Statistical treatment in search for VH (H→b$\bar{b}$) with the ATLAS detector

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Introduction

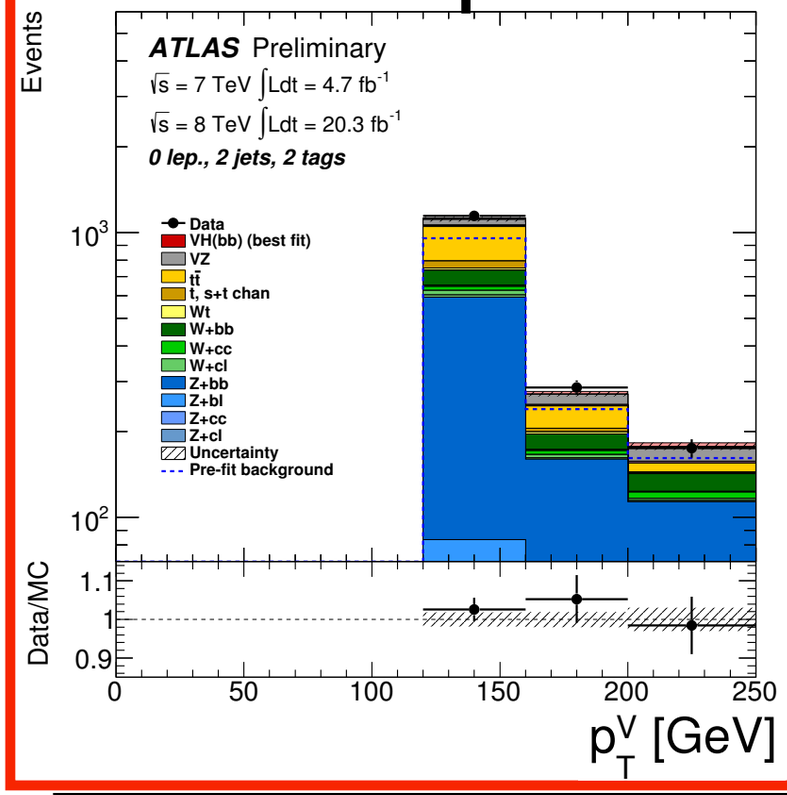
- **Why H→$b\bar{b}$? Why perform VH analysis?**
- **Complex analysis with numerous categories :**
  - **VH : ZH (Z→ ν+ν), WH (W→ l+ν) and ZH (Z→ l+l).**
  - **Signal regions : 2 jets and 3jets.**
  - **Control regions for W/Z + jets and Top background.**
    - **Each region have 5(3) W/Z P_T bins.**
- **Background modeling**
  - **QCD : data driven**
  - **W/Z + jets : Δϕ(jj) correction, normalization float in global fit.**
  - **Top : Top P_T correction, normalization float in global fit.**
  - **Single top, Diboson : from MC.**

Statistical treatment :

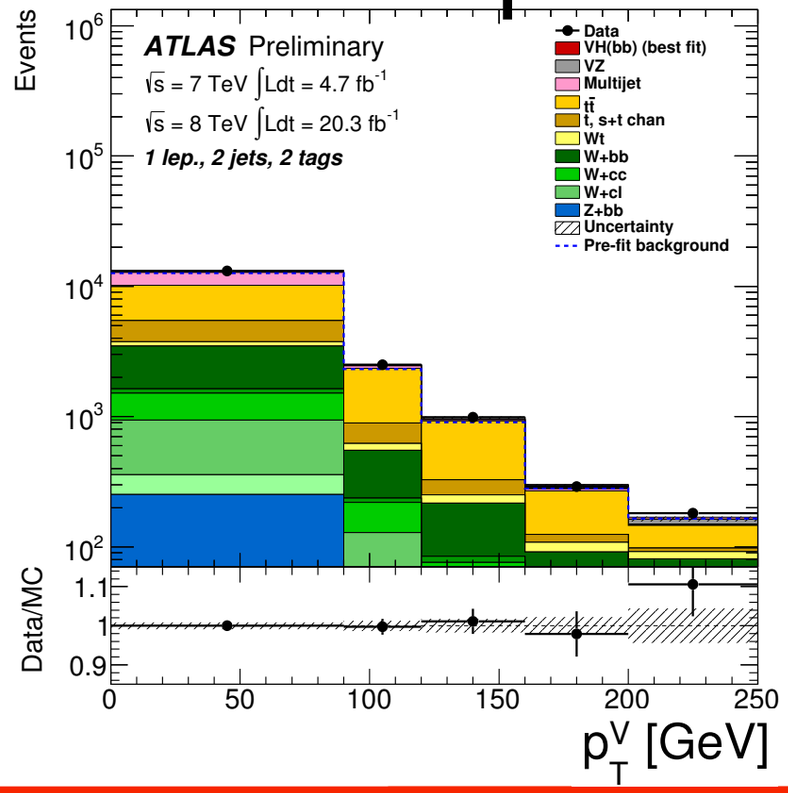
- **Global Fit : Use complimentary information from all regions to constrain background normalizations and shapes.**
- **SM Diboson Fit : Validation of fit model with identical procedure used for the Higgs boson search.**
- **Higgs Fit : Perform search for the VH ($H \rightarrow b\bar{b}$) production.**

Global fit : input

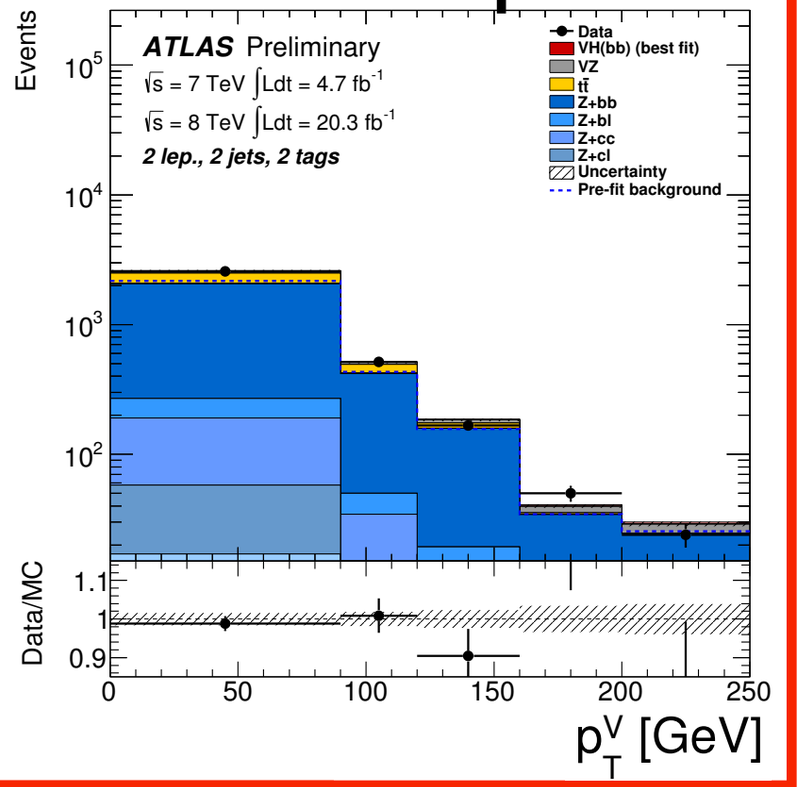
Zero Lepton



One Lepton



Two Lepton



	2Jets(1b-tag)	3Jets(1b-tag)	2Jets(2b-tag)	3Jets(2b-tag)	e-μ region
0Lepton	W+c / Z+c / Top	W+c / Z+c / Top	Z+b	Top	Z+b	Top	–
1Lepton	W+c	Top	W+c	Top	W+b	Top	Top	–
2Lepton	Z+c	Z+c	Z+b	Z+b	Top

Signal region

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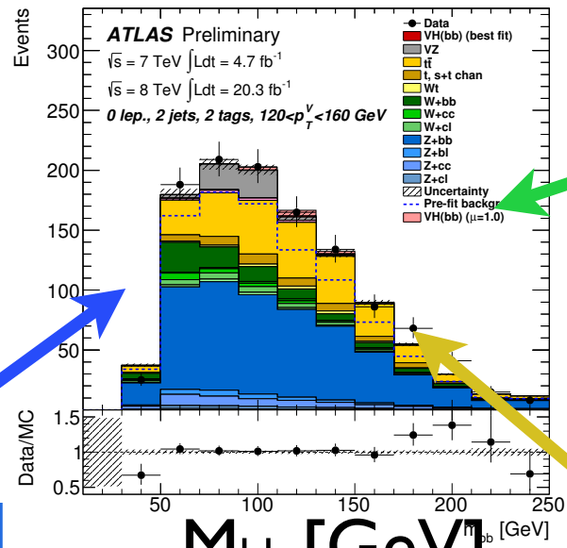
m_{bb} shape information are used in the signal regions.

Global fit : constrain normalization

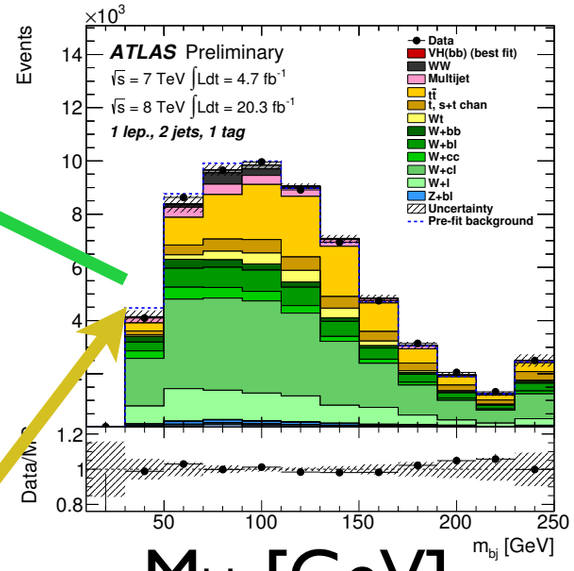
All categories used in the global fit

0 lepton



Mbb [GeV]

1 lepton



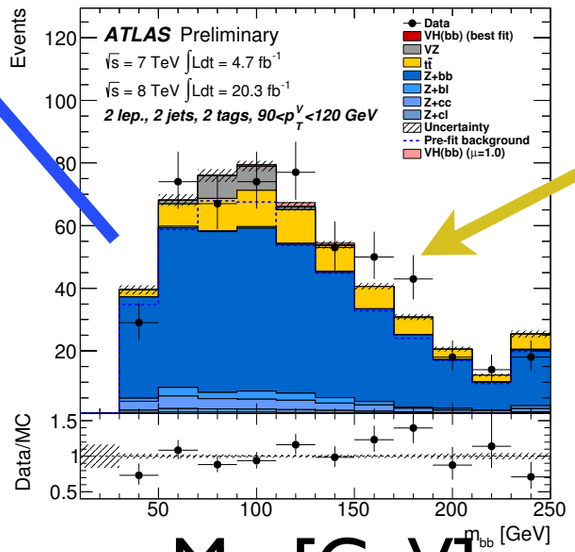
Mbb [GeV]

W+jets

Z+jets

Top

2 lepton



Mbb [GeV]

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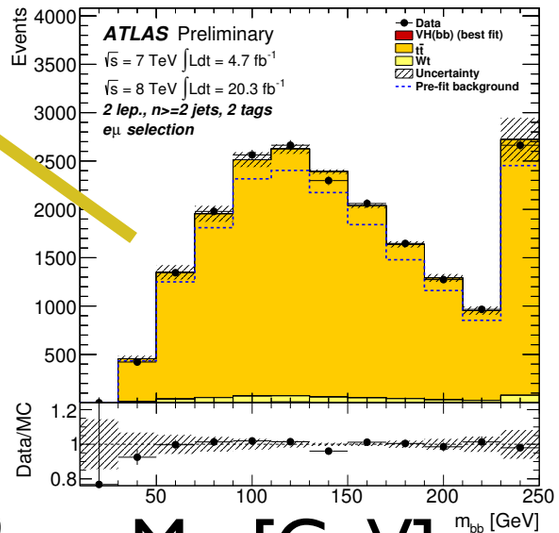
e-μ region



Mbb [GeV]

Global fit : constrain systematics

Experimental :

- JER/JES
- B-tagging
- Lepton ID
- MET

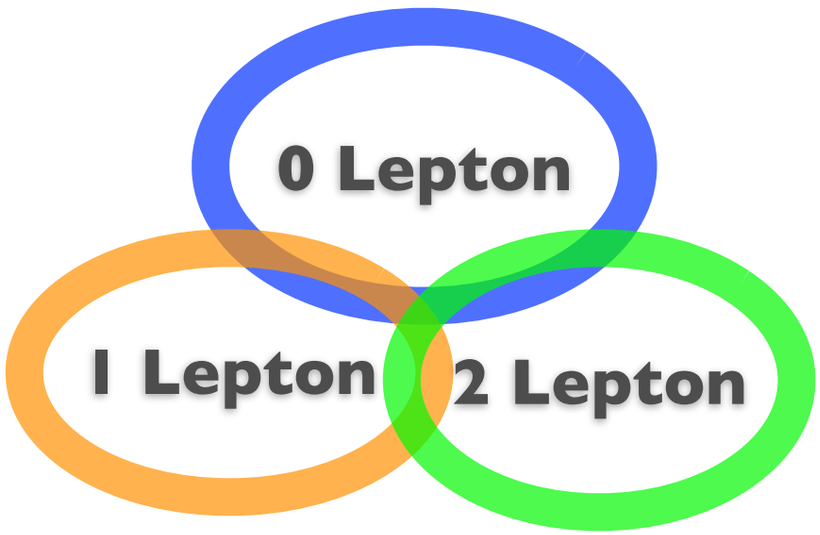
Modeling :

- m_{bb}
- W/Z P_T
- Top P_T
- Jet multiplicity

Global fit : constrain systematics

Experimental :

- JER/JES
- B-tagging
- Lepton ID
- MET



Migration between channels through lepton systematics

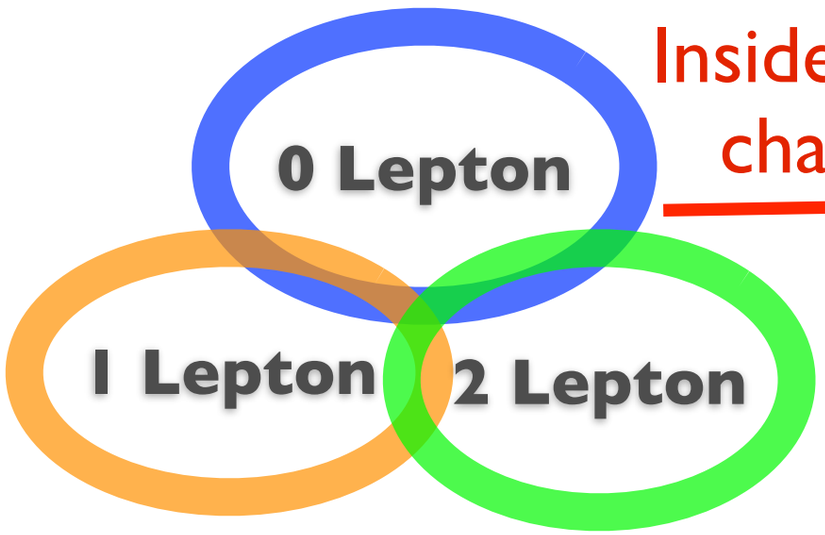
Modeling :

- m_{bb}
- W/Z P_T
- Top P_T
- Jet multiplicity

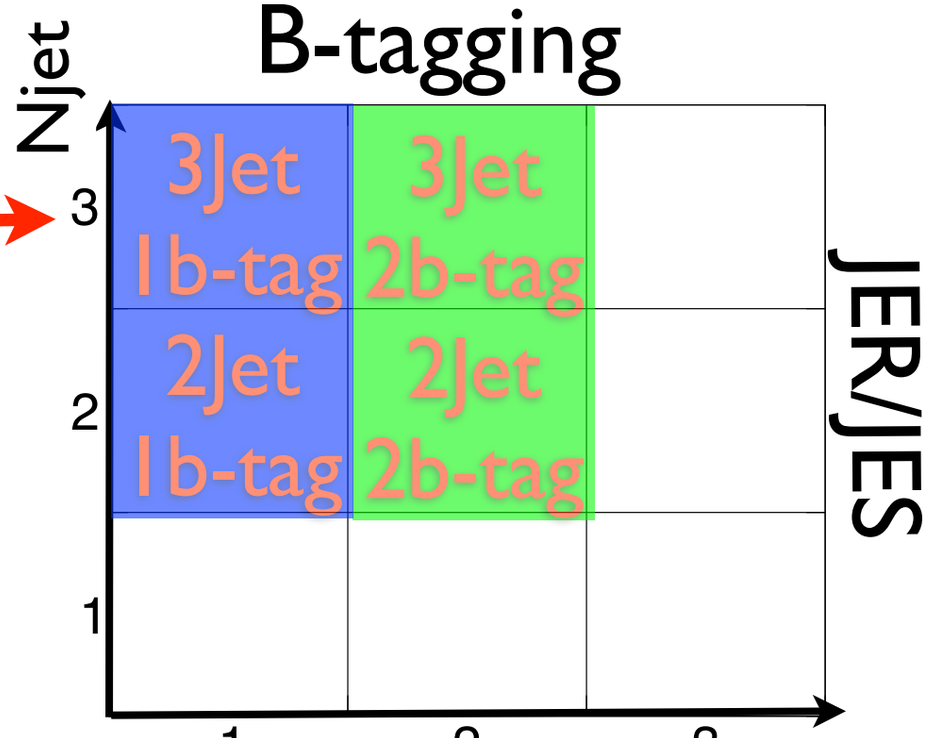
Global fit : constrain systematics

Experimental :

- JER/JES
- B-tagging
- Lepton ID
- MET



Inside each channel



Migration between channels through lepton systematics

Nbjet

Modeling :

- m_{bb}
- W/Z P_T
- Top P_T
- Jet multiplicity

Global fit : constrain systematics

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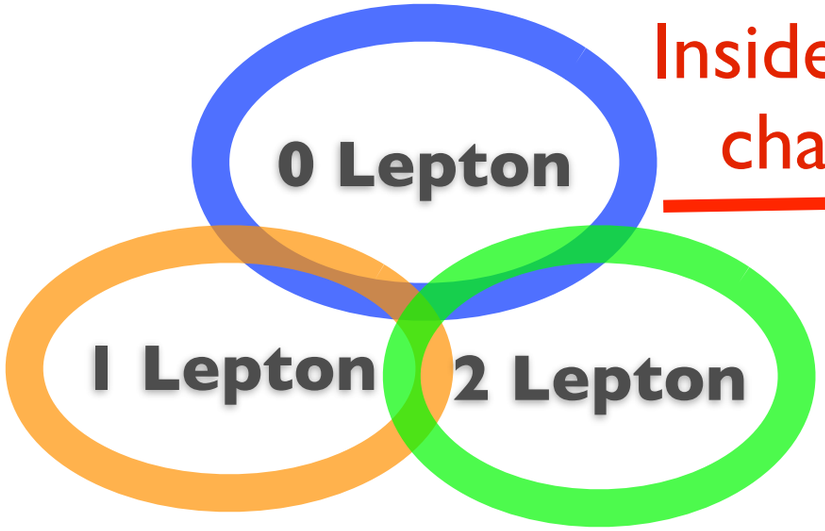
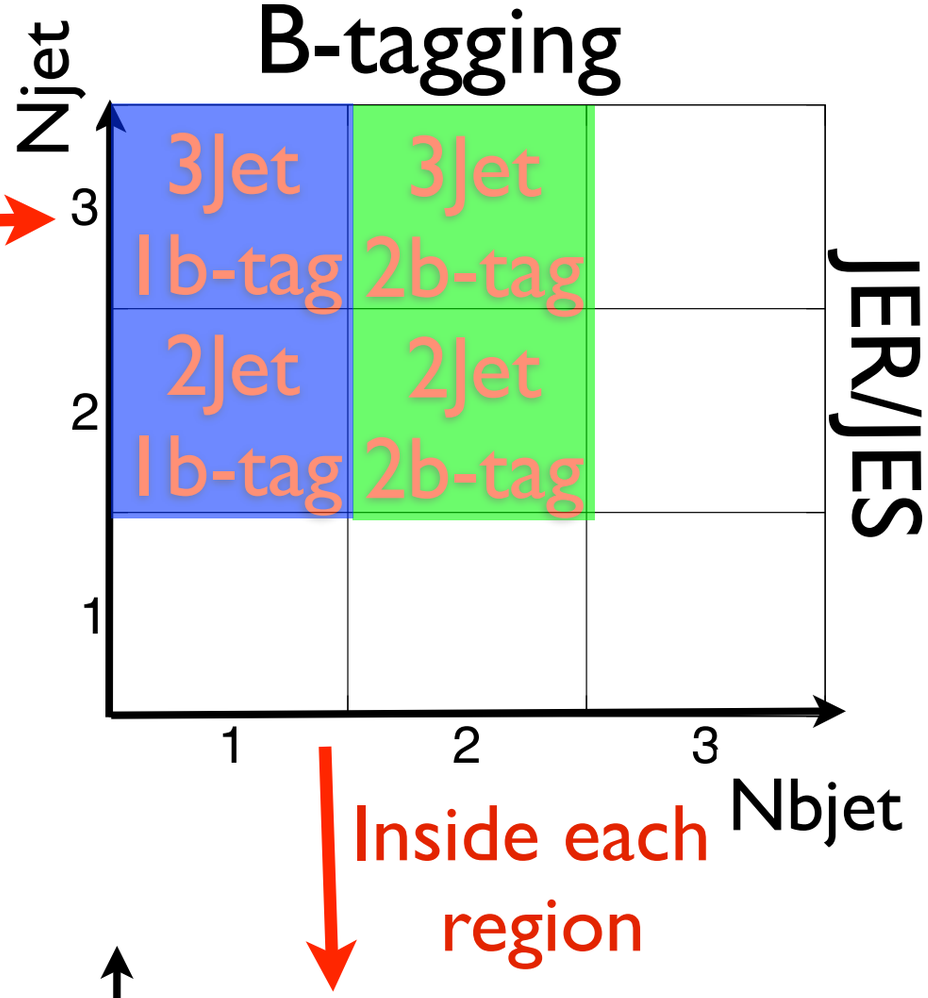
Experimental :

- JER/JES
- B-tagging
- Lepton ID
- MET



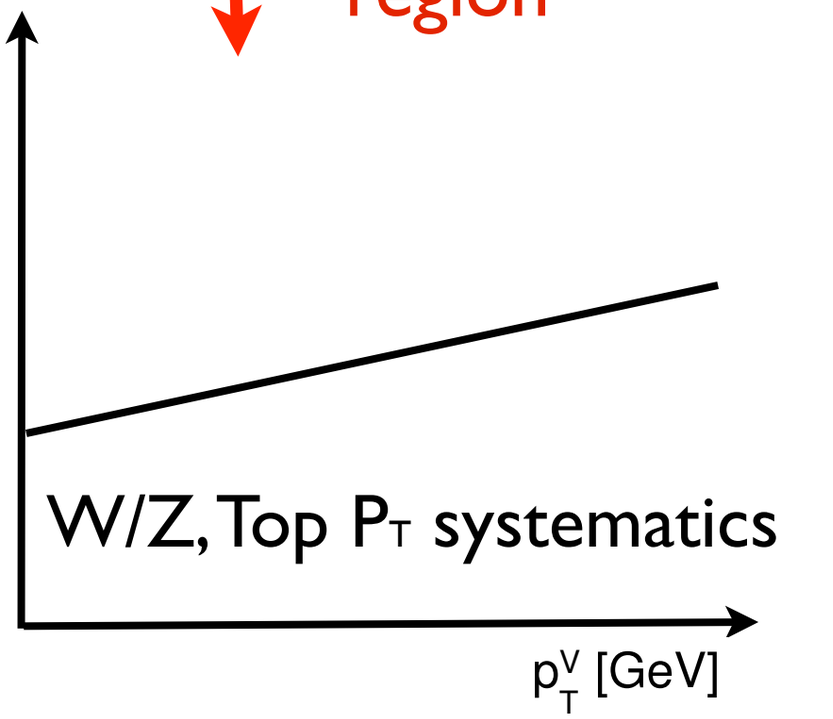
Inside each channel



Migration between channels through lepton systematics

Modeling :

- m_{bb}
- W/Z P_T
- Top P_T
- Jet multiplicity



Global fit : constrain systematics

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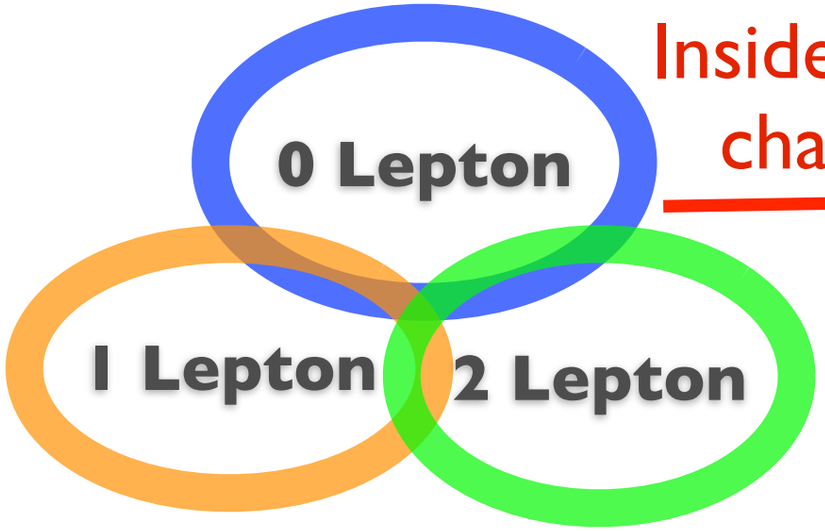
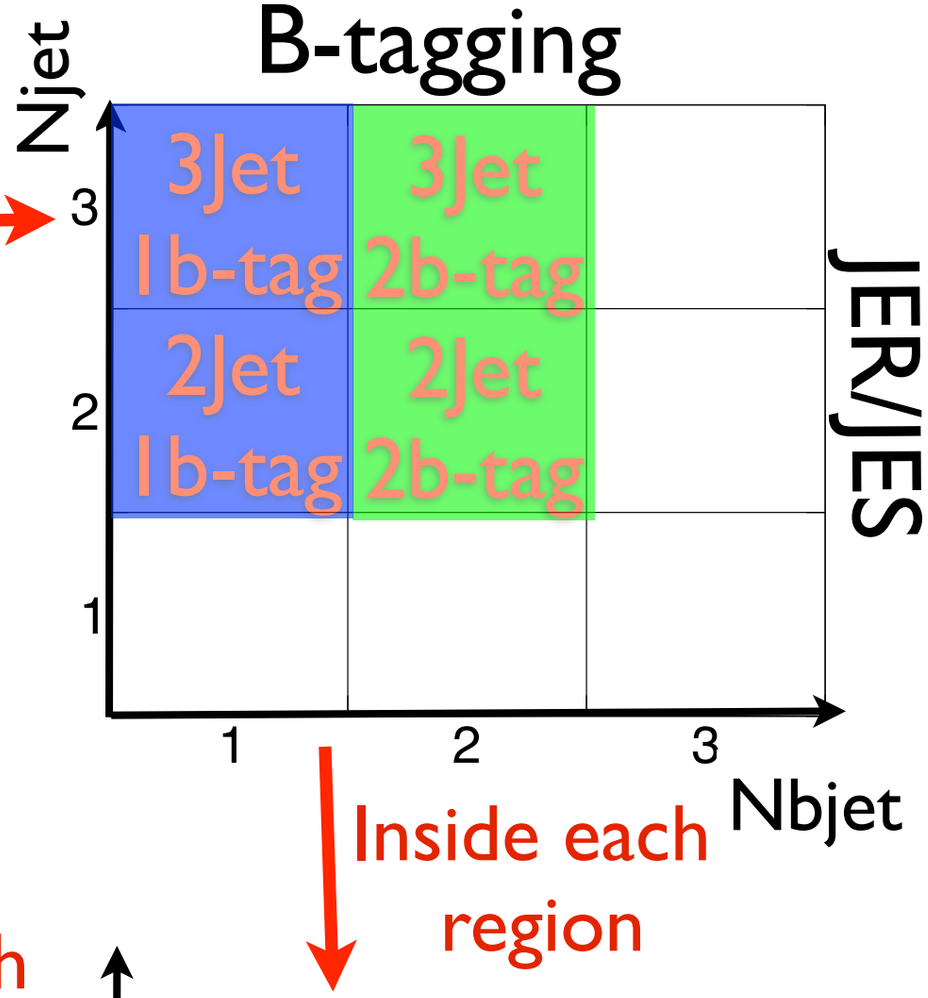
Experimental :

- JER/JES
- B-tagging
- Lepton ID
- MET



Inside each channel



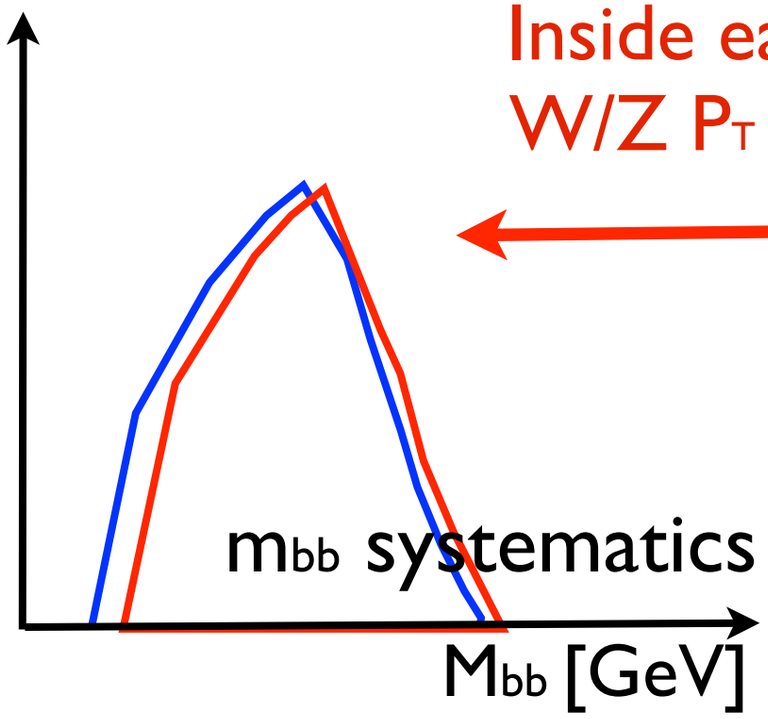
Migration between channels through lepton systematics

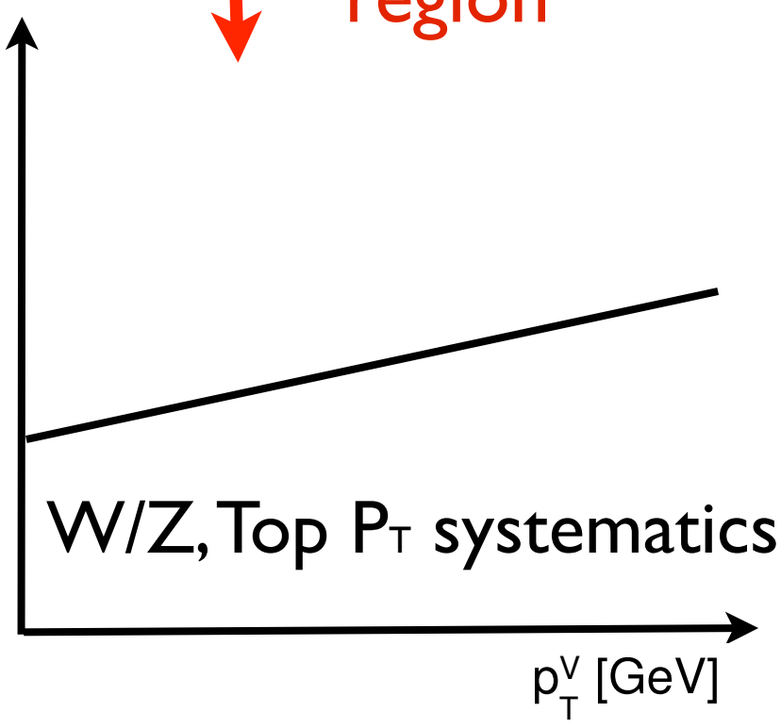
Inside each region

Modeling :

- m_{bb}
- W/Z P_T
- Top P_T
- Jet multiplicity

Inside each W/Z P_T bin





Global fit : results

•Strictly require the normalization of all backgrounds to be controlled by the same parameter globally.

TTbar	TTbar (float)
Wb	Wbb, Wcc, Wbl (float)
Wcl	Wcl (float)
Zb	Zbb, Zcc, Zbl (float)
Zcl	Zcl (float)
Wl	10%
Zl	10%
Singletop	4%-7%
Diboson	5%-7%

Process	Scale factor
$t\bar{t}$	1.13 ± 0.05
Wb	0.89 ± 0.15
Wcl	1.05 ± 0.14
Zb	1.30 ± 0.07
Zcl	0.89 ± 0.48

Scale factors for normalizations of each background.
Obtained from global fit of 7+8TeV

Global fit : results

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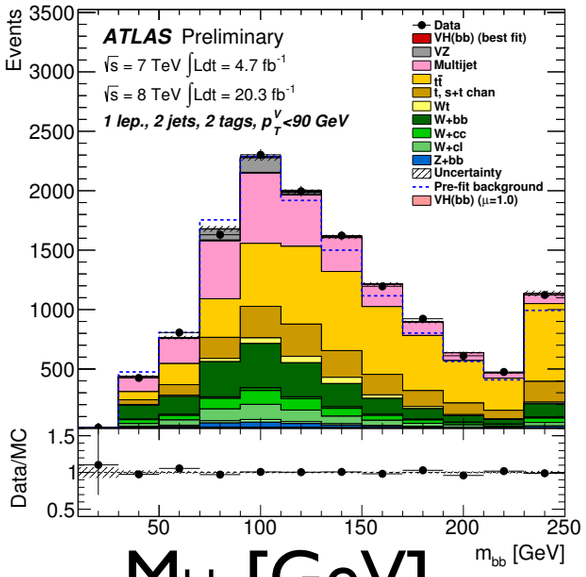
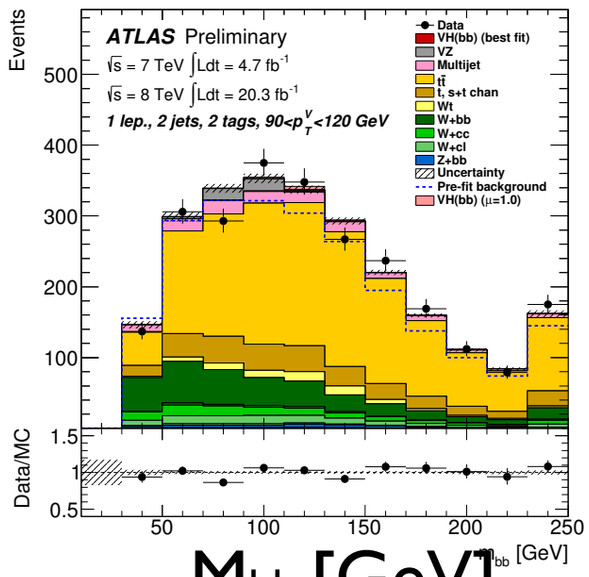
WPT < 90 GeV



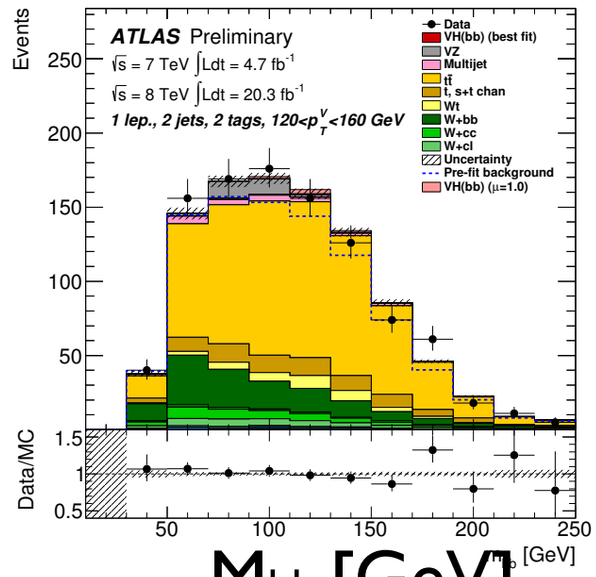
Mbb [GeV]

90 GeV < WPT < 120 GeV



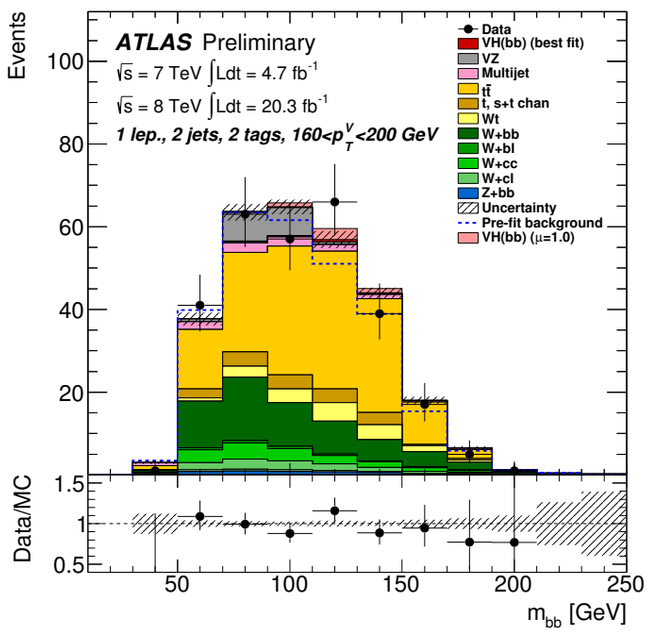
Mbb [GeV]

120 GeV < WPT < 160 GeV



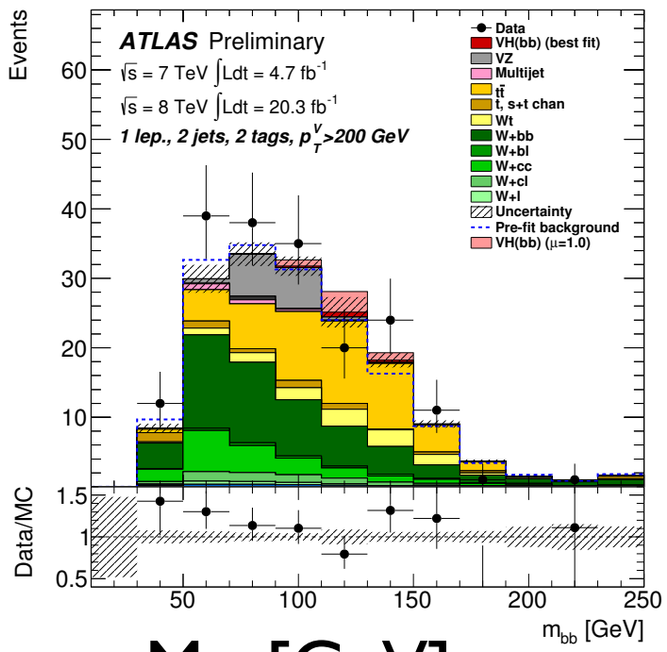
Mbb [GeV]

160 GeV < WPT < 200 GeV



Mbb [GeV]

200 GeV < WPT



Mbb [GeV]

1 Lepton : 2jet(2b-tag)

Same level of agreement in all 3 channels.

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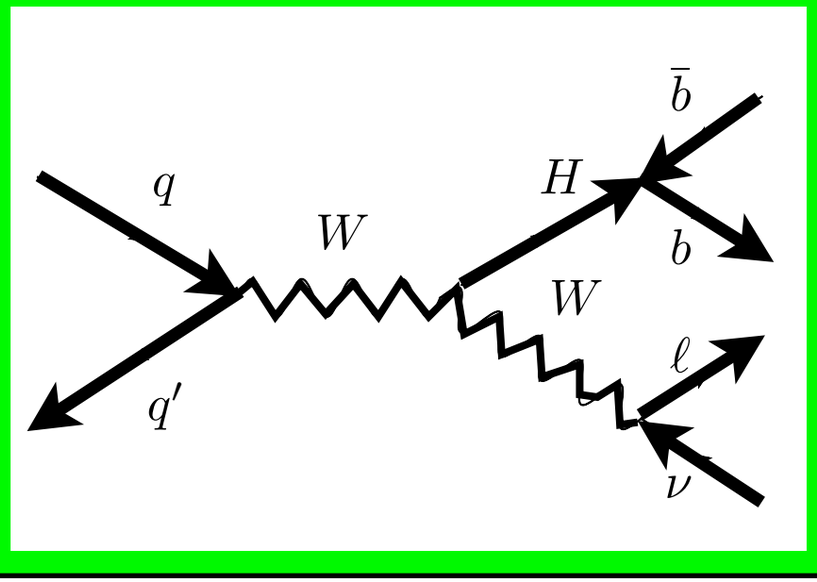
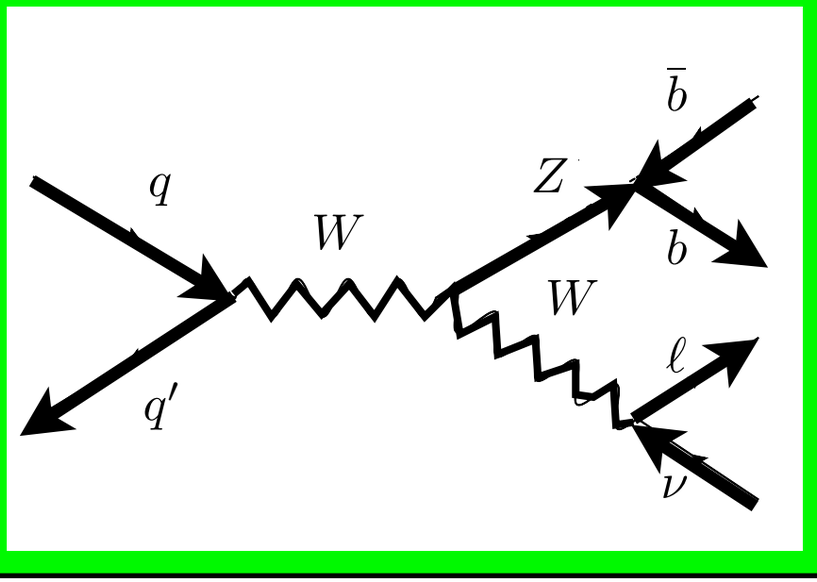
SM diboson fit (I)





•Diboson with a Z boson decaying to a pair of b quarks has a signature very similar to the one considered in this analysis.

- ✦ Softer P_{Tbb} spectrum.
- ✦ Lower m_{bb} value
- ✦ Larger cross-section (5×)

- Perform diboson fit as a validation of the analysis procedure
  - ✦ Allow normalization of diboson to float with scale factor μ_{VZ}.
  - ✦ SM Higgs boson treated as a background with 50% uncertainty on the cross-section
  - ✦ Small contribution of WW is considered as a background.

SM diboson fit (ll)

Observed significance σ : 4.8

Expected significance σ : 5.1

μ_{VZ} values calculated for 7TeV, 8TeV separately and combined together.

The individual μ_{VZ} values for the lepton channels are obtained from a simultaneous fit with the signal strength for each channel floating independently.

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

Agrees with the SM expectation of $\mu_{VZ} = 1.0$

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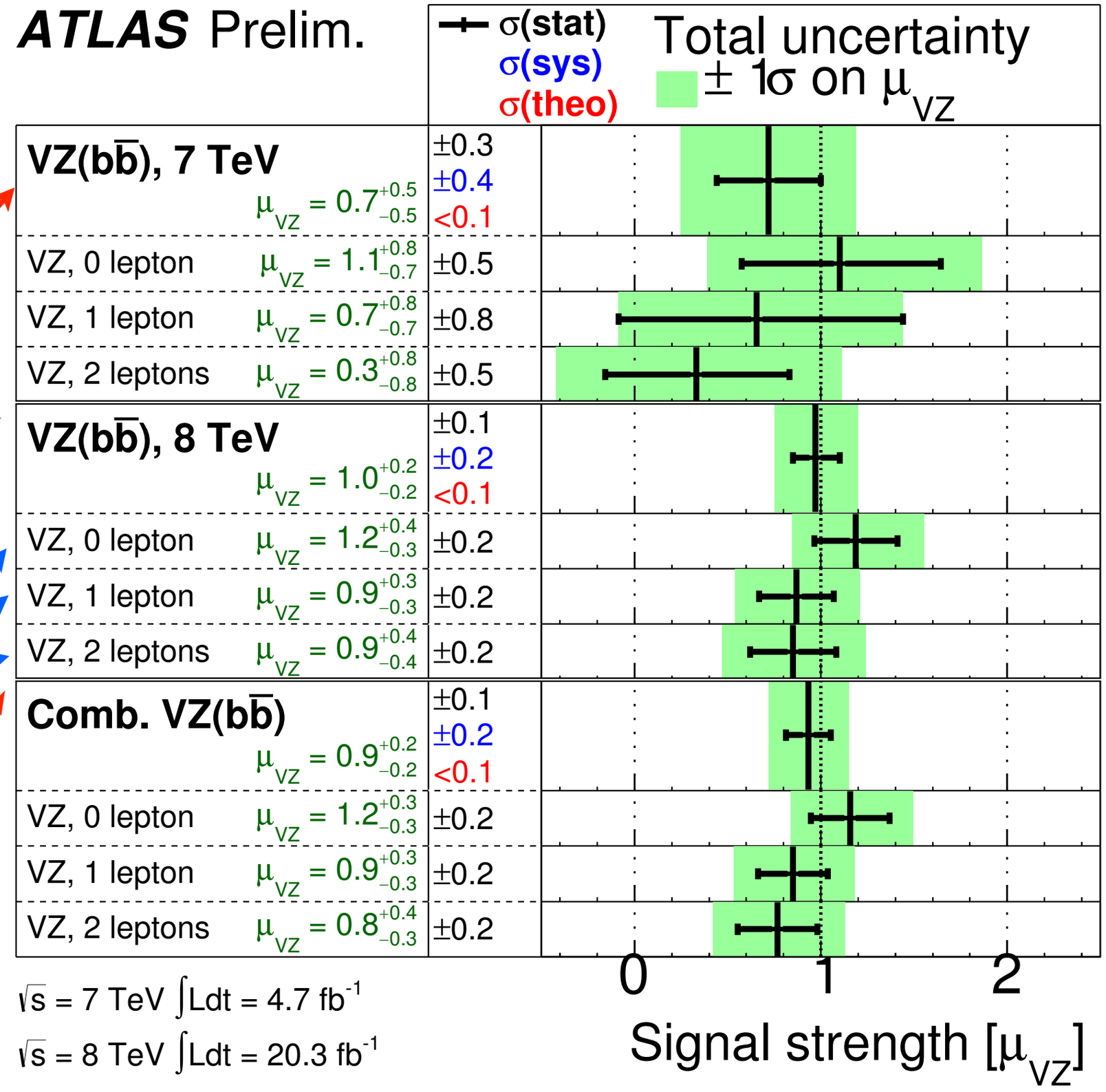
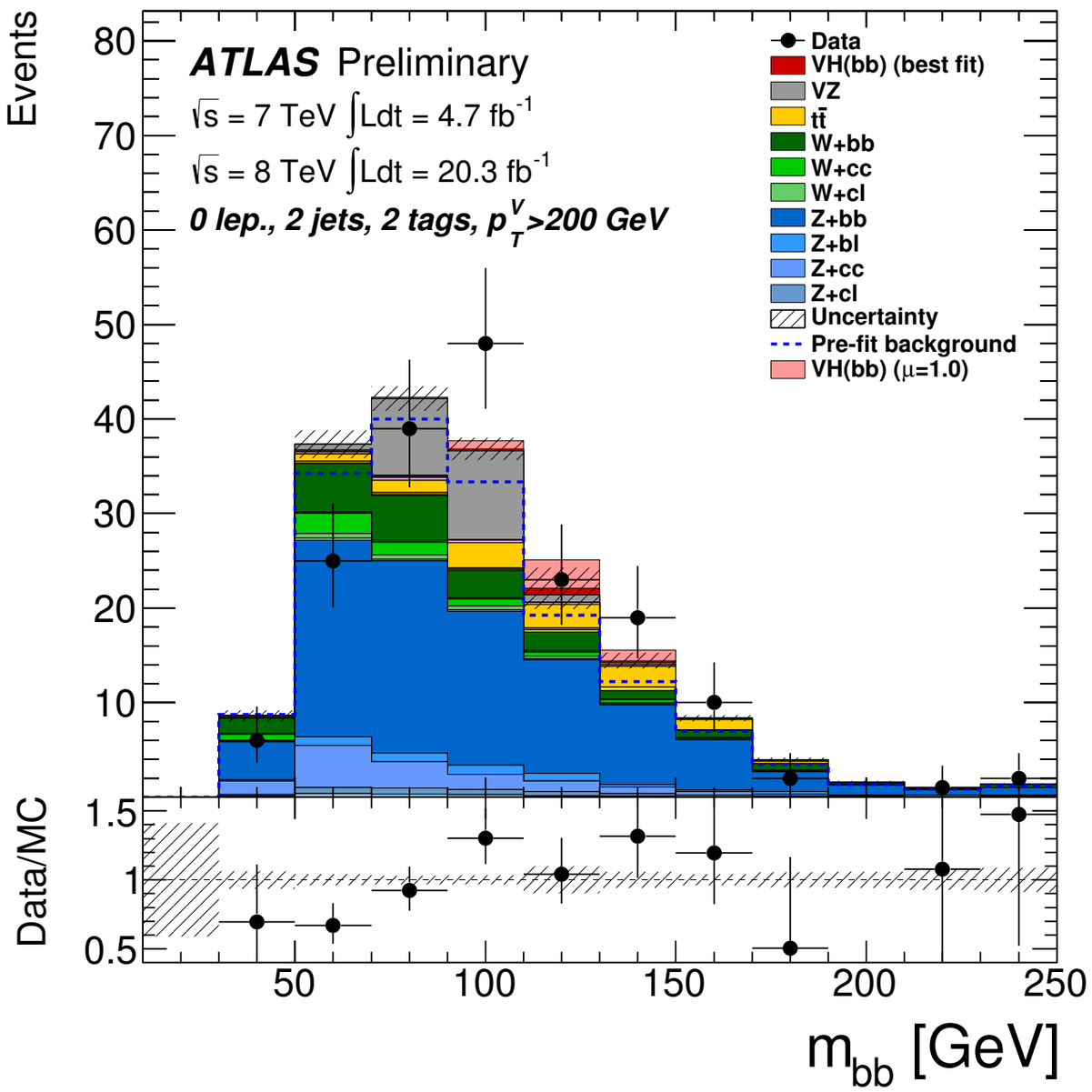


Higgs fit : Zero Lepton

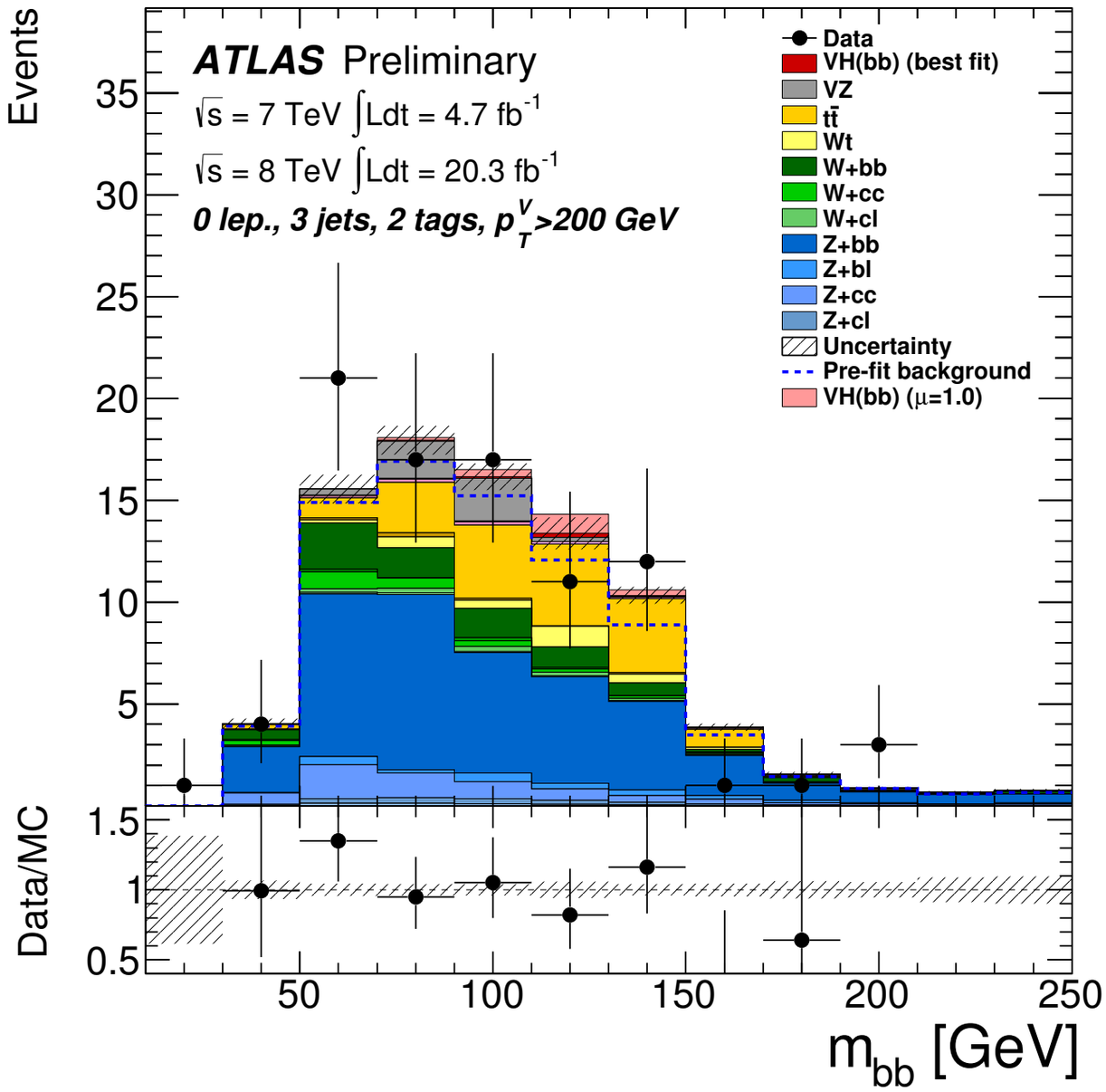
Fit with diboson contributions constrained to their SM values within uncertainties and with the Higgs boson signal strength μ as a free parameter.

Zero Lepton ATLAS-CONF-2013-079

2jet(2b-tag) Z P_T > 200 GeV



3jet(2b-tag) Z P_T > 200 GeV

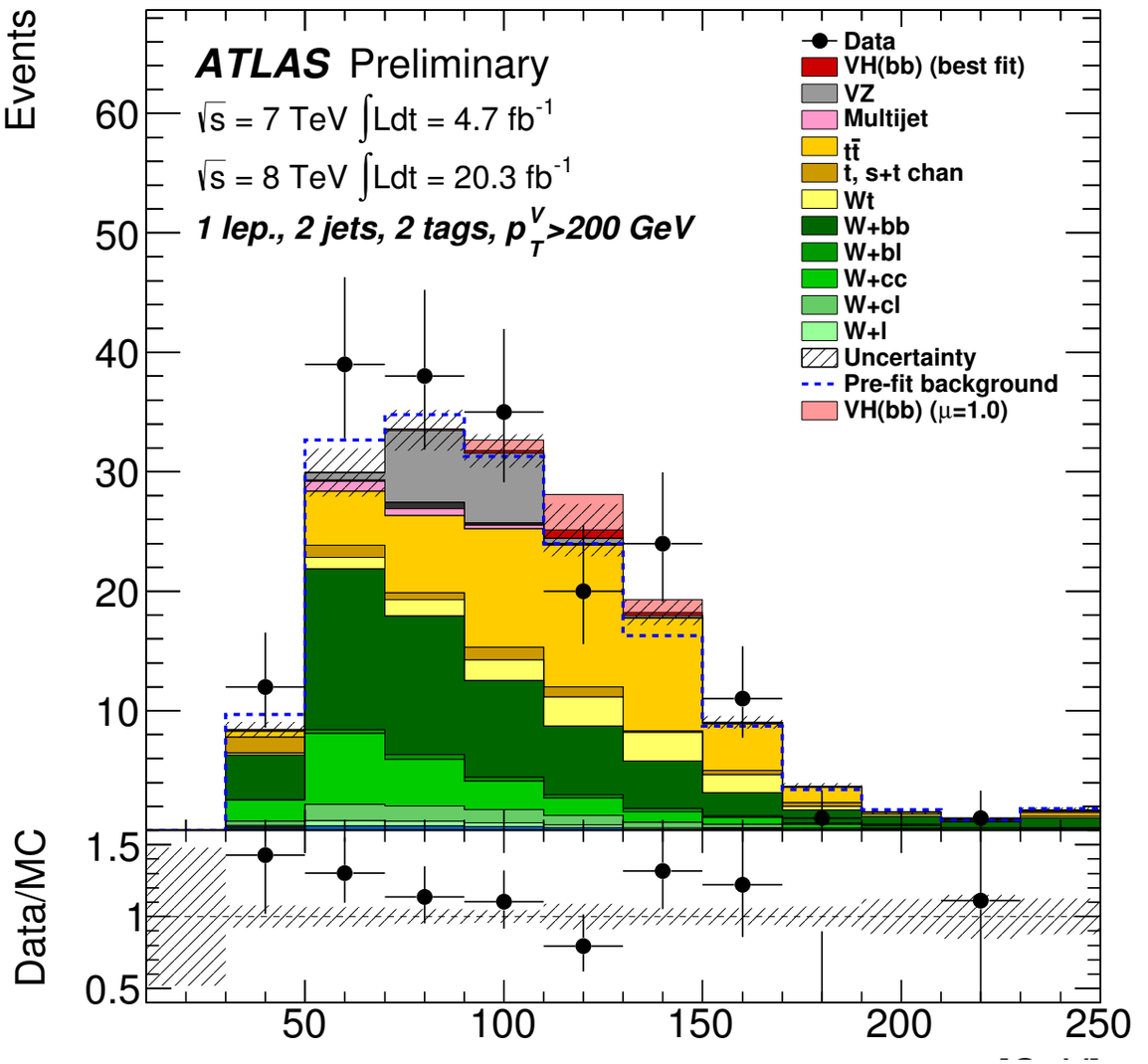


Higgs fit : One Lepton

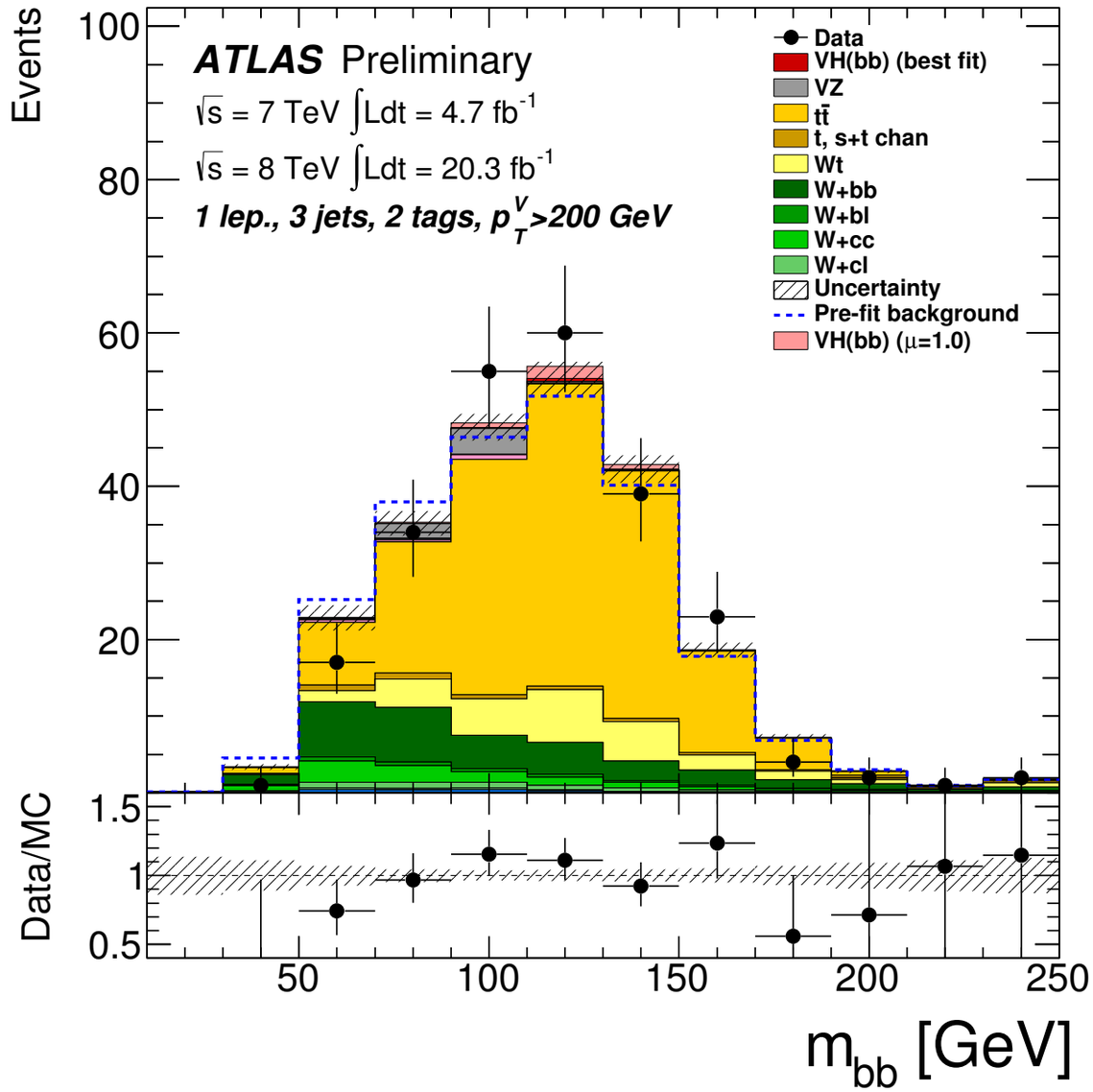
Fit with diboson contributions constrained to their SM values within uncertainties and with the Higgs boson signal strength μ as a free parameter.

One Lepton ATLAS-CONF-2013-079

2jet(2b-tag) W P_T > 200 GeV



3jet(2b-tag) W P_T > 200 GeV

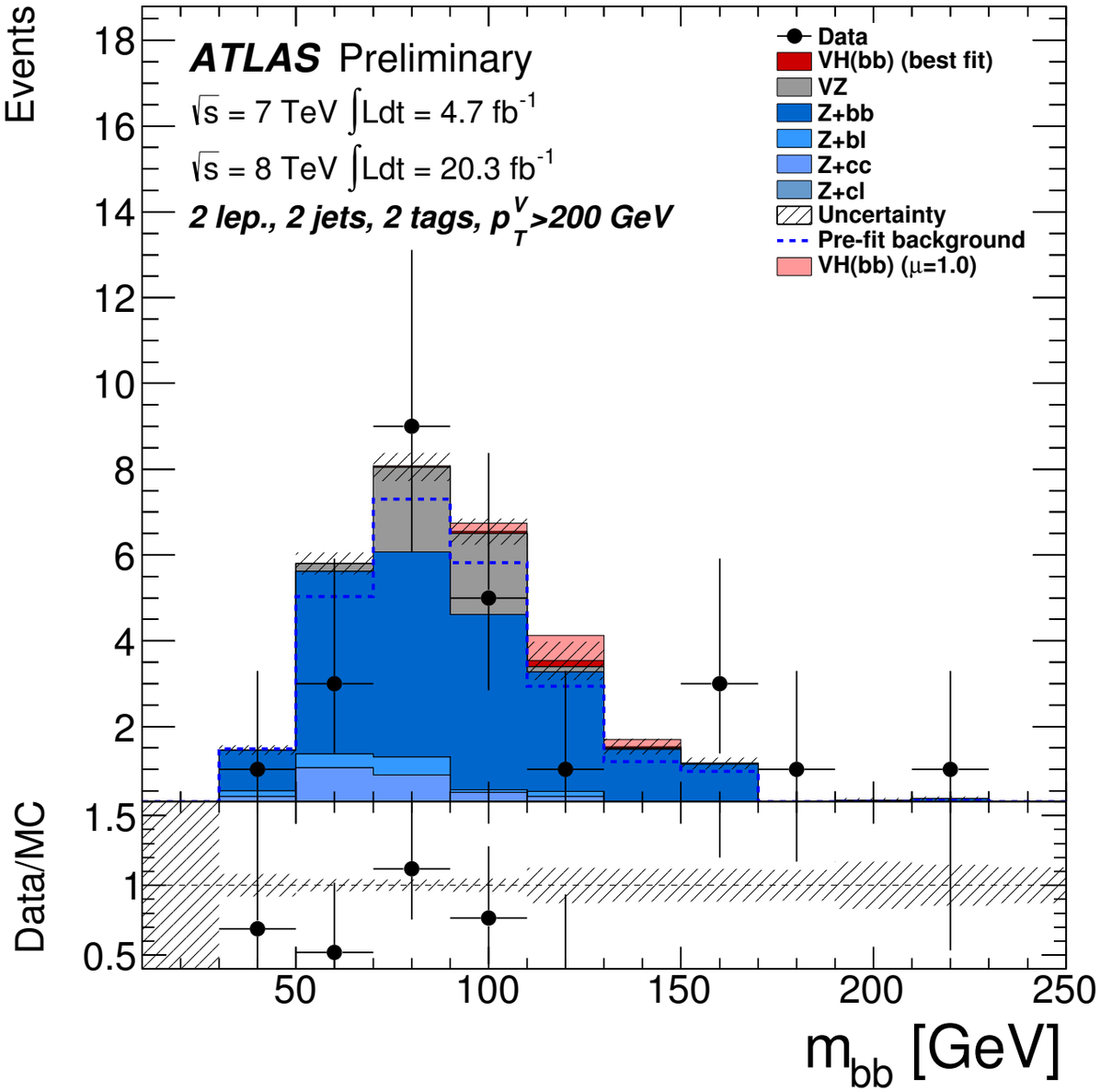


Higgs fit : Two Lepton

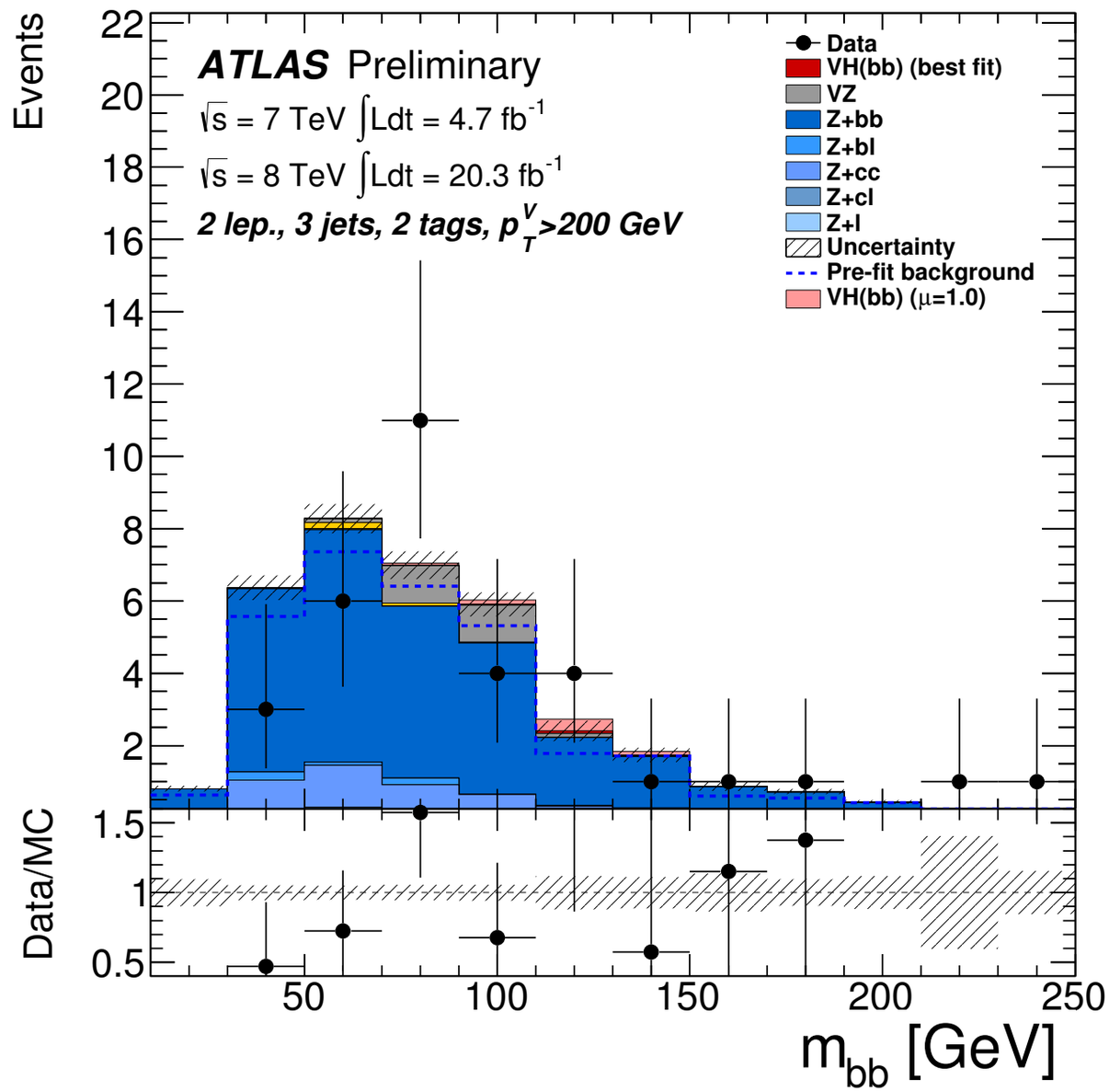
Fit with diboson contributions constrained to their SM values within uncertainties and with the Higgs boson signal strength μ as a free parameter.

Two Lepton ATLAS-CONF-2013-079

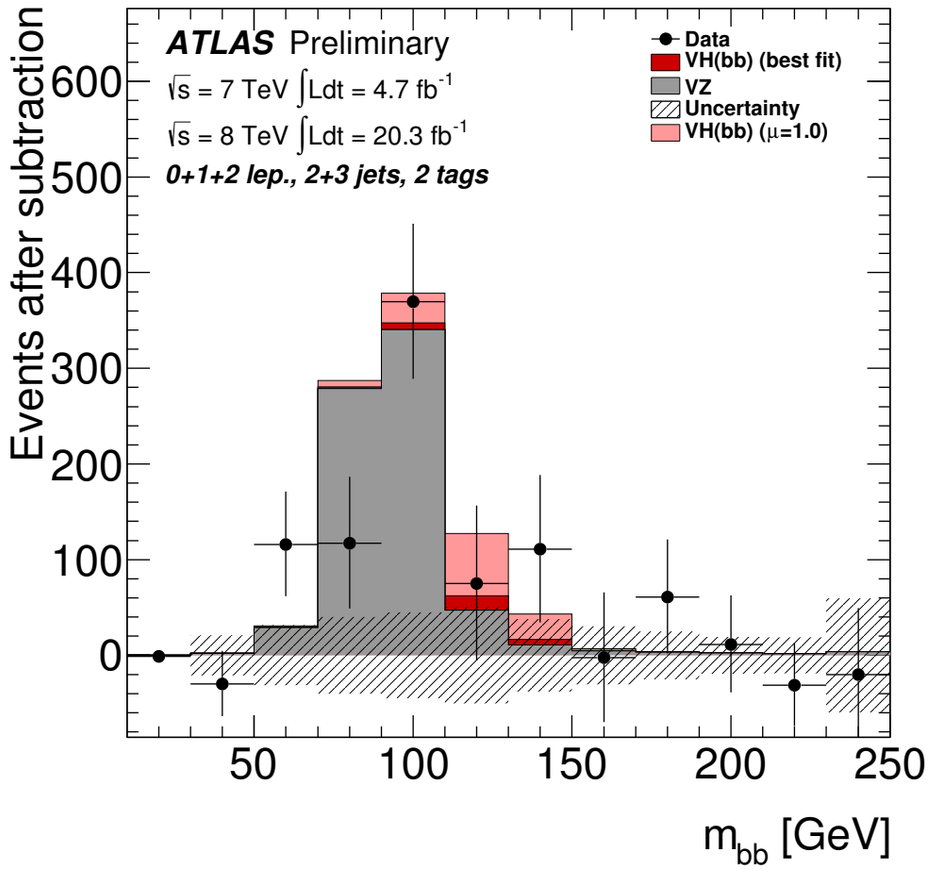
2jet(2b-tag) Z P_T > 200 GeV



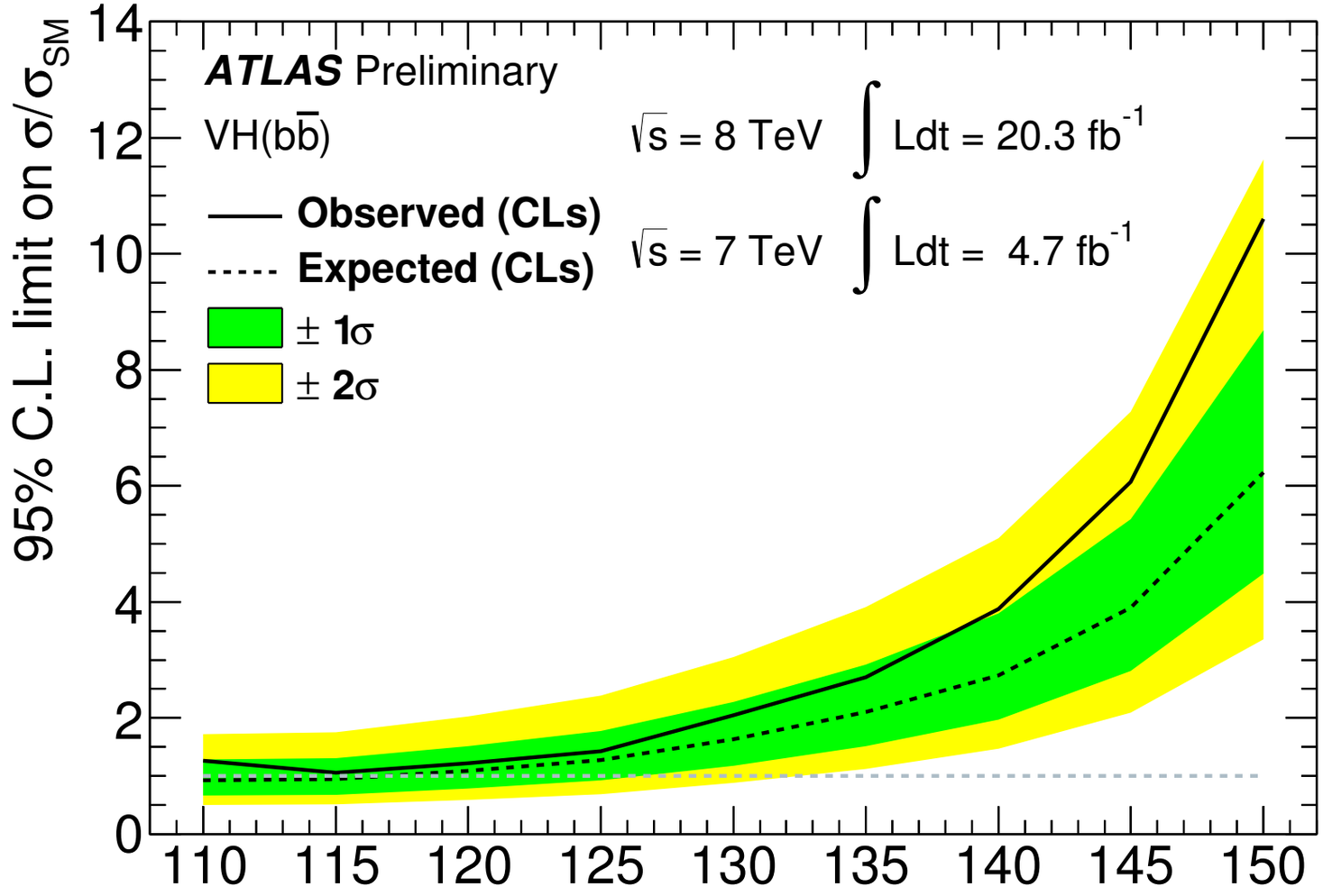
3jet(2b-tag) Z P_T > 200 GeV



Results : Limits for VH (H→b$\bar{b}$)



The m_{bb} distribution in data after subtraction of all backgrounds except diboson.



Observed limit : 1.4 × SM

Expected limit : 1.3 × SM

m_H = 125 GeV

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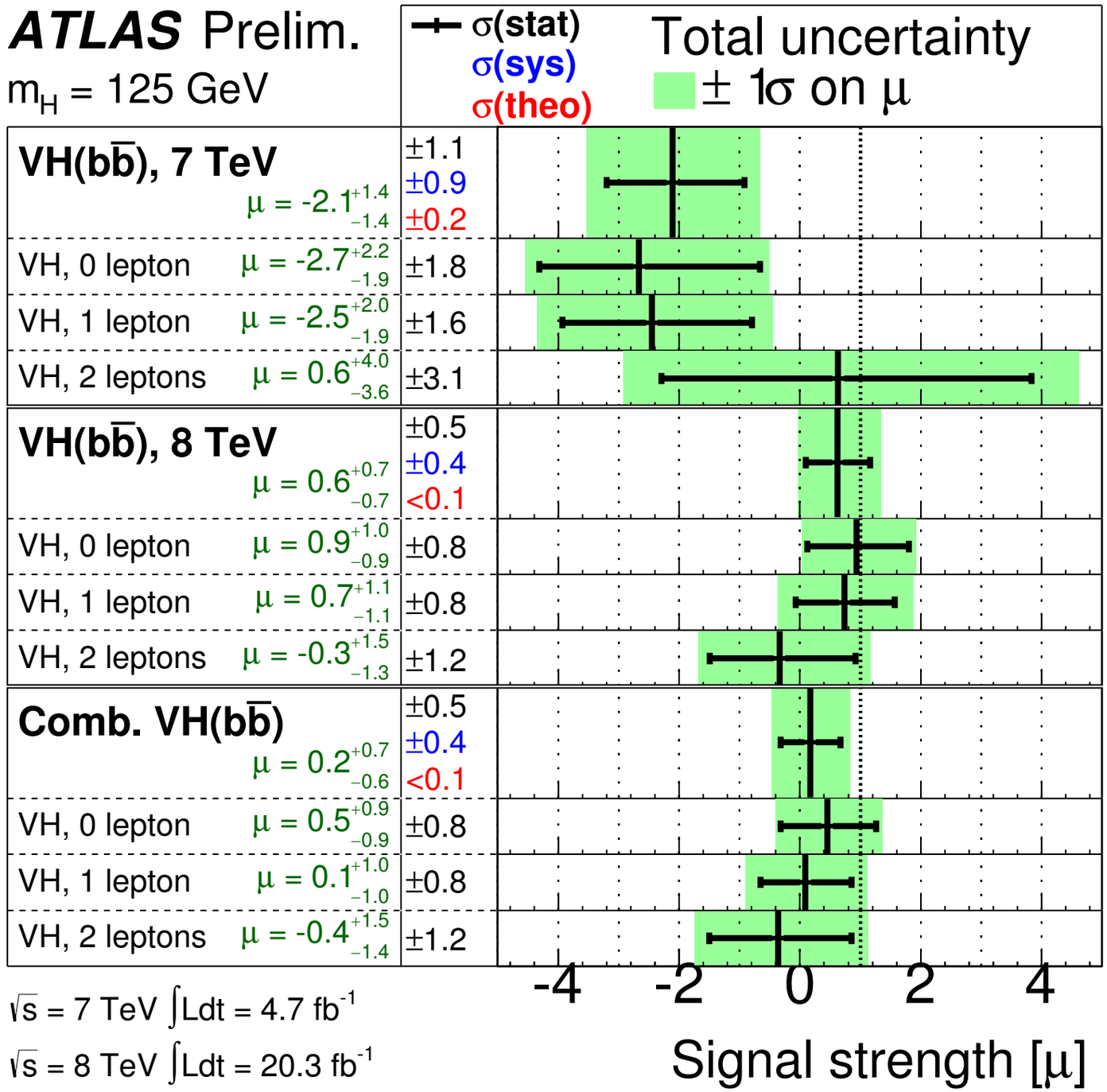
Results : Signal strength for VH (H→bb̄)

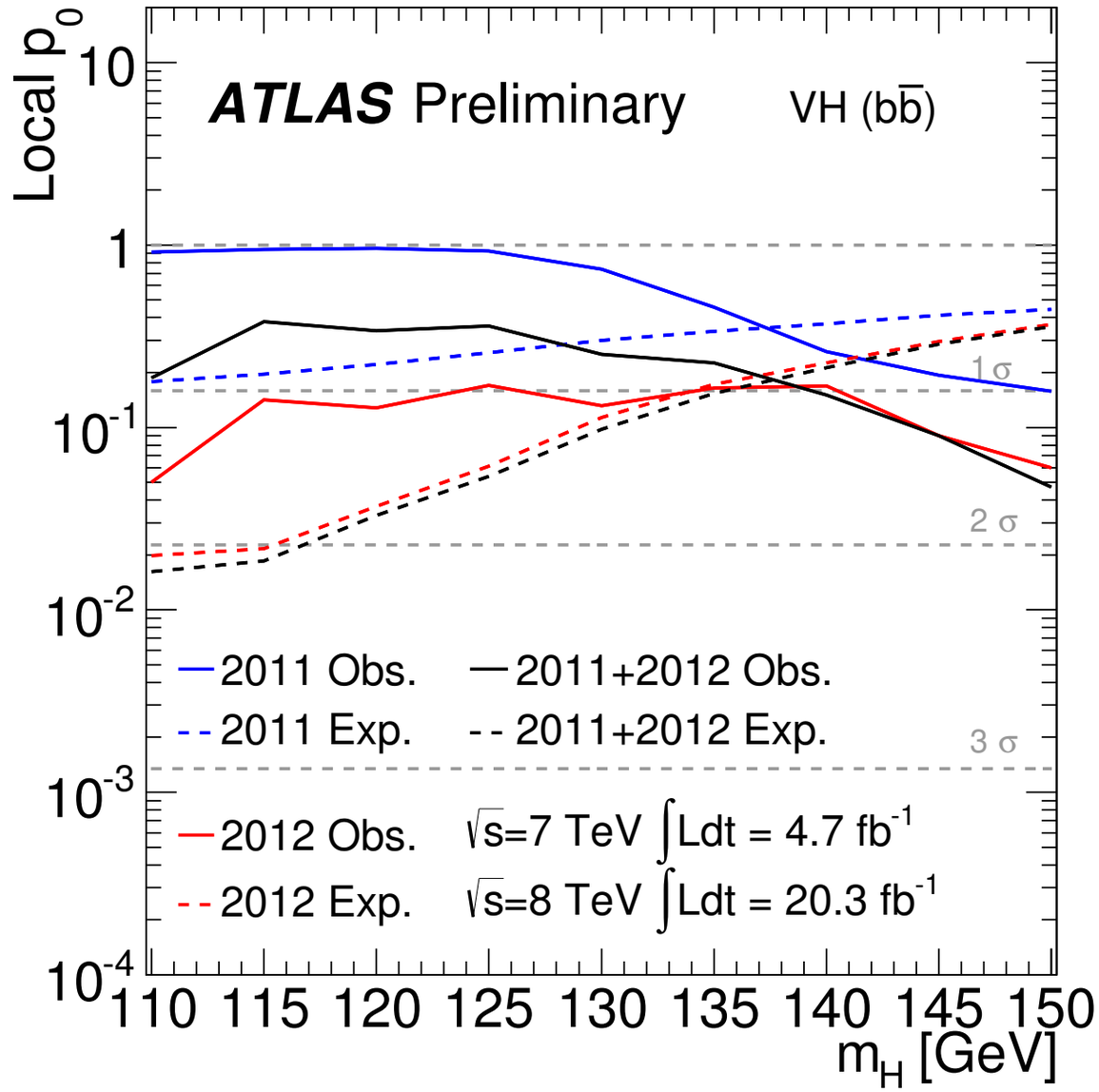


m_H=125GeV

The fitted value of the signal strength parameter is :

ATLAS-CONF-2013-079 $\mu = 0.2 \pm 0.5(\text{stat}) \pm 0.4(\text{syst})$

Results : Significance for VH (H→b$\bar{b}$)



m_H=125GeV

Observed significance σ : 0.36

Expected significance σ : 1.64

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Conclusions

- **New preliminary results from the ATLAS search for VH, H→$b\bar{b}$ production, combination of full 7 TeV (4.7 fb^{-1}) and 8 TeV (20.3 fb^{-1}) datasets.**
- **Complex analysis split into numerous categories to improve sensitivities.**
- **For Validation of the analysis, the diboson VZ cross-section is measured. The result 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) × SM at 95% CL is obtained.**
- **The observed signal strength is $0.2 \pm 0.5(stat.) \pm 0.4(syst.)$ at $m_H = 125GeV$.**
- **Fit is consistent with both a SM Higgs and no SM Higgs.**
- **More data needed.....**

back up

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Global fit : background treatment

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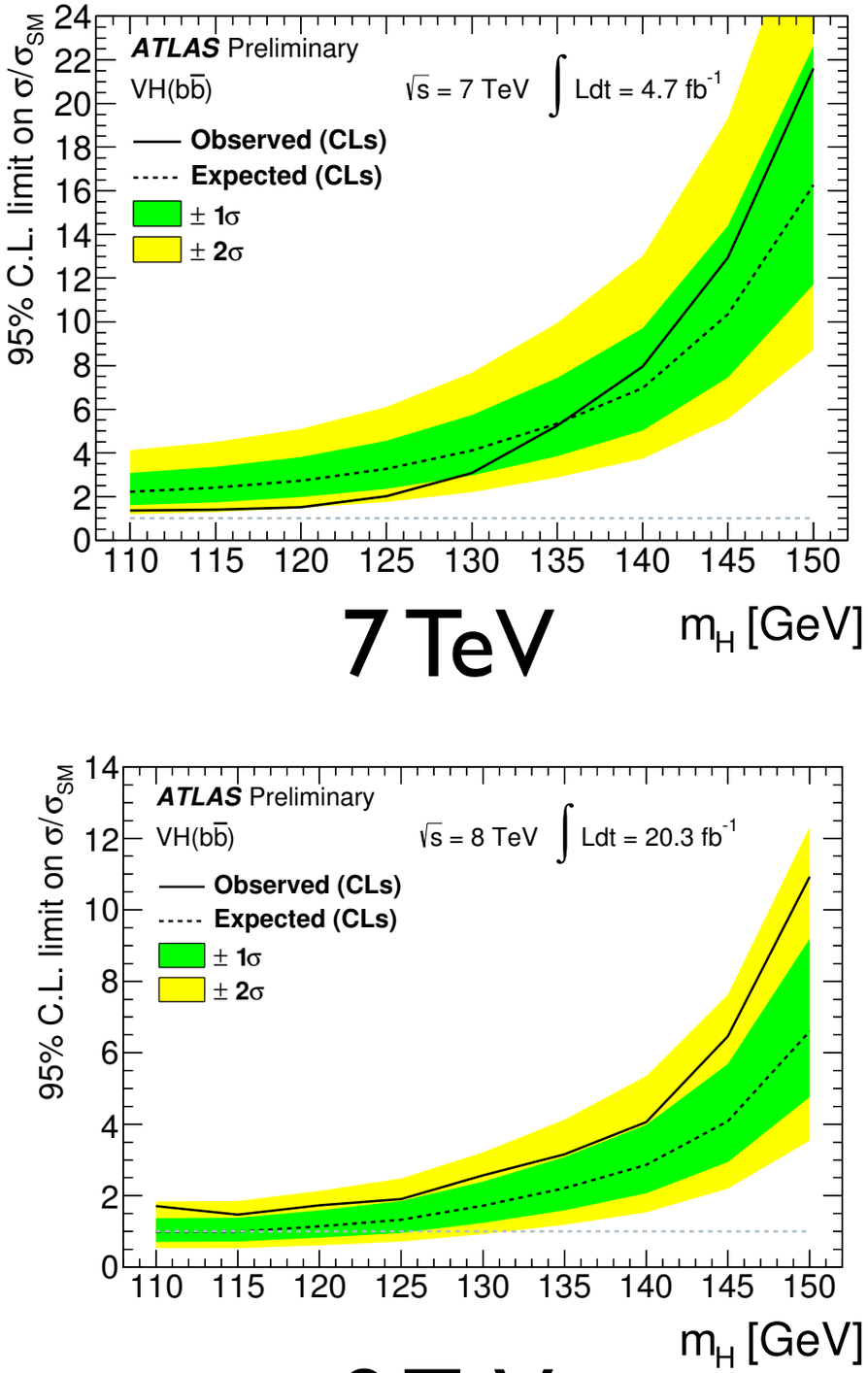
- Use complimentary information from ***many*** regions to constrain background normalization and shape.

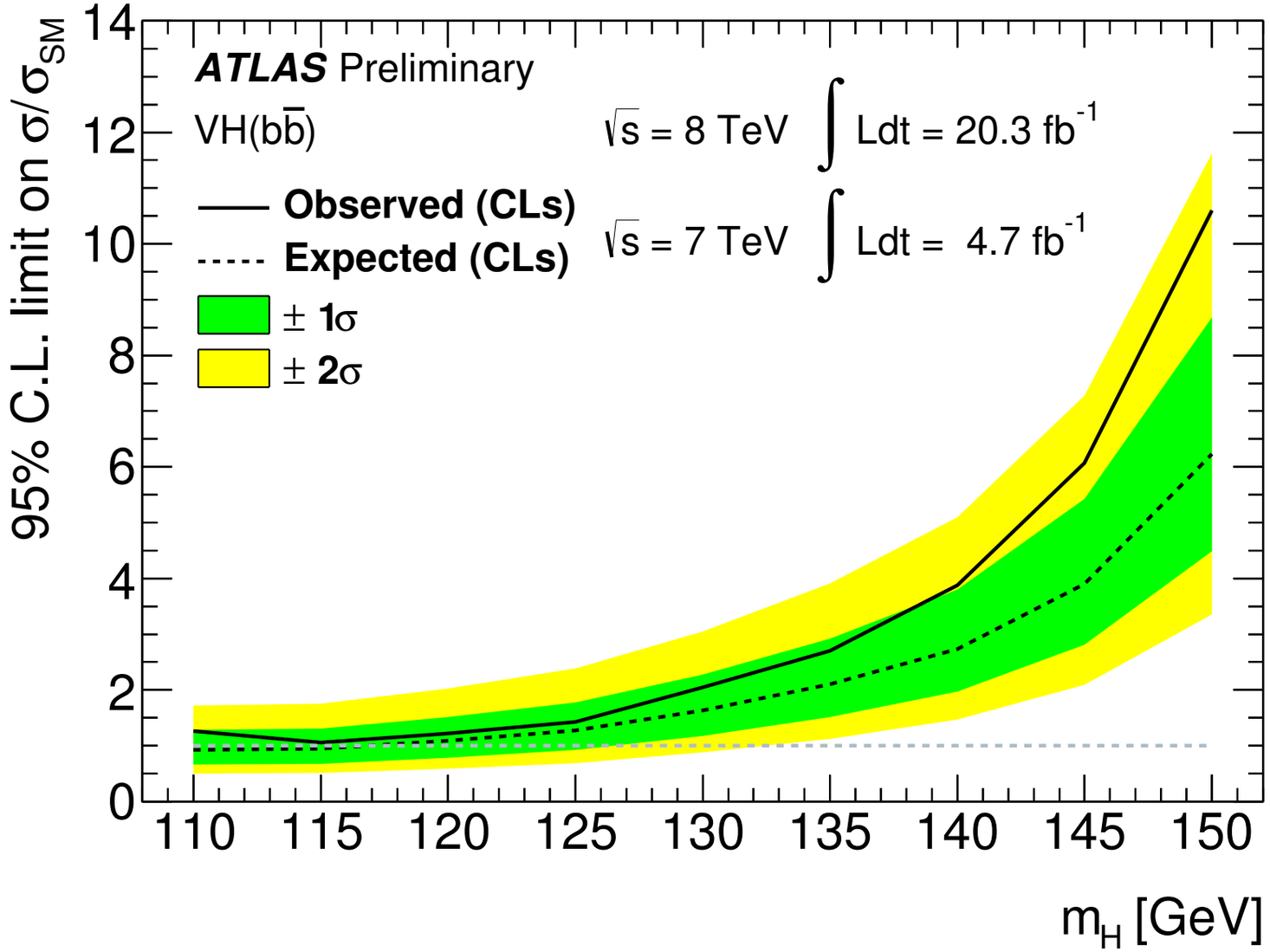
- **Multijet** : Normalizations and shapes are estimated from data.
- **Other backgrounds** : Taken from the simulation.
  - Normalizations of the **W/Z + jets and Top backgrounds** are parameters in the global fit.
  - **Single top, diboson** sample use the theoretical cross-section.
- Background contributions are different among channels, regions, and W/Z P_T bins, use global fit to constrain the W/Z+jets and Top.

Results : Limits for VH (H->bb)



7 TeV

8 TeV



Observed limit : 1.4 × SM

Expected limit : 1.3 × SM

m_H = 125 GeV

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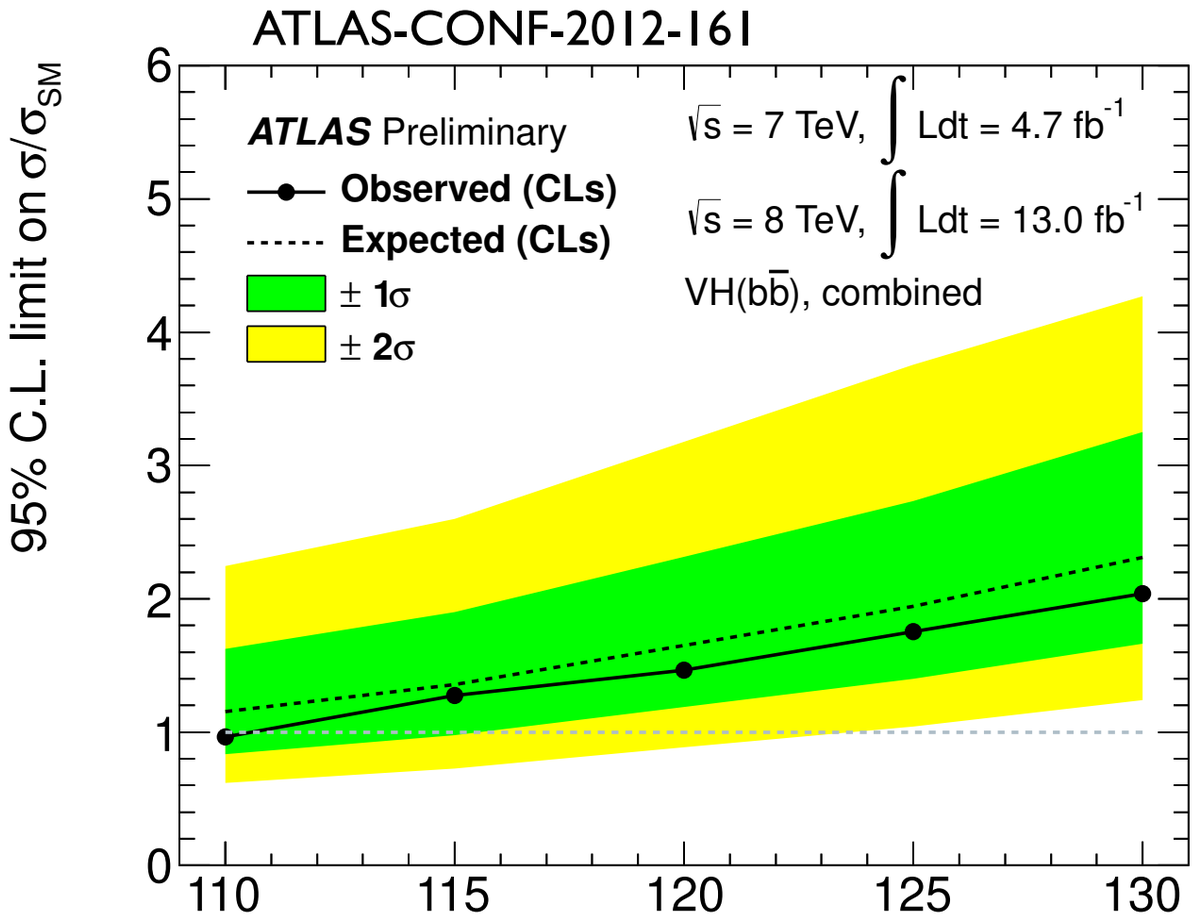
HCP 2012 review

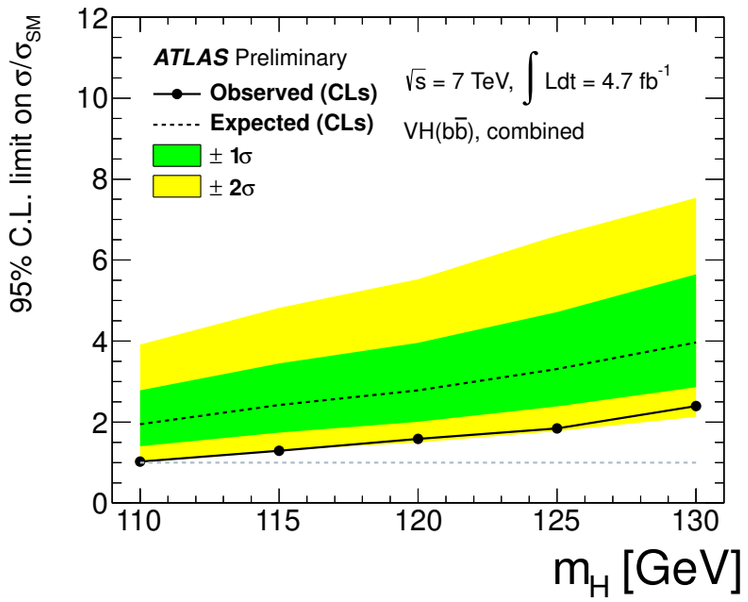


7 + 8 TeV

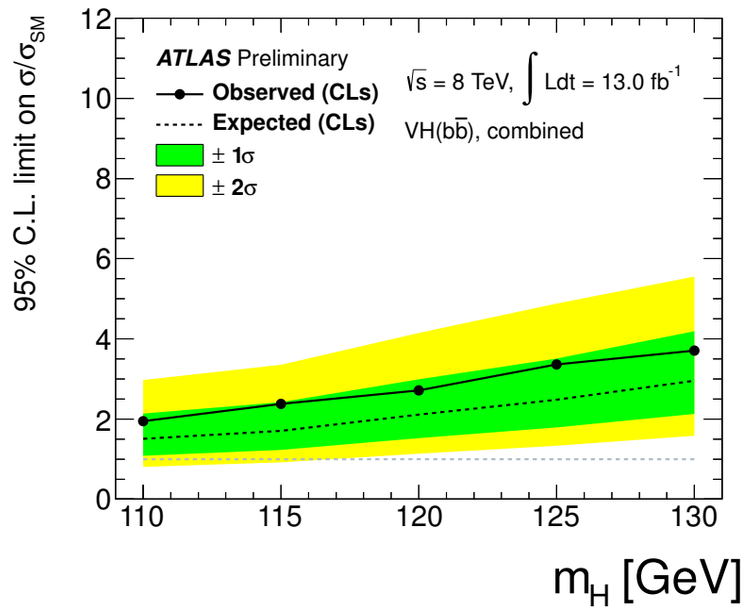
Observed limit : 1.8 × SM

Expected limit : 1.9 × SM

mH=125GeV



7 TeV



8 TeV

HCP 2012 dataset

7TeV 4.7 fb^{-1}

8TeV 13.0 fb^{-1}

EPS 2013 dataset

7TeV 4.7 fb^{-1}

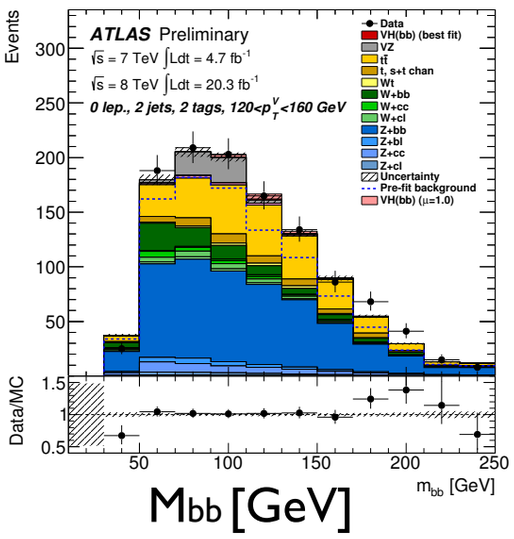
8TeV 20.3 fb^{-1}

Higgs fit : Zero Lepton

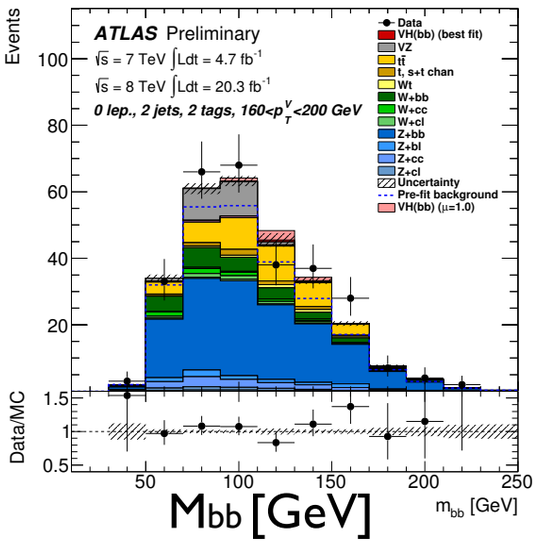
Fit with diboson contributions constrained to their SM values within uncertainties and with the Higgs boson signal strength μ as a free parameter.

Zero Lepton ATLAS-CONF-2013-079

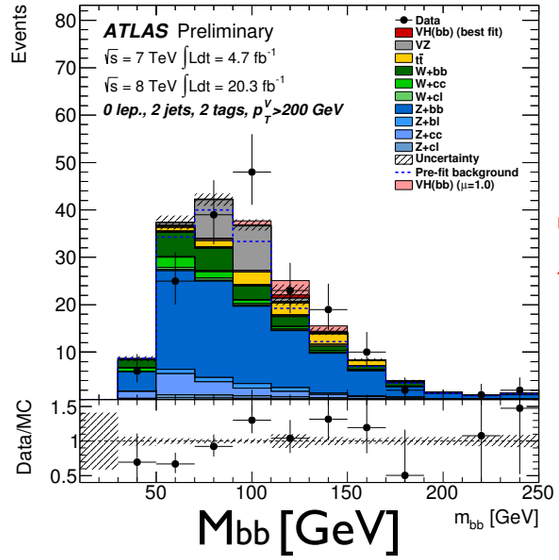
120 GeV < Z P_T< 160 GeV



160 GeV < Z P_T< 200 GeV

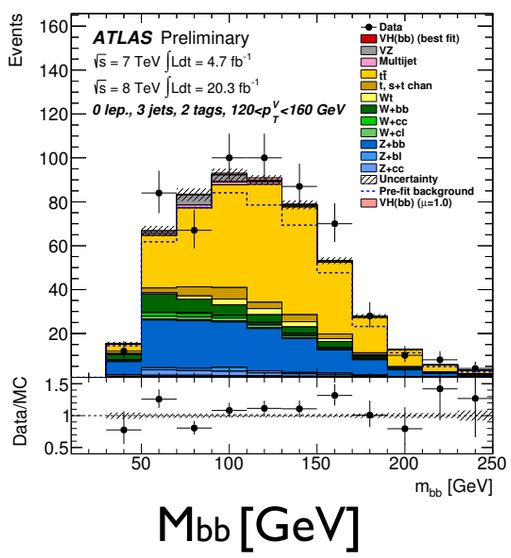


200 GeV < Z P_T

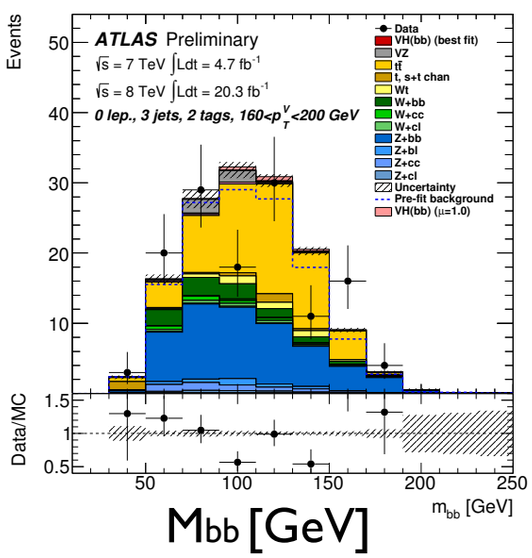


2jet(both tagged)

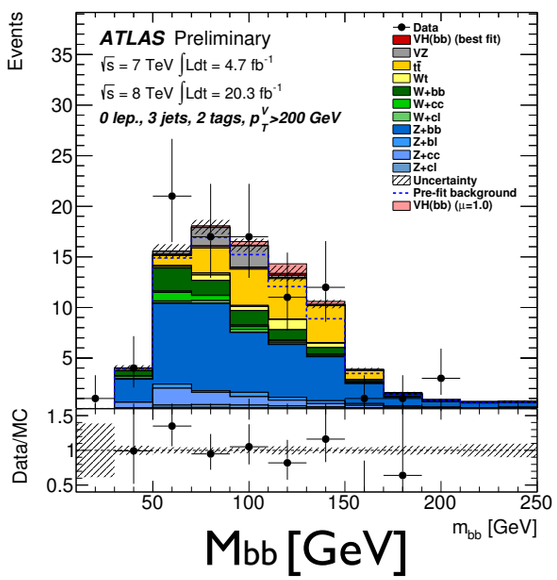
120 GeV < Z P_T< 160 GeV



160 GeV < Z P_T< 200 GeV



200 GeV < Z P_T



3jet(2 tagged)

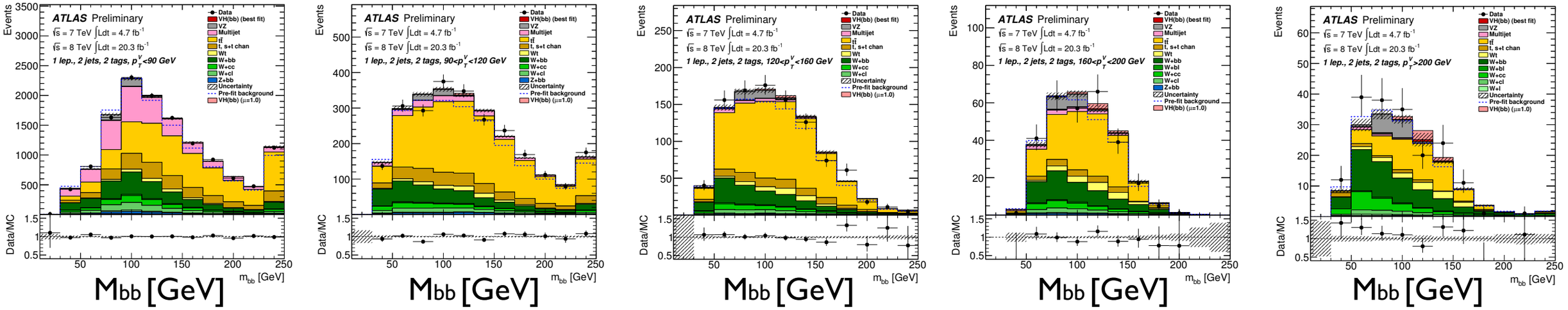
Higgs fit : One Lepton

Fit with diboson contributions constrained to their SM values within uncertainties and with the Higgs boson signal strength μ as a free parameter.

One Lepton ATLAS-CONF-2013-079

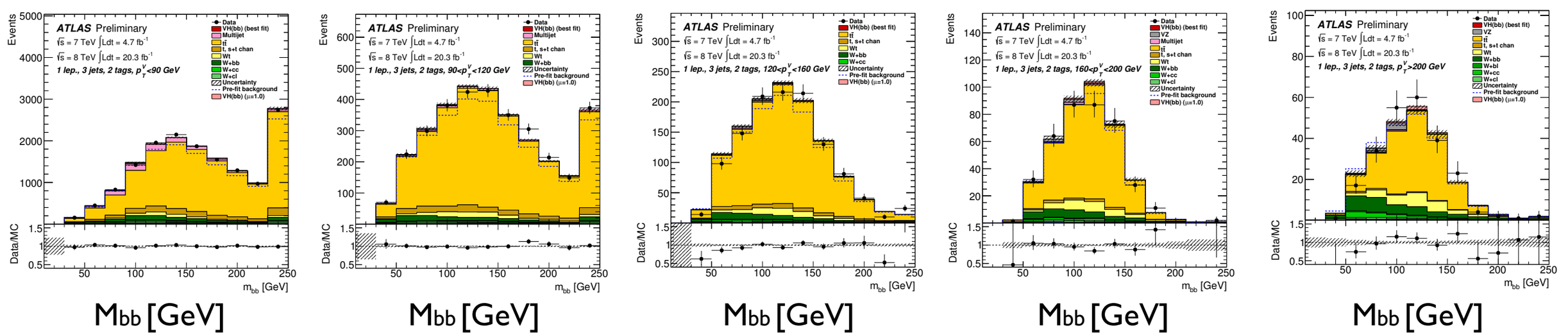
2jet(both tagged)

W P_T< 90 GeV | 90 GeV < W P_T< 120 GeV | 120 GeV < W P_T< 160 GeV | 160 GeV < W P_T< 200 GeV | 200 GeV < W P_T



3jet(2 tagged)

W P_T< 90 GeV | 90 GeV < W P_T< 120 GeV | 120 GeV < W P_T< 160 GeV | 160 GeV < W P_T< 200 GeV | 200 GeV < W P_T



Higgs fit : Two Lepton

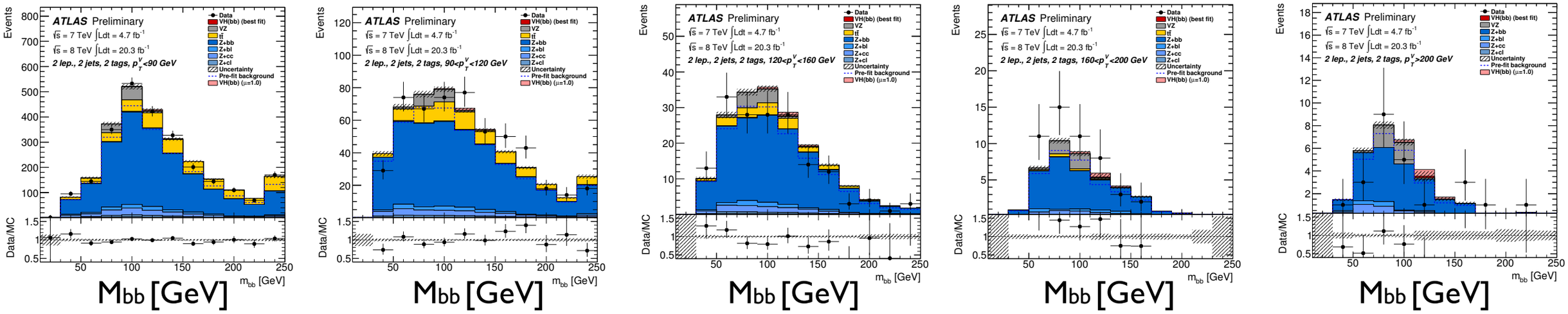
Fit with diboson contributions constrained to their SM values within uncertainties and with the Higgs boson signal strength μ as a free parameter.

Two Lepton

ATLAS-CONF-2013-079

2jet(both tagged)

Z P_T< 90 GeV | 90 GeV < Z P_T< 120 GeV | 120 GeV < Z P_T< 160 GeV | 160 GeV < Z P_T< 200 GeV | 200 GeV < Z P_T



3jet(2 tagged)

Z P_T< 90 GeV | 90 GeV < Z P_T< 120 GeV | 120 GeV < Z P_T< 160 GeV | 160 GeV < Z P_T< 200 GeV | 200 GeV < Z P_T