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Measurement of cross sections and couplings of the Higgs boson in fermionic production and decays

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In this talk...

- Yukawa coupling
- Run 1 ATLAS+CMS combination
- Higgs coupling to fermions
 - decays
 - $\tau\tau$
 - bb
 - $\mu\mu$
 - production
 - $t\bar{t}H$
- Summary

Higgs couplings to fermions

- In the SM the Higgs field couples to fermions through a Yukawa interaction
- The coupling strength between the standard model Higgs boson and a fermion is proportional to the mass of the fermion (well known from experiment)
- SM can predict accurately the Higgs decay rates to fermions
- We are trying to measure the decay and production rates of processes that involve fermions
- Enhanced or decreased couplings, asymmetries in up/down type quarks, evidence of lepton flavour violation would be signs of new physics.

Combined ATLAS and CMS results

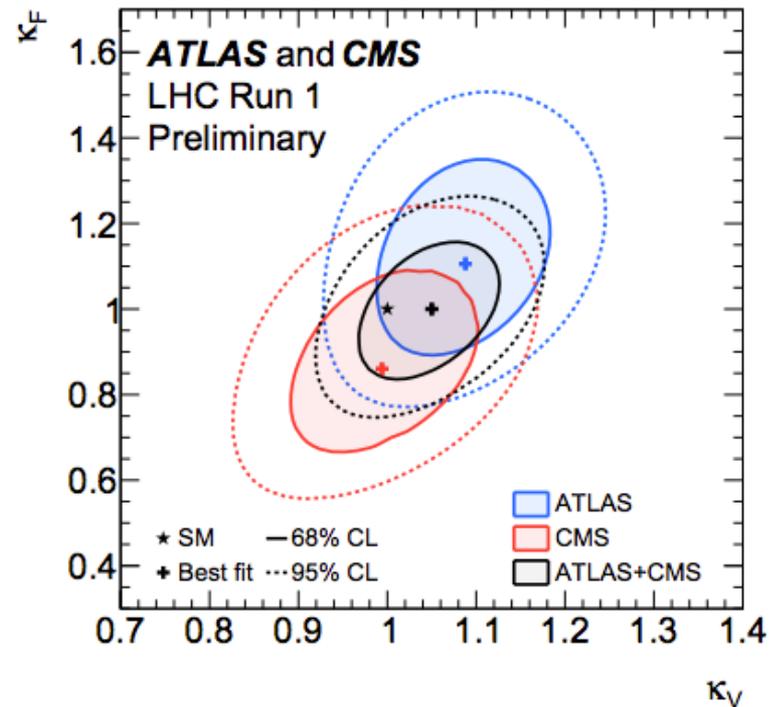
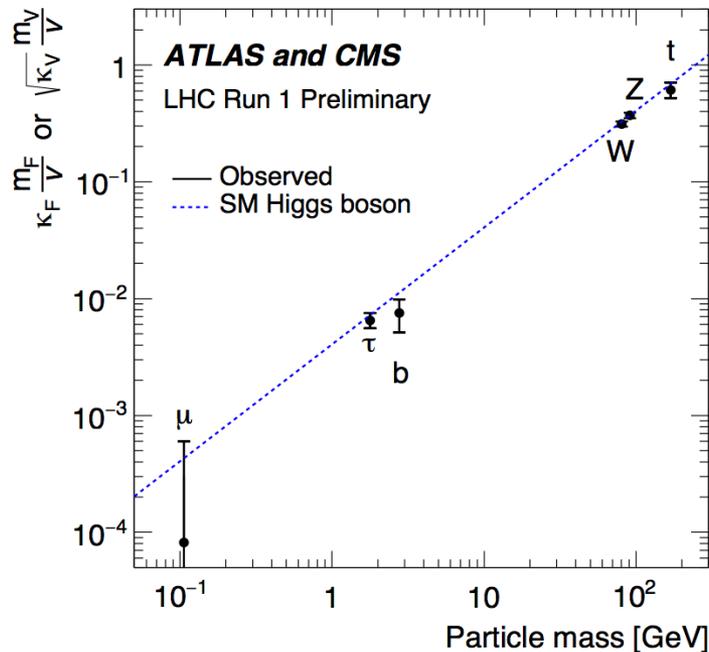
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Run 1 dataset

7 TeV, $\sim 5\text{fb}^{-1}$

8 TeV, $\sim 20\text{fb}^{-1}$

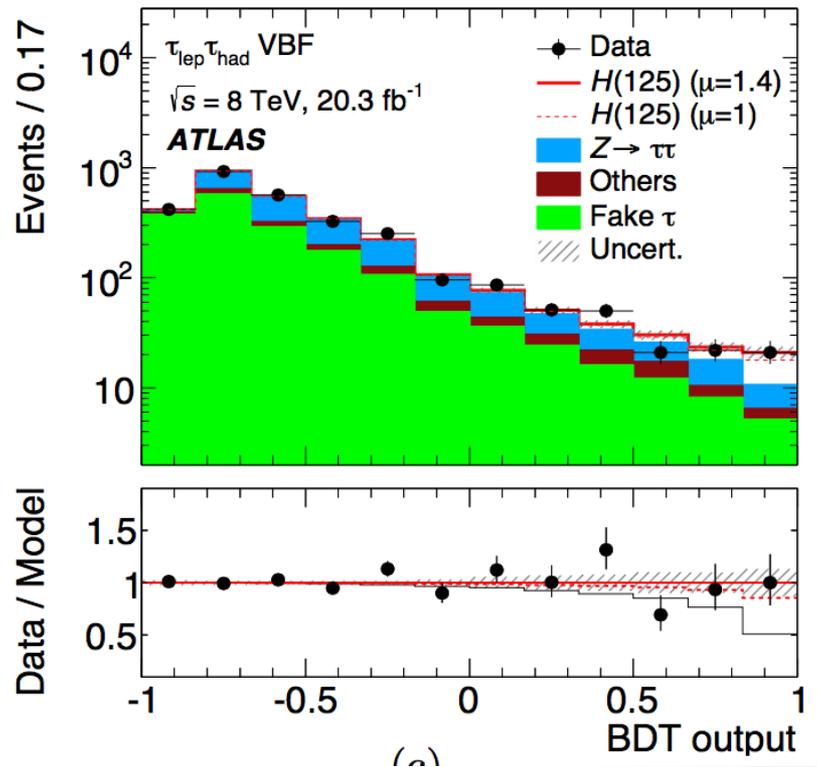
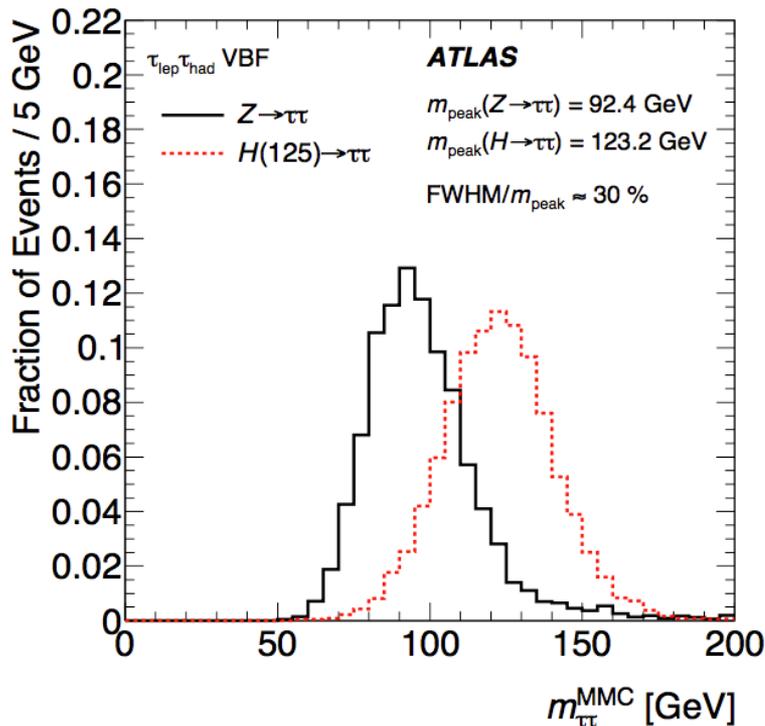
Production process	Measured significance (σ)	Expected significance (σ)
VBF	5.4	4.7
WH	2.4	2.7
ZH	2.3	2.9
VH	3.5	4.2
ttH	4.4	2.0
Decay channel		
$H \rightarrow \tau\tau$	5.5	5.0
$H \rightarrow bb$	2.6	3.7



H \rightarrow $\tau\tau$

- SM BR 6%
- 7 and 8 TeV Run 1 data, 4.5 fb⁻¹ and 20.3 fb⁻¹
 - new measurements coming in the summer stay tuned!
- channels lelep, lephad, hadhad
- VBF and boosted categories
- Ditau mass reconstructed using the MMC algorithm (missing mass calculator)

<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-32/>

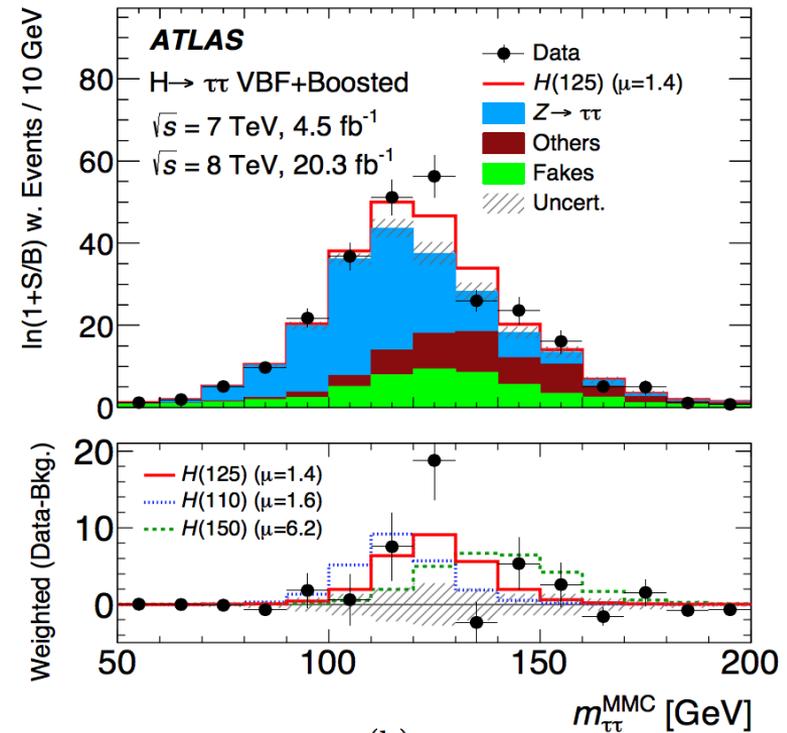


H → ττ

- Signal selection performed with multivariate Boosted Decision Trees
- Observed 4.5 σ excess over other SM processes
- Signal strength consistent with the predicted Yukawa coupling

$$\mu = 1.43^{+0.27}_{-0.26}(\text{stat.})^{+0.32}_{-0.25}(\text{syst.}) \pm 0.09(\text{theory syst.}).$$

Channel and Category	Expected Significance (σ)	Observed Significance
τ _{lep} τ _{lep} VBF	1.15	1.88
τ _{lep} τ _{lep} Boosted	0.57	1.72
τ _{lep} τ _{lep} Total	1.25	2.40
τ _{lep} τ _{had} VBF	2.11	2.23
τ _{lep} τ _{had} Boosted	1.11	1.01
τ _{lep} τ _{had} Total	2.33	2.33
τ _{had} τ _{had} VBF	1.70	2.23
τ _{had} τ _{had} Boosted	0.82	2.56
τ _{had} τ _{had} Total	1.99	3.25
Combined	3.43	4.54

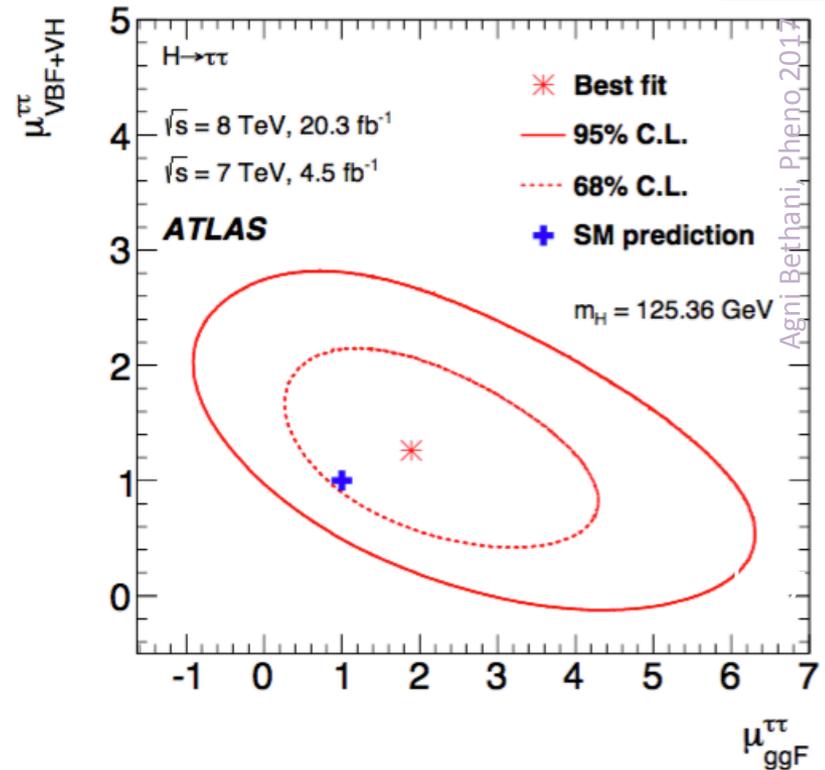


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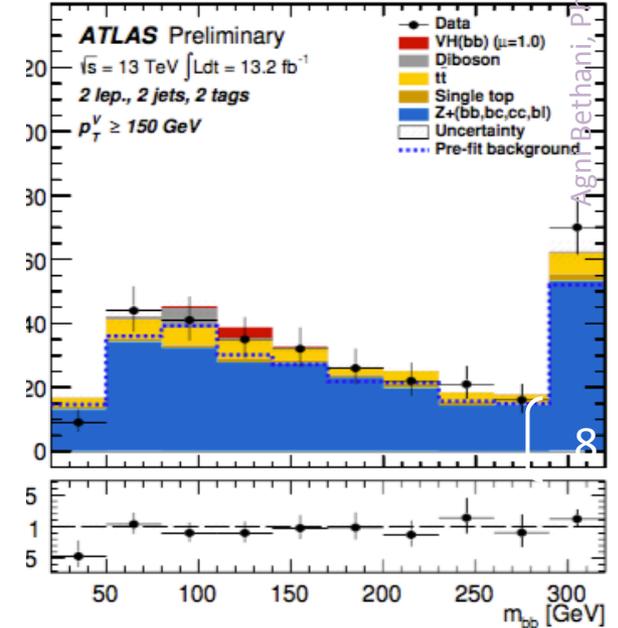
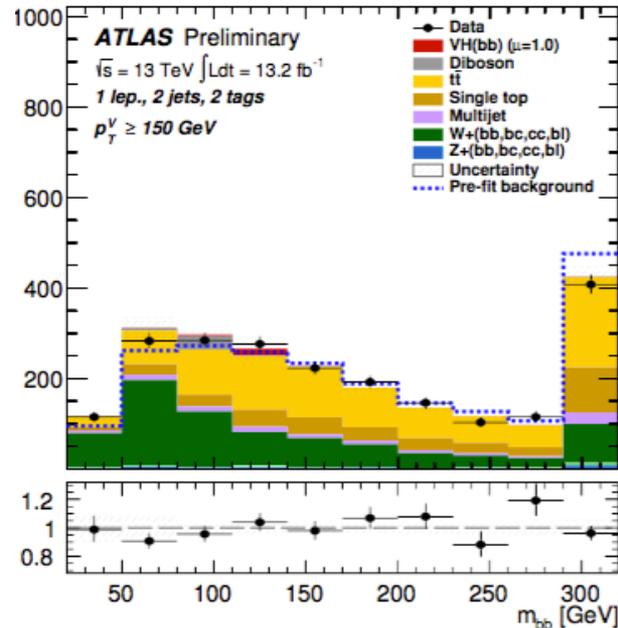
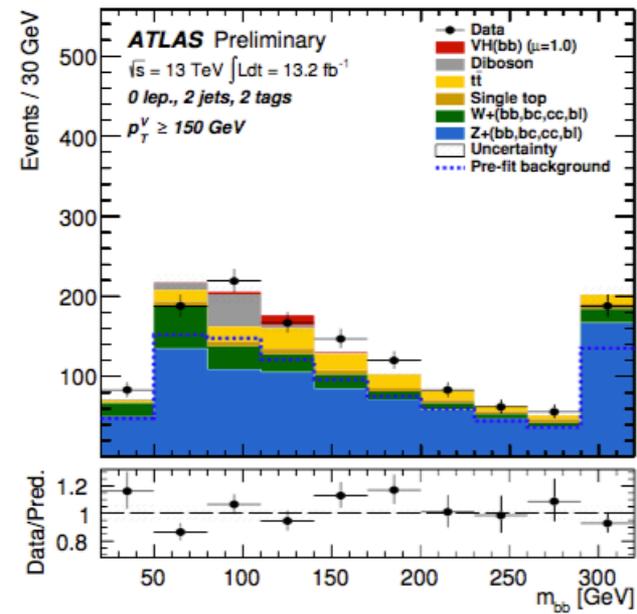
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VH \rightarrow bb

- BR $H \rightarrow bb$ 57%
- 13 TeV result 13.2 fb⁻¹
- ZH $\rightarrow bb$, 0 and 2 lepton channels
 - Z $\rightarrow \nu\nu$
 - Z $\rightarrow ll$
- WH $\rightarrow bb$, 1 lepton channel
 - W $\rightarrow lv$
- Signal selection using multivariate discriminants (BDTs)

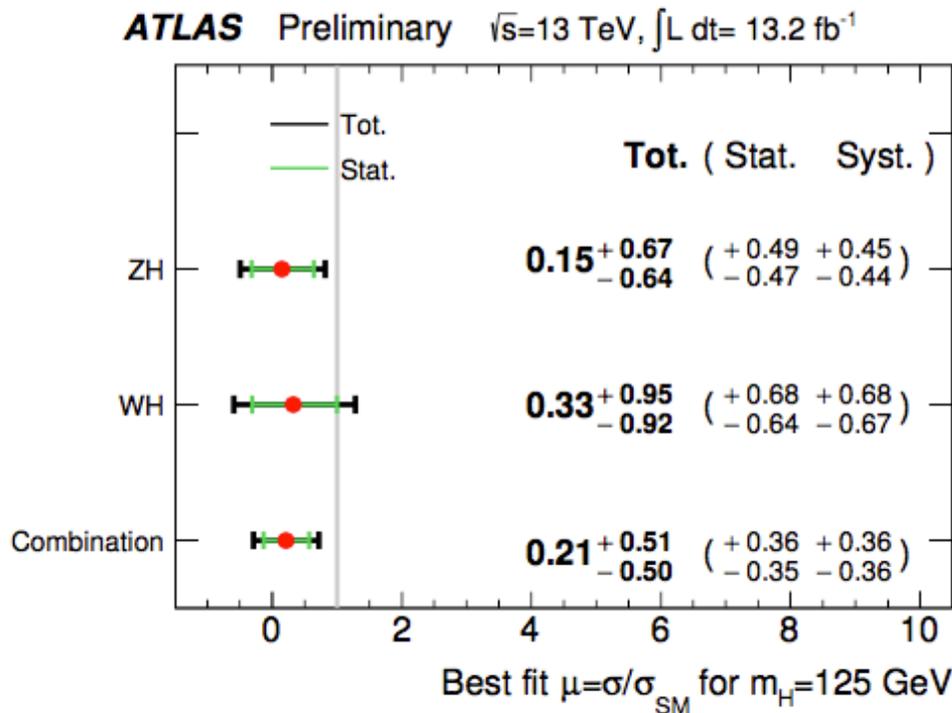
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VH \rightarrow bb

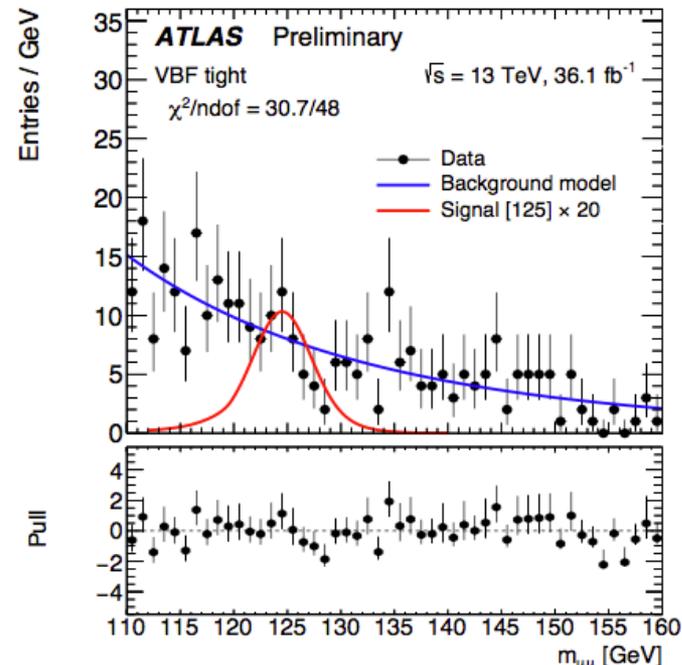
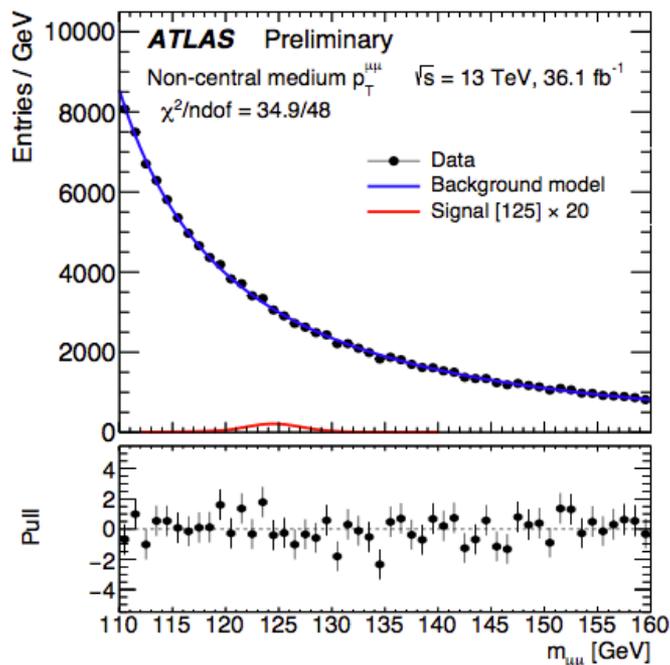
Dataset	Limit		p_0		Significance	
	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.
0-lepton	$1.4^{+0.6}_{-0.4}$	2.0	0.07	0.15	1.45	1.02
1-lepton	$2.0^{+0.8}_{-0.6}$	2.1	0.15	0.46	1.04	0.10
2-lepton	$1.8^{+0.7}_{-0.5}$	1.7	0.13	0.57	1.14	-0.17
Combined	$1.0^{+0.4}_{-0.3}$	1.2	0.03	0.34	1.94	0.42

Small deficit
wrt SM
expectation



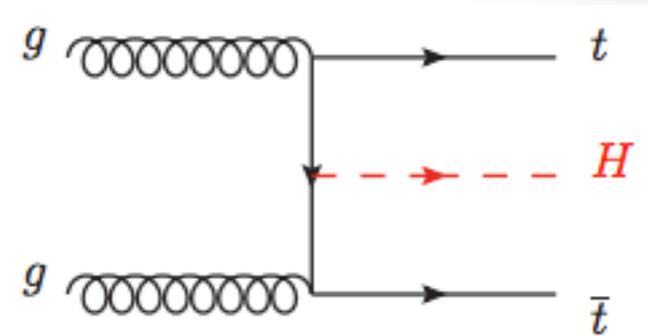
$H \rightarrow \mu\mu$

- SM BR 0.022 % <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2017-014/>
- 13 TeV, 36.1 fb⁻¹
- Sensitive to second generation fermions with a clean signature
- VBF and gluon fusion categories
- analytical distribution of signal and background
 - Steeply falling distribution for the DY process
- The observed upper limit on μ_s at 95% CL is found to be 3.0 consistent with the expected 3.1



ttH production

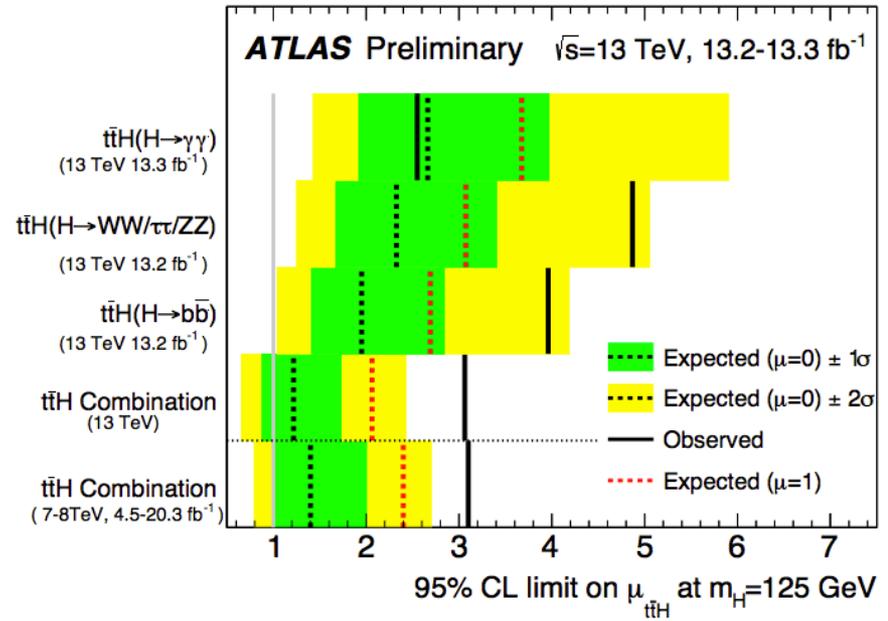
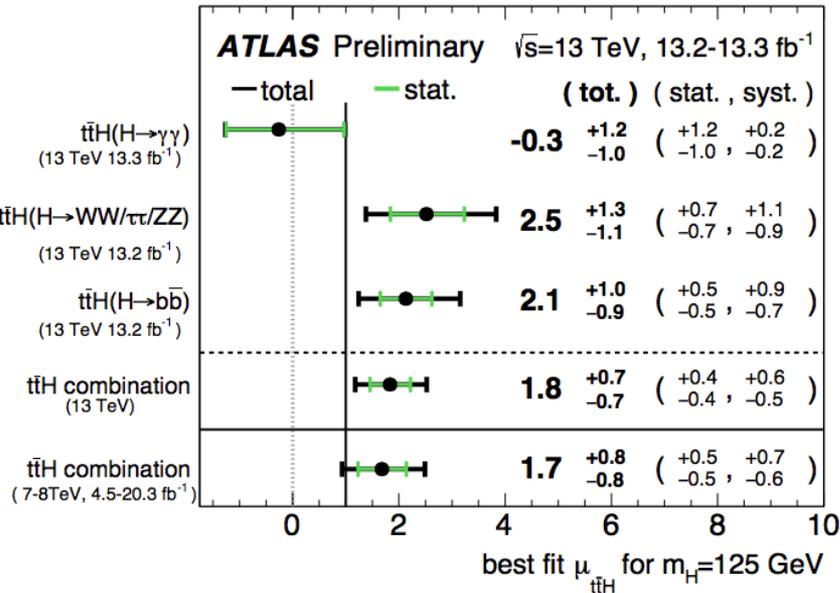
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- SM cross section 0.51 pb
 - 2 orders of magnitude smaller than gluon fusion
- Only way to measure the direct Higgs coupling to top quark
 - indirect constrains from gluon fusion and $H \rightarrow \gamma\gamma$ decay
- In the SM this is the biggest Higgs coupling
- Decays studied:
 - $H \rightarrow \gamma\gamma$ in both the hadronic and leptonic tt decay channels
 - excellent di-photon mass resolution
 - $H \rightarrow$ leptons ($WW, \tau\tau, ZZ$) all combinations
 - multiple channels exploited
 - $H \rightarrow bb$ single lepton and opposite-charge dilepton tt decay channels.
 - 4 and 3 jets respectively at least 2 b-tagged

ttH production

- Combined result signal strength: $\mu_{t\bar{t}H} = 1.8^{+0.4}_{-0.4} \text{ (stat.) } ^{+0.6}_{-0.5} \text{ (syst.)} = 1.8^{+0.7}_{-0.7}$



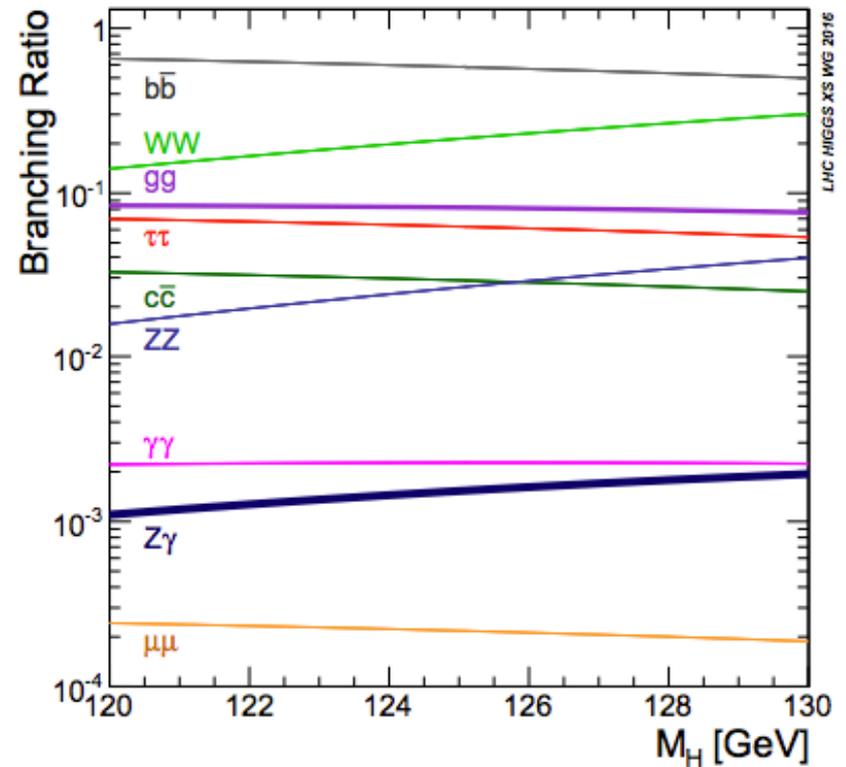
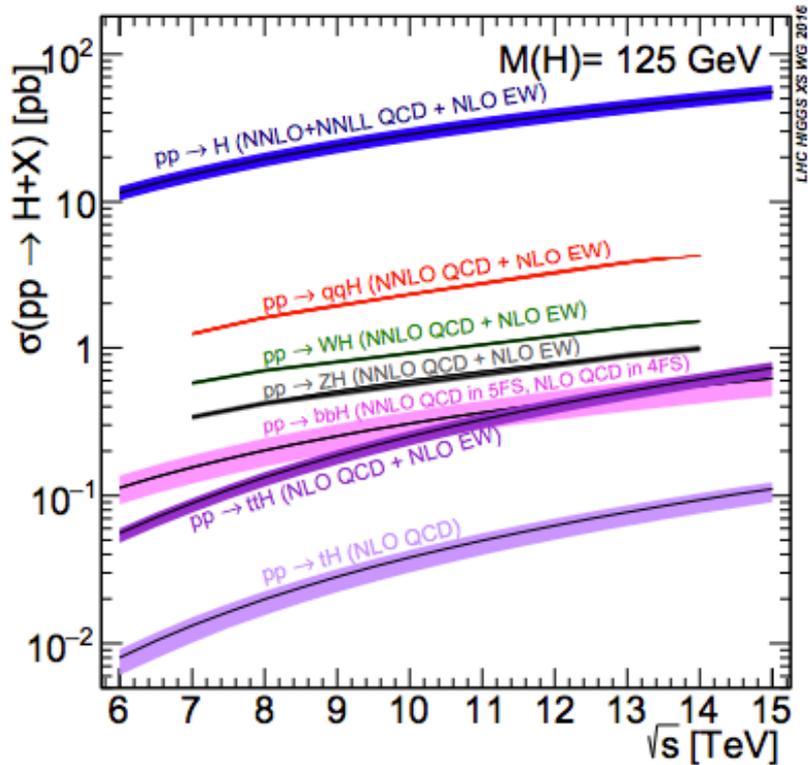
Channel	Significance	
	Observed [σ]	Expected [σ]
$t\bar{t}H, H \rightarrow \gamma\gamma$	-0.2	0.9
$t\bar{t}H, H \rightarrow (WW, \tau\tau, ZZ)$	2.2	1.0
$t\bar{t}H, H \rightarrow b\bar{b}$	2.4	1.2
$t\bar{t}H$ combination	2.8	1.8

Summary

- ATLAS exploring all decays and productions of interest
 - $H \rightarrow \tau\tau, H \rightarrow bb, H \rightarrow \mu\mu, ttH$
 - Analysis of run 2 data on going
 - New results in the summer!
- Many BSM searches involving fermionic Higgs decays take place within ATLAS
 - Lepton flavor violating Higgs decays
 - Additional Higgses (heavy or light)
 - other heavy resonances

Back up material

SM Higgs BR and cross sections



MSSM

- MSSM has two Higgs doublets, 5 Higgs: h, H, A, H^\pm
- Searching for H/A , the neutral heavier Higgs.
- At tree level, can describe MSSM Higgs sector with m_A and $\tan\beta$ (ratio of the v.e.v. of the two doublets)
- For large $\tan\beta$, couplings to down-type fermions are enhanced
 - Higher $H \rightarrow \tau$ branching fraction
 - Enhanced production associated with b-quarks