Charged Particle Identification Performances in Belle II

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Abstract

An efficient Particle identification(PID) is crucial for Belle II as it deals with a much higher event rate than Belle and ultimately with a more extensive background. PID is advantageous in suppressing background, studying rare decays, and for the flavor tagging of B-mesons. We study the charged Kaon and Pion identification performances based on the data collected by the Belle II experiment corresponding to a luminosity of $207 fb^{-1}$ and compare it with Monte Carlo simulations. For the study, the decay mode $D^{*+} \to D^0[\to K^-\pi^+\pi^0]\pi^+$ is reconstructed as it helps to probe the lower momentum region(< 0.5 GeV/c). The kaon efficiency and pion misidentification rates are calculated in bins of momentum and polar angle for the different PID criteria.

1 Introduction

SuperKEKB is an asymmetric e^+e^- collider located in Tsukuba, Japan, an upgraded version of the KEKB collider[1]. The primary goal of SuperKEKB is to achieve an instantaneous luminosity of $6 \times 10^{35}, \mathrm{cm}^{-2}\mathrm{s}^{-1}$. It operates by colliding electrons (7 GeV) and positrons (4 GeV) near the $\Upsilon(4S)$ mass resonance, with a significant energy asymmetry between the beams. This energy asymmetry enables improved separation of B meson vertices[2].

Belle II[3] detector is positioned at the interaction point of SuperKEKB, aiming to meet the demands of advanced physics research and detector requirements. Belle II incorporates two specialized sub-detectors: the Time-of-Propagation counter (TOP) and the Aerogel RICH counter (ARICH), both designed for efficient particle identification (PID). The PID capabilities of TOP and ARICH rely on Cerenkov angle measurements, while the Central Drift Chamber (CDC) utilizes specific ionization (dE/dx) to provide complementary PID information. This comprehensive approach to PID plays a crucial role in reconstructing decay modes, suppressing background, studying rare decays, and performing B meson tagging.

Particle identification is performed by analyzing the likelihood given by each subdetector for the particle of interest. The combined Particle ID for a given species is the combination of the likelihood for all detectors $\mathcal{L}_p = \sum \mathcal{L}_p^i$ (p=particle, i=subdetector). The Binary PID likelihood ratio will be used to study PID performance, which is defined as $\mathcal{R}_{K/\pi} = \frac{\mathcal{L}_K}{\mathcal{L}_K + \mathcal{L}_\pi}$ The kaon identification efficiency (ϵ_K) and and the pion mis-identification rate (f) is defined as:

$$\epsilon_K = \frac{\text{no. of K tracks identified as K}}{\text{no. of K tracks}}, f_\pi = \frac{\text{no. of } \pi \text{ tracks identified as K}}{\text{no. of } \pi \text{ tracks}} \quad (1)$$

2 Data Sample and Event Selection

We analyze data from Belle II corresponding to a 207 fb^{-1} integrated luminosity. The results are compared to the official Belle II Monte Carlo.

Specific event selection criteria are employed for the charged tracks identified as kaons and pions. These criteria include enforcing track origin requirements, such as limiting the impact parameters ($dr < 0.5$ cm in the x-y plane and $|dz| < 2$ cm along the z axis). Additionally, a minimum of 20 hits in the Central Drift Chamber (CDC) is required to ensure reliable particle identification (PID) likelihood information.

To reconstruct D^0 meson kaon and pion tracks with opposite charge and π^0 candidates from $\pi^0 \to \gamma\gamma$ decays are combined. The γ candidates must have an energy greater than 0.075 GeV and an E9/E25 ratio larger than 0.9. Another slow pion track (with an opposite charge as that of the kaon track) is combined with D^0 to reconstruct D^{*+} meson candidates. The reconstruction uses the treeFitter algorithm[4], which incorporates constraints on the impact parameter (IP) and the π^0 mass. Only candidates with a χ^2 value exceeding 0.01 are retained for further analysis.

To select D^{*+} meson candidates originating from the $e^+e^- \to c\bar{c}$ process, the momentum of the D^{*+} candidate in the e^+e^- center-of-mass (CM) frame ($P_{D^{*+}}$) should exceed 2.5 GeV/c. To ensure a cleaner sample, the π^0 candidates must also satisfy a mass window of [0.121, 0.147] GeV/c^2 and have a momentum exceeding 0.35 GeV/c. Finally, a requirement is imposed on the flight distance of the D^0 meson candidates, which must be greater than 40 μm.

3 Method

To study the PID performance, a fit to the $M[D^0]$ distributions fig 1 is performed with all the aforementioned criteria. The $M[D^0]$ distributions are fitted with a sum of one Novosibirsk[5] and one Asymmetric Gaussian function with a common mean and a first-order polynomial to describe the signal and background shapes, respectively.

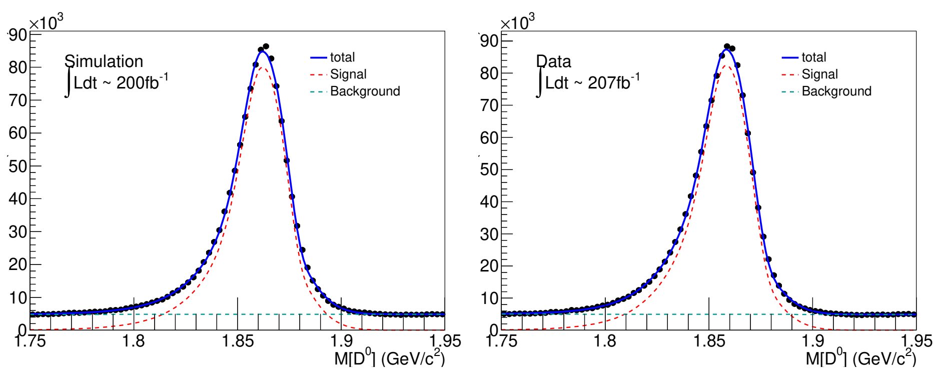

Figure 1: $M[D^0]$ distribution with a criterion $|\Delta M - 0.14543| < 1.5$ MeV/c^2 in MC sample (left), data sample (right)

We investigate PID performance for different $\mathcal{R}_{K/\pi}$ values as well as the performance in momentum and polar angle bins where a binary PID criterion $\mathcal{R}_{K/\pi} > 0.5$ is applied. A simultaneous fit is performed on the $M[D^0]$ distribution for tracks passing or failing the PID criteria, obtaining efficiency/misidentification rates.

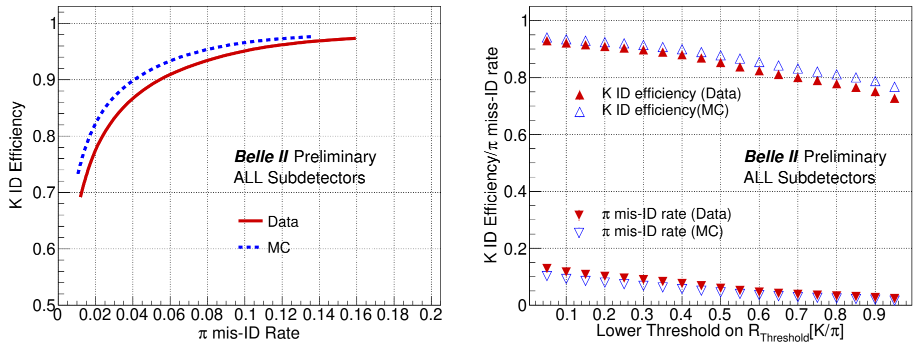

Figure 2: The K efficiency *vs.* π misidentification rate (left) and K efficiency and π misidentification rate *vs.* combined PID criteria (right) for the data sample (red) along with MC sample (blue).

K efficiency and π misidentification rate are analyzed for a specific PID criterion $\mathcal{R}_{K/\pi} > 0.5$ in momentum (0.2-4 GeV/c) and polar angle ($\cos\theta$) bins fig 3. The discrepancy between data and MC in K efficiency is primarily observed at higher momenta (>2 GeV/c). For momenta below 1.5 GeV/c, the π misidentification rate is slightly higher in the data than the MC. Regarding the polar angle, the difference in K efficiency is most significant in the mid-forward direction.

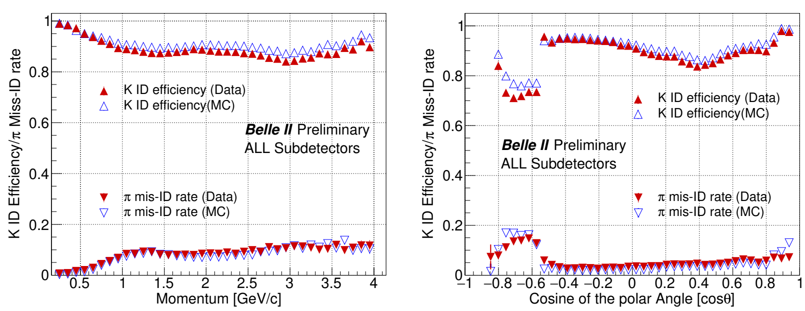

Figure 3: K efficiency and π misidentification rate in the data sample (red) compared with MC sample (blue) in the bins of momentum (left) and $\cos\theta$ (right).

4 Summary

The decay mode $D^{*+} \to D^0[K^-\pi^+\pi^0]\pi^+$ helps studying the K identification efficiencies and π misidentification rates. The PID performance is studied for different threshold cuts on the PID variable and in bins of momentum and polar angle. For PID > 0.5, we have a K efficiency of $(89.20 \pm 0.04)\%$ with a π mis-id rate $(5.08 \pm 0.02)\%$

References

1. Kurokawa S and Kikutani E. Overview of the KEKB accelerators. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 2003;499:1–7.
2. Robertson SH. The Belle II Experiment. Journal of Physics: Conference Series 2019;1271:012011.
3. Abe T et al. Belle II Technical Design Report. 2010.
4. Krohn JF, Tenchini F, et al. Global decay chain vertex fitting at Belle II. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 2020;976:164269.
5. Ikeda H et al. A detailed test of the CsI(T) calorimeter for BELLE with photon beams of energy between 20 MeV and 5.4 GeV. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 2000;441:401–26.