Some Notes on 2HDM Benchmarking

N. Rompotis
(with many thanks to Oscar Stall)

The problem

- The CP-conserving 2HDM (with a softly broken Z_2) has 7 parameters on top of SM:

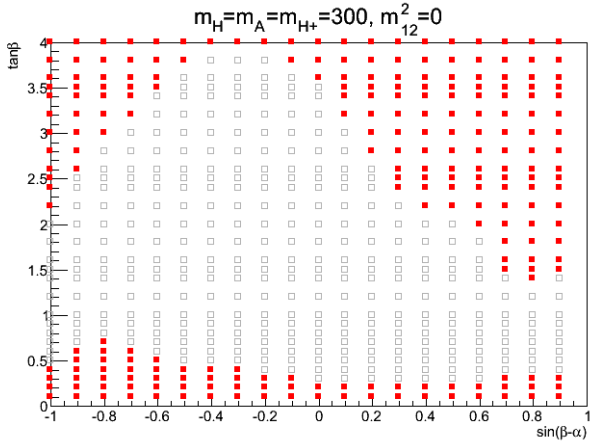
$$V = m_{11}^2 \Phi_1^\dagger \Phi_1 + m_{22}^2 \Phi_2^\dagger \Phi_2 - m_{12}^2 \left(\Phi_1^\dagger \Phi_2 + \Phi_2^\dagger \Phi_1\right) + \frac{\lambda_1}{2}\left(\Phi_1^\dagger \Phi_1\right)^2 + \frac{\lambda_2}{2}\left(\Phi_2^\dagger \Phi_2\right)^2$$
$$+\lambda_3 \Phi_1^\dagger \Phi_1 \Phi_2^\dagger \Phi_2 + \lambda_4 \Phi_1^\dagger \Phi_2 \Phi_2^\dagger \Phi_1 + \frac{\lambda_5}{2}\left[\left(\Phi_1^\dagger \Phi_2\right)^2 + \left(\Phi_2^\dagger \Phi_1\right)^2\right],$$

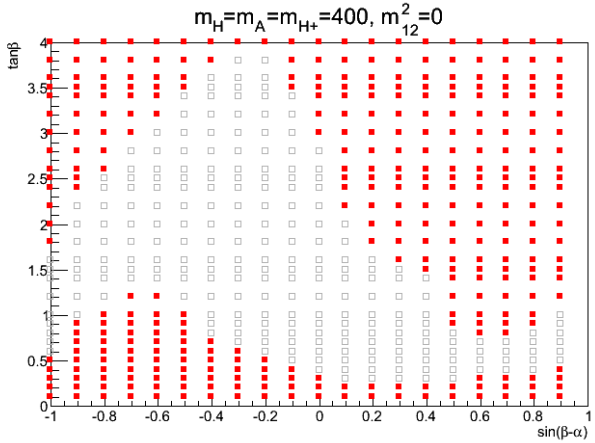
4 masses: h, H, A, H±
2 angles: θ, α
1 potential parameter m_{12}

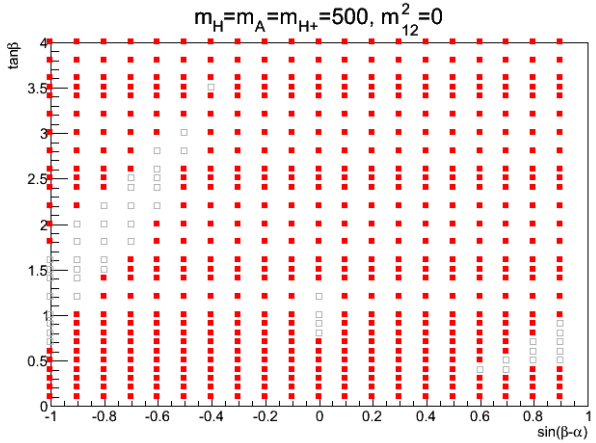
- We are interested in defining 2HDM Benchmarks over a wide range range of m_H, $\sin(\beta - \alpha)$ and fixed $m_h = 125$ GeV
  - We want mH high (>500 GeV) since there are channels which are sensitive to high mass Higgs (e.g. ZZ, WW)
  - We want $\sin(\beta - \alpha)$ not exactly 1, since HVV coupling is ~ $\cos(\beta - \alpha)$

Some benchmarks

- The parameter space can be reduced by assuming m_h = 125 GeV and $m_H = m_A = m_{H\pm}$ (or $m_{H\pm}$ > exp limit from charged scalar searches). This leaves 4 parameters to play: tanβ , sin(β – α), m_H and m_{12}.
- A first obvious option is to assume a perfect Z_2 symmetry, i.e. m_{12} = 0. This has the problem that at mH = 400 GeV most parameter space is killed by theory (unitarity, perturbativity and potential stability considerations)

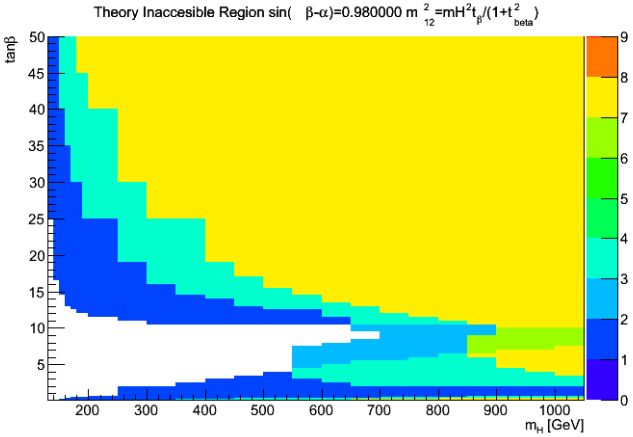




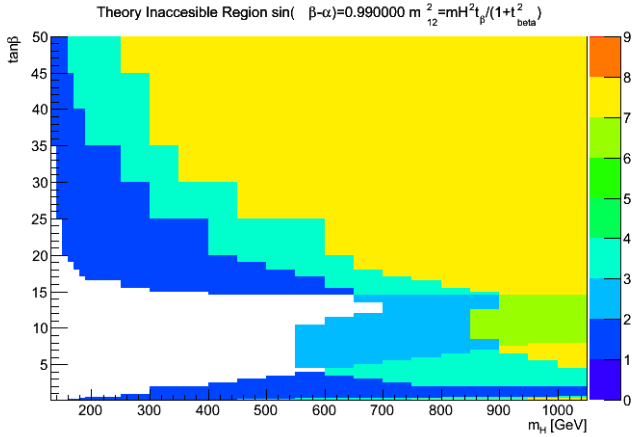


Some benchmarks

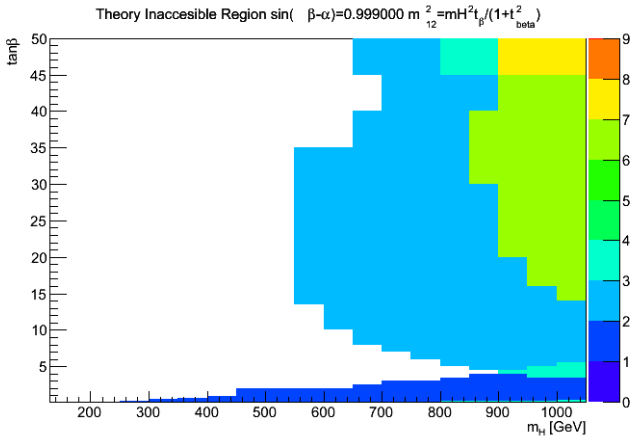
- Another choice would be to choose an MSSM-like m12: $m^2_{12} = m^2_H \tan\beta / (1 + \tan^2\beta)$
- This works well for $\sin(\beta - \alpha) \rightarrow 1$, but fails as you go further from 1.



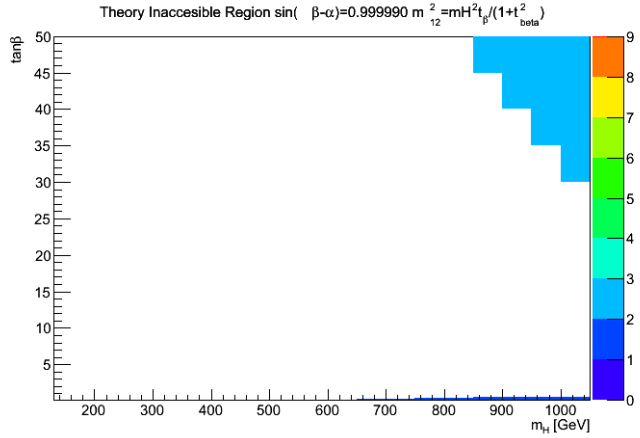
$\sin(\beta - \alpha) = 0.98$



$\sin(\beta - \alpha) = 0.99$



$\sin(\beta - \alpha) = 0.999$

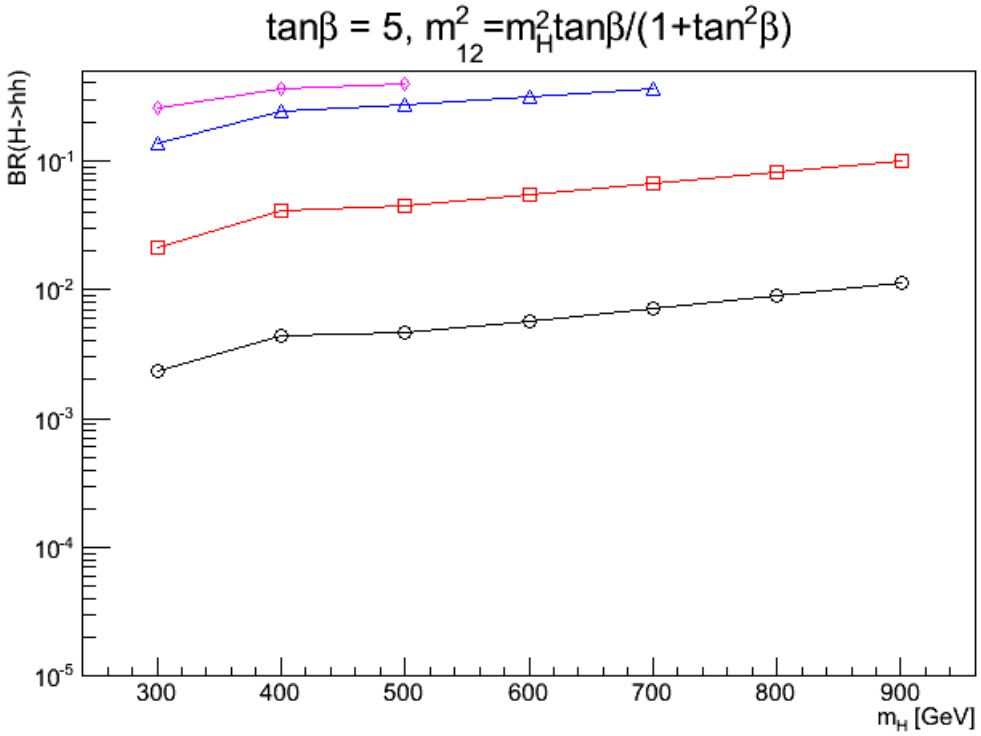


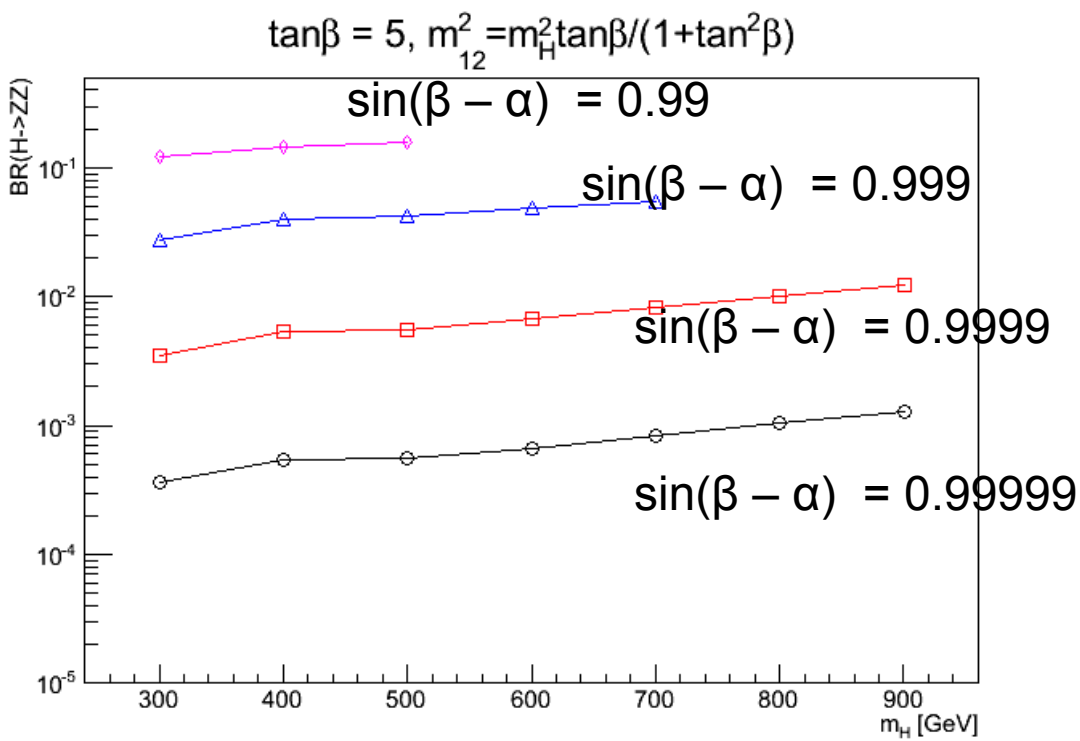
$\sin(\beta - \alpha) = 0.99999$

In the limit $\sin(\beta - \alpha) \rightarrow 1$ all space is available but intersting couplings go to zero.

Some benchmarks

- Branching ratio H → ZZ for various sin(β – α)





Final Words

- Is that all we can do in terms of 2HDM benchmarks for high mass mH (>500 GeV)?
  - If this is the case it is useful for us to know
  - Otherwise we would be interested in looking in other benchmarks too