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Muon vs. pion separation at low momenta

Searches for New Physics effects at the intensity frontier are based on very precise measurements of observables involving rare processes within the Standard Model. Semileptonic decays of B meson are particularly interesting due to persistent hints of Lepton Flavour Universality (LFU) violation seen in $b \to c\tau\nu_\tau$ transitions with a massive τ lepton in the final state. Compared to the decays involving light leptons (electrons and muons) in the final state, where charged leptons can be detected directly, in semitauonic decays τ lepton must be reconstructed from its long-lived decay products making these decays experimentally more challenging. One of the crucial steps in the analysis of semitauonic decays is particle identification. In the Belle II experiment the sub-detectors designed for particle identification are: Time-of-Propagation (TOP) detector in the barrel region and the Aerogel Ring-Imaging Cherenkov detector (ARICH) in the forward endcap for hadron identification, while the outermost Klong-and-Muon (KLM) system provides K_L^0 and muon identification. Due to the large mass of the τ lepton its charged decay products (e. g., e or μ) are expected to have low momenta; this affects mainly the muon identification efficiency since muons from these decays often have momentum too low to be within the acceptance of the dedicated sub-detector KLM. One possibility to improve identification for momenta below $0.8\ \mathrm{GeV/c}$ would be the Cherenkov based TOP detector. At such low momenta, however, multiple scattering in the quartz bar blurs the pattern considerably making the identification with the TOP counter very inefficient. To mitigate this problem, we are exploring a possible extension of muon identification coverage ($p_T < 0.6\ \mathrm{GeV/c}$) by using the information from the electromagnetic calorimeter (ECL). Our main goal is to improve the separation of low momentum muons from hadronic background (mainly pions) using the information from the ECL in a form of 11×11 images, where the pixel intensity is set on the energy deposited by the charged particle in the ECL crystals. As a classifier we are using the Convolutional Neural Network (CNN), a powerful machine learning technique designed for working with two dimensional images. Using CNN on ECL images allows us to access the information on the shape of the energy deposition without depending on cluster reconstruction or track-cluster matching, i. e., the currently used high-level features. Comparing the performance of the classifiers based only on the ECL information on the simulated events, the CNN outperforms the existing classifiers based on expert-engineered ECL variables. Furthermore, combining the newly obtained information from the ECL in the global likelihood also improves the muon identification compared to the existing likelihood combination, using the standard likelihood from the ECL.

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