# 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 tan$\beta$.

| 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 | 20AA | ATLS | $H_2^0/A^0 \to \tau^+\tau^-$ |
| | | [5] AAD | 20C | ATLS | $H_2^0 \to H^0 H^0$ |
| | | [6] AAD | 20L | ATLS | $H_2^0 \to b\overline{b}$ |
| | | [7] SIRUNYAN | 20AC | CMS | $A^0 \to Z H^0$ |
| | | [8] SIRUNYAN | 20AF | CMS | $H_2^0/A^0 \to t\overline{t}$ |
| | | [9] SIRUNYAN | 20Y | CMS | $H_2^0 \to W^+W^-$ |
| | | [10] SIRUNYAN | 19CR | CMS | $H_2^0/A^0 \to \mu^+\mu^-$ |
| | | [11] SIRUNYAN | 18A | CMS | $H_2^0 \to H^0 H^0$ |
| | | [12] SIRUNYAN | 18BP | CMS | $pp \to H_2^0/A^0 + b + X$, $H_2^0/A^0 \to b\overline{b}$ |
| | | [13] AABOUD | 16AA | ATLS | $A^0 \to \tau^+\tau^-$ |
| | | [14] KHACHATRY... | 16A | CMS | $H_{1,2}^0/A^0 \to \mu^+\mu^-$ |
| | | [15] KHACHATRY... | 16P | CMS | $H_2^0 \to H^0 H^0$, $A^0 \to Z H^0$ |
| | | [16] KHACHATRY... | 15AY | CMS | $pp \to H_{1,2}^0/A^0 + b + X$, $H_{1,2}^0/A^0 \to b\overline{b}$ |
| | | [17] AAD | 14AW | ATLS | $pp \to H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \to \tau\tau$ |
| | | [18] KHACHATRY... | 14M | CMS | $pp \to H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \to \tau\tau$ |

| | | | | | |
|---|---|---|---|---|---|
| | | [19] AAD | 13O | ATLS | $pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$, $\mu^+\mu^-$ |
| | | [20] AAIJ | 13T | LHCB | $pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$ |
| | | [21] CHATRCHYAN | 13AG | CMS | $pp \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$ |
| | | [22] AALTONEN | 12AQ | TEVA | $p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$ |
| | | [23] AALTONEN | 12X | CDF | $p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$ |
| | | [24] ABAZOV | 12G | D0 | $p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$ |
| | | [25] CHATRCHYAN | 12K | CMS | $pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$ |
| | | [26] ABAZOV | 11K | D0 | $p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$ |
| | | [27] ABAZOV | 11W | D0 | $p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$ |
| | | [28] 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 | | [29] ABDALLAH | 08B | DLPH | $E_{cm} \le 209$ GeV |
| $>$ 93.4 | 95 | [30] SCHAEL | 06B | LEP | $E_{cm} \le 209$ GeV |
| | | [31] ACOSTA | 05Q | CDF | $p\overline{p} \to H^0_{1,2}/A^0 + X$ |
| $>$ 85.0 | 95 | [32,33] ABBIENDI | 04M | OPAL | $E_{cm} \le 209$ GeV |
| | | [34] ABBIENDI | 03G | OPAL | $H^0_1 \to A^0 A^0$ |
| $>$ 86.5 | 95 | [32,35] ACHARD | 02H | L3 | $E_{cm} \le 209$ GeV, $\tan\beta > 0.4$ |
| | | [36] AKEROYD | 02 | RVUE | |
| $>$ 90.1 | 95 | [32,37] 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 20AA search for $H^0_2/A^0 \to \tau^+\tau^-$ produced by gluon fusion or $b$-associated production using 139 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 2(c) for excluded region in the $M_h^{125}$ scenario of MSSM. Values of tan$\beta$ > 8 (21) are excluded for $m_{A^0}$ = 1.0 (1.5) TeV at 95%CL.

[5] 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.

[6] AAD 20L search for $b$-associated production of $H^0_2$ decaying to $b\overline{b}$ in 27.8 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 9 for excluded regions in hMSSM, $m_h^{mod+}$ and $m_h^{mod-}$ scenarios of MSSM.

[7] SIRUNYAN 20AC search for gluon-fusion and $b$-associated production of $A^0$ decaying to $Z H^0$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 6 for excluded regions in the $M^{125}_{hEFT}$ and hMSSM scenarios of the MSSM.

[8] SIRUNYAN 20AF search for $H^0_2/A^0 \to t\overline{t}$ with one or two charged leptons in the final state using kinematic variables in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 8 for excluded region in the hMSSM scenario of MSSM. Values of tan$\beta$ below 1.0–1.5 are excluded for $m_{A^0}$ = 0.4–0.75 TeV at 95%CL.

[9] SIRUNYAN 20Y search for gluon-fusion and vector-boson-fusion production of $H^0_2$ decaying to $W^+W^-$ in the final states $\ell\nu\ell\nu$ and $\ell\nu q q$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Figs. 8 and 9 for excluded regions in various MSSM scenarios.

[10] 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 $m_h^{mod+}$ and hMSSM scenarios.

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

[12] SIRUNYAN 18BP search for production of $H^0_2/A^0 \to b\overline{b}$ 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($\beta$) plane in several MSSM scenarios.

[13] 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 $A^0 \to \tau^+\tau^-$ 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 $m_h^{mod+}$ and hMSSM scenarios.

[14] 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 $H^0_{1,2}/A^0 \to \mu^+\mu^-$ 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 $m_h^{mod+}$ benchmark scenario and Fig. 9 for limits on cross section times branching ratio.

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

[16] 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.

[17] 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 tan$\beta > 5.4$ is excluded at 95% CL in the $m_h^{max}$ scenario.

[18] 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 tan$\beta > 3.8$ is excluded at 95% CL in the $m_h^{max}$ scenario.

[19] 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 tan$\beta = 50$, $m_{A^0}$ below 470 GeV is excluded at 95% CL in the $m_h^{max}$ scenario.

[20] 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.

[21] 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 $E_{cm}$ = 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 tan$\beta$ of 18–42 at 95% CL are obtained in the $m_h^{max}$ scenario with $\mu = +200$ GeV.

[22] 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.

[23] 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 $E_{cm}$ = 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.

[24] 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 $E_{cm}$ = 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 $m_h^{max}$ scenario.

[25] 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 $E_{cm}$ = 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 tan$\beta > 7.1$ is excluded at 95% CL in the $m_h^{max}$ scenario. Superseded by KHACHATRYAN 14M.

[26] ABAZOV 11K search for associated production of a Higgs boson and a $b$ quark, followed by the decay $H^0_{1,2}/A^0 \to b\overline{b}$, in 5.2 fb$^{-1}$ of $p\overline{p}$ collisions at $E_{cm}$ = 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.

[27] ABAZOV 11W search for associated production of a Higgs boson and a $b$ quark, followed by the decay $H^0_{1,2}/A^0 \to \tau\tau$, in 7.3 fb$^{-1}$ of $p\overline{p}$ collisions at $E_{cm}$ = 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.

[28] 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 $E_{cm}$ = 1.96 TeV. See their Fig. 2 for the limit on $\sigma \cdot$ B($H^0_{1,2}/A^0 \to \tau^+\tau^-$) for different Higgs masses, and see their Fig. 3 for the excluded region in the MSSM parameter space.

[29] 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.

[30] 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 $m_{H^0_1}$ 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($H^0 \to b\overline{b}, \tau^+\tau^-$) and $\sigma(H^0_1 H^0_2)\cdot$ B($H^0_1,H^0_2 \to b\overline{b},\tau^+\tau^-$).

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

[32] Search for $e^+e^- \to H^0_1 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$, and $e^+e^- \to H^0_1 Z$. 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.

[33] ABBIENDI 04M exclude 0.7 < tan$\beta$ < 1.9, assuming $m_t$ = 174.3 GeV. Limits for other MSSM benchmark scenarios, as well as for $CP$ violating cases, are also given.

[34] 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 no-mixing scenario, the region $m_{H^0_1}$ = 45-85 GeV and $m_{A^0}$ = 2-9.5 GeV is excluded at 95% CL.

[35] ACHARD 02H also search for the final state $H^0_1 Z \to 2A^0 q\overline{q}$, $A^0 \to q\overline{q}$. In addition, the MSSM parameter set in the "large-$\mu$" and "no-mixing" scenarios are examined.

[36] AKEROYD 02 examine the possibility of a light $A^0$ with tan$\beta$ <1. Electroweak measurements are found to be inconsistent with such a scenario.

[37] HEISTER 02 excludes the range 0.7 <tan$\beta$ < 2.3. A wider range is excluded with different stop mixing assumptions. Updates BARATE 01C.

## Mass Limits for $H^0_1$ (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, tan$\beta$ > 0.4 |
| >89.8 | 95 | [3,6] HEISTER | 02 | ALEP | $E_{cm} \leq$ 209 GeV, tan$\beta$ > 0.5 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| | | [7] AALTONEN | 12AQ | TEVA | $p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$ |

[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 $m_h^{\text{max}}$ 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 $\sigma(Z H^0) \cdot \text{B}(H^0 \to b\overline{b}, \tau^+\tau^-)$ and $\sigma(H_1^0 H_2^0) \cdot \text{B}(H_1^0, H_2^0 \to b\overline{b}, \tau^+\tau^-)$.

[3] Search for $e^+e^- \to H_1^0 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$, and $e^+e^- \to H_1^0 Z$. 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 $m_h^{\text{max}}$ scenario.

[4] ABBIENDI 04M exclude $0.7 < \tan\beta < 1.9$, 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 $H_1^0 Z \to 2A^0 q\overline{q}$, $A^0 \to q\overline{q}$. In addition, the MSSM parameter set in the "large-$\mu$" and "no-mixing" scenarios are examined.

[6] HEISTER 02 excludes the range $0.7 < \tan\beta < 2.3$. 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] AAD | 20L | ATLS | $H_2^0 \to b\overline{b}$ |
| | | [3] SIRUNYAN | 20AA | CMS | $H_2^0 \to Z A^0$ or $A^0 \to Z H_2^0$ |
| | | [4] SIRUNYAN | 20Y | CMS | $H_2^0 \to W^+W^-$ |
| | | [5] SIRUNYAN | 19AE | CMS | $A^0 \to \tau^+\tau^-$ |
| | | [6] SIRUNYAN | 19AV | CMS | $A^0 \to Z H^0$ |
| | | [7] AABOUD | 18AH | ATLS | $A^0 \to Z H_2^0$ |

| | | | | |
|---|---|---|---|---|
| | | [8] AABOUD | 18AI ATLS | $A^0 \to Z H^0$ |
| | | [9] AABOUD | 18BF ATLS | $H_2^0 \to Z Z$ |
| | | [10] AABOUD | 18CE ATLS | $p p \to H_2^0 / A^0 t \overline{t}$, $H_2^0 / A^0 \to t \overline{t}$ |
| | | [11] HALLER | 18 RVUE | global fits |
| | | [12] SIRUNYAN | 18BP CMS | $p p \to H_2^0 / A^0 + b + X$, $H_2^0 / A^0 \to b \overline{b}$ |
| | | [13] SIRUNYAN | 18ED CMS | $A^0 \to Z H^0$ |
| | | [14] AABOUD | 17AN ATLS | $H_2^0$, $A^0 \to t \overline{t}$ |
| | | [15] SIRUNYAN | 17AX CMS | $A^0 b \overline{b}$, $A^0 \to \mu^+ \mu^-$ |
| | | [16] AAD | 16AX ATLS | $H_2^0 \to Z Z$ |
| | | [17] KHACHATRY... | 16P CMS | $H_2^0 \to H^0 H^0$, $A^0 \to Z H^0$ |
| | | [18] KHACHATRY... | 16W CMS | $A^0 b \overline{b}$, $A^0 \to \tau^+ \tau^-$ |
| | | [19] KHACHATRY... | 16Z CMS | $H_2^0 \to Z A^0$ or $A^0 \to Z H_2^0$ |
| | | [20] AAD | 15BK ATLS | $H_2^0 \to H^0 H^0$ |
| | | [21] AAD | 15S ATLS | $A^0 \to Z H^0$ |
| | | [22] KHACHATRY... | 15BB CMS | $H_2^0$, $A^0 \to \gamma \gamma$ |
| | | [23] KHACHATRY... | 15N CMS | $A^0 \to Z H^0$ |
| | | [24] AAD | 14M ATLS | $H_2^0 \to H^{\pm} W^{\mp} \to H^0 W^{\pm} W^{\mp}$, $H^0 \to b \overline{b}$ |
| | | [25] KHACHATRY... | 14Q CMS | $H_2^0 \to H^0 H^0$, $A^0 \to Z H^0$ |
| | | [26] AALTONEN | 09AR CDF | $p \overline{p} \to H_{1,2}^0 / A^0 + X$, $H_{1,2}^0 / A^0 \to \tau^+ \tau^-$ |
| none 1–55 | 95 | [27] ABBIENDI | 05A OPAL | $H_1^0$, Type II model |
| $>$110.6 | 95 | [28] ABDALLAH | 05D DLPH | $H^0 \to$ 2 jets |
| | | [29] ABDALLAH | 04O DLPH | $Z \to f \overline{f} H$ |
| | | [30] ABDALLAH | 04O DLPH | $e^+ e^- \to H^0 Z$, $H^0 A^0$ |
| | | [31] ABBIENDI | 02D OPAL | $e^+ e^- \to b \overline{b} H$ |
| none 1–44 | 95 | [32] ABBIENDI | 01E OPAL | $H_1^0$, Type-II model |
| $>$ 68.0 | 95 | [33] ABBIENDI | 99E OPAL | $\tan\beta > 1$ |
| | | [34] ABREU | 95H DLPH | $Z \to H^0 Z^*$, $H^0 A^0$ |
| | | [35] 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 $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 18 for excluded regions in various 2HDMs.

[2] AAD 20L search for $b$-associated production of $H_2^0$ decaying to $b \overline{b}$ in 27.8 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Figs. 10 and 11 for excluded regions in the flipped two Higgs doublet model.

[3] SIRUNYAN 20AA search for $H_2^0 \to Z A^0$, $A^0 \to b \overline{b}$ or $A^0 \to Z H_2^0$, $H_2^0 \to b \overline{b}$ in 35.9 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Figs. 8 and 9 for excluded regions in the parameter space of Type-II two Higgs doublet model.

[4] SIRUNYAN 20Y search for gluon-fusion and vector-boson-fusion production of $H_2^0$ decaying to $W^+ W^-$ in the final states $\ell \nu \ell \nu$ and $\ell \nu q q$ in 35.9 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 7 for excluded regions in Type I and II two Higgs doublet models.

[5] 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 $p p$ 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.

6 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 $p p$ collisions at $E_{cm}$ = 13 TeV. See their Figs. 6 and 7 for excluded regions in the parameter space of various 2HDMs.

7 AABOUD 18AH search for production of an $A^0$ in gluon-gluon fusion and in association with a $b \overline{b}$, decaying to $Z H_2^0 \rightarrow \ell^+ \ell^- b \overline{b}$ in 36.1 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 6 for excluded regions in the parameter space of various 2HDMs.

8 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 $p p$ collisions at $E_{cm}$ = 13 TeV. See their Figs. 7 and 8 for excluded regions in the parameter space in various 2HDMs.

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

10 AABOUD 18CE search for the process $p p \rightarrow H_2^0 / A^0 t \overline{t}$ followed by the decay $H_2^0 / A^0 \rightarrow t \overline{t}$ in 36.1 fb$^{-1}$ of $p p$ 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.

11 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.

12 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 $p p$ 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.

13 SIRUNYAN 18ED 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 $\nu \overline{\nu} b \overline{b}$ or $\ell^+ \ell^- b \overline{b}$ in 35.9 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 9 for excluded regions in the parameter space in Type I and II 2HDMs.

14 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 $p p$ collisions at $E_{cm}$ = 8 TeV. See their Fig. 3 and Table III for excluded parameter regions in Type II Two-Higgs-Doublet-Models.

15 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 $p p$ collisions at $E_{cm}$ = 8 TeV. Limits are set in the range $m_{A^0}$ = 25–60 GeV. See their Fig. 5 for upper limits on $\sigma(A^0 b \overline{b}) \cdot B(A^0 \rightarrow \mu^+ \mu^-)$.

16 AAD 16AX search for production of a heavy $H^0$ state decaying to $Z Z$ 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 $p p$ collisions at $E_{cm}$ = 8 TeV. See their Figs. 13 and 14 for excluded parameter regions in Type I and II models.

17 KHACHATRYAN 16P search for gluon fusion production of an $H_2^0$ 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 $p p$ collisions at $E_{cm}$ = 8 TeV. See their Fig. 11 for limits on tan$\beta$ for $m_{A^0}$ = 230–350 GeV.

18 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 $p p$ collisions at $E_{cm}$ = 8 TeV. See their Fig. 3 for upper limits on $\sigma(A^0 b \overline{b}) \cdot B(A^0 \rightarrow \tau^+ \tau^-)$.

19 KHACHATRYAN 16Z search for $H_2^0 \rightarrow Z A^0$ followed by $A^0 \rightarrow b \overline{b}$ or $\tau^+ \tau^-$, and $A^0 \rightarrow Z H_2^0$ followed by $H_2^0 \rightarrow b \overline{b}$ or $\tau^+ \tau^-$, in 19.8 fb$^{-1}$ of $p p$ collisions at $E_{cm}$

= 8 TeV. See their Fig. 4 for cross section limits and Fig. 5 for excluded region in the parameter space.

[20] 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 $E_{cm}$ = 8 TeV. See their Figs. 15–18 for excluded regions in the parameter space.

[21] 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 $E_{cm}$ = 8 TeV. See their Figs. 4 and 5 for excluded regions in the parameter space.

[22] KHACHATRYAN 15BB search for $H_2^0$ , $A^0 \rightarrow \gamma\gamma$ in 19.7 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 8 TeV. See their Fig. 10 for excluded regions in the two-Higgs-doublet model parameter space.

[23] 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 $E_{cm}$ = 8 TeV. See their Fig. 5 for excluded regions in the $\tan\beta - \cos(\beta - \alpha)$ plane for $m_{A^0}$ = 300 GeV.

[24] 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 IV for limits in a two-Higgs-doublet model for $m_{H_2^0}$= 325–1025 GeV and $m_{H^+}$= 225–825 GeV.

[25] KHACHATRYAN 14Q search for $H_2^0 \rightarrow H^0 H^0$ and $A^0 \rightarrow Z H^0$ in 19.5 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 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.

[26] 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 $E_{cm}$ = 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.

[27] 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 $H_1^0 \rightarrow A^0 A^0$.

[28] 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.

[29] 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 $4\tau$. See paper for limits on Yukawa couplings.

[30] 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 $E_{cm}$ = 189–208 GeV. See paper for limits on couplings.

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

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

[33] ABBIENDI 99E search for $e^+ e^- \rightarrow H^0 A^0$ and $H^0 Z$ at $E_{cm}$ = 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.

[34] 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.

[35] 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 $\pi^\pm$, $\eta$ 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 $E_{cm}$ = 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 $E_{cm}$ = 1.96 TeV.

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

[4] ABAZOV 13G search for $H^0 \to W W^{(*)}$ in 9.7 fb$^{-1}$ of $p\overline{p}$ collisions at $E_{cm}$ = 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 $H^0 \to \gamma\gamma$ in 9.6 fb$^{-1}$ of $p\overline{p}$ collisions at $E_{cm}$ = 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 $E_{cm}$ = 1.96 TeV. The search is sensitive to $W H^0$, $Z H^0$ and vector-boson fusion Higgs production with $H^0 \to W W^{(*)}$. 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 $E_{cm}$ = 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 $E_{cm}$ = 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 $E_{cm}$ = 7 and 8 TeV.

[10] AAD 12N search for $H^0 \rightarrow \gamma\gamma$ with 4.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 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 $E_{cm}$ = 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 $E_{cm}$ = 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 $E_{cm}$ = 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 $E_{cm} \leq$ 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 $E_{cm}$= 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 $E_{cm} \leq$ 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 $\sigma(e^+e^- \to H^0 Z^0)\times$B($H^0 \to \gamma\gamma)\times$B($X^0 \to f\overline{f}$) 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($H^0 \to \gamma\gamma$)= 0.80–0.34 pb are obtained in the mass range $m_{H^0}$= 65–150 GeV.

[26] ABREU 99P search for $e^+e^- \to H^0\gamma$ with $H^0 \to b\overline{b}$ or $\gamma\gamma$, and $e^+e^- \to H^0 q\overline{q}$ with $H^0 \to \gamma\gamma$. 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 | $pp \to H^0 WX$, $H^0 ZX$ |
| | | [3] AAD | 15BH | ATLS | jet + missing $E_T$ |
| | | [4] AAD | 14BA | ATLS | secondary vertex |
| | | [5] AAD | 14O | ATLS | $pp \to H^0 ZX$ |
| | | [6] CHATRCHYAN | 14B | CMS | $pp \to H^0 ZX$, $qqH^0X$ |
| | | [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 | $E_{cm} \le$ 209 GeV |
| >106.4 | 95 | [15] BARATE | 01C | ALEP | $E_{cm} \le$ 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 $pp \to H^0 WX$ and $pp \to H^0 ZX$ with $W$ or $Z$ decaying hadronically and $H^0$ decaying to invisible final states in 20.3 fb$^{-1}$ at $E_{cm}$ = 8TeV. 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($H'^0 \to$ 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 $H^0 \to X^0 X^0$, 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 $pp \to H^0 Z X$, $Z \to \ell\ell$, 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 $pp \to H^0 Z X$, $Z \to \ell\ell$ and $Z \to b\overline{b}$, and also $pp \to q q H^0 X$ 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 $H^0 \to X^0 X^0$, 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 $H^0 \to X^0 X^0$, 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 $H^0 \to X^0 X^0$, $X^0 \to \mu^+ \mu^- X'^0$ 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 $H^0 \to X^0 X^0$, 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 $H^0 \to X^0 X^0$, 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 $H^0 \to X^0 X^0$, 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 $e^+ e^- \to H^0 Z$ with $H^0$ decaying invisibly. The limit assumes SM production cross section and B($H^0 \to$ invisible) = 1.

[14] ABBIENDI 07 search for $e^+ e^- \to H^0 Z$ with $Z \to q\overline{q}$ 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($H^0 \to$ 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] AAD | 20AE | ATLS | $H^0 \to Z A^0$ |
| | [2] AABOUD | 18AP | ATLS | $H^0 \to A^0 A^0$ |
| | [3] KHACHATRY... | 17AZ | CMS | $H^0 \to A^0 A^0$ |
| | [4] ABLIKIM | 16E | BES3 | $J/\psi \to A^0 \gamma$ |
| | [5] KHACHATRY... | 16F | CMS | $H^0 \to A^0 A^0$ |
| | [6] LEES | 15H | BABR | $\Upsilon(1S) \to A^0 \gamma$ |

| | | | |
|---|---|---|---|
| [7] LEES | 13C | BABR | $\Upsilon(1S) \to A^0\gamma$ |
| [8] LEES | 13L | BABR | $\Upsilon(1S) \to A^0\gamma$ |
| [9] LEES | 13R | BABR | $\Upsilon(1S) \to A^0\gamma$ |
| [10] ABLIKIM | 12 | BES3 | $J/\psi \to A^0\gamma$ |
| [11] CHATRCHYAN | 12V | CMS | $A^0 \to \mu^+\mu^-$ |
| [12] AALTONEN | 11P | CDF | $t \to bH^+$, $H^+ \to W^+A^0$ |
| [13,14] ABOUZAID | 11A | KTEV | $K_L \to \pi^0\pi^0A^0$, $A^0 \to \mu^+\mu^-$ |
| [15] DEL-AMO-SA... | 11J | BABR | $\Upsilon(1S) \to A^0\gamma$ |
| [16] LEES | 11H | BABR | $\Upsilon(2S,3S) \to A^0\gamma$ |
| [17] ANDREAS | 10 | RVUE | |
| [14,18] HYUN | 10 | BELL | $B^0 \to K^{*0}A^0$, $A^0 \to \mu^+\mu^-$ |
| [14,19] HYUN | 10 | BELL | $B^0 \to \rho^0A^0$, $A^0 \to \mu^+\mu^-$ |
| [20] AUBERT | 09P | BABR | $\Upsilon(3S) \to A^0\gamma$ |
| [21] AUBERT | 09Z | BABR | $\Upsilon(2S) \to A^0\gamma$ |
| [22] AUBERT | 09Z | BABR | $\Upsilon(3S) \to A^0\gamma$ |
| [14,23] TUNG | 09 | K391 | $K_L \to \pi^0\pi^0A^0$, $A^0 \to \gamma\gamma$ |
| [24] LOVE | 08 | CLEO | $\Upsilon(1S) \to A^0\gamma$ |
| [25] BESSON | 07 | CLEO | $\Upsilon(1S) \to \eta_b\gamma$ |
| [26] PARK | 05 | HYCP | $\Sigma^+ \to pA^0$, $A^0 \to \mu^+\mu^-$ |
| [27] BALEST | 95 | CLE2 | $\Upsilon(1S) \to A^0\gamma$ |
| [28] ANTREASYAN | 90C | CBAL | $\Upsilon(1S) \to A^0\gamma$ |

[1] AAD 20AE search for the decay $H^0 \to ZA^0$, $Z \to \ell^+\ell^-$, $A^0$ decaying hadronically ($A^0 \to gg$ or $s\overline{s}$), in 139 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. Limit on the product of production cross section and the $H^0 \to ZA^0$ branching ratio in the range 17–340 pb (95% CL) is given for $m_{A^0}$ = 0.5–4.0 GeV, see their Table I.

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

[3] KHACHATRYAN 17AZ search for the decay $H^0 \to A^0A^0 \to \tau^+\tau^-\tau^+\tau^-$, $\mu^+\mu^-b\overline{b}$, 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.

[4] 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 $2.8\times10^{-8}$–$5.0\times10^{-6}$ (90% CL) for $0.212 \le m_{A^0} \le 3.0$ GeV. See their Fig. 5.

[5] KHACHATRYAN 16F search for the decay $H^0 \to A^0A^0 \to \tau^+\tau^-\tau^+\tau^-$ 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.

[6] 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 $7.4\times10^{-5}$–$2.4\times10^{-3}$ (90% CL) for $4.00 \le m_{A^0} \le 8.95$ and $9.10 \le m_{A^0} \le 9.25$ GeV. See their Fig. 6.

[7] LEES 13C search for the process $\Upsilon$(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 $0.212 \le m_{A^0} \le 9.20$ GeV. See their Fig. 5(e) for limits on the $b-A^0$ Yukawa coupling derived by combining this result with AUBERT 09Z.

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

[9] LEES 13R search for the process $\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^- \rightarrow A^0\gamma\pi^+\pi^-$ with $A^0$ decaying to $\tau^+\tau^-$ and give limits on B($\Upsilon(1S) \rightarrow A^0\gamma$)·B($A^0 \rightarrow \tau^+\tau^-$) 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.

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

[11] CHATRCHYAN 12V search for $A^0$ production in the decay $A^0 \rightarrow \mu^+\mu^-$ with 1.3 fb$^{-1}$ of $pp$ collisions at $E_{cm} = 7$ TeV. A limit on $\sigma(A^0)$·B($A^0 \rightarrow \mu^+\mu^-$) 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.

[12] 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.

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

[14] The search was motivated by PARK 05.

[15] DEL-AMO-SANCHEZ 11J search for the process $\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^- \rightarrow A^0\gamma\pi^+\pi^-$ with $A^0$ decaying to invisible final states. They give limits on B($\Upsilon(1S) \rightarrow A^0\gamma$)·B($A^0 \rightarrow$ 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.

[16] LEES 11H search for the process $\Upsilon$(2S, 3S) $\rightarrow A^0\gamma$ with $A^0$ decaying hadronically and give limits on B($\Upsilon$(2S, 3S) $\rightarrow A^0\gamma$)·B($A^0 \rightarrow$ hadrons) in the range $1 \times 10^{-6}$–$8 \times 10^{-5}$ (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.

[17] 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.

[18] HYUN 10 search for the decay chain $B^0 \rightarrow K^{*0}A^0$, $A^0 \rightarrow \mu^+\mu^-$ and give a limit on B($B^0 \rightarrow K^{*0}A^0$) · B($A^0 \rightarrow \mu^+\mu^-$) 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 $2.26 \times 10^{-8}$.

[19] HYUN 10 search for the decay chain $B^0 \rightarrow \rho^0A^0$, $A^0 \rightarrow \mu^+\mu^-$ and give a limit on B($B^0 \rightarrow \rho^0A^0$) · B($A^0 \rightarrow \mu^+\mu^-$) 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 $1.73 \times 10^{-8}$.

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

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

[22] 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($\Upsilon(3S) \to A^0\gamma$)·B($A^0 \to \mu^+\mu^-$) in the range (0.3–5) $\times 10^{-6}$ (90% CL).

[23] 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($K_L \to \pi^0\pi^0 A^0$) · 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 $\times 10^{-7}$.

[24] 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($\Upsilon(1S) \to A^0\gamma$) · B($A^0 \to \ell^+\ell^-$) in the range $10^{-6}$–$10^{-4}$ (90% CL) are given.

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

[26] 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($\Sigma^+ \to pA^0$)·B($A^0 \to \mu^+\mu^-$) $= (3.1^{+2.4}_{-1.9} \pm 1.5) \times 10^{-8}$.

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

[28] ANTREASYAN 90C give limits B($\Upsilon(1S) \to A^0\gamma$) ¡ 5.6 $\times 10^{-5}$ 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] SIRUNYAN | 21A | CMS | $H_2^0 \to ZA^0$, $A^0 \to$ invisible |
| | | [2] AAD | 20AA | ATLS | $H_2^0/A^0 \to \tau^+\tau^-$ |
| | | [3] AAD | 20AI | ATLS | $H^0 \to A^0A^0$ |
| | | [4] AAD | 20AO | ATLS | $H_2^0 \to H^0H^0$ |
| | | [5] AAD | 20C | ATLS | $H_2^0 \to H^0H^0$ |
| | | [6] AAD | 20L | ATLS | $H_2^0 \to b\bar{b}$ |
| | | [7] AAD | 20X | ATLS | $H_2^0 \to H^0H^0$ |
| | | [8] AAIJ | 20AL | LHCB | $A^0 \to \mu^+\mu^-$ |
| | | [9] SIRUNYAN | 20 | CMS | $H^0 \to A^0A^0$ |
| | | [10] SIRUNYAN | 20AA | CMS | $H_2^0 \to ZA^0$ or $A^0 \to ZH_2^0$ |
| | | [11] SIRUNYAN | 20AC | CMS | $A^0 \to ZH^0$ |
| | | [12] SIRUNYAN | 20AD | CMS | $H_2^0 \to \mu\tau,\ e\tau$ |
| | | [13] SIRUNYAN | 20AF | CMS | $H_2^0/A^0 \to t\bar{t}$ |
| | | [14] SIRUNYAN | 20AP | CMS | $H^0$, $H_2^0 \to A^0A^0$ |
| | | [15] SIRUNYAN | 20Y | CMS | $H_2^0 \to W^+W^-$ |
| | | [16] SIRUNYAN | 20Z | CMS | $t\bar{t}H_{1,2}^0$ or $t\bar{t}A^0$, $H_{1,2}^0/A^0 \to e^+e^-$, $\mu^+\mu^-$ |
| | | [17] AABOUD | 19A | ATLS | $H_2^0 \to H^0H^0$ |
| | | [18] AABOUD | 19AG | ATLS | $H^0 \to A^0A^0$ |
| | | [19] AABOUD | 19O | ATLS | $H_2^0 \to H^0H^0$ |

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|---|---|---|---|
| [20] AABOUD | 19T | ATLS | $H_2^0 \rightarrow H^0 H^0$ |
| [21] AABOUD | 19V | ATLS | two doublet + pseudoscalar model |
| [22] AABOUD | 19Y | ATLS | $H_2^0 \rightarrow \mu^+ \mu^-$ |
| [23] AALTONEN | 19 | CDF | $H_{1,2}^0 \rightarrow b\overline{b}$ |
| [24] SIRUNYAN | 19 | CMS | $H_2^0 \rightarrow H^0 H^0$ |
| [25] SIRUNYAN | 19AE | CMS | $A^0 \rightarrow \tau^+ \tau^-$ |
| [26] SIRUNYAN | 19AN | CMS | $A_2^0 \rightarrow H^0 A_1^0$ |
| [27] SIRUNYAN | 19AV | CMS | $A^0 \rightarrow Z H^0$ |
| [28] SIRUNYAN | 19B | CMS | $H_{1,2}^0 / A^0 \rightarrow b\overline{b}$ |
| [29] SIRUNYAN | 19BB | CMS | $H_1^0 \rightarrow \gamma\gamma$ |
| [30] SIRUNYAN | 19BD | CMS | $H^0 \rightarrow A^0 A^0$ |
| [31] SIRUNYAN | 19BE | CMS | $H_2^0 \rightarrow H^0 H^0$ |
| [32] SIRUNYAN | 19BQ | CMS | $H_{1,2}^0 \rightarrow A^0 A^0$ |
| [33] SIRUNYAN | 19CR | CMS | $H_2^0 / A^0 \rightarrow \mu^+ \mu^-$ |
| [34] SIRUNYAN | 19H | CMS | $H_2^0 \rightarrow H^0 H^0$ |
| [35] AABOUD | 18AA | ATLS | $H_2^0 \rightarrow Z\gamma$ |
| [36] AABOUD | 18AG | ATLS | $H^0 \rightarrow A^0 A^0$ |
| [37] AABOUD | 18AH | ATLS | $A^0 \rightarrow Z H_2^0$ |
| [38] AABOUD | 18AI | ATLS | $A^0 \rightarrow Z H^0$ |
| [39] AABOUD | 18BF | ATLS | $H_2^0 \rightarrow ZZ$ |
| [40] AABOUD | 18BU | ATLS | $H_2^0 \rightarrow H^0 H^0$ |
| [41] AABOUD | 18BX | ATLS | $H^0 \rightarrow A^0 A^0$ |
| [42] AABOUD | 18CQ | ATLS | $H_2^0 \rightarrow H^0 H^0$ |
| [43] AABOUD | 18F | ATLS | $H_2^0 \rightarrow W^+ W^-$, $ZZ$ |
| [44] AAIJ | 18AM | LHCB | $H_{1,2}^0 \rightarrow \mu\tau$ |
| [45] AAIJ | 18AQ | LHCB | $A^0 \rightarrow \mu^+ \mu^-$ |
| [46] AAIJ | 18AQ | LHCB | $H^0 \rightarrow A^0 A^0$, $A^0 \rightarrow \mu^+ \mu^-$ |
| [47] SIRUNYAN | 18AF | CMS | $H_2^0 \rightarrow H^0 H^0$ |
| [48] SIRUNYAN | 18BA | CMS | $H_2^0 \rightarrow ZZ$ |
| [49] SIRUNYAN | 18CW | CMS | $H_2^0 \rightarrow H^0 H^0$ |
| [50] SIRUNYAN | 18DK | CMS | $H_2^0 \rightarrow Z\gamma$ |
| [51] SIRUNYAN | 18DT | CMS | $H^0 \rightarrow A^0 A^0$ |
| [52] SIRUNYAN | 18DU | CMS | $H_2^0 \rightarrow \gamma\gamma$ |
| [53] SIRUNYAN | 18ED | CMS | $A^0 \rightarrow Z H^0$ |
| [54] SIRUNYAN | 18EE | CMS | $H^0 \rightarrow A^0 A^0$ |
| [55] SIRUNYAN | 18F | CMS | $pp$, 13 TeV, $H_2^0 \rightarrow H^0 H^0$ |
| [56] AABOUD | 17 | ATLS | $H_2^0 \rightarrow Z\gamma$ |
| [57] AABOUD | 17AW | ATLS | $H_2^0 \rightarrow Z\gamma$ |
| [58] KHACHATRY... | 17AZ | CMS | $H^0 \rightarrow A^0 A^0$ |
| [59] KHACHATRY... | 17D | CMS | $pp$, 8, 13 TeV, $H_2^0 \rightarrow Z\gamma$ |
| [60] KHACHATRY... | 17R | CMS | $H_2^0 \rightarrow \gamma\gamma$ |
| [61] SIRUNYAN | 17CN | CMS | $pp$, 8 TeV, $H_2^0 \rightarrow H^0 H^0$ |
| [62] SIRUNYAN | 17Y | CMS | $pp$, 8, 13 TeV, $H_2^0 \rightarrow Z\gamma$ |

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|---|---|---|---|---|---|
| | | [63] AABOUD | 16AB | ATLS | $H^0 \to A^0 A^0$ |
| | | [64] AABOUD | 16AE | ATLS | $H_2^0 \to W^+ W^-$, $Z Z$ |
| | | [65] AABOUD | 16H | ATLS | $H_2^0 \to \gamma\gamma$ |
| | | [66] AABOUD | 16I | ATLS | $H_2^0 \to H^0 H^0$ |
| | | [67] AAD | 16AX | ATLS | $H^0 \to Z Z$ |
| | | [68] AAD | 16C | ATLS | $H^0 \to W^+ W^-$ |
| | | [69] AAD | 16L | ATLS | $H^0 \to A^0 A^0$ |
| | | [70] AAD | 16L | ATLS | $H_2^0 \to A^0 A^0$ |
| | | [71] AALTONEN | 16C | CDF | $H_1^0 H^\pm \to H_1^0 H_1^0 W^*$, $H_1^0 \to \gamma\gamma$ |
| | | [72] KHACHATRY... | 16BG | CMS | $H_2^0 \to H^0 H^0$ |
| | | [73] KHACHATRY... | 16BQ | CMS | $p p$, 8 TeV, $H_2^0 \to H^0 H^0$ |
| | | [74] KHACHATRY... | 16F | CMS | $H^0 \to H_1^0 H_1^0$ |
| | | [75] KHACHATRY... | 16M | CMS | $H_2^0 \to \gamma\gamma$ |
| | | [76] KHACHATRY... | 16P | CMS | $H_2^0 \to H^0 H^0$ |
| | | [77] KHACHATRY... | 16P | CMS | $A^0 \to Z H^0$ |
| | | [78] AAD | 15BK | ATLS | $H_2^0 \to H^0 H^0$ |
| | | [79] AAD | 15BZ | ATLS | $H^0 \to A^0 A^0$ |
| | | [80] AAD | 15BZ | ATLS | $H_2^0 \to A^0 A^0$ |
| | | [81] AAD | 15CE | ATLS | $H_2^0 \to H^0 H^0$ |
| | | [82] AAD | 15H | ATLS | $H_2^0 \to H^0 H^0$ |
| | | [83] AAD | 15S | ATLS | $A^0 \to Z H^0$ |
| | | [84] KHACHATRY... | 15AW | CMS | $H_2^0 \to W^+ W^-$, $Z Z$ |
| | | [85] KHACHATRY... | 15BB | CMS | $H^0 \to \gamma\gamma$ |
| | | [86] KHACHATRY... | 15N | CMS | $A^0 \to Z H^0$ |
| | | [87] KHACHATRY... | 15O | CMS | $A^0 \to Z H^0$ |
| | | [88] KHACHATRY... | 15R | CMS | $H_2^0 \to H^0 H^0$ |
| | | [89] AAD | 14AP | ATLS | $H^0 \to \gamma\gamma$ |
| | | [90] AAD | 14M | ATLS | $H_2^0 \to H^\pm W^\mp \to H^0 W^\pm W^\mp$, $H^0 \to b \overline{b}$ |
| | | [91] CHATRCHYAN | 14G | CMS | $H^0 \to W W^{(*)}$ |
| | | [92] KHACHATRY... | 14P | CMS | $H^0 \to \gamma\gamma$ |
| | | [93] AALTONEN | 13P | CDF | $H'^0 \to H^\pm W^\mp \to H^0 W^+ W^-$ |
| | | [94] CHATRCHYAN | 13BJ | CMS | $H^0 \to A^0 A^0$ |
| | | [95] AALTONEN | 11P | CDF | $t \to b H^+$, $H^+ \to W^+ A^0$ |
| | | [96] ABBIENDI | 10 | OPAL | $H^0 \to \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$ |
| | | [97] SCHAEL | 10 | ALEP | $H^0 \to A^0 A^0$ |
| | | [98] ABAZOV | 09V | D0 | $H^0 \to A^0 A^0$ |
| none 3–63 | 95 | [99] ABBIENDI | 05A | OPAL | $A^0$, Type II model |
| $>104$ | 95 | [100] ABBIENDI | 04K | OPAL | $H^0 \to$ 2 jets |
| | | [101] ABDALLAH | 04 | DLPH | $H^0 V V$ couplings |
| $>110.3$ | 95 | [102] ACHARD | 04B | L3 | $H^0 \to$ 2 jets |
| | | [103] ACHARD | 04F | L3 | Anomalous coupling |
| | | [104] ABBIENDI | 03F | OPAL | $e^+ e^- \to H^0 Z$, $H^0 \to$ any |
| | | [105] ABBIENDI | 03G | OPAL | $H_1^0 \to A^0 A^0$ |

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|---|---|---|---|---|---|
| >105.4 | 95 | [106,107] HEISTER | 02L | ALEP | $H_1^0 \to \gamma\gamma$ |
| >109.1 | 95 | [108] HEISTER | 02M | ALEP | $H^0 \to$ 2 jets or $\tau^+\tau^-$ |
| none 12–56 | 95 | [109] ABBIENDI | 01E | OPAL | $A^0$, Type-II model |
| | | [110] ACCIARRI | 00R | L3 | $e^+e^- \to H^0\gamma$ and/or $H^0 \to \gamma\gamma$ |
| | | [111] ACCIARRI | 00R | L3 | $e^+e^- \to e^+e^- H^0$ |
| | | [112] GONZALEZ... | 98B | RVUE | Anomalous coupling |
| | | [113] KRAWCZYK | 97 | RVUE | $(g-2)_\mu$ |
| | | [114] ALEXANDER | 96H | OPAL | $Z \to H^0\gamma$ |

[1] SIRUNYAN 21A search for $H_2^0 \to Z A^0$ with $Z \to \ell^+\ell^-$, $A^0$ decaying invisibly, in 137 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 8 for excluded regions in the mass parameter space of two Higgs doublet plus singlet model with a certain choice of the model parameters.

[2] AAD 20AA search for $H_2^0/A^0 \to \tau^+\tau^-$ produced by gluon fusion or $b$-associated production using 139 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 2(a), 2(b) for limits on the product of cross section and branching ratio for $m_{H_2^0}$, $m_{A^0}$ = 0.2–2.5 TeV.

[3] AAD 20AI search for $Z H^0$ production followed by the decay $H^0 \to A^0 A^0 \to b\overline{b}b\overline{b}$ in 36 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. The search looks for collimated $A^0 \to b\overline{b}$ decays and is complementary to AABOUD 18BX. See their Fig. 10 for limits on the product of production cross section and branching ratios in the range $m_{A^0}$ = 15–30 GeV.

[4] AAD 20AO search for gluon fusion production of $H_2^0$ decaying to $H^0 H^0 \to \tau^+\tau^- b\overline{b}$ (with hadronically decaying $\tau^+\tau^-$) using 139 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. Limit on the product of production cross section times branching ratios in the range 28–817 fb (95% CL) is given for $m_{A^0}$ = 1.0–3.0 TeV, see their Fig. 13.

[5] 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.

[6] AAD 20L search for $b$-associated production of $H_2^0$ decaying to $b\overline{b}$ in 27.8 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 8 for limits on the product of cross section and branching ratio for $m_{H_2^0}$ = 0.45–1.4 TeV.

[7] AAD 20X search for vector-boson-fusion production of $H_2^0$ decaying to $H^0 H^0$ using 126 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 5 for limits on the product of cross section and branching ratio for the assumptions of a narrow- and broad-width resonance.

[8] AAIJ 20AL search for dimuon resonance in the mass range 0.2–60 GeV in 5.1 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV, in inclusive and $b$ quark associated production. Displaced decays are searched for for masses below 3 GeV. See their Figs. 7–9 for cross section limits and Fig. 10 for limits for mixing angle in two Higgs doublet plus singlet model (at 90% CL).

[9] 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.

[10] SIRUNYAN 20AA search for $H_2^0 \to Z A^0$, $A^0 \to b\overline{b}$ or $A^0 \to Z H_2^0$, $H_2^0 \to b\overline{b}$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 7 for limits on the product of cross section and branching ratio for $m_{H_2^0}$ = 0.12–1 TeV and $m_{A^0}$ = 0.03–1 TeV.

[11] SIRUNYAN 20AC search for gluon-fusion production of $A^0$ decaying to $Z H^0$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 5 for limits on the product of cross section and branching ratios for $m_{A^0}$ = 220–400 GeV.

[12] SIRUNYAN 20AD search for lepton-flavor violating decays $H_2^0 \rightarrow \mu\tau$, $e\tau$ of gluon-fusion-produced $H_2^0$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 5 (9) and Table 5 (6) for limits on production cross section times branching ratio for $m_{H_2^0}$ = 0.2–0.9 TeV for the $\mu\tau$ ($e\tau$) final state.

[13] SIRUNYAN 20AF search for $H_2^0/A^0 \rightarrow t\overline{t}$ with one or two charged leptons in the final state using kinematic variables in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Figs. 5 and 6 for limits on top Yukawa coupling of $H_2^0$ and $A^0$ for $m_{H_2^0}$, $m_{A^0}$ = 0.4–0.75 TeV for various width assumptions.

[14] SIRUNYAN 20AP search for the decay $H^0$ or $H_2^0 \rightarrow A^0 A^0 \rightarrow \mu^+\mu^-\tau^+\tau^-$ (for $m_{H_2^0}$ = 300 GeV) with boosted final-state topology in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 7 for limits on the product of production cross section (normalized to the SM) and branching ratios in the range $m_{A^0}$ = 3.6–21 GeV, and Figs. 8 and 9 for its interpretation in terms of models with two Higgs doublets plus a singlet.

[15] SIRUNYAN 20Y search for gluon-fusion and vector-boson-fusion production of $H_2^0$ decaying to $W^+W^-$ in the final states $\ell\nu\ell\nu$ and $\ell\nu qq$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 6 for limits on the product of cross section and branching ratio for $m_{H_2^0}$ = 0.2–3 TeV.

[16] SIRUNYAN 20Z search for $H_{1,2}^0$ or $A^0$ production in association with a $t\overline{t}$ pair, decaying to $e^+e^-$ or $\mu^+\mu^-$, in 137 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 12 for limits on production cross section times branching ratio for $m_{H_{1,2}^0}$, $m_{A^0}$ = 15–75 GeV and 108–340 GeV.

[17] AABOUD 19A search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ 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.

[18] AABOUD 19AG search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \mu^+\mu^- b\overline{b}$ 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.

[19] AABOUD 19O search for a scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}WW^*$ 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.

[20] AABOUD 19T search for a scalar resonance decaying to $H^0 H^0 \rightarrow WW^*WW^*$ 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 $H^0$.

[21] 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.

[22] 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.

[23] 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 $m_{H^0_{1,2}}$ = 100–300 GeV.

[24] SIRUNYAN 19 search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow \gamma\gamma b\overline{b}$ 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 $m_{H^0_2}$ = 260–900 GeV.

[25] 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.

[26] SIRUNYAN 19AN search for production of $A^0_2$ decaying to $H^0 A^0_1$ followed by $H^0 \rightarrow b\overline{b}$, $A^0_1 \rightarrow$ invisible in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV, in the mass range $m_{A^0_2}$ = 0.2–1.6 TeV, $m_{A^0_1}$ = 0.15–0.5 TeV. See their Fig. 6 for limits in terms of two-Higgs-doublet plus singlet pseudoscalar model.

[27] 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 $E_{cm}$ = 13 TeV. See their Fig. 5 for cross section limits for $m_{A^0}$ = 0.22–1.0 TeV.

[28] 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 $E_{cm}$ = 13 TeV. See their Figs. 7 and 8 for limits on cross section times branching ratio for the resonance mass of 50–350 GeV.

[29] SIRUNYAN 19BB search for the decay $H^0_1 \rightarrow \gamma\gamma$ in 19.7 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 8 TeV and 35.9 fb$^{-1}$ at $E_{cm}$ = 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).

[30] 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 $E_{cm}$ = 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.

[31] SIRUNYAN 19BE combine searches for $H^0_2 \rightarrow H^0 H^0$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 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.

[32] 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 $E_{cm}$ = 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.

[33] 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. 6 for limits on cross section times branching ratio.

[34] 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 $E_{cm}$ = 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).

[35] 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 $E_{cm}$ = 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.

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

[37] 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 $p p$ collisions at $E_{cm}$ = 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.

[38] 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 $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 6 for cross section limits for $m_{A^0}$ = 0.2–2 TeV. See also AABOUD 18CC.

[39] AABOUD 18BF search for production of a heavy $H^0_2$ state decaying to $Z Z$ in the final states $\ell^+ \ell^- \ell^+ \ell^-$ and $\ell^+ \ell^- \nu\overline{\nu}$ in 36.1 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 6 for upper limits on cross section times branching ratio for $m_{H^0_2}$ = 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 $m_{H^0_2}$ = 0.4–1.0 TeV assuming ggF, and with several assumptions on its width.

[40] 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 $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 4 for limits on cross section times branching ratios for $m_{H^0_2}$ = 260–500 GeV.

[41] 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 $p p$ collisions at $E_{cm}$ = 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.

[42] 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 $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 2 (above) for limits on cross section times branching ratios for $m_{H^0_2}$ = 260–1000 GeV.

[43] AABOUD 18F search for production of a narrow scalar resonance decaying to $W^+ W^-$ and $Z Z$, followed by hadronic decays of $W$ and $Z$, in 36.7 fb$^{-1}$ of $p p$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 5(c) for limits on cross section times branching ratio for $m_{H^0_2}$ = 1.2–3.0 TeV.

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

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

[46] 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 $p p$ collisions at $E_{cm}$ = 8 TeV and 0.98 fb$^{-1}$ at $E_{cm}$ = 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 $E_{cm}$ = 8 TeV data set).

[47] 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 $p p$ collisions at $E_{cm}$ = 13 TeV, where both $b\overline{b}$ pairs are not resolved. See their Fig. 9 for limits on cross section times branching ratios for $m_{H^0_2}$ = 0.75–3 TeV.

[48] SIRUNYAN 18BA search for production of a heavy $H^0_2$ state decaying to $Z Z$ 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 $p p$ collisions at $E_{cm}$ =

13 TeV. See their Figs. 10 and 11 for upper limits on cross section times branching ratio for $m_{H^0_2}$ = 0.13–3 TeV with several assumptions on its width and on the fraction of Vector-Boson-Fusion of the total production cross section.

[49] 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 $E_{cm}$ = 13 TeV, where both $b\overline{b}$ pairs are resolved. See their Fig. 9 for limits on cross section times branching ratios for $m_{H^0_2}$ = 260–1200 GeV.

[50] 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 $E_{cm}$ = 13 TeV. See their Fig. 7 for limits on cross section times branching ratio for $m_{H^0_2}$ = 0.35–4 TeV for different assumptions on the width of the resonance.

[51] 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 $E_{cm}$ = 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.

[52] 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 $E_{cm}$ = 13 TeV. See their Fig. 3 (right) for limits on cross section times branching ratio for $m_{H^0_2}$ = 0.5–5 TeV for several values of its width-to-mass ratio.

[53] SIRUNYAN 18ED 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 $\nu\overline{\nu}b\overline{b}$ or $\ell^+\ell^- b\overline{b}$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 8 for cross section limits for $m_{A^0}$ = 0.8–2 TeV.

[54] 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 $E_{cm}$ = 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.

[55] SIRUNYAN 18F search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow W W b\overline{b}$ or $Z Z b\overline{b}$ in the final state $\ell\ell\nu\nu b\overline{b}$ in 35.9 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 7 for limits on cross section times branching ratios for $m_{H^0_2}$ = 250–900 GeV.

[56] AABOUD 17 search for production of a scalar resonance decaying to $Z\gamma$ in 3.2 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 4 for the limits on cross section times branching ratio for $m_{H^0_2}$ = 0.25–3.0 TeV.

[57] AABOUD 17AW search for production of a scalar resonance decaying to $Z\gamma$ in 36.1 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 13 TeV. See their Fig. 7 for limits on cross section times branching ratio for $m_{H^0_2}$ = 0.25–2.4 TeV.

[58] 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 $E_{cm}$ = 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.

[59] KHACHATRYAN 17D search for production of a scalar resonance decaying to $Z\gamma$ in 19.7 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 8 TeV and 2.7 fb$^{-1}$ at $E_{cm}$ = 13 TeV. See their Figs. 3 and 4 for the limits on cross section times branching ratio for $m_{H^0_2}$ = 0.2–2.0 TeV.

[60] 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 $E_{cm}$ = 13 TeV. See their Fig. 2 for limits on cross section times branching ratio for $m_{H^0_2}$ = 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.

[61] 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 $E_{cm}$ = 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.

[62] SIRUNYAN 17Y search for production of a scalar resonance decaying to $Z\gamma$ in 19.7 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 8 TeV and 2.7 fb$^{-1}$ at $E_{cm}$ = 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.

[63] AABOUD 16AB search for associated production of $WH^0$ with the decay $H^0 \rightarrow A^0 A^0 \rightarrow b\overline{b}b\overline{b}$ 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.

[64] 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 $m_{H_2^0}$ = 0.5–3 TeV.

[65] 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 $m_{H_2^0}$ = 0.2–2 TeV with different assumptions on the width.

[66] AABOUD 16I search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ 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 $m_{H_2^0}$ = 0.5–3 TeV.

[67] 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($H^0 \rightarrow ZZ$) for $m_{H^0}$ ranging from 140 GeV to 1000 GeV.

[68] 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($H^0 \rightarrow W^+W^-$) for $m_{H^0}$ ranging from 300 GeV to 1000 or 1500 GeV with various assumptions on the total width of $H^0$.

[69] AAD 16L search for the decay $H^0 \rightarrow A^0 A^0 \rightarrow \gamma\gamma\gamma\gamma$ 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.

[70] AAD 16L search for the decay $H_2^0 \rightarrow A^0 A^0 \rightarrow \gamma\gamma\gamma\gamma$ 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 $m_{H_2^0}$ = 600 GeV and $m_{A^0}$ = 10–245 GeV, and Table 5 for limits for $m_{H_2^0}$= 300 and 900 GeV.

[71] AALTONEN 16C search for electroweak associated production of $H_1^0 H^\pm$ followed by the decays $H^\pm \rightarrow H_1^0 W^*$, $H_1^0 \rightarrow \gamma\gamma$ for $m_{H_1^0}$ = 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 $H_1^0$ has no direct decay to fermions.

[72] KHACHATRYAN 16BG search for a narrow scalar resonance decaying to $H^0 H^0 \rightarrow b\overline{b}b\overline{b}$ 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 $m_{H_2^0}$ = 1.15–3 TeV.

[73] KHACHATRYAN 16BQ search for a resonance decaying to $H^0 H^0 \rightarrow \gamma\gamma b\overline{b}$ 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 $m_{H_2^0}$ = 0.26–1.1 TeV.

[74] KHACHATRYAN 16F search for the decay $H^0 \rightarrow H_1^0 H_1^0 \rightarrow \tau^+\tau^-\tau^+\tau^-$ in 19.7 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 8 TeV. See their Fig. 8 for cross section limits for $m_{H_1^0}$ = 4–8 GeV.

[75] 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 $m_{H_2^0}$ = 0.5–4 TeV.

[76] 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 $E_{cm}$ = 8 TeV. See their Fig. 8 (lower right) for cross section limits for $m_{H_2^0}$ = 260–350 GeV.

[77] 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 $E_{cm}$ = 8 TeV. See their Fig. 10 for cross section limits for $m_{H_2^0}$ = 220–350 GeV.

[78] 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 $E_{cm}$ = 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.

[79] 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 $E_{cm}$ = 8 TeV. See their Fig. 6 for limits on cross section times branching ratio for $m_{A^0}$ = 3.7–50 GeV.

[80] 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 $E_{cm}$ = 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.

[81] 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 $E_{cm}$ = 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.

[82] 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 $E_{cm}$ = 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.

[83] 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 $E_{cm}$ = 8 TeV. See their Fig. 3 for cross section limits for $m_{A^0}$ = 200–1000 GeV.

[84] 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 $ZZ$ in up to 5.1 fb$^{-1}$ of $pp$ collisions at $E_{cm}$ = 7 TeV and up to 19.7 fb$^{-1}$ at $E_{cm}$ = 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.

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

[86] 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 $E_{cm}$ = 8 TeV. See their Fig. 3 for limits on cross section times branching ratios for $m_{A^0}$ = 225–600 GeV.

[87] 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 $E_{cm}$ = 8 TeV. See their Fig. 6 for limits on cross section times branching ratios for $m_{A^0}$ = 800–2500 GeV.

[88] 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 $E_{cm}$ = 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.

[89] 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.

[90] 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.

[91] CHATRCHYAN 14G search for a second $H^0$ state decaying to $W W^{(*)}$ 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.

[92] 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.

[93] 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.

[94] 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.

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

[96] ABBIENDI 10 search for $e^+e^- \rightarrow Z H^0$ with the decay chain $H^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$, $\widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0$ + ($\gamma$ 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 $Z H^0$ cross section and B($H^0 \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$) = 1.

[97] 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 $H^0 Z Z$ 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.

[98] 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.

[99] 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 $H_1^0 \rightarrow A^0 A^0$.

[100] 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.

[101] 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.

[102] 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.

[103] 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.

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

[105] 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 region $m_{H_1^0}$ = 45-86 GeV and $m_{A^0}$ = 2-11 GeV. See their Fig. 7 for the limits.

[106] 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 $E_{cm} \leq$ 209 GeV. The limit is for a $H^0$ with SM production cross section and B($H^0 \rightarrow f\overline{f}$)=0 for all fermions $f$.

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

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

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

[110] ACCIARRI 00R search for $e^+e^- \rightarrow H^0\gamma$ with $H^0 \rightarrow b\overline{b}$, $Z\gamma$, 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.

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

[112] 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 $H \rightarrow \gamma\gamma$ decay which is induced by higher-dimensional operators. See their Figs. 1 and 2 for limits on the anomalous couplings.

[113] KRAWCZYK 97 analyse the muon anomalous magnetic moment in a two-doublet Higgs model (with type II Yukawa couplings) assuming no $H_1^0 ZZ$ coupling and obtain $m_{H_1^0} \gtrsim$ 5 GeV or $m_{A^0} \gtrsim$ 5 GeV for $\tan\beta >$ 50. Other Higgs bosons are assumed to be much heavier.

[114] ALEXANDER 96H give B($Z \rightarrow H^0\gamma$)$\times$B($H^0 \rightarrow q\overline{q}$) < 1–4 $\times 10^{-5}$ (95%CL) and B($Z \rightarrow H^0\gamma$)$\times$B($H^0 \rightarrow b\overline{b}$) < 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 $\Gamma_W$ 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 $\Gamma_W$ 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 $\Gamma_W$ 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 $\Gamma_W$ measurements available in 2005 with $\Delta\alpha^{(5)}_{\rm had}(m_Z) = 0.02758 \pm 0.00035$. The 95% CL limit is 285 GeV.

# SEARCHES FOR NEUTRAL HIGGS BOSONS REFERENCES


| | | | | |
|---|---|---|---|---|
| SIRUNYAN | 21A | EPJ C81 13 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| AAD | 20 | PR D101 012002 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20AA | PRL 125 051801 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20AE | PRL 125 221802 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20AI | PR D102 112006 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20AO | JHEP 2011 163 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20C | PL B800 135103 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20L | PR D102 032004 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 20X | JHEP 2007 108 | G. Aad *et al.* | (ATLAS Collab.) |
| AAIJ | 20AL | JHEP 2010 156 | R. Aaij *et al.* | (LHCb Collab.) |
| SIRUNYAN | 20 | PL B800 135087 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20AA | JHEP 2003 055 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20AC | JHEP 2003 065 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20AD | JHEP 2003 103 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20AF | JHEP 2004 171 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20AP | JHEP 2008 139 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20Y | JHEP 2003 034 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| SIRUNYAN | 20Z | JHEP 2003 051 | 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.) |
| SIRUNYAN | 18F | JHEP 1801 054 | A.M. Sirunyan *et al.* | (CMS Collab.) |
| 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.) |
| KHACHATRY... | 16A | PL B752 221 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 16BG | EPJ C76 371 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 16BQ | PR D94 052012 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 16F | JHEP 1601 079 | V. Khachatryan *et al.* | (CMS Collab.) |
| 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.) |
| KHACHATRY... | 16Z | PL B759 369 | V. Khachatryan *et al.* | (CMS Collab.) |
| 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.) |
| AAD | 15CE | PR D92 092004 | G. Aad *et al.* | (ATLAS Collab.) |
| 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.) |
| KHACHATRY... | 15AY | JHEP 1511 071 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 15BB | PL B750 494 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 15N | PL B748 221 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 15O | PL B748 255 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 15R | PL B749 560 | V. Khachatryan *et al.* | (CMS Collab.) |
| LEES | 15H | PR D91 071102 | J.P. Lees *et al.* | (BABAR Collab.) |
| AAD | 14AP | PRL 113 171801 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 14AW | JHEP 1411 056 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 14BA | JHEP 1411 088 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 14M | PR D89 032002 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 14O | PRL 112 201802 | G. Aad *et al.* | (ATLAS Collab.) |
| CHATRCHYAN | 14B | EPJ C74 2980 | S. Chatrchyan *et al.* | (CMS Collab.) |
| CHATRCHYAN | 14G | JHEP 1401 096 | S. Chatrchyan *et al.* | (CMS Collab.) |
| KHACHATRY... | 14M | JHEP 1410 160 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 14P | EPJ C74 3076 | V. Khachatryan *et al.* | (CMS Collab.) |
| KHACHATRY... | 14Q | PR D90 112013 | V. Khachatryan *et al.* | (CMS Collab.) |
| AAD | 13AG | PL B721 32 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 13AT | NJP 15 043009 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 13O | JHEP 1302 095 | G. Aad *et al.* | (ATLAS Collab.) |
| AAIJ | 13T | JHEP 1305 132 | R. Aaij *et al.* | (LHCb Collab.) |
| AALTONEN | 13K | PR D88 052012 | T. Aaltonen *et al.* | (CDF Collab.) |
| AALTONEN | 13L | PR D88 052013 | T. Aaltonen *et al.* | (CDF Collab.) |
| AALTONEN | 13M | PR D88 052014 | T. Aaltonen *et al.* | (CDF and D0 Collabs.) |
| AALTONEN | 13P | PRL 110 121801 | T. Aaltonen *et al.* | (CDF Collab.) |
| ABAZOV | 13G | PR D88 052006 | V.M. Abazov *et al.* | (D0 Collab.) |
| ABAZOV | 13H | PR D88 052007 | V.M. Abazov *et al.* | (D0 Collab.) |
| ABAZOV | 13I | PR D88 052008 | V.M. Abazov *et al.* | (D0 Collab.) |
| ABAZOV | 13J | PR D88 052009 | V.M. Abazov *et al.* | (D0 Collab.) |
| ABAZOV | 13L | PR D88 052011 | V.M. Abazov *et al.* | (D0 Collab.) |
| CARENA | 13 | EPJ C73 2552 | M. Carena *et al.* | |
| CHATRCHYAN | 13AG | PL B722 207 | S. Chatrchyan *et al.* | (CMS Collab.) |
| CHATRCHYAN | 13AL | PL B725 36 | S. Chatrchyan *et al.* | (CMS Collab.) |
| CHATRCHYAN | 13BJ | PL B726 564 | S. Chatrchyan *et al.* | (CMS Collab.) |
| LEES | 13C | PR D87 031102 | J.P. Lees *et al.* | (BABAR Collab.) |
| LEES | 13L | PR D88 031701 | J.P. Lees *et al.* | (BABAR Collab.) |
| LEES | 13R | PR D88 071102 | J.P. Lees *et al.* | (BABAR Collab.) |

| | | | | |
|---|---|---|---|---|
| AAD | 12AI | PL B716 1 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 12AQ | PRL 108 251801 | G. Aad *et al.* | (ATLAS Collab.) |
| AAD | 12N | EPJ C72 2157 | G. Aad *et al.* | (ATLAS Collab.) |
| 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.) |
| AALTONEN | 12X | PR D85 032005 | T. Aaltonen *et al.* | (CDF Collab.) |
| ABAZOV | 12G | PL B710 569 | V.M. Abazov *et al.* | (D0 Collab.) |
| ABLIKIM | 12 | PR D85 092012 | M. Ablikim *et al.* | (BESIII Collab.) |
| BAAK | 12 | EPJ C72 2003 | M. Baak *et al.* | (Gfitter Group) |
| BAAK | 12A | EPJ C72 2205 | M. Baak *et al.* | (Gfitter Group) |
| 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.) |