Searching for additional Higgs bosons at ATLAS

On behalf of the ATLAS collaboration

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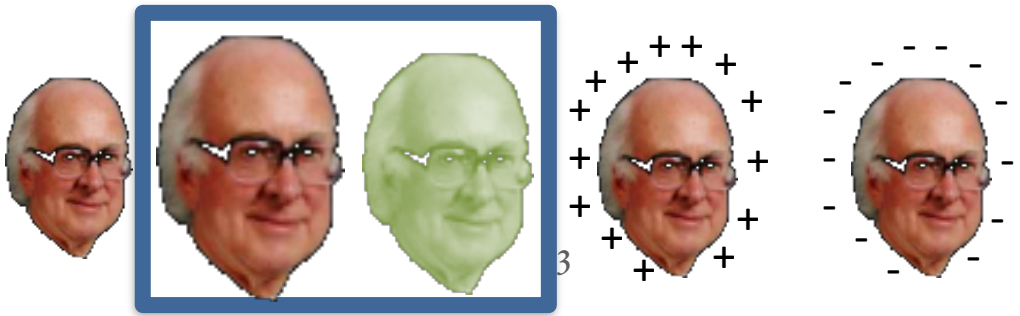
LLWI2024

Outline

- Beyond the Standard Model
  - Very low mass $\gamma\gamma$
  - Low mass $\gamma\gamma$
  - $Z\gamma$
  - $H^{\pm} \rightarrow cb$
  - FCNC $t \rightarrow qX$, $X \rightarrow bb$
- Summary

Beyond the SM

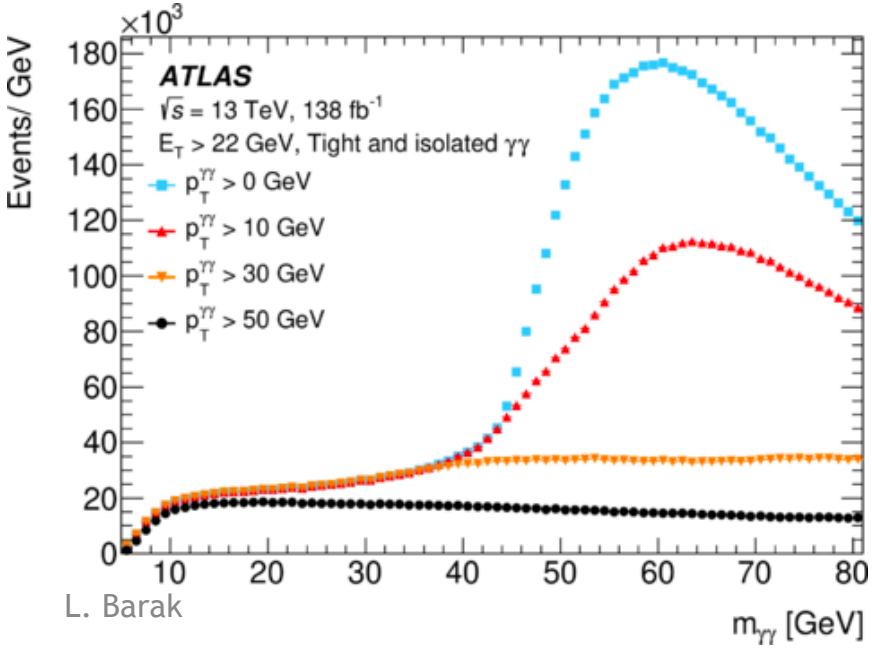
- Standard Model (SM):
  One doublet of Higgs, only one neutral Higgs boson.
- SM needs to be extended:
  ν mass, dark matter…
- Fermions (leptons and quarks) come in three generations, why only one Higgs doublet?
- In many extensions of the SM:
  Prediction of two complex Higgs doublets (2HDM).
- Five physical states: H^+, H^-, h^0, H^0, A^0.

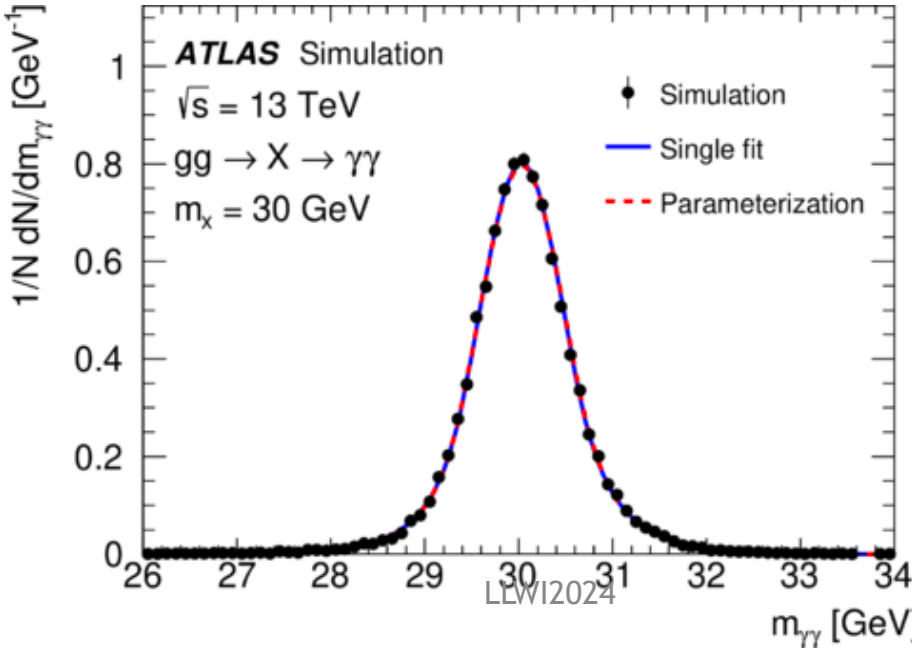


Very Low Mass H→ γγ

JHEP 07 (2023) 155

- **Search for boosted diphoton resonances in the 10 to 70 GeV mass range using 138 fb^{-1} at 13 TeV.**
- Require at least two photons with E_T > 22 GeV and additional $P_{T\gamma\gamma}$ > 50 GeV (motivated by the low mass range).
- The signal is modeled using Double Sided Crystal Ball, composed of a Gaussian core with power-law tails.

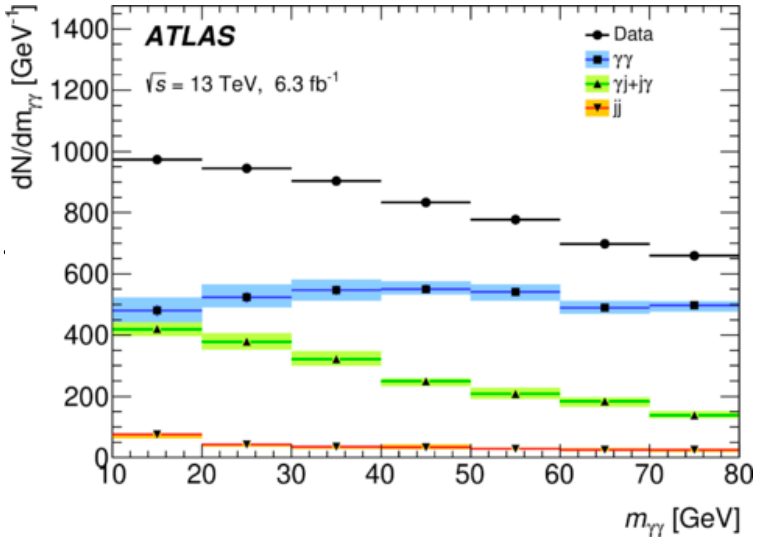


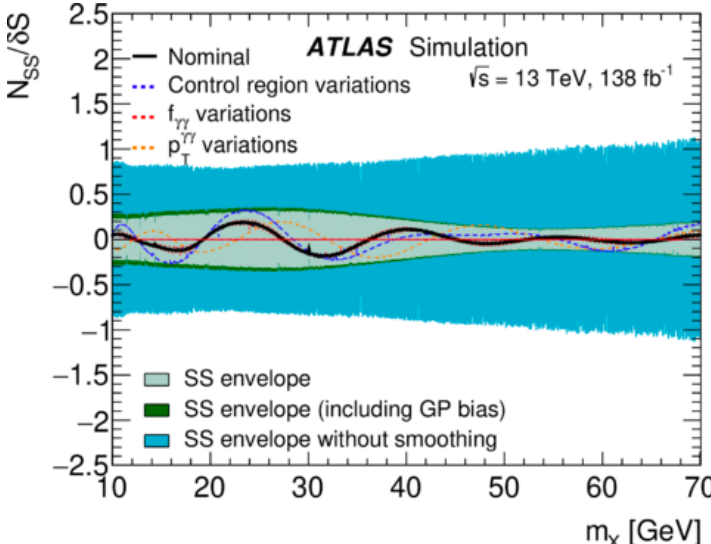


Very Low Mass H→ γγ

JHEP 07 (2023) 155

- Background estimation:
  - Irreducible (γγ) from MC.
  - Reducible (γj,jγ,jj) from data driven methods.
  - Mixed according to data-driven purities.
  - Fluctuations suppressed using the Gaussian Processes fit.
- Background modeling:
  - Fit range: 9-77 GeV.
  - Two complicated functional forms with ten parameters.
  - Uncertainty obtained using the spurious signal method.





Very Low Mass H→ γγ

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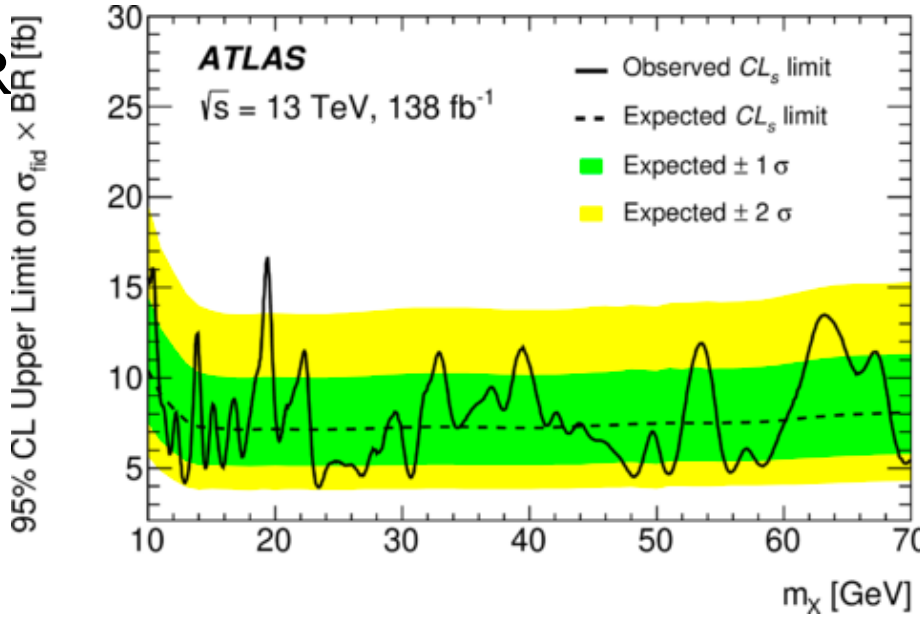
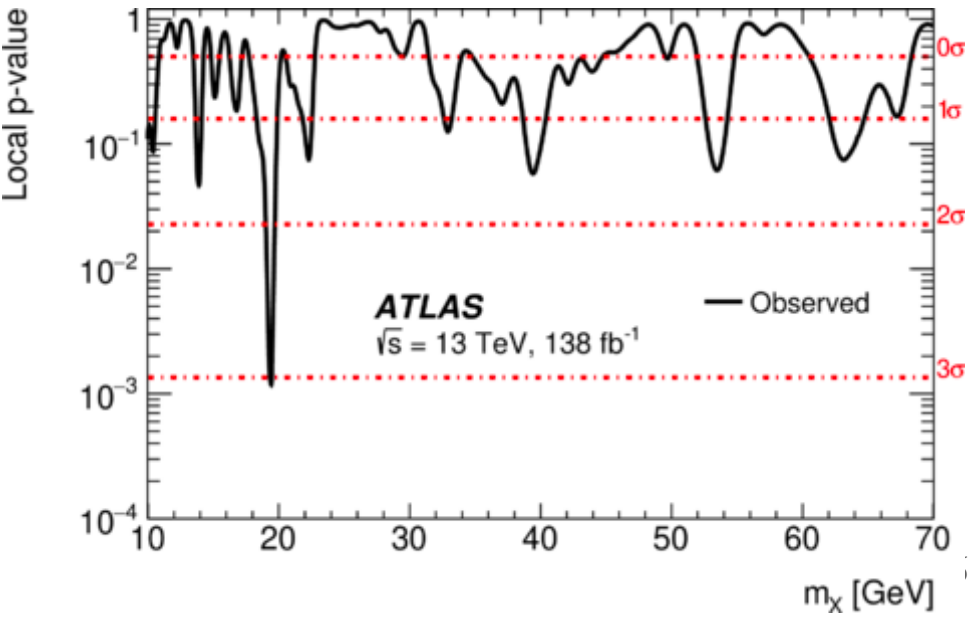
- Upper limits on the fiducial XS*BR are set at the 95% CLs 17–4 fb.
- Highest local (global) is 3.1σ (1.5σ) at m = 19.4 GeV.

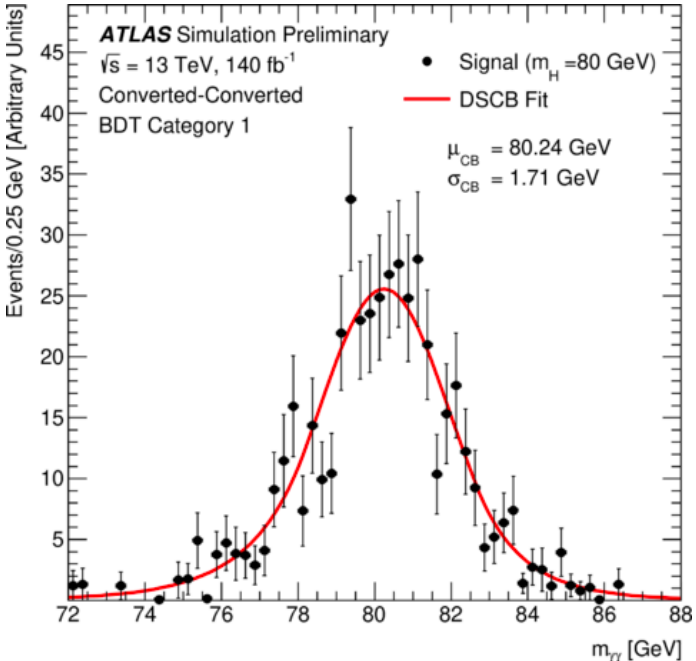


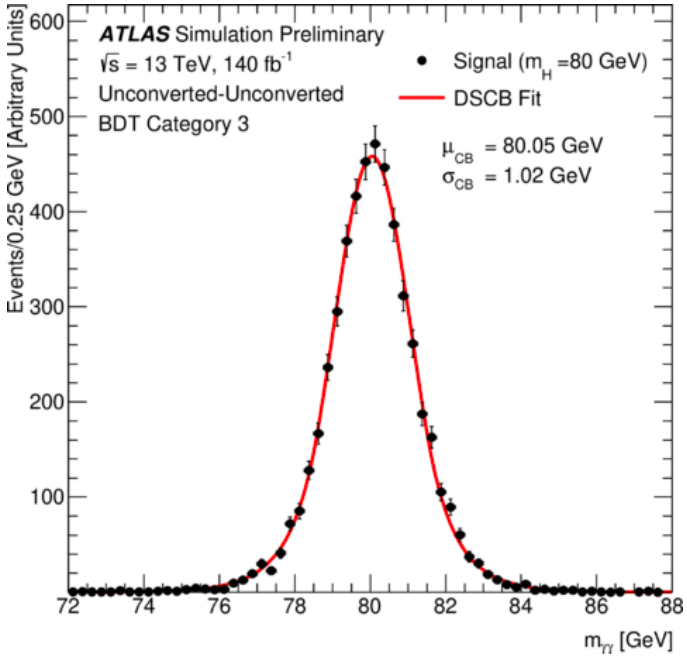


$H \rightarrow \gamma\gamma$

ATLAS-CONF-2023-035

- **Search for diphoton resonances in the 66 to 110 GeV mass range using 140 fb^{-1} at 13 TeV.**
- Special features:
  - Two searches: model independent and model dependent (assuming SM Higgs like production XS and using a BDT to discriminate photons from electrons).
  - Objetc selections: additional $E_T/m_{\gamma\gamma} > 0.38$ for each γ instead of the $P_{T\gamma\gamma}$ cut.
  - Additional background: Drell-Yan originates from $Z/\gamma^* \rightarrow e^+e^-$ with electrons faking photons.
    - Shape and normalization constrained using a data-driven measurement of $e \rightarrow \gamma$ events in $Z \rightarrow ee$ decays.
  - Categories based on the photon reconstruction: both unconverted (UU), one converted and one unconverted (CU) or both converted (CC).

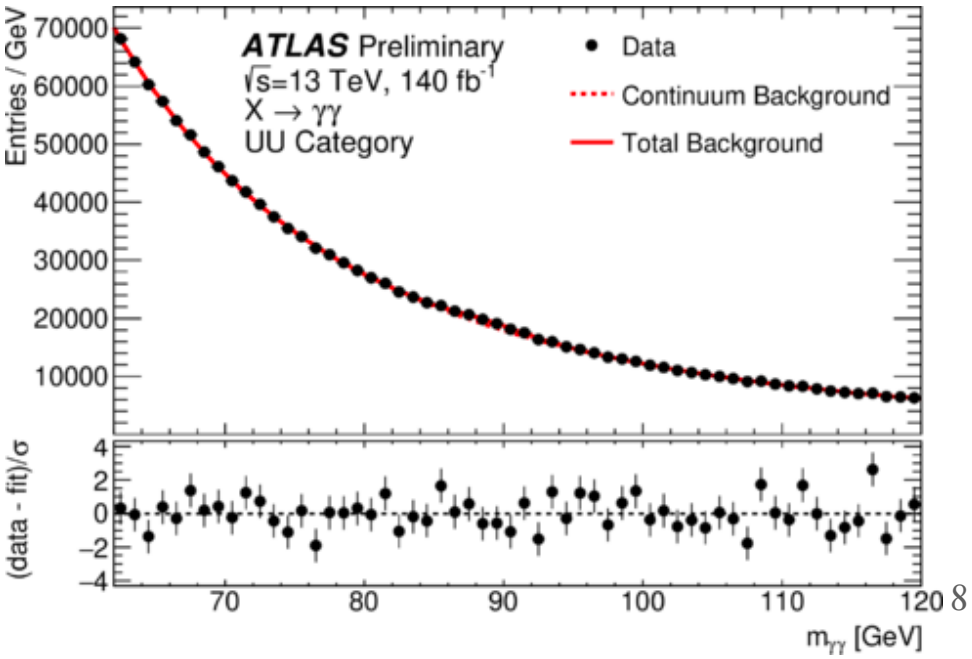


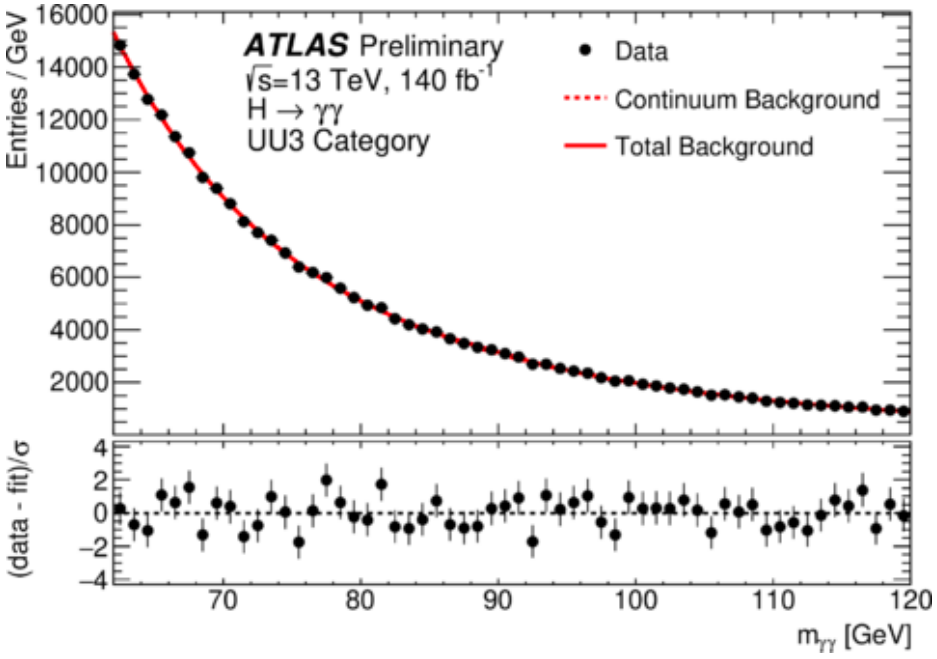


$H \rightarrow \gamma\gamma$

ATLAS-CONF-2023-035

- Background estimation:
  - Both the non-resonant continuum and the resonant DY are estimated separately in each category.
  - The continuum is fitted on data, with the normalization and function parameters free, while for the DY both shape and normalization are fitted but constrained by control regions.

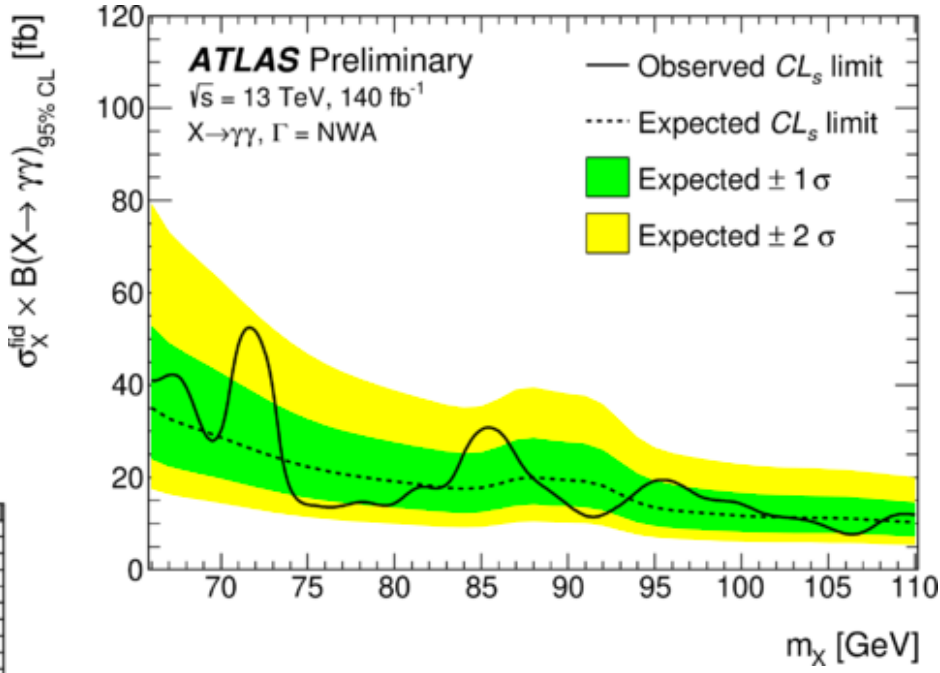


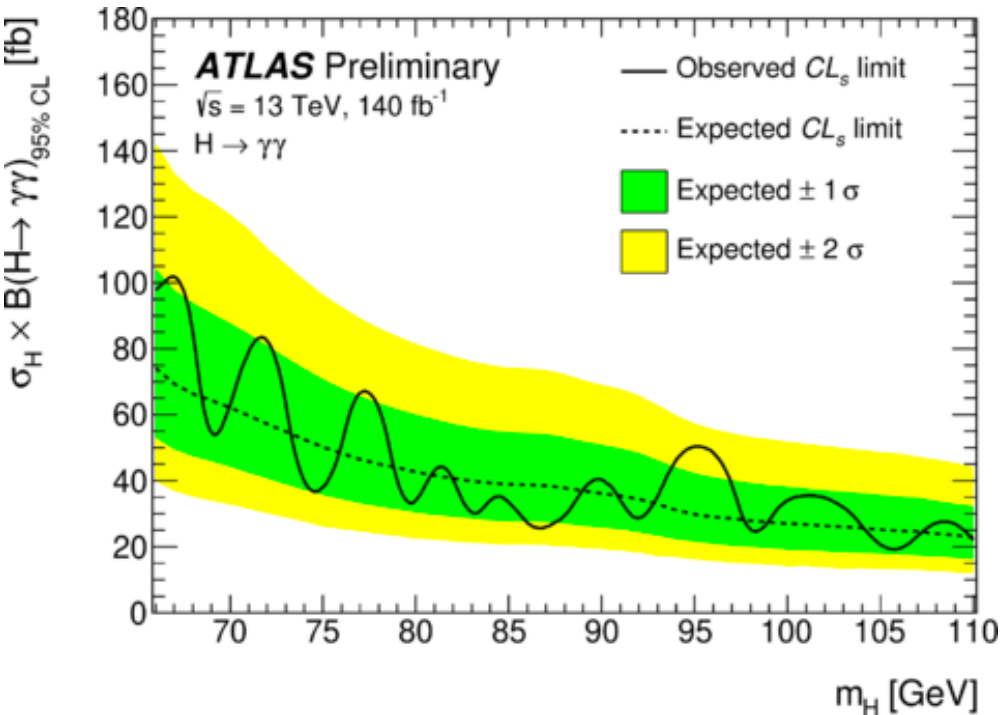


H→ γγ

ATLAS-CONF-2023-035

- Upper limits on the fiducial XS*BR are set at the 95% CLs:
  - Model independent: 53 - 8 fb.
  - Model dependent: 102 - 19 fb



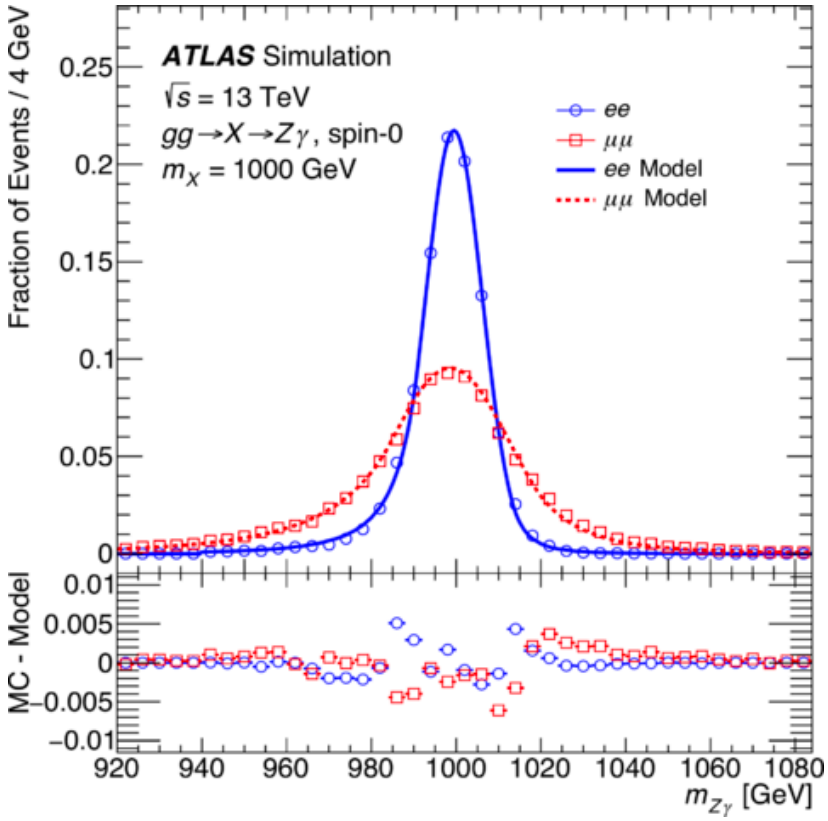


Zγ

Phys. Lett. B 848 (2024) 138394

Search for the Zγ decay mode of new high-mass resonances at 13 TeV.

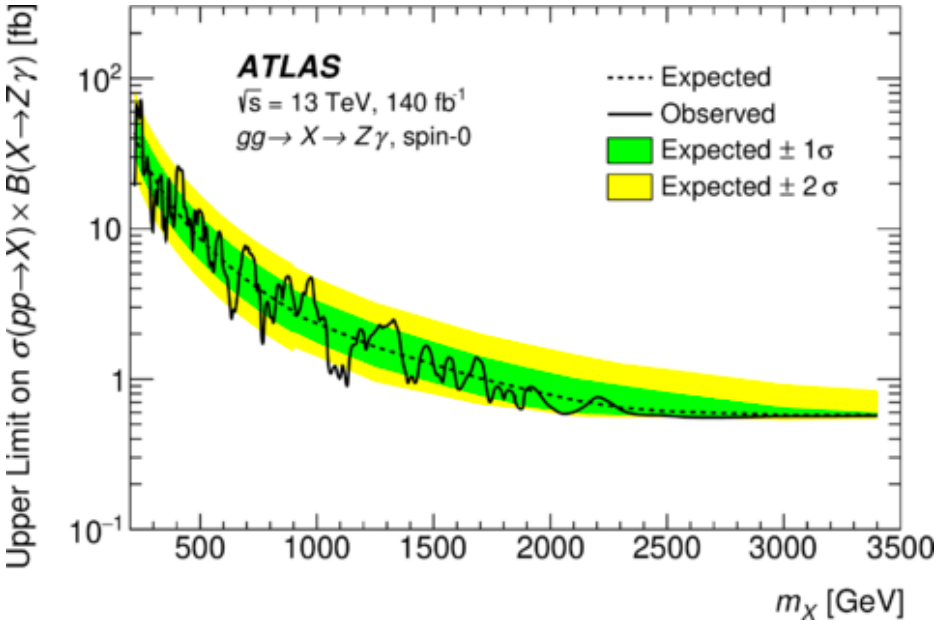
- Mass range: 220 - 3400 GeV.
- Event selections: a photon with additional two light leptons (collimated for the higher mass range).
- Main background: non resonant Z+γ (Z+jet).
- Both signal and background are estimated using functional forms.
- Usage of a dedicated MVA for the electron collimated ID.

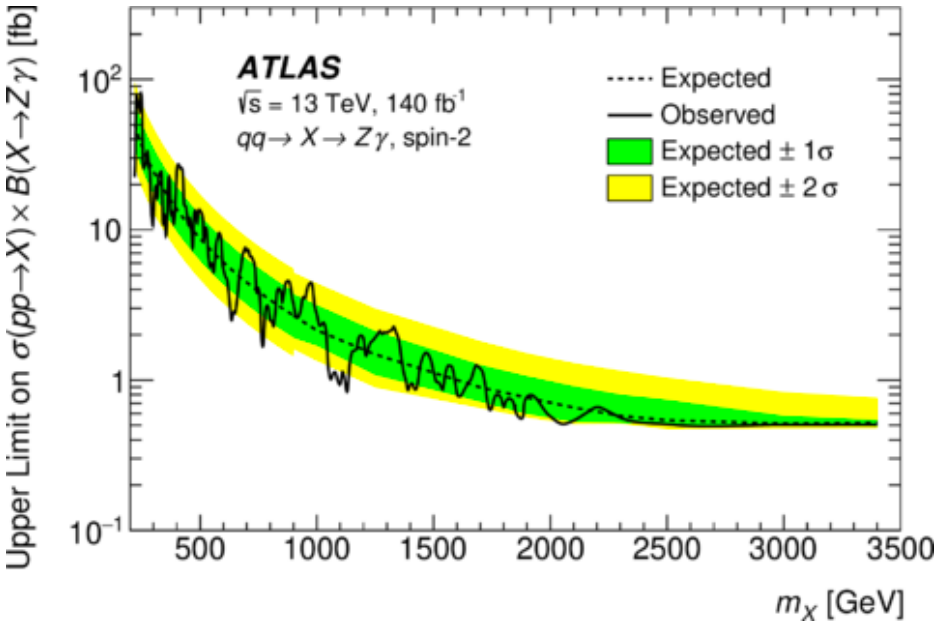


Zγ

Phys. Lett. B 848 (2024) 138394

- Upper limits on the fiducial XS*BR are set at the 95% CLs :
  - Spin 0: 65.5 - 0.6 fb.
  - Spin 2 gg initiated: 77.4 - 0.6 fb.
  - Spin 2 qq initiated: 76.1 - 0.5 fb.



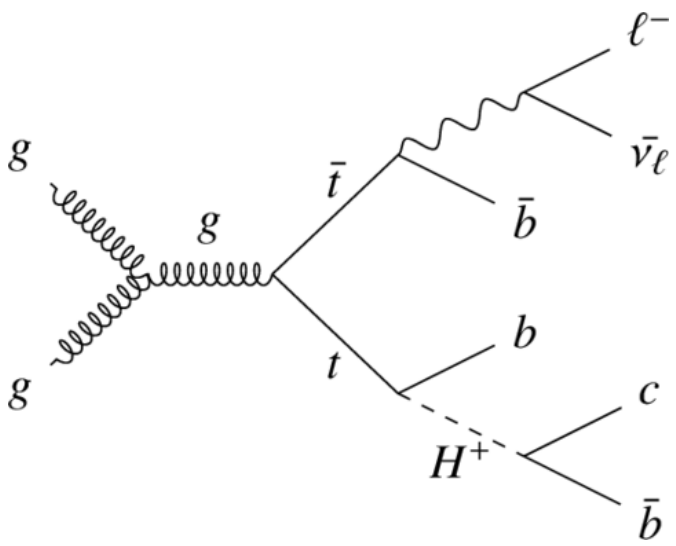


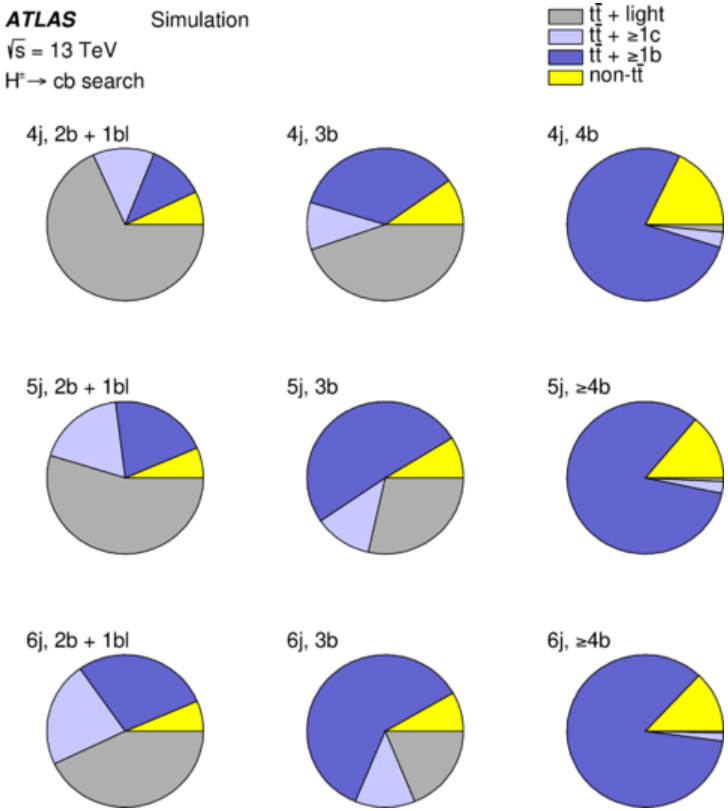
$H^{\pm} \rightarrow cb$

JHEP 09 (2023) 004

Search for a light charged Higgs boson in $t \rightarrow H^{\pm}b$ decays, with $H^{\pm} \rightarrow cb$, in the lepton+jets final state at 13 TeV.

- Mass range: 60 - 160 GeV.
- Event selections: ==1 isolated light lepton, >=4j out of them >=2b, E_T^{miss} >20 GeV, $E_T^{miss} + M_T^W$ >20 GeV.
- Main background: ttbar (single t, V+jets).
- The fit is done on NN score.

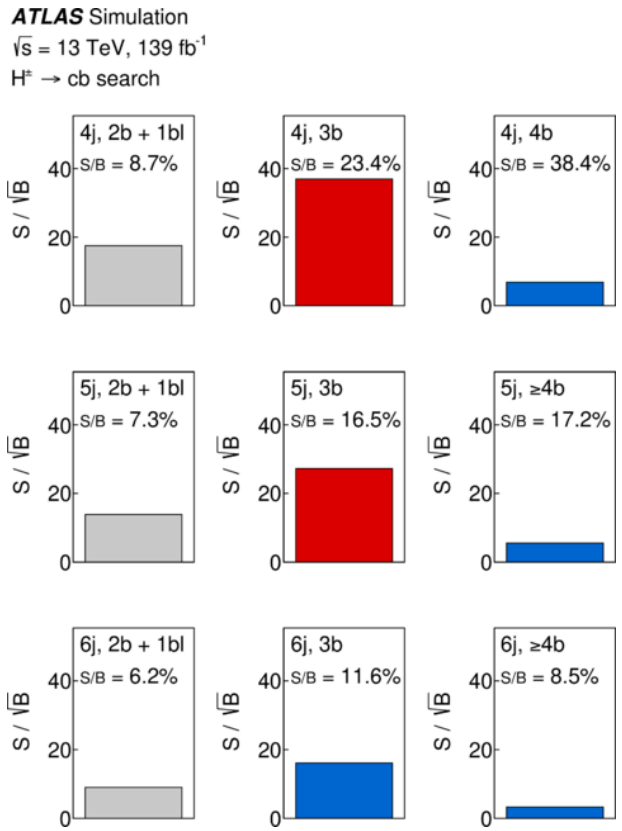


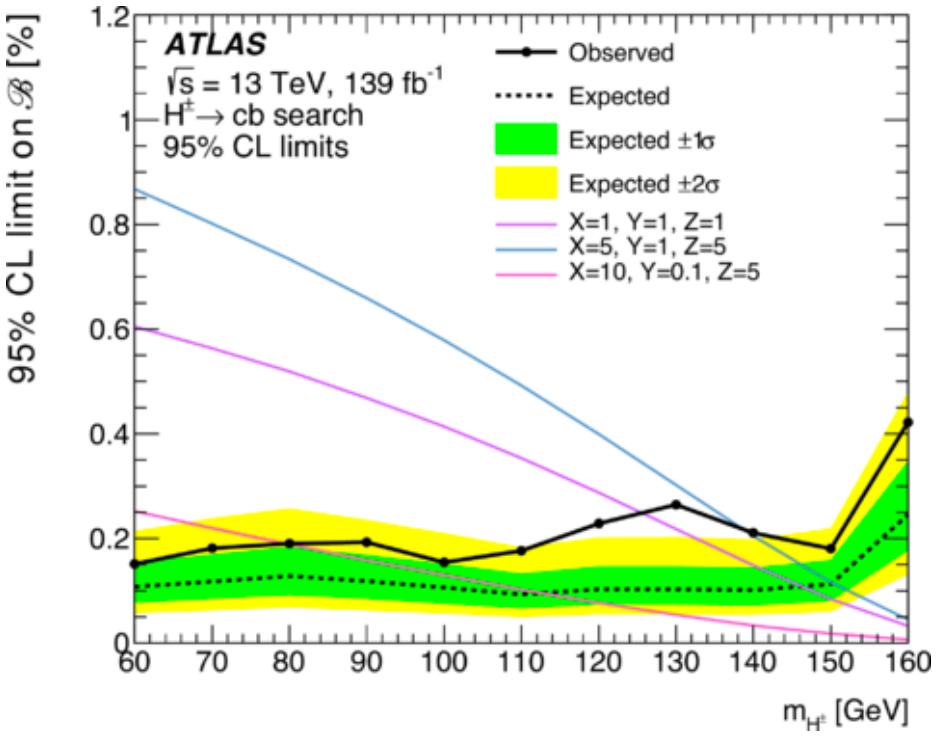


$H^{\pm} \rightarrow cb$

JHEP 09 (2023) 004

- Upper limits on the BR are set at the 95% CLs: 0.15% - 0.42%.
- Predictions from the 3HDM are superimposed too.
- Highest local (global) is 3σ (2.5σ) at m = 130 GeV.



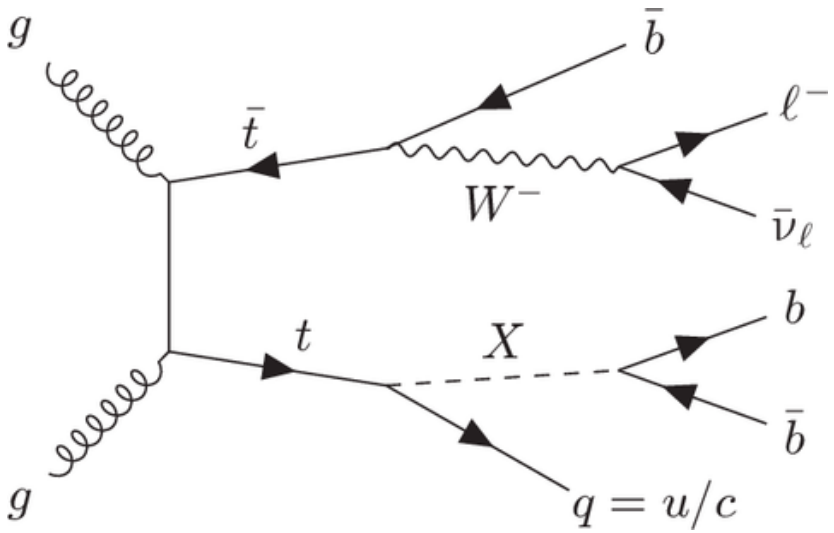


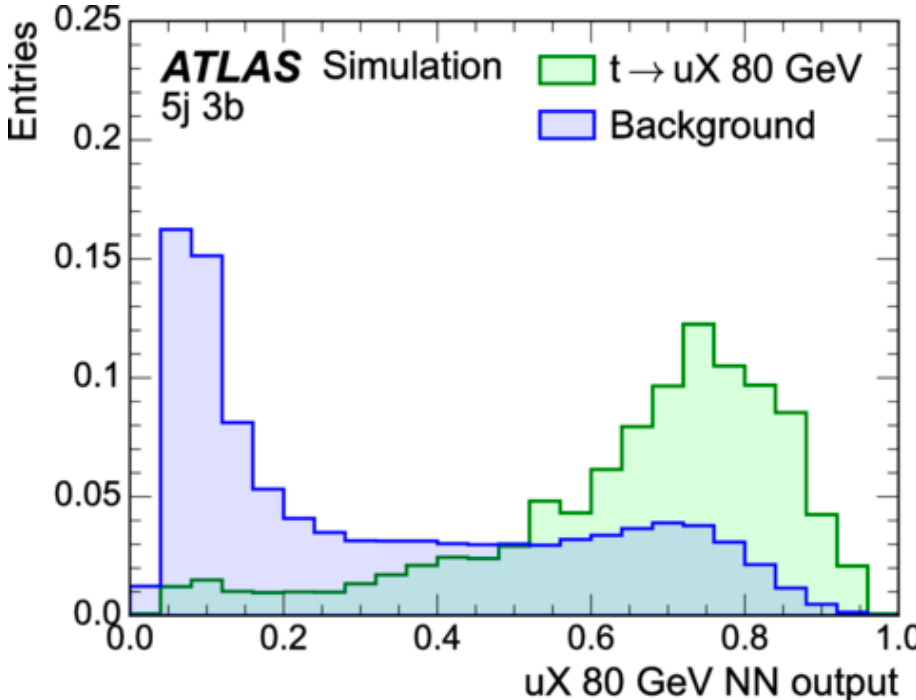
FCNC t→qX, X→bb

JHEP 07 (2023) 199

Search for a new scalar resonance in flavour-changing neutral-current top-quark decays t→qX, X→bb at 13 TeV.

- Mass range: 20 - 160 GeV.
- Event selections: ==1 isolated light lepton, >=4j out of them >=2b & >=1looseb, E_T^{miss} >20 GeV, $E_T^{miss} + M_T^W$ >60 GeV.
- Main background: ttbar (single t, V+jets).
- Dedicated signal samples for both t→uX and t→cX.

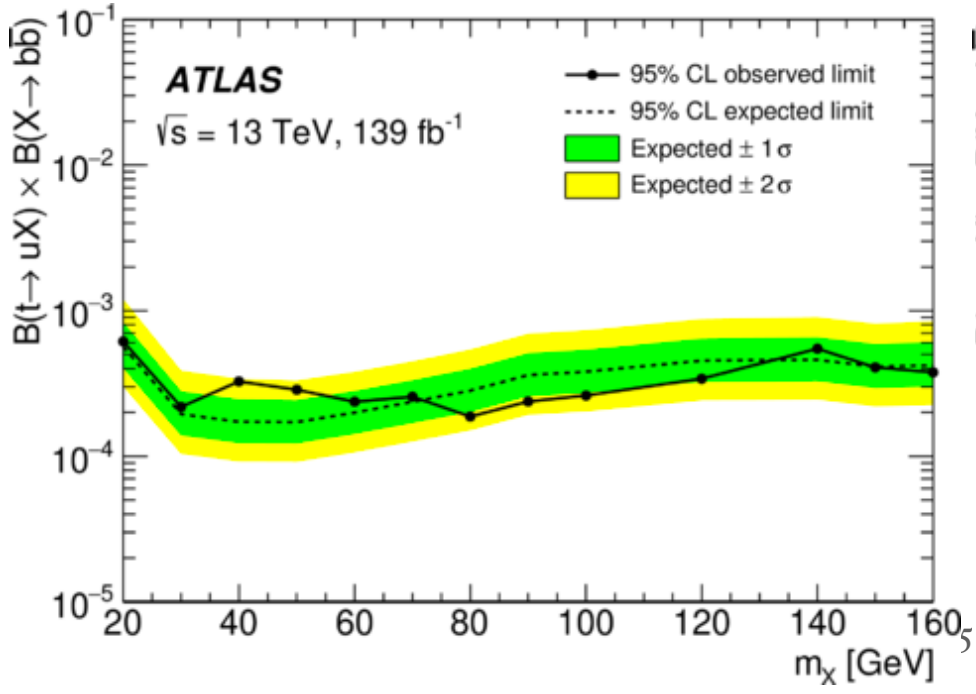


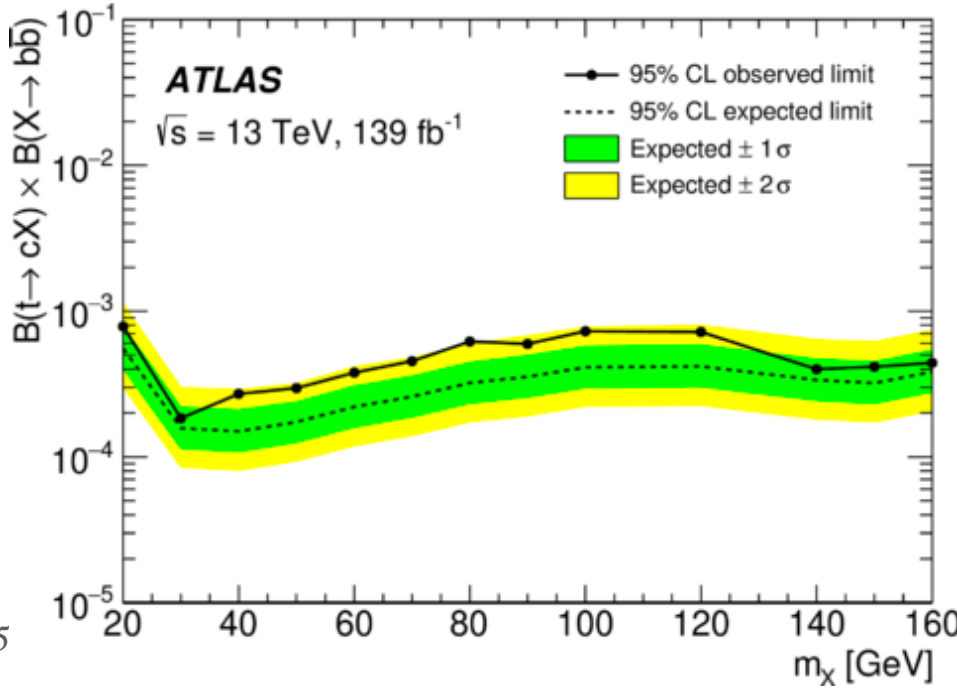


FCNC t→qX, X→bb

JHEP 07 (2023) 199

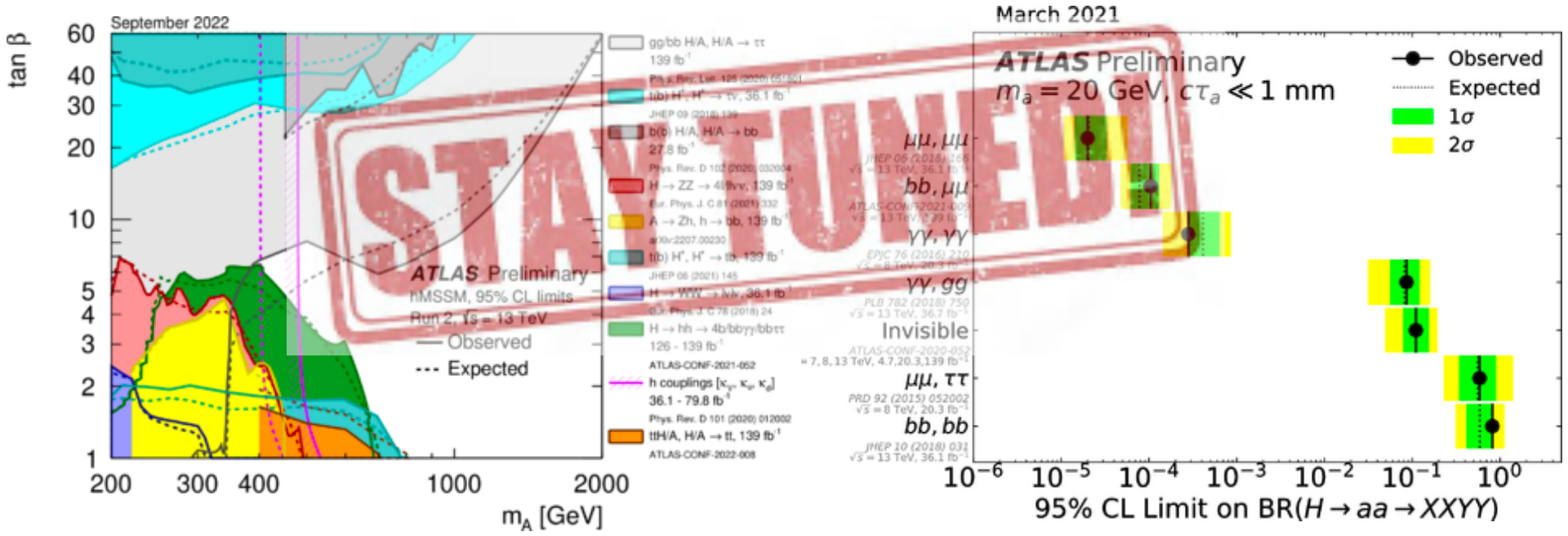
- Upper limits on the BR are set at the 95% CLs:
  - B($t \rightarrow uX$): 0.019% - 0.062%.
  - B($t \rightarrow u$H): 0.077%.
- Upper limits on the BR are set at the 95% CLs:
  - B($t \rightarrow cX$): 0.018% - 0.078%.
  - B($t \rightarrow c$H): 0.12%.





Summary

- ATLAS is searching for a new physics in various production and decay modes, under different spin assumptions.
- Unfortunately, no significant deviation from the SM prediction has been observed.
- Many more exciting results to come using the full Run 2 dataset.
- Soon to have new results using Run 3 dataset….



THANK YOU
FOR YOUR ATTENTION

The LHC

- Run 2 is over with more than 150 fb^{-1} of data delivered during 2015-2018.
  - Almost 140 fb^{-1} are good for physics.