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

OUR EVALUATION of 172.5 ± 1.5 ± 2.3 GeV (TEVEWWG 07A) is an average of top mass measurements from Tevatron Run-I (1992–1996) and Run-II (2001−present) that were published at the time of preparing this *Review*. This average was provided by the Tevatron Electroweak Working Group (TEVEWWG). It takes correlated uncertainties properly into account and has a χ^2 of 9.4 for 8 degrees of freedom. Including the most recent unpublished top mass measurements from Run-II, the TEVEWWG reports an average top mass of 170.9 ± 1.1 ± 1.5 GeV (TEVEWWG 07). See the note "The Top Quark" in these Quark Particle Listings.

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

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
172.5± 2.7 OUR EVALUATION	See comments in the header above.			
177.1± 4.9± 4.7	[1,2] AALTONEN	07	CDF	6 jets with ≥ 1 b vtx
164.5± 3.9± 3.9	[3,4] ABULENCIA	07D	CDF	dilepton
$170.3^{+4.1}_{-4.5}{}^{+1.2}_{-1.8}$	[4,5] ABAZOV	06U	D0	lepton + jets (b-tag)
$173.5^{+3.7}_{-3.6}\pm 1.3$	[6,7] ABULENCIA	06D	CDF	lepton + jets
180.1± 3.6± 3.9	[8,9] ABAZOV	04G	D0	lepton + jets
176.1± 5.1± 5.3	[10] AFFOLDER	01	CDF	lepton + jets
167.4±10.3± 4.8	[11,12] ABE	99B	CDF	dilepton
168.4±12.3± 3.6	[9] ABBOTT	98D	D0	dilepton
186 ±10 ± 5.7	[11,13] ABE	97R	CDF	6 or more jets
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$173.2^{+2.6}_{-2.4}\pm 3.2$	[6,14] ABULENCIA	06D	CDF	lepton + jets
165.2± 6.1± 3.4	[4,15] ABULENCIA	06G	CDF	dilepton
170.1± 6.0± 4.1	[7,16] ABULENCIA	06V	CDF	dilepton
178.5±13.7± 7.7	[17,18] ABAZOV	05	D0	6 or more jets
176.1± 6.6	[19] AFFOLDER	01	CDF	lepton + jets, dileptons, all-jets
172.1± 5.2± 4.9	[20] ABBOTT	99G	D0	di-lepton, lepton+jets
176.0± 6.5	[12,21] ABE	99B	CDF	dilepton, lepton+jets, and all jets
173.3± 5.6± 5.5	[9,22] ABBOTT	98F	D0	lepton + jets
175.9± 4.8± 5.3	[11,23] ABE	98E	CDF	lepton + jets
161 ±17 ±10	[11] ABE	98F	CDF	dilepton
172.1± 5.2± 4.9	[24] BHAT	98B	RVUE	dilepton and lepton+jets
173.8± 5.0	[25] BHAT	98B	RVUE	dilepton, lepton+jets, and all jets
173.3± 5.6± 6.2	[9] 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 310 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.
[2] Ideogram method.
[3] Result is based on 1.0 fb^{-1} of data at $\sqrt{s}$ = 1.96 TeV. ABULENCIA 07D improves the matrix element description by including the effects of initial-state radiation.
[4] Matrix element technique.
[5] Result is based on $\sim$ 400 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV. The first error includes statistical and systematic jet energy scale uncertainties, the second error is from the other systematics. The result is obtained with the b-tagging information. The result without b-tagging is $169.2^{+5.0}_{-7.4}{}^{+1.5}_{-1.4}$ GeV.
[6] Result is based on 318 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.
[7] Template method.
[8] This result is obtained by re-analysis of the lepton + jets candidate events that led to ABBOTT 98F. It is based upon the maximum likelihood method which makes use of the leading order matrix elements.
[9] Result is based on 125 $\pm$ 7 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV.
[10] AFFOLDER 01 result uses lepton + jets topology. It is based on $\sim$ 106 pb^{-1} of data at $\sqrt{s}$= 1.8 TeV.
[11] Result is based on 109 $\pm$ 7 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV.
[12] See AFFOLDER 01 for details of systematic error re-evaluation.
[13] 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 AFFOLDER 01, appendix C.
[14] Dynamical likelihood method.
[15] Result is based on 340 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.
[16] Result is based on 360 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.
[17] Result is based on 110.2 $\pm$ 5.8 pb^{-1} at $\sqrt{s}$ = 1.8 TeV.
[18] ABAZOV 05 result is based on the all hadronic decays of $t\overline{t}$ pairs. Single b-quark tagging via the decay chain $b \rightarrow c \rightarrow \mu$ was used to select signal enriched multijet events. The result was obtained by the maximum likelihood method after bias correction.
[19] AFFOLDER 01 is obtained by combining the measurements in the lepton + jets [AFFOLDER 01], all-jets [ABE 97R, ABE 99B], and dilepton [ABE 99B] decay topologies.
[20] ABBOTT 99G result is obtained by combining the D0 result m_t (GeV) = 168.4 $\pm$ 12.3 $\pm$ 3.6 from 6 di-lepton events (see also ABBOTT 98D) and m_t (GeV) = 173.3 $\pm$ 5.6 $\pm$ 5.5 from lepton+jet events (ABBOTT 98F).
[21] ABE 99B result is obtained by combining the CDF results of m_t (GeV)=167.4$\pm$10.3$\pm$4.8 from 8 dilepton events, m_t (GeV)=175.9 $\pm$ 4.8 $\pm$ 5.3 from lepton+jet events (ABE 98E), and m_t (GeV)=186.0 $\pm$ 10.0 $\pm$ 5.7 from all-jet events (ABE 97R). The systematic errors in the latter two measurements are changed in this paper.
[22] See ABAZOV 04G.
[23] The updated systematic error is listed. See AFFOLDER 01, appendix C.
[24] BHAT 98B result is obtained by combining the DØ results of m_t(GeV)=168.4 $\pm$ 12.3 $\pm$ 3.6 from 6 dilepton events and m_t(GeV)=173.3 $\pm$ 5.6 $\pm$ 5.5 from 77 lepton+jet events.
[25] 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
$172.3^{+10.2}_{-7.6}$ OUR EVALUATION				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$173\ {}^{+13}_{-10}$	[26] LEP-SLC	06	RVUE	Z parameters
$162\ \pm 15\ {}^{+25}_{-5}$	[27] ABBIENDI	01A	OPAL	Z parameters
170.7 ± 3.8	[28] FIELD	00	RVUE	Z parameters without b-jet + Direct
$171.2^{+3.7}_{-3.8}$	[29] FIELD	99	RVUE	Z parameters without b jet + Direct
$172.0^{+5.8}_{-5.7}$	[30] DEBOER	97B	RVUE	Electroweak + Direct
$157\ {}^{+16}_{-12}$	[31] ELLIS	96C	RVUE	Z parameters, m_W, low energy
$175\ \pm 11\ {}^{+17}_{-19}$	[32] ERLER	95	RVUE	Z parameters, m_W, low energy
$180 \pm 9 ^{+19}_{-21} \mp 2.6 \pm 4.8$	[33] MATSUMOTO	95	RVUE	
$157\ {}^{+36}_{-48}\ {}^{+19}_{-20}$	[34] ABREU	94	DLPH	Z parameters
$158\ {}^{+32}_{-40}\ \pm 19$	[35] ACCIARRI	94	L3	Z parameters
$190\ {}^{+39}_{-48}\ {}^{+12}_{-14}$	[36] ARROYO	94	CCFR	ν_μ iron scattering
$184\ {}^{+25}_{-29}\ {}^{+17}_{-18}$	[37] BUSKULIC	94	ALEP	Z parameters
$153\ \pm 15$	[38] ELLIS	94B	RVUE	Electroweak
$177\ \pm 9\ {}^{+16}_{-20}$	[39] GURTU	94	RVUE	Electroweak
$174\ {}^{+11}_{-13}\ {}^{+17}_{-18}$	[40] MONTAGNA	94	RVUE	Electroweak
$171\ \pm 12\ {}^{+15}_{-21}$	[41] NOVIKOV	94B	RVUE	Electroweak
$160\ {}^{+50}_{-60}$	[42] ALITTI	92B	UA2	m_W, m_Z

[26] LEP-SLC 06 result is from the final electroweak measurements taken at the Z resonance, consisting of 17 million Z decays at LEP, and 600 thousand Z decays at SLC. Result is obtained without constraining m_H.

[27] ABBIENDI 01A result is from fit with free α_s when m_H is fixed to 150 GeV. The second errors are for m_H= 90 GeV (lower) and 1000 GeV (upper). The fit also finds α_s= $0.125 \pm 0.005^{+0.004}_{-0.001}$.

[28] 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.

[29] 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.

[30] 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 constraints: 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.

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

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

[33] 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 $\alpha_s(m_Z) = 0.116 \pm 0.005$, the fourth error is for $\delta\alpha_{\rm had} = 0.0283 \pm 0.0007$.

[34] 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.

[35] 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.

[36] 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 $1-m^2_W/m^2_Z = 0.2218 \pm 0.0059$, yielding the quoted m_t value. The second error corresponds to $m_H = 300^{+700}_{-240}$ GeV.

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

[38] 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 $\alpha_s(m_Z) = 0.118 \pm 0.007$ 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.

[39] 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.

[40] 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.

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

[42] 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	$W q (q = b, s, d)$			
Γ_2	$W b$			
Γ_3	$\ell \nu_\ell$ anything	[a,b]	(9.4±2.4) %	
Γ_4	$\tau \nu_\tau b$			
Γ_5	$\gamma q (q=u,c)$	[c]	< 5.9 $\times 10^{-3}$	95%

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

Γ_6	$Z q (q{=}u,c)$	$T1$	[d] < 13.7	%	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 $\Gamma(t \to \gamma q)/\Gamma(t \to W b)$.
[d] This limit is for $\Gamma(t \to Z q)/\Gamma(t \to W b)$.

t BRANCHING RATIOS

$\Gamma(W b)/\Gamma(W q(q = b, s, d))$ — Γ_2/Γ_1

VALUE	DOCUMENT ID		TECN
$1.06^{+0.16}_{-0.14}$ OUR AVERAGE			
$1.03^{+0.19}_{-0.17}$	[43] ABAZOV	06K	D0
$1.12^{+0.21}_{-0.19}{}^{+0.17}_{-0.13}$	[44] ACOSTA	05A	CDF
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$0.94^{+0.26}_{-0.21}{}^{+0.17}_{-0.12}$	[45] AFFOLDER	01C	CDF

[43] ABAZOV 06K result is from the analysis of $t\overline{t} \to \ell\nu + \geq 3$ jets with 230 pb^{-1} of data at $\sqrt{s} = 1.96$ TeV. It gives R > 0.61 and $|V_{tb}| > 0.78$ at 95% CL.

[44] ACOSTA 05A result is from the analysis of lepton + jets and di-lepton + jets final states of $t\overline{t}$ candidate events with $\sim$ 162 pb^{-1} of data at $\sqrt{s} = 1.96$ TeV. The first error is statistical and the second systematic. It gives R > 0.61, or $|V_{tb}| > 0.78$ at 95% CL.

[45] AFFOLDER 01C measures the top-quark decay width ratio $R = \Gamma(W b)/\Gamma(W q)$, where q is a d, s, or b quark, by using the number of events with multiple b tags. The first error is statistical and the second systematic. A numerical integration of the likelihood function gives $R > 0.61$ (0.56) at 90% (95%) CL. By assuming three generation unitarity, $|V_{tb}| = 0.97^{+0.16}_{-0.12}$ or $|V_{tb}| > 0.78$ (0.75) at 90% (95%) CL is obtained. The result is based on 109 pb^{-1} of data at $\sqrt{s} = 1.8$ TeV.

$\Gamma(\ell \nu_\ell \text{anything})/\Gamma_{\text{total}}$ — Γ_3/Γ

VALUE	DOCUMENT ID		TECN
0.094 ± 0.024	[46] ABE	98X	CDF

[46] 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_4/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[47] ABULENCIA	06R	CDF	$\ell\tau$ + jets
	[48] ABE	97V	CDF	$\ell\tau$ + jets

[47] ABULENCIA 06R looked for $t\overline{t} \to (\ell\nu_\ell)(\tau\nu_\tau) b\overline{b}$ events in 194 pb^{-1} of $p\overline{p}$ collisions at $\sqrt{s} = 1.96$ TeV. 2 events are found where 1.00 ± 0.17 signal and 1.29 ± 0.25 background events are expected, giving a 95% CL upper bound for the partial width ratio $\Gamma(t \to \tau\nu q) / \Gamma_{SM}(t \to \tau\nu q) < 5.2$.

[48] 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_5/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.0132	95	[49] AKTAS	04	H1	$B(t \to \gamma u)$
<0.0059	95	[50] CHEKANOV	03	ZEUS	$B(t \to \gamma u)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0465	95	[51] ABDALLAH	04C	DLPH	$B(\gamma c$ or $\gamma u)$
<0.041	95	[52] ACHARD	02J	L3	$B(t \to \gamma c$ or $\gamma u)$
<0.032	95	[53] ABE	98G	CDF	$t\overline{t} \to (W b)\ (\gamma c$ or $\gamma u)$

[49] AKTAS 04 looked for single top production via FCNC in $e^{\pm}$ collisions at HERA with 118.3 pb^{-1}, and found 5 events in the e or μ channels. By assuming that they are due to statistical fluctuation, the upper bound on the $t u \gamma$ coupling $\kappa_{t u \gamma} < 0.27$ (95% CL) is obtained. The conversion to the partial width limit, when $B(\gamma c) = B(Z u) = B(Z c) = 0$, is from private communication, E. Perez, May 2005.

[50] CHEKANOV 03 looked for single top production via FCNC in the reaction $e^{\pm} p \to e^{\pm}$ (t or $\overline{t}$) X in 130.1 pb^{-1} of data at $\sqrt{s}$=300–318 GeV. No evidence for top production and its decay into $b W$ was found. The result is obtained for m_t=175 GeV when $B(\gamma c)$=$B(Z q)$=0, where q is a u or c quark. Bounds on the effective t-u-γ and t-u-Z couplings are found in their Fig. 4. The conversion to the constraint listed is from private communication, E. Gallo, January 2004.

[51] ABDALLAH 04C looked for single top production via FCNC in the reaction $e^+ e^- \to \overline{t} c$ or $\overline{t} u$ in 541 pb^{-1} of data at $\sqrt{s}$=189–208 GeV. No deviation from the SM is found, which leads to the bound on $B(t \to \gamma q)$, where q is a u or a c quark, for m_t = 175 GeV when $B(t \to Z q)$=0 is assumed. The conversion to the listed bound is from private communication, O. Yushchenko, April 2005. The bounds on the effective t-q-γ and t-q-Z couplings are given in their Fig. 7 and Table 4, for m_t = 170–180 GeV, where most conservative bounds are found by choosing the chiral couplings to maximize the negative interference between the virtual γ and Z exchange amplitudes.

[52] ACHARD 02J looked for single top production via FCNC in the reaction $e^+ e^- \to \overline{t} c$ or $\overline{t} u$ in 634 pb^{-1} of data at $\sqrt{s}$= 189–209 GeV. No deviation from the SM is found, which leads to a bound on the top-quark decay branching fraction $B(\gamma q)$, where q is a u or c quark. The bound assumes $B(Z q)$=0 and is for m_t= 175 GeV; bounds for m_t=170 GeV and 180 GeV and $B(Z q) \neq 0$ are given in Fig. 5 and Table 7.

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

$\Gamma(Z q(q{=}u,c))/\Gamma_{\text{total}}$ Γ_6/Γ

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.159	95	[54] ABDALLAH	04C	DLPH	$e^+ e^- \to \overline{t} c$ or $\overline{t} u$
<0.137	95	[55] ACHARD	02J	L3	$e^+ e^- \to \overline{t} c$ or $\overline{t} u$
<0.14	95	[56] HEISTER	02Q	ALEP	$e^+ e^- \to \overline{t} c$ or $\overline{t} u$
<0.137	95	[57] ABBIENDI	01T	OPAL	$e^+ e^- \to \overline{t} c$ or $\overline{t} u$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.17	95	[58] BARATE	00S	ALEP	$e^+ e^- \to \overline{t} c$ or $\overline{t} u$
<0.33	95	[59] ABE	98G	CDF	$t\overline{t} \to (W b)\ (Z c$ or $Z u)$

[54] ABDALLAH 04C looked for single top production via FCNC in the reaction $e^+e^- \rightarrow \overline{t}c$ or $\overline{t}u$ in 541 pb^{-1} of data at $\sqrt{s}$=189–208 GeV. No deviation from the SM is found, which leads to the bound on B($t \rightarrow Zq$), where q is a u or a c quark, for m_t = 175 GeV when B($t \rightarrow \gamma q$)=0 is assumed. The conversion to the listed bound is from private communication, O. Yushchenko, April 2005. The bounds on the effective t-q-γ and t-q-Z couplings are given in their Fig. 7 and Table 4, for m_t = 170–180 GeV, where most conservative bounds are found by choosing the chiral couplings to maximize the negative interference between the virtual γ and Z exchange amplitudes.

[55] ACHARD 02J looked for single top production via FCNC in the reaction $e^+e^- \rightarrow \overline{t}c$ or $\overline{t}u$ in 634 pb^{-1} of data at $\sqrt{s}$= 189–209 GeV. No deviation from the SM is found, which leads to a bound on the top-quark decay branching fraction B(Zq), where q is a u or c quark. The bound assumes B(γq)=0 and is for m_t= 175 GeV; bounds for m_t=170 GeV and 180 GeV and B(γq) $\neq$0 are given in Fig. 5 and Table 7. Table 6 gives constraints on t-c-e-e four-fermi contact interactions.

[56] HEISTER 02Q looked for single top production via FCNC in the reaction $e^+e^- \rightarrow \overline{t}c$ or $\overline{t}u$ in 214 pb^{-1} of data at $\sqrt{s}$= 204–209 GeV. No deviation from the SM is found, which leads to a bound on the branching fraction B(Zq), where q is a u or c quark. The bound assumes B(γq)=0 and is for m_t= 174 GeV. Bounds on the effective t- (c or u)-γ and t- (c or u)- Z couplings are given in their Fig. 2.

[57] ABBIENDI 01T looked for single top production via FCNC in the reaction $e^+e^- \rightarrow \overline{t}c$ or $\overline{t}u$ in 600 pb^{-1} of data at $\sqrt{s}$= 189–209 GeV. No deviation from the SM is found, which leads to bounds on the branching fractions B(Zq) and B(γq), where q is a u or c quark. The result is obtained for m_t= 174 GeV. The upper bound becomes 9.7% (20.6%))) for m_t= 169 (179) GeV. Bounds on the effective t- (c or u)-γ and t- (c or u)-Z couplings are given in their Fig. 4.

[58] BARATE 00S looked for single top production via FCNC in the reaction $e^+e^- \rightarrow \overline{t}c$ or $\overline{t}u$ in 411 pb^{-1} of data at c.m. energies between 189 and 202 GeV. No deviation from the SM is found, which leads to a bound on the branching fraction. The bound assumes B(γq)=0. Bounds on the effective t- (c or u)-γ and t- (c or u)-Z couplings are given in their Fig. 4.

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

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t Decay Vertices in $p\overline{p}$ Collisions

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.056 \pm 0.080 \pm 0.057$		[60] ABAZOV	07D	D0	$F_+ = B(t \rightarrow W_+ b)$
$0.74 {}^{+0.22}_{-0.34}$		[61] ABULENCIA	06U	CDF	$F_0 = B(t \rightarrow W_0 b)$
<0.27	95	[61] ABULENCIA	06U	CDF	$F_+ = B(t \rightarrow W_+ b)$
0.56 ± 0.31		[62] ABAZOV	05G	D0	$F_0 = B(t \rightarrow W_0 b)$
$0.00 \pm 0.13 \pm 0.07$		[63] ABAZOV	05L	D0	$F_+ = B(t \rightarrow W_+ b)$
<0.25	95	[63] ABAZOV	05L	D0	$F_+ = B(t \rightarrow W_+ b)$
<0.80	95	[64] ACOSTA	05D	CDF	$F_{V+A} = B(t \rightarrow W b_R)$
<0.24	95	[64] ACOSTA	05D	CDF	$F_+ = B(t \rightarrow W_+ b)$
$0.91 \pm 0.37 \pm 0.13$		[65] AFFOLDER	00B	CDF	$F_0 = B(t \rightarrow W_0 b)$
0.11 ± 0.15		[65] AFFOLDER	00B	CDF	$F_+ = B(t \rightarrow W_+ b)$

[60] Based on 370 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV, using the ℓ + jets and dilepton decay channels. The result assumes F_0 = 0.70, and it gives $F_+ < 0.23$ at 95% CL.

[61] Result is based on 200 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV. $t \to W b \to \ell \nu b$ ($\ell = e$ or μ). The errors are stat + syst.

[62] ABAZOV 05G studied the angular distribution of leptonic decays of W bosons in $t\overline{t}$ candidate events with lepton + jets final states, and obtained the fraction of longitudinally polarized W under the constraint of no right-handed current, $F_+ = 0$. It is based on 125 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV.

[63] ABAZOV 05L studied the angular distribution of leptonic decays of W bosons in $t\overline{t}$ events, where one of the W's from t or $\overline{t}$ decays into e or μ and the other decays hadronically. The fraction of the "+" helicity W boson is obtained by assuming F_0 = 0.7, which is the generic prediction for any linear combination of V and A currents. The first error is statistical and the second one is systematic. The results are based on 230 ± 15 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.

[64] ACOSTA 05D measures the $m^2_{\ell+b}$ distribution in $t\overline{t}$ production events where one or both W's decay leptonically to $\ell = e$ or μ, and finds a bound on the V+A coupling of the tbW vertex. By assuming the SM value of the longitudinal W fraction F_0 = B($t \to W_0 b$) = 0.70, the bound on F_+ is obtained. If the results are combined with those of AFFOLDER 00B, the bounds become $F_{V+A} < 0.61$ (95% CL) and $F_+ < 0.18$ (95 %CL), respectively. ACOSTA 05D results are based on 109 ± 7 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV (run I).

[65] 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.

Single t-Quark Production Cross Section in $p\overline{p}$ Collisions

Direct probes of the tbW coupling and possible new physics.

VALUE (pb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 6.4	95	[66] ABAZOV	05P	D0	$p\overline{p} \to tb + X$
< 5.0	95	[66] ABAZOV	05P	D0	$p\overline{p} \to tqb + X$
<10.1	95	[67] ACOSTA	05N	CDF	$p\overline{p} \to tqb + X$
<13.6	95	[67] ACOSTA	05N	CDF	$p\overline{p} \to tb + X$
<17.8	95	[67] ACOSTA	05N	CDF	$p\overline{p} \to tb + X$, $tqb + X$
<24	95	[68] ACOSTA	04H	CDF	$p\overline{p} \to tb + X$, $tqb + X$
<18	95	[69] ACOSTA	02	CDF	$p\overline{p} \to tb + X$
<13	95	[70] ACOSTA	02	CDF	$p\overline{p} \to tqb + X$

[66] ABAZOV 05P bounds single top-quark production from either the s-channel W-exchange process, $q'\overline{q} \to t\overline{b}$, or the t-channel W-exchange process, $q'g \to qt\overline{b}$, based on ~ 230 pb^{-1} of data at $\sqrt{s}$=1.96 TeV.

[67] ACOSTA 05N bounds single top-quark production from the t-channel W-exchange process ($q'g \to qt\overline{b}$), the s-channel W-exchange process ($q'\overline{q} \to t\overline{b}$), and from the combined cross section of t- and s-channel. The results are based on ~ 162 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.

[68] ACOSTA 04H bounds single top-quark production from the s-channel W-exchange process, $q'\overline{q} \to t\overline{b}$, and the t-channel W-exchange process, $q'g \to qt\overline{b}$. It is based on ~ 106 pb^{-1} of data at $\sqrt{s}$ = 1.8 TeV (run I).

[69] ACOSTA 02 bounds the cross section for single top-quark production via the s-channel W-exchange process, $q' \overline{q} \rightarrow t \overline{b}$. It is based on $\sim$ 106 pb^{-1} of data at $\sqrt{s}$=1.8 TeV.

[70] ACOSTA 02 bounds the cross section for single top-quark production via the t-channel W-exchange process, $q' g \rightarrow q t \overline{b}$. It is based on $\sim$ 106 pb^{-1} of data at $\sqrt{s}$=1.8 TeV.

Single t-Quark Production Cross Section in $e p$ Collisions

VALUE (pb)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.55	95	[71] AKTAS	04	H1	$e^{\pm} p \rightarrow e^{\pm} t X$

[71] AKTAS 04 looked for single top production via FCNC in $e^{\pm}$ collisions at HERA with 118.3 pb^{-1}, and found 5 events in the e or μ channels while 1.31 $\pm$ 0.22 events are expected from the Standard Model background. No excess was found for the hadronic channel. The observed cross section of $\sigma(e p \rightarrow e t X) = 0.29^{+0.15}_{-0.14}$ pb at $\sqrt{s} = 319$ GeV gives the quoted upper bound if the observed events are due to statistical fluctuation.

$t \overline{t}$ production cross section in $p \overline{p}$ collisions

VALUE (pb)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$6.6 \pm 0.9 \pm 0.4$	[72] ABAZOV	06X	D0	ℓ + jets, vtx b-tag
$8.7 \pm 0.9^{+1.1}_{-0.9}$	[73] ABULENCIA	06Z	CDF	ℓ + jets, vtx b-tag
$5.8 \pm 1.2^{+0.9}_{-0.7}$	[74] ABULENCIA,A	06C	CDF	missing E_T + jets, vtx b-tag
$7.5 \pm 2.1^{+3.3}_{-2.2}{}^{+0.5}_{-0.4}$	[75] ABULENCIA,A	06E	CDF	6–8 jets, b-tag
$8.9 \pm 1.0^{+1.1}_{-1.0}$	[76] ABULENCIA,A	06F	CDF	$\ell + \geq 3$ jets, b-tag
$8.6^{+1.6}_{-1.5} \pm 0.6$	[77] ABAZOV	05Q	D0	ℓ + n jets
$8.6^{+3.2}_{-2.7} \pm 1.1 \pm 0.6$	[78] ABAZOV	05R	D0	di-lepton + n jets
$6.7^{+1.4}_{-1.3}{}^{+1.6}_{-1.1} \pm 0.4$	[79] ABAZOV	05X	D0	ℓ + jets / kinematics
$5.3 \pm 3.3^{+1.3}_{-1.0}$	[80] ACOSTA	05S	CDF	ℓ + jets / soft μ b-tag
$6.6 \pm 1.1 \pm 1.5$	[81] ACOSTA	05T	CDF	ℓ + jets / kinematics
$6.0^{+1.5}_{-1.6}{}^{+1.2}_{-1.3}$	[82] ACOSTA	05U	CDF	ℓ + jets / kinematics + vtx b-tag
$5.6^{+1.2}_{-1.1}{}^{+0.9}_{-0.6}$	[83] ACOSTA	05V	CDF	ℓ + n jets
$7.0^{+2.4}_{-2.1}{}^{+1.6}_{-1.1} \pm 0.4$	[84] ACOSTA	04I	CDF	di-lepton + jets + missing ET

[72] Measured at $\sqrt{s}$ = 1.96 TeV using $\sim$ 425 pb^{-1}. Assuming m_t = 175 GeV. The first error is statistical and systematic, the second one is luminosity.

[73] Measured at $\sqrt{s}$ = 1.96 TeV using $\sim$ 318 pb^{-1}. Assuming m_t = 178 GeV. The cross section changes by $\pm$0.08 pb for each $\mp$1 GeV change in the assumed m_t. Result is for at least one b-tag. For at least two b-tagged jets, $t \overline{t}$ signal of significance greater than 5σ is found, and the cross section is $10.1^{+1.6}_{-1.4}{}^{+2.0}_{-1.3}$ pb for m_t = 178 GeV.

[74] Measured at $\sqrt{s}$ = 1.96 TeV using $\sim$ 311 pb^{-1}. Assuming m_t = 178 GeV. The first error is statistical and the second systematic. For m_t = 175 GeV, the result is $6.0 \pm 1.2^{+0.9}_{-0.7}$. This is the first CDF measurement without lepton identification, and hence it has sensitivity to the $W \rightarrow \tau \nu$ mode.

[75] ABULENCIA,A 06E measures the $t\bar{t}$ production cross section in the all hadronic decay mode by selecting events with 6 to 8 jets and at least one b-jet. S/B = 1/5 has been achieved. Measured at $\sqrt{s}$ = 1.96 TeV using 311 pb^{-1}. Assuming m_t = 178 GeV. The first error is statistical, the second is systematic, and the third one is luminosity.

[76] Measured at $\sqrt{s}$ = 1.96 TeV using ∼ 318 pb^{-1}. Assuming m_t = 178 GeV. Result is for at least one *b*-tag. For at least two *b*-tagged jets, the cross section is $11.1^{+2.3}_{-1.9}{}^{+2.5}_{-1.9}$ pb.

[77] ABAZOV 05Q measures the top-quark pair production cross section at $\sqrt{s}$=1.96 TeV with ∼ 230 pb^{-1} of data, based on the analysis of *W* plus n-jet events where W decays into *e* or μ plus neutrino, and at least one of the jets is *b*-jet like. The first error is statistical and systematic, and the second accounts for the luminosity uncertainty. The result assumes m_t = 175 GeV; the mean value changes by (175−m_t(GeV)) × 0.06 pb in the mass range 160 to 190 GeV.

[78] ABAZOV 05R measures the top-quark pair production cross section at $\sqrt{s}$=1.96 TeV with 224–243 pb^{-1} of data, based on the analysis of events with two charged leptons in the final state. The first error is statistical, the second one is systematic, and the last one gives the luminosity uncertainty. The result assumes m_t = 175 GeV; the mean value changes by (175−m_t(GeV)) × 0.08 pb in the mass range 160 to 190 GeV.

[79] Measured at $\sqrt{s}$ = 1.96 TeV using 230 pb^{-1}. Assuming m_t = 175 GeV. The last error accounts for the luminosity uncertainty.

[80] Measured at $\sqrt{s}$ = 1.96 TeV using 194 pb^{-1}. Assuming m_t = 175 GeV.

[81] Measured at $\sqrt{s}$ = 1.96 TeV using 194 ± 11 pb^{-1}. Assuming m_t = 175 GeV.

[82] Measured at $\sqrt{s}$ = 1.96 TeV using 162 ± 10 pb^{-1}. Assuming m_t = 175 GeV.

[83] ACOSTA 05V measures the top-quark pair production cross section at $\sqrt{s}$ = 1.96 TeV with ∼ 162 pb^{-1} data, based on the analysis of *W* plus n-jet events where *W* decays into *e* or μ plus neutrino, and at least one of the jets is *b*-jet like. Assumes m_t = 175 GeV.The first error is statistical and the latter is systematic, which include the luminosity uncertainty.

[84] ACOSTA 04I measures the top-quark pair production cross section at $\sqrt{s}$=1.96 TeV with 197 ± 12 pb^{-1} data, based on the analysis of events with two charged leptons in the final state. Assumes m_t = 175 GeV. The first error is statistical, the second one is systematic, and the last one gives the luminosity uncertainty.

t-Quark Electric Charge

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
	[85] ABAZOV	07C	D0	fraction of $\lvert q\rvert$=4e/3 pair

[85] ABAZOV 07C reports an upper limit ρ < 0.80 (90% CL) on the fraction ρ of exotic quark pairs $Q\overline{Q}$ with electric charge $\lvert q\rvert$ = 4e/3 in $t\bar{t}$ candidate events with high p_T lepton, missing E_T and ≥ 4 jets. The result is obtained by measuring the fraction of events in which the quark pair decays into W^- + *b* and W^+ + $\overline{b}$, where *b* and $\overline{b}$ jets are discriminated by using the charge and momenta of tracks within the jet cones. The maximum CL at which the model of CHANG 99 can be excluded is 92%. Based on 370 pb^{-1} of data at $\sqrt{s}$ = 1.96 TeV.

t-Quark REFERENCES

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ABULENCIA	07D	PR D75 031105R	A. Abulencia *et al.*	(CDF Collab.)
TEVEWWG	07	hep-ex/0703034	CDF, D0 Collab., Tevatron Electroweak Working Group	
TEVEWWG	07A	Private communication	CDF, D0 Collab., Tevatron Electroweak Working Group	
ABAZOV	06K	PL B639 616	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	06U	PR D74 092005	V.M. Abazov *et al.*	(D0 Collab.)
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ABULENCIA	06D	PRL 96 022004	A. Abulencia *et al.*	(CDF Collab.)
Also		PR D73 032003	A. Abulencia *et al.*	(CDF Collab.)
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Also		PR D74 032009	A. Abulencia *et al.*	(CDF Collab.)
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