Searches for New Physics in Top Events at the Tevatron

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(on behalf of the CDF and D0 collaborations)

Rencontres de Moriond
QCD and High Energy Interactions
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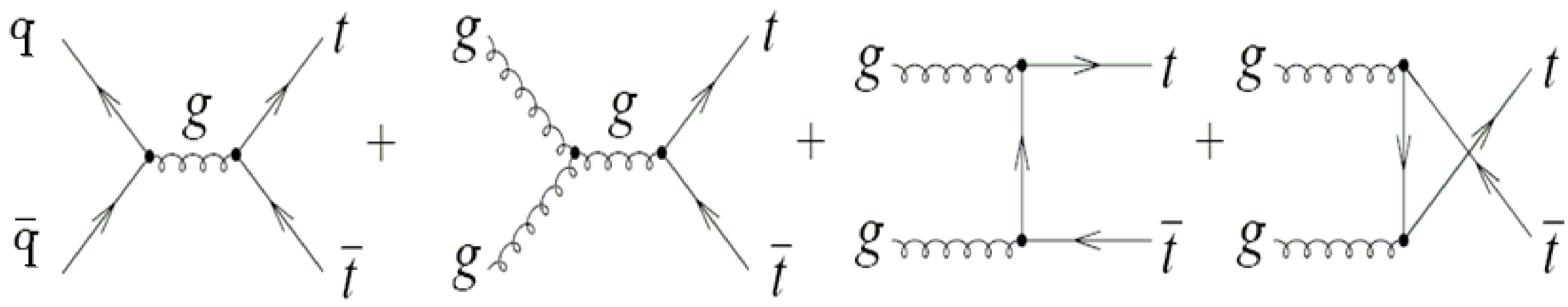
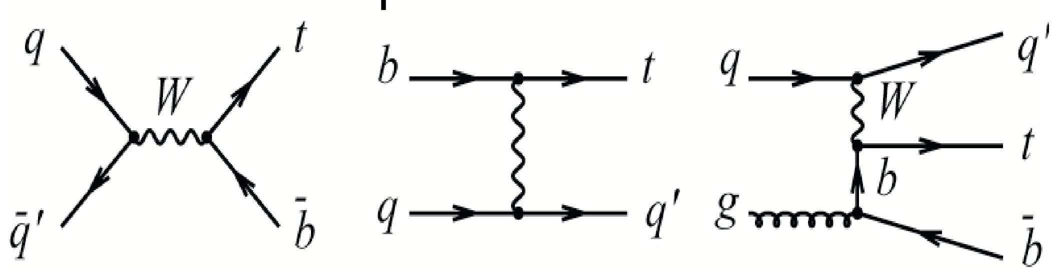
Top Quark Production at the Tevatron

- **produced in pairs:** via the strong interactions.

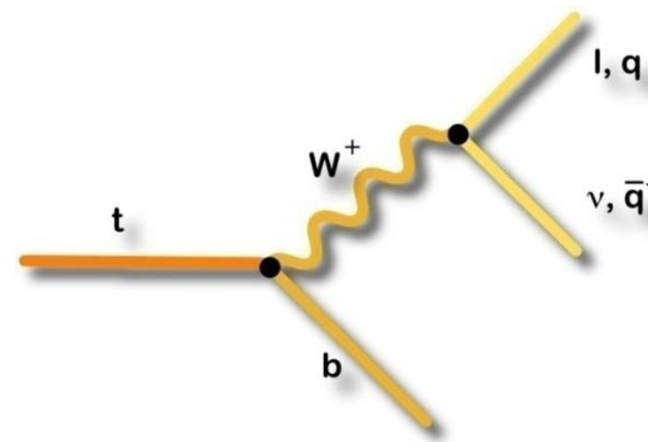


- **single produced:** in association with other particles



W-gluon fusion

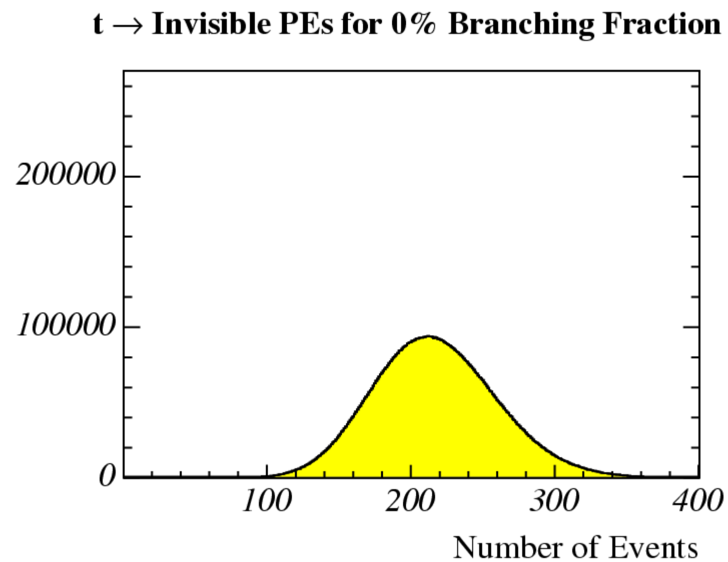
- **SM: BR(t→W$^+$b) >0.99@95%CL**



- **Analyses in this talk take advantage of either single and pair-produced top quarks.**
- **Analyses are selected from either CDF or D0. Most of the results have a counterpart analysis from the other detector.**

Top Anomalous Decays

- **Basic idea:**
  - top decays to other signatures can decrease the expected SM $t\bar{t}$ contribution. M. Cacciari, *et al*. arXiv:0804.2800 [hep-ph] (2008)
- **Consider several scenarios**
  - $t \rightarrow Zc$,
  - $t \rightarrow \gamma c$,
  - $t \rightarrow gc$,
  - $t \rightarrow$ invisible



- **Use lepton+jets event selection**
  - Lepton, ME_T, ≥3 jets, two (loose) b-tags

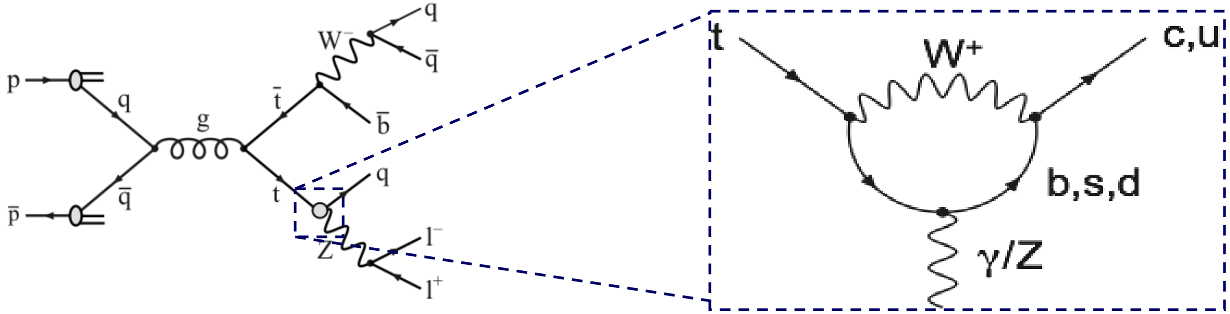
CDF Run II Preliminary 1.9 fb^{-1}

Decay	$\mathscr{R}_{wx/ww}$ (%)	Upper Limit (%) (175 GeV)	Upper Limit (%) (172.5 GeV)	Upper Limit (%) (170 GeV)
$\mathscr{B}(t \rightarrow Zc)$	32	13	15	18
$\mathscr{B}(t \rightarrow gc)$	27	12	14	17
$\mathscr{B}(t \rightarrow \gamma c)$	18	11	12	15
$\mathscr{B}(t \rightarrow \text{invisible})$	0	9	10	12

World's best limit on t→invisible

Flavor Changing Neutral Currents

- No Flavor Changing Neutral Currents (FCNC) at tree level in SM.

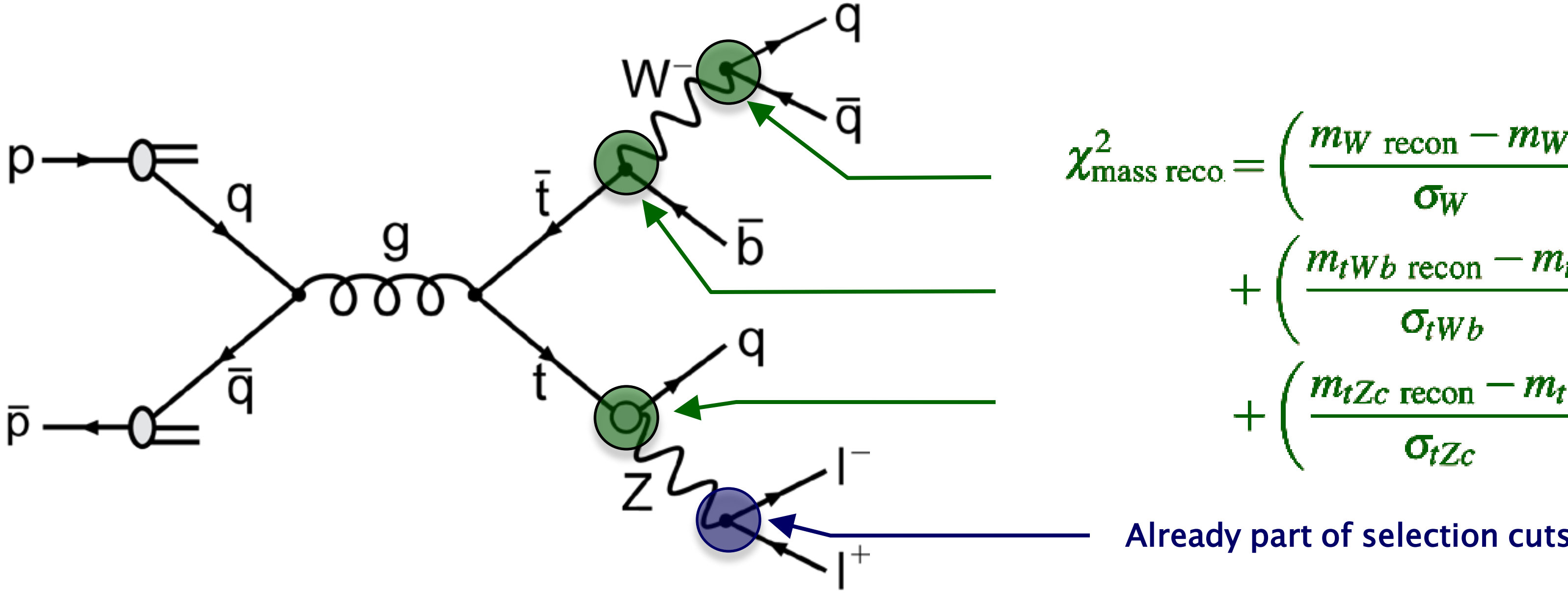


Allowed at higher orders, but heavily suppressed (GIM, small CKM elements)

Beyond SM models predict branching ratios up to O(10^{-4})…

- **SUSY, extra quark singlets , extra Higgs doublets (see hep-ph 0409342)**

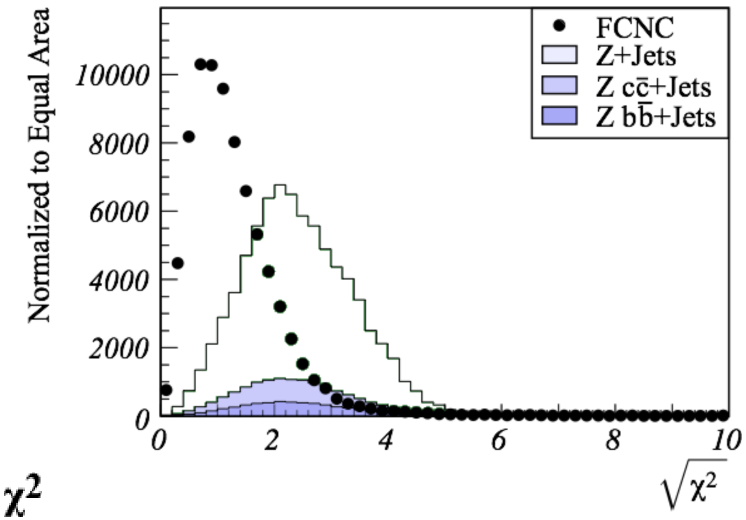
- Search in the Z+4 jets channel. Event reconstruction



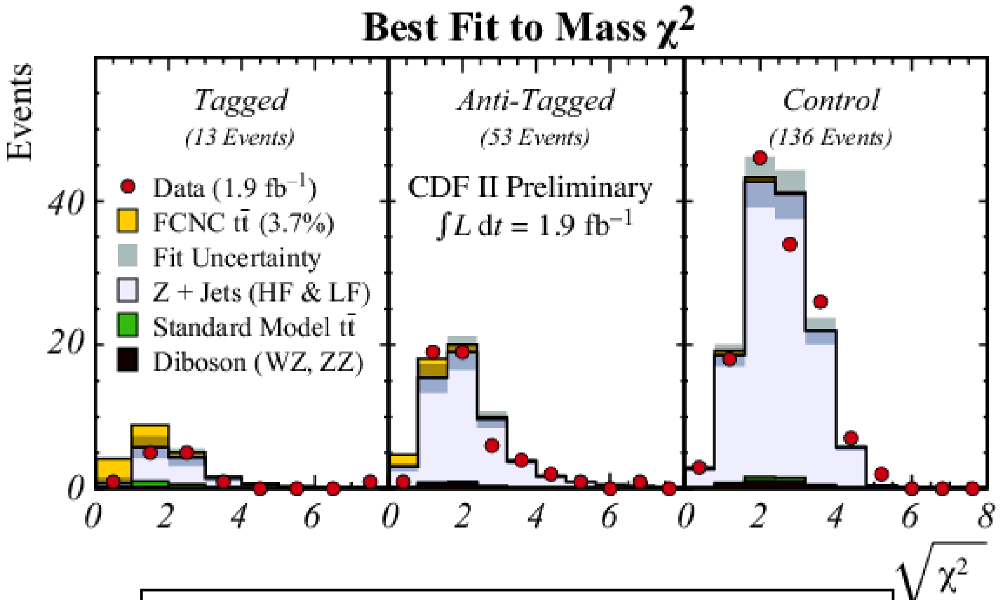
$$\chi^2_{\text{mass reco}} = \left(\frac{m_{W\ \text{recon}} - m_W}{\sigma_W}\right)^2 + \left(\frac{m_{tWb\ \text{recon}} - m_t}{\sigma_{tWb}}\right)^2 + \left(\frac{m_{tZc\ \text{recon}} - m_t}{\sigma_{tZc}}\right)^2$$

Top FCNC Search: Results

- **Full reconstruction χ^2:**
  - Good discriminant power



- **Results: Signal and control regions**
  - Signal: passing kinematic cuts
    - Separate tagged from anti-tagged
  - Control: failing kinematic cuts



B(t→Zq) < 3.7% @ 95% C.L.

World's best limit. Improved previous limit (13.7% @ L3) by a factor of 3.5

Top Couplings: tbW vertex

➲ **Most general tbW vertex:**

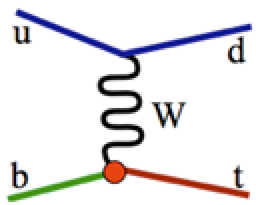
$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}(f_1^L P_L + f_1^R P_R)tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}(f_2^L P_L + f_2^R P_R)tW_{\mu}^{-} + h.c.$$

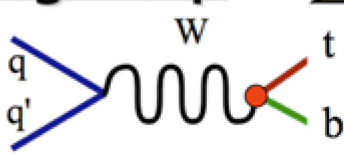
=1 in SM

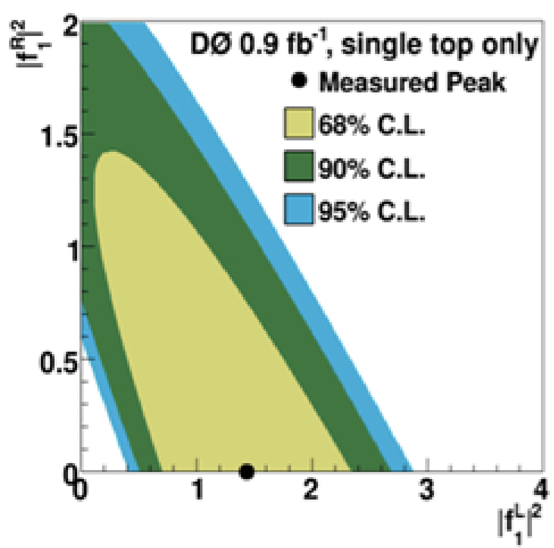
=0 in SM

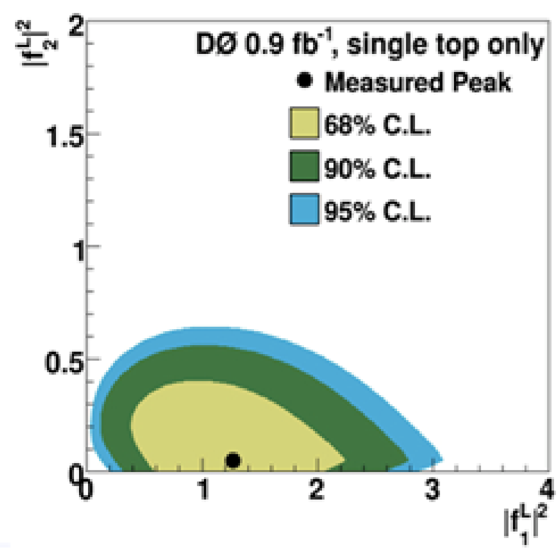
single top

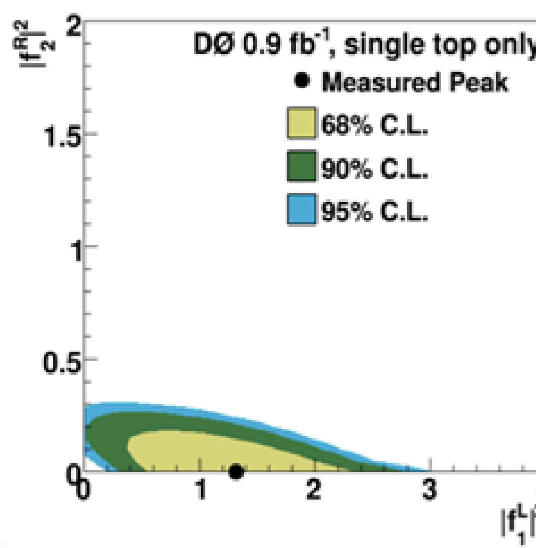
1.0 fb^{-1}











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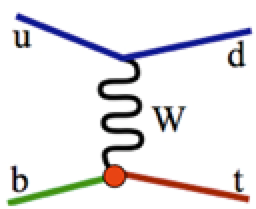
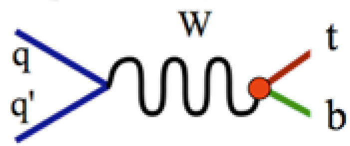
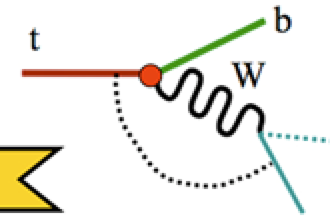
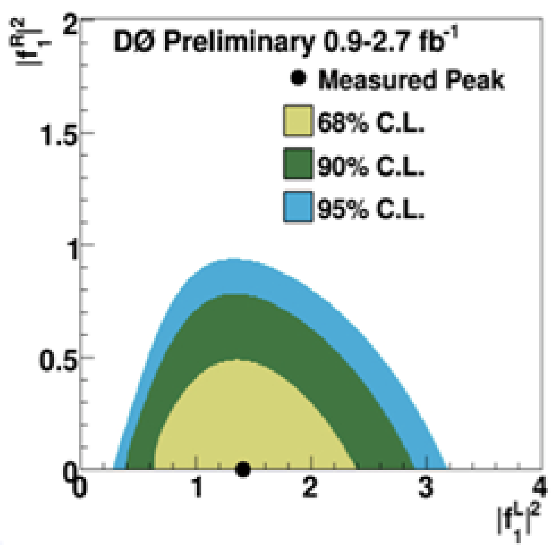


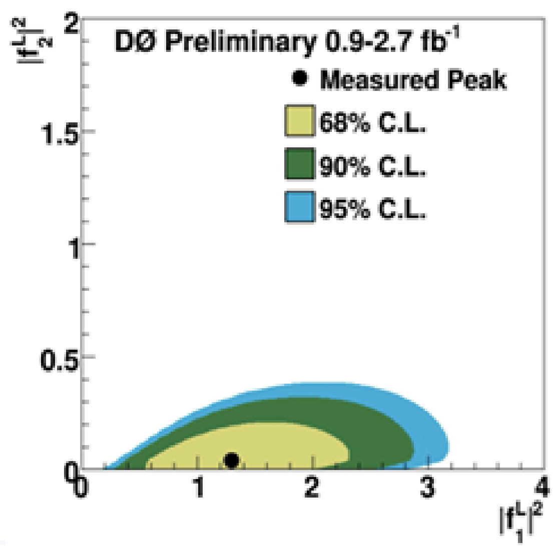


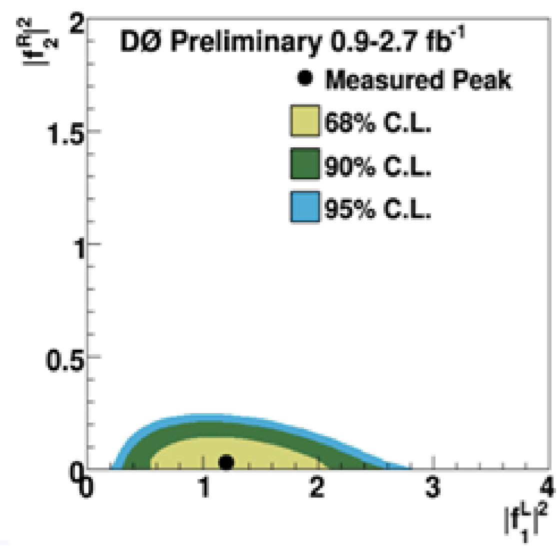
W helicity

2.7 fb^{-1}









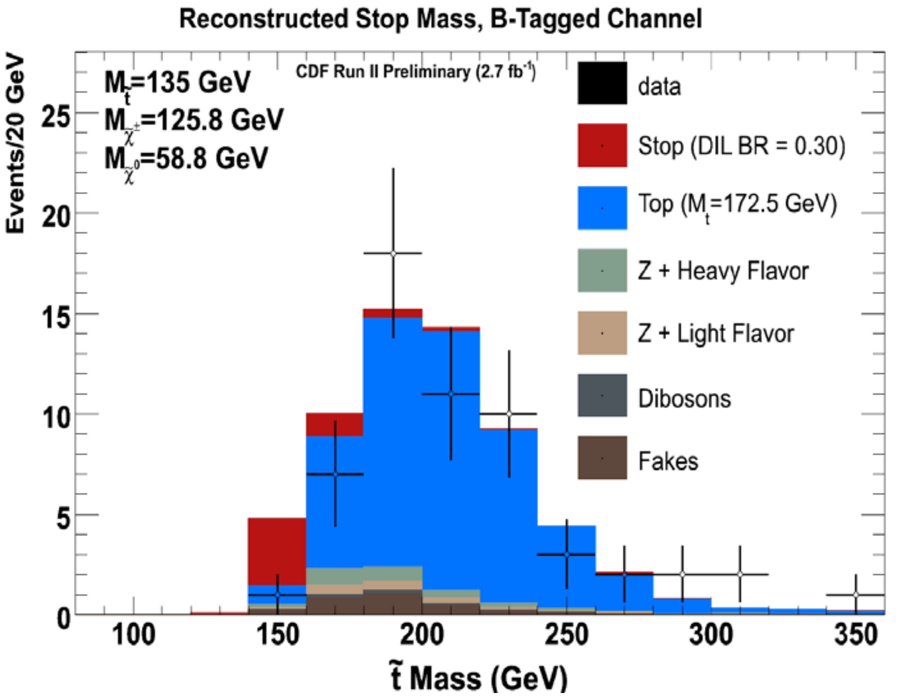
Pair Production of Stop Quarks

- **If** $\tilde{\chi}_1^0$ is the LSP, and $\tilde{q}, \tilde{\ell}, \tilde{\nu}$ are heavy
  $m_{\tilde{t}_1} \lesssim m_t$
  $m_{\tilde{\chi}_1^+} < m_{\tilde{t}_1} - m_b$
- **Then, dominant stop decay mode is to b quark and chargino, then decays such as**

$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm} \rightarrow b\tilde{\chi}_1^0 l\nu$$

- **Will look just like top events in the detector!**
  - Search in the dilepton channel using separately b-tagged and untagged event
  - Reconstruct stop mass and use to discriminate from SM.
  - Optimize event selection including all systematics

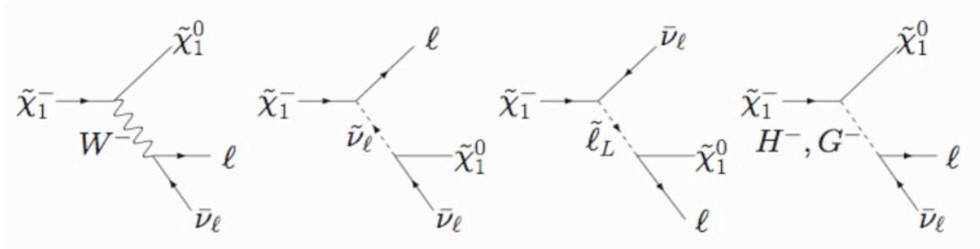
- **Example**
  - for a particular choice of stop, neutralino, and chargino masses.



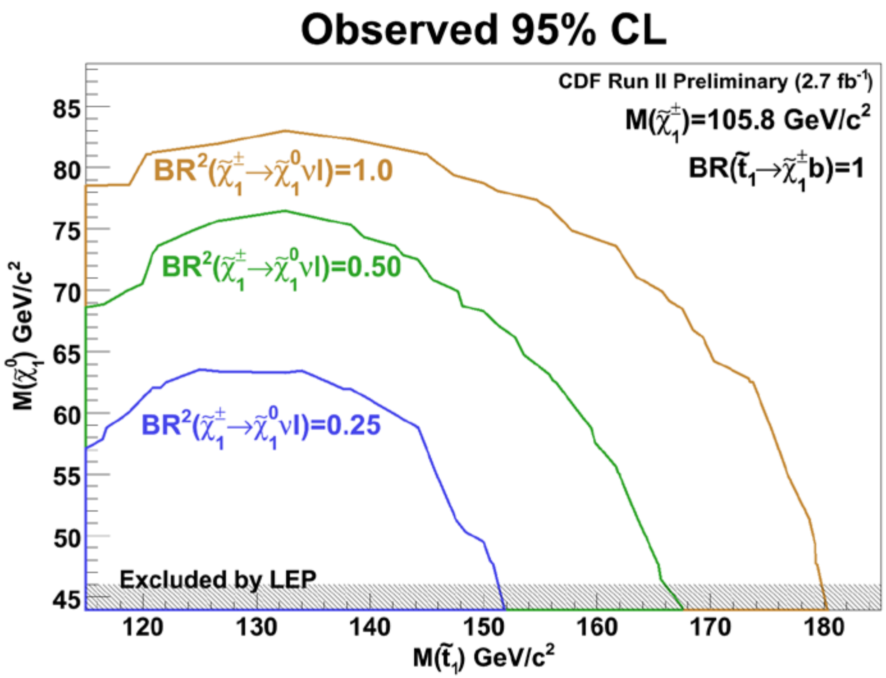
Reconstructed stop signal plotted at the amount excluded at 95%,

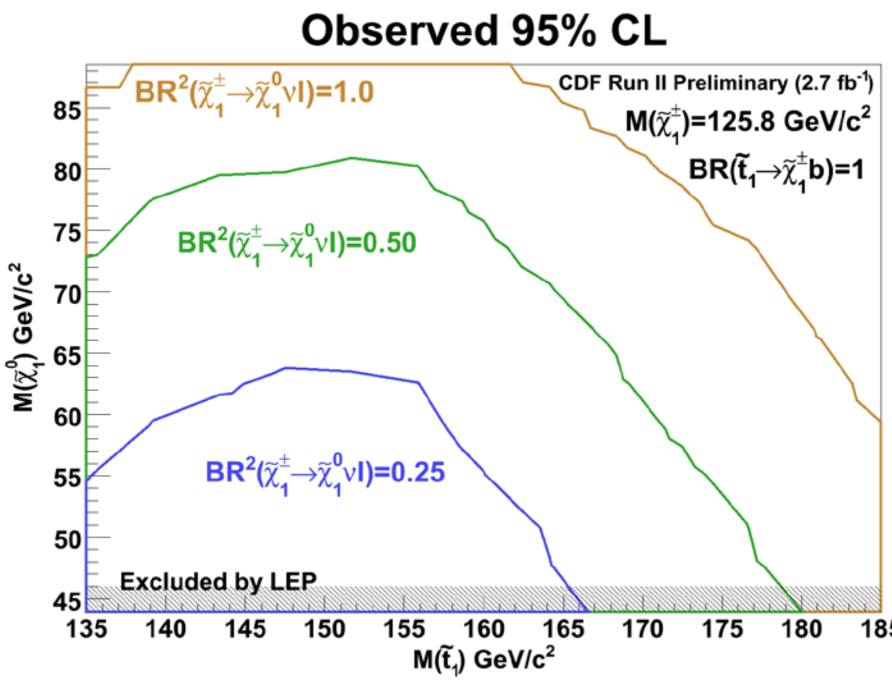
Stop Quark Search: Results

- **Depending on SUSY parameters:**
  - The chargino may decay in a number of ways, potentially enhancing the dilepton branching ratio to almost 1.



chargino decays mimicking a top



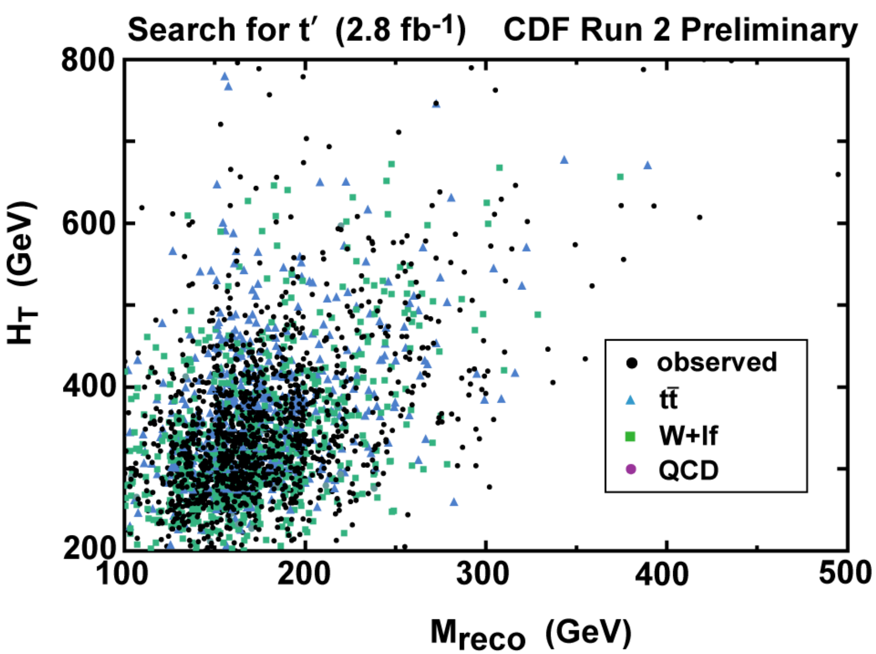


- Chargino Mass of 105.8 GeV
- Chargino Mass of 125.8 GeV

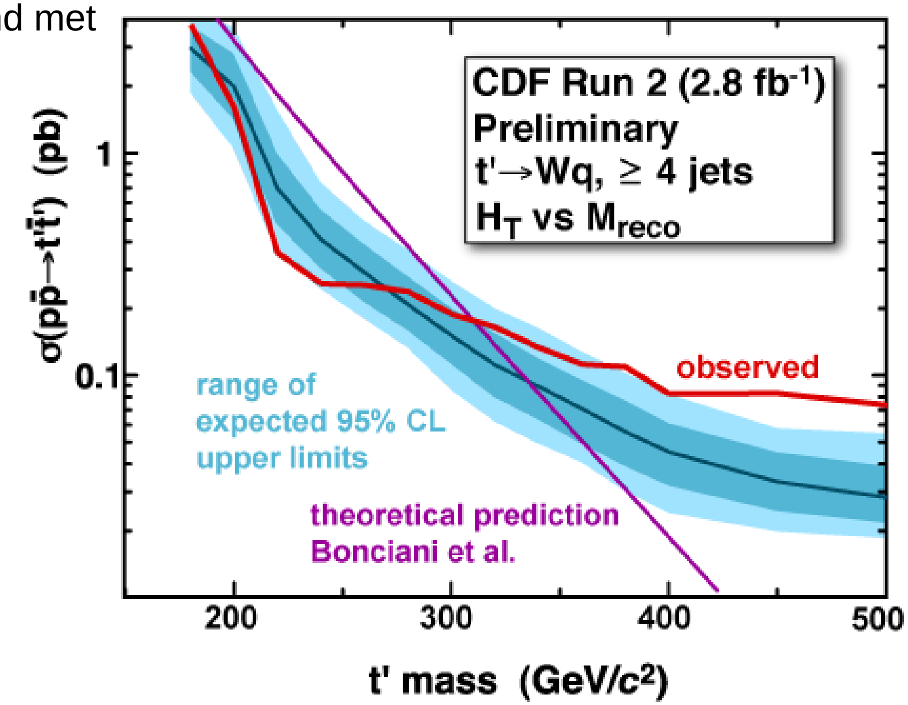
See also D0 results arXiv:0901.1063 [hep-ex], accepted by PLB.

Search for 4th generation top (t')

- Appear in some models
  - Beautiful mirrors, Little Higgs
- Search for t'→Wq in lepton+jets channel
- Use a 2D likelihood fit. In each event
  - Reconstruct the stop mass
  - Compute **H_T**: scalar sum of the lepton, jets and met in the event.



- EWK data:
  can accommodate an extra chiral family without other new particles (hep-ph 0102144)
- Results:

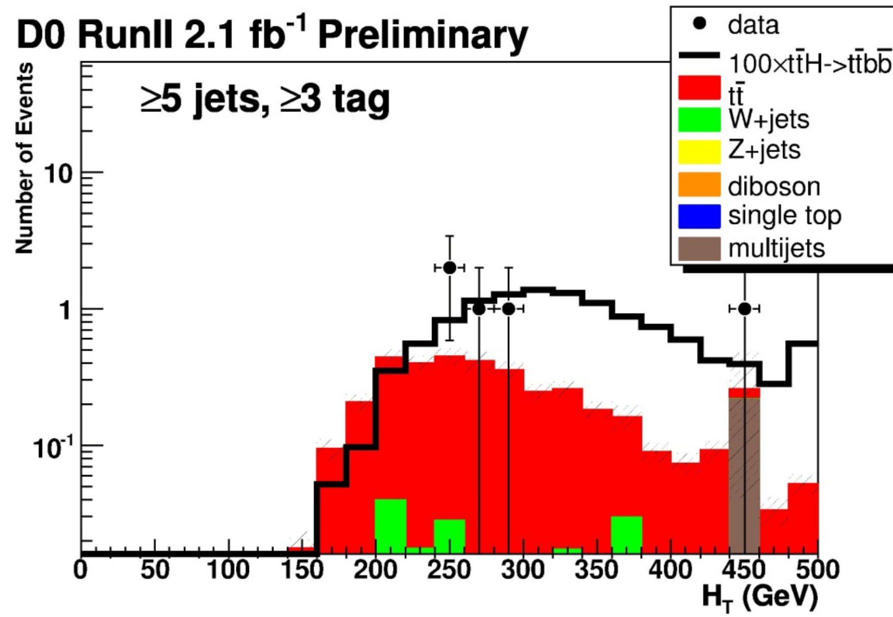


Exclude t' below 311 GeV @ 95% C.L.

Higgs Production Associated with $t\bar{t}$

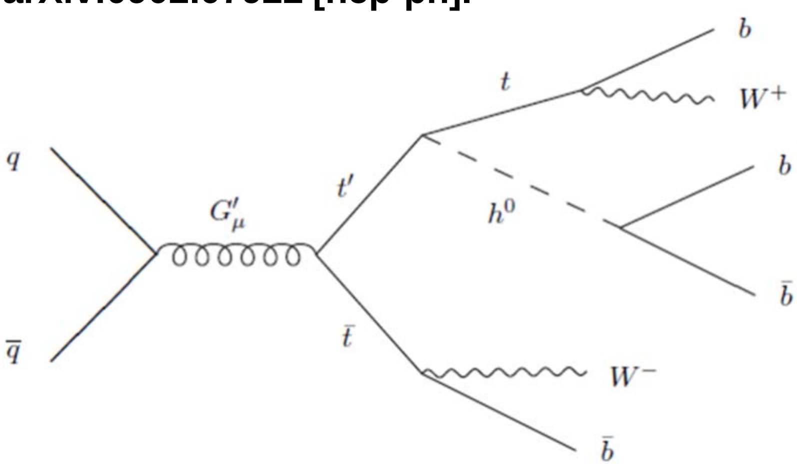
- **Search of $t\bar{t}H$ with $H \rightarrow b\bar{b}$**
  - Unusual high number of b-tags
- **Results**
  - 95%CL limits on $t\bar{t}H$/ SM xs.

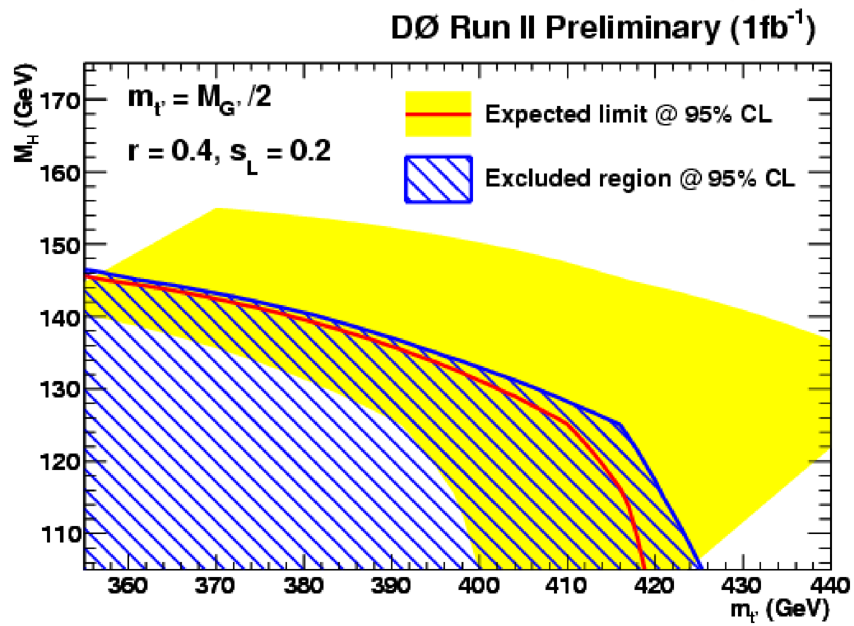
Higgs mass (GeV)	expected	observed
105	34.3	48.2
115	45.3	63.9
125	64.2	84.8
135	109	151
145	221	291
155	674	835



- **Interpret as limits pp→G→$t\bar{t}$'**

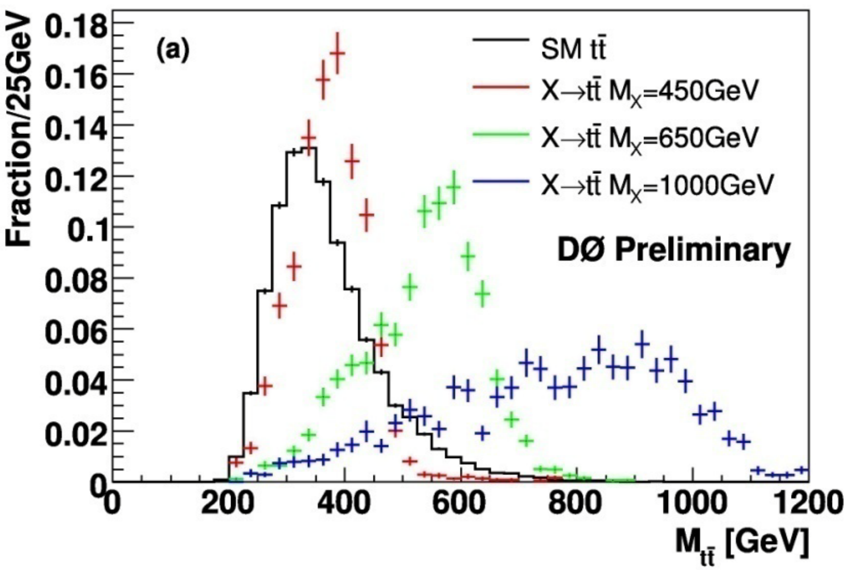
B. A. Dobrescu, K. Kong and R. Mahbubani, arXiv:0902.07922 [hep-ph].





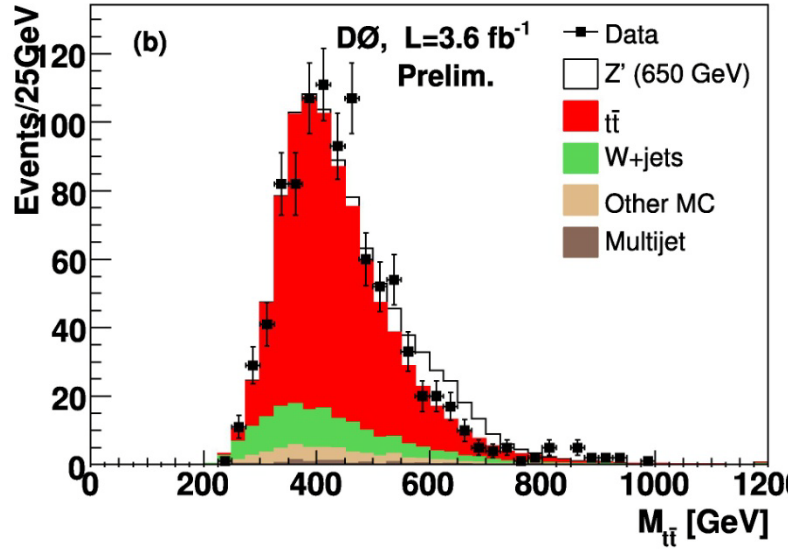
NEW Top Quark Pair Resonances

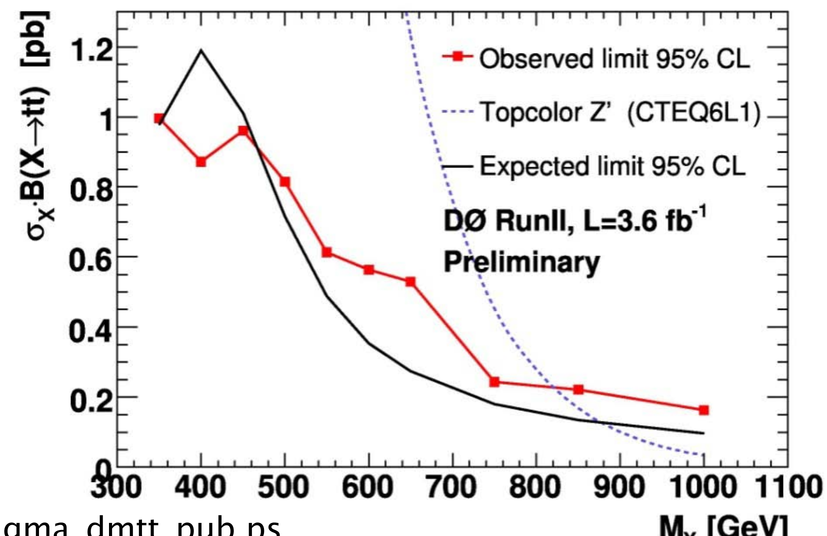
- **Search for $X \to t\bar{t}$**
  - 0.35 TeV<M_X<1.2 TeV.
  - Width $\Gamma_X = 0.012\ M_X$
  - Lepton, ME_T, ≥3 jets, ≥1 b-tag
- **Topcolor technicolor model**
  - Leptophobic Z' boson.



Excluded $M_{Z'}$<820 GeV @ 95% C.L.

- **Results**





See CDF result in conference note 9157
www-cdf.fnal.gov/physics/new/top/confNotes/cdf9157_dsigma_dmtt_pub.ps

Conclusions

➲ Top Samples at CDF and D0

- Exhaustive set of analyses probing its different properties in and beyond the context of the SM.
  - ► No indication of physics beyond the Standard Model in the top sample, yet.

- Much more data already collected, yet to include into these analyses.

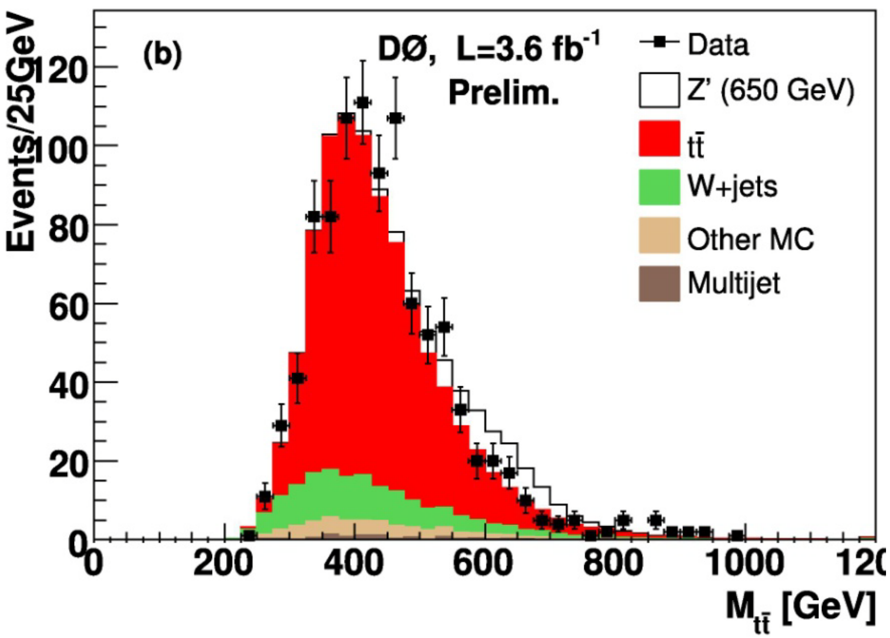
- Get more information from:
  - ► **CDF at http://www-cdf.fnal.gov/physics/physics.html**
  - ► **D0 at http://www-d0.fnal.gov/Run2Physics/WWW/results.htm**

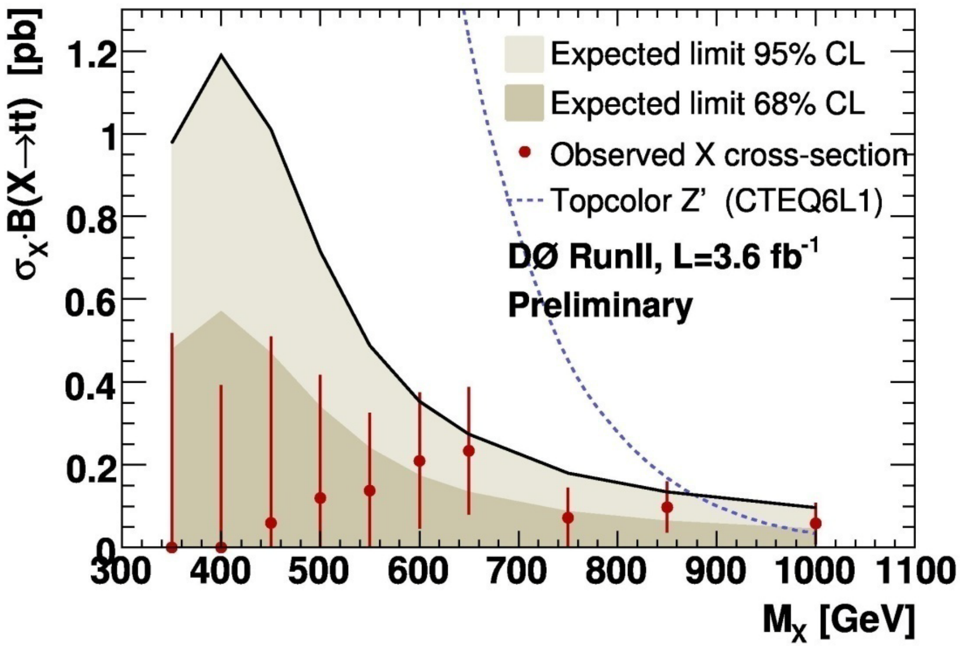
Thank you.

Top Quark Pair Resonances

NEW

- **Search for $X \rightarrow t\bar{t}$**
  - $0.35\ \text{TeV} < M_X < 1.2\ \text{TeV}$.
  - Width $\Gamma_X = 0.012\ M_X$
  - Lepton, ME_T, ≥3 jets, ≥1 b-tag
- **Results for leptophobic Z'**





Excluded $M_{Z'}$<820 GeV@ 95% C.L.

See CDF result in conference note 9157

www-cdf.fnal.gov/physics/new/top/confNotes/cdf9157_dsigma_dmtt_pub.ps

Top Quark Couplings

- **Most general CP-conserving Wtb vertex:**

$$L_{tWb} = \frac{g}{\sqrt{2}} W_\mu^- \bar{b} \gamma^\mu \left(f_1^L P_L + f_1^R P_R \right) t - \frac{g}{\sqrt{2} M_W} \partial_\nu W_\mu^- \bar{b} \sigma^{\mu\nu} \left(f_2^L P_L + f_2^R P_R \right) t$$

  - In the Standard Model: $f_1^L \approx 1,\ f_2^L = f_1^R = f_2^R = 0$

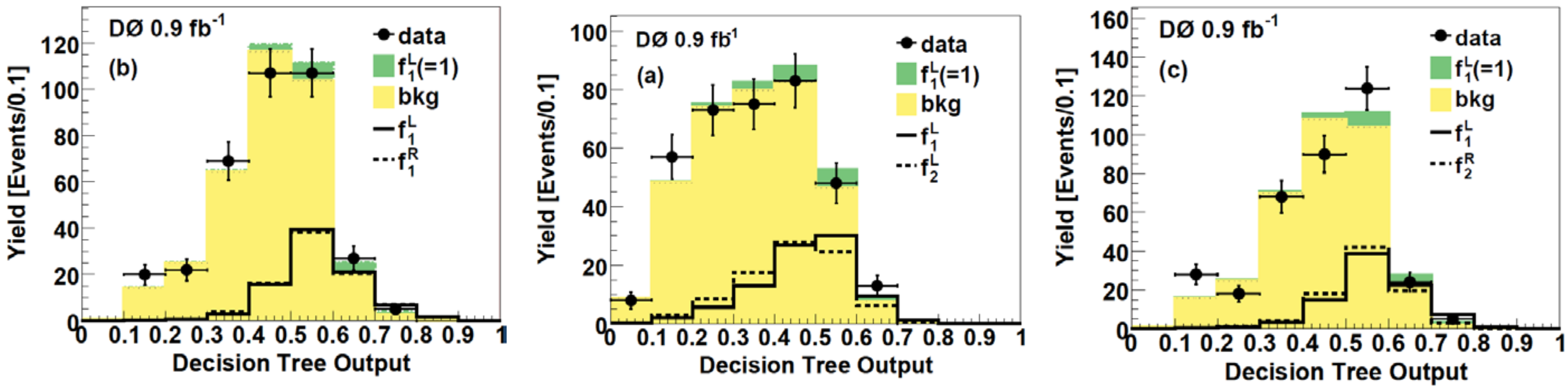
- **These couplings can be determined from knowing:**
  - Single top production in s-channel
  - Single top production in t-channel
  - Fraction of helicity states of the W boson
    - Needs two: e.g. longitudinal and right fraction.

- **Explore two parameters at the time:**
  - Set limits in three independent scenarios

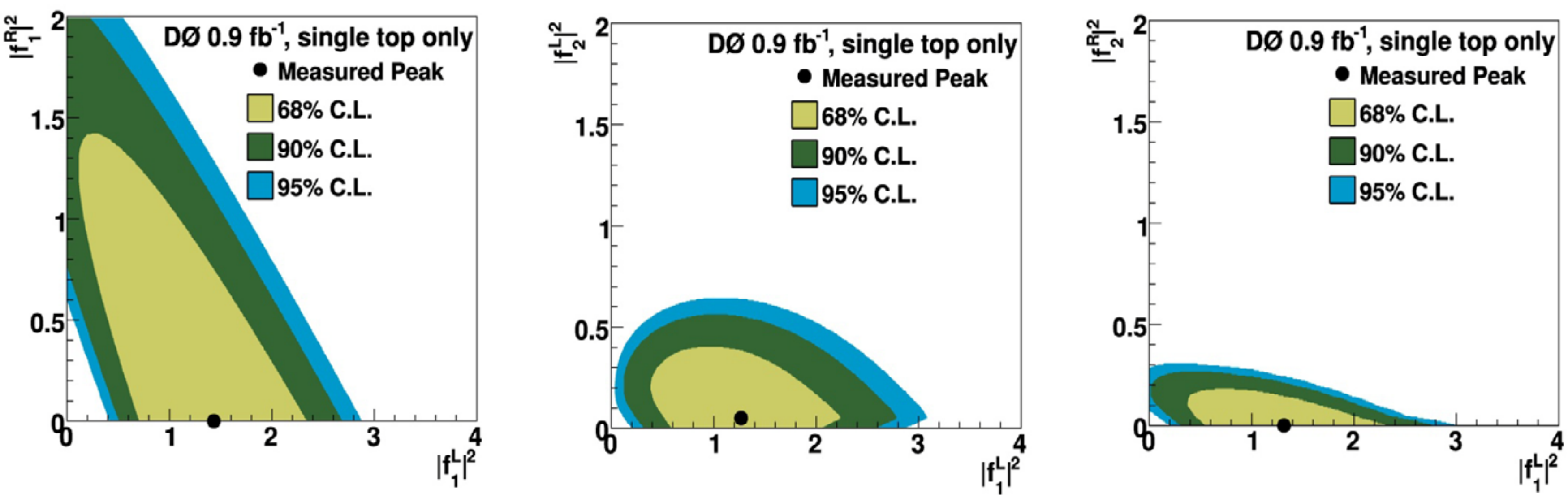
	Vary	fix to SM
Scen. 1:	f_1^L, f_1^R	f_2^L f_2^R
Scen. 2:	f_1^L, f_2^L	f_1^R f_2^R
Scen. 3:	f_1^L, f_2^R	f_1^R f_2^L

Top Couplings From Single Top

- **Couplings change the production rate and kinematic properties**
  - Use multivariate technique (Boosted Decision Tree)

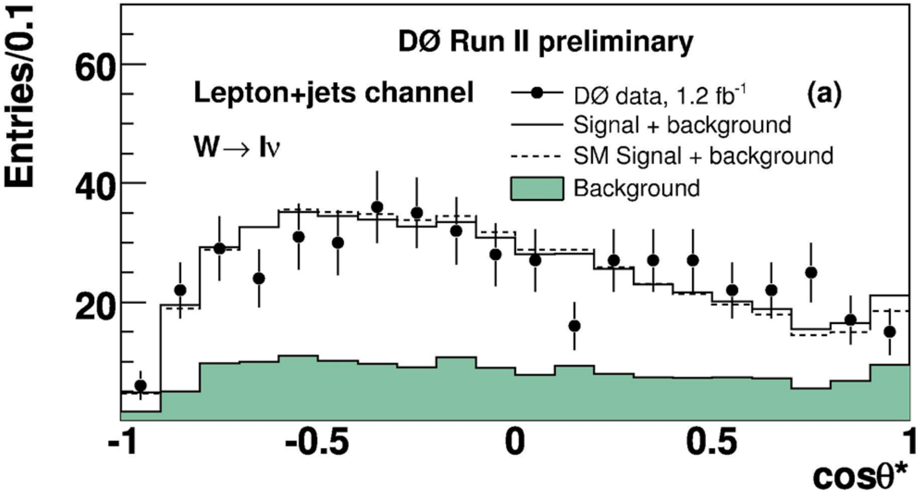


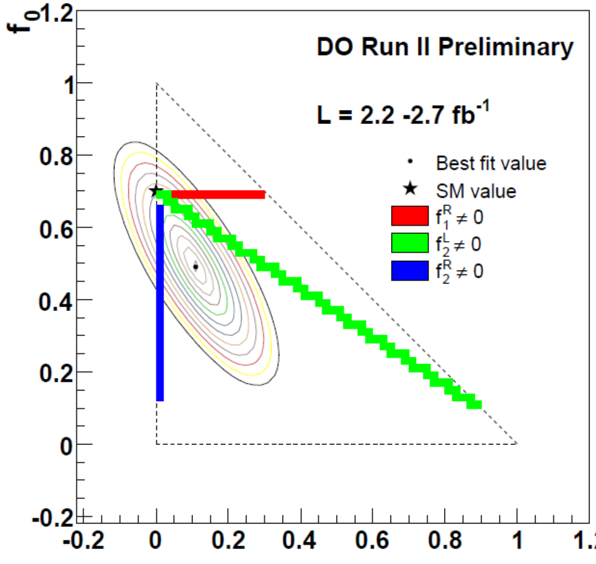
- **Results**



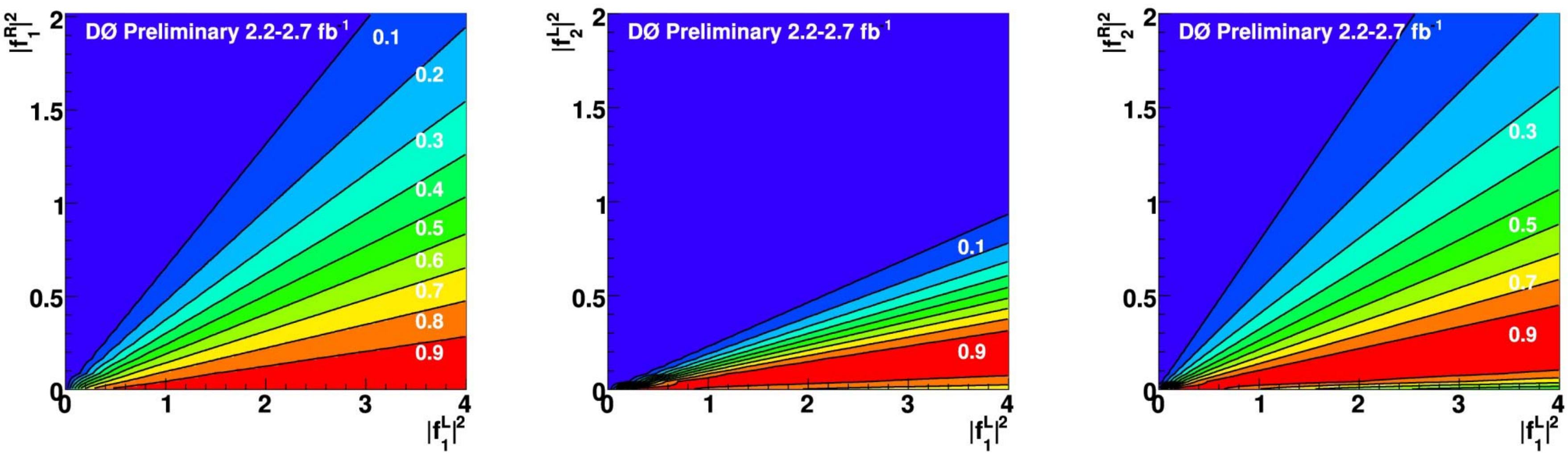
Top Couplings From W–Helicity

- W-Helicity measurement: using lepton+jets and dilepton channels





- Use to help constrain the couplings



Top Coupling Combination

➲ **Combination of couplings obtained from Whelicity and Single Top**

Scenario	Coupling	Coupling if $f_1^L = 1$
(f_1^L, f_1^R)	$\|f_1^L\|^2 = 1.36^{+0.56}_{-0.46}$	
	$\|f_1^R\|^2 < 0.72$	$\|f_1^R\|^2 < 0.72$
(f_1^L, f_2^L)	$\|f_1^L\|^2 = 1.44^{+0.65}_{-0.51}$	
	$\|f_2^L\|^2 < 0.30$	$\|f_2^L\|^2 < 0.19$
(f_1^L, f_2^R)	$\|f_1^L\|^2 = 1.16^{+0.51}_{-0.44}$	
	$\|f_2^R\|^2 < 0.19$	$\|f_2^R\|^2 < 0.20$

➲ **Bayesian statistics:**

- W-Helicity results used as prior probabilities