



bbH/bH experimental results

19th Workshop of the LHC Higgs WG
WG3 Plenary
28 November 2022

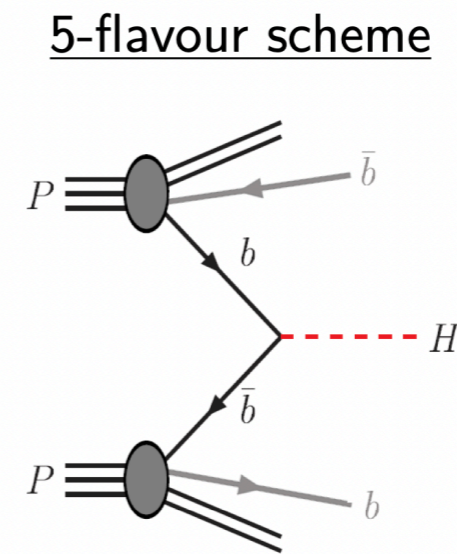
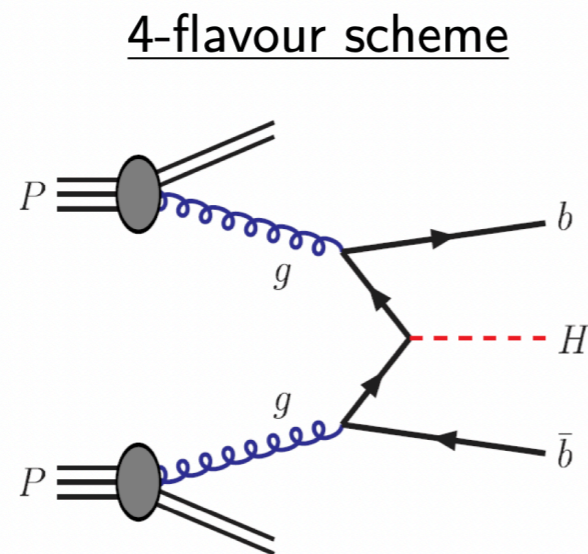
bbH/bH subgroup:

C. Asawatangtrakuldee (CU), T. Barklow (SLAC),
M. Spira (PSI), M. Wiesemann (MPI)

Introduction

★ Goal of the bbH subgroup ([Twiki](#)) :

- to provide inclusive and exclusive cross-sections for bbH production and MC generation tools



★ Recommendation since 2019 ([talk](#) by Marius Wiesemann)

★ Inclusive cross-section (4FS+5FS) using $\text{NLO} + \text{NNLO}_{\text{partial}} + \text{y}_{\text{b}} \text{y}_{\text{t}}$ matching

★ Available 3 MC generators in 4FS and 5FS

- MG5_aMC@NLO at NLO+PS in 4FS and 5FS (**ATLAS, CMS**)
- POWHEG at NLO+PS in 4FS (**CMS**)
- SHERPA at NLO+PS in 4FS and 5FS (**ATLAS**)

Run-2 summary

★ bbH related analyses from ATLAS and CMS

Channel	ATLAS	CMS
$H/A \rightarrow \tau\tau$	139 fb⁻¹ Phys. Rev. Lett. 125 (2020) 051801	138 fb⁻¹ arXiv:2208.02717
$H/A \rightarrow bb$	28 fb ⁻¹ Phys. Rev. D 102 (2020) 032004	36 fb ⁻¹ JHEP 08 (2018) 113
$H/A \rightarrow \mu\mu$	36 fb ⁻¹ JHEP 07 (2019) 117	36 fb ⁻¹ Phys. Lett. B 798 (2019) 134992
$A \rightarrow Zh$	139 fb⁻¹ arXiv:2207.00230 (Z $\rightarrow \ell\ell/\nu\nu$, h $\rightarrow bb$)	36 fb ⁻¹ EPJC 79 (2019) 564 (Z $\rightarrow \ell\ell/\nu\nu$, h $\rightarrow bb$) 36 fb ⁻¹ JHEP 03 (2020) 065 (Z $\rightarrow \ell\ell$, h $\rightarrow \tau\tau$)
$A \rightarrow ZH$ $H \rightarrow ZA$	139 fb⁻¹ EPJC 81 (2021) 396 (Z $\rightarrow \ell\ell$, H $\rightarrow bb$ and WW)	36 fb ⁻¹ JHEP 03 (2020) 055 (Z $\rightarrow \ell\ell$, A/H $\rightarrow bb$)

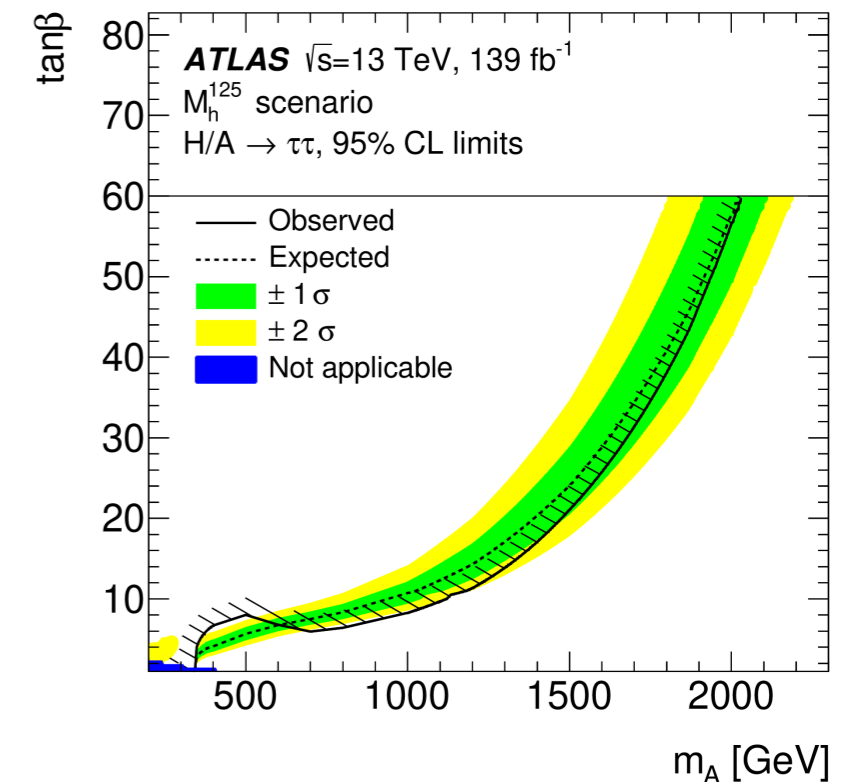
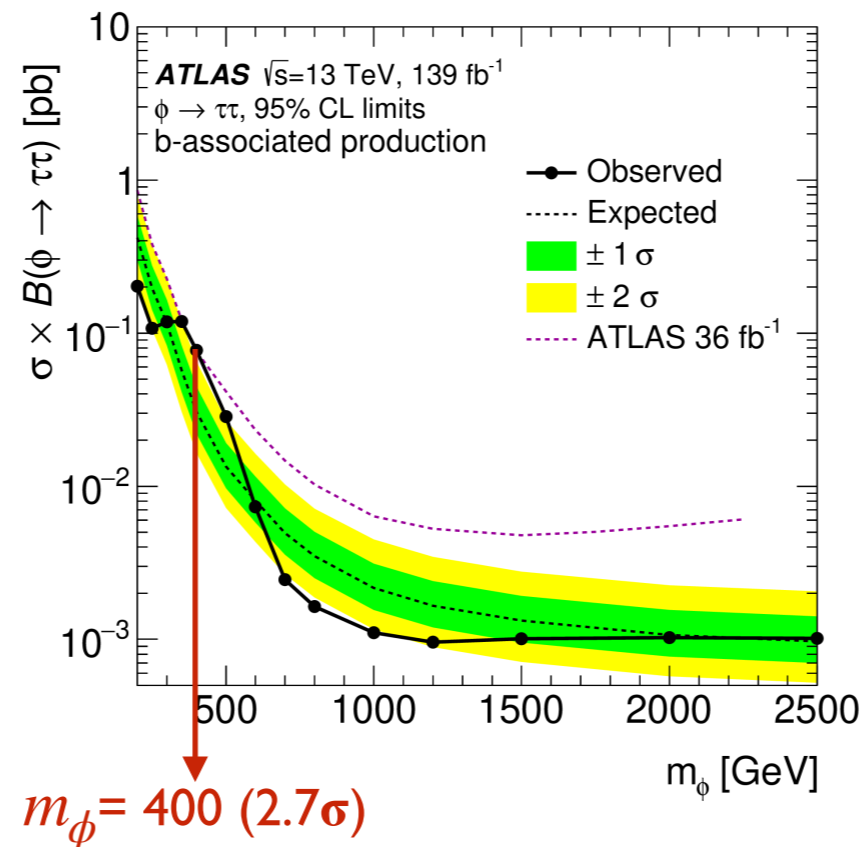
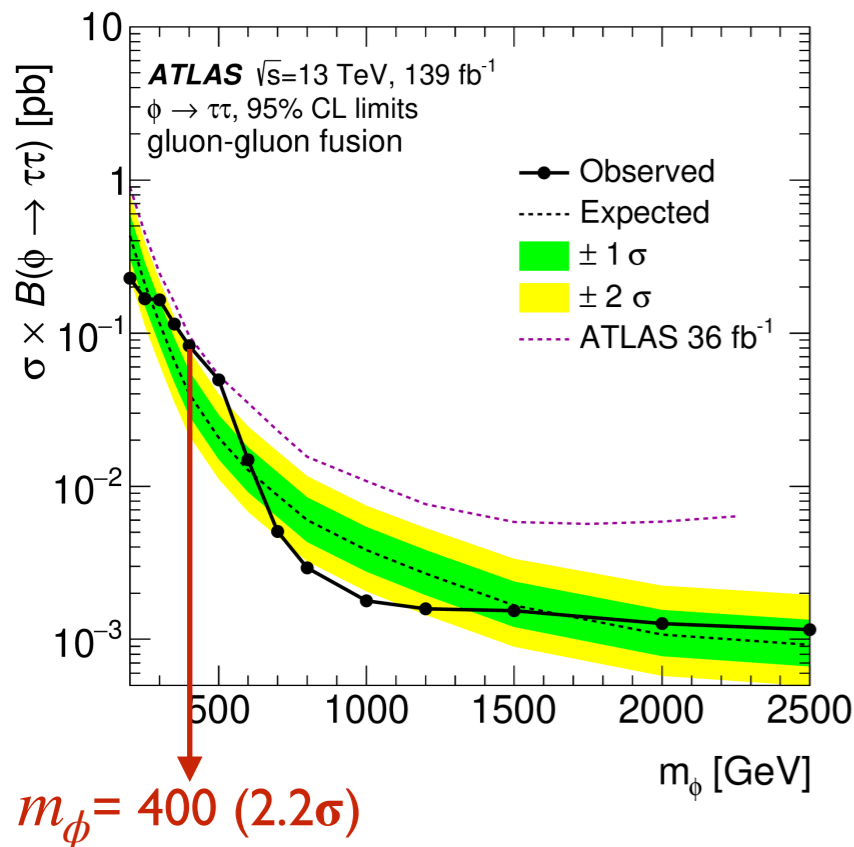
★ Some new results with full Run-2 data

★ Many analyses are ongoing to publish full Run-2 results

A/H $\rightarrow \tau\tau$ (ATLAS)

Phys. Rev. Lett. 125 (2020) 051801

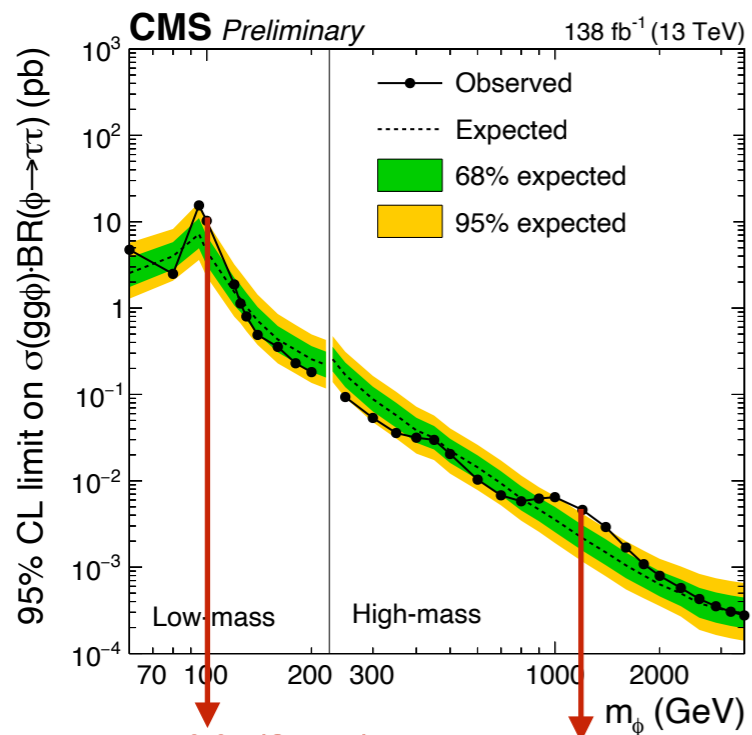
- ★ Search for heavy resonances in mass range of 0.2 – 2.5 TeV
- ★ **MG5_aMC@NLO (4FS+5FS)** is used for bbH signal
- ★ 3 sensitive channels ($\tau_{\text{lep}}\tau_{\text{had}}$, $\tau_{\text{had}}\tau_{\text{had}}$) \times 2 categories (*b*-tag and *b*-veto)
- ★ Total transverse mass (m_T^{tot}) distributions as observable for signal extraction



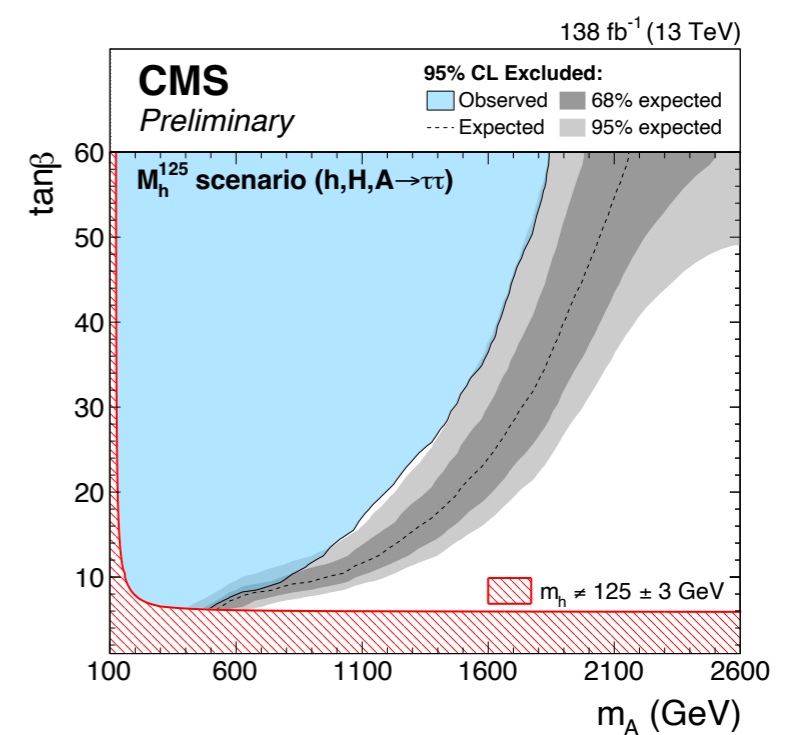
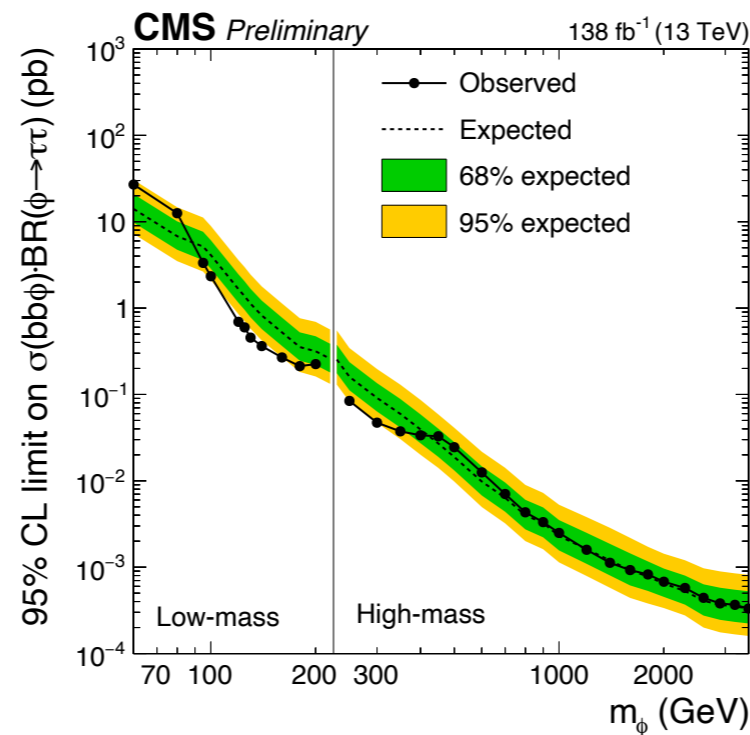
Upper limit $\sigma \times B(\phi \rightarrow \tau\tau)$ in **ggF** and **bbH** range between **240 – 1.2 fb** and **230 – 1.0 fb**
 In M_h^{125} scenario, $\tan\beta > 8$ for $m_A = 1.0$ TeV and $\tan\beta > 21$ for $m_A = 1.5$ TeV are excluded

A/H \rightarrow $\tau\tau$ (CMS)

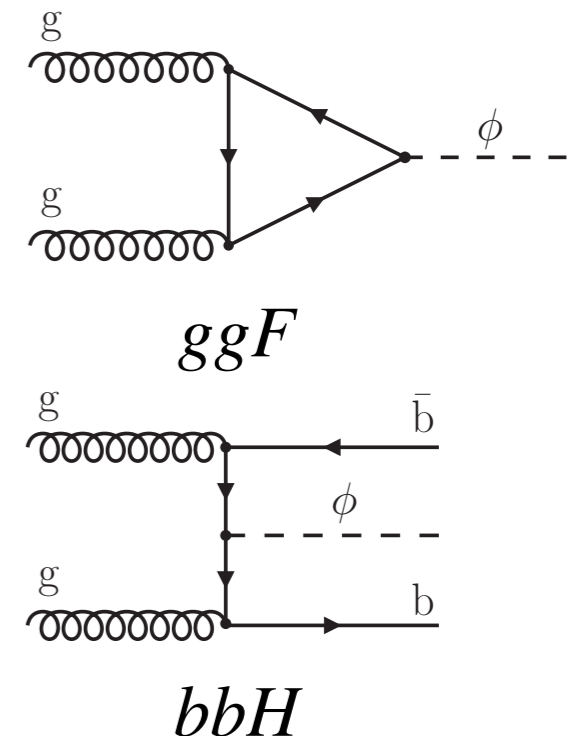
arXiv:2208.02717



$m_\phi = 100$ (3.1σ)
 $m_\phi = 95$ (2.6σ)
 $m_\phi = 1200$ (2.8σ)



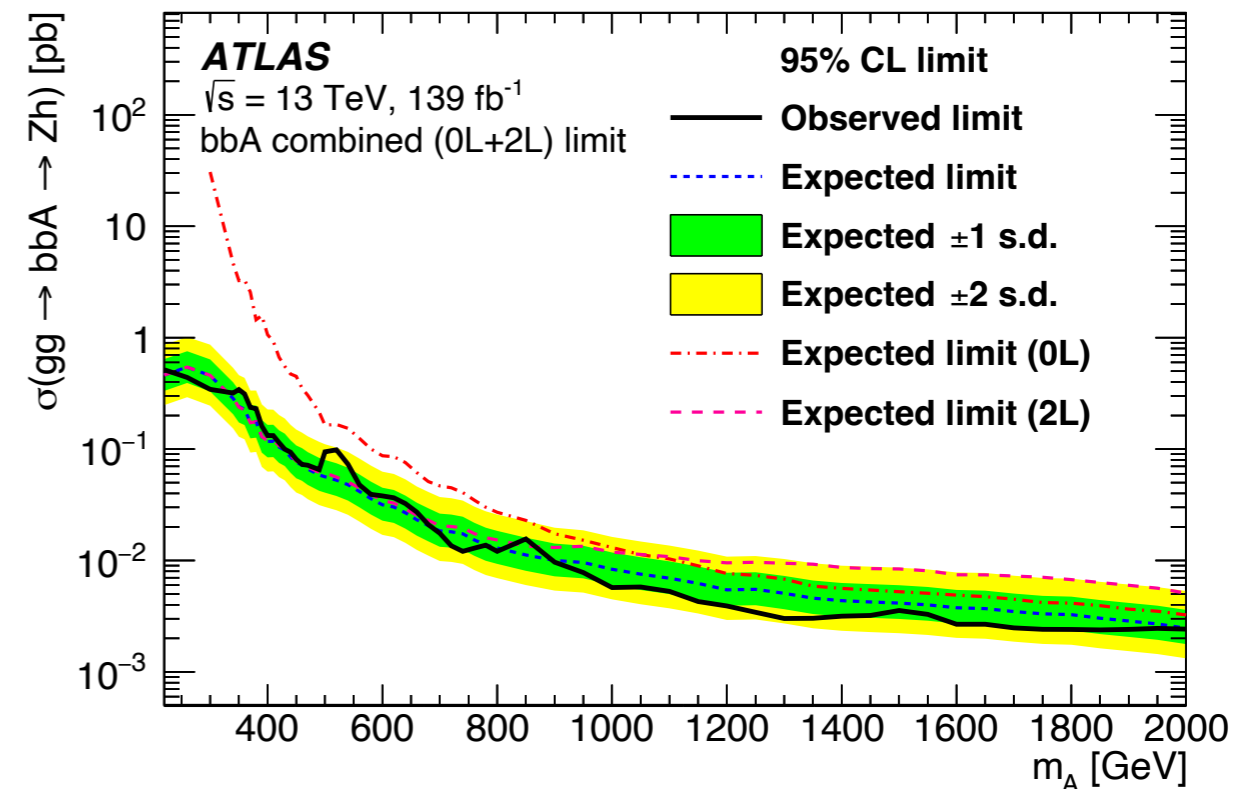
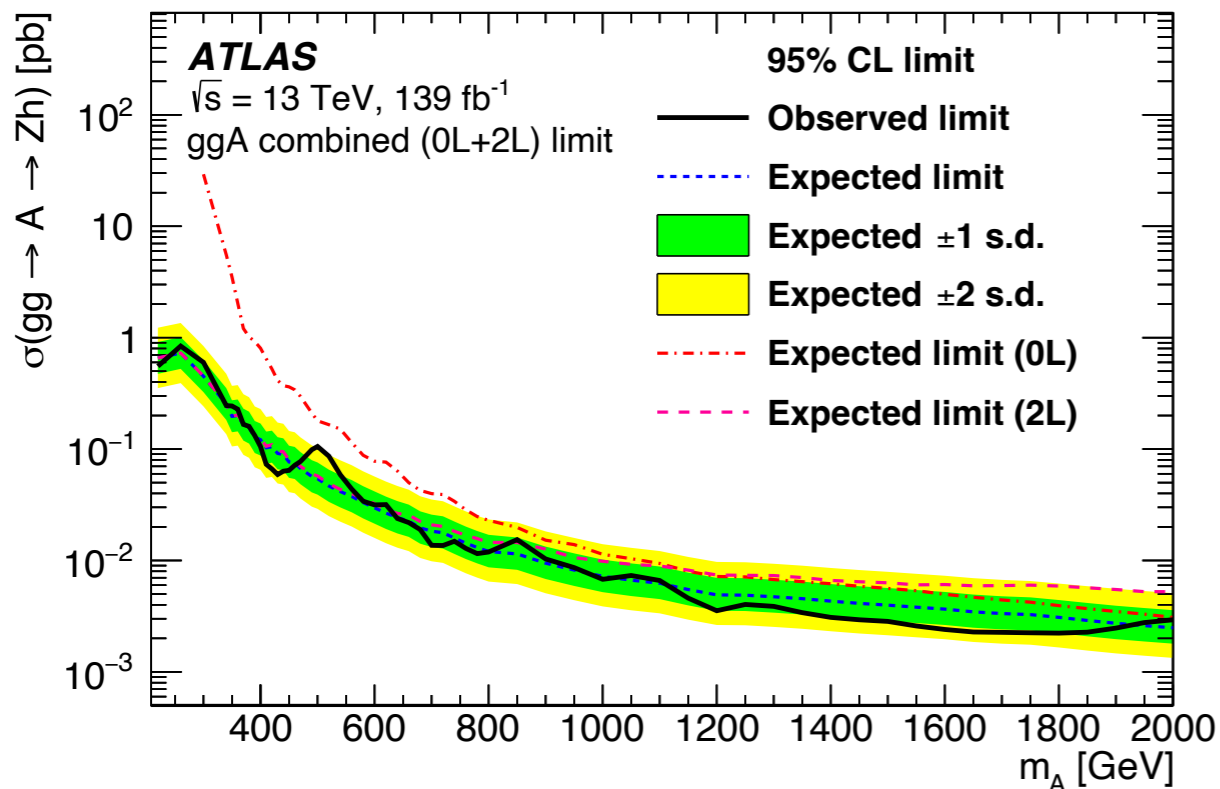
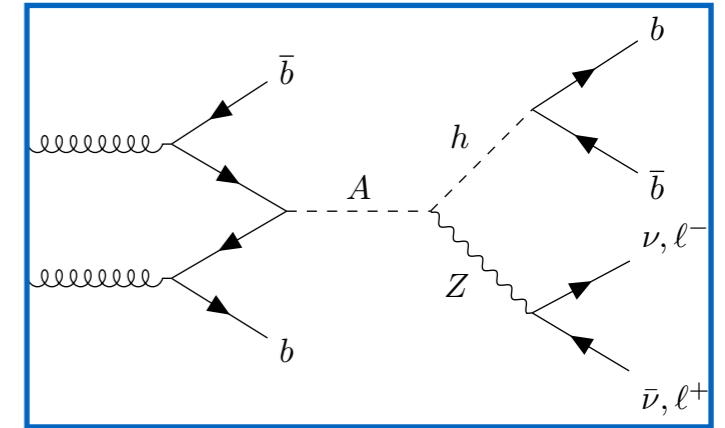
- ★ bbH and ggF signals produced by [POWHEG at NLO+PS \(4FS\)](#)
- ★ 4 most sensitive channels ($e\mu$, $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$)
- ★ Signal extracted from total transverse mass (m_T^{tot})
 - Model-independent search for ϕ in mass range of [60, 3500] GeV
 - MSSM benchmark scenarios
 - t -channel exchange of a vector leptoquark U_1



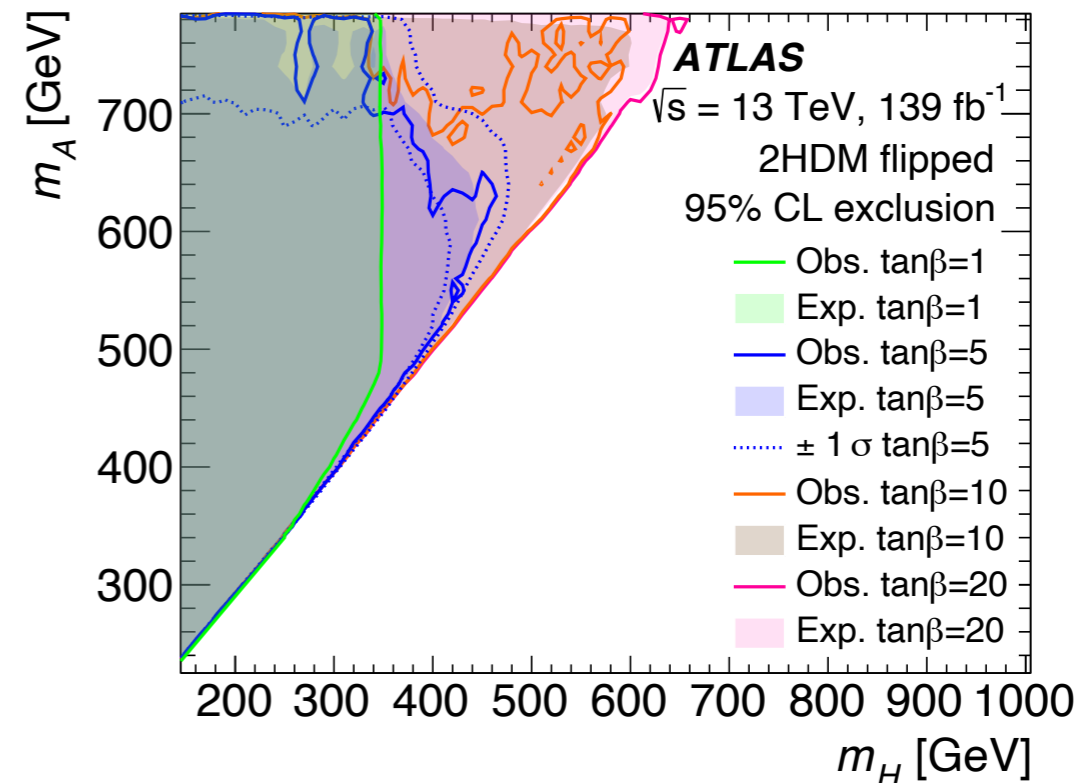
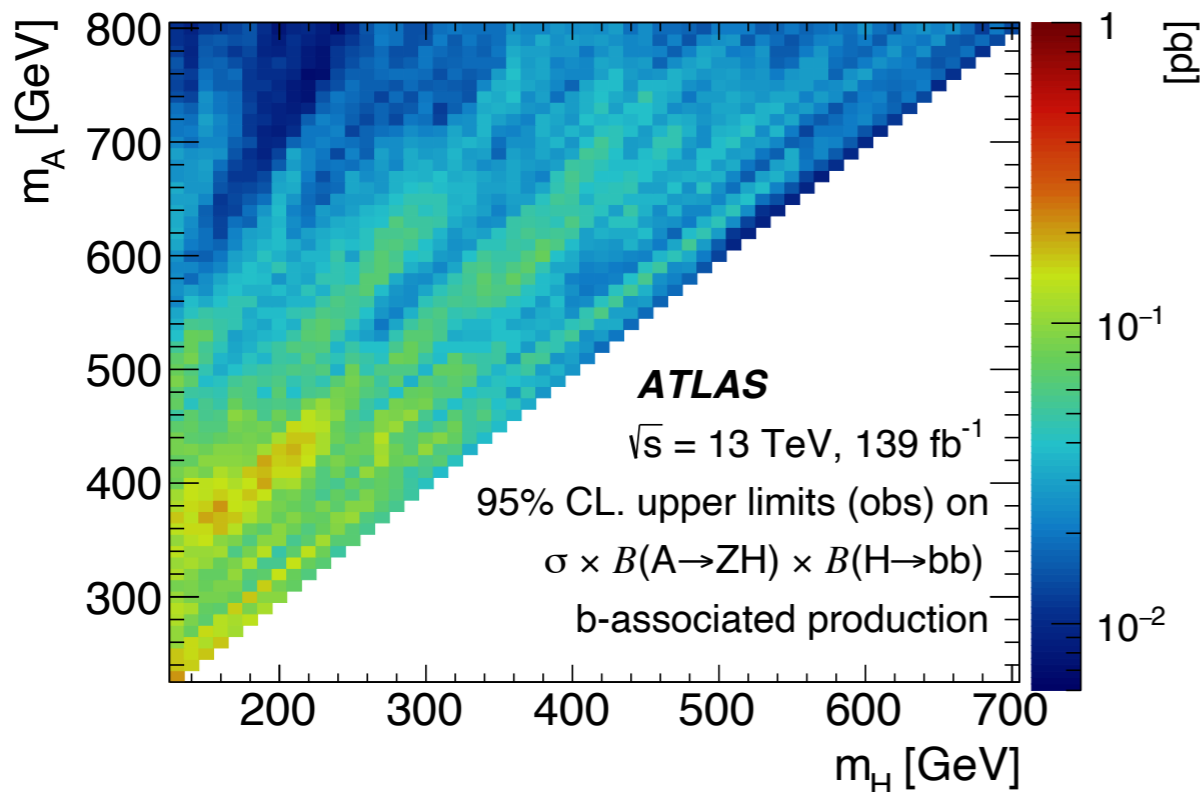
A \rightarrow Zh (ATLAS)

arXiv:2207.00230

- ★ Search for heavy resonances decaying to Zh in mass range of [220, 2000] GeV
 - $Z \rightarrow \ell\ell/\nu\nu$ and $h \rightarrow bb$ in resolved & merged categories
 - including search for $W' \rightarrow Wh$ and $Z' \rightarrow Zh$
- ★ bbH signals produced by **MG5_aMC@NLO at NLO+PS (4FS)**
- ★ Theoretical uncertainties (PS, ISR/FSR, PDF) $\sim 2\% - 7\%$



A → ZH (ATLAS)



★ Considering two heavy Higgs bosons A/H have different mass in context of 2HDM

⊙ $m_A \in [230, 800] \text{ GeV}$ & $m_H \in [130, 700] \text{ GeV}$ for $H \rightarrow bb$ (ggF and bbH)

⊙ $m_A \in [300, 800] \text{ GeV}$ & $m_H \in [200, 700] \text{ GeV}$ for $H \rightarrow WW$ (ggF only)

★ bbH signals produced by **MG5_aMC@NLO** at **NLO+PS**

★ Signal extraction using $m_{\ell\ell bb}$ and $m_{2\ell 4q}$ as observables

Summary

- ★ Run-2 analyses followed the calculation of total cross-section and MC generator tools as recommended since 2019

- ★ Many analyses are finalizing full Run-2 results for publication

- ★ Ongoing activities
 - ◉ Discussion and ongoing effort on bbH NLO cross-section with HH subgroup as important irreducible background for HH searches
 - ◉ The NLO study, including both y_t and y_b contributions, is underway (talk by Javier in the morning)

- ★ Contact us : lhc-higgs-bbh-convener@cern.ch

Backup

