Higgs Bosons — H^0 and $H^\pm$

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H^0 (Higgs Boson)

The observed signal is called a Higgs Boson in the following, although its detailed properties and in particular the role that the new particle plays in the context of electroweak symmetry breaking need to be further clarified. The signal was discovered in searches for a Standard Model (SM)-like Higgs. See the following section for mass limits obtained from those searches.

H^0 MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
125.9±0.4 OUR AVERAGE				
125.8±0.4±0.4	[1] CHATRCHYAN	13J	CMS	pp, 7 and 8 TeV
126.0±0.4±0.4	[2] AAD	12AI	ATLS	pp, 7 and 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
126.2±0.6±0.2	[3] CHATRCHYAN	13J	CMS	pp, 7 and 8 TeV
125.3±0.4±0.5	[4] CHATRCHYAN	12N	CMS	pp, 7 and 8 TeV

[1] Combined value from ZZ and $\gamma\gamma$ final states.
[2] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV and 5.8–5.9 fb^{-1} at $E_{\rm cm}$ = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. See also AAD 12DA.
[3] Result based on $ZZ \rightarrow 4\ell$ final states in 5.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV and 12.2 fb^{-1} at $E_{\rm cm}$ = 8 TeV.
[4] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at $E_{\rm cm}$ = 7 TeV and 5.1–5.3 fb^{-1} at $E_{\rm cm}$ = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. See also CHATRCHYAN 12BY.

H^0 SPIN AND *CP* PROPERTIES

The observation of the signal in the $\gamma\gamma$ final state rules out the possibility that the discovered particle has spin 1, as a consequence of the Landau-Yang theorem. This argument relies on the assumptions that the decaying particle is an on-shell resonance and that the decay products are indeed two photons rather than two pairs of boosted photons, which each could in principle be misidentified as a single photon.

Concerning distinguishing the spin 0 hypothesis from a spin 2 hypothesis, some care has to be taken in modelling the latter in order to ensure that the discriminating power is actually based on the spin properties rather than on unphysical behavior that may affect the model of the spin 2 state.

While for spin analyses it is sufficient to discriminate between distinct hypotheses, the determination of the *CP* properties is in general experimentally much more difficult since in principle the observed state could consist of any admixture of *CP*-even and *CP*-odd components. As a first step, the compatibility of the data with the distinct hypotheses of a pure *CP*-even and a pure *CP*-odd state has been investigated. In CHATRCHYAN 13J angular distributions of the lepton pairs have been studied in the ZZ^* channel where both Z bosons decay to e or μ pairs. Under the assumption that the observed particle has spin 0 the data are found to be consistent with the pure *CP*-even hypothesis, while the pure *CP*-odd hypothesis is disfavored.

H^0 DECAY WIDTH

The total decay width for a light Higgs boson with a mass in the observed range is not expected to be directly observable at the LHC. For the case of the Standard Model the prediction for the total width is about 4 MeV, which is several orders of magnitude smaller than the experimental mass resolution. There is no indication from the results observed so far that the natural width is broadened by new physics effects to such an extent that it could be directly observable. Furthermore, as all LHC Higgs channels rely on the identification of Higgs decay products, the total Higgs width cannot be measured indirectly without additional assumptions. This implies that without further assumptions only ratios of couplings can be determined at the LHC rather than absolute values of couplings.

H^0 DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$W W^*$	seen
Γ_2	$Z Z^*$	seen
Γ_3	$\gamma\gamma$	seen
Γ_4	$b \overline{b}$	possibly seen
Γ_5	$\tau^+ \tau^-$	possibly seen

H^0 SIGNAL STRENGTHS IN DIFFERENT CHANNELS

The H^0 signal strength in a particular final state xx is given by the cross section times branching ratio in this channel normalised to the Standard Model value, $\sigma \cdot \text{B}(H^0 \to xx) / (\sigma \cdot \text{B}(H^0 \to xx))_{\text{SM}}$, for the specified mass value of H^0.

Combined Final States

More precise but preliminary measurements by ATLAS and CMS of the signal strengths in different channels were reported at the EPS HEP 2013 conference just as we were going to press, see: http://eps-hep2013.eu/program.html. These results are not included in the PDG averages shown below. The averages of results from the EPS HEP meeting are consistent within one sigma with the predictions of the SM Higgs boson signal strengths in each channel.

VALUE	DOCUMENT ID		TECN	COMMENT
1.07±0.26 OUR AVERAGE	Error includes scale factor of 1.4.			
1.4 ±0.3	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 7, 8 TeV
0.87±0.23	[2] CHATRCHYAN	12N	CMS	$pp \to H^0 X$, 7, 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.2 ±0.4	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 7 TeV
1.5 ±0.4	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 8 TeV

[1] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at $E_{\text{cm}} = 7$ TeV and 5.8–5.9 fb^{-1} at $E_{\text{cm}} = 8$ TeV. An excess of events over background with a local significance of 5.9 σ is observed at $m_{H^0} = 126$ GeV. The quoted signal strengths are given for $m_{H^0} = 126.0$ GeV. See also AAD 12DA.

[2] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at $E_{\text{cm}} =$ 7 TeV and 5.1–5.3 fb^{-1} at $E_{\text{cm}} = 8$ TeV. An excess of events over background with a local significance of 5.0 σ is observed at about $m_{H^0} = 125$ GeV. The quoted signal strengths are given for $m_{H^0} = 125.5$ GeV. See also CHATRCHYAN 12BY.

$W W^*$ Final State

More precise but preliminary measurements by ATLAS and CMS of the signal strengths in different channels were reported at the EPS HEP 2013 conference just as we were going to press, see: http://eps-hep2013.eu/program.html. These results are not included in the PDG averages shown below. The averages of results from the EPS HEP meeting are consistent within one sigma with the predictions of the SM Higgs boson signal strengths in each channel.

VALUE	DOCUMENT ID		TECN	COMMENT
0.88±0.33 OUR AVERAGE	Error includes scale factor of 1.1.			
1.3 ±0.5	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 7, 8 TeV
$0.60^{+0.42}_{-0.37}$	[2] CHATRCHYAN	12N	CMS	$pp \to H^0 X$, 7, 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.5 ±0.6	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 7 TeV
1.9 ±0.7	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 8 TeV

[1] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. The quoted signal strengths are given for m_{H^0} = 126.0 GeV. See also AAD 12DA.

[2] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. The quoted signal strengths are given for m_{H^0} = 125.5 GeV. See also CHATRCHYAN 12BY.

ZZ^* Final State

More precise but preliminary measurements by ATLAS and CMS of the signal strengths in different channels were reported at the EPS HEP 2013 conference just as we were going to press, see: http://eps-hep2013.eu/program.html. These results are not included in the PDG averages shown below. The averages of results from the EPS HEP meeting are consistent within one sigma with the predictions of the SM Higgs boson signal strengths in each channel.

VALUE	DOCUMENT ID		TECN	COMMENT
$0.89^{+0.30}_{-0.25}$ OUR AVERAGE				
$0.80^{+0.35}_{-0.28}$	[1] CHATRCHYAN	13J	CMS	$pp \to H^0 X$, 7, 8 TeV
1.2 ±0.6	[2] AAD	12AI	ATLS	$pp \to H^0 X$, 7, 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.4 ±1.1	[2] AAD	12AI	ATLS	$pp \to H^0 X$, 7 TeV
1.1 ±0.8	[2] AAD	12AI	ATLS	$pp \to H^0 X$, 8 TeV
$0.73^{+0.45}_{-0.33}$	[3] CHATRCHYAN	12N	CMS	$pp \to H^0 X$, 7, 8 TeV

[1] Result based on $ZZ \to 4\ell$ final states in 5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 12.2 fb^{-1} at E_{cm} = 8 TeV. The quoted signal strength is given for m_{H^0} = 125.8 GeV.

[2] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. The quoted signal strengths are given for m_{H^0} = 126.0 GeV. See also AAD 12DA.

[3] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. The quoted signal strengths are given for m_{H^0} = 125.5 GeV. See also CHATRCHYAN 12BY.

$\gamma\gamma$ Final State

More precise but preliminary measurements by ATLAS and CMS of the signal strengths in different channels were reported at the EPS HEP 2013 conference just as we were going to press, see: http://eps-hep2013.eu/program.html. These results are not included in the PDG averages shown below. The averages of results from the EPS HEP meeting are consistent within one sigma with the predictions of the SM Higgs boson signal strengths in each channel.

VALUE	DOCUMENT ID		TECN	COMMENT
1.65±0.33 OUR AVERAGE				
1.8 ±0.5	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 7, 8 TeV
$1.54^{+0.46}_{-0.42}$	[2] CHATRCHYAN	12N	CMS	$pp \to H^0 X$, 7, 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.2 ±0.7	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 7 TeV
1.5 ±0.6	[1] AAD	12AI	ATLS	$pp \to H^0 X$, 8 TeV

[1] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. The quoted signal strengths are given for m_{H^0} = 126.0 GeV. See also AAD 12DA.

[2] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. The quoted signal strengths are given for m_{H^0} = 125.5 GeV. See also CHATRCHYAN 12BY.

$b\overline{b}$ Final State

More precise but preliminary measurements by ATLAS and CMS of the signal strengths in different channels were reported at the EPS HEP 2013 conference just as we were going to press, see: http://eps-hep2013.eu/program.html. These results are not included in the PDG averages shown below. The averages of results from the EPS HEP meeting are consistent within one sigma with the predictions of the SM Higgs boson signal strengths in each channel.

VALUE	DOCUMENT ID		TECN	COMMENT
$0.5^{+0.8}_{-0.7}$ OUR AVERAGE				
0.5 ±2.2	[1] AAD	12AI	ATLS	$pp \to H^0 W X$, $H^0 Z X$, 7 TeV
	[2] AALTONEN	12T	TEVA	$p\overline{p} \to H^0 W X$, $H^0 Z X$, 1.96 TeV
$0.48^{+0.81}_{-0.70}$	[3] CHATRCHYAN	12N	CMS	$pp \to H^0 W X$, $H^0 Z X$, 7, 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[4] AALTONEN	12P	CDF	$p\overline{p} \to H^0 W X$, $H^0 Z X$, 1.96 TeV
$1.2^{+1.2}_{-1.1}$	[5] ABAZOV	12N	D0	$p\overline{p} \to H^0 W X$, $H^0 Z X$, 1.96 TeV

[1] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. The quoted signal strengths are given for m_{H^0} = 126.0 GeV. See also AAD 12DA.

[2] AALTONEN 12T combine AALTONEN 12Q, AALTONEN 12R, AALTONEN 12S, ABAZOV 12O, ABAZOV 12P, and ABAZOV 12K. An excess of events over background is observed which is most significant in the region m_{H^0} = 120–135 GeV, with a local significance of up to 3.3 σ. The local significance at m_{H^0} = 125 GeV is 2.8 σ, which corresponds to $(\sigma(H^0 W) + \sigma(H^0 Z)) \cdot B(H^0 \rightarrow b\overline{b}) = (0.23^{+0.09}_{-0.08})$ pb, compared to the Standard Model expectation at m_{H^0} = 125 GeV of 0.12 ± 0.01 pb.

[3] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. The quoted signal strengths are given for m_{H^0} = 125.5 GeV. See also CHATRCHYAN 12BY.

[4] AALTONEN 12P combine AALTONEN 12Q, AALTONEN 12R, and AALTONEN 12S. An excess of events over background is observed in the region m_{H^0} = 100–150 GeV, with a local significance of 2.7 σ for m_{H^0} = 125 GeV. This corresponds to $(\sigma(H^0 W) + \sigma(H^0 Z)) \cdot B(H^0 \rightarrow b\overline{b}) = (291^{+118}_{-113})$ fb.

[5] ABAZOV 12N combine ABAZOV 12O, ABAZOV 12P, and ABAZOV 12K. An excess of events over background is observed in the region m_{H^0} = 120–145 GeV with a local significance of 1.0–1.7 σ. The quoted signal strength is given for m_{H^0} = 125 GeV.

$\tau^+\tau^-$ Final State

More precise but preliminary measurements by ATLAS and CMS of the signal strengths in different channels were reported at the EPS HEP 2013 conference just as we were going to press, see: http://eps-hep2013.eu/program.html. These results are not included in the PDG averages shown below. The averages of results from the EPS HEP meeting are consistent within one sigma with the predictions of the SM Higgs boson signal strengths in each channel.

VALUE	DOCUMENT ID		TECN	COMMENT
0.1 ±0.7 OUR AVERAGE				
0.4 $^{+1.6}_{-2.0}$	[1] AAD	12AI	ATLS	$pp \rightarrow H^0 X$, 7 TeV
0.09 $^{+0.76}_{-0.74}$	[2] CHATRCHYAN	12N	CMS	$pp \rightarrow H^0 X$, 7, 8 TeV

[1] AAD 12AI obtain results based on 4.6–4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV. The quoted signal strengths are given for m_{H^0} = 126.0 GeV. See also AAD 12DA.

[2] CHATRCHYAN 12N obtain results based on 4.9–5.1 fb^{-1} of pp collisions at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV. The quoted signal strengths are given for m_{H^0} = 125.5 GeV. See also CHATRCHYAN 12BY.

STANDARD MODEL H^0 (Higgs Boson) MASS LIMITS

These limits apply to the Higgs boson of the three-generation Standard Model with the minimal Higgs sector. For a review and a bibliography, see the above review on "Higgs Bosons: Theory and Searches."

The limits quoted below are compatible with the observed signal described in the section "H^0 (Higgs Boson)."

H^0 Direct Search Limits

All data that have been superseded by newer results are marked as "not used" or have been removed from this compilation, and are documented in previous editions of this *Review* of Particle Physics.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
> 122 and none 127–600 (CL = 95%) OUR EVALUATION					
none 111–122, 131–559	95	[1] AAD	12AI	ATLS	$pp \to H^0 X$ combined
none 127–600	95	[2] CHATRCHYAN	12B	CMS	$pp \to H^0 X$
none 110–121.5, 128–145	95	[3] CHATRCHYAN	12N	CMS	$pp \to H^0 X$ combined
>114.1	95	[4] ABDALLAH	04	DLPH	$e^+ e^- \to H^0 Z$
>112.7	95	[4] ABBIENDI	03B	OPAL	$e^+ e^- \to H^0 Z$
>114.4	95	[4,5] HEISTER	03D	LEP	$e^+ e^- \to H^0 Z$
>111.5	95	[4,6] HEISTER	02	ALEP	$e^+ e^- \to H^0 Z$
>112.0	95	[4] ACHARD	01C	L3	$e^+ e^- \to H^0 Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[7] AALTONEN	13B	CDF	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[8] AALTONEN	13C	CDF	$p\overline{p} \to H^0 W X$, $H^0 Z X$, $H^0 q\overline{q}'$, $H^0 \to b\overline{b}$
		[9] AAD	12	ATLS	$pp \to H^0 X$, $H^0 \to ZZ$
none 133–261	95	[10] AAD	12AJ	ATLS	$pp \to H^0 X$, $H^0 \to W W^{(*)}$
none 111.4–116.6, 119.4–122.1, 129.2–541	95	[11] AAD	12BD	ATLS	$pp \to H^0 X$
		[12] AAD	12BU	ATLS	$pp \to H^0 X$, $H^0 \to \tau^+ \tau^-$
none 319–558	95	[13] AAD	12BZ	ATLS	$pp \to H^0 X$, $H^0 \to ZZ$
none 300–322, 353–410	95	[14] AAD	12CA	ATLS	$pp \to H^0 X$, $H^0 \to ZZ$
		[15] AAD	12CN	ATLS	$pp \to H^0 W X$, $H^0 Z X$, $H^0 \to b\overline{b}$
		[16] AAD	12CO	ATLS	$pp \to H^0 X$, $H^0 \to W W$
none 134–156, 182–233, 256–265, 268–415	95	[17] AAD	12D	ATLS	$pp \to H^0 X$, $H^0 \to Z Z^{(*)}$
none 112.9–115.5, 131–238, 251–466	95	[18] AAD	12E	ATLS	$pp \to H^0 X$
none 145–206	95	[19] AAD	12F	ATLS	$pp \to H^0 X$, $H^0 \to W W^{(*)}$
none 113–115, 134.5–136	95	[20] AAD	12G	ATLS	$pp \to H^0 X$, $H^0 \to \gamma\gamma$
		[21] AALTONEN	12	CDF	$H^0 \to \gamma\gamma$

		[22] AALTONEN	12AA CDF	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[23] AALTONEN	12AE CDF	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[24] AALTONEN	12AK CDF	$p\overline{p} \to H^0 t\overline{t} X$
		[25] AALTONEN	12AM CDF	$p\overline{p} \to H^0 X$, inclusive 4ℓ
		[26] AALTONEN	12AN CDF	$p\overline{p} \to H^0 X$, $H^0 \to \gamma\gamma$
		[27] AALTONEN	12H CDF	$p\overline{p} \to H^0 Z X$, $H^0 \to b\overline{b}$
		[28] AALTONEN	12J CDF	$p\overline{p} \to H^0 X$, $H^0 \to \tau\tau$
none 90–96	95	[29] AALTONEN	12P CDF	$p\overline{p} \to H^0 W X$, $H^0 Z X$, $H^0 \to b\overline{b}$
		[30] AALTONEN	12Q CDF	$p\overline{p} \to H^0 Z X$, $H^0 \to b\overline{b}$
		[31] AALTONEN	12R CDF	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[32] AALTONEN	12S CDF	$p\overline{p} \to H^0 Z X$, $H^0 W X$, $H^0 \to b\overline{b}$
none 100–106	95	[33] AALTONEN	12T TEVA	$p\overline{p} \to H^0 W X$, $H^0 Z X$, $H^0 \to b\overline{b}$
		[34] AALTONEN	12Y CDF	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[35] ABAZOV	12J D0	$p\overline{p} \to H^0 X$, τ
		[36] ABAZOV	12K D0	$p\overline{p} \to H^0 Z X$, $H^0 W X$, $H^0 \to b\overline{b}$
none 100–102	95	[37] ABAZOV	12N D0	$p\overline{p} \to H^0 W X, H^0 Z X, H^0 \to b\overline{b}$
		[38] ABAZOV	12O D0	$p\overline{p} \to H^0 Z X$, $H^0 \to b\overline{b}$
		[39] ABAZOV	12P D0	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[40] ABAZOV	12V D0	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[41] ABAZOV	12W D0	$p\overline{p} \to H^0 X$, $H^0 \to W W^{(*)}$
		[42,43] CHATRCHYAN	12AY CMS	$p p \to H^0 W X$, $H^0 Z X$
		[44] CHATRCHYAN	12C CMS	$p p \to H^0 X$, $H^0 \to Z Z$
		[45] CHATRCHYAN	12D CMS	$p p \to H^0 X$, $H^0 \to Z Z^{(*)}$
none 129–270	95	[46] CHATRCHYAN	12E CMS	$p p \to H^0 X$, $H^0 \to W W^{(*)}$
		[47] CHATRCHYAN	12F CMS	$p p \to H^0 W X$, $H^0 Z X$
none 128–132	95	[48] CHATRCHYAN	12G CMS	$p p \to H^0 X$, $H^0 \to \gamma\gamma$
none 134–158, 180–305, 340–465	95	[49] CHATRCHYAN	12H CMS	$p p \to H^0 X$, $H^0 \to Z Z^{(*)}$
none 270–440	95	[50] CHATRCHYAN	12I CMS	$p p \to H^0 X$, $H^0 \to Z Z$
		[51] CHATRCHYAN	12K CMS	$p p \to H^0 X$, $H^0 \to \tau^+\tau^-$
		[52] AAD	11AB ATLS	$p p \to H^0 X$, $H^0 \to W W$
none 340–450	95	[53] AAD	11V ATLS	$p p \to H^0 X$, $H^0 \to Z Z$
		[54] AAD	11W ATLS	$p p \to H^0 X$
		[55] AALTONEN	11AA CDF	$p\overline{p} \to H^0 W X$, $H^0 Z X$, $H^0 q\overline{q} X$
		[56] ABAZOV	11AB D0	$p\overline{p} \to H^0 W X$, $H^0 Z X$
		[57] ABAZOV	11G D0	$p\overline{p} \to H^0 X$, $H^0 \to W W^{(*)}$
		[58] ABAZOV	11J D0	$p\overline{p} \to H^0 W X$, $H^0 \to b\overline{b}$
		[59] ABAZOV	11Y D0	$H^0 \to \gamma\gamma$
		[60] CHATRCHYAN	11J CMS	$p p \to H^0 X$, $H^0 \to W W$
		[61] AALTONEN	10AD CDF	$p\overline{p} \to H^0 Z X$
none 162–166	95	[62] AALTONEN	10F TEVA	$p\overline{p} \to H^0 X$, $H^0 \to W W^{(*)}$
		[63] AALTONEN	10G CDF	$p\overline{p} \to H^0 X$, $H^0 \to W W^{(*)}$
		[64] AALTONEN	10J CDF	$p\overline{p} \to H^0 Z X$, $H^0 W X$

65 AALTONEN	10M	TEVA	$p\overline{p} \rightarrow g g X \rightarrow H^0 X$, $H^0 \rightarrow W W^{(*)}$
66 ABAZOV	10B	D0	$p\overline{p} \rightarrow H^0 X$, $H^0 \rightarrow W W^{(*)}$
67 ABAZOV	10C	D0	$p\overline{p} \rightarrow H^0 Z X$, $H^0 W X$
68 ABAZOV	10T	D0	$p\overline{p} \rightarrow H^0 Z X$
69 AALTONEN	09A	CDF	$p\overline{p} \rightarrow H^0 X$, $H^0 \rightarrow W W^{(*)}$
70 AALTONEN	09AI	CDF	$p\overline{p} \rightarrow H^0 W X$
71 ABAZOV	09U	D0	$H^0 \rightarrow \tau^+\tau^-$
72 ABAZOV	08Y	D0	$p\overline{p} \rightarrow H^0 W X$
73 ABAZOV	06	D0	$p\overline{p} \rightarrow H^0 X$, $H^0 \rightarrow W W^*$
74 ABAZOV	06O	D0	$p\overline{p} \rightarrow H^0 W X$, $H^0 \rightarrow W W^*$

1 AAD 12AI search for H^0 production in pp collisions for the final states $H^0 \rightarrow Z Z^{(*)}$, $\gamma\gamma$, $W W^{(*)}$, $b\overline{b}$, $\tau\tau$ with 4.6–4.8 fb^{-1} at E_{cm} = 7 TeV, and $H^0 \rightarrow Z Z^{(*)} \rightarrow 4\ell$, $\gamma\gamma$, $W W^{(*)} \rightarrow e\nu\mu\nu$ with 5.8–5.9 fb^{-1} at E_{cm} = 8 TeV. The 99% CL excluded range is 113–114, 117–121, and 132–527 GeV. An excess of events over background with a local significance of 5.9 σ is observed at m_{H^0} = 126 GeV.

2 CHATRCHYAN 12B combine CHATRCHYAN 12E, CHATRCHYAN 12F, CHATRCHYAN 12G, CHATRCHYAN 12H, CHATRCHYAN 12I, CHATRCHYAN 12C, CHATRCHYAN 12D, as well as a search in the decay mode $H^0 \rightarrow \tau\tau$. The 99% CL exclusion range is 129–525 GeV. An excess of events over background with a local significance of 3.1 σ is observed at about m_{H^0} = 124 GeV.

3 CHATRCHYAN 12N search for H^0 production in pp collisions for the final states $H^0 \rightarrow Z Z^{(*)}$, $\gamma\gamma$, $W W^{(*)}$, $b\overline{b}$, $\tau\tau$ with 4.9–5.1 fb^{-1} at E_{cm} = 7 TeV and 5.1–5.3 fb^{-1} at E_{cm} = 8 TeV. An excess of events over background with a local significance of 5.0 σ is observed at about m_{H^0} = 125 GeV.

4 Search for $e^+e^- \rightarrow H^0 Z$ at $E_{cm} \leq$ 209 GeV in the final states $H^0 \rightarrow b\overline{b}$ with $Z \rightarrow \ell\overline{\ell}$, $\nu\overline{\nu}$, $q\overline{q}$, $\tau^+\tau^-$ and $H^0 \rightarrow \tau^+\tau^-$ with $Z \rightarrow q\overline{q}$.

5 Combination of the results of all LEP experiments.

6 A 3σ excess of candidate events compatible with m_{H^0} near 114 GeV is observed in the combined channels $q\overline{q}q\overline{q}$, $q\overline{q}\ell\overline{\ell}$, $q\overline{q}\tau^+\tau^-$.

7 AALTONEN 13B search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 9.45 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which corresponds to (0.7–11.8) times the expected Standard Model cross section is given for m_{H^0} = 90–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 3.1, where 3.3 is expected.

8 AALTONEN 13C search for associated $H^0 W$ and $H^0 Z$ as well as vector-boson fusion $H^0 q\overline{q}'$ production in the final state $H^0 \rightarrow b\overline{b}$, $W/Z \rightarrow q\overline{q}$ with 9.45 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (7.0–64.6) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 9.0, where 11.0 is expected.

9 AAD 12 search for H^0 production with $H \rightarrow Z Z \rightarrow \ell^+\ell^- q\overline{q}$ in 1.04 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (1.7–13) times larger than the expected Standard Model cross section is given for m_{H^0} = 200–600 GeV at 95% CL. The best limit is at m_{H^0} = 360 GeV. Superseded by AAD 12CA.

10 AAD 12AJ search for H^0 production in the decay $H^0 \rightarrow W W^{(*)} \rightarrow \ell\nu\ell\nu$ with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which corresponds to (0.2–10) times the expected Standard Model cross section is given for m_{H^0} = 110–600 GeV at 95% CL.

[11] AAD 12BD search for H^0 production in the decay modes $H^0 \rightarrow \gamma\gamma$, $W W^{(*)}$, $Z Z^{(*)}$, $\tau^+\tau^-$, and $b\overline{b}$ with 4.6 to 4.9fb^{-1} of pp collisions at E_{cm} = 7 TeV. The 99% CL excluded range is 130.7–506 GeV. A limit on cross section times branching ratio which corresponds to (0.2–2) times the expected Standard Model cross section is given for m_{H^0} = 110–600 GeV at 95% CL. An excess of events over background with a local significance of 2.9 σ is observed at about m_{H^0} = 126 GeV. Superseded by AAD 12AI.

[12] AAD 12BU search for H^0 production in the decay $H \rightarrow \tau^+\tau^-$ with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (2.9–11.7) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL.

[13] AAD 12BZ search for H^0 production in the decay $H \rightarrow Z Z \rightarrow \ell^+\ell^-\nu\overline{\nu}$ with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which corresponds to (0.2–4) times the expected Standard Model cross section is given for m_{H^0} = 200–600 GeV at 95% CL.

[14] AAD 12CA search for H^0 production in the decay $H \rightarrow Z Z \rightarrow \ell^+\ell^- q\overline{q}$ with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which corresponds to (0.7–9) times the expected Standard Model cross section is given for m_{H^0} = 200–600 GeV at 95% CL.

[15] AAD 12CN search for associated $H^0 W$ and $H^0 Z$ production in the channels $W \rightarrow \ell\nu$, $Z \rightarrow \ell^+\ell^-$, $\nu\overline{\nu}$, and $H^0 \rightarrow b\overline{b}$, with 4.7fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (2.5–5.5) times larger than the expected Standard Model cross section is given for m_{H^0} = 110–130 GeV at 95% CL.

[16] AAD 12CO search for H^0 production in the decay $H \rightarrow W W \rightarrow \ell\nu q\overline{q}$ with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (1.9–10) times larger than the expected Standard Model cross section is given for m_{H^0} = 300–600 GeV at 95% CL.

[17] AAD 12D search for H^0 production with $H \rightarrow Z Z^{(*)} \rightarrow 4\ell$ in 4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 110–600 GeV. An excess of events over background with a local significance of 2.1 σ is observed at 125 GeV.

[18] AAD 12E combine data from AAD 11V, AAD 11AB, AAD 12, AAD 12D, AAD 12F, AAD 12G. The 99% CL exclusion range is 133–230 and 260–437 GeV. An excess of events over background with a local significance of 3.5 σ is observed at about m_{H^0} = 126 GeV. Superseded by AAD 12AI.

[19] AAD 12F search for H^0 production with $H \rightarrow W W^{(*)} \rightarrow \ell^+\nu\ell^-\overline{\nu}$ in 2.05 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 110–300 GeV. Superseded by AAD 12AJ.

[20] AAD 12G search for H^0 production with $H \rightarrow \gamma\gamma$ in 4.9 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 110–150 GeV. An excess of events over background with a local significance of 2.8 σ is observed at 126.5 GeV.

[21] AALTONEN 12 search for $H^0 \rightarrow \gamma\gamma$ in 7.0 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (8.5–29) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. Superseded by AALTONEN 12AN.

[22] AALTONEN 12AA search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 5.6fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (2.1–35.3) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. Superseded by AALTONEN 12AE.

[23] AALTONEN 12AE search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 7.5fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (1.1–34.4) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 4.4, where 3.7 is expected. Superseded by AALTONEN 12R.

[24] AALTONEN 12AK search for associated $H^0 t\overline{t}$ production in the decay chain $t\overline{t} \rightarrow WWbb \rightarrow \ell\nu qqbb$ with 9.45 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (10–40) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 20.5, where 12.6 is expected.

[25] AALTONEN 12AM search for H^0 production in inclusive four-lepton final states coming from $H^0 \rightarrow ZZ$, $H^0 Z \rightarrow WW^{(*)}\ell\ell$, or $H^0 Z \rightarrow \tau\tau\ell\ell$, with 9.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (7.2–42.4) times larger than the expected Standard Model cross section is given for m_{H^0} = 120–300 GeV at 95% CL. The best limit is for m_{H^0} = 200 GeV.

[26] AALTONEN 12AN search for H^0 production in the decay $H^0 \rightarrow \gamma\gamma$ with 10 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (7.7–21.3) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 17.0, where 9.9 is expected.

[27] AALTONEN 12H search for associated $H^0 Z$ production in the final state $Z \rightarrow \ell^+\ell^-$, $H^0 \rightarrow b\overline{b}$ with 7.9fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (2.8–22) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The best limit is for m_{H^0} = 100 GeV. Superseded by AALTONEN 12Q.

[28] AALTONEN 12J search for H^0 production in the decay $H^0 \rightarrow \tau^+\tau^-$ (one leptonic, the other hadronic) with 6.0 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (14.6–70.2) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The best limit is for m_{H^0} = 120 GeV.

[29] AALTONEN 12P combine AALTONEN 12Q, AALTONEN 12R, and AALTONEN 12S. An excess of events over background is observed in the region m_{H^0} = 100–150 GeV, with a local significance of 2.7 σ for m_{H^0} = 125 GeV. This corresponds to ($\sigma(H^0 W)$ + $\sigma(H^0 Z)$)·B($H^0 \rightarrow b\overline{b}$) = (291^{+118}_{-113}) fb.

[30] AALTONEN 12Q search for associated $H^0 Z$ production in the final state $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \ell^+\ell^-$ with 9.45 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which corresponds to (1.0–37.5) times the expected Standard Model cross section is given for m_{H^0} = 90–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 7.1, where 3.9 is expected. A broad excess of events for m_{H^0} > 110 GeV is observed, with a local significance of 2.4 σ at m_{H^0} = 135 GeV.

[31] AALTONEN 12R search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 9.45 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (1.4–21.7) times larger than the expected Standard Model cross section is given for m_{H^0} = 90–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 4.9, where 2.8 is expected. Superseded by AALTONEN 13B.

[32] AALTONEN 12S search for associated $H^0 Z$ production in the final state $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \nu\overline{\nu}$, and $H^0 W$ production in $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ (ℓ not identified) with 9.45 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (1.7–27.2) times larger than the expected Standard Model cross section is given for m_{H^0} = 90–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 6.7, where 3.6 is expected.

[33] AALTONEN 12T combine AALTONEN 12Q, AALTONEN 12R, AALTONEN 12S, ABAZOV 12O, ABAZOV 12P, and ABAZOV 12K. An excess of events over background is observed which is most significant in the region m_{H^0} = 120–135 GeV, with a local significance of up to 3.3 σ. The local significance at m_{H^0} = 125 GeV is 2.8 σ, which corresponds to $(\sigma(H^0 W) + \sigma(H^0 Z))$ B$(H^0 \rightarrow b\overline{b})) = (0.23^{+0.09}_{-0.08})$ pb, compared to the Standard Model expectation at m_{H^0} = 125 GeV of 0.12 $\pm$ 0.01 pb.

[34] AALTONEN 12Y search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 2.7fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (3.6–61.1) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. Superseded by AALTONEN 12AA.

[35] ABAZOV 12J search for H^0 and associated $H^0 W$, $H^0 Z$ production, in the final state including a τ and e/μ with 7.3 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (6.8–29.9) times larger than the expected Standard Model cross section is given for m_{H^0} = 105–200 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 15.7, where 12.8 is expected.

[36] ABAZOV 12K search for associated $H^0 Z$ production in the final state $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \nu\overline{\nu}$, and $H^0 W$ production with $W \rightarrow \ell\nu$ (ℓ not identified) with 9.5 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (1.9–16.8) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 4.3, where 3.9 is expected.

[37] ABAZOV 12N combine ABAZOV 12O, ABAZOV 12P, and ABAZOV 12K. A limit on cross section times branching ratio which corresponds to (0.94–14) times the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. An excess of events over background is observed in the region m_{H^0} = 120–145 GeV with a local significance of 1.0–1.7 σ.

[38] ABAZOV 12O search for associated $H^0 Z$ production in the final state $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \ell^+\ell^-$ with 9.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (1.8–53) times larger than the expected Standard Model cross section is given for m_{H^0} = 90–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 7.1, where 5.1 is expected.

[39] ABAZOV 12P search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 9.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (2.6–21.8) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 5.2, where 4.7 is expected.

[40] ABAZOV 12V search for associated $H^0 W$ production in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$ with 5.3 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (2.7–30.4) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 6.6, where 6.8 is expected. Superseded by ABAZOV 12P.

[41] ABAZOV 12W search for H^0 production in the decay $H^0 \rightarrow W W^{(*)} \rightarrow \ell\nu\ell\nu$ with 8.6 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (1.1–13.3) times larger than the expected Standard Model cross section is given for m_{H^0} = 115–200 GeV at 95% CL. The best limit is at m_{H^0} = 160 GeV. The limit for m_{H^0} = 125 GeV is 5.0, where 3.8 is expected.

[42] CHATRCHYAN 12AY search for associated $H^0 W$ and $H^0 Z$ production in the channels $W \rightarrow \ell\nu$, $Z \rightarrow \ell^+\ell^-$, and $H^0 \rightarrow \tau\tau$, $W W^{(*)}$, with 5 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (3.1–9.1) times larger than the expected Standard Model cross section is given for m_{H^0} = 110–200 GeV at 95% CL.

[43] CHATRCHYAN 12AY combine CHATRCHYAN 12F and CHATRCHYAN 12AO in addition and give a limit on cross section times branching ratio which is (2.1–3.7) times larger than the expected Standard Model cross section for m_{H^0} = 110–170 GeV at 95% CL. The limit for m_{H^0} = 125 GeV is 3.3.

[44] CHATRCHYAN 12C search for H^0 production with $H \to ZZ \to \ell^+\ell^-\tau^+\tau^-$ in 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (4–12) times larger than the expected Standard Model cross section is given for m_{H^0} = 190–600 GeV at 95% CL. The best limit is at m_{H^0} = 200 GeV.

[45] CHATRCHYAN 12D search for H^0 production with $H \to ZZ^{(*)} \to \ell^+\ell^- q\overline{q}$ in 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which corresponds to (1–22) times the expected Standard Model cross section is given for m_{H^0} = 130–164 GeV, 200–600 GeV at 95% CL. The best limit is at m_{H^0} = 230 GeV. In the Standard Model with an additional generation of heavy quarks and leptons which receive their masses via the Higgs mechanism, m_{H^0} values in the ranges m_{H^0} = 154–161 GeV and 200–470 GeV are excluded at 95% CL.

[46] CHATRCHYAN 12E search for H^0 production with $H \to WW^{(*)} \to \ell^+\nu\ell^-\overline{\nu}$ in 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 110–600 GeV.

[47] CHATRCHYAN 12F search for associated $H^0 W$ and $H^0 Z$ production followed by $W \to \ell\nu$, $Z \to \ell^+\ell^-$, $\nu\overline{\nu}$, and $H^0 \to b\overline{b}$, in 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (3.1–9.0) times larger than the expected Standard Model cross section is given for m_{H^0} = 110–135 GeV at 95% CL. The best limit is at m_{H^0} = 110 GeV.

[48] CHATRCHYAN 12G search for H^0 production with $H \to \gamma\gamma$ in 4.8 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 110–150 GeV. An excess of events over background with a local significance of 3.1 σ is observed at 124 GeV.

[49] CHATRCHYAN 12H search for H^0 production with $H \to ZZ^{(*)} \to 4\ell$ in 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 110–600 GeV. Excesses of events over background are observed around 119, 126 and 320 GeV. The region m_{H^0} = 114.4–134 GeV remains consistent with the expectation for the production of a SM-like Higgs boson.

[50] CHATRCHYAN 12I search for H^0 production with $H \to ZZ \to \ell^+\ell^-\nu\overline{\nu}$ in 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV in the mass range m_{H^0} = 250–600 GeV.

[51] CHATRCHYAN 12K search for H^0 production in the decay $H \to \tau^+\tau^-$ with 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (3.2–7.0) times larger than the expected Standard Model cross section is given for m_{H^0} = 110–145 GeV at 95% CL.

[52] AAD 11AB search for H^0 production with $H \to W^+W^- \to \ell\nu q\overline{q}$ in 1.04 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (2.7–20) times larger than the expected Standard Model cross section is given for m_{H^0} = 240–600 GeV at 95% CL. The best limit is at m_{H^0} = 400 GeV. Superseded by AAD 12CO.

[53] AAD 11V search for H^0 production with $H \to ZZ \to \ell^+\ell^-\nu\overline{\nu}$ in 1.04 fb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which corresponds to (0.6–6) times the expected Standard Model cross section is given for m_{H^0} = 200–600 GeV at 95% CL. Superseded by AAD 12BZ.

[54] AAD 11W search for Higgs boson production in the decay channels $\gamma\gamma$, $ZZ^{(*)} \to 4\ell$, $ZZ \to \ell\ell\nu\nu$, $ZZ \to \ell\ell qq$, $WW^{(*)} \to \ell\ell\nu\nu$, $WW^{(*)} \to \ell\nu qq$ in 35–40 pb^{-1} of pp collisions at E_{cm} = 7 TeV. A limit on cross section times branching ratio which is (2–40) times larger than the expected Standard Model cross section is given for m_{H^0} = 110–600 GeV at 95% CL. In the Standard Model with an additional generation of heavy quarks and leptons which receive their masses via the Higgs mechanism, m_{H^0} values

between 140 and 185 GeV are excluded at 95% CL. The results for the Standard Model Higgs are superseded by AAD 12E.

[55] AALTONEN 11AA search in 4.0 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV for associated $H^0 W$ and $H^0 Z$ production followed by $W/Z \rightarrow q\overline{q}$, and for $p\overline{p} \rightarrow H^0 q\overline{q}X$ (vector boson fusion), both with $H^0 \rightarrow b\overline{b}$. A limit on cross section times branching ratio which is (9–100) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The best limit is at m_{H^0} = 115 GeV.

[56] ABAZOV 11AB search for associated $H^0 W$ and $H^0 Z$ production followed by $H^0 \rightarrow W W^{(*)}$ in like-sign dilepton final states using 5.3 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (6.4–18) times larger than the expected Standard Model cross section is given for m_{H^0} = 115–200 GeV at 95% CL. The best limit is for m_{H^0} = 135 and 165 GeV.

[57] ABAZOV 11G search for H^0 production in 5.4 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow W W^{(*)} \rightarrow \ell \nu q \overline{q}'$ (and processes with similar final states). A limit on cross section times branching ratio which is (3.9–37) times larger than the expected Standard Model cross section is given for m_{H^0} = 115–200 GeV at 95% CL. The best limit is at m_{H^0} = 160 GeV.

[58] ABAZOV 11J search for associated $H^0 W$ production in 5.3 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the final state $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell \nu$. A limit on cross section times branching ratio which is (2.7–30) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL. The limit at m_{H^0} = 115 GeV is 4.5 times larger than the expected Standard Model cross section. Superseded by ABAZOV 12P.

[59] ABAZOV 11Y search for $H^0 \rightarrow \gamma\gamma$ in 8.2 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A limit on cross section times branching ratio which is (10–25) times larger than the expected Standard Model cross section is given for m_{H^0} = 100–150 GeV at 95% CL.

[60] CHATRCHYAN 11J search for H^0 production with $H \rightarrow W^+ W^- \rightarrow \ell\ell\nu\nu$ in 36 pb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 6 for a limit on cross section times branching ratio for m_{H^0} = 120–600 GeV at 95% CL. In the Standard Model with an additional generation of heavy quarks and leptons which receive their masses via the Higgs mechanism, m_{H^0} values between 144 and 207 GeV are excluded at 95% CL.

[61] AALTONEN 10AD search for associated $H^0 Z$ production in 4.1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \ell^+ \ell^-$. A limit $\sigma \cdot$ B($H^0 \rightarrow b\overline{b}$) < (4.5–43) $\sigma \cdot$ B$_{(SM)}$ (95% CL) is given for m_{H^0} = 100–150 GeV. The limit for m_{H^0} = 115 GeV is 5.9 times larger than the expected Standard Model cross section. Superseded by AALTONEN 12H.

[62] AALTONEN 10F combine searches for H^0 decaying to $W^+ W^-$ in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with 4.8 fb^{-1} (CDF) and 5.4 fb^{-1} (DØ).

[63] AALTONEN 10G search for H^0 production in 4.8 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow W W^{(*)}$. A limit on $\sigma(H^0)$ which is (1.3–39) times larger than the expected Standard Model cross section is given for m_{H^0} = 110–200 GeV at 95% CL. The best limit is obtained for m_{H^0} = 165 GeV.

[64] AALTONEN 10J search for associated $H^0 W$ and $H^0 Z$ production in 2.1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the final state with (b) jets and missing p_T. A limit σ < (5.8–50) σ_{SM} (95% CL) is given for m_{H^0} = 110–150 GeV. The limit for m_{H^0} = 115 GeV is 6.9 times larger than the expected Standard Model cross section. Superseded by AALTONEN 12S.

[65] AALTONEN 10M combine searches for H^0 decaying to $W^+ W^-$ in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with 4.8 fb^{-1} (CDF) and 5.4 fb^{-1} (DØ) and derive limits $\sigma(p\overline{p} \rightarrow H^0) \cdot$ B($H^0 \rightarrow W^+ W^-$) < (1.75–0.38) pb for m_H = 120–165 GeV, where H^0 is produced

in gg fusion. In the Standard Model with an additional generation of heavy quarks, m_{H^0} between 131 and 204 GeV is excluded at 95% CL.

[66] ABAZOV 10B search for H^0 production in 5.4 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow W W^{(*)}$. A limit on $\sigma(H^0)$ which is (1.6–21) times larger than the expected Standard Model cross section is given for m_{H^0} = 115–200 GeV at 95% CL. The best limit is obtained for m_{H^0} = 165 GeV. Superseded by ABAZOV 12W.

[67] ABAZOV 10C search for associated $H^0 Z$ and $H^0 W$ production in 5.2 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the final states $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \nu\overline{\nu}$, and $W \rightarrow (\ell)\nu$, where ℓ is not identified. A limit $\sigma \cdot$ B($H^0 \rightarrow b\overline{b}$) < (3.4–38) $\sigma \cdot$ B$_{(SM)}$ (95% CL) is given for m_{H^0} = 100–150 GeV. The limit for m_{H^0} = 115 GeV is 3.7 times larger than the expected Standard Model cross section. Superseded by ABAZOV 12K.

[68] ABAZOV 10T search for associated $H^0 Z$ production in 4.2 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow b\overline{b}$, $Z \rightarrow \ell^+\ell^-$. A limit $\sigma \cdot$ B($H^0 \rightarrow b\overline{b}$) < (3.0–49) $\sigma \cdot$ B$_{(SM)}$ (95% CL) is given for m_{H^0} = 100–150 GeV. The limit for m_{H^0} = 115 GeV is 5.9 times larger than the expected Standard Model cross section. Superseded by ABAZOV 12O.

[69] AALTONEN 09A search for H^0 production in $p\overline{p}$ collisions at E_{cm} =1.96 TeV in the decay mode $H^0 \rightarrow W W^{(*)} \rightarrow \ell^+\ell^-\nu\overline{\nu}$. A limit on $\sigma(H^0) \cdot$ B($H^0 \rightarrow W W^{(*)}$) between 0.7 and 2.5 pb (95% CL) is given for m_{H^0} = 110–200 GeV, which is 1.7–45 times larger than the expected Standard Model cross section. The best limit is obtained for m_{H^0} = 160 GeV.

[70] AALTONEN 09AI search for associated $H^0 W$ production in 2.7 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$. A limit on $\sigma(H^0 W)\cdot$ B($H^0 \rightarrow b\overline{b}$) (95% CL) is given for m_{H^0} = 100–150 GeV, which is 3.3–75.5 times larger than the expected Standard Model cross section. The limit for m_{H^0} = 115 GeV is 5.6 times larger than the expected Standard Model cross section. Superseded by AALTONEN 12AA.

[71] ABAZOV 09U search for $H^0 \rightarrow \tau^+\tau^-$ with $\tau \rightarrow$ hadrons in 1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. The production mechanisms include associated W/Z+H^0 production, weak boson fusion, and gluon fusion. A limit (95% CL) is given for m_{H^0} = 105–145 GeV, which is 20–82 times larger than the expected Standard Model cross section. The limit for m_{H^0} = 115 GeV is 29 times larger than the expected Standard Model cross section.

[72] ABAZOV 08Y search for associated $H^0 W$ production in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the decay mode $H^0 \rightarrow b\overline{b}$, $W \rightarrow \ell\nu$. A limit $\sigma(H^0 W) \cdot$ B($H^0 \rightarrow b\overline{b}$) < (1.9–1.6) pb (95% CL) is given for m_{H^0} = 105–145 GeV, which is 10–93 times larger than the expected Standard Model cross section. These results are combined with ABAZOV 06, ABAZOV 06O, ABAZOV 06Q, and ABAZOV 07X to give cross section limits for m_{H^0} = 100–200 GeV which are 6–24 times larger than the Standard Model expectation. Superseded by ABAZOV 12N.

[73] ABAZOV 06 search for Higgs boson production in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with the decay chain $H^0 \rightarrow W W^* \rightarrow \ell^\pm\nu\ell'^\mp\overline{\nu}$. A limit $\sigma(H^0)\cdot$B($H^0 \rightarrow W W^*$) < (5.6–3.2) pb (95 %CL) is given for m_{H^0} = 120–200 GeV, which far exceeds the expected Standard Model cross section.

[74] ABAZOV 06O search for associated $H^0 W$ production in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with the decay $H^0 \rightarrow W W^*$, in the final states $\ell^\pm\ell'^\mp\nu\nu' X$ where $\ell = e$, μ. A limit $\sigma(H^0 W)\cdot$ B($H^0 \rightarrow W W^*$) < (3.2–2.8) pb (95 %CL) is given for m_{H^0} = 115–175 GeV, which far exceeds the expected Standard Model cross section.

H^0 Indirect Mass Limits from Electroweak Analysis

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. For indirect limits obtained from other considerations of theoretical nature, see the Note on "Searches for Higgs Bosons."

VALUE (GeV)	*DOCUMENT ID*		*TECN*
$\mathbf{94^{+25}_{-22}}$	[1] BAAK	12A	RVUE
• • • We do not use the following data for averages, fits, limits, etc. • • •			
91^{+30}_{-23}	[2] BAAK	12	RVUE
91^{+31}_{-24}	[3] ERLER	10A	RVUE
80^{+30}_{-23}	[4] FLACHER	09	RVUE
129^{+74}_{-49}	[5] LEP-SLC	06	RVUE

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

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

[3] 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.

[4] FLACHER 09 make Standard Model fits to Z and neutral current parameters, m_t, m_W, and Γ_W measurements available in 2008 (using also preliminary data). The 2σ (3σ) interval is 39–155 (26–209) GeV. The quoted results are obtained from a fit that does not include the limit from the direct Higgs searches. Superseded by BAAK 12.

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

SEARCHES FOR OTHER HIGGS BOSONS

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^0_1 and H^0_2, where we define $m_{H^0_1} < m_{H^0_2}$], a pseudoscalar (A^0), and a charged Higgs pair ($H^\pm$). H^0_1 and H^0_2 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 "Searches for Higgs Bosons" in this Volume these relations are violated by radiative corrections.

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 $b\overline{b}\tau^+\tau^-$. 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 "Searches for Higgs Bosons" 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. The 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 $m_h^{\rm max}$ benchmark scenario (which gives rise to the most conservative upper bound on the mass of H_1^0 for given values of m_{A^0} and $\tan\beta$), see CARENA 99B and CARENA 03.

Limits in the low-mass region of H_1^0, as well as other by now obsolete limits from different techniques, have been removed from this compilation, and can be found in earlier editions of this Review. Unless otherwise stated, the following results assume no invisible H_1^0 or A^0 decays.

The observed signal described in the section "H^0 (Higgs Boson)" can be interpreted as one of the neutral Higgs bosons of the minimal supersymmetric model.

H_1^0 (Higgs Boson) MASS LIMITS in Supersymmetric Models

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>89.7		[1] ABDALLAH	08B	DLPH	$E_{\rm cm} \leq 209$ GeV
>92.8	95	[2] SCHAEL	06B	LEP	$E_{\rm cm} \leq 209$ GeV
>84.5	95	[3,4] ABBIENDI	04M	OPAL	$E_{\rm cm} \leq 209$ GeV
>86.0	95	[3,5] ACHARD	02H	L3	$E_{\rm cm} \leq 209$ GeV, $\tan\beta > 0.4$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[6] AAD	13O	ATLS	$pp \rightarrow H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \rightarrow \tau^+\tau^-$, $\mu^+\mu^-$
		[7] AALTONEN	12AQ	TEVA	$p\overline{p} \rightarrow H_{1,2}^0/A^0 + b + X$, $H_{1,2}^0/A^0 \rightarrow b\overline{b}$
		[8] AALTONEN	12X	CDF	$p\overline{p} \rightarrow H_{1,2}^0/A^0 + b + X$, $H_{1,2}^0/A^0 \rightarrow b\overline{b}$
		[9] ABAZOV	12	D0	$p\overline{p} \rightarrow H_{1,2}^0/A^0 + X$, $H_{1,2}^0/A^0 \rightarrow \tau^+\tau^-$

		[10] ABAZOV	12G	D0	$p\overline{p} \rightarrow H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[11] CHATRCHYAN	12K	CMS	$pp \rightarrow H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[12] AAD	11R	ATLS	$pp \rightarrow H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[13] ABAZOV	11K	D0	$p\overline{p} \rightarrow H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \rightarrow b\overline{b}$
		[14] ABAZOV	11W	D0	$p\overline{p} \rightarrow H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[15] CHATRCHYAN	11H	CMS	$pp \rightarrow H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[16] AALTONEN	09AR	CDF	$p\overline{p} \rightarrow H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[17] ABAZOV	08W	D0	$p\overline{p} \rightarrow H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$
		[18] ABBIENDI	03G	OPAL	$H^0_1 \rightarrow A^0 A^0$
>89.8	95	[3,19] HEISTER	02	ALEP	$E_{cm} \leq 209$ GeV, $\tan\beta > 0.5$

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

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

[3] Search for $e^+e^- \rightarrow H^0_1 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$, and $e^+e^- \rightarrow H^0_1 Z$. Universal scalar mass of 1 TeV, SU(2) gaugino mass of 200 GeV, and $\mu = -200$ GeV are assumed, and two-loop radiative corrections incorporated. The limits hold for m_t=175 GeV, and for the m_h^{max} scenario.

[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 $H^0_1 Z \rightarrow 2A^0 q\overline{q}$, $A^0 \rightarrow q\overline{q}$. In addition, the MSSM parameter set in the "large-μ" and "no-mixing" scenarios are examined.

[6] 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.

[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.

[8] 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.

[9] ABAZOV 12 search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 5.4 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 Fig. 3 for the excluded region in the MSSM parameter space. Superseded by ABAZOV 12G.

[10] 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.

[11] 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 tanβ > 7.1 is excluded at 95% CL in the m_h^{max} scenario.

[12] AAD 11R search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 36 pb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 3 for the limit on cross section times branching ratio and for the excluded region in the MSSM parameter space. Superseded by AAD 13O.

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

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

[15] CHATRCHYAN 11H search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 36 pb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 2 for the limit on cross section times branching ratio and Fig. 3 for the excluded region in the MSSM parameter space. Superseded by CHATRCHYAN 12K.

[16] 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.

[17] ABAZOV 08W search for Higgs boson production in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV with the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$. See their Fig. 3 for the limit on $\sigma \cdot$ B($H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$) for different Higgs masses, and see their Fig. 4 for the excluded region in the MSSM parameter space. Superseded by ABAZOV 12.

[18] ABBIENDI 03G search for $e^+e^- \rightarrow H^0_1 Z$ followed by $H^0_1 \rightarrow A^0 A^0$, $A^0 \rightarrow c\overline{c}$, 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.

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

A^0 (Pseudoscalar Higgs Boson) MASS LIMITS in Supersymmetric Models

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>90.4		[1] ABDALLAH	08B	DLPH	$E_{cm} \leq 209$ GeV
>93.4	95	[2] SCHAEL	06B	LEP	$E_{cm} \leq 209$ GeV
>85.0	95	[3,4] ABBIENDI	04M	OPAL	$E_{cm} \leq 209$ GeV
>86.5	95	[3,5] ACHARD	02H	L3	$E_{cm} \leq 209$ GeV, $\tan\beta > 0.4$
>90.1	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] AAD	13O	ATLS	$pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$, $\mu^+\mu^-$
		[8] AALTONEN	12AQ	TEVA	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[9] AALTONEN	12X	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[10] ABAZOV	12	D0	$p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[11] ABAZOV	12G	D0	$p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[12] CHATRCHYAN	12K	CMS	$pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[13] AAD	11R	ATLS	$pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[14] ABAZOV	11K	D0	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to b\overline{b}$
		[15] ABAZOV	11W	D0	$p\overline{p} \to H^0_{1,2}/A^0 + b + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[16] CHATRCHYAN	11H	CMS	$pp \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[17] AALTONEN	09AR	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
		[18] ACOSTA	05Q	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + X$
		[19] ABBIENDI	03G	OPAL	$H^0_1 \to A^0 A^0$
		[20] AKEROYD	02	RVUE	

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

[2] SCHAEL 06B make a combined analysis of the LEP data. The quoted limit is for the m_h^{max} scenario with $m_t = 174.3$ GeV. In the CP-violating CPX scenario no lower bound on $m_{H^0_1}$ 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($H^0_1,H^0_2 \to b\overline{b},\tau^+\tau^-$).

[3] Search for $e^+e^- \rightarrow H^0_1 A^0$ in the final states $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$, and $e^+e^- \rightarrow H^0_1 Z$. Universal scalar mass of 1 TeV, SU(2) gaugino mass of 200 GeV, and $\mu= -200$ GeV are assumed, and two-loop radiative corrections incorporated. The limits hold for m_t=175 GeV, and for the m_h^{max} scenario.

[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 $H^0_1 Z \rightarrow 2A^0 q\overline{q}$, $A^0 \rightarrow q\overline{q}$. In addition, the MSSM parameter set in the "large-μ" and "no-mixing" scenarios are examined.

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

[7] 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.

[8] 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.

[9] 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.

[10] ABAZOV 12 search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 5.4 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 Fig. 3 for the excluded region in the MSSM parameter space. Superseded by ABAZOV 12G.

[11] 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.

[12] 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.

[13] AAD 11R search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \rightarrow \tau^+\tau^-$ in 36 pb^{-1} of pp collisions at $E_{cm} = 7$ TeV. See their Fig. 3 for the limit on cross section times branching ratio and for the excluded region in the MSSM parameter space. Superseded by AAD 13O.

[14] ABAZOV 11K search for associated production of a Higgs boson and a b quark, followed by the decay $H^0_{1,2}/A^0 \rightarrow b\overline{b}$, in 5.2 fb^{-1} of $p\overline{p}$ collisions at $E_{cm} = 1.96$ 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.

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

[16] CHATRCHYAN 11H search for production of a Higgs boson followed by the decay $H^0_{1,2}/A^0 \to \tau^+\tau^-$ in 36 pb^{-1} of pp collisions at E_{cm} = 7 TeV. See their Fig. 2 for the limit on cross section times branching ratio and Fig. 3 for the excluded region in the MSSM parameter space. Superseded by CHATRCHYAN 12K.

[17] 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.

[18] 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.

[19] 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.

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

H^0 (Higgs Boson) MASS LIMITS 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 Note on 'Searches for Higgs Bosons' at the beginning of this Chapter). See the footnotes or the comment lines for details on the nature of the models to which the limits apply.

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] AALTONEN	09AR	CDF	$p\overline{p} \to H^0_{1,2}/A^0 + X$, $H^0_{1,2}/A^0 \to \tau^+\tau^-$
none 1–55	95	[2] ABBIENDI	05A	OPAL	H^0_1, Type II model
>110.6	95	[3] ABDALLAH	05D	DLPH	$H^0 \to$ 2 jets
		[4] ABDALLAH	04O	DLPH	$Z \to f\overline{f}H$
		[5] ABDALLAH	04O	DLPH	$e^+e^- \to H^0 Z$, $H^0 A^0$
		[6] ABBIENDI	02D	OPAL	$e^+e^- \to b\overline{b}H$
none 1–44	95	[7] ABBIENDI	01E	OPAL	H^0_1, Type-II model
> 68.0	95	[8] ABBIENDI	99E	OPAL	tan$\beta > 1$
		[9] ABREU	95H	DLPH	$Z \to H^0 Z^*$, $H^0 A^0$
		[10] PICH	92	RVUE	Very light Higgs

[1] 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.

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

[3] 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.

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

[5] 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.

[6] ABBIENDI 02D search for $Z \rightarrow b\overline{b}H^0_1$ and $b\overline{b}A^0$ with $H^0_1/A^0 \rightarrow \tau^+\tau^-$, in the range $4 < m_H < 12$ GeV. See their Fig. 8 for limits on the Yukawa coupling.

[7] 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^0_1, $A^0 \rightarrow q\overline{q}$, gg are searched for. See their Figs. 15,16 for excluded regions.

[8] 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.

[9] 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 tanβ >1, the region $m_{H^0}+m_{A^0} \lesssim$ 87 GeV, m_{H^0} <47 GeV is excluded at 95% CL.

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

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. • • •					
none 110–118, 119.5–121	95	[1] AAD	12N	ATLS	$H^0 \rightarrow \gamma\gamma$
>114	95	[2] AALTONEN	12	CDF	$H^0 \rightarrow \gamma\gamma$
>114	95	[3] AALTONEN	12AN	CDF	$H^0 \rightarrow \gamma\gamma$
none 110–194	95	[4] CHATRCHYAN	12AO	CMS	$H^0 \rightarrow \gamma\gamma$, $WW^{(*)}$, $ZZ^{(*)}$
>112.9	95	[5] ABAZOV	11Y	D0	$H^0 \rightarrow \gamma\gamma$
>106	95	[6] AALTONEN	09AB	CDF	$H^0 \rightarrow \gamma\gamma$
>100	95	[7] ABAZOV	08U	D0	$H^0 \rightarrow \gamma\gamma$
>105.8	95	[8] SCHAEL	07	ALEP	$e^+e^- \rightarrow H^0 Z$, $H^0 \rightarrow WW^*$
>104.1	95	[9,10] ABDALLAH	04L	DLPH	$e^+e^- \rightarrow H^0 Z$, $H^0 \rightarrow \gamma\gamma$
>107	95	[11] ACHARD	03C	L3	$H^0 \rightarrow WW^*$, ZZ^*, $\gamma\gamma$
>105.5	95	[9,12] ABBIENDI	02F	OPAL	$H^0_1 \rightarrow \gamma\gamma$
>105.4	95	[13] ACHARD	02C	L3	$H^0_1 \rightarrow \gamma\gamma$
> 98	95	[14] AFFOLDER	01H	CDF	$p\overline{p} \rightarrow H^0 W/Z$, $H^0 \rightarrow \gamma\gamma$
> 94.9	95	[15] ACCIARRI	00S	L3	$e^+e^- \rightarrow H^0 Z$, $H^0 \rightarrow \gamma\gamma$

>100.7	95	[16] BARATE	00L	ALEP	$e^+e^- \to H^0 Z$, $H^0 \to \gamma\gamma$
> 96.2	95	[17] ABBIENDI	99O	OPAL	$e^+e^- \to H^0 Z$, $H^0 \to \gamma\gamma$
> 78.5	95	[18] ABBOTT	99B	D0	$p\overline{p} \to H^0 W/Z$, $H^0 \to \gamma\gamma$
		[19] ABREU	99P	DLPH	$e^+e^- \to H^0\gamma$ and/or $H^0 \to \gamma\gamma$

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

[2] AALTONEN 12 search for $H^0 \to \gamma\gamma$ in 7.0 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the mass range m_{H^0} = 100–150 GeV. Superseded by AALTONEN 12AN.

[3] AALTONEN 12AN search for $H^0 \to \gamma\gamma$ 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.

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

[5] ABAZOV 11Y search for $H^0 \to \gamma\gamma$ in 8.2 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV in the mass range m_{H^0} = 100–150 GeV.

[6] AALTONEN 09AB search for $H^0 \to \gamma\gamma$ 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.

[7] ABAZOV 08U search for $H^0 \to \gamma\gamma$ 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($H^0 \to \gamma\gamma$), and see their Fig. 3 for the excluded region in the m_{H^0} — B($H^0 \to \gamma\gamma$) plane.

[8] 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.

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

[10] Updates ABREU 01F.

[11] ACHARD 03C search for $e^+e^- \to ZH^0$ followed by $H^0 \to WW^*$ 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($H^0 \to WW^*$) + B($H^0 \to ZZ^*$) = 1, m_{H^0} > 108.1 GeV is obtained. See fig. 6 for the limits under different BR assumptions.

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

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

[14] 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($H^0 \to \gamma\gamma$)< 1.

[15] 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($H^0 \to \gamma\gamma$)=1, m_{H^0} > 98 GeV is obtained. See their Fig. 5 for limits on B($H \to \gamma\gamma$)$\cdot\sigma(e^+e^- \to Hf\overline{f})/\sigma(e^+e^- \to Hf\overline{f})$ (SM).

[16] 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($H \rightarrow \gamma\gamma$)$\cdot\sigma(e^+e^- \rightarrow H f\overline{f})/\sigma(e^+e^- \rightarrow H f\overline{f})$ (SM).

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

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

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

Limits for H^0 Decaying to Invisible Final States

These limits are for 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] AAD	12AQ	ATLS	secondary vertex
		[2] AALTONEN	12U	CDF	secondary vertex
>108.2	95	[3] ABBIENDI	10	OPAL	
		[4] ABBIENDI	07	OPAL	large width
>112.3	95	[5] ACHARD	05	L3	
>112.1	95	[5] ABDALLAH	04B	DLPH	
>114.1	95	[5] HEISTER	02	ALEP	$E_{cm} \leq 209$ GeV
>106.4	95	[5] BARATE	01C	ALEP	$E_{cm} \leq 202$ GeV
> 89.2	95	[6] ACCIARRI	00M	L3	

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

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

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

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

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

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

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] LEES	13C	BABR	$\Upsilon(1S) \to A^0\gamma$
	[2] CHATRCHYAN	12V	CMS	$A^0 \to \mu^+\mu^-$
	[3] AALTONEN	11P	CDF	$t \to bH^+$, $H^+ \to W^+A^0$
	[4,5] ABOUZAID	11A	KTEV	$K_L \to \pi^0\pi^0A^0$, $A^0 \to \mu^+\mu^-$
	[6] DEL-AMO-SA...	11J	BABR	$\Upsilon(1S) \to A^0\gamma$
	[7] LEES	11H	BABR	$\Upsilon(2S, 3S) \to A^0\gamma$
	[8] ANDREAS	10	RVUE	
	[5,9] HYUN	10	BELL	$B^0 \to K^{*0}A^0$, $A^0 \to \mu^+\mu^-$
	[5,10] HYUN	10	BELL	$B^0 \to \rho^0A^0$, $A^0 \to \mu^+\mu^-$
	[11] AUBERT	09P	BABR	$\Upsilon(3S) \to A^0\gamma$
	[12] AUBERT	09Z	BABR	$\Upsilon(2S) \to A^0\gamma$
	[13] AUBERT	09Z	BABR	$\Upsilon(3S) \to A^0\gamma$
	[5,14] TUNG	09	K391	$K_L \to \pi^0\pi^0A^0$, $A^0 \to \gamma\gamma$
	[15] LOVE	08	CLEO	$\Upsilon(1S) \to A^0\gamma$
	[16] BESSON	07	CLEO	$\Upsilon(1S) \to \eta_b\gamma$
	[17] PARK	05	HYCP	$\Sigma^+ \to pA^0$, $A^0 \to \mu^+\mu^-$

[1] 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 $B(\Upsilon(1S) \to A^0\gamma) \cdot B(A^0 \to \mu^+\mu^-)$ in the range $(0.3–9.7) \times 10^{-6}$ (90% CL) for $0.212 \leq m_{A^0} \leq 9.20$ GeV. See their Fig. 5(e) for limits on the $b-A^0$ Yukawa coupling derived by combining this result with AUBERT 09Z.

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

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

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

[5] The search was motivated by PARK 05.

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

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

[8] 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.

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

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

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

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

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

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

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

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

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

Other Limits

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[1] AALTONEN	11P	CDF	$t \to bH^+$, $H^+ \to W^+ A^0$
		[2] ABBIENDI	10	OPAL	$H^0 \to \tilde{\chi}^0_1 \tilde{\chi}^0_2$
		[3] SCHAEL	10	ALEP	$H^0 \to A^0 A^0$
		[4] ABAZOV	09V	D0	$H^0 \to A^0 A^0$
none 3–63	95	[5] ABBIENDI	05A	OPAL	A^0, Type II model
>104	95	[6] ABBIENDI	04K	OPAL	$H^0 \to$ 2 jets
		[7] ABDALLAH	04	DLPH	$H^0 VV$ couplings
>110.3	95	[8] ACHARD	04B	L3	$H^0 \to$ 2 jets
		[9] ACHARD	04F	L3	Anomalous coupling
		[10] ABBIENDI	03F	OPAL	$e^+e^- \to H^0 Z$, $H^0 \to$ any
		[11] ABBIENDI	03G	OPAL	$H^0_1 \to A^0 A^0$
>105.4	95	[12,13] HEISTER	02L	ALEP	$H^0_1 \to \gamma\gamma$
>109.1	95	[14] HEISTER	02M	ALEP	$H^0 \to$ 2 jets or $\tau^+\tau^-$
none 12–56	95	[15] ABBIENDI	01E	OPAL	A^0, Type-II model
		[16] ACCIARRI	00R	L3	$e^+e^- \to H^0\gamma$ and/or $H^0 \to \gamma\gamma$
		[17] ACCIARRI	00R	L3	$e^+e^- \to e^+e^- H^0$
		[18] GONZALEZ-G..	98B	RVUE	Anomalous coupling
		[19] KRAWCZYK	97	RVUE	$(g-2)_\mu$
		[20] ALEXANDER	96H	OPAL	$Z \to H^0\gamma$

[1] 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.

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

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

[4] 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.

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

[6] 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.

[7] 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.

[8] 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.

[9] 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.

[10] 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.

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

[12] 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.

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

[14] 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.

[15] 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^0_1, $A^0 \rightarrow q\overline{q}$, gg are searched for. See their Figs. 15,16 for excluded regions.

[16] 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.

[17] 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.

[18] 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.

[19] 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.

[20] 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.

$H^\pm$ (Charged Higgs) MASS LIMITS

Unless otherwise stated, the limits below assume B$(H^+ \rightarrow \tau^+\nu)$+B$(H^+ \rightarrow c\overline{s})$=1, and hold for all values of B$(H^+ \rightarrow \tau^+\nu_\tau)$, and assume H^+ weak isospin of T_3=+1/2. In the following, $\tan\beta$ is the ratio of the two vacuum expectation values in two-doublet models (2HDM).

The limits are also applicable to point-like technipions. For a discussion of techniparticles, see the Review of Dynamical Electroweak Symmetry Breaking in this Review.

For limits obtained in hadronic collisions before the observation of the top quark, and based on the top mass values inconsistent with the current measurements, see the 1996 (Physical Review **D54** 1 (1996)) Edition of this Review.

Searches in e^+e^- collisions at and above the Z pole have conclusively ruled out the existence of a charged Higgs in the region $m_{H^+} \lesssim$ 45 GeV, and are meanwhile superseded by the searches in higher energy e^+e^- collisions at LEP. Results that are by now obsolete are therefore not included in this compilation, and can be found in a previous Edition (The European Physical Journal **C15** 1 (2000)) of this Review.

In the following, and unless otherwise stated, results from the LEP experiments (ALEPH, DELPHI, L3, and OPAL) are assumed to derive from the study of the $e^+e^- \rightarrow H^+H^-$ process. Limits from $b \rightarrow s\gamma$ decays are usually stronger in generic 2HDM models than in Supersymmetric models.

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$>$ 76.3	95	[1] ABBIENDI	12	OPAL	$e^+e^- \rightarrow H^+H^-$,$E_{cm} \leq$ 209GeV
$>$ 74.4	95	ABDALLAH	04I	DLPH	$E_{cm} \leq$ 209 GeV
$>$ 76.5	95	ACHARD	03E	L3	$E_{cm} \leq$ 209 GeV
> 79.3	95	HEISTER	02P	ALEP	$E_{cm} \leq$ 209 GeV

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

		[2] AAD	13V	ATLS	$t \rightarrow bH^+$, lepton non-universality
		[3] AAD	12BH	ATLS	$t \rightarrow bH^+$
		[4] CHATRCHYAN	12AA	CMS	$t \rightarrow bH^+$
		[5] AALTONEN	11P	CDF	$t \rightarrow bH^+$, $H^+ \rightarrow W^+ A^0$
>316	95	[6] DESCHAMPS	10	RVUE	Type II, flavor physics data
		[7] AALTONEN	09AJ	CDF	$t \rightarrow bH^+$
		[8] ABAZOV	09AC	D0	$t \rightarrow bH^+$
		[9] ABAZOV	09AG	D0	$t \rightarrow bH^+$
		[10] ABAZOV	09AI	D0	$t \rightarrow bH^+$
		[11] ABAZOV	09P	D0	$H^+ \rightarrow t\overline{b}$
>240	95	[12] FLACHER	09	RVUE	Type II, flavor physics data
		[13] ABULENCIA	06E	CDF	$t \rightarrow bH^+$
> 92.0	95	ABBIENDI	04	OPAL	$B(\tau\nu) = 1$
> 76.7	95	[14] ABDALLAH	04I	DLPH	Type I
		[15] ABBIENDI	03	OPAL	$\tau \rightarrow \mu\overline{\nu}\nu$, $e\overline{\nu}\nu$
		[16] ABAZOV	02B	D0	$t \rightarrow bH^+$, $H \rightarrow \tau\nu$
		[17] BORZUMATI	02	RVUE	
		[18] ABBIENDI	01Q	OPAL	$B \rightarrow \tau\nu_\tau X$
		[19] BARATE	01E	ALEP	$B \rightarrow \tau\nu_\tau$
>315	99	[20] GAMBINO	01	RVUE	$b \rightarrow s\gamma$
		[21] AFFOLDER	00I	CDF	$t \rightarrow bH^+$, $H \rightarrow \tau\nu$
> 59.5	95	ABBIENDI	99E	OPAL	$E_{cm} \le 183$ GeV
		[22] ABBOTT	99E	D0	$t \rightarrow bH^+$
		[23] ACKERSTAFF	99D	OPAL	$\tau \rightarrow e\nu\nu$, $\mu\nu\nu$
		[24] ACCIARRI	97F	L3	$B \rightarrow \tau\nu_\tau$
		[25] AMMAR	97B	CLEO	$\tau \rightarrow \mu\nu\nu$
		[26] COARASA	97	RVUE	$B \rightarrow \tau\nu_\tau X$
		[27] GUCHAIT	97	RVUE	$t \rightarrow bH^+$, $H \rightarrow \tau\nu$
		[28] MANGANO	97	RVUE	$B_{u(c)} \rightarrow \tau\nu_\tau$
		[29] STAHL	97	RVUE	$\tau \rightarrow \mu\nu\nu$
>244	95	[30] ALAM	95	CLE2	$b \rightarrow s\gamma$
		[31] BUSKULIC	95	ALEP	$b \rightarrow \tau\nu_\tau X$

[1] ABBIENDI 12 also search for the decay mode $H^+ \rightarrow A^0 W^*$ with $A^0 \rightarrow b\overline{b}$.

[2] AAD 13V search for $t\overline{t}$ production followed by $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu$ through violation of lepton universality with 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. Upper limits on $B(t \rightarrow bH^+)$ between 0.032 and 0.044 (95% CL) are given for m_{H^+} = 90–140 GeV and $B(H^+ \rightarrow \tau^+\nu) = 1$. By combining with AAD 12BH, the limits improve to 0.008 to 0.034 for m_{H^+} = 90–160 GeV. See their Fig. 7 for the excluded region in the m_h^{max} scenario of the MSSM.

[3] AAD 12BH search for $t\overline{t}$ production followed by $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu$ with 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. Upper limits on $B(t \rightarrow bH^+)$ between 0.01 and 0.05 (95% CL) are given for m_{H^+} = 90–160 GeV and $B(H^+ \rightarrow \tau^+\nu) = 1$. See their Fig. 8 for the excluded region in the m_h^{max} scenario of the MSSM.

[4] CHATRCHYAN 12AA search for $t\overline{t}$ production followed by $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu$ with 2 fb^{-1} of pp collisions at E_{cm} = 7 TeV. Upper limits on $B(t \rightarrow bH^+)$ between 0.019 and 0.041 (95% CL) are given for m_{H^+} = 80–160 GeV and $B(H^+ \rightarrow \tau^+\nu)$=1.

[5] 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.

[6] DESCHAMPS 10 make Type II two Higgs doublet model fits to weak leptonic and semileptonic decays, $b \rightarrow s\gamma$, B, B_s mixings, and $Z \rightarrow b\overline{b}$. The limit holds irrespective of $\tan\beta$.

[7] AALTONEN 09AJ search for $t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$ in $t\overline{t}$ events in 2.2 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. Upper limits on B($t \rightarrow bH^+$) between 0.08 and 0.32 (95% CL) are given for m_{H^+} = 60–150 GeV and B($H^+ \rightarrow c\overline{s}$) = 1.

[8] ABAZOV 09AC search for $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu$ in $t\overline{t}$ events in 0.9 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. Upper limits on B($t \rightarrow bH^+$) between 0.19 and 0.25 (95% CL) are given for m_{H^+} = 80–155 GeV and B($H^+ \rightarrow \tau^+\nu$) = 1. See their Fig. 4 for an excluded region in a MSSM scenario.

[9] ABAZOV 09AG measure $t\overline{t}$ cross sections in final states with ℓ + jets ($\ell = e$, μ), $\ell\ell$, and $\tau\ell$ in 1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV, which constrains possible $t \rightarrow bH^+$ branching fractions. Upper limits (95% CL) on B($t \rightarrow bH^+$) between 0.15 and 0.40 (0.48 and 0.57) are given for B($H^+ \rightarrow \tau^+\nu$) = 1 (B($H^+ \rightarrow c\overline{s}$) = 1) for m_{H^+} = 80–155 GeV.

[10] ABAZOV 09AI search for $t \rightarrow bH^+$ in $t\overline{t}$ events in 1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. Final states with ℓ + jets ($\ell = e$, μ), $\ell\ell$, and $\tau\ell$ are examined. Upper limits on B($t \rightarrow bH^+$) (95% CL) between 0.15 and 0.19 (0.19 and 0.22) are given for B($H^+ \rightarrow \tau^+\nu$) = 1 (B($H^+ \rightarrow c\overline{s}$) = 1) for m_{H^+} = 80–155 GeV. For B($H^+ \rightarrow \tau^+\nu$) = 1 also a simultaneous extraction of B($t \rightarrow bH^+$) and the $t\overline{t}$ cross section is performed, yielding a limit on B($t \rightarrow bH^+$) between 0.12 and 0.26 for m_{H^+} = 80–155 GeV. See their Figs. 5–8 for excluded regions in several MSSM scenarios.

[11] ABAZOV 09P search for H^+ production by $q\overline{q}'$ annihilation followed by $H^+ \rightarrow t\overline{b}$ decay in 0.9 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. Cross section limits in several two-doublet models are given for m_{H^+} = 180–300 GeV. A region with 20 $\lesssim \tan\beta \lesssim$ 70 is excluded (95% CL) for 180 GeV $\lesssim m_{H^+} \lesssim$ 184 GeV in type-I models.

[12] FLACHER 09 make Type II two Higgs doublet model fits to weak leptonic and semileptonic decays, $b \rightarrow s\gamma$, and $Z \rightarrow b\overline{b}$. The limit holds irrespective of $\tan\beta$.

[13] ABULENCIA 06E search for associated $H^0 W$ production in $p\overline{p}$ collisions at E_{cm} = 1.96 TeV. A fit is made for $t\overline{t}$ production processes in dilepton, lepton + jets, and lepton + τ final states, with the decays $t \rightarrow W^+ b$ and $t \rightarrow H^+ b$ followed by $H^+ \rightarrow \tau^+\nu$, $c\overline{s}$, $t^*\overline{b}$, or $W^+ H^0$. Within the MSSM the search is sensitive to the region $\tan\beta$ < 1 or > 30 in the mass range m_{H^+} = 80–160 GeV. See Fig. 2 for the excluded region in a certain MSSM scenario.

[14] ABDALLAH 04I search for $e^+e^- \rightarrow H^+H^-$ with $H^\pm$ decaying to $\tau\nu$, cs, or $W^* A^0$ in Type-I two-Higgs-doublet models.

[15] ABBIENDI 03 give a limit m_{H^+} > 1.28$\tan\beta$ GeV (95%CL) in Type II two-doublet models.

[16] ABAZOV 02B search for a charged Higgs boson in top decays with $H^+ \rightarrow \tau^+\nu$ at E_{cm}=1.8 TeV. For m_{H^+}=75 GeV, the region $\tan\beta$ > 32.0 is excluded at 95%CL. The excluded mass region extends to over 140 GeV for $\tan\beta$ values above 100.

[17] BORZUMATI 02 point out that the decay modes such as $b\overline{b}W$, $A^0 W$, and supersymmetric ones can have substantial branching fractions in the mass range explored at LEP II and Tevatron.

[18] ABBIENDI 01Q give a limit $\tan\beta/m_{H^+}$ < 0.53 GeV^{-1} (95%CL) in Type II two-doublet models.

[19] BARATE 01E give a limit $\tan\beta/m_{H^+} < 0.40$ GeV^{-1} (90% CL) in Type II two-doublet models. An independent measurement of $B \rightarrow \tau\nu_\tau X$ gives $\tan\beta/m_{H^+} < 0.49$ GeV^{-1} (90% CL).

[20] GAMBINO 01 use the world average data in the summer of 2001 B($b \rightarrow s\gamma$)= $(3.23 \pm 0.42) \times 10^{-4}$. The limit applies for Type-II two-doublet models.

[21] AFFOLDER 00I search for a charged Higgs boson in top decays with $H^+ \rightarrow \tau^+\nu$ in $p\overline{p}$ collisions at E_{cm}=1.8 TeV. The excluded mass region extends to over 120 GeV for $\tan\beta$ values above 100 and B($\tau\nu$)=1. If B($t \rightarrow bH^+$) $\gtrsim 0.6$, m_{H^+} up to 160 GeV is excluded. Updates ABE 97L.

[22] ABBOTT 99E search for a charged Higgs boson in top decays in $p\overline{p}$ collisions at E_{cm}=1.8 TeV, by comparing the observed $t\overline{t}$ cross section (extracted from the data assuming the dominant decay $t \rightarrow bW^+$) with theoretical expectation. The search is sensitive to regions of the domains $\tan\beta \lesssim 1$, $50 < m_{H^+}$(GeV) $\lesssim 120$ and $\tan\beta \gtrsim 40$, $50 < m_{H^+}$(GeV) $\lesssim 160$. See Fig. 3 for the details of the excluded region.

[23] ACKERSTAFF 99D measure the Michel parameters ρ, ξ, η, and $\xi\delta$ in leptonic τ decays from $Z \rightarrow \tau\tau$. Assuming e-μ universality, the limit $m_{H^+} > 0.97 \tan\beta$ GeV (95%CL) is obtained for two-doublet models in which only one doublet couples to leptons.

[24] ACCIARRI 97F give a limit $m_{H^+} > 2.6 \tan\beta$ GeV (90% CL) from their limit on the exclusive $B \rightarrow \tau\nu_\tau$ branching ratio.

[25] AMMAR 97B measure the Michel parameter ρ from $\tau \rightarrow e\nu\nu$ decays and assumes e/μ universality to extract the Michel η parameter from $\tau \rightarrow \mu\nu\nu$ decays. The measurement is translated to a lower limit on m_{H^+} in a two-doublet model $m_{H^+} > 0.97 \tan\beta$ GeV (90% CL).

[26] COARASA 97 reanalyzed the constraint on the ($m_{H^\pm}$,$\tan\beta$) plane derived from the inclusive $B \rightarrow \tau\nu_\tau X$ branching ratio in GROSSMAN 95B and BUSKULIC 95. They show that the constraint is quite sensitive to supersymmetric one-loop effects.

[27] GUCHAIT 97 studies the constraints on m_{H^+} set by Tevatron data on $\ell\tau$ final states in $t\overline{t} \rightarrow (Wb)(Hb)$, $W \rightarrow \ell\nu$, $H \rightarrow \tau\nu_\tau$. See Fig. 2 for the excluded region.

[28] MANGANO 97 reconsiders the limit in ACCIARRI 97F including the effect of the potentially large $B_c \rightarrow \tau\nu_\tau$ background to $B_u \rightarrow \tau\nu_\tau$ decays. Stronger limits are obtained.

[29] STAHL 97 fit τ lifetime, leptonic branching ratios, and the Michel parameters and derive limit $m_{H^+} > 1.5 \tan\beta$ GeV (90% CL) for a two-doublet model. See also STAHL 94.

[30] ALAM 95 measure the inclusive $b \rightarrow s\gamma$ branching ratio at $\Upsilon(4S)$ and give B($b \rightarrow s\gamma$)$< 4.2 \times 10^{-4}$ (95% CL), which translates to the limit $m_{H^+} >[244 + 63/(\tan\beta)^{1.3}]$ GeV in the Type II two-doublet model. Light supersymmetric particles can invalidate this bound.

[31] BUSKULIC 95 give a limit $m_{H^+} > 1.9 \tan\beta$ GeV (90% CL) for Type-II models from $b \rightarrow \tau\nu_\tau X$ branching ratio, as proposed in GROSSMAN 94.

MASS LIMITS for $H^{\pm\pm}$ (doubly-charged Higgs boson)

This section covers searches for a doubly-charged Higgs boson with couplings to lepton pairs. Its weak isospin T_3 is thus restricted to two possibilities depending on lepton chiralities: $T_3(H^{\pm\pm}) = \pm 1$, with the coupling $g_{\ell\ell}$ to $\ell^-_L \ell'^-_L$ and $\ell^+_R \ell'^+_R$ ("left-handed") and $T_3(H^{\pm\pm}) = 0$, with the coupling to $\ell^-_R \ell'^-_R$ and $\ell^+_L \ell'^+_L$ ("right-handed"). These Higgs bosons appear in some left-right symmetric models based on the gauge group

SU(2)$_L$×SU(2)$_R$×U(1). These two cases are listed separately in the following. Unless noted, one of the lepton flavor combinations is assumed to be dominant in the decay.

LIMITS for $H^{\pm\pm}$ with $T_3 = \pm1$

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>398	95	[1] AAD	12CQ	ATLS	$\mu\mu$
>375	95	[1] AAD	12CQ	ATLS	$e\mu$
>409	95	[1] AAD	12CQ	ATLS	ee
>169	95	[2] CHATRCHYAN	12AU	CMS	$\tau\tau$
>300	95	[2] CHATRCHYAN	12AU	CMS	$\mu\tau$
>293	95	[2] CHATRCHYAN	12AU	CMS	$e\tau$
>395	95	[2] CHATRCHYAN	12AU	CMS	$\mu\mu$
>391	95	[2] CHATRCHYAN	12AU	CMS	$e\mu$
>382	95	[2] CHATRCHYAN	12AU	CMS	ee
> 98.1	95	[3] ABDALLAH	03	DLPH	$\tau\tau$
> 99.0	95	[4] ABBIENDI	02C	OPAL	$\tau\tau$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>330	95	[5] AAD	13Y	ATLS	$\mu\mu$
>237	95	[5] AAD	13Y	ATLS	$\mu\tau$
>355	95	[6] AAD	12AY	ATLS	$\mu\mu$
>128	95	[7] ABAZOV	12A	D0	$\tau\tau$
>144	95	[7] ABAZOV	12A	D0	$\mu\tau$
>245	95	[8] AALTONEN	11AF	CDF	$\mu\mu$
>210	95	[8] AALTONEN	11AF	CDF	$e\mu$
>225	95	[8] AALTONEN	11AF	CDF	ee
>114	95	[9] AALTONEN	08AA	CDF	$e\tau$
>112	95	[9] AALTONEN	08AA	CDF	$\mu\tau$
>168	95	[10] ABAZOV	08V	D0	$\mu\mu$
		[11] AKTAS	06A	H1	single $H^{\pm\pm}$
>133	95	[12] ACOSTA	05L	CDF	stable
>118.4	95	[13] ABAZOV	04E	D0	$\mu\mu$
		[14] ABBIENDI	03Q	OPAL	$E_{cm} \leq 209$ GeV, single $H^{\pm\pm}$
		[15] GORDEEV	97	SPEC	muonium conversion
		[16] ASAKA	95	THEO	
> 45.6	95	[17] ACTON	92M	OPAL	
> 30.4	95	[18] ACTON	92M	OPAL	
none 6.5–36.6	95	[19] SWARTZ	90	MRK2	

[1] AAD 12CQ search for $H^{++}H^{--}$ production with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. The limit assumes 100% branching ratio to the specified final state. See their Table 1 for limits assuming smaller branching ratios.

[2] CHATRCHYAN 12AU search for $H^{++}H^{--}$ production with 4.9 fb^{-1} of pp collisions at E_{cm} = 7 TeV. The limit assumes 100% branching ratio to the specified final state. See their Table 6 for limits including associated $H^{++}H^{-}$ production or assuming different scenarios.

[3] ABDALLAH 03 search for $H^{++}H^{--}$ pair production either followed by $H^{++} \rightarrow \tau^+\tau^+$, or decaying outside the detector.

[4] ABBIENDI 02C searches for pair production of $H^{++}H^{--}$, with $H^{\pm\pm} \rightarrow \ell^\pm\ell^\pm$ (ℓ,ℓ' = e,μ,τ). The limit holds for ℓ=ℓ'=τ, and becomes stronger for other combinations of leptonic final states. To ensure the decay within the detector, the limit only applies for $g(H\ell\ell) \gtrsim 10^{-7}$.

[5] AAD 13Y search for $H^{++}H^{--}$ production in a generic search of events with three charged leptons in 4.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. The limit assumes 100% branching ratio to the specified final state.

[6] AAD 12AY search for $H^{++}H^{--}$ production with 1.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. The limit assumes 100% branching ratio to the specified final state.

[7] ABAZOV 12A search for $H^{++}H^{--}$ production in 7.0 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV.

[8] AALTONEN 11AF search for $H^{++}H^{--}$ production in 6.1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV.

[9] AALTONEN 08AA search for $H^{++}H^{--}$ production in $p\overline{p}$ collisions at E_{cm}= 1.96 TeV. The limit assumes 100% branching ratio to the specified final state.

[10] ABAZOV 08V search for $H^{++}H^{--}$ production in $p\overline{p}$ collisions at E_{cm}= 1.96 TeV. The limit is for B($H \rightarrow \mu\mu$) = 1. The limit is updated in ABAZOV 12A.

[11] AKTAS 06A search for single $H^{\pm\pm}$ production in ep collisions at HERA. Assuming that H^{++} only couples to $e^+\mu^+$ with $g_{e\mu}$ = 0.3 (electromagnetic strength), a limit $m_{H^{++}}$ > 141 GeV (95% CL) is derived. For the case where H^{++} couples to $e\tau$ only the limit is 112 GeV.

[12] ACOSTA 05L search for $H^{++}H^{--}$ pair production in $p\overline{p}$ collisions. The limit is valid for $g_{\ell\ell'} < 10^{-8}$ so that the Higgs decays outside the detector.

[13] ABAZOV 04E search for $H^{++}H^{--}$ pair production in $H^{\pm\pm} \rightarrow \mu^\pm\mu^\pm$. The limit is valid for $g_{\mu\mu} \gtrsim 10^{-7}$.

[14] ABBIENDI 03Q searches for single $H^{\pm\pm}$ via direct production in $e^+e^- \rightarrow e^\mp e^\mp H^{\pm\pm}$, and via t-channel exchange in $e^+e^- \rightarrow e^+e^-$. In the direct case, and assuming B($H^{\pm\pm} \rightarrow \ell^\pm\ell^\pm$) = 1, a 95% CL limit on h_{ee} < 0.071 is set for $m_{H^{\pm\pm}}$ < 160 GeV (see Fig. 6). In the second case, indirect limits on h_{ee} are set for $m_{H^{\pm\pm}}$ < 2 TeV (see Fig. 8).

[15] GORDEEV 97 search for muonium-antimuonium conversion and find $G_{M\overline{M}}/G_F < 0.14$ (90% CL), where $G_{M\overline{M}}$ is the lepton-flavor violating effective four-fermion coupling. This limit may be converted to $m_{H^{++}}$ > 210 GeV if the Yukawa couplings of H^{++} to ee and $\mu\mu$ are as large as the weak gauge coupling. For similar limits on muonium-antimuonium conversion, see the muon Particle Listings.

[16] ASAKA 95 point out that H^{++} decays dominantly to four fermions in a large region of parameter space where the limit of ACTON 92M from the search of dilepton modes does not apply.

[17] ACTON 92M limit assumes $H^{\pm\pm} \rightarrow \ell^\pm\ell^\pm$ or $H^{\pm\pm}$ does not decay in the detector. Thus the region $g_{\ell\ell} \approx 10^{-7}$ is not excluded.

[18] ACTON 92M from $\Delta\Gamma_Z$ <40 MeV.

[19] SWARTZ 90 assume $H^{\pm\pm} \rightarrow \ell^\pm\ell^\pm$ (any flavor). The limits are valid for the Higgs-lepton coupling g($H\ell\ell$) $\gtrsim 7.4 \times 10^{-7}/[m_H/\text{GeV}]^{1/2}$. The limits improve somewhat for ee and $\mu\mu$ decay modes.

LIMITS for $H^{\pm\pm}$ with $T_3 = 0$

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>306	95	[1] AAD	12CQ	ATLS	$\mu\mu$
>310	95	[1] AAD	12CQ	ATLS	$e\mu$
>322	95	[1] AAD	12CQ	ATLS	ee
> 97.3	95	[2] ABDALLAH	03	DLPH	$\tau\tau$
> 97.3	95	[3] ACHARD	03F	L3	$\tau\tau$
> 98.5	95	[4] ABBIENDI	02C	OPAL	$\tau\tau$

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

>251	95	[5] AAD	12AY	ATLS	$\mu\mu$
>113	95	[6] ABAZOV	12A	D0	$\mu\tau$
>205	95	[7] AALTONEN	11AF	CDF	$\mu\mu$
>190	95	[7] AALTONEN	11AF	CDF	$e\mu$
>205	95	[7] AALTONEN	11AF	CDF	ee
>145	95	[8] ABAZOV	08V	D0	$\mu\mu$
		[9] AKTAS	06A	H1	single $H^{\pm\pm}$
>109	95	[10] ACOSTA	05L	CDF	stable
> 98.2	95	[11] ABAZOV	04E	D0	$\mu\mu$
		[12] ABBIENDI	03Q	OPAL	$E_{cm} \leq 209$ GeV, single $H^{\pm\pm}$
		[13] GORDEEV	97	SPEC	muonium conversion
> 45.6	95	[14] ACTON	92M	OPAL	
> 25.5	95	[15] ACTON	92M	OPAL	
none 7.3–34.3	95	[16] SWARTZ	90	MRK2	

[1] AAD 12CQ search for $H^{++}H^{--}$ production with 4.7 fb^{-1} of pp collisions at E_{cm} = 7 TeV. The limit assumes 100% branching ratio to the specified final state. See their Table 1 for limits assuming smaller branching ratios.

[2] ABDALLAH 03 search for $H^{++}H^{--}$ pair production either followed by $H^{++} \rightarrow \tau^+\tau^+$, or decaying outside the detector.

[3] ACHARD 03F search for $e^+e^- \rightarrow H^{++}H^{--}$ with $H^{\pm\pm} \rightarrow \ell^\pm\ell'^\pm$. The limit holds for $\ell = \ell' = \tau$, and slightly different limits apply for other flavor combinations. The limit is valid for $g_{\ell\ell'} \gtrsim 10^{-7}$.

[4] ABBIENDI 02C searches for pair production of $H^{++}H^{--}$, with $H^{\pm\pm} \rightarrow \ell^\pm\ell^\pm$ (ℓ,ℓ' = e,μ,τ). the limit holds for ℓ=ℓ'=τ, and becomes stronger for other combinations of leptonic final states. To ensure the decay within the detector, the limit only applies for $g(H\ell\ell) \gtrsim 10^{-7}$.

[5] AAD 12AY search for $H^{++}H^{--}$ production with 1.6 fb^{-1} of pp collisions at E_{cm} = 7 TeV. The limit assumes 100% branching ratio to the specified final state.

[6] ABAZOV 12A search for $H^{++}H^{--}$ production in 7.0 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV.

[7] AALTONEN 11AF search for $H^{++}H^{--}$ production in 6.1 fb^{-1} of $p\overline{p}$ collisions at E_{cm} = 1.96 TeV.

[8] ABAZOV 08V search for $H^{++}H^{--}$ production in $p\overline{p}$ collisions at E_{cm}= 1.96 TeV. The limit is for B($H \rightarrow \mu\mu$) = 1. The limit is updated in ABAZOV 12A.

[9] AKTAS 06A search for single $H^{\pm\pm}$ production in ep collisions at HERA. Assuming that H^{++} only couples to $e^+\mu^+$ with $g_{e\mu}$ = 0.3 (electromagnetic strength), a limit $m_{H^{++}}$ > 141 GeV (95% CL) is derived. For the case where H^{++} couples to $e\tau$ only the limit is 112 GeV.

[10] ACOSTA 05L search for $H^{++}H^{--}$ pair production in $p\overline{p}$ collisions. The limit is valid for $g_{\ell\ell'} < 10^{-8}$ so that the Higgs decays outside the detector.

[11] ABAZOV 04E search for $H^{++}H^{--}$ pair production in $H^{\pm\pm} \rightarrow \mu^\pm\mu^\pm$. The limit is valid for $g_{\mu\mu} \gtrsim 10^{-7}$.

[12] ABBIENDI 03Q searches for single $H^{\pm\pm}$ via direct production in $e^+e^- \rightarrow e^\mp e^\mp H^{\pm\pm}$, and via t-channel exchange in $e^+e^- \rightarrow e^+e^-$. In the direct case, and assuming B($H^{\pm\pm} \rightarrow \ell^\pm\ell^\pm$) = 1, a 95% CL limit on h_{ee} < 0.071 is set for $m_{H^{\pm\pm}}$ < 160 GeV (see Fig. 6). In the second case, indirect limits on h_{ee} are set for $m_{H^{\pm\pm}}$ < 2 TeV (see Fig. 8).

[13] GORDEEV 97 search for muonium-antimuonium conversion and find $G_{M\overline{M}}/G_F < 0.14$ (90% CL), where $G_{M\overline{M}}$ is the lepton-flavor violating effective four-fermion coupling.

This limit may be converted to $m_{H^{++}} > 210$ GeV if the Yukawa couplings of H^{++} to ee and $\mu\mu$ are as large as the weak gauge coupling. For similar limits on muonium-antimuonium conversion, see the muon Particle Listings.

[14] ACTON 92M limit assumes $H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm}$ or $H^{\pm\pm}$ does not decay in the detector. Thus the region $g_{\ell\ell} \approx 10^{-7}$ is not excluded.

[15] ACTON 92M from $\Delta\Gamma_Z <$40 MeV.

[16] SWARTZ 90 assume $H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm}$ (any flavor). The limits are valid for the Higgs-lepton coupling g($H\ell\ell$) $\gtrsim 7.4 \times 10^{-7}/[m_H/\mathrm{GeV}]^{1/2}$. The limits improve somewhat for ee and $\mu\mu$ decay modes.

H^0 and $H^{\pm}$ REFERENCES

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AAD	13V	JHEP 1303 076	G. Aad *et al.*	(ATLAS Collab.)
AAD	13Y	PR D87 052002	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	13B	PR D87 052008	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	13C	JHEP 1302 004	T. Aaltonen *et al.*	(CDF Collab.)
CHATRCHYAN	13J	PRL 110 081803	S. Chatrchyan *et al.*	(CMS Collab.)
LEES	13C	PR D87 031102	J.P. Lees *et al.*	(BABAR Collab.)
AAD	12	PL B707 27	G. Aad *et al.*	(ATLAS Collab.)
AAD	12AI	PL B716 1	G. Aad *et al.*	(ATLAS Colalb.)
AAD	12AJ	PL B716 62	G. Aad *et al.*	(ATLAS Collab.)
AAD	12AQ	PRL 108 251801	G. Aad *et al.*	(ATLAS Collab.)
AAD	12AY	PR D85 032004	G. Aad *et al.*	(ATLAS Collab.)
AAD	12BD	PR D86 032003	G. Aad *et al.*	(ATLAS Collab.)
AAD	12BH	JHEP 1206 039	G. Aad *et al.*	(ATLAS Collab.)
AAD	12BU	JHEP 1209 070	G. Aad *et al.*	(ATLAS Collab.)
AAD	12BZ	PL B717 29	G. Aad *et al.*	(ATLAS Collab.)
AAD	12CA	PL B717 70	G. Aad *et al.*	(ATLAS Collab.)
AAD	12CN	PL B718 369	G. Aad *et al.*	(ATLAS Collab.)
AAD	12CO	PL B718 391	G. Aad *et al.*	(ATLAS Collab.)
AAD	12CQ	EPJ C72 2244	G. Aad *et al.*	(ATLAS Collab.)
AAD	12D	PL B710 383	G. Aad *et al.*	(ATLAS Collab.)
AAD	12DA	SCI 338 1576	G. Aad *et al.*	(ATLAS Collab.)
AAD	12E	PL B710 49	G. Aad *et al.*	(ATLAS Collab.)
AAD	12F	PRL 108 111802	G. Aad *et al.*	(ATLAS Collab.)
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AAD	12N	EPJ C72 2157	G. Aad *et al.*	(ATLAS Collab.)
AALTONEN	12	PRL 108 011801	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12AA	PR D85 072001	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12AE	PR D86 032011	T. Aaltonen *et al.*	(CDF Colalb.)
AALTONEN	12AK	PRL 109 181802	T. Aaltonen *et al.*	(CDF Colalb.)
AALTONEN	12AM	PR D86 072012	T. Aaltonen *et al.*	(CDF Colalb.)
AALTONEN	12AN	PL B717 173	T. Aaltonen *et al.*	(CDF Colalb.)
AALTONEN	12AQ	PR D86 091101	T. Aaltonen *et al.*	(CDF and D0 Collabs.)
AALTONEN	12H	PL B715 98	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12J	PRL 108 181804	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12P	PRL 109 111802	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12Q	PRL 109 111803	T. Aaltonen *et al.*	(CDF Colalb.)
AALTONEN	12R	PRL 109 111804	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12S	PRL 109 111805	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12T	PRL 109 071804	T. Aaltonen *et al.*	(CDF and D0 Colalb.)
AALTONEN	12U	PR D85 012007	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	12X	PR D85 032005	T. Aaltonen *et al.*	(CDF Colalb.)
AALTONEN	12Y	PR D85 052002	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	12	PL B707 323	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	12A	PRL 108 021801	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	12G	PL B710 569	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	12J	PL B714 237	V.M. Abazov *et al.*	(D0 Colalb.)
ABAZOV	12K	PL B716 285	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	12N	PRL 109 121802	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	12O	PRL 109 121803	V.M. Abazov *et al.*	(D0 Colalb.)
ABAZOV	12P	PRL 109 121804	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	12V	PR D86 032005	V.M. Abazov *et al.*	(D0 Colalb.)
ABAZOV	12W	PR D86 032010	V.M. Abazov *et al.*	(D0 Collab.)
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CHATRCHYAN	12AO	JHEP 1209 111	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12AU	EPJ C72 2189	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12AY	JHEP 1211 088	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12B	PL B710 26	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12BY	SCI 338 1569	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12C	JHEP 1203 081	S. Chatrchyan *et al.*	(CMS Collab.)
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CHATRCHYAN	12E	PL B710 91	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12F	PL B710 284	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.)
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CHATRCHYAN	12V	PRL 109 121801	S. Chatrchyan *et al.*	(CMS Collab.)
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AAD	11R	PL B705 174	G. Aad *et al.*	(ATLAS Collab.)
AAD	11V	PRL 107 221802	G. Aad *et al.*	(ATLAS Collab.)
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ABAZOV	11G	PRL 106 171802	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	11J	PL B698 6	V.M. Abazov *et al.*	(D0 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.)
ABAZOV	11Y	PRL 107 151801	V.M. Abazov *et al.*	(D0 Collab.)
ABOUZAID	11A	PRL 107 201803	E. Abouzaid *et al.*	(KTeV Collab.)
CHATRCHYAN	11H	PRL 106 231801	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	11J	PL B699 25	S. Chatrchyan *et al.*	(CMS Collab.)
DEL-AMO-SA...	11J	PRL 107 021804	P. del Amo Sanchez *et al.*	(BABAR Collb.)
LEES	11H	PRL 107 221803	J.P. Lees *et al.*	(BABAR Collab.)
AALTONEN	10AD	PRL 105 251802	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	10F	PRL 104 061802	T. Aaltonen *et al.*	(CDF and D0 Collab.)
AALTONEN	10G	PRL 104 061803	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	10J	PRL 104 141801	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	10M	PR D82 011102	T. Aaltonen *et al.*	(CDF and D0 Collab.)
ABAZOV	10B	PRL 104 061804	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	10C	PRL 104 071801	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	10T	PRL 105 251801	V.M. Abazov *et al.*	(D0 Collab.)
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ANDREAS	10	JHEP 1008 003	S. Andreas *et al.*	(DESY)
DESCHAMPS	10	PR D82 073012	O. Deschamps *et al.*	(CLER, ORSAY, LAPP)
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HYUN	10	PRL 105 091801	H.J. Hyun *et al.*	(BELLE Collab.)
SCHAEL	10	JHEP 1005 049	S. Schael *et al.*	(ALEPH Collab.)
AALTONEN	09A	PRL 102 021802	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09AB	PRL 103 061803	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09AI	PRL 103 101802	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09AJ	PRL 103 101803	T. Aaltonen *et al.*	(CDF Collab.)
AALTONEN	09AR	PRL 103 201801	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	09AC	PR D80 051107	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	09AG	PR D80 071102	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	09AI	PL B682 278	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	09P	PRL 102 191802	V.M. Abazov *et al.*	(D0 Collab.)
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AUBERT	09Z	PRL 103 081803	B. Aubert *et al.*	(BABAR Collab.)
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TUNG	09	PRL 102 051802	Y.C. Tung *et al.*	(KEK E391a Collab.)
AALTONEN	08AA	PRL 101 121801	T. Aaltonen *et al.*	(CDF Collab.)
ABAZOV	08U	PRL 101 051801	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	08V	PRL 101 071803	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	08W	PRL 101 071804	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	08Y	PL B663 26	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.)
ABAZOV	07X	PL B655 209	V.M. Abazov *et al.*	(D0 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.)
ABAZOV	06	PRL 96 011801	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	06O	PRL 97 151804	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	06Q	PRL 97 161803	V.M. Abazov *et al.*	(D0 Collab.)
ABULENCIA	06E	PRL 96 042003	A. Abulencia *et al.*	(CDF Collab.)
AKTAS	06A	PL B638 432	A. Aktas *et al.*	(H1 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	05L	PRL 95 071801	D. Acosta *et al.*	(CDF 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.)
ABAZOV	04E	PRL 93 141801	V.M. Abazov *et al.*	(D0 Collab.)
ABBIENDI	04	EPJ C32 453	G. Abbiendi *et al.*	(OPAL 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	04I	EPJ C34 399	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	03	PL B551 35	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	03B	EPJ C26 479	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	03F	EPJ C27 311	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	03G	EPJ C27 483	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	03Q	PL B577 93	G. Abbiendi *et al.*	(OPAL Collab.)
ABDALLAH	03	PL B552 127	J. Abdallah *et al.*	(DELPHI Collab.)
ACHARD	03C	PL B568 191	P. Achard *et al.*	(L3 Collab.)
ACHARD	03E	PL B575 208	P. Achard *et al.*	(L3 Collab.)
ACHARD	03F	PL B576 18	P. Achard *et al.*	(L3 Collab.)
CARENA	03	EPJ C26 601	M.S. Carena *et al.*	
HEISTER	03D	PL B565 61	A. Heister *et al.*	(ALEPH, DELPHI, L3+)
ALEPH, DELPHI, L3, OPAL, LEP Higgs Working Group				
ABAZOV	02B	PRL 88 151803	V.M. Abazov *et al.*	(D0 Collab.)
ABBIENDI	02C	PL B526 221	G. Abbiendi *et al.*	(OPAL 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.*	
BORZUMATI	02	PL B549 170	F.M. Borzumati, A. Djouadi	
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.)
HEISTER	02P	PL B543 1	A. Heister *et al.*	(ALEPH Collab.)
ABBIENDI	01E	EPJ C18 425	G. Abbiendi *et al.*	(OPAL Collab.)
ABBIENDI	01Q	PL B520 1	G. Abbiendi *et al.*	(OPAL Collab.)
ABREU	01F	PL B507 89	P. Abreu *et al.*	(DELPHI Collab.)
ACHARD	01C	PL B517 319	P. Achard *et al.*	(L3 Collab.)
AFFOLDER	01H	PR D64 092002	T. Affolder *et al.*	(CDF Collab.)
BARATE	01C	PL B499 53	R. Barate *et al.*	(ALEPH Collab.)
BARATE	01E	EPJ C19 213	R. Barate *et al.*	(ALEPH Collab.)
GAMBINO	01	NP B611 338	P. Gambino, M. Misiak	
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.)
AFFOLDER	00I	PR D62 012004	T. Affolder *et al.*	(CDF Collab.)
BARATE	00L	PL B487 241	R. Barate *et al.*	(ALEPH Collab.)
PDG	00	EPJ C15 1	D.E. Groom *et al.*	
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.)
ABBOTT	99E	PRL 82 4975	B. Abbott *et al.*	(D0 Collab.)
ABREU	99P	PL B458 431	P. Abreu *et al.*	(DELPHI Collab.)
ACKERSTAFF	99D	EPJ C8 3	K. Ackerstaff *et al.*	(OPAL Collab.)
CARENA	99B	hep-ph/9912223	M.S. Carena *et al.*	
CERN-TH/99-374				
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-G...	98B	PR D57 7045	M.C. Gonzalez-Garcia, S.M. Lietti, S.F. Novaes	
PDG	98	EPJ C3 1	C. Caso *et al.*	
ABE	97L	PRL 79 357	F. Abe *et al.*	(CDF Collab.)
ACCIARRI	97F	PL B396 327	M. Acciarri *et al.*	(L3 Collab.)
AMMAR	97B	PRL 78 4686	R. Ammar *et al.*	(CLEO Collab.)
COARASA	97	PL B406 337	J.A. Coarasa, R.A. Jimenez, J. Sola	
GORDEEV	97	PAN 60 1164	V.A. Gordeev *et al.*	(PNPI)
		Translated from YAF 60 1291.		
GUCHAIT	97	PR D55 7263	M. Guchait, D.P. Roy	(TATA)
KRAWCZYK	97	PR D55 6968	M. Krawczyk, J. Zochowski	(WARS)
MANGANO	97	PL B410 299	M. Mangano, S. Slabospitsky	
STAHL	97	ZPHY C74 73	A. Stahl, H. Voss	(BONN)
ALEXANDER	96H	ZPHY C71 1	G. Alexander *et al.*	(OPAL Collab.)
PDG	96	PR D54 1	R. M. Barnett *et al.*	
ABREU	95H	ZPHY C67 69	P. Abreu *et al.*	(DELPHI Collab.)
ALAM	95	PRL 74 2885	M.S. Alam *et al.*	(CLEO Collab.)
ASAKA	95	PL B345 36	T. Asaka, K.I. Hikasa	(TOHOK)
BUSKULIC	95	PL B343 444	D. Buskulic *et al.*	(ALEPH Collab.)
GROSSMAN	95B	PL B357 630	Y. Grossman, H. Haber, Y. Nir	
GROSSMAN	94	PL B332 373	Y. Grossman, Z. Ligeti	
STAHL	94	PL B324 121	A. Stahl	(BONN)
ACTON	92M	PL B295 347	P.D. Acton *et al.*	(OPAL Collab.)
PICH	92	NP B388 31	A. Pich, J. Prades, P. Yepes	(CERN, CPPM)
SWARTZ	90	PRL 64 2877	M.L. Swartz *et al.*	(Mark II Collab.)