$ZH \longrightarrow llb\bar{b}$, $WH \longrightarrow l\nu b\bar{b}$ Status

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(on behalf of the HSG5 group)

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Higgs Meeting

Introduction

- Preliminary CONF note result on 1fb^{-1} in the summer
- No publication on these channels (ATLAS or CMS) yet
- Preliminary result lacked optimisation
- Progress since then
  - Improve top rejection in WH by using lepton and jet vetos
  - Divide analysis into p_T^V bins to improve sensitivity
  - For paper same channels as summer $ZH \rightarrow llbb$ and $WH \rightarrow l\nu bb$ where $l = e, \mu$.
  - Work on $ZH \rightarrow \nu\nu bb$ and boosted analysis in group

Datasets

- Data
  - Use full 2011 data from period B-M
  - Corresponds to 4.7 fb^{-1} (pro10)
- Signal (MC11b)
  - ZH and WH: POWHEG/HERWIG $Z \to ll, W \to l\nu$, $l = e, \nu\tau$ $H \to bb$
  - $m_H = 110 - 150$ GeV in steps of 5 GeV
- Background (MC11b)
  - Z/W+jets: ALPGEN with PYTHIA as a shape systematic
  - High statistics Wbb using POWHEG
    - Removal of overlap between light and bb sample (HFOR)
  - Top: $t\bar{t}$ + single top from MC@NLO
  - Diboson: $ZZ/WZ/WW$ from MC@NLO
  - QCD background
    - ZH multi-jet electron from loose-loose no medium data scaled (not yet included)
    - WH electron and muon from anti-isolation data scaled

Lepton Selection

- Electrons
  - `medium++` (`tight++`) with $p_T > 20(25)$ GeV and $|\eta| < 2.47$ for $Z(W)$
  - Include crack region
  - Track isolation: $\sum_{tracks}/p_T < 0.1$ within $\Delta R = 0.2$
  - For WH: Impact parameter cut $d_0 < 0.1$ mm
  - Latest recommended smearing and efficiency corrections
  - For veto in WH use `loose++` and Forward with $p_T > 10$ GeV and $|\eta| < 4.5$. Require track isolation (except Forward)
- Muons
  - STACO(Muid) comb./tagged with $p_T > 20(25)$ GeV and $|\eta| < 2.5$ for $Z(W)$
  - Track isolation: $\sum_{tracks}/p_T < 0.1$ within $\Delta R = 0.2$
  - Impact paramter cuts $d_0 < 1(0.1)$ mm for $Z(W)$
  - Impact parameter cut against cosmics $z_0 < 10$ mm
  - Latest recommended smearing and efficiency corrections
  - For veto in WH extend to standalone, $p_T > 10$ GeV and $|\eta| < 2.7$. Require track isolation (except standalone)

Jet + E_T^{miss} Selection

- Jets
  - Anti-k_T 4 with $p_T > 25$ GeV and $|\eta| < 2.5$ "AntiKt4TopoEMJets"
  - For jet veto in WH $p_T > 20$ GeV and $|\eta| < 4.5$
  - Remove events with jets pointing to the bad FEB region
  - Pile-up: reject jets with $|JVF| < 0.75$ for jets with $|\eta| < 2.5$
  - Current JES/JER uncertainty includinh pile-up, close by and b JES
- b-tagging
  - JetFitterCOMBNN with $w > 0.35$ ($\approx 70\%$ efficiency)
    - Applying corrections and uncertainties derived by b-tagging group for MC11a - being updated for MC11b. New treatment of correlations between p_T bins to reduce systematic uncertainty.
- MET
  - MET_RefFinal out-of-the-box
  - Apply pile-up reweighting for each MC run period
  - At the moment no additional μ scaling to deal with issues due to pile-up model (pythia 8) for MC11b

Event Selection

- Common selection
  - Using WZ+jets GRL (includes b-tagging)
  - Triggers: Standard single and dilepton triggers
  - Primary vertex containing at least 3 tracks
- $ZH \rightarrow llbb$
  - Exactly 2 leptons with $76 < m_{ll} < 106$ 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
- $WH \rightarrow l\nu bb$ selection
  - 1 lepton and $M_T > 40$ GeV
  - $E_T^{miss} > 25$ GeV
  - Exactly 2 jets(1 jet with p_T >45 GeV) and both b tagged

Lepton/Jet Veto Selection (WH)

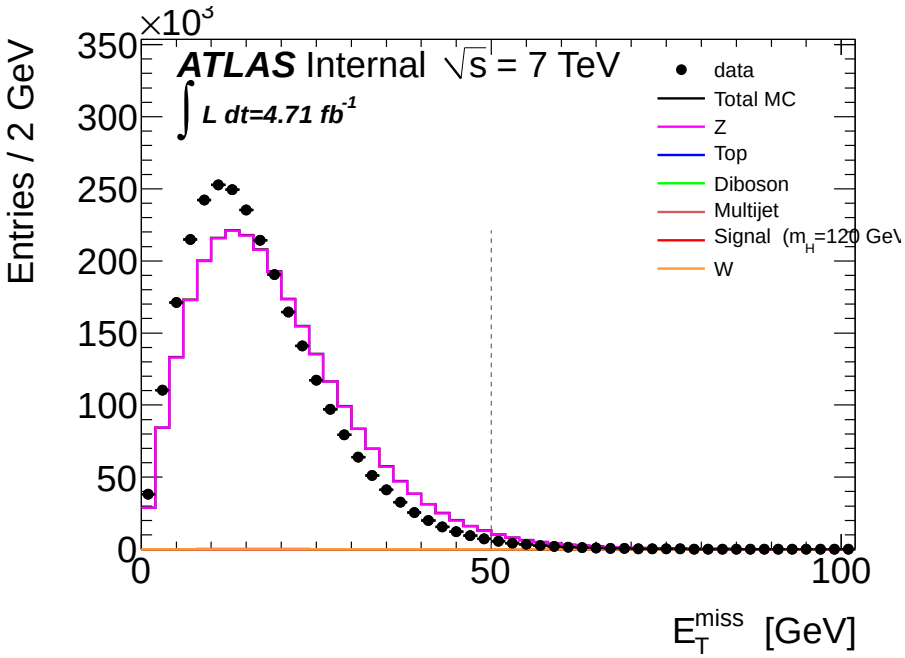
Further rejection of top. Veto jet has $p_T > 20$ GeV and $|\eta| < 4.5$. Veto lepton has wider η range than trigger electron (standalone muons, forward electrons).

- Object overlap removal
  - if $p_T^e > 20$ GeV and $\Delta R(jet, e) < 0.4$, remove jet
  - if $p_T^e < 20$ GeV and $\Delta R(jet, e) < 0.4$, remove e
  - if $\Delta R(jet, \mu) < 0.4$, remove μ
- Remove any event with trigger lepton and
  - 1 extra lepton with $p_T > 20$ GeV
  - 1 extra *same sign* lepton with $p_T < 20$ GeV
  - > 1 extra leptons
- Remove any event with
  - with ≥ 3 jets with $p_T > 20$ GeV

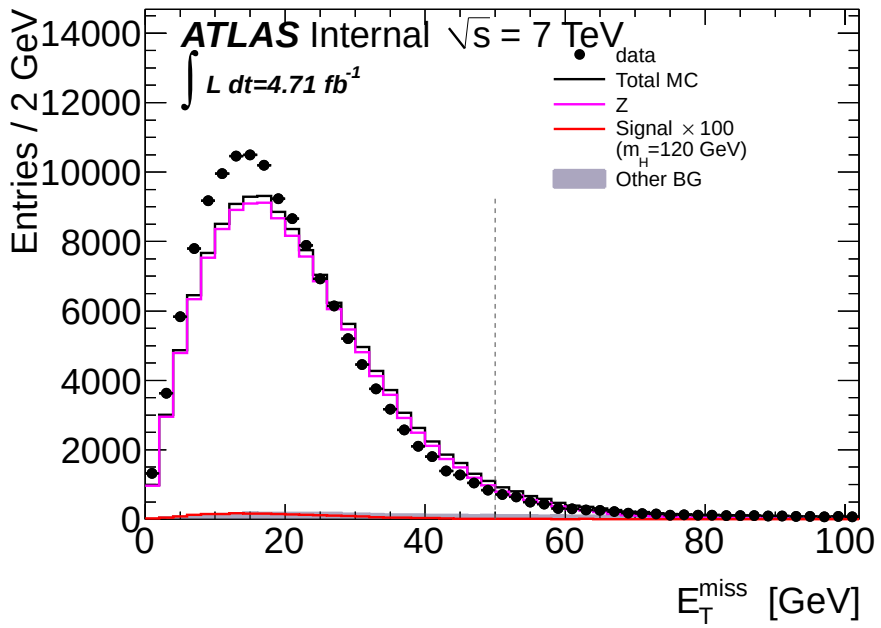
ZH: E_T^{miss} in Z Events

- MET, after M_Z cut, now using mc11b and reweighting for full lumi period - MET description worsens - similar to what other groups see.

All Events



N Jet ≥ 2

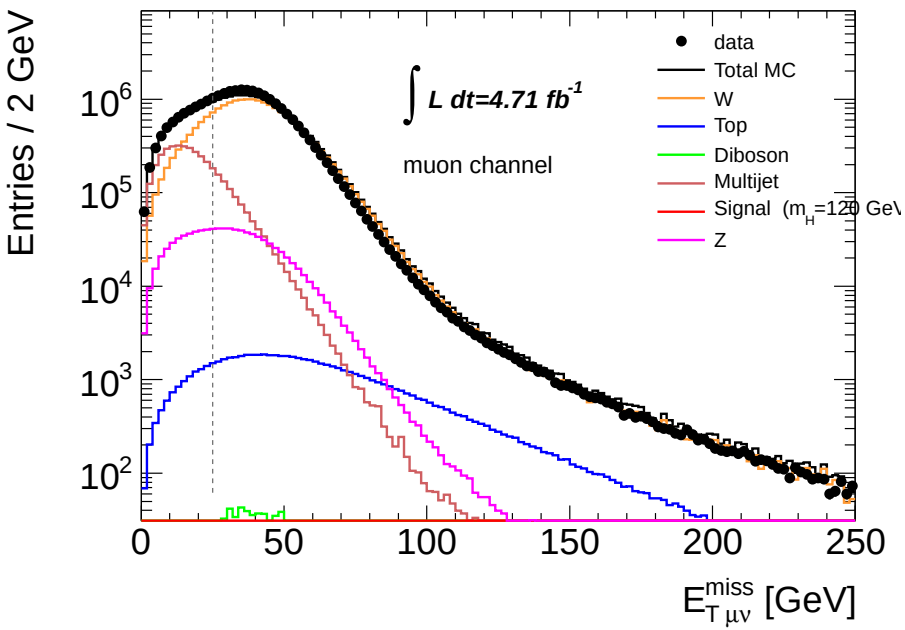


Will be covered by proposed missing Et errors?

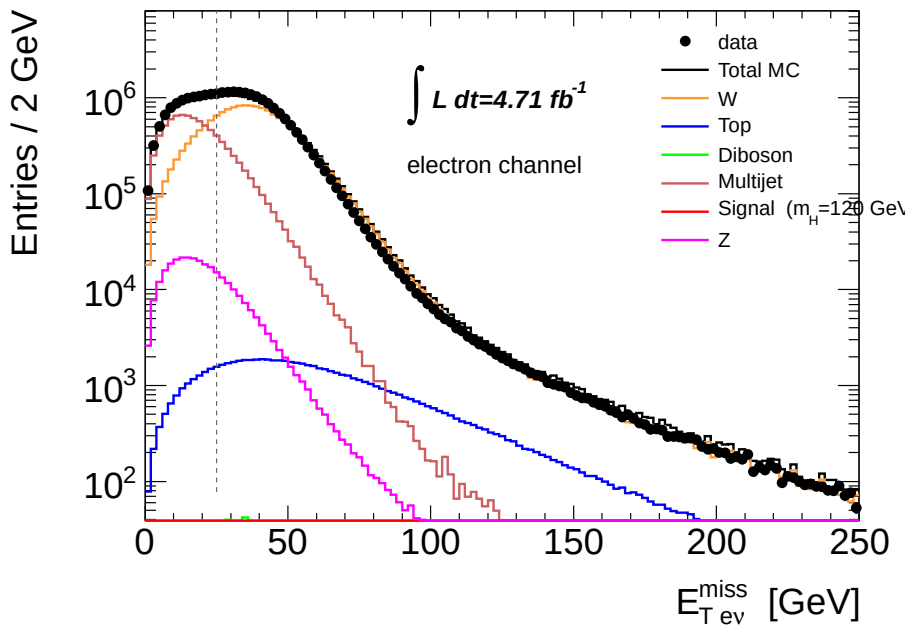
WH: E_T^{miss} in W Events

- Better agreement, although still differences
- QCD background from data (anti-isolation) fit to data

$W \to \mu\nu$



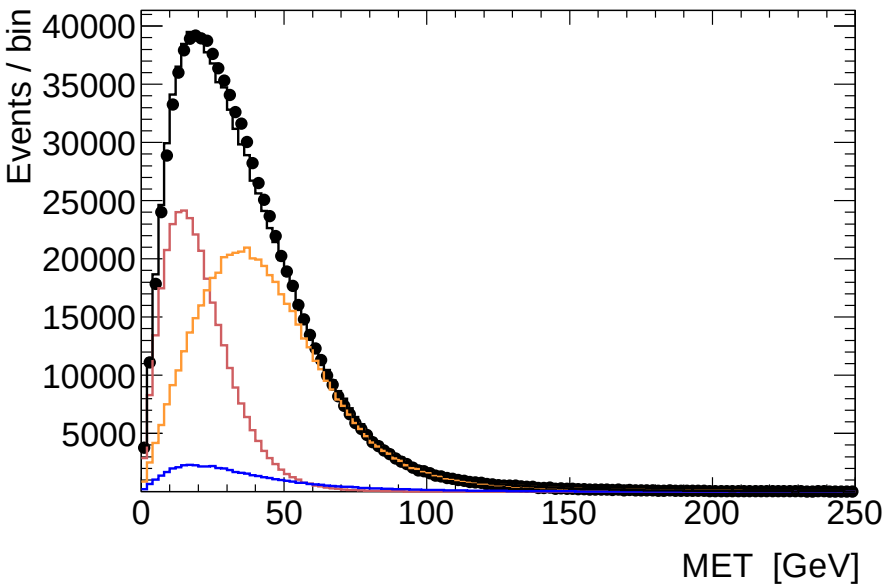
$W \to e\nu$



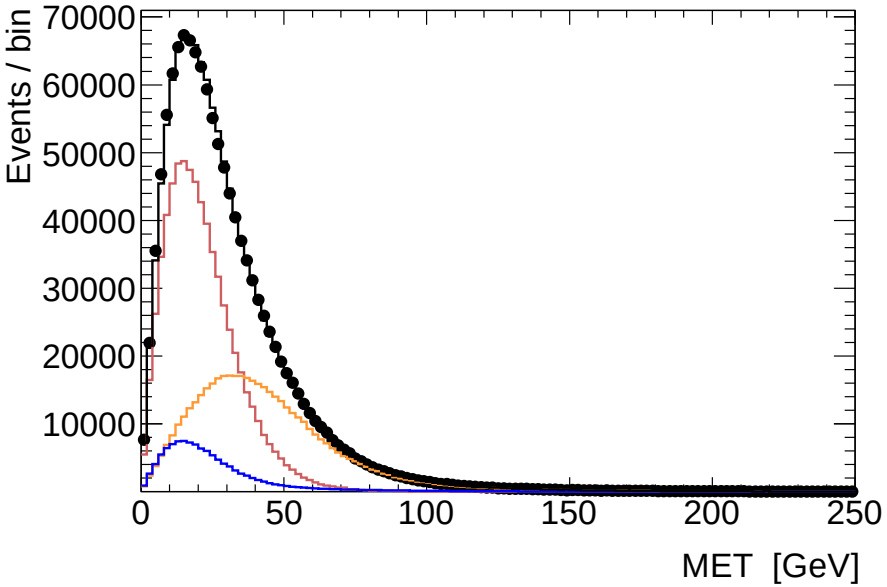
WH: E_T^{miss} in W Dijet Events

- Better agreement for events with jets
- Large QCD background for electrons. Calo isolation studies ongoing.

$W \to \mu\nu$



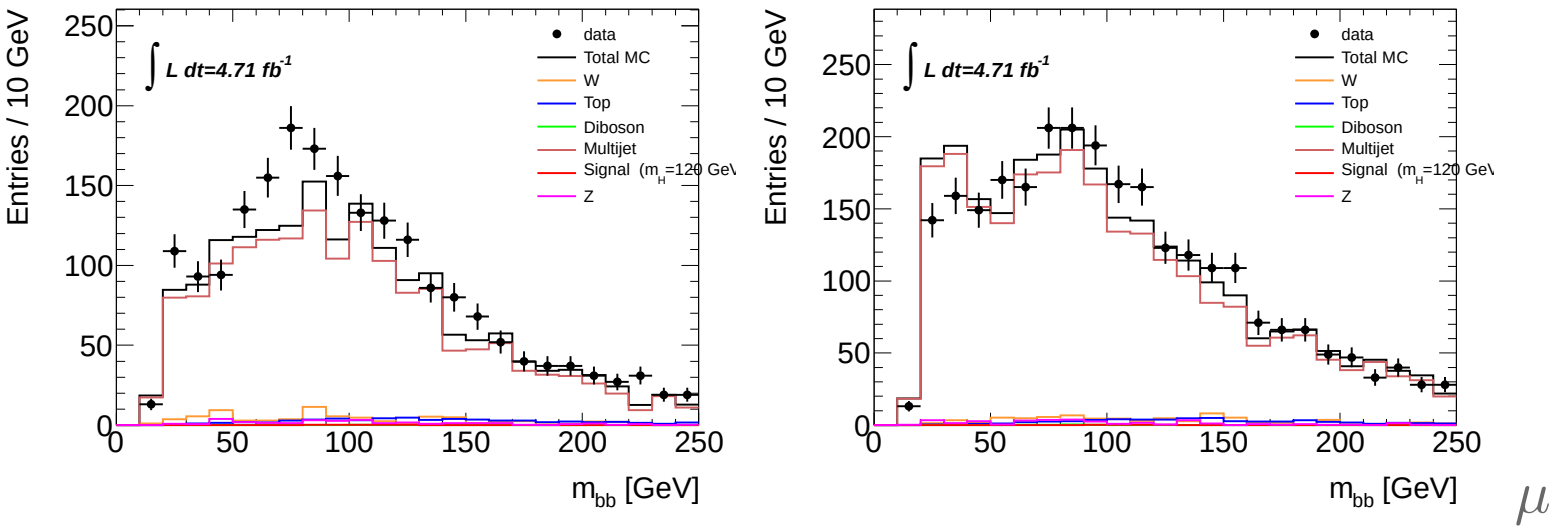
$W \to e\nu$



Add legend? Cut line?

QCD Background

m_{bb} in control region: MET<25 GeV and M_T <40 GeV

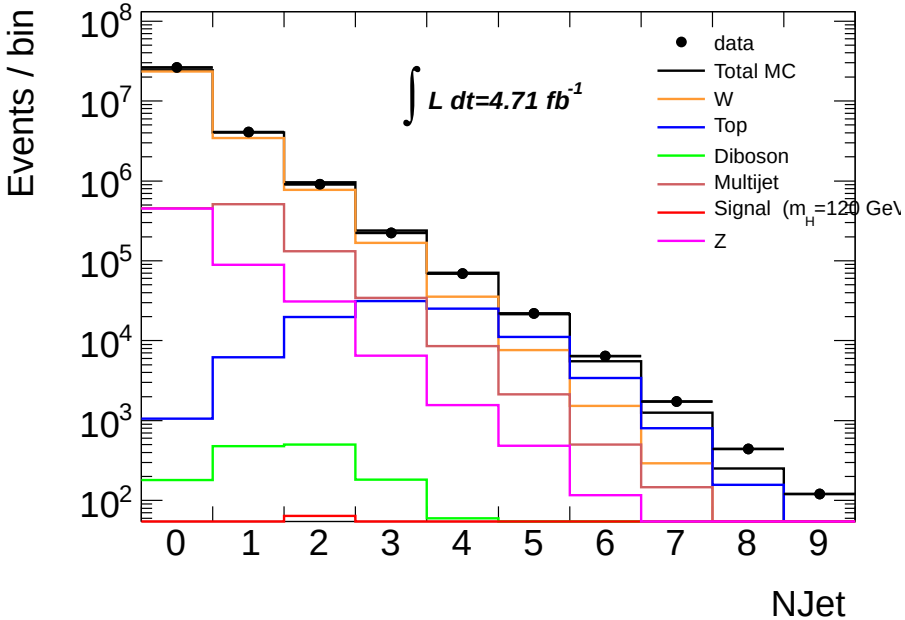


Anti-isolation sample (Multijet) does OK within the present 50% uncertainty. Low statistics for m_{bb} template. Studies ongoing to extend QCD template sample to 3^{rd} jet(increase statistics) and cuts to improve description in control region.

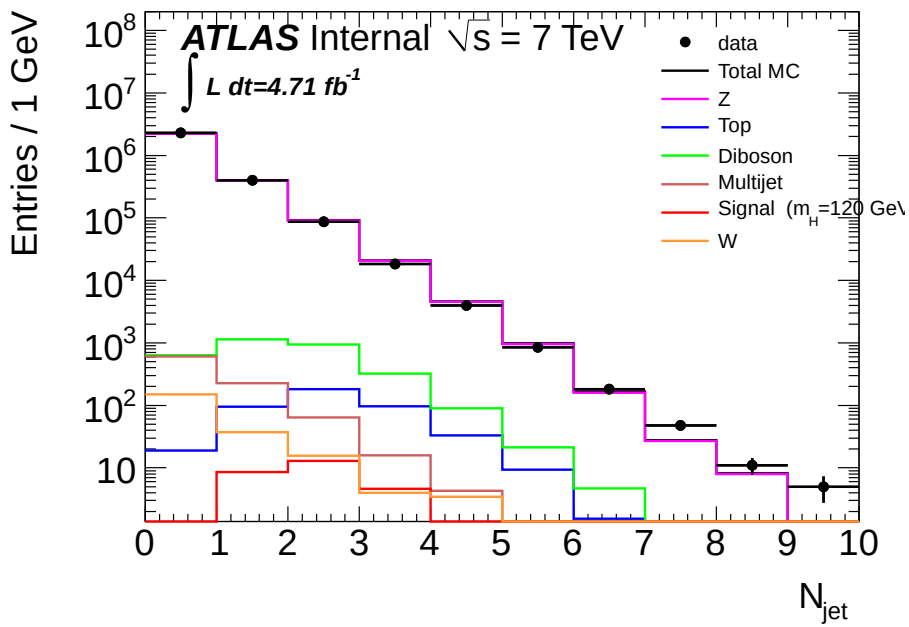
Jet Multiplicity

- Descriptions look reasonable

W

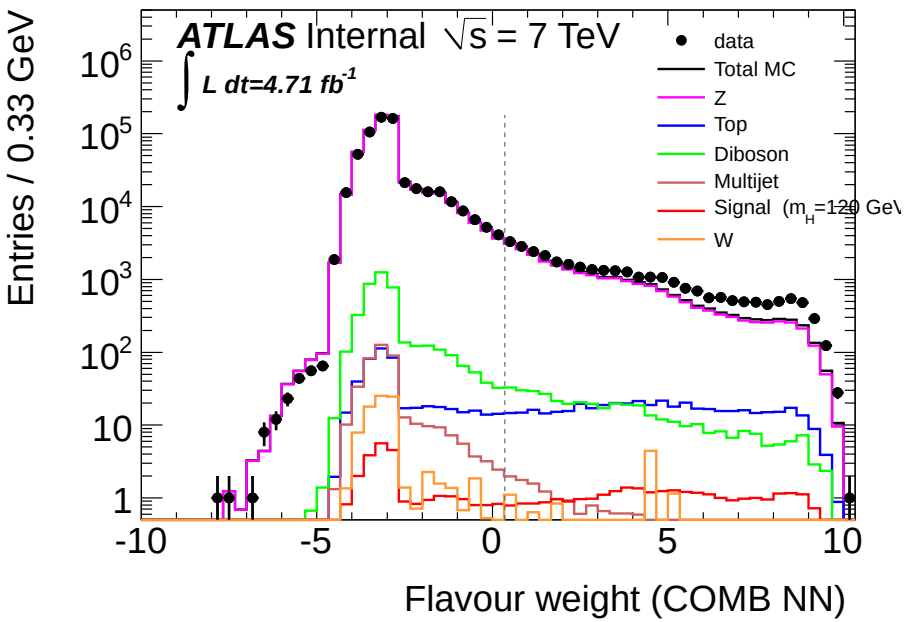


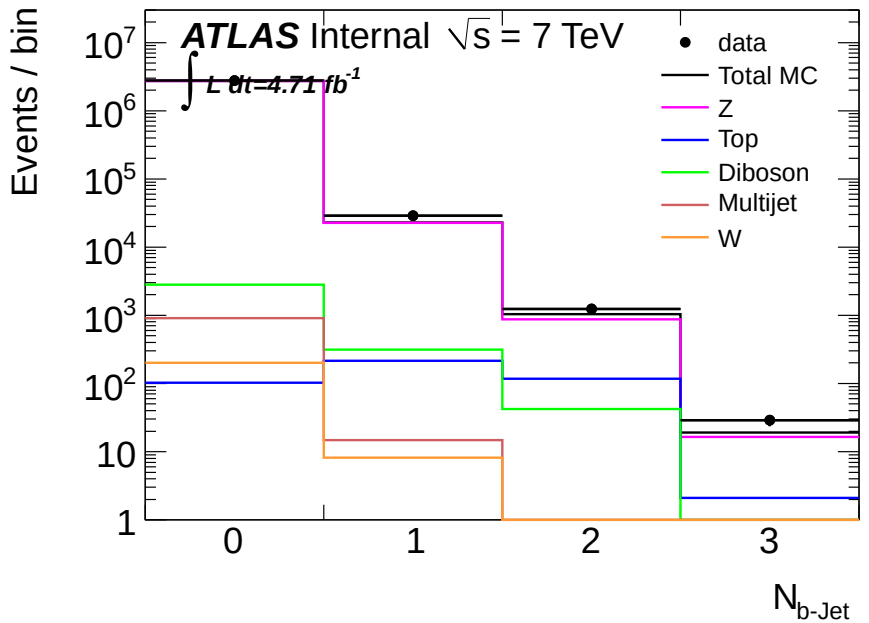
Z



ZH: *b*-tagging

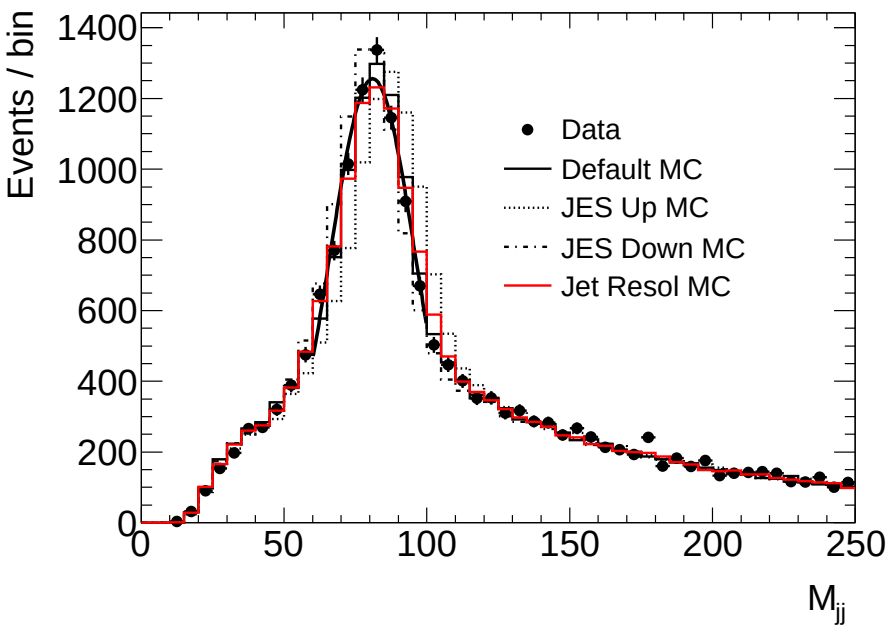
- Reasonable description of tagger weight: some discrepancy at high weight but good where cut
  - *b*-tagging corrections and systematics to be applied
  - Plots after m_{ll} and E_T^{miss} *selection*

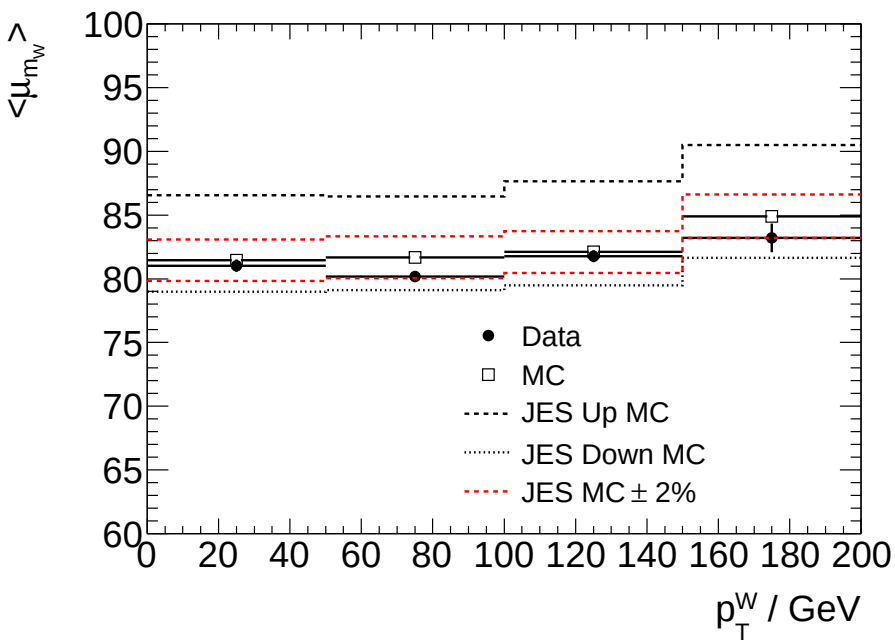




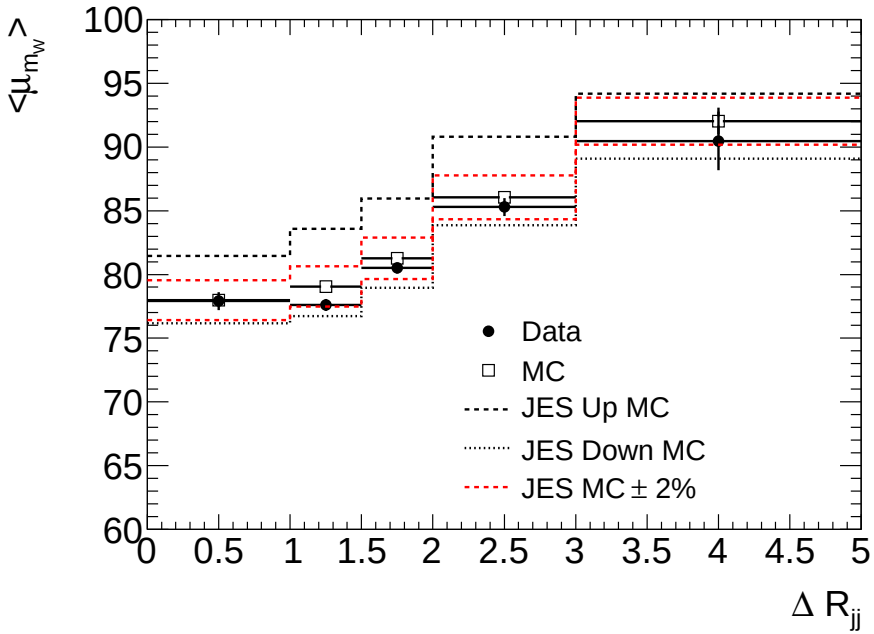
Reduce Jet Energy Error?

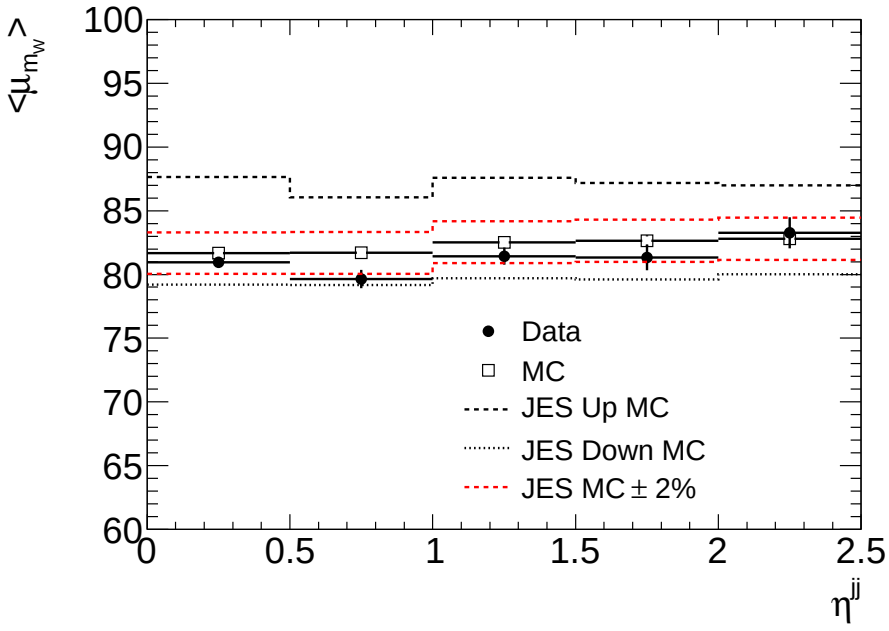
- Channel removed from combination - problem with overestimated uncertainties in limit setting. Can we reduce total jet energy systematic error(scale, pile-up, close-by, etc.) for jets in our sample?
  - Look at $M_{W\to jj}$ in $tt \to l\nu jjbb$ events
  - Mean of peak vs p_T^W. Compare with effect of total error on jet energy
  - Data agrees with MC well to within 2%





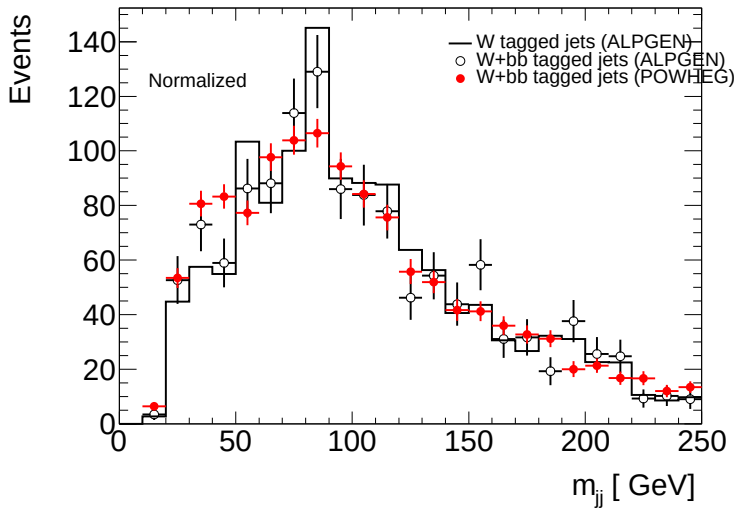
Jet Energy Scale Error





Reduced uncertainty also seems OK as a function of ΔR_{jj} and η^{jj}

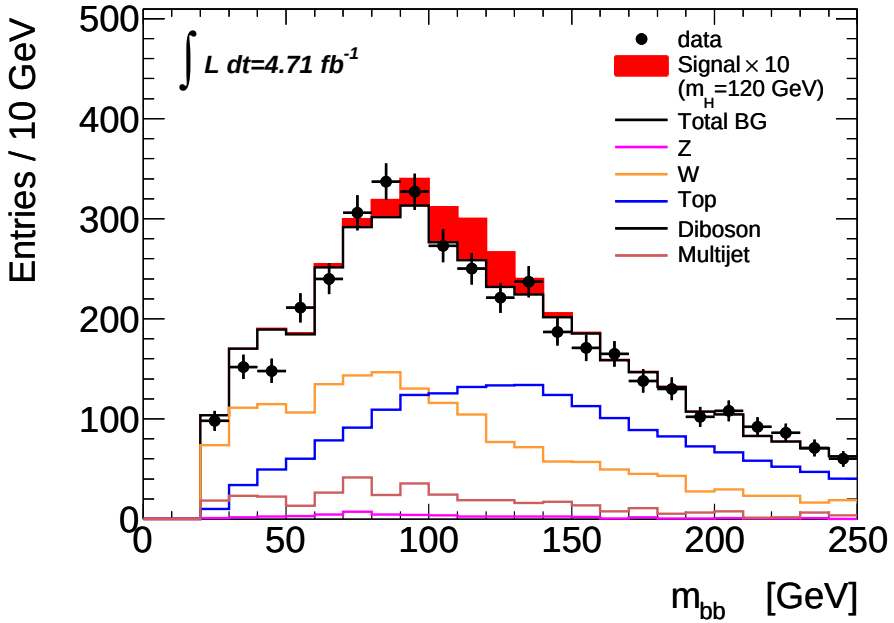
Modelling *Wbb*



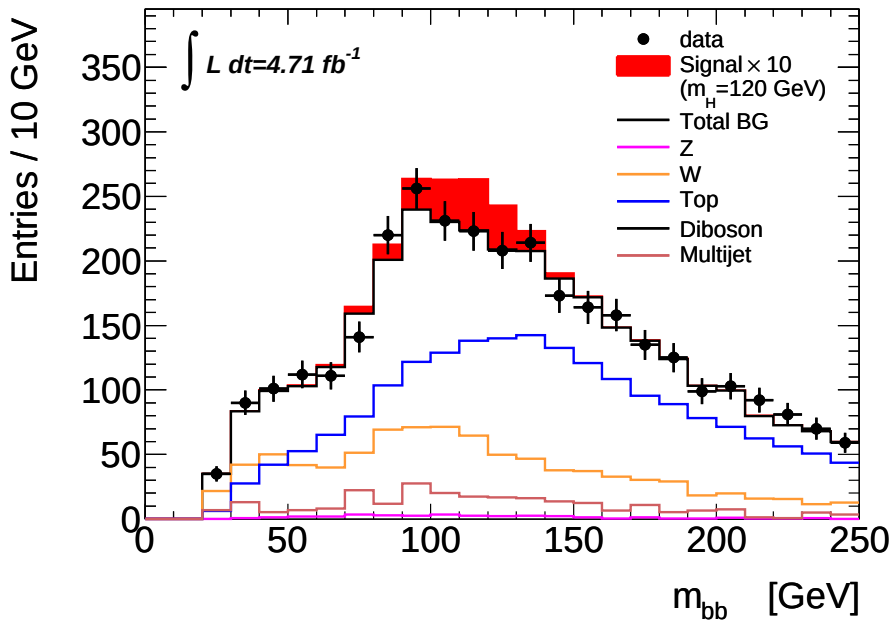
- ALPGEN W+jets OK for studying inclusive distributions but low stats
- m_{bb} composition from ALPGEN: 60% bb, 15% bl, 15% cc(cl) 10% ll
- Now have Atlfast Wbb using POWHEG samples. Tagged shapes consistent.
- But may be better to model with *Wc* and *Wl* from ALPGEN (weight untagged events with *b*-tagging factor). Model dependence for Wbb p_T dependence evaluated, but what about e.g. Wc error? Data driven method for Wbb? E.g. use looser tagged data.

WH: m_{bb}

m_{bb} for all events and with at least 1 jet $P_T^{\text{jet}} > 45$ GeV



No Cuts

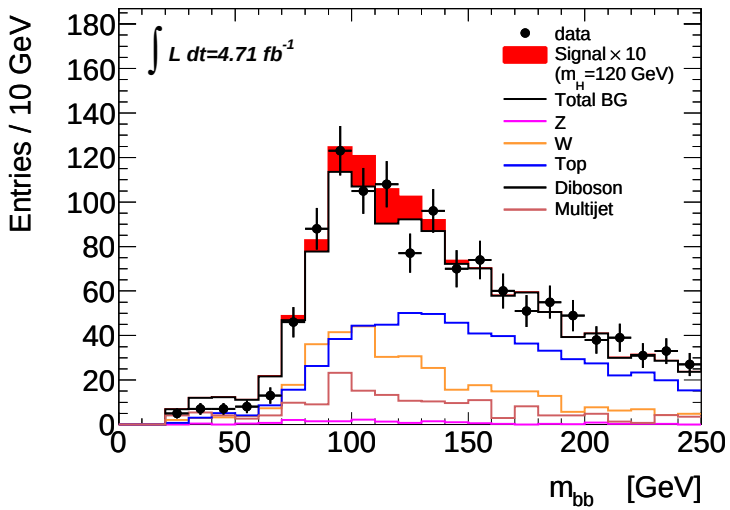


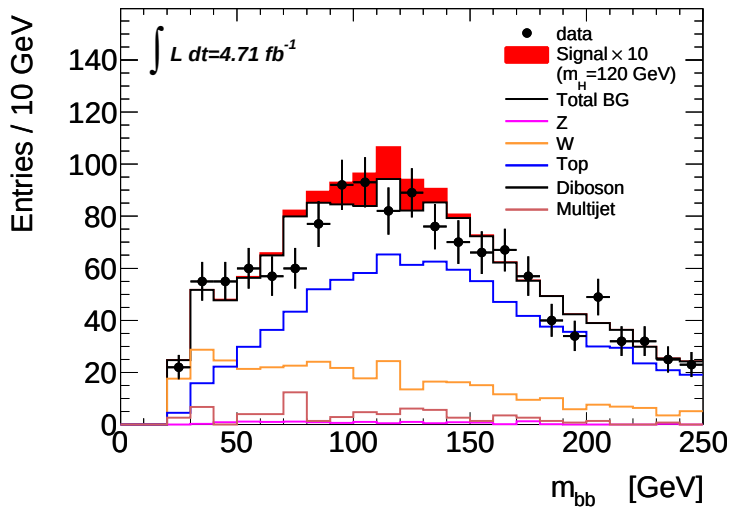
$P_T^{\text{jet}} > 45$ GeV

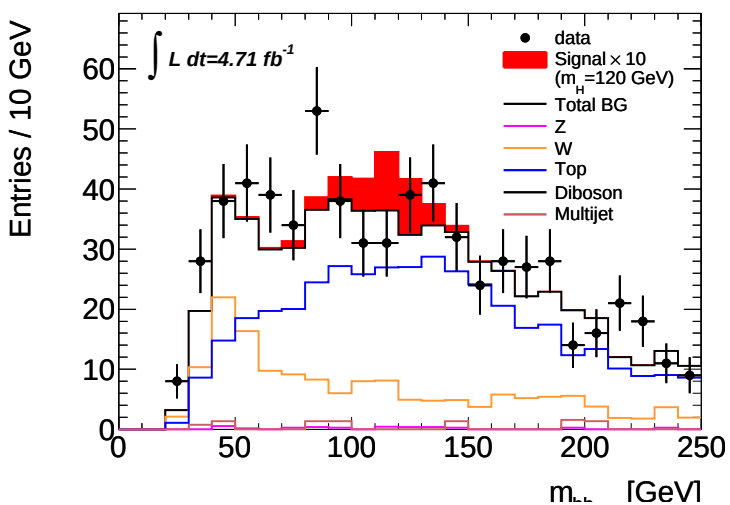
With reduced top and p_T^W bins become more sensitive to description of Wbb (particulary in $p_T^W < 50$ GeV region). Requiring 1 jet with $P_T^{\text{jet}} > 45$ GeV improves the description.

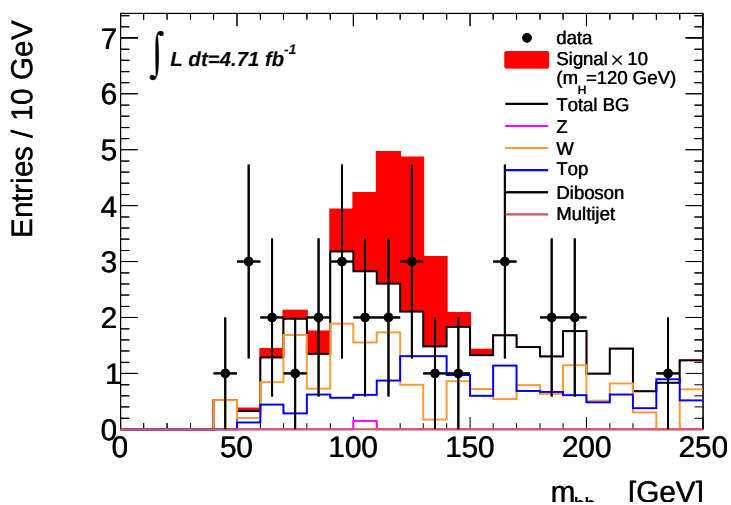
WH Dijet Mass in p_T^W bins

Increase sensitivity by splitting data into several P_T^W bins $(0 - 50 - 100 - 200 -)$



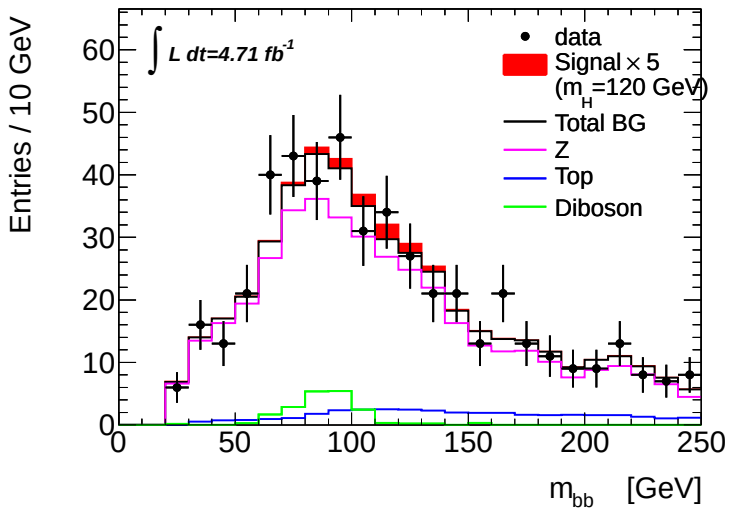


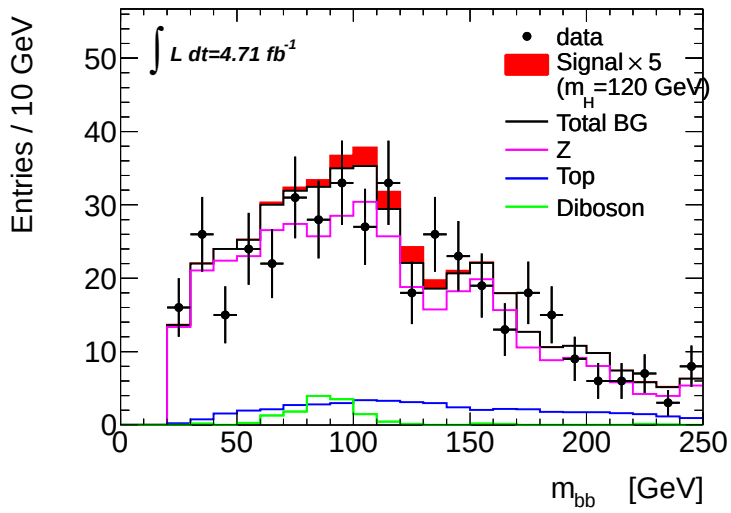


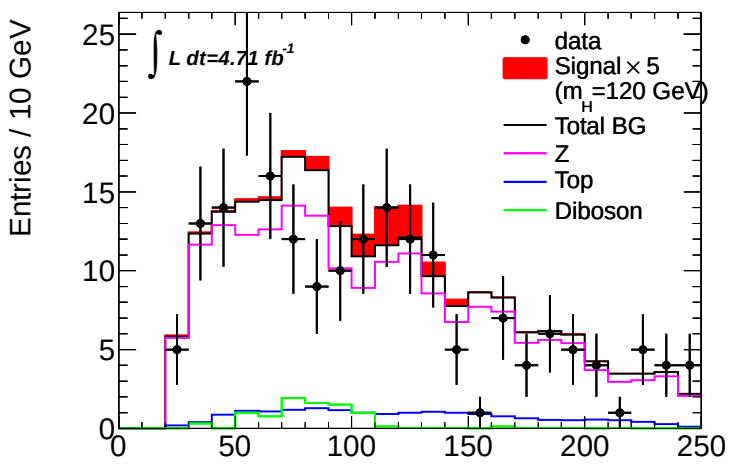


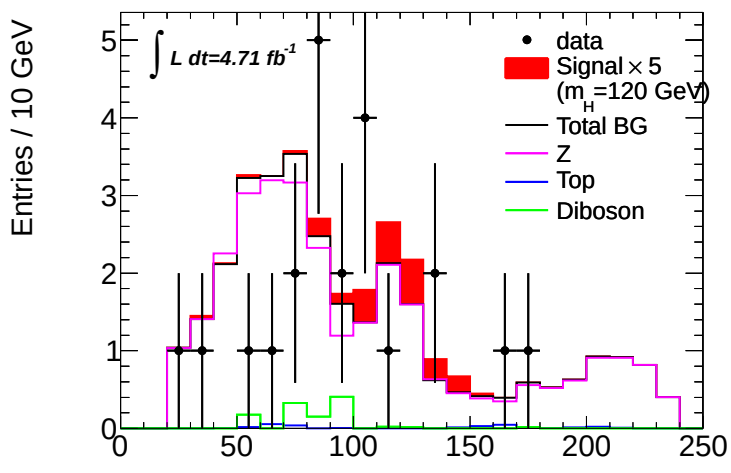
ZH Dijet Mass in p_T^Z bins

- $p_T^{\text{jet}} > 45$ GeV cut applied









Status/To do

Many done, but outstanding issues include:
Signal MC:

- Error on signal acceptance due to MC generator studied at hadron level for WH in bins of p_T^W. Being done also for ZH.
- Signal MC(now POWHEG NLO) just arrived. Need to check the $p_T > 45$ Gev cut, jet veto etc. at reconstruction level with this MC sample.

Description of Wbb:

- Number of approches: Wbb only, mix Wbb and Wc/Wl(from untagged sample with b-tagging weight applied).
- data driven method? Still being investigated.

Systematics:

- Scope to reduce total error on jet energy scale? Important for this channel.