section "H^0", can be interpreted as one of the neutral Higgs bosons of an extended Higgs sector.

Mass Limits in General two-Higgs-doublet Models

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] AAD	20	ATLS	H^0 properties
		[2] SIRUNYAN	19AE	CMS	$A^0 \to \tau^+\tau^-$
		[3] SIRUNYAN	19AV	CMS	$A^0 \to Z H^0$
		[4] AABOUD	18AH	ATLS	$A^0 \to Z H^0_2$
		[5] AABOUD	18AI	ATLS	$A^0 \to Z H^0$
		[6] AABOUD	18BF	ATLS	$H^0_2 \to Z Z$
		[7] AABOUD	18CE	ATLS	$p p \to H^0_2 / A^0 t\overline{t}$, $H^0_2 / A^0 \to t\overline{t}$
		[8] HALLER	18	RVUE	global fits
		[9] SIRUNYAN	18BP	CMS	$p p \to H^0_2 / A^0 + b + X$, $H^0_2 / A^0 \to b\overline{b}$
		[10] SIRUNYAN	18ED	CMS	$A^0 \to Z H^0$
		[11] AABOUD	17AN	ATLS	H^0_2, $A^0 \to t\overline{t}$
		[12] SIRUNYAN	17AX	CMS	$A^0 b\overline{b}$, $A^0 \to \mu^+\mu^-$
		[13] AAD	16AX	ATLS	$H^0_2 \to Z Z$
		[14] KHACHATRY...	16P	CMS	$H^0_2 \to H^0 H^0$, $A^0 \to Z H^0$
		[15] KHACHATRY...	16W	CMS	$A^0 b\overline{b}$, $A^0 \to \tau^+\tau^-$
		[16] KHACHATRY...	16Z	CMS	$H^0_2 \to Z A^0$ or $A^0 \to Z H^0_2$
		[17] AAD	15BK	ATLS	$H^0_2 \to H^0 H^0$
		[18] AAD	15S	ATLS	$A^0 \to Z H^0$
		[19] KHACHATRY...	15BB	CMS	H^0_2, $A^0 \to \gamma\gamma$
		[20] KHACHATRY...	15N	CMS	$A^0 \to Z H^0$
		[21] AAD	14M	ATLS	$H^0_2 \to H^\pm W^\mp \to H^0 W^\pm W^\mp$, $H^0 \to b\overline{b}$
		[22] KHACHATRY...	14Q	CMS	$H^0_2 \to H^0 H^0$, $A^0 \to Z H^0$
		[23] AALTONEN	09AR	CDF	$p\overline{p} \to H^0_{1,2} / A^0 + X$, $H^0_{1,2} / A^0 \to \tau^+\tau^-$

none 1–55	95	[24] ABBIENDI	05A	OPAL	H_1^0, Type II model
>110.6	95	[25] ABDALLAH	05D	DLPH	$H^0 \rightarrow$ 2 jets
		[26] ABDALLAH	04O	DLPH	$Z \rightarrow f\overline{f}H$
		[27] ABDALLAH	04O	DLPH	$e^+e^- \rightarrow H^0 Z$, $H^0 A^0$
		[28] ABBIENDI	02D	OPAL	$e^+e^- \rightarrow b\overline{b}H$
none 1–44	95	[29] ABBIENDI	01E	OPAL	H_1^0, Type-II model
> 68.0	95	[30] ABBIENDI	99E	OPAL	$\tan\beta > 1$
		[31] ABREU	95H	DLPH	$Z \rightarrow H^0 Z^*$, $H^0 A^0$
		[32] PICH	92	RVUE	Very light Higgs

[1] AAD 20 combine measurements on H^0 production and decay using data taken in years 2015–2017 (up to 79.8 fb^{-1}) of pp collisions at E_{cm} = 13 TeV. See their Fig. 18 for excluded regions in various 2HDMs.

[2] SIRUNYAN 19AE search for a pseudoscalar resonance produced in association with a $b\overline{b}$ pair, decaying to $\tau^+\tau^-$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 4 for cross section limits for m_{A^0} = 25–70 GeV and comparison with some representative 2HDMs.

[3] SIRUNYAN 19AV search for a scalar resonance produced by gluon fusion or b associated production, decaying to $ZH^0 \rightarrow \ell^+\ell^- b\overline{b}$ ($\ell = e, \mu$) or $\nu\overline{\nu}b\overline{b}$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Figs. 6 and 7 for excluded regions in the parameter space of various 2HDMs.

[4] AABOUD 18AH search for production of an A^0 in gluon-gluon fusion and in association with a $b\overline{b}$, decaying to $ZH_2^0 \rightarrow \ell^+\ell^- b\overline{b}$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 6 for excluded regions in the parameter space of various 2HDMs.

[5] AABOUD 18AI search for production of an A^0 in gluon-gluon fusion and in association with a $b\overline{b}$, decaying to ZH^0 in the final states $\nu\overline{\nu}b\overline{b}$ and $\ell^+\ell^- b\overline{b}$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Figs. 7 and 8 for excluded regions in the parameter space in various 2HDMs.

[6] AABOUD 18BF search for production of a heavy H_2^0 state decaying to ZZ in the final states $\ell^+\ell^-\ell^+\ell^-$ and $\ell^+\ell^-\nu\overline{\nu}$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Figs. 8 and 9 for excluded parameter regions in 2HDM Type I and II.

[7] AABOUD 18CE search for the process $pp \rightarrow H_2^0/A^0\, t\overline{t}$ followed by the decay $H_2^0/A^0 \rightarrow t\overline{t}$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 12 for limits on cross section times branching ratio, and for lower limits on $\tan\beta$ for $m_{H_2^0}$, m_{A^0} = 0.4–1.0 TeV in the 2HDM type II.

[8] HALLER 18 perform global fits in the framework of two-Higgs-doublet models (type I, II, lepton specific, flipped). See their Fig. 8 for allowed parameter regions from fits to LHC H^0 measurements, Fig. 9 bottom and charm decays, Fig. 10 muon anomalous magnetic moment, Fig. 11 electroweak precision data, and Fig. 12 by combination of all data.

[9] SIRUNYAN 18BP search for production of $H_2^0/A^0 \rightarrow b\overline{b}$ by b-associated prodution in 35.7 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 6 for the limits on cross section times branching ratio for $m_{H_2^0}$, m_{A^0} = 0.3–1.3 TeV, and Figs. 8 and 9 for excluded regions in the parameter space of type-II and flipped 2HDMs.

[10] SIRUNYAN 18ED search for production of an A^0 in gluon-gluon fusion and in association with a $b\overline{b}$, decaying to ZH^0 in the final states $\nu\overline{\nu}b\overline{b}$ or $\ell^+\ell^- b\overline{b}$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 9 for excluded regions in the parameter space in Type I and II 2HDMs.

[11] AABOUD 17AN search for production of a heavy H_2^0 and/or A^0 decaying to $t\overline{t}$ in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 3 and Table III for excluded parameter regions in Type II Two-Higgs-Doublet-Models.

[12] SIRUNYAN 17AX search for $A^0 b\overline{b}$ production followed by the decay $A^0 \rightarrow \mu^+\mu^-$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. Limits are set in the range m_{A^0} = 25–60 GeV. See their Fig. 5 for upper limits on $\sigma(A^0 b\overline{b})\cdot$B$(A^0 \rightarrow \mu^+\mu^-)$.

[13] AAD 16AX search for production of a heavy H^0 state decaying to ZZ in the final states $\ell^+\ell^-\ell^+\ell^-$, $\ell^+\ell^-\nu\overline{\nu}$, $\ell^+\ell^- q\overline{q}$, and $\nu\overline{\nu}q\overline{q}$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Figs. 13 and 14 for excluded parameter regions in Type I and II models.

[14] KHACHATRYAN 16P search for gluon fusion production of an H^0_2 decaying to $H^0 H^0 \rightarrow b\overline{b}\tau^+\tau^-$ and an A^0 decaying to $ZH^0 \rightarrow \ell^+\ell^-\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 11 for limits on tanβ for m_{A^0} = 230–350 GeV.

[15] KHACHATRYAN 16W search for $A^0 b\overline{b}$ production followed by the decay $A^0 \rightarrow \tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 3 for upper limits on $\sigma(A^0 b\overline{b})\cdot$B$(A^0 \rightarrow \tau^+\tau^-)$.

[16] KHACHATRYAN 16Z search for $H^0_2 \rightarrow ZA^0$ followed by $A^0 \rightarrow b\overline{b}$ or $\tau^+\tau^-$, and $A^0 \rightarrow ZH^0_2$ followed by $H^0_2 \rightarrow b\overline{b}$ or $\tau^+\tau^-$, in 19.8 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 4 for cross section limits and Fig. 5 for excluded region in the parameter space.

[17] AAD 15BK search for production of a heavy H^0_2 decaying to $H^0 H^0$ in the final state $b\overline{b}b\overline{b}$ in 19.5 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Figs. 15–18 for excluded regions in the parameter space.

[18] AAD 15S search for production of A^0 decaying to $ZH^0 \rightarrow \ell^+\ell^- b\overline{b}$, $\nu\overline{\nu}b\overline{b}$ and $\ell^+\ell^-\tau^+\tau^-$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Figs. 4 and 5 for excluded regions in the parameter space.

[19] KHACHATRYAN 15BB search for H^0_2, $A^0 \rightarrow \gamma\gamma$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 10 for excluded regions in the two-Higgs-doublet model parameter space.

[20] KHACHATRYAN 15N search for production of A^0 decaying to $ZH^0 \rightarrow \ell^+\ell^- b\overline{b}$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 5 for excluded regions in the tanβ − cos$(\beta-\alpha)$ plane for m_{A^0} = 300 GeV.

[21] AAD 14M search for the decay cascade $H^0_2 \rightarrow H^\pm W^\mp \rightarrow H^0 W^\pm W^\mp$, H^0 decaying to $b\overline{b}$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Table IV for limits in a two-Higgs-doublet model for $m_{H^0_2}$= 325–1025 GeV and m_{H^+}= 225–825 GeV.

[22] KHACHATRYAN 14Q search for $H^0_2 \rightarrow H^0 H^0$ and $A^0 \rightarrow ZH^0$ in 19.5 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Figs. 4 and 5 for limits on cross section times branching ratio for m_{H_2,A^0}= 260–360 GeV and their Figs. 7–9 for limits in two-Higgs-doublet models.

[23] AALTONEN 09AR search for Higgs bosons decaying to $\tau^+\tau^-$ in two doublet models in 1.8 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. See their Fig. 2 for the limit on $\sigma\cdot$B$(H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-)$ for different Higgs masses, and see their Fig. 3 for the excluded region in the MSSM parameter space.

[24] ABBIENDI 05A search for $e^+e^- \rightarrow H^0_1 A^0$ in general Type-II two-doublet models, with decays H^0_1, $A^0 \rightarrow q\overline{q}$, gg, $\tau^+\tau^-$, and $H^0_1 \rightarrow A^0 A^0$.

[25] ABDALLAH 05D search for $e^+e^- \rightarrow H^0 Z$ and $H^0 A^0$ with H^0, A^0 decaying to two jets of any flavor including gg. The limit is for SM $H^0 Z$ production cross section with B$(H^0 \rightarrow jj)$ = 1.

[26] ABDALLAH 04O search for $Z \rightarrow b\overline{b}H^0$, $b\overline{b}A^0$, $\tau^+\tau^- H^0$ and $\tau^+\tau^- A^0$ in the final states $4b$, $b\overline{b}\tau^+\tau^-$, and 4τ. See paper for limits on Yukawa couplings.

[27] ABDALLAH 04O search for $e^+e^- \rightarrow H^0 Z$ and $H^0 A^0$, with H^0, A^0 decaying to $b\overline{b}$, $\tau^+\tau^-$, or $H^0 \rightarrow A^0 A^0$ at $E_{\rm cm}$ = 189–208 GeV. See paper for limits on couplings.

[28] ABBIENDI 02D search for $Z \to b\overline{b}H_1^0$ and $b\overline{b}A^0$ with $H_1^0/A^0 \to \tau^+\tau^-$, in the range $4<m_H<12$ GeV. See their Fig. 8 for limits on the Yukawa coupling.

[29] ABBIENDI 01E search for neutral Higgs bosons in general Type-II two-doublet models, at $E_{\rm cm} \leq 189$ GeV. In addition to usual final states, the decays H_1^0, $A^0 \to q\overline{q}$, $g g$ are searched for. See their Figs. 15,16 for excluded regions.

[30] ABBIENDI 99E search for $e^+e^- \to H^0 A^0$ and $H^0 Z$ at $E_{\rm cm} = 183$ GeV. The limit is with $m_H=m_A$ in general two Higgs-doublet models. See their Fig. 18 for the exclusion limit in the m_H–m_A plane. Updates the results of ACKERSTAFF 98S.

[31] See Fig. 4 of ABREU 95H for the excluded region in the $m_{H^0} - m_{A^0}$ plane for general two-doublet models. For $\tan\beta >1$, the region $m_{H^0}+m_{A^0} \lesssim 87$ GeV, $m_{H^0} <47$ GeV is excluded at 95% CL.

[32] PICH 92 analyse H^0 with $m_{H^0} < 2m_\mu$ in general two-doublet models. Excluded regions in the space of mass-mixing angles from LEP, beam dump, and $\pi^\pm$, η rare decays are shown in Figs. 3,4. The considered mass region is not totally excluded.

Mass Limits for H^0 with Vanishing Yukawa Couplings

These limits assume that H^0 couples to gauge bosons with the same strength as the Standard Model Higgs boson, but has no coupling to quarks and leptons (this is often referred to as "fermiophobic").

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
	95	[1] AALTONEN	13K	CDF	$H^0 \to W W^{(*)}$
none 100–113	95	[2] AALTONEN	13L	CDF	$H^0 \to \gamma\gamma$, $W W^*$, $Z Z^*$
none 100–116	95	[3] AALTONEN	13M	TEVA	$H^0 \to \gamma\gamma$, $W W^*$, $Z Z^*$
		[4] ABAZOV	13G	D0	$H^0 \to W W^{(*)}$
none 100–113	95	[5] ABAZOV	13H	D0	$H^0 \to \gamma\gamma$
		[6] ABAZOV	13I	D0	$H^0 \to W W^{(*)}$
		[7] ABAZOV	13J	D0	$H^0 \to W W^{(*)}$, $Z Z^{(*)}$
none 100–114	95	[8] ABAZOV	13L	D0	$H^0 \to \gamma\gamma$, $W W^*$, $Z Z^*$
none 110–147	95	[9] CHATRCHYAN	13AL	CMS	$H^0 \to \gamma\gamma$
none 110–118, 119.5–121	95	[10] AAD	12N	ATLS	$H^0 \to \gamma\gamma$
none 100–114	95	[11] AALTONEN	12AN	CDF	$H^0 \to \gamma\gamma$
none 110–194	95	[12] CHATRCHYAN	12AO	CMS	$H^0 \to \gamma\gamma$, $W W^{(*)}$, $Z Z^{(*)}$
none 70–106	95	[13] AALTONEN	09AB	CDF	$H^0 \to \gamma\gamma$
none 70–100	95	[14] ABAZOV	08U	D0	$H^0 \to \gamma\gamma$
>105.8	95	[15] SCHAEL	07	ALEP	$e^+e^- \to H^0 Z$, $H^0 \to W W^*$
>104.1	95	[16,17] ABDALLAH	04L	DLPH	$e^+e^- \to H^0 Z$, $H^0 \to \gamma\gamma$
>107	95	[18] ACHARD	03C	L3	$H^0 \to W W^*$,$Z Z^*$, $\gamma\gamma$
>105.5	95	[16,19] ABBIENDI	02F	OPAL	$H^0 \to \gamma\gamma$
>105.4	95	[20] ACHARD	02C	L3	$H^0 \to \gamma\gamma$
none 60–82	95	[21] AFFOLDER	01H	CDF	$p\overline{p} \to H^0 W/Z$, $H^0 \to \gamma\gamma$
> 94.9	95	[22] ACCIARRI	00S	L3	$e^+e^- \to H^0 Z$, $H^0 \to \gamma\gamma$
>100.7	95	[23] BARATE	00L	ALEP	$e^+e^- \to H^0 Z$, $H^0 \to \gamma\gamma$
> 96.2	95	[24] ABBIENDI	99O	OPAL	$e^+e^- \to H^0 Z$, $H^0 \to \gamma\gamma$
> 78.5	95	[25] ABBOTT	99B	D0	$p\overline{p} \to H^0 W/Z$, $H^0 \to \gamma\gamma$
		[26] ABREU	99P	DLPH	$e^+e^- \to H^0\gamma$ and/or $H^0 \to \gamma\gamma$

[1] AALTONEN 13K search for $H^0 \to W W^{(*)}$ in 9.7 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm} = 1.96$ TeV. A limit on cross section times branching ratio which corresponds to (1.3–6.6) times the expected cross section is given in the range $m_{H^0} = 110$–200 GeV at 95% CL.

[2] AALTONEN 13L combine all CDF searches with 9.45–10.0 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV.

[3] AALTONEN 13M combine all Tevatron data from the CDF and D0 Collaborations of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV.

[4] ABAZOV 13G search for $H^0 \rightarrow WW^{(*)}$ in 9.7 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. A limit on cross section times branching ratio which corresponds to (2–9) times the expected cross section is given for m_{H^0} = 100–200 GeV at 95% CL.

[5] ABAZOV 13H search for $H^0 \rightarrow \gamma\gamma$ in 9.6 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV.

[6] ABAZOV 13I search for H^0 production in the final state with one lepton and two or more jets plus missing E_T in 9.7 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. The search is sensitive to WH^0, ZH^0 and vector-boson fusion Higgs production with $H^0 \rightarrow WW^{(*)}$. A limit on cross section times branching ratio which corresponds to (8–30) times the expected cross section is given in the range m_{H^0} = 100–200 GeV at 95% CL.

[7] ABAZOV 13J search for H^0 production in the final states $ee\mu$, $e\mu\mu$, $\mu\tau\tau$, and $e^{\pm}\mu^{\pm}$ in 8.6–9.7 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV. The search is sensitive to WH^0, ZH^0 production with $H^0 \rightarrow WW^{(*)}$, $ZZ^{(*)}$, decaying to leptonic final states. A limit on cross section times branching ratio which corresponds to (2.4–13.0) times the expected cross section is given in the range m_{H^0} = 100–200 GeV at 95% CL.

[8] ABAZOV 13L combine all D0 results with up to 9.7 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV.

[9] CHATRCHYAN 13AL search for $H^0 \rightarrow \gamma\gamma$ in 5.1 fb^{-1} and 5.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 and 8 TeV.

[10] AAD 12N search for $H^0 \rightarrow \gamma\gamma$ with 4.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV in the mass range m_{H^0} = 110–150 GeV.

[11] AALTONEN 12AN search for $H^0 \rightarrow \gamma\gamma$ with 10 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV in the mass range m_{H^0} = 100–150 GeV.

[12] CHATRCHYAN 12AO use data from CHATRCHYAN 12G, CHATRCHYAN 12E, CHATRCHYAN 12H, CHATRCHYAN 12I, CHATRCHYAN 12D, and CHATRCHYAN 12C.

[13] AALTONEN 09AB search for $H^0 \rightarrow \gamma\gamma$ in 3.0 fb^{-1} of $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV in the mass range m_{H^0} = 70–150 GeV. Associated $H^0 W$, $H^0 Z$ production and WW, ZZ fusion are considered.

[14] ABAZOV 08U search for $H^0 \rightarrow \gamma\gamma$ in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.96 TeV in the mass range m_{H^0} = 70–150 GeV. Associated $H^0 W$, $H^0 Z$ production and WW, ZZ fusion are considered. See their Tab. 1 for the limit on $\sigma \cdot$ B($H^0 \rightarrow \gamma\gamma$), and see their Fig. 3 for the excluded region in the m_{H^0} — B($H^0 \rightarrow \gamma\gamma$) plane.

[15] SCHAEL 07 search for Higgs bosons in association with a fermion pair and decaying to WW^*. The limit is from this search and HEISTER 02L for a H^0 with SM production cross section.

[16] Search for associated production of a $\gamma\gamma$ resonance with a Z boson, followed by $Z \rightarrow q\overline{q}$, $\ell^+\ell^-$, or $\nu\overline{\nu}$, at $E_{\rm cm} \leq$ 209 GeV. The limit is for a H^0 with SM production cross section.

[17] Updates ABREU 01F.

[18] ACHARD 03C search for $e^+e^- \rightarrow ZH^0$ followed by $H^0 \rightarrow WW^*$ or ZZ^* at $E_{\rm cm}$= 200-209 GeV and combine with the ACHARD 02C result. The limit is for a H^0 with SM production cross section. For B($H^0 \rightarrow WW^*$) + B($H^0 \rightarrow ZZ^*$) = 1, m$_{H^0}$ > 108.1 GeV is obtained. See fig. 6 for the limits under different BR assumptions.

[19] For B($H^0 \rightarrow \gamma\gamma$)=1, m_{H^0} >117 GeV is obtained.

[20] ACHARD 02C search for associated production of a $\gamma\gamma$ resonance with a Z boson, followed by $Z \rightarrow q\overline{q}$, $\ell^+\ell^-$, or $\nu\overline{\nu}$, at $E_{\rm cm} \leq$ 209 GeV. The limit is for a H^0 with SM production cross section. For B($H^0 \rightarrow \gamma\gamma$)=1, m_{H^0} >114 GeV is obtained.

[21] AFFOLDER 01H search for associated production of a $\gamma\gamma$ resonance and a W or Z (tagged by two jets, an isolated lepton, or missing E_T). The limit assumes Standard Model values for the production cross section and for the couplings of the H^0 to W and Z bosons. See their Fig. 11 for limits with B($H^0 \rightarrow \gamma\gamma$)$< 1$.

[22] ACCIARRI 00S search for associated production of a $\gamma\gamma$ resonance with a $q\overline{q}$, $\nu\overline{\nu}$, or $\ell^+\ell^-$ pair in e^+e^- collisions at E_{cm}= 189 GeV. The limit is for a H^0 with SM production cross section. For B($H^0 \rightarrow \gamma\gamma$)=1, $m_{H^0} > 98$ GeV is obtained. See their Fig. 5 for limits on B($H \rightarrow \gamma\gamma$)$\cdot\sigma(e^+e^- \rightarrow Hf\overline{f})/\sigma(e^+e^- \rightarrow Hf\overline{f})$ (SM).

[23] BARATE 00L search for associated production of a $\gamma\gamma$ resonance with a $q\overline{q}$, $\nu\overline{\nu}$, or $\ell^+\ell^-$ pair in e^+e^- collisions at E_{cm}= 88–202 GeV. The limit is for a H^0 with SM production cross section. For B($H^0 \rightarrow \gamma\gamma$)=1, $m_{H^0} > 109$ GeV is obtained. See their Fig. 3 for limits on B($H \rightarrow \gamma\gamma$)$\cdot\sigma(e^+e^- \rightarrow Hf\overline{f})/\sigma(e^+e^- \rightarrow Hf\overline{f})$ (SM).

[24] ABBIENDI 99O search for associated production of a $\gamma\gamma$ resonance with a $q\overline{q}$, $\nu\overline{\nu}$, or $\ell^+\ell^-$ pair in e^+e^- collisions at 189 GeV. The limit is for a H^0 with SM production cross section. See their Fig. 4 for limits on $\sigma(e^+e^- \rightarrow H^0 Z^0)\times$B($H^0 \rightarrow \gamma\gamma$)$\times$B($X^0 \rightarrow f\overline{f}$) for various masses. Updates the results of ACKERSTAFF 98Y.

[25] ABBOTT 99B search for associated production of a $\gamma\gamma$ resonance and a dijet pair. The limit assumes Standard Model values for the production cross section and for the couplings of the H^0 to W and Z bosons. Limits in the range of $\sigma(H^0+Z/W)\cdot$B($H^0 \rightarrow \gamma\gamma$)= 0.80–0.34 pb are obtained in the mass range m_{H^0}= 65–150 GeV.

[26] ABREU 99P search for $e^+e^- \rightarrow H^0\gamma$ with $H^0 \rightarrow b\overline{b}$ or $\gamma\gamma$, and $e^+e^- \rightarrow H^0 q\overline{q}$ with $H^0 \rightarrow \gamma\gamma$. See their Fig. 4 for limits on $\sigma\times$B. Explicit limits within an effective interaction framework are also given.

Mass Limits for H^0 Decaying to Invisible Final States

These limits are for a neutral scalar H^0 which predominantly decays to invisible final states. Standard Model values are assumed for the couplings of H^0 to ordinary particles unless otherwise stated.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] AABOUD	19AI	ATLS	WW/ZZ fusion
		[2] AAD	15BD	ATLS	$pp \rightarrow H^0 WX$, $H^0 ZX$
		[3] AAD	15BH	ATLS	jet + missing E_T
		[4] AAD	14BA	ATLS	secondary vertex
		[5] AAD	14O	ATLS	$pp \rightarrow H^0 ZX$
		[6] CHATRCHYAN	14B	CMS	$pp \rightarrow H^0 ZX$, $qqH^0 X$
		[7] AAD	13AG	ATLS	secondary vertex
		[8] AAD	13AT	ATLS	electron jets
		[9] CHATRCHYAN	13BJ	CMS	
		[10] AAD	12AQ	ATLS	secondary vertex
		[11] AALTONEN	12AB	CDF	secondary vertex
		[12] AALTONEN	12U	CDF	secondary vertex
$>$108.2	95	[13] ABBIENDI	10	OPAL	
		[14] ABBIENDI	07	OPAL	large width
$>$112.3	95	[15] ACHARD	05	L3	
$>$112.1	95	[15] ABDALLAH	04B	DLPH	
$>$114.1	95	[15] HEISTER	02	ALEP	$E_{cm} \leq 209$ GeV

>106.4	95	[15] BARATE	01C	ALEP	$E_{cm} \leq 202$ GeV
> 89.2	95	[16] ACCIARRI	00M	L3	

[1] AABOUD 19AI search for $H^0_{1,2}$ production by vector boson fusion and decay to invisible final states in 36.1 fb^{-1} of pp collisions at $E_{cm} = 13$ TeV. See their Fig. 6(b) for limits on cross section times branching ratios for $m_{H^0_{1,2}} = 0.1$–3 TeV.

[2] AAD 15BD search for $pp \rightarrow H^0 W X$ and $pp \rightarrow H^0 Z X$ with W or Z decaying hadronically and H^0 decaying to invisible final states in 20.3 fb^{-1} at $E_{cm} = 8$TeV. See their Fig. 6 for a limit on the cross section times branching ratio for $m_{H^0} = 115$–300 GeV.

[3] AAD 15BH search for events with a jet and missing E_T in 20.3 fb^{-1} of pp collisions at $E_{cm} = 8$ TeV. Limits on $\sigma(H'^0)$ B($H'^0 \rightarrow$ invisible) $<$ (44–10) pb (95%CL) is given for $m_{H'^0} = 115$–300 GeV.

[4] AAD 14BA search for H^0 production in the decay mode $H^0 \rightarrow X^0 X^0$, where X^0 is a long-lived particle which decays to collimated pairs of $e^+ e^-$, $\mu^+ \mu^-$, or $\pi^+ \pi^-$ plus invisible particles, in 20.3 fb^{-1} of pp collisions at $E_{cm} = 8$ TeV. See their Figs. 15 and 16 for limits on cross section times branching ratio.

[5] AAD 14O search for $pp \rightarrow H^0 Z X$, $Z \rightarrow \ell\ell$, with H^0 decaying to invisible final states in 4.5 fb^{-1} at $E_{cm} = 7$ TeV and 20.3 fb^{-1} at $E_{cm} = 8$ TeV. See their Fig. 3 for a limit on the cross section times branching ratio for $m_{H^0} = 110$–400 GeV.

[6] CHATRCHYAN 14B search for $pp \rightarrow H^0 Z X$, $Z \rightarrow \ell\ell$ and $Z \rightarrow b\overline{b}$, and also $pp \rightarrow q q H^0 X$ with H^0 decaying to invisible final states using data at $E_{cm} = 7$ and 8 TeV. See their Figs. 10, 11 for limits on the cross section times branching ratio for $m_{H^0} =$ 100–400 GeV.

[7] AAD 13AG search for H^0 production in the decay mode $H^0 \rightarrow X^0 X^0$, where X^0 is a long-lived particle which decays to $\mu^+ \mu^- X'^0$, in 1.9 fb^{-1} of pp collisions at $E_{cm} = 7$ TeV. See their Fig. 7 for limits on cross section times branching ratio.

[8] AAD 13AT search for H^0 production in the decay $H^0 \rightarrow X^0 X^0$, where X^0 eventually decays to clusters of collimated $e^+ e^-$ pairs, in 2.04 fb^{-1} of pp collisions at $E_{cm} = 7$ TeV. See their Fig. 3 for limits on cross section times branching ratio.

[9] CHATRCHYAN 13BJ search for H^0 production in the decay chain $H^0 \rightarrow X^0 X^0$, $X^0 \rightarrow \mu^+ \mu^- X'^0$ in 5.3 fb^{-1} of pp collisions at $E_{cm} = 7$ TeV. See their Fig. 2 for limits on cross section times branching ratio.

[10] AAD 12AQ search for H^0 production in the decay mode $H^0 \rightarrow X^0 X^0$, where X^0 is a long-lived particle which decays mainly to $b\overline{b}$ in the muon detector, in 1.94 fb^{-1} of pp collisions at $E_{cm} = 7$ TeV. See their Fig. 3 for limits on cross section times branching ratio for $m_{H^0} = 120$, 140 GeV, $m_{X^0} = 20$, 40 GeV in the $c\tau$ range of 0.5–35 m.

[11] AALTONEN 12AB search for H^0 production in the decay $H^0 \rightarrow X^0 X^0$, where X^0 eventually decays to clusters of collimated $\ell^+ \ell^-$ pairs, in 5.1 fb^{-1} of $p\overline{p}$ collisions at $E_{cm} = 1.96$ TeV. Cross section limits are provided for a benchmark MSSM model incorporating the parameters given in Table VI.

[12] AALTONEN 12U search for H^0 production in the decay mode $H^0 \rightarrow X^0 X^0$, where X^0 is a long-lived particle with $c\tau \approx 1$ cm which decays mainly to $b\overline{b}$, in 3.2 fb^{-1} of $p\overline{p}$ collisions at $E_{cm} = 1.96$ TeV. See their Figs. 9 and 10 for limits on cross section times branching ratio for $m_{H^0} =$ (130–170) GeV, $m_{X^0} = 20$, 40 GeV.

[13] ABBIENDI 10 search for $e^+ e^- \rightarrow H^0 Z$ with H^0 decaying invisibly. The limit assumes SM production cross section and B($H^0 \rightarrow$ invisible) = 1.

[14] ABBIENDI 07 search for $e^+ e^- \rightarrow H^0 Z$ with $Z \rightarrow q\overline{q}$ and H^0 decaying to invisible final states. The H^0 width is varied between 1 GeV and 3 TeV. A limit $\sigma \cdot$ B($H^0 \rightarrow$ invisible) $<$ (0.07–0.57) pb (95%CL) is obtained at $E_{cm} = 206$ GeV for $m_{H^0} = 60$–114 GeV.

[15] Search for $e^+ e^- \to H^0 Z$ with H^0 decaying invisibly. The limit assumes SM production cross section and B($H^0 \to$ invisible) = 1.

[16] ACCIARRI 00M search for $e^+ e^- \to Z H^0$ with H^0 decaying invisibly at E_{cm}=183–189 GeV. The limit assumes SM production cross section and B($H^0 \to$ invisible)=1. See their Fig. 6 for limits for smaller branching ratios.

Mass Limits for Light A^0

These limits are for a pseudoscalar A^0 in the mass range below $\mathcal{O}(10)$ GeV.

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[1] AABOUD	18AP	ATLS	$H^0 \to A^0 A^0$
	[2] KHACHATRY...	17AZ	CMS	$H^0 \to A^0 A^0$
	[3] ABLIKIM	16E	BES3	$J/\psi \to A^0 \gamma$
	[4] KHACHATRY...	16F	CMS	$H^0 \to A^0 A^0$
	[5] LEES	15H	BABR	$\Upsilon(1S) \to A^0 \gamma$
	[6] LEES	13C	BABR	$\Upsilon(1S) \to A^0 \gamma$
	[7] LEES	13L	BABR	$\Upsilon(1S) \to A^0 \gamma$
	[8] LEES	13R	BABR	$\Upsilon(1S) \to A^0 \gamma$
	[9] ABLIKIM	12	BES3	$J/\psi \to A^0 \gamma$
	[10] CHATRCHYAN	12V	CMS	$A^0 \to \mu^+ \mu^-$
	[11] AALTONEN	11P	CDF	$t \to b H^+$, $H^+ \to W^+ A^0$
	[12,13] ABOUZAID	11A	KTEV	$K_L \to \pi^0 \pi^0 A^0$, $A^0 \to \mu^+ \mu^-$
	[14] DEL-AMO-SA...	11J	BABR	$\Upsilon(1S) \to A^0 \gamma$
	[15] LEES	11H	BABR	$\Upsilon(2S, 3S) \to A^0 \gamma$
	[16] ANDREAS	10	RVUE	
	[13,17] HYUN	10	BELL	$B^0 \to K^{*0} A^0$, $A^0 \to \mu^+ \mu^-$
	[13,18] HYUN	10	BELL	$B^0 \to \rho^0 A^0$, $A^0 \to \mu^+ \mu^-$
	[19] AUBERT	09P	BABR	$\Upsilon(3S) \to A^0 \gamma$
	[20] AUBERT	09Z	BABR	$\Upsilon(2S) \to A^0 \gamma$
	[21] AUBERT	09Z	BABR	$\Upsilon(3S) \to A^0 \gamma$
	[13,22] TUNG	09	K391	$K_L \to \pi^0 \pi^0 A^0$, $A^0 \to \gamma\gamma$
	[23] LOVE	08	CLEO	$\Upsilon(1S) \to A^0 \gamma$
	[24] BESSON	07	CLEO	$\Upsilon(1S) \to \eta_b \gamma$
	[25] PARK	05	HYCP	$\Sigma^+ \to p A^0$, $A^0 \to \mu^+ \mu^-$
	[26] BALEST	95	CLE2	$\Upsilon(1S) \to A^0 \gamma$
	[27] ANTREASYAN	90C	CBAL	$\Upsilon(1S) \to A^0 \gamma$

[1] AABOUD 18AP search for the decay $H^0 \to A^0 A^0 \to \mu^+ \mu^- \mu^+ \mu^-$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 10(b) for limits on B($H^0 \to A^0 A^0$) in the range m_{A^0} = 1–2.5, 4.5–8 GeV, assuming a type-II two-doublet plus singlet model with $\tan(\beta) = 5$.

[2] KHACHATRYAN 17AZ search for the decay $H^0 \to A^0 A^0 \to \tau^+ \tau^- \tau^+ \tau^-$, $\mu^+ \mu^- b\overline{b}$, and $\mu^+ \mu^- \tau^+ \tau^-$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Figs. 4, 5, and 6 for cross section limits in the range m_{A^0} = 5–62.5 GeV. See also their Figs. 7, 8, and 9 for interpretation of the data in terms of models with two Higgs doublets and a singlet.

[3] ABLIKIM 16E search for the process $J/\psi \to A^0 \gamma$ with A^0 decaying to $\mu^+ \mu^-$ and give limits on B($J/\psi \to A^0 \gamma$)·B($A^0 \to \mu^+ \mu^-$) in the range 2.8×10^{-8}–5.0×10^{-6} (90% CL) for $0.212 \leq m_{A^0} \leq 3.0$ GeV. See their Fig. 5.

[4] KHACHATRYAN 16F search for the decay $H^0 \to A^0 A^0 \to \tau^+\tau^-\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 8 for cross section limits for m_{A^0} = 4–8 GeV.

[5] LEES 15H search for the process $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^- \to A^0\gamma\pi^+\pi^-$ with A^0 decaying to $c\overline{c}$ and give limits on B($\Upsilon(1S) \to A^0\gamma$)·B($A^0 \to c\overline{c}$) in the range 7.4×10^{-5}–2.4×10^{-3} (90% CL) for $4.00 \leq m_{A^0} \leq 8.95$ and $9.10 \leq m_{A^0} \leq 9.25$ GeV. See their Fig. 6.

[6] LEES 13C search for the process Υ(2S, 3S)$\to \Upsilon(1S)\pi^+\pi^- \to A^0\gamma\pi^+\pi^-$ with A^0 decaying to $\mu^+\mu^-$ and give limits on B($\Upsilon(1S) \to A^0\gamma$)·B($A^0 \to \mu^+\mu^-$) in the range (0.3–9.7) $\times 10^{-6}$ (90% CL) for $0.212 \leq m_{A^0} \leq 9.20$ GeV. See their Fig. 5(e) for limits on the $b-A^0$ Yukawa coupling derived by combining this result with AUBERT 09Z.

[7] LEES 13L search for the process $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^- \to A^0\gamma\pi^+\pi^-$ with A^0 decaying to gg or $s\overline{s}$ and give limits on B($\Upsilon(1S) \to A^0\gamma$)·B($A^0 \to gg$) between 1×10^{-6} and 2×10^{-2} (90% CL) for $0.5 \leq m_{A^0} \leq 9.0$ GeV, and B($\Upsilon(1S) \to A^0\gamma$)·B($A^0 \to s\overline{s}$) between 4×10^{-6} and 1×10^{-3} (90%CL) for $1.5 \leq m_{A^0} \leq 9.0$ GeV. See their Fig. 4.

[8] LEES 13R search for the process $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^- \to A^0\gamma\pi^+\pi^-$ with A^0 decaying to $\tau^+\tau^-$ and give limits on B($\Upsilon(1S) \to A^0\gamma$)·B($A^0 \to \tau^+\tau^-$) in the range 0.9–13 $\times 10^{-5}$ (90% CL) for $3.6 \leq m_{A^0} \leq 9.2$ GeV. See their Fig. 4 for limits on the $b - A^0$ Yukawa coupling derived by combining this result with AUBERT 09P.

[9] ABLIKIM 12 searches for the process $\psi(3686) \to \pi\pi J/\psi$, $J/\psi \to A^0\gamma$ with A^0 decaying to $\mu^+\mu^-$. It gives mass dependent limits on B($J/\psi \to A^0\gamma$)·B($A^0 \to \mu^+\mu^-$) in the range 4×10^{-7}–2.1×10^{-5} (90% C.L.) for $0.212 \leq m_{A^0} \leq 3.0$ GeV. See their Fig. 2.

[10] CHATRCHYAN 12V search for A^0 production in the decay $A^0 \to \mu^+\mu^-$ with 1.3 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on $\sigma(A^0)$·B($A^0 \to \mu^+\mu^-$) in the range (1.5–7.5) pb is given for m_{A^0} = (5.5–8.7) and (11.5–14) GeV at 95% CL.

[11] AALTONEN 11P search in 2.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV for the decay chain $t \to bH^+$, $H^+ \to W^+A^0$, $A^0 \to \tau^+\tau^-$ with m_{A^0} between 4 and 9 GeV. See their Fig. 4 for limits on B($t \to bH^+$) for $90 < m_{H^+} < 160$ GeV.

[12] ABOUZAID 11A search for the decay chain $K_L \to \pi^0\pi^0A^0$, $A^0 \to \mu^+\mu^-$ and give a limit B($K_L \to \pi^0\pi^0A^0$) · B($A^0 \to \mu^+\mu^-$) $< 1.0 \times 10^{-10}$ at 90% CL for m_{A^0} = 214.3 MeV.

[13] The search was motivated by PARK 05.

[14] DEL-AMO-SANCHEZ 11J search for the process $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^- \to A^0\gamma\pi^+\pi^-$ with A^0 decaying to invisible final states. They give limits on B($\Upsilon(1S) \to A^0\gamma$)·B($A^0 \to$ invisible) in the range (1.9–4.5) $\times 10^{-6}$ (90% CL) for $0 \leq m_{A^0} \leq 8.0$ GeV, and (2.7–37) $\times 10^{-6}$ for $8.0 \leq m_{A^0} \leq 9.2$ GeV.

[15] LEES 11H search for the process Υ(2S, 3S) $\to A^0\gamma$ with A^0 decaying hadronically and give limits on B(Υ(2S, 3S) $\to A^0\gamma$)·B($A^0 \to$ hadrons) in the range 1×10^{-6}–8×10^{-5} (90% CL) for $0.3 < m_{A^0} < 7$ GeV. The decay rates for $\Upsilon(2S)$ and $\Upsilon(3S)$ are assumed to be equal up to the phase space factor. See their Fig. 5.

[16] ANDREAS 10 analyze constraints from rare decays and other processes on a light A^0 with $m_{A^0} < 2m_\mu$ and give limits on its coupling to fermions at the level of 10^{-4} times the Standard Model value.

[17] HYUN 10 search for the decay chain $B^0 \to K^{*0}A^0$, $A^0 \to \mu^+\mu^-$ and give a limit on B($B^0 \to K^{*0}A^0$) · B($A^0 \to \mu^+\mu^-$) in the range (2.26–5.53) $\times 10^{-8}$ at 90%CL for m_{A^0} = 212–300 MeV. The limit for m_{A^0} = 214.3 MeV is 2.26×10^{-8}.

[18] HYUN 10 search for the decay chain $B^0 \to \rho^0 A^0$, $A^0 \to \mu^+\mu^-$ and give a limit on $B(B^0 \to \rho^0 A^0) \cdot B(A^0 \to \mu^+\mu^-)$ in the range $(1.73–4.51) \times 10^{-8}$ at 90%CL for m_{A^0} = 212–300 MeV. The limit for m_{A^0} = 214.3 MeV is 1.73×10^{-8}.

[19] AUBERT 09P search for the process $\Upsilon(3S) \to A^0\gamma$ with $A^0 \to \tau^+\tau^-$ for 4.03 $< m_{A^0} <$ 9.52 and 9.61 $< m_{A^0} <$ 10.10 GeV, and give limits on $B(\Upsilon(3S) \to A^0\gamma) \cdot B(A^0 \to \tau^+\tau^-)$ in the range $(1.5–16) \times 10^{-5}$ (90% CL).

[20] AUBERT 09Z search for the process $\Upsilon(2S) \to A^0\gamma$ with $A^0 \to \mu^+\mu^-$ for 0.212 $< m_{A^0} <$ 9.3 GeV and give limits on $B(\Upsilon(2S) \to A^0\gamma) \cdot B(A^0 \to \mu^+\mu^-)$ in the range $(0.3–8) \times 10^{-6}$ (90% CL).

[21] AUBERT 09Z search for the process $\Upsilon(3S) \to A^0\gamma$ with $A^0 \to \mu^+\mu^-$ for 0.212 $< m_{A^0} <$ 9.3 GeV and give limits on $B(\Upsilon(3S) \to A^0\gamma) \cdot B(A^0 \to \mu^+\mu^-)$ in the range $(0.3–5) \times 10^{-6}$ (90% CL).

[22] TUNG 09 search for the decay chain $K_L \to \pi^0\pi^0 A^0$, $A^0 \to \gamma\gamma$ and give a limit on $B(K_L \to \pi^0\pi^0 A^0) \cdot B(A^0 \to \gamma\gamma)$ in the range $(2.4–10.7) \times 10^{-7}$ at 90%CL for m_{A^0} = 194.3–219.3 MeV. The limit for m_{A^0} = 214.3 MeV is 2.4×10^{-7}.

[23] LOVE 08 search for the process $\Upsilon(1S) \to A^0\gamma$ with $A^0 \to \mu^+\mu^-$ (for $m_{A^0} < 2m_\tau$) and $A^0 \to \tau^+\tau^-$. Limits on $B(\Upsilon(1S) \to A^0\gamma) \cdot B(A^0 \to \ell^+\ell^-)$ in the range 10^{-6}–10^{-4} (90% CL) are given.

[24] BESSON 07 give a limit $B(\Upsilon(1S) \to \eta_b\gamma) \cdot B(\eta_b \to \tau^+\tau^-) < 0.27\%$ (95% CL), which constrains a possible A^0 exchange contribution to the η_b decay.

[25] PARK 05 found three candidate events for $\Sigma^+ \to p\mu^+\mu^-$ in the HyperCP experiment. Due to a narrow spread in dimuon mass, they hypothesize the events as a possible signal of a new boson. It can be interpreted as a neutral particle with $m_{A^0} = 214.3 \pm 0.5$ MeV and the branching fraction $B(\Sigma^+ \to pA^0) \cdot B(A^0 \to \mu^+\mu^-) = (3.1^{+2.4}_{-1.9} \pm 1.5) \times 10^{-8}$.

[26] BALEST 95 give limits $B(\Upsilon(1S) \to A^0\gamma)$ ¡ 1.5×10^{-5} at 90% CL for $m_{A^0} <$ 5 GeV. The limit becomes $< 10^{-4}$ for $m_{A^0} <$ 7.7 GeV.

[27] ANTREASYAN 90C give limits $B(\Upsilon(1S) \to A^0\gamma)$ ¡ 5.6×10^{-5} at 90% CL for $m_{A^0} <$ 7.2 GeV. A^0 is assumed not to decay in the detector.

Other Mass Limits

We use a symbol H_1^0 if mass < 125 GeV or H_2^0 if mass > 125 GeV. The notation H^0 is reserved for the 125 GeV particle.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] AAD	20C	ATLS	$H_2^0 \to H^0 H^0$
		[2] SIRUNYAN	20	CMS	$H^0 \to A^0 A^0$
		[3] AABOUD	19A	ATLS	$H_2^0 \to H^0 H^0$
		[4] AABOUD	19AG	ATLS	$H^0 \to A^0 A^0$
		[5] AABOUD	19O	ATLS	$H_2^0 \to H^0 H^0$
		[6] AABOUD	19T	ATLS	$H_2^0 \to H^0 H^0$
		[7] AABOUD	19V	ATLS	two doublet + pseudoscalar model
		[8] AABOUD	19Y	ATLS	$H_2^0 \to \mu^+\mu^-$
		[9] AALTONEN	19	CDF	$H_{1,2}^0 \to b\overline{b}$
		[10] SIRUNYAN	19	CMS	$H_2^0 \to H^0 H^0$

[11] SIRUNYAN	19AE	CMS	$A^0 \to \tau^+\tau^-$
[12] SIRUNYAN	19AN	CMS	$A^0_2 \to H^0 A^0_1$
[13] SIRUNYAN	19AV	CMS	$A^0 \to Z H^0$
[14] SIRUNYAN	19B	CMS	$H^0_{1,2}/A^0 \to b\overline{b}$
[15] SIRUNYAN	19BB	CMS	$H^0_1 \to \gamma\gamma$
[16] SIRUNYAN	19BD	CMS	$H^0 \to A^0 A^0$
[17] SIRUNYAN	19BE	CMS	$H^0_2 \to H^0 H^0$
[18] SIRUNYAN	19BQ	CMS	$H^0_{1,2} \to A^0 A^0$
[19] SIRUNYAN	19CR	CMS	$H^0_2/A^0 \to \mu^+\mu^-$
[20] SIRUNYAN	19H	CMS	$H^0_2 \to H^0 H^0$
[21] AABOUD	18AA	ATLS	$H^0_2 \to Z\gamma$
[22] AABOUD	18AG	ATLS	$H^0 \to A^0 A^0$
[23] AABOUD	18AH	ATLS	$A^0 \to Z H^0_2$
[24] AABOUD	18AI	ATLS	$A^0 \to Z H^0$
[25] AABOUD	18BF	ATLS	$H^0_2 \to Z Z$
[26] AABOUD	18BU	ATLS	$H^0_2 \to H^0 H^0$
[27] AABOUD	18BX	ATLS	$H^0 \to A^0 A^0$
[28] AABOUD	18CQ	ATLS	$H^0_2 \to H^0 H^0$
[29] AABOUD	18F	ATLS	$H^0_2 \to W^+ W^-$, $Z Z$
[30] AAIJ	18AM	LHCB	$H^0_{1,2} \to \mu\tau$
[31] AAIJ	18AQ	LHCB	$A^0 \to \mu^+\mu^-$
[32] AAIJ	18AQ	LHCB	$H^0 \to A^0 A^0$, $A^0 \to \mu^+\mu^-$
[33] SIRUNYAN	18AF	CMS	$H^0_2 \to H^0 H^0$
[34] SIRUNYAN	18BA	CMS	$H^0_2 \to Z Z$
[35] SIRUNYAN	18CW	CMS	$H^0_2 \to H^0 H^0$
[36] SIRUNYAN	18DK	CMS	$H^0_2 \to Z\gamma$
[37] SIRUNYAN	18DT	CMS	$H^0 \to A^0 A^0$
[38] SIRUNYAN	18DU	CMS	$H^0_2 \to \gamma\gamma$
[39] SIRUNYAN	18ED	CMS	$A^0 \to Z H^0$
[40] SIRUNYAN	18EE	CMS	$H^0 \to A^0 A^0$
[41] SIRUNYAN	18F	CMS	pp, 13 TeV, $H^0_2 \to H^0 H^0$
[42] AABOUD	17	ATLS	$H^0_2 \to Z\gamma$
[43] AABOUD	17AW	ATLS	$H^0_2 \to Z\gamma$
[44] KHACHATRY...	17AZ	CMS	$H^0 \to A^0 A^0$
[45] KHACHATRY...	17D	CMS	pp, 8, 13 TeV, $H^0_2 \to Z\gamma$
[46] KHACHATRY...	17R	CMS	$H^0_2 \to \gamma\gamma$
[47] SIRUNYAN	17CN	CMS	pp, 8 TeV, $H^0_2 \to H^0 H^0$
[48] SIRUNYAN	17Y	CMS	pp, 8, 13 TeV, $H^0_2 \to Z\gamma$
[49] AABOUD	16AB	ATLS	$H^0 \to A^0 A^0$
[50] AABOUD	16AE	ATLS	$H^0_2 \to W^+ W^-$, $Z Z$
[51] AABOUD	16H	ATLS	$H^0_2 \to \gamma\gamma$
[52] AABOUD	16I	ATLS	$H^0_2 \to H^0 H^0$
[53] AAD	16AX	ATLS	$H^0 \to Z Z$

		[54] AAD	16C	ATLS	$H^0 \to W^+ W^-$
		[55] AAD	16L	ATLS	$H^0 \to A^0 A^0$
		[56] AAD	16L	ATLS	$H_2^0 \to A^0 A^0$
		[57] AALTONEN	16C	CDF	$H_1^0 H^\pm \to H_1^0 H_1^0 W^*$, $H_1^0 \to \gamma\gamma$
		[58] KHACHATRY...	16BG	CMS	$H_2^0 \to H^0 H^0$
		[59] KHACHATRY...	16BQ	CMS	$p p$, 8 TeV, $H_2^0 \to H^0 H^0$
		[60] KHACHATRY...	16F	CMS	$H^0 \to H_1^0 H_1^0$
		[61] KHACHATRY...	16M	CMS	$H_2^0 \to \gamma\gamma$
		[62] KHACHATRY...	16P	CMS	$H_2^0 \to H^0 H^0$
		[63] KHACHATRY...	16P	CMS	$A^0 \to Z H^0$
		[64] AAD	15BK	ATLS	$H_2^0 \to H^0 H^0$
		[65] AAD	15BZ	ATLS	$H^0 \to A^0 A^0$
		[66] AAD	15BZ	ATLS	$H_2^0 \to A^0 A^0$
		[67] AAD	15CE	ATLS	$H_2^0 \to H^0 H^0$
		[68] AAD	15H	ATLS	$H_2^0 \to H^0 H^0$
		[69] AAD	15S	ATLS	$A^0 \to Z H^0$
		[70] KHACHATRY...	15AW	CMS	$H_2^0 \to W^+ W^-$, $Z Z$
		[71] KHACHATRY...	15BB	CMS	$H^0 \to \gamma\gamma$
		[72] KHACHATRY...	15N	CMS	$A^0 \to Z H^0$
		[73] KHACHATRY...	15O	CMS	$A^0 \to Z H^0$
		[74] KHACHATRY...	15R	CMS	$H_2^0 \to H^0 H^0$
		[75] AAD	14AP	ATLS	$H^0 \to \gamma\gamma$
		[76] AAD	14M	ATLS	$H_2^0 \to H^\pm W^\mp \to H^0 W^\pm W^\mp$, $H^0 \to b\overline{b}$
		[77] CHATRCHYAN	14G	CMS	$H^0 \to W W^{(*)}$
		[78] KHACHATRY...	14P	CMS	$H^0 \to \gamma\gamma$
		[79] AALTONEN	13P	CDF	$H'^0 \to H^\pm W^\mp \to H^0 W^+ W^-$
		[80] CHATRCHYAN	13BJ	CMS	$H^0 \to A^0 A^0$
		[81] AALTONEN	11P	CDF	$t \to b H^+$, $H^+ \to W^+ A^0$
		[82] ABBIENDI	10	OPAL	$H^0 \to \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$
		[83] SCHAEL	10	ALEP	$H^0 \to A^0 A^0$
		[84] ABAZOV	09V	D0	$H^0 \to A^0 A^0$
none 3–63	95	[85] ABBIENDI	05A	OPAL	A^0, Type II model
>104	95	[86] ABBIENDI	04K	OPAL	$H^0 \to$ 2 jets
		[87] ABDALLAH	04	DLPH	$H^0 V V$ couplings
>110.3	95	[88] ACHARD	04B	L3	$H^0 \to$ 2 jets
		[89] ACHARD	04F	L3	Anomalous coupling
		[90] ABBIENDI	03F	OPAL	$e^+ e^- \to H^0 Z$, $H^0 \to$ any
		[91] ABBIENDI	03G	OPAL	$H_1^0 \to A^0 A^0$
>105.4	95	[92,93] HEISTER	02L	ALEP	$H_1^0 \to \gamma\gamma$
>109.1	95	[94] HEISTER	02M	ALEP	$H^0 \to$ 2 jets or $\tau^+ \tau^-$
none 12–56	95	[95] ABBIENDI	01E	OPAL	A^0, Type-II model
		[96] ACCIARRI	00R	L3	$e^+ e^- \to H^0 \gamma$ and/or $H^0 \to \gamma\gamma$
		[97] ACCIARRI	00R	L3	$e^+ e^- \to e^+ e^- H^0$

[98]	GONZALEZ...	98B	RVUE	Anomalous coupling
[99]	KRAWCZYK	97	RVUE	$(g-2)_\mu$
[100]	ALEXANDER	96H	OPAL	$Z \to H^0 \gamma$

[1] AAD 20C combine searches for a scalar resonance decaying to $H^0 H^0$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV from AABOUD 19A, AABOUD 19O, AABOUD 18CQ, AABOUD 19T, AABOUD 18CW, and AABOUD 18BU. See their Fig. 5(a) for limits on cross section times branching ratio for $m_{H_2^0}$ = 0.26–3 TeV.

[2] SIRUNYAN 20 search for the decay $H^0 \to A^0 A^0 \to \tau^+ \tau^- \tau^+ \tau^-$ or $\tau^+ \tau^- \mu^+ \mu^-$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 10 for limits on the product of production cross section (normalized to the SM) and branching ratios in the range m_{A^0} = 4–15 GeV.

[3] AABOUD 19A search for a narrow scalar resonance decaying to $H^0 H^0 \to b\overline{b} b\overline{b}$ in 27.5–36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 9(a) for limits on cross section times branching ratios for $m_{H_2^0}$ = 0.26–3 TeV.

[4] AABOUD 19AG search for the decay $H^0 \to A^0 A^0 \to \mu^+ \mu^- b\overline{b}$ in 36.7 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 6 (a) for limits on the product of production cross section (normalized to the SM) and branching ratios in the range m_{A^0} = 20–60 GeV.

[5] AABOUD 19O search for a scalar resonance decaying to $H^0 H^0 \to b\overline{b} W W^*$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 12 (left) for limits on cross section times branching ratio for $m_{H_2^0}$ = 0.5–3 TeV.

[6] AABOUD 19T search for a scalar resonance decaying to $H^0 H^0 \to W W^* W W^*$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 3 for limits on cross section times branching ratio for $m_{H_2^0}$ = 260–500 GeV, assuming SM decay rates for the H^0.

[7] AABOUD 19V combine published ATLAS data to constrain two-Higgs-doublet plus singlet pseudoscalar model with A_1^0 decaying to invisible final states. See their Fig. 19 for excluded parameter regions.

[8] AABOUD 19Y search for a narrow scalar resonance produced by gluon fusion or b associated production, decaying to $\mu^+ \mu^-$ in 36.1 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Figs. 4 and 5(a) for cross section limits for $m_{H_2^0}$ = 0.2–1.0 TeV.

[9] AALTONEN 19 search for b associated production of a scalar particle decaying to $b\overline{b}$ in 5.4 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. See their Fig. 3 for limits on cross section times branching ratio for $m_{H_{1,2}^0}$ = 100–300 GeV.

[10] SIRUNYAN 19 search for a narrow scalar resonance decaying to $H^0 H^0 \to \gamma\gamma b\overline{b}$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 9 (left) for limits on cross section times branching ratios for $m_{H_2^0}$ = 260–900 GeV.

[11] SIRUNYAN 19AE search for a scalar resonance produced in association with a $b\overline{b}$ pair, decaying to $\tau^+ \tau^-$ in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 4 for cross section limits for m_{A^0} = 25–70 GeV.

[12] SIRUNYAN 19AN search for production of A_2^0 decaying to $H^0 A_1^0$ followed by $H^0 \to b\overline{b}$, $A_1^0 \to$ invisible in 35.9 fb^{-1} of pp collisions at E_{cm} = 13 TeV, in the mass range $m_{A_2^0}$ = 0.2–1.6 TeV, $m_{A_1^0}$ = 0.15–0.5 TeV. See their Fig. 6 for limits in terms of two-Higgs-doublet plus singlet pseudoscalar model.

[13] SIRUNYAN 19AV search for a scalar resonance produced by gluon fusion or b-associated production, decaying to $Z H^0 \rightarrow \ell^+ \ell^- b\overline{b}$ ($\ell = e, \mu$) or $\nu\overline{\nu} b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 5 for cross section limits for m_{A^0} = 0.22–1.0 TeV.

[14] SIRUNYAN 19B search for gluon fusion production of narrow scalar resonance with large transverse momentum, decaying to $b\overline{b}$, in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Figs. 7 and 8 for limits on cross section times branching ratio for the resonance mass of 50–350 GeV.

[15] SIRUNYAN 19BB search for the decay $H^0_1 \rightarrow \gamma\gamma$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV and 35.9 fb^{-1} at $E_{\rm cm}$ = 13 TeV. See their Figs. 4–6 for limits on cross section times branching ratio for $m_{H^0_1}$ = 80–110 GeV (some results in Fig. 5 for $m_{H^0_1}$ = 70–110 GeV).

[16] SIRUNYAN 19BD search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \mu^+ \mu^- b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 5 for limits on the product of cross section times branching ratios in the range m_{A^0} = 20–62.5 GeV. See also their Figs. 6 and 7 for interpretation of the data in terms of models with two Higgs doublets and a singlet.

[17] SIRUNYAN 19BE combine searches for $H^0_2 \rightarrow H^0 H^0$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV in various H^0 decay modes, from SIRUNYAN 18A, SIRUNYAN 18AF, SIRUNYAN 18CW, SIRUNYAN 19, and SIRUNYAN 19H. See their Fig. 3 for limits on cross section times branching ratios for $m_{H^0_2}$ = 0.25–3 TeV.

[18] SIRUNYAN 19BQ search for production of $H^0_{1,2}$ decaying to $A^0 A^0 \rightarrow \mu^+ \mu^- \mu^+ \mu^-$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 2 for limits on cross section times branching ratio for $m_{H^0_{1,2}}$ = 90–150 GeV, m_{A^0} = 0.25–3.55 GeV.

[19] SIRUNYAN 19CR search for production of H^0_2 / A^0 in gluon fusion and in association with a $b\overline{b}$ pair, decaying to $\mu^+ \mu^-$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 6 for limits on cross section times branching ratio.

[20] SIRUNYAN 19H search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV, where one $b\overline{b}$ pair is resolved and the other not. Limits on cross section times branching ratios for $m_{H^0_2}$ = 0.75–1.6 TeV are obtained and combined with data from SIRUNYAN 18AF. See their Fig. 5 (right).

[21] AABOUD 18AA search for production of a scalar resonance decaying to $Z\gamma$, with Z decaying hadronically, in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 8(a) for limits on cross section times branching ratio for $m_{H^0_2}$ = 1.0–6.8 TeV.

[22] AABOUD 18AG search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \gamma\gamma g g$ in 36.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 2 and Table 6 for cross section limits in the range m_{A^0} = 20–60 GeV.

[23] AABOUD 18AH search for production of an A^0 in gluon-gluon fusion and in association with a $b\overline{b}$, decaying to $Z H^0_2 \rightarrow \ell^+ \ell^- b\overline{b}$ in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 5 for cross section limits for m_{A^0} = 230–800 GeV and $m_{H^0_2}$ = 130–700 GeV.

[24] AABOUD 18AI search for production of an A^0 in gluon-gluon fusion and in association with a $b\overline{b}$, decaying to $Z H^0$ in the final states $\nu\overline{\nu} b\overline{b}$ and $\ell^+ \ell^- b\overline{b}$ in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 6 for cross section limits for m_{A^0} = 0.2–2 TeV. See also AABOUD 18CC.

[25] AABOUD 18BF search for production of a heavy H_2^0 state decaying to ZZ in the final states $\ell^+\ell^-\ell^+\ell^-$ and $\ell^+\ell^-\nu\overline{\nu}$ in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 6 for upper limits on cross section times branching ratio for $m_{H_2^0}$ = 0.2–1.2 TeV assuming ggF or VBF with the NWA. See their Fig. 7 for upper limits on cross section times branching ratio for $m_{H_2^0}$ = 0.4–1.0 TeV assuming ggF, and with several assumptions on its width.

[26] AABOUD 18BU search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow \gamma\gamma W W^*$ in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 4 for limits on cross section times branching ratios for $m_{H_2^0}$ = 260–500 GeV.

[27] AABOUD 18BX search for associated production of $W H^0$ or $Z H^0$ followed by the decay $H^0 \rightarrow A^0 A^0 \rightarrow b\overline{b}b\overline{b}$ in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 9 for limits on cross section times branching ratios for m_{A^0} = 20–60 GeV. See also their Fig. 10 for the dependence of the limit on A^0 lifetime.

[28] AABOUD 18CQ search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}\tau^+\tau^-$ in 36.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 2 (above) for limits on cross section times branching ratios for $m_{H_2^0}$ = 260–1000 GeV.

[29] AABOUD 18F search for production of a narrow scalar resonance decaying to $W^+ W^-$ and ZZ, followed by hadronic decays of W and Z, in 36.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 5(c) for limits on cross section times branching ratio for $m_{H_2^0}$ = 1.2–3.0 TeV.

[30] AAIJ 18AM search for gluon-fusion production of $H_{1,2}^0$ decaying to $\mu\tau$ in 2 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 2 for limits on cross section times branching ratio for $m_{H_{1,2}^0}$ = 45–195 GeV.

[31] AAIJ 18AQ search for gluon-fusion production of a scalar particle A^0 decaying to $\mu^+\mu^-$ in 1.99 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV and 0.98 fb^{-1} at $E_{\rm cm}$ = 7 TeV. See their Fig. 4 for limits on cross section times branching ratio for m_{A^0} = 5.5–15 GeV (using the $E_{\rm cm}$ = 8 TeV data set).

[32] AAIJ 18AQ search for the decay $H^0 \rightarrow A^0 A^0$, with one of the A^0 decaying to $\mu^+\mu^-$, in 1.99 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV and 0.98 fb^{-1} at $E_{\rm cm}$ = 7 TeV. See their Fig. 5 (right) for limits on the product of branching ratios for m_{A^0} = 5.5–15 GeV (using the $E_{\rm cm}$ = 8 TeV data set).

[33] SIRUNYAN 18AF search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV, where both $b\overline{b}$ pairs are not resolved. See their Fig. 9 for limits on cross section times branching ratios for $m_{H_2^0}$ = 0.75–3 TeV.

[34] SIRUNYAN 18BA search for production of a heavy H_2^0 state decaying to ZZ in the final states $\ell^+\ell^-\ell^+\ell^-$, $\ell^+\ell^- q\overline{q}$, and $\ell^+\ell^-\nu\overline{\nu}$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Figs. 10 and 11 for upper limits on cross section times branching ratio for $m_{H_2^0}$ = 0.13–3 TeV with several assumptions on its width and on the fraction of Vector-Boson-Fusion of the total production cross section.

[35] SIRUNYAN 18CW search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV, where both $b\overline{b}$ pairs are resolved. See their Fig. 9 for limits on cross section times branching ratios for $m_{H_2^0}$ = 260–1200 GeV.

[36] SIRUNYAN 18DK search for production of a scalar resonance decaying to $Z\gamma$, with Z decaying to $\ell^+\ell^-$ or hadronically, in 35.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 13 TeV. See their Fig. 7 for limits on cross section times branching ratio for $m_{H_2^0}$ = 0.35–4 TeV for different assumptions on the width of the resonance.

[37] SIRUNYAN 18DT search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \tau^+ \tau^- b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 7 for limits on the product of branching ratios in the range $m_{A^0} = 15$–60 GeV. See also their Fig. 8 for interpretation of the data in terms of models with two Higgs doublets and a singlet.

[38] SIRUNYAN 18DU search for production of a narrow scalar resonance decaying to $\gamma\gamma$ in 35.9 fb^{-1} (taken in 2016) of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 3 (right) for limits on cross section times branching ratio for $m_{H_2^0} = 0.5$–5 TeV for several values of its width-to-mass ratio.

[39] SIRUNYAN 18ED search for production of an A^0 in gluon-gluon fusion and in association with a $b\overline{b}$, decaying to ZH^0 in the final states $\nu\overline{\nu}b\overline{b}$ or $\ell^+\ell^- b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 8 for cross section limits for $m_{A^0} = 0.8$–2 TeV.

[40] SIRUNYAN 18EE search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \mu^+ \mu^- \tau^+ \tau^-$ in 35.9 fb^{-1} of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 4 for limits on the product of branching ratios in the range $m_{A^0} = 15$–62.5 GeV, normalized to the SM production cross section. See also their Fig. 5 for interpretation of the data in terms of models with two Higgs doublets and a singlet.

[41] SIRUNYAN 18F search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow WWb\overline{b}$ or $ZZb\overline{b}$ in the final state $\ell\ell\nu\nu b\overline{b}$ in 35.9 fb^{-1} of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 7 for limits on cross section times branching ratios for $m_{H_2^0} = 250$–900 GeV.

[42] AABOUD 17 search for production of a scalar resonance decaying to $Z\gamma$ in 3.2 fb^{-1} of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 4 for the limits on cross section times branching ratio for $m_{H_2^0} = 0.25$–3.0 TeV.

[43] AABOUD 17AW search for production of a scalar resonance decaying to $Z\gamma$ in 36.1 fb^{-1} of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 7 for limits on cross section times branching ratio for $m_{H_2^0} = 0.25$–2.4 TeV.

[44] KHACHATRYAN 17AZ search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \tau^+ \tau^- \tau^+ \tau^-$, $\mu^+ \mu^- b\overline{b}$, and $\mu^+ \mu^- \tau^+ \tau^-$ in 19.7 fb^{-1} of pp collisions at $E_{\text{cm}} = 8$ TeV. See their Figs. 4, 5, and 6 for cross section limits in the range $m_{A^0} = 5$–62.5 GeV. See also their Figs. 7, 8, and 9 for interpretation of the data in terms of models with two Higgs doublets and a singlet.

[45] KHACHATRYAN 17D search for production of a scalar resonance decaying to $Z\gamma$ in 19.7 fb^{-1} of pp collisions at $E_{\text{cm}} = 8$ TeV and 2.7 fb^{-1} at $E_{\text{cm}} = 13$ TeV. See their Figs. 3 and 4 for the limits on cross section times branching ratio for $m_{H_2^0} = 0.2$–2.0 TeV.

[46] KHACHATRYAN 17R search for production of a narrow scalar resonance decaying to $\gamma\gamma$ in 12.9 fb^{-1} (taken in 2016) of pp collisions at $E_{\text{cm}} = 13$ TeV. See their Fig. 2 for limits on cross section times branching ratio for $m_{H_2^0} = 0.5$–4.5 TeV for several values of its width-to-mass ratio. Limits from combination with KHACHATRYAN 16M are shown in their Figs. 4 and 6.

[47] SIRUNYAN 17CN search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}\tau^+\tau^-$ in 18.3 fb^{-1} of pp collisions at $E_{\text{cm}} = 8$ TeV. See their Fig. 5 (above) and Table II for limits on the cross section times branching ratios for $m_{H_2^0} = 0.3$–1 TeV, and Fig. 6 (above) and Table III for the corresponding limits by combining with data from KHACHATRYAN 16BQ and KHACHATRYAN 15R.

[48] SIRUNYAN 17Y search for production of a scalar resonance decaying to $Z\gamma$ in 19.7 fb^{-1} of pp collisions at $E_{\text{cm}} = 8$ TeV and 2.7 fb^{-1} at $E_{\text{cm}} = 13$ TeV. See their Figs. 3, 4 and Table 3 for limits on cross section times branching ratio for $m_{H_2^0} = 0.7$–3.0 TeV, and Fig. 5 for the corresponding limits for $m_{H_2^0} = 0.2$–3.0 TeV from combination with KHACHATRYAN 17D data.

[49] AABOUD 16AB search for associated production of $W H^0$ with the decay $H^0 \to A^0 A^0 \to b\overline{b}b\overline{b}$ in 3.2 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 8 for limits on cross section times branching ratios for m_{A^0} = 20–60 GeV.

[50] AABOUD 16AE search for production of a narrow scalar resonance decaying to $W^+ W^-$ and ZZ in 3.2 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 4 for limits on cross section times branching ratio for $m_{H^0_2}$ = 0.5–3 TeV.

[51] AABOUD 16H search for production of a scalar resonance decaying to $\gamma\gamma$ in 3.2 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 12 for limits on cross section times branching ratio for $m_{H^0_2}$ = 0.2–2 TeV with different assumptions on the width.

[52] AABOUD 16I search for a narrow scalar resonance decaying to $H^0 H^0 \to b\overline{b}b\overline{b}$ in 3.2 fb^{-1} of pp collisions at E_{cm} = 13 TeV. See their Fig. 10(c) for limits on cross section times branching ratios for $m_{H^0_2}$ = 0.5–3 TeV.

[53] AAD 16AX search for production of a heavy H^0 state decaying to ZZ in the final states $\ell^+\ell^-\ell^+\ell^-$, $\ell^+\ell^-\nu\overline{\nu}$, $\ell^+\ell^- q\overline{q}$, and$\nu\overline{\nu}q\overline{q}$ in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig.12 for upper limits on $\sigma(H^0)$ B($H^0 \to ZZ$) for m_{H^0} ranging from 140 GeV to 1000 GeV.

[54] AAD 16C search for production of a heavy H^0 state decaying to $W^+ W^-$ in the final states $\ell\nu\ell\nu$ and $\ell\nu qq$ in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Figs. 12, 13, and 16 for upper limits on $\sigma(H^0)$ B($H^0 \to W^+ W^-$) for m_{H^0} ranging from 300 GeV to 1000 or 1500 GeV with various assumptions on the total width of H^0.

[55] AAD 16L search for the decay $H^0 \to A^0 A^0 \to \gamma\gamma\gamma\gamma$ in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 4 (upper right) for limits on cross section times branching ratios (normalized to the SM H^0 cross section) for m_{A^0} = 10–60 GeV.

[56] AAD 16L search for the decay $H^0_2 \to A^0 A^0 \to \gamma\gamma\gamma\gamma$ in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 4 (lower right) for limits on cross section times branching ratios for $m_{H^0_2}$ = 600 GeV and m_{A^0} = 10–245 GeV, and Table 5 for limits for $m_{H^0_2}$= 300 and 900 GeV.

[57] AALTONEN 16C search for electroweak associated production of $H^0_1 H^\pm$ followed by the decays $H^\pm \to H^0_1 W^*$, $H^0_1 \to \gamma\gamma$ for $m_{H^0_1}$ = 10–105 GeV and $m_{H^\pm}$ = 30–300 GeV. See their Fig. 3 for excluded parameter region in a two-doublet model in which H^0_1 has no direct decay to fermions.

[58] KHACHATRYAN 16BG search for a narrow scalar resonance decaying to $H^0 H^0 \to b\overline{b}b\overline{b}$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 6 for limits on the cross section times branching ratios for $m_{H^0_2}$ = 1.15–3 TeV.

[59] KHACHATRYAN 16BQ search for a resonance decaying to $H^0 H^0 \to \gamma\gamma b\overline{b}$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 9 for limits on the cross section times branching ratios for $m_{H^0_2}$ = 0.26–1.1 TeV.

[60] KHACHATRYAN 16F search for the decay $H^0 \to H^0_1 H^0_1 \to \tau^+\tau^-\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 8 for cross section limits for $m_{H^0_1}$ = 4–8 GeV.

[61] KHACHATRYAN 16M search for production of a narrow resonance decaying to $\gamma\gamma$ in 19.7 fb^{-1} of pp collisions at E_{cm} = 8 TeV and 3.3 fb^{-1} at E_{cm} = 13 TeV. See their Fig. 3 (top) for limits on cross section times branching ratio for $m_{H^0_2}$ = 0.5–4 TeV.

[62] KHACHATRYAN 16P search for gluon fusion production of an H_2^0 decaying to $H^0 H^0 \rightarrow b\overline{b}\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 8 (lower right) for cross section limits for $m_{H_2^0}$ = 260–350 GeV.

[63] KHACHATRYAN 16P search for gluon fusion production of an A^0 decaying to $Z H^0 \rightarrow \ell^+\ell^-\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 10 for cross section limits for $m_{H_2^0}$ = 220–350 GeV.

[64] AAD 15BK search for production of a heavy H_2^0 decaying to $H^0 H^0$ in the final state $b\overline{b}b\overline{b}$ in 19.5 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 14(c) for $\sigma(H_2^0)$ B($H_2^0 \rightarrow H^0 H^0$) for $m_{H_2^0}$ = 500–1500 GeV with $\Gamma_{H_2^0}$ = 1 GeV.

[65] AAD 15BZ search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \mu^+\mu^-\tau^+\tau^-$ (m_{H^0} = 125 GeV) in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 6 for limits on cross section times branching ratio for m_{A^0} = 3.7–50 GeV.

[66] AAD 15BZ search for a state H_2^0 via the decay $H_2^0 \rightarrow A^0 A^0 \rightarrow \mu^+\mu^-\tau^+\tau^-$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 6 for limits on cross section times branching ratio for $m_{H_2^0}$ = 100–500 GeV and m_{A^0} = 5 GeV.

[67] AAD 15CE search for production of a heavy H_2^0 decaying to $H^0 H^0$ in the final states $b\overline{b}\tau^+\tau^-$ and $\gamma\gamma W W^*$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV and combine with data from AAD 15H and AAD 15BK. A limit $\sigma(H_2^0)$ B($H_2^0 \rightarrow H^0 H^0$) $<$ 2.1–0.011 pb (95% CL) is given for $m_{H_2^0}$ = 260–1000 GeV. See their Fig. 6.

[68] AAD 15H search for production of a heavy H_2^0 decaying to $H^0 H^0$ in the finalstate $\gamma\gamma b\overline{b}$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV.A limit of $\sigma(H_2^0)$ B($H_2^0 \rightarrow H^0 H^0$) $<$ 3.5–0.7 pb is given for $m_{H_2^0}$ = 260–500 GeV at 95% CL. See their Fig. 3.

[69] AAD 15S search for production of A^0 decaying to $Z H^0 \rightarrow \ell^+\ell^- b\overline{b}$, $\nu\overline{\nu}b\overline{b}$ and $\ell^+\ell^-\tau^+\tau^-$ in 20.3 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 3 for cross section limits for m_{A^0} = 200–1000 GeV.

[70] KHACHATRYAN 15AW search for production of a heavy state H_2^0 of an electroweak singlet extension of the Standard Model via the decays of H_2^0 to $W^+ W^-$ and $Z Z$ in up to 5.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV and up to 19.7 fb^{-1} at $E_{\rm cm}$ = 8 TeV in the range $m_{H_2^0}$ = 145–1000 GeV. See their Figs. 8 and 9 for limits in the parameter space of the model.

[71] KHACHATRYAN 15BB search for production of a resonance H^0 decaying to $\gamma\gamma$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 7 for limits on cross section times branching ratio for m_{H^0} = 150–850 GeV.

[72] KHACHATRYAN 15N search for production of A^0 decaying to $Z H^0 \rightarrow \ell^+\ell^- b\overline{b}$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 3 for limits on cross section times branching ratios for m_{A^0} = 225–600 GeV.

[73] KHACHATRYAN 15O search for production of a high-mass narrow resonance A^0 decaying to $Z H^0 \rightarrow q\overline{q}\tau^+\tau^-$ in 19.7 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 6 for limits on cross section times branching ratios for m_{A^0} = 800–2500 GeV.

[74] KHACHATRYAN 15R search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ in 17.9 fb^{-1} of pp collisions at $E_{\rm cm}$ = 8 TeV. See their Fig. 5 (top) for limits on cross section times branching ratios for $m_{H_2^0}$ = 0.27–1.1 TeV.

[75] AAD 14AP search for a second H^0 state decaying to $\gamma\gamma$ in addition to the state at about 125 GeV in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Fig. 4 for limits on cross section times branching ratio for m_{H^0} = 65–600 GeV.

[76] AAD 14M search for the decay cascade $H_2^0 \rightarrow H^{\pm} W^{\mp} \rightarrow H^0 W^{\pm} W^{\mp}$, H^0 decaying to $b\overline{b}$ in 20.3 fb^{-1} of pp collisions at E_{cm} = 8 TeV. See their Table III for limits on cross section times branching ratio for $m_{H_2^0}$= 325–1025 GeV and m_{H^+}= 225–925 GeV.

[77] CHATRCHYAN 14G search for a second H^0 state decaying to $WW^{(*)}$ in addition to the observed signal at about 125 GeV using 4.9 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 19.4 fb^{-1} at E_{cm} = 8 TeV. See their Fig. 21 (right) for cross section limits in the mass range 110–600 GeV.

[78] KHACHATRYAN 14P search for a second H^0 state decaying to $\gamma\gamma$ in addition to the observed signal at about 125 GeV using 5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 19.7 fb^{-1} at E_{cm} = 8 TeV. See their Figs. 27 and 28 for cross section limits in the mass range 110–150 GeV.

[79] AALTONEN 13P search for production of a heavy Higgs boson H'^0 that decays into a charged Higgs boson $H^{\pm}$ and a lighter Higgs boson H^0 via the decay chain $H'^0 \rightarrow H^{\pm} W^{\mp}$, $H^{\pm} \rightarrow W^{\pm} H^0$, $H^0 \rightarrow b\overline{b}$ in the final state $\ell\nu$ plus 4 jets in 8.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. See their Fig. 4 for limits on cross section times branching ratio in the $m_{H^{\pm}}-m_{H'^0}$ plane for m_{H^0} = 126 GeV.

[80] CHATRCHYAN 13BJ search for H^0 production in the decay chain $H^0 \rightarrow A^0 A^0$, $A^0 \rightarrow \mu^+\mu^-$ in 5.3 fb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 2 for limits on cross section times branching ratio.

[81] AALTONEN 11P search in 2.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV for the decay chain $t \rightarrow bH^+$, $H^+ \rightarrow W^+ A^0$, $A^0 \rightarrow \tau^+\tau^-$ with m_{A^0} between 4 and 9 GeV. See their Fig. 4 for limits on B($t \rightarrow bH^+$) for 90 < m_{H^+} < 160 GeV.

[82] ABBIENDI 10 search for $e^+e^- \rightarrow ZH^0$ with the decay chain $H^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$, $\widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0$ + (γ or Z^*), when $\widetilde{\chi}_1^0$ and $\widetilde{\chi}_2^0$ are nearly degenerate. For a mass difference of 2 (4) GeV, a lower limit on m_{H^0} of 108.4 (107.0) GeV (95% CL) is obtained for SM ZH^0 cross section and B($H^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$) = 1.

[83] SCHAEL 10 search for the process $e^+e^- \rightarrow H^0 Z$ followed by the decay chain $H^0 \rightarrow A^0 A^0 \rightarrow \tau^+\tau^-\tau^+\tau^-$ with $Z \rightarrow \ell^+\ell^-$, $\nu\overline{\nu}$ at E_{cm} = 183–209 GeV. For a $H^0 ZZ$ coupling equal to the SM value, B($H^0 \rightarrow A^0 A^0$) = B($A^0 \rightarrow \tau^+\tau^-$) = 1, and m_{A^0} = 4–10 GeV, m_{H^0} up to 107 GeV is excluded at 95% CL.

[84] ABAZOV 09V search for H^0 production followed by the decay chain $H^0 \rightarrow A^0 A^0 \rightarrow \mu^+\mu^-\mu^+\mu^-$ or $\mu^+\mu^-\tau^+\tau^-$ in 4.2 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. See their Fig. 3 for limits on $\sigma(H^0)\cdot$B($H^0 \rightarrow A^0 A^0$) for m_{A^0} = 3.6–19 GeV.

[85] ABBIENDI 05A search for $e^+e^- \rightarrow H_1^0 A^0$ in general Type-II two-doublet models, with decays H_1^0, $A^0 \rightarrow q\overline{q}$, gg, $\tau^+\tau^-$, and $H_1^0 \rightarrow A^0 A^0$.

[86] ABBIENDI 04K search for $e^+e^- \rightarrow H^0 Z$ with H^0 decaying to two jets of any flavor including gg. The limit is for SM production cross section with B($H^0 \rightarrow jj$) = 1.

[87] ABDALLAH 04 consider the full combined LEP and LEP2 datasets to set limits on the Higgs coupling to W or Z bosons, assuming SM decays of the Higgs. Results in Fig. 26.

[88] ACHARD 04B search for $e^+e^- \rightarrow H^0 Z$ with H^0 decaying to $b\overline{b}$, $c\overline{c}$, or gg. The limit is for SM production cross section with B($H^0 \rightarrow jj$) = 1.

[89] ACHARD 04F search for H^0 with anomalous coupling to gauge boson pairs in the processes $e^+e^- \rightarrow H^0\gamma$, $e^+e^- H^0$, $H^0 Z$ with decays $H^0 \rightarrow f\overline{f}$, $\gamma\gamma$, $Z\gamma$, and $W^* W$ at E_{cm} = 189–209 GeV. See paper for limits.

[90] ABBIENDI 03F search for $H^0 \to$ anything in $e^+e^- \to H^0 Z$, using the recoil mass spectrum of $Z \to e^+e^-$ or $\mu^+\mu^-$. In addition, it searched for $Z \to \nu\overline{\nu}$ and $H^0 \to e^+e^-$ or photons. Scenarios with large width or continuum H^0 mass distribution are considered. See their Figs. 11–14 for the results.

[91] ABBIENDI 03G search for $e^+e^- \to H^0_1 Z$ followed by $H^0_1 \to A^0 A^0$, $A^0 \to c\overline{c}$, gg, or $\tau^+\tau^-$ in the region $m_{H^0_1}$ = 45-86 GeV and m_{A^0} = 2-11 GeV. See their Fig. 7 for the limits.

[92] Search for associated production of a $\gamma\gamma$ resonance with a Z boson, followed by $Z \to q\overline{q}$, $\ell^+\ell^-$, or $\nu\overline{\nu}$, at $E_{\text{cm}} \leq 209$ GeV. The limit is for a H^0 with SM production cross section and B($H^0 \to f\overline{f}$)=0 for all fermions f.

[93] For B($H^0 \to \gamma\gamma$)=1, $m_{H^0} > 113.1$ GeV is obtained.

[94] HEISTER 02M search for $e^+e^- \to H^0 Z$, assuming that H^0 decays to $q\overline{q}$, gg, or $\tau^+\tau^-$ only. The limit assumes SM production cross section.

[95] ABBIENDI 01E search for neutral Higgs bosons in general Type-II two-doublet models, at $E_{\text{cm}} \leq 189$ GeV. In addition to usual final states, the decays H^0_1, $A^0 \to q\overline{q}$, gg are searched for. See their Figs. 15,16 for excluded regions.

[96] ACCIARRI 00R search for $e^+e^- \to H^0\gamma$ with $H^0 \to b\overline{b}$, $Z\gamma$, or $\gamma\gamma$. See their Fig. 3 for limits on $\sigma\cdot$B. Explicit limits within an effective interaction framework are also given, for which the Standard Model Higgs search results are used in addition.

[97] ACCIARRI 00R search for the two-photon type processes $e^+e^- \to e^+e^- H^0$ with $H^0 \to b\overline{b}$ or $\gamma\gamma$. See their Fig. 4 for limits on $\Gamma(H^0 \to \gamma\gamma)\cdot$B($H^0 \to \gamma\gamma$or $b\overline{b}$) for m_{H^0}=70–170 GeV.

[98] GONZALEZ-GARCIA 98B use DØ limit for $\gamma\gamma$ events with missing E_T in $p\overline{p}$ collisions (ABBOTT 98) to constrain possible ZH or WH production followed by unconventional $H \to \gamma\gamma$ decay which is induced by higher-dimensional operators. See their Figs. 1 and 2 for limits on the anomalous couplings.

[99] KRAWCZYK 97 analyse the muon anomalous magnetic moment in a two-doublet Higgs model (with type II Yukawa couplings) assuming no $H^0_1 ZZ$ coupling and obtain $m_{H^0_1} \gtrsim$ 5 GeV or $m_{A^0} \gtrsim$ 5 GeV for $\tan\beta > 50$. Other Higgs bosons are assumed to be much heavier.

[100] ALEXANDER 96H give B($Z \to H^0\gamma$)×B($H^0 \to q\overline{q}$) $<$ 1–4 $\times 10^{-5}$ (95%CL) and B($Z \to H^0\gamma$)×B($H^0 \to b\overline{b}$) $<$ 0.7–2 $\times 10^{-5}$ (95%CL) in the range 20 $< m_{H^0} <$ 80 GeV.

SEARCHES FOR A HIGGS BOSON WITH STANDARD MODEL COUPLINGS

These listings are based on experimental searches for a scalar boson whose couplings to W, Z and fermions are precisely those of the Higgs boson predicted by the three-generation Standard Model with the minimal Higgs sector.

For a review and a bibliography, see the review on "Status of Higgs Boson Physics."

Indirect Mass Limits for H^0 from Electroweak Analysis

The mass limits shown below apply to a Higgs boson H^0 with Standard Model couplings whose mass is a priori unknown.

For limits obtained before the direct measurement of the top quark mass, see the 1996 (Physical Review **D54** 1 (1996)) Edition of this Review. Other studies based on data available prior to 1996 can be found in the 1998 Edition (The European Physical Journal **C3** 1 (1998)) of this Review.

VALUE (GeV)	*DOCUMENT ID*		*TECN*
$\mathbf{90^{+21}_{-18}}$	[1] HALLER	18	RVUE
• • • We do not use the following data for averages, fits, limits, etc. • • •			
91^{+30}_{-23}	[2] BAAK	12	RVUE
94^{+25}_{-22}	[3] BAAK	12A	RVUE
91^{+31}_{-24}	[4] ERLER	10A	RVUE
129^{+74}_{-49}	[5] LEP-SLC	06	RVUE

[1] HALLER 18 make Standard Model fits to Z and neutral current parameters, m_t, m_W, and Γ_W measurements available in 2018. The direct mass measurement at the LHC is not used in the fit.

[2] BAAK 12 make Standard Model fits to Z and neutral current parameters, m_t, m_W, and Γ_W measurements available in 2010 (using also preliminary data). The quoted result is obtained from a fit that does not include the limit from the direct Higgs searches. The result including direct search data from LEP2, the Tevatron and the LHC is 120^{+12}_{-5} GeV.

[3] BAAK 12A make Standard Model fits to Z and neutral current parameters, m_t, m_W, and Γ_W measurements available in 2012 (using also preliminary data). The quoted result is obtained from a fit that does not include the measured mass value of the signal observed at the LHC and also no limits from direct Higgs searches.

[4] ERLER 10A makes Standard Model fits to Z and neutral current parameters, m_t, m_W measurements available in 2009 (using also preliminary data). The quoted result is obtained from a fit that does not include the limits from the direct Higgs searches. With direct search data from LEP2 and Tevatron added to the fit, the 90% CL (99% CL) interval is 115–148 (114–197) GeV.

[5] LEP-SLC 06 make Standard Model fits to Z parameters from LEP/SLC and m_t, m_W, and Γ_W measurements available in 2005 with $\Delta\alpha^{(5)}_{\text{had}}(m_Z) = 0.02758 \pm 0.00035$. The 95% CL limit is 285 GeV.

SEARCHES FOR NEUTRAL HIGGS BOSONS REFERENCES

AAD	20	PR D101 012002	G. Aad *et al.*	(ATLAS Collab.)
AAD	20C	PL B800 135103	G. Aad *et al.*	(ATLAS Collab.)
SIRUNYAN	20	PL B800 135087	A.M. Sirunyan *et al.*	(CMS Collab.)
AABOUD	19A	JHEP 1901 030	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	19AG	PL B790 1	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	19AI	PL B793 499	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	19O	JHEP 1904 092	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	19T	JHEP 1905 124	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	19V	JHEP 1905 142	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	19Y	JHEP 1907 117	M. Aaboud *et al.*	(ATLAS Collab.)
AALTONEN	19	PR D99 052001	T. Aaltonen *et al.*	(CDF Collab.)
SIRUNYAN	19	PL B788 7	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19AE	JHEP 1905 210	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19AN	EPJ C79 280	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19AV	EPJ C79 564	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19B	PR D99 012005	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19BB	PL B793 320	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19BD	PL B795 398	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19BE	PRL 122 121803	A.M. Sirunyan *et al.*	(CMS Collab.)

SIRUNYAN	19BQ	PL B796 131	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19CR	PL B798 134992	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	19H	JHEP 1901 040	A.M. Sirunyan *et al.*	(CMS Collab.)
AABOUD	18AA	PR D98 032015	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18AG	PL B782 750	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18AH	PL B783 392	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18AI	JHEP 1803 174	M. Aaboud *et al.*	(ATLAS Collab.)
Also		JHEP 1811 051 (errat.)	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18AP	JHEP 1806 166	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18BF	EPJ C78 293	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18BU	EPJ C78 1007	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18BX	JHEP 1810 031	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18CC	JHEP 1811 051 (errat.)	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18CE	JHEP 1812 039	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18CQ	PRL 121 191801	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18CW	JHEP 1811 040	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18F	PL B777 91	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	18G	JHEP 1801 055	M. Aaboud *et al.*	(ATLAS Collab.)
AAIJ	18AM	EPJ C78 1008	R. Aaij *et al.*	(LHCb Collab.)
AAIJ	18AQ	JHEP 1809 147	R. Aaij *et al.*	(LHCb Collab.)
HALLER	18	EPJ C78 675	J. Haller *et al.*	(Gfitter Group)
SIRUNYAN	18A	PL B778 101	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18AF	PL B781 244	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18BA	JHEP 1806 127	A.M. Sirunyan *et al.*	(CMS Collab.)
Also		JHEP 1903 128 (errat.)	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18BP	JHEP 1808 113	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18CW	JHEP 1808 152	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18CX	JHEP 1809 007	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18DK	JHEP 1809 148	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18DT	PL B785 462	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18DU	PR D98 092001	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18ED	JHEP 1811 172	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	18EE	JHEP 1811 018	A.M. Sirunyan *et al.*	(CMS Collab.)
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AABOUD	17	PL B764 11	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	17AN	PRL 119 191803	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	17AW	JHEP 1710 112	M. Aaboud *et al.*	(ATLAS Collab.)
KHACHATRY...	17AZ	JHEP 1710 076	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	17D	JHEP 1701 076	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	17R	PL B767 147	V. Khachatryan *et al.*	(CMS Collab.)
SIRUNYAN	17AX	JHEP 1711 010	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	17CN	PR D96 072004	A.M. Sirunyan *et al.*	(CMS Collab.)
SIRUNYAN	17Y	PL B772 363	A.M. Sirunyan *et al.*	(CMS Collab.)
AABOUD	16AA	EPJ C76 585	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	16AB	EPJ C76 605	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	16AE	JHEP 1609 173	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	16H	JHEP 1609 001	M. Aaboud *et al.*	(ATLAS Collab.)
AABOUD	16I	PR D94 052002	M. Aaboud *et al.*	(ATLAS Collab.)
AAD	16AX	EPJ C76 45	G. Aad *et al.*	(ATLAS Collab.)
AAD	16C	JHEP 1601 032	G. Aad *et al.*	(ATLAS Collab.)
AAD	16L	EPJ C76 210	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	16C	PR D93 112010	T. Aaltonen *et al.*	(CDF Collab.)
ABLIKIM	16E	PR D93 052005	M. Ablikim *et al.*	(BESIII Collab.)
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KHACHATRY...	16BG	EPJ C76 371	V. Khachatryan *et al.*	(CMS Collab.)
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KHACHATRY...	16M	PRL 117 051802	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	16P	PL B755 217	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	16W	PL B758 296	V. Khachatryan *et al.*	(CMS Collab.)
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AAD	15BD	EPJ C75 337	G. Aad *et al.*	(ATLAS Collab.)
AAD	15BH	EPJ C75 299	G. Aad *et al.*	(ATLAS Collab.)
Also		EPJ C75 408 (errat.)	G. Aad *et al.*	(ATLAS Collab.)
AAD	15BK	EPJ C75 412	G. Aad *et al.*	(ATLAS Collab.)
AAD	15BZ	PR D92 052002	G. Aad *et al.*	(ATLAS Collab.)
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AAD	15H	PRL 114 081802	G. Aad *et al.*	(ATLAS Collab.)
AAD	15S	PL B744 163	G. Aad *et al.*	(ATLAS Collab.)
KHACHATRY...	15AW	JHEP 1510 144	V. Khachatryan *et al.*	(CMS Collab.)
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KHACHATRY...	15BB	PL B750 494	V. Khachatryan *et al.*	(CMS Collab.)
KHACHATRY...	15N	PL B748 221	V. Khachatryan *et al.*	(CMS Collab.)
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AAD	14M	PR D89 032002	G. Aad *et al.*	(ATLAS Collab.)
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KHACHATRY...	14M	JHEP 1410 160	V. Khachatryan *et al.*	(CMS Collab.)
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AAD	13O	JHEP 1302 095	G. Aad *et al.*	(ATLAS Collab.)
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AALTONEN	12AB	PR D85 092001	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12AN	PL B717 173	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12AQ	PR D86 091101	T. Aaltonen *et al.*	(CDF and D0 Collabs.)
AALTONEN	12U	PR D85 012007	T. Aaltonen *et al.*	(CDF Collab.)
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CHATRCHYAN	12AO	JHEP 1209 111	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12C	JHEP 1203 081	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12D	JHEP 1204 036	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12E	PL B710 91	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12G	PL B710 403	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12H	PRL 108 111804	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12I	JHEP 1203 040	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12K	PL B713 68	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12N	PL B716 30	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12V	PRL 109 121801	S. Chatrchyan *et al.*	(CMS Collab.)
AALTONEN	11P	PRL 107 031801	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	11K	PL B698 97	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	11W	PRL 107 121801	V.M. Abazov *et al.*	(D0 Collab.)
ABOUZAID	11A	PRL 107 201803	E. Abouzaid *et al.*	(KTeV Collab.)
DEL-AMO-SA...	11J	PRL 107 021804	P. del Amo Sanchez *et al.*	(BABAR Collab.)
LEES	11H	PRL 107 221803	J.P. Lees *et al.*	(BABAR Collab.)
ABBIENDI	10	PL B682 381	G. Abbiendi *et al.*	(OPAL Collab.)
ANDREAS	10	JHEP 1008 003	S. Andreas *et al.*	(DESY)
ERLER	10A	PR D81 051301	J. Erler	(UNAM)
HYUN	10	PRL 105 091801	H.J. Hyun *et al.*	(BELLE Collab.)
SCHAEL	10	JHEP 1005 049	S. Schael *et al.*	(ALEPH Collab.)
AALTONEN	09AB	PRL 103 061803	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09AR	PRL 103 201801	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	09V	PRL 103 061801	V.M. Abazov *et al.*	(D0 Collab.)

AUBERT	09P	PRL 103 181801	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	09Z	PRL 103 081803	B. Aubert *et al.*	(BABAR Collab.)
TUNG	09	PRL 102 051802	Y.C. Tung *et al.*	(KEK E391a Collab.)
ABAZOV	08U	PRL 101 051801	V.M. Abazov *et al.*	(D0 Collab.)
ABDALLAH	08B	EPJ C54 1	J. Abdallah *et al.*	(DELPHI Collab.)
Also		EPJ C56 165 (errat.)	J. Abdallah *et al.*	(DELPHI Collab.)
LOVE	08	PRL 101 151802	W. Love *et al.*	(CLEO Collab.)
ABBIENDI	07	EPJ C49 457	G. Abbiendi *et al.*	(OPAL Collab.)
BESSON	07	PRL 98 052002	D. Besson *et al.*	(CLEO Collab.)
SCHAEL	07	EPJ C49 439	S. Schael *et al.*	(ALEPH Collab.)
LEP-SLC	06	PRPL 427 257	ALEPH, DELPHI, L3, OPAL, SLD and working groups	
SCHAEL	06B	EPJ C47 547	S. Schael *et al.*	(LEP Collabs.)
ABBIENDI	05A	EPJ C40 317	G. Abbiendi *et al.*	(OPAL Collab.)
ABDALLAH	05D	EPJ C44 147	J. Abdallah *et al.*	(DELPHI Collab.)
ACHARD	05	PL B609 35	P. Achard *et al.*	(L3 Collab.)
ACOSTA	05Q	PR D72 072004	D. Acosta *et al.*	(CDF Collab.)
PARK	05	PRL 94 021801	H.K. Park *et al.*	(FNAL HyperCP Collab.)
ABBIENDI	04K	PL B597 11	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	04M	EPJ C37 49	G. Abbiendi *et al.*	(OPAL Collab.)
ABDALLAH	04	EPJ C32 145	J. Abdallah *et al.*	(DELPHI Collab.)
ABDALLAH	04B	EPJ C32 475	J. Abdallah *et al.*	(DELPHI Collab.)
ABDALLAH	04L	EPJ C35 313	J. Abdallah *et al.*	(DELPHI Collab.)
ABDALLAH	04O	EPJ C38 1	J. Abdallah *et al.*	(DELPHI Collab.)
ACHARD	04B	PL B583 14	P. Achard *et al.*	(L3 Collab.)
ACHARD	04F	PL B589 89	P. Achard *et al.*	(L3 Collab.)
ABBIENDI	03F	EPJ C27 311	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	03G	EPJ C27 483	G. Abbiendi *et al.*	(OPAL Collab.)
ACHARD	03C	PL B568 191	P. Achard *et al.*	(L3 Collab.)
ABBIENDI	02D	EPJ C23 397	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	02F	PL B544 44	G. Abbiendi *et al.*	(OPAL Collab.)
ACHARD	02C	PL B534 28	P. Achard *et al.*	(L3 Collab.)
ACHARD	02H	PL B545 30	P. Achard *et al.*	(L3 Collab.)
AKEROYD	02	PR D66 037702	A.G. Akeroyd *et al.*	
HEISTER	02	PL B526 191	A. Heister *et al.*	(ALEPH Collab.)
HEISTER	02L	PL B544 16	A. Heister *et al.*	(ALEPH Collab.)
HEISTER	02M	PL B544 25	A. Heister *et al.*	(ALEPH Collab.)
ABBIENDI	01E	EPJ C18 425	G. Abbiendi *et al.*	(OPAL Collab.)
ABREU	01F	PL B507 89	P. Abreu *et al.*	(DELPHI Collab.)
AFFOLDER	01H	PR D64 092002	T. Affolder *et al.*	(CDF Collab.)
BARATE	01C	PL B499 53	R. Barate *et al.*	(ALEPH Collab.)
ACCIARRI	00M	PL B485 85	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	00R	PL B489 102	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	00S	PL B489 115	M. Acciarri *et al.*	(L3 Collab.)
BARATE	00L	PL B487 241	R. Barate *et al.*	(ALEPH Collab.)
ABBIENDI	99E	EPJ C7 407	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	99O	PL B464 311	G. Abbiendi *et al.*	(OPAL Collab.)
ABBOTT	99B	PRL 82 2244	B. Abbott *et al.*	(D0 Collab.)
ABREU	99P	PL B458 431	P. Abreu *et al.*	(DELPHI Collab.)
ABBOTT	98	PRL 80 442	B. Abbott *et al.*	(D0 Collab.)
ACKERSTAFF	98S	EPJ C5 19	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	98Y	PL B437 218	K. Ackerstaff *et al.*	(OPAL Collab.)
GONZALEZ...	98B	PR D57 7045	M.C. Gonzalez-Garcia, S.M. Lietti, S.F. Novaes	
PDG	98	EPJ C3 1	C. Caso *et al.*	(PDG Collab.)
KRAWCZYK	97	PR D55 6968	M. Krawczyk, J. Zochowski	(WARS)
ALEXANDER	96H	ZPHY C71 1	G. Alexander *et al.*	(OPAL Collab.)
PDG	96	PR D54 1	R. M. Barnett *et al.*	(PDG Collab.)
ABREU	95H	ZPHY C67 69	P. Abreu *et al.*	(DELPHI Collab.)
BALEST	95	PR D51 2053	R. Balest *et al.*	(CLEO Collab.)
PICH	92	NP B388 31	A. Pich, J. Prades, P. Yepes	(CERN, CPPM)
ANTREASYAN	90C	PL B251 204	D. Antreasyan *et al.*	(Crystal Ball Collab.)