ttH(bb) in ATLAS

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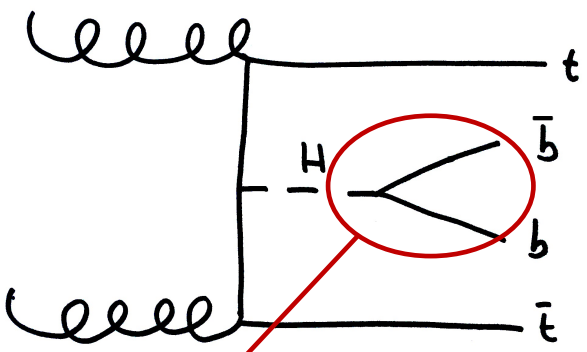
Spanish LHC network meeting

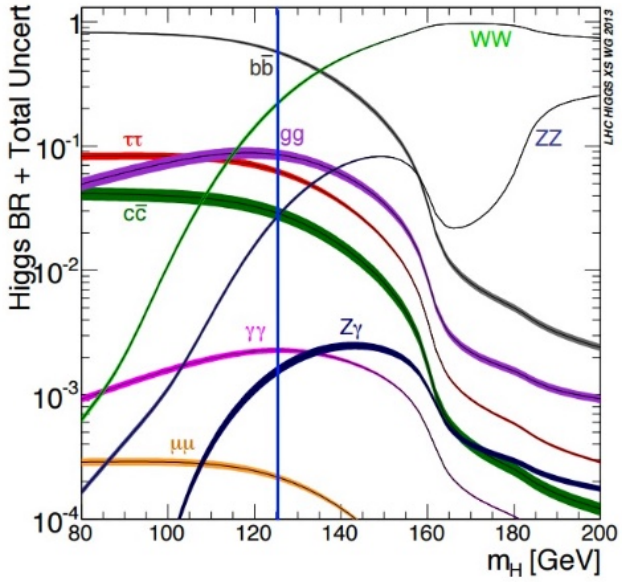
Introduction

- Direct measurement of Higgs-top Yukawa coupling → deviation hint for new physics

Cross-section (fb)	ttH (NLO)	ttW (NLO)	ttZ (NLO)	tt(NNLO)
8 TeV	133	232	206	2.53×10^5
13 TeV	507	566	760	8.32×10^5
Ratio	3.8	2.4	3.7	3.3



1% of total Higgs production cross section

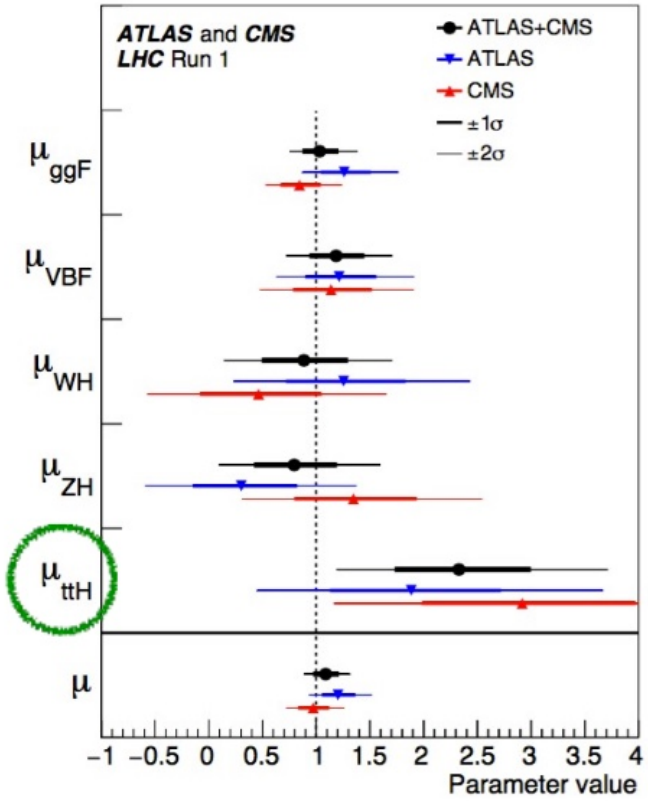


Higgs decay mode	Branching ratio (%)
H→bb	58.1
H→WW	21.5
H→ττ	6.3
H→ZZ	2.6
H→γγ	0.23

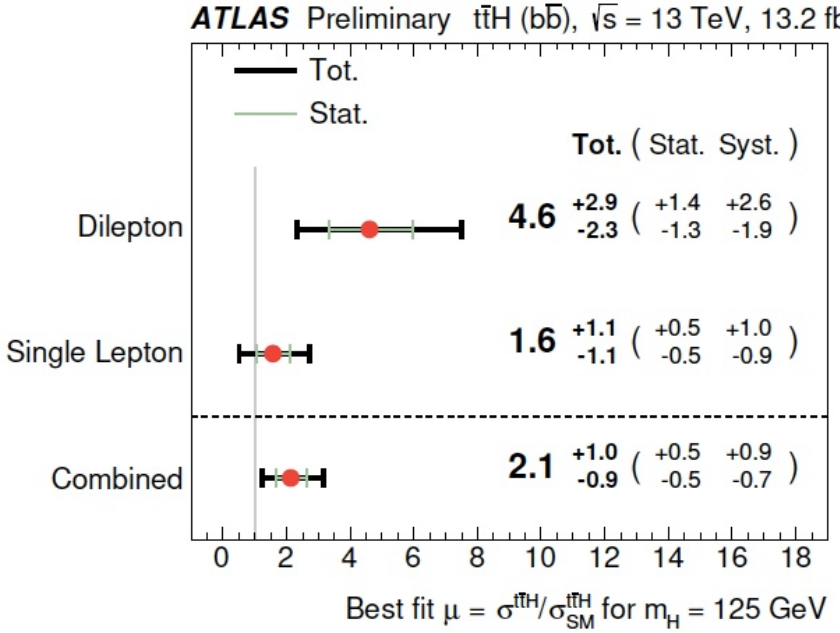
- Largest branching ratio but large background
- Sensitivity to the Higgs-bottom Yukawa coupling

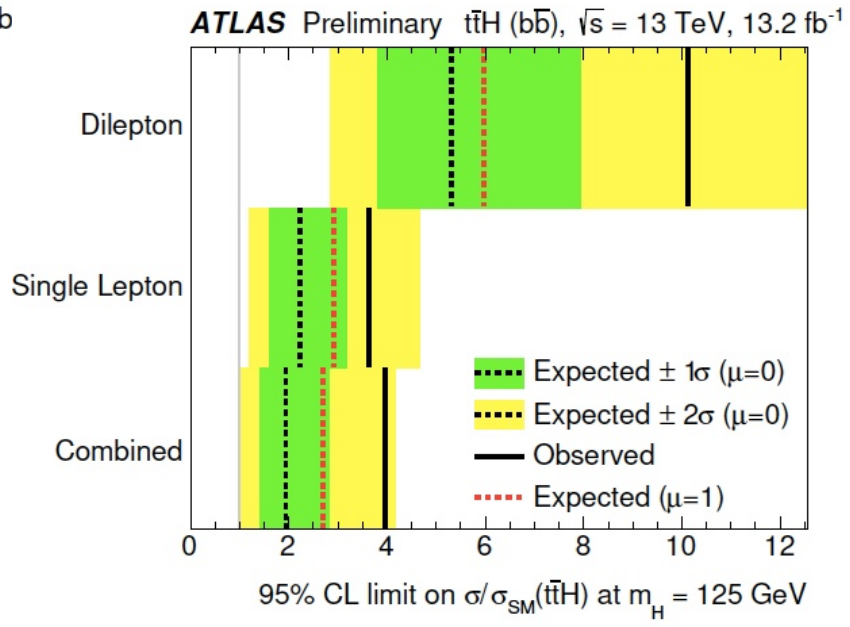
Previous results

Run 1



Run 2 ICHEP conf note

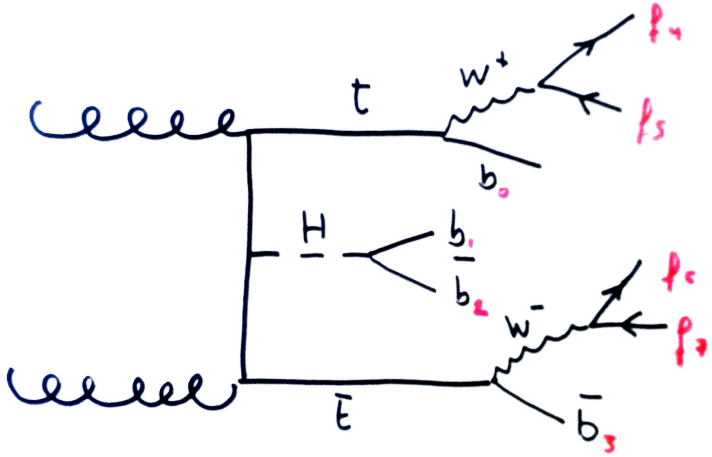




- 4.4 σ combined significance
- Cross section above SM value, but consistent within large uncertainty

Analysis strategy

(4 b-originated jets: b_0, b_1, b_2, b_3)



- Two channels depending on Ws decay:
  - Single lepton (6 jets + lepton + ν)
  - Di-lepton (4 jets + 2 leptons +2 ν)
- Preselection:
  - Single lepton triggers
  - Single lepton: only one lepton, at least four jets
  - Di-lepton: two opposite charge leptons (exclude Z peak region)
  - At least two b-tagged jets (at 85% WP)

Analysis strategy

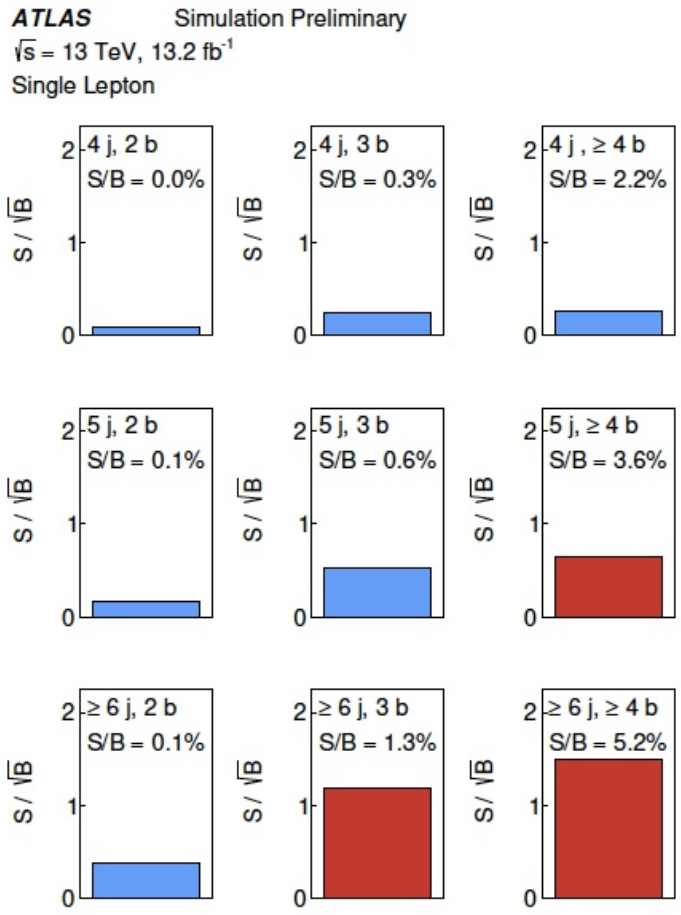
single lepton

2 3 ≥4 tags

4

5

≥6 jets

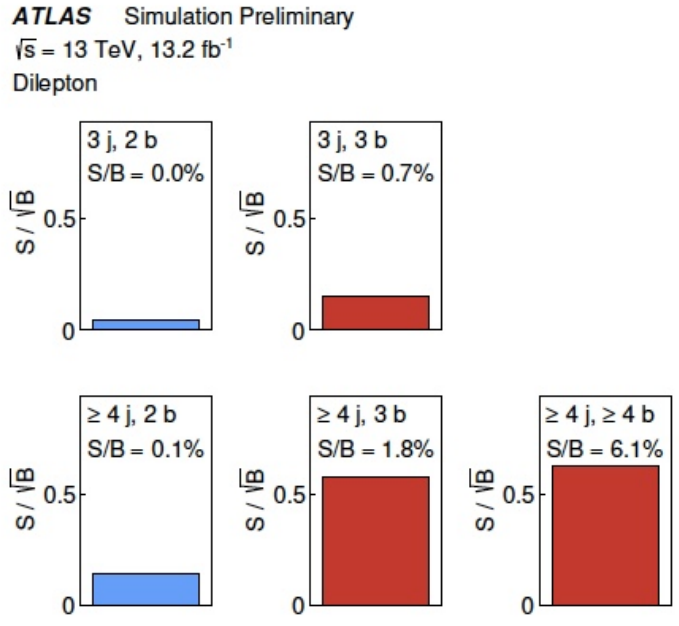


di-lepton

2 3 ≥4 tags

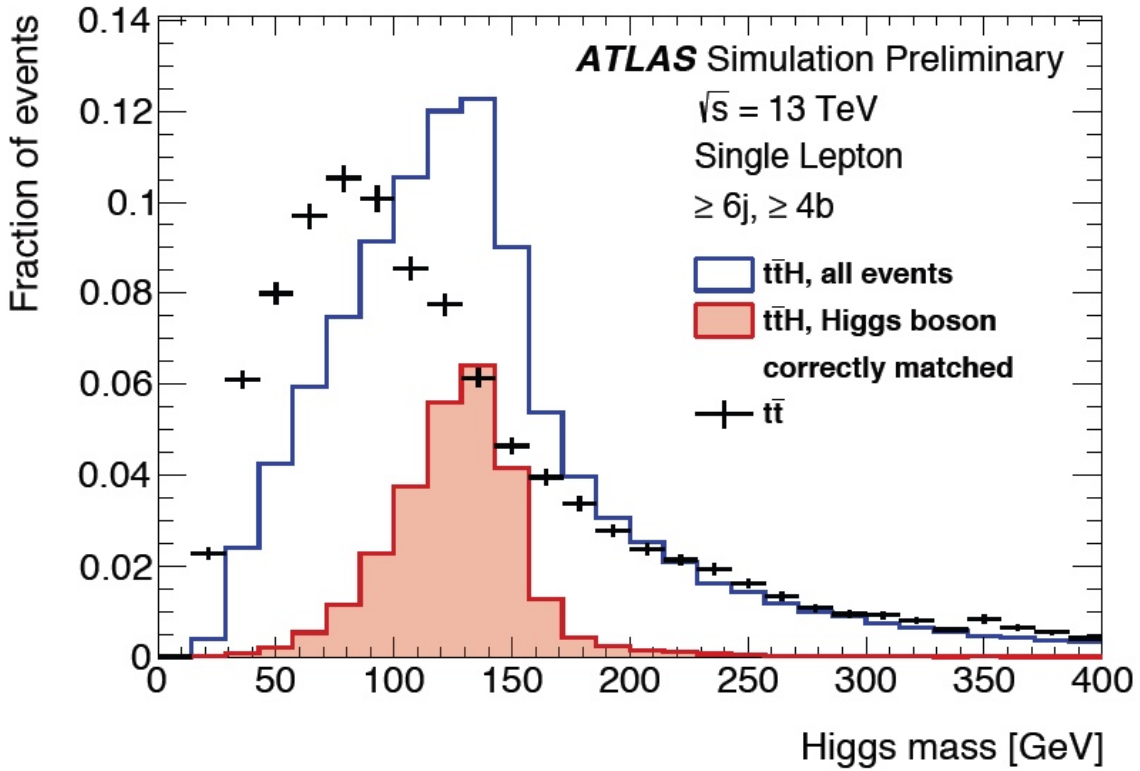
3

≥4 jets

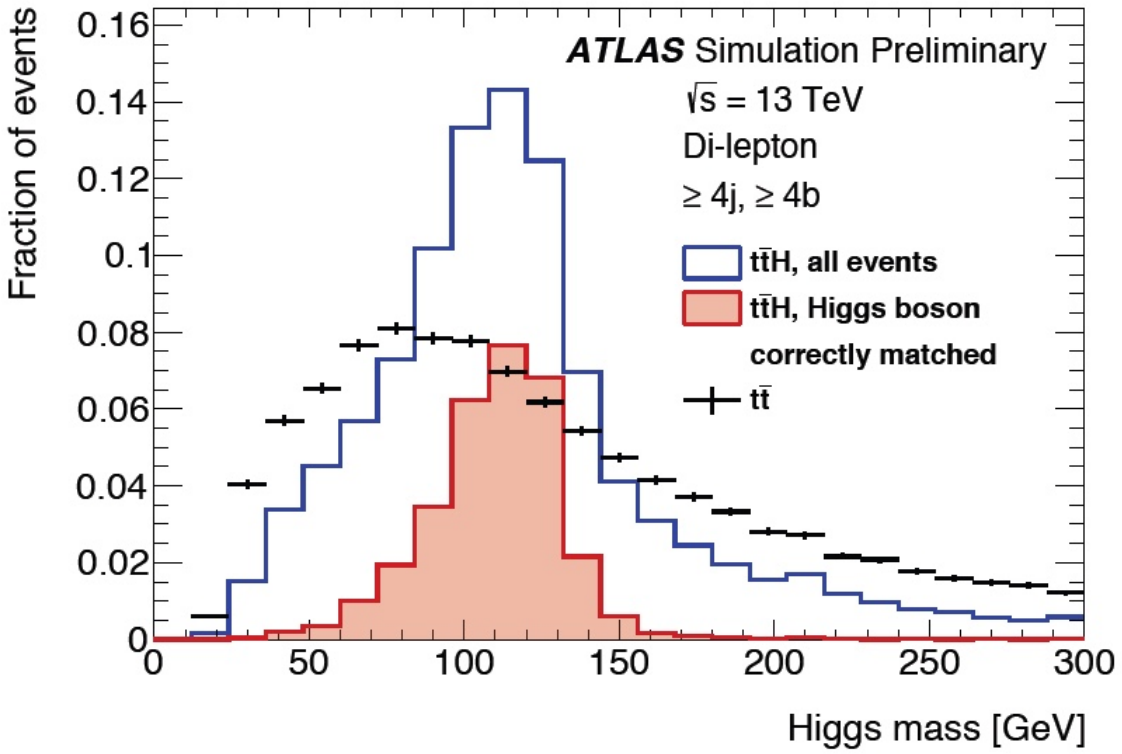


Reconstruction BDT

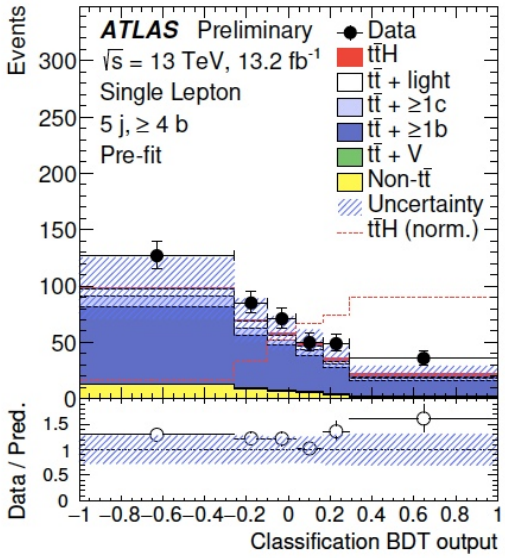
single lepton

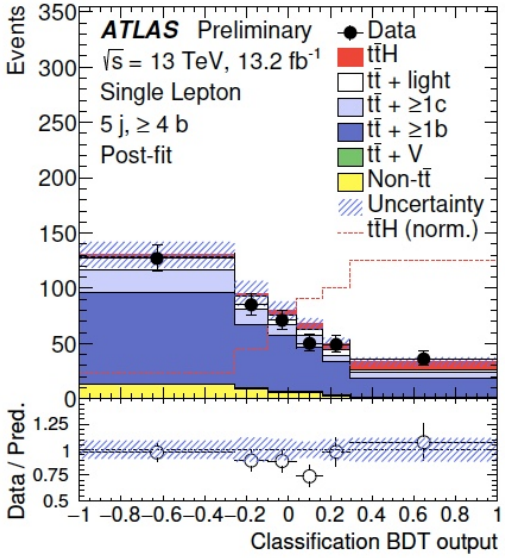


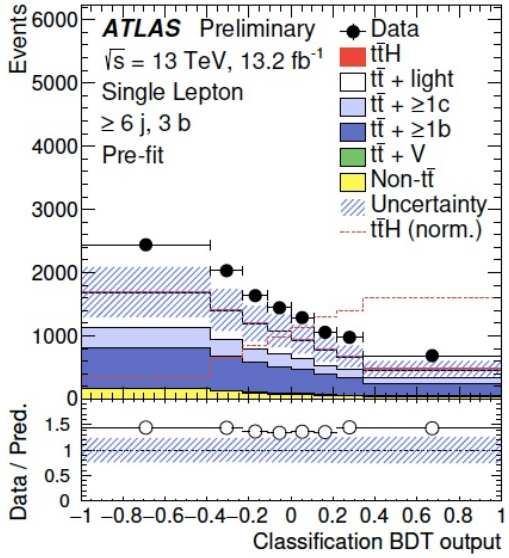
di-lepton

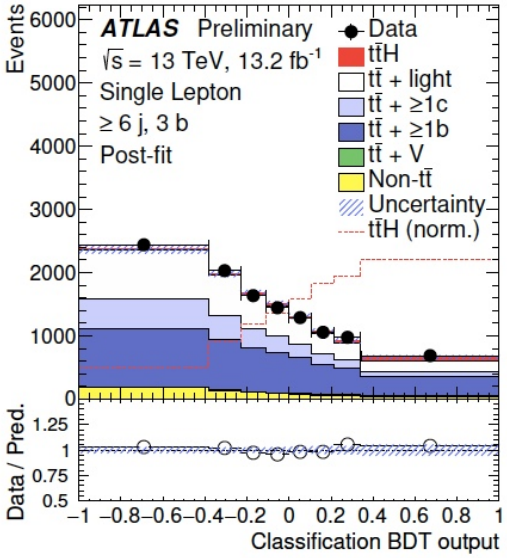


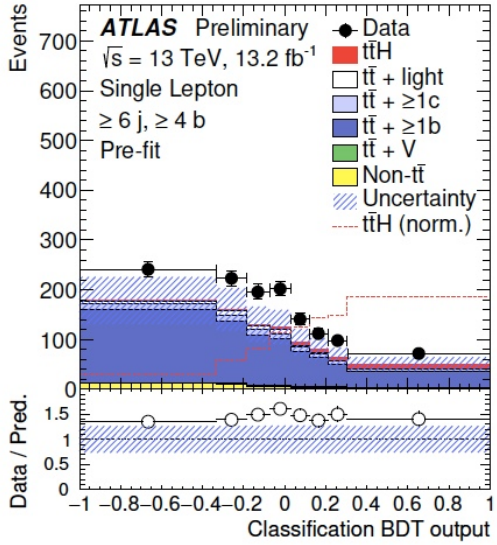
Classification BDT

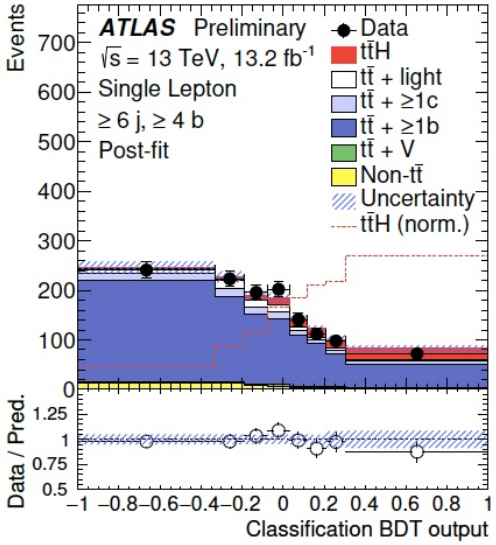






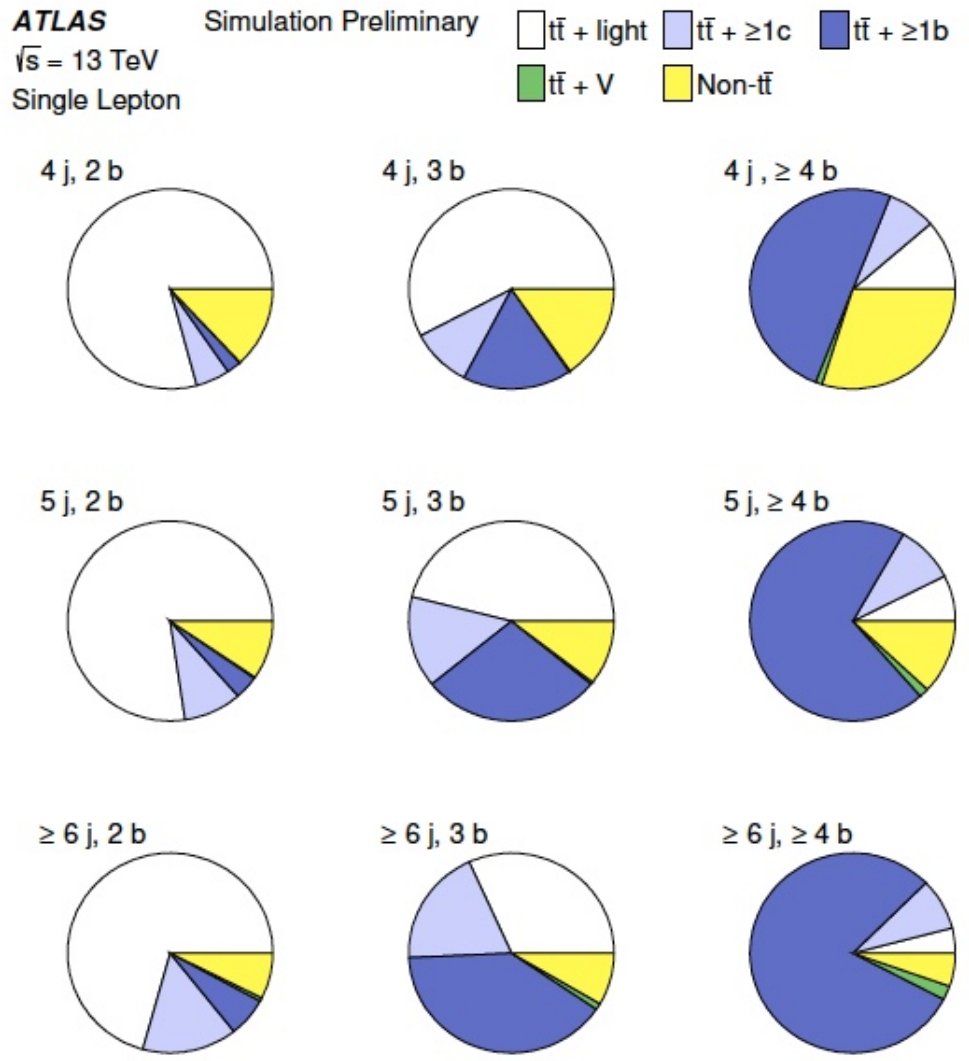






Background modelling

- Background dominated by ttbar + jets production (inclusive $\sigma = 832^{+46}_{-51}$ pb)
  - ✓ Split into light/heavy flavour based on extra jets: ttbar+light, ttbar+≥1c, **ttbar+≥1b**
- Other backgrounds:
  - ✓ **ttbar+V: ttbar+W, ttbar+Z**
  - ✓ **Non-ttbar: tH, Wt, other top (Zt, s- and t-channels), diboson, W+jets, Z+jets, fakes**

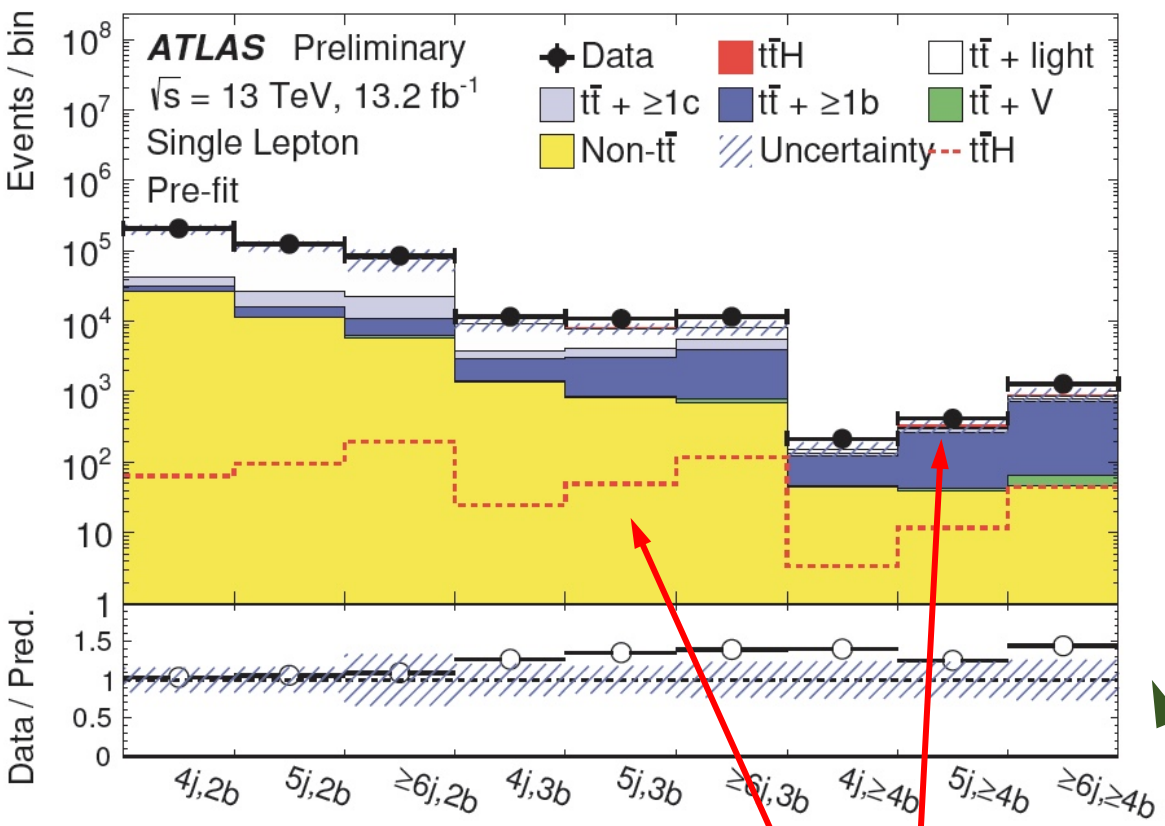


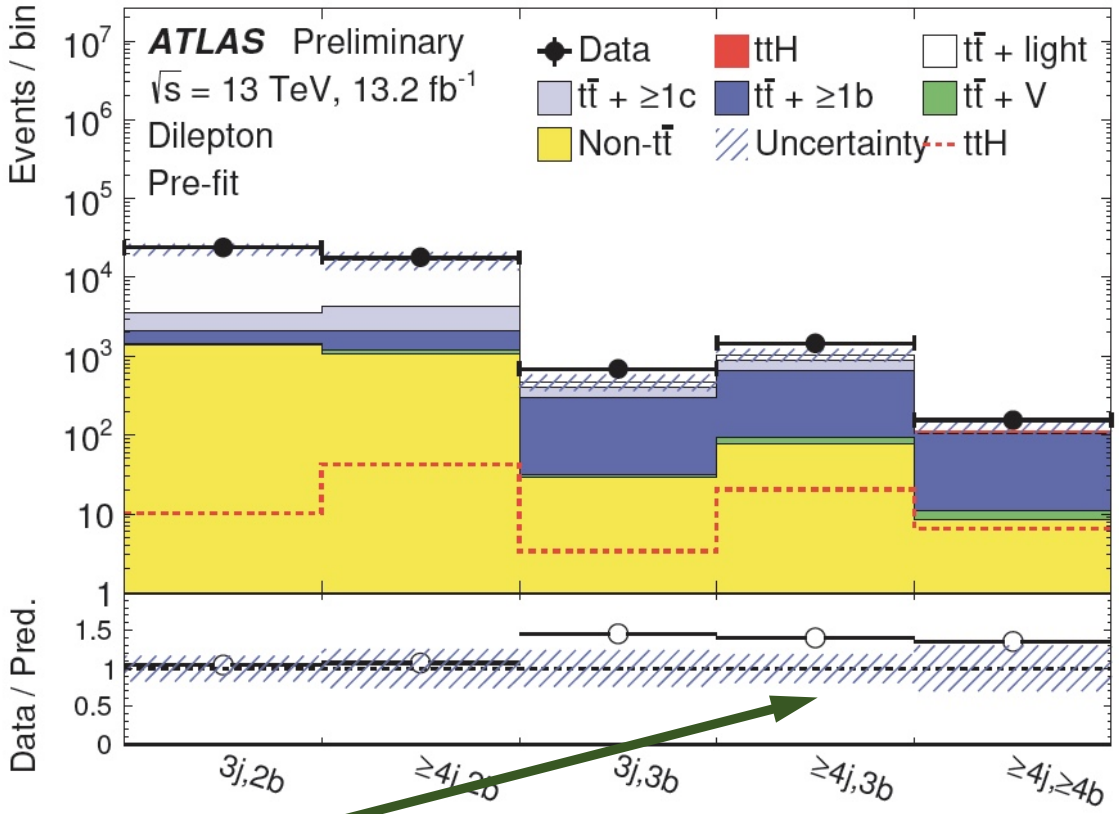
ttbar+≥1b dominates in SR

Fitting procedure

- ✓ Simultaneous (profile likelihood) fit of:
  - SR with signal enriched selections
  - CR to control backgrounds and uncertainties
- ✓ Use BDT output in SR and H_T^{had} in CR
- ✓ Main background: **ttbar+≥1b**
- ✓ **ttbar+≥1c** and **ttbar+≥1b** yields allowed to vary freely

Predicted and observed yields

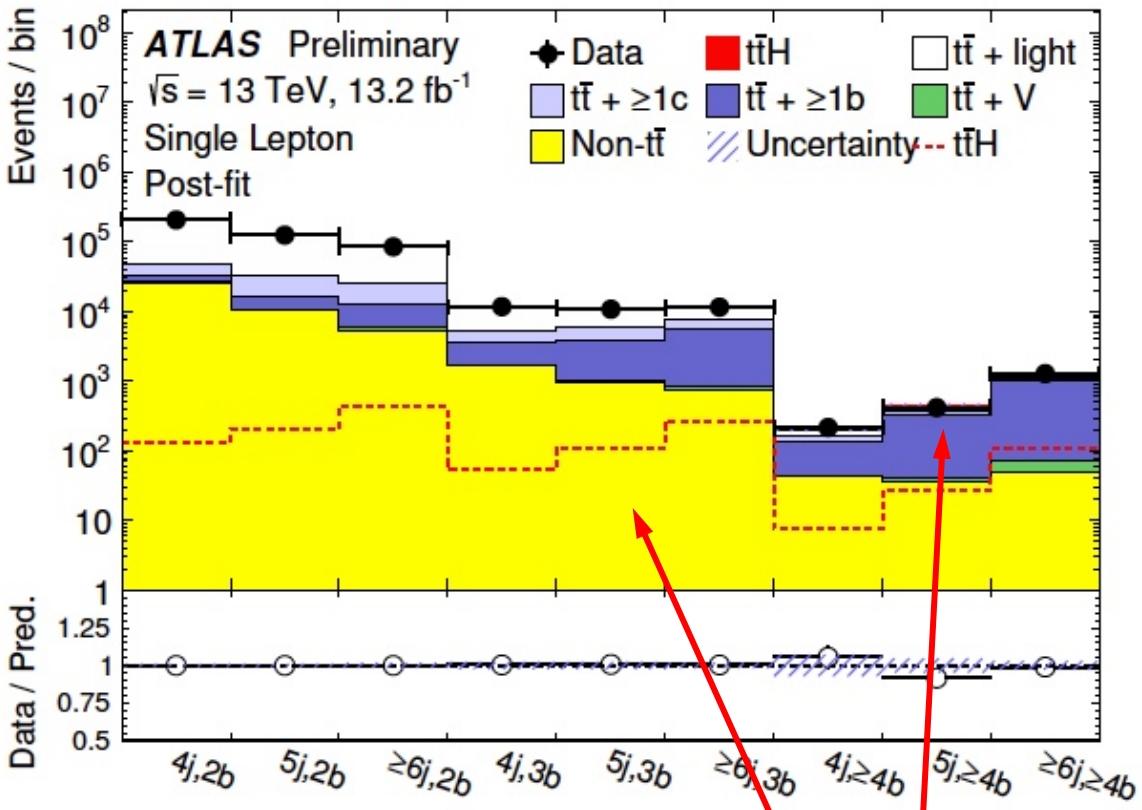


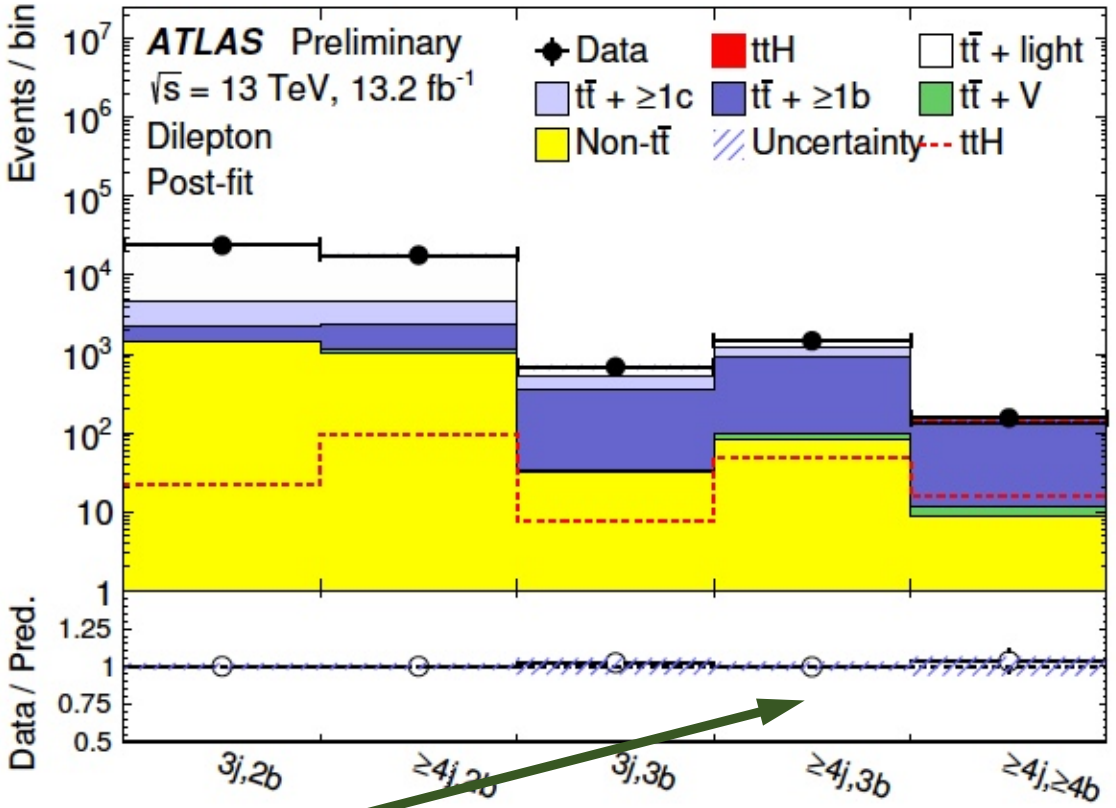


MC underestimates data in SR

ttH shown both stacked on top of background and separately

Fitted and observed yields

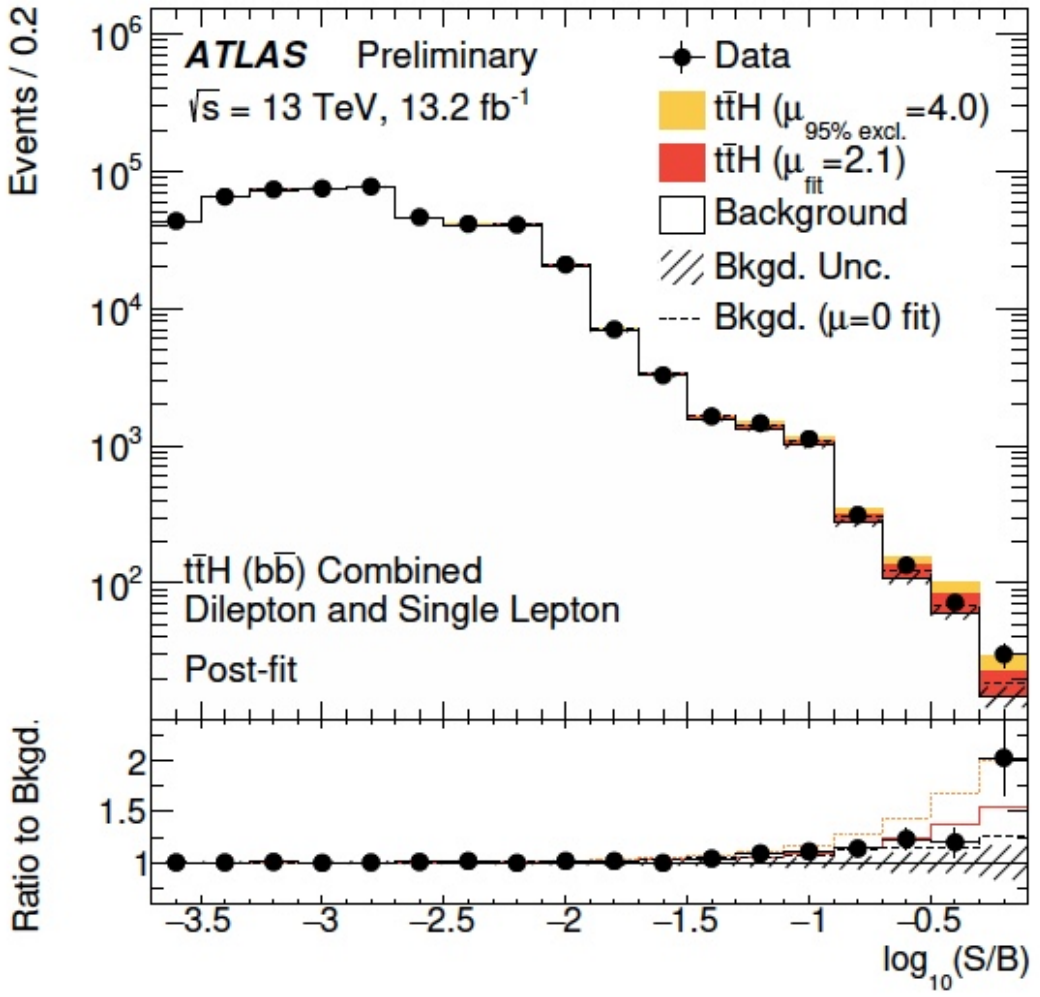




Post-fit agreement

ttH shown both stacked on top of background and separately

Fitted and observed yields

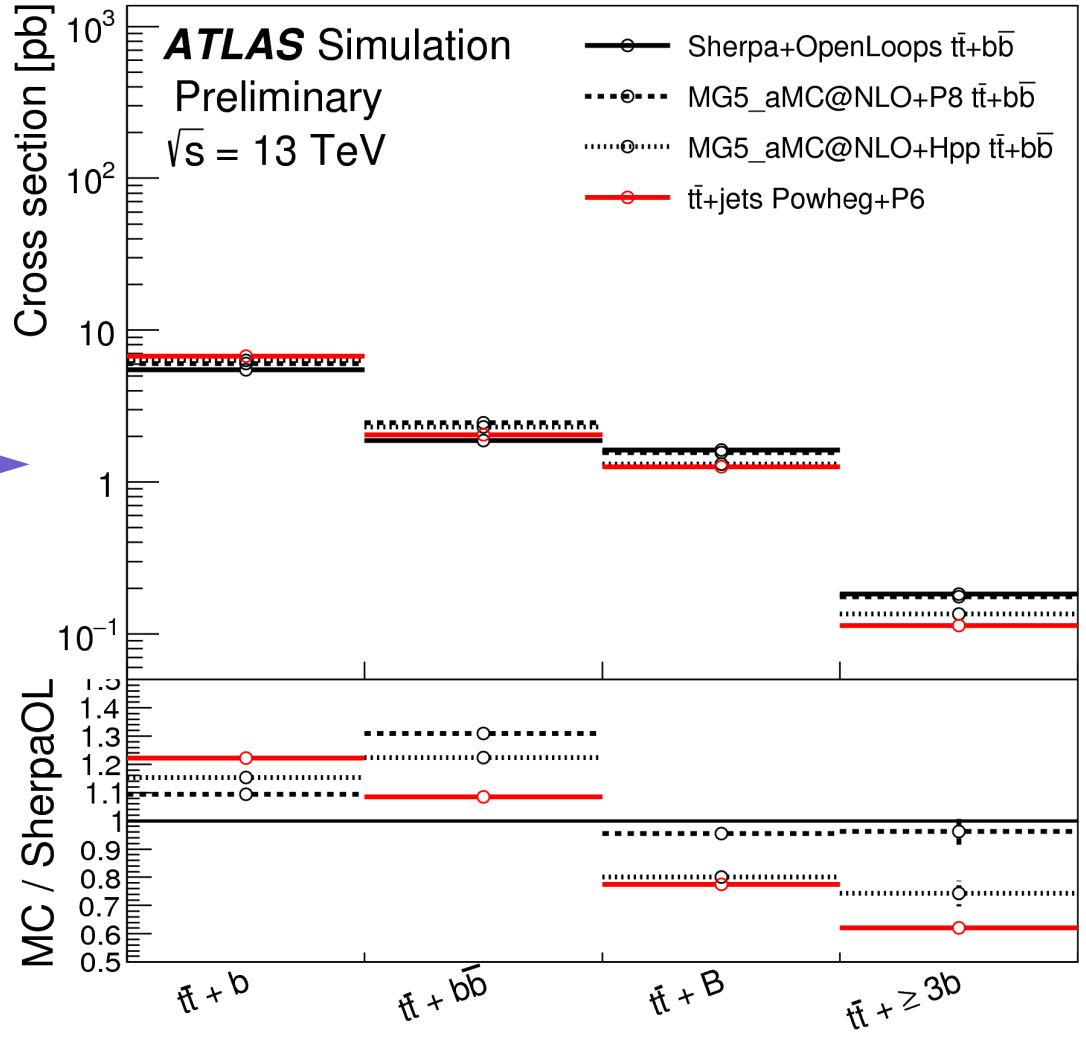


Post-fit agreement

ttbar modelling

ttbar modelled using *Powheg + Pythia 6*

- ✓ ttbar+light, ttbar+≥1c: p_T^{ttbar} and p_T^{t} reweighted to NNLO prediction
- ✓ **ttbar+≥1b**: 2D (p_T^{ttbar} , p_T^{t}) reweighting to NLO *Sherpa+OpenLoops* (4F) prediction maintaining inclusive normalisation in nominal and alternative samples



ttbar modelling systematic uncertainties

Inclusive **ttbar**

- ✓ NNLO+NNLL cross section (6%): Include variations of μ_F, μ_R, PDF, α_s, m_t
- ✓ Generator: *POWHEG* vs *MG5_aMC@NLO* (both *HERWIG*++) (5FS)
- ✓ PS + hadronisation: *(POWHEG) PYTHIA6 vs HERWIG*++ (5FS)
- ✓ ISR/FSR: (*POWHEG+PYTHIA6*) (5FS) radiation increased (μ_F/2, μ_R/2, hdamp x 2) and decreased (μ_F x 2, μ_R x 2, hdamp/2)

} decorrelated for ttbar+light, ttbar+≥1c and ttbar+≥1b

ttbar+≥1b

- ✓ Vary μ_F and μ_R in *SHERPA+OPEN LOOPS* (4FS)
- ✓ Consider two alternative PDFs and shower recoil scheme *SHERPA+OL* (4FS)
- ✓ Generator: *SHERPA+OL* (4FS) vs *MG5_aMC@NLO + PYTHIA8* (4FS)
- ✓ PS + hadronisation: (*MG5_aMC@NLO) PYTHIA8* (4FS) vs *HERWIG*++ (4FS)
- ✓ 50% contribution from MPI

ttbar+≥1c

- ✓ Default *c*-jets in PS vs *c*-jets in ME (*MG5@MC@NLO + HERWIG*++) (3FS)

ttbar+light and ttbar+≥1c

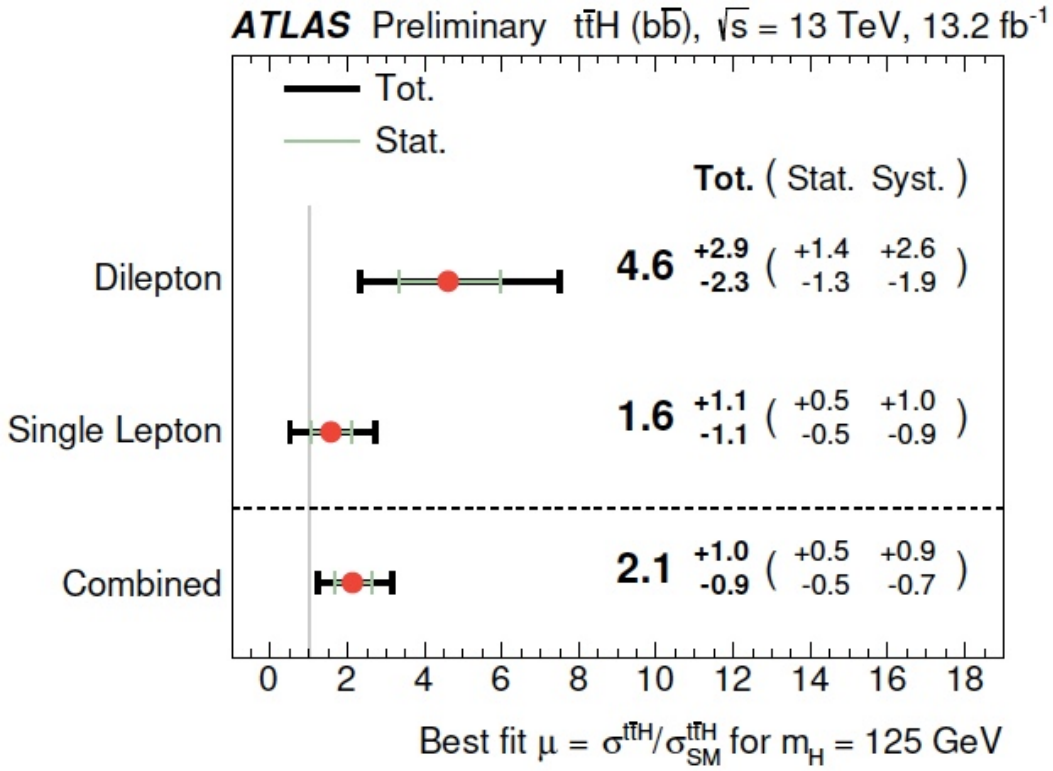
- ✓ p_T^t and p_T^{ttbar} reweighting: largest difference between nominal and any uncorrected alternative sample

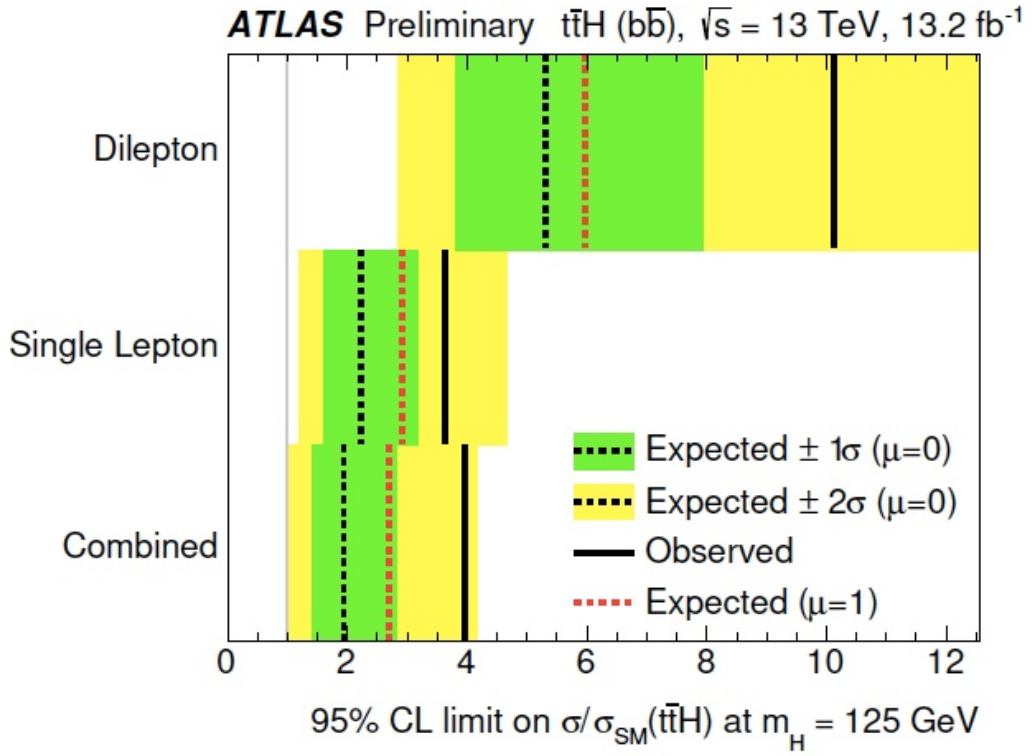
Systematic uncertainties

- ✓ Dominated by ttbar modelling, especially heavy flavour
- ✓ Detector largest contributions: b-tagging and JES/JER

Uncertainty source	$\Delta\mu$	
$t\bar{t}+\geq 1b$ modelling	+0.53	−0.53
Jet flavour tagging	+0.26	−0.26
$t\bar{t}H$ modelling	+0.32	−0.20
Background model statistics	+0.25	−0.25
$t\bar{t}+\geq 1c$ modelling	+0.24	−0.23
Jet energy scale and resolution	+0.19	−0.19
$t\bar{t}$+light modelling	+0.19	−0.18
Other background modelling	+0.18	−0.18
Jet-vertex association, pileup modelling	+0.12	−0.12
Luminosity	+0.12	−0.12
$t\bar{t}Z$ modelling	+0.06	−0.06
Light lepton (e, μ) ID, isolation, trigger	+0.05	−0.05
Total systematic uncertainty	+0.90	−0.75
$t\bar{t}+\geq 1b$ normalisation	+0.34	−0.34
$t\bar{t}+\geq 1c$ normalisation	+0.14	−0.14
Statistical uncertainty	+0.49	−0.49
Total uncertainty	+1.02	−0.89

Results


ATLAS Preliminary ttH (bb), √s = 13 TeV, 13.2 fb-1
Tot.
Stat.
Tot. (Stat. Syst.)
Dilepton
4.6 +2.9 -2.3 (+1.4 -1.3 +2.6 -1.9)
Single Lepton
1.6 +1.1 -1.1 (+0.5 -0.5 +1.0 -0.9)
Combined
2.1 +1.0 -0.9 (+0.5 -0.5 +0.9 -0.7)
0 2 4 6 8 10 12 14 16 18
Best fit μ = σttH/σttHSM for mH = 125 GeV


ATLAS Preliminary ttH (bb), √s = 13 TeV, 13.2 fb-1
Dilepton
Single Lepton
Combined
Expected ± 1σ (μ=0)
Expected ± 2σ (μ=0)
Observed
Expected (μ=1)
0 2 4 6 8 10 12
95% CL limit on σ/σSM(ttH) at mH = 125 GeV

Summary

- ✓ Performed search for ttH
- ✓ Focused on Higgs decays to bbbar
- ✓ Observed data consistent with either the background-only hypothesis or with the SM ttH prediction
- ✓ Signal strength measured to be $2.1^{+1.0}_{-0.9}$
- ✓ Run II preliminary result: ATLAS-CONF-2016-080
- ✓ Current plans (including complete 2015+2016 dataset):
  - ➢ Improve background modelling
  - ➢ Improve S/B discrimination including likelihood discriminant