Searches for exotic Higgs production and decays with the ATLAS detector

Katja Mankinen
on behalf of the ATLAS collaboration

1st Mediterranean Conference on Higgs Physics
23-26 September 2019
Faculté des Sciences et Techniques de Tanger, Tangier, Morocco

Introduction

- Need to extend the SM: hierarchy problem, baryon asymmetry, dark matter, neutrino masses...

- Search for new physics by
  - Looking for deviations from the SM in 125 GeV Higgs properties measurements (couplings, decay rates)
  - Directly searching for BSM objects
    - Additional Higgs bosons decaying to SM particles
    - Interactions of the SM Higgs with other new particles (e.g. SUSY, invisible decays)

Beyond Standard Model Higgs

2HDM: two Higgs doublets ϕ_1, ϕ_2

5 Higgs bosons:

h: "SM" Higgs } CP-even

H: heavy Higgs } CP-even

A: pseudoscalar — CP-odd

$H^{\pm}$: charged Higgs

parameters: m_h, m_H, m_A, $m_{H\pm}$, m_{12}, $\tan\beta$, α

($\tan\beta$: ratio of VEV of ϕ_1 and ϕ_2; α: h,H mixing angle)

2HDM	u-type	d-type	charged leptons	
type I	ϕ_2	ϕ_2	ϕ_2	
type II	ϕ_2	ϕ_1	ϕ_1	← MSSM-like
type X	ϕ_2	ϕ_2	ϕ_1	← "Lepton-specific"
type Y	ϕ_2	ϕ_1	ϕ_2	← "Flipped"

2HDM-MSSM:

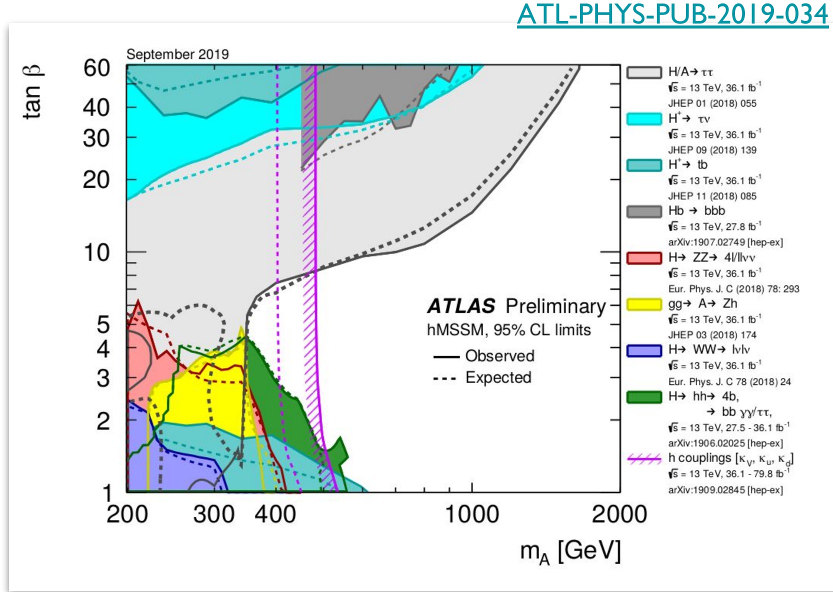
define benchmarks such as

$m_h^{mod\pm}$, hMSSM

Higgs Triplet Models:

add ϕ^{++}, ϕ^{+}, ϕ^{0}

ATL-PHYS-PUB-2019-034



Only a part of all 13 TeV 27.8-139 fb^{-1} searches!

Exotic Higgs searches at ATLAS

Heavy neutral Higgs

$H \to WW/ZZ$
$A \to Zh/ZH$
$A/H \to bb$
$A/H \to \tau\tau$
$A/H \to \mu\mu$

Charged Higgs

$H^{\pm\pm} \to \ell^{\pm}\ell^{\pm}$
$H^{\pm\pm} \to W^{\pm}W^{\pm}$
$H^{\pm} \to \tau^{\pm}\nu$
$H^{\pm} \to \tau^{\pm}b$

Decays to dark sector

$H \to Z_d Z_d \to 4\ell$
$H \to ZZ_d \to 4\ell$

Decays to light scalars

$h \to aa \to bb\mu\mu$
$h \to aa \to bbbb$
$h \to aa \to 4\ell$
$h \to aa \to \gamma\gamma jj$

Rare decays

$h \to cc$
$h \to \rho\gamma$ / $\phi\gamma$
$h \to J/\psi\gamma$, $\psi(2S)\gamma$, $\Upsilon(nS)\gamma$

LFV, FCNC

$H \to e\tau/\mu\tau$
$H \to e\mu$

$t \to Hq$

ATLAS public Higgs physics results:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HDBSPublicResults

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Decays to dark sector

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$H \to Z Z_d \to 4\ell$

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LFV, FCNC

$H \to e\tau/\mu\tau$
$H \to e\mu$

$t \to Hq$

- + invisible decays: Xin Chen's talk
- + di-Higgs: Kathryn Grimm's talk
- + SUSY: Steve Muanza's talk!

ATLAS public Higg

https://twiki.cern.ch/twiki/bin/view … Results

https://twiki.cern.ch/twiki/bin/view/ … DBSPublicResults

13 TeV, up to 80 fb^{-1}

Higgs couplings

- Combination of SM Higgs coupling measurements constrains the Higgs total width
- Explore three different scenarios for the total width:

  1) $B_{inv} = B_{undet} = 0$

  2) B_{inv} free, $B_{undet} \geq 0$, $\kappa_{W,Z} \leq 1$:

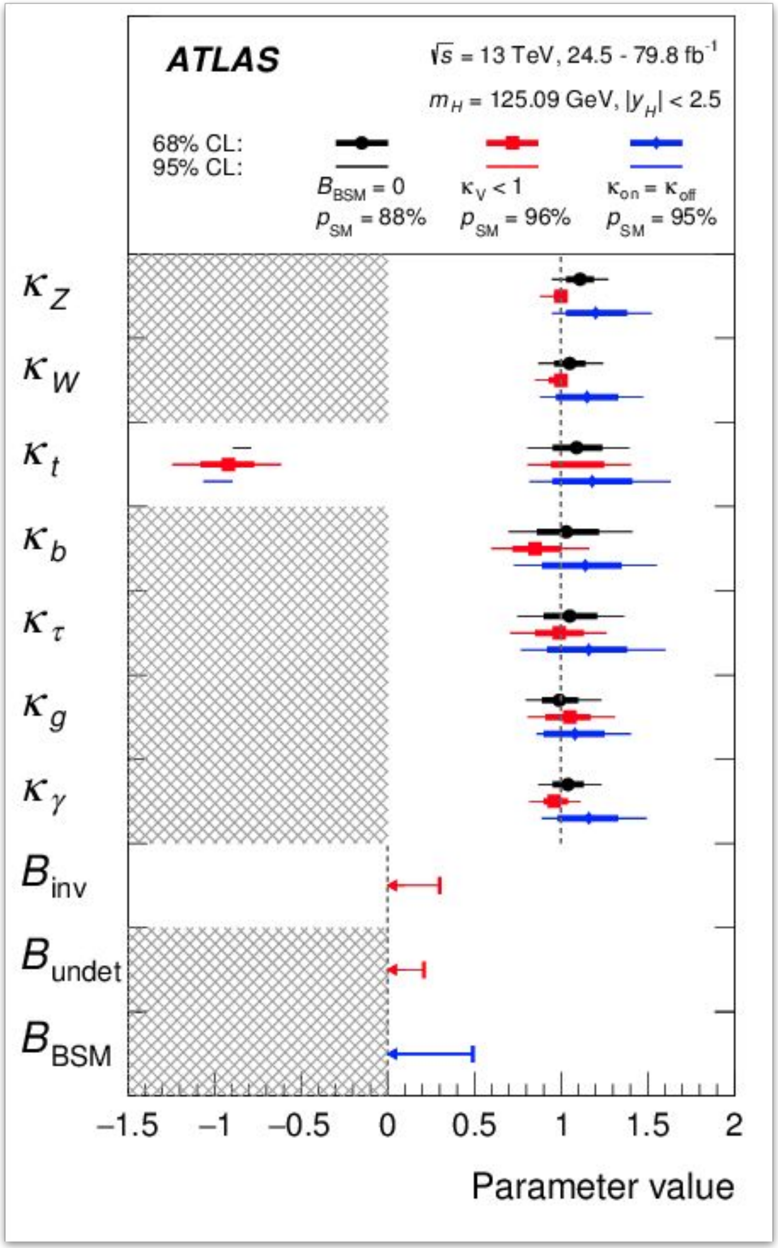
  $B_{inv} < 0.30\ (0.16)$ at 95% CL

  $B_{undet} < 0.21\ (0.36)$ at 95% CL

  3) $B_{BSM}=B_{inv}+B_{undet} \geq 0$; $\kappa_{off} = \kappa_{on}$; off-shell Higgs production:

  $B_{BSM} < 0.49\ (0.51)$

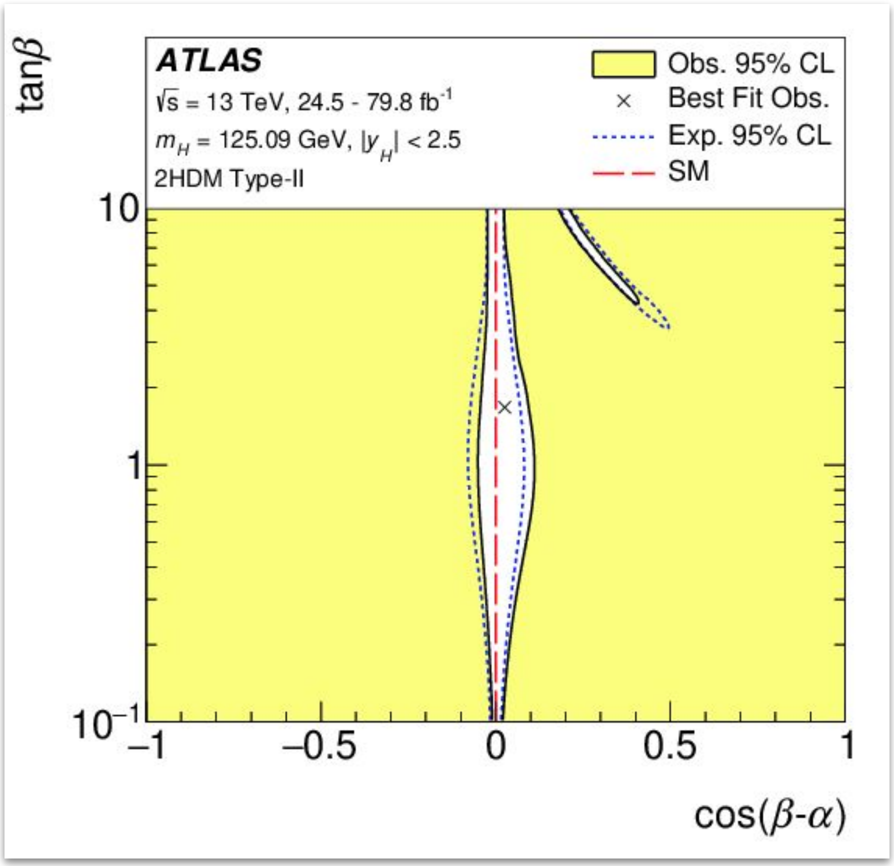
- All coupling modifiers measured to be compatible with the SM predictions

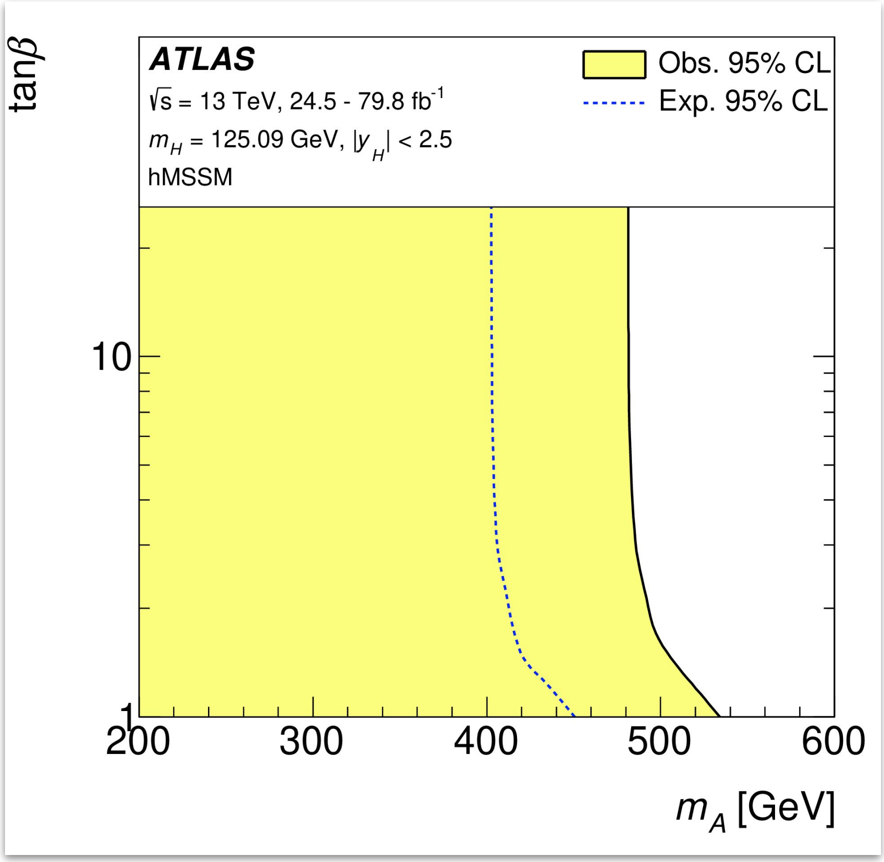


13 TeV, up to 80 fb^{-1}

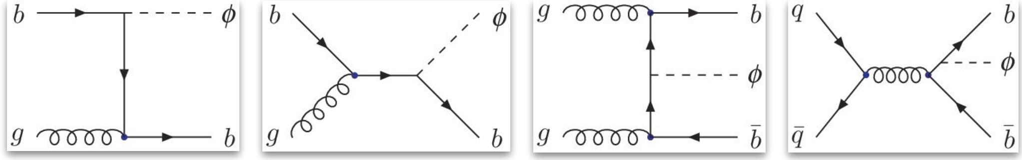
Higgs couplings

Combination of SM Higgs coupling measurements can exclude large regions of 2HDM and hMMSM phase space





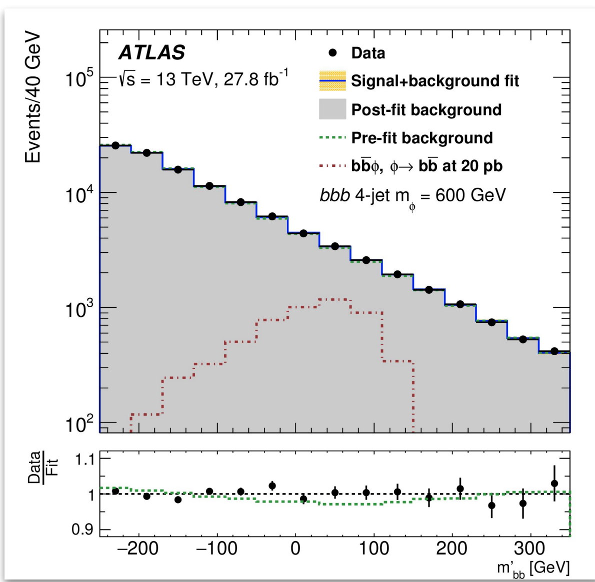
arXiv:1907.02749 HIGG-2016-32

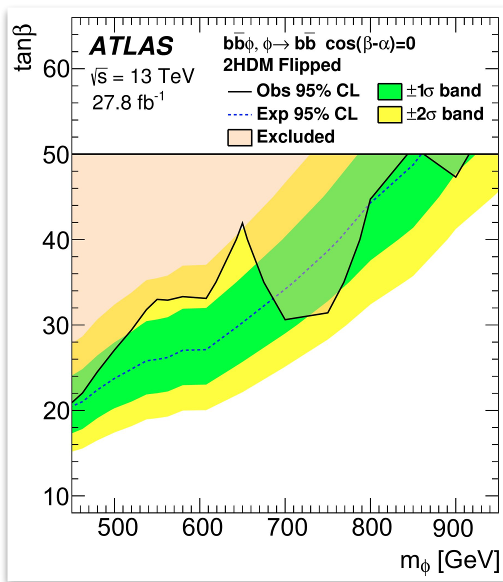


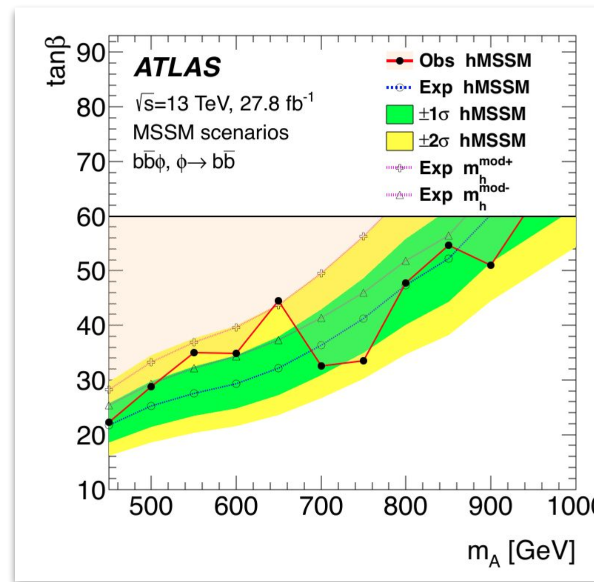
13 TeV, 27.8 fb^{-1}

Heavy neutral Higgs: bbϕ, ϕ→bb

- Heavy neutral Higgs bosons decays to a pair of b-quarks, m(ϕ)=450-1400 GeV
- Signal region defined with the selection of three energetic b-jets
- Data-driven background estimation using the sample where 3rd jet not b-tagged
- Interpretation in 2HDM Type Y (flipped) and MSSM scenarios







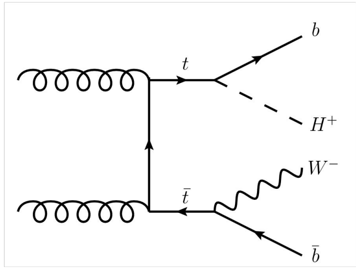
Charged Higgs bosons

Any extension to the Higgs sector, beyond adding a singlet scalar, implies existence of charged scalars (2HDM, nMSSM, Triplet, etc.)

light $H^{\pm}$

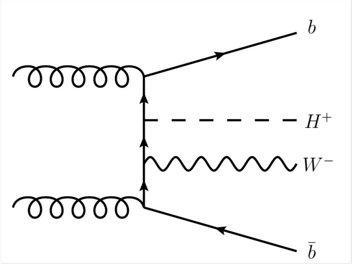
heavy $H^{\pm}$

$m_{H\pm} < m_t$

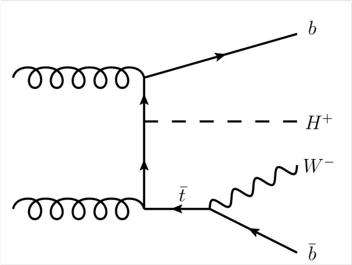


$t \to bH^{\pm}$

$m_{H\pm} \sim m_t$



$m_{H\pm} > m_t$



$gg \to tbH^{\pm}$

- $H^{\pm} \to \tau\nu$ dominates in a type-II 2HDM
- at low tanβ also $H^{\pm} \to$ cs/cb

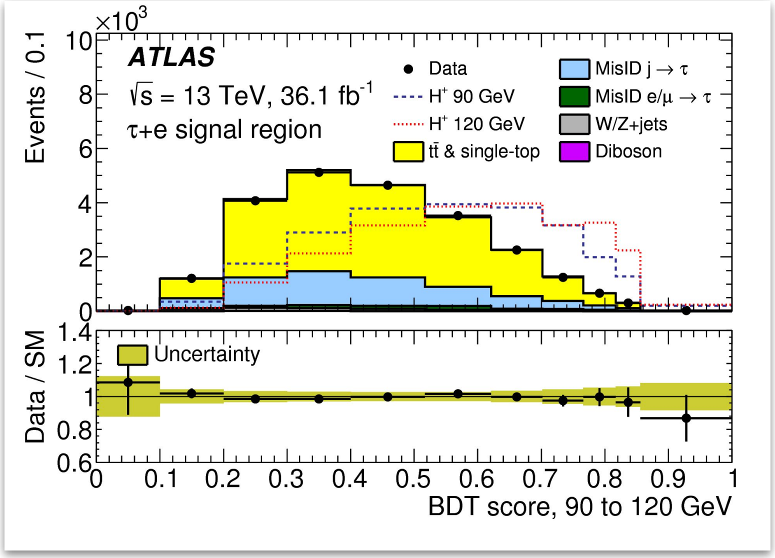
- $H^{\pm} \to$tb dominates at close to alignment limit
- at large tanβ in type-II 2HDM B($H^{\pm} \to \tau\nu$) can be 10-15%

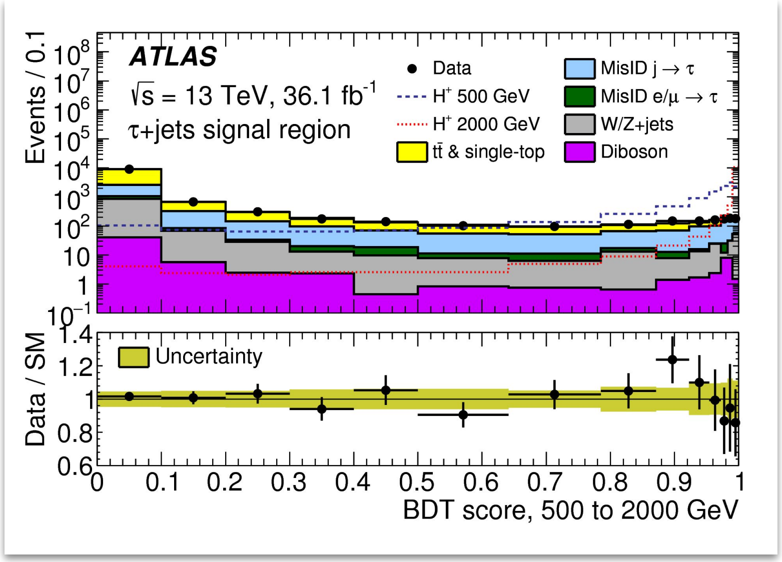
13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm} \rightarrow \tau\nu$

- Search for $H^{\pm}$ over wide mass range: 90-2000 GeV
- Channels:
  - τ_{had} + jets : sensitive to high $H^{\pm}$ mass
  - τ_{had} + lepton: sensitive to low and intermediate $H^{\pm}$ mass
- Main backgrounds:

  top-antitop, jets misidentified as taus
- BDTs used to discriminate signal from background

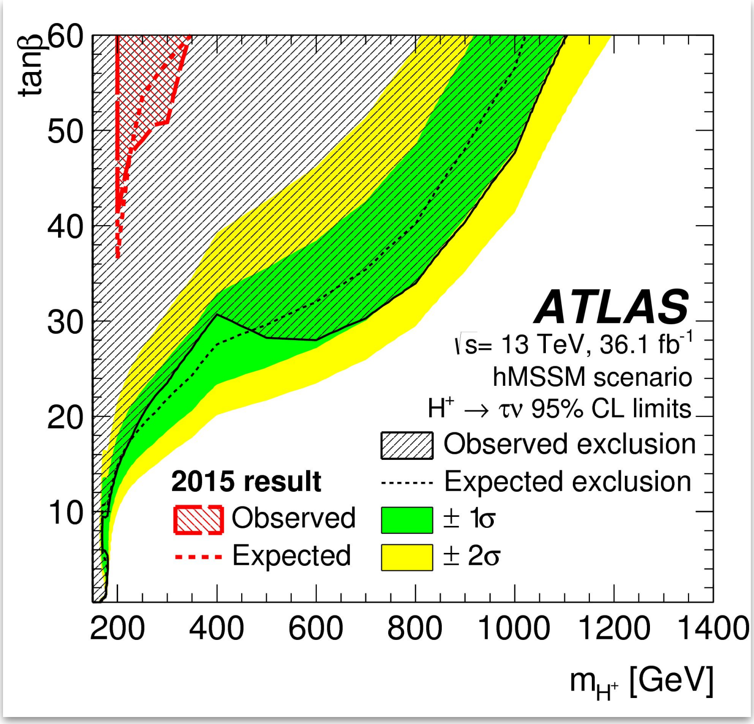


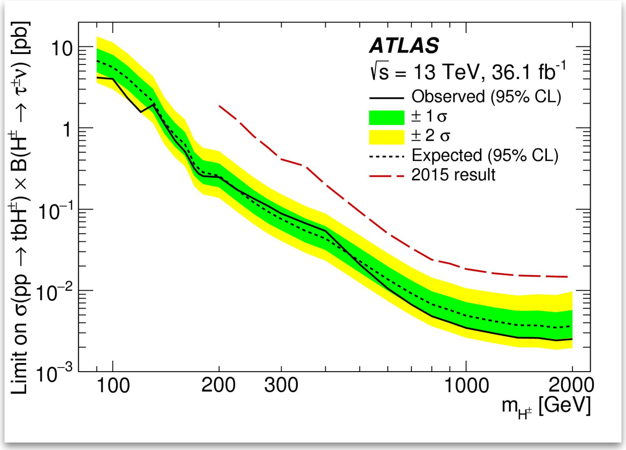


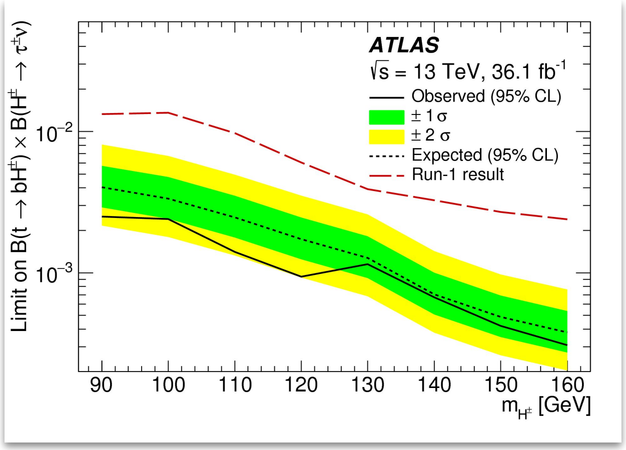
13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm} \to \tau\nu$

- Combined limits as a function of $H^{\pm}$ mass:
  - $\sigma(pp \to tbH^{\pm}) \times BR(H^{\pm} \to \tau\nu)$ 4.2 pb – 2.5 fb
  - $BR(t \to bH^{\pm}) \times BR(H^{\pm} \to \tau\nu)$ 0.25% – 0.031%
- Interpreted obtained results in context of hMSSM scenario
  - all $\tan\beta$ values excluded for 90 GeV < $m_{H\pm}$ < 160 GeV



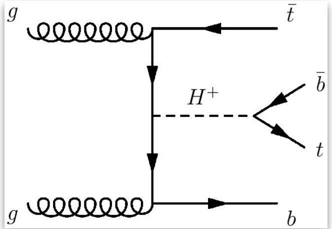




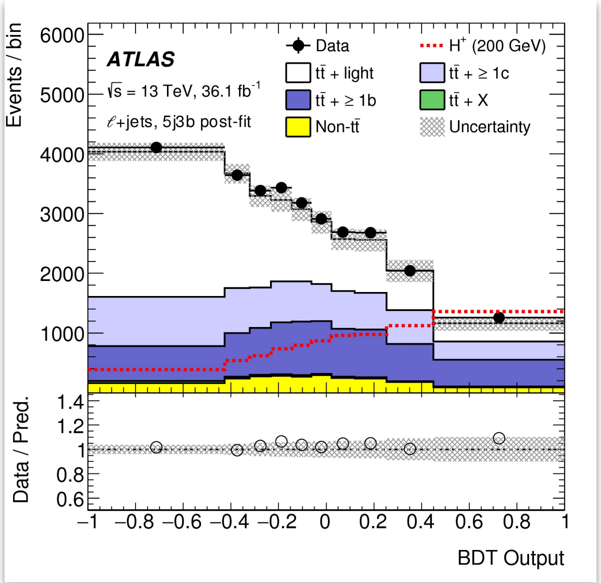
arXiv:1808.03599 HIGG-2017-04

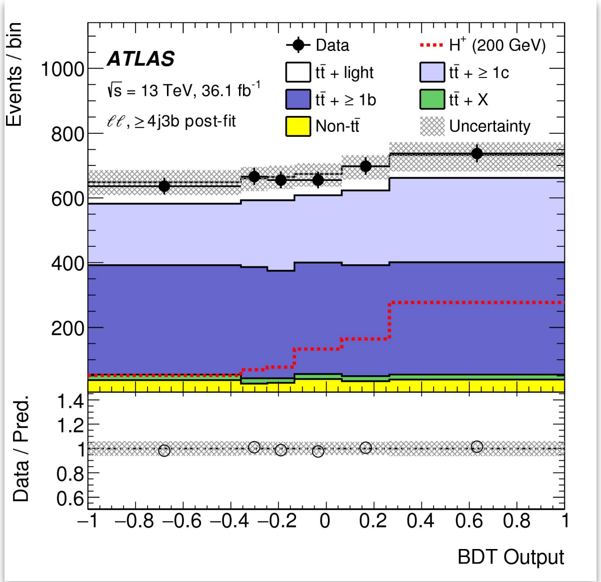
13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm} \to tb$



- For $m^{H+} > m_t + m_b$: $gg \to tb(H^{\pm} \to tb)$ dominant
- The search performed for $m_{H\pm}$ in 200-2000 GeV
- Channels:
  ℓ+jets: 5j3b, 5j≥4b, ≥6j3b, ≥6j≥4b
  ℓℓ+jets: ≥4j4b, ≥4j≥4b, 3j3b
- BDTs are trained for each mass point, signal region and final state
- Largest backgrounds from top-antitop estimated from MC



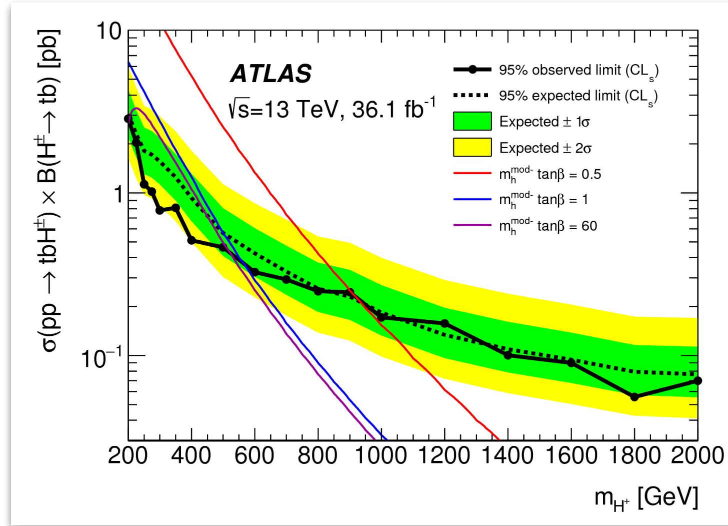


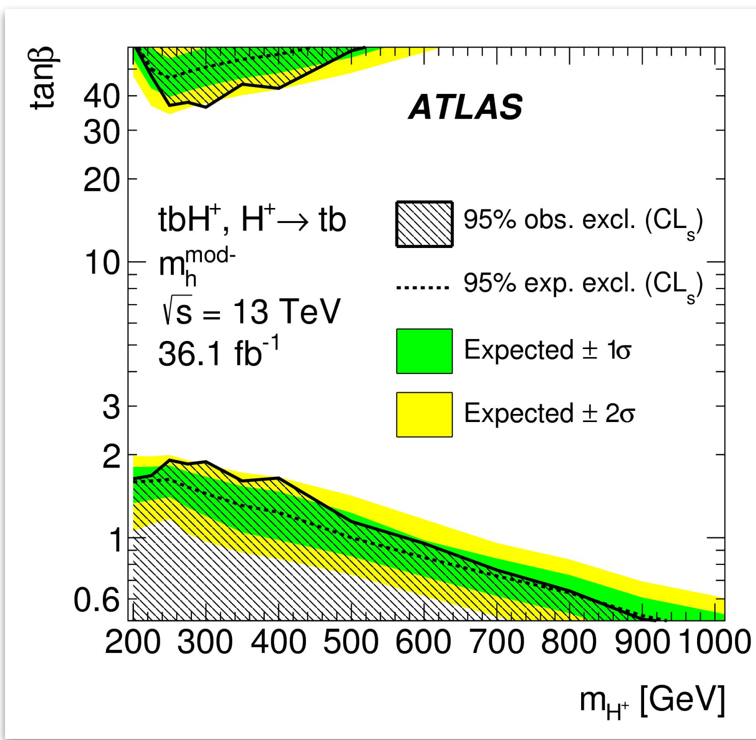
arXiv:1808.03599 HIGG-2017-04

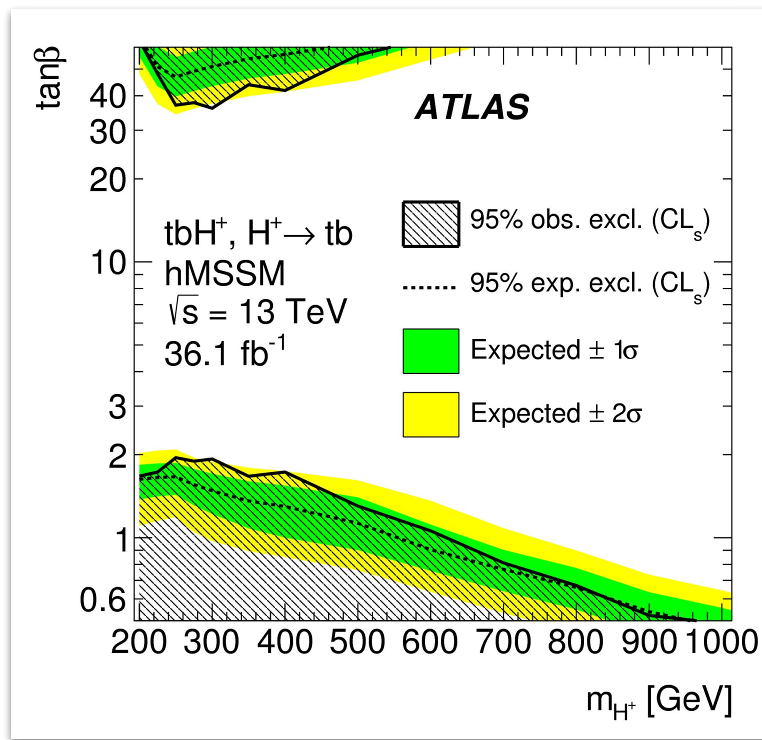
13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm} \to tb$

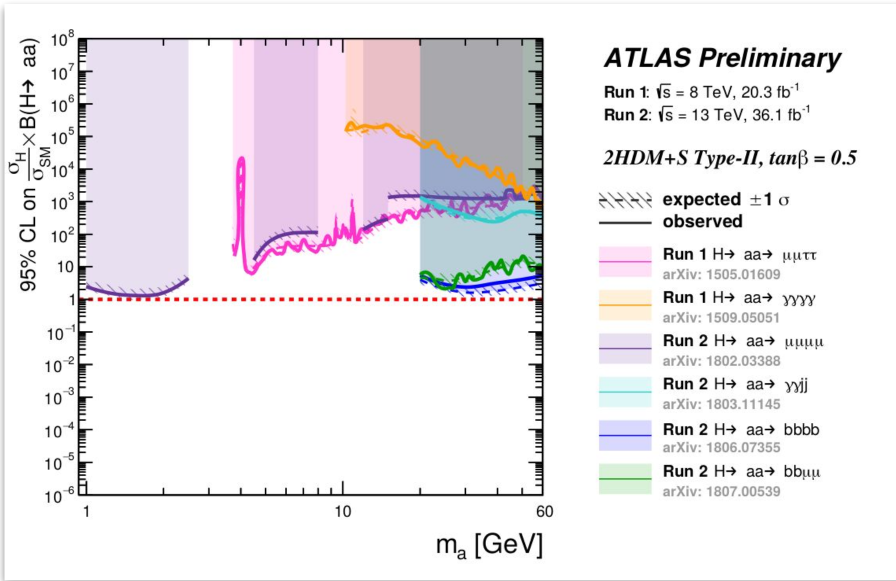
- Model-independent limits σ×BR 2.9 pb – 0.070 fb
- Exclusion of m_h^{mod} and hMSSM in $\tan\beta$ – $m_{H\pm}$ space

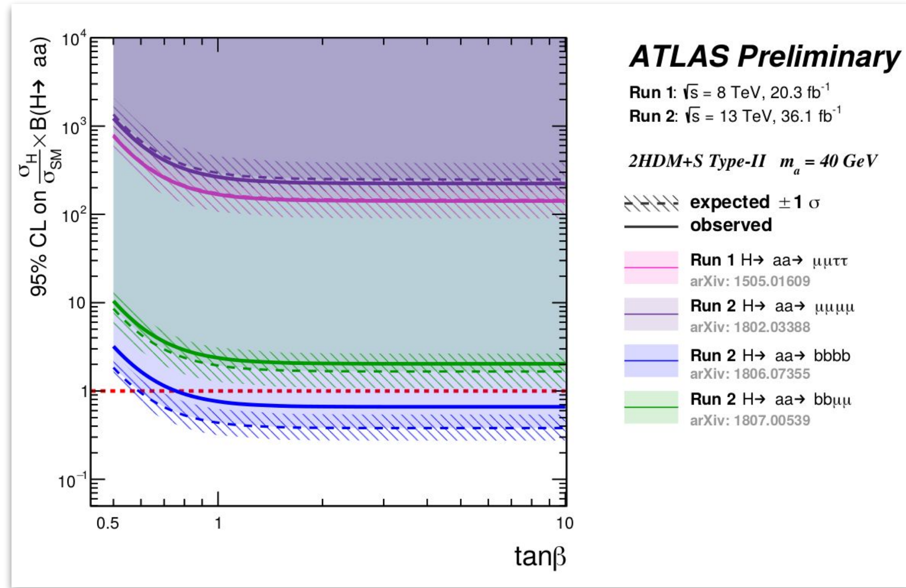






Decays to light scalars





Multiple h→aa searches place upper limits on σ_H/σ_{SM} x B(h→aa) in 2HDM+S scenarios:

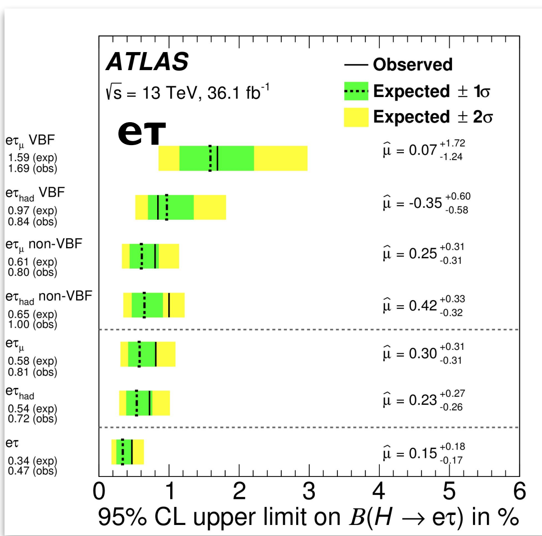
- for m_a using fixed tanβ values
- for different tanβ values for a fixed mass m_a

arXiv:1907.06131 HIGG-2017-08 ($H \to e\tau_\mu$, $H \to \mu\tau$)
ATLAS-CONF-2019-037 ($H \to e\mu$)

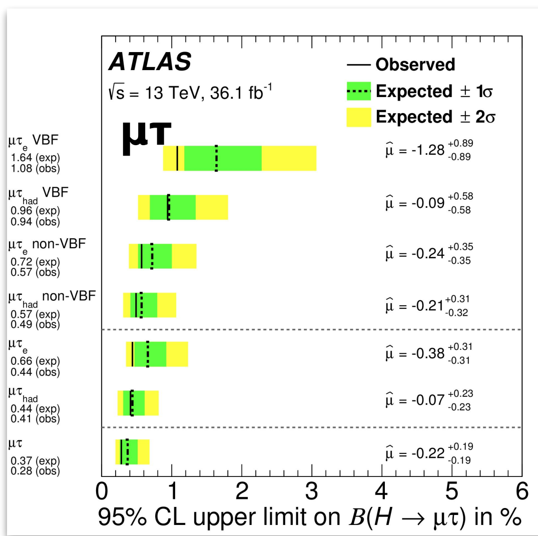
Lepton flavour violating Higgs decays

- Charged LFV (cLFV) produced by neutrino oscillations is vanishing small
- Sizeable cLFV is allowed in several SM extensions

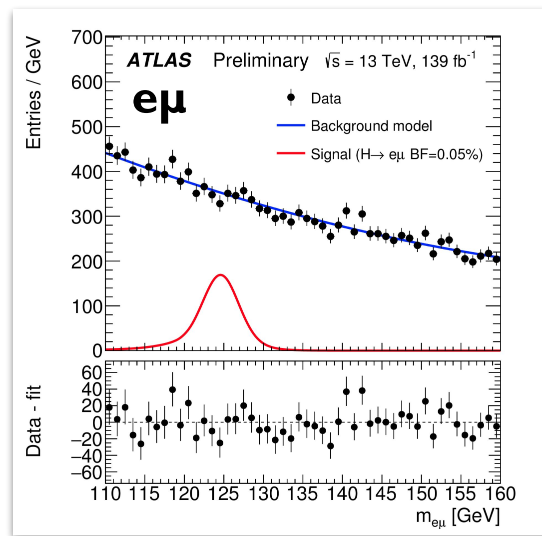
- 95% CL observed (expected) upper limits on the LFV Higgs branching ratio:
- $B(H \to e\tau)$: 0.47% (0.34%) } 13 TeV, 36.1 fb^{-1}
- $B(H \to \mu\tau)$: 0.28% (0.37%) } 13 TeV, 36.1 fb^{-1}
- $B(H \to e\mu)$: 6.1×10^{-5} (5.8×10^{-5}) 13 TeV, 139 fb^{-1}



HIGG-2017-08



HIGG-2017-08

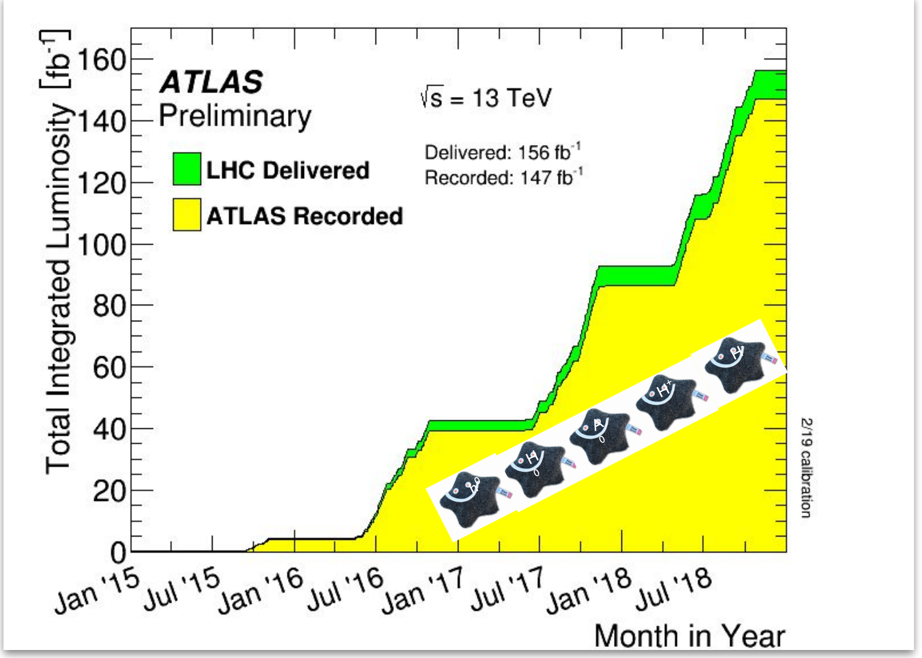


ATLAS-CONF-2019-037

Summary

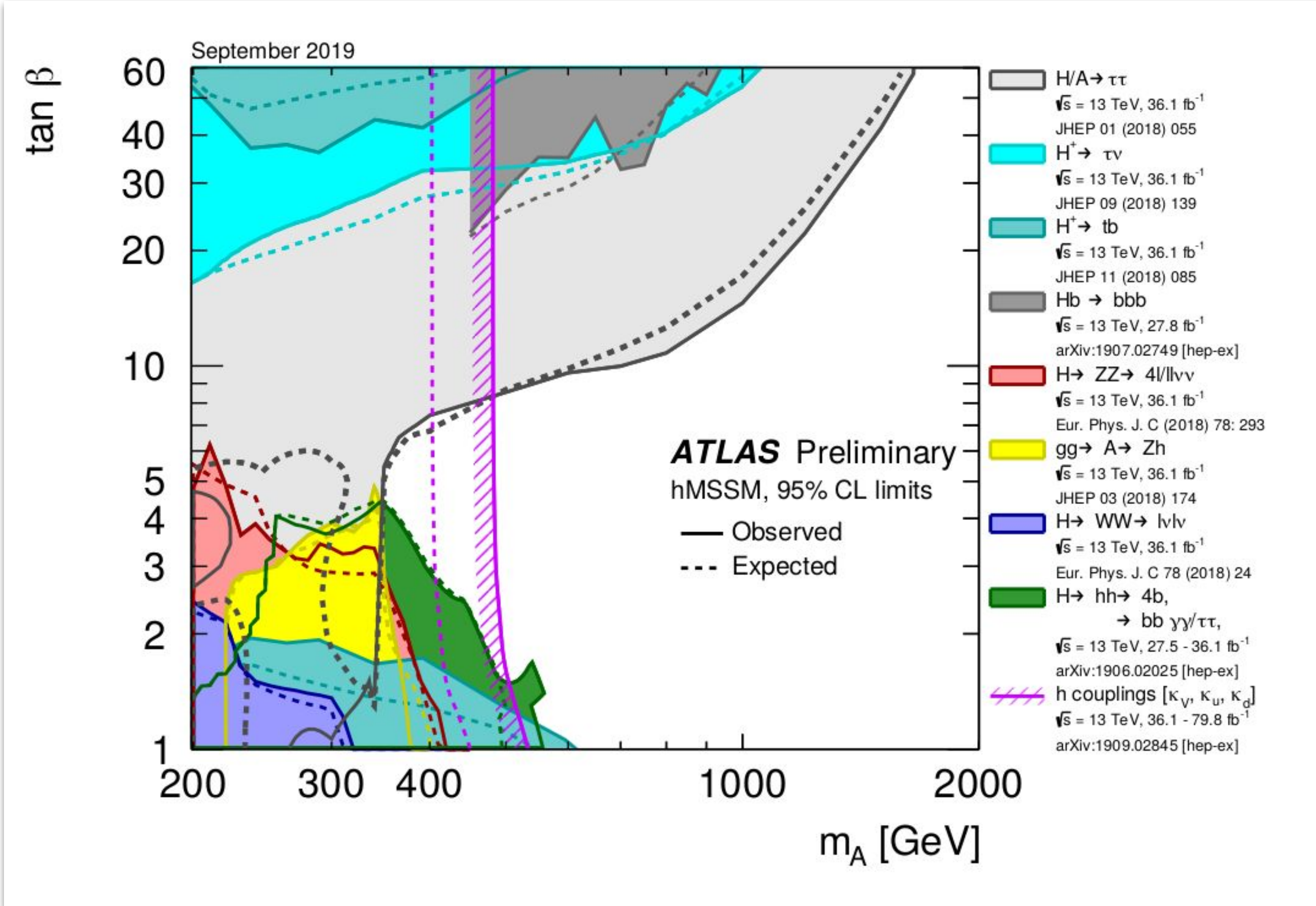
- Exotic Higgs bosons searched extensively at ATLAS
- Excluding large fractions of the available phase space
  - Many results with the full Run 2 dataset of 140 fb^{-1} to come
- No sign of BSM Higgs, yet - but we keep looking!

LuminosityPublicResultsRun2



BACKUP

ATLAS Higgs Summary plots ATL-PHYS-PUB-2019-034

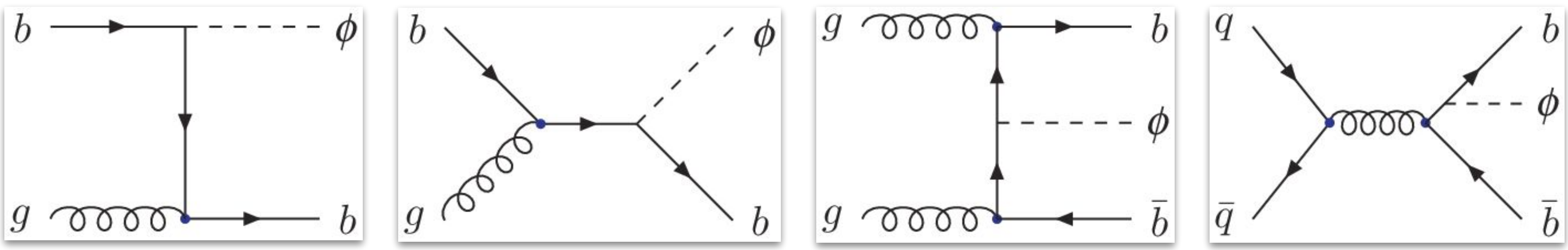


Regions of the [m_A, tanβ] plane excluded in the hMSSM model via direct searches for heavy Higgs bosons and fits to the measured rates of observed Higgs boson production and decays. Limits are quoted at 95% CL and are indicated for the data (solid lines) and the expectation for the SM Higgs sector (dashed lines). The light shaded or hashed regions indicate the observed exclusions.

arXiv:1907.02749 HIGG-2016-32

13 TeV, 27.8 fb^{-1}

Heavy neutral Higgs: bbϕ, ϕ→bb

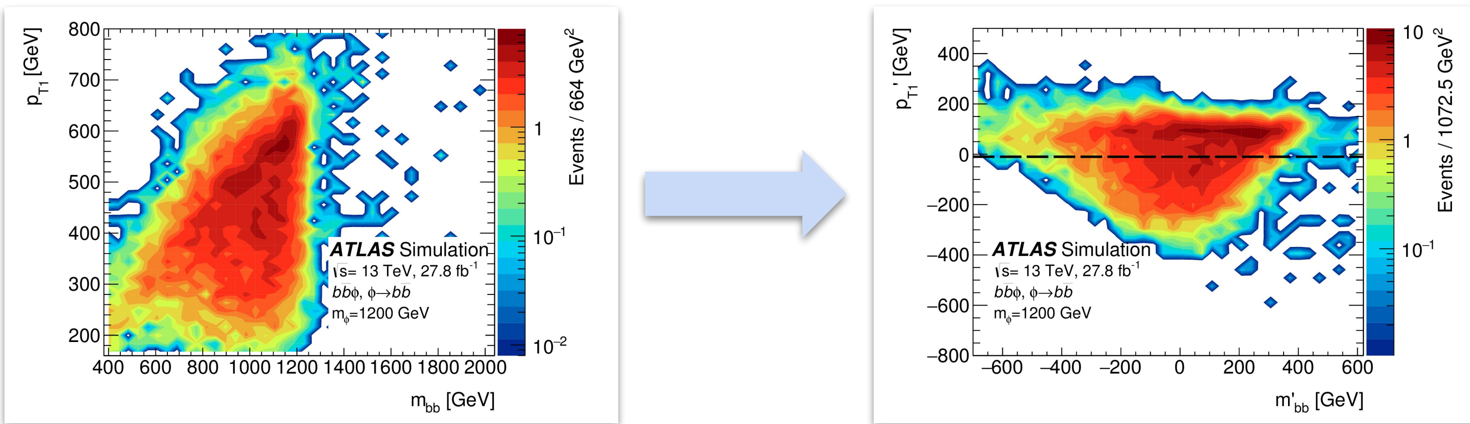


- A search for heavy neutral Higgs bosons produced in association with 1 or 2 b-jets and decaying to bb in the mass range of 450-1400 GeV
- Sensitive to the Type II and flipped scenarios of the 2HDM when $\tan\beta \gg 1$
- Strategy: Select events with
  - p_T > 160, 60 GeV for leading and subleading b-jets; p_T > 20 GeV for other jets
  - ΔR between 3rd jet and two leading jets > 0.8 to reduce g→bb
  - Flavour category: signal if 3rd jet is a b-jet; otherwise background
  - Number of jets category: 3 jet, 4 jet, 5+ jets

13 TeV, 27.8 fb^{-1}

Heavy neutral Higgs: bbϕ, ϕ→bb

- As m_ϕ increases, jets from ϕ decay produce additional FSR
  - m_{bb} from the two highest p_T jets broadened
- Signal sensitivity is enhanced using Principal Component Analysis to perform rotation to principal axis of (m_{bb},p_{T1}, p_{T2}) distribution
  - using m_{bb}' separates event with low and high FSR in ϕ decay
- Use **rotated m_{bb}'** as a discriminating variable



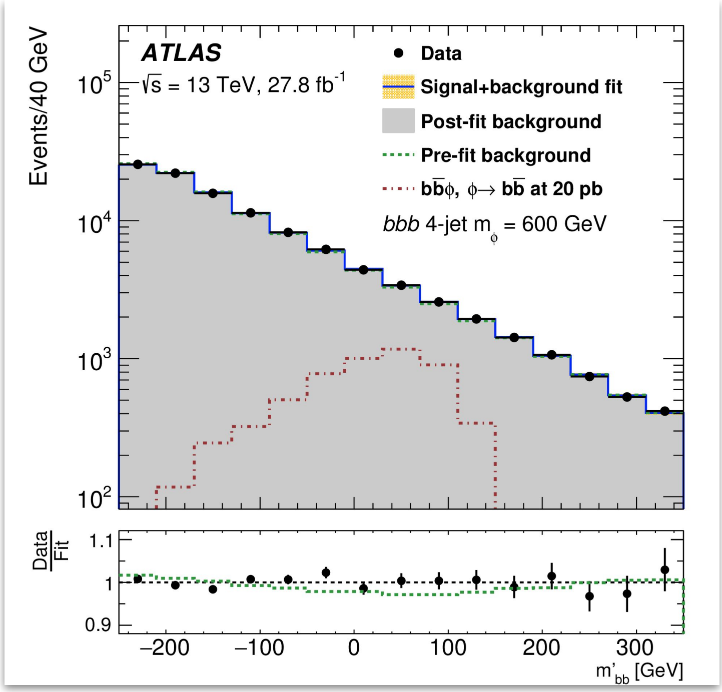
- Final cuts: p_{T1}' > -10 GeV, p_{T2}' > -50 GeV, independent of n-jet and m_ϕ
- Background estimation is fully data driven
- Main background from the production of multiple b-jets

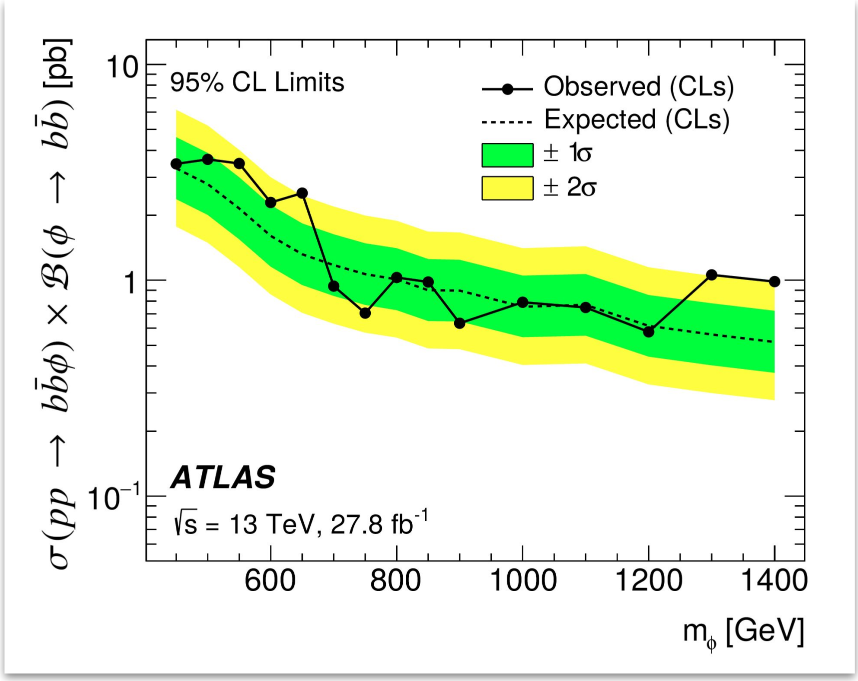
arXiv:1907.02749 HIGG-2016-32

13 TeV, 27.8 fb^{-1}

Heavy neutral Higgs: bbϕ, ϕ→bb

- Binned maximum likelihood fit simultaneously to m_{bb}' distributions in six categories
- The 95% CL upper limits for σ(bbϕ)×BR(ϕ→bb) 0.6-4.0 pb





arXiv:1907.02749 HIGG-2016-32

13 TeV, 27.8 fb^{-1}

Heavy neutral Higgs: bbϕ, ϕ→bb

Source of uncertainty	$m_\phi = 600$ GeV $\Delta(\sigma \times \mathcal{B})$ [pb]	$m_\phi = 1200$ GeV $\Delta(\sigma \times \mathcal{B})$ [pb]
Total	0.80	0.29
Statistical	0.77	0.26
Systematic	0.20	0.11
Experimental uncertainties		
Jet-related	0.05	0.05
Flavor-tagging	0.12	0.05
Trigger	0.04	0.05
Luminosity	0.02	0.01
Theoretical and modeling uncertainties		
Generator	0.03	0.03
PDF	0.08	0.04
MC statistical	0.09	0.04

arXiv:1807.07915

13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm}\rightarrow\tau\nu$

τ_{had} + jets channel:

- at least one τ_{had} with p_T > 40 GeV
- no loose leptons (e, μ) with p_T > 20 GeV
- at least 3 jets with p_T > 25 GeV, at least 1 b-jet
- E_T^{miss} > 150 GeV
- m_T > 50 GeV

E_T^{miss} trigger

τ_{had} + lepton channel:

- exactly 1 lepton with p_T > 30 GeV
- exactly one τ_{had} with p_T > 30 GeV (opposite charge)
- at 1 b-jet with p_T > 25 GeV
- E_T^{miss} > 50 GeV

Single-lepton triggers

arXiv:1807.07915 HIGG-2016-11

13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm}\to\tau\nu$

BDT input variable	$\tau_{\text{had-vis}}$+jets	$\tau_{\text{had-vis}}$+lepton
E_T^{miss}	✓	✓
p_T^{τ}	✓	✓
$p_T^{b\text{-jet}}$	✓	✓
p_T^{ℓ}		✓
$\Delta\phi_{\tau,\,\text{miss}}$	✓	✓
$\Delta\phi_{b\text{-jet},\,\text{miss}}$	✓	✓
$\Delta\phi_{\ell,\,\text{miss}}$		✓
$\Delta R_{\tau,\,\ell}$		✓
$\Delta R_{b\text{-jet},\,\ell}$		✓
$\Delta R_{b\text{-jet},\,\tau}$	✓	
Υ	✓	✓

Source of systematic uncertainty	Impact on the expected limit (stat. only) in % m_{H^+} = 170 GeV	m_{H^+} = 1000 GeV
Experimental		
luminosity	2.9	0.2
trigger	1.3	<0.1
$\tau_{\text{had-vis}}$	14.6	0.3
jet	16.9	0.2
electron	10.1	0.1
muon	1.1	<0.1
E_T^{miss}	9.9	<0.1
Fake-factor method	20.3	2.7
Υ modelling	0.8	–
Signal and background models		
$t\bar{t}$ modelling	6.3	0.1
W/Z+jets modelling	1.1	<0.1
cross-sections ($W/Z/VV/t$)	9.6	0.4
H^+ signal modelling	2.5	6.4
All	52.1	13.8

13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm} \rightarrow tb$

Triggers: single lepton triggers

- $\ell\ell$ selection:
  - Exactly two OS leptons (ee/μμ/eμ)
  - leading p_T > 27 GeV, sub-leading p_T > 10 GeV (p_T > 15 GeV for ee)
  - ee/μμ: m > 15 GeV excluding Z-mass (83 GeV < m < 99 GeV)
  - ≥ 3 jets (≥ 2 b-tagged), p_T > 25 GeV

- ℓ+jets selection
  - Exactly one lepton, p_T > 27 GeV
  - ≥5 jets (≥ 2 b-tagged), p_T > 25 GeV
  - Veto dilepton selection

13 TeV, 36.1 fb^{-1}

Charged Higgs: $H^{\pm} \to tb$

Systematic uncertainty	Type	Number of components
Luminosity	N	1
Pile-up	NS	1
Electron reconstruction	NS	6
Muon reconstruction	NS	13
Jet and E_T^{miss} reconstruction	NS	28
Flavour tagging, 70% efficiency calibration (*)	NS	27
Flavour tagging, step-wise efficiency calibration (*)	NS	126
Signal QCD scale and PDF	NS	31
Background modelling, $t\bar{t}$ + jets	NS	29
Background modelling, other top	NS	25
Background modelling, non-top (ℓ+jets final state)	N	13
Background modelling, non-top ($\ell\ell$ final state)	N	4

Uncertainty Source	$\Delta\mu(H^+_{200})$ [pb]	$\Delta\mu(H^+_{800})$ [pb]
Jet flavour tagging	0.70	0.050
$t\bar{t} + \geq 1b$ modelling	0.65	0.008
Jet energy scale and resolution	0.44	0.031
$t\bar{t}$+light modelling	0.44	0.019
MC statistics	0.37	0.044
$t\bar{t} + \geq 1c$ modelling	0.36	0.032
Other background modelling	0.36	0.039
Luminosity	0.24	0.010
Jet-vertex assoc., pile-up modelling	0.10	0.006
Lepton, E_T^{miss}, ID, isol., trigger	0.08	0.003
H^+ modelling	0.03	0.006
Total systematic uncertainty	1.4	0.11
$t\bar{t} + \geq 1b$ normalisation	0.61	0.022
$t\bar{t} + \geq 1c$ normalisation	0.28	0.012
Total statistical uncertainty	0.69	0.050
Total uncertainty	1.5	0.12

arXiv:1907.06131 HIGG-2017-08

LVF Higgs $H \to e\tau$, $H \to \mu\tau$

Baseline event selection and categorisation:

+ single-lepton triggers

Selection	$\ell\tau_{\ell'}$	$\ell\tau_{\text{had}}$
Baseline	exactly $1e$ and 1μ, OS	exactly 1ℓ and $1\tau_{\text{had-vis}}$, OS
	$p_T^{\ell_1} > 45$ GeV	$p_T^{\ell} > 27.3$ GeV
	$p_T^{\ell_2} > 15$ GeV	$p_T^{\tau_{\text{had-vis}}} > 25$ GeV, $\lvert\eta^{\tau_{\text{had-vis}}}\rvert < 2.4$
	$30\text{ GeV} < m_{\text{vis}} < 150\text{ GeV}$	$\sum_{i=\ell,\tau_{\text{had-vis}}} \cos\Delta\phi(i, E_T^{\text{miss}}) > -0.35$
	$p_T^e(\text{track})/p_T^e(\text{cluster}) < 1.2$ ($\mu\tau_e$ only)	$\lvert\Delta\eta(\ell, \tau_{\text{had-vis}})\rvert < 2$
	b-veto (for jets with $p_T > 25$ GeV and $\lvert\eta\rvert < 2.4$)	
VBF	Baseline	
	≥ 2 jets, $p_T^{j_1} > 40$ GeV, $p_T^{j_2} > 30$ GeV	
	$\lvert\Delta\eta(j_1, j_2)\rvert > 3$, $m(j_1, j_2) > 400$ GeV	
	–	$p_T^{\tau_{\text{had-vis}}} > 45$ GeV
Non-VBF	Baseline plus fail VBF categorization	
	$m_T(\ell_1, E_T^{\text{miss}}) > 50$ GeV	–
	$m_T(\ell_2, E_T^{\text{miss}}) < 40$ GeV	–
	$\lvert\Delta\phi(\ell_2, E_T^{\text{miss}})\rvert < 1.0$	–
	$p_T^{\tau}/p_T^{\ell_1} > 0.5$	–
Top-quark CR VBF and non-VBF	inverted b-veto: ≥ 1 b-tagged jet ($p_T > 25$ GeV and $\lvert\eta\rvert < 2.4$)	
$Z \to \tau\tau$ CR VBF and non-VBF	inverted $p_T^{\ell_1}$ requirement: $35\text{ GeV} < p_T^{\ell_1} < 45\text{ GeV}$	

BDT input variables:

$\ell\tau_{\ell'}$ Variable	VBF	non-VBF	$\ell\tau_{\text{had}}$ Variable	VBF	non-VBF
m_{MMC}	HR	HR	m_{coll}	HR	HR
$p_T^{\ell_1}$	•	•	p_T^{ℓ}	•	HR
$p_T^{\ell_2}$	HR	HR	$p_T^{\tau_{\text{had-vis}}}$	•	HR
$\Delta R(\ell_1, \ell_2)$	HR	•	$\Delta R(\ell, \tau_{\text{had-vis}})$	•	•
$m_T(\ell_1, E_T^{\text{miss}})$	•	HR	$m_T(\ell, E_T^{\text{miss}})$	HR	•
$m_T(\ell_2, E_T^{\text{miss}})$	HR	•	$m_T(\tau_{\text{had-vis}}, E_T^{\text{miss}})$	HR	HR
$\Delta\phi(\ell_1, E_T^{\text{miss}})$	•	•	$\Delta\phi(\ell, E_T^{\text{miss}})$	HR	•
$\Delta\phi(\ell_2, E_T^{\text{miss}})$		HR	$\Delta\phi(\tau_{\text{had-vis}}, E_T^{\text{miss}})$	•	
$m(j_1, j_2)$	•		$m(j_1, j_2)$	•	
$\Delta\eta(j_1, j_2)$	HR		$\Delta\eta(j_1, j_2)$	•	
$p_T^{\tau}/p_T^{\ell_1}$		HR	$\sum_{i=\ell,\tau_{\text{had-vis}}} \cos\Delta\phi(i, E_T^{\text{miss}})$	•	•
			E_T^{miss}	HR	•
			m_{vis}		HR
			$\Delta\eta(\ell, \tau_{\text{had-vis}})$		•
			η^{ℓ}		•
			$\eta^{\tau_{\text{had-vis}}}$		•
			ϕ^{ℓ}		•
			$\phi^{\tau_{\text{had-vis}}}$		•
			$\phi(E_T^{\text{miss}})$		•

Systematic uncertainties:

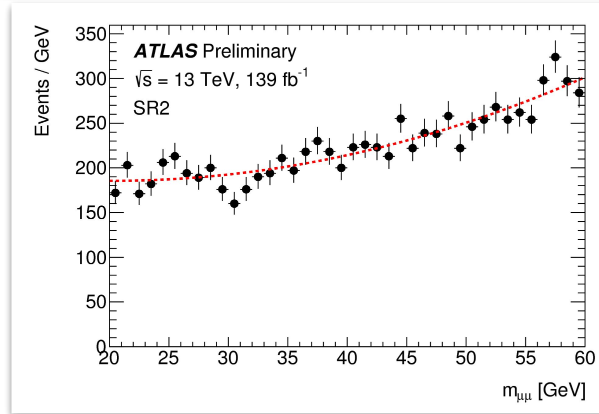
Source of uncertainty	Impact on $\mathcal{B}(H \to e\tau)$ [%] Measured	Expected	Impact on $\mathcal{B}(H \to \mu\tau)$ [%] Measured	Expected
Electron	+0.05/ – 0.05	+0.06/ – 0.06	+0.03/ – 0.03	+0.02/ – 0.02
Muon	+0.04/ – 0.04	+0.04/ – 0.04	+0.10/ – 0.10	+0.08/ – 0.10
$\tau_{\text{had-vis}}$	+0.02/ – 0.02	+0.02/ – 0.02	+0.04/ – 0.04	+0.04/ – 0.05
Jet	+0.09/ – 0.08	+0.09/ – 0.09	+0.11/ – 0.12	+0.11/ – 0.12
E_T^{miss}	+0.02/ – 0.02	+0.02/ – 0.03	+0.05/ – 0.08	+0.03/ – 0.05
b-tag	+0.02/ – 0.03	+0.03/ – 0.03	+0.01/ – 0.01	+0.01/ – 0.01
Mis-ID backg. ($\ell\tau_{\ell'}$)	+0.08/ – 0.07	+0.09/ – 0.08	+0.07/ – 0.07	+0.07/ – 0.07
Mis-ID backg. ($\ell\tau_{\text{had}}$)	+0.12/ – 0.11	+0.11/ – 0.12	+0.11/ – 0.11	+0.10/ – 0.10
Pile-up modelling	+0.02/ – 0.01	+0.01/ – 0.01	+0.05/ – 0.03	+0.08/ – 0.06
Luminosity	< 0.01	< 0.01	< 0.01	< 0.01
Background norm.	+0.05/ – 0.04	+0.05/ – 0.03	+0.04/ – 0.02	+0.05/ – 0.03
Theor. uncert. (backg.)	+0.04/ – 0.03	+0.04/ – 0.03	+0.08/ – 0.07	+0.09/ – 0.09
Theor. uncert. (signal)	+0.01/ – 0.01	+0.01/ – 0.01	+0.04/ – 0.02	+0.02/ – 0.02
MC statistics	+0.04/ – 0.04	+0.03/ – 0.03	+0.04/ – 0.04	+0.05/ – 0.04
Full systematic	+0.17/ – 0.16	+0.17/ – 0.17	+0.18/ – 0.18	+0.19/ – 0.20
Data statistics	+0.07/ – 0.07	+0.07/ – 0.07	+0.07/ – 0.07	+0.08/ – 0.08
Total	+0.18/ – 0.17	+0.18/ – 0.18	+0.19/ – 0.19	+0.20/ – 0.21

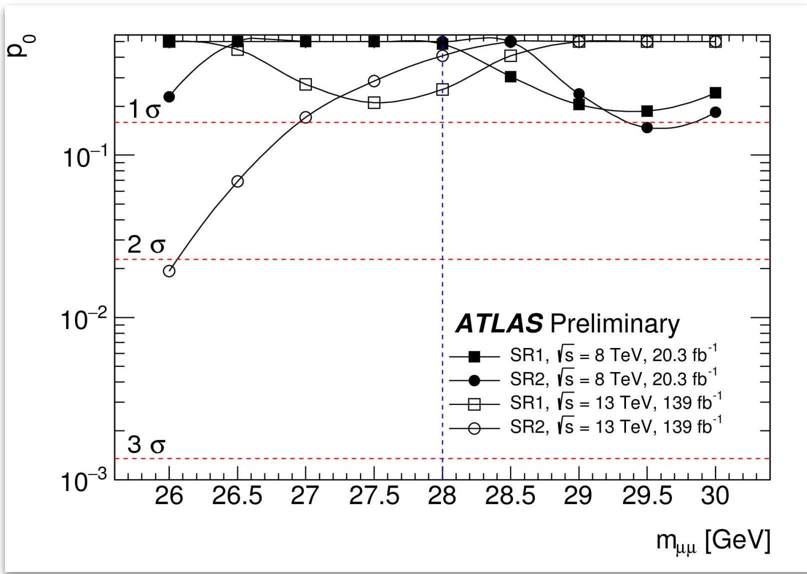
ATLAS-CONF-2019-036

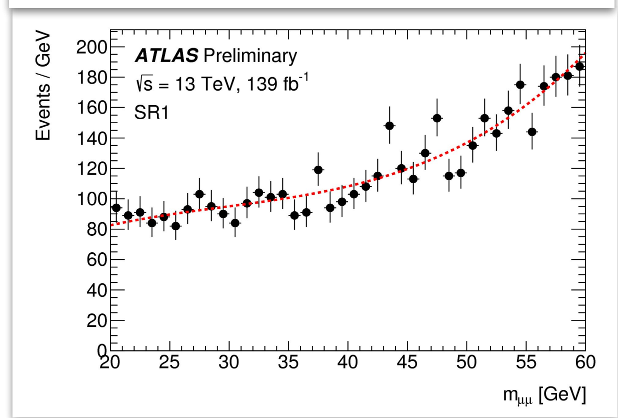
Search for a resonance decaying to μμ in 26-30 GeV

- No experimental exclusion of light (pseudo)scalars, e.g. those predicted in 2HDM and NMSSM
- Datasets: 20 fb^{-1} at 8 TeV and 139 fb^{-1} at 13 TeV
- No significant excess in the dimuon invariant masses of 26-30 GeV
- The maximum local significance in the mass range 26–30 GeV is found in SR2 (exactly 2 jets) for both datasets

Preselection	
2 OS muons with $\lvert\eta\rvert < 2.1$ and $p_T > 25$ GeV Leading muon $p_T > 27$ GeV (13 TeV dataset only) $m_{\mu\mu} > 12$ GeV $\geq$2 jets with $p_T > 30$ GeV ≥ 1 b-tagged (60%) jet with $\lvert\eta\rvert < 2.4$	
SR1	SR2
Exactly one jet with $\lvert\eta\rvert < 2.4$ ≥ 1 jet with $2.4 < \lvert\eta\rvert < 4.5$	Exactly two jets with $\lvert\eta\rvert < 2.4$ No jets with $2.4 < \lvert\eta\rvert < 4.5$ $MET < 40$ GeV $\Delta\phi$ (jj,$\mu\mu$)> 2.5







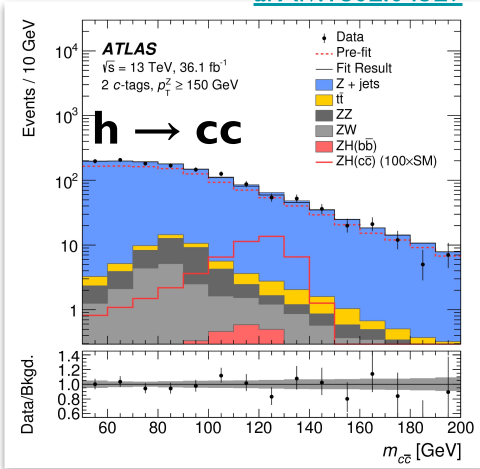
Rare Higgs decays

- Add limits on production cross section times branching fraction for further decay channels at the 95% CL

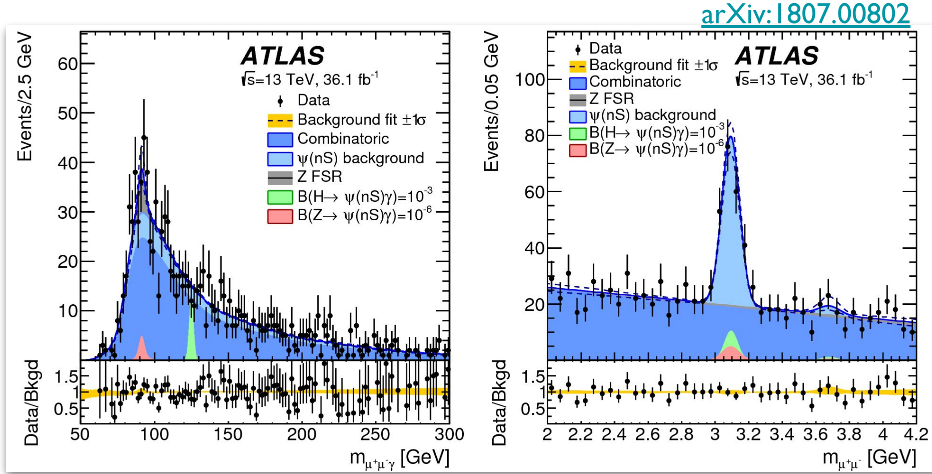
- $h \rightarrow cc$: < 110 × SM arXiv:1802.04329
- $h \rightarrow \rho\gamma$: < 52 × SM arXiv:1712.02758
- $h \rightarrow \phi\gamma$: < 208 × SM arXiv:1712.02758
- $h \rightarrow Z\gamma$: < 6.6 × SM arXiv:1708.00212
- $h \rightarrow \mu\mu$: < 1.7 x SM ATLAS-CONF-2019-028

- $h \rightarrow J/\psi\gamma$: $B(H \rightarrow J/\psi\gamma) < 3.5\times10^{-4}$ arXiv:1807.00802
- $h \rightarrow \psi(2S)\gamma$: $B(H \rightarrow \psi(2S)\gamma) < 2.0\times10^{-3}$ arXiv:1807.00802
- $h \rightarrow \Upsilon(nS)\gamma$: $B(H \rightarrow \Upsilon(nS)\gamma) < (4.9, 5.9, 5.7)\times10^{-4}$ for (n = 1, 2, 3) final states arXiv:1807.00802

arXiv:1802.04329

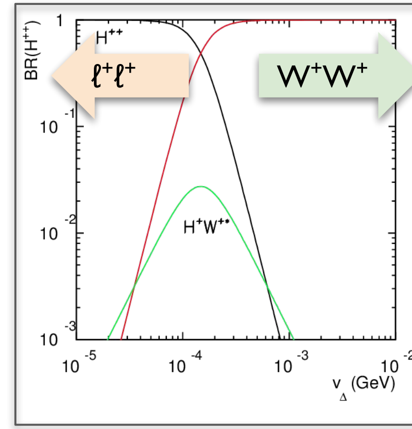


arXiv:1807.00802



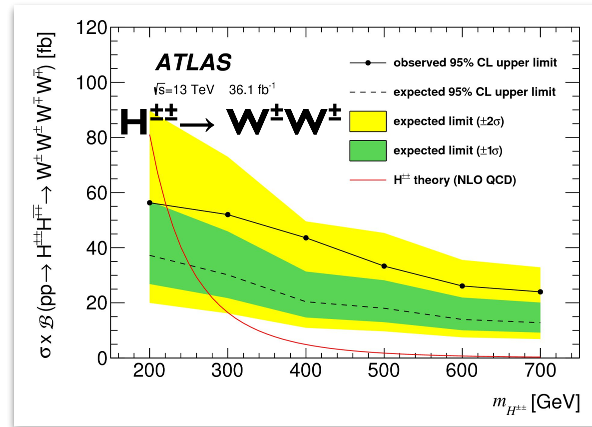
Doubly charged Higgs

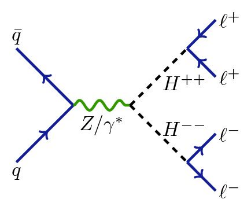
13 TeV, 36.1 fb^{-1}



- Doubly charged Higgs bosons in many theories: left-right symmetric models, Higgs triplet models, the little Higgs model, type-II see-saw models, the Georgi–Machacek model, etc
- Include a scalar triplet in addition to the SM scalar doublet

- **$H^{\pm\pm} \to W^{\pm}W^{\pm}$** arXiv:1808.01899 HIGG-2016-09
  - multi-lepton events in three channels (a pair of same-sign leptons, three leptons and four leptons) with missing transverse momentum and jets
  - the model considered is excluded at 95% CL $H^{\pm\pm}$ boson masses between 200 and 220 GeV





- **$H^{\pm\pm} \to \ell^{\pm}\ell^{\pm}$** arXiv:1710.09748 EXOT-2016-07
  - multi-lepton events: 2 same-sign leptons, 3 leptons and 4 leptons (2 SS pairs) channels
  - Observed limit on the doubly charged Higgs mass between 770 GeV and 870 GeV for the $H^{\pm\pm}_L$ with $(H^{\pm\pm} \to \ell^{\pm}\ell^{\pm})=100\%$, and are above 450 GeV for $B(H^{\pm\pm} \to \ell^{\pm}\ell^{\pm}) \geq 10\%$