Search for radiative D_s decays

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Abstract. The study of weak radiative decays of charmed mesons is still in its developing stage. The weak decays of D mesons pose challenges due to significant final-state interactions. However, decays mediated by $c \to u\gamma$ transitions can be affected by potential contributions coming from the non-minimal supersymmetry, which is a New Physics (NP) scenario. The ratio of branching fractions for radiative D^0 decays could be violated already in the SM framework, while a similar ratio for D_s^+ radiative decays offers much better prospects for new physics. We present herein the first sensitivity study of the radiative charm decays $D_s^+ \to \rho^+\gamma$ and $D_s^+ \to K^{*+}\gamma$ with simulated data collected by the Belle experiment.

Keywords: radiative, charm decays, Belle

1 Introduction

In the Standard Model (SM), the physics of charmed mesons faces certain challenges compared to strange and beauty mesons because the CP asymmetries and D^0 - $\bar{D}^0$ oscillations are small. Further, the weak decays of D mesons are difficult to investigate due to significant final-state interactions. However, it has been pointed out that the oscillations and $c \to u\gamma$ decays might have some contributions coming from the non-minimal supersymmetry (a NP scenario) [1]. Therefore, one can search for NP using $c \to u\gamma$ transitions. It was suggested that the NP would result in a deviation from the ratio of branching fractions:

$$R_{\rho/\omega} \equiv \frac{\Gamma(D^0 \to \rho^0/\omega\gamma)}{\Gamma(D^0 \to \bar{K}^{*0}\gamma)} = \frac{\tan^2\theta_c}{2}, \tag{1}$$

where θ_c is the Cabibbo angle. In order to find the best mode to study $c \to u\gamma$ transitions, the ratios between various Cabibbo-suppressed and Cabibbo-allowed radiative decays of charmed mesons are calculated within the SM. It has been noticed that Eq. (1) could be violated already in the SM framework because of a large, unknown correction, while a similar ratio for D_s^+ radiative decays

$$R_K \equiv \frac{\Gamma(D_s^+ \to K^{*+}\gamma)}{\Gamma(D_s^+ \to \rho^+\gamma)} = \tan^2\theta_c, \tag{2}$$

offers a much better probe for a NP signal, as the latter is less sensitive to the SM correction [2]. These radiative decays are largely governed by long-distance, non-perturbative processes, potentially enhancing branching fractions

(BFs). Therefore, measurements of BFs of these decays can be used to test the quantum chromodynamics (QCD)-based calculations that model long-distance dynamics. The BF of $D_s^+ \to \rho^+\gamma$ [$D_s^+ \to K^{*+}\gamma$] is expected to lie within the range of $O(10^{-5}) - O(10^{-3})$ [$O(10^{-8}) - O(10^{-4})$], according to the predictions of different theoretical models [7], which differ significantly depending on the D_s decay mode. The BF of $D_s^+ \to \gamma\rho(770)^+$ is measured to be $(2.2 \pm 0.9 \pm 0.2) \times 10^{-4}$, corresponding to an upper limit of 6.1×10^{-4} at the 90% confidence level, by the BESIII collaboration [8]. We present herein the first sensitivity study of these radiative D_s meson decays with simulated data from the Belle experiment.

2 KEKB and Belle

The Belle detector was located at the interaction point of the KEKB asymmetric-energy e^+e^- collider. It was a large-solid-angle magnetic spectrometer comprising six subdetectors [3], namely a silicon vertex detector, central drift chamber, aerogel Cherenkov counter, time-of-flight counter, CsI(Tl) crystal electromagnetic calorimeter, and K_L^0 and muon detector.

3 Analysis Strategy

We optimize the selection of signal candidates using simulated samples generated with the EvtGen [4] and Geant packages [5]. We reconstruct D_s^+ from $D_s^+ \to \rho^+\gamma$ and $D_s^+ \to K^{*+}\gamma$, where $\rho^+ \to \pi^+\pi^0$, $K^{*+} \to K_S^0\pi^+$ and $K^{*+} \to K^+\pi^0$. These studies are based on MC samples corresponding to an integrated luminosity of 711 fb^{-1}. The kinematic variable that distinguishes signal from background is the invariant mass of D_s^+. A π^0 veto is applied to suppress significant background contributions from decays where D_s or D^0 mesons produce final states including π^0, which lead to peaking backgrounds. We perform a dedicated background MC study in which the continuum background is found to be dominant. We employ multivariate analysis (MVA) based on the FastBDT package [6] to get rid of background processes such as $e^+e^- \to u\bar{u}, d\bar{d}, s\bar{s}$. After applying a cut on the output of MVA classifiers for the $D_s^+ \to \rho^+\gamma$ ($D_s^+ \to K^{*+}\gamma$) decay mode, we find a rejection of 65% (76%) of uds background at the cost of 10% (24%) of signal loss. The reconstruction efficiency is 0.5%, 3.1% and 0.8% for $D_s^+ \to \rho^+\gamma$, $D_s^+ \to [K^{*+} \to K_s^0\pi^+]\gamma$ and $D_s^+ \to [K^{*+} \to K^+\pi^0]\gamma$ decay modes. For $D_s^+ \to [\rho^+ \to \pi^+\pi^0]\gamma$ and $D_s^+ \to [K^{*+} \to K^+\pi^0]\gamma$ decay modes, the peaking background mostly comes from $D_s^+ \to \rho^+\eta$ and $D^{*+} \to D^0\pi^+$, while for $D_s^+ \to [K^{*+} \to K_s^0\pi^+]\gamma$, it is mostly from $D^0 \to K_S^0\pi^0$ and $D^0 \to K_S^0\eta$ decay modes.

4 Control Sample Study

We use the peaking backgrounds $D_s^+ \to \rho^+[\eta \to \gamma\gamma]$, $D^{*0} \to [D^0 \to K_S^0\eta]\gamma$ and $D^{*0} \to [D^0 \to K_S^0\pi^0]\gamma$, as our control sample to validate the signal extraction

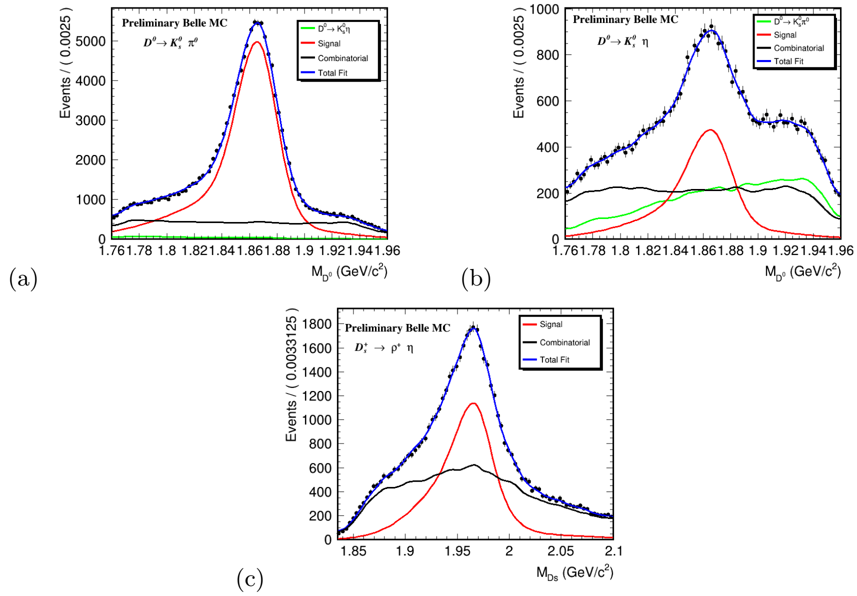

Fig. 1. Fitted distribution of Invariant mass of D^0 and D_s^+ for (a) $D^0 \to K_S^0\pi^0$, (b) $D^0 \to K_S^0\eta$ and (c) $D_s^+ \to \rho^+\eta$ decay modes.

procedure and to calibrate possible differences in the signal resolution between data and simulation. Figure 1 shows the unbinned maximum-likelihood fit performed on M_{D_s} and M_{D^0} for (a) $D_s^+ \to \rho^+\eta$, (b) $D^0 \to K_S^0\pi^0$, and (c) $D^0 \to K_S^0\eta$ decay modes using MC samples corresponding to an integrated luminosity of 711 fb^{-1}.

5 Signal Extraction

We have performed 1D unbinned maximum likelihood fit to extract signal yield. Figure 2 shows the total fitted distribution of M_{D_s} for (a) $D_s^+ \to \rho^+\gamma$, (b) $D_s^+ \to [K^{*+} \to K_s^0\pi^+]\gamma$ and (c) $D_s^+ \to [K^{*+} \to K^+\pi^0]\gamma$ decay modes, respectively.

6 Preliminary Results and Outlook

We are expecting 150-200, 20-30 and 8-12 events for $D_s^+ \to \rho^+\gamma$, $D_s^+ \to [K^{*+} \to K_s^0\pi^+]\gamma$ and $D_s^+ \to [K^{*+} \to K^+\pi^0]\gamma$, respectively. These expectations assume a branching fraction on the order of 10^{-4} for $D_s^+ \to \rho^+\gamma$ and 10^{-5} for $D_s^+ \to K^{*+}\gamma$, with a data sample corresponding to an integrated luminosity of 921 fb^{-1}.

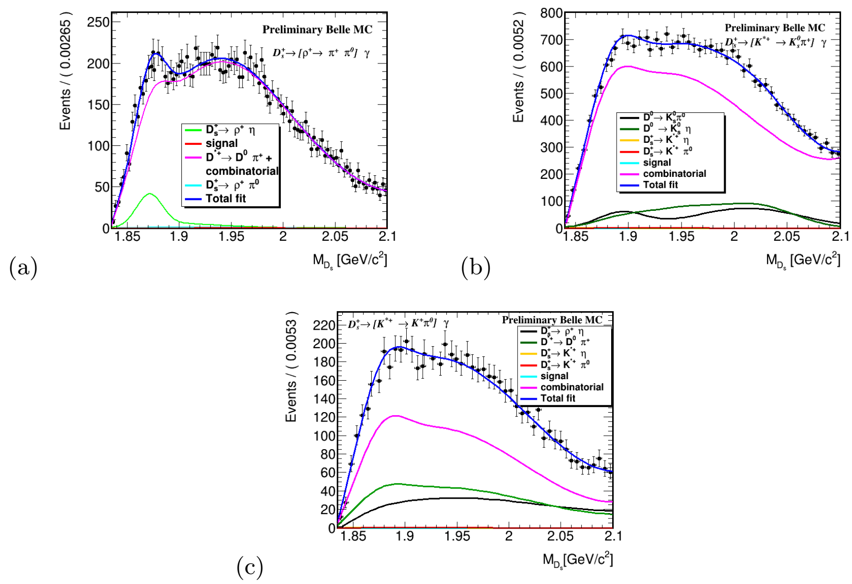

Fig. 2. Fitted distribution of Invariant mass of D_s^+ for (a)$D_s^+ \to \rho^+\gamma$, (b)$D_s^+ \to [K^{*+} \to K_s^0\pi^+]\gamma$ and (c)$D_s^+ \to [K^{*+} \to K^+\pi^0]\gamma$ decay modes.

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