UCDAVIS
UNIVERSITY OF CALIFORNIA

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

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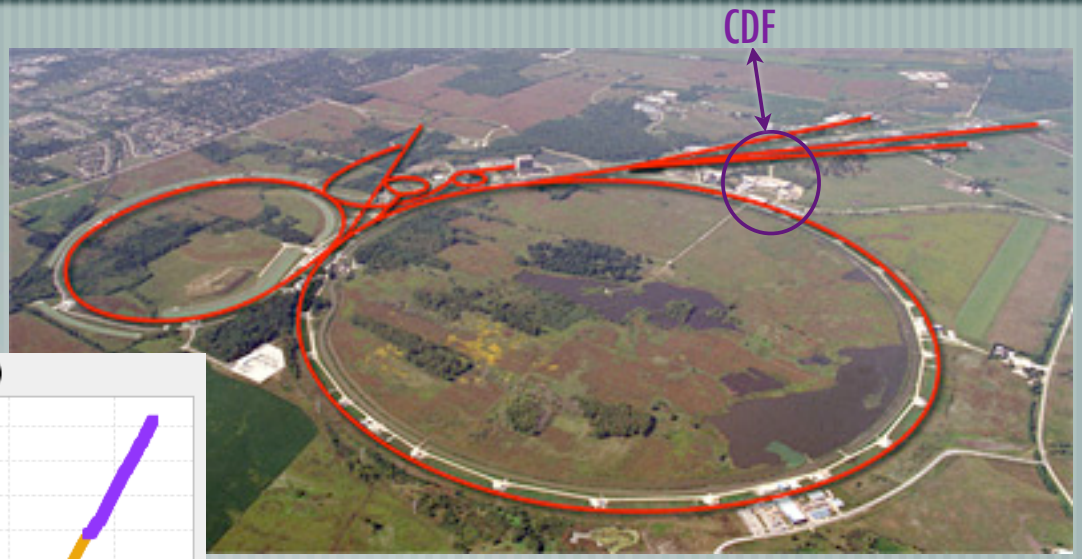
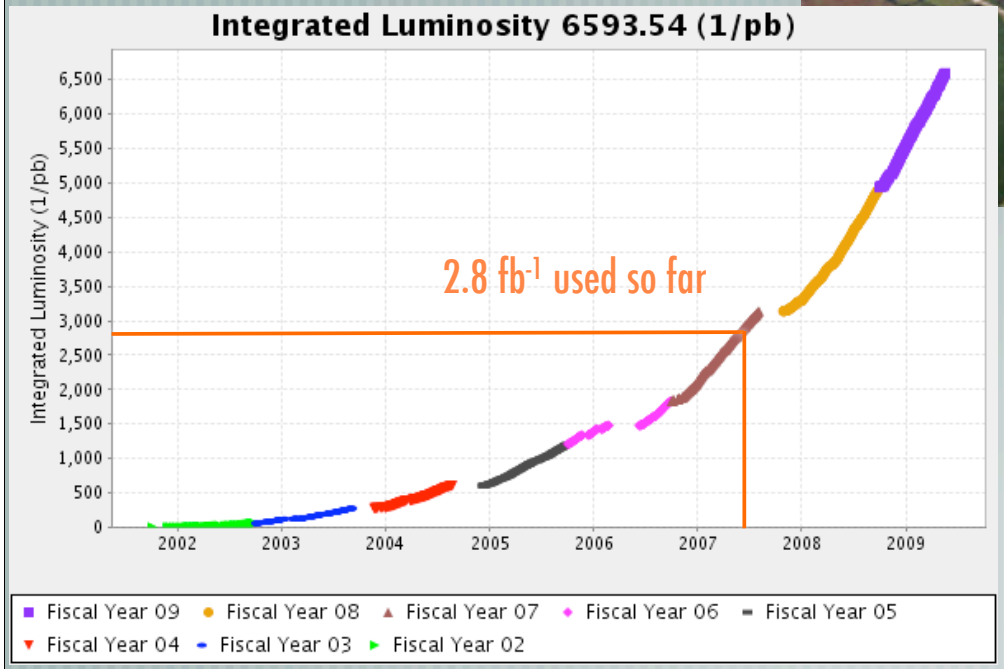
on behalf of the CDF Collaboration
DPF Meeting, 2009

CDF & the Tevatron

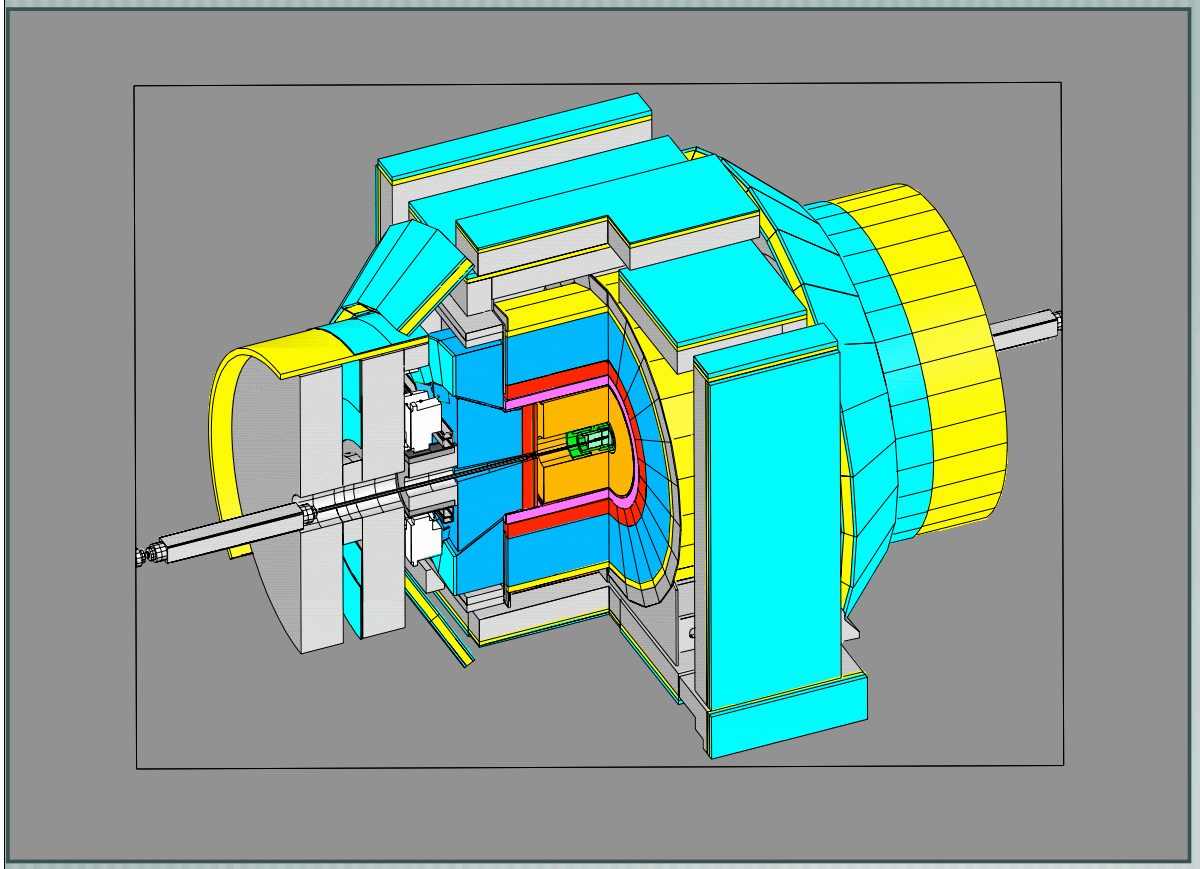
$p\bar{p}$ collisions at 1.96 TeV





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

CDF Detector

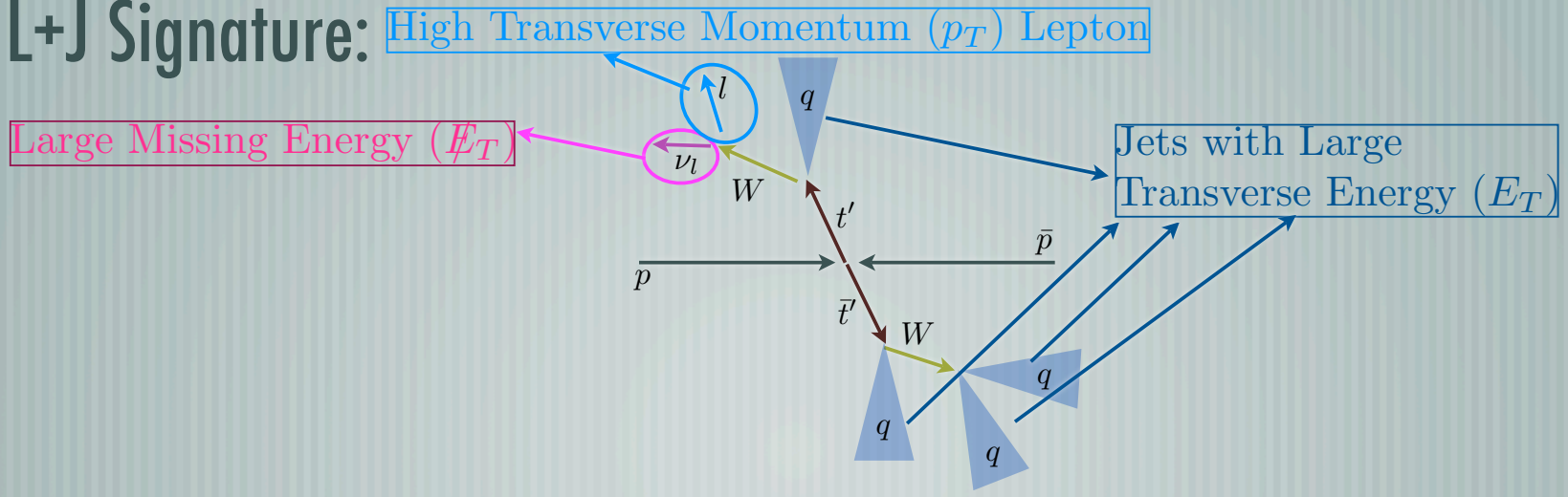


The CDF detector is a general purpose solenoidal detector which combines precision charged particle tracking with projective calorimetry and fine grained muon detection

What is a t′ quark

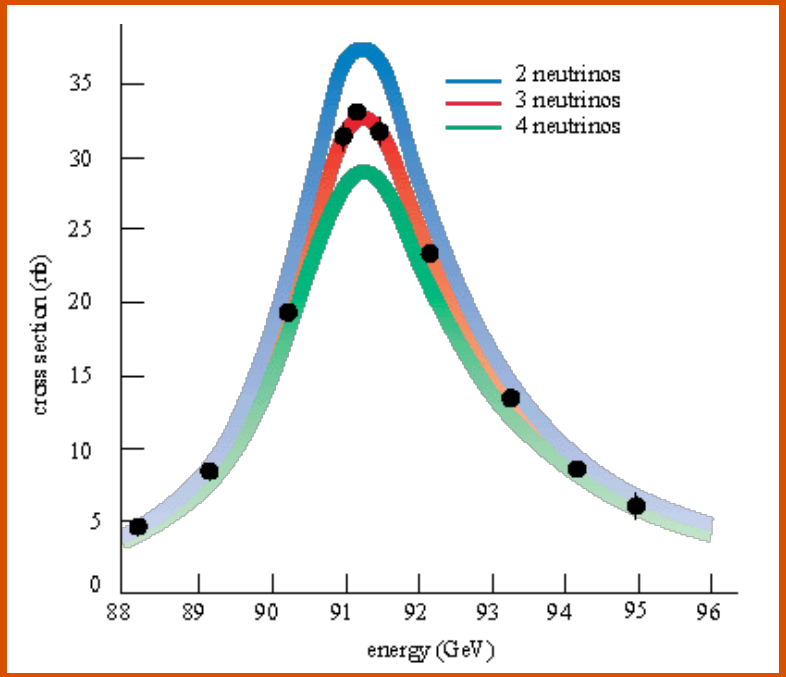
- A t′ is a fourth generation top-like quark or similar object
  - Predicted by a variety of theoretical models: Flavor democracy, GUT SO(1,13), Two Higgs doublet scenarios, Beautiful Mirrors, Little Higgs

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]

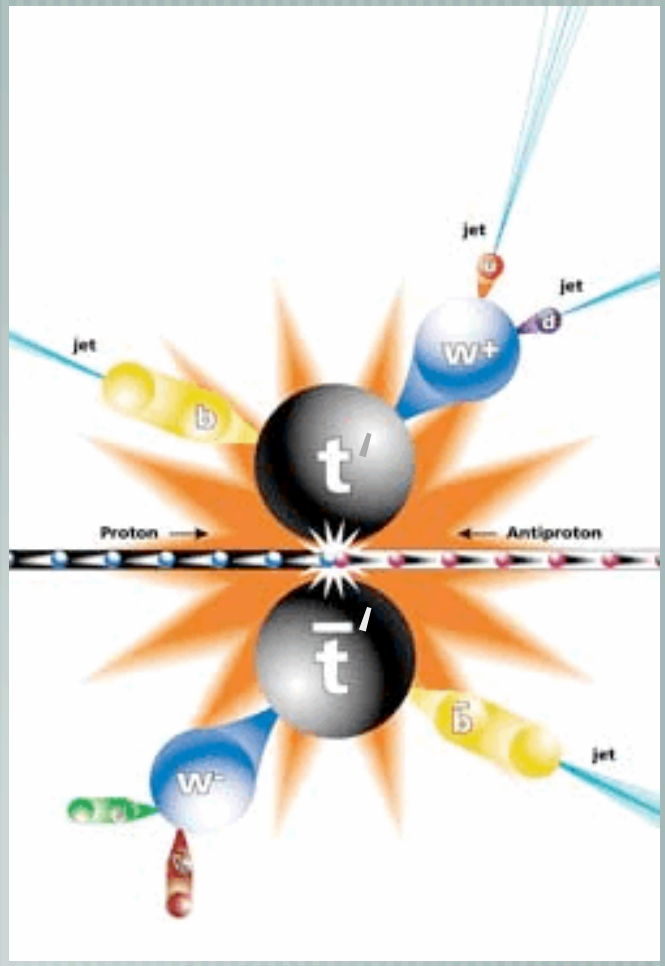
Two Higgs Doublet: N=2 Supersymmetry requires 3 additional fermion generations [Phys. Rev. D64 (2001) 053004]

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′ → Wq (BR ≈100%) *
  - t′ is pair produced strongly
  - t′ mass > top quark mass



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

Event Selection

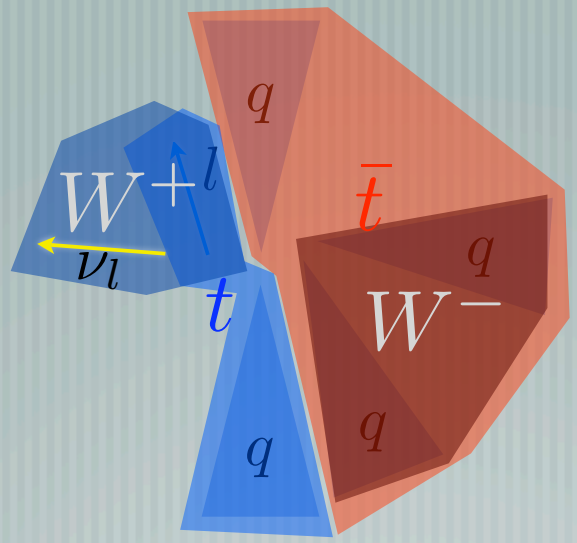
- Exactly one high-p_T ($p_T \geq 20$ GeV/c) isolated electron or muon
- Large missing transverse energy ($\not\!\!E_T \geq 35$ GeV)
- At least four energetic jets ($E_T \geq 20$ GeV)
- Highly energetic lead jet ($E_T \geq 60$ GeV)

Search Technique

- To distinguish between backgrounds and signal we fit to the observed 2D distribution of reconstructed mass and total transverse energy ($H_T = \sum_{jets} E_T + E_{T,l} + \not\!\!E_T$)
- 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 (Gaussian) uncertainties

M_{reco} - Kinematic Fitter

Calculate a χ^2 based on the kinematic quantities

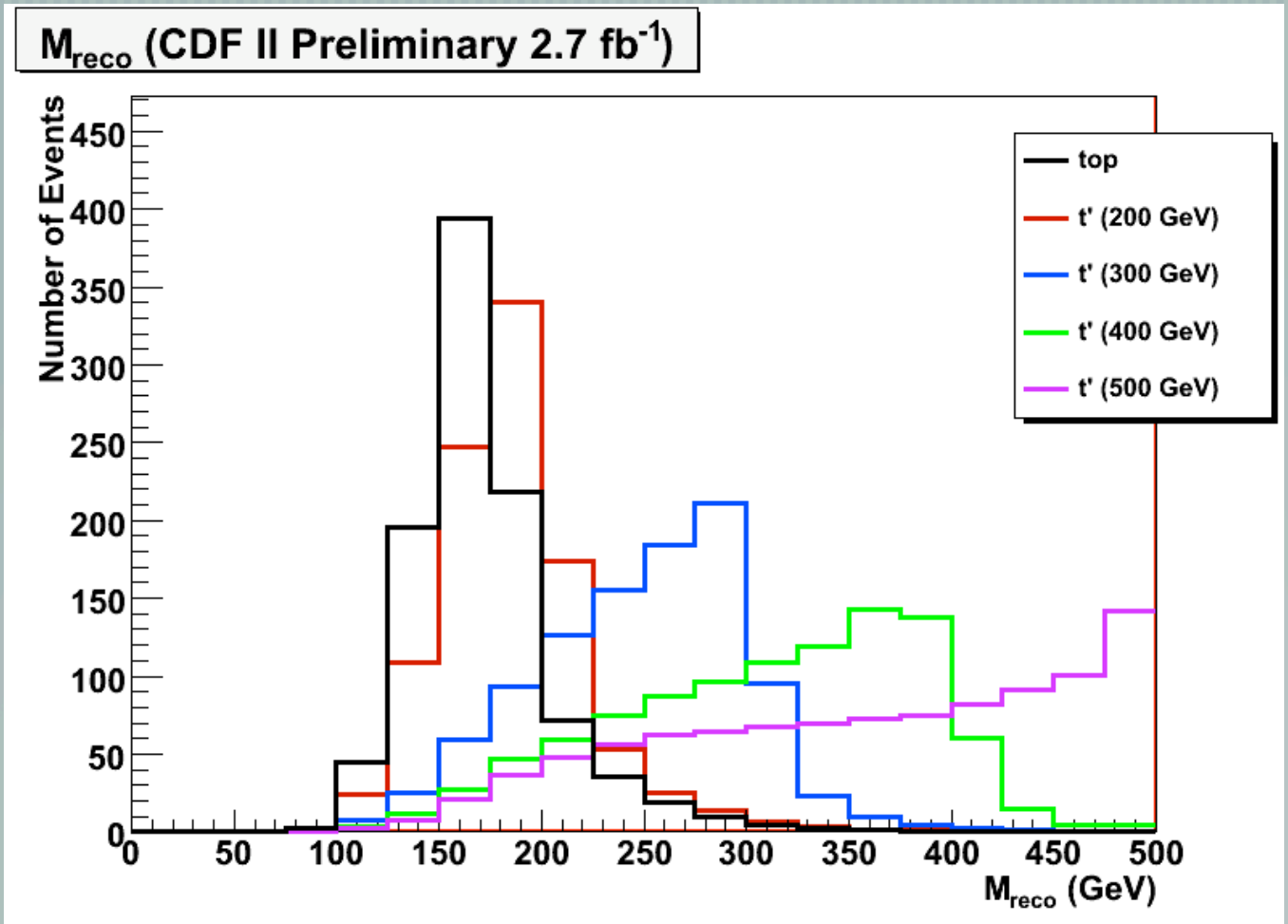


Constrain W decay products to W mass and the top / anti-top mass to be equal

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

UE = unclustered energy

Kinematic Fitter Output

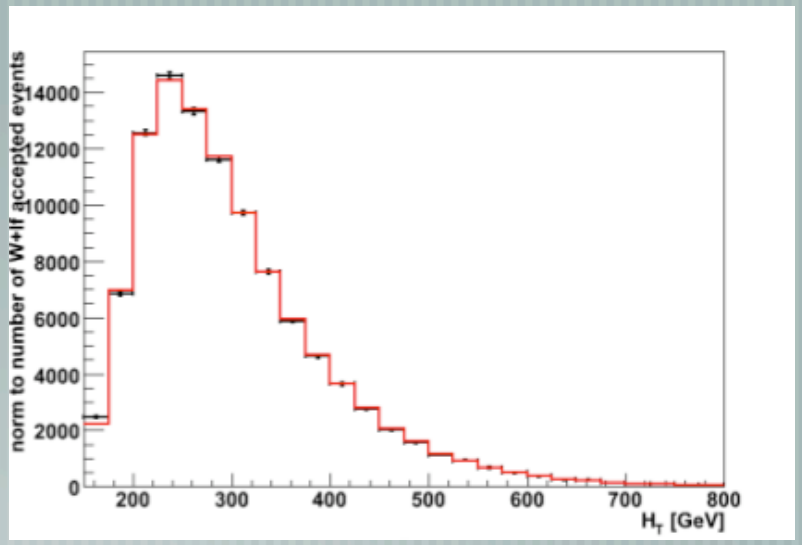


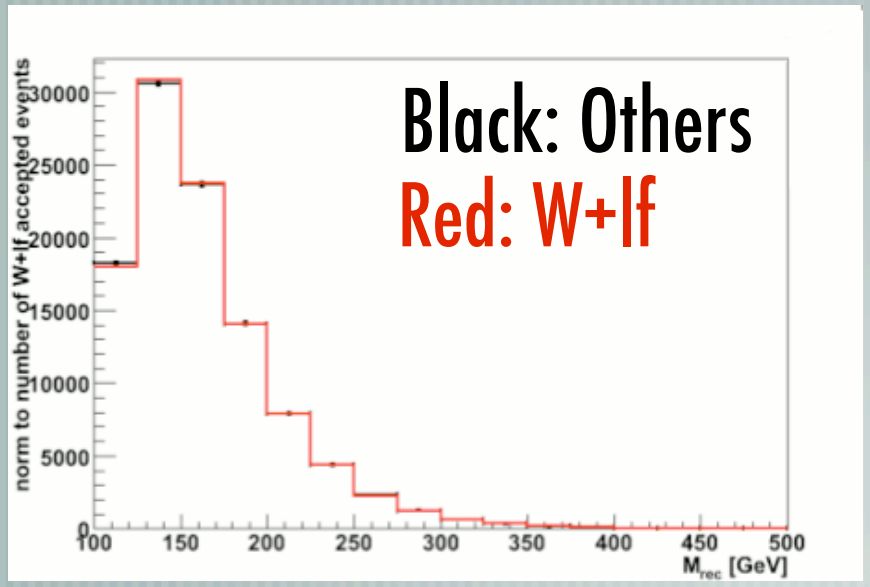
Background

- We model our main backgrounds with three different samples of events
  - ttbar MC events produced using PYTHIA with a top mass of 175 GeV/c
  - Fake lepton (QCD) events constructed using a data sample which fails some electron id cuts
  - An ALPGEN+PYTHIA generated MC sample of W+light flavor events

Other Backgrounds

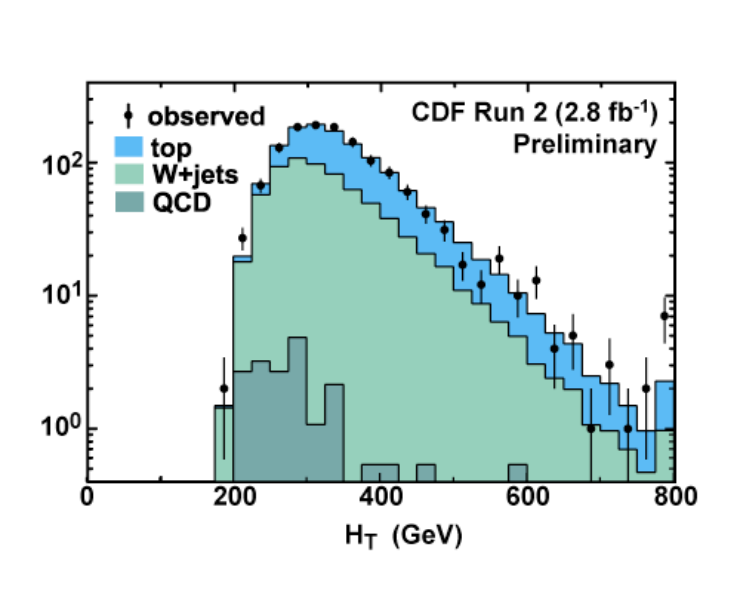
Model small backgrounds:
Diboson, single top,
W+heavy flavor, Z+jets
with W+light flavor

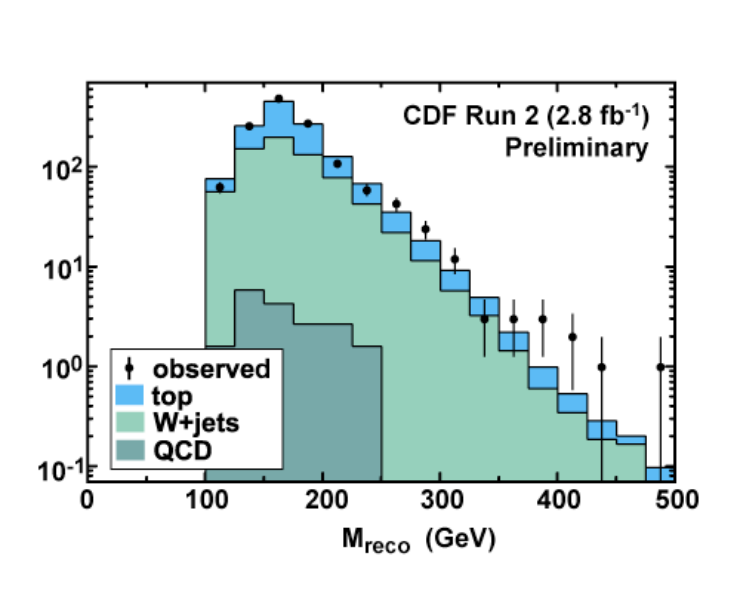




For our sample W+lf has a similar shape to other backgrounds

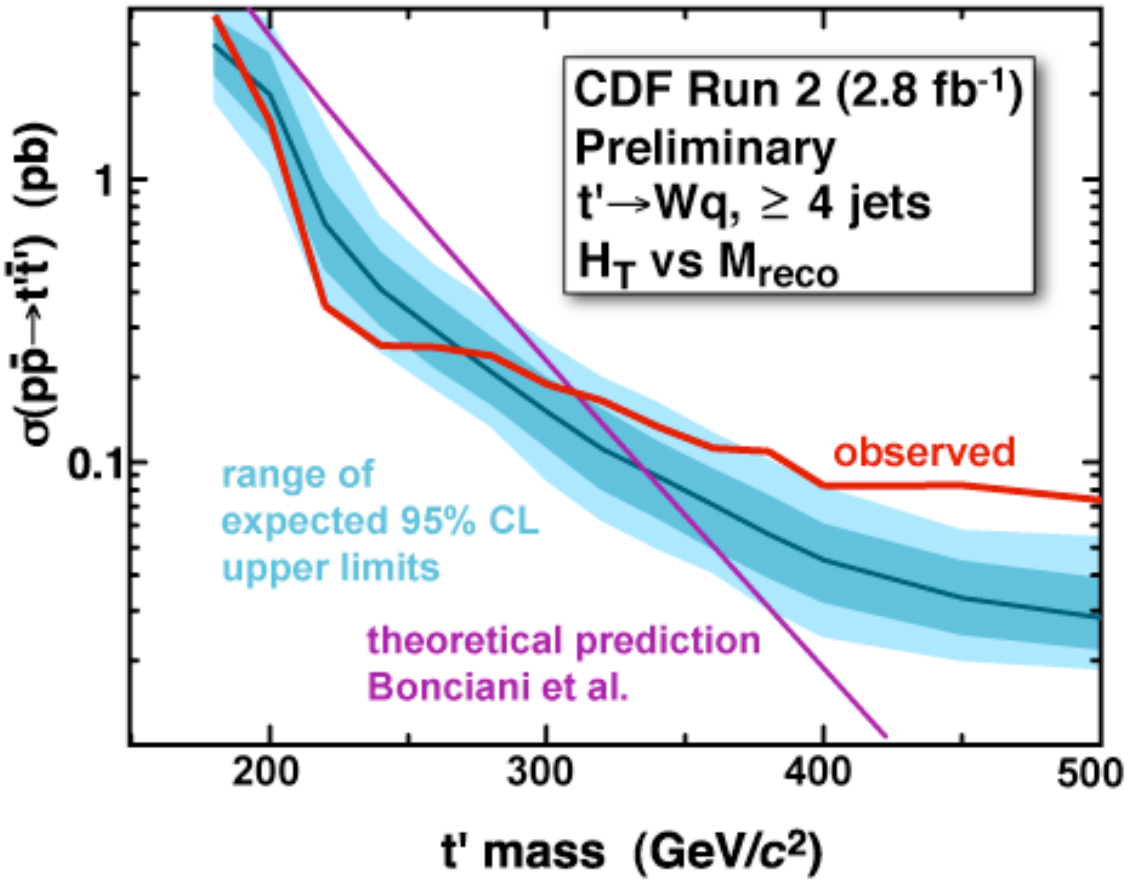
Search Results





The W+jets & t′ cross sections float in the fit. The top cross section is constrained to a normal distribution with mean at 6.7 pb

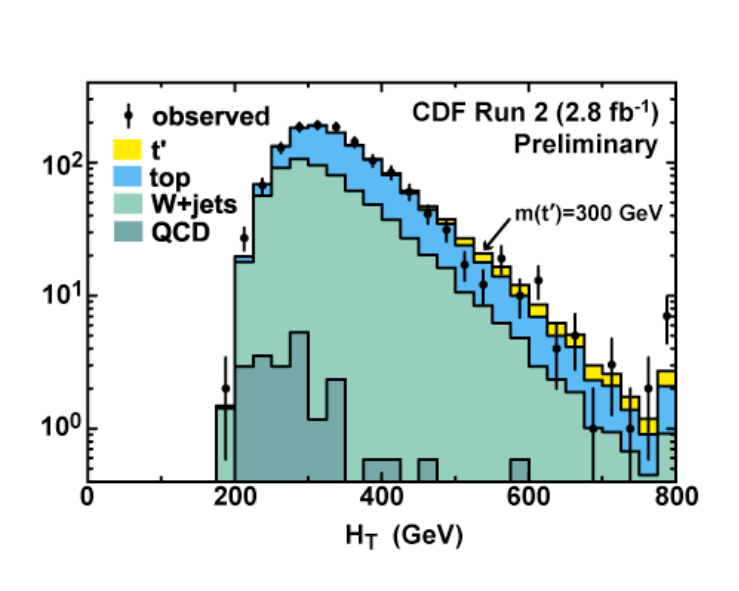
Search Results

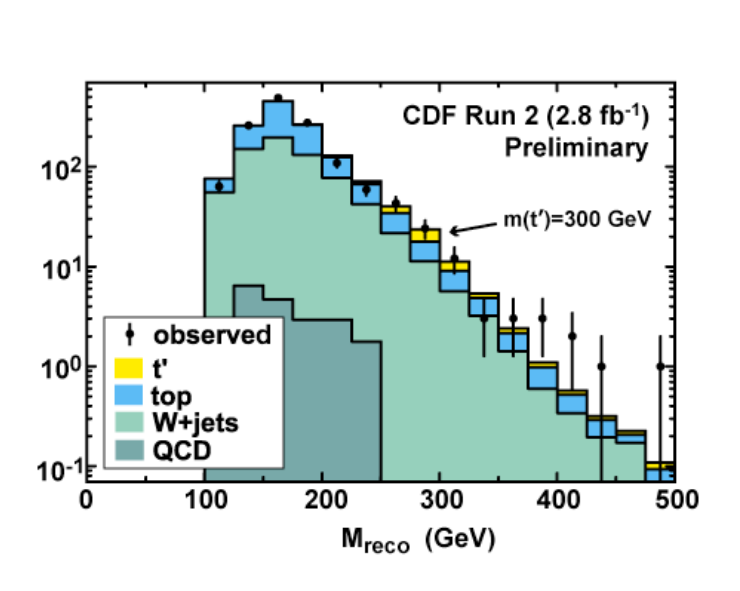


Latest 95% CL exclusion limit

t′ mass > 311 GeV/c^2

Search Results



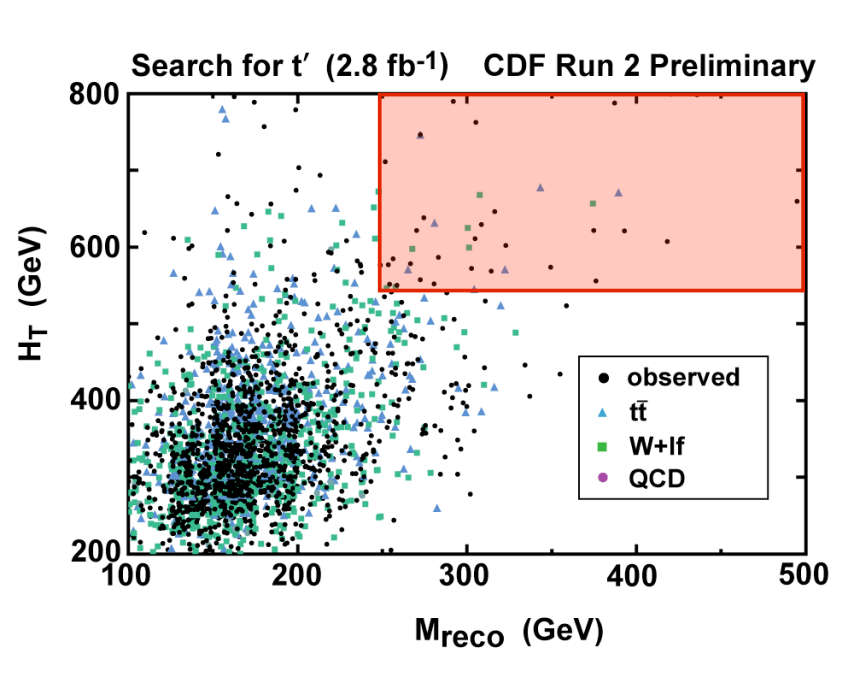


Distributions shown for the maximum likelihood when the t' cross section is set to it's 95% CL upper limit

Search Results

Cut and Count

n	Min M_{rec} [GeV/c^2]	Min H_T [GeV]	observed	expected	p-value
1	475	775	0	0.021	1.000
2	450	750	0	0.116	1.000
3	425	725	1	0.228	0.2040
4	400	700	2	0.371	0.0540
5	375	675	3	0.718	0.0364
6	350	650	4	1.503	0.0660
7	325	625	4	2.876	0.3251
8	300	600	12	5.498	0.0110
9	275	575	14	9.885	0.1273
10	250	550	29	18.03	0.0105
11	225	525	41	31.34	0.0555
12	200	500	58	52.05	0.2219
13	175	475	92	91.14	0.4779
14	150	450	152	158.7	0.7141
15	125	425	222	231.0	0.7318



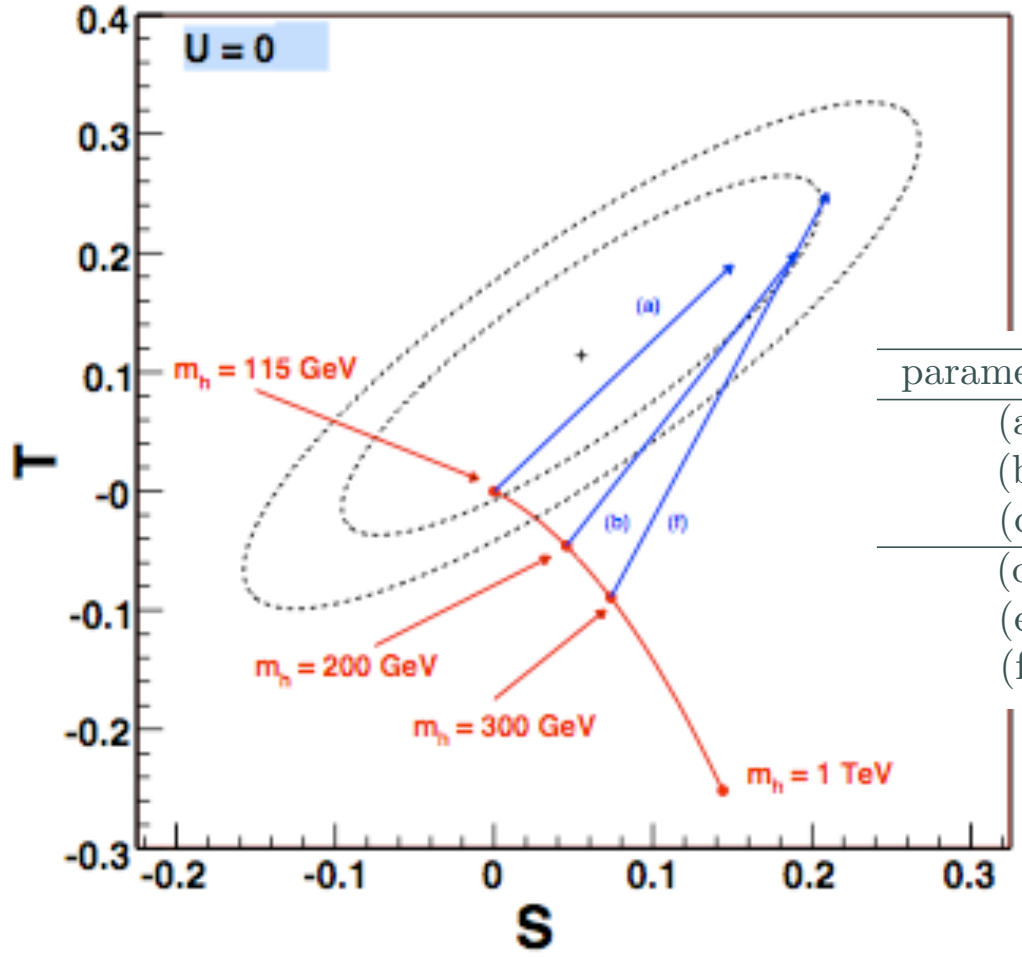
Note: global p-value less significant than value for a single cut and count

Conclusions

- Current t′ 95% CL exclusion: 311 GeV/c^2
- We're adding more data and including sensitivity improvements
- New and improved results expected soon
- More information at

http://www-cdf.fnal.gov/physics/new/top/2008/tprop/Tprime2.8/public.html

Backup



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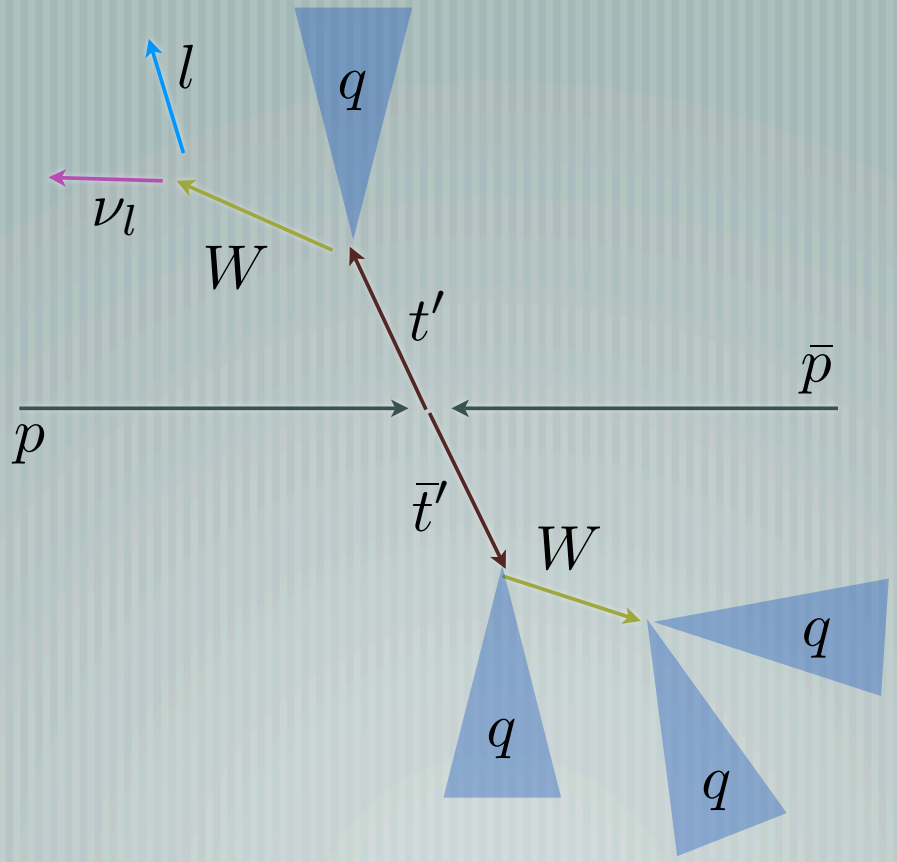
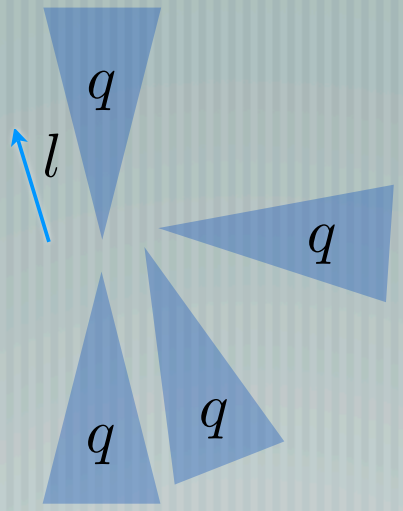
M_{reco} - Kinematic Fitter

An Event



M_{reco} - Kinematic Fitter

As seen in the detector



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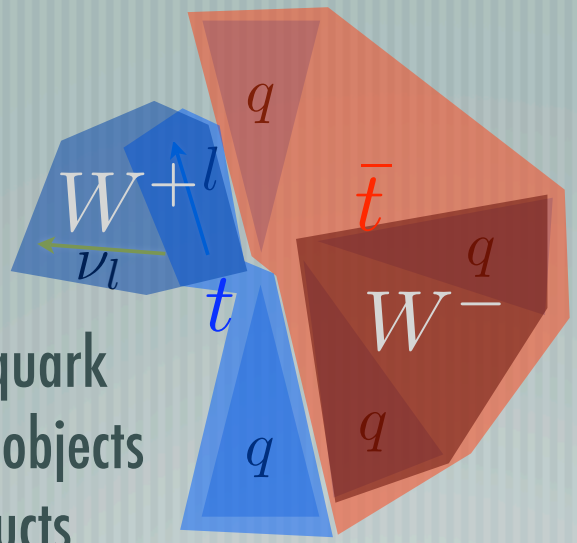

Need to reconstruct the ν_l first then the W's then the base quarks

To reconstruct a base quark need to assign detected objects to quark decay products

12 different possible ways of assigning jets to partons plus an unknown ν p_z
Gives 24 possibilities per event

Coming Improvements

- Complementary search for b′
- Including dilepton channel
- New optimizations by dividing signal region based on quality of reconstruction
- Include additional triggers adding (≈33% more data)
- B-tagging (Assume t′ → Wb instead of t′ → Wq)
- Examine other production models / limit more theories

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