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Multi-photon decays of the Higgs boson at the LHC

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Many new physics scenarios predict multi-photon Higgs resonances. One such scenario is the dark axion portal. The primary decay chain that we study is the Higgs to dark photon (γ_D) pairs that subsequently decay into a photon and an axion-like particle (a). The axion-like particles then decay into photon pairs. Hence, the signal is a six-photon Higgs decay: $h \to \gamma_D\,\gamma_D \to 2\,\gamma 2\,a \to 6\gamma$. However, depending on the relevant kinematics, the photons can become well-collimated and appear as photon-jets (multiple photons that appear as a single photon in the detector) or ξ-jets (non-isolated multi-photon signals that do not pass the isolation criterion). These effects cause the true six-photon resonance to appear as other multi-photon signals, e.g., four or two photons. The four photon signal is particularly interesting. These events mainly occur when the photons from the axion are collimated into a photon jet. The apparent decay of the dark photon is then $\gamma_D \to \gamma a \to \gamma + \gamma$-jet. This decay seems to violate the Landau-Yang Theorem at the detector level since the dark photon appears to decay into a pair of massless photons. We explore and examine the multi-photon signals that could appear at the Large Hadron Collider (LHC). The mass regions where two, four, and six-photon resonances dominate are determined. Some additional signal categories involving ξ-jets are considered. All of these multi-photon signals provide excellent footing to explore new physics at the LHC and beyond.

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