Search for a Heavy SM Higgs Boson in the $H \rightarrow ZZ \rightarrow llqq$ Channel at ATLAS

Carl Gwilliam

UNIVERSITY OF LIVERPOOL

(on behalf of the ATLAS Collaboration)

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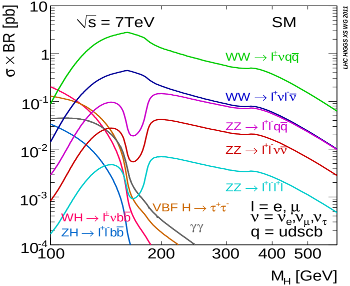
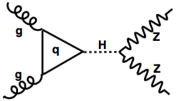
Introduction

- For a high mass Higgs ($m_H > 200$ GeV) *ZZ* and *WW* decay modes dominate
- "Golden" $H \rightarrow ZZ \rightarrow 4l$ is very clean but suffers from low branching fraction
- $H \rightarrow ZZ \rightarrow llqq$ has larger background but benefits from significantly higher BF

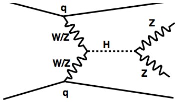


- Present the sensitivity of the ATLAS detector in this channel for $1.04\ \mathrm{fb}^{-1}$ at $\sqrt{s} = 7$ TeV in the range $200 \leq m_H \leq 600$ GeV

gluon fusion (dominant)



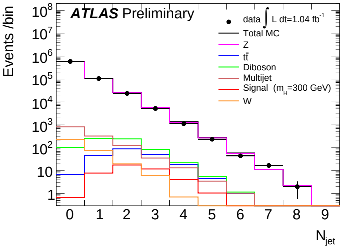
vector boson fusion (10-20%)

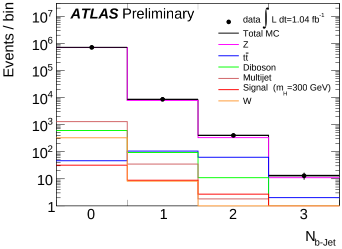


Signal modelled by NLO POWHEG MC generator interfaced to PYTHIA

Selection

- Leptonic Z candidate
  - 2 good isolated leptons (e/μ) with $p_T > 20$ GeV and $|\eta| < 2.5$
  - $76 < m_{ll} < 106$ GeV
- $E_T^{\mathrm{miss}} < 50$ GeV
- Hadronic Z candidate
  - ≥ 2 jets with $p_T > 25$ GeV & $|\eta| < 2.5$
  - $70 < m_{jj} < 105$ GeV
- At high m_H the Z bosons from the H decay are boosted $\rightarrow$ Additional cuts:
  - $P_T^{\mathrm{jet}} > 45$ GeV
  - $\Delta\phi_{ll} < 90°$ and $\Delta\phi_{jj} < 90°$

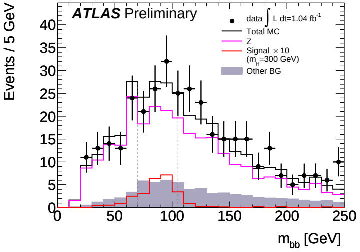




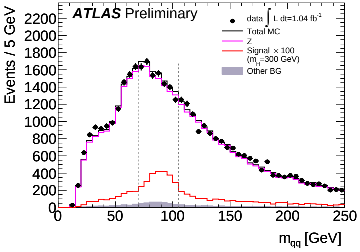
Selection (2)

- Split into two samples based on identification of jets from *b* decays
  - Based on a combination of secondary vertex reconstruction and impact parameter significance of tracks within jet to primary vertex $\rightarrow \epsilon_b \approx 70\%$

- "Tagged"
  - Events with exactly 2 *b*-jets
  - Form invariant mass from the 2 tagged jets



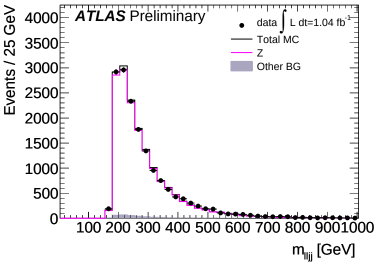
- "Untagged"
  - Events with < 2 *b*-jets
  - Form invariant mass from all combinations of 3 leading jets



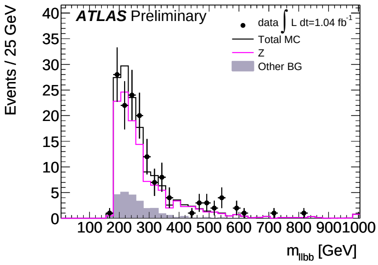
Z+jets Background

- Z+jets is the dominant background and is constrained using the m_{qq} sidebands
  - $40 < m_{qq} < 70$ GeV and $105 < m_{qq} < 150$ GeV
- Shape well described by ALPGEN but normalisation ≈ 10% high
  - Consistent between tagged and untagged samples
- Use control region to determine scale factors to normalise MC

low m_H untagged

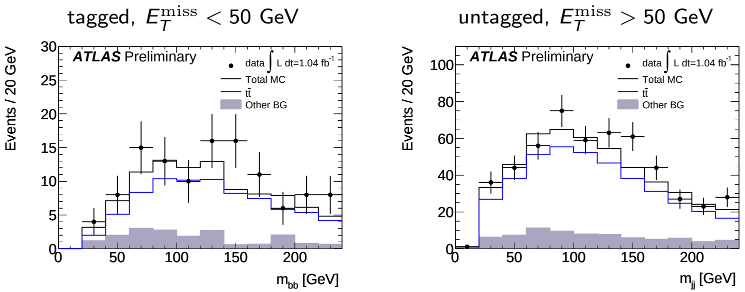


low m_H tagged



Top Background

- Top is an important background, particularly in the tagged sample
- Cross-checked using the sidebands of the m_{ll} distribution
  - $60 < m_{ll} < 76$ GeV and $106 < m_{ll} < 150$ GeV
  - For untagged sample also reverse E_T^{miss} cut
- Good description by MC@NLO Monte Carlo within errors

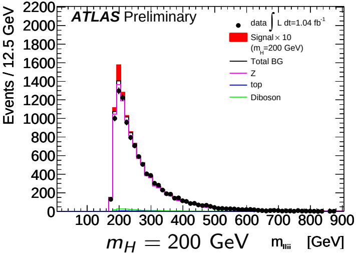


- Other backgrounds: QCD multijet production, also determined from data, and ZZ/WZ production, which are taken from MC@NLO

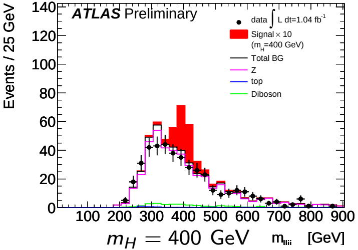
Results

- No significant excess over SM background observed

untagged

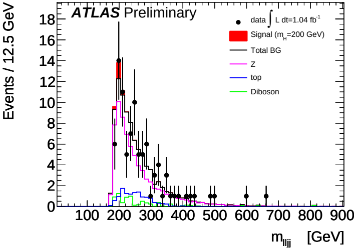


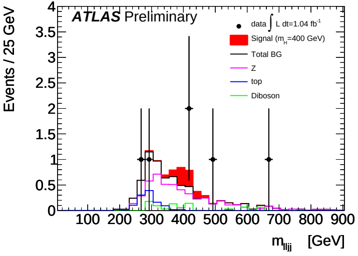
$m_H = 200$ GeV



$m_H = 400$ GeV

tagged



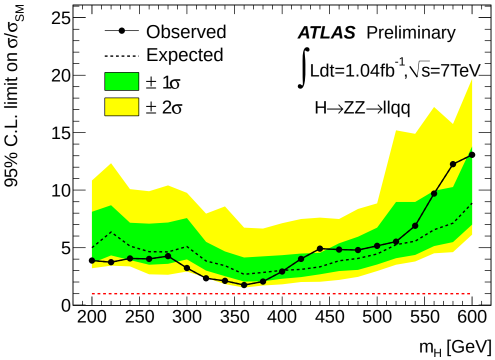


Systematic Uncertainties

- Signal
  - Cross section uncertainty: $15-20\%$ for $gg \to H$ & $3-9\%$ for $qq \to qqH$
  - Acceptance uncertainty by comparing POWHEG and PYTHIA
- Background normalisation
  - Z+jets uncertainty from comparing low and high m_{qq} sidebands $\to$ 1.4%/8.1% for low/high m_H untagged sample and 18% for tagged sample
  - 100% uncertainty for QCD multijet and 50% for W+jets
  - Theoretical uncertainty for top (9%) and ZZ/WZ (11%)
- Background shape
  - Z+jets: comparison between ALPGEN and PYTHIA
  - ZZ: comparison between MC@NLO and PYTHIA
- Luminosity: 3.7% (where normalisation not determined from data)
- Detector-related uncertainties on efficiency, E or p scale & resolution
  - Tagged: dominated by uncertainty on b-tagging efficiency (15-25%)
  - Untagged: Largest contribution is jet E scale (up to $\approx 5\%$) but jet E resolution, E_T^{miss} and b-tagging uncertainties also important

Exclusion Limits

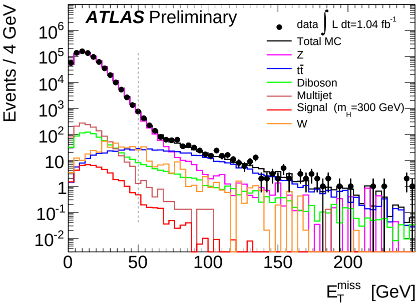
- Combined exclusion limit on σ/σ_{SM} from tagged and untagged samples at 95% CL using *CLs* method
  - Use modified frequentist formalism with profile likelihood test statistic
  - The likelihood compares the full m_{lljj} distribution bin-by-bin to expected background or sum of expected signal and background
- Limit approaching σ_{SM} with $\int Ldt = 1.04\ \mathrm{fb}^{-1}$
- Exclude $1.7 \times \sigma_{SM}$ at $m_H = 360$ GeV
  - Correspnding expected limit is $2.7 \times \sigma_{SM}$
- Combined high mass $H \to ZZ/WW$ channels sensitive to σ_{SM}

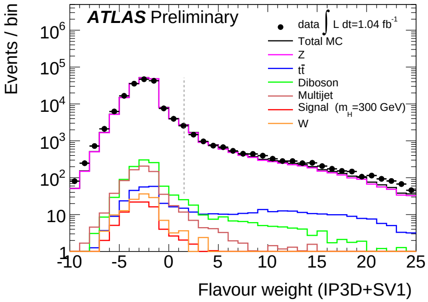


Conclusion

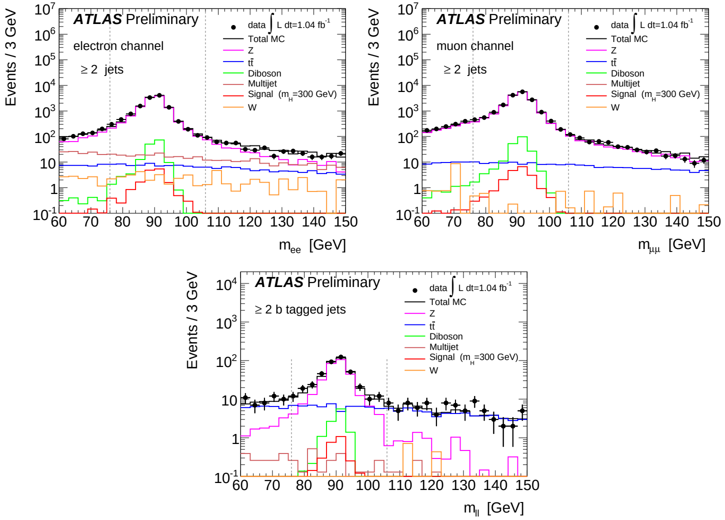
- Have presented the sensitivity of the ATLAS detector in the $H \to ZZ \to 2l2q$ channel with $1.04\ \mathrm{fb}^{-1}$ at $\sqrt{s} = 7$ TeV
- No evidence for an excess above SM expectation observed
- Sensitivity ranges between 1.7 and 13 times SM cross section in the range $200 \leq M_H \leq 600$ GeV, with maximal sensitivity at 360 GeV
- Channel contributes significantly to the combined exclusion limit in the high mass range
- LHC and ATLAS are performing well so expect improved sensitivity very soon

E_T^{miss} and *b*-tagging



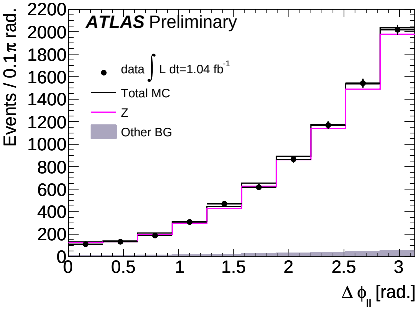


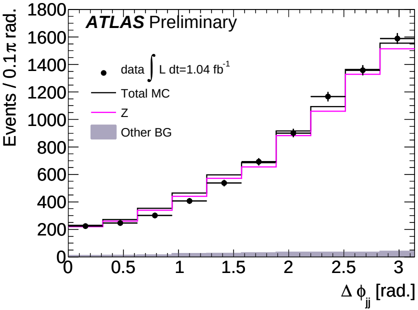
m_{ll}



ATLAS Preliminary
electron channel
≥ 2 jets
data ∫ L dt=1.04 fb⁻¹
Total MC
Z
tt̄
Diboson
Multijet
Signal (m_H=300 GeV)
W
Events / 3 GeV
m_ee [GeV]
ATLAS Preliminary
muon channel
≥ 2 jets
m_μμ [GeV]
ATLAS Preliminary
≥ 2 b tagged jets
m_ll [GeV]

$\Delta\phi_{ll}$ and $\Delta\phi_{jj}$





Results Table

ATLAS Preliminary

The expected number of signal and background candidates for the Higgs boson search for 1.04 fb^{-1} in the $H \to ZZ \to \ell\ell qq$ channel, along with the observed numbers of candidates in data. Numbers with uncertainties are ± (stat.) ± (syst.), respectively, and the statistical component assumes Gaussian uncertainties.

	Untagged		Tagged	
	Low-m_H	High-m_H	Low-m_H	High-m_H
Z+jets	10352. ± 61. ± 155.	423. ± 12. ± 30.	72. ± 1. ± 15.	4.9 ± 0.2 ± 1.0
W+jets	10. ± 2. ± 5.	0.2 ± 0.2 ± 0.1	0.0 ± 0.0 ± 0.0	0.0 ± 0.0 ± 0.0
Top	40. ± 1. ± 6.	3.0 ± 0.3 ± 0.6	13. ± 1. ± 3.	1.1 ± 0.2 ± 0.3
Multijet	64. ± 3. ± 64.	2.0 ± 0.5 ± 2.0	0.3 ± 0.2 ± 0.3	0.0 ± 0.0 ± 0.0
ZZ	107. ± 4. ± 15.	8.5 ± 1.1 ± 1.8	6.9 ± 1.0 ± 2.0	0.79 ± 0.23 ± 0.30
WZ	143. ± 3. ± 29.	17. ± 1. ± 3.	0.5 ± 0.2 ± 0.3	0.03 ± 0.02 ± 0.01
Total background	10718. ± 62. ± 173.	453. ± 13. ± 31.	92. ± 1. ± 15.	6.9 ± 0.4 ± 1.2
Data	10495	419	91	6
Signal				
$m_H = 200$ GeV	33. ± 1. ± 6.		2.2 ± 0.2 ± 0.6	
$m_H = 300$ GeV		7.0 ± 0.3 ± 1.5		0.58 ± 0.08 ± 0.19
$m_H = 400$ GeV		9.8 ± 0.3 ± 1.8		1.1 ± 0.1 ± 0.3
$m_H = 500$ GeV		5.5 ± 0.1 ± 1.0		0.63 ± 0.04 ± 0.19
$m_H = 600$ GeV		2.5 ± 0.1 ± 0.5		0.28 ± 0.02 ± 0.08