Search for Higgs boson pair production in the $\gamma\gamma WW^*$ channel using $pp$ collision data recorded at 13 TeV with the ATLAS detector

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on behalf of the ATLAS collaboration

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Motivations

- SM di-Higgs production can probe trilinear Higgs self-coupling.
- BSM models with extended Higgs sectors predict a heavy Higgs boson, which can decay into a pair of SM Higgs bosons.
- \( h \rightarrow WW^* \): second largest branching ratio after \( h \rightarrow b\bar{b} \).
- \( h \rightarrow \gamma\gamma \): excellent diphoton mass resolution distinguishes signal and backgrounds.

<table>
<thead>
<tr>
<th>BR</th>
<th>bb</th>
<th>WW*</th>
<th>tt</th>
<th>ZZ</th>
<th>\gamma\gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>b\bar{b}</td>
<td>33%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WW*</td>
<td>25%</td>
<td>4.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tt</td>
<td>7.4%</td>
<td>2.5%</td>
<td>0.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZZ</td>
<td>3.1%</td>
<td>1.2%</td>
<td>0.3%</td>
<td>0.08%</td>
<td></td>
</tr>
<tr>
<td>\gamma\gamma</td>
<td>0.26%</td>
<td>0.1%</td>
<td>0.029%</td>
<td>0.013%</td>
<td>0.005%</td>
</tr>
</tbody>
</table>
Review

  - Observed (expected) upper limit for non-resonant production is 1150 (680) $\times$ SM (10.15 fb).

- ATLAS Run 2 (13.3 fb$^{-1}$): ATLAS-CONF-2016-071
  - Observed (expected) upper limit for non-resonant production is 748 (386) $\times$ SM (33.41 fb).
Run 2 analysis with 36.1 fb$^{-1}$

- Focus on semi-leptonic WW decay (HH → γγlvjj).
- Trigger & Event selections:
  - Di-photon trigger.
  - Two tight photons with $p_T > 25$ GeV;
  - $p_T / m_{\gamma\gamma} > 0.35$ (0.25) for leading (subleading) photon.
  - At least one lepton;
  - At least two jets, b-veto.
  - $p_T(\gamma\gamma) > 100$ GeV for $m_X \geq 400$ GeV and non-resonant production.
  - $105 \text{ GeV} < m_{\gamma\gamma} < 160$ GeV.
  - $|m_{\gamma\gamma} - 125.09 \text{ GeV}| < 2\sigma$ ($\sigma = 1.7$ GeV).

Analysis strategy:
→ Continuum background (γγlvjj) estimated with side-band data (~90%);
→ Single Higgs backgrounds by MC.
Systematics

- The dominant uncertainties come from continuum background modelling (spurious signal).

- Fit a signal-plus-background model to a large-size simulated background-only sample, which consists of irreducible ($\gamma\gamma lvjj$) and reducible processes (where one or two hadronic jets are misidentified as photons).

- The maximum fitted signal yields reach $0.46 (0.26)$ when (not) applying the $p_T(\gamma\gamma)$ cut among non-resonant and resonant signal models ($\sim0.04$ for predicted SM Higgs yield).
A fit to the $m_{\gamma\gamma}$ distribution is performed to extract the signal yield.

$$\mathcal{L}(\mu, \theta) = \prod_i \left((n_{\text{Signal}}(\mu, \theta) + n_{ss}) \times f_{\text{DSCB}}^1(m^i_{\gamma\gamma}, \theta) + n_{\text{Cont}} \times f_{\text{Cont}}(m^i_{\gamma\gamma}, \theta) + n_{\text{SM-one-Higgs}}(\theta) \times f_{\text{DSCB}}^2(m^i_{\gamma\gamma}, \theta) + n_{\text{SM-di-Higgs}} \times f_{\text{DSCB}}^3(m^i_{\gamma\gamma}, \theta) \right) \prod G(0|\theta, 1)$$
Results

- A modified CLs method is used to calculate the 95% CL exclusion limits with the asymptotic approximation.
- The observed (expected) limit for non-resonant production is 230 (160) × SM.
- The observed (expected) limit for resonant production ranges from 40 pb (17.6 pb) to 6.1 pb (4.4 pb).
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Stay tuned!  
Thank you!
Back up
95% CL limits on $\sigma(gg \rightarrow X) \times BR(X \rightarrow HH \rightarrow \gamma\gamma WW)$ [pb]

$\sqrt{s} = 13$ TeV, 36.1 fb$^{-1}$

**ATLAS** Preliminary

- Observed
- Expected
- $\pm 1\sigma$ expected
- $\pm 2\sigma$ expected

m$_x$ [GeV]