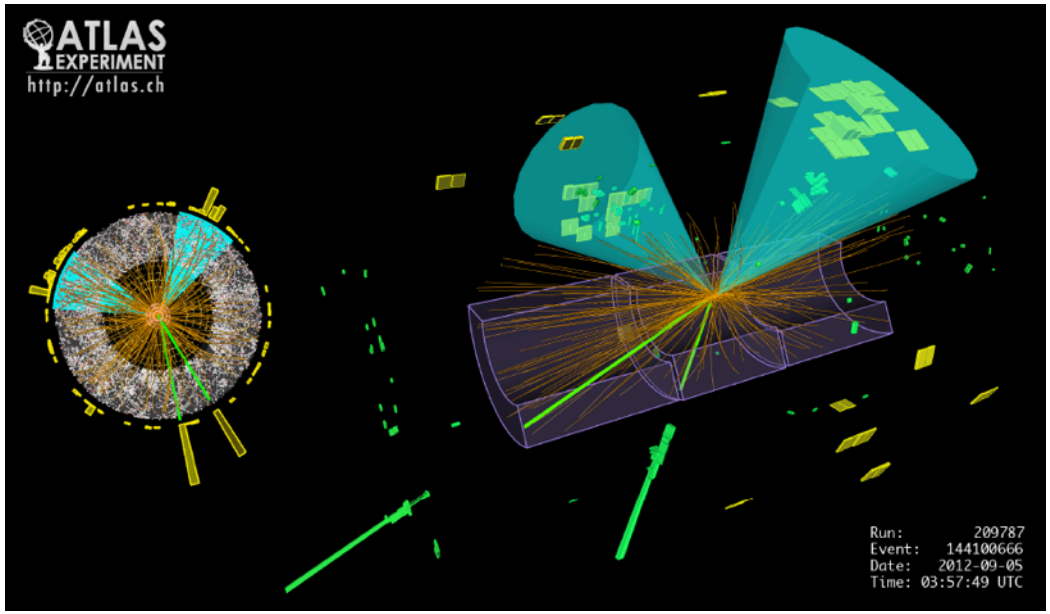
Search for the Higgs Boson in the VH(H→bb) Channel using the ATLAS Detector



- Introduction
- Event selection
- Modeling of backgrounds
- Diboson fit results
- Higgs fit results
- Conclusions

David López Mateos, Harvard University, for the ATLAS Collaboration,
EPS High Energy Conference, July 18th, 2013

Introduction

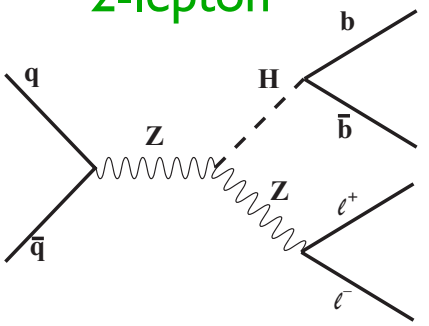
- Search for H→bb associated with V (Z or W) exploring 3 channels simultaneously (Z→νν, Z→ℓℓ, W→ℓν)

- Hope to provide first evidence/measurement of coupling to b-quarks at the LHC

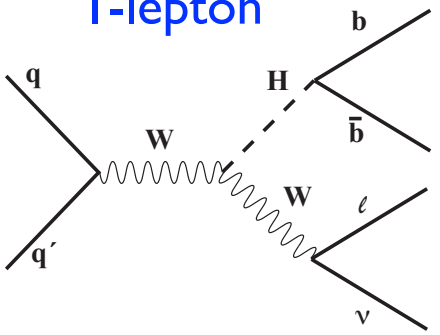
- Previous result used only 13 fb^{-1} of 2012 data (+5 fb^{-1} of 2011 data), improvements were needed to reach SM sensitivity (ATLAS-CONF-2012-161)

- First presentation of full 2012 dataset for this analysis with significant analysis improvements (ATLAS-CONF-2013-079)

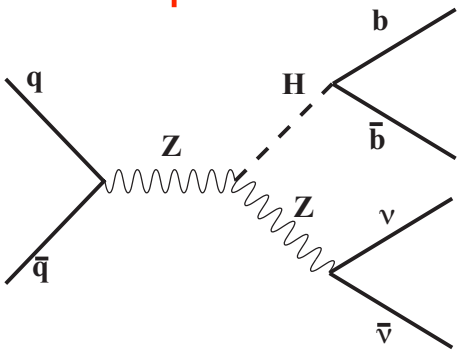
2-lepton



1-lepton



0-lepton



Event Selection

Common selection

-At least two jets with p_T^1>45 GeV, p_T^2>20 GeV and |η|<2.5

-Leading (subleading) lepton (e, μ) p_T>25 (10) GeV

-Leptons (e, μ) required to be isolated

p_T^V bin (GeV)	0-90 1-lep, 2-lep	90-120 1-lep, 2-lep	120-160 all channels	160-200 all channels	>200 all channels
ΔR(j,j)	0.7-3.4	0.7-3.0	0.7-2.3	0.7-1.8	<1.4

- Additional channel-specific selections for boson selection and QCD rejection (see back-up slides)

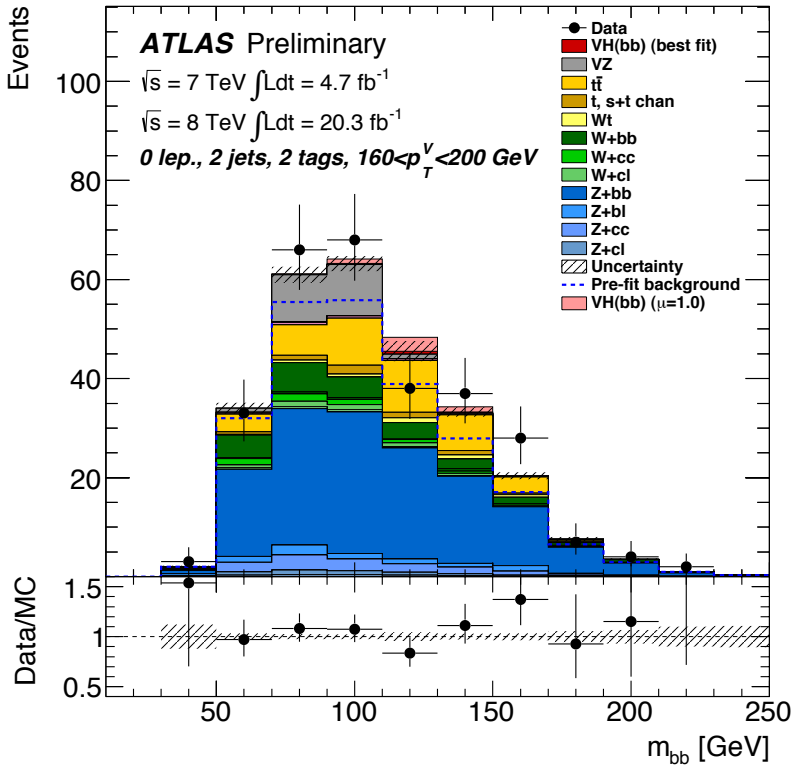
	2jets, 1tag	3jets, 1tag	2jets, 2tag	3jets, 2tag	top e-μ CR
3 p_T^V bins x **0-lepton**	CR	CR	SR	SR	-
5 p_T^V bins x **1-lepton**	CR	CR	SR	SR	-
5 p_T^V bins x **2-lepton**	CR	CR	SR	SR	CR

CR=Control Region (low S/B)
SR=Signal Region

1 electron+1 muon
$m_{e\mu}$>40 GeV

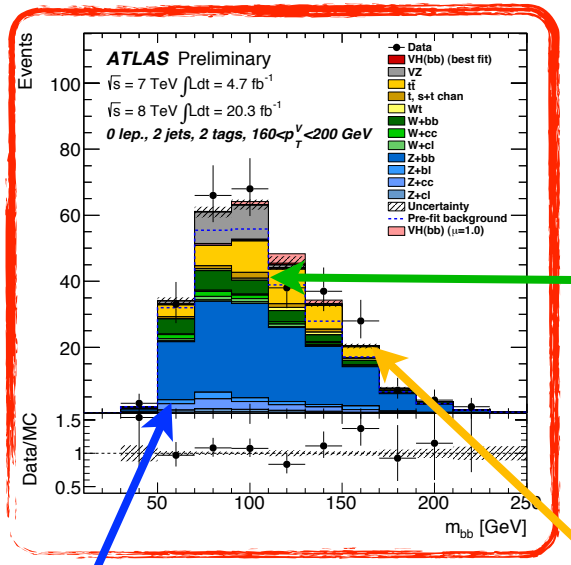
Regions Entering the Fit

		2jets, 1tag	3jets, 1tag	2jets, 2tag	3jets, 2tag	top e-μ CR
3 p_T^V bins x	**0-lepton**	Norm.	Norm.	Shape	Shape	-
5 p_T^V bins x	**1-lepton**	Norm.	Norm.	Shape	Shape	-
5 p_T^V bins x	**2-lepton**	Norm.	Norm.	Shape	Shape	Norm.

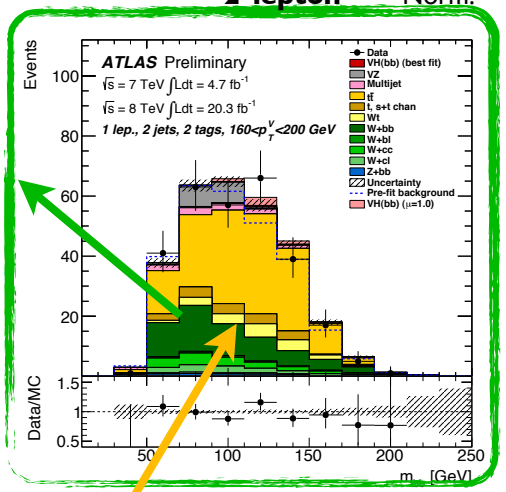


Interactions Between Regions in the Fit

	2jets, 1tag	3jets, 1tag	2jets, 2tag	3jets, 2tag	top e-μ CR
0-lepton	Norm.	Norm.	Shape	Shape	-
1-lepton	Norm.	Norm.	Shape	Shape	-
2-lepton	Norm.	Norm.	Shape	Shape	Norm.

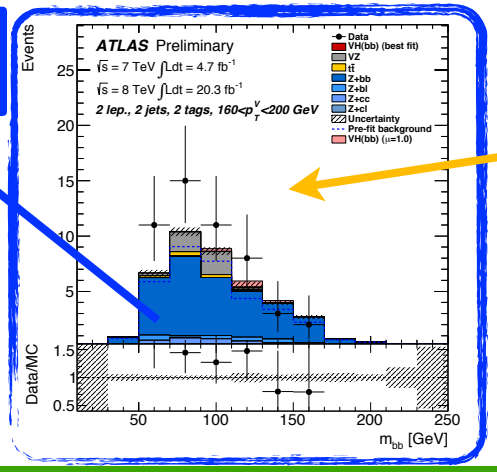


W+jets

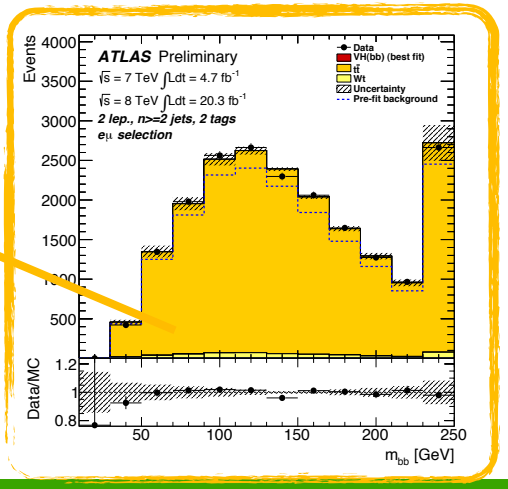


- Common nuissance parameters across regions
- Systematics on extrapolation of backgrounds between regions

Z+jets



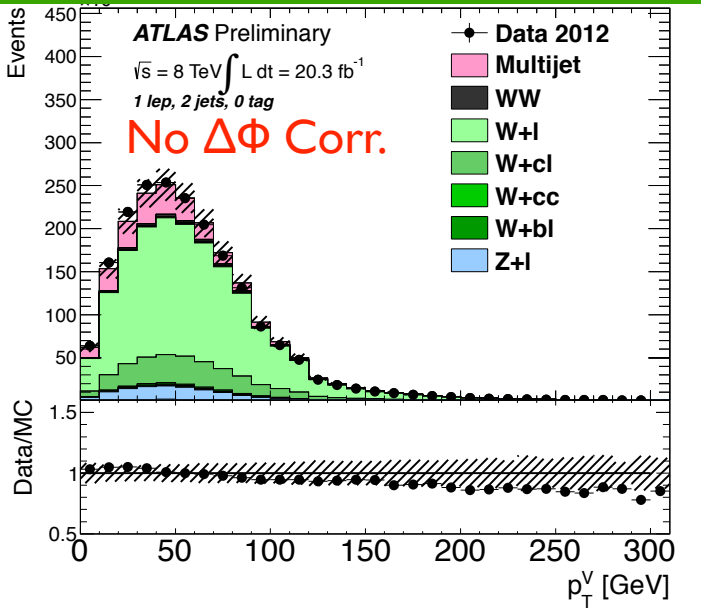
Top

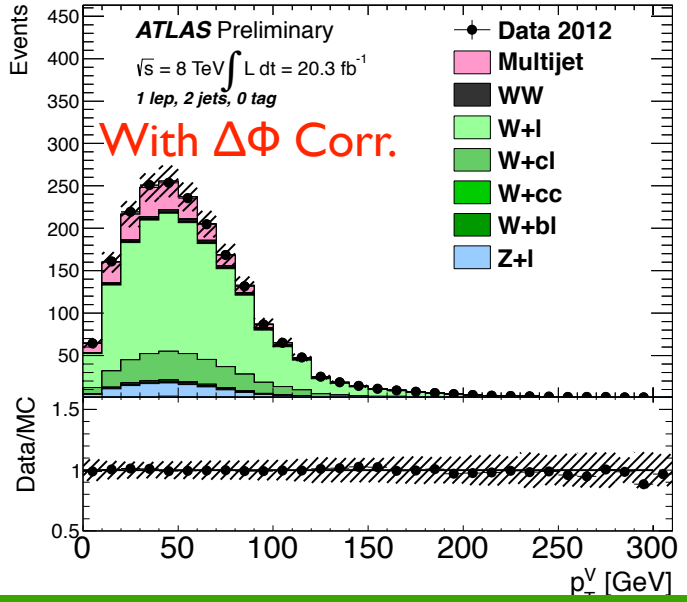


Background Modeling Systematics

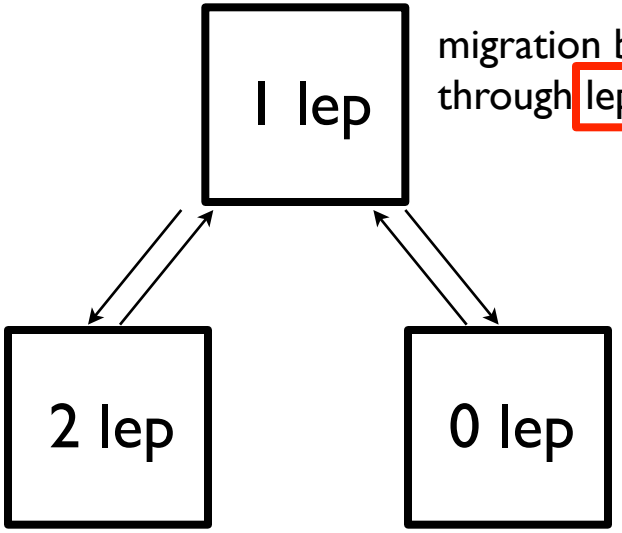
	m_{bb}	$\Delta\Phi$	$p_T^{V,top}$	3-to-2-jet ratio
tt	MC	-	data	MC
W+jets	MC	data	data	MC
Z+jets	data	data	-	MC
single top	MC	-	MC	MC
Diboson	MC	-	MC	MC

- $\Delta\Phi$ correction derived from data, consistent with NLO expectations (modifies p_T^V)
- MC-based systematics include different UE/PS tunes, generators, NLO vs LO (when available), renormalization scales



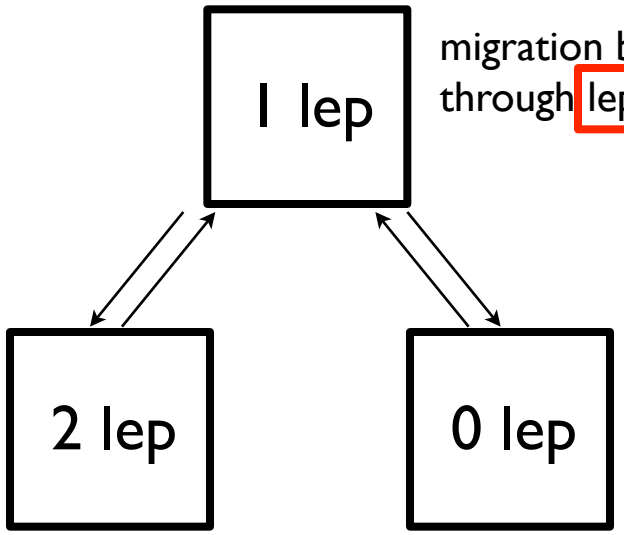


The Fit Model



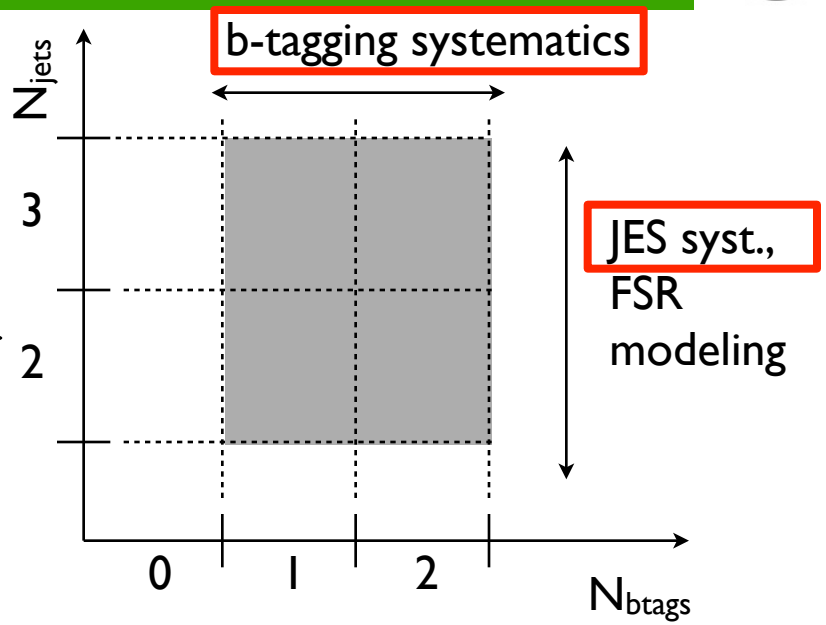
migration between channels
through lepton systematics

The Fit Model

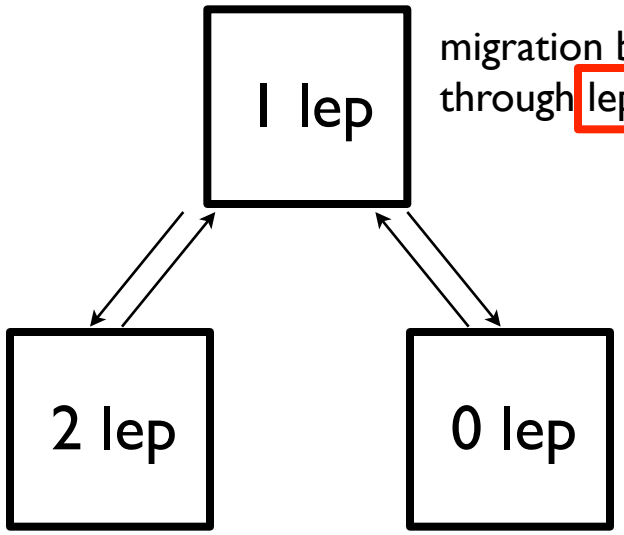


migration between channels through lepton systematics

for each channel

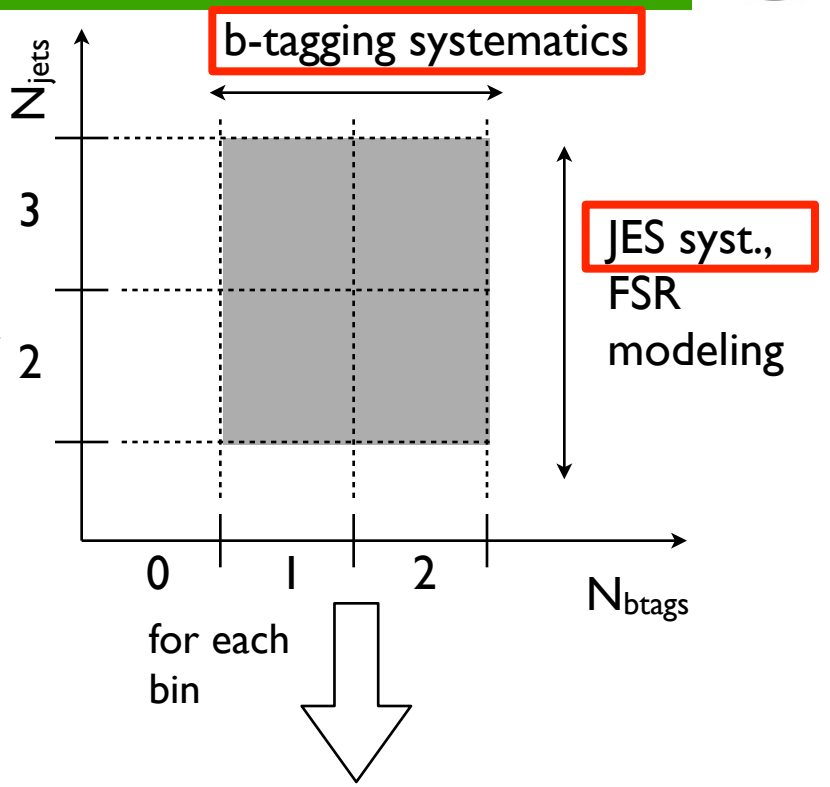


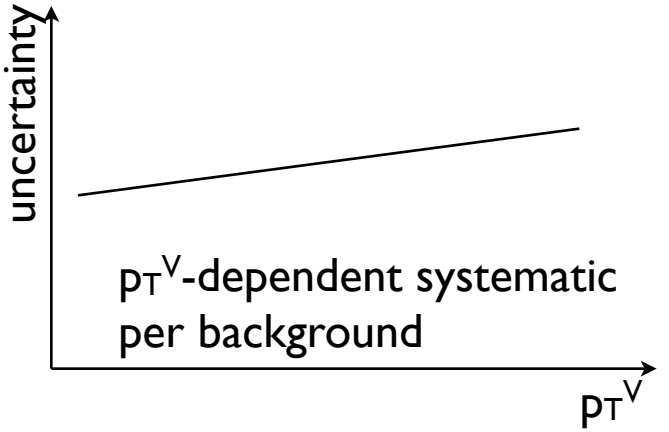
The Fit Model



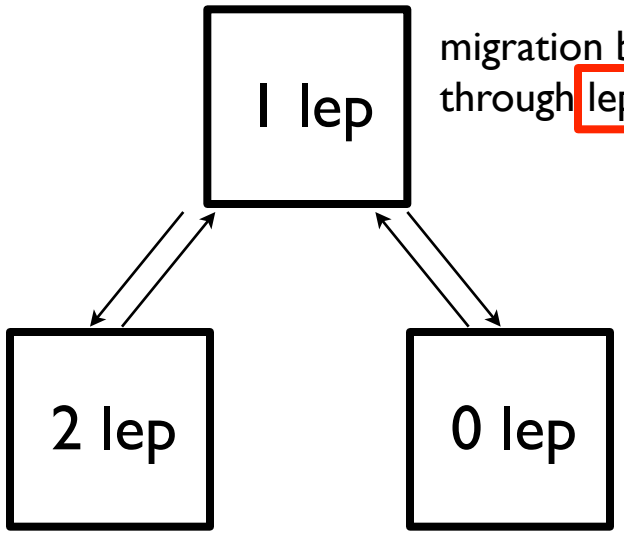
migration between channels through lepton systematics

for each channel



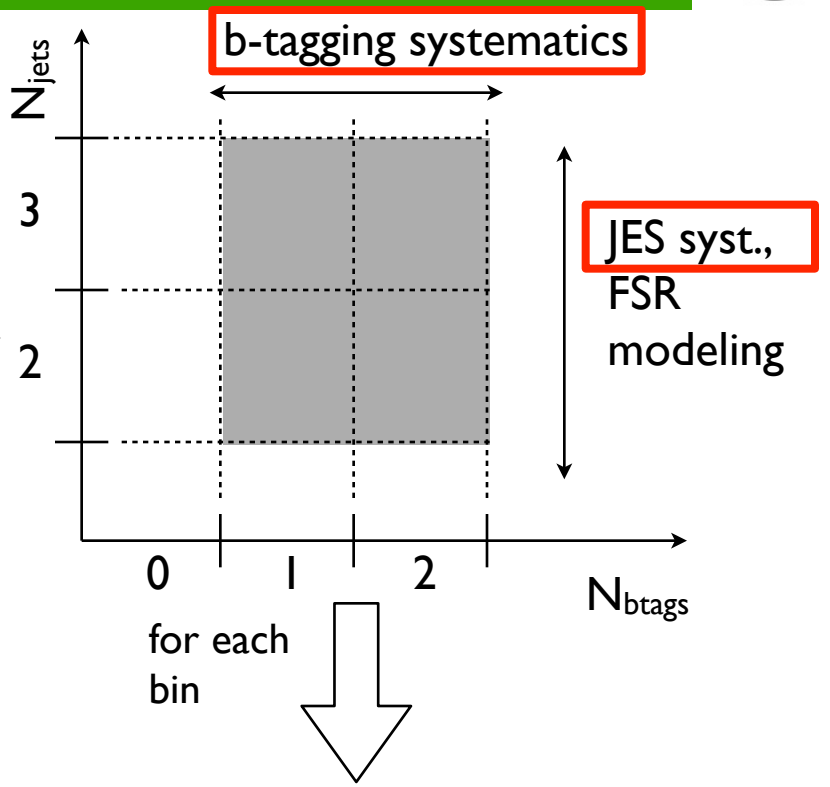


The Fit Model

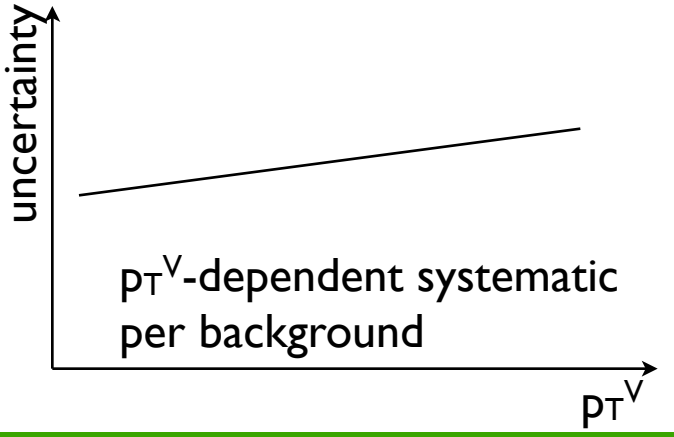


migration between channels through lepton systematics

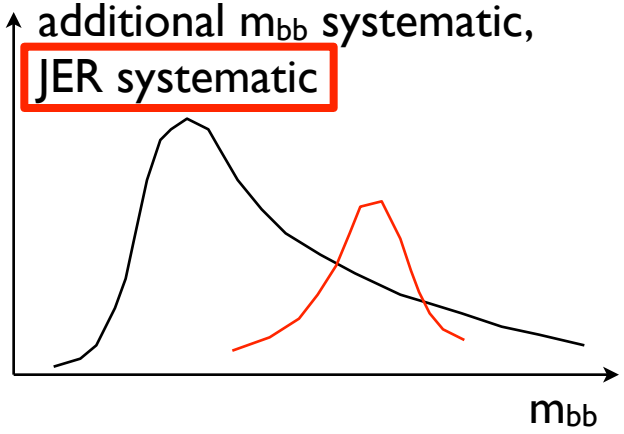
for each channel



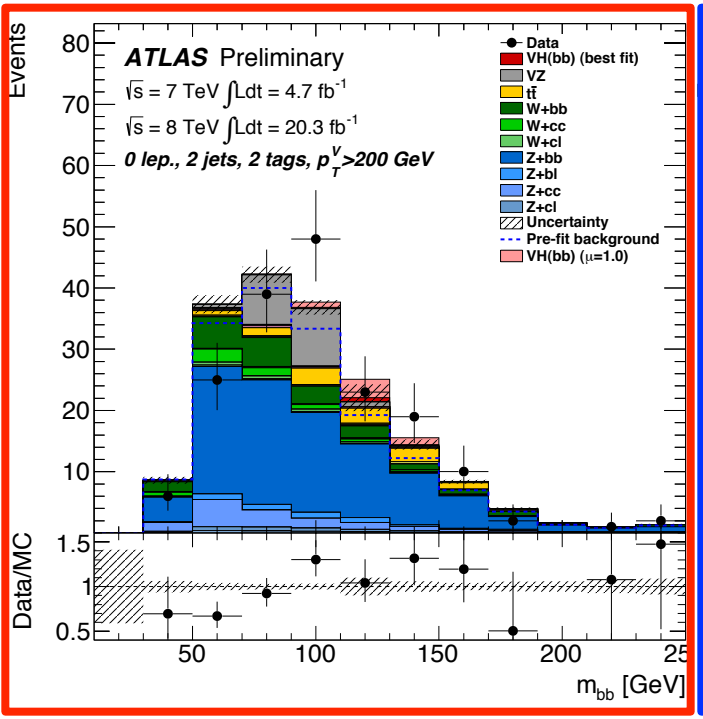
for each bin

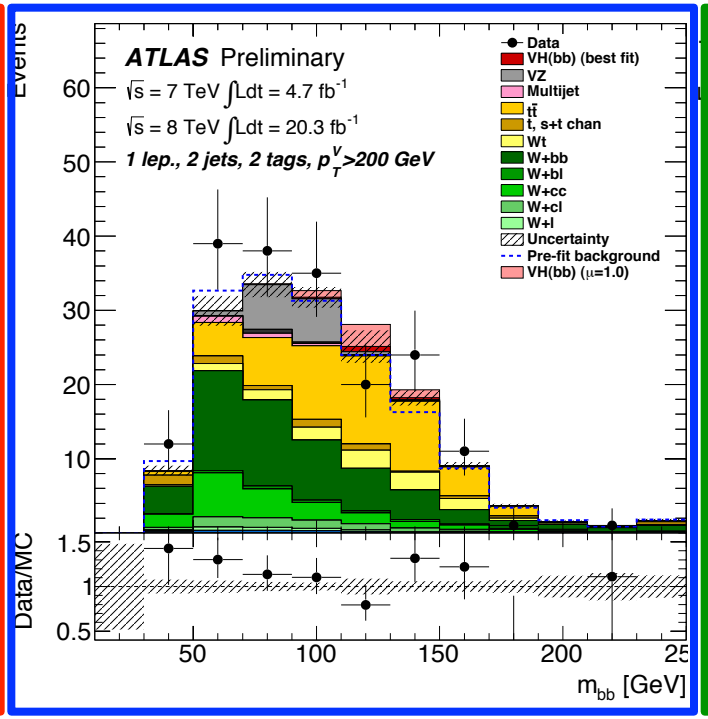


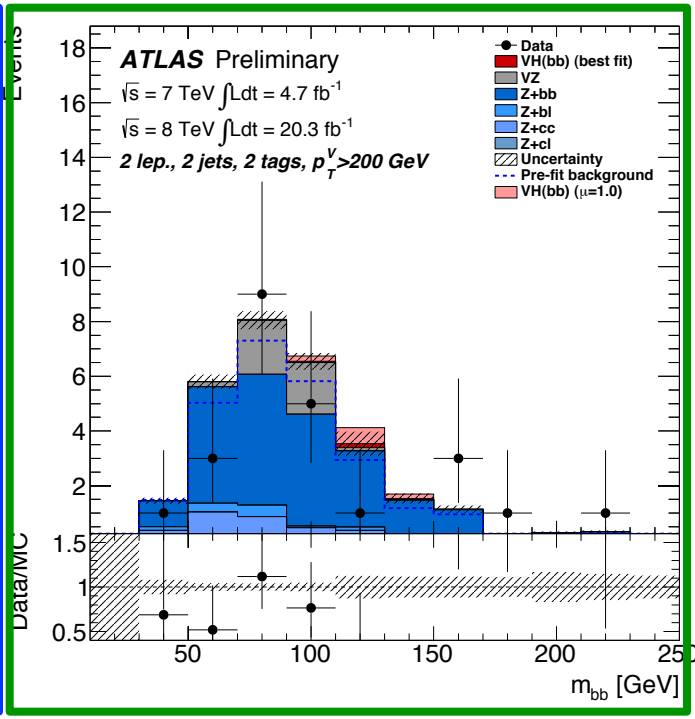
for each p_T^V bin



Fit Results

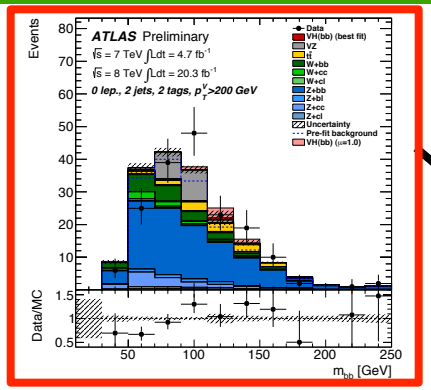


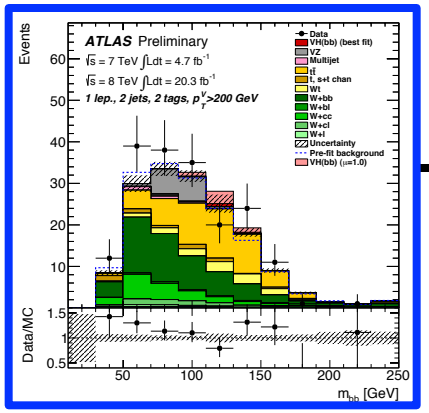


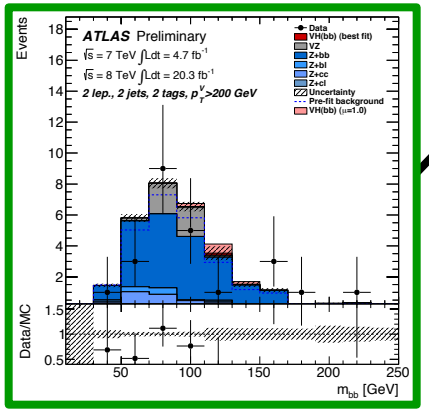


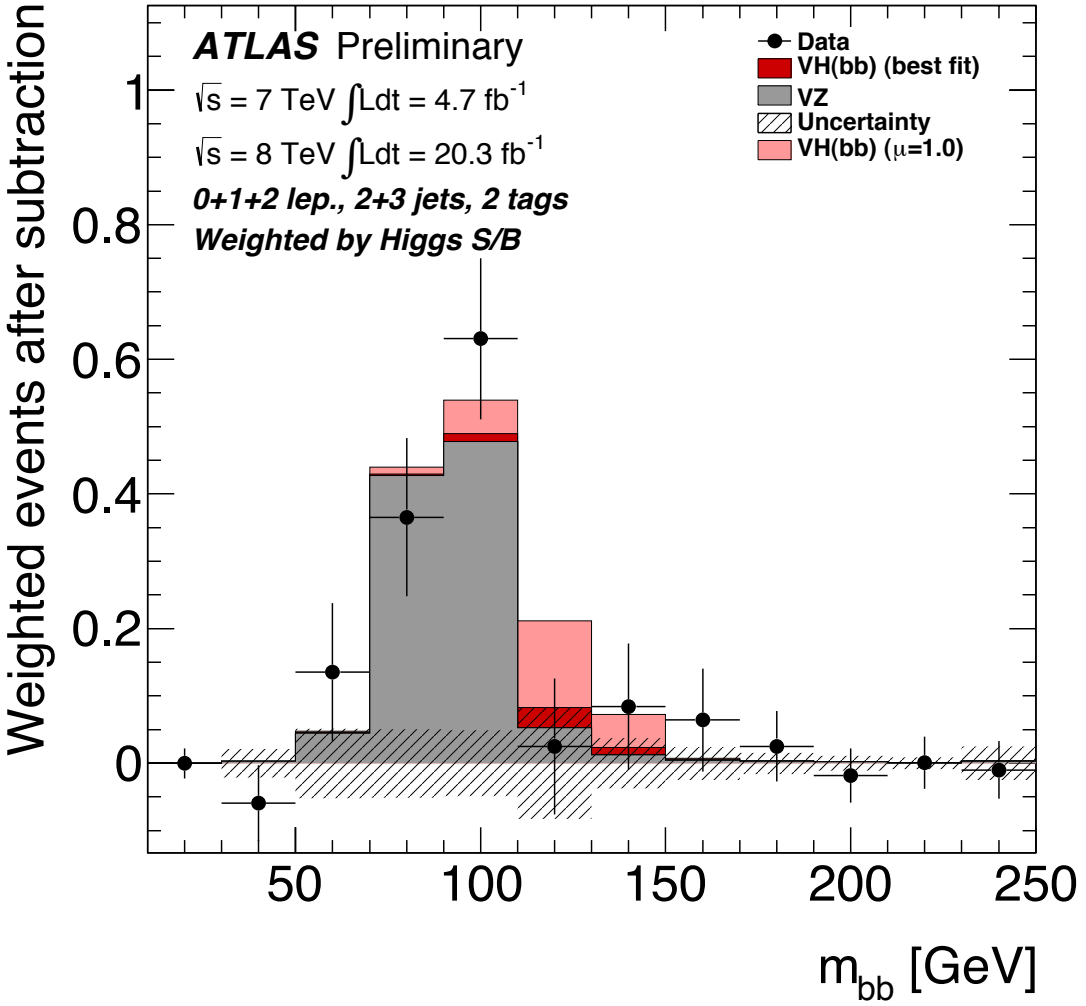
- Sample post-fit m_{bb} distributions in the highest p_T^V bin (>200 GeV) for 0-lepton, 1-lepton and 2-lepton channels
- Agreement between data and Monte Carlo in normalization and shapes (other p_T^V bins and control regions in the back-up slides)

The VZ (Z→bb) Peak





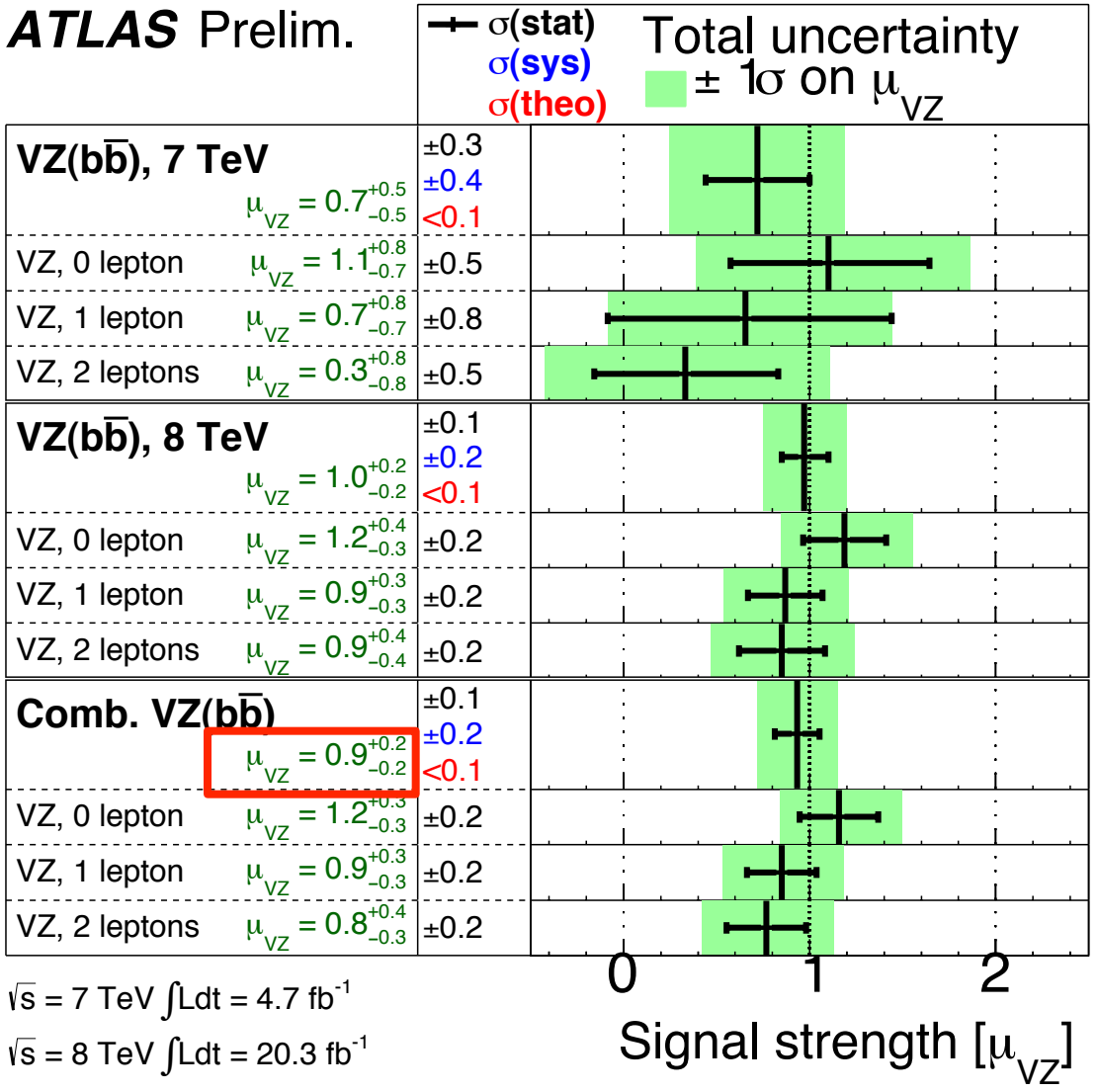




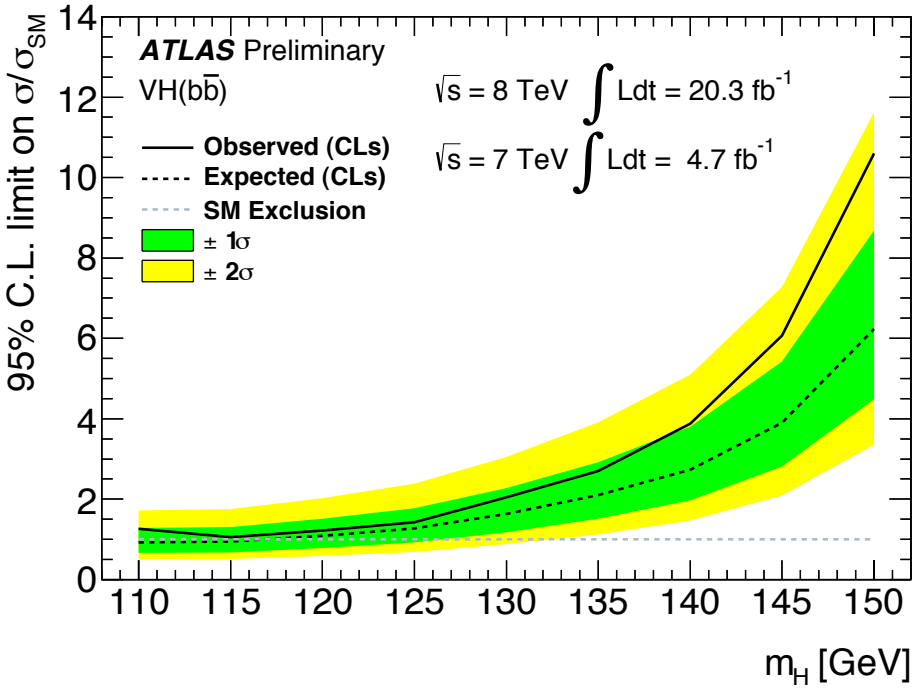
- Fit to diboson peak fixing Higgs peak to SM expectation
- Significance of 4.8σ

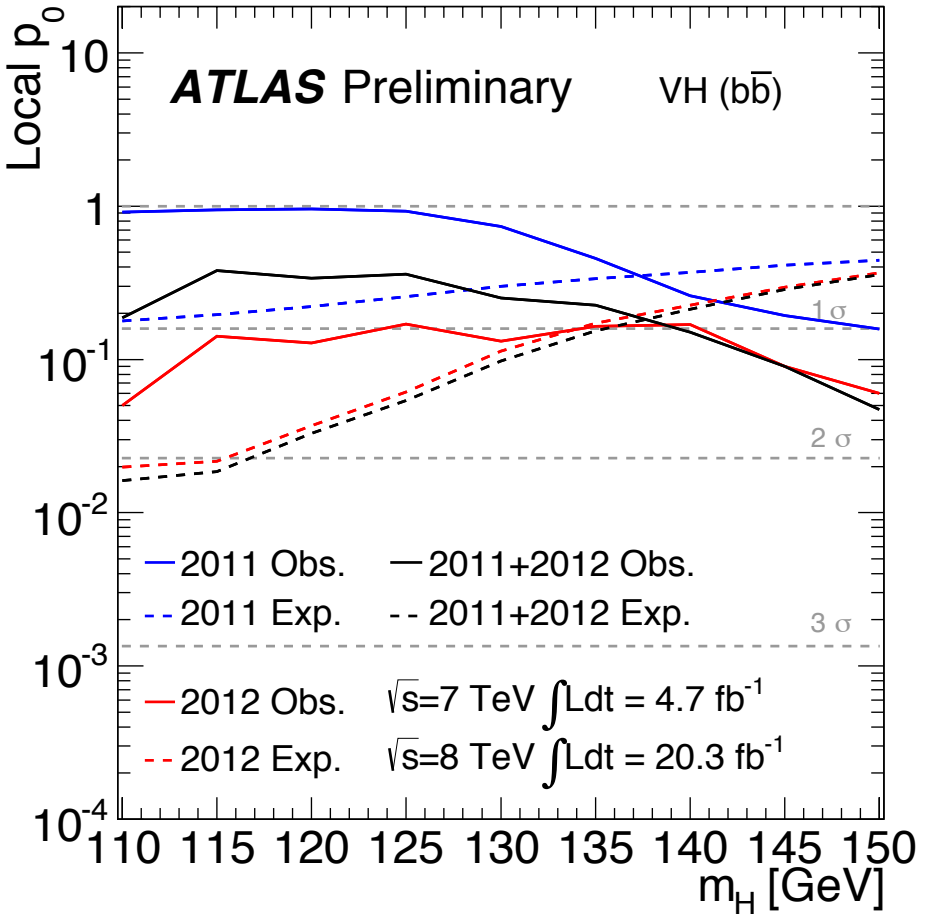
Diboson Fit Results

- $\mu = \dfrac{\sigma_{\mathrm{meas}}}{\sigma_{\mathrm{SM}}}$
- Fit summary for each year and channel
- Result consistent with SM expectation (combined achieves 4.8σ significance)
- Achieved 20% uncertainty with combined dataset



Higgs Limits

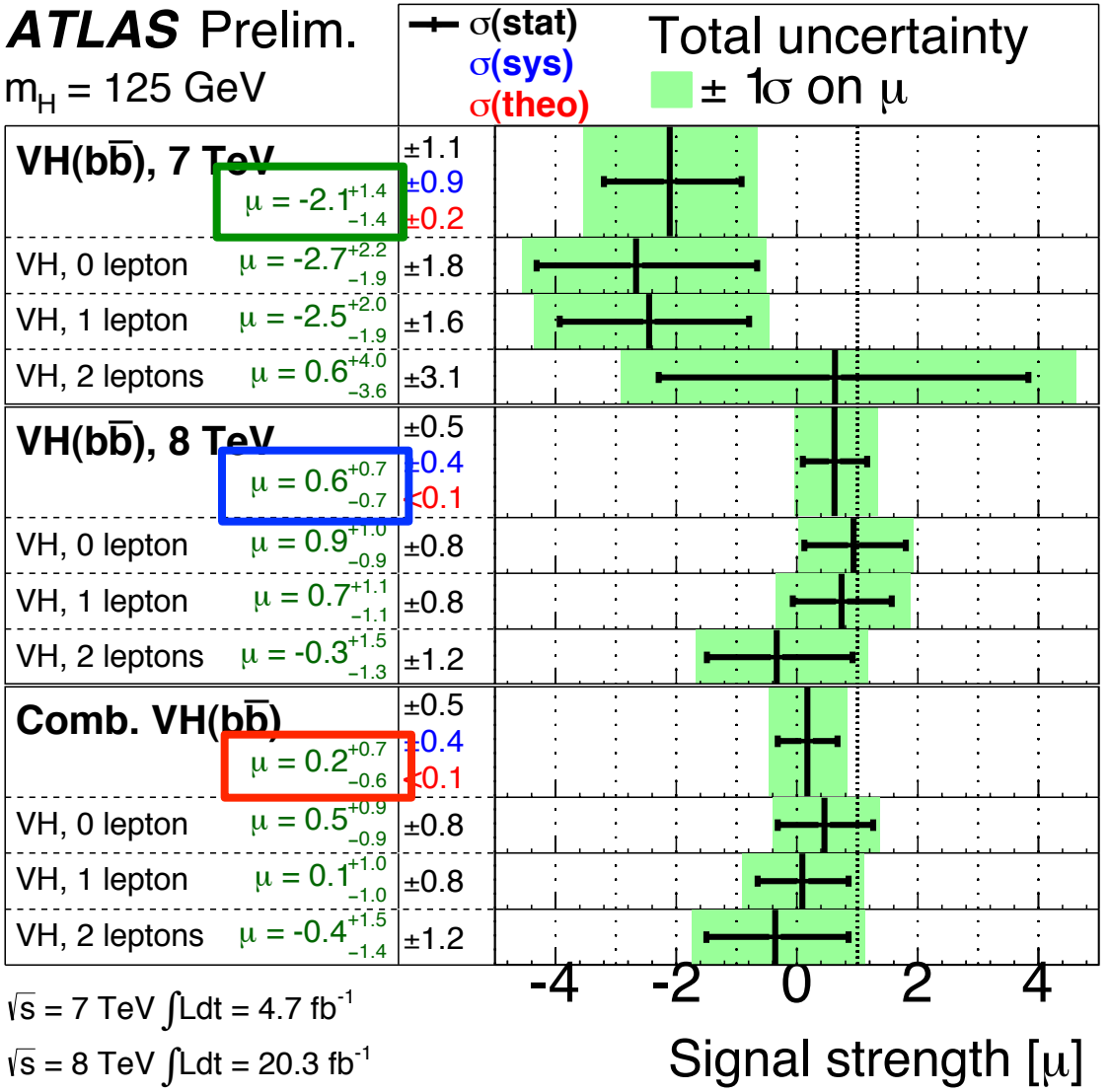




- 1σ excess in 2012 data at m_H=125 GeV, excess at higher masses too
- Deficit in 7 TeV data already observed in previous analysis leads to a small excess in combined result at m_H=125 GeV

Fit to the Higgs Cross Section

- Fit summary for each year and channel
- Combined result consistent with μ=0:
  - 1.3σ away from μ=1
  - 0.3σ away from μ=0
- 8 TeV result has some excess:
  - 0.5σ away from μ=1
  - 1.1σ away from μ=0
- 2σ deficit in 7 TeV result with respect to SM expectation
- Results dominated by statistical uncertainties



Conclusions

- New results on the associated production search for Higgs decaying to a pair of b-quarks using the full 2011 and 2012 datasets
- A large gain (35%) in significance through various optimizations and reduced systematic uncertainties with respect to the previous analysis
- Fit to diboson (VZ) peak consistent with Standard Model expectation, corresponds to a 4.8σ excess over the background-only hypothesis
- Fit to Higgs peak is consistent with both a SM Higgs and no SM Higgs: we need more data to resolve the two hypotheses
- Combined fit to the cross section results in $\frac{\sigma_{VH\to b\bar{b}}}{\sigma_{\mathrm{SM}}} = 0.2^{+0.7}_{-0.6}$

BACK-UP SLIDES

Detailed Event Selection

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		
	+ ≤ 1 extra jets		-
Missing E_T	$E_{\mathrm{T}}^{\mathrm{miss}} > 120$ GeV $p_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV $\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, p_{\mathrm{T}}^{\mathrm{miss}}) < \pi/2$ $\min[\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, \mathrm{jet})] > 1.5$ $\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, b\bar{b}) > 2.8$	$E_{\mathrm{T}}^{\mathrm{miss}} > 25$ Gev	$E_{\mathrm{T}}^{\mathrm{miss}} < 60$ GeV
Vector Boson	-	$m_{\mathrm{T}}^{W} < 120$ GeV	$83 < m_{\ell\ell} < 99$ GeV

	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 channel	$E_{\mathrm{T}}^{\mathrm{miss}}$ (GeV)	>25				>50
	m_{T}^{W} (GeV)	40-120			<120	

Inner workings of the fit

- Construct a likelihood of Poisson probabilities

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

- Signal and background are parameterized as

$$s_i = s_{\mathrm{tot}} \int_{\mathrm{bin},i} f_s(x;\theta_s)dx$$

$$b_i = b_{\mathrm{tot}} \int_{\mathrm{bin},i} f_b(x;\theta_b)dx$$

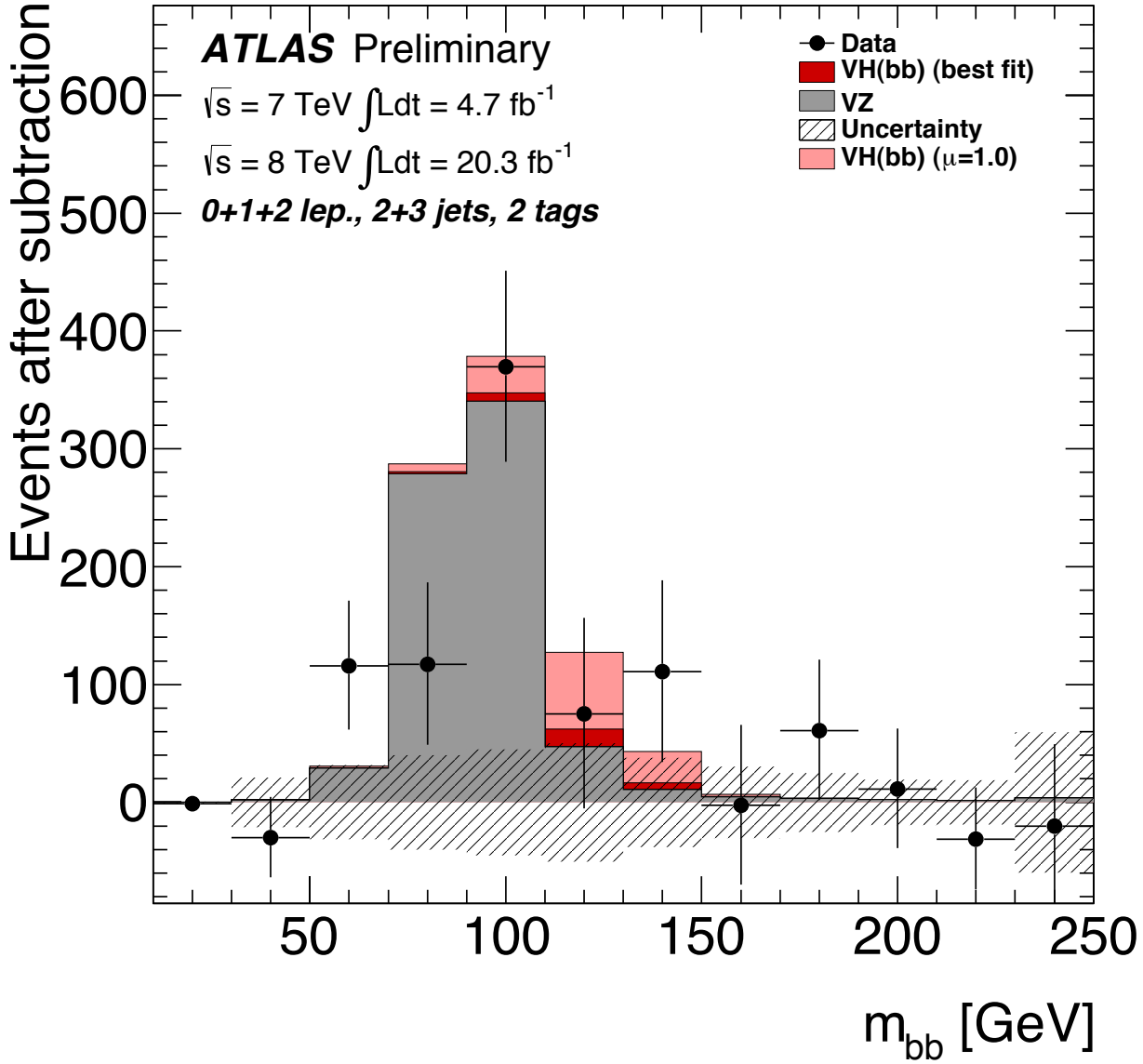
- For coupling measurement the signal is represented as

$$n_{\mathrm{signal}}^k = \left(\sum_i \sigma_{i,\mathrm{SM}} \times A_{if}^k \times \epsilon_{if}^k \right) \times \mu_f \times B_{f,\mathrm{SM}} \times \mathcal{L}^k$$

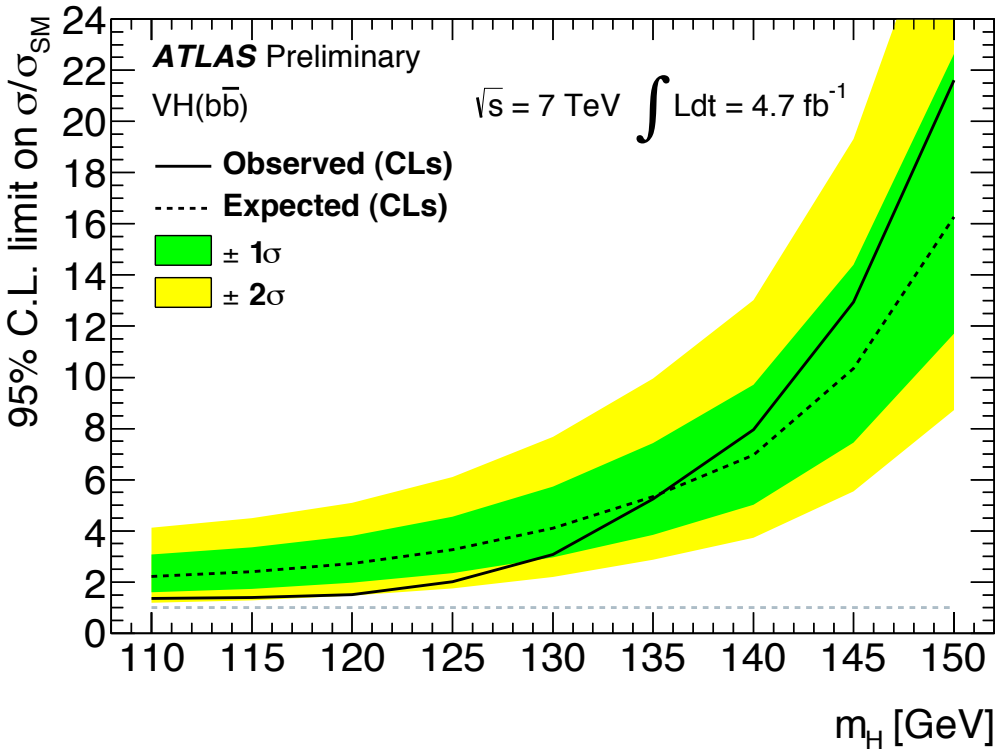
- Test hypothesized values of μ with a test statistics

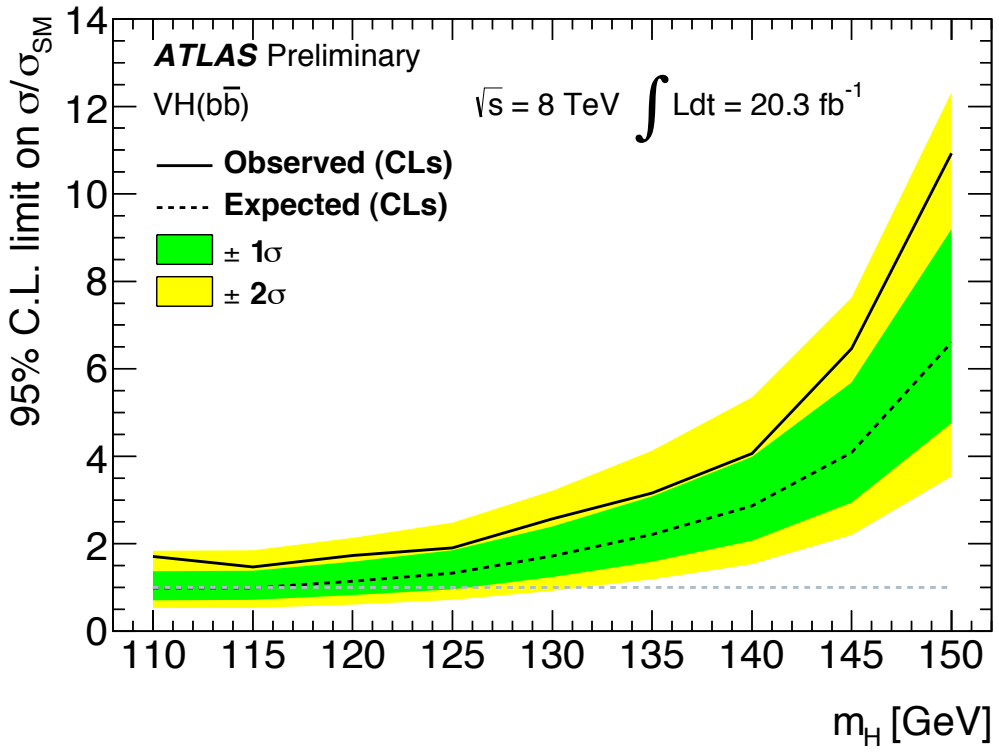
$$\Lambda(\mu) = \frac{L(\mu, \hat{\hat{\theta}}(\mu))}{L(\hat{\mu},\hat{\theta})}$$

Unweighted Z→bb Fit



7 TeV/8 TeV Limits

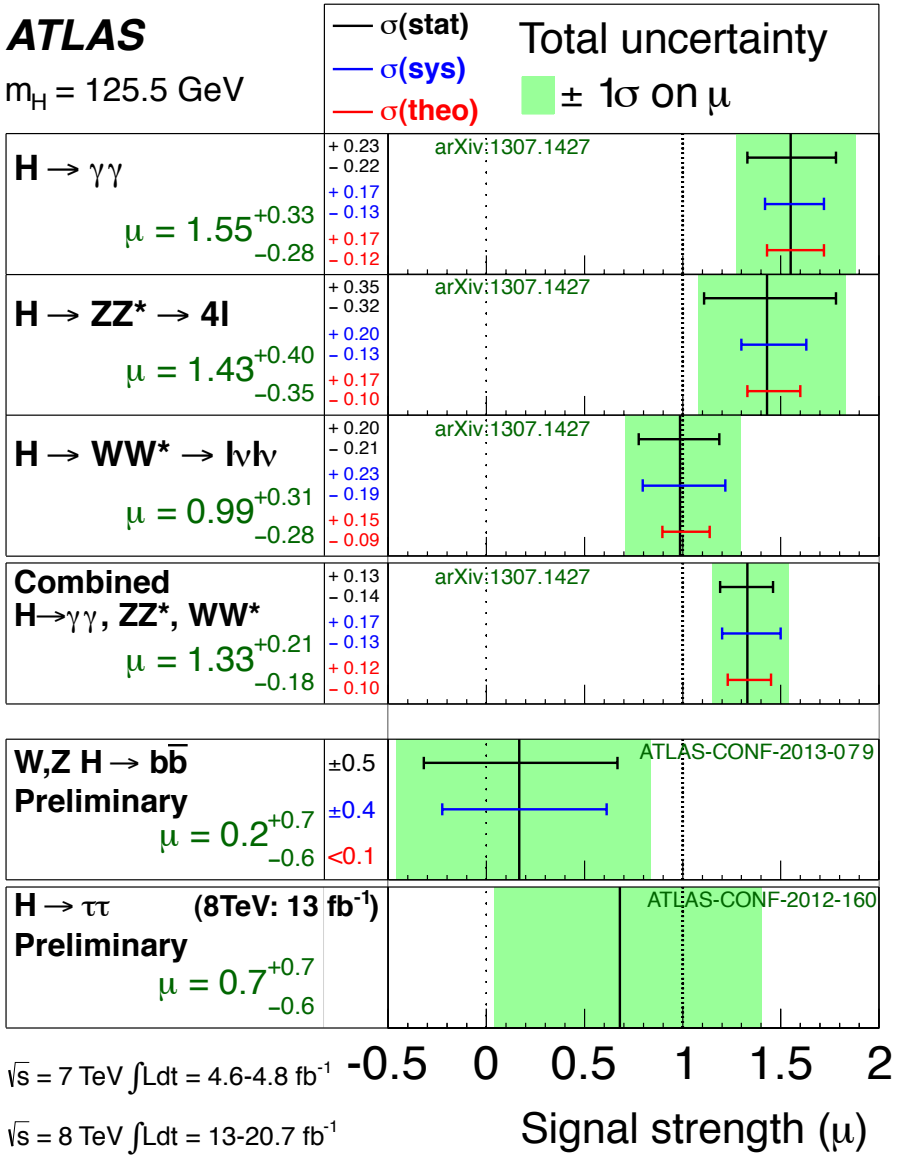




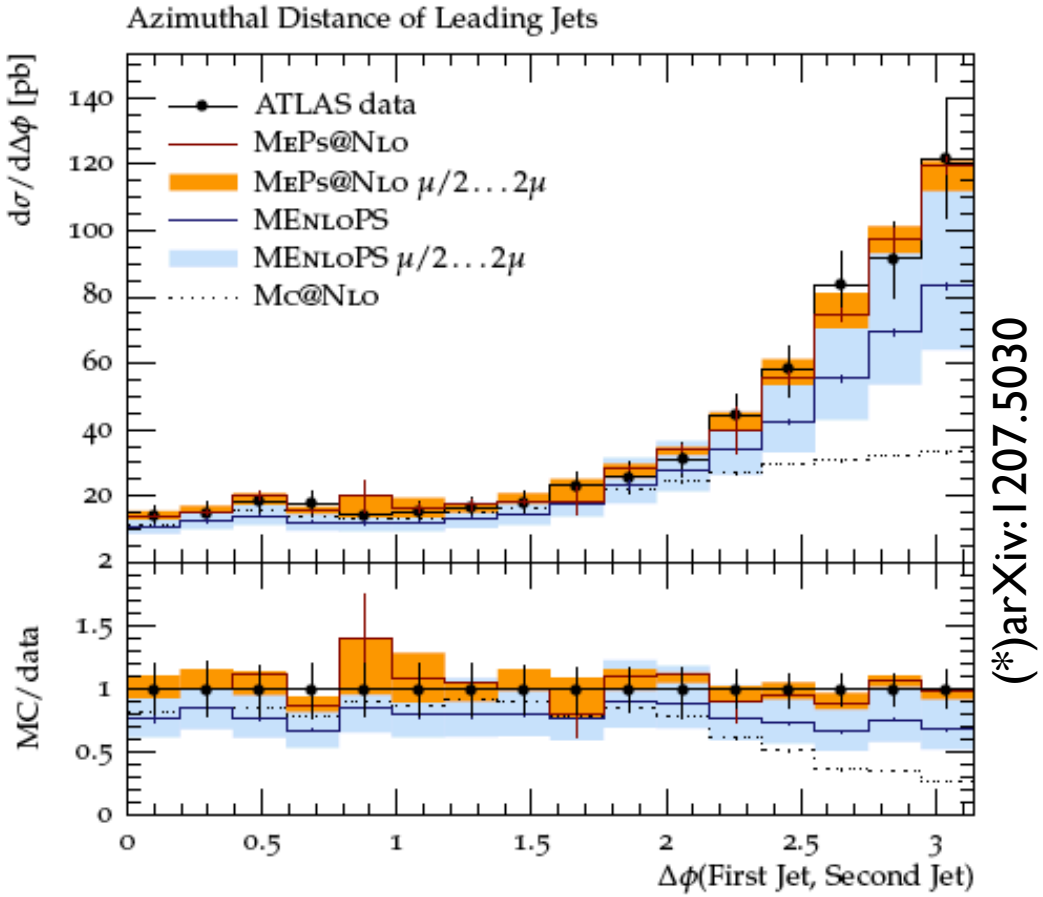
Modeling Systematics in Detail

	m_{bb}	$\Delta\varphi$	p_T^V	3-to-2-jet ratio	Normalization
tt	-Herwig++/Pyt -ISR/FSR -Alpgen/MC@NLO/Powheg	-	-50% of corr. applied	-Herwig++/Pyt -ISR/FSR -Alpgen/MC@NLO/Powheg	-Freely floating
W+jets	-Sherpa/Powheg/ MC@NLO	-50% of corr. applied	-Residual data systematic	MC	-Wcl/Wbb freely floating -Relative ratios to others: 30% (NLO/ Sherpa)
Z+jets	-Extrapolation from sidebands	-50% of corr. applied	-	MC MC	-Zcl/Zbb freely floating -Relative ratios to others: 30% (NLO/ Sherpa)
single top	-Herwig++/Pyt -ISR/FSR -Alpgen/MC@NLO/Powheg	-	-Herwig++/Pyt -ISR/FSR -Alpgen/MC@NLO/ Powheg	MC	-Approx. NNLO uncertainties
Diboson	-Pythia/Herwig	-	-LO/MCFM		-NLO calculation uncertainties

Combination with other Higgs Channels

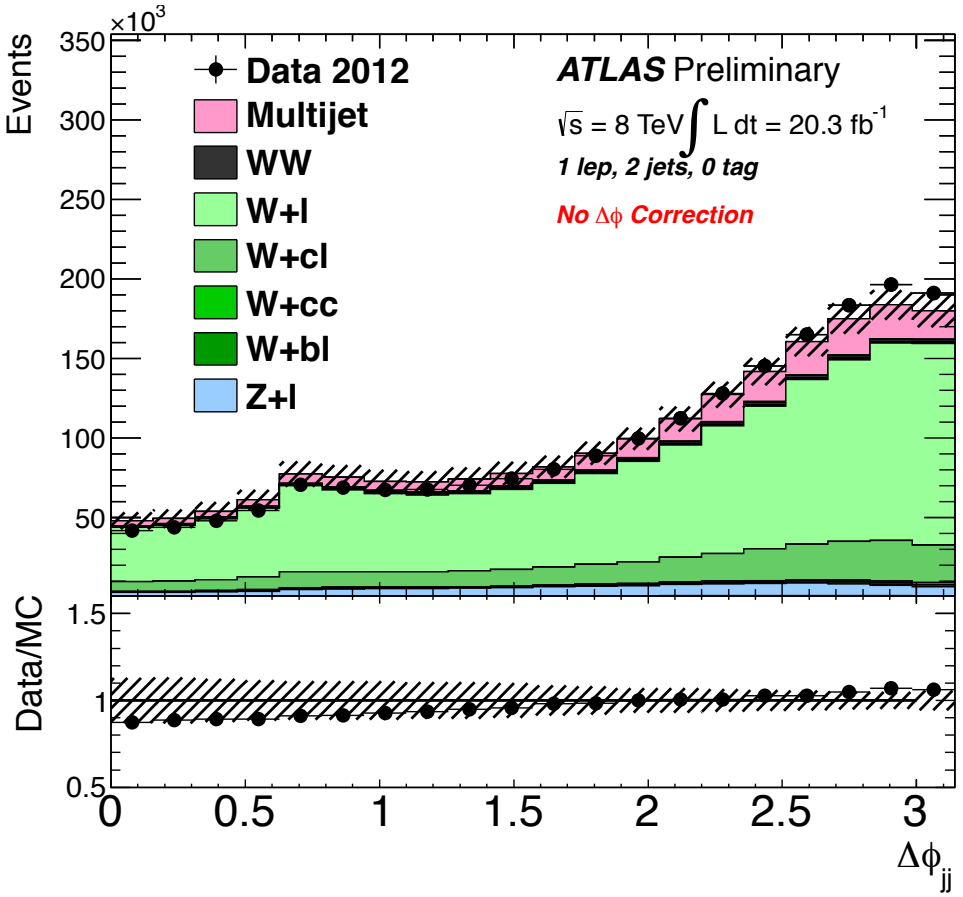


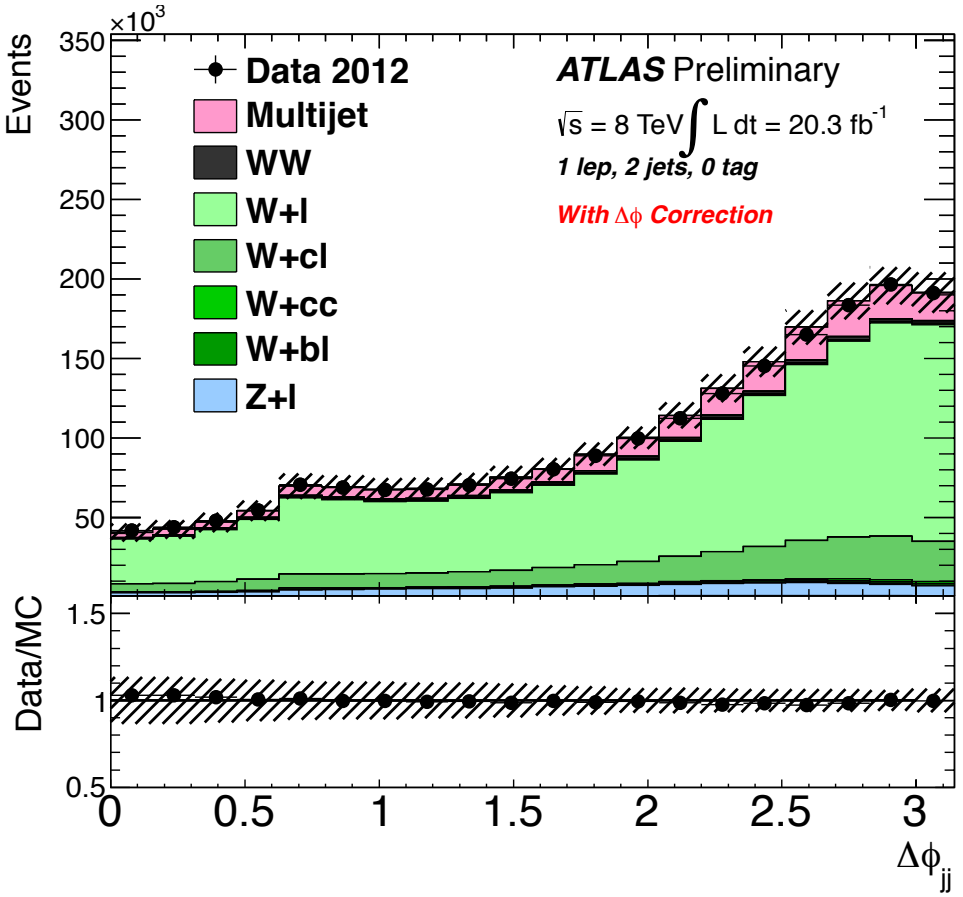
Δφ in NLO Calculations



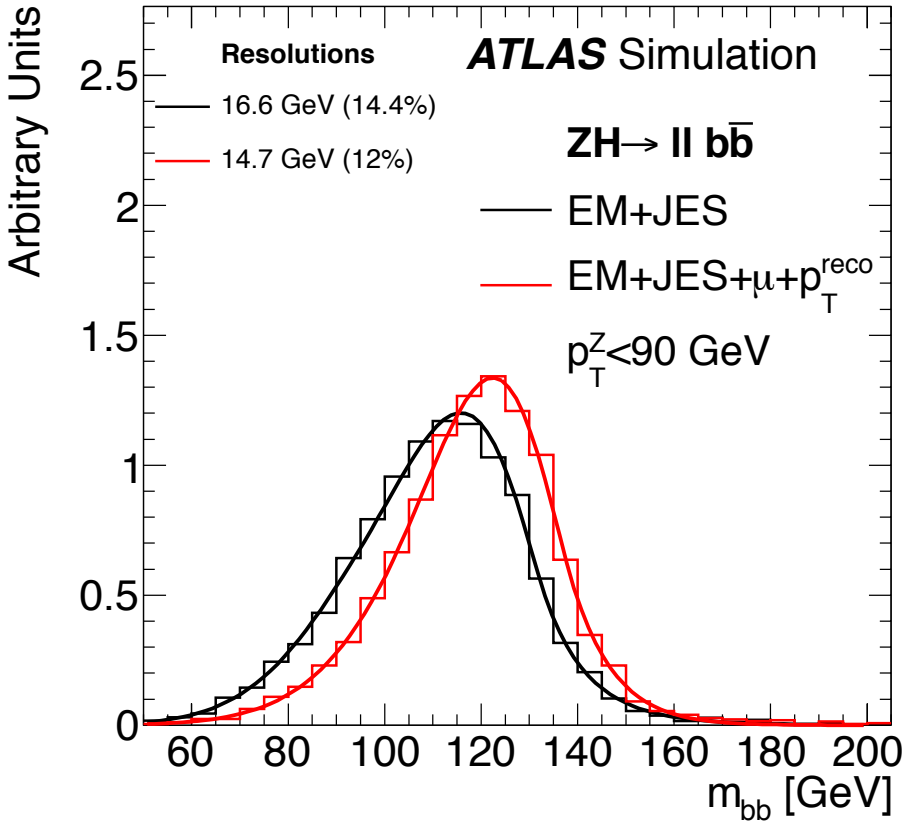
(*)arXiv:1207.5030

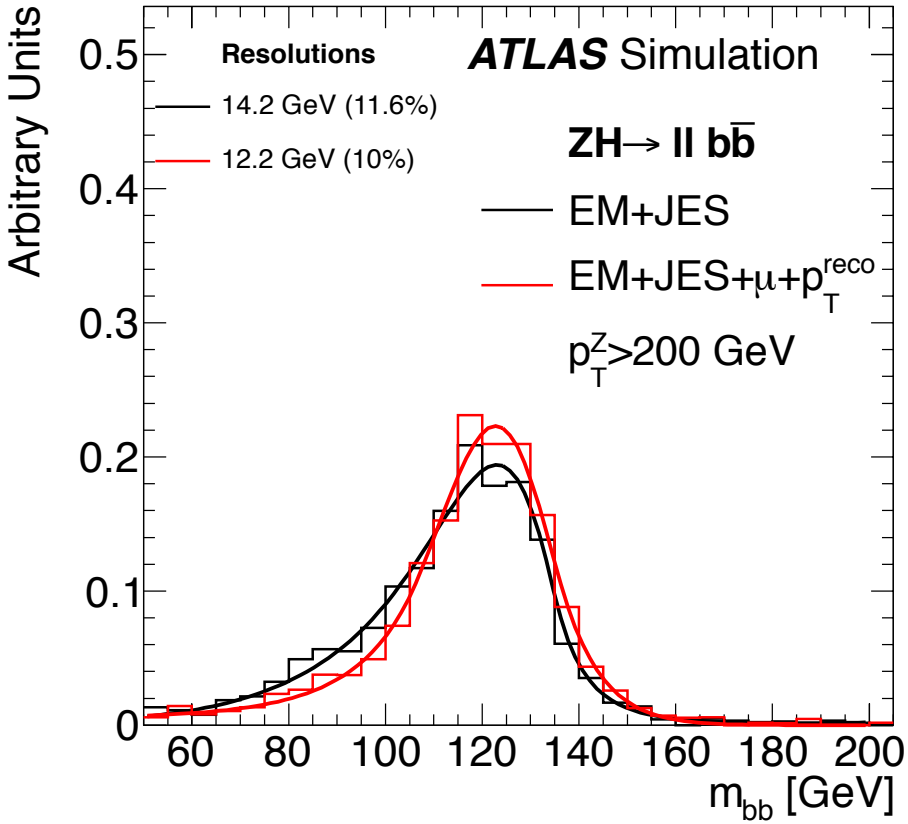
Δφ Correction



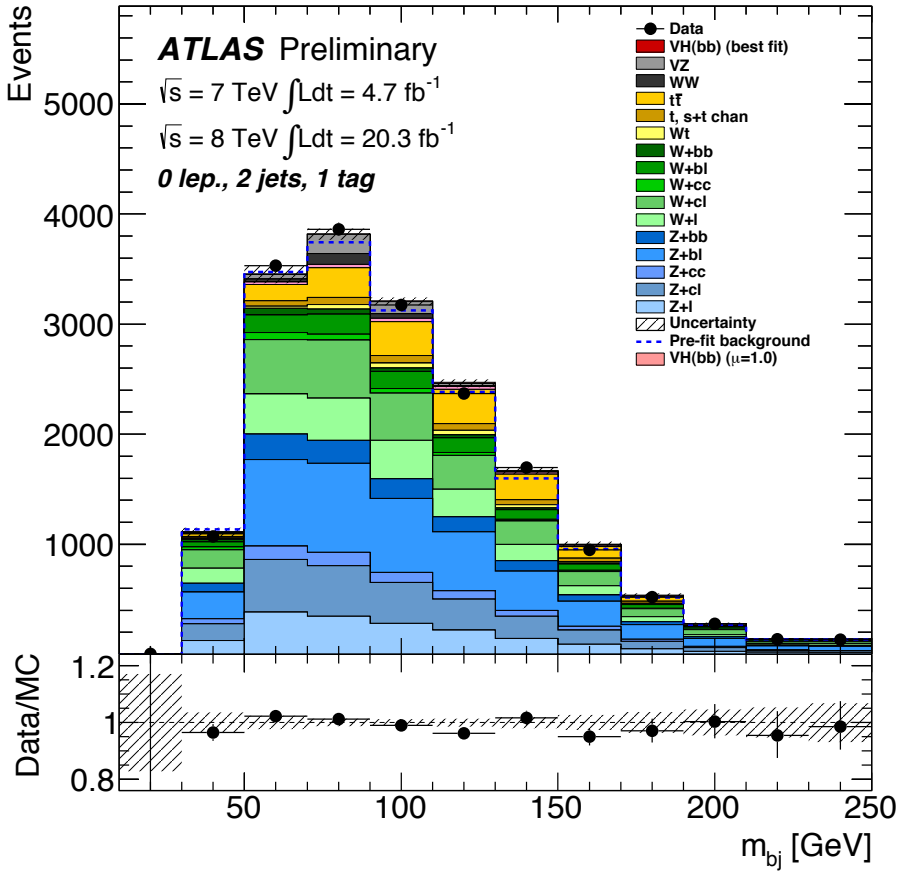


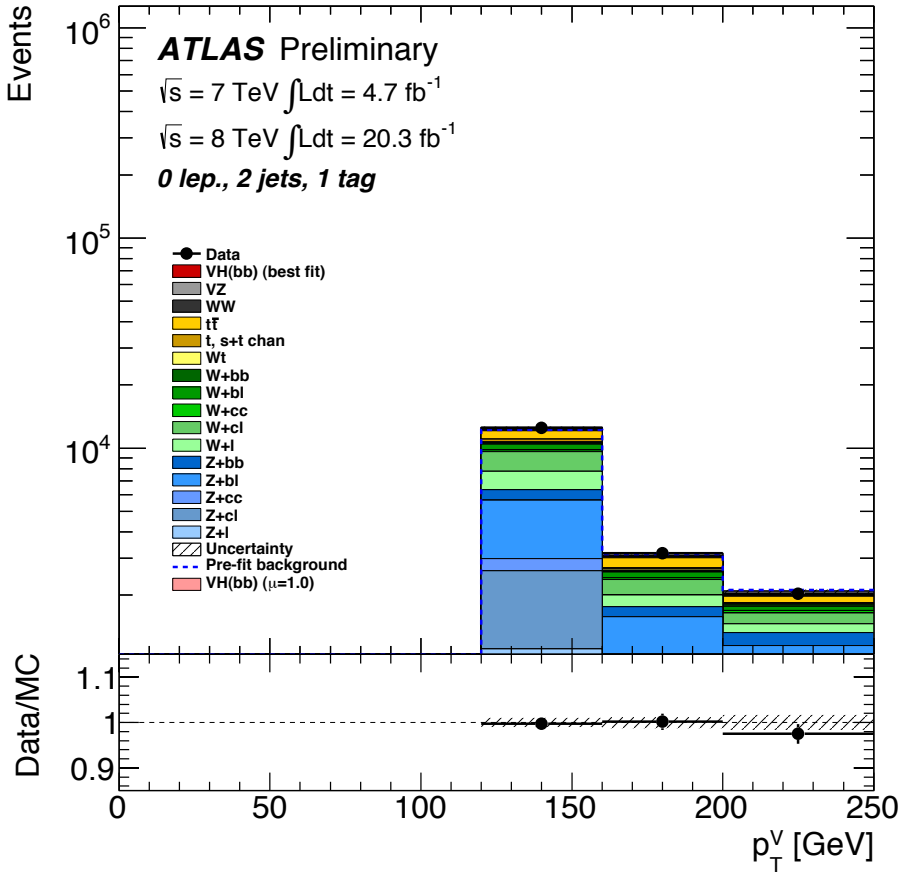
Invariant Mass Resolution



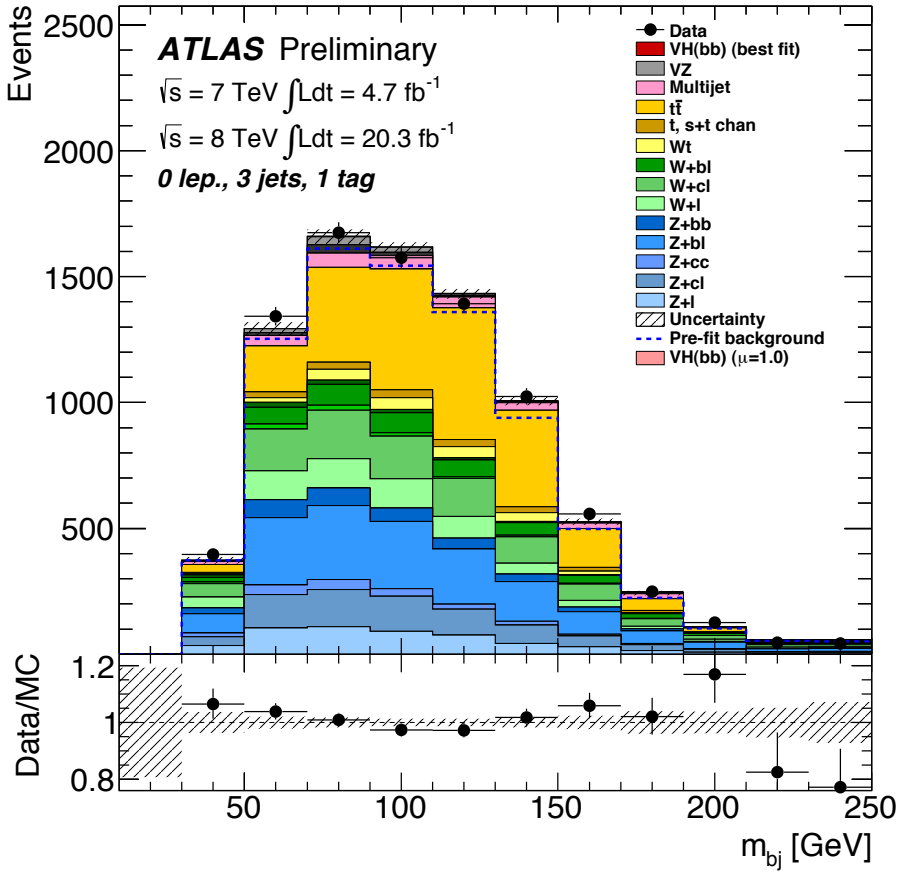


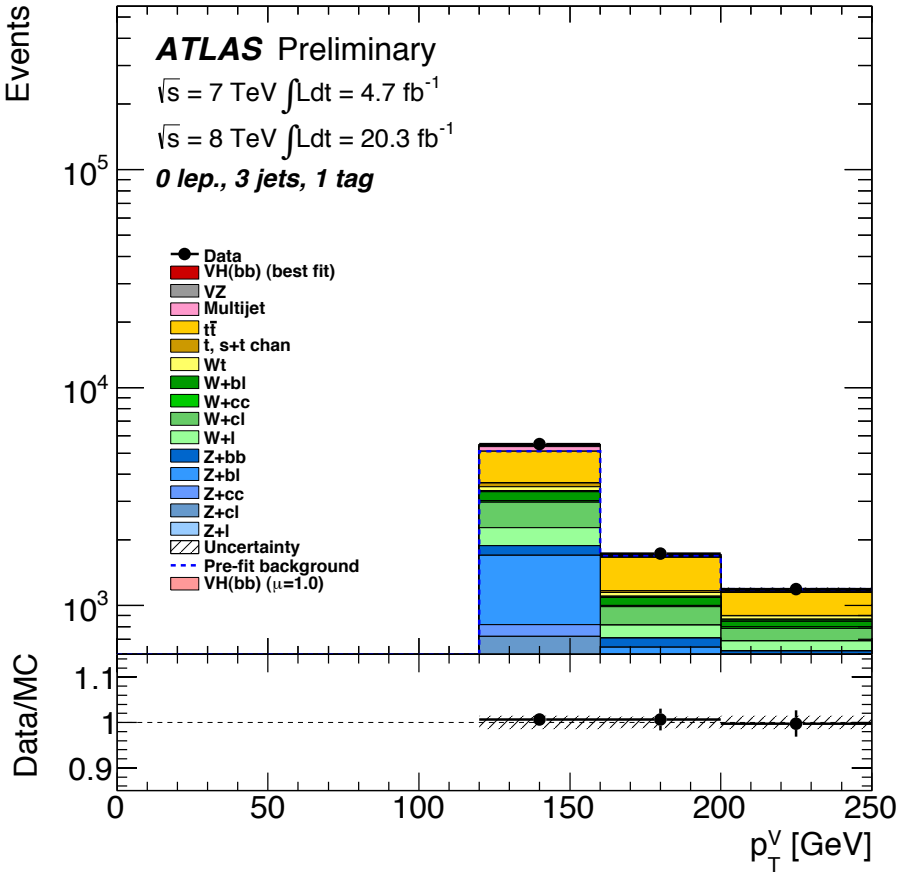
0-lepton Post-Fit Plots (1-tag, 2-jet)



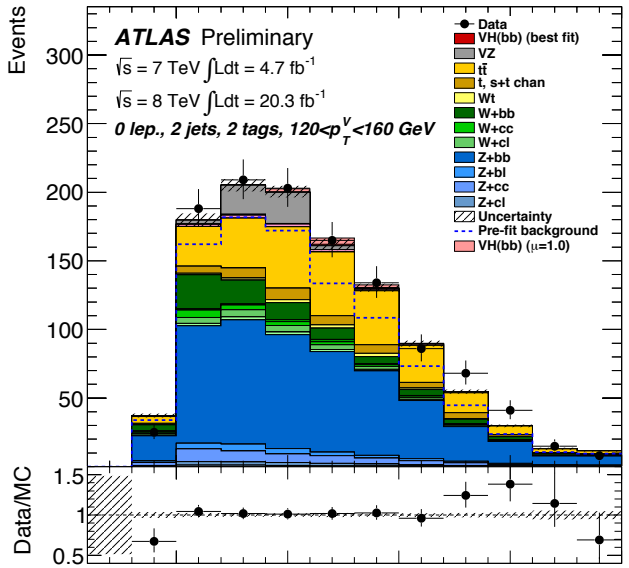


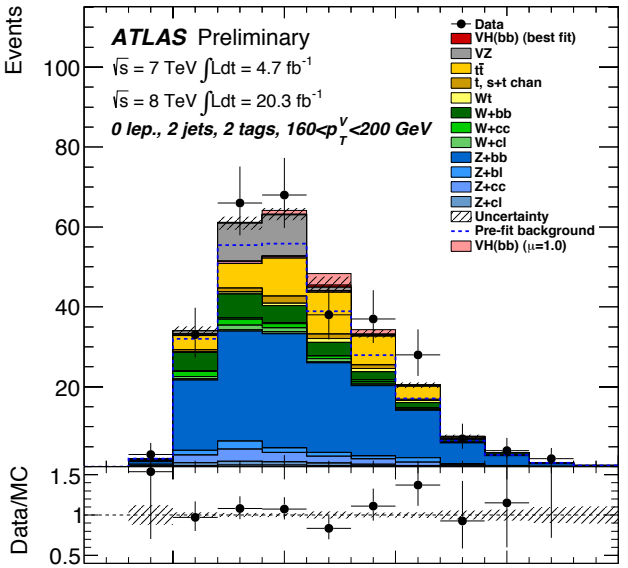
0-lepton Post-Fit Plots (1-tag, 3-jet)

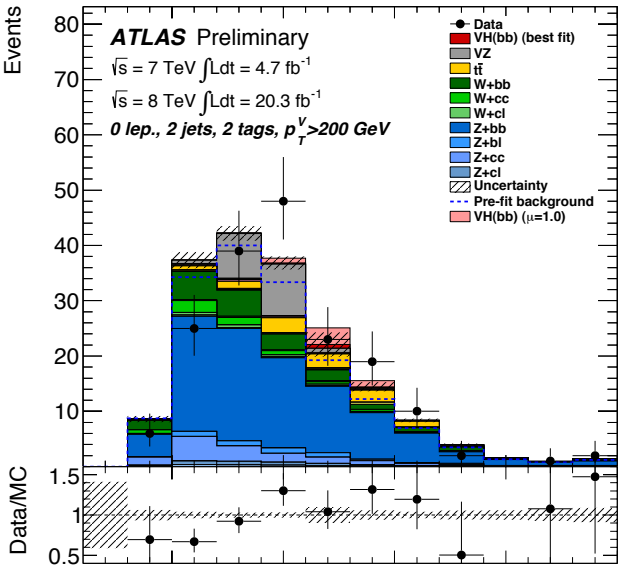


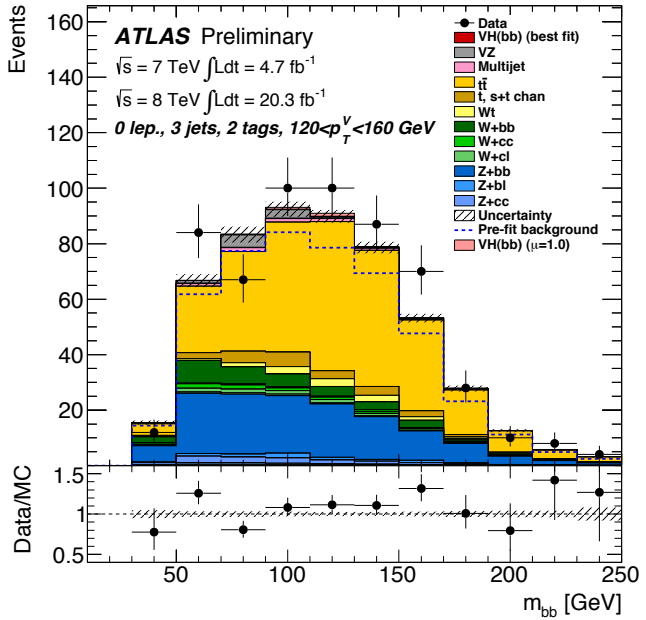


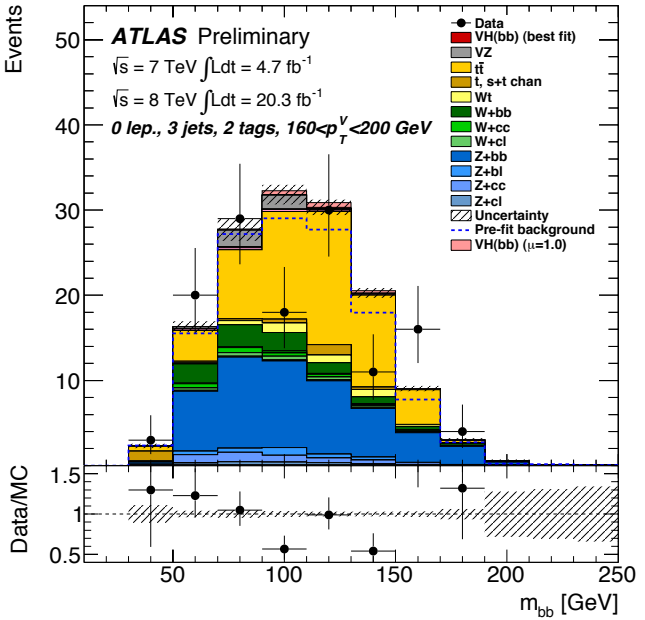
0-lepton Post-Fit Plots (2-tag)

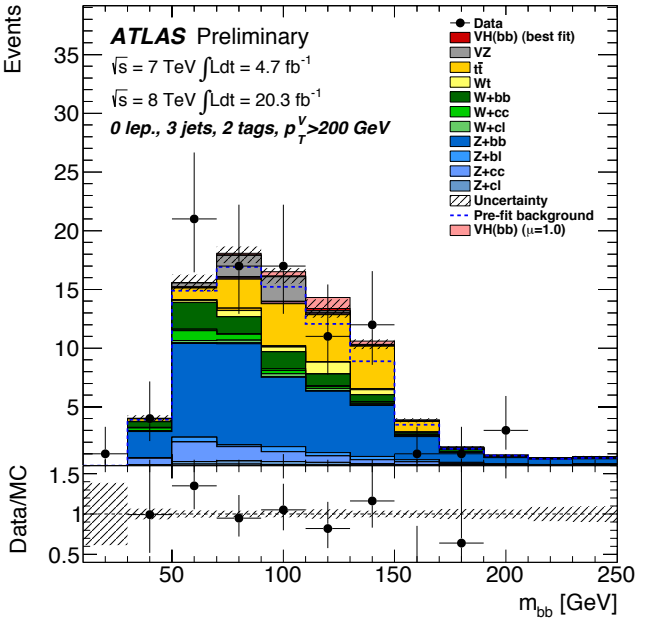




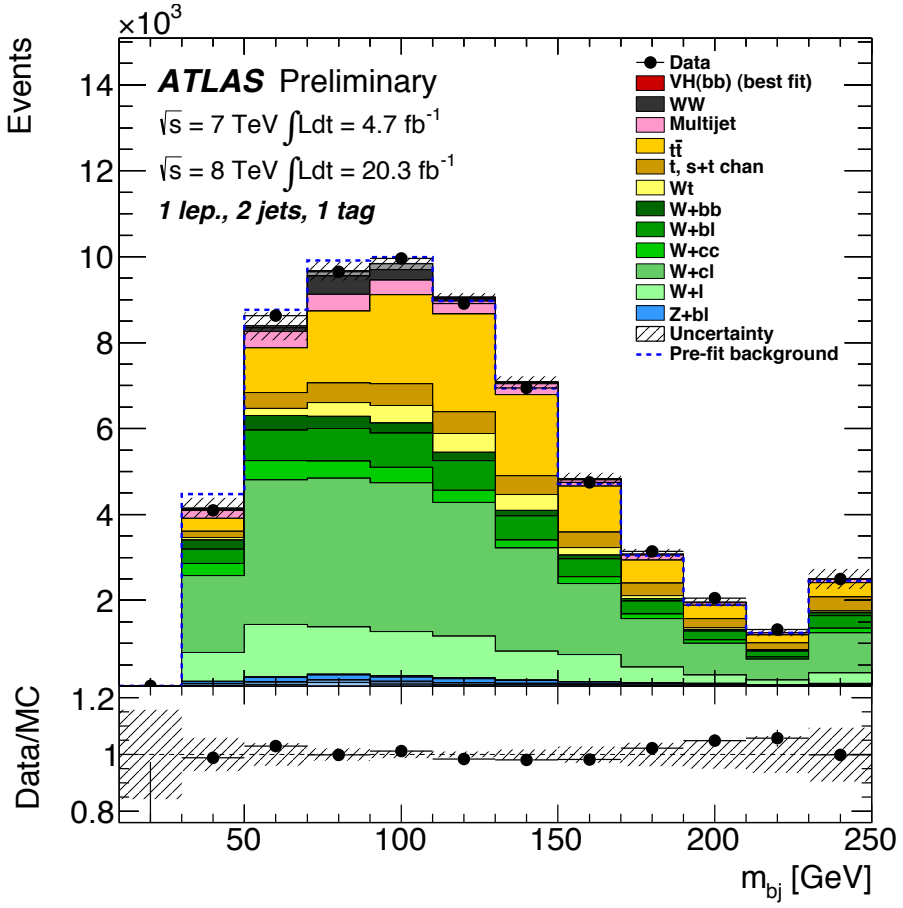


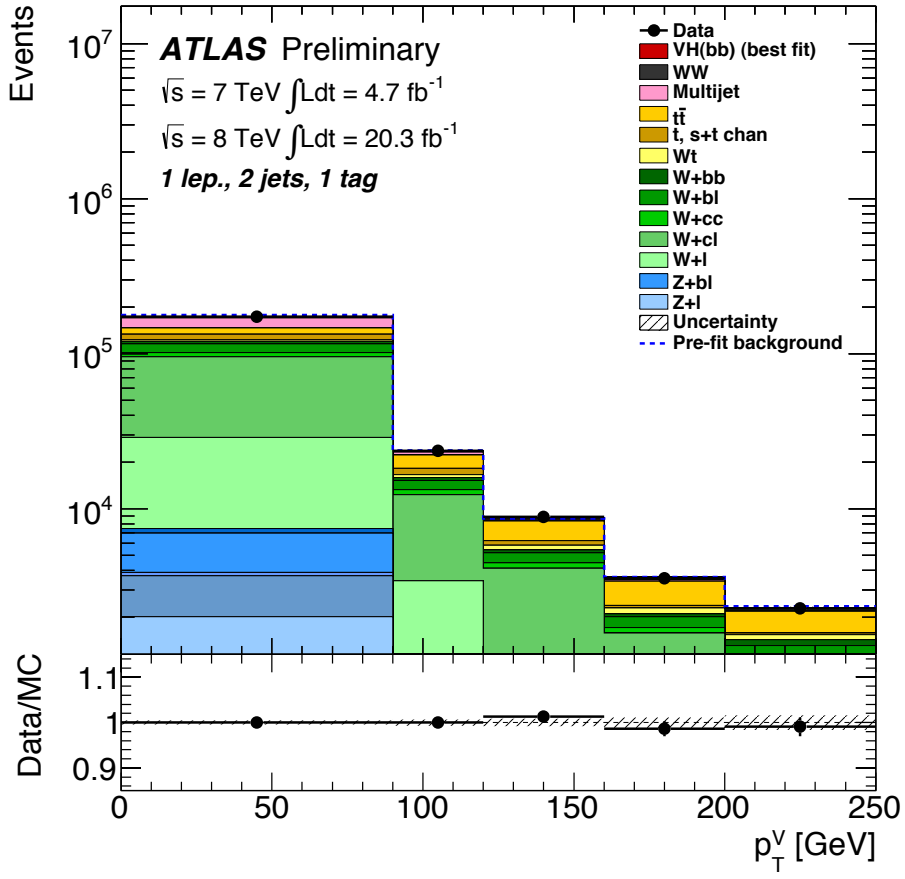




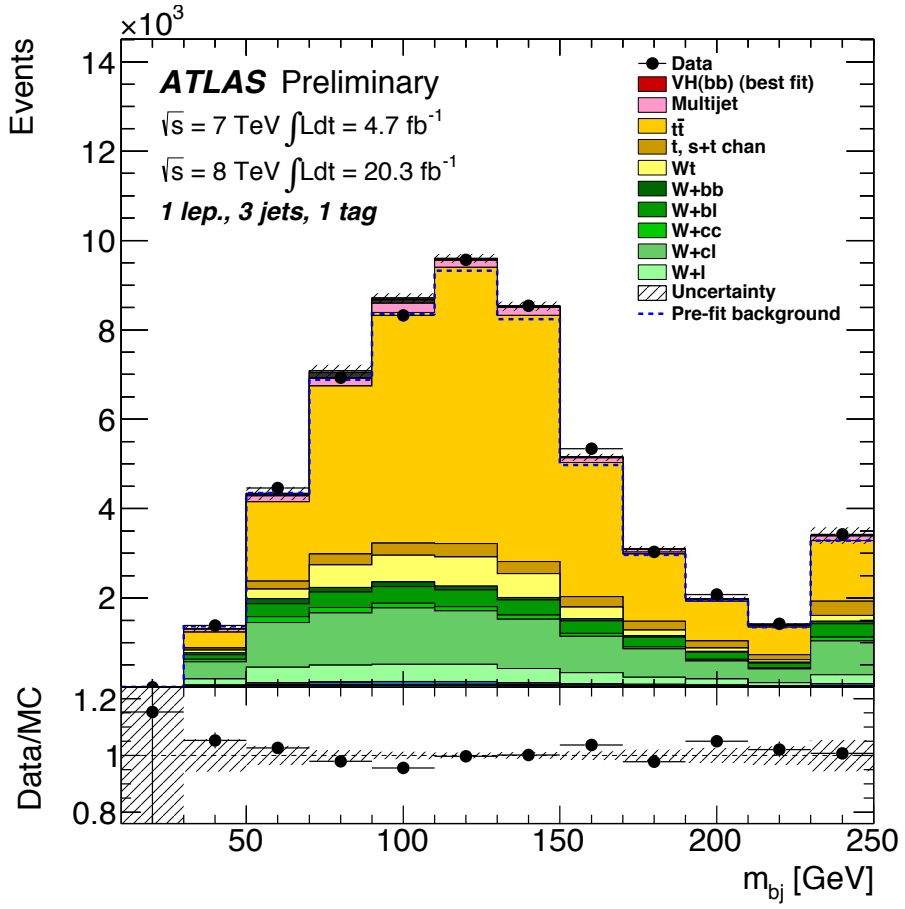


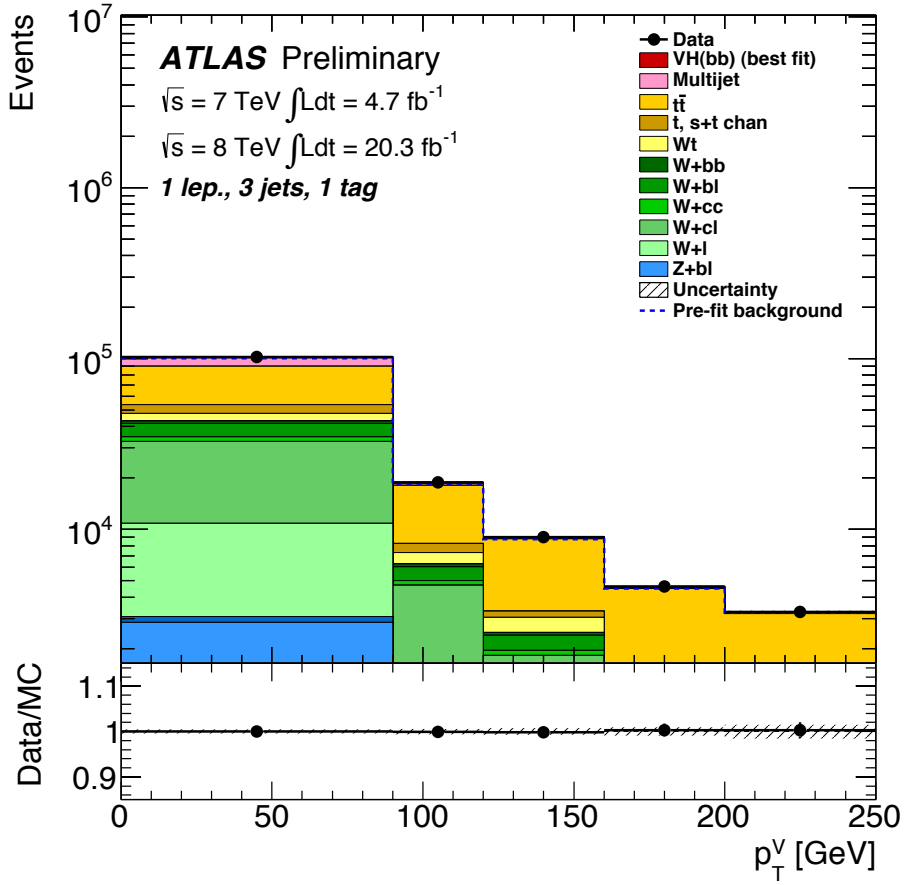
1-lepton Post-Fit Plots (1-tag, 2-jet)





1-lepton Post-Fit Plots (1-tag, 3-jet)





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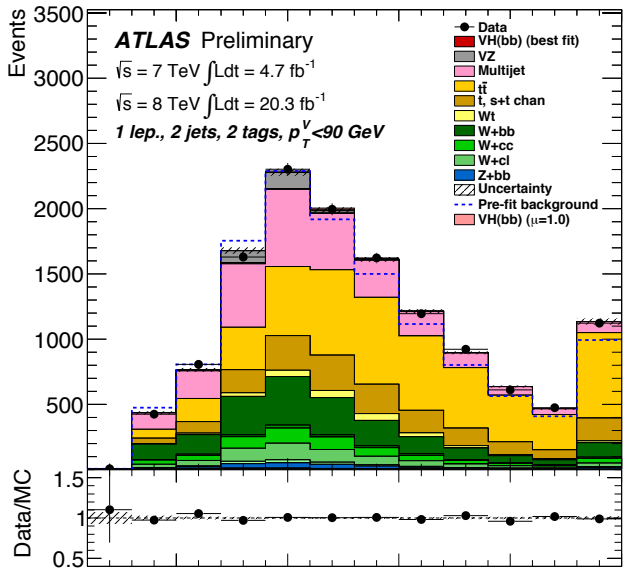
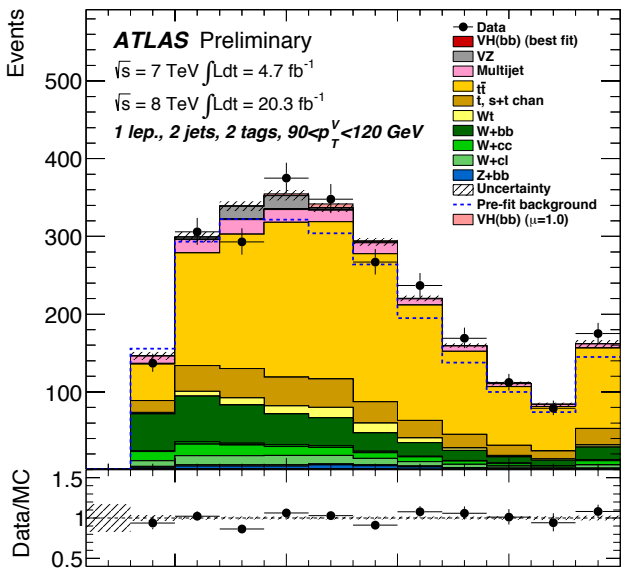
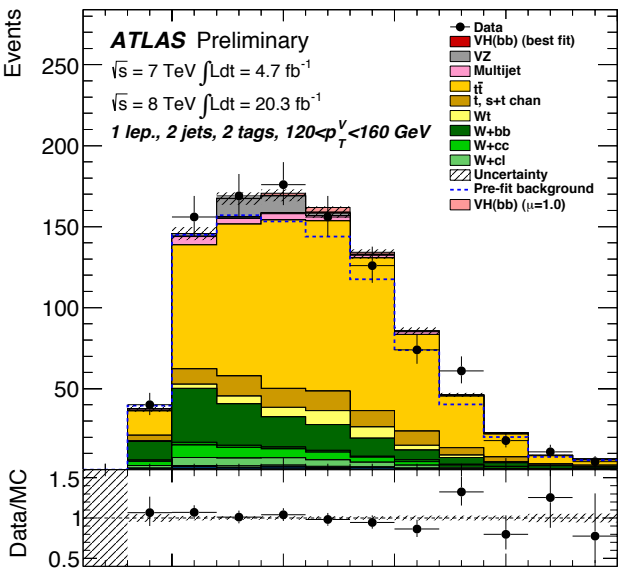
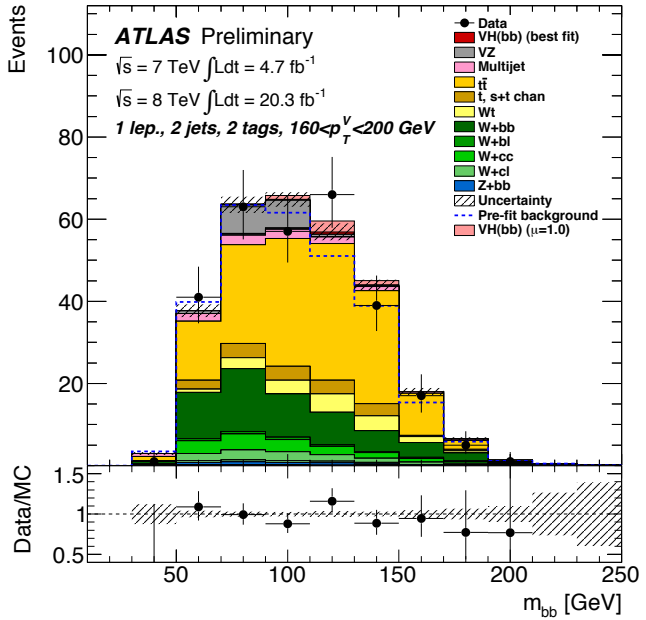
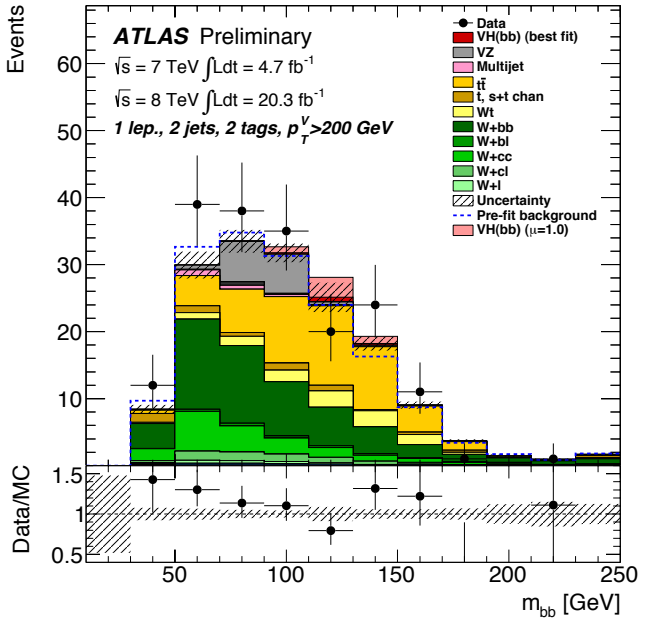
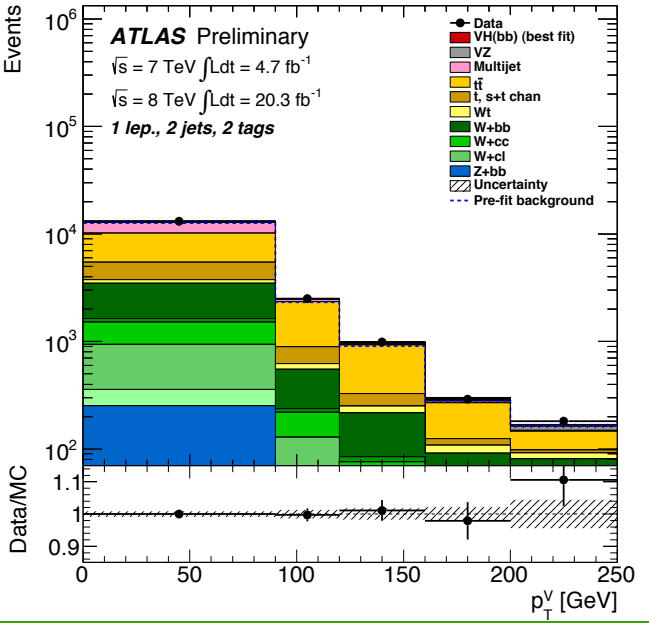




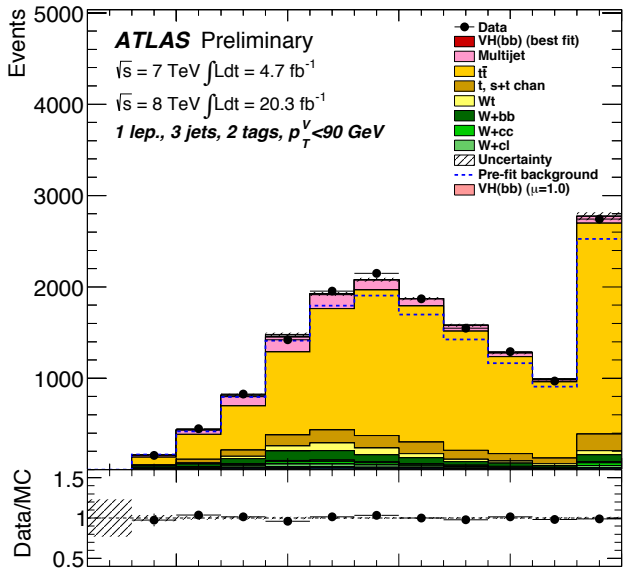


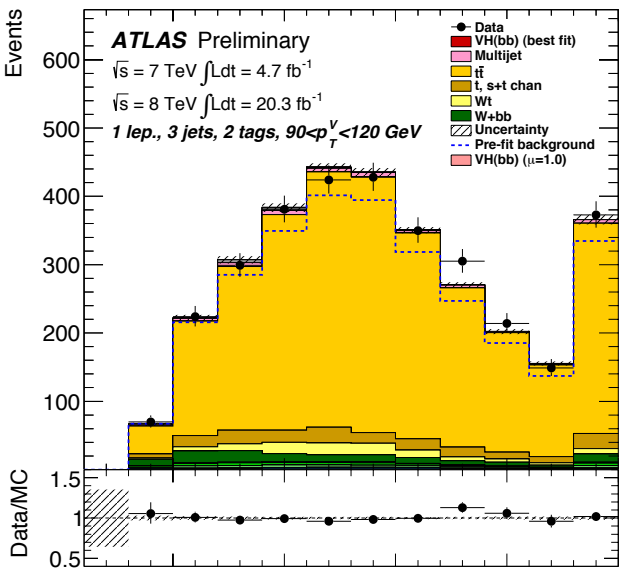


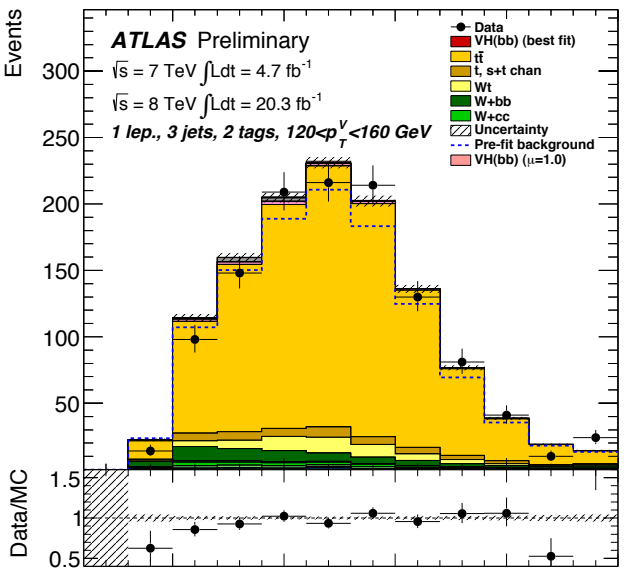


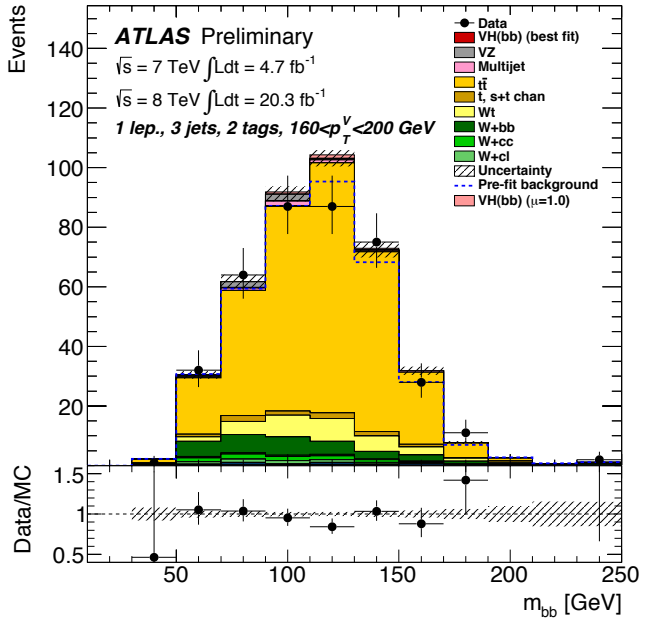


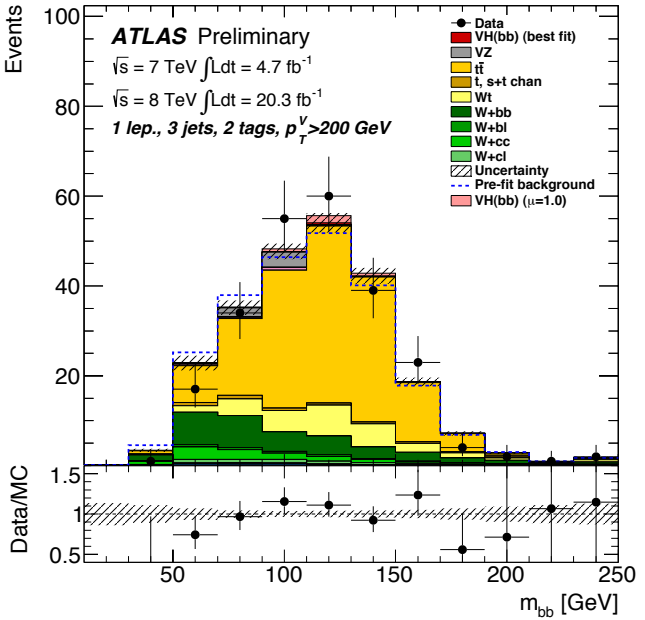
1-lepton Post-Fit Plots (2-tag, 3-jet)

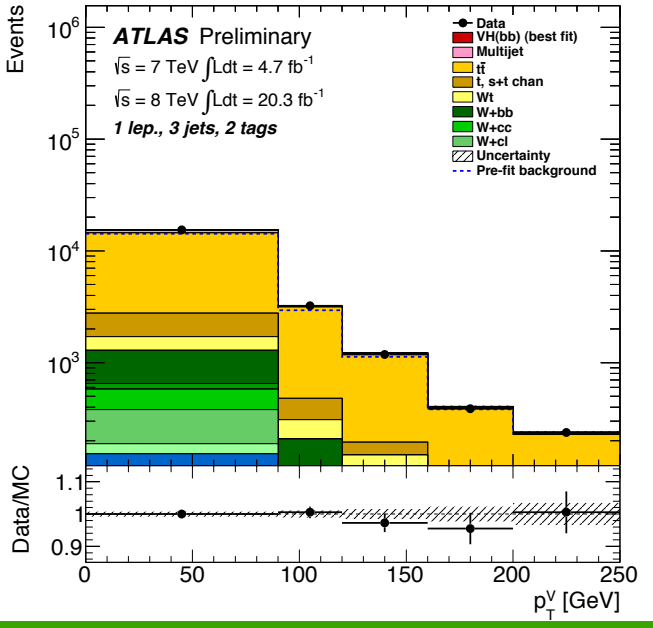




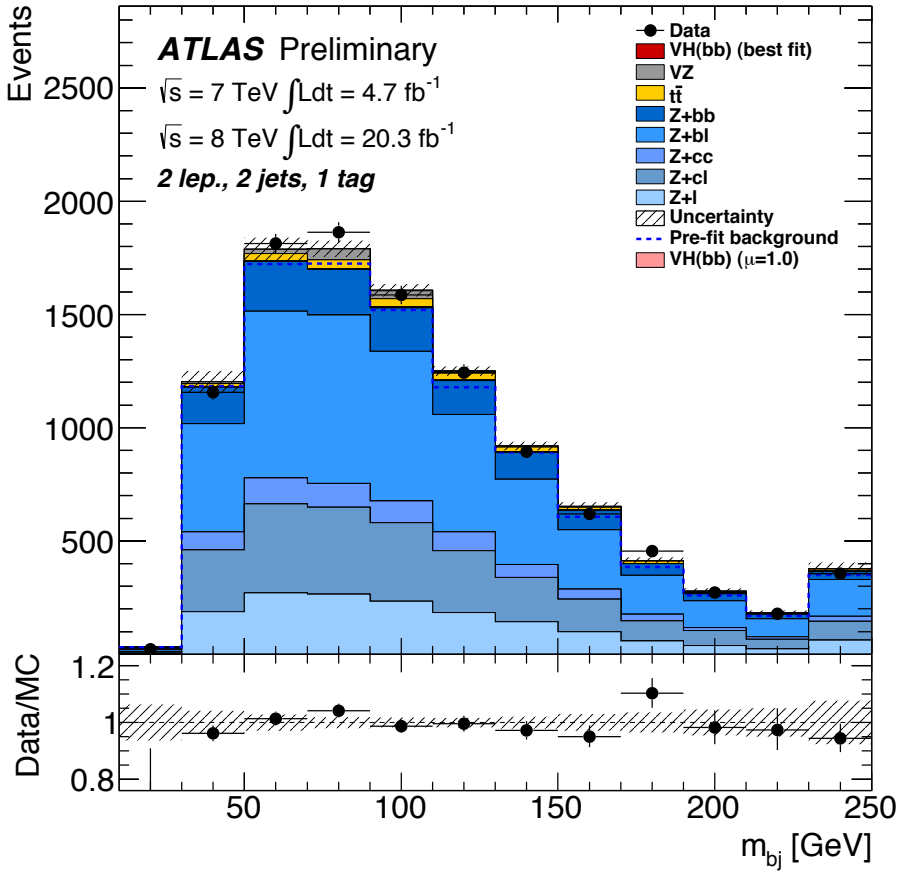


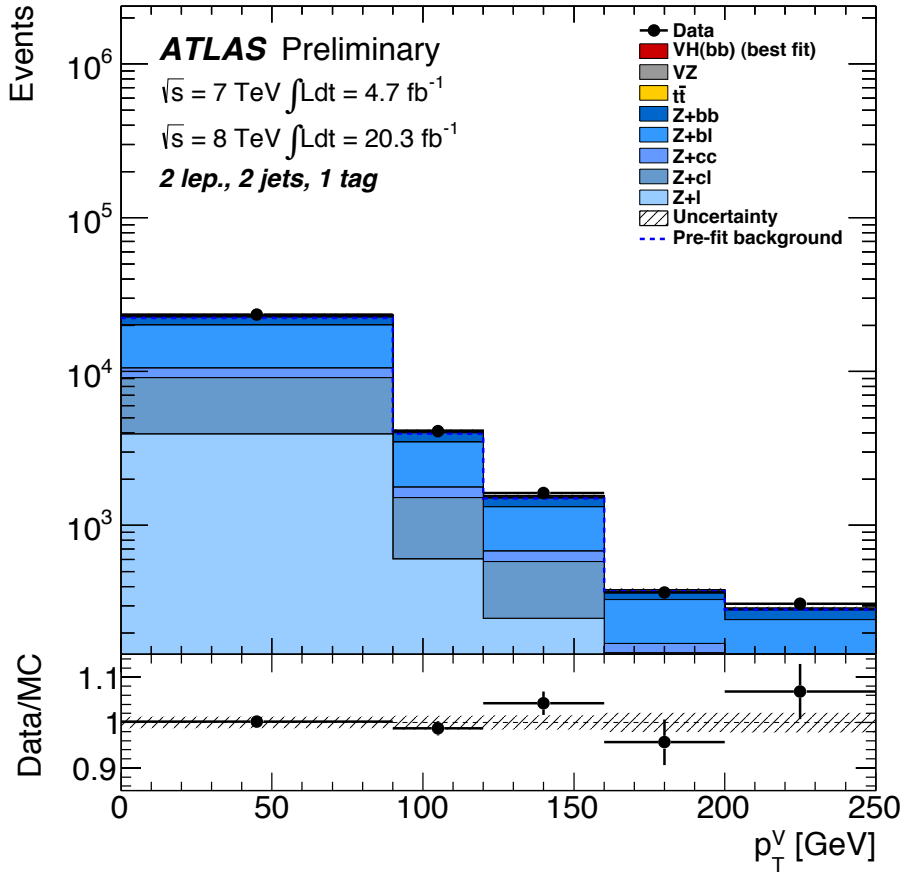




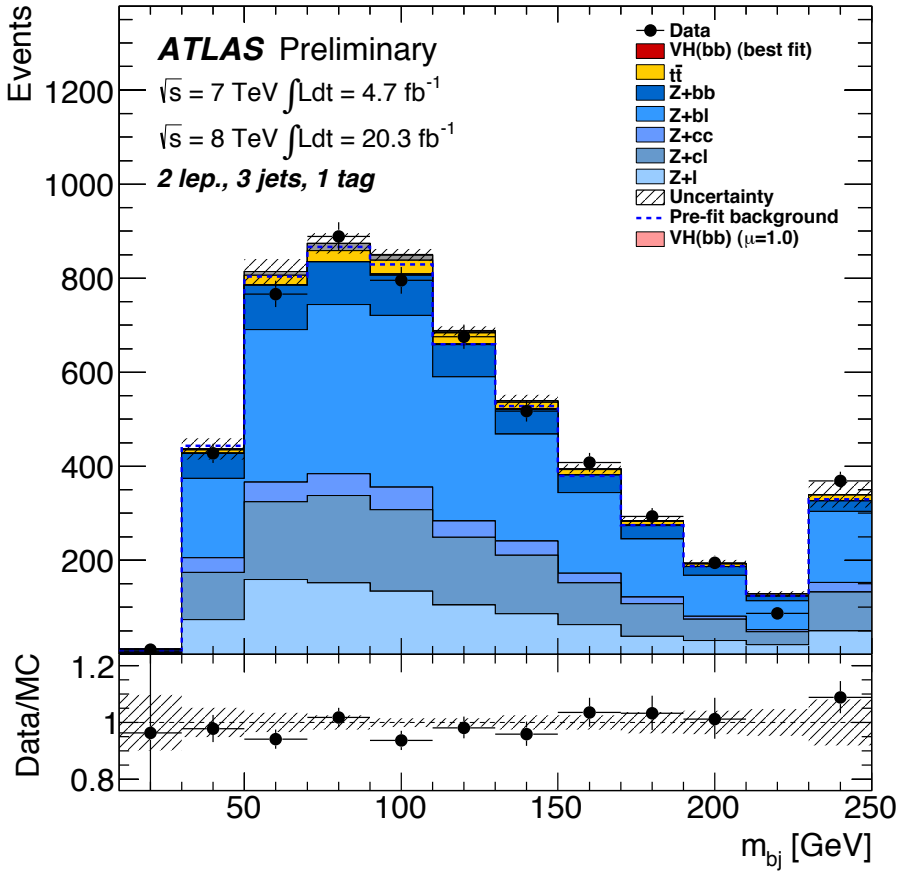


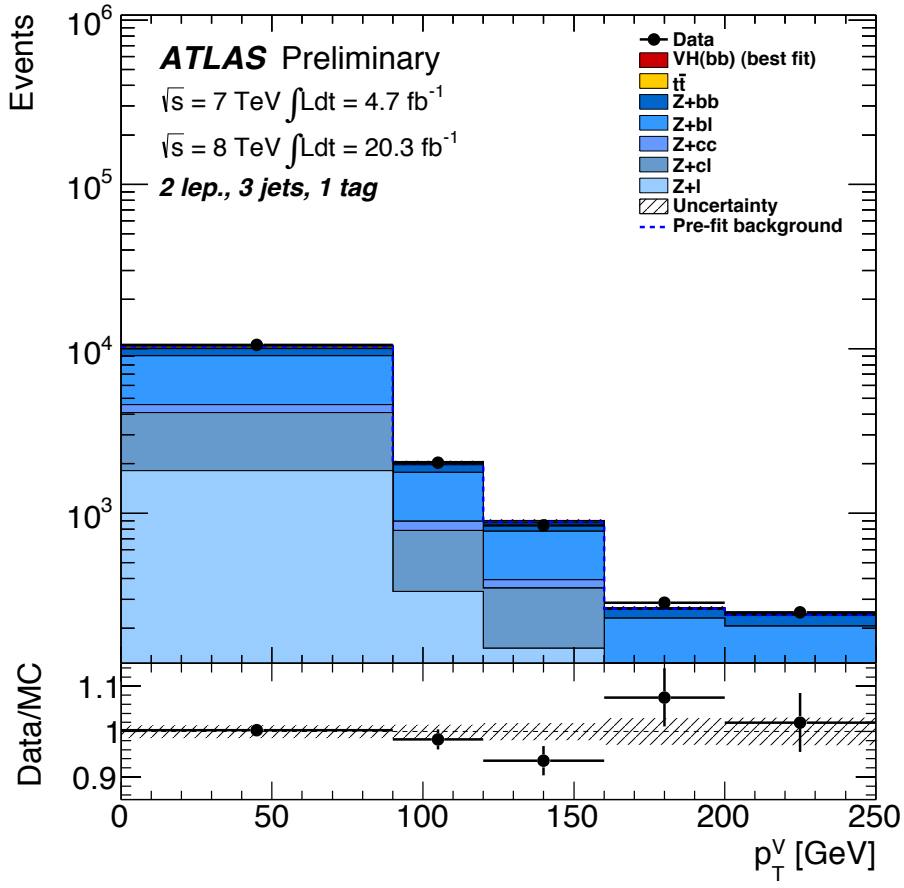
2-lepton Post-Fit Plots (1-tag, 2-jet)



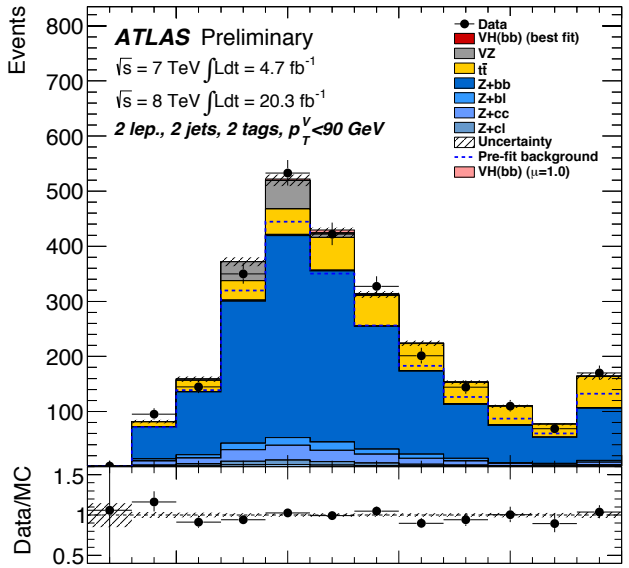


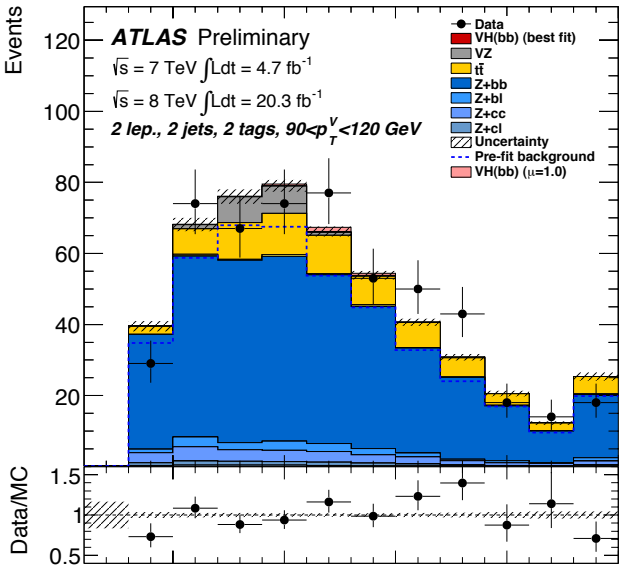
2-lepton Post-Fit Plots (2-tag, 3-jet)

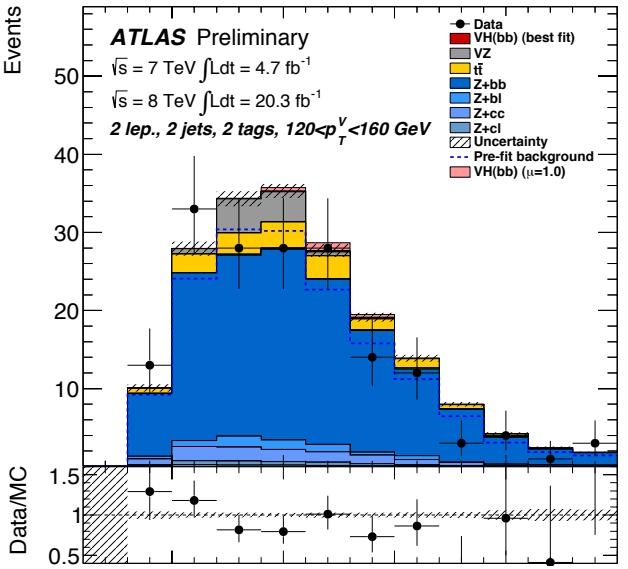


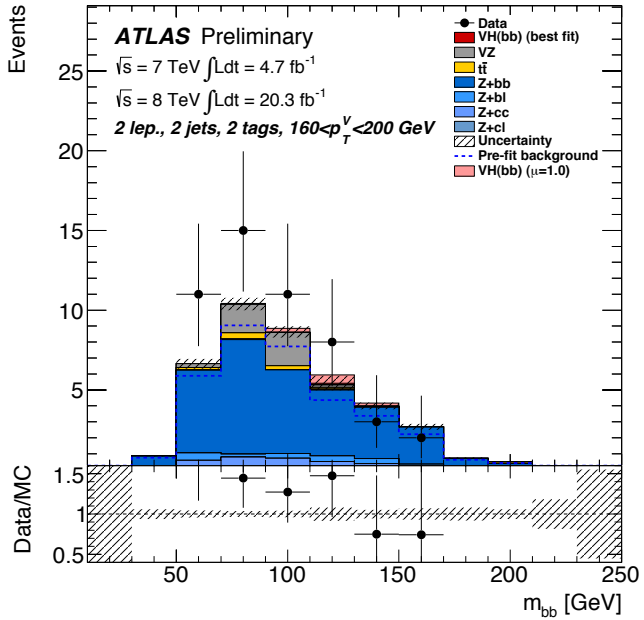


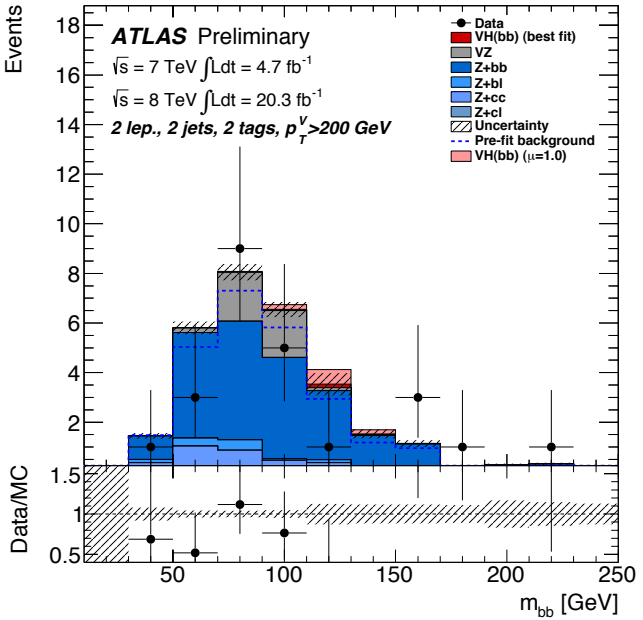
2-lepton Post-Fit Plots (2-tag, 2-jet)

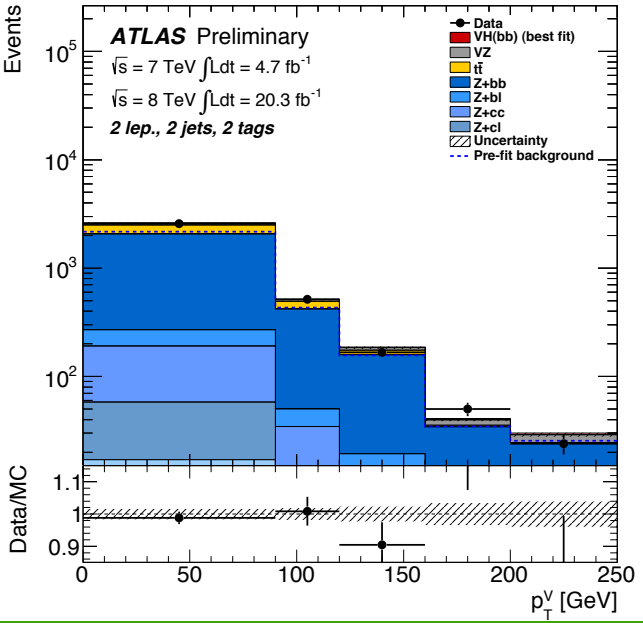




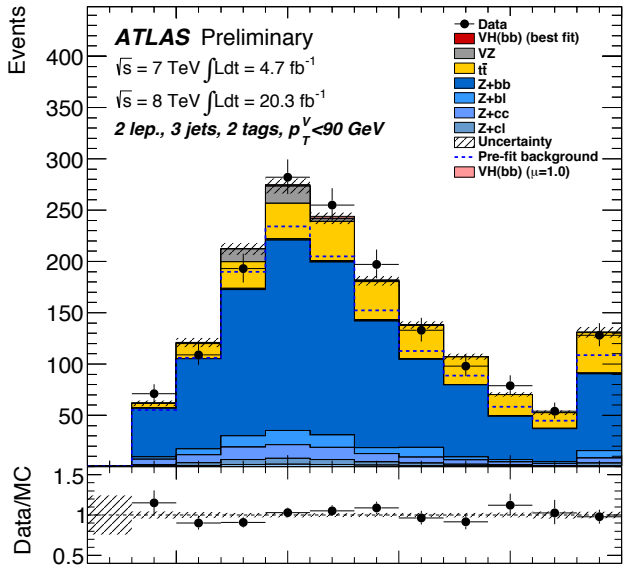


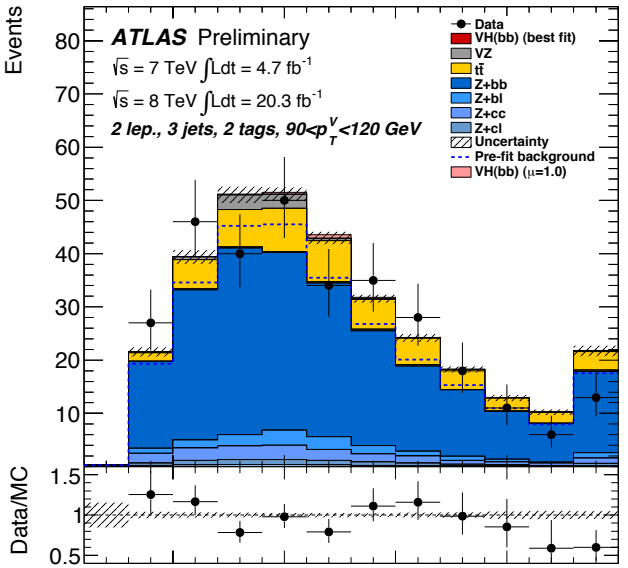


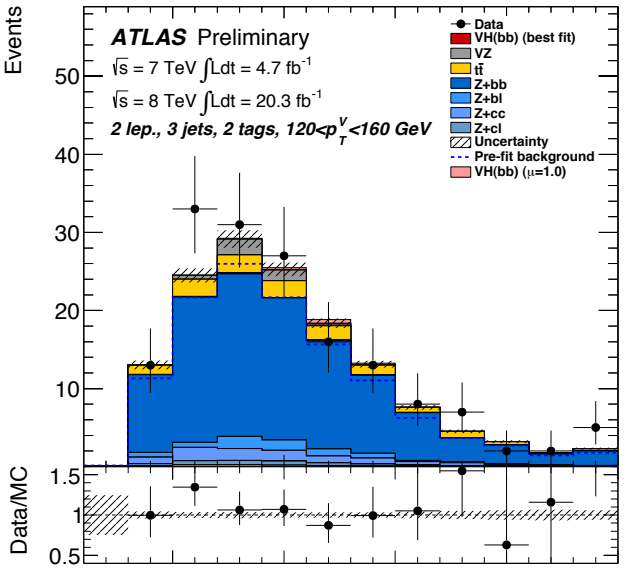


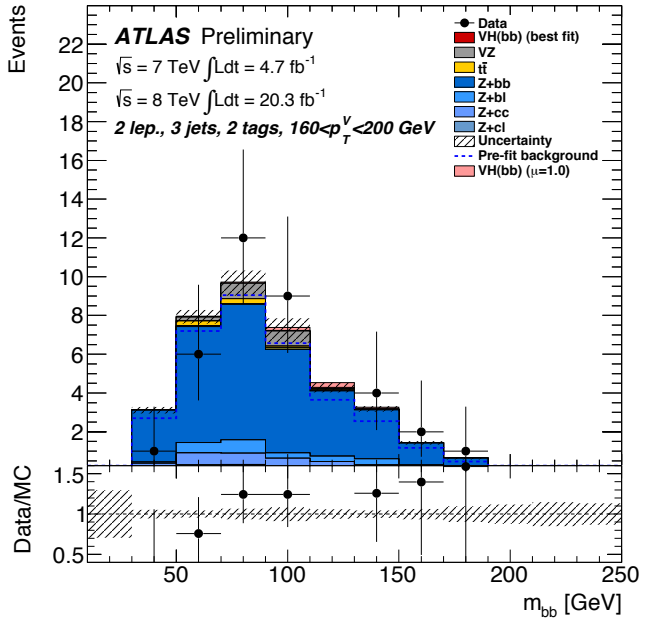


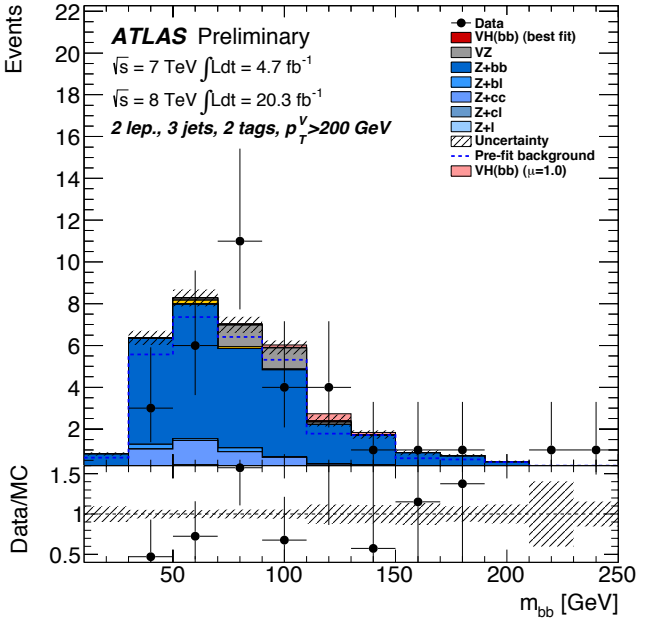
2-lepton Post-Fit Plots (2-tag, 3-jet)

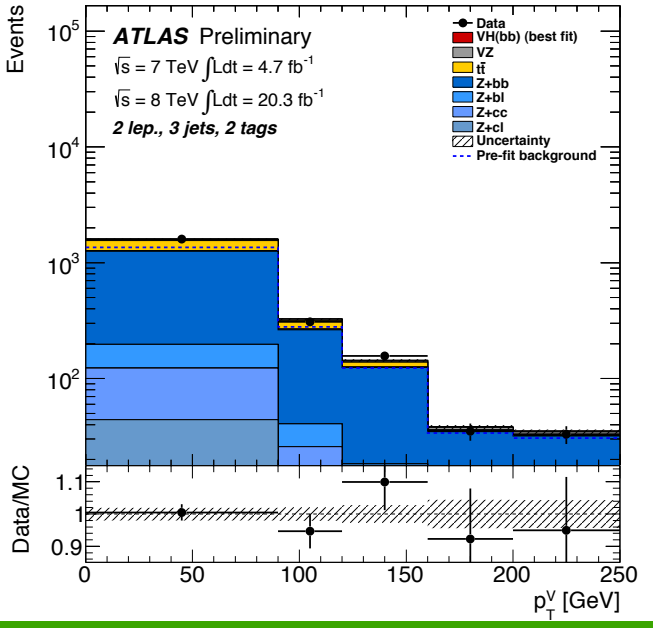




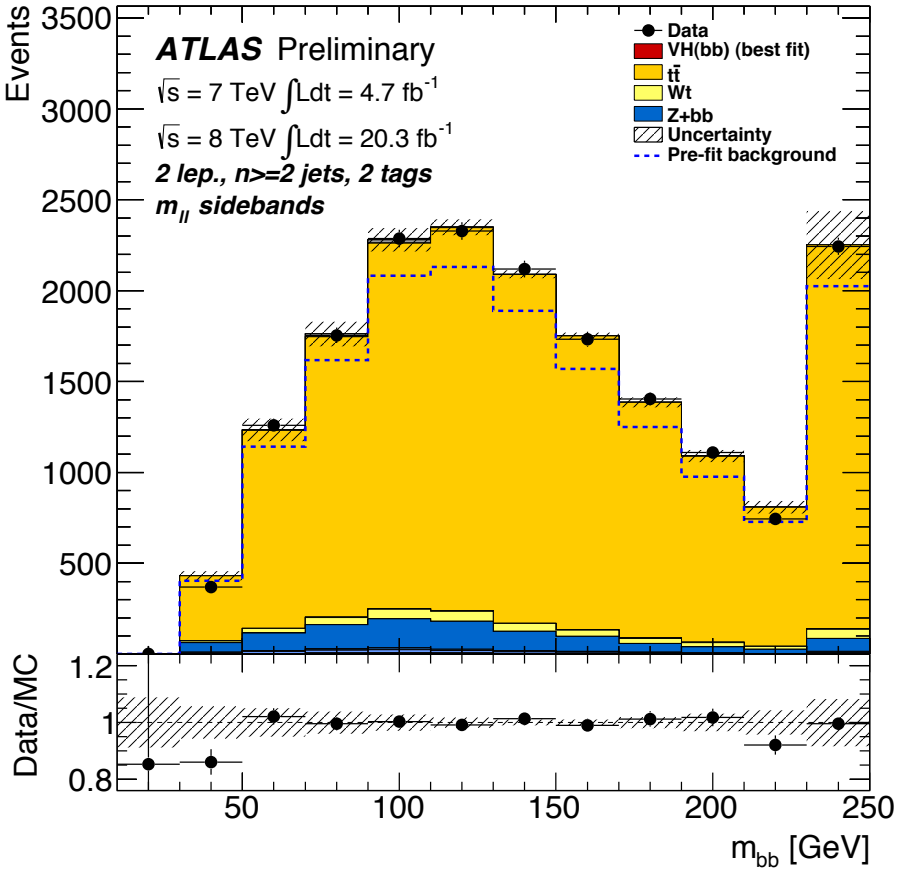


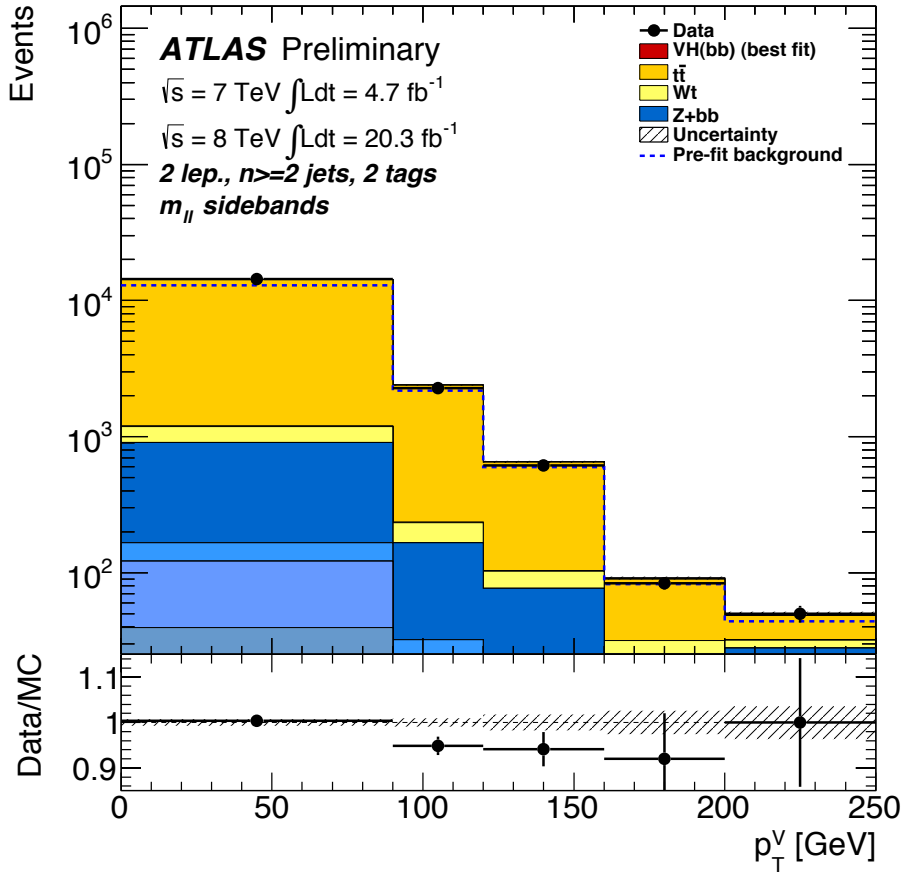






2-lepton Post-Fit Plots (top CR)





2-lepton Post-Fit Plots (top e-μ CR)