Higgs results with direct top and b-Yukawas with ATLAS

Zhijun Liang (IHEP,Beijing)

On behalf of ATLAS collaboration

The fifth Annual Large Hadron Collider Physics conference（LHCP2017）

Outline

- Direct measurement of Higgs-bottom Yukawa coupling
  - VH, VBF H->bb and ttH($H \rightarrow bb$)
- Direct measurement of Higgs-Top Yukawa coupling
  - ttH(bb)
  - ttH (multi-lepton), including $H \rightarrow W^+W^-$, $H \rightarrow \tau\tau$, $H \rightarrow ZZ$
  - ttH($\gamma\gamma$)

Higgs-bottom Yukawa coupling

- H→bb has the largest predicted branching ratio (~58%)
  - Test of Yukawa coupling between b-quarks and Higgs boson
- ATLAS+CMS Results in Run 1: observed significance 2.6σ (expected 3.7σ)

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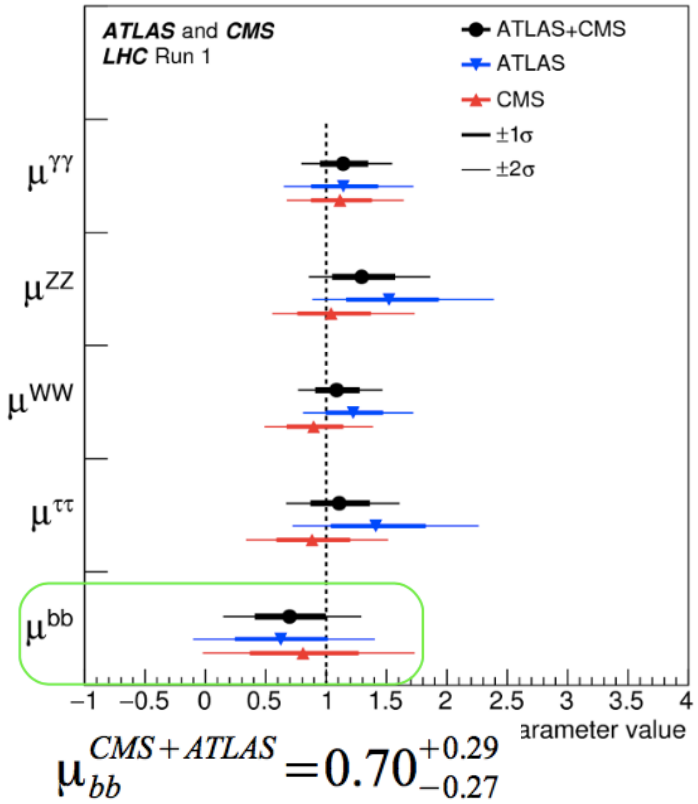


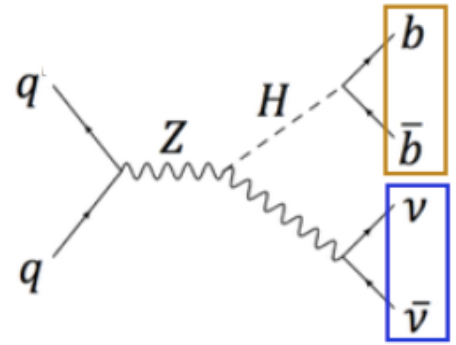
VH(bb) only

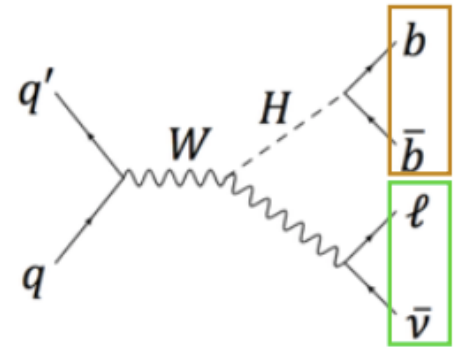
channels with a first Run-2 result

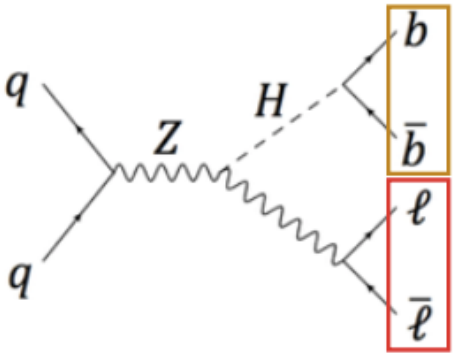
channel	Reference	Integrated Lumiosity
VH($b\bar{b}$)	ATLAS-CONF-2016-091	13.2 fb^{-1} (13TeV)
VBF H(bb)γ	ATLAS-CONF-2016-063	12.5 fb^{-1} (13TeV)

VH(bb) searches : 3 channels

ATLAS-CONF-2016-091







- 0-lepton:
  - E_T^{miss} > 150 GeV
- 1-lepton:
  - e/μ, p_T>25 GeV
  - Tight isolation
  - Missing E_T
  - p_T^V > 150 GeV
- 2-leptons:
  - Isolated ee, μμ
  - p_T^1>25 GeV, p_T^2>7 GeV
  - No missing E_T,
  - m_{ll} compatible with m_Z

- Two jets
  - anti-kT with R=0.4
  - P_T^{j1}>45 GeV
  - p_T^{j2}>20 GeV
- Improved b-tagging with respect to Run 1:
  - Eff: 70%, light jet rejection: 380, charm rejection: 12
- Analysis categories:

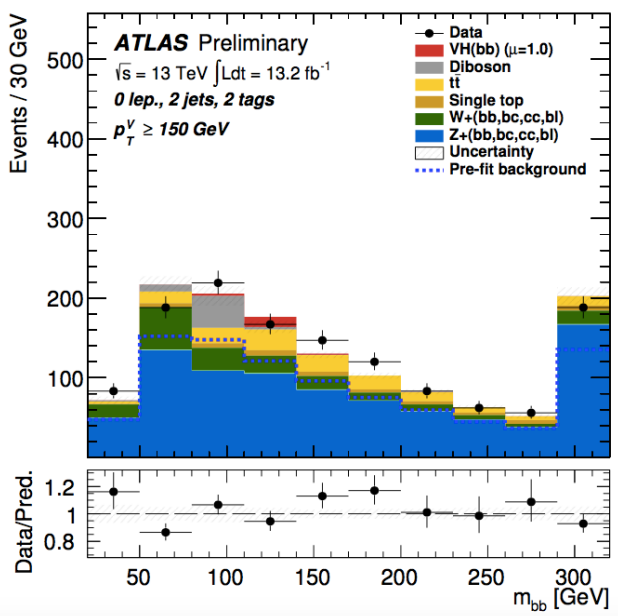
	0 lepton	1 lepton	2 leptons
2 jets	$p_V^T > 150$GeV	$p_V^T > 150$GeV	$p_V^T < 150$GeV
			$p_V^T > 150$GeV
3 jets	$p_V^T > 150$GeV	$p_V^T > 150$GeV	$p_V^T < 150$GeV
			$p_V^T > 150$GeV

Major Background in VH(bb) searches

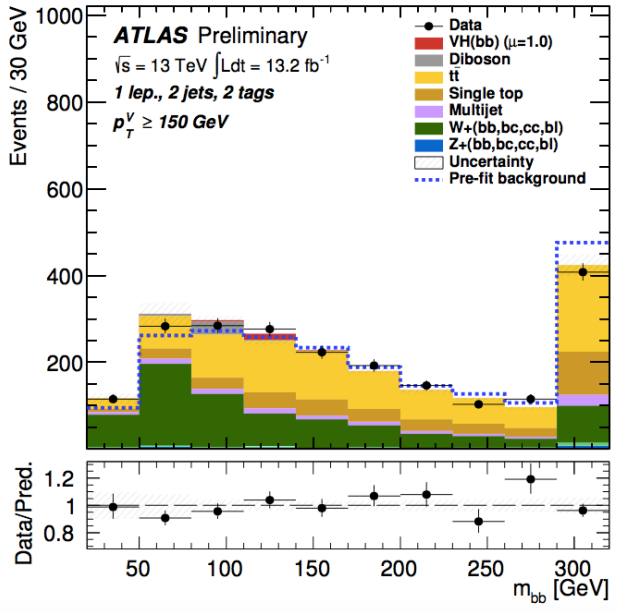
ATLAS-CONF-2016-091

- Z+bjets dominates in 0, 2 lepton channels
- Top quark and W+jets in 1 lepton channel
- Multi-jet background
  - negligible in 0/2 lepton channels after anti-QCD cuts
  - Data-driven estimate in 1 lepton channel

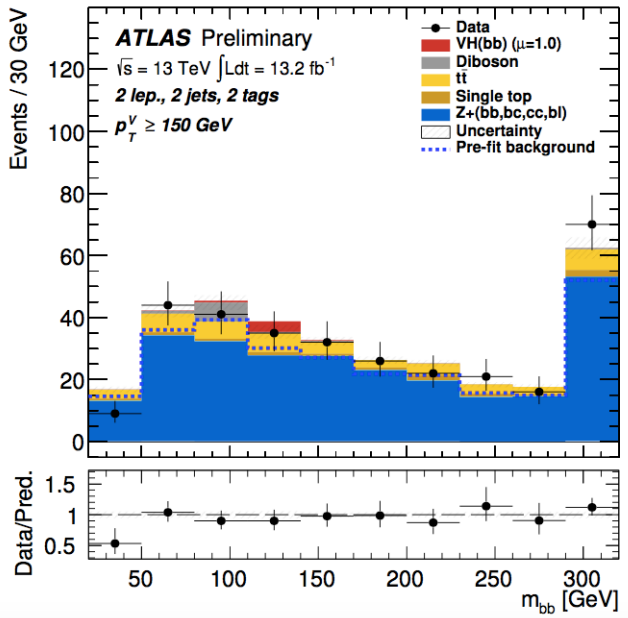
0 Lepton



1 Lepton



2 Lepton



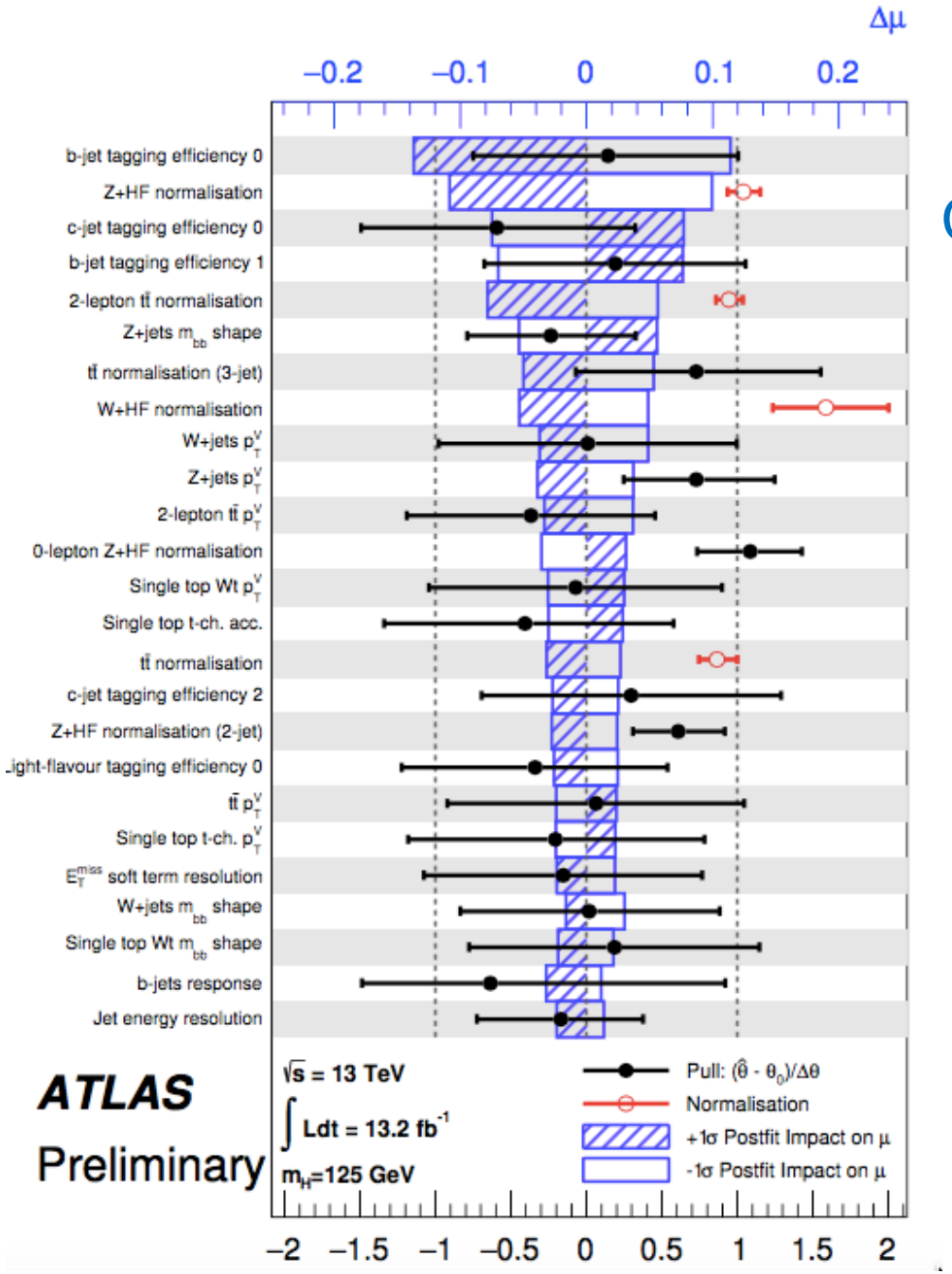
VH(bb) searches : results

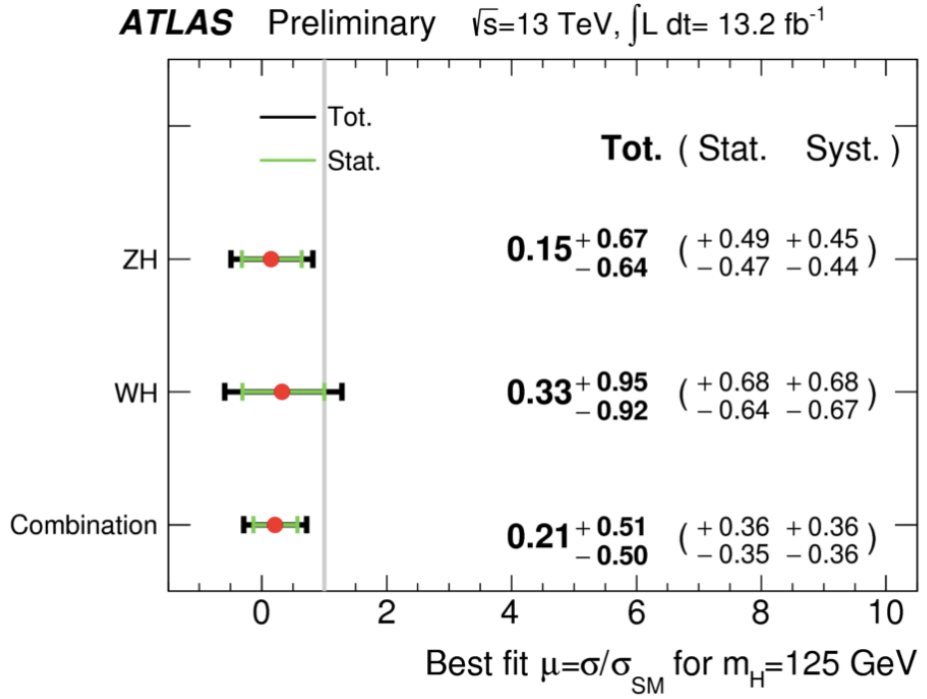
ATLAS-CONF-2016-091

Combined signal strength with 13.2 fb^{-1} at $\sqrt{s}$= 13 TeV

$$\mu_{VH,H\to bb} = 0.21^{+0.51}_{-0.50}$$

- Systematic and statistical uncertainties of the same size
- Dominant systematics from b-tagging and
- background normalization modelling (W+jets, Z+jets, top)

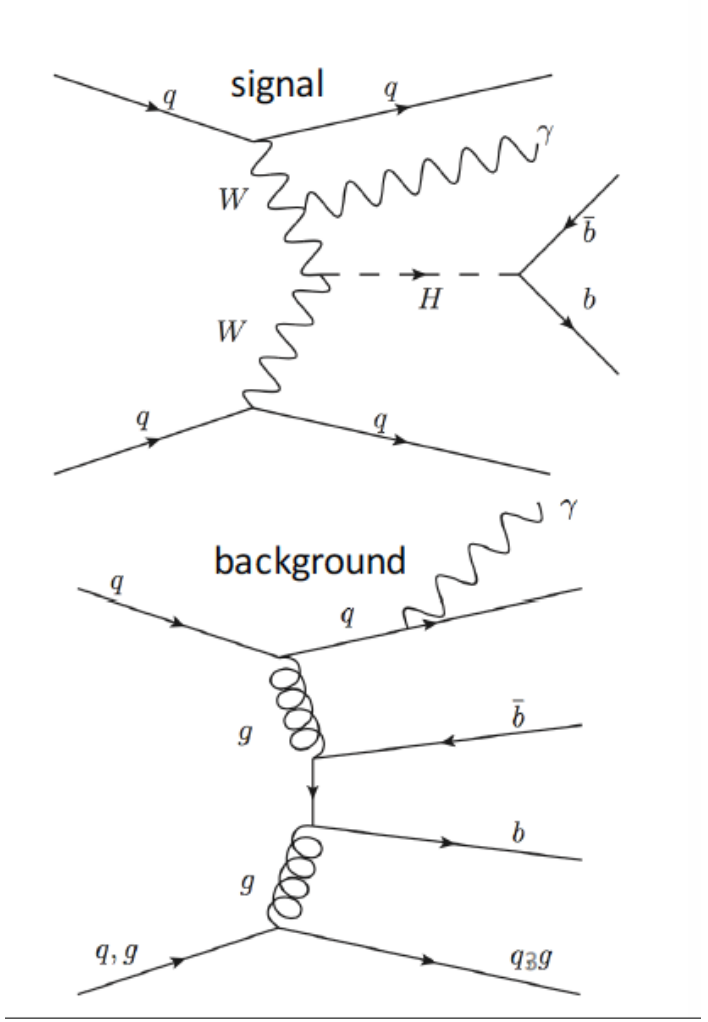




VBF H(bb)γ

ATLAS-CONF-2016-063

- Search for H->bb in VBF events containing a central photon
- Advantages of requiring a photon
  - extra handle for trigger
  - suppresses QCD background
  - Special VBF production
  - Sensitive to WWH VBF production
  - not sensitive to ZZH VBF
- Existing results for inclusive VBF (H->bb)
  - ATLAS in Run 1
    - observed (expected) upper limit : 4.4 (5.4) x SM
  - CMS in Run 1
    - observed (expected) significance : 2.2 (0.8) x SM
    - observed (expected) upper limit : 5.5 (2.5) x SM
  - CMS in Run 2 (2015 data)
    - observed (expected) upper limit: 3.0 (5.0) x SM



VBF H(bb)γ : event selection

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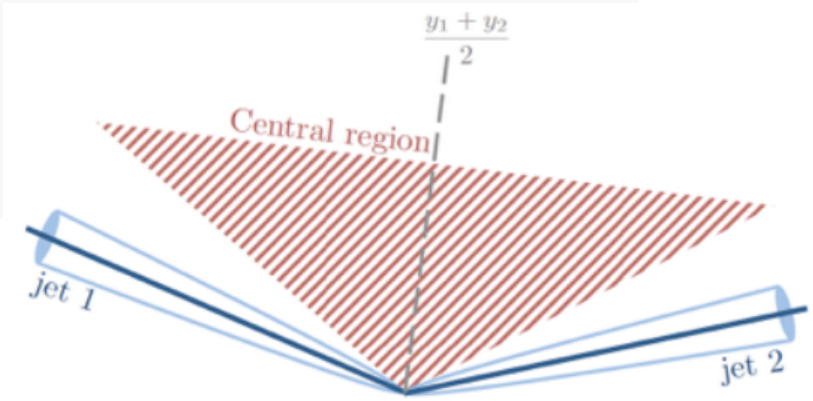
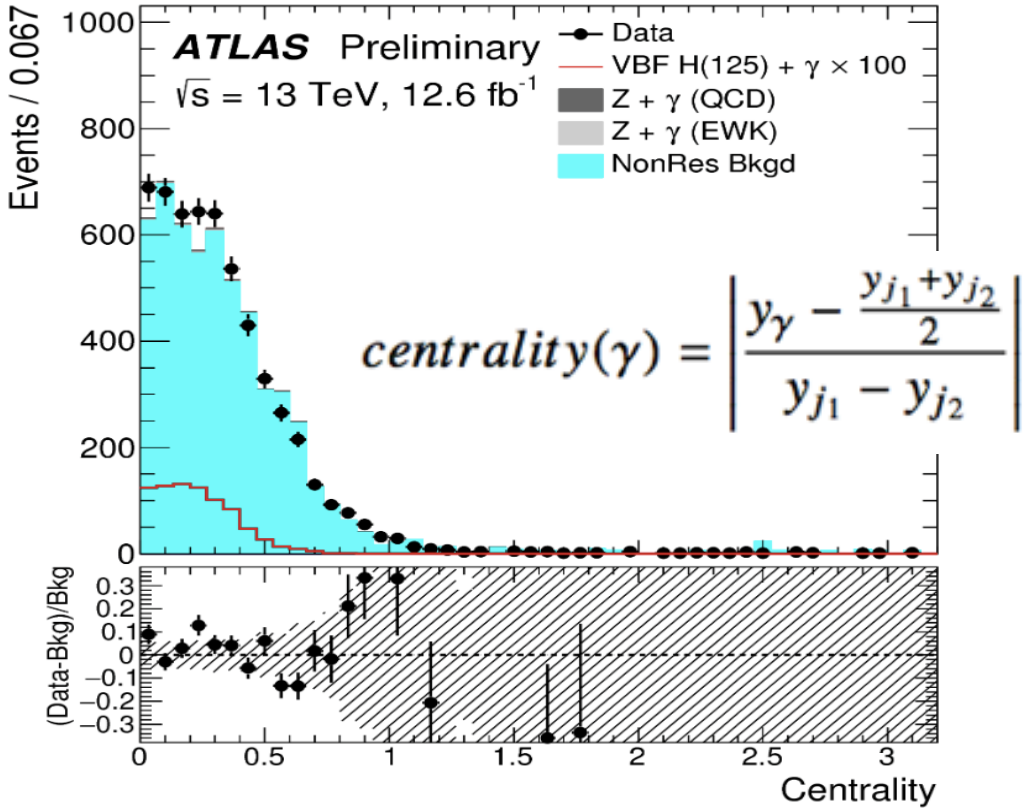


- Trigger:
  - L1 trigger: single photon (pT > 25 GeV)
  - High level trigger: 4 jets pT > 35 GeV, mjj> 700 GeV
- Offline Selection:
  - Tight ID photon, pT > 30 GeV
  - 4 jets with pT> 40 GeV
  - 2 central(|η|<2.5) b-tagged jets
  - pT(bb)>80GeV
  - mjj> 800 GeV



- BDT discriminant

$$\Delta R(jet, \gamma), m_{jj}, \Delta\eta_{jj}, H_T^{soft}, jet\ width, \gamma\ centrality, p_T^{balance}$$

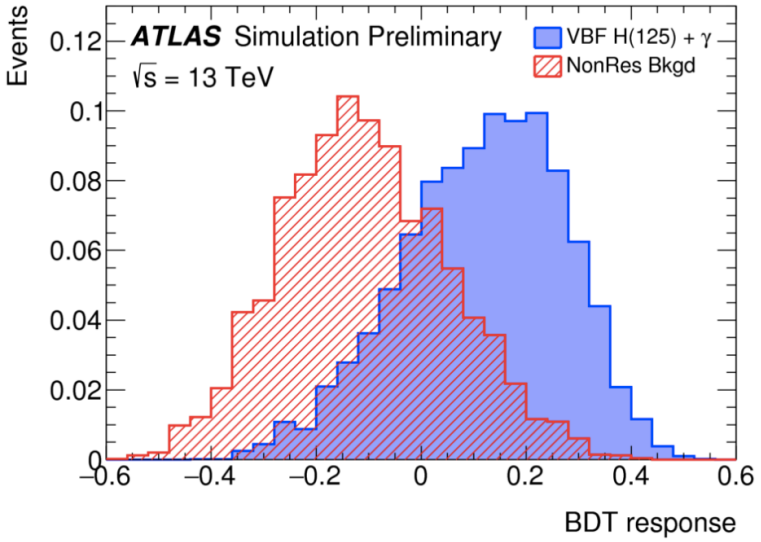
- Define 3 regions with different S/B
- Fit m_{bb} in 3 regions

VBF H(bb)γ: signal extraction

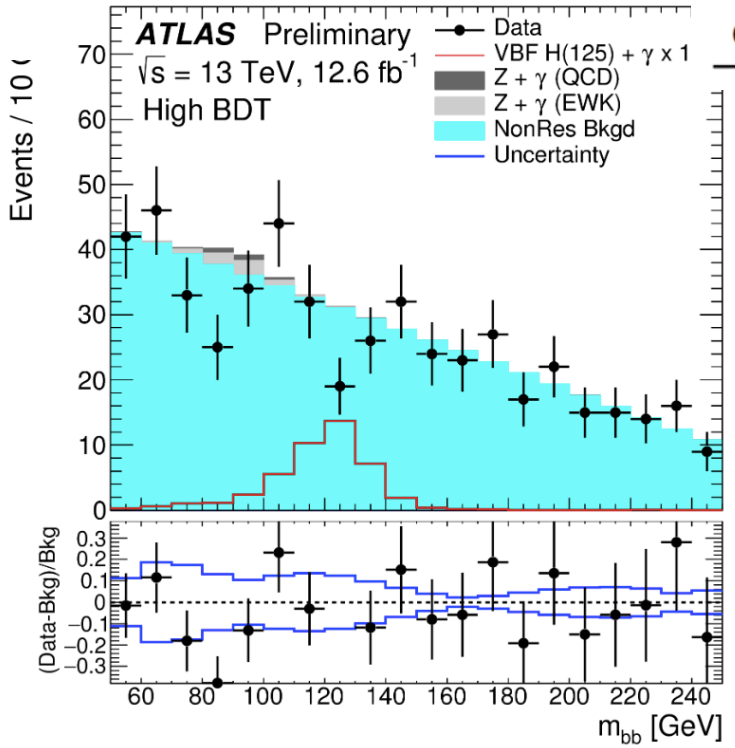
ATLAS-CONF-2016-063

- Non-resonant background (γ+jets) estimated with 2nd order polynomial fit.
- Simultaneous fit on three signal regions
  - Low/medium/high BDT regions

BDT output



High BDT score region



Result	$H(\to b\bar{b})+\gamma jj$	$Z(\to b\bar{b})+\gamma jj$
Expected significance	0.4	1.3
Expected p-value	0.4	0.1
Observed p-value	0.9	0.4
Expected limit	$6.0\ ^{+2.3}_{-1.7}$	$1.8\ ^{+0.7}_{-0.5}$
Observed limit	4.0	2.0
Observed signal strength μ	$-3.9\ ^{+2.8}_{-2.7}$	$0.3\ \pm 0.8$

VBF H (bb) γ production cross section limit

- Expected 95% CL limit:

$$6.0^{+2.3}_{-1.7}$$

- Observed 95% CL limit:

$$4\times(\sigma\times BR)^{SM}$$

Higgs-top Yukawa coupling

- Direct measurement of Higgs-Top coupling via ttH production.
- ttH signal strength (μ_{ttH}) measured in LHC Run 1
  - 4.4 sigma observed significance (ATLAS+CMS run1 combination)
  - 2.0 sigma expected significance

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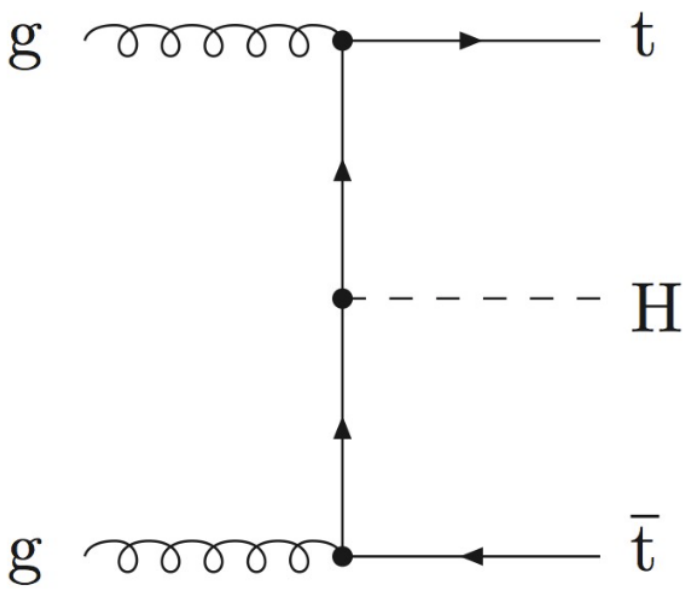
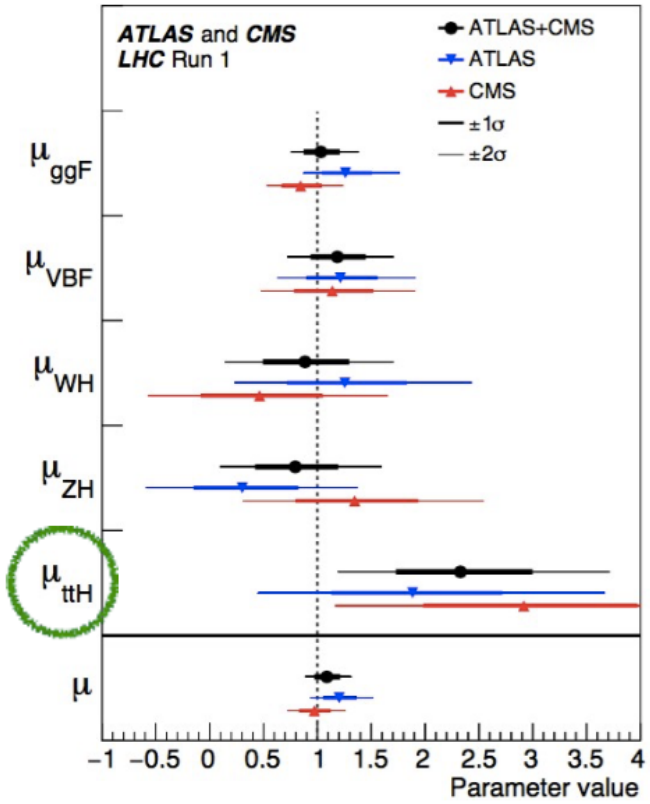
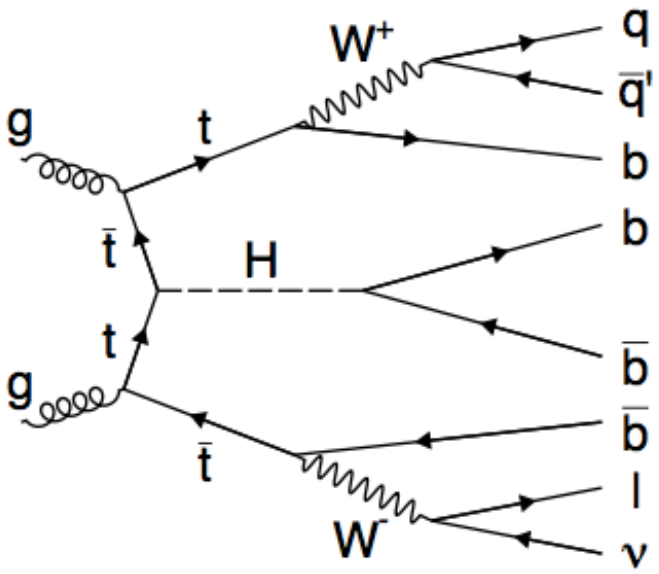
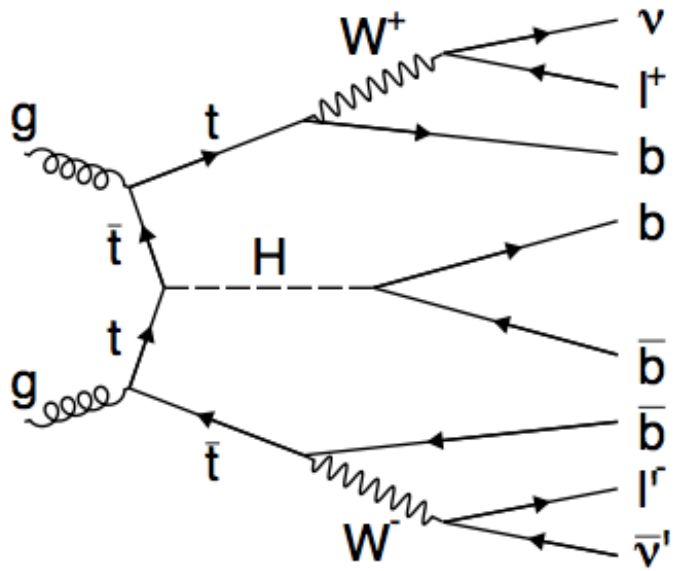




ttH(bb)

ATLAS-CONF-2016-080





Single Lepton Channel

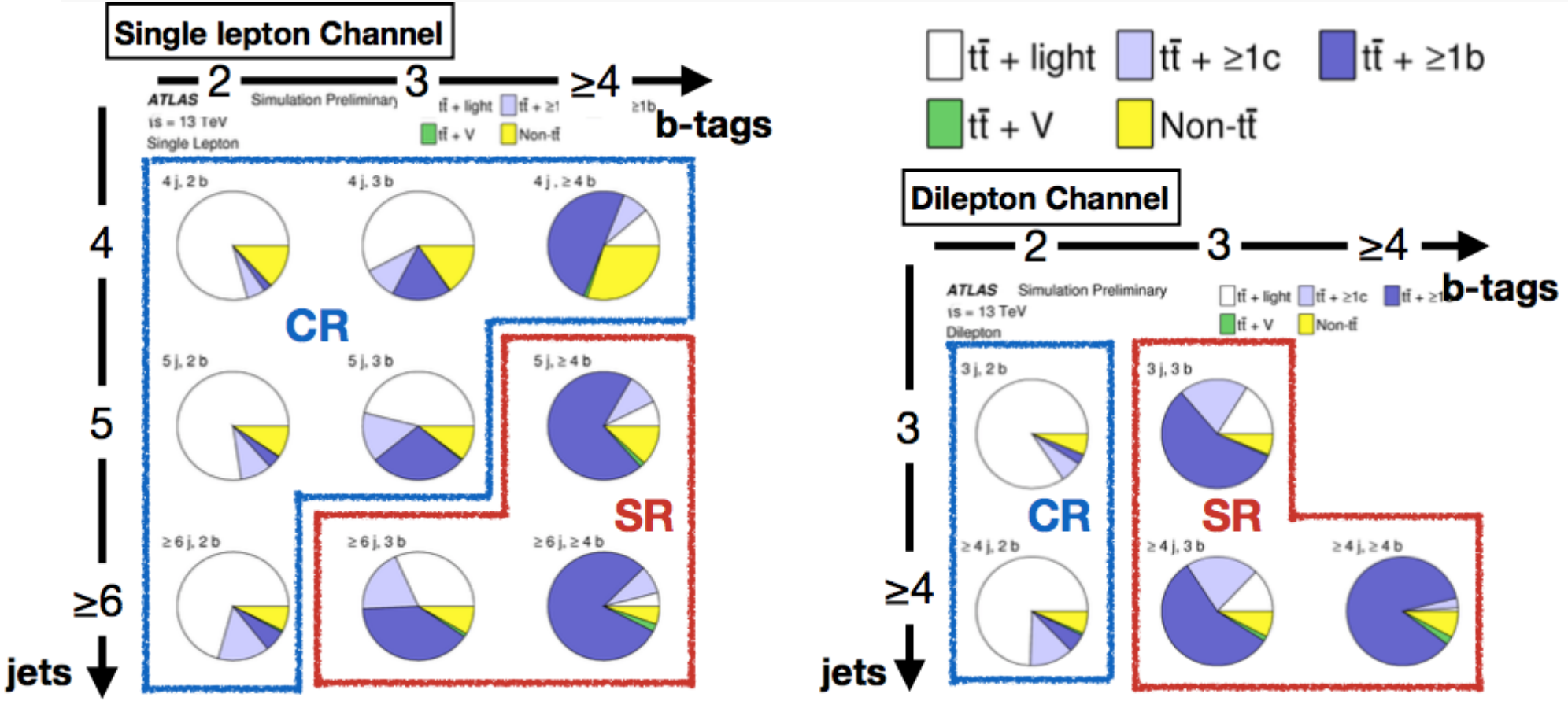
- 1 light lepton (e,μ)
- At least 4 jets
- At least 2 b-tagged jets

Dilepton Channel

- 2 opposite charge light leptons (e,μ)
- At least 3 jets
- At least 2 b-tagged jets
- Z mass veto

ttH(bb)

ATLAS-CONF-2016-080



Signal Region (SR) : Enriched in signal.

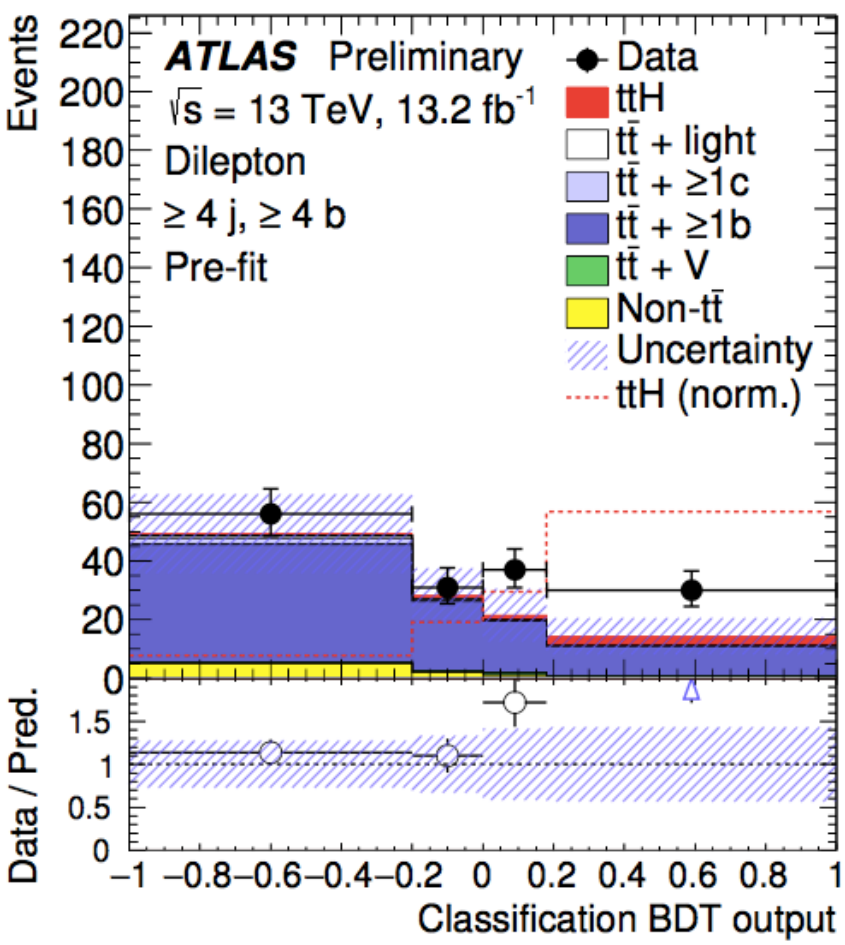
Control Region (CR) : Use to constraint backgrounds.

tt + ≥1 bjet, tt + ≥1 cjet, and tt + light jets are the dominant backgrounds

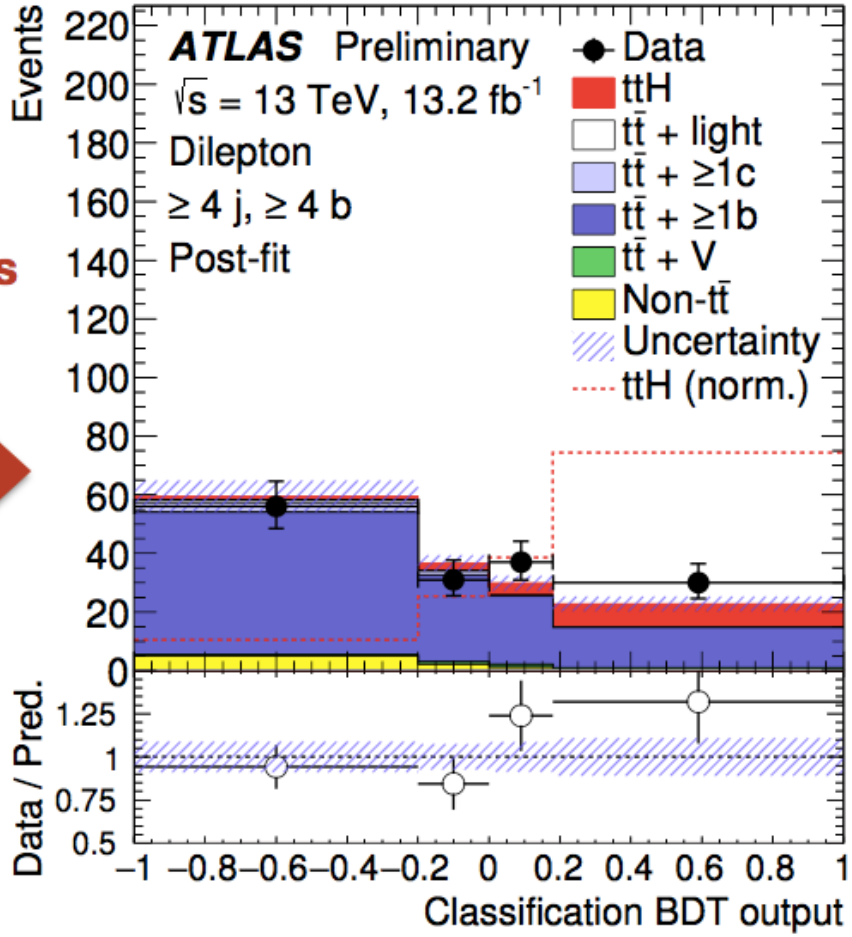
ttH(bb)

ATLAS-CONF-2016-080

- In SR, “Classification BDT” is used to extract signal in
- Simultaneous fit to all region



Simultaneous Fit with CR

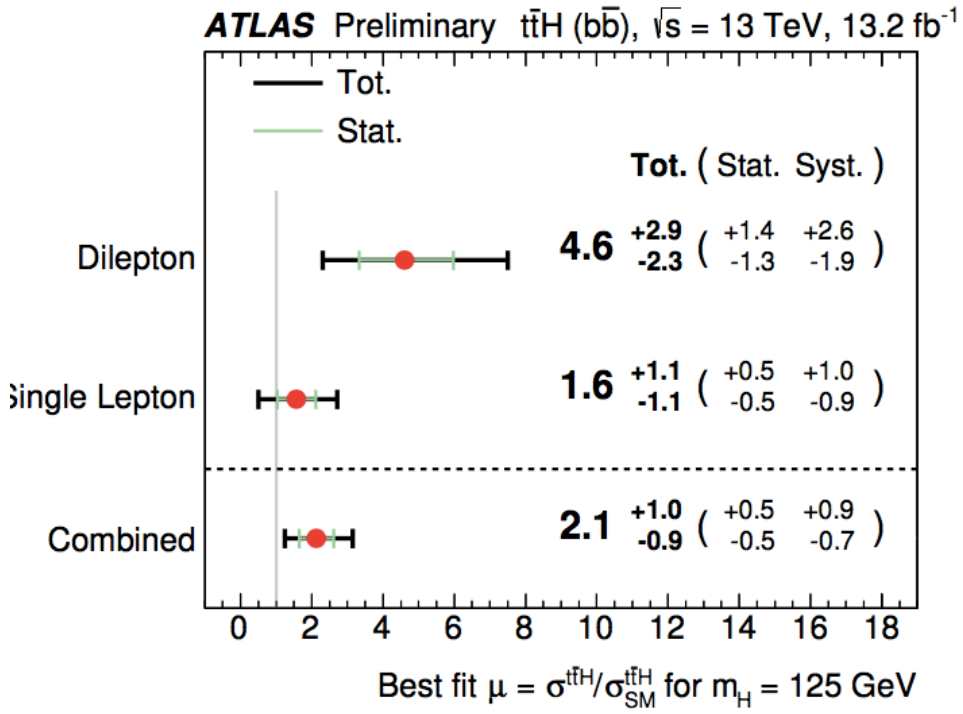


ttH(bb)

ATLAS-CONF-2016-080

- Summary of signal strength measurements
- Major systematics: tt+X modelling, jet flavor tagging

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



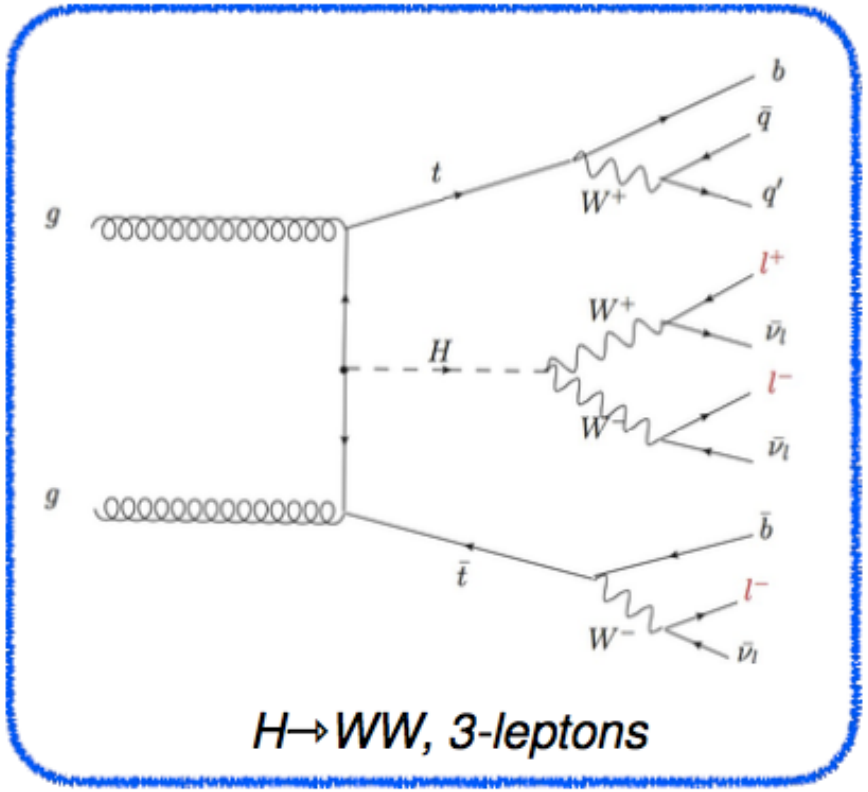
ttH (multi-leptons) analysis: event selection and background

ATLAS-CONF-2016-058

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

$t\bar{t}H$(multileptons) channel has many possible final states → focus on those with clean signature and low backgrounds.

$t\bar{t}H$(multileptons) Feynman diagram



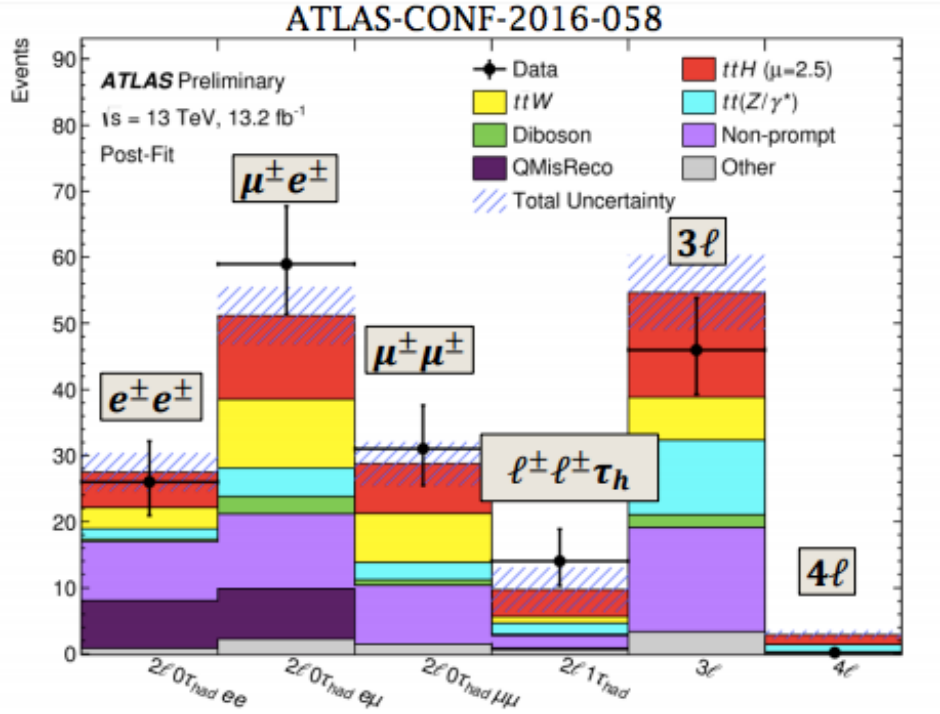
H→WW, 3-leptons

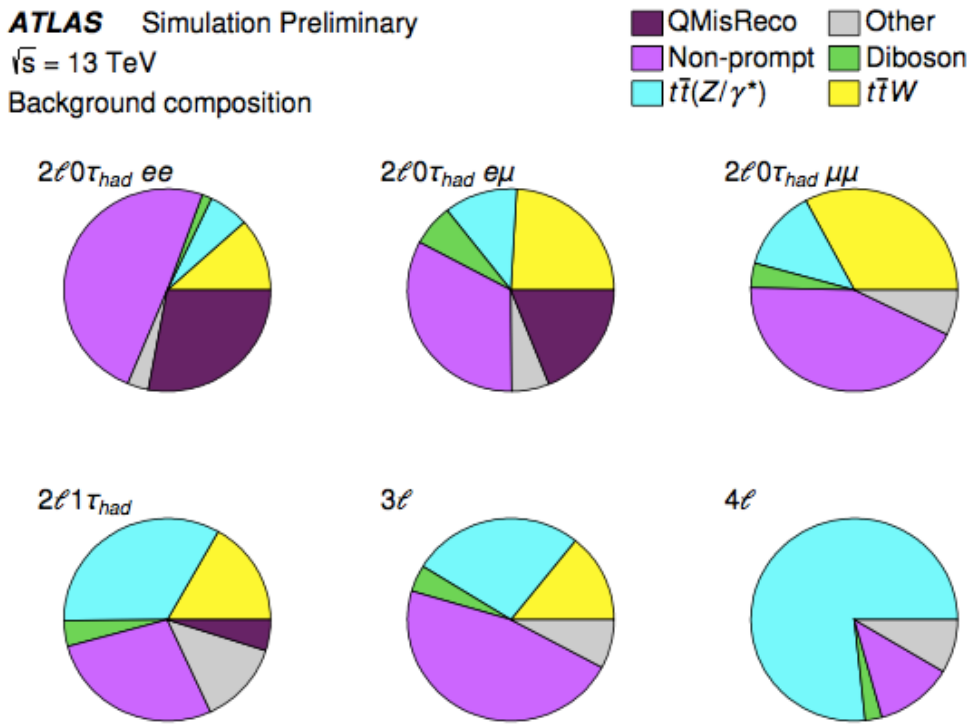
ttH (multi-leptons) analysis: event selection and background

ATLAS-CONF-2016-058

- two same charge light leptons + no τ_{had} → 2/ 0τ_{had}
  - ➢ (at least 5 jets and at least 1 bjet)
- two same charge light leptons + one τ_{had} → 2/ 1τ_{had}
  - ➢ (at least 4 jets and at least 1 bjet)
- three light leptons → 3/ (≥ 4jets, ≥ 1bjet, or 3jets, ≥ 2bjets)
- four light leptons → 4/ (≥ 2jets, ≥ 1bjet)

Cut and count analysis in 6 categories

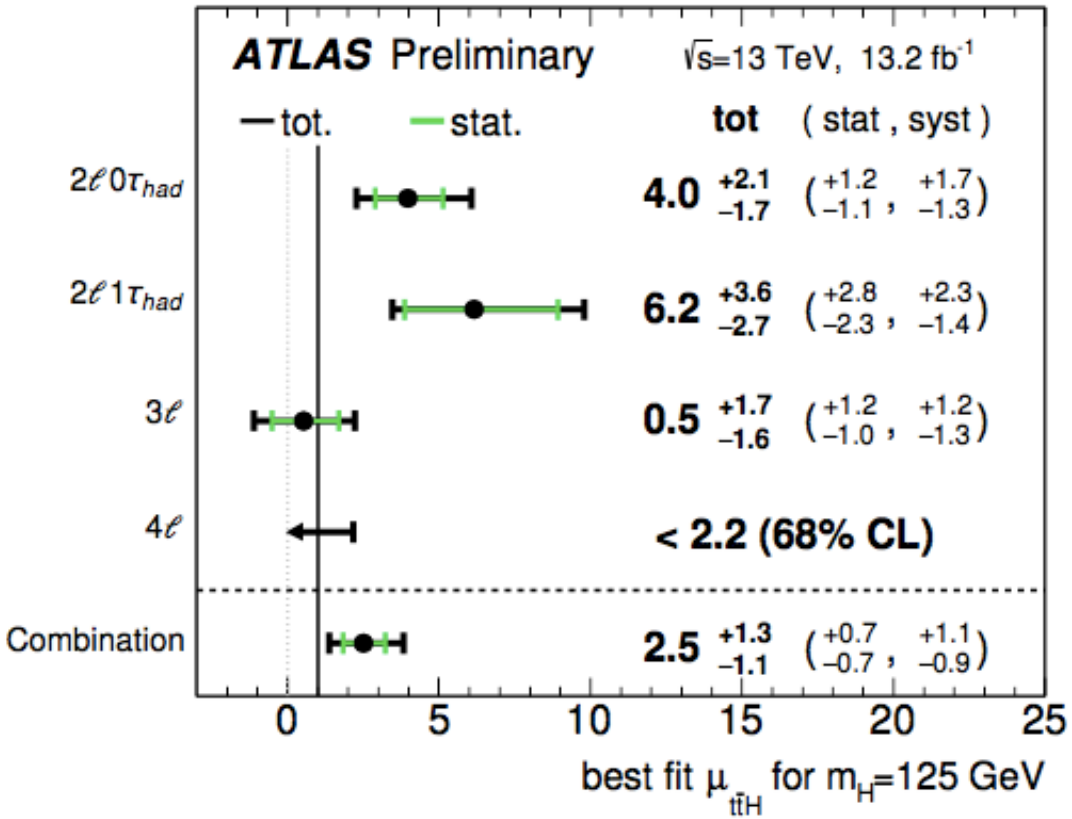


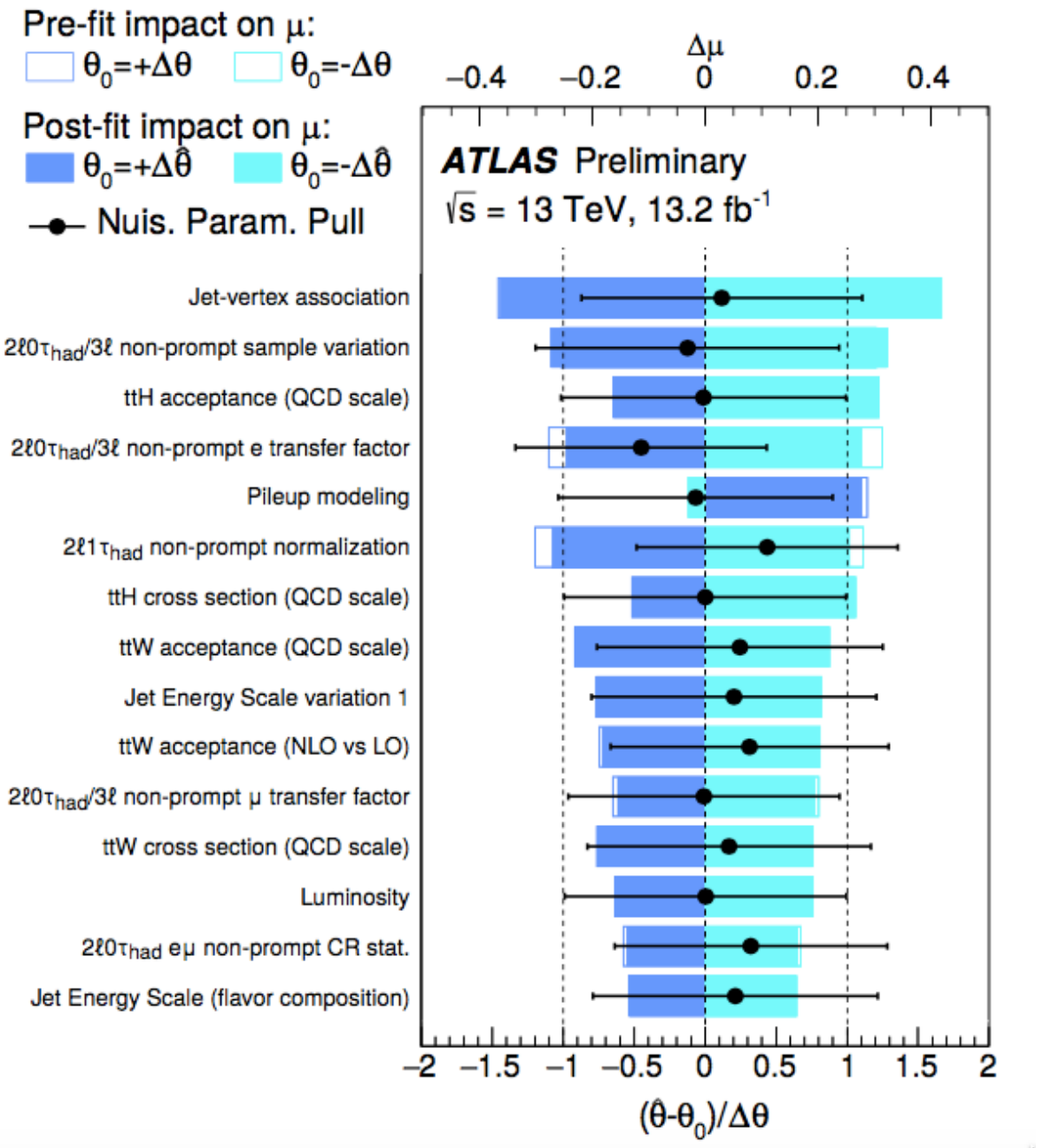


ttH (multi-leptons) analysis: Results

ATLAS-CONF-2016-058

- Systematic uncertainty is dominated by
  - non-prompt background estimates in the 2ℓ 0τ_{had}, 2ℓ 1τ_{had}, and 3ℓ channels.
  - ttV modelling , pileup modelling

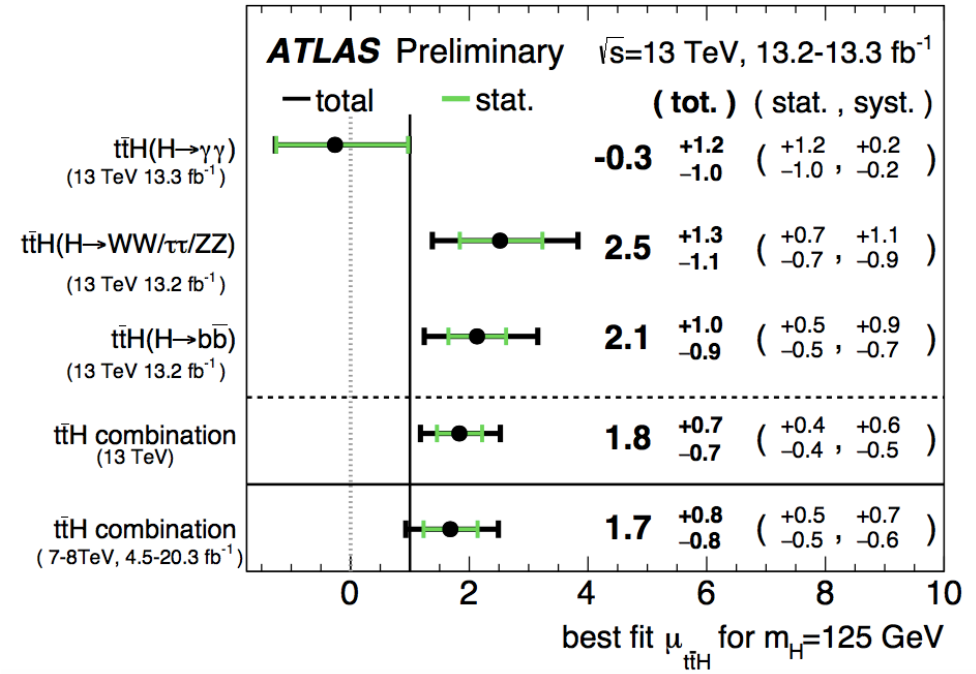




ttH analyses: combination

ATLAS-CONF-2016-068

- Summary of the ttH signal strength measurements



- Expected and observed significance

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

Summary

- The search for the Higgs decays to b-quarks in ATLAS
  - Using part of 2015-2016 data (~13fb^{-1})
  - VH(bb) : Expected (observed) significance: 1.92 (0.42)
  - VBF H(bb)γ: first ATLAS result (ever)
    Expected (observed) 95% CL limit: 6 (4) times the SM expectation

- A search for ttH production process has been performed in three channels
  - Using part of 2015-2016 data (~13fb^{-1})
  - ttH (bb), ttH (multileptons), and ttH (γγ)
  - The best fit value of the ttH signal strength is 1.8 ± 0.7.
  - Observed significance: 2.8 sigma (1.8 expected from SM).
- The results with full 2015-2016 dataset are coming soon.
- Stay Tuned!

ttH (multi-lepton) systematics

Uncertainty Source	$\Delta\mu$	
Non-prompt leptons and charge misreconstruction	+0.56	−0.64
Jet-vertex association, pileup modeling	+0.48	−0.36
$t\bar{t}W$ modeling	+0.29	−0.31
$t\bar{t}H$ modeling	+0.31	−0.15
Jet energy scale and resolution	+0.22	−0.18
$t\bar{t}Z$ modeling	+0.19	−0.19
Luminosity	+0.19	−0.15
Diboson modeling	+0.15	−0.14
Jet flavor tagging	+0.15	−0.12
Light lepton (e, μ) and τ_{had} ID, isolation, trigger	+0.12	−0.10
Other background modeling	+0.11	−0.11
Total systematic uncertainty	+1.1	−0.9