SMU

Searches for resonances decaying to boson pairs in ATLAS

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On Behalf of the ATLAS Collaboration

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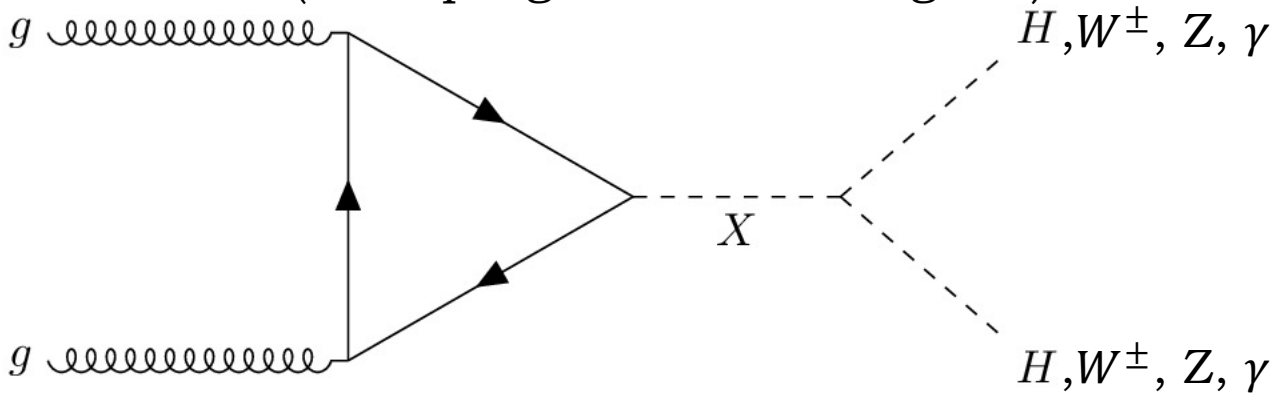
Introduction

- Many models for new physics include modifications to the Higgs sector (e.g. additional Higgs doublet fields).
- In these models, there are often new high mass Higgs-like particles which would decay into known particles.

(Example gluon-fusion diagram)



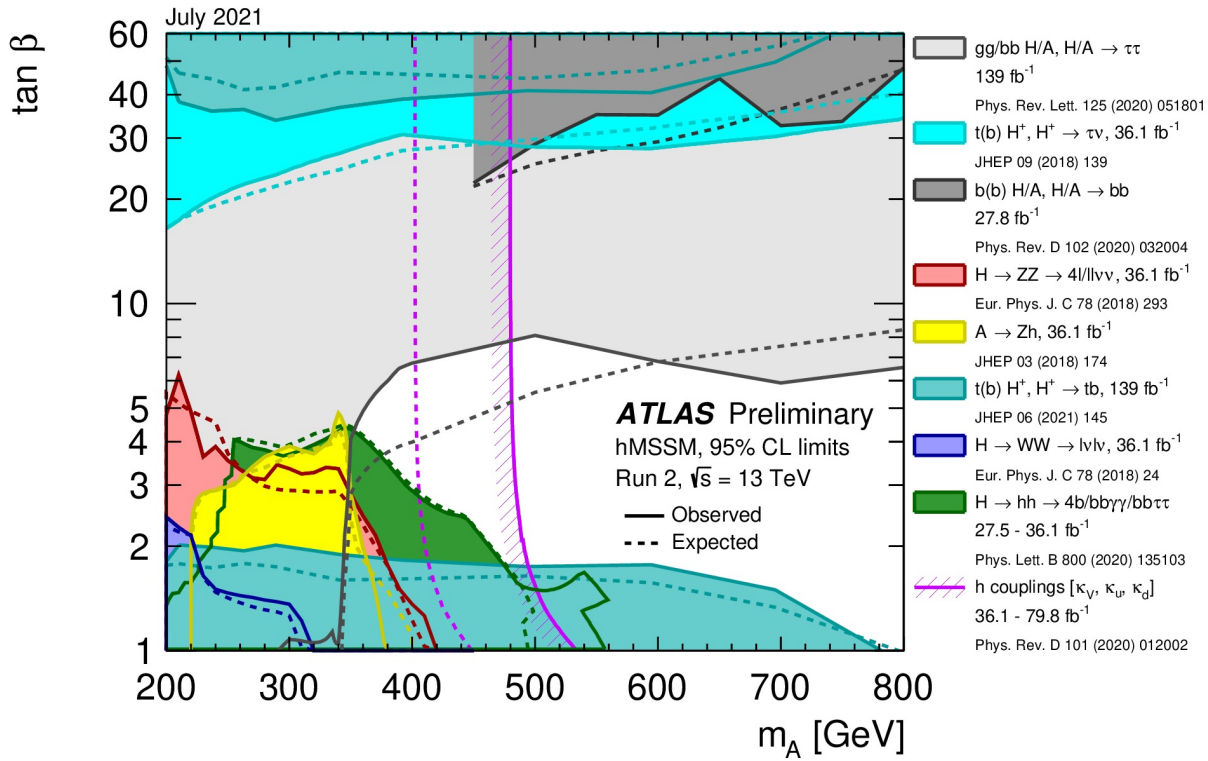
- ATLAS conducts many searches for these Higgs-like particles, typically targeting a generic spin-0 resonance.
- At the highest masses, these searches require new techniques in boson-tagging.
- Today, I will focus on decays of **heavy spin-0 resonances (X)** into **bosons**: WW, ZZ, $\gamma\gamma$, and hh (SM-like Higgs bosons).

Overall Look at Latest Results

Summary of Current Status in ATLAS

- H→WW: ***Eur. Phys. J. C 78 (2018) 24***
- H→ZZ: ***Eur. Phys. J. C 81 (2021) 332***
- H→ $\gamma\gamma$: ***Phys. Lett. B 822 (2021) 136651***
- H→hh: Several channels and combination
  - H→hh→$b\bar{b}\tau^+\tau^-$:
    - ***JHEP 11 (2020) 163***, **ATLAS-CONF-2021-016**
  - H→hh→$b\bar{b}\gamma\gamma$: **ATLAS-CONF-2021-016**
  - H→hh→$b\bar{b}b\bar{b}$: **ATLAS-CONF-2021-035**
  - Combination: **ATLAS-CONF-2021-052**
- A→Zh:
  - h SM-like: ***JHEP 03 (2018) 174***
  - h not SM-like: ***Eur. Phys. J. C. 81 (2021) 396***

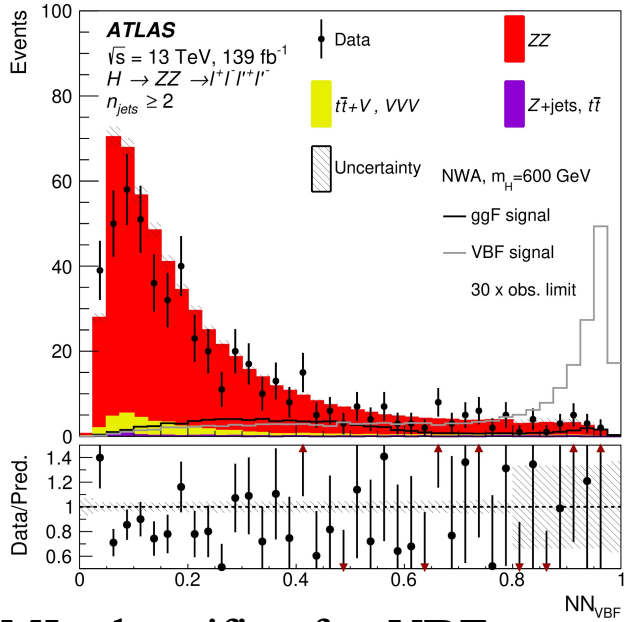
Today's talk to cover the latest results (highlighted).



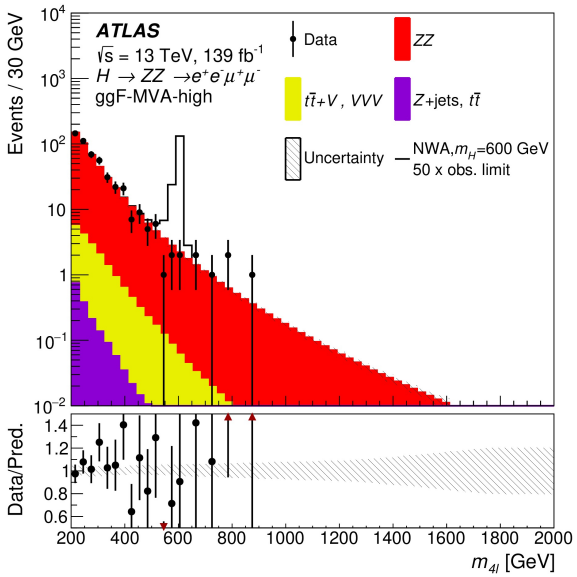
Summary plot in the hMSSM – does not include latest HH, ZZ and $\gamma\gamma$ results.

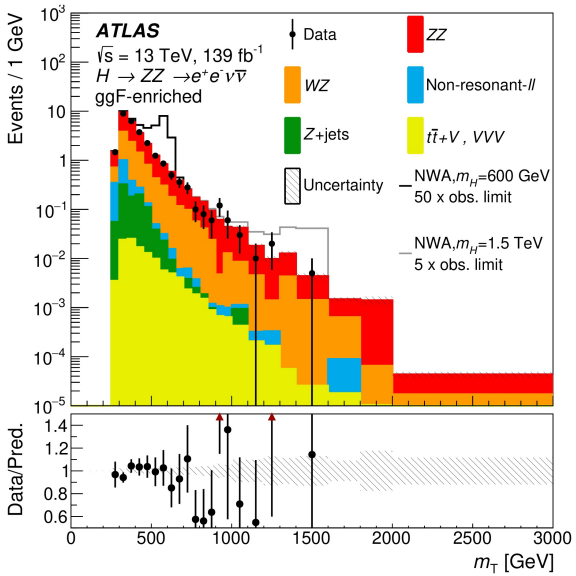
High Mass H→ZZ

- Search focuses on mass range 200-2000 GeV with 139 fb^{-1} of data.
- Covers final states of 4 leptons or 2 leptons and 2 neutrinos, and both ggF and VBF production modes.
- Other main updates since analysis shown on summary plot:
  - Improved **lepton reconstruction** and **isolation**
  - **Particle flow jet algorithm** that combines tracking and calorimeter information
  - **SM ZZ** normalization is **derived from data**
  - **ML optimization** for different production mechanisms
  - Use of an **m_T variable** in the 2l2ν final state



ML classifier for VBF events.

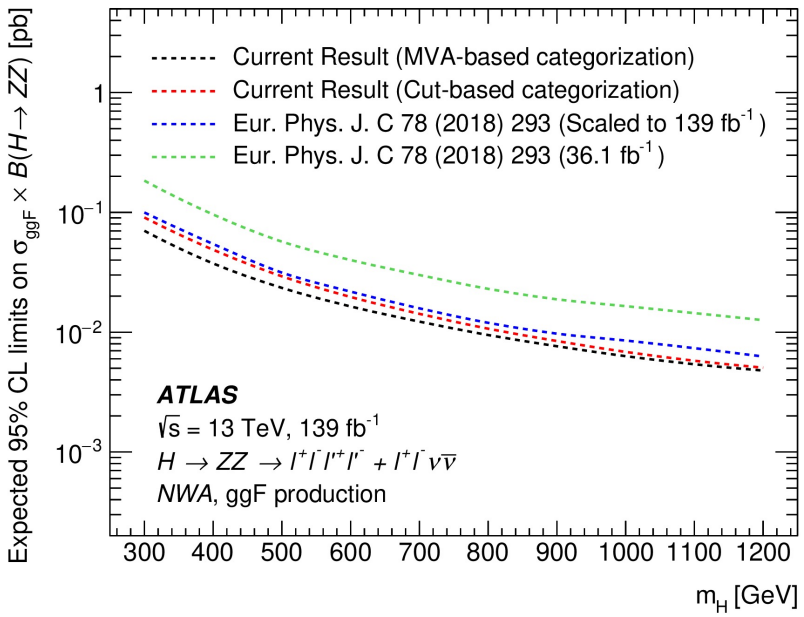


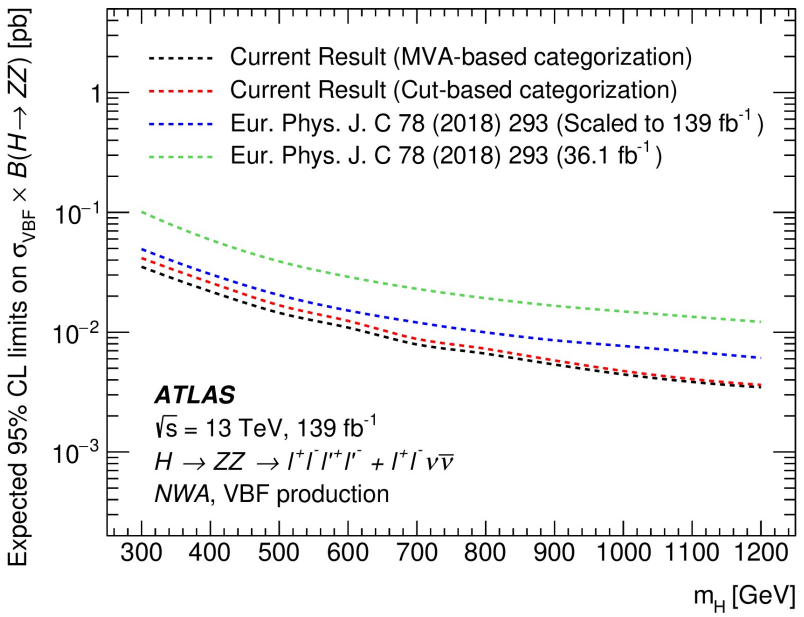


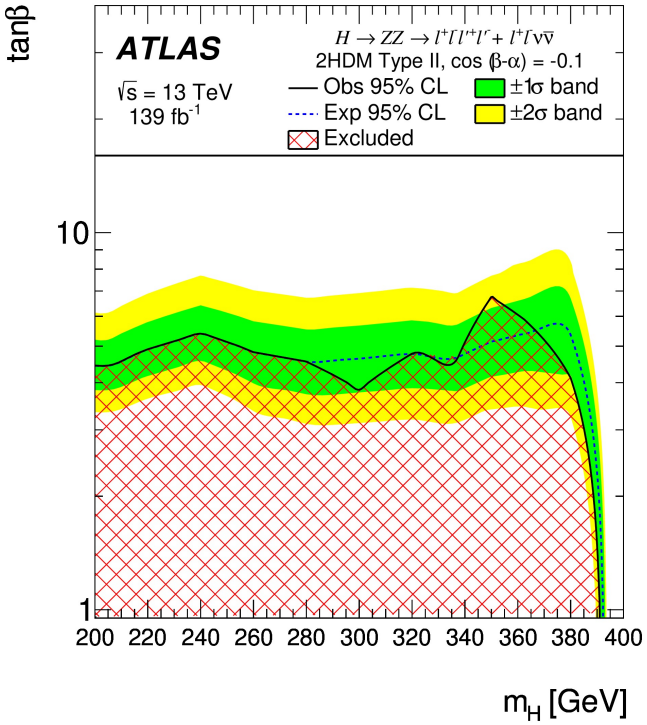
Mass variables for a ggF 4l and 2l2ν signal region.

High Mass H→ZZ Results

- Demonstration of improvement over previous result and over cut-based approach, for ggF and VBF production.
- Improvement of 40% relative to the previous result with luminosity scaled to 139 fb^{-1}!
- Limits in a Type-2 Two-Higgs-Doublet-Model (MSSM, shown on summary plot, has 2 Higgs doublets in the Higgs sector).

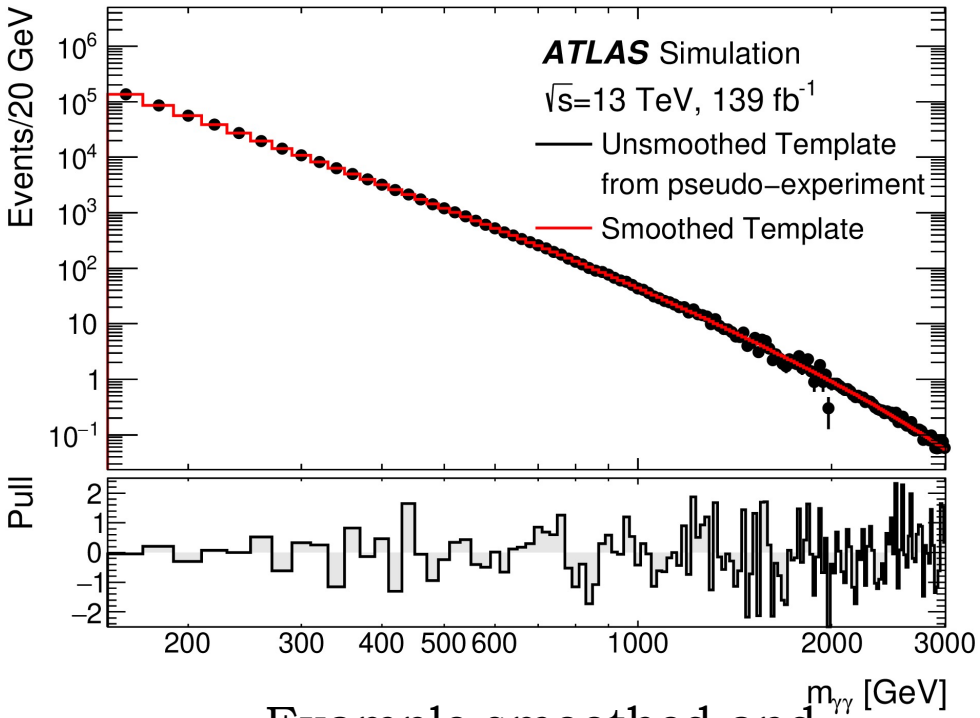






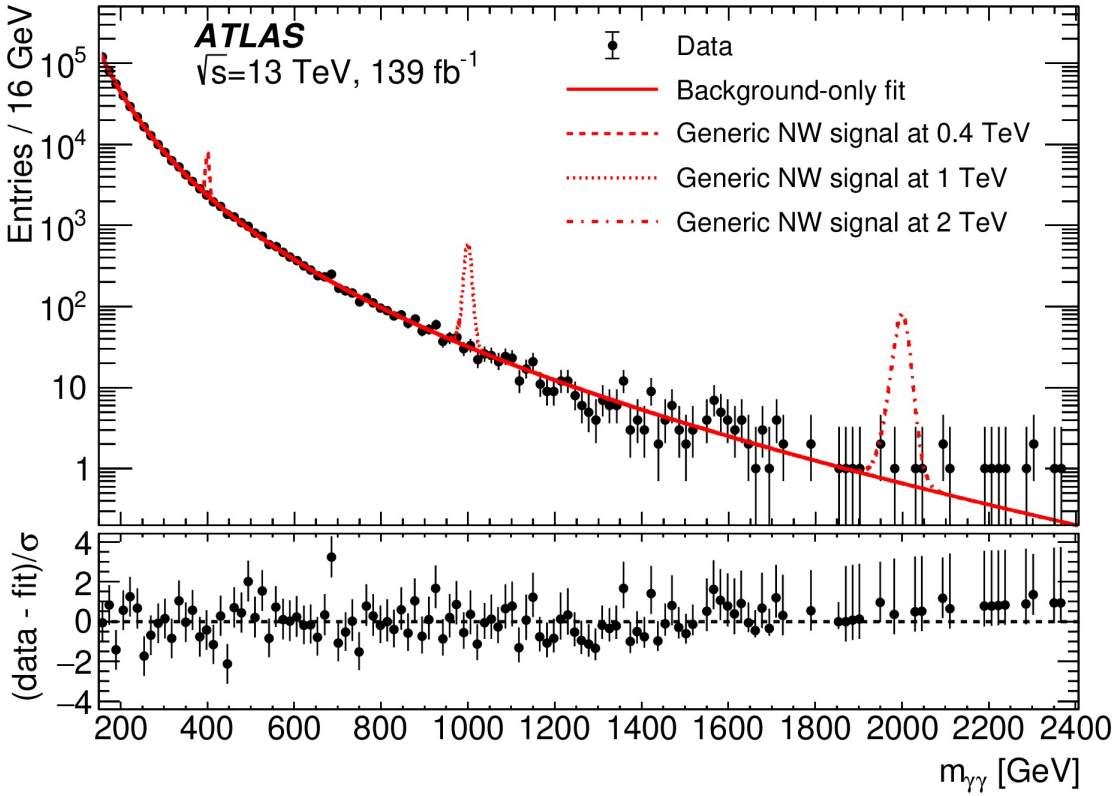
High Mass H→γγ

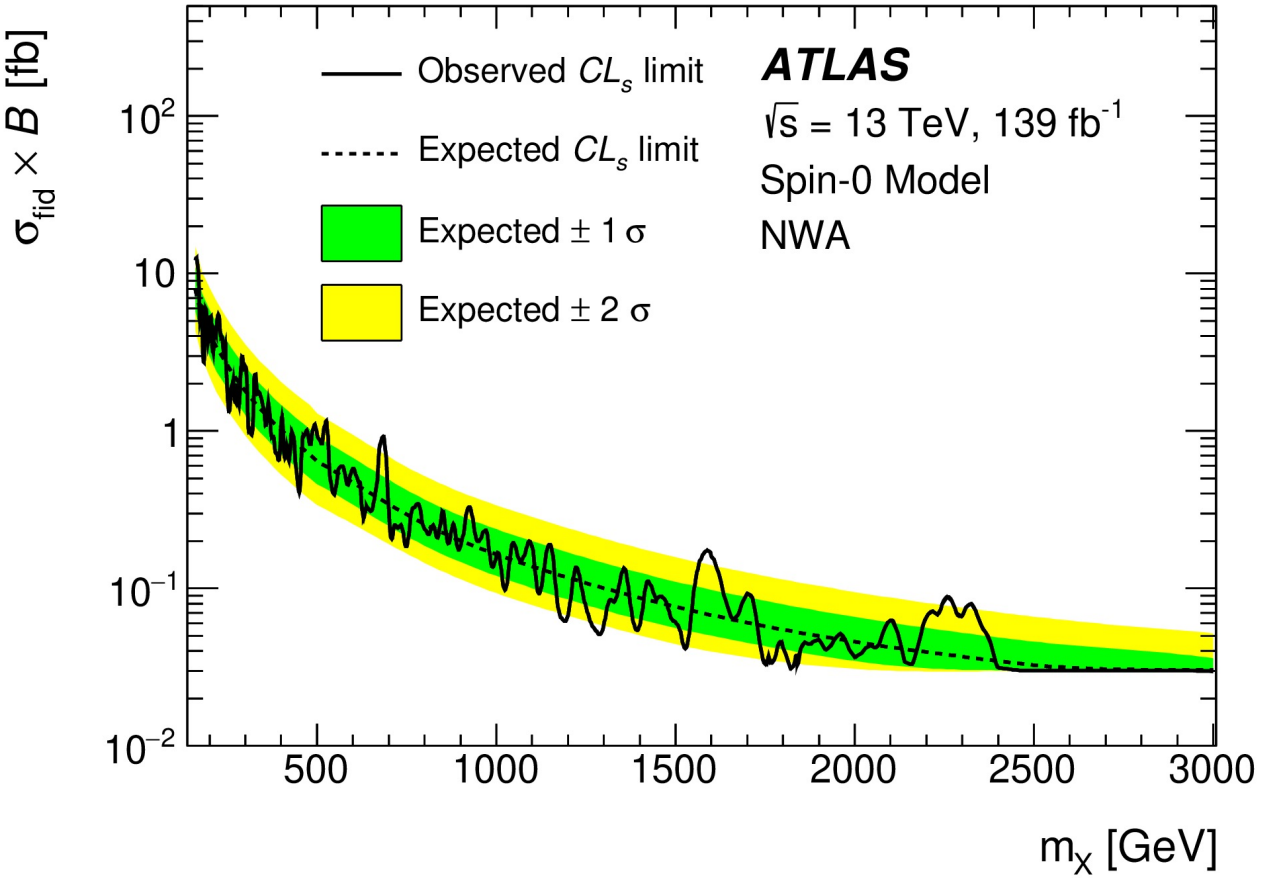
- Search is in a mass range of 200-3000 GeV and considers ggF production with 139 fb^{-1} of data.
- Changes to previous search include:
  - Improved photon **reconstruction**, **identification**, **isolation**, and energy **calibration**.
  - Use of a **functional decomposition** method to assess spurious signal uncertainty.
- **What is spurious signal?**
  - Background templates are fit with an analytic function.
  - Any fitted signal yield is considered 'spurious signal'
  - In simulated samples with limited numbers of events, this effect is dominated by statistical fluctuations.
  - Use of **functional decomposition** fits a linear combination of orthonormal exponential functions to the background template, and the result is used as a **smoothed background template.**
  - Use of the smoothed template improves the expected limit by **up to 25%!**



Example smoothed and unsmoothed background template.

High Mass H→γγ Results

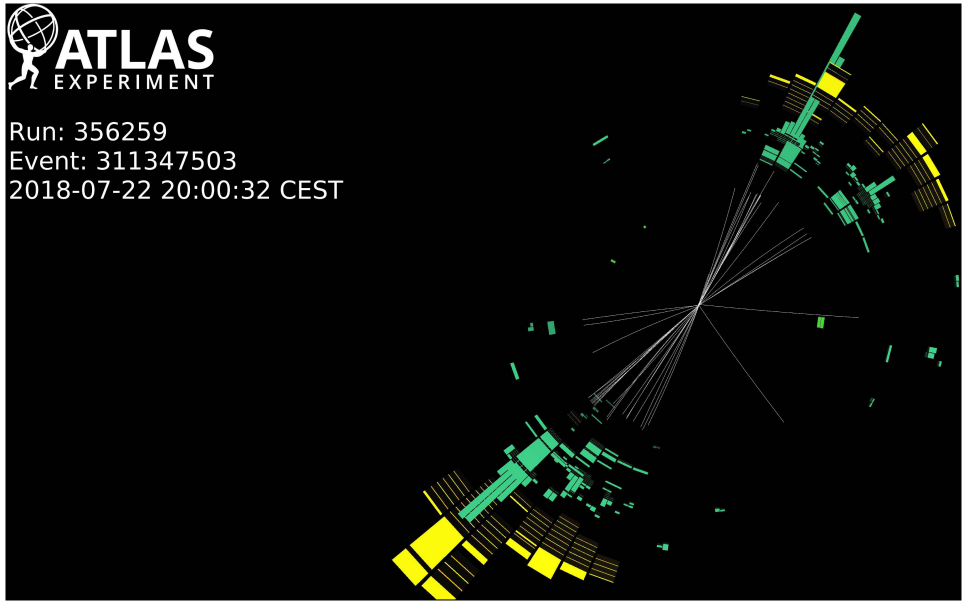




- Left: Background-only fit to data, with several signal hypotheses overlaid
- Right: Limit as a function of resonance mass.

High Mass H→hh

- Latest combination for heavy Higgs-like particles decaying to hh include $bb\tau\tau$, $bb\gamma\gamma$ and $bbbb$ final states (charge conjugation is implied), covering m_x = 251 – 3000 GeV.
  - $bb\tau\tau$: Separate boosted (m_x = 1-3TeV) and resolved (0.251 – 1.6 TeV) analyses *(See talk by Christopher Deutsch)*
  - $bb\gamma\gamma$: Considers mass range of 251—1000 GeV (*See talk by Jannicke Pearkes*)
  - $bbbb$: Boosted and resolved channels in the range of 251—3000 TeV

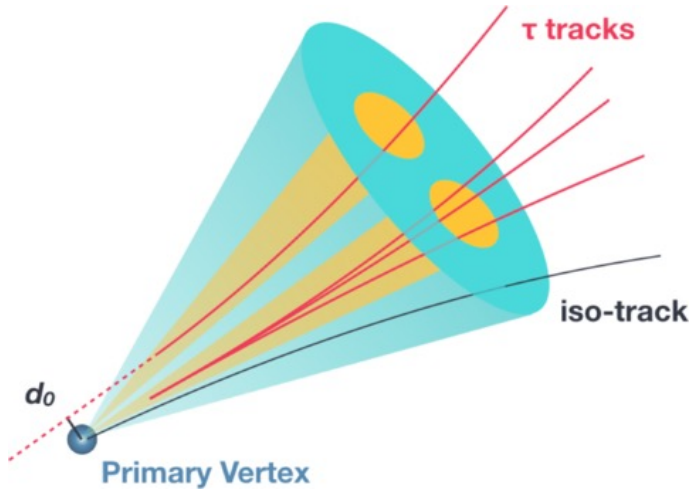


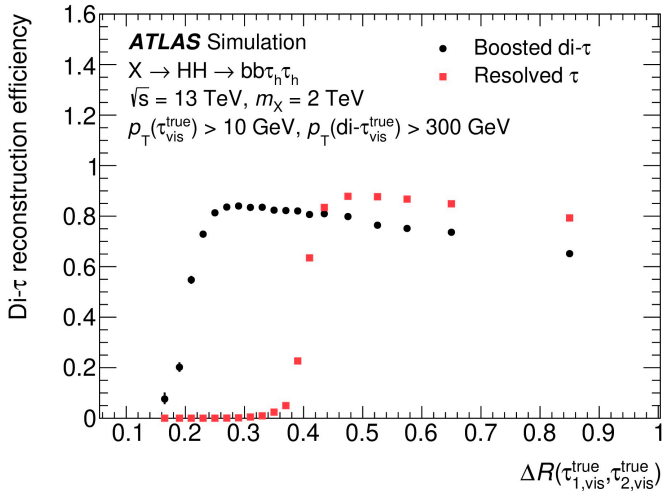
An event that passes the boosted X→HH→4b selection.

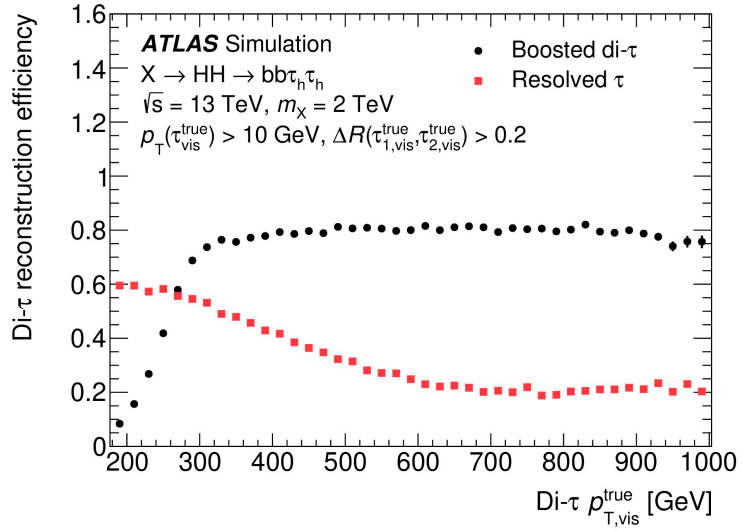
For more hh information, see talks by Marco Valente and Ivan Sayago Galvan

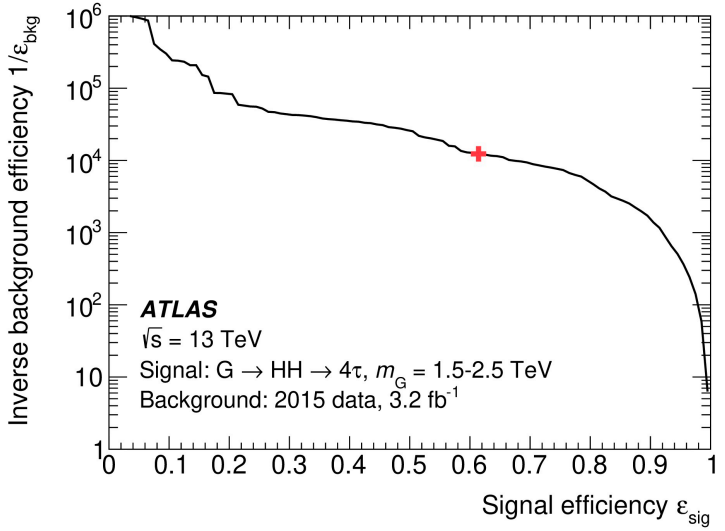
High Mass H→hh: di-tau tagger

- In the boosted $bb\tau\tau$ analysis, a tagger is commissioned for selecting taus that are close together ($\Delta R < 0.4$) in the detector.
- Reconstruction of di-$\boldsymbol{\tau}$ objects requires:
  - ✓ A large-R jet with R=1.0 and P_T > 300 GeV
  - ✓ This jet contains at least 2 R=0.2 sub-jets with P_T > 10 GeV and at least 1 associated track.
- A BDT is then trained using information about clusters in the calorimeter, tracks, and vertices.



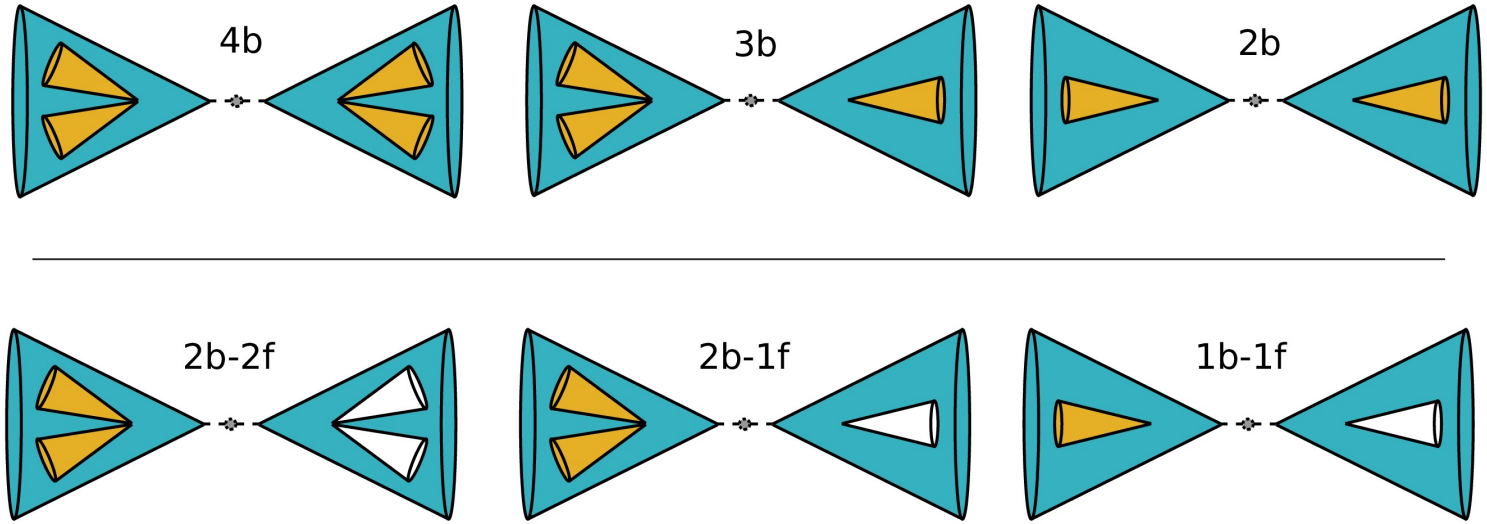






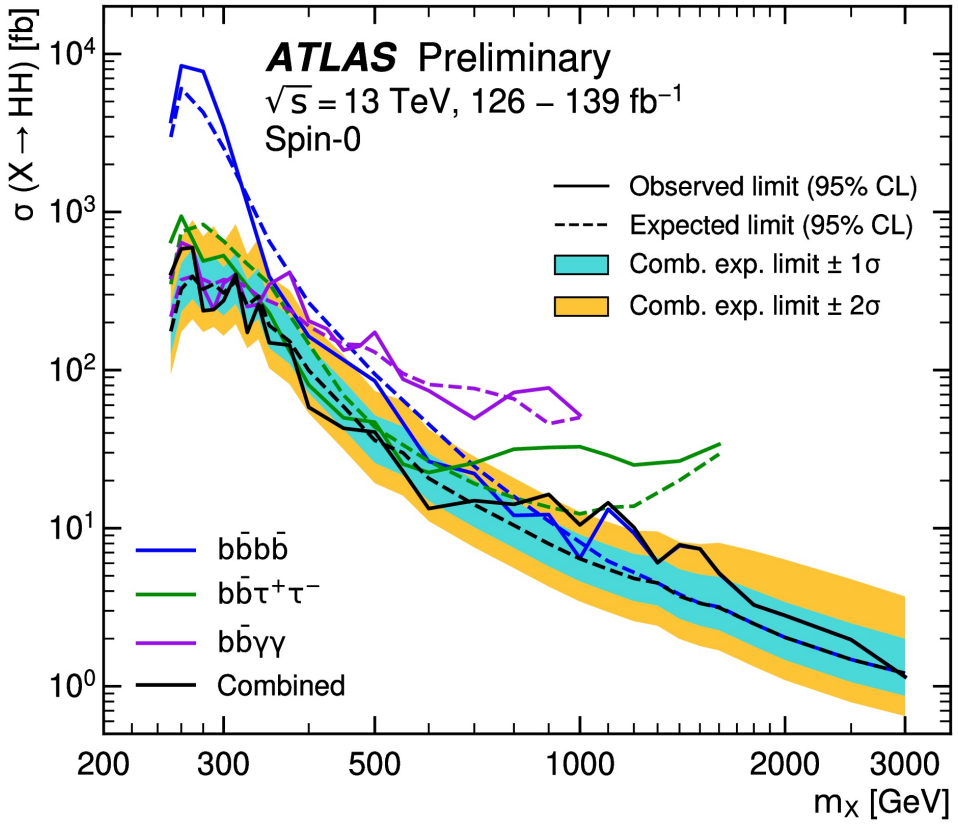
High Mass H→hh: H→bb tagging

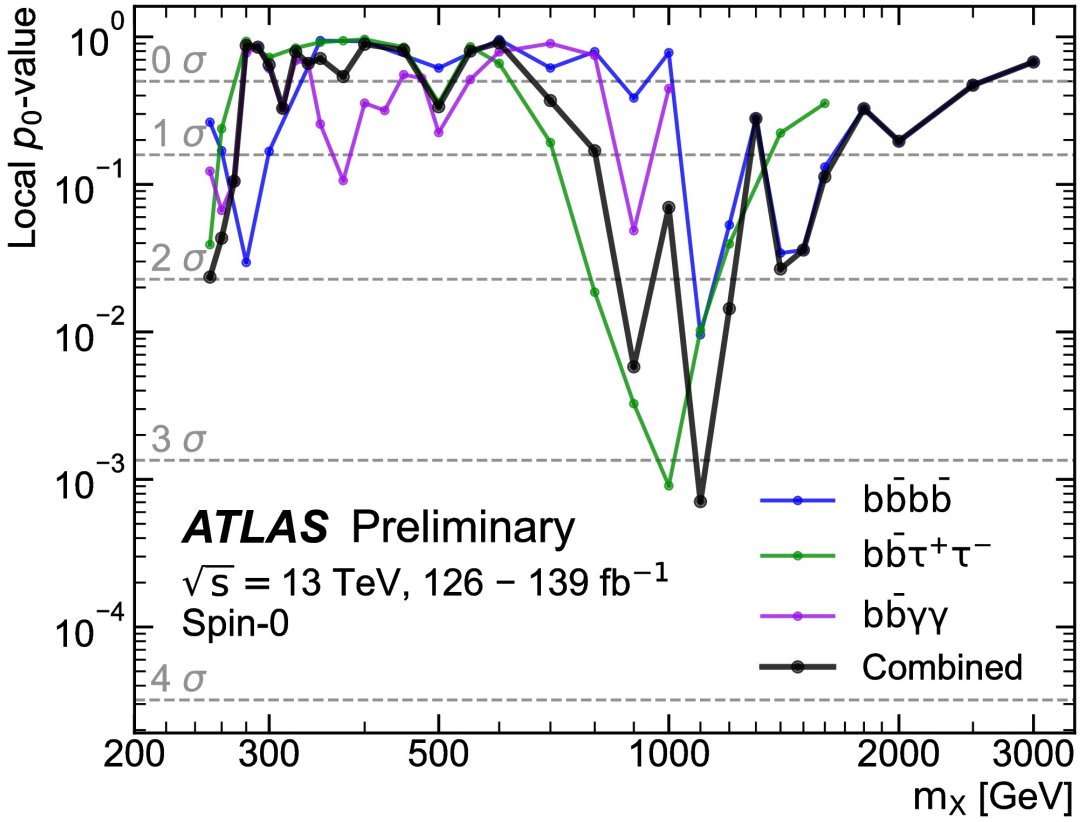
- In the 4b boosted channel, tagging methods are used to identify H→bb with b-jets close together in the detector.
- Within a large radius ($R < 1.0$) jet, 'track jets' with a variable radius are defined.
- Track jets are reclustered using the anti-kt algorithm with a radius parameter varying as R = 30 GeV/pT, with an absolute minimum of R = 0.02 and maximum of R = 0.4.
- These track jets are b-tagged using the DL1r algorithm (current ATLAS standard tagger) at a 77% efficient working point.



- Events with 1-2 b-tagged track jets per H candidate are considered for the analysis, while events with un-tagged (f=failed tag) track jets in the large R jet are used for background control.

Latest Combined HH Results

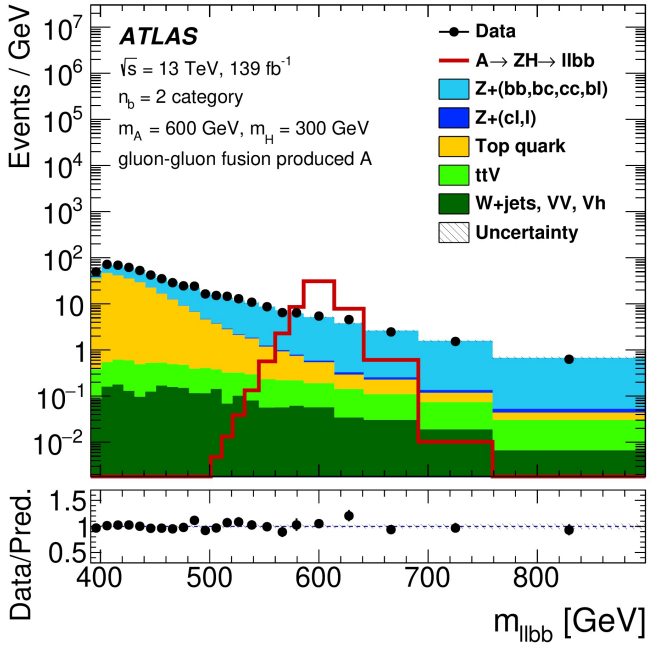


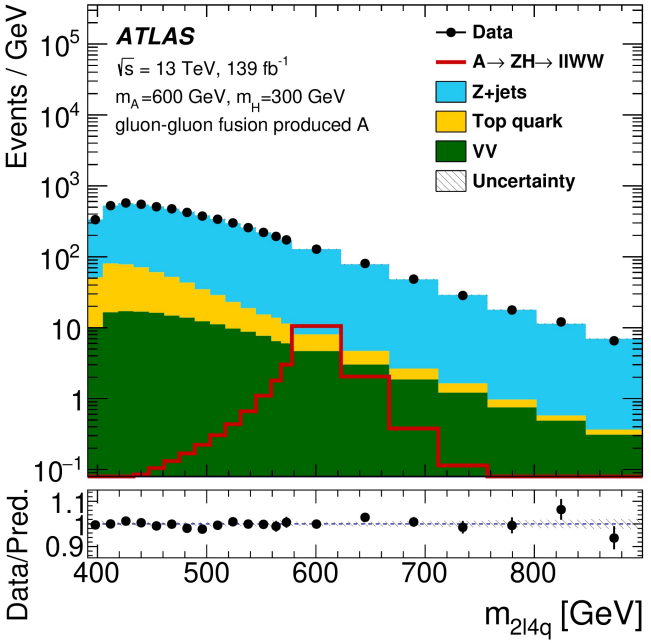


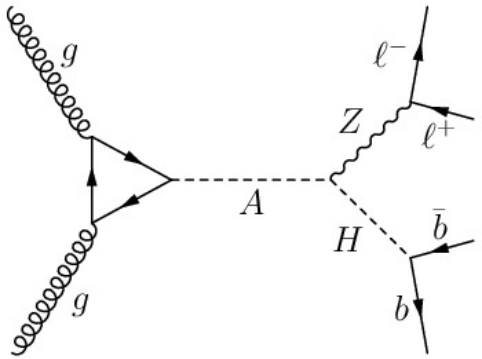
- Latest resonant results, with a mild excess at 1.1 TeV with approximately 2.1 sigma global significance.
- Individual channels are stronger than the previous combination!

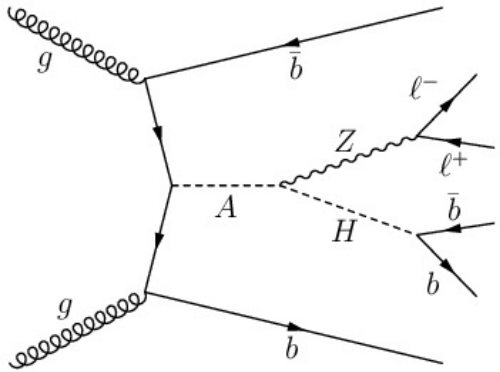
Search for A→ZH

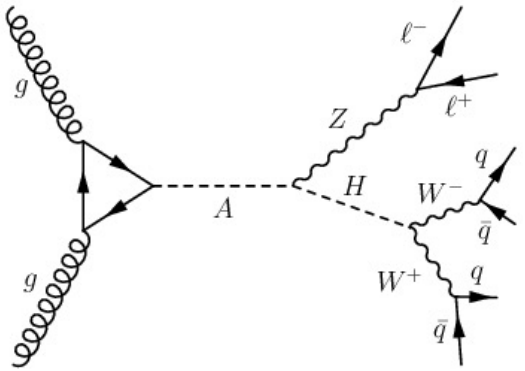
- This search includes 2 new Higgs-like particles, with m_A = 230-800 GeV and m_H =130-700 GeV.
- Considers events with same-flavor opposite sign electrons or muons (associated with the Z) and either at least 2 b-jets or 4 light quark jets.
- For llWW analysis, jets from each W are paired using a dedicated discriminant, and then required to be compatible with the Higgs boson mass.
- Considered diagrams are below, and example signal regions to the right.





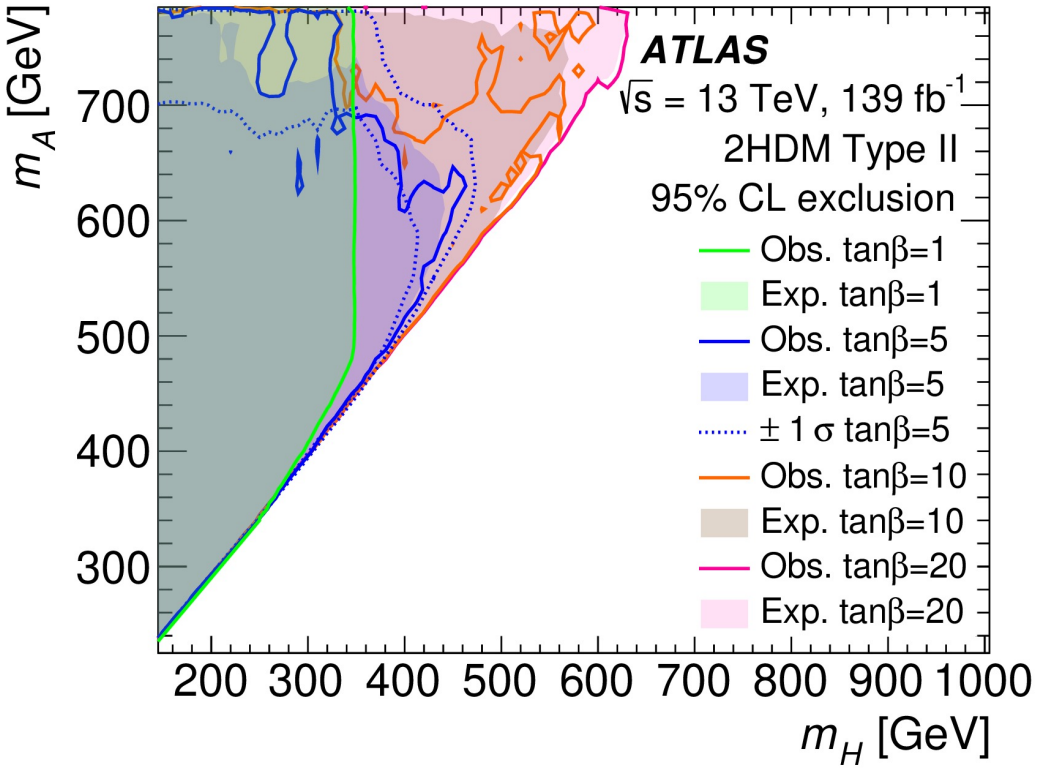


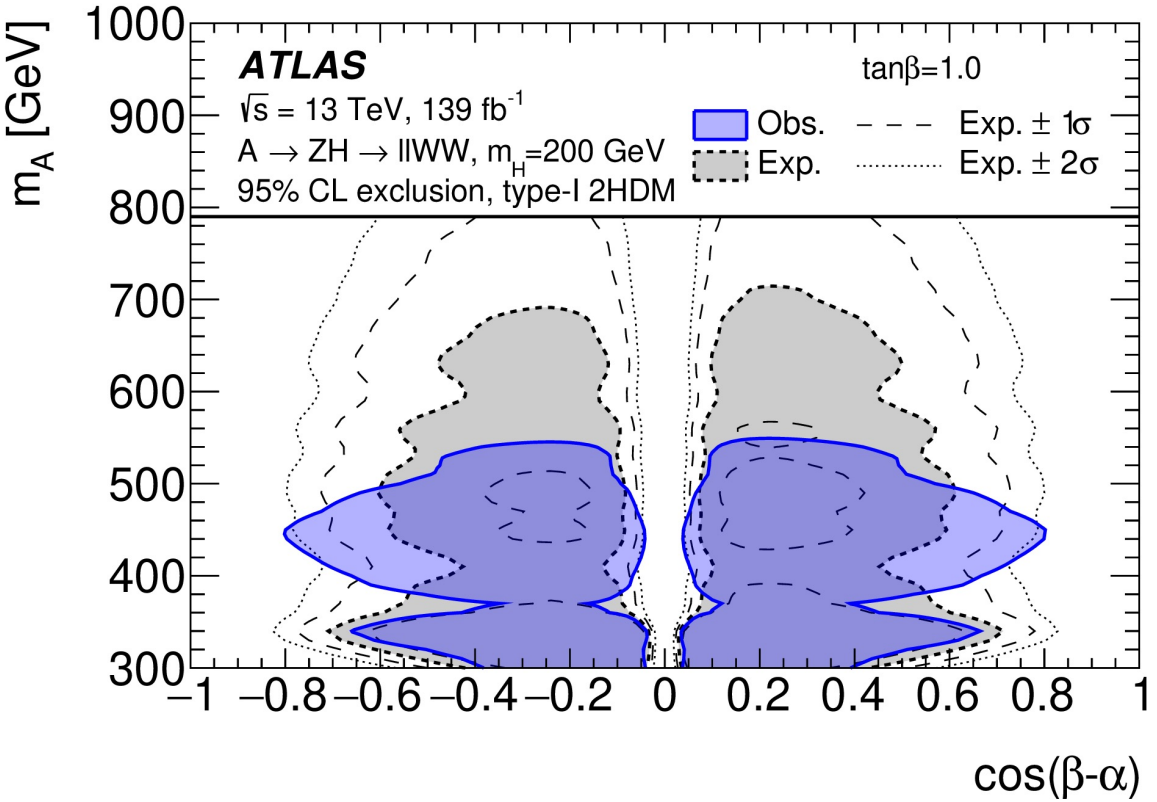




Search for A→Zh Results

First ATLAS result in the llWW final state!





Limits for the two channels 2l2b (2l4q) in a Type-2 (1) 2HDM, respectively.

In Type 2, b-associated production dominates, whereas only ggF is present in Type-1.

Summary

There are many searches for new spin-0 Higgs-like particles decaying into bosons.

Results are wrapping up for Run 2 – some exciting places to keep looking for Run 3 and beyond!