Thoughts on 2HDM Benchmarks

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WG3/Extended scalars
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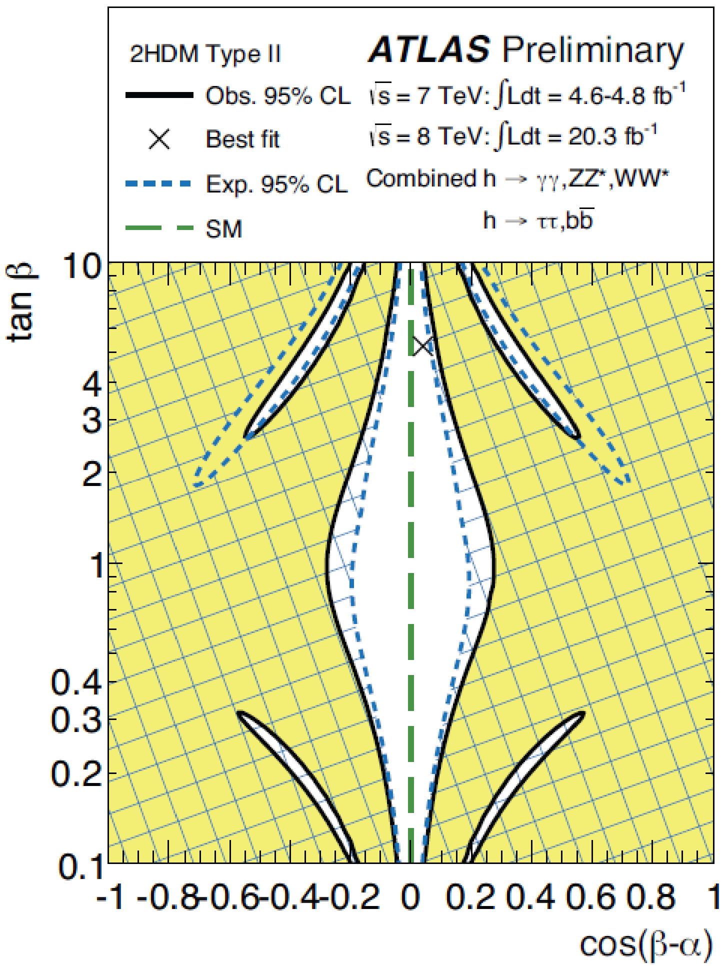
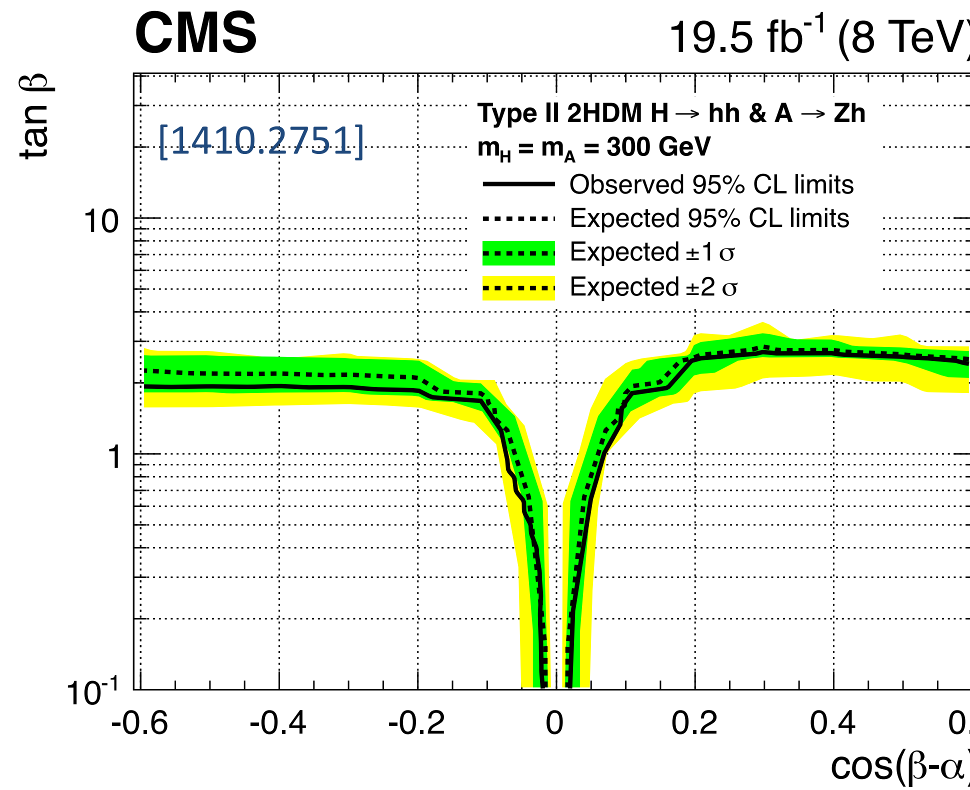
LHC analyses of 2HDM

- Interpretation of 125 GeV coupling measurements

ATLAS-CONF-2014-010





- Genuine 2HDM searches

- Model sensitivity:
  BR(H -> hh) depends on full model
  SM h -> γγ sensitive to H^+H^-h

Idea of Benchmarks

- Like probably most theorists, I favor keeping experimental searches as model-independent as possible.

- Still, in many situations it also makes sense to consider specific models.

- The role of benchmarks is to:
  - Motivate experimental searches to exploit all channels
  - Improve search strategies using model-specific information
  - Combine different channels to improve sensitivity
  - Define unambiguous and complete sets of parameters to
    be able to consider relevant model constraints
    enable calculations of higher-order corrections
    provide language to compare exp <-> exp and exp <-> th

The Higgs basis

- Among the 2HDM basis choices, there is one special case: the *Higgs basis,* where only one of the doublets acquires a vev:

$$H_1 = \cos\beta\Phi_1 + \sin\beta\Phi_2 \qquad \langle H_1^0\rangle = \frac{v}{\sqrt{2}} \qquad \langle H_2^0\rangle = 0$$

$$H_2 = -\sin\beta\Phi_1 + \cos\beta\Phi_2$$

$$\begin{aligned}\mathcal{V} \;=\; & Y_1 H_1^\dagger H_1 + Y_2 H_2^\dagger H_2 + [Y_3 H_1^\dagger H_2 + \text{h.c.}] \\ & +\tfrac{1}{2}Z_1(H_1^\dagger H_1)^2 + \tfrac{1}{2}Z_2(H_2^\dagger H_2)^2 + Z_3(H_1^\dagger H_1)(H_2^\dagger H_2) + Z_4(H_1^\dagger H_2)(H_2^\dagger H_1) \\ & + \left\{\tfrac{1}{2}Z_5(H_1^\dagger H_2)^2 + \big[Z_6(H_1^\dagger H_1) + Z_7(H_2^\dagger H_2)\big]H_1^\dagger H_2 + \text{h.c.}\right\} ,\end{aligned}$$

- Soft Z_2-breaking condition (existence of basis with $\lambda_6 = \lambda_7 = 0$):

$$(Z_1 - Z_2)\big[Z_1 Z_7 + Z_2 Z_6 - Z_{345} Z_{67}\big] + 2Z_{67}^2(Z_6 - Z_7) = 0$$

2HDM Hybrid basis

H.E. Haber, OS [to appear]

- Even with restrictions to CP conservation and soft Z_2 (Types) there remains seven free parameters in the 2HDM:

$$\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, m_{12}^2, \tan\beta$$

or

$$m_h, m_H, m_A, m_{H^\pm}, \sin(\beta-\alpha), m_{12}^2, \tan\beta$$

or

- Hybrid basis: $m_h, m_H, \cos(\beta-\alpha), \tan\beta, Z_4, Z_5, Z_7$

$$m_H > m_h$$

$$0 < \beta < \pi/2 \qquad 0 \le s_{\beta-\alpha} \le 1$$

- "Type" condition on the Yukawa couplings implicit
Z_2 symmetry manifest ($\lambda_6 = \lambda_7 = 0$) in basis with specified $\tan\beta$

Mass relations in hybrid basis

- Remaining masses fixed by the quartic Higgs basis couplings:

$$m_A^2 = m_H^2 s_{\beta-\alpha}^2 + m_h^2 c_{\beta-\alpha}^2 - Z_5 v^2$$

$$m_{H^\pm}^2 = m_A^2 - \frac{1}{2}(Z_4 - Z_5)v^2$$

  Z_7 enters only in triple/quartic scalar interactions

- Theoretical constraints:

$$|Z_i| \lesssim \mathcal{O}(1)$$

- Practical to use hybrid basis to find theoretically allowed regions of 2HDM parameter space.
  Predictions presented in terms of physical parameters.

Overview of scenarios

H.E. Haber, OS [to appear]

- Scenario A
  "Standard" scenario with lightest Higgs at 125 GeV
  $M_h = 125$ GeV $< M_H < M_A = M_{H+}$.
  Useful for H searches in standard modes and H -> h h

- Scenario B
  "Inverted" scenario with heavy CP-even Higgs at 125 GeV
  $M_h < M_H = 125$ GeV $< M_A = M_{H+}$. Useful for h searches.

- Scenario C
  Overlapping CP-even and CP-odd Higgses @ 125 GeV
  $M_h = M_A = 125$ GeV $< M_H = M_{H+}$. Test sensitivity to mixed CP.

Overview of scenarios

H.E. Haber, OS [to appear]

- Scenario D
  "Inverted" scenario with heavy CP-even Higgs having non-SM cascade decays, e.g. H -> A Z, H -> H^+W^-. $M_A/M_{H+} < M_H$.

- Scenario E
  Scenario with heavy CP-odd / charged Higgs in cascades
  A -> H^+ W^- or H^+ -> A W^+.

- Scenario F
  h with SM-like couplings to up-type fermions and vector bosons, but flipped sign of coupling to down-type fermions.

- Scenario G
  "MSSM"-like (mass-degenerate) scenario for heavy Higgs bosons
  M_h = 125 GeV < $M_H = M_A = M_{H+}$, decoupling as M >> v.

2HDMC (2-Higgs Doublet Model Calculator)

- Public, object-oriented C++ code implementing calculations for the general (CP-conserving) 2HDM in different parametrizations

D. Eriksson (Ericsson), OS (Stockholm), J. Rathsman (Lund)
[0902.0851]
http://2hdmc.hepforge.org

- First released in 2009, current public version is 1.6.5

- Predictions for all benchmark scenarios of branching ratios and LHC cross sections – link to SusHi

R. Harlander, S. Liebler, H. Mantler, [1212.3249]

- Part of XSWG interim recommendations for the 2HDM

R. Harlander, M. Muhlleitner, J. Rathsman, M. Spira, OS [1312.5571]

Example: Scenario G (MSSM-like)

- Start from MSSM tree-level values for the Higgs potential

$$\lambda_1 = \lambda_2 = \frac{g^2 + g'^2}{4}, \quad \lambda_3 = \frac{g^2 - g'^2}{4}, \quad \lambda_4 = -\frac{g^2}{2}, \quad \lambda_5 = \lambda_6 = \lambda_7 = 0.$$

$$m_{12}^2 = \frac{1}{2} m_A^2 \sin 2\beta$$

- Assume dominant radiative corrections to the (2,2) element of the CP-even Higgs mass matrix is due to λ_2.
  Define:

$$\lambda_2 \to \lambda_2 + \delta$$

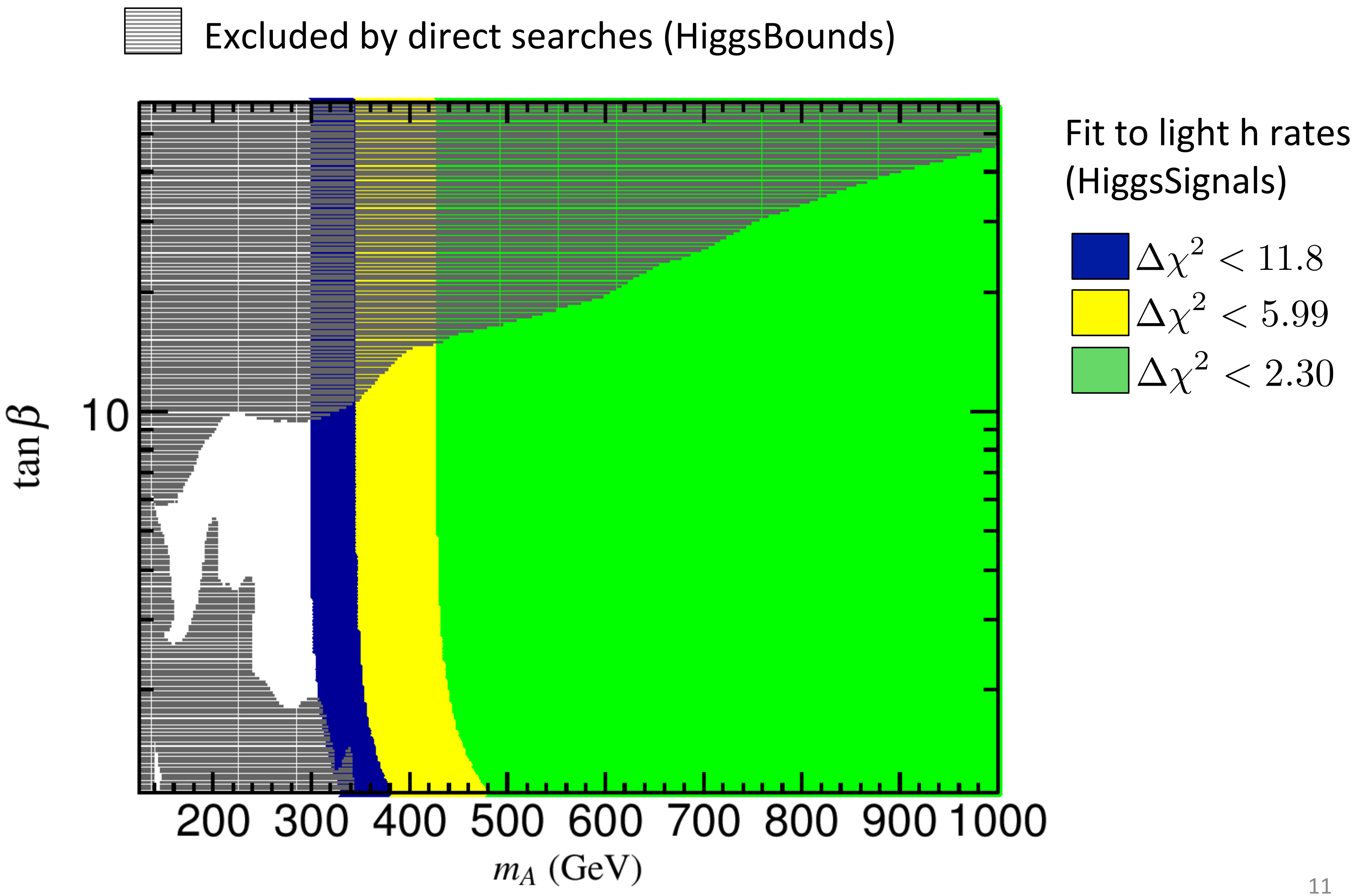
  Use measured value of m_h as input to fix δ. Input parameters:

$$m_A,\ \tan\beta,\ m_h$$

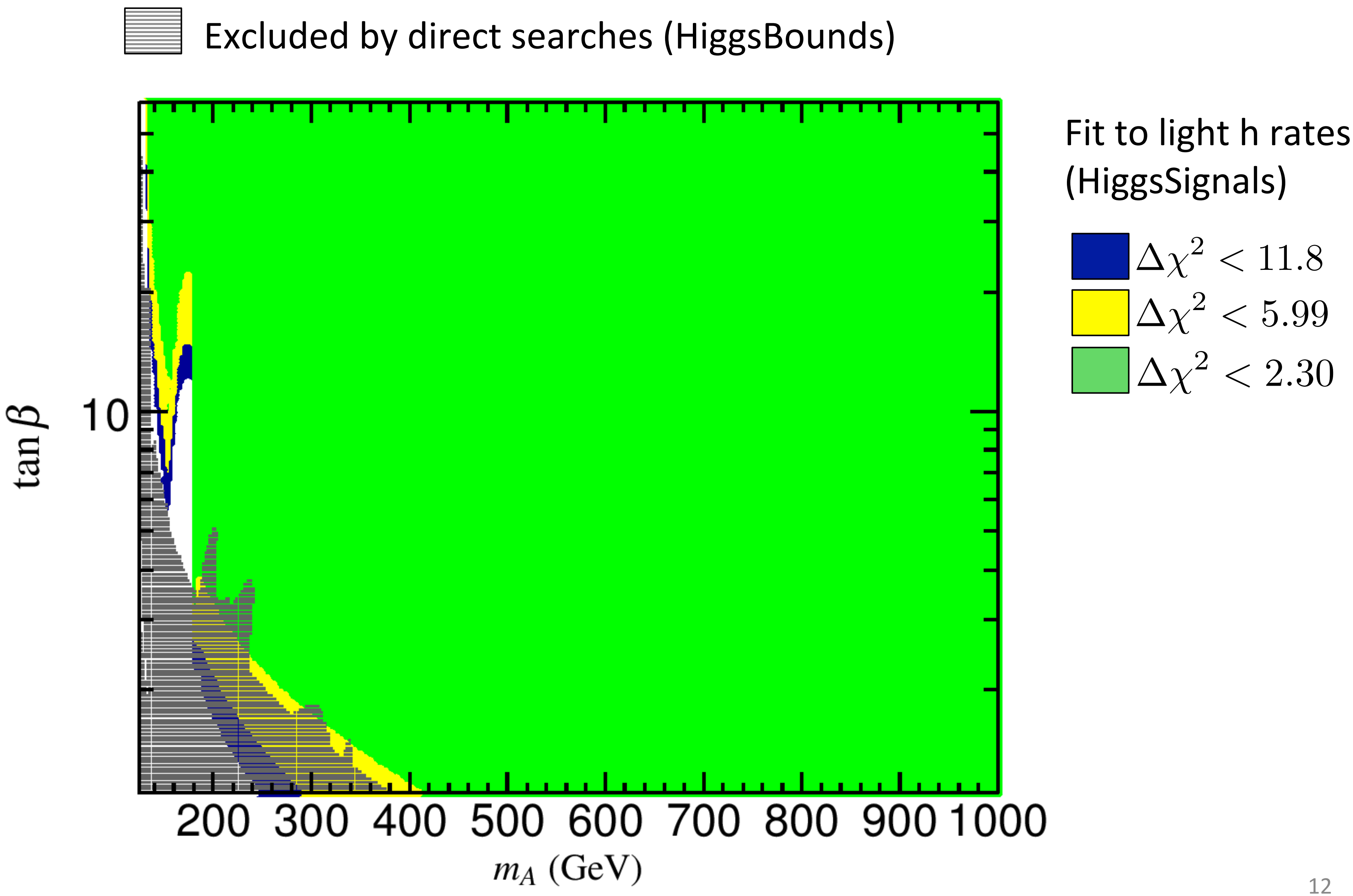
- Phenomenology similar to "hMSSM" approach

A. Djouadi, et al [1307.5205], [1502.05653]

Most MSSM-like scenario (Type-II)



Less MSSM-like scenario (Type-I)



Backup

The general two-Higgs-doublet Model (2HDM)

- Two complex SU(2) doublets (Y=1): $\Phi_1 \,, \Phi_2$

- Scalar potential:

$$V_{2\mathrm{HDM}} = m_{11}^2|\Phi_1|^2 + m_{22}^2|\Phi_2|^2 - \left[m_{12}^2\Phi_1^\dagger\Phi_2 + \mathrm{h.c.}\right]$$
$$+ \frac{1}{2}\lambda_1|\Phi_1|^4 + \frac{1}{2}\lambda_2|\Phi_2|^4 + \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4\left(\Phi_1^\dagger\Phi_2\right)\left(\Phi_2^\dagger\Phi_1\right)$$
$$+ \left\{\frac{1}{2}\lambda_5\left(\Phi_1^\dagger\Phi_2\right)^2 + \left[\lambda_6\left(\Phi_1^\dagger\Phi_1\right) + \lambda_7\left(\Phi_2^\dagger\Phi_2\right)\right]\left(\Phi_1^\dagger\Phi_2\right) + \mathrm{h.c.}\right\}$$

- Complex phases on λ_5, λ_6, λ_7 and m_{12} can give rise to tree-level CP-violation (restricted by data). This talk: CP conservation.

- Reparametrization invariance: $\Phi_a = U_{ab}\Phi_b \quad (a = 1, 2)$

Review: [arXiv:1106.0034]

The general two-Higgs-doublet Model (2HDM)

- Introducing an explicit basis in (Φ_1, Φ_2) space: $\tan\beta = \dfrac{v_2}{v_1}$

$$\Phi_1 = \frac{1}{\sqrt{2}} \begin{pmatrix} \sqrt{2}\,(G^+ \cos\beta - H^+ \sin\beta) \\ v\cos\beta - h\sin\alpha + H\cos\alpha + \mathrm{i}\,(G^0\cos\beta - A\sin\beta) \end{pmatrix}$$

$$\Phi_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} \sqrt{2}\,(G^+ \sin\beta + H^+ \cos\beta) \\ v\sin\beta + h\cos\alpha + H\sin\alpha + \mathrm{i}\,(G^0\sin\beta + A\cos\beta) \end{pmatrix}$$

- Five physical Higgs states following EWSB:
  Two CP-even Higgs bosons: h, H
  $m_h < m_H$, mixing angle α
  One CP-odd Higgs boson: A
  One charged Higgs pair: H^{+-}

Higgs Couplings

- Couplings to vector bosons determined by mixing angle

$$\frac{g_{hVV}}{g_{hVV}^{\rm SM}} = \sin(\beta-\alpha) \qquad \frac{g_{HVV}}{g_{HVV}^{\rm SM}} = \cos(\beta-\alpha) \qquad g_{AVV} = 0$$

SM-like Higgs $\sin(\beta-\alpha) \to 1$ possible with or without decoupling

- 2HDM Yukawa couplings in arbitrary basis

$$\begin{aligned}
-\mathcal{L}_{\rm Y} = {} & \frac{1}{\sqrt{2}}\overline{D}\Big[\kappa^D s_{\beta-\alpha} + \rho^D c_{\beta-\alpha}\Big]Dh + \frac{1}{\sqrt{2}}\overline{D}\Big[\kappa^D c_{\beta-\alpha} - \rho^D s_{\beta-\alpha}\Big]DH + \frac{\rm i}{\sqrt{2}}\overline{D}\gamma_5\rho^D DA \\
& + \frac{1}{\sqrt{2}}\overline{U}\Big[\kappa^U s_{\beta-\alpha} + \rho^U c_{\beta-\alpha}\Big]Uh + \frac{1}{\sqrt{2}}\overline{U}\Big[\kappa^U c_{\beta-\alpha} - \rho^U s_{\beta-\alpha}\Big]UH - \frac{\rm i}{\sqrt{2}}\overline{U}\gamma_5\rho^U UA \\
& + \frac{1}{\sqrt{2}}\overline{L}\Big[\kappa^L s_{\beta-\alpha} + \rho^L c_{\beta-\alpha}\Big]Lh + \frac{1}{\sqrt{2}}\overline{L}\Big[\kappa^L c_{\beta-\alpha} - \rho^L s_{\beta-\alpha}\Big]LH + \frac{\rm i}{\sqrt{2}}\overline{L}\gamma_5\rho^L LA \\
& + \Big[\overline{U}\big(V_{\rm CKM}\rho^D P_R - \rho^U V_{\rm CKM} P_L\big)DH^+ + \overline{\nu}\rho^L P_R L H^+ + {\rm h.c.}\Big].
\end{aligned}$$

H.E.Haber, D.O'Neil [hep-ph/0602242]

- If ρ^F and κ^F are not simultaneously diagonal the Higgs sector mediates tree-level FCNC (-> strongly restricted from data)

Absence of tree-level FCNC –> 2HDM Types

- To get rid of these FCNC naturally, implement a (softly broken) Z_2 symmetry -> 2HDM *Types* depending on fermion Z_2 charges

$$\rho_F \propto \kappa_F = \frac{\sqrt{2}}{v} M_F$$

Barger, Hewitt, Philips, PRD41 (1990)

Type	U_R	D_R	L_R	ρ^U	ρ^D	ρ^L
I	$+$	$+$	$+$	$\kappa^U \cot\beta$	$\kappa^D \cot\beta$	$\kappa^L \cot\beta$
II	$+$	$-$	$-$	$\kappa^U \cot\beta$	$-\kappa^D \tan\beta$	$-\kappa^L \tan\beta$
III	$+$	$-$	$+$	$\kappa^U \cot\beta$	$-\kappa^D \tan\beta$	$\kappa^L \cot\beta$
IV	$+$	$+$	$-$	$\kappa^U \cot\beta$	$\kappa^D \cot\beta$	$-\kappa^L \tan\beta$

Type III = Type Y = “Flipped” Type IV = Type X = “Lepton-spec.”

- Promotes tan β to a physical parameter (basis with $\lambda_6 = \lambda_7 = 0$)

- MSSM: Type-II couplings <u>at tree level</u>, broken by Δ_b corrections

From Hybrid basis to Higgs basis

- Higgs basis condition for soft Z_2-breaking:

$$(Z_1 - Z_2)\big[Z_1 Z_7 + Z_2 Z_6 - Z_{345} Z_{67}\big] + 2Z_{67}^2 (Z_6 - Z_7) = 0$$

- Preferred basis in which soft Z_2-breaking is manifest:

$$\tan 2\beta = \pm \frac{|Z_6| + \varepsilon_6 \varepsilon_7 |Z_7|}{Z_2 - Z_1}$$

- Remaining quartic couplings (in the Higgs basis) determine the CP-odd and charged Higgs mases:

$$m_A^2 = m_H^2 s_{\beta-\alpha}^2 + m_h^2 c_{\beta-\alpha}^2 - Z_5 v^2$$

$$m_{H^\pm}^2 = m_A^2 - \frac{1}{2}(Z_4 - Z_5) v^2$$

Alignment and Decoupling

- Assuming that the lightest 2HDM state (h) is the 125 GeV Higgs, SM-like couplings are obtained for $\cos(\beta-\alpha) \simeq 0$

- Without approximation, the following relation holds:

$$\sin(\beta-\alpha)\cos(\beta-\alpha) = -\frac{Z_6 v^2}{m_H^2 - m_h^2}$$

- Two ways in which the 2HDM can mimic the SM:

Alignment: $Z_6 \to 0$ (independent of m_H)

Decoupling: $m_H \gg v$ (independently of Z_6)

-> Measuring SM-like Higgs does not necessarily imply $m_H \gg v$

Scenario A

"Standard" scenario with lightest Higgs at 125 GeV

M_h = 125 GeV < M_H < M_A = M_{H+}.

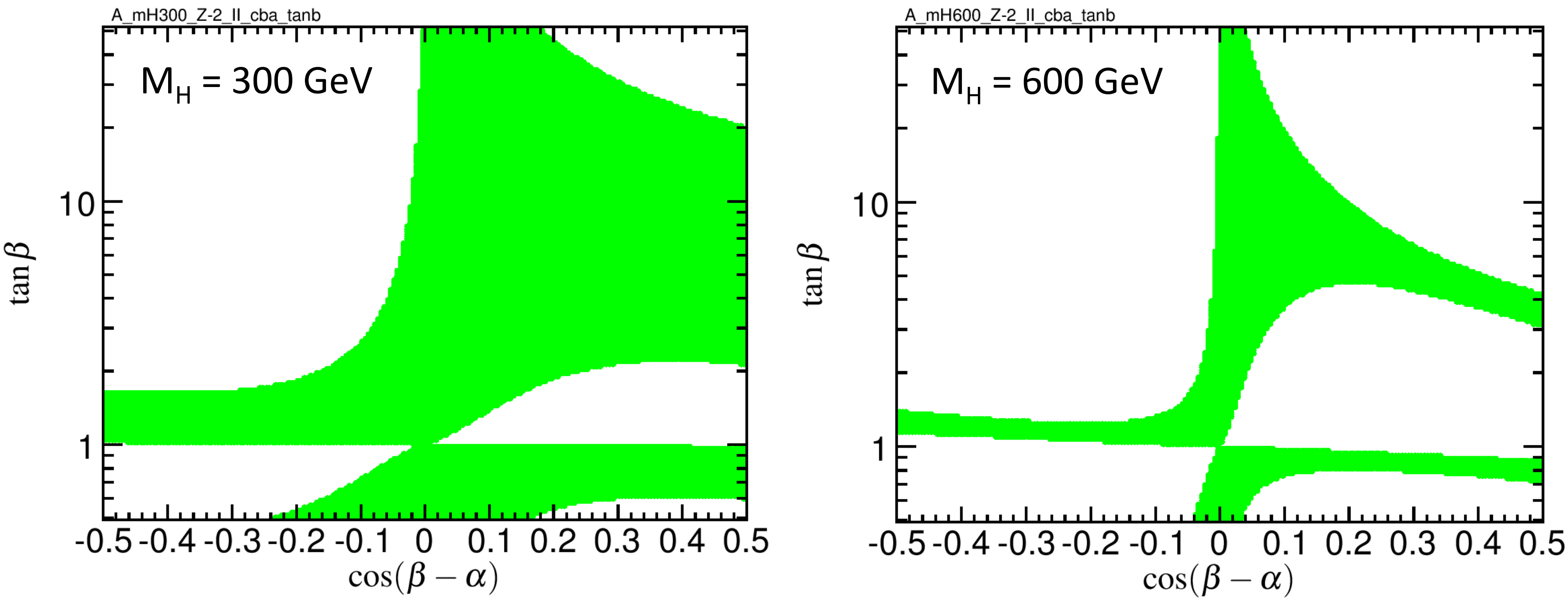
$$Z_4 = Z_5 = -2 \qquad Z_7 = 0$$

Theoretical constraints restricts coupling space

- As before, S-matrix unitarity and positivity of Higgs potential:

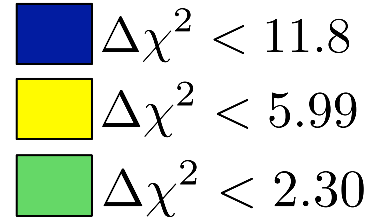
$$Z_i \sim \mathcal{O}(1)$$

Ex: M_h = 125 GeV < M_H < M_A = M_{H+} ($Z_4 = Z_5 < -2$, $Z_7 = 0$)



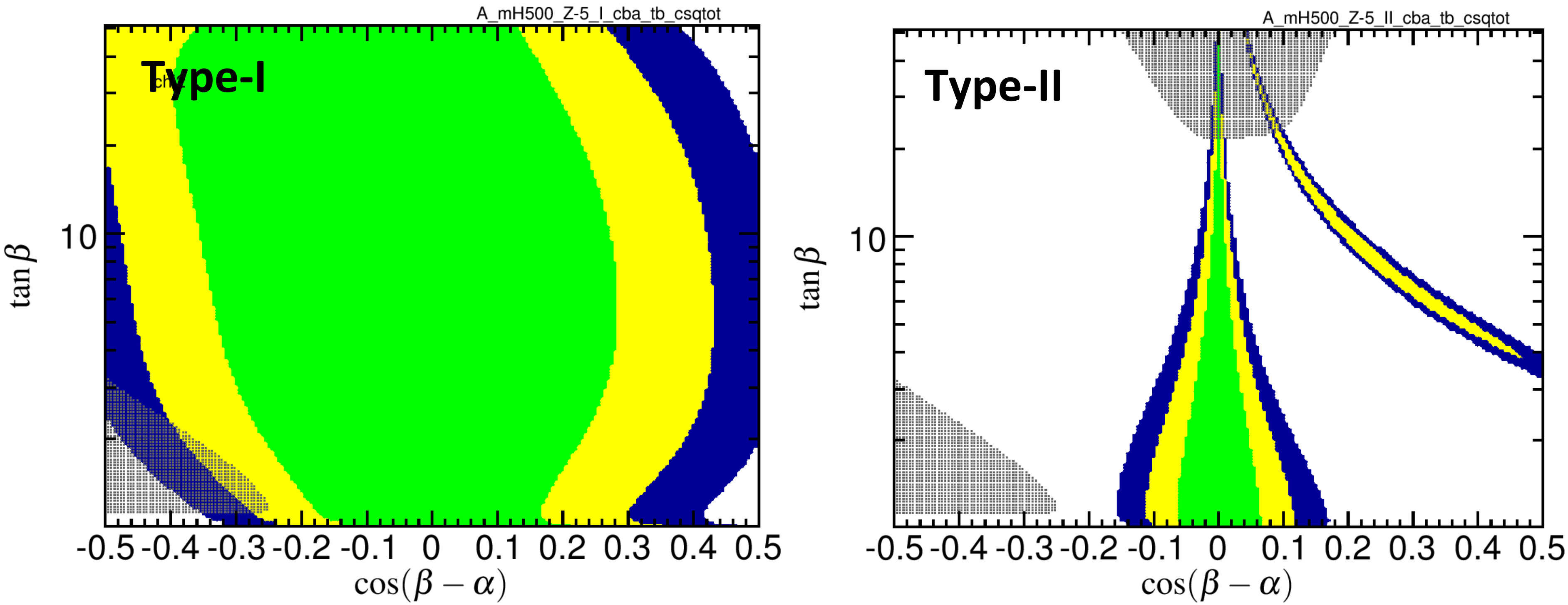
- Allowed parameter region tends towards SM ($c_{\beta-\alpha} \to 0$) at high tan β, positive values of $c_{\beta-\alpha}$ preferred for tan β > 1

Scenario A: Lightest 2HDM Higgs@125 GeV



- χ^2 fit of light Higgs signal rates with HiggsSignals

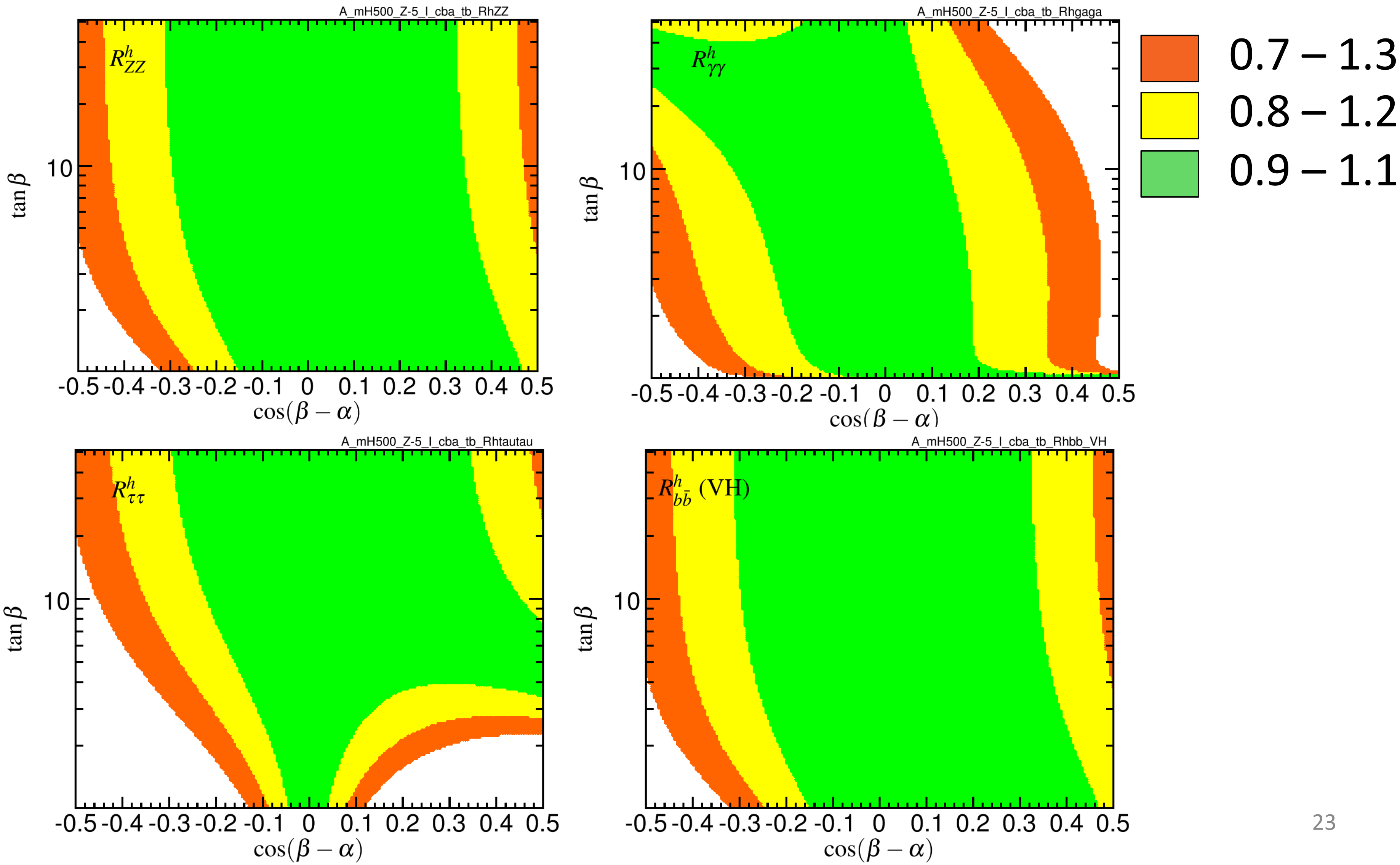
$M_H = 500\,\text{GeV} < M_A = M_{H^\pm}$



- Type-II couplings much more restricted around alignment, in particular for high tan β. Exception: flipped-sign scenario (F)

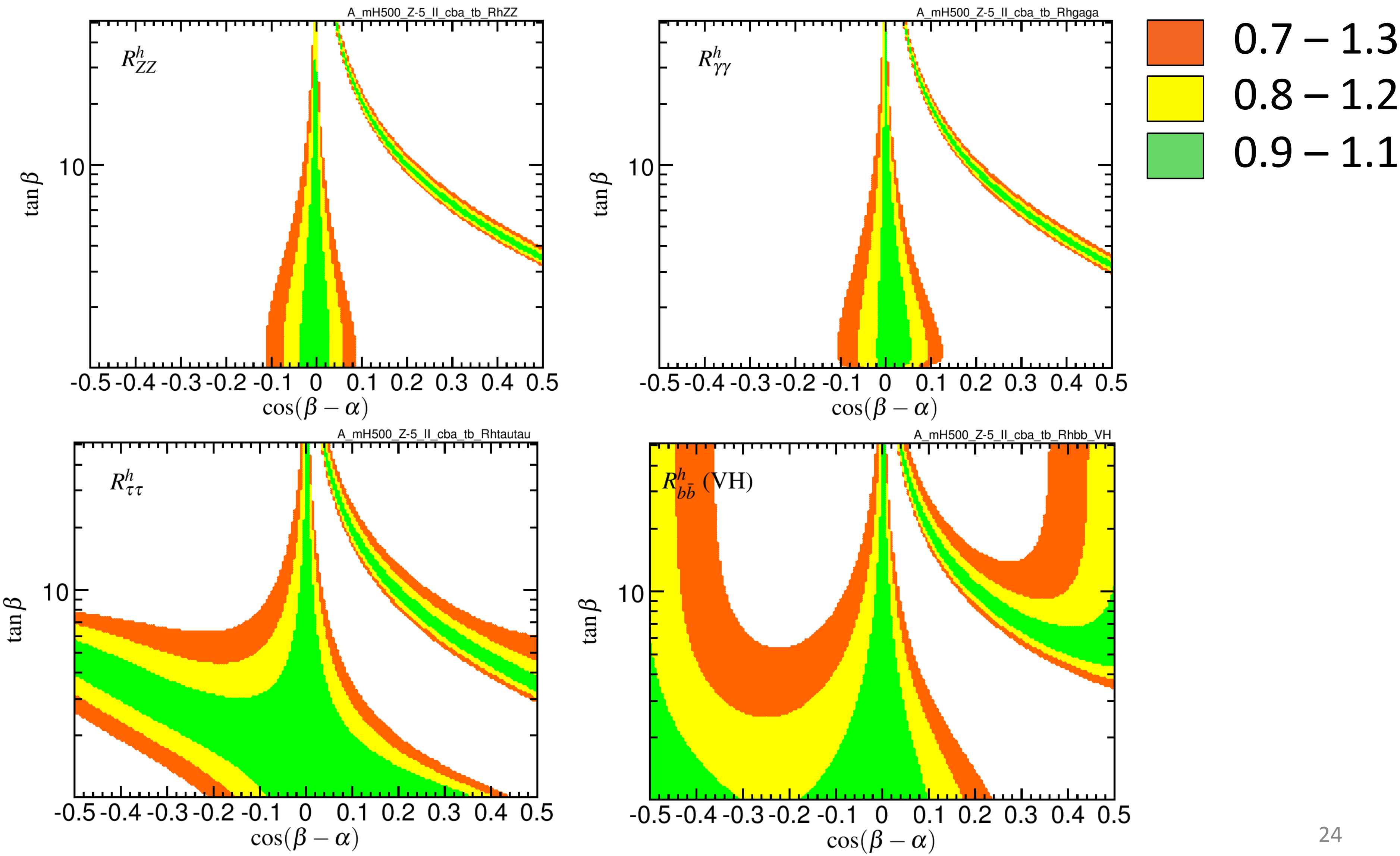
Ferreira, Haber, Gunion, Santos, [1403.4736]

Scenario A (Type-I): Light Higgs rates

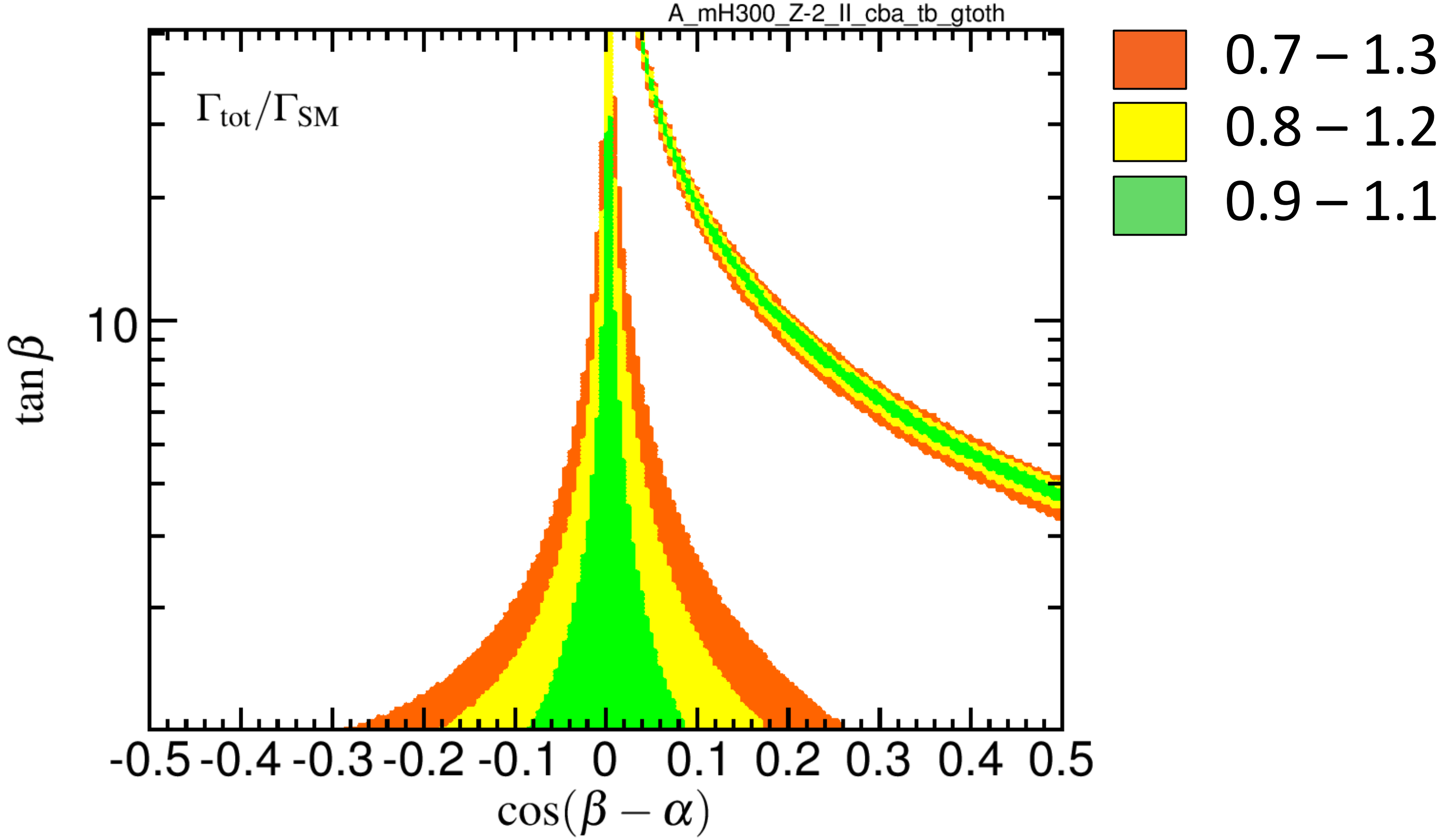


Scenario A (Type-II): Light Higgs rates

- Allowed region driven by total width (h -> bb)



Total width

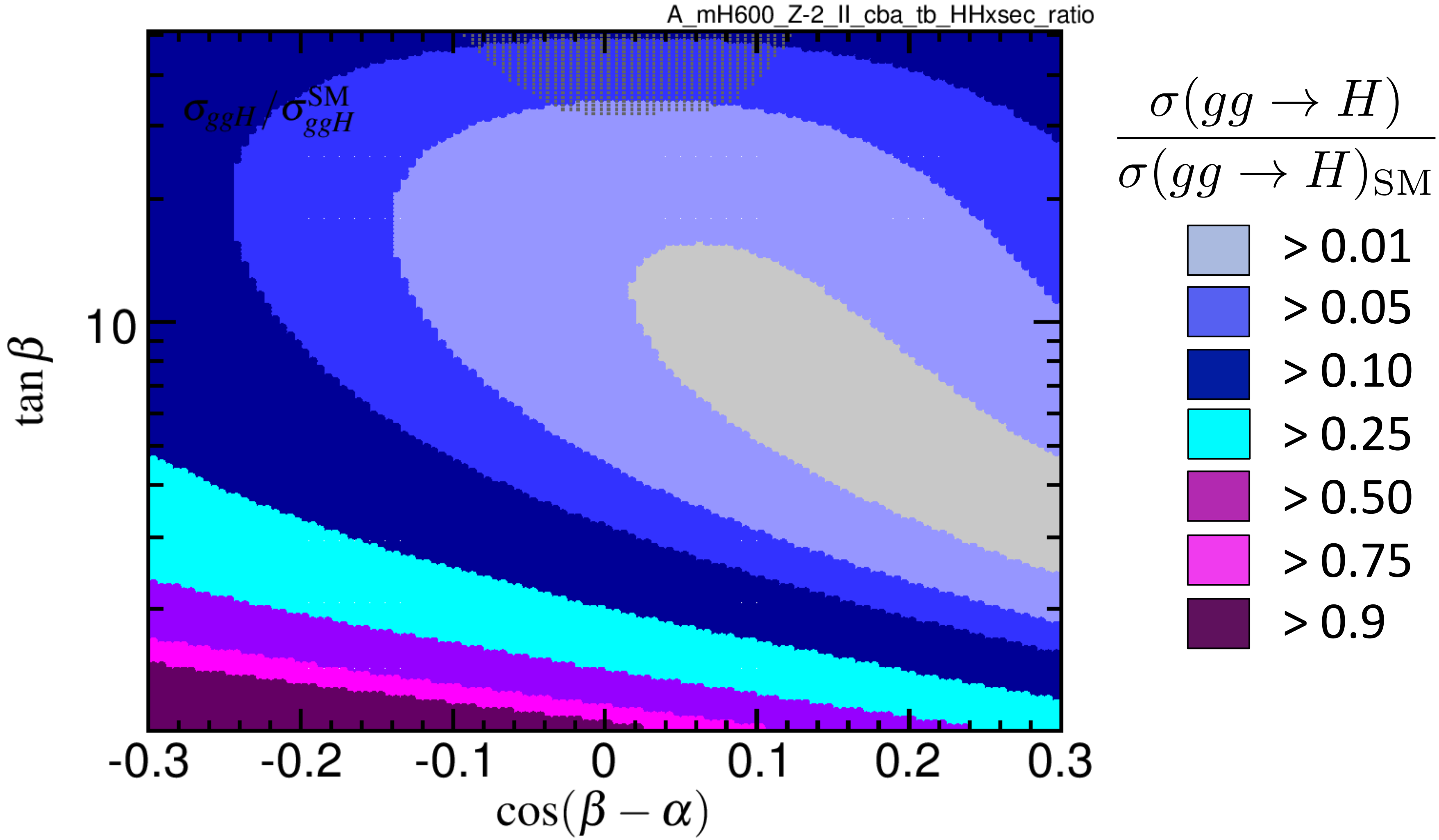


- The experimentally favored region is driven by the total h width, which in turns follow closely the coupling to b quarks

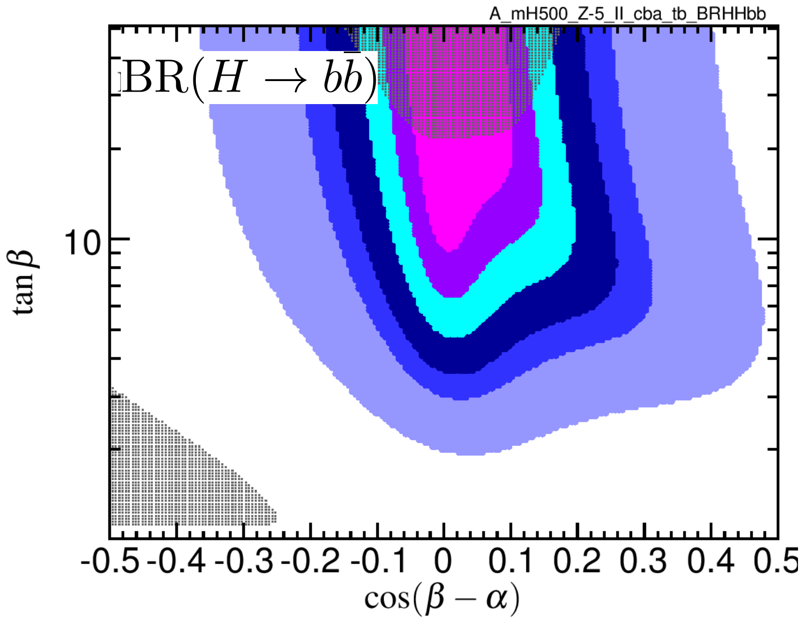
$$\frac{g_{hd\bar{d}}}{g_{hd\bar{d}}^{\mathrm{SM}}} = \sin(\beta-\alpha) - \tan\beta\cos(\beta-\alpha)$$

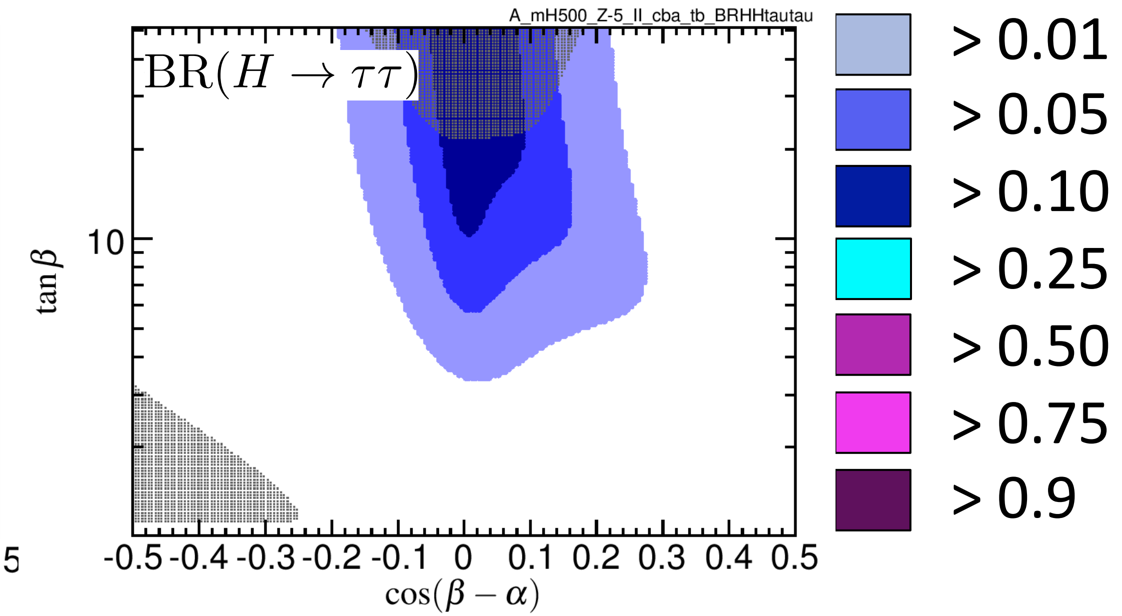
Type-II: Heavy Higgs production

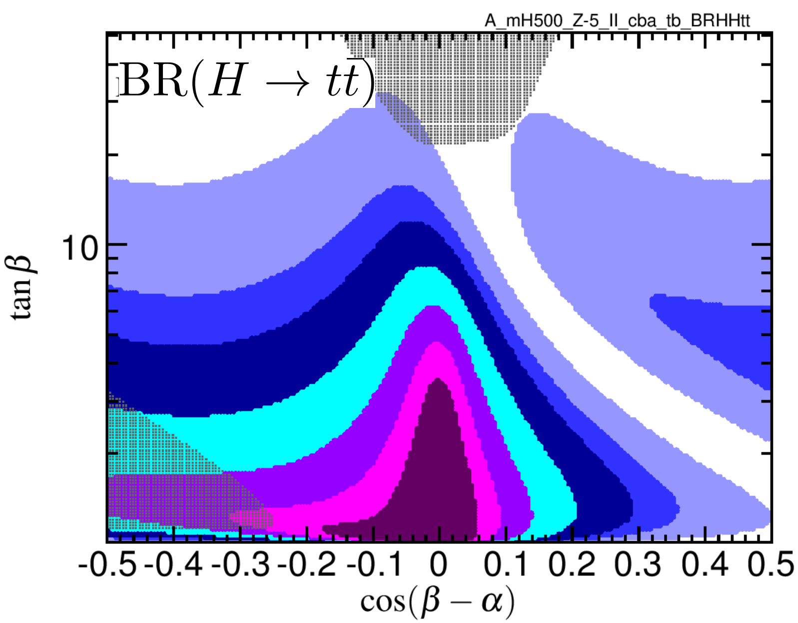
- Since the H must have suppressed couplings to gauge bosons, only $gg \to H$ and $b\bar{b} \to H$ (at high tan β)



Type-II: H decays to fermions



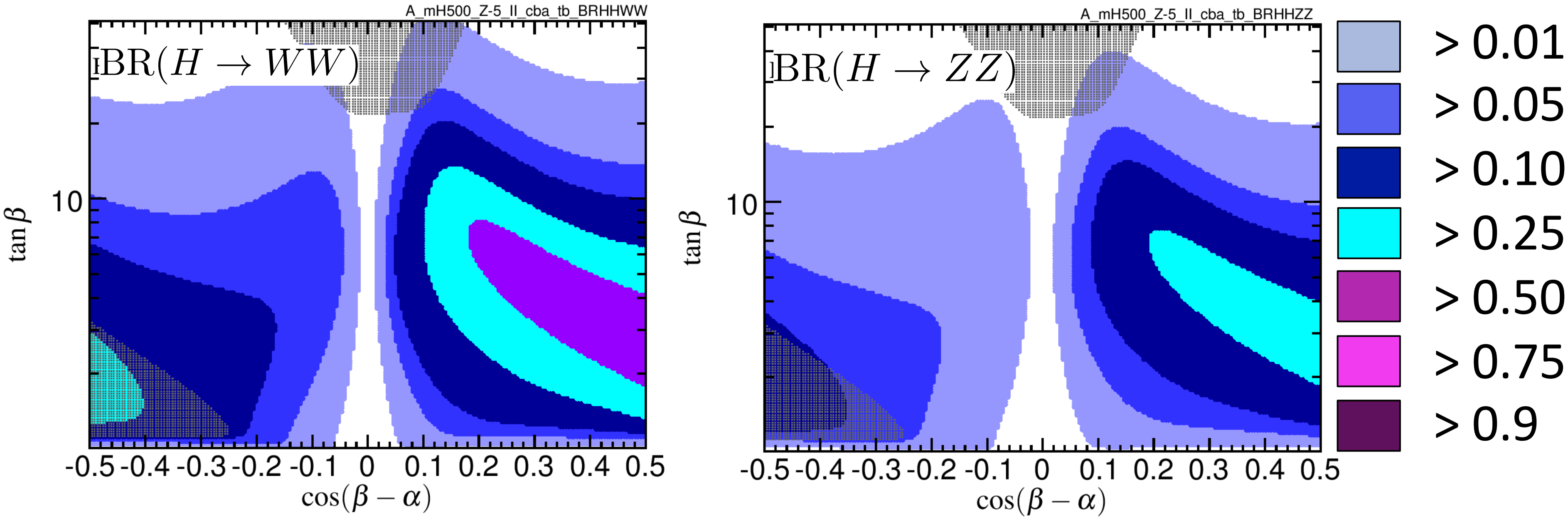


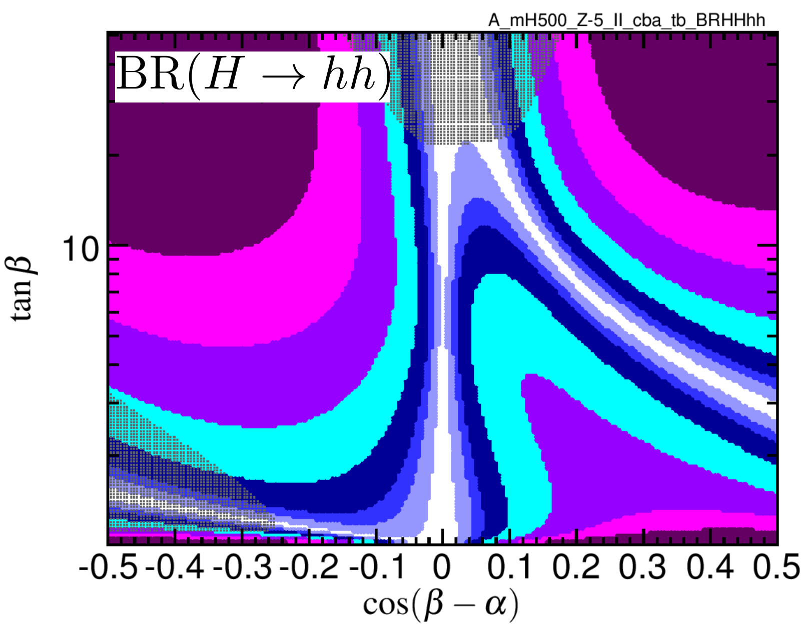


$$m_H = 500\,\mathrm{GeV}$$

- Fermions dominate when h becomes SM-like, $c_{\beta-\alpha} \to 0$
- Complementarity between up- and down-type modes typical of Type-II

Type-II: H decays to bosons

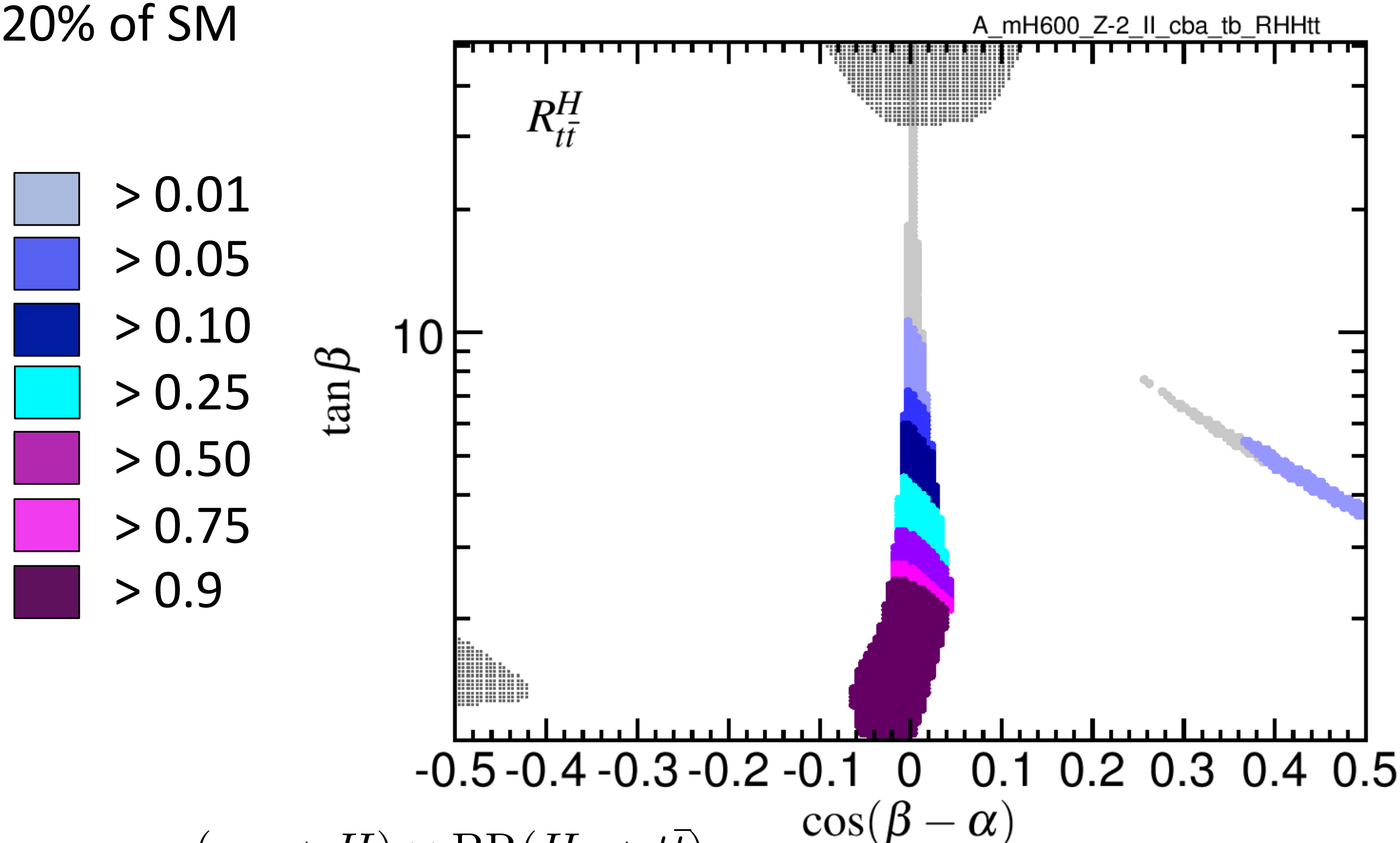




- Bosonic modes become important away from $c_{\beta-\alpha} = 0$
- Difficult to have appreciable rate in region allowed by 125 GeV measurements (for Type-II)

Type-II: The allowed parameter space

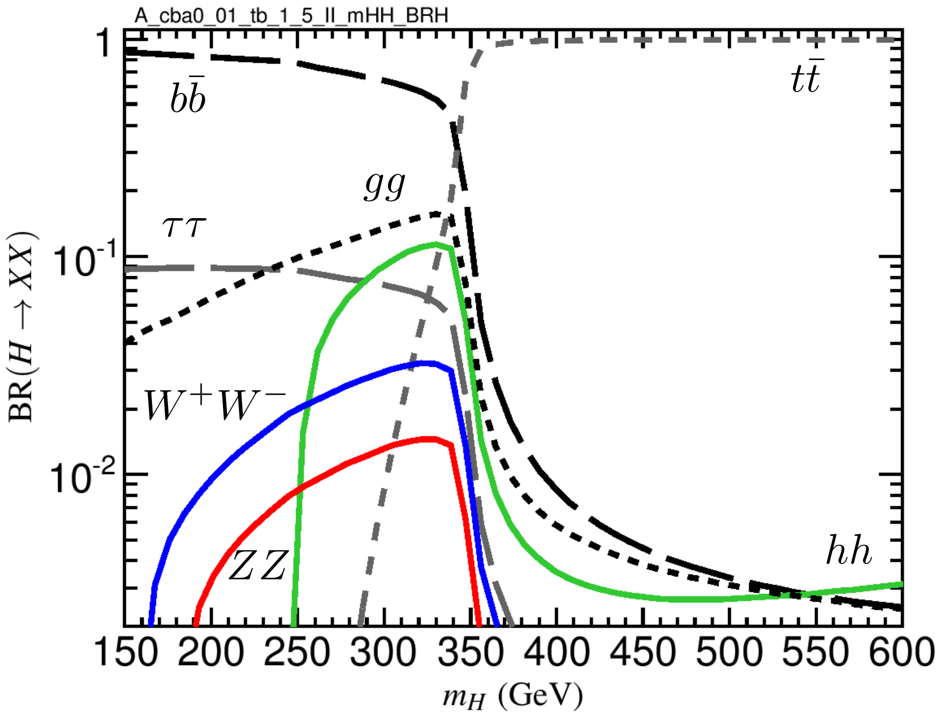
- Applying theory constraints and rates of 125 GeV Higgs within 20% of SM

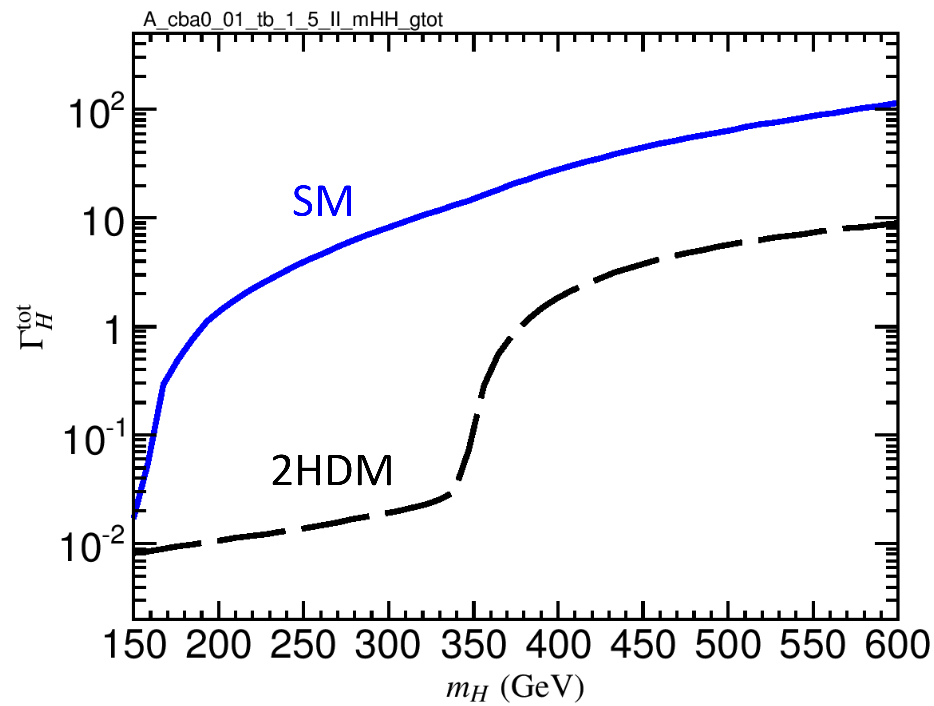


$$R^H_{t\bar{t}} = \frac{\sigma(gg \to H) \times \mathrm{BR}(H \to t\bar{t})}{[\sigma(gg \to H) \times \mathrm{BR}(H \to t\bar{t})]_{\mathrm{SM}}}$$

Scenario A: Type-II Benchmark

- 1D Benchmark can be defined by choosing fixed values for $c_{\beta\text{-}\alpha}$ and tan β inside allowed region, Ex: cos(β−α) = 0.01, tan β = 1.5

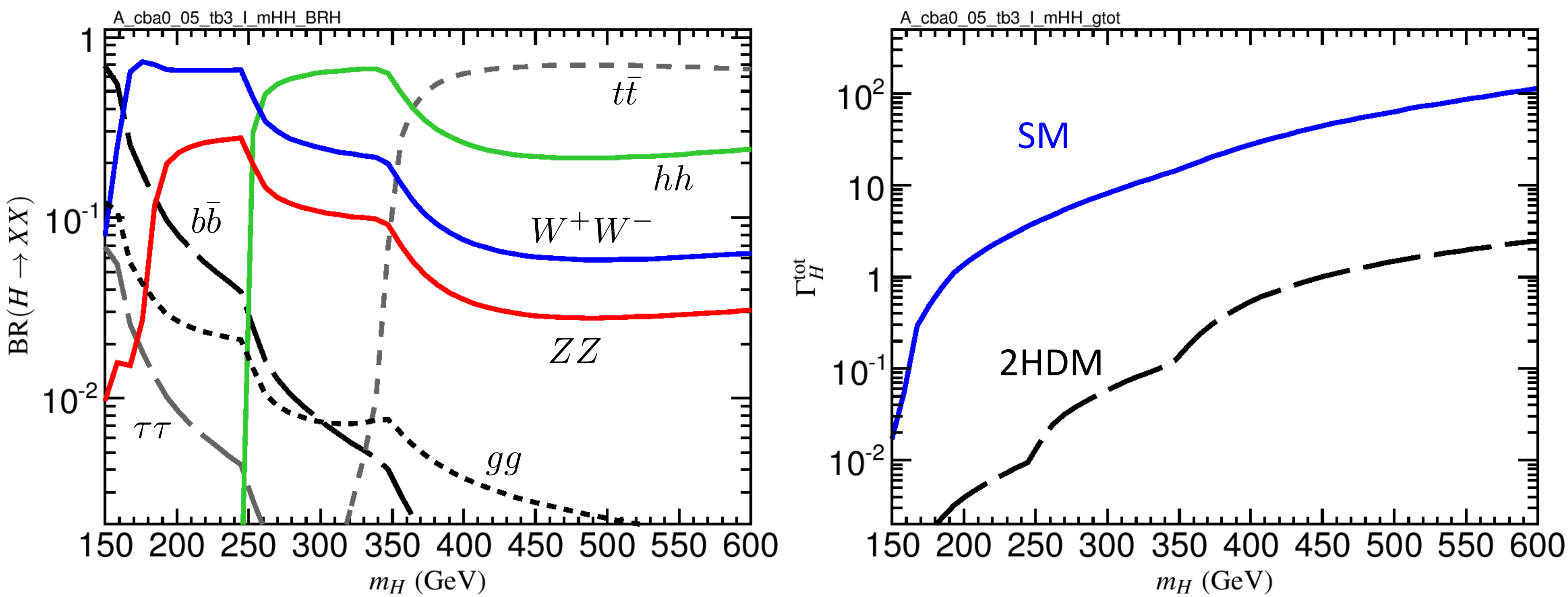




- Maximizes production and decay to tt
  Total H width remains relatively small, $\Gamma_H/\Gamma_{\rm SM} < 0.1$

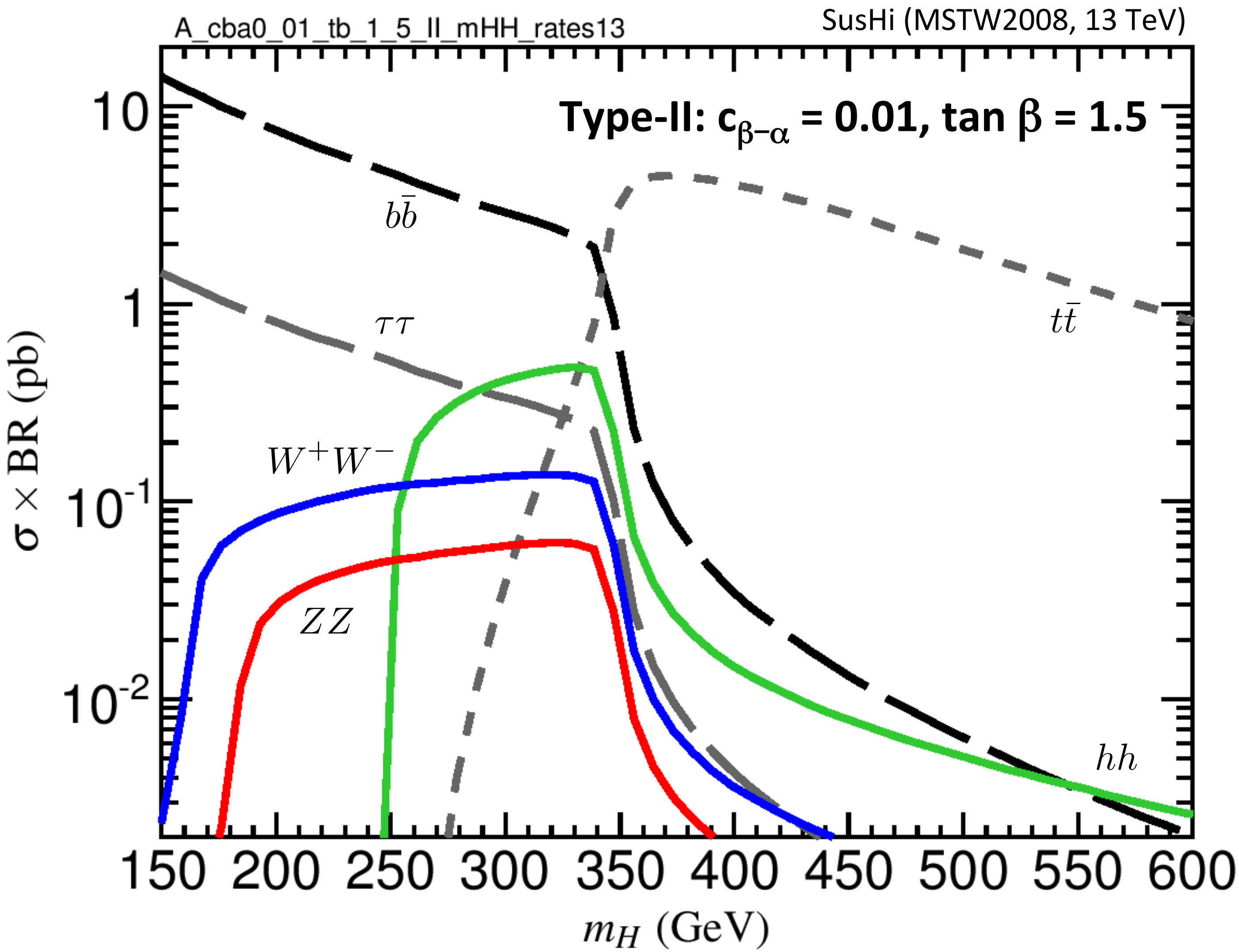
Scenario A: Type-I Benchmark

- For Type-I, larger deviations from SM in the coupling to vector bosons is allowed. Ex: cos(β−α) = 0.05, tan β = 3

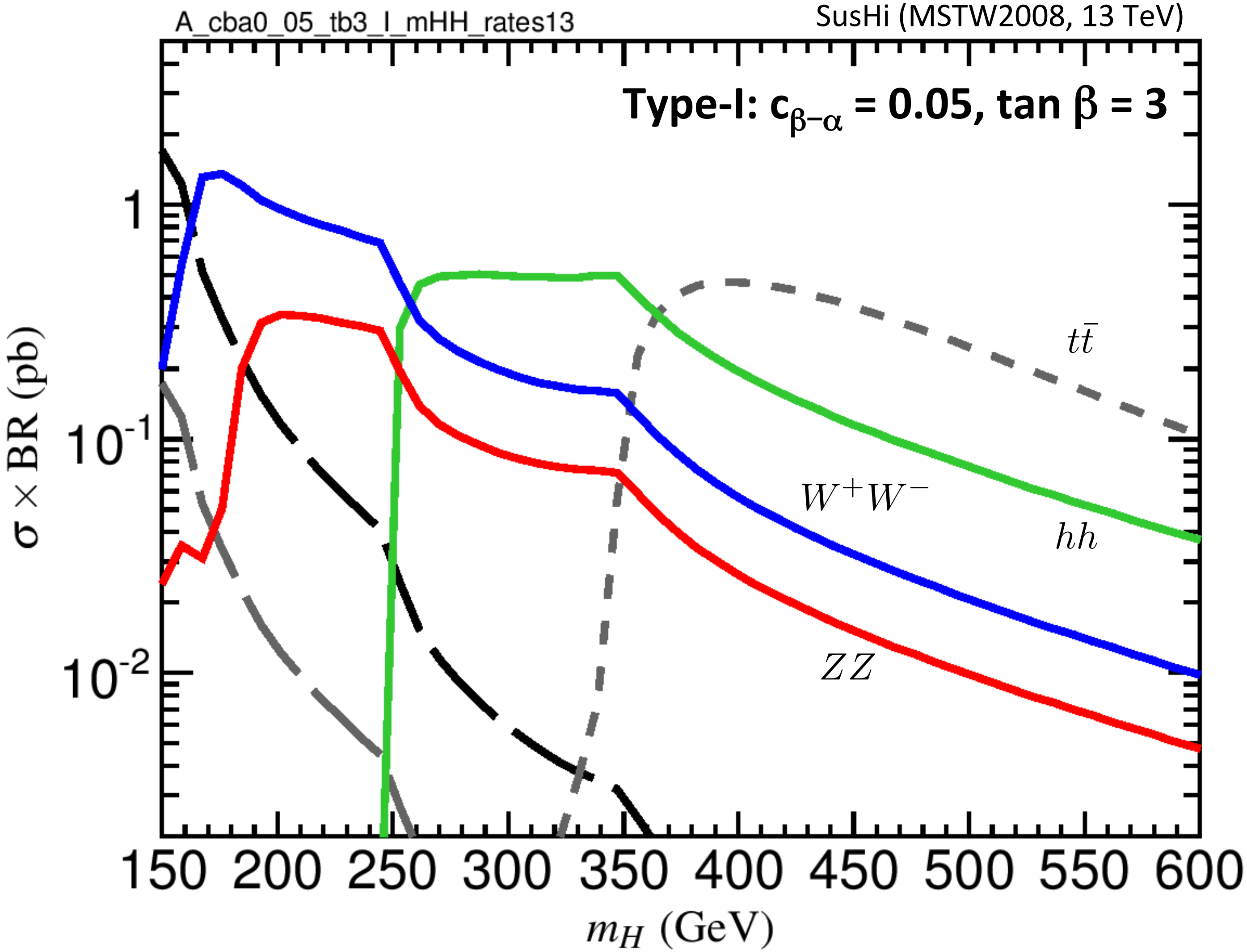


- Sizeable branching ratios to bosonic final states, total width small Without perturbativity constraint H -> hh, grows without control

Total rates for LHC-13



Total rates for LHC-13



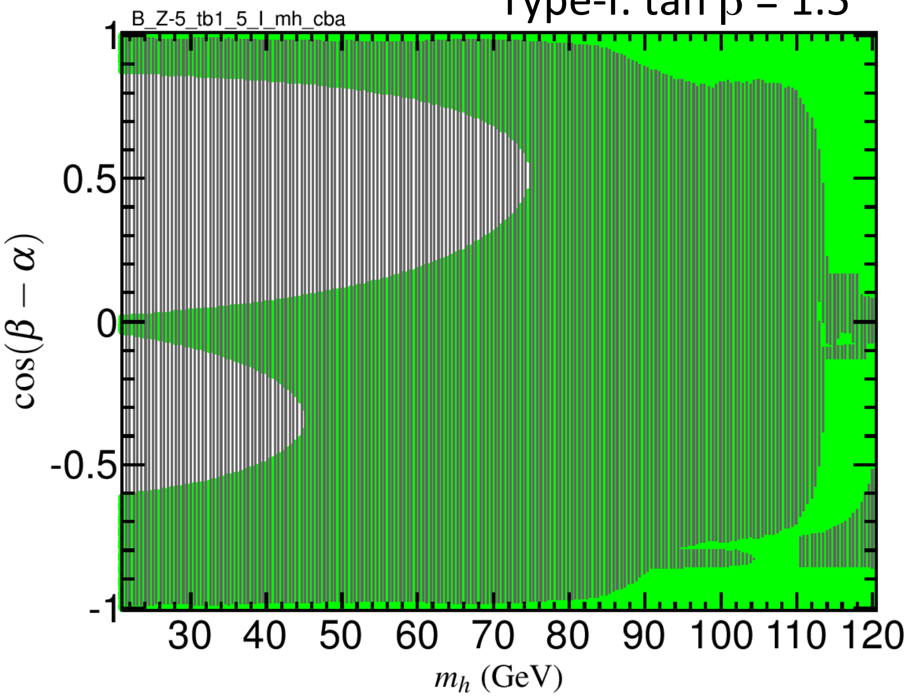
Scenario B

"Inverted" scenario with heavy CP-even Higgs at 125 GeV
$M_h < M_H = 125$ GeV < $M_A = M_{H+}$. Useful for light h searches.

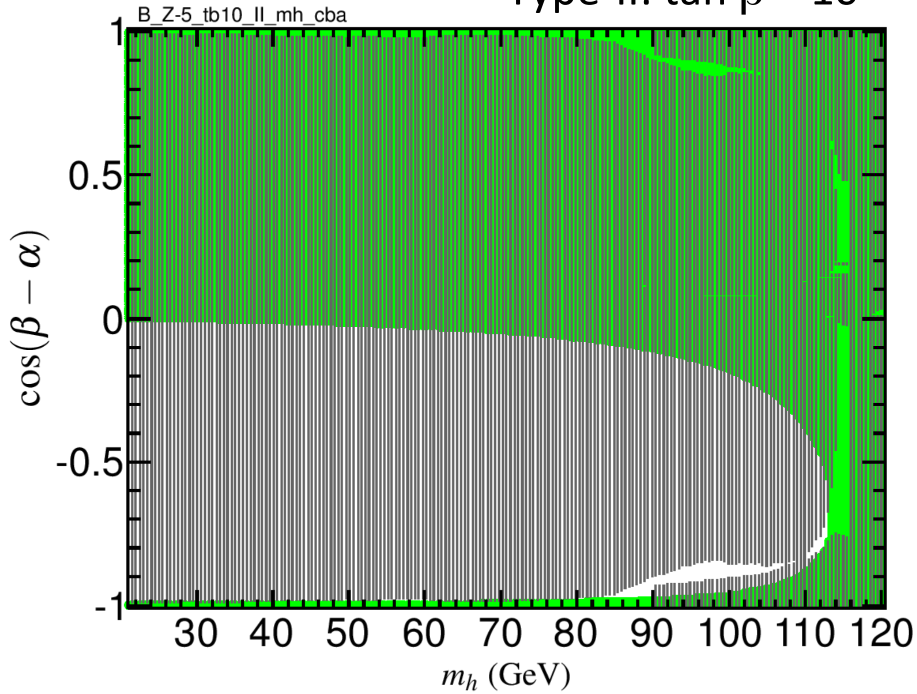
Scenario B

- "Inverted" scenario with lightest Higgs below 125 GeV, second CP-even Higgs, H, as the SM-like Higgs at 125
  $M_h < M_H = 125$ GeV $< M_A = M_{H+}$ (M_{H+} above 350 GeV for Type-II)

Type-I: tan β = 1.5



Type-II: tan β = 10

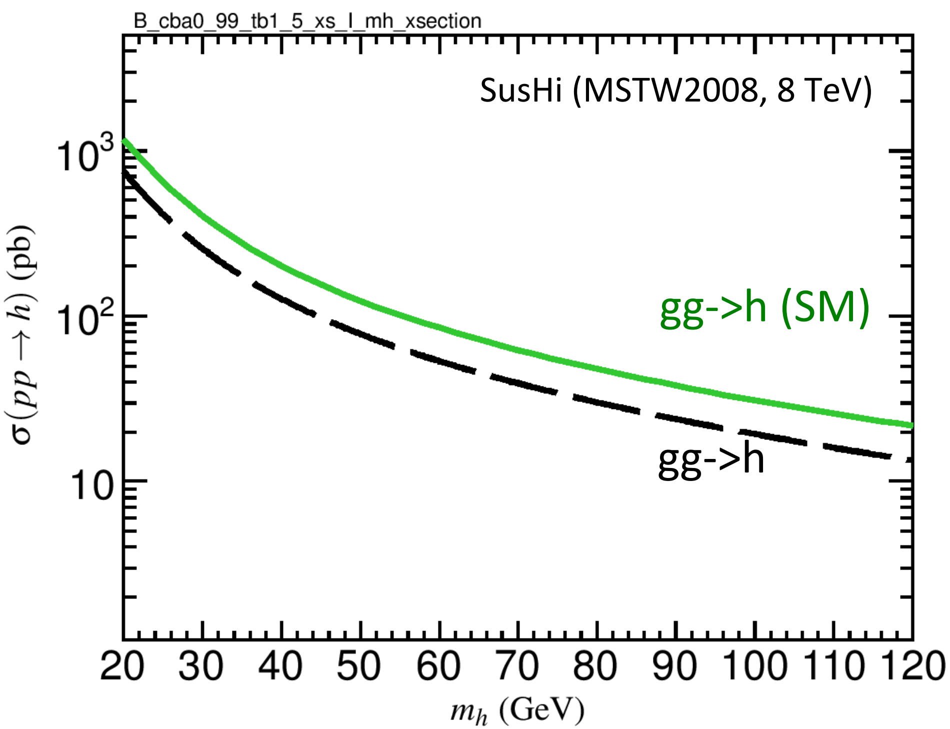


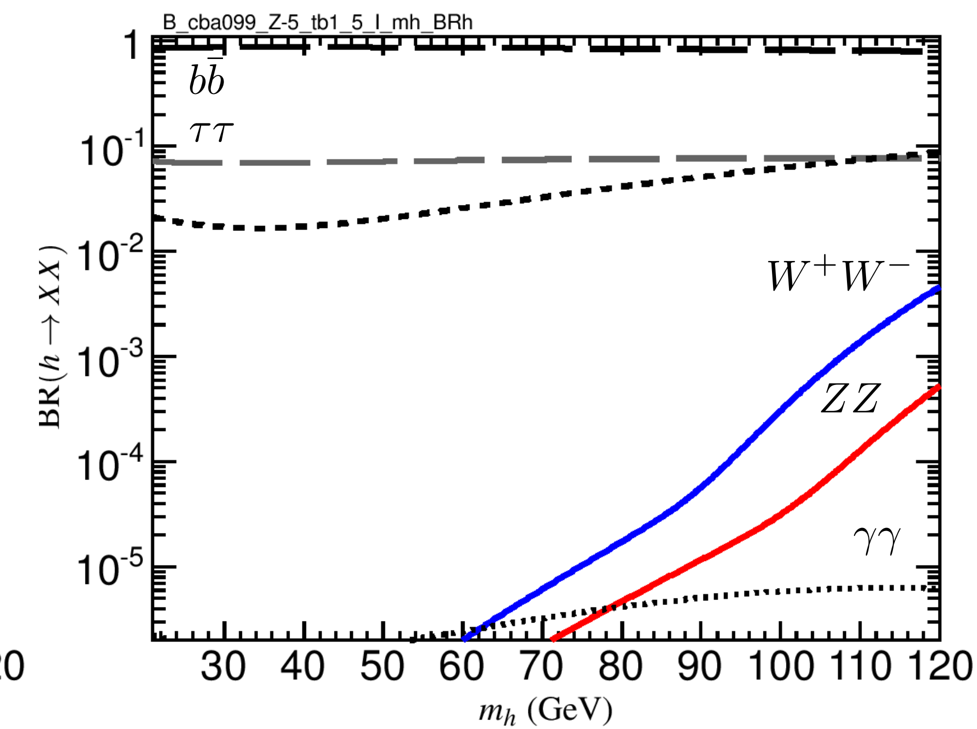
- Constraints from LEP/Tevatron/LHC (gray). Below 90 GeV only allowed solution is alignment of heavy Higgs: $|c_{\beta-\alpha}| \to 1$
  In Type-II also LHC constraints at higher tan β for $m_h > 90$ GeV.

Scenario B (Type-I): Decays

- Fix the remaining free parameter $c_{\beta-\alpha}$ to ensure H SM-like, get predictions for varying M_h

Type-I: tan β = 1.5, $c_{\beta-\alpha}$ = 0.99, M_H = 125.5 GeV





- gg->h cross section can be factor ~2 lower than SM. A -> hZ ?

Scenario C

Overlapping CP-even and CP-odd Higgses @ 125 GeV

$M_h = M_A = 125$ GeV $< M_H = M_{H+}$

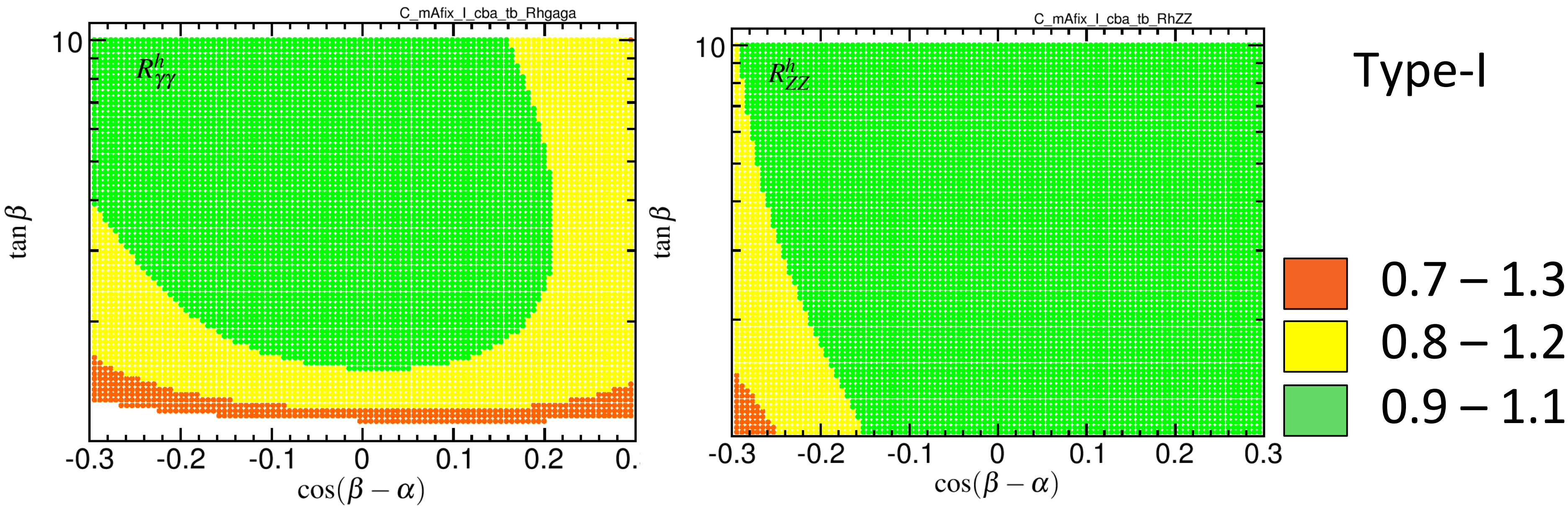
$$Z_5 = \frac{m_H^2 - m_h^2}{v^2} s^2_{\beta-\alpha} \qquad Z_4 = -Z_5 - 2\frac{m_H^2 - m_h^2}{v^2} c^2_{\beta-\alpha}$$

$$Z_7 = -Z_5$$

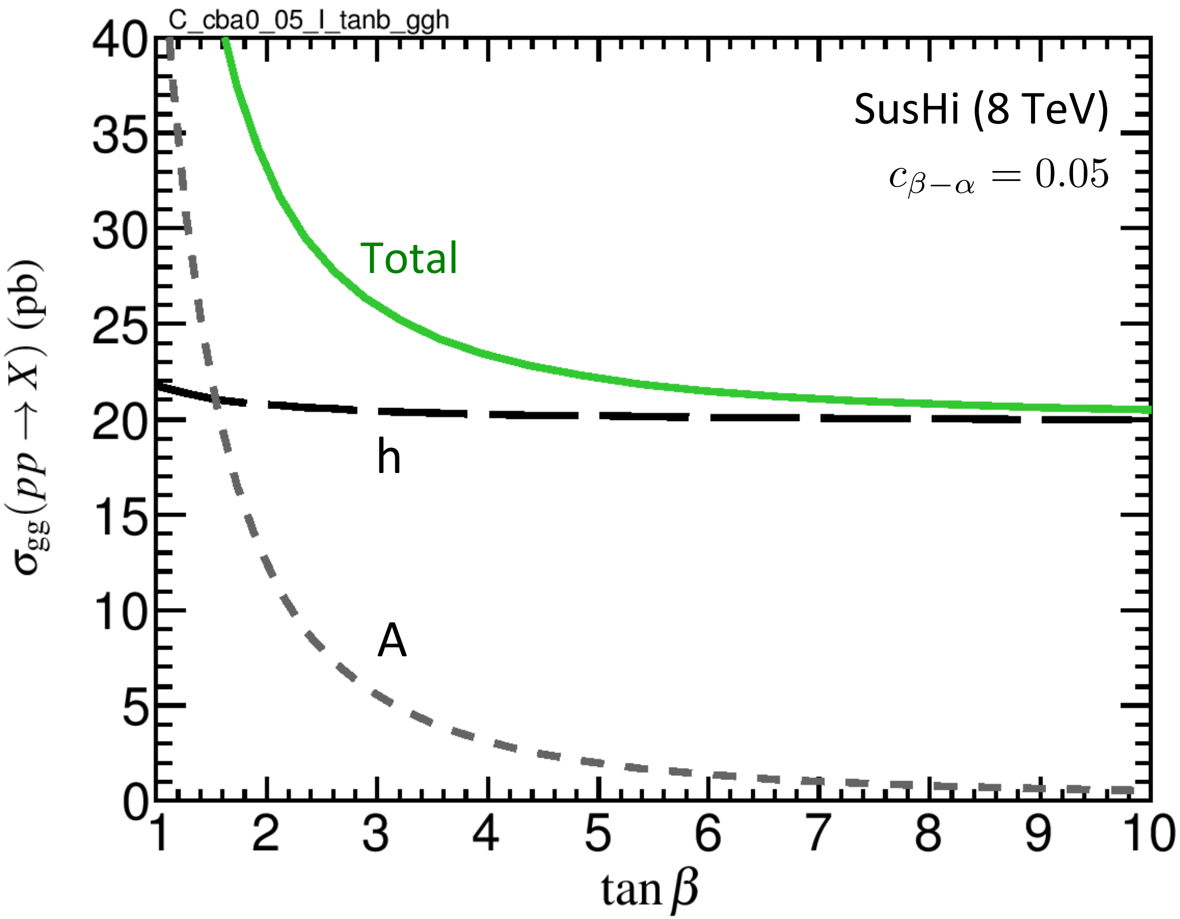
Scenario C: Degenerate states

- Our framework is CP-conserving, but Scenario C can "emulate" a CP-admixture for the signal in some channels:

  h/A -> γγ (inclusive) – *A* contribution exists, O(%) – interesting?
  h/A -> WW/ZZ (inclusive) – no tree-level A coupling
  h/A -> bb (VH) – no tree-level A coupling (inclusive/ttH - yes)
  h/A -> ττ (inclusive) – similar h/A contributions possible



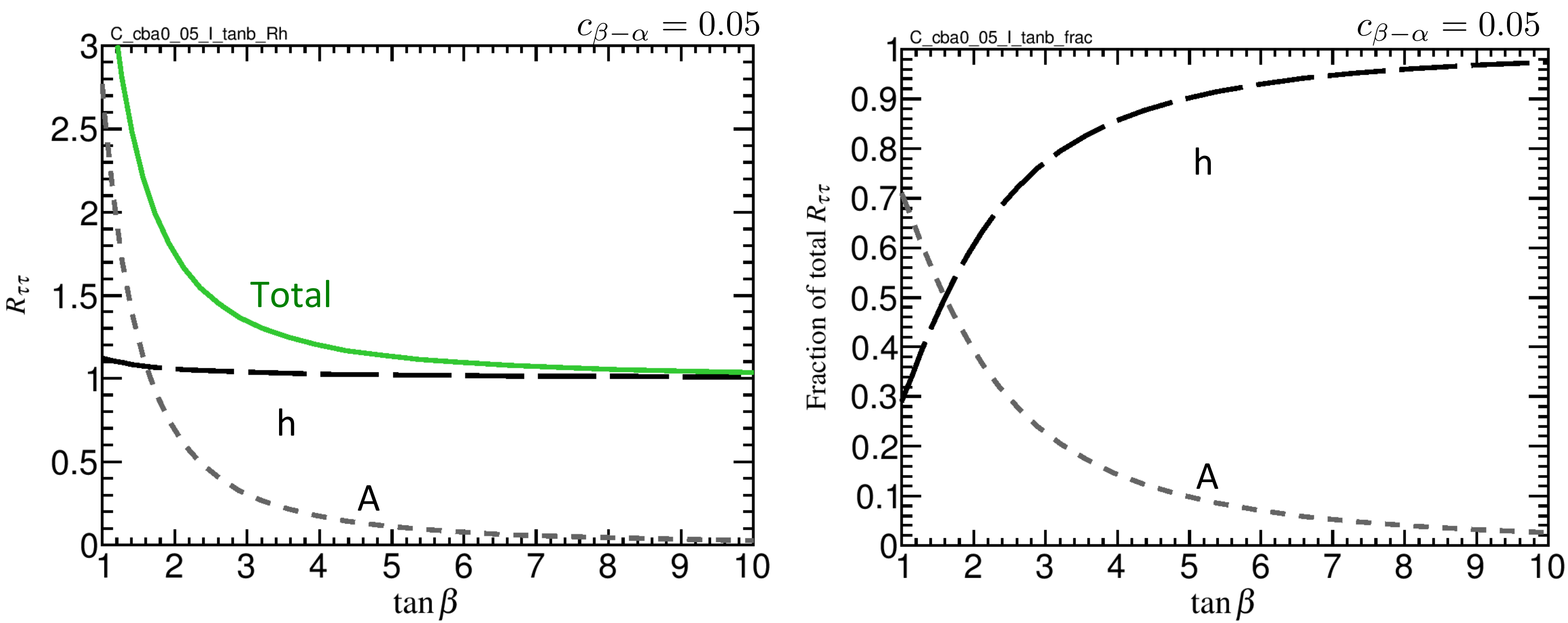
Scenario C: h/A production



- Total cross section dominated by SM-like h for high tan β (Yukawa decoupling in Type-I)

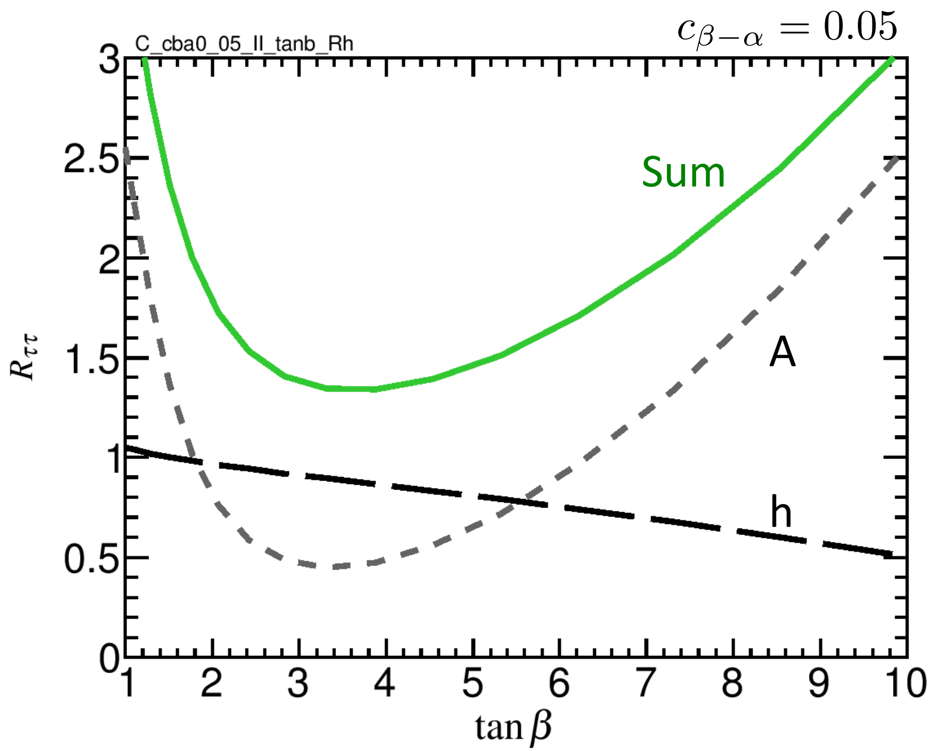
Inclusive ττ signal composition

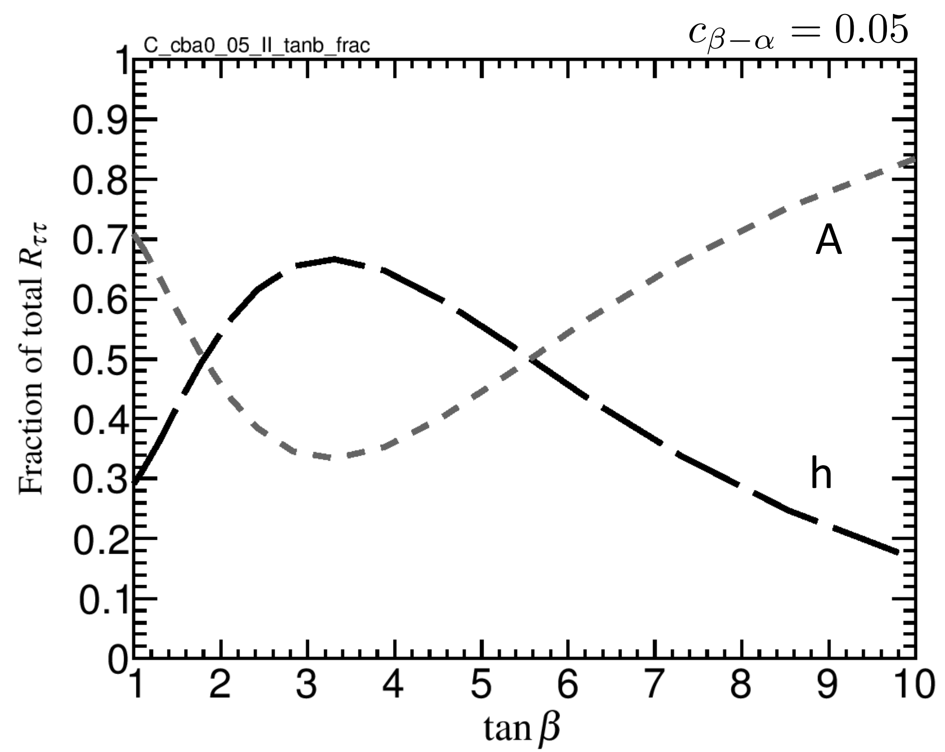
$$R_{\tau\tau}^{h/A} = \frac{\sigma(pp \to h/A) \times \mathrm{BR}(h/A \to \tau\tau)}{\sigma(pp \to H_{\mathrm{SM}}) \times \mathrm{BR}(H_{\mathrm{SM}} \to \tau\tau)}$$



- The currently allowed value for the ττ rate (within errors) could easily accommodate for a large CP-odd contribution

Scenario C (Type-II): ττ composition





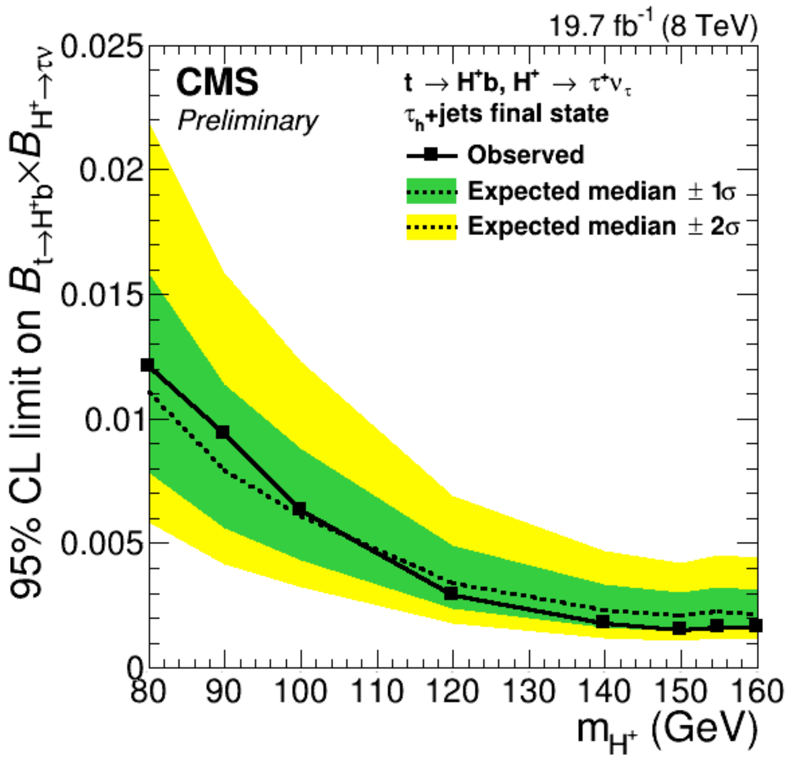
- Larger variation in h rate from BR(h -> ττ) (non-zero $c_{\beta-\alpha}$)
  Relative contribution of CP-odd Higgs always above 35%

- Low/high tan β in principle excluded from direct searches / rates
  Define benchmark at minimum of combined rate

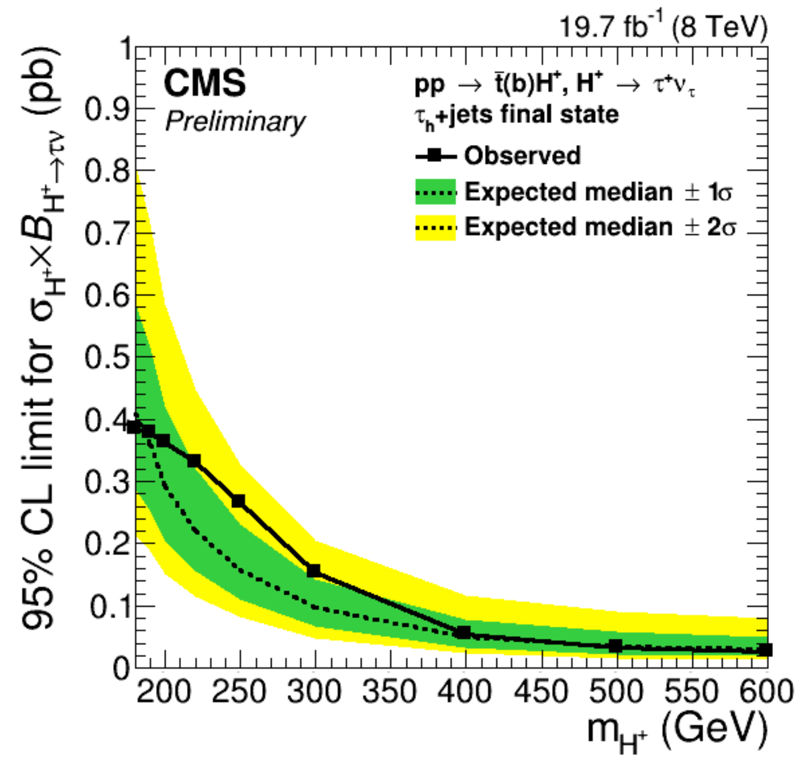
Charged Higgs

- Interesting component of all models with multiple Higgs doublets, mass related to neutral scalars through SU(2) (custodial) symmetry
- Fewer signatures to consider (if neutral Higgs channels closed)

$$M_{H^\pm} < m_t$$

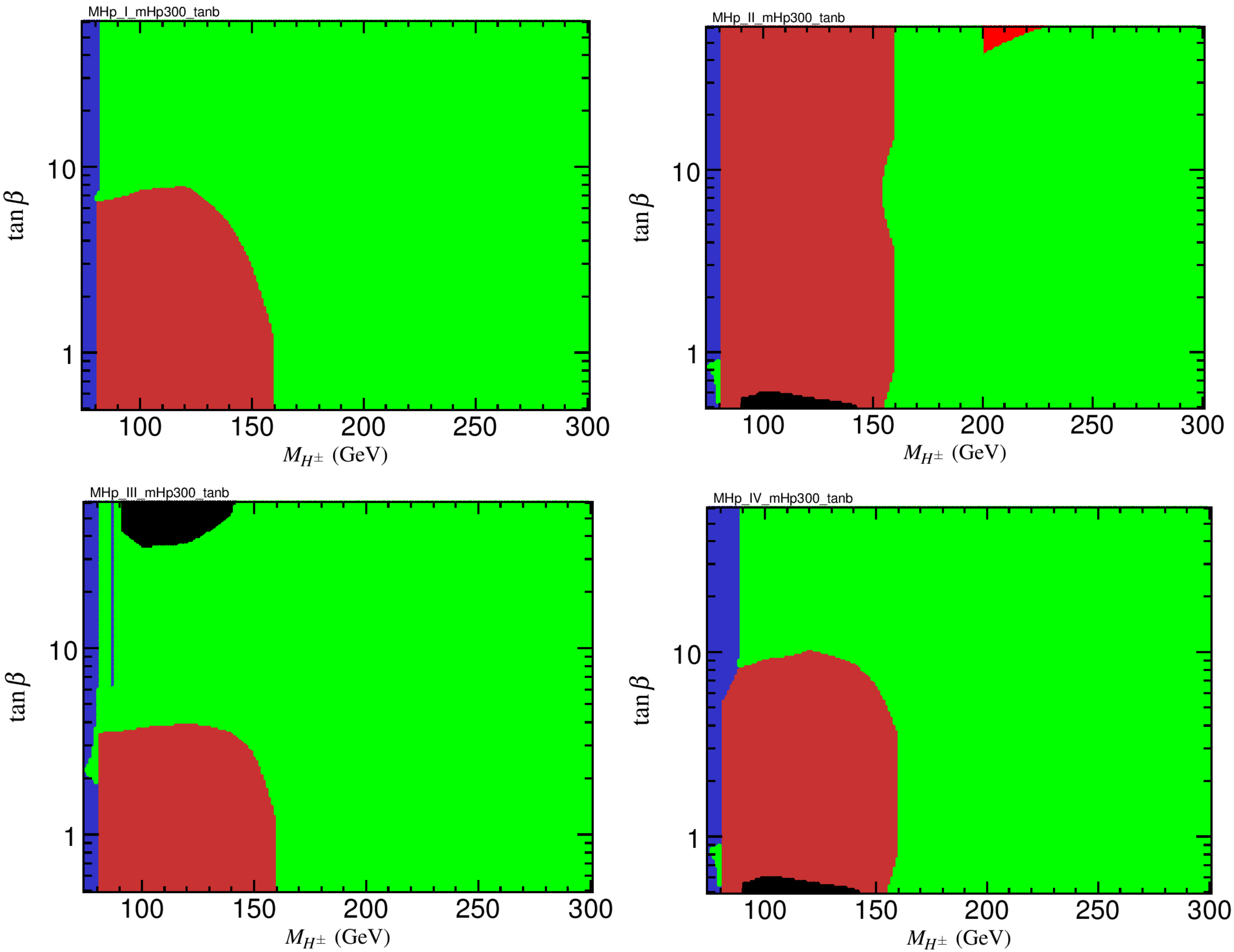


$$M_{H^\pm} > m_t$$



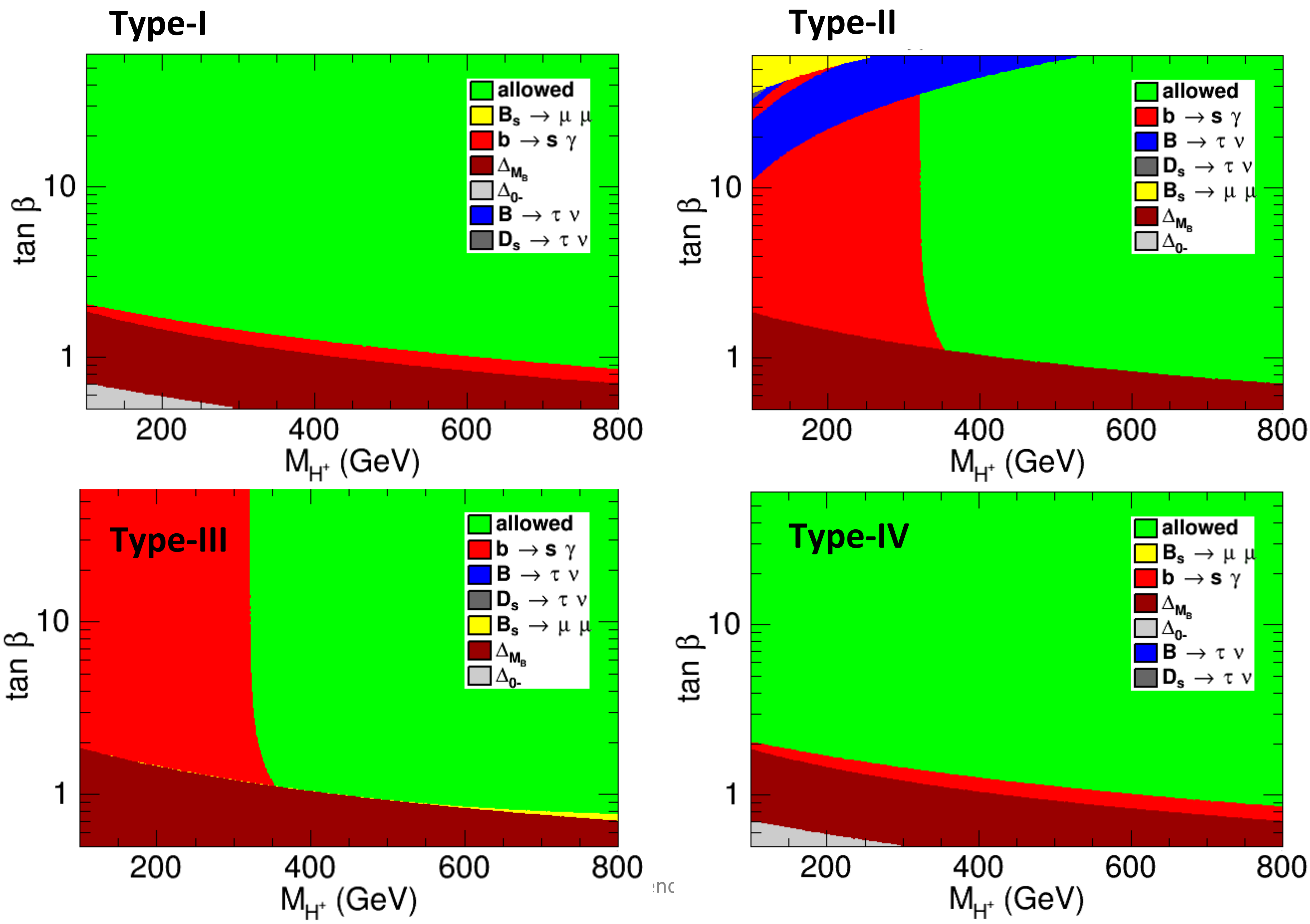
2HDM interpretation of Charged Higgs searches

F. Mahmoudi, OS



Low-energy constraints

F. Mahmoudi, OS, [to appear]



Model predictions for the LHC

- Two bundles of codes provide complete 2HDM predictions of cross sections + branching ratios, including available higher-order (mostly QCD) corrections

SusHi + 2HDMC

Harlander, Mantler, Liebler, [1212.3249]
Eriksson, Rathsman, OS, [0902.0851]

HIGLU+HDECAY

Spira et al, [hep-ph/9510347], [hep-ph/9704448]

LHC Higgs Cross Section Working Group

Interim recommendations for the evaluation of Higgs production cross sections and branching ratios at the LHC in the Two-Higgs-Doublet Model

R. Harlander[1], M. Mühlleitner[2], J. Rathsman[3], M. Spira[4], O. Stål[5]

[LHCHXSWG-2013-001], [1312.5571]

Numerical comparisons

[1312.5571]

		2HDMC		HDECAY		
		BR	Γ (GeV)	BR	Γ (GeV)	Γ_{2H}/Γ_{HD}
$h \to$	$b\bar{b}$	0.6812	3.790×10^{-3}	0.6827	3.820×10^{-3}	0.992
	$\tau^+\tau^-$	6.587×10^{-2}	3.664×10^{-4}	6.548×10^{-2}	3.664×10^{-4}	1.000
	$\mu^+\mu^-$	2.332×10^{-4}	1.297×10^{-6}	2.318×10^{-4}	1.297×10^{-6}	1.000
	$s\bar{s}$	2.484×10^{-4}	1.382×10^{-6}	2.503×10^{-4}	1.400×10^{-6}	0.987
	$c\bar{c}$	3.059×10^{-2}	1.701×10^{-4}	2.976×10^{-2}	1.665×10^{-4}	1.022
	gg	8.110×10^{-2}	4.511×10^{-4}	8.166×10^{-2}	4.569×10^{-4}	0.987
	$\gamma\gamma$	1.130×10^{-3}	6.284×10^{-6}	1.117×10^{-3}	6.250×10^{-6}	1.006
	$Z\gamma$	8.728×10^{-4}	4.855×10^{-6}	8.677×10^{-4}	4.855×10^{-6}	1.000
	W^+W^-	0.1233	6.859×10^{-4}	0.1226	6.860×10^{-4}	1.000
	ZZ	1.540×10^{-2}	8.569×10^{-5}	1.531×10^{-2}	8.566×10^{-5}	1.000
Total width			$\mathbf{5.563 \times 10^{-3}}$		$\mathbf{5.595 \times 10^{-3}}$	**0.994**
$H \to$	$b\bar{b}$	8.492×10^{-5}	1.536×10^{-4}	8.526×10^{-5}	1.542×10^{-4}	0.996
	$\tau^+\tau^-$	9.667×10^{-6}	1.748×10^{-5}	9.667×10^{-6}	1.748×10^{-5}	1.000
	$\mu^+\mu^-$	3.419×10^{-8}	6.182×10^{-8}	3.419×10^{-8}	6.183×10^{-8}	1.000
	$s\bar{s}$	3.070×10^{-8}	5.552×10^{-8}	3.115×10^{-7}	5.636×10^{-8}	0.985
	$c\bar{c}$	3.787×10^{-6}	6.848×10^{-6}	3.706×10^{-6}	6.706×10^{-6}	1.021
	$t\bar{t}$	5.976×10^{-6}	1.081×10^{-5}	5.986×10^{-6}	1.082×10^{-5}	0.998
	gg	8.382×10^{-5}	1.516×10^{-4}	8.669×10^{-5}	1.568×10^{-4}	0.967
	$\gamma\gamma$	1.642×10^{-5}	2.969×10^{-5}	1.653×10^{-5}	2.989×10^{-5}	0.993
	$Z\gamma$	5.300×10^{-5}	9.584×10^{-5}	5.300×10^{-5}	9.584×10^{-5}	1.000
	W^+W^-	0.5872	1.062	0.5872	1.062	1.000
	ZZ	0.2606	0.4713	0.2606	0.4712	1.000
	hh	0.1493	0.2699	0.1493	0.2700	1.000
	$W^\pm H^\mp$	2.658×10^{-3}	4.806×10^{-3}	2.663×10^{-3}	4.815×10^{-3}	0.998
Total width			**1.808**		**1.808**	**1.000**