Limits on Charged Higgs using $t\bar{t}$ cross section measurements

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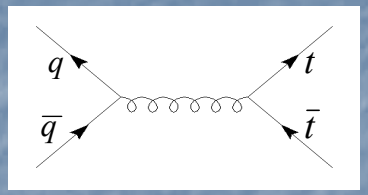
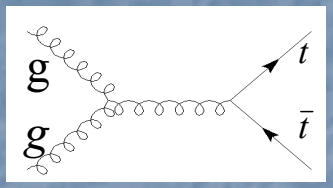
on behalf of the CDF Collaboration

DPF 2004

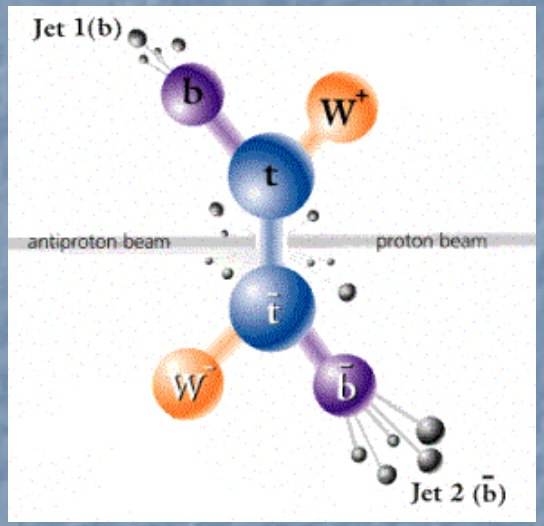
$t\bar{t}$ cross section measurements

Tevatron :





- Top production in pairs
- Top decays to t→Wb before hadronizing
- Events Classified by the W decays :



- *"Dilepton" (e.μ well identified) (5% of total $t\bar{t}$ pairs)*
  - *$t\bar{t} \rightarrow$ blνblν*
- *"Lepton (e,μ) + jets" (30%)*
  - *$t\bar{t} \rightarrow$ blνbqq'*
- *"Lepton (e,μ)+ Had. Tau" (2%)*
  - *$t\bar{t} \rightarrow$ blνbτν ; $\tau \rightarrow$*hadronically
- *"All Jets" (45 %) (not used here)*
  - *$t\bar{t} \rightarrow$ bqq'bqq*

- Production cross section σ calculated from :

$$N^{obs} = N^{back} + \sigma\, \varepsilon_{t\bar{t}\rightarrow WbWb} \int Ldt \longrightarrow \sim 193\ pb^{-1}$$

from data | from data/MC | from MC

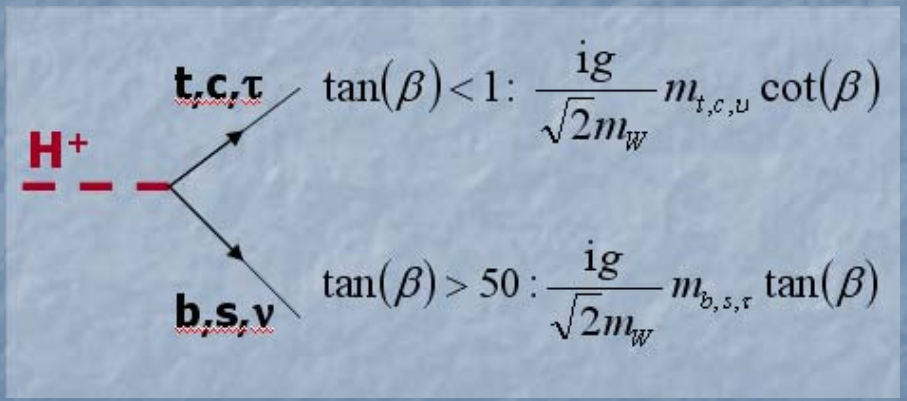
Higgs sector

- **SM neutral Higgs not yet found**
- **Extensions of SM based on a two doublet Higgs model (2HDM)**
  - **One couples to u-type quark and leptons, other to d-type quark and neutrinos**
  - **E.S.B results in 5 Higgs bosons, 3 neutral (h^0, H^0, A^0) and 2 charged ($H^{\pm}$)**

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 $H^{\pm}$



Top		Higgs	
t→W b		$H^+ \to c\,\underline{s}$	
$t \to H^+ b$		$H^+ \to \tau\ \upsilon$	
		$H^+ \to W\underline{b}\underline{b}$	
tt➔W bWb		1	channel
tt➔W bHb		3	channels
tt➔HbHb		6	channels

•Large H^+tb coupling at $\tan(\beta) \leq 0.3$ and $\tan(\beta) \geq 175$

New decay channels

- For each top quark we have 4 possible decay modes
  - 1) t→Wb
  - 2) t→Hb->τνb
  - 3) t→Hb→t*$\bar{b}$b→Wb$\bar{b}$b
  - 4) t→Hb→c$\bar{s}$b

- The number of expected candidates N^{exp} is

$$N^{\exp} = N^{back} + \sigma \cdot \varepsilon_{tt} \cdot \int L dt$$

$\int L dt \rightarrow$ ~193 pb^{-1}

N^{back}: from XS meas.

σ: $\sigma^{theo}=(6.7\pm0.7)$pb, hep-ph 0303085

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

$\varepsilon_{i,j}$: from MC

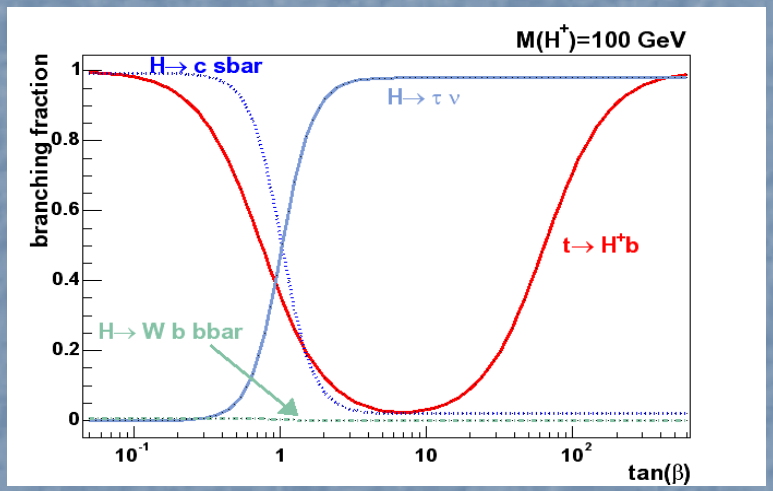
$B_i B_j$: Branching fractions of each decay mode

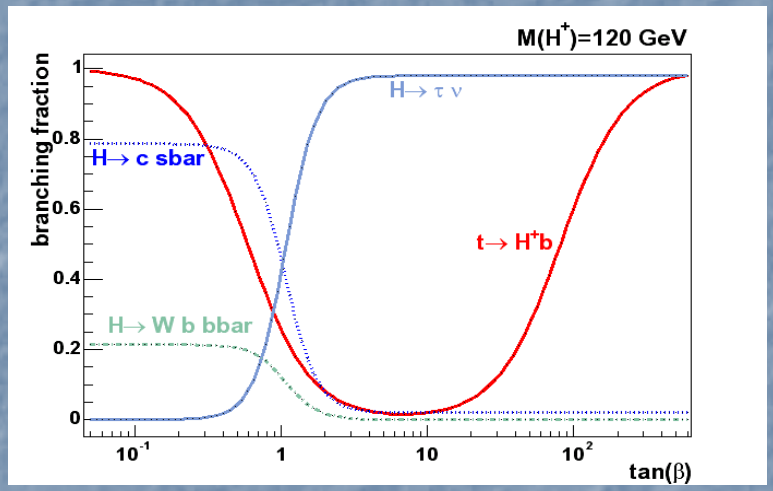
  - $\varepsilon_{t\bar{t}} = \varepsilon_{t\bar{t}}(\{B_i\})$ Need to get the B_i to find $\varepsilon_{t\bar{t}}$

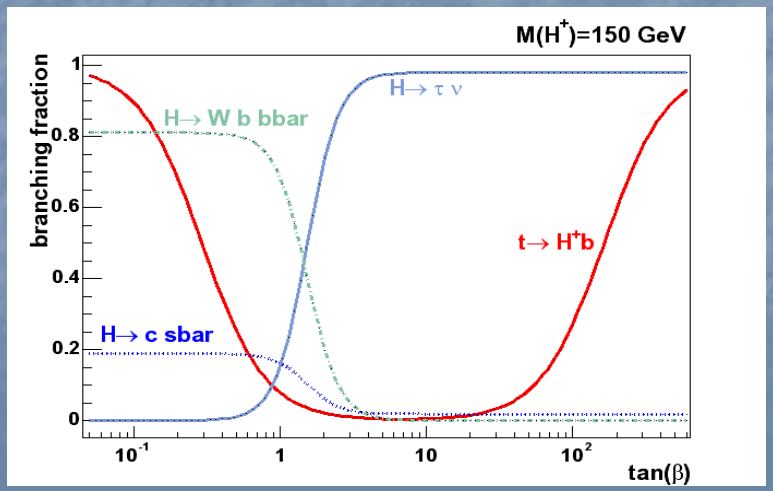
- Then compare N^{obs} to N^{exp} for each cross section measurement

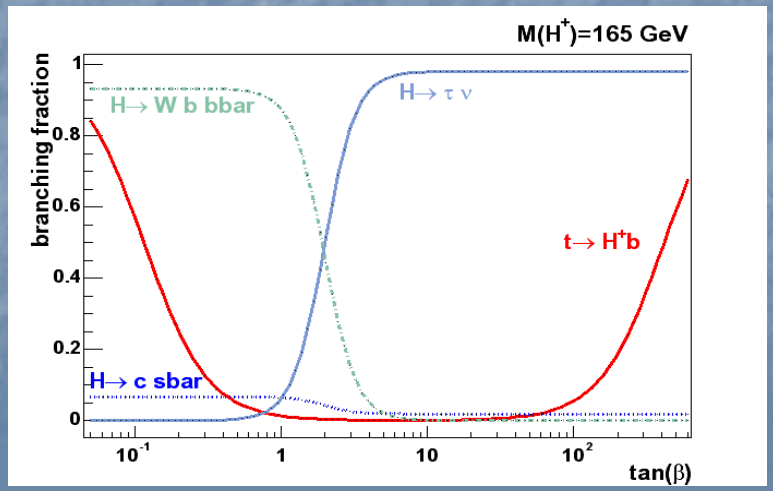
Getting $\{B_i\}$

- **Higgs sector of type II 2HDM** :At tree level a point in parameter space $(m_H, \tan(\beta))$ completely determines the decay modes of the top and Higgs









N^{obs} – N^{exp} comparison

- **We use bayesian statistics**

$$P(\tan(\beta)\,|\,n_{ll},n_{lj},n_{l\tau},m_H)=\frac{L(n_{ll},n_{lj},n_{l\tau},m_H\,|\,\tan(\beta))\;\pi(\tan(\beta))}{\int_{\tan(\beta)} L(n_{ll},n_{lj},n_{l\tau},m_H\,|\,\tan(\beta)')\;\pi(\tan(\beta)')d\tan(\beta)'}$$

- **Where the likelihood is**

$$L(n_{ll},n_{lj},n_{l\tau},m_H\,|\,\tan(\beta))=$$

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

  - **and the μ's are**

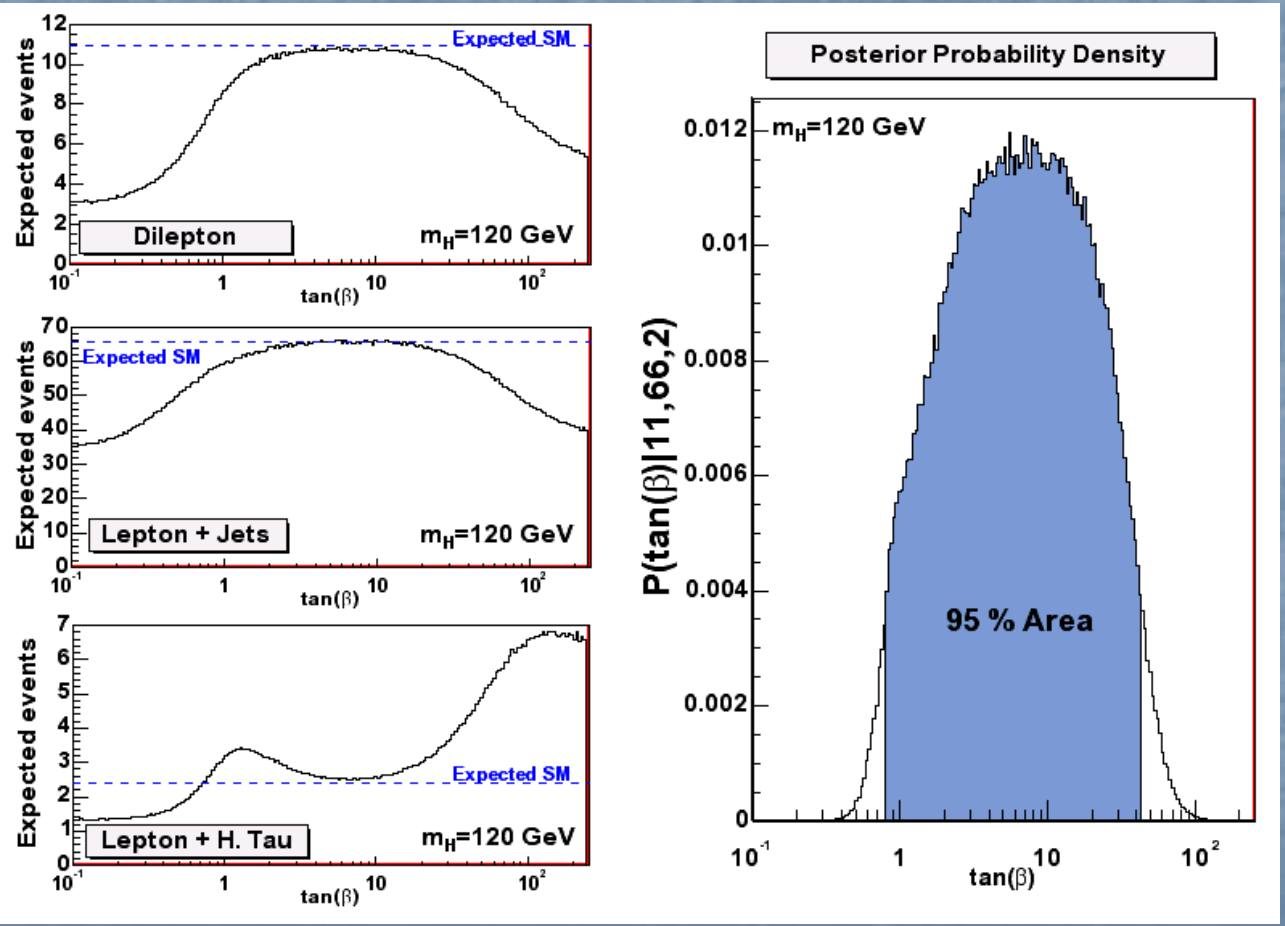
$$\mu^{tt}_{XS}=b_{XS}+L\,\sigma^{prod}_{tt}\,\varepsilon_{XS}(\rho)$$

***XS*={"*Dilepton*","*Lepton+Jets*","*Lepton +Had. Tau*"}**

- **Integrate P(tan(β)) over the maximum likelihood density to obtain the 95%CL**

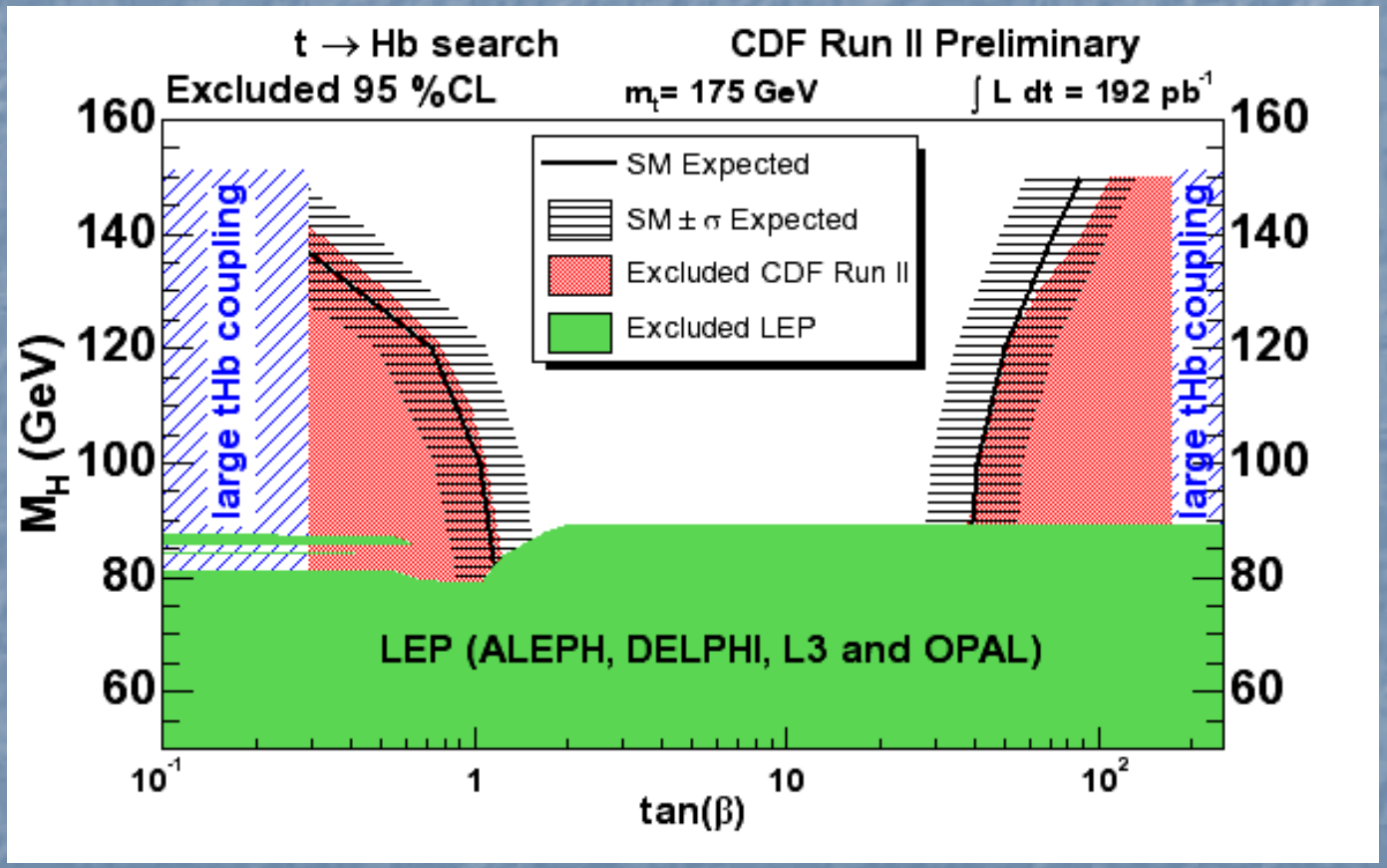
Number of expected events

- **With SM only we would expect {11,66,2} events in {"Dilepton","L+Jets","L+Had.Tau"} cross section measurements**

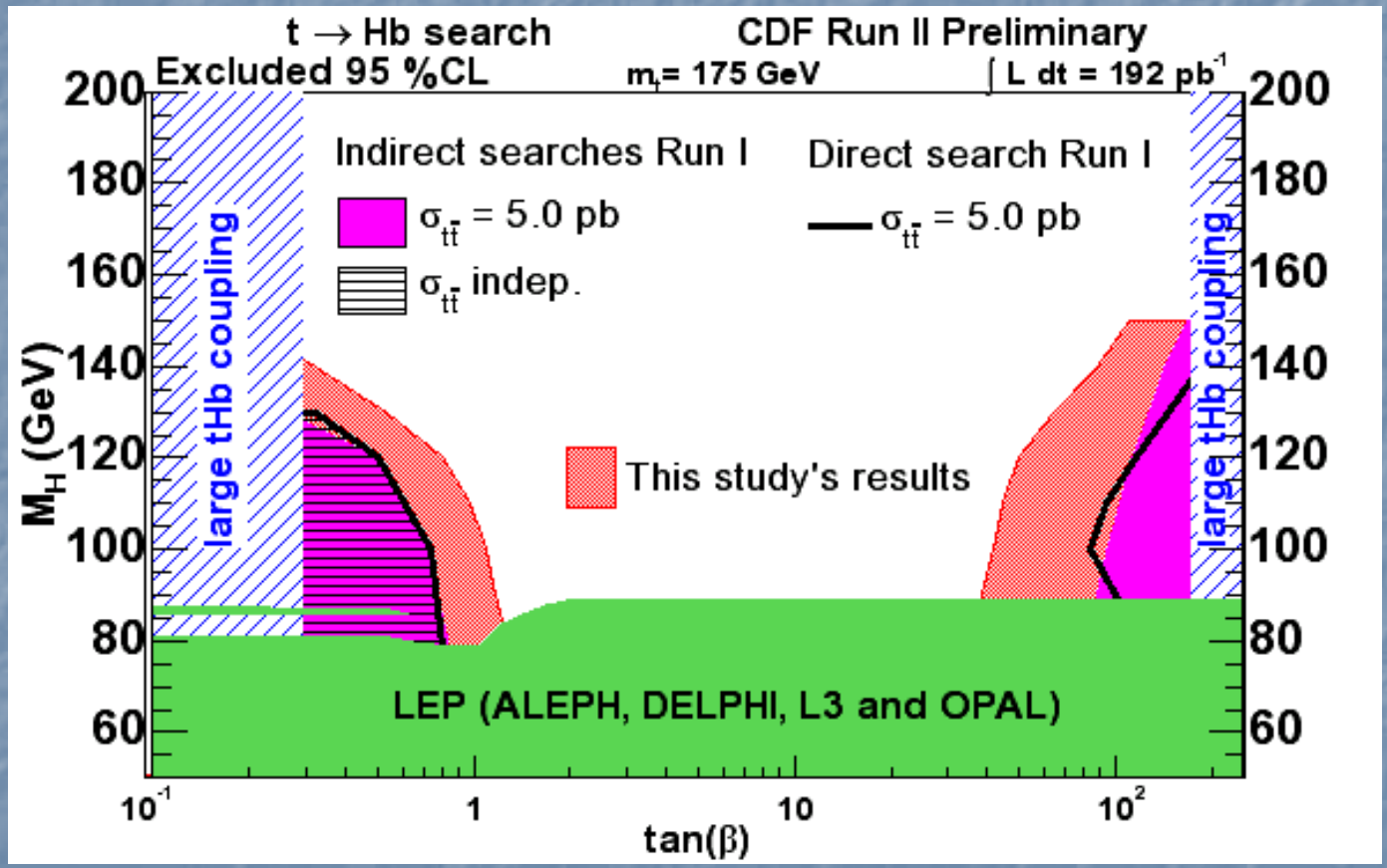


- **But we observe {13,57,2} events in data.**

Tree level MSSM results



Tree level MSSM comparison to Run I results



Model Independent

- Loop correction may significantly affect the BR's, but we can deal with the BR's directly, treating them as unknowns:

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

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

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

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

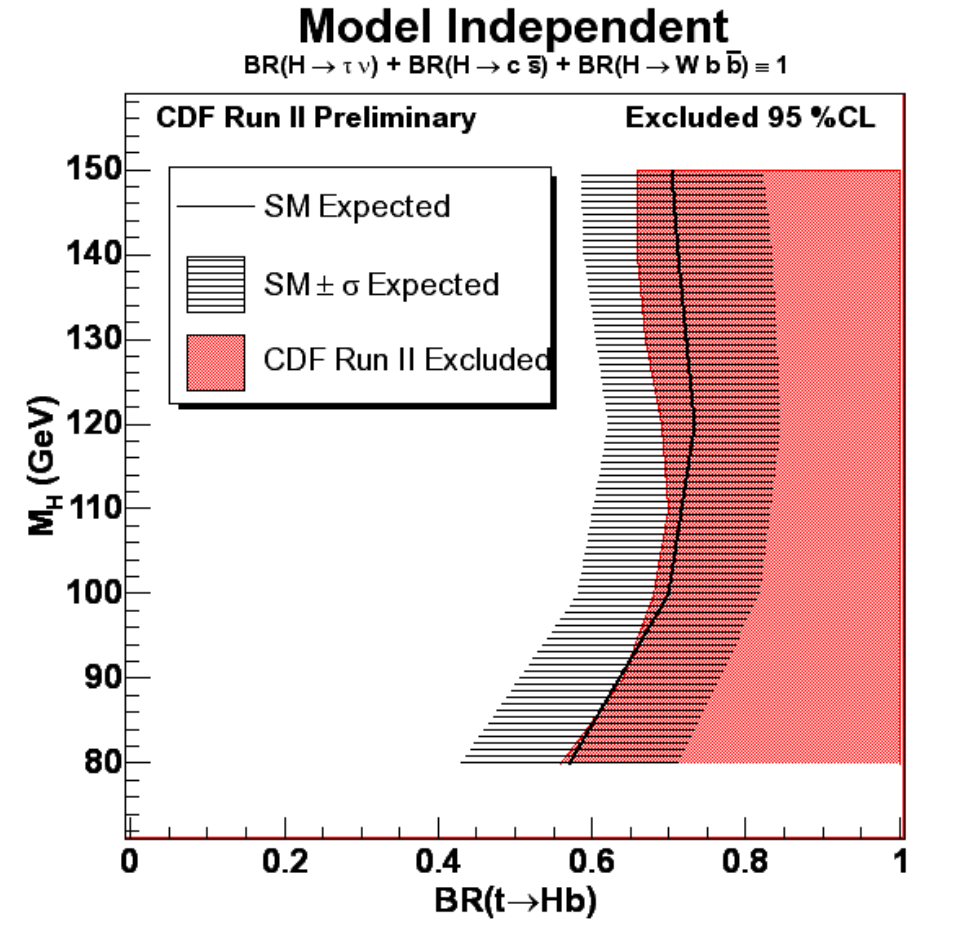
$$P(\alpha,\beta,\gamma \,|\, n_{ll}, n_{lj}, n_{l\tau}) = \frac{L(n_{ll}, n_{lj}, n_{l\tau} \,|\, \alpha,\beta,\gamma)\ \pi(\alpha)\pi(\beta)\pi(\gamma)}{\iiint L(n_{ll}, n_{lj}, n_{l\tau} \,|\, \alpha',\beta',\gamma')\ \pi(\alpha')\pi(\beta'')\pi(\gamma')\, d\alpha' d\beta' d\gamma'}$$

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

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

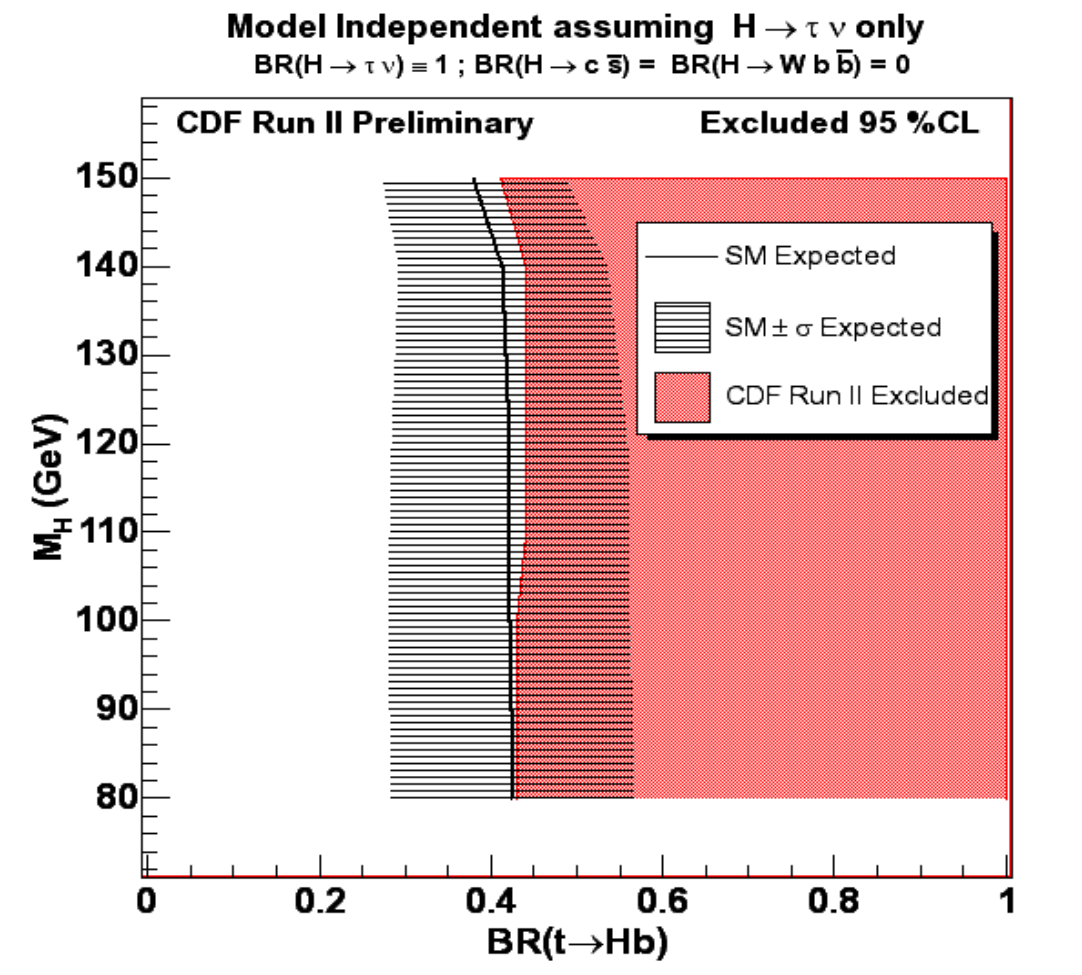
- Get the 95 % CL on $P(\alpha|n_{ll},n_{lj},n_{lT})$

Model Independent results



Limit does not depend on the model's loop corrections to the BR's !!

Model Independent results



Limit does not depend on the model's loop corrections to the BR's !!

Conclusions

- We have set limits at tree level MSSM
  - Stricter than Run I limits done under same assumptions
  - Most restrictive limits to date
- We introduced "model independent" limits
  - Novel technique
  - results independent of potentially large loop corrections
- Future Plans
  - Extend the reach to higher Higgs masses
  - Include loop corrections to the best of the current knowledge
  - Optimize the event selections for higher sensitivity