Boost 2012
Valencia, July 23rd-27th

Recent results on the search for H→bb with the ATLAS detector at the LHC

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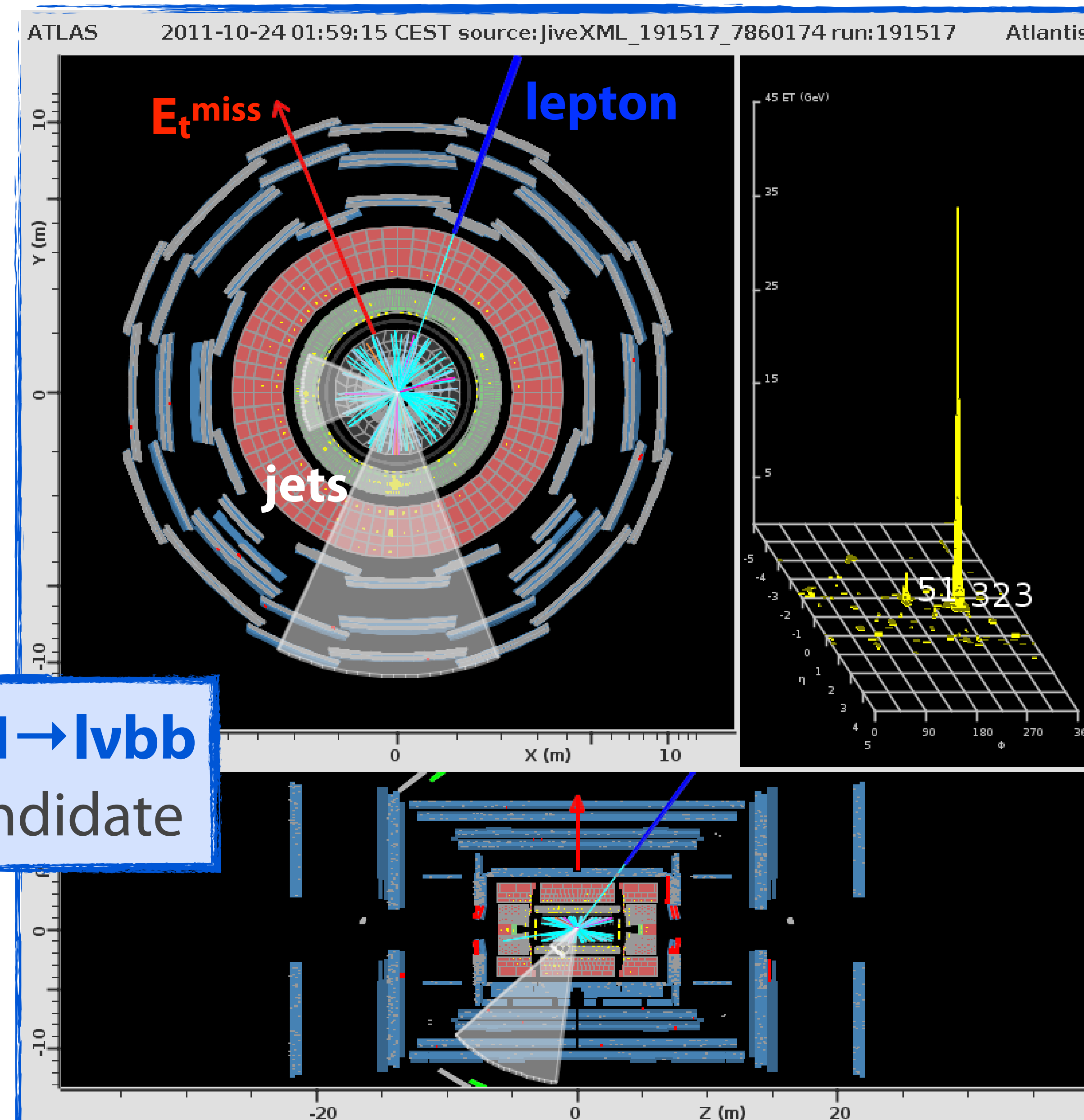
Outline

Aim of the talk:
Recent results on a light SM Higgs boson decaying to a bb pair.
Observation of fermionic decays of a 125GeV mass particle key to prove SM Higgs discovery.

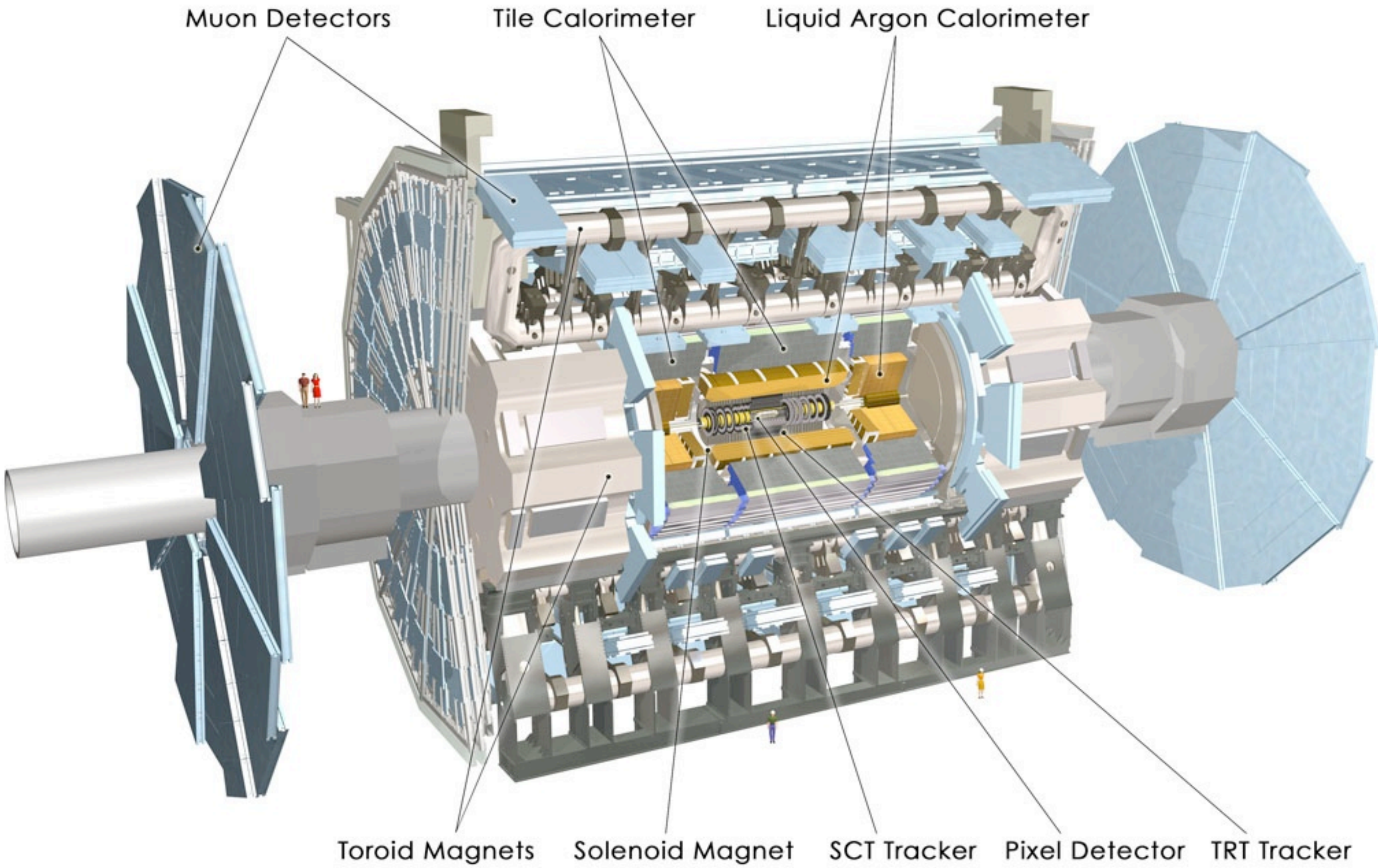
- ✦ ATLAS detector and performance
- ✦ SM VH→leptons+bb
- ✦ Analysis outline
- ✦ Background treatment
- ✦ Results
- ✦ Conclusions and future work

arXiv:1207.0210



WH→lνbb candidate

The ATLAS detector



Calorimeters

- Pb/LAr accordion structure for **EM**
- provides e/γ energy measurement with $\sigma/E \sim 10\%/\sqrt{E(GeV)} \oplus 0.7\%$

- Iron scintillator tiles for **hadronic**
- provides jet and E_t^{miss} measurement with $\sigma/E \sim 50\%/\sqrt{E}$ (GeV)$\oplus 3\%$

- Forward calorimeter: FCAL covers up to $|\eta|<4.9$

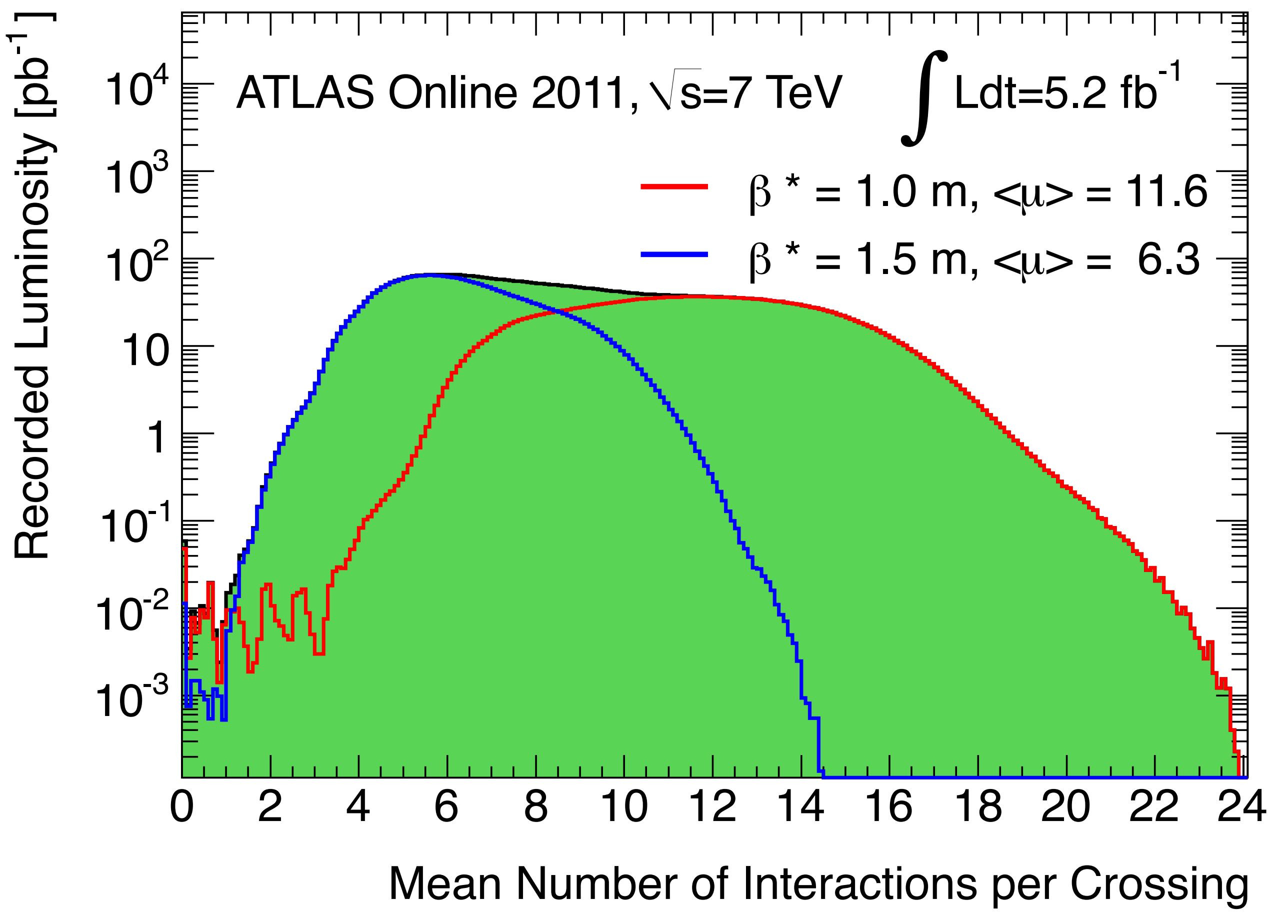
Inner detector

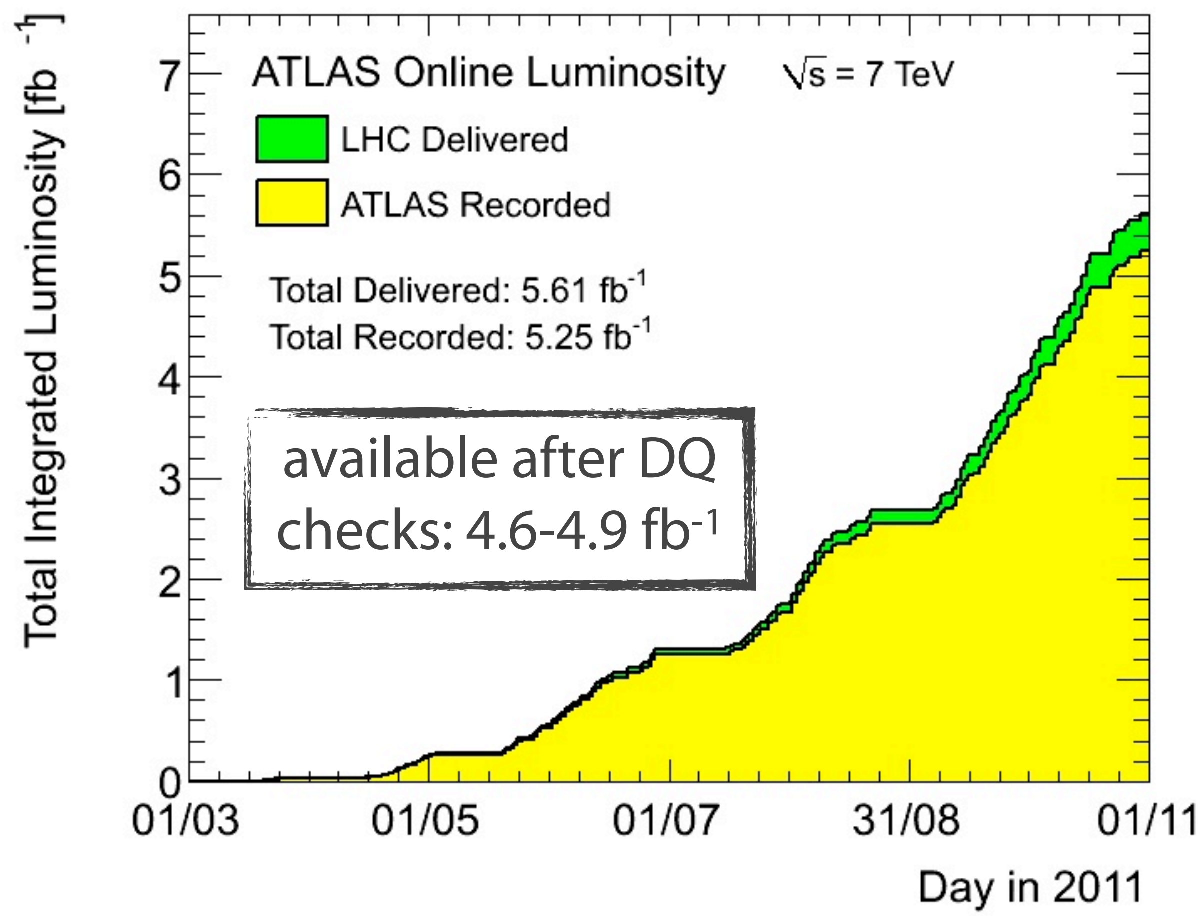
- for $\eta=0$, track has typically 3 Pixel, 8 SCT and 30 TRT hits
- magnetic field (~2 T) produced by solenoid
- coverage: $|\eta|<2.5$ (2.0 for TRT)
- resolution: $\sigma(p_t)/p_t=0.05\% \oplus 1\%$

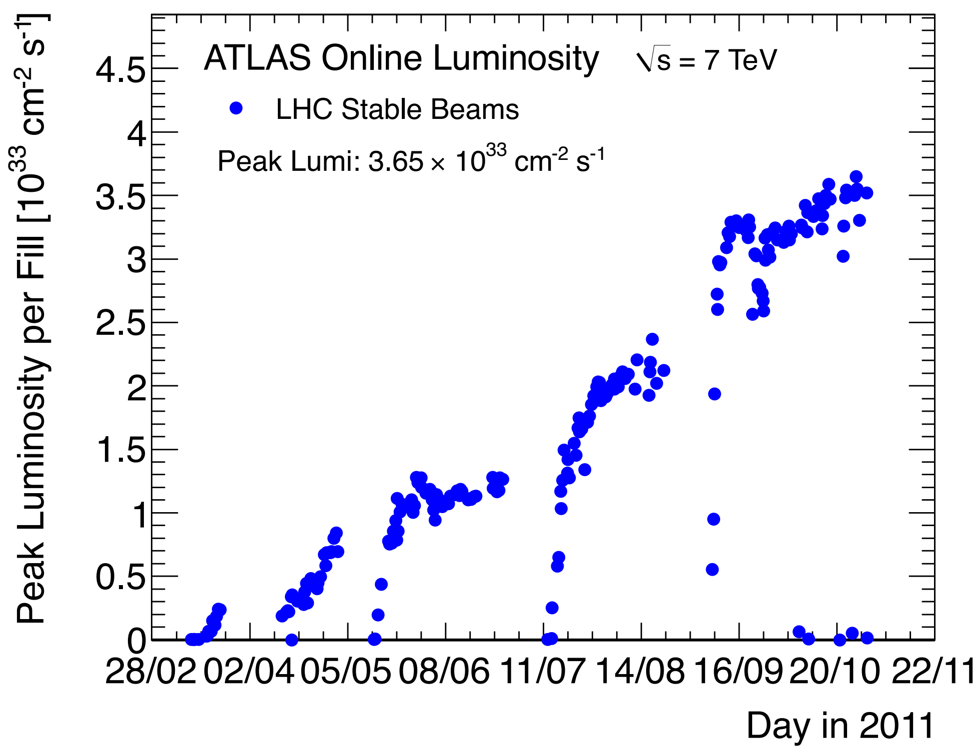
Muon spectrometer

- coverage: $|\eta|<2.7$
- magnetic field (~0.5 T) produced by toroids
- $\sigma(p_t)/p_t \approx 10\%$ for $p_t=1$TeV

ATLAS detector performance







Data taking efficiency ~94%

Fraction of operational channels from all subsystems >96%

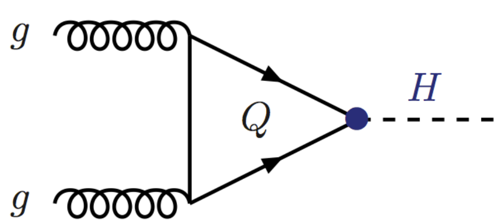
High pileup environment
⇒ challenging for analyses

Theoretical introduction

SM Higgs production

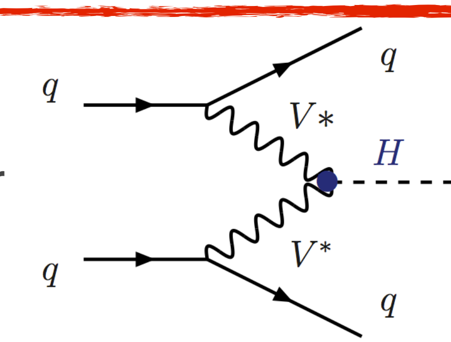
Higgs mechanism explains **EW Symmetry breaking**
In SM coupling to the **scalar** Higgs field, vector bosons and fermions acquire mass

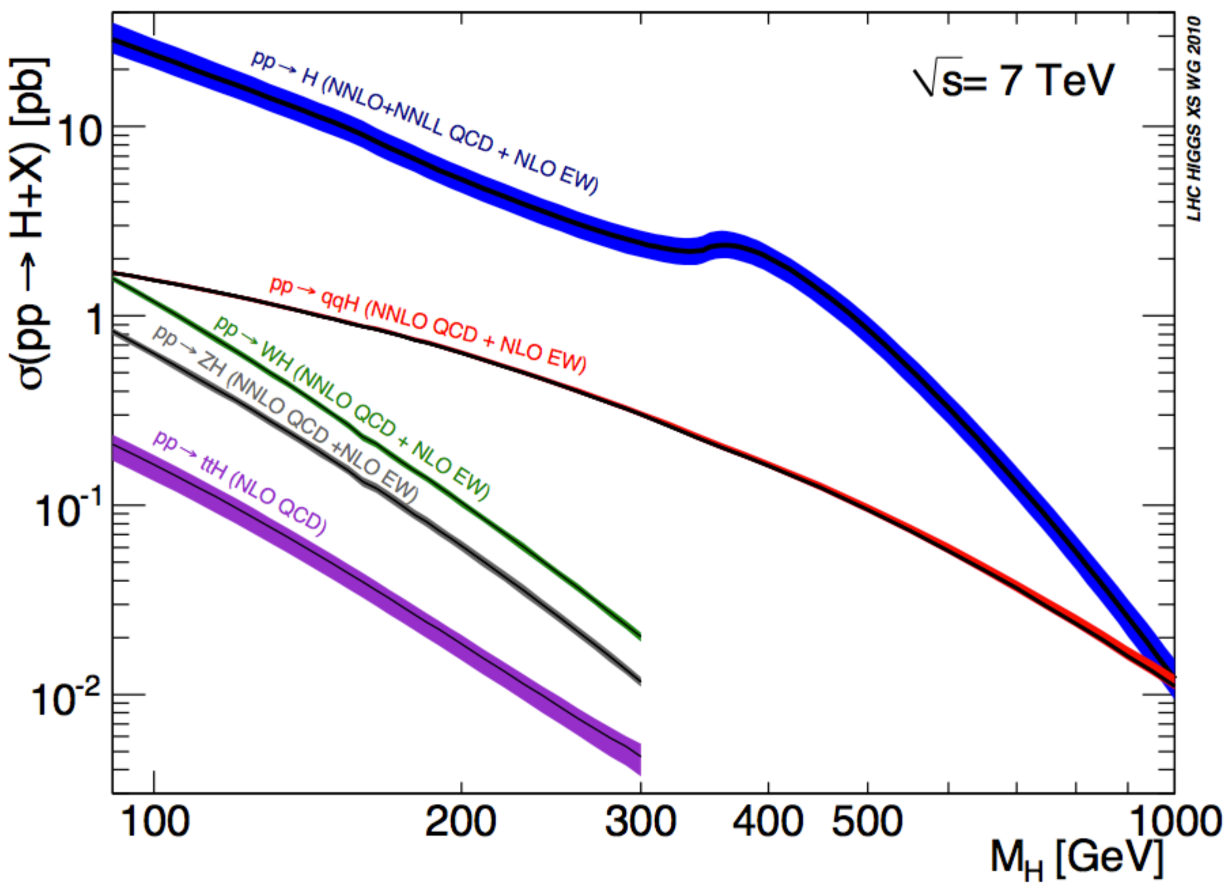
Several Production channels:



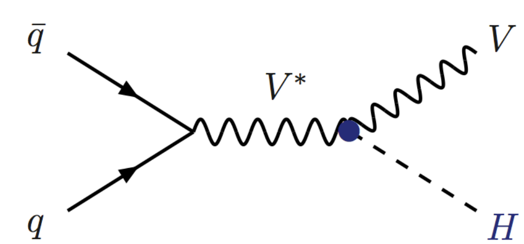
GLUON FUSION
highest contribution from top quark loop

VECTOR BOSON FUSION
distinct signature in detector with two forward jets



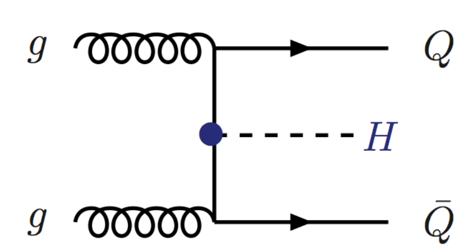


ASSOCIATED PRODUCTION



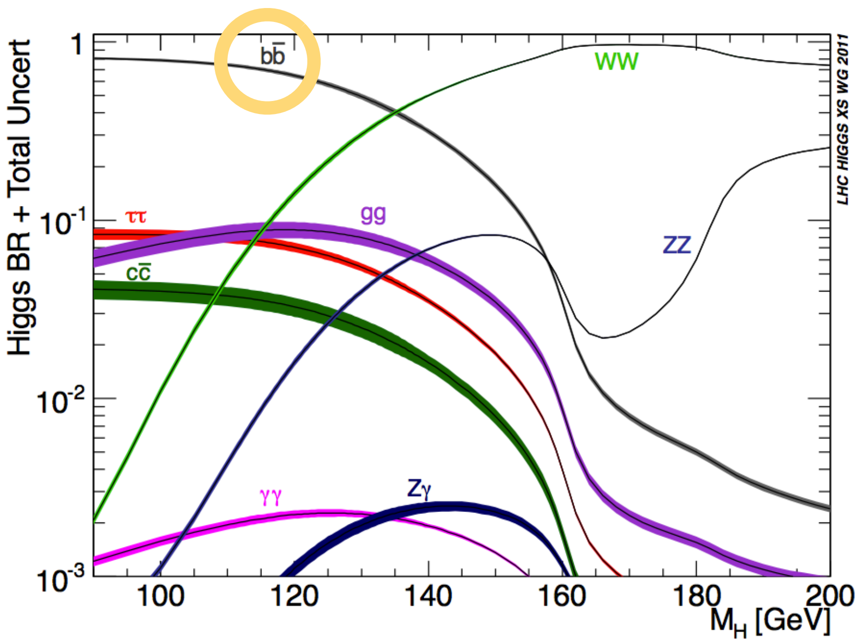
- with **W** or **Z**

- with qq - main contribution from **tt**



important for H→bb searches

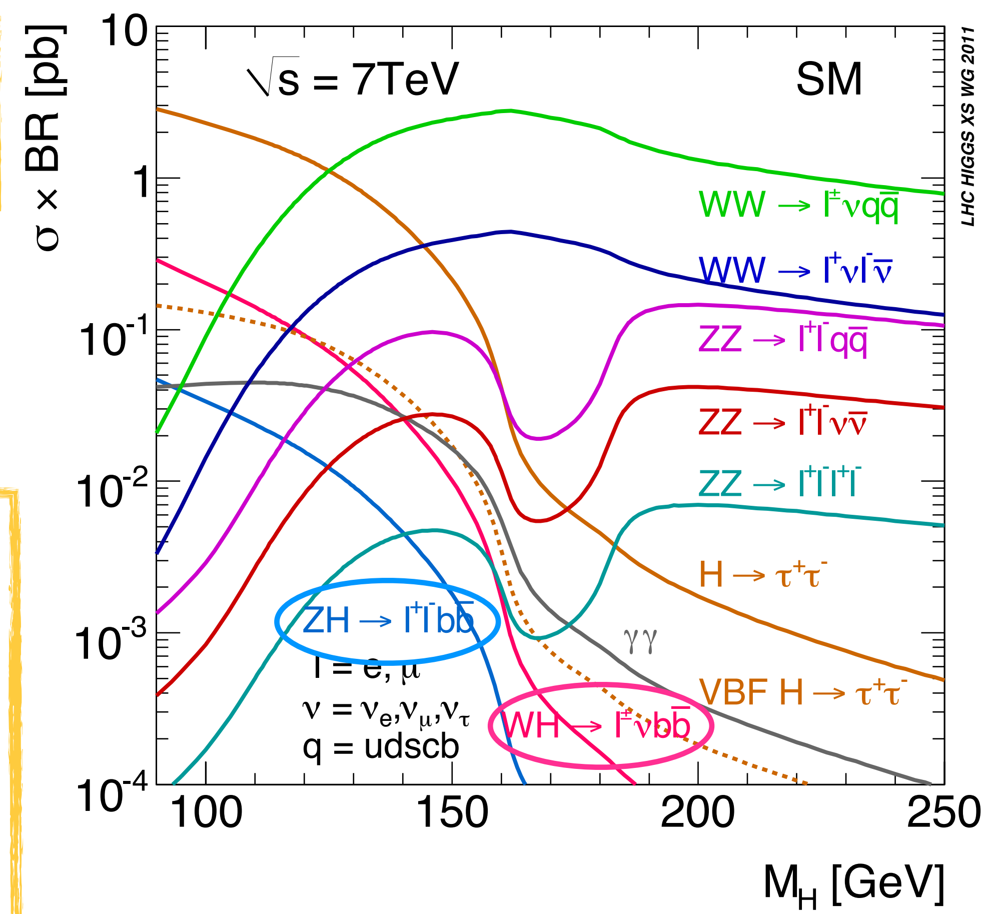
Higgs decays



H→bb dominant decay
in 110≲m_H/GeV≲130

H→bb observation important
to confirm or discard
a SM Higgs boson.
Direct **coupling with fermions**.

Despite very high BR in low
mass region, **challenging**:
difficult to discriminate signal
from leading backgrounds
(much larger than other
decay channels) and
poor mass resolution.



Method used in H→bb searches: look for associated
production with W/Z and exploit **leptonic** vector bosons decays.
Distinct signature in the detector.

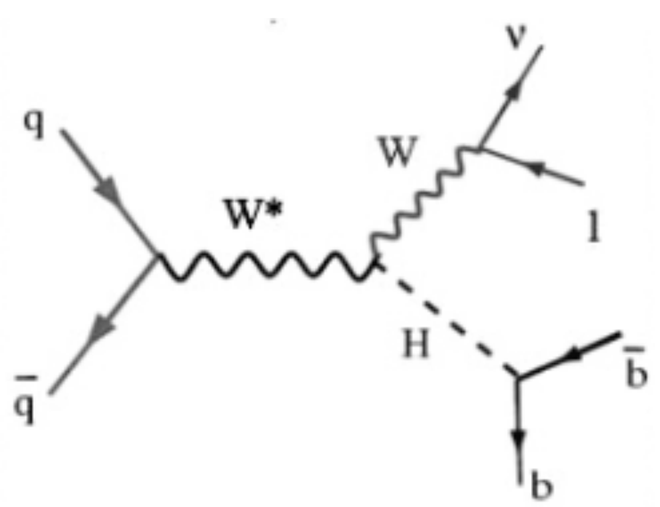
Event Selection

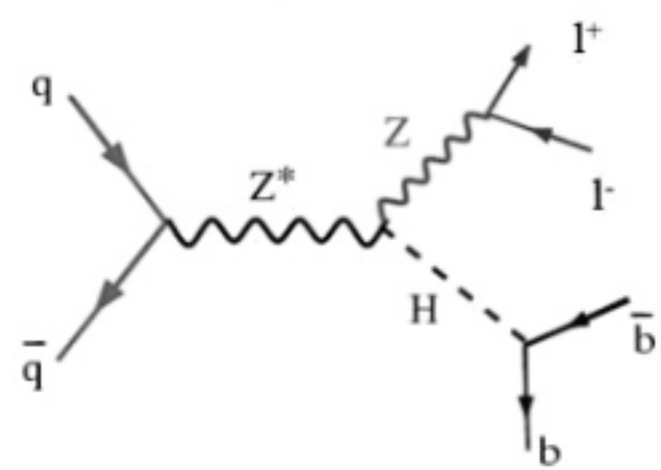
Strategy (I)

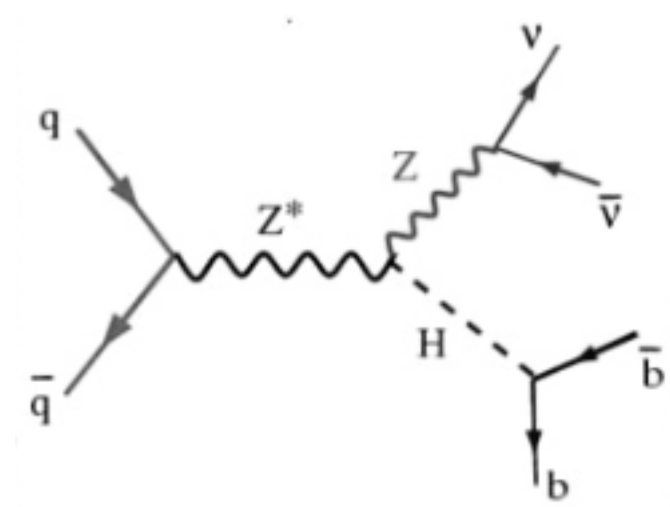
Look at 3 channels: **WH→lνbb**, **ZH→l⁺l⁻bb**, **ZH→ννbb**

$l^{\pm}=e^{\pm},\mu^{\pm}$

Analysis performed on **4.6** (νν channel) and **4.7** (other channels) **fb^{-1}** integrated luminosity collected in **2011** at **√s=7TeV**







TRIGGER SELECTION

WH→lνbb	ZH→l⁺l⁻bb	ZH→ννbb
single lepton trigger	**single lepton + di-electron trigger**	**E_t^{miss} trigger (threshold 70GeV)**
efficiency wrt offline selection ~100% for e's and ~90% for μ's	efficiency wrt offline selection ~100% for e's and ~95% for μ's	efficiency wrt offline selection ~95%

μ chambers φ-coverage < tracker
⇒ lower μ trigger efficiency

Strategy (II)

Physics objects identification

- **E_t^{miss}** from calorimeter energy clusters in $|\eta|<4.9$ including muon corrections. Supplemented by track-based p_t^{miss} (only for $ZH\rightarrow\nu\nu bb$ channel)

- **Electrons** from calorimeter shower shapes and Inner Detector matched tracks with quality requirements applied. Use up to $|\eta|<4.5$ to reject backgrounds

- **Muons** from combined ID and Muon Chambers tracks for W and Z identification. Use also muons from muon system only (up to $|\eta|<2.7$) to suppress background.

- **Jets** from energy deposits in calorimeter, reconstructed using the anti-kt clustering algorithm with R=0.4

- For **pileup suppression** definition of JVF
  Pileup jets suppressed requiring **JVF>75%**

$$JVF = \frac{\Sigma p_t(\text{tracks with } p_t>400\text{MeV associated to jet matched to primary vertex})}{\Sigma p_t(\text{all tracks with } p_t>400\text{MeV associated to jet})}$$

- Jets are **b-tagged** if the flavour weight is higher than ~0.6

Strategy (III)

Selection efficiency on signal: 2.4%

$WH \rightarrow l\nu bb$

- **only one lepton** with $p_t>25GeV$
- $\mathbf{E_t^{miss}>25GeV}$
- $\mathbf{M_t^W>40GeV}$
- **one b-tagged jet** with $\mathbf{p_t>45GeV}$, $|\eta|<2.5$
- a **second b-tagged jet** with $p_t>25GeV$, $|\eta|<2.5$
- **no additional jets** with $p_t>20GeV$, $|\eta|<4.5$

Selection efficiency on signal: 5.0%

$ZH \rightarrow l^+l^-bb$

- **two leptons** with $p_t>20GeV$
- $\mathbf{|m_{ll}-91GeV|<8GeV}$
- **one b-tagged jet** with $\mathbf{p_t>45GeV}$, $|\eta|<2.5$
- a **second b-tagged jet** with $p_t>25GeV$, $|\eta|<2.5$
- $\mathbf{E_t^{miss}<50GeV}$

$ZH \rightarrow \nu\nu bb$ (has contribution from $WH \rightarrow l\nu bb$)

Selection efficiency on signal: 2.1% for $ZH \rightarrow \nu\nu bb$ and 0.2% for $WH \rightarrow l\nu bb$

- $\mathbf{E_t^{miss}>120GeV}$ (allows for multi-jet background rejection)
- **one b-tagged jet** with $\mathbf{p_t>45GeV}$, $|\eta|<2.5$
- a **second b-tagged jet** with $p_t>25GeV$, $|\eta|<2.5$
- **no additional jets** with $p_t>25GeV$, $|\eta|<2.5$
- **topological cuts** on $\Delta R(bb)$ and $\Delta\varphi(bb,E_t^{miss})$ dependent on E_t^{miss} value

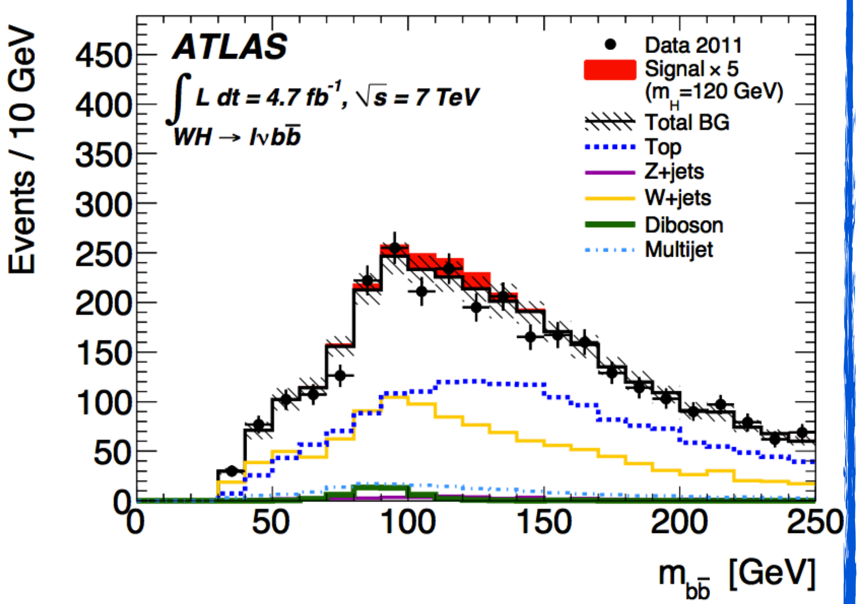
Look for an **excess** in m_{bb} distribution. Mass hypothesis shown: $\mathbf{m_H=120\ GeV}$.
m_{bb} shifted by 1.05. Reason: jet mis-measurement because of losses from soft μ's and ν's

Results and background treatment

m_{bb} and background contributions

m_{bb} shape evaluated from MC and normalisation of leading backgrounds from data,
outside Signal Region: 80< m_{bb}/GeV<150 and in dedicated top control regions

WH→lνbb

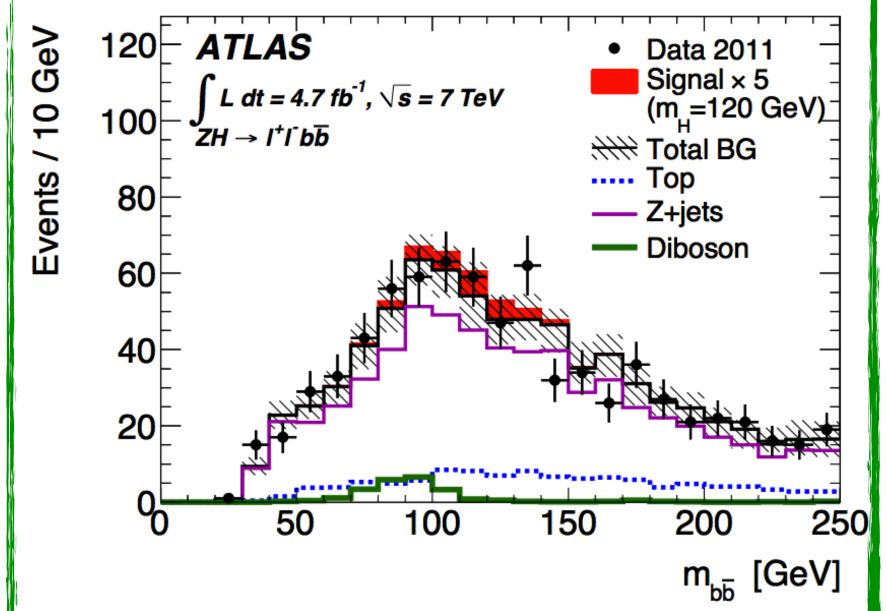


Main backgrounds

top (single top + tt production)
and **W+jets**

Scale factors extracted
from m_{bb} sidebands and
WH top control region

ZH→l⁺l⁻bb

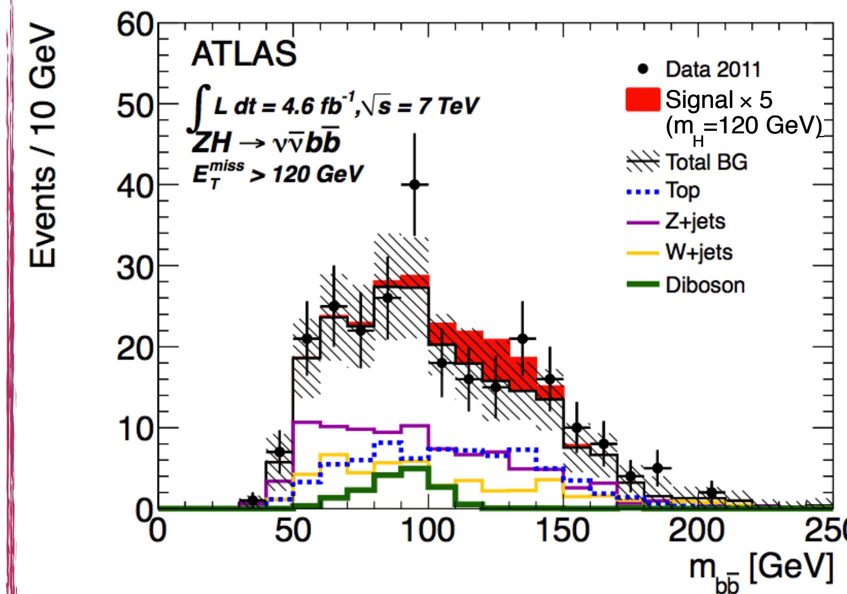


Main backgrounds

Z+jets and **top**

Scale factors from m_{bb} sidebands
and ZH top control region

ZH→ννbb



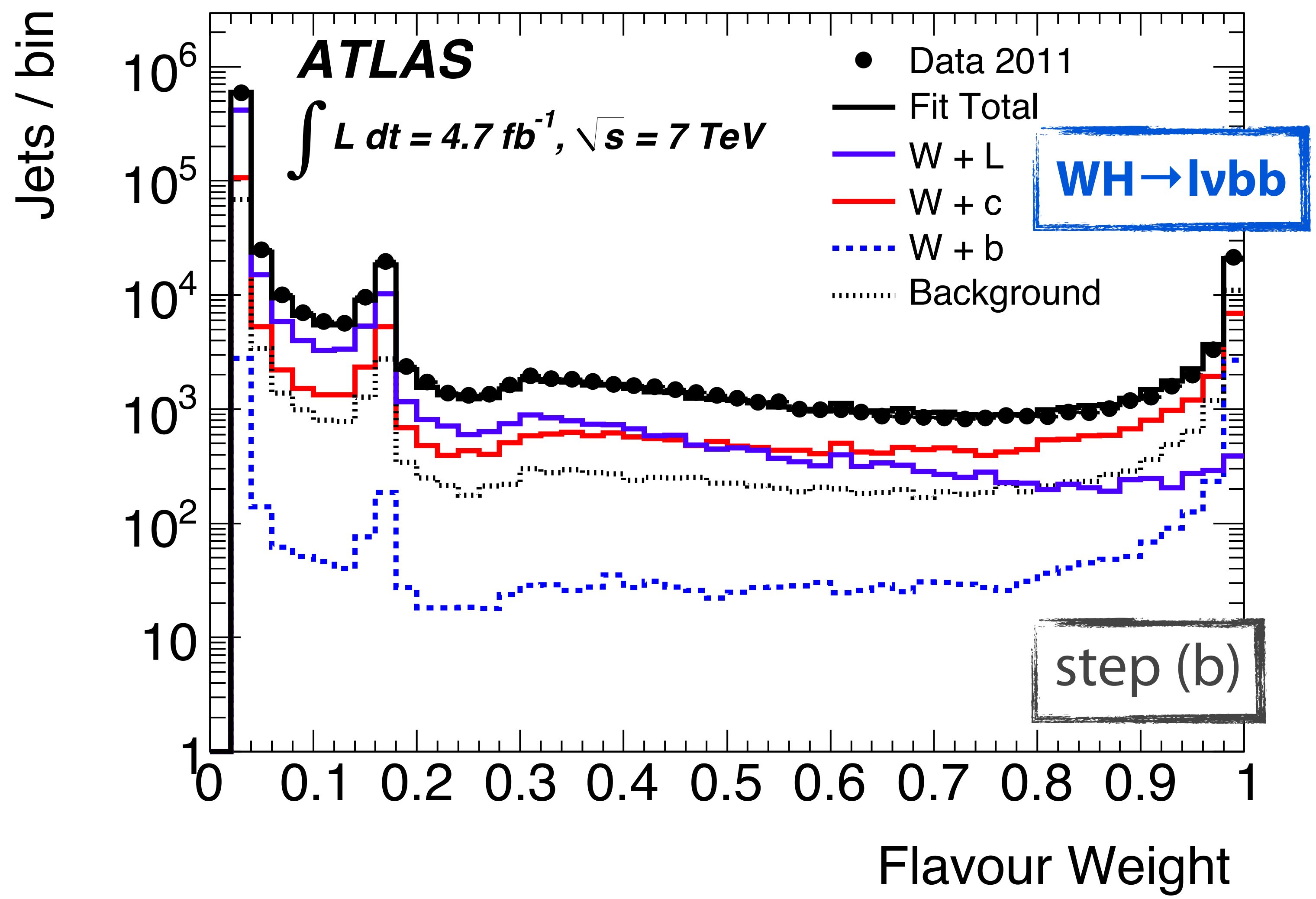
Main backgrounds

Z+jets, top, W+jets
and **diboson**

Scale factors from other
channels, cross-checked
in specific control regions

V+jets background treatment

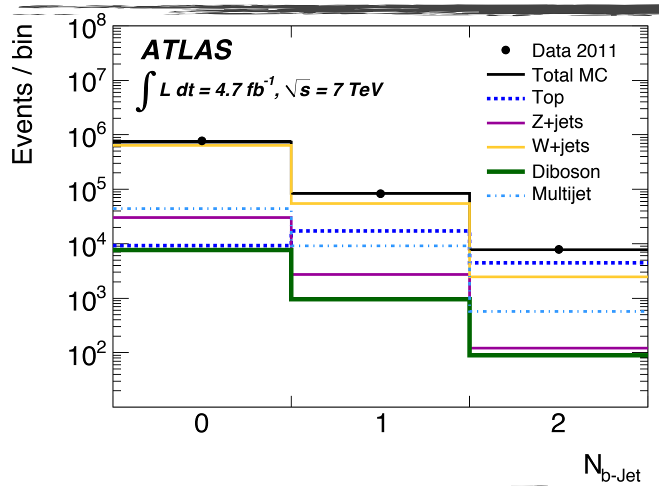
V+b, **V+c** and **V+light**-jet fractions determined **separately** from data in events with 2 jets and m_{jj}<80GeV



Two steps:

(a) fit events with **one b-tagged jet** and use the flavour weight of the second jet

(b) fit events with **no b-tagged jets** and use the flavour weight of the first two jets



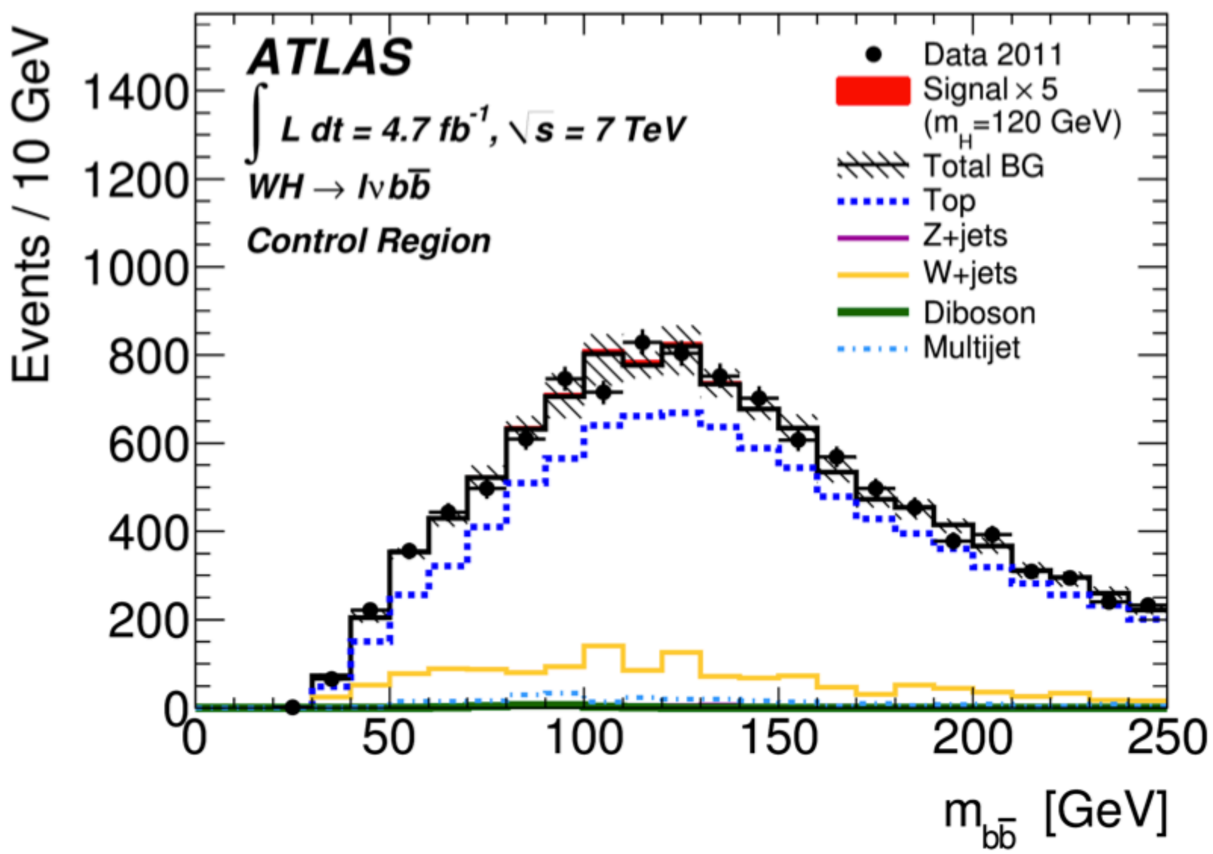
b-tagging algorithm: NN combination of different ATLAS algorithms (3D impact parameter, inclusive vertex finder, PV→b→c decay chain fit)

Working point with **ε~70% for b-jets**, c-rejection factor ~5, light rejection factor ~130

Top background treatment

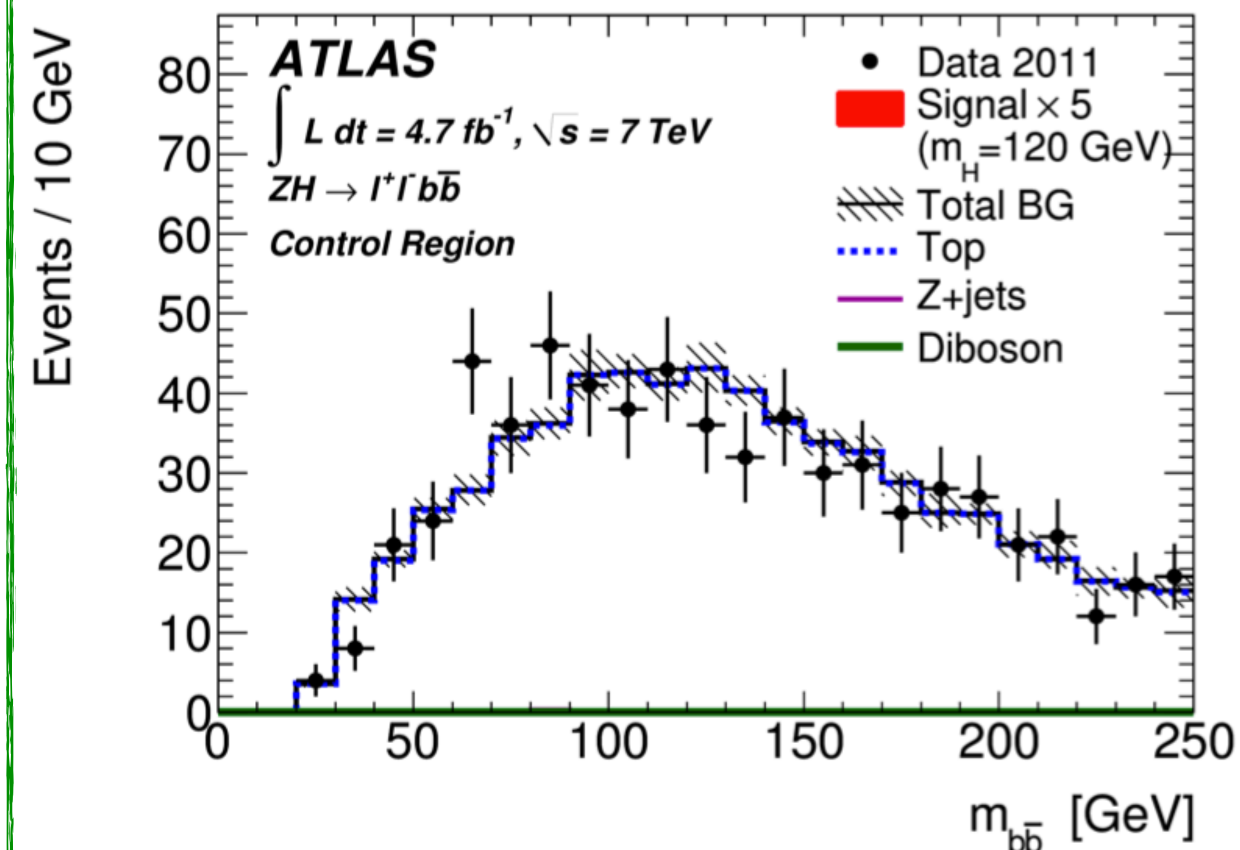
Top control region for WH→lνbb

- events with 3 jets instead of 2 (like signal selection)



Top control region for ZH→l⁺l⁻bb

- $|m_{ll}$-91GeV$|$>15GeV
- E_t^{miss}>50GeV



Top control regions used to check top normalisation and modelling

WH case: normalisation for W+jets background evaluated independently in 2 jet and 3 jet bin

Single top to pair production **ratio** evaluated from NLO QCD comparison (30% systematic uncertainty)

Simultaneous fit to top and V+jet background normalisations ⇒ **good agreement** in m_{bb} shape

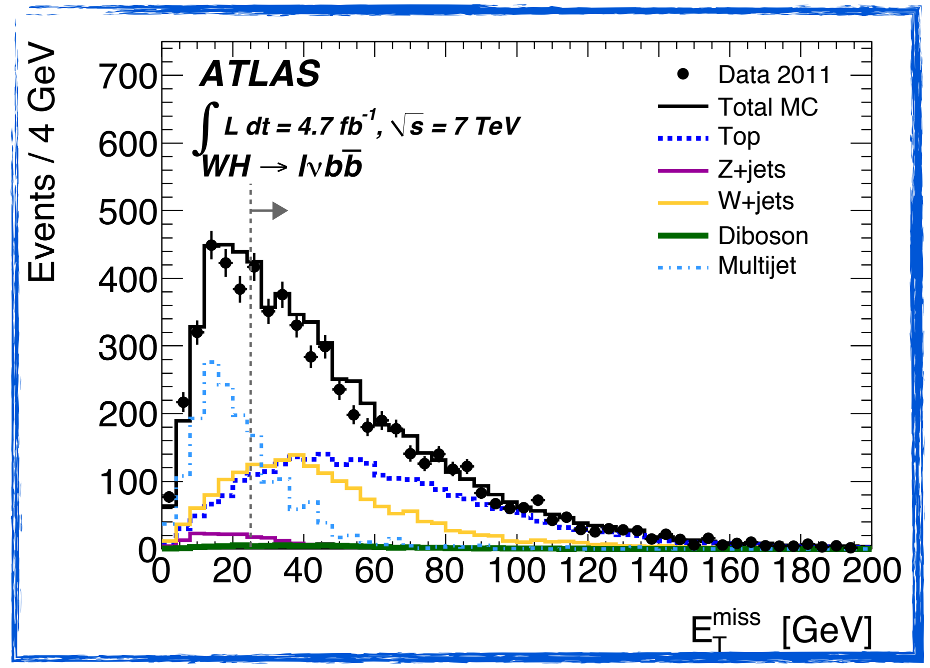
Multi-jet background treatment (I)

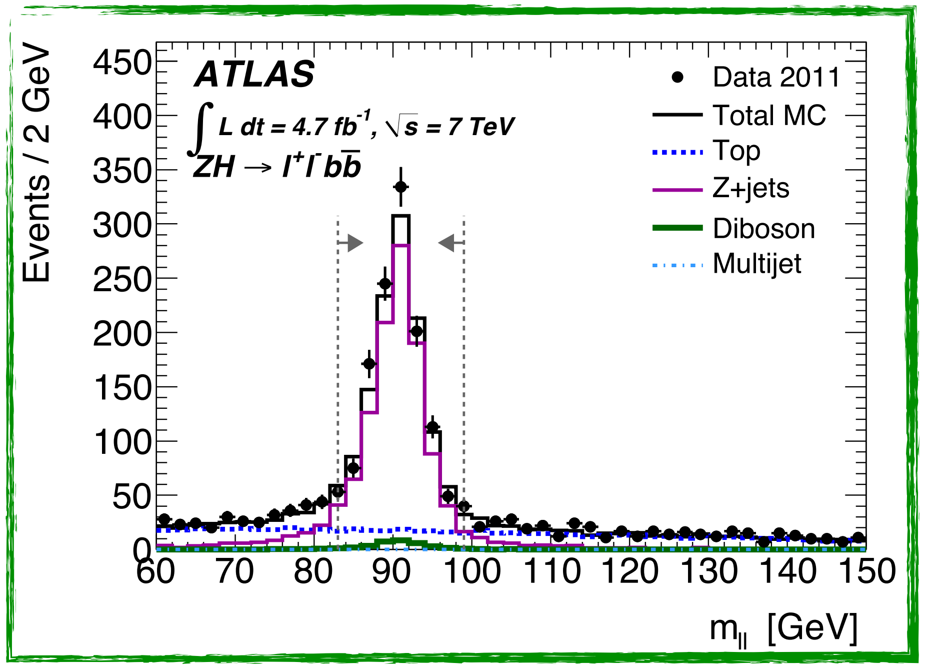
Strongly suppressed by analysis cuts:

- **WH→lνbb** track and calorimeter based isolation requirements on signal charged lepton to avoid contamination from semi-leptonic decays of heavy flavour hadrons and fake leptons in multi-jet events
- **ZH→l⁺l⁻bb** track based isolation on signal leptons
- **ZH→ννbb** topological cuts:
  1. $|\Delta\varphi(E_t^{miss},p_t^{miss})|<\pi/2$
  2. $|\min(\Delta\varphi(E_t^{miss},jets))|>1.8$

Estimated from data for first two cases:

- **WH→lνbb** E_t^{miss} templates obtained **reverting isolation** requirements for charged signal leptons and fit to data. **30%** uncertainty determined from data/normalised templates comparison in multi-jet control region $E_t^{miss}<25GeV$, $m_t^W<40GeV$





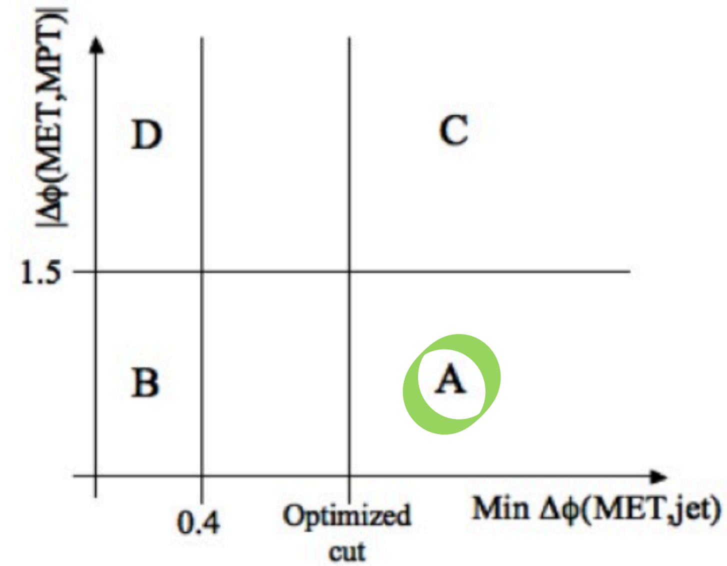
- **ZH→l⁺l⁻bb** normalisation from m_{ll} sidebands in events with $N_{jets}\geq2$: **contribution <1%** ⇒ neglected

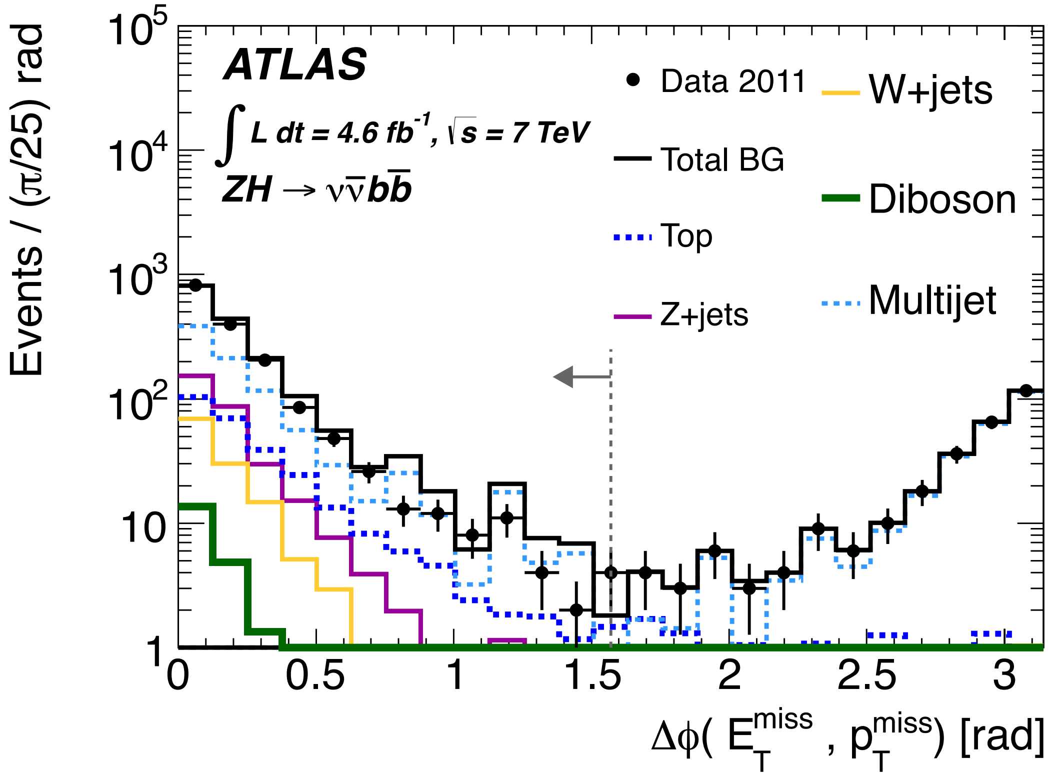
Multi-jet background treatment (II)

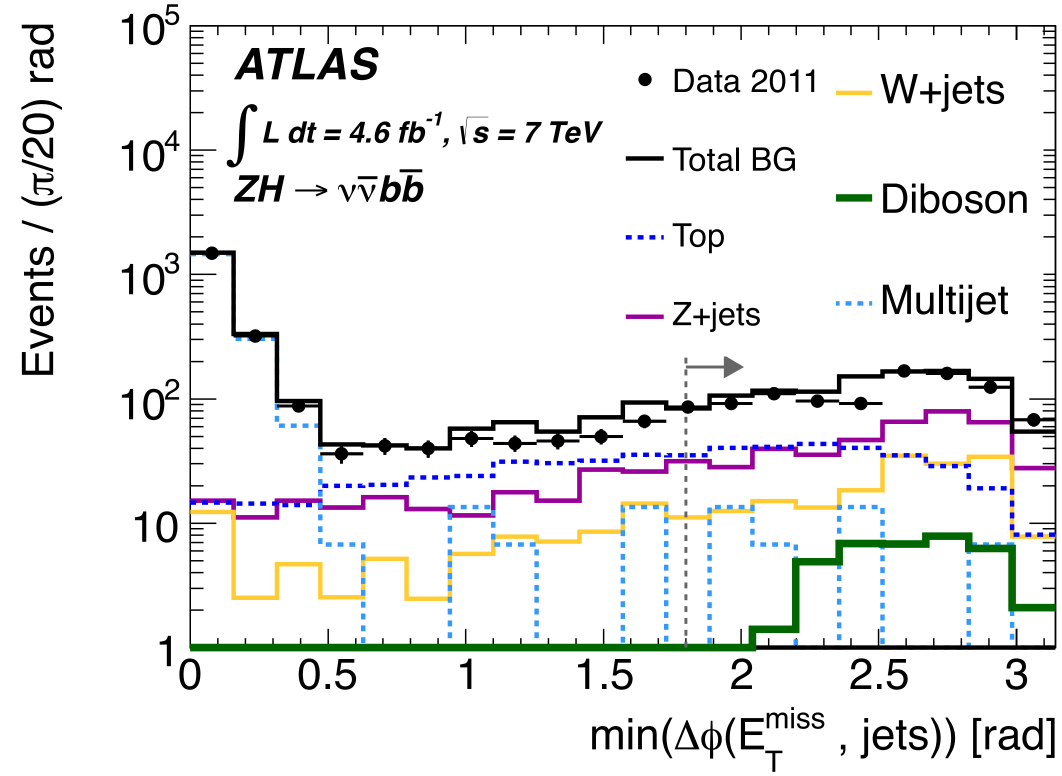
ZH→ννbb case

Lack of correlation between $\Delta\varphi(E_t^{miss}, p_t^{miss})$ and $\min(\Delta\varphi(E_t^{miss}, jets))$ in case of multi-jet events ⇒ estimate of contamination in **signal region**:

$$N_{QCD}(A) = (N(B)/N(D)) \times N(C)$$







Contamination ranging from 0.04 to 0.85 in different E_t^{miss} intervals

Result affected by **limited statistics** in the control regions

Small contamination in signal region ⇒ **neglect** contribution from the background

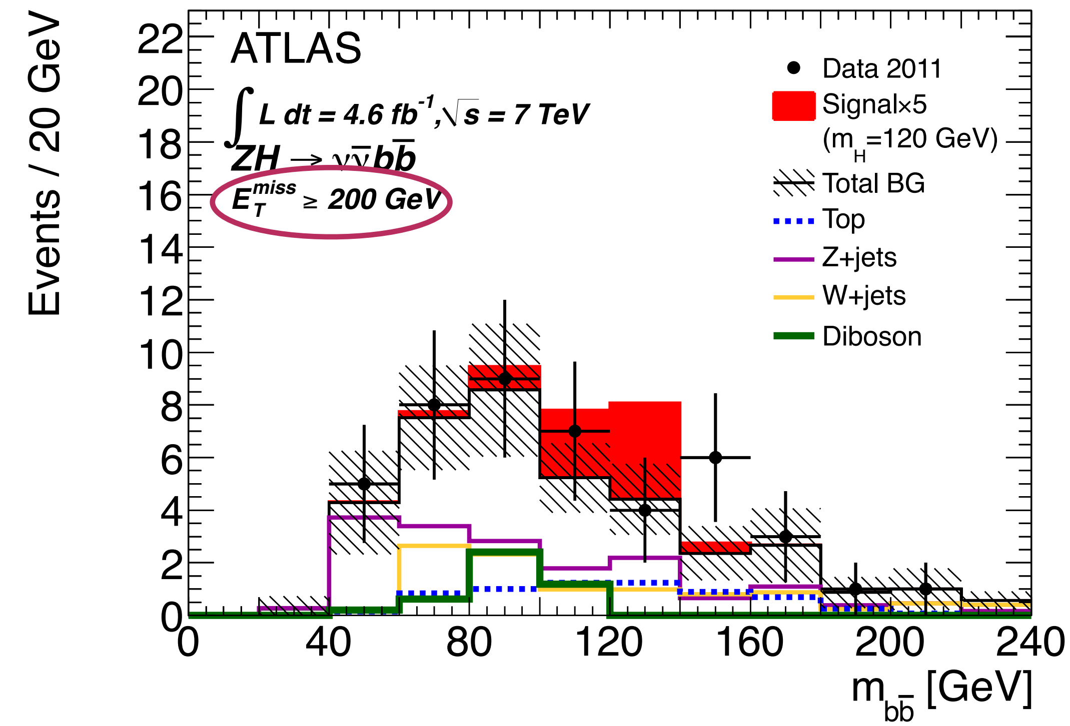
Analysis optimisation

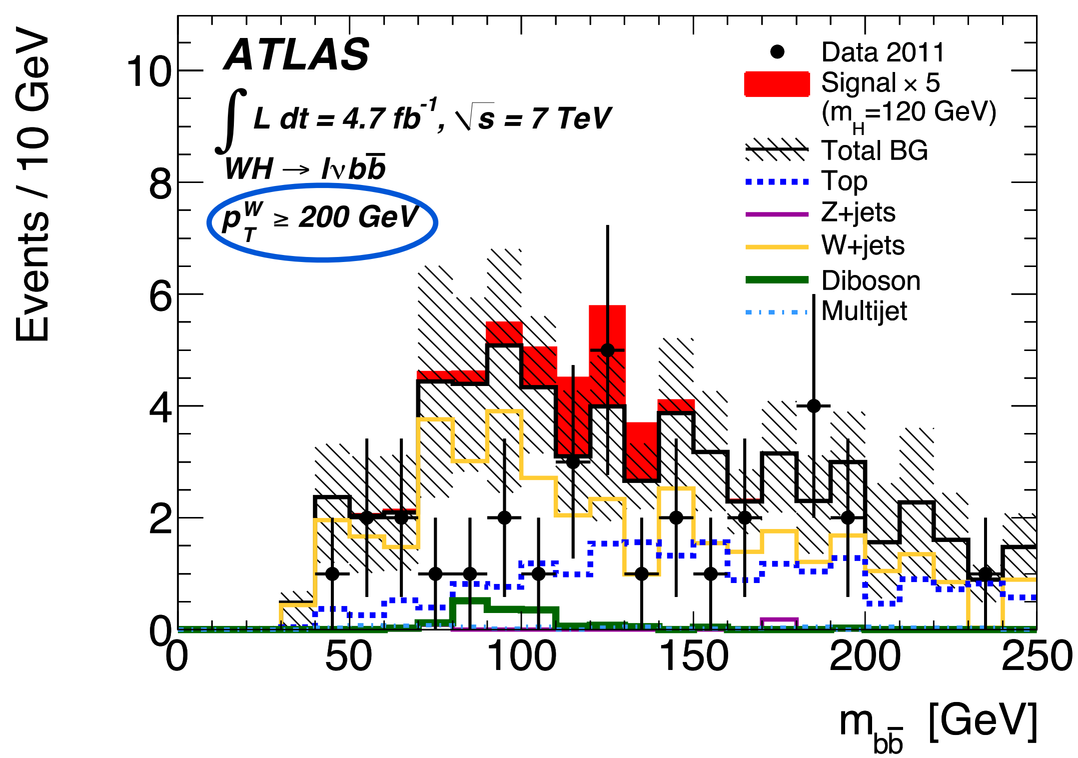
Divide in $\mathbf{p_t^V}$ bins to exploit higher S/B in high p_t phase space region

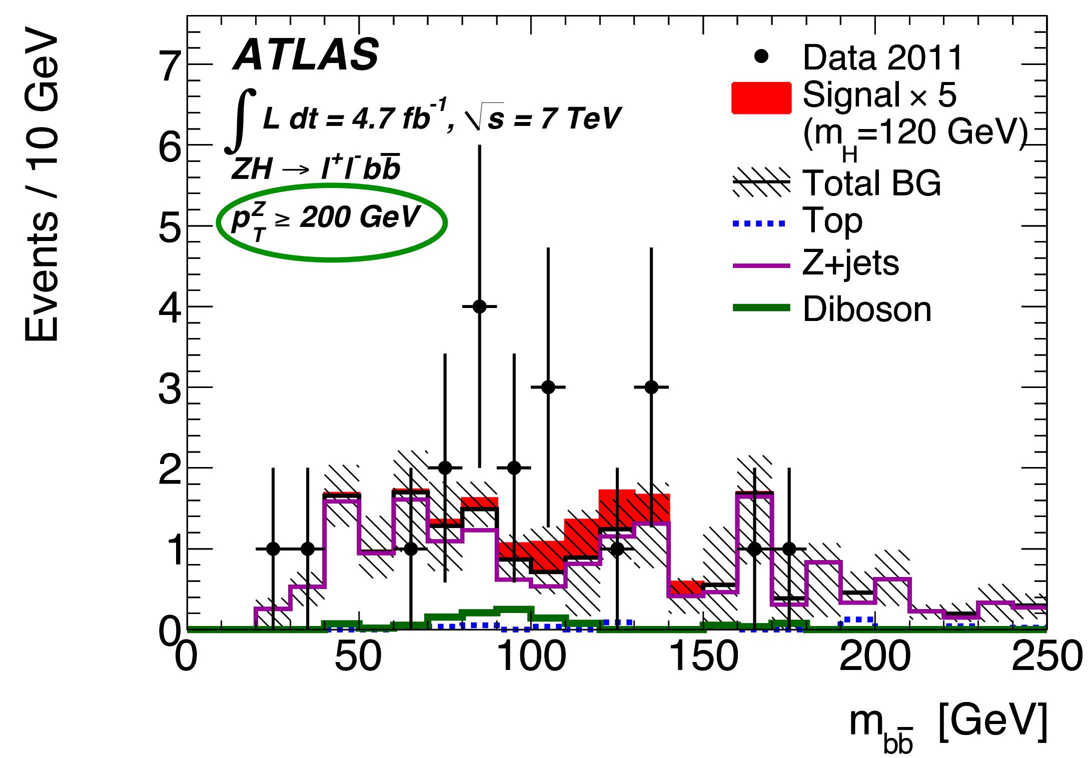
- **WH→lνbb**, **ZH→l⁺l⁻bb**
  p_t^V/GeV ∈ [0,50], (50,100], (100,200], >200
- **ZH→ννbb** p_t^Z/GeV ∈ [120,160], (160,200], >200

Exploit harder p_t^V spectrum in signal case

Correct estimate of p_t^V modelling crucial





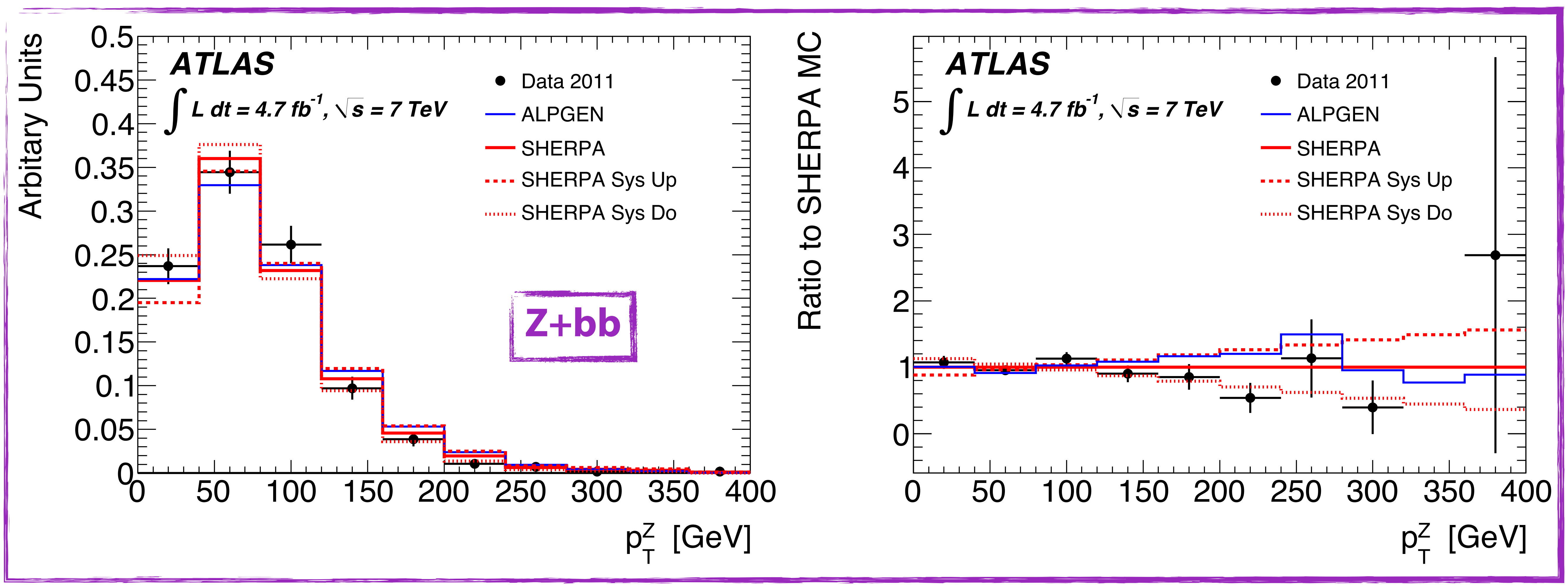


More on V+jets background

Source of systematic uncertainty from different **modelling** of m_{bb} and p_t^V shapes.

Treatment:

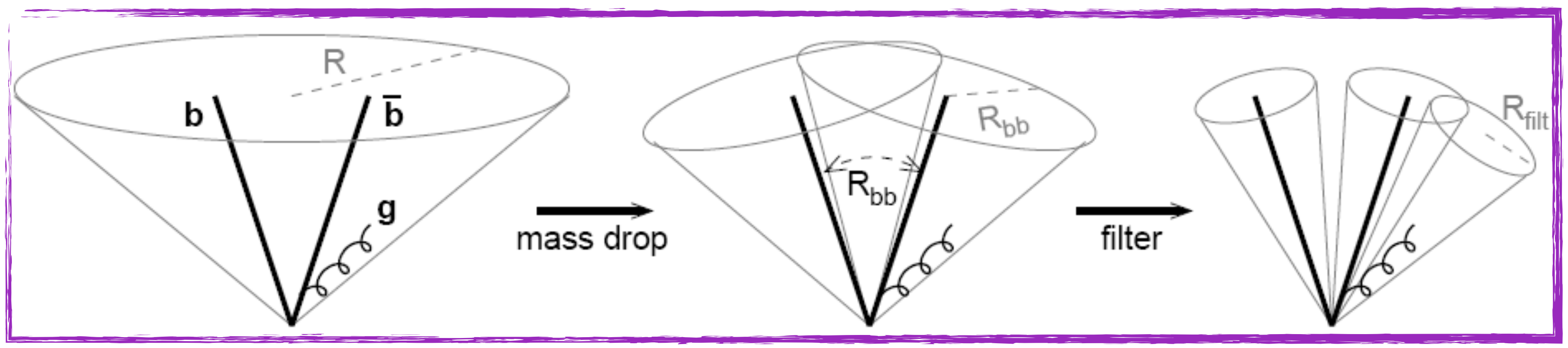
- **W+bb** compare different MC models and take largest difference as 1/σ systematic variation
- **Z+bb** consider difference between data and MC in m_{bb} sidebands (example in plots)

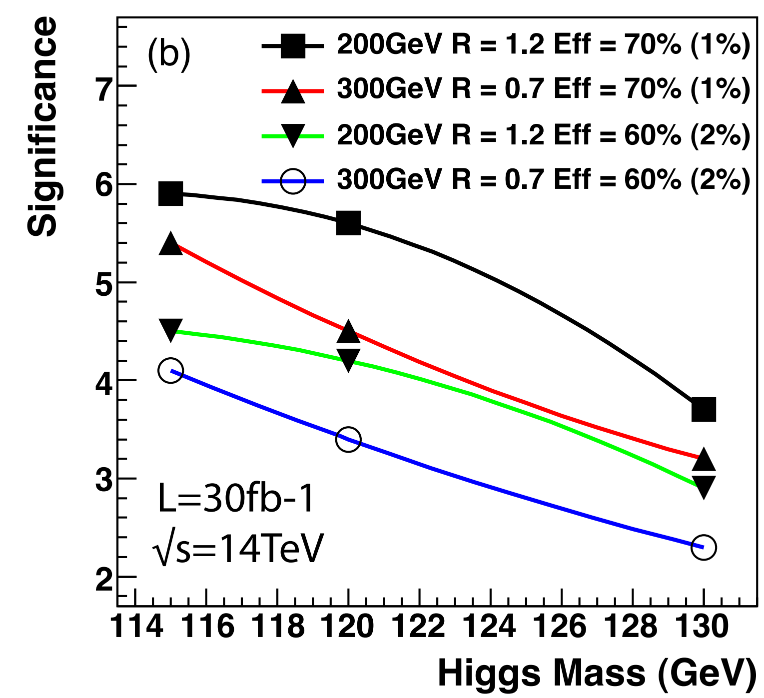


High p_t region and substructure

Highest p_t bin (>200 GeV) ⇒ best S/B (estimated up to ~15%)

In this area of phase space: proposed analysis using jet substructure techniques (BDRS method) - arXiv:0802.2470
Use Cambridge/Aachen jets of 1.2 radius to identify the Higgs candidate and apply **splitting-filtering** procedure to exploit the jet substructure and resolve the two b-jets and eventual additional hard radiation





Still under study for H → bb with 7 and 8 TeV data
→ a lot of work in performance in ATLAS for large-R jets

Will highlight numbers and plots relevant for p_t >200 GeV region, to get a flavour of the situation for a substructure analysis in this channel

Event yields and systematics

Event yields

Mass hypothesis: $\mathbf{m_H=120}$ **GeV**

Number of events in Signal Region ($80<m_{bb}/GeV<150$) for the three different channels **divided in bins of p_t^V**

$WH\rightarrow l\nu bb$

p_t^W [GeV] bins	0-50	50-100	100-200	>200
signal	5.0±0.6	5.1±0.6	3.7±0.4	1.2±0.2
total background	596±23	598±16	302±10	27±5
data	614	588	271	15
S/√B (stat)	0.20	0.21	0.22	0.22

$ZH\rightarrow \nu\nu bb$

p_t^Z [GeV] bins	120-160	160-200	>200
signal	2.0±0.2	1.2±0.1	1.5±0.2
total background	85±2	32±3	20±3
data	105	22	25
S/√B (stat)	0.22	0.21	0.34

$ZH\rightarrow l^+l^-bb$

p_t^Z [GeV] bins	0-50	50-100	100-200	>200
signal	1.3±0.1	1.8±0.2	1.6±0.2	0.4±0.1
total background	148±10	150±6	67±4	6.9±1.2
data	141	163	61	13
S/√B (stat)	0.11	0.15	0.20	0.17

Leading background uncertainties

Theory + b-tagging efficiency

Relative systematic uncertainties on the backgrounds (expressed in %)

Theoretical uncertainty **dominant**, particularly **in highest p_t bin**
Up to ~**15%**

Coming mainly from differences in various models for m_{bb} and p_t^V in **V+jets** background

b-tagging efficiency contributes to the systematic uncertainties rather heavily: ~1-7%

Note:

- ✦ uncertainty on b-tagging efficiency per jet ranging between 5 and 19% depending on the jet p_t
- ✦ **p_t dependence** taken into account using full covariance matrix of measured b-tagging efficiency in various p_t bins

$WH \to l\nu bb$

p_t^W [GeV] bins	0-50	50-100	100-200	>200
theory uncertainty (%)	2.2	0.3	1.6	14.8
b-tagging eff (%)	0.9	1.3	0.9	7.2

$ZH \to l^+l^-bb$

p_t^Z [GeV] bins	0-50	50-100	100-200	>200
theory uncertainty (%)	5.2	1.3	4.7	14.9
b-tagging eff (%)	1.4	1.0	0.3	4.8

$ZH \to \nu\nu bb$

p_t^Z [GeV] bins	120-160	160-200	>200
theory uncertainty (%)	2.9	4.0	7.7
b-tagging eff (%)	4.1	4.2	5.5

Leading background uncertainties

Background normalisation + jets and E_t^{miss}

Statistical error from background normalisation ranging from 2 to 5%

Strongly dependent on statistics in **sidebands** for data, used to determine the scale factors for the various background components

Error coming from **η and p_t dependent** jet and E_t^{miss} calibration: 2-12%

- **E_t^{miss}** component **dominant in ZH→ννbb** - largest systematic in this channel
- impact of pileup uncertainties reduced by dedicated corrections

WH→lνbb

p_t^W [GeV] bins	0-50	50-100	100-200	>200
backgr norm (%)	2.7	1.8	1.8	4.5
jet-E_t^{miss} (%)	1.5	1.4	2.1	9.5

ZH→l⁺l⁻bb

p_t^Z [GeV] bins	0-50	50-100	100-200	>200
backgr norm (%)	3.6	3.4	3.6	3.8
jet-E_t^{miss} (%)	2.1	1.2	2.7	5.1

ZH→ννbb

p_t^Z [GeV] bins	120-160	160-200	>200
backgr norm (%)	2.7	2.2	3.2
jet-E_t^{miss} (%)	7.7	8.2	12.1

Total background uncertainty

Additional uncertainties taken into account:

- charged leptons ~0.1-3.4% (not relevant in ZH→ννbb analysis)

- luminosity (applied only to backgrounds not normalised to data) ~0.1-0.7%

- pileup ~0.1-3.0% (more relevant in ZH→ννbb analysis)

Background scale factors redetermined for each systematic.
Shape uncertainties important.

WH→lνbb

p_t^W [GeV] bins	0-50	50-100	100-200	>200
total uncertainty (%)	3.9	2.7	3.4	**19.6**

ZH→l⁺l⁻bb

p_t^Z [GeV] bins	0-50	50-100	100-200	>200
total uncertainty (%)	6.9	4.3	6.6	**17.3**

ZH→ννbb

p_t^Z [GeV] bins	120-160	160-200	>200
total uncertainty (%)	9.7	10.6	**16.0**

Total signal uncertainty

- **b-tagging** efficiency **~6-14%** (most relevant)
- **Theory**, calculated applying variations to factorisation and renormalisation scales + uncertainties on PDFs, α_s and H→bb BR **~3-8%**
  - Also differential QCD and EW uncertainties considered
  - **NB**: EW NLO corrections reduce cross section at **high p_t**
- **jet/E_t^{miss} ~3-7%**
- Smaller contributions from:
  - charged leptons (~1-3%) in WH→lνbb and ZH→l⁺l⁻bb channels
  - luminosity (3.9%) and pileup (~0-2%) in **all channels**

WH→lνbb

p_t^W [GeV] bins	0-50	50-100	100-200	>200
total uncertainty (%)	11.4	10.8	11.0	**16.0**

ZH→l^+l^-bb

p_t^Z [GeV] bins	0-50	50-100	100-200	>200
total uncertainty (%)	10.1	9.1	9.6	**16.5**

ZH→ννbb

p_t^Z [GeV] bins	120-160	160-200	>200
total uncertainty (%)	11.8	11.4	**13.4**

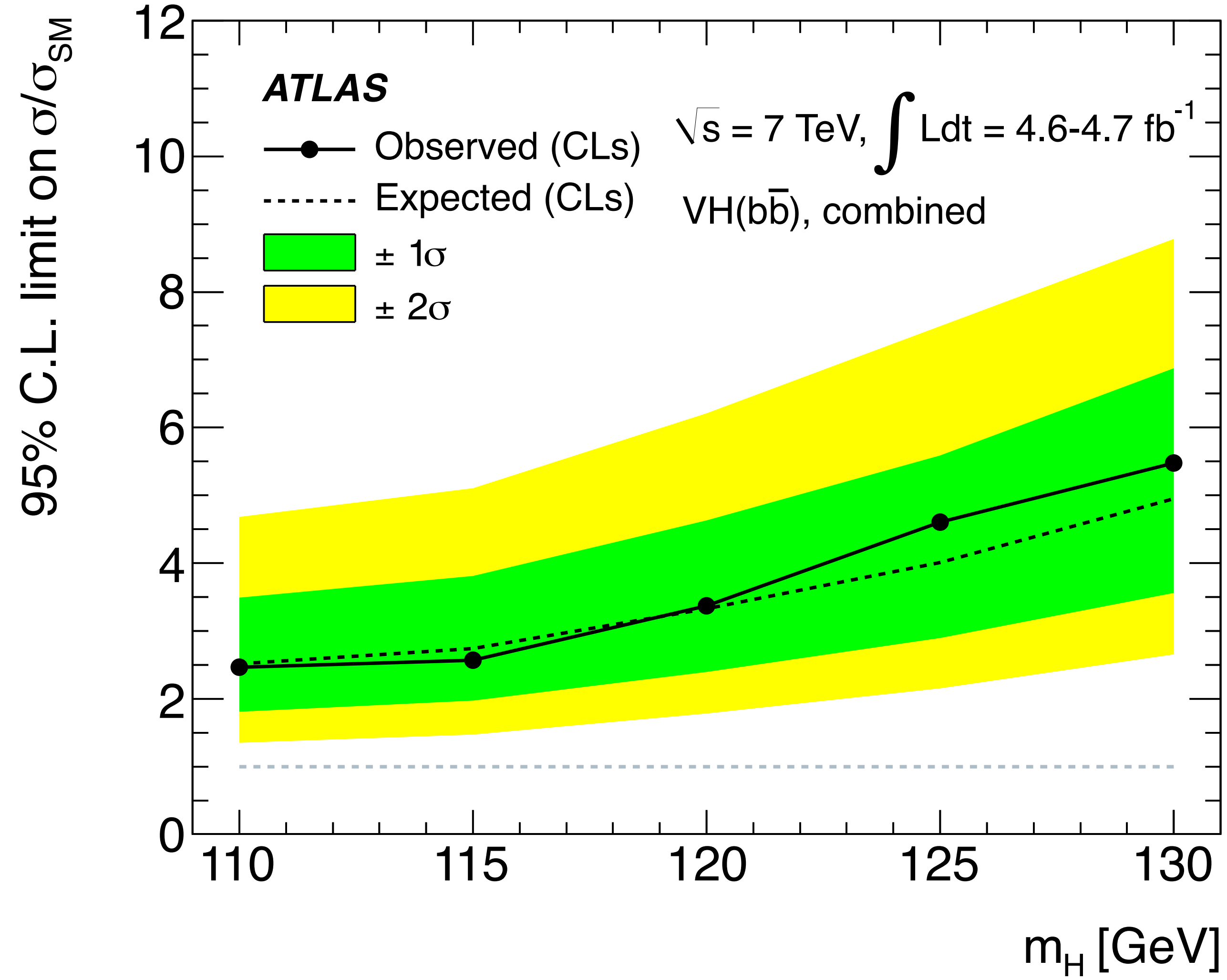
Limit setting, combination and conclusions

Limit extraction - combination

Signal **resolution ~15 GeV** dominated by jet resolution
No significant excess in m_{bb} distribution ⇒ set exclusion limit

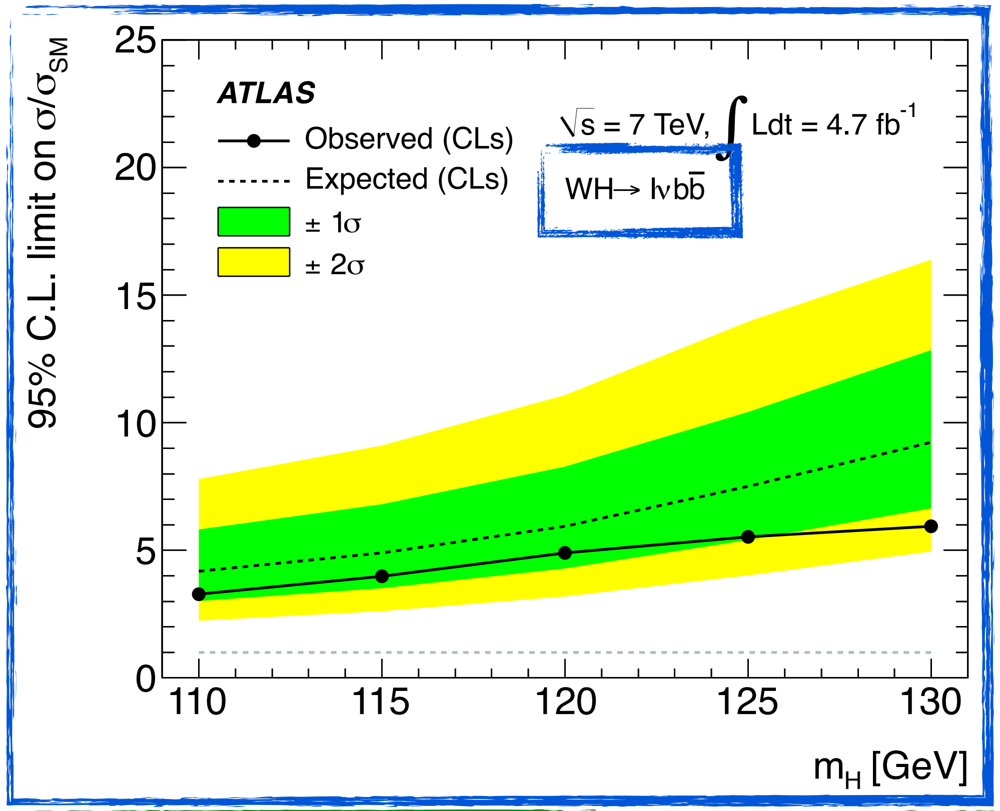
Five Higgs boson mass hypotheses: 110-115-120-125-130 GeV
Signal hypothesis tested with fit of m_{bb} distribution in Signal Region (80-150 GeV)
Calculate upper limit of $\mu=\sigma/\sigma_{SM}$ at 95%CL (CL_s method)

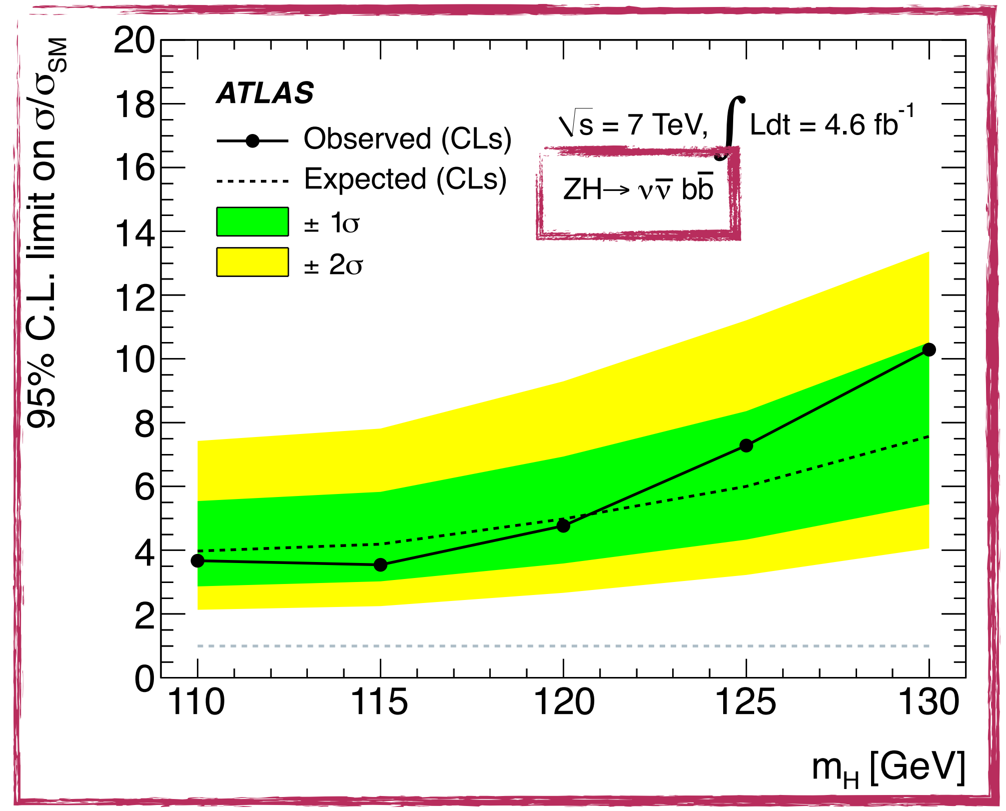
Treatment of **systematics**: add template and normalisation dependence on additional nuisance parameters (one for each uncertainty) constrained by gaussian terms
Worsen limit of 25-40% depending on the channel

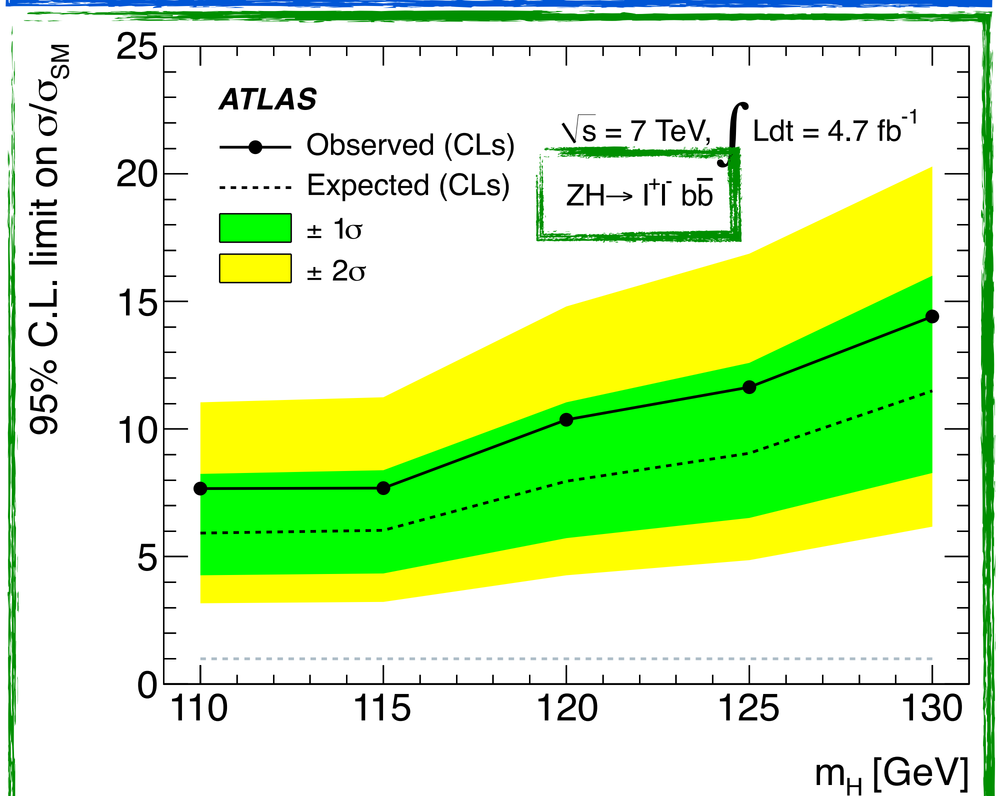


Expected exclusion limit: 2.5-4.9 ×SM
Observed exclusion limit: **2.5-5.5 ×SM**
Exclude ~4.6 ×SM at m_H=125GeV

Limit extraction - separate channels







Most sensitive channels:

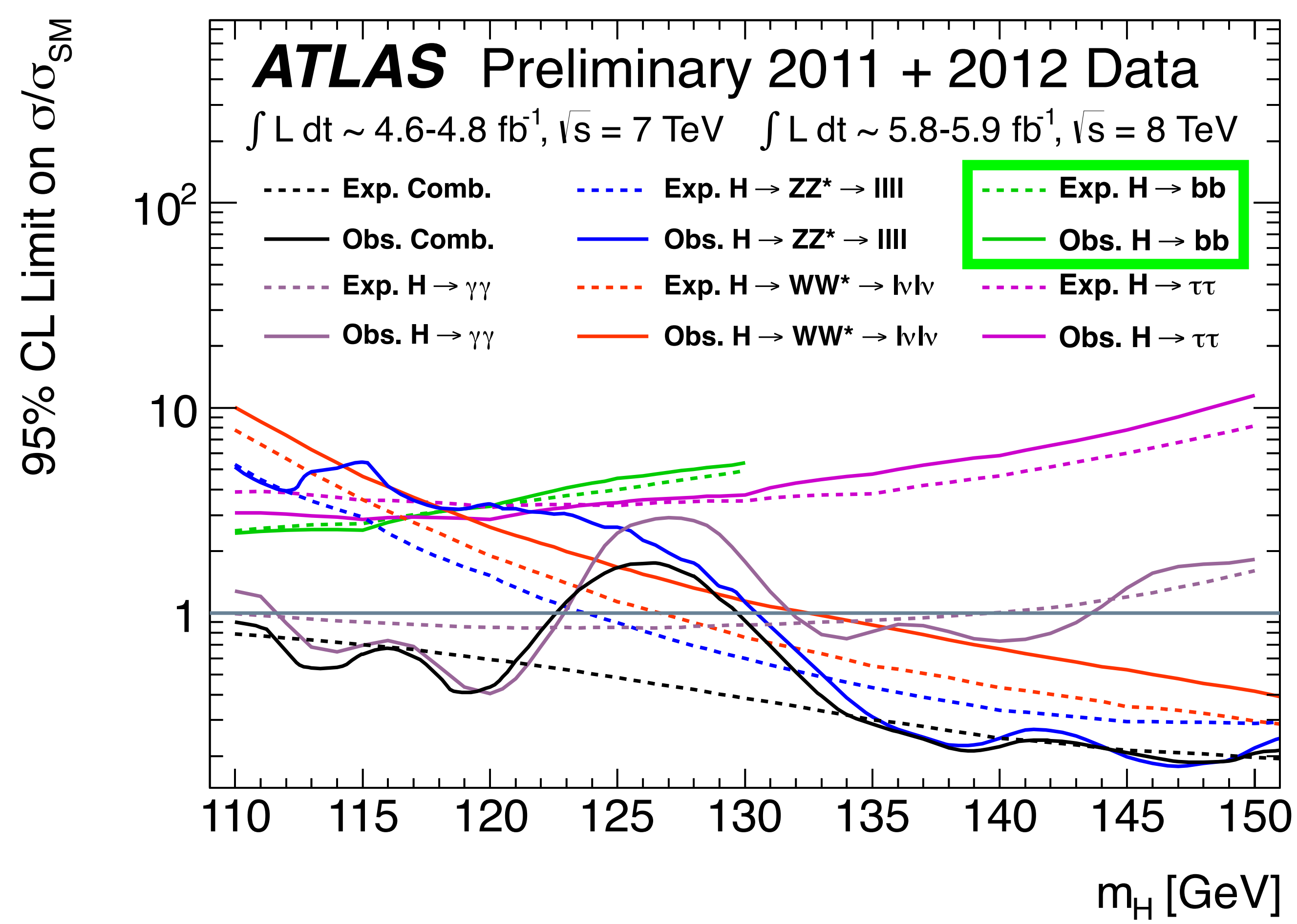
WH→lνbb and **ZH→ννbb**

Conclusions & Future work

- excellent performance of the ATLAS detector
- presented results on the search for SM VH→leptons+bb on 4.6-4.7 fb^{-1} collected in 2011 at $\sqrt{s}$=7 TeV submitted to **Phys. Rev. Lett. B** - arXiv:1207.0210
  - exclude **~4.6×SM** at m_H=125 GeV at 95% CL
  - need to work to reduce size of systematic uncertainty to improve sensitivity
- analysis on 2012 $\sqrt{s}$=8 TeV data **ongoing**
- Upcoming analyses:
  - boosted substructure analysis
  - ttH analysis

Combination of ATLAS results on Higgs searches.

Contribution of H→ττ and H→bb only with 2011 data

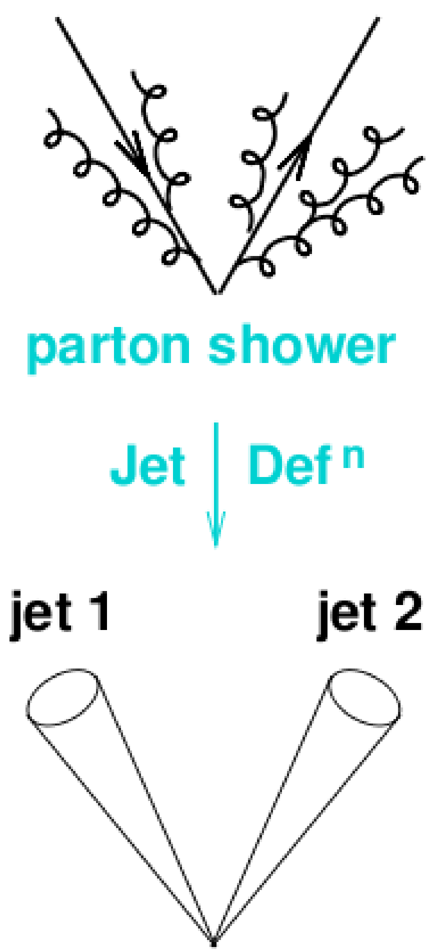


Backup

Jet clustering - anti-kt algorithm

From topoclusters to jets

$\{t_i\} \rightarrow$ reconstruction algorithm $\rightarrow \{j_k\}$

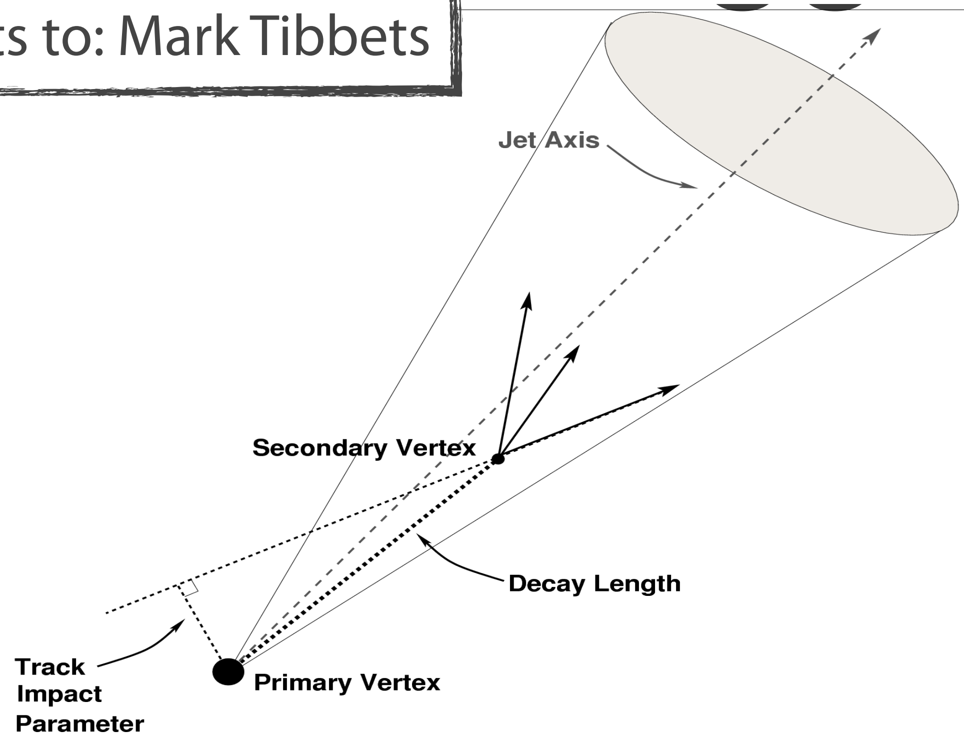


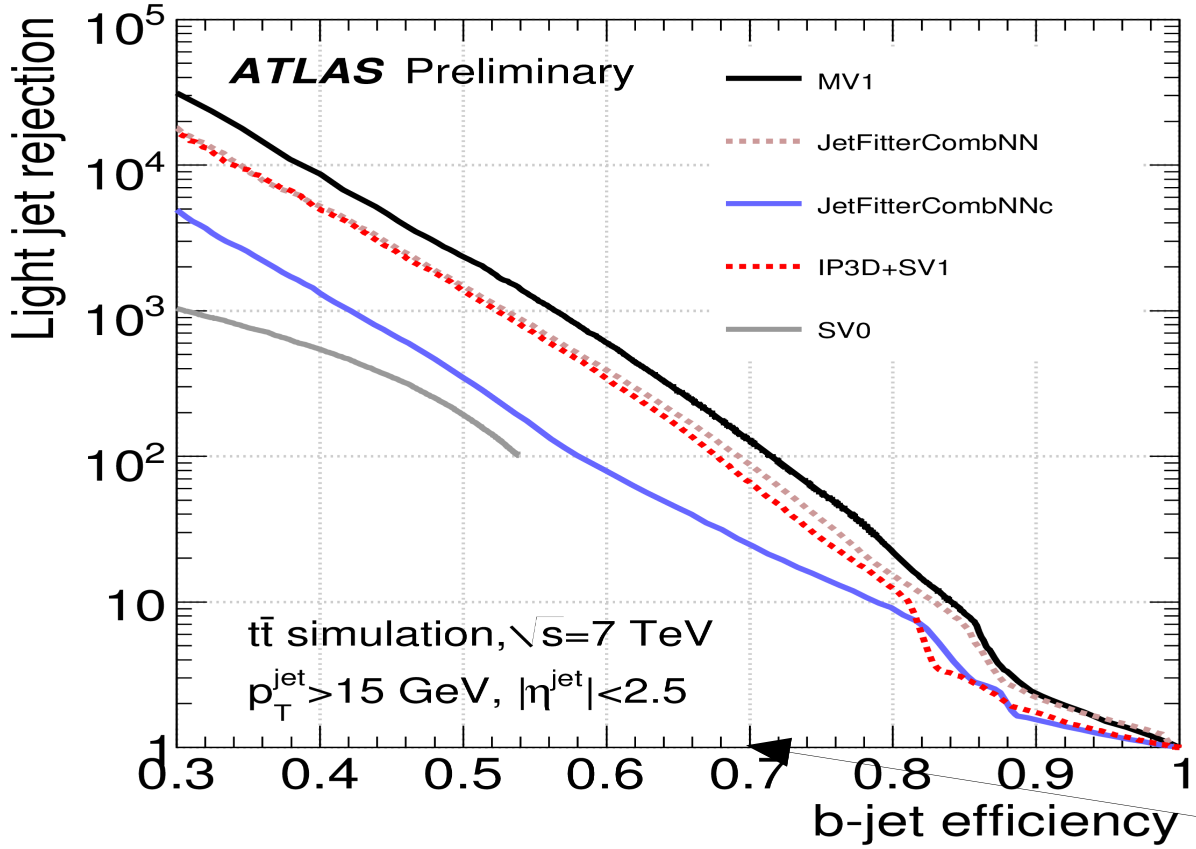
Anti-kt algorithm

- ✦ default for ATLAS jet reconstruction
- ✦ recursive algorithm - combines sequentially pairs of constituents
- ✦ combination dependent on p_t, (η,φ) distance
- ✦ clustering starts from most energetic constituents
- ✦ advantage: high-p_t anti-kt jets have regular shapes guaranteeing stability against pile-up

b-tagging in ATLAS

Credits to: Mark Tibbets





- Algorithms to identify heavy flavour content in reconstructed jets
- Impact parameter of tracks in jet
  - **IP3D** uses track weights based on longitudinal and transverse IP significance
- Displaced secondary vertex
  - **SV1** reconstructs inclusive displaced vertex
  - **JetFitter** reconstructs multiple vertices along implied b-hadron line of flight
    - Cascade decay topologies
- Advanced NN based algorithms
  - **JetFitterCombNN**: IP3D+JetFitter
  - **MV1**: IP3D+JetFitterCombNN+SV1

MC calibration results illustrated with MV1 @ 70% b-jet efficiency

MC samples used in the analyses

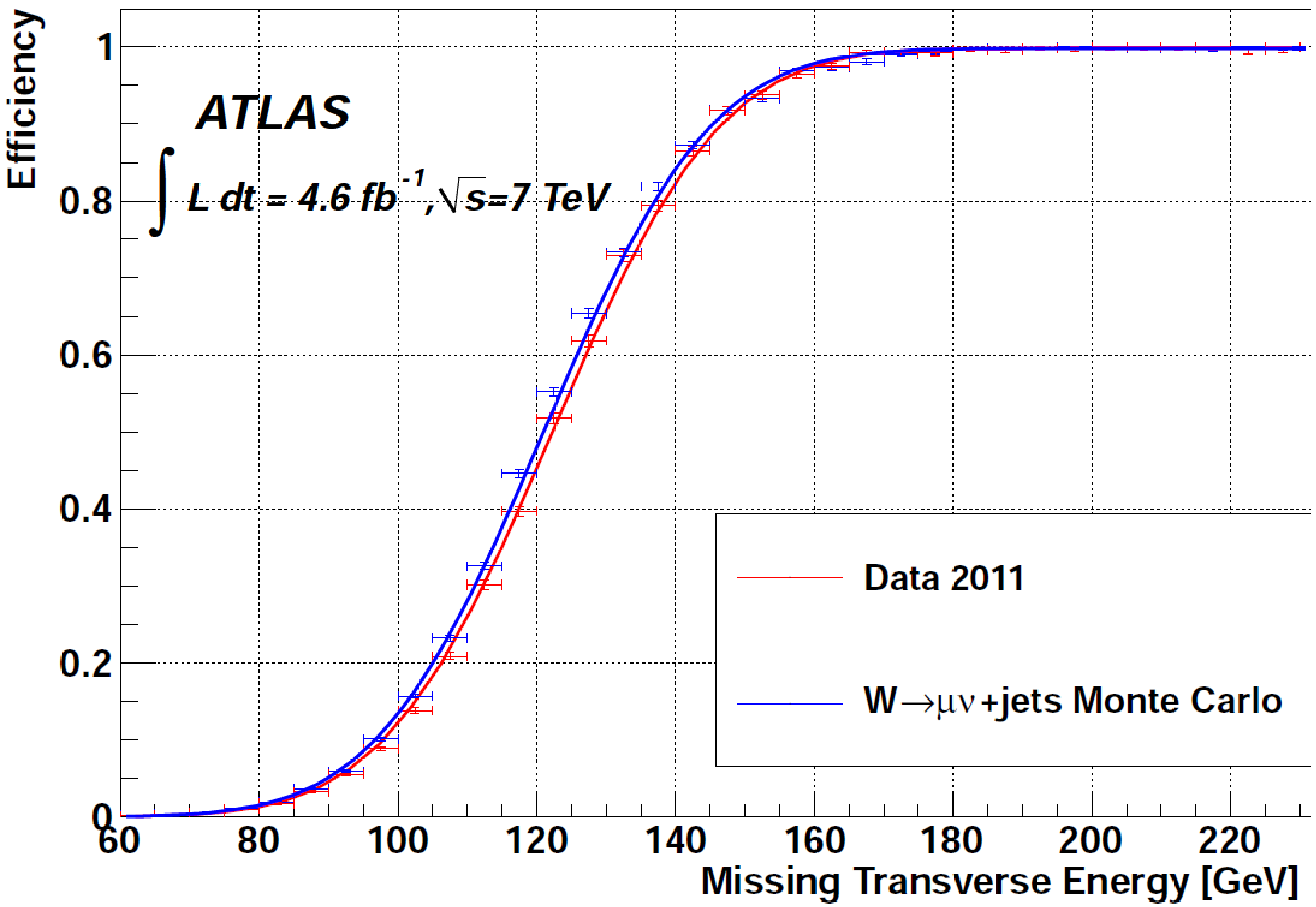
- WH and ZH signal:
  - Pythia interfaced with MRST LO* PDFs, tuned with AUET2B for PS, hadronisation and MPIs

- Background processes:
  - W+≥1b-jet: Powheg, MSTW 2008 NLO PDFs, Pythia for PS and hadronisation
  - Z+≥1b-jet, Z+≥1c-jet: Sherpa
  - W+≥1c-jet, W+light-jets, Z+light-jets: Alpgen interfaced with Herwig
  - single t, tt: MC@NLO, CT10 NLO PDFs, interfaced with Herwig
  - diboson (WW, ZZ, WZ): Herwig

NB: Herwig with AUET2 tune for PS and hadronisation, MRST LO* PDFs (not for top), interfaced with Jimmy for MPI modelling

All samples are simulated with Geant4

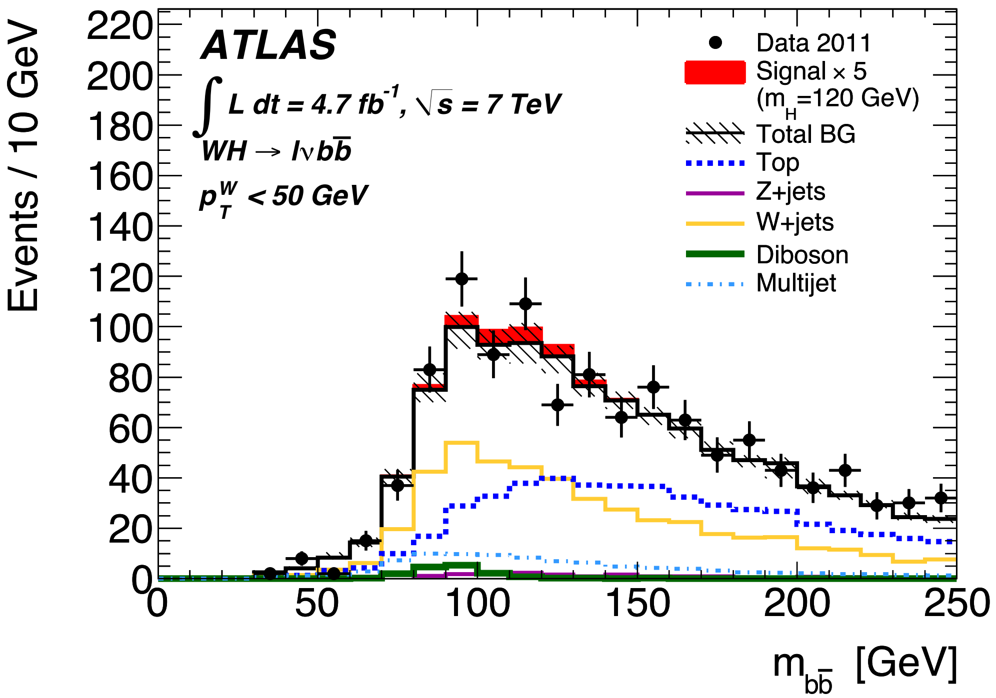
Trigger efficiency in ZH→ννbb



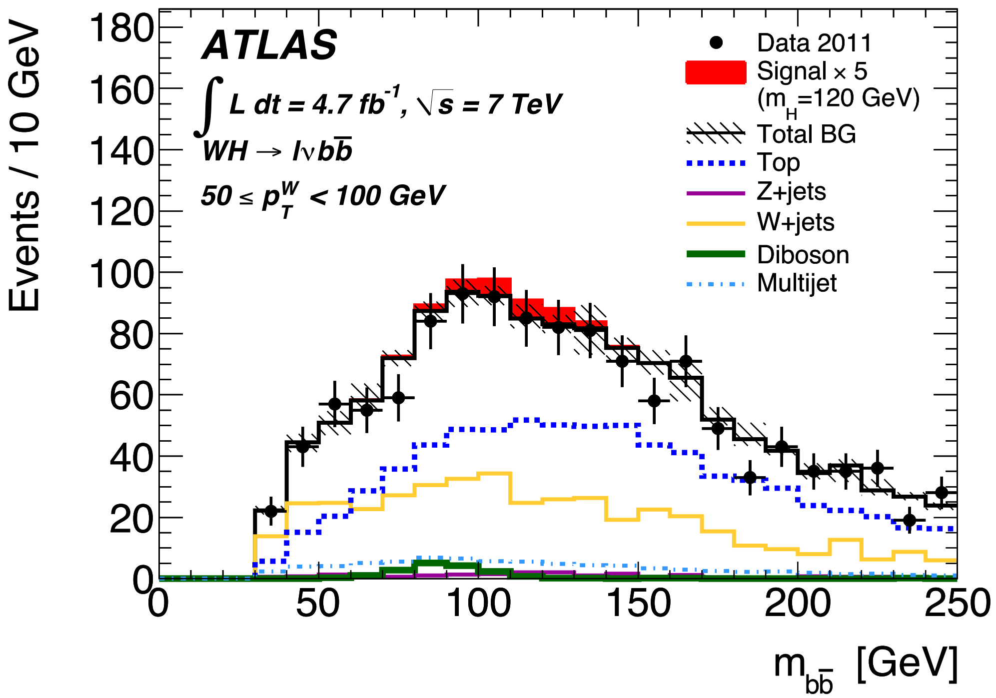
Evaluated from W+jets sample, extracted from data using muon triggers - uncorrelated from E_t^{miss} ones

Efficiency >50% for E_t^{miss}>120 GeV (analysis cut)
Efficiency ~99% for E_t^{miss}>170 GeV

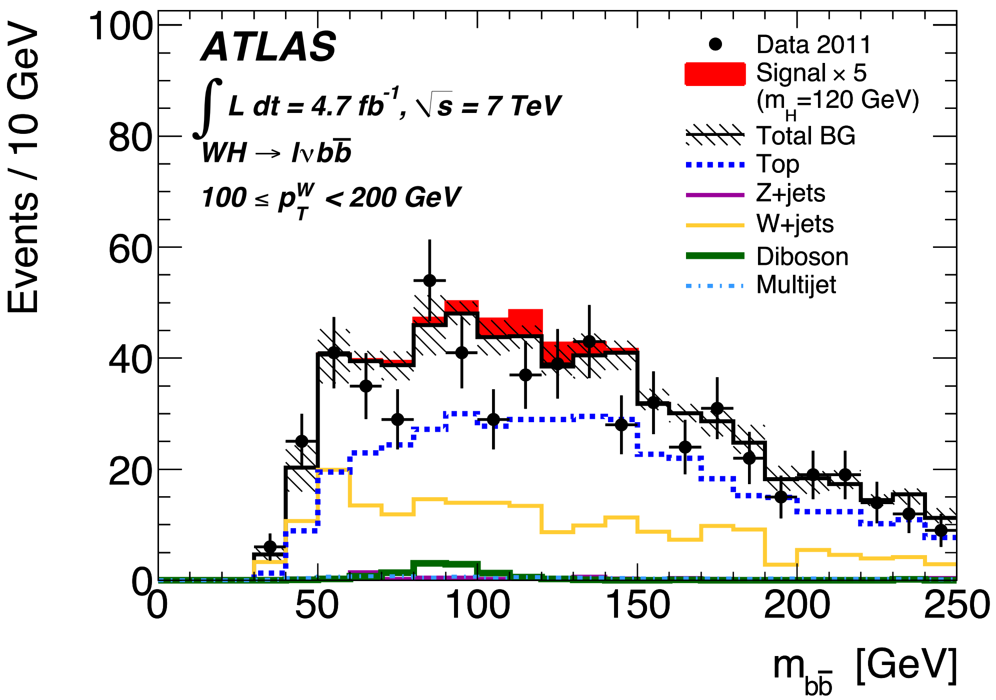
m_{bb} plots - WH→lνbb



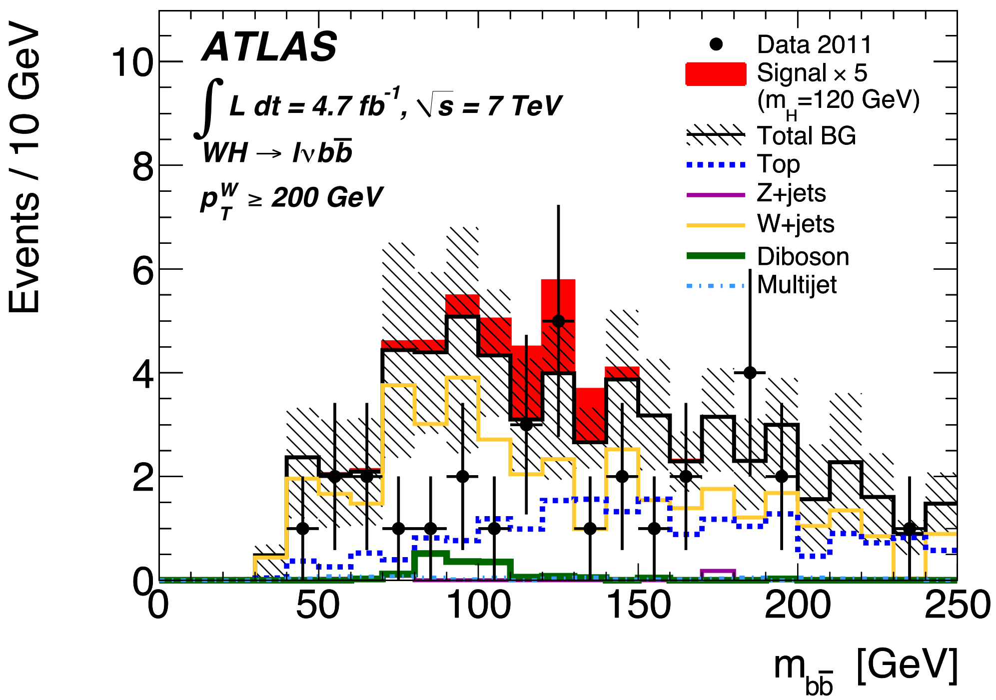
(a)



(b)

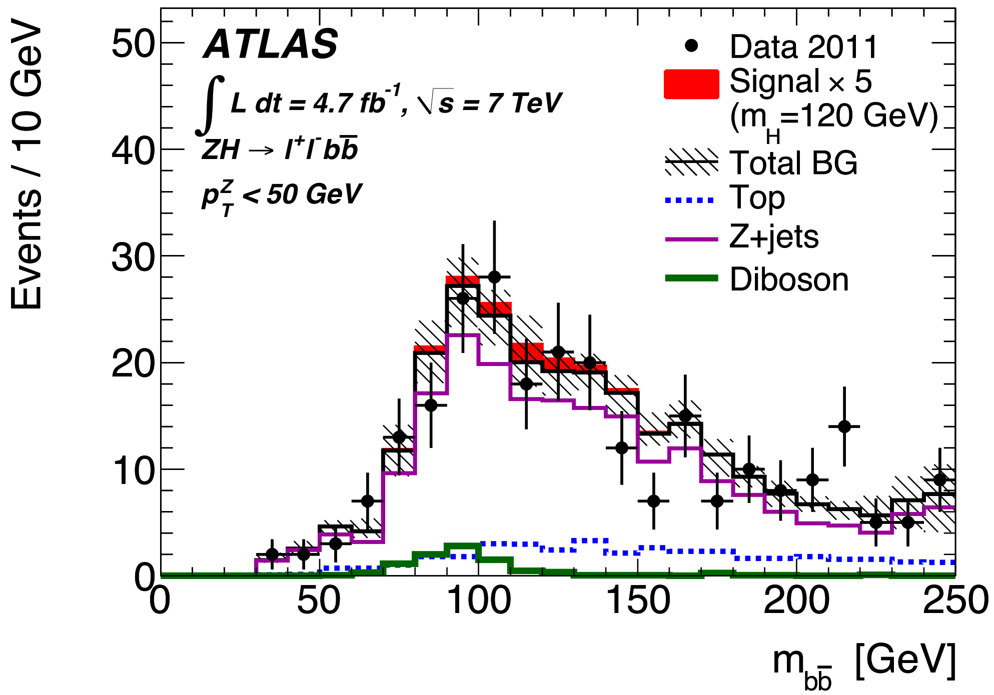


(c)

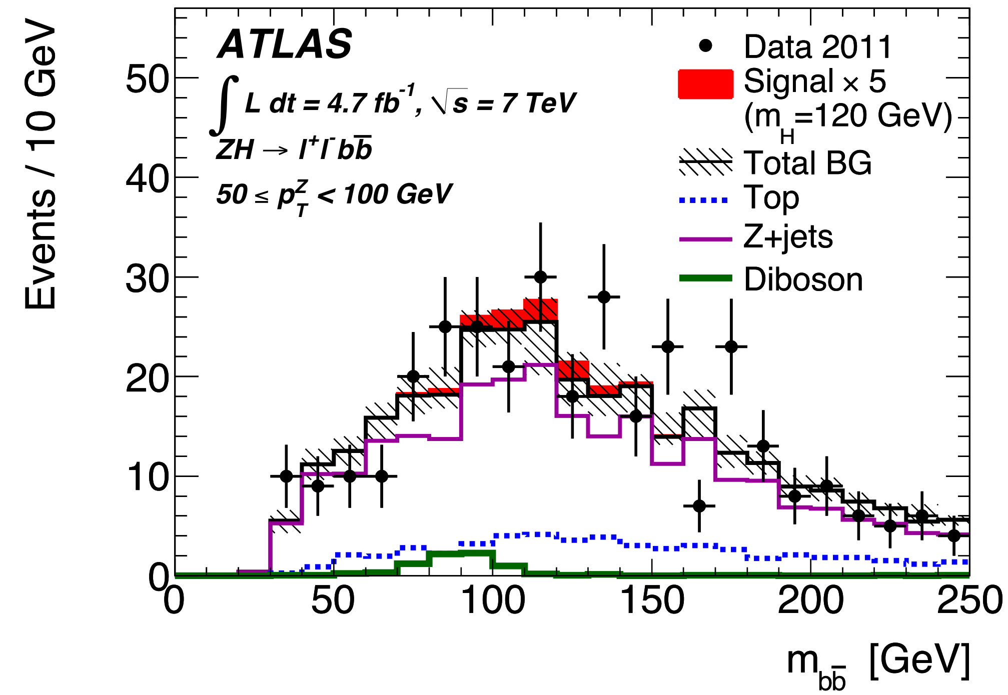


(d)

m_{bb} plots - $ZH \rightarrow llbb$



(a)



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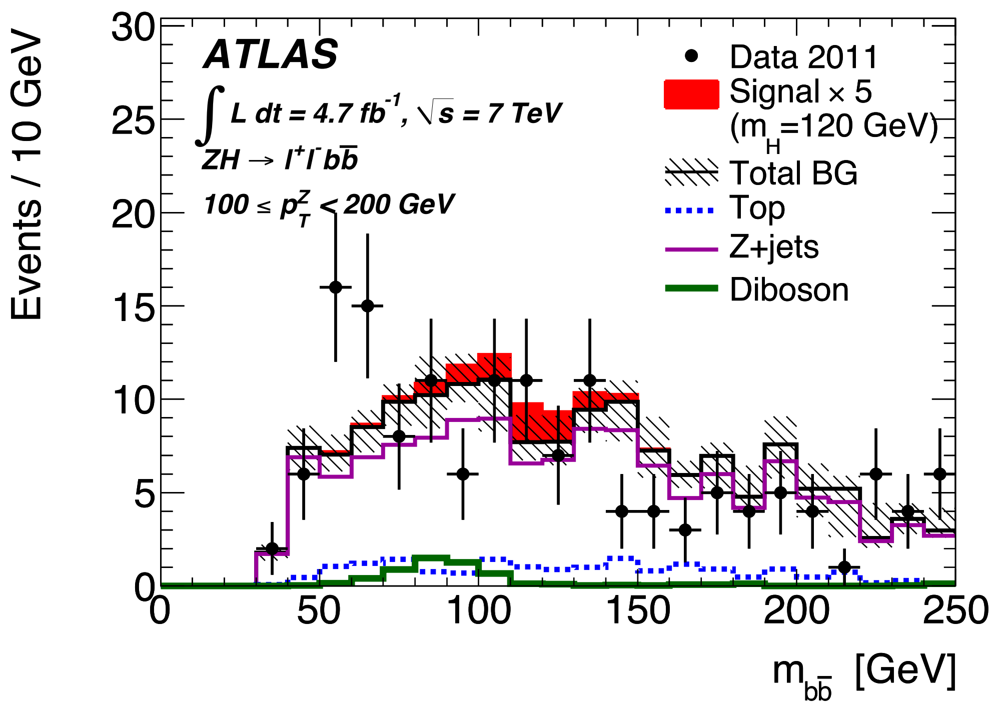

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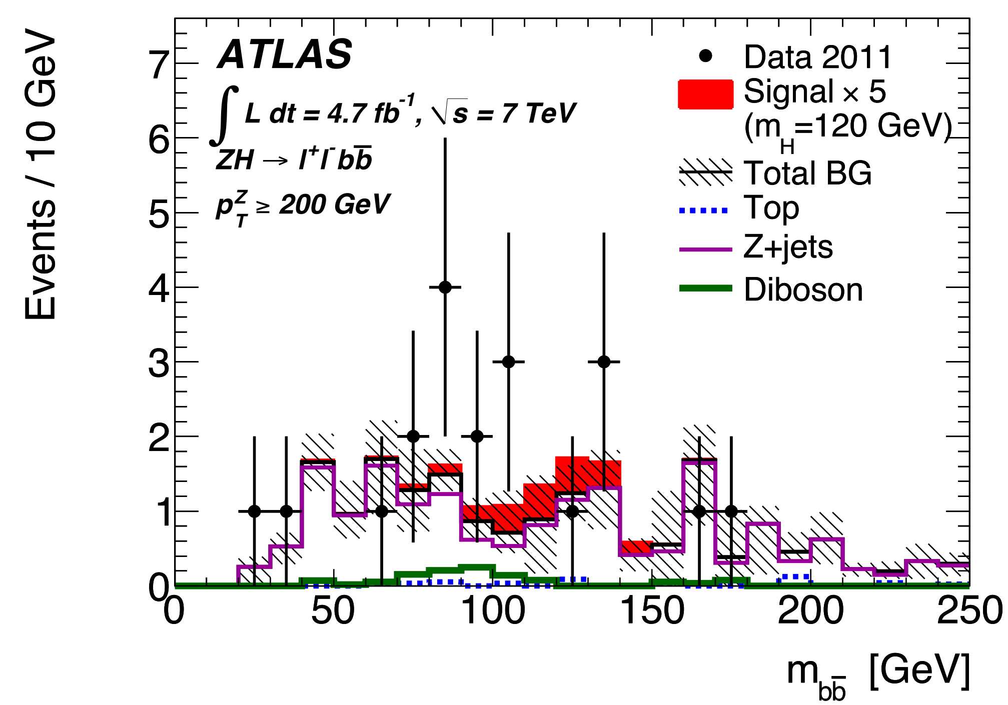
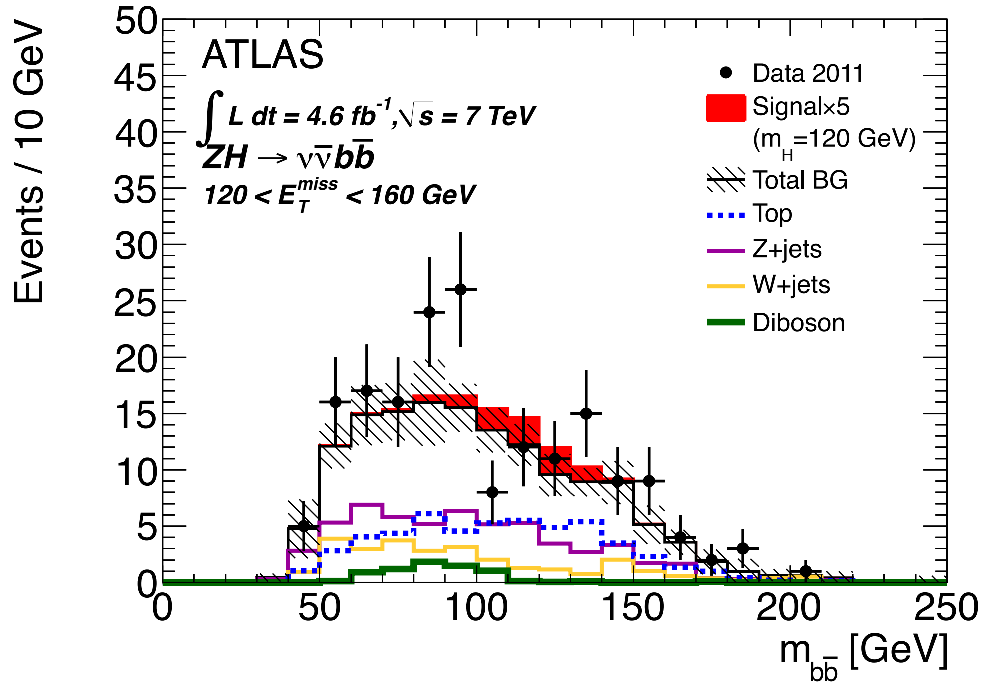
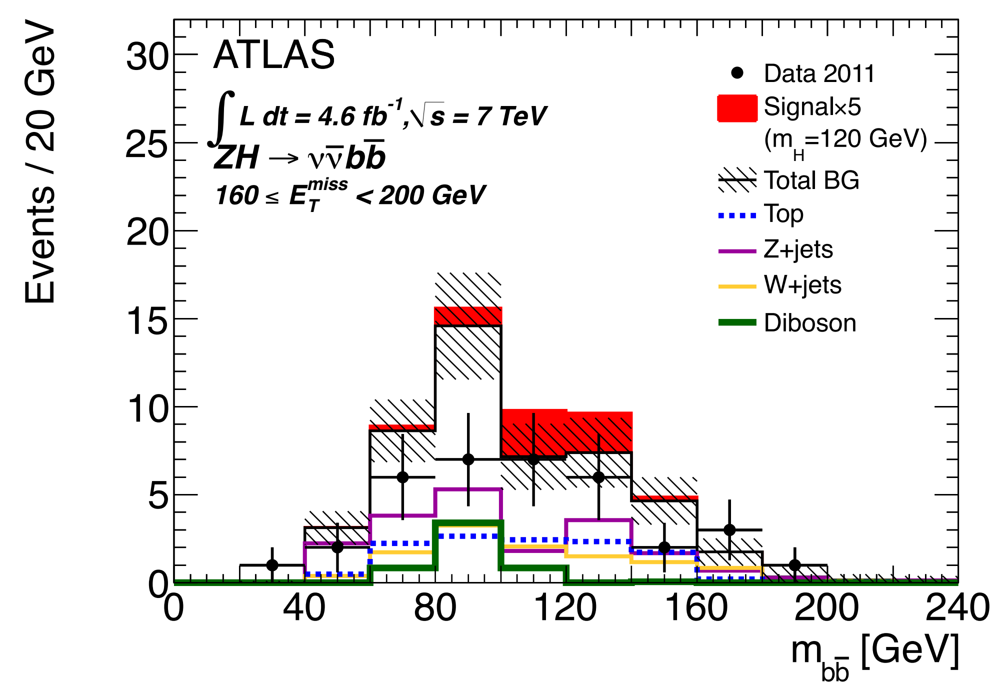


(d)

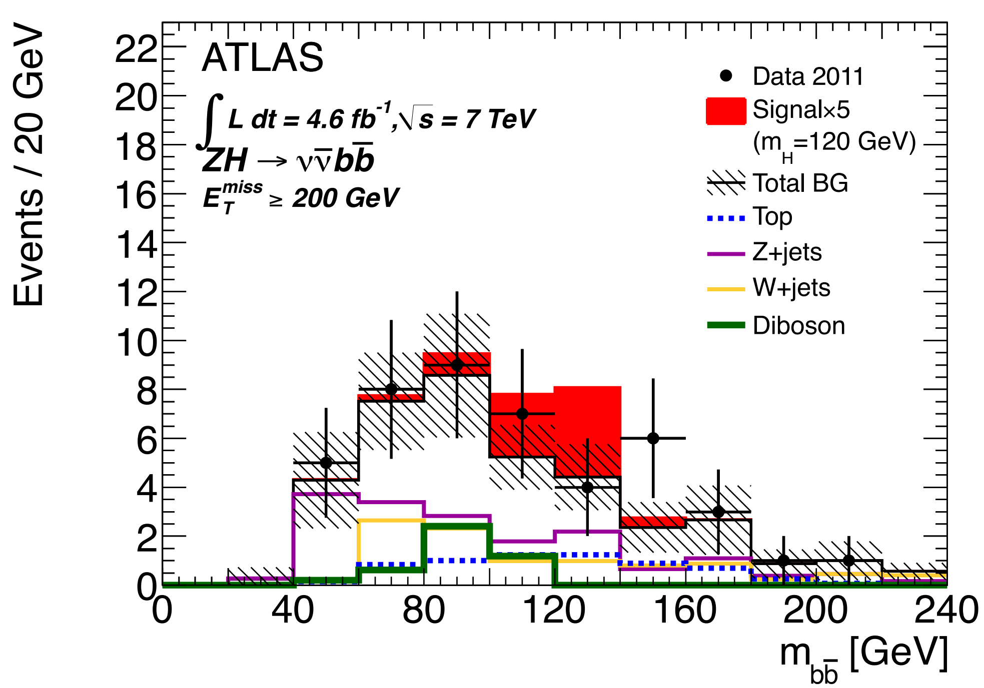
m_{bb} plots - ZH→ννbb



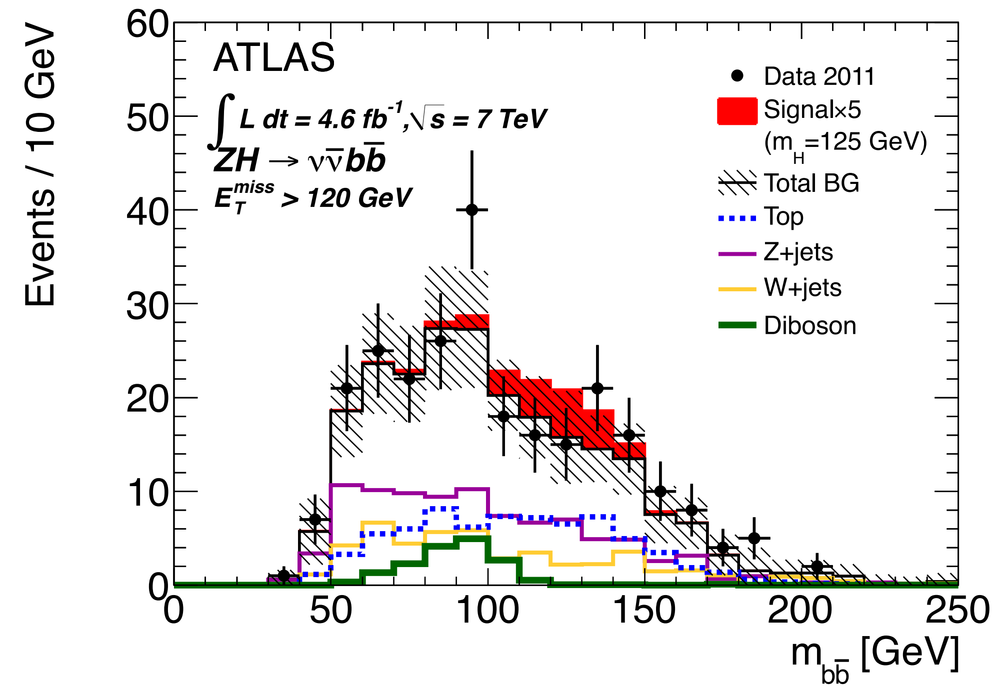
(a)



(b)



(c)



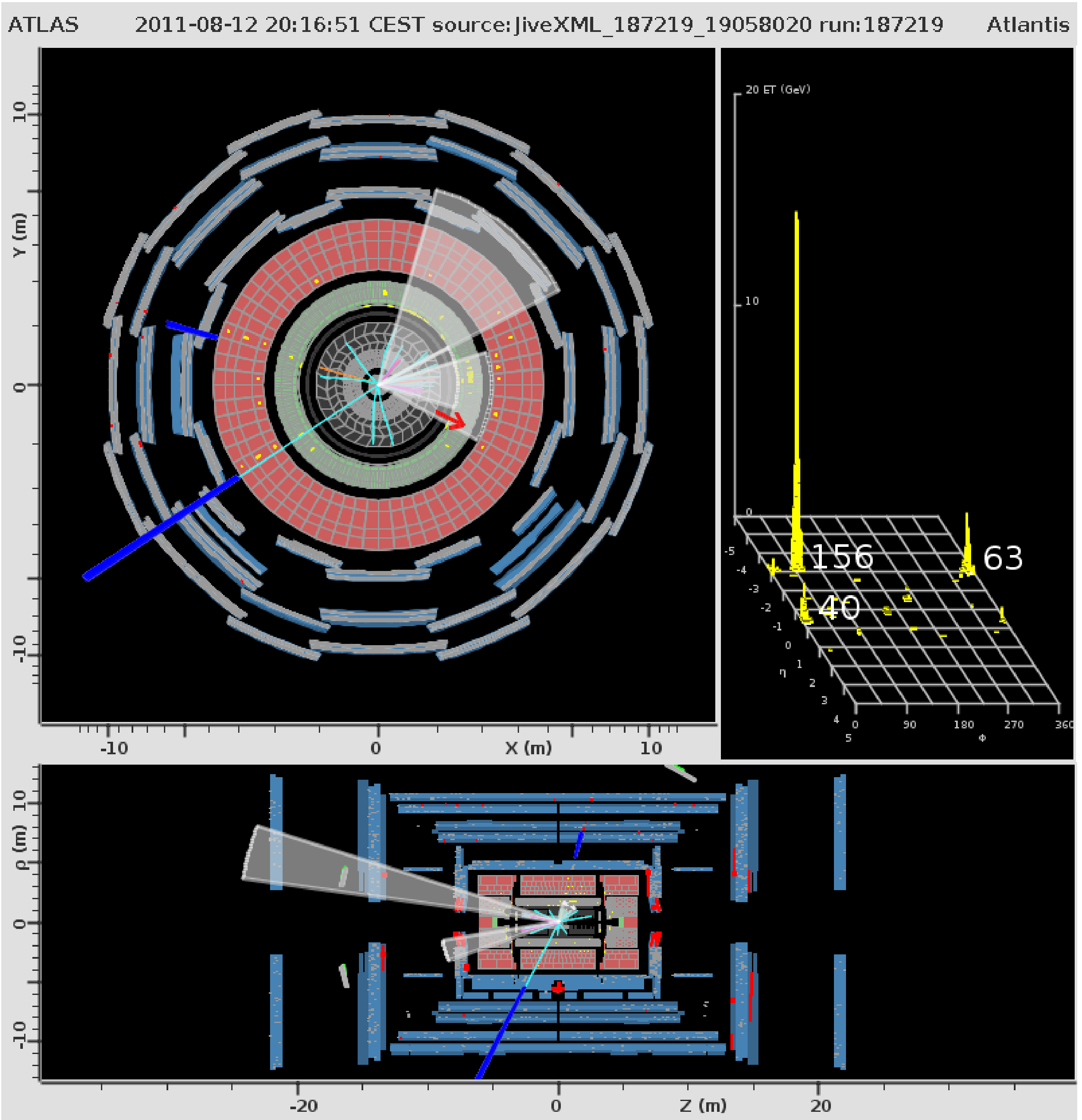
(d)

Yields and uncertainties

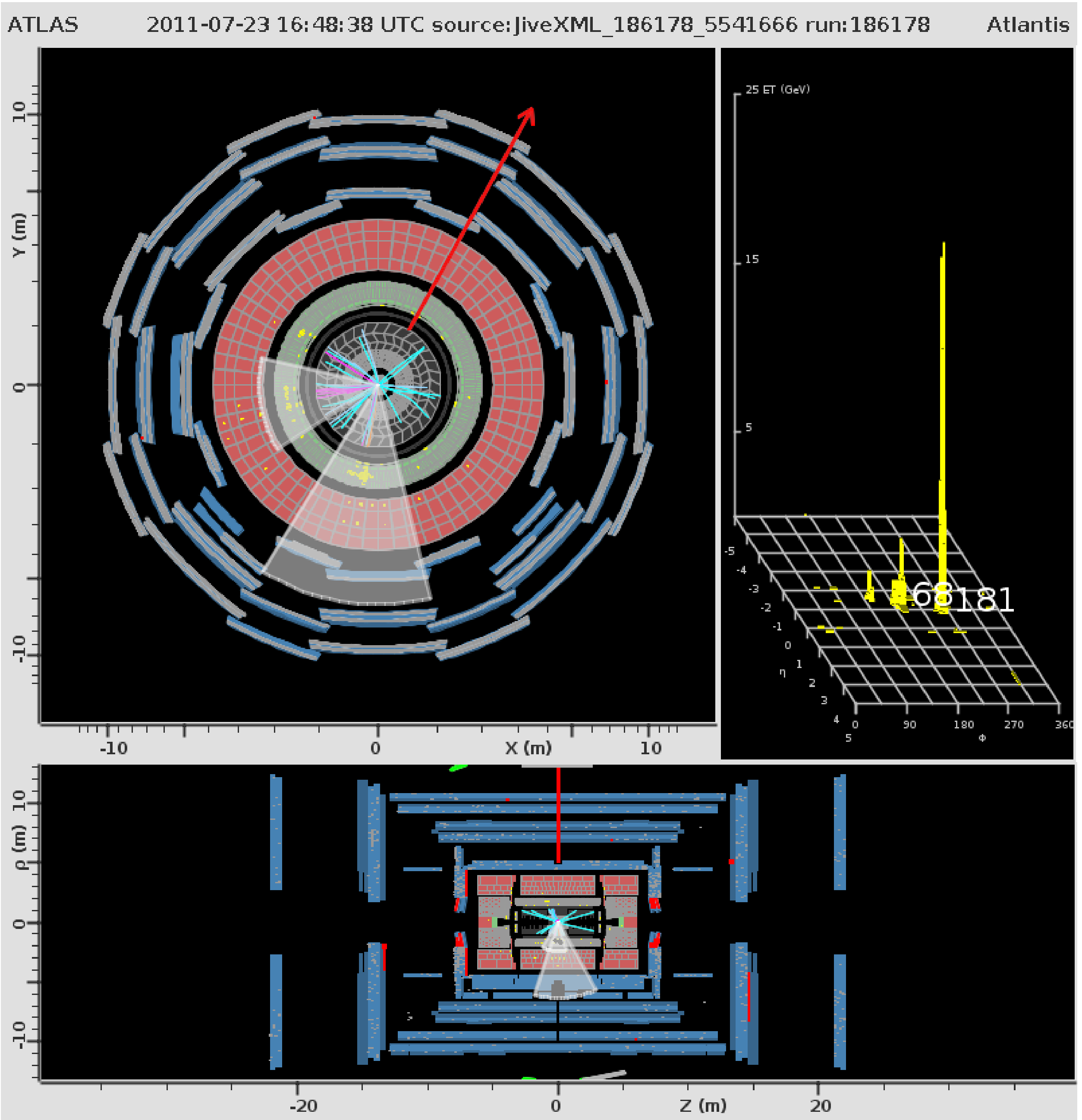
bin	$ZH \to \ell^+\ell^- b\bar{b}$ p_T^V [GeV] 0-50	50-100	100-200	>200	$WH \to \ell\nu b\bar{b}$ p_T^V [GeV] 0-50	50-100	100-200	>200	$ZH \to \nu\bar{\nu}b\bar{b}$ p_T^V [GeV] 120-160	160-200	>200
Number of events for $80 < m_{b\bar{b}} < 150$ GeV											
signal	1.3 ± 0.1	1.8 ± 0.2	1.6 ± 0.2	0.4 ± 0.1	5.0 ± 0.6	5.1 ± 0.6	3.7 ± 0.4	1.2 ± 0.2	2.0 ± 0.2	1.2 ± 0.1	1.5 ± 0.2
top	17.4	24.1	7.3	0.2	229.9	342.7	201.3	8.2	35.2	8.3	4.1
W+jets	–	–	–	–	285.9	193.6	85.8	17.5	13.2	7.8	4.8
Z+jets	123.2	119.9	55.9	6.1	11.1	10.5	2.8	0.0	31.5	11.9	7.1
diboson	7.2	5.6	3.6	0.7	12.6	11.9	7.8	1.4	4.6	4.3	3.6
multijet	–	–	–	–	55.5	38.2	3.6	0.2	–	–	–
total BG	148 ± 10	150 ± 6	67 ± 4	6.9 ± 1.2	596 ± 23	598 ± 16	302 ± 10	27 ± 5	85 ± 8	32 ± 3	20 ± 3
data	141	163	61	13	614	588	271	15	105	22	25
Components of the relative systematic uncertainties of the background [%]											
b-tag eff	1.4	1.0	0.3	4.8	0.9	1.3	0.9	7.2	4.1	4.2	5.5
BG norm	3.6	3.4	3.6	3.8	2.7	1.8	1.8	4.5	2.7	2.2	3.2
jets/E_T^{miss}	2.1	1.2	2.7	5.1	1.5	1.4	2.1	9.5	7.7	8.2	12.1
leptons	0.2	0.3	1.1	3.4	0.1	0.2	0.2	1.7	0.0	0.0	0.0
luminosity	0.2	0.1	0.2	0.4	0.1	0.1	0.1	0.2	0.2	0.5	0.7
pileup	0.9	1.6	0.5	1.3	0.1	0.2	0.8	0.5	1.6	2.5	3.0
theory	5.2	1.3	4.7	14.9	2.2	0.3	1.6	14.8	2.9	4.0	7.7
total BG	6.9	4.3	6.6	17.3	3.9	2.7	3.4	19.6	9.7	10.6	16.0
Components of the relative systematic uncertainties of the signal [%]											
b-tag eff	6.4	6.4	7.0	13.7	6.4	6.4	7.0	12.1	7.1	8.2	9.2
jets/E_T^{miss}	4.9	3.2	3.5	5.5	5.8	4.6	3.7	3.3	7.3	5.1	6.3
leptons	0.9	1.2	1.7	2.6	3.0	3.0	3.0	3.2	0.0	0.0	0.0
luminosity	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
pileup	0.5	1.1	1.8	2.2	1.2	0.3	0.3	1.6	0.2	0.2	0.0
theory	4.6	3.6	3.3	5.3	4.4	4.7	5.0	8.0	3.3	3.3	5.6
total signal	10.1	9.1	9.6	16.5	11.4	10.8	11.0	16.0	11.8	11.4	13.4

signal ⇒ m_H=120 GeV

Event displays



ZH→l⁺l⁻bb



ZH→ννbb