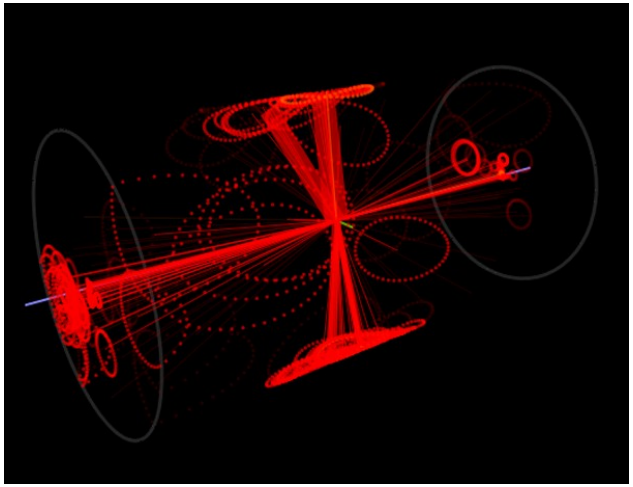
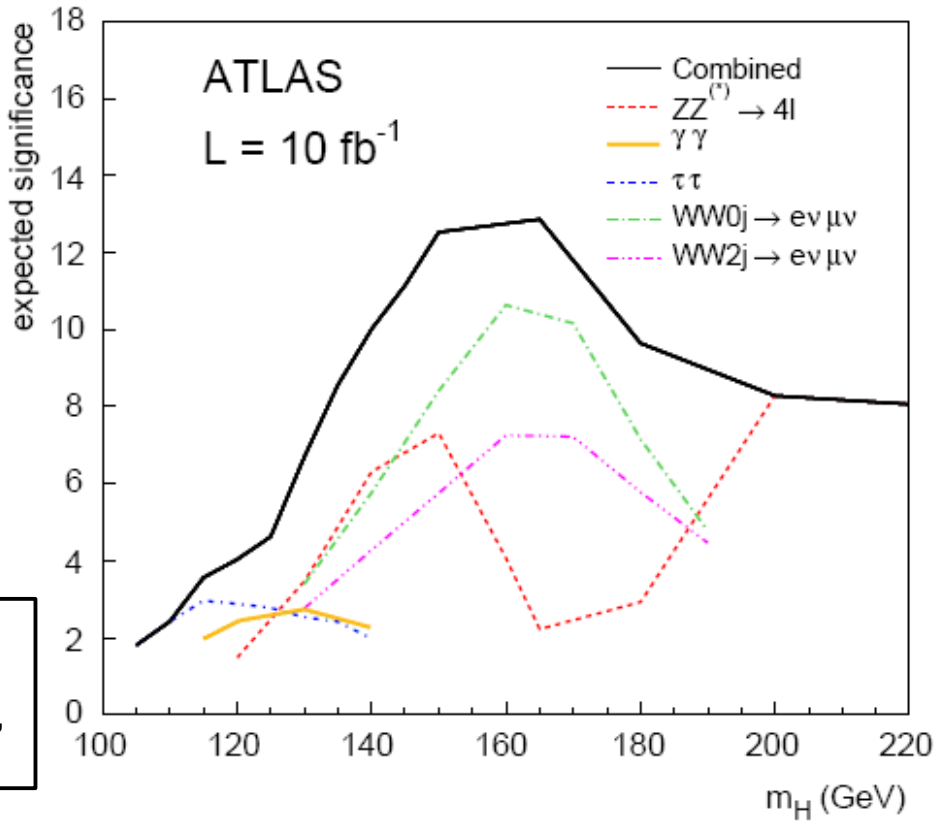
Jet Substructure as a new Higgs Search
at the LHC

Adam Davison



ATLAS Standard Model Higgs Search

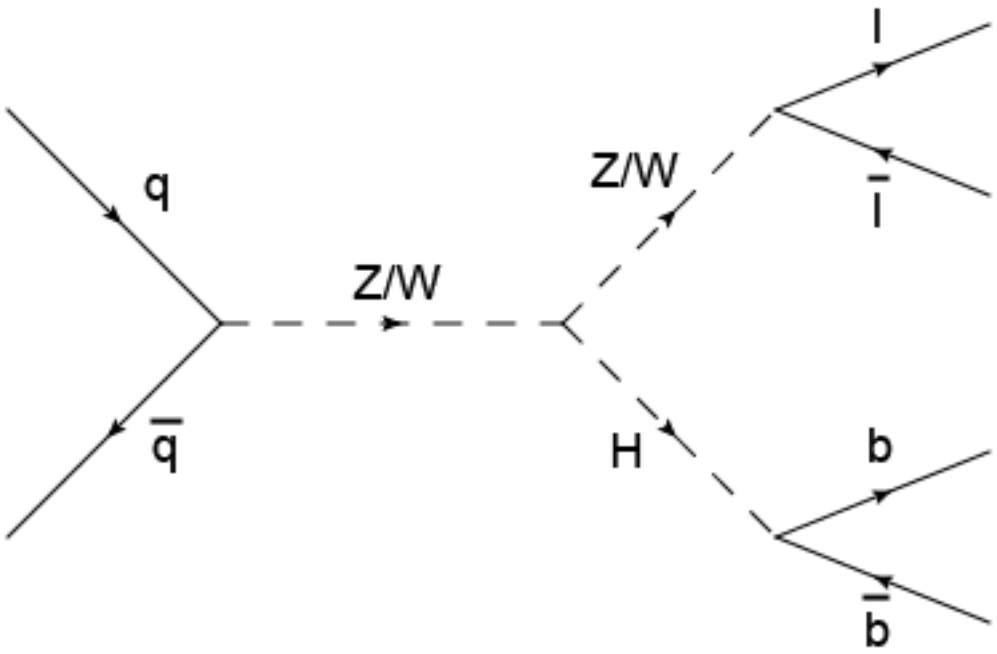
- A low mass Higgs is still the most problematic
- Electroweak fits still favour lowest mass (115GeV)
- In this region H→bb branching ratio is ~70%
- Yet H→ττ dominates ATLAS discovery potential...



ATLAS Collaboration,
Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics,
CERN-OPEN-2008-020, Geneva, 2008.

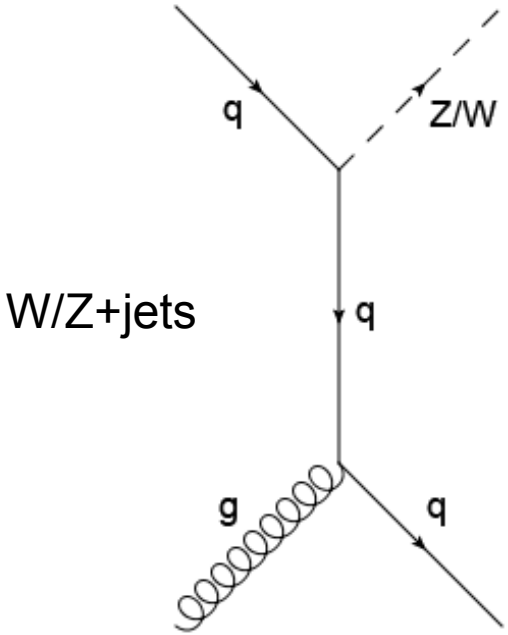
WH/ZH

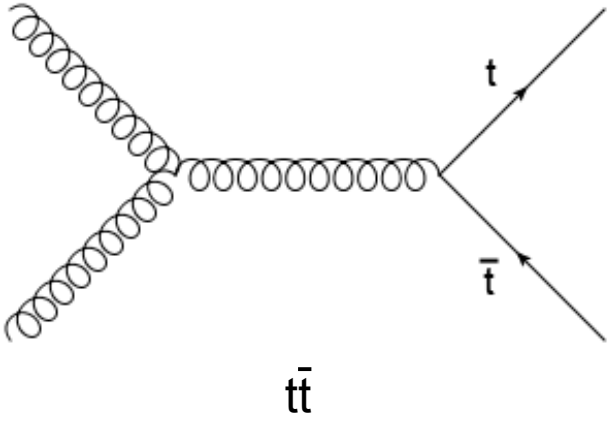
- Signal is H→bb in association with W or Z
- W or Z decays to leptons



WH/ZH

- Backgrounds are anything that produces a W or Z and a hadronic system that can simulate H→bb
- Such as:





WH/ZH at ATLAS

- Last ATLAS study
- Major issues with systematics, control of background shapes
- “very difficult ... even under the most optimistic assumptions”

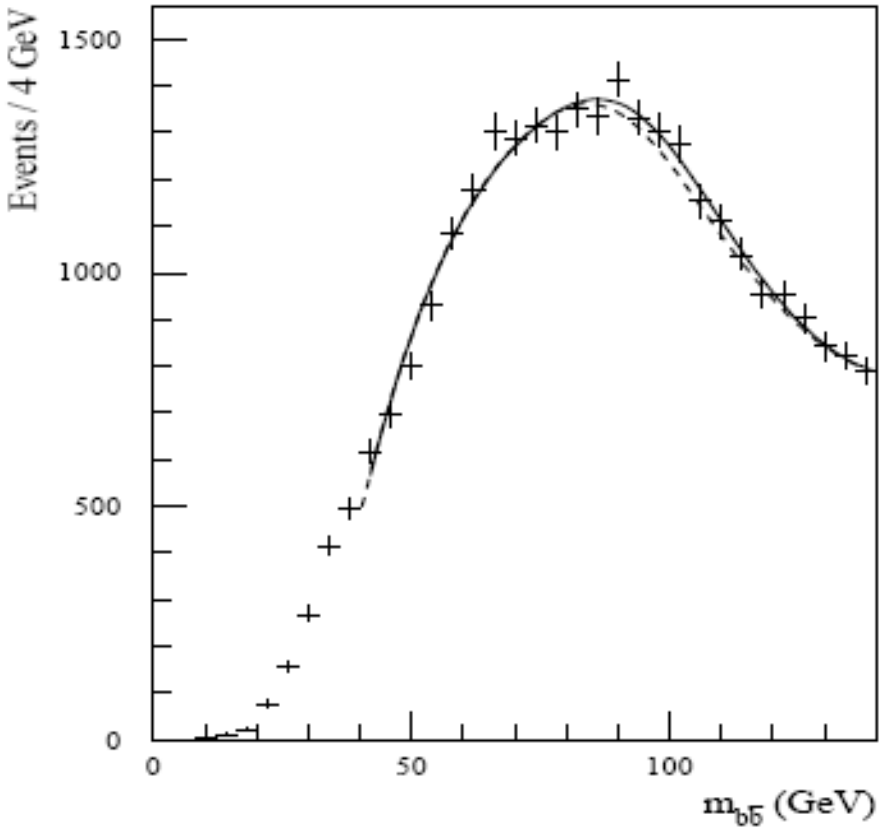
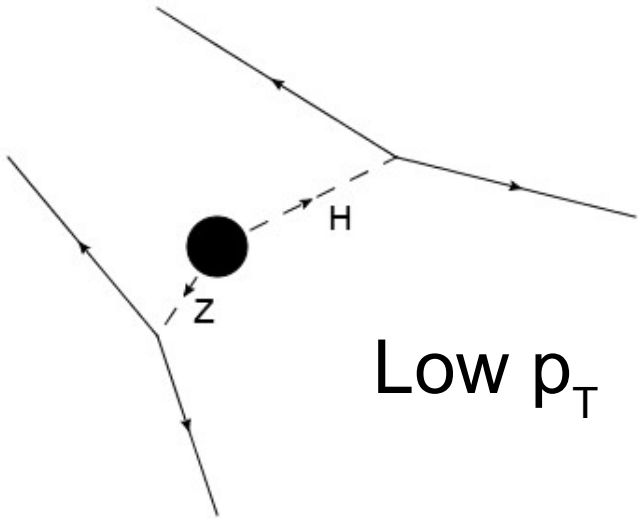


Figure 19-7 Expected *WH* signal with $H \rightarrow b\bar{b}$ above the summed background for m_H = 100 GeV and for an integrated luminosity of 30 fb^{-1}. The dashed line represents the shape of the background.

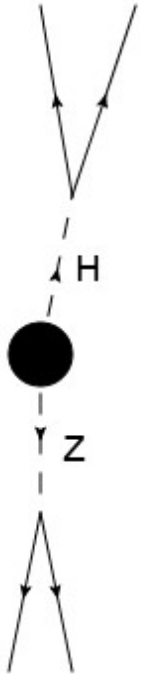
ATLAS Collaboration, **ATLAS: Detector and physics performance technical design report. Volume 2.** *CERN-LHCC-99-15, ATLAS-TDR-15*, May 1999

A New Approach

- Many reasons to still want to observe H→bb
- Consider only the high p_T case
- Event topology becomes much simpler
- Systematics significantly reduced



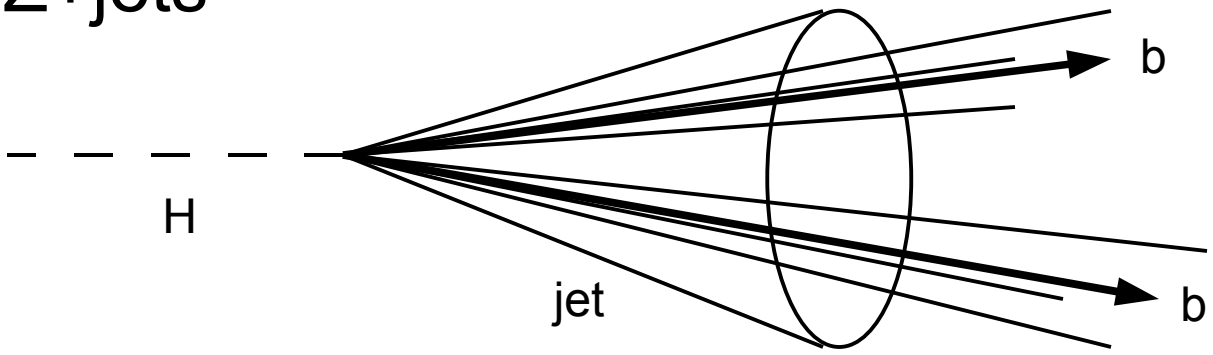
Low p_T



High p_T

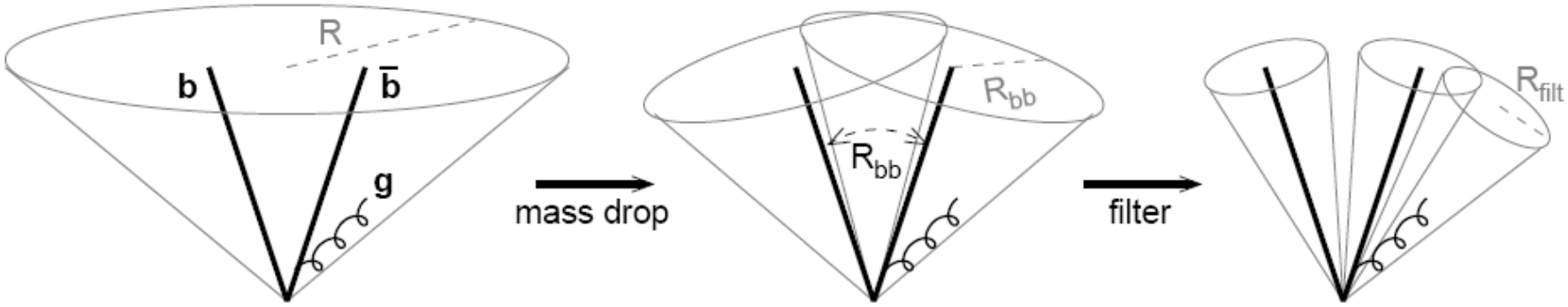
Jet Substructure

- If a highly boosted Higgs decays, often reconstruct a single high p_T massive jet in the event
- As well as high mass, such jets have distinctive structure due to the relatively hard splitting of the Higgs decay
- By studying the structure of jets we can more effectively reject QCD backgrounds to HW/Z such as W/Z+jets



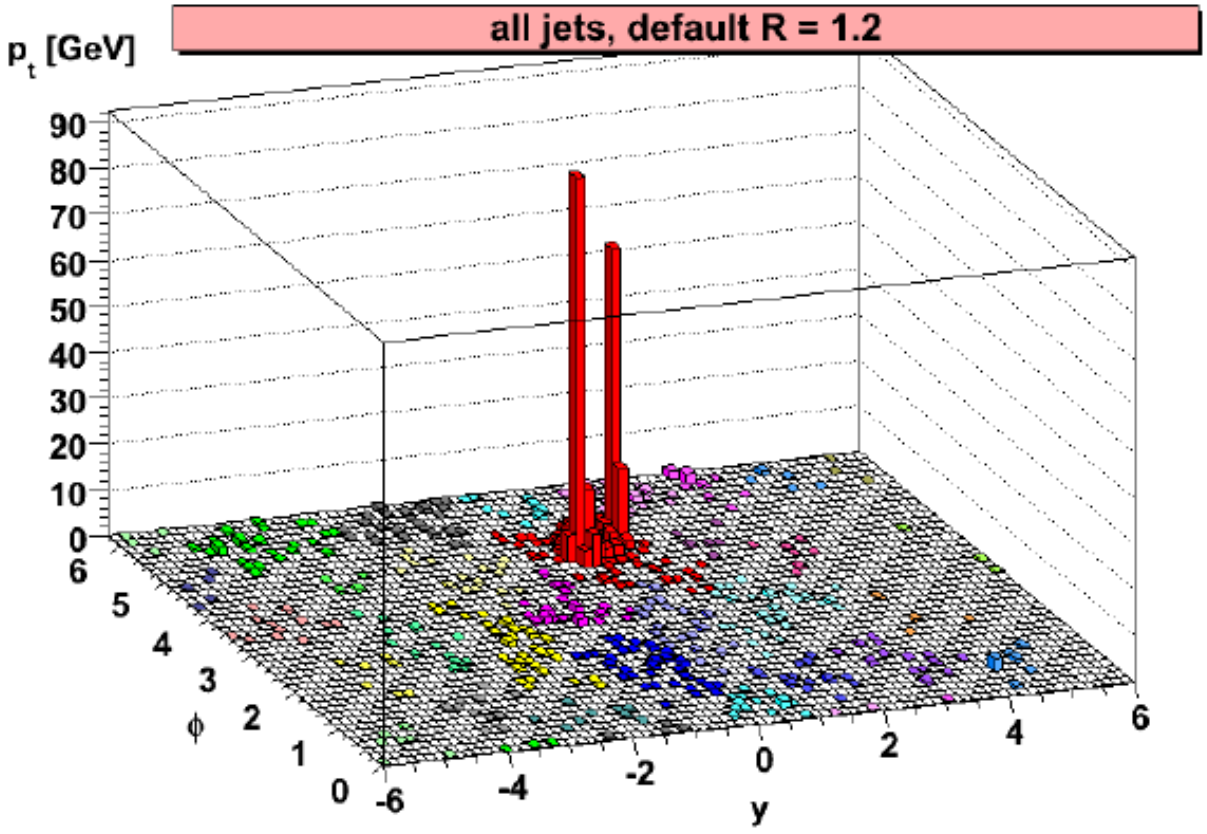
The Procedure

- Using the Cambridge-Aachen jet algorithm
  - Recombines closest pair of objects in the event up to R
- When finding a jet that passes a pT cut
  - Clustering can be undone one step at a time
  - Reverse clustering until a large drop in mass is observed
  - Check this splitting is not too asymmetric
  - Recluster remaining constituents with smaller R



$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



Cluster event, C/A, R=1.2

These slides from an excellent talk by G. Salam at SUSY08

SIGNAL

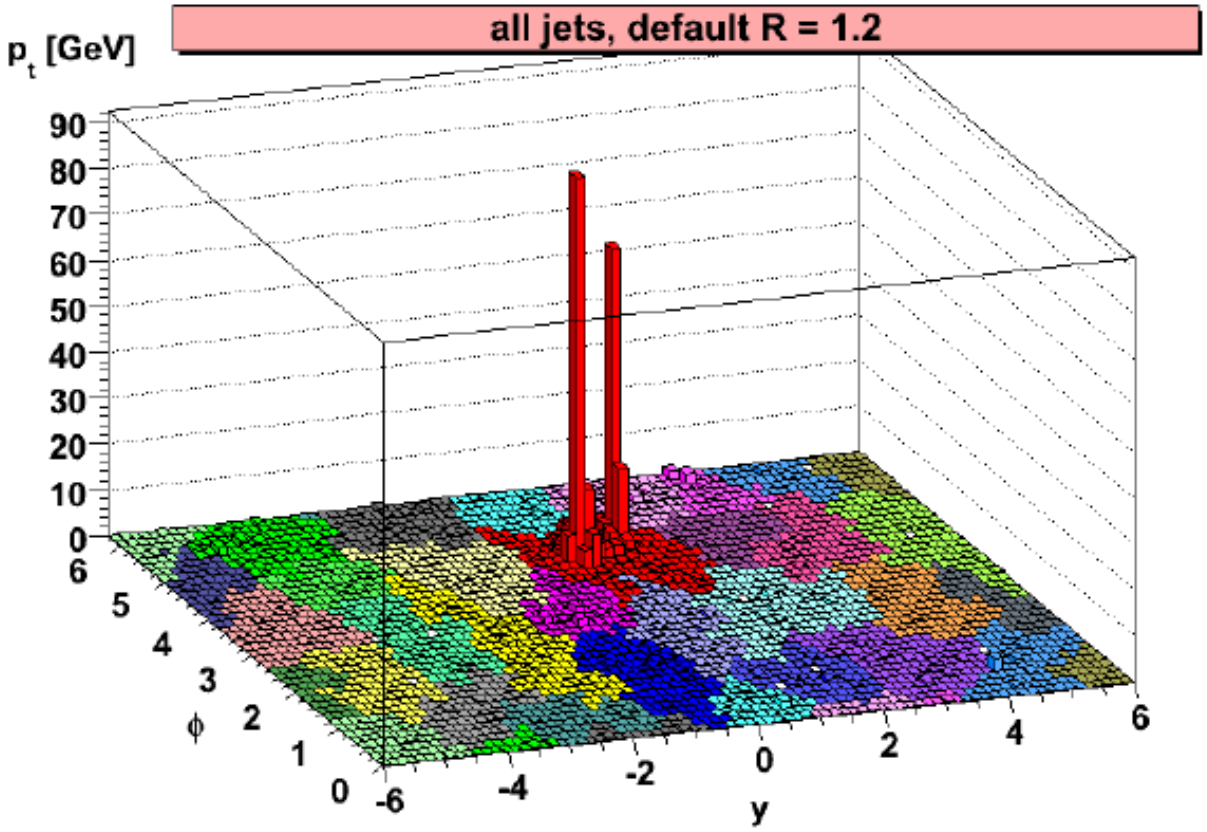
Zbb BACKGROUND

arbitrary norm.

$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

SIGNAL

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



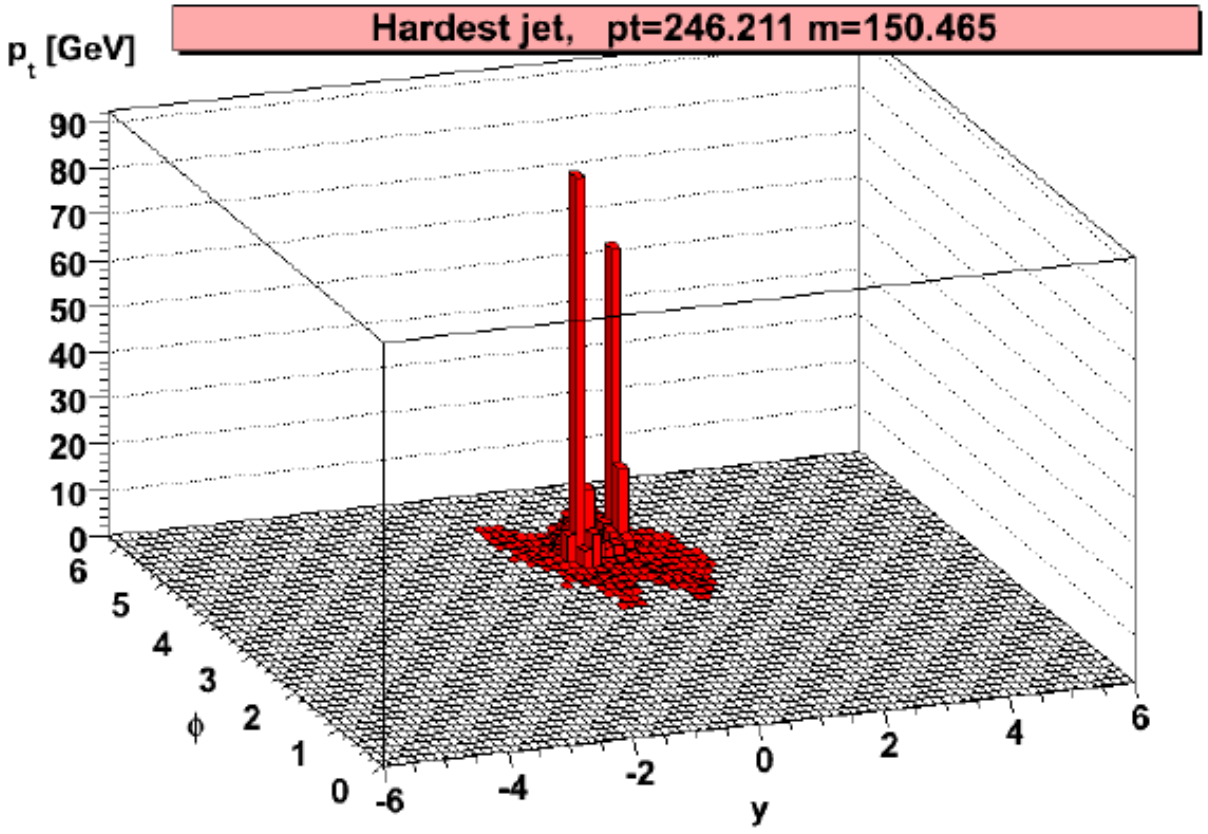
Zbb BACKGROUND

Fill it in, → show jets more clearly

arbitrary norm.

$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



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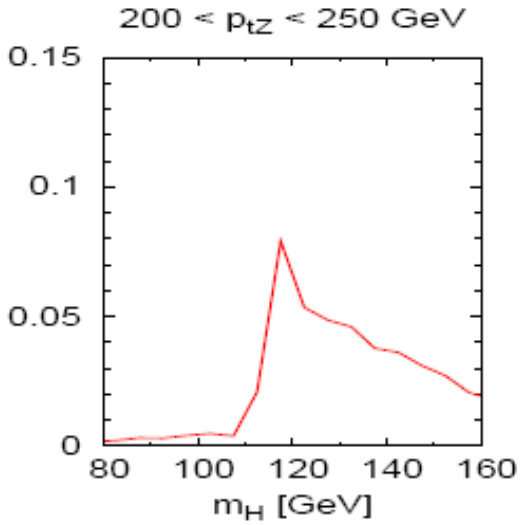
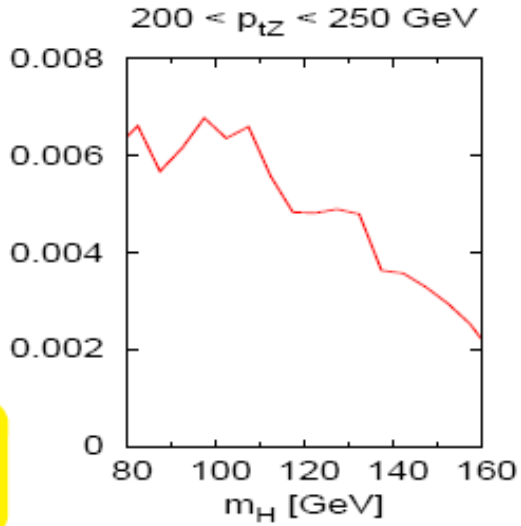


Zbb BACKGROUND

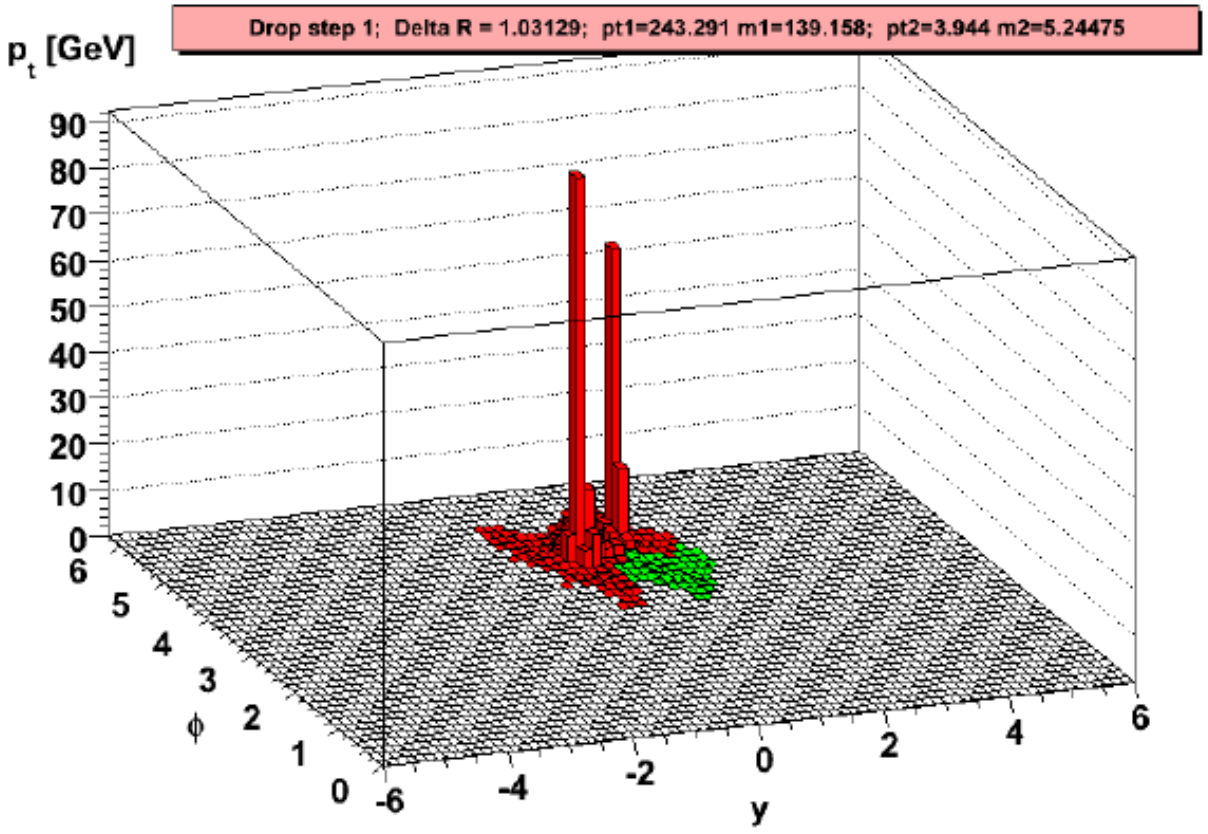


Consider hardest jet, $m = 150$ GeV

arbitrary norm.

$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



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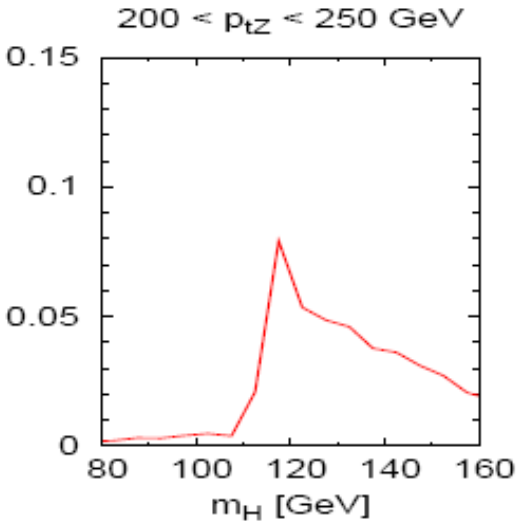
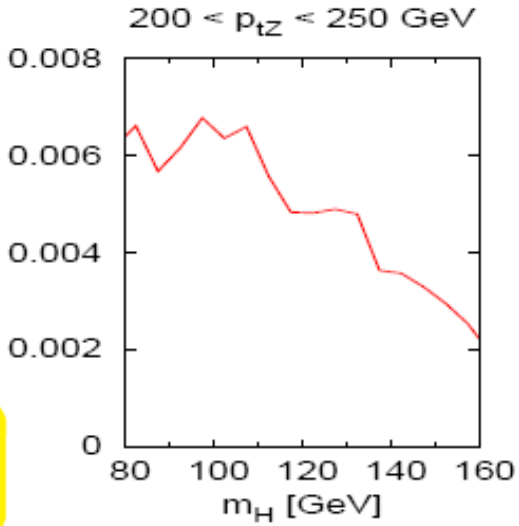


Zbb BACKGROUND

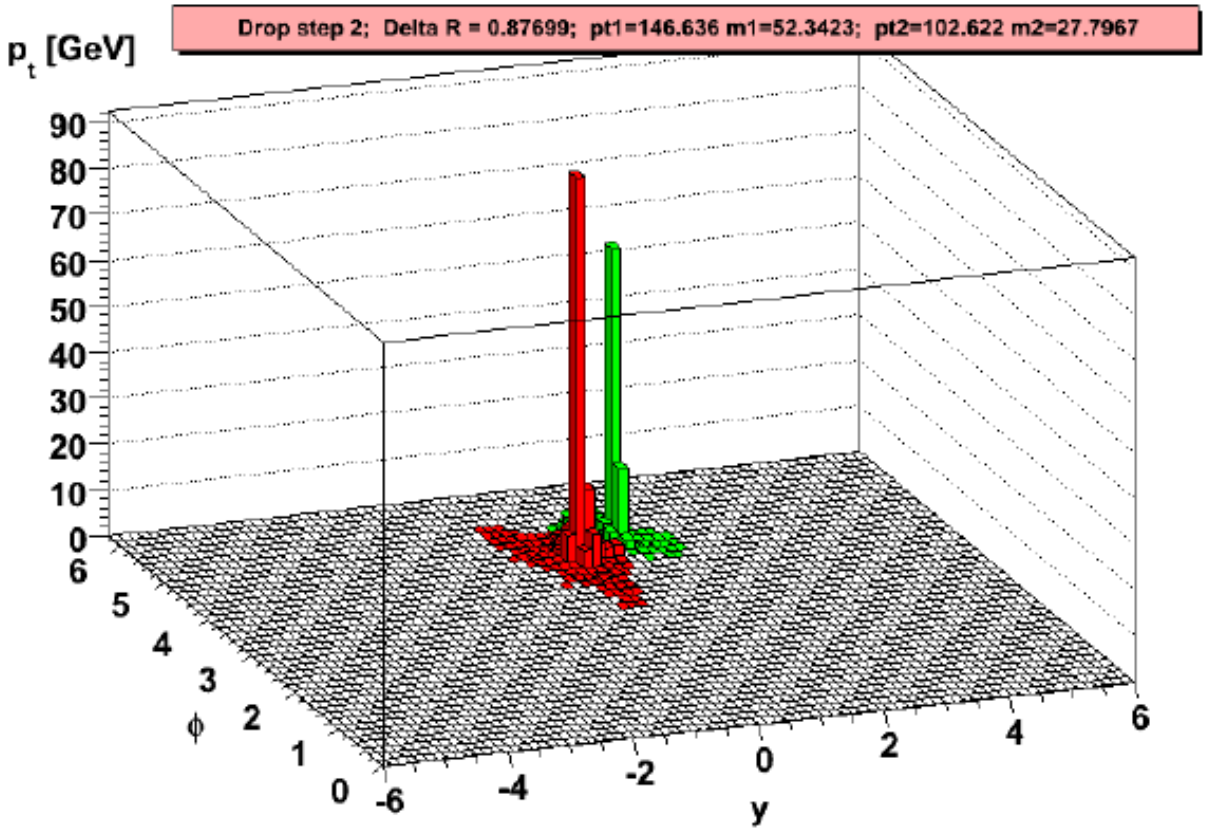


split: $m = 150$ GeV, $\frac{\max(m_1, m2)}{m} = 0.92 \to$ repeat

arbitrary norm.

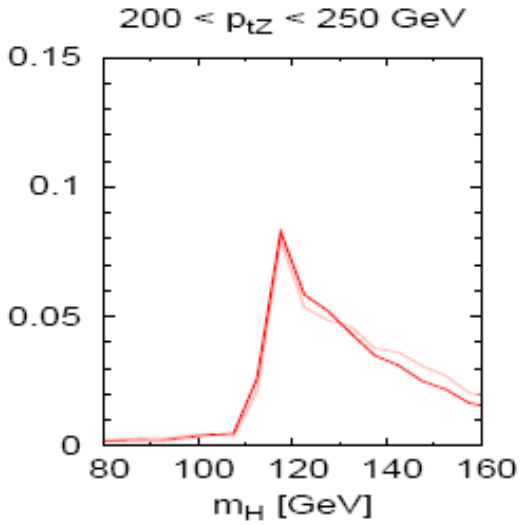
$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3

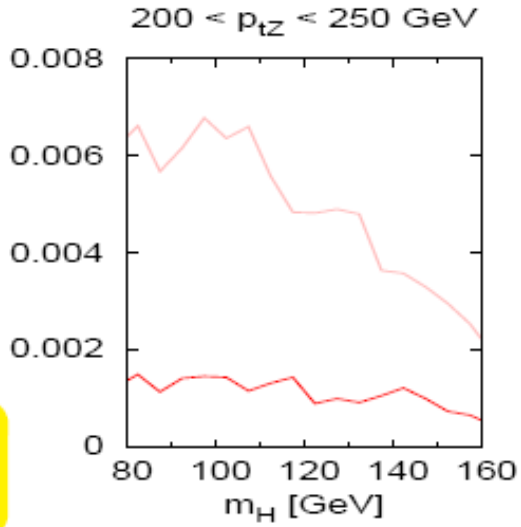


split: $m = 139$ GeV, $\frac{\max(m_1, m2)}{m} = 0.37 \to$ mass drop

SIGNAL



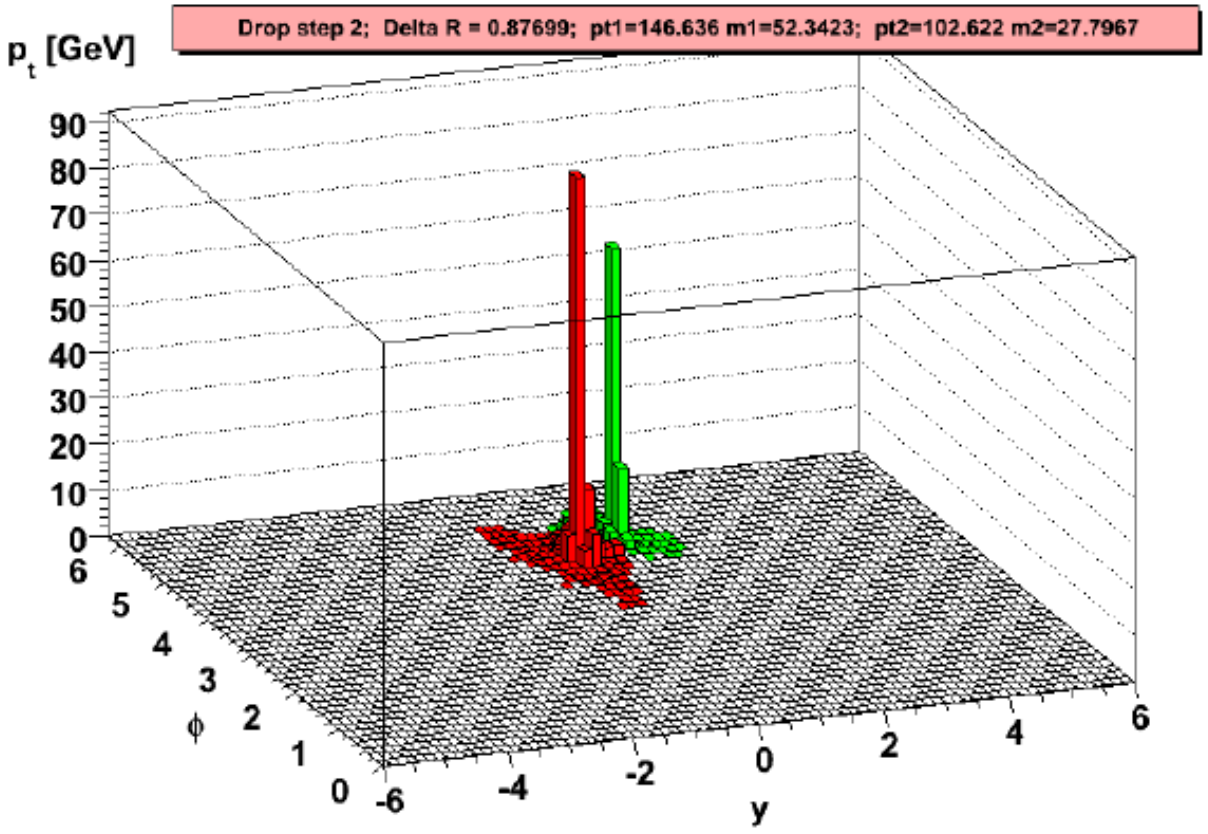
Zbb BACKGROUND



arbitrary norm.

$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



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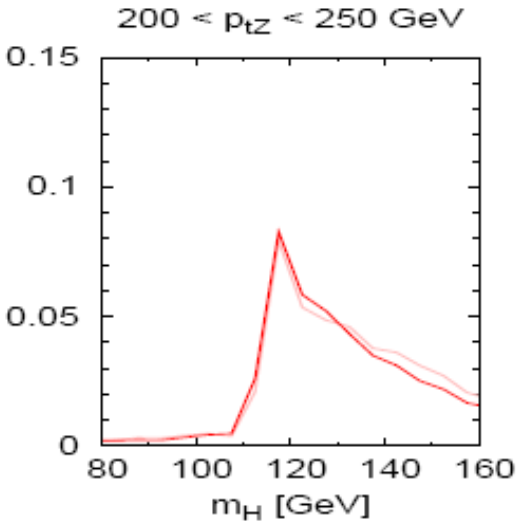

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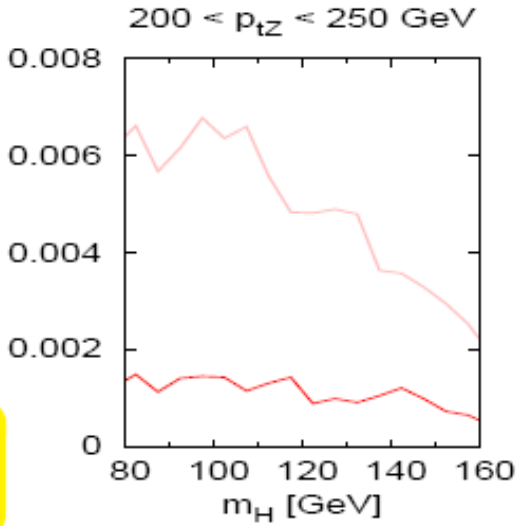
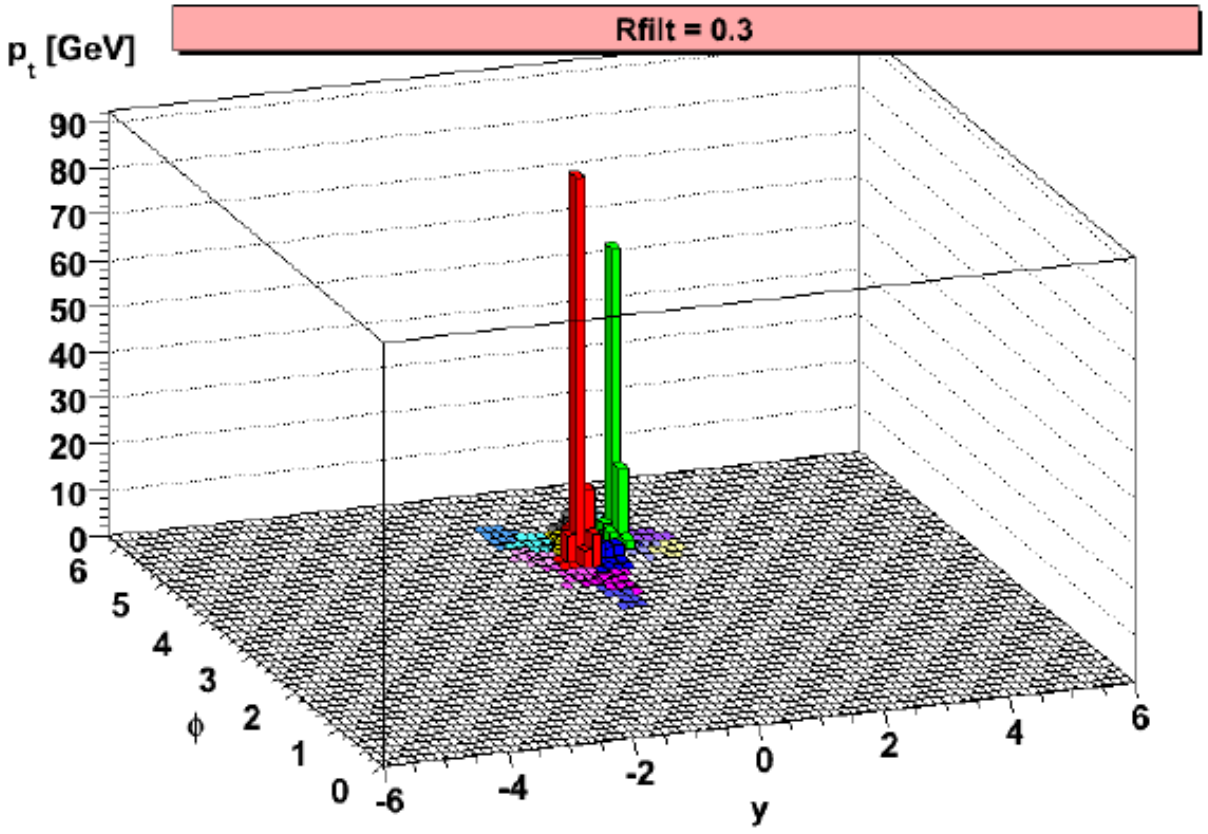


arbitrary norm.

check: $y_{12} \simeq \frac{p_{t2}}{p_{t1}} \simeq 0.7 \to$ OK + 2 b-tags (anti-QCD)

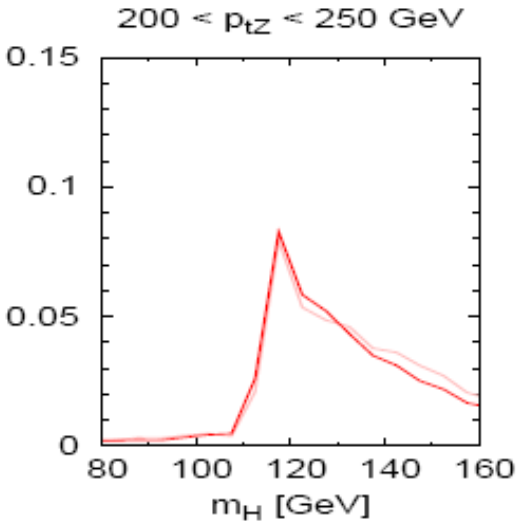
$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



$R_{filt} = 0.3$

SIGNAL



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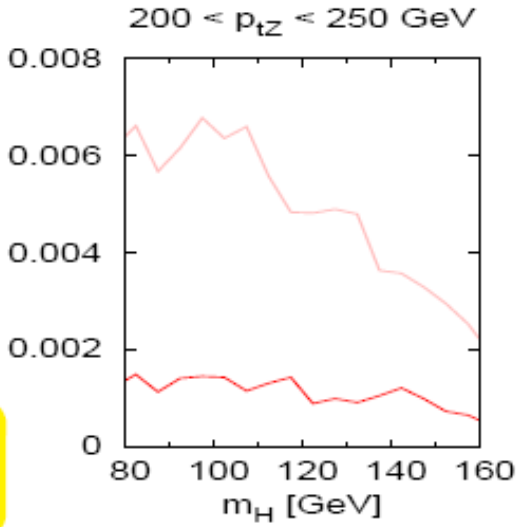
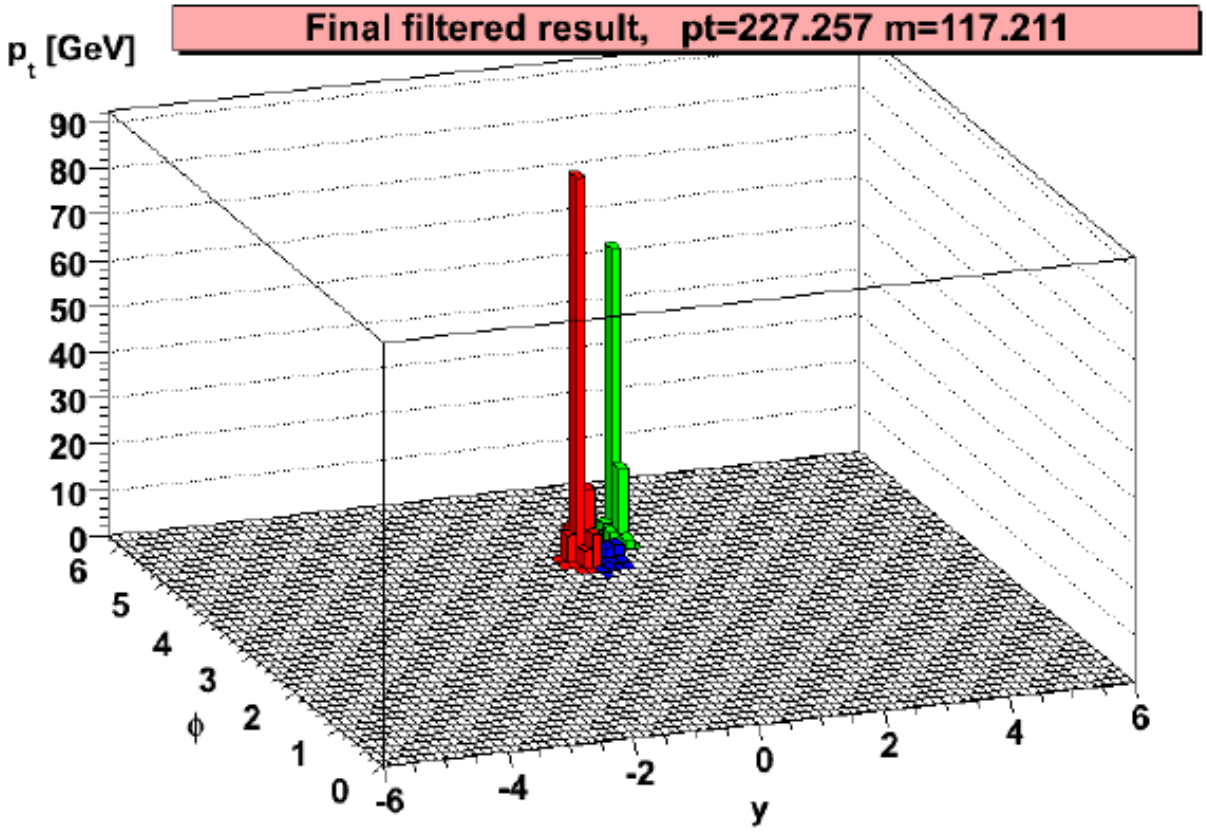


arbitrary norm.

$pp \to ZH \to \nu\bar{\nu}b\bar{b}$, @14 TeV, $m_H = 115$ GeV

Herwig 6.510 + Jimmy 4.31 + FastJet 2.3



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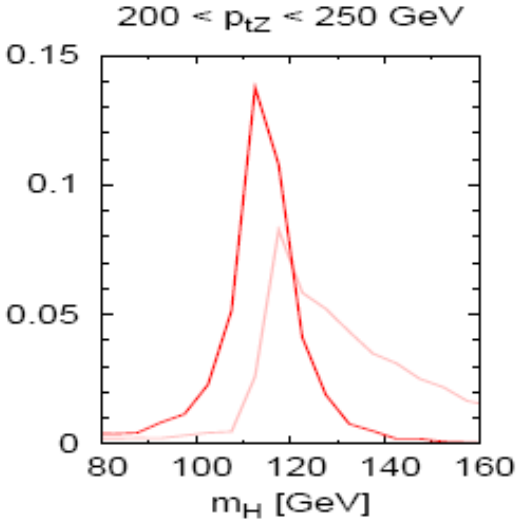
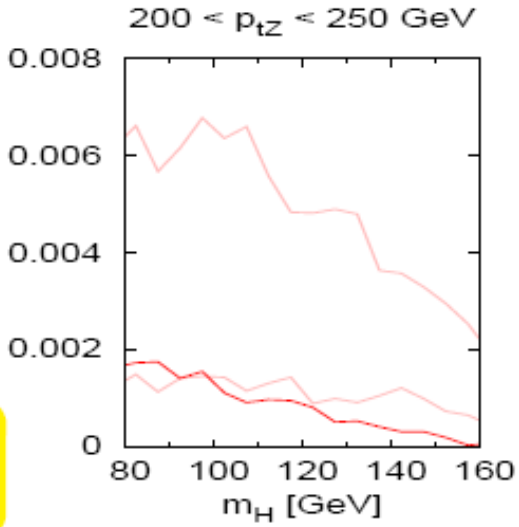


Zbb BACKGROUND

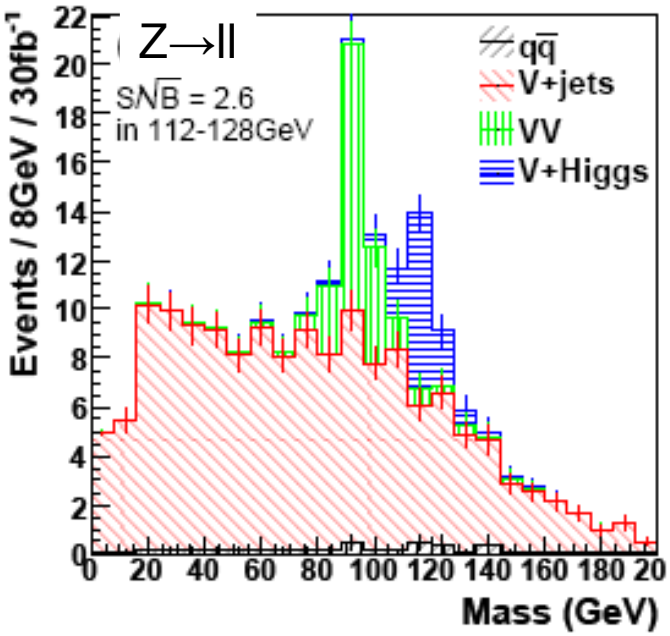


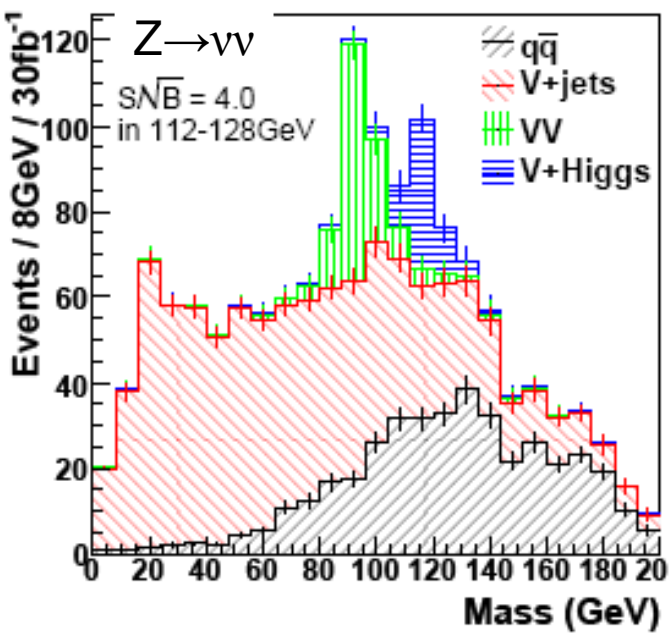
arbitrary norm.

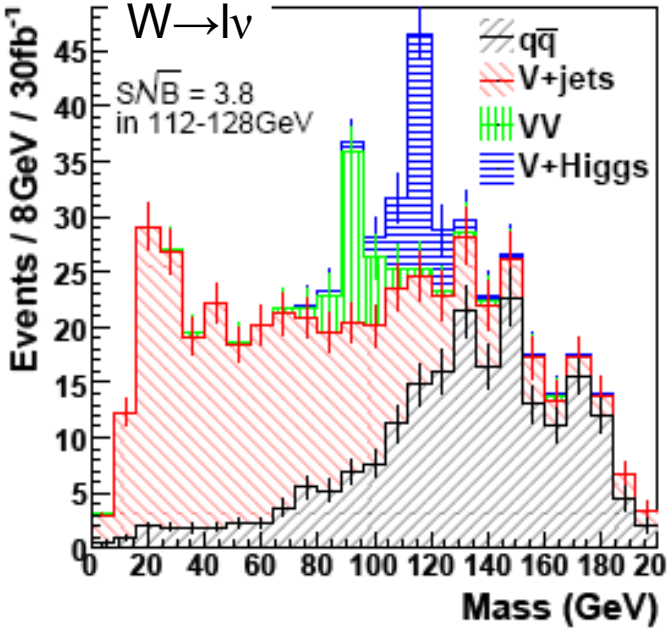
$R_{filt} = 0.3$: take 3 hardest, **m = 117 GeV**

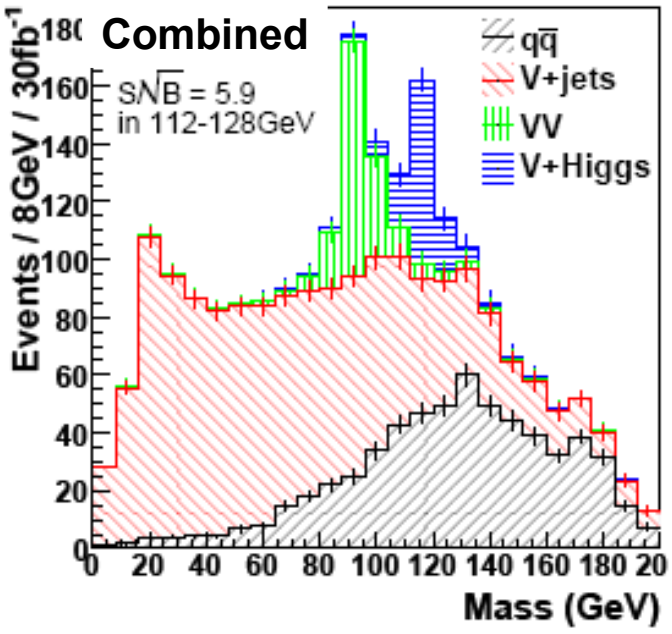
Analysis

- Perform a hadron level analysis (no detector simulation) but try to make cuts and windows of reasonable values given our knowledge of ATLAS
- Generate samples of HZ, HW, WW, WZ, ZZ, $t\bar{t}$, single top, W+jets, Z+jets with Herwig
- Try to select three types of event
  - ZH with $Z \rightarrow ll$
  - ZH with $Z \rightarrow \nu\nu$
  - WH with $W \rightarrow l\nu$
- Then look for Higgs candidates and plot the mass









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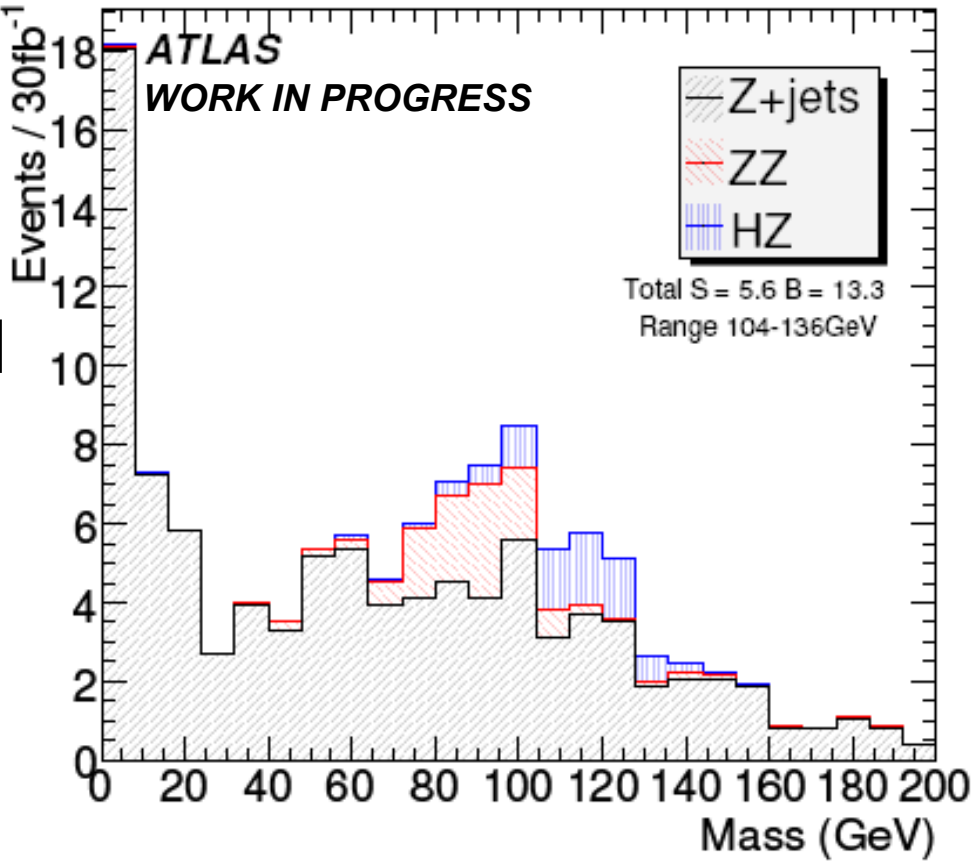
Detector Level Results

- Apply official ATLAS detector simulation (Atlfast-II)
- ZH with Z→ll shown
- Also similar progress in
  - ZH with Z→νν
  - WH with W→lν
- Most of the signal in WH



Conclusions

- Studying only the high p_T part of WH/ZH
- Combined with new jet structure techniques
- This radical new approach makes observing HZ/HW with ATLAS possible again
- Feasible that this will be one of the first discovery channels for ATLAS at low mass
- Also an important opportunity to confirm couplings
- Public results at detector level by Summer