UC DAVIS
UNIVERSITY OF CALIFORNIA

Search for a heavy top $t' \rightarrow Wq$ in top events

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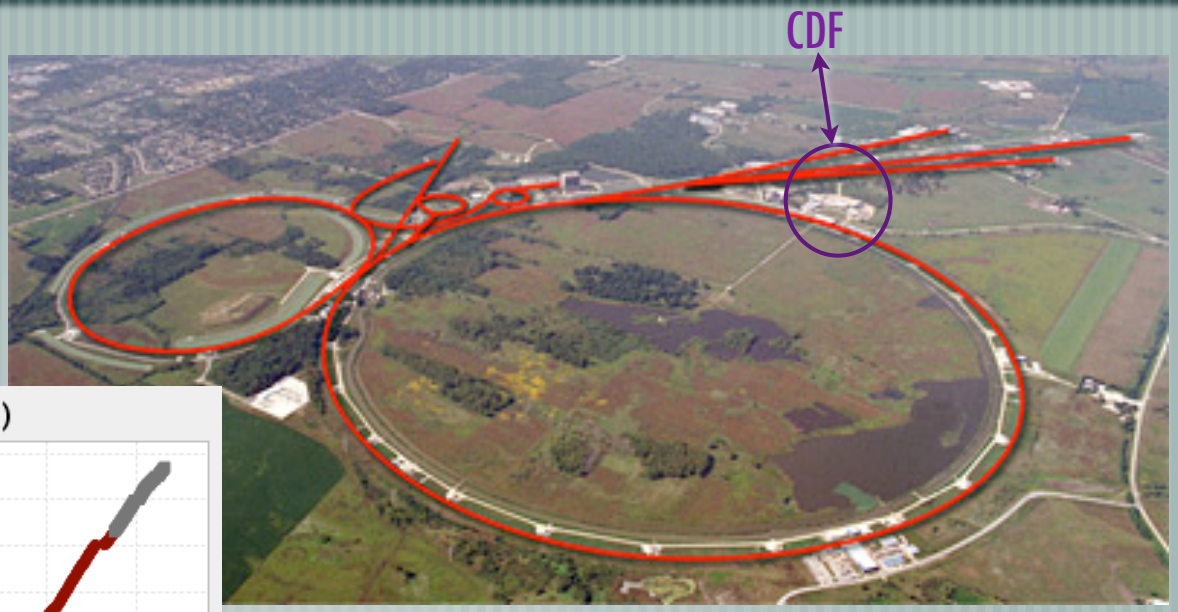
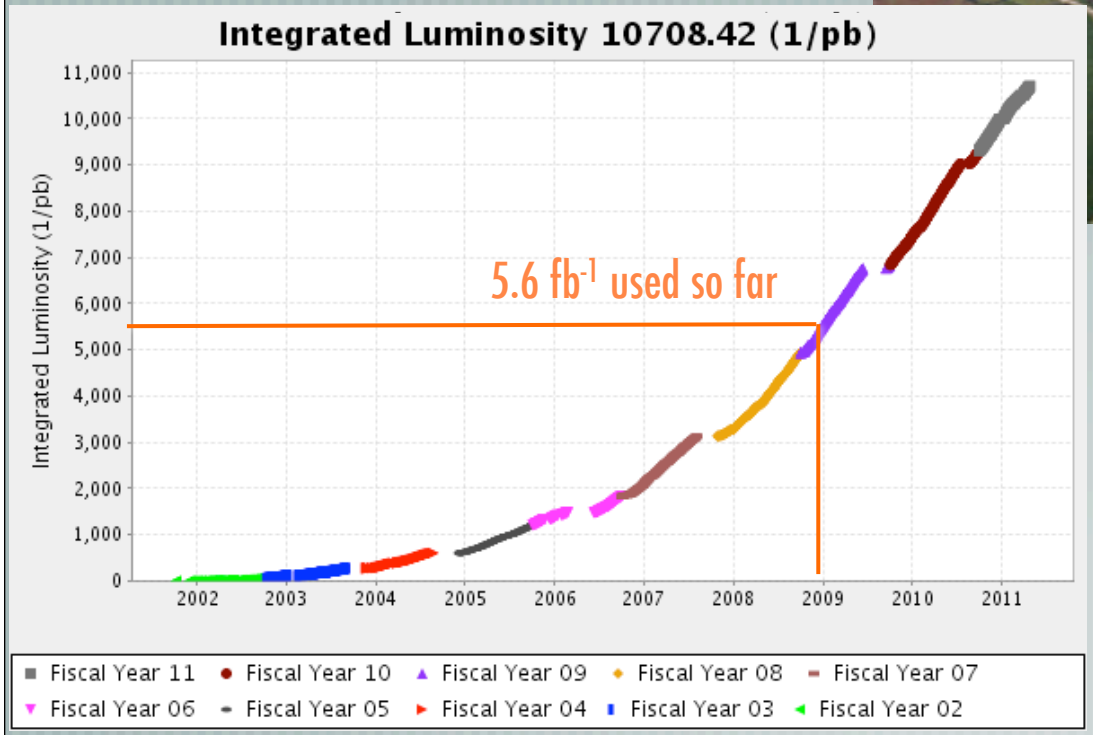
on behalf of the CDF Collaboration

New Perspectives, 2011

CDF & the Tevatron

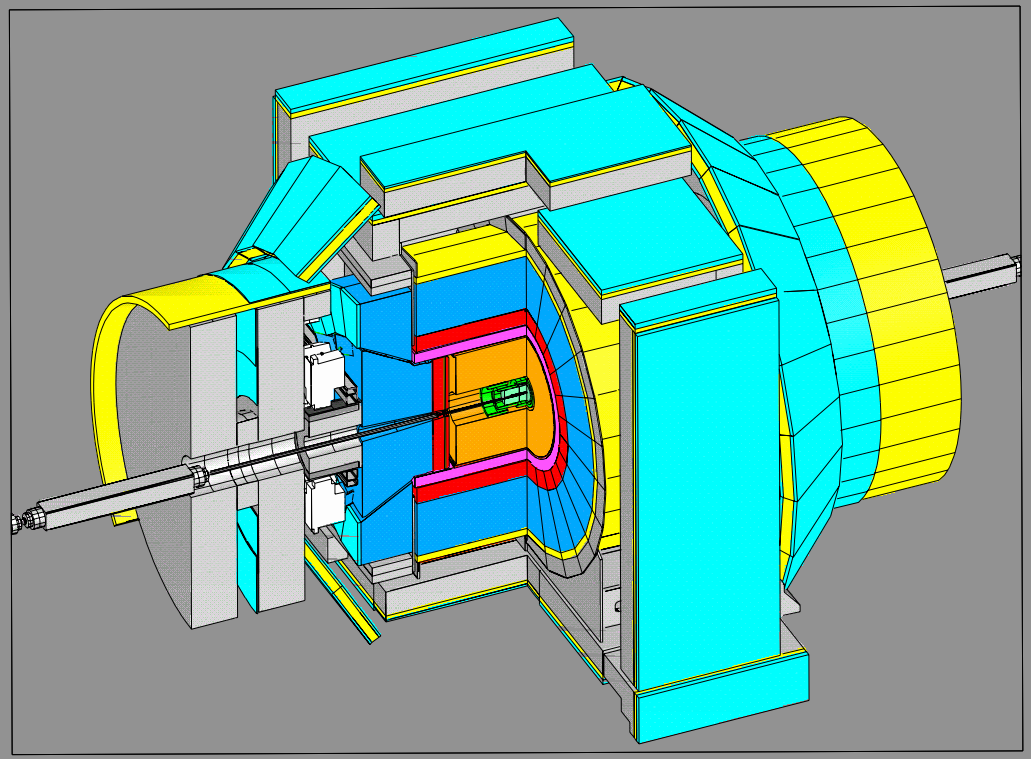
$p\bar{p}$ collisions at 1.96 TeV





Continual improvements in instantaneous luminosity means more data per year for CDF every year

CDF Detector

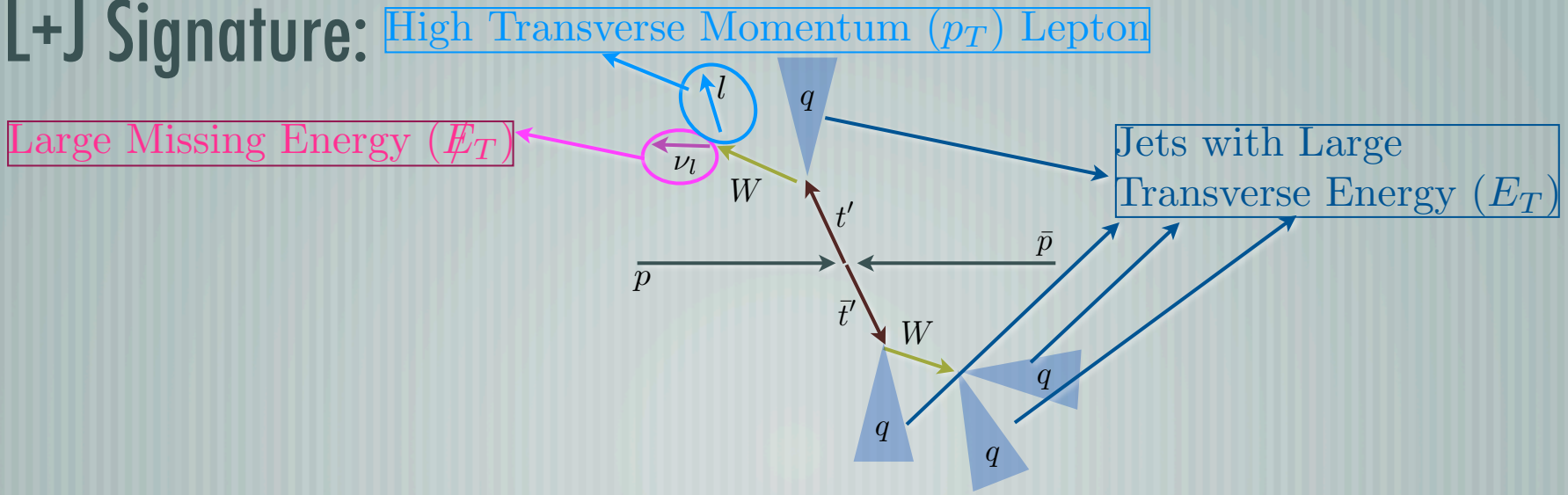


The CDF detector is a general purpose solenoidal detector which combines precision charged particle tracking with projective calorimetry and fine grained muon detection

What is a t′ quark

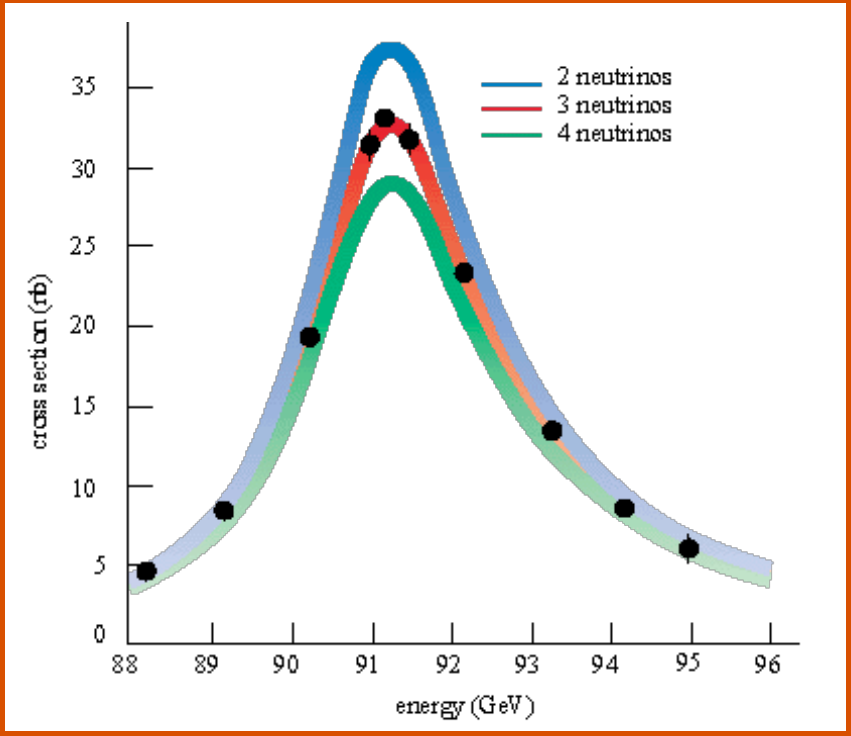
- A t′ is a fourth generation top-like quark or similar object
  - Predicted by a variety of theoretical models: Flavor democracy, GUT SO(1,13), Two Higgs doublet scenarios, Beautiful Mirrors, Little Higgs

L+J Signature:



Existing Limits

LEP measurements of the Z boson exclude a light fourth neutrino



Constraints from radiative corrections to electroweak parameters also exist (parameterized with S,T,U)

parameter set	$m_{t'}$	$m_{b'}$	m_H	ΔS_{tot}	ΔT_{tot}
(a)	310	260	115	0.15	0.19
(b)	320	260	200	0.19	0.20
(c)	330	260	300	0.21	0.22
(d)	400	350	115	0.15	0.19
(e)	400	340	200	0.19	0.20
(f)	400	325	300	0.21	0.25

$m_{\nu_4} = 100$ GeV/c $\quad m_{l_4} = 155$ GeV/c

There are reasonable constructions of a fourth generation which are not excluded

Source: Phys. Rev. D76:075016, 2007 arXiv:0706.3718v1

Why look for it?

- Several theoretical models predict it
- Presence of a fourth generation relaxes Higgs bounds
- Some models improve the fit to the electroweak observables with a fourth generation
- Why not?

Theory Overview

Flavor Democracy: Four generations of leptons with equal Yukawa couplings - t′,b′ required for anomaly cancellation [JHEP 0212 (2002) 036]

GUT SO(1,13): Four generations from symmetry breaking [Bled workshops in physics, Vol.7, No.2, DMFA-Zaloznistvo, Ljubljana, Dec. 2006]

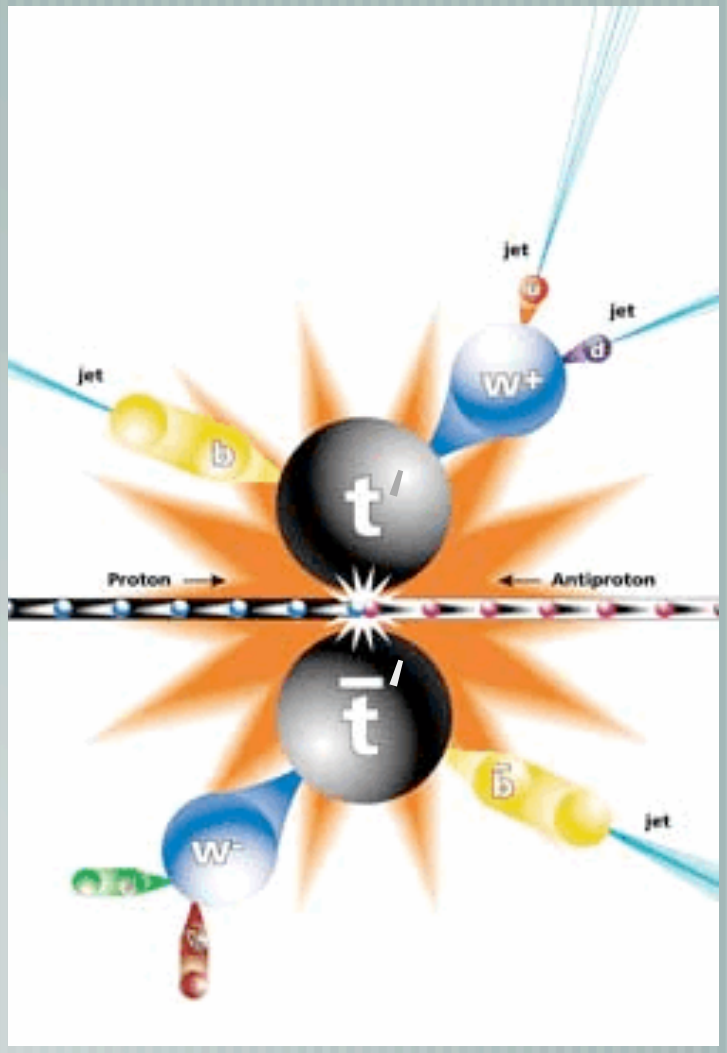
Two Higgs Doublet: N=2 Supersymmetry requires 3 additional fermion generations [Phys. Rev. D64 (2001) 053004]

Little Higgs: Cancels quadratic divergences using additional particles (Not supersymmetric) [Phys. Rev. D 68, 097301 (2003)]

Beautiful Mirrors: Extra quarks improve agreement between measured asymmetry and predicted (Possible vector-like coupling) [Phys. Rev. D65:053002, 2002]

The t′ search at CDF

- Assumptions
  - $t' \rightarrow Wq$ (BR $\cong$ 100%) or
    $t' \rightarrow Wb$ (BR $\cong$ 100%)*
  - t′ is pair produced strongly
  - t′ mass > top quark mass



*: Usually $M_{t'} - M_{b'} < M_W$

Selection for t′ → Wb (Wq)

- Exactly one high-p_T ($p_T \geq 20$ (25) GeV) isolated electron or muon
- Large missing transverse energy ($\not\!\!E_T \geq 20$ GeV)
- At least four energetic jets ($E_T \geq 20$ GeV)
- For t′ → Wq we also require two jets with $E_T \geq 25$ GeV
- For t′ → Wb we require one of the jets to be tagged as coming from a b-jet with the secondary vertex tagging algorithm

Cuts for t′ → Wq for QCD

- To reduce QCD background we require
  - Transverse boson mass ($M_{T,W}$) > 20 GeV
  - Missing E_T significance > 0.5 · $M_{T,W}$ + 3.5

$$\not\!\!E_{T,sig} = \frac{\not\!\!E_T}{\sqrt{\sum_{jets} C_{JES}^2 \cos^2(\Delta\phi_{\vec{\not\!\!E}_T,jet}) + \cos^2(\Delta\phi_{\vec{\not\!\!E}_T uncorr}, \vec{\not\!\!E}_T{}^{corr})}}$$

Mismodeling Cuts ($t' \rightarrow Wq$)

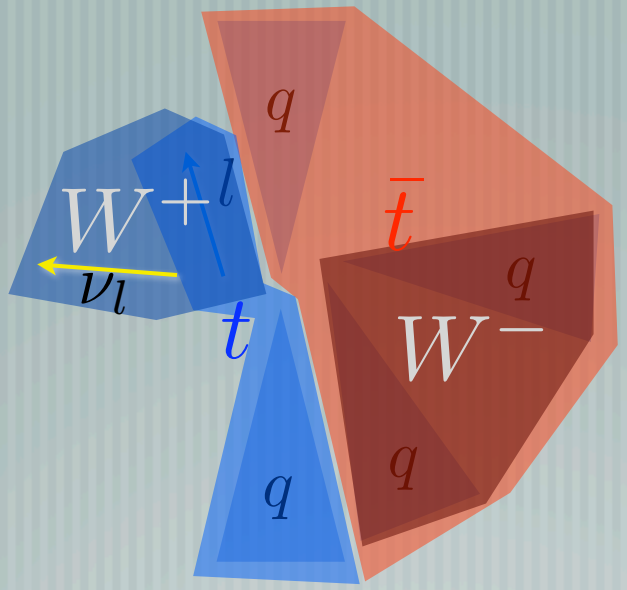
- For electron events with lead jet E_T > 160 GeV we require
  - $\Delta\phi(\vec{\not{E}}_T, Lead\ Jet)$ > 0.6 rad
- For electron events with lepton p_T > 120 GeV we require
  - $\Delta\phi(\vec{\not{E}}_T, Lepton)$ < 2.6 rad
- For muons with lepton p_T > 120 GeV we require
  - $\Delta\phi(\vec{\not{E}}_T, Lepton)$ < 2.6 rad (tight)
  - 0.4 rad < $\Delta\phi(\vec{\not{E}}_T, Lepton)$ < 2.6 rad (loose)

Search Technique

- To distinguish between backgrounds and signal we fit to the observed 3D distribution of reconstructed mass, total transverse energy ($H_T = \sum_{jets} E_T + E_{T,l} + \not{E}_T$) and jet category (number of jets and χ^2)
- The fit used is a binned likelihood fit
- Systematic errors are treated as parameters in the fit and are allowed to float within their expected uncertainties

M_{reco} - Kinematic Fitter

Calculate a χ^2 based on the kinematic quantities

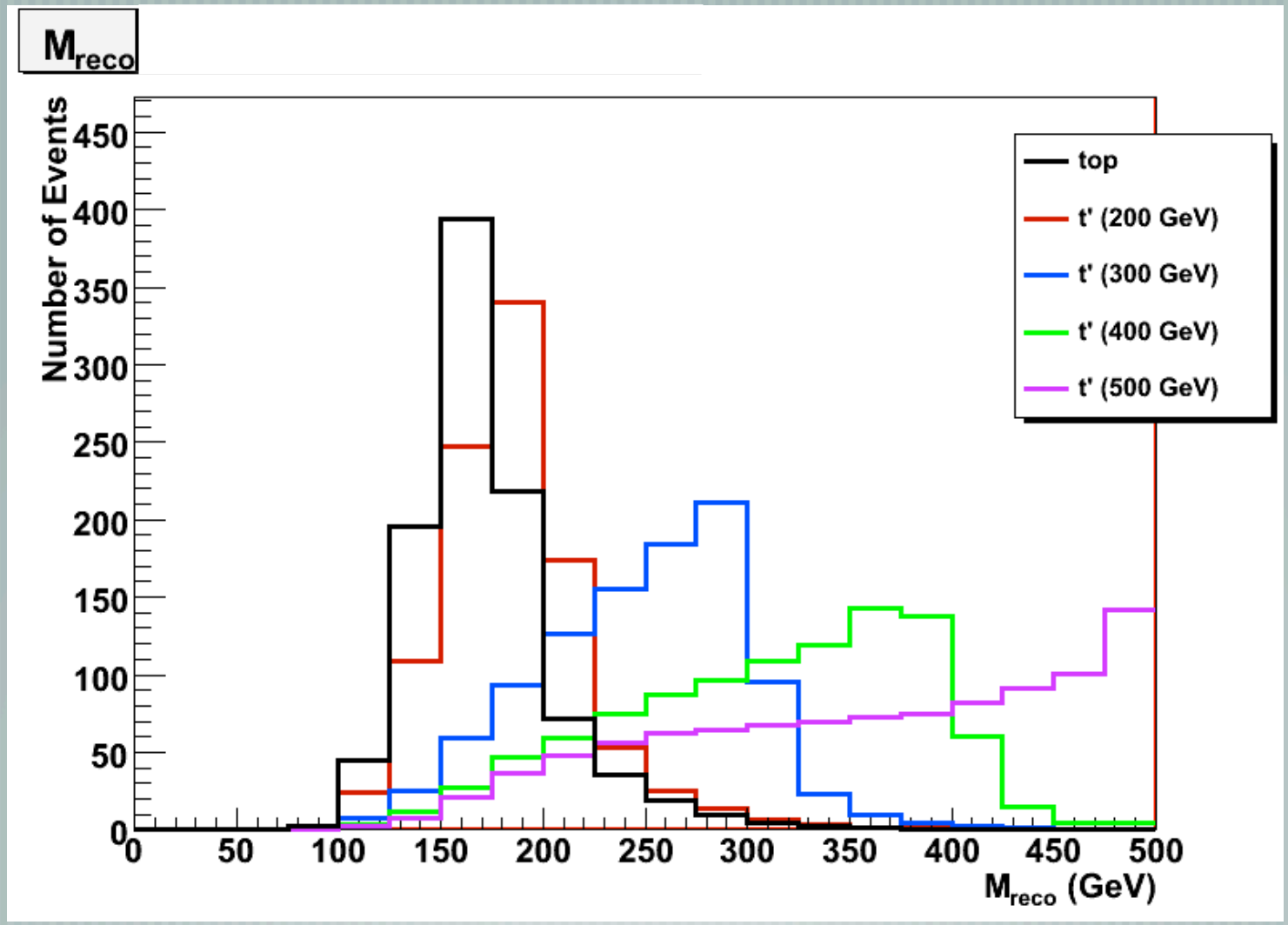


Constrain W decay products to W mass and the top / anti-top mass to be equal

$$\chi^2 = \sum_{i=\ell,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,fit} - p_j^{UE,meas})^2}{\sigma_j^2} + \frac{(m_{jj} - m_W)^2}{\Gamma_W^2} + \frac{(m_{\ell\nu} - m_W)^2}{\Gamma_W^2} + \frac{(m_{bjj} - m_t)^2}{\Gamma_t^2} + \frac{(m_{b\ell\nu} - m_t)^2}{\Gamma_t^2}$$

UE = unclustered energy

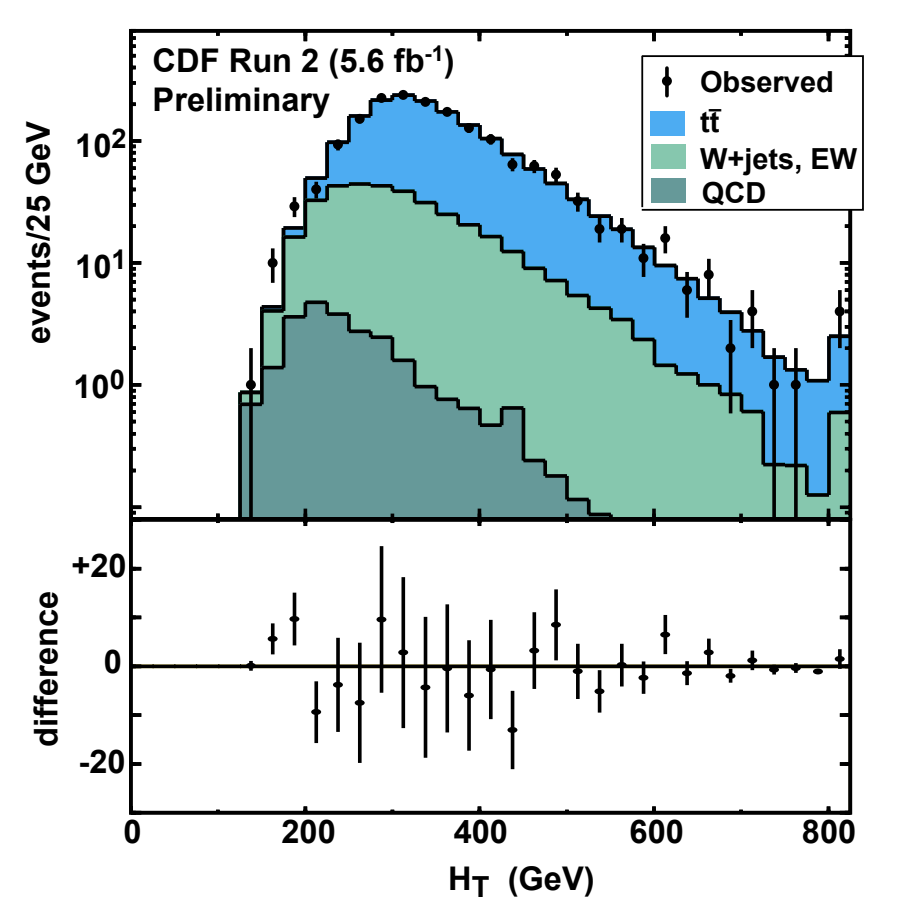
Kinematic Fitter Output

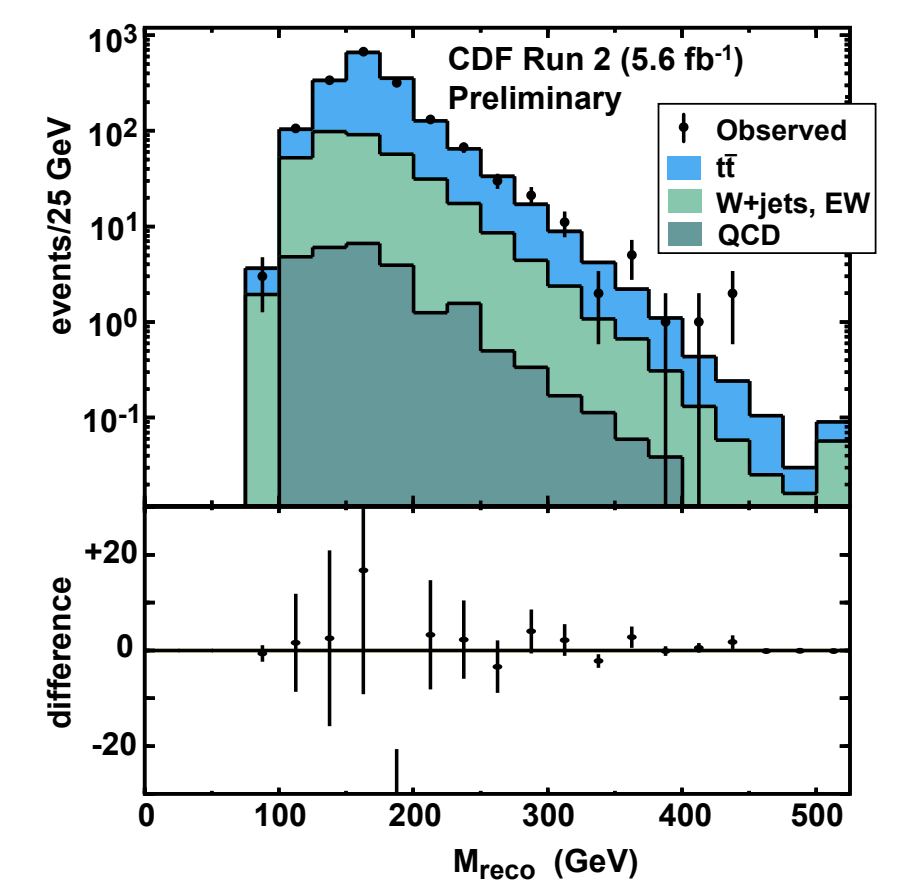


Backgrounds

- We model our backgrounds in three separate ways
  - The backgrounds from $t\bar{t}$ production and electroweak processes are modeled via MC samples whose normalization is constrained to expected values
  - The backgrounds from W+jets is modeled with MC and it's normalization is allowed to float in the fit
  - The QCD background is modeled from a sample of data collected using jet triggers in which some of the lepton id requirements were loosened

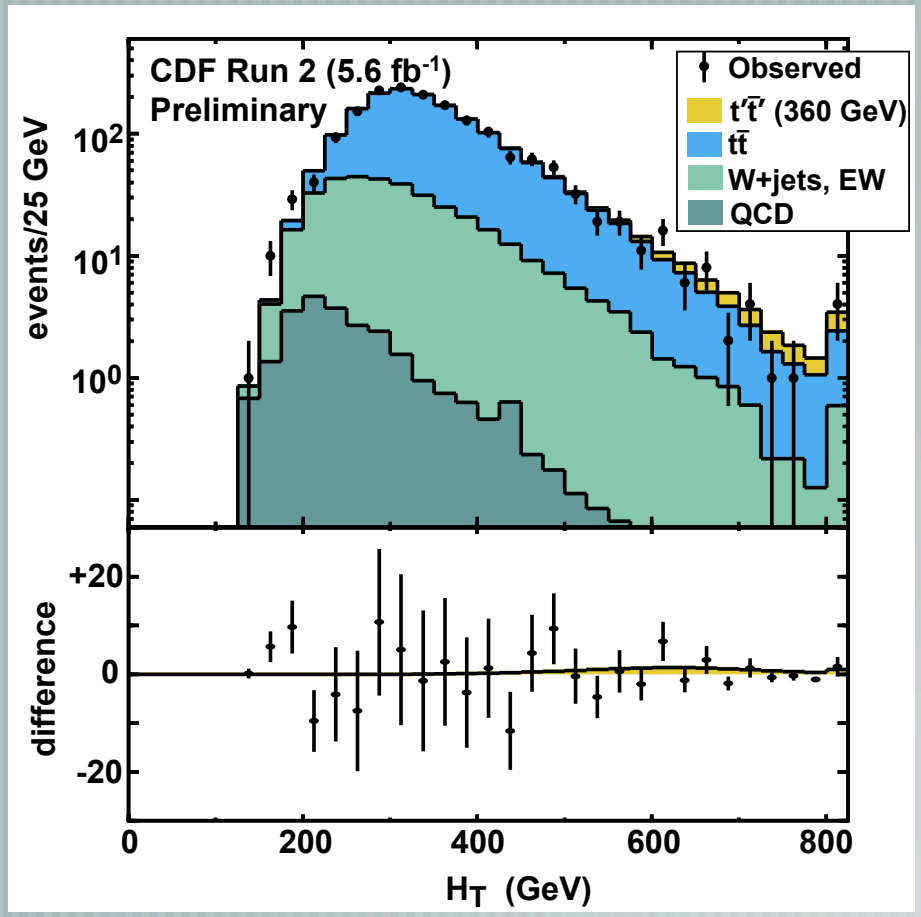
Search Results t′ → Wb

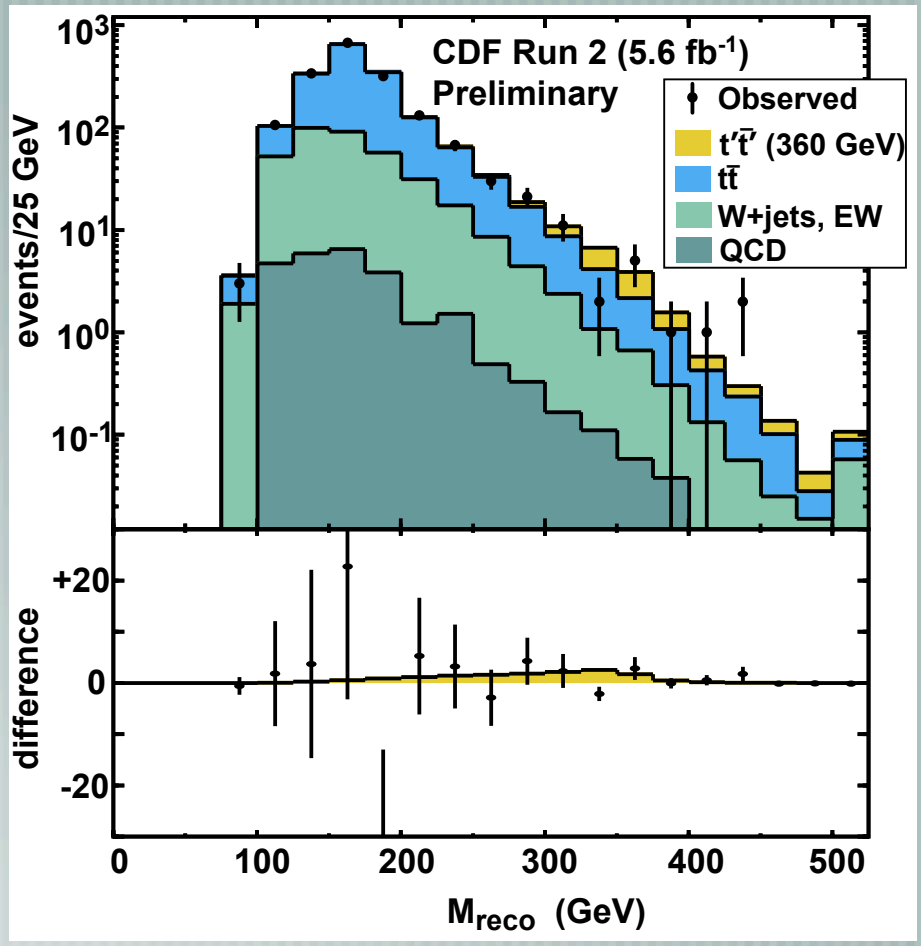




The W+jets & t′ cross sections float in the fit. The top cross section is constrained to a normal distribution with mean at 7.23 pb

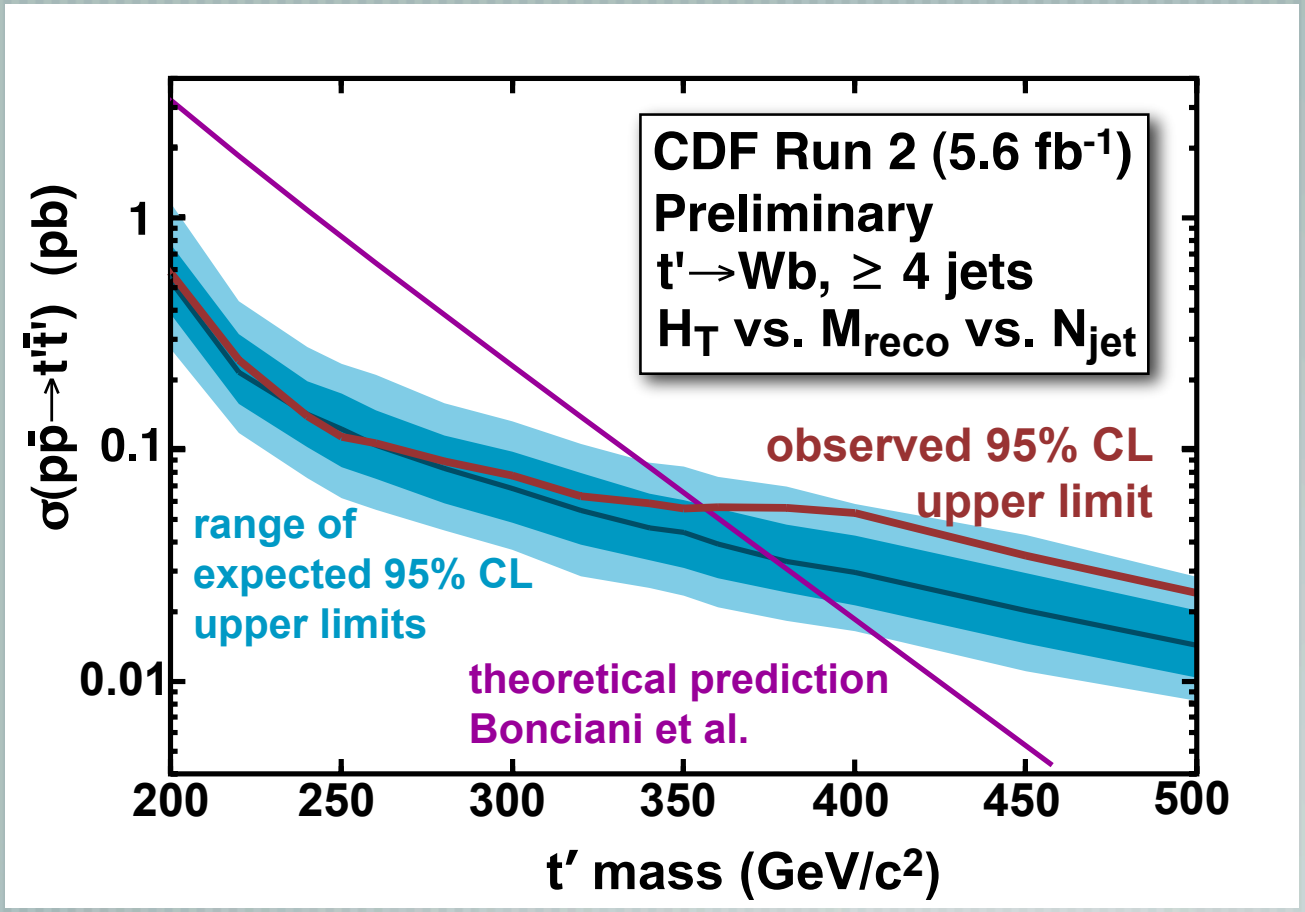
Search Results $t' \rightarrow Wb$





Distributions shown for the maximum likelihood

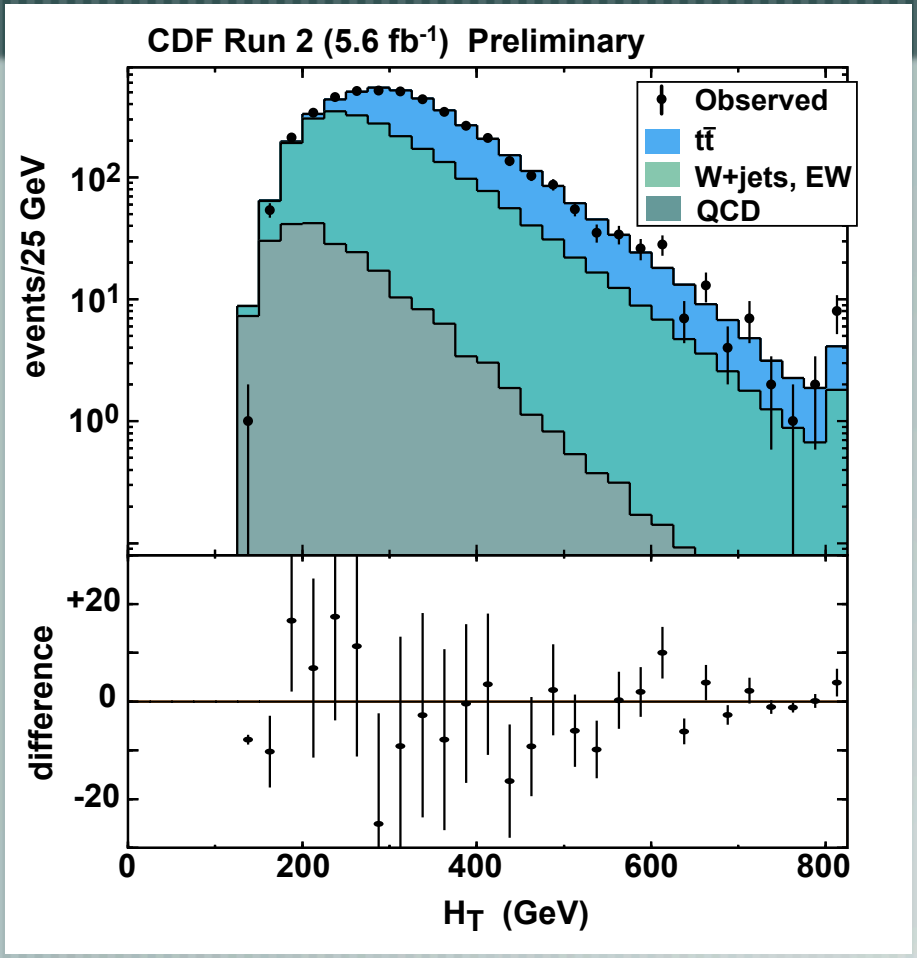
Search Results t′ → Wb

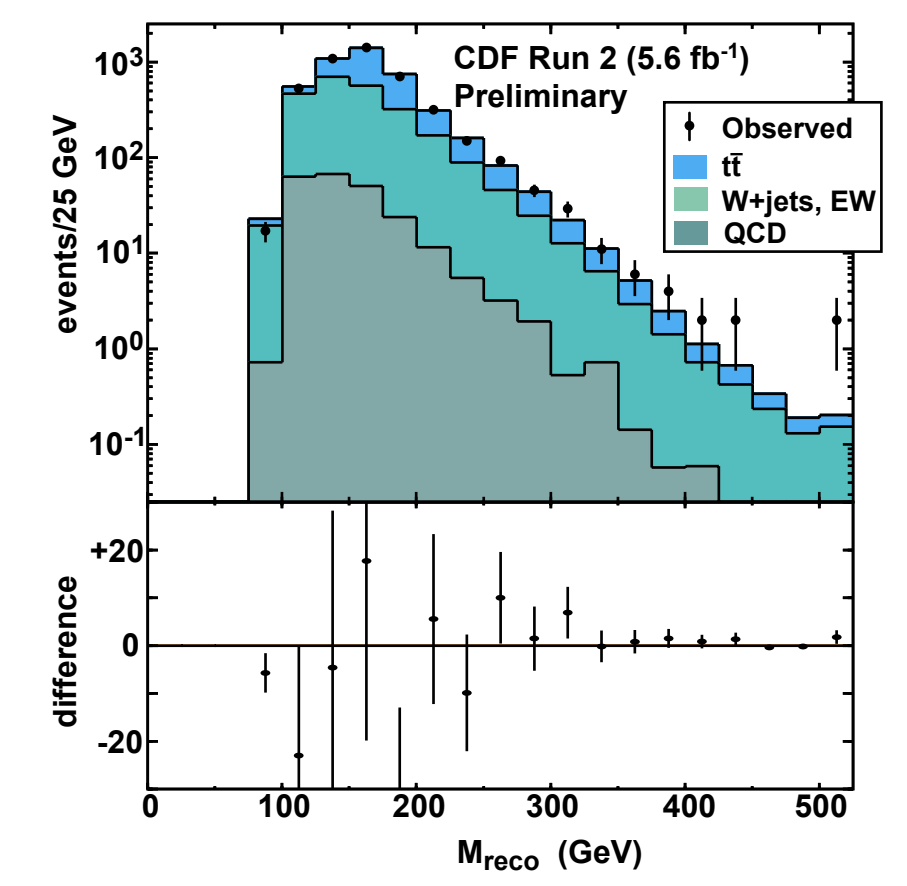


Latest 95% CL exclusion limit

t′ mass > 358 GeV/c^2

Search Results t′ → Wq





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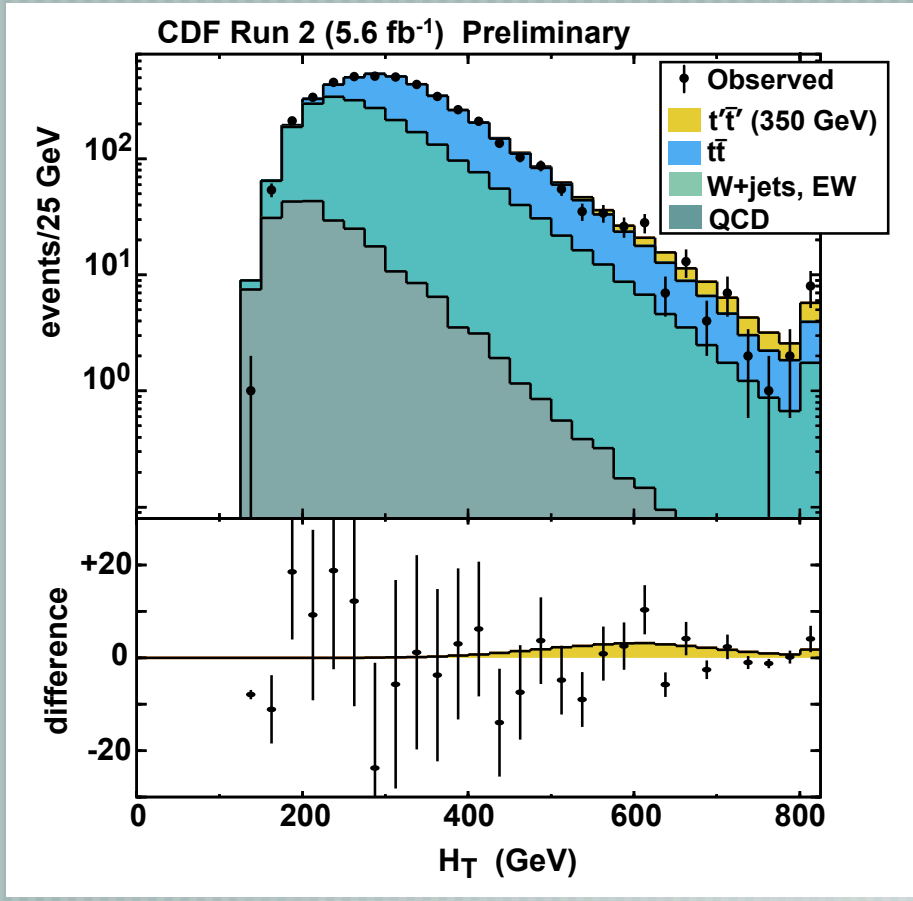

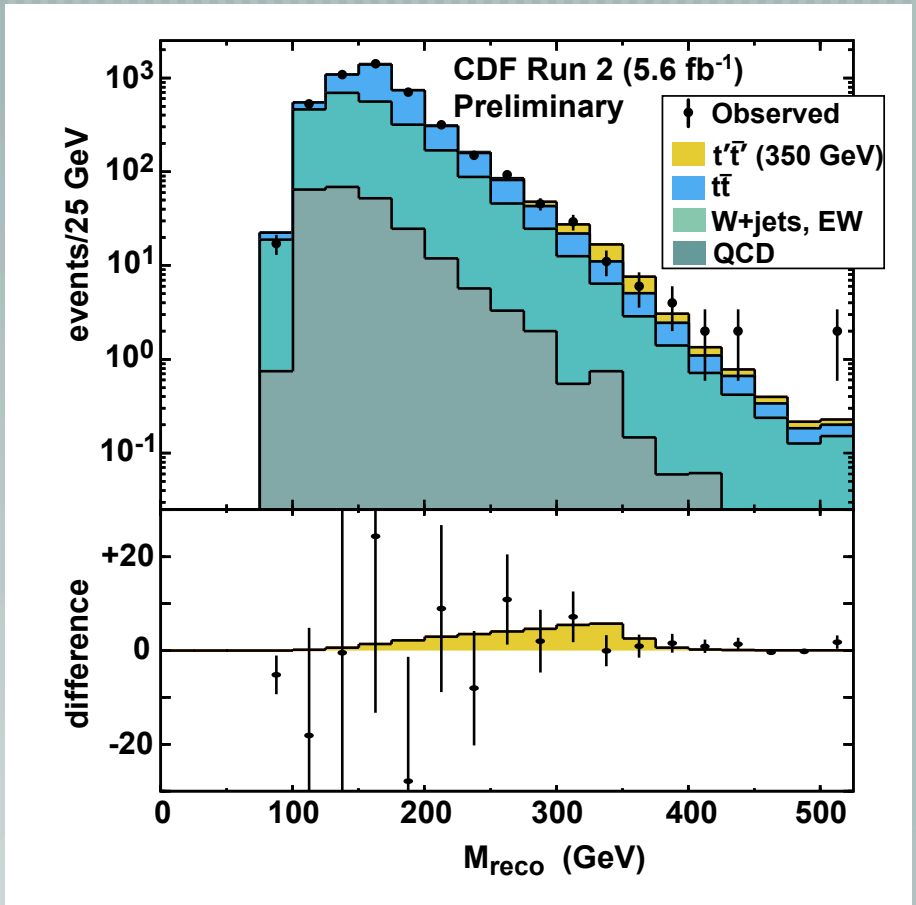

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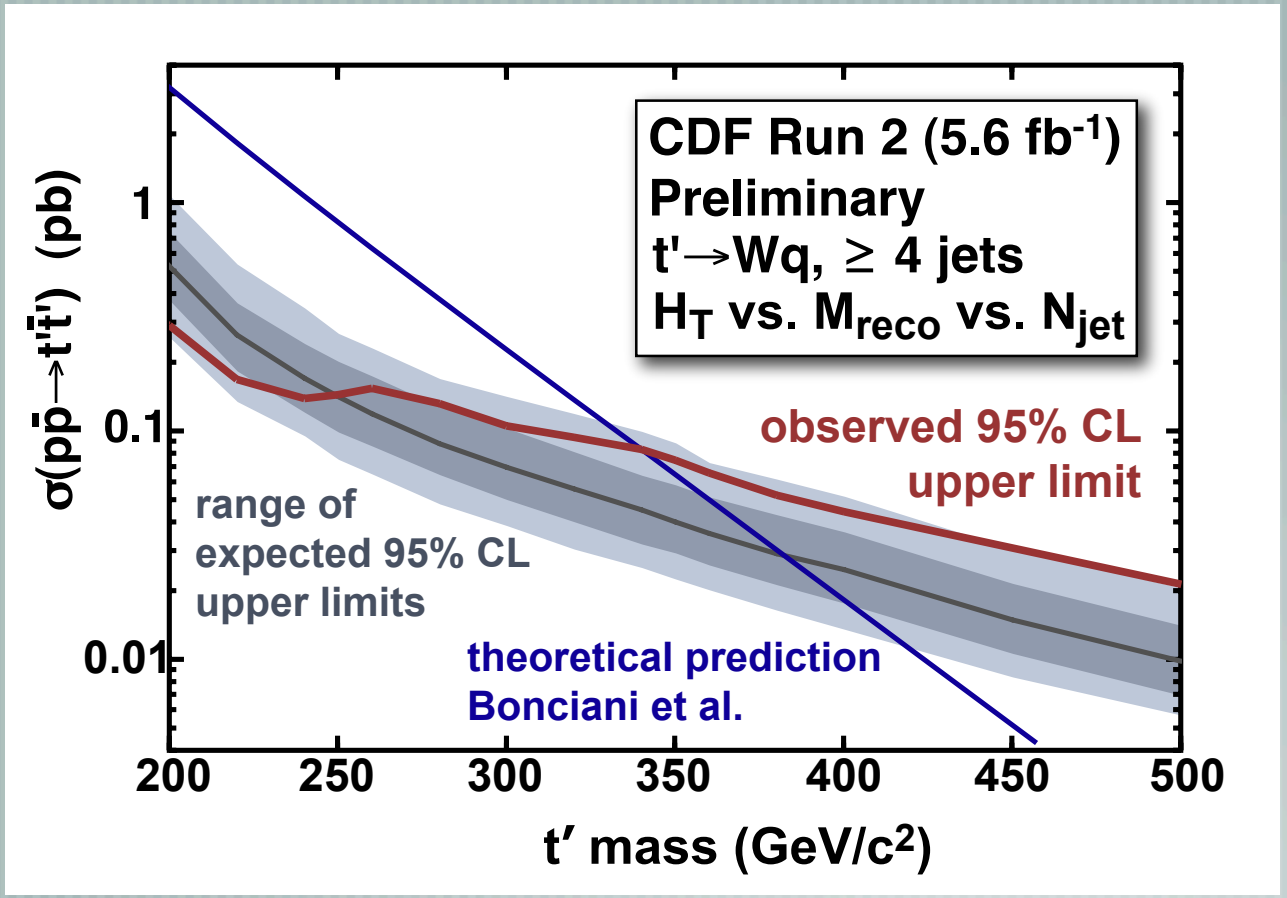


Latest 95% CL exclusion limit

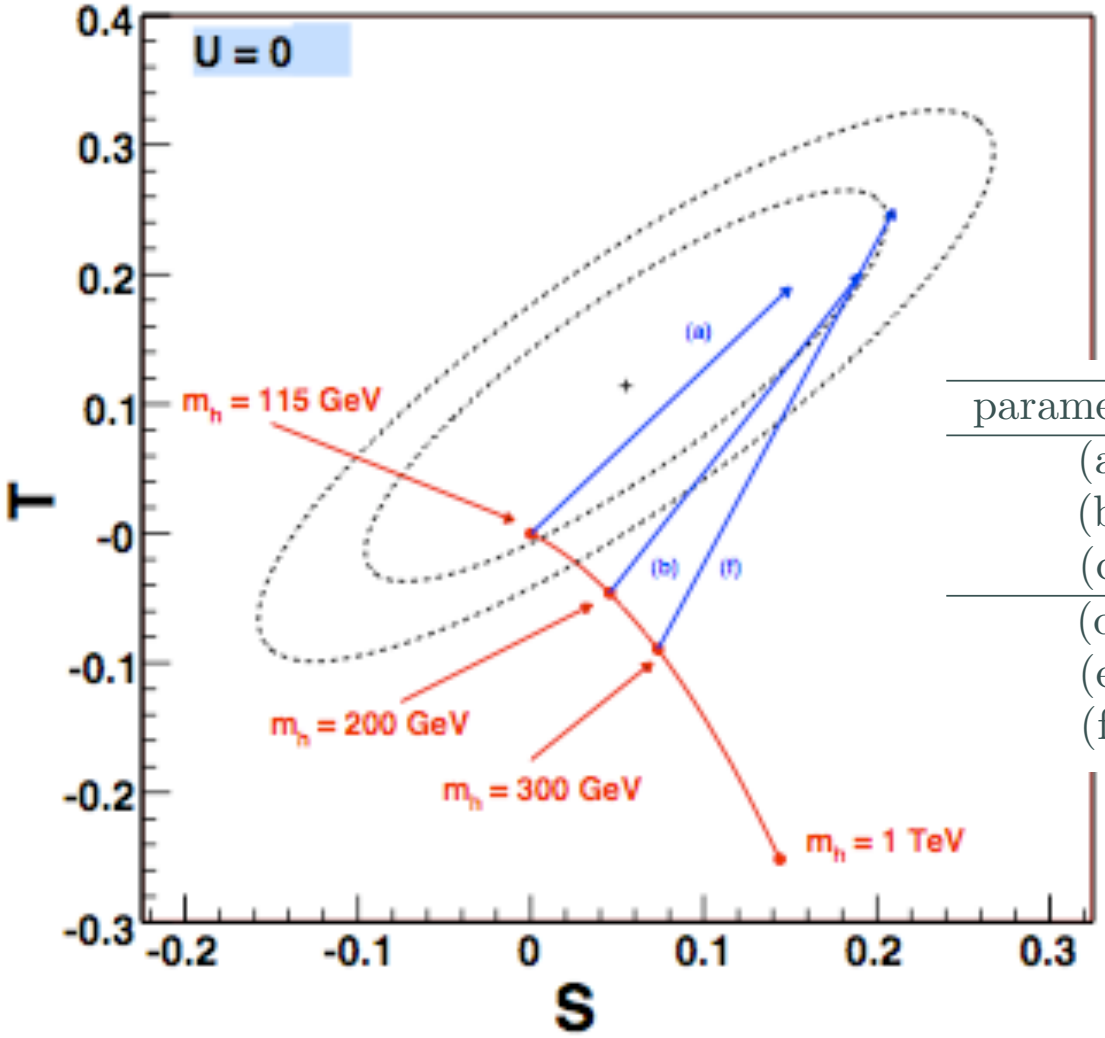
t′ mass > 340 GeV/c^2

Conclusions

- Current t' 95% CL exclusion: 358 (Wb) or 340 (Wq) GeV/c^2
- PRL coming soon
- More information at

http://www-cdf.fnal.gov/physics/new/top/2011/search_tprime/public_5.6.html

Backup



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