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Evaluation of PID Performance at CEPC and Optimization with Combined dN/dx and Time-of-Flight Data

This work presents a comprehensive study of charged-hadron particle identification (PID) at the Circular Electron-Positron Collider (CEPC), based on full simulation of hadronic Z-pole events. A unified PID strategy is developed by combining energy loss measurements (dN/dx) from the time projection chamber (TPC) and time-of-flight (ToF) information from both the inner (ITK) and outer (OTK) silicon trackers. The PID discriminant is constructed using residuals between measured and expected observables under multiple particle hypotheses, with identification regions optimized to maximize kaon efficiency and purity across bins of momentum and polar angle. Results show that the TPC alone, while highly efficient (99.3%), suffers from severe pion-induced contamination, yielding only 14.3% purity. Incorporating ToF from OTK improves the purity to 25.7%. A full combination of ITK, TPC, and OTK significantly enhances performance, achieving 96.8% efficiency and 87.4% purity (product: 84.6%). Furthermore, a momentum-dependent strategy that dynamically selects the optimal detector combination achieves the best overall performance, with 99.4% efficiency and 92.4% purity, corresponding to a 91.8% kaon identification quality. These results demonstrate that the CEPC baseline detector fulfills the requirements for precision flavor tagging and provide clear guidance for future optimization of timing detector configurations.

Primary authors: YU, Dian (Tsung-Dao Lee Institute); Mr DING, Houqian (Nanjing University); FAN（樊云云）, Yunyun (IHEP)

Presenter: YU, Dian (Tsung-Dao Lee Institute)

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