2HDM @ CEPC 360

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Physics potential for top threshold
run at e+e- collider
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2HDM Higgs Sector

- **Two Higgs Doublet Model (CP-conserving)**

$$\Phi_i = \begin{pmatrix} \phi_i^+ \\ (v_i + \phi_i^0 + iG_i)/\sqrt{2} \end{pmatrix}$$

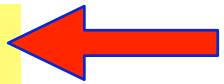
$$v_u^2 + v_d^2 = v^2 = (246\text{GeV})^2$$
$$\tan\beta = v_u/v_d$$

$$\begin{pmatrix} H^0 \\ h^0 \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} \phi_1^0 \\ \phi_2^0 \end{pmatrix}, \quad \begin{aligned} A &= -G_1 \sin\beta + G_2 \cos\beta \\ H^\pm &= -\phi_1^\pm \sin\beta + \phi_2^\pm \cos\beta \end{aligned}$$

after EWSB, 5 physical Higgses
CP-even Higgses: h, H , CP-odd Higgs: A, Charged Higgses: H±

Alignment limit

- **h 125 GeV, cos(β-α)~0, H non-SM like**
- **H 125 GeV, sin(β-α)~0**



2HDM parameters

	Φ_1	Φ_2
Type I	u,d,l	
Type II	u	d,l
lepton-specific	u,d	l
flipped	u,l	d

Model	κ_V	κ_u	κ_d	κ_ℓ
2HDM-I	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
2HDM-II	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$
2HDM-L	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$
2HDM-F	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$

- parameters (CP-conserving, flavor limit, Z_2 symmetry)

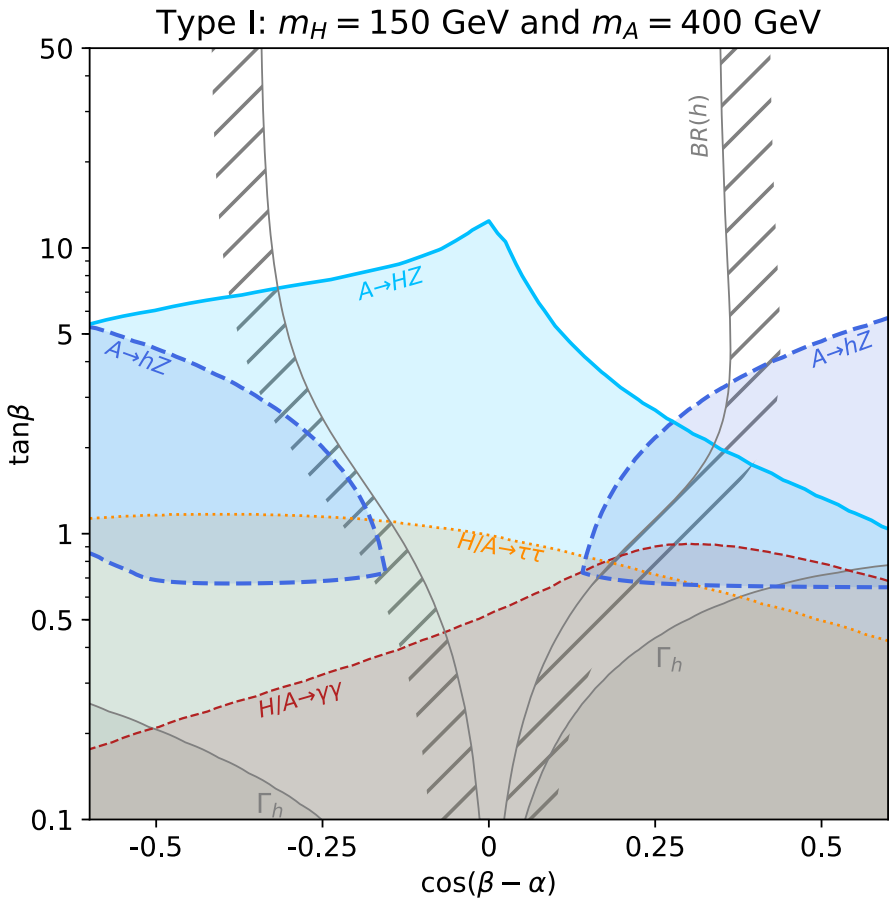
246 GeV 125 GeV

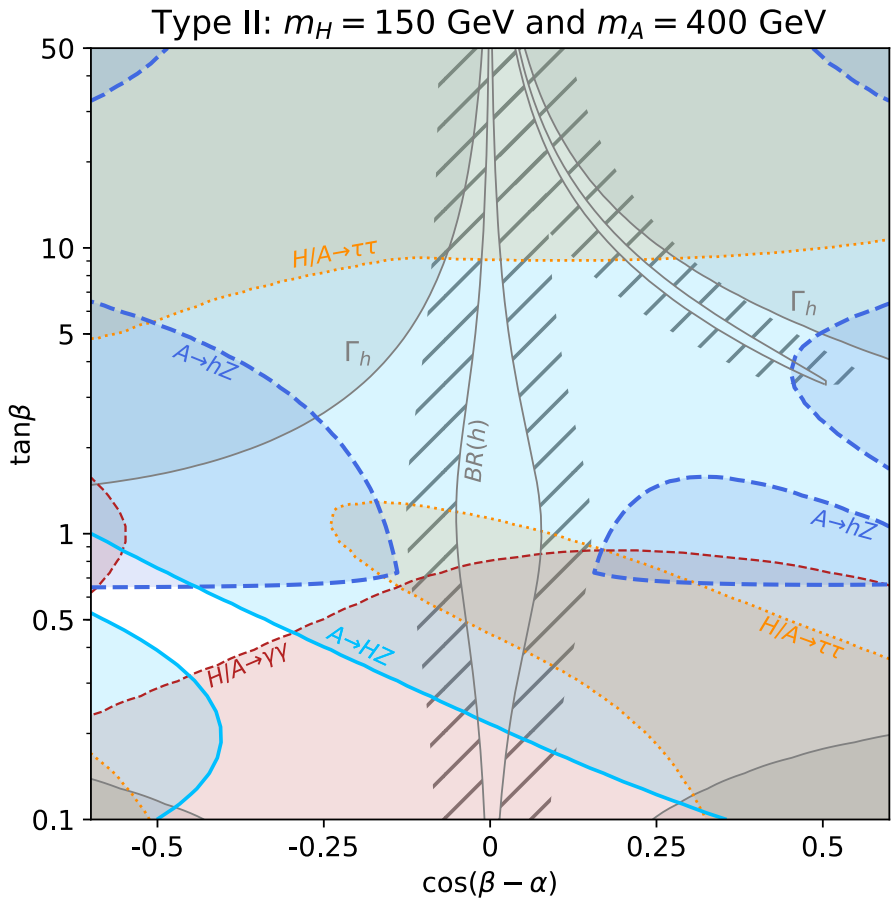
$m_{11}^2,\ m_{22}^2,\ \lambda_1,\ \lambda_2,\ \lambda_3,\ \lambda_4,\ \lambda_5$ → $v, \tan\beta, \alpha, m_h, m_H, m_A, m_{H^\pm}$

soft Z2 breaking: m_{12}^2

tanβ, cos(β-α),
control tree level h^0 couplings

Higgs Precision Search Limits





2HDM Higgs Sector

- **h/H VV coupling**

$$g_{H^0VV} = \frac{m_V^2}{v}\cos(\beta-\alpha), \quad g_{h^0VV} = \frac{m_V^2}{v}\sin(\beta-\alpha)$$

- **Higgs-Higgs-V coupling**

$$g_{AH^0Z} = -\frac{g\sin(\beta-\alpha)}{2\cos\theta_w}(p_{H^0}-p_A)^\mu, \quad g_{Ah^0Z} = \frac{g\cos(\beta-\alpha)}{2\cos\theta_w}(p_{h^0}-p_A)^\mu,$$
$$g_{H^\pm H^0W^\mp} = \frac{g\sin(\beta-\alpha)}{2}(p_{H^0}-p_{H^\pm})^\mu, \quad g_{H^\pm h^0W^\mp} = \frac{g\cos(\beta-\alpha)}{2}(p_{h^0}-p_{H^\pm})^\mu,$$
$$g_{H^\pm AW^\mp} = \frac{g}{2}(p_A-p_{H^\pm})^\mu,$$

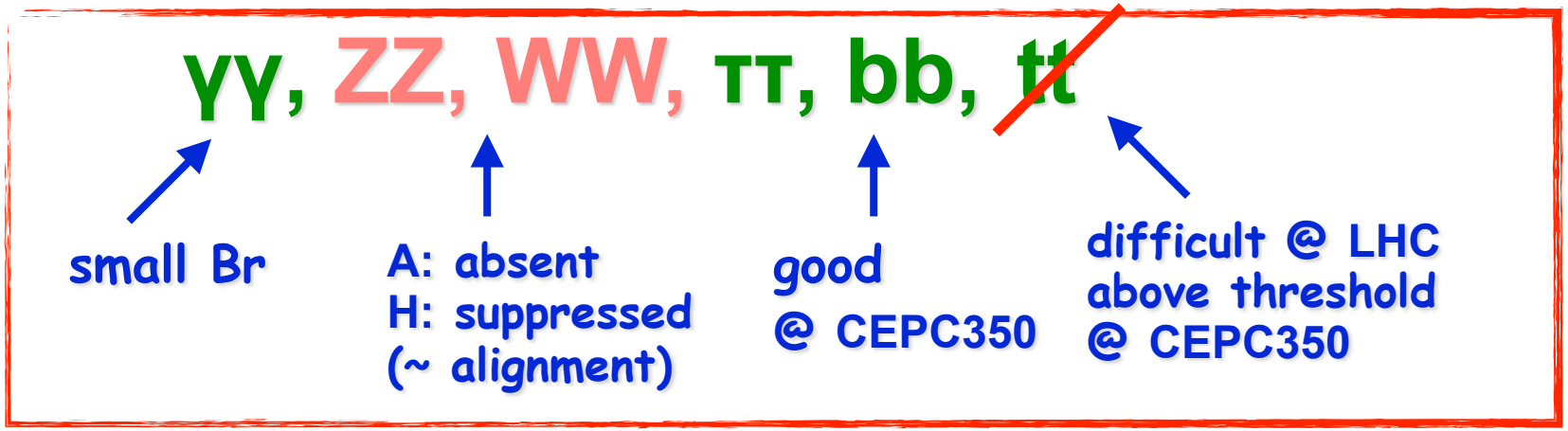
Two non-SM like Higgses have unsuppressed couplings to gauge boson.

Dominant Production (~alignment)

- dominant pair production @ CEPC360 (~ alignment)

  Drell-Yan: $e^+e^- \to HA$, $e^+e^- \to H^+H^-$

- Neutral Higgses: conventional search channel

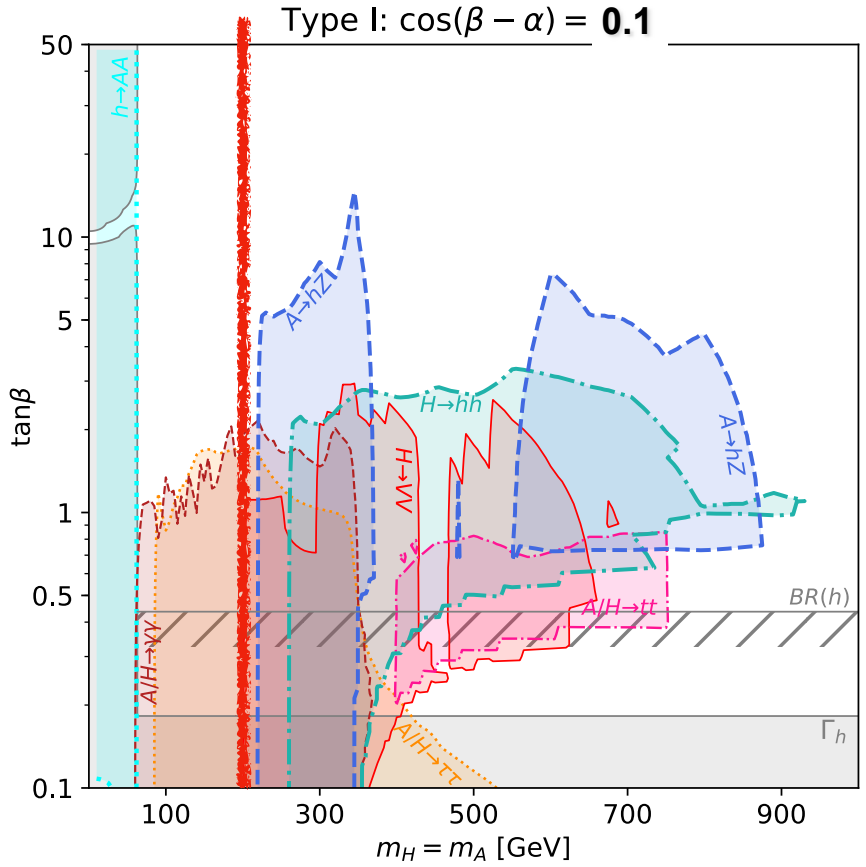


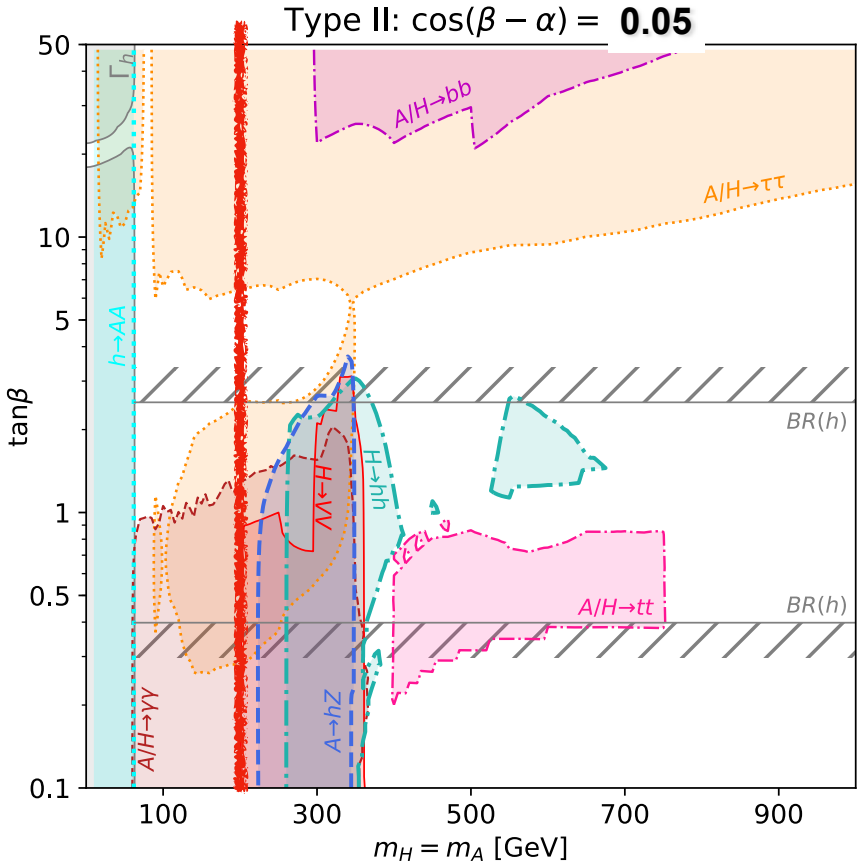
- Neutral Higgses: exotic search channel when phase space open

  unsupressed: $H \to ZA, AA, H^+H^-, WH^\pm$, $A \to ZH, WH^\pm$

  suppressed: $H \to h_{SM}\, h_{SM}$, $A \to Zh_{SM}$

Current Direct Search Limits





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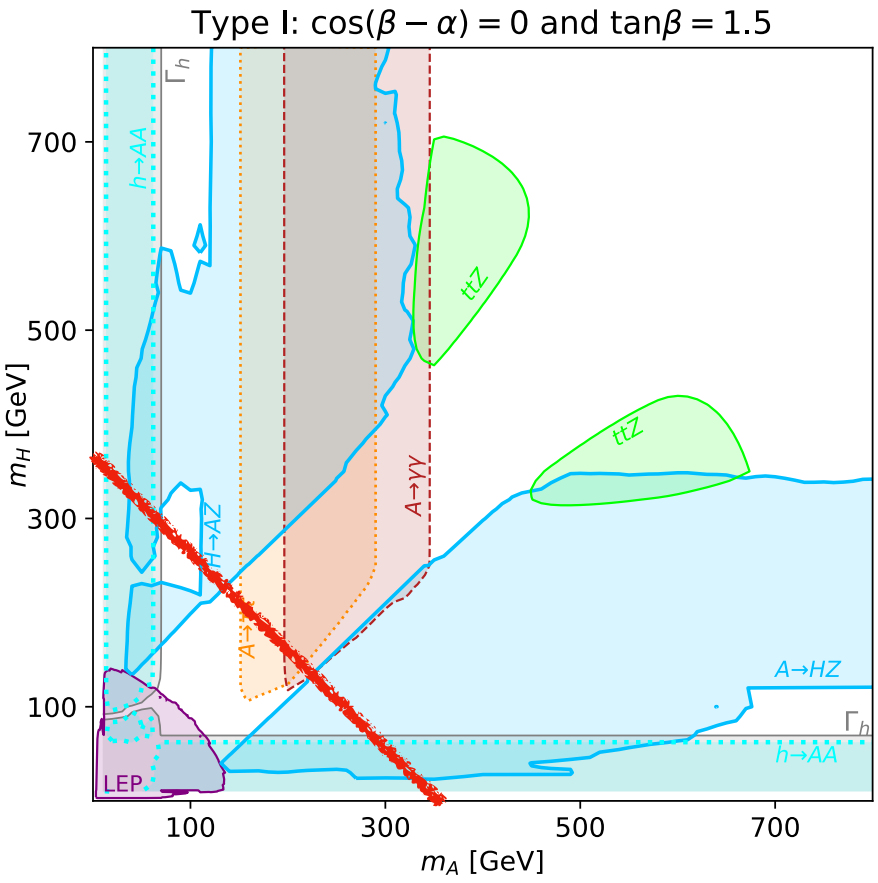
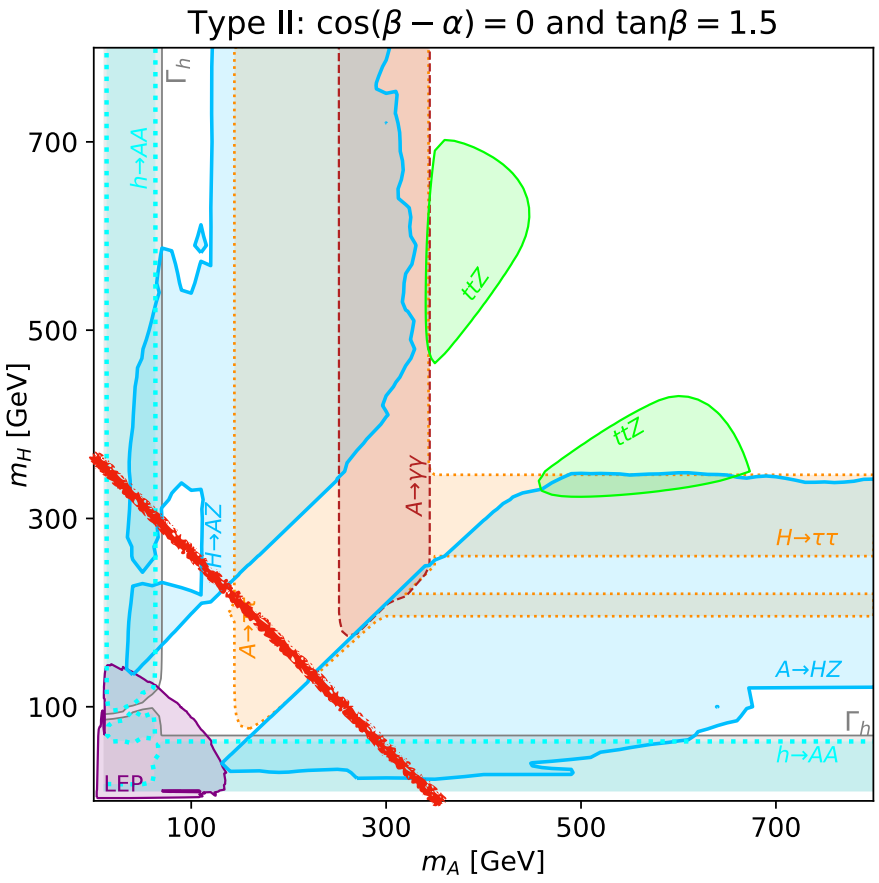
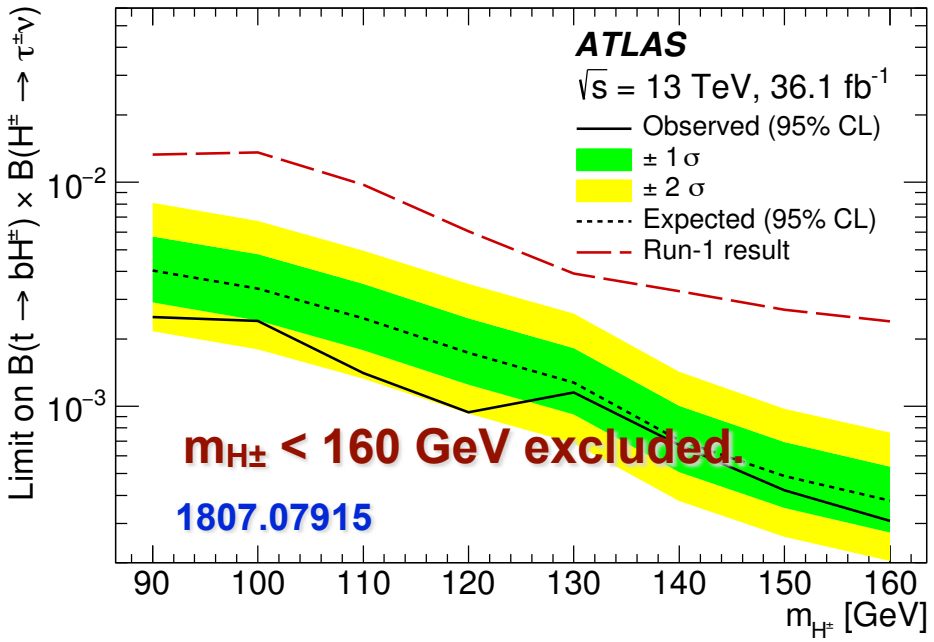


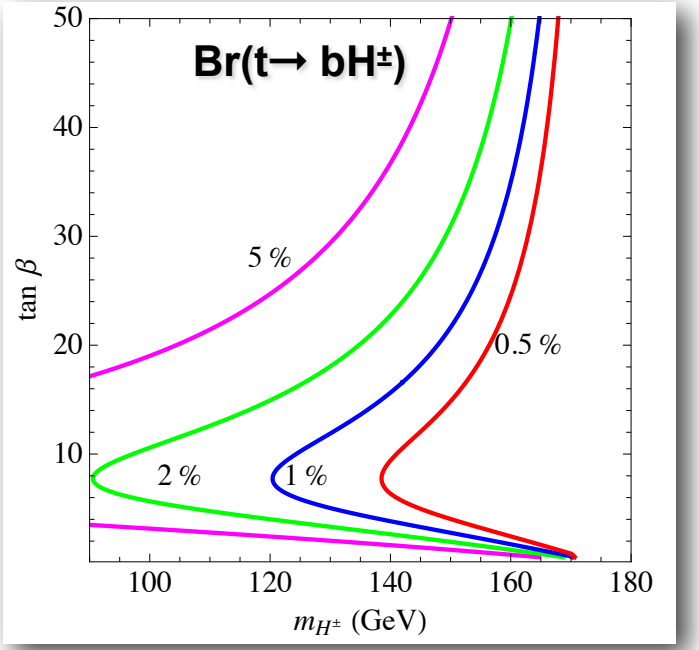


Search for BSM Higgses

- Charged Higgs is challenge @ LHC !
- Flavor constraints:
  - ➡ Type II 2HDM: $m_{H^\pm} > 650$ GeV
  - ➡ Type I 2HDM: light Higgs allowed.
- Conventional search channel

$m_{H^\pm} < m_t$:
ttbar production with
$t \to bH^\pm$, $H^\pm \to \tau\nu$ or cs





Search for non-SM Higgses

Other possible processes

- suppressed production of $e^+e^- \to A\, h_{SM}$
- CP-violating 2HDM: H_iH_j production with $H_i \to H_j\, H_k$
- singlet mixing with a light singlet: $H_i \to h_{SM}\, S$
- ...