

# First Look at 2012 $H \rightarrow ZZ \rightarrow llqq$

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30<sup>th</sup> January 2013  
 $H \rightarrow ZZ \rightarrow llqq$  Meeting

# Introduction

- First look at high mass  $H \rightarrow ZZ \rightarrow llqq$  channel in 2012 data
- Using 8 TeV HCP datasets + corrections
- Cuts absed on  $ZH \rightarrow llbb$  selection
- Framework: dump small ntuple directly from AOD after 2 leptons + 2 jets selection
  - Previously, histograms directly from AOD
  - More flexibilty: can rerun on ntuple in  $\approx 30$  mins
- Today: Outline of current status / open quesitons + first plots ...

# Event Selection

Based on: <https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/VHbbBaseLine2012>

- Single/dilepton triggers
- 1 medium ( $p_T > 25$  GeV) + 1 loose lepton ( $p_T > 10$  GeV)
  - Electrons: Medium++ and Loose++ respectively
  - MuID Muons: Use combined, segment-tagged, standalone ( $2.5 < |\eta| < 2.7$ ) and calo ( $|\eta| < 0.1$ ); only combined or segment-tagged in medium case
  - Track isolation:  $\sum p_T(\Delta R < 0.2)/p_T < 0.1$  + IP cuts
- No additional loose leptons
- $83 < m_{ll} < 99$  GeV
- $E_T^{miss} < 60$  GeV
- $\geq 2$  anti- $k_t$  4 jets with  $p_T > 20$  GeV and  $|\eta| < 2.5$
- $70 < m_{jj} < 105$  GeV (no 1.05 for  $m_{bb}$  now so prob. suboptimal)
- No  $\Delta R_{bb} > 0.7$  for now
- High mass selection (unchanged) for  $m_H > 300$  GeV:
  - $P_T^{jet} > 45$  GeV
  - $\Delta\phi_{ll} < \pi/2$  and  $\Delta\phi_{jj} < \pi/2$

# Data, Signal and Backgrounds

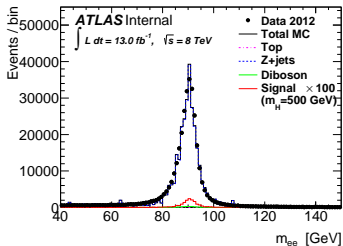
- Pre-repro Muon/Egamma streams:  $13.0 \text{ fb}^{-1}$  @  $\sqrt{s} = 8 \text{ TeV}$
- Signal: Powheg with CPS or NWA above 400 GeV (SM below)
  - Some only every 100 GeV so far
  - No samples for 7 TeV  $\rightarrow$  need to think if want to request these
- Backgrounds:
  - $Z$ +jets
    - Separate Sherpa samples for light/ $c$  and  $b$
    - Insufficient stats, particularly for light
    - New high-stats HSG5 requests pretty much there
    - Make most of stats for  $b/c$  by truth tagging
  - $t\bar{t}$ : MC@NLO
  - Single top: MC@NLO/Acer
  - Diboson ( $ZZ/WZ/WW$ ): Herwig (bugged)
  - QCD Multijet: loosened lepton template normalised to  $m_{ll}$  SBs

# Analysis Strategy

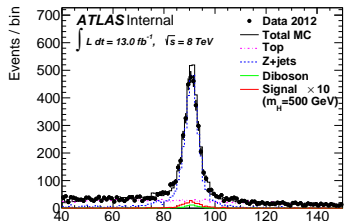
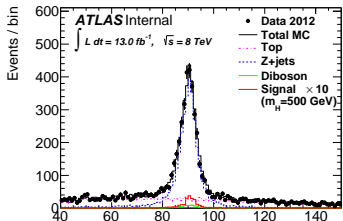
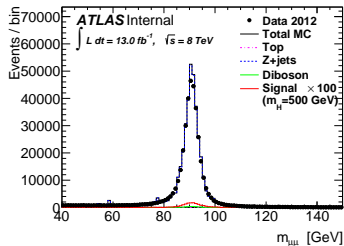
- Split into 0/1/2  $b$ -tags (using MV1 @ 70%)
  - Previously combined 0/1  $b$ -tags as untagged → still optimal?
  - Splitting allows to use truth tagging for 1  $b$ -tag
- Only 1 jet combination for now (previously multiple in untagged)
  - 2 highest  $b$ -tag weights for 2  $b$ -tag ( $m_{bb}$  resolution corrections applied)
  - Highest  $b$ -tag weight + highest  $p_T$  for 1  $b$ -tag
  - 2 highest  $p_T$  for 0  $b$ -tag
- Low stats for  $Z$ +light-jets (as will see) may mean we have to do something more data-driven in 0  $b$ -tag (depends on new samples)
- Using HCP SFs for  $Z + l/c/b$  and top from  $ZH \rightarrow llbb$  for now
  - Slightly different phase space ( $p_T^{\text{lead}} > 45$  GeV and  $\Delta R_{bb}$  cuts)
  - Look at CRs but not extracted SFs yet → Do in limit fitting?
- No  $\Delta R_{bb} > 0.7$  cut as yet: reduces sensitivity at high  $m_H$
- Look for additional Higgs bosons up to  $\geq 1$  TeV
  - Implemented recommended interference (+CPS) reweighting for signal
  - Likely need to reoptimise cuts for very high  $m_H$

- Pretty good discription of overall normalisation

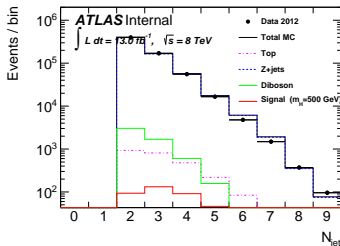
0  $b$ -tag



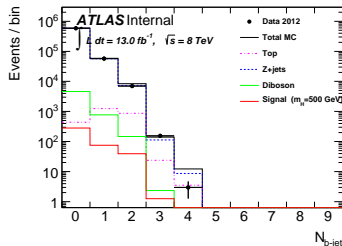
2  $b$ -tag



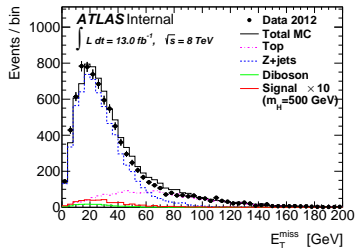
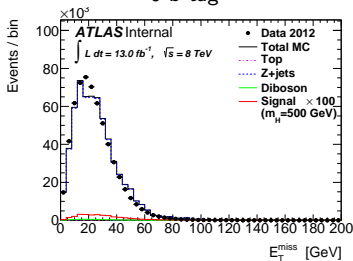
# Jet + $E_T^{\text{miss}}$



0 b-tag

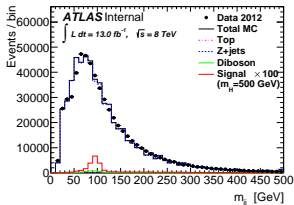


2 b-tag

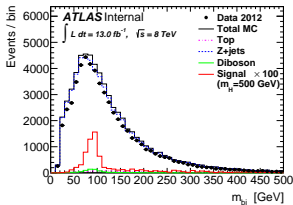


- Reasonable for low  $m_H$  (top); some discrepancy for high  $m_H$  (bottom)
  - Remember normalisation from  $ZH \rightarrow llbb$
- Starting to see lack of stats, particularly for high  $m_H$

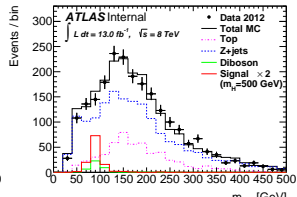
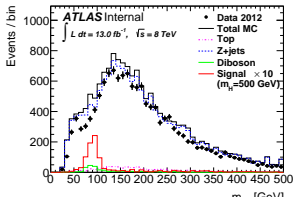
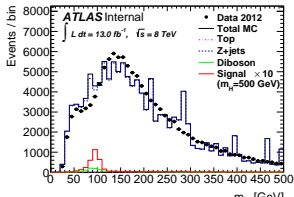
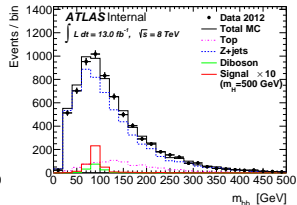
0 b-tag



1 b-tag



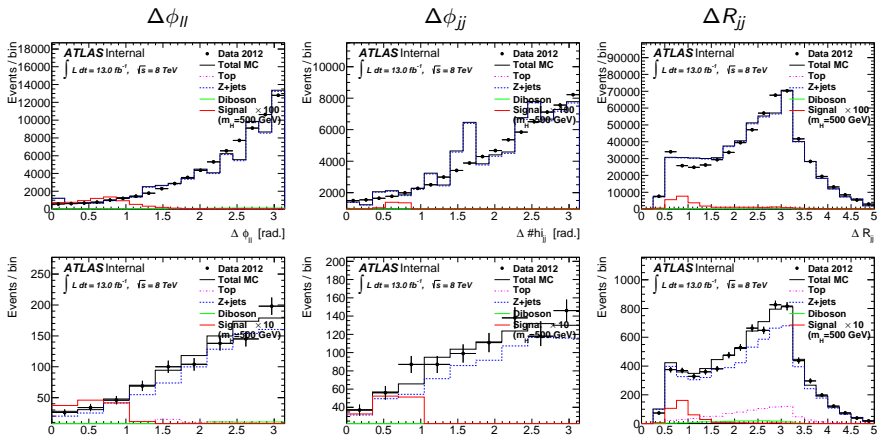
2 b-tag





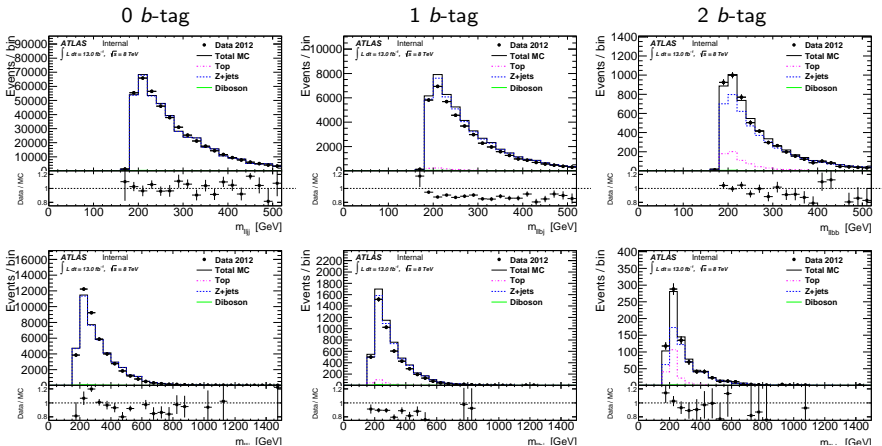
# Angular Distributions

- For 0 (top) and 2 (bottom)  $b$ -tags
- $\Delta\phi_{jj}$  not so well modelled  $\rightarrow$  Could think about using  $p_T^Z$  instead.
- $\Delta R_{jj}$  reasonably well modelled, including below 0.7.



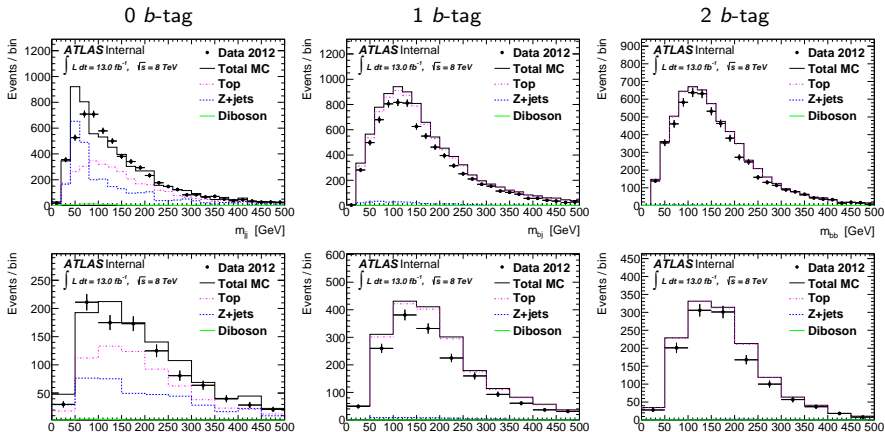
# Z+jets CR

- $m_{jj}$  sidebands for low  $m_H$  (top) and high  $m_H$  (bottom)
- Shape pretty OK and  $ZH \rightarrow llbb$  SFs not doing a bad job
  - High- $m_H$  2  $b$ -tag quite off

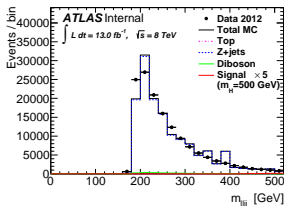
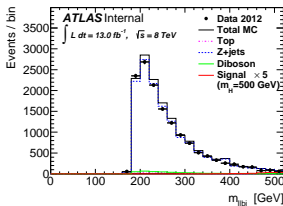
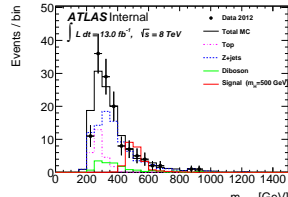
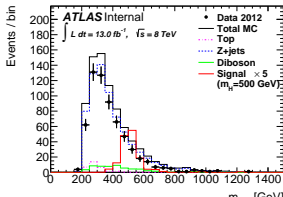
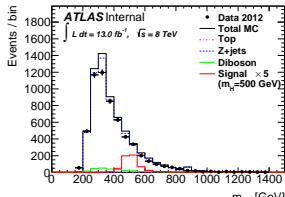
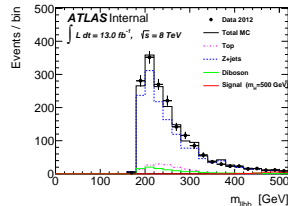


# Top CR

- $m_{ll}$  SBs ( $m_{ll} \ni 76 - 106$  GeV) with  $E_T^{\text{miss}} < 60$  GeV. Also have  $e\mu$ .
- Not so well described (esp. 1  $b$ -tag) and single SF wouldn't fix
- Significantly more  $Z$ +jets contamination in 0  $b$ -tag than previously



- Not too bad, except high  $m_H$  0  $b$ -tag but suffering from stats there
- Can also see lack of stats at high  $m_{lljj}$ 
  - Hopefully improved with new boosted samples

0  $b$ -tag

1  $b$ -tag

2  $b$ -tag


# Summary

- Things looking pretty good for a first look!
- Still need update to full dataset + updated corrections
- But would be good to have a first look at limit extraction
- Open questions:
  - MC statistics in new samples → look at asap
  - Data-driven method for background shapes, particularly in 0  $b$ -tag
  - $b$ -tag categories and jet-pair combinations
  - Rethink high  $m_H$  cuts (not so well described) and optimise selection, particularly for  $m_H > 600$  GeV
  - Do we still care about  $m_H < 300$  GeV?
  - What exactly set limits on: NWA/CPS, 2D scan (EW singlet, 2HDM)?
  - Fit CR in final limit setting?
  - What do for 7 TeV?