New Physics In Top at the Tevatron

Andrew Ivanov
Kansas State University
(for the CDF and D0 Collaborations)

Aspen Winter Conference
January 19, 2010
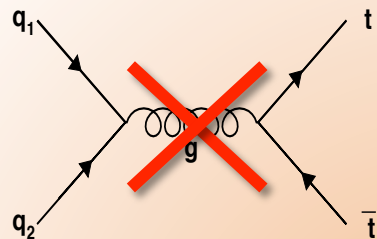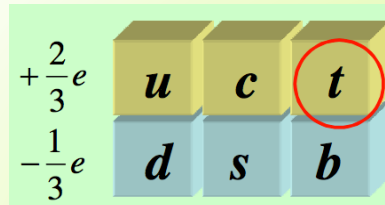
Searches for New Physics in the Top Quark Sector

New Production Mechanism

q_1 t

g

q_2 $\bar{t}$

Z', KK,.. ?
Resonant Production
Forward-Backward Assymetry

Intrinsic Properties of Top Quark

$+\frac{2}{3}e$ u c t

$-\frac{1}{3}e$ d s b

Charge, Mass, Width, Lifetime ...

Non-SM Top Decays

W^+ l, q

$\nu, \bar{q}'$

t

$m_{top} > m_W + m_b$ b
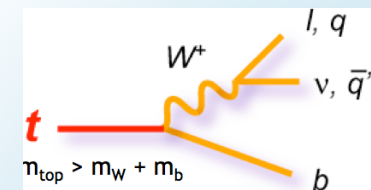
$t \rightarrow H^+ b$ - ?

$H^+ \rightarrow cs, \tau\nu, WA$

New Physics Admixture in a Sample of Top Quarks

t t t
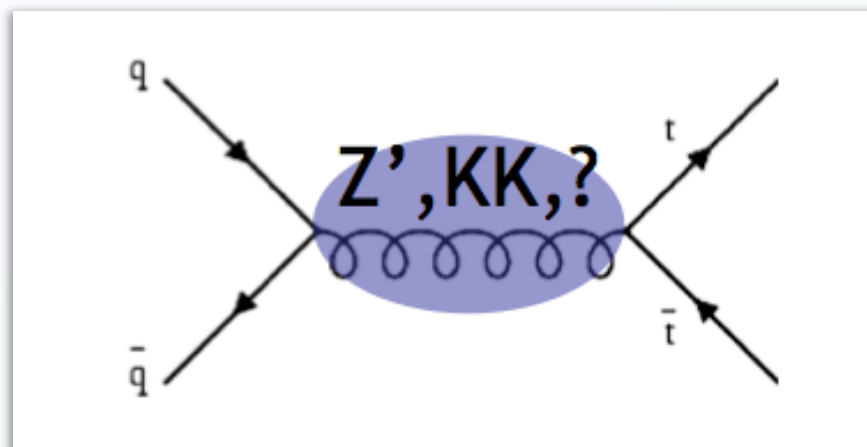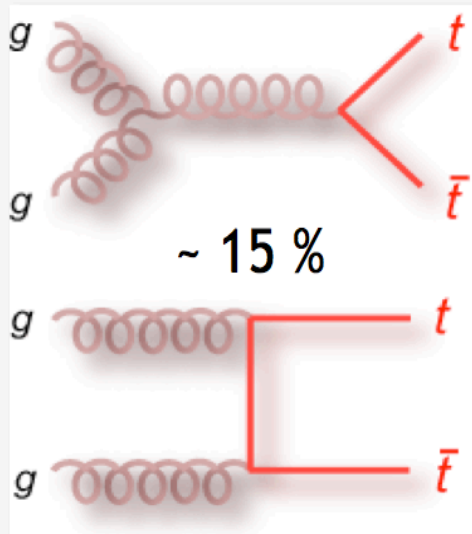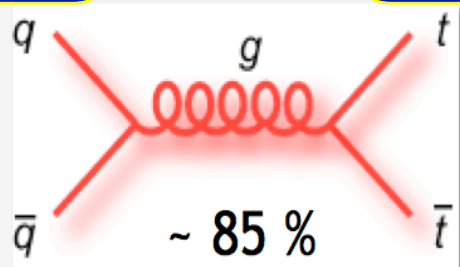t $\tilde{t}$ t
t t t
t t

T, t', stop, ...
SUSY with (di-)lepton + jets + met signatures

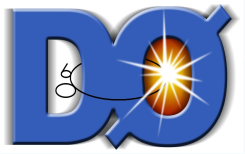``The pure and simple truth is rarely pure and never simple''
– Oscar Wilde

New Production Mechanism

Standard Model

~ 85 %

~ 15 %

Z',KK,?

- Resonant ttbar production is expected from the decays of massive Z-like bosons

- Topcolor
  Hill, Parke PRD 49, 4454 (1994)

- KK gluon excitation in RS model
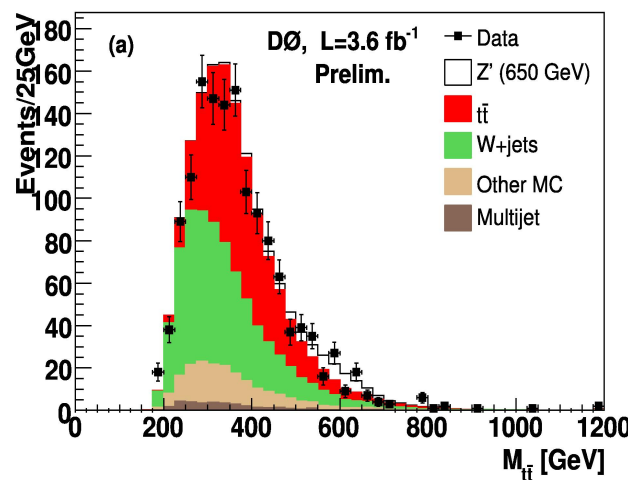 **Lillie, Randal, Wang JHEP 0709,074 (2007)**

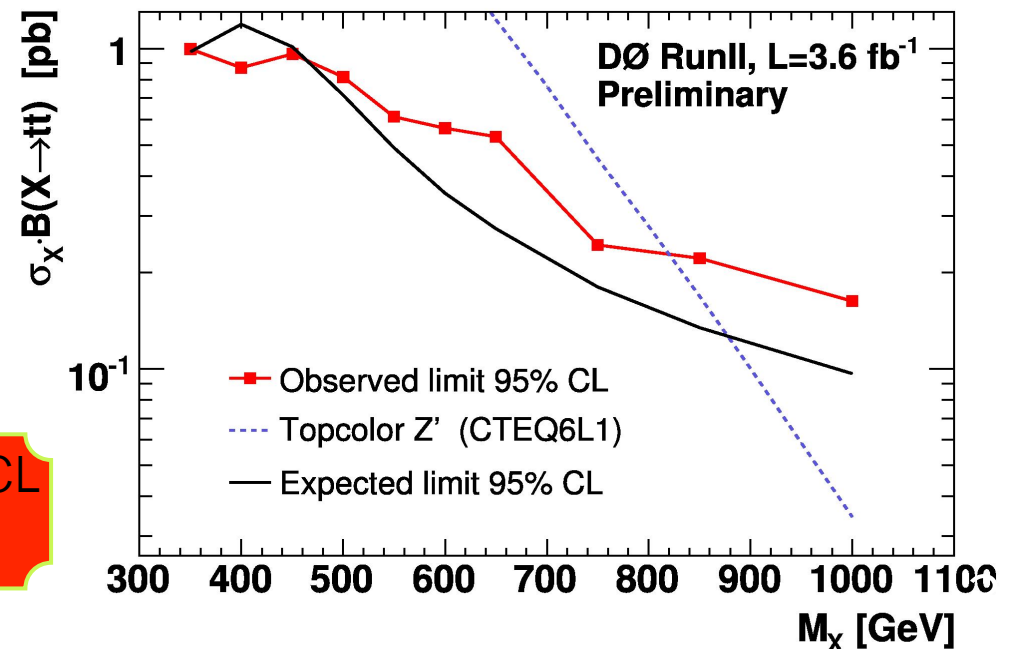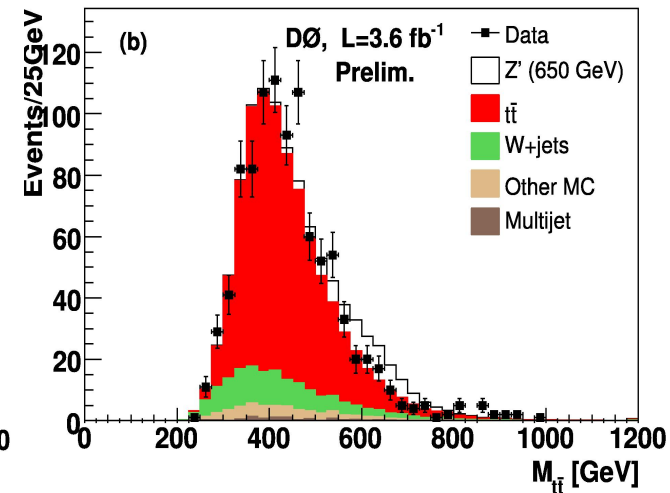# Search in lepton+jets events

- Event Selection:
  - Lepton (e or μ) pT > 25 GeV, |η| < 1.1(2.0)
  - 3 or more jets with Et > 20 GeV , |η| < 2.5
  - Leading jet Et > 40 GeV
  - At least one b-tagged (NN) jet
  - Missing Et > 20 (25 GeV) and not collinear to lepton direction
  - Solve for p_z of the neutrino and construct tt invariant mass from four-momenta

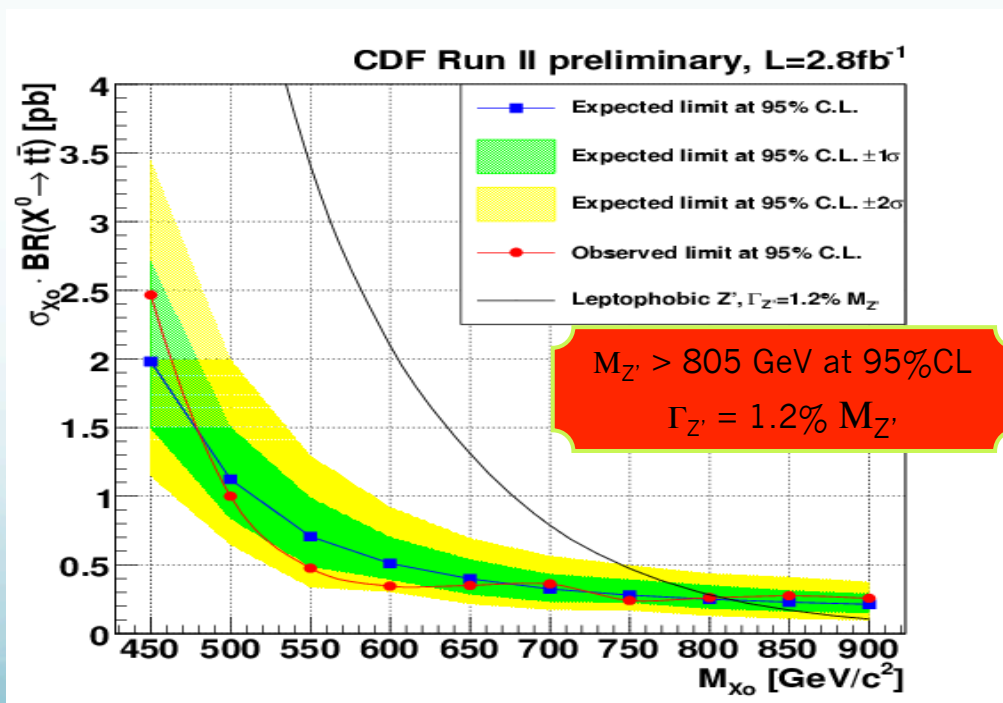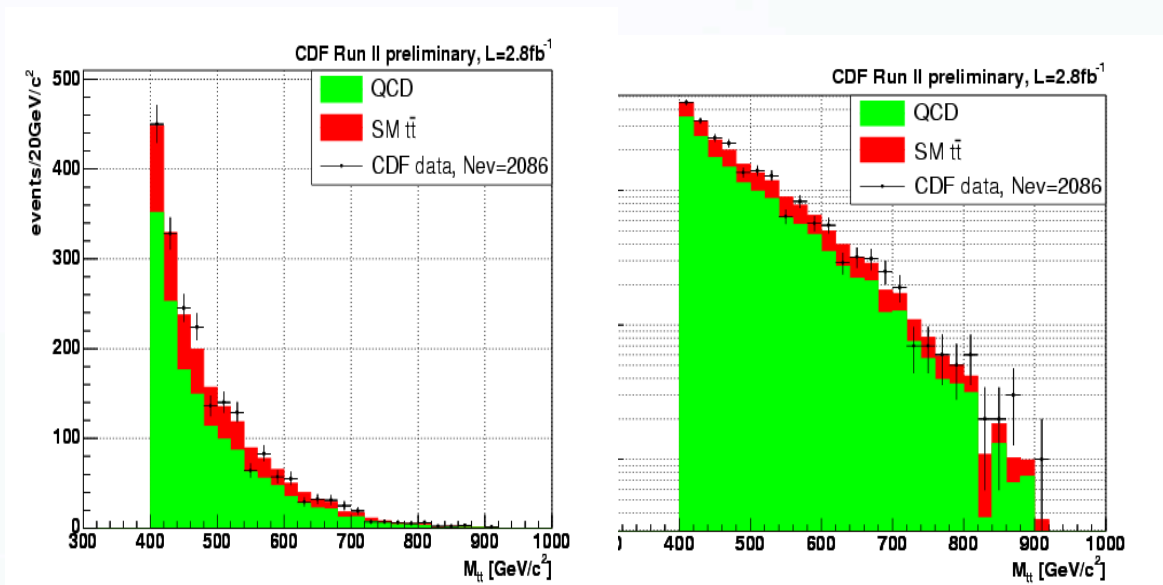$M_{Z'} > 820$ GeV at 95%CL

$\Gamma_{Z'} = 1.2\%\ M_{Z'}$

= 3 jets

>= 4 jets

Search in all-hadronic mode

- ## Multi-jet trigger

- ## Event Selection:
  - ### 6 or 7 jets with Et > 15 GeV , $|\eta| < 2.0$

  - ### Build the tag rate matrix using the QCD enriched data sample and apply it to pre-tag events

  - ### Employ the ANN machinery to improve S/B ratio
  - ### Reconstruct tt mass using matrix element approach

$M_{Z'} > 805$ GeV at 95%CL

$\Gamma_{Z'} = 1.2\%\ M_{Z'}$

Andrew Ivanov ,KSU

01/19/10

Forward-Backward Assymetry

- The SM prediction:
  - Symmetric at LO

- At NLO in ttbar rest frame

- Asymmetry is due to interference of ME amplitudes for the same final state

- Afb = 0.05 +/- 0.015
  - **Kuhn, Pordrigo PRL 81,89 (1998)**

- Several BSM production mechanims predict an observable asymmetry (Z', Axigluons)
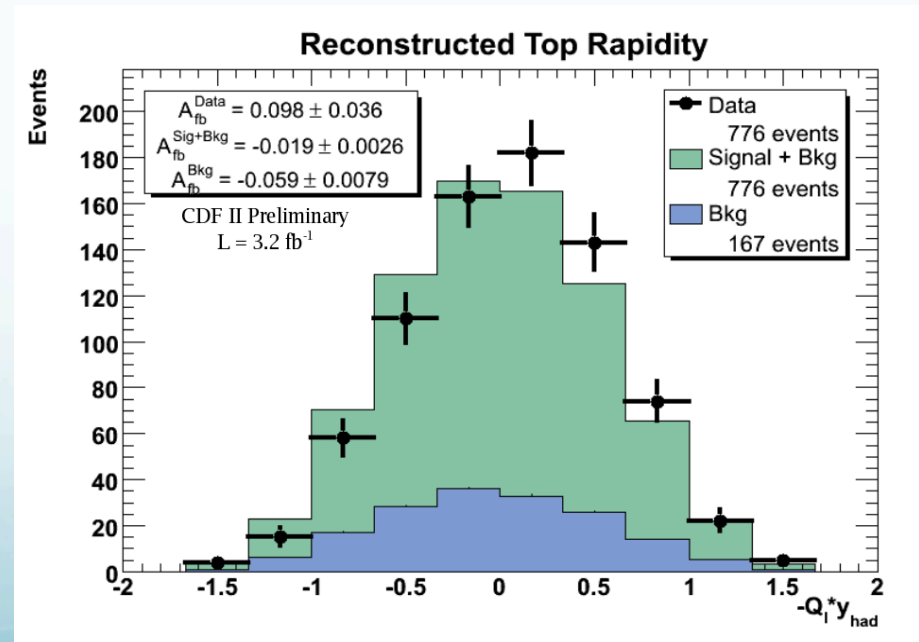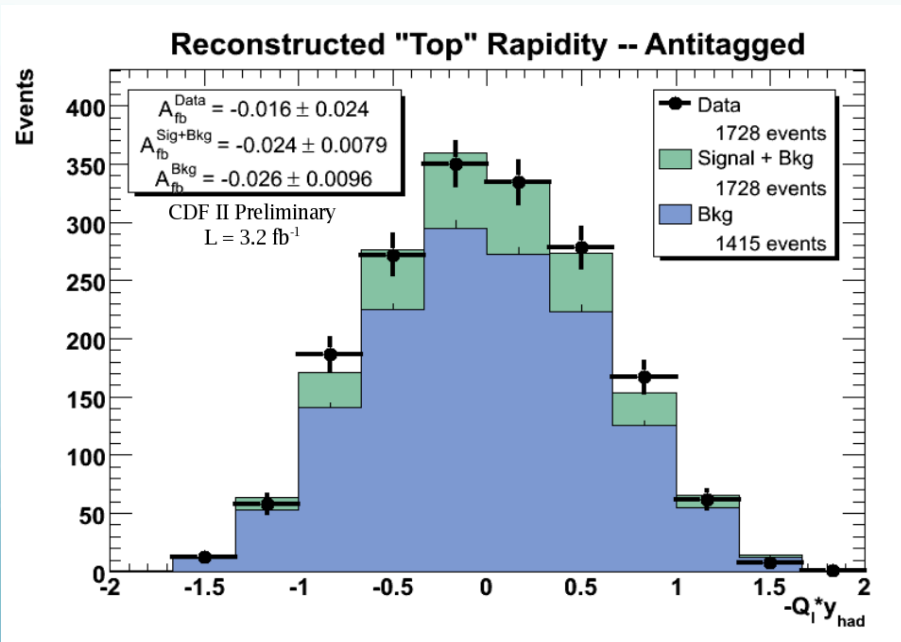
- Especially interesting for wide resonances
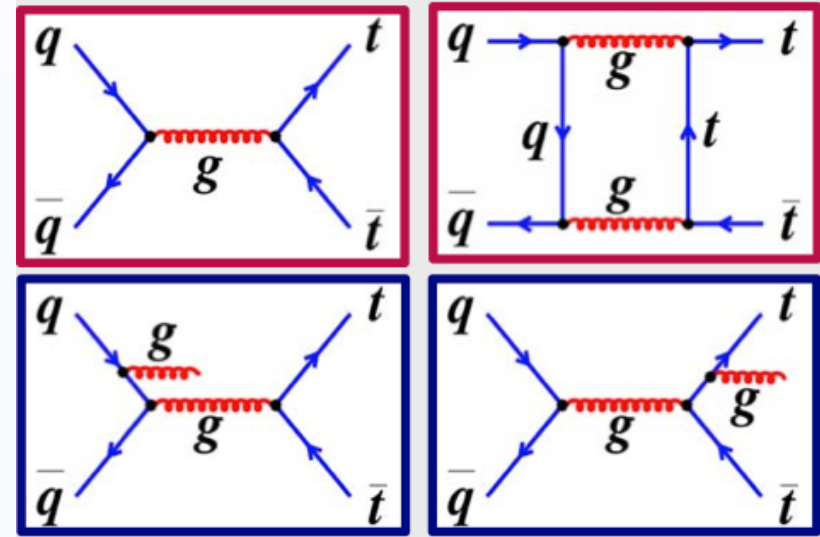
$$A_{fb} = \frac{N_t(p) - N_t(\bar{p})}{N_t(p) + N_t(\bar{p})}$$

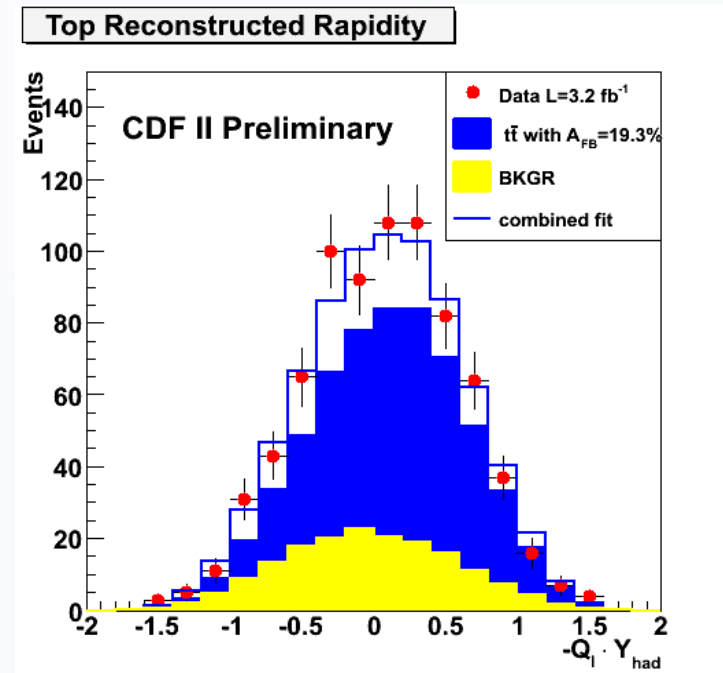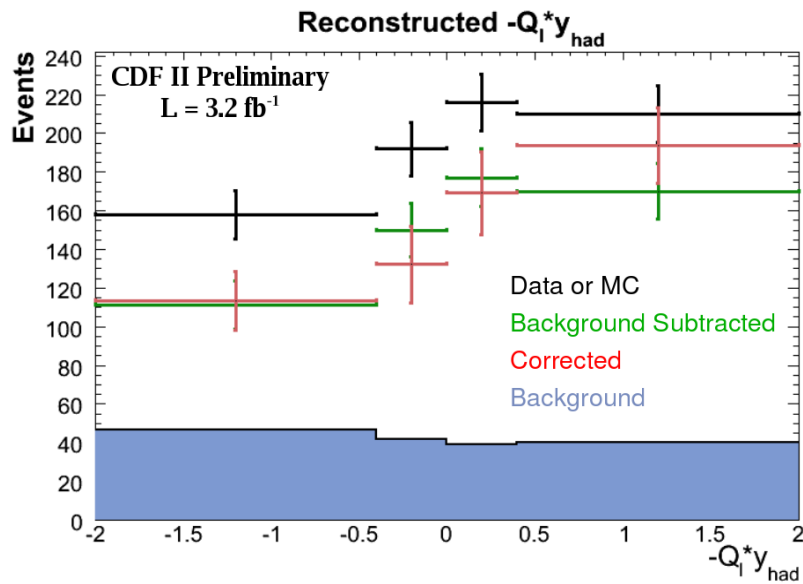# Forward-Backward Asymmetry

$$A_{fb} = \frac{N_t(p) - N_t(\bar{p})}{N_t(p) + N_t(\bar{p})}$$

- Use lepton+jets channel

- Lepton charge provides an information about top/anti-top

- Kinematic event reconstruction similar to top mass analyses

- Use the system of jets from hadronically decaying top quark

Andrew Ivanov ,KSU

01/19/10

Forward-Backward Asymmetry

Reconstructed -Q_l*y_{had}

CDF II Preliminary
L = 3.2 fb^{-1}

Data or MC
Background Subtracted
Corrected
Background

Top Reconstructed Rapidity

CDF II Preliminary

- Data L=3.2 fb^{-1}
- $t\bar{t}$ with A_{FB}=19.3%
- BKGR
- combined fit

- Employ an unfolding procedure to go from reconstructed to parton level:

  - 1. Subtract the background
  - 2. Unfold for bin-to-bin migration effects due to detector resolution and event selection effects

$$A_{fb} = 19.3\% +/- 6.5\% \text{ (stat)} +/- 2.4\% \text{ (syst)}$$

- Systematic uncertainty includes various assumptions about the shape of –Q_l·Y_{had} distribution

Top Charge

$$+\frac{2}{3}e \quad u \quad c \quad t$$
$$-\frac{1}{3}e \quad d \quad s \quad b$$
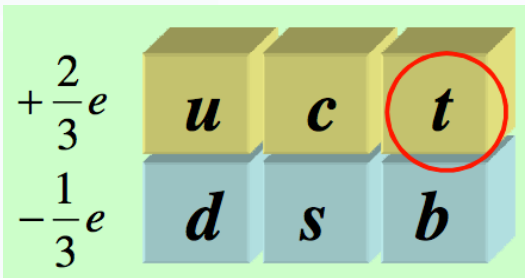
- t-> bW⁻ is conceivable due to ambiguity in assigning b-jets to W

- That corresponds to an exotic (XM) quark of charge – 4/3

- While the SM top quark could have even higher mass

- Motivated by the improvement in EWK fit due to modified b-couplings

 - **Chang et al, PRD 59, 091503 (1999)**
  - **Ma et al, hep-ph/9909537**

Top Charge Measurement

- Event Selection:
  lepton+ >= 4 jets

- >= 1 SECVTX b-jet

- and >= 1 SLT b-jet

- Charge Reconstruction:

  - Identifying leptonic and hadronic b (kinematic fitter based on invariant mass constraints)

  - Determining flavor (b or anti-b)
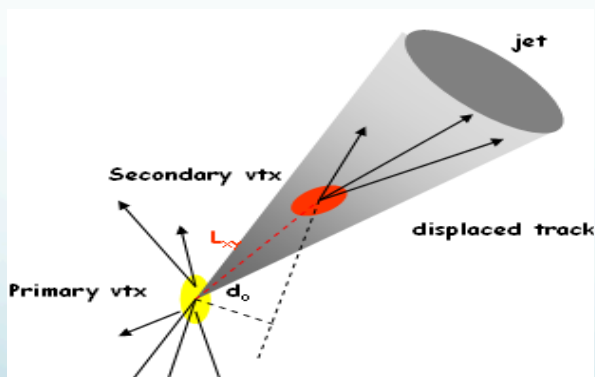
SECondary VerTeX tagger (SECVTX)
B-Jet Tag Efficiency   50%
MiTag Rate (QCD jets)   2.5%

- $b \rightarrow \ell\nu c$ (BR $\sim 20\%$)
- $b \rightarrow c \rightarrow \ell\nu s$ (BR $\sim 20\%$)
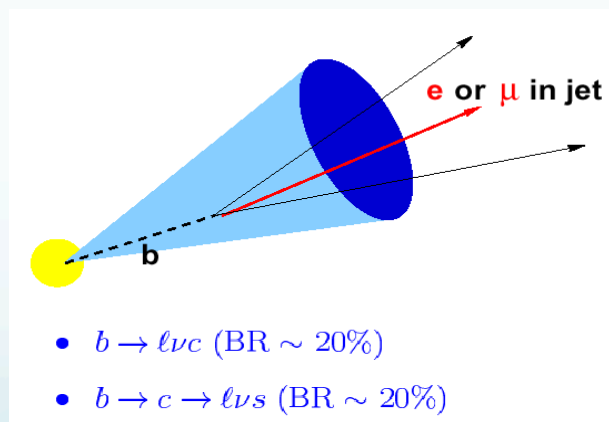
SLT (Soft Lepton Tagger)
B-Jet Tag Efficiency   40% (e) , 73% (m)
MisTag Rate   0.3 %(e), 0.4 % (m)

Top Charge Measurement

- Asymmetry measurement

$$A_t = \frac{1}{D} \frac{N_{SM} - N_{XM} - Bkg \times D_{Bkg}}{N_{SM} + N_{XM} - Bkg} \qquad (3)$$

- Figure of merit is εD^2,

- Where ε (~ 2%) is the reconstruction efficiency

- D= 2P-1 is the dilution, P(~ 60%) is a purity

- N_{SM} = 29

- N_{XM} = 16

- D is calibrated in data di-jet events

New

CDF Run II Preliminary (2.7 fb^{-1})

— XM p-value
---- XM (Stat. Only)

— SM p-value
---- SM (Stat. Only)

Measured

p(XM)obs = 0.0094
p(SM)exp = 0.028

p(SM)obs = 0.69
p(SM)exp = 0.5

Normalized Asymmetry

α versus β

Measured   Expected

β (Type II Error Rate)

Exclude a charge of +4/3 at 95%C.L.

(c)

CDF Run II, 2.7 fb^{-1}

α (Type I Error Rate)

Non-SM Top Decays
Search for Charged Higgs

- Analyze event yields in several channels simultaneously
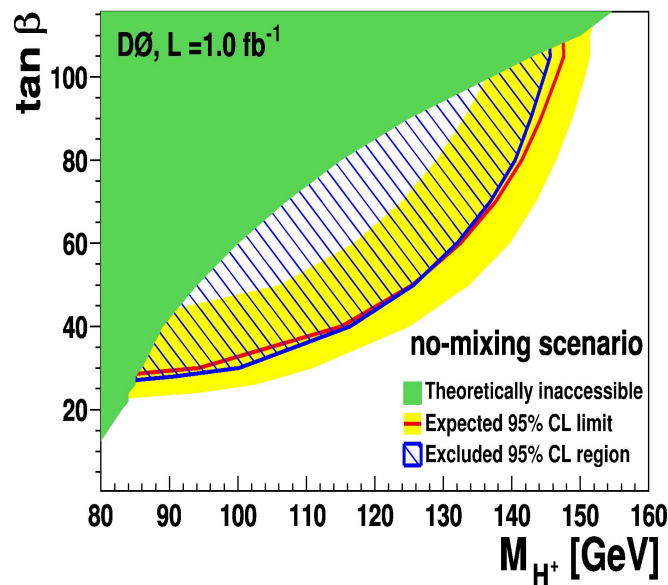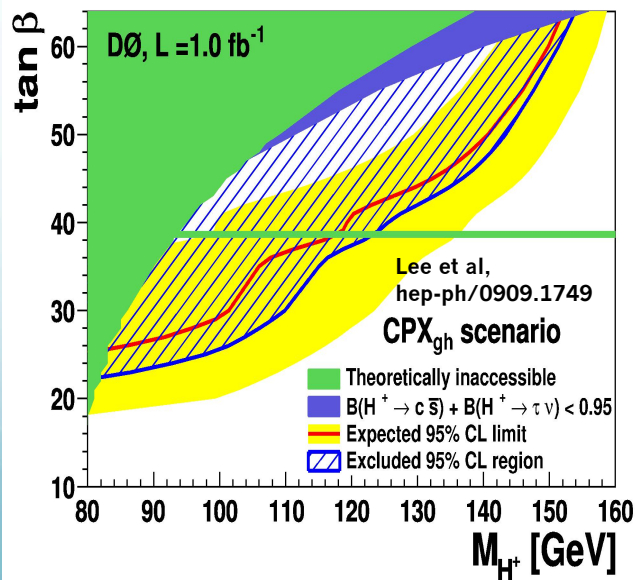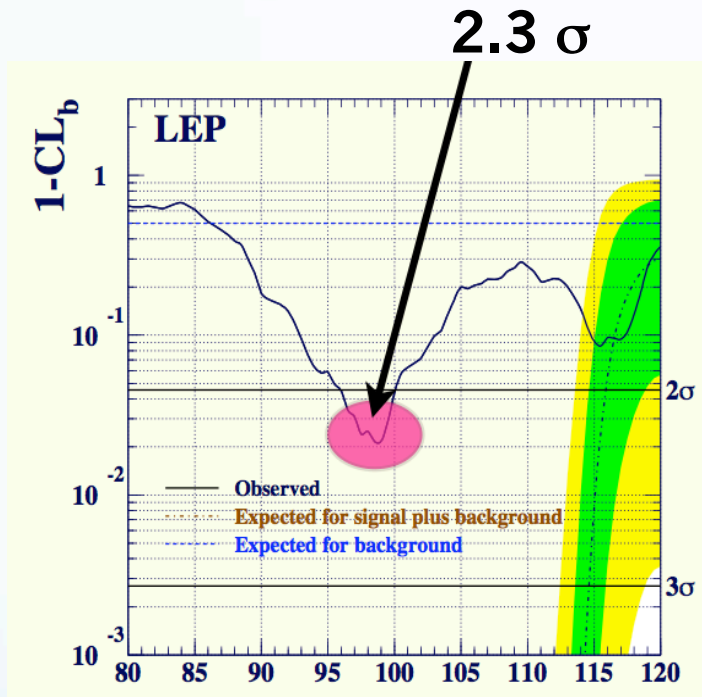
- Data prefers no H+ Contribution

Andrew Ivanov ,KSU

01/19/10

PLB 682, 278 (2009)

Andrew Ivanov ,KSU

01/19/10
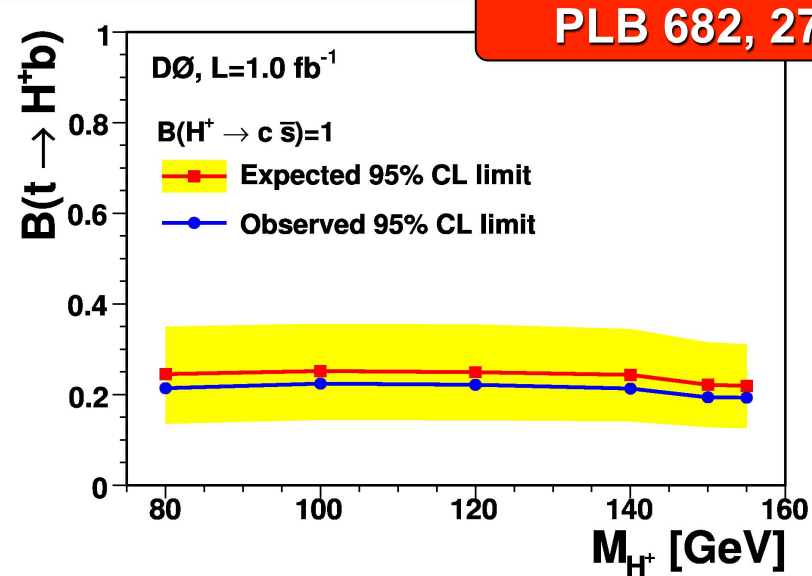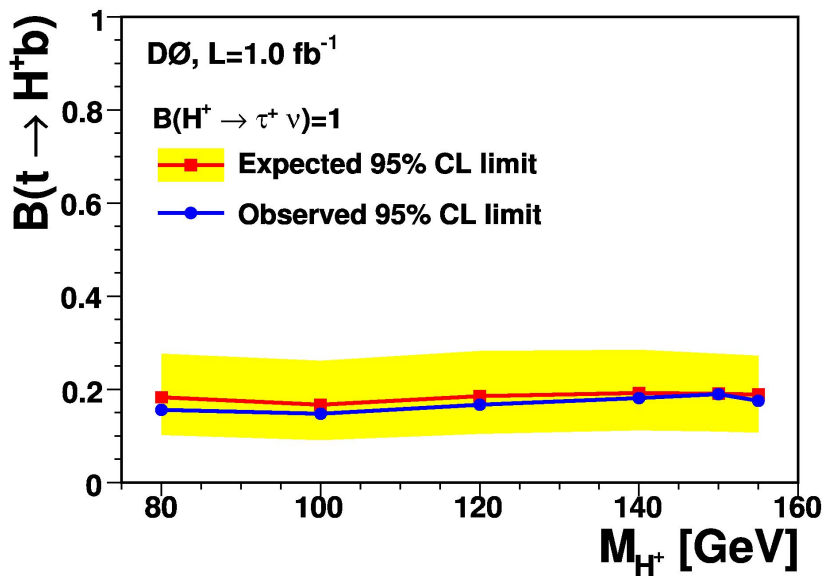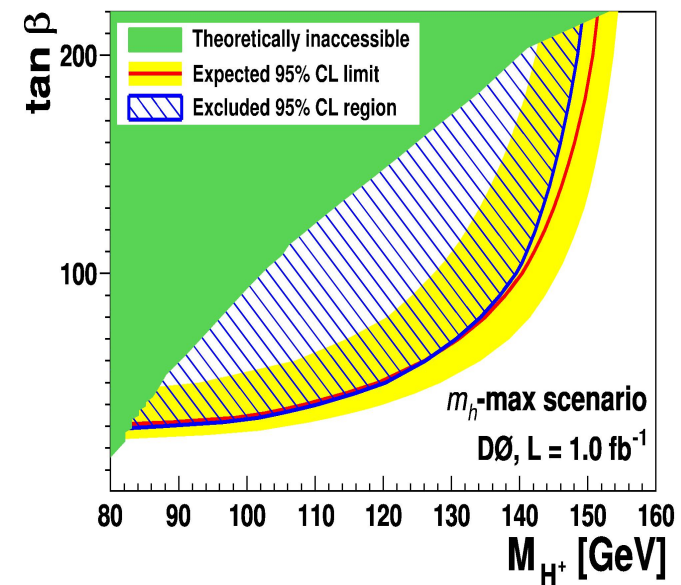
Non-SM Top Decays (nMSSM Higgs)

2.3 σ

- Light Higgs (A with mass $m_A < 2m_b$) is motivated by inconsistencies in Higgs mass fit

- H-> AA with A -> $\tau\tau$ could sufficiently change Br(H->bb) to avoid SM LEP limits

Dermisek & Gunion, PRL 95, 041801 (2005), PRD 73, 111701 (2006)

- 2.8σ excess in Br($W^{\pm}$ -> $\tau\,\nu$) at LEP using WW events

- Can be re-conciled with $H^{\pm}$ -> $\tau\,\nu$
  - **Dermisek, arXiv:hep-ph/0807.2135**

- At tree level $m_H = \sqrt{m_W^2 + m_A^2}$

- Light A requires $m_H \approx m_W$ and opens decay $H^{\pm}$ -> W*A

- For low tanβ Br (t -> $H^{\pm}$b) could be as high as 40%
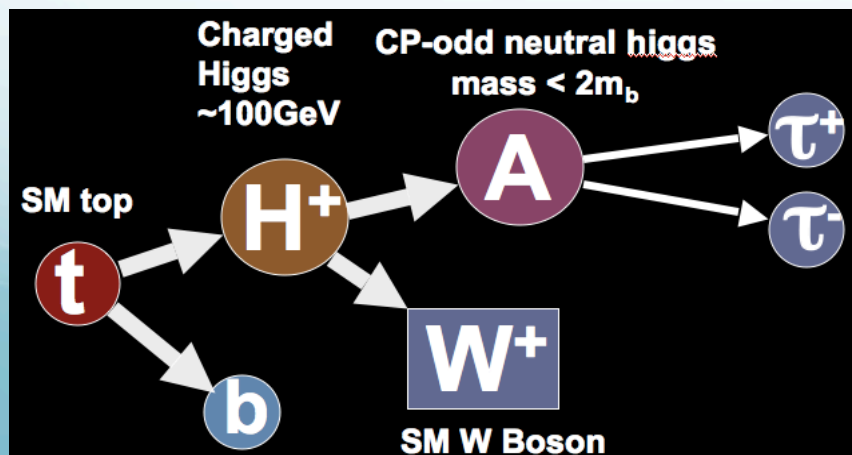
Search for nMSSM Higgs in Top Decays
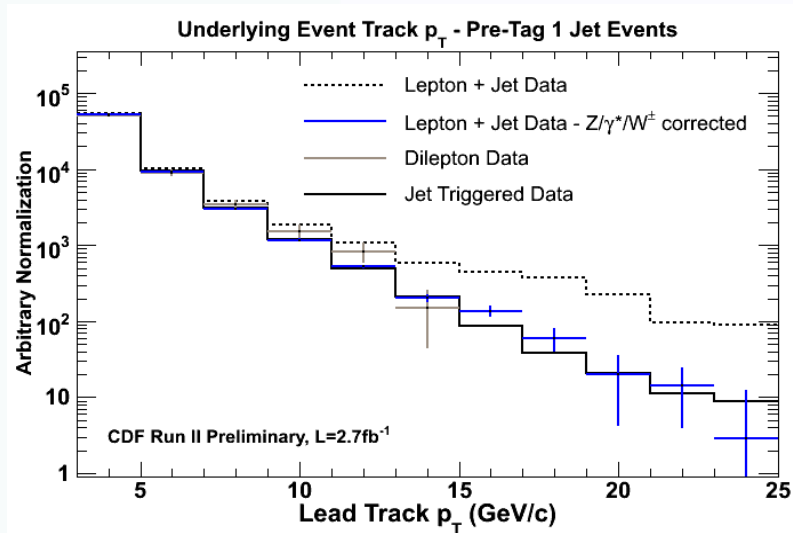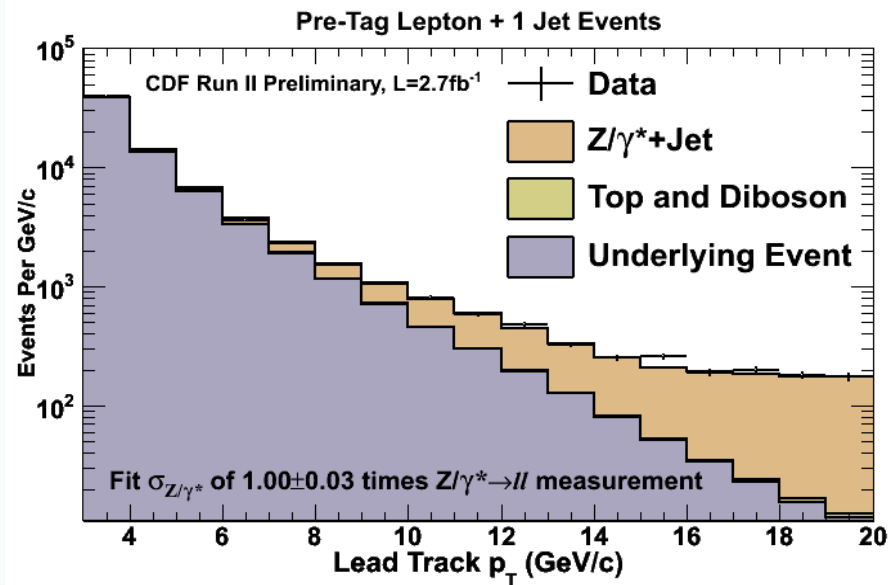

- Standard lepton+jets selection

- Plus at least one isolated soft track with pT in [3,20] GeV
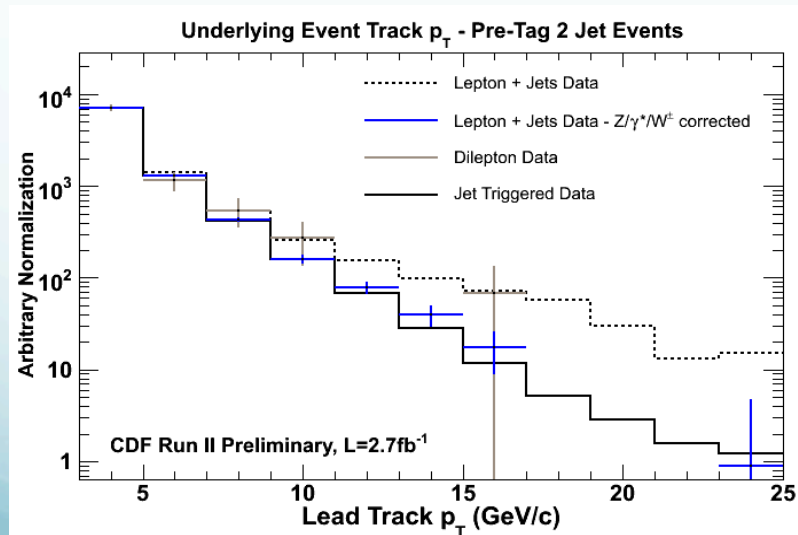
- In SM additional tracks come mostly from soft parton interactions - Underlying Event

- Employ invariance of track Pt spectrum
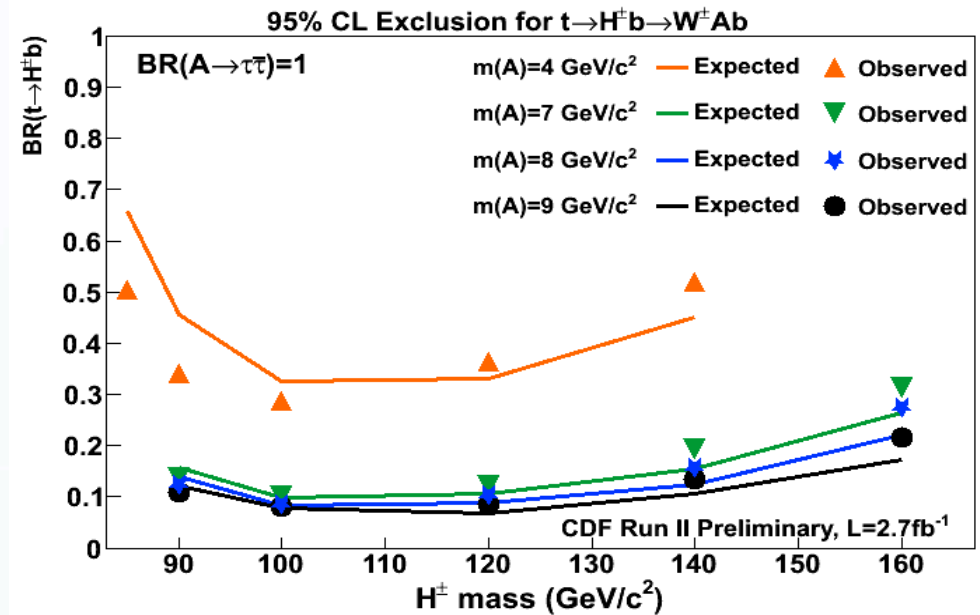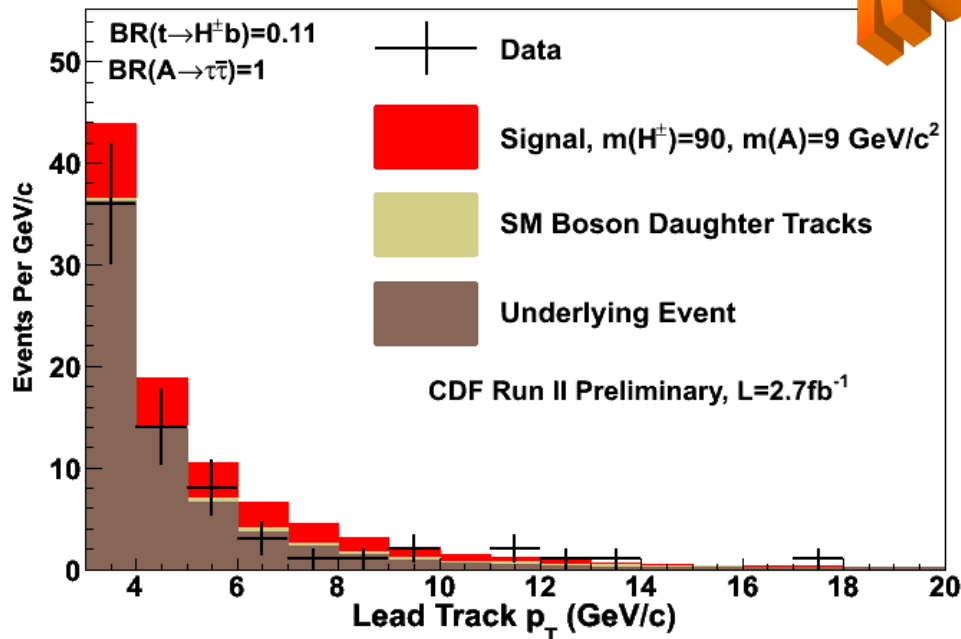
Search for nMSSM Higgs in Top Decays
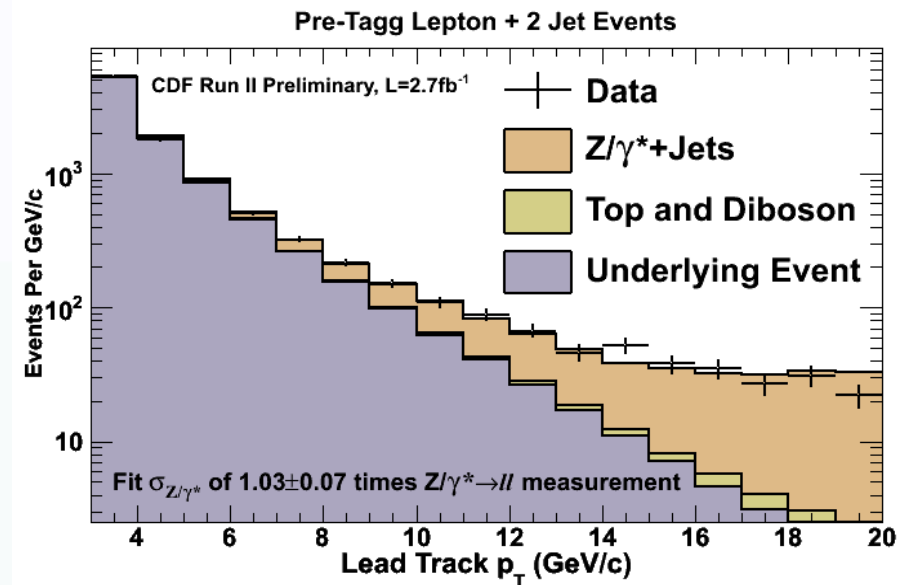
- The performance is validated in various control regions

- The UE contribution is floating freely in the fit

- Validate by measuring consistent Z/gamma cross section

Search for nMSSM Higgs in Top Decays

- Signal Region

- Lepton +>=3 jets

- >=1 b-jet

- No evidence for nMSSM Higgs in top decays
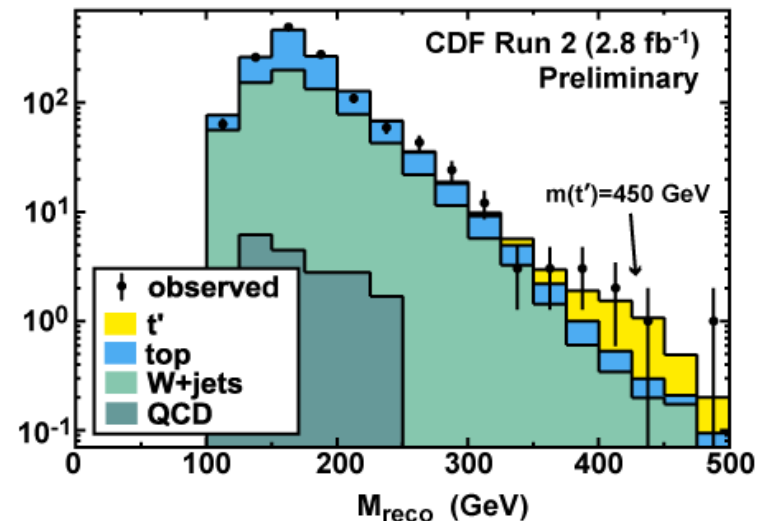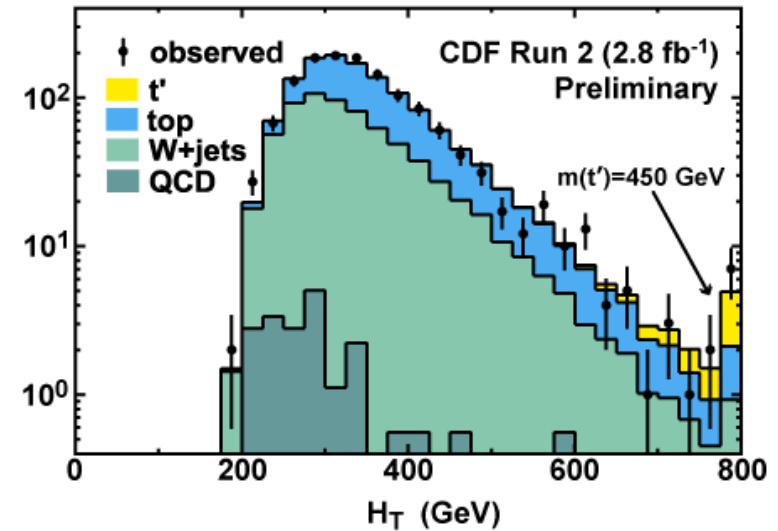
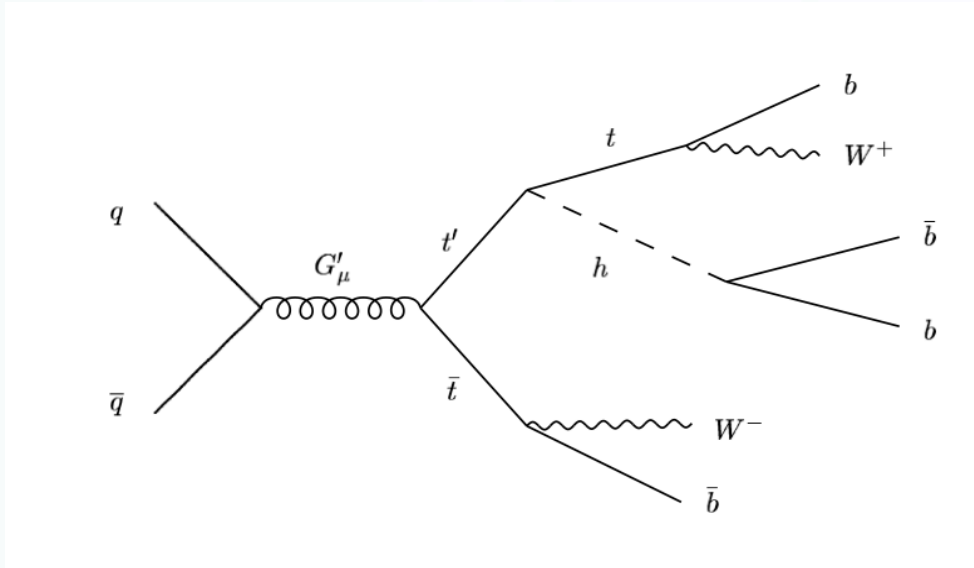- First limits on BR(t->H$^+$b) in this decay channel

Search for t-prime

- Signal Region:

- Lepton +>=4 jets

- Use H_T – scalar sum of all transverse momenta

- Perform mass reconstruction similar to top mass

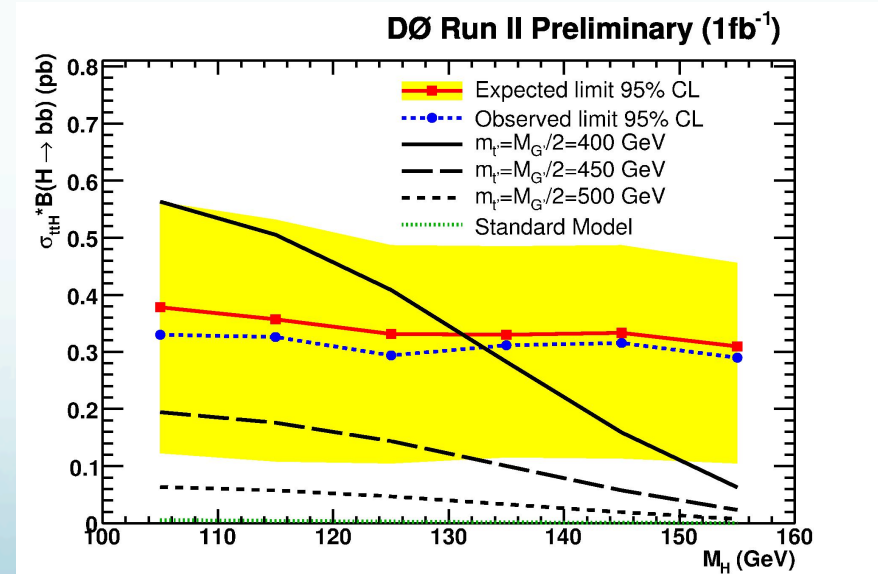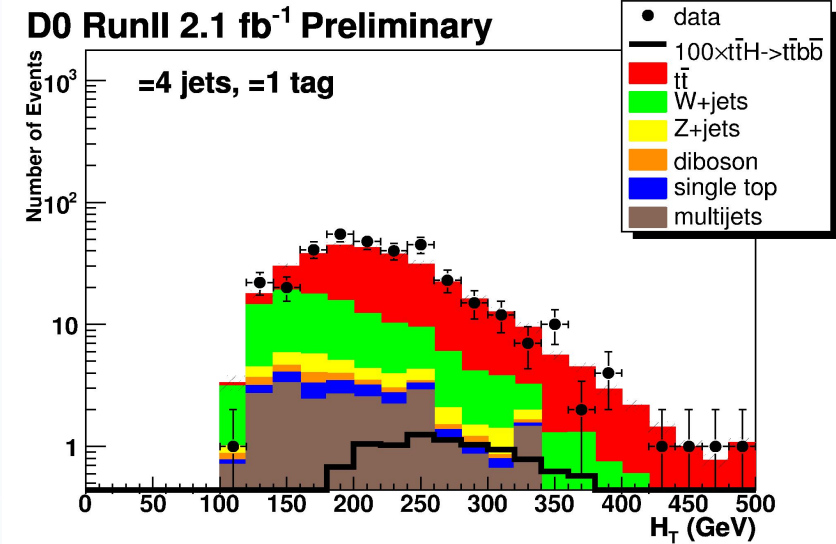- Excess is larger than due to strong production mechanism
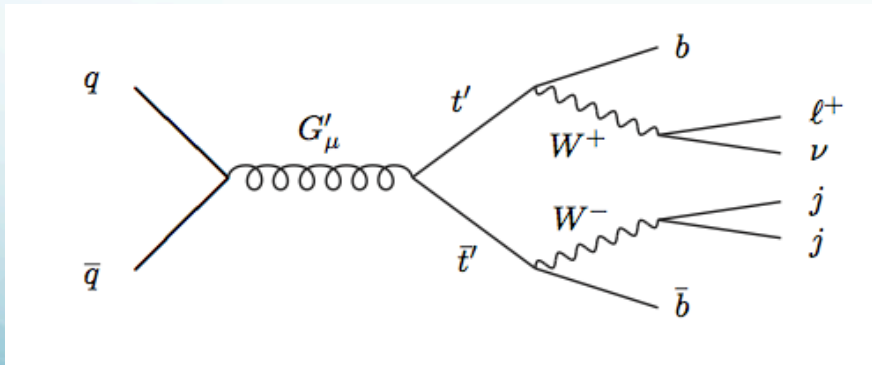
Dobrescu et al, JHEP 0906, 001 (2009)

01/19/10

Search for t't

- Lepton + >=4 jets channel

- Search for extra b-jets from Higgs

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

Conclusion

- Our knowledge of the top quark has come a long way since its discovery in 1995

- Many top quark properties are measured to much higher precision

- No evidence for new physics, although there are some hints (Afb asymetry, t')

- With much higher ttbar cross section lots of LHC new physics searches producing (di-)lepton + jets signatures will be searches in the top sample

- The Tevatron experience will be invaluable for establishing discoveries at LHC
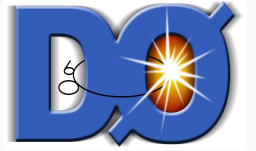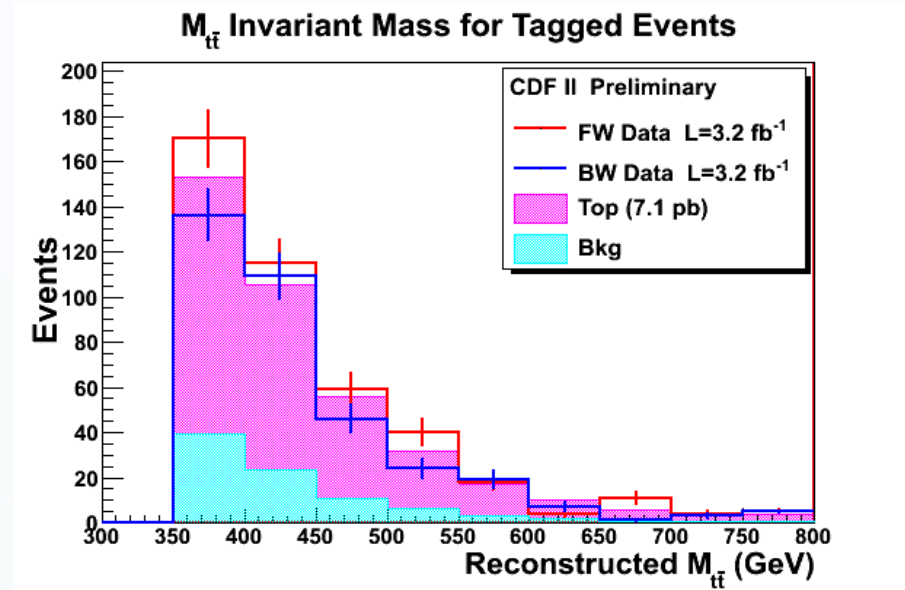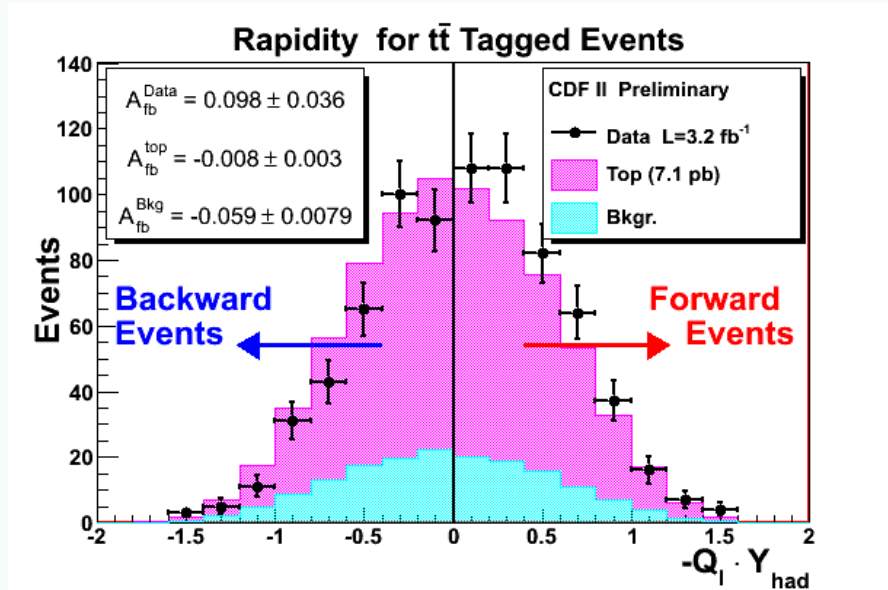
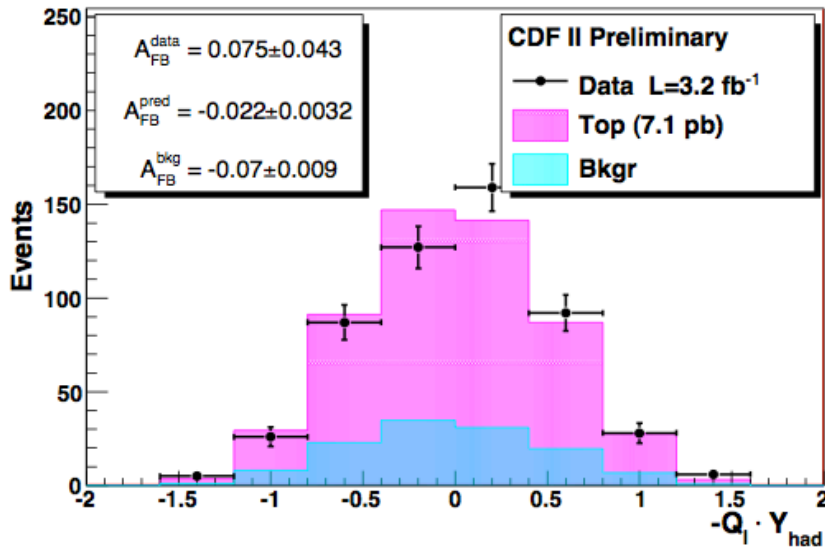# Thank You!
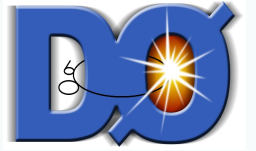
Backup Slides

Asymmetry Dependence on Mttbar

- **Idea:**
  - Study observed Afb asymmetry as a function of Mttbar mass

- Split events into four bins:

- Forward, low Mttbar   Forward, high Mttbar

- Backward, low Mttbar   Backward, high Mttbar

Assymetry Dependence on Mttbar

A_{fb} = 15% +/- 10% (stat) +6% (syst)
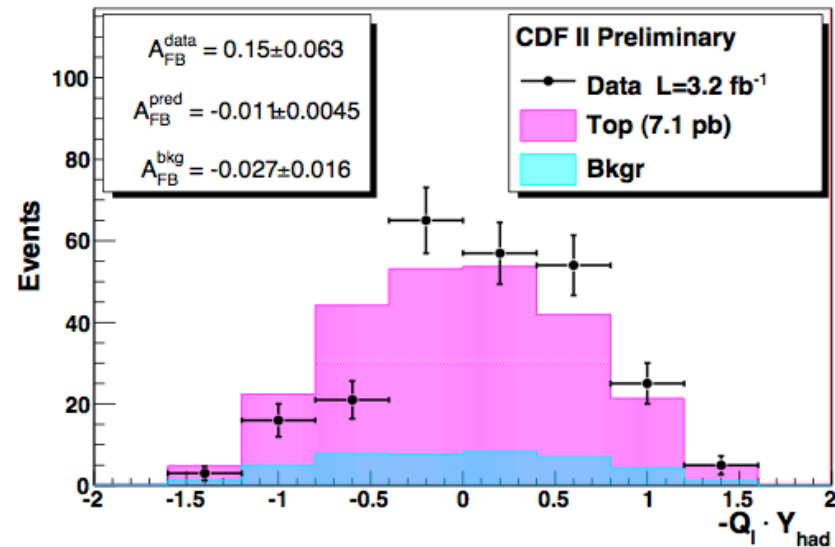
A_{fb} = 24% +/- 12% (stat) +8% (syst)

- Unfolding is done in four bins similar to Afb measurement

Asymmetry Dependence on Mttbar

- M$_{ttbar}$ Scan Results