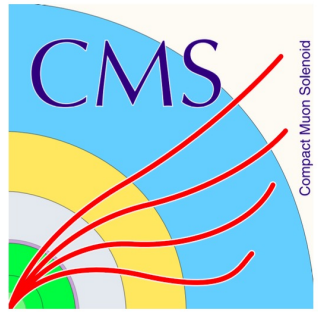
IMPERIAL



Searches for BSM Higgs Bosons at ATLAS and CMS

George Uttley

On behalf of the ATLAS and CMS collaborations

Moriond Electroweak Interactions & Unified Theories

25th March 2024

Motivation

- Extensions to the SM Higgs sector can introduce additional fields that produce additional Higgs bosons.

  - Two Higgs Doublet Model (2HDM, e.g. MSSM):
    - CP conserving case: 5 Higgs bosons:

  - 2HDM + singlet (e.g. NMSSM)
    - 7 Higgs bosons:
      - 5 of the 2HDM
      - 2 additional neutral bosons (1 CP-even and 1-CP odd)

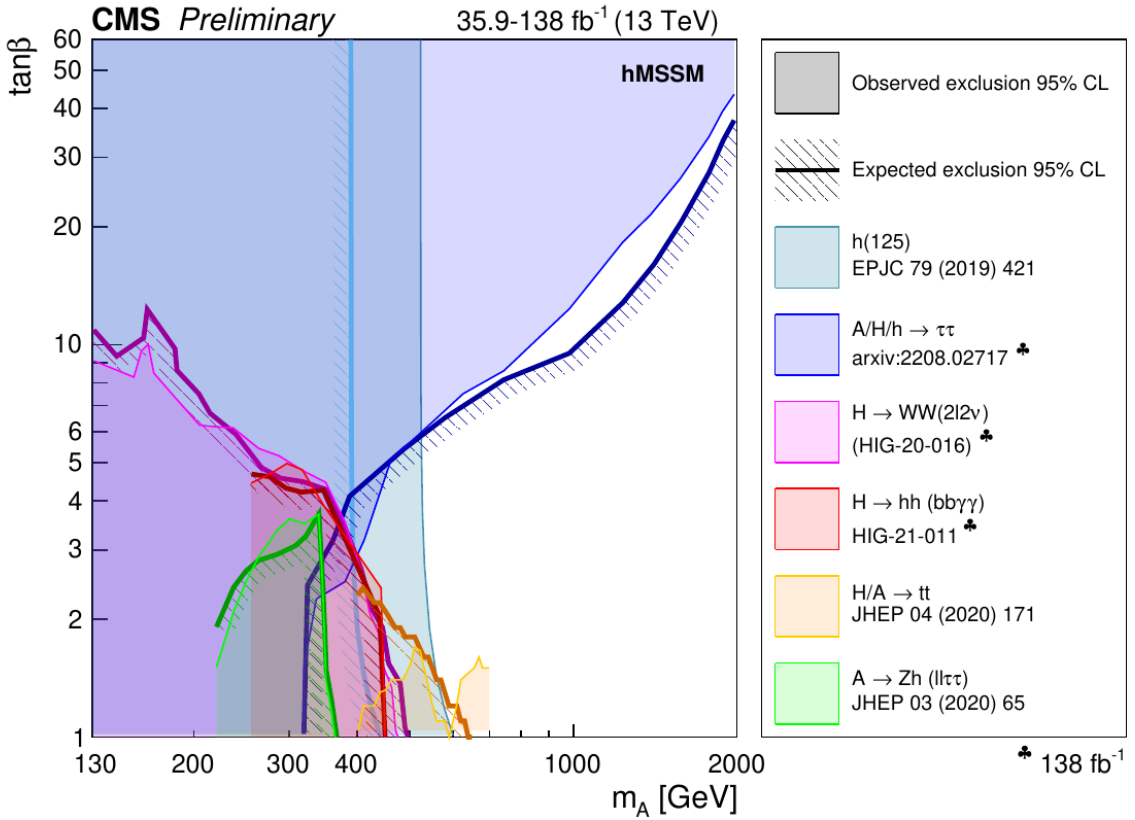
  - Many other models with extended Higgs sectors:
    - Electroweak Singlet model
    - Higgs triplet model
    - Georgi-Machacek model
    - + many more

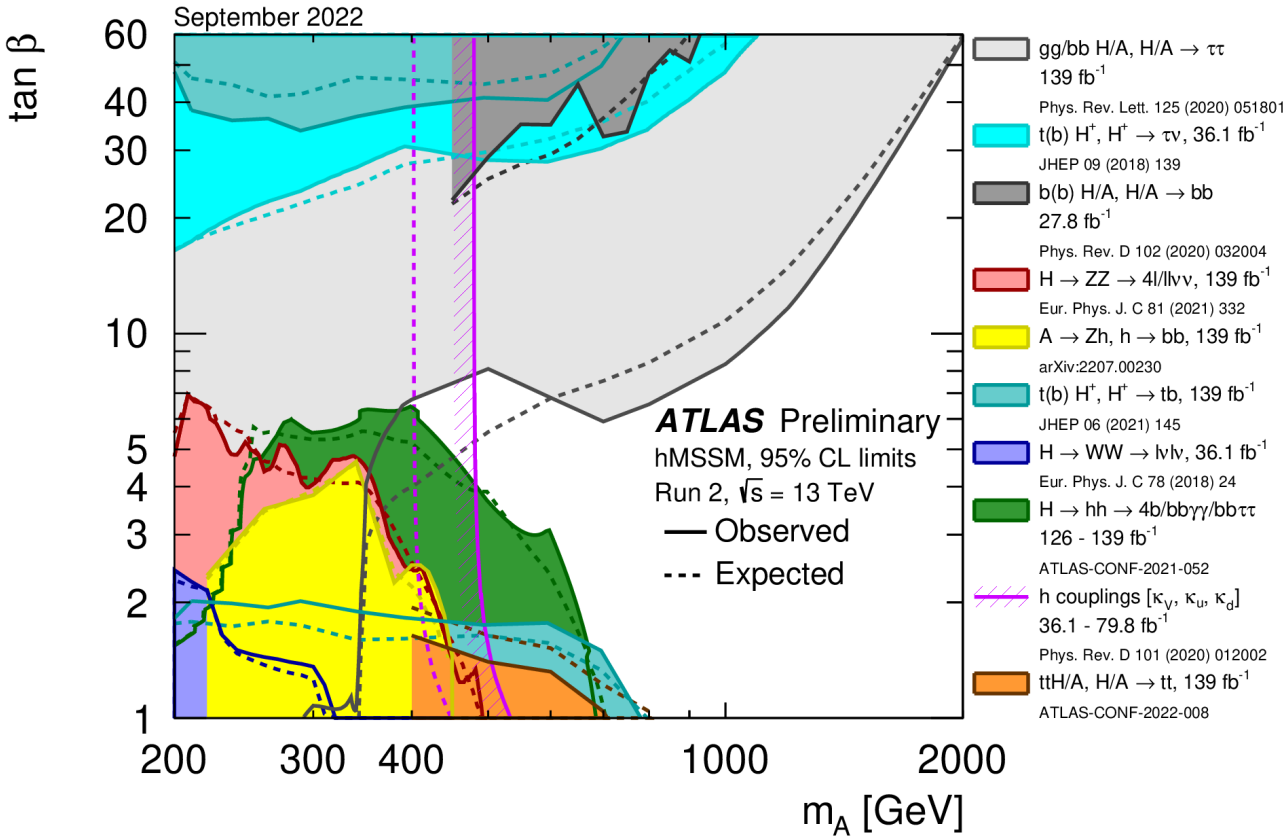
Plan for Talk

- Many BSM Higgs results using the full LHC run 2 dataset from CMS and ATLAS.
- I will present a small subset, including a few moderately new and some new results.

Current Status

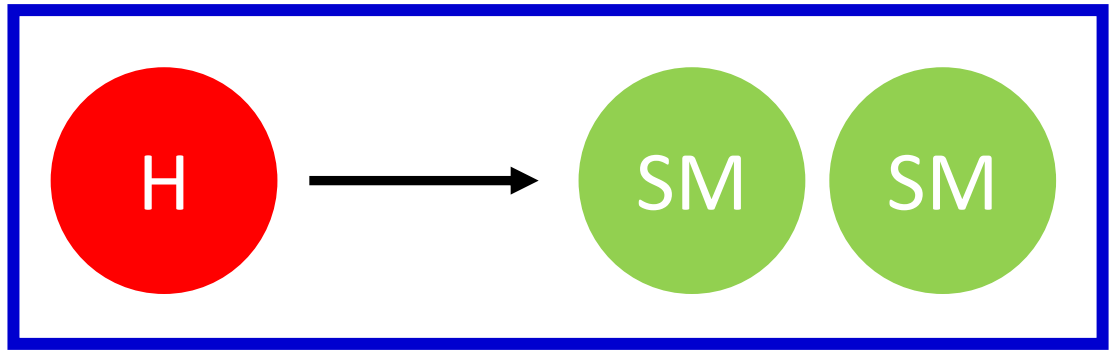
- Showing the current status of the hMSSM (type II 2HDM) with CMS and ATLAS exclusions.
- Still a few full run 2 results to be released and added to these plots.





https://twiki.cern.ch/twiki/bin/view/CMSPublic/SummaryResultsHIG

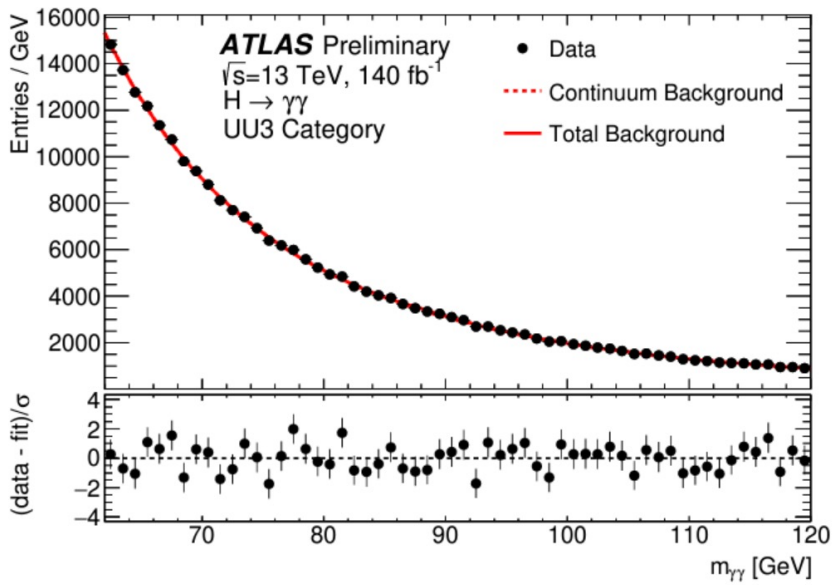
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2022-043/

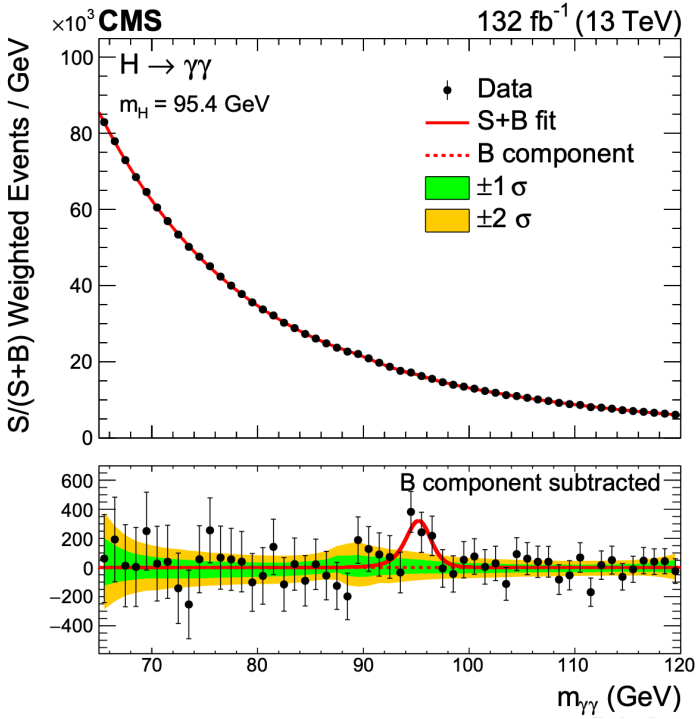

H
SM
SM

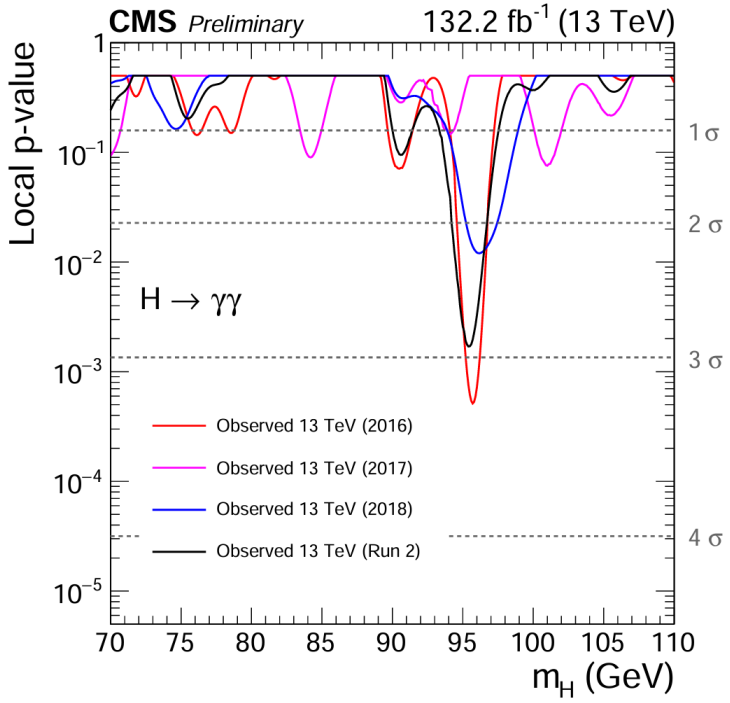
Low Mass $H \to \gamma\gamma$

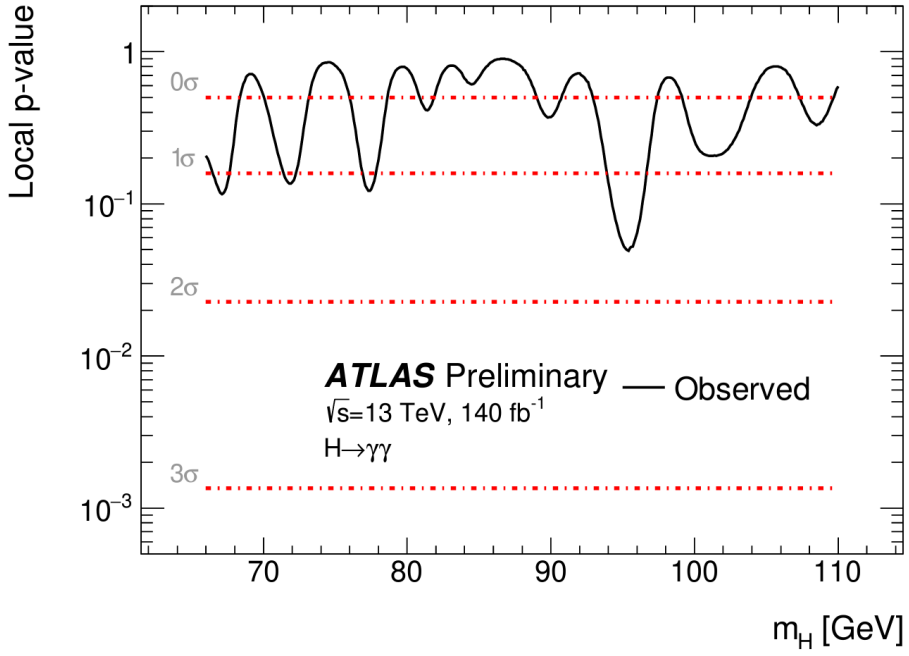
ATLAS-CONF-2023-035 CMS-PAS-HIG-20-002

- There are many 2HDM extensions which can give rise to additional low mass Higgs bosons.
- CMS observe an excess of local (global) significance of 2.9σ (1.3σ) at 95.4 GeV.
- ATLAS observe a local significance of 1.7σ at 95.4 GeV.





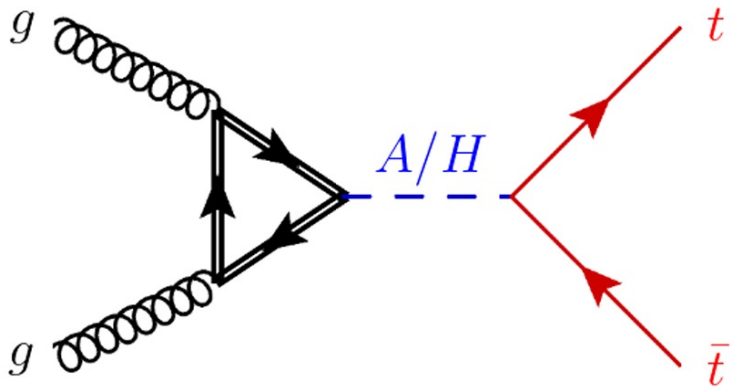




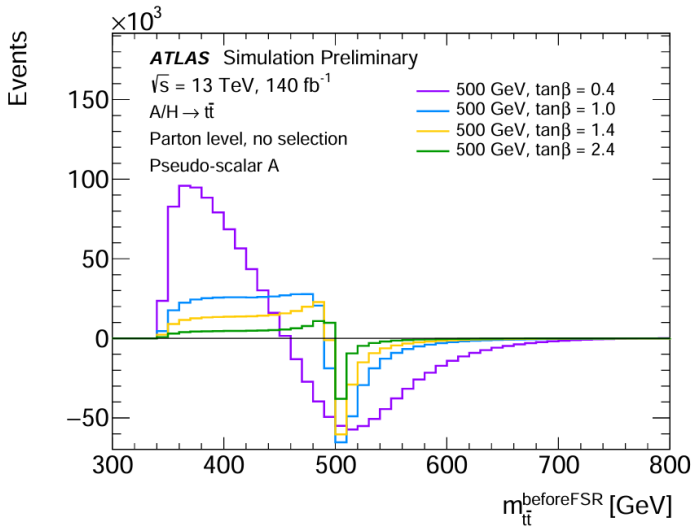
BSM $H/A \rightarrow t\bar{t}$

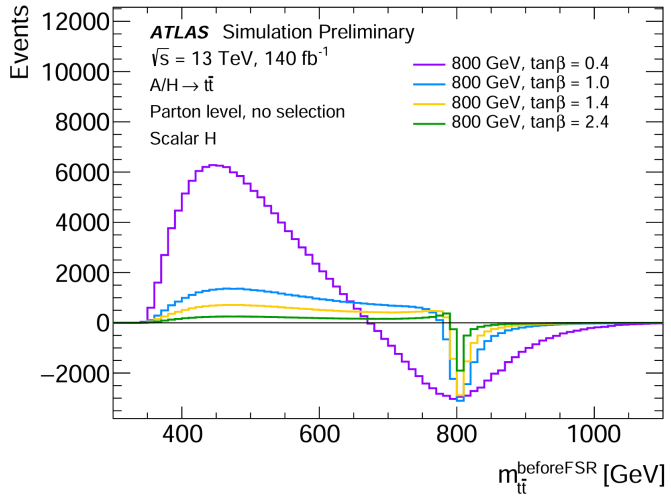
NEW RESULT

ATLAS-CONF-2024-001

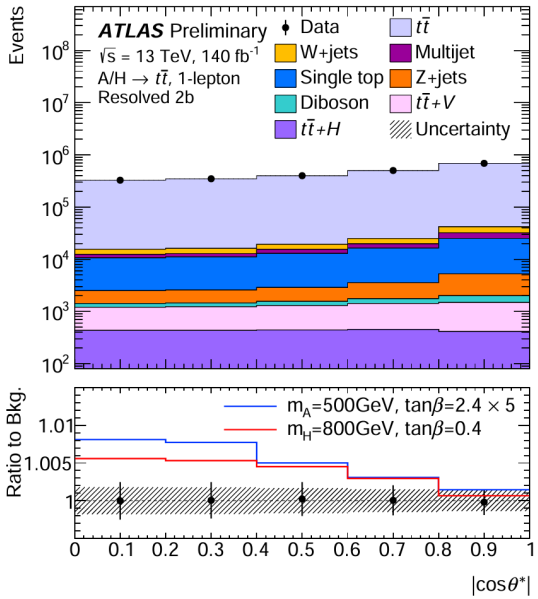


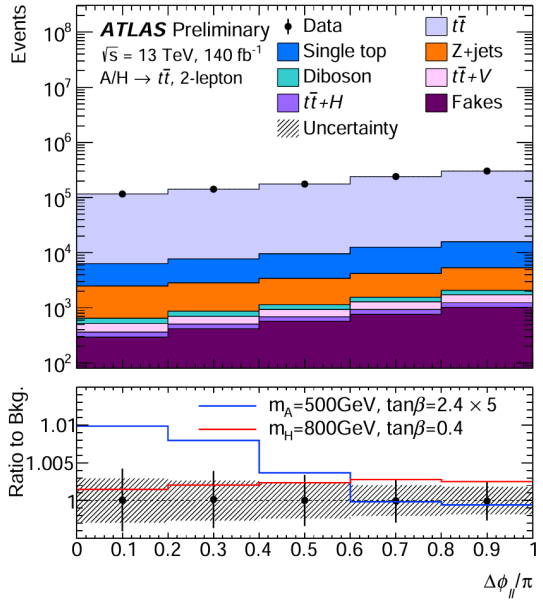
- Search motivated by 2HDM (e.g. hMSSM).
- Large interference effects with SM background.





- Use resolved and merged b jet categories as well as 1 and 2 lepton final states.
- The resolved events with 1 lepton are categorised in $|\cos\theta^*|$ and number of b jet bins.
- The 2 lepton events are categorised in $\Delta\varphi_{ll}$ bins.
- Reconstructed H/A mass is used as the final discriminator.

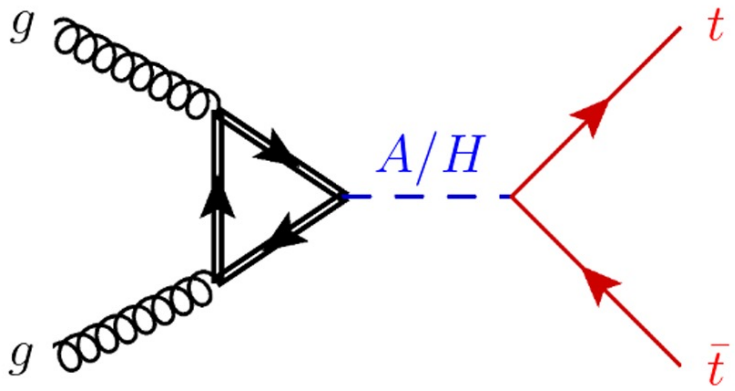




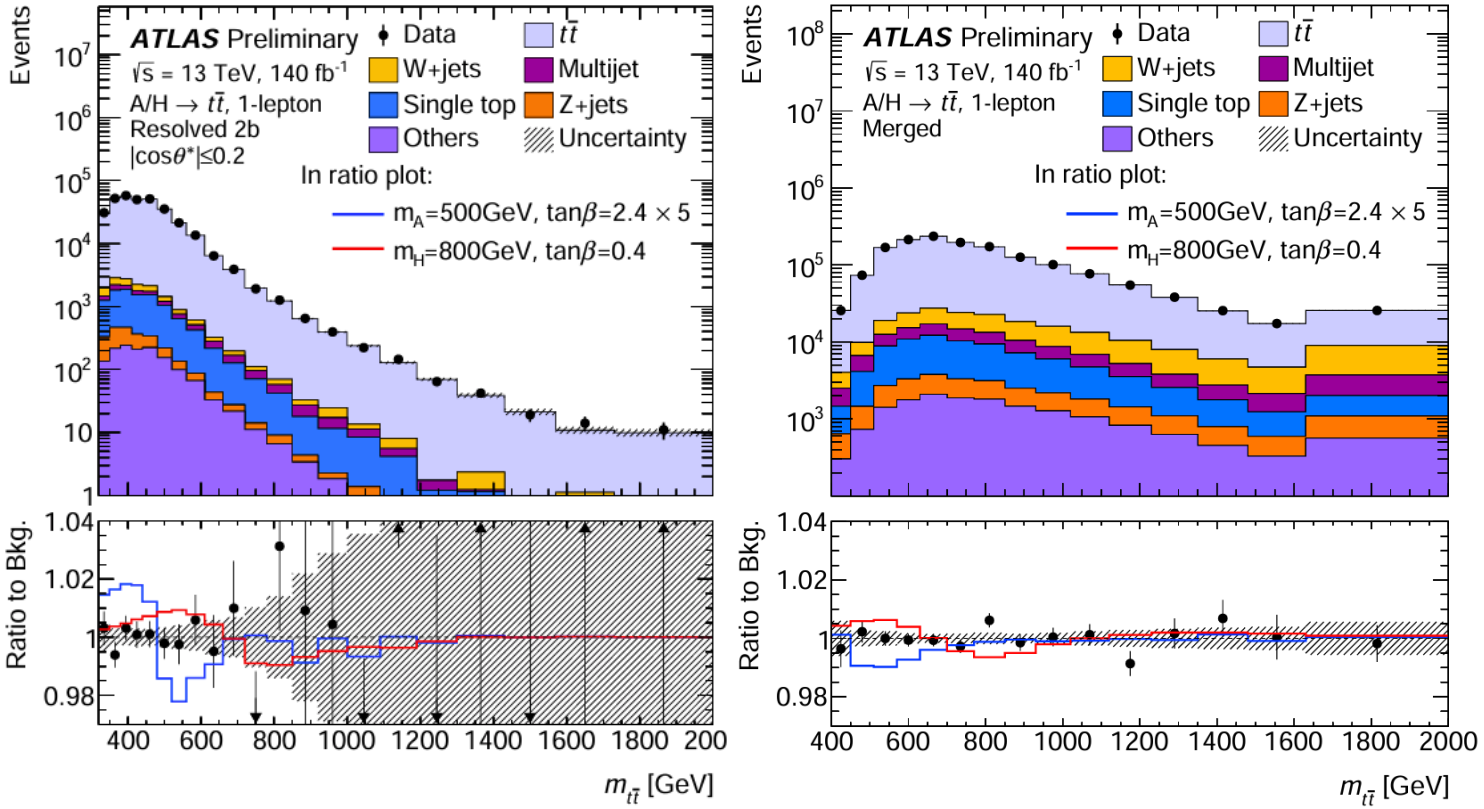
BSM $H/A \rightarrow t\bar{t}$

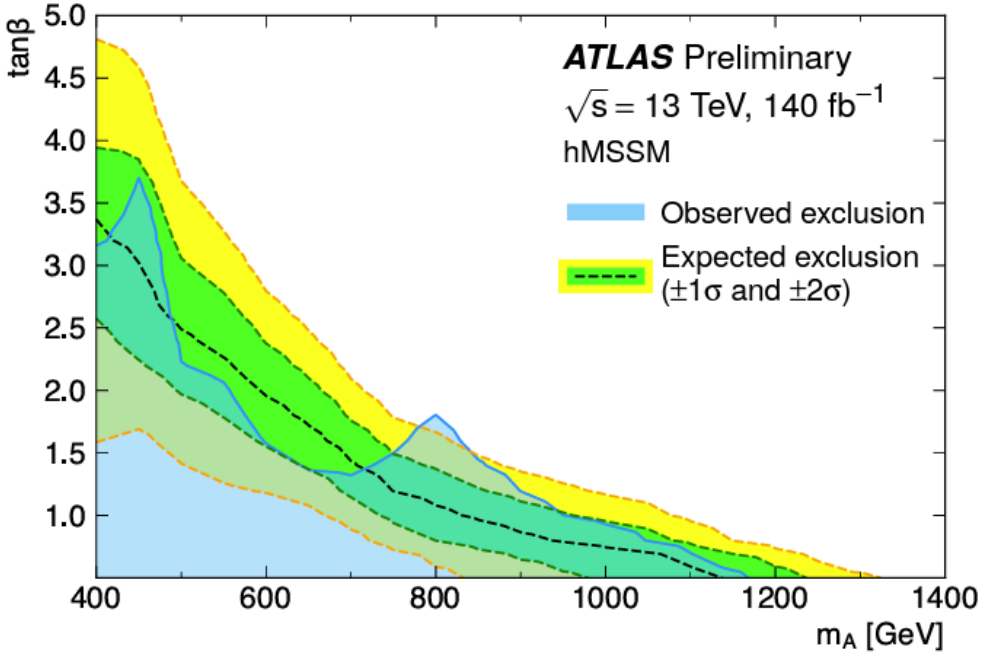
NEW RESULT

ATLAS-CONF-2024-001



- Results showed no statistically significant fluctuation away from the SM expectation.
- Small deviation was observed at 800 GeV with a local significance of 2.3σ.
- hMSSM exclusion limits range from $\tan\beta$ at 3.5 to 0.5 for a A masses between 400 GeV and 1.1 TeV.

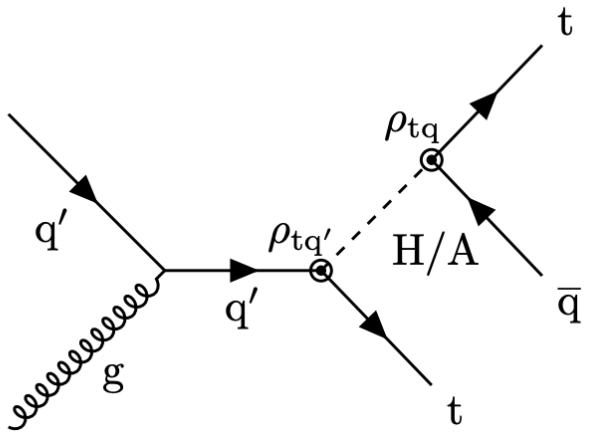


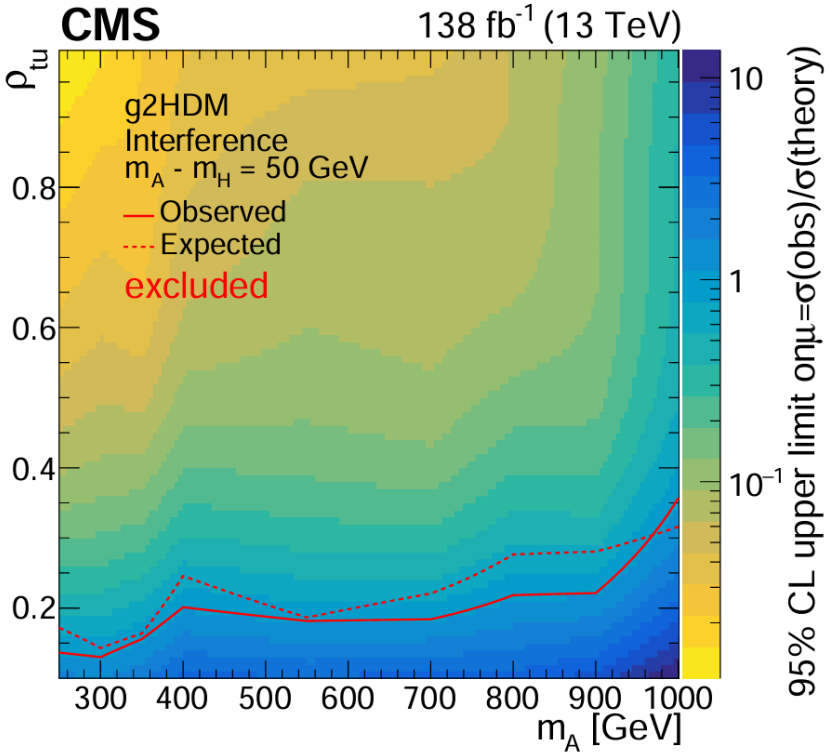


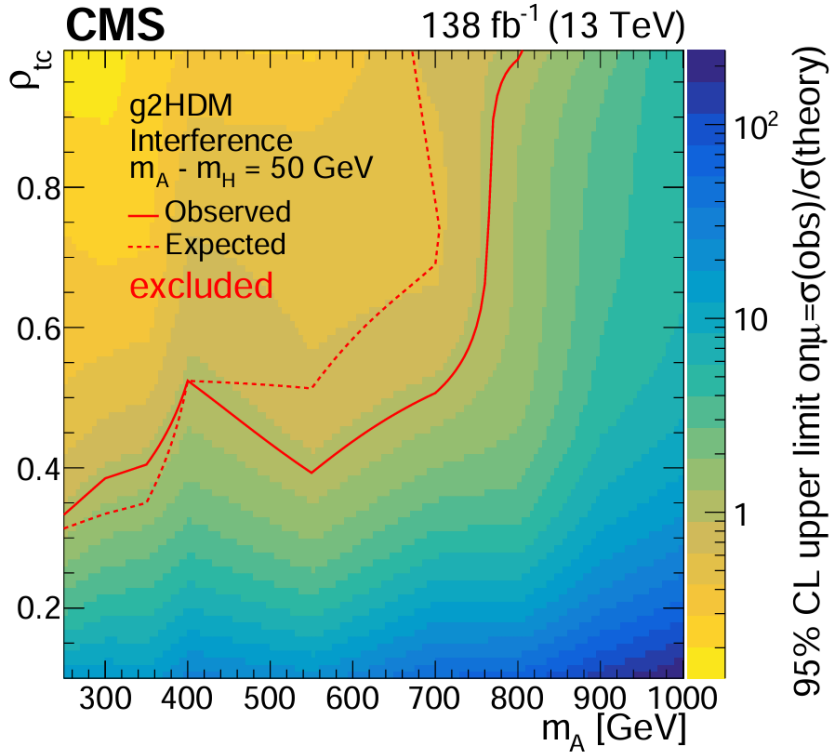
BSM $qg \rightarrow tH/A \rightarrow tt\bar{q}$

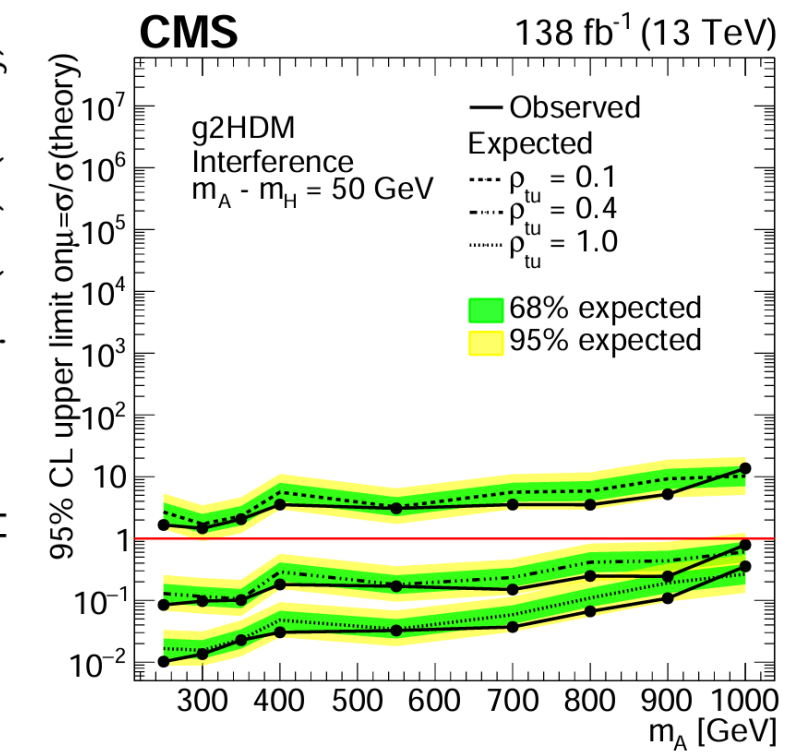
PLB 850 (2024) 138478

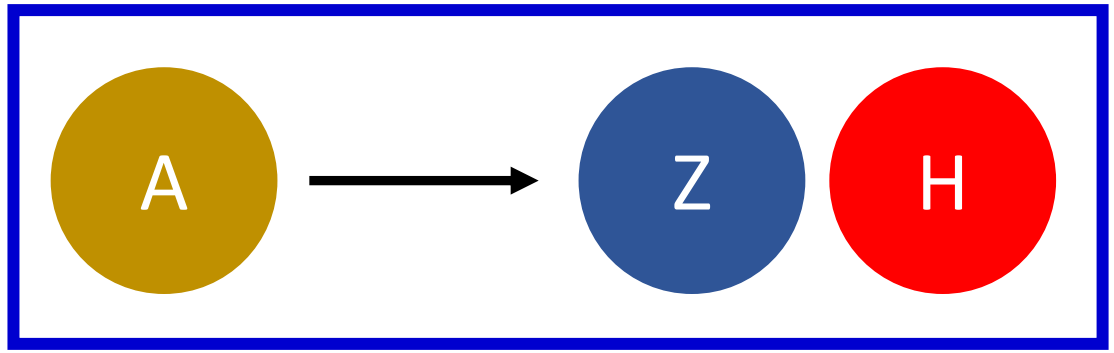
- Motivated by the g2HDM (2HDM without Z_2 symmetry). Of interest for baryogenesis and the muon g-2 anomaly.
- The analysis is optimized with a boosted decision tree to target both ρ_{tu} and ρ_{tc}.
- No deviations from the SM predictions observed.







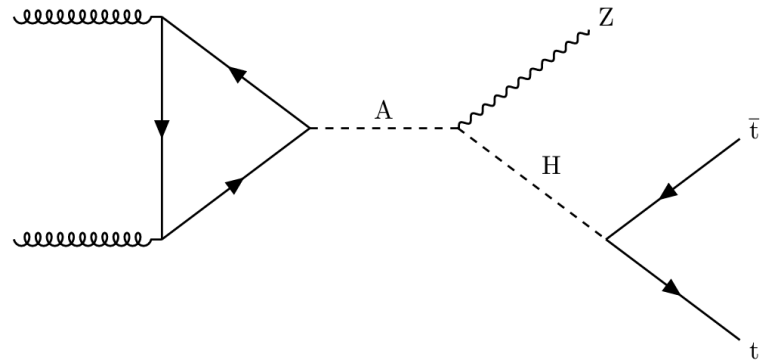



A
Z
H

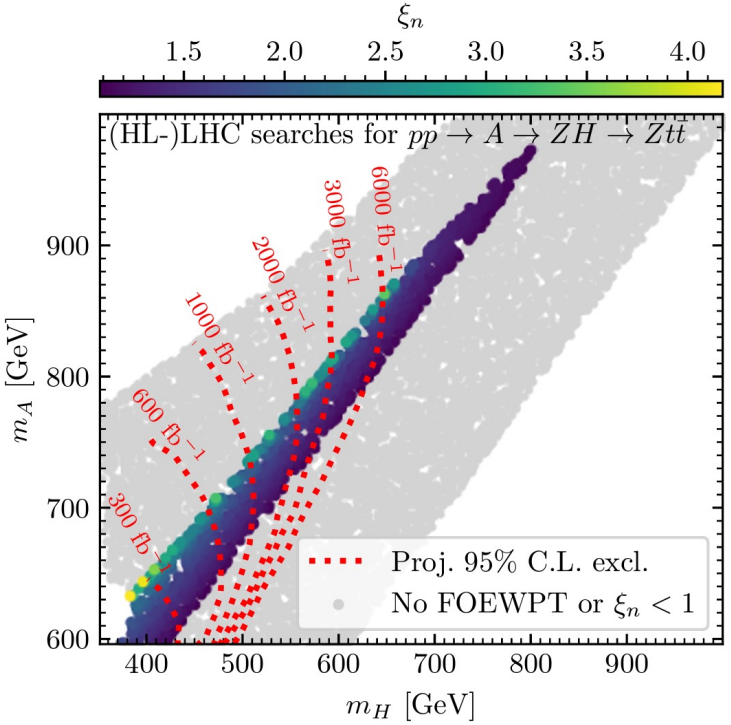
$A \to ZH \to ll t\bar{t}$

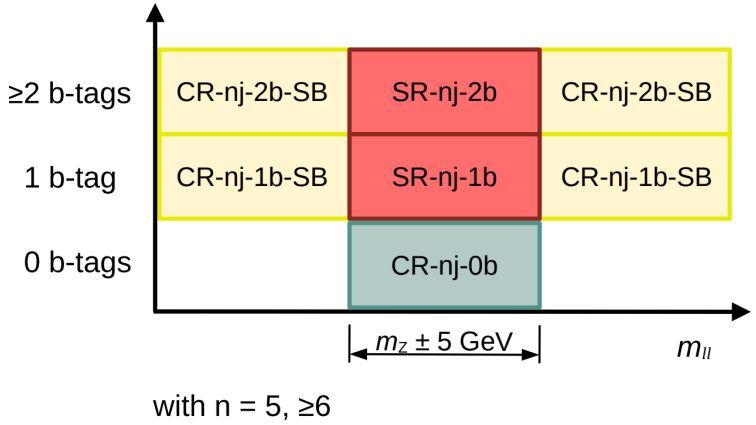
NEW RESULT

CMS-PAS-B2G-23-006

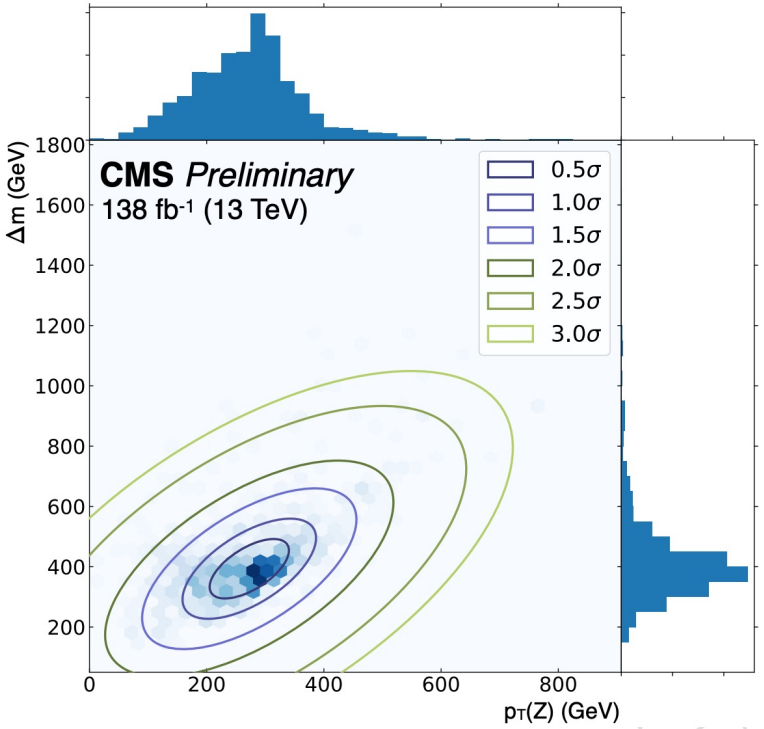


- "Smoking gun" channel for first-order electroweak phase transition in the 2HDM.





with n = 5, ≥6



Thomas Biekötter *et al* JCAP03(2023)031

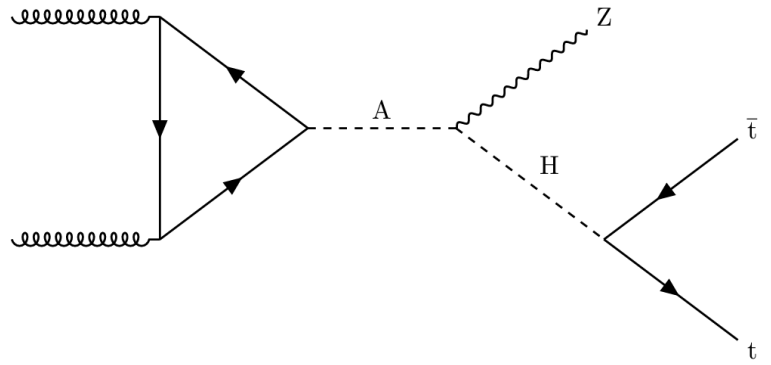
- Use fully hadronic decays of the top quark pair.
- The analysis uses signal categories binned in the number of jets and b jets.
- As a final discriminator , an unrolled distribution of p_T^Z and Δm is used.

$$\Delta m = m_{\mathrm{t\bar{t}Z}} - m_{\mathrm{t\bar{t}}} \approx m_{\mathrm{A}} - m_{\mathrm{H}}$$

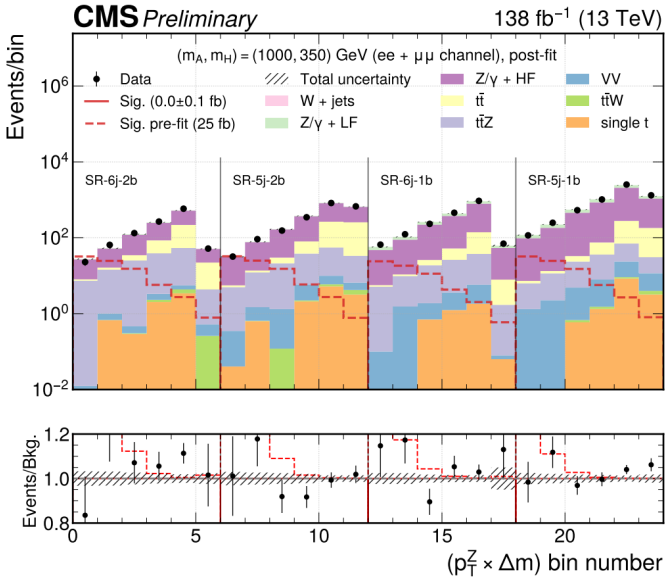
$A \to ZH \to llt\bar{t}$

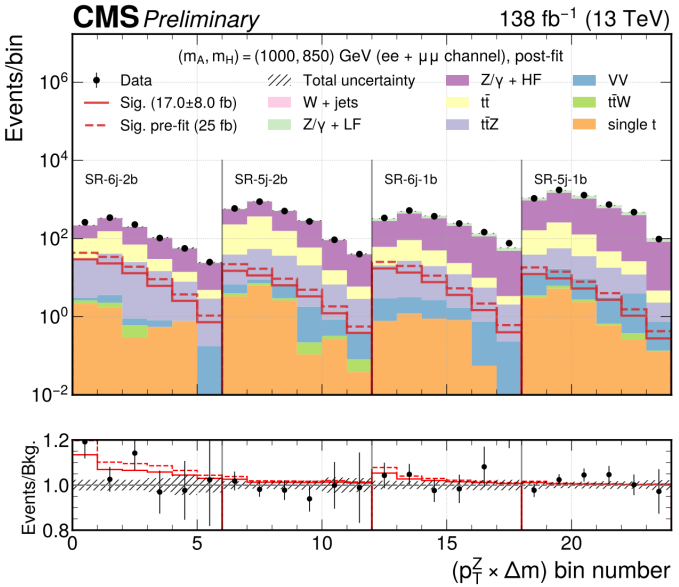
NEW RESULT

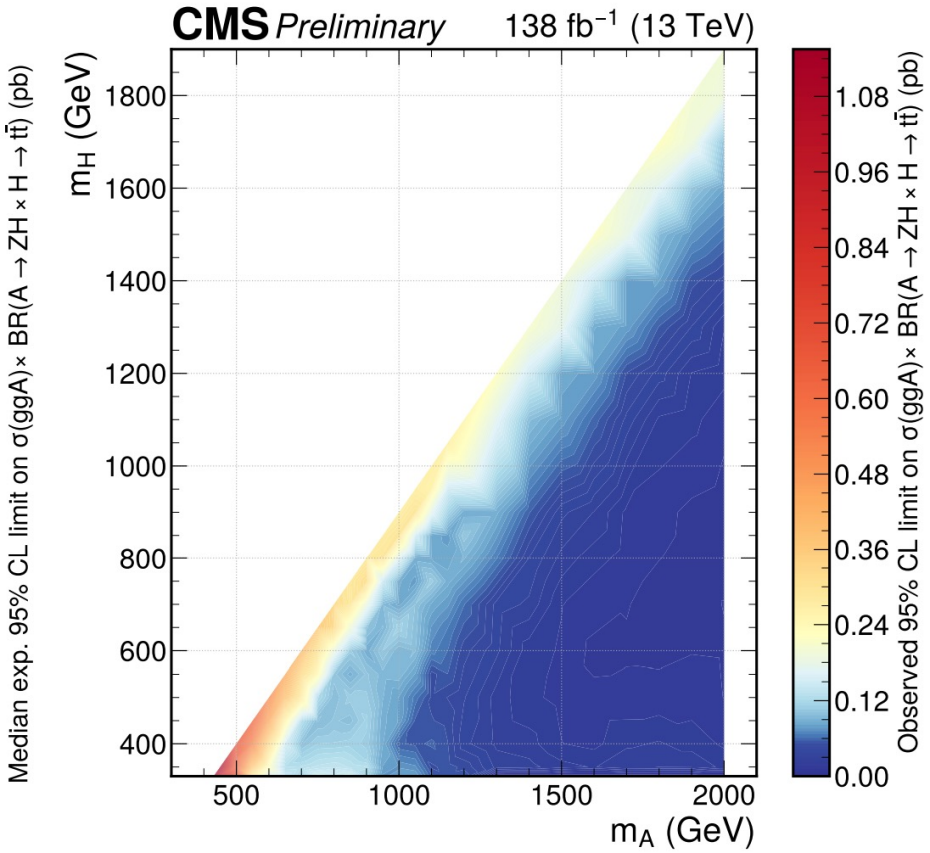
CMS-PAS-B2G-23-006

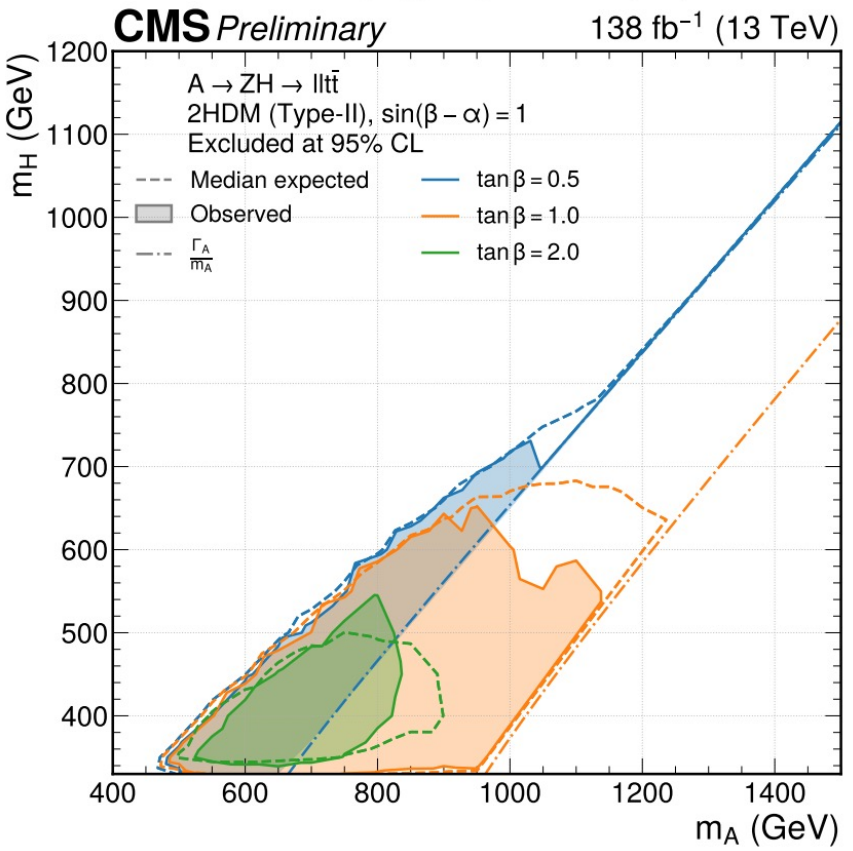


- No statistically significant deviation from the SM expectation was observed.
- Type II 2HDM exclusions limits set at low tan β values.





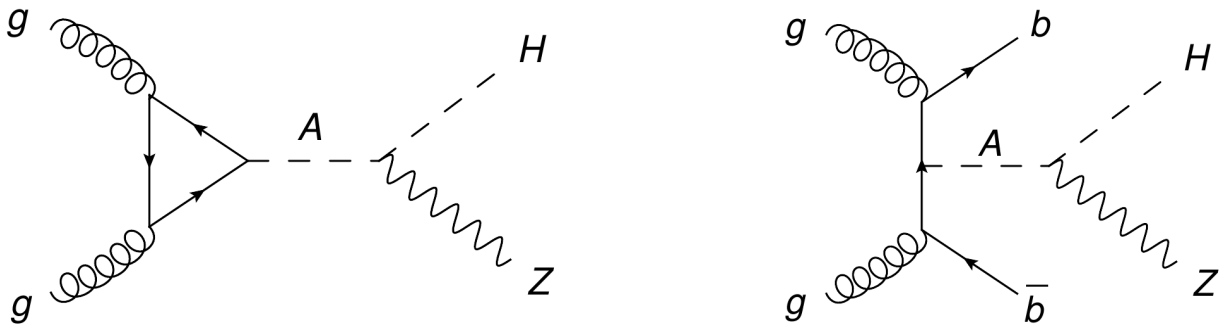


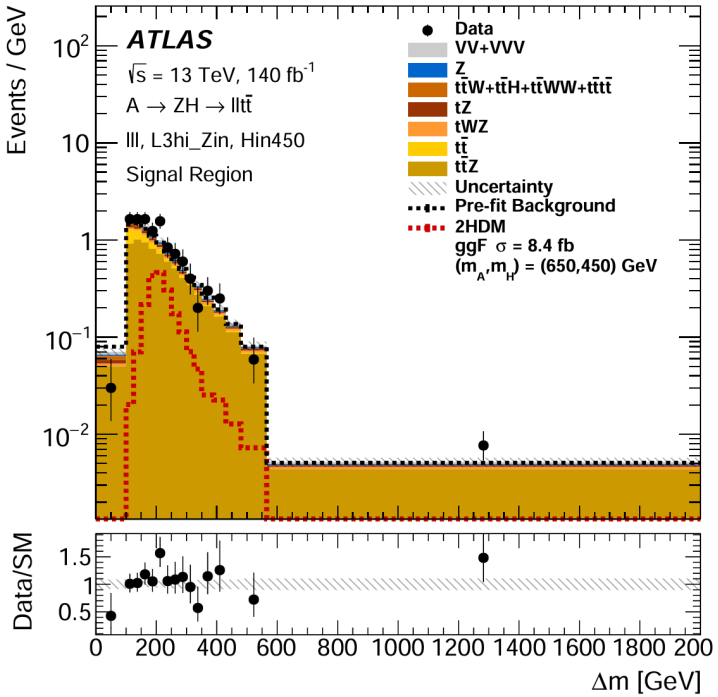


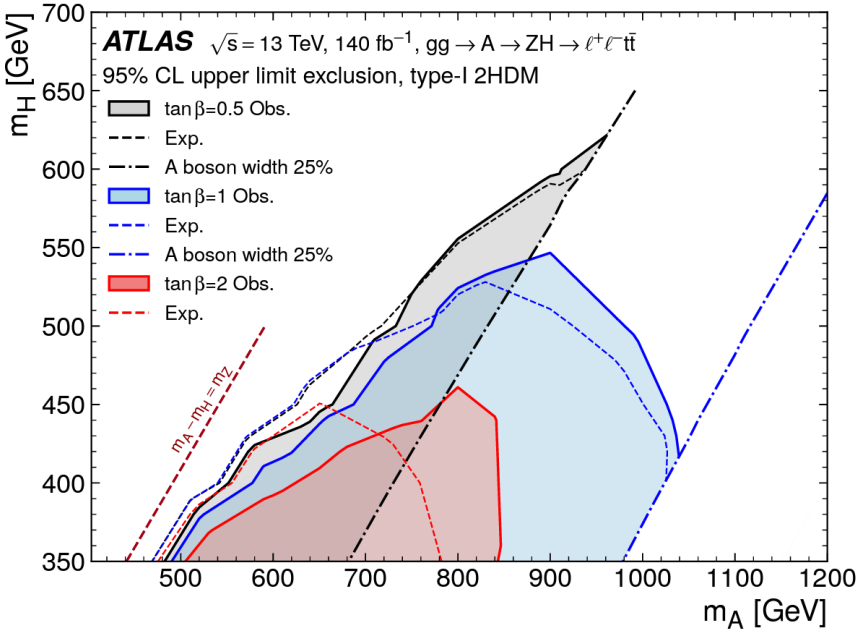
$A \to ZH \to llt\bar{t}$ and $\nu\nu b\bar{b}$

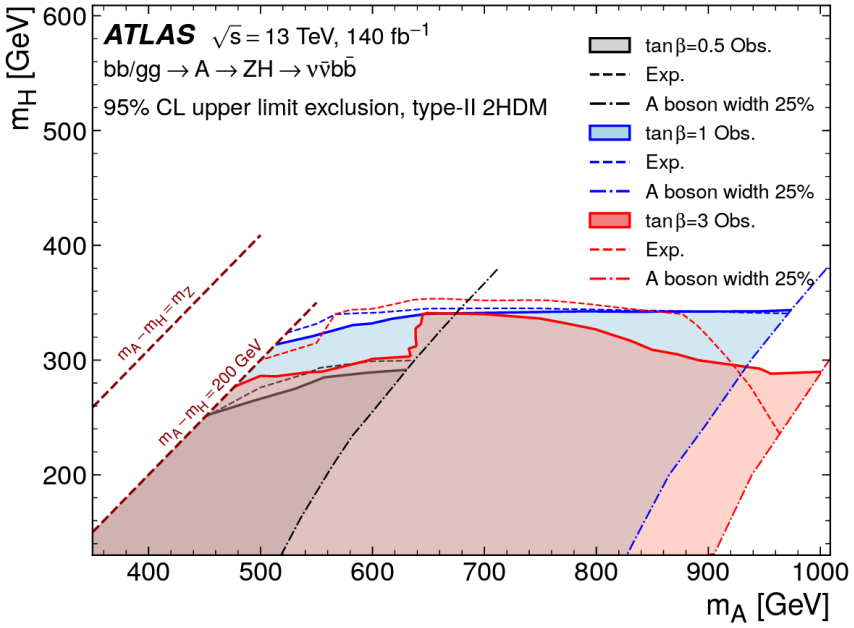
arXiv:2311.04033

- Complementary searches as they are sensitive to different regions of phase space.
- Use semi-leptonic decays of the top-quark pair in the $llt\bar{t}$ channel.
- Observed a 2.85σ local excess at (m_A,m_H) = (650,450) GeV in the $llt\bar{t}$ channel.







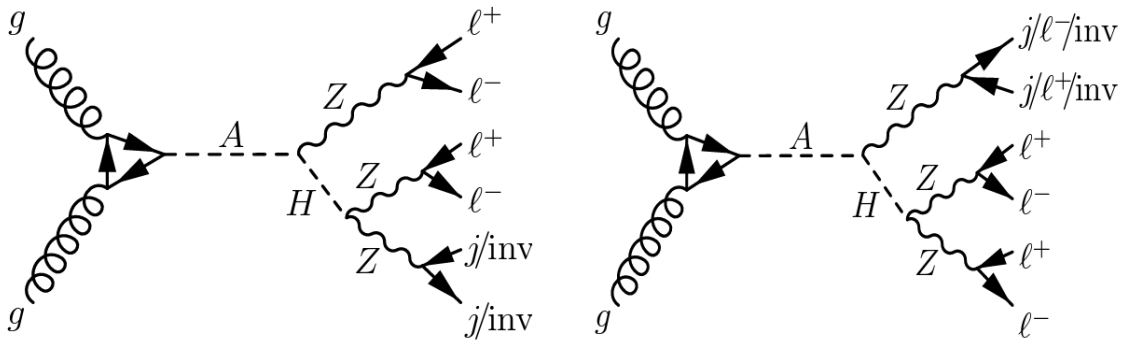


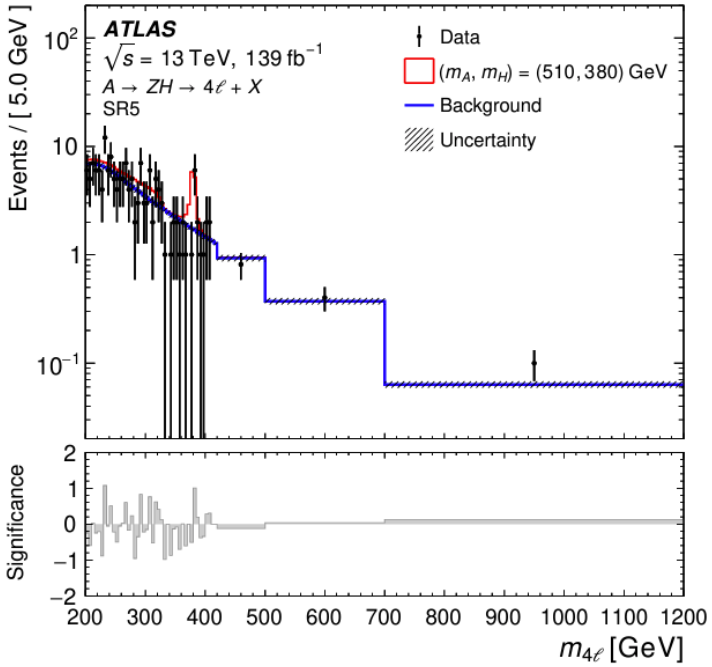
$A \to ZH \to 4l + jj/E_{miss}^{T}$

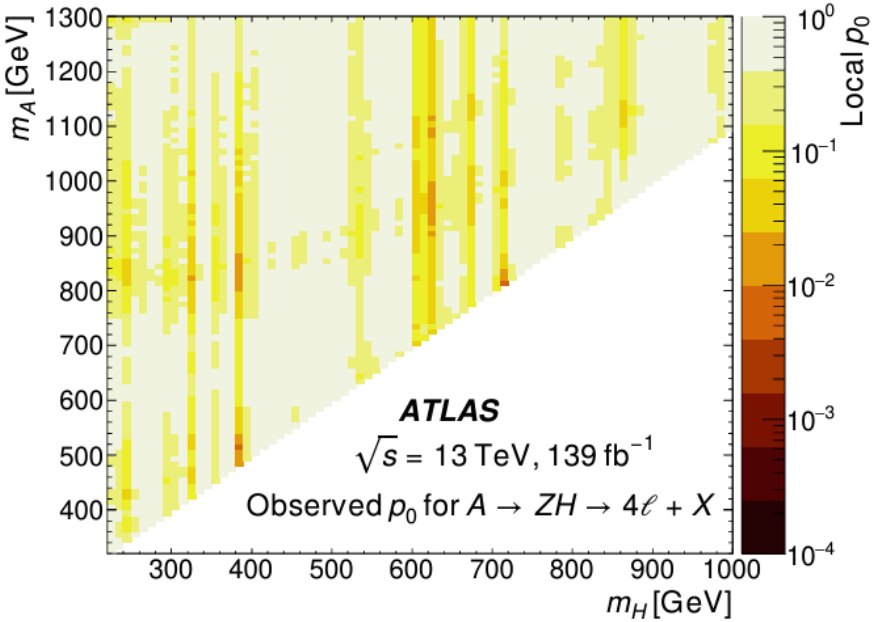
NEW RESULT

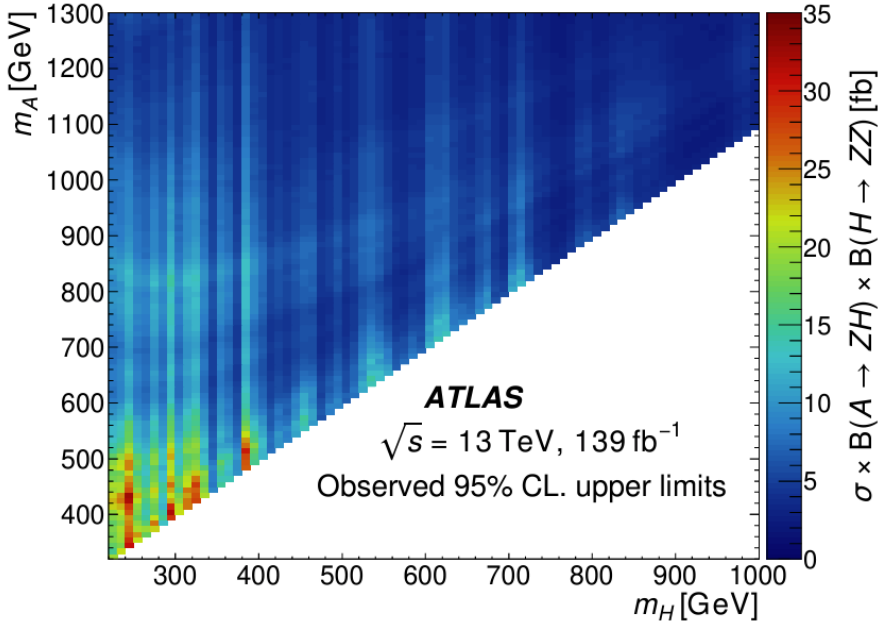
2401.04742

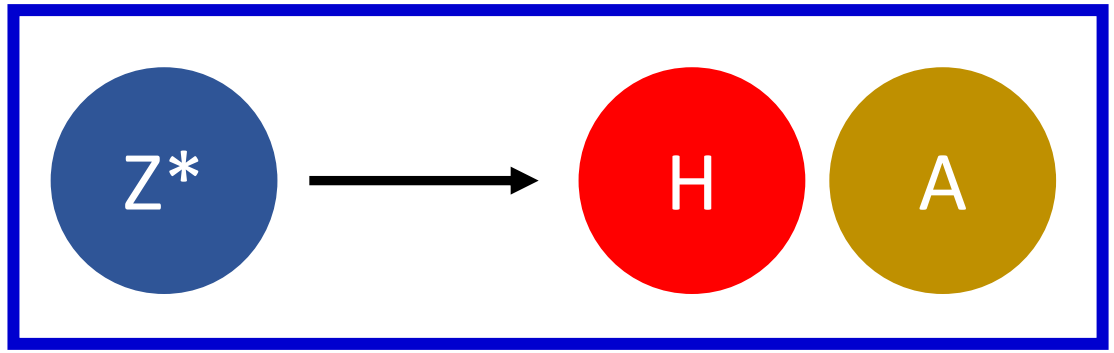
- Motivated by the 2HDM and 2HDM+S.
- Targets final states with 4 leptons (either from the Z or H) and one of two jets or some missing energy.
- Search fits the 4-lepton mass spectrum with various categories to target the other final state object/MET.
- No significant deviation is observed.







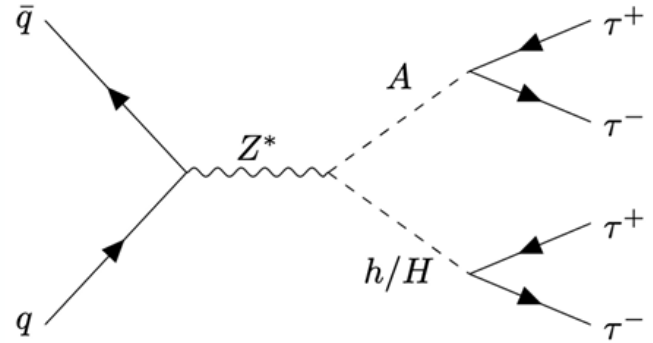


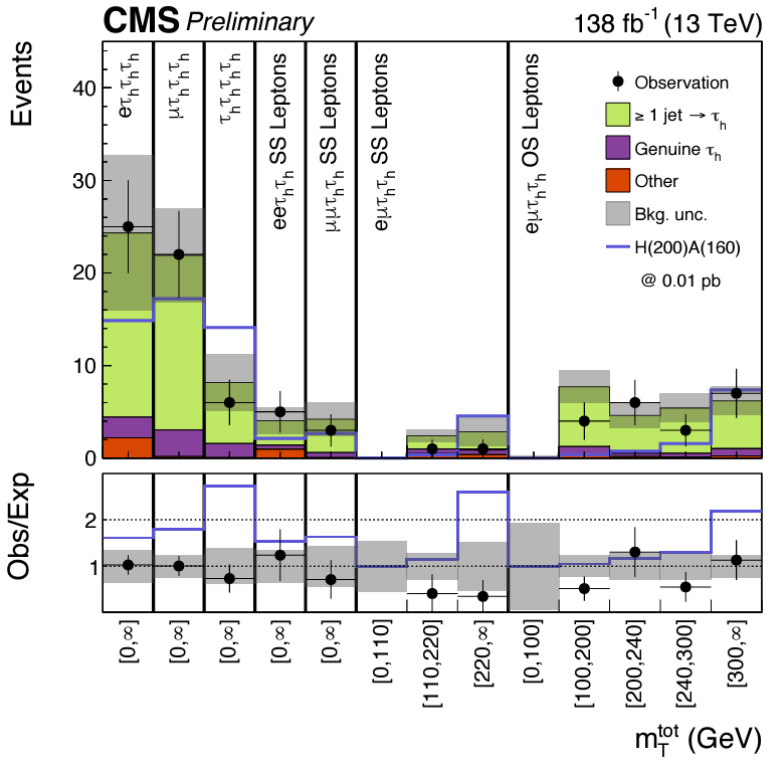

Z*
H
A

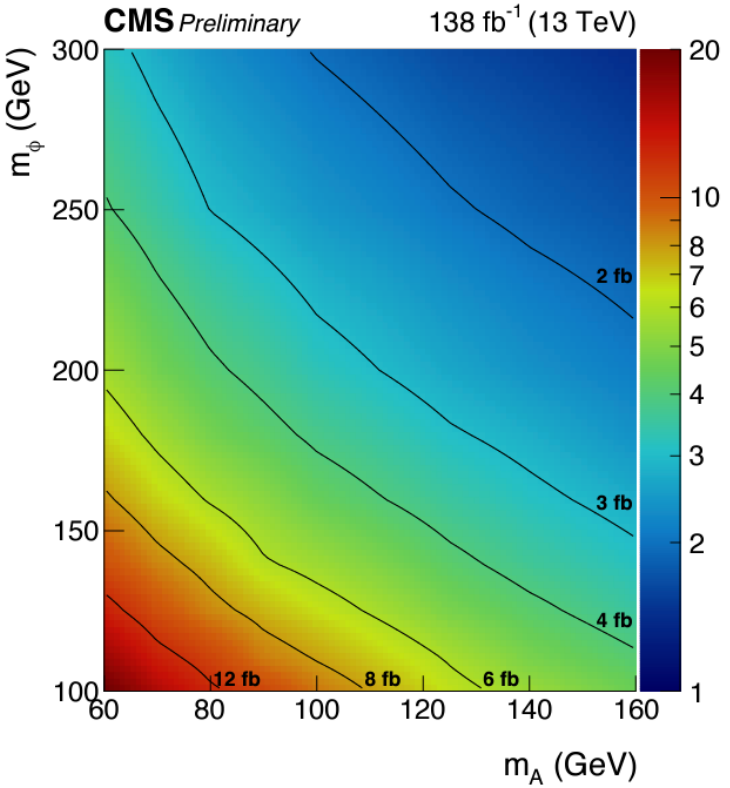
$Z^* \to h/HA \to 4\tau$

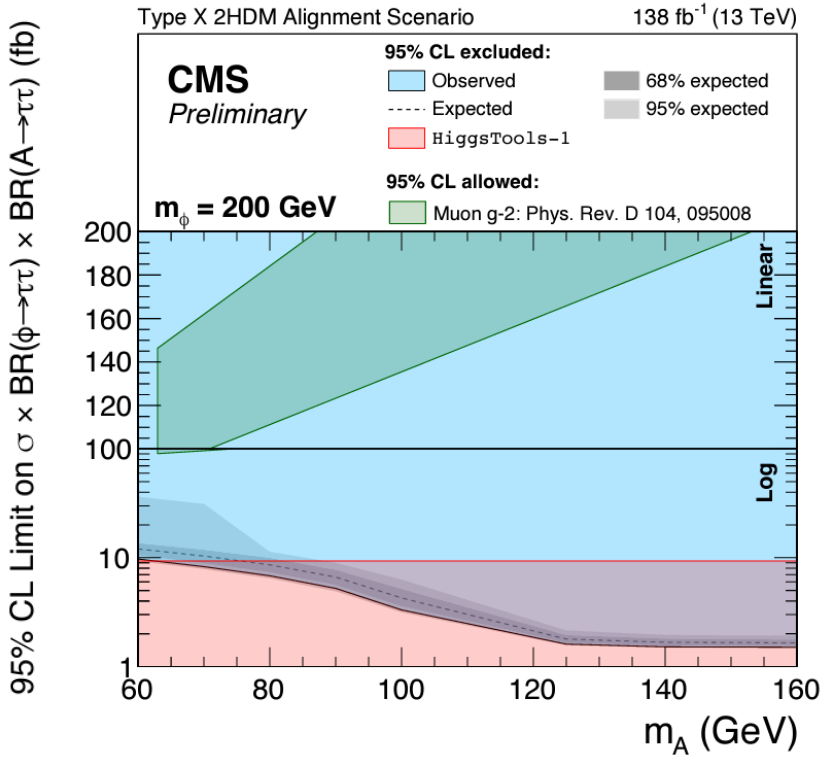
CMS-PAS-SUS-23-007

- Motivated by the type X 2HDM at large tanβ as an explanation of the muon g-2 anomaly.
- Search excludes the allowed region for the g-2 anomaly with a type X 2HDM.
- A complete exclusion of the type X 2HDM for many of the mass points scanned.





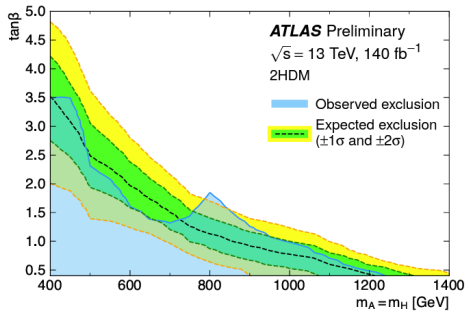




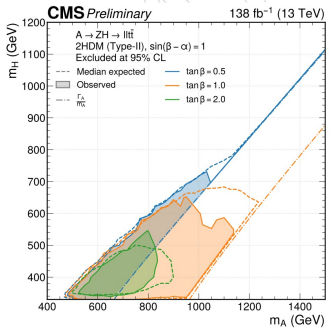
Conclusion

- Wide scope of BSM Higgs boson searches released by ATLAS and CMS!
- New results presented:

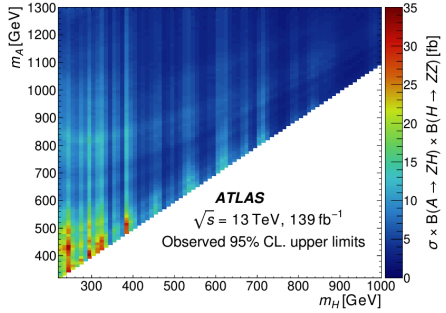
ATLAS EXPERIMENT BSM $H/A \to t\bar{t}$ NEW RESULT



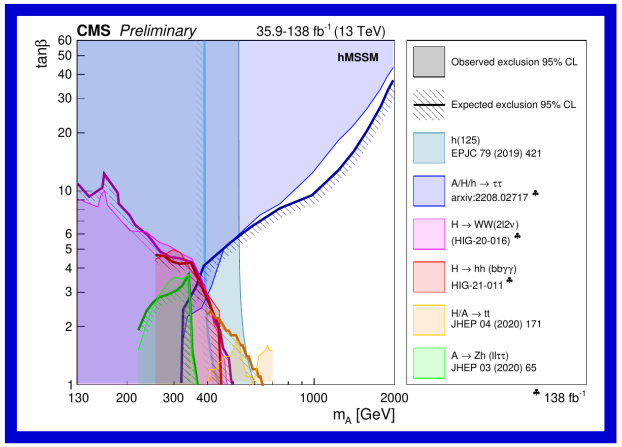
CMS $A \to ZH \to lltt$ NEW RESULT

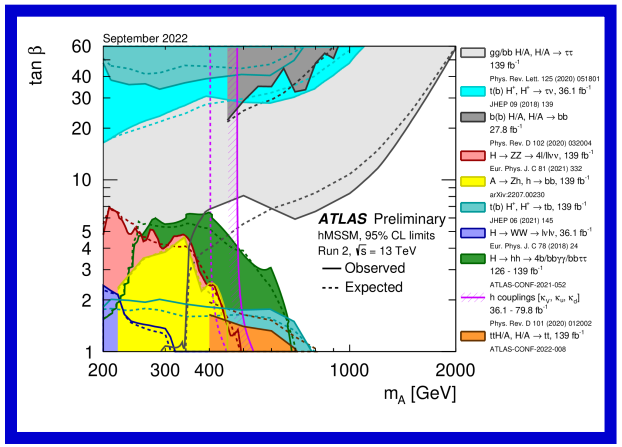


ATLAS EXPERIMENT $A \to ZH \to 4l + jj/E_{miss}^{T}$ NEW RESULT



- Still a large amount of phase space available for extended Higgs sectors.





- Looking forward to more run 2 and first run 3 results BSM Higgs results!