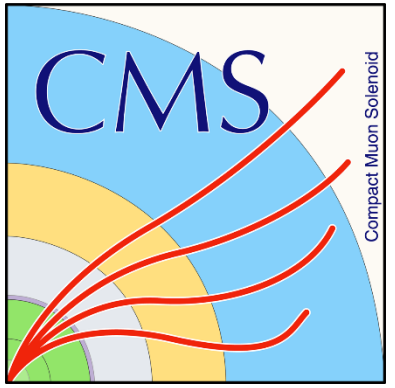
Beyond the SM Higgs physics at LHC (Direct and indirect from Higgs couplings)

- Charged Higgs
- Neutral Higgs
- Heavy resonance to HH (more see "Search for heavy resonances at the LHC" by D. Duda)



Tiesheng Dai

The University of Michigan

On behalf of the ATLAS and CMS Collaborations

Particles and Nuclei International Conference 2021

Lisbon, Portugal, Sept. 5-10 2021

Introduction

- **SM is very successful with Higgs discovery, data agree with the SM predictions**
- **But some big questions are not explained:**
  - What are the origins of 95% energy and mass in the universe (dark matter and energy)?
  - What is the source of matter-antimatter asymmetry in our universe?
  - Hierarchy problem, why SM m_H << m_{Planck} (Grand Unification Energy) ?

- **Many theoretical models beyond the Standard Model (BSM) predict new scalars: SUSY, extra Higgs doublets …**
- **Rich phenomenology and final states to explore at the LHC**

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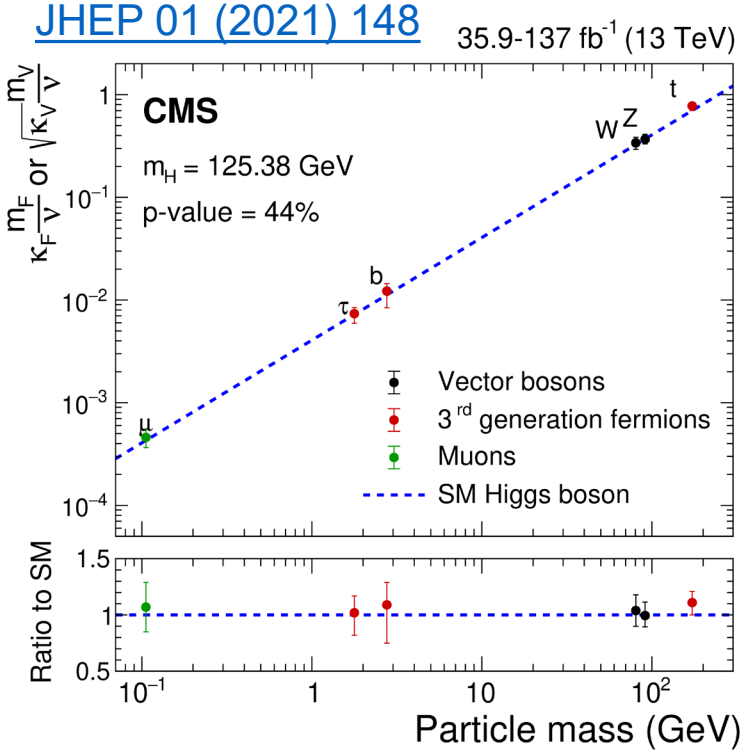

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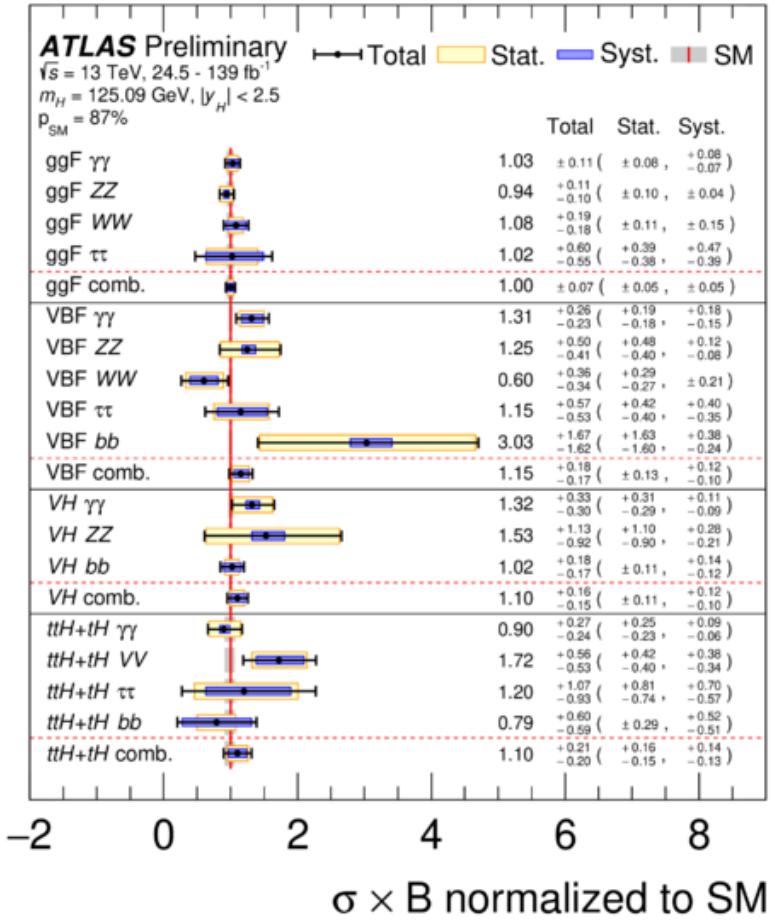


BSM Higgs Models

- **2HDM (2 Higgs Doublet Model):**
  - h(125) & H: two neutral Higgs bosons which are CP-even (scalar);
  - A: neutral Higgs boson and CP-odd (pseudo-scalar);
  - $H^{\pm}$: charged Higgs bosons
  - tanβ: the ratio of the VEV of the two Higgs doublets;
  - α: the mixing angle between the CP-even Higgs bosons

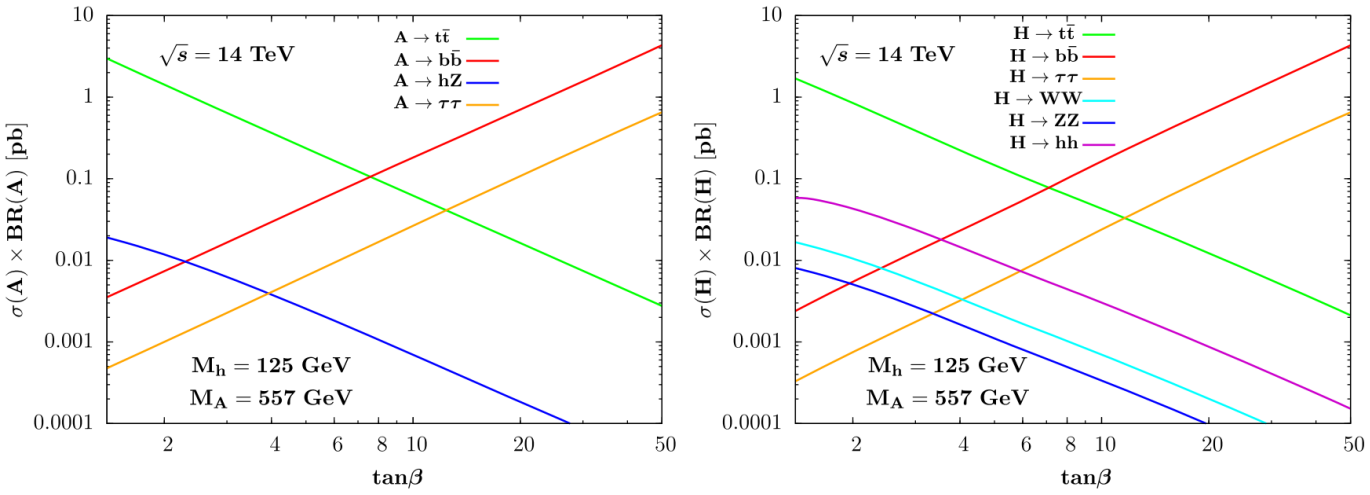
Phys. Rept. 516, 1 (2012)

Models which lead to natural flavour conservation. The superscript i is a generation index. By convention, the u_R^i always couple to Φ_2.

Model	u_R^i	d_R^i	e_R^i
Type I	Φ_2	Φ_2	Φ_2
Type II	Φ_2	Φ_1	Φ_1
Lepton-specific	Φ_2	Φ_2	Φ_1
Flipped	Φ_2	Φ_1	Φ_2

- **hMSSM (habemus Minimal Supersymmetric Standard Model) approach:**
  - From LHC:
    - SM Higgs mass M_h around 125 GeV;
    - SUSY breaking scale M_s > 1 TeV;
  - Could ignore the complicated radiative corrections on Higgs masses to simplify phenomenological analyses in the MSSM

Eur. Phys. J. C (2013) 73:2650

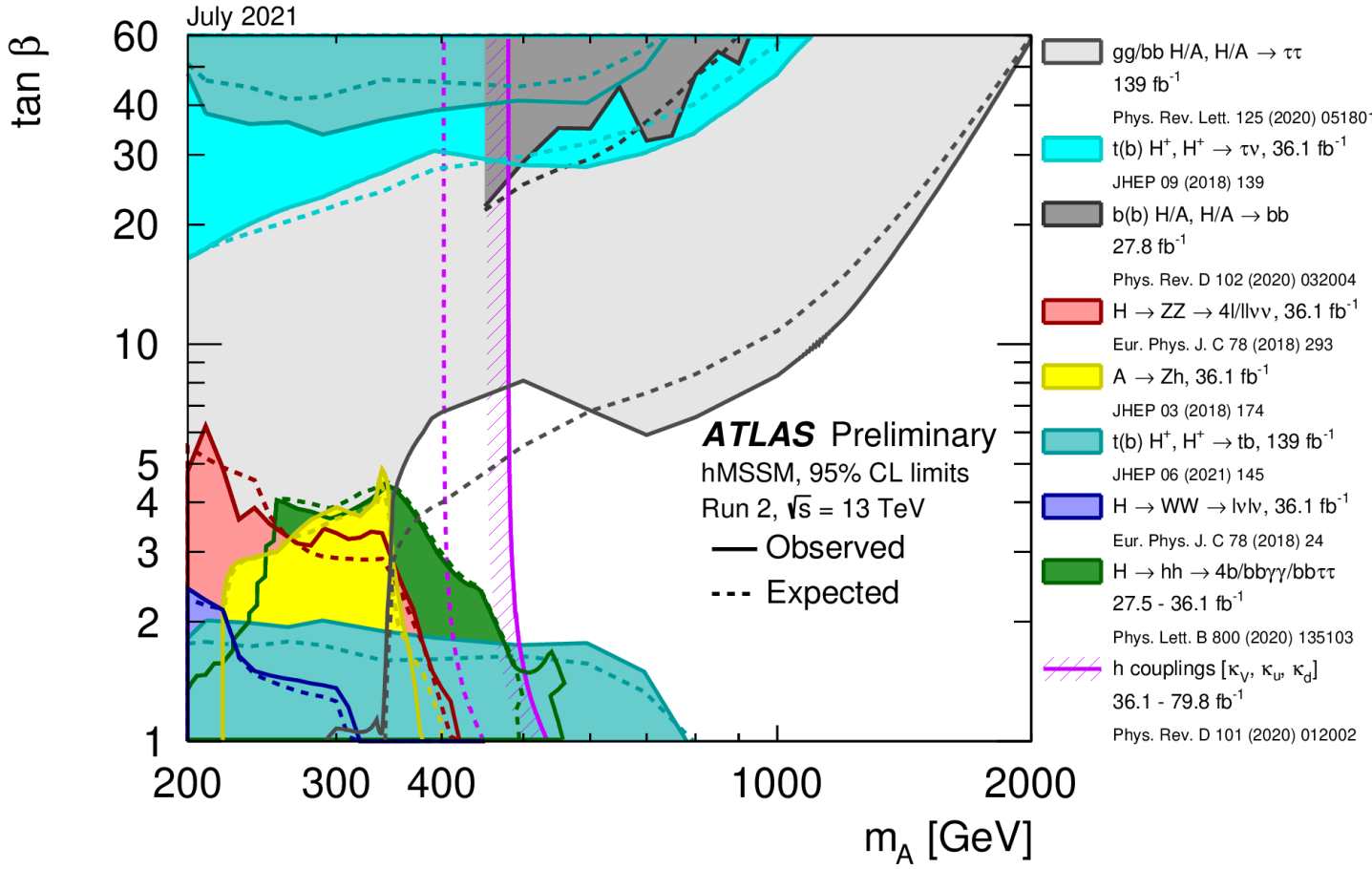


Many searches are interpreted in 2HDM with listed parameters, and also interpreted in hMSSM

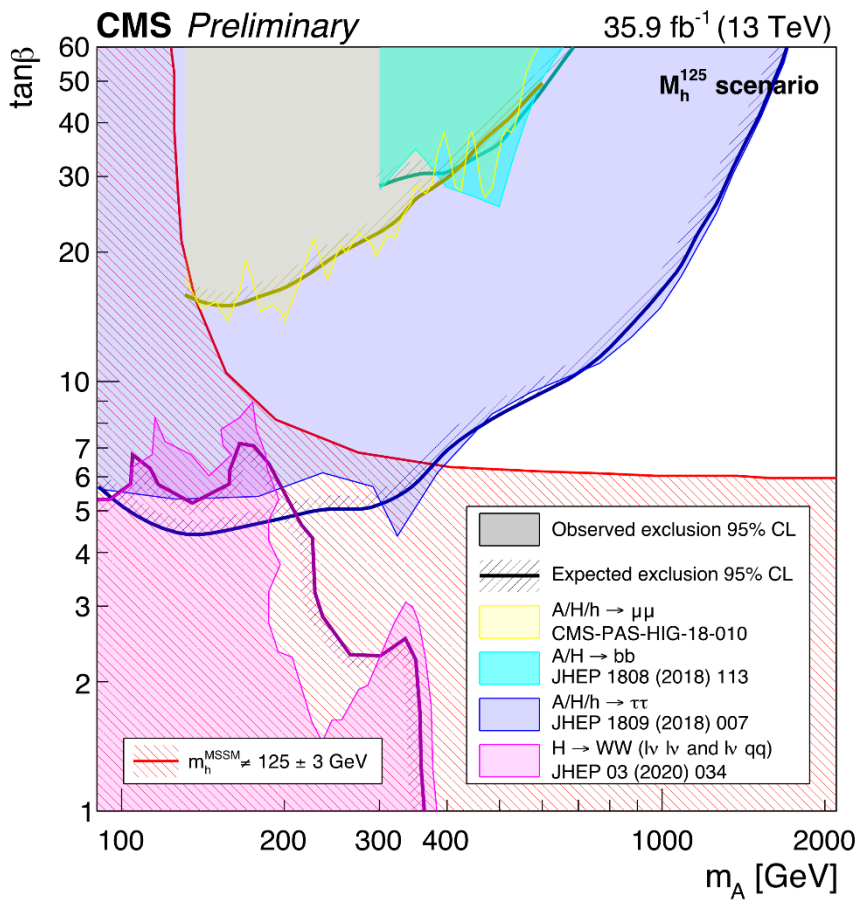
Direct BSM Higgs Searches

- Both ATLAS and CSM explored signals in hMSSM and different M_h^{125} MSSM scenarios;
- Heavy Higgs ***complementary*** searches with its many possible decay channels;
- Excluded large parameter space in several MSSM models, but still plenty space to explore.

ATL-PHYS-PUB-2021-030



CMS Higgs Summary Plots



Charged Higgs ($m_{H^\pm} > m_t$) $H^\pm \rightarrow tb$

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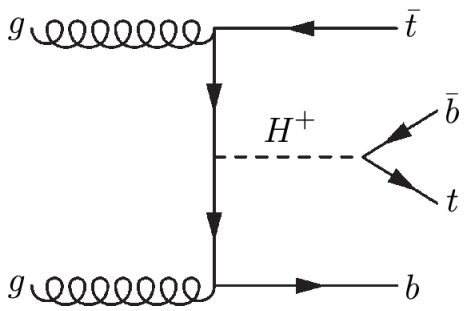
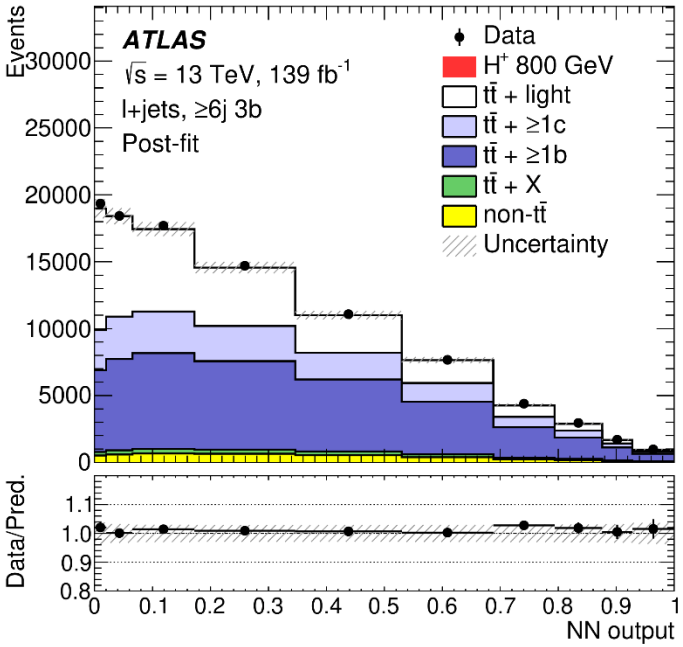
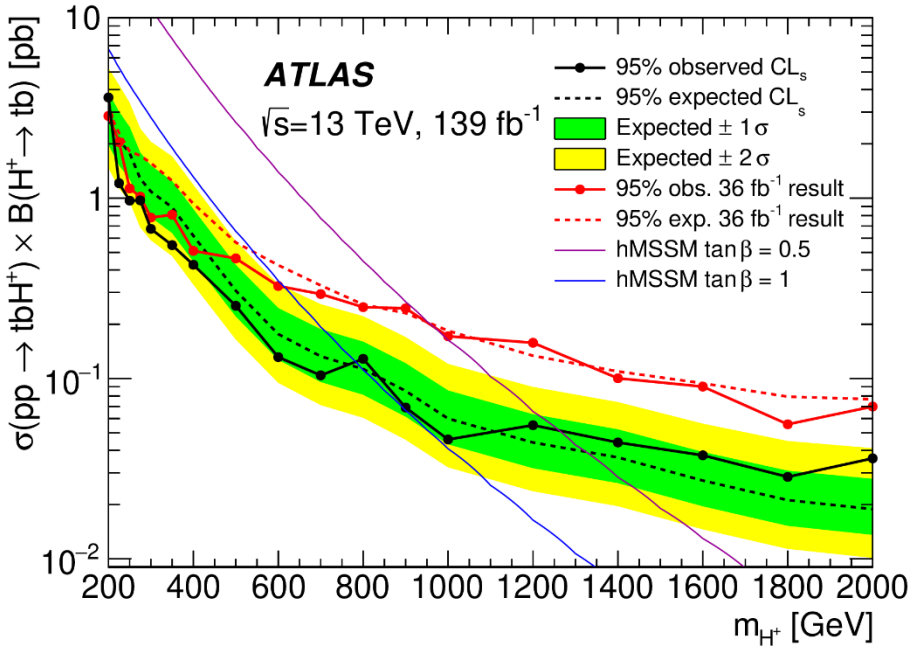
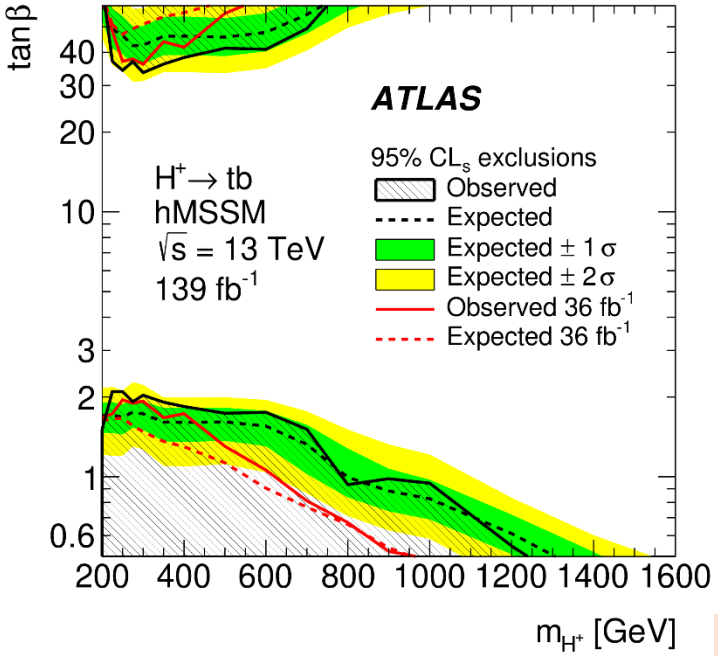


- **Charged Higgs bosons produced in association with a top and a bottom quarks;**
- Events selected with 1 e/μ, categorise them according to number of jets and b-jets;
- Major backgrounds dominated by tt+jets (MC simul. but corrected from data).

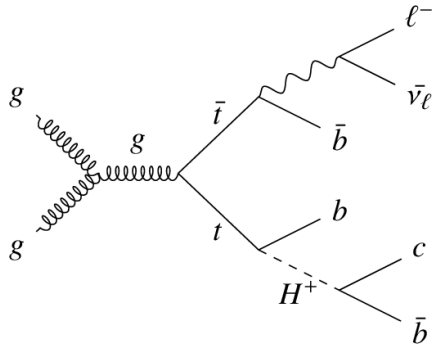
- A Neural Network (NN) is used to discriminate between signal and backgrounds;
- Signals extracted from a simultaneous binned maximum-likelihood fit to the data on the NN output distributions in the four analysis regions, **no significant excess over background observed in data, new upper limits are set on cross sections and the hMSSM parameter space**







Light Charged Higgs ($m_{H^\pm} < m_t$): $H^\pm \to cs$/$H^\pm \to cb$

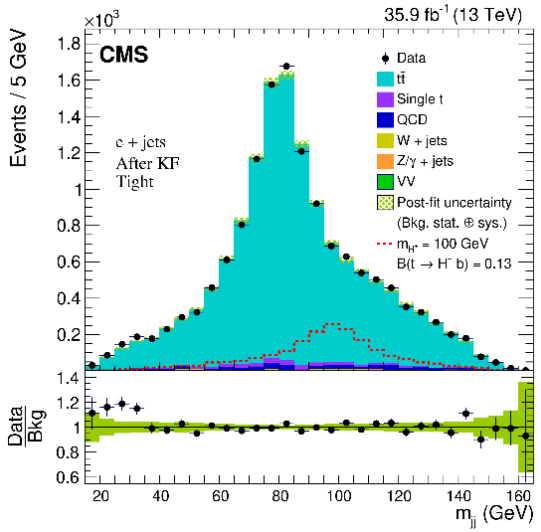


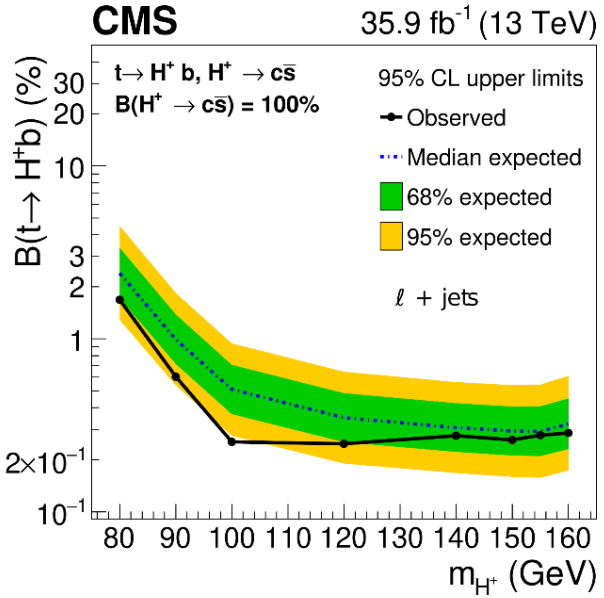
- **Type-II 2HDM or 3HDM : top pair production with one t → H^+b (CMS: $H^+ \to cs$; ATLAS: $H^+ \to cb$), another t → W^-b;**
- **Signature: 1 lep (e, μ) + missing energy, at least 4-jets (CMS: 2 b-jets & 1 c-jet; ATLAS: 3 b-jets);**

- The signal extraction from a binned maximum likelihood fit to the final discriminant m_{jj} for **CMS** and NN on 3 SRs and 6 CRs for **ATLAS**

CMS: No significant excess beyond SM predictions ➔ an upper limit in the range 1.68–0.25% on Br(t → H^+b) for a charged m(H^+) between 80 and 160 GeV.

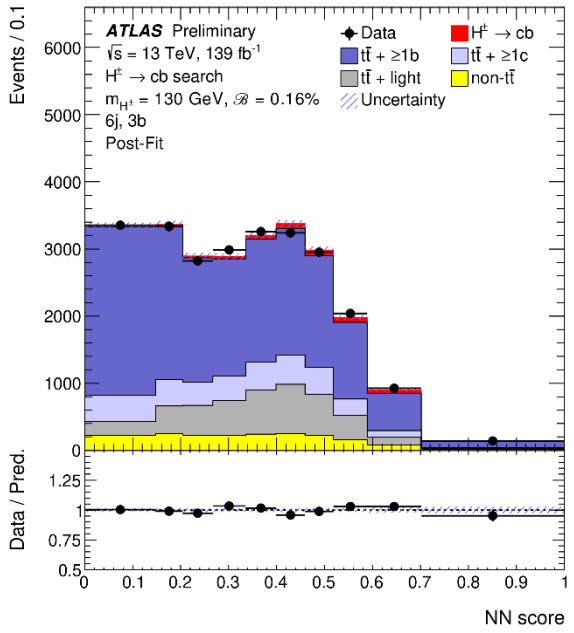
Phys. Rev. D 102, 072001 (2020)



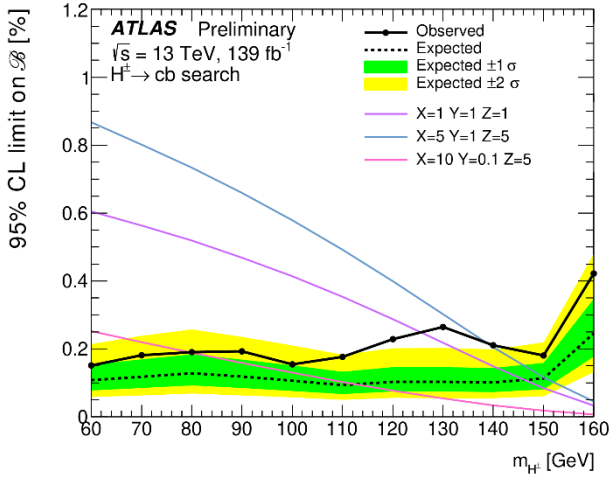


ATLAS: excess at m_{H^+} = 130 GeV, with local(global) significance of 3σ(2σ)

ATLAS-CONF-2021-037

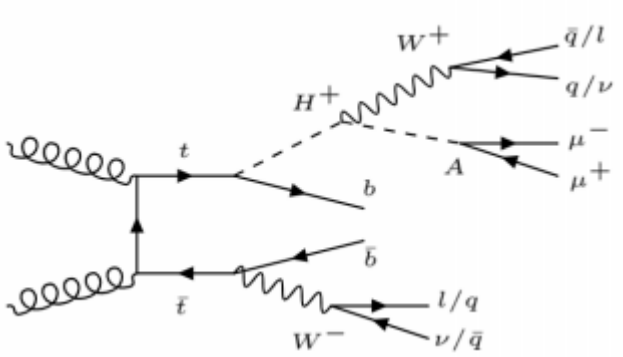


Upper limits on B = B(t → H±b) × B(H± → cb) @95 CL

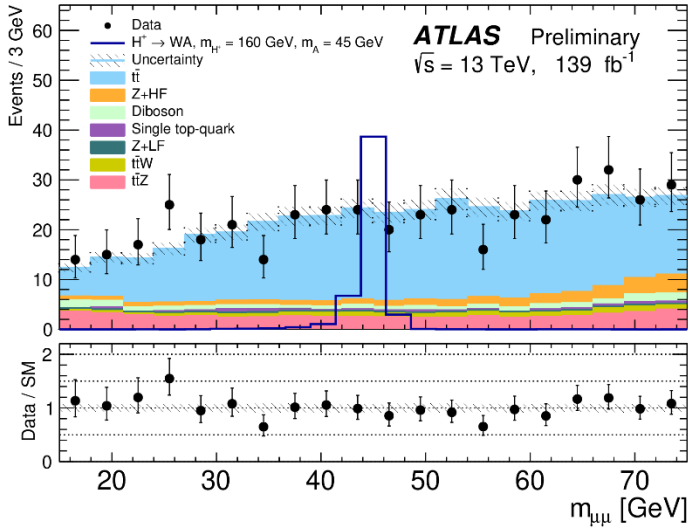


Light Charged/Neutral Higgs $H^{\pm} \rightarrow AW^{\pm} \rightarrow \mu\mu W^{\pm}$

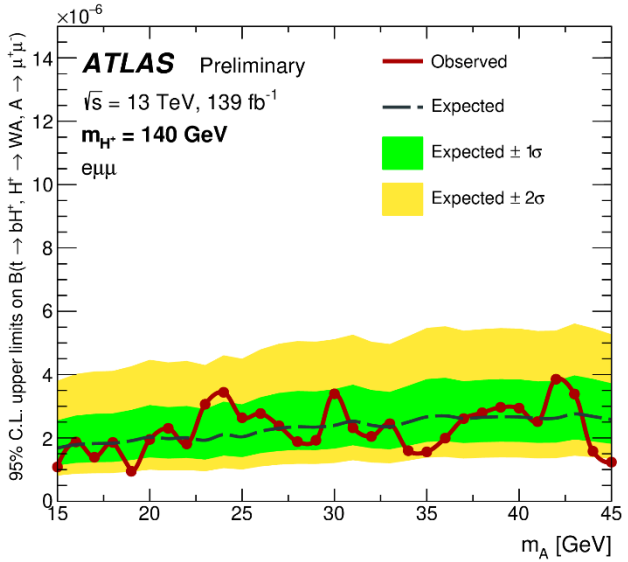
ATLAS-CONF-2021-047

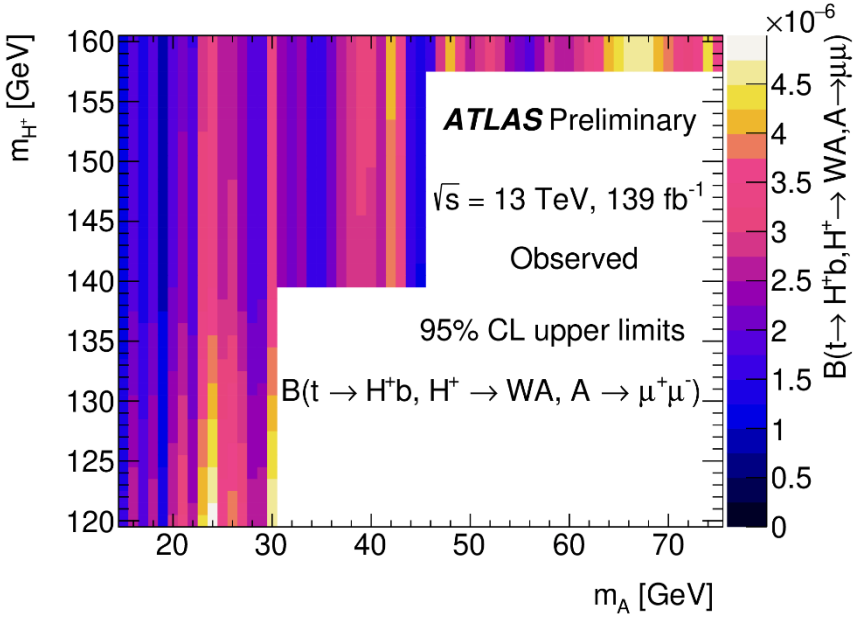


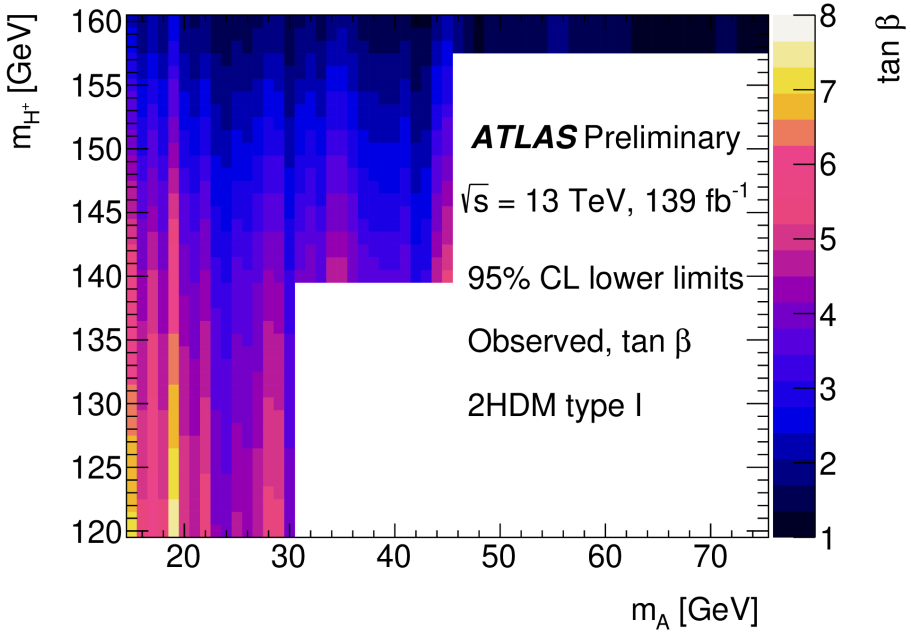
- **Type-I 2HDM charged Higgs from top decaying to a pseudoscalar Higgs(A) and a W;**
- Events: $\mu^+\mu^-$, 1 e, $\geq$ 3 jets & $\geq$ 1 b-jet;
- Major BKGs tt, ttZ, Z+HF estimated by fitting 3 corresponding data CRs with MC templates, & validated using VR.



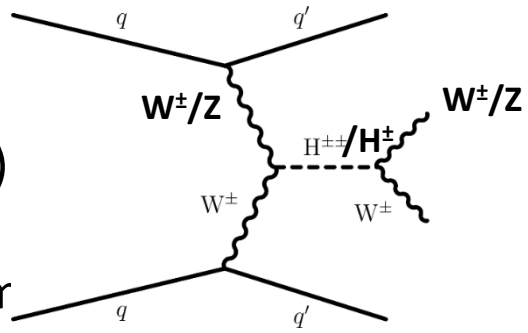
- No signal observation on Signal Strength μ_{sig} of each pseudoscalar Higgs (A) mass point by the profile likelihood ratio from signal + BKG fit on $m_{\mu\mu}$ ➔ type-I 2HDM limits of $B(t \rightarrow bH^{\pm}, H^{\pm} \rightarrow W^{\pm}A, A \rightarrow \mu^+\mu^-)$ obs.(exp.) 0.9 (1.6)×10^{-6} to 6.9 (9.9)×10^{-6}.
- Explored 2HDM parameter spaces with upper/lower limits at 95% CL.







Charged Higgs $H^{\pm}/H^{\pm\pm} \rightarrow W^{\pm}Z/W^{\pm}W^{\pm}$



- Georgi–Machacek (GM) model for charged and doubly charged Higgs produced via VBF;
- Events from vector boson leptonic decay modes ➔ two isolated same-sign leptons (SS 2ℓ) or three isolated lepton (3ℓ) with two VBF jets;
- Major BKGs: vector boson pairs (WZ and WW from MC simul.) and nonprompt lepton from HV decays and mis-identification (estimated from data);
- Signal extraction using binned max. likelihood fit using the VV transverse mass m_T and dijet invariant mass m_{jj} distributions.

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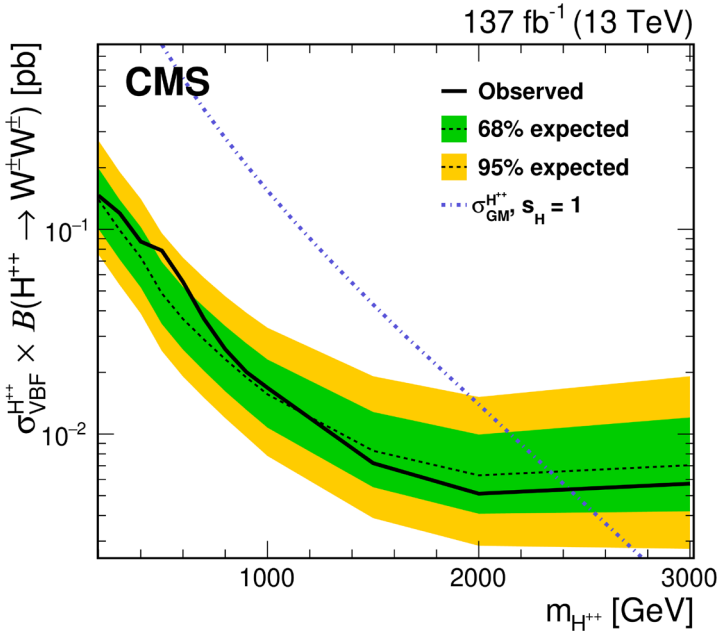
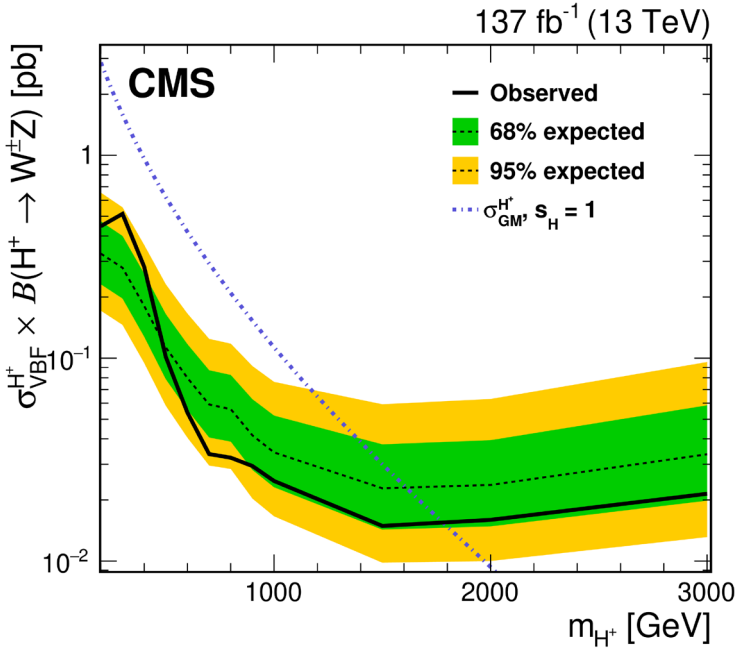
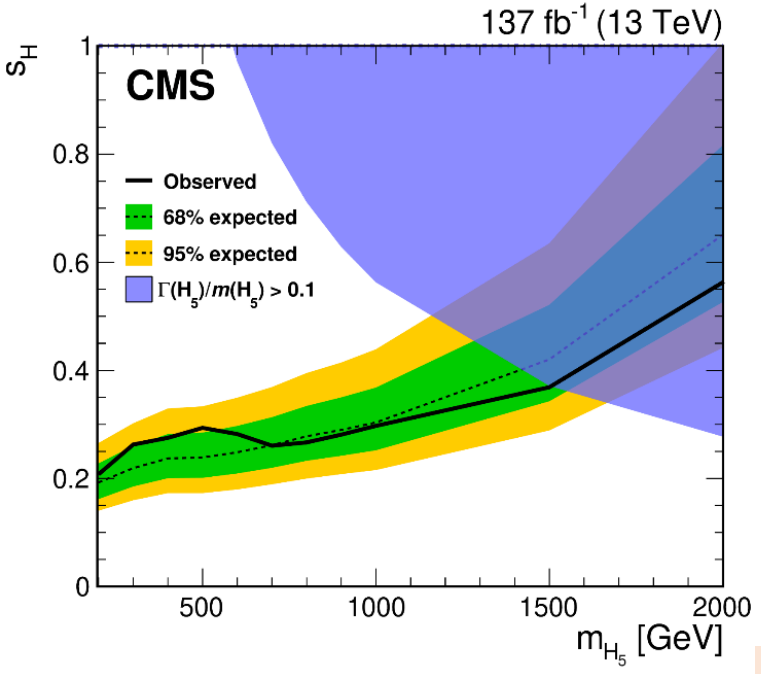
➔ **Excluded GM S_H parameter values > 0.20–0.35 for the mass range from 200 to 1500 GeV at 95% CL!**







Double Charged Higgs $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$

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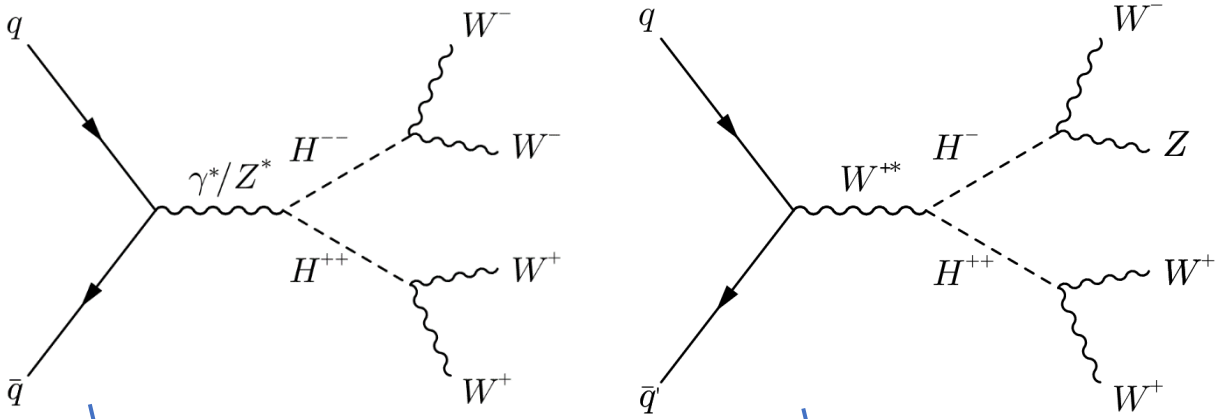
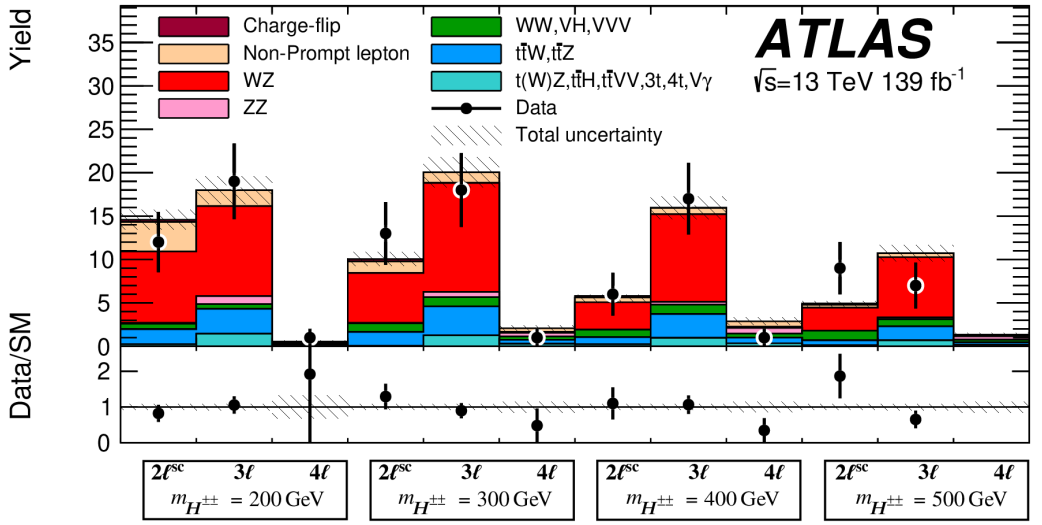
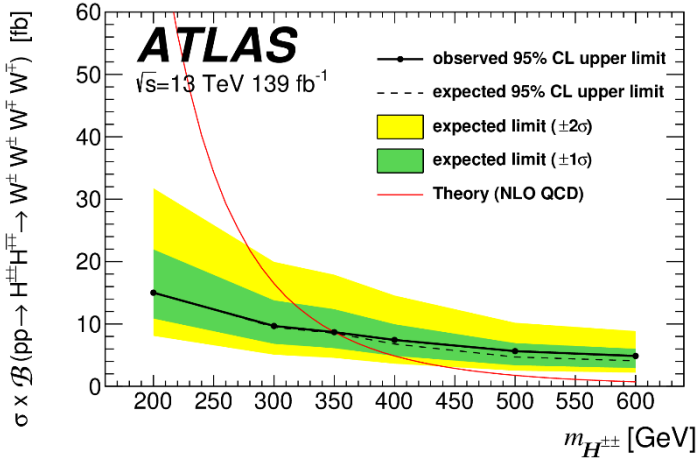


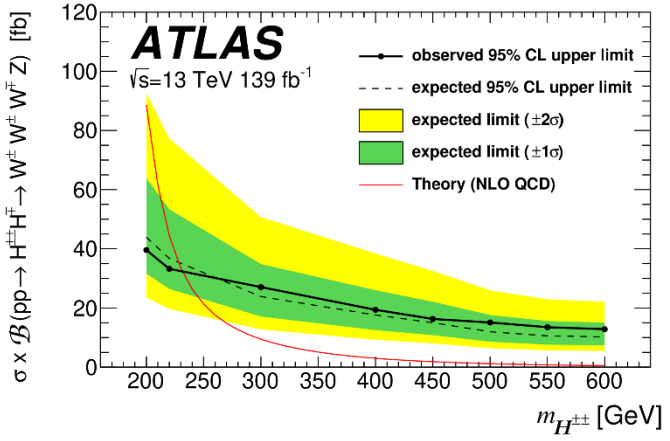


$m_{H^{\pm}} - m_{H^{\pm\pm}} >= 100$GeV



Excluded $H^{\pm\pm}$ boson masses below 350 GeV @95 CL;

$|m_{H^{\pm}} - m_{H^{\pm\pm}}| <= 5$ GeV



Excluded $H^{\pm\pm}$ boson masses below 230 GeV @95 CL;

- **Type-II seesaw model ➔ pair productions of $H^{++}H^{--}$ and $H^{++}H^{-}$/ $H^{--}H^{+}$;**
- Signatures: 2 same charge leptons, or three or four leptons with a variety of charge combinations, missing transverse momentum and jets.

Heavy Neutral Higgs A → ZH

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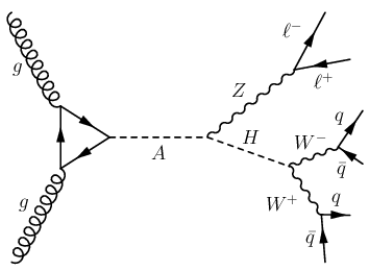
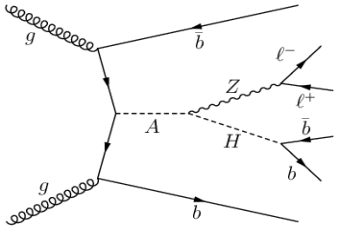
gluon Fusion (ggF) **b-associated prod. (bbA)**

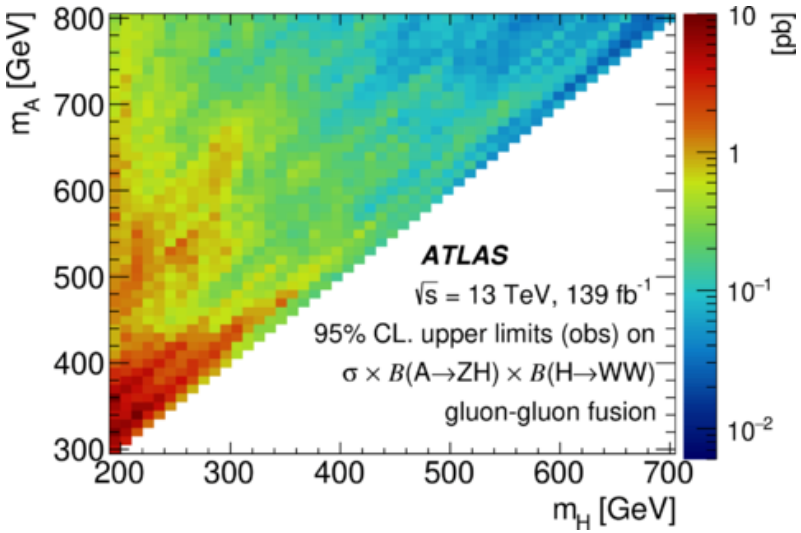


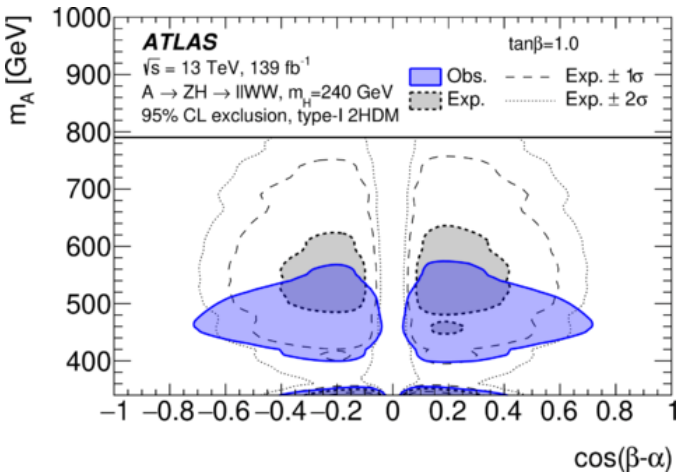


- Analysis on ℓℓbb (H→bb) from ggF and bbA to **explore the weak decoupling limit** while ℓℓWW→ℓℓ4q (H→WW) from ggF **for the vicinity of the weak decoupling limit**;

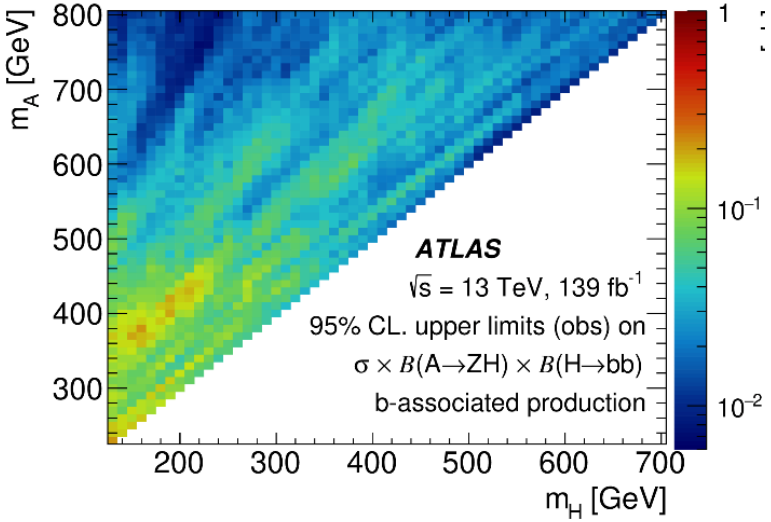
- Events: a Z candidate with $m_{\ell\ell}$ from 80 to 100 GeV, 2 b-jets or >= 3 b-jets or >= 4 jets depending on analysis;
- No significant access ➔ upper limits on σxBr(A→ZH)xBr(H→decays) @95 CL with different Higgs width;
- Interpreted the results in 2HDM parameter spaces from different models (type-I, type-II, lepton-specific & flipped).

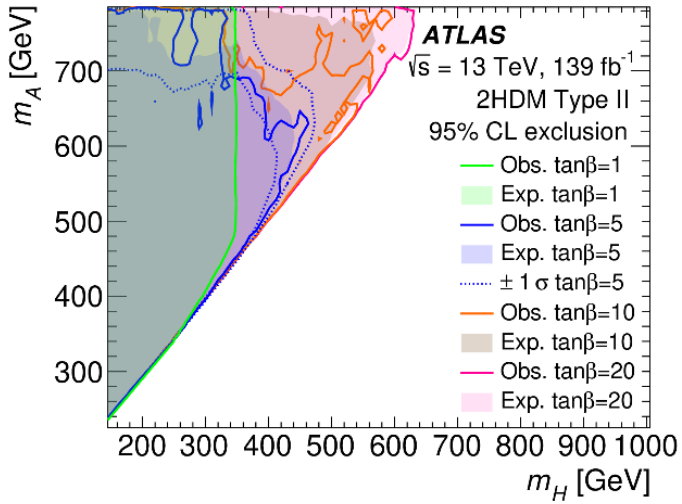
From ℓℓ4q (H→WW)





from ℓℓbb (H→bb)

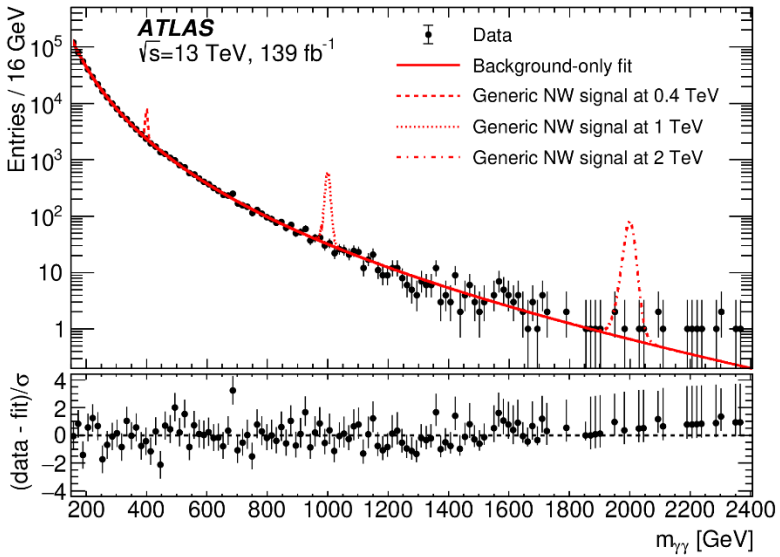


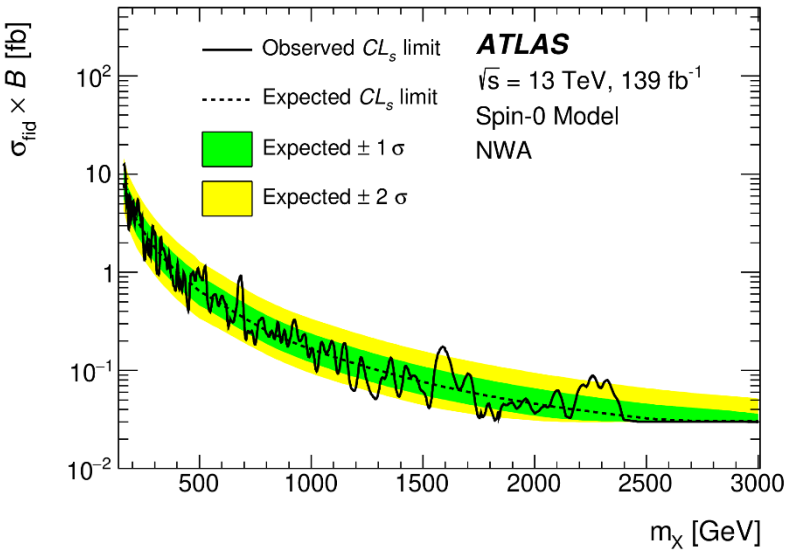


Heavy Neutral Higgs

❖ H → γγ [arXiv:2102.13405]

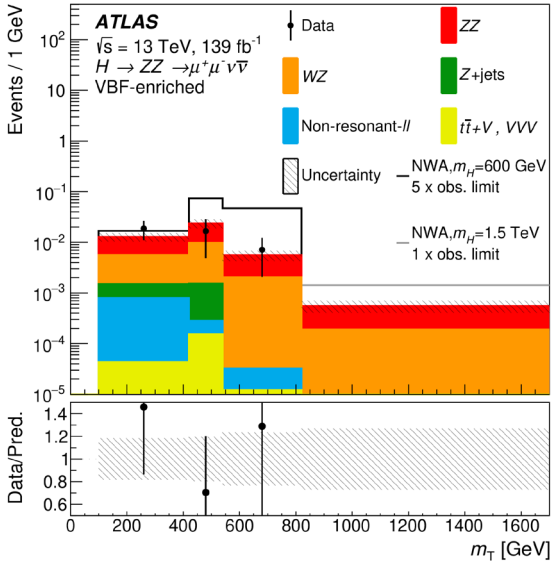
- Signals: narrow width approximation (NWA) modeled by a double-sided Crystal Ball function (DSCB);
- BKG template by using $\gamma\gamma$ MC events and obtained by fitting to γ+jet events from data of control region;

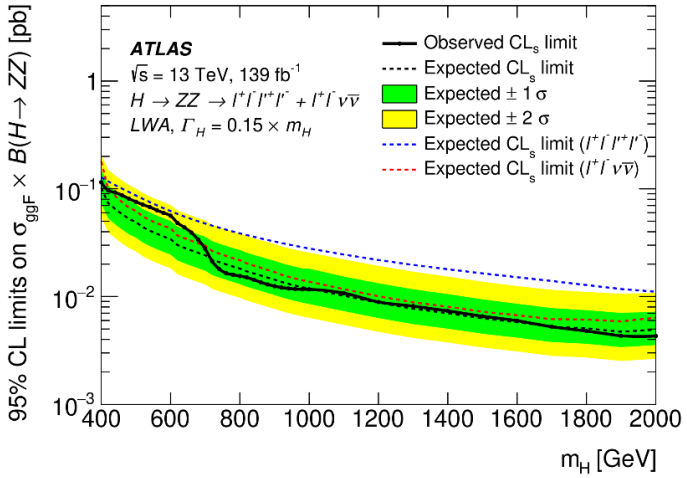


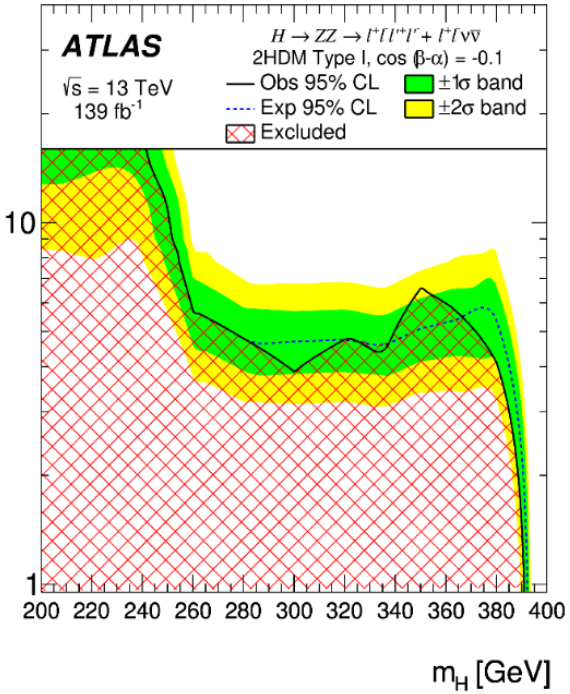


❖ H → ZZ → 4ℓ or 2ℓ 2ν [Eur. Phys. J. C 81 (2021) 332]

- Two classifiers (ggF & VBF) of Deep neural networks (DNN) to improve the sensitivity of NWA Higgs;
- **No signification deviation from SM predictions →** upper limits on σxBr(H→ZZ) with different Higgs widths & on type-I/type-II 2HDM parameter spaces @95% CL.

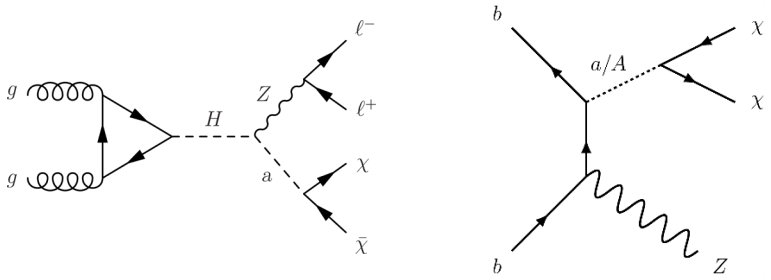






Heavy Neutral Higgs A → Za → ℓℓχχ & ZA → ℓℓχχ

- **2HDM+a: H→Za (Z→ℓℓ & a→χχ) & bb→Za/A ((Z→ℓℓ & a/A→χχ)**
- **Events: $m_{\ell\ell}$ compatible to m_Z & large missing energy/p_T & M_T**



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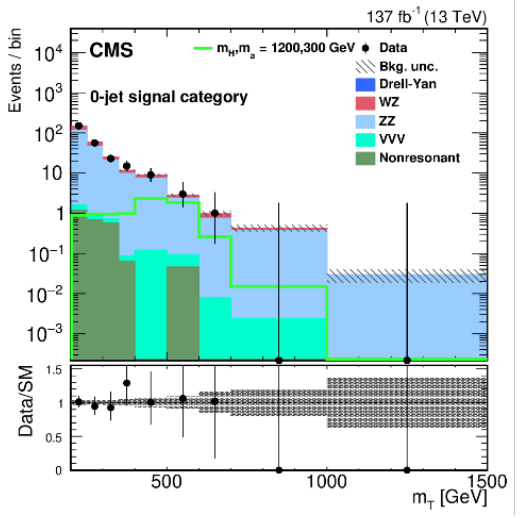
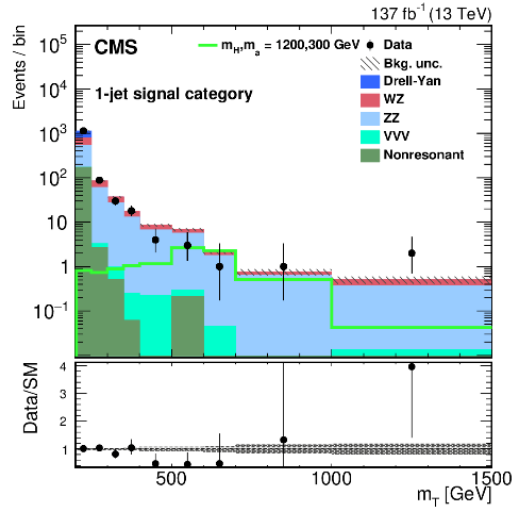
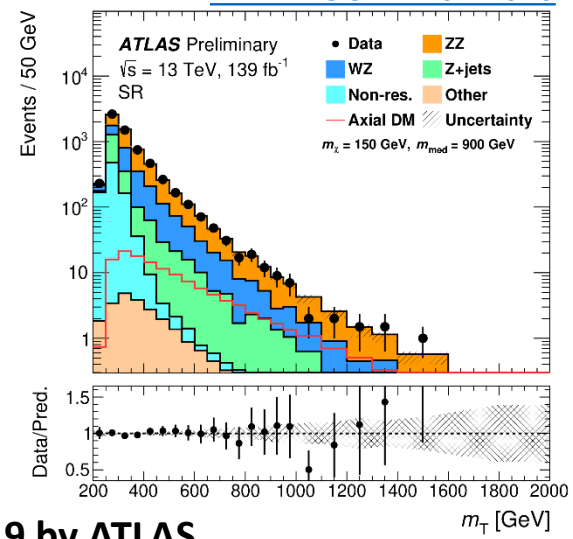


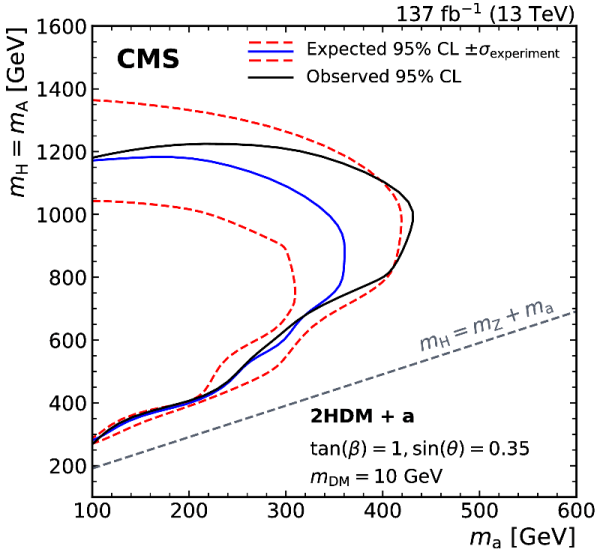


ATLAS-CONF-2021-029

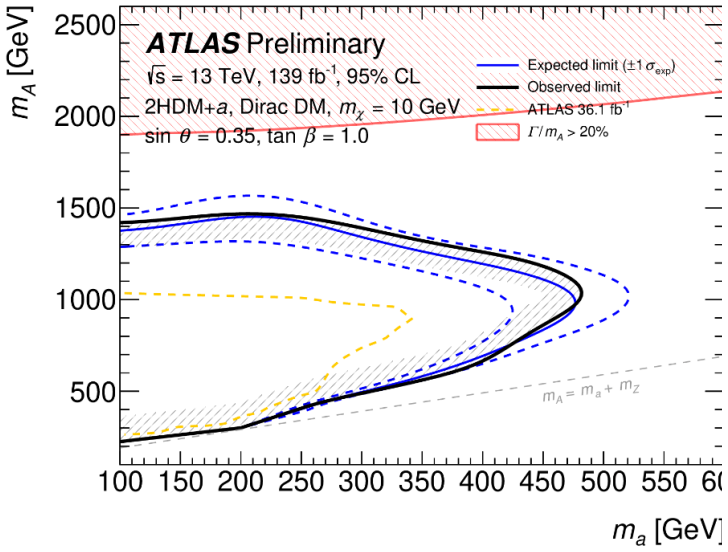


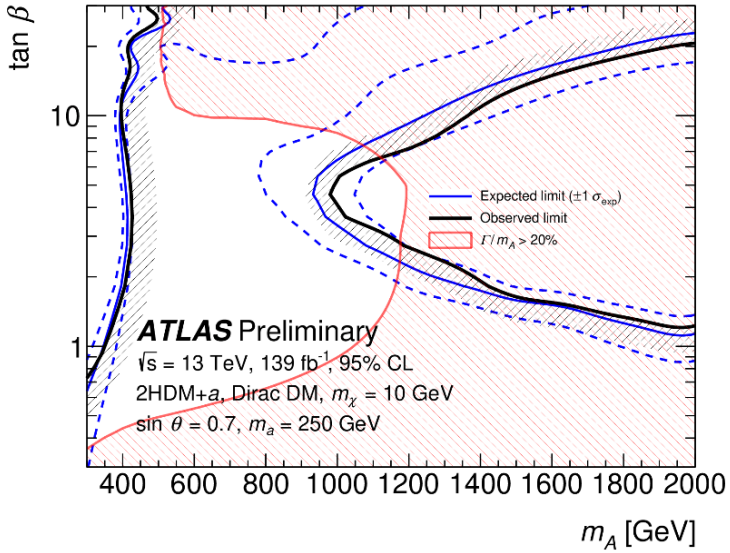
- **BKGs from MC, Z-jet BKG cross-checked from a sample of γ + jets events with missing E_T significant < 9 by ATLAS**
- **Signals extracted by simultaneous binned maximum-likelihood fit to M_T distributions on SRs & CRs**

Eur. Phys. J. C 81 (2021) 13



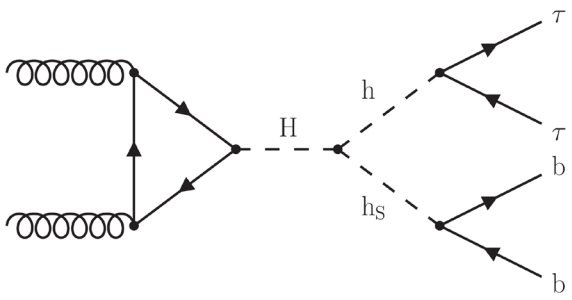
ATLAS-CONF-2021-029

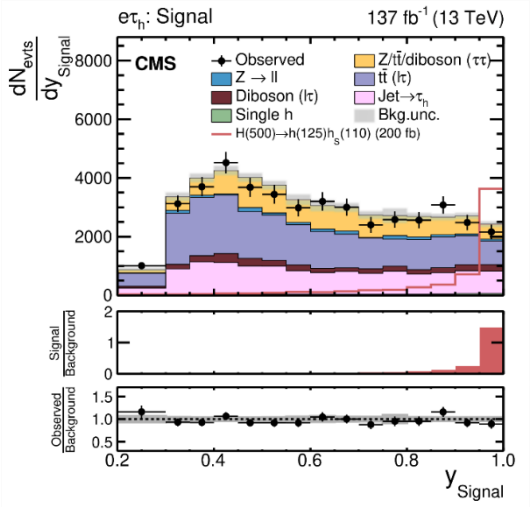




Heavy Neutral Higgs H→h(125)h_s→ττbb

arXiv:2106.10361

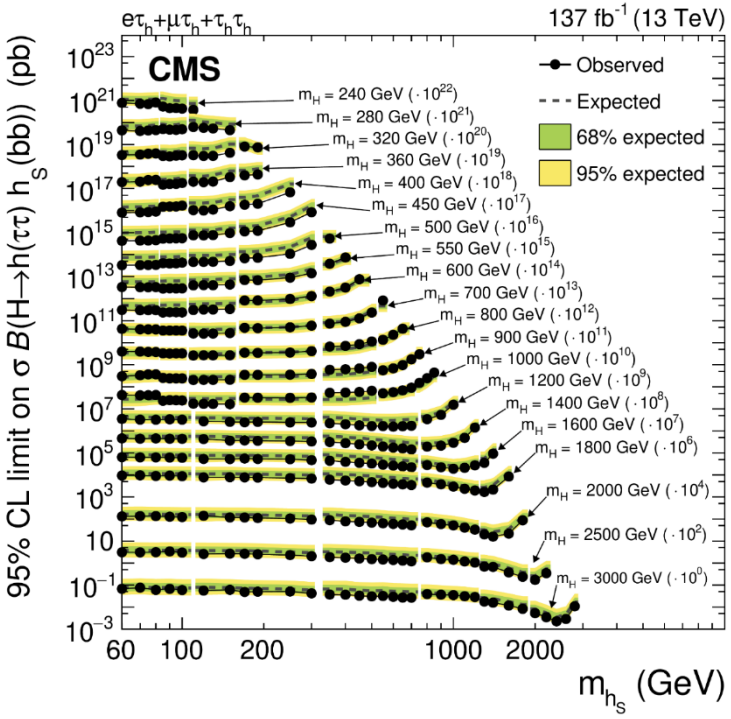


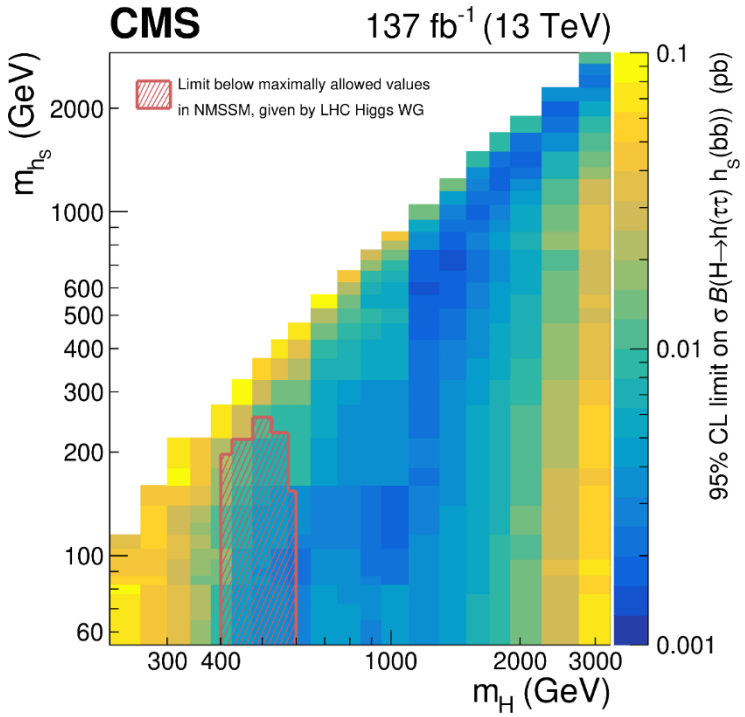


- **First search** with a heavy Higgs boson decaying into SM h(125) and another neutral Higgs boson h_s, motivated by the extended Next-MSSM Higgs sector by one more singlet field;

- Events categorized based on τ decay modes: $\tau_e\tau_h$, $\tau_\mu\tau_h$, $\tau_h\tau_h$

Upper limits are set to 125 fb (m_H = 240 GeV) to 2.7 fb (m_H = 3 TeV)



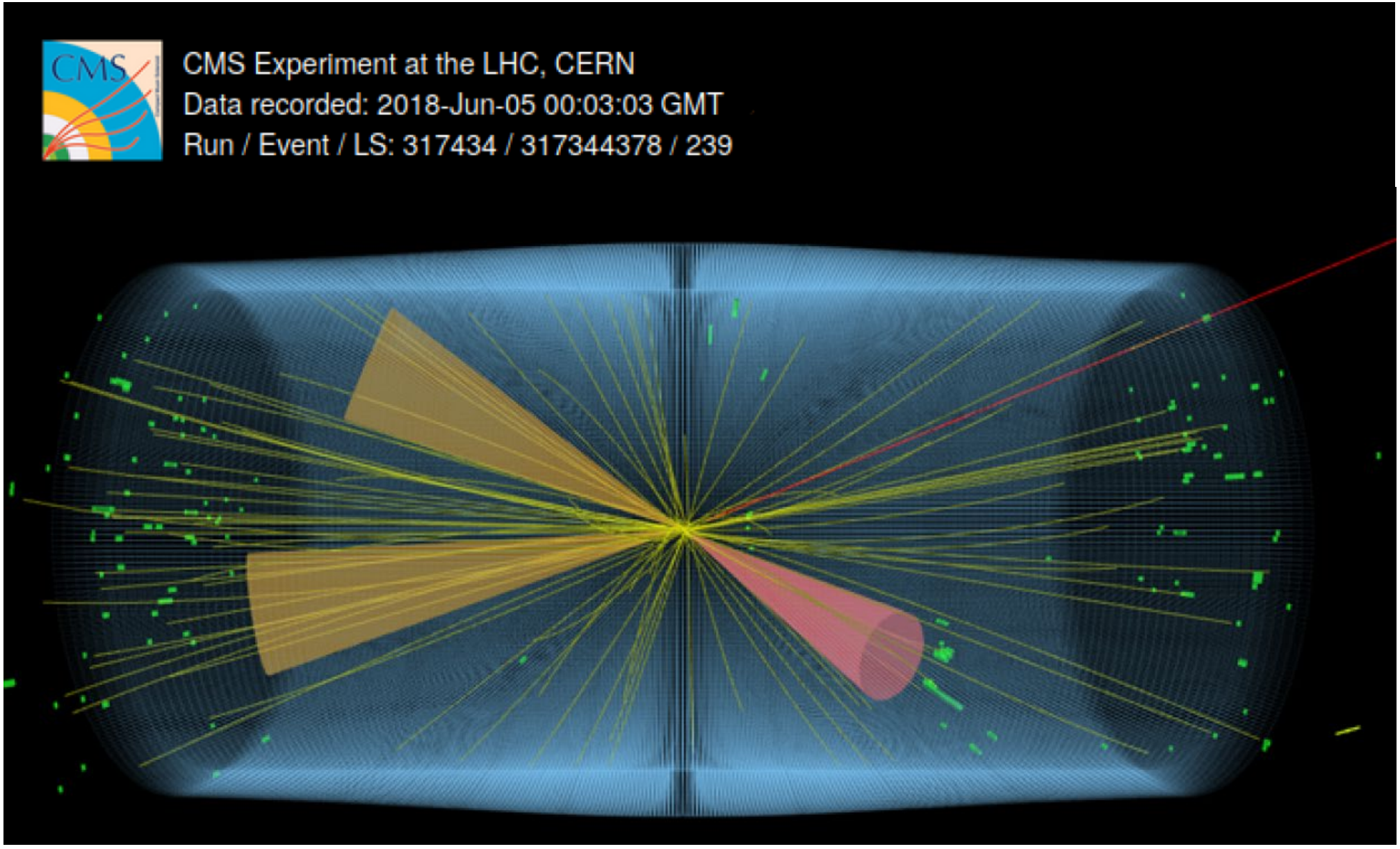


- A neural network (NN) multi-classification both for event categorization and signal extraction;

- No surprise ➔ Set 95% CL limits of σxB(H→h(ττ)h_s(bb)) in m_H, and m_H vs m_{Hs} spaces from NMSSM, where **Red hatched area: the observed limits fall below the maximally allowed values of σ B(H → h(ττ)h_s(bb))**

Heavy neutral Higgs H→h(125)h_S→ττbb (Event Display)

arXiv:2106.10361



$\tau_\mu\tau_h$ final state;

y_{Signal}=0.70

Orange cones: b-jets;

μ red line;

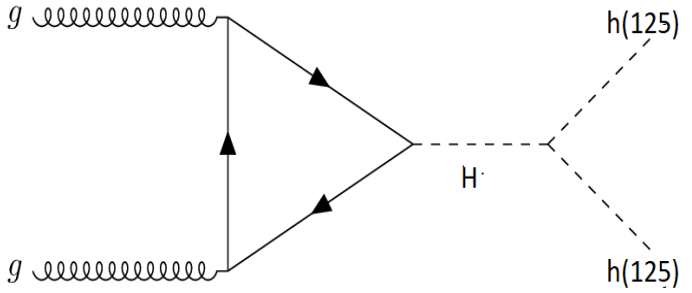
τ_h red cone;

Heavy Neutral Higgs H→h(125)h(125)→bbγγ [ATLAS-CONF-2021-016]

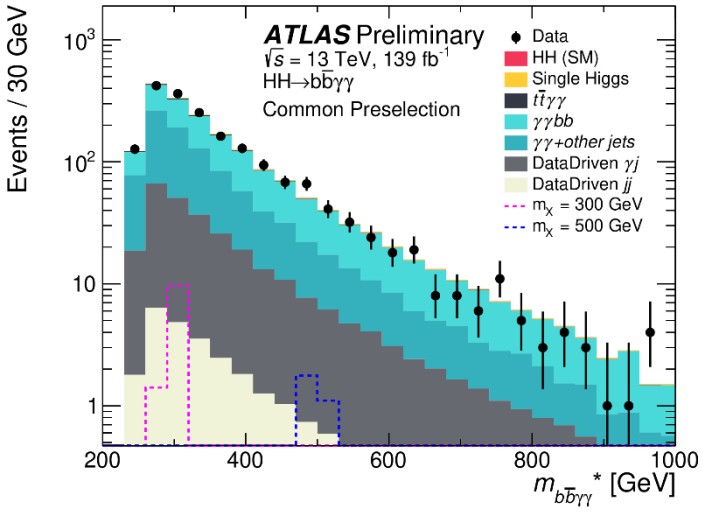
- **Search for a narrow-width CP-even scalar particle H;**
- **$BDT_{\gamma\gamma}$ & $BDT_{SingleH}$ for better separation the signal from BKGs;**
- **Combined BDT score is used to select events**

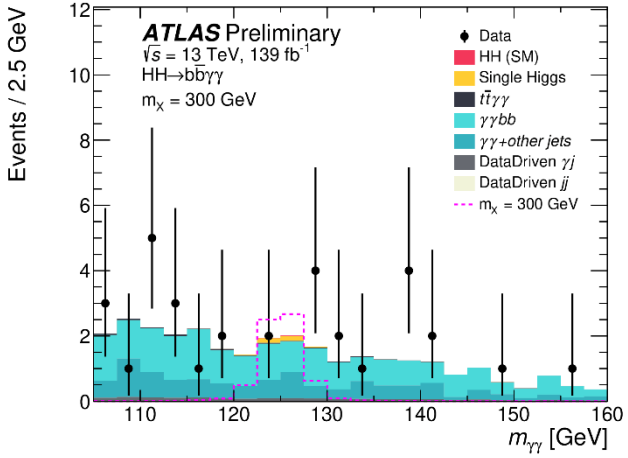
$$BDT_{tot} = \frac{1}{\sqrt{C_1^2 + C_2^2}} \sqrt{C_1^2 \left(\frac{BDT_{\gamma\gamma} + 1}{2}\right)^2 + C_2^2 \left(\frac{BDT_{SingleH} + 1}{2}\right)^2}$$

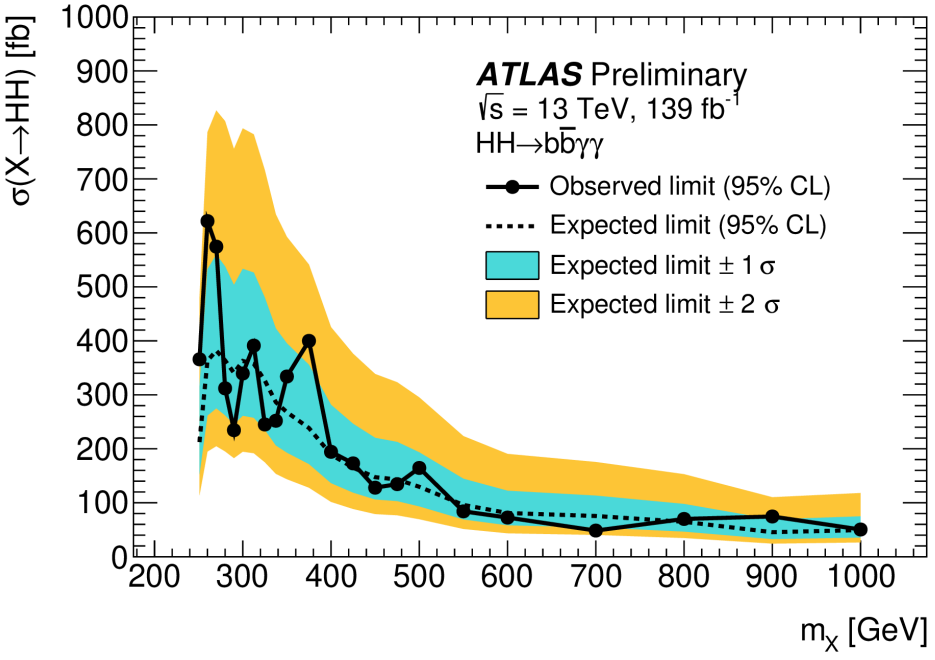
Coefficients C_2=1-C_1



- **Major BKGs: γγbb, γγ+others;**
- **Signal extraction from $m_{\gamma\gamma}$**

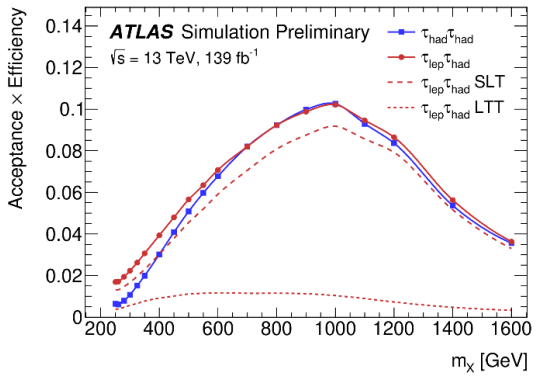


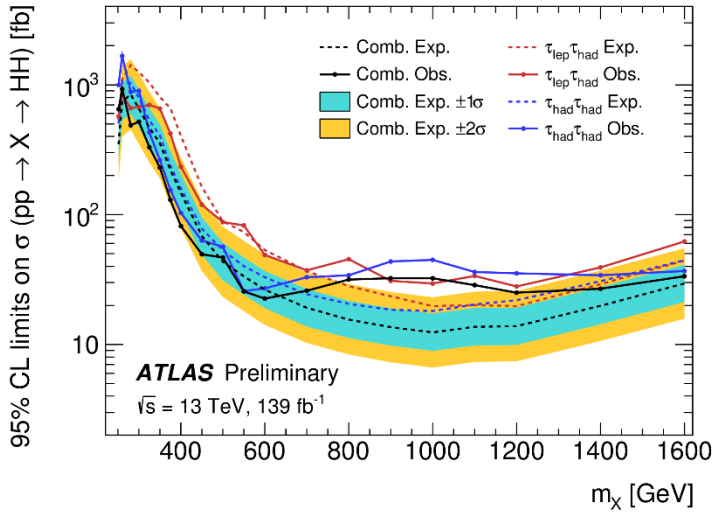




H→h(125)h(125)→bbττ ATLAS-CONF-2021-030

- Events categorized into $\tau_{lep}\tau_{had}$ & $\tau_{had}\tau_{had}$:
- BKGs: Top, Z+HF jets (MC simu.), QCD (data driven);
- Parameterized neural networks (PNNs) for hh narrow resonant searches;
- **Simultaneous binned maximum-likelihood fit to the MVA output distributions in 3 SRs and $m_{\ell\ell}$ in Z+HF CR**



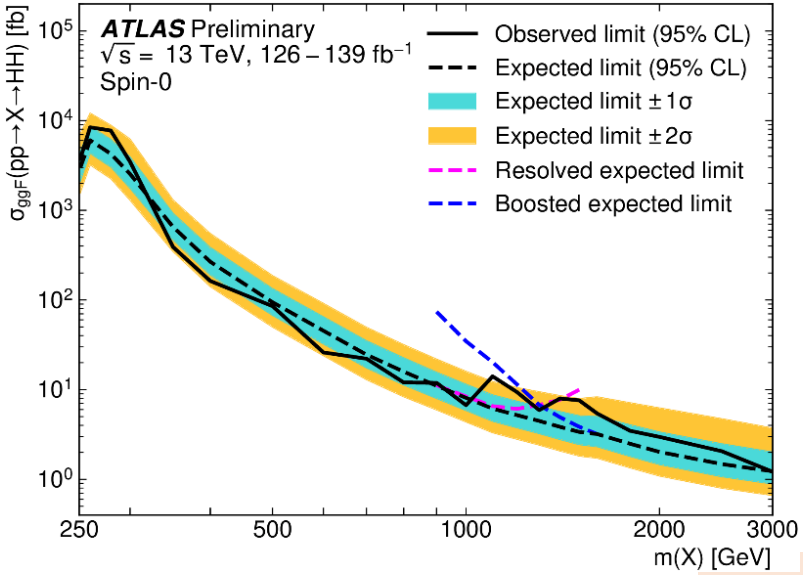


Resonance (H→hh) production cross-section limits: 23 to 920 fb depending on m_H

local (global) significance at 1 TeV: 3.0σ (2.0σ)

H→ h(125)h(125) →4b ATLAS-CONF-2021-035

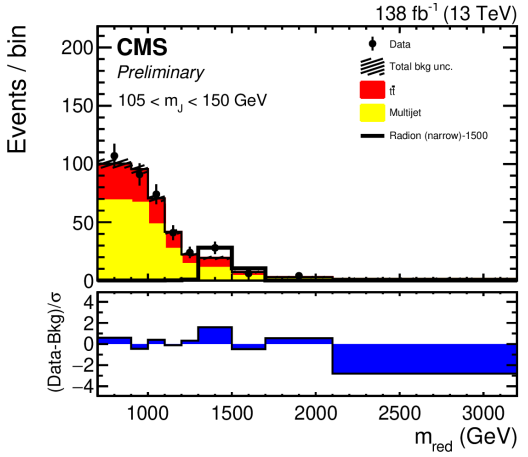
- Signals: **a generic spin-0 boson by 2HDM/MSSM;**
- SR: 4b (2b from each Higgs) and CRs: 3b (2b/1b from Higgs) and 2b (1b from each Higgs);
- BKGs: tt (MC simu.), multi-jets (data driven);
- Analysis divided into two complementary channels:
  - ✓ Resolved: 4 b-jets reconstructed;
  - ✓ Boosted: Higgs reconstructed as large-radius jet
- **Limits from simultaneous likelihood fit to m_{hh} distributions in SR only;**

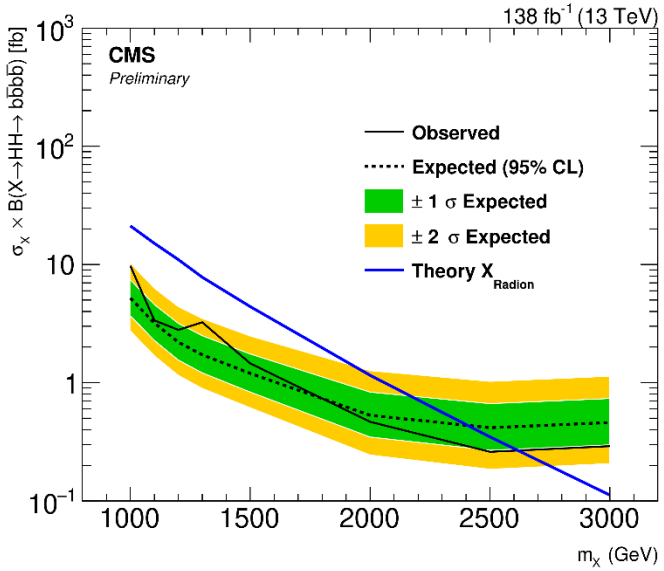


X→ h(125)h(125) →4b

CMS-PAS-B2G-20-004

- Signal: spin-0 radion of Warped Extra Dimension (WED)
- A deep neural-network-based tagger, “DeepAK8” for b-jet, increased the search sensitivity by about 2.5;
- Used the reduced mass $m_{red} = m_{jj} - (m_J - m_h) - (m_{J2} - m_h)$;
- **Results from the combination of semi-resolved and fully-merged b-jet event categories.**



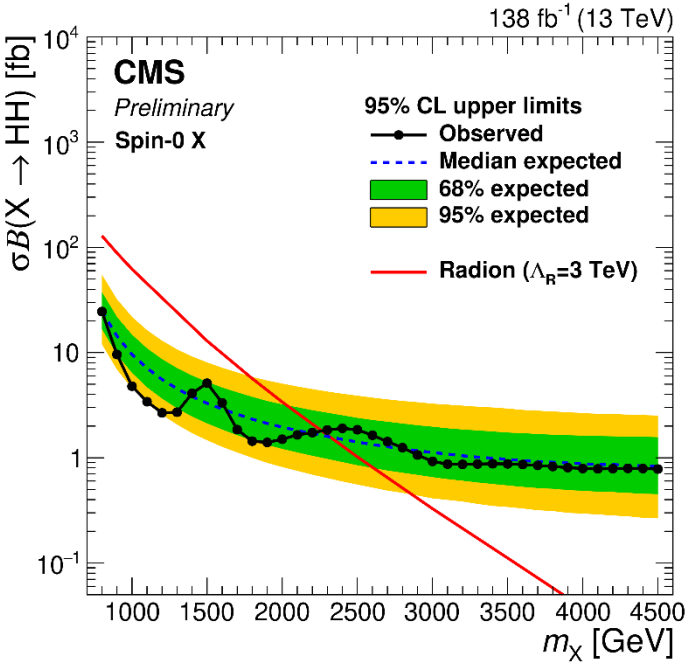


- **Limits from the combined 2-D binned likelihoods to m_J vs m_{red} distributions in SRs and CRs.**

X→ h(125)h(125) →bbWW*/ττ

CMS-PAS-B2G-20-007

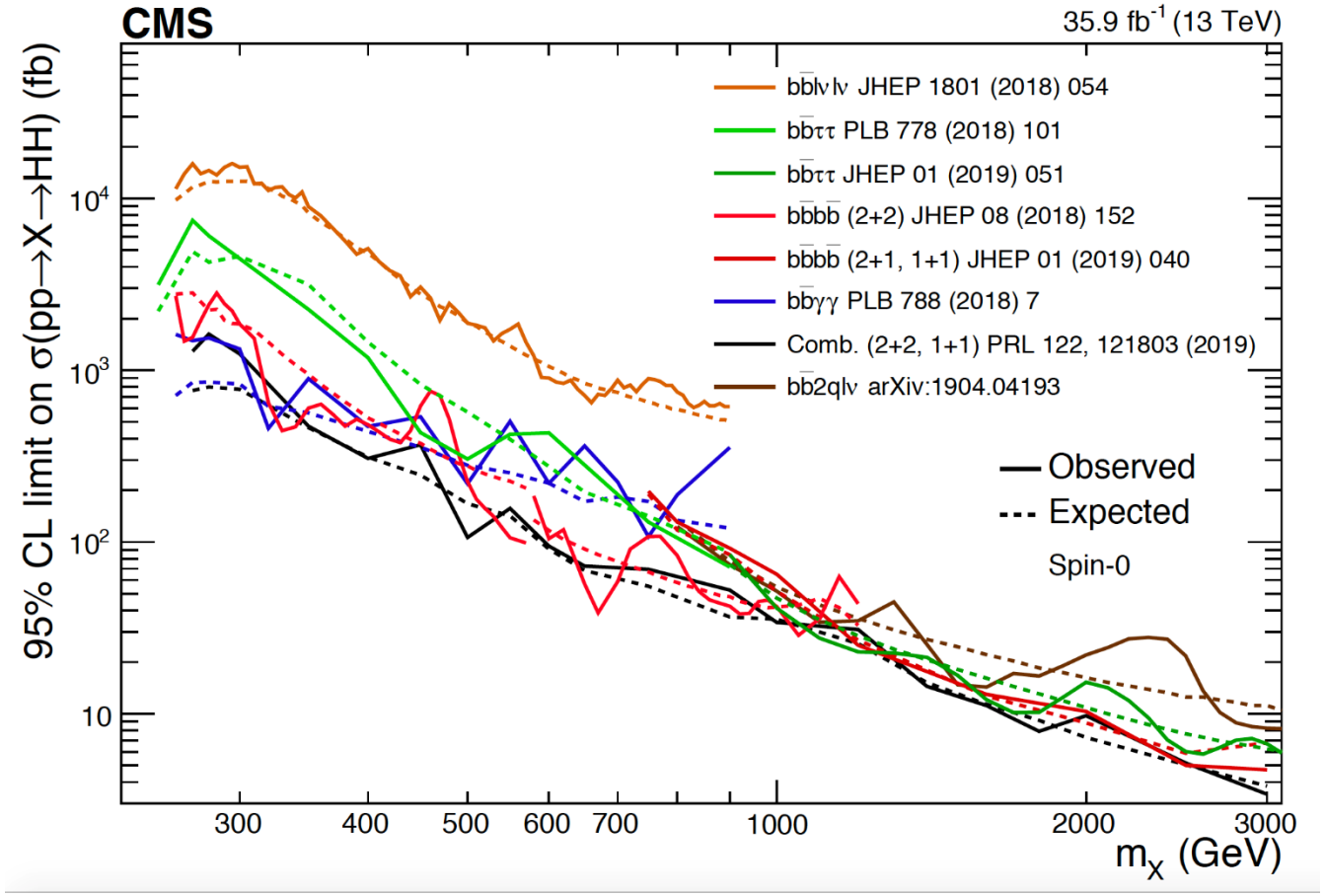
- Signal: spin-0 radion of Warped Extra Dimension (WED);
- Events: 2 b-jets (from a Higgs) + 1 e/u and 2 jets (from WW*) or 2 leptons + large missing p_T (from WW* or ττ)
- Reconstruct H→WW*→ℓνqq or H→WW*/ττ→ℓℓ’+neutrinos fully ➔ m_{HH}
- **Signals extracted using a 2-D maximum likelihood simultaneous fit of the m_{bb} of H→bb and HH invariant mass distributions on both signal and control regions without surprise ➔ limits are set with assumed a branching fraction of 25% to HH and an ultraviolet cutoff Λ_R = 3 TeV**



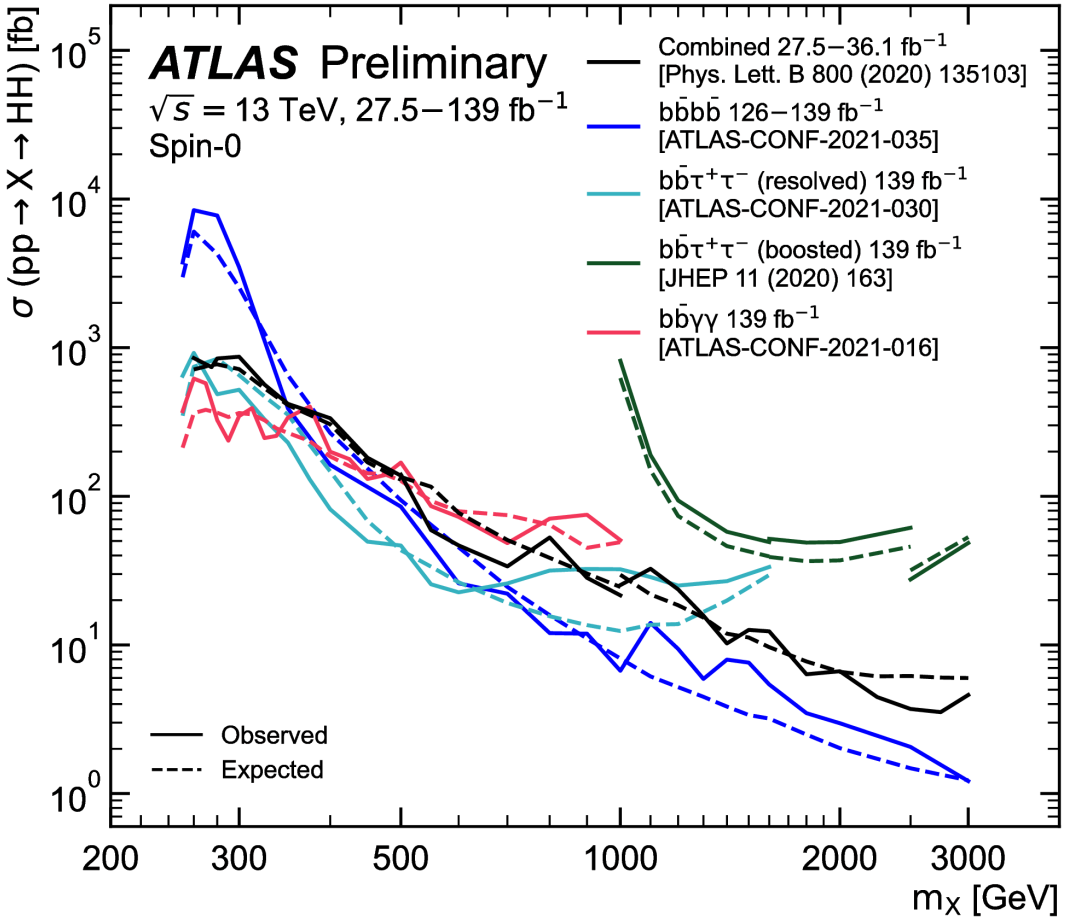
Combination of Heavy Spin-0 Higgs H→hh Searches

Expected and observed exclusion limits at 95% CL

CMS Higgs Summary Plots



ATL-PHYS-PUB-2021-031

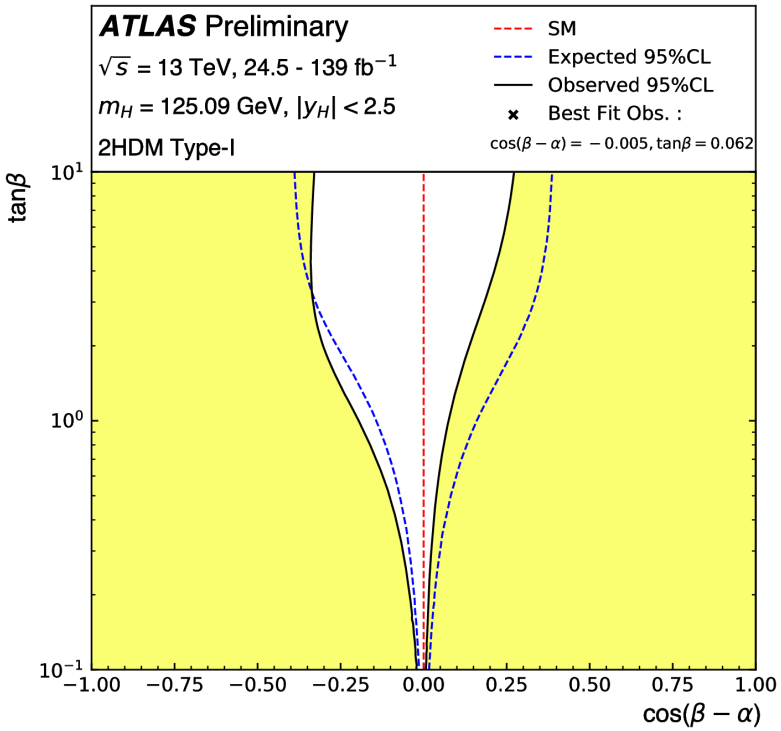


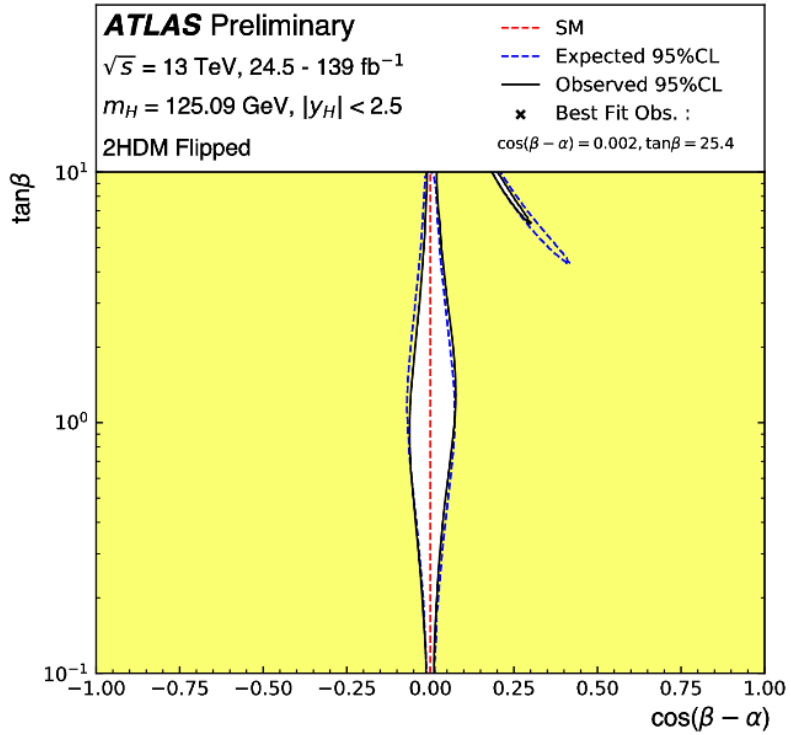
Interpretation SM Higgs σ and Br Measurements

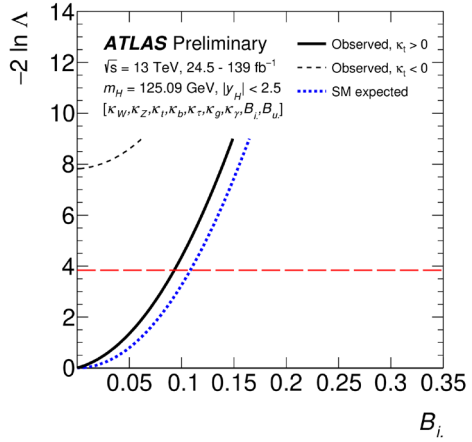
ATLAS-CONF-2020-027

For all measured Higgs boson production cross sections and branching fractions:

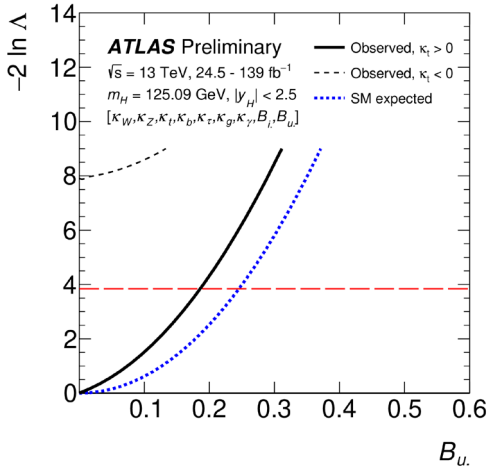
- Both O(10%) upper limits of BSM branching ratio of Higgs to invisible or undetected Higgs decays, similar results from combined h125→invisible searches ATLAS-CONF-2020-052;
- Constrain in 2HDM parameter spaces from different models (type-I, type-II, lepton-specific & flipped).





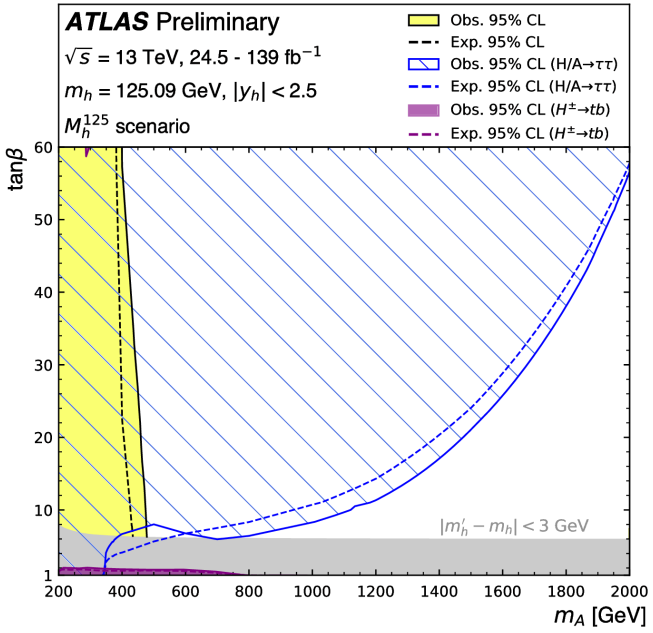


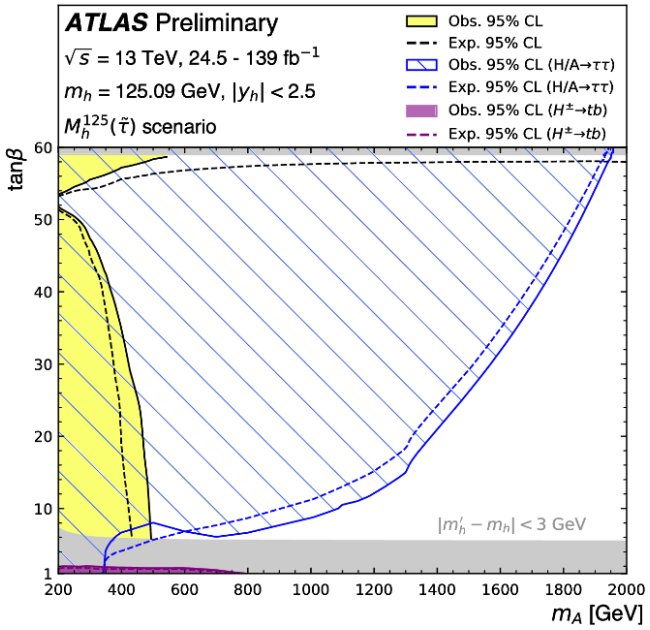
B_i : Branching ratio of SM Higgs to invisible of BSM



B_i : Branching ratio of SM Higgs to undetected of BSM

MSSM Interpretations from SM Higgs STXS Measurements





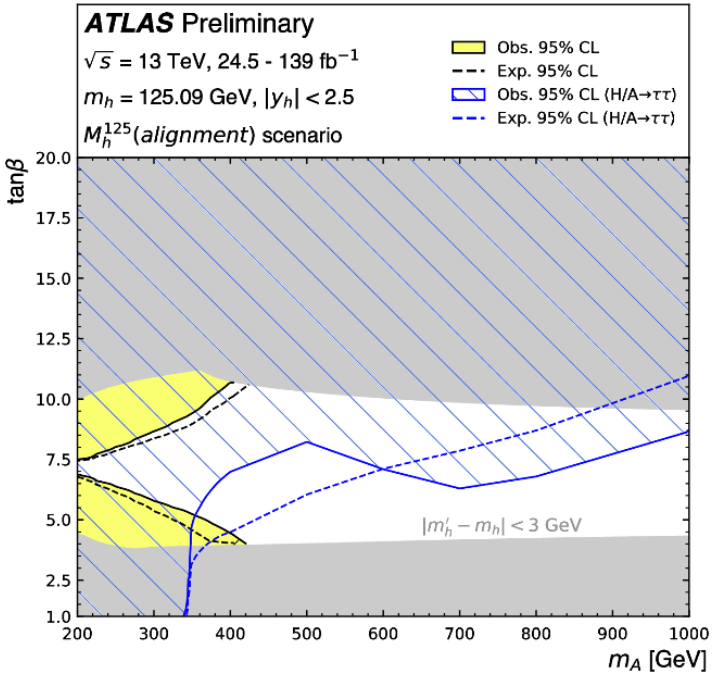
Assuming observed light Higgs from MSSM, the MSSM signal strength:

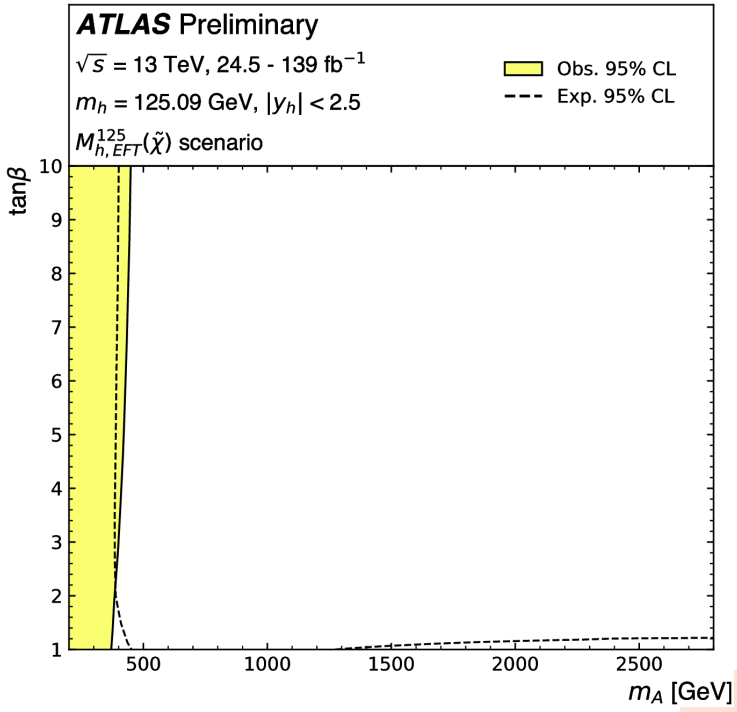
ATLAS-CONF-2020-053

$$\mu^{i,X}(m_A, \tan\beta) = \frac{\sigma^i(m_A, \tan\beta)}{\sigma^i_{\mathrm{SM}}} \cdot \frac{B^X(m_A, \tan\beta)}{B^X_{\mathrm{SM}}}$$

fit to measured STXS SM Higgs signal strength,

no significant deviation from SM ➔ upper limits on parameter spaces on various MSSM scenarios





Brief Summary of Direct and Indirect BSM Higgs Searches

Process/Measurements	Model	Explored Search Area
$H^{\pm} \rightarrow tb$	hMSSM	$m_{H^{\pm}} > m_t$ and $\tan\beta < 2$ or $\tan\beta > 30$
$H^{\pm} \rightarrow cs$ or cb		$m_{H^{\pm}} < m_t$
$H^{\pm} \rightarrow AW^{\pm} \rightarrow \mu\mu W^{\pm}$	Type-I 2HDM	100 GeV $< m_{H^{\pm}} < m_t$ and 10 GeV $< m_A <$ 70 GeV and $\tan\beta < 8$
$H^{\pm}/H^{\pm\pm} \rightarrow W^{\pm}Z/W^{\pm}W^{\pm}$	GM	200 GeV $< m_{H^{\pm}}$ (or $m_{H^{\pm\pm}}$) up to 3 TeV
$H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ of $H^{\pm\pm}$ pair prod.	Type-II seesaw	200 GeV $< m_{H^{\pm\pm}} <$ 600 GeV with $m_{H^{\pm}} - m_{H^{\pm\pm}} >= 100$ GeV
$H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ of $H^{\mp}H^{\pm\pm}$ prod.	Type-II seesaw	200 GeV $< m_{H^{\pm\pm}} <$ 600 GeV with $\lvert m_{H^{\pm}} - m_{H^{\pm\pm}} \rvert <= 5$ GeV
$A \rightarrow ZH \rightarrow \ell\ell bb$ (ggF and bbA)	4 diff. 2HDM	300 GeV $< m_A <$ 800 GeV, 100 GeV $< m_H <$ 700 GeV, Weak Decoupling Limit
$A \rightarrow ZH \rightarrow \ell\ell WW$ (bbA)	4 diff. 2HDM	300 GeV $< m_A <$ 800 GeV, 100 GeV $< m_H <$ 700 GeV, vicinity of above WDT
$H \rightarrow \gamma\gamma$	Narrow Width Scalar	Searches from 200 GeV to 2.5 TeV
$H \rightarrow ZZ \rightarrow 4\ell$ or $2\ell\,2\nu$	Type-I/Type-II 2HDM	200 GeV $< m_H <$ 390 GeV and $\tan\beta <$ 11, constrains on Higgs H coupling $\cos(\beta-\alpha)$
$H \rightarrow Za \rightarrow \ell\ell\chi\chi$	2HDM+a	300 GeV $< m_A$ up to 2 TeV and $\tan\beta < 30$ depending on Dirac DM mass
SM Higgs σ and Br measurements	4 diff. 2HDM, h == h_{SM}	$\tan\beta <=$ 10, constrains on Higgs H coupling $\cos(\beta-\alpha)$
SM Higgs STXS μ_{sig} Measurements	MSSM, mass h ~125 GeV	200 GeV $< m_H <$ 400 GeV and $\tan\beta <$ 10 to 60 depending on scenario (used 6 scenarios)
$H \rightarrow h(125)h_S \rightarrow \tau\tau bb$	Next-MSSM	σxB($H \rightarrow h(\tau)h_s(bb)$) limits for 200 GeV $< m_H <$ 2.4 TeV
$H \rightarrow h(125)h(125) \rightarrow bb\gamma\gamma$	Narrow Width Scalar	σxB($H \rightarrow hh$) limits for 200 GeV $< m_H <$ 1.0 TeV
$H \rightarrow h(125)h(125) \rightarrow bb\tau\tau$/4b	2HDM/MSSM/WED	σxB($H \rightarrow hh$) limits for 200 GeV $< m_H <$ 1.6/3.0 TeV
$X \rightarrow h(125)h(125) \rightarrow bbWW^*/bb\tau\tau$	WED	σxB($H \rightarrow hh$) limits for 200 GeV $< m_H <$ 4.5 TeV

Conclusion

- **ATLAS & CMS searched for signature of BMS Higgs boson neutral or charged including heavy Higgs boson decays to hh (or similar) from different BSM theory models;**
- **Multivariable analysis enhances new physics searching sensitivities;**
- **No deviation is observed from the SM background predictions**
- **New experiment techniques together with future Run 3 data will give us many new exciting results with potential new physics discovery.**

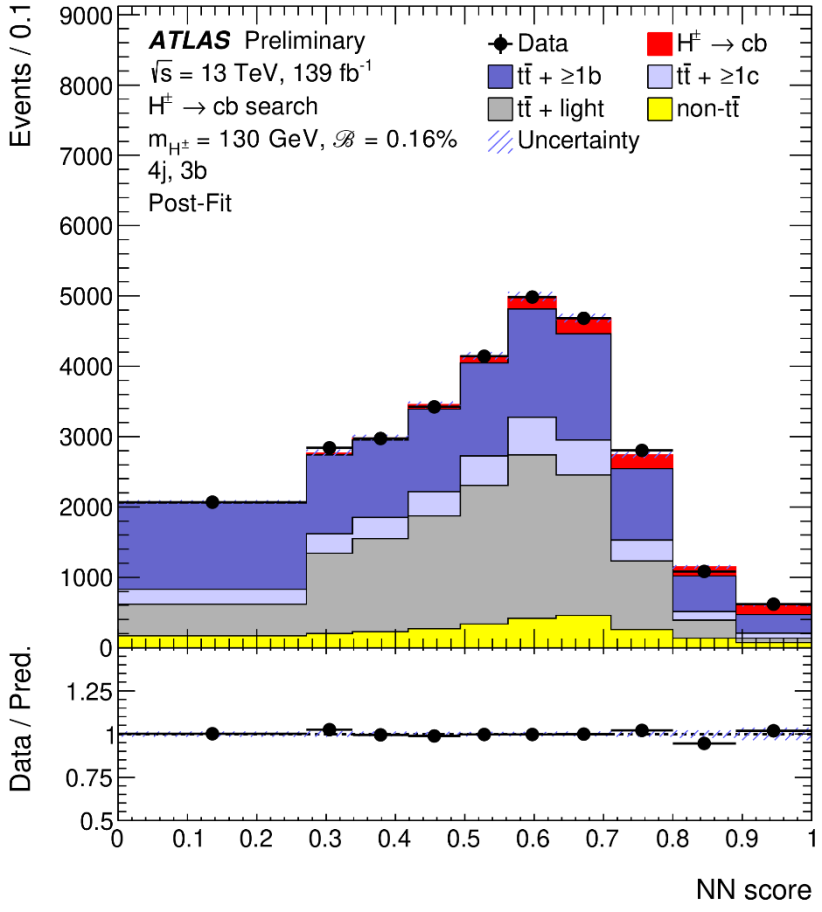
Thank you!!!

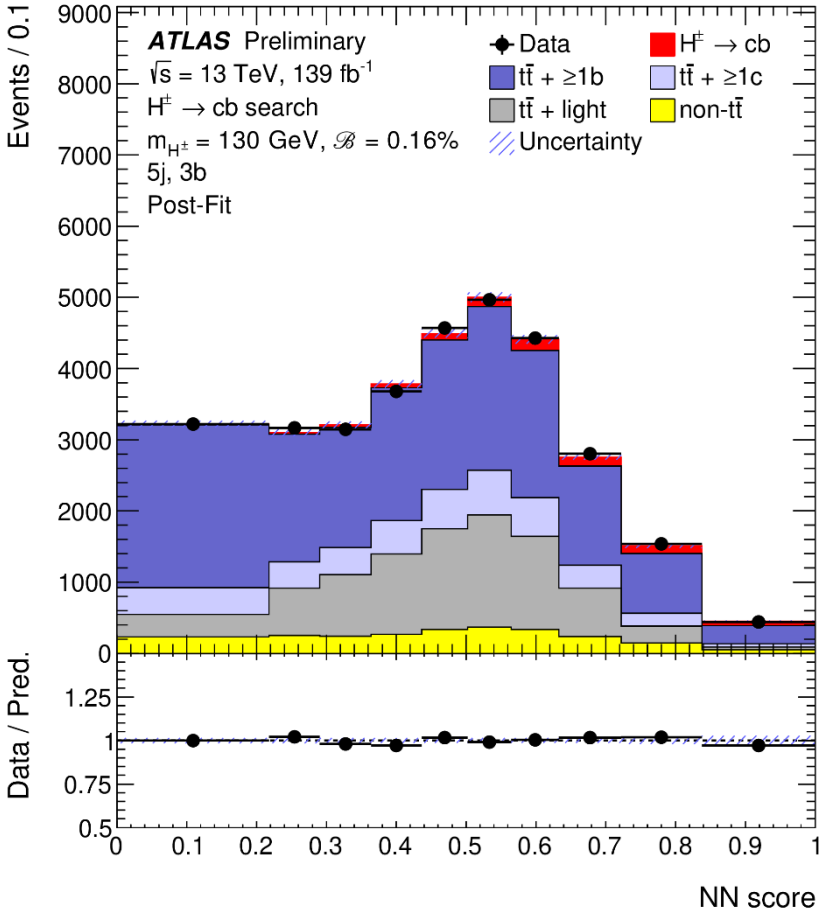
Backups

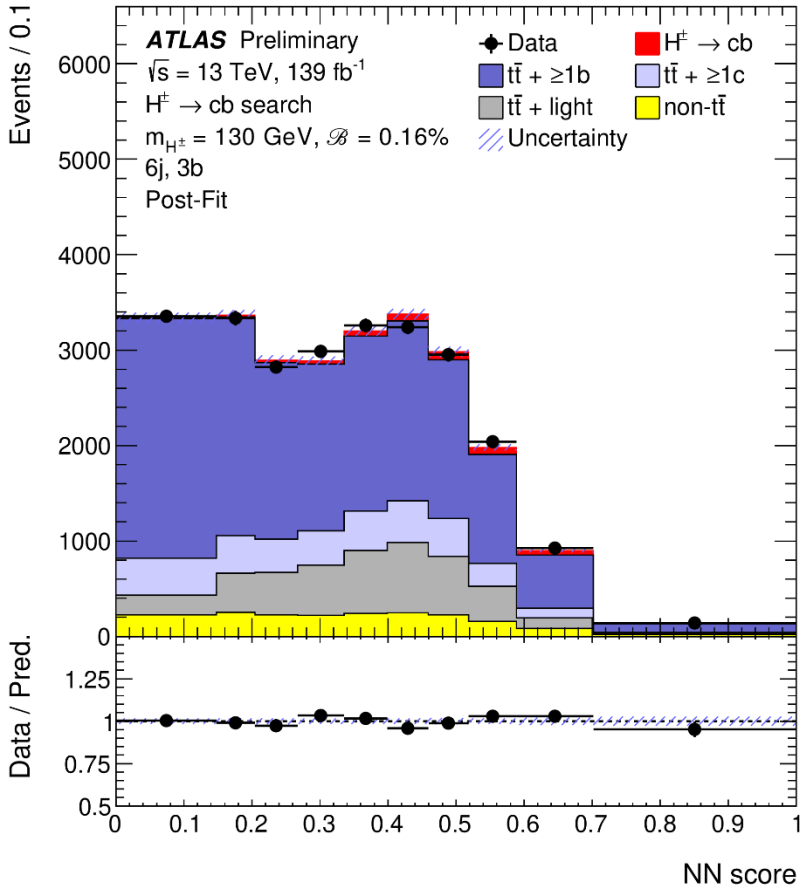
Light Charged Higgs ($m_{H^\pm} < m_t$): $H^\pm \rightarrow cb$, Post-fit $m_{H^\pm}$ 130 GeV

The post-fit $H^\pm$ signal for $m_{H^\pm}$ =130 GeV, a red histogram with the best-fit branching fraction of 0.16%.

ATLAS-CONF-2021-037



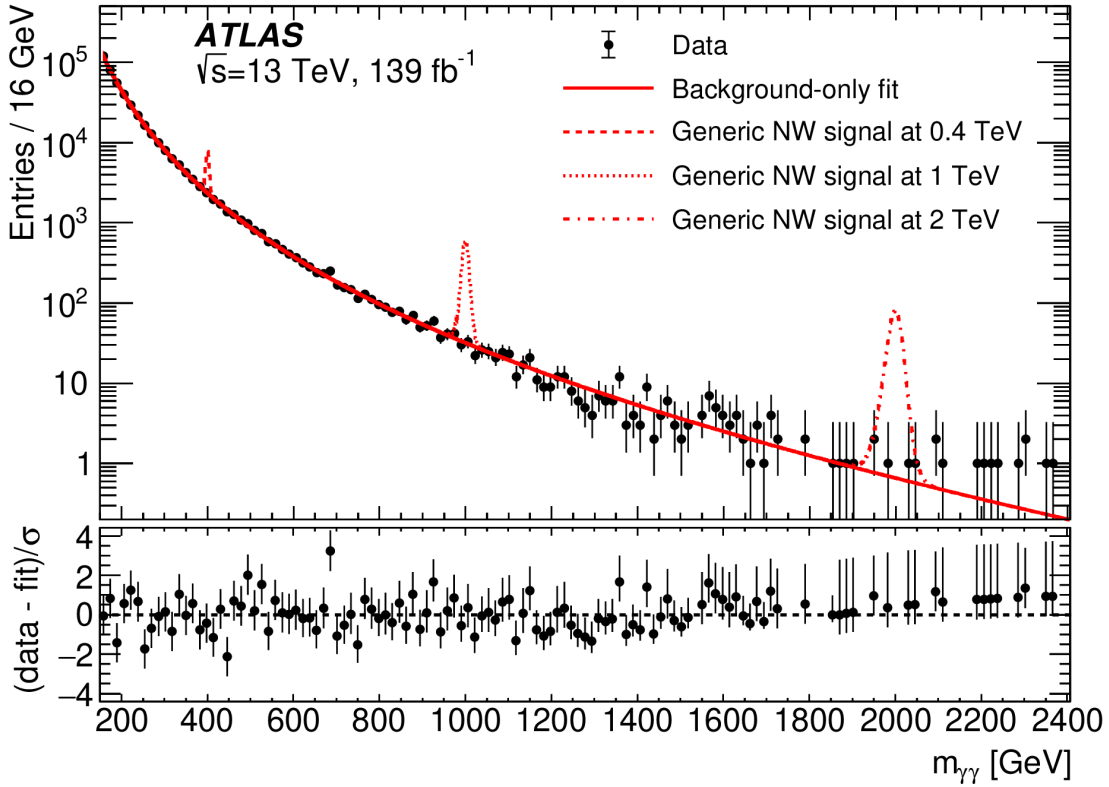


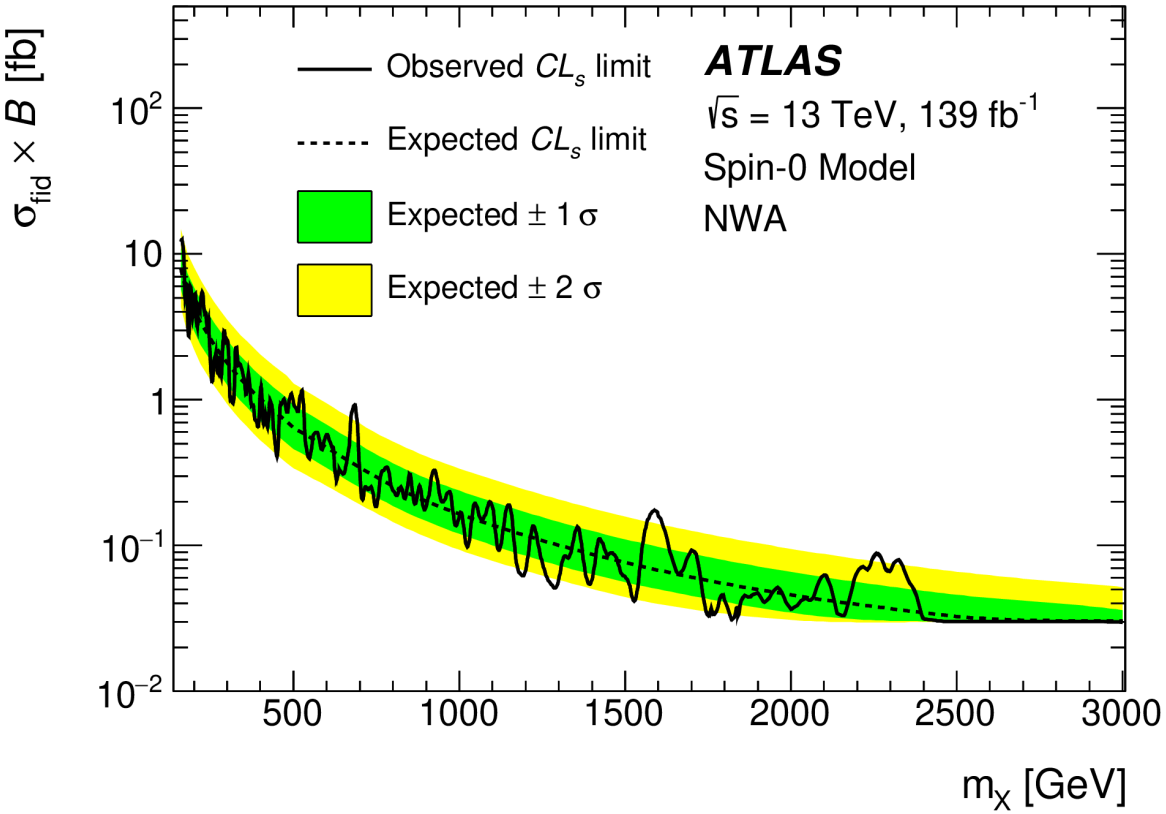


Heavy Neutral Higgs H → γγ

arXiv:2102.13405

- **Require at least 2 photons (fulfilling tight identification criteria) with E_T > 22 GeV and $|\eta|$ < 2.37, excluding the barrel-to-endcap transition regions of the calorimeter, 1.37 < $|\eta|$ < 1.52.**
- Signals: narrow width approximation (NWA) modeled by a double-sided Crystal Ball function (DSCB);
- BKG template by using $\gamma\gamma$ MC events and by fitting to γ+jet events from data of control region;
- **No significant deviation from SM predictions.**





Heavy Neutral Higgs H → ZZ → 4ℓ or 2ℓ 2ν

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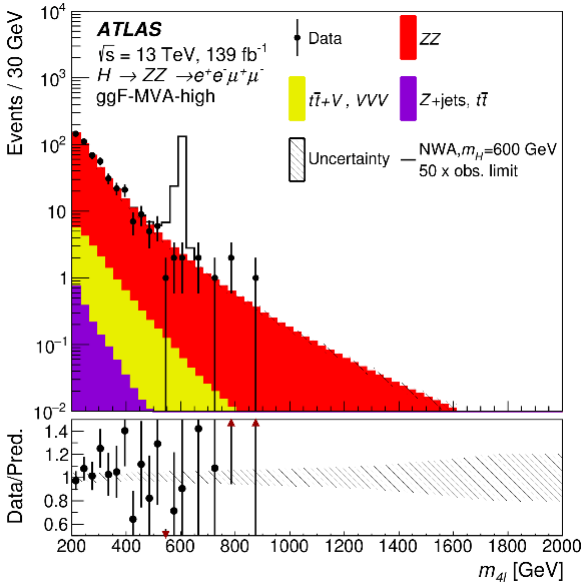
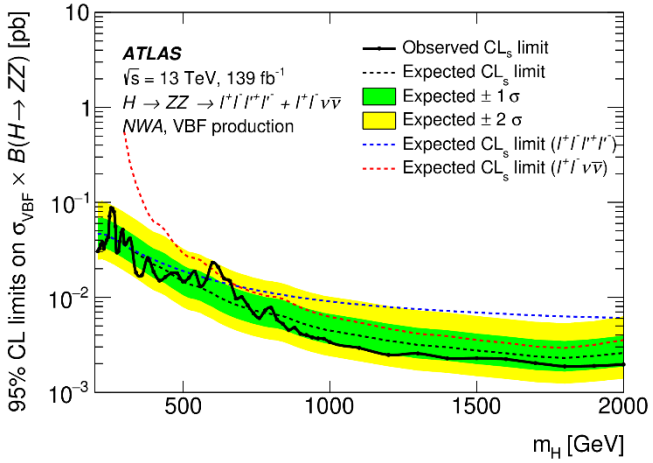
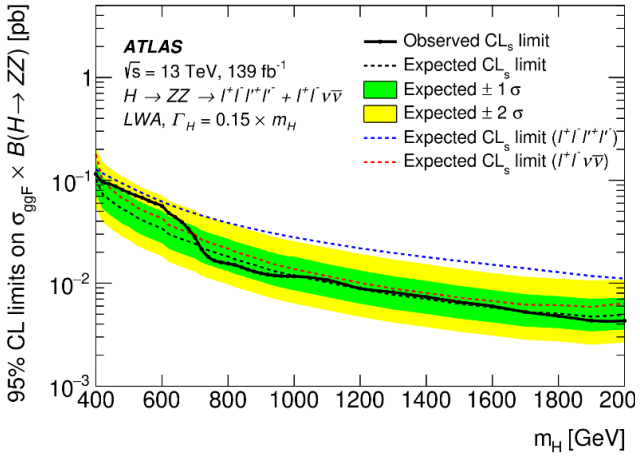
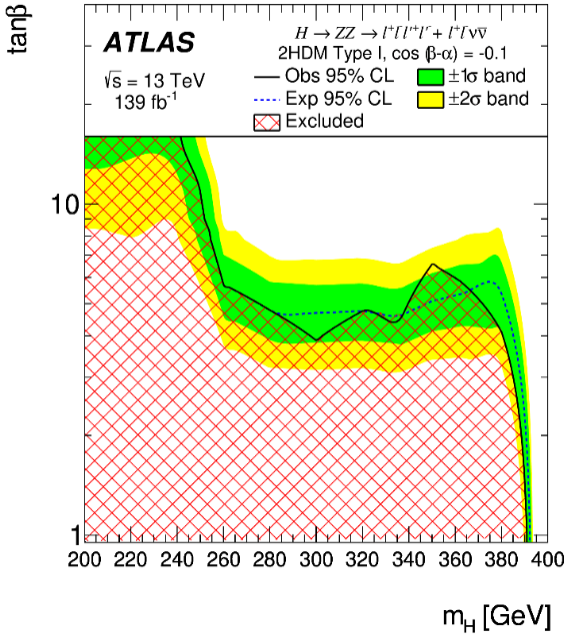
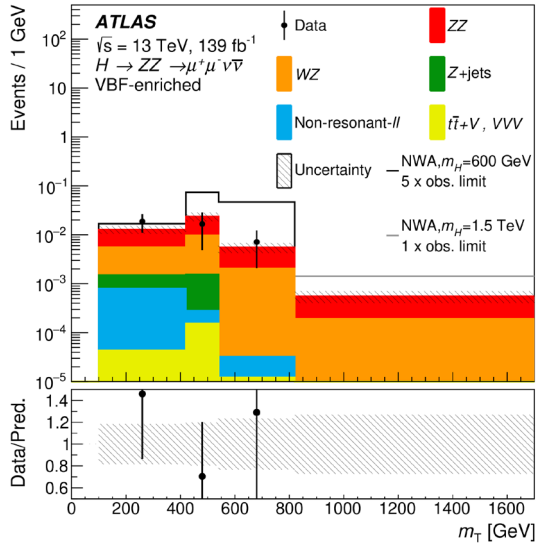
- **$50<m_{12}<106$ & $50<m_{34}<115$ for 4ℓ events, $76<m_{\ell\ell}<115$ for 2ℓ2ν events;**
- Two classifiers (ggF & VBF) of Deep neural networks (DNN) to improve the sensitivity Narrow Width Approximation (NWA) Higgs boson from ggF;
- Categorized events into **5 groups for 4ℓ, 4 groups for 2ℓ2ν;**
- **No significant deviation from SM predictions** ➔ upper limits on σxBr(H→ZZ) with different Higgs width & type-I/type-II 2HDM parameter spaces @95% CL.











Scenarios light MSSM Higgs Mass ~125 GeV

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1. M_h^{125} **scenario:** all superparticles heavy ➔ mildly affect on production and decays of MSSM Higgs by their presence;
2. $M_h^{125}(\tilde{\chi})$ **scenario:** relative light charginos and neutralinos with significant higgsino-gaugino mixing ➔ affecting the decays of the heavier Higgs bosons, weakening the H/A → ττ, as well as the SM-like Higgs boson to photons;
3. $M_h^{125}(\tilde{\tau})$ **scenario:** light staus and light gaugino-like charginos and neutralinos ➔ affecting the decays of the heavier Higgs bosons, as well as the SM-like Higgs boson to photons;
4. M_h^{125}**(alignment) scenario:** "alignment without decoupling", SM-like couplings for one of the two neutral CP-even scalars Higgs at a given tanβ
5. $M_{h,EFT}^{125}$ **scenario:** adjust the sfermion mass scale M_{SUSY} from 6 to 10^{16} TeV to achieve a 125 GeV Higgs and all superparticles heavy ➔ mildly affect on production and decays of MSSM Higgs by their presence. The SUSY contribution to the Higgs properties is calculated with an effective field theory (EFT);
6. $M_{h,EFT}^{125}(\tilde{\chi})$ **scenario:** adjust the sfermion mass scale M_{SUSY} from 6 to 10^{16} TeV to achieve a 125 GeV Higgs and relative light charginos and neutralinos. The SUSY contribution to the Higgs properties is calculated with an effective field theory (EFT);