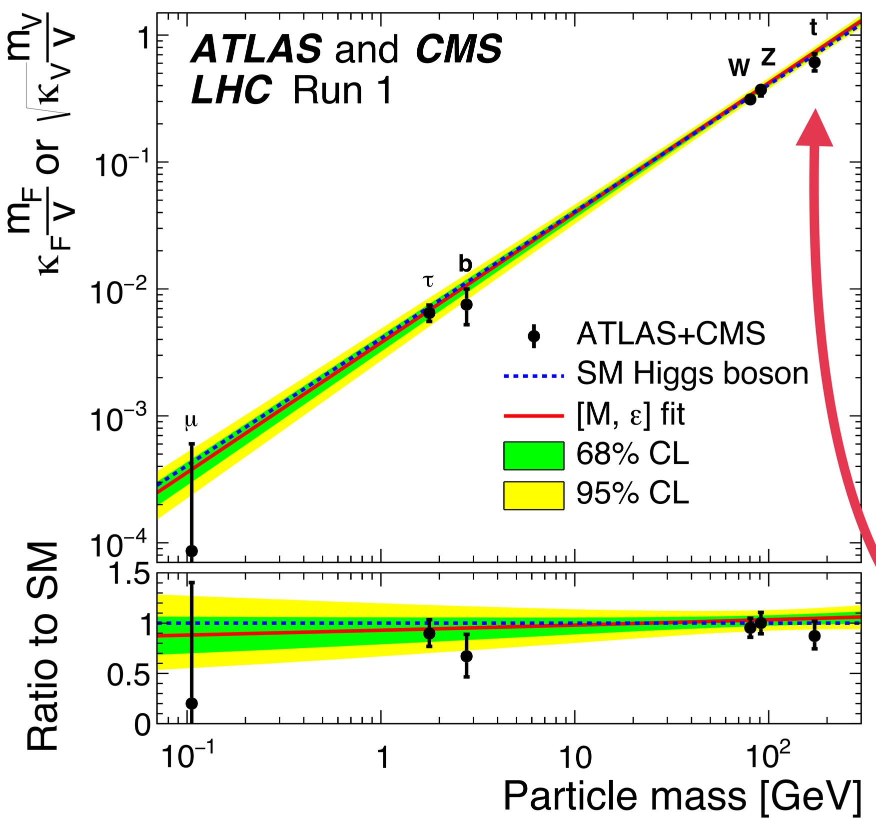
# Search for Higgs boson production in association with a pair of top quarks with the ATLAS detector

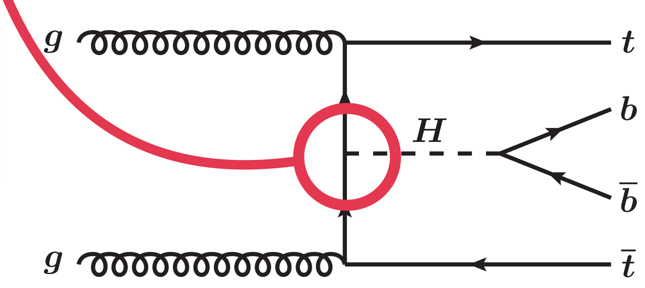
## ICHEP, Seoul, 4-11 July 2018

based on Phys. Rev. D 97 (2018) 072016 and arXiv:1806.00425

## Motivation



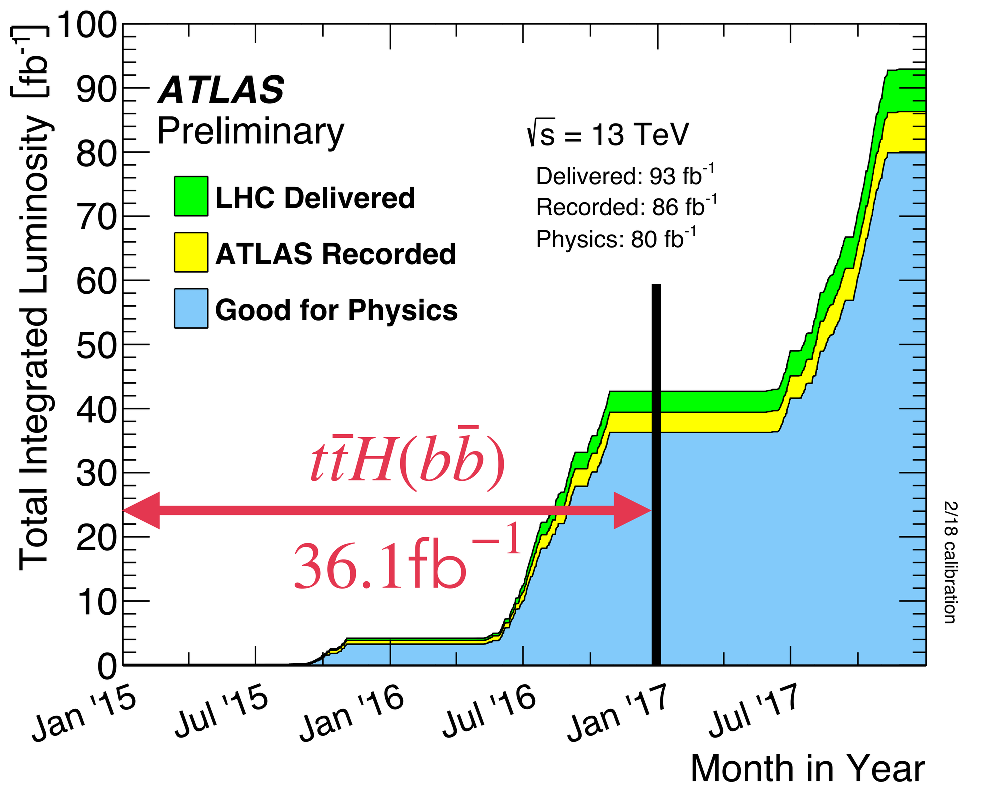

- Top quark is heaviest particle in the Standard Model.
- Fermions acquire mass via Higgs mechanism through **Yukawa couplings.**
- ttH provides the possibility to observe directly if the Higgs boson couples to the top quark



$t\bar{t}H(b\bar{b})$ signal diagram

## Dataset

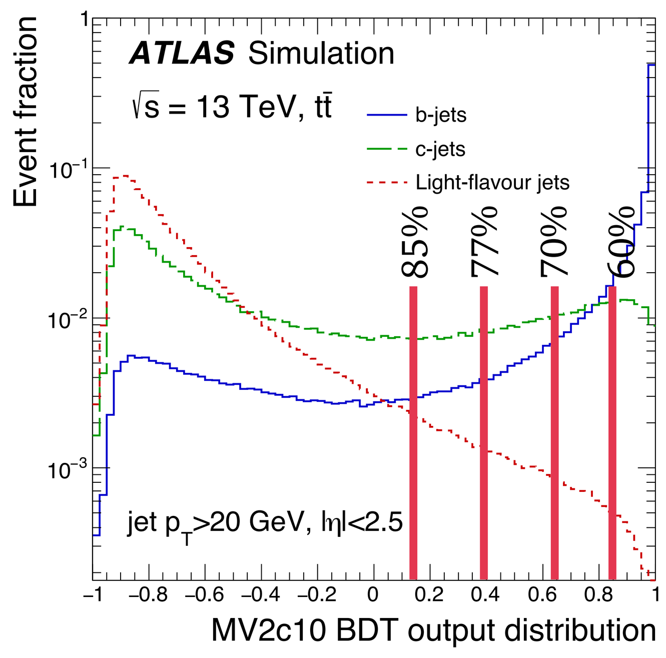
- **Excellent performance** from LHC and ATLAS in Run II
- ttH(bb) analysis uses 36.1fb$^{-1}$, data from 2015 and 2016
- Combination uses up to 79.8fb$^{-1}$, data from 2015, 2016 and 2017
- More data still to be collected in 2018



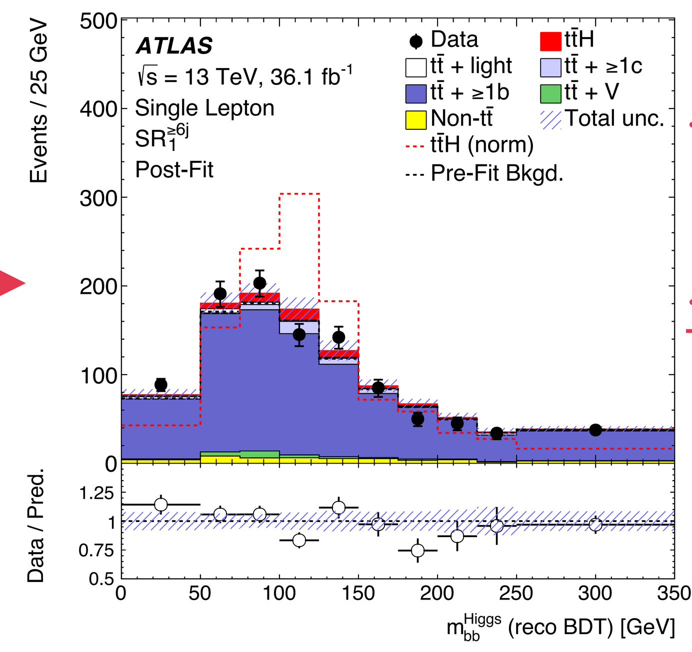

## Strategy and challenges

- **Exploiting H→ bb final state owing to high branching fraction**
- Up to 4 b-jets in final state from tt-decay and Higgs decay.
- Very challenging analysis:
  - **Low efficiency** to reconstruct all particles.
  - **Ambiguity** to match origin from from 4 b-jets correctly.
  - **Large background** from tt+jets

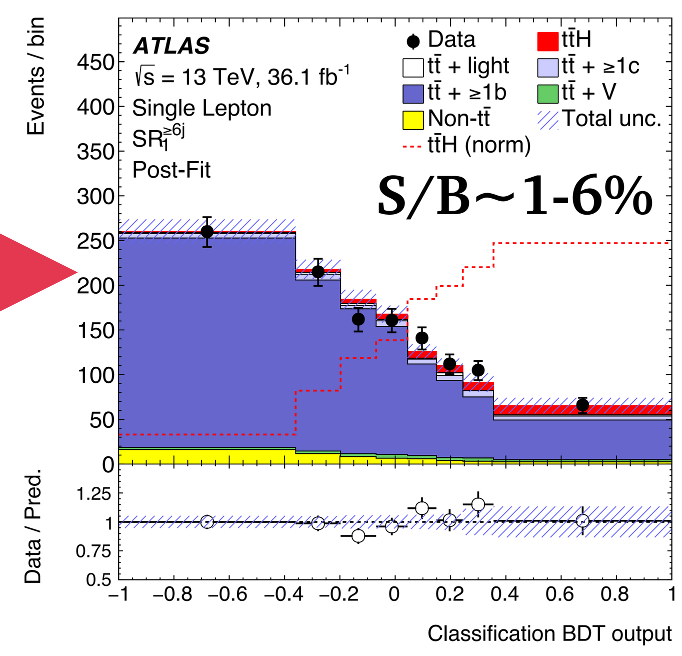
Many regions with different composition in tt+≥1b, tt+≥1c, tt+light, ttH




In signal regions




event kinematics




**Categorisation:**

- one or two leptons (e, mu)
- b-tag score of jets exploiting 4 different efficiencies
- **10 signal and 9 control regions**

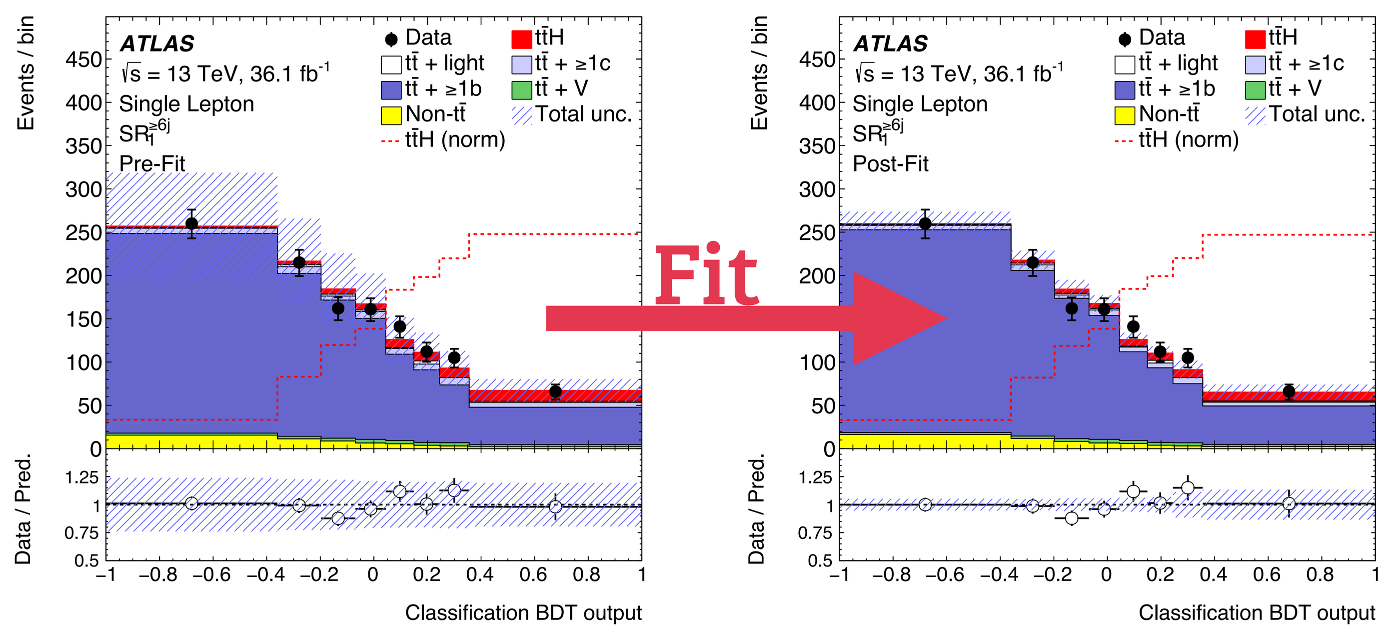
**Overcoming ambiguity in matching b-jets:**

- Reconstruction BDT, likelihood discriminant and matrix element method

**Separation between ttH and background:**

- Classification BDT exploiting event information

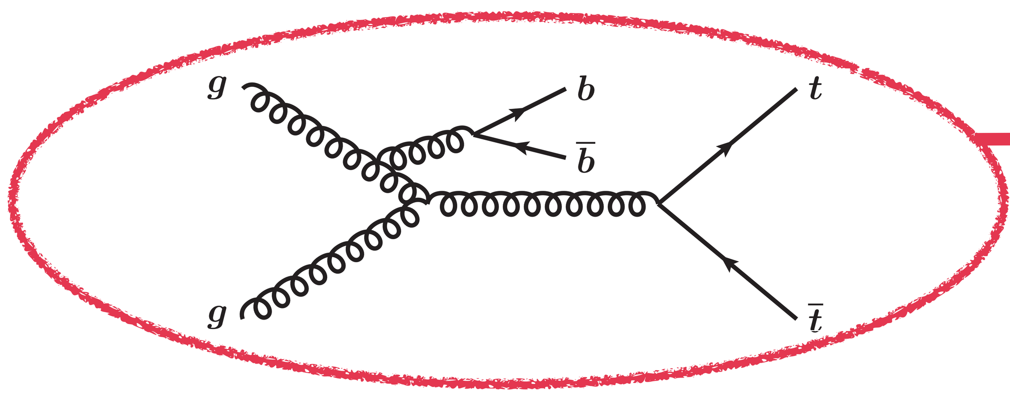
## Result




$$\mu = \sigma^{\mathrm{obs.}}_{t\bar{t}H}/\sigma^{\mathrm{SM}}_{t\bar{t}H} = 0.84^{+0.64}_{-0.61}\ (^{+0.29}_{-0.39}\ \mathrm{stat.}\ ^{+0.57}_{-0.54}\ \mathrm{syst.})$$

- tt+≥1b, tt+≥1c normalisations free floating in binned profile likelihood fit
- **Result is compatible with SM prediction**

## Background Modelling & systematic uncertainties



- ttbb is irreducible background to ttH(bb)
- Nominal prediction at NLO from tt+jets in 5-flavor scheme from Powheg+Pythia8
- Reweighting of tt+≥1b sub-components to ttbb prediction at NLO from Sherpa+OpenLoops (4-flavor scheme)
- **precise and accurate modelling challenging**

| Uncertainty source | $\Delta\mu$ | |
|---|---|---|
| $t\bar{t}+\geq 1b$ modeling | +0.46 | −0.46 |
| Background-model stat. unc. | +0.29 | −0.31 |
| $b$-tagging efficiency and mis-tag rates | +0.16 | −0.16 |
| Jet energy scale and resolution | +0.14 | −0.14 |
| $t\bar{t}H$ modeling | +0.22 | −0.05 |
| $t\bar{t}+\geq 1c$ modeling | +0.09 | −0.11 |
| JVT, pileup modeling | +0.03 | −0.05 |
| Other background modeling | +0.08 | −0.08 |
| $t\bar{t}$ + light modeling | +0.06 | −0.03 |
| Luminosity | +0.03 | −0.02 |
| Light lepton $(e, \mu)$ id., isolation, trigger | +0.03 | −0.04 |
| Total systematic uncertainty | +0.57 | −0.54 |
| $t\bar{t}+\geq 1b$ normalization | +0.09 | −0.10 |
| $t\bar{t}+\geq 1c$ normalization | +0.02 | −0.03 |
| Intrinsic statistical uncertainty | +0.21 | −0.20 |
| Total statistical uncertainty | +0.29 | −0.29 |
| Total uncertainty | +0.64 | −0.61 |

## Combination with other channels

- ttH(bb) analysis is part of larger effort to establish the ttH process
- Performing combination with other ttH analysis, such as ttH Multilepton, ttH(4l), ttH($\gamma\gamma$)
- ttH(bb) analysis, despite large H→ bb branching ratio, has limited sensitivity due to systematic uncertainties
- Combination result mainly driven by ttH($\gamma\gamma$) and ttH Multilepton analyses despite low branching fraction but pure in S/B

| Analysis | Integrated luminosity [fb$^{-1}$] | $t\bar{t}H$ cross section [fb] | Obs. sign. | Exp. sign. |
|---|---|---|---|---|
| $H\to\gamma\gamma$ | 79.8 | $710\ ^{+210}_{-190}$ (stat.) $^{+120}_{-90}$ (syst.) | 4.1 $\sigma$ | 3.7 $\sigma$ |
| $H\to$ multilepton | 36.1 | 790 ±150 (stat.) $^{+150}_{-140}$ (syst.) | 4.1 $\sigma$ | 2.8 $\sigma$ |
| $H\to b\bar{b}$ | 36.1 | $400\ ^{+150}_{-140}$ (stat.) ± 270 (syst.) | 1.4 $\sigma$ | 1.6 $\sigma$ |
| $H\to ZZ^*\to 4\ell$ | 79.8 | <900 (68% CL) | 0 $\sigma$ | 1.2 $\sigma$ |
| Combined (13 TeV) | 36.1–79.8 | 670 ± 90 (stat.) $^{+110}_{-100}$ (syst.) | 5.8 $\sigma$ | 4.9 $\sigma$ |
| Combined (7, 8, 13 TeV) | 4.5, 20.3, 36.1–79.8 | – | 6.3 $\sigma$ | 5.1 $\sigma$ |

# Observation of $t\bar{t}H$ with 6.3$\sigma$ (obs.) and 5.1$\sigma$ (exp.) significance!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ATLAS EXPERIMENT