Search for new phenomena in diboson production with lepton and photon final states with the ATLAS Detector

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on behalf of the ATLAS collaboration
University of Alberta

at EPS-HEP 2019, Ghent, Belgium
July 10-17
Introduction

• Advantages of the lepton and photon channels
  • Good resolution, relatively high signal-to-background ratio
  • Benefit from the well developed analysis technic from higgs measurement channels

• Analysis covered:
  • Diphoton high mass search
    • 36.7 fb^{-1}; Phys. Lett. B 775 (2017) 105
  • Diphoton low mass search
    • 80.4 fb^{-1}; ATLAS-CONF-2018-025
  • ZZ high mass search.
  • WW high mass search
  • Z\gamma high mass search
    • 36.1 fb^{-1}; JHEP 10 (2017) 112
Diphoton high mass search

- Looking for resonances or deviations in diphoton invariant mass spectrum
- Kinematic selections optimized separately for spin-0 and spin-2 signals
- Fraction of jet-faking-photon background < 10%

- Resonant signal: functional form
- ADD signal: MC simulation

- Spin-0: background modeled by functional form
- Spin-2: Target Graviton signal at TeV scale, limited statistics. Shape of diphoton background from simulation, shapes of jet-faking-photon backgrounds from control samples, relative fractions from decomposition study

[Graphs showing data and fitted background for spin-0 and spin-2 signals]
Diphoton high mass search

Spin-0: largest deviation at 730 GeV for narrow width, local (global) p-value 2.6 (0) σ
Spin=2: largest deviation at 708 GeV for $k/M_{Pl}=0.3$, local (global) p-value 3.0 (0.8) σ

Limits on spin-0 NWA, spin-2 RS Graviton, spin-2 ADD model.

Limits on ADD model based on counting with $M>2240$ GeV:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ADD formalism</th>
<th>GRW</th>
<th>Hewett</th>
<th>HLZ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M_S$ observed limit [TeV]</td>
<td>$n = 3$</td>
<td>$n = 4$</td>
<td>$n = 5$</td>
</tr>
<tr>
<td>Without K-factor</td>
<td>6.8</td>
<td>6.1</td>
<td>8.1</td>
<td>6.8</td>
</tr>
<tr>
<td>With K-factor</td>
<td>7.2</td>
<td>6.5</td>
<td>8.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>
• Several model predict new resonances below higgs mass
• Search resonances in $m_{\gamma\gamma}$ 65-110 GeV

Challenges:
• trigger threshold effect at low mass
• DY process with ee final states with e faking $\gamma$

Categorization:
• UU: zero converted photon
• CU: one converted photon
• CC: two converted photon

Signal and continuous background modeling similar to high mass search

DY modelling:
• Data-driven based on data $m_{ee}^{DY}$ template, with MC-based shape correction and further data-driven e-$\gamma$ fake rate correction.
• modeled by functional form
Diphoton low mass search

- No significant excess observed
- limits on NWA signals
ZZ high mass search

ZZ->4l final states
• Good resolution and high signal-to-background ratio; good for low mass
• Invariant mass as discriminate variable
• 4e, 2e2µ, 4µ
• ggF and VBF enriched
• ZZ, ttbar+V, VVV, ZZ(EW): MC simulation
• Z+jets, ttbar: data-driven

ZZ->llνν final states
• Large branch ratio; good for high mass
• Transverse mass as discriminant variable
• eeνν, μμνν
• ggF and VBF enriched
• ZZ, Other backgrounds(ttbar+V, VVV): MC simulation
• WZ, Z+jets, WW, Wt, ttbar, Z- >tautau: data-driven

ZZ high mass search

- Two excesses found in 4l channel at 240 and 700 GeV, each with local (global) significance 3.6 (2.2) $\sigma$
- Excess at 240 GeV mostly from 4e channel
- No excess at 700 GeV in $\ell\ell\nu$ 

- Limits on spin-0 narrow width approximation (NWA) and large width approximation (LWA) signals. In LWA, width up to 10% and including interference between H-h and H-B.
- Limits also on Type-I and Type-II 2HDM, RS Graviton.
WW high mass search

- **WW → eνμν** final states
- Categorization: ggF, VBF 1jet and VBF 2jets
- Background:
  - Top and WW: simultaneous fit in signal and control regions
  - W+jets: control region scaled by fake factor
  - Others: MC simulation
WW high mass search

- No significant excess found
- Limits set on Higgs with NWA and LWA (up to 15% width)
- Also interpreted for 2HDM, Georgi-Machacek model, Heavy Vector Triplet (HVT), RS graviton and effective Lagrangian model (ELM)

<table>
<thead>
<tr>
<th></th>
<th>SR$_{ggF}$</th>
<th>Top CR$_{ggF}$</th>
<th>WW CR$_{ggF}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW</td>
<td>11500 ± 800</td>
<td>820 ± 120</td>
<td>3360 ± 220</td>
</tr>
<tr>
<td>Top quark</td>
<td>11800 ± 600</td>
<td>52550 ± 330</td>
<td>2610 ± 180</td>
</tr>
<tr>
<td>Z/γ*</td>
<td>1420 ± 110</td>
<td>111 ± 20</td>
<td>20.9 ± 2.0</td>
</tr>
<tr>
<td>W+jets</td>
<td>1180 ± 320</td>
<td>710 ± 190</td>
<td>280 ± 70</td>
</tr>
<tr>
<td>VV</td>
<td>866 ± 34</td>
<td>101 ± 12</td>
<td>250 ± 11</td>
</tr>
<tr>
<td>Background</td>
<td>26740 ± 170</td>
<td>54290 ± 250</td>
<td>6510 ± 80</td>
</tr>
<tr>
<td>Data</td>
<td>26739</td>
<td>54295</td>
<td>6515</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>SR$_{VBF1J}$</th>
<th>SR$_{VBF2J}$</th>
<th>Top CR$_{VBF}$</th>
<th>WW CR$_{VBF1J}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW</td>
<td>390 ± 50</td>
<td>120 ± 26</td>
<td>61 ± 11</td>
<td>265 ± 32</td>
</tr>
<tr>
<td>Top quark</td>
<td>450 ± 50</td>
<td>391 ± 24</td>
<td>5650 ± 90</td>
<td>167 ± 18</td>
</tr>
<tr>
<td>Z/γ*</td>
<td>45 ± 11</td>
<td>24 ± 6</td>
<td>68 ± 19</td>
<td>74 ± 12</td>
</tr>
<tr>
<td>W+jets</td>
<td>52 ± 13</td>
<td>8.9 ± 2.5</td>
<td>91 ± 24</td>
<td>43 ± 11</td>
</tr>
<tr>
<td>VV</td>
<td>32 ± 7</td>
<td>16.6 ± 1.9</td>
<td>20 ± 9</td>
<td>38 ± 4</td>
</tr>
<tr>
<td>Background</td>
<td>972 ± 29</td>
<td>563 ± 22</td>
<td>5890 ± 80</td>
<td>596 ± 22</td>
</tr>
<tr>
<td>Data</td>
<td>978</td>
<td>560</td>
<td>5889</td>
<td>594</td>
</tr>
</tbody>
</table>
Zγ high mass search

- Z(-ee/μμ)γ final states.
- Two categories eγ and μγ

- Signal modeled by functional form
- Background modeled by functional form
  - Shape: Zγ from simulation, Z+jets from data control samples
  - Background fraction: data-driven method
Zγ high mass search

- Largest derivation 2.96 (0.8) σ for local (global) p-value at 960 GeV
- Limits on spin-0 signals, as well spin-2 signals with Higgs Characterisation Model (HCM)
Summary

• Analyses presented for ZZ high mass search (36.1 fb\(^{-1}\)), WW high mass search (36.1 fb\(^{-1}\)), diphoton high mass search (36.7 fb\(^{-1}\)), Z\(\gamma\) high mass search (36.1 fb\(^{-1}\)), and diphoton low mass search (80.4 fb\(^{-1}\)).

• No significant excess found, limits set on various models.
Backup
95% CL Upper Limit on $\sigma_{\text{fid}} \cdot B$ [fb]

**ATLAS Preliminary**

$\sqrt{s} = 13$ TeV, 80 fb$^{-1}$

$X \rightarrow \gamma\gamma$

Expected

- All systematics
- Only spurious signal systematic
- No systematics

$\pm 1 \sigma$

$\pm 2 \sigma$
**ATLAS Simulation**

\( \sqrt{s} = 13 \text{ TeV} \)

\[ H \rightarrow ZZ \rightarrow l^+l^-l^+l^- \]

- \( \mu^+\mu^+\mu^- \)
- \( \mu^+\mu^-e^+e^- + e^+e^-\mu^+\mu^- \)
- \( e^+e^-e^+e^- \)