VW -> lv jj at 8 TeV
at the ATLAS detector
IOP 2015, Manchester
David Freeborn
Analysis Overview

Goals of the Analysis
Building from experience of 7TeV analysis (JHEP 1501 (2015) 049)
8 TeV analysis gives new opportunities for exploring Electroweak physics:

- Measure the combined WW/WZ production cross-section
  → fit to $m_{jj}$ for signal extraction
  → profile likelihood fit to control systematics
- Searches for new Physics:
  → Anomalous triple gauge coupling (aTGC)
  → sensitive to new heavy particles coupling to $W$ and $Z$ Bosons

Two separate topologies:
- Resolved region, in which we study the hadronic $W$ Boson decaying into two distinct jets
- Boosted region, in which at very high $p_T$ (i.e. a high Lorentz boost), the entire hadronic $W$ Boson decay is captured by a single large-radius “fat jet”

It is often possible to write some parameters as functions of other parameters, thereby reducing the number of independent parameters. (The function is the parameter value which maximizes the likelihood given the value of the other parameters.) This procedure is called concentration of the parameters and results in the concentrated likelihood function, also occasionally known as the maximized likelihood function, but most often called the profile likelihood function.
Event and Object selection

Jet Definition

Anti kT radius 0.4 or 1.0, \( p_T > 25 \text{ GeV}, |\eta| < 2.5 \)

Electron Definition

\( E_T > 25 \text{ GeV}, |\eta| < 2.47 \)

Muon Definition

\( p_T > 25 \text{ GeV}, |\eta| < 2.5 \)

<table>
<thead>
<tr>
<th></th>
<th>Resolved Analysis</th>
<th>Boosted Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>lepton veto</td>
<td>No 2nd lepton &gt; 10 GeV</td>
<td>No 2nd lepton &gt; 15 GeV</td>
</tr>
<tr>
<td>MET</td>
<td>MET &gt; 40 GeV</td>
<td>MET &gt; 50 GeV</td>
</tr>
<tr>
<td>leptons</td>
<td>Precisely 1 lepton &gt; 25 GeV</td>
<td>Precisely 1 lepton &gt; 25 GeV</td>
</tr>
<tr>
<td>jets</td>
<td>Exactly 2 anti kT jets radius 0.4, &gt; 25 GeV</td>
<td>1 highly boosted anti kT jet of radius 1.0, ( p_T &gt; 250 \text{ GeV} )</td>
</tr>
<tr>
<td>other</td>
<td>( W ) candidate (lepton + Missing ET) &gt; 40 GeV</td>
<td>No additional anti kT jets, radius 4, outside “fat” jet</td>
</tr>
</tbody>
</table>
Systematic Uncertainties

Largest sources of systematic uncertainty include:

- **Jet energy resolution uncertainty (JER)**
  - 0.3% for W+jets background
  - 0.7% for signal

- **Jet energy scale uncertainty (JES)**
  - 2.1% for W+jets background
  - 0.8% for signal

- **Pileup uncertainty**
  - 0.2% for W+jets background
  - 0.2% for signal

- **Other small uncertainties**
  - 4.5% total for W+jets background
  - 2.1% total for signal

(In addition with \(ptW(lv)>100\) GeV and \(pt (Wjj)>100\) GeV)

Dashed lines: before smoothing; solid colour: after smoothing
Jet shape variables for W tagging in the Boosted Analysis

  
  (N + 1) point correlation functions are sensitive to N-prong substructure, with an angular exponent \( \beta \) that can be adjusted to optimize the discrimination power.

- I use parameters \( D2_{\beta} = 1 \)

\[
D2 = ECF(3, \beta) \times \frac{ECF(1, \beta)^3}{ECF(2, \beta)^3}
\]

where

\[
ECF(0, \beta) = 1,
ECF(1, \beta) = \sum_{i \in J} p_{T_i},
ECF(2, \beta) = \sum_{i < j \in J} p_{T_i} p_{T_j} (R_{ij})^\beta,
ECF(3, \beta) = \sum_{i < j < k \in J} p_{T_i} p_{T_j} p_{T_k} (R_{ij} R_{ik} R_{jk})^\beta,
ECF(4, \beta) = \sum_{i < j < k < \ell \in J} p_{T_i} p_{T_j} p_{T_k} p_{T_\ell} (R_{ij} R_{ik} R_{i\ell} R_{jk} R_{j\ell} R_{k\ell})^\beta.
\]


\[
z_{cut} = \min(p_{Ti}, p_{Tj}) / p_{T(i+j)}
\]
Cuts on leading leading jet mass

Looking at mass window : 65 < leading jet mass < 100

<table>
<thead>
<tr>
<th>EEC: D2_beta 1 &lt; 0.20</th>
<th>Zcut &lt; 0.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal events :</td>
<td>278</td>
</tr>
<tr>
<td>Background events:</td>
<td>759</td>
</tr>
<tr>
<td>Signal/Background</td>
<td>= 0.36</td>
</tr>
<tr>
<td>Signal/sqrt(Background)</td>
<td>= 9.96</td>
</tr>
</tbody>
</table>

Signal events : 278
Background events: 759
Signal/Background = 0.36
Signal/sqrt(Background) = 9.96

Slightly better s/b and s/sqrt(b) from the D2_beta 1 cut

Resolved and Boosted analysis must be orthogonal (entirely separate events);

Potential overlap of events with the resolved channel: about 30 signal events, 60-80 background events in the signal region for both channels

Events in resolved channel which pass boosted selection will be analysed only in boosted selection as this has superior sensitivity in the signal region
Studies of aTGCs (anomalous triple gauge couplings)

- Self couplings of gauge bosons are specified by kinetic terms in the Standard Model Lagrangian.
- Only allowed couplings are WWZ, WW\gamma -neutral couplings not allowed.
- Deviations from the SM are then expressed in terms of the anomalous triple gauge coupling.
- Typically, inclusion of aTGCs will lead to an enhancement in the production cross section for bosons at high pT.
- aTGC’s are introduced via an effective Lagrangian with couplings:

\[ \alpha \to a(s) \equiv \frac{\alpha}{(1 + \hat{s} / \Lambda_{FF}^2)^n} \]

where \( \Lambda_{FF} \) is the energy scale and \( s \) is the centre of mass energy of the collision.

Feynman diagram for diboson production and decay
The red dot indicates the triple vertex.
aTGC models in the highly boosted regime

Consider aTGC model paramaterised by $\lambda = 0.04$

Compare data-MC $P_T$ distributions with aTGC samples within mass window 65-100 GeV to set exclusion limits

Limits will be set for exclusion of aTGC models
Summary

Many aspects of the analysis progressing in parallel in resolved and boosted selection

• aTGC approach: combining both analyses
  - events failing boosted cuts (including substructure) will be considered by resolved analysis

• fiducial cross section: two possibilities
  - same approach as aTGC: one combined cross section? This would require using substructure quantities in the fiducial particle level definition)
  - OR quoting 2 fiducial cross sections in non orthogonal regions: it will have the advantage of a much cleaner fiducial definition not involving substructure cuts.

• Event selection has been significantly optimised
• Building a complete fit model with systematic uncertainties included
• Data-driven cross-check for W+jets background and QCD background
• Detailed studies of aTGC samples now ongoing
Backup
Detailed selection: resolved

<table>
<thead>
<tr>
<th>Electron channel</th>
<th>Muon channel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal selection</strong></td>
<td><strong>Nominal selection</strong></td>
</tr>
<tr>
<td><strong>Template selection</strong></td>
<td><strong>Template selection</strong></td>
</tr>
<tr>
<td>TightPP ID</td>
<td>combined staco muons</td>
</tr>
<tr>
<td>$p_T &gt; 25 \text{ GeV},</td>
<td>\eta^Z</td>
</tr>
<tr>
<td>etCone$^{30}/pt &lt; 0.14$</td>
<td>$2 \text{ GeV} &lt; \text{etCone}^{30} &lt; 20 \text{ GeV}$</td>
</tr>
<tr>
<td>ptCone$^{30}/pt &lt; 0.07$</td>
<td>$\text{ptCone}^{20}/pt &lt; 0.1$</td>
</tr>
<tr>
<td>$d_{0}^{\text{sig}} &lt; 5$</td>
<td>$d_{0}^{\text{sig}} &lt; 3$</td>
</tr>
<tr>
<td>$</td>
<td>z_0 \cdot \sin(\theta)</td>
</tr>
<tr>
<td>Veto on 2nd MediumPP electron with $p_T &gt; 10 \text{ GeV}$</td>
<td>Veto on 2nd combined muon with $p_T &gt; 10 \text{ GeV}$</td>
</tr>
</tbody>
</table>

**Jet selection**

$p_T > 25 \text{ GeV}, |\eta| < 2.5$, loose cleaning
Initial Selection:
GRL (for data only)
LArError !=2
tileError !=2
Tile trips (corrupted events)
Core flags (incomplete events)
Hot tile cell removal
Primary vertex selection: > 2 tracks
Trigger: EF_mu24i_tight || EF_mu36_tight ||
EF_e24vhi_medium1 || EF_e60_medium1

Channel Definition:
Require precisely (==) 1 good lepton >25 GeV
No 2nd lepton > 15 GeV
Require 1 highly boosted AK10 jet
(p_T>250GeV)
Missing ET > 50 GeV
No additional antikT 4 jets greater than 25 GeV, which are:
  - not overlapping lepton (deltaR < 0.3)
  - not overlapping the Ak_T10 jet (deltaR < 1.0)

Muons:
• Currently looking at staco muons
• p_T > 25 GeV
• abs(eta) < 2.4
• ID track requirements: standard prescription
• Impact parameter significance wrt primary vertex < 3.0
• mu_ptcone30/muonpt < 0.07

Electrons:
el_author = 1 or 3
• E_T > 25 GeV
• abs(eta) < 2.47
• Trigger matched
• fabs(el_trackz0pvunbiased*sin(el_tracktheta)) < 0.5 mm
• fabs(el_trackd0pvunbiased/el_tracksigd0pvunbiased) < 3
• el_ptcone30[i]/electronpt[i] < 0.07
• el_ETcone30[i]/electronpt[i] > 0.14

Jets:
• For Antik_T10, Antik_T4
• Pileup: Require |JVF| > 0.5 for jets with
  |eta| < 2.4 and pT < 50 GeV
• p_T > 25 GeV, abs(y) < 4.4
• Lepton overlap removal: (deltaR < 0.4) and Ak_T10 jets close to a selected electron or muon (deltaR < 0.10 )
Resolved Analysis: $Wp_T > 100$ GeV cut

- Tighter selection than 7TeV analysis: a cut on $Wp_T > 100$
  - increase S/B
  - reduce the relative impact of the MC statistical uncertainty
  - increases the shape separation