t

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

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

A REVIEW GOES HERE – Check our WWW List of Reviews

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

The *t* quark has been observed. Its mass is sufficiently high that decay is expected to occur before hadronization. OUR EVALUATION is an AVERAGE which incorporates correlations between systematic errors of the five different measurements. The average was done by a joint CDF/DØ working group and is reported in DEMORTIER 99, an FNAL Technical Memo. They report 174.3 ± 3.2 ± 4.0 GeV, which yields "OUR EVALUATION" when statistical and systematic errors are combined.

For earlier search limits see the *Review of Particle Physics*, Phys. Rev. **D54**,1 (1996).

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
174.3± 5.1 OUR EVALUATION				
167.4±10.3± 4.8	[1] ABE	99B	CDF	dilepton
168.4±12.3± 3.6	[2] ABBOTT	98D	D0	dilepton
173.3± 5.6± 5.5	[2] ABBOTT	98F	D0	lepton + jets
175.9± 4.8± 5.3	[1,3] ABE	98E	CDF	lepton + jets
186 ±10 ± 5.7	[1,4] ABE	97R	CDF	6 or more jets
• • • We do not use the following data for averages, fits, limits, etc. • • •				
172.1± 5.2± 4.9	[5] ABBOTT	99G	D0	di-lepton, lepton+jets
176.0± 6.5	[6] ABE	99B	CDF	dilepton, lepton+jets, and all jets
161 ±17 ±10	[1] ABE	98F	CDF	dilepton
172.1± 5.2± 4.9	[7] BHAT	98B	RVUE	dilepton and lepton+jets
173.8± 5.0	[8] BHAT	98B	RVUE	dilepton, lepton+jets, and all jets
173.3± 5.6± 6.2	[2] ABACHI	97E	D0	lepton + jets
$199\ ^{+19}_{-21}\ \pm 22$	ABACHI	95	D0	lepton + jets
176 ± 8 ±10	ABE	95F	CDF	lepton + *b*-jet
$174\ \pm 10\ ^{+13}_{-12}$	ABE	94E	CDF	lepton + *b*-jet

[1] Result is based on 109 ± 7 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV.

[2] Result is based on 125 ± 7 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV.

[3] The updated systematic error is listed. See ABE 99B.

[4] ABE 97R result is based on the first observation of all hadronic decays of $t\overline{t}$ pairs. Single *b*-quark tagging with jet-shape variable constraints was used to select signal enriched multi-jet events. The updated systematic error is listed. See ABE 99B.

[5] ABBOTT 99G result is obtained by combining the D0 result m_t (GeV) = 168.4 ± 12.3 ± 3.6 from 6 di-lepton events (see also ABBOTT 98D) and m_t (GeV) = 173.3 ± 5.6 ± 5.5 from lepton+jet events (ABBOTT 98F).

[6] ABE 99B result is obtained by combining the CDF results of m_t (GeV)=167.4±10.3±4.8 from 8 dilepton events, m_t (GeV)=175.9 ± 4.8 ± 5.3 from lepton+jet events (ABE 98E), and m_t (GeV)=186.0 ± 10.0 ± 5.7 from all-jet events (ABE 97R). The systematic errors in the latter two measurements are changed in this paper.

[7] BHAT 98B result is obtained by combining the DØ results of m_t(GeV)=168.4 ± 12.3 ± 3.6 from 6 dilepton events and m_t(GeV)=173.3 ± 5.6 ± 5.5 from 77 lepton+jet events.

[8] BHAT 98B result is obtained by combining the DØ results from dilepton and lepton+jet events, and the CDF results (ABE 99B) from dilepton, lepton+jet events, and all-jet events.

Indirect t-Quark Mass from Standard Model Electroweak Fit

"OUR EVALUATION" below is from the fit to electroweak data described in the "Electroweak Model and Constraints on New Physics" section of this Review. This fit result does not include direct measurements of m_t.

The RVUE values are based on the data described in the footnotes. RVUE's published before 1994 and superseded analyses are now omitted. For more complete listings of earlier results, see the 1994 edition (Physical Review **D50** 1173 (1994)).

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
$168.2^{+9.6}_{-7.4}$ OUR EVALUATION				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
170.7 ± 3.8	[9] FIELD	00	RVUE	Z parameters without b-jet + Direct
$171.2^{+3.7}_{-3.8}$	[10] FIELD	99	RVUE	Z parameters without b jet + Direct
$172.0^{+5.8}_{-5.7}$	[11] DEBOER	97B	RVUE	Electroweak + Direct
$157\ ^{+16}_{-12}$	[12] ELLIS	96C	RVUE	Z parameters, m_W, low energy
$175\ \pm 11\ ^{+17}_{-19}$	[13] ERLER	95	RVUE	Z parameters, m_W, low energy
$180 \pm 9^{+19}_{-21} \mp 2.6 \pm 4.8$	[14] MATSUMOTO	95	RVUE	
$157\ ^{+36}_{-48}\ ^{+19}_{-20}$	[15] ABREU	94	DLPH	Z parameters
$158\ ^{+32}_{-40}\ \pm 19$	[16] ACCIARRI	94	L3	Z parameters
$132\ ^{+41}_{-48}\ ^{+24}_{-18}$	[17] AKERS	94	OPAL	Z parameters
$190\ ^{+39}_{-48}\ ^{+12}_{-14}$	[18] ARROYO	94	CCFR	ν_μ iron scattering
$184\ ^{+25}_{-29}\ ^{+17}_{-18}$	[19] BUSKULIC	94	ALEP	Z parameters
$153\ \pm 15$	[20] ELLIS	94B	RVUE	Electroweak
$177\ \pm\ 9\ ^{+16}_{-20}$	[21] GURTU	94	RVUE	Electroweak
$174\ ^{+11}_{-13}\ ^{+17}_{-18}$	[22] MONTAGNA	94	RVUE	Electroweak
$171\ \pm 12\ ^{+15}_{-21}$	[23] NOVIKOV	94B	RVUE	Electroweak
$160\ ^{+50}_{-60}$	[24] ALITTI	92B	UA2	m_W, m_Z

[9] FIELD 00 result updates FIELD 99 by using the 1998 EW data (CERN-EP/99-15). Only the lepton asymmetry data are used together with the direct measurement constraint m_t=173.8 ± 5.0 GeV, $\alpha_s(m_Z)$ = 0.12, and $1/\alpha(m_Z)$ = 128.896. The result is from a two parameter fit with free m_t and m_H, yielding also m_H=$38.0^{+30.5}_{-19.8}$ GeV.

[10] FIELD 99 result is from the two-parameter fit with free m_t and m_H, yielding also m_H= $47.2^{+29.8}_{-24.5}$ GeV. Only the lepton and charm-jet asymmetry data are used together with the direct measurement constraint m_t= 173.8 ± 5.0 GeV, and $1/\alpha(m_Z)$= 128.896.

[11] DEBOER 97B result is from the five-parameter fit which varies m_Z, m_t, m_H, α_s, and $\alpha(m_Z)$ under the contraints: m_t=175 ± 6 GeV, $1/\alpha(m_Z)$=128.896 ± 0.09. They found $m_H = 141^{+140}_{-\ 77}$ GeV and $\alpha_s(m_Z)$=0.1197 ± 0.0031.

[12] ELLIS 96C result is a the two-parameter fit with free m_t and m_H, yielding also $m_H = 65^{+117}_{-\ 37}$ GeV.

[13] ERLER 95 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding $\alpha_s(m_Z)$ = 0.127(5)(2).

[14] MATSUMOTO 95 result is from fit with free m_t to Z parameters, M_W, and low-energy neutral-current data. The second error is for $m_H = 300^{+700}_{-240}$ GeV, the third error is for $\alpha_s(m_Z)$ = 0.116 ± 0.005, the fourth error is for $\delta\alpha_{\text{had}}$ = 0.0283 ± 0.0007.

[15] 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.

[16] 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.

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

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

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

[20] 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 DØ 's production cross-section measurements. Fits excluding the A_{LR} data from SLD are also given.

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

[22] 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.

[23] 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.

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

t DECAY MODES

	Mode		Fraction (Γ_i/Γ)	Confidence level
Γ_1	$W b$			
Γ_2	$\ell \nu_\ell$ anything	[*a*,*b*]	(9.4±2.4) %	
Γ_3	$\tau \nu_\tau b$			
Γ_4	$\gamma q (q=u,c)$	[*c*]	< 3.2 %	95%

$\Delta T = 1$ weak neutral current (*T1*) modes

Γ_5	$Z q (q=u,c)$	*T1*	[*d*] < 33	%	95%

[*a*] ℓ means e or μ decay mode, not the sum over them.

[*b*] Assumes lepton universality and W-decay acceptance.

[*c*] This limit is for $\Gamma(t \to \gamma q)/\Gamma(t \to Wb)$.

[*d*] This limit is for $\Gamma(t \to Zq)/\Gamma(t \to Wb)$.

t BRANCHING RATIOS

$\Gamma(\ell \nu_\ell \text{anything})/\Gamma_{\text{total}}$ — Γ_2/Γ

VALUE	*DOCUMENT ID*		*TECN*
0.094±0.024	[25] ABE	98X	CDF

[25] ℓ means e or μ decay mode, not the sum. Assumes lepton universality and W-decay acceptance.

$\Gamma(\tau \nu_\tau b)/\Gamma_{\text{total}}$ — Γ_3/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[26] ABE	97V	CDF	$\ell\tau$ + jets

[26] ABE 97V searched for $t\overline{t} \to (\ell \nu_\ell)(\tau \nu_\tau) b\overline{b}$ events in 109 pb^{-1} of $p\overline{p}$ collisions at $\sqrt{s} = 1.8$ TeV. They observed 4 candidate events where one expects ~ 1 signal and ~ 2 background events. Three of the four observed events have jets identified as b candidates.

$\Gamma(\gamma q (q=u,c))/\Gamma_{\text{total}}$ — Γ_4/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
<0.032	95	[27] ABE	98G	CDF

[27] ABE 98G looked for $t\overline{t}$ events where one t decays into $q\gamma$ while the other decays into bW. The quoted bound is for $\Gamma(\gamma q)/\Gamma(W b)$.

$\Gamma(Z q (q=u,c))/\Gamma_{\text{total}}$ — Γ_5/Γ

Test for ΔT=1 weak neutral current. Allowed by higher-order electroweak interaction.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
<0.33	95	[28] ABE	98G	CDF

[28] ABE 98G looked for $t\overline{t}$ events where one t decays into three jets and the other decays into qZ with $Z \to \ell\ell$. The quoted bound is for $\Gamma(Zq)/\Gamma(Wb)$.

t DECAY WIDTH

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<17 \times 10^{-2}$	95	[29] BARATE	00S	ALEP	B($t \to Zc$ or Zu)

[29] BARATE 00S looked for single top production via FCNC in the reaction $e^+e^- \to \overline{t}c$ or $\overline{t}u$ in 411/pb of data at c.m. energies between 189 and 202 GeV. No deviation from the SM is found, which leads to a model-independent bound on the branching fraction. Bounds on the effective t- (c or u)-γ and t- (c or u)-Z couplings are given in their Fig. 4.

t DECAY VERTICES

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$0.91 \pm 0.37 \pm 0.13$	[30] AFFOLDER 00B	CDF	$F_0 = W_L/(W_L + W_T)$
0.11 ± 0.15	[30] AFFOLDER 00B	CDF	$B(t \to W_+ b)$

[30] AFFOLDER 00B studied the angular distribution of leptonic decays of W bosons in $t \to W b$ events. The ratio F_0 is the fraction of the helicity zero (longitudinal) W bosons in the decaying top quark rest frame. The first error is statistical and the second systematic. $B(t \to W_+ b)$ is the fraction of positive helicity (right-handed) positive charge W bosons in the top quark decays. It is obtained by assuming the Standard Model value of F_0.

t-Quark REFERENCES

AFFOLDER	00B	PRL 84 216	T. Affolder *et al.*	(CDF Collab.)
BARATE	00S	PL B494 33	S. Barate *et al.*	(ALEPH Collab.)
FIELD	00	PR D61 013010	J.H. Field	
ABBOTT	99G	PR D60 052001	B. Abbott *et al.*	(D0 Collab.)
ABE	99B	PRL 82 271	F. Abe *et al.*	(CDF Collab.)
Also	99G	PRL 82 2808 (erratum)	F. Abe *et al.*	(CDF Collab.)
DEMORTIER	99	FNAL-TM-2084	L. Demortier *et al.*	(CDF/D0 Working Group)
FIELD	99	MPL A14 1815	J.H. Field	
ABBOTT	98D	PRL 80 2063	B. Abbott *et al.*	(D0 Collab.)
ABBOTT	98F	PR D58 052001	B. Abbott *et al.*	(D0 Collab.)
ABE	98E	PRL 80 2767	F. Abe *et al.*	(CDF Collab.)
ABE	98F	PRL 80 2779	F. Abe *et al.*	(CDF Collab.)
ABE	98G	PRL 80 2525	F. Abe *et al.*	(CDF Collab.)
ABE	98X	PRL 80 2773	F. Abe *et al.*	(CDF Collab.)
BHAT	98B	IJMP A13 5113	P.C. Bhat, H.B. Prosper, S.S. Snyder	
ABACHI	97E	PRL 79 1197	S. Abachi *et al.*	(D0 Collab.)
ABE	97R	PRL 79 1992	F. Abe *et al.*	(CDF Collab.)
ABE	97V	PRL 79 3585	F. Abe *et al.*	(CDF Collab.)
DEBOER	97B	ZPHY C75 627	W. de Boer *et al.*	
ELLIS	96C	PL B389 321	J. Ellis, G.L. Fogli, E. Lisi	(CERN, BARI)
ABACHI	95	PRL 74 2632	S. Abachi *et al.*	(D0 Collab.)
ABE	95F	PRL 74 2626	F. Abe *et al.*	(CDF Collab.)
ERLER	95	PR D52 441	J. Erler, P. Langacker	(PENN)
MATSUMOTO	95	MPL A10 2553	S. Matsumoto	(KEK)
ABE	94E	PR D50 2966	F. Abe *et al.*	(CDF Collab.)
Also	94F	PRL 73 225	F. Abe *et al.*	(CDF Collab.)
ABREU	94	NP B418 403	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	94	ZPHY C62 551	M. Acciarri *et al.*	(L3 Collab.)
AKERS	94	ZPHY C61 19	R. Akers *et al.*	(OPAL Collab.)
ARROYO	94	PRL 72 3452	C.G. Arroyo *et al.*	(COLU, CHIC, FNAL+)
BUSKULIC	94	ZPHY C62 539	D. Buskulic *et al.*	(ALEPH Collab.)
ELLIS	94B	PL B333 118	J. Ellis, G.L. Fogli, E. Lisi	(CERN, BARI)
GURTU	94	MPL A9 3301	A. Gurtu	(TATA)
MONTAGNA	94	PL B335 484	G. Montagna *et al.*	(INFN, PAVI, CERN+)
NOVIKOV	94B	MPL A9 2641	V.A. Novikov *et al.*	(GUEL, CERN, ITEP)
PDG	94	PR D50 1173	L. Montanet *et al.*	(CERN, LBL, BOST+)
ALITTI	92B	PL B276 354	J. Alitti *et al.*	(UA2 Collab.)