[53] The 95%CL upper limit is 218 GeV.

[54] DELAGUILA 91C study bound on m_t in the presence of extra Z' (Z_{LR} and Z_χ) from various electroweak data. The upper bound on m_t is more strict for lower Z' masses. See their Fig. 2. See also DELAGUILA 92.

[55] GONZALEZ-GARCIA 91 result is based on low-energy neutral current data, Z mass and widths, m_W from ABE 90G. m_{H^0} = 100 GeV assumed.

[56] HIOKI 91 uses m_Z, $\Gamma_{\text{total}}(Z)$, and m_W. m_{H^0} = 100 GeV, α_s = 0.12 assumed. For m_{H^0} = 1 TeV, one finds $m_t = 162^{+43}_{-46}$ GeV.

[57] LANGACKER 91 is a fit to various electroweak data. The second error is from $m_{H^0} = 250^{+750}_{-200}$ GeV. $\alpha_s = 0.12 \pm 0.02$ used. The 95%CL upper limit is 182 GeV [for m_{H^0} = 1 TeV]. For arbitrary Higgs structure, one obtains m_t < 310 GeV.

[58] ADACHI 90F limit is from R at PEP, PETRA, and TOPAZ at TRISTAN. Top mass dependence enters via radiative correction. Minimal standard model with m_Z = 91.1 GeV, m_{H^0} = 100 GeV assumed. $\Lambda_{\overline{\text{MS}}}$ is varied in the fit.

[59] ADEVA 90I analysis is based on m_Z measured by L3 and $\sin^2\theta_W = 0.2284 \pm 0.0043$ determined from m_W/m_Z and νN scattering data. 40 < m_H < 1000 GeV assumed. The 1σ range is $m_t = 130^{+38}_{-42}$ GeV.

[60] BARGER 90C limit is a fit using only LEP and m_W data. m_{H^0} = 100 GeV assumed. The most likely value is m_t = 151 GeV. The limit increases to 225 GeV for m_H = 1000 GeV.

[61] BLONDEL 90 limit comes from $R_{\overline{\nu}} = \sigma^{\text{NC}}(\overline{\nu}N) \,/\, \sigma^{\text{CC}}(\overline{\nu}N)$ and R_ν. Comparison of R_ν and m_W (the latter from ALBAJAR 89 and ANSARI 87) gives an independent limit m_t < 240 GeV (90%CL).

[62] DECAMP 90P result is from m_Z, $\Gamma(Z \rightarrow \ell\ell)$, and m_W/m_Z from UA2 (ALITTI 90B), m_W from CDF (APS conf. '90), and νN neutral current data from CDHS and CHARM.

[63] ELLIS 90B limit is a fit to various electroweak data. $m_{H^0} = m_Z$ assumed. m_c = 1.45 GeV is used for νN data.

[64] KENNEDY 90 limit is a fit to neutral current data, W, Z masses, and Z widths. $m_H = m_Z$ assumed. For m_H = 1 TeV, the limit is 212 GeV. For nonminimal Higgs sector (with $\rho \neq 1$), one obtains m_t < 350 GeV (90%CL).

[65] ELLIS 89B limit is a fit to various electroweak data. $m_{H^0} = m_Z$ assumed. m_c = 1.45 GeV is used for νN data. Superseded by ELLIS 90B.

[66] LANGACKER 89 limit is a fit to various electroweak data. m_{H^0} = 100 GeV assumed. The 90%CL upper limit is 190(210) GeV for m_{H^0} = 100(1000) GeV.

[67] COSTA 88 limit is a fit to various electroweak data. $m_{H^0} = m_Z$ assumed. m_c = 1.5 GeV is used for νN data.

[68] ELLIS 88C limit is a fit to neutral current data and W, Z masses. $m_{H^0} = m_Z$ assumed. m_c = 1.45 GeV is used for νN data. Varying m_c relaxes the limit to 185 GeV. Superseded by ELLIS 89B.

[69] FOGLI 88 limit is a fit to neutrino deep-inelastic scattering data.

[70] AMALDI 87 limit is a fit to various electroweak data. m_{H^0} < 100 GeV assumed.

MASS LIMITS for Top Hadrons in e^+e^- Collisions

The last column specifies measured quantities: S = Sphericity, T = Thrust.

For limits prior to 1987, see our 1990 edition, Physics Letters **B239**, p. VII.167 (1990).

VALUE (GeV)	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
>45.8	95	[71] DECAMP 90F	ALEP	isolated charged particle and aplanarity
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		[72] ADRIANI 93G	L3	Quarkonium
>41.8	95	ADRIANI 93M	L3	$\Gamma(Z)$
>43	95	[71] ABREU 91F	DLPH	$\Gamma(Z)$
>30.2	95	ABE 90D	VNS	Event shape
>44.5	95	[71] ABREU 90D	DLPH	Event shape
>44.0	95	[71,73] ABREU 90D	DLPH	$t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$, $\tau^+\nu$
>33.5	95	[74] ABREU 90D	DLPH	$\Gamma(Z \rightarrow$ hadrons)
>44.5	95	[75] AKRAWY 90B	OPAL	Acoplanarity
>44.3	95	[76] AKRAWY 90B	OPAL	$t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$, $\tau\nu$
>40.7	95	[77] ABRAMS 89C	MRK2	Event shape
>42.5	95	ABRAMS 89C	MRK2	$t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$
>29.9	95	[78] ADACHI 89C	TOPZ	μ
>29.9	95	[79] ENO 89	AMY	μ, e
>25.8	95	[80] ADACHI 88	TOPZ	R, T, Acoplanarity
>25.9	95	[81] IGARASHI 88	AMY	$T + (\mu,e)$
>25.9	95	[82] SAGAWA 88	AMY	R, T
none E_{cm}=50	95	[83] ABE 87	VNS	R, T, Acoplanarity
>25.5	95	[84] YOSHIDA 87	VNS	R, T, Acoplanarity

[71] Search was near the Z peak at LEP.

[72] ADRIANI 93G search for vector quarkonium states near Z and give limit on quarkonium-Z mixing parameter δm^2 <(10–30) GeV^2 (95%CL) for the mass 88–94.5 GeV. Using Richardson potential, a 1S toponium state is excluded for the mass range 87.9–88.7, 89.1–94.3 GeV. This range is very sensitive to the potential choice.

[73] Assumed $m_{H^+} < m_t - 6$ GeV.

[74] Superseded by ABREU 91F.

[75] AKRAWY 90B search was restricted to data near the Z peak at E_{cm} = 91.26 GeV at LEP. The excluded region is between 23.4 and 44.5 GeV if no H^+ decays exist.

[76] AKRAWY 90B limit applies for any H^+ branching ratio B($c\overline{s}$). Limit increases to 45.2 GeV if B($c\overline{s}$) = 1. The lower end of the excluded region is m_{H^+} + 5 GeV.

[77] The ABRAMS 89C limit from an isolated track search is 40.0 GeV.

[78] ADACHI 89C search was at E_{cm} = 56.5–60.8 GeV at TRISTAN using multi-hadron events accompanying muons.

[79] ENO 89 search at E_{cm} = 50–60.8 GeV at TRISTAN.

[80] ADACHI 88 set limit σ(top) < 8.2 pb at CL=95% for top-flavored-hadron production from event shape analyses at E_{cm} = 52 GeV. By using the quark-parton model cross-section formula with first-order QCD corrections near the threshold, the above limit leads to a lower mass limit of 25.8 GeV at 95% confidence level for top quarks.

[81] IGARASHI 88 searches for leptons in low-thrust events and gives $\Delta R(t)$ < 0.15 (95% CL) at E_{cm} = 50–52 GeV.

[82] SAGAWA 88 set limit σ(top) < 6.1 pb at CL=95% for top-flavored hadron production from event shape analyses at E_{cm} = 52 GeV. By using the quark parton model cross-section formula near threshold, the above limit leads to lower mass bounds of 25.9 GeV for charge 2/3 quarks.

[83] ABE 87 set limit σ(top) < 16 pb at CL=95% for top-flavored hadron production, which should be compared with the full top-quark production cross section of 45.9 pb.

[84] YOSHIDA 87 set limit σ(top) < 17 pb at CL=95% for top-flavored hadron production from event shape analyses at E_{cm} = 52 GeV. This limit should be compared with the full top-quark production cross section of 34 pb, which takes into account the effect of weak neutral current but neglects its axial-vector coupling contribution expected to be suppressed near threshold. After considering the radiative effects, top quarks of mass below 25.5 GeV can be excluded by the above limit.

REFERENCES FOR Searches for t Quark

ABACHI 94 PRL 72 2138 +Abbott, Abolins, Acharya, Adam+ (D0 Collab.)
ABE 94B PRL (to be pub.) +Albrow, Amidei, Anway-Wiese+ (CDF Collab.)
Fermilab-PUB-94-051-E
ABE 94E PR D (to be pub.) +Albrow, Amidei, Antos, Anway-Wiese+ (CDF Collab.)
Fermilab-PUB-94-097-E
Also 94F PRL (subm.) Abe, Albrow, Amidei, Antos, Anway-Weise+ (CDF Collab.)
Fermilab-PUB-94-116-E
ABREU 94 NP B418 403 +Adam, Adye, Agasi+ (DELPHI Collab.)
ACCIARRI 94 ZPHY C62 551 +Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)
AKERS 94 ZPHY C61 19 +Alexander, Allison+ (OPAL Collab.)
BUSKULIC 94 ZPHY C62 539 +Casper, De Bonis, Decamp, Ghez, Goy+ (ALEPH Collab.)
ELLIS 94 PL B324 173 +Fogli, Lisi (CERN, BARI)
LAENEN 94 PL B321 254 +Smith, van Neerven (FNAL, UTRE, LEID)
ACTON 93D ZPHY C58 219 +Alexander, Allison+ (OPAL Collab.)
ADRIANI 93G PL B313 326 +Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ADRIANI 93M PRPL 236 1 +Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ALTARELLI 93 NP B405 3 +Barbieri, Caravaglios (CERN, PISA, PISAI, SNSP)
BLONDEL 93 PL B311 346 +Verzegnassi (EPOL, TRSTT, TRSTI)
BUSKULIC 93J ZPHY C60 71 +Decamp, Goy, Lees, Minard+ (ALEPH Collab.)
BUSKULIC 93M PL B313 535 +De Bonis, Decamp+ (ALEPH Collab.)
ELLIS 93B PL B318 148 +Fogli, Lisi (CERN, BARI)
MONTAGNA 93 PL B303 170 +Nicrosini, Passarino (PAVI, TORI)
MONTAGNA 93B NP B401 3 +Piccinini, Nicrosini, Passarino, Pittau (PAVI, TORI)
NOVIKOV 93B PL B308 123 +Okun, Vysotsky, Yurov (SERP, CERN)
PASSARINO 93 PL B313 213 (TORI)
QUAST 93 MPL A8 675 (DESY)
ABE 92 PRL 68 447 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
Also 92G PR D45 3921 Abe, Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE 92I PRL 69 28 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ALITTI 92 PL B276 365 +Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
ALITTI 92B PL B276 354 +Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
ALITTI 92F PL B280 137 +Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
BANERJEE 92 IJMP A7 1853 +Ganguli, Gurtu (TATA)
BLONDEL 92 PL B293 253 +Djouadi, Verzegnassi (EPOL, DESY, TRSTI, TRSTT)
DECAMP 92B ZPHY C53 1 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.)
DELAGUILA 92 NP B372 3 del Aguila+ (CERN, GRAN, MPIM, BRUXT, MADE)
Also 91C NP B361 45 del Aguila, Moreno, Quiros (BARC, MADE)
DELAGUILA 92B NP B381 451 del Aguila, Martinez, Quiros (GRAN, CERN)
ELLIS 92 PL B274 456 +Fogli, Lisi (CERN, BARI)
ELLIS 92E PL B292 427 +Fogli, Lisi (CERN, BARI)
LANGACKER 92B PR D45 278 +Luo (PENN)
LEP 92 PL B276 247 +ALEPH, DELPHI, L3, OPAL (LEP Collabs.)
PDG 92 PR D45, 1 June, Part II Hikasa, Barnett, Stone+ (KEK, LBL, BOST+)
RENTON 92 ZPHY C56 355 (OXF)
SCHAILE 92 ZPHY C54 387 (FREIE)
ABE 91 PR D43 664 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE 91B PR D43 2070 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE 91C PR D44 29 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABREU 91F NP B367 511 +Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
ADEVA 91E ZPHY C51 179 +Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.)
ALBAJAR 91 PL B253 503 +Albrow, Allkofer, Ankoviak, Apsimon+ (UA1 Collab.)
ALBAJAR 91B PL B257 459 +Albrow, Allkofer, Ankoviak, Apsimon+ (UA1 Collab.)
ALEXANDER 91F ZPHY C52 175 +Allison, Allport, Anderson, Arcelli+ (OPAL Collab.)
BAER 91B PR D44 725 +Drees, Godbole+ (FSU, DESY, BOMB, UCD, HAWA)
DELAGUILA 91C NP B361 45 del Aguila, Moreno, Quiros (BARC, MADE)
GONZALEZ-G... 91 PL B259 365 Gonzalez-Garcia, Valle (VALE)
HIOKI 91 MPL A6 2129 (TOKU)
LANGACKER 91 PR D44 817 +Luo (PENN)
ABE 90 PRL 64 152 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE 90B PRL 64 147 +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE 90C PRL 64 142 +Amidei, Apollinari, Atac+ (CDF Collab.)
Also 91 PR D43 664 Abe, Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE 90D PL B234 382 +Amako, Arai, Asano+ (VENUS Collab.)
ABE 90G PRL 65 2243 +Amidei, Apollinari, Atac+ (CDF Collab.)
ABREU 90D PL B242 536 +Adam, Adami, Adye, Alekseev, Allaby+ (DELPHI Collab.)
ADACHI 90F PL B234 525 +Doser, Enomoto, Fujii+ (TOPAZ Collab.)
ADEVA 90I PL B249 341 +Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.)
AKESSON 90 ZPHY C46 179 +Alitti, Ansari, Ansorge, Bagnaia+ (UA2 Collab.)
AKRAWY 90B PL B236 364 +Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ALBAJAR 90B ZPHY C48 1 +Albrow, Allkofer, Andrieu, Ankoviak+ (UA1 Collab.)
ALITTI 90B PL B241 150 +Ansari, Ansorge, Autiero+ (UA2 Collab.)
ALITTI 90C ZPHY C47 11 +Ansari, Ansorge, Bagnaia+ (UA2 Collab.)
BARGER 90C PRL 65 1313 +Hewett, Rizzo (WISC, ISU)
BARGER 90E PR D41 3421 +Hewett, Phillips (WISC, RAL)
BLONDEL 90 ZPHY C45 361 +Boeckmann, Burkhardt, Dydak, Grant+ (CDHSW Collab.)
DECAMP 90F PL B236 511 +Deschizeaux, Lees, Minard+ (ALEPH Collab.)
DECAMP 90P ZPHY C48 365 +Deschizeaux, Goy, Lees+ (ALEPH Collab.)
ELLIS 90B PL B249 543 +Fogli (CERN)
KENNEDY 90 PRL 65 2967 +Langacker (PENN)
ABRAMS 89C PRL 63 2447 +Adolphsen, Averill, Ballam+ (Mark II Collab.)
ADACHI 89C PL B229 427 +Aihara, Doser, Enomoto, Fujii+ (TOPAZ Collab.)
ALBAJAR 89 ZPHY C44 15 +Albrow, Allkofer, Arnison, Astbury+ (UA1 Collab.)
ELLIS 89B PL B232 139 +Fogli (CERN, BARI)
ENO 89 PRL 63 1910 +Auchincloss, Blanis, Bodek, Budd+ (AMY Collab.)
LANGACKER 89 PRL 63 1920 (PENN)
ADACHI 88 PRL 60 97 +Aihara, Dijkstra+ (TOPAZ Collab.)
ALBAJAR 88 ZPHY C37 505 +Albrow, Allkofer+ (UA1 Collab.)
ALTARELLI 88 NP B308 724 +Diemoz, Martinelli, Nason (CERN, ROMA, ETH)
COSTA 88 NP B297 244 +Ellis, Fogli+ (PADO, CERN, BARI, WISC, LBL)
ELLIS 88C PL B213 526 +Fogli (CERN, BARI)
FOGLI 88 ZPHY C40 379 +Haidt (BARI, DESY)
IGARASHI 88 PRL 60 2359 +Myung, Chiba, Hanaoka+ (AMY Collab.)
SAGAWA 88 PRL 60 93 +Mori, Abe+ (AMY Collab.)
ABE 87 JPSJ 56 3763 +Amako, Arai+ (VENUS Collab.)
AMALDI 87 PR D36 1385 +Bohm, Durkin, Langacker+ (CERN, AACH3, OSU+)
ANSARI 87 PL B186 440 +Bagnaia, Banner, Battiston+ (UA2 Collab.)
YOSHIDA 87 PL B198 570 +Chiba, Endo+ (VENUS Collab.)