

Run2 Standard Model VH($b\bar{b}$) Analysis at ATLAS

Yanhui Ma

Shandong University

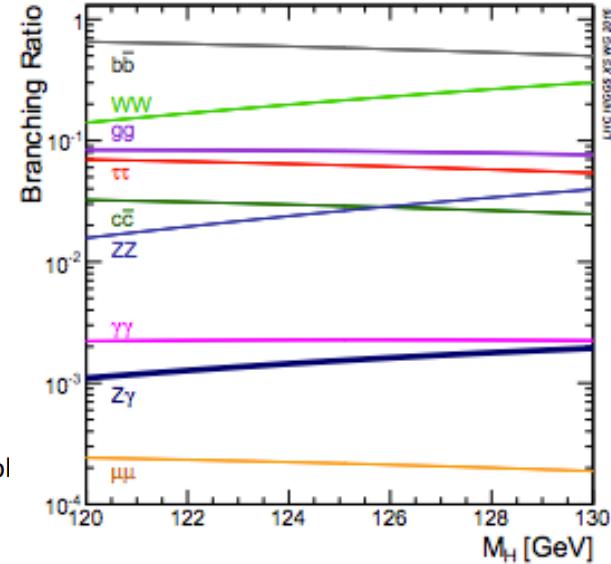
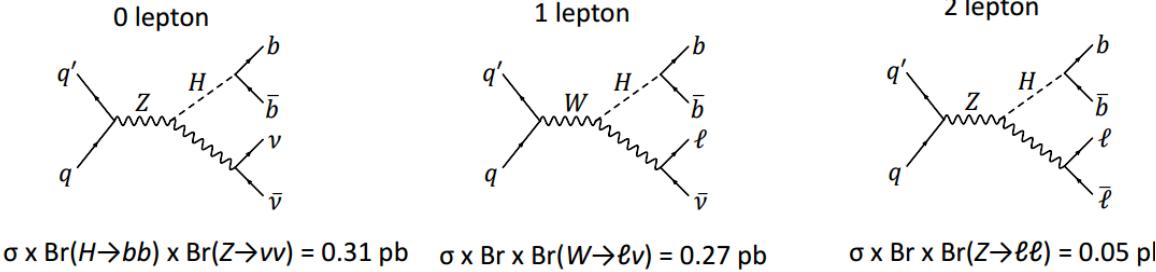
CLHCP @ PKU

2016-12-17

Introduction

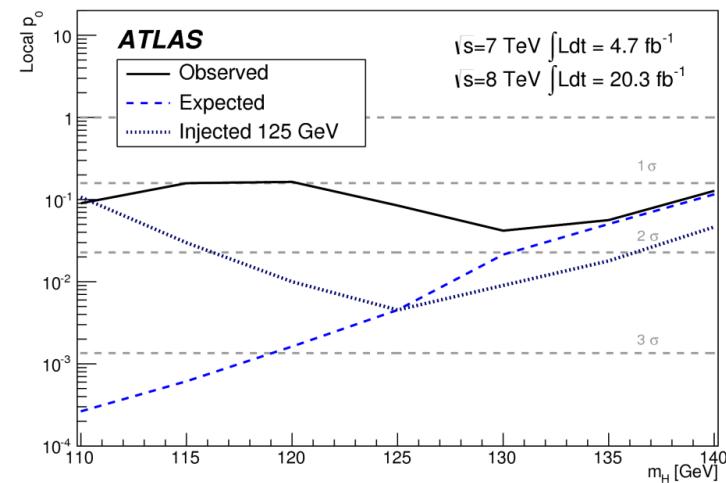
➤ Search for a SM Higgs boson produced in association with a vector boson(W/Z), and decaying to a pair of b-quarks.

➤ 3 channels



➤ Not yet observed in Run1

- ATLAS: 1.4σ (2.6σ) in observed (exp.)
- CMS VH: 2.1σ (2.1σ)
- ATLAS + CMS: 2.6σ (3.7σ)



Data and Simulated Samples

➤ Data

- Total 13.2 fb⁻¹ data was used for the ICHEP analysis.
- 3.2(2015) + 10(2016)

➤ Signal

- $q\bar{q} \rightarrow VH$: Pythia8 (A14)
- $gg \rightarrow ZH$: Powheg+Pythia8 (AZNLO)

➤ Background

- $V+jets$: Sherpa 2.2
- $t\bar{t}$: Powheg+Pythia6
- single-top : Powheg+Pythia6
- VV : Sherpa 2.1 improved
- Multijet : Data-driven in 1-lepton, negligible in 0 and 2-lepton channel.

Object Selection

Electron Selection	p_T	η	ID	d_0^{sig}	$ \Delta z_0^{BL} \sin \theta $	Isolation
VH - loose	>7 GeV	$ \eta < 2.47$	LH Loose + B-layer cut	< 5	< 0.5 mm	LooseTrackOnly
ZH - signal	>25 GeV	$ \eta < 2.47$	LH Loose + B-layer cut	< 5	< 0.5 mm	LooseTrackOnly
WH - signal	>25 GeV	$ \eta < 2.47$	LH Tight	< 5	< 0.5 mm	FixedCutTight

Muon Selection	p_T	η	ID	d_0^{sig}	$ \Delta z_0^{BL} \sin \theta $	Isolation
VH-Loose	>7 GeV	$ \eta < 2.7$	Loose quality	< 3	< 0.5 mm	LooseTrackOnly
ZH-Signal	>25 GeV	$ \eta < 2.5$	Loose quality	< 3	< 0.5 mm	LooseTrackOnly
WH-Signal	>25 GeV	$ \eta < 2.5$	Medium quality	< 3	< 0.5 mm	FixedCutTightTrackOnly

Jet Category	Selection Requirements
Forward Jets	jet cleaning $p_T > 30 \text{ GeV}$ $2.5 \leq \eta < 4.5$
Signal Jets	$p_T > 20 \text{ GeV}$ and $ \eta < 2.5$ jet cleaning $JVT \geq 0.64$ if ($p_T < 60 \text{ GeV}$ and $ \eta < 2.4$)

➤ B-tagging

- MV2c10

- 70 % WP

Event Categorization and Selection

		0 lepton	1 lepton	2 lepton
p_T^V	< 150 GeV			○
	> 150 GeV	○	○	○
n-jets	2-jets	○	○	○
	3-jets	○	○	○
b-tag	-1-tag	○	○	○
	2-tag	○	○	○

≥ 3 jets for 2 leptons

- The 1-tag region is not currently included in order to simplify the fit model and systematic uncertainties.

Selection	0-lepton	1-lepton	2-lepton
Trigger	E_T^{miss}	E_T^{miss} (μ sub-channel)	
		Lowest unprescaled single lepton	
Leptons	0 loose lepton	1 tight lepton	2 loose leptons (≥ 1 medium lepton)
Lepton pair	-	-	Same flavour opposite-charge for $\mu\mu$
E_T^{miss}	> 150 GeV	> 30 GeV (e sub-channel)	-
m_{ll}	-	-	$71 < m_{ll} < 121$ GeV
S_T	> 120 (2 jets), > 150 GeV (3 jets)	-	-
Jets	Exactly 2 or 3 signal jets		Exactly 2 or ≥ 3 signal jets
b -jets	2 b -tagged signal jets		
Leading jet p_T	> 45 GeV		
$\min\Delta\phi(E_T^{\text{miss}}, \text{jet})$	> 20°	-	-
$\Delta\phi(E_T^{\text{miss}}, h)$	> 120°	-	-
$\Delta\phi(\text{jet1}, \text{jet2})$	< 140°	-	-
$\Delta\phi(E_T^{\text{miss}}, E_{T,\text{trk}})$	< 90°	-	-
p_T^V regions	[0, 150] GeV (2-lepton), [150, ∞] GeV		

- In the 1-lepton channel, due to the **modelling difficulties** related to the estimate of the high multijet background contamination, the [0, 150] GeV region is not considered.

Muon-in-jet correction

- It is important to find **muons derived from B-hadron semileptonic decays** for better b-jet energy resolution
- in about **12% of b-jets**, there is an muon and a neutrino within the b-jet cone.
- Muons inside jets are required to have $p_T > 4 \text{ GeV}$, $|\eta| < 2.7$ and medium quality
- Choose the closest muon in ΔR to the jet. The muon 4-vector is added to the jet 4-vector, while the 4-vector of the energy deposited by the muon in the calorimeter is removed.

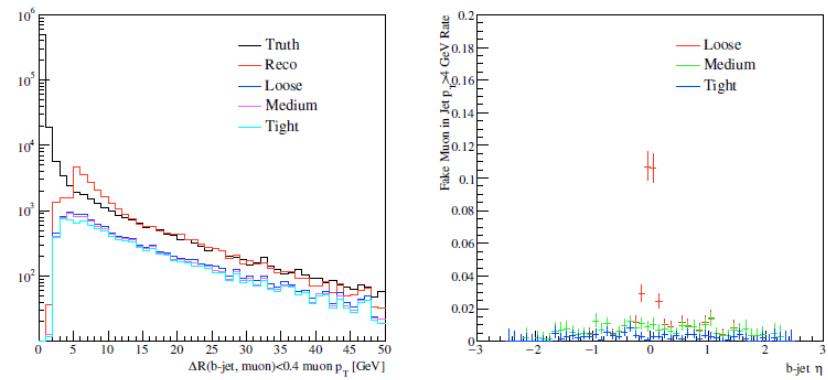
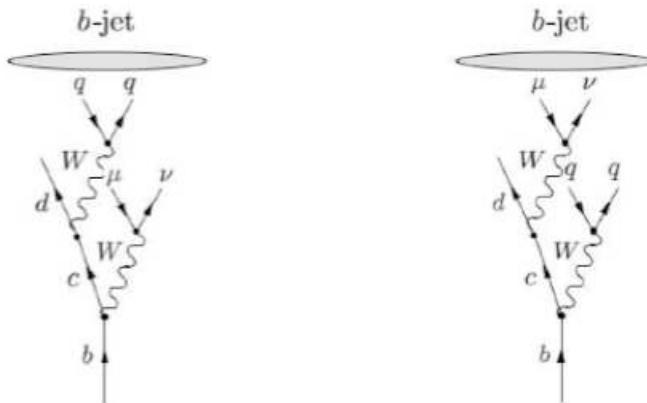
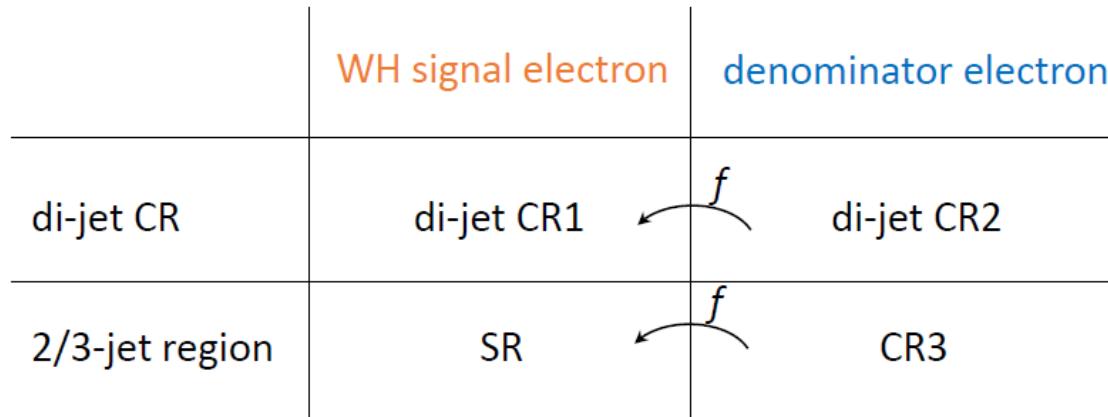


Figure 12: Left: muon p_T distribution for various muon quality, muons inside jet are selected by $\Delta R_{b\text{-jet},\mu} < 0.4$. Right: η distribution of fake muon inside jet. Fake muons are selected from jets without Truth muon.

Multi-jet in 1 lepton channel---fake factor method

- Dijet CR: exactly 1 signal jet



Lepton Mode	Isolation variable	Threshold for numerator	Threshold for denominator
Electron	$E_{\text{Tcone}20}/p_T$	< 0.06	> 0.06
Muon	$p_{\text{Tvarcone}30}/p_T$	< 0.06	> 0.06

Table 48: The isolation criteria in the di-jet control regions.

- fake factor $f = CR1/CR2$ $SR = f \times CR3$

Multi-jet in 1 lepton channel---fake factor method

- The electroweak contamination is removed from the di-jet control regions using the **simulated MC prediction**
- the normalization of the electroweak processes in the di-jet control regions is scaled with fits in **high lepton purity region:**
150 < MET < 250 GeV.

	Normalisation Scale Factor
Electron Channel	1.17 ± 0.06
Muon Channel	1.18 ± 0.06

- Fake factors derived for $5 pT(\mu) \times 3 |\eta(\mu)$ regions using di-jet control regions

$ \eta^{\text{muon}} $	{0, 1.05, 1.5, 2.5}
p_T^{muon}	{25, 42, 59, 76, 99, ∞ } GeV

Table 49: Binning for fake factor in the muon channel .

- MET in fake electron events is strongly correlated with the energy mis-measurement of the fake electrons

E_T^{miss}	η^{electron}	{0, 1.37, 1.52, 2.47}
for $25 < p_T^{\text{electron}} < 115$ GeV	p_T^{electron}	{25, 115, 135, 155, 190, ∞ } GeV
for $115 < p_T^{\text{electron}} < 135$ GeV		{0, 60, 75, ∞ } GeV
for $135 < p_T^{\text{electron}} < 155$ GeV		{0, 38, 52, ∞ } GeV
for $155 < p_T^{\text{electron}} < 190$ GeV		{0, 26, 43, ∞ } GeV
for $190 < p_T^{\text{electron}}$ GeV		{0, 25, 45, ∞ } GeV
		{0, 34, 62, ∞ } GeV

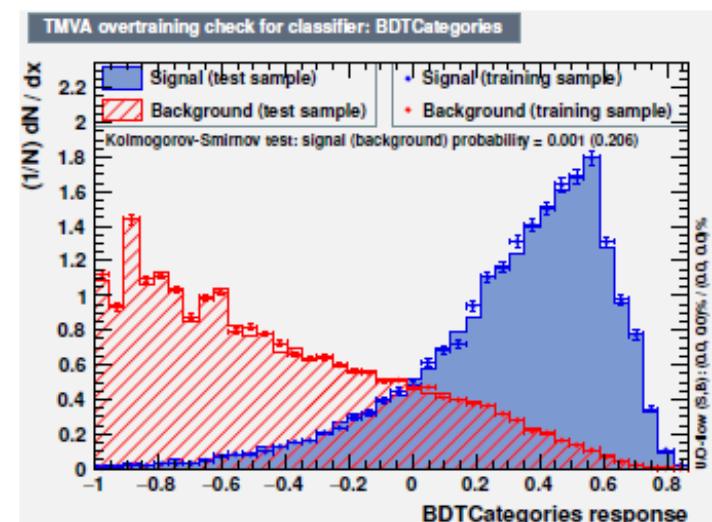
Table 50: Binning for fake factor in the electron channel . 8

Multi-Variate Analysis

TMVA Setting	Value	Definition
BoostType	AdaBoost	Boost procedure
AdaBoostBeta	0.15	Learning rate
SeparationType	GiniIndex	Node separation gain
PruneMethod	NoPruning	Pruning method
NTrees	200	Number of trees
MaxDepth	4	Maximum tree depth
nCuts	100	Number of equally spaced cuts tested per variable per node
nEventsMin	100	Minimum number of events in a node

Table 19: BDT configuration parameters.

- based on Run1 experience
- no change on configuration
- pile-up reweighting is not applied, truth tagging(for V+cc, cl, l sample) is applied, to increase the MC statistics to get a more stable, optimal training.



Multi-Variate Analysis

➤ adding mtop and $\Delta Y(W, H)$ for 1 lepton channel(expected increase of significance $\sim 7\%$)

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	✓	✓	✓

Statistical Treatment

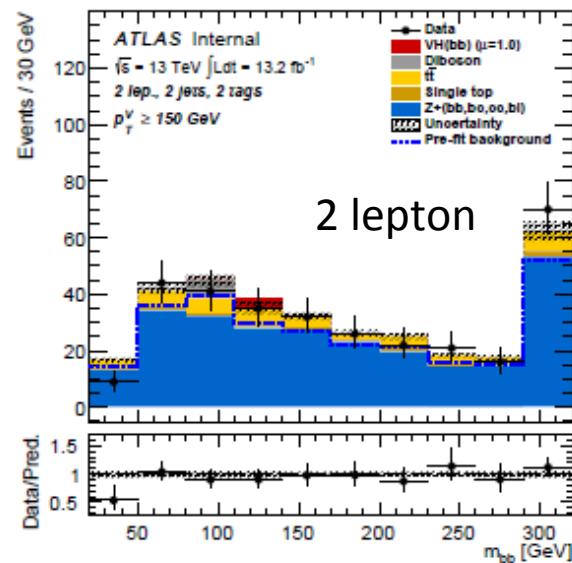
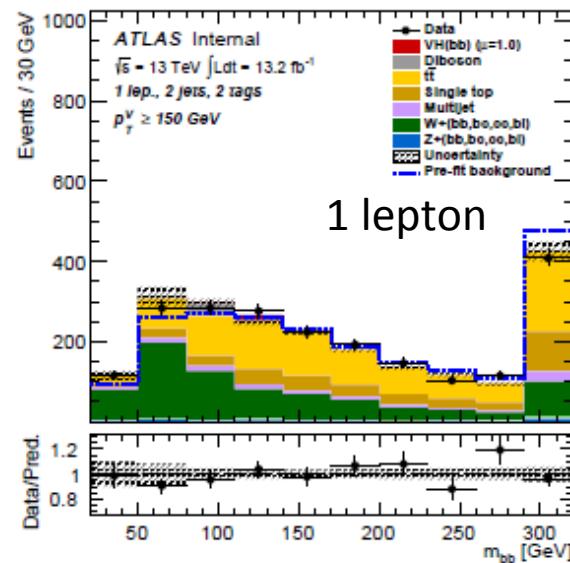
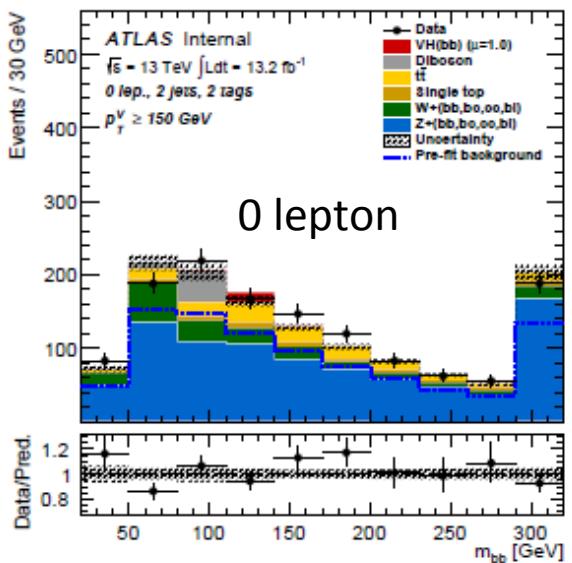
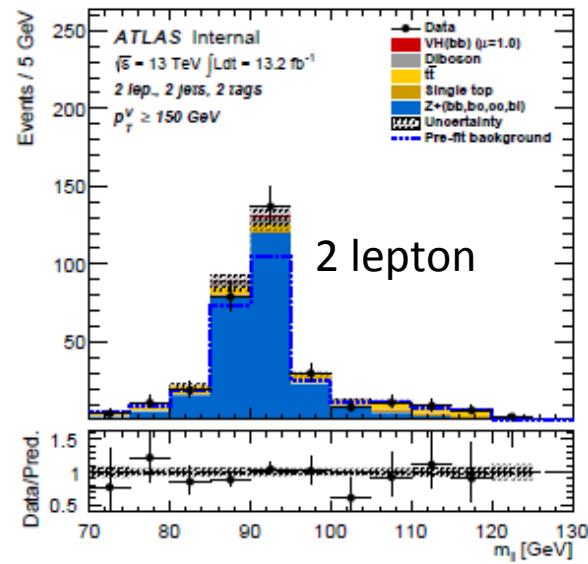
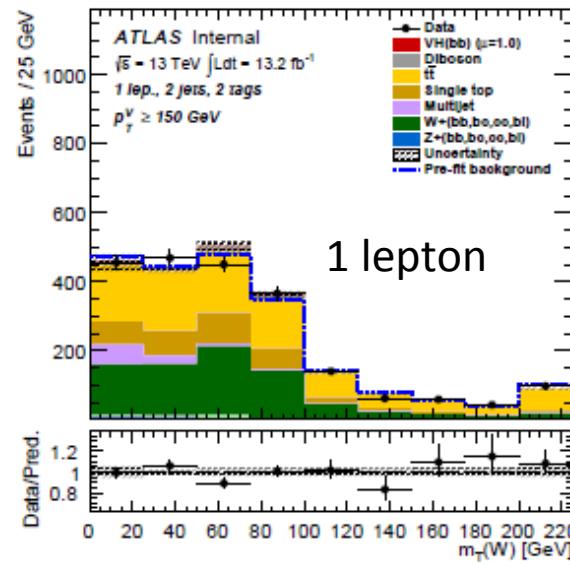
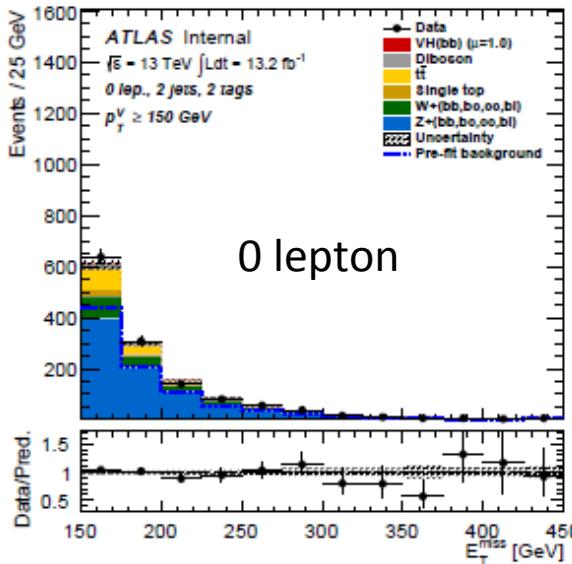
- Binned maximum likelihood fit simultaneously in 8 regions
- Input variable : BDT_{VH}
- Parameter of interest : Common signal strength
 $\mu = \sigma_{fit} / \sigma_{SM}$ *across channels and regions*
- Associating either floating scale factors (Zbb, Wbb, ttbar) or nuisance parameters (NP) for the normalisation
- Shape systematic uncertainties: mBB, pTV
- VZ Fit validation ($BDTvz$) → *Unblind VH Fit*
 - Re-training BDT to extract “VZ “signal
 - setup as much as possible consistent with main fit
 - Significance : 2.97 (3.18) *obs. (exp.)*

Sample	Scale factor
$t\bar{t}$ 0+1-lepton	0.86 ± 0.13
$t\bar{t}$ 2-lepton	0.94 ± 0.09
$W + HF$	1.59 ± 0.39
$Z + HF$	1.04 ± 0.11

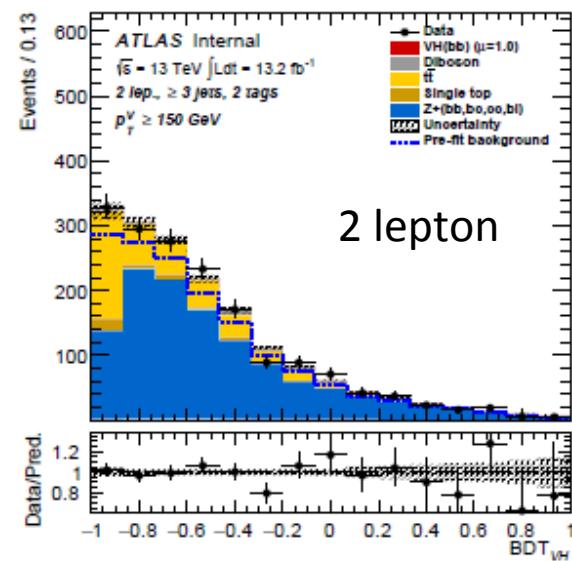
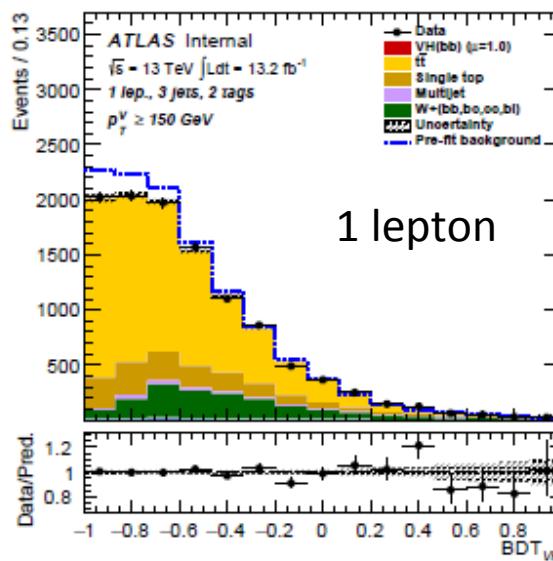
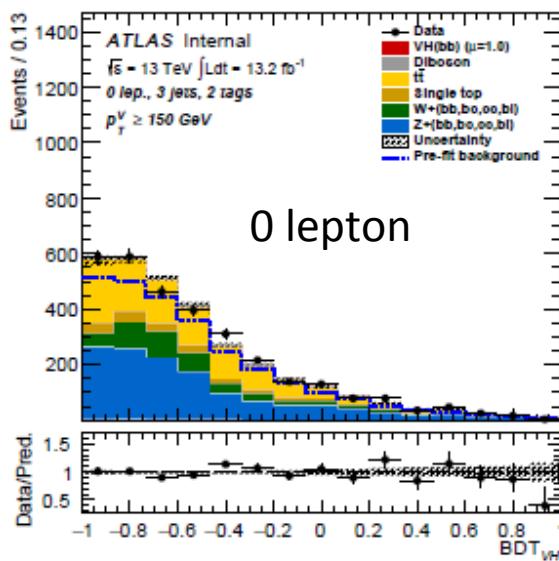
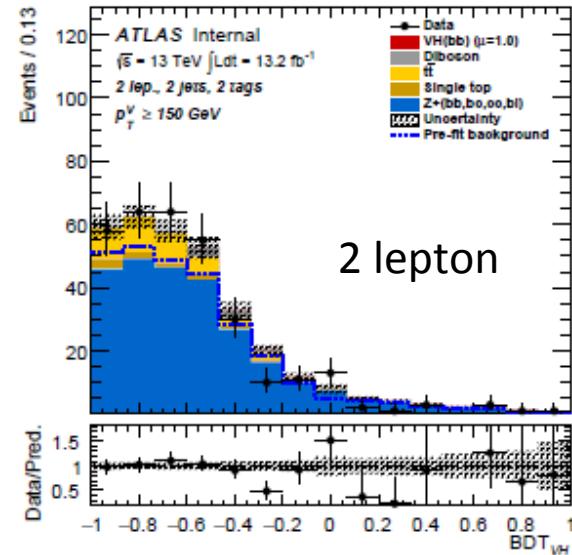
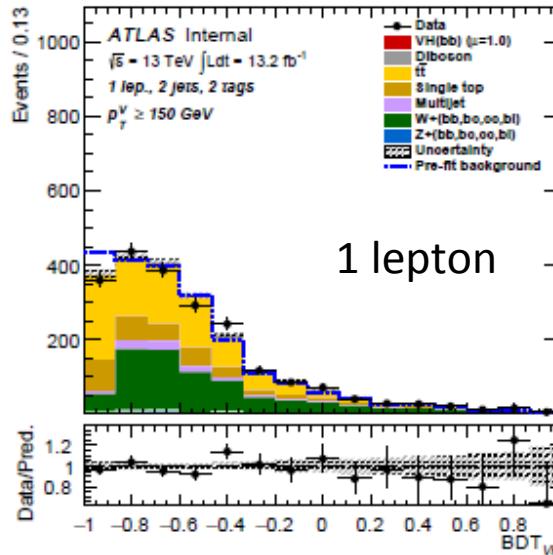
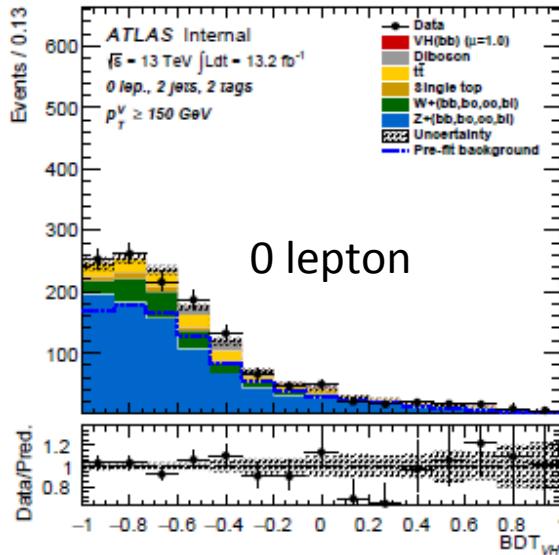
Experimental Systematic Uncertainties

- Luminosity
- Pileup
- B-tagging
 - ▶ SysFT EFF extrapolation
 - ▶ SysFT EFF extrapolation from charm
 - ▶ SysFT EFF Eigen Light 0/1/2/3/4
 - ▶ SysFT EFF Eigen B 0/1/2/3/4
 - ▶ SysFT EFF Eigen C 0/1/2/3/4
- Jets
 - ▶ SysJET JER SINGLE NP
 - ▶ JES 19 NP
- Muons
 - ▶ MUONS ID/MS/SCALE
 - ▶ MUON ISO SYS/STAT
 - ▶ MUON EFF SYS/STAT/
TrigStatUncertainty/TrigSystUncertainty
 - ▶ MUON TTVA SYS/STAT
- MET
 - ▶ SysMETTrigStat
 - ▶ SysMETTrigTop
 - ▶ SysMETTrigZ
 - ▶ SysMET JetTrk Scale
 - ▶ SysMET SoftTrk ResoPerp
 - ▶ SysMET SoftTrk ResoPara
 - ▶ SysMET SoftTrk Scale
- Electrons
 - ▶ EG RESOLUTION ALL
 - ▶ EG SCALE ALL
 - ▶ EG EFF ID/Iso/Reco/TriggerTotalCorr
Uncertainty
- MC stat

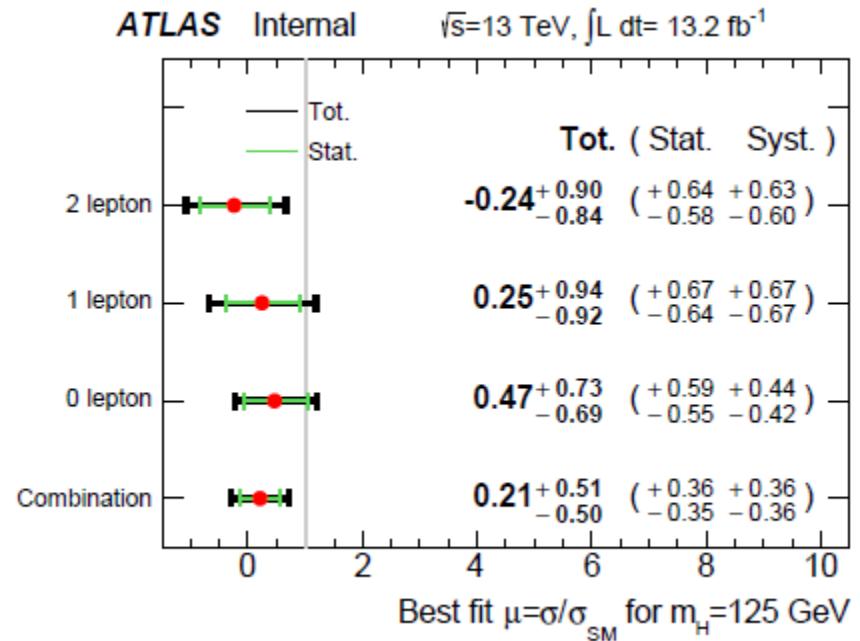
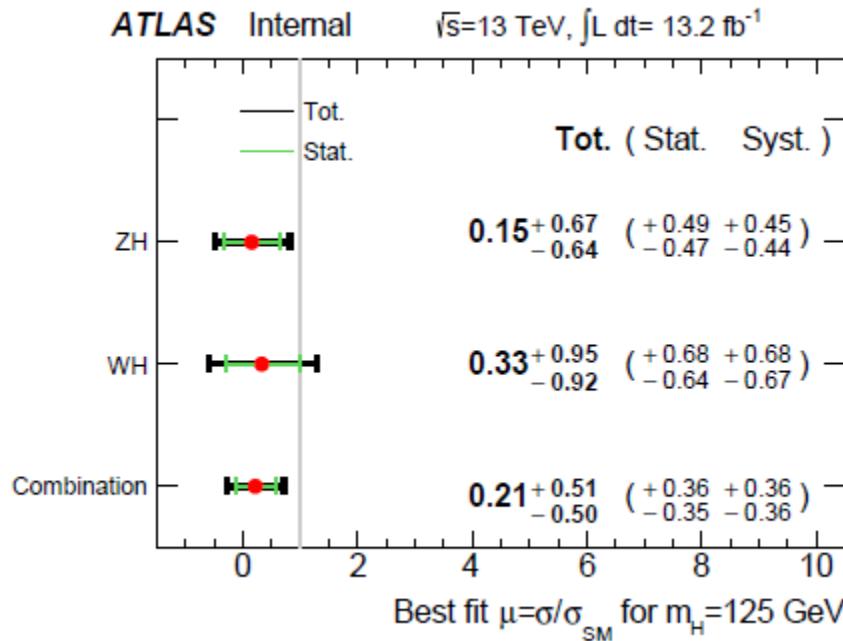
VH Fit Results : Posfit plots



VH Fit Results : Posfit plots



VH Fit : Results



- The measured signal strength with respect to the SM expectation is found to be
 - $\mu = 0.21^{+0.36}_{-0.35} \text{ (stat.)} \pm 0.36 \text{ (syst.)}$.

VH Fit Results

muhat: 0.20959

nll_val_true: 103301.495523

Set of nuisance parameters	Impact on error			
----------------------------	-----------------	--	--	--

Total	+	0.508	-	0.499
DataStat	+	0.361	-	0.346
FullSyst	+	0.358	-	0.360
Floating normalizations	+	0.099	-	0.150
All normalizations	+	0.126	-	0.171
All but normalizations	+	0.315	-	0.320
Jets MET	+	0.050	-	0.046
BTag	+	0.162	-	0.190
Leptons	+	0.010	-	0.011
Luminosity	+	0.017	-	0.011
Diboson	+	0.022	-	0.022
Zjets	+	0.118	-	0.179
Wjets	+	0.097	-	0.136
Model ttbar	+	0.090	-	0.145
Model Single Top	+	0.042	-	0.031
Model Multi Jet	+	0.015	-	0.016
Signal Systematics	+	0.081	-	0.027
MC stat	+	0.208	-	0.215

Impact on error quadratically subtracted from total, except for:
 DataStat All but normalizations

Dataset	Limit		p_0		Significance	
	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.
0-lepton	$1.4^{+0.6}_{-0.4}$	2.0	0.07	0.15	1.45	1.02
1-lepton	$2.0^{+0.8}_{-0.6}$	2.1	0.15	0.46	1.04	0.10
2-lepton	$1.8^{+0.7}_{-0.5}$	1.7	0.13	0.57	1.14	-0.17
Combined	$1.0^{+0.4}_{-0.3}$	1.2	0.03	0.34	1.94	0.42

- Data stat and systematic uncertainties dominate μ error in the same level

Summary

- First Run2 result of SM $VH(b\bar{b})$ analysis at ATLAS
- 13.2 fb $^{-1}$ data is used
- Significance : 0.42σ (1.94σ) obs. (exp.)
- Aim for quick publication on 2017 Moriond timescale with full 2015 + 2016 dataset

Back Up

Cut-based analysis

- ▶ Additional cuts
 - ▶ 0-lepton : $dR(b1,b2) < 1.8$ (low MET); < 1.2 (high MET)
 - ▶ 1-lepton : $dR(b1,b2) < 1.8$ (low pTV); < 1.2 (high pTV),
 $mTW < 120$ GeV
 - ▶ 2-lepton : $dR(b1,b2) < 1.8$ (low pTV); < 1.2 (high pTV),
 $81 < m(ll) [\text{GeV}] < 101$, MET Significance: $\text{MET}/\sqrt{\text{HT}} < 3.5 \sqrt{\text{GeV}}$
- ▶ Additional pTV split (150-200, 200- in 0 and 2 lepton)
- ▶ Low pTV in 2 lepton no shape, only normalization (1bin)
- ▶ Some differences are observed. Evaluating consistency
- ▶ Pulls, VH, VZ

VH result	Expected		Observed	
	Cut based	MVA	Cut based	MVA
Combined	1.53	1.94	1.91	0.42
0-lepton	1.04	1.45	1.00	1.02
1-lepton	0.77	1.04	1.70	0.10
2-lepton	0.81	1.14	0.60	-0.17

Event Categorization and Selection

- Muon channel are triggered using MET trigger → to increase the trigger efficiency for single high pT muons
- The combination of the MET trigger and muon trigger can offer only a small increase in the signal acceptance → do not used to simplify the analysis

0 lep	1 lep	2 lep
HLT_xe70	HLT_xe70 HLT_e24_lhmedium_L1EM20VH (data) OR HLT_e24_lhmedium_L1EM18VH (MC) OR HLT_e60_lhmedium	HLT_mu20_iloose_L1MU15 OR HLT_mu50 HLT_e24_lhmedium_L1EM20VH (data) OR HLT_e24_lhmedium_L1EM18VH (MC) OR HLT_e60_lhmedium OR HLT_e120_lhloose

Table 5: Summary table of triggers used in 2015 Data.

period	0 lep	1 lep	2 lep
A	HLT_xe90_mht_L1XE50	HLT_xe90_mht_L1XE50 HLT_e24_lhtight_no_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e60_medium OR HLT_e140_lhloose_nod0	HLT_mu24_iloose OR HLT_mu40 HLT_e24_lhtight_no_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e60_medium OR HLT_e140_lhloose_nod0
B-D3	HLT_xe90_mht_L1XE50	HLT_xe90_mht_L1XE50 HLT_e24_lhtight_no_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e60_medium OR HLT_e140_lhloose_nod0	HLT_mu24_ivarmedium OR HLT_mu26_ivarmedium OR HLT_mu50 HLT_e24_lhtight_no_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e60_medium OR HLT_e140_lhloose_nod0
$\geq D4$	HLT_xe100_mht_L1XE50	HLT_xe100_mht_L1XE50 HLT_e24_lhtight_no_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e60_medium OR HLT_e140_lhloose_nod0	HLT_mu24_ivarmedium OR HLT_mu26_ivarmedium OR HLT_mu50 HLT_e24_lhtight_no_ivarloose OR HLT_e60_lhmedium_nod0 OR HLT_e60_medium OR HLT_e140_lhloose_nod0

Table 6: Summary table of triggers used in 2016 Data.

- The trigger efficiency, for events with a reconstructed MET = 150 GeV, is about 85%, the efficiency plateau is reached at about MET = 180 GeV.
- In order to handle properly triggers in simulation, we use the **random run number** provided by **pile-up reweighting tool** to define if the event is associated to 2015 or 2016 data.

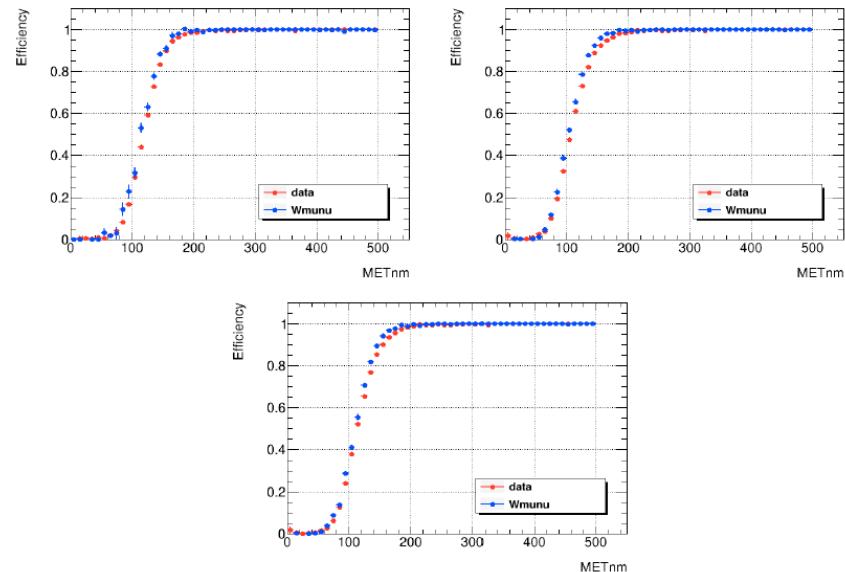
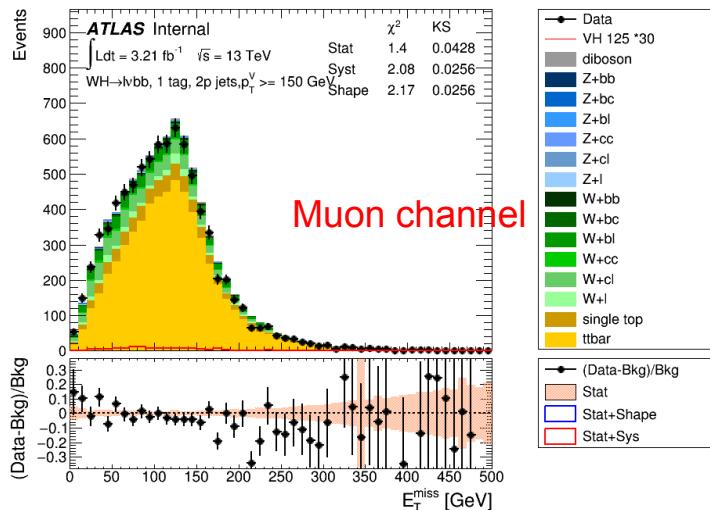
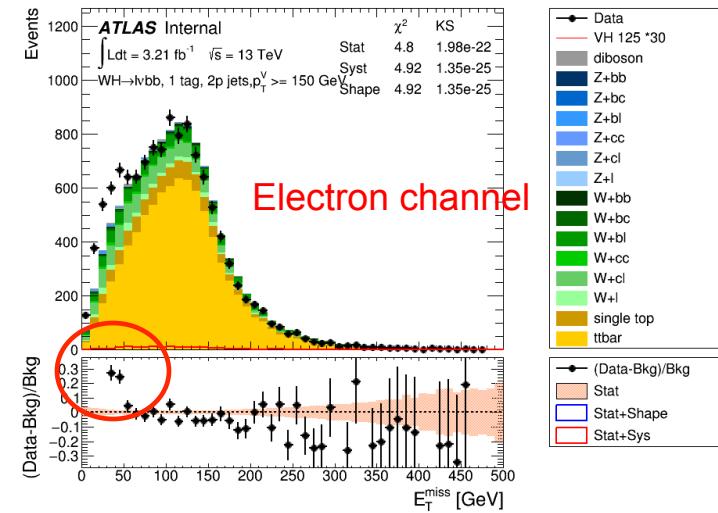
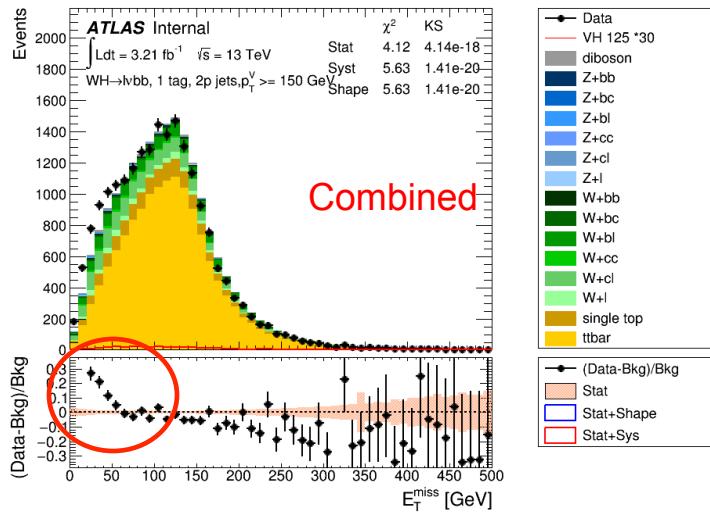


Figure 5: Measured E_T^{miss} trigger efficiencies as function of offline E_T^{miss} for $W(\mu, \nu) + \text{jets}$ events for HLT_xe70(left), HLT_xe90_mht_L1XE50(right) and HLT_xe100_mht_L1XE50(bottom).

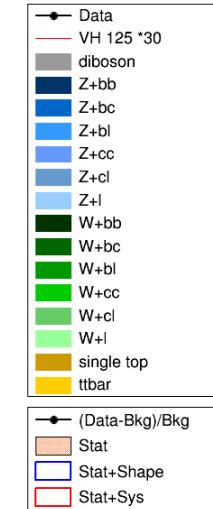
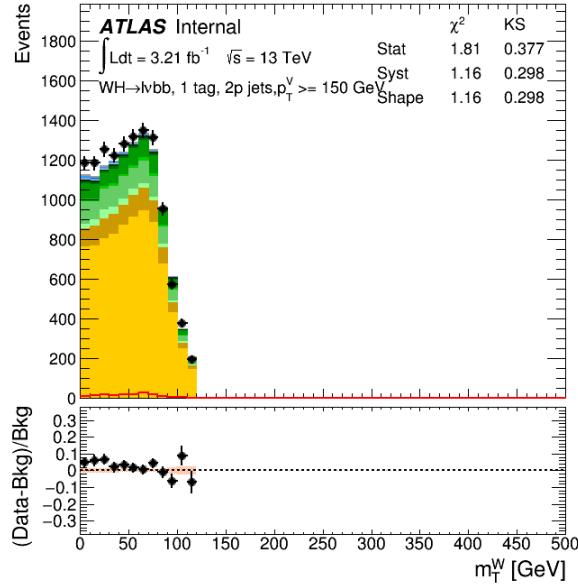
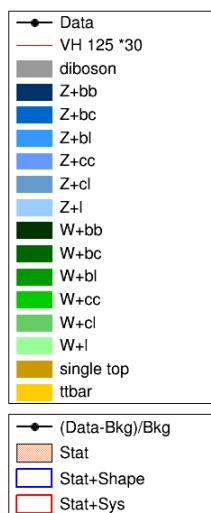
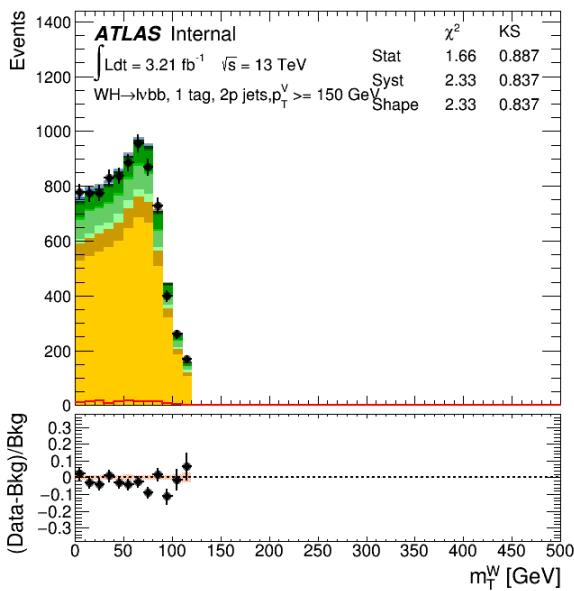
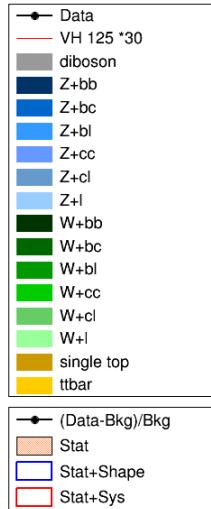
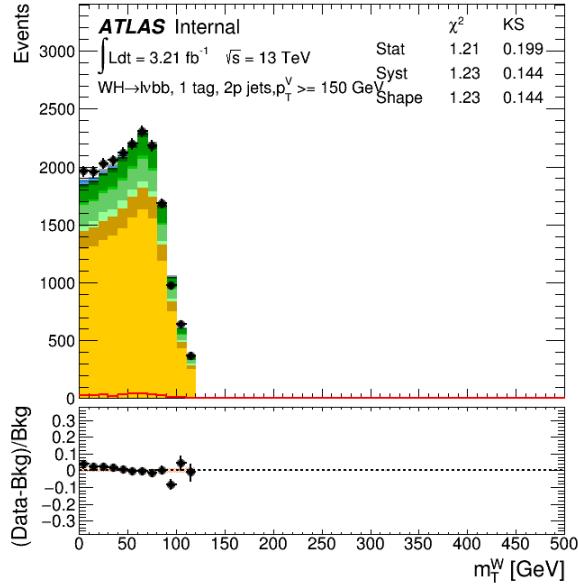
Event Categorization and Selection-1lepton channel

- Due to the **increased likelihood** for a jet to be reconstructed incorrectly as an electron compared to a muon, **separate anti- multijet** selections have been optimised for the electron and muon channels.



- Obviously overshoot for data can be seen for MET distribution in low MET bins
- mostly due to the electron channel, muon channel looks fine

Event Categorization and Selection---1 lepton channel

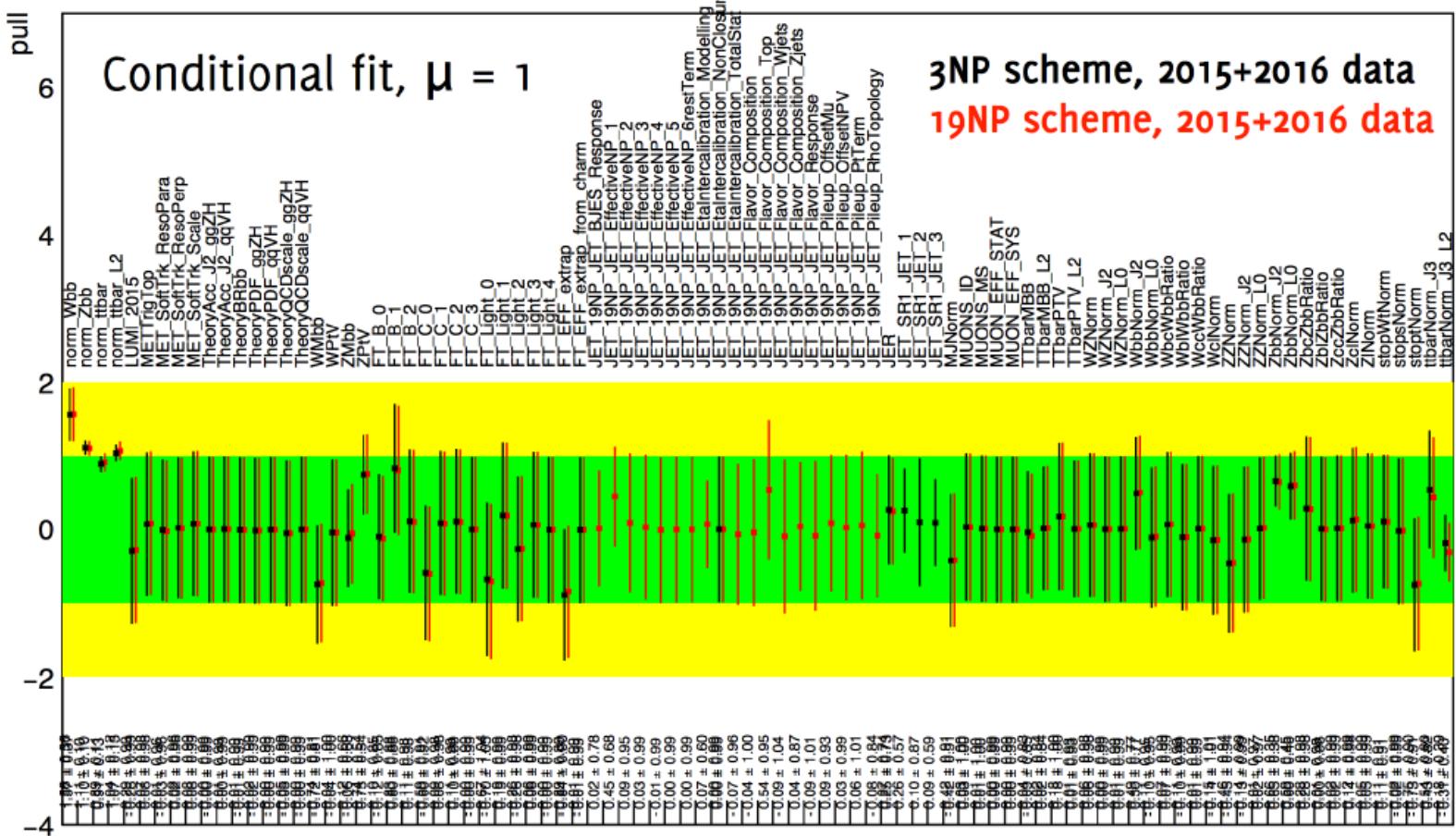


Combined

Electron channel

Muon channel

- » Comparing effect of 19 globally reduced NP scheme/ 3 strongly reduced NP scheme
 - » Almost no effect on pulls of other nuisance parameters
 - » **No change in expected significance:**
 - » **1.60 in both cases**
 - » Will use 19 NP scheme for combination with Run-1 result



- » Comparison of correlating/de-correlating $t\bar{t}$ m_{bb} and pTV shape systematics
 - » Combined fit for all 3 channels
 - » **No change in expected significance:**
 - » **1.60 in both cases**
 - » Will use de-correlated configuration as default

de-correlated

Set of nuisance parameters	Impact on error		
Total	+ 0.683	- 0.634	
DataStat	+ 0.529	- 0.502	
FullSyst	+ 0.432	- 0.386	
Top shape systematics	+ 0.073	- 0.066	
All but top shape systematics	+ 0.532	- 0.505	
Impact on error quadratically subtracted from total, except for: DataStat All but top shape systematics			

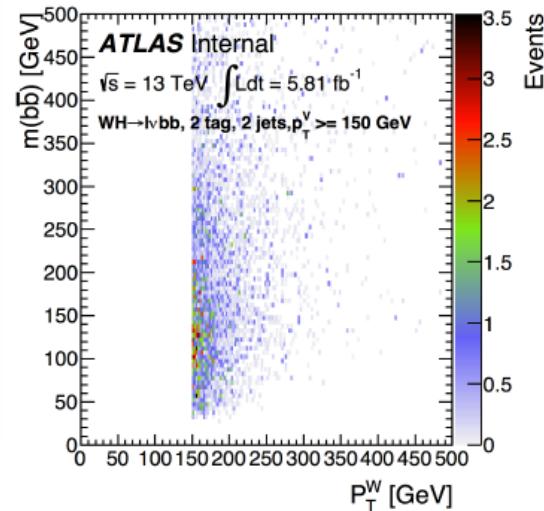
Set of nuisance parameters	Fractional impact on error (square of fraction of total)		
DataStat	+ 0.60	- 0.63	
FullSyst	+ 0.40	- 0.37	
Top shape systematics	+ 0.01	- 0.01	
All but top shape systematics	+ 0.61	- 0.63	

correlated

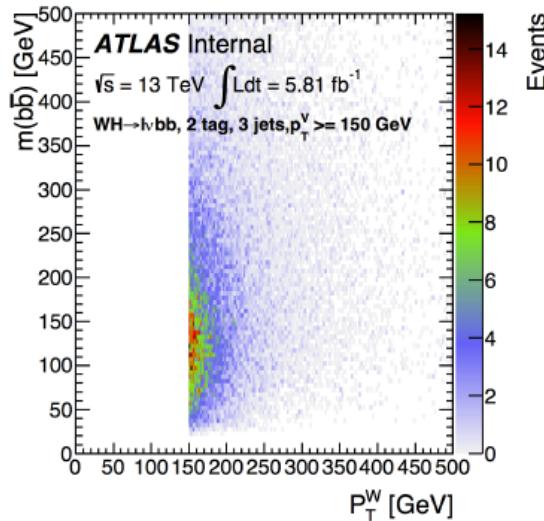
Set of nuisance parameters	Impact on error		
Total	+ 0.684	- 0.634	
DataStat	+ 0.529	- 0.502	
FullSyst	+ 0.433	- 0.388	
Top shape systematics	+ 0.080	- 0.072	
All but top shape systematics	+ 0.530	- 0.503	
Impact on error quadratically subtracted from total, except for: DataStat All but top shape systematics			

Set of nuisance parameters	Fractional impact on error (square of fraction of total)		
DataStat	+ 0.60	- 0.63	
FullSyst	+ 0.40	- 0.37	
Top shape systematics	+ 0.01	- 0.01	
All but top shape systematics	+ 0.60	- 0.63	

- » m_{bb} and pT^V chosen as dominant variables to derive shape uncertainties for $t\bar{t}$
- » Only expected to be weakly correlated, and therefore most important shape uncertainties to study
- » Observed that in 1-lepton channel, these variables are only weakly correlated

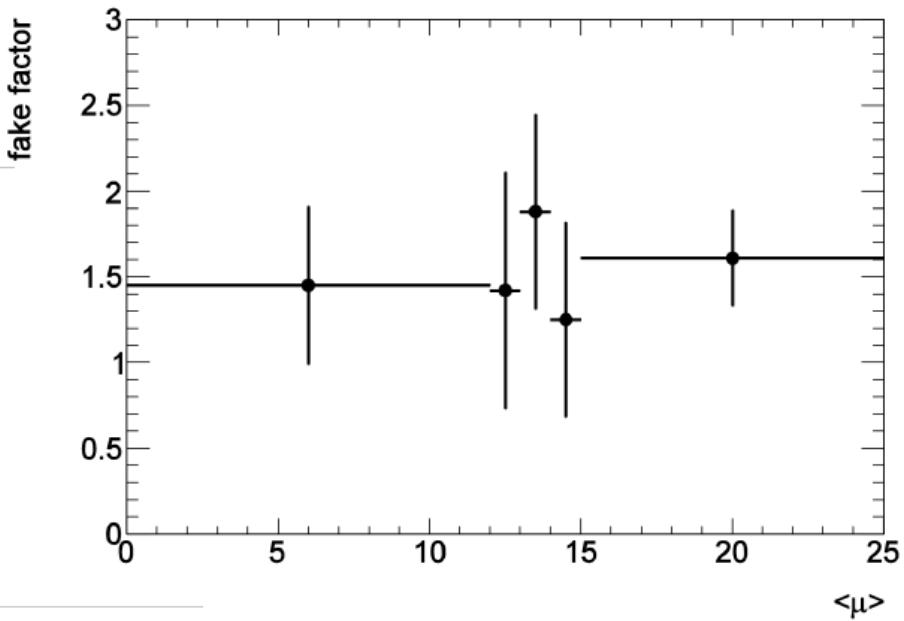


Correlation coefficient: 0.27



Correlation coefficient: 0.20

- » Check fake factor as a function of 5 $\langle\mu\rangle$ regions
- » Using 2015 data
- » Only electron channel studied
- » Inclusive of all p_T , η and MET regions
- » No dependence on $\langle\mu\rangle$ observed:
 - » Change in $\langle\mu\rangle$ profile from 2015 to 2016 not likely to affect fake factor estimation



- ▶ 5.8 fb^{-1} results
 - ▶ $\hat{\mu} : 0.65 + 0.76 - 0.73$
 - ▶ Significance : $0.9 (1.4) \sigma$ obs.(exp.)
 - ▶ p-value : $0.2 (0.1)$ obs.(exp.)
- ▶ Significance : $0.42 (1.94) \sigma$ obs. (exp.)
 - ▶ 0-lepton $1.02 (1.45)$
 - ▶ 1-lepton $0.10 (1.04)$
 - ▶ 2-lepton $-0.17 (1.14)$
- ▶ 95% CL Limit : $1.17 (1.00^{+0.39}_{-0.28})$ obs. (exp.)
 - ▶ 0-lepton $2.03 (1.43^{+0.56}_{-0.40})$
 - ▶ 1-lepton $2.05 (1.95^{+0.77}_{-0.55})$
 - ▶ 2-lepton $1.73 (1.81^{+0.71}_{-0.51})$

Mtop and dYWH

- mtop is the reconstructed leptonically decaying top mass
- $\Delta Y(W, H)$ is the reconstructed pseudo-rapidity difference of the Higgs candidate and leptonically decaying W boson
- Both of these variables require $p_z(\nu)$ to be determined, using m_W as a constraint to solve the quadratic equation

$$p_z^\nu = \frac{1}{2(p_T^l)^2} \left[p_z^l X \pm E_l \sqrt{X^2 - 4(p_T^l)^2(E_T^{\text{miss}})^2} \right],$$

$$X = m_W^2 + 2p_x^l E_x^{\text{miss}} + 2p_y^l E_y^{\text{miss}}.$$

- mtop is then reconstructed by selecting the jet from the two leading jets and solution to $p_z(\nu)$ which minimises mtop.

Overlap removal algorithm

- The electron will be removed when:

1. A reconstructed muon and electron share the same matched ID track
3. Any electrons reconstructed within $\Delta R < 0.4$ around the jet axis of a surviving jet

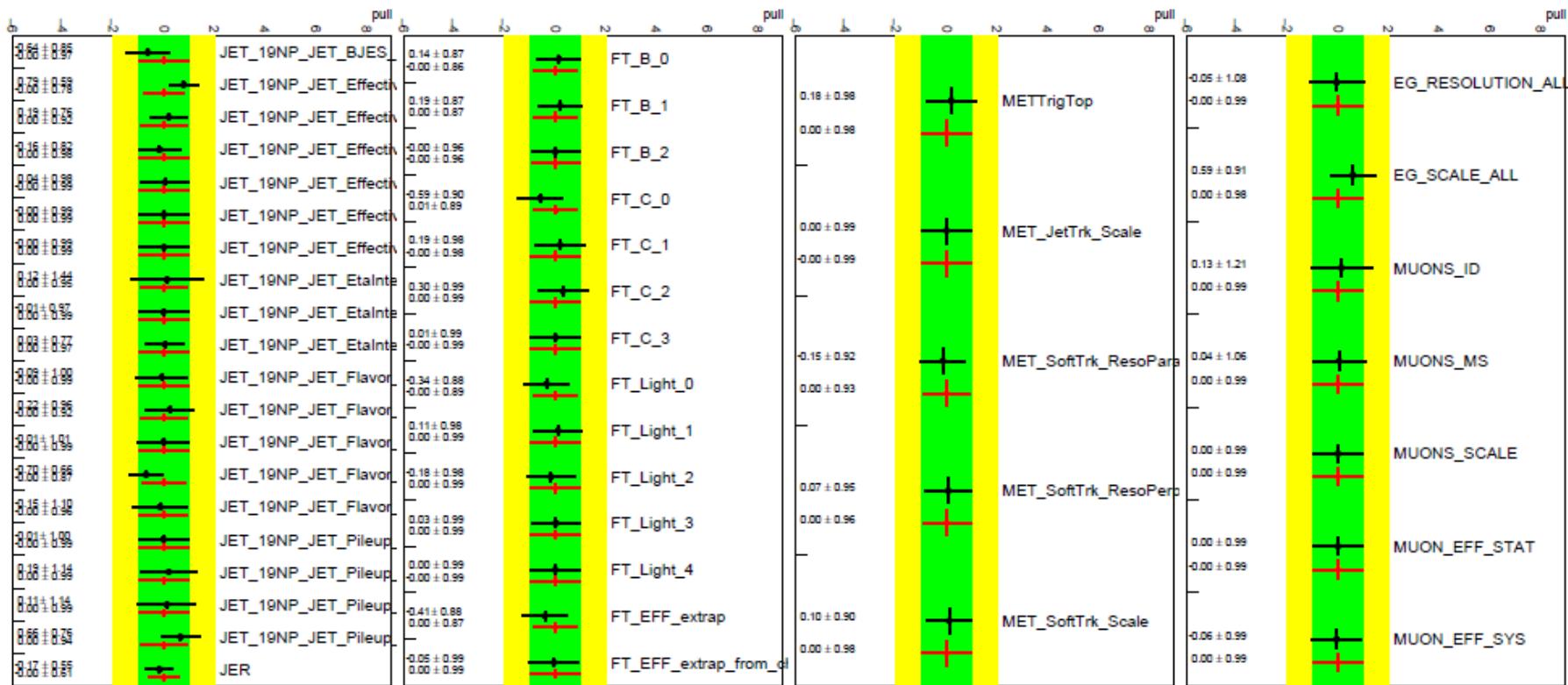
- The Muon will be removed when:

5. A muon is reconstructed within a cone of radius $\Delta R = 0.4$ around the jet axis of any surviving jets

- The Jet will be removed when:

2. The closest jet to an electron within a cone of radius $\Delta R = 0.2$ around the electron
4. A jet is reconstructed within $\Delta R < 0.2$ around a muon and the jet has fewer than three associated tracks
6. Jets that are reconstructed within a cone of radius $\Delta R = 0.2$ around the axis of a tau candidate

VH Fit Validation : NP Pulls

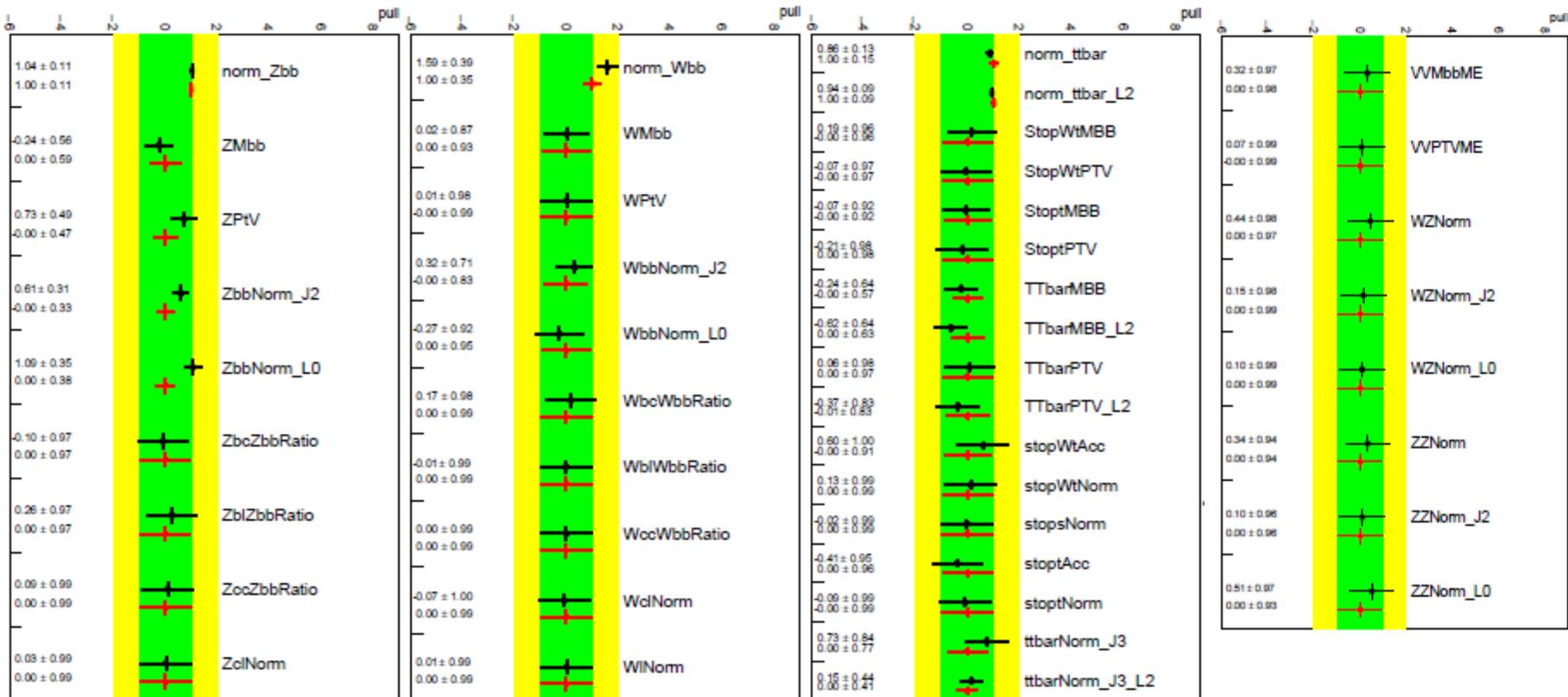


➤ Jet, b-tag, MET, lepton

➤ Asimov (red), data (black)

➤ Overall good behavior

VH Fit Validation : NP Pulls

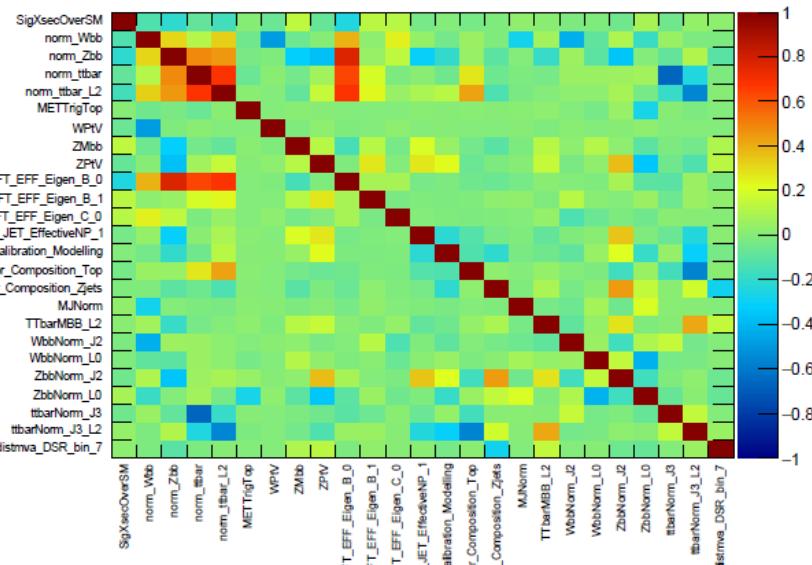
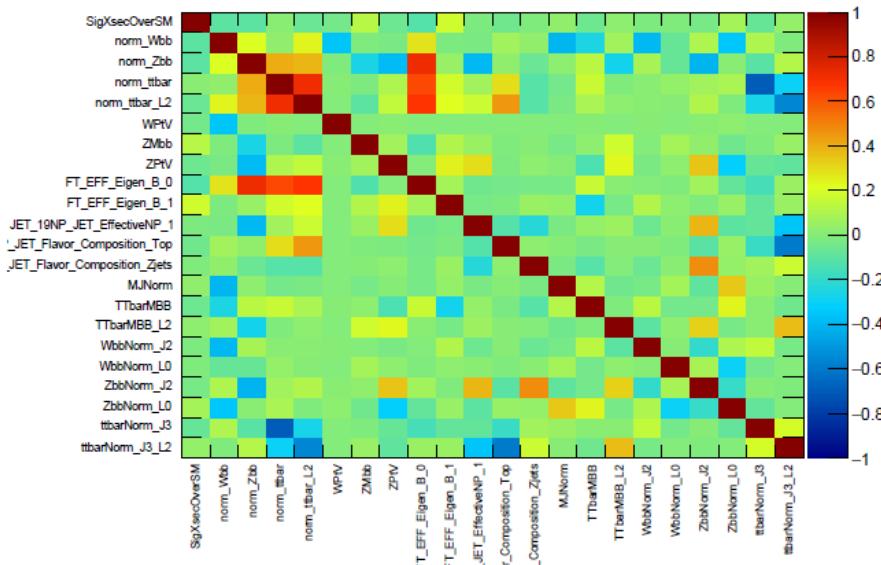


➤ Zjets, Wjets, Top, Diboson

➤ Asimov (red), data (black)

➤ Overall good behavior

VH Fit Validation : Correlation Matrices



➤ Asimov (left) and data (right) show the same pattern

Muon-in-jet correction

For the 0- and 1-lepton channels the second correction, PtReco, is a scaling of the jet 4-vector as a function of the jet pT after the muon-in-jet correction, derived in simulation by comparing the calibrated jet energy to the energy of matching truth jets.

In the 2-lepton channel, where the full $Z H \rightarrow llbb$ event kinematics can be reconstructed, an improvement in the Higgs boson mass reconstruction is achieved through the use of a likelihood based kinematic fit, instead of the PtReco correction

Jet correction variation	Sensitivity	
Jet correction	2 b -tagged 2jet	2 b -tagged 3jet
GSC (no correction)	0.316	0.230
OneMu (muon-in-jet)	0.329	0.239
PtReco	0.335	0.240
KF	0.340	0.249