Model Independent Limits on Anomalous Scalar Charged Bosons in Top Quark Decays

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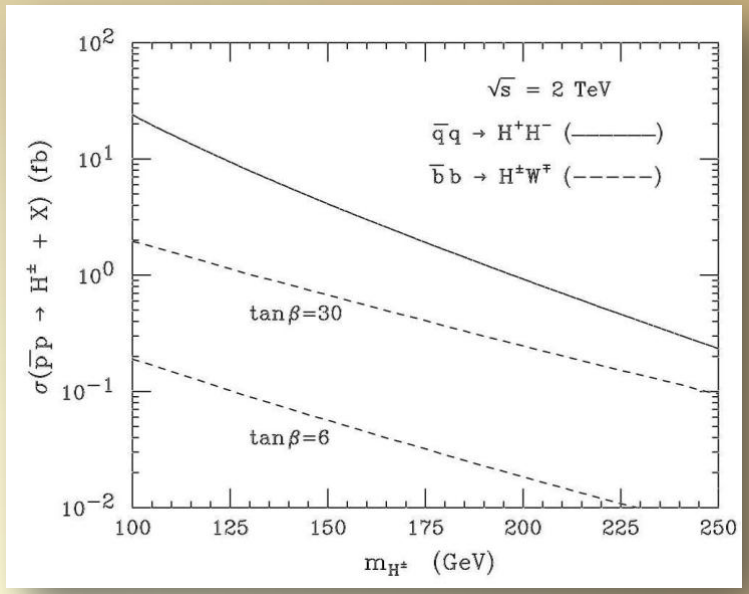
Introduction

- Charged Higgs search in top quark decays
  - Strategy for charged Higgs search
  - CDF II detector at Tevatron
  - Event Selection
  - Observed dijet mass in 2.2 fb^{-1} CDF data
  - Extracting upper limits on $B(t \rightarrow H^{+}b)$
  - Including Systematic Uncertainty
  - Upper limits on $B(t \rightarrow H^{+}b)$
- Extend search for generic scalar charged boson in top quark decays
  - Motivation
  - Analysis with $u\bar{d}$ decays
- Summary

Charged Higgs ($H^{\pm}$)

- Two Higgs Doublet Model for electro-weak symmetry breaking beyond the Standard Model
  - H^0, h^0, A^0, $H^{\pm}$
- Too small direct production cross section of charged Higgs at Tevatron
  - Smaller than top quark production by a factor of 1000
- Minimal Supersymmetric Standard Model (MSSM) predicts charged Higgs in top quark decays
  - $M(H^+)<M(t)-M(b)$
  - Focus on $H^+ \rightarrow cs$ at low tan β

$$\tan\beta = \frac{v_2}{v_1}, v_1^2 + v_2^2 = (246\,\text{GeV})^2$$



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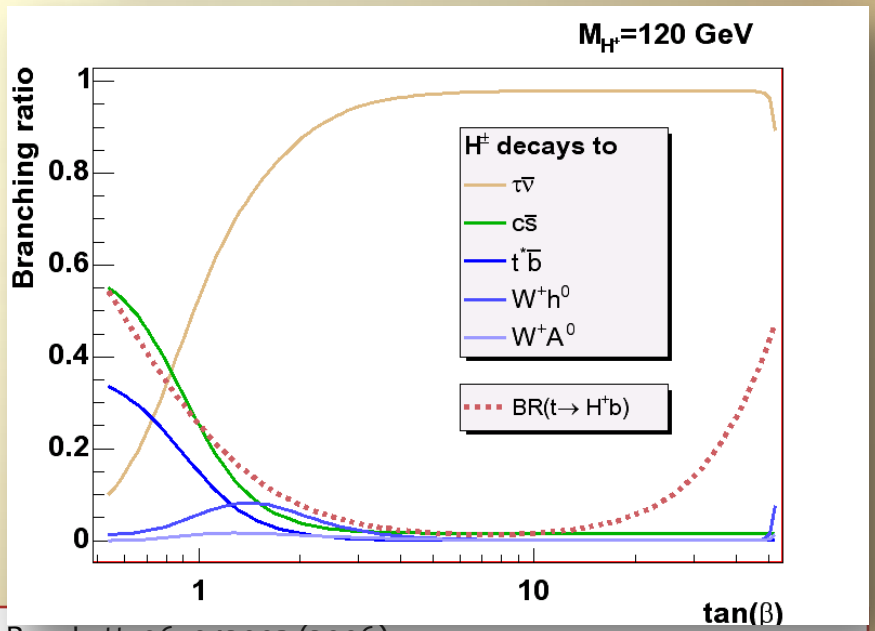

Phys. Rev. Lett. 96, 042003 (2006)
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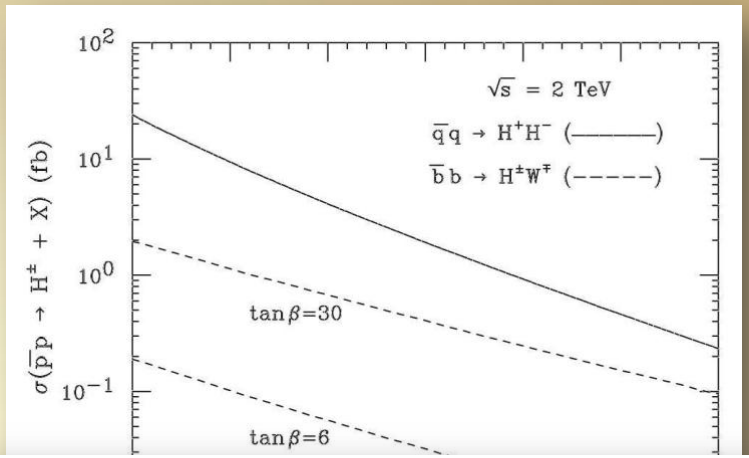

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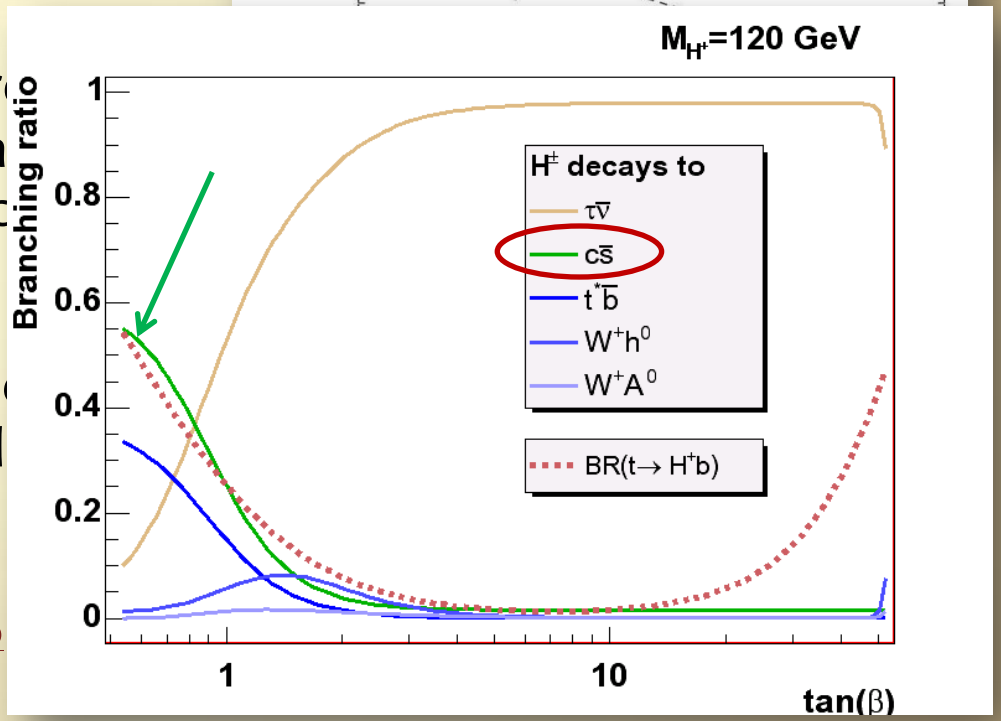

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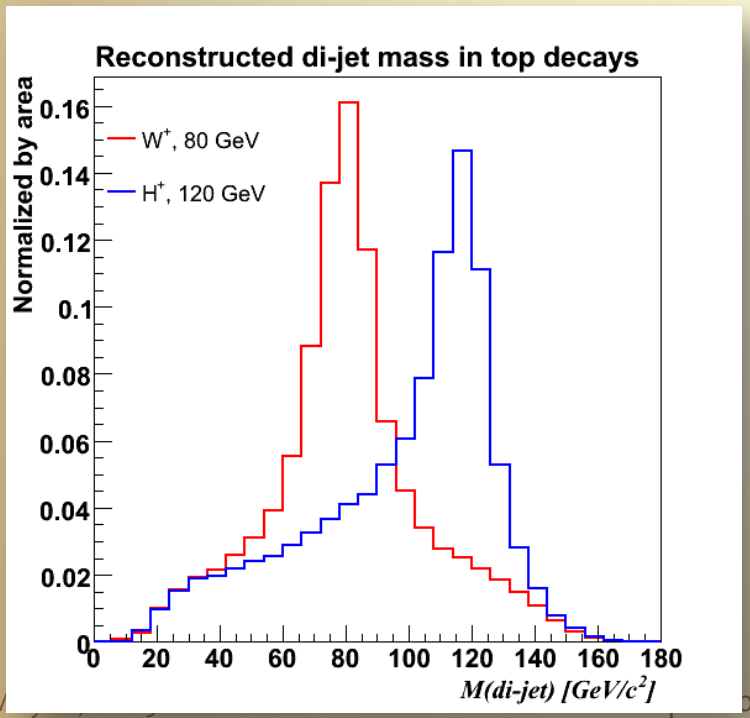
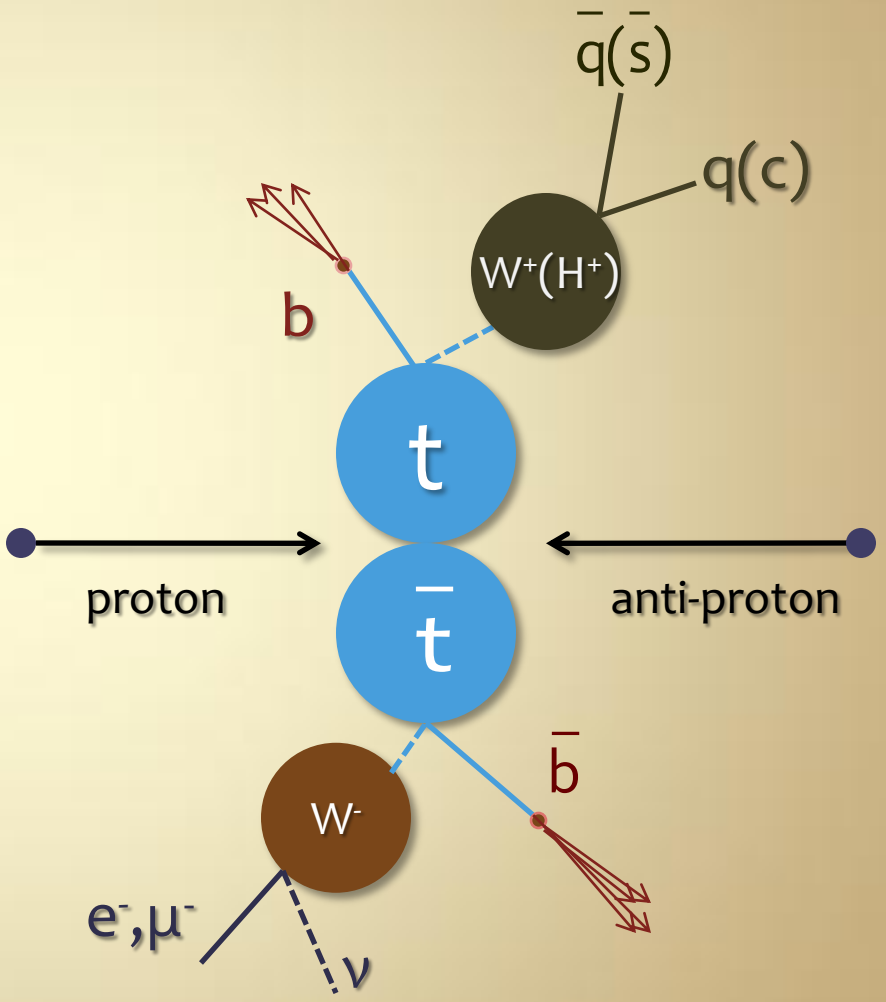
Charged Higgs in Top Decays

- Lepton+jets top pair events
  - Best signal-to-background ratio
  - Decays to lepton, neutrino, 4 quarks
- Same final state from W^+ and H^+

  $W^+ \rightarrow q\bar{q}' \rightarrow jj$ vs. $H^+ \rightarrow c\bar{s} \rightarrow jj$
- Search for second mass bump in the di-jet mass spectrum

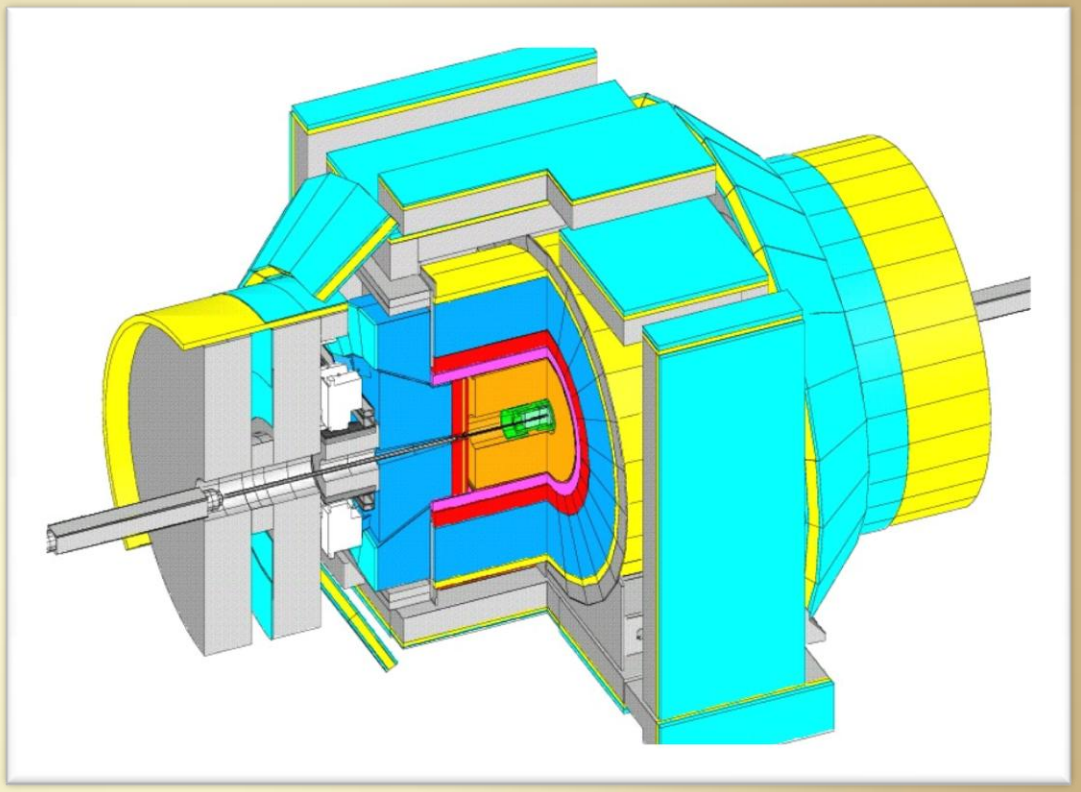




CDF II detector at Tevatron

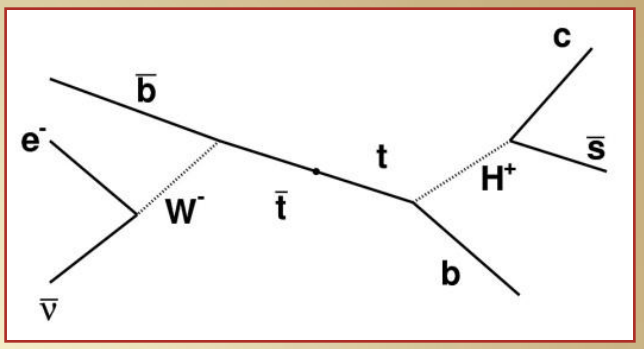
- Use 2.2 fb^{-1} data, acquired by 08/2007

- As of May 1st
  - Delivered 6.6 fb^{-1}
  - Acquired 5.4 fb^{-1}

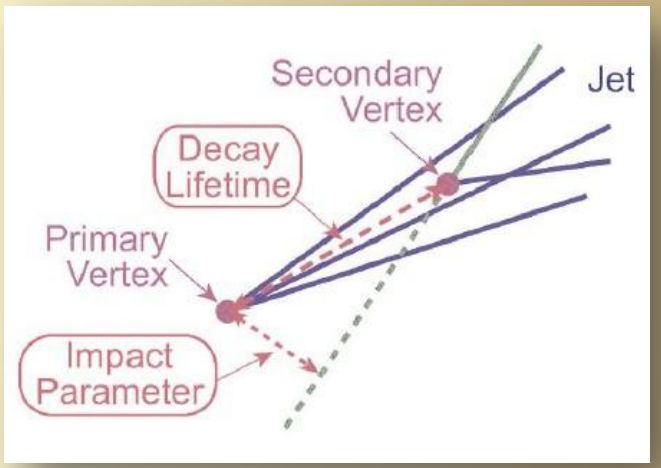


-Silicon Detector -Central Outer Tracker
-Solenoid (1.4T) -EM Calorimeter
-HAD Calorimeter -Muon Chamber

Event Selection



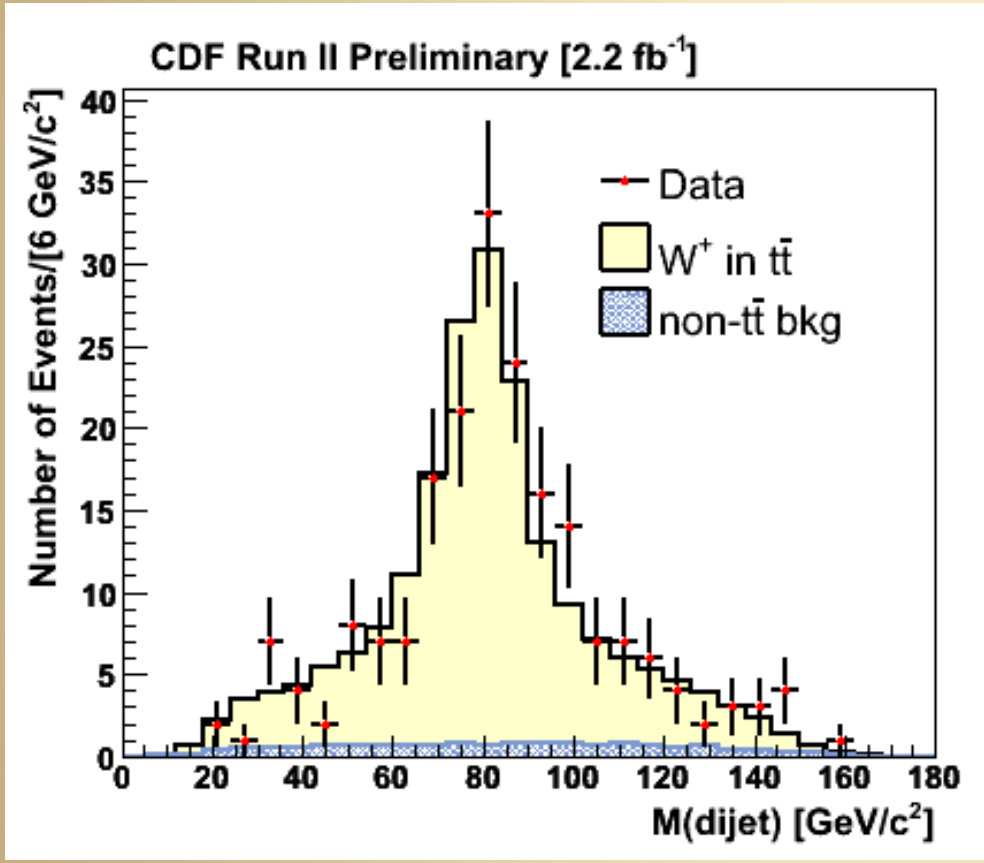
Final State Object	Requirement
A lepton (e/μ)	$p_T \geq 20$ GeV/c, $\|\eta\|<1$
Missing transverse energy	≥20 GeV
Number of Jets	≥4
Jet	$E_T \geq 20$ GeV, $\|\eta\|<2$
Number of b-jets	≥2



p_T: transverse momentum
E_T: energy transverse to the beam line
η: pseudo rapidity (longitudinal direction)

- Use *the most energetic four jets (leading jets)*
- Veto events including
  - Z boson ($\rightarrow l^+l^-$)/two leptons/Cosmic muon/Conversion($\gamma \rightarrow e^+e^-$)

Dijet mass spectrum (2.2 fb^{-1})



Estimated using Pythia Monte Carlo simulation samples and data

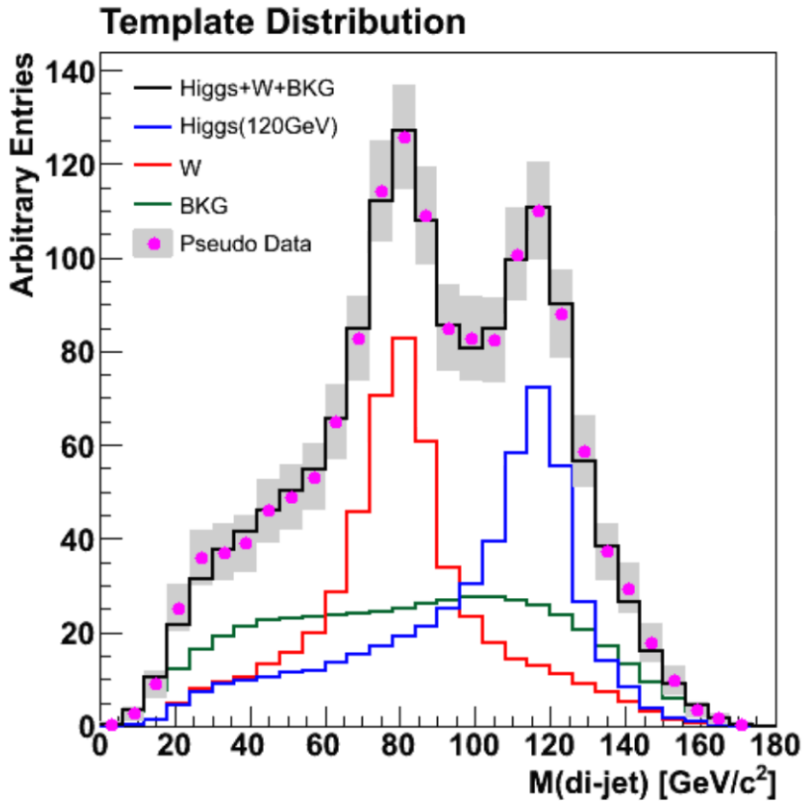
Dijet composition	Fraction (%)
$t\bar{t}$ (assuming $\sigma_{t\bar{t}}$ =6.7 pb)	91.6
Non-$t\bar{t}$ Events	8.4
W + heavy flavor jets	4.5
W + light flavor jets	1.1
Single Top	1.0
Non-W (QCD)	0.9
Diboson (WW/ZZ/WZ)	0.4
Z + light flavor jets	0.3

Observed 200 $t\bar{t}$ candidates

Extracting B(t→H⁺b)

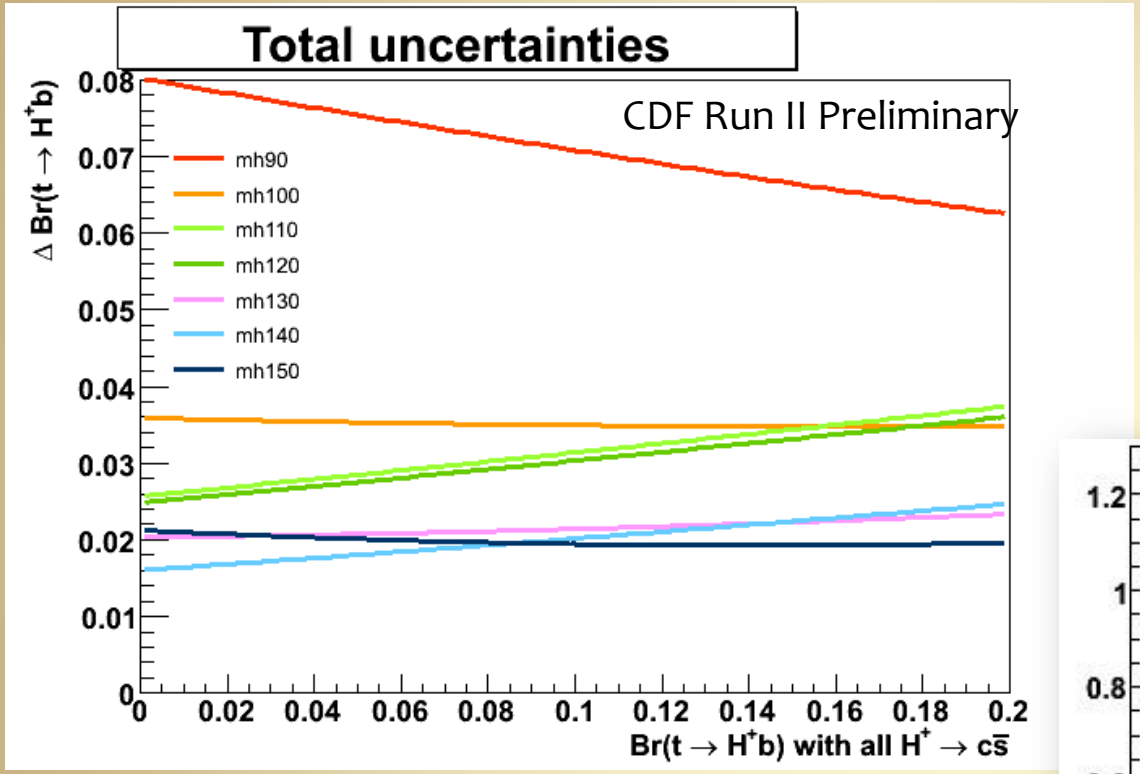
- Use maximum binned likelihood method
- N_{bkb} (Non-$t\bar{t}$) is constrained using Gaussian statistics
- Event composition in dijet mass is estimated using templates :
  - W, H^+, non-$t\bar{t}$ distribution
- Maximum LH returns
  - N(W), N(H^+), N(non-$t\bar{t}$)
- Calculate B(t→H^+b) using N(W) and N(H^+)

$$LH = \prod \frac{\nu_i^{n_i} \times e^{-\nu_i}}{n_i!} \bigotimes G(N_{bkg}, \sigma_{bkg})$$

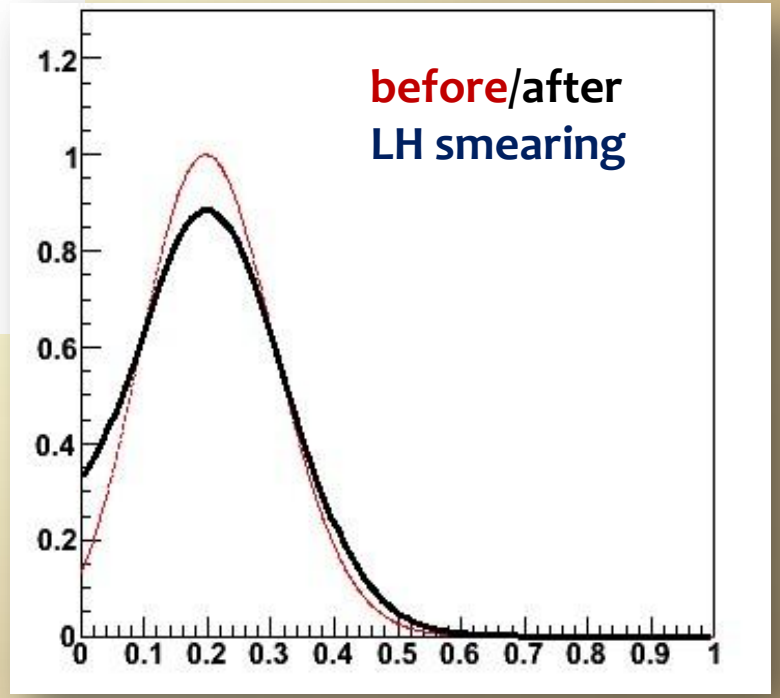


N(W)=N(H+)=N(non-$t\bar{t}$)

Systematic Uncertainty



- Likelihood shape is smeared out including systematic uncertainty as a Gaussian error



- Dominant systematic errors come from dijet mass shape perturbation due to:
  - Jet Energy Scale Correction
  - Monte Carlo Program (Pythia vs. Herwig)
  - More/Less Initial/Final state radiation
  - W+jet production scale (Q^2)

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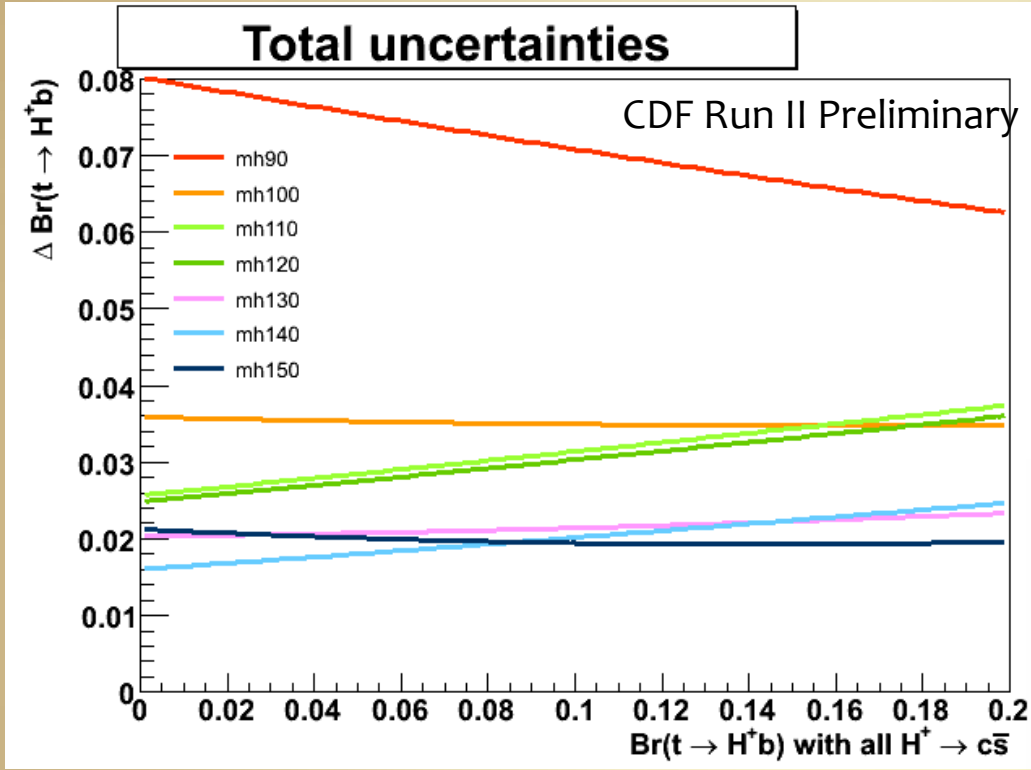
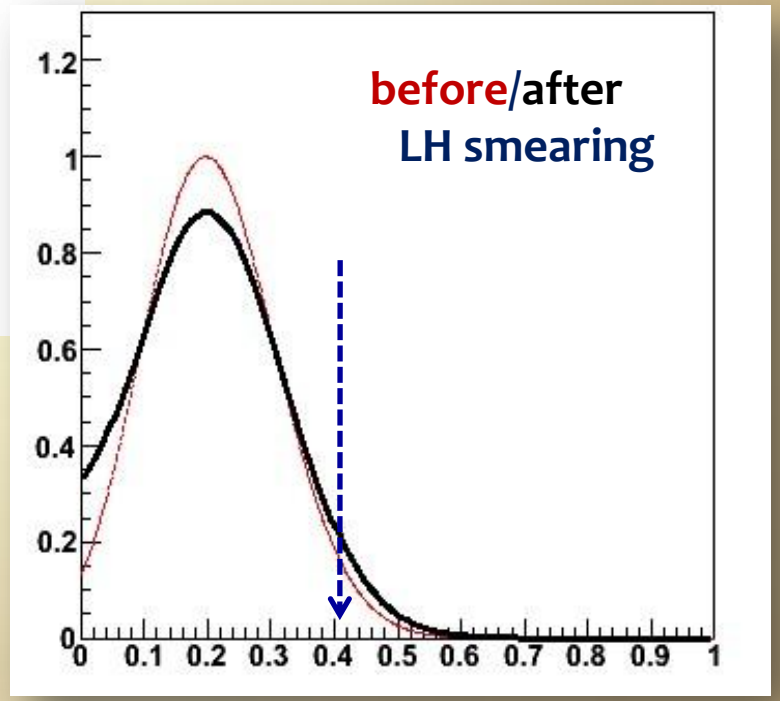


- Likelihood shape is smeared out including systematic uncertainty as a Gaussian error
- 95% integration of the positive branching ratio area

→Gives an upper limit with 95% C.L.



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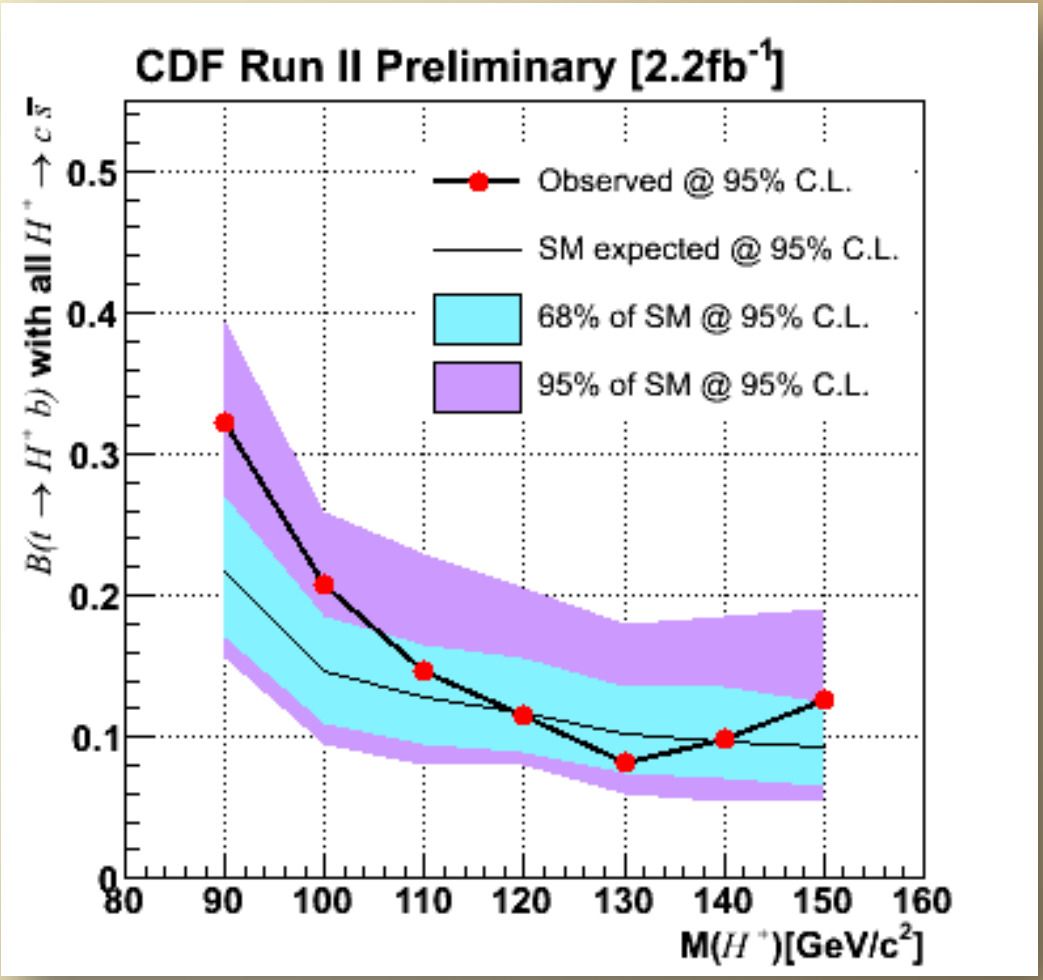
Upper Limits on B(t→H+(→$c\bar{s}$)b)

- Observed limits from 2.2 fb^{-1} data agree with the SM expectation
- SM expected upper limits are estimated from 1000 SM pseudoexperiments

M(H^+)>80 GeV from LEP data



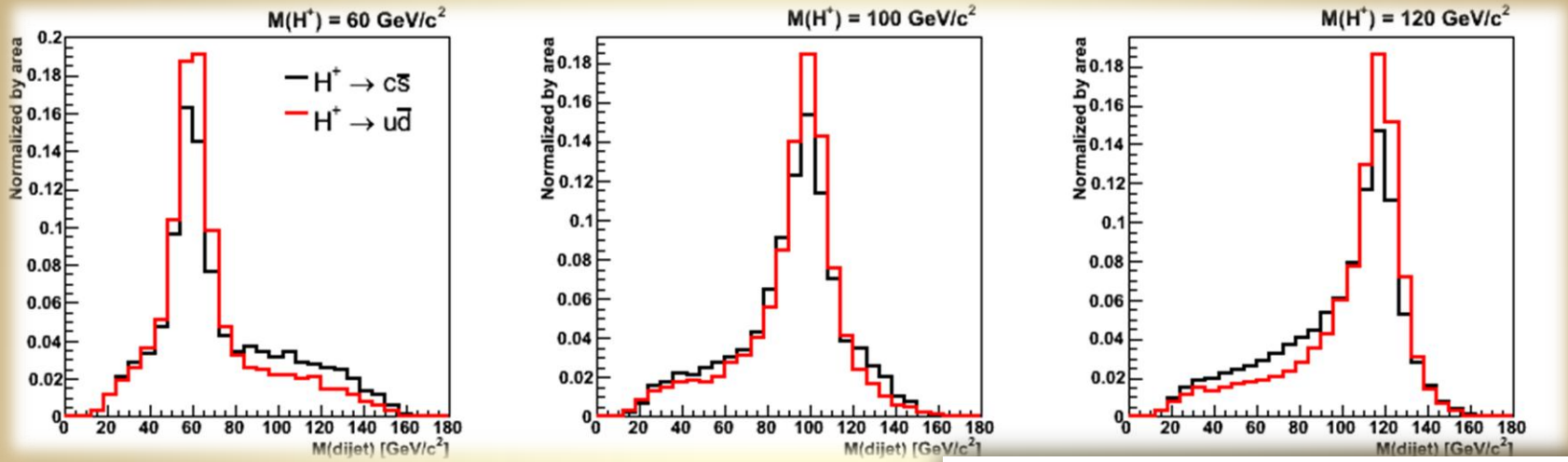
Extending the limits to generic scalar charged boson in top decays

Motivation

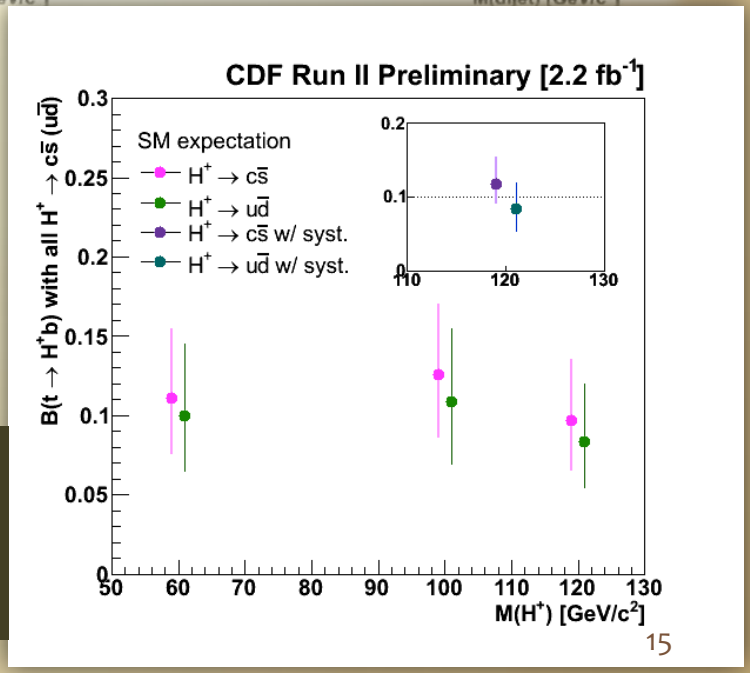
- The charged Higgs search is performed independent of any model specific parameters
- Assumptions for charged Higgs (H^+):
  - Scalar charged boson
  - Narrow width
    - Which is predicted for the light H^+ in MSSM
  - $H^+ \rightarrow c\bar{s}$ 100%
- The search is extended to
  - Mass below W boson (down to 60 GeV)
  - Same analysis is performed for another two jets decay mode ($u\bar{d}$)

Analysis with $u\bar{d}$ Decays

CDF Run II Preliminary

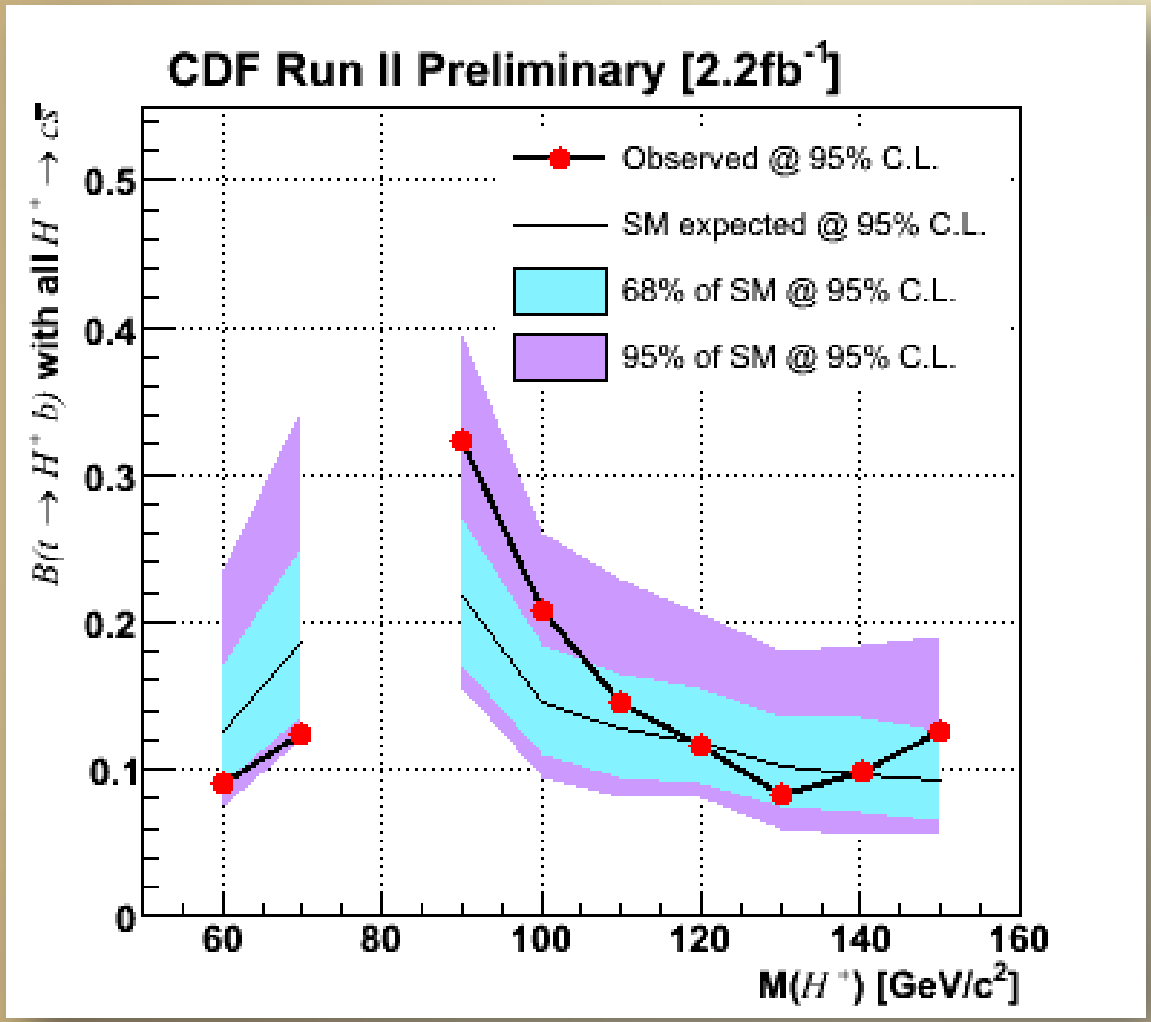


- Dijet mass of $u\bar{d}$ decays is narrower than that of $c\bar{s}$ decays
- Better mass separation between W and charged boson (→$u\bar{d}$) results in lower upper limits by ~10%



The upper limits for $c\bar{s}$ decays can be used conservative limits for any generic non-SM scalar charged boson in top quark decays

Model Independent Upper Limits



For any non-SM scalar charged boson production in top quark decays

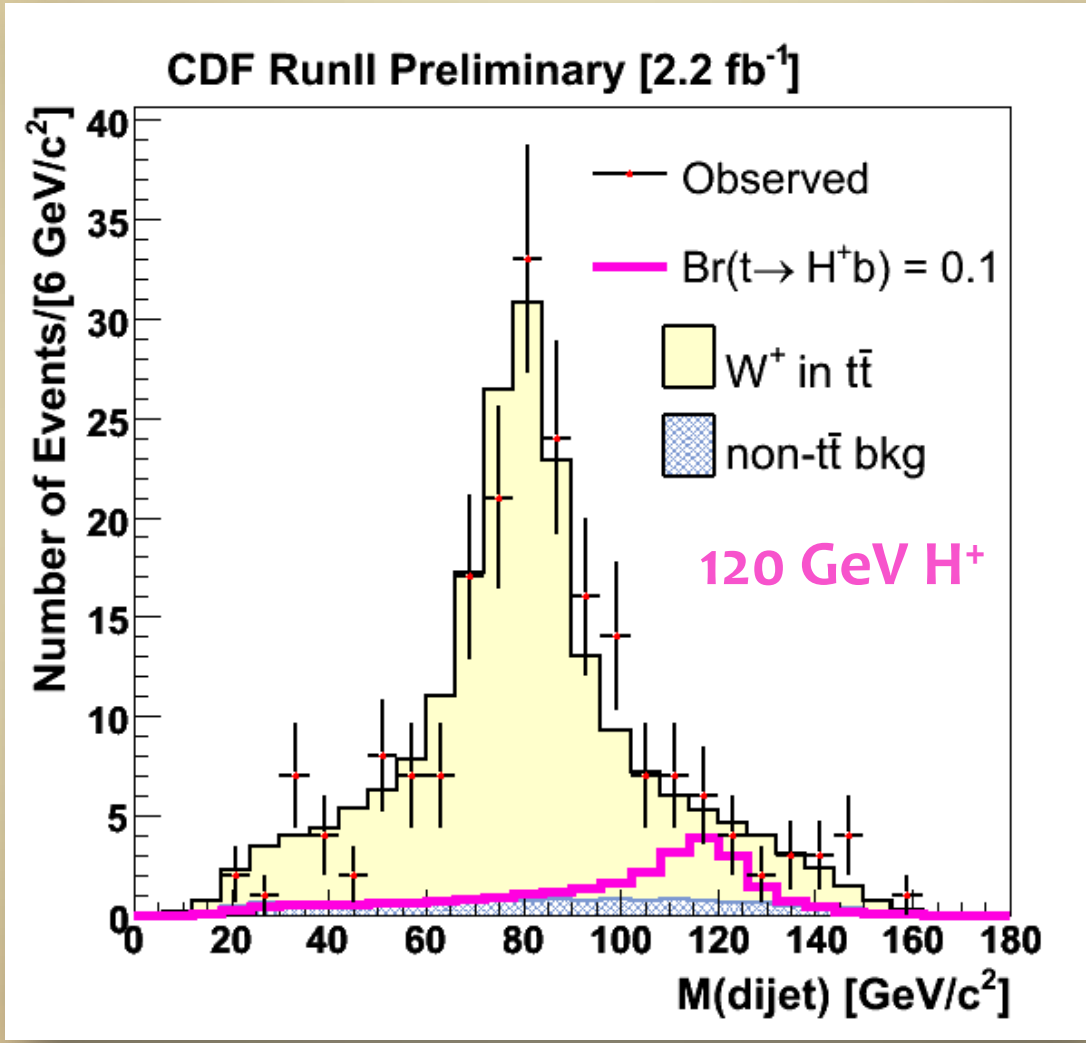
- Assumptions for a generic charged boson:
  - Spin-0 particle
  - Hadronic decays
  - Narrow width

Summary

- The MSSM charged Higgs has been searched in lepton+jets top quark decays
  - This is the first attempt of $H^+ \rightarrow c\bar{s}$ search using fully reconstructed mass
    - No SUSY parameters used
  - In 2.2 fb^{-1} CDF II data we observe no evidence of the charged Higgs
- Based on simulation upper limits on $B(t \rightarrow H^+b)$ can be used as model independent limits for anomalous scalar charged boson production in top quark decays
- This analysis is about to be submitted to PRL soon

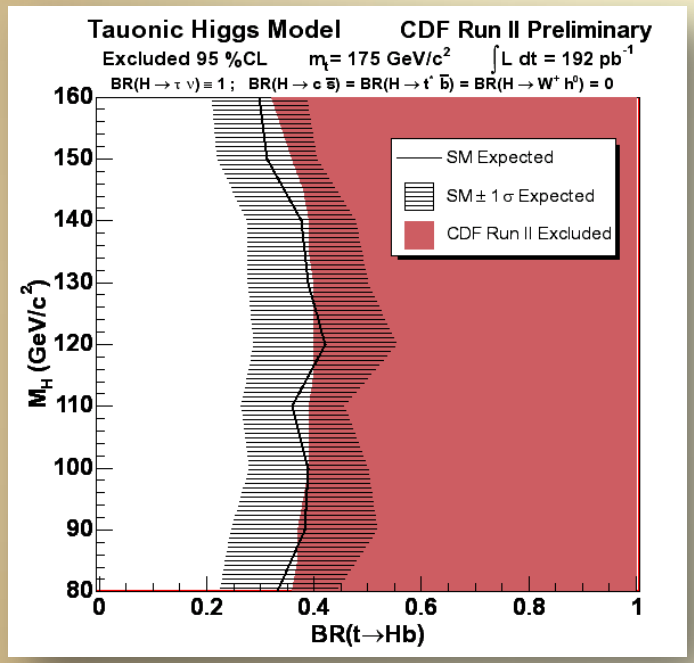
Backup Slides

Dijet mass with H^+ signal



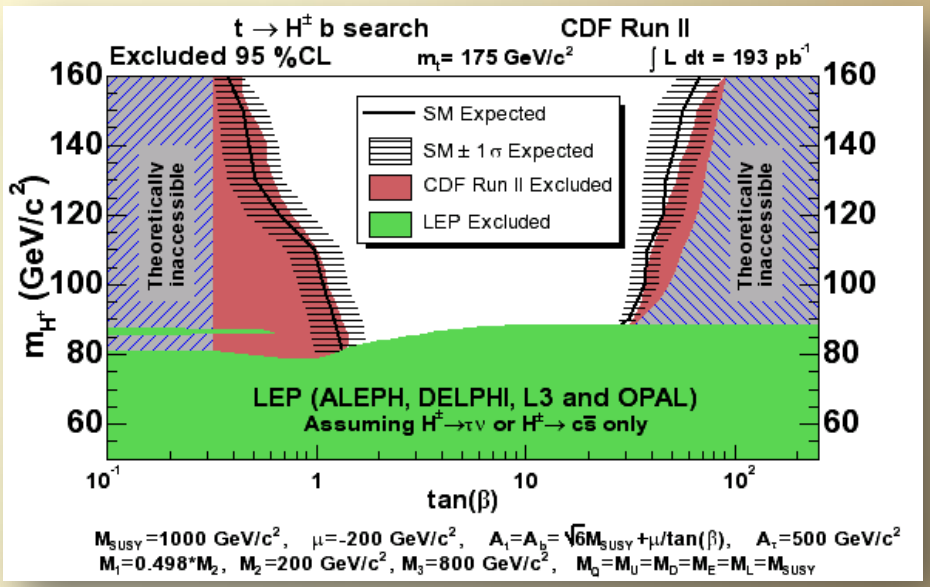
Previous charged Higgs search at CDF

In 193 pb^{-1} by R. Eusebi



B(t→H^+b) <0.4 @ 95% C.L.
for 80 GeV < m(H^+) < 160 GeV

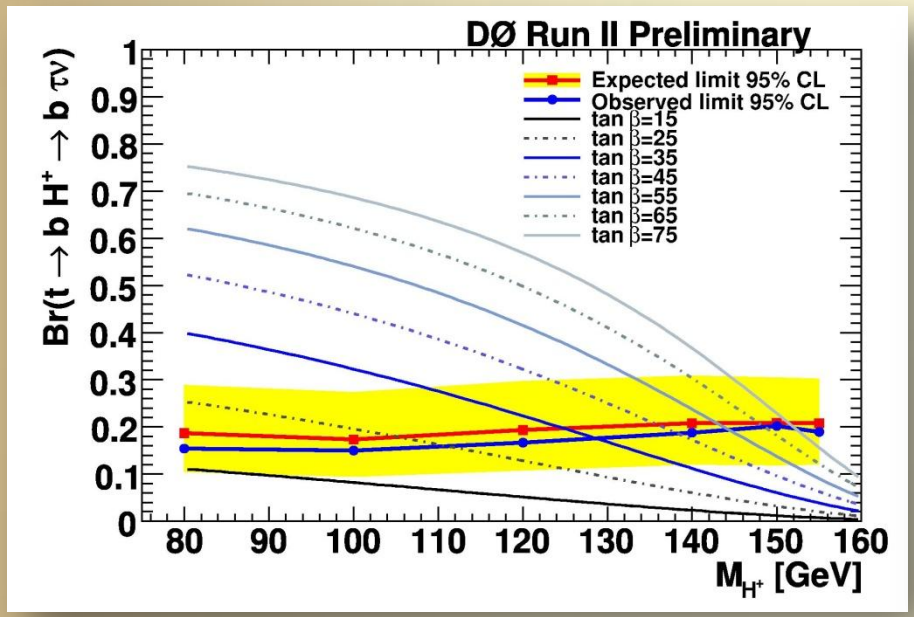
Maximum stop mixing scenario

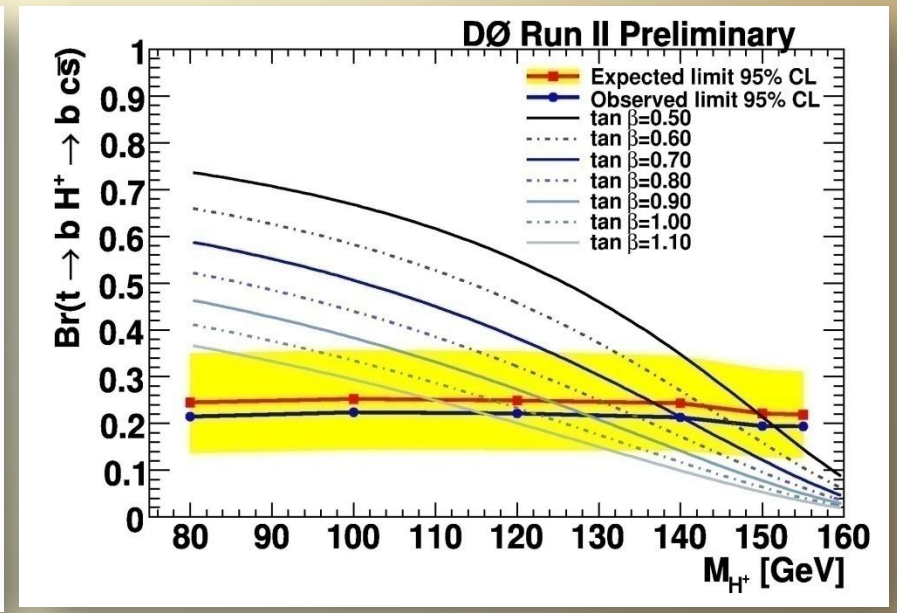


Count excess/deficiency of top quarks in various channels

Recent charged Higgs search at D0

In 1.0 fb^{-1} by Y. Peters





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