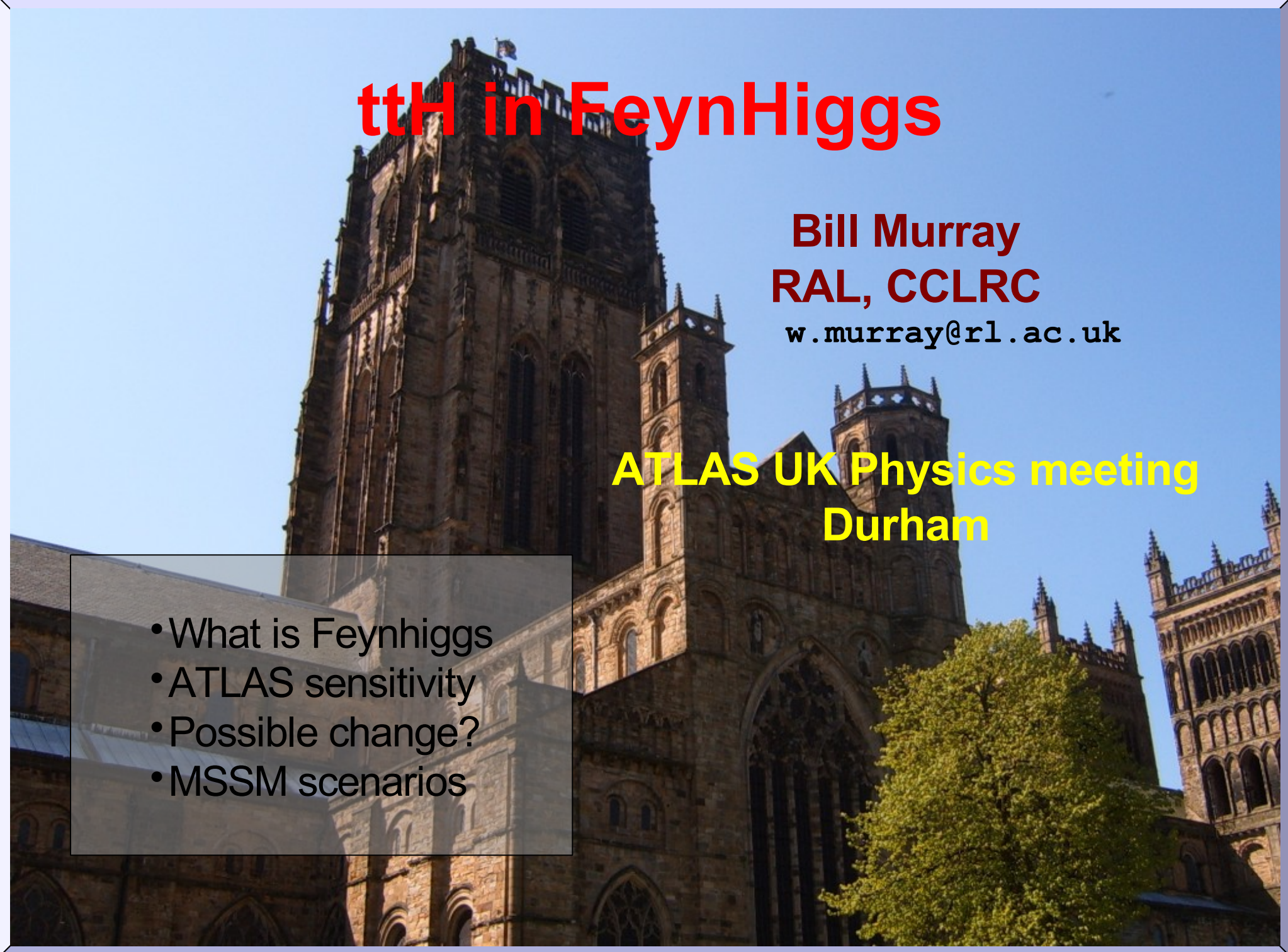

# ttH in FeynHiggs

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**ATLAS UK Physics meeting**
**Durham**

- What is Feynhiggs
- ATLAS sensitivity
- Possible change?
- MSSM scenarios

# Investigate ttH in SUSY?

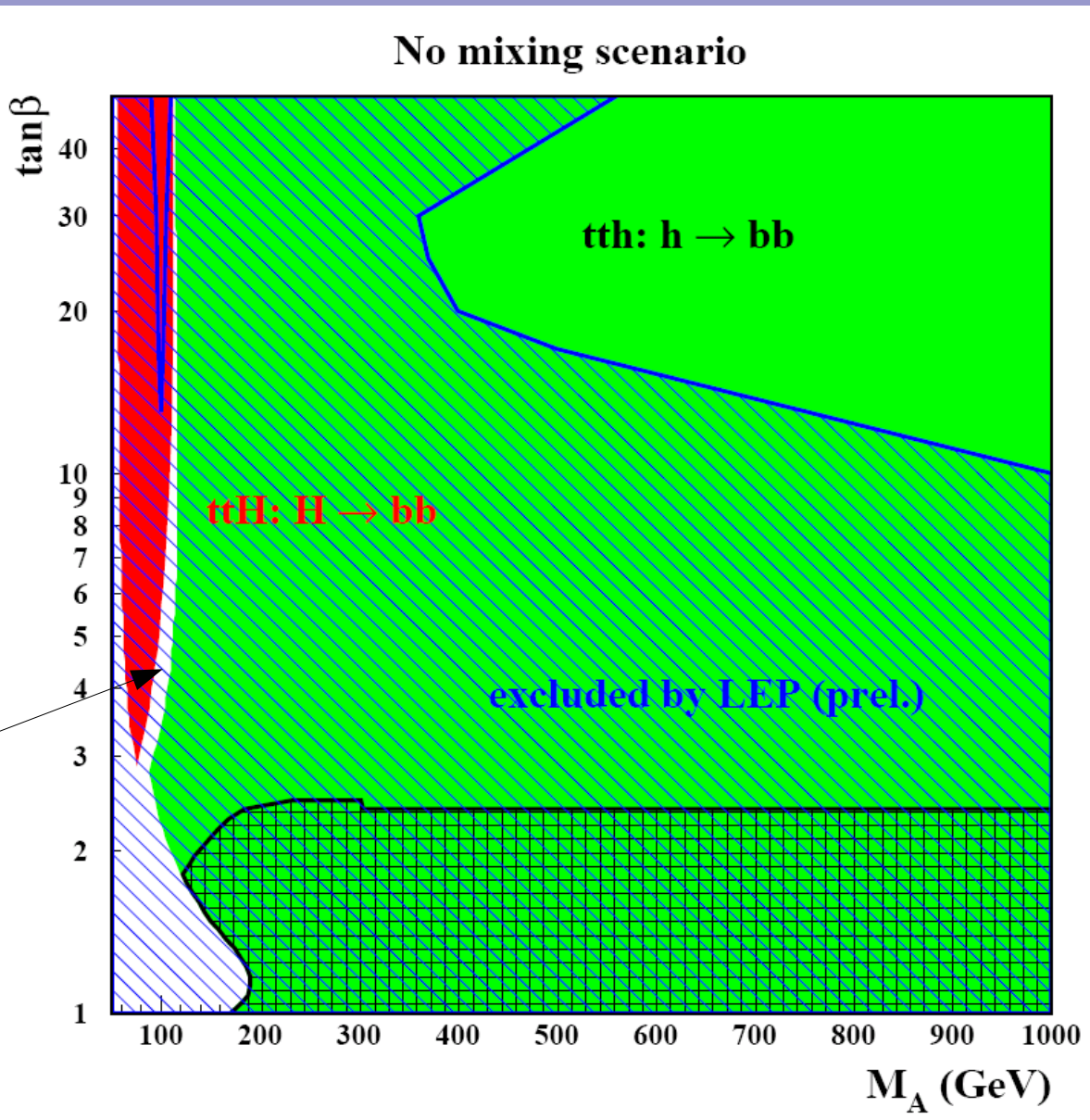
- mSUGRA inspired model
- Use FeynHiggs 2.4.1
  - Feynman-diagrammatic code, major 2-loops
  - Degrassi, Heinemeyer, Hollik, Slavich and Weiglein
- It requires Higgs parameters:
  - $m_A$, tanβ
  - Also $A_t$, μ, $m_{susy}$, $m_2$, $m_3$: radiative corrections
- $m_h$, $m_H$, branching ratios, coupling, cross-sections

# What SUSY parameters?

- Investigate benchmark parameter sets
  - No-mix,
  - mh-max,
  - gluo-phobic,
  - small alpha-eff
  - CPX
- Warnings!
  - watch for 'funny' points; some instabilities
  - In CPX scenarios do not set CP phase to 90 degrees!

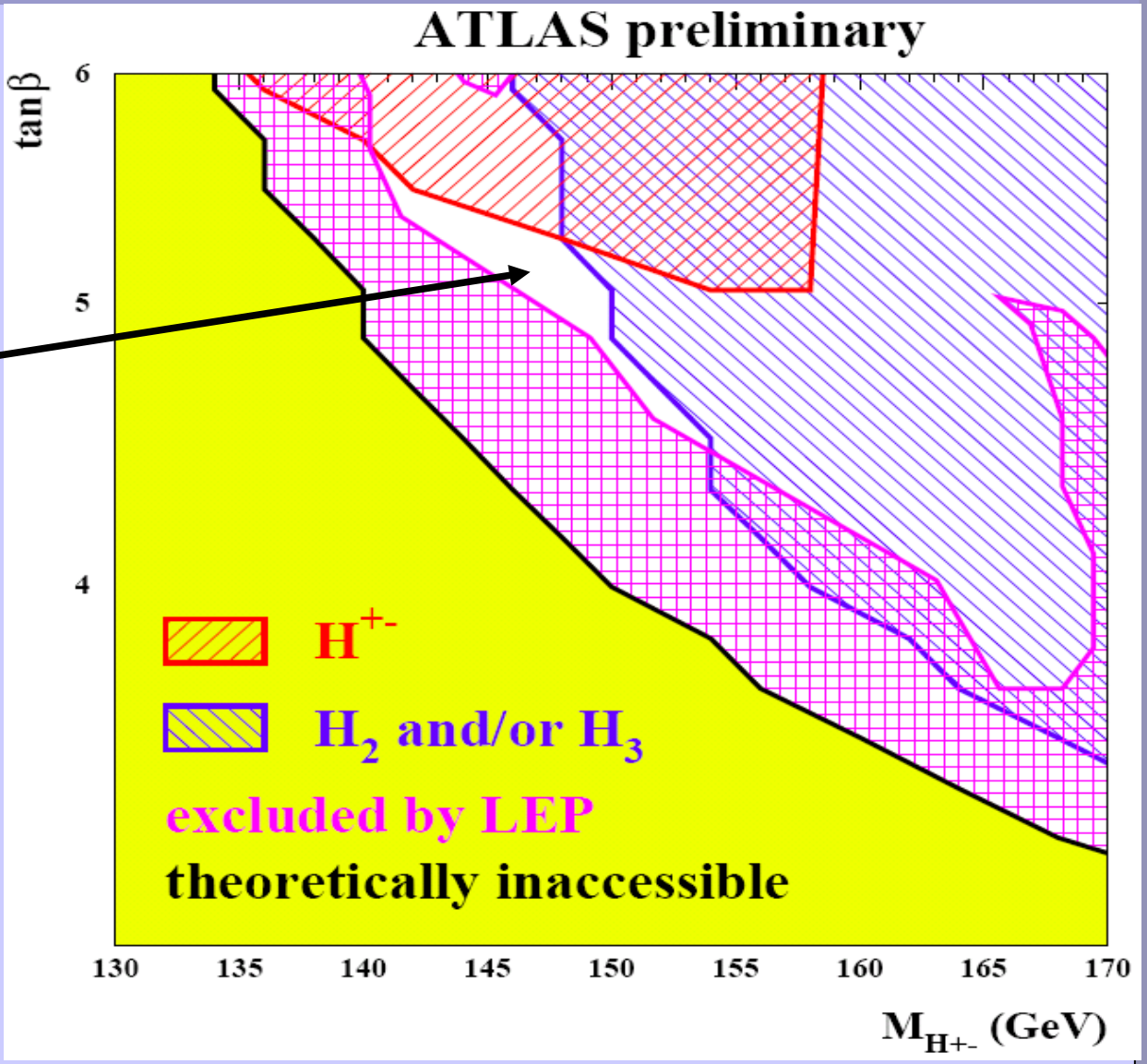
# h and H of MSSM: no-mix

- tth can be seen for some parameters
- ttH for others
- Always a thin gap!



# CPX scenario

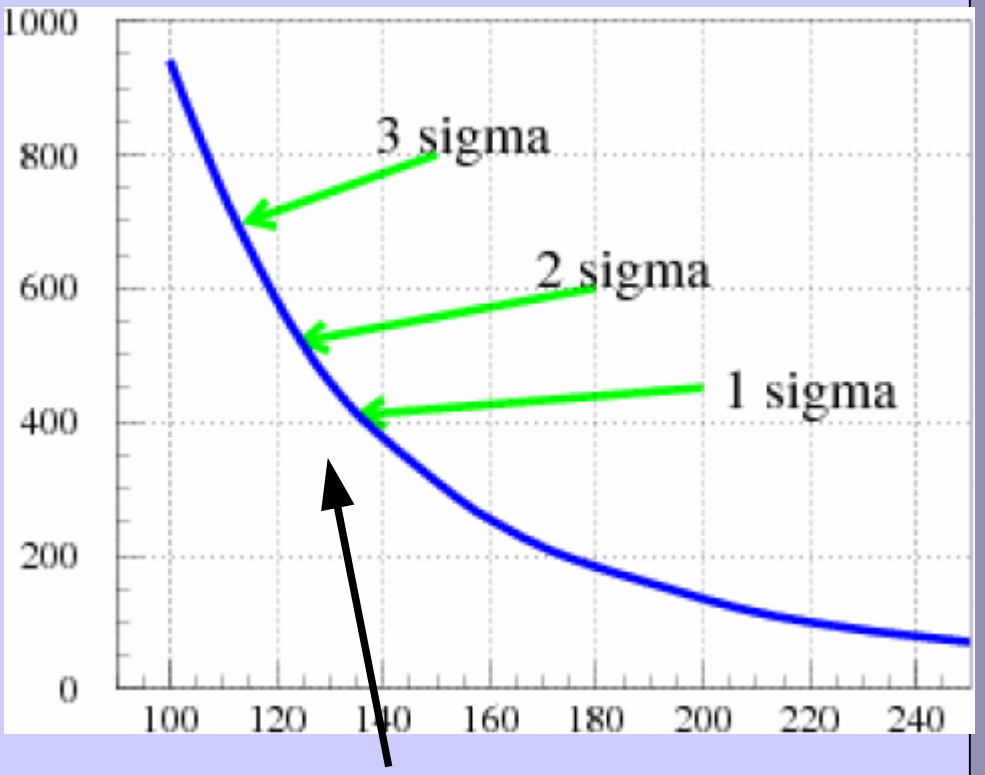
- ATLAS finds this difficult for $M_{H+}$=150, tan-beta=5
- Can ttH do more?



# SM tth Higgs: 30fb$^{-1}$

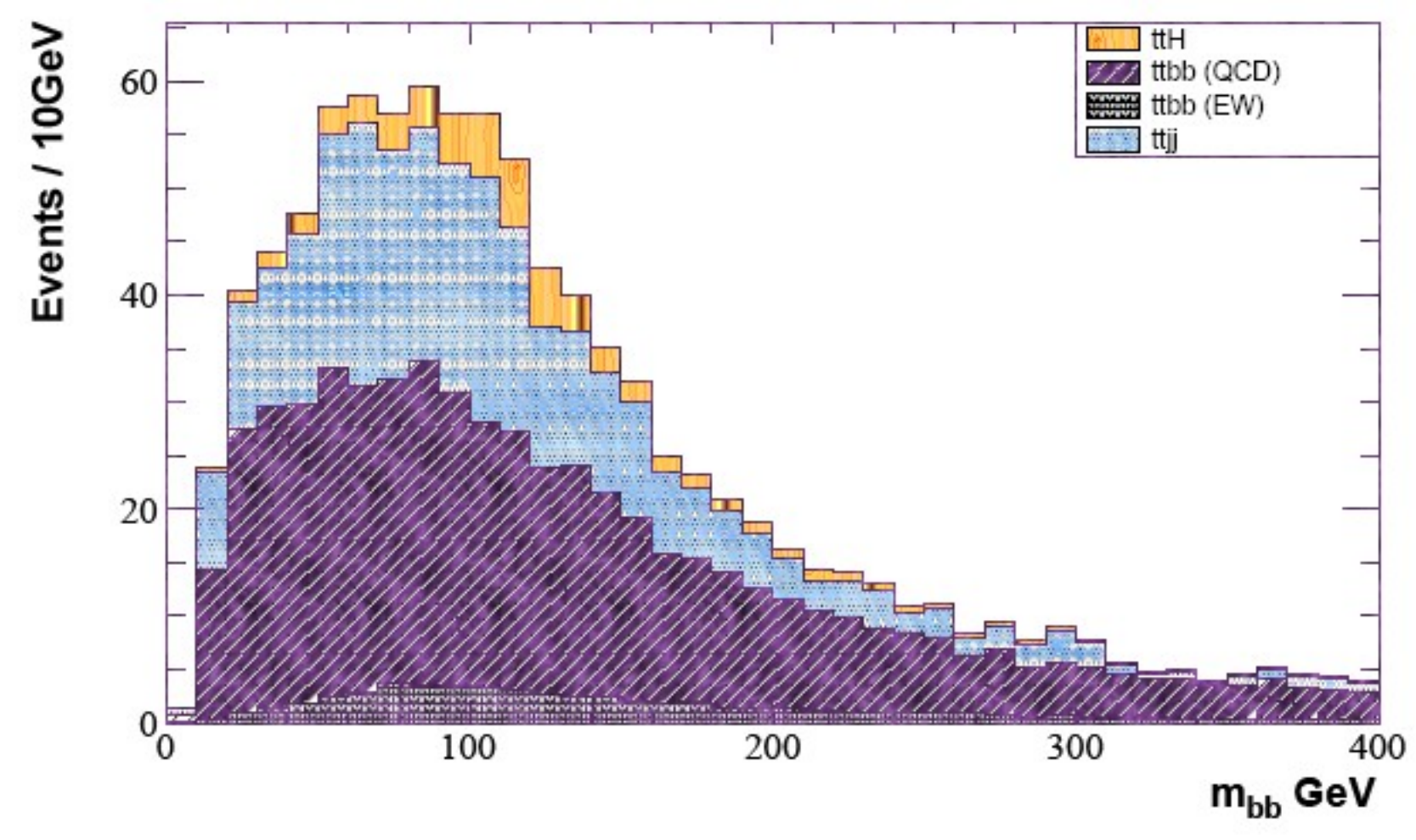
- tth cross-section times branching ratio
- A cross-section of 500 for tth allows interesting study

- Nb: Final mass is not a good variable. If we don't use it can we ADD event rates?




Janice Droghan

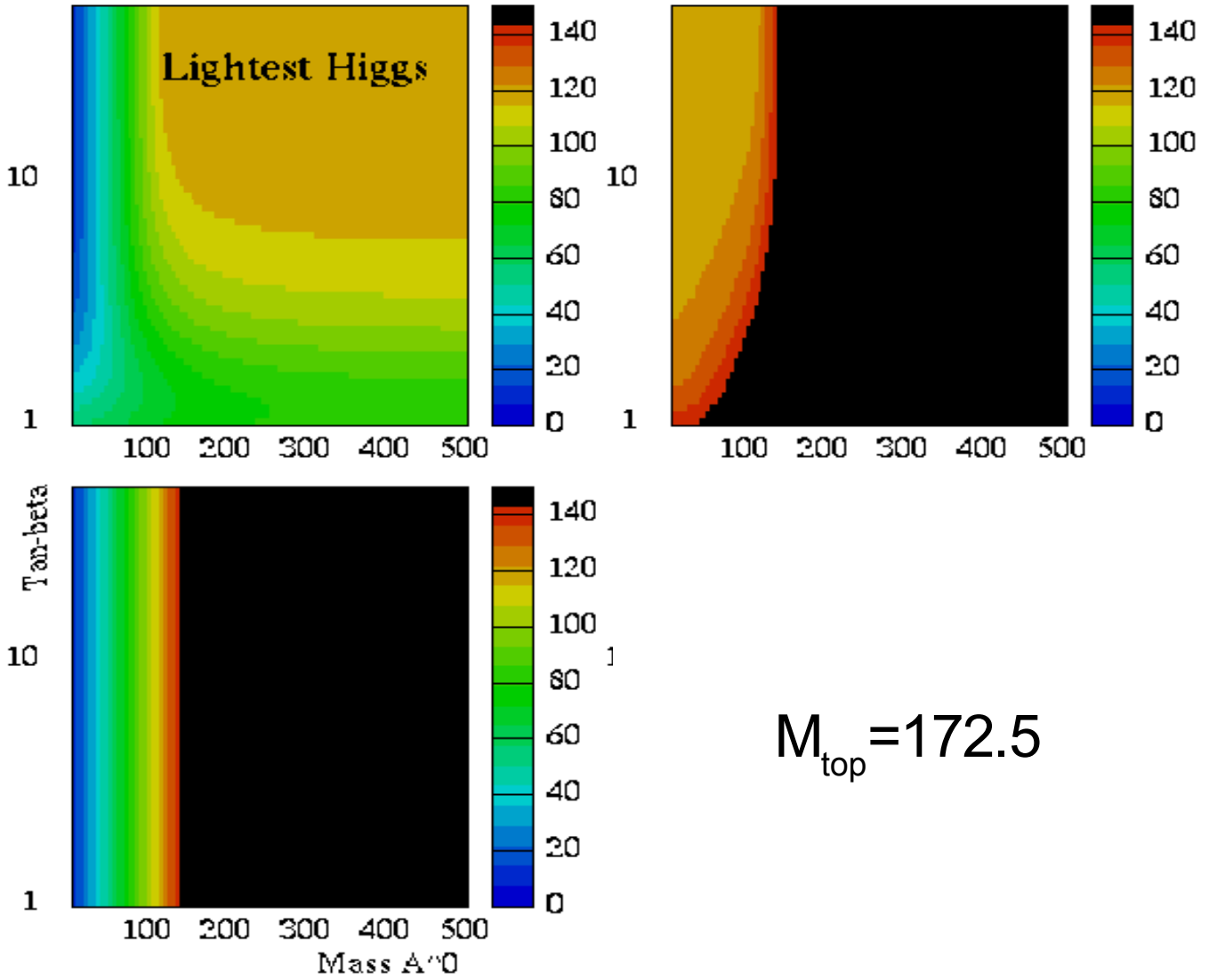
# ttH mass spectrum




- Incorrect jet pairs, energy resolution, etc. spread peak

# no-mixing Higgs masses

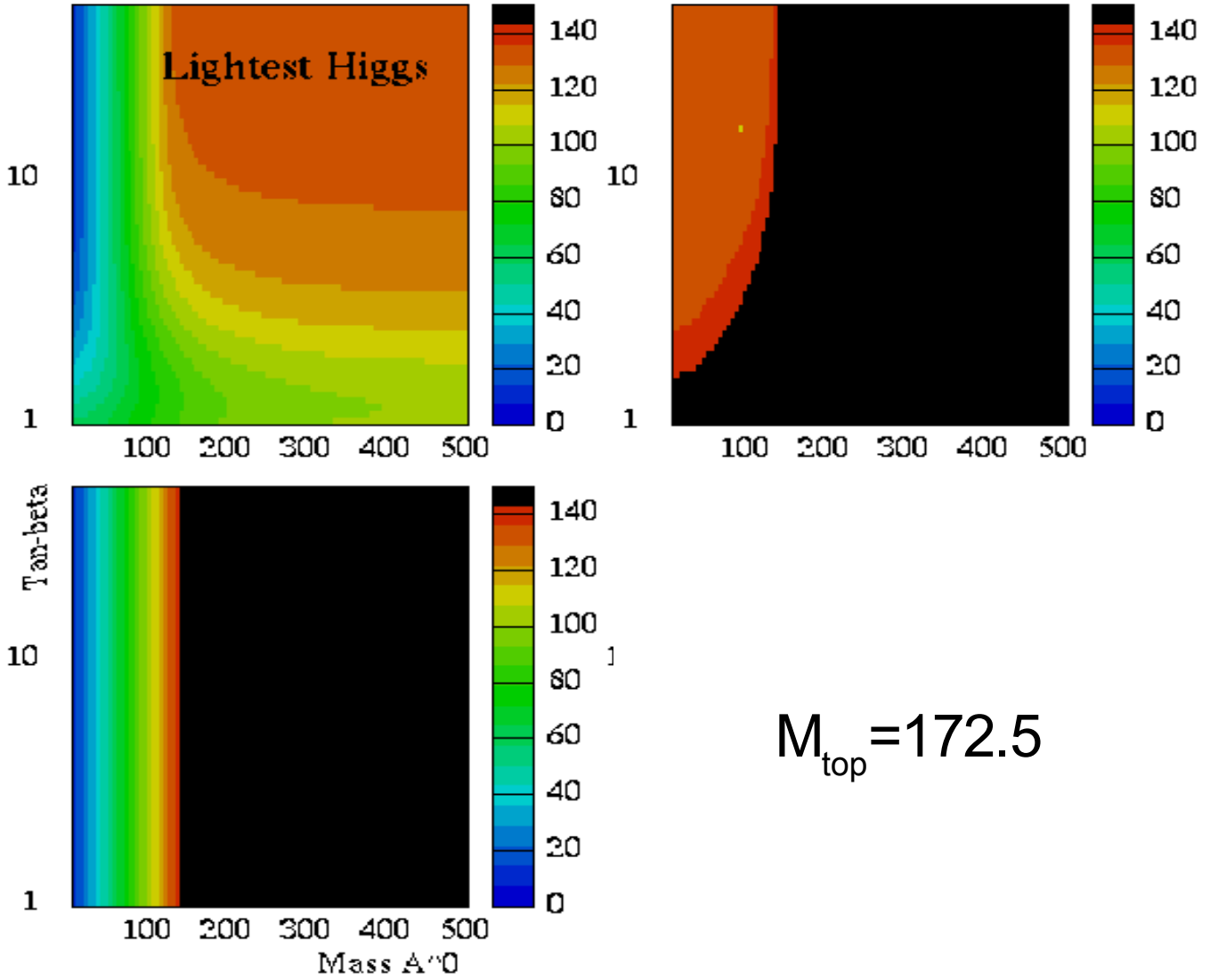
- Plots show masses of h, H and A in plane $m_A$ v tan-beta
- Black masses, >140GeV, have few tth
- Maximum mass 120GeV




$M_{top}$=172.5

# mh-max Higgs masses

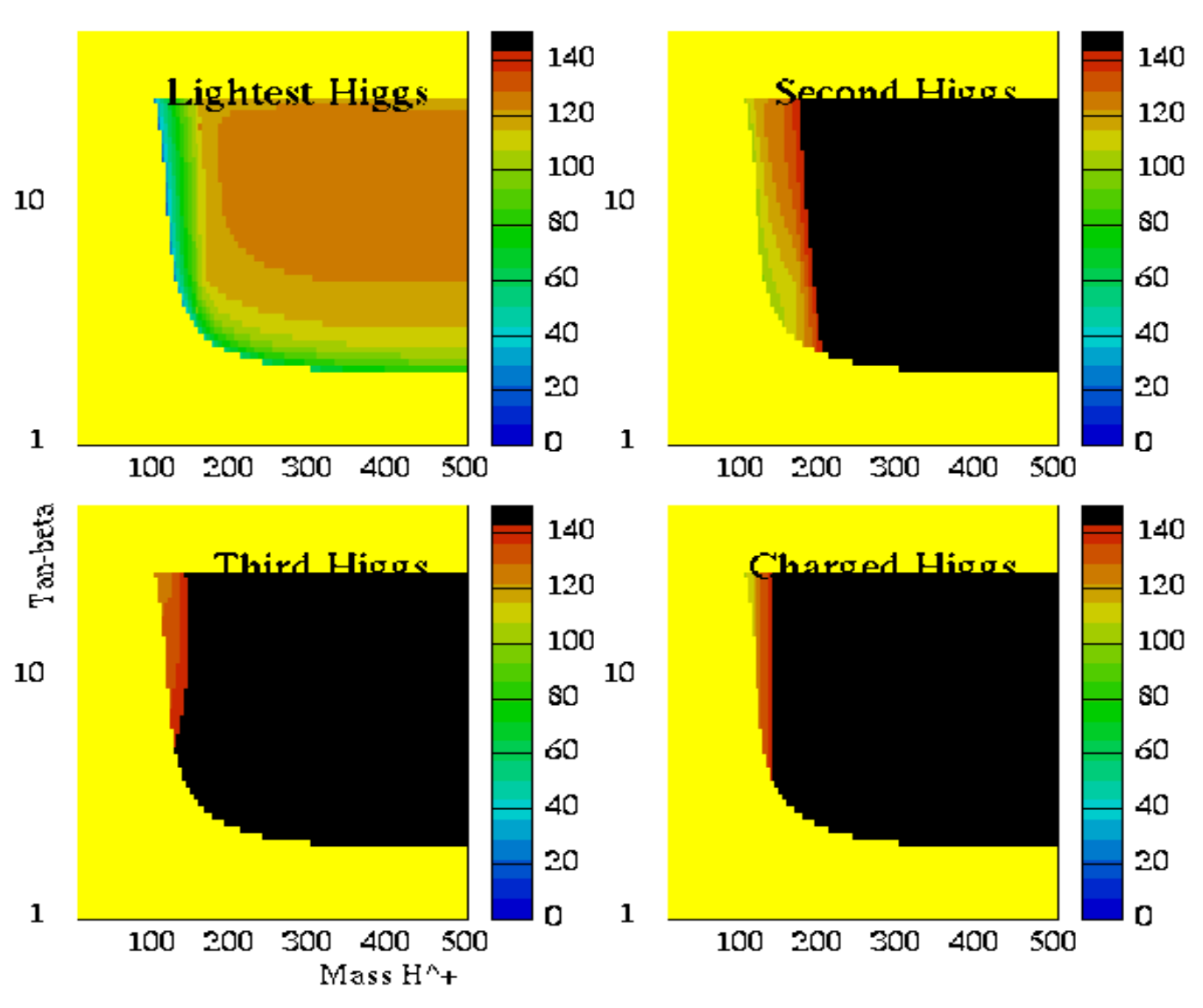
- Plots show masses of h, H and A in plane $m_A$ v tan-beta
- Black masses, >140GeV, have few tth
- Maximum mass 135GeV




$M_{top}$=172.5

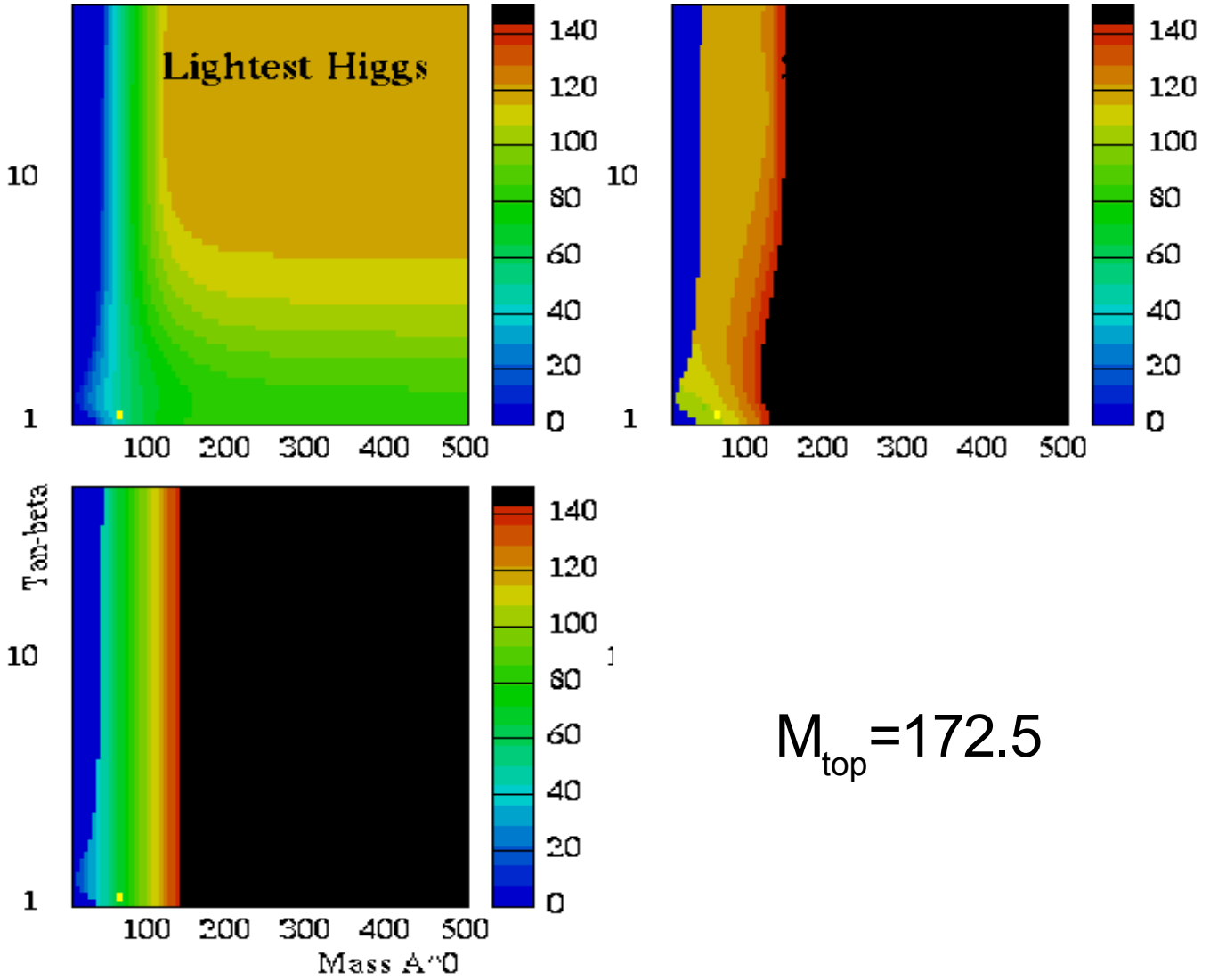
# CPX Higgs masses

- Plots show masses of h, H and A in plane $m_A$ v tan-beta
- Yellow: no solution found by FeynHiggs
- Black masses, >140GeV, have few tth



# Low α-eff Higgs masses

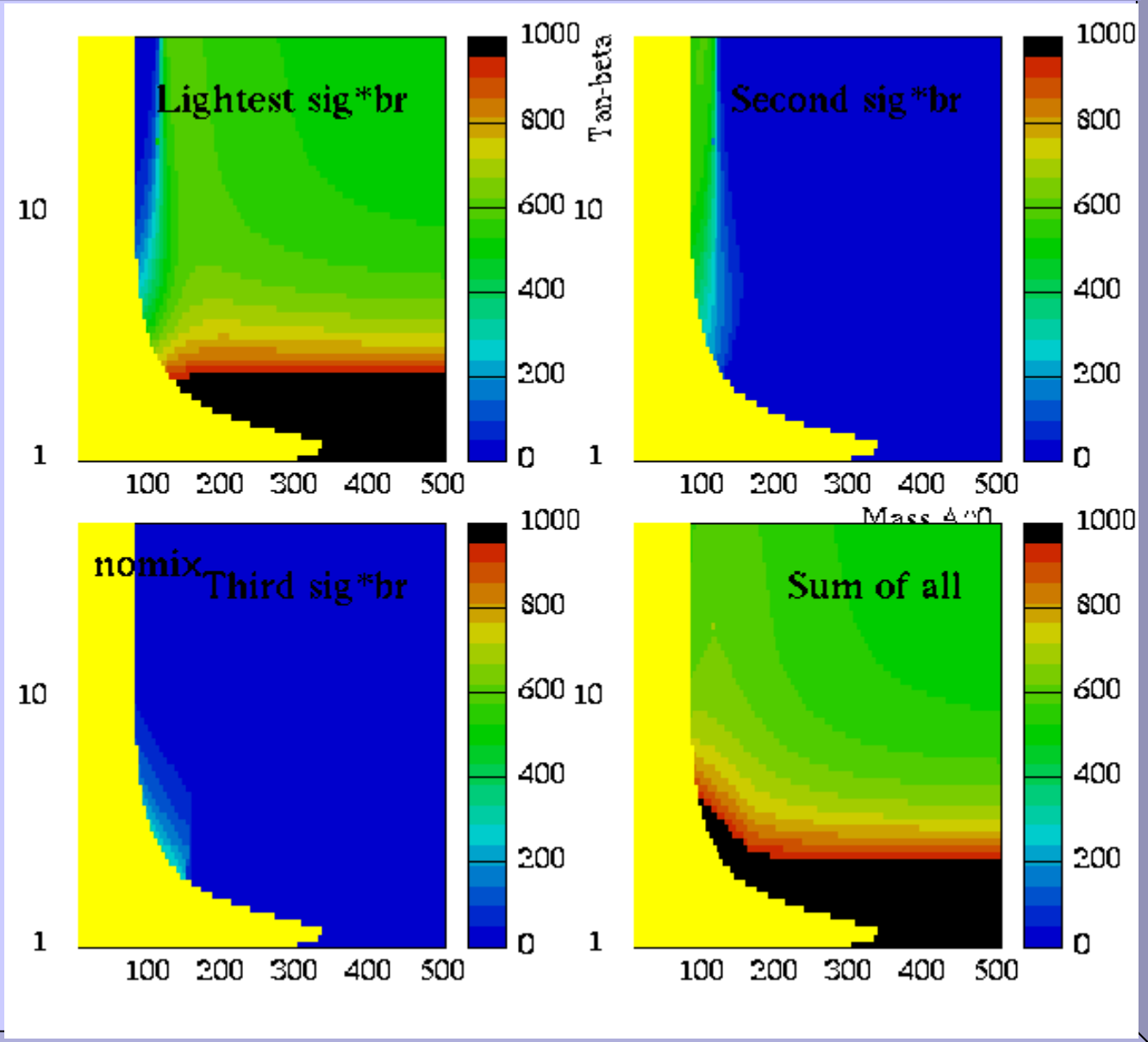
- Plots show masses of h, H and A in plane $m_A$ v tan-beta
- Black masses, >140GeV, have few tth




$M_{top}$=172.5

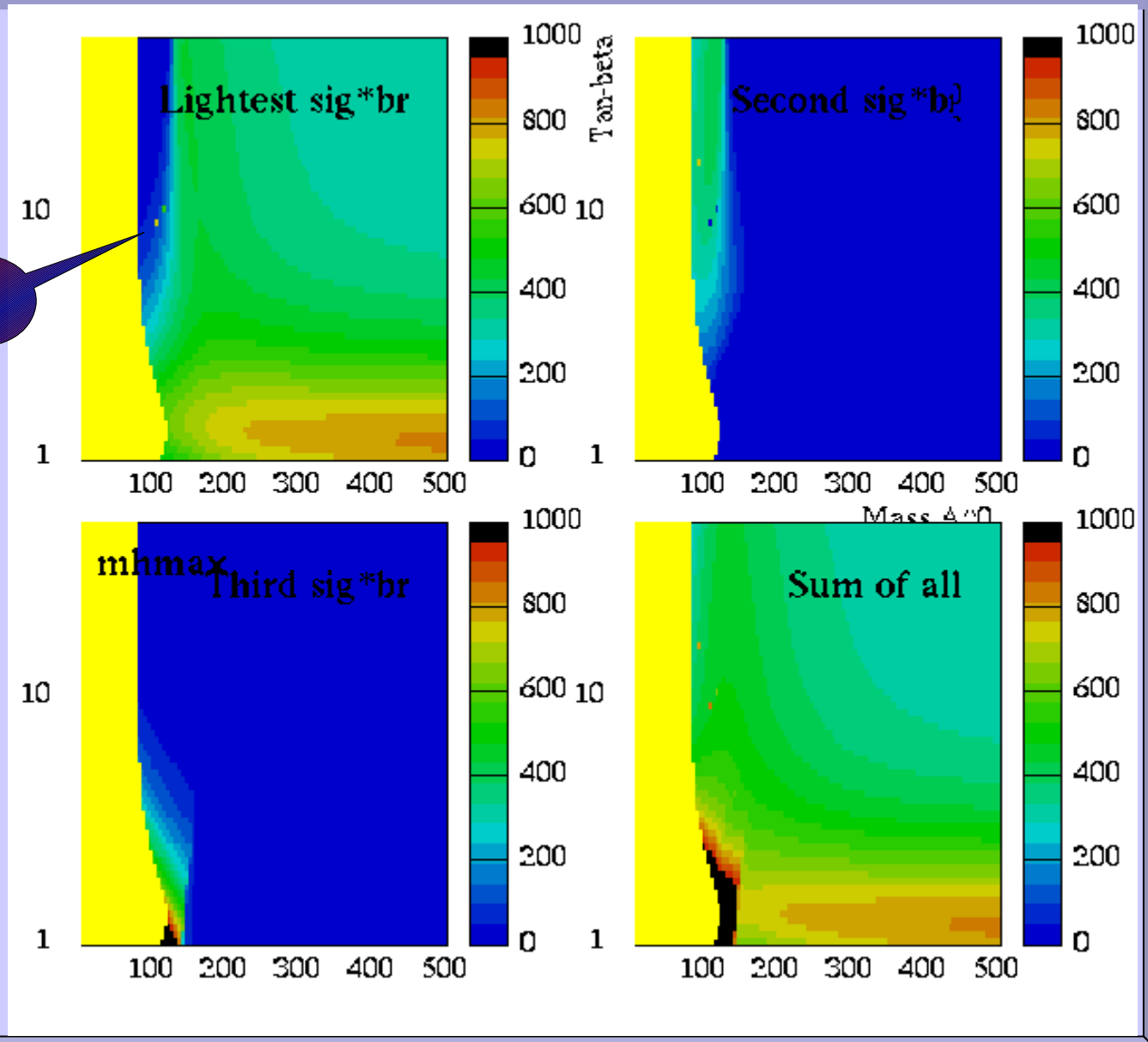
# No-mix tth rates

- h, H and A tth rates
- Fourth plot is total
- Green is 500fb: two sigma?
- Green+ for all parameter space
- Sigma tth for Mh<80 not calculated: yellow



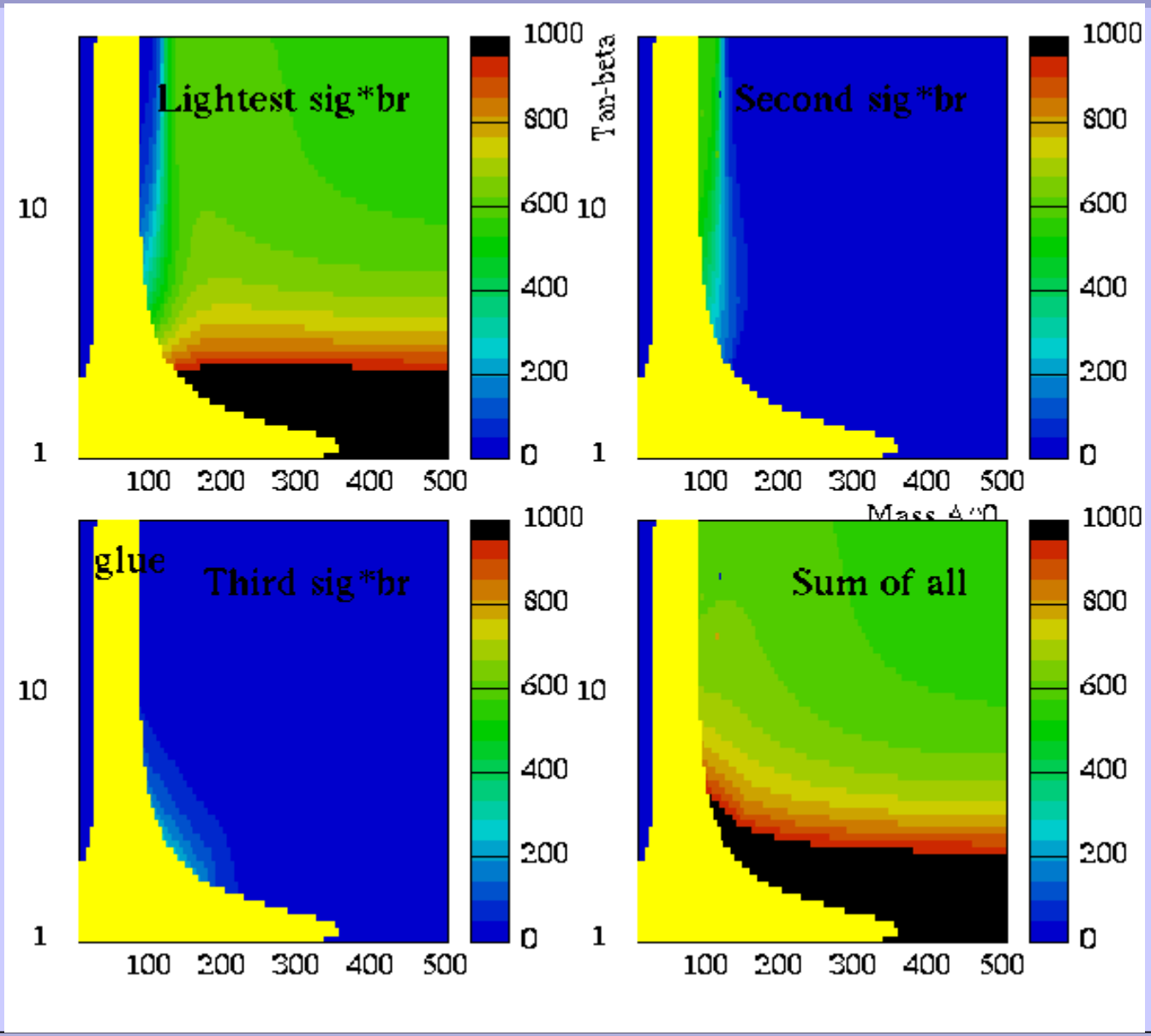
# mh-max tth rates

- h, H and A tth rates
- Fourth plot is total
- Green is 500fb: two sigma?
- Falls towards 1 sigma for this scenario:
- Always some sensitivity



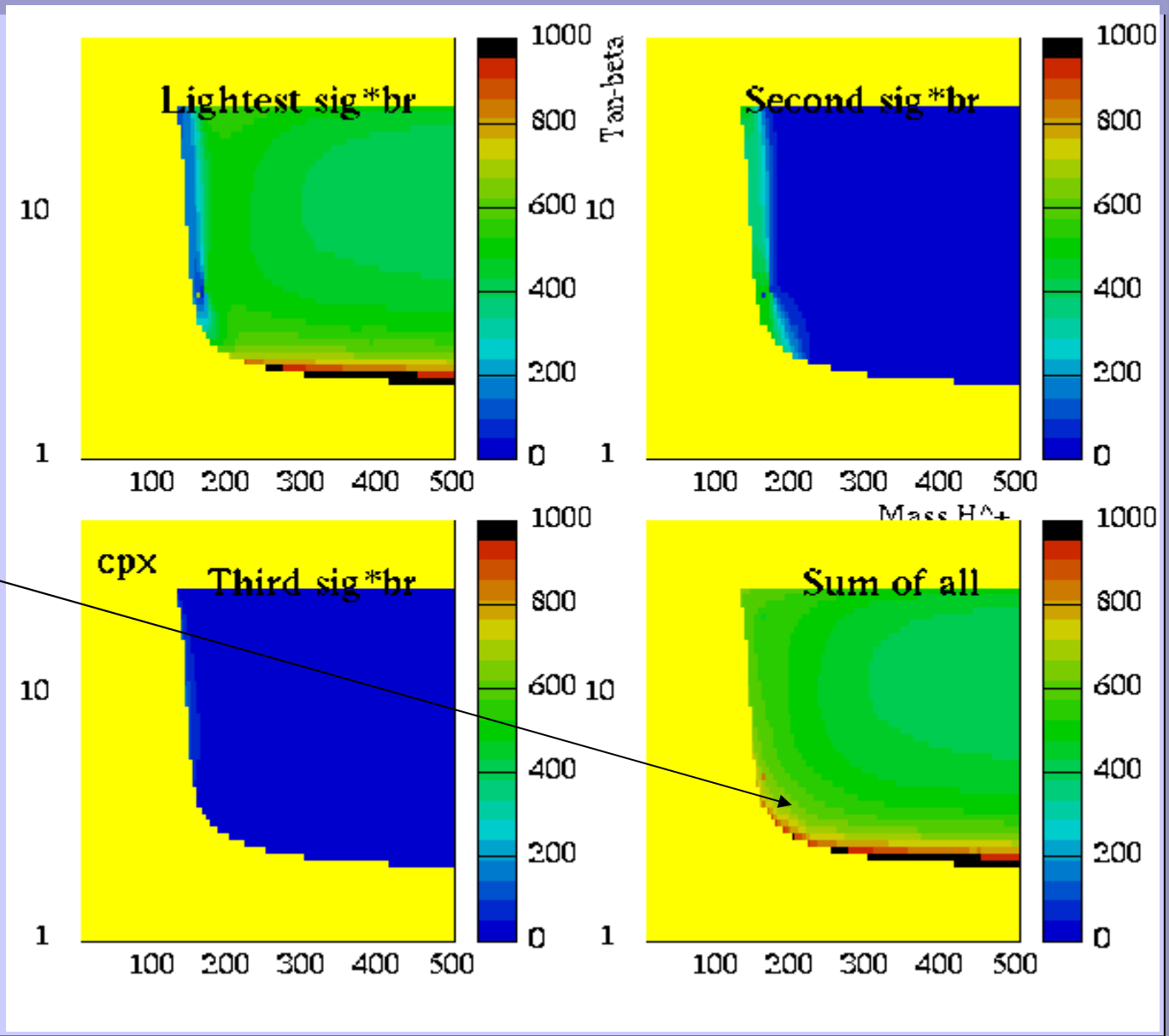
# Gluo-phobic tth rates

- h, H and A tth rates
- Fourth plot is total
- Green is 500fb: two sigma?
- Two sigma or better: no holes



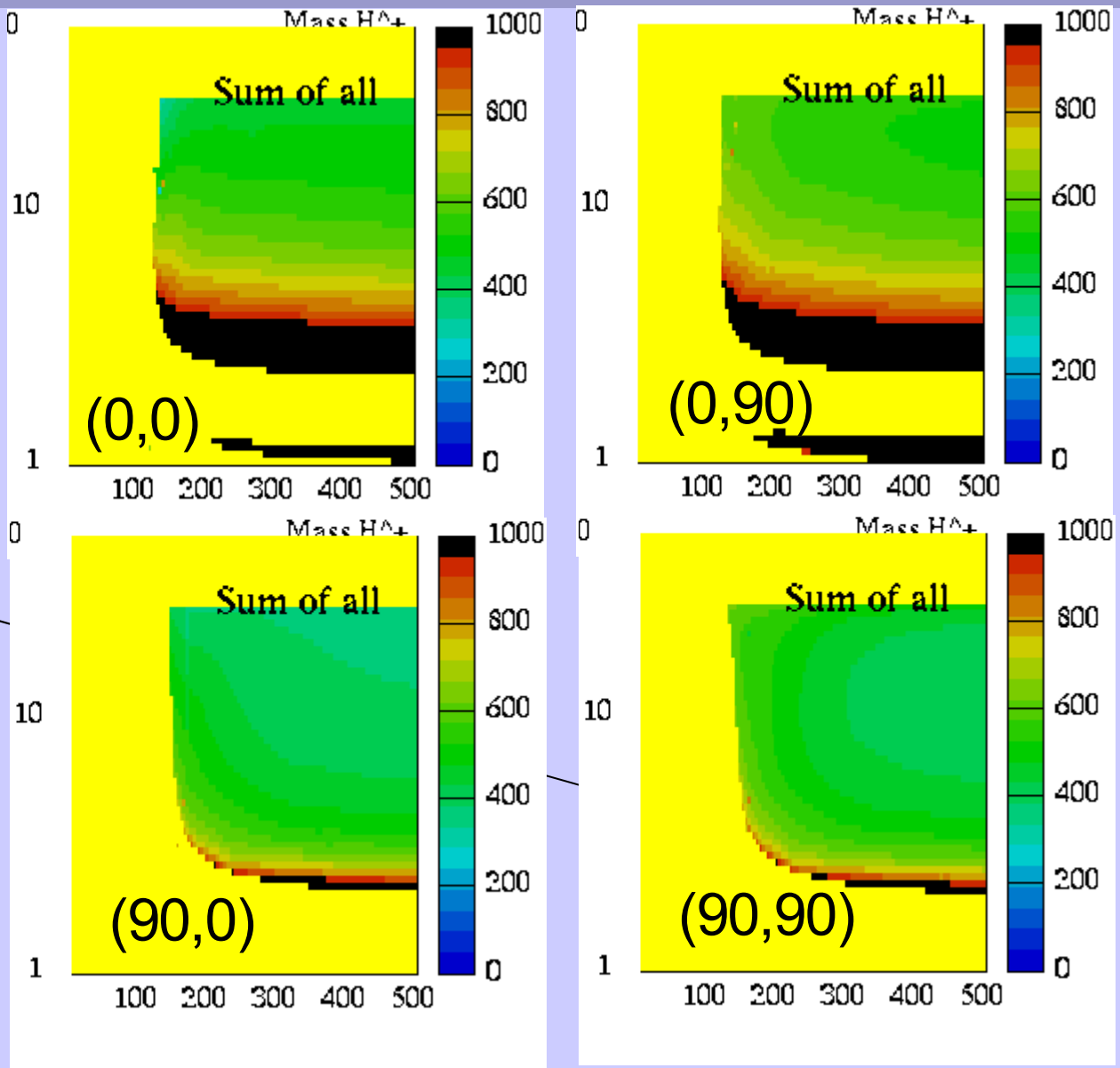
# CPX tth rates

- h, H and A tth rates
- Fourth plot is total
- Green is 500fb: two sigma?
- Hole at 150,5 gone?
- Need to look at $m_H$<80GeV



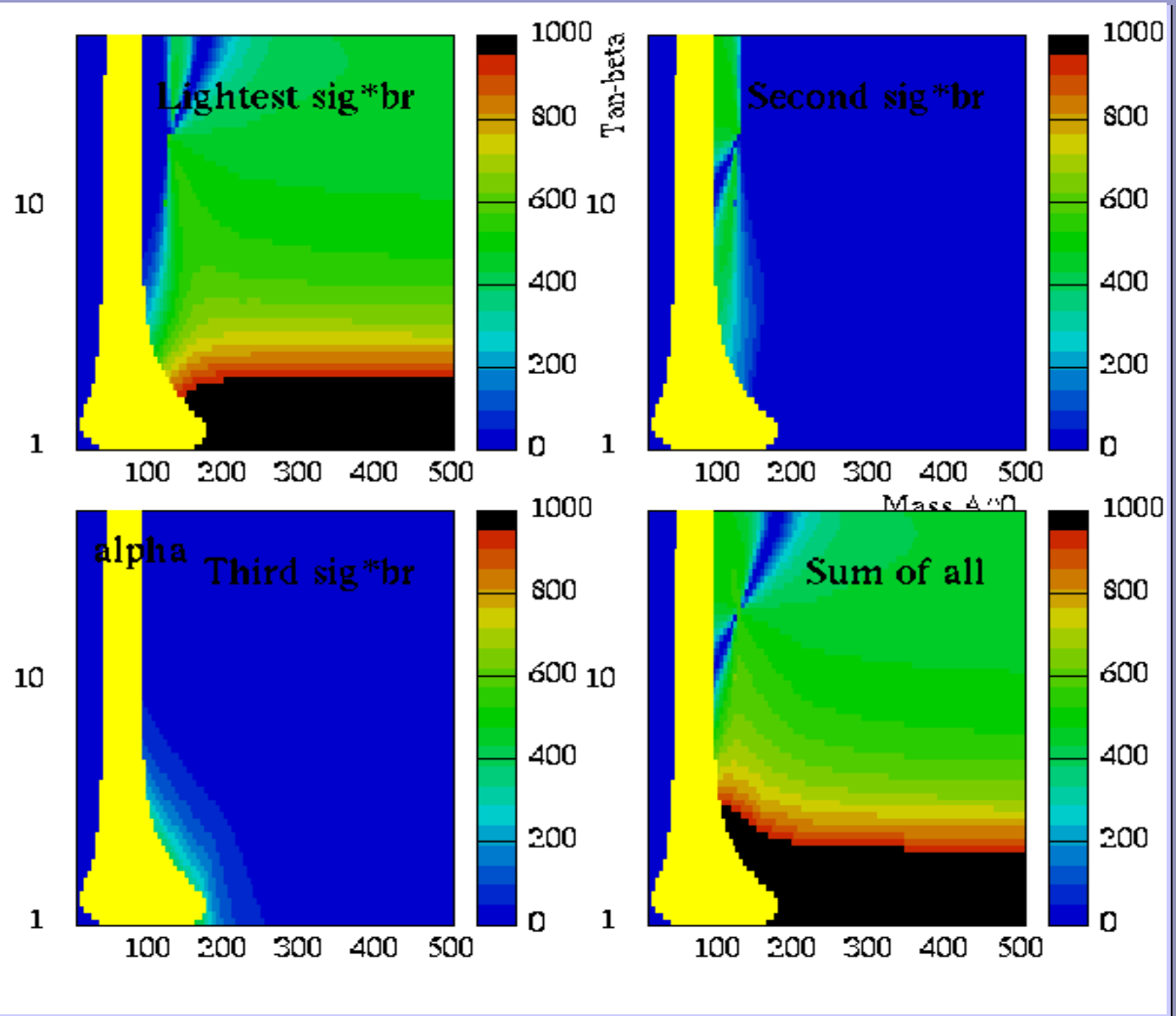
# CPV tth rates

- Other CPV scenarios
- CPX but phase of $A_t$, $M_3$ independent
  - (0,0)
  - (0,90)
  - (90,0)
  - (90,90)
- There is always a decent signal



# Small α-eff tth rates

- h, H and A tth rates
- This scenario designed to have small bbh coupling.
- ttH, tth, bbh and bbH conspire
- SUSY always has an escape route



# Couplings of SUSY Higgs

| | $t$ | $b,\tau,\mu$ | $W,Z$ |
|---|---|---|---|
| $h^0$ | $\cos\alpha / \sin\beta$ | $-\sin\alpha/\cos\beta$ | $\sin(\beta-\alpha)$ |
| $H^0$ | $\sin\alpha / \sin\beta$ | $\cos\alpha/\cos\beta$ | $\cos(\beta-\alpha)$ |
| $A^0$ | $-i\gamma_5 \cot\beta$ | $-i\gamma_5 \tan\beta$ | 0 |

$$\tan 2\alpha = \tan 2\beta \left(\frac{M_A^2 + M_Z^2}{M_A^2 - M_Z^2}\right)$$

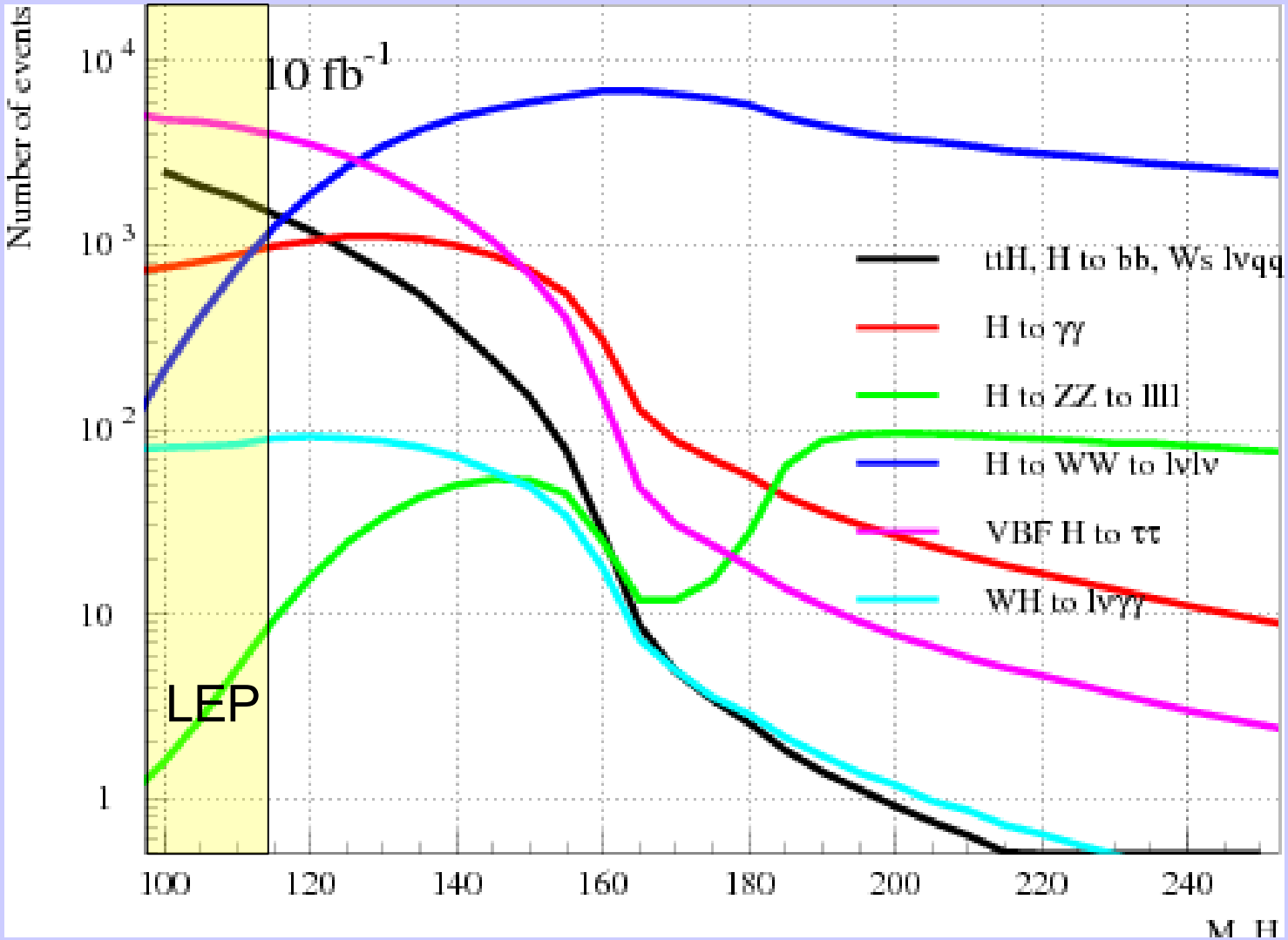
Tree level

# Summary

- MSSM higgs very often appears in tth
- At least one of the Higgses should be there
  - Only very unusual parameter choices suppress it
- Difficult region in CPX can be addressed
  - Search to $m_h$ below 80 should be included

- Of course, it is a difficult channel
- Only two sigma for 30fb$^{-1}$.
- But very great range of MSSM gives signals

# SM Rates for 10fb$^{-1}$




- Rates in major channels
  - from Pythia
- No cuts, just branching ratios
- l: e or μ

# h and H of MSSM: MhMax

- tth can be seen for some parameters
- ttH for others