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Event Selection and Analysis Strategy for Diphoton Resonance Searches Accompanied by Leptonic Final States in 2022-2024 ATLAS Run 3 data

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The search for new scalar resonances at the Large Hadron Collider (LHC) is motivated by beyond the Standard Model (BSM) scenarios such as the Two-Higgs-Doublet Model with an additional scalar singlet (2HDM+S) and the Real Higgs Triplet Model. The 2HDM+S and Triplet model BSM frameworks is being used to study new scalar particles that may decay into final states involving photons and leptons. In particular, these models motivate searches for di-photon signatures accompanied by leptons. This study focuses on scalar resonance production via the process $gg \rightarrow H \rightarrow SS'$, where $S \rightarrow \gamma\gamma$, and S' decays into one or more leptons and/or hadrons. Relevant decay modes of S' include $\tau, \ell + b$ ($\ell = e, \mu$), and multi-body final states such as $2\ell, 2\tau$, or combinations thereof. Among the various final states, particular attention is given to the channels $\gamma\gamma + \ell$ and $\gamma\gamma + 2\ell/2\tau$, given their sensitivity to scalar resonances and experimental accessibility. We are currently developing analysis strategies and selection tools in preparation for the analysis of Run~3 data, corresponding to an integrated luminosity of 183 fb^{-1} at $\sqrt{s} = 13.6 \text{ TeV}$. The goal is to identify signal-like events while mitigating dominant SM backgrounds.

Keywords: $\gamma\gamma + \ell, \gamma\gamma + 2\ell$

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