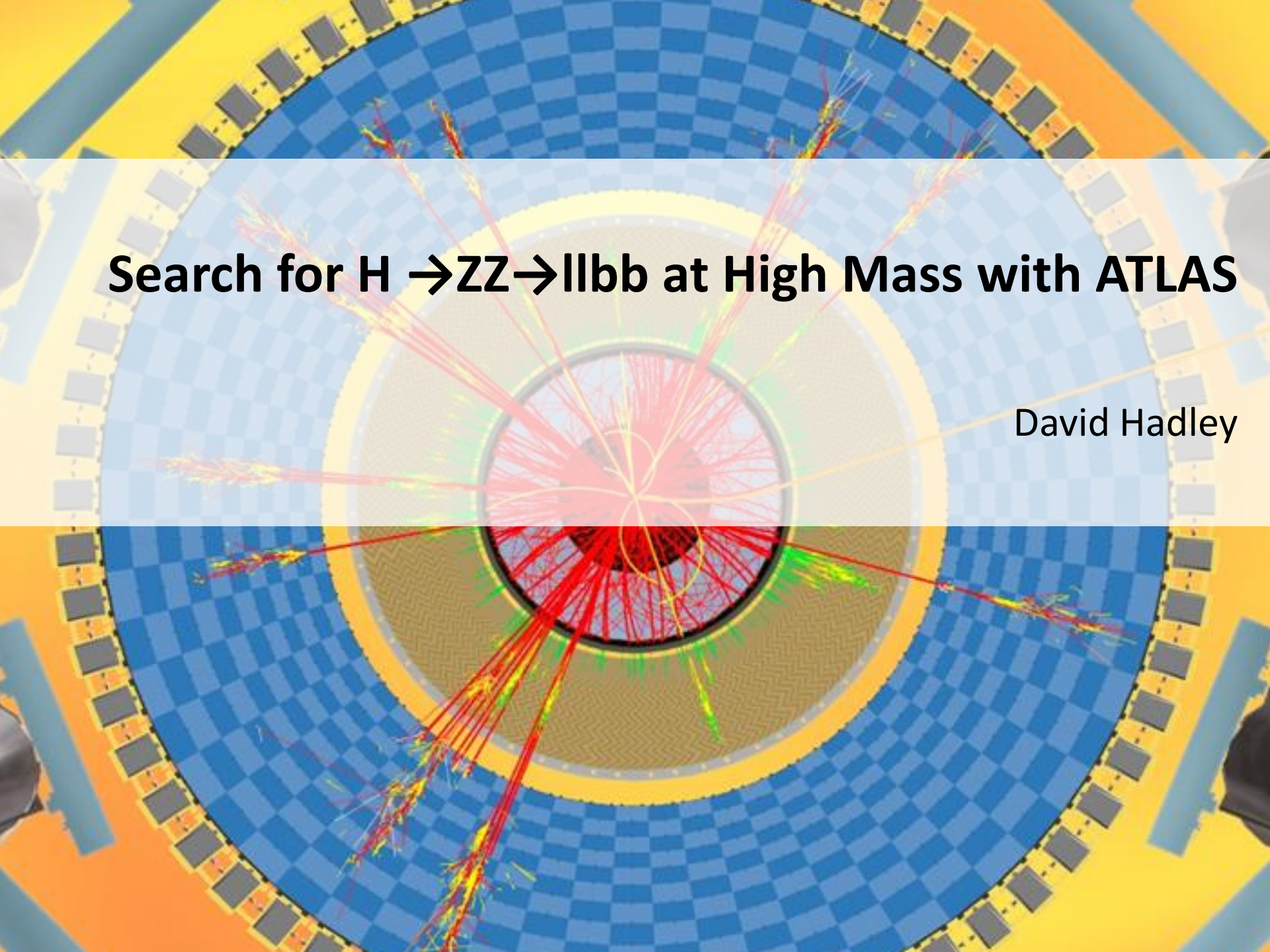
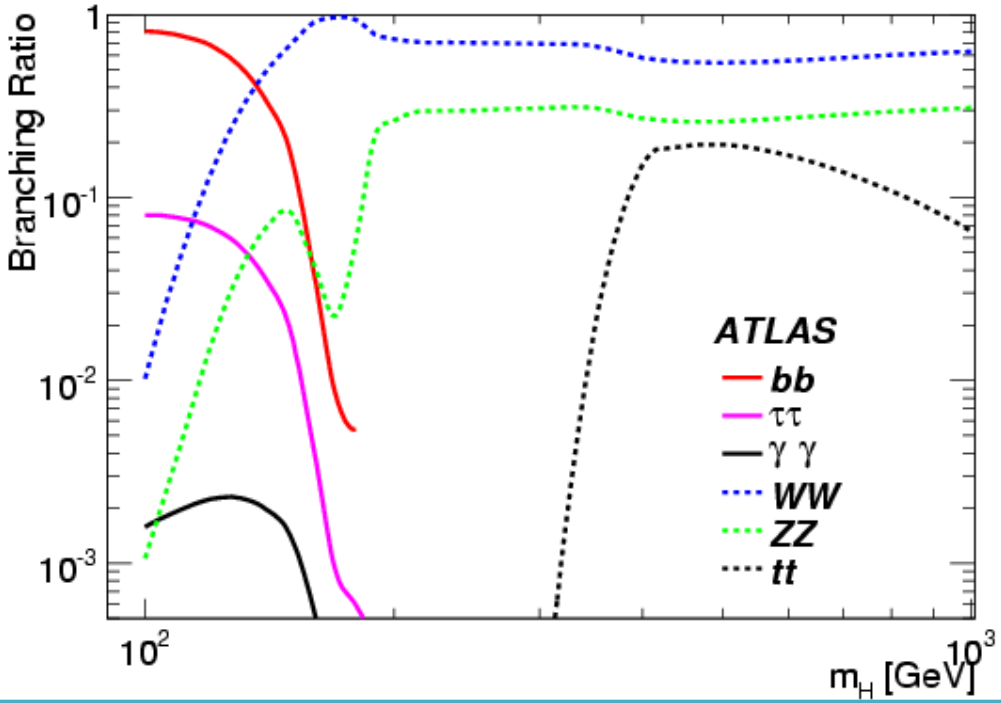


Search for H →ZZ→llbb at High Mass with ATLAS

David Hadley

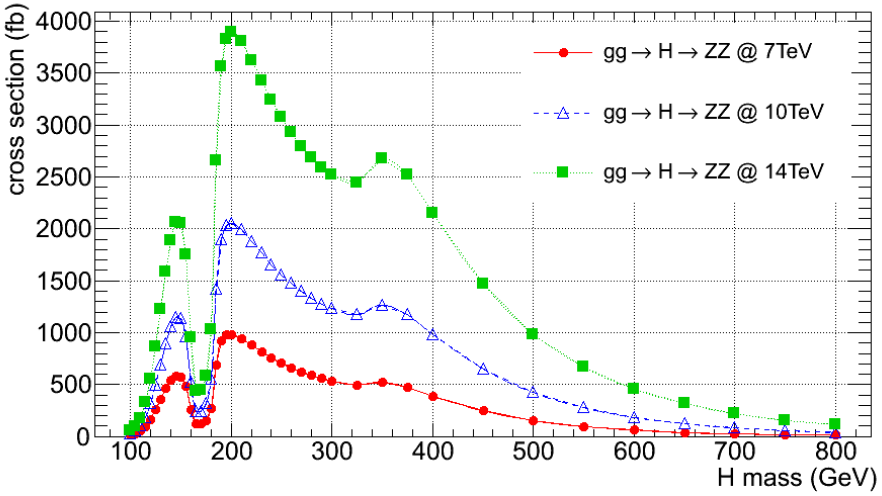
Motivation

- The main high mass channel is H→4l.
- H→ZZ→llbb has higher backgrounds but also higher branching fraction.
  - BR(ZZ→llbb) / BR(ZZ→4l) = 4.5
- Useful at high masses to add to significance of discovery/exclusion.
- An independent channel to cross-check results.



Signal and background cross sections

- Significant backgrounds to contend with.
- MCFM NLO signal cross-section × BR(ZZ):



- Signal ≈ 4pb in best case Higgs mass at 14TeV.
- Main backgrounds are:
  - Z (≈ 60nb @ 14TeV)
  - ttbar (≈ 900pb @ 14TeV)
  - ZZ (≈ 15pb @ 14TeV)
- Many orders of magnitude difference in cross-sections.

Event Selection

Reconstruction

- Electrons (p_T>15GeV,η<2.5, “medium” selection).
- Muons (p_T>15GeV, η<2.5).
- Jets (p_T>20GeV, η<2.5).
- Overlap Removal.

Lepton Selection

- 2 electrons (at least one p_T>20GeV, and at least one “tight”).
- or 2 muons (p_T>15GeV).

Jet Selection

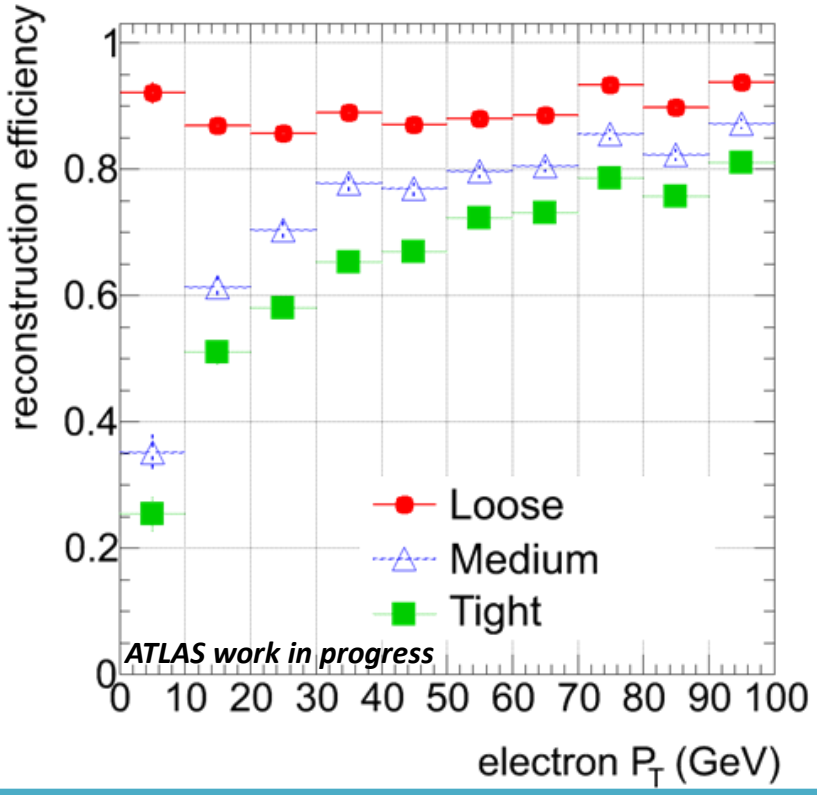
- 2 b-tagged jets
- Allow a 3rd anti-b-tagged jet.
- $\Delta\phi$(bb) cut (at high mass).

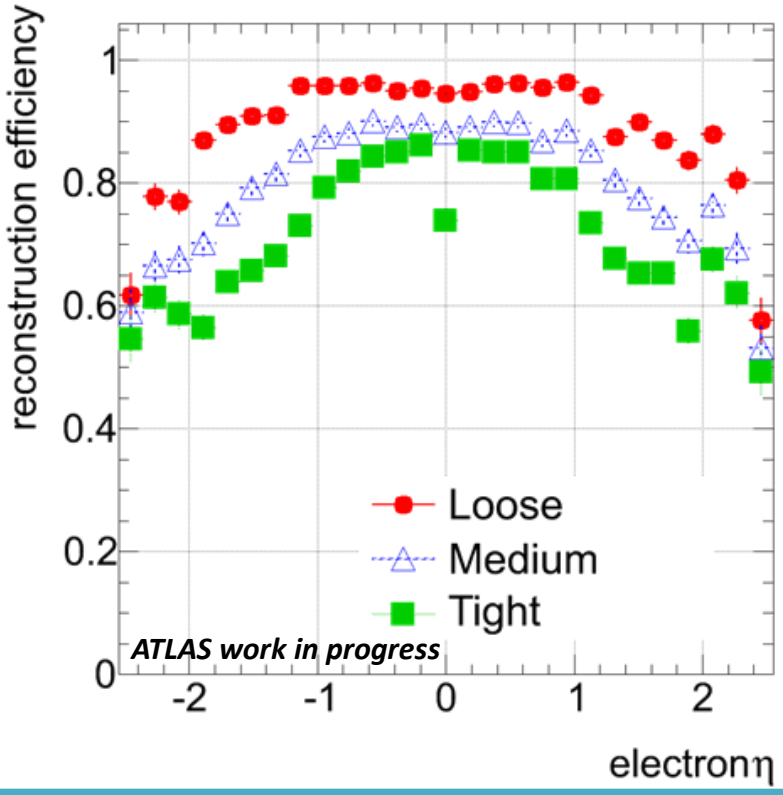
Z Mass Reconstruction

- 86GeV < M_{ll} < 96GeV.
- 70GeV < M_{bb} < 110GeV.

Electron Reconstruction

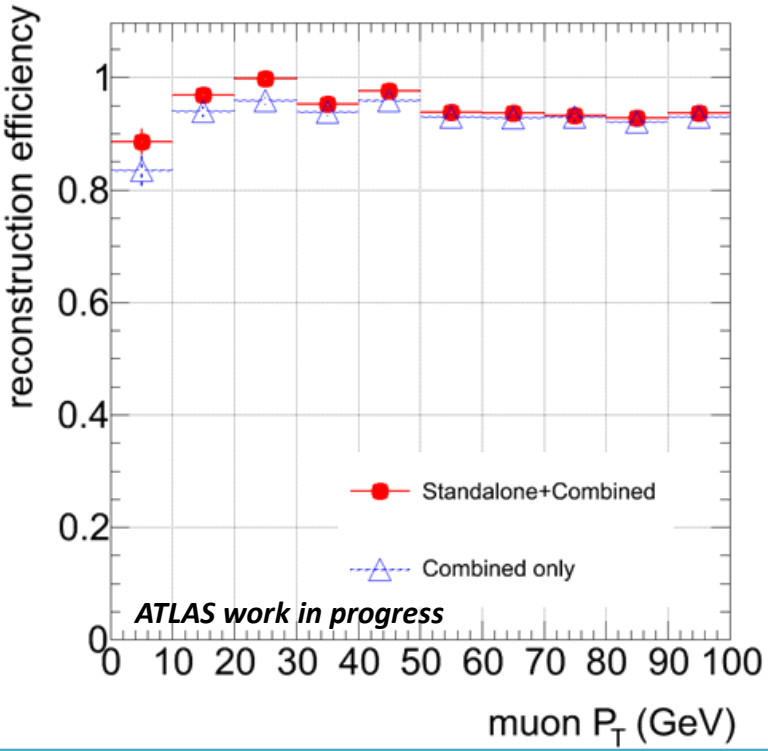
- Electron identification cuts on many variables:
  - Hadronic leakage and calorimeter shower shape
  - Track quality cuts and track-cluster matching
  - Transition radiation tracker.
  - Three standard sets of cuts used in ATLAS:
    - Loose (best efficiency), medium, tight (best background rejection).

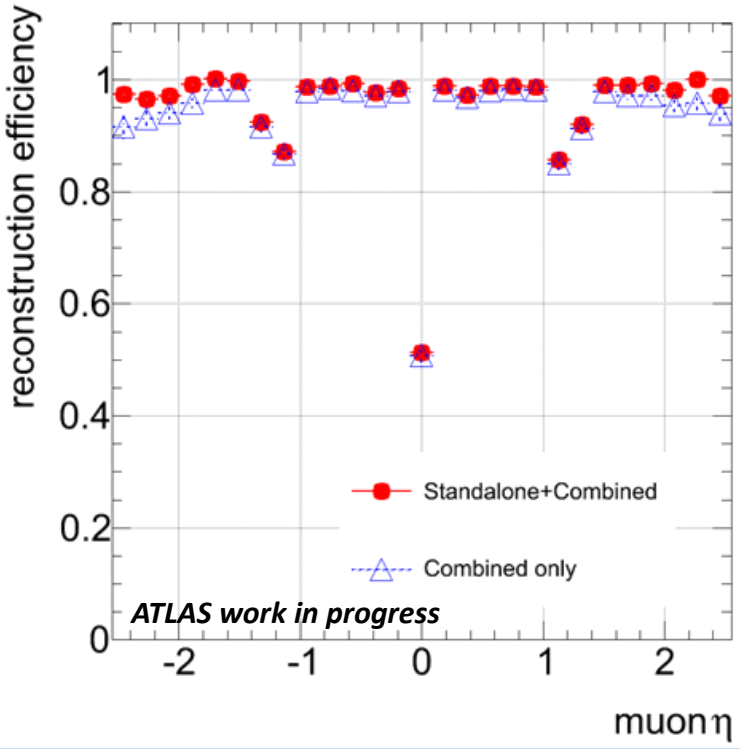




Muon Reconstruction

- Several muon reconstruction algorithms:
  - Match muon spectrometer tracks to interaction point (stand-alone).
  - Combine muon spectrometer tracks with inner detector tracks (combined muons).





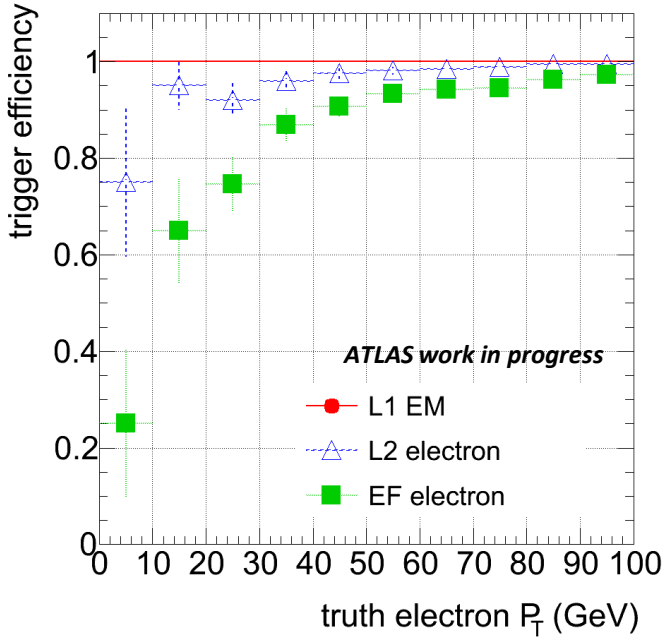
Trigger Efficiency

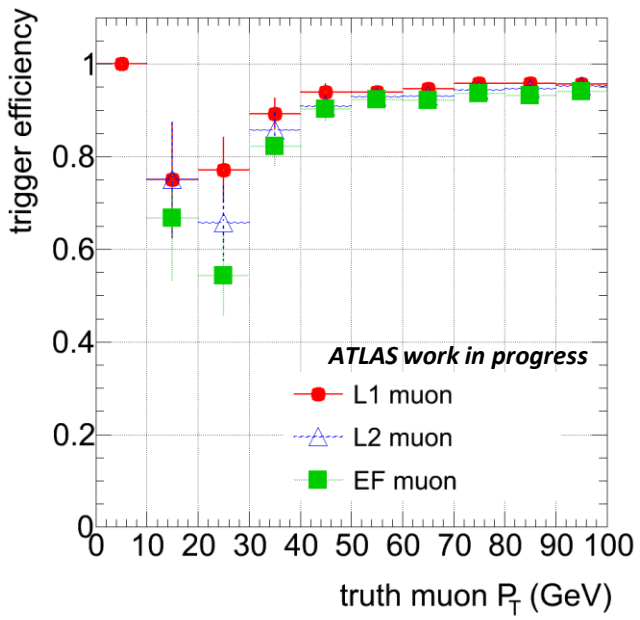
- An efficient lepton trigger is essential for this study.

- ATLAS trigger consists of:
  - Level 1 (L1) hardware based trigger.
  - Level 2 (L2) and Event Filter (EF).

- Efficiencies have been checked against the primary electron/muon triggers in the 10^{31} trigger menu.

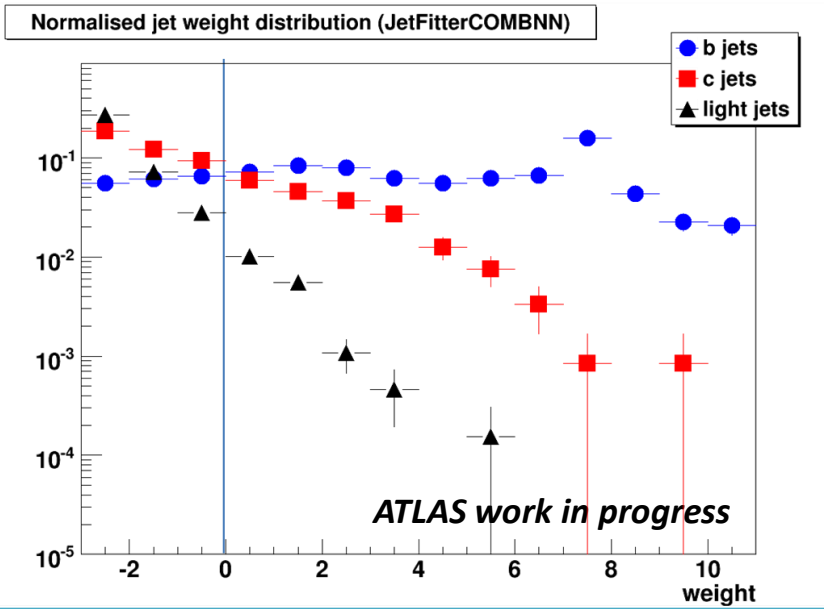
- Trigger efficiency after event selection ≈98%.





Jet Selection

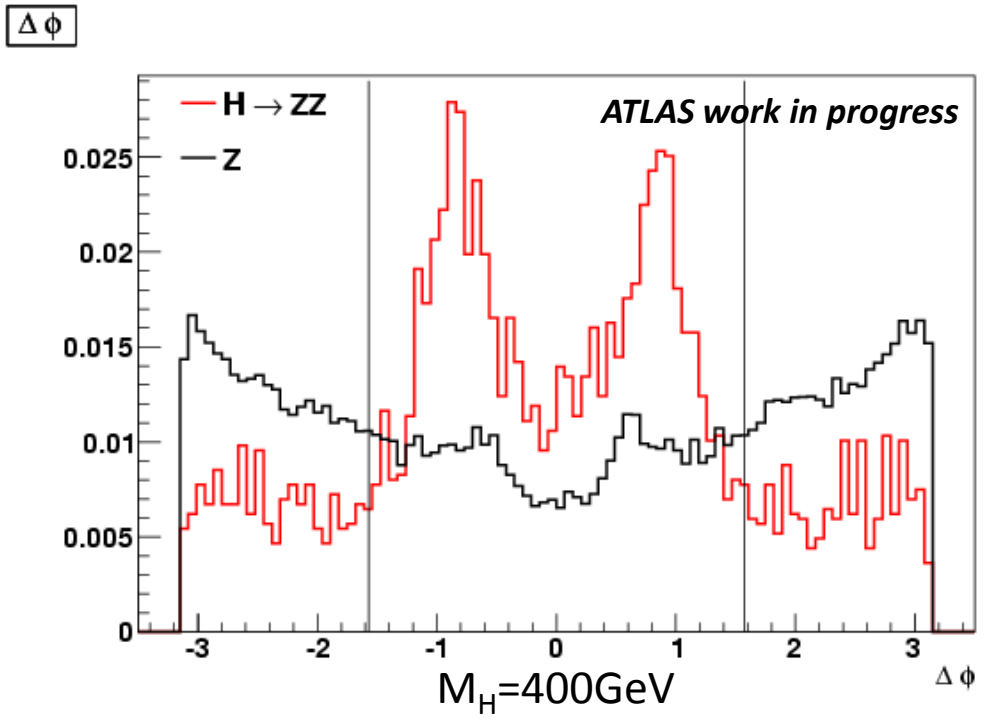
- B-tagging required to reduce the large backgrounds.
- Several b-tagging algorithms used in ATLAS.
- High precision tracking used to identify:
  - Secondary vertices.
  - Tracks with high impact parameter.
- Use advanced b-tagging algorithm to estimate expected performance when tracking and flavour tagging are fully commissioned.



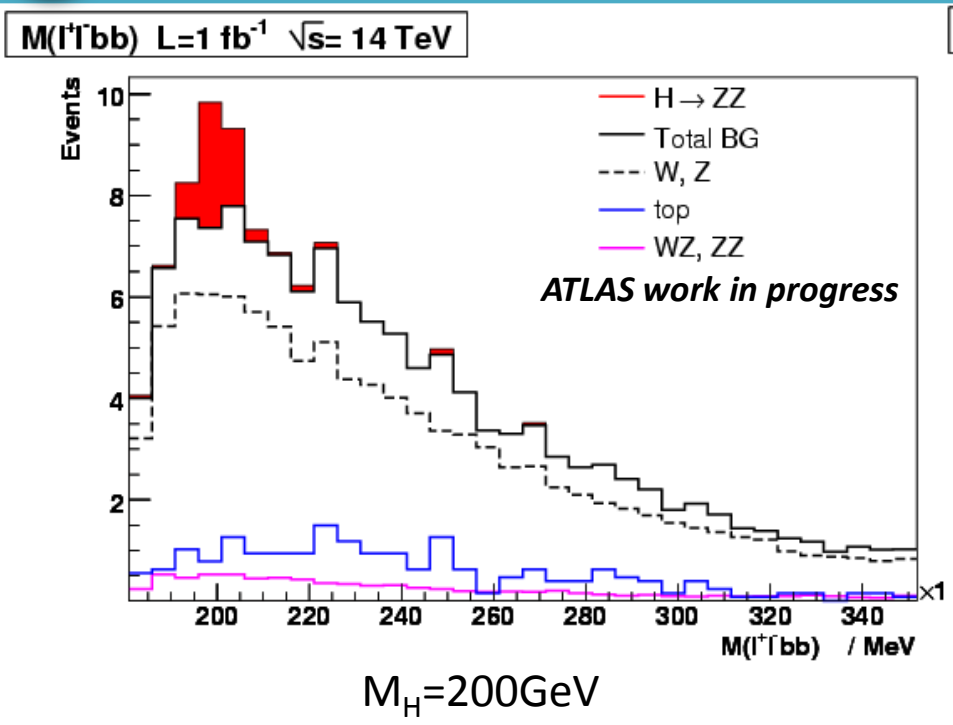
- Require 2 jets with weight > 0.
- Excellent rejection of light jets.

Jet Selection

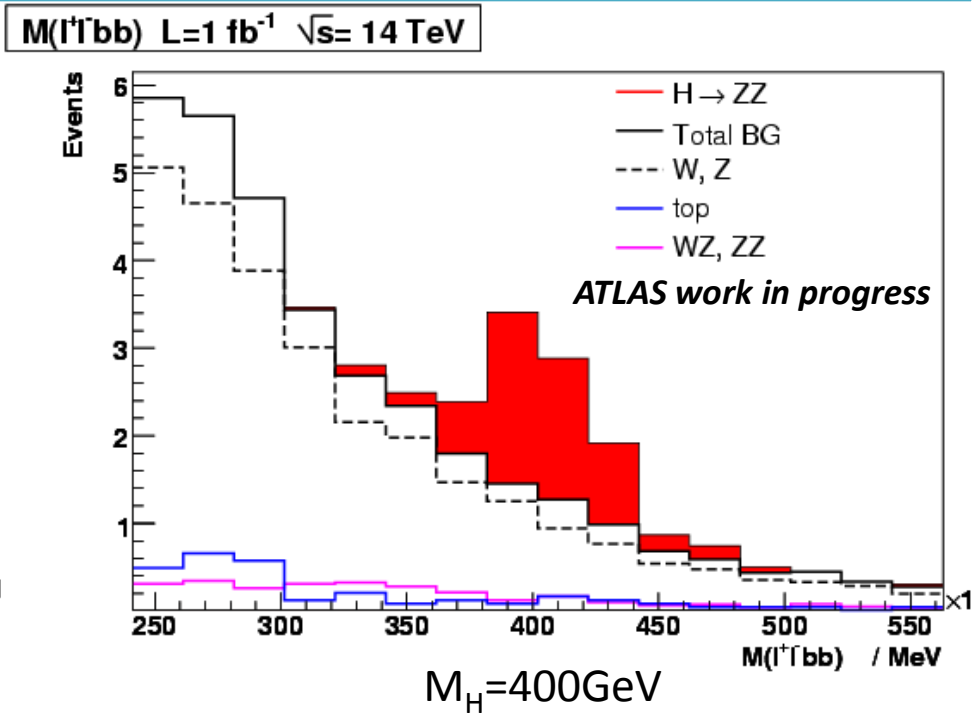
- At high Higgs mass, Z are boosted.
- b-jets are correlated in ϕ.
- Require $\Delta\phi<\pi/2$ for $M_H \geq 300$GeV.



Invariant Mass



M_H=200GeV

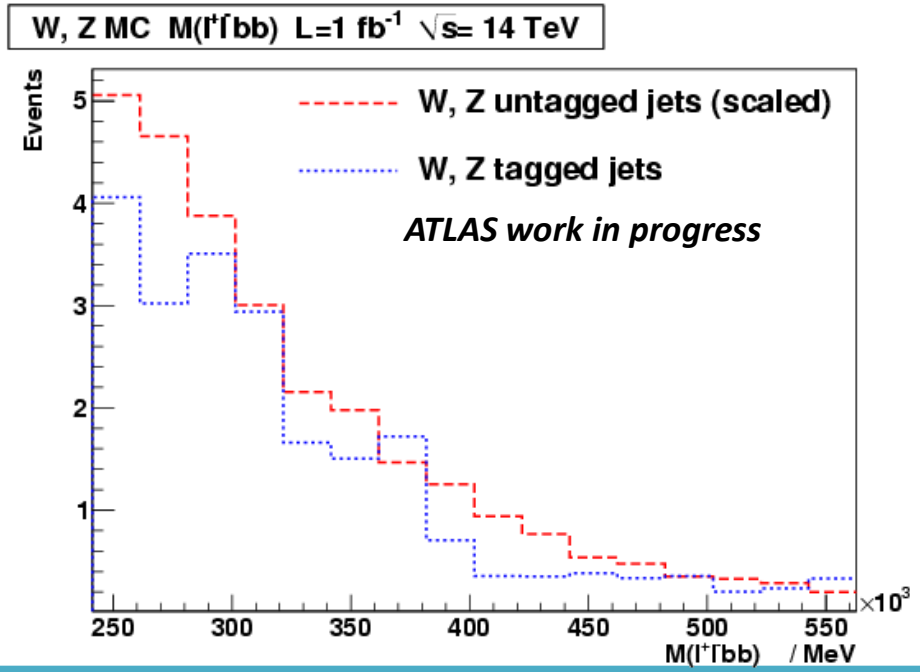


M_H=400GeV

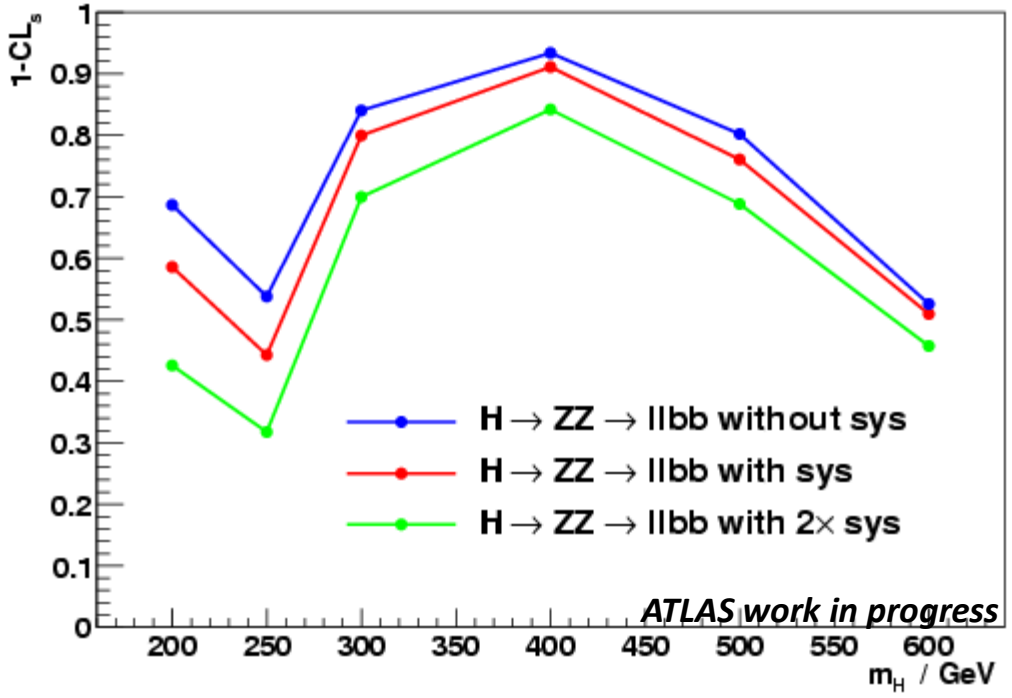
- Signal and background after event selection for 2 mass points. Scaled to $1fb^{-1}$.
- Simple scaling of jet energy to Z mass to improve resolution.
- Low event yields.
- Good signal to background ratio at higher masses.

Systematic Uncertainties

- Estimate expected confidence limits using the CL_S method
  - Calculated with mclimit (T.Junk, Nucl. Instrum. Methods A 434, 435).
- Normalisation uncertainties of signal and backgrounds.
  - 10% normalisation error on signal and backgrounds.
  - Luminosity 5% (all channels correlated).
  - b-tag efficiency uncertainty 5% (all channels correlated).
- Estimate of shape uncertainty is taken from un-tagged mass distribution.

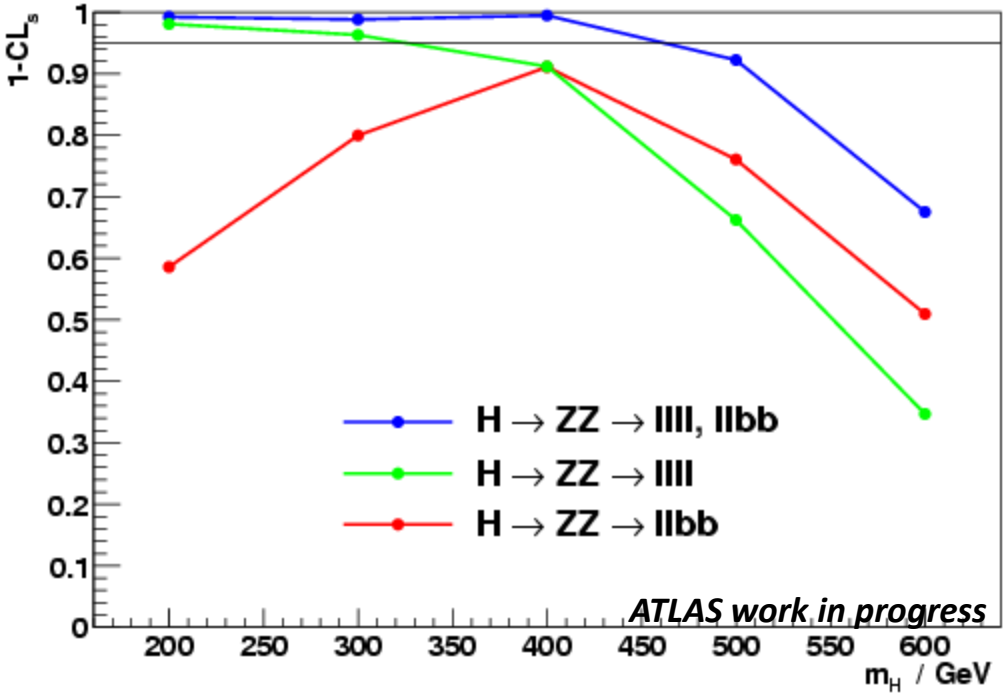


Expected Exclusion Confidence Limits



- Expected exclusion limits with 1fb^{-1}. without systematics, with systematics:
  - 10% signal+background normalisation
  - 5% luminosity
  - 5% b-tagging
  - shape error from untagged distribution.
- Good exclusion power even with pessimistic systematics.

Expected Exclusion Confidence Limits



- Expected exclusion limits with 1fb^{-1} compared with 4l results.
- 4l includes only statistical errors.
- Competitive with 4l, especially at very high mass.
- Improved sensitivity when the channels are combined.

Summary

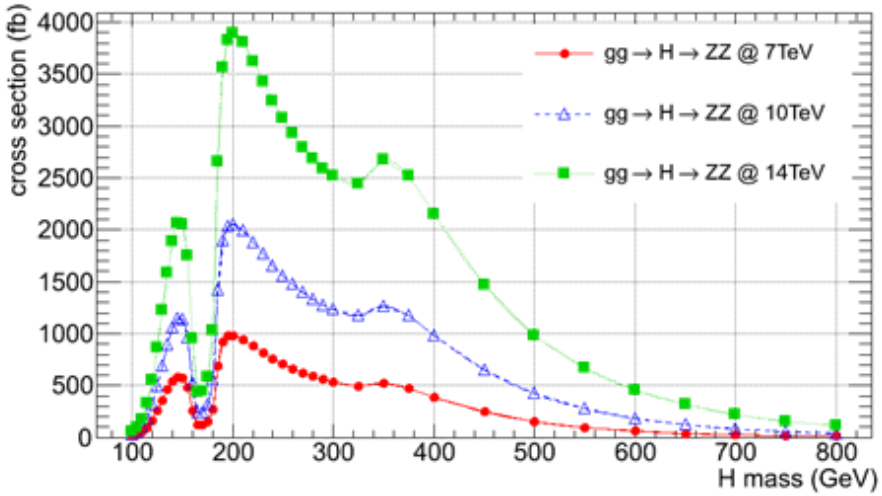
- Results show that this can be a useful channel to add significance to a discovery/exclusion especially at high mass (M_H>300GeV).
- Systematics are small compared to statistics (at 1fb^{-1}).
- Results shown are for 14TeV. Repeat of analysis for 7TeV is underway.
- Work on going to improve/optimise the analysis.
- Focus is on high mass where this channel is most useful.

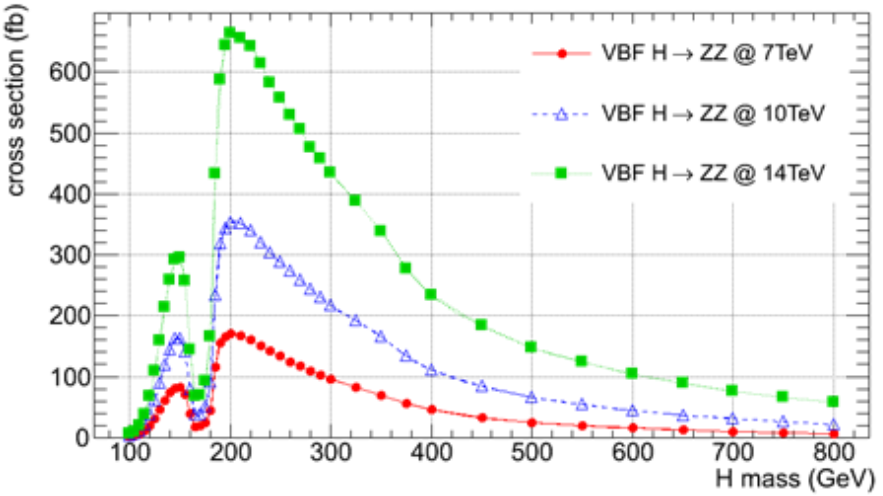
Backup Slides

Cut Flow

Cut	Signal Efficiency (M_H=400)	Z->ee rejection	Z->mumu rejection	ttbar Rejection
All	100	1	1	1
2e	0.36	3	-	22
2mu	0.42	-	2	46
MET cut	0.64	3	2	86
Zll mass	0.60	3	2	378
Bjet	0.18	7037	5758	1663
Zbb mass	0.15	18095	14729	6414

Cross-section X Branching Fraction





- MCFM cross-section X branching fraction for gluon-gluon fusion (left) and vector-boson fusion (right) for 7TeV, 10TeV and 14TeV.
- gg is the dominant production mode.