First Measurements of Absolute Branching Fractions of the $\Xi^0_c$ Baryon at Belle

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We present the first measurements of absolute branching fractions of $\Xi^0_c$ decays into $\Xi^{-}\pi^+$, $\Lambda K^-\pi^+$, and $pK^-K^+\pi^+$ final states. The measurements are made using a dataset comprising $(772 \pm 11) \times 10^6 \bar{B}B$ pairs collected at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB $e^+e^-$ collider. We first measure the absolute branching fraction for $B^- \rightarrow \Lambda^-\Xi_c^0$ using a missing-mass technique; the result is $B(B^- \rightarrow \Lambda^-\Xi_c^0) = (9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$. We subsequently measure the product branching fractions $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$, $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow \Lambda K^-\pi^+)$, and $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow pK^-K^+\pi^+)$ with improved precision. Dividing these product branching fractions by the result for $B^- \rightarrow \Lambda^-\Xi_c^0$ yields the following branching fractions: $B(\Xi_c^0 \rightarrow \Xi^-\pi^+) = (1.80 \pm 0.50 \pm 0.14)\%$, $B(\Xi_c^0 \rightarrow \Lambda K^-\pi^+) = (1.17 \pm 0.37 \pm 0.09)\%$, and $B(\Xi_c^0 \rightarrow pK^-K^+\pi^+) = (0.58 \pm 0.23 \pm 0.05)\%$. For the above branching fractions, the first uncertainties are statistical and the second are systematic. Our result for $B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$ can be combined with $\Xi_c^0$ branching fractions measured relative to $\Xi_c^0 \rightarrow \Xi^-\pi^+$ to yield other absolute $\Xi_c^0$ branching fractions.

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Half a century after the theory of quantum chromodynamics (QCD) was developed, understanding the nonperturbative property of the strong interaction still remains a challenge. Weak decays of charmed hadrons play a unique role in the study of strong interactions, as the charm mass scale is near the boundary between perturbative and nonperturbative QCD. The charmed-baryon sector offers an excellent laboratory for testing heavy-quark symmetry and light-quark chiral symmetry, both of which have important implications for the low-energy dynamics of heavy baryons interacting with Goldstone bosons [1]. In exclusive charm decays, the heavy-quark expansion does not work, and experimental data are needed to extract nonperturbative quantities in the decay amplitudes [2–5]. Decays of charmed baryons with an additional quark and spin of 1/2 provide complementary information to that of charm-meson decays.

Unlike in the charmed-meson sector, where $D^0$, $D^*$, and $D_{sJ}$ decays are all well measured, in the charmed-baryon sector only $\Lambda_c^+$ absolute branching fractions have been measured [6,7]. Thus, the branching fractions of $\Xi_c^0$ baryons are all measured relative to the $\Xi_c^0 \rightarrow \Xi^-\pi^+$ mode. Thus a measurement of the absolute branching fraction $B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$ is needed to determine the absolute branching fractions of other $\Xi_c^0$ decays. In charmed-baryon decays, nonfactorizable contributions to the decay amplitude are important, and a variety of models have been developed to predict the decay rate in such processes [8–17]. For example, the $B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$ has been predicted to be $0.74\%$ or $1.12\%$ [15], $(2.24 \pm 0.34)\%$ [16], and $(1.91 \pm 0.17)\%$ [17]. Experimental information is crucial to validate these models as well as to constrain the model parameters.

The $B(\Xi_c^0 \rightarrow \Lambda K^-\pi^+)$ and $B(\Xi_c^0 \rightarrow pK^-K^+\pi^+)$ have been measured relative to $B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$ to be $1.07 \pm 0.12 \pm 0.07$ and $0.33 \pm 0.03 \pm 0.03$ [18], respectively. The decay $\Xi_c^0 \rightarrow pK^-K^+\pi^+$ plays a key role in many bottom-baryon studies at LHCb [19,20]. The decay $B^- \rightarrow \Lambda^-\Xi_c^0$, which proceeds via a $b \rightarrow c\bar{s}s$ transition, has a branching fraction predicted to be of the order $10^{-3}$ [21]. However, this has not been measured because the absolute branching fractions of $\Xi_c^0$ are unknown. The measured product branching fractions are $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow \Xi^-\pi^+) = (2.4 \pm 0.9) \times 10^{-5}$ and $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow \Lambda K^-\pi^+) = (2.1 \pm 0.9) \times 10^{-5}$ [22–24].

In this Letter, we perform an analysis of $B^- \rightarrow \Lambda^-\Xi_c^0$ with $\Lambda_c^+$ reconstructed via $pK^+\pi^-$ and $\bar{p}K_0^\mp$ modes, and $\Xi_c^0$ reconstructed both inclusively and exclusively via $\Xi^-\pi^+$, $\Lambda K^-\pi^+$, and $pK^-K^+\pi^+$ modes [25]. We present first a measurement of the absolute branching fraction for $B^- \rightarrow \Lambda^-\Xi_c^0$ using a missing-mass technique. For this analysis we fully reconstruct the tag-side $B^+$ decay. We subsequently measure the product branching fractions $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$, $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow \Lambda K^-\pi^+)$, and $B(B^- \rightarrow \Lambda^-\Xi_c^0)B(\Xi_c^0 \rightarrow pK^-K^+\pi^+)$. For these measurements we do not reconstruct the recoiling $B^+$ decay, as the signal decays are fully reconstructed. Dividing these product branching fractions by $B(B^- \rightarrow \Lambda^-\Xi_c^0)$ yields the branching fractions $B(\Xi_c^0 \rightarrow \Xi^-\pi^+)$, $B(\Xi_c^0 \rightarrow \Lambda K^-\pi^+)$, and $B(\Xi_c^0 \rightarrow pK^-K^+\pi^+)$. This analysis is based on the full data sample of $702.6 \text{ fb}^{-1}$ collected at the $\Upsilon(4S)$ resonance by the Belle detector [26] at the KEKB asymmetric-energy
$e^+e^-$ collider [27]. The detector is described in detail elsewhere [26].

To optimize signal selection criteria and calculate the signal reconstruction efficiency, we use Monte Carlo (MC) simulated events. Signal events of $B$ meson decays are generated using EVTGEN [28], while inclusive $\Xi_c^0$ decays are generated using PYTHIA [29]. The MC events are processed with a detector simulation based on GEANT3 [30]. MC samples of $\Upsilon(4S) \to BB$ events with $B = B^+$ or $B^0$, and $e^+e^- \to q\bar{q}$ events with $q = u, d, s, c$ at $\sqrt{s} = 10.58$ GeV, are used as background samples.

To select signal candidates, well-reconstructed tracks and particle identification are performed using the same method as in Ref. [31], as well as the $\Lambda \to p\pi^-$ and $K_S^0 \to \pi^+\pi^-$ candidates [31].

For the inclusive analysis of the $\Xi_c^0$ decay, the tag-side $B^+$ meson candidate, $B^+_\text{tag}$, is reconstructed using a neural network based on a full hadron-reconstruction algorithm [32]. Each $B^+_\text{tag}$ candidate has an associated output value $O_{NN}$ from the multivariate analysis that ranges from 0 to 1. A candidate with larger $O_{NN}$ is more likely to be a true $B$ meson. If multiple $B^+_\text{tag}$ candidates are found in an event, the candidate with the largest $O_{NN}$ is selected. To improve the purity of the $B^+_\text{tag}$ sample, we require $O_{NN} > 0.005$, $M_{bc} > 5.27$ GeV/$c^2$, and $|\Delta E^{tag}| < 0.04$ GeV, where the latter two intervals correspond to approximately $3\sigma$ in resolution. The variables $M_{bc}^{tag}$ and $\Delta E^{tag}$ are defined as

$$M_{bc}^{tag} = \sqrt{E_{beam}^2 - \left(\sum p_i^2\right)^2}$$

and

$$\Delta E^{tag} = \sum E_i^{tag} - E_{beam},$$

where $E_{beam} = \sqrt{s}/2$ is the beam energy and $(E_i^{tag}, p_i^{tag})$ is the four-momentum of the $B^+_\text{tag}$ daughter $i$ in the $e^+e^-$ center-of-mass system (c.m.s.). After reconstructing a $B^+_\text{tag}$ candidate, $\Lambda_c^- \to \bar{p}K^+\pi^-$ and $\bar{\Lambda}_c^- \to \bar{p}K^0_S$ decays are reconstructed from among the remaining tracks. We perform a fit for the decay vertex and require that $\chi^2_{\text{vertex}}/\text{n.d.f.} < 15$, where n.d.f. is the number of degrees of freedom. If there is more than one $\bar{\Lambda}_c^-$ candidate in an event, the candidate with the smallest $\chi^2_{\text{vertex}}/\text{n.d.f.}$ is selected. We define a $\Lambda_c^-$ signal region $|M_{pK^+\pi^-/\bar{p}K^0_S} - m_{\Lambda_c^-}| < 10$ MeV/$c^2$ (3.0$\sigma$), where $m_{\Lambda_c^-}$ is the nominal mass of the $\Lambda_c^-$ [22].

The “recoil mass” of the daughter $X$ in $B^- \to \bar{\Lambda}_c^- + X$ is calculated using $M_{BC}^{rcol B_{tag} \Lambda_c^-} = \sqrt{(P_{c.m.s.} - P_{B_{tag} \Lambda_c^-} - P_{\Lambda_c^-})^2}$, where $P_{c.m.s.}$, $P_{B_{tag} \Lambda_c^-}$, and $P_{\Lambda_c^-}$ are the four-momenta of the initial $e^+e^-$ system, the tagged $B$ meson, and the reconstructed $\bar{\Lambda}_c^-$ baryon. To improve the recoil mass resolution, we use

$$M_{B_{tag} \Lambda_c^-} \equiv M_{B_{tag} \Lambda_c^-} + M_{B_{tag} \Lambda_c^-} - M_B + M_{\Lambda_c^-} - m_{\Lambda_c^-},$$

where $M_{B_{tag} \Lambda_c^-}$ is the invariant mass of the $B^+_\text{tag}$ candidate, $M_{\Lambda_c^-}$ is the reconstructed mass of the $\bar{\Lambda}_c^-$ candidate, and $m_B$ is the nominal mass of the $B$ meson [22].

The distribution of $M_{bc}^{\Lambda_c^-}$ of the $B^+_\text{tag}$ candidates versus $M_{\Lambda_c^-}$ of the selected $B^- \to \bar{\Lambda}_c^- \Xi_c^0$ signal candidates summed over the two reconstructed $\bar{\Lambda}_c^- \Xi_c^0$ decay modes is shown in Fig. 1, for $2.40 < M_{B_{tag} \Lambda_c^-} < 2.53$ GeV/$c^2$. We observe a significant excess of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$ candidates in the signal region denoted as the solid box in Fig. 1. To check for possible peaking backgrounds, we define $M_{bc}^{tag}$ and $M_{\Lambda_c^-}$ sidebands, represented by the dashed and dash-dotted boxes in Fig. 1. Each sideband box is the same size as the signal box. The background contribution in the signal box is estimated using half the number of events in the blue dashed sideband boxes minus one-fourth the number of events in the red dash-dotted sideband boxes. The $M_{B_{tag} \Lambda_c^-}^{rec}$ distribution of events in both the signal and sideband boxes is shown in Fig. 2. No peaking backgrounds in the studied recoil $\Xi_c^0$ mass region are found in the $M_{bc}^{tag}$ and $M_{\Lambda_c^-}$ sideband events, as shown with the shaded histogram in Fig. 2.

FIG. 1. The distribution of $M_{bc}^{tag}$ of $B^+_\text{tag}$ of selected $B^- \to \bar{\Lambda}_c^- \Xi_c^0$ candidates with $\Xi_c^0 \to \text{anything}$, summed over the two reconstructed $\bar{\Lambda}_c^-$ decay modes. The solid box shows the signal region, and the dashed and dash-dotted boxes define the $M_{bc}^{tag}$ and $M_{\Lambda_c^-}$ sidebands described in the text.

FIG. 2. The fit to the $M_{bc}^{rcol B_{tag} \Lambda_c^-}$ distribution of the selected candidate events. The points with error bars represent the data, the solid blue curve is the best fit, the dashed curve is the fitted background (BKG), the cyan shaded histogram is from the scaled $M_{bc}^{tag}$ and $M_{\Lambda_c^-}$ sidebands, the red open histogram is from the sum of the MC-simulated contributions from the $e^+e^- \to q\bar{q}$ with $q = u, d, s, c$, and $\Upsilon(4S) \to BB$ generic-decay backgrounds with the number of events normalized to the number of events from the normalized $M_{bc}^{tag}$ and $M_{\Lambda_c^-}$ sidebands.
To extract the $\Xi^0$ signal yield, an unbinned maximum-likelihood fit is performed to the $M^\text{rec}_{B^+\Lambda^-}$ distribution. A double-Gaussian function (its parameters are fixed to those from a fit to the MC-simulated signal distribution) is used to model the $\Xi^0$ signal shape, and a first-order polynomial is taken as the background shape. The fit results are shown in Fig. 2.

The fitted $N_{\Xi^0}$ signal yield is $N_{\Xi^0} = 40.9 \pm 9.0$, with a statistical significance of 5.5σ. The significance is calculated using $\sqrt{-2 \ln \left( \frac{L_0}{L_{\max}} \right)}$, where $L_0$ and $L_{\max}$ are the likelihoods of the fits without and with a signal component, respectively. The $B(B^- \rightarrow \Lambda^-\Xi^0)$ is calculated using $N_{\Xi^0}/|N_B| (e_1 B_1 + e_2 B_2)$. In this expression, $B_1 = B(\Lambda^- \rightarrow \bar{p}K^+\pi^-)$, $B_2 = B(\Lambda^- \rightarrow \bar{p}K^+)/(S_K \rightarrow \pi^+\pi^-)$, and $N_B = 2N_{Y(4S)}B[Y(4S) \rightarrow B^+\bar{B}^-]$, where $N_{Y(4S)}$ is the number of $Y(4S)$ events, and $B[Y(4S) \rightarrow B^+\bar{B}^-] = (51.4 \pm 0.6)\%$ [22]. The reconstruction efficiencies $e_1$ and $e_2$ of the two $\Xi^0$ signal modes are obtained from MC simulation. The $B(\Lambda^- \rightarrow \bar{p}K^+\pi^-)$, $B(\Lambda^- \rightarrow \bar{p}K^+)$, and $B(\Xi^0 \rightarrow \pi^+\pi^-)$ are taken from Ref. [22]. The result is $B(B^- \rightarrow \Lambda^-\Xi^0) = (9.51 \pm 2.10(\text{stat})) \times 10^{-4}$.

For the analysis of the exclusive $\Xi^0$ decays, we again use $B^- \rightarrow \Lambda^-\Xi^0$ decays in which $\Lambda^- \rightarrow (\bar{p}K^+\pi^-)$, $\bar{p}K^+\pi^-$, and $\bar{p}K^+\pi^+$, where $\Xi^- \rightarrow \Lambda\pi^- \pi^+$ and $\Lambda \rightarrow p\pi^-$. Fits to the $B^-\Xi^0$, and $\Xi^-\Lambda\pi^-$ decay vertices are performed. If there is more than one $B^-$ candidate in an event, the one with the smallest $\chi^2_{\text{vertex}}/n.d.f.$ from the $B^-$ vertex fit is selected. We subsequently require $\chi^2_{\text{vertex}}/n.d.f. < 50$, 15, and 15 for reconstructed $B^-$, $\Xi^0$, and $\Xi^-$ candidates, respectively. The $\Xi^-$ and $\Xi^0$ signal ranges are defined as $|M_{\Lambda^-\pi^-} - m_{\Xi^-}| < 10$ MeV/GeV and $|M_{\Xi^0} - m_{\Xi^0}| < 20$ MeV/GeV (3.0σ), where $M_{\Lambda^-\pi^-}$ and $M_{\Xi^0}$ are the invariant masses of the selected $\Xi^-$ and $\Xi^0$ candidates, and $m_{\Xi^-}$ and $m_{\Xi^0}$ are the nominal masses of $\Xi^-$ and $\Xi^0$ [22]. The $\Lambda^-\Xi^0$ signal interval is the same as in the inclusive analysis of $\Xi^0$ decays. The $B^-$ signal candidates are identified using the beam-energy-constrained mass $M_{\text{bc}}$ and the energy difference $\Delta E$, where $M_{\text{bc}}$ and $\Delta E$ are calculated in the same manner as done for $B^+_{\text{tag}}$ candidates, but, here, tracks from the $B^-$ signal candidate decay are used.

FIG. 3. The distributions of $M_{\Xi^0}$ versus $M_{\Lambda^-}$ in (a) and the fits to the $M_{\text{bc}}$ (b) and $\Delta E$ (c) distributions of the selected $B^+ \rightarrow \Lambda^-\Xi^0$ candidates with $\Xi^0 \rightarrow \Xi^0 \rightarrow \Xi^-\pi^+$ (1), $\Xi^0 \rightarrow \Lambda K^-\pi^+$ (2), and $\Xi^0 \rightarrow \bar{p}K^+\pi^+$ (3) decays, summed over the two reconstructed $\Lambda^-\Xi^0$ decay modes. In (a), the central solid box defines the signal region. The red dash-dotted and blue dashed boxes show the $M_{\Xi^0}$ and $M_{\Lambda^-}$ sideband regions used for the estimation of the non-$\Xi^0$ and non-$\Lambda^-\Xi^0$ backgrounds (see text). In (b) and (c), the dots with error bars represent the data, the blue solid curves represent the best fits, and the dashed curves represent the fitted background contributions. The shaded and red open histograms have the same meaning as in Fig. 2.
TABLE I. Summary of the measured branching fractions and ratios of $\Xi^0$ decays (last column), and the corresponding systematic uncertainties (%). For the branching fractions and ratios, the first uncertainties are statistical and the second are systematic.

| Observable | Efficiency | Fit | $\Lambda_c$ decays | $B_{\text{tag}}$ | $N_{B^+}$ | Sum | Measured value |
|------------|------------|-----|---------------------|-----------------|-----------|-----|----------------|
| $B(\bar{B}^0 \to \Lambda_c^- \Xi^0(1236))$ | 3.46 | 4.80 | 5.51 | 4.2 | 1.82 | 9.3 | $(9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$ |
| $B(\bar{B}^0 \to \Lambda_c^- \Xi^0(1520))B(\Xi^0 \to \Xi^-\pi^+)$ | 4.74 | 3.49 | 5.75 | ... | 1.82 | 8.4 | $(1.71 \pm 0.28 \pm 0.15) \times 10^{-5}$ |
| $B(\bar{B}^0 \to \Lambda_c^- \Xi^0(1520))B(\Xi^0 \to \Lambda K^-\pi^+)$ | 4.56 | 4.03 | 5.82 | ... | 1.82 | 8.6 | $(1.11 \pm 0.26 \pm 0.10) \times 10^{-5}$ |
| $B(\bar{B}^0 \to \Lambda_c^- \Xi^0(1800))B(\Xi^0 \to pK^-K^-\pi^+)$ | 7.25 | 5.11 | 5.03 | ... | 1.82 | 10.5 | $(5.47 \pm 1.78 \pm 0.57) \times 10^{-6}$ |
| $B(\Xi^0 \to \Xi^-\pi^+)$ | 2.94 | 5.9 | ... | 4.2 | ... | 7.8 | $(1.80 \pm 0.50 \pm 0.14)\%$ |
| $B(\Xi^0 \to \Lambda K^-\pi^+)$ | 2.65 | 6.3 | ... | 4.2 | ... | 8.0 | $(1.17 \pm 0.37 \pm 0.09)\%$ |
| $B(\Xi^0 \to pK^-K^-\pi^+)$ | 3.84 | 7.0 | ... | 4.2 | ... | 9.0 | $(0.58 \pm 0.23 \pm 0.05)\%$ |
| $B(\Xi^0 \to pK^-K^-\pi^+)/B(\Xi^0 \to \Xi^-\pi^+)$ | 1.36 | 5.3 | ... | ... | ... | 5.5 | $0.65 \pm 0.18 \pm 0.04$ |
| $B(\Xi^0 \to pK^-K^-\pi^+)/B(\Xi^0 \to \Xi^-\pi^+)$ | 5.24 | 6.2 | ... | ... | ... | 8.1 | $0.32 \pm 0.12 \pm 0.07$ |

We define a $B^-$ signal region as $M_{bc} > 5.27$ GeV/$c^2$ and $|\Delta E| < 0.03$ GeV. The distributions of $M_{\Xi^-}$ versus $M_{\Lambda_c^+}$ for events in the $B^-$ signal region are shown in Figs. 3(a1)–3(a3) after all selection criteria are applied. The central solid boxes define the $\Xi^0$ and $\bar{\Lambda}_c$ signal regions. The backgrounds from non-$\Xi^0$ and non-$\bar{\Lambda}_c$ events are estimated from $M_{\Xi^-}$ and $M_{\Lambda_c^+}$, sidebands, represented by the dashed boxes in Figs. 3(a1)–3(a3). The sideband’s contribution is estimated similarly to the inclusive analysis. Figures 3(b) and 3(c) show the $M_{\Xi^-}$ and $\Delta E$ distributions in the $\Xi^0$ and $\bar{\Lambda}_c$ signal regions from the selected $B^0 \to \bar{\Lambda}_c^- \Xi^0$ candidates with (1) $\Xi^0 \to \Xi^-\pi^+$, (2) $\Xi^0 \to \Lambda K^-\pi^+$, and (3) $\Xi^0 \to pK^-K^-\pi^+$. All distributions are summed over the two reconstructed $\bar{\Lambda}_c$ decay modes.

The number of $B^0 \to \bar{\Lambda}_c^- \Xi^0$ signal events is extracted by performing an unbinned two-dimensional maximum-likelihood fit to the $M_{bc}$ versus $\Delta E$ distributions. For the $M_{bc}$ distribution, the signal shape is modeled with a Gaussian function and the background is described using an ARGUS function [33]. For the $\Delta E$ distribution, the signal shape is modeled using a double-Gaussian function and the background is described by a first-order polynomial. All shape parameters of the signal functions are fixed to the values obtained from the fits to the MC-simulated signal distributions. The fit results are shown in Fig. 3.

We obtain $N_{\Xi^-} = 44.8 \pm 7.3$, $N_{\Lambda_c^-} = 24.1 \pm 5.5$, and $N_{pK^-\pi^+} = 16.6 \pm 5.4$ signal events with statistical significances of $9.5\sigma$, $6.8\sigma$, and $4.6\sigma$. Using the efficiencies calculated from the MC simulation, we obtain $B(\bar{\Lambda}_c^- \Xi^0)B(\Xi^0 \to \Xi^-\pi^+) = [1.71 \pm 0.28(\text{stat})] \times 10^{-5}$, $B(\bar{\Lambda}_c^- \Xi^0)B(\Xi^0 \to \Lambda K^-\pi^+) = [1.11 \pm 0.26(\text{stat})] \times 10^{-5}$, and $B(\bar{\Lambda}_c^- \Xi^0)B(\Xi^0 \to pK^-K^-\pi^+) = [5.47 \pm 1.78(\text{stat})] \times 10^{-6}$.

There are several sources of systematic uncertainties as listed in Table I. The reconstruction-efficiency-related uncertainties include those for tracking efficiency (0.35% per track), particle identification efficiency (0.9% per kaon, 0.9% per pion, and 3.6% per proton), as well as $\Lambda$ (3.0% [34]) and $K^0_s$ (1.6% [35]) reconstruction efficiencies. Assuming that all the above sources of systematic uncertainty are independent, the reconstruction-efficiency-related uncertainties are summed in quadrature for each decay mode, yielding 4.0%–8.4%, depending on the specific decay mode. For the four branching-fraction measurements, the final uncertainties related to the efficiency of the reconstruction are summed in quadrature over the two reconstructed $\bar{\Lambda}_c$ decay modes using weight factors equal to the product of the total efficiency and the $\bar{\Lambda}_c$ partial decay width.

We estimate the systematic uncertainties associated with the fit by changing the order of the background polynomial, the fitting range, and by enlarging the mass resolution by 20%. The observed deviations are taken as systematic uncertainties. Uncertainties on $B(\bar{\Lambda}_c^- \to pK^-\pi^+)$ and $\Gamma(\bar{\Lambda}_c^- \to pK^-\pi^+)$ are taken from Ref. [22]. The final uncertainties on the two $\bar{\Lambda}_c$ partial decay widths are summed in quadrature with the reconstruction efficiency as a weighting factor. The uncertainty due to the $B$ tagging efficiency is 4.2% [36]. The uncertainty on $B(\Upsilon(4S) \to B^+ B^-)$ is 1.2% [22]. The systematic uncertainty on $N_{\Upsilon(4S)}$ is 1.37% [37]. For the $\Xi^0$ branching fractions and the corresponding ratios, some common systematic uncertainties cancel, including tracking, particle identification, $\bar{\Lambda}_c$ branching fractions, $\Lambda$ and $K^0_s$ selections, and $N_{B^0}$. The sources of uncertainty summarized in Table I are assumed to be independent and thus are added in quadrature to obtain the total systematic uncertainty.

In summary, based on $(772 \pm 11) \times 10^6 B\bar{B}$ pairs collected by Belle, we have performed an analysis of $B^0 \to \bar{\Lambda}_c^- \Xi^0$ inclusively with respect to the $\Xi^0$ decay using a hadronic $B$-tagging method based on a full reconstruction algorithm [32], and exclusively for $\Xi^0$ decays into $\Xi^-\pi^+$, $\Lambda K^-\pi^+$, and $pK^-K^-\pi^+$ final states. We report the first measurements of the absolute branching fractions

$$B(\Xi^0 \to \Xi^-\pi^+) = (1.80 \pm 0.50 \pm 0.14)\%,$$

$$B(\Xi^0 \to \Lambda K^-\pi^+) = (1.17 \pm 0.37 \pm 0.09)\%,$$

$$B(\Xi^0 \to pK^-K^-\pi^+) = (0.58 \pm 0.23 \pm 0.05)\%.$$
For the above branching fractions, the first uncertainties are statistical and the second systematic. The product branching fractions are $B(B^+ \to \bar{\Lambda}^0 \Xi^0) = (9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$.

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