

MACHINE-LEARNING CLASSIFICATION OF Λ_b DECAYS USING TMVA AND DEEP NEURAL NETWORK

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Pentaquarks are exotic hadronic states that may manifest as resonant structures in the $\Lambda_c^+ \bar{D}^{*0}$ subsystem of $\Lambda_b^0 \rightarrow \Lambda_c^+ \bar{D}^{*0} K^-$ decays. The study of such states requires distinguishing decay contributions proceeding via an intermediate resonance from non-resonant events. Traditional kinematic selection criteria applied to variables such as transverse momentum p_T , invariant mass, or decay vertex quality can suppress background but ignore the correlations between variables. Multivariate methods address this problem by considering several variables simultaneously and accounting for their relationships.

ROOT, the open-source data analysis framework developed at CERN, has a subsystem, TMVA (Toolkit for Multivariate Analysis), which provides machine-learning algorithms such as Boosted Decision Trees (BDT) and Multi-Layer Perceptrons (MLP). Deep neural networks (DNN), in contrast, are more flexible models capable of learning complex non-linear dependencies, making them well suited for problems when features are strongly correlated.

In this project, simulated $\Lambda_b^0 \rightarrow \Lambda_c^+ \bar{D}^{*0} K^-$ decays were used to study the separation of resonant and non-resonant decay contributions. Events were generated using `RapidSim`, with detector smearing and the LHCb detector geometry. The non-resonant contribution corresponds to direct three-body decays with the same final state but without an intermediate resonance.

Classifier performance was evaluated using Receiver Operating Characteristic (ROC) curves, signal efficiency versus background rejection, and stability across different feature sets.

[1] R. Aaij et al. (LHCb Collaboration), Observation of J/ψ p resonances consistent with pentaquark states in $\Lambda_b^0 \rightarrow J/\psi K^- p$ decays.

[2] R. Aaij et al. (LHCb Collaboration), First observation of the $\Lambda_b^0 \rightarrow \Lambda_c^+ D_s^- K^+ K^-$ decay and search for pentaquarks in the $\Lambda_c^+ D_s^-$ system.