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A Neural-Network-defined Gaussian Mixture Model for particle identification in LHCb

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Presented is a novel method for analyzing particle identification (PID) by incorporating machine learning techniques, applied to a physics case within the fixed-target program at the LHCb experiment at CERN. Typically, a PID classifier is constructed by integrating responses from specialized subdetectors, utilizing diverse techniques to ensure redundancy and broad kinematic coverage. The efficiency of PID selections varies with several experimental observables, such as particle momentum, collision geometry, and experimental conditions. To accurately model the PID classifier distribution and address simulation imperfections, extensive calibration samples from data reconstruction and selection are essential but not always available.

In this proposed approach the PID classifier is modeled using a Gaussian Mixture Model by combining the well-established maximum-likelihood technique with state-of-the-art machine learning libraries and methods. The model parameters are determined by Multi-Layer Perceptrons, which are fed with relevant experimental features. This ensures that the PID classifier's non-trivial dependencies are learned. The presented approach has been demonstrated on a proof-of-principle physics case to match or improve detailed simulations, especially when limited calibration data is available. It is applicable to a wide range of cases involving experimental observables dependent on numerous experimental features. For the LHCb experiment's fixed-target program, this approach serves to mitigate the dominant experimental uncertainties.

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