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Exploring Exotic Decays of the Higgs Boson to Multi-Photons at the LHC via Multimodal Learning Approaches

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The LHC has not yet fully constrained the physics associated with the Higgs boson, leaving room for such possibilities. Among the various potential mass scales of the dark sector, the sub-GeV mass range is particularly intriguing. This parameter space presents significant challenges for DM direct detection experiments that rely on nuclear recoils.
Due to the significantly lower mass of particles in the dark sector compared to the Higgs boson, these particles are expected to be highly boosted following the Higgs boson's decay.
We employ a well-motivated leptophobic Z'_B model as a prototype to analyze the distinctive signatures from Higgs boson exotic decays into multi-photons. These signatures consist of collimated photons that fail to meet the photon isolation criteria, forming jet-like objects. Conventional analyses relying solely on the purity of energy deposits in the electromagnetic calorimeter would fail to detect these signatures, as they would be overwhelmed by background events from Quantum Chromodynamics. To effectively distinguish between such novel signal signatures and SM background events, we leverage advanced machine learning techniques, specifically the transformer encoder in a multimodal network structure.

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