Searches for New Phenomena in Leptonic or Hadronic Final States using the ATLAS Detector

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on behalf of the ATLAS Collaboration
Introduction

- ATLAS collected 139 fb\(^{-1}\) pp data for physics analyses in run-2 (2015-2018)
- A large number of analyses are analyzing this data for precision measurements and BSM searches
- Relatively recent analyses with hadronic/leptonic final states covered here
Vector-like Quark: $B \rightarrow bH(bb)$

- Search for $-\frac{1}{3}$ charged VLB quark decaying to $H + b$ with $H \rightarrow bb$
- All hadronic final state: reconstructed Higgs Candidate (HC) based on large-R jet pT, mass, and associated b-tagged track jets
- Fitted on reconstructed VLB mass: $m_B = m(HC + jet)$ with $dR(\text{jet, HC}) > 2.5$
- Data driven estimation for QCD multijet background using ABCD method

$$N_A = N_B \times \left( \frac{N_C}{N_D} \right)$$
Vector-like Quark: $B \rightarrow bH(bb)$

- Excludes VLBs up to 2 TeV in doublet representations for moderate and higher couplings
- Interpretation: Limits on coupling as a function of VLB mass for doublet representation
Multi b-jet Resonance Search

ATLAS-CONF-2021-019

- Search for resonances decaying to a pair of b jets: fully hadronic final state
- Dedicated tri-jet trigger with asymmetric thresholds - data cannot be modelled by usual empirical functional forms
- Background estimation based on functional decomposition with exponential basis functions
- $Z'$ mass excluded up to 1.45 TeV
**LFV: $Z \rightarrow \tau + e/\mu$**

- Single lepton ($e/\mu$) final state with hadronic $\tau$ candidate
- Reconstructed $\tau$ from 1 or 3 matched jet tracks (1 prong / 3 prong taus)
- Multiple neural networks trained to classify signal against $W+\text{jets}$, $Z\rightarrow\tau\tau$, and $Z\rightarrow ll$
- Combined NN output is determined by a weighted mean squared value of the NN outputs
- Limits on LFV BRs supercede the previous bounds from LEP

### Graphs

**Graph 1:**
- ATLAS
- $\ell = 13$ TeV, 139 fb$^{-1}$
- SR, $e/\mu$ 1P
- Data, $Z\rightarrow e/\mu$ fake, $Z\rightarrow\tau\tau$, $Z\rightarrow l\ell$, Others
- Total uncertainty
- $Z\rightarrow e/\mu (6.5 \times 10^{-6})$

**Graph 2:**
- ATLAS
- $\ell = 13$ TeV, 139 fb$^{-1}$
- SR, $\mu$ $\tau$ 3P
- Data, $W\rightarrow\tau\ell$, $Z\rightarrow e/\mu$ fake, $Z\rightarrow\tau\tau$, $Z\rightarrow l\ell$, Others
- Total uncertainty
- $Z\rightarrow e/\mu (5 \times 10^{-6})$

**Results:**
- $\text{BR}(Z\rightarrow\mu\tau) < 9.5 \times 10^{-6}$
- $\text{BR}(Z\rightarrow e\tau) < 8.1 \times 10^{-6}$

[arxiv:2010.02566]
Type III Seesaw Heavy Leptons

- Di-lepton (e/μ) + inclusive di-jet final state
- Opposite sign and same sign signatures
- Control, validation, and signal regions defined according to the OS/SS category along with the lepton flavor combination

$$\begin{array}{c|c|c|c|c|c|c|c|c|c|c|c|c} & \text{OS} (\ell^+\ell^- = e^+e^-, \mu^+\mu^-) & \text{SS} (\ell^+\ell^- = e^+e^-, \mu^+\mu^-) \\
\hline
\text{N(jet)} & \geq 2 & \geq 2 & \geq 2 & \geq 2 & \geq 2 & \geq 2 \\
\text{N(b-jet)} & \geq 2 & 0 & 0 & 0 & 0 & 0 \\
\text{m}_{jj} [\text{GeV}] & (60, 100) & (35, 60) \cup (100, 125) & (60, 100) & (60, 100) & (0, 60) \cup (100, 300) & (0, 60) \cup (100, 300) & (60, 100) \\
\text{m}_{\ell\ell} [\text{GeV}] & \geq 110 & \geq 110 & \geq 110 & \geq 100 & \geq 100 & \geq 100 \\
\text{S(E}_{T\text{miss}}) & \geq 5 & \geq 10 & \geq 10 & \geq 5 & \geq 5 & \geq 7.5 \\
\Delta(\text{E}_{T\text{miss}}, \ell_{\text{min}}) & - & - & - & - & - & - \\
\text{p}_{T}(jj) [\text{GeV}] & - & - & - & - & - & - \\
\text{p}_{T}(\ell\ell) [\text{GeV}] & - & - & - & - & - & - \\
\text{H}_{T} + E_{T} [\text{GeV}] & \geq 300 & \geq 300 & \geq 300 & (300, 500) & \geq 500 & \geq 300 \\
\end{array}$$

Type III Seesaw Heavy Leptons

- Data-driven estimation of misidentified leptons and fake
- Binned likelihood fitting of $H_T$ (scalar sum of jet and lepton $p_T$) + MET
- Excludes masses up to ~800 GeV for doublet masses
Non-resonant Dilepton Search

- Model-independent non-resonant search with control and signal regions defined based on interference pattern according to Contact Interactions (CI) model
- Background fitted against a smoothly falling functional form in CR and extrapolated in the SR
- Limits interpreted in terms of compositeness energy scale ($\Lambda$) for all combinations of dilepton chirality structure and interference type
Three and Four Lepton Final States

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- 22 signal regions based on invariant mass of leptons, on/off-shell Z and MET threshold
- Additional WZ and ZZ control regions for 3l and 4l selections
- Fakes estimated by determining data-driven fake factors in dedicated regions and propagating them to CR/SRs
- Cross-section upper limits calculated in each SR (appended in backup)
Summary

- Recent ATLAS results setting strong constraints on model-specific and model-independent BSM searches
- ATLAS continues work on BSM searches with the Run 2 dataset. More results are in the pipeline
- Additional ATLAS results presented in dedicated LQ, Higgs pair production talks
LFV: $Z \rightarrow \tau + e/\mu$

[Diagram with various plots showing data and predictions for different channels: $f_s = 13$ TeV, $139$ fb$^{-1}$]
### Three and Four Lepton Final States

#### Link to Results

<table>
<thead>
<tr>
<th>Mass Range</th>
<th>$N_{95}$ (exp.)</th>
<th>$N_{95}$ (obs.)</th>
<th>$\sigma_{vis}$ [fb] (exp.)</th>
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<tbody>
<tr>
<td>$3\ell$, On-Z, $E_{T}^{miss} &lt; 50$ GeV</td>
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<td>&lt;200 GeV</td>
<td>96 $^{+38}_{-27}$</td>
<td>90</td>
<td>0.69 $^{+0.27}_{-0.19}$</td>
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<td>200-400 GeV</td>
<td>77 $^{+30}_{-21}$</td>
<td>61</td>
<td>0.55 $^{+0.22}_{-0.15}$</td>
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<td>400-600 GeV</td>
<td>25 $^{+10}_{-7}$</td>
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<td>0.18 $^{+0.08}_{-0.05}$</td>
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<td>&gt;600 GeV</td>
<td>14 $^{+6}_{-4}$</td>
<td>7</td>
<td>0.10 $^{+0.04}_{-0.03}$</td>
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<td>&gt;400 GeV</td>
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