Search for di-Higgs Production with ATLAS Detector

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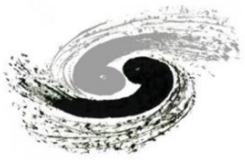
on Behalf of the ATLAS Collaboration

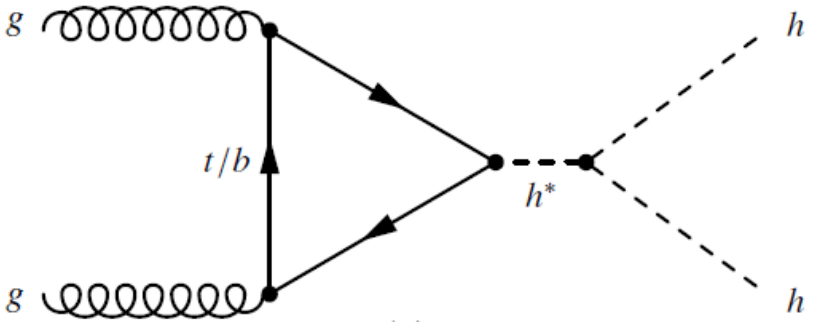
DIS2018 at Kobe



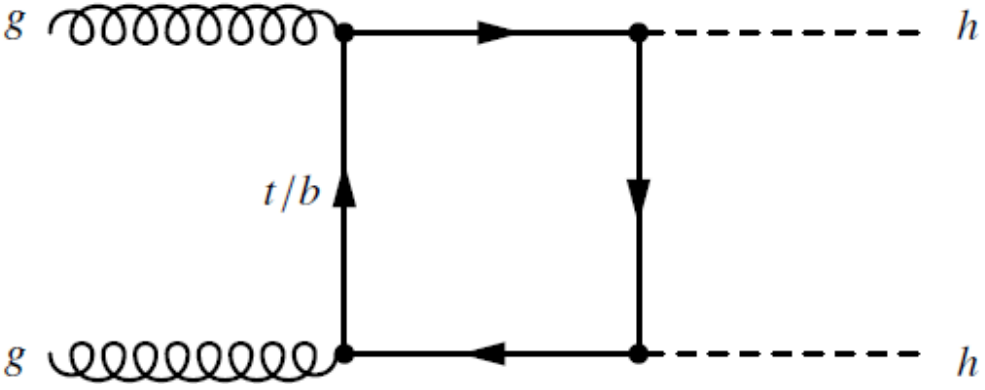
April 16-20, 2018

hh analyses

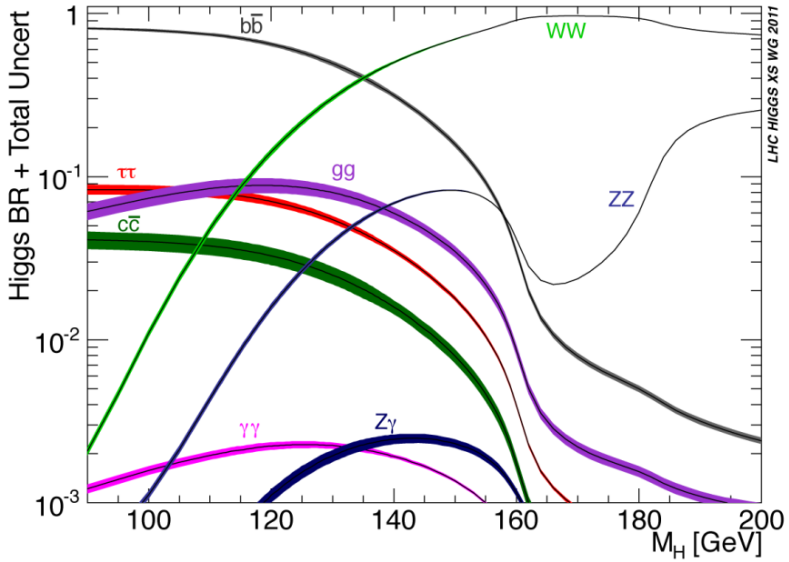
the decay of SM Higgs boson (h)



Resonance



Non-resonance



- The bb, WW, tautau channels have the highest BRs
- $\gamma\gamma$ has the di-photon mass resonance (bump search)
- SM di-higgs cross-section at at 13TeV, less than 0.1% that of SM Higgs
- Some BSM models (2HDM,KK-Gravitons, new scalar) can enhance the cross-section significantly in some region of phase space.

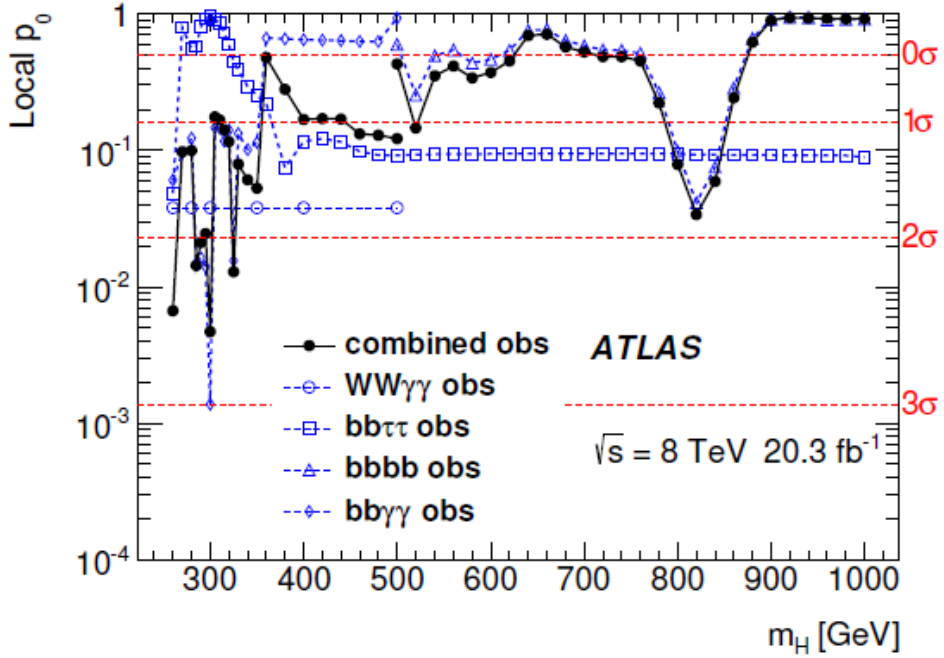
Overview of different channels at ATLAS/RUN2

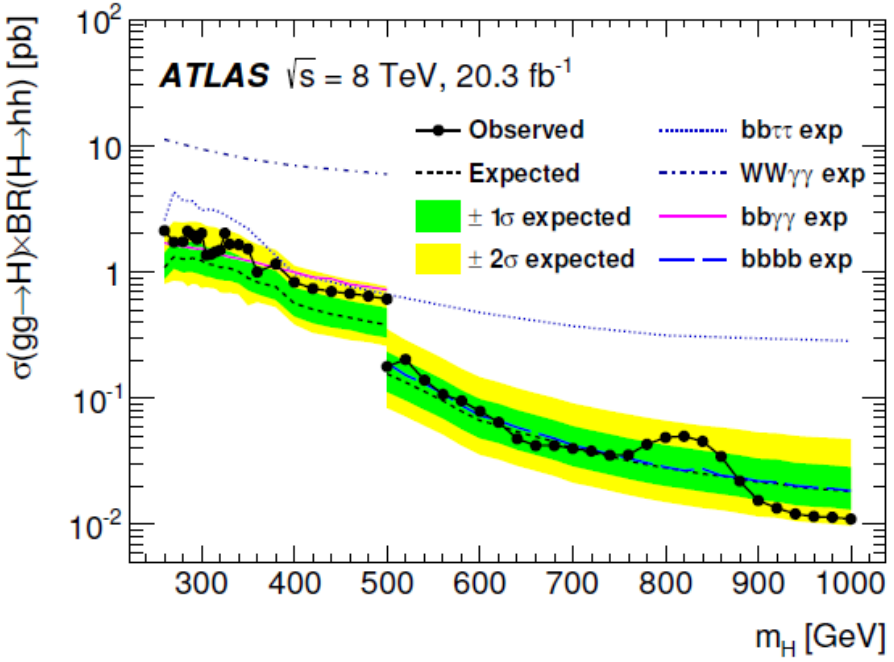
- $\gamma\gamma bb$: di-photon provides a sharp mass peak and bb can further help to suppress QCD bkg in addition to di-photon requirements.
  - RUN2 results: L=3.2 fb^{-1}, ATLAS-CONF-2016-004
- **WW(lvqq)$\gamma\gamma$**: In principle, lvqq is not very sensitive at low mass due to huge QCD; however, di-photon can improve the situation here. Statistics will be low although it is clean. lvlv$\gamma\gamma$ will start to be sensitive with more RUN2 data.
  - RUN2 results : L = 13.3 fb^{-1}, ATLAS-CONF-2016-071
- ***bbbb***: this channel is sensitive at high mass region with highly boosted jets.
  - Run2 results : L=27.5 fb^{-1}, 36.1 fb^{-1} ATLAS-EXOT-2016-31

Results are preliminary, more new results with 36 fb^{-1} are coming out in the next months

Results for Run 1

Phys.Rev.D92,092004(2015)





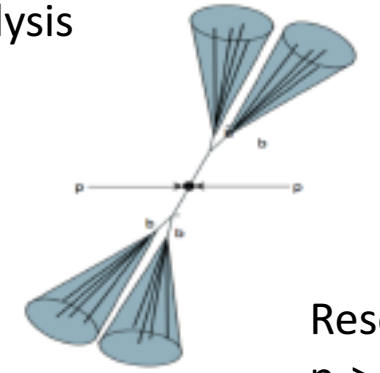
- With run1 data, four channels (bbγγ,WWγγ, bbbbb, bbtautau)are taken into account in the analyses and are combined:
  - No obvious excess has been seen.
- The upper limit can reach O(1) pb (low mass)- O(10) fb (high mass)for resonance search; for non-resonance search, ~50 SM gg->hh cross-section is excluded.

Run2 analyses:

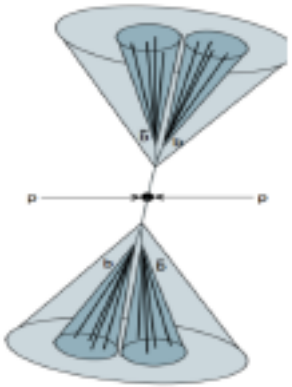
Object definitions:

Objects	Selections
Photons	TightID FixedCutLoose Lead $P_T/m_{\gamma\gamma}>0.35$, Sub $P_T/m_{\gamma\gamma}>0.25$
Jets	$P_T>25$ GeV, $\|\eta\|<2.5$ Jet vertex tagger (JVT) selection
Muons	Medium ID $P_T>4$ GeV, $\|\eta\|<2.5$, $d_0$significance, Z_0 selection B-jet muon correction
Electrons	Loose Likelihood ID, $P_T>10$ GeV $\|\eta\|<2.47$ excluding the crack region
b-jets	B-tagging selection Lead $P_T>55$ GeV, Sub $P_T>35$ GeV

4b analysis

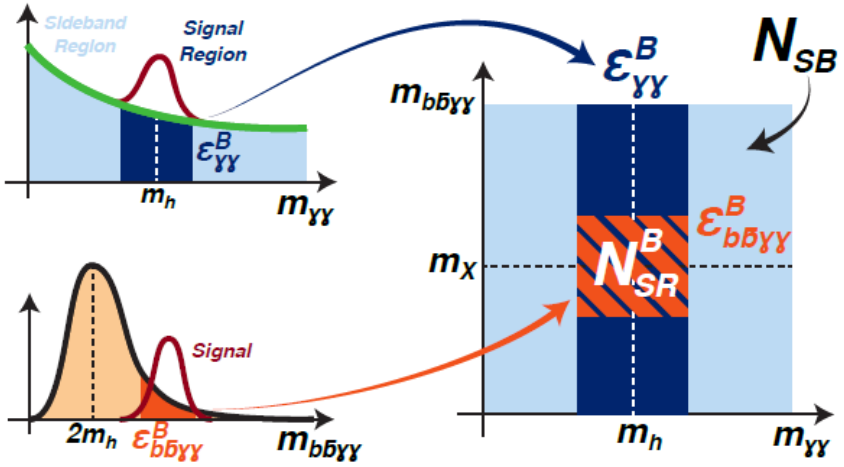


Resolved bjet :
$p_T>40$ GeV, $|\eta|<2.5$



Boosted bjet :
$p_T>250$ GeV $|\eta|<2.5$
$M_j>50$ GeV

$bb\gamma\gamma$: Continuous Background estimation



$$N^B_{SR} = N_{SB}\frac{\varepsilon^B_{m_{\gamma\gamma}}}{1-\varepsilon^B_{m_{\gamma\gamma}}}\varepsilon^B_{m_{b\bar{b}\gamma\gamma}}$$

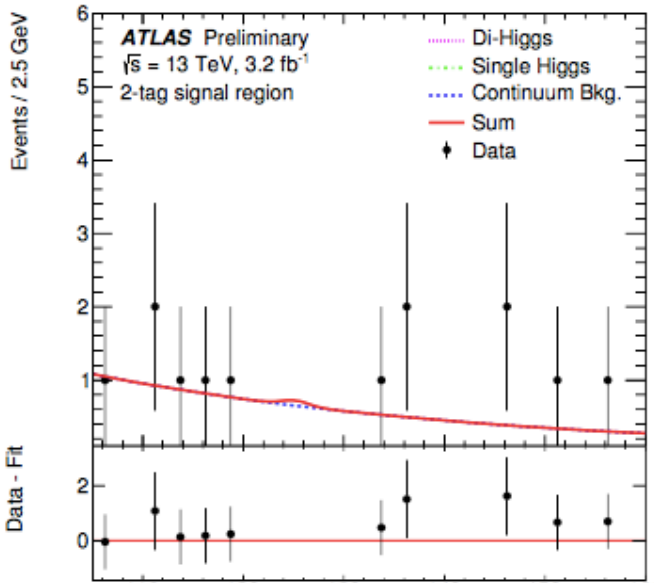
- Since the analysis is dominated by statistical uncertainty, a cut and count analysis is used for the resonant search.
- The efficiencies of $\varepsilon^B_{m_{\gamma\gamma}}$ and $\varepsilon^B_{m_{b\bar{b}\gamma\gamma}}$ (efficiencies passing the mass window cuts of $m_{\gamma\gamma}$ and $m_{bb\gamma\gamma}$) for continuous bkg are obtained from sideband fit.
- High statistical sideband sample $\gamma\gamma$+2jets (no b-tagging) is used to estimate $\varepsilon^B_{m_{b\bar{b}\gamma\gamma}}$

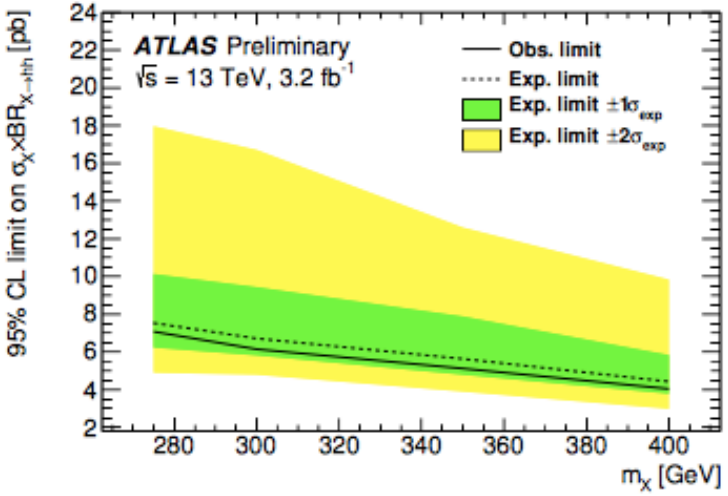
Run2 analyses: bbγγ with 3.2 fb^{-1}

Further Selections:

- Veto events with 3 b-jets.
- 0 b-jet category as control region to derive bkg shape.
- 2 b-jet as the signal region: 95<|m_{bb}|<135 GeV.

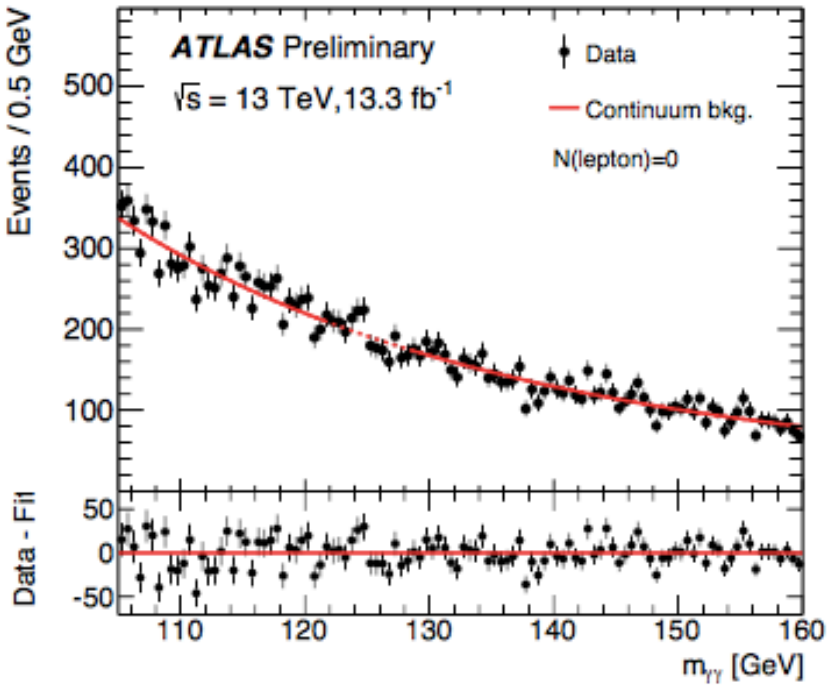
Process	0-tag	2-tag
Continuum background	35.8 ± 2.1	1.63 ± 0.30
SM single-Higgs	1.8 ± 1.5	0.14 ± 0.05
SM di-Higgs	<0.001	0.027 ± 0.006
Observed	27	0

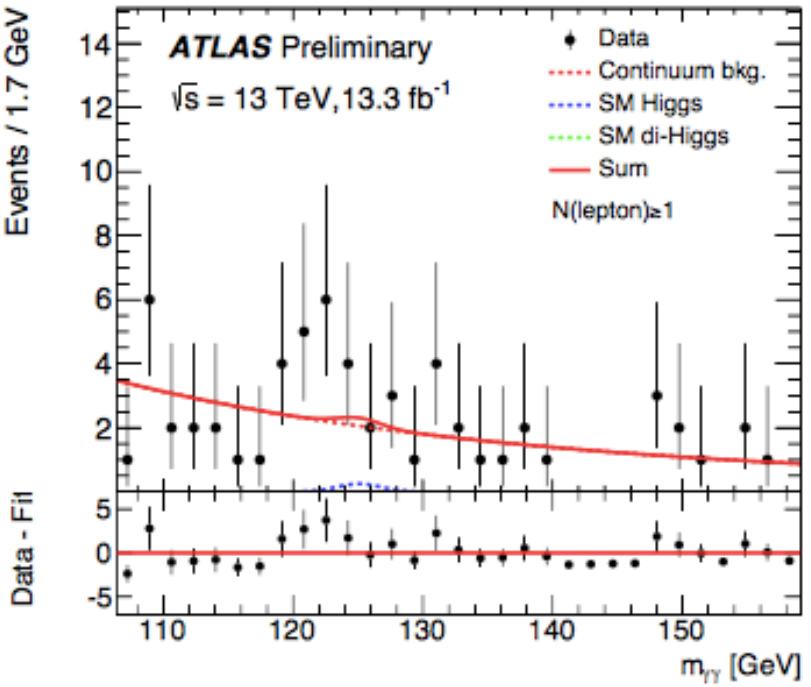




For non-resonance search:
the observed(expected) limits are 3.9(5.4)pb, i.e. 116(162) SM di-higgs prediction.
For the resonance search (mass 275-400 GeV):
the observed(expected)limit ranges between 4.0-7.0 (4.4-7.5) pb.

$WW\gamma\gamma$: Continuous Background estimation





- Due to the lack of statistics in the 1-lepton (right plot), a simultaneous fit with 2nd exponential function on 0-lepton (left plot) and 1-lepton di-photon mass spectra is implemented to extract the continuum bkg.

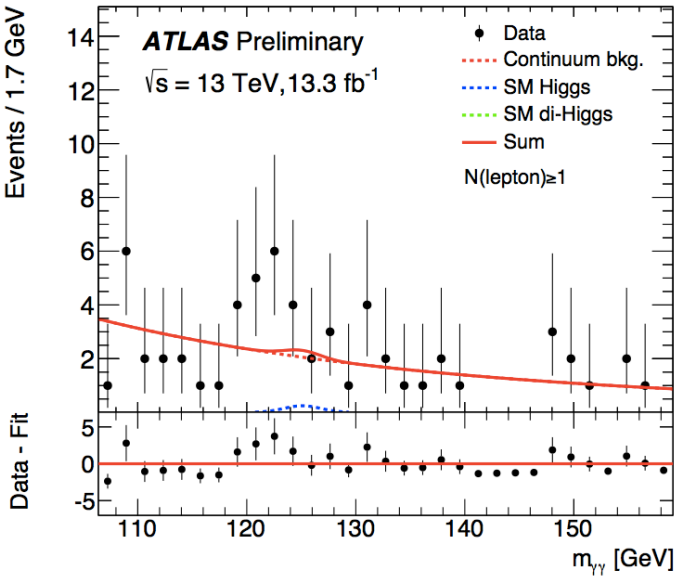
Run2 analyses: WWγγ with 13.3 fb^{-1}

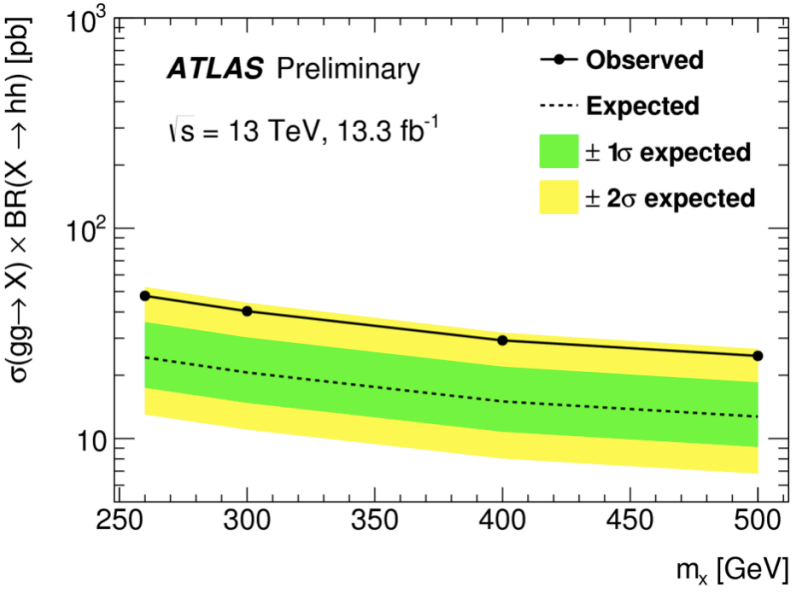
Further Selections:

- At least two central jets
- B-veto.
- At least one lepton with Pt>10 GeV
- Fit sideband (0lep, 1lepton simultaneously)directly to extract the continuum bkg.

$m_H \pm 2\sigma$

Process	Number of events	
Continuum background	7.26	± 1.23
SM single-Higgs	0.616	± 0.115
SM di-Higgs	0.0187	± 0.00224
Observed		15



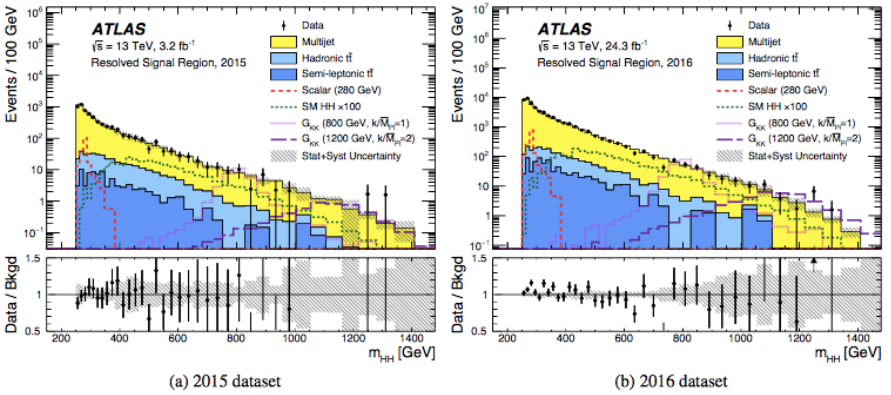


For non-resonance search:
the observed(expected) limits are 25.0(12.9)pb.
For the resonance search (mass 275-400 GeV):
the observed(expected)limit ranges between
24.7-47.7 (12.7-24.3) pb.

Run2 analyses: *bbbb* with 27.5-36.1 fb^{-1}

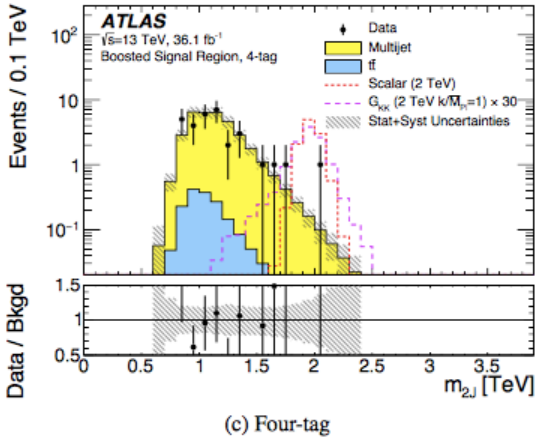
Further Selections:

- Resolved analysis : 4 b-tagged jets : 260<m_{hh}<1400 GeV
- Boosted analysis : 2 larger-R jets with the 2/3/4-tag small-R b-tagged jets : 800-3000 GeV
- Higgs candidates are around higgs mass within its resolution.



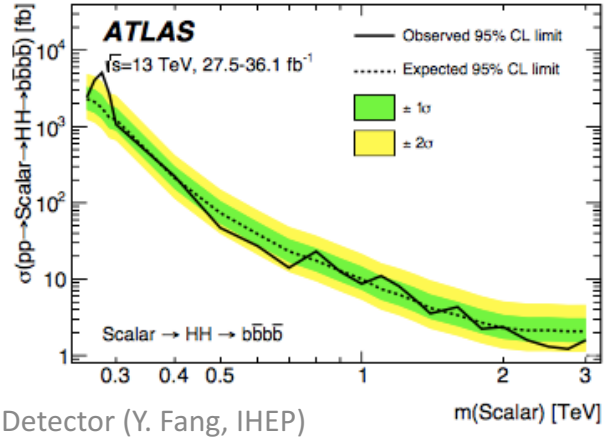
(a) 2015 dataset (b) 2016 dataset

Boosted analysis	Two-tag	Three-tag	Four-tag
Multijet	3390 ± 150	702 ± 63	32.9 ± 6.9
$t\bar{t}$	860 ± 110	80 ± 33	1.7 ± 1.4
Total	4250 ± 130	782 ± 51	34.6 ± 6.1
G_{KK} (2 TeV)	0.97 ± 0.29	1.23 ± 0.16	0.40 ± 0.13
Scalar (2 TeV)	28.2 ± 9.0	35.0 ± 4.6	10.9 ± 3.5
Data	4376	801	31



(c) Four-tag

For non-resonance search:
the upper limit 13XSM di-higgs prediction.
For the resonance search (mass 260-3000 GeV):
Different models (narrow-width scalar, spin-2 resonances)has been exploited.
No significant excess has been observed.
A deviation of 2.3σ has been found at 280 GeV.



Conclusion

- Different channels bbbb, bb$\gamma\gamma$, ww$\gamma\gamma$ have been exploited in ATLAS detector with RUN1 and RUN2 data.
  - No obvious excess has been observed.
  - limits have been set from O(pb) to O(fb)
  - The best limit for non-resonance is 13XSM.
- More results will be come very soon with RUN2 data.