t' (4^{th} Generation) Quark, Searches for

t'-quark/hadron mass limits in $p\overline{p}$ and pp collisions

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>656	95	[1] AAD	13F	ATLS	$B(t' \to W b) = 1$
>350	95	[2] AAD	12BC	ATLS	$B(t' \to W q)$=1 (q=d,s,b)
>420	95	[3] AAD	12C	ATLS	$t' \to X t$ ($m_X < 140$ GeV)
>685	95	[4] CHATRCHYAN	12BH	CMS	$m_{b'} = m_{t'}$
>557	95	[5] CHATRCHYAN	12P	CMS	$t'\overline{t}' \to W^+ b W^- \overline{b} \to b\ell^+ \nu \overline{b} \ell^- \overline{\nu}$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>404	95	[6] AAD	12AR	ATLS	$B(t' \to W b) = 1$
>570	95	[7] CHATRCHYAN	12BC	CMS	$t'\overline{t}' \to W^+ b W^- \overline{b}$
>400	95	[8] AALTONEN	11AH	CDF	$t' \to X t$ ($m_X < 70$ GeV)
>358	95	[9] AALTONEN	11AL	CDF	$t' \to W b$
>340	95	[9] AALTONEN	11AL	CDF	$t' \to W q$ (q=d,s,b)
>360	95	[10] AALTONEN	11O	CDF	$t' \to X t$ ($m_X < 100$ GeV)
>285	95	[11] ABAZOV	11Q	D0	$t' \to W q$ (q=d,s,b)
>256	95	[12,13] AALTONEN	08H	CDF	$t' \to W q$

[1] Based on 4.7 fb^{-1} of data at LHC7. No signal is found for the search of heavy quark pair production that decay into W and a b quark in the events with a high p_T isolated lepton, large $\not\!\!E_T$ and at least 3 jets ($\geq$ 1 b-tag). Vector-like quark of charge 2/3 with $400 < m_{t'} < 550$ GeV and $B(t' \to W b) > 0.63$ is excluded at 95% CL.

[2] Based on 1.04 fb^{-1} of data at LHC7. No signal is found for the search of heavy quark pair production that decay into W and a quark in the events with dileptons, large $\not\!\!E_T$, and $\geq$ 2 jets.

[3] Based on 1.04 fb^{-1} of data in pp collisions at 7 TeV. AAD 12C looked for $t'\overline{t}'$ production followed by t' decaying into a top quark and X, an invisible particle,in a final state with an isolated high-P_T lepton, four or more jets, and a large missing transverse energy. No excess over the SM ttbar production gives the upper limit on $t'\overline{t}'$ production cross section as a function of $m_{t'}$ and m_X. The result is obtained for $B(t' \to W t) = 1$.

[4] Based on 5 fb^{-1} of data at LHC7. CHATRCHYAN 12BH searched for QCD and EW production of single and pair of degenerate 4'th generation quarks that decay to $W b$ or $W t$. Absence of signal in events with one lepton, same-sign dileptons or tri-leptons gives the bound. With a mass difference of 25 GeV/c^2 between $m_{t'}$ and $m_{b'}$, the corresponding limit shifts by about $\pm$20 GeV/c^2.

[5] Based on 5.0 fb^{-1} of data at LHC7. CHATRCHYAN 12P looked for $t'\overline{t}'$ production events with two isolated high p_T leptons, large $\not\!\!E_T$, and 2 high p_T jets with b-tag. The absence of signal above the SM background gives the limit for $B(t' \to W b) = 1$.

[6] Based on 1.04 fb^{-1} of data at LHC7. No signal is found in the search for pair produced heavy quarks that decay into W boson and a b quark in the events with a high p_T isolated lepton, large $\not\!\!E_T$ and at least 3 jets (≥ 1 b-tag).

[7] Based on 5.0 fb^{-1} of data at LHC7. CHATRCHYAN 12BC looked for $t'\overline{t}'$ production events with a single isolated high p_T lepton, large $\not\!\!E_T$ and at least 4 high p_T jets with a b-tag. The absence of signal above the SM background gives the limit for $B(t' \to W b) = 1$.

[8] Based on 5.7 fb^{-1} of data in $p\overline{p}$ collisions at 1.96 TeV. AALTONEN 11AH looked for $t'\overline{t}'$ production followed by t' decaying into a top quark and X, an invisible particle, in the all hadronic decay mode of $t\overline{t}$. No excess over the SM ttbar production gives the upper limit on $t'\overline{t}'$ production cross section as a function of $m_{t'}$ and m_X. The result is obtained for B($t' \rightarrow\ X\,t$) = 1.

[9] Based on 5.6 fb^{-1} of data in ppbar collisions at 1.96 TeV. AALTONEN 11AL looked for $\ell +\ \geq$ 4j events and set upper limits on $\sigma(t'\overline{t}')$ as functions of $m_{t'}$.

[10] Based on 4.8 fb^{-1} of data in $p\overline{p}$ collisions at 1.96 TeV. AALTONEN 11O looked for $t'\overline{t}'$ production signal when t' decays into a top quark and X, an invisible particle, in ℓ + $\not\!\!E_T$ + jets channel. No excess over the SM ttbar production gives the upper limit on $t'\overline{t}'$ production cross section as a function of $m_{t'}$ and m_X. The result is obtained for B($t' \rightarrow\ X\,t$) = 1.

[11] Based on 5.3 fb^{-1} of data in $p\overline{p}$ collisions at 1.96 TeV. ABAZOV 11Q looked for ℓ + $\not\!\!E_T$ + $\geq$ 4j events and set upper limits on $\sigma(t'\overline{t}')$ as functions of $m_{t'}$.

[12] Searches for pair production of a new heavy top-like quark t' decaying to a W boson and another quark by fitting the observed spectrum of total transverse energy and reconstructed t' mass in the lepton + jets events.

[13] HUANG 08 reexamined the t' mass lower bound of 256 GeV obtained in AALTONEN 08H that assumes B($b' \rightarrow\ q\,Z$) = 1 for $q = u$, c which does not hold when $m_{b'} < m_{t'} - m_W$ or the mixing $\sin^2(\theta_{b\,t'})$ is so tiny that the decay occurs outside of the vertex detector. Fig. 1 gives that lower bound on $m_{t'}$ in the plane of $\sin^2(\theta_{b\,t'})$ and $m_{b'}$.

t' mass limits from single production in $p\overline{p}$ and pp collisions

VALUE (GeV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
>403	95	[14] ABAZOV	11F	D0	$q\,d \rightarrow\ q'\,t' \rightarrow\ q'(W\,d)$ $\widetilde{\kappa}_{d\,t'}$=1, B($t' \rightarrow\ W\,d$)=1
>551	95	[14] ABAZOV	11F	D0	$q\,u \rightarrow\ q\,t' \rightarrow\ q(Z\,u)$ $\widetilde{\kappa}_{u\,t'}$=$\sqrt{2}$, B($t' \rightarrow\ Z\,u$)=1

[14] Based on 5.4 fb^{-1} of data in ppbar collisions at 1.96 TeV. ABAZOV 11F looked for single production of t' via the Z or E coupling to the first generation up or down quarks, respectively. Model independent cross section limits for the single production processes $p\overline{p} \rightarrow\ t'\,q \rightarrow (W\,d)q$, and $p\overline{p} \rightarrow\ t'\,q \rightarrow (Z\,d)q$ are given in Figs. 3 and 4, respectively, and the mass limits are obtained for the model of ATRE 09 with degenerate bi-doublets of vector-like quarks.

REFERENCES FOR Searches for (Fourth Generation) t' Quark

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AAD	12AR	PRL 108 261802	G. Aad *et al.*	(ATLAS Collab.)
AAD	12BC	PR D86 012007	G. Aad *et al.*	(ATLAS Collab.)
AAD	12C	PRL 108 041805	G. Aad *et al.*	(ATLAS Collab.)
CHATRCHYAN	12BC	PL B718 307	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12BH	PR D86 112003	S. Chatrchyan *et al.*	(CMS Collab.)
CHATRCHYAN	12P	PL B716 103	S. Chatrchyan *et al.*	(CMS Collab.)
AALTONEN	11AH	PRL 107 191803	T. Aaltonen *et al.*	(CDF Collab.)
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ABAZOV	11F	PRL 106 081801	V.M. Abazov *et al.*	(D0 Collab.)
ABAZOV	11Q	PRL 107 082001	V.M. Abazov *et al.*	(D0 Collab.)
ATRE	09	PR D79 054018	A. Atre *et al.*	
AALTONEN	08H	PRL 100 161803	T. Aaltonen *et al.*	(CDF Collab.)
HUANG	08	PR D77 037302	P.Q. Hung, M. Sher	(UVA, WILL)