Discussions on 2HDM (parametrization)

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2HDM

- 2HDM has two Higgs doublets, it predicts
  - Neutral CP-even higgs: h H
  - Neutral CP-odd Higgs: A
  - Charged Higgs: H^{+-}

5 BSM Higgs

$$V(\Phi_1,\Phi_2) = m_{11}^2\Phi_1^\dagger\Phi_1 + m_{22}^2\Phi_2^\dagger\Phi_2 - (m_{12}^2\Phi_1^\dagger\Phi_2 + \text{h.c}) + \frac{1}{2}\lambda_1(\Phi_1^\dagger\Phi_1)^2 + \frac{1}{2}\lambda_2(\Phi_2^\dagger\Phi_2)^2 + \lambda_3(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_2)$$

$$+\lambda_4(\Phi_1^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1) + \left\{\frac{1}{2}\lambda_5(\Phi_1^\dagger\Phi_2)^2 + [\lambda_6(\Phi_1^\dagger\Phi_1) + \lambda_7(\Phi_2^\dagger\Phi_2)](\Phi_1^\dagger\Phi_2) + \text{h.c}\right\} \quad (1)$$

- Very large phase space for all the parameters, but one can narrow it down by theoretical and experimental constratints
  - Motivated by experiments, h is the SM-like Higgs **Alignment limit**
  - Assume the masses of H, A, H^{+-} are the same, since the electroweak precision tests disfavor large mass splitting
  - Assume only soft Z_2 symmetry breaking, so $\lambda_6=\lambda_7=0$
  - Keep CP conservation and flavor conservation

2HDM parametrization

- Then the number of reduced parameters is 7:
  - Masses of h, H, A, H^{+-}
  - Angles tanβ, cos(β-α)
  - Z_2 symmetry breaking term m_{12}^2
- **In this case, all the productions can be parameterized with only two parameters:**
  - **tanβ, cos(β-α), lambda$_5$**

- Look at A->Zh and H->hh
- Both are proportional to cos(β-α)~0 when approaching alignment limit
- When **close to** (or just small deviation from) alignment limit, these two processes are dominant
- But **at** alignment limit, they both vanish, A/H->yy, tautau will be enhanced parametrically

A->Zh/H->hh

- A->Zh

$$g_{hZA} = \frac{1}{2}\sqrt{g^2 + g'^2}\cos(\beta - \alpha)$$

- H->hh

$$\begin{aligned} g_{Hhh} = \frac{\cos(\beta-\alpha)}{v}\Bigg[&\left(3m_A^2 + 3\lambda_5 v^2 - 2m_h^2 - m_H^2\right)\left(\cos(2\beta-2\alpha) - \frac{\sin(2\beta-2\alpha)}{\tan(2\beta)}\right) \\ &- m_A^2 - \lambda_5 v^2 + \frac{\lambda_6 v^2}{2}\left(-\cot\beta + 3\sin(2\beta-2\alpha) + 3\cot\beta\cos(2\beta-2\alpha)\right) \\ &+ \frac{\lambda_7 v^2}{2}\left(-\tan\beta - 3\sin(2\beta-2\alpha) + 3\tan\beta\cos(2\beta-2\alpha)\right)\Bigg] \end{aligned} \qquad (2.11)$$

- H->hh when MSSM

$$g_{Hhh}^{\mathrm{MSSM}} = -\frac{m_Z^2}{v}\Big[2\sin(2\alpha)\sin(\beta+\alpha) - \cos(2\alpha)\cos(\beta+\alpha)\Big]$$

- H->hh when Z_2 exchange symmetry

$$g_{Hhh}^{Z_2} = -\frac{\cos(\beta-\alpha)}{v}\left[\left(2m_h^2 + m_H^2\right)\left(\cos(2\beta-2\alpha) - \frac{\sin(2\beta-2\alpha)}{\tan(2\beta)}\right)\right]$$

To constrain the parameters

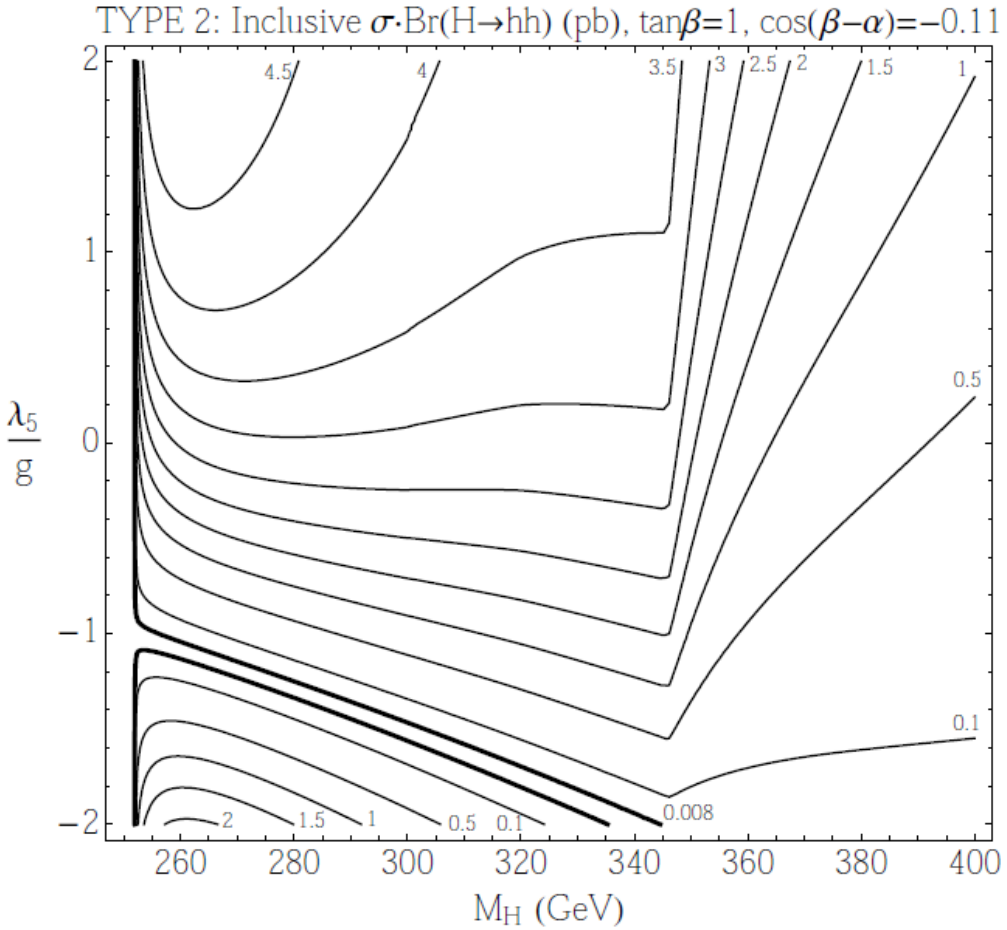
- So we can constrain these parameters from our experiaments

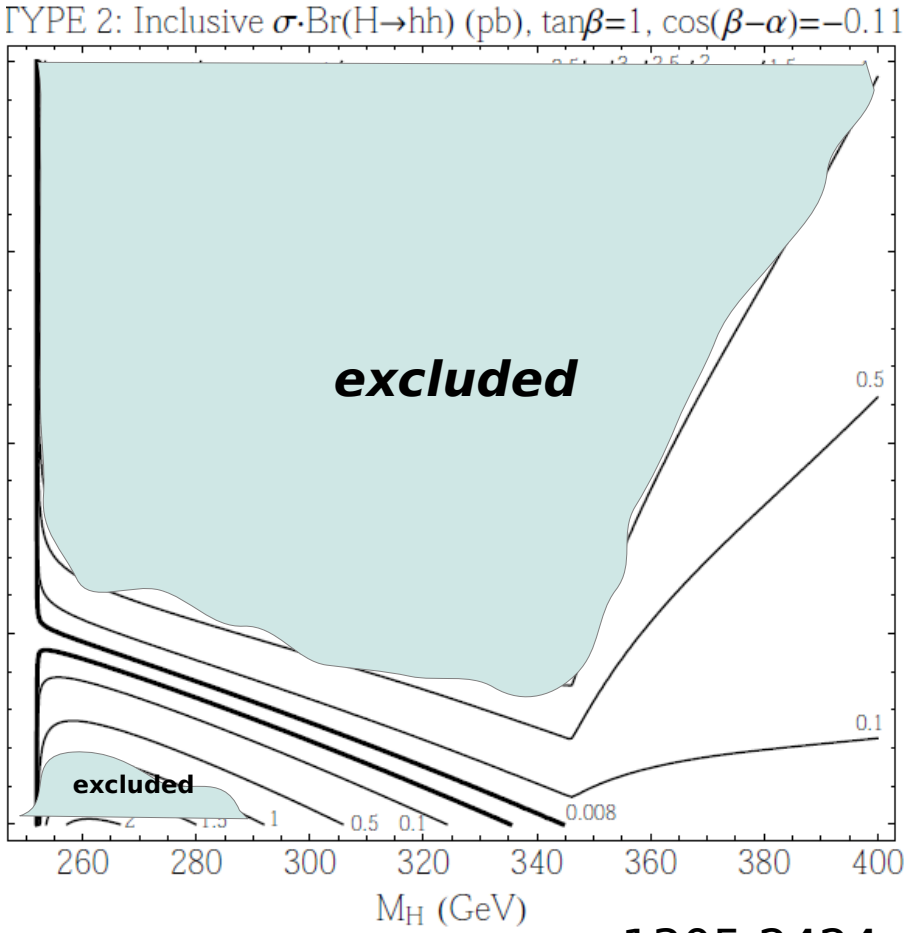
XS of
A->Zh
H->hh

tanβ
cos(β-α)
lambda$_5$

Example on H->hh => (labmda$_5$,M$_H$)

- Left is the phase space of the two parameters
- Right is the expected exclusion in the phase space of the two parameters, when ex. the upper limit of the measured H->hh cross section is 1pb for all the mass points





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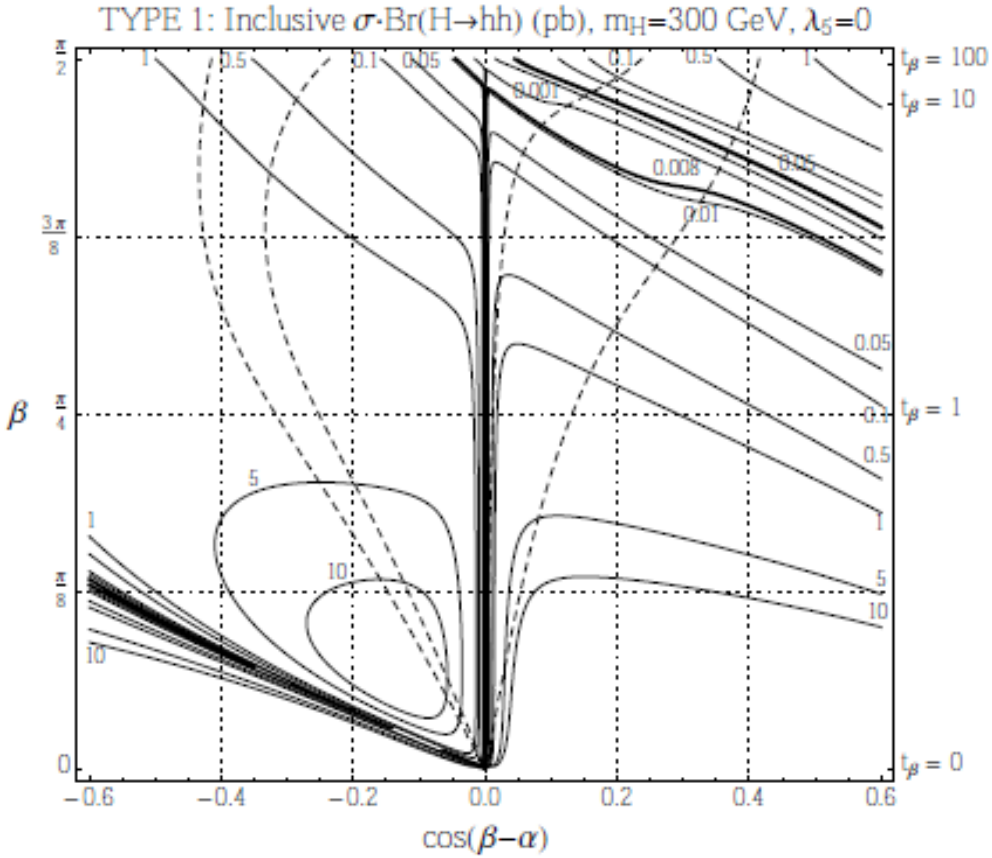
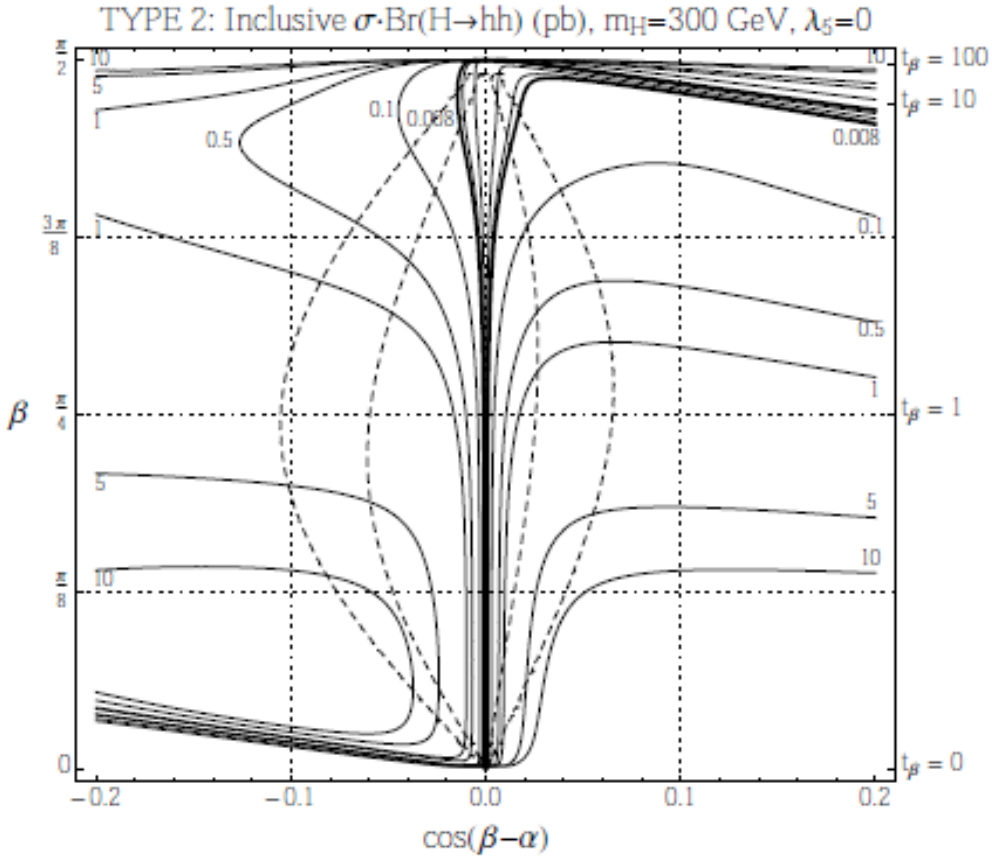
Example on H->hh => (beta,cos(beta-alpha))





The inner (outer) dashed contour denotes the 68% (95%) CL best fit to the signals of the SM-like Higgs from the real data

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