[35] SCHAILE 92 performs fit to LEP electroweak data (as of summer 1991) as well as m_W (UA2/CDF) and νN (CDHS/CHARM). The fit with the constraint $m_H > 50$ GeV gives $m_H = 50^{+192}_{-0}$ GeV. However, the m_H dependence of the χ^2 is not consistent from that expected from the present statistics and the sensitivity to m_H arises from the fact that the measured values of g_A and A^b_{FB} deviate from the Standard Model expectation. Therefore, the result is not considered to be significant.

From Quarkonium Decay

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>0.086	90	[36] ANTREASYAN 90C	CBAL	$\Upsilon(1S) \rightarrow H^0\gamma$
none 0.29–0.57	90	[37] ALBRECHT 89	ARG	$\Upsilon(1S) \rightarrow H^0\gamma$ $(H^0 \rightarrow \pi^+\pi^-)$
none 0.21–5	90	[38] LEE-FRANZINI 88	CUSB	$\Upsilon(1S,3S) \rightarrow \gamma H^0$
		[39] DRUZHININ 87	ND	$\phi \rightarrow \gamma H^0$ $(H^0 \rightarrow \pi^0\pi^0)$

[36] ANTREASYAN 90C obtain $B(\Upsilon(1S) \rightarrow H^0\gamma) < 3.5\times10^{-5}$ at 90% CL for $m_{H^0} < 2m_e$ and similar limits for heavier Higgs masses. The listed limit assumes the QCD/relativistic reduction factor for the width of 0.5. The limit is reduced to 39 MeV if 0.25 is used instead.

[37] ALBRECHT 89 give a limit $B(\Upsilon(1S) \rightarrow H^0\gamma)\cdot B(H^0 \rightarrow \pi^+\pi^-) < 3$–$4.5 \times 10^{-5}$ for $m_{H^0} = 290$–570 MeV, which is lower than the predition including first order QCD corrections and assuming $B(H^0 \rightarrow \pi^+\pi^-) > 45\%$.

[38] LEE-FRANZINI 88 presents updated results from the CUSB experiment (see FRANZINI 87 for more details). First order QCD correction included with $\alpha_s \simeq 0.2$ ($\Lambda = 0.2$ GeV and $n(f) = 4$). The order α_s correction reduced the rate for $\Upsilon(1S) \rightarrow H^0\gamma$ by a factor of 2 (yielding these limits). The impact of order α_s^2 and of relativistic corrections are unknown. If they amounted to another factor of 2 suppression, the above limit would be essentially eliminated.

[39] DRUZHININ 87 sets limit $B(\phi \rightarrow \gamma H^0)\cdot B(H^0 \rightarrow \pi^0\pi^0) < 8 \times 10^{-5}$ at CL=90% for $m_{H^0} = 0.6$–1 GeV which is still far from the standard Higgs model prediction and does not exclude the existence of light Higgs bosons.

From *B* Decay

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
none 0.21–3.57		[40] DAWSON 90	RVUE	$B \rightarrow \mu^+\mu^- X$; $B \rightarrow K(\mu^+\mu^-, \pi^+\pi^-, K^+K^-)$
none 0.21–1.0	90	[41] ALAM 89B	CLEO	$B \rightarrow H^0 K$, $(H^0 \rightarrow \mu^+\mu^-, \pi^+\pi^-)$
none 1.0–3.6	90	[41] ALAM 89B	CLEO	$B \rightarrow H^0 X$ $(H^0 \rightarrow \mu^+\mu^-)$
none 3.6–4.6		[42] EILAM 89	RVUE	$B \rightarrow H^0 X$ $(H^0 \rightarrow \mu^+\mu^-)$
none 0.211–0.700		[43] RABY 89	RVUE	$B \rightarrow \mu^+\mu^- X$ $m_{top} > 80$ GeV
none 0.07–0.21	90	[44] SNYDER 89	MRK2	$B \rightarrow H^0 X$ $(H^0 \rightarrow e^+e^-)$
none 0.00103–3.57		[43] CHIVUKULA 88	RVUE	$B \rightarrow H^0 X$, $m(\text{top}) > 80$ GeV
none 2–3.7		[43] GRINSTEIN 88	RVUE	$B \rightarrow H^0 X$, $m(\text{top}) > 80$ GeV

[40] Based on ALTHOFF 84G, ALAM 89B, and ALBRECHT 87D. Some processes considered require the assumption $B(B \rightarrow H^0 K)/B(B \rightarrow H^0 X) > 0.01$. Other processes require theoretical assumptions regarding $B(H \rightarrow \pi^+\pi^-)$ when considering masses in the interval 0.9–1.2 GeV.

[41] ALAM 89B searched for inclusive and exclusive decays of B mesons into H^0 and can exclude the mass range $2m_\mu$–$2m_\tau$ with a wide margin provided $m_t \gtrsim m_W$, possibly except for masses near $\chi_0(3410)$, where the mixing effect can reduce $B(H^0 \rightarrow \mu^+\mu^-)$ significantly.

[42] EILAM 89 assume $m_{top} > 90$ GeV and vary $|V_{ub}/V_{cb}|^2$ from 0 to 0.026.

[43] Limits assume $m(\text{top}) > 80$ GeV and $|V_{ts}V^*_{tb}/V_{cb}| \approx 1$. CHIVUKULA 88 excludes m_{H^0} between $2m_e$ and $2m_\tau$ from the limits on $B \rightarrow \mu^+\mu^- + X$ by taking the $B(H^0 \rightarrow \mu^+\mu^-)$ estimate of VOLOSHIN 86. GRINSTEIN 88 argues that this estimate of VOLOSHIN 86 is unreliable, and excludes m_{H^0} between 2 GeV and 3.7 GeV where perturbative QCD is used to estimate $B(H^0 \rightarrow \mu^+\mu^-)$.

[44] SNYDER 89 exclude the mass range 70–210 MeV with a wide margin provided that $m_t \gtrsim m_W$. A limit $B(B \rightarrow H^0 X)\cdot B(H^0 \rightarrow e^+e^-) < 22\%$ (90% CL) is given for $m_{H^0} = 50$ MeV.

From *K* Decay

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>0.026	90	[45] ATIYA 90	CNTR	$K^+ \rightarrow \pi^+ H^0$
		[46] ATIYA 90B	CNTR	$K^+ \rightarrow \pi^+ H^0$, $H^0 \rightarrow \gamma\gamma$
none 0.012–0.211	90	[47] BARR 90	NA31	$K^0_L \rightarrow \pi^0 H^0$ $(H^0 \rightarrow e^+e^-)$
>0.32		[48] DAWSON 90	RVUE	K decays
>0.3		[49] LEUTWYLER 90	RVUE	$K^+ \rightarrow \pi^+ H^0$
none 0.22–0.32		[50] ATIYA 89	CNTR	$K^+ \rightarrow \pi^+ H^0$ $(H^0 \rightarrow \mu^+\mu^-)$
>0.28		[51] CHENG 89	RVUE	$K^\pm \rightarrow \pi^\pm H$
>0.36		[52] CHIVUKULA 88	RVUE	$K \rightarrow \pi^+ H^0$
	90	[53] BAKER 87	CALO	$K^\pm \rightarrow \pi^\pm H^0$ $(H^0 \rightarrow e^+e^-)$
none 0.05–0.211		[54] WILLEY 86	RVUE	$K^\pm \rightarrow \pi^\pm H^0$ $(H^0 \rightarrow e^+e^-)$

[45] ATIYA 90 sets limits on $B(K^+ \rightarrow \pi^+ H^0)$ varying from $< 6.4 \times 10^{-9}$ for $m_{H^0} \approx 0$ MeV to $< 10^{-6}$ for $m_{H^0} = 26$ MeV.

[46] ATIYA 90B give 90% CL limits on $B(K^+ \rightarrow \pi^+ H^0)\cdot B(H^0 \rightarrow \gamma\gamma)$ for $m_{H^0} < 100$ MeV ranging from 10^{-4} to 10^{-7} depending on the mass.

[47] BARR 90 set m_{H^0}-dependent limits on $B(K^0_L \rightarrow \pi^0 H^0)$ in the region where $B(H^0 \rightarrow e^+e^-) \approx 1$. The limit varies from $B(K^0_L \rightarrow \pi^0 H^0) < 10^{-7}$ at $m_{H^0} = 12$ MeV to $< 2 \times 10^{-8}$ for $50 \le m_{H^0} \le 211$ MeV. BARR 90 allow for nonzero H^0 lifetime.

[48] Based on ASANO 81B, YAMAZAKI 84, BAKER 87, ATIYA 89, and BARR 90. DAWSON 90 used theoretical calculations and various assumptions such as $m_t > 80$ GeV and Im $V^*_{td}V_{ts} > 0.2\sin^5\theta_c$.

[49] LEUTWYLER 90 give a consistent analysis of the $K \rightarrow \pi H^0$ amplitude based on chiral theory and find that all contributions except the t-quark loop are unimportant numerically provided the t-quark mass is of order or bigger than 100 GeV. Hence, a light Higgs can probably be ruled out.

[50] ATIYA 89 give a limit $B(K^+ \rightarrow \pi^+ H^0)\cdot B(H^0 \rightarrow \mu^+\mu^-) < 1.5 \times 10^{-7}$ (90% CL) for $m_{H^0} = 220$–320 MeV, which is lower than the prediction unless there is an accidental cancellation in the CP-conserving part of the amplitude and the CP-violating part is unexpectedly small. See WILLEY 89 and CHENG 89.

[51] CHENG 89 concludes even if real part of $K^+ \rightarrow \pi^+ H$ amplitude is cancelled accidentally, the imaginary contribution alone rules out $m_H < 2m_\pi$.

[52] CHIVUKULA 88 uses chiral perturbation theory to estimate $K \rightarrow \pi^+ H^0$ amplitudes with a conservative sign assignment for the relative sign of the $\Delta I = 1/2$ term, and exclude m_{H^0} below 0.36 GeV barring cancellation among terms, by using the limits on $K \rightarrow \pi^+ X$ with $X = \mu^+\mu^-$, e^+e^-, or missing particles. For a criticism see DAWSON 90.

[53] BAKER 87 sets limit $B(K^\pm \rightarrow \pi^\pm H^0)\cdot B(H^0 \rightarrow e^+e^-) < 8 \times 10^{-7}$ at CL=90% for $m_{H^0} < 100$ MeV if H^0 travels much less than 1.4 cm in the lab frame ($p(K^+) = 5.8$ GeV). The expected lifetime of the standard H^0 is too long to be effectively detected by the experiment and their limit on the branching ratio is significantly weakened accordingly. In view of the uncertainty in the theoretical prediction for $B(K \rightarrow \pi H)$, no definite conclusion can be drawn from the result. See also DAWSON 90.

[54] WILLEY 86 re-examined the theoretical estimate of the decay $K^\pm \rightarrow \pi^\pm H^0$ rate via the one-loop sdH^0 coupling. The experimental bound $B(K \rightarrow \pi\mu\mu) < 2.4 \times 10^{-6}$ is not strong enough to rule out $2m_\mu < m_{H^0} < 2m_{\pi^0}$. For a criticism see DAWSON 90.

From Coupling with Nucleons

Some of the experiments for a light Higgs utilize its coupling with nucleons. We parameterize the Higgs-nucleon coupling (which is dominantly isoscalar) as $g_{HNN} = \eta_{HNN}(\sqrt{2}G_F)^{1/2}\, m_N$. The limits depend on the value of η_{HNN} used. Shifman *et al.* [Physics Letters **78B** 443 (1978)] obtained $\eta_{HNN} = 0.22$ assuming three heavy flavors. More recently, T.P. Cheng [Physical Review **D38** 2869 (1988)], H.-Y. Cheng [Physics Letters **B219** 347 (1989)], and Barbieri and Curci [Physics Letters **B219** 503 (1989)] took into account the strange-quark content of the proton as well as the heavy quark effects, and derived $\eta_{HNN} = 0.56$.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
>0.0009	95	[55] BLUEMLEIN 92	BDMP	$pN \rightarrow H^0 X$, $H^0 Z \rightarrow \ell^+\ell^- Z$ $(\ell=e,\mu)$
>0.0128	90	[56] LEEB 92	RVUE	$nN \rightarrow nN$
none 0.001–0.08	95	BLUEMLEIN 91	BDMP	$pN \rightarrow H^0 X$ $(H^0 \rightarrow e^+e^-, 2\gamma)$
>0.018		[57] GRIFOLS 89	RVUE	$\sigma_{total}(n\text{Pb})$
none 0.03–0.20		[58] YEPES 89B	RVUE	$pN \rightarrow H^0 X$ $(H^0 \rightarrow e^+e^-)$
>0.010	68	[59] BELTRAMI 86	SPEC	Muonic atoms
none 0.003–0.012	95	[60] FREEDMAN 84	CNTR	$\text{He}^* \rightarrow \text{He}H^0$ $(H^0 \rightarrow e^+e^-)$
none 0.00103–0.00584		[61] MUKHOPAD... 84	RVUE	$\text{O}^* \rightarrow \text{O}H^0$ $(H^0 \rightarrow e^+e^-)$
		[62] HOFFMAN 83	CNTR	$\pi p \rightarrow nH^0$ $(H^0 \rightarrow e^+e^-)$
>0.006		[63] BARBIERI 75	RVUE	$nN \rightarrow nN$

[55] BLUEMLEIN 92 exclude very light Standard Model Higgs using bremsstrahlung Higgs production from beam dump followed by Bethe-Heitler production of lepton pairs by H^0 on nuclei. If combined with BLUEMLEIN 91, the range $m_H < 0.08$ GeV is excluded.

[56] LEEB 92 use the neutron-lead total cross section measurement by SCHMIEDMAYER 91 as well as neutron optics data to obtain bounds on new long-range neutron interactions. The limit uses $\eta_{HNN} = 0.56$.

[57] GRIFOLS 89 use the neutron-lead total cross-section measurement at kinetic energies of 50 eV – 50 keV by SCHMIEDMAYER 88 and argue that the agreement of the measured energy dependence with the prediction of a hard-core potential model is lost by light-Higgs exchange. The limit of 18 MeV is obtained for $\eta_{HNN} = 0.56$ and is reduced to 12 MeV for $\eta_{HNN} = 0.22$. LEEB 92 argue against the use of a hard-core potential and obtain a weaker limit.

[58] YEPES 89B reanalyzed a Fermilab experiment (BECHIS 78), which looked for a long-lived neutral lepton and found none, and argues that their limit is many orders of magnitude lower than expected from low-mass Higgs bremsstrahlung production followed by the decay to e^+e^-.