Working Towards a Boosted \(Z \rightarrow bb\) Measurement with ATLAS

IoP 2013, Liverpool

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Boosted Z$\rightarrow$bb: Motivation

- For searches in hadronic decay channels it is often advantageous to look for the decay of objects with a high $p_T$, so-called ‘boosted objects’
  - Observing boosted Z$\rightarrow$bb would be an important stepping stone in the development of boosted hadronic analyses at the LHC
- The Z$\rightarrow$bb peak could be used:
  - To help assess systematics for analyses involving b-jets, e.g. H$\rightarrow$bb
  - As a test bed for techniques to improve the bb mass resolution, e.g. substructure
- Everything shown is work in progress
An event display showing the $Z\rightarrow bb$ signal topology:
3 high $p_T$ jets: 1 that balances the $Z$ and two nearby 
b-jets from the $Z$ decay

Basic Event Selection

- Two anti-$k_t$ $R = 0.4$ jets, both jets with $p_T > 30$ GeV
- Two of these jets with a vector added $p_T > 200$ GeV
- Both of these jets b-tagged
- $\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2}$ between the two jets < 1.2
Key challenges facing analysis:

**Bad MC description of background** (Pythia 6 and Herwig+Jimmy)

**Low S/B**

- After the initial selection the S/B is ~1% over the whole mass range
- The signal/background, in the mass window [80,110] GeV, predicted by simulation is 3.3% with ~950 recorded events for 2011 data
  - Need to increase this to stand a chance of observing $Z \rightarrow bb$
- So search for variables that discriminate QCD from $Z \rightarrow bb$
Properties of Balancing jet in Event

Here we define the balancing jet in the event as the one that best balances the $bb$ dijet, in the transverse plane, when added vectorially.

\[ \alpha_T = \frac{p_T \text{ of balancing jet}}{\text{mass of dijet-balancing jet system}} \]

All MC in these plots is Pythia 6
Plot on the left shows the number of jets in the event.

Plot on the right shows the scalar sum of the E_T of jets in the event. This excludes the two b-tagged Z candidate jets and the balancing jet.
Here, we look at the scalar sum of track $p_T$ in the event. We exclude tracks associated to the two Z candidate b-tagged jets and the balancing jet in the event. The tracks pass a series of quality cuts.

This is split into two areas:

(1) A cone of $R=1.5$ around the bb dijet axis

(2) The rest of the event
Also use the b-tagging weights of the two b-tagged jets together with the other variables. Combine them into an MVA to take account of the correlations to get maximum discrimination of signal from background.
A neural network was found to give the best separation between signal and background.

A cut at 70% signal efficiency improves the s/d by a factor of ~2 and doesn’t have much of an impact on the data mass distribution.

<table>
<thead>
<tr>
<th>In Mass Window [80,110] GeV:</th>
<th>S/B</th>
<th>S/√B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before NN cut</td>
<td>3.1%</td>
<td>4.7</td>
</tr>
<tr>
<td>After cut on NN</td>
<td>6.4%</td>
<td>5.9</td>
</tr>
</tbody>
</table>

ATLAS Work in Progress

\( \sqrt{s} = 7 \text{ TeV} \int L \, dt = 4.7 \text{ fb}^{-1} \)
The trigger we use for 2011 data consisted of a high-$p_T$ cut on a single jet as well as a cut on the overall energy in the event
- Signal efficiency of $\sim 45\%$

The idea for the 2012 trigger is to look for events with at least 3 high-$p_T$ jets, with at least 2 of those jets b-tagged, to keep the trigger rate low

Trigger ran in 2012 menu and combining with a few others we get $\sim 90\%$ overall signal efficiency
• The boosted $Z \rightarrow bb$ analysis effort is ongoing
• Pythia and Herwig do a bad job of modeling QCD high $p_T$ $bb$ events
• Using an MVA of event topology variables, we can increase the, initially low, signal to background ratio by a factor of $\sim 2$
• There was a more efficient trigger running unprescaled for the 2012 data-taking period. This gives us access to a significantly larger sample of $Z \rightarrow bb$ events in data than in 2011
Backup Slides

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Cut efficiencies and optimal cut value

- **Signal efficiency**: Blue line
- **Background efficiency**: Red line
- **Signal purity**: Dotted blue line
- **Signal efficiency * purity**: Green line
- **S / √S+B**: Black line

For 1070 signal and 33710 background events, the maximum S / √S+B is 6.1587 when cutting at 0.2177.

**Kolmogorov-Smirnov test**: signal (background) probability = 0.759 (0.984)

TMVA overtraining check for classifier: MLP_ANN_RoughOptimised