Measurements of charmless B decays at Belle

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Recent results of the charmless B decays from Belle, namely the first inclusive mesurement of $B \to X_s \eta$ where X_s stands for anything containing unit strangeness in the final states, are presented. These include the partial branching fraction as well as the differential braching fractions as a function of M_{X_s} for $M_{X_s} < 2.6$ GeV/c^2, and the corresponding direct CP asymmetries. This study is based on a 605 fb^{-1} data sample, consisting of 657 million $B\bar{B}$ pairs, collected by the Belle detector at the KEKB asymmetric energy e^+e^- (3.5 on 8 GeV) collider.

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1. Introduction

Charmless B decays are very interesting because there is no dominant $b \to c$ amplitude. It is quite possible that a large direct CP violation could be found due to the interference between decay amplitudes of comparable size, e.g. the $b \to s$ penguin and the $b \to u$ tree processes. It is also sensitive to new physics beyond the Standard Model through additional contributions from unknown heavy virtual particles in the $b \to s(d)$ penguin loop. Last but not the least, the information obtained from two-body charmless B decays is very useful to determine the elements of the Cabibbo-Kobayashi-Maskawa (CKM) matrix and constrains the unitary triangle.

It is quite important to measure the inclusive process experimentally since the theoretical estimation of the corresponding B decay branching fraction is more accurate due to less uncertainty introduced in the hadornization part. The first observation of the inclusive charmless hadronic B decays, $B \to X_s \eta'$ [1, 2], revealed an unexpected contribution in the high M_{X_s} region. The magnitude of the partial branching fraction is also difficult to explain theoretically. Some efforts have been made to explain this phenomenon, for example, the QCD anomaly model [3], a large intrinsic $c\bar{c}$ component of the η' [4] and new physics sources [5]. A recent development [6] based on the soft collinear effective theory indicates that the information from $B \to X_s \eta$ could be complementary and useful to understand the contribution from charming penguin amplitudes or higher order gluonic operators to both the η and η' processes.

In this presentation, we will show the first inclusive measurement of $B \to X_s \eta$ [7]. The data sample used in this study is about 605 fb^{-1} which contains 657×10^6 $B\bar{B}$ pairs collected with the Belle detector [8] on the $\Upsilon(4S)$ resonance at the KEKB asymmetric energy $e^+ e^-$ (3.5 and 8 GeV) collider [9].

2. Event selection and signal extraction

We use a pseudo-inclusive method to reconstruct $B \to X_s \eta$ candidates, where X_s consists of a K^+ or K_S^0 and up to four pions, of which at most one can be a π^0. The event selection criteria for charged kaons and pions are based on the information obtained from the tracking system and the hadron identification system. K_S^0 candidates are reconstructed via the $\pi^+ \pi^-$ decay channel with an invariant mass close to its nominal mass [10]. The candidate must have a displaced vertex and flight direction consistent with a K_S^0 originating from the interaction point. η and π^0 candidates are reconstructed by $\gamma\gamma$ with energies and positions determined by the electro-magnetic calorimeter and their momenta are recalculated by constraining the two photon invariant masses to the nominal ones [10]. Besides some minimum energy cuts on these γ's to reduce background, there is a special cut on the η momentum in the center-of-mass (CM) frame, $p_\eta^{CM} > 2.0$ GeV/c, which is useful to suppress secondary η's from $b \to c \to \eta$. We also reject candidate events when the final state particles can form D^0, D^+, D_s^+, η_c or η'.

The challenge of studying rare B decays is the suppression of overwhelmingly large background from the continuum $e^+ e^- \to q\bar{q}$ processes, where q stands for u, d, s, or c quark. One can use event-shape variables to separate the more spherically B events from the jet-like continuum events. A GEANT [11] based Monte Carlo (MC) package is used to simulate signal events and estimate efficiencies in bins of X_s mass, M_{X_s}. The MC samples consist of $B \to K\eta$, $B \to K^*\eta$, and

$B \to X_s \eta$ components, where the X_s mass spectrum is assumed to be flat and its fragmentation into hadrons is done via PYTHIA.

The collision kinematics at a B-factory provide an over-constrained system in which both the mass and energy of the B meson are known in the CM frame. We choose two kinematic variables in the CM frame to identify the reconstructed B meson candidates: the beam energy constrained mass $M_{bc} = \sqrt{E_{beam}^2 - p_B^2}$, and the energy difference $\Delta E = E_B - E_{beam}$, where E_{beam} is the beam energy, and p_B and E_B are the momentum and energy, respectively, of the reconstructed B meson. We use the ΔE information to select the best candidate if there are multiple candidates per event. We perform an unbinned extended likelihood fit on M_{bc} to determine the signal yield in 200 MeV/c^2 bins of M_{X_s} up to 2.6 GeV/c^2. The signal probability density function (PDF) is a Gaussian peaking at the B meson mass. The continuum background is modeled by the ARGUS function [12]. There are non-negligible background events from $B \to X_c \to X_s \eta$ and its PDF can be described by a Gaussian peaking component and the ARGUS function. The background from rare B decays like $B \to X_s \eta'$, $B \to X_s \gamma$, and $B \to X_d \eta$ is estimated to be small. The expected yields are subtracted from the fit yields in order to get the final results.

3. Results

The fit to the M_{bc} spectrum with $M_{X_s} < 2.6$ GeV/c^2 is shown in Fig 1. There are about 1000 signal events observed after background subtraction. Its significance is ~ 23 and the significance is defined as $\sqrt{-2\ln(L_0/L_{max})}$, where L_0 and L_{max} are the likelihood values returned by the fit with the signal yield fixed to zero and at its best fit value, respectively. We perform the same fitting procedure in 200 MeV/c^2 bins in M_{X_s} to get the signal yields. After the efficiency correction, the differential branching fraction as a function of M_{X_s} is shown in Fig. 2. There is a significant contribution from the high M_{X_s} region. This feature is the same as that observed in $B \to X_s \eta'$. We also check the direct CP asymmetry in bins of M_{X_s} where the B flavor is inferred from the charged kaon in the final state. There is no significant direct CP asymmetry observed. The overall value is $-0.13 \pm 0.04^{+0.02}_{-0.03}$ for $M_{X_s} < 2.6$ GeV/c^2 assuming the $B^+ \to \pi^+ \eta$ background contributes a CP asymmetry consistent with the existing world average [10].

Acknowledgments

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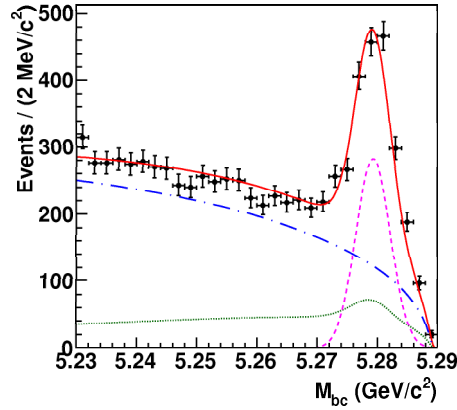
Figure 1: Distribution of M_{bc} for candidate events with $M_{X_s} < 2.6$ GeV/c^2. The solid curve represents the fit projection which is the sum of signal (Gaussian peak), continuum background (dash-dotted curve) and $b \rightarrow c$ background (dotted curve) estimations.
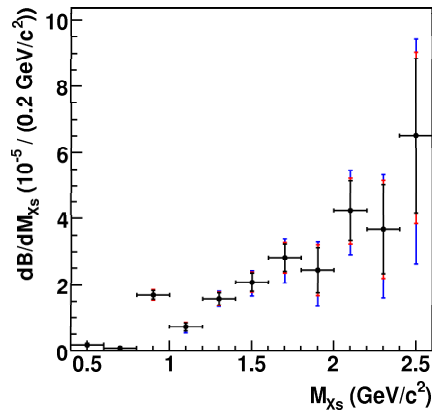
Figure 2: The differential branching fractions for $B \rightarrow X_s \eta$ as a function of M_{X_s}. The three error bars correspond to statistical error only, statistical plus systematic error, and total error.

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