Observation of electroweak production of a same-sign W boson pair in association with two jets in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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On behalf of the ATLAS Collaboration

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The ATLAS Experiment

- One of the Large Hadron Collider’s (LHC) general purpose detectors.

LHC Run II: 2015-2018

The total integrated luminosity recorded by ATLAS in 2015 and 2016 amounted to 36.1 fb⁻¹
Overview of SM measurements in ATLAS

\textbf{ATLAS Preliminary}

Run 1,2, \( \sqrt{s} = 5, 7, 8, 13 \) TeV

Standard Model Production Cross Section Measurements

\begin{itemize}
\item LHC pp, \( \sqrt{s} = 5 \) TeV
  \begin{itemize}
  \item Data \( 0.025 \) fb\(^{-1}\)
\end{itemize}
\item LHC pp, \( \sqrt{s} = 7 \) TeV
  \begin{itemize}
  \item Data \( 4.5 - 4.9 \) fb\(^{-1}\)
\end{itemize}
\item LHC pp, \( \sqrt{s} = 8 \) TeV
  \begin{itemize}
  \item Data \( 20.2 - 20.3 \) fb\(^{-1}\)
\end{itemize}
\item LHC pp, \( \sqrt{s} = 13 \) TeV
  \begin{itemize}
  \item Data \( 3.2 - 79.8 \) fb\(^{-1}\)
\end{itemize}
\end{itemize}
**$W^{-}W^{+}jj$: Motivation**

2. Vector Boson Scattering (VBS): $\sigma \propto s^2$ at high $\sqrt{s}$ in the absence of the Higgs.
   - Unique test of the SM ElectroWeak (EW) sector and the Higgs mechanism.
   - Sensitive to triple, quartic and Higgs couplings
$W^\pm W^\pm jj$: Event selection

- Two isolated same-charge leptons with high transverse momentum ($p_T$).
- Large Missing Transverse Energy ($E_T^{\text{miss}}$).
- Two forward jets with large dijet invariant mass ($M_{jj}$) and a large rapidity separation ($\Delta y_{jj}$).
**$W^\pm W^\pm jj$: Background estimation**

**Non-prompt**
- $t\bar{t}$, $W+$jets, single top
- jet mis-reconstructed as lepton
- lepton from hadronic decays
- estimated from data

**Prompt**
- $WZ$, $ZZ$, $VVV$
- two same-charge leptons are picked up
- estimated from data and simulation

**$e/\gamma$ conversions**
- $W^\pm W^{\mp}$, $V\gamma$
- lepton is assigned a wrong charge
- $\gamma$ mis-reconstructed as $e$
- estimated from data and simulation

**QCD $W^\pm W^\pm$**
- estimated from simulation
Background due to $\gamma$ conversions in $V\gamma$

We used a region dominated by $Z\gamma$ events with $Z \rightarrow \mu^+\mu^-$ and $\gamma \rightarrow e^-e^+$. 

Event selection

- $\mu^+\mu^- + e^{\pm}$
- $E_T^{\text{miss}} < 30$ GeV
- $75 < M_{\mu\mu e} < 100$ GeV

Obtained a Scale Factor (SF) by comparing data to $Z\gamma$ events.

$$SF = \frac{\text{Data} - \text{OtherProcesses}}{Z\gamma}$$

$V\gamma$ events in the signal region were scaled by SF.

Uncertainty on SF was added as a systematic uncertainty.
$W^\pm W^\pm jj$: Observation

**Significance extraction**
- Maximum likelihood fit
- 4 bins of $M_{jj}$
- Fiducial region (fid): $M_{jj} > 500$ GeV

$W^\pm W^\pm$ signal: SHERPA

![Graph showing data distribution](image)

**Observed significance:** $6.9\sigma$

**Signal strength:** $1.47 \pm 0.25\,(\text{stat}) \pm 0.12\,(\text{sys})$
**W^±W^± jj**: Cross section measurement

**ATLAS Preliminary**

\[ \sqrt{s} = 13 \text{ TeV}, 36.1 \text{ fb}^{-1} \]

Experimental uncertainties

Theoretical uncertainties

Interference with strong production and NLO EW

corrections are not included in theoretical predictions

\[
\sigma_{\text{fid}}^{\text{meas}} = 2.91^{+0.51}_{-0.47}\text{(stat)} \pm 0.23\text{(sys)} \text{ fb}
\]

Chilufya Mwewa (UCT-ATLAS)
Summary

- The VBS EW production of $W^\pm W^\pm$ has been observed by ATLAS at a significance of $6.9\sigma$ and a cross-section of $2.91 \text{ fb}$.  
- Only $36.1 \text{ fb}^{-1}$ has been utilized for this measurement.

![Graph showing ATLAS data accumulation]

- This analysis is being repeated on the full RunII data set.
- More statistics $\Rightarrow$ higher precision!!
- More potential to probe new physics scenarios.

☆ Check this link for details on the results shown in this talk
Back up
Particle identification in ATLAS
Same sign WW EW VBS production

\[ W^+ W^- jj \text{ at ATLAS} \]
Same sign WW EW non-VBS and QCD production

\[ W^±W^±jj \text{ at ATLAS} \]
Same sign WW analysis selections

- **Event cleaning**
  - exactly two signal leptons with $p_T > 27$ GeV and the same electrical charge
  - with $|\eta| < 2.5$ for muons and
  - with $|\eta| < 2.47$ excluding $1.37 \leq |\eta| \leq 1.52$ for electrons
  - with $|\eta| < 1.37$ in the $ee$ channel

- $m_{\ell\ell} \geq 20$ GeV
- remove events with three or more preselected leptons

- $|m_{ee} - m_Z| > 15$ GeV in the $ee$-channel
- $E_T^{\text{miss}} \geq 30$ GeV

- at least two jets
  - leading and subleading jets satisfying $p_T > 65$ GeV and $p_T > 35$ GeV, respectively

- $m_{jj} \geq 200$ GeV

- $b$-jet veto using the MV2c10 tagger with the 85% efficiency working point

- $|\Delta y_{jj}| > 2$
## Pre-fit yields

<table>
<thead>
<tr>
<th></th>
<th>$e^+e^+$</th>
<th>$e^-e^-$</th>
<th>$e^+\mu^+$</th>
<th>$e^-\mu^-$</th>
<th>$\mu^+\mu^+$</th>
<th>$\mu^-\mu^-$</th>
<th>combined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>$WZ$</strong></td>
<td>1.7 ± 0.6</td>
<td>1.2 ± 0.4</td>
<td>13 ± 4</td>
<td>8.1 ± 2.5</td>
<td>5.0 ± 1.6</td>
<td>3.3 ± 1.1</td>
<td>32 ± 9</td>
</tr>
<tr>
<td><strong>Non-prompt</strong></td>
<td>4.1 ± 2.4</td>
<td>2.3 ± 1.8</td>
<td>9 ± 6</td>
<td>6 ± 4</td>
<td>0.57 ± 0.16</td>
<td>0.67 ± 0.26</td>
<td>23 ± 12</td>
</tr>
<tr>
<td><strong>$e/\gamma$ conversions</strong></td>
<td>1.74 ± 0.31</td>
<td>1.8 ± 0.4</td>
<td>6.1 ± 2.4</td>
<td>3.7 ± 1.0</td>
<td>-</td>
<td>-</td>
<td>13.4 ± 3.5</td>
</tr>
<tr>
<td><strong>Other prompt</strong></td>
<td>0.17 ± 0.06</td>
<td>0.14 ± 0.05</td>
<td>0.90 ± 0.24</td>
<td>0.60 ± 0.25</td>
<td>0.36 ± 0.12</td>
<td>0.19 ± 0.07</td>
<td>2.4 ± 0.5</td>
</tr>
<tr>
<td><strong>$W^\pm W^\pm jj$ strong</strong></td>
<td>0.38 ± 0.13</td>
<td>0.16 ± 0.06</td>
<td>3.0 ± 1.0</td>
<td>1.2 ± 0.4</td>
<td>1.8 ± 0.6</td>
<td>0.76 ± 0.26</td>
<td>7.3 ± 2.5</td>
</tr>
<tr>
<td><strong>Expected background</strong></td>
<td>8.1 ± 2.4</td>
<td>5.6 ± 1.9</td>
<td>32 ± 7</td>
<td>20 ± 5</td>
<td>7.7 ± 1.7</td>
<td>4.9 ± 1.1</td>
<td>78 ± 15</td>
</tr>
<tr>
<td><strong>$W^\pm W^\pm jj$ electroweak</strong></td>
<td>3.80 ± 0.30</td>
<td>1.49 ± 0.13</td>
<td>16.5 ± 1.2</td>
<td>6.5 ± 0.5</td>
<td>9.1 ± 0.7</td>
<td>3.50 ± 0.29</td>
<td>40.9 ± 2.9</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>10</td>
<td>4</td>
<td>44</td>
<td>28</td>
<td>25</td>
<td>11</td>
<td>122</td>
</tr>
</tbody>
</table>