WG3-NMSSM

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NMSSM: MSSM + a complex scalar (whose VEV solves the μ-problem of the MSSM) + a singlino, a good dark matter candidate

$\rightarrow$ More states in the Higgs sector

$\rightarrow$ More complex sparticle decay cascades (if the singlino is the LSP)

$\rightarrow$ But: Many parameters in the Higgs sector: 2 dim.-less couplings λ, κ, 2 trilinear Higgs couplings A_λ, A_κ, 3 masses for 3 complex scalars

$\rightarrow$ These are constrained in a quite nonlinear way (incl. radiative corrections) by the W, Z and SM-like Higgs masses and couplings

Tasks:

– Propose NMSSM specific final states/signal regions that are not yet searched for in the experiments

– Need to know the allowed ranges of involved particle masses, production cross sections and branching fractions which are not in conflict with present search results

– To this end one needs to know the constraints on the NMSSM specific parameters from re-interpretions of available searches at the LHC

– In some cases – e.g. searches for BSM Higgs states in ggF or b(b)H in various final states – the interpretation in terms of masses, production cross sections and branching fractions is straightforward, but the "translation" into the NMSSM parameter space requires numerical codes

– In other cases such as involved sparticle decay cascades into a singlino LSP elaborate simulations are required (see the talk by A. Titterton Wednesday afternoon).

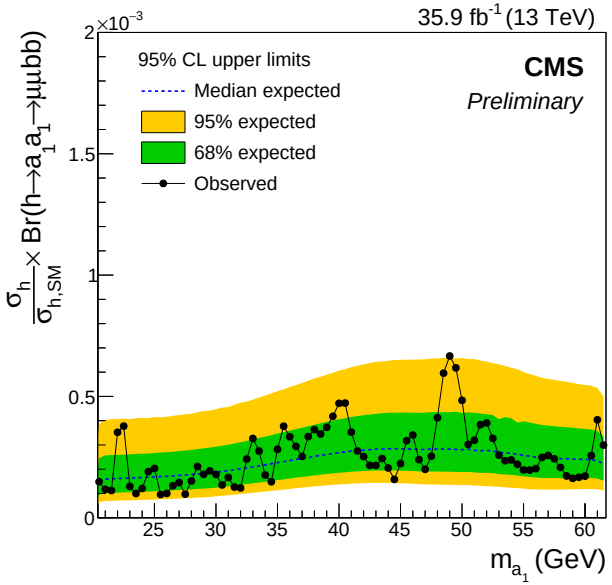
– The "wish lists" of the experimental collaborations consist typically in benchmark planes in the space of possible signal rates/masses/parameters which clarify which ranges of parameters could be tested by specific searches (analogous to the $M_A - \tan\beta$ plane in the MSSM)

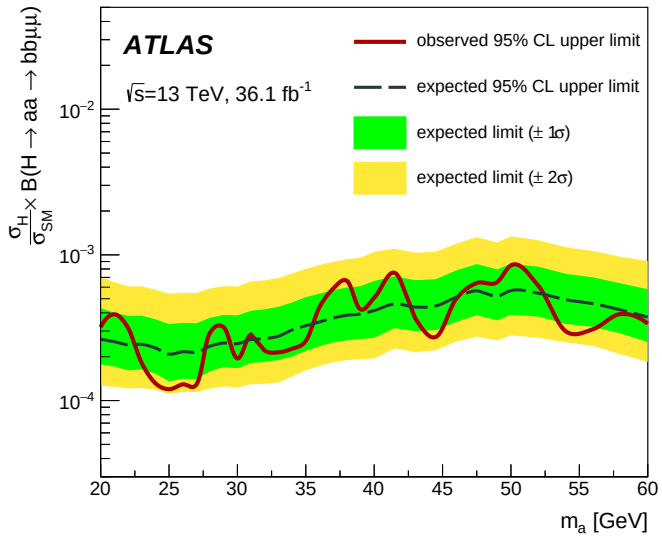
– Provided can be benchmark planes in the space of possible signal rates and masses which result from scans over the parameter space, after imposing existing constraints (using e.g. HiggsBounds, NMSSMCALC, NMSSMTools...)

Examples:

1) Exotic decays of $H_{SM} \to A + A \to XXXX$ (or $S + S \to XXXX$):

Many interesting results from ATLAS and CMS, e.g. into $bb\mu\mu$:
CMS-PAS-HIG-18-011 ATLAS arXiv:1807.00539

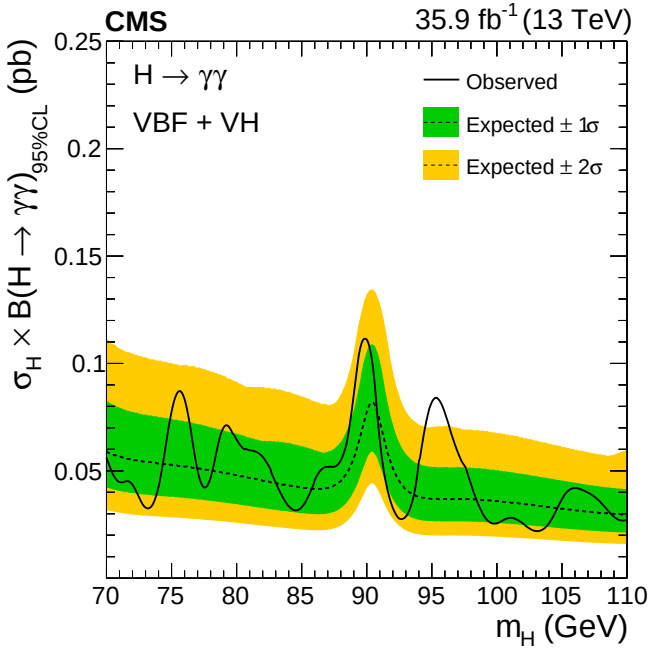


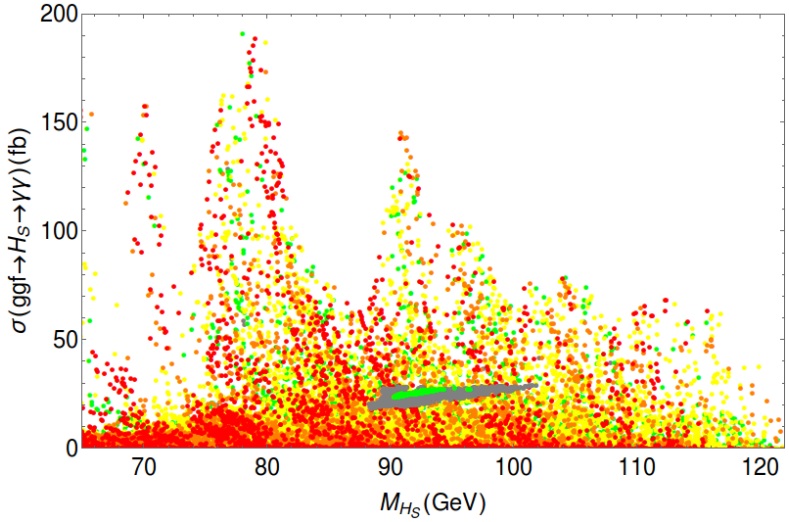


The recent coupling measurements of H_{SM} by ATLAS and CMS imply upper limits on possible $BRs(H_{SM} \to AA \to XXXX)$ in the NMSSM.

To do: Which channels (depending on M_A) remain the most promising ones for future searches?

2) Direct production of mostly singlet-like H_S (A_S), in ggF or in ass. with b(b), typically in the diphoton final state. These searches are sensitive to the NMSSM parameter space:





From CMS-HIG-17-013 (13 TeV)

Possibilities in the NMSSM for 13 TeV using limits from 8 TeV, from 1512.04281, to update

3) Prospects for searches for $H_3 \to H_{SM} + H_S$ where H_3 is MSSM-like, produced via ggF or in ass. with b(b), in various final states:

Compare $H_3 \to H_{SM} + H_S$ to $H_3 \to H_{SM} + H_{SM}$

Trilinear scalar couplings have dimension of a mass

A bit of group theory, using that H_3 and H_{SM} are SU(2) doublets:

Coupling $H_3 \times H_{SM} \times H_{SM}$: 3 SU(2) doublets contain no singlet

$\to$ Such a coupling cannot exist in the Lagrangian, it must originate from a quartic coupling involving another doublet which aquires a VEV (the SM-like Higgs after diagonalisation of the Higgs mass matrix)

$\to$ It is bounded from above by (dim.less coupling const.)$\times$(Higgs VEV)

Coupling $H_3 \times H_{SM} \times H_S$: 2 SU(2) doublets contain a singlet

$\to$ Such a coupling can exist in the Lagrangian and can be a large parameter, or originate from a large singlet VEV

$\to$ the $BR(H_3 \to H_{SM} + H_S)$ can be dominant!

This argument applies to the NMSSM and to non-susy 2HDM+singlet extensions of the Higgs sector

A large $BR(H_3 \to H_{SM} + H_S)$ alleviates constraints from (MSSM-) searches for $pp \to H_3 \to \tau^+\tau^-$ in the $M_A - \tan\beta$ plane

$\to$ A promising search, similar to resonant H_{SM} pair production but now involving two unknown masses M_{H_3} and M_{H_S}

Searches in various final states are possible, sensitivities will depend on M_{H_S} which may be smaller or larger than 125 GeV.
Searches will automatically be sensitive also to pseudoscalars in $pp \to A_2 \to H_{SM} + A_S$.

Earlier proposals (see also the WG3/NMSSM twiki page, $\Phi \equiv H_3$ or A_2):

M. Mühlleitner et al.:
1408.1120: $\Phi \to H_{125} + H_S \to 4b/bb\tau\tau/4\tau/bb\gamma\gamma$
1512.05335: $\Phi \to H_{125} + H_S \to 4b$

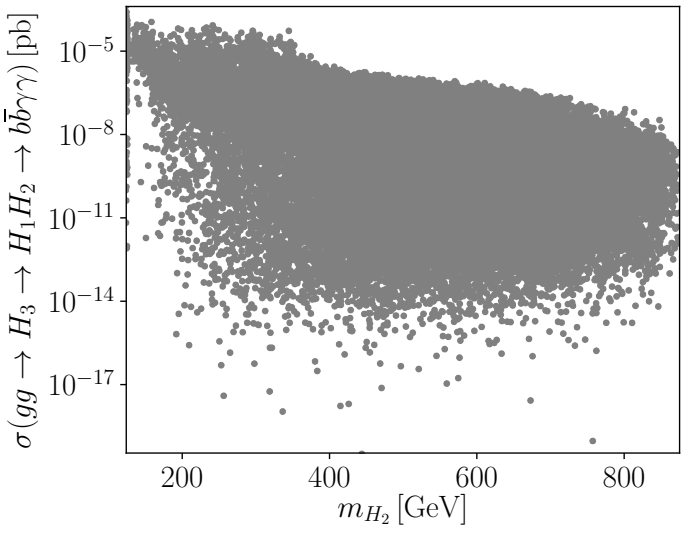
W. de Boer et al., 1602.08707: $\Phi \to H_{125} + H_S$

U.E. et al., 1707.08522: $\Phi \to H_{125} + H_S \to 4b, bb\gamma\gamma, bb\tau\tau$
(incl. studies of background/sensitivities)

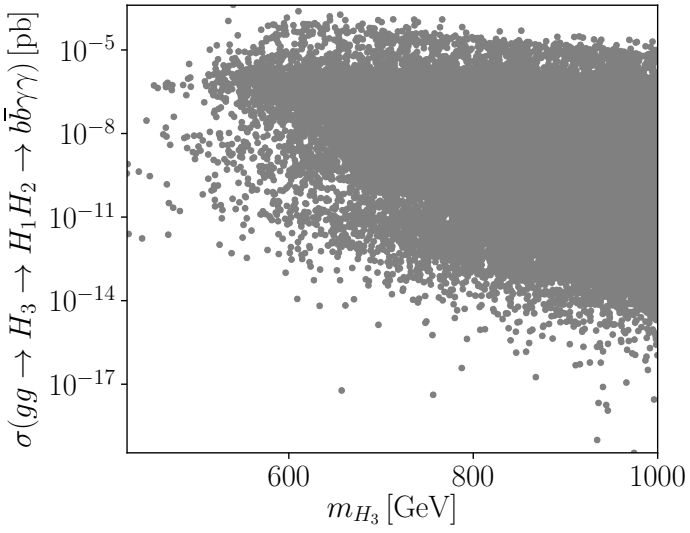
Ongoing work:

Prepare benchmark planes "signal rates vs. masses" for various final states; e.g. $H_3 \to H_{125} + H_S \to b\bar{b}\gamma\gamma$

From Phillip Basler (KIT Karlsruhe/ M. Mühlleitner, preliminary):

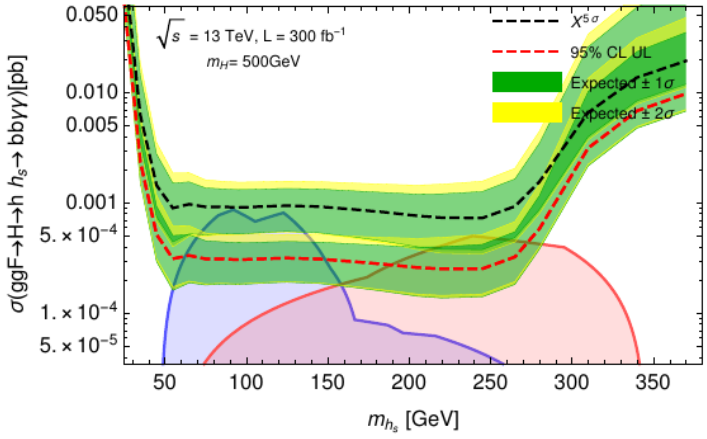


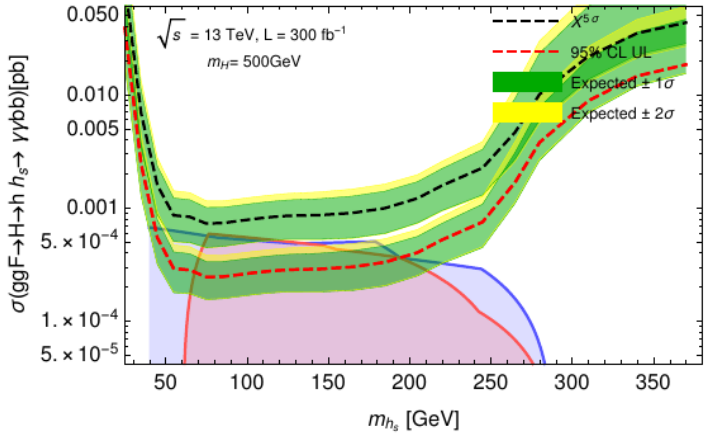
Sum over M_{H_3}



Sum over M_{H_2}

From M. Rodríguez-Vázquez (LPT Orsay/ U. Ellwanger, 1707.08522), incl. estimated sensitivities after 300 fb^{-1}:





$M_{H_3} = 500$ GeV, $\gamma\gamma$ from H_S $\gamma\gamma$ from H_{SM}

Blue: $H_3 \to H_{125} + H_S$, red: $A_2 \to H_{125} + A_S$

Under discussion:

→ Which planes? Dependence on NMSSM parameters useful?

→ Updates of scans?

More NMSSM specific heavy Higgs decays:

(M. Mühlleitner et al., 1408.1120)

$H_3 \to Z + A_S$ or $A_2 \to Z + H_S$

$H_3 \to A_S + A_S$ or $A_2 \to A_S + H_S$

More involved decay cascades into 3 bosons:

$H_3 \to H_{SM} + H_S \to H_{SM} + A_S + A_S$

$A_2 \to H_S + A_S \to A_S + A_S + A_S$

$A_2 \to H_S + Z \to A_S + A_S + Z$

and H/A mixtures in case of CP violation

More NMSSM specific H_{125} decays beyond $H_{125} \to A + A$:

$H_{125} \to Z + A$, $A \to b\bar{b}, \gamma\gamma$ etc. (Under discussion)

...and we get more input from talks at WG3/NMSSM meetings like this Wednesday afternoon