



NMSSM Subgroup: Experiment Update

The 17th Workshop of the LHC Higgs Working Group - 10.11.2020

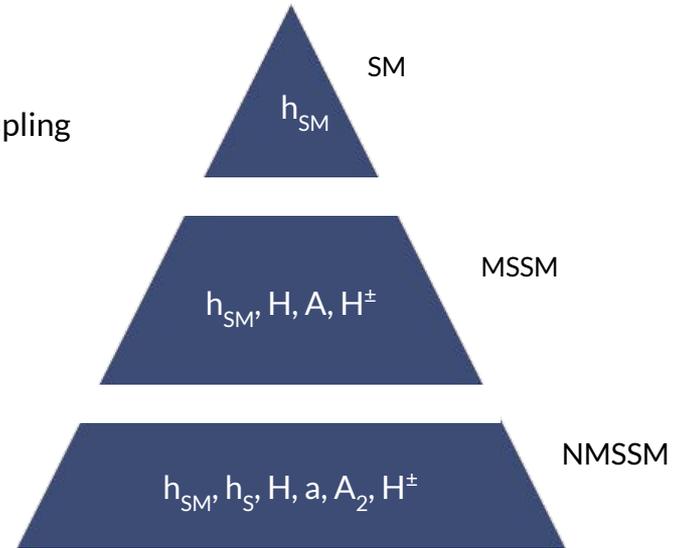
Janek Bechtel and Nikolaos Rompotis for the CMS and ATLAS collaborations

The Higgs sector in the NMSSM

$$W_{\text{NMSSM}} = W_{\text{MSSM}} + \lambda S \phi_u \phi_d + \frac{1}{3} \kappa S^3$$

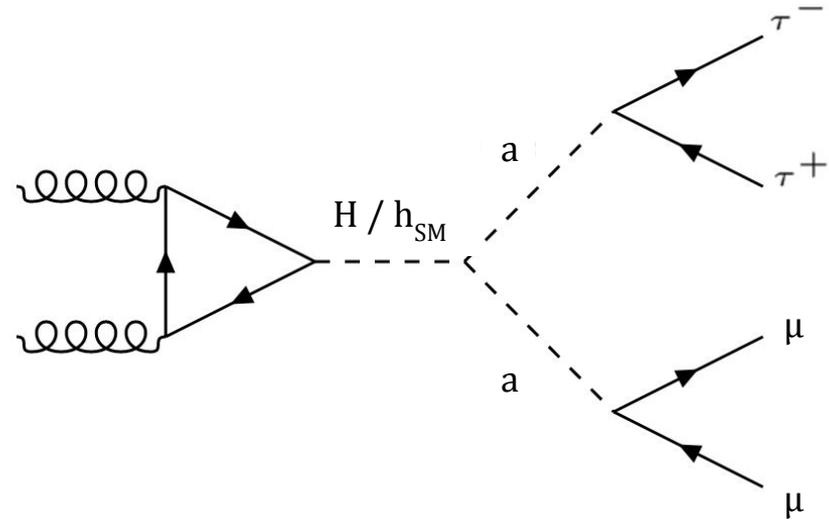
↑ NMSSM superpotential ↑ MSSM superpotential ↑ Coupling of singlet to doublet fields ↑ Singlet self-coupling

- In the NMSSM, an additional complex Higgs singlet S with respect to the MSSM is introduced to alleviate the highly constrained Higgs sector of the MSSM and solve the unnaturalness (“ μ problem”) in the model
- The modifications in the Higgs sector lead to seven Higgs bosons and a generally richer / more complex phenomenology



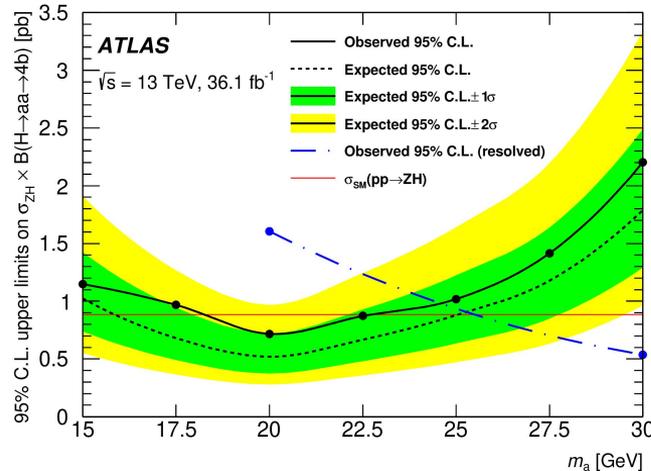
Searches for NMSSM Higgs bosons

- Higgs bosons with strong singlet admixture can have **reduced couplings to SM gauge fields, quarks or leptons** and the direct production can be strongly suppressed
- NMSSM Higgs bosons can be **light (<125 GeV) and still undiscovered**
- Past NMSSM searches have been associated for a long time with the **search for light pseudoscalars**



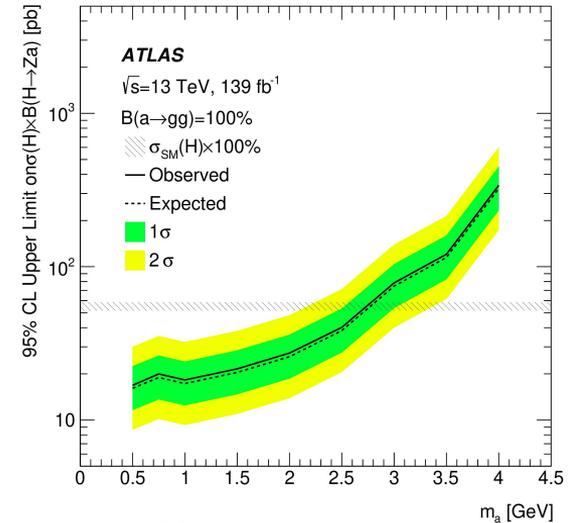
Recent searches for light pseudoscalars: $h_{SM} \rightarrow aa$, $h_{SM} \rightarrow Z+a$

- Two ATLAS searches:
 - Higgs decays to light Higgs states decaying into b-quarks, $aa \rightarrow 4b$, using the 2016 dataset
 - Higgs decays to $Z+a$, in which $Z \rightarrow \ell\ell$, $a \rightarrow jj$



May 2020

<https://arxiv.org/abs/2005.12236>

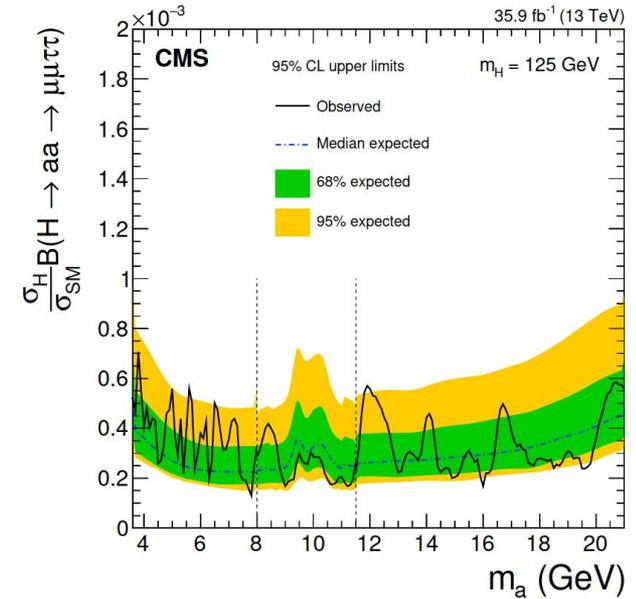
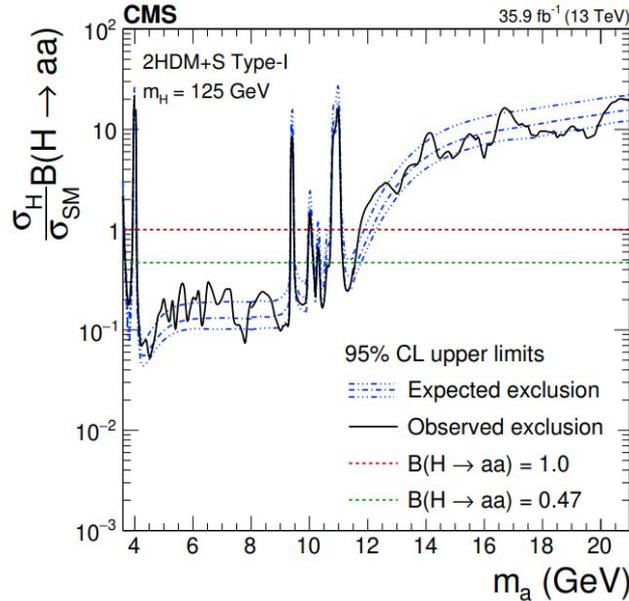


April 2020

<https://arxiv.org/abs/2004.01678>

Recent searches for light pseudoscalars: $h_{SM}/H \rightarrow aa$

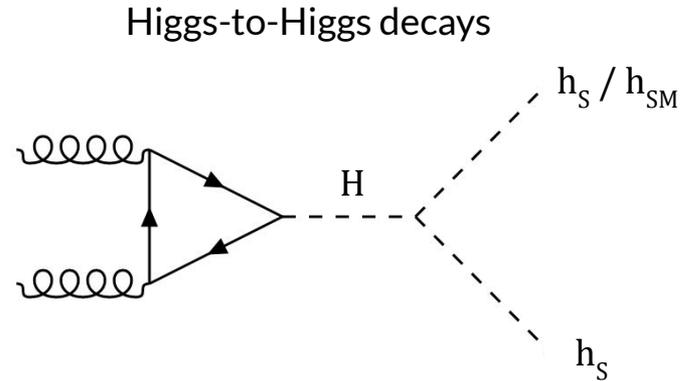
- CMS search for 125 GeV or higher-mass Higgs bosons decaying into light Higgs states
- $aa \rightarrow \mu\mu\tau\tau$ final state is considered



August 2020
[https://doi.org/10.1007/JHEP08\(2020\)139](https://doi.org/10.1007/JHEP08(2020)139)

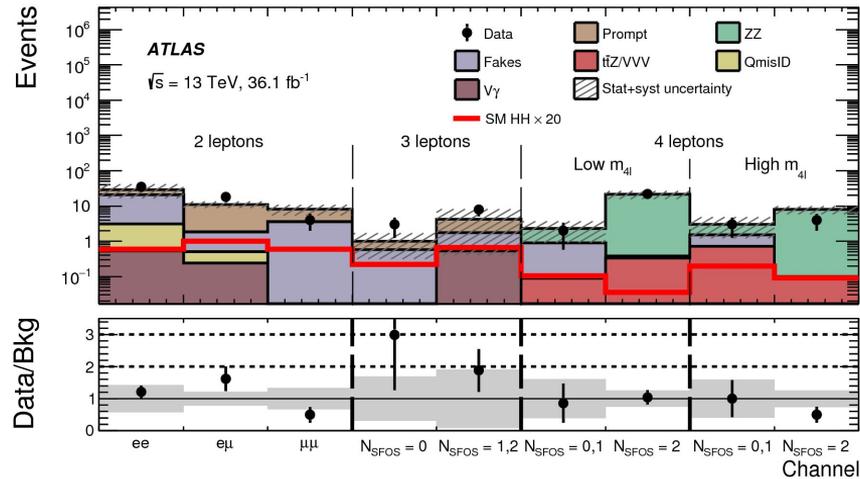
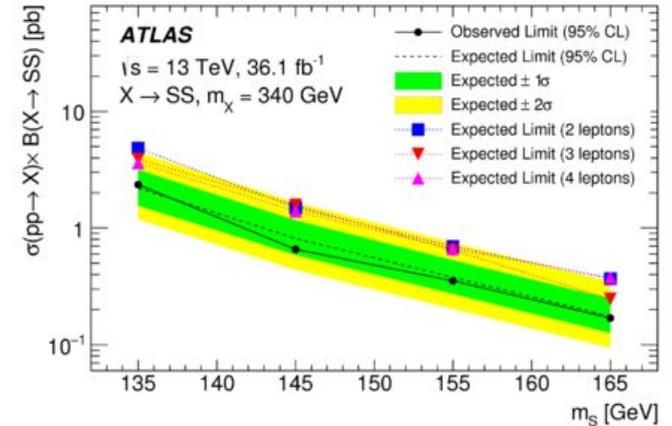
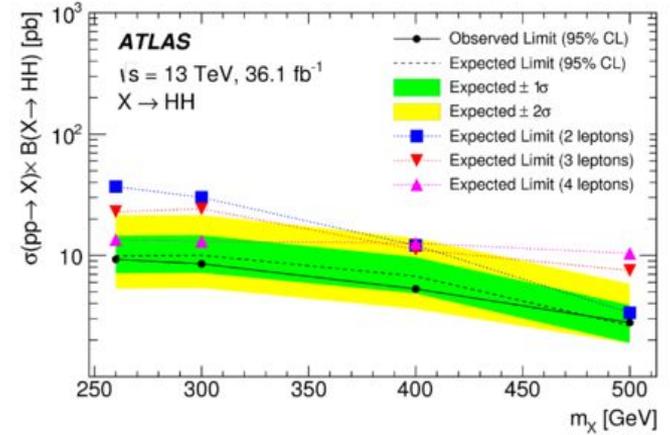
Searches for NMSSM Higgs bosons - Prospects

- For the full Run-2 results, The NMSSM sub-group moves to signatures featuring higher mass Higgs bosons
 - Higgs-to-Higgs decays
 - Higgs-to-Gauge-plus-Higgs decays
- These signatures are often not considered by the experiments to be NMSSM yet
 - Opportunity for **novel searches with promising possible signal rates and interesting final states** with multiple quarks, leptons or photons
- Two examples from ATLAS on the following slides



$$X \rightarrow h_{SM} h_{SM} / h_S h_S \rightarrow 4W$$

- Final state with 4 W bosons
- It is an $h_{SM} h_{SM} \rightarrow 4W$ search that is extended to include $X \rightarrow h_S h_S$ final states as well

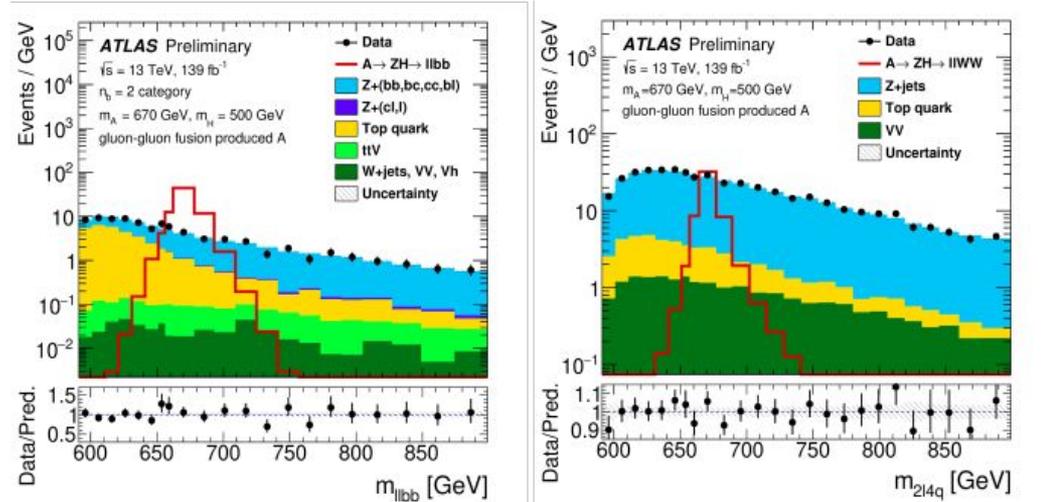


$A \rightarrow Z+H$

- Heavy Higgs boson decaying to a Z boson and another heavy Higgs
- Large mass splitting between A and H
- Final states considered: $\ell\ell b\bar{b}$ and $\ell\ell WW$
- Both b-associated production and gluon fusion for $\ell\ell b\bar{b}$, gluon fusion for $\ell\ell WW$
- Strategy:
Reconstruct A and H masses, select H mass compatible with m_H and fit m_A



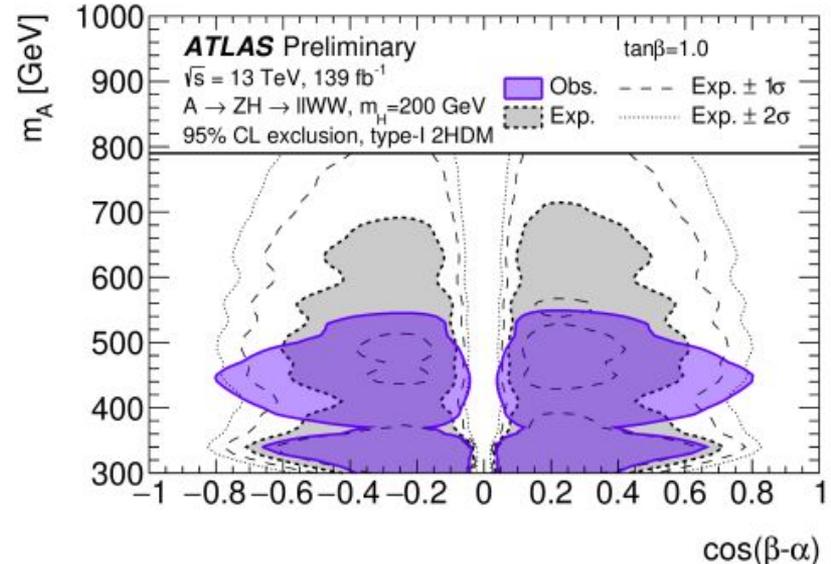
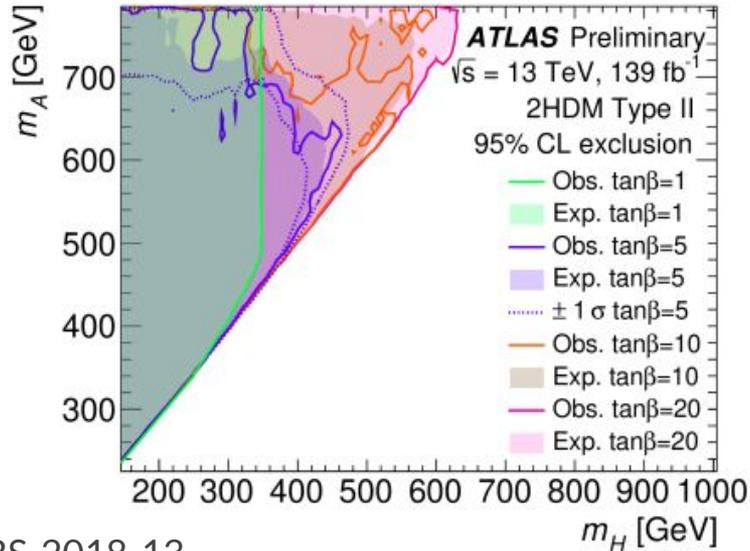
Examples of the fitted mass distributions



$A \rightarrow Z+H$



- The results are interpreted in the context of 2HDM
- Alignment limit for the $\ell\ell b\bar{b}$ channel
- Variable $\cos(\beta-\alpha)$ for the $\ell\ell WW$ channel (vanishes in decoupling limit)



Conclusions

- The addition of the complex singlet to the NMSSM Higgs sector leads to a rich and complex phenomenology
- The singlet-like NMSSM Higgs bosons **can be light, escaping experimental constraints** due to their low coupling to SM gauge fields and fermions
- Constraining the NMSSM is ramping up within the experiments, with additional search prospects being investigated for Run-2 and beyond
- Promising search prospects include the search for Higgs-to-Higgs or Higgs-to-Gauge-plus-Higgs decays with potentially large signal rates