

Di-Higgs Results from ATLAS

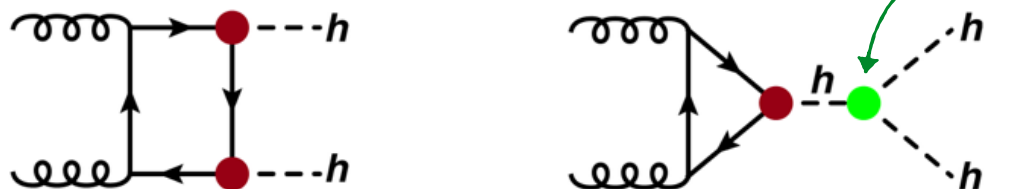
Suyog Shrestha (Ohio State University)

On behalf of the ATLAS Collaboration



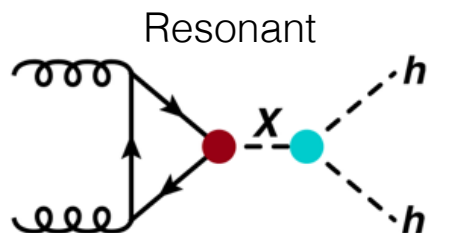
Higgs Pair Production

Standard Model

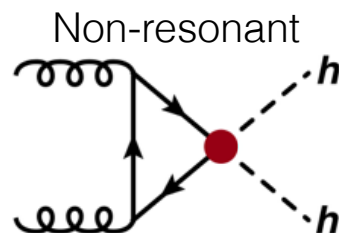


33.4 fb @ 13 TeV (significant destructive interference)

Beyond Standard Model



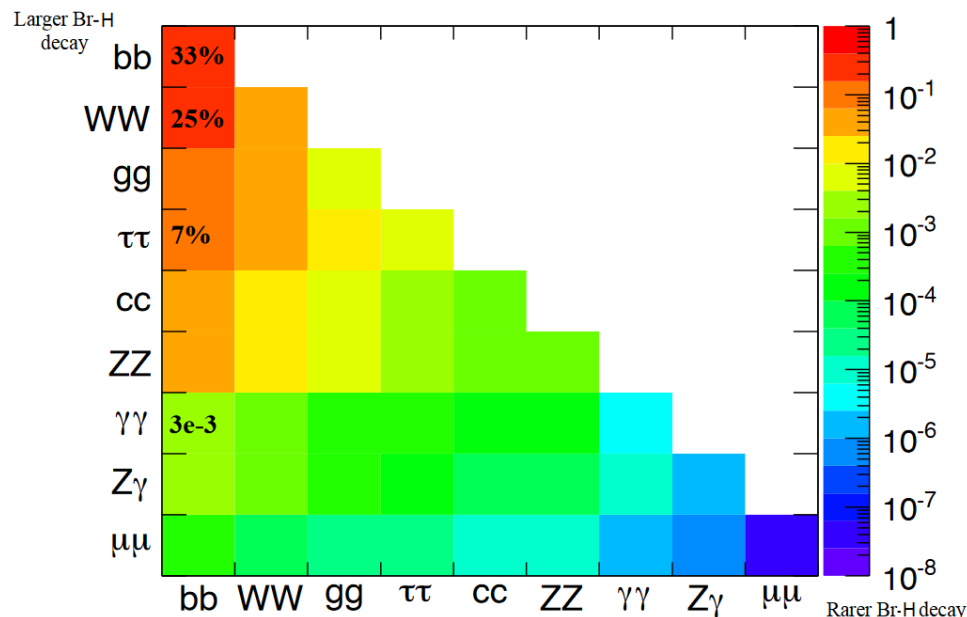
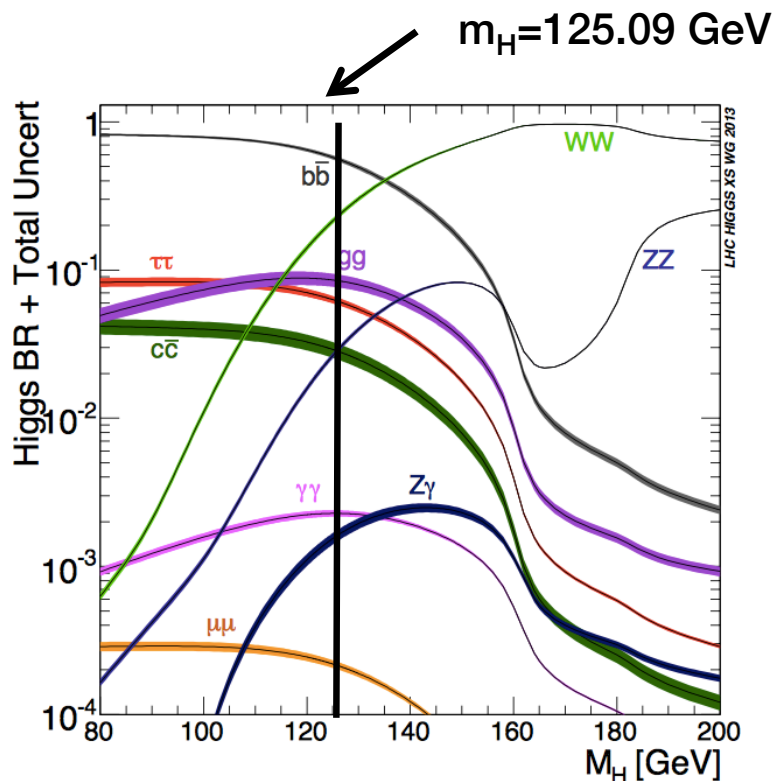
Resonant
KK gravitons, heavy higgs, ...



Non-resonant
tthh vertex, coloured scalars, ...

- Coupling strength directly related to Higgs potential
 - λ_{hhh} determined in SM through v_{ev} & m_h , its measurement is test of Higgs potential
- λ_{hhh} can be measured at LHC through observation of Higgs boson pair production
 - Potential enhancement of cross-section due to BSM physics and modified λ_{hhh}

Di-Higgs \rightarrow Diverse Final States



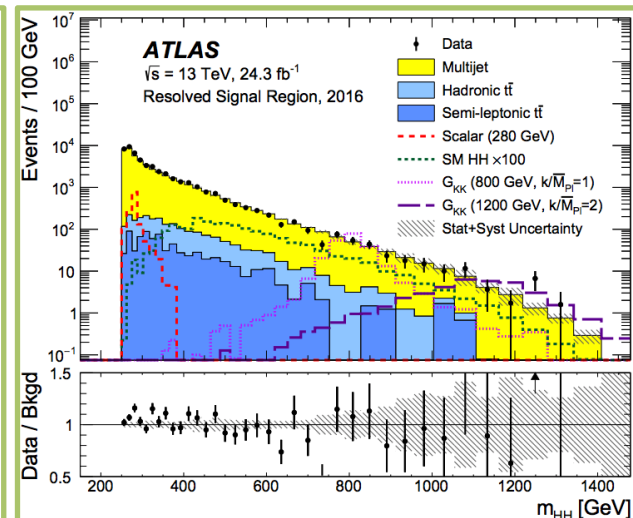
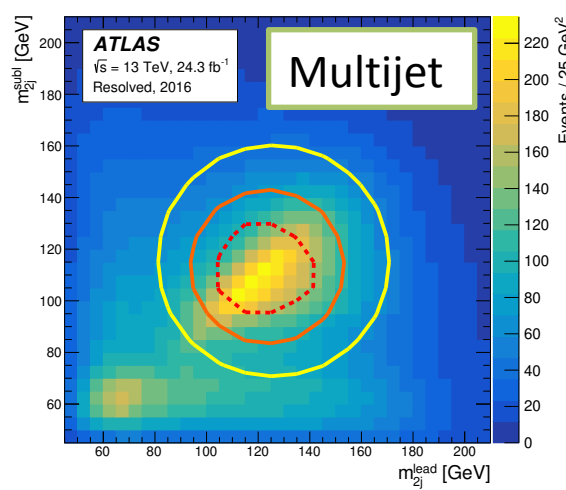
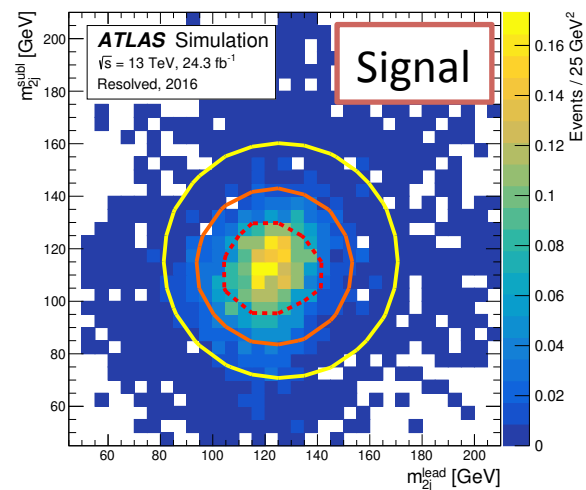
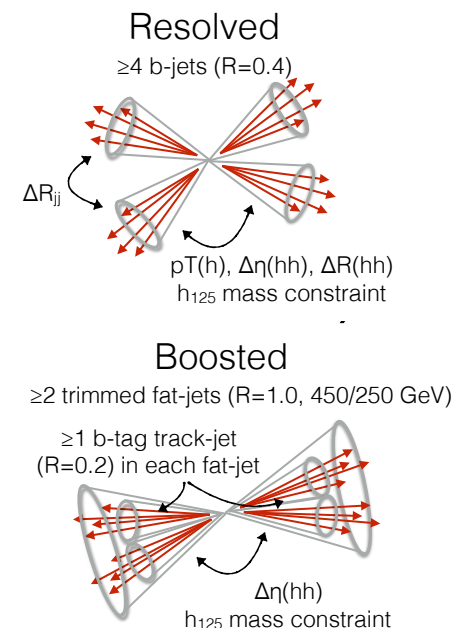
Channel	Lumi. (fb^{-1})	Reference
$b\bar{b}b\bar{b}$	36.1	JHEP01(2019)030
$b\bar{b}\tau\bar{\tau}$	27.5-36.1	PRL 121.191801
$b\bar{b}\gamma\gamma$	36.1	JHEP11(2018)040
$b\bar{b}WW^*$	36.1	JHEP04(2019)092
WW^*WW^*	36.1	JHEP05(2019)124
$WW^*\gamma\gamma$	36.1	EPJC78(2018)1007

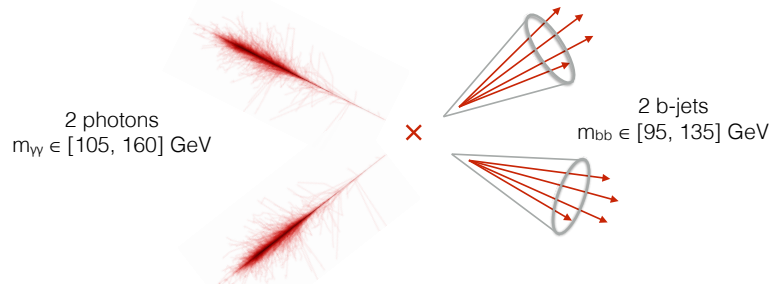
Latest Results

$b\bar{b}b\bar{b}(VBF)$	126	ATLAS-CONF-2019-030
$b\bar{b}WW^*$	139	In prepration

- Di-Higgs decay leads to diverse final states
- Some of highest BRs and cleanest channels studied so far
- Will present a selection of 27 – 139 fb^{-1} results

- “Resolved” and “Boosted” topologies targeting non-res/low-mass and high-mass resonances respectively
- Reconstruct 2 Higgs boson candidates from 4 b-jets
- Biggest background is QCD multijet, shape from 2 b-tag sample while normalization comes from fit to sidebands
- For top-quark, shape from MC while normalization from fit to data
- Final discriminant is m_{HH} , perform fit to m_{HH}

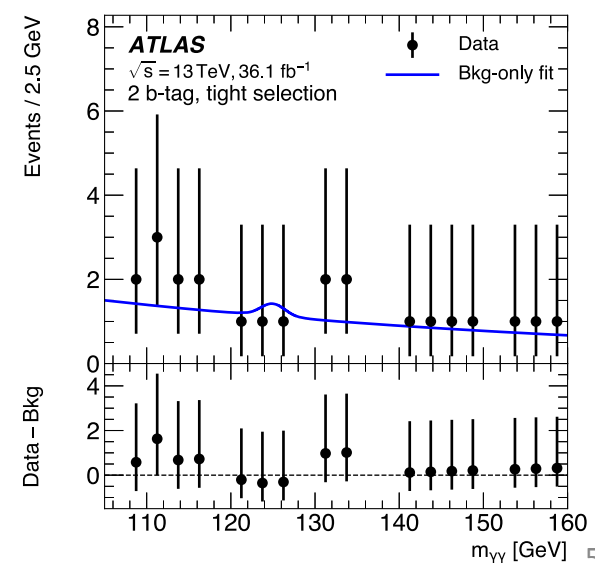
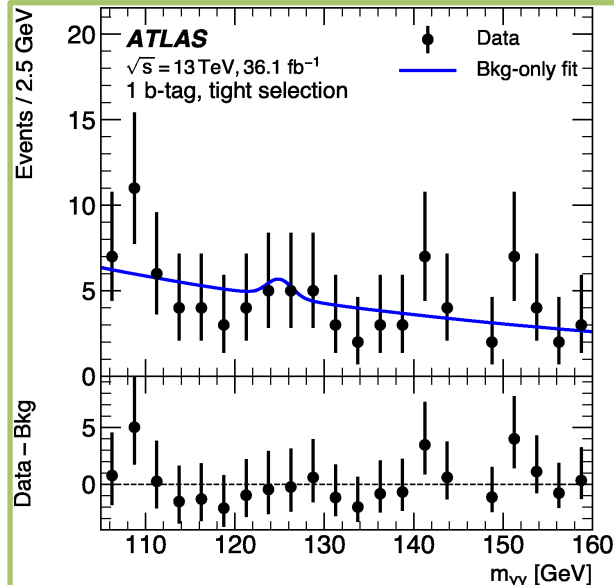
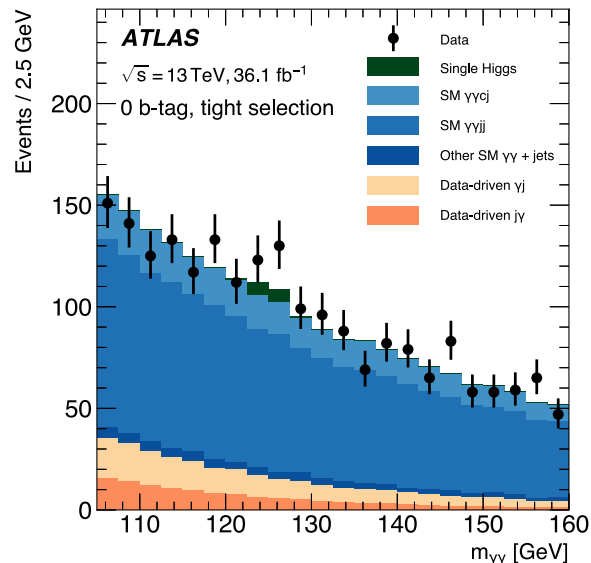




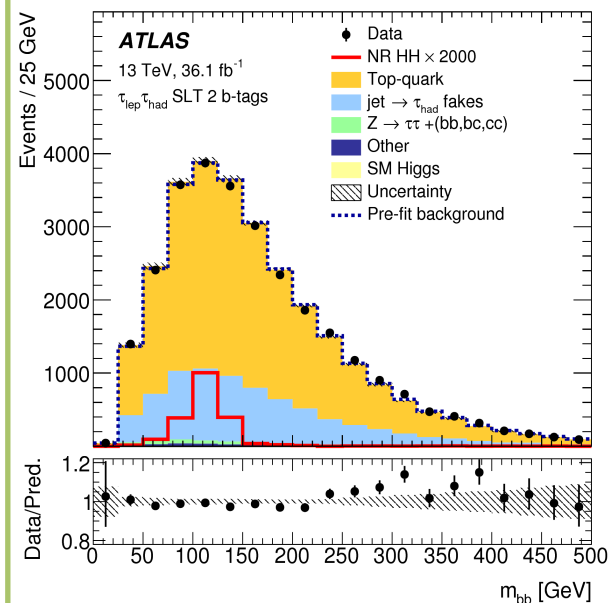
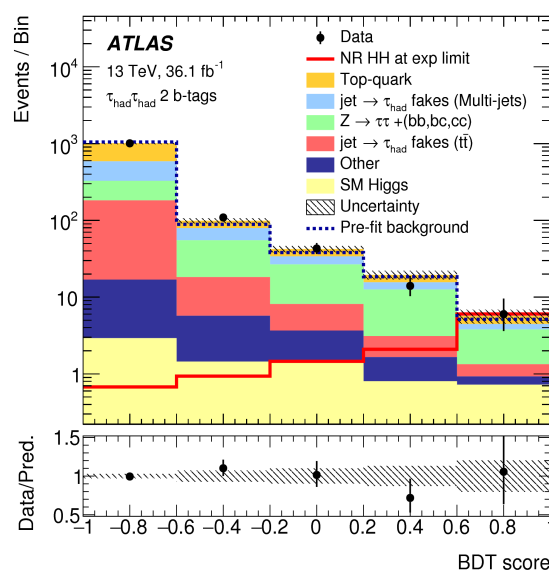
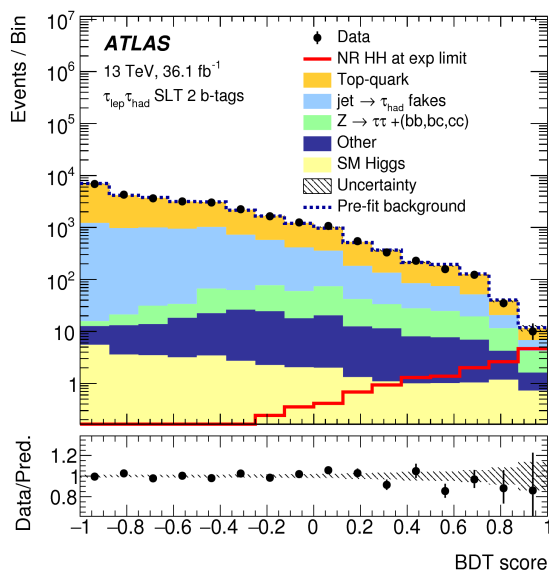
$$HH \rightarrow bb\gamma\gamma$$

JHEP 11 (2018) 040

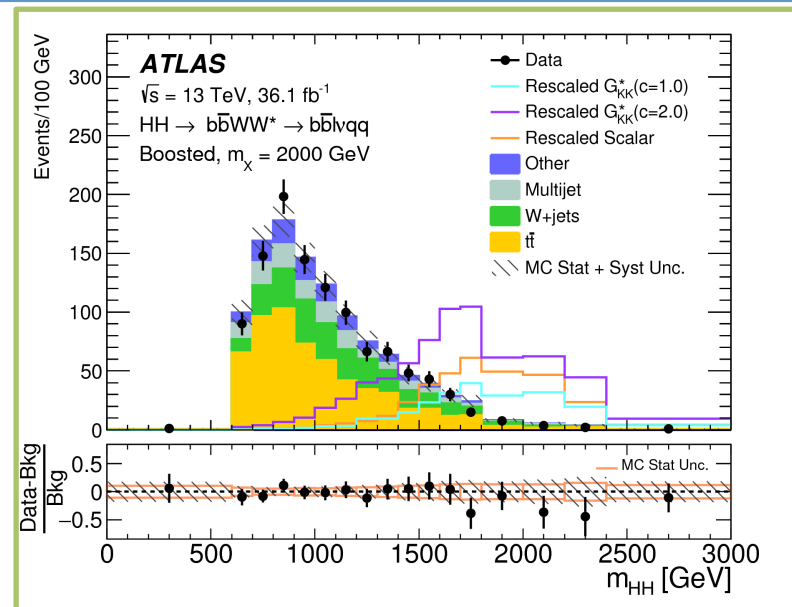
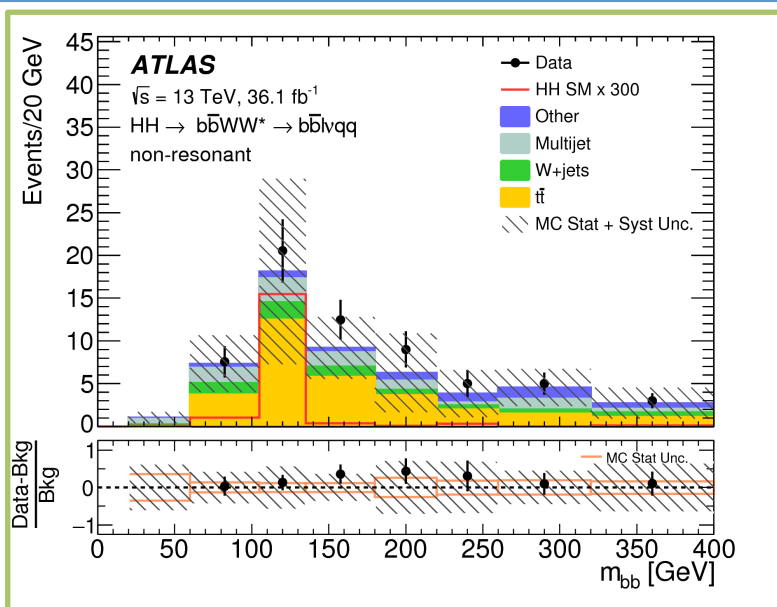
- Fairly clean signature with two photons and two b-jets
- SR categories according to #b-jets (1 and 2)
- Bkg: Fit exponential + DSCB function in 0-tag region
- Perform unbinned fit to $m_{\gamma\gamma}$ (m_{HH}) non-res (res) case



- Target final states with e/μ and hadronic- τ , together with 2 b-jets and MET
- Train BDT with several discriminating variables in $\tau_{\text{lep}} + \tau_{\text{had}}$ and $\tau_{\text{had}} + \tau_{\text{had}}$ channels
- Dominant backgrounds: top-quark and Z+HF, constrained in data CR
- Signal extraction through fit to BDT output



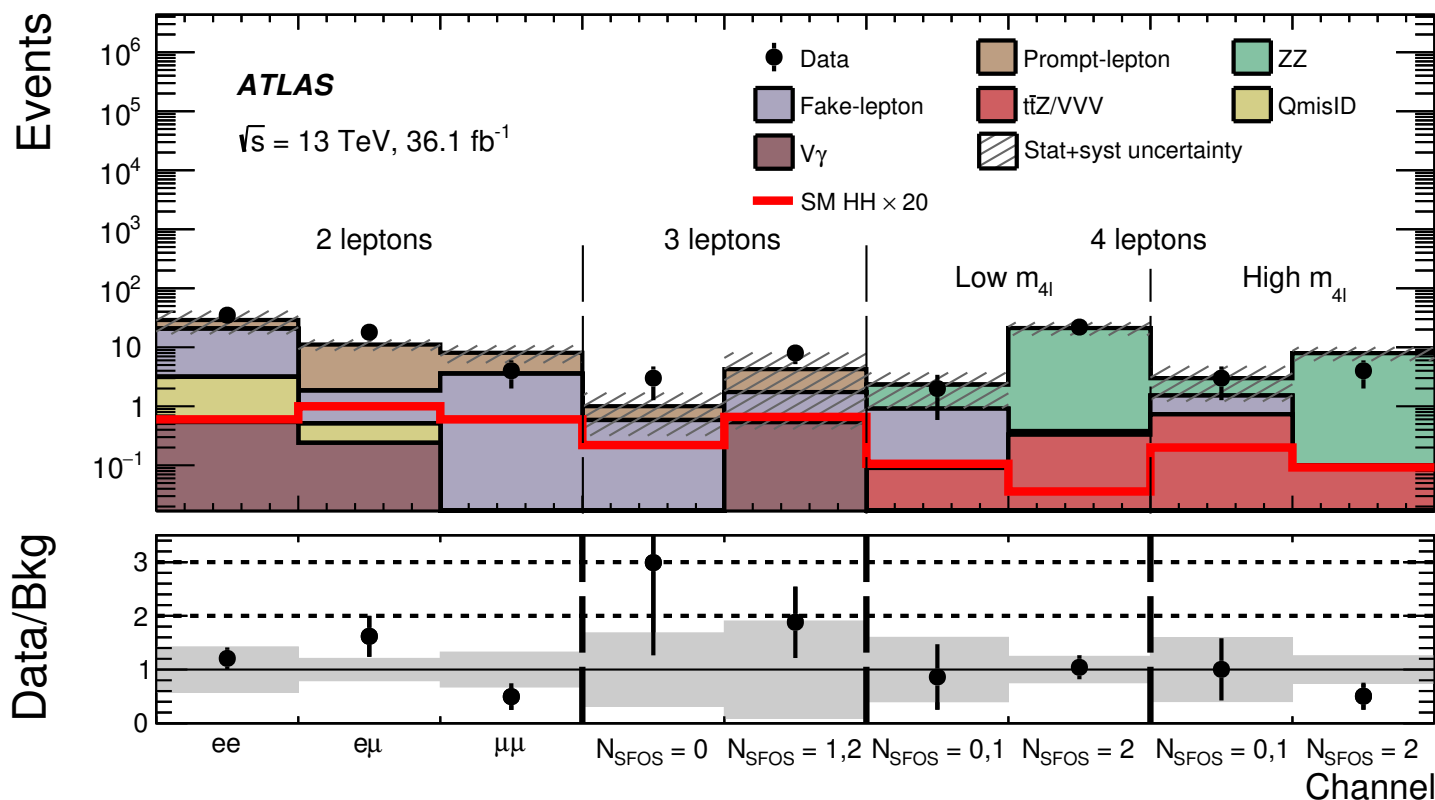
- Resolved and boosted event selection targeting low-mass and high-mass regions respectively
- Most SM bkg from MC simulation, except:
 - Top bkg normalized in dedicated CR in resolved case
 - Multijet bkg from data-driven method
- Count events in m_{HH} windows for resonant (resolved) or fit m_{HH} shape (boosted)



$HH \rightarrow WW^* WW^*$

JHEP 05 (2019) 124

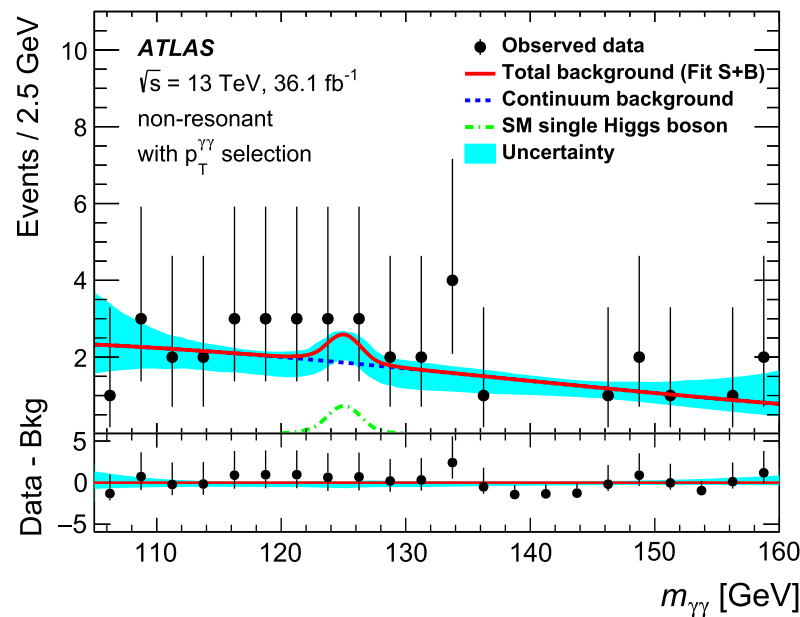
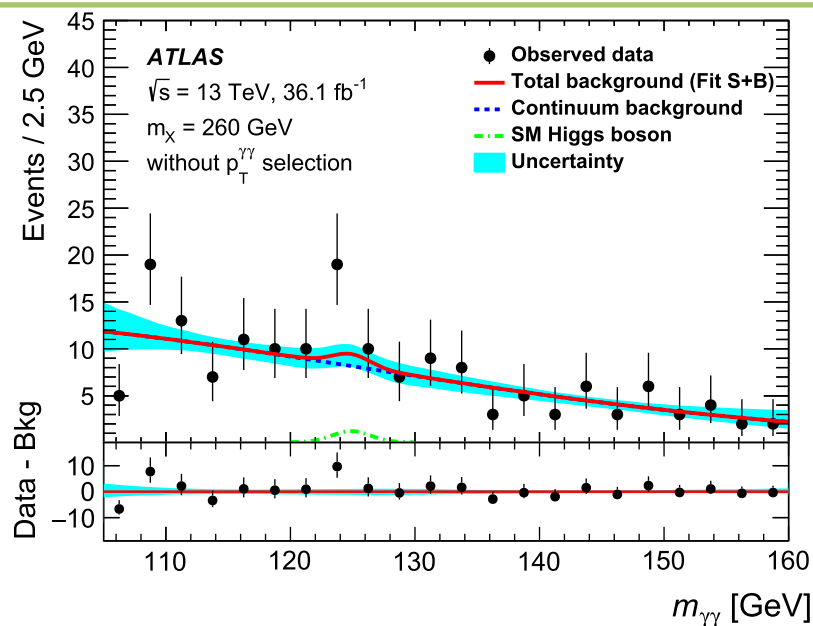
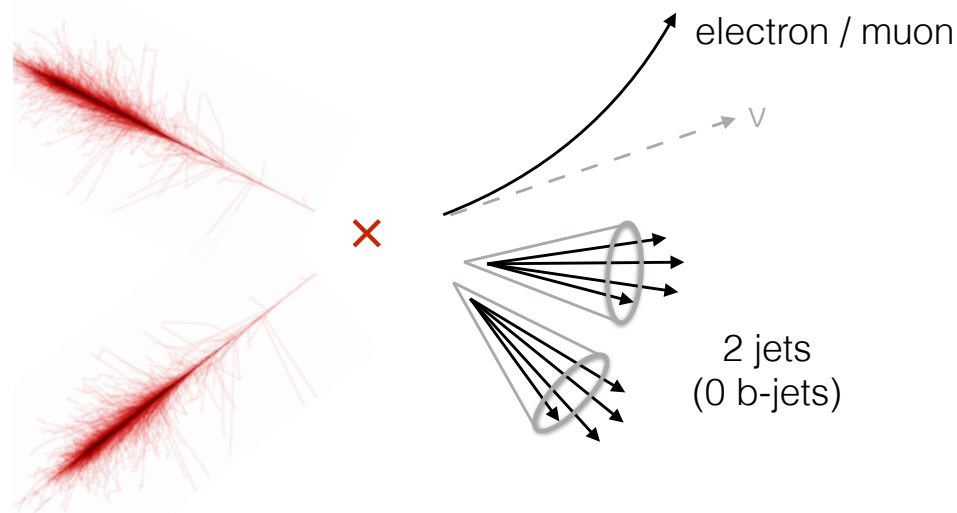
- In addition to Higgs pair, also search for heavier S bosons
- Data-drive background estimate for dominant V+jets, WZ, and mis-identified charge while MC simulation for smaller backgrounds
- Cut & count analysis exploiting kinematics in various #lepton bins



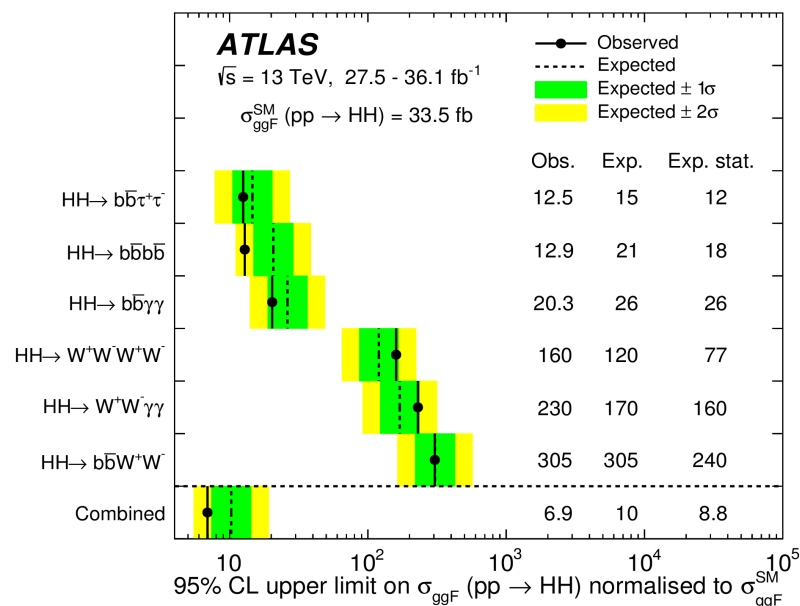
$HH \rightarrow \gamma\gamma WW^*$

EPJC 78 (2018) 1007

- Select at least 2 photons, 1 lepton, & 2 central jets
- Require $p_{T_{\gamma\gamma}} > 100$ GeV for high mass resonances
- Bkg from $m_{\gamma\gamma}$ sidebands
- Fit $m_{\gamma\gamma}$ spectrum

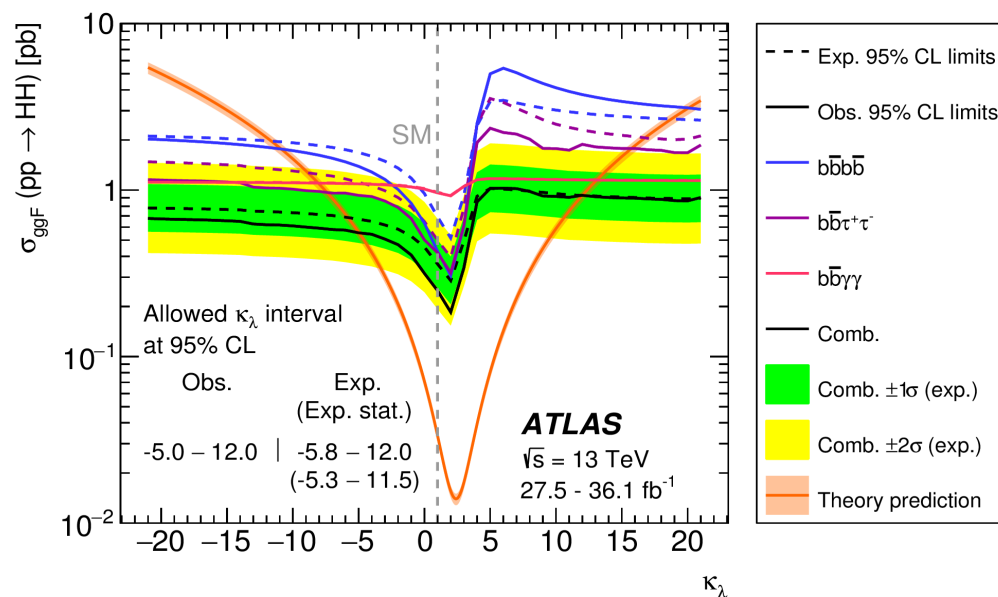


- Simultaneous fit to data for signal cross-section and nuisance parameters (for statistical and systematic uncertainties), using the CLs approach



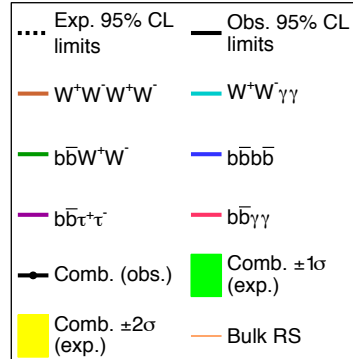
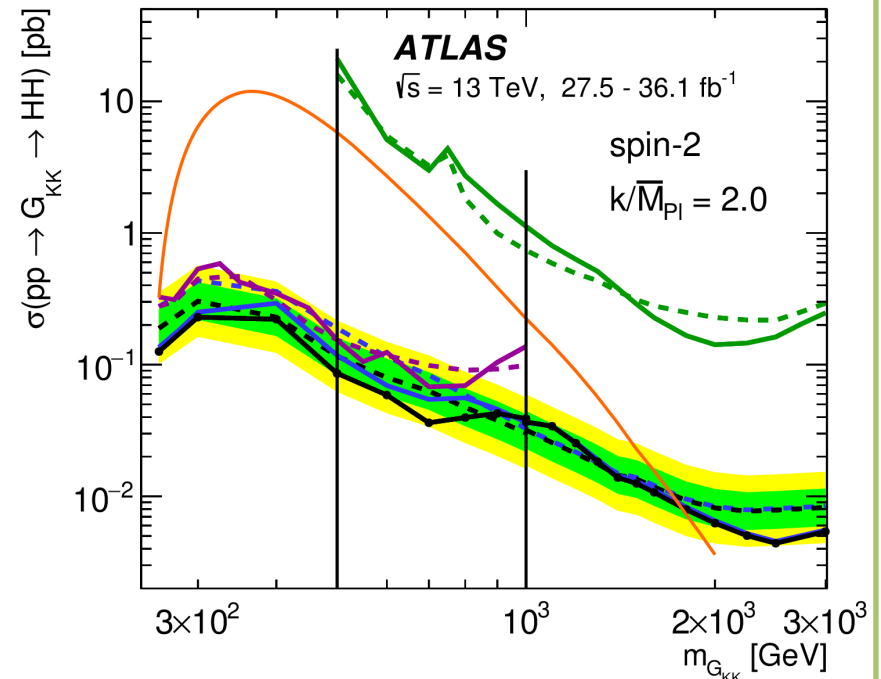
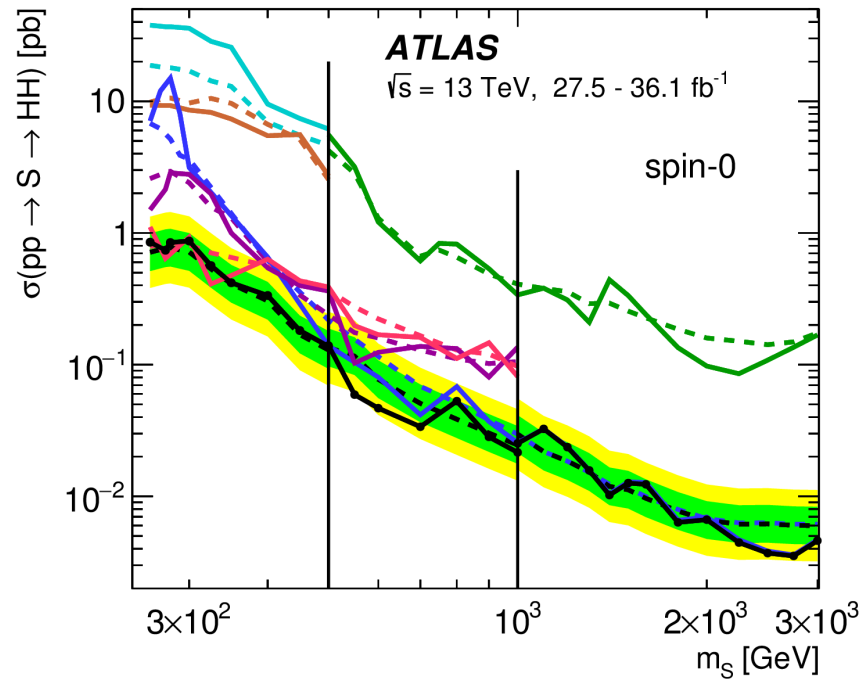
95% CL limit for $\kappa_\lambda = 1$:

6.9 (10) X SM obs. (exp.)



95% CL confidence intervals:

κ_λ : obs. [-5,12] (exp. [-5.8, 12])



EWK Singlet:

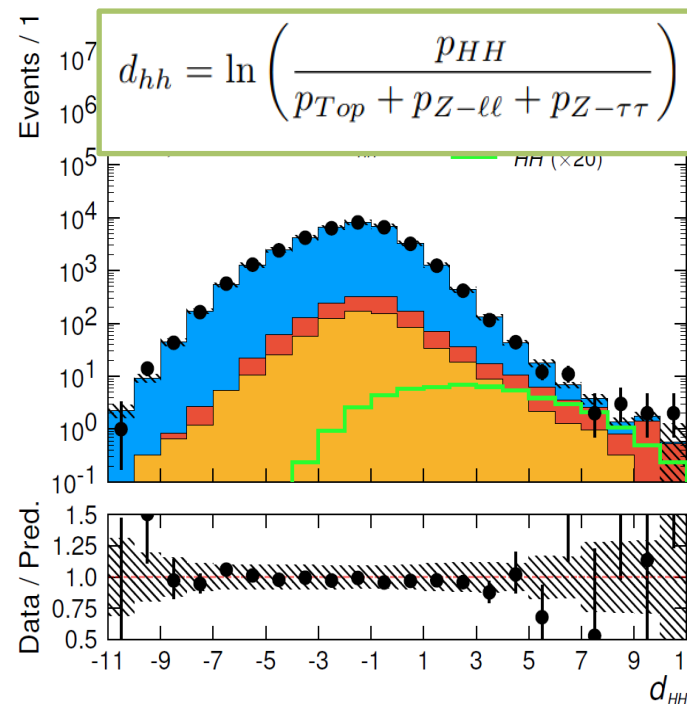
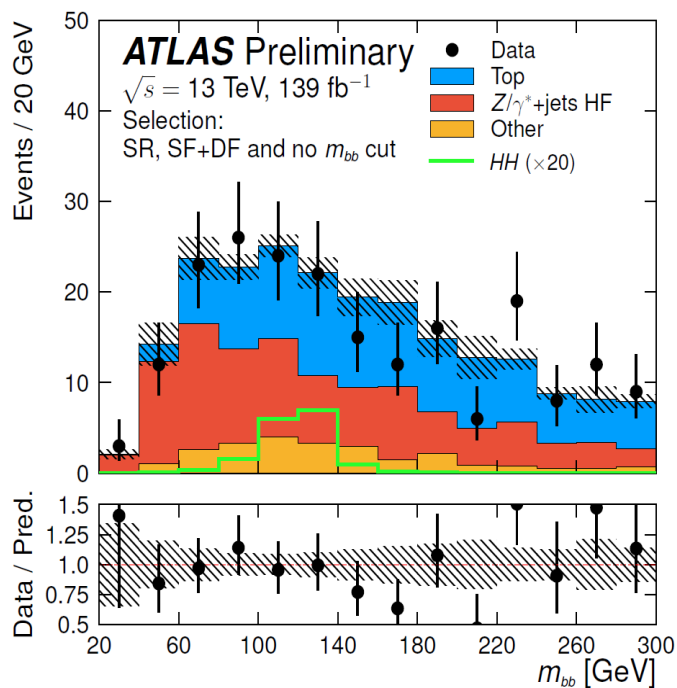
Exclusion limits in $(m_S, \sin\alpha)$ and $(\sin\alpha, \tan\beta)$

hMSSM:

Exclusion limits in $(m_A, \tan\beta)$

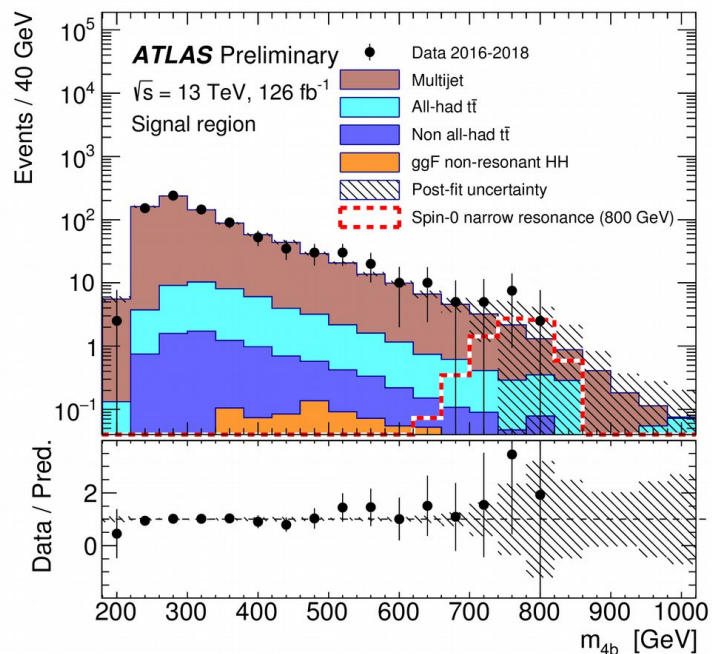
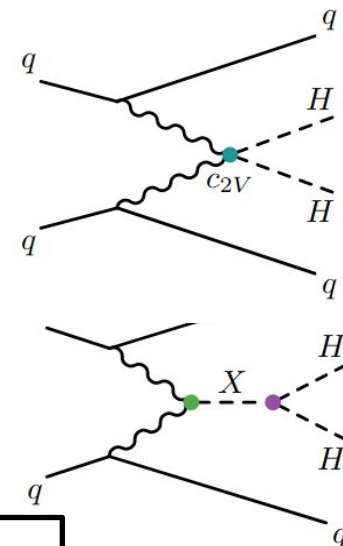
New Result in bbl+MET channel

- New channel targeting bbl+MET final state
- Can be sensitive to bbZZ, bbWW, and bbtatautau
- Dominant backgrounds ttbar and Z+HF from CRs
- DNN for signal vs background classification with multi-class output



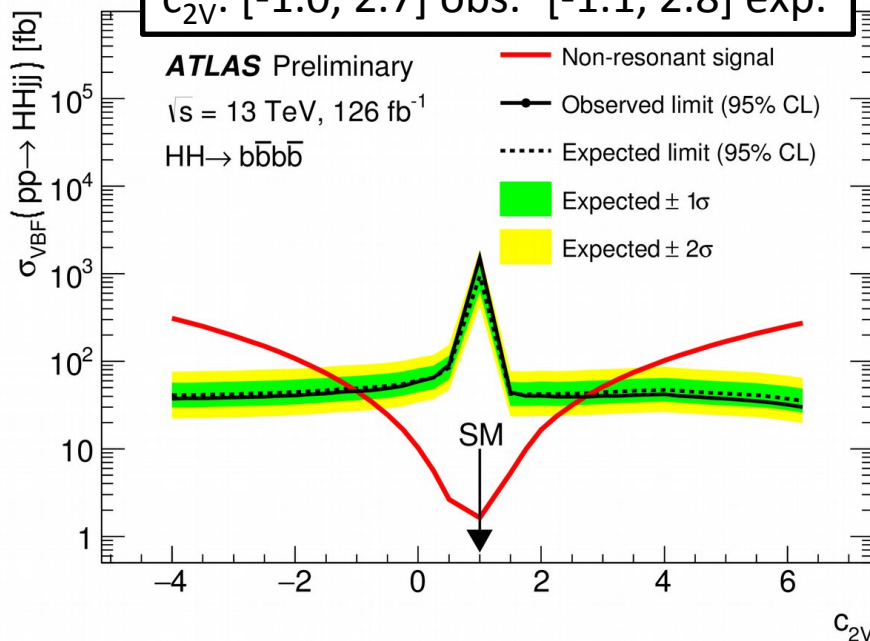
	-2σ	-1σ	Expected	$+1\sigma$	$+2\sigma$	Observed
$\sigma(gg \rightarrow HH) [\text{pb}]$	0.5	0.6	0.9	1.3	1.9	1.2
$\sigma(gg \rightarrow HH) / \sigma^{\text{SM}}(gg \rightarrow HH)$	14	20	29	43	62	40

- First analysis targeting VVHH vertex
- Analysis strategy similar to other 4b analysis with two 2 VBF jets in opposite hemispheres
- Dominant QCD multijet bkg estimated from data in 2-btag CR
- Signal extracted from fit to m_{4b} shape



95% CL intervals:

c_{2V} : [-1.0, 2.7] obs. [-1.1, 2.8] exp.



Conclusion & Outlook

- Search for diHiggs production and measurement of the Higgs trilinear self-coupling is one of the major goals of the (HL-) LHC
- Several channels with high BRs and/or clean final states have been studied by ATLAS so far
- First combination of all analyses with 2015-16 data completed, and two more analyses public now
- No enhanced Higgs pair production observed yet
- Most stringent limit set by the combination of ATLAS analyses using 2015-16 data
- Stay tuned for more results with full run2 data