Searches for 4th Generation Fermions at Tevatron

Andrew Ivanov
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On behalf of CDF and D0
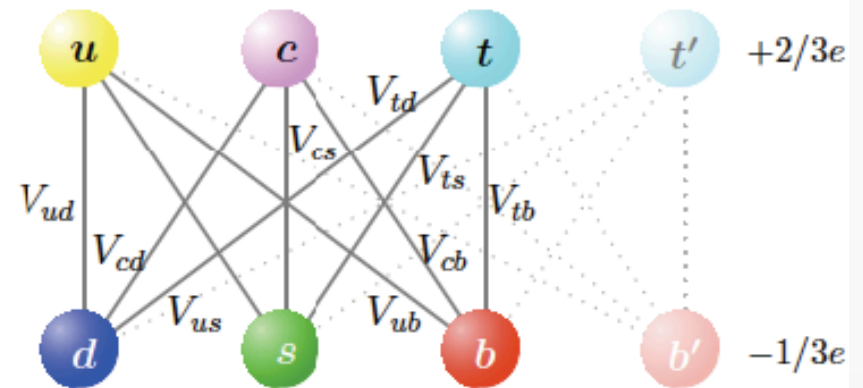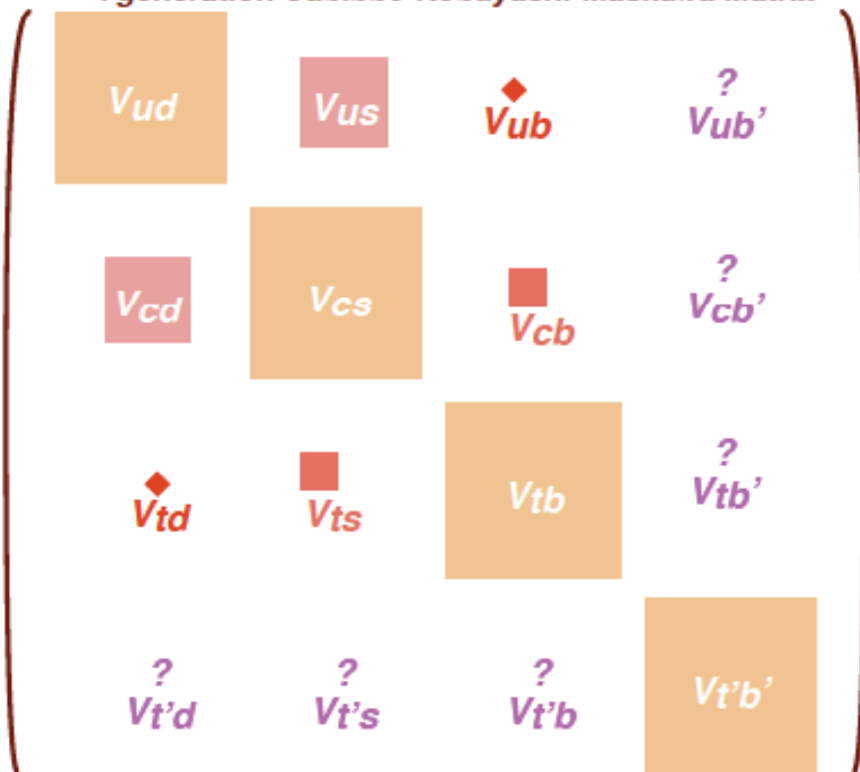Collaborations

FPCP- 2011
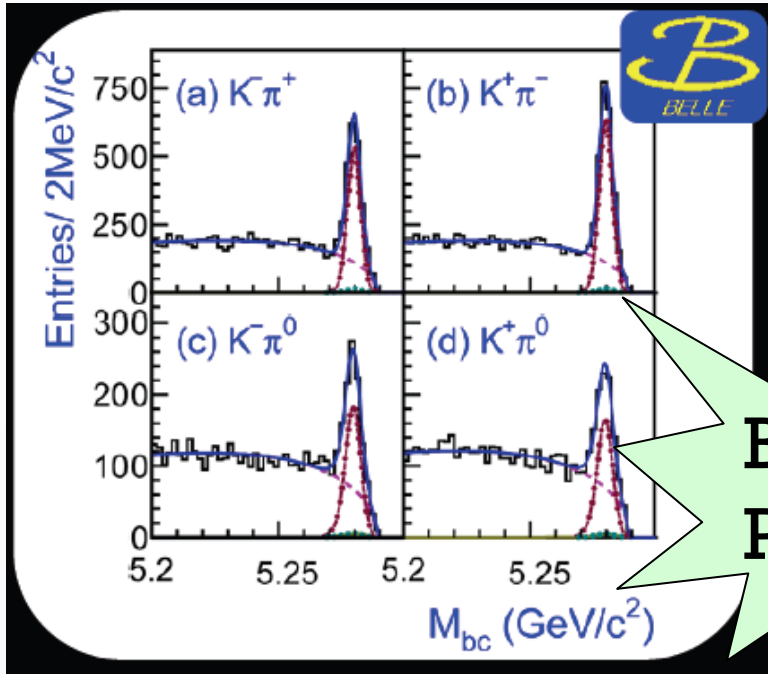**Kibbutz Maale Hachamisha,
Israel**
26 May, 2011

4th Generation

- SM4 is a simplest extension of SM3
- It barely presents a solution to any theoretical problems in modern particle physics
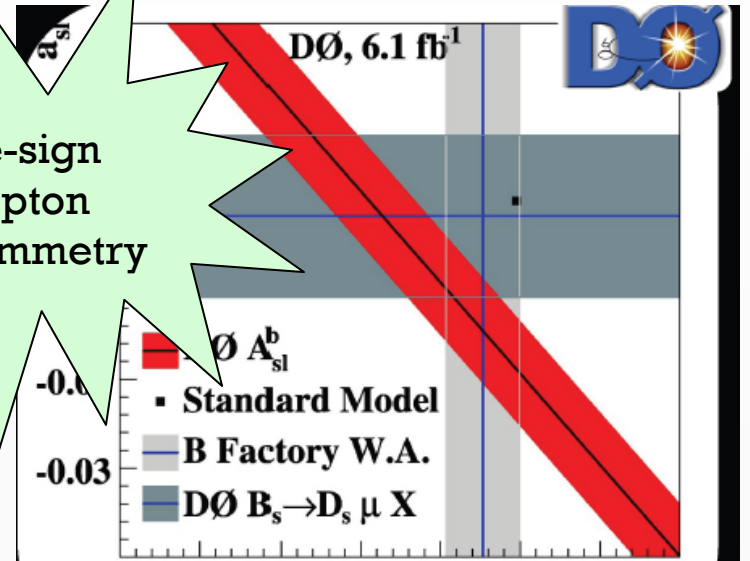- But could explain some observed discrepancies

4th Generation and Flavor Physics
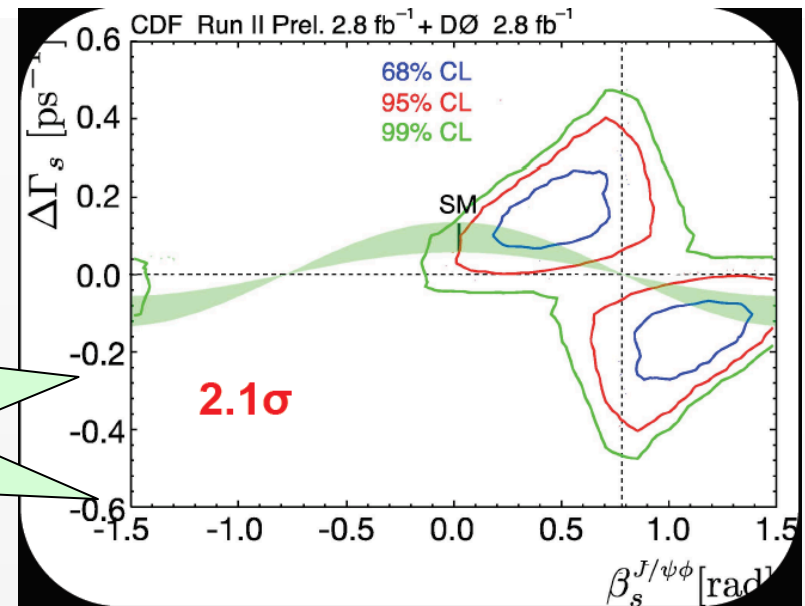

$$\Delta\mathcal{A} \equiv \mathcal{A}_{K^\pm\pi^0} - \mathcal{A}_{K^\pm\pi^\mp} = +0.164 \pm 0.037$$

$$A_{sl}^b = -0.00957 \pm 0.00251 \ (\text{stat}) \pm 0.00146 \ (\text{syst})$$

B-> Kπ Puzzle

Like-sign Dilepton Asymmetry
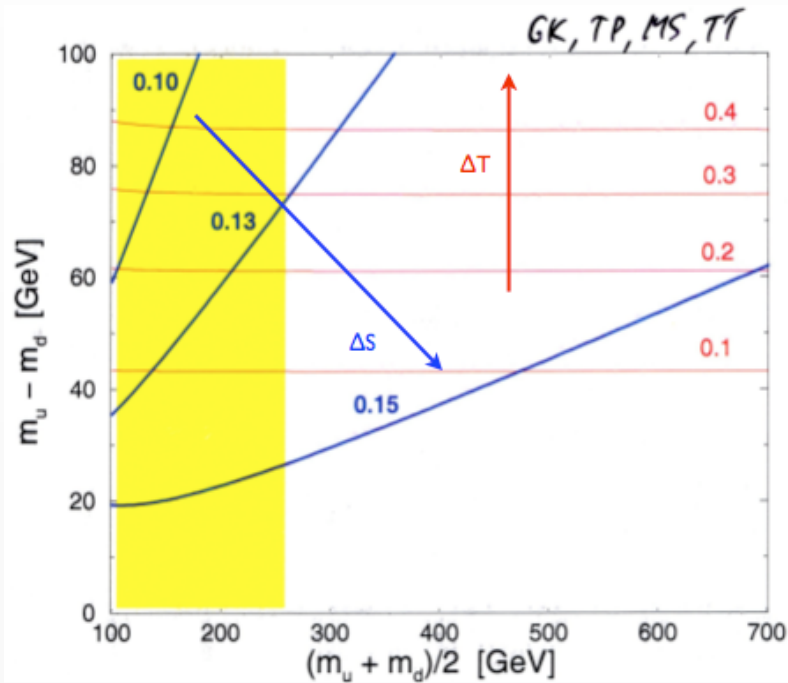
Mixing phase $B_s \rightarrow J/\psi\ \phi$

4th Generation and Electroweak Physics
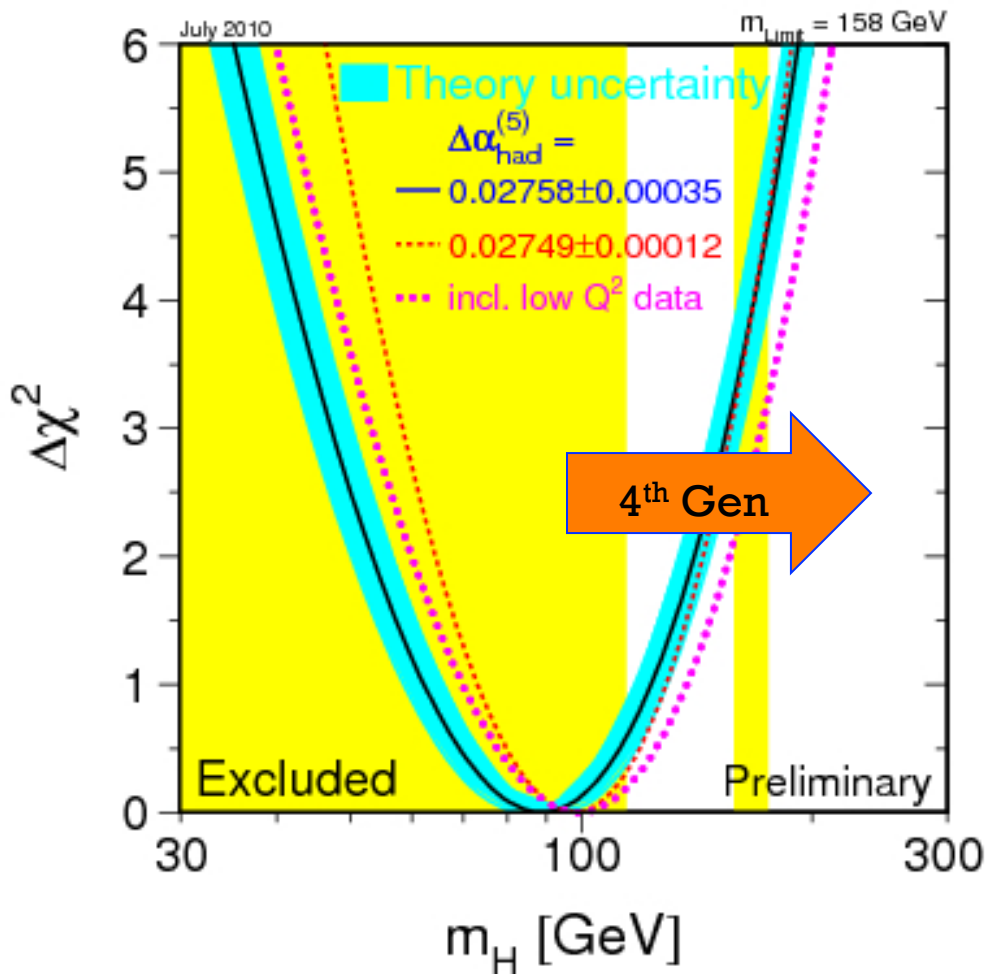
- Resolves tension for Higgs mass prediction between LEP limit and electroweak precision fit

- CP violation is significantly enhanced to account for baryon asymmetry in the Universe
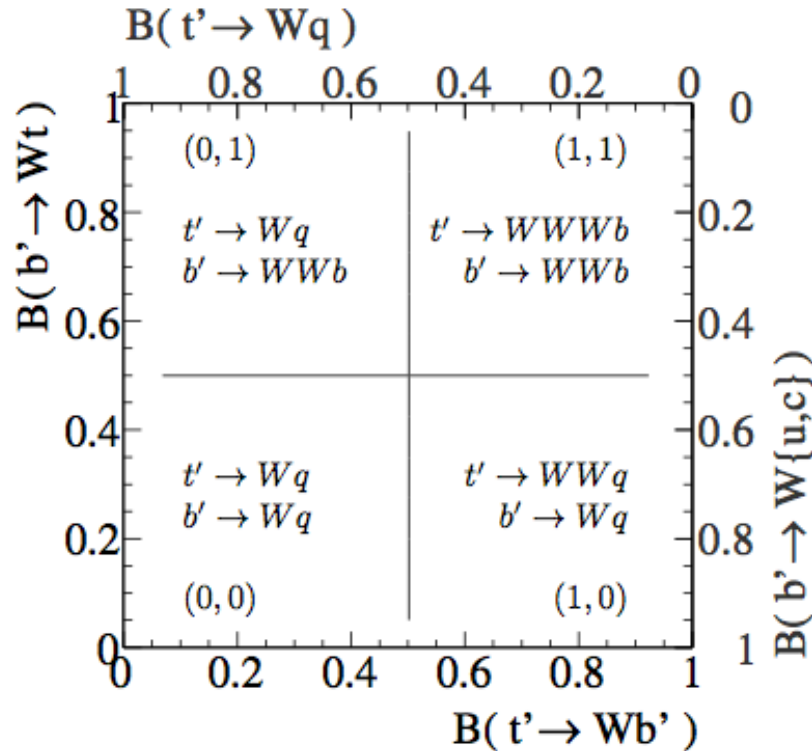
- W. Hou, F.Lee, C. Ma

- PRD 79, 07302 (2009)

4th Generation

G. Kribs, T. Plehn, M. Spannowsky, T. Tait
PRD 76 (2007) 075016

- Constraints from electroweak precision data require small oblique corrections: ΔS, ΔT, ΔU

-

- If SM4 exists:

- Small mass splitting between 4-th generation t' and b':

- m(t') −m(b') < mW

- m(t') and m(b')

  ~ a few hundreds GeV

Search for t't': t'->Wq, Wb

- Main Decay Modes:
- t'->Wb, Wq
- b'-> tW, Wq
- <u>Search for:</u>
- Q->Wq, Wb, tW=WWb

- t'->Wq (or b)
- Similar to top quark production and decay
- <u>Search Strategy:</u>

- Reconstruct mass of the top (t') quark

Search for t't': t'->Wq, Wb

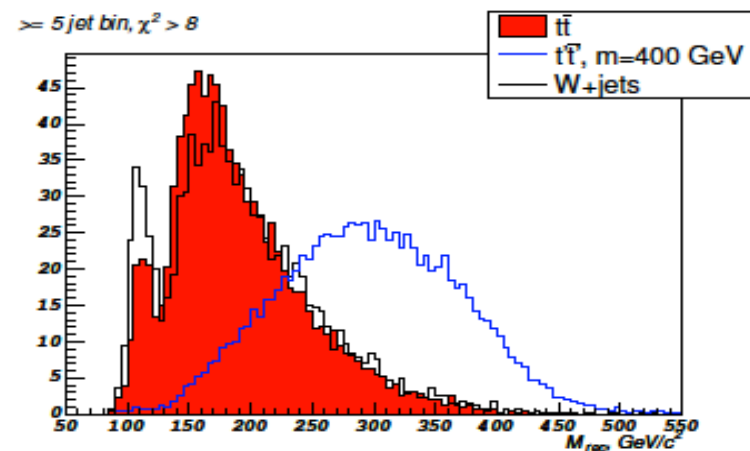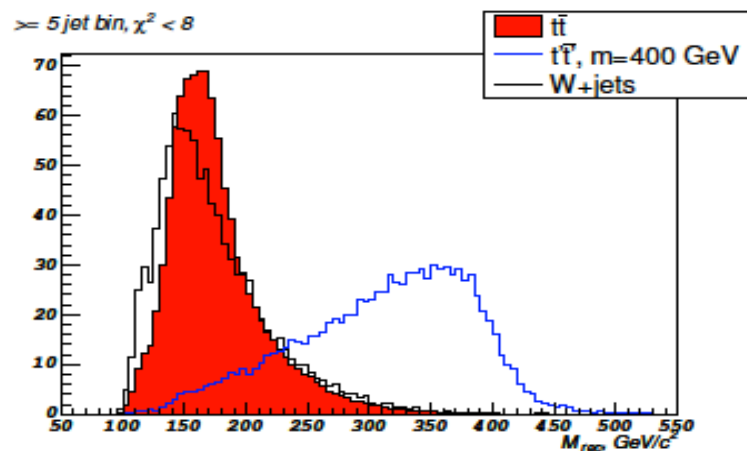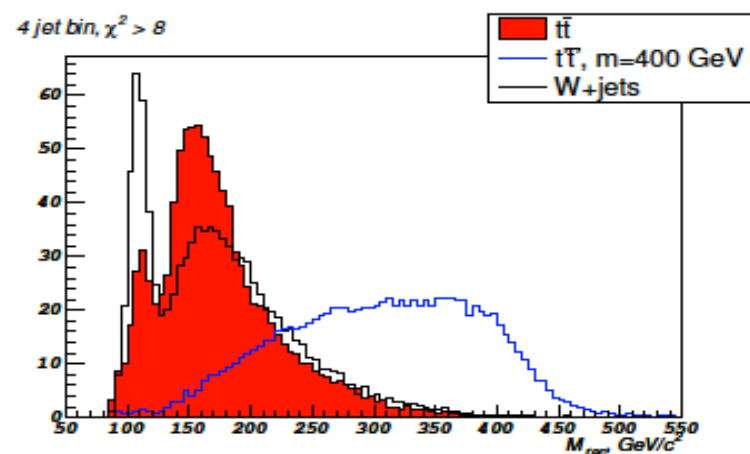- Select μ or e with p_T > 20 GeV; >= 4 jets , E_T > 20 GeV; MET > 20 GeV
- Require >=1 b-tag for t'->Wb analysis

- Perform 2D- fit to H_T = scalar Σ (Jet E_T + lepton E_T + MET)
   and reconstructed top (t') mass distribution
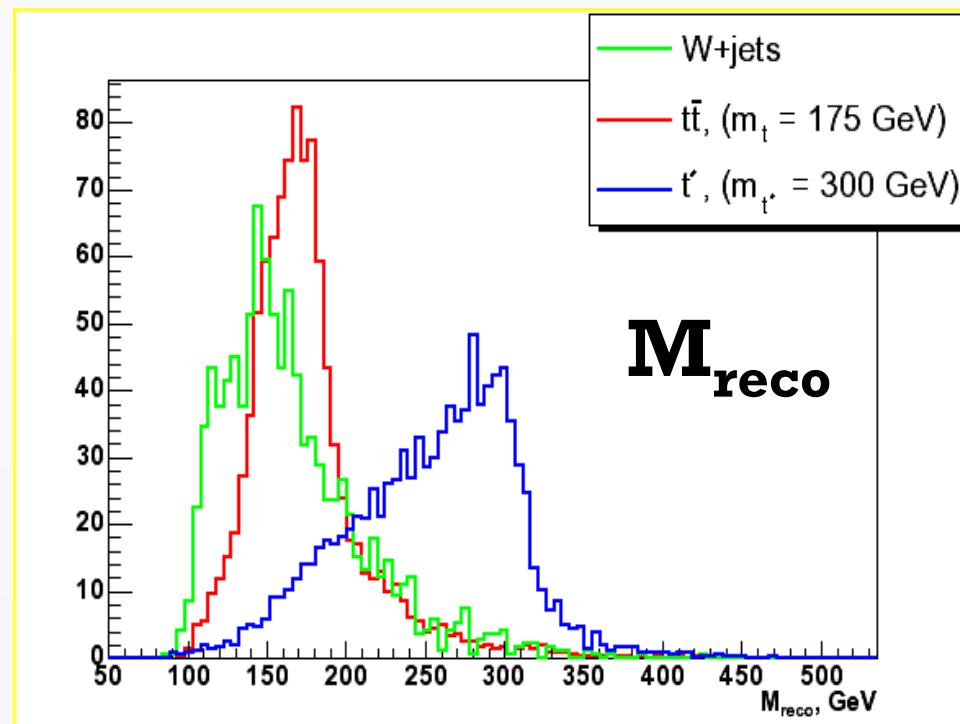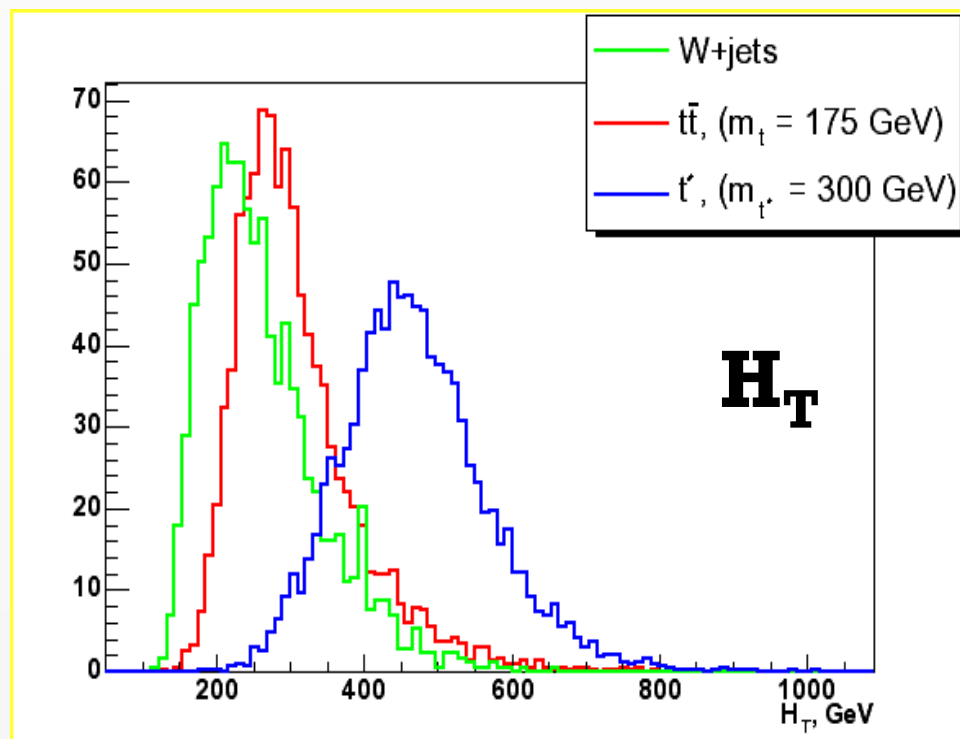
Search for t't': t'->Wq, Wb

- Improve the sensitivity by splitting events into separate categories, based on quality of mass reconstruction
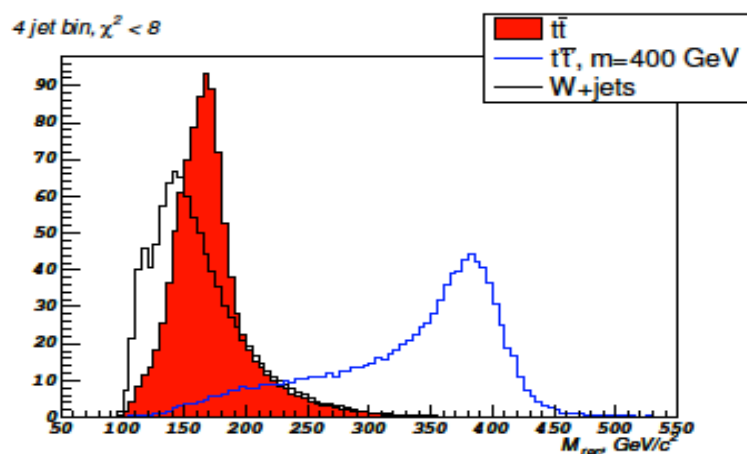
Results for t't': t'-> Wq
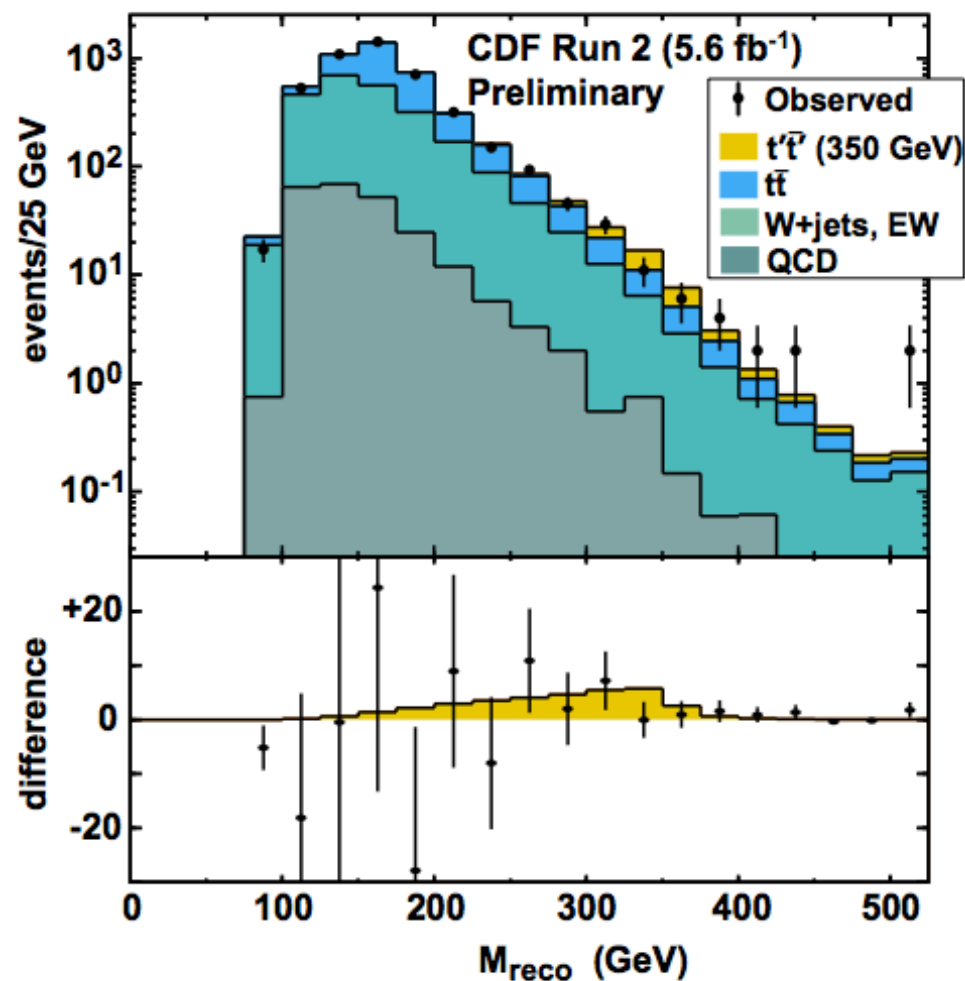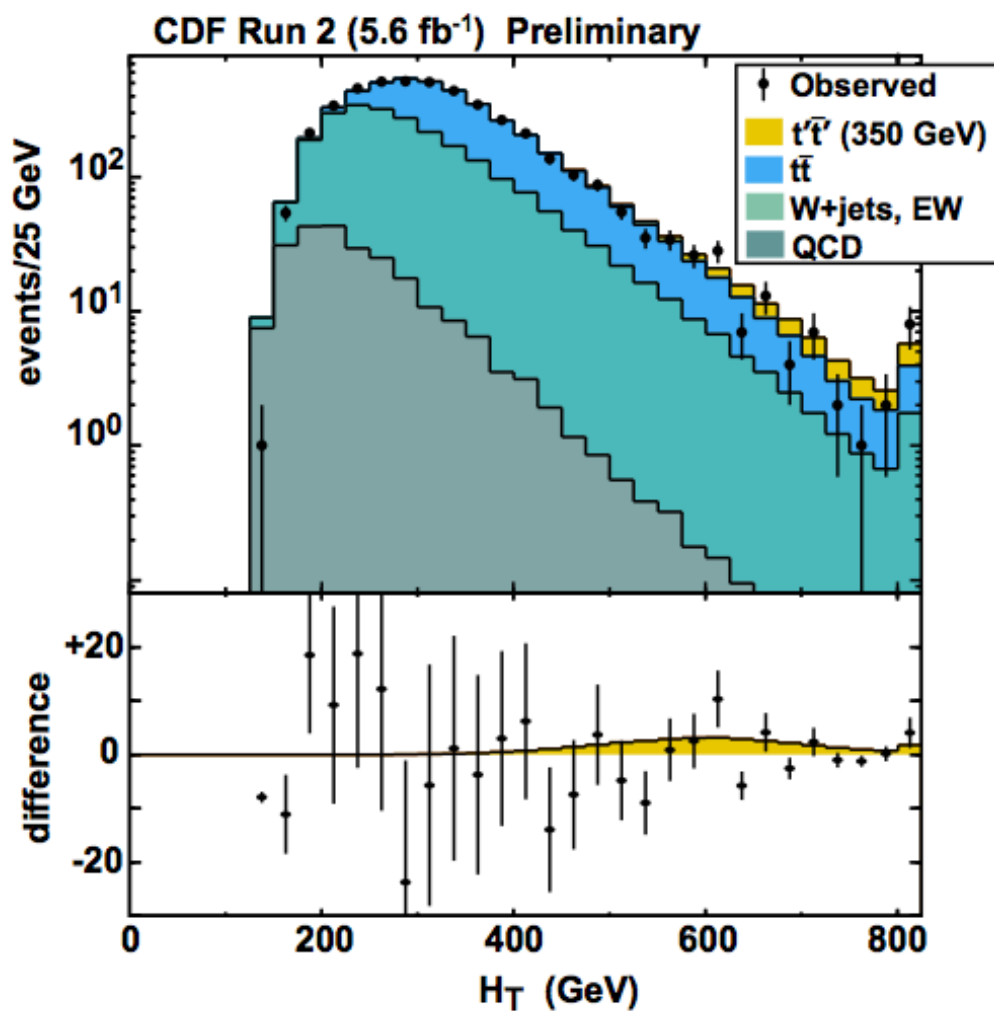
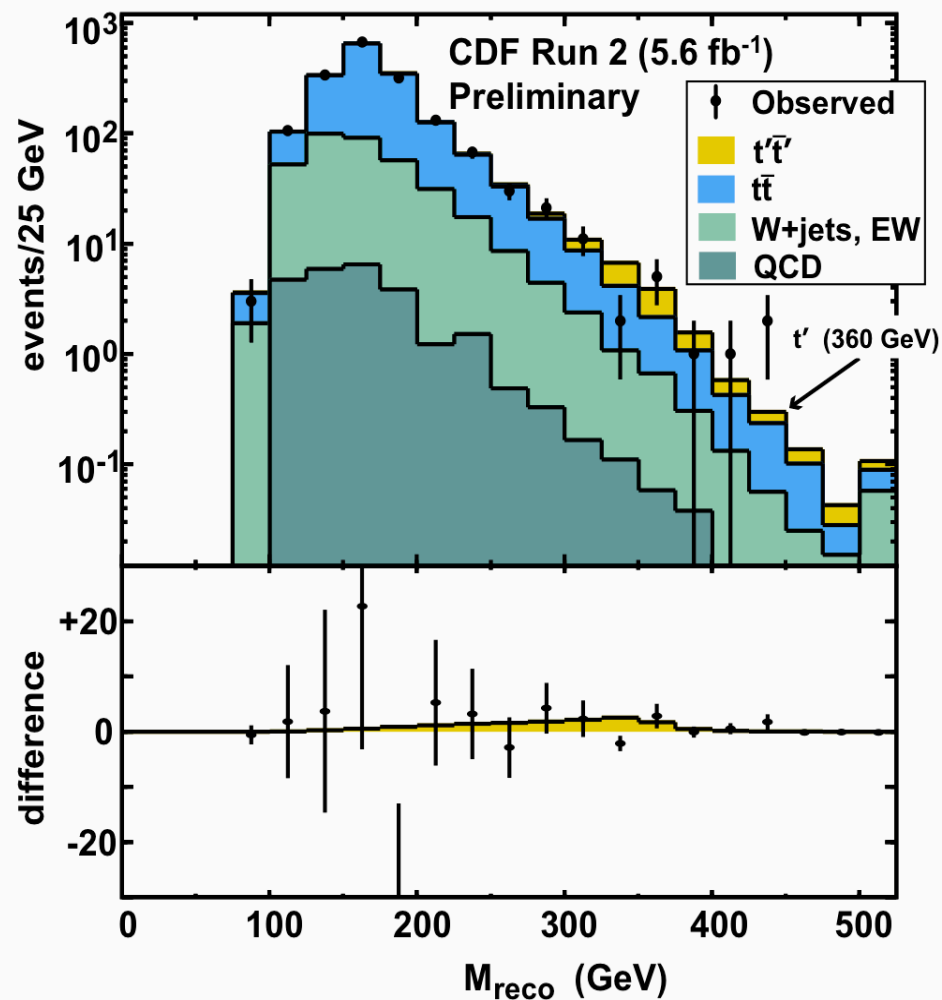- 2D– fit to H_T = scalar Σ (Jet E_T + lepton E_T + MET)
  and reconstructed mass distribution

Results for t't': t'-> Wb

- 2D– fit to H_T = scalar Σ (Jet E_T + lepton E_T + MET)
  and reconstructed mass distribution
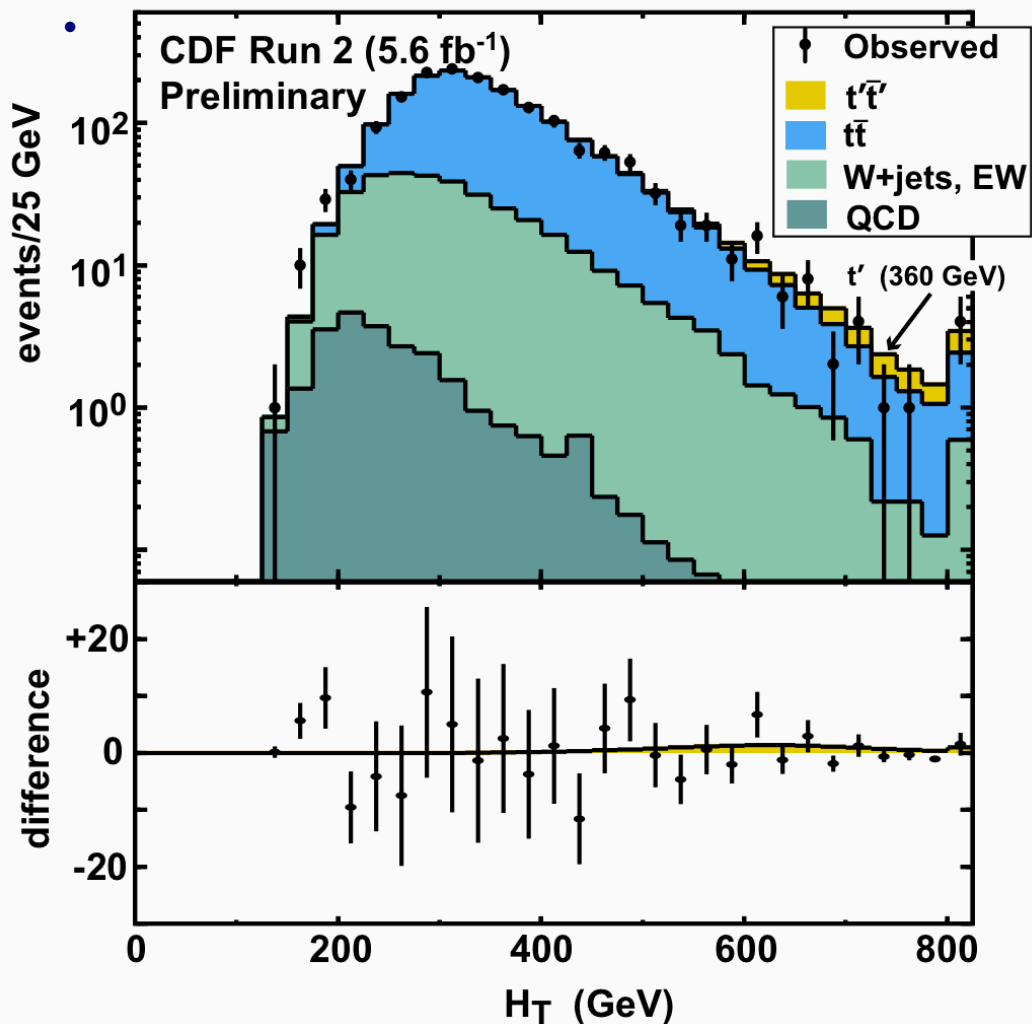
Search for t't': t'->Wq, Wb

- t'->Wb
- M(t') > 358 GeV at 95% C.L.

- t'->Wq
- M(t') > 340 GeV at 95% C.L.
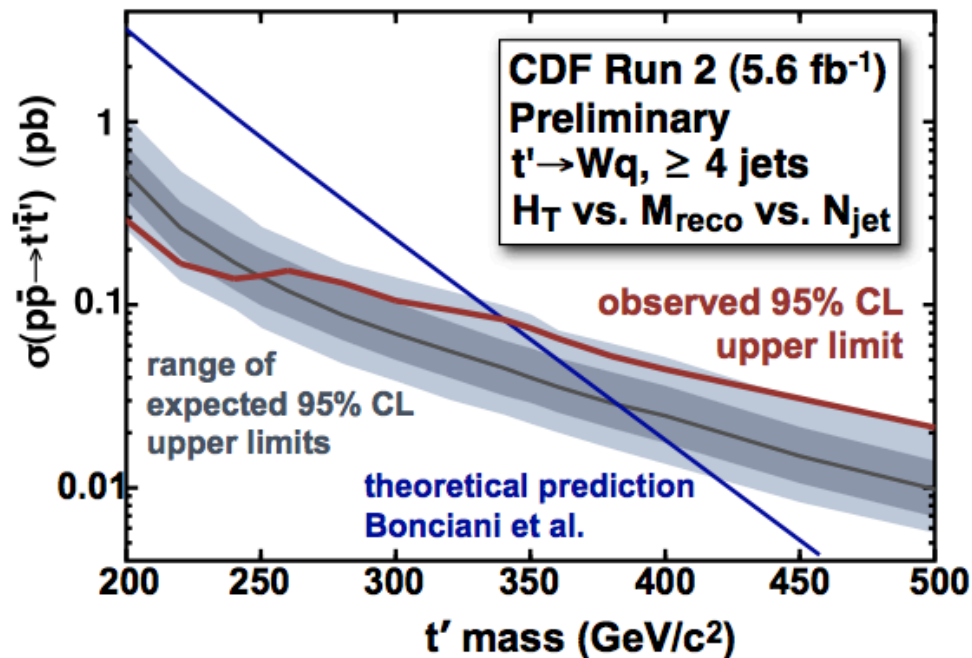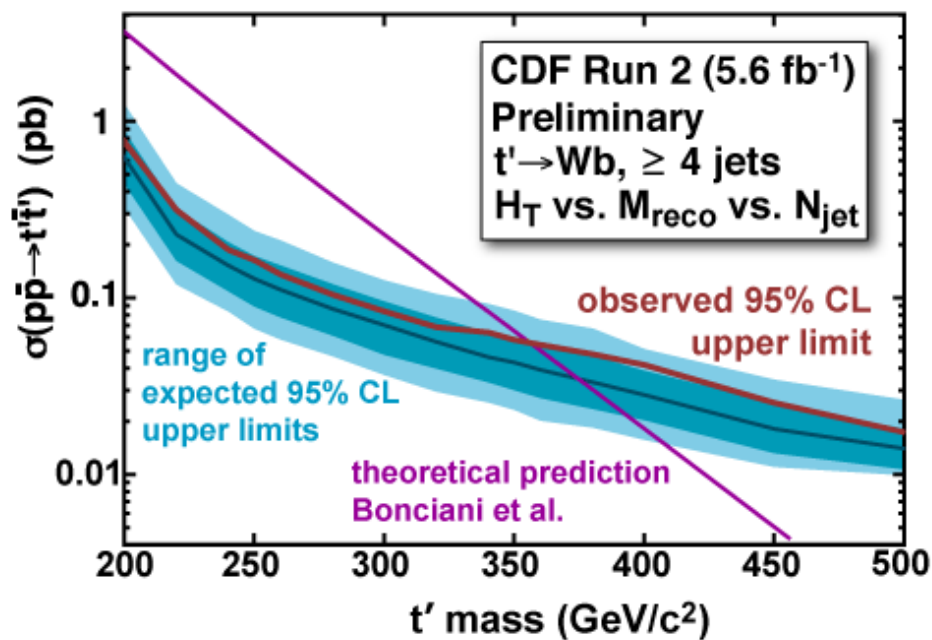
Search for t't': t'->Wq

- e + jets

- μ + jets

Andrew Ivanov, KSU
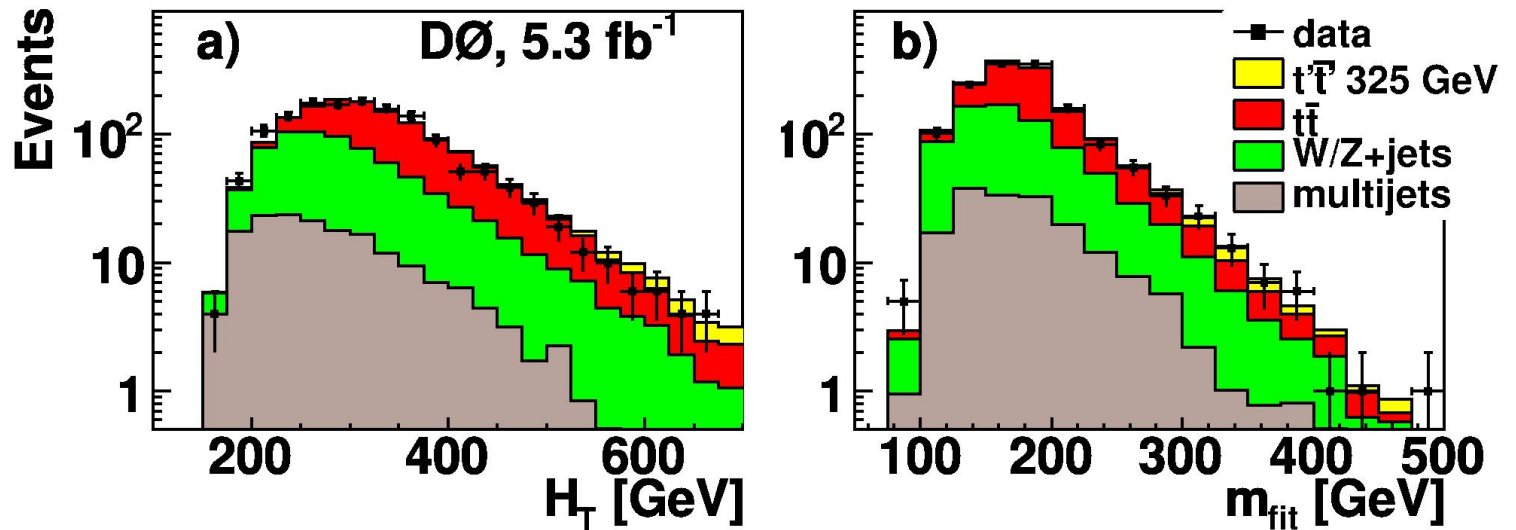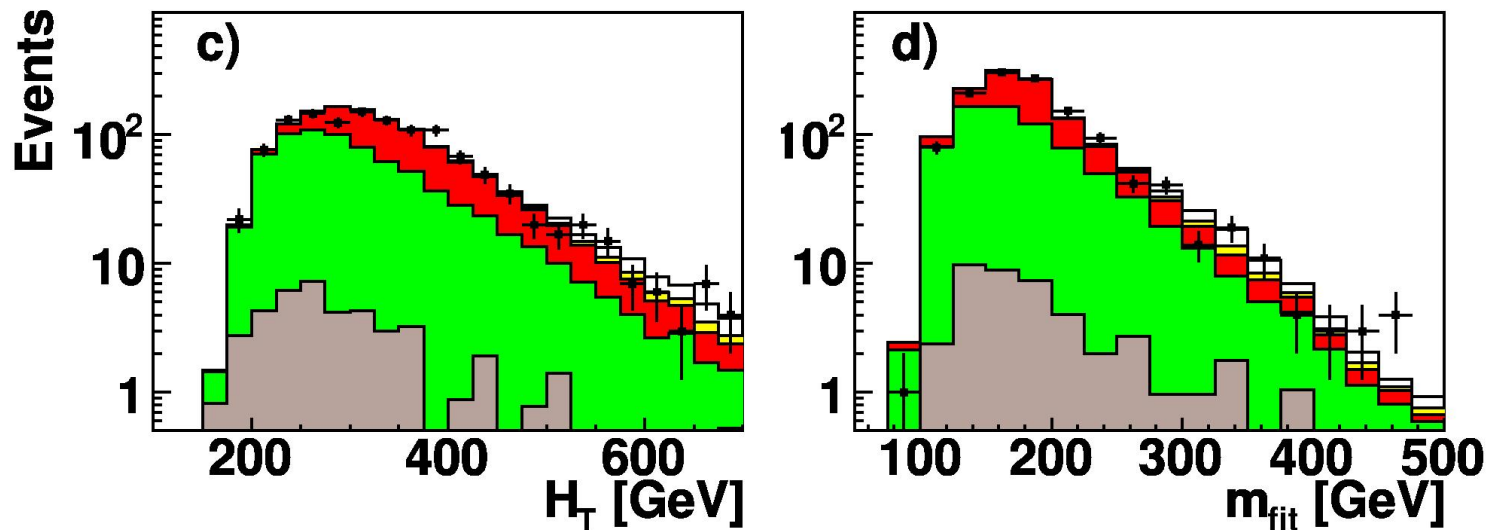
Search for t't': t'->Wq
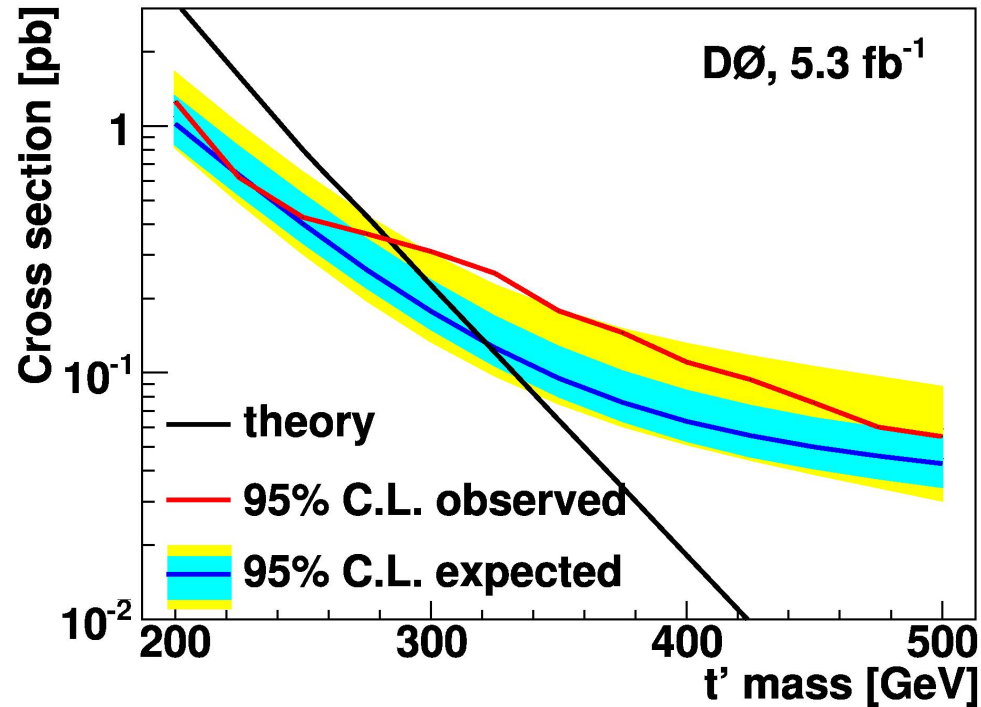
- t'->Wq
- M(t') > 285 GeV at 95% C.L.

- No evidence of t' production

- arXiv: 1104.4522
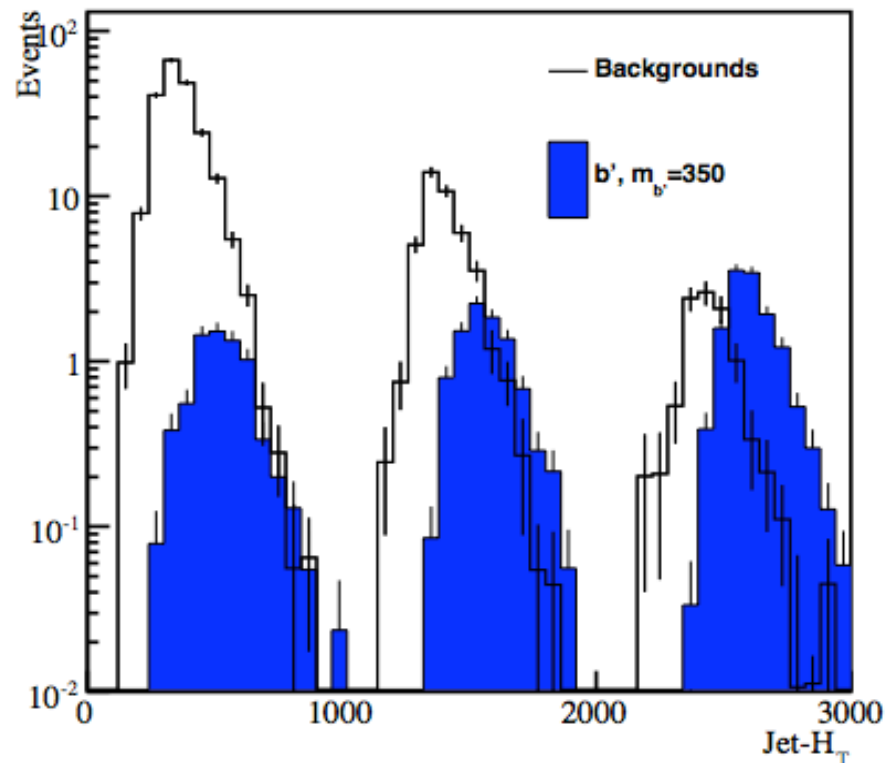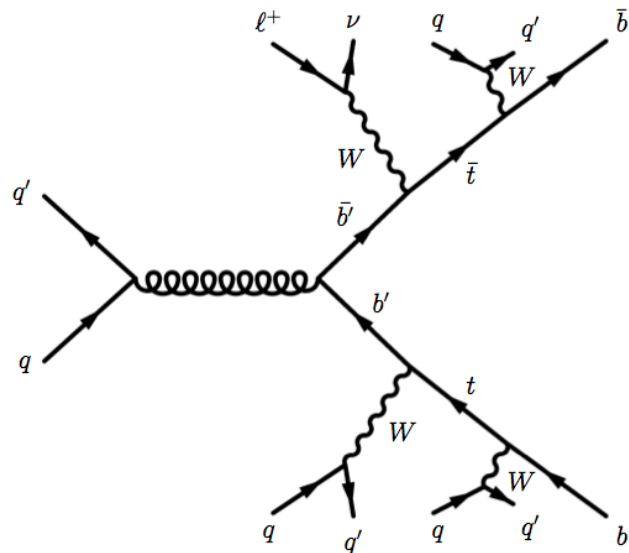
- Best sensitivity in "single lepton +jets" channel

- Require μ or e with p_T > 20 GeV

- >= 6 jets , E_T > 20 GeV

- MET > 20 GeV

-

- Search for b'b'-> ttWW by fitting to

- H_T = scalar Σ (Jet E_T + lepton E_T + MET)

across different jet multiplicity bins

Search for b'b': b'->tW

- Exclude b' quark below 385 GeV at 95%C.L.

- PRL 106, 141803 (2011)

Vector-like Quarks

- b-quark Forward-Backward Asymmetry shows ~ 2.6 σ deviation
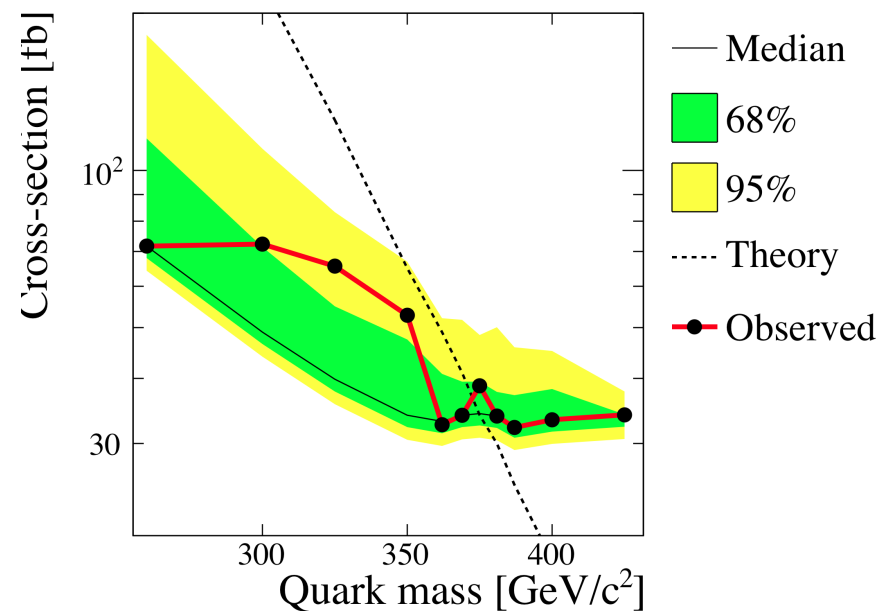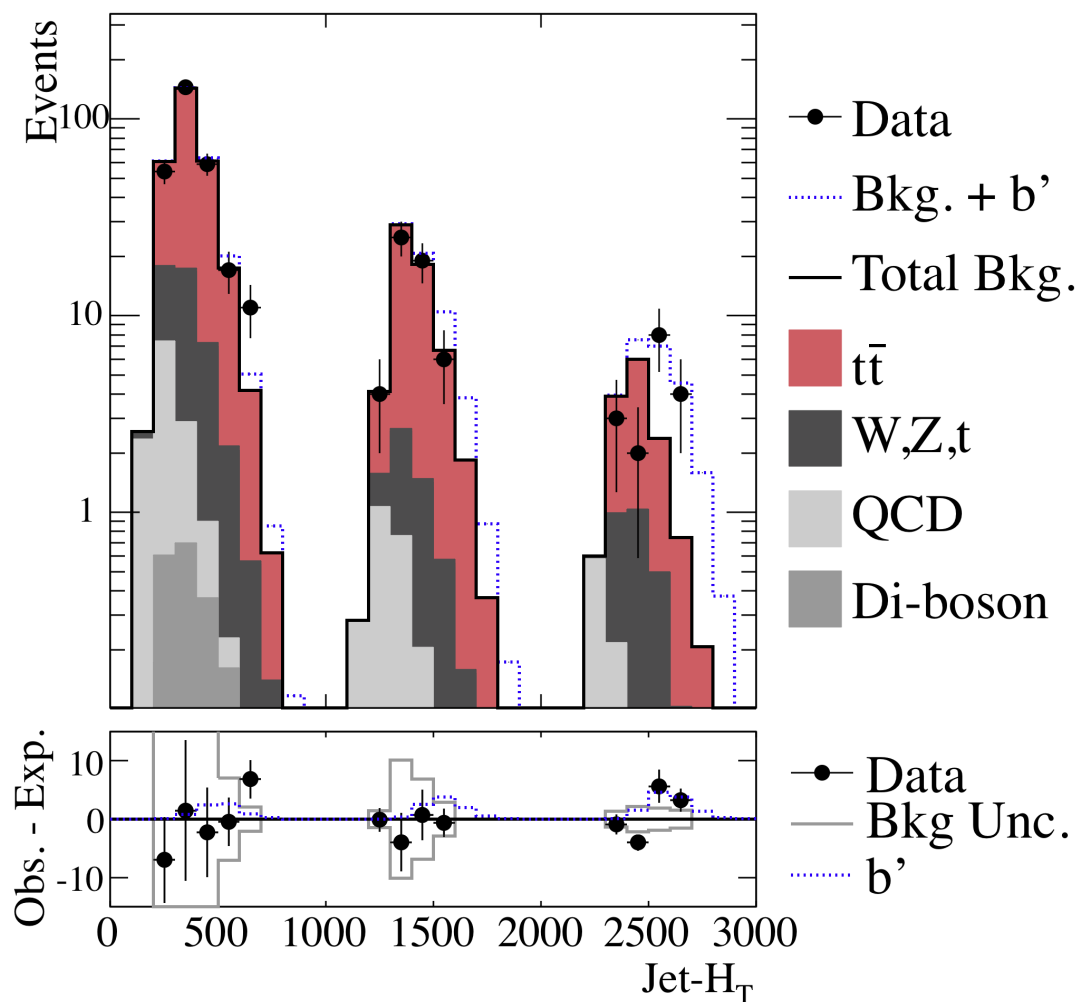- Results in different predictions for Higgs mass
- Tension could be resolved by introducing quarks with non-V-A-couplings
- e.g.
- D. Choudhury, T. Tait C. Wagner, PRD 65 (2002) 053002

Fits to leptonic data

$+A^c_{FB}$

$+A^b_{FB}$

95% C.L.

$\Delta\chi^2$

$m_H(GeV)$
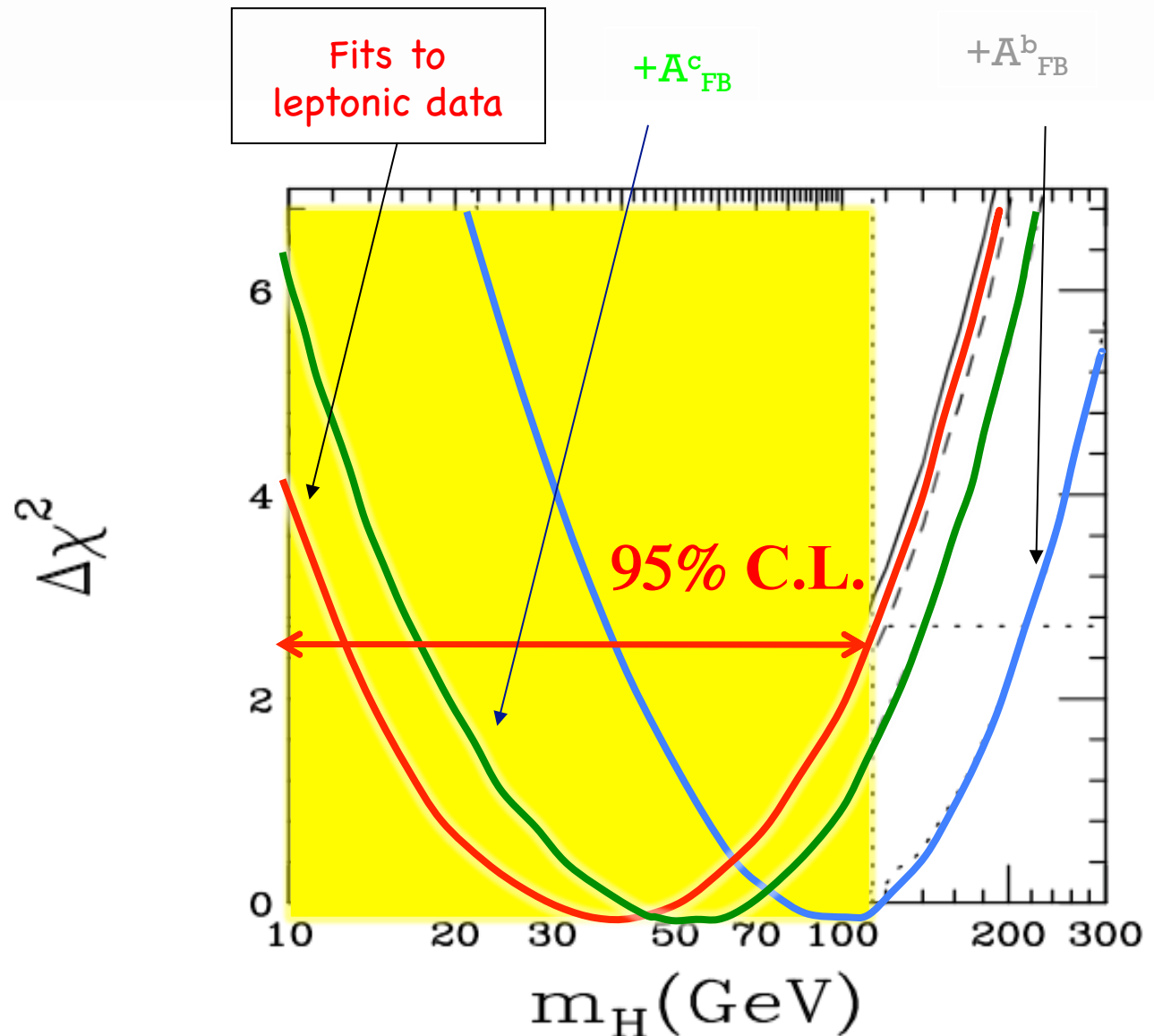
M. Chanowitz, PRL 97 (2001) 231802

Vector-like Quarks

- No FCNC-suppression opens new decay modes, e.g. $t' \to th$, $t' \to tZ$

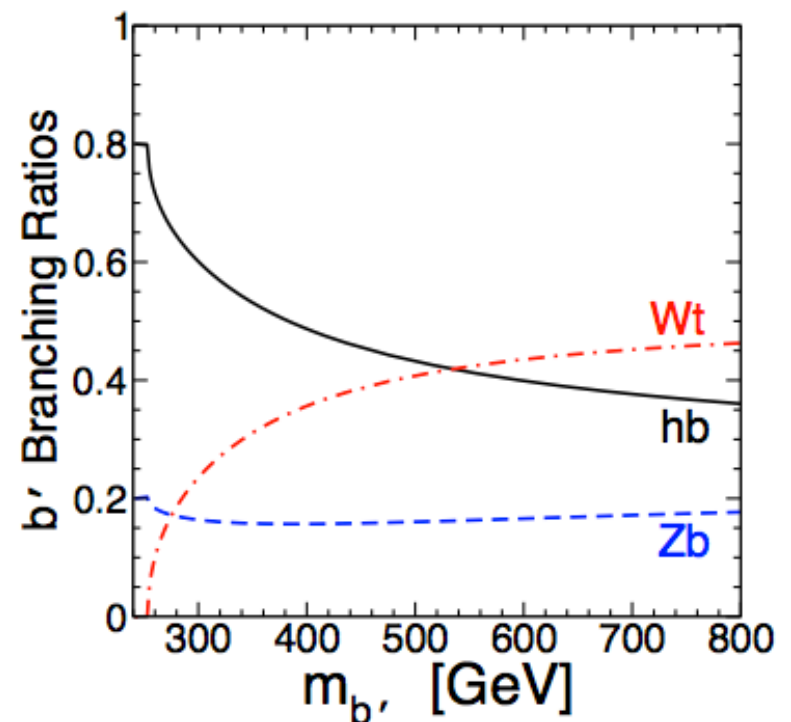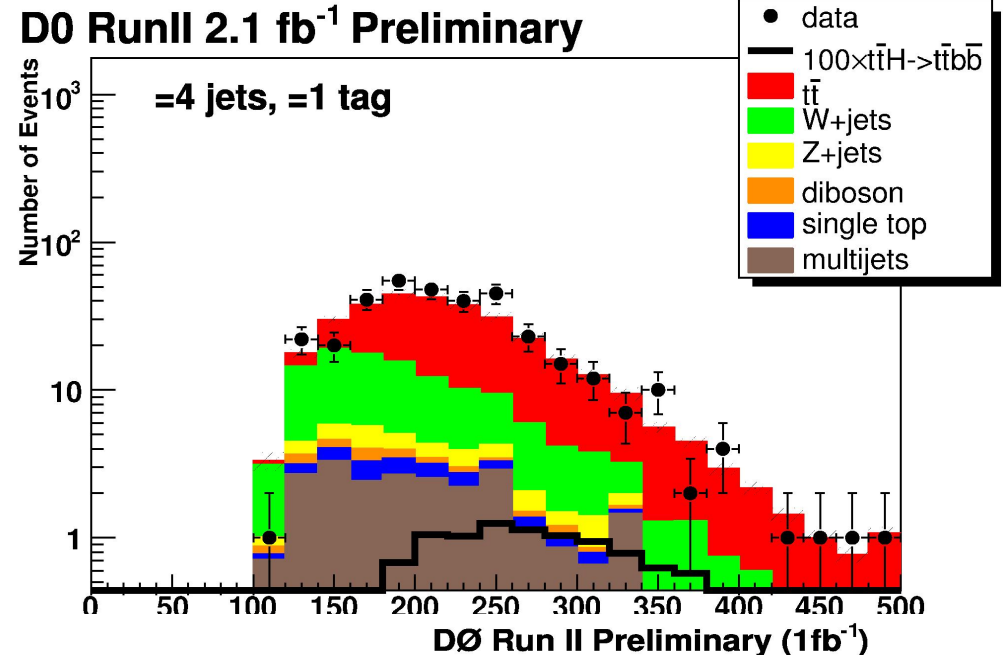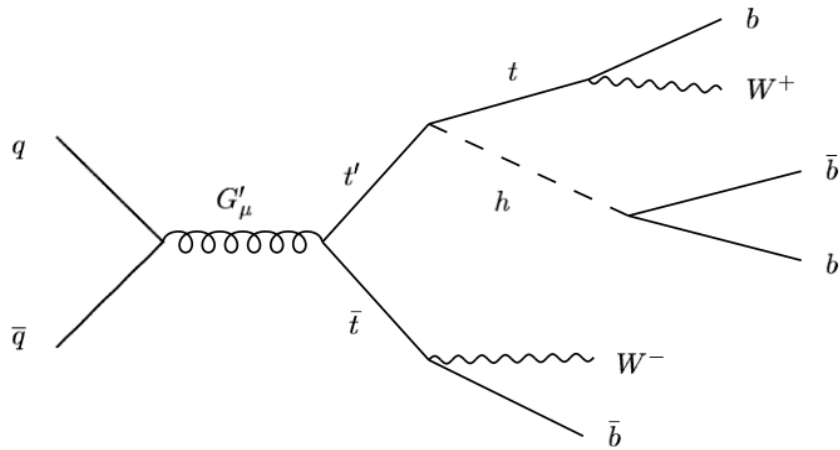- Can have production cross section enhanced due to different couplings to gauge bosons

- Example:
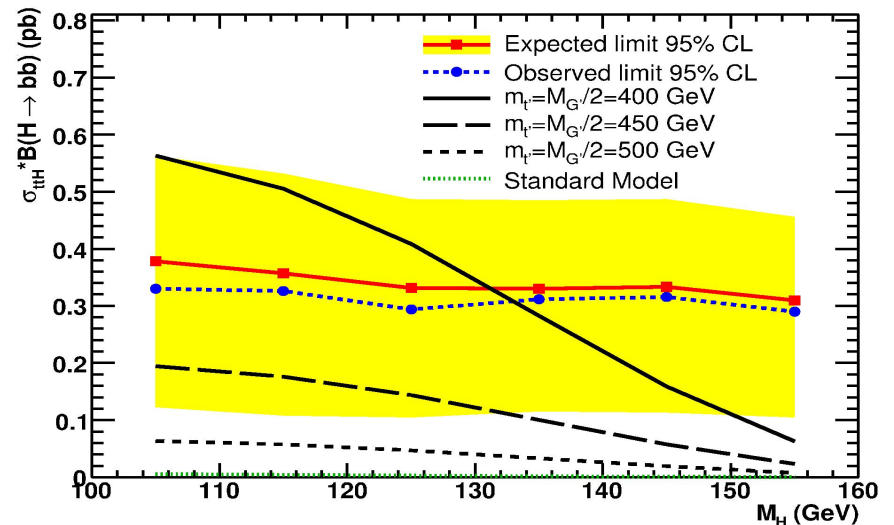 S. Martin
  arXiV:0910.2732
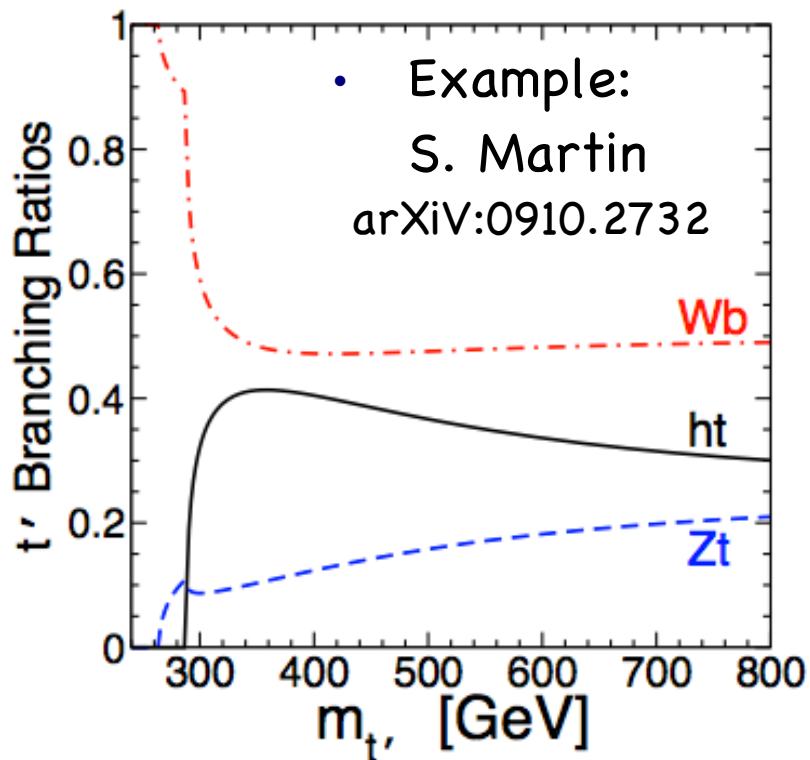
Search for t't

- Lepton + >=4 jets channel

- Search for extra b-jets from Higgs

- Perform simultaneous fit to HT in = 4, >=5 jets and = 1-tag, = 2-tag, >=3 tag regions

Search for single new heavy quarks Q->Wq
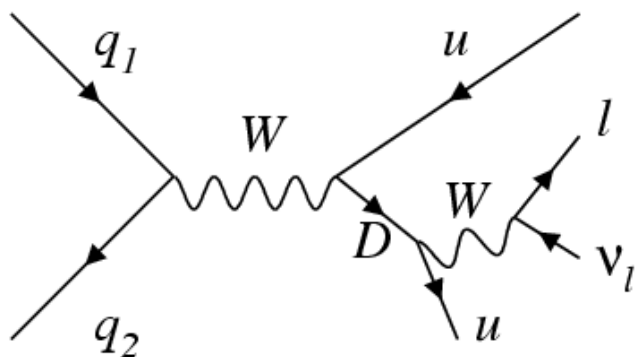
- 4-th generation or 'exotic' quark
- Enhanced production cross section for "Vector-like" quarks – quarks with vector couplings to gauge bosons

- W+2jets topology
- Main Background: W+ Jets
- Select μ (e) with p_T > 20(25) GeV
- = 2 jets , E_T > 60, 20 GeV
- MET > 30 GeV

- Validate SM in control regions
- Fit to reconstructed mass
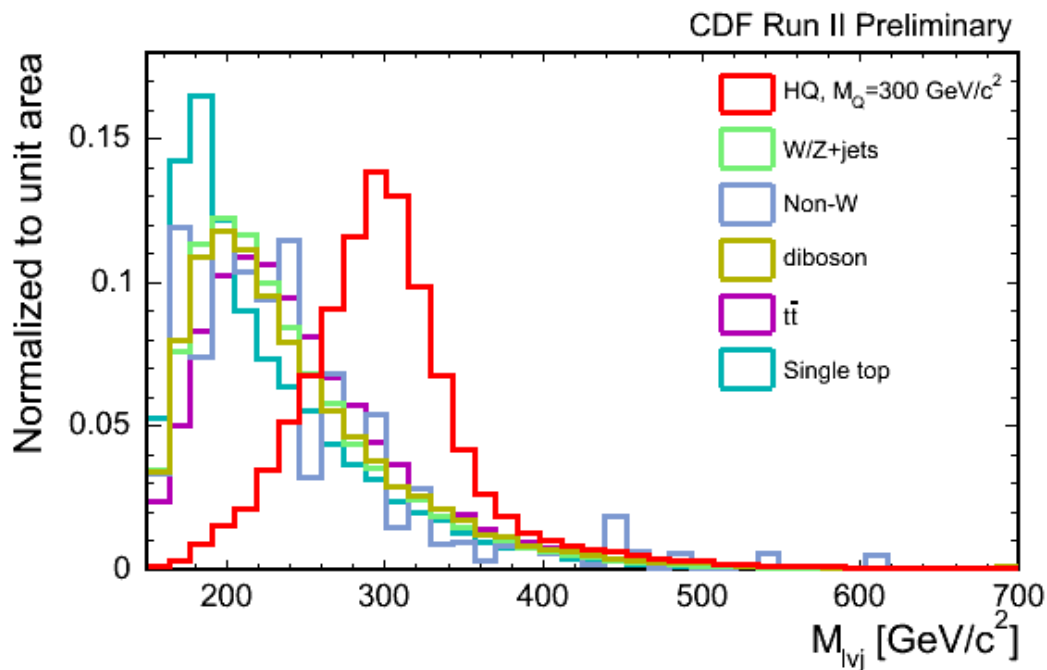
Search for single new heavy quarks Q->Wq

- Validate in control regions, such Leading jet ET [20,60] GeV

- No discrpeancy from SM predictions

Search for single new heavy quarks Q->Wq, Zq

- **W+Jets Channel**

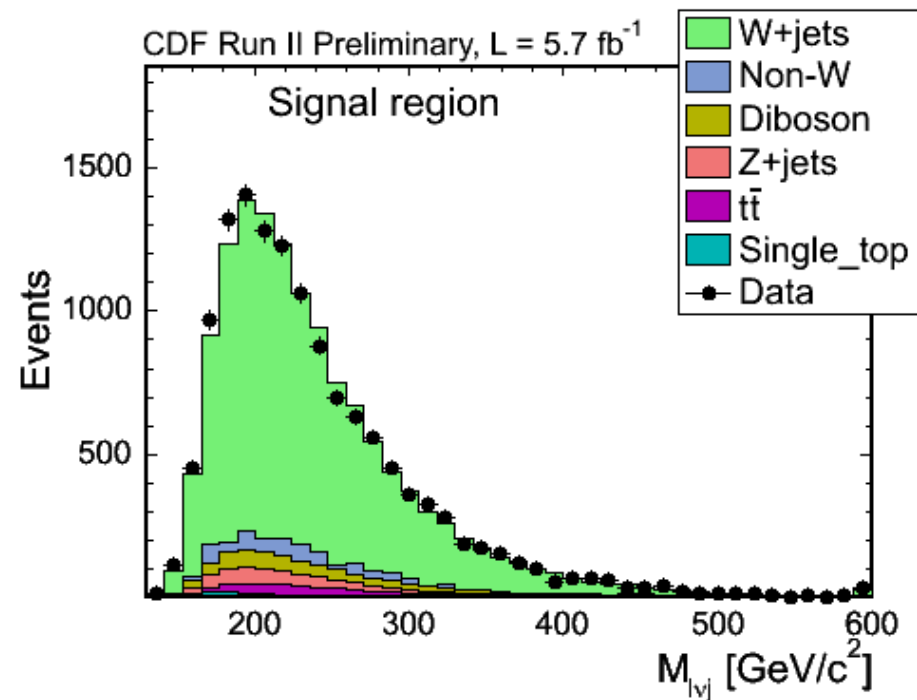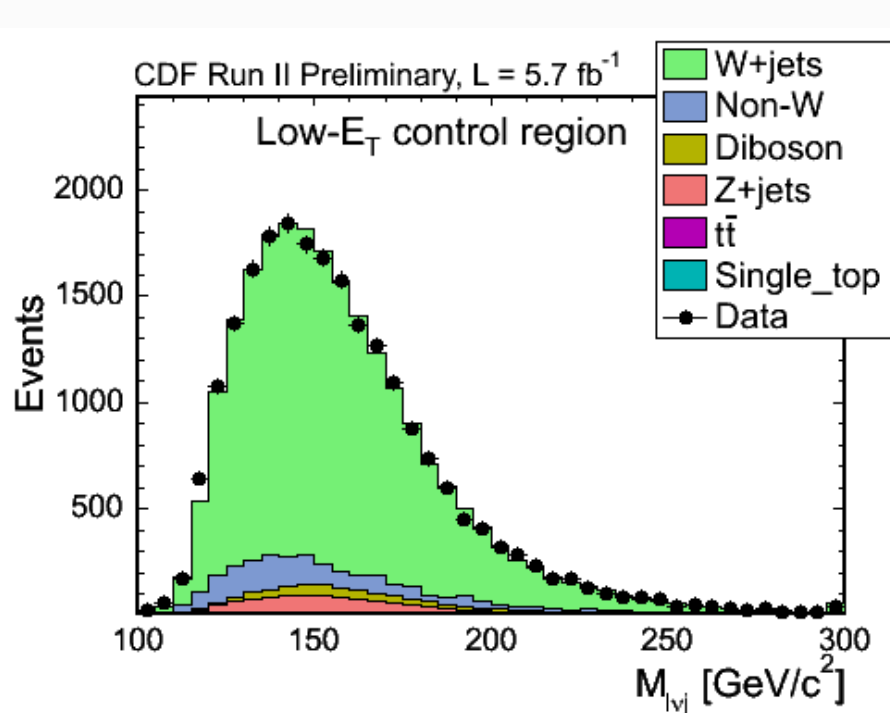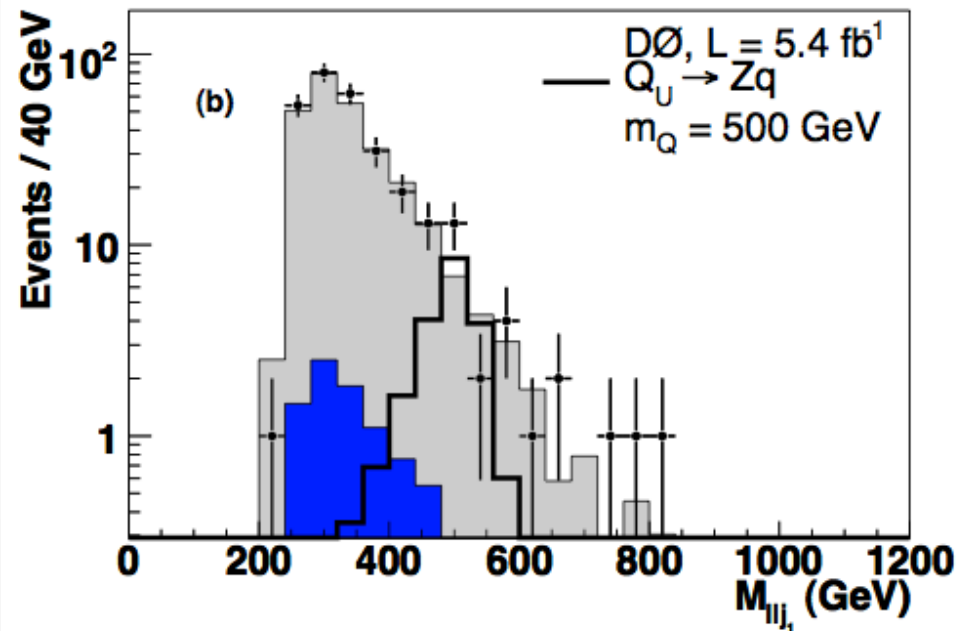- μ OR e with $p_T > 50$ GeV

- = 2 jets , $E_T > 100, 20$ GeV

- MET > 40 GeV

- $2M_T^W$ + MET > 80 GeV

- $M_T^W < 150$ GeV

- $Q_l \times \eta_{j2} > 0$

- **Z+Jets Channel**

- $2\,\mu$ OR $2\,e$ with $p_T > 20$ GeV

- M_{ll} = [70,110] GeV

- MET < 50 GeV

- $P_{T\,(ll)} > 100$ GeV

- Jet Et > 100 GeV
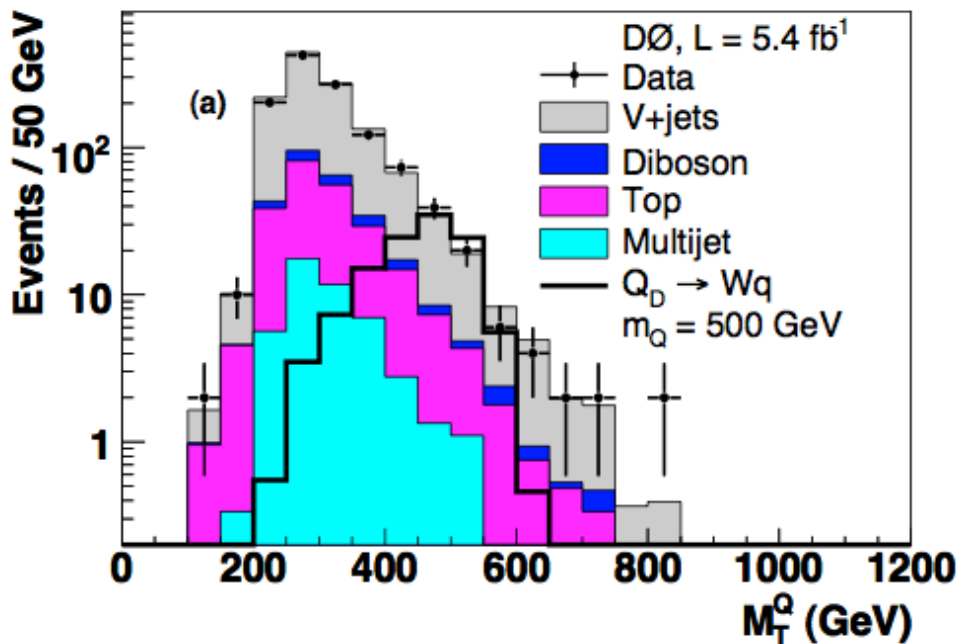
Search for single new heavy quarks Q->Wq, Zq

- W+Jets Channel
- $M_Q > 693$ GeV at 95% C.L.

- Z+Jets Channel
- $M_Q > 551$ GeV at 95% C.L.
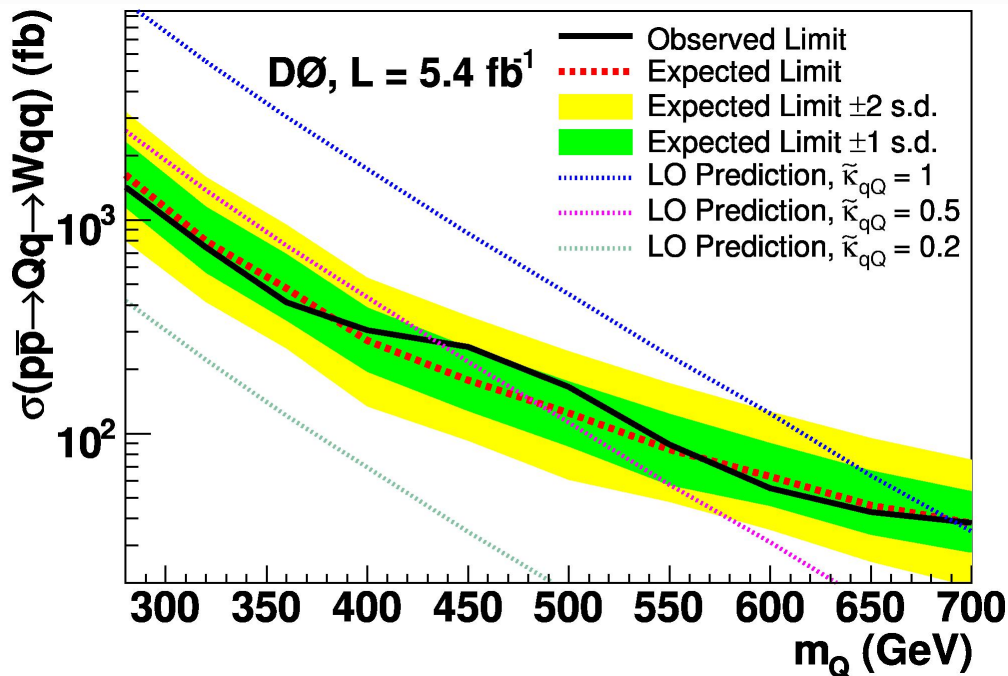
- PRL 106, 081801 (2011)
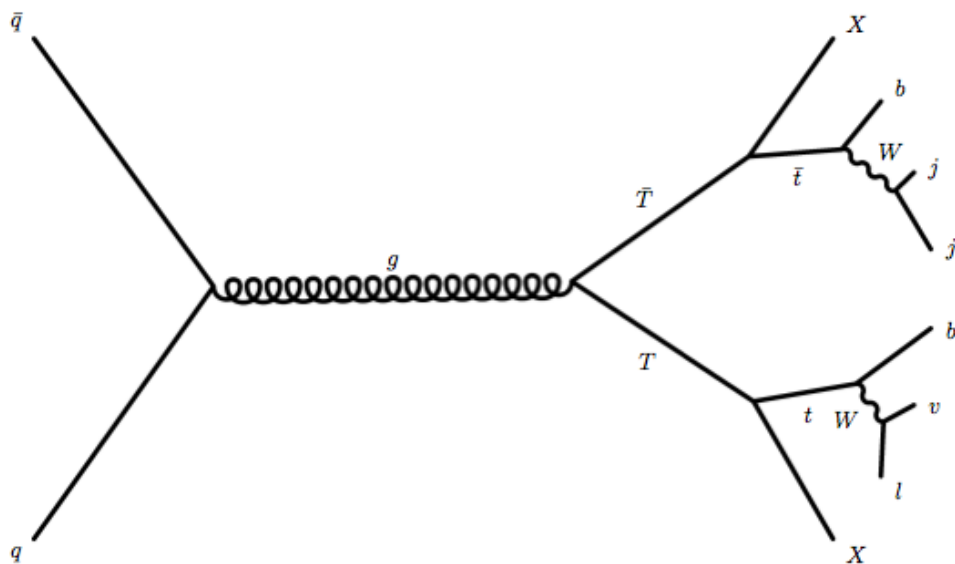
- Exotic 4-th generation quarks t'-> tX, where X is a dark matter candidate
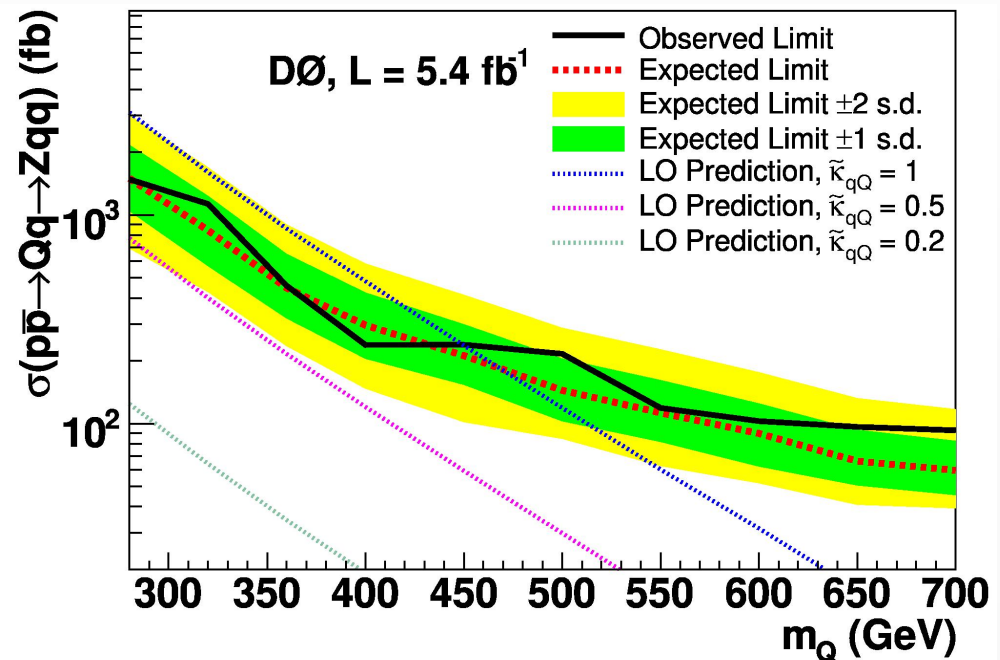- J.Feng et al, arXiv:1002.3366
- Other scenario:
  - stop -> top + neutralino

- Signature tt + MET
- Select e OR μ with p_T > 20 GeV
- >=4 jets , E_T > 20 GeV
- MET > 100-160 GeV

- Dominant backgrounds are tt and W+jets

Search for T'T': T'->tX

Signal Region(njets≥4, $E\!\!\!/_T$>100)
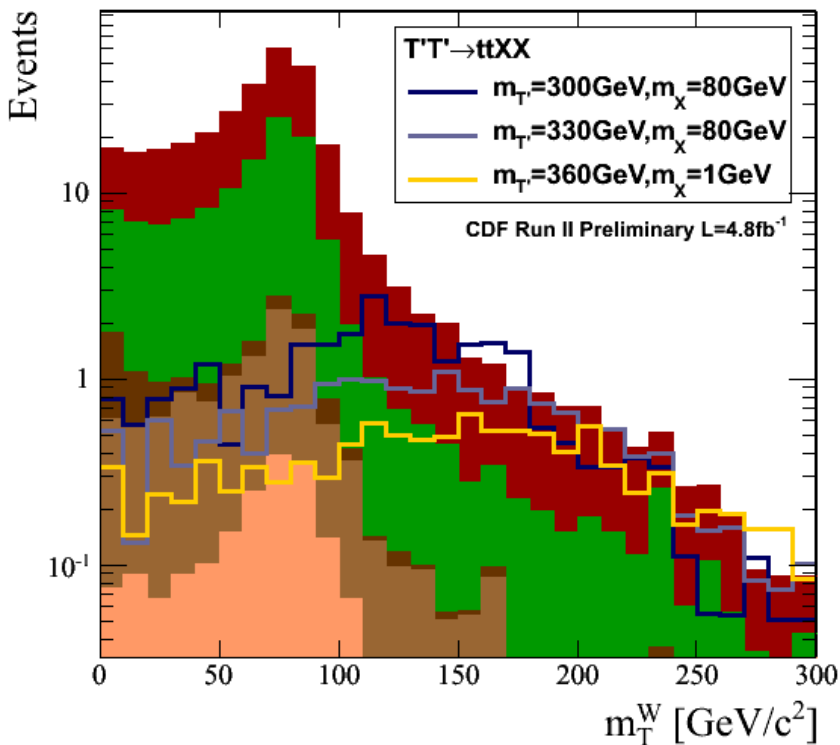
T'T'→ttXX
$m_{T'}$=300GeV, m_X=80GeV
$m_{T'}$=330GeV, m_X=80GeV
$m_{T'}$=360GeV, m_X=1GeV

CDF Run II Preliminary L=4.8fb^{-1}

- $t\bar{t}$
- QCD
- W+jets
- Single top
- Diboson
- Z+jets
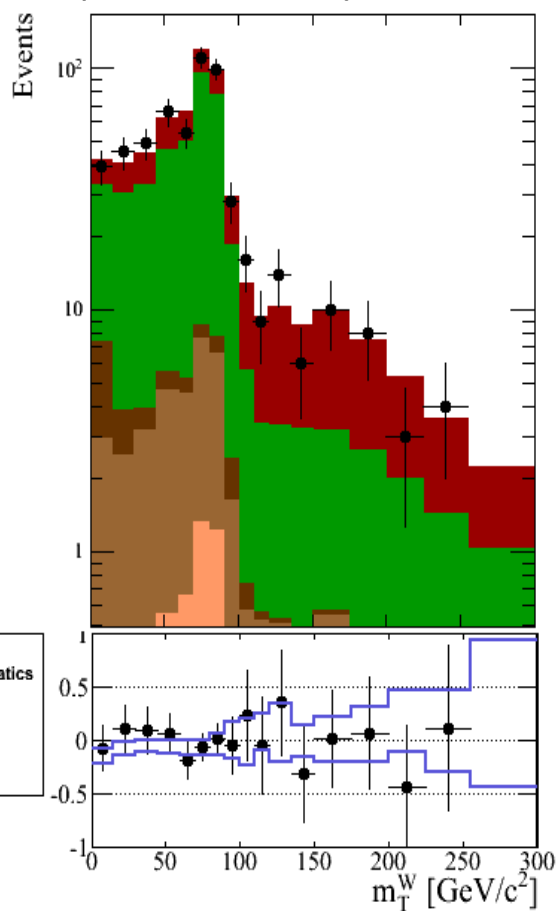
- Analysis: Fit background + signal to W transverse mass distribution
- Optimize MET cut using S/√B for each new physics point in ($m_{T'}$, m_X) plane

- Observe 309 events for
         MET > 100 GeV
- Expect 310 ± 80 from SM

- For MET > 150 GeV
- 42 data events (45± 14 exp.)

Search for T'T': T'->tX

High E_T Control Region(njets==3, E_T>100 GeV/c^2)

Low E_T Control Region(njets>=4, E_T<100 GeV/c^2)

Signal Region(njets>=4, E_T>100 GeV/c^2)

CDF Run II Preliminary L=4.8fb^{-1}

- $t\bar{t}$
- QCD
- W+jets
- Single top
- Diboson
- Z+jets
- Data

Bg Unc from systematics

$\frac{Data-bg}{bg}$
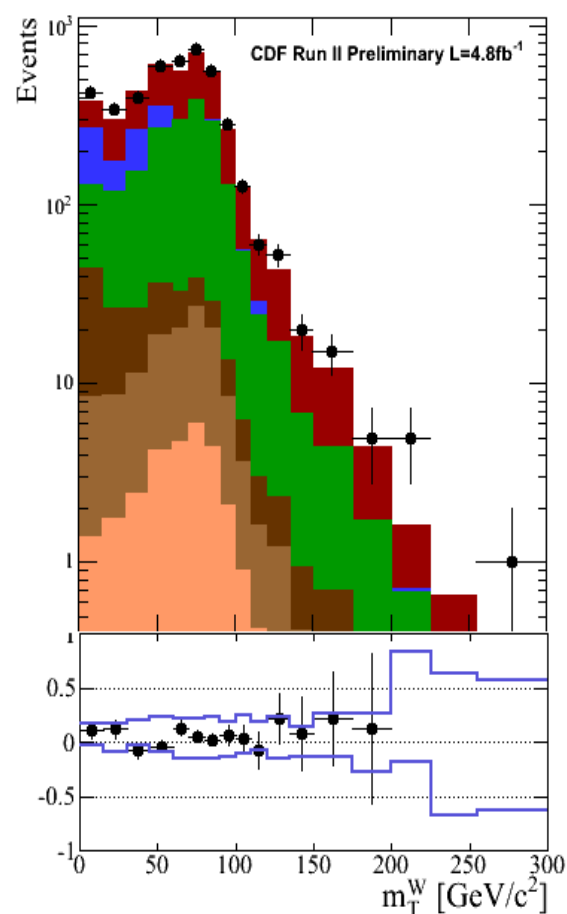
m_T^W [GeV/c^2]
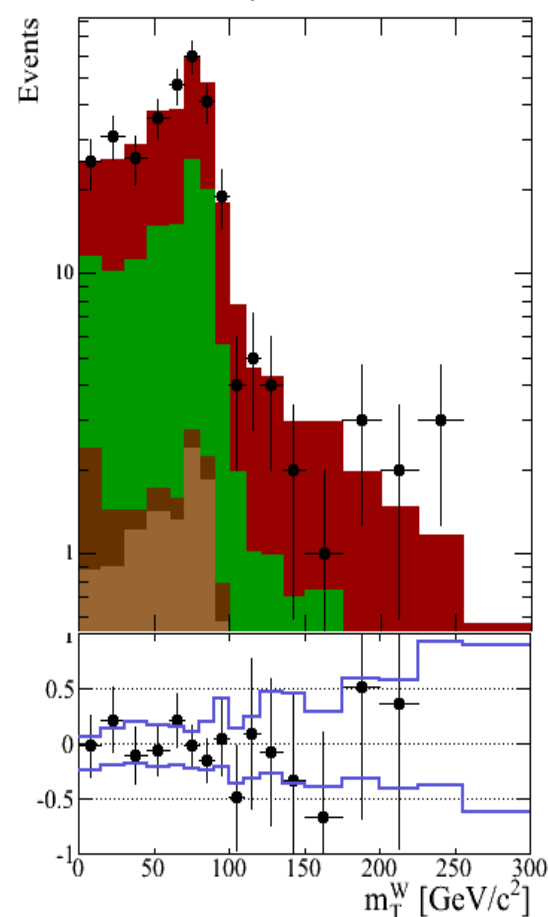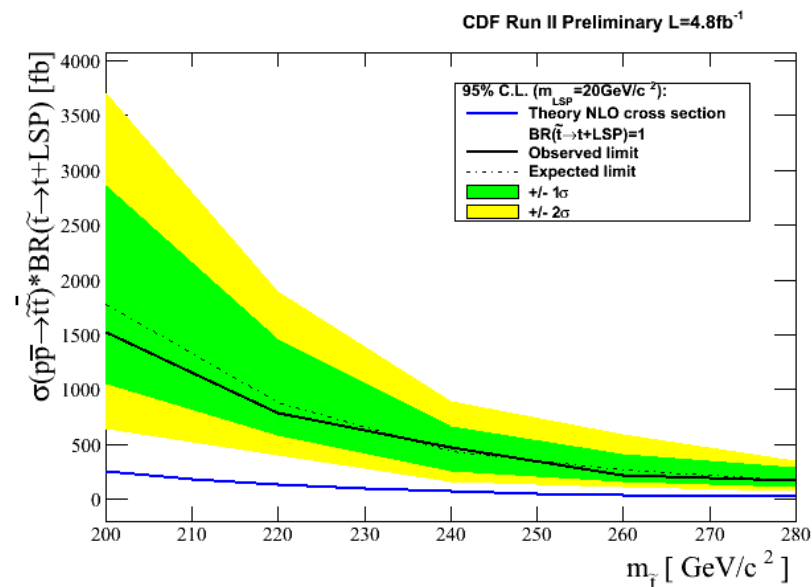
- Test modeling of distributions in control regions (= 3jets, low MET)

Search for T'T': T'->tX
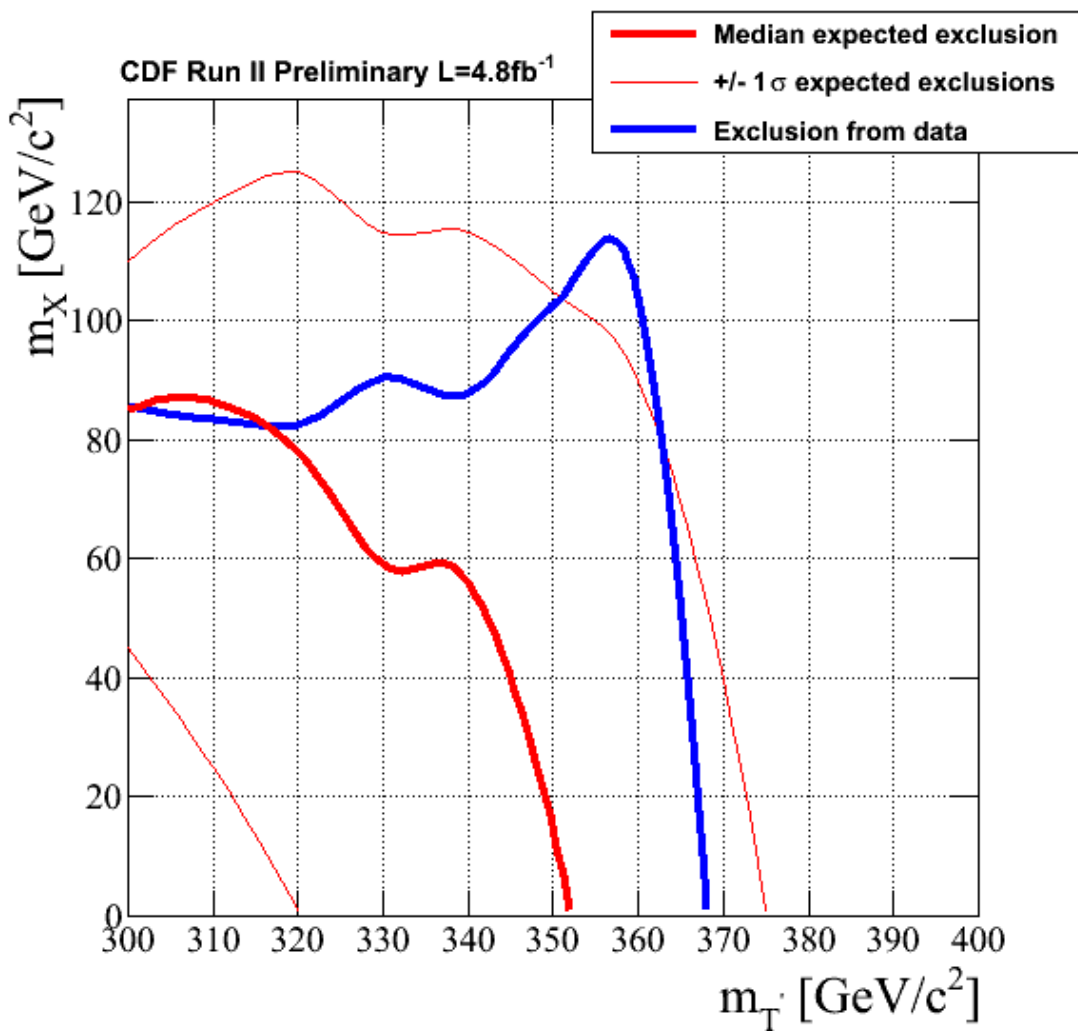
- Scan 2D-plane of $(m_{T'}, m_X)$
- Set a 95% limit using Neuman construction

- No sensitivity to supersymmetric top due to small cross section

Summary

- Tevatron currently sets the best 95% C.L limits on masses 4-th generation quarks
- But this is going to change !
- LHC is expected to collect ~ $1fb^{-1}$ of data and cover the entire allowed phase space
- We either see an evidence or rule out the SM 4-th generation already in 2011

- Stay tuned !
- Future is now !