

Status and plans of the MSSM subgroup (theory)

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The 17th workshop of the LHC Higgs working group

Outline

Subgroup mission

- To be a common ground for discussion between experimentalists and theorists.
- To clarify theoretical aspects important for experimental studies.
- To provide benchmark scenarios to be used by experimental collaboration.
- To discuss possible future developments on probing the MSSM Higgs sector at the LHC.

Changes

- A. Gilbert (NWU) → A. Gottman (KIT) [experiment].
- S. Liebler → E. Bagnaschi (PSI) [theory].

A. Gottmann will provide an experimental update in the following talk.

Task list

Rich program of activities planned.

- Scenarios/ROOT files
- Experimental/phenomenological aspects
- A/H Higgs transverse momentum distribution
- Working group notes

Task	Status	Timescale \uparrow
Keep an eye on potentially missing signatures	In progress	Continuous
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Release ROOT files for mh125 variants with negative μ	In progress	Soon
Update of the ROOT files (SM BRs, HDECAY update, FeynHiggs proper version)	In progress	Soon
Provide updated ROOT files for end RunII analyses	Complete	End 2018
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New branching-ratio framework

- Re-wrote in Python the infrastructure used to combine the branching ratio predictions from HDECAY and FeynHiggs.
- Support from Sven Heinemeyer (BRs working group) in re-running HDECAY and FeynHiggs for part of the scenarios.
- Make possible to release those scenarios which include predictions from FeynHiggs (or HDECAY) only.
- Handle the inclusion of “SM-like” BRs of the Higgs at $\simeq 125$ GeV. Useful for those studies which probe the scenarios via the observed Higgs properties. the scenarios by looking at the properties of the observed state at the LHC.

FH+HD prescription (HXS WG YR4, section I.3.2)

$$\Gamma_{\phi} = \Gamma_{\phi \rightarrow \tau^+ \tau^-}^{\text{FH}} + \Gamma_{\phi \rightarrow \mu^+ \mu^-}^{\text{FH}} + \Gamma_{\phi \rightarrow W^{(*)} W^{(*)}}^{\text{FH/P4f}} + \Gamma_{\phi \rightarrow Z^{(*)} Z^{(*)}}^{\text{FH/P4f}} + \Gamma_{\phi \rightarrow b \bar{b}}^{\text{HD}} + \Gamma_{\phi \rightarrow t \bar{t}}^{\text{HD}} + \Gamma_{\phi \rightarrow c \bar{c}}^{\text{HD}} \\ + \Gamma_{\phi \rightarrow g g}^{\text{HD}} + \Gamma_{\phi \rightarrow \gamma \gamma}^{\text{HD}} + \Gamma_{\phi \rightarrow Z \gamma}^{\text{HD}} + \Gamma_{\phi \rightarrow Z h}^{\text{FH}} + \Gamma_{\phi \rightarrow h h}^{\text{FH}} + \Gamma_{\phi \rightarrow Z A}^{\text{FH}} + \Gamma_{\phi \rightarrow A A}^{\text{FH}} + \Gamma_{\phi \rightarrow H \pm W \mp}^{\text{HD}} + \Gamma_{\phi \rightarrow \text{SUSY}}^{\text{FH}}$$

$$\Gamma_{H \pm} = \Gamma_{H \pm \rightarrow \tau \nu_{\tau}}^{\text{FH}} + \Gamma_{H \pm \rightarrow \mu \nu_{\mu}}^{\text{FH}} + \Gamma_{H \pm \rightarrow h W}^{\text{FH}} + \Gamma_{H \pm \rightarrow H W}^{\text{FH}} + \Gamma_{H \pm \rightarrow A W}^{\text{FH}} + \Gamma_{H \pm \rightarrow t b}^{\text{HD}} + \Gamma_{H \pm \rightarrow t s}^{\text{HD}} \\ + \Gamma_{H \pm \rightarrow t d}^{\text{HD}} + \Gamma_{H \pm \rightarrow c b}^{\text{HD}} + \Gamma_{H \pm \rightarrow c s}^{\text{HD}} + \Gamma_{H \pm \rightarrow c d}^{\text{HD}} + \Gamma_{H \pm \rightarrow u b}^{\text{HD}} + \Gamma_{H \pm \rightarrow u s}^{\text{HD}} + \Gamma_{H \pm \rightarrow \text{SUSY}}^{\text{FH}}$$

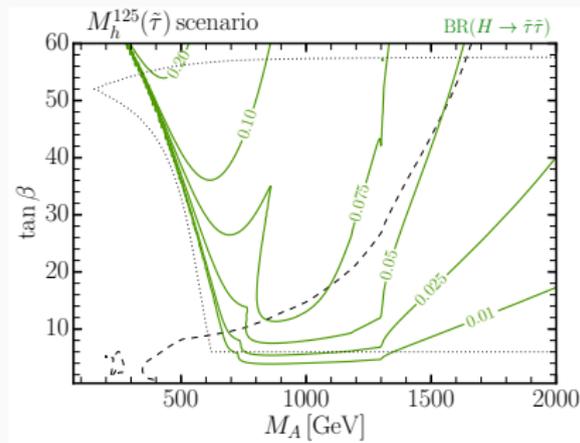
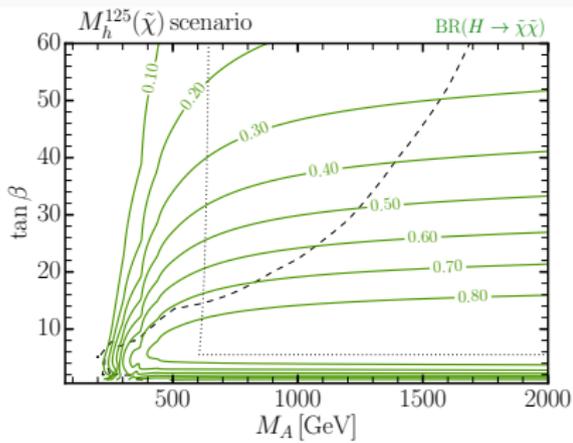
Next update of the ROOT files

Extensive validation procedure currently being implemented to guarantee the correctness of the results. The following issues have been found and will be fixed in the next release.

- Update to HDECAY 6.53 where a modification of the SUSY-QCD corrections for proper Δ_b terms has been implemented to recover the decoupling behavior. The changes impacts all Higgses and (indirectly) all channels.
- Update to the public FeynHiggs 2.14.3 release. This fixes again the values of some BRs.
- Fixed zero value being stored for the BRs/width of $t \rightarrow H^\pm b$ in the ROOT files of the non-EFT scenarios.
- Fixed wrong Δ_b values (all scenarios) and implemented support for complex Δ_b ($M_{h_1}^{125}(CPV)$). Impact at low $\tan\beta$ where bottom negligible.
- Fixed wrong BRs (ROOT file generation framework): H^\pm to $u\bar{b}$.
- Removed unreliable/not well defined BRs: decay to electrons; H^\pm to $u\bar{d}$.
- Fixed official interface access for: $h \rightarrow Z\gamma$; H^\pm to quarks.

A/H to SUSY states

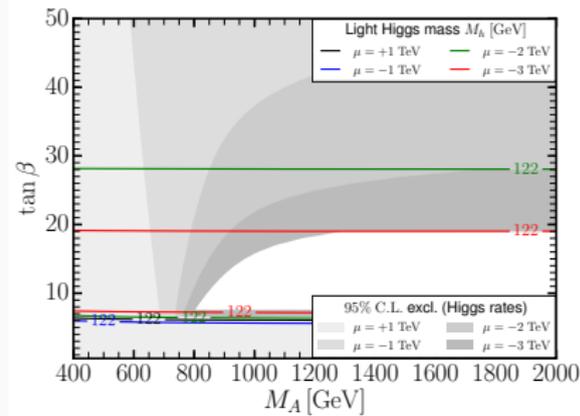
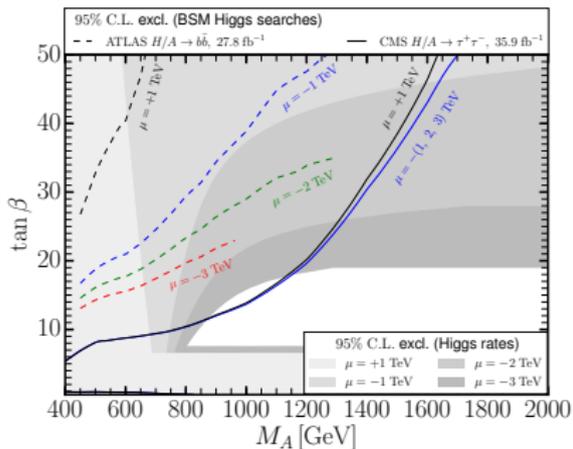
- Some of the scenarios are characterized by large branching ratios to SUSY states.
- A separate set of ROOT files will be released with the different channels saved separately (in the current ROOT files all the BRs to SUSY are summed in a single histogram).
- Discussions in progress to see whether there is interest from the experimental community in probing these decay channels. Feedback welcome.



ROOT files for scenarios with $\mu < 0$

New scenarios with $\mu < 0$ have been released in [Eur.Phys.J.C 80 (2020) 10, 916].

- Same SUSY parameters as M_h^{125} aside from $\mu = -1, -2, -3$ TeV.
- Enhanced bottom Yukawa coupling \rightarrow change in the relative sensitivity of the $b\bar{b}$ and $\tau^+\tau^-$ heavy Higgs searches, modifications of the light Higgs properties.



Open issues and developments

Two updates foreseen: a first one with the fix of all the issues previously mentioned and the release of the $\mu < 0$ scenarios; a second one with the following improvements.

- Fix the renormalization scheme mismatch between FeynHiggs and HDECAY due to FeynHiggs writing OS soft SUSY-breaking parameters in the SLHA file.
- New hMSSM release with a yet-to-be-released HDECAY version which includes the corrections from [\[Eur.Phys.J.C 79 \(2019\) 1\]](#).
- Possibly release the ROOT files on Zenodo to ease the tracking of the various versions and their use.
- Release a WG note with the description of the procedure used to generate the ROOT files and the description of the official interface.

Higgs p_{\perp}^{ϕ} reweighting

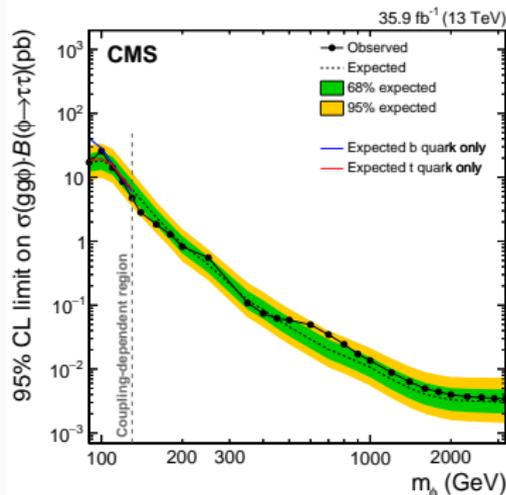
Goal: account for the impact on the acceptance of the different shape of the Higgs p_{\perp}^{ϕ} distribution in the MSSM

- Several theoretical studies in the literature [JHEP 02 (2012) 088, JHEP 11 (2014) 116, JHEP 01 (2016) 056, JHEP 01 (2016) 090]
- State of the art predictions available in the POWHEG-BOX, aMCSusHi, MoRe-SusHi.
- Effect included in the CMS analysis [JHEP 09 (2018) 007].

Current prescription is to treat each term differently

$$\frac{d\sigma}{dp_{\perp}^{\phi}} = \frac{d\sigma}{dp_{\perp}^{\phi}} \Big|_{\text{top}} + \frac{d\sigma}{dp_{\perp}^{\phi}} \Big|_{\text{bot}} + \frac{d\sigma}{dp_{\perp}^{\phi}} \Big|_{\text{int}}$$

- Grid based on a 2HDM calculation.
- Release a public access tool and a public note.



Summary and outlook

- A lot of ongoing work on the scenarios.
- Two updates of the ROOT files already scheduled.
- Ongoing activity on the Higgs p_{\perp}^{ϕ} framework.
- We plan to publish two working group notes.

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