Search for Charged Higgs in Top Decays using 2.2 fb^{-1} of CDF data

Geumbong Yu

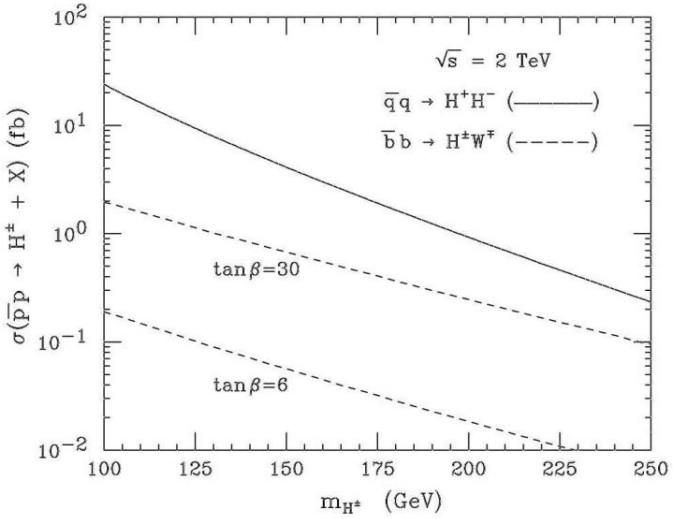
University of Rochester

On behalf of the CDF collaboration

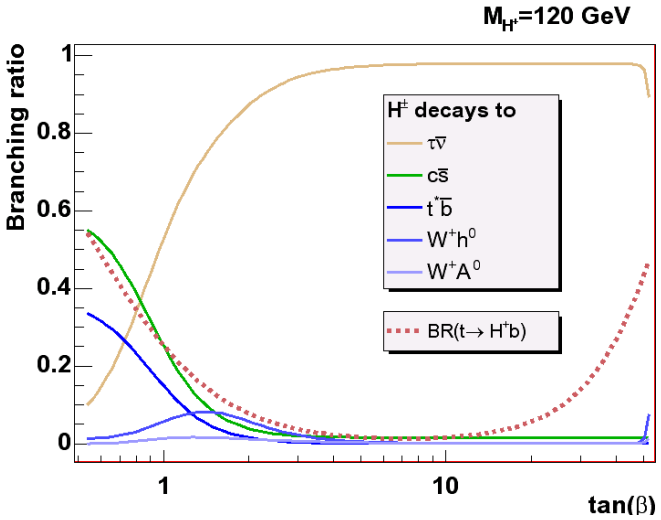
UNIVERSITY of ROCHESTER

Introduction

- Two Higgs Doublet Model beyond the Standard Model
  - ☑ H^0, h^0, A^0, $H^{\pm}$
- Too small direct production cross section of charged Higgs
  - ☑ Order of fb level
- Search for charged Higgs in top decays
  - ☑ $M(H^+) < M(t) - M(b)$
  - ☑ Focus on $H^+ \to c\bar{s}$ at low tan β



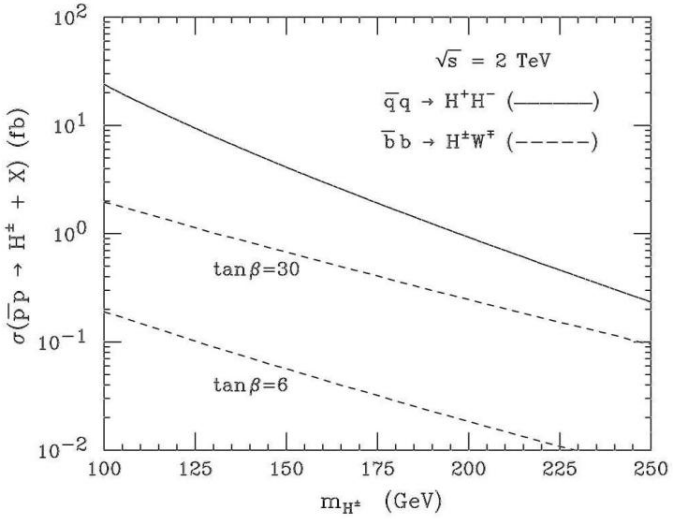
Prog.Part.Nucl.Phys.50:63–152,2003



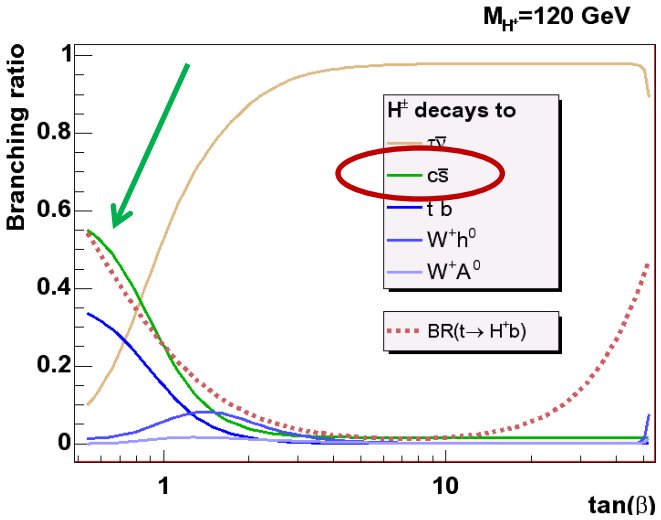
Phys. Rev. Lett. 96, 042003 (2006)

Introduction

- Two Higgs Doublet Model beyond the Standard Model
  - ☑ H^0, h^0, A^0, $H^{\pm}$
- Too small direct production cross section of charged Higgs
  - ☑ Order of fb level
- Search for charged Higgs in top decays
  - ☑ $M(H^+) < M(t) - M(b)$
  - ☑ Focus on $H^+ \to c\bar{s}$ at low tan β

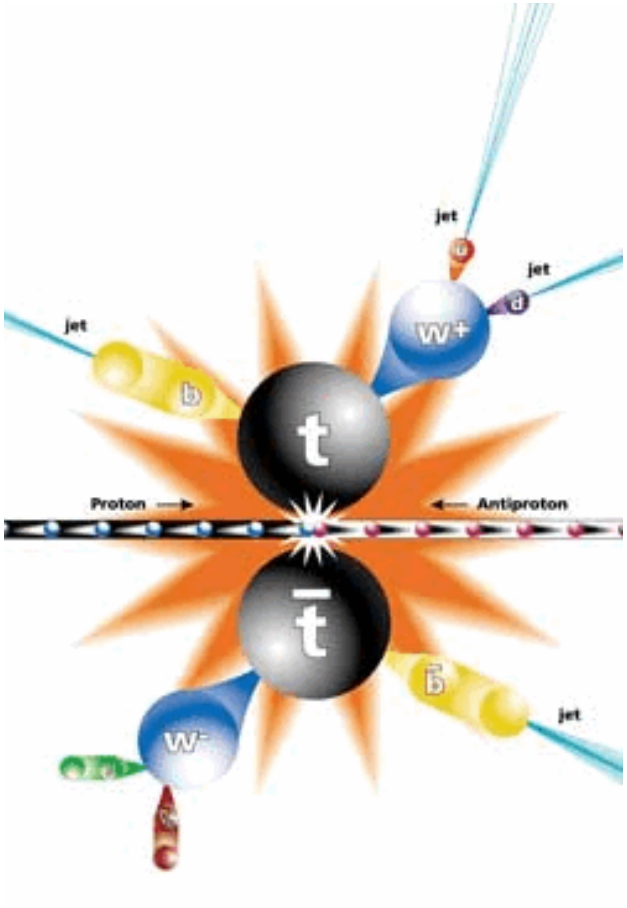


Prog.Part.Nucl.Phys.50:63–152,2003



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

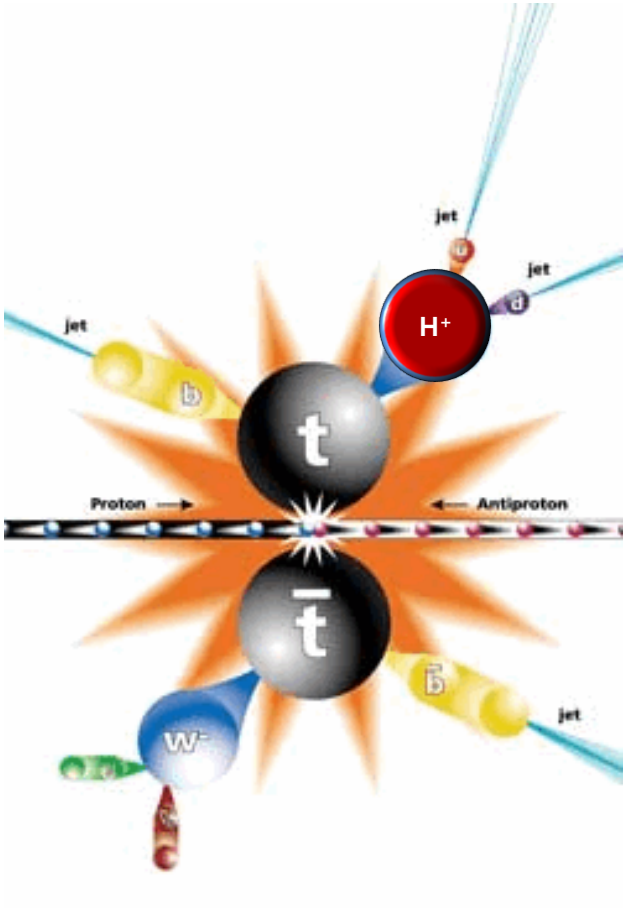
Charged Higgs in Top Decays



- Lepton+jets top pair events
  - ☑ Consists of lepton, missing Et, >=4 jets
  - ☑ 30% of total $t\bar{t}$ events
- Same final state from W^+ and H^+

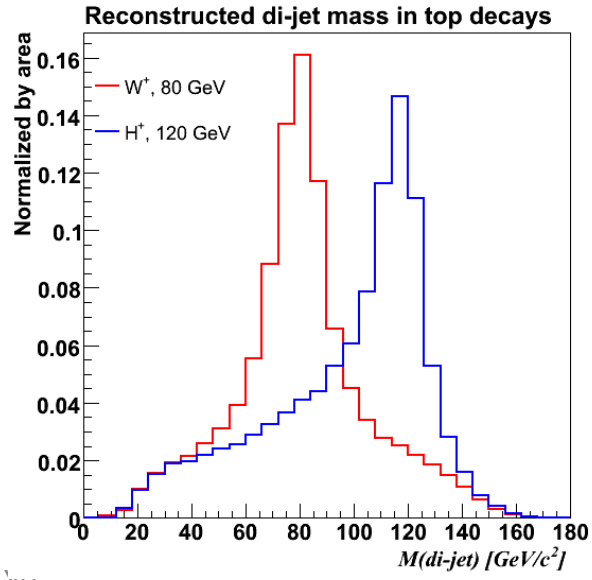
  $W^+ \to u\bar{d} / c\bar{s} \to jj$ vs. $H^+ \to c\bar{s} \to jj$
- Search for higher mass bump in the di-jet mass distribution

Charged Higgs in Top Decays



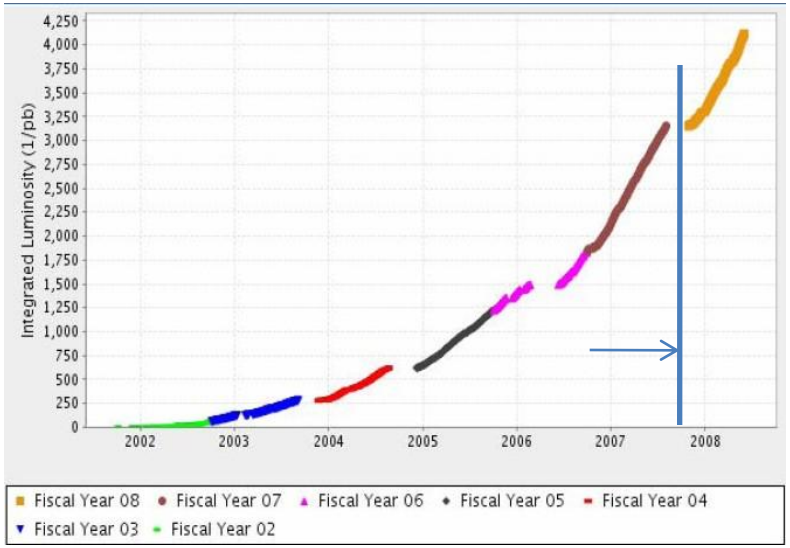
- Lepton+jets top pair events
  - ☑ Consists of lepton, missing Et, >=4 jets
  - ☑ 30% of total $t\bar{t}$ events
- Same final state from W^+ and H^+

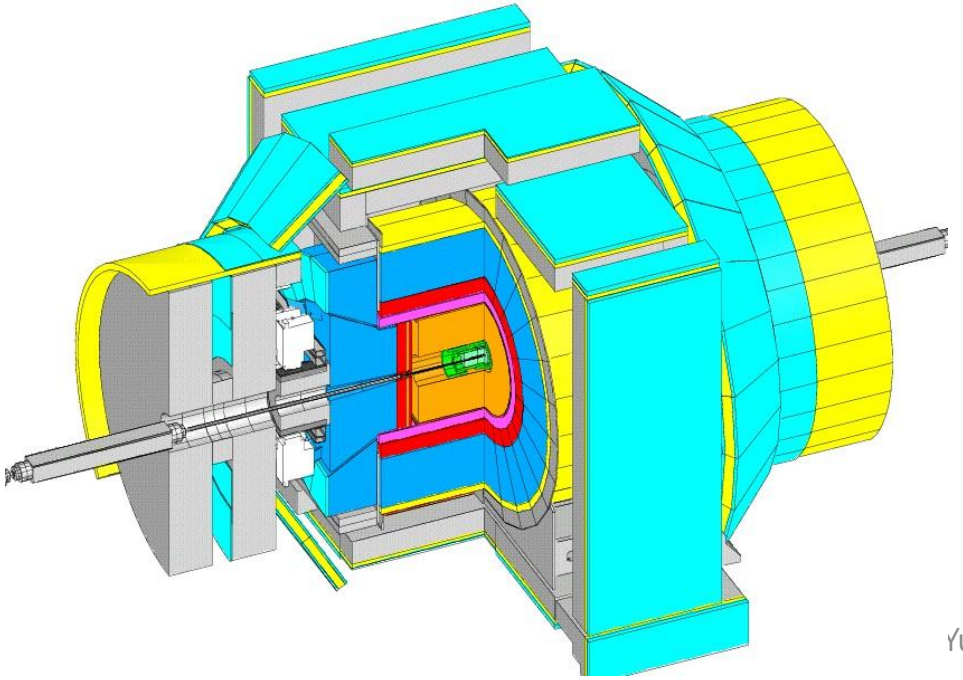
  $W^+ \to u\bar{d} / c\bar{s} \to jj$ vs. $H^+ \to c\bar{s} \to jj$
- Search for higher mass bump in the di-jet mass distribution



CDF @ Tevatron

- $p\bar{p}$ collisions @ $\sqrt{s}$ = 1.96 TeV
- Analyze 2.2 fb^{-1} of CDF data
  - ☑ Taken by Aug 2007
- Tevatron delivered 4.217 fb^{-1}, and CDF acquired 3.452 fb^{-1} as of Jun 12th



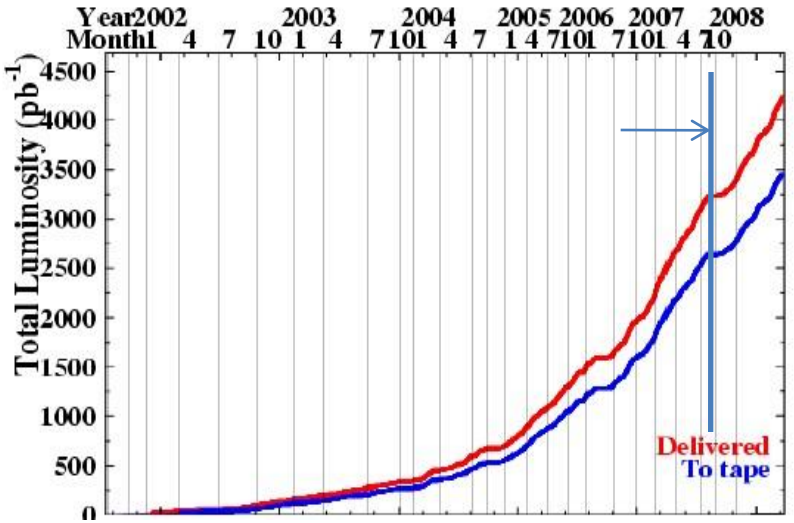


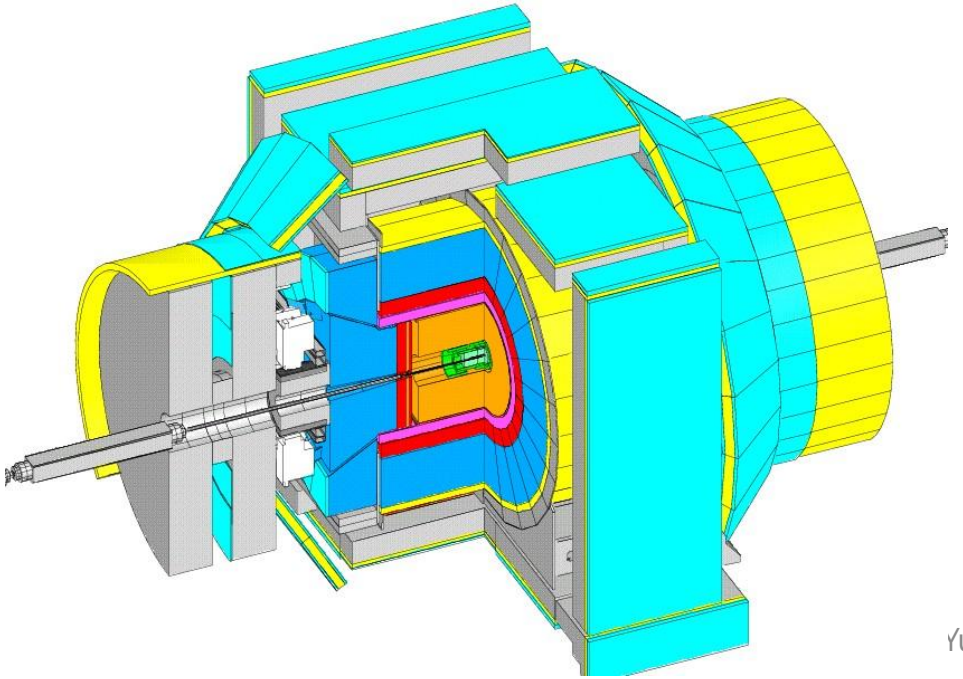
- CDF: inner to outer
  - -Silicon Detector
  - -Central Outer Tracker
  - -Solenoid (1.4T)
  - -EM Calorimeter
  - -HAD Calorimeter
  - -Muon Chamber

Yu

CDF @ Tevatron

- $p\bar{p}$ collisions @ $\sqrt{s}$ = 1.96 TeV
- Analyze 2.2 fb^{-1} of CDF data
  - ☑ Taken by Aug 2007
- Tevatron delivered 4.217 fb^{-1}, and CDF acquired 3.452 fb^{-1} as of Jun 12th





- CDF: inner to outer
  - -Silicon Detector
  - -Central Outer Tracker
  - -Solenoid (1.4T)
  - -EM Calorimeter
  - -HAD Calorimeter
  - -Muon Chamber

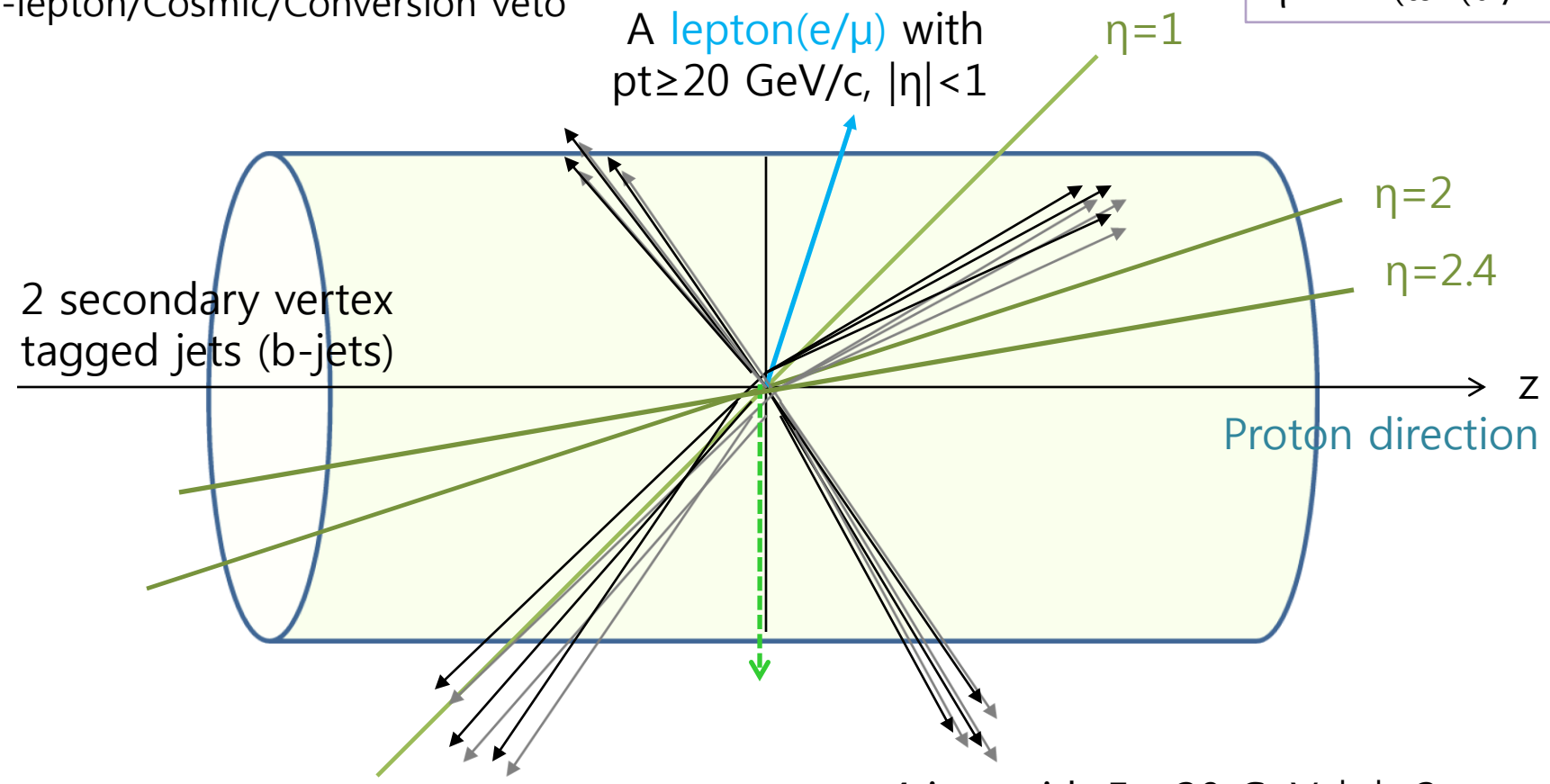
Yu

Event Selection

Detector in x-y plane

Z/Di-lepton/Cosmic/Conversion veto

Pseudo rapidity
$\eta = -\ln(\tan(\theta / 2))$

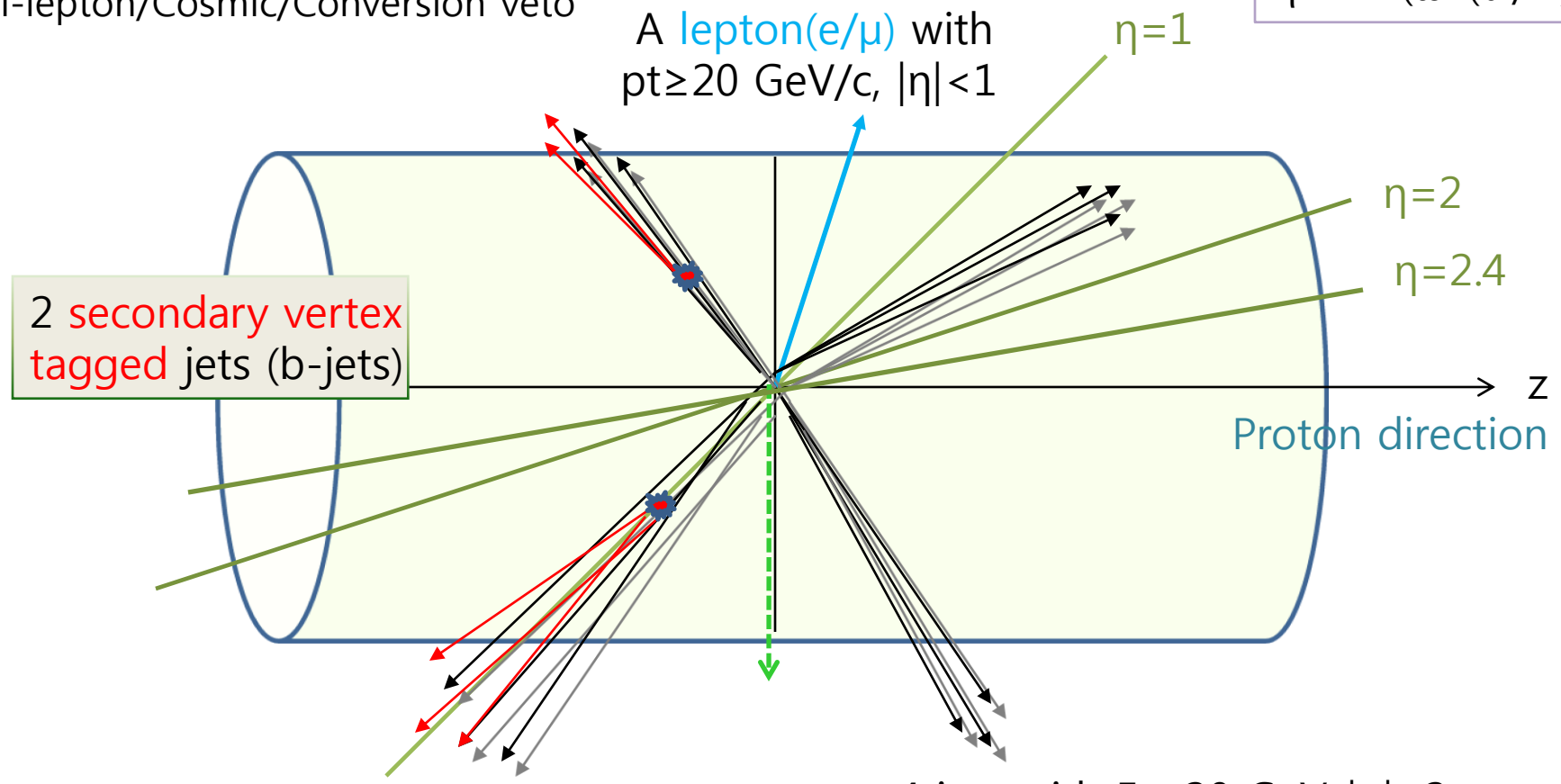


Event Selection

Detector in x-y plane

Z/Di-lepton/Cosmic/Conversion veto

Pseudo rapidity
$\eta = -\ln(\tan(\theta / 2))$

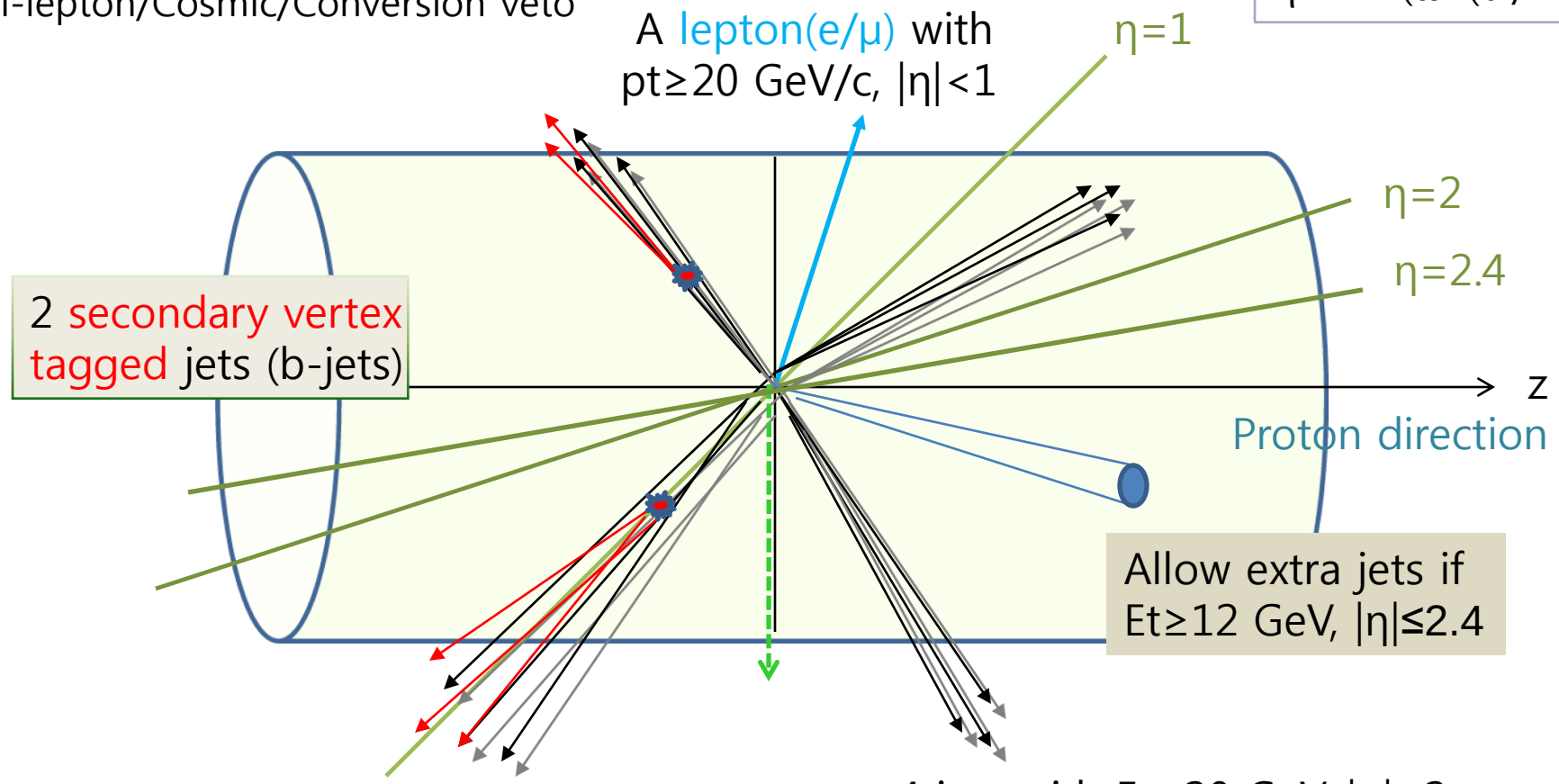


Event Selection

Detector in x-y plane

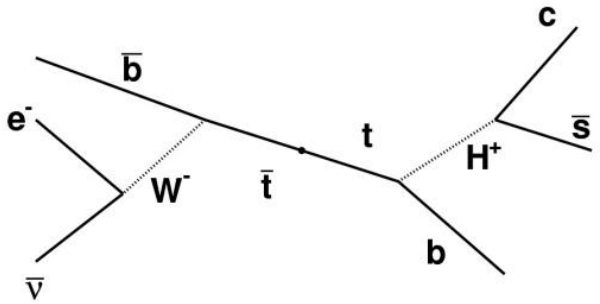
Z/Di-lepton/Cosmic/Conversion veto

Pseudo rapidity
$\eta = -\ln(\tan(\theta / 2))$



Top Event Reconstruction

- Matching final state objects to the partons in kinematic χ^2 fitter:
  - ☑ Leading 4 jets
  - ☑ Lepton
  - ☑ Un-clustered energy for missing Et calculation
- Constrain top and leptonic W mass
- Vary energies within 1σ in the fitter

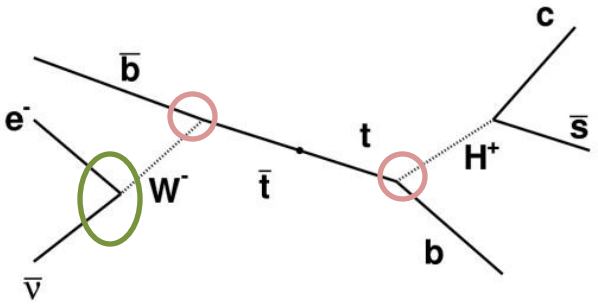


$$\chi^2 = \sum_{i=l,4\,jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_T^{UE,fit} - p_T^{UE,meas})^2}{\sigma_j^2}$$

$$+ \frac{(m_{jj} - m_{jj}^{reco})^2}{\Gamma_W^2} + \frac{(m_{l\nu} - m_W)^2}{\Gamma_W^2} + \frac{(m_{bjj} - m_t)^2}{\Gamma_t^2} + \frac{(m_{bl\nu} - m_t)^2}{\Gamma_t^2}$$

Top Event Reconstruction

- Matching final state objects to the partons in kinematic χ^2 fitter:
  - ☑ Leading 4 jets
  - ☑ Lepton
  - ☑ Un-clustered energy for missing Et calculation
- Constrain top and leptonic W mass
- Vary energies within 1σ in the fitter



$$\chi^2 = \sum_{i=l,4\,jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_T^{UE,fit} - p_T^{UE,meas})^2}{\sigma_j^2}$$

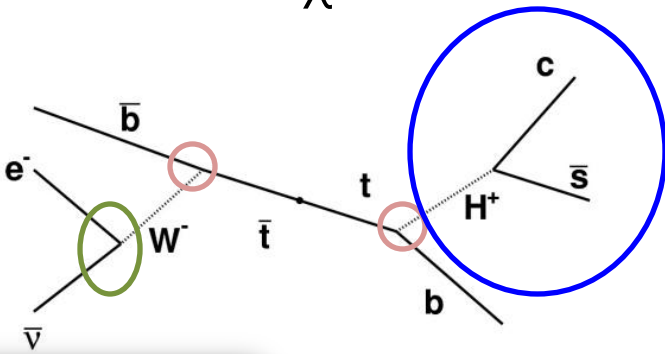
$$+ \frac{(m_{jj} - m_{jj}^{reco})^2}{\Gamma_W^2} + \frac{(m_{l\nu} - m_W)^2}{\Gamma_W^2} + \frac{(m_{bjj} - m_t)^2}{\Gamma_t^2} + \frac{(m_{bl\nu} - m_t)^2}{\Gamma_t^2}$$

M_W=80GeV

M_t=175GeV

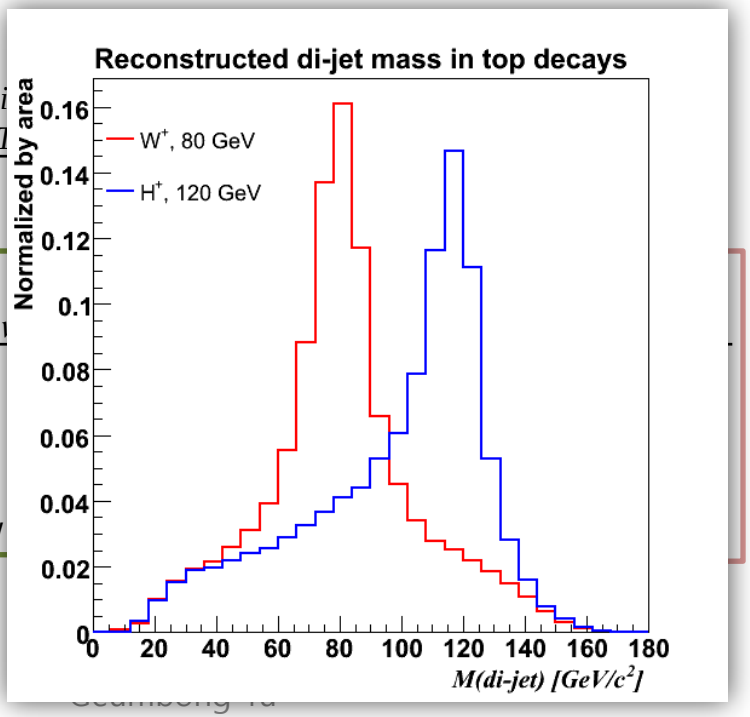
Top Event Reconstruction

- Matching final state objects to the partons in kinematic χ^2 fitter:
  - ☑ Leading 4 jets
  - ☑ Lepton
  - ☑ Un-clustered energy for missing Et calculation
- Constrain top and leptonic W mass
- Vary energies within 1σ in the fitter



$$\chi^2 = \sum_{i=l,4\,jets} \frac{(p_T^{i,fit} - p_T^{i}}{\sigma_i^2} + \frac{(m_{jj} - m_{jj}^{reco})^2}{\Gamma_W^2} + \frac{(m_{l\nu}}{}$$

M_W



Analysis Method

1. Improvement on di-jet mass resolution

2. Di-jet mass fit with binned likelihood

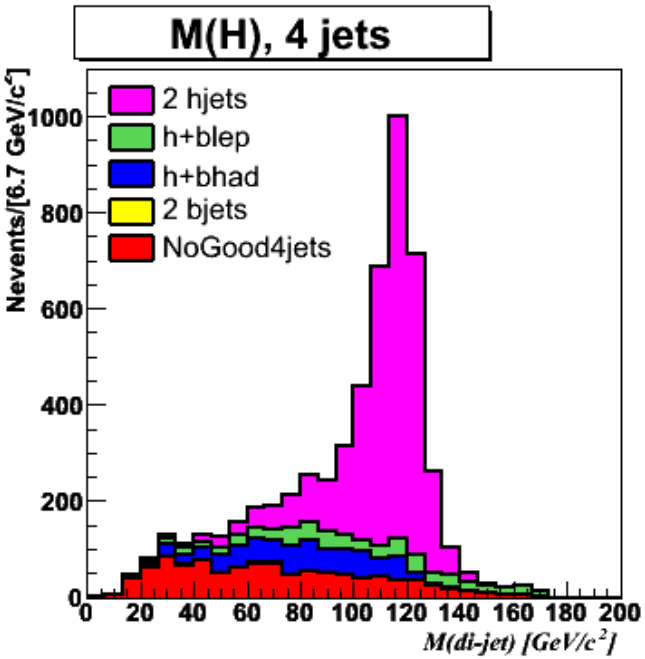
3.Evaluate Systematic Uncertainties

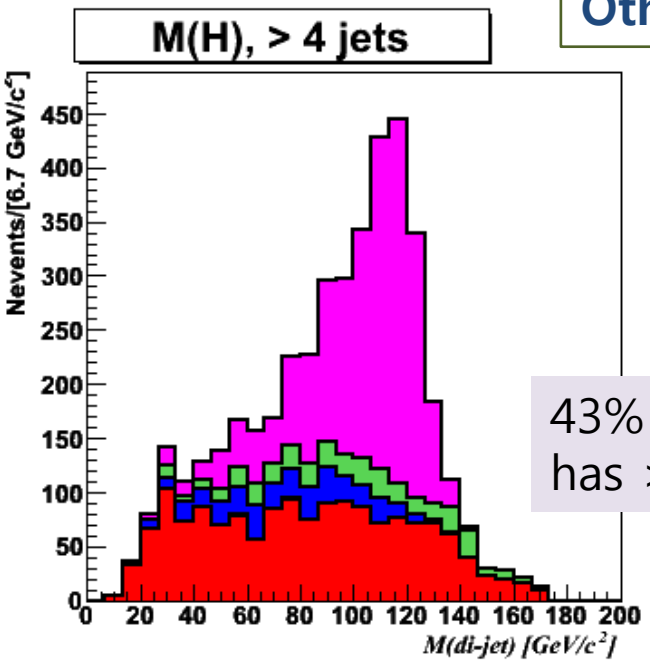
4. Set the upper limits on the br($t \rightarrow H^{+}b$)

Di-jet Mass vs. Number of Jets

1

Good Higgs
Others bad



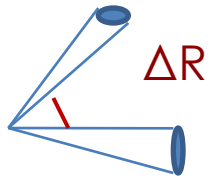


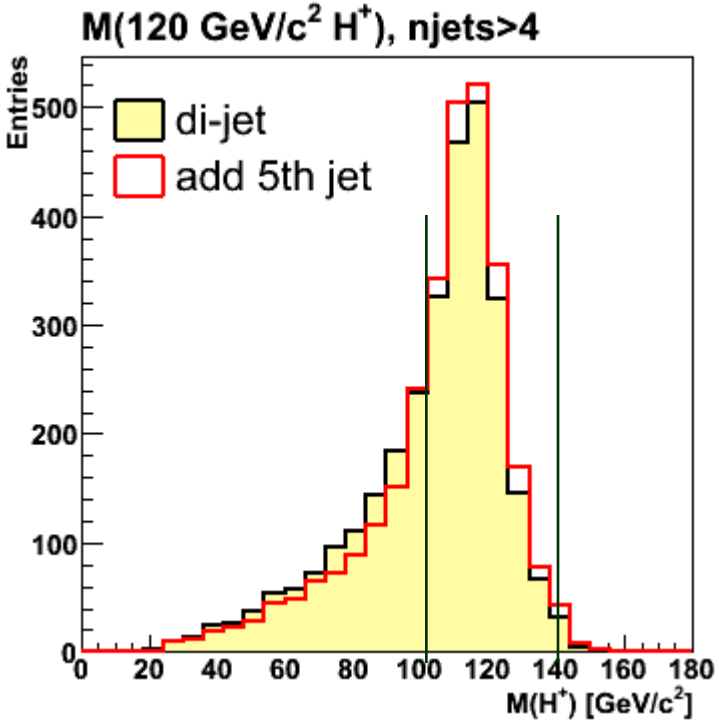
43% of events has > 4 jets

- Worse Higgs di-jet mass resolution with additional jets in $t\bar{t}$
- Energy loss by final state radiation from the Higgs particle

Improvement on Di-jet Mass

1





- Add 5th jet to the closest leading jet if ΔR<1.0
  - ☑ Jet cone size : 0.4
  - ☑ 5th jet = the most energetic extra jet
- The overall mean mass
  - ☑ 103.3±21.8 GeV → 105.7±20.8 GeV
- 100 GeV<M(H+)<140 GeV
  - ☑ Entries increased by 7.4%
- Not affect on W^+ and non-$t\bar{t}$ bkgd

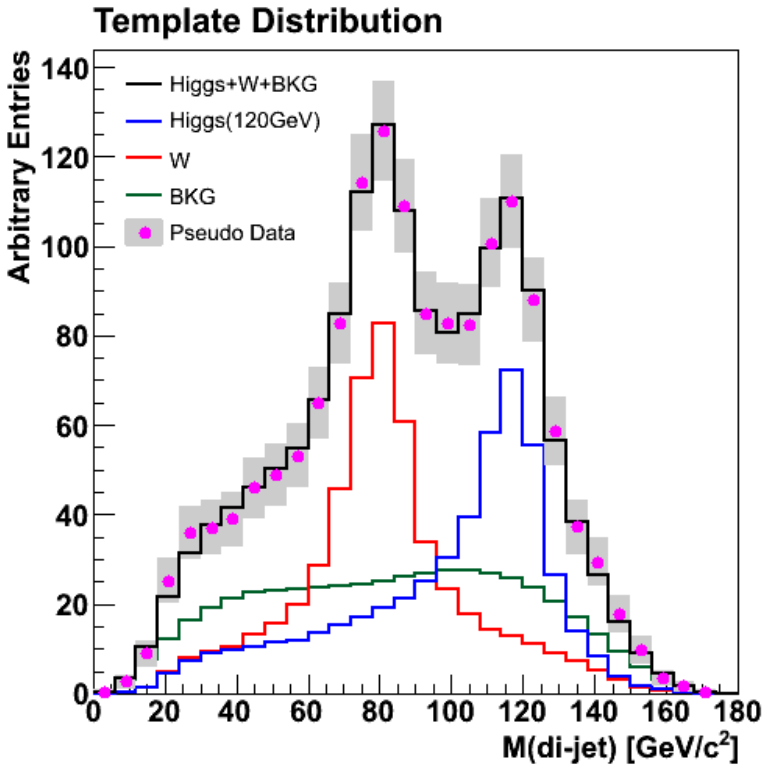
Reconstruct di-jet mass after adding nearby 5th jet

Extracting br(t→H⁺b)

2

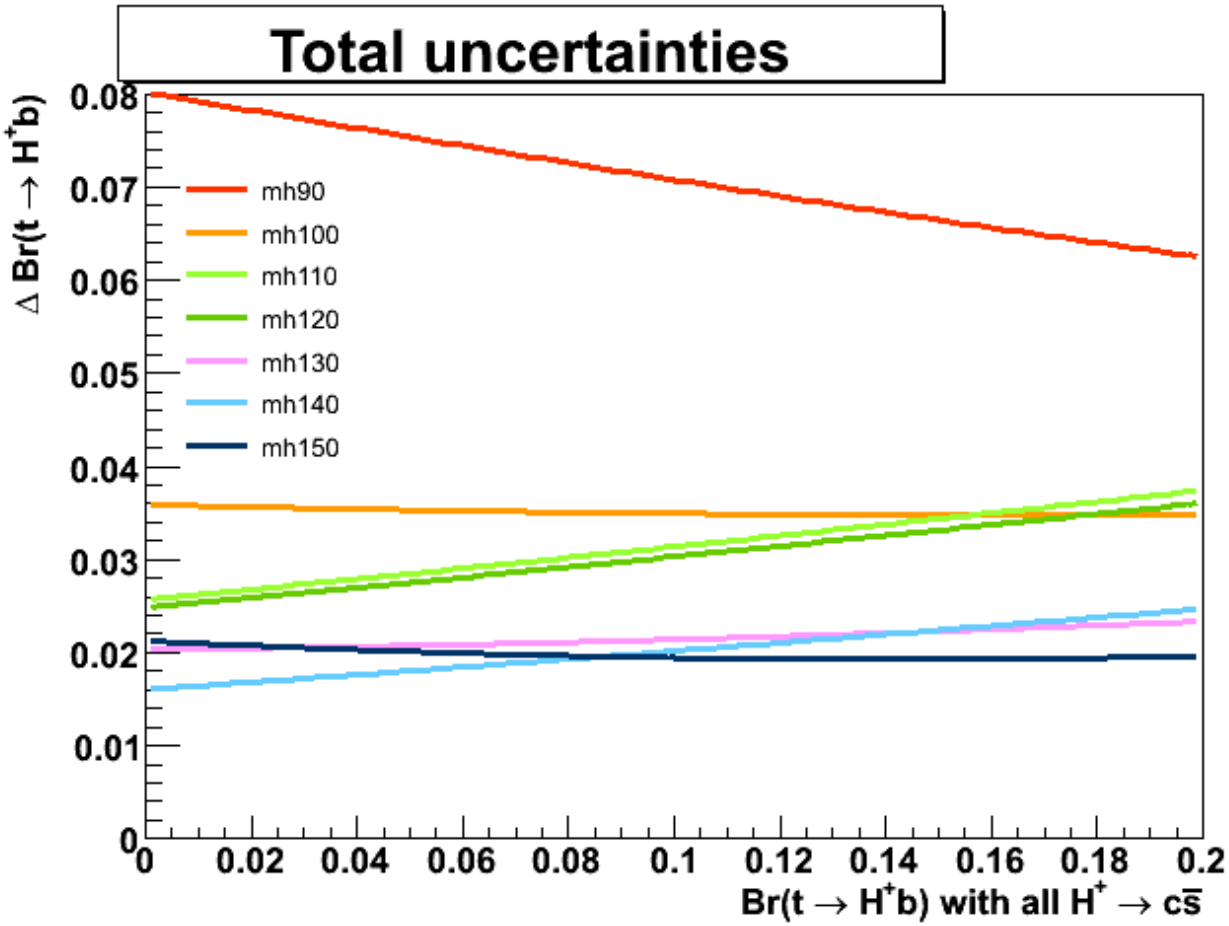
$$LH = \prod \frac{\nu_i^{n_i} \times e^{-\nu_i}}{n_i!} \bigotimes G(N_{bkg}, \sigma_{bkg})$$

- The binned likelihood function is constructed using:
  - ☑ Poisson probability
  - ☑ Gaussian constraints on number of non-$t\bar{t}$ background
- Di-jet mass distribution is fitted with the template :
  - ☑ H^+,W^+, and non-$t\bar{t}$ shape
- Likelihood fitter returns
  - ☑ Br(t→H^+b) where br(H^+→$c\bar{s}$)=100%
  - ☑ Total number of $t\bar{t}$
  - ☑ Number of non-$t\bar{t}$ background
- We study Higgs mass values at
  - ☑ 90 GeV, 100 GeV, …, 150 GeV



Systematic Uncertainties

3

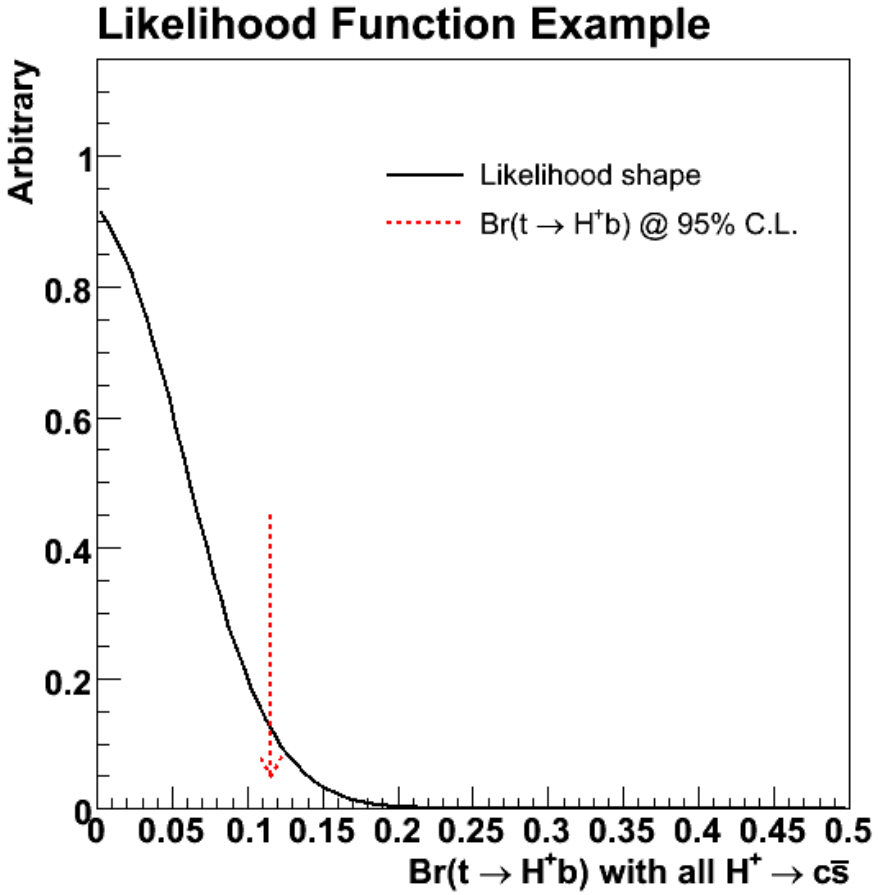


The systematic uncertainties are symmetrized and are put into as a Gaussian input for smearing the likelihood value in each br(t→H+b)

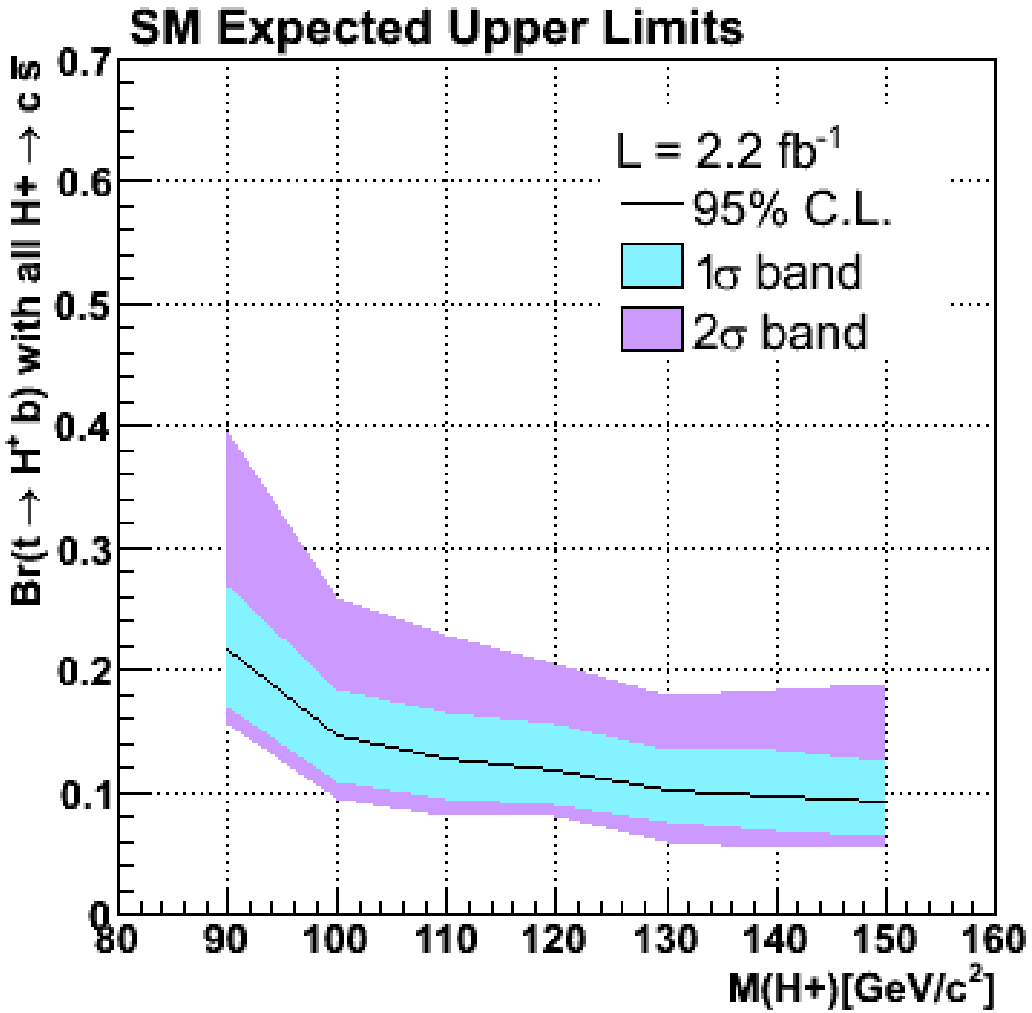
Upper Limit on Br(t→H⁺b)

4

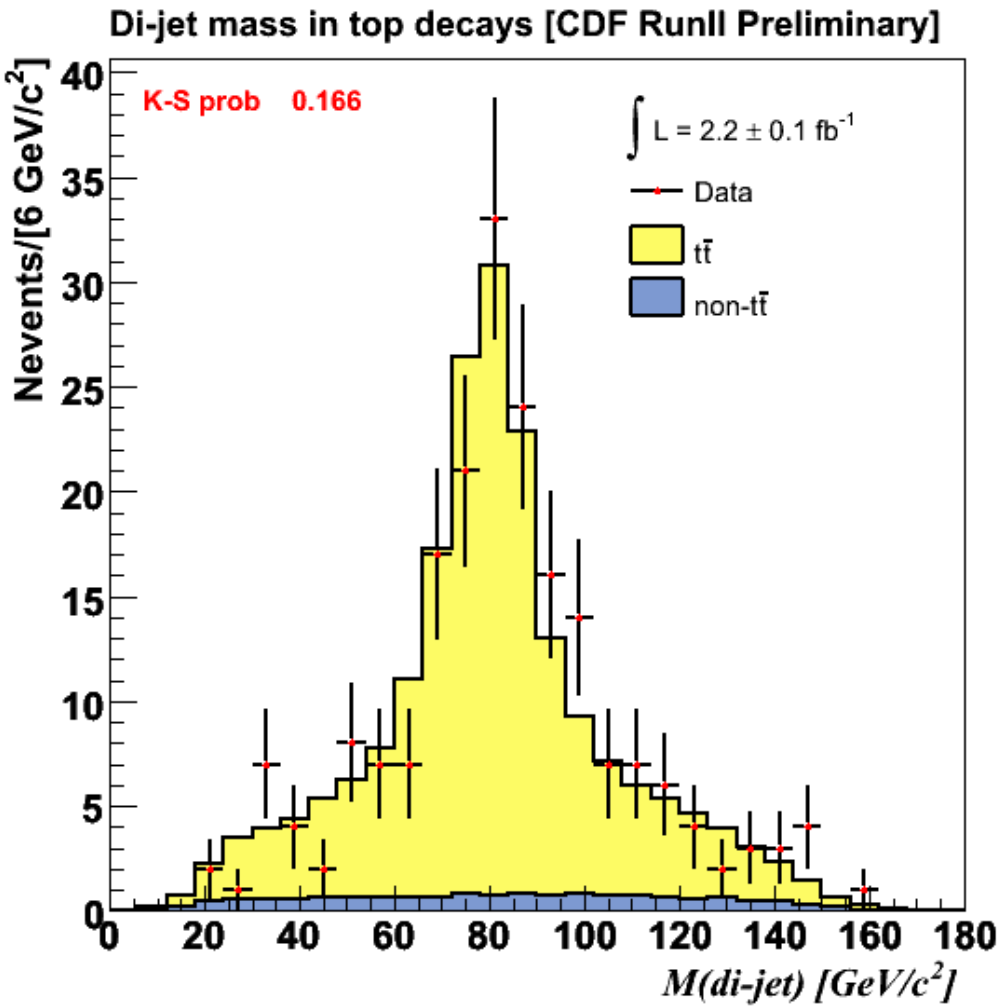
- Upper limit on the br(t→H⁺b) is calculated by
  - ☑ Integration of the likelihood function up to 95% of positive (physical) branching ratio area
  - ☑ Projection onto x-axis is the upper limit on the branching ratio at 95% C.L.



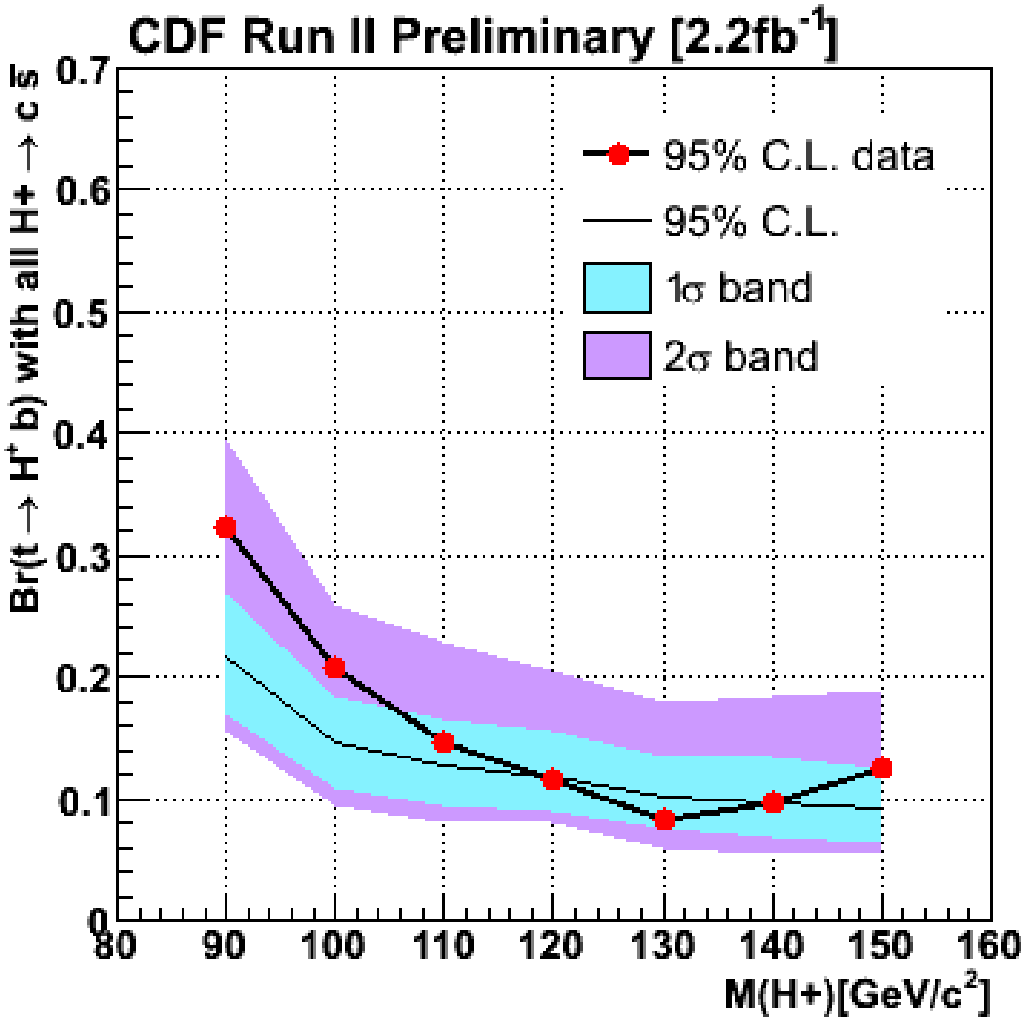
Expected Limit on Br(t→H⁺b)



Di-jet Mass in 2.2 fb^{-1} Top Decays



Upper Limit Br(t→H⁺b) @ 95% C.L.

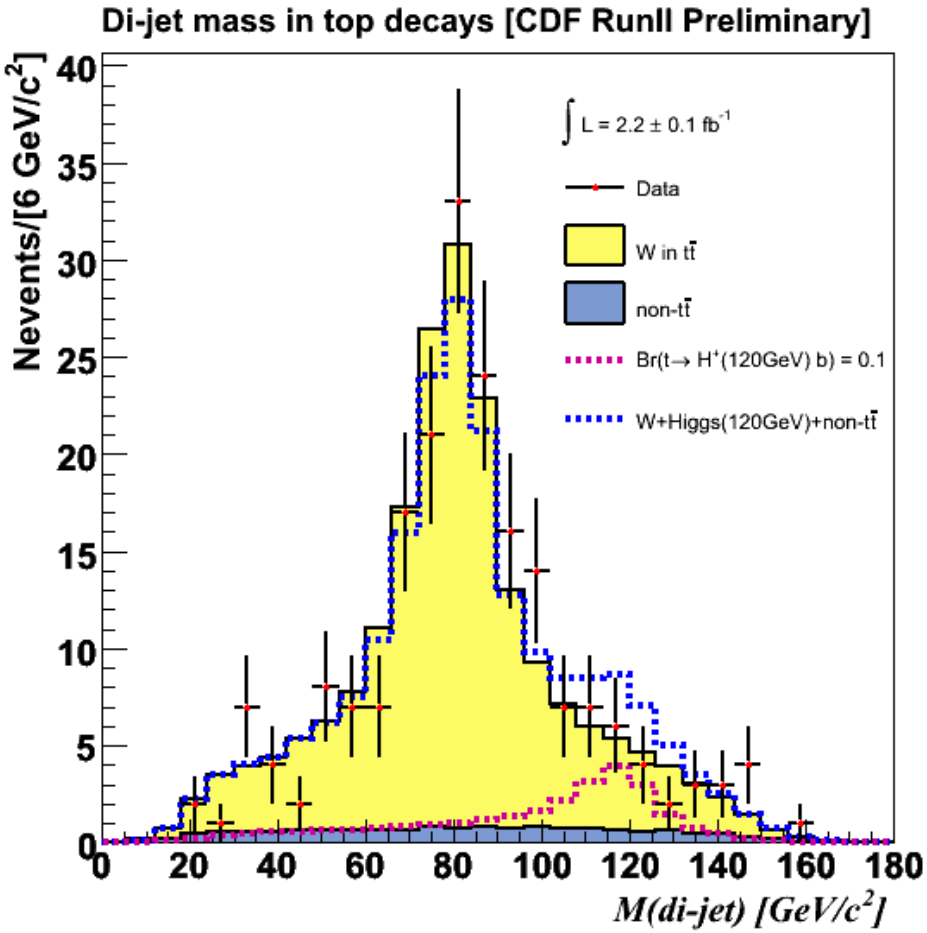


Conclusion

- Search for the charged Higgs in lepton+jets top decays
  - ☑ Look for an anomalous mass bump in di-jet mass distribution in hadronic side top decays
  - ☑ Di-jet mass resolution is improved by adding up near by extra jet to the closest leading jet
- Looking at the 2.2fb^{-1} of CDF data
  - ☑ No significant excess in the di-jet mass distribution
  - ☑ Set the upper limit on br($t \rightarrow H^{+}b$), 0.32 to 0.1, for Higgs mass, 90 GeV – 150 GeV.

BACKUP SLIDES

Assume 120 GeV H^+ events in top decays



- The top events including H^+ (dashed) vs. top (yellow) events without H^+
- The charged Higgs entries corresponds to upper limit on br(t→H+b) = 0.1 @ 95% C.L.

How the 5th jet is distributed

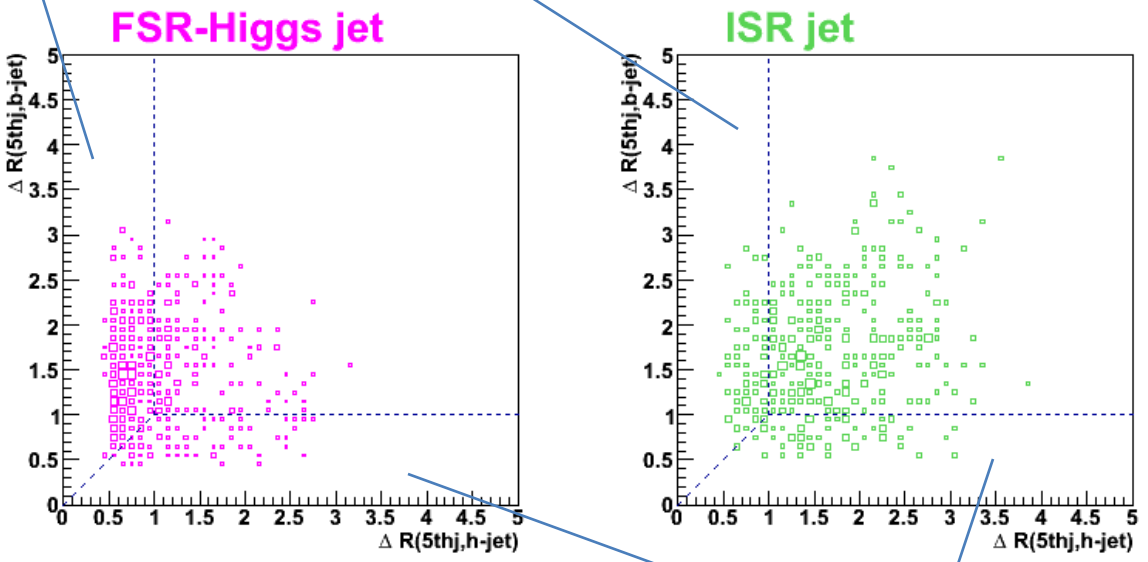
- The 5th jet in $t\bar{t}$ events from Higgs particle (FSR) or incoming quarks (ISR)

$$\Delta R(jet_1, jet_2) = \sqrt{(\eta_{jet1} - \eta_{jet2})^2 + (\varphi_{jet1} - \varphi_{jet2})^2}$$

5th jet added to Higgs jet

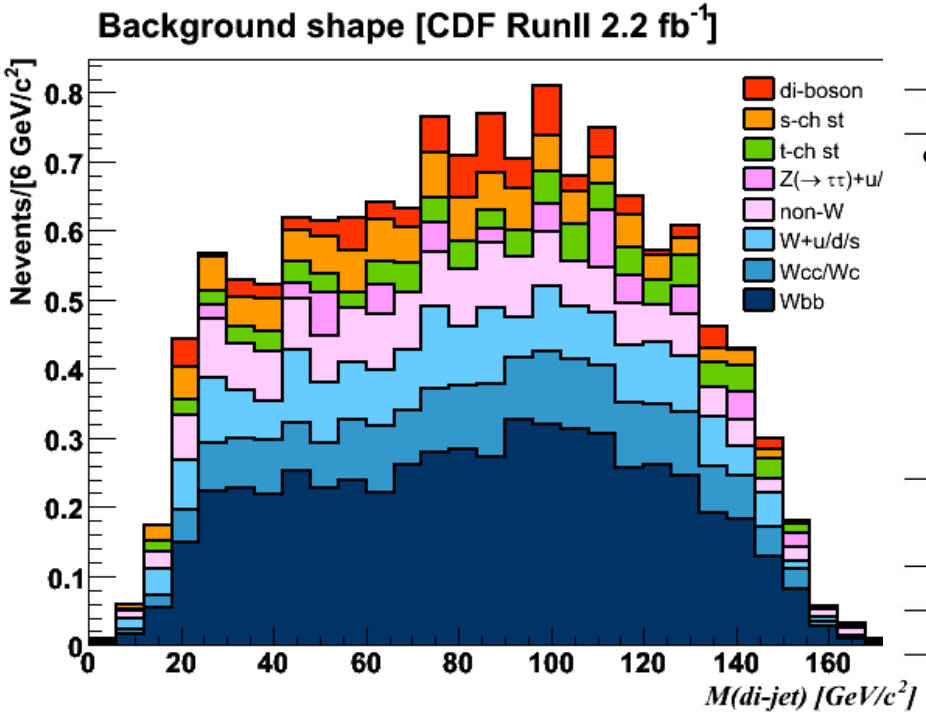
ΔR(5th jet,h-jet) in X-axis
ΔR(5th jet,b-jet) in Y-axis

78% is a real FSR Higgs jet.



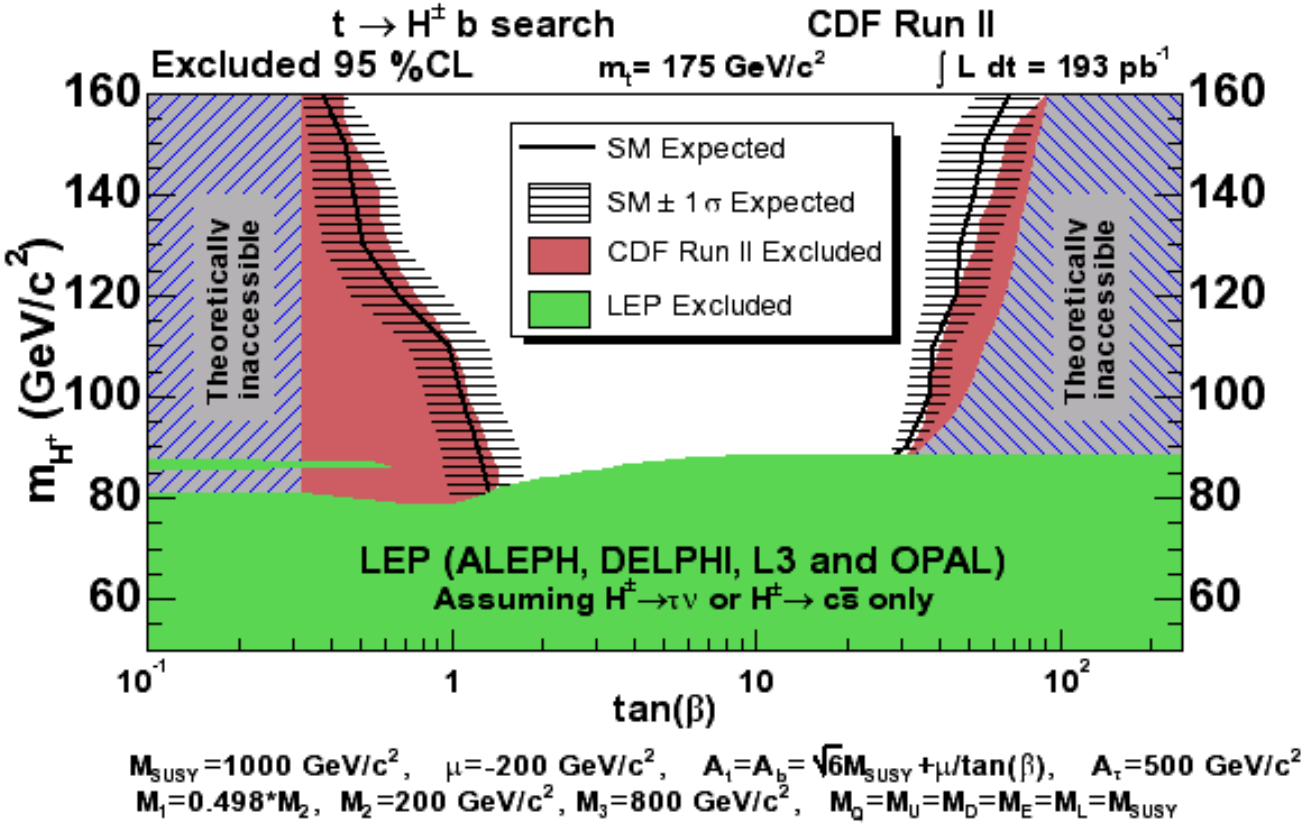
5th jet added to b-jet

Non-ttbar background composition



Process	CDF Run II Preliminary (2.2 fb^{-1}) $\geq$ 4 tight jets	fraction(%)
di-boson(WW/ZZ/WZ)	0.7 ± 0.1	0.4
s-channel single Top	1.0 ± 0.1	0.5
t-channel single Top	0.8 ± 0.1	0.5
Z+lf	0.5 ± 0.1	0.3
W+bb	5.6 ± 2.3	3.4
W+cc/W+c	1.9 ± 0.8	1.1
W+lf	1.9 ± 0.6	1.1
non-W	1.6 ± 3.3	0.9
non-$t\bar{t}$	13.9 ± 7.5	8.4
$t\bar{t}$ (6.7pb)	152.6 ± 25.0	91.6
Total Prediction	166.5 ± 32.4	100
Observed	200	

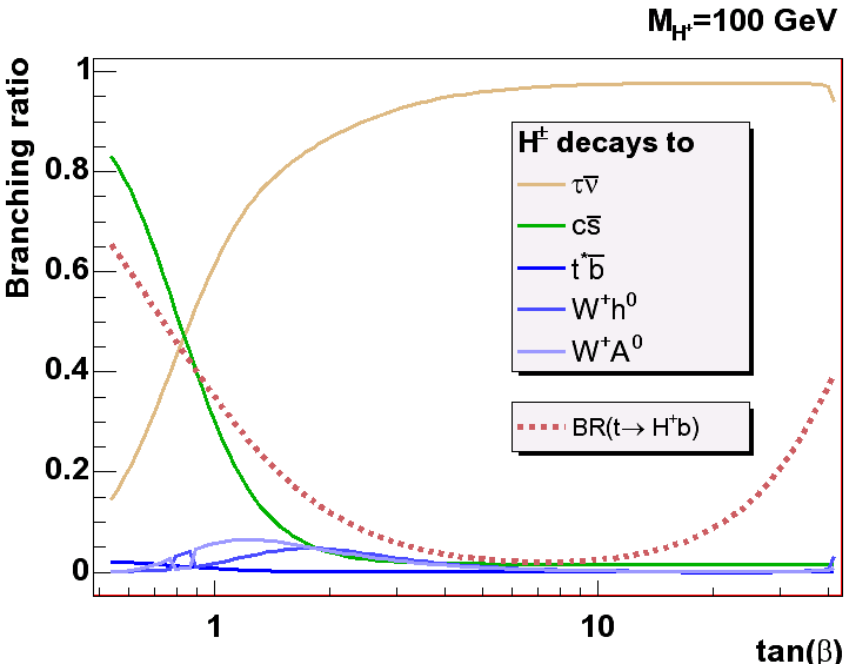
MSSM exclusion

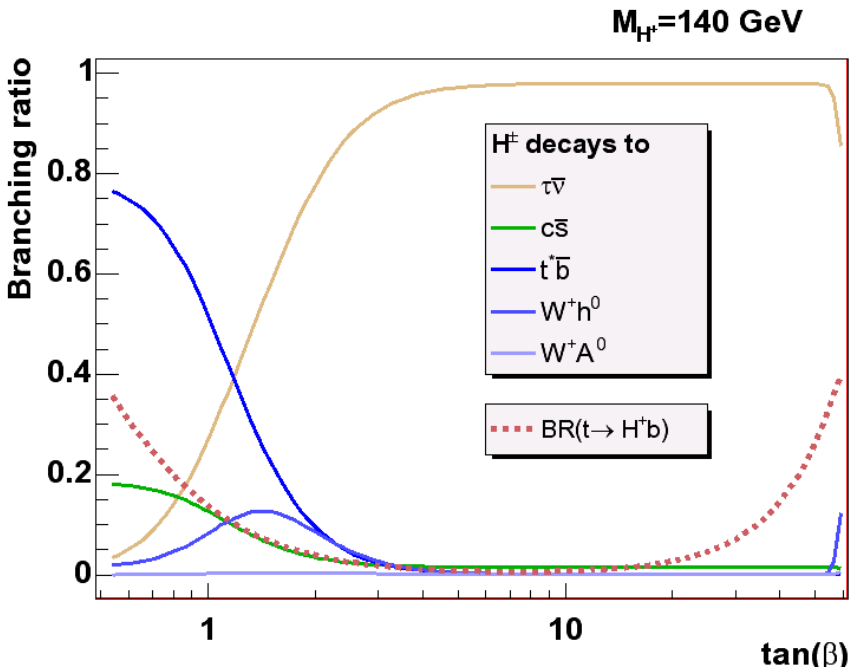


R. Eusebi et al., The CDF Collaboration, Phys. Rev. Lett. 96, 042003 (2006)

This is the typical benchmark scenario developed for the search of h0 at LEP (hep-ph/9912223). The value of At is computed as a function of tan(β), allowing for the maximum mass of the h0 for each value of tan(β).

Branching ratio for other Higgs mass

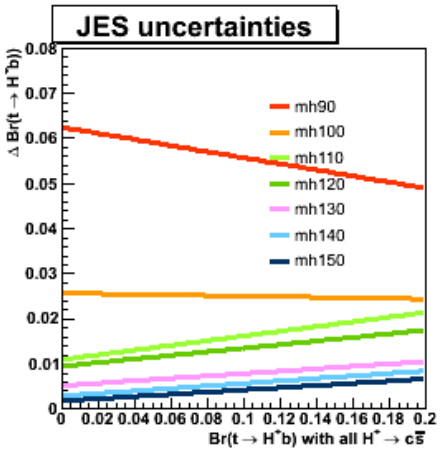


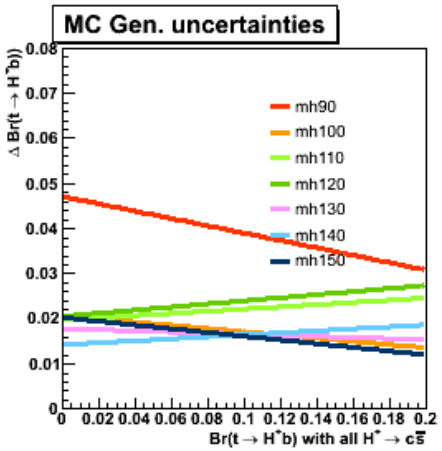


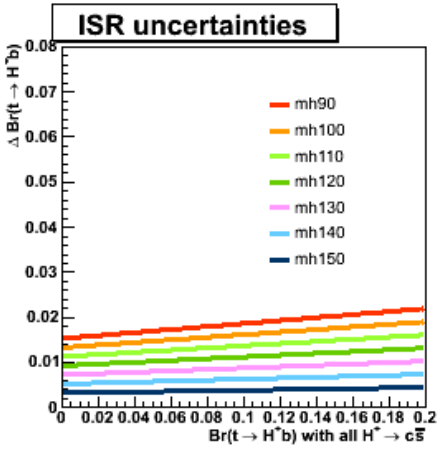
$$\tan\beta=\frac{v_2}{v_1}, v_1^2+v_2^2=\frac{2m_w}{g}$$

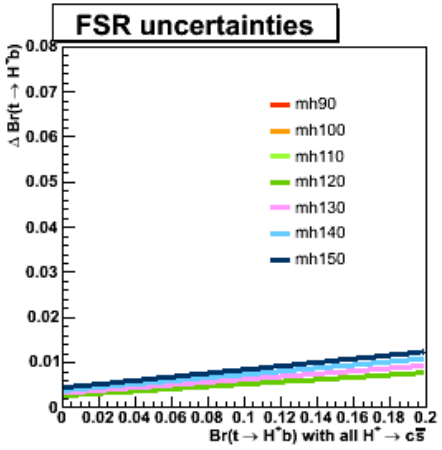
Systematic Uncertainties
in detail

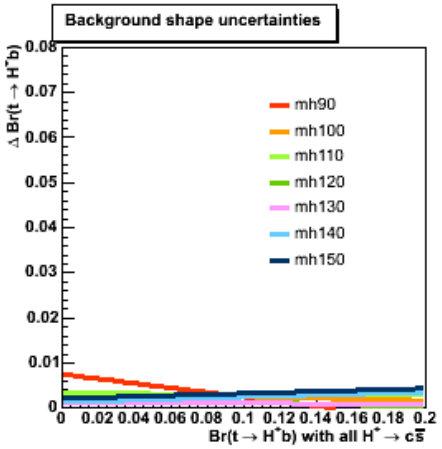
- Jet energy scale correction
- Selection of MC generator (Pythia vs. Herwig)
- Initial State Radiation
- Final State Radiation
- Q^2 scale difference for W+jets background generation
- B-tagging Efficiencies

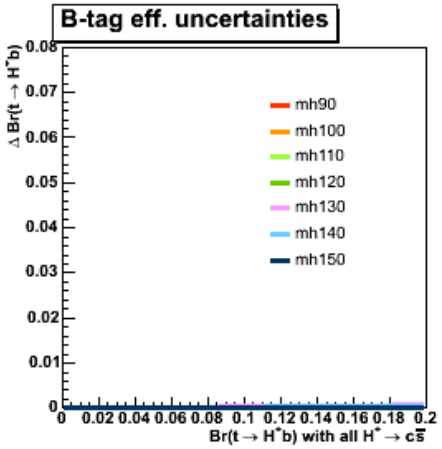












Likelihood Integrity