How MSSM Higgs BRs are Calculated for the LHCHXSWG

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Main idea:

$\boxed{\text{Use best code for individual decay widths}}$

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Codes used:

- FeynHiggs
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- Hdecay

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Tool for combination:

the "Script"

Author: Daniela Rebuzzi (with some help from S.H.)

"Official" calculation of MSSM BR's: [*LHCHXSWG '11-'15*]

1. Input parameters to FeynHiggs (native format or SLHA)

2. FeynHiggs $\Rightarrow$ Higgs masses, couplings, decay widths/BRs

   Output via SLHA file (total width and BRs)

3. SLHA file is stored and fed to HDECAY

4. HDECAY $\Rightarrow$ decay widths

   Output via SLHA file (total width and BRs)

5. "Script" reads both SLHA files, extracts total and branching ratios
   $\Rightarrow$ calculation of partial widths

6. "Script" calculates total width:

$$\Gamma_\phi = \Gamma^{\mathrm{FH}}_{\phi\to\tau\tau} + \Gamma^{\mathrm{FH}}_{\phi\to\mu\mu} + \Gamma^{\mathrm{FH/P4f}}_{\phi\to W^{(*)}W^{(*)}} + \Gamma^{\mathrm{FH/P4f}}_{\phi\to Z^{(*)}Z^{(*)}} + \Gamma^{\mathrm{HD}}_{\phi\to b\bar{b}} + \Gamma^{\mathrm{HD}}_{\phi\to t\bar{t}} + \Gamma^{\mathrm{HD}}_{\phi\to c\bar{c}} + \Gamma^{\mathrm{HD}}_{\phi\to gg} + \Gamma^{\mathrm{HD}}_{\phi\to\gamma\gamma} + \Gamma^{\mathrm{HD}}_{\phi\to Z\gamma}$$

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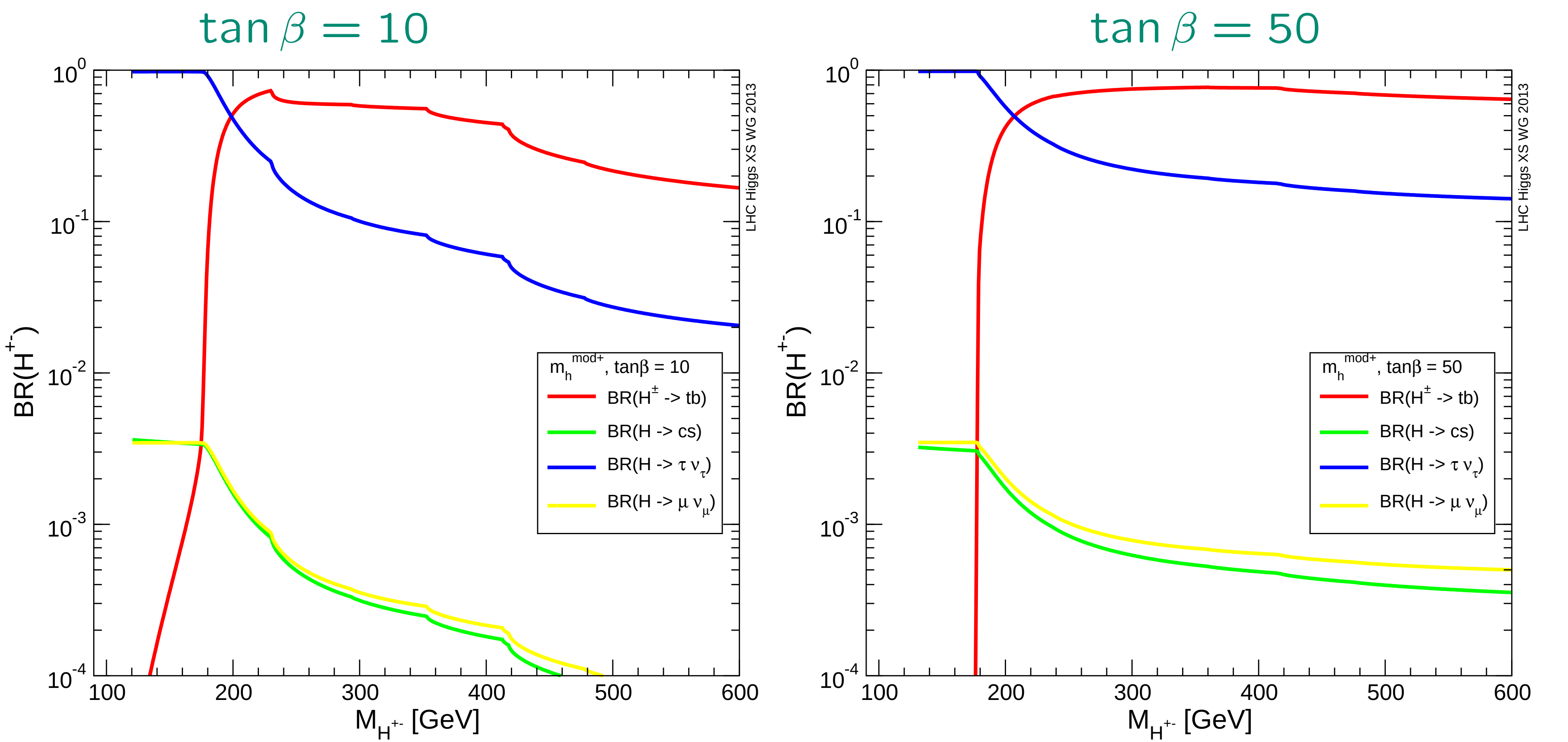
$$\Gamma_{H^\pm} = \Gamma^{\mathsf{HD}}(H^\pm \to tb) + \Gamma^{\mathsf{FH}}(H^\pm \to \tau\nu_\tau) + \Gamma^{\mathsf{FH}}(H^\pm \to \mu\nu_\mu) \\ + \Gamma^{\mathsf{HD}}(H^\pm \to cs) + \Gamma^{\cdots}(H^\pm \to AW) + \Gamma^{\cdots}(H^\pm \to HW) + \ldots$$

7. "Script" calculates BRs

Example results: charged Higgs BRs in $m_h^{\text{mod}+}$ scenario: [*LHCHXSWG '13*]



$\Rightarrow$ kinks from chargino/neutralino thresholds

Decays to SUSY particles:

- Taken into account in the total width
- Not yet individual output
- can (easily?) be changed

Results exist for:

“classic benchmarks”

- $m_h^{\rm max-up}$
- $m_h^{\rm mod+}$
- $m_h^{\rm mod-}$
- light-stop
- light-stau
- tau-phobic
- low-M_H

New results wanted?

$\to$ send an email to Daniela and S.H. :-)

New additions:

- $H \to hh$ and $A \to hZ$ included
  $\to$ request by ATLAS/CMS

- Extended range of $M_A = 5 \dots 90$ GeV included
  $\to$ request for light charged Higgs searches
  Currently running: $M_A = 1000 \dots 2000$ GeV

- BR$(t \to H^{\pm} b)$ included (in a preliminary way!)
  $\to$ request for light charged Higgs searches

  To-do: agree on code, redo runs!

- Extended range of $\mu = \pm 1000, \pm 500, \pm 200$ GeV (wip)
  $\to$ request by the $\phi \to b\bar{b}$ group

- proposal for a new benchmark scenario: "low-tb-high"
  $\to$ request by ATLAS/CMS to have a scenario valid at low $\tan\beta$
  to get large BR$(H \to hh)$, BR$(A \to Ah)$

  $\Rightarrow$ to be scrutinized/approved/rejected by MSSM subgroup ...

  $\Rightarrow$ new parameter spaces, new problems, ... but we got it right!

New, interesting decays/scenarios?

From my email with Stefania :-)

Stefania:

For the specific case of the MSSM, we are thinking to decays of the type $h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \to \gamma \tilde{G}$ (with $\tilde{G}$ the gravitino and $\tilde{\chi}_1^0$ mainly bino).

Sven:

I understand that BR($\tilde{\chi}_1^0 \to \gamma \tilde{G}$) = 1 is assumed, but that the parameters $m_{\tilde{\chi}_1^0}$, $m_{3/2}$ and the neutralino mixing matrix are still relevant. The longer the life time the better? Probably up to a certain limit that gives you displaced photons (with a decay length ctau). What are your preferred values?

BR($h \tilde{\chi}_1^0 \tilde{\chi}_1^0$) is in principle evaluated in our machinery. So far it did not play a role, because in the benchmark scenarios so far $m_{\tilde{\chi}_1^0} > M_h/2$.

Sven: (cont.)

So we need a scenario with $M_1 \neq M_2$ at the GUT scale, equivalent to $M_1 \neq M_2/2$ at the EW scale. The easiest would be to treat M_1 and M_2 independent paraemters.

One could start with a known benchmark scenario but just keep M_1 as a free parameter, then scan M_A, $\tan\beta$ and M_1, evaluate $\mathrm{BR}(h\tilde{\chi}_1^0\tilde{\chi}_1^0)$ and ctau to find interesting regions.

Thoughts?