

Searches for BSM Higgs at ATLAS

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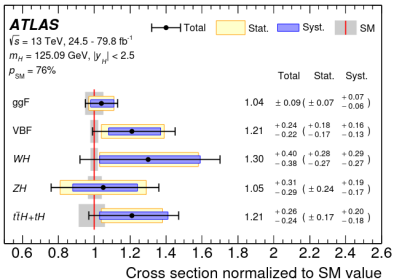
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Introduction

A 125 GeV Higgs boson



The scalar particle predicted by the SM to break the EW symmetry?

The first state of an extended Higgs sector?

Several BSM models predict an extended scalar sector

SUSY

DM

Axions

Baryogenesis models

2HDM: add another SU(2) doublet to the SM

5 physical states:

(CP conserving case)

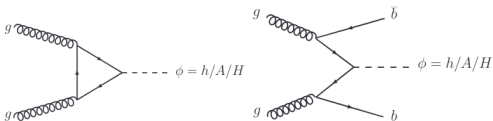


2HDM+s (singlet)

2 additional physical states:

Possibly light ($m < m_h$)





- Two Signal Regions (SR)
 - ggF \rightarrow b-jet veto
 - b associated $\rightarrow \geq 1$ b-jet

Discriminant variable

$$m_T^{tot} = \sqrt{(p_T^{\tau_1} + p_T^{\tau_2} + E_T^{miss})^2 - (\mathbf{p}_T^{\tau_1} + \mathbf{p}_T^{\tau_2} + \mathbf{E}_T^{miss})^2}$$

Dominant bkg

$\mathcal{T}_{lep}\mathcal{T}_{had}$: Processes where \mathcal{T}_{had} from jet

lep not OK: from jets \rightarrow multijet

$\mathcal{T}_{had}\mathcal{T}_{had}$: Multijet production

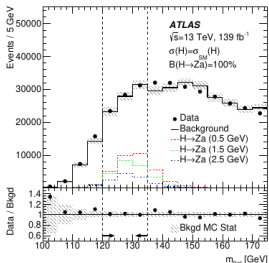
lep OK: from W+jets (b-veto)
or $t\bar{t}$ (b-tag)

- Data driven estimation in Control Regions (CR)
- Except for $Z/\gamma^* \rightarrow \tau\tau$ (b-veto) and $t\bar{t}$ (b-tag) from MC

light spin-0 boson

η_c or J/ψ (access h couplings to c)

- Hadronically decaying light resonances **challenging** \rightarrow multijet bkg
- Jet substructure techniques \rightarrow MLP classifier



- resonance reco as single jet (mass < 4 GeV)

SR: $M > 0.0524$ && $120 \text{ GeV} < m_{\ell\ell j} < 135 \text{ GeV}$

Bkg: modified ABCD method

A $\rightarrow 0.0341 < M < 0.0524$ && $155 \text{ GeV} < m_{\ell\ell j} < 175 \text{ GeV}$

B $\rightarrow m_{\ell\ell j}$ as in SR && M as in A

C $\rightarrow M$ as in SR && $m_{\ell\ell j}$ as in A

D \rightarrow SR

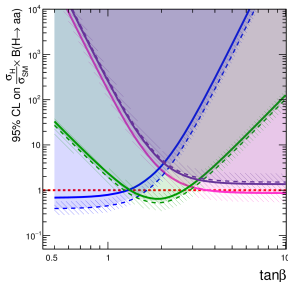
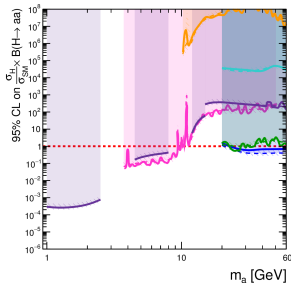
- Results **compatible** with the SM bkg only expectation.
- Upper limits at 95% CL set on $\sigma(pp \rightarrow H)\mathcal{B}(H \rightarrow Z(Q/a))$:

• $H \rightarrow Z\eta_c$: 110 pb • $H \rightarrow ZJ/\psi$: 100 pb • $H \rightarrow Za$: [17-340] pb

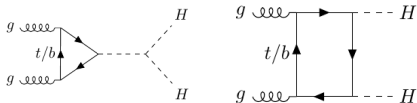
First direct limit on had decays of a non-SM Higgs boson with $m < 4 \text{ GeV}$.

$h \rightarrow aa$ ATL-PHYS-PUB-2018-045

- Observed and expected limits on $\frac{\sigma_H}{\sigma_{SM}} \times \mathcal{B}(H \rightarrow aa)$ in 2HDM+S type-II $\tan \beta = 2$ scenario



- Different channels important for different values of $\tan \beta$
- Searches complement each other



$H \rightarrow bb \quad H \rightarrow WW^*/ZZ^*/\tau\tau$

DNN classifier \rightarrow 4 outputs

Discriminant variable

$$d_{HH} = \ln[p_{HH}/(p_{Top} + p_{Z-\ell\ell} + p_{Z-\tau\tau})]$$

SR-SF: $d_{HH} > 5.45$

SR-DF: $d_{HH} > 5.55$

Signal region

$m_{\ell\ell} \in (20,60)$ GeV, $m_{bb} \in (110,140)$ GeV

2 OP ℓ + 2 b-jets

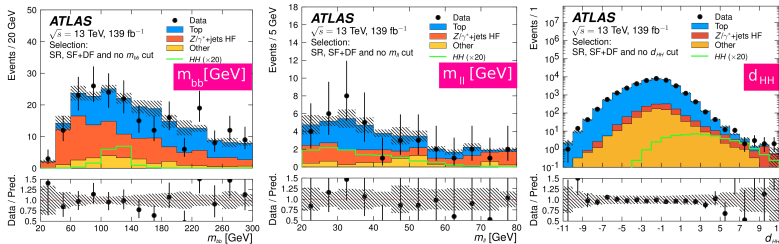
- Same Flavour
- Diff Flavour

$\rightarrow Z/\gamma^*$ bkg more SF

Bkg estimation

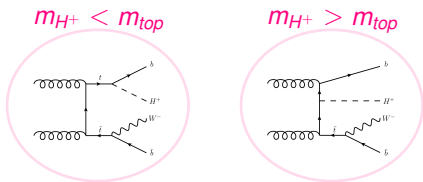
- Dominant bkg: Top and Z/γ^*
- CRs for data driven normalisation:
 - CR-Top
 - CR-Z+HF (Z/γ^* in assoc with jets from HF hadrons)

- Dists. after performing background-only fits to data in the CRs



- Data in agreement with predictions for SM bkg
- 95% CL upper limit set on the cross-section for the production of diHiggs \rightarrow 40 (29) times SM prediction

	-2σ	-1σ	Expected	$+1\sigma$	$+2\sigma$	Observed
$\sigma(gg \rightarrow HH)$ [pb]	0.5	0.6	0.9	1.3	1.9	1.2
$\sigma(gg \rightarrow HH) / \sigma^{\text{SM}}(gg \rightarrow HH)$	14	20	29	43	62	40



2 final states :

- τ +jets
- τ +lepton

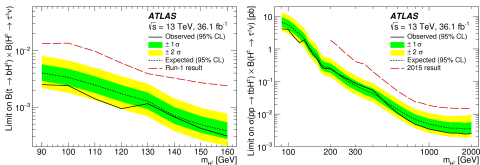
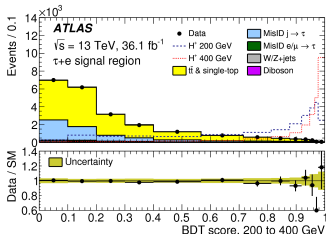
BDT to discriminate between signal and background

Independently trained for two final stages and tau pronginess

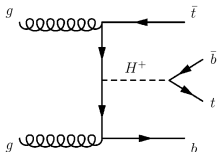
At low m_{H^\pm} : $t \rightarrow bH^\pm$ and $t \rightarrow bW$ kinematics very similar:

→ use tau polarisation to discriminate

$$\gamma = \frac{E_T^{\pi^\pm} - E_T^{\tau^0}}{E_T^\tau}$$

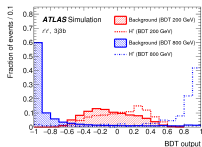


Data compatible with bkg only hypothesis



$$M_H > m_b + m_{top}$$

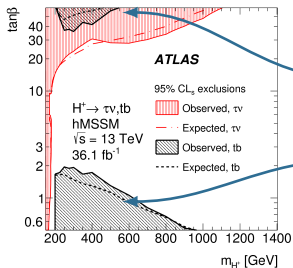
Event categorisation in SR and CR according to number of jets and b-jets



BDT to discriminate between signal and bkg:

trained in different mass regions

for each signal against all bkgs ($\ell+$ jets channel) or $t\bar{t}$ bkg ($\ell\ell$ channel)

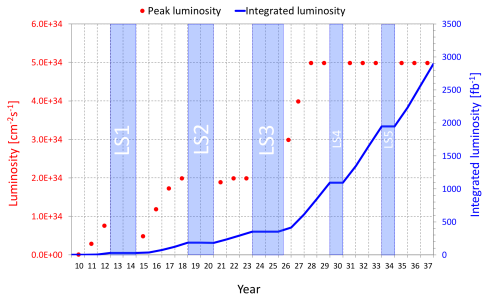


Exclusions at low masses and high $\tan \beta$ from $H^\pm \rightarrow \tau\nu$

Low $\tan \beta$ strongest limits from $H^\pm \rightarrow tb$

Conclusions

- Several searches for additional Higgs bosons in ATLAS
- Many not covered in this talk (H^{++} , $H \rightarrow VV$, $A \rightarrow Zh$, more pair production final states (bbbb, $bb\gamma\gamma$, $bb\tau\tau$, combination), etc.
- Presented some new full Run-2 analyses \rightarrow No significant deviations from SM observed so far
- Many more 140 fb^{-1} analyses to come.
- Plenty of years to collect more data and discover new particles!



back up

