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Study of $B \to X_c \Lambda^0 K_s / K$ with recoil mass approach

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In this study we search for decays $B^0 \longrightarrow X_c^- \Lambda^0 K^+$ and $B^0 \longrightarrow \overline{X}_c^0 \Lambda^0 K_s^0$ in Belle, where X_c represents a charm baryon. Belle collected data at a center of mass energy close to $\Upsilon(4S)$ resonance, which decays only to two B mesons almost every time. We follow a recoil approach where the other B meson is reconstructed in various hadronic modes, and the charm baryon is looked for in the recoil of the accompanying Λ^0 and K/K_s coming from signal B. This study will provide a comprehensive insight into $B \longrightarrow$ baryonic decays and the impact of $s\bar{s}$ quark pair production on the branching fractions.

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1. Introduction

The inclusive $B \to$ baryonic modes contribute approximately 6.8% of all B meson decays, as reported by ARGUS [1]. In contrast, the cumulative percentage for exclusive baryonic modes in B meson decays is approximately ~1% [2]. The decay mechanism for B mesons predominantly involves $b \to cW$ transitions, particularly leading to the creation of charmed baryons or mesons. While $B \to$ charm meson modes have been extensively studied, the examination of charm baryon modes has always been concentrated towards Λ_c, such as $B \to \Lambda_c p(n)\pi$ (n=1,2,3,4) [3][4] and $B \to \Lambda_c \Xi_c$ [5]. Notably, these decays either proceed via $b \to c$ transitions with $u\bar{u}$, $d\bar{d}$ production or $b \to s$ transitions. Decays involving $b \to c$ with $s\bar{s}$ production have received less attention. Our investigation focuses on $B \to \overline{\text{Baryon}_c}$ Baryon_s Meson_s (where the subscripts refer to the flavor, c- charm, s- strange), necessitating at least one $s\bar{s}$ production coupled with a $b \to c$ transition. This exploration aims to shed light on how $s\bar{s}$ production influences the branching fraction ($\mathcal{B}$) of these decays. With heavier and excited charm baryons, the exclusive reconstruction becomes challenging for their complicated decay processes. The charmed baryon is looked for in the recoil to deal with this.

The analysis is conducted using the Belle simulation, which involves $e^+e^- \to \Upsilon(4S) \to B^+B^-$, $B^0 \to \Upsilon(4S) \to B^0\overline{B}^0$, $q\overline{q}(q = u, d, s, c)$. The Belle detector [6], which operated at the KEKB asymmetric- energy e^+e^- collider [7], collected data at a center of Mass energy close to $\Upsilon(4S)$ mass resonance from 1999 to 2010. Our analysis builds upon the inherent characteristic observed in Belle, where the two B mesons stemming from the $\Upsilon(4S)$ resonance display a distinct behavior. Specifically, they undergo a back-to-back decay when viewed within the rest frame of the $\Upsilon(4S)$. This fundamental property forms the basis for our investigation.

2. Event Selection

For $B \to X_c^- \Lambda^0 K^+$, X_c can be Λ_c/Σ_c or any excited state of these baryons, and similarly for $B \to X_c^0 \Lambda^0 K_s^0$, X_c can be Σ_c or other higher resonances of Σ_c. A comprehensive determination of the kinematic parameters necessitates the reconstruction of one B meson, denoted as B_{tag}, through fully hadronic modes. The reconstruction is facilitated by an algorithm named FEI (Full Event Reconstruction). To maximize the chances of getting a correct B_{tag}, it's beam-constrained mass $M_{bc}(= \sqrt{(E^{CMS}/2)^2 - \vec{p}_B^{\,2}})$ must be greater than 5.27 GeV/c^2. Additionally, the absolute value of the energy difference $\Delta E(= E_B^{CMS} - E^{CMS}/2)$ calculated should lie below 0.05 GeV. For more purity, the classifier output of FEI, $\mathcal{P}_{FEI}$ must be larger than 0.01. Whenever more than one B_{tag} is present in an event, the one with the highest $\mathcal{P}_{FEI}$ is considered for the analysis. Following the reconstruction of the B_{tag} meson, the subsequent step entails the identification of a Λ^0 and a K/K_S^0 within the system.

2.0.1 Λ^0 Selection

The Λ^0 candidates are reconstructed from the decay $\Lambda^0 \to p^+\pi^-$. Due to the long lifetime of the Λ^0 particle, which allows it to travel a substantial distance before decaying, a dedicated Belle algorithm is employed for its identification. This algorithm incorporates additional selection criteria based on a range of properties characterizing the Λ^0, including its momentum, flight distance, and daughter particle characteristics. Applying these criteria allows a considerable background of fake Λ^0 candidates to be effectively suppressed. For the final selection of Λ^0 candidates, a mass window of 3σ is implemented, which constrains $M[\Lambda^0]$ to lie in [1.113, 1.118] GeV/c^2.

2.0.2 K_S^0 Selection

The K_S^0 candidates are required to decay via $K_S^0 \to \pi^+\pi^-$. The selection is similar to the selection of Λ^0, and the mass of K_S^0 must lie between [0.490,0.505]GeV/c^2.

2.0.3 K Selection

Selection of the kaon track includes constraints on the impact parameters in the transverse plane < 1 cm and along the longitudinal axis < 3 cm. These requirements effectively pinpoint the trajectory of the kaon track relative to the interaction point. Furthermore, particle identification variables distinguish the kaon from other particles. In particular, a minimum requirement of a $L_{K/\pi} > 0.4$ is imposed, where $L_{K/\pi}$ represents the likelihood ratio between the kaon and pion hypotheses.

3. Background Suppression

After all the selections, we look into the recoil mass (M_{recoil}) distribution, where the background due to the light quarks, $e^+e^- \to q\bar{q}$ known as continuum background make up nearly 54% of the total background. This background is suppressed using FastBDT. The classifier is trained with several event-shape variables. After optimization, only events that qualify the FBDT output of 0.45 are considered for the analysis. For a further pure sample, only some B_{tag} modes are considered out of all hadronic modes reconstructed by FEI.

4. Signal yield estimation

After all the selection and background suppression, the signal yield is estimated by a 1D unbinned maximum likelihood fit to M_{recoil}. The signal PDFs are modelled with a sum of 2 Gaussians, and an exponential function describes the backgrounds. The statistical significance

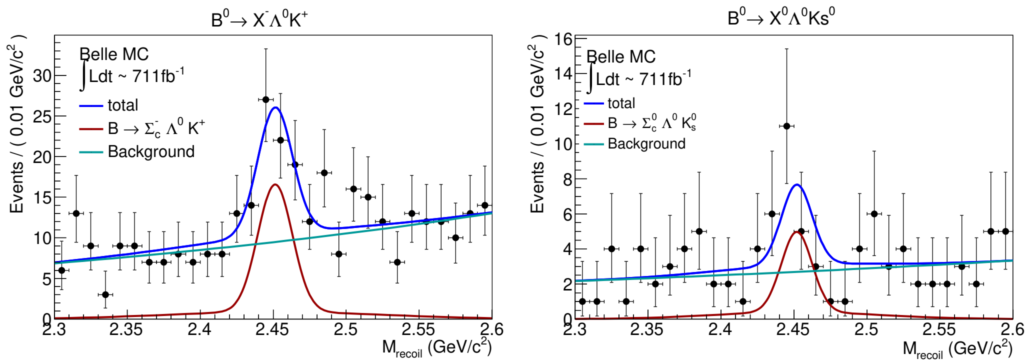

Figure 1: fit to M_{recoil} of $B^0 \to X_c^- \Lambda^0 K^+$(left) and $B^0 \to X_c^0 \Lambda^0 K_s^0$(right)

obtained for $N_{\Sigma_c^-}$ is 5.8σ, where as that for $N_{\Sigma_c^0}$ is 2.5σ. The significance is calculated using $\sqrt{-2\ln(\mathcal{L}_0/\mathcal{L}_{max})}$ where $\mathcal{L}_0$ represents the likelihood without signal hypothesis and $\mathcal{L}_{max}$ is the likelihood with a signal component.

5. Result and Discussion

The signal yield obtained from the fit of M_{recoil} is used to calculate the $\mathcal{B}$ of the decays mentioned. The $\mathcal{B}$ of $B^0 \to \Sigma_c^- \Lambda^0 K^+$ is calculated as

$$\mathcal{B}(B^0 \to X_c^- \Lambda^0 K^+) = \frac{N_{sig}}{N_{B\overline{B}} \times \epsilon \times \mathcal{B}(\Lambda^0 \to p^+\pi^-)}$$

whereas for $B^0 \to X_c^0 \Lambda^0 K_s^0$,

$$\mathcal{B}(B^0 \to \overline{X}_c^0 \Lambda^0 K_s^0) = \frac{N_{sig}}{N_{B\overline{B}} \times \epsilon \times \mathcal{B}(\Lambda^0 \to p^+\pi^-) \times \mathcal{B}(K_s^0 \to \pi^+\pi^-)}$$

Where ϵ is the efficiency of reconstruction, calculated from dedicated high statistics simulated samples of $B^0 \to \Sigma_c^- \Lambda^0 K^+$ and $B^0 \to \bar{\Sigma}_c^0 \Lambda^0 K_s^0$. The efficiency of reconstruction and $\mathcal{B}$ obtained are listed in the table below. The calculated $\mathcal{B}$ is found to be consistent with generated value.The

Decay	$\epsilon(10^{-4})$	Yield	$\mathcal{B}(10^{-4})$
$B^0 \to \Sigma_c^- \Lambda^0 K^+$	6.16±0.25	62±13	2.02± 0.43
$B^0 \to \bar{\Sigma}_c^0 \Lambda^0 K_s^0$	1.89±0.14	17±7	2.4±0.95

Table 1: Summary of efficiency, Signal Yield, $\mathcal{B}$ for $B^0 \to \Sigma_c^- \Lambda^0 K^+$ and $B^0 \to \bar{\Sigma}_c^0 \Lambda^0 K_s^0$

whole study is done with a simulated sample using phase space, whereas the underlying mechanism in data might show a new picture. The excited states of the baryons are not simulated, but their presenece in data may direct towards new unknown modes.

References

[1] H. Albrecht et al. (ARGUS Collaboration), *Z. Phys. C 56, 1 (1992).*

[2] R.L. Workmanet al.(Particle Data Group), *Prog.Theor.Exp.Phys.2022, 083C01 (2022).*

[3] S. A. Dytman et al. (CLEO Collaboration) *Phys. Rev. D 66, 091101(R) (2002).*

[4] J. P. Lees et al. (BABAR Collaboration), *Phys. Rev. D 87, 092004 (2013).*

[5] Y. Li et al. (Belle Collaboration), *Phys. Rev. D 100, 112010.*

[6] A. Abashian et al. (Belle Collaboration), *Nucl. Instrum. Methods Phys. Res., Sect. A 479, 117 (2002).*

[7] S. Kurokawa and E. Kikutani, *Nucl. Instrum. Methods Phys. Res., Sect. A 499, 1 (2003).*