Decay of heavy Higgses in the MSSM at the LHC Run 2

Rachid Benbrik & Hicham Harouiz

1st Mediterranean Conference on Higgs Physics (MCHP)

MARRAKECH
جامعة القاضي عياض
UNIVERSITÉ CADI AYYAD

Introduction

- The discovered of the higgs boson at the LHC validated the standard model (SM) as a low energy theory (EW scale)
- Two questions: is the discovered Higgs boson a pure Standard Model (SM) Higgs or SM-like Higgs from new physics theory?
- Searches for new physics should be complemented by studying the properties of the heavy Higgs bosons in the extended Higgs sector of SM.
- Minimal Supersymmetric Standard Model (MSSM) could be a natural solution.

MSSM: Higgs sector

Two Higgs doublets:

$$\mathcal{H}_u = \begin{pmatrix} \phi_u^+ \\ (\upsilon_u + \phi_u^0 + i\chi_u^0)/\sqrt{2} \end{pmatrix} \quad , \quad \mathcal{H}_d = \begin{pmatrix} (\upsilon_d + \phi_d^0 - i\chi_d^0)/\sqrt{2} \\ -\phi_d^- \end{pmatrix}$$

The Higgs potential:

$$\mathcal{V}_{Higgs} = \left(m_{\mathcal{H}_u}^2 + |\mu|^2\right)|\mathcal{H}_u|^2 + \left(m_{\mathcal{H}_d}^2 + |\mu|^2\right)|\mathcal{H}_d|^2 + B\mu\left(\mathcal{H}_u.\mathcal{H}_d + h.c.\right) + \frac{g_2^2+g_1^2}{8}\left(|\mathcal{H}_u|^2 - |\mathcal{H}_d|^2\right)^2 + \frac{g_2^2}{2}\left|\mathcal{H}_d^\dagger \mathcal{H}_u\right|^2$$

Electroweak Symmetry Breaking $\Rightarrow$ 5 physical states

$\mathcal{CP}$**-even** h^0, H^0, $\mathcal{CP}$**-odd** A^0, **Charged** $H^\pm$

Two independent parameters at tree-level : m_A, $\tan\beta$

MSSM Benchmark Scenarios

- $m_h^{\text{mod+}}$ scenario: [Carena, Heinemeyer, Stål, Wagner & Weiglein, 1302.7033]
  - Modified m_h^{max} scenario
  - A large region of parameter space where the mass of the light $\mathcal{CP}$-even Higgs boson is in good agreement with the mass value of the particle recently discovered at the LHC
  - Parameters: $M_{Q_3} = M_{U_3} = M_{D_3} = 1000$ GeV, $M_{L_3} = M_{E_3} = 1000$ GeV, $\mu = 200$ GeV, $M_2 = 200$ GeV, $M_3 = 1.5$ TeV, $X_t = 2$ TeV, $A_b = A_\tau = A_t$
- *h*MSSM scenario: [Djouadi, Maiani, Moreau, Polosa, Quevillon & Riquer, 1307.5205]
  - The lighter h boson has a mass of approximately 125 GeV.
  - Fix the values of dominant radiative corrections.
  - The Higgs sector can be described by only two parameters, $\tan\beta$ and M_{A^0} even at two-loop order.
  - Only two inputs for Higgs sector

$$M_{H^0}^2 = \frac{(M_{A^0}^2+M_Z^2-M_h^2)(M_Z^2\cos^2\beta+M_{A^0}^2\sin^2\beta)-M_{A^0}^2M_Z^2\cos^2 2\beta}{M_Z^2\cos^2\beta+M_{A^0}^2\sin^2\beta-M_h^2}, \quad \alpha = -\arctan\left(\frac{(M_Z^2+M_{A^0}^2)\cos\beta\sin\beta}{M_Z^2\cos^2\beta+M_{A^0}^2\sin^2\beta-M_h^2}\right), \quad M_{H^\pm}^2 = M_{A^0}^2 + M_W^2$$

- m_h^{125} scenario: [Bagnaschi, Bahl, Fuchs, Hahn, Heinemeyer, Lieblerg, Patel, Slavich, Stefaniak, Wagner & Weiglein, 1808.07542]
  - All SUSY masses are chosen to be so heavy (at or above 1 TeV)
  - 2HDM Higgs sector with SUSY properties
  - Parameters: $M_{Q_3} = M_{U_3} = M_{D_3} = 1.5$ TeV, $M_{L_3} = M_{E_3} = 2$ TeV, $\mu = 1$ TeV, $M_1 = 1$ TeV, $M_2 = 1$ TeV, $M_3 = 2.5$ TeV, $X_t = 2.8$ TeV, $A_b = A_\tau = A_t$

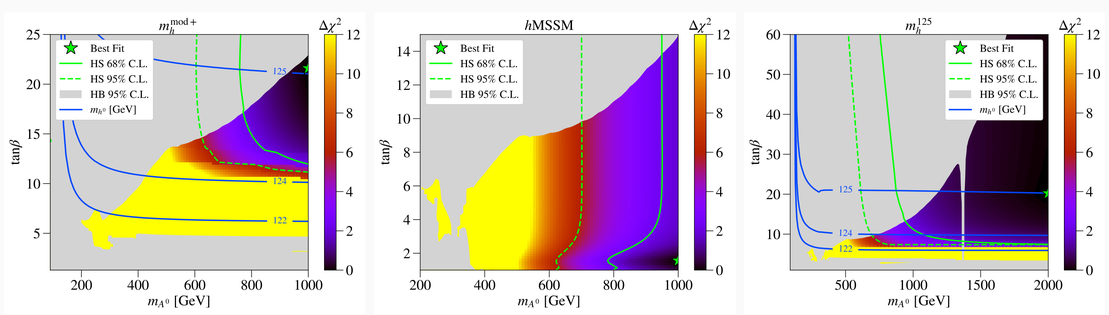

Figure 1: The allowed regions on the (M_{A^0},$\tan\beta$) plane in $m_h^{\text{mod+}}$ (left), hMSSM (middle) and m_h^{125} (right). The blue lines are level curves for the SM-like Higgs mass. By definition, in the hMSSM, m_{h^0} is fixed at 125 GeV.

Heavy Higgs decays

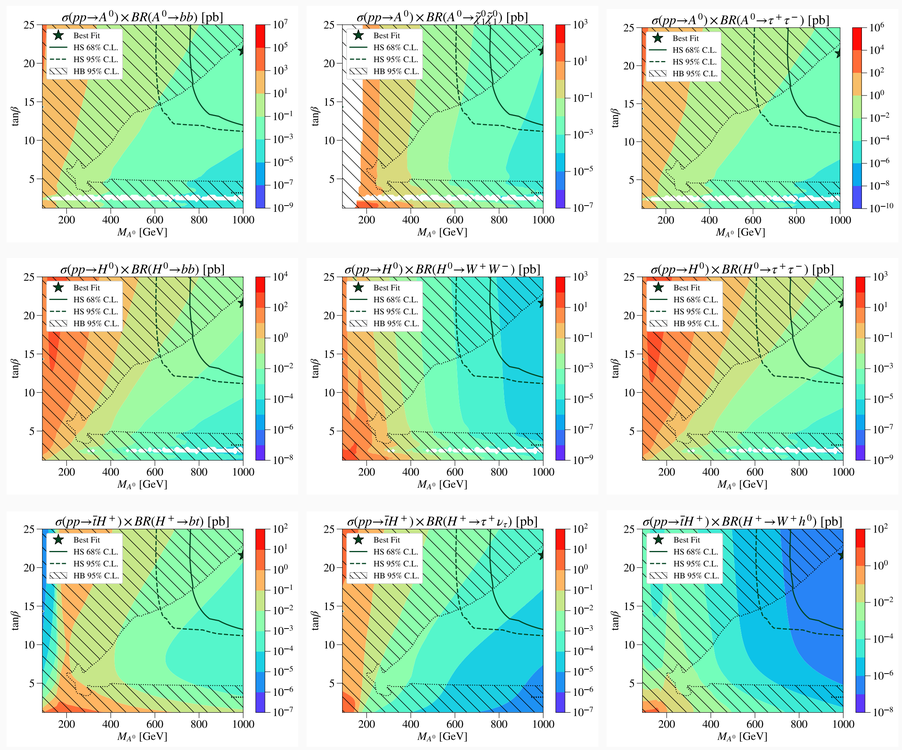

Figure 2: The (M_{A^0},$\tan\beta$) plane in the $m_h^{\text{mod+}}$ scenario. The exclusion regions are shown as above, while the color coding in the allowed region indicates total cross section for inclusive production of heavy scalar Higgs boson: A^0 (top), H^0 (middle) and $H^\pm$ (bottom) at the LHC ($\sqrt{s} = 13$ TeV).

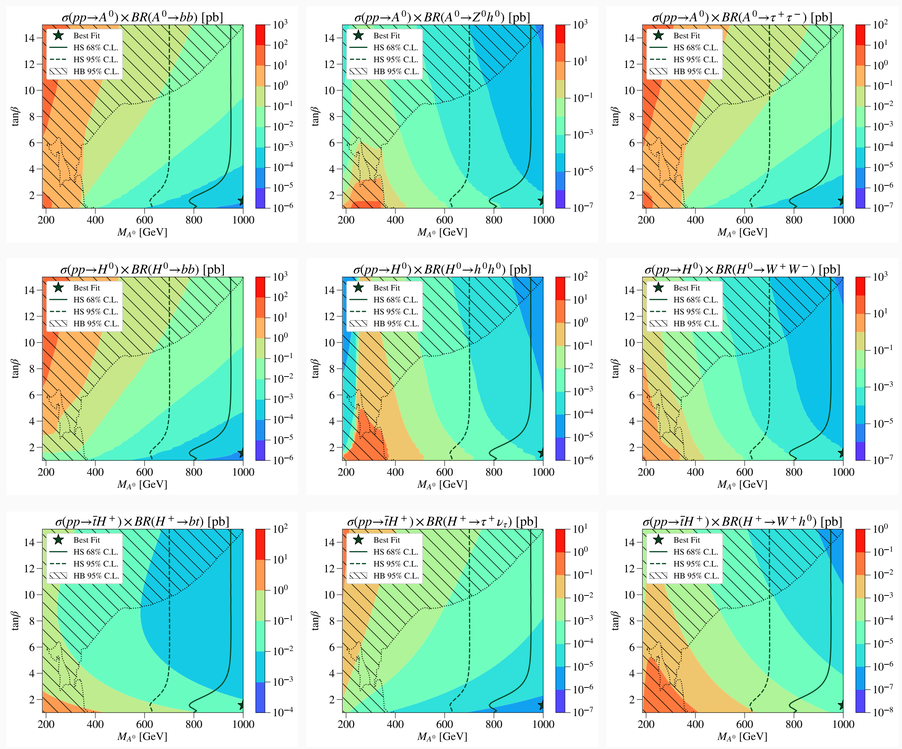

Figure 3: The (M_{A^0},$\tan\beta$) plane in the hMSSM scenario. The exclusion regions are shown as above, while the color coding in the allowed region indicates total cross section for inclusive production of heavy scalar Higgs boson: A^0 (top), H^0 (middle) and $H^\pm$ (bottom) at the LHC ($\sqrt{s} = 13$ TeV).

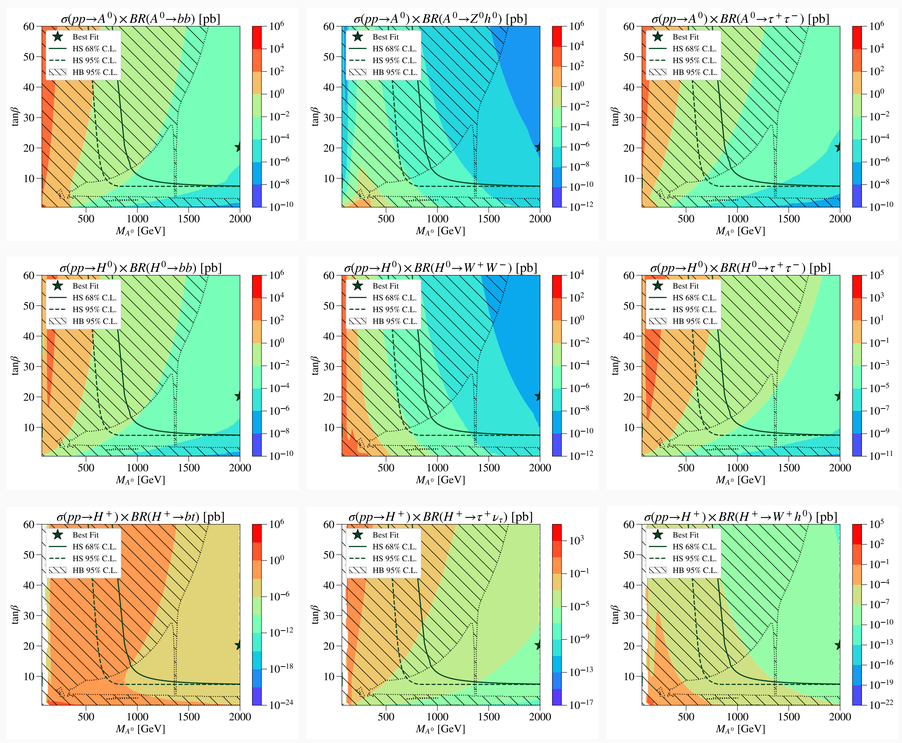

Figure 4: The (M_{A^0},$\tan\beta$) plane in the m_h^{125} scenario. The exclusion regions are shown as above, while the color coding in the allowed region indicates total cross section for inclusive production of heavy scalar Higgs boson: A^0 (top), H^0 (middle) and $H^\pm$ (bottom) at the LHC ($\sqrt{s} = 13$ TeV).