HSG5: Status and Plans

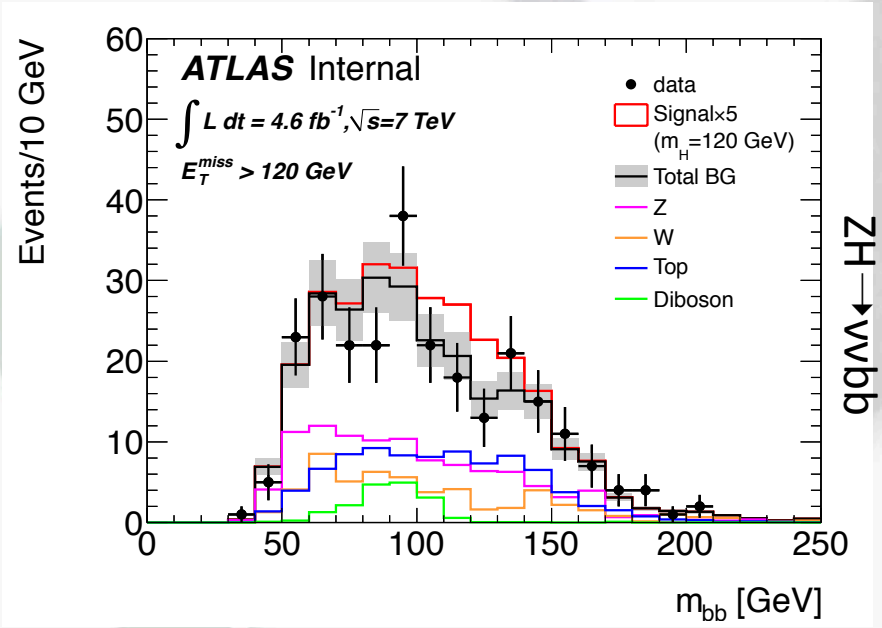
Ricardo Gonçalo (RHUL)
on behalf of Higgs Subgroup 5 (H->bb)

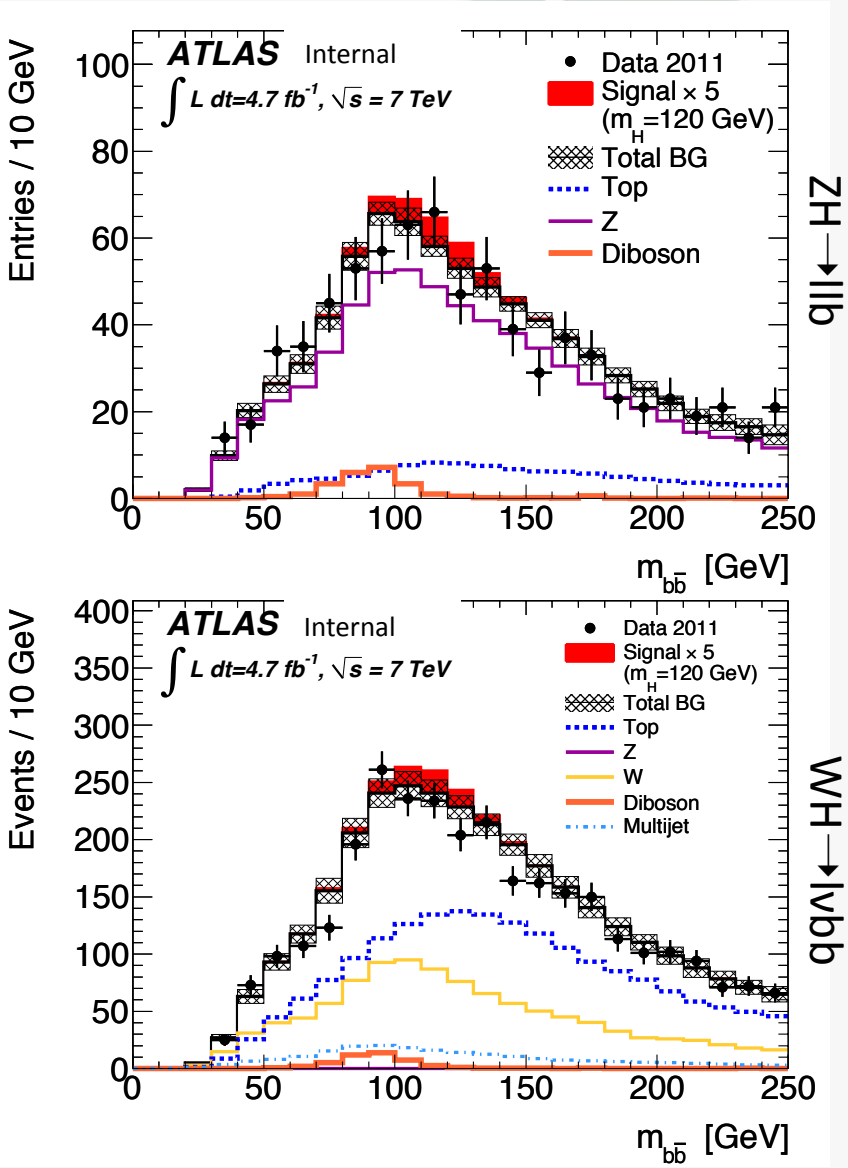
Outlook

- Inclusive analyses:
  - Analysis results and status of paper draft
- Boosted Z->bb status
- Analysis plans up to Summer

Inclusive analyses

- Cut-based analyses
- ZH→llbb and WH→lνbb and ZH→ννbb
- Select Z or W or large E_T^{miss} and search for 2 additional b jets
- Search Higgs in m_{bb} spectrum
- Determine main backgrounds from data (sidebands & control regions)
- Both ZH and WH (≈20%) contribute to ZH→ννbb





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Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a b-quark pair with the ATLAS detector at the LHC

- Paper CDS record: https://cdsweb.cern.ch/record/1425880
- Draft 1 under approval as CONF note: https://cdsweb.cern.ch/record/1428142
- Support material:
  - ZH→llb & WH→lvbb: https://cdsweb.cern.ch/record/1404176/
  - ZH→vvbb: https://cdsweb.cern.ch/record/1418230

A list of supporting internal notes and their authors can be found at:

https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/Higgsbb

Supporting internal notes

ATL-COM-PHYS-2011-1648	https://cdsweb.cern.ch/record/1404176/
ATL-COM-PHYS-2012-062	https://cdsweb.cern.ch/record/1418230

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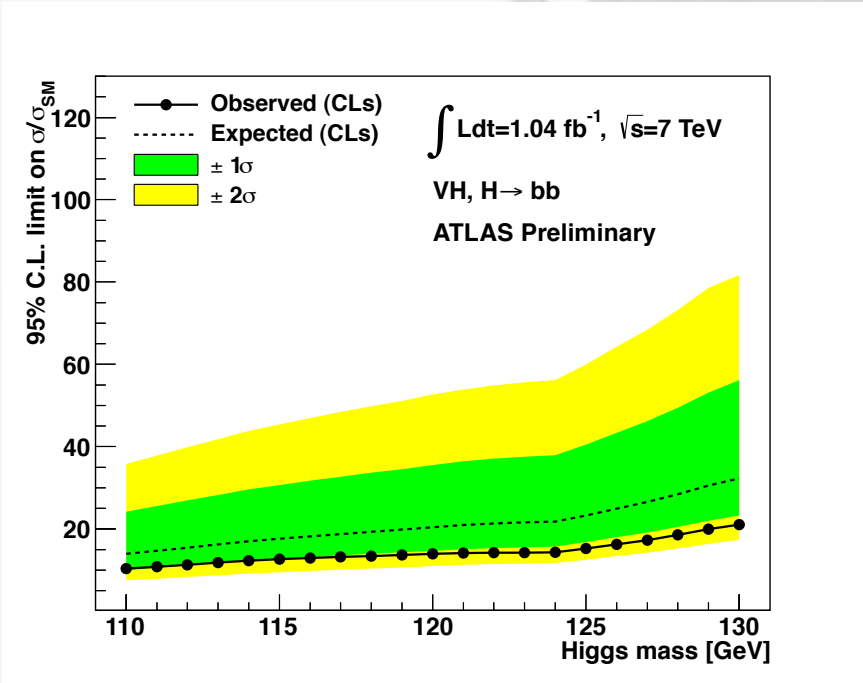
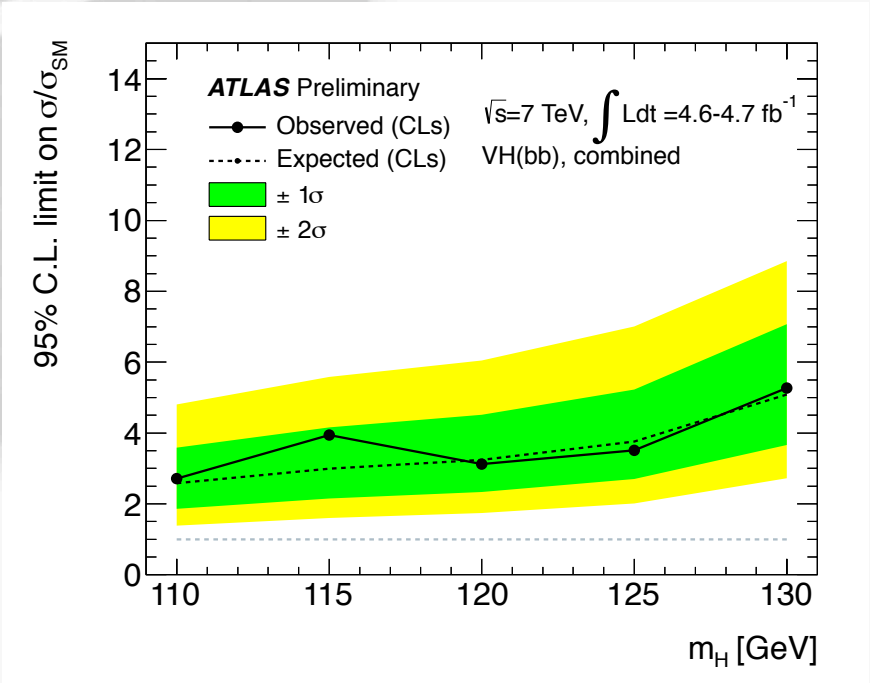
Pippa Wells	(Pippa.Wells@cern.ch)
Elzbieta Richter-Was	(Elzbieta.Richter-Was@cern.ch)
Christian Weiser	(Christian.Weiser@cern.ch)
Gavin Hesketh	(Gavin.Hesketh@cern.ch)

Comments are due by: February 28, 2012

The state of the art…

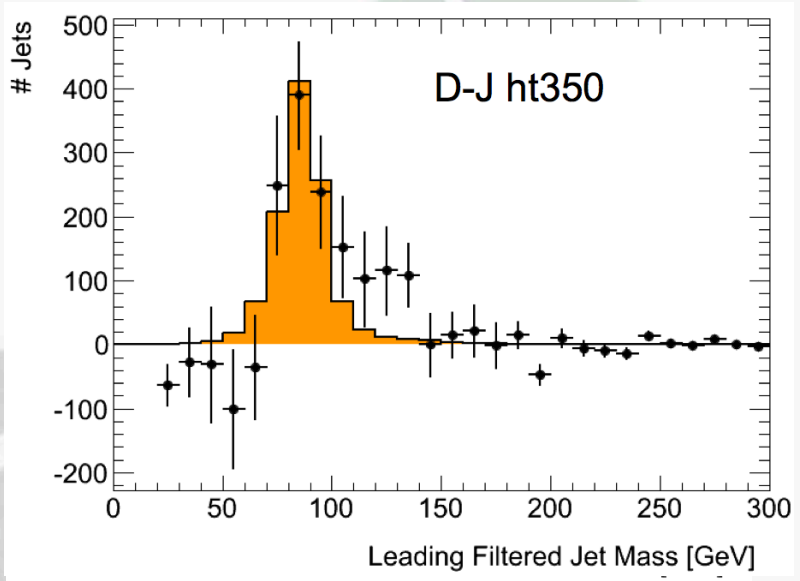
- Previous results – EPS2011: 15 – 20 x SM (expected)
  - ZH→llbb and WH→lvbb (1.04 fb^{-1})
- Since last Summer:
  - Cuts changed mainly to suppress top background
  - Lumi increased by 4.5x and included ZH→vvbb
- Latest results – under approval: 2.6 – 5.1 x SM (expected)
  - ZH→llbb and WH→lvbb (4.7 fb^{-1}) and ZH→vvbb (4.6 fb^{-1})

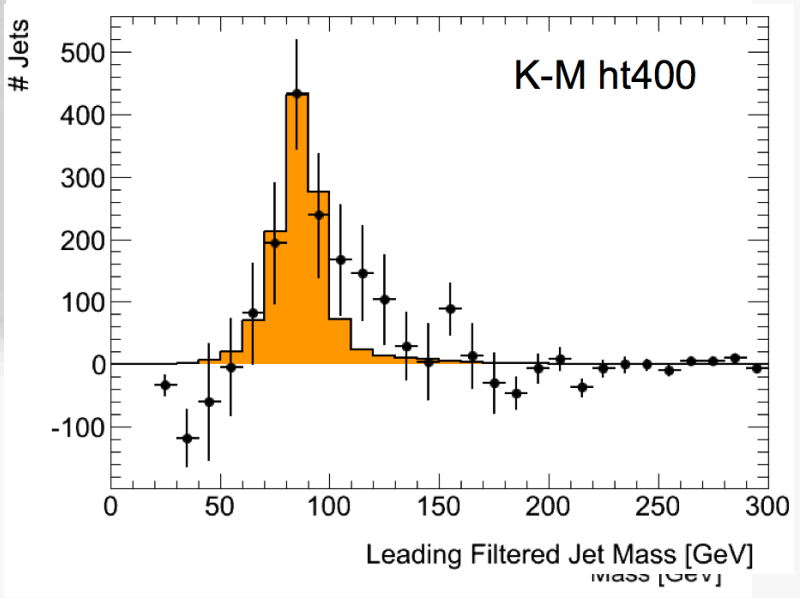




Boosted Z->bb

- Z->bb analysis with jet substructure in HSG5
  - Perfect calibration for boosted H->bb!
- An exciting Z->bb peak can be seen after background subtraction
  - And (perhaps even more exciting?!) there is a shoulder just above the Z mass… at around 126GeV ☺
  - Caveat: get excited, but don't get too excited!
  - A lot of work has been going on to test the results
- Much progress made so far
  - But many questions remain and must be answered
  - Observing the Z->bb in this analysis would be fantastic!
- Current status:
  - Now looking at full simulation MC
  - Observations in D-J is still there in periods K-M!
    - D – J with trigger EF_j100_a4tc_EFFS_ht350
    - K – M with trigger EF_j100_a4tc_EFFS_ht400
    - See Luke Lambourne's talk at HSG5 meeting: https://indico.cern.ch/conferenceDisplay.py?confId=167396





Plans up to Summer - I

- H->bb paper:
  - The CONF note for Moriond is the first draft
  - Must finish paper soon to contribute to combination(s)

- Expect other analyses to converge, e.g.:
  - Z->bb work will continue to evolve
  - Boosted H->bb analysis very lively:
    - Aim to converge for Summer results
    - Try to merge with inclusive analyses at the highest pT(W/Z) bin
    - First results point at significant improvement – see talk by Ines Ochoa at the last HSG5 meeting: https://indico.cern.ch/conferenceDisplay.py?confId=167398
  - ttH has shown first baseline results:
    - Stat-only limits of ≈15xSM with 1fb-1
    - => expect ≈7xSM with full 2011 data (stats only) – See Donnachda Quilty's talk here: https://indico.cern.ch/conferenceDisplay.py?confId=167391
    - ttH cross section may help a lot for √s = 8TeV (≈2x?)
- … and much more!

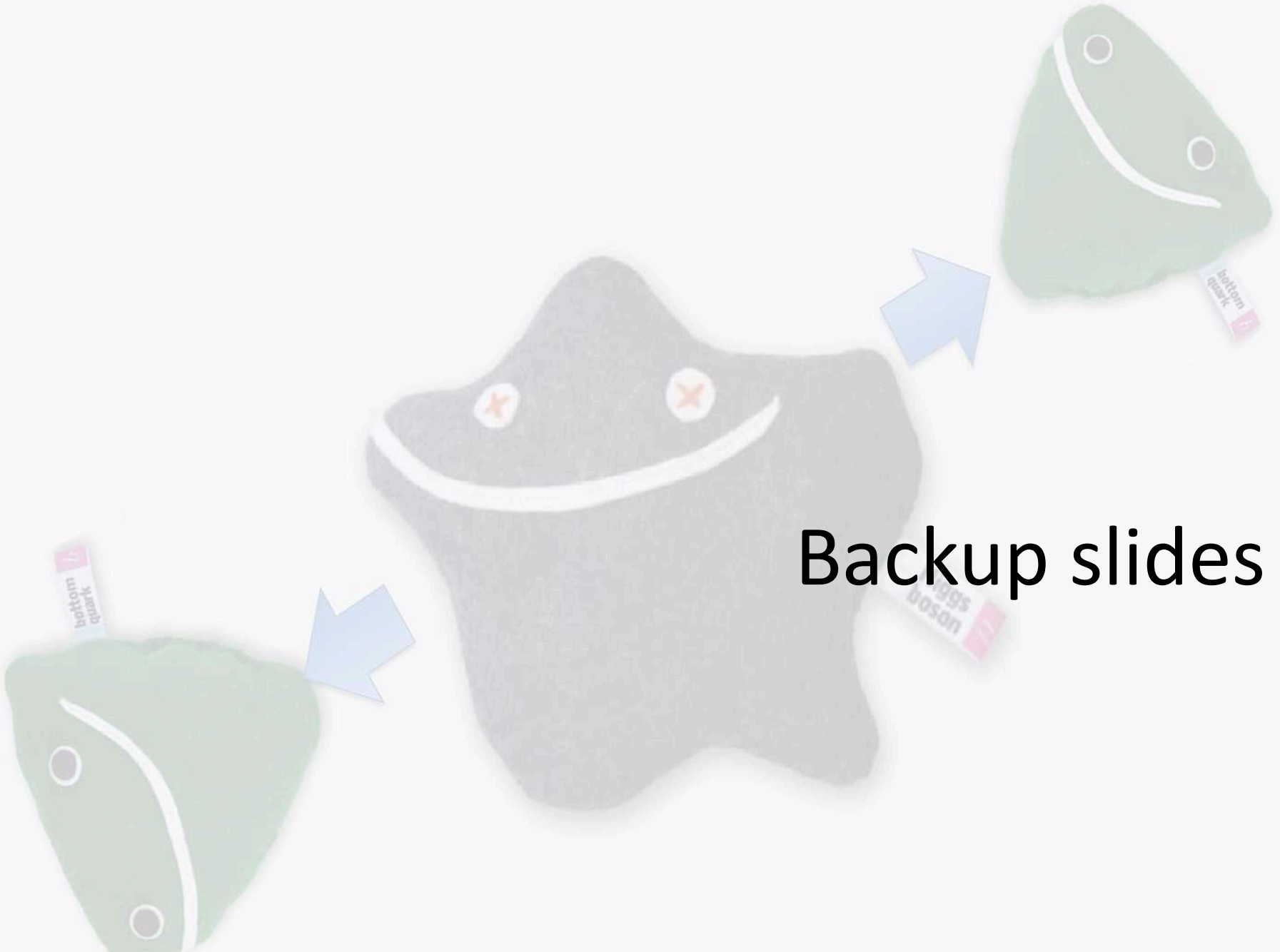
Plans up to Summer - II

- Continue to work on the existing channels:
  - $ZH \rightarrow \nu\nu bb$ had first iteration, but has space to evolve
  - MV methods not yet explored enough

- Essential to get the best of our data:
  - More interaction with CP groups:
    - Main points and open questions in current analyses are on jets, MET and b-tagging
    - Would benefit (a lot!!) from better understanding of jet energy scale, MET, di-jet mass resolution
    - Trigger – e.g. MET trigger, trigger for VBF H->bb, b(b)H, etc
  - Preparing list of MC samples needed for MC12
    - Crucial to get enough MC (and of the right kind)

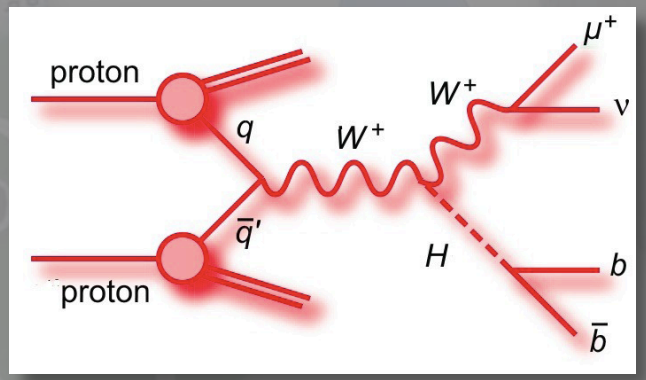
- Produce new results for ICHEP2012 with 2012 data

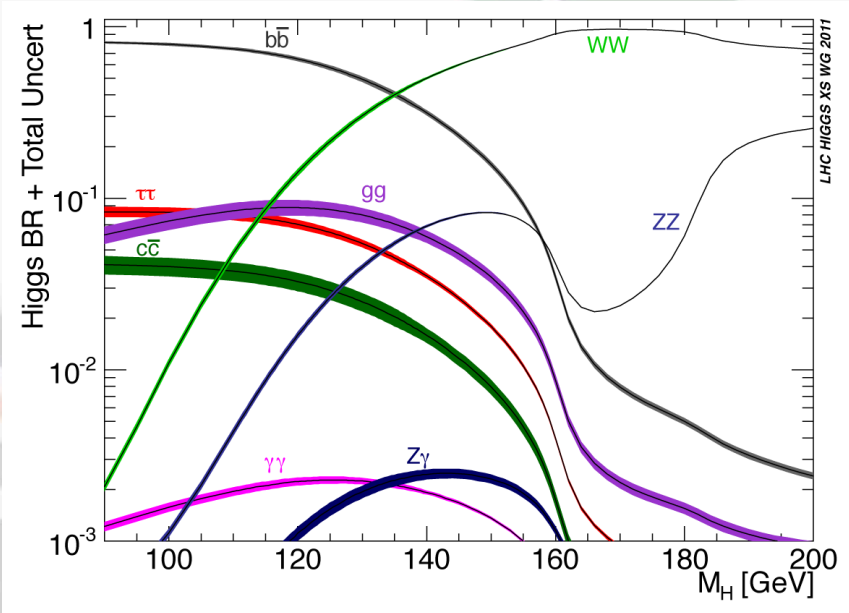
…maybe shortly after… see the Higgs in H->bb ☺



Backup slides

- This paper:
  - ZH→llb, WH→lνbb and ZH→ννbb
  - 4.6 – 4.7 fb^{-1} analyzed
- H->bb dominant at low mass
  - WH cross section factor ≈2x higher than ZH, but important top background
- Cut-based analyses:
  - Select Z or W or large E_T^{miss} and search for 2 additional b jets
  - Search Higgs in m_{bb} spectrum





m_H (GeV)	$\sigma(WH)$ (pb)	$\sigma(ZH)$ (pb)	Branching Ratios $H \to b\bar{b}$
110	0.8754	0.4721	0.745
115	0.7546	0.3598	0.705
120	0.6561	0.3158	0.649
125	0.5729	0.2778	0.578
130	0.5008	0.2453	0.494

Monte Carlo samples

Process	Generator	$\sigma \times BR$
WH	PYTHIA	See Tab. 3
ZH	PYTHIA	See Tab. 3
$W \to \ell\nu$	ALPGEN , POWHEG	10.46 nb [45,46]
$Z/\gamma* \to \ell\ell$	ALPGEN, SHERPA	
$m_{\ell\ell} > 40$ GeV		1.07nb [45,47]
$m_{\ell\ell} > 60$ GeV		0.989 nb [45,47]
WW	MC@NLO+gg2WW	46.23 pb [31,32]
$WW \to \ell\nu qq$	HERWIG	46.23 pb [31,32]
WZ	MC@NLO	
$66 < m_{\ell\ell} < 116$ GeV		18.0 pb [31]
ZZ	MC@NLO, PYTHIA	
$66 < m_{\ell\ell} < 116$ GeV		5.96 pb [31]
Top-quark		
$t\bar{t}$	MC@NLO	166.8 pb [30,36]
t−channel	MC@NLO	64.57 pb [48]
s−channel	MC@NLO	4.63 pb [48]
Wt−channel	MC@NLO	15.74 pb [49]

Datasets

- Full 2011 data from periods B-M
  - 4.7 fb^{-1} e/μ streams ($ZH \rightarrow llb$, $WH \rightarrow l\nu bb$)/4.6 fb^{-1} JetTauETmiss ($ZH \rightarrow \nu\nu bb$)
- Signal (MC11c)
  - $ZH \rightarrow llbb$, $WH \rightarrow l\nu bb$, $ZH \rightarrow \nu\nu bb$ simulated in Pythia
  - Normalized to NLO (EW) + NNLO (QCD) from LHC Higgs cross section WG (Yellow Report I)
  - m_H = 110 − 130 GeV in steps of 5 GeV
- Background (MC11c)
  - Z/W+jets: ALPGEN to model l (l and c jets) for Z(W)
  - High statistics Zcc/Zbb(Wbb) using SHERPA(POWHEG)
  - Top: ttbar + single top from MC@NLO
  - Diboson: ZZ/WZ/WW from MC@NLO
- QCD background
  - $ZH \rightarrow llbb$ multi-jet electron from loose-loose no medium data scaled
  - $WH \rightarrow l\nu bb$ electron and muon from anti-isolation data scaled
  - $ZH \rightarrow \nu\nu bb$ from data (ABCD method) – negligible

Lepton Selection: $WH \rightarrow llb$, $WH \rightarrow l\nu bb$

- Electrons
  - medium++ (tight++) with pT > 20(25) GeV and |η| < 2.47 for Z(W)
  - Include crack region
  - Trackisolation: Ptracks /pT < 0.1 within R = 0.2
  - For WH: Calo isolation: Pcalo /ET < 0.14 within R = 0.3
  - For WH: Impact parameter cut d0 < 0.1 mm
  - Latest recommended smearing and efficiency corrections
  - Veto in WH: use central loose++ with pT > 10 GeV and forward loose
  - with pT > 20 GeV(|η| < 4.5). Require trk/calo isolation (except forward)

- Muons
  - STACO(Muid) tight with pT > 20(25) GeV and |η| < 2.5 for Z(W)
  - Track isolation (as for electrons); For WH calo isolation
  - Impact paramter cuts d0 < 1(0.1) mm for Z(W)
  - Impact parameter cut against cosmics z0 < 10 mm
  - Latest recommended smearing and efficiency corrections
  - For veto in WH extend to Loose/standalone, pT > 10 GeV and
  - |η| < 2.7. Require track isolation (except standalone)

Jet/E_t^{miss} selection

- Jets – *not updated to last week's recommendations*
  - Anti-kT 4 with pT > 25 GeV and |η| < 2.5 "AntiKt4TopoEMJets"
  - For jet veto in WH pT > 20 GeV and |η| < 4.5
  - Remove events with jets pointing to the bad FEB region
  - Pile-up: reject jets with |JVF| < 0.75 for jets with |η| < 2.5
  - Current JES/JER uncertainty including pile-up, close by and b JES

- b-tagging – *not updated to last week's version*
  - MV1 with w > 0.602 (70% efficiency)
  - Applying corrections and uncertainties derived by b-tagging group.

- MET – *not updated to last week's version*
  - MET RefFinal out-of-the-box
  - Apply pile-up reweighting for each MC run period
  - Additional μ scaling reweighting: scale <μ> by 1.03±0.03

Lepton and jet veto: ZH→ννbb, WH→lνbb

- Veto leptons:
  - Electron : medium , pT>10 GeV, |η|<2.47, pTcone20/pT<0.1
  - Muon : Combined & segmented-tagged STACO, pT>10 GeV, |η|<2.4, pTcone20/pT<0.1
- Veto on any event having an object with:
  - pT > 20 GeV. Veto lepton has wider range than trigger electron
  - (standalone muons, forward electrons).
- Remove any event with:
  - 1 extra lepton with pT > 20 GeV
  - 1 extra opposite sign lepton with pT < 20 GeV
  - > 1 extra leptons
- Remove any event with ≥ 3 jets (veto jet: pT > 20 GeV and |η| < 4.5)
- In ZH→llbb, WH→lνbb: remove overlaps between electrons, muons, jets

Event selection

- Common selection
  - Using WZ+jets GRL (incl. b-tagging)
  - Primary vertex containing at least 3 tracks
- ZH→llb
  - Triggers: single and dilepton triggers
  - Exactly 2 leptons with 83 < mll < 99 GeV
  - Opposite charge required for muons
  - E_T^{miss} < 50 GeV
  - At least 2 jets (1 jet with p_T >45 GeV), exactly 2 b tagged
- WH→lvbb
  - Triggers: single lepton trigger
  - 1 lepton and MT > 40 GeV
  - Emiss
  - T > 25 GeV
  - Exactly 2 jets(1 jet with pT >45 GeV) and both b tagged

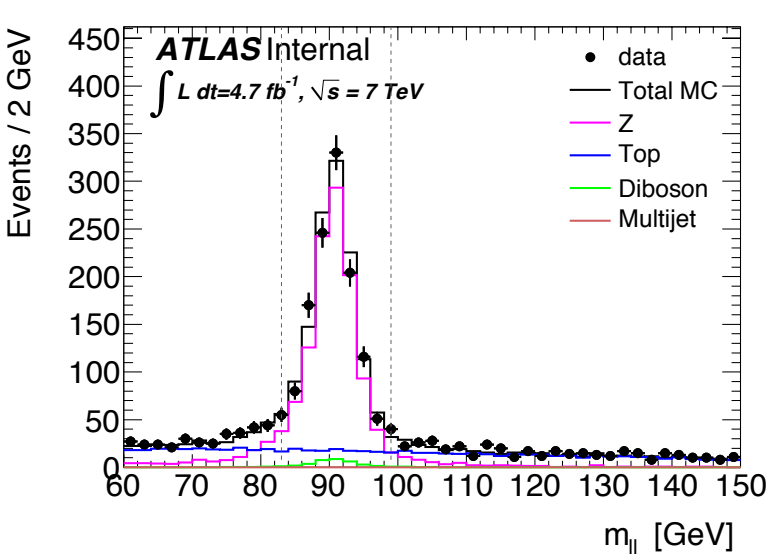
- ZH→vvbb
  - Trigger: EF_xe70_noMu
  - No lepton (e or μ)
  - Etmiss > 120 GeV
  - Ptmiss > 30 GeV (remove events with fake high Etmiss)
  - 2 or 3 jets, exactly 2 b-tagged jets
  - Leading jet Pt>45 GeV (new)
  - B-tagged jets separated by dR (b1,b2)>0.7 (for 120<Etmiss<200 GeV)
  - Δϕ(Etmiss, Ptmiss) < π/2 (new)
  - Plus optimized angular cuts (table)

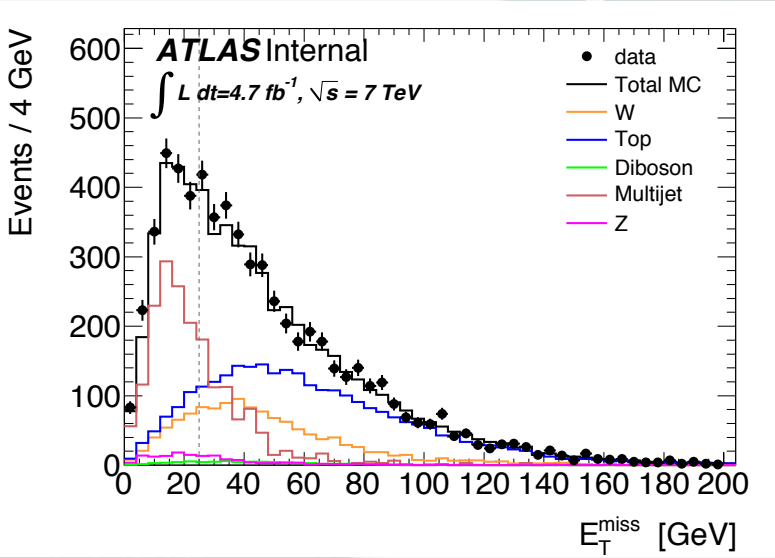
	E_T^{miss}(GeV)		
Cuts	120 - 160	160 - 200	> 200
$N\,jets$	= 2	= 2	= 2
$\Delta R(B\,jet1, B\,jet2)$	< 2.0	< 1.7	< 1.7
$\Delta\phi(V, H)$	> 2.7	> 2.9	> 2.9
$min\_\Delta\phi(E_T^{miss}, jet)$	> 1.8	> 1.8	> 1.8

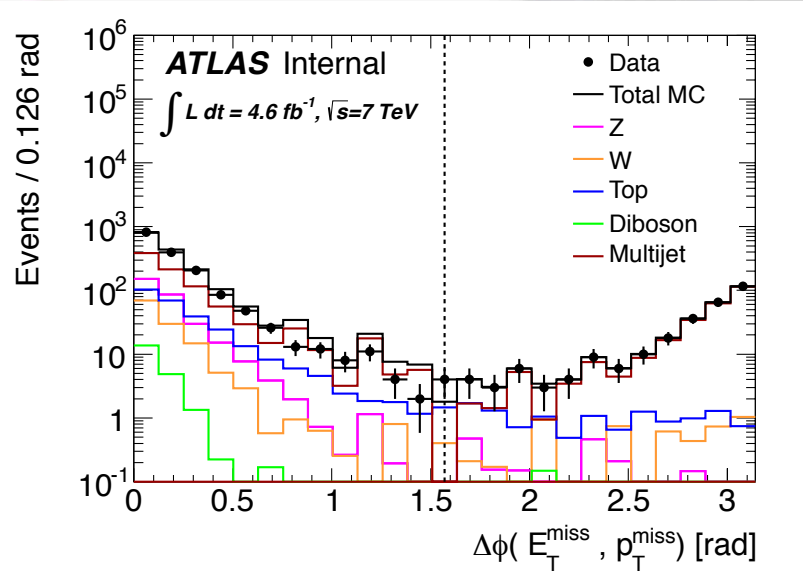
Other aspects of the analysis

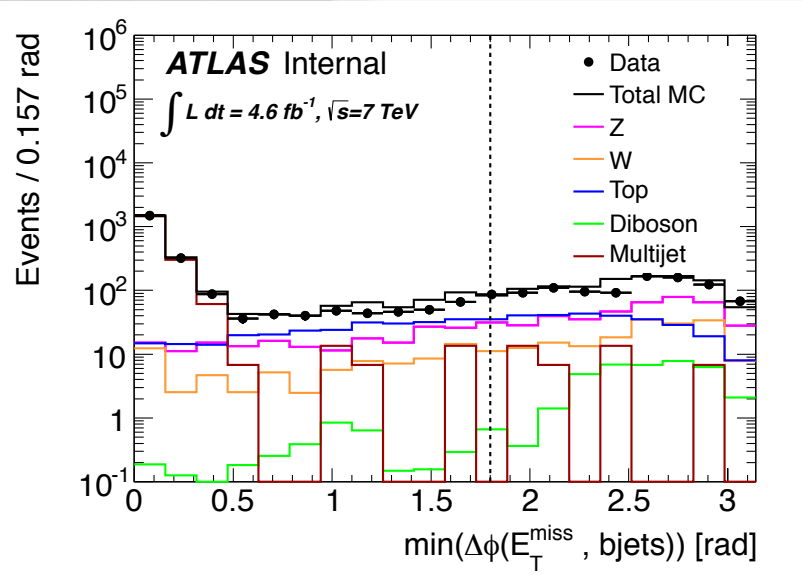
- Selected sample is divided into pT(W/Z) categories to increase significance
- Some cuts are optimized for each bin in ZH→vvbb analysis
- Heavily data-driven estimation of backgrounds
- Normalization of main backgrounds transferred from
- ZH→llbb/WH→lvbb analysis to ZH→vvbb analysis
- More info in support material:
  - ZH→llb & WH→lvbb: https://cdsweb.cern.ch/record/1404176/
  - ZH→vvbb: https://cdsweb.cern.ch/record/1418230

Plots for approval – Fig.1



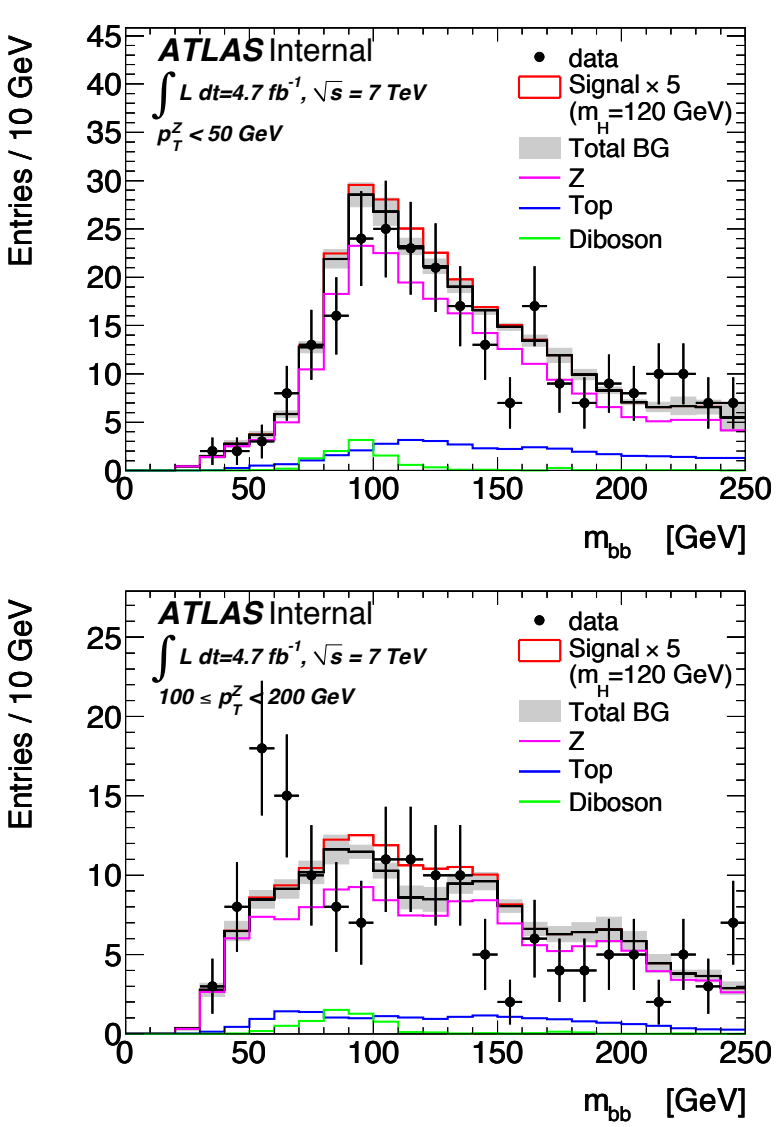


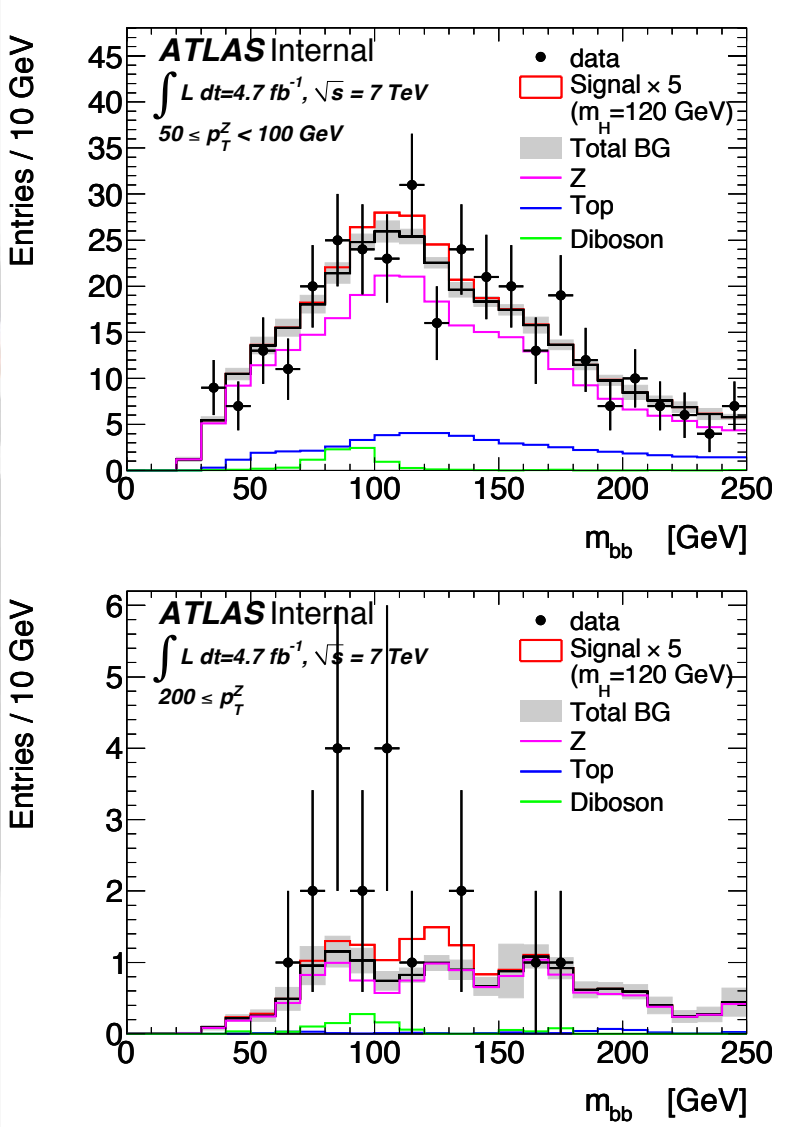




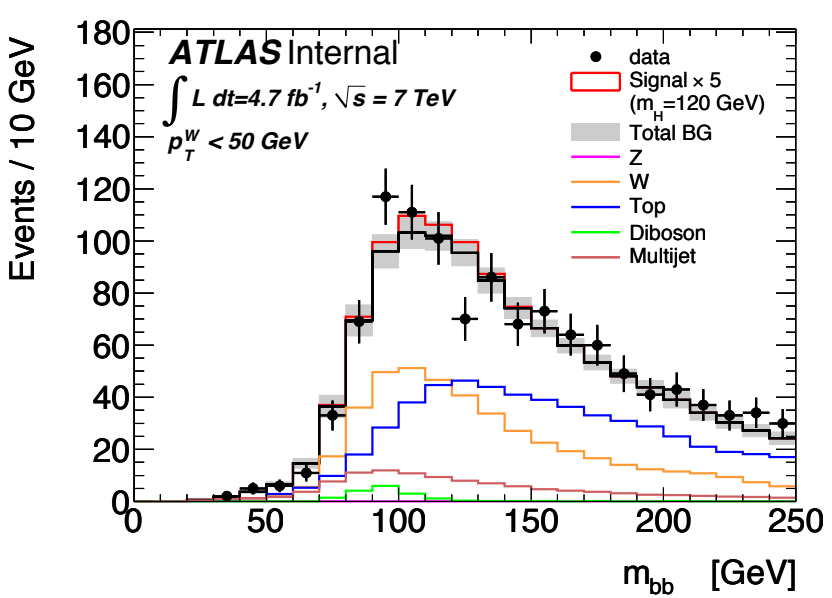
Bin	$ZH \to \ell^+\ell^- b\bar{b}$ p_T^Z[GeV]				$WH \to \ell\nu b\bar{b}$ p_T^W[GeV]				$ZH \to \nu\bar{\nu}b\bar{b}$ E_T^{miss}[GeV]		
	0-50	50-100	100-200	>200	0-50	50-100	100-200	>200	120-160	160-200	>200
Number of events for $80 < m_{b\bar{b}} < 150$ [GeV]											
Data	139	164	62	13	622	597	276	15	103	22	24
Signal	1.4 ± 0.2	2.0 ± 0.3	1.7 ± 0.3	0.4 ± 0.1	4.7 ± 0.9	5.2 ± 1.0	4.1 ± 0.9	1.4 ± 0.3	2.3 ± 0.5	1.3 ± 0.3	1.8 ± 0.5
Top	18	25	7	0	260	383	219	8.6	42	9	4
W+jets		-			285	181	72	12	13	7	4
Z+jets	132	126	58	5.6	0.4	0.3	0.1	0.0	33	12	7
Diboson	8	6	4	1	13	13	8	1	5	5	4
QCD		-			64	42	4	1		-	
Total Bkg	157 ± 15	157 ± 11	70 ± 7	6 ± 2	625 ± 36	620 ± 24	303 ± 13	23 ± 4	93 ± 10	33 ± 5	20 ± 5
Components of the Background Systematic Uncertainties [%]											
B-tag Eff	3.1	2.8	2.2	7.7	1.4	1.7	2.5	11.3	4.1	9.2	15.6
Bkg Norm	5.2	5.0	5.2	5.6	4.0	2.8	2.7	5.5	3.1	3.9	4.2
Jets/E_T^{miss}	1.0	2.8	3.5	3.1	2.1	1.6	1.6	6.4	8.2	10.7	16.9
Leptons	0.4	0.5	1.1	3.6	1.0	0.4	0.7	6.1		-	
Luminosity	0.2	0.1	0.2	0.4	0.1	0.1	0.1	0.2	0.2	0.5	0.8
Pile Up	0.7	1.8	1.5	6.9	0.6	0.7	1.1	2.5	0.7	2.6	1.9
Theory	7.3	1.7	7.2	23.4	3.1	1.0	1.1	11.9	3.7	6.3	11.1
Total Bkg	9.6	6.9	10.0	26.6	5.8	3.9	4.4	19.6	10.4	16.1	26.0
Components of the Signal Systematic Uncertainties [%]]											
B-tag Eff	10	11	13	16	10	11	13	15	13	16	21
JES/MET	6.5	4.6	4.0	3.7	6.7	6.8	7.8	4.7	11.0	5.4	9.9
Leptons	1.1	1.5	1.5	3.6	3.2	4.2	5.0	5.5		-	
Luminosity		3.9				3.9				3.9	
Pile Up	0.7	1.2	2.4	3.4	1.4	3.9	3.2	3.4	0.5	0.8	2.1
Theory		5				13				13	
Total Signal	13.6	13.3	14.9	18.3	18.5	19.4	21.4	21.5	21.8	21.7	26.8

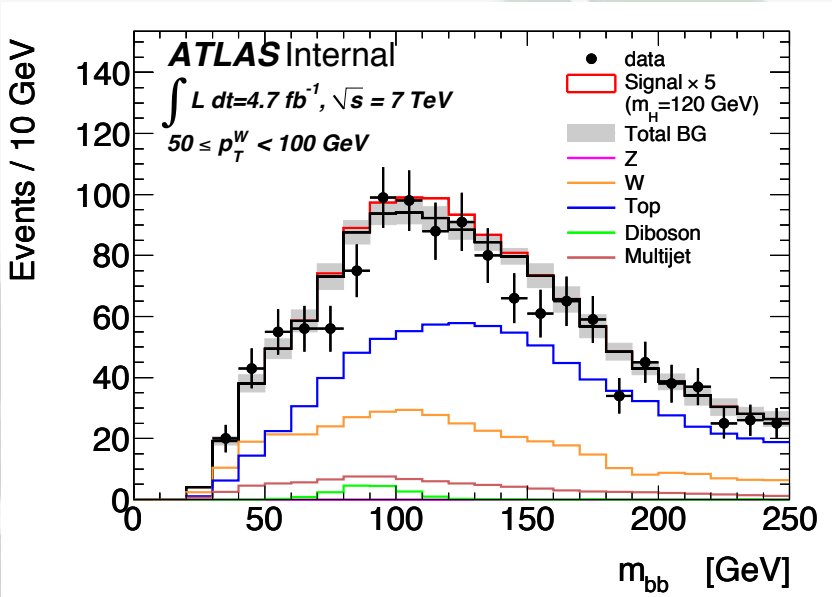
Plots for approval – Fig.2 (ZH→llbb)

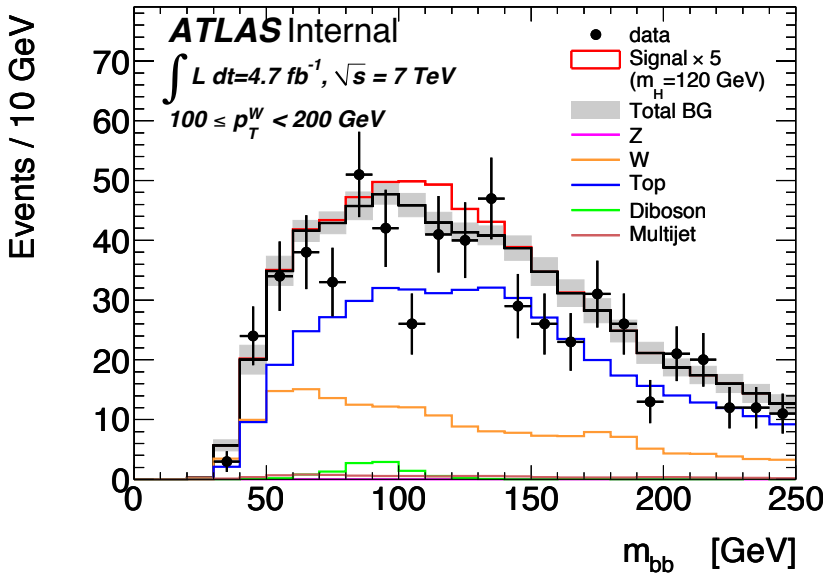


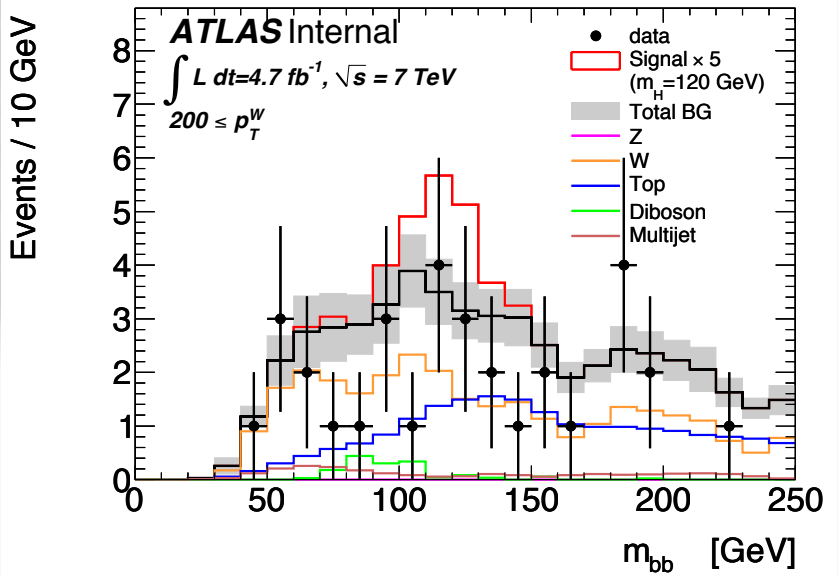


Plots for approval – Fig.3 (WH→lvbb)

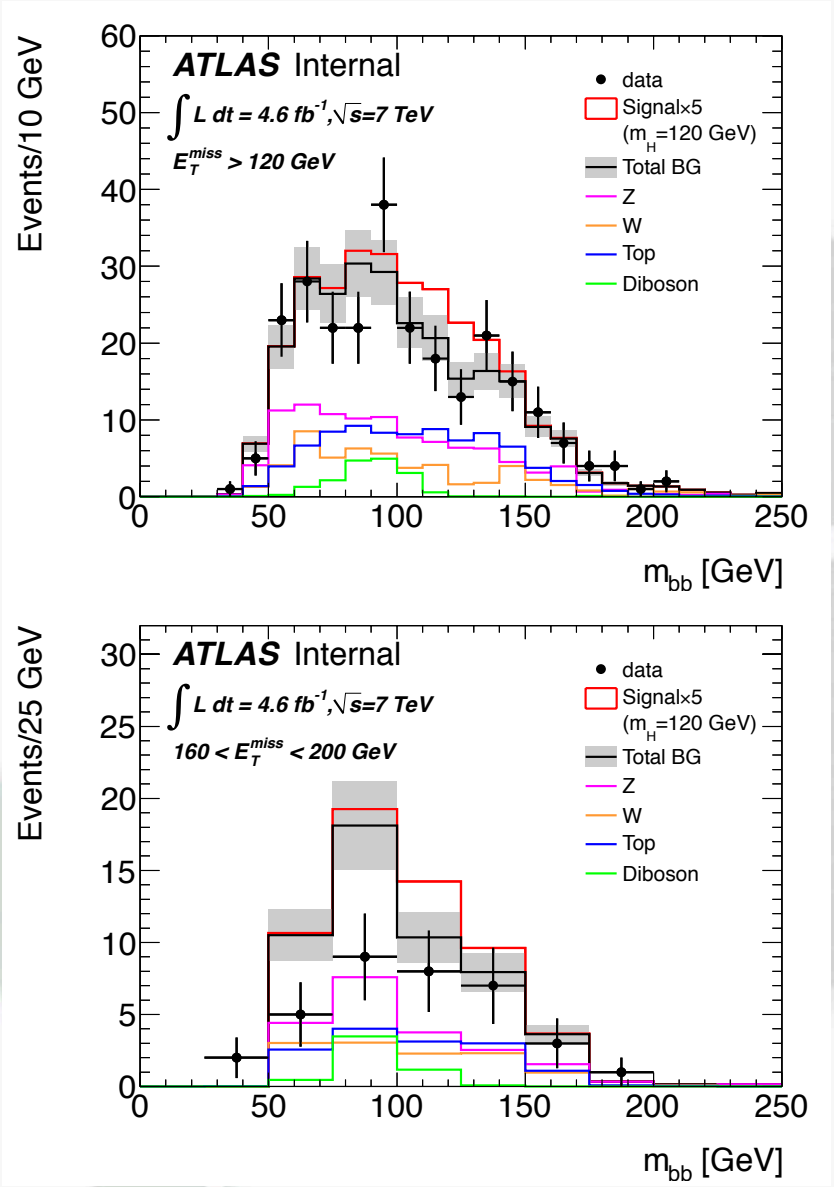


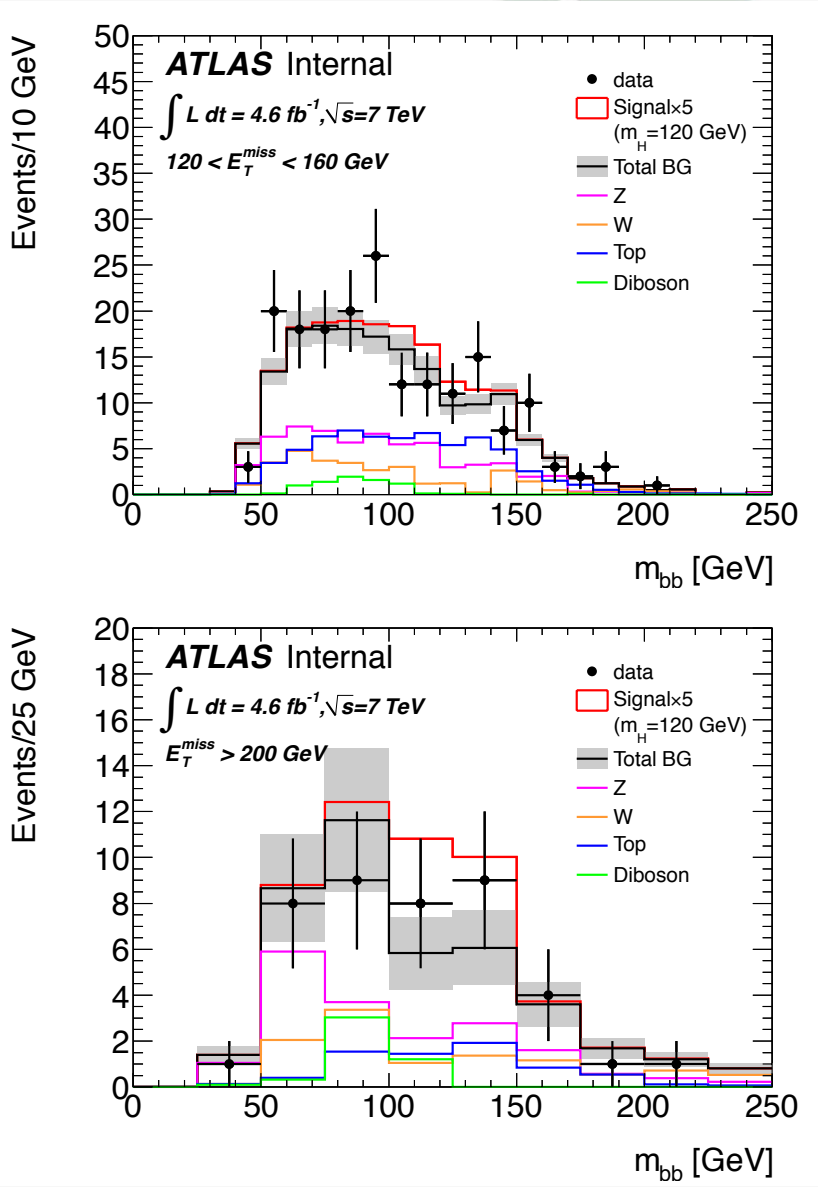




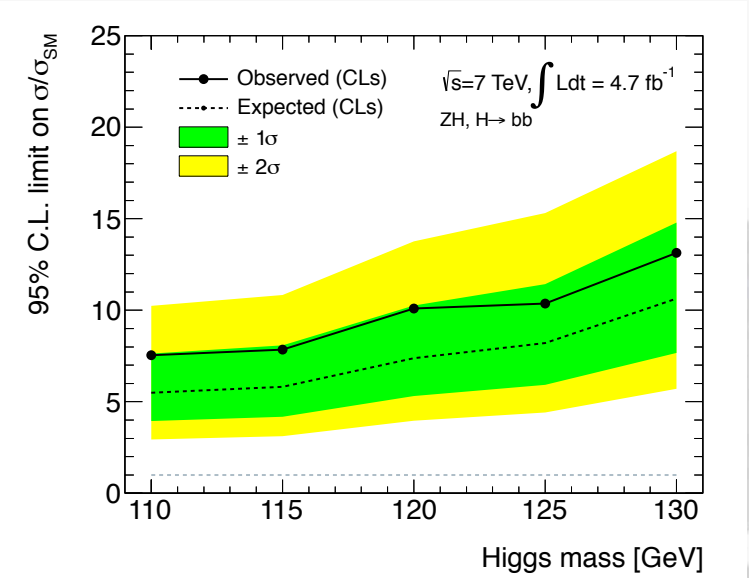


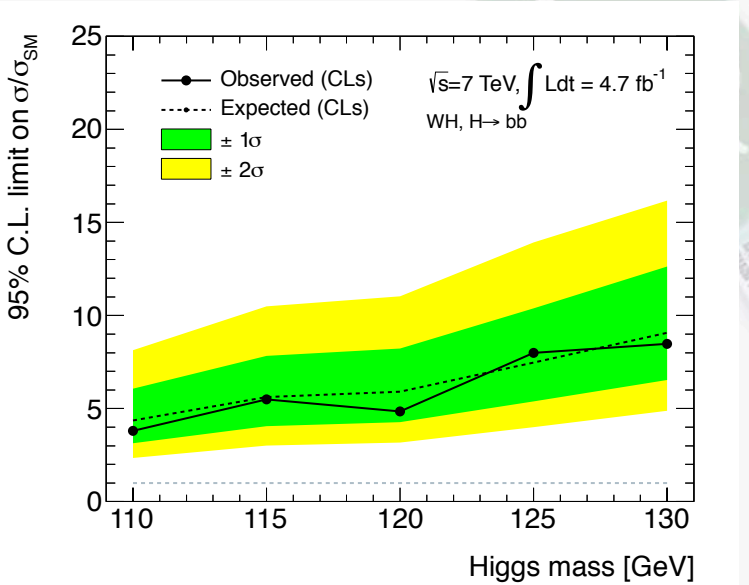
Plots for approval – Fig.4 (WH→lvbb)

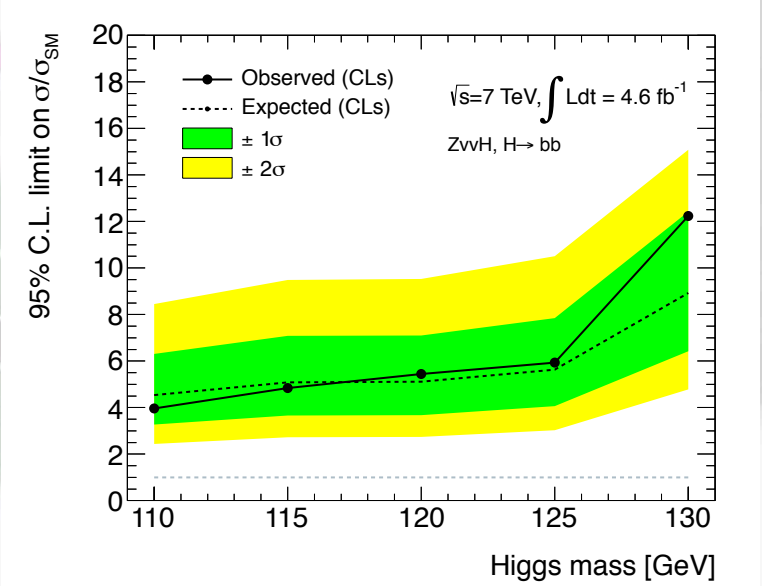


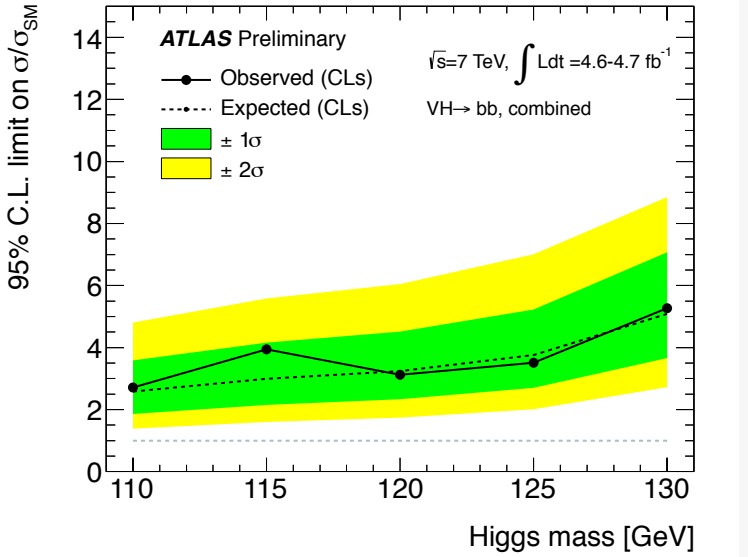


Limits plots for approval



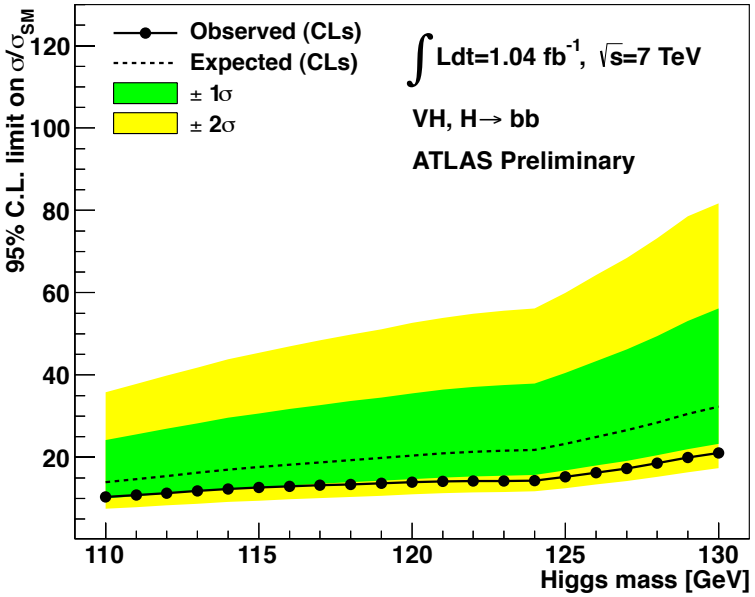


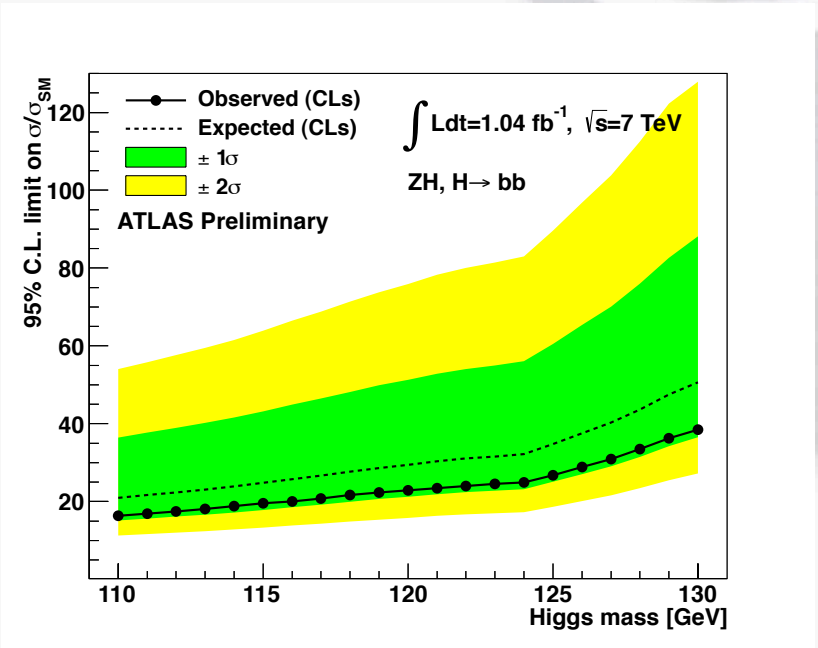


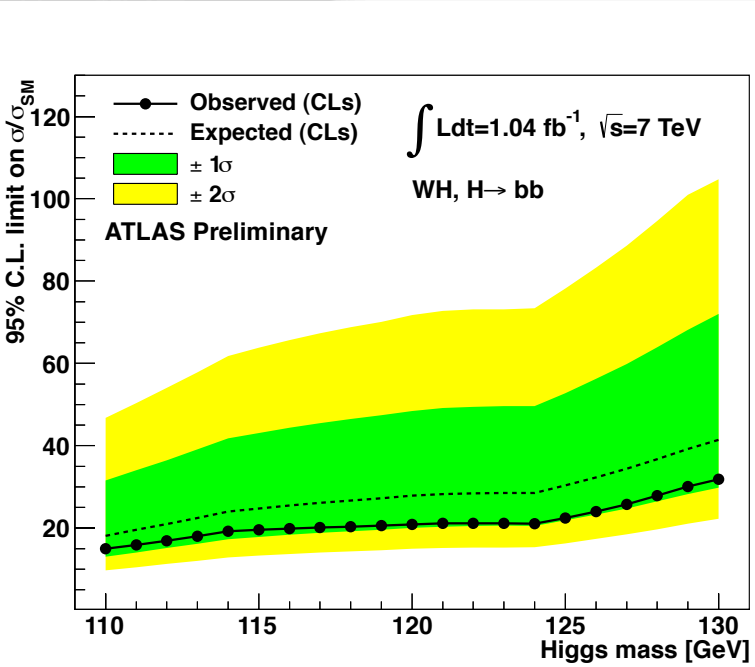


Last public results:

- First H→bb search from the LHC shown at EPS – July 2011
- ZH→llb, WH→lvbb only
- 1fb^{-1} @ 7 TeV
- Combined sensitivity: ≈10-20xSM
- Ref.: ATLAS-CONF-2011-103

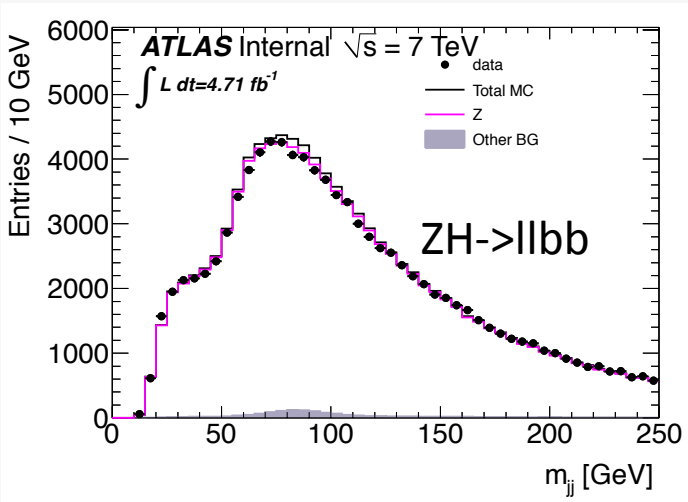


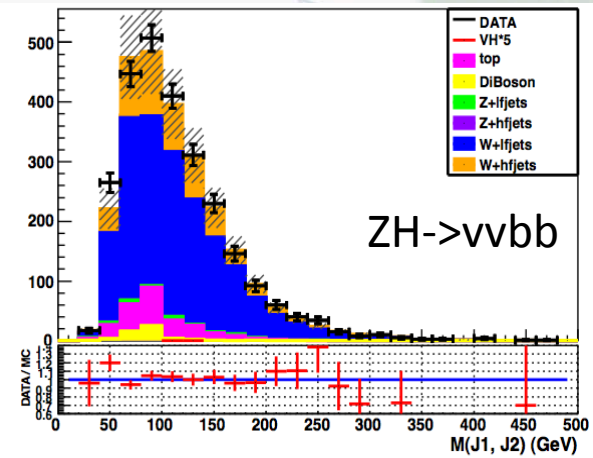


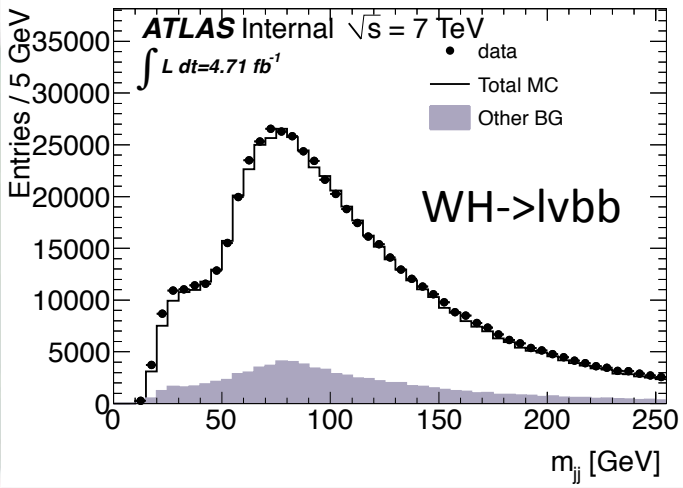


Un-tagged m(j,j) plots

- Added to WH/ZH support note (appendix O.7): https://cdsweb.cern.ch/record/1404176/
- Also in control regions of ZH->vvbb support note: https://cdsweb.cern.ch/record/1418230







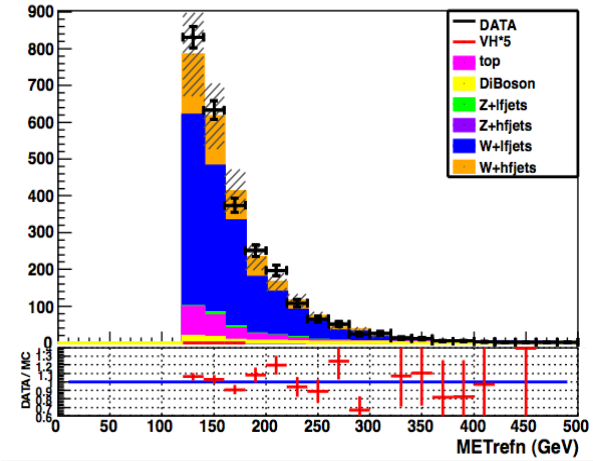


Table 2 – Exclusion Limits

Table 2: The expected 95% C.L. exclusion limits for each channel and the combined exclusion limits for the three channels, in multiples of the SM Higgs boson cross section, as a function of the hypothesized Higgs boson mass.

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