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Studies of the semileptonic $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_\ell$ and $B^- \to D^0\ell^-\bar{\nu}_\ell$ decay processes with 34.6 fb^{-1} of Belle II data

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Abstract

We report measurements of the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^0\ell^-\overline{\nu}_l$ processes using 34.6 fb^{-1} of collision events recorded by the Belle II experiment at the SuperKEKB asymmetric-energy e^+e^- collider. For the $B^- \to D^0\ell^-\bar{\nu}_\ell$ channel, we present first studies that isolate this decay from other semileptonic processes and backgrounds. We report a measurement of the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ branching fraction and obtain $\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l) = (4.60 \pm 0.05_{\rm stat} \pm 0.17_{\rm syst} \pm 0.45_{\pi_s})\,\%$, in agreement with the world average. Here the uncertainties are statistical, systematic, and related to slow pion reconstruction, respectively. The systematic uncertainties are limited by the statistics of auxiliary measurements and will improve in the future. We also report differential branching fractions in five bins of the hadronic recoil parameter w for $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$, unfolded to account for resolution and efficiency effects.

1. INTRODUCTION

Precision measurements of the decays of $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^0\ell^-\overline{\nu}_l$ ($\ell = e$ or μ) play an important role in the determination of the magnitude of the Cabibbo-Kobayashi-Maskawa matrix element $|V_{cb}|$ and are probes for the understanding of the hadronic dynamics of B meson decays. These processes also constitute a source of background for measurements of charmless semileptonic decays and their understanding is important to study $\overline{B}^0 \to D^{(*)+}\tau^-\overline{\nu}_\tau$. This motivates measurements of their branching fractions and kinematic distributions at Belle II. The most precise measurements of $\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l)$ and $\mathcal{B}(B^- \to D^0\ell^-\overline{\nu}_l)$ were obtained by the BABAR [1, 2] and Belle [3] collaborations. Since March 2019, the Belle II experiment has been collecting e^+e^- collision events with the full detector and in this conference note studies, using an integrated luminosity of 34.6 fb^{-1}, are reported.

2. THE BELLE II DETECTOR AND DATA SAMPLE

The Belle II detector [4, 5] operates at the SuperKEKB asymmetric-energy electron-positron collider [6], located at the KEK laboratory in Tsukuba, Japan. The detector consists of several nested detector subsystems arranged around the beam pipe in a cylindrical geometry. The innermost subsystem is the vertex detector, which includes two layers of silicon pixel detectors and four outer layers of silicon strip detectors. Currently, the second pixel layer is installed in only a small part of the solid angle, while the remaining vertex detector layers are fully installed. Most of the tracking volume consists of a helium and ethane-based small-cell drift chamber. Outside the drift chamber, a Cherenkov-light imaging and time-of-propagation detector provides charged-particle identification in the barrel region. In the forward endcap, this function is provided by a proximity-focusing, ring-imaging Cherenkov detector with an aerogel radiator. Further out is an electromagnetic calorimeter, consisting of a barrel and two endcap sections made of CsI(Tl) crystals. A uniform 1.5 T magnetic field is provided by a superconducting solenoid situated outside the calorimeter. Multiple layers of scintillators and resistive plate chambers, located between the magnetic flux-return iron plates, constitute the K_L and muon identification system.

The data used in this analysis were collected in 2019 and 2020 at a center-of-mass (CM) energy of 10.58 GeV, corresponding to the mass of the $\Upsilon(4S)$ resonance. The energies of the electron and positron beams are 7 GeV and 4 GeV, respectively, resulting in a boost of $\beta\gamma = 0.28$ of the CM frame relative to the lab frame. The number of B meson pairs in the analyzed collision events has been counted using event-shape variables and has been determined to be $N_{B\bar{B}} = (37.7 \pm 0.6) \times 10^6$.

Simulated Monte Carlo (MC) samples of signal events, with the subsequent decays $D^{*+} \to D^0\pi^+$ (for $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$) and $D^0 \to K^-\pi^+$ (for both processes), are used to obtain the reconstruction efficiencies and signal kinematic distributions. These events were generated with EvtGen [7]. Samples of background events are used to obtain kinematic distributions of the background. These include a sample of $e^+e^- \to B\bar{B}$ with generic B meson decays, generated with EvtGen, and corresponding to an integrated luminosity of 100 fb^{-1} and 200 fb^{-1} for the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^0\ell^-\overline{\nu}_l$ analyses, respectively. Sample of continuum $e^+e^- \to q\bar{q}$ ($q = u, d, s, c$) is simulated with KKMC [8] interfaced with

PYTHIA [9]. All recorded collisions and simulated events were analyzed in the basf2 [10] framework and a summary of the track reconstruction algorithms can be found in Ref. [11].

3. EVENT SELECTION

We reconstruct candidate events for both final states by reconstructing the $D^0 \to K^-\pi^+$ decay and for $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ the $D^{*+} \to D^0\pi_s^+$ cascade. Here, π_s indicates the soft pion originating from the D^{*+} decay. Reconstruction of the charge-conjugate decays is implied.

Signal candidate reconstruction begins with the selection of charged-particle tracks. The distance of closest approach between each track and the interaction point is required to be less than 2 cm along the z direction (parallel to the beams) and less than 0.5 cm in the transverse $r-\phi$ plane and must have a CM frame momentum in the range $p_\ell^* \in [1.2, 2.4]$ GeV/c. The lepton candidate must also satisfy lepton-identification (lepton-ID) criteria based on information from all available detectors. A dedicated algorithm identifies photons from bremsstrahlung processes and corrects the momentum of reconstructed electron candidates if such can be identified. Given the high purity of the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ decay chain, application of kaon or pion identification criteria is deemed unnecessary and is thus not performed. For the $B^- \to D^0\ell^-\overline{\nu}_l$ decay we apply loose kaon and pion identification criteria to increase the purity of the selected events.

3.1. $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ Reconstruction

From the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ selection, a vertex fit is applied to the D^0 candidate, constraining its $K^-\pi^+$ daughter tracks to originate from a common point. The invariant mass of the D^0 candidate is required to satisfy $m_{K\pi} \in [1.85, 1.88]$ GeV/c^2 after the fit. The $D^{*+} \to D^0\pi_s^+$ candidate decay is also subjected to a vertex fit, after which the mass difference between the D^* and D^0 candidates is required to satisfy $\Delta m \in [0.144, 0.148]$ GeV/c^2. Continuum background is suppressed by requiring the momentum of the D^* candidate in the CM frame to be less than 2.5 GeV/c. Further continuum suppression is achieved by requiring $R_2 < 0.3$, where R_2 is the ratio of the second and zeroth Fox-Wolfram moments [12], calculated using all the tracks and photon candidates in the event. After applying all the selection criteria above, multiple $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ candidates are found in only about 2% of the events. For all candidates, we perform a vertex fit for the decay $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and in events with multiple candidates per event, we select the candidate with the smallest value of the vertex-fit χ^2. The signal efficiency after all selection criteria is $\epsilon = (21.3 \pm 2.2)\%$ for $\overline{B}^0 \to D^{*+}e^-\overline{\nu}_e$ and $\epsilon = (21.8 \pm 2.2)\%$ for $\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu$. These values are obtained from signal MC with lepton-ID efficiency corrections obtained from data-MC comparisons of reconstructed $J/\psi \to \ell^+\ell^-$, $e^+e^- \to \ell^+\ell^-$ and $e^+e^- \to e^+e^-\ell^+\ell^-$ decays. The quoted uncertainties are dominated by the uncertainties on the slow pion reconstruction efficiency. This uncertainty was estimated by studying slow pions from $B \to D^*\pi$ and $B \to D^*\rho$ decays, and will be reduced in the future.

3.2. $B^- \to D^0\ell^-\overline{\nu}_l$ Reconstruction

To reduce the sizeable background of $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^{*0}\ell^-\overline{\nu}_l$ decays in the reconstructed $B^- \to D^0\ell^-\overline{\nu}_l$ candidates, an active veto is applied. This is done by combining charged and neutral soft pion candidates and photons to explicitly reconstruct the $D^{*+} \to D^0\pi_s^+$, $D^{*0} \to D^0\pi^0$ and $D^{*0} \to D^0\gamma$ decay cascades. Candidates using charged or neutral slow pions or photons are vetoed if a combination is found with $\Delta m \in [0.144, 0.148]$ GeV/c^2 or $\Delta m \in [0.141, 0.145]$ GeV/c^2, respectively. To further control these backgrounds, a multivariate classifier in the form of a deep neural network is trained. Its input layer consists of the four-momenta of the final state particles, and variables characterizing cluster properties in the electromagnetic calorimeter. The latter can be used to identify further neutral soft pions and photons from $D^{*0} \to D^0\pi^0$ and $D^{*0} \to D^0\gamma$ decays, which were missed in the explicit reconstruction. The most important distinguishing input feature to veto $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ events are the D^0 and lepton momenta. Finally, we demand that the invariant mass of the $D^0\ell$ system is smaller than 3.15 GeV/c^2 and the momentum of the candidate lepton in the laboratory frame is below 3 GeV/c. No best candidate selection is carried out and all candidate events are analyzed.

4. SIGNAL AND BACKGROUND SEPARATION

For each candidate, we calculate the angle between the $Y = D^{*+}\ell$ or $Y = D^0\ell$ system and the B meson in the center-of-mass frame of the collision. It can be calculated using the reconstructed momenta and energies via

$$\cos\theta_{BY} = \frac{2\,E_B^* E_Y^* - m_B^2 - m_Y^2}{2|p_B^*||p_Y^*|}, \tag{1}$$

where E_Y^*, $|p_Y^*|$, and m_Y are the CM energy, momentum, and invariant mass of the $D^{*+}\ell$ or $D^0\ell$ system, m_B is the nominal B mass [13], and E_B^*, $|p_B^*|$ are the CM energy and momentum of the B; the CM is inferred from the beam four-momenta. For correctly reconstructed $B^- \to D^0\ell^-\overline{\nu}_l$ and $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ candidates with perfect detector resolution and correct values of E_B^* and p_B^*, the value of $\cos\theta_{BY}$ ranges between the geometric range of $[-1, 1]$. Due to the finite beam-energy spread, final-state radiation, and detector resolution, the $\cos\theta_{BY}$ distributions of signal events is smeared beyond the geometric range, but retains an excellent sensitivity to separate signal from background processes.

4.1. Signal Yield Determination

We determine the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^0\ell^-\overline{\nu}_l$ signal event yields by carrying out a binned maximum-likelihood fit to the $\cos\theta_{BY}$ distribution. The probability density functions (PDFs) used in this fit are determined from simulated samples. We apply momentum- and polar-angle-dependent corrections to the lepton-identification efficiencies of leptons and hadrons. For leptons, corrections of the order of a few percent are obtained from $J/\psi \to \ell^+\ell^-$ ($\ell = e, \mu$) decays. Corrections for hadrons misidentified as leptons are obtained from samples of reconstructed $K_S \to \pi^+\pi^-$ decays. The $B^- \to D^0\ell^-\overline{\nu}_l$ fit uses four components, for signal, D^* background from $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^{*0}\ell^-\overline{\nu}_l$, background from other $B\overline{B}$ processes, and continuum processes. The $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ fit uses three components for signal, background from B mesons, and continuum processes.

Figure 1 shows the fitted $\cos\theta_{BY}$ distributions for $B^- \to D^0\ell^-\overline{\nu}_l$ and $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$. The fitted distribution describe the measured spectra well. The selected $B^- \to D^0\ell^-\overline{\nu}_l$ candidates have a sizeable contamination from $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ processes, but the signal can be clearly isolated. In total, we find 6186 ± 234 and 5800 ± 231 $B^- \to D^0\ell^-\overline{\nu}_l$ candidates in the electron and muon channels, respectively. The $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ channel is much cleaner, in contrast, and in total we fit 9583 ± 134 and 9860 ± 132 signal events.

4.2. Branching Fraction determination for $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$

For $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ we determine the measured branching fraction of the measured signal yields N_s using

$$\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l) = \frac{N_\mathrm{s}}{\epsilon \times N_{B^0} \times \mathcal{B}(D^{*+} \to D^0\pi^+) \times \mathcal{B}(D^0 \to K^-\pi^+)}\,, \tag{2}$$

where ϵ is the product of the signal reconstruction efficiency and acceptance, and N_{B^0} is the number of B^0 mesons in the data sample, further discussed in Section 5. We determine

$$\mathcal{B}(\overline{B}^0 \to D^{*+}e^-\overline{\nu}_e) = (4.59 \pm 0.06_\mathrm{stat} \pm 0.48_\mathrm{syst})\,\%\,, \tag{3}$$

$$\mathcal{B}(\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu) = (4.62 \pm 0.06_\mathrm{stat} \pm 0.49_\mathrm{syst})\,\%\,. \tag{4}$$

Both branching fractions are below, but compatible with, the current world average of $\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l) = (5.05 \pm 0.14)\,\%$ from Ref. [14] within 0.9 and 0.8 standard deviations, respectively. The first uncertainty is from statistics and the second from systematic uncertainties, further discussed in Section 5. The combined branching fraction is

$$\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l) = (4.60 \pm 0.05_\mathrm{stat} \pm 0.17_\mathrm{syst} \pm 0.45_{\pi_s})\,\%\,, \tag{5}$$

where we single out the dominant uncertainty from the slow pion efficiency. The combined branching fraction is obtained by a variance weighted average of Eqs. 3 and 4, taking into account the systematic correlations. The ratio of the electron and muon branching fraction is sensitive to lepton-flavor violating processes predicted in theories extending the Standard Model [15]. We find for the ratio

$$R_{e\mu} = \frac{\mathcal{B}(\overline{B}^0 \to D^{*+}e^-\overline{\nu}_e)}{\mathcal{B}(\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu)} = 0.99 \pm 0.03\,, \tag{6}$$

which is compatible with the Standard Model expectation of near unity.

4.3. Reconstruction of the hadronic recoil parameter w for $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$

For $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ we reconstruct the hadronic recoil parameter w, defined as

$$w = \frac{m_B^2 - m_{D^{*+}}^2 - q^2}{2 m_B m_{D^{*+}}} = v_B \cdot v_{D^{*+}}\,. \tag{7}$$

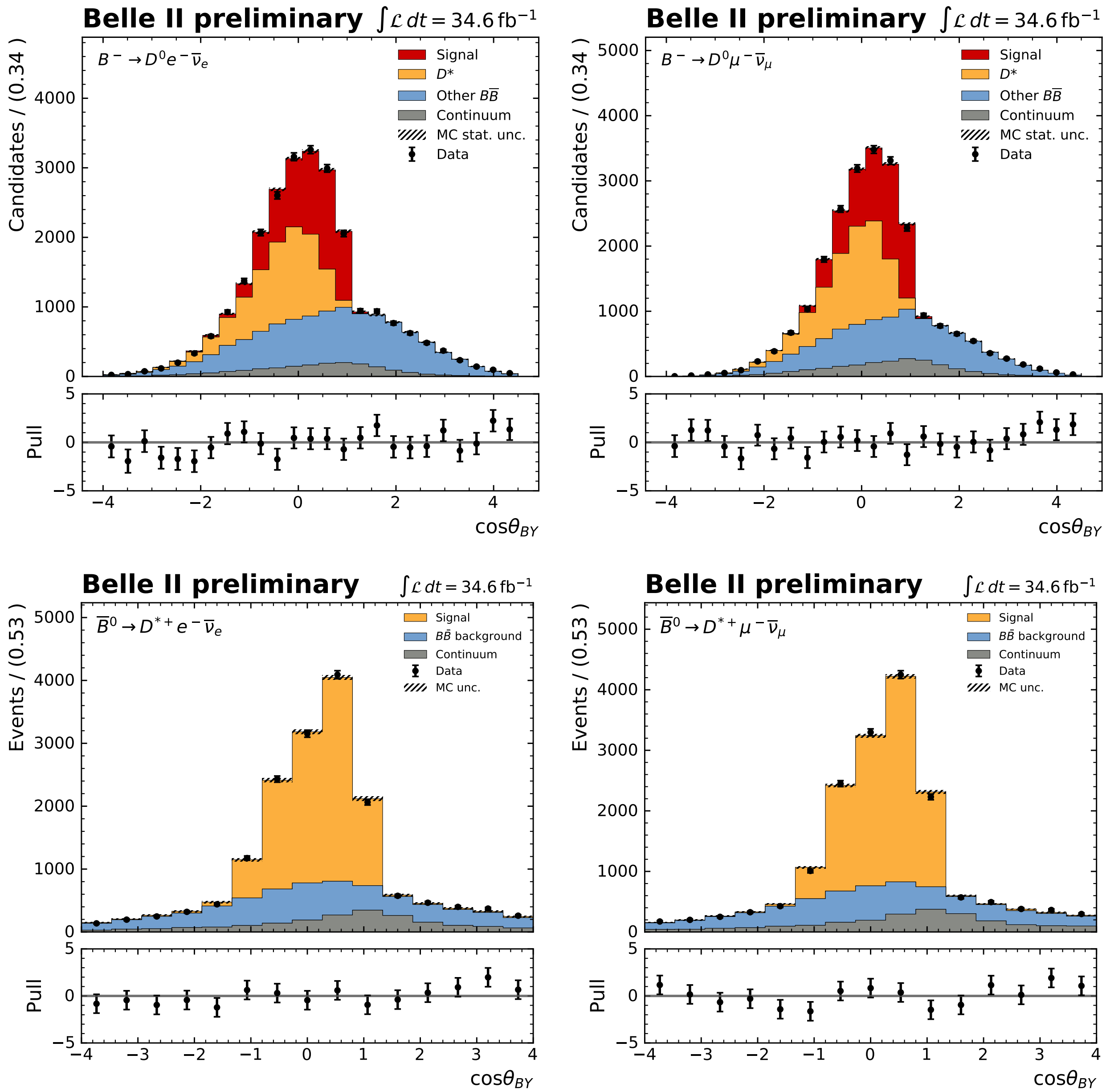

FIG. 1. The fitted $\cos\theta_{BY}$ distributions for the selected electron (left) and muon (right) candidates are shown. The top row displaying $B^- \to D^0\ell^-\bar{\nu}_l$ and the bottom row shows the results for $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_l$.

Here $q^2 = (p_B - p_{D^{*+}})^2$ denotes the four-momentum transfer square of the B- to the D^{*+}-meson system. Further, v_B and $v_{D^{*+}}$ denote the four-velocities of the B- and D^{*+}-mesons, respectively. Measurements of the partial branching fraction in bins of w are sensitive to the non-perturbative dynamics of the $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_l$ decay and a key step to determine $|V_{cb}|$ from $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}_l$ and $B^- \to D^0\ell^-\bar{\nu}_l$ decays.

In order to reconstruct w, the true direction of the signal B meson needs to be estimated. This is done by exploiting that the magnitude of the B meson momentum vector in the CM

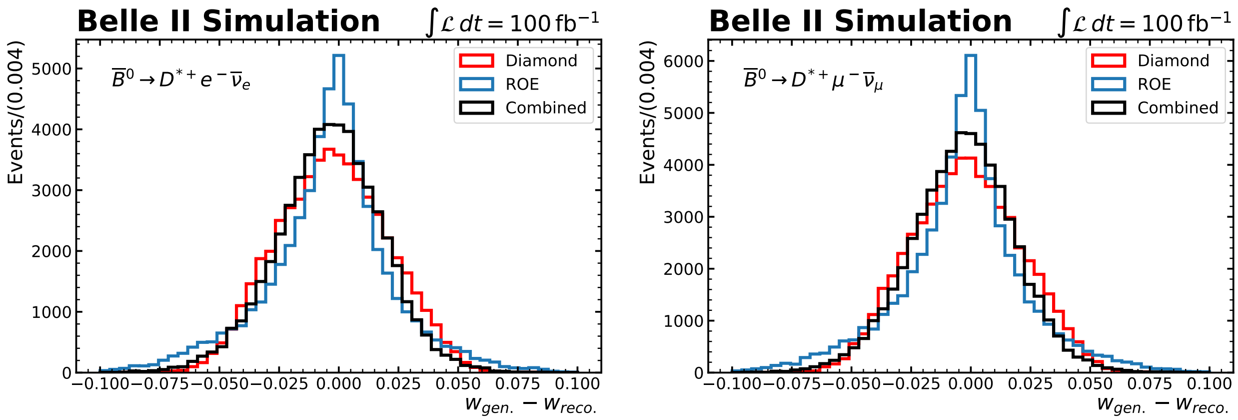

FIG. 2. The residual of the generated and reconstructed w values, after the final reconstruction and for the electron (left) and muon (right) channel, are shown. The three compared methods are: diamond frame (red), ROE (blue), and the used combined approach. For more details, see text.

is determined by the beam energy and its known mass. The momentum direction of the B meson is constrained to lie on a cone around the momentum direction of the combined $D^{*+}\ell$ system. We combine the diamond frame reconstruction detailed in Ref. [16] with the estimated direction of the B meson, as constrained by the remaining tracks and neutral clusters not used in the $D^{*+}\ell$ reconstruction (called the rest of event or ROE). This is done by modifying the diamond frame weights: cone directions opposite to the ROE retain a higher weight, whereas cone directions more parallel to the ROE are weighted down. This is implemented using weights $\frac{1}{2}(1 - \widehat{p}_{\mathrm{ROE}} \cdot \widehat{p}_{\mathrm{cone}})$, with $\widehat{p}$ denoting the normalized momentum vectors of the ROE or a cone direction. We reconstruct five bins of w with bin widths larger than the expected resolution of about 0.02. A comparison of the reconstruction resolution, comparing the reconstruction performance using the diamond frame, the estimated direction from the rest-of-the event (ROE), or the used combined approach, is shown in Figure 2. We choose four bins with equal bin widths of 0.1 between 1 and 1.4, and one bin ranging from 1.4 to $w_{\mathrm{max}} = (m_B^2 + m_{D^{*+}}^2)/(2m_B\, m_{D^{*+}}) = 1.504$. In each reconstructed w bin, we determine the number of signal events by fitting $\cos\theta_{BY}$. The post-fit distribution of the measured w spectra for the electron and muon final states are shown in Figure 3. In Figures 4 and 5, the fitted $\cos\theta_{BY}$ distribution of each bin are shown.

4.4. Unfolding of the hadronic recoil parameter w for $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$

In order to confront the measured w distributions with predictions for the decay rate, effects from resolution and efficiencies have to be reverted. This is done by constructing a χ^2 function of the form

$$\chi^2 = \left(\mathbf{N}_\mathrm{s} - \overline{\mathbf{N}}_\mathrm{s} \times \mathcal{M}\right) C_{\mathrm{exp}}^{-1} \left(\mathbf{N}_\mathrm{s} - \overline{\mathbf{N}}_\mathrm{s} \times \mathcal{M}\right) . \quad (8)$$

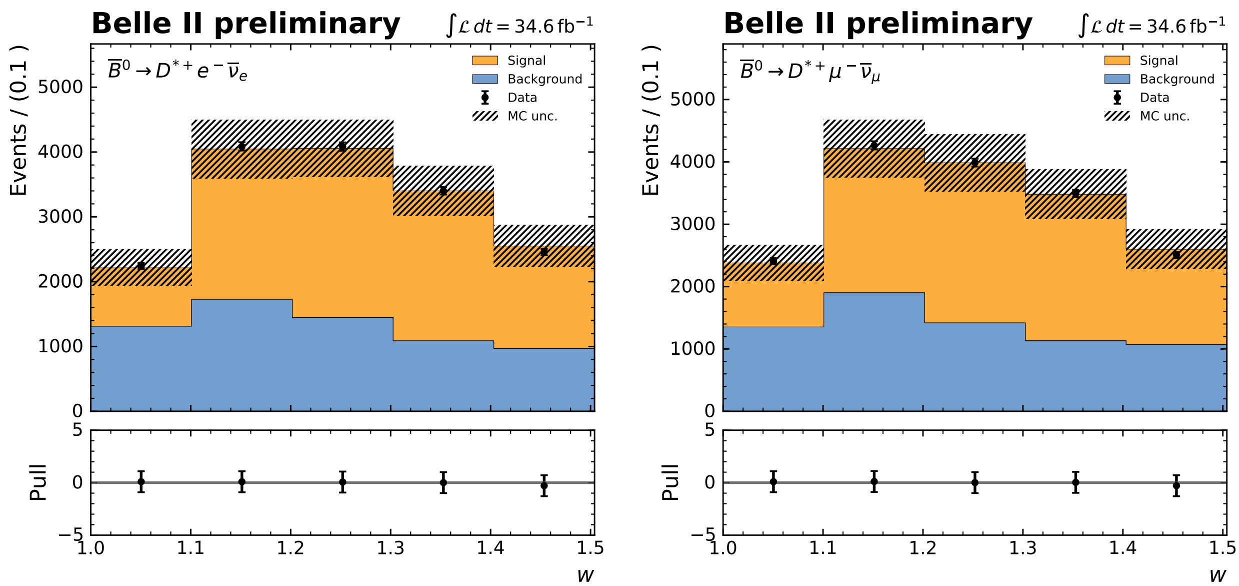

FIG. 3. The fitted w distribution for electron (left) and muon (right) $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ candidates are shown, after fitting $\cos\theta_{BY}$ in each bin. The background can be described adequately as can be seen by the near zero pulls in each bin.

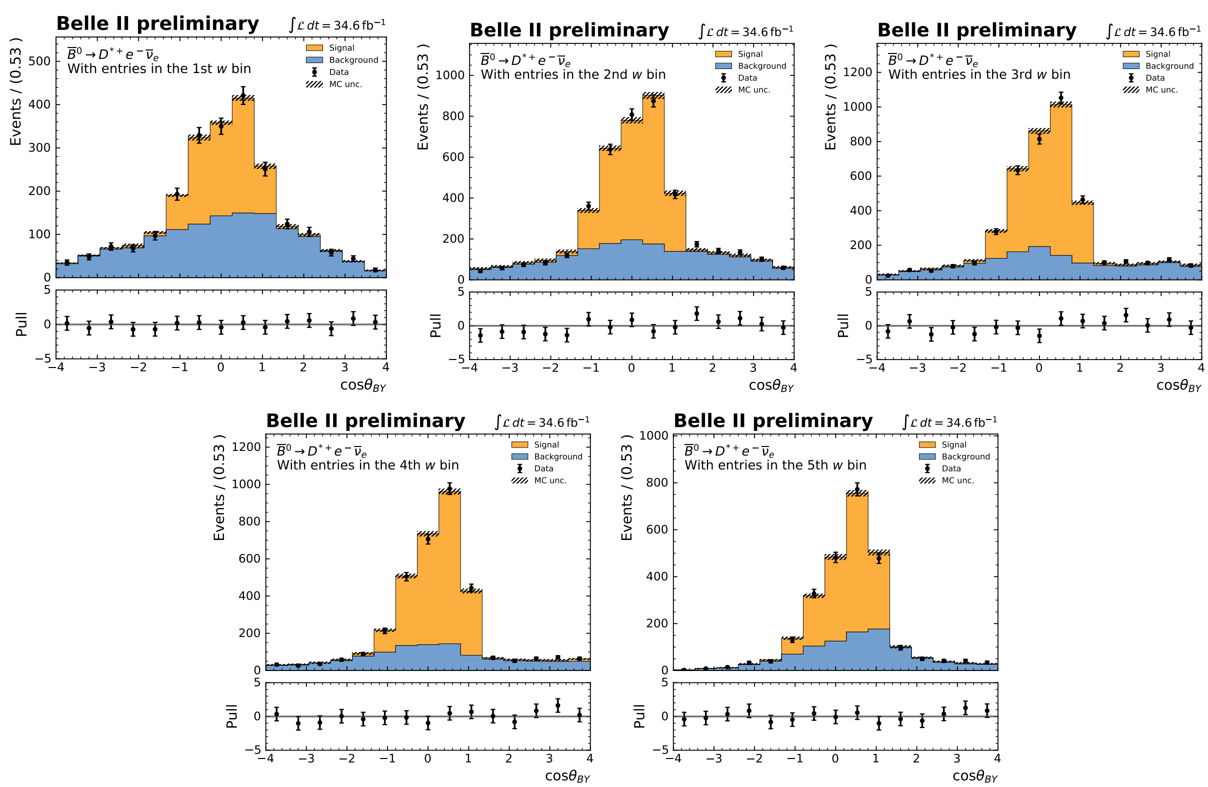

FIG. 4. The fitted $\cos\theta_{BY}$ distributions of all w bins of $\overline{B}^0 \to D^{*+}e^-\overline{\nu}_e$ for the electron final state are shown.

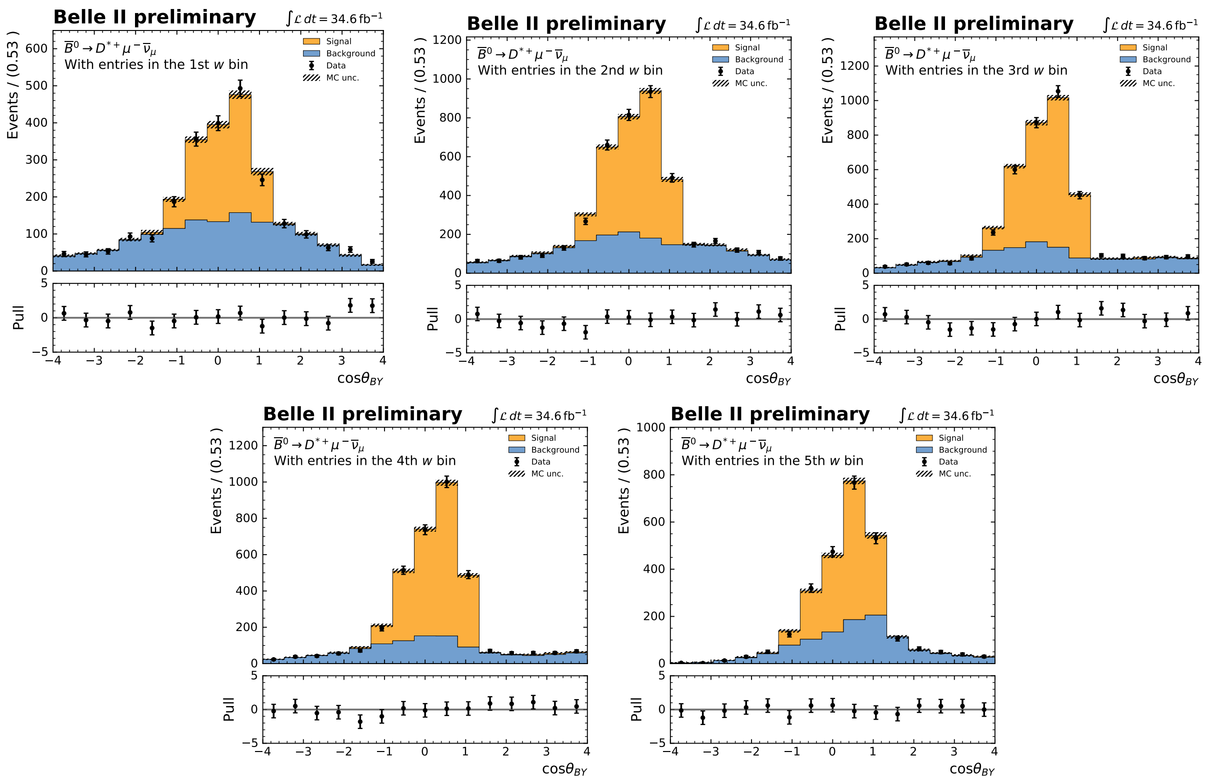

FIG. 5. The fitted $\cos\theta_{BY}$ distributions of all w bins of $\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu$ for the muon final state are shown.

Here, C_{exp} denotes the experimental covariance of the measurement. The migration matrix $\mathcal{M}$ denotes the conditional probabilities

$$\mathcal{M}_{ij} = \mathcal{P}(\text{measured value in bin } i | \text{true value in bin } j)\,, \tag{9}$$

mapping the reconstructed signal yields $\mathbf{N_s}$, expressed as a vector of the bins, into their unfolded values $\overline{\mathbf{N}}_\mathbf{s}$. The unfolded yields are converted into partial decay rates using

$$\Delta\Gamma_i = \frac{\overline{N}_{\text{s}\,i} \times \tau_{B^0}}{\epsilon_i \times N_{B^0} \times \mathcal{B}(D^{*+} \to D^0\pi^+) \times \mathcal{B}(D^0 \to K^-\pi^+)}\,, \tag{10}$$

with $\tau_{B^0} = (1.519 \pm 0.004)$ ps the B^0 meson lifetime. Further, ϵ_i denotes the reconstruction efficiency and acceptance of signal events with true values of w in bin i. The resulting unfolded distributions are shown in Figure 6 and compared to the BGL form factor parameters of Ref. [17, 18].

5. SYSTEMATIC UNCERTAINTIES

The relative systematic uncertainties affecting the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ branching fraction measurement are listed in Table I. We assume no correlation among the individual sources

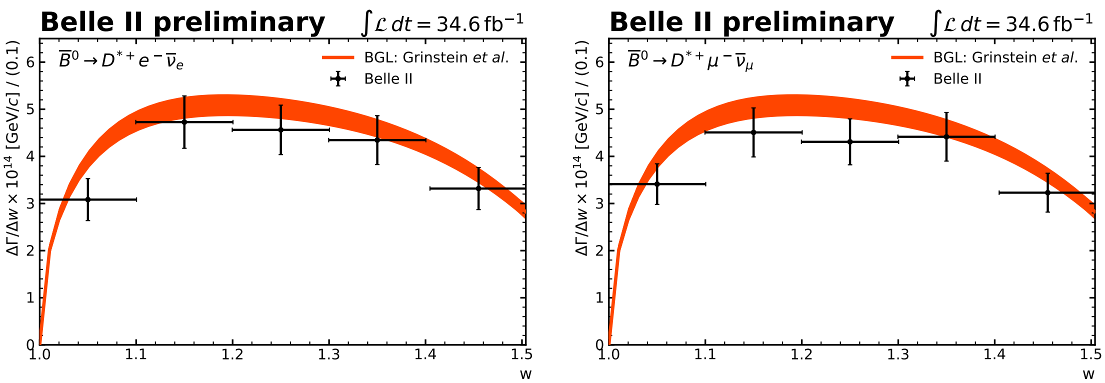

FIG. 6. The measured partial decay rates for electrons and muons are compared to the BGL form factor parameters of Ref. [17, 18].

Source	Relative uncertainty (%)	
	$\overline{B}^0 \to D^{*+} e^- \overline{\nu}_e$	$\overline{B}^0 \to D^{*+} \mu^- \overline{\nu}_\mu$
PDF shape uncertainties	0.7	0.6
$\mathcal{B}(\bar{B} \to D^{**} \ell \bar{\nu})$	0.1	< 0.1
Lepton-ID	0.4	1.9
MC statistics, efficiency	< 0.1	< 0.1
Tracking of K, π, ℓ	2.4	2.4
Tracking of π_s	9.9	9.9
N_{B^0}	2.0	2.0
Charm branching fractions	1.1	1.1
$\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_l$ Form Factors	1.1	1.1
Total	10.5	10.7

TABLE I. Summary of the relative systematic uncertainties for the measurements of $\mathcal{B}(\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_l)$. The first two uncertainties impact the extracted signal yield, while the others impact the other factors of Eq. (2).

of uncertainty and sum them in quadrature to obtain the total systematic uncertainty. The methods used for obtaining these uncertainties are detailed below.

The lepton-identification corrections are measured with statistical uncertainties that arise from the limited size of the control samples, as well as systematic uncertainties. We produce 500 sets of correction values sampled from Gaussian distributions that reflect these uncertainties, accounting for systematic correlations. Each set of corrections is used to estimate the uncertainty on the efficiencies and on the $\cos\theta_{BY}$ distributions.

The impact of the finite sizes of the MC samples is directly incorporated into the fit procedure via nuisance parameters.

The semileptonic decays $\bar{B} \to D^{**} \ell \bar{\nu}$, where D^{**} indicates an excited charm meson heavier than the D^*, have a similar particle content to that of signal decays. As a result, the fit may be biased if the branching fractions of $\bar{B} \to D^{**}\ell\bar{\nu}$ are incorrect in the generic MC sample. To estimate the systematic uncertainty, we obtain the $B\bar{B}$ PDF from the MC after varying the branching fractions for these decays by $\pm 25\%$, which is twice the relative uncertainty on $\mathcal{B}(\bar{B} \to D^0\pi^+\ell^-\bar{\nu})$. The resulting change in the signal yield is taken as the systematic uncertainty.

The tracking efficiency uncertainty for the lepton, kaon, and pion is 0.80% per track. This is obtained by comparing $R_{2/3}$ for $e^+e^- \to \tau^+\tau^-$ events in data and MC, where $R_{2/3}$ is the fraction of 3-prong τ decays in which only two hadron tracks are found. The uncertainty on the soft pion tracking efficiency is determined by the study of $B \to D^*\pi$ and $B \to D^*\rho$ decays and estimated to be 9.9%.

To obtain the number of B^0 mesons in the sample, we use the relation

$$N_{B^0} = 2 \times N_{B\bar{B}} \times (1 + f_{+0})^{-1} \; . \tag{11}$$

Here $f^{+0} = \mathcal{B}(\Upsilon(4S) \to B^+ B^-)/\mathcal{B}(\Upsilon(4S) \to B^0 \overline{B}^0) = 1.058 \pm 0.024$ [14]. The number of B meson pairs in the analyzed data set is determined to be $N_{B\bar{B}} = (37.7 \pm 0.6) \times 10^6$.

The uncertainties of the selection efficiencies on the used form factors used to simulate $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ are taken from Ref. [17, 18] and varied within their uncertainties.

Lastly, we account for the impact of the uncertainties in the charm branching fractions, $\mathcal{B}(D^{*+} \to D^0\pi^+) = (67.7 \pm 0.5)\%$ and $\mathcal{B}(D^0 \to K^-\pi^+) = (3.950 \pm 0.031)\%$ [13], on the signal branching fraction.

6. SUMMARY AND CONCLUSIONS

We present measurements of the semileptonic $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^0\ell^-\overline{\nu}_l$ processes using 34.6 fb^{-1} of recorded collision events of Belle II data. We demonstrate the capability to reconstruct and separate $B^- \to D^0\ell^-\overline{\nu}_l$ candidates from the large backgrounds from $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and other processes. In addition, we measure the $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ branching fraction and obtain a value of

$$\mathcal{B}(\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l) = (4.60 \pm 0.05_{\rm stat} \pm 0.17_{\rm syst} \pm 0.45_{\pi_s})\,\% \, , \tag{12}$$

lower, but in good agreement with, the current world average. The largest systematic uncertainty stems from the knowledge of the slow pion reconstruction efficiency. This uncertainty will improve with the statistics of the control samples that will become soon available. In addition, we demonstrate the capability to reconstruct the hadronic recoil parameter w and present unfolded partial decay rates. Such measurements in both $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}_l$ and $B^- \to D^0\ell^-\overline{\nu}_l$ are crucial for future precision measurements of $|V_{cb}|$ in these channels by Belle II.

7. ACKNOWLEDGEMENTS

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[1] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. **D77**, 032002 (2008), arXiv:0705.4008 [hep-ex].

[2] B. Aubert *et al.* (BaBar), Phys. Rev. Lett. **104**, 011802 (2010), arXiv:0904.4063 [hep-ex].

[3] E. Waheed *et al.* (Belle Collaboration), Phys. Rev. **D100**, 052007 (2019), arXiv:1809.03290 [hep-ex].

[4] T. Abe *et al.* (Belle II Collaboration), (2010), arXiv:1011.0352 [physics.ins-det].

[5] E. Kou *et al.*, PTEP **2019**, 123C01 (2019).

[6] K. Akai, K. Furukawa, and H. Koiso (SuperKEKB Collaboration), Nucl. Instrum. Meth. **A907**, 188 (2018).

[7] D. J. Lange, *Proceedings, 7th International Conference on B physics at hadron machines (BEAUTY 2000): Maagan, Israel, September 13-18, 2000*, Nucl. Instrum. Meth. **A462**, 152 (2001).

[8] B. Ward, S. Jadach, and Z. Was, Nucl. Phys. B Proc. Suppl. **116**, 73 (2003), arXiv:hep-ph/0211132.

[9] T. Sjostrand, S. Mrenna, and P. Z. Skands, Comput. Phys. Commun. **178**, 852 (2008), arXiv:0710.3820 [hep-ph].

[10] T. Kuhr, C. Pulvermacher, M. Ritter, T. Hauth, and N. Braun (Belle-II Framework Software Group), Comput. Softw. Big Sci. **3**, 1 (2019), arXiv:1809.04299 [physics.comp-ph].

[11] V. Bertacchi *et al.* (Belle II Tracking), (2020), arXiv:2003.12466 [physics.ins-det].

[12] G. C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).

[13] P. A. Zyla *et al.* (Particle Data Group), to be published in Prog. Theor. Exp. Phys. **2020**, 083C01 (2020).

[14] P. Z. et al. and P. D. Group (Particle Data Group), Prog. Theor. Exp. Phys. **083C01** (2020).

[15] M. Jung and D. M. Straub, JHEP **01**, 009 (2019), arXiv:1801.01112 [hep-ph].

[16] A. J. Bevan *et al.* (*BABAR* & Belle Collaborations), Eur. Phys. J. **C74**, 3026 (2014), arXiv:1406.6311 [hep-ex].

[17] B. Grinstein and A. Kobach, Phys. Lett. B **771**, 359 (2017), arXiv:1703.08170 [hep-ph].

[18] D. Bigi, P. Gambino, and S. Schacht, Phys. Lett. B **769**, 441 (2017), arXiv:1703.06124 [hep-ph].