Future of the MSSM Neutral Higgs Group

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Current Work

- We generally provide ROOT files for various MSSM benchmark scenarios:
  - m_h^{max}, $m_h^{mod+/-}$, tauphobic, light stop, light stau
  - Scenarios targeting low tanβ: hMSSM, low-tanβ-high.
  - All provided on the webpage: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGMSSMNeutral
- The low tanβ scenarios are discussed in **LHCHXSWG-2015-002** and **YR4**.
- This year, the ROOT files were extended to 2 TeV.
  - Unfortunately, extrapolation function for bbϕ cross section fit the 1-2 TeV m_A range inadequately. This was already fixed in the files and repaired.

Current Work

For now the available ROOT files are:

scenario	m_A [GeV]	$\tan\beta$	$\sqrt{s}$ [TeV]	authors
"low-tb-high"	$150 - 500$	$0.5 - 10$	$8, 13$	[Heinemeyer '15]
hMSSM	$130 - 1000$	$1 - 60$	$8, 13$	[Maiani et al. '13; Djouadi et al. '13 '15]
m_h^{max}	$90 - 2000$	$0.5 - 60$	$13, 14$	[Carena et al. '13]
$m_h^{\text{mod}+}, \mu \in \mu^{\text{val}}$	$90 - 2000$	$0.5 - 60$	$8, 13, 14$	[Carena et al. '13]
$m_h^{\text{mod}-}$	$90 - 2000$	$0.5 - 60$	$13, 14$	[Carena et al. '13]
light stau	$90 - 2000$	$0.5 - 60$	$13, 14$	[Carena et al. '13]
light stop	$90 - 650$	$0.5 - 60$	$13, 14$	[Carena et al. '13]
τ-phobic	$90 - 2000$	$0.5 - 50$	$13, 14$	[Carena et al. '13]

$\mu \in \mu^{\text{val}} = \{-1000, -500, -200, 200, 500, 1000\}$ GeV

- The setup of the ROOT files was completely rewritten in 2015. They contain as a function of m_A and tanβ for $\phi \in \{h, H, A\}$:
  - Higgs masses mϕ (h (mostly) compatible with SM Higgs ~ 125 GeV)
  - Gluon fusion XS
  - Bottom-quark annihilation XS in 4FS/5FS and Santander-matched XS
  - Branching ratios
  - Scale and PDF+α_s uncertainties
  - Charged Higgs information: $m_{H^\pm}$, $t \to H^\pm b$ (for $m_{H^\pm} < m_{top}$), $H^\pm \to tb$
  - ✓ Soon to add charged Higgs cross sections for $m_{H^\pm} > 200$ GeV (thanks to Panu Keskinen).
- YR4 contains a detailed description of how the information for the ROOT files was produced, how it can be accessed and how the input parameters were chosen.
- The ROOT files are used with a C++ class+header file or a python wrapper. Usage of C++ class:
  - mssm_xs_tools mssm("scenario.root",INT,0);
  - mssm.COMMAND(STRING, mA, tanβ);
  - with COMMAND=mass/br/xsec, STRING="H"/"gg → H"/. . .

Ongoing Work: MSSM ggϕ (A/H) → ττ

- Rene Caspart and Yuta Takahashi have been studying the p_T-modelling of heavy Higgs bosons.

- Codes available for analytic resummation, e.g. MoRe-SusHi, or resummation through parton shower, e.g. POWHEG-BOX / aMCSusHi.

- Idea: Save computing time by combining results obtained individually for *t*, *b* and *t*−*b*-interference
  - In the SM the *t*−*b*-interference can only be obtained with large numerical uncertainty.
  - Thus, extract the components in a type II 2HDM with a larger value of tan β(~ 10).

- The final result can be reweighted to the inclusive MSSM cross section.
  - ✓ In principle, this information could be included in our ROOT files.

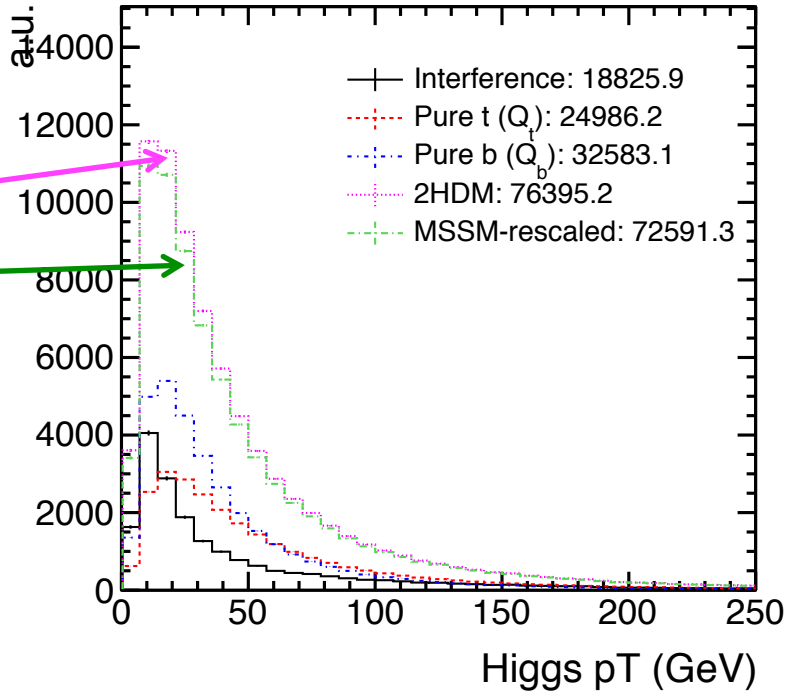
Ongoing Work: MSSM ggϕ (A/H) → ττ

- Higgs p_T depends on the quark Yukawa couplings.
- Successfully set up procedure to disentangle three terms (*b*-only, *t*-only, *t*—*b* interference), generate separately, and derive desired spectrum using tanβ-dependent weights.

$$\left(\frac{Y_{t,\mathrm{MSSM}}}{Y_{t,2\mathrm{HDM}}}\frac{Y_{b,\mathrm{MSSM}}}{Y_{b,2\mathrm{HDM}}}\right)\left\{\sigma^{t+b}_{2\mathrm{HDM}}(Q_{tb})-\sigma^{t}_{2\mathrm{HDM}}(Q_{tb})-\sigma^{b}_{2\mathrm{HDM}}(Q_{tb})\right\}$$

- *t*-*b* interference reweighted from 2HDM to MSSM.

- Evaluate uncertainty for the modeled p_T distribution?



Near-Term Work

- ✓ We plan to redo the ROOT files with new SM input and N3LO contribution for the light Higgs boson. Due to the small expected impact and the excitement about the 750 GeV diphoton bump, this has been delayed.
  - ✓ Note: SQCD corrections are only known at NLO in approximate (and full) calculations and only approximately up to NNLO for the top-induced contributions→this is an interesting area for future theoretical developments.

- The current ROOT files were produced before LHCHXSWG-INT-2015-006 was released, and had been used already in public results (e.g. [ATLAS 1509.00672 JHEP 1511 (2015) 206]).

- The most prominent differences are:

$$\alpha_s(m_Z) = 0.119 \leftrightarrow 0.118$$

$$m_b(m_b) = 4.16\,\text{GeV} \leftrightarrow 4.18\,\text{GeV}$$

PDF sets: MSTW2008 $\leftrightarrow$ PDF4LHC15 $\rightarrow$ special sets for bbϕ!

We plan to keep the old ROOT files for documentation, but to produce a new round with updated SM parameters soon.

- ✓ Add a scenario using a "true" 2HDM EFT setup with heavy SUSY (using results of Lee, Wagner and their recently published code: (http://gabrlee.com/code/).

Further in the Future

A crucial question for the "MSSM neutral" subgroup is whether or not the 750 GeV resonance is confirmed:

- It is not easy to accommodate the 750 GeV resonance with pure MSSM, so the future focus of the subgroup could be dramatically changed.
- Nevertheless, our experience in providing ROOT files and precise predictions beyond the SM is helpful in any BSM subgroup. → More after ICHEP.

If the 750 GeV results are negative and all new physics searches are negative until the end of 2016:

- One focus can be on deviations for the light Higgs boson cross sections and branching ratios, i.e. trying to classify deviations.
  - due to delayed decoupling, SUSY particles, etc.
- Another focus could be on various aspects:
  - More emphasis on EFT methods for heavy-SUSY scenarios.
  - Possible future projects: CP violation, Flavour violation.
  - Add other production processes (e.g. VH) and/or interference effects (e.g. as in gg→ H→ZZ)?