Limits on charged Higgs using the XS measurements.

Full Status Report

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Documentation

- http://b0urpc.fnal.gov/~eusebi/HiggsAnalysis.html
- CDF note 7151

Outline

- Introduction / Motivation
- Present limits
- Methods :
  - Model Independent
  - Model dependent
- Results
- Conclusions / Future

Introduction

MSSM : Higgs sector based in a two scalar doublet model.

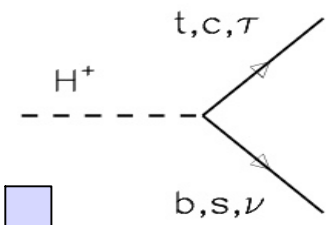
E.S.B results in 5 Higgs bosons, 3 neutral and 2 charged.

Lagrangian : (diagonal CKM approx.)

$$L = \frac{g}{\sqrt{2}m_W} H^+ \left[\cot(\beta) m_{ui} \bar{u}_i d_{iL} + \tan(\beta) m_{di} \bar{u}_i d_{iR} + \tan(\beta) m_{li} \bar{\nu}_i l_{iR} \right] + H.c.$$

Parameter space (m_H , tan(β)) Determines the decays modes for top and $H^\pm$

H^+ coupling to fermions



$\tan\beta < 1 : \frac{ig}{\sqrt{2}\, m_w} m_{t,c,\nu} \cot\beta$

$\tan\beta > 50 : \frac{ig}{\sqrt{2}\, m_w} m_{b,s,\tau} \tan\beta$

Top	**t→W b**	**Higgs**	**H→c s**
	t→H b		**H→τ υ**
			H→Wbb

tt➔W bWb	1	channel
tt➔W bHb	3	channels
tt➔HbHb	6	channels

•Large H^+tb coupling at tan(β) ≤ 0.3 and tan(β) ≥175

Tevatron : $H^\pm$ production from $t\bar{t}$ via t->$H^\pm$b, competes with t->Wb

How likely is this scenario, given the measured cross sections?

Present limits

- **LEP :** Direct search; M_H > 78.6 GeV/c2 @ 95 % CL, irrespective of tan(b). Combined result from ALEPH, DELPHI, L3 and OPAL collaborations.

- **CLEO :** Indirect limit; measurement of b->sg decay rate results in M_H>(244 + 63/tan(b)$^{1.3)}$ GeV assuming 2HDM only. Can be circumvented in SUSY.

- **ALEPH :** Direct search; b->t n :tan(b)<0.52 GeV M_H @ 90 % CL.

- **Tevatron :** Run I, results in the (m_H,tan(b)) plane :
  - CDF : Direct search in t->Hb->t nb.
  - CDF & D0 : indirect searches using the "Lepton+Jets" (+"Dilepton" for CDF) analyses using leading order calculations in similar to this studies.
  - D0 : analysis using NN.

We will compare our results to all the LEP and Tevatron results at the result section of this talk.

Method

For each top quark we have 4 possible decay modes

1) $t \to Wb$ 2) $t \to Hb \to c\bar{s}b$

3) $t \to Hb \to \tau\upsilon b$ 4) $t \to Hb \to Wb\bar{b}b$

In a $t\underline{t}$ cross section measurement the efficiency is

$$\varepsilon_{tot} = \sum_{i,j=1}^{4} \varepsilon_{i,j} B_i B_j$$

Total Efficiency for Cross section

Efficiency for decay mode i,j
$e_{i,j}=F(m_H)$
$e_{1,1}=const$

Branching fractions
$=F(M_H,\tan(b))$

We will recalculate the efficiency of three cross section analyses.

Method (cont.)

$$Define \quad \alpha \equiv BR(t \to H^{\pm} b) \qquad (\text{Cross Section Mode})\text{XSM} \equiv \{\text{Dilepton}, \quad \text{L+Jets}, \quad \text{others...}\}$$

$$N_{XSM}^{tt} = N_{\text{XSM}}^{\text{back}} + \sigma_{tt}^{prod}\left[(1-\alpha)^2 \varepsilon_{WW,XSM} + 2\alpha(1-\alpha)\varepsilon_{WH,XSM}(m_H,\beta) + \alpha^2 \varepsilon_{HH,XSM}(m_H,\beta)\right]$$

We can factorize the tan(β) dependence out of the efficiencies

$$\begin{aligned}
\varepsilon_{WW,XSM} &= \varepsilon_{WW,XSM}\,!! \\
\varepsilon_{WH,XSM} &= BR(H \to c\bar{s})\varepsilon_{WH \to Wc\bar{s},XSM}(m_H) \\
&\quad + BR(H \to \tau\upsilon)\varepsilon_{WH \to W\tau\upsilon,XSM}(m_H) + BR(H \to Wb\bar{b})\varepsilon_{WH \to WWb\bar{b},XSM}(m_H) \\
\varepsilon_{HH,XSM} &= BR^2(H \to c\bar{s})\varepsilon_{HH \to \bar{c}sc\bar{s},XSM}(m_H) \\
&\quad + BR^2(H \to \tau\upsilon)\varepsilon_{HH \to \tau\bar{\upsilon}\bar{\tau}\upsilon,XSM}(m_H) \\
&\quad + BR^2(H \to Wb\bar{b})\varepsilon_{HH \to \bar{W}\bar{b}bWb\bar{b},XSM}(m_H) \\
&\quad + 2BR(H \to c\bar{s})BR(H \to \tau\upsilon)\varepsilon_{HH \to c\bar{s}\,\tau\upsilon,XSM}(m_H) \\
&\quad + 2BR(H \to c\bar{s})BR(H \to Wb\bar{b})\varepsilon_{HH \to c\bar{s}\,Wb\bar{b},XSM}(m_H) \\
&\quad + 2BR(H \to Wb\bar{b})BR(H \to \tau\upsilon)\varepsilon_{HH \to Wb\bar{b}\tau\upsilon,XSM}(m_H)
\end{aligned}$$

We can get the 10 eff's from MC.

Question : Where do we get the BR's from?

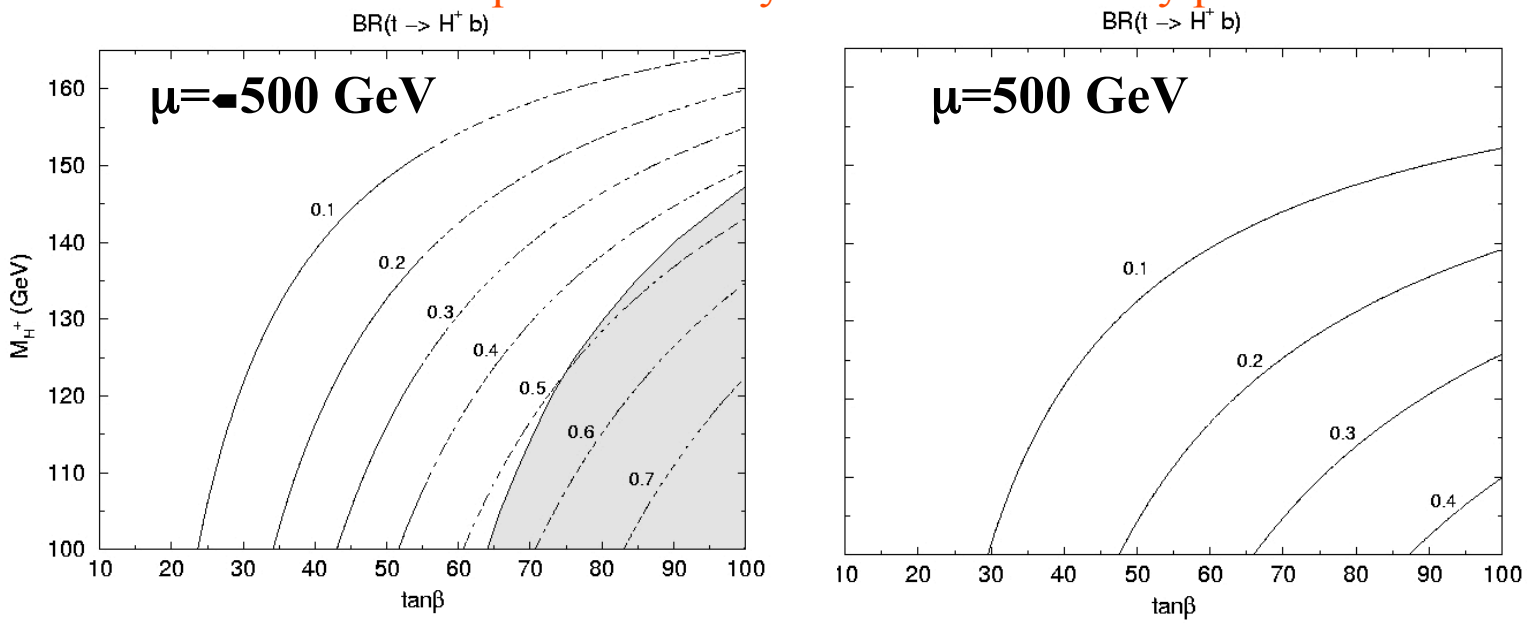
Branching Ratios from ME

Question : Where do we get the BR's from?

A1: We can get BR's from ME calculations.

Caveat: Loop corrections are huge and model dependent.

In MSSM correction depends on many other unknown susy parameters.



Extracted from hep-ph/9912516.

D0's result from Run I can be made null by choice of **μ**

Branching Ratios, explicit ignorance

Question : Where do we get the BR's from?

A2: Can we get a measurement of **BR(t→Hb)** explicitly expressing our ignorance in the **BR(H → xx)** ?

YES. Caveat: Limits may not be as strong as with a specific model.

We'll pursue both answers and get limits using two models :

Model Independent / Simplified Model

Get limits of **BR(t→Hb)** without assumptions on H decays.

Model Specific

Include specifics of the model in the eff's. (BR's, Widths, 3Body decay topology, etc)

Get limits for some specific benchmark parameters.

Example : MSSM=F(parameters) predicts BR's, set limits on parameters.

Likelihood in bayesian statistics

- In general we use the same calculation in both models, only difference is the set of parameters ρ .
- Probability of parameters given the obtained number of candidates :

$$P(\rho \mid n_{ll}, n_{lj}, n_{l\tau}) = \frac{L(n_{ll}, n_{lj}, n_{l\tau} \mid \rho)\pi(\rho)}{\int_P L(n_{ll}, n_{lj}, n_{l\tau} \mid \rho')\pi(\rho')d\rho'}$$

Where L is the likelihood and $\pi(\rho)$ is the prior probability density in the parameters. In general we will take flat priors.

- L can be written as :

$$L(n_{ll}, n_{lj}, n_{l\tau} \mid \rho) =$$

$$= \frac{1}{N}\int_0^\infty\int_0^\infty\cdots\int_0^\infty \prod_{XS=ll}^{l\tau}\left\{\frac{\mu'^{n_{XS}}_{XS} e^{-\mu'_{XS}}}{n_{XS}!} G(\varepsilon'_{XS}, \varepsilon_{XS}) G(b'_{XS}, b_{XS}) d\varepsilon'_{XS} db'_{XS}\right\}$$

and the μ's are : $\mu^{tt}_{XS} = b_{XS} + L\sigma^{prod}_{tt}\varepsilon_{XS}(\rho)$

Likelihood evaluation

- Evaluate the likelihood using MC integration.

$$L(n_{ll}, n_{lj}, n_{l\tau} \mid \rho) \cong \frac{1}{N} \sum_{n=1}^{N} \frac{\mu_{ll}'^{\,n_{ll}} e^{-\mu_{ll}'}}{n_{ll}!} \times \frac{\mu_{lj}'^{\,n_{lj}} e^{-\mu_{lj}'}}{n_{lj}!} \times \frac{\mu_{l\tau}'^{\,n_{l\tau}} e^{-\mu_{l\tau}'}}{n_{l\tau}!}$$

- In each element of the sum the independent numbers are allow to vary within its errors. The errors in the correlated numbers are then calculated. With all numbers at hand the three different μ's are calculated :

$$\mu_{XS}^{tt} = b_{XS} + L\sigma_{tt}^{prod}\varepsilon_{XS}(\rho) \quad \mathrm{XS} = \{\mathrm{Dilep}, \mathrm{LJets}, \mathrm{LTauH}\}$$

- The product of the Poisson's is computed and added to average. This procedure take naturally into account all correlations. See CDF note 7151 for details.

Model Independent : Extracting info from Cross Sections

- **Parameter set :**

$$\beta = BR(H^+ \to c\bar{s})$$

$$\alpha = BR(t \to H^+ b) \quad \gamma = BR(H^+ \to Wb\bar{b})$$

$$\delta \equiv BR(H^+ \to \bar{\tau}\upsilon) \equiv 1 - \beta - \gamma$$

- Probability of the diff BR's given the obtained number of candidates :

$$P(\alpha, \beta, \gamma \mid n_{ll}, n_{lj}, n_{l\tau}) = \frac{L(n_{ll}, n_{lj}, n_{l\tau} \mid \alpha, \beta, \gamma)\, \pi(\alpha)\pi(\beta)\pi(\gamma)}{\iiint L(n_{ll}, n_{lj}, n_{l\tau} \mid \alpha', \beta', \gamma')\, \pi(\alpha')\pi(\beta'')\pi(\gamma')\, d\alpha' d\beta' d\gamma'}$$

- $\pi(\alpha)$,$\pi(\beta)$,$\pi(\gamma)$ are the prior probability densities in the branching ratios. We take them uniform in this model independent study.

Model Independent : P(t->Hb)

- Assuming the theoretical $\sigma^{\tau\tau}$ =(6.7+0.7) pb^{-1}we'd expect :

  11 events in the Dilepton channel .

  66 events in the L+Jets channel.

  2 events in the L+Hadronic Tau channel.

- Calculate L(11,66,2|α,β,γ) for all α,β,γ (Eq. slide 9)

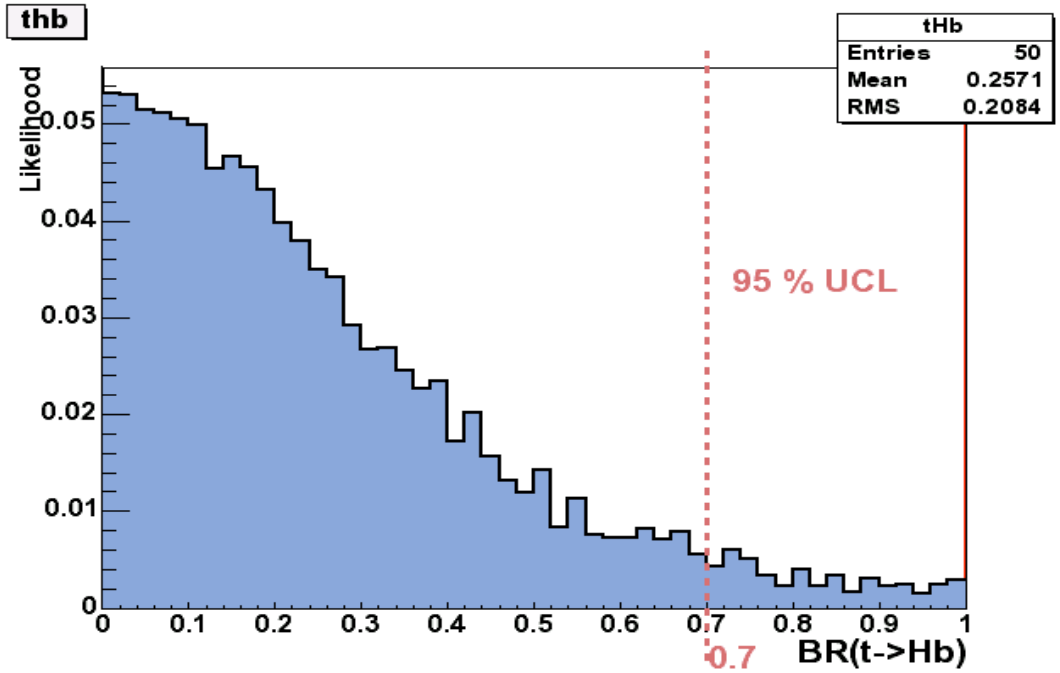
- Calculate the P(α|11,66,2) by integrating Eq. in slide 11

$$P(\alpha,|\, n_{ll}, n_{lj}, n_{l\tau}) = \frac{\int_0^1 d\beta' \int_0^{1-\beta'} d\gamma' \; L(n_{ll}, n_{lj}, n_{l\tau} \,|\, \alpha, \beta', \gamma')\, \pi(\alpha)\pi(\beta')\pi(\gamma')}{\iiint L(n_{ll}, n_{lj}, n_{l\tau} \,|\, \alpha', \beta', \gamma')\, \pi(\alpha')\pi(\beta'')\pi(\gamma')\, d\alpha' d\beta' d\gamma'}$$

- Get the 95 % CL on P(α|11,66,2)

Model Independent : P(t->Hb) (cont)

For M_H = 120 GeV, assuming SM production only.
We obtain for P(α|11,66,2):



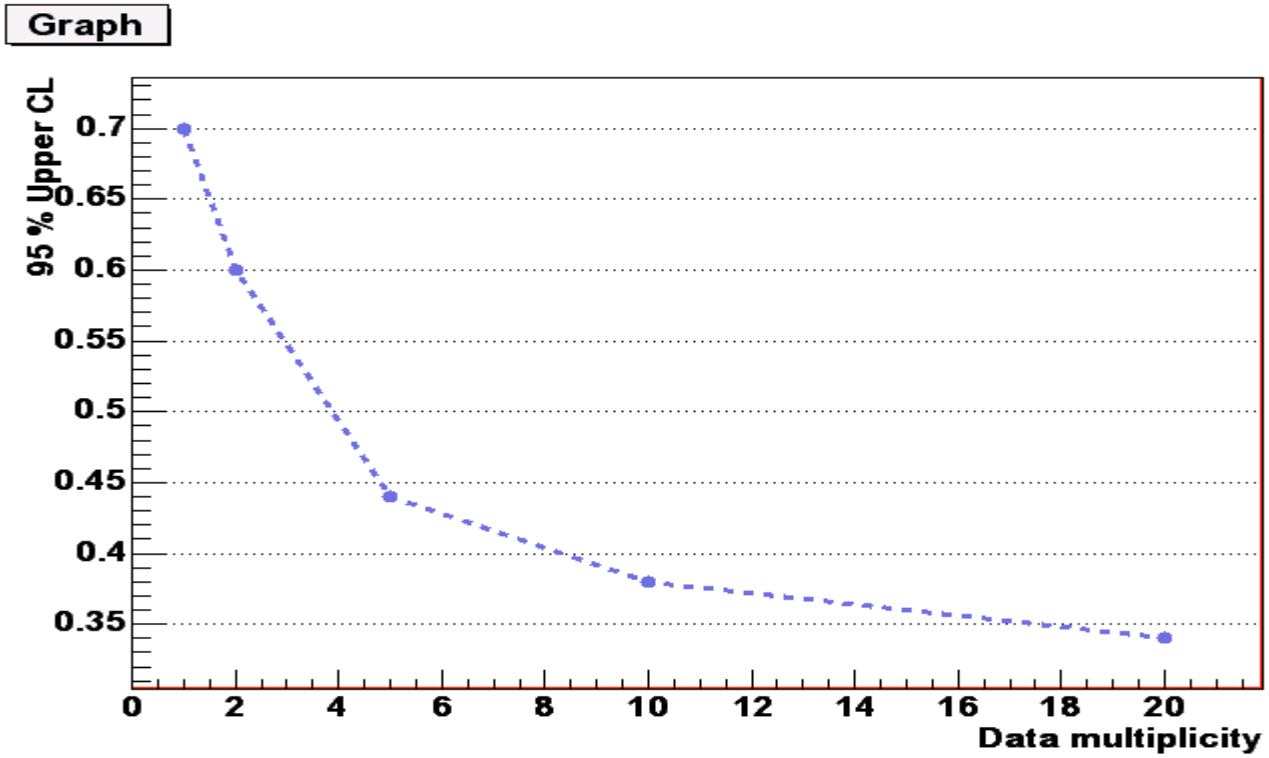
From that **BR(t→Hb)**<0.70 @ 95% CL

Weak limit, but consider the HUGE variable phase space we have.

•Now repeat for different data multiplicities. See how the limits change.

Model Independent : P(t->Hb) sensitivity

Find P(α) for mH = 120 GeV and different data multiplicities:



The 95%UCL evolution with data amount.

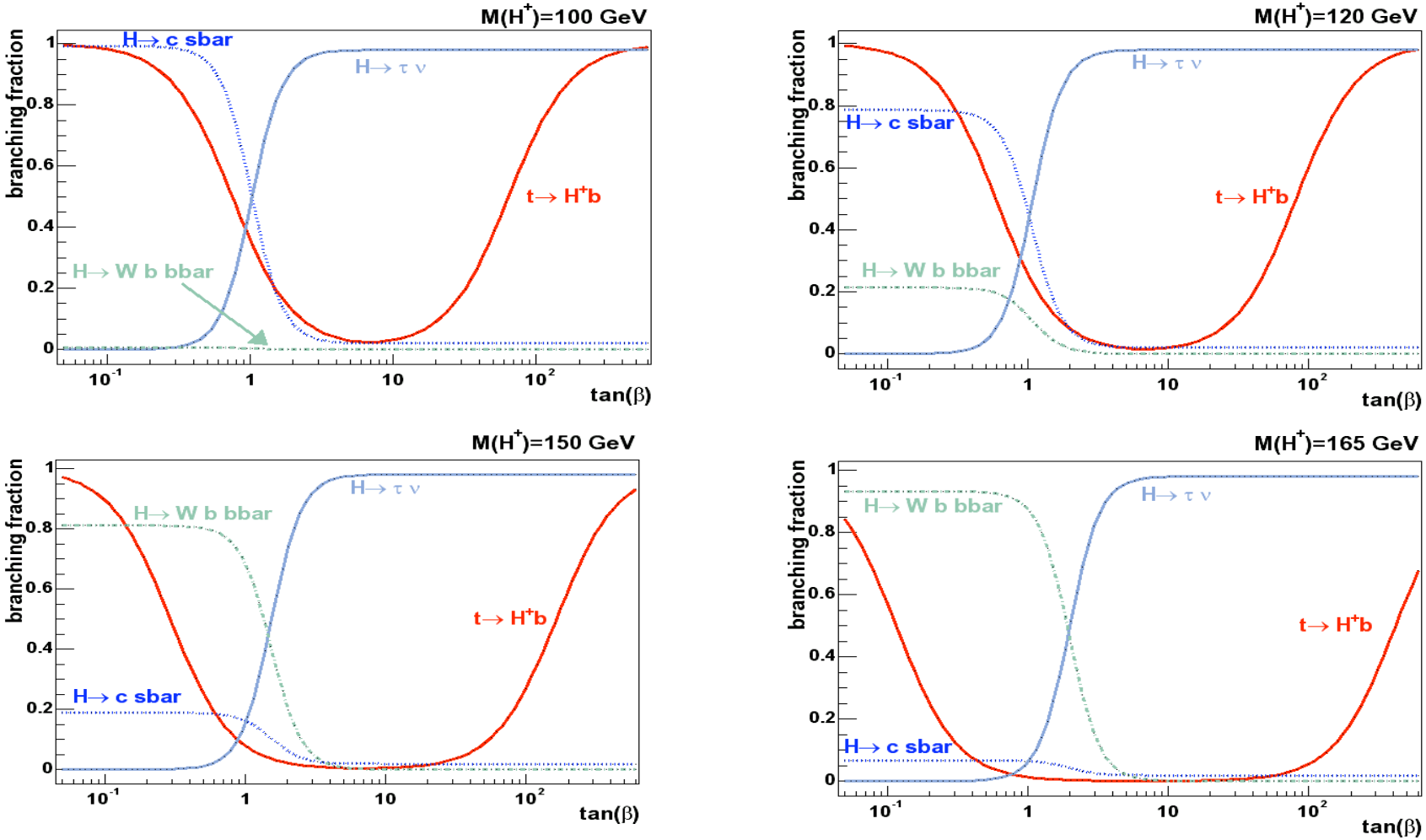
•Limits get stricter, note that with 5 times the current luminosity we should be able to put a limit below 0.44 at 95%CL. No assumptions about H decays used.

Model Independent : Results

Find P(α) for different Higgs' masses using N={13,57,2} obtaining :

Higgs Mass (GeV)	BR(t➔Hb) **Upper 95% CL**
80	0.57
90	0.64
100	0.70
110	0.70
120	0.72
130	0.73
140	0.73
150	0.73

Model Dependent : Tree level branching fractions in MSSM



Model dependent : SUSY

Let start by comparing to what was done in Run 1 (CDF 4295), in which all calculations were done at tree level.

- Datasets with mH =80,100, 120 ,140 and =150 GeV
  - Top mass = 165,175 and 185 GeV
  - BR's fixed to get roughly even number of events per channel.
  - The Higgs width fixed to 1 GeV

- Calculate the efficiencies for all channels in the different XS analysis.
  - Correct eff's to account for widths variations

- Parameter set r = (m_H,tan(β)) . Compute the BR's according to tree level SUSY(mHiggs,tan(β))

Model dependent : SUSY, width corrections

Width-related corrections to eff. Widths grow with phase space and couplings.

Couplings :

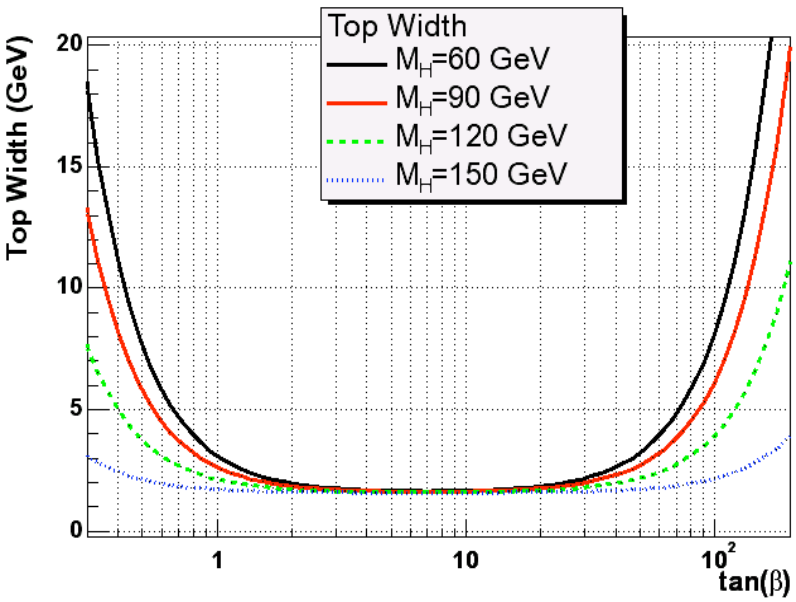
t->Hb coupling get large at high and low tanbeta.

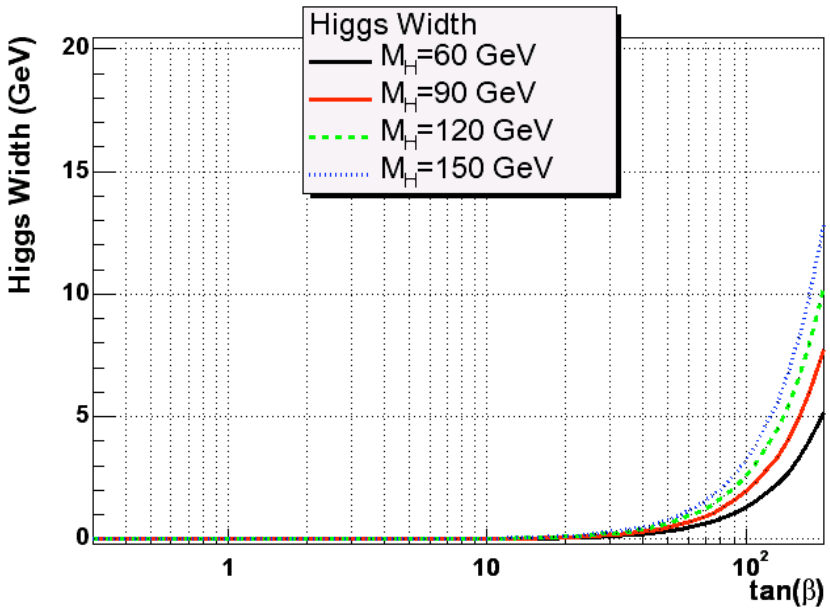
H->τν grows with tan(β)^2.

Phase space :

High m_H ; low Γ_{top} high Γ_H

Low m_H ; high Γ_{top} low Γ_H





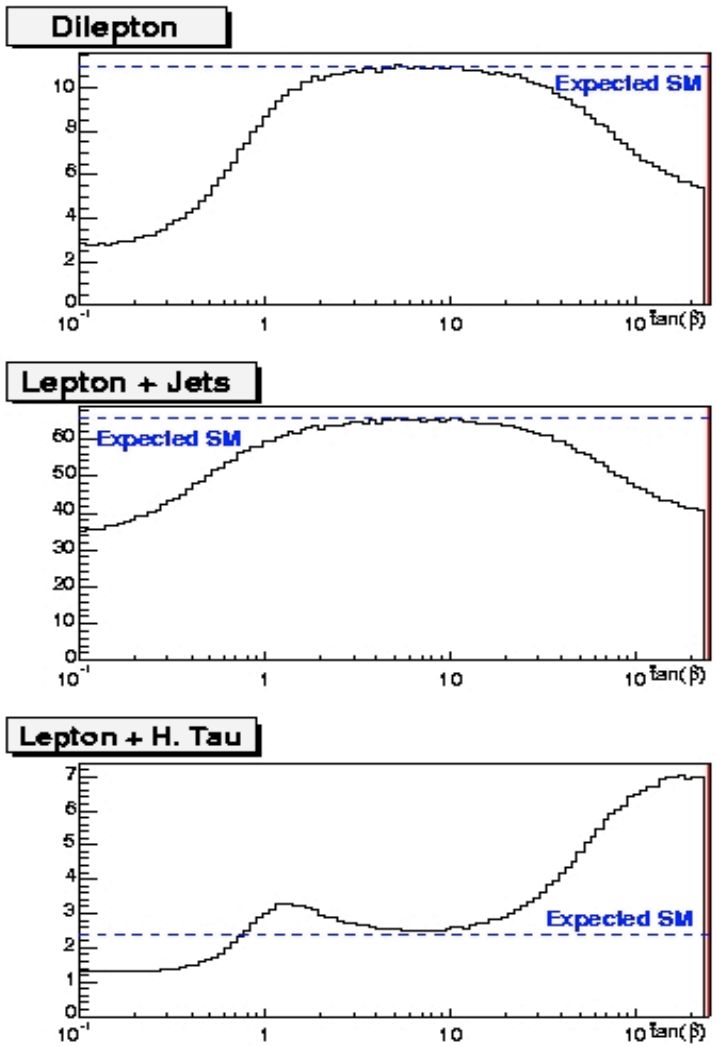
Higgs width correction, high tanbeta region, accounted for here.

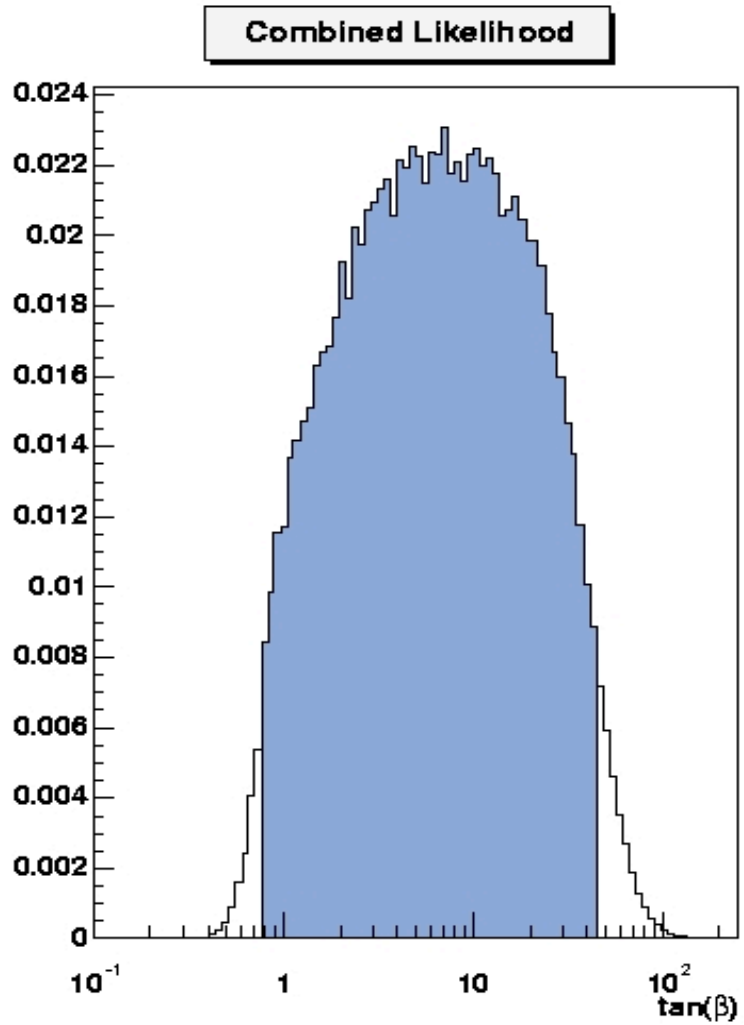
Top width correction accounted too.

Note that it decreases with mHiggs.

Fairly symmetrical below 15 GeV. Don't expect and don't see much change in eff.

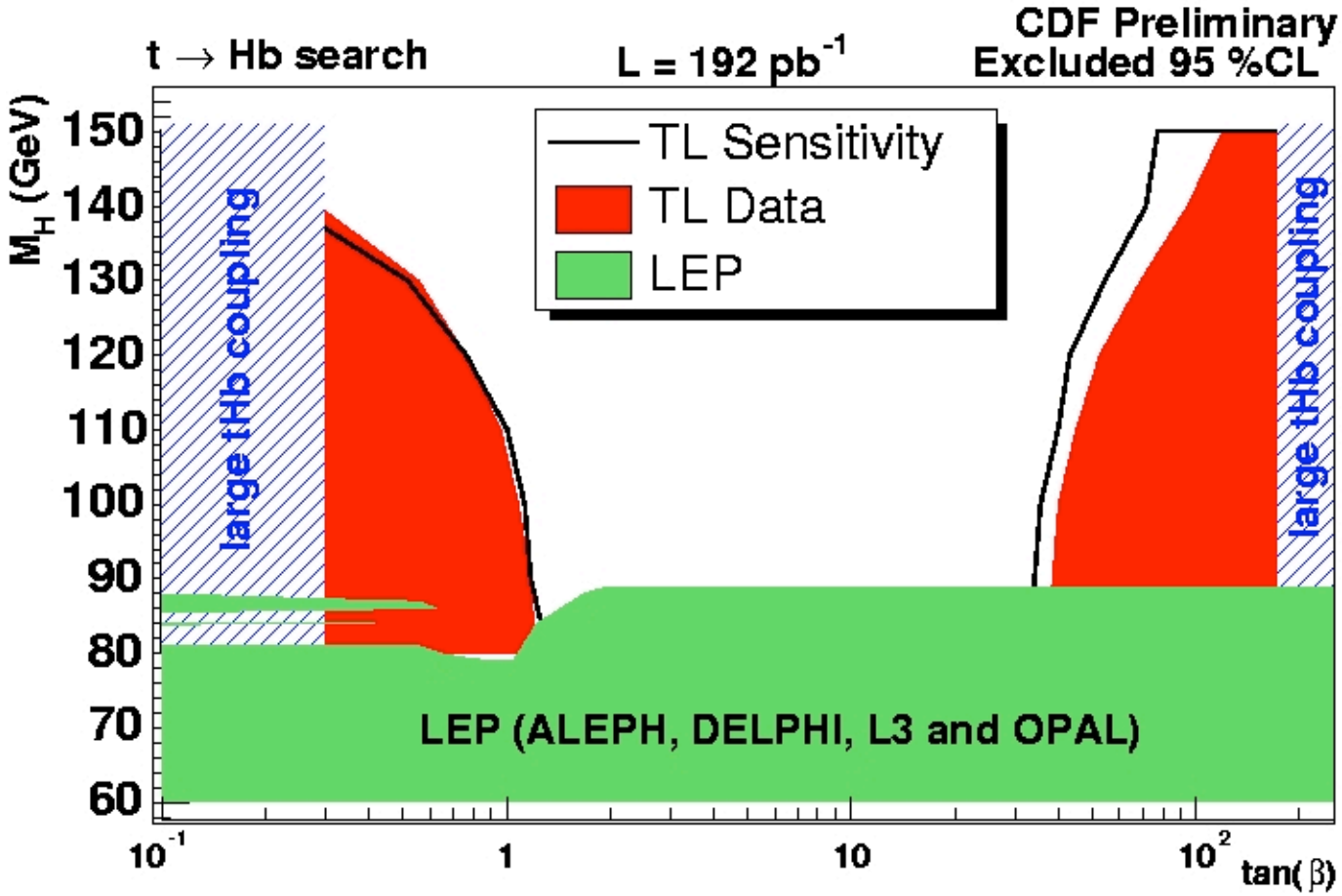
Model dependent : SUSY, expected limits





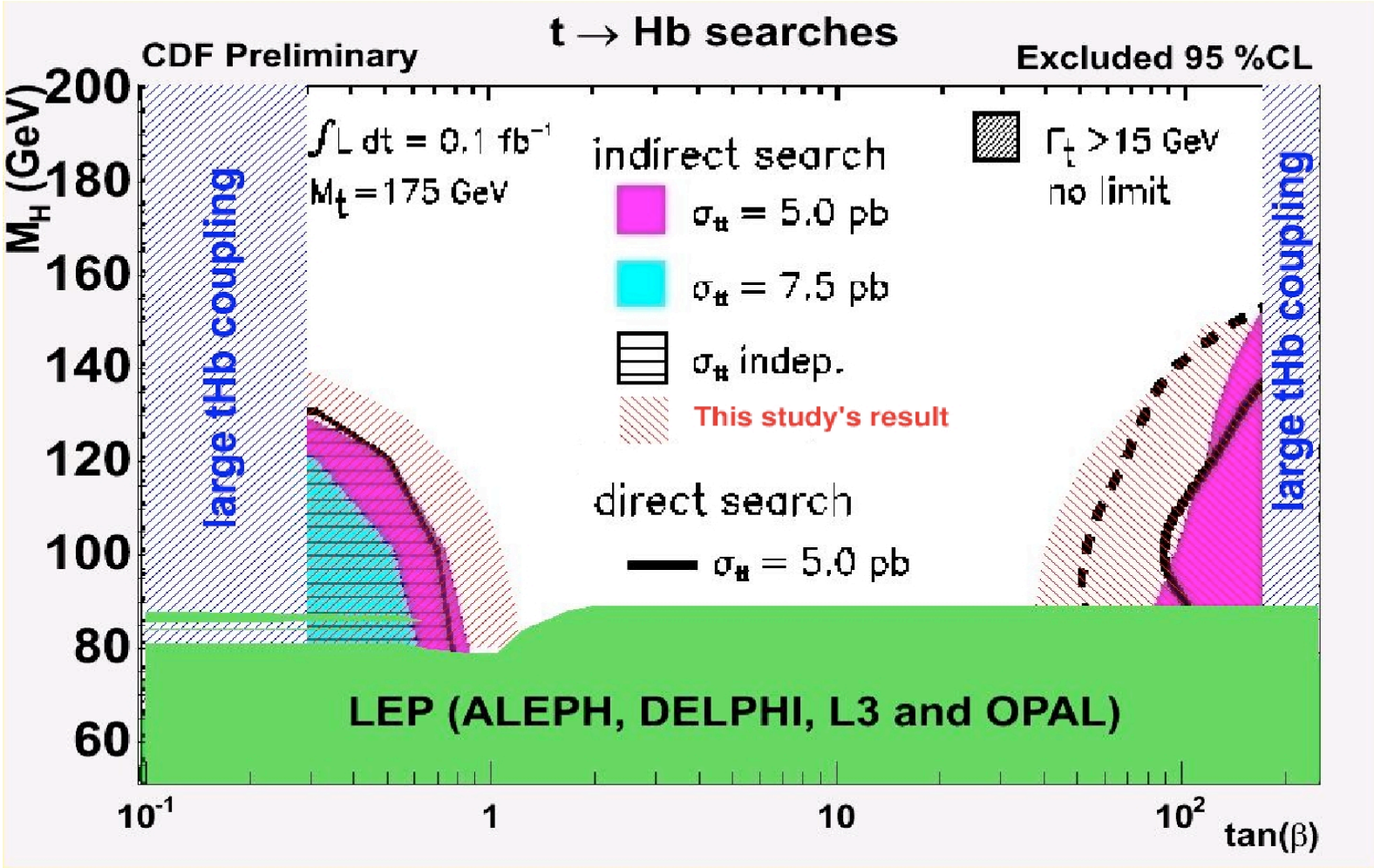
Sensitivity

Model dependent : SUSY, results



Expected and observed limits in good agreement at low tan(β).
High tan(β) region shows a gap.
Pseudoexperiments the next talk!!

Model dependent : SUSY, results at tree level



Results are better at low and high tan(β).

Conclusions :

✓We set limit to BR(t➔Hb) in a model independent fashion.

✓Assuming leading order calculations we set limits in the (m_H,tan(β)) plane.

✓ Our limits are very competitive, surpassing limits set by previous studies under the same assumptions.

To Come:

- PseudoExperiments: obtain the 1-sigma confidence band in the sensitivity lines.
- Loop corrections:
  - Incorporate full corrections, account for QCD, SUSY-QCD and SUSY-EW loop corrections using the formulae that represent the best of the present knowledge.
  - HDecay provides a good estimate of the H BR's. Formulae including all types of loop corrections for high tanbeta is available.
- Sensitivity improvements
  - We are trying to add kinematic analysis to weight in the events. This may have a large impact at large and small tan(β).
- XS analysis
  - Might help optimization of XS analysis. For the moment use them as blessed.
  - Is it worth to include the double b-tag XS analysis?? Might help al low tan(β)

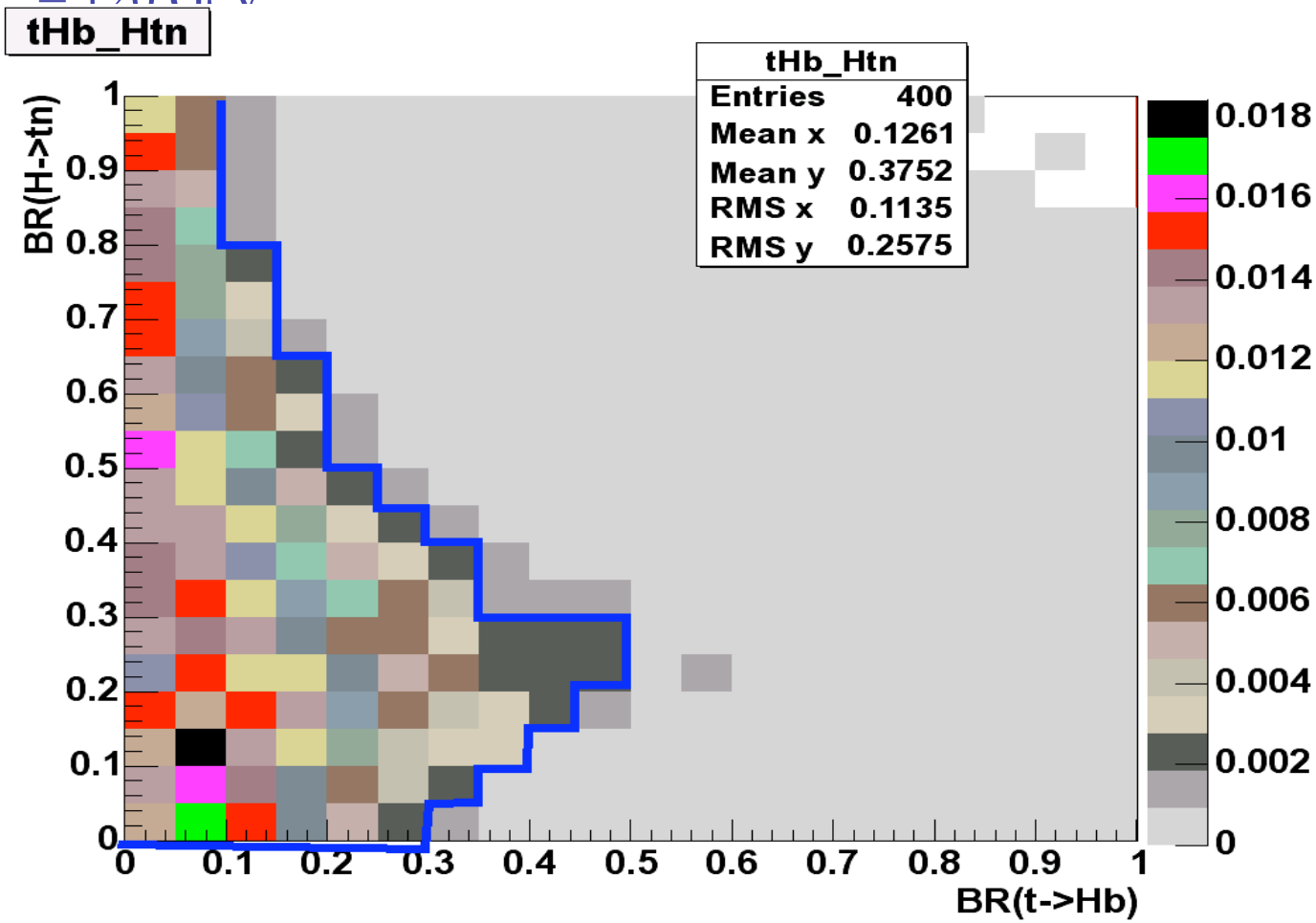
Backup slides

To solve :

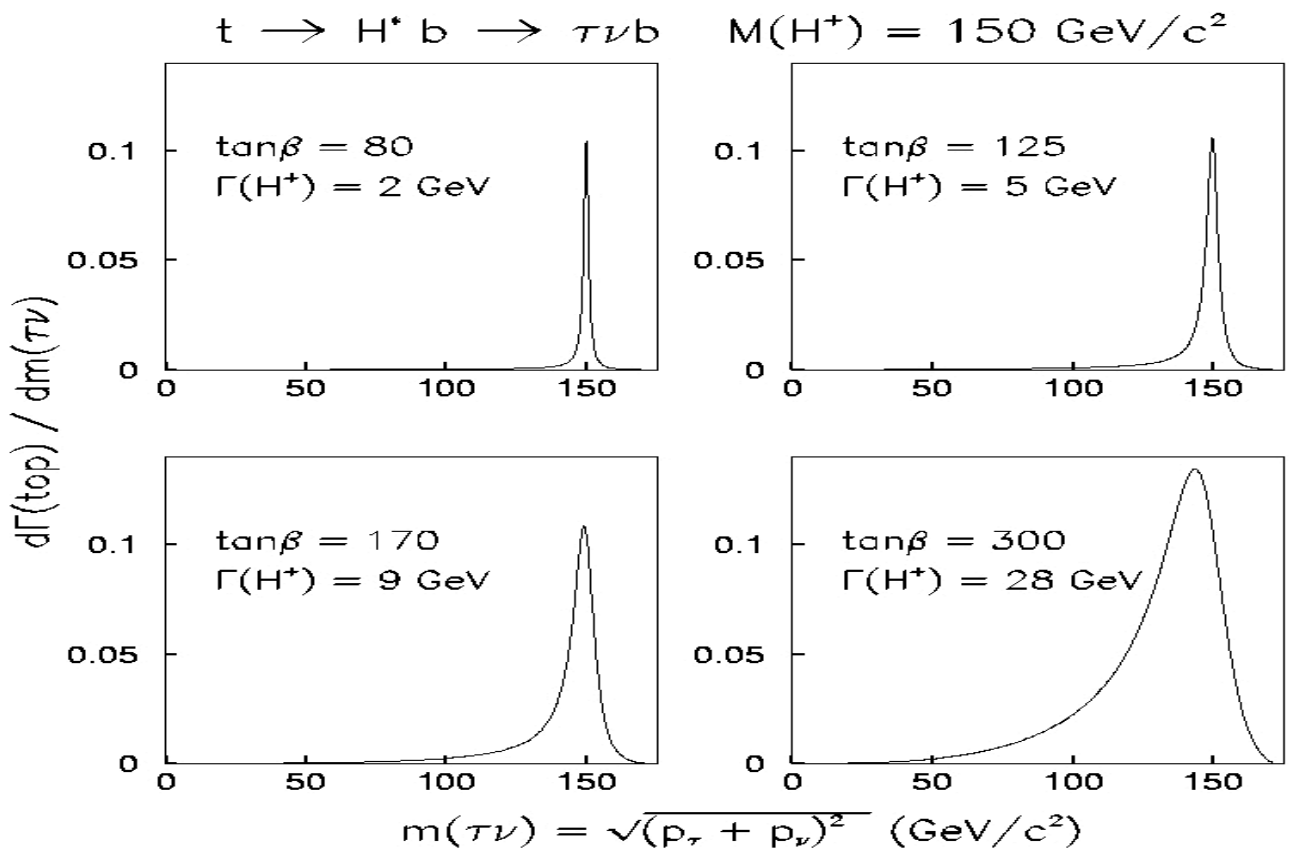
- The decay $H \rightarrow t^*b \rightarrow Wbb$ homogenously populate the phase space. SUSY ME deforms this topology.
  - But Pythia lacks the ME calculations of this decay!!
  - CDF 4295 suggest that this is a small effect, although does not make quantitative statements.

Model Independent : BR(t->Hb) Vs BR(H->tau nu)

Likelihood in the BR(t->Hb), BR(H->Tau nu) plane. mHiggs = 120 GeV



Model dependent : SUSY H-width corrections



The final efficiency is calculated by :

$$\varepsilon(mH_0) = \int_0^{\infty} \varepsilon(mH')\, WF(mH', mH_0)\, dmH'$$

provided the Width Function is normalized