Evidence for the H→bb decay in VH production with the ATLAS Detector

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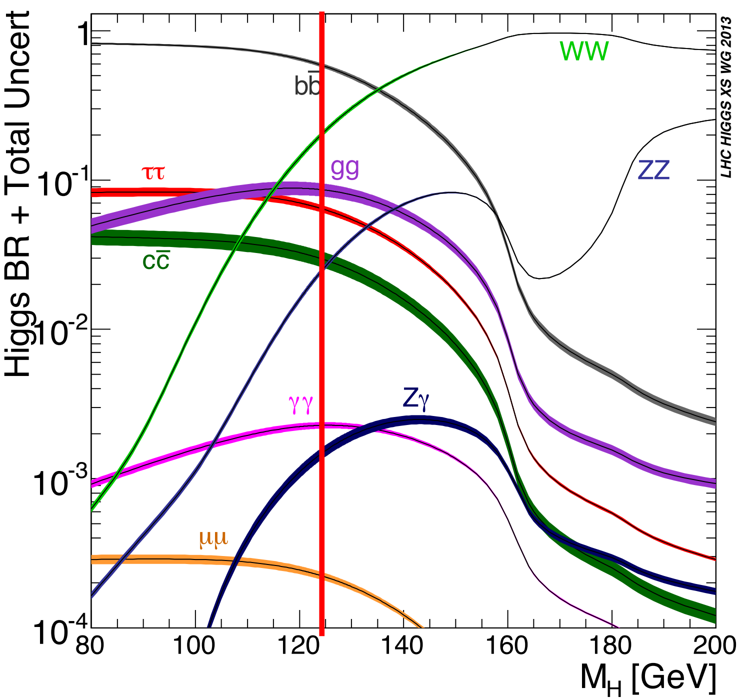
Introduction

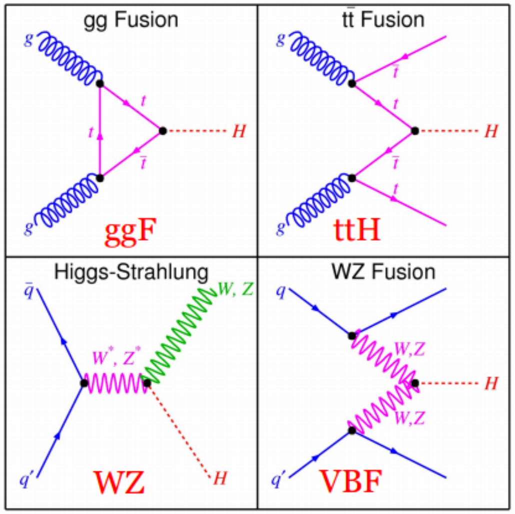
➢ **Why H→bb**

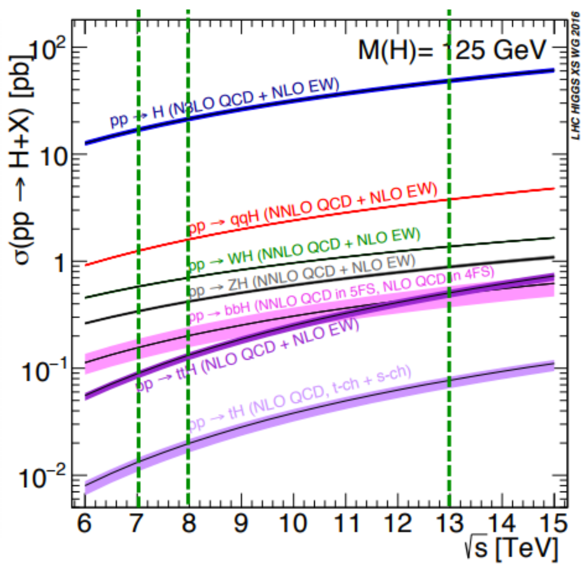
Most Higgs bosons are expected to decay to a pair of b-quarks, with the Standard Model predicting a branching fraction of about 58%. Probing this decay is important to furthering our understanding of the Higgs sector

➢ **Why VH production**

Their (W or Z boson) leptonic decay modes lead to clean signatures that can be efficiently triggered on, while rejecting most of the multi-jet backgrounds







Introduction

Previous VH, H → bb results (mH ~125 GeV)

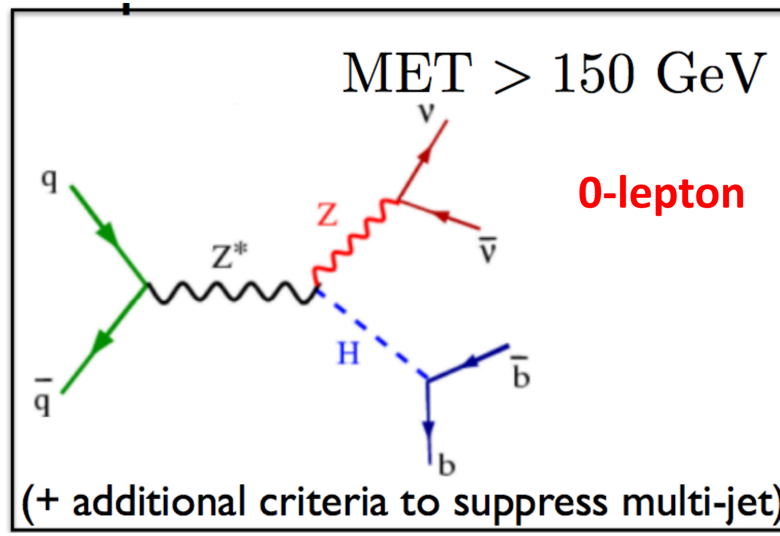
	Signal strength	Significance (expected)	Significance (observed)
CDF+DØ combination [1]	$1.9^{+0.8}_{-0.7}$	1.5σ	2.8σ (3.1σ global)
ATLAS Run-I [2]	$0.52^{+0.40}_{-0.37}$	2.6σ	1.4σ
CMS Run-I [3]	$0.89^{+0.47}_{-0.44}$	2.5σ	2.1σ
ATLAS+CMS Run-I* [4]	$0.70^{+0.29}_{-0.27}$	3.7σ	2.6σ

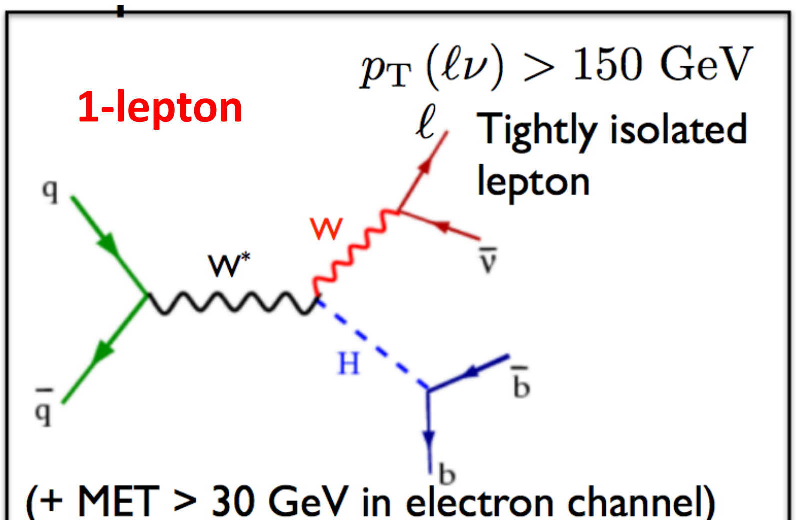
*with sub-leading contribution from ttH, H → bb

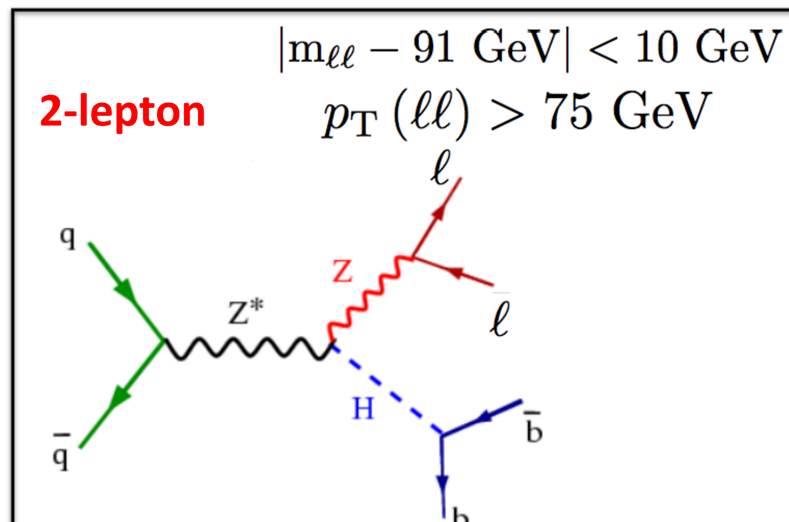
[1] Phys. Rev. Lett. **109** (2012) 071804
[2] JHEP01(2015)069
[3] Eur.Phys.J. C75(5), 212 (2015) + twiki
[4] JHEP08(2016)045

Event Selection

- Full Run-II 2015+2016 datasets (36.1 fb-1) @ 13 TeV
- Channels denoted by the number of charged leptons (e or μ)
- Trigger based on single lepton and MET
- Exactly 2 b-tagged jets with (>45, >20) GeV
- Exactly 2 or 3 jets (0,1-lepton), 2 or ≥3 jets (2-lepton)

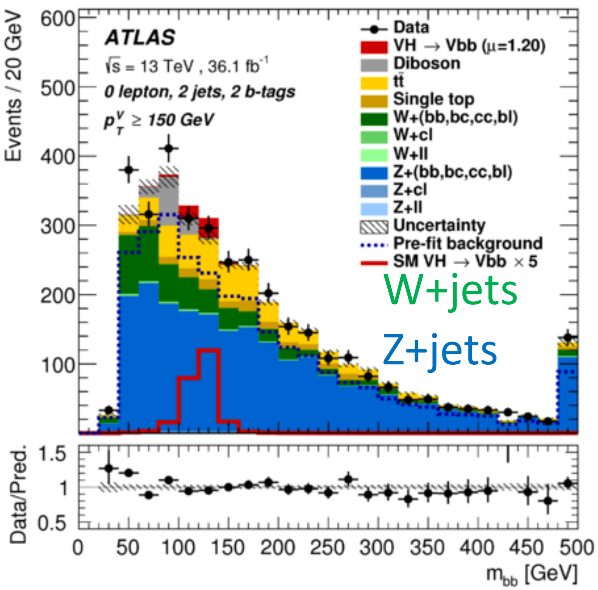




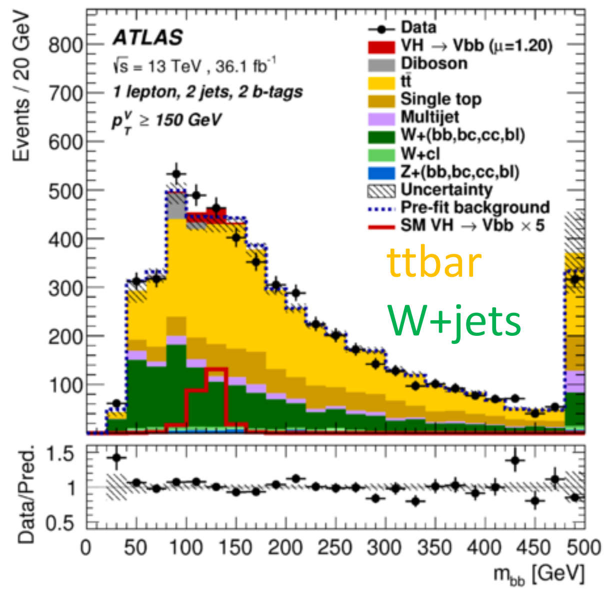


Main backgrounds

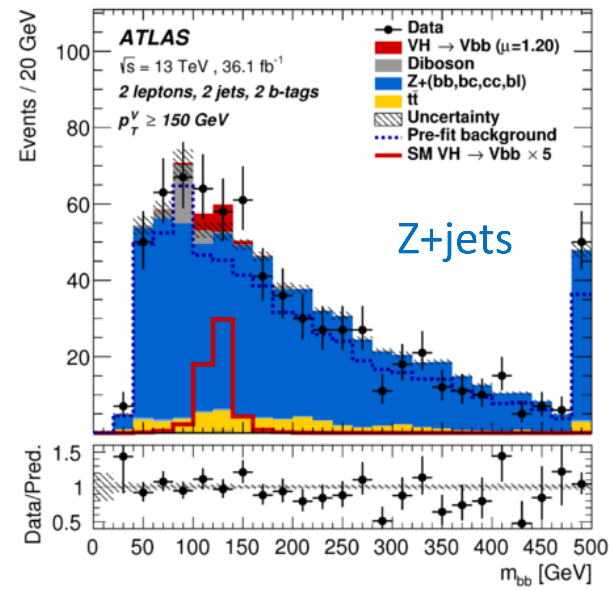
0-lepton



1-lepton

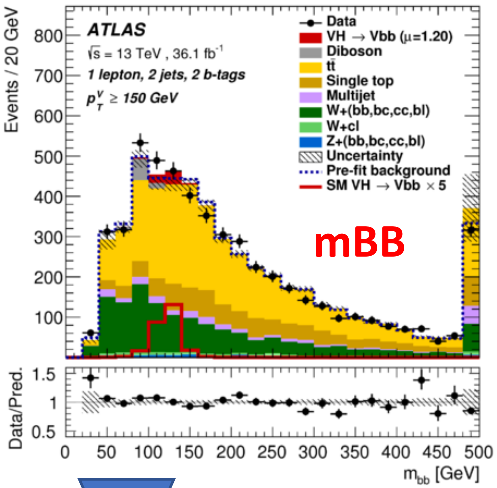


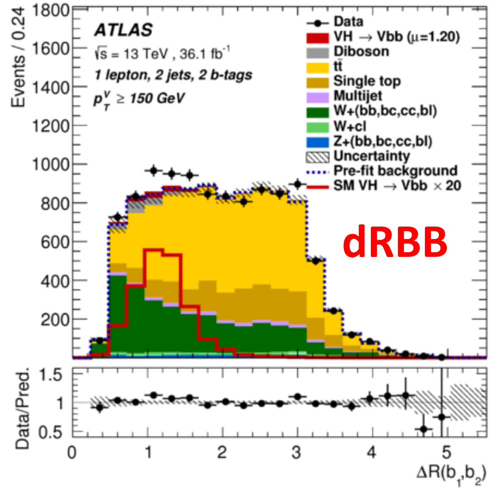
2-lepton

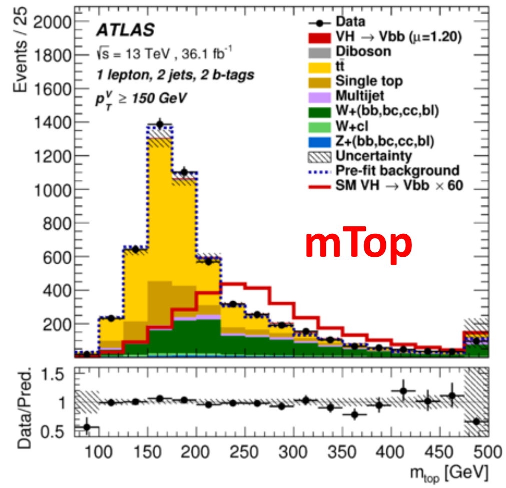


- Non-resonant backgrounds from W/Z+jets, ttbar and single-top
- Resonant VZ, Z → bb background, used to validate the analysis procedure
- Small residual multi-jet background component in 1-lepton channel (<5%)

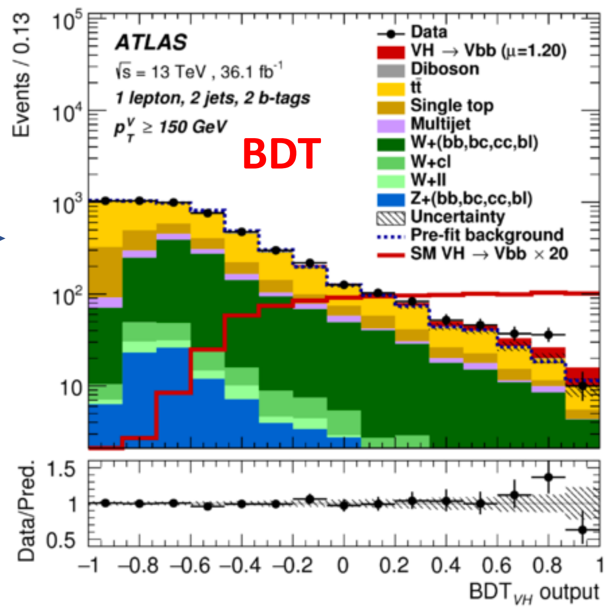
Multi Variate Analysis techniques







Variable	0-lepton	1-lepton	2-lepton
p_T^V	$\equiv E_T^{miss}$	×	×
E_T^{miss}	×	×	×
$p_T^{b_1}$	×	×	×
$p_T^{b_2}$	×	×	×
m_{bb}	×	×	×
$\Delta R(\vec{b}_1, \vec{b}_2)$	×	×	×
$\|\Delta\eta(\vec{b}_1, \vec{b}_2)\|$	×		
$\Delta\phi(\vec{V}, \vec{bb})$	×	×	×
$\|\Delta\eta(\vec{V}, \vec{bb})\|$			×
m_{eff}	×		
$\min[\Delta\phi(\vec{\ell}, \vec{b})]$		×	
m_T^W		×	
$m_{\ell\ell}$			×
m_{top}		×	
$\|\Delta Y(\vec{V}, \vec{bb})\|$		×	
	Only in 3-jet events		
$p_T^{jet_3}$	×	×	×
m_{bbj}	×	×	×

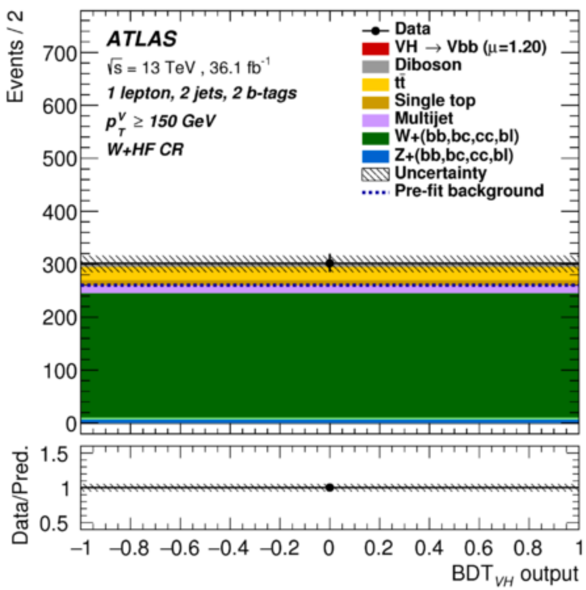


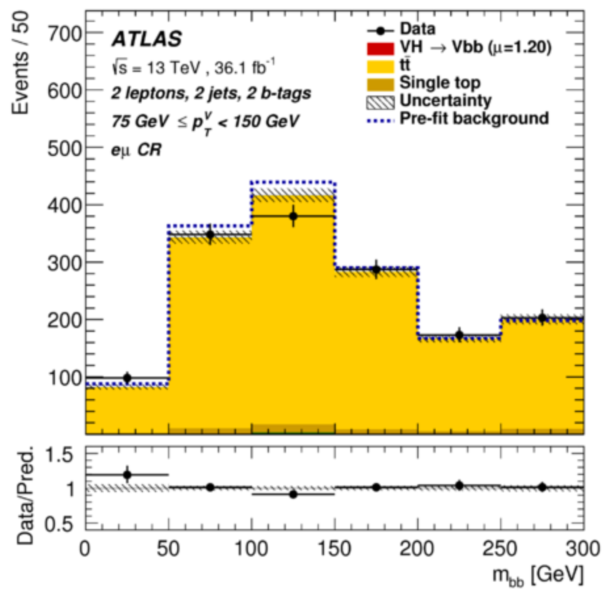
- A BDT discriminant is formed from selected variables, trained individually in each channel and category, to improve the signal to background separation

Control Regions

➢ Dedicated control regions (CRs) are defined to better isolate specific background processes:

Control Region	W+HF	ttbar
Channel	1-lepton	2-lepton
Selections	Mbb < 75GeV and Mtop > 225GeV	Samples as signal region, but require e+μ final state
Analysis Regions	2-/3- jets	2-/>=3 jets
Purity	~75%-80%	>99%
Fit observable	Yield only	mBB





- mbb distribution in CR used to constrain systematics on mbb shape

Signal and background model

- State-of-the-art Monte Carlo generators used for the description of all signals and backgrounds (except for multi-jet that is data-driven)

Process	ME generator	ME PDF	PS and Hadronisation	UE model tune	Cross-section order	ace2.5cm
Signal						
$qq \to WH$ $\to \ell\nu b\bar{b}$	Powheg-Box v2 [19] + GoSam [22] + MiNLO [23,24]	NNPDF3.0NLO$^{(\star)}$ [20]	Pythia8.212 [13]	AZNLO [21]	NNLO(QCD)+ NLO(EW) [25,26,27,28,29,30,31]	
$qq \to ZH$ $\to \nu\nu b\bar{b}/\ell\ell b\bar{b}$	Powheg-Box v2 + GoSam + MiNLO	NNPDF3.0NLO$^{(\star)}$	Pythia8.212	AZNLO	NNLO(QCD)$^{(\dagger)}$+ NLO(EW)	
$gg \to ZH$ $\to \nu\nu b\bar{b}/\ell\ell b\bar{b}$	Powheg-Box v2	NNPDF3.0NLO$^{(\star)}$	Pythia8.212	AZNLO	NLO+ NLL [32,33,34,35,36]	
Top quark						
$t\bar{t}$	Powheg-Box v2 [37]	NNPDF3.0NLO	Pythia8.212	A14 [38]	NNLO+NNLL [39]	
s-channel	Powheg-Box v1 [40]	CT10 [41]	Pythia6.428 [42]	P2012 [43]	NLO [44]	
t-channel	Powheg-Box v1 [40]	CT10f4	Pythia6.428	P2012	NLO [45]	
Wt	Powheg-Box v1 [46]	CT10	Pythia6.428	P2012	NLO [47]	
Vector boson + jets						
$W \to \ell\nu$	Sherpa 2.2.1 [16,48,49]	NNPDF3.0NNLO	Sherpa 2.2.1 [50,51]	Default	NNLO [52]	
$Z/\gamma^* \to \ell\ell$	Sherpa 2.2.1	NNPDF3.0NNLO	Sherpa 2.2.1	Default	NNLO	
$Z \to \nu\nu$	Sherpa 2.2.1	NNPDF3.0NNLO	Sherpa 2.2.1	Default	NNLO	
Diboson						
WW	Sherpa 2.1.1	CT10	Sherpa 2.1.1	Default	NLO	
WZ	Sherpa 2.2.1	NNPDF3.0NNLO	Sherpa 2.2.1	Default	NLO	
ZZ	Sherpa 2.2.1	NNPDF3.0NNLO	Sherpa 2.2.1	Default	NLO	

- Nominal samples are generated with PowHeg-Box for signals and top backgrounds, and with Sherpa for V+jets and diboson.

Signal and background model

Signal

Signal	
Cross-section (scale)	0.7% (qq), 27% (gg)
Cross-section (PDF)	1.9% ($qq \to WH$), 1.6% ($qq \to ZH$), 5% (gg)
Branching ratio	1.7 %
Acceptance from scale variations (var.)	2.5 – 8.8% (Stewart–Tackmann jet binning method)
Acceptance from PS/UE var. for 2 or more jets	10 – 14% (depending on lepton channel)
Acceptance from PS/UE var. for 3 jets	13%
Acceptance from PDF+α_S var.	0.5 – 1.3%
m_{bb}, p_T^V, from scale var.	S
m_{bb}, p_T^V, from PS/UE var.	S
m_{bb}, p_T^V, from PDF+α_S var.	S
p_T^V from NLO EW correction	S

- Extrapolation uncertainties across regions parametrized in terms of uncertainties on ratio of yields
- Shape deformations on BDT output are factorized into independent shape deformations of the two most discriminant input variables: mbb and pT(V).
- Both yield ratios and shape uncertainties for each process are derived either based on detailed MC studies, or on data to Monte Carlo comparisons in control regions

Backgrounds

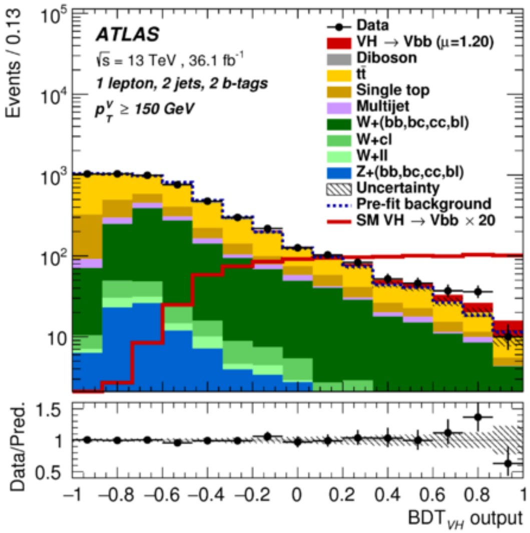
Z + jets	
$Z + ll$ normalisation	18%
$Z + cl$ normalisation	23%
$Z + bb$ normalisation	Floating (2-jet, 3-jet)
$Z + bc$-to-$Z + bb$ ratio	30 – 40%
$Z + cc$-to-$Z + bb$ ratio	13 – 15%
$Z + bl$-to-$Z + bb$ ratio	20 – 25%
0-to-2 lepton ratio	7%
m_{bb}, p_T^V	S
W + jets	
$W + ll$ normalisation	32%
$W + cl$ normalisation	37%
$W + bb$ normalisation	Floating (2-jet, 3-jet)
$W + bl$-to-$W + bb$ ratio	26% (0-lepton) and 23% (1-lepton)
$W + bc$-to-$W + bb$ ratio	15% (0-lepton) and 30% (1-lepton)
$W + cc$-to-$W + bb$ ratio	10% (0-lepton) and 30% (1-lepton)
0-to-1 lepton ratio	5%
W + HF CR to SR ratio	10% (1-lepton)
m_{bb}, p_T^V	S
$t\bar{t}$ (all are uncorrelated between the 0+1 and 2-lepton channels)	
$t\bar{t}$ normalisation	Floating (0+1 lepton, 2-lepton 2-jet, 2-lepton 3-jet)
0-to-1 lepton ratio	8%
2-to-3-jet ratio	9% (0+1 lepton only)
W + HF CR to SR ratio	25%
m_{bb}, p_T^V	S
Single top quark	
Cross-section	4.6% (s-channel), 4.4% (t-channel), 6.2% (Wt)
Acceptance 2-jet	17% (t-channel), 35% (Wt)
Acceptance 3-jet	20% (t-channel), 41% (Wt)
m_{bb}, p_T^V	S (t-channel, Wt)
Multi-jet (1-lepton)	
Normalisation	60 – 100% (2-jet), 100 – 400% (3-jet)
BDT template	S

Main analysis strategy

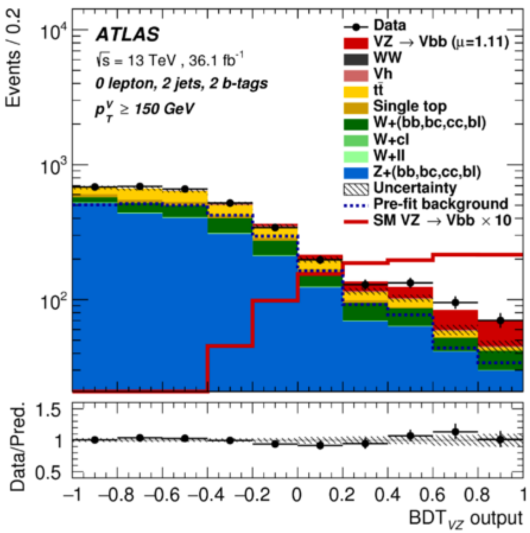
- A likelihood fit is applied across channels and multiple analysis regions to extract the signal significance / signal strength

- A nominal analysis (main observable: BDTVH output), two validation analyses (main observable: BDTVZ output and mbb).

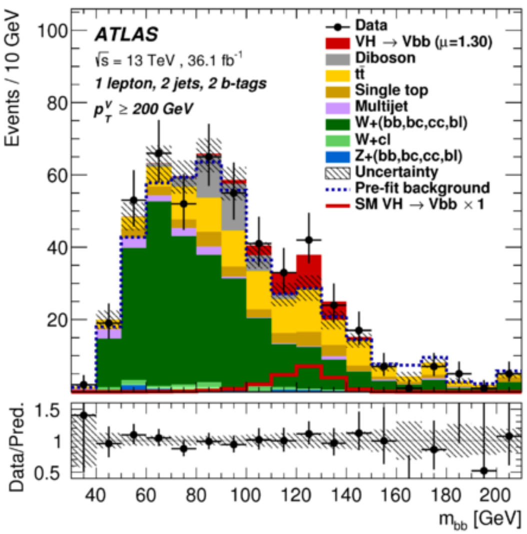
BDT_VH



BDT_VZ

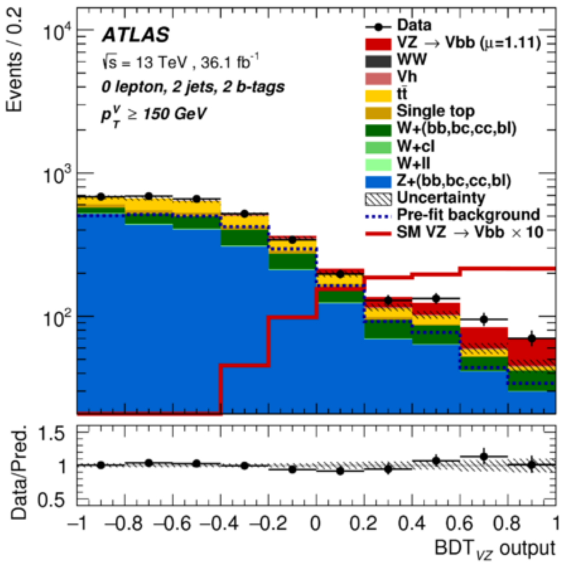


mBB

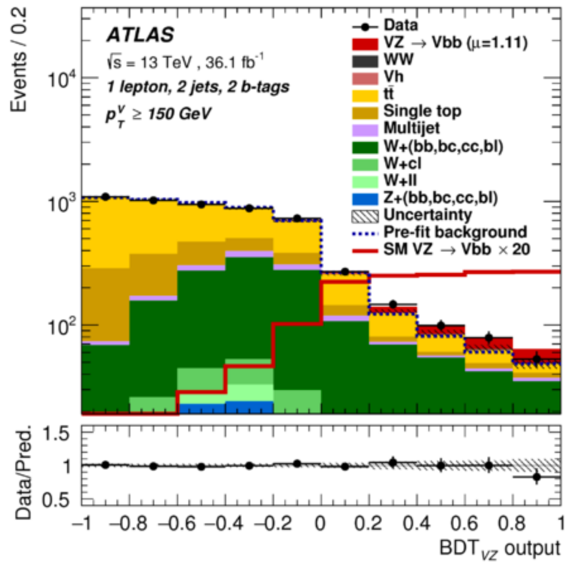


Results : Fit of VZ, Z → bb signal

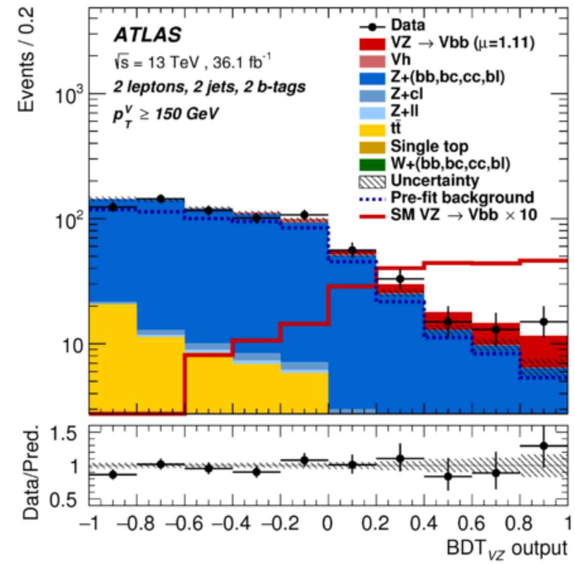
0-lepton

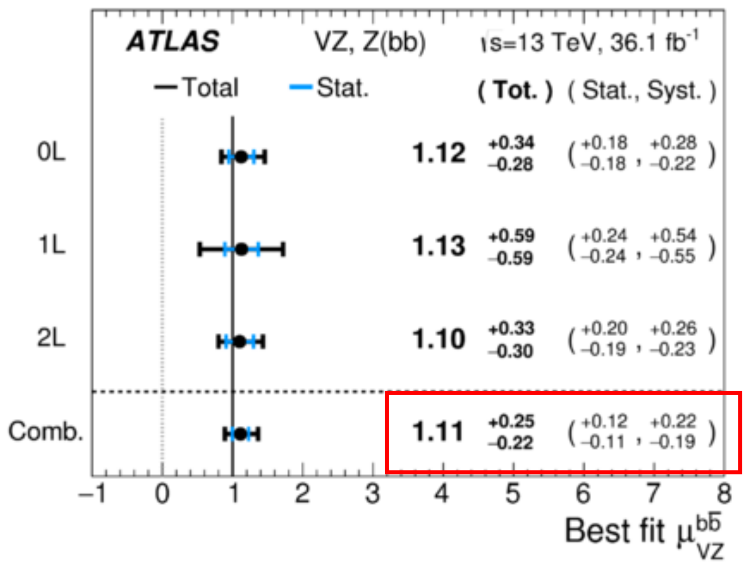


1-lepton



2-lepton



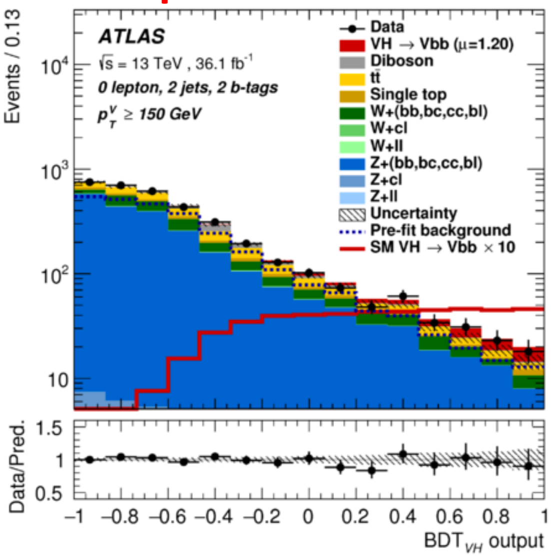


Significance :
5.8σ observed
5.3σ expected

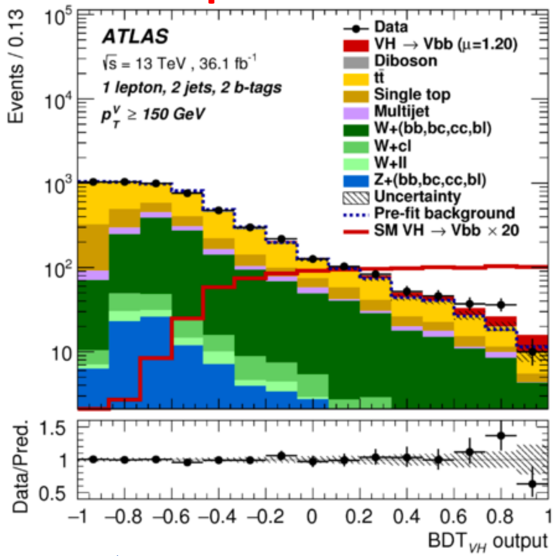
- Compatible with SM expectation within 1σ
- Validates BDT analysis

Results : Fit of VH, H → bb signal

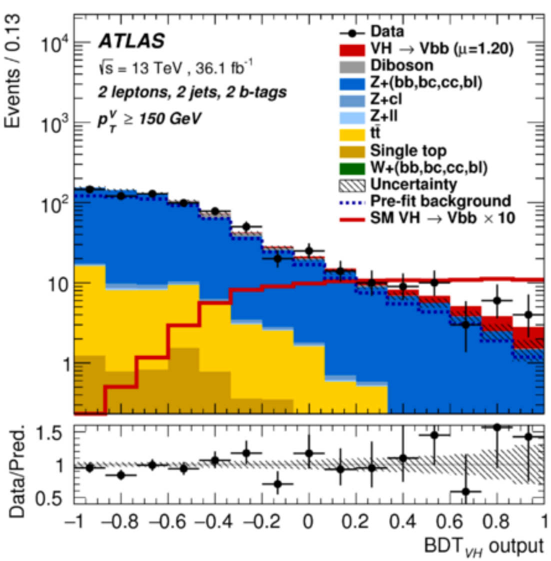
0-lepton



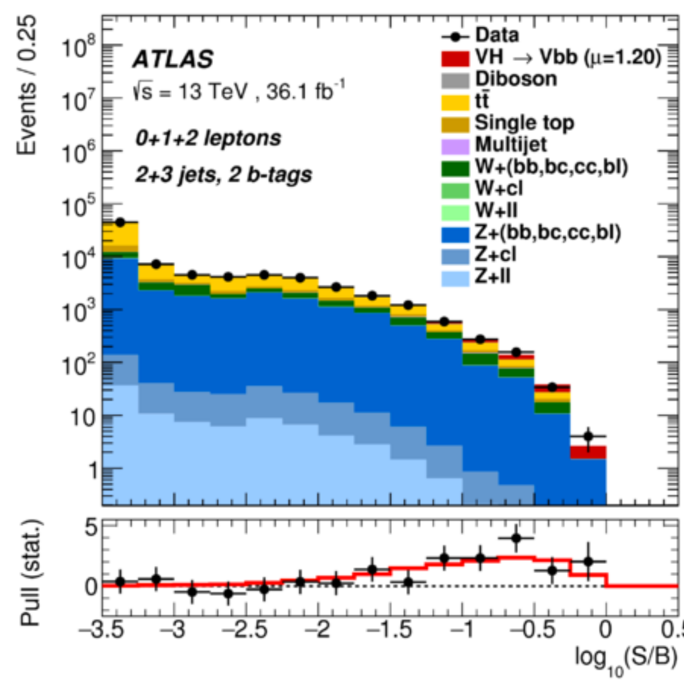
1-lepton



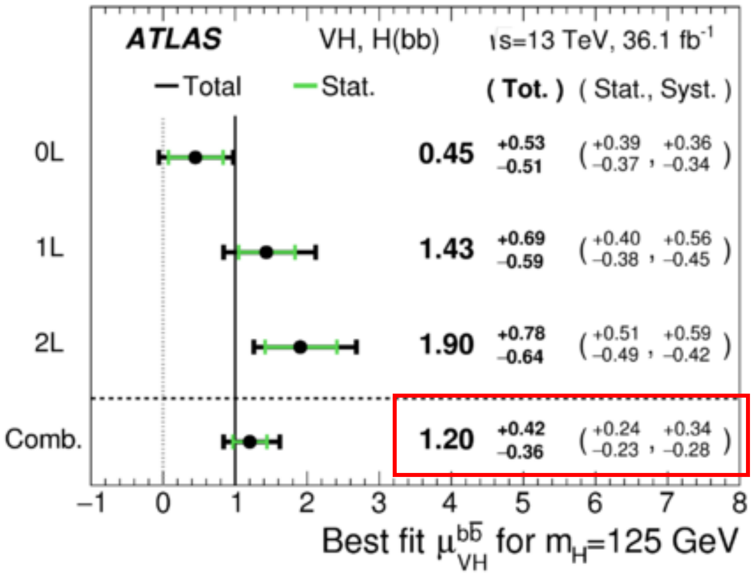
2-lepton

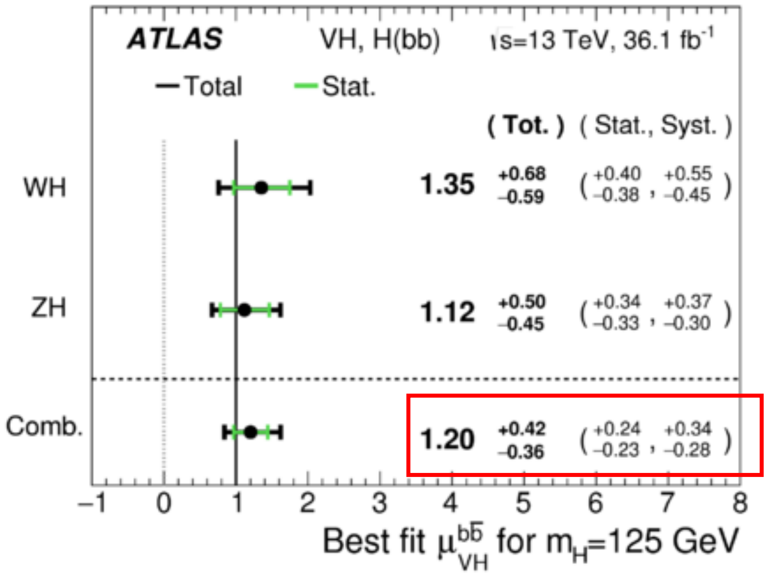


141 BDT bins in 14 regions



Results : Fit of VH, H → bb signal





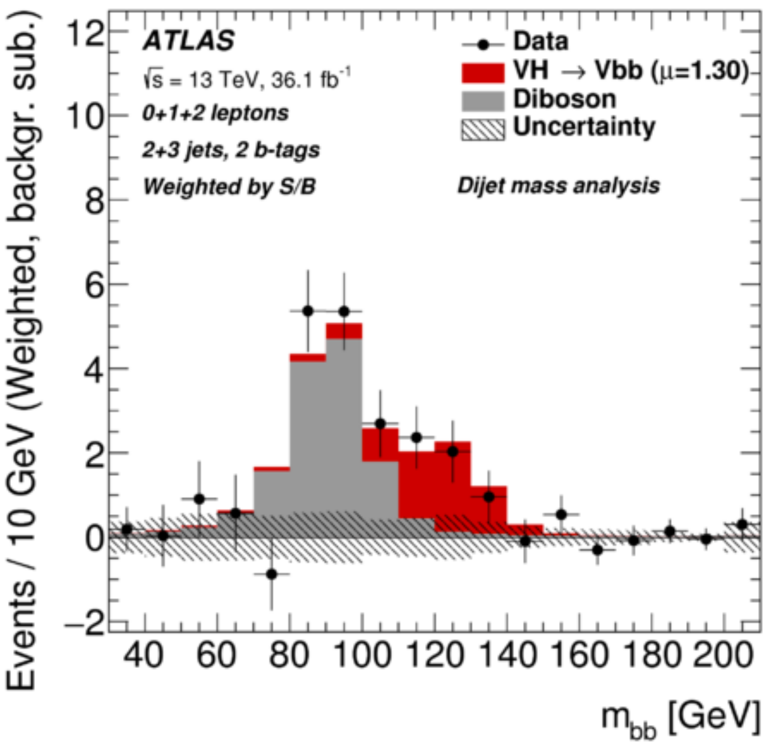
Significance :
3.5σ observed
3.0σ expected

- 3.5σ evidence for VH, H → bb!
- Compatible with SM expectation within 1σ

Results : Fit of VH, H → bb signal (mBB analysis)

Channel			
Selection	0-lepton	1-lepton	2-lepton
m_T^W	-	< 120 GeV	-
$E_T^{miss}/\sqrt{S_T}$	-	-	$< 3.5\sqrt{\text{GeV}}$

p_T^V regions			
p_T^V	(75, 150] GeV (2-lepton only)	(150, 200] GeV	(200, ∞) GeV
$\Delta R(\vec{b}_1, \vec{b}_2)$	<3.0	<1.8	<1.2



- A tighter selection is applied in the mbb analysis, on top of the selection of the MVA analysis
- To fully exploit the "high pT" regime :

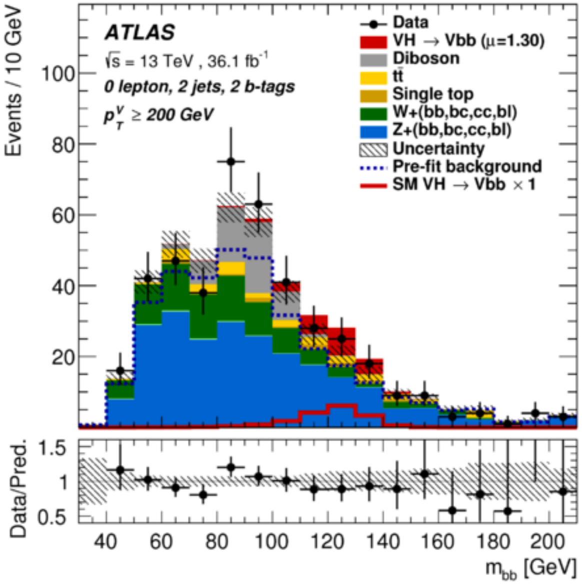
  An additional category for events with pT(V) > 200 GeV

  Topological requirements that require smaller ΔR(b1,b2) for increasing pT(V)

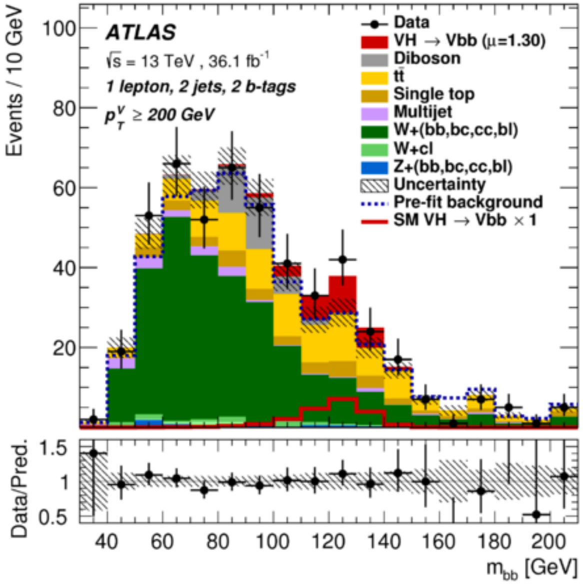
- After fit to data, m(bb) distributions from different regions are summed up, weighted by S/B of each region
- All backgrounds are subtracted except for VZ, Z → bb and VH, H → bb
- A shoulder emerges in data on the right of the Z → bb peak

Results : Fit of VH, H → bb signal (mBB analysis)

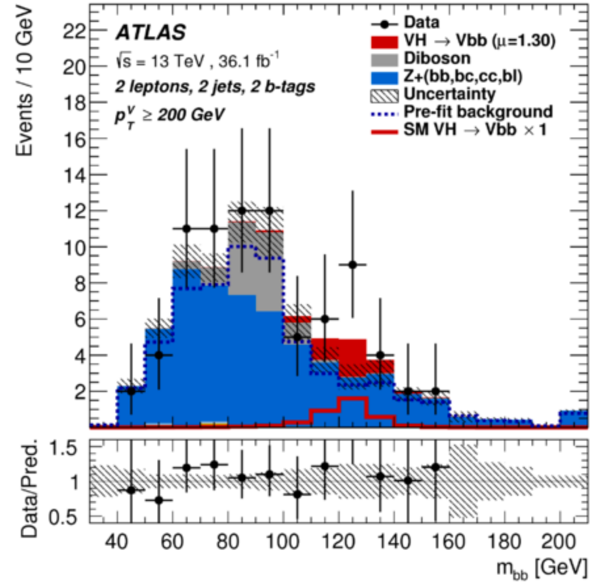
0-lepton



1-lepton



2-lepton



- A fit to the mbb observable is applied in 18 analysis regions (283 bins)

Higgs boson signal strength:

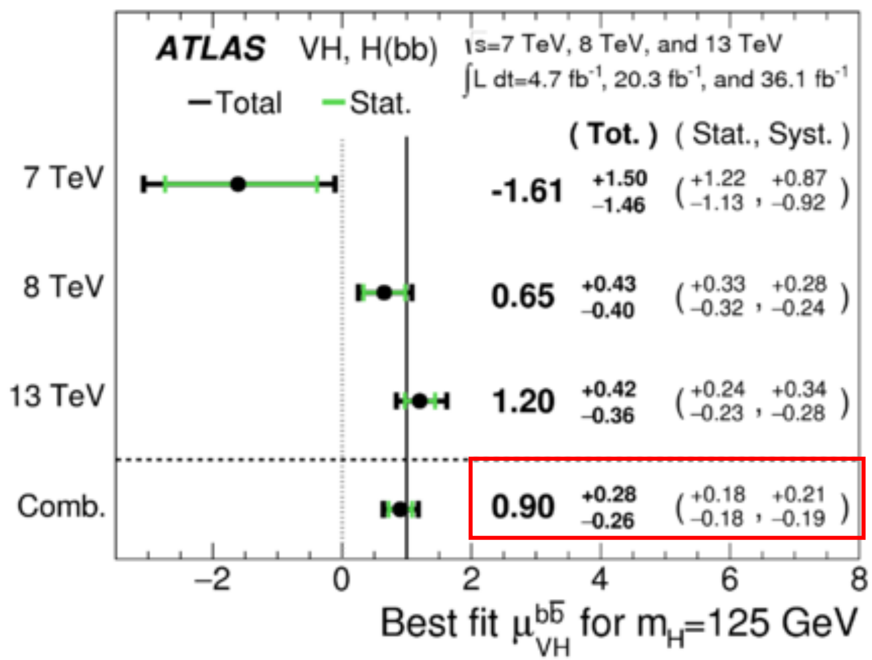
$$\mu = 1.30^{+0.28}_{-0.27}(\text{stat.})^{+0.37}_{-0.29}(\text{syst.}),$$

Significance :
3.5σ observed
2.8σ expected

- Important validation of BDT analysis

Results : Run-1 + Run-2 Combination

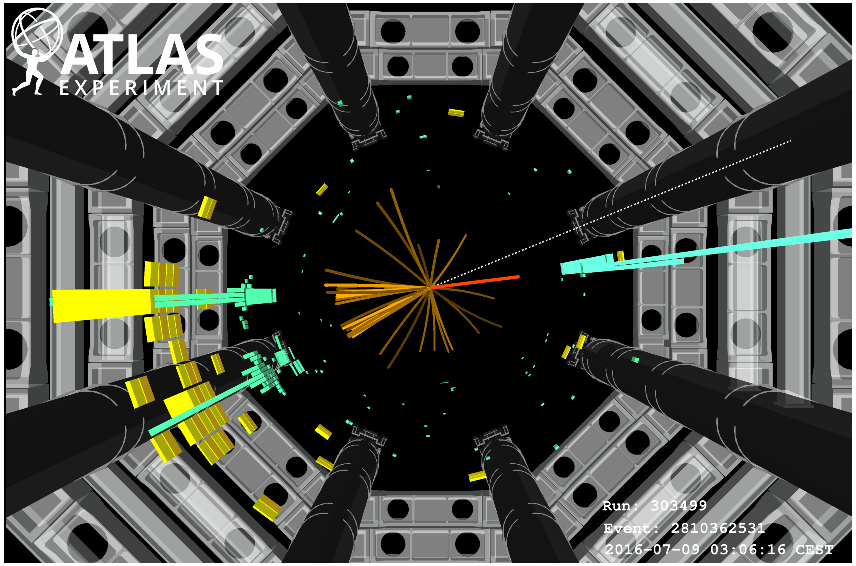
- The Run-2 BDT VH, H → bb analysis is combined with the corresponding Run-1 analysis.
- Signal uncertainties and b-jet energy scale uncertainties are correlated across years. The impact of correlations in other uncertainties was cross-checked and found to be negligible

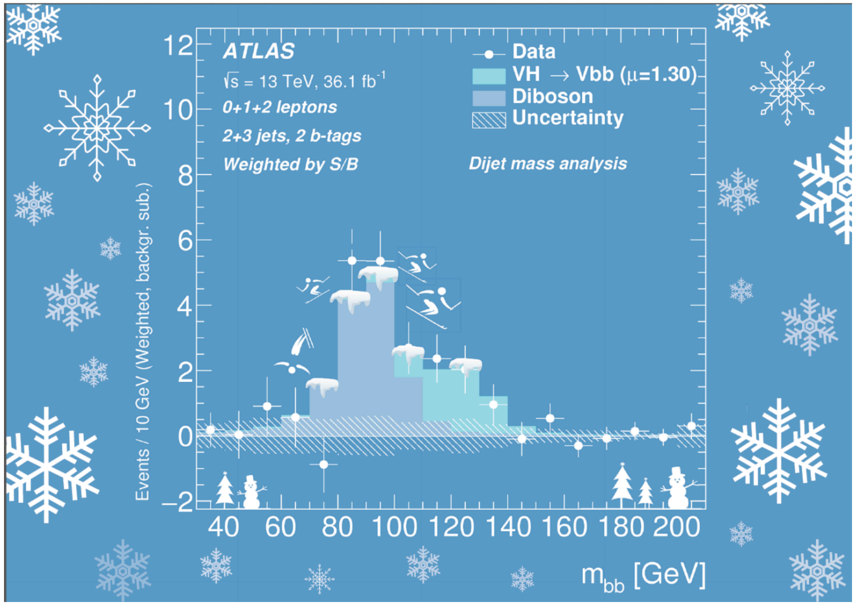


Significance :
3.6σ observed
4.0σ expected

- Compatible with SM expectation within 1σ

Conclusions





- 3.6σ evidence (4.0σ expected) has been presented for Higgs boson decays to b-quarks and for its production in association with a vector boson
- Important milestone on the way to observation
- The results agrees with the SM prediction, with an uncertainty of ~30%
- With the additional data being and to be collected in Run II, observation and more precise measurements are in sight

Back Up

Analysis Strategy : Event Selection

- Using lowest un-prescaled triggers :

- Met trigger for 0 lepton and one muon channel (1 lep). Single electron trigger for one (1 lep) and two (2 lep) electron channel. Single muon trigger for two muon channel (2 lep)

- Select a W / Z: MET, ℓ+MET, ℓℓ

- Remove QCD MJ: topological cuts ; dedicated lepton isolation

- Events with 2 jets or 3 (>=3) jets for 0 and 1 lepton (2 lepton) channel

- Require exactly 2 b-tagged jets: MV2c10 @ 70% eff

Common Selections	
Jets	≥ 2 central jets
b-jets	2 b-tagged signal jets
Leading jet p_T	> 45 GeV
$\lvert\Delta R(\text{jet1,jet2})\rvert$ (cut-based only)	≤ 1.8 (p_T^V < 200 GeV), ≤ 1.2 (p_T^V > 200 GeV)
0 Lepton	
Trigger	`HLT_xe70`, `xe90_mht`, and `xe110_mht`
Leptons	0 VH-loose lepton
E_T^{miss}	> 150 GeV
S_T	> 120 (2 jets), >150 GeV (3 jets)
$\lvert\min\Delta\phi(E_T^{miss}, \text{jet})\rvert$	> 20° (2jet) , > 30°(3jet)
$\lvert\Delta\phi(E_T^{miss}, h)\rvert$	> 120°
$\lvert\Delta\phi(\text{jet1,jet2})\rvert$	< 140°
$\lvert\Delta\phi(E_T^{miss}, E_{T,trk}^{miss})\rvert$	< 90°
p_T^V regions (BDT)	> 150 GeV
p_T^V regions (cut-based)	[150, 200] GeV, [200, ∞] GeV
1 Lepton	
Trigger	*e* channel: un-prescaled single electron Tables 5 and 6 of Ref. [15] *μ* channel: see 0-lepton triggers
Leptons	1 WH-signal lepton > 1 VH-loose lepton veto
E_T^{miss}	> 30 GeV (*e* channel)
m_{top}	< 225 GeV or m_{bb} > 75 GeV
m_T^W (cut-based only)	< 120 GeV
p_T^V regions (BDT)	> 150 GeV
p_T^V regions (cut-based)	[150, 200] GeV, [200, ∞] GeV
2 Lepton	
Trigger	un-prescaled single lepton Tables 5 and 6 of Ref. [15]
Leptons	2 VH-loose leptons (≥ 1 ZH-signal lepton) Same flavor, opposite-charge for *μμ*
$m_{\ell\ell}$	81 < $m_{\ell\ell}$ < 101 GeV
E_T^{miss} significance (cut-based)	$E_T^{miss}/\sqrt{HT} < 3.5\sqrt{GeV}$
p_T^V regions (BDT)	[75, 150], [150, ∞] GeV
p_T^V regions (cut-based)	[75,150], [150, 200], [200, ∞] GeV

Table 8: Summary of the signal event selection in the 0-, 1- and 2-lepton analyses.

Analysis Strategy : BDT Discriminant

- A BDT discriminant is formed from selected variables, trained individually in each channel and category, to improve the signal to background separation

- Perform a binned maximum likelihood fit simultaneously in SR(CR) categories to extract signal significance / signal strength

Variable	Name	0-lepton	1-lepton	2-lepton
p_T^V	pTV		✓	✓
E_T^{miss}	MET	✓	✓	✓
p_T^{jet1}	pTB1	✓	✓	✓
p_T^{jet2}	pTB2	✓	✓	✓
m_{jj}	mBB	✓	✓	✓
$\Delta R(jet_1, jet_2)$	dRBB	✓	✓	✓
$\|\Delta\eta(jet_1, jet_2)\|$	dEtaBB	✓		
$\Delta\phi(V, H)$	dPhiVBB	✓	✓	✓
$\Delta\eta(V, H)$	dEtaVBB			✓
$M_{eff}(M_{eff3})$	HT	✓		
$\min(\Delta\phi(\ell, jet))$	dPhiLBmin		✓	
m_T^W	mTW		✓	
m_{ll}	mLL			✓
$\Delta Y(W, H)$	dYWH		✓	
m_{top}	mTop		✓	
	Only in 3 Jet Events			
p_T^{jet3}	pTJ3	✓	✓	✓
m_{jjj}	mBBJ	✓	✓	✓

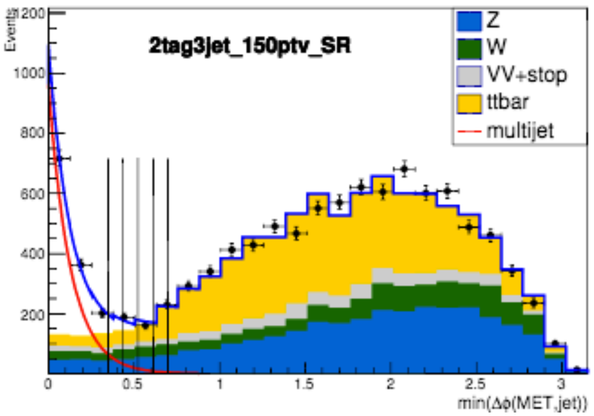
- Updated MVA training with increased statistical sensitivity for all three channels

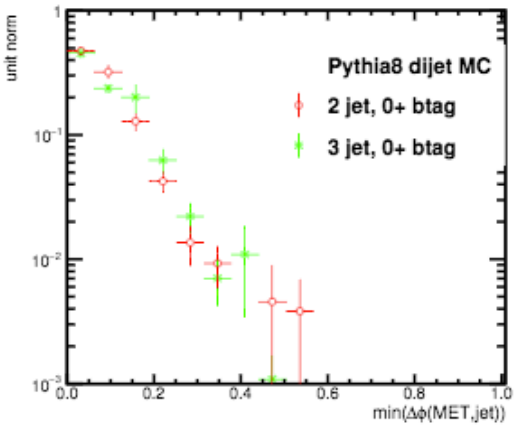
- Transformation (rebinning) of the BDT outputs with finer bins in the signal rich regions and at the same time sufficient background statistics in each bin

- Adding DY(W,H) and Mtop in 1 lepton channel in Run 2 analysis

Multijet in 0 lepton Channel

- Multi-jet yield estimated from min(deltaPhi(MET,jets)) distribution by fitting the low side to an exponential function
- Only possible in 3-jet category as QCD totally negligible in 2-jets after standard anti-QCD cuts





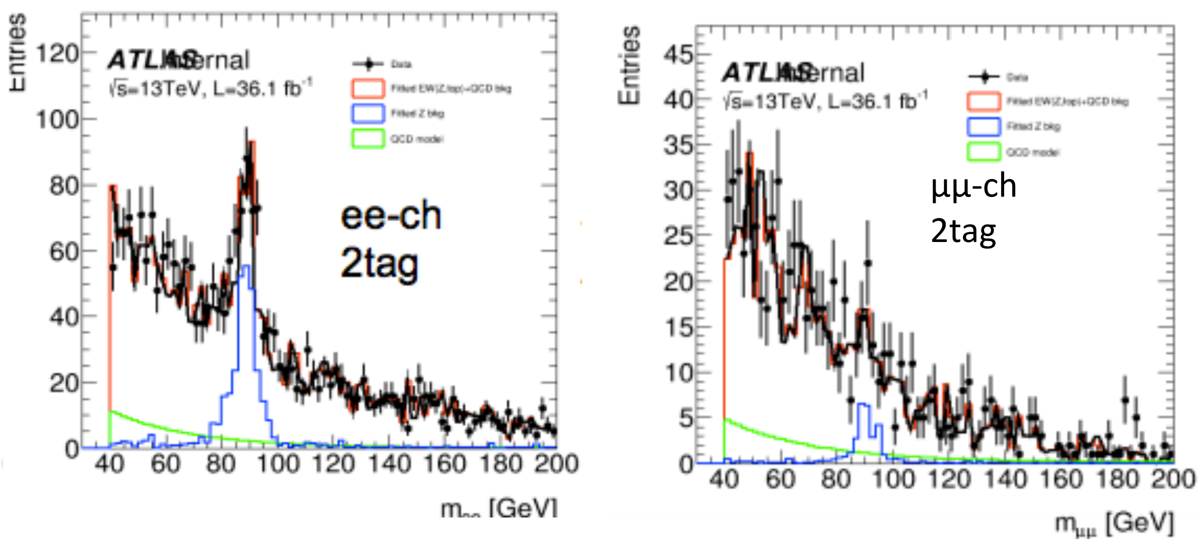
Cut	VH	Multijet	Multijet/VH	Multijet/VH 80 GeV< m(bb) < 160 GeV
20 deg	56.40	65.44	1.16	0.44
25 deg	55.26	33.23	0.60	0.23
30 deg	54.12	16.87	0.31	0.12
35 deg	52.94	8.57	0.16	0.06
40 deg	51.89	4.35	0.08	0.03

- Raised the cut from min(deltaPhi(MET,jets) >20deg to >30deg
- Remaining multi-jet is negligible (<1% of the total background, <10% of the signal), MJ has same shape as floating backgrounds

Multijet in 2 lepton Channel

- For ICHEP demonstrated that MJ was negligible – re-check this assumption with full dataset
- Template Method
  - Extract mult-jet template from same sign events (multi-jet model : simple exponential function)
  - Assuming m(ll) yield/shape of SS (same sign) is equal to OS (opposite sign)
  - Estimate multi-jet contamination in OS signal region

SS distribution



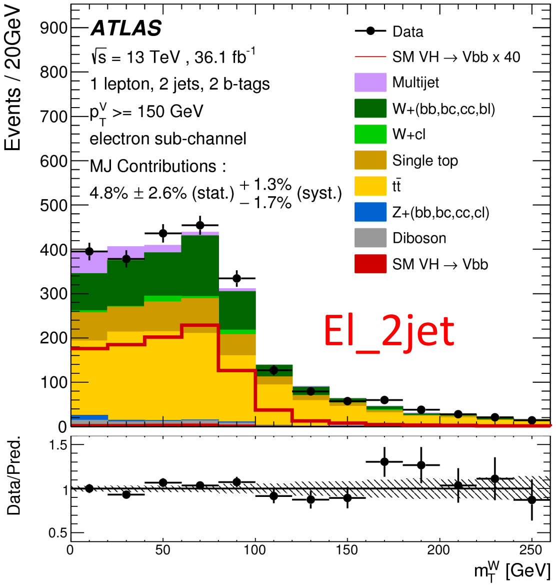
- Remaining multi-jet is negligible (<0.2% of the total background, <10% of the signal)

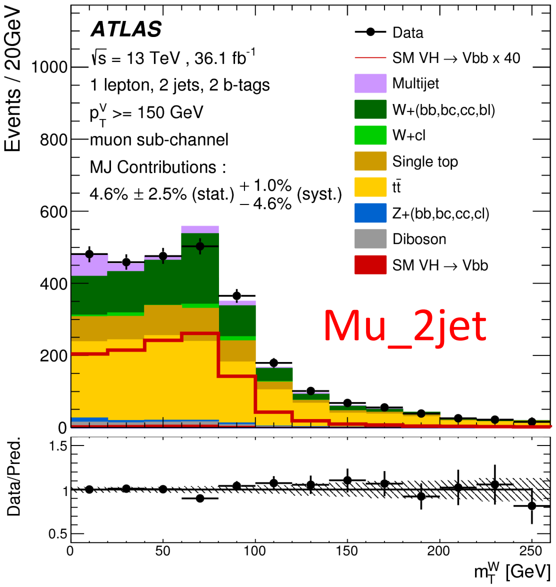
- MJ has same shape as floating backgrounds

1 lepton channel MJ estimation

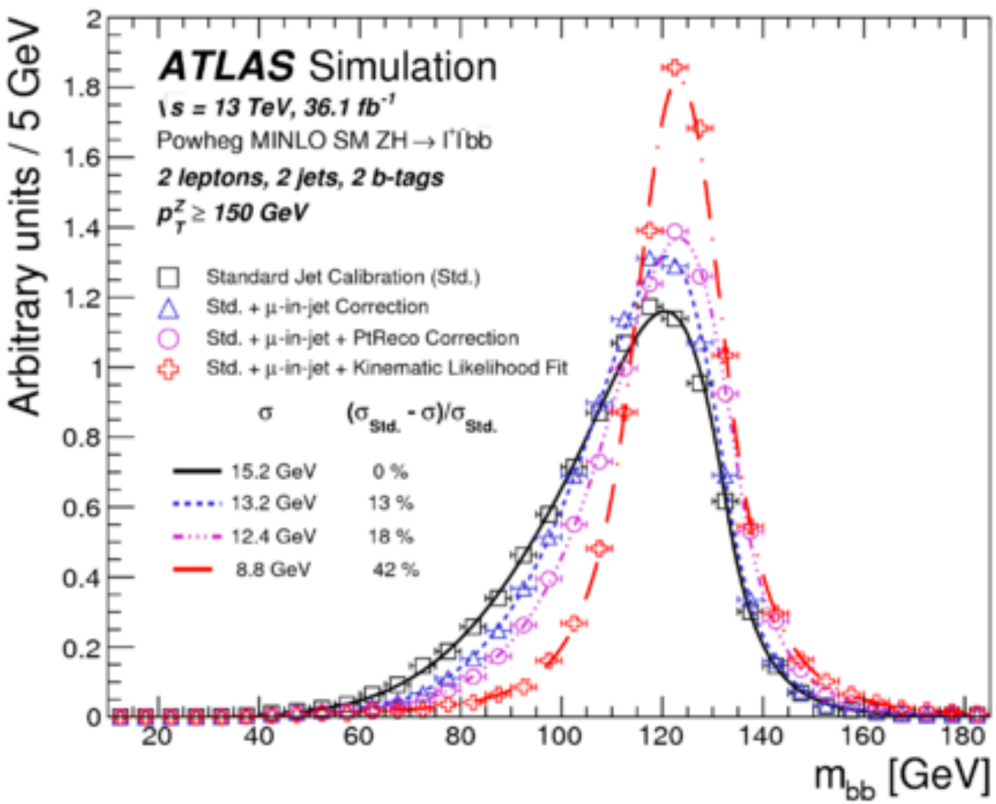
- **Dedicated isolation WPs to further reduce MJ background**
  - Topoetcone20 <3.5GeV for electron channel;
  - Ptcone20<1.25GeV for muon channel
- **Use inverted isolation region in 1 tag region to estimate MJ shape**
- **Use fit to mTW in 2-tag signal region to extract MJ normalization**
  - The template for the EW contribution in the signal region is obtained directly from MC predictions
  - The variable mTW is chosen as it offers the clearest discrimination between the multi-jet and EW processes
- **Main assumption: shape in inverted region accurately depicts that in SR**
  - 1tag Vs. 2tag; inverted isolation requirements
- **Systematics to cover this assumption**
- **Estimated separately in the electron and muon sub-channels, and in the 2- and 3-jet categories, using similar procedures**

	MJ contamination (2-jet)	MJ contamination (3-jet)
e-channel	4.8%	0.3%
mu-channel	4.6%	0.5%



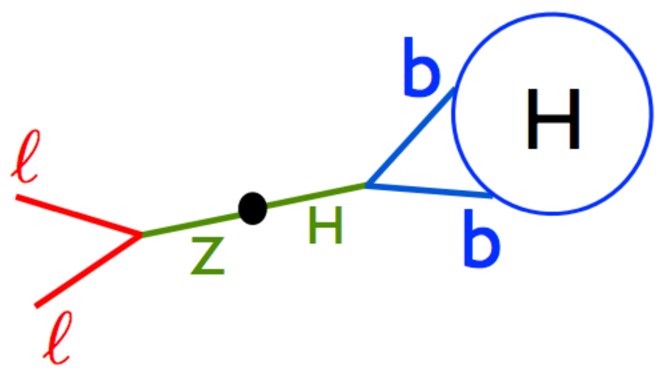


mBB resolution



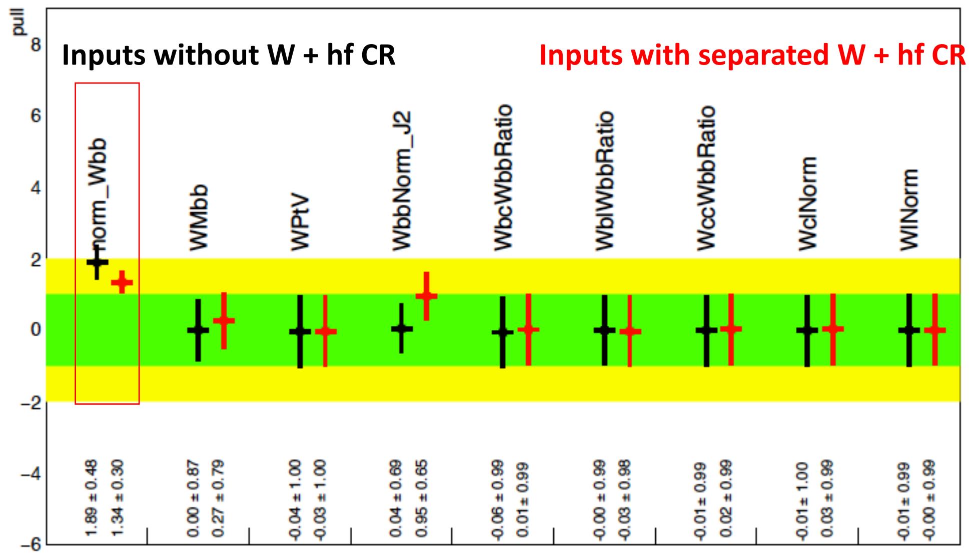
- muon-in-jet correction: if available, add muon to jet momentum (+13%)
- For 2-lepton channel (≤3 jets), use full kinematic likelihood fit, exploiting constraint:

$$\vec{p}_{T,b\bar{b}} = \sum_{\ell} \vec{p}_{T,\ell}$$

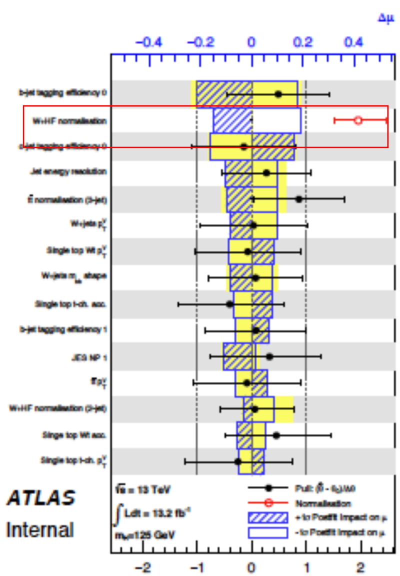


(+20%)

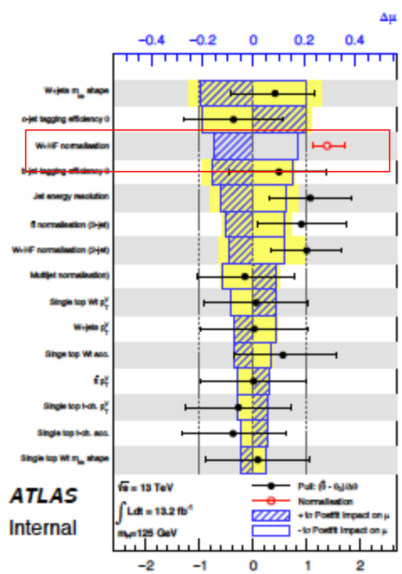
1 lepton Channel New W+ hf Control Region



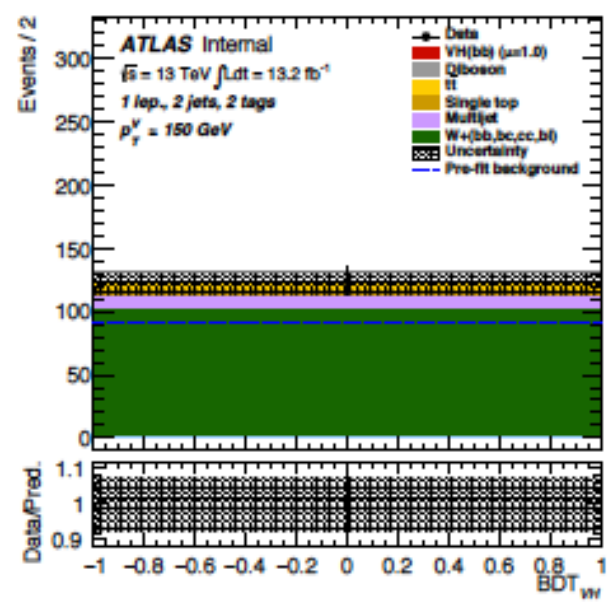
- Can see large reduction in Wbb normalization uncertainty: 0.48 → 0.30
- W+hf normalization more strongly constrained with new control region
- Using only normalization in the global fit



1-lepton New Input NP Ranking

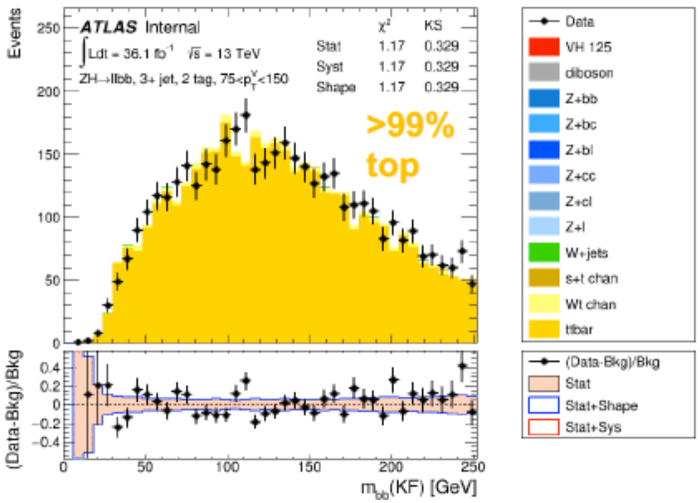


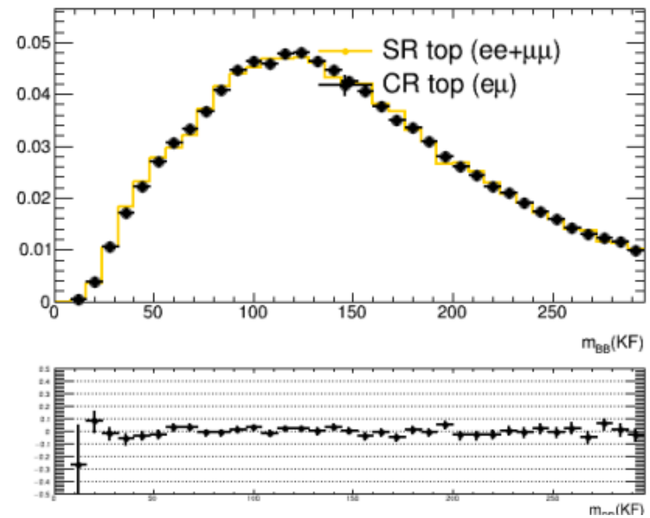
1-lepton New Input NP Ranking, with W+hf CR



2 lepton Channel eμ ttbar Control Region

- ttbar is “flavor-symmetry” background in 2 lepton analysis
  - eμ channel is a good control region with very high top purity and same kinematics of ttbar with SR.
  - Constraints top background normalization and shape



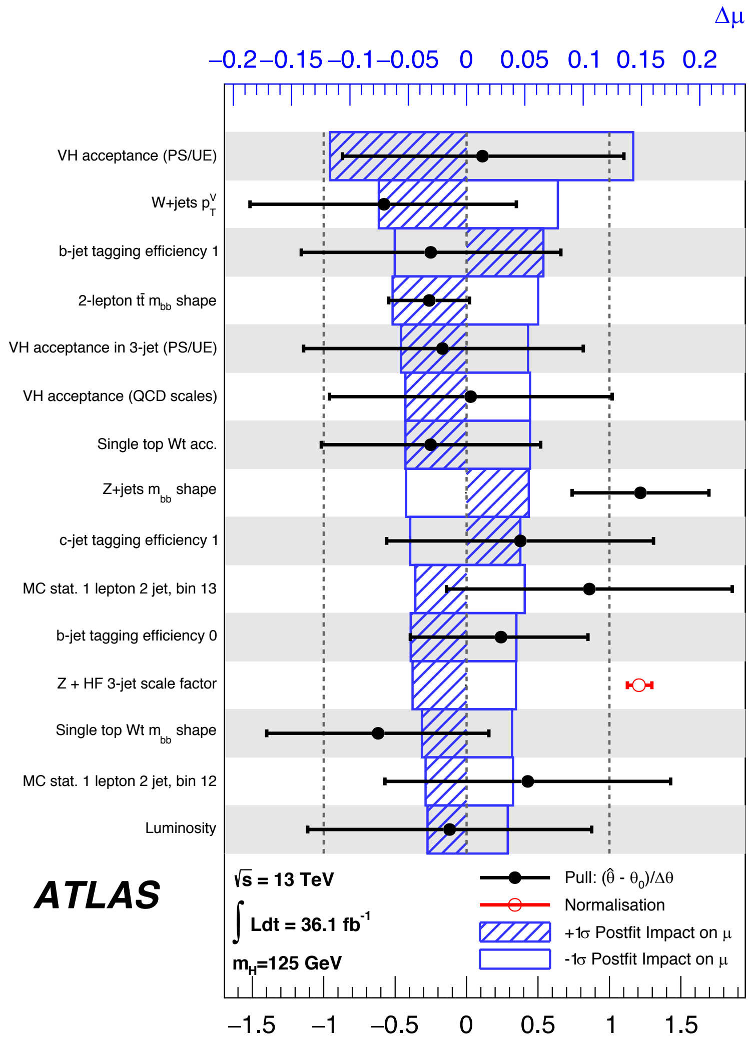


  - Use the top eμ control region to extract information on ttbar normalization and shape for 2 jets and 3+jets in 2 lepton channel

- Cross check---data-driven ttbar estimation(more in back up)
  - take data from CR and use it as top template in SR

$m_H = 125$ GeV at $\sqrt{s} = 13$ TeV				
Process	Cross-section $\times$ B [fb]	Acceptance [%]		
		0-lepton	1-lepton	2-lepton
$qq \to ZH \to \ell\ell b\bar{b}$	29.9	< 0.1	< 0.1	7.0
$gg \to ZH \to \ell\ell b\bar{b}$	4.8	< 0.1	< 0.1	15.7
$qq \to WH \to \ell\nu b\bar{b}$	269.0	0.2	1.0	–
$qq \to ZH \to \nu\nu b\bar{b}$	89.1	1.9	–	–
$gg \to ZH \to \nu\nu b\bar{b}$	14.3	3.5	–	–

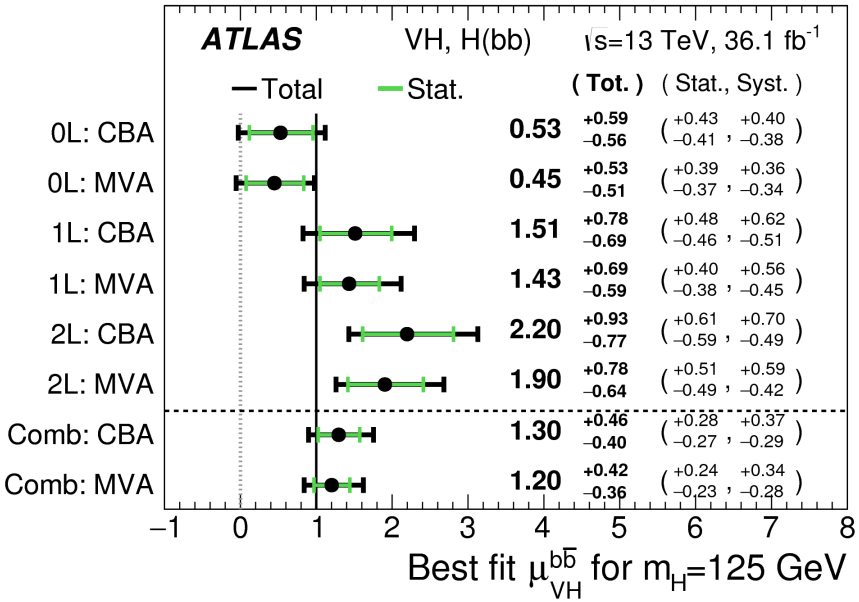
Process	Normalisation factor
$t\bar{t}$ 0- and 1-lepton	0.90 ± 0.08
$t\bar{t}$ 2-lepton 2-jet	0.97 ± 0.09
$t\bar{t}$ 2-lepton 3-jet	1.04 ± 0.06
$W +$ HF 2-jet	1.22 ± 0.14
$W +$ HF 3-jet	1.27 ± 0.14
$Z +$ HF 2-jet	1.30 ± 0.10
$Z +$ HF 3-jet	1.22 ± 0.09



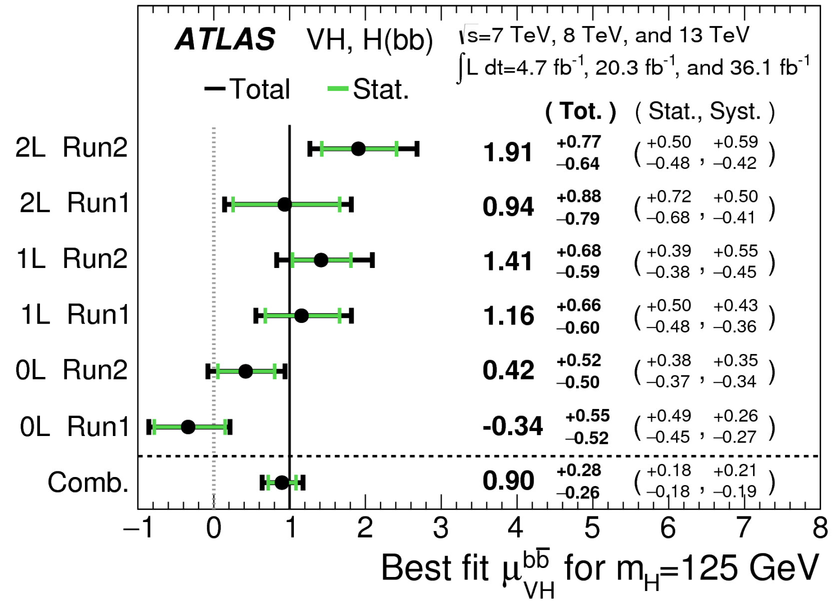
Source of uncertainty		σ_μ
Total		0.39
Statistical		0.24
Systematic		0.31
Experimental uncertainties		
Jets		0.03
E_T^{miss}		0.03
Leptons		0.01
b-tagging	b-jets	0.09
	c-jets	0.04
	light jets	0.04
	extrapolation	0.01
Pile-up		0.01
Luminosity		0.04
Theoretical and modelling uncertainties		
Signal		0.17
Floating normalisations		0.07
Z + jets		0.07
W + jets		0.07
$t\bar{t}$		0.07
Single top quark		0.08
Diboson		0.02
Multijet		0.02
MC statistical		0.13

Process	Bin 11	Bin 12	Bin 13	Bin 14
Data	274	156	34	4
Signal (fit)	32.4	25.0	11.1	1.1
Total Background	238.3	113.7	27.3	1.5
$Z + ll$	0.2	0.1	< 0.1	< 0.1
$Z + cl$	0.7	0.4	< 0.1	< 0.1
Z + HF	86.1	51.3	10.5	1.5
$W + ll$	0.20	0.1	< 0.1	–
$W + cl$	1.6	0.2	< 0.1	–
W + HF	58.9	24.5	6.9	–
Single top quark	19.2	7.6	2.9	–
$t\bar{t}$	61.3	25.7	6.2	–
Diboson	4.7	1.7	0.4	< 0.1
Multi-jet e sub-ch.	0.1	–	–	–
Multi-jet μ sub-ch.	5.2	2.0	< 0.1	–

Dataset	p_0		Significance	
	Exp.	Obs.	Exp.	Obs.
0-lepton	4.2%	30%	1.7	0.5
1-lepton	3.5%	1.1%	1.8	2.3
2-lepton	3.1%	0.019%	1.9	3.6
Combined	0.12%	0.019%	3.0	3.5



ATLAS
VH, H(bb)
√s=13 TeV, 36.1 fb-1
Total
Stat.
(Tot.) (Stat., Syst.)
0L: CBA 0.53 +0.59 −0.56 (+0.43 −0.41 , +0.40 −0.38)
0L: MVA 0.45 +0.53 −0.51 (+0.39 −0.37 , +0.36 −0.34)
1L: CBA 1.51 +0.78 −0.69 (+0.48 −0.46 , +0.62 −0.51)
1L: MVA 1.43 +0.69 −0.59 (+0.40 −0.38 , +0.56 −0.45)
2L: CBA 2.20 +0.93 −0.77 (+0.61 −0.59 , +0.70 −0.49)
2L: MVA 1.90 +0.78 −0.64 (+0.51 −0.49 , +0.59 −0.42)
Comb: CBA 1.30 +0.46 −0.40 (+0.28 −0.27 , +0.37 −0.29)
Comb: MVA 1.20 +0.42 −0.36 (+0.24 −0.23 , +0.34 −0.28)
Best fit μ for mH=125 GeV



ATLAS
VH, H(bb)
√s=7 TeV, 8 TeV, and 13 TeV
∫L dt=4.7 fb-1, 20.3 fb-1, and 36.1 fb-1
Total
Stat.
(Tot.) (Stat., Syst.)
2L Run2 1.91 +0.77 −0.64 (+0.50 −0.48 , +0.59 −0.42)
2L Run1 0.94 +0.88 −0.79 (+0.72 −0.68 , +0.50 −0.41)
1L Run2 1.41 +0.68 −0.59 (+0.39 −0.38 , +0.55 −0.45)
1L Run1 1.16 +0.66 −0.60 (+0.50 −0.48 , +0.43 −0.36)
0L Run2 0.42 +0.52 −0.50 (+0.38 −0.37 , +0.35 −0.34)
0L Run1 -0.34 +0.55 −0.52 (+0.49 −0.45 , +0.26 −0.27)
Comb. 0.90 +0.28 −0.26 (+0.18 −0.18 , +0.21 −0.19)
Best fit μ for mH=125 GeV