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H^0 (Higgs Boson) MASS LIMITS

These limits apply to the Higgs boson of the three-generation Standard Model with the minimal Higgs sector. Limits that depend on the $Ht\overline{t}$ coupling may also apply to a Higgs boson of an extended Higgs sector whose couplings to up-type quarks are comparable to or larger than those of the standard one-doublet model H^0 couplings.

For comprehensive reviews, see Gunion, Haber, Kane, and Dawson, "The Higgs Hunter's Guide," (Addison-Wesley, Menlo Park, CA, 1990) and R.N. Cahn, Reports on Progress in Physics **52** 389 (1989). For a review of theoretical bounds on the Higgs mass, see M. Sher, Physics Reports (Physics Letters C) **179** 273 (1989).

Limits from Coupling to $Z/W^{\pm}$

VALUE (GeV)	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
>58.4	**(CL = 95%) OUR LIMIT**			
>55.7	95	[1] ABREU 94G	DLPH	$Z \to H^0 Z^*$
>56.9	95	[2] AKERS 94B	OPAL	$Z \to H^0 Z^*$
>57.7	95	[3] ADRIANI 93C	L3	$Z \to H^0 Z^*$
>58.4	95	[4] BUSKULIC 93H	ALEP	$Z \to H^0 Z^*$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>60	95	[5] GROSS 93	RVUE	$Z \to H^0 Z^*$
		[6] ABREU 92D	DLPH	$Z \to H^0 \gamma$
>38	95	[7] ABREU 92J	DLPH	$Z \to H^0 Z^*$
>52	95	[8] ADEVA 92B	L3	$Z \to H^0 Z^*$
		[9] ADRIANI 92F	L3	$Z \to H^0 \gamma$
>48	95	[10] DECAMP 92	ALEP	$Z \to H^0 Z^*$
> 0.21	99	[11] ABREU 91B	DLPH	$Z \to H^0 Z^*$
>11.3	95	[12] ACTON 91	OPAL	$H^0 \to$ anything
>41.8	95	[13] ADEVA 91	L3	$Z \to H^0 Z^*$
		[14] ADEVA 91D	L3	$Z \to H^0 \gamma$
none 3–44	95	[15] AKRAWY 91	OPAL	$Z \to H^0 Z^*$
none 3–25.3	95	[16] AKRAWY 91C	OPAL	$Z \to H^0 Z^*$
none 0.21–0.818	90	[17] ABE 90E	CDF	$p\overline{p} \to (W^{\pm}, Z) + H^0 + X$
none 0.846–0.987	90	[17] ABE 90E	CDF	$p\overline{p} \to (W^{\pm}, Z) + H^0 + X$
none 0.21–14	95	[18] ABREU 90C	DLPH	$Z \to H^0 Z^*$
none 2–32	95	[19] ADEVA 90H	L3	$Z \to H^0 Z^*$
> 2	99	[20] ADEVA 90N	L3	$Z \to H^0 Z^*$
none 3.0–19.3	95	[21] AKRAWY 90C	OPAL	$Z \to H^0 Z^*$
> 0.21	95	[22] AKRAWY 90P	OPAL	$Z \to H^0 Z^*$
none 0.032–15	95	[23] DECAMP 90	ALEP	$Z \to H^0 Z^*$
none 11–24	95	[24] DECAMP 90H	ALEP	$Z \to H^0 Z^*$
> 0.057	95	[25] DECAMP 90M	ALEP	$Z \to H^0 ee, H^0 \mu\mu$
none 11–41.6	95	[26] DECAMP 90N	ALEP	$Z \to H^0 Z^*$

[1] ABREU 94G searched for $Z \to H^0 + (e^+e^-, \mu^+\mu^-, \tau^+\tau^-, \nu\overline{\nu})$ with $H^0 \to q\overline{q}$. Four $\ell^+\ell^-$ candidates were found (all yielding low mass) consistent with expected backgrounds.

[2] AKERS 94B searched for $Z \to H^0 + (e^+e^-, \mu^+\mu^-, \nu\overline{\nu})$ with $H^0 \to q\overline{q}$. One $\nu\overline{\nu}$ and one $\mu^+\mu^-$ candidate were found consistent with expected backgrounds.

[3] ADRIANI 93C searched for $Z \to H^0 + (\nu\overline{\nu}, e^+e^-, \mu^+\mu^-)$ with H^0 decaying hadronically or to $\tau\overline{\tau}$. Two e^+e^- and one $\mu^+\mu^-$ candidates are found consistent with expected background.

[4] BUSKULIC 93H searched for $Z \to H^0\nu\overline{\nu}$ (acoplanar jets) and $Z \to H^0 + (e^+e^-, \mu^+\mu^-)$ (lepton pairs in hadronic events).

[5] GROSS 93 combine data taken by four LEP experiments through 1991.

[6] ABREU 92D give $\sigma(e^+e^- \to Z \to H^0\gamma)\cdot B(H^0 \to \text{hadrons}) <8$ pb (95% CL) for $m_{H^0} <75$ GeV and $E_\gamma >8$ GeV.

[7] ABREU 92J searched for $Z \to H^0 + (ee, \mu\mu, \tau\tau, \nu\overline{\nu})$ with $H^0 \to q\overline{q}$. Only one candidate was found, in the channel ee + 2jets, with a dijet mass 35.4 ± 5 GeV/c^2, consistent with the expected background of 1.0 ± 0.2 events in the 3 channels e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$, and of 2.8 ± 1.3 events in all 4 channels. This paper excludes 12–38 GeV. The range 0–12 GeV is eliminated by combining with the analyses of ABREU 90C and ABREU 91B.

[8] ADEVA 92B searched for $Z \to H^0 + (\nu\overline{\nu}, ee, \mu\mu, \tau\tau)$ with $H^0 \to$ anything, $Z \to H^0 + \tau\tau$ with $H^0 \to q\overline{q}$, and $Z \to H^0 + q\overline{q}$ with $H^0 \to \tau\tau$. The analysis excludes the range $30 < m_{H^0} < 52$ GeV.

[9] ADRIANI 92F give $\sigma(e^+e^- \to Z \to H^0\gamma)\cdot B(H^0 \to \text{hadrons}) <$(2–10) pb (95% CL) for m_{X^0} = 25–85 GeV. Using $\sigma(e^+e^- \to Z) = 30$ nb, we obtain $B(Z \to H^0\gamma)B(H^0 \to \text{hadrons}) <(0.7\text{–}3) \times 10^{-4}$ (95% CL).

[10] DECAMP 92 searched for most possible final states for $Z \to H^0 Z^*$.

[11] ABREU 91B searched for $Z \to H^0 + \ell\overline{\ell}$ with missing H^0 and $Z \to H^0 + (\nu\overline{\nu}, \ell\overline{\ell}, q\overline{q})$ with $H^0 \to ee$.

[12] ACTON 91 searched for $e^+e^- \to Z^* H^0$ where $Z^* \to e^+e^-, \mu^+\mu^-$, or $\nu\overline{\nu}$ and $H^0 \to$ anything. Without assuming the minimal Standard Model mass-lifetime relationship, the limit is $m_{H^0} > 9.5$ GeV.

[13] ADEVA 91 searched for $Z \to H^0 + (\mu\mu, ee, \nu\overline{\nu})$. This paper only excludes $15 < m_{H^0} < 41.8$ GeV. The 0–15 GeV range is excluded by combining with the analyses of previous L3 papers.

[14] ADEVA 91D obtain a limit $B(Z \to H^0\gamma)\cdot B(H^0 \to \text{hadrons}) < 4.7 \times 10^{-4}$ (95%CL) for m_{H^0} = 30–86 GeV. The limit is not sensitive enough to exclude a standard H^0.

[15] AKRAWY 91 searched for the channels $Z \to H^0 + (\nu\overline{\nu}, ee, \mu\mu, \tau\tau)$ with $H^0 \to q\overline{q}, \tau\tau$, and $Z \to H^0 q\overline{q}$ with $H^0 \to \tau\tau$.

[16] AKRAWY 91C searched the decay channels $Z \to H^0 + (\nu\overline{\nu}, ee, \mu\mu)$ with $H^0 \to q\overline{q}$.

[17] ABE 90E looked for associated production of H^0 with $W^{\pm}$ or Z in $p\overline{p}$ collisions at $\sqrt{s}$ = 1.8 TeV. Searched for H^0 decays into $\mu^+\mu^-$, $\pi^+\pi^-$, and K^+K^-. Most of the excluded region is also excluded at 95% CL.

[18] ABREU 90C searched for the channels $Z \to H^0 + (\nu\overline{\nu}, ee, \mu\mu)$ and $H^0 + q\overline{q}$ for $m_H < 1$ GeV.

[19] ADEVA 90H searched for $Z \to H^0 + (\mu\mu, ee, \nu\overline{\nu})$.

[20] ADEVA 90N looked for $Z \to H^0 + (ee, \mu\mu)$ with missing H^0 and with $H^0 \to ee, \mu\mu, \pi^+\pi^-, K^+K^-$.

[21] AKRAWY 90C based on 825 nb^{-1}. The decay $Z \to H^0\nu\overline{\nu}$ with $H^0 \to \tau\overline{\tau}$ or $q\overline{q}$ provides the most powerful search means, but the quoted results sum all channels.

[22] AKRAWY 90P looked for $Z \to H^0 + (ee, \mu\mu)$ (H^0 missing) and $Z \to H^0\nu\overline{\nu}$, $H^0 \to e^+e^-, \gamma\gamma$.

[23] DECAMP 90 limits based on 11,550 Z events. They searched for $Z \to H^0 + (\nu\overline{\nu}, ee, \mu\mu, \tau\tau, q\overline{q})$. The decay $Z \to H^0\nu\overline{\nu}$ provides the most powerful search means, but the quoted results sum all channels. Different analysis methods are used for $m_{H^0} < 2m_\mu$ where Higgs would be long-lived. The 99% confidence limits exclude m_{H^0} = 0.040–12 GeV.

[24] DECAMP 90H limits based on 25,000 $Z \to$ hadron events.

[25] DECAMP 90M looked for $Z \to H^0\ell\ell$, where H^0 decays outside the detector.

[26] DECAMP 90N searched for the channels $Z \to H^0 + (\nu\overline{\nu}, ee, \mu\mu, \tau\tau)$ with $H^0 \to$ (hadrons, $\tau\tau$).

Limits from Other Techniques

H^0 Indirect Mass Limits from Electroweak Analysis

VALUE (GeV)	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$35\ ^{+205}_{-\ 26}$		[27] ELLIS 94	RVUE	
$73\ ^{+178}_{-\ 13}$		[28] BLONDEL 93	RVUE	
$10\ ^{+\ 25}_{-\ \ 8}$		[29] ELLIS 93B	RVUE	
$10\ ^{+\ 60}_{-\ \ 8}$		[30] NOVIKOV 93B	RVUE	
		[31] DELAGUILA 92B	RVUE	
> 1.4	68	[32] ELLIS 92	RVUE	Electroweak
$25\ ^{+275}_{-\ 19}$		[33] ELLIS 92E	RVUE	
$50\ ^{+353}_{-\ \ 0}$		[34] RENTON 92	RVUE	
		[35] SCHAILE 92	RVUE	

[27] ELLIS 94 fit to LEP, SLD, W-mass, and neutrino data available in the summer of 1993. The fit to m_H, m_t, and α_s yields $m_t = 140^{+21}_{-22}$ GeV and $\alpha_s(m_Z) = 0.116^{+0.007}_{-0.006}$.

[28] BLONDEL 93 perform two dimensional ($m_t - m_H$) fit to LEP electroweak data available in the spring of 1993. $\alpha_s = 0.117 \pm 0.005$ is used and $m_t >108$ GeV, $m_H > 62.5$ GeV imposed. $m_{H^0} = 1$ TeV is compatible with the data within two standard deviations.

[29] ELLIS 93B fit to LEP and neutrino data available in the summer of 1993. m_t is adjusted to minimize χ^2 and $\alpha_s(m_Z) = 0.123 \pm 0.006$ is used. 95% CL limit for $m_H <250$ GeV is claimed.

[30] NOVIKOV 93B use a subset of the most accurate and "gluon-free" data available in the spring of 1993. They use m_W, $\Gamma(\ell\ell)$, and $A^{\ell\ell}_{FB}$.

[31] DELAGUILA 92B perform two dimensional ($m_t - m_H$) fit to various LEP, neutrino, eH, and $p\overline{p}$ data available through 1991 with direct limits on m_t, m_H. The result $m_H = 65^{+245}_{-\ \ 4}$ is not expected from the statistical sensitivity of the data but due to deviation of the data from the Standard Model expectation.

[32] ELLIS 92 result is from a fit to electroweak data from LEP and elsewhere. They also find $m_H <160$ GeV at 68%CL and $0.5 < m_H <1500$ GeV at 90%CL with m_t unconstrained.

[33] ELLIS 92E perform fit to electroweak data available in the spring of 1992. m_t is adjusted to minimize χ^2 and $\alpha_s(m_Z) = 0.118 \pm 0.008$ is used.

[34] RENTON 92 use electroweak data available in 1991 and require $m_H >50$ GeV. The constraint $\alpha_s = 0.114 \pm 0.007$ was used.