# t

$I(J^P) = 0(\frac{1}{2}^+)$

Charge $= \frac{2}{3}\,e$ Top $= +1$

## $t$-Quark Mass in $p\overline{p}$ Collisions

The $t$ quark has now been observed. Its mass is sufficiently high that decay is expected to occur before hadronization. Search limits are based on the assumption that no nonstandard decay modes such as $t \rightarrow bH^+$ are available, except as shown in the comments.

| VALUE (GeV) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **180±12 OUR AVERAGE** | | | | | | |
| $199^{+19}_{-21}\pm22$ | | | [1] ABACHI | 95 | D0 | $\ell$ + jet |
| $176\pm\ 8\pm10$ | | | [2] ABE | 95F | CDF | $\ell$ + $b$-jet |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| >131 | 95 | | [3] ABACHI | 94 | D0 | $\ell\ell$ + jets, $\ell$ + jets |
| $174\pm10^{+13}_{-12}$ | | 7 | [4] ABE | 94E | CDF | $\ell$ + $b$-jet |
| >118 | 95 | | [4] ABE | 94E | CDF | $\ell\ell$ |
| | | | [5] ABE | 94H | CDF | $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu_\tau$ |
| | | | [6] ABE | 94I | CDF | $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu_\tau$ |
| > 91 | 95 | | [7] ABE | 92 | CDF | $\ell\ell$, $\ell$ + $b$-jet |
| | | | [8] ALITTI | 92F | UA2 | $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu_\tau$ |
| > 60 | 95 | | [9] ALBAJAR | 91B | UA1 | $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu_\tau$ |
| | | | [10] BAER | 91B | RVUE | $t \rightarrow \tilde{t}_1\tilde{\chi}^0_1$ |
| > 72 | 95 | | [11] ABE | 90B | CDF | $e$ + $\mu$ |
| > 77 | 95 | | [12] ABE | 90C | CDF | $e$ + jets + missing $E_T$ |
| > 69 | 95 | | [13] AKESSON | 90 | UA2 | $e$ + jets + missing $E_T$ |
| > 60 | 95 | | ALBAJAR | 90B | UA1 | $e$ or $\mu$ + jets, $\mu\mu$ + jet |
| | | | [14] BARGER | 90E | RVUE | $t \rightarrow bH^+$ |
| > 41 | 95 | | [15] ALBAJAR | 88 | UA1 | $e$ or $\mu$ + jets |

[1] ABACHI 95 search for $\ell\ell$+jets ($e\mu$, $ee$, and $\mu\mu$) and $\ell$+jets ($\ell$=$e$ or $\mu$). The $\ell$+jets search is done in two ways, using either topological cuts or requiring $\mu$ tagging. They observe 17 (3 $\ell\ell$, 6 $\ell$+$b$-jets, and 8 $\ell$+jets topological) events with an expected background of 3.8 ± 0.6. These seven analysis channels combine to give a 4.6 standard deviation effect. The mass fit is from 24 $\ell$+4-jet events obtained with looser cuts.

[2] ABE 95F search for $\ell\ell$ ($ee$, $e\mu$, and $\mu\mu$) final states and $\ell$ + $b$-jet final states. They find 37 $\ell$ + $b$-jet candidates containing 27 secondary vertex tags and 23 lepton tags with expected backgrounds of 6.7 ± 2.1 and 15.4 ± 2.0 respectively. They find 6 $\ell\ell$ events with an expected background of 1.3 ± 0.3 These three observations combine to give a 4.8 standard deviation effect. The mass fit is from 19 $\ell$+4-jet events with a $b$-tag. The shape of the mass distribution is consistant with top and this increases the significance of the effect to 5.0$\sigma$.

[3] ABACHI 94 search for $e\mu$ + jets, $ee$ + jets, $e$ + jets, and $\mu$ + jets. Production cross section with soft-gluon resummation of LAENEN 94 is used. The limit decreases to >122 GeV if $\mathcal{O}(\alpha_s{}^3)$ cross section is employed for comparison with ABE 92.

[4] ABE 94E search for $ee$, $e\mu$, and $\mu\mu$ dilepton final states and single lepton + $b$-jet final states. They observe a total of 15 top topology tags (12 events of which three are doubly tagged) with an expected background of $5.96^{+0.49}_{-0.44}$. The mass determination is from 7 single-lepton + $b$-jet events which have four jets. Their $\ell\ell$ limit uses the production cross section with soft gluon resummation from LAENEN 94. Superseded by ABE 95F.

[5] ABE 94H searched for $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu_\tau$ with $\tau$ decaying hadronically. The search was done in the region 45 GeV $< m_{H^+} < m_t - m_b$ and 55 GeV $< m_t < m_W + m_b$. See their Fig. 3 for the 95% CL excluded regions in the $(m_{H^+}, m_t)$ plane for $B(H^+ \rightarrow \tau^+\nu_\tau)$ = 1, 0.75, and 0.5.

[6] ABE 94I searched for $t \rightarrow bH^+$, $H^+ \rightarrow \tau^+\nu_\tau$, $\tau^+ \rightarrow \ell^+\nu_\ell\overline{\nu}_\tau$. The search was done in the region 45 GeV $< m_{H^+} < m_t - m_b$ and 62 GeV $< m_t <$ 110 GeV. See their Fig. 2 for the 95% CL excluded regions in the $(m_{H^+}, m_t)$ plane for $B(H^+ \rightarrow \tau^+\nu_\tau)$ = 1, 0.75, and 0.5. The entire region of the plane is excluded for $B(H^+ \rightarrow \tau^+\nu_\tau)$ > 0.75 when $m_t < m_W + m_b$.

[7] ABE 92 search for $ee$, $e\mu$, $\mu\mu$ dilepton final states and ($e$ or $\mu$) plus a $b$-quark jet. The $b$ jet is tagged by a soft muon. The 90%CL limit is 95 GeV. Superseded by ABE 94E $\ell\ell$ limit.

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)

[8] ALITTI 92F search for $t \to bH^+$, $H^+ \to \tau^+\nu_\tau$ with $\tau^+$ decaying hadronically. $m_t$ between 50 and 70 GeV is excluded if $m_t - m_{H^+} = m_b + (\lesssim$ a few–10 GeV). See their Figs. 5,6 for the excluded region for B($H^+ \to \tau^+\nu_\tau$) = 1, 0.5.

[9] ALBAJAR 91B searched for the decay $t \to H^+ b$ using single muon and dimuon events and assuming B($H^+ \to \tau^+\nu$) $\geq$ 0.95. The limit holds for $m_{H^+} \lesssim m_t - m_b -$ (3–6) GeV.

[10] BAER 91B argue that a top quark as light as 60 GeV (65 GeV, if the minimal SUSY framework is assumed) may have escaped detection at CDF if a supersymmetric decay mode is open.

[11] ABE 90B exclude the region 28–72 GeV.

[12] ABE 90C cannot exclude $m_t$ < 40 GeV, but this region is ruled out by other experiments. They study events with an energetic electron, missing transverse energy and two or more jets. Only the $t\bar{t}$ contribution (not $W \to tb$) is relevant for these masses. See also ABE 91.

[13] AKESSON 90 searched for events having an electron with $p_T$ > 12 GeV, missing momentum > 15 GeV, and a jet with $E_T$ > 10 GeV, $|\eta|$ < 2.2, and excluded $m_t$ between 30 and 69 GeV.

[14] BARGER 90E claim that ABE 90C data exclude most regions of two-Higgs-doublet models with $m_t$ < 80 GeV even if $t \to bH^+$ decay is allowed.

[15] ALBAJAR 88 value quoted here is revised using the full $O(\alpha_s^3)$ cross section of ALTARELLI 88. Superseded by ALBAJAR 90B.

## Indirect *t*-Quark Mass from Standard Model Electroweak Fit

"OUR NEW EVALUATION" below is for a fit to electroweak data similar to that described in the "Standard Model of Electroweak Interactions" section of the 1994 Edition of this Review (Physical Review **D50** 1173 (1994)) but updated to include the new data added to the Full Listings in this 1995 update on the World-Wide Web. This fit result does not include direct measurements of $m_t$. The second error corresponds to $m_H$=300$^{+700}_{-240}$ GeV.

If we include new preliminary data as of June 1995 from SLD (http://www-sld.slac.stanford.edu/sldwww/physics/alr/1995_preliminary.html) and LEP (LEP electroweak working group results for Moriond, in LEPEWWG//95-01) the indirect top mass becomes

$$m_t(\text{preliminary})=183 \pm 8^{+17}_{-19} \text{ GeV}.$$

The RVUE values are based on the data described in the footnotes. Earlier RVUE's are superseded but have been left in the Listings to show the progress.

| *VALUE* (GeV) | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **$178\pm12^{+17}_{-20}$ OUR EVALUATION** | | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $157^{+36}_{-48}{}^{+19}_{-20}$ | | [16] ABREU | 94 | DLPH | $Z$ parameters |
| $115^{+52}_{-82}{}^{+23}_{-24}$ | | [17] ABREU | 94H | DLPH | $Z$ parameters |
| $158^{+32}_{-40}\pm19$ | | [18] ACCIARRI | 94 | L3 | $Z$ parameters |
| $132^{+41}_{-48}{}^{+24}_{-18}$ | | [19] AKERS | 94 | OPAL | $Z$ parameters |
| $190^{+39}_{-48}{}^{+12}_{-14}$ | | [20] ARROYO | 94 | CCFR | $\nu_\mu$ iron scattering |
| $184^{+25}_{-29}{}^{+17}_{-18}$ | | [21] BUSKULIC | 94 | ALEP | $Z$ parameters |
| $140^{+21}_{-22}$ | | [22] ELLIS | 94 | RVUE | Electroweak |
| $153\pm15$ | | [23] ELLIS | 94B | RVUE | Electroweak |
| $177\pm\ 9^{+16}_{-20}$ | | [24] GURTU | 94 | RVUE | Electroweak |
| $174^{+11}_{-13}{}^{+17}_{-18}$ | | [25] MONTAGNA | 94 | RVUE | Electroweak |
| $161^{+15}_{-16}{}^{+16}_{-22}$ | | [26] NOVIKOV | 94 | RVUE | Electroweak |

| | | | | | |
|---|---|---|---|---|---|
| $171 \pm 12^{+15}_{-21}$ | | [27] NOVIKOV | 94B | RVUE | Electroweak |
| $91 \pm 46 \pm 9$ | | [28] ACTON | 93D | OPAL | $Z$ parameters |
| $152^{+36}_{-46} \pm 20$ | | [29] ADRIANI | 93M | L3 | $Z$ parameters |
| $<207$ | 95 | [30] ALTARELLI | 93 | RVUE | $Z b \overline{b}$ vertex |
| $143^{+19}_{-18}$ | | [31] BLONDEL | 93 | RVUE | $Z$ parameters |
| $174^{+27}_{-32}{}^{+17}_{-22}$ | | [32] BUSKULIC | 93J | ALEP | $Z$ parameters |
| $<228$ | 95 | [33] BUSKULIC | 93M | ALEP | $\Gamma(Z \rightarrow b \overline{b})$ |
| $132^{+20}_{-22}$ | | [34] ELLIS | 93B | RVUE | |
| $102^{+35}_{-32}{}^{+19}_{-18}$ | | [35] MONTAGNA | 93 | RVUE | $Z$ parameters |
| $114^{+32}_{-42}$ | | [36] MONTAGNA | 93B | RVUE | $Z$ parameters |
| | | [37] NOVIKOV | 93B | RVUE | |
| $146^{+18}_{-19} \pm 17$ | | [38] PASSARINO | 93 | RVUE | Electroweak |
| $147^{+22}_{-26}{}^{+17}_{-22}$ | | [39] QUAST | 93 | RVUE | $Z$ parameters |
| $160^{+50}_{-60}$ | | [40] ALITTI | 92B | UA2 | $m_W$, $m_Z$ |
| $123^{+33}_{-38} \pm 19$ | | [41] BANERJEE | 92 | RVUE | Electroweak |
| $<208$ | 95 | [42] BLONDEL | 92 | RVUE | $Z b \overline{b}$ vertex |
| $170^{+42}_{-55}{}^{+21}_{-14}$ | | [43,44] DECAMP | 92B | ALEP | $Z$ parameters |
| $112^{+22}_{-23}$ | | [45] DELAGUILA | 92 | RVUE | Electroweak |
| $122^{+25}_{-20}$ | | [46] DELAGUILA | 92B | RVUE | |
| $120^{+27}_{-28}$ | | [47] ELLIS | 92 | RVUE | Electroweak |
| $124^{+26}_{-28}$ | | [48] ELLIS | 92E | RVUE | |
| | | [49] LANGACKER | 92B | RVUE | $Z'$ |
| $124^{+40}_{-56} \pm 21$ | | [50] LEP | 92 | RVUE | $Z$ parameters |
| $132^{+27}_{-31}{}^{+18}_{-19}$ | | [50] LEP | 92 | RVUE | Electroweak |
| $150^{+23}_{-26} \pm 16$ | | [51] PDG | 92 | RVUE | Electroweak |
| $137^{+22}_{-25}{}^{+18}_{-22}$ | | [52] RENTON | 92 | RVUE | Electroweak |
| $150^{+29}_{-34}{}^{+20}_{-22}$ | | [53] SCHAILE | 92 | RVUE | $Z$ parameters |
| $144^{+23}_{-26}{}^{+19}_{-21}$ | | [53] SCHAILE | 92 | RVUE | Electroweak |
| $<220$ | 95 | [54] ABE | 91B | RVUE | $m_W$, $m_Z$ |
| $<215$ | 95 | [43] ABREU | 91F | DLPH | $Z$ parameters |
| $193^{+52}_{-69} \pm 16$ | | [43,55] ADEVA | 91E | L3 | $Z$ parameters |
| $100^{+70}_{-52}{}^{+24}_{-11}$ | | [56,57] ALEXANDER | 91F | OPAL | $Z$ parameters |
| | | [58] DELAGUILA | 91C | RVUE | $Z'$ |
| $119^{+39}_{-45}$ | | [59] GONZALEZ-G... | 91 | RVUE | Electroweak |
| $134^{+47}_{-48}$ | | [60] HIOKI | 91 | RVUE | Electroweak |
| $124^{+28}_{-34}{}^{+20}_{-15}$ | | [61] LANGACKER | 91 | RVUE | Electroweak |
| $<366$ | 90 | [62] ADACHI | 90F | RVUE | $\sigma(e^+ e^- \rightarrow$ hadrons) |
| $<200$ | 95 | [63] ADEVA | 90I | RVUE | Electroweak |
| $<200$ | 95 | [64] BARGER | 90C | RVUE | Electroweak |
| $<240$ | 90 | [65] BLONDEL | 90 | CDHS | $\nu N \rightarrow \nu X$ or $\overline{\nu} N \rightarrow \overline{\nu} X$ |
| $120 \pm 40 \pm 20$ | | [66] DECAMP | 90P | RVUE | Electroweak |
| $127^{+24}_{-30}$ | | [67] ELLIS | 90B | RVUE | Electroweak |
| $<190$ | 95 | [68] KENNEDY | 90 | RVUE | Electroweak |
| $132^{+31}_{-37}$ | | [69] ELLIS | 89B | RVUE | Electroweak |
| $140^{+43}_{-52}$ | | [70] LANGACKER | 89 | RVUE | Electroweak |

| | | | | | |
|---|---|---|---|---|---|
| <168 | 90 | [71] COSTA | 88 | RVUE | Electroweak |
| <153 | 68 | [72] ELLIS | 88C | RVUE | Electroweak |
| <291 | 90 | [73] FOGLI | 88 | RVUE | $\nu N \rightarrow \nu X$ |
| <180 | 90 | [74] AMALDI | 87 | RVUE | Electroweak |

[16] ABREU 94 value is for $\alpha_s(m_Z)$ constrained to 0.123 ± 0.005. The second error corresponds to $m_H = 300^{+700}_{-240}$ GeV.

[17] ABREU 94H value is for $\alpha_s(m_Z)$ constrained to 0.123 ± 0.005. The second error corresponds to $m_H = 300^{+700}_{-240}$ GeV. Superseded by ABREU 94.

[18] ACCIARRI 94 value is for $\alpha_s(m_Z)$ constrained to 0.124 ± 0.006. The second error corresponds to $m_H = 300^{+700}_{-240}$ GeV.

[19] AKERS 94 result is from fit with free $\alpha_s$. The second error corresponds to $m_H$=$300^{+700}_{-240}$ GeV. The 95%CL limit is $m_t$ <210 GeV.

[20] ARROYO 94 measures the ratio of the neutral-current and charged-current deep inelastic scattering of $\nu_\mu$ on an iron target. By assuming the SM electroweak correction, they obtain $1-m_W^2/m_Z^2 = 0.2218 \pm 0.0059$, yielding the quoted $m_t$ value. The second error corresponds to $m_H = 300^{+700}_{-240}$ GeV.

[21] BUSKULIC 94 result is from fit with free $\alpha_s$. The second error is from $m_H$=$300^{+700}_{-240}$ GeV.

[22] ELLIS 94 is fit to electroweak data available in summer 1993. $m_t$, $m_H$, and $\alpha_s$ are adjusted to minimize $\chi^2$, yielding $m_t$ above, $m_H = 35^{+205}_{-\ 26}$ GeV, and $\alpha_s(m_Z) = 0.116^{+0.007}_{-0.006}$.

[23] ELLIS 94B result is fit to electroweak data available in spring 1994, including the 1994 $A_{LR}$ data from SLD. $m_t$ and $m_H$ are two free parameters of the fit for $\alpha_s(m_Z)$ = 0.118 ± 0.007 yielding $m_t$ above, and $m_H = 35^{+70}_{-22}$ GeV. ELLIS 94B also give results for fits including constraints from CDF's direct measurement of $m_t$ and CDF's and D∅'s production cross-section measurements. Fits excluding the $A_{LR}$ data from SLD are also given.

[24] GURTU 94 result is from fit with free $m_t$ and $\alpha_s(m_Z)$, yielding $m_t$ above and $\alpha_s(m_Z)$ = 0.125 ± $0.005^{+0.003}_{-0.001}$. The second errors correspond to $m_H = 300^{+700}_{-240}$ GeV. Uses LEP, $M_W$, $\nu N$, and SLD electroweak data available in spring 1994.

[25] MONTAGNA 94 result is from fit with free $m_t$ and $\alpha_s(m_Z)$, yielding $m_t$ above and $\alpha_s(m_Z)$ = 0.124. The second errors correspond to $m_H = 300^{+700}_{-240}$ GeV. Errors in $\alpha(m_Z)$ and $m_b$ are taken into account in the fit. Uses LEP, SLC, and $M_W/M_Z$ data available in spring 1994.

[26] NOVIKOV 94 result is from fit with free $m_t$ and $\alpha_s(m_Z)$, yielding $m_t$ above and $\alpha_s(m_Z)$ = 0.119 ± 0.006 ± 0.002. The second errors correspond to $m_H = 300^{+700}_{-240}$ GeV. Uses LEP and $M_W/M_Z$ data available in 1993.

[27] NOVIKOV 94B result is from fit with free $m_t$ and $\alpha_s(m_Z)$, yielding $m_t$ above and $\alpha_s(m_Z)$ = 0.125 ± 0.005 ± 0.002. The second errors correspond to $m_H = 300^{+700}_{-240}$ GeV. Uses LEP and CDF electroweak data available in spring 1994.

[28] ACTON 93D result is from fit with free $\alpha_s$. The second error corresponds to $m_H$=$300^{+700}_{-240}$ GeV. The 95%CL limit is $m_t$ <180 GeV. Negative statistical error is larger than −46. Superseded by AKERS 94.

[29] ADRIANI 93M used $\alpha_s(m_Z)$=0.124 ± 0.006. Second error corresponds to $m_H$=50 GeV − 1 TeV. Superseded by ACCIARRI 94.

[30] ALTARELLI 93 limit is from fit to electroweak data available in summer '92 but uses only the parameter corresponding to $Zb\overline{b}$ vertex correction. $\alpha_s(m_Z)$ = 0.118 ± 0.007 is used.

[31] BLONDEL 93 is $m_t - m_H$ fit to LEP data available in spring '93. $\alpha_s$ = 0.117 ± 0.005 is used and $m_t$ >108 GeV, $m_H$ > 62.5 GeV imposed. 95%CL limit is 185 GeV.

[32] BUSKULIC 93J second error is from $m_H$=$300^{+700}_{-250}$ GeV. Superseded by BUSKULIC 94.

[33] BUSKULIC 93M limit is from $\Gamma(b\overline{b})/\Gamma(\text{had})$ = 0.2193 ± 0.0029. The best value is $m_t$ = 50 ± 70 GeV. The CDF limit $m_t$ >91 GeV is imposed to obtain the limit.

[34] ELLIS 93B fit to electroweak data available in spring '93. $m_H$ is adjusted to minimize $\chi^2$ (even below the present direct limit) and $\alpha_s(m_Z)$ = 0.123 ± 0.006 is used. 95%CL limit of $m_t$ <155 GeV is claimed.

[35] MONTAGNA 93 perform fit to LEP cross-section and asymmetry data taken in 1989/90. The second error corresponds to $m_H$ =$300^{+700}_{-235}$ GeV. Direct limits on $m_t$, $m_H$ are imposed. $\alpha_s$ is adjusted to minimize $\chi^2$. Updated in MONTAGNA 93B.

[36] MONTAGNA 93B is an update of MONTAGNA 93, including fits to realistic (i.e. with experimental cuts) cross sections and asymmetries. $m_Z$ and $\alpha_s$ are adjusted to minimize $\chi^2$. $m_H$ is fixed at $m_H$ = 300 GeV.

[37] See Fig. 2 of NOVIKOV 93B for $\chi^2$ contour in $m_t - m_H$ plane calculated from $m_W$, $\Gamma(\ell\ell)$, and $A_{FB}^{\ell\ell}$ data available in summer '92.

38 PASSARINO 93 fit is to LEP and $m_W$ data available in spring '93. $\alpha_s$ is adjusted to minimize $\chi^2$. The second error is from $m_H$=$300^{+700}_{-240}$ GeV.

39 QUAST 93 is fit to LEP data taken up to 1991. $\alpha_s$ is fitted (0.133 ± 0.008 ± 0.002). The second error is from $m_H$=$300^{+700}_{-240}$ GeV.

40 ALITTI 92B assume $m_H$ = 100 GeV. The 95%CL limit is $m_t$ < 250 GeV for $m_H$ < 1 TeV.

41 BANERJEE 92 is a fit to LEP data taken in '90 as well as $m_W$. The second error is from $m_H$=$300^{+700}_{-250}$ GeV. $\alpha_s(m_Z) = 0.118 \pm 0.008$ is used. Fit to LEP data only gives $m_t$ = 99 ± 48 ± 22 GeV.

42 BLONDEL 92 limit is from $\Gamma(b\overline{b})/\Gamma(\text{had})$, $\sin^2\theta_W^{\text{eff}}$ from asymmetries, and $\alpha_s(m_Z)$ = 0.117 ± 0.004 (data available in spring '92). $m_t$ >91 GeV imposed. The limit is sensitive to the value of $\alpha_s$.

43 Limit from $Z$ cross sections, leptonic forward-backward asymmetries, $\tau$ polarization asymmetry, quark charge asymmetry, and $b\,b$ and $c\,c$ forward-backward asymmetries.

44 DECAMP 92B uses $\alpha_s$ = 0.121 ± 0.008. The second error is from $m_{H^0}$ = $200^{+800}_{-150}$ GeV. The "Electroweak" value combines ALEPH $Z$ data and $m_W/m_Z$ from ALITTI 90B and ABE 90G.

45 DELAGUILA 92 is fit to electroweak data including LEP data taken '90. The value is for $m_H$ = 100 GeV, $\alpha_s(m_Z)$ = 0.12 fixed. For $m_H$ = 1 TeV, $m_t$ = $140^{+19}_{-21}$ GeV.

46 DELAGUILA 92B perform two-dimensional fit to various electroweak data with direct limits on $m_t$,$m_H$.

47 ELLIS 92 is an update of ELLIS 90B to include the latest LEP, UA2, CDF, and CHARM II results presented at the Lepton-Photon and EPS Conference, July 1991. $\alpha_s$ = 0.115 ± 0.008 assumed and $m_H$ left free. Fit gives 1.3 GeV < $m_H$ < 160 GeV, CL = 68% for $m_t$ = 130 GeV.

48 ELLIS 92E perform fit to electroweak data available in spring '92. $m_H$ is adjusted to minimize $\chi^2$ and $\alpha_s(m_Z)$ = 0.118 ± 0.008 is used.

49 LANGACKER 92B consider the effect of an extra $Z$ boson ($Z'_{\text{SM}}$, $Z_{LR}$, $Z_\chi$, $Z_\psi$, $Z_\eta$) on the top mass determination. The fit including $Z'$ does not change the limit on $m_t$.

50 The LEP 92 values are combined results of the four LEP collaborations: ALEPH, DELPHI, L3, and OPAL. The "Electroweak" result includes $m_W$ and $m_W/m_Z$ from ABE 90G and ALITTI 92B, and neutral current data from CDHS and CHARM. Uses $\alpha_s$ = 0.118 ± 0.008. Second error corresponds to $m_H$ = $300^{+700}_{-250}$ GeV.

51 PDG 92 value comes from a fit by P. Langacker to recent data as discussed in the minireview above.

52 RENTON 92 is a fit to LEP data taken up to '90 as well as $m_W$, $\nu N$, and atomic parity violation data. The second error is from $m_H$=$300^{+700}_{-250}$ GeV. $\alpha_s(m_Z) = 0.114 \pm 0.007$ is used. The 95%CL limit is 193 GeV. The fit to LEP data only gives $m_t$=$142^{+30}_{-37}$ ± 20 GeV.

53 SCHAILE 92 performs fit to LEP electroweak data (as of summer 1991) as well as $m_W$ (UA2/CDF) and $\nu N$ (CDHS/CHARM). The second error is from $m_H$=$300^{+700}_{-250}$ GeV.

54 The ABE 91B limit is derived from their $m_W$ with $m_Z$ = 91.161 GeV. Combining with the $m_W$ measurement of ALITTI 90B, one obtains $m_t$ < 230 GeV (95%CL).

55 $\alpha_s$ = 0.115 ± 0.009. The second error is from $m_{H^0}$ = $300^{+700}_{-250}$ GeV.

56 ALEXANDER 91F use $\alpha_s$ = 0.118 ± 0.008. The second error comes from $m_H$ = $300^{+700}_{-250}$ GeV.

57 The 95%CL upper limit is 218 GeV.

58 DELAGUILA 91C study bound on $m_t$ in the presence of extra $Z'$ ($Z_{LR}$ and $Z_\chi$) 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.

59 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.

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

61 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 ± 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.

62 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. $\Lambda_{\overline{MS}}$ is varied in the fit.

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

[64] 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.

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

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

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

[68] 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).

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

[70] 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.

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

[72] 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 $\nu N$ data. Varying $m_c$ relaxes the limit to 185 GeV. Superseded by ELLIS 89B.

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

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

## MASS LIMITS for *t* Quark or Hadron Independent of *t* Decay Mode

These limits are derived from $\Gamma(W)$ values shown in the $W$ width section. Independent of the top decay mode, any $W$ decay to $t\overline{b}$ would increase the total width of the $W$ boson.

| *VALUE* (GeV) | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| >62 | 95 | [75] ABE | 94B | CDF | $E^{p\overline{p}}_{\rm cm} = 1800$ GeV |
| >45 | 95 | [76] ABE | 92I | CDF | $E^{p\overline{p}}_{\rm cm} = 1800$ GeV |
| >53 | 95 | [77] ALITTI | 92 | UA2 | $E^{p\overline{p}}_{\rm cm} = 630$ GeV |
| >55 | 95 | [78] ALITTI | 92 | RVUE | |
| >43 | 95 | [79] ABE | 91C | CDF | $E^{p\overline{p}}_{\rm cm} = 1800$ GeV |
| >38 | 90 | [80] ALBAJAR | 91 | UA1 | $E^{p\overline{p}}_{\rm cm} = 630$ GeV |
| >51 | 90 | [81] ALBAJAR | 91 | RVUE | $\Gamma(W)$ |

[75] ABE 94B result is from $\Gamma(W) = 2.063 \pm 0.061 \pm 0.060$ GeV.

[76] ABE 92I data include both $e$ and $\mu$ final states. The result is derived from $\Gamma(W) = 2.16 \pm 0.17$ GeV. At 90%CL, the limit is >49 GeV.

[77] ALITTI 92 result is derived from $\Gamma(W) = 2.10 \pm 0.16$ GeV.

[78] Limit is from combined data of ALBAJAR 91, ALITTI 92, and ABE 90: $\Gamma(W) = 2.15 \pm 0.11$ GeV.

[79] ABE 91C result is derived from $\Gamma(W) = 2.12 \pm 0.20$ GeV. At 90%CL, the limit is > 48 GeV.

[80] ALBAJAR 91 result is derived from $\Gamma(W) = 2.18^{+0.26}_{-0.24} \pm 0.04$ GeV.

[81] Limit is from combined data of ALBAJAR 91, ALITTI 90C, and ABE 90.

## 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* |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | [82] ADRIANI | 93G | L3 | Quarkonium |
| >41.8 | 95 | ADRIANI | 93M | L3 | $\Gamma(Z)$ |
| >43 | 95 | [83] ABREU | 91F | DLPH | $\Gamma(Z)$ |
| >30.2 | 95 | ABE | 90D | VNS | Event shape |
| >44.5 | 95 | [83] ABREU | 90D | DLPH | Event shape |
| >44.0 | 95 | [83,84] ABREU | 90D | DLPH | $t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$, $\tau^+\nu$ |
| >33.5 | 95 | [85] ABREU | 90D | DLPH | $\Gamma(Z \rightarrow$ hadrons) |
| >44.5 | 95 | [86] AKRAWY | 90B | OPAL | Acoplanarity |
| >44.3 | 95 | [87] AKRAWY | 90B | OPAL | $t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$, $\tau\nu$ |
| >45.8 | 95 | [83] DECAMP | 90F | ALEP | isolated charged particle and aplanarity |
| >40.7 | 95 | [88] ABRAMS | 89C | MRK2 | Event shape |
| >42.5 | 95 | ABRAMS | 89C | MRK2 | $t \rightarrow bH^+$, $H^+ \rightarrow c\overline{s}$ |
| >29.9 | 95 | [89] ADACHI | 89C | TOPZ | $\mu$ |
| >29.9 | 95 | [90] ENO | 89 | AMY | $\mu$, $e$ |
| >25.8 | 95 | [91] ADACHI | 88 | TOPZ | $R$, $T$, Acoplanarity |
| >25.9 | 95 | [92] IGARASHI | 88 | AMY | $T + (\mu,e)$ |
| >25.9 | 95 | [93] SAGAWA | 88 | AMY | $R$, $T$ |
| none $E_{\rm cm}$=50 | 95 | [94] ABE | 87 | VNS | $R$, $T$, Acoplanarity |
| >25.5 | 95 | [95] YOSHIDA | 87 | VNS | $R$, $T$, Acoplanarity |

[82] ADRIANI 93G search for vector quarkonium states near $Z$ and give limit on quarkonium-$Z$ mixing parameter $\delta m^2 <$(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.

[83] Search was near the $Z$ peak at LEP.

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

[85] Superseded by ABREU 91F.

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

[87] 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.

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

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

[90] ENO 89 search at $E_{\rm cm}$ = 50–60.8 GeV at TRISTAN.

[91] ADACHI 88 set limit $\sigma$(top) < 8.2 pb at CL=95% for top-flavored-hadron production from event shape analyses at $E_{\rm cm}$ = 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.

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

[93] SAGAWA 88 set limit $\sigma$(top) < 6.1 pb at CL=95% for top-flavored hadron production from event shape analyses at $E_{\rm cm}$ = 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.

[94] ABE 87 set limit $\sigma$(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.

[95] YOSHIDA 87 set limit $\sigma$(top) < 17 pb at CL=95% for top-flavored hadron production from event shape analyses at $E_{\rm cm}$ = 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.

## *t*-Quark REFERENCES


| | | | | |
|---|---|---|---|---|
| ABACHI | 95 | PRL 74 2632 | +Abbot, Abolins, Acharya, Adam+ | (D0 Collab.) |
| ABE | 95F | PRL 74 2626 | +Akimoto, Akopian, Albrow, Amendolia+ | (CDF Collab.) |
| ABACHI | 94 | PRL 72 2138 | +Abbott, Abolins, Acharya, Adam+ | (D0 Collab.) |
| ABE | 94B | PRL 73 220 | +Albrow, Amidei, Anway-Wiese+ | (CDF Collab.) |
| ABE | 94E | PR D50 2966 | +Albrow, Amendolia, Amidei, Antos+ | (CDF Collab.) |
| Also | 94F | PRL 73 225 | Abe, Albrow, Amidei, Antos, Anway-Weise+ | (CDF Collab.) |
| ABE | 94H | PRL 72 1977 | +Albrow, Amidei, Anway-Wiese, Apollinari+ | (CDF Collab.) |
| ABE | 94I | PRL 73 2667 | +Albrow, Amidei, Antos, Anway-Wiese+ | (CDF Collab.) |
| ABREU | 94 | NP B418 403 | +Adam, Adye, Agasi+ | (DELPHI Collab.) |
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| ACCIARRI | 94 | ZPHY C62 551 | +Adam, Adriani, Aguilar-Benitez+ | (L3 Collab.) |
| AKERS | 94 | ZPHY C61 19 | +Alexander, Allison+ | (OPAL Collab.) |
| ARROYO | 94 | PRL 72 3452 | +King, Bachman+ | (COLU, CHIC, FNAL, ROCH, WISC) |
| BUSKULIC | 94 | ZPHY C62 539 | +Casper, De Bonis, Decamp, Ghez, Goy+ | (ALEPH Collab.) |
| ELLIS | 94 | PL B324 173 | +Fogli, Lisi | (CERN, BARI) |
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| GURTU | 94 | MPL A9 3301 | | (TATA) |
| LAENEN | 94 | PL B321 254 | +Smith, van Neerven | (FNAL, UTRE, LEID) |

| | | | | |
|---|---|---|---|---|
| MONTAGNA | 94 | PL B335 484 | +Nicrosini, Passarino, Piccinini | (INFN, PAVI, CERN, TORI) |
| NOVIKOV | 94 | PL B331 433 | +Okun, Rozanov, Vysotsky, Yurov | (CERN, ITEP) |
| NOVIKOV | 94B | MPL A9 2641 | +Okun, Rozanov, Vysotsky | (GUEL, CERN, ITEP) |
| PDG | 94 | PR D50 1173 | Montanet+ | (CERN, LBL, BOST, IFIC+) |
| 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.) |
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| ELLIS | 93B | PL B318 148 | +Fogli, Lisi | (CERN, BARI) |
| MONTAGNA | 93 | PL B303 170 | +Nicrosini, Passarino | (PAVI, TORI) |
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| 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.) |
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| 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.) |
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| 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.) |