$VH, H \to b\bar{b}$ in ATLAS

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for the ATLAS collaboration

Higgs Hunting Conference
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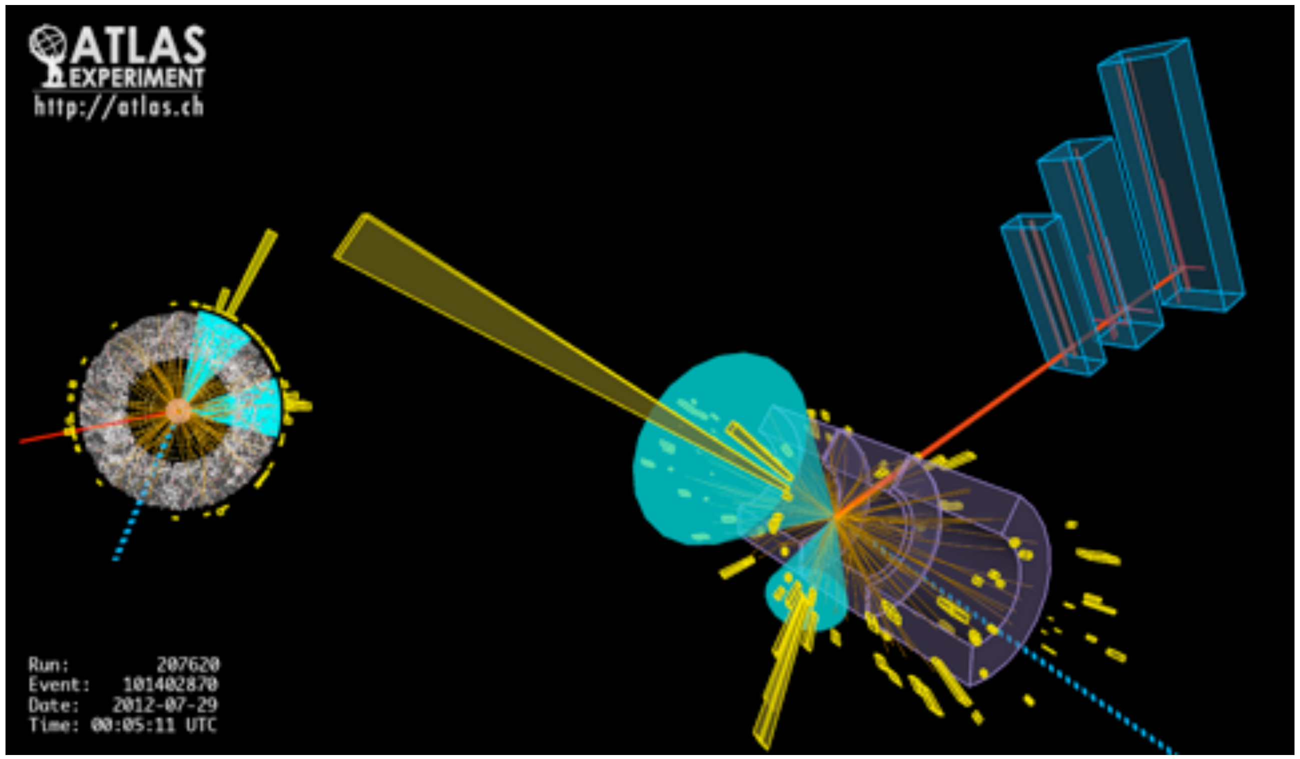
Introduction

Overview of ATLAS search of the VH, H→bb process*



Outline:

+ Event selection
+ Search strategy
+ Background modeling
+ Systematic uncertainties
+ Diboson Fit
+ Higgs Results

Latest result combines the full 2011 and 2012 ATLAS datasets

7 TeV pp collisions 4.7 fb^{-1}

8 TeV pp collisions 20.3 fb^{-1}

Result reported in: ATLAS-CONF-2013-079

*see Jason Lee's talk for more H→bb (SM and BSM)

Analysis overview

Associated production VH, H→bb
+ provides signatures for triggering and to reduce backgrounds

Common selection:

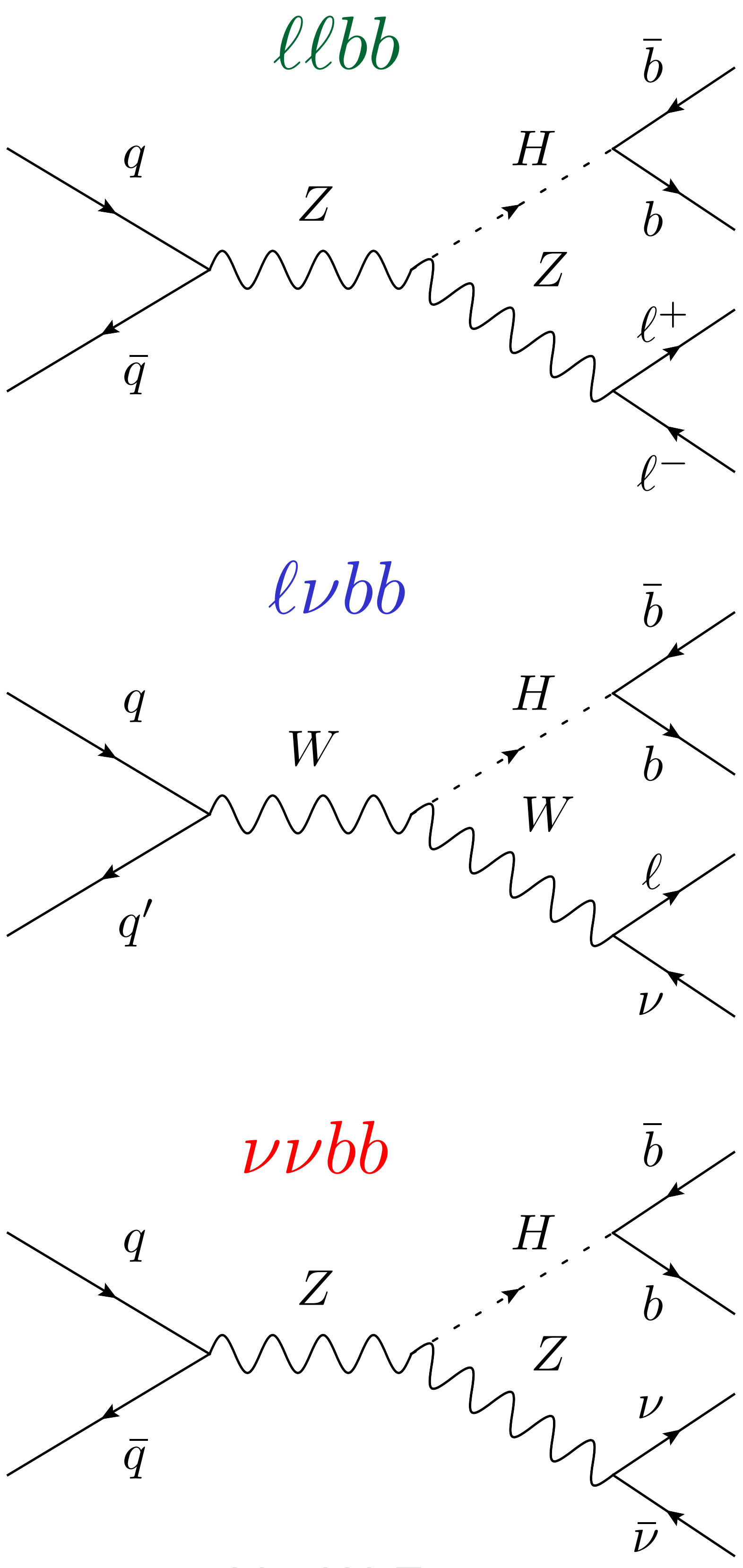
+ Reconstruct vector boson candidate (W→lν, Z→νν, Z→ll; l=e,μ)

+ Reconstruct the Higgs candidate
    + 2 jets (pT > 20 GeV and central region)
    + Leading jet pT > 45 GeV
    + Both jets b-tagged (70% efficiency)
    + ΔR cuts between the two leading jets depending on transverse momentum of vector boson - $p_T(V)$

+ Channel-specific kinematic cuts to suppress QCD and other backgrounds (see backup slides)

$p_T(V)$ defined as:

W→lν: p_T(l+missing transverse energy)
Z→ll: p_T(ll)
Z→νν: p_T(missing transverse energy)



V = W, Z

Search Strategy

Perform analysis by defining different event categories to exploit different sensitivities

- Different categories are dominated by different backgrounds

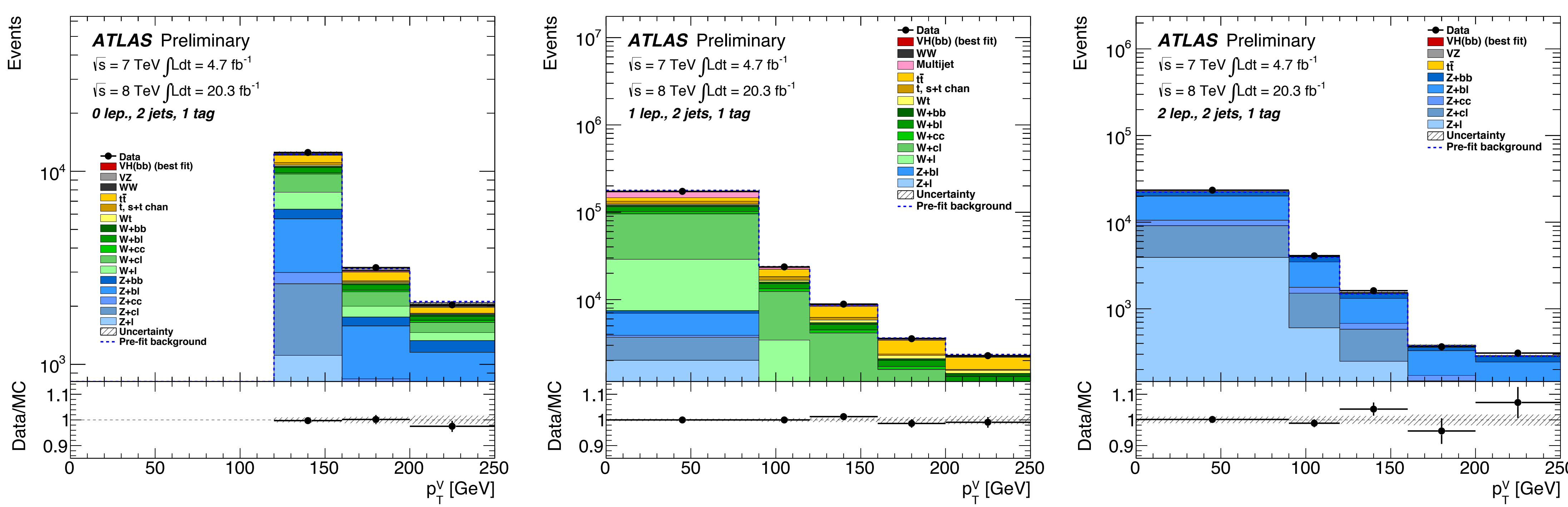
MET trigger efficiency, backgrounds

signal region

	2 jets, 1 tag	3 jets, 1 tag	2 jets, 2tags	3 jets, 2 tags	top eμ CR	
0-lepton	W+jets/Z+jets	W+j/Z+j/Top	Top/Z+b	Top/Z+b	-	x 3 $p_T(V)$ bins
1-lepton	W+c	W+c / Top	W+b / Top	Top	-	x 5 $p_T(V)$ bins
2-lepton	Z+c	Z+c	Z+b	Z+b	Top	x 5 $p_T(V)$ bins
	norm.	norm.	shape	shape	norm.	

- Each category divided in bins of $p_T(V)$:

	$p_T(V)$	0-90	90-120	120-160	160-200	>200
1-lepton 2-tag 2-jet e.g.	$S/\sqrt{(S+B)}$	0.10	0.06	0.06	0.09	0.13



2-jet 1-tag $p_T(V)$ distribution

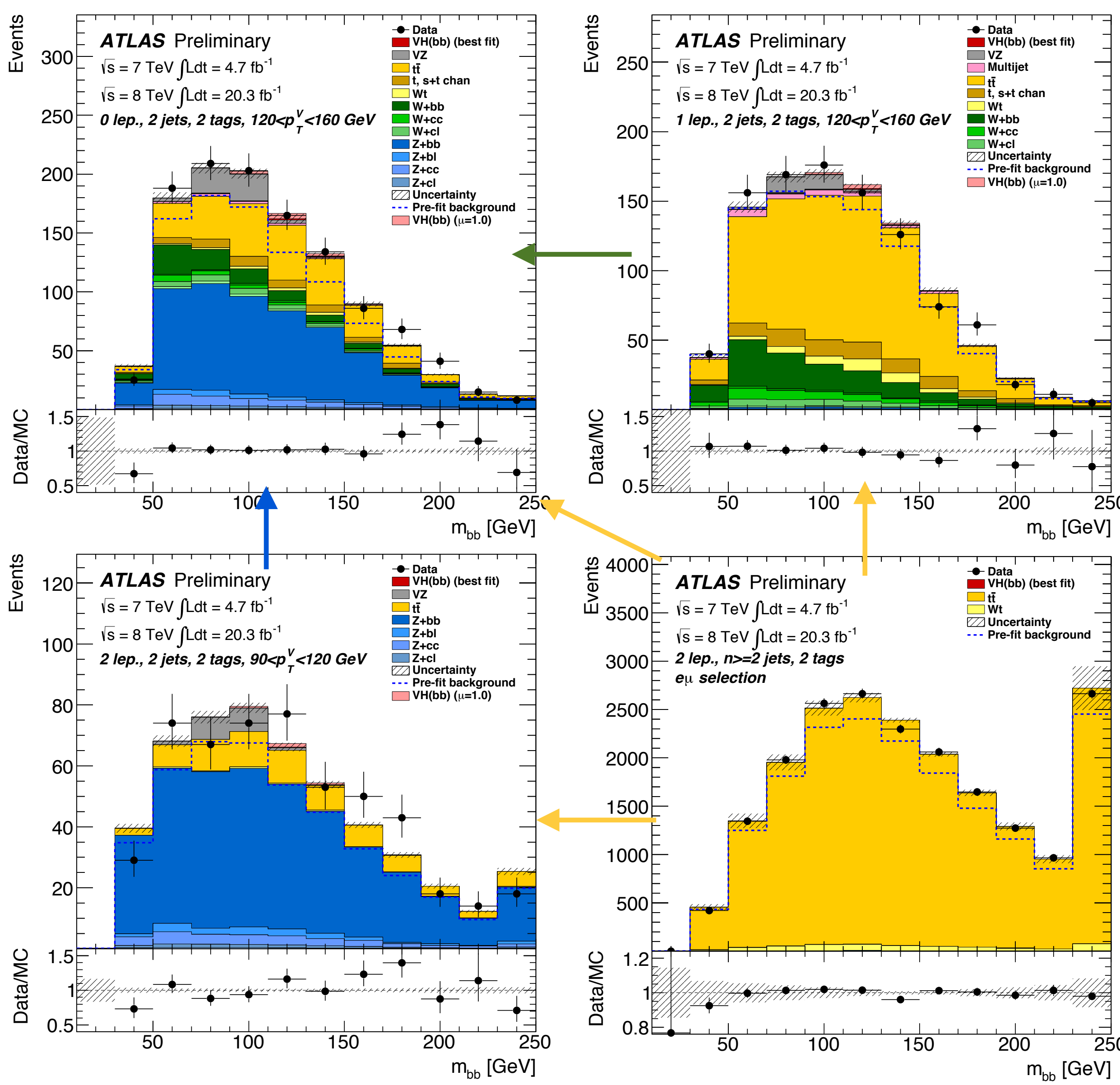
Background modeling

Global fit

Interplay between regions helps constrain shape and normalization of backgrounds, within uncertainties

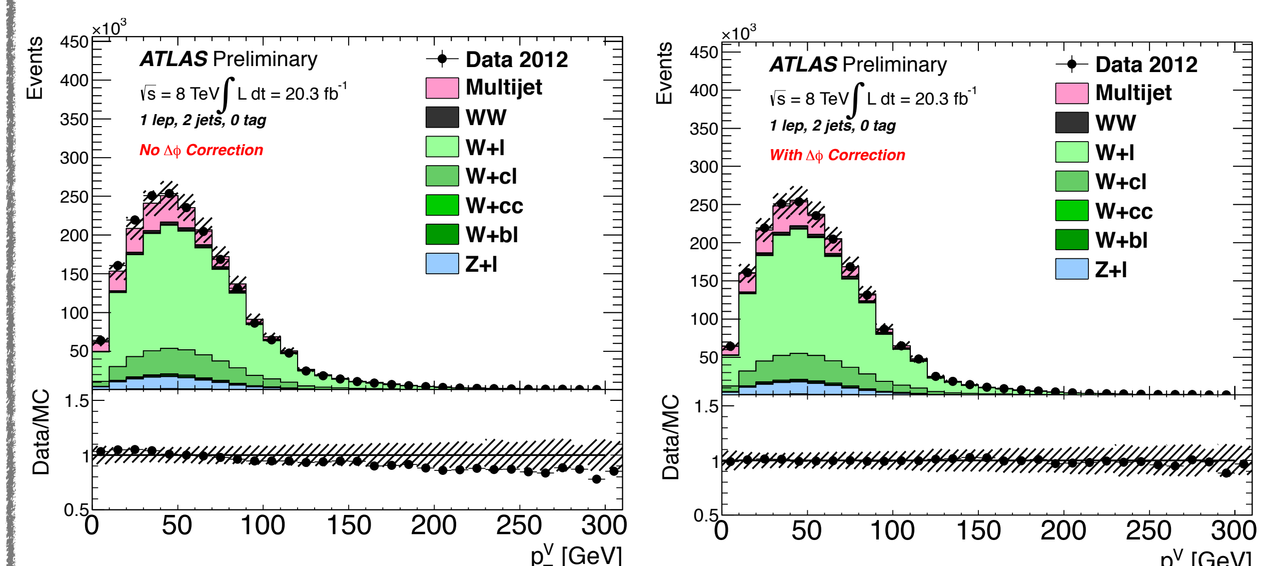
+ Normalization freely-floating in the fit for main background processes
+ MC generators consistent across channels and datasets (2011 and 2012)

Example post-fit plots: 2-tag 2-jet and top CR



MC mismodeling of data

+ truth top p_T correction derived from dedicated study
+ Δϕ correction for V+jets Sherpa, improving modeling of other distributions



ttbar Powheg+Pythia	W+jets (ll,cl,cc,bl,bb) Sherpa	Z+jets (ll,cl,cc,bl,bb) Sherpa	WH/ZH Pythia8	single-top Acer/Powheg	Diboson Herwig	Multijet data-driven

Systematic uncertainties

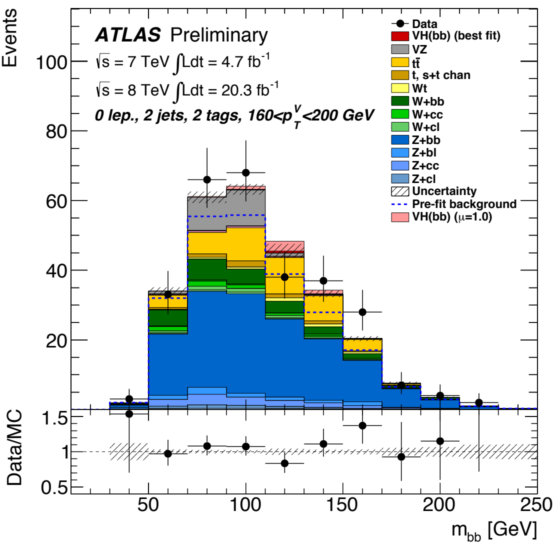
Background Modeling

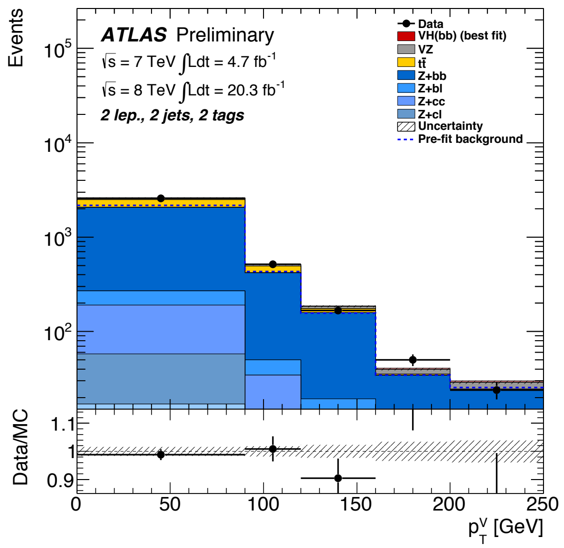
MC comparisons, data-driven studies

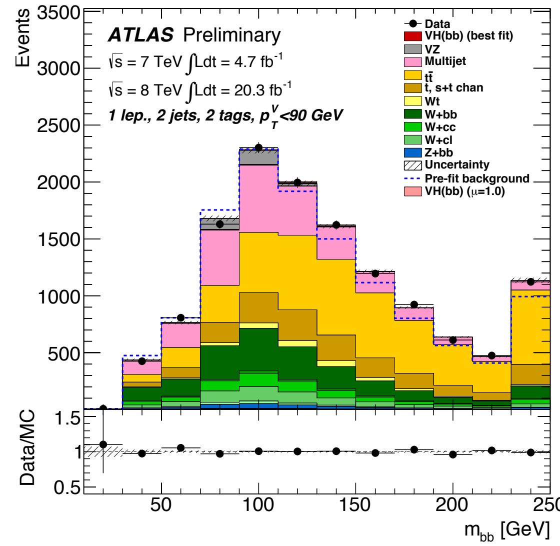
Mbb shape

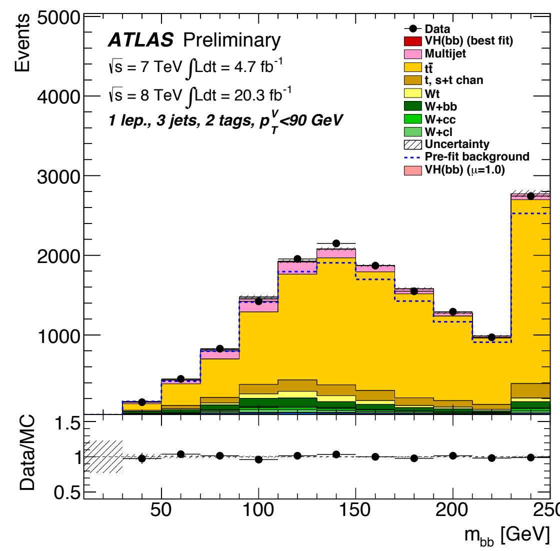
$p_T(V)$ bin norm.

2 to 3 jet ratio









Determine how these shapes and ratios are affected by:

+ ISR/FSR
+ higher order effects in QCD
+ shower and hadronization models

Diboson MCFM

ttbar MC@NLO/Powheg+Herwig/AcerMC

single-top MC@NLO/Powheg+Herwig/AcerMC

W+bb Powheg and aMC@NLO

data-driven for Z+jets and multijet

+ uncertainties on flavor composition, cross-section

Theoretical (signal)

+ NLO EW corrections
+ ren. and fact. scales
+ PDF's
+ signal acceptance

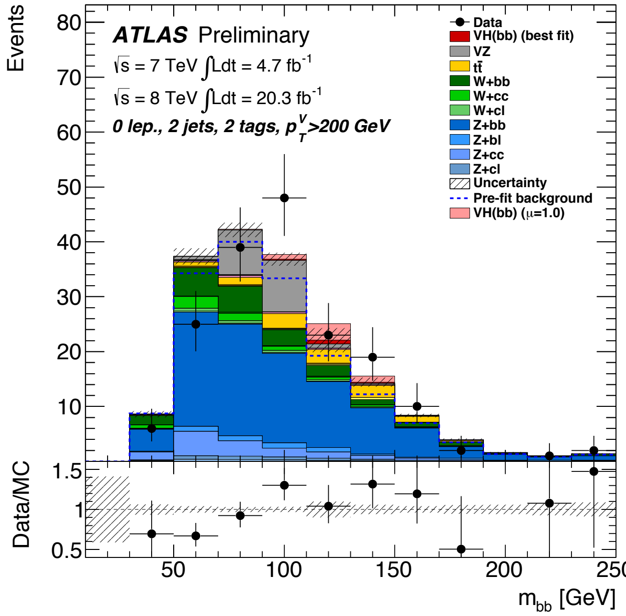
Experimental

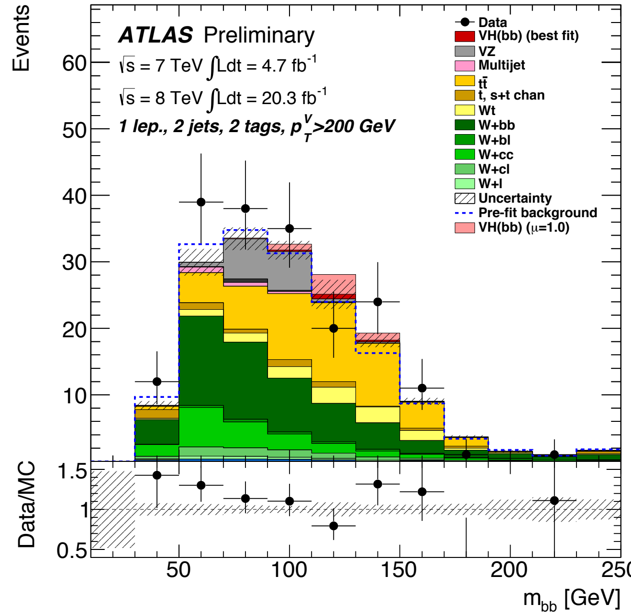
+ luminosity
+ trigger
+ lepton ID & reconstruction
+ b-tagging uncertainties
+ jet energy scale

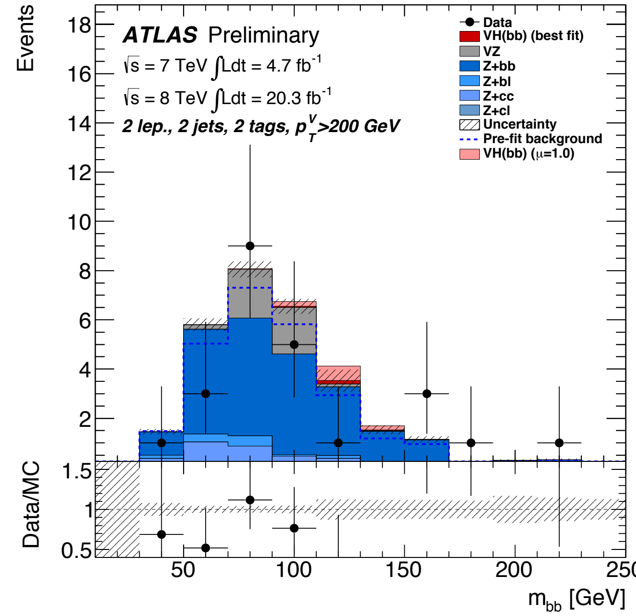
Dominant systematic uncertainties are related to b-tagging and top modeling

All treated as nuisance parameters in the global fit

Fit validation: diboson peak







Fit Results

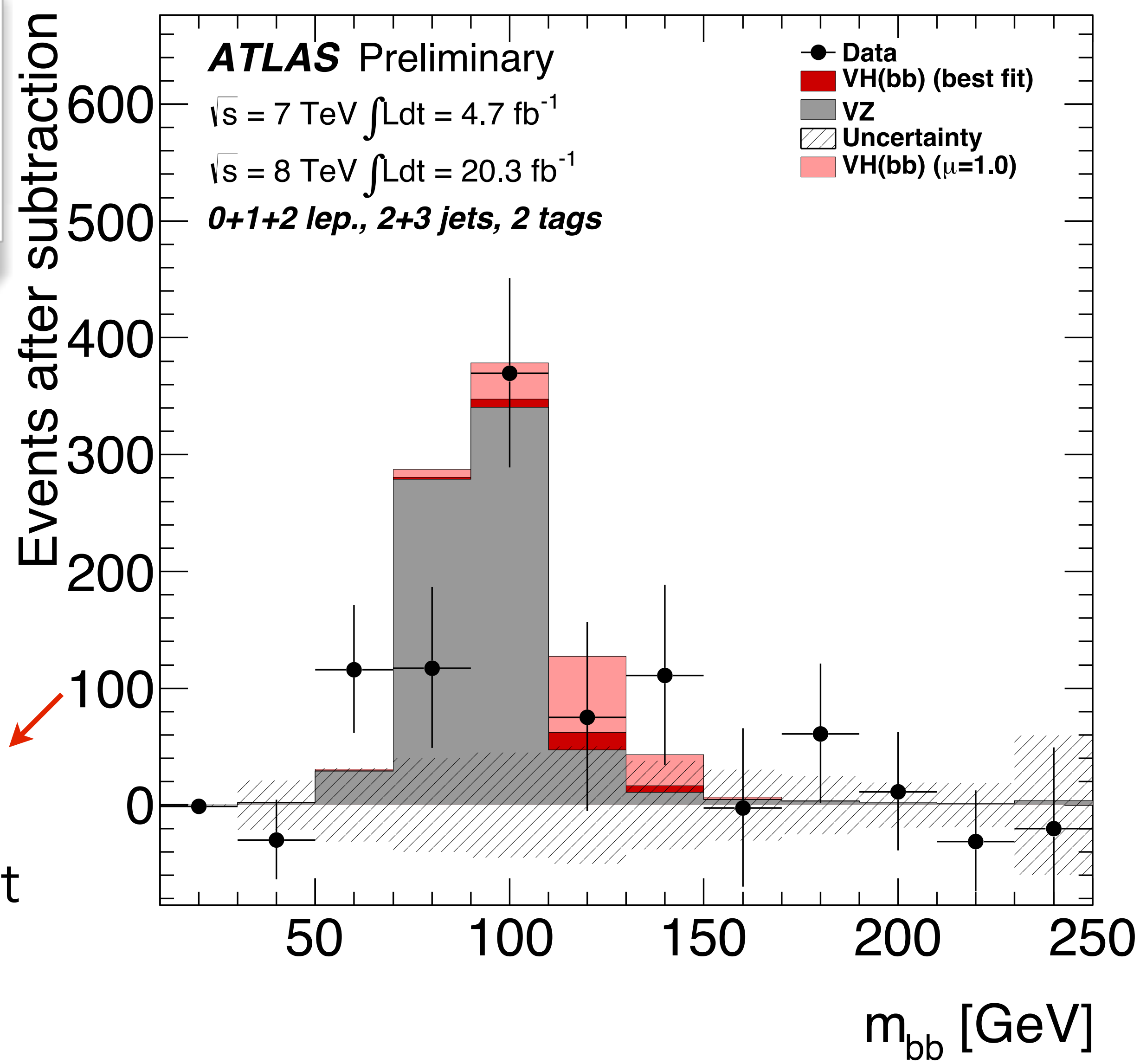
M_{bb} for 2-jet 2-tag highest $p_T(V)$ bin

Good agreement between data and signal +background expectation

Validation of fit model with identical procedure used for the Higgs boson search

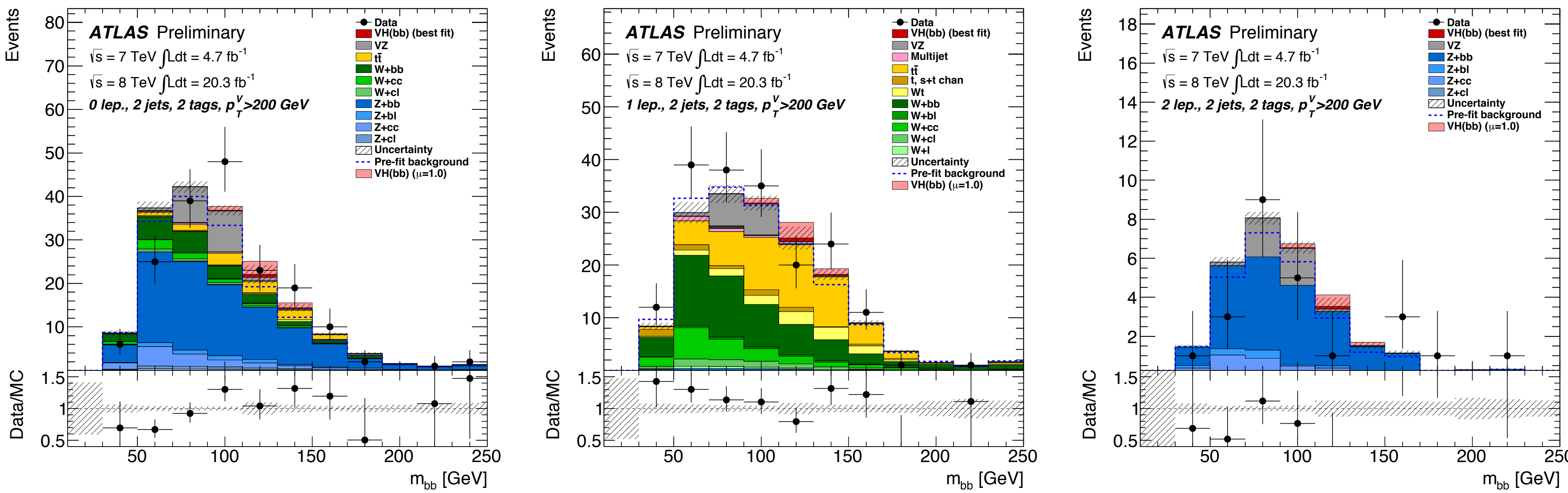
Diboson production with a Z→bb (ZZ, WZ)

Obs. (exp.) significance 4.8 (5.1) s.d.



In light red: SM Higgs peak with μ = 1
In dark red: Higgs peak with fit μ result

Fit validation: diboson peak



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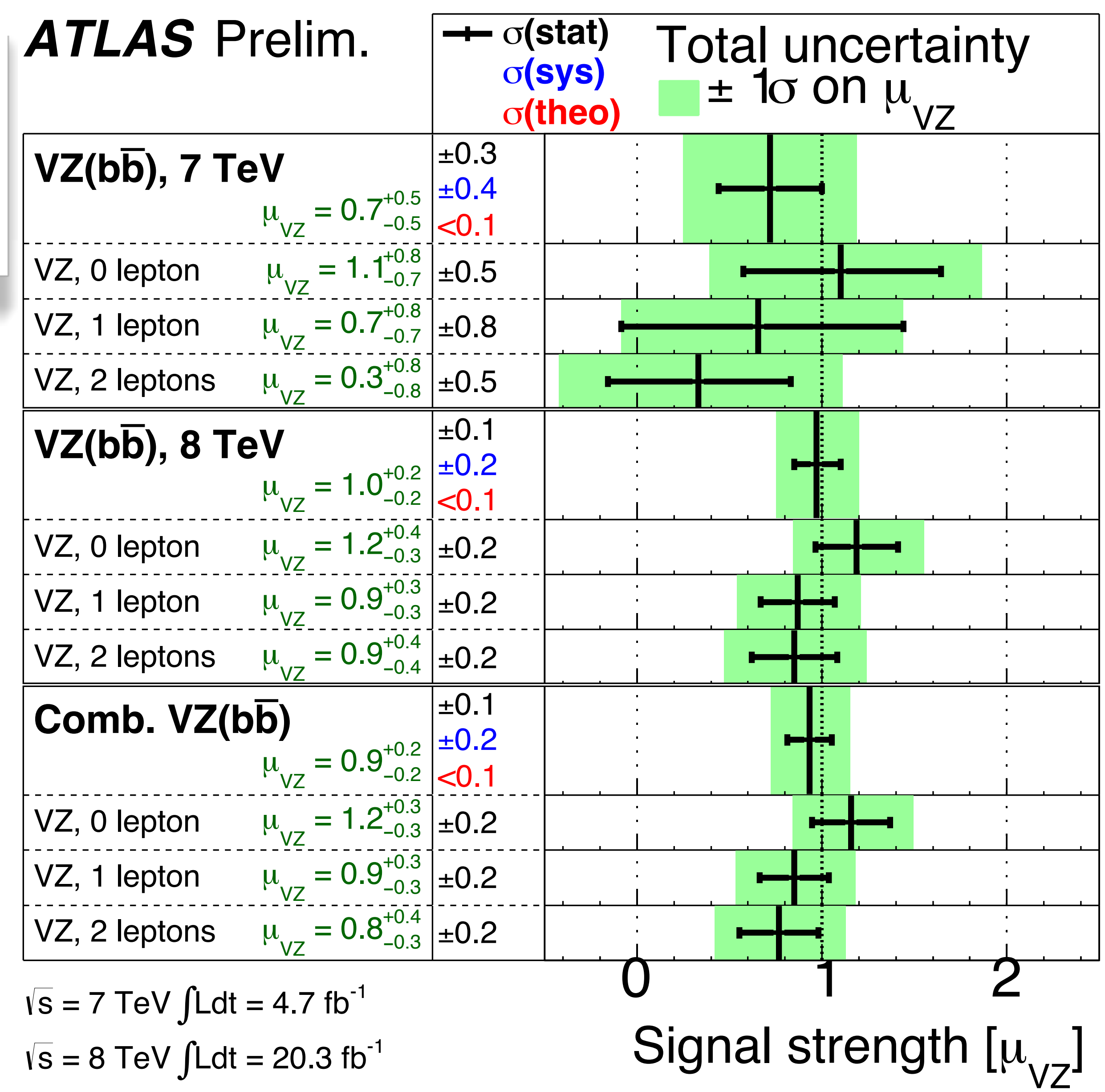
Diboson production with a Z→bb (ZZ, WZ)

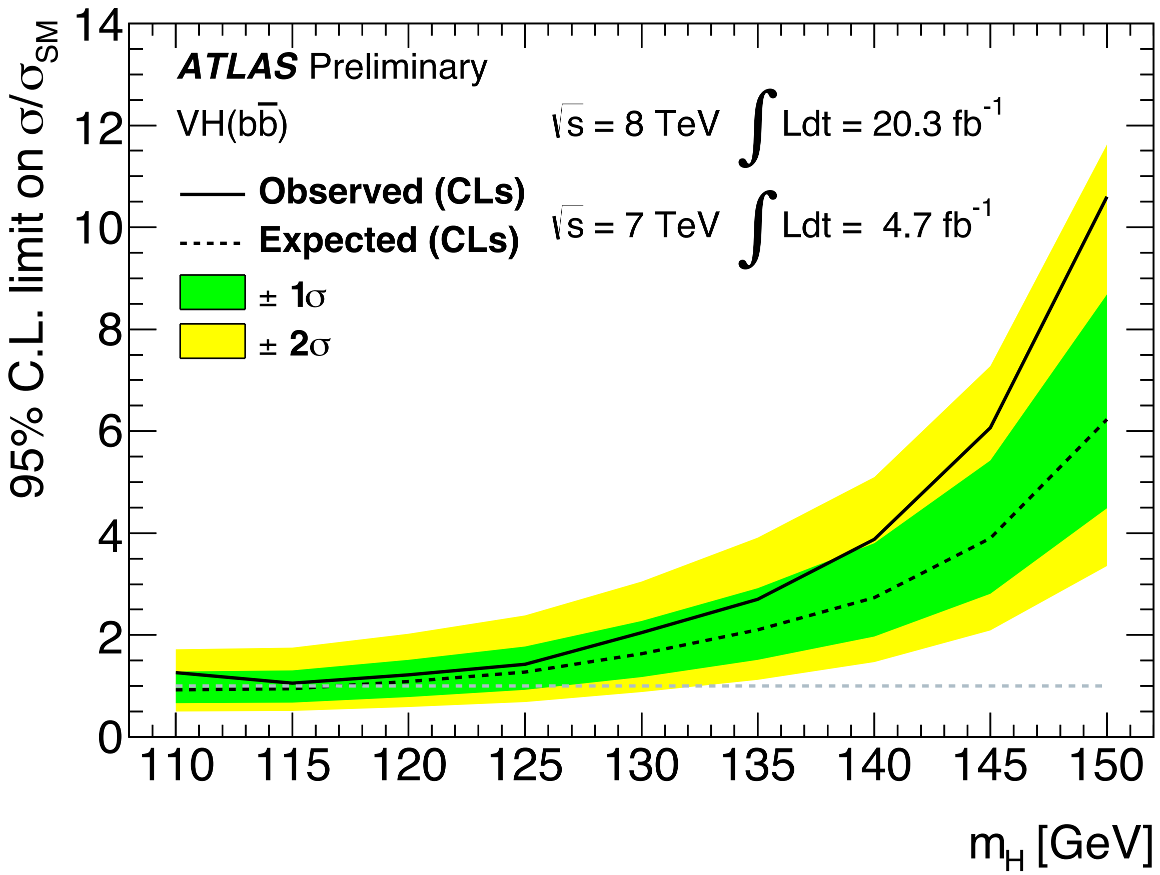
$$\mu_{VZ} = 0.9 \pm 0.2$$

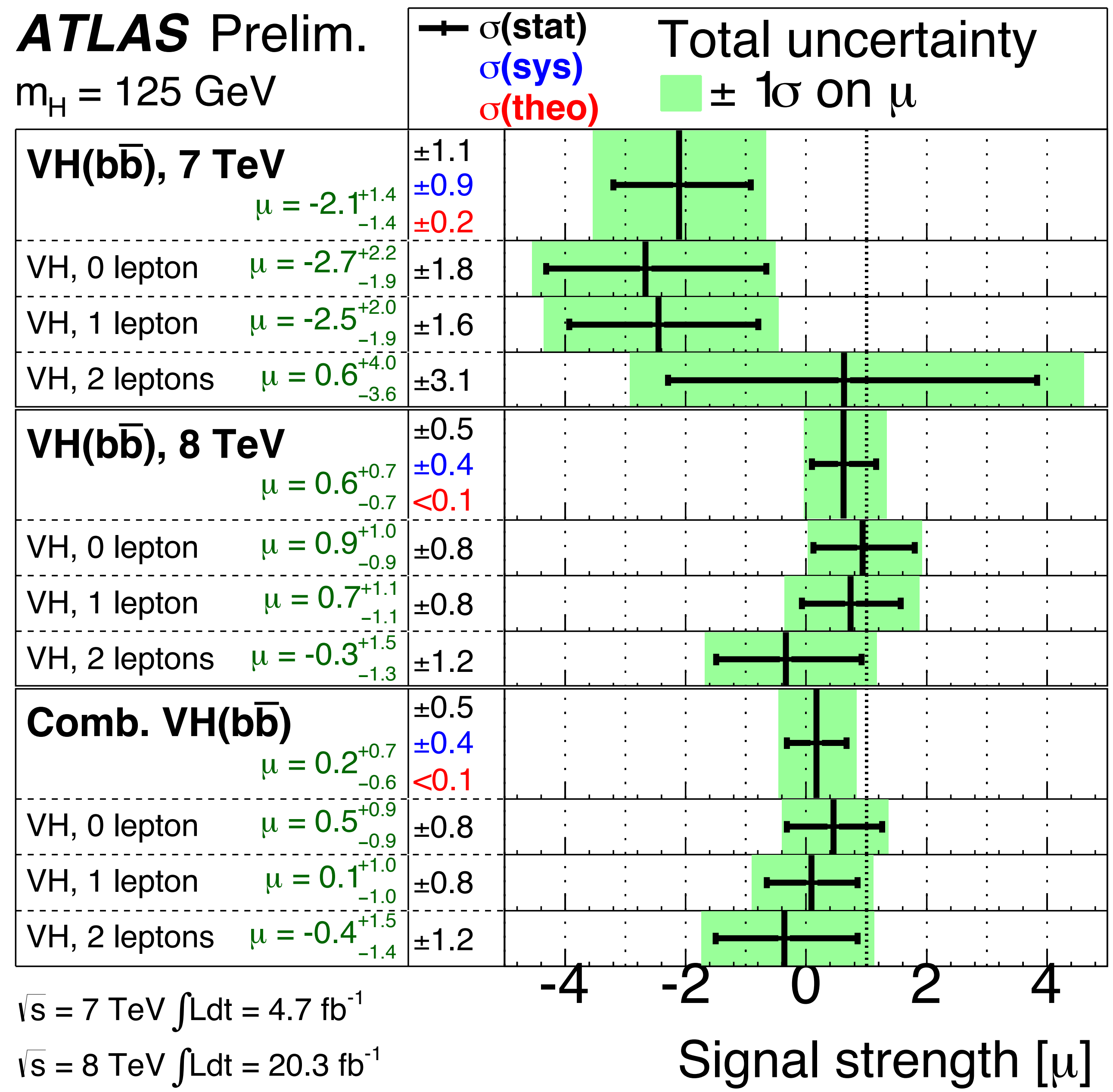
compatible with SM expectation of 1



Perform fit for the Higgs signal

+ diboson contributions now constrained to their Standard Model values
+ no significant excess is observed





+ obs. (exp.) limits at 125 GeV: 1.4 (1.3) xSM @ 95% CL

+ obs. (exp.) probability of obtaining a result at least as signal-like: 0.36 (0.05)

The fitted value of the signal strength parameter is:

$$\mu = 0.2 \pm 0.5(\text{stat.}) \pm 0.4(\text{syst.})$$

$$m_H = 125\text{GeV}$$

Summary

+ New preliminary results on the ATLAS search for VH, H→bb production
    + combination of full 7 TeV (4.7 fb^{-1}) and 8 TeV (20.3 fb^{-1}) datasets

+ The diboson VZ cross-section measurement is consistent with SM prediction with an observed (expected) significance of 4.8 (5.1) standard deviations.

+ The search for VH production is performed and a combined observed (expected) limit of 1.4 (1.3) x SM at 95% CL is obtained

+ The observed signal strength is $\frac{\sigma_{VH\to b\bar{b}}}{\sigma_{SM}} = 0.2 \pm 0.5(\mathrm{stat.}) \pm 0.4(\mathrm{syst.})$

Beyond the gain from the increased integrated luminosity, the analysis has achieved ~35% increase in sensitivity

Fit to Higgs peak is consistent with both a SM Higgs and no SM Higgs: more data needed to resolve the two hypotheses

Backup slides

Analysis cuts

Table 1: The basic event selection for the three channels.

Object	0-lepton	1-lepton	2-lepton
Leptons	0 loose leptons	1 tight lepton + 0 loose leptons	1 medium lepton + 1 loose lepton
Jets	2 b-tags $p_{\mathrm{T}}^{jet_1} > 45$ GeV $p_{\mathrm{T}}^{jet_2} > 20$ GeV $+ \leq 1$ extra jets		
Missing E_T	$E_{\mathrm{T}}^{\mathrm{miss}} > 120$ GeV $p_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV $\Delta\phi(\boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}, \boldsymbol{p}_{\mathrm{T}}^{\mathrm{miss}}) < \pi/2$ $\min[\Delta\phi(\boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}, \mathrm{jet})] > 1.5$ $\Delta\phi(\boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}, bb) > 2.8$	$E_{\mathrm{T}}^{\mathrm{miss}} > 25$ Gev	$E_{\mathrm{T}}^{\mathrm{miss}} < 60$ GeV
Vector Boson	-	$m_{\mathrm{T}}^{W} < 120$ GeV	$83 < m_{\ell\ell} < 99$ GeV

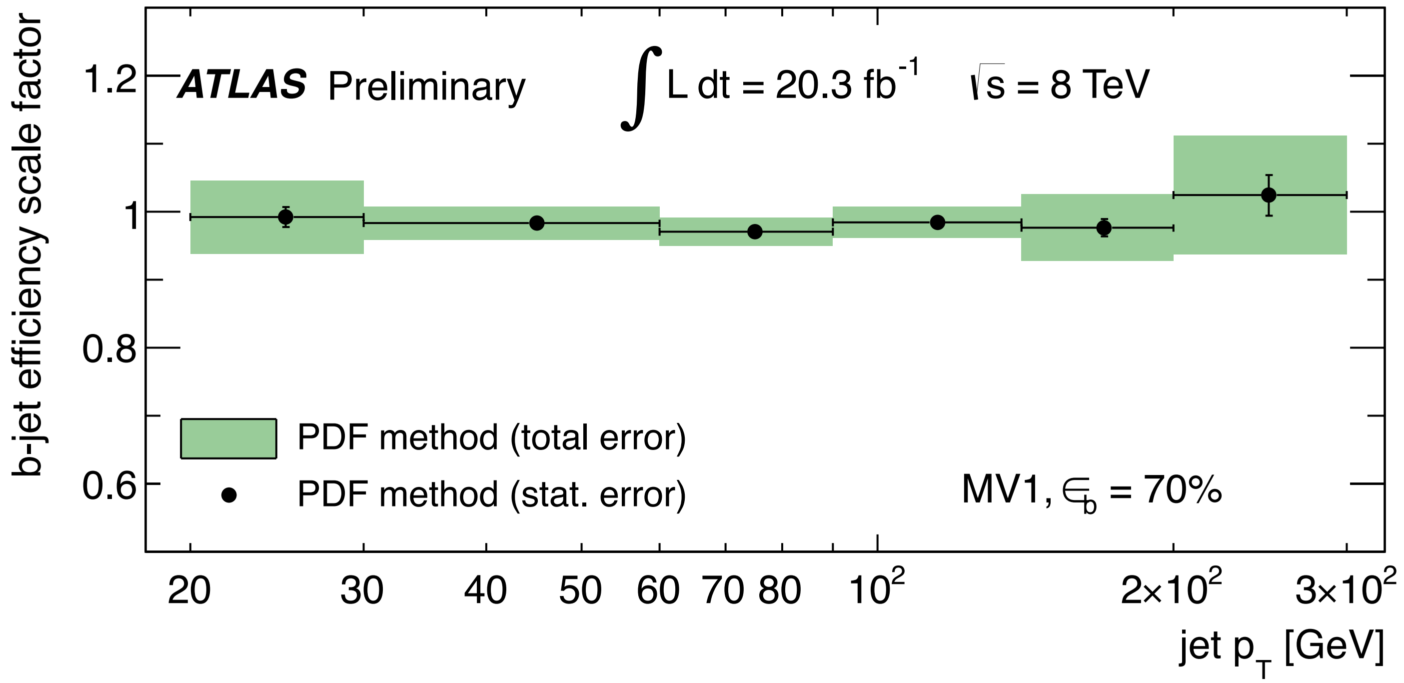
Table 2: Further topological criteria in p_{T}^{V} intervals. The 0-lepton channel does not use the lowest two p_{T}^{V} intervals.

	p_{T}^{V} [GeV]	0-90	90-120	120-160	160-200	>200
All Channels	$\Delta R(b, \bar{b})$	0.7-3.4	0.7-3.0	0.7-2.3	0.7-1.8	<1.4
1-lepton	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	>25				>50
	m_{T}^{W} [GeV]	40-120			<120	

Main changes since previous result

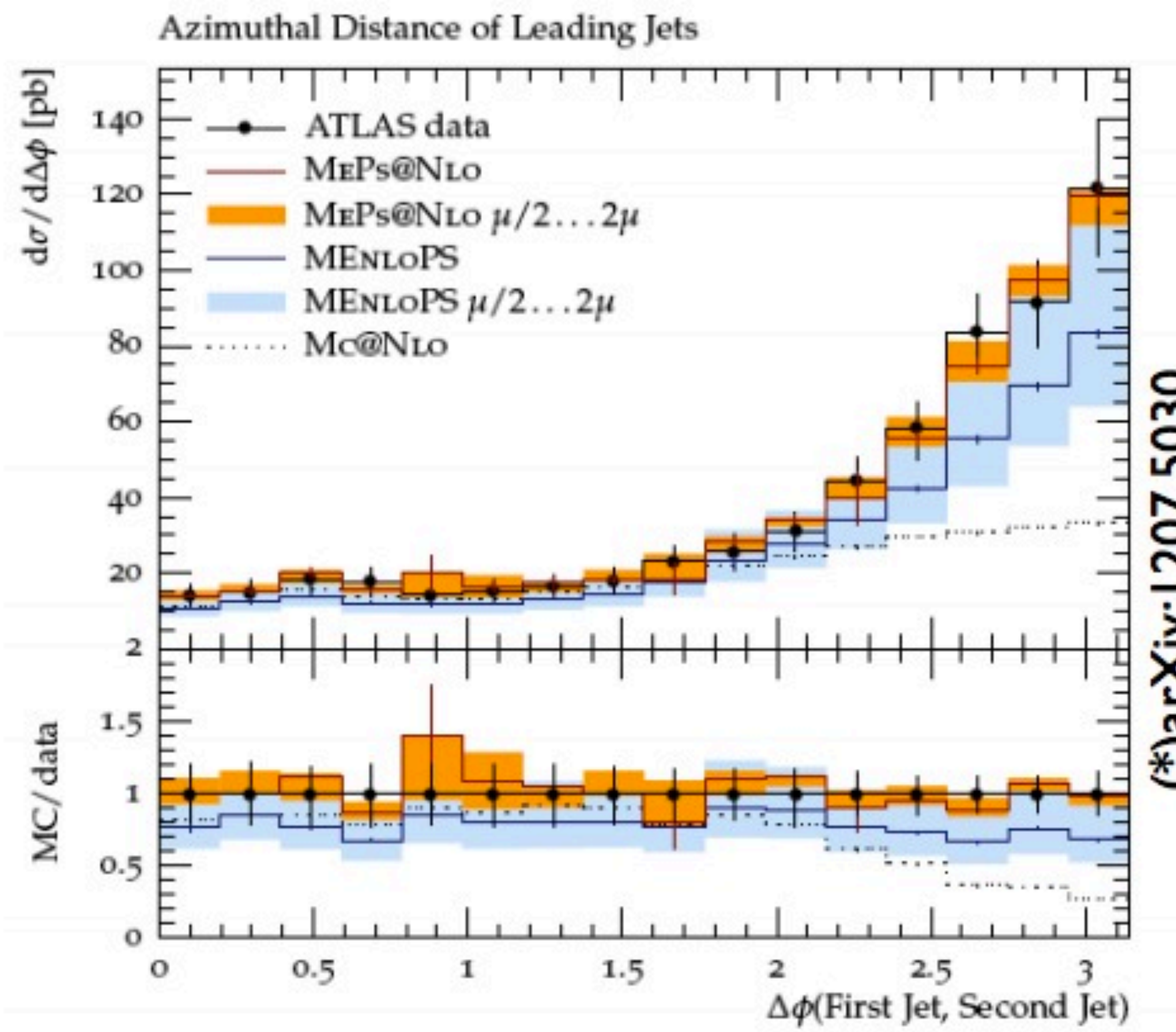
- Improved Monte-Carlo statistics and coherent choice of generators
- Optimization and uniformization of selection cuts
- New control region for top background with high purity
- Missing transverse energy based trigger to recover sensitivity in 1-lepton selection
- Reduced impact of experimental systematic uncertainties
  - improved b-tagging systematic assignment based on top eμ sample with >=4 jets
- Better understanding of background modeling systematics for all backgrounds
  - detailed studies on top and W+jets

b-tagging calibration



reduced uncertainties from 5% to 2%
on the intermediate p_T region

Delta Phi in NLO calculations



(*)arXiv:1207.5030

Fit Model

Description of the procedure

Combined profile likelihood fit

+ Likelihood of Poisson probabilities:

$$L(\mu,\theta) = \prod_{j=1}^{N} \frac{(\mu s_j + b_j)^{n_j}}{n_j!} e^{-(\mu s_j + b_j)} \prod_{k=1}^{M} \frac{u_k^{m_k}}{m_k!} e^{-u_k}$$

+ signal and background parameterizations:

$$s_i = s_{tot} \int_{\text{bin } i} f_s(x;\theta_s)dx \qquad b_i = b_{tot} \int_{\text{bin } i} f_b(x;\theta_b)dx$$

+ test mu hypothesis with a test statistic:

$$\Lambda(\mu) = \frac{L(\mu,\hat{\hat{\theta}}(\mu))}{L(\hat{\mu},\hat{\theta})}$$

θ : “nuisance parameters”

Detailed results