LHC-ATLAS実験における$ZH \rightarrow \nu\bar{\nu}b\bar{b}$過程を用いたヒッグス粒子の探索

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永井 義一, 木内 健司[A], 音野 瑛俊[B]

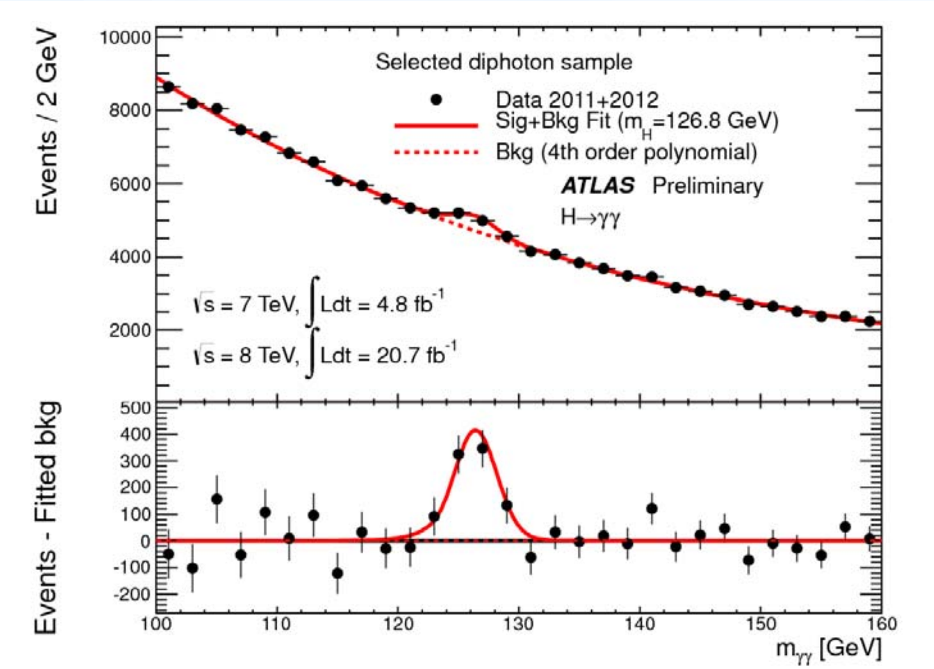
CPPM Aix-Marseille Univ., 筑波大[A], 大阪大[B]

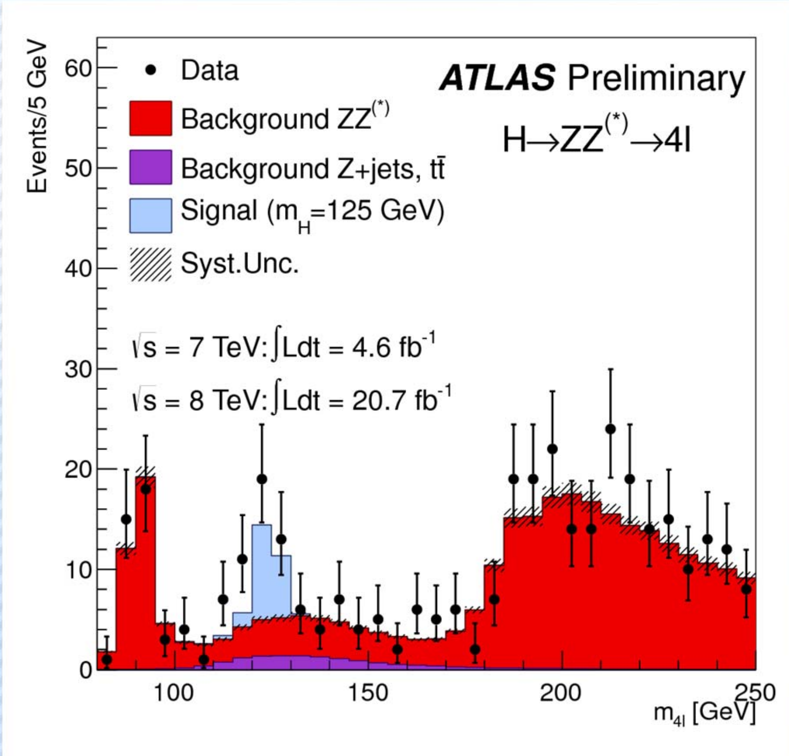
Talk Outline

- Introduction
- Analysis
  - Event selection
  - Analysis Strategy
  - Signal & background yield and M_{bb} distribution
- Result
  - H→bb search result
- Summary and Prospects

Introduction

- Last summer, new Higgs-like boson observation was announced by both ATLAS & CMS around 125 GeV & recently both group update result with full dataset of 2011 & 2012

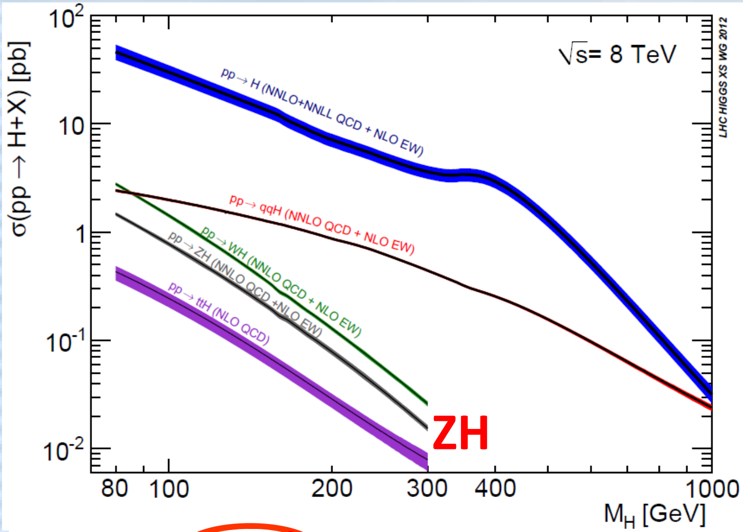




Introduction

What is the next step?

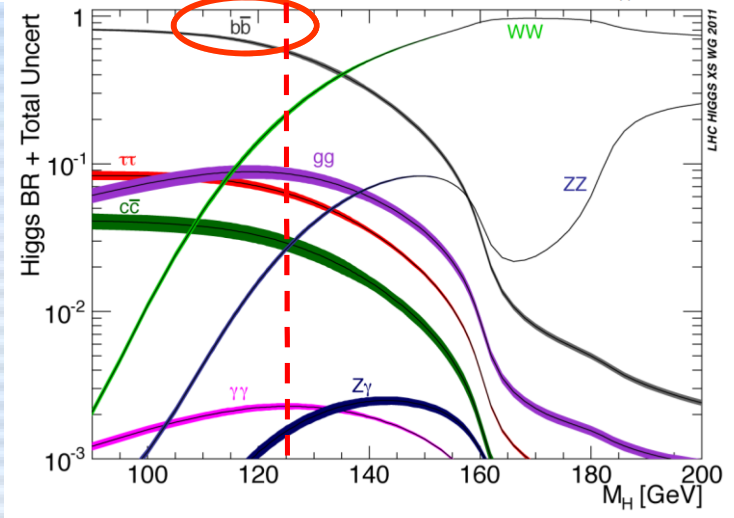
Confirm nature of new boson.
SM Higgs boson? Or something else?



Property measurement (mass, spin/CP, coupling)

is ongoing mainly using bosonic decay mode

(H→γγ, ZZ, WW)



If the new boson is the SM Higgs boson,
it predominately decays to the b quark pair

ggH: highest cross-section, but suffer from QCD multijet background (BG)

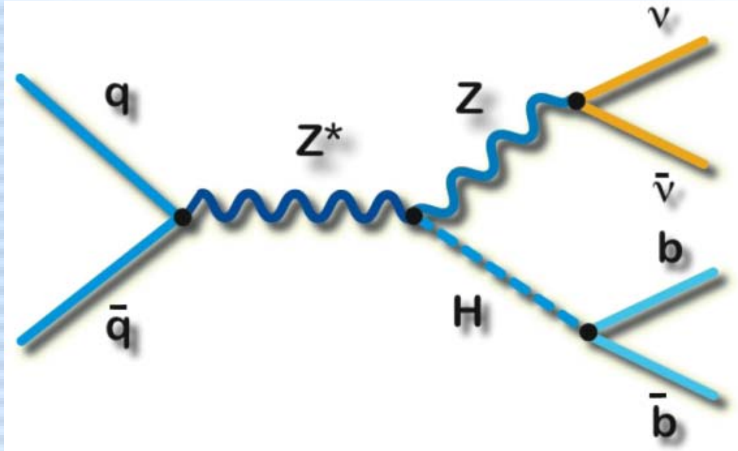
VBF: 2nd highest at m_H = 125 GeV, but QCD is issue as well

VH: Higgs association production with vector boson process, possible to suppress QCD BG by requiring its leptonic decay and boosted Higgs production

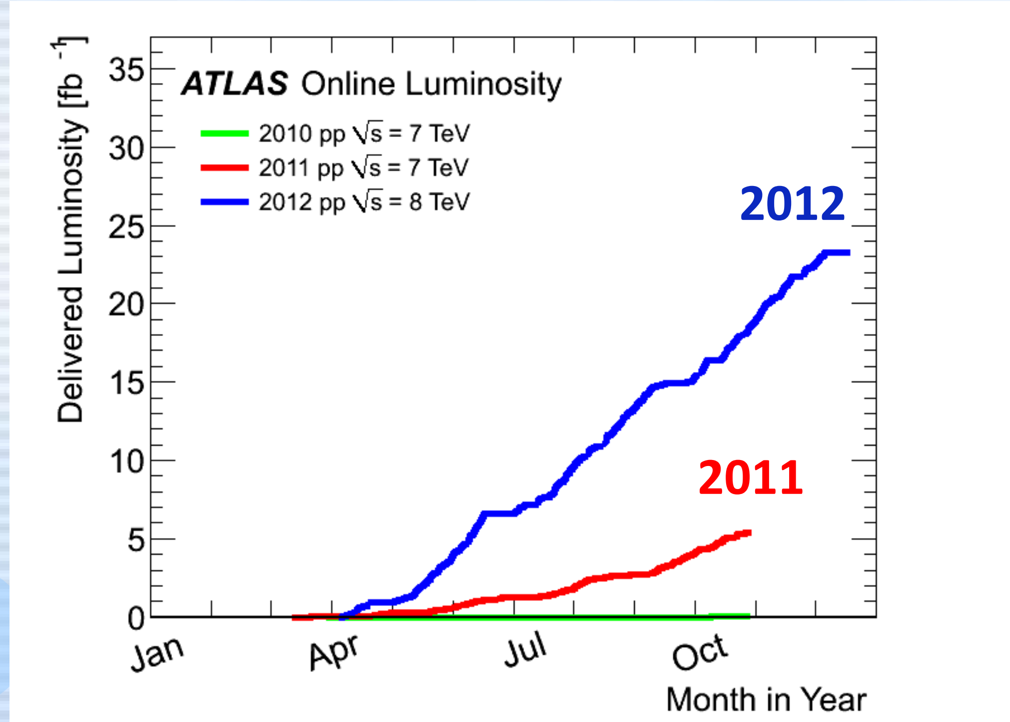
→ Focus on ZH process with Z→νν decay

For m_H = 125 GeV
σ(ZH) = 0.316 pb for 7 TeV
= 0.394 pb for 8 TeV
Br(H→bb) = 0.577

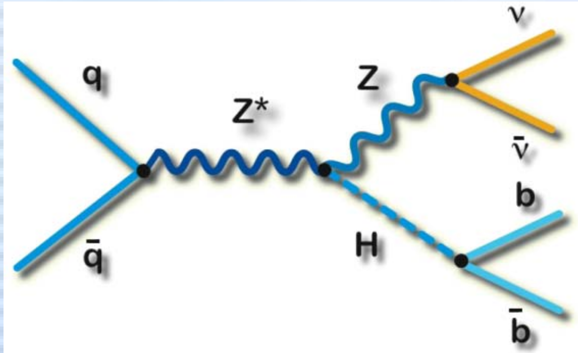
ZH→ννbb Analyses



dataset:
4.7 fb-1 (2011, 7 TeV)
13.0 fb-1 (2012, 8 TeV)
(about half of 2012 data)



Event Selection



Event trigger: Missing E_T (MET) trigger with **MET > 80 GeV**

Baseline selection:

- Large MET (**MET > 120 GeV**) ← **Take largely boosted Z and Higgs boson**
- 0 lepton (**no electrons, no muons**)
- 2 or 3 High p_T jets with $p_T^1 > 45$ GeV, $p_T^{2,3} > 20$ GeV, $|\eta| < 2.5$
- Exactly **2 b-tagged jets**

  (b-jet identification with **70% efficiency, 0.7% fake rate**)

QCD multijets rejection:

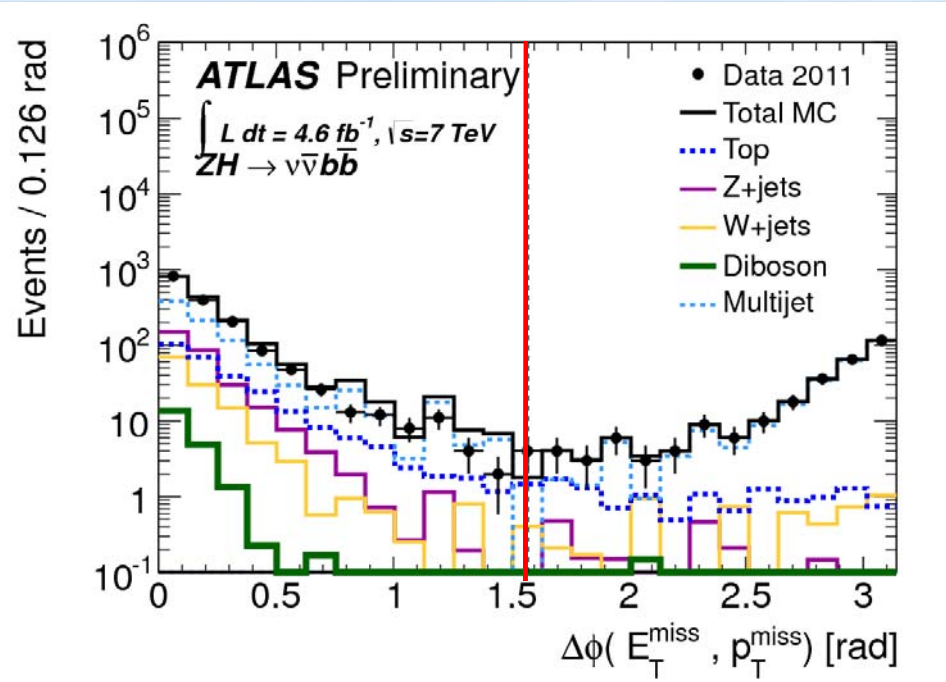
- Missing transverse momentum (**MPT > 30 GeV**)

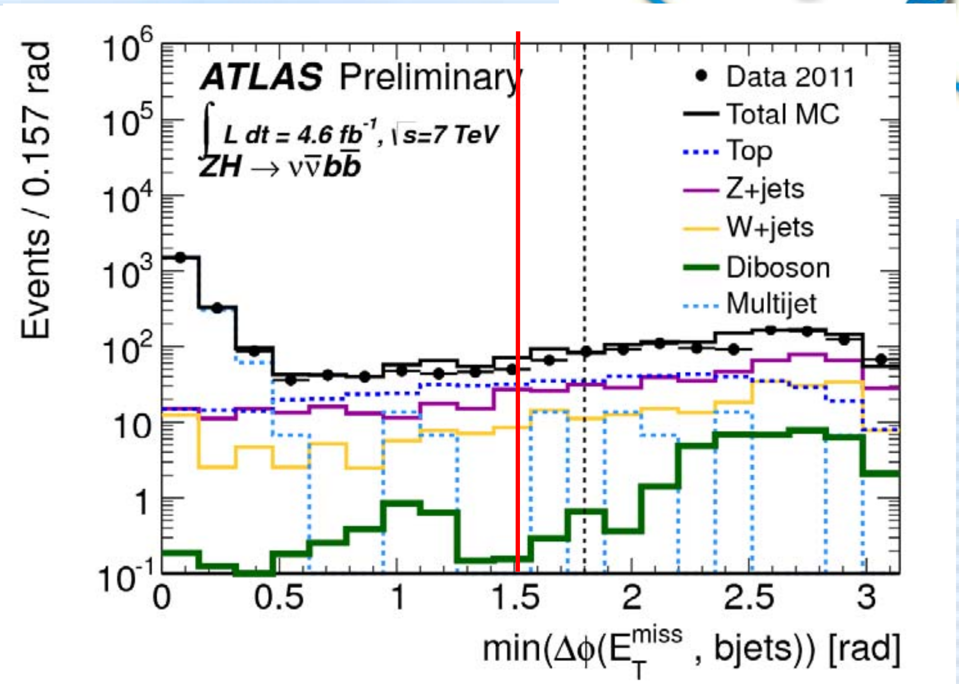
  (Calculated using reconstructed track information at inner detector)
- $\Delta\phi$(MET, MPT) < $\pi/2$
- Min [$\Delta\phi$(MET, jet)] > 1.5
- $\Delta\phi$(MET, bb) > 2.8

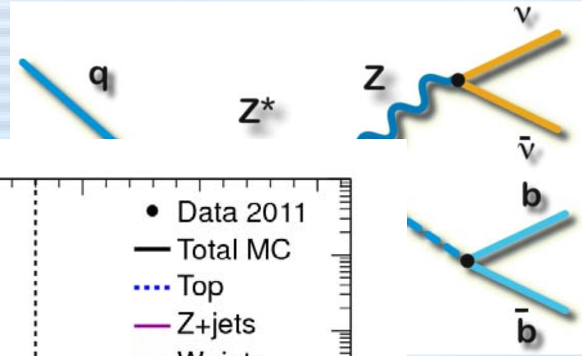
Signal: MET from $Z \rightarrow \nu\nu$ decay
→ **MET and MPT have close direction**
→ **MET and jets tends to go opposite direction**

QCD multijets: MET from jet energy mis-measurement
→ **MET and MPT are close or opposite direction**
→ **MET and one jet tend to go close direction**

Event Selection







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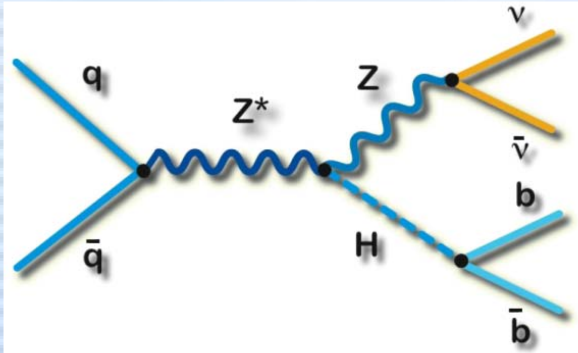
Event Selection



- **Event trigger:** Missing E_T (MET) trigger with **MET > 80 GeV**
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  - 2 or 3 High p_T jets with **$p_T^1 > 45$ GeV, $p_T^{2,3} > 20$ GeV, $|\eta| < 2.5$**
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    (b-jet identification with **70% efficiency, 0.7% fake rate**)
- **QCD multijets rejection:**
  - Missing transverse momentum (**MPT > 30 GeV**)

    (Calculated using reconstructed track information at inner detector)
  - **$\Delta\phi$(MET, MPT) < $\pi/2$**
  - **Min [$\Delta\phi$(MET, jet)] > 1.5**
  - **$\Delta\phi$(MET, bb) > 2.8** → To extract signal topology, Z boson and Higgs boson direction is back-to-back

Analysis Strategy

Signal region categorization

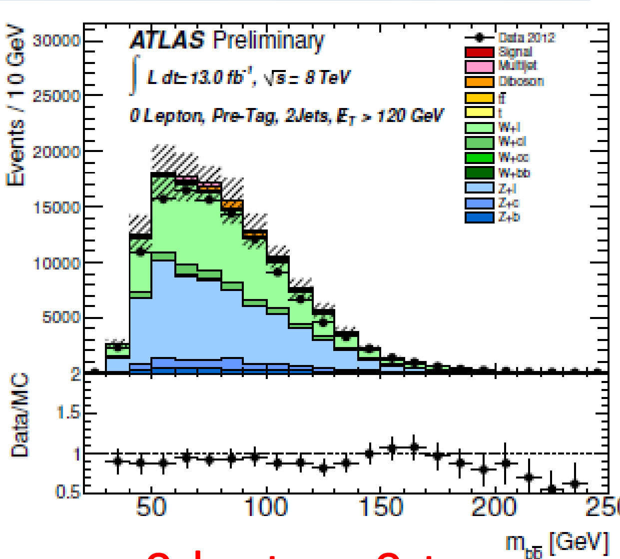
- Sub-divide to **3 $p_T(Z)$** and **2/3 jet bin** signal regions to improve sensitivity
  → **6 signal regions for ZH→ννbb in total**
- Cut value on di-jet separation (dR(b,b)) is optimized for each signal region

0-lepton channel			
E_T^{miss} (GeV)	120-160	160-200	>200
$\Delta R(b,\bar{b})$	0.7-1.9	0.7-1.7	<1.5

Background estimation

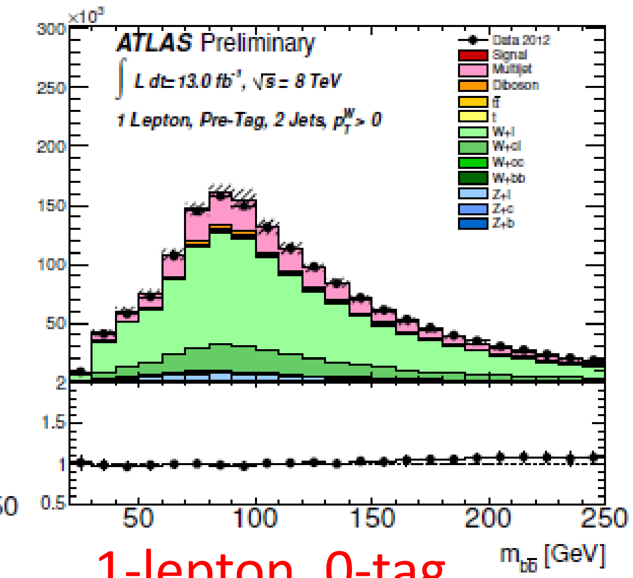
- **QCD multi-jets** → **negligible (< 1%)** after applying QCD rejection cut
- **W+jets** (b, c, light-flavor), **Z+jets** (b, c, light-flavor), **top production**
  → These are **dominant background** for ZH→ννbb analysis
  → Estimate **scale factor from theory prediction by simultaneous fit with control region** (next slide)
  → Perform **fit with 1-lepton (WH→lνbb) and 2-lepton (ZH→llbb)**
- **Di-boson (WW, WZ, ZZ) production**
  → small contribution, estimated from theoretical estimation

Control region distribution (M_{bb})



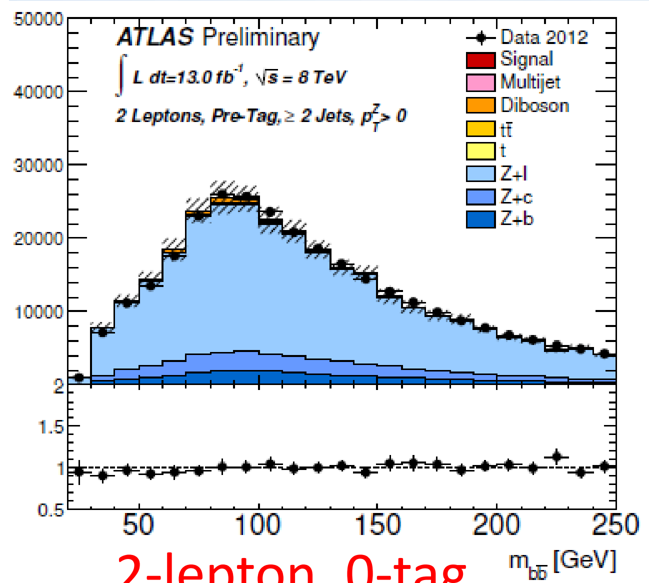
0-lepton, 0-tag

→ W+Light, Z+Light



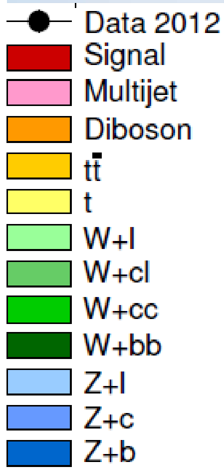
1-lepton, 0-tag

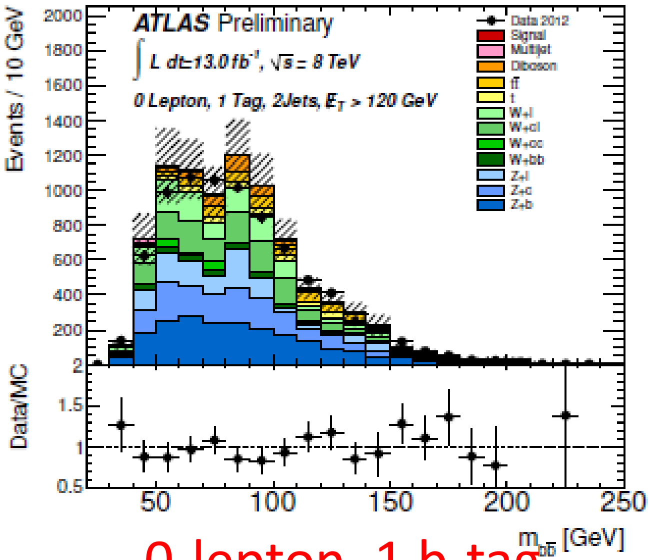
→ W+Light



2-lepton, 0-tag

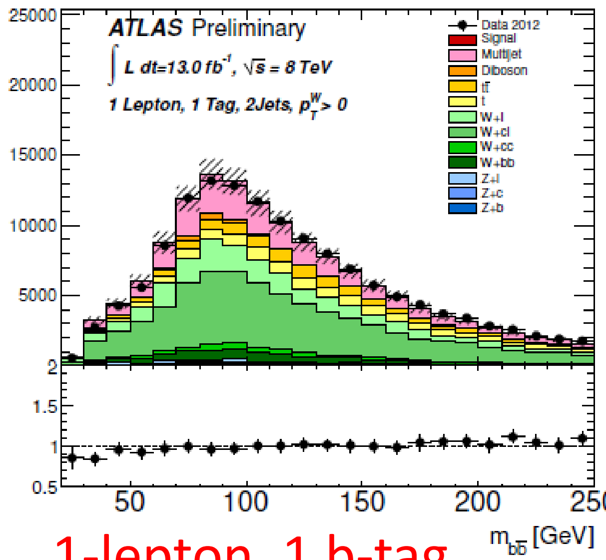
→ Z+Light





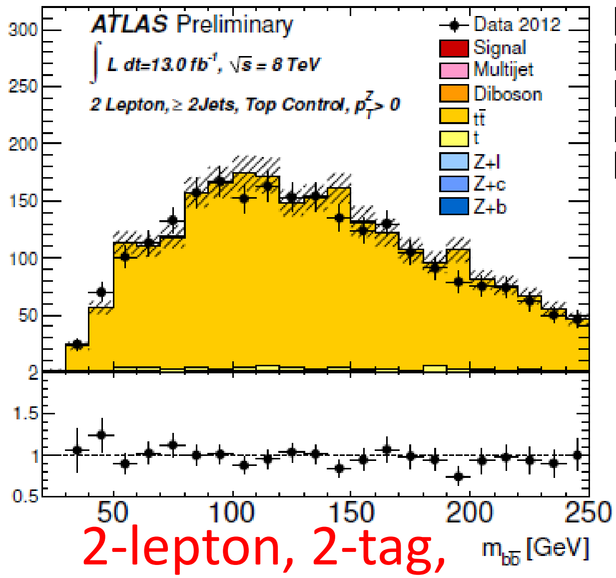
0-lepton, 1 b-tag

→ W+b/c, Z+b/c



1-lepton, 1 b-tag

→ W+b/c



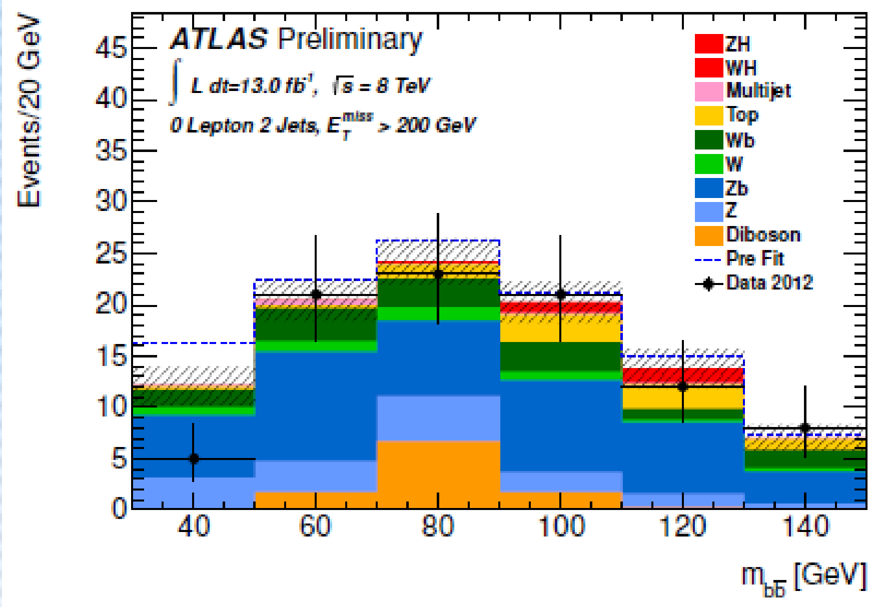
2-lepton, 2-tag,

NOT 83 < M_{ll} < 99 GeV

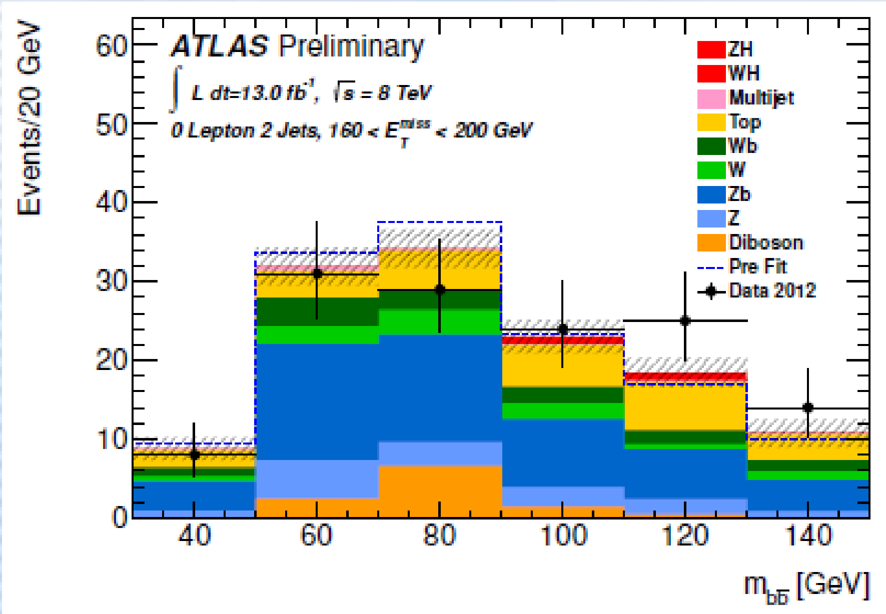
→ top

Background & Signal yields and M_{bb} distribution

	0-lepton, 2 jet			0-lepton, 3 jet		
Bin	E_T^{miss} [GeV]					
	120-160	160-200	>200	120-160	160-200	>200
ZH	2.9	2.1	2.6	0.8	0.8	1.1
WH	0.8	0.4	0.4	0.2	0.2	0.2
Top	89	25	8	92	25	10
$W+c$,light	30	10	5	9	3	2
$W+b$	35	13	13	8	3	2
$Z+c$,light	35	14	14	8	5	8
$Z+b$	144	51	43	41	22	16
Diboson	23	11	10	4	4	3
Multijet	3	1	1	1	1	0
Total Bkg.	361 ± 29	127 ± 11	98 ± 12	164 ± 13	63 ± 8	42 ± 5
Data	342	131	90	175	65	32
S/N	0.01	0.02	0.03	0.01	0.02	0.03
S/sqrt(N)	0.19	0.22	**0.30**	0.08	0.13	0.20

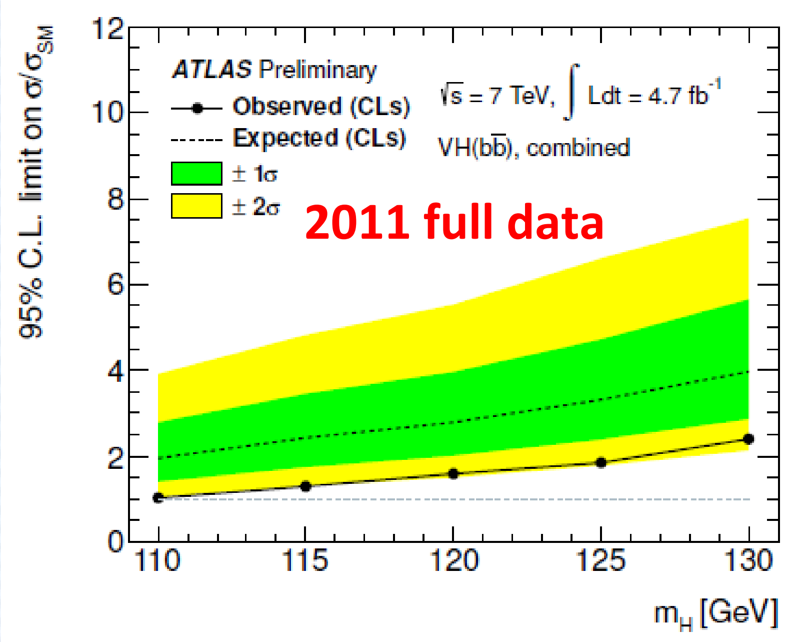


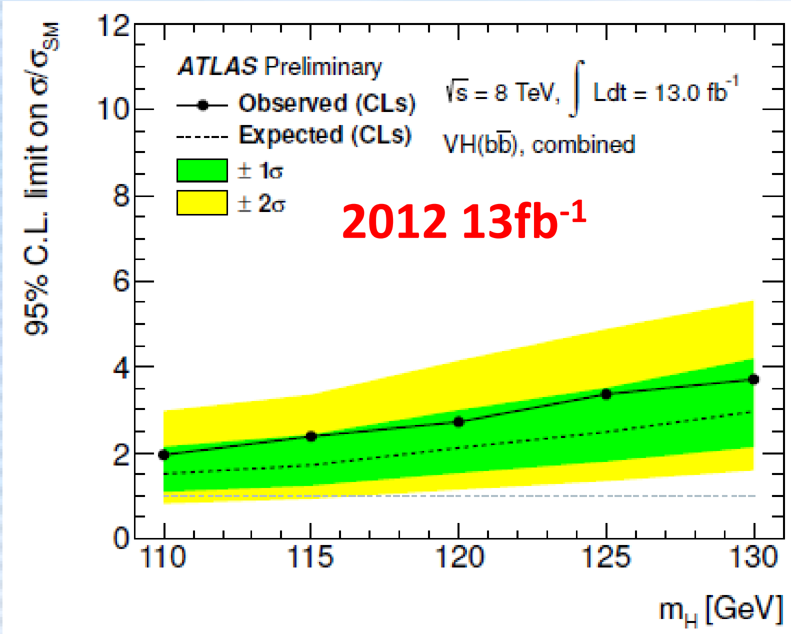
0-lepton, 2-jets, MET > 200 GeV



0-lepton, 2-jets, 160 < MET < 200 GeV

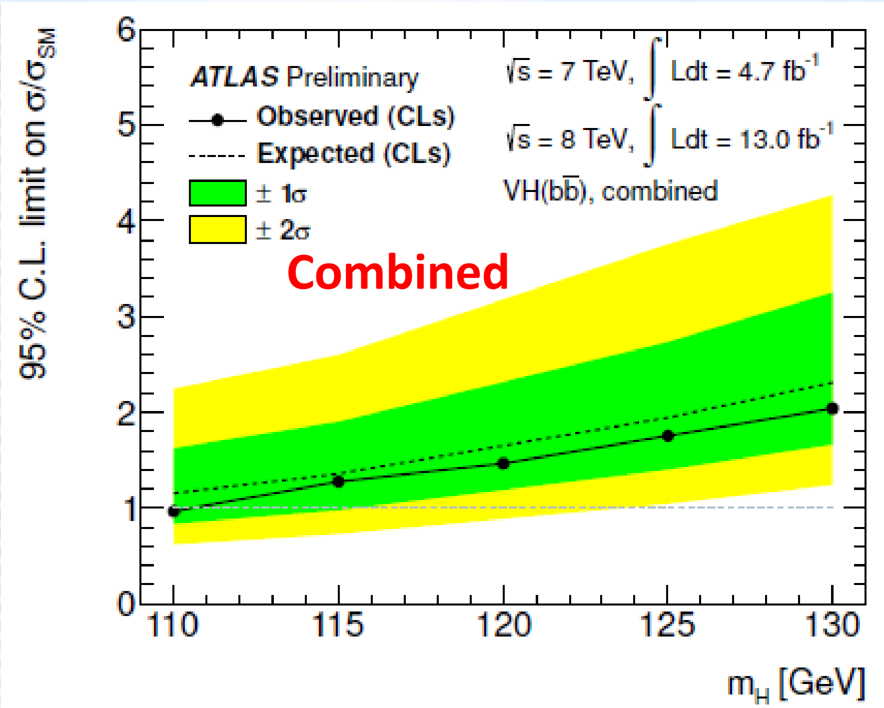
Result





Obs. (Exp.) limit @125 GeV: 1.8 (1.9) x σ(SM) μ = -0.4 ±0.7(stat.)±0.8(syst.)

(ZH→ννbb, WH→lνbb, ZH→llbb combined result)



Summary & future

- We have performed searches for the low mass SM Higgs boson with H→bb process at ATLAS using 2011 + half of 2012 data
- We have achieved **1.8 x σ(SM) @ 125 GeV/c^2** with combining 3 VH→Vbb channels
- Current analysis has yet to use full 2012 dataset, we can expect further search sensitivity improvement
- We are currently working to achieve further analysis improvement
  - Analysis optimization (cut, new signal category, etc)
  - Cut base analysis → MVA analysis

Stay tuned!!

Backup

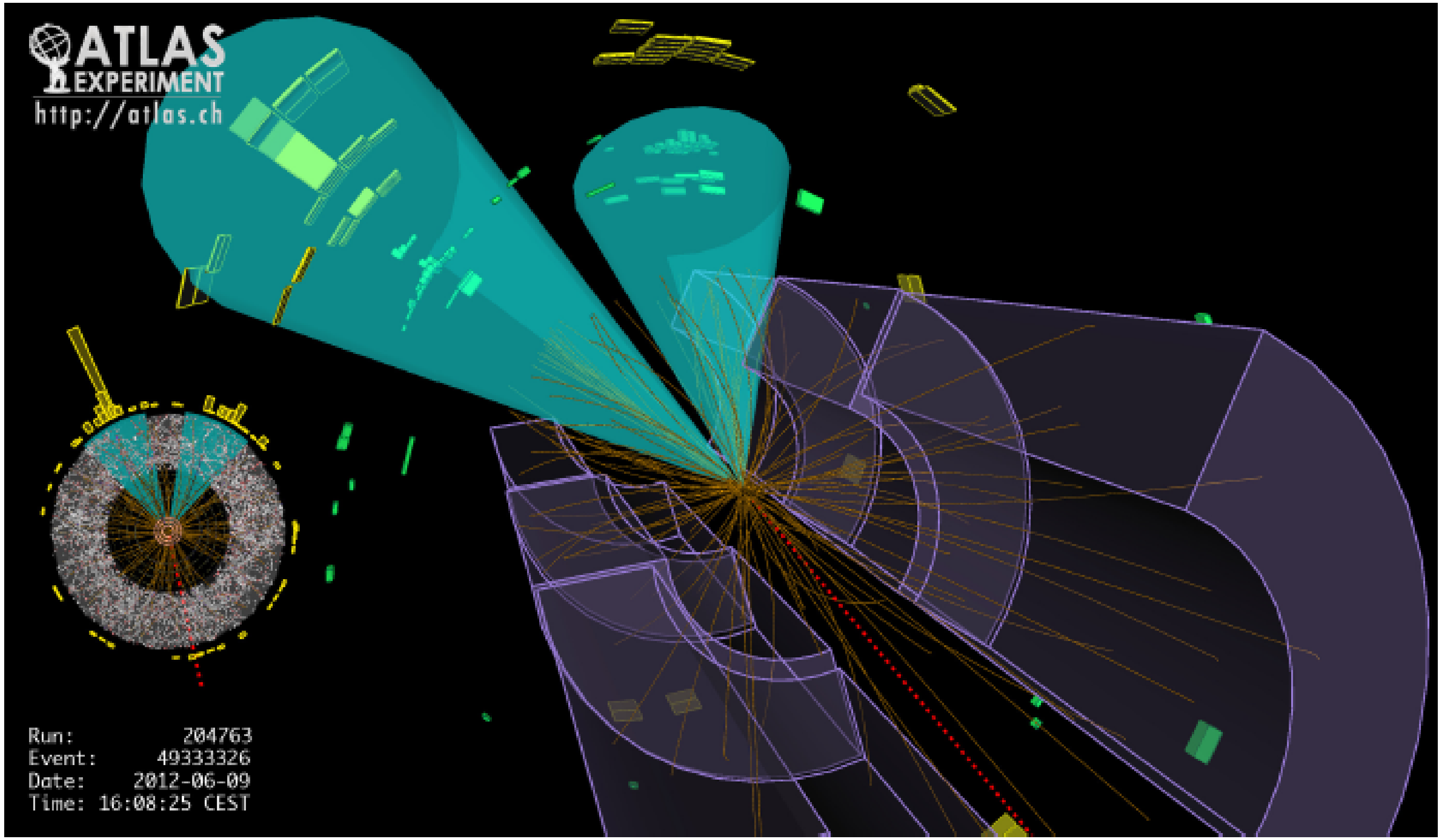


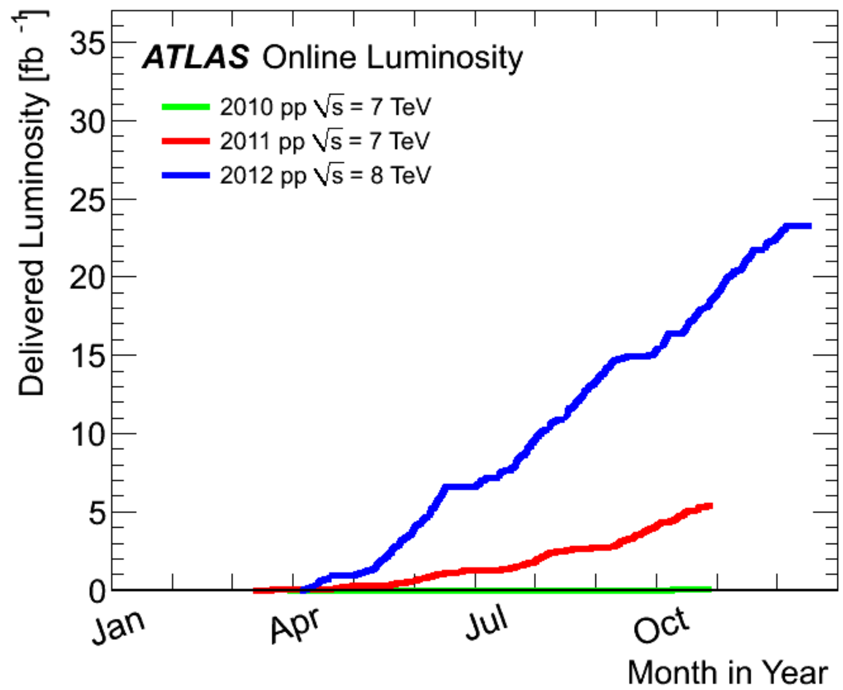
Figure 19: Display of a Higgs boson candidate event with zero selected leptons. The event contains two identified b-jets with transverse momenta of 193 GeV and 78 GeV, respectively, with an invariant mass of 123 GeV. The missing energy in the transverse plane is 271 GeV.

LHC and ATLAS

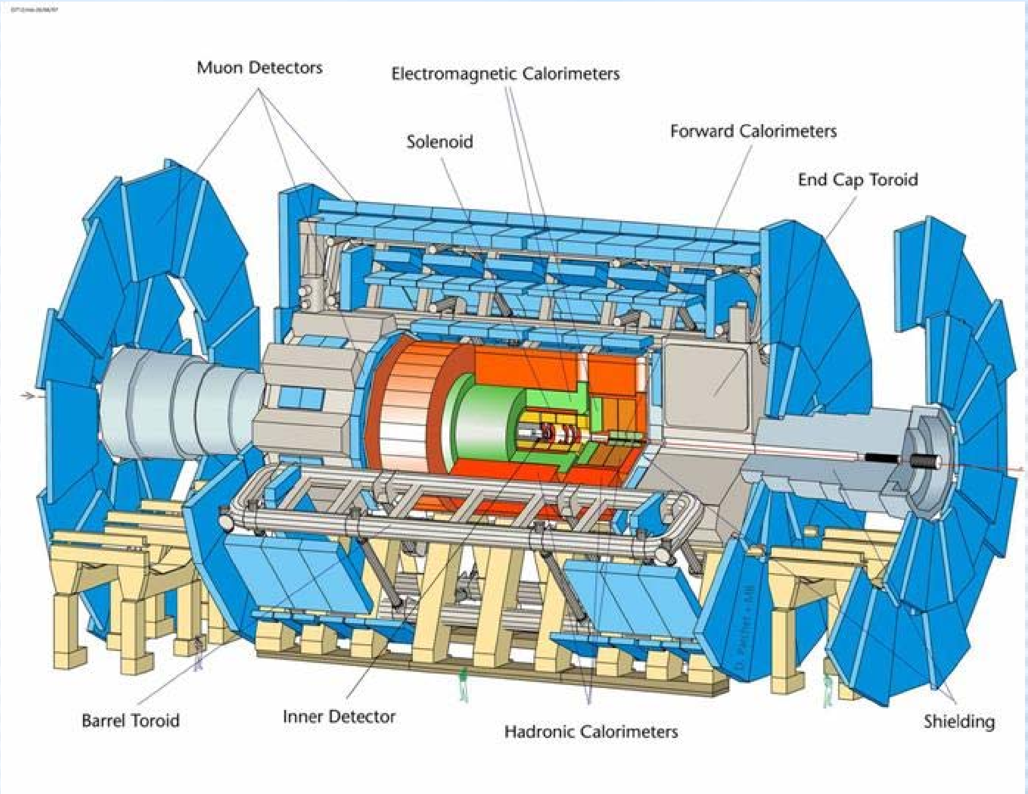
- proton-proton collisions at 7 TeV (2011) and 8 TeV (2012)
- The peak instantaneous luminosity at 8 TeV is 7.7 x 10^{33} cm^{-2} s^{-1}
- ATLAS is one of general purpose detectors built on the LHC

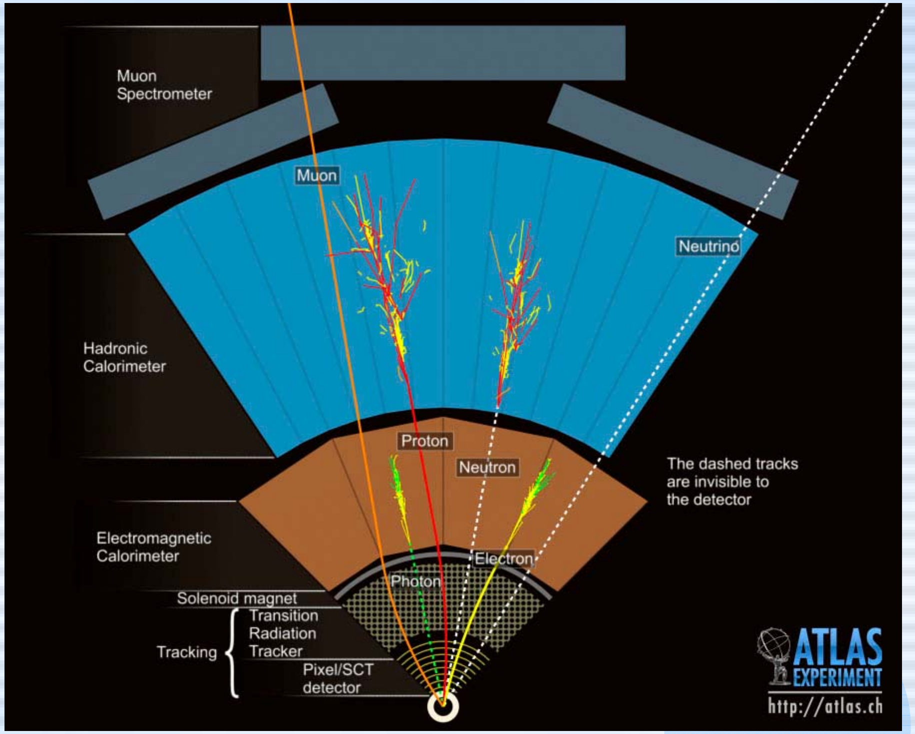
Integrated Luminosity

- ATLAS recorded > 5.0 fb^{-1} (2011) and > 23 fb^{-1} (2012)



ATLAS detector



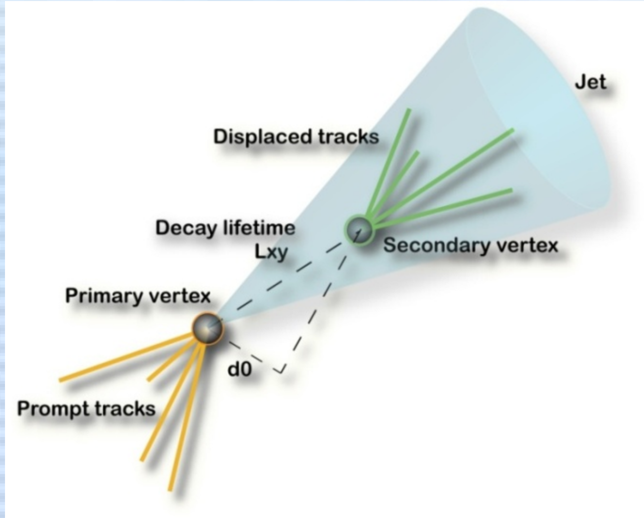


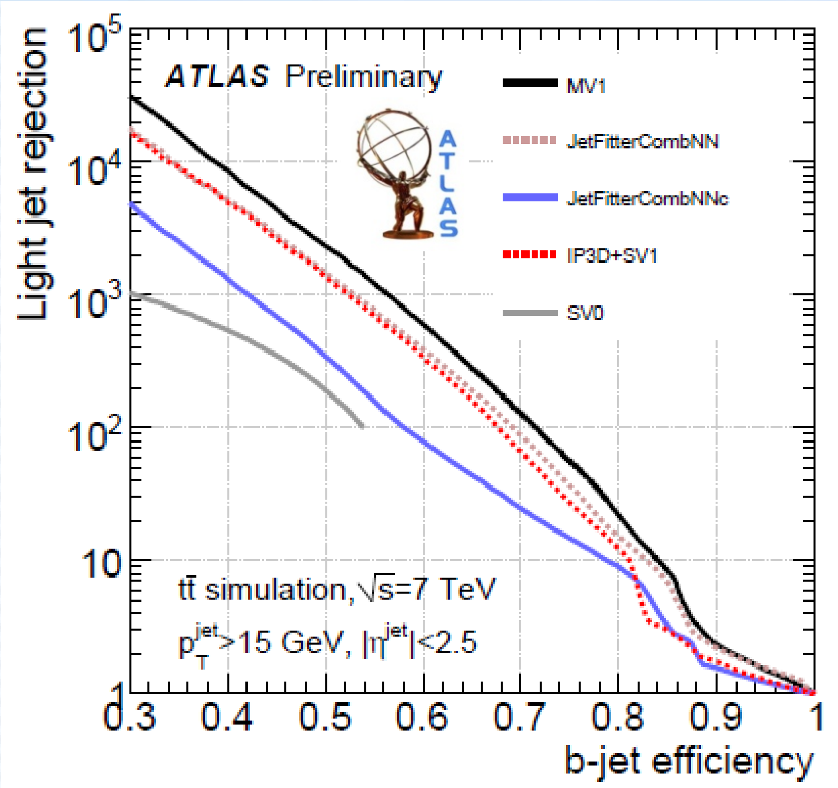
b-tagging

Algorithm

- **ATLAS: multivariate b-ID (MV1)**

  Use 70% efficiency (0.7% fake rate)





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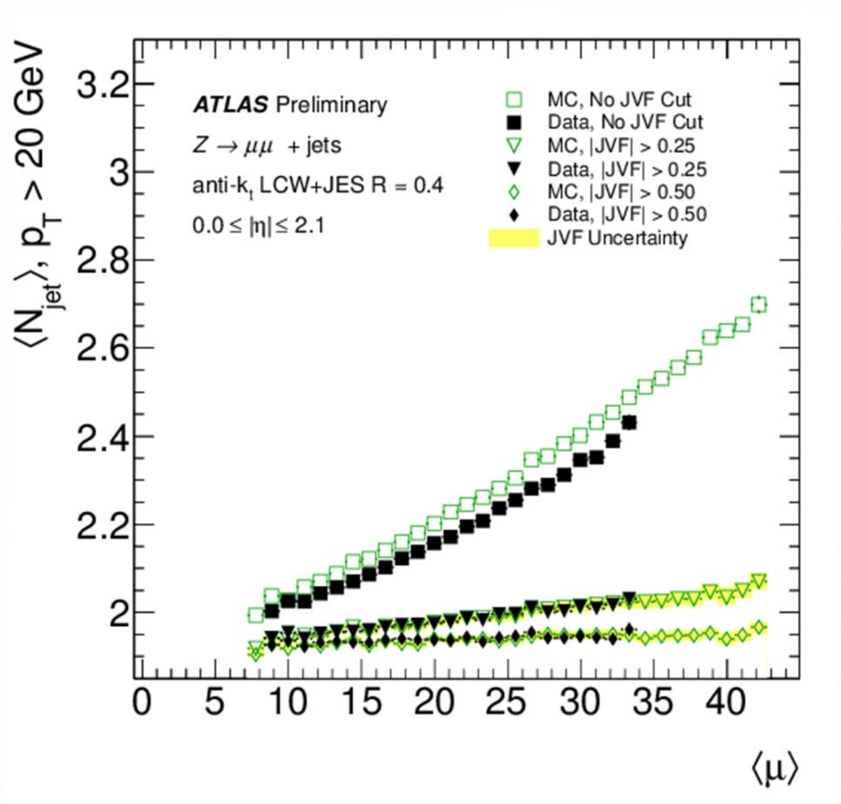
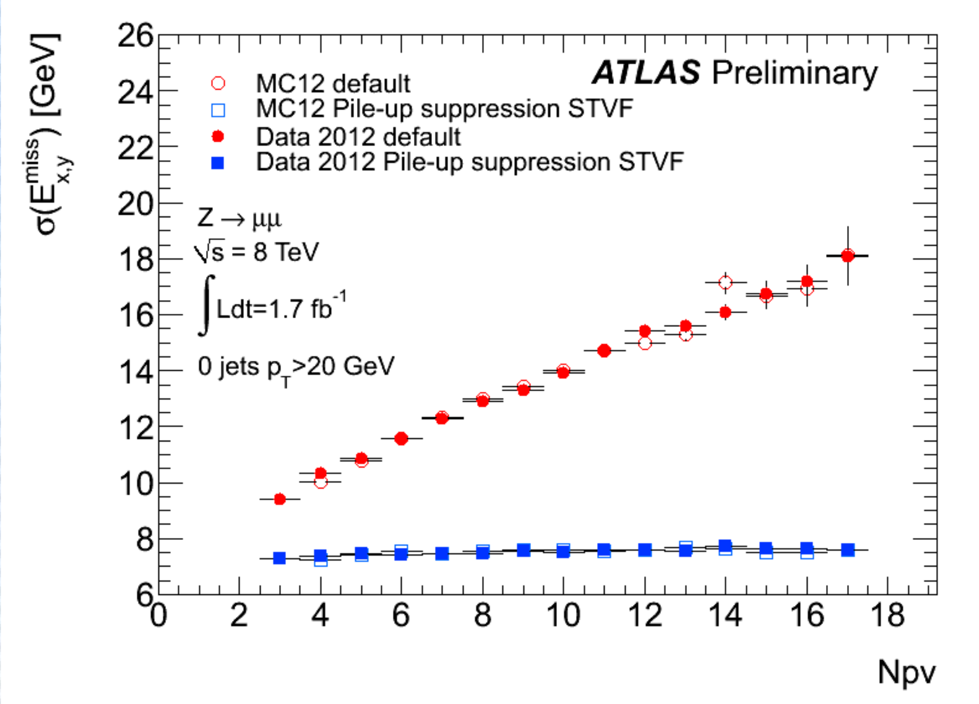
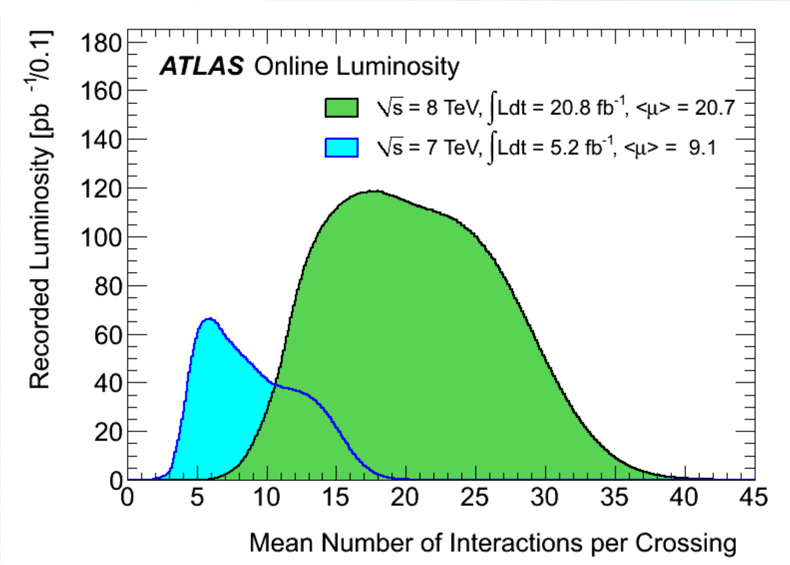
JET/MET performance







Background Normalization

Table 7: Rescaling factors obtained from the fit to the data for the $V + b$ and top backgrounds. The error includes statistical and systematic uncertainties.

	$\sqrt{s} = 7$ TeV	$\sqrt{s} = 8$ TeV
Top	1.10 ± 0.14	1.29 ± 0.16
$Z + b$	1.22 ± 0.20	1.11 ± 0.15
$W + b$	1.19 ± 0.23	0.79 ± 0.20

Table 3: Rescaling factors obtained from a fit to the data for the V+ light and c-jet backgrounds. The error includes statistical and systematic uncertainties. The numbers for $Z + c$ are not expected to match between years; see text for details.

	$\sqrt{s} = 7$ TeV	$\sqrt{s} = 8$ TeV
$Z + c$	1.99 ± 0.51	0.71 ± 0.23
Z+ light	0.91 ± 0.12	0.98 ± 0.11
$W + c$	1.04 ± 0.23	1.04 ± 0.24
W+ light	1.03 ± 0.08	1.01 ± 0.14

	0-lepton, 2 jet			0-lepton, 3 jet		
Bin	E_T^{miss} [GeV]					
	120-160	160-200	>200	120-160	160-200	>200
ZH	2.9	2.1	2.6	0.8	0.8	1.1
WH	0.8	0.4	0.4	0.2	0.2	0.2
Top	89	25	8	92	25	10
$W + c$,light	30	10	5	9	3	2
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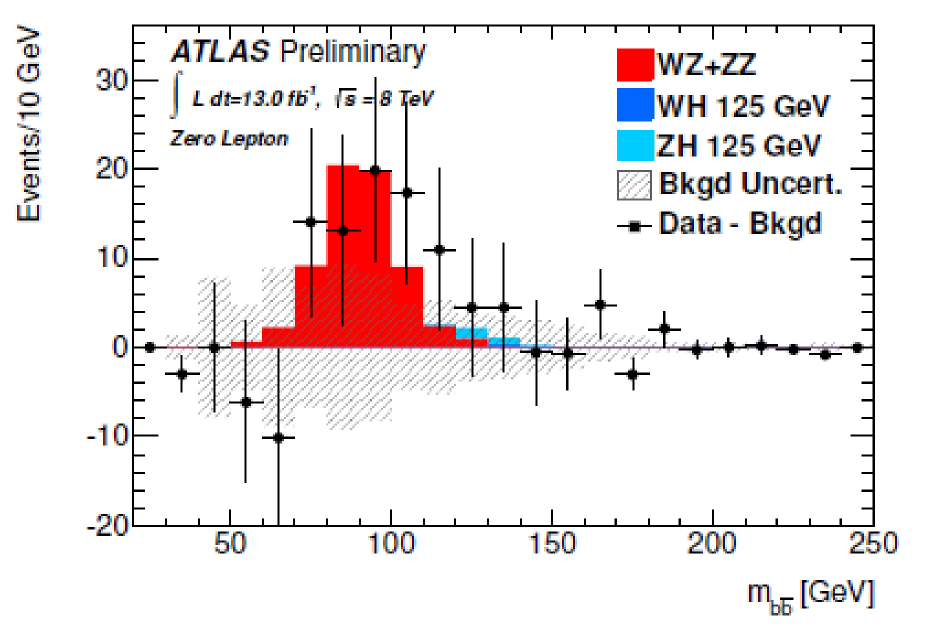
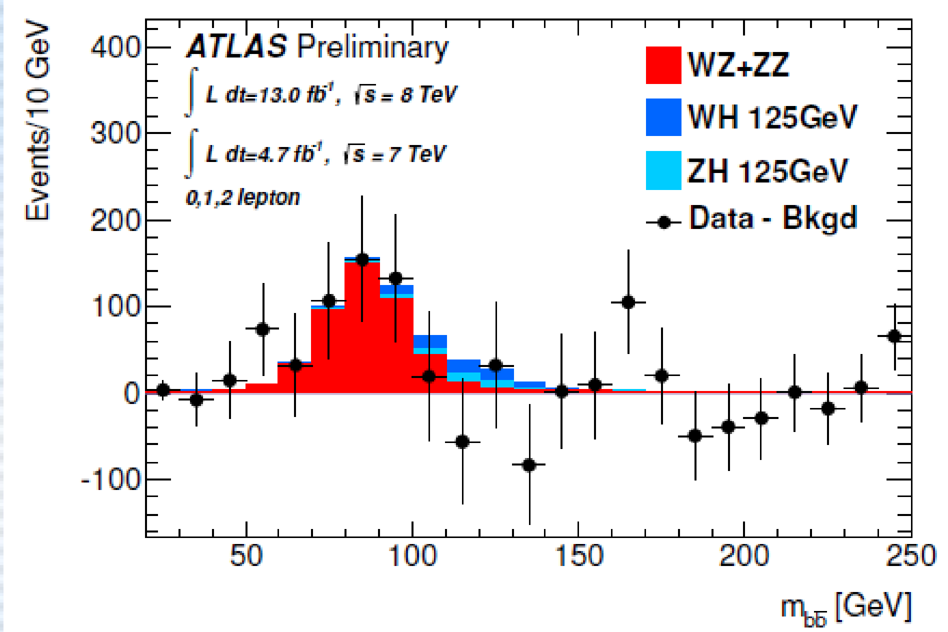
Data	342	131	90	175	65	32

Di-boson peak

- **Backgrounds are subtracted except diboson & Higgs signals**
  Good cross-check of Higgs search method using well-known SM diboson (VZ→Vbb) process

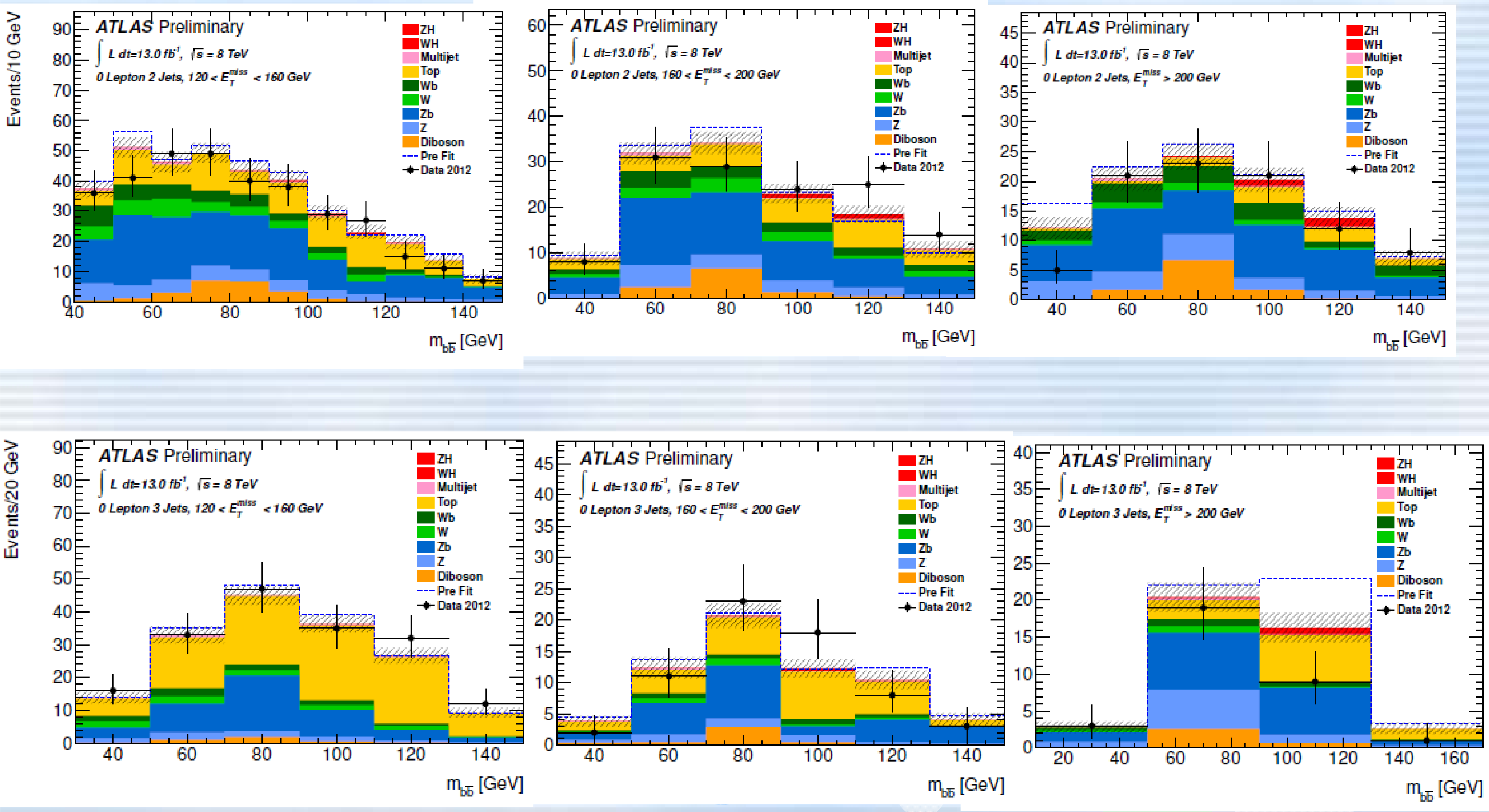




Clearly diboson peak is visible,
good agreement with SM prediction

Combine with 1-lepton/2-leptons channel,
μ_D = 1.09±0.20(stat.)±0.22(syst.)
Significance 4.0σ

Final M_{bb} distributions



Systematic uncertainties

Background

Uncertainty [%]	0 lepton
b-tagging	6.5
c-tagging	7.3
light tagging	2.1
Jet/Pile-up/E_T^{miss}	20
Lepton	0.0
Top modelling	2.7
W modelling	1.8
Z modelling	2.8
Diboson	0.8
Multijet	0.6
Luminosity	3.6
Statistical	8.3
Total	25

Signal

Uncertainty [%]	0 lepton	
	ZH	*WH*
b-tagging	8.9	9.0
Jet/Pile-up/E_T^{miss}	19	25
Lepton	0.0	0.0
$H \to bb$ BR	3.3	3.3
VH p_T-dependence	5.3	8.1
VH theory PDF	3.5	3.5
VH theory scale	1.6	0.4
Statistical	4.9	18
Luminosity	3.6	3.6
Total	24	34

Main experimental systematics

- b-tagging
- Jet/MET
- MC statistics

Final result (only with full 7 TeV data)

	2-lepton		1-lepton		0-lepton			
mass	$ZH \to \ell^+\ell^- b\bar{b}$		$WH \to \ell\nu b\bar{b}$		$ZH \to \nu\bar{\nu}b\bar{b}$		Combined	
[GeV]	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
110	7.5	5.5	3.8	4.4	4.0	4.5	2.7	2.6
115	7.8	5.8	5.5	5.6	4.8	5.1	3.9	3.0
120	10.1	7.4	4.9	5.9	5.4	5.1	3.1	3.2
125	10.4	8.2	8.0	7.5	5.9	5.6	3.5	3.8
130	13.1	10.6	8.5	9.1	12.2	8.9	5.3	5.1

ATLAS-CONF-2012-15

95% C.L. upper limit on σ(VH) x BR(H→bb) normalized to SM expectation