The Search for Dark Matter Through Soft Unclustered Energy Patterns at CMS

Park, Michelle (School: Solon High School)

The identity and behavior of the invisible dark matter, which constitutes most of the mass in the universe, is a central yet unresolved question at both the cosmological and quantum scales. Potential candidates for dark matter particles are soft unclustered energy patterns (SUEPs), which are spherically symmetric and highly populated showers of low-energy particles. However, SUEPs are unexplored as their low-energy constituents cannot be distinguished from common high-energy background events at the Compact Muon Solenoid (CMS) particle detector. Here, solutions are developed for CMS by investigating Monte Carlo simulations of SUEP and background events, modeled from SUEP mass benchmarks and the Large Hadron Collider's Run 2 data, respectively. I implemented boosting, a novel method that changes the frame of reference so that the SUEP's spherical event shape becomes more distinct from background events. The discriminatory power of the variable selections, measured by the ratio of the experimental cross section to the theoretical cross section, was tested before and after boosting for several SUEP masses. At the more challenging lower mass benchmarks, all boosted selections had sufficient data collected for each mass benchmark and outperformed their unboosted counterparts in SUEP discrimination. At higher mass benchmarks, SUEP candidates were fully separated from the background for all unboosted and boosted selections. Thus, the present study is the first to implement and conclude that boosting is a necessary approach for discriminating SUEP candidates, especially for those with low masses.

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