

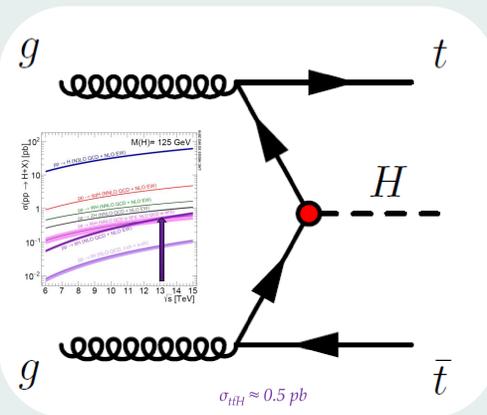
Search for the SM Higgs boson produced in association with top quarks (ttH) at $\sqrt{s} = 13$ TeV with the ATLAS detector at the LHC

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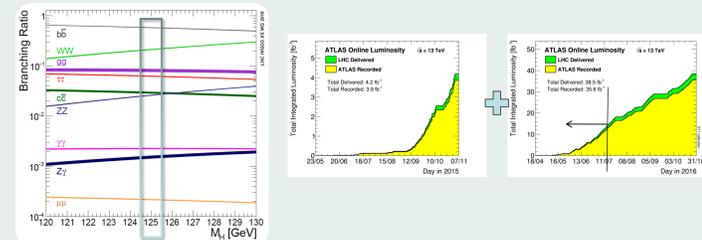
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Introduction and motivations

- Presented today: **associated top-Higgs production (ttH)**
- Due to its small production cross-section ($\sim 1\%$ of total Higgs boson cross-section), this production mechanism has not been directly observed
- Indirect constraints on the top-Higgs Yukawa coupling come from ggF and $H \rightarrow \gamma\gamma$ (through loop)
- ttH production allows direct (tree level) probe of top-Higgs Yukawa coupling
- Any deviation could be a hint of new physics
- ATLAS+CMS Run I result: observation at 4.4σ (2.0σ exp.) [1]



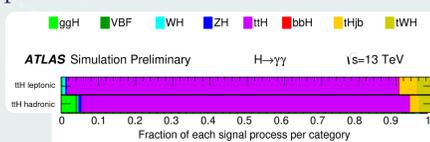
- Can be studied in a variety of final states/channels, depending on the top quark decay topology and the Higgs boson decay mode: $\gamma\gamma$, $WW/ZZ/\tau\tau$ (multi-lepton) and bb
- Results here based on 2015 + partial 2016 data, 13.2 fb $^{-1}$



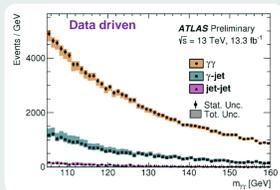
Analyses presented

ttH, H $\rightarrow \gamma\gamma$ [2]

- Clean signature thanks to excellent mass resolution, but small branching ratio (BR $\sim 0.23\%$)
- 2 channels, depending on the top quark pair system decay: all-hadronic and (semi)leptonic
- Events selected and categorised in regions enriched with ttH production mode

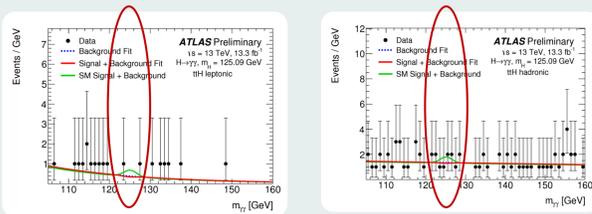


- Looking for narrow signal peak in the di-photon invariant mass spectrum on top of a smoothly falling background



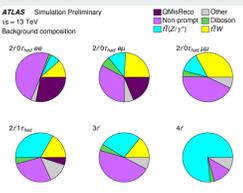
- Control regions with inverted photon identification for background ($\gamma\gamma$, γ -jet and jet-jet) estimation

- Search dominated by statistical uncertainties



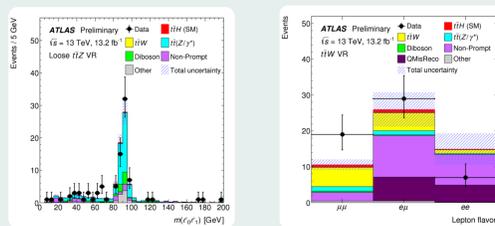
ttH, H $\rightarrow WW/ZZ/\tau\tau$ [3]

- (Semi)-leptonic final states with low background, but with additional sensitivity to ttW/ttZ background
- Cut-and-count analysis in 4 categories, depending on the number, charge and flavour of leptons (ℓ): 2 same sign (ss) $\ell\ell + 0\tau_{had}$, 2ssl+1 τ_{had} , 3 ℓ and 4 ℓ

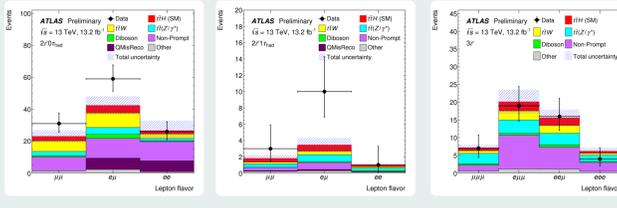


Category	WW*	$\tau\tau$	ZZ*	Other	$A \times \epsilon$ ($\times 10^{-4}$)
2/0 τ_{had}	77%	17%	3%	3%	14
2/1 τ_{had}	46%	51%	2%	1%	2.2
3 ℓ	74%	20%	4%	2%	9.2
4 ℓ	72%	18%	9%	2%	0.88

- 3 validation regions in order to study ttV background, data driven estimations of non-prompt lepton, fake τ , and processes with mis-identified charged lepton

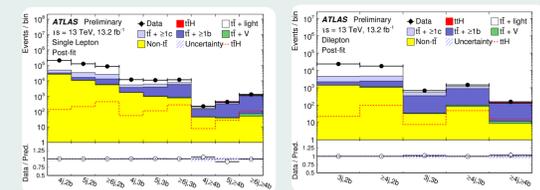


- Main systematic uncertainty: fakes and charge mis-ID

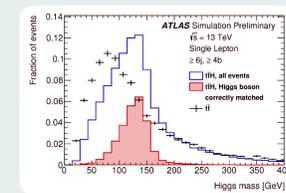


ttH, H $\rightarrow bb$ [4]

- Small signal on top of large background dominated by production of tt+heavy flavour (HF) jets
- 2 channels, depending on the top quark pair system decay: single lepton (1 ℓ) and opposite-sign dilepton (2 ℓ)
- Events categorised according to jet and b-jet multiplicities: 6 control (CR) and 3 signal regions (SR) in 1 ℓ and 2 CR and 3 SR in 2 ℓ channels

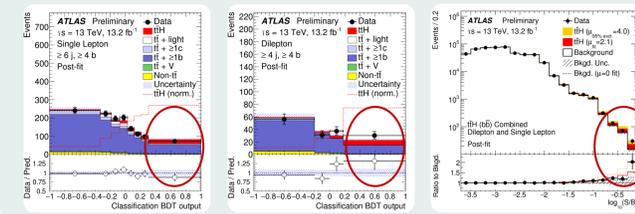


- Analysis strategy uses 2-step multivariate technique: reconstruction BDT (match jets) and discrimination NN/BDT (kinematics)



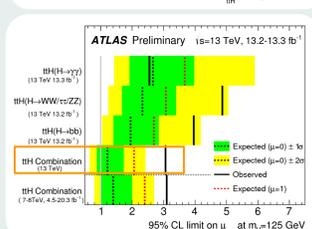
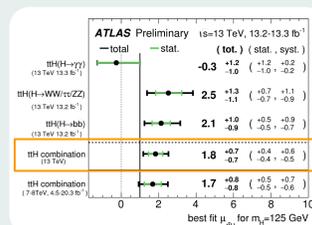
Variable	Definition	Region
Control Region	Control Region	CR
Signal Region	Signal Region	SR
Background	Background	Bkg
Uncertainty	Uncertainty	Unc
Other	Other	Other

- Theory uncertainty on tt+HF dominates the search



Combination and prospects

- Combination of the three presented ATLAS ttH analyses [5]:
- Measured signal strength $\mu = 1.8 \pm 0.7$
- Corresponds to an observed (expected) significance of 2.8σ (1.8σ) and exceeds the Run I ATLAS expected significance (1.5σ)
- Observed (expected) 95% C.L. limit on μ is 3.0 (2.1)
- All three analyses are within 1.5σ of the central value
- Largest systematic uncertainty contribution is related tt+b/c modelling uncertainties affecting the ttH($H \rightarrow bb$) analysis



- Projections with full 2015+2016 LHC data
- Optimistic projection with 2015 + full 2016 data (36.5 fb $^{-1}$), after several optimisations, combination could achieve 3σ
- Work in progress within ATLAS: updates soon!
- At HL-LHC with $L=3000$ fb $^{-1}$, expected precision on ttH signal strength using only $H \rightarrow \gamma\gamma$ [6]:

Production mode	$\Delta\hat{\mu}/\hat{\mu}$ (%)			
	Total	Statistical	Experimental	Theoretical
ttH	+21 -17	+13 -12	+5 -4	+17 -11

References

[1] ATLAS and CMS Collaborations, JHEP 08 (2016) 045
 [2] ATLAS Collaboration: ATLAS-CONF-2016-067 (2016)
 [3] ATLAS Collaboration: ATLAS-CONF-2016-058 (2016)

[4] ATLAS Collaboration: ATLAS-CONF-2016-080 (2016)
 [5] ATLAS Collaboration: ATLAS-CONF-2016-068 (2016)
 [6] ATLAS Collaboration: ATLAS-PUB-2014-012 (2014)