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Implementation of Machine Learning Algorithms to Form Di-Muons from Off-Shell Parent Particles

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In high energy physics, Machine Learning (ML) has been applied to a broad range of problems: from jet tagging to particle identification, from the separation of signal over background, to fast simulation of event data, to to name a few. In this presentation, ML algorithms and techniques are explored to form lepton pairs (di-leptons) in a dark fermionic model.
In this model, the final-state leptons are the products of off-shell dark Z (Z_D) bosons. This presents a unique challenge since the identification of their parent particle cannot be done by a simple invariant mass comparison calculation. Machine learning can greatly simplify this imposing task of matching final-state muons with their associated parent particles by exposure to correctly matched events and invalid permutations of these muons.
Monte Carlo-simulated proton-proton collision data at $\sqrt{s}$ = 13 TeV, corresponding to an integrated luminosity of 35.9 fb^{-1} are preprocessed, and the resulting muon observables such as ϕ, η, p_T, and charge, as well as higher-level, calculated observables, such as the ΔR and the invariant mass of the formed dimuon pair are used as input features to ML algorithms, including `XGBoost`, deep neural networks, boosted decisions trees, support vector machine learning, as well as ensemble methods of the aforementioned models.
These models are trained and hyperparameter tuning is performed to achieve the highest classification accuracy. The performance of these models are compared and discussed. The methods presented here can be applied to both MC-generated and real data from the LHC, and a wide range of problems in which efficiently matching final-state particles to the decaying off-shell parent particle are necessary for proper event reconstruction.

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