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The study of the Cabibbo-favored semileptonic decay $\Lambda_c^+ \to \Lambda e^+ \nu_e$ is reported using a 4.5 fb^{-1} data sample of e^+e^- annihilations collected at center-of-mass energies ranging from 4.600 GeV to 4.699 GeV with the BESIII detector at the BEPCII collider. The branching fraction of the decay is measured to be $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.56 \pm 0.11_{\rm stat} \pm 0.07_{\rm syst})\%$, which is the most precise measurement to date.

Furthermore, we perform an investigation of the internal dynamics in $\Lambda_c^+ \to \Lambda e^+ \nu_e$. We provide the first direct comparisons of the differential decay rate and form factors with those predicted from lattice quantum chromodynamics (LQCD) calculations. Combining the measured branching fraction with a q^2-integrated rate predicted by LQCD, we determine $|V_{cs}| = 0.936 \pm 0.017_{\mathcal{B}} \pm 0.024_{\rm LQCD} \pm 0.007_{\tau_{\Lambda_c}}$.

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The study of Λ_c^+ semileptonic (SL) decays provides valuable information about weak and strong interactions in baryons containing a heavy quark. [1] Measurement of the SL decay rate of the Λ_c^+ can help to elucidate the role of nonperturbative effects in strong interactions [2]. In particular, the Cabibbo-favored (CF) SL decay $\Lambda_c^+ \to \Lambda \ell^+ \nu_\ell$ ($\ell = e$, μ), which is the dominant component in Λ_c^+ SL decays [3], is the most interesting to measure. Its decay rate depends on the weak quark mixing Cabibbo-Kobayashi-Maskawa (CKM) matrix [4] element $|V_{cs}|$ and strong interaction effects parametrized by form factors describing the hadronic transition between the initial and the final baryons. Measurement of $|V_{cs}|$ via $\Lambda_c^+ \to \Lambda \ell^+ \nu_\ell$ is an important consistency test for the standard model (SM) and a probe for new physics beyond the SM [2,5], complementary to D meson analyses.

In recent years, significant progress has been achieved in the study of Λ_c^+ SL decays, both experimentally [6–8] and theoretically [9–26]. In 2015, the BESIII Collaboration reported the first measurement of the absolute branching fraction (BF) for $\Lambda_c^+ \to \Lambda e^+ \nu_e$ with $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.63 \pm 0.38_{\rm stat} \pm 0.20_{\rm syst})\%$ [6]. The absolute BF for $\Lambda_c^+ \to \Lambda \mu^+ \nu_\mu$ [8] was reported later. These BESIII measurements motivated the first lattice quantum chromodynamics (LQCD) calculation on the CF SL decay $\Lambda_c^+ \to \Lambda \ell^+ \nu_\ell$ in 2017, with a predicted BF $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.80 \pm 0.19_{\rm LQCD} \pm 0.11_{\tau_{\Lambda_c^+}})\%$ [15], which is consistent with the BESIII result. Reference [15] also investigated the internal dynamics and predicted the form factors and differential decay rates in $\Lambda_c^+ \to \Lambda e^+ \nu_e$ decay. This was followed by a series of other LQCD calculations [23–26] in this sector. This theoretical work is important for understanding the decay mechanism in SL decays in the charmed baryon sector. However, there are no direct experimental data for testing and calibrating calculations of differential decay rates and form factors. Experimental studies of the dynamics in $\Lambda_c^+ \to \Lambda e^+ \nu_e$ can provide this information.

In this Letter, we report an improved measurement of the absolute BF of $\Lambda_c^+ \to \Lambda e^+ \nu_e$ using datasets collected at the BESIII at the center-of-mass energies $\sqrt{s} = 4.600$, 4.612, 4.628, 4.641, 4.661, 4.682, and 4.699 GeV. The total integrated luminosity for these data samples is 4.5 fb^{-1} [27,28], which includes and is about 7 times larger than that used in Ref. [6]. Furthermore, for the first time, we measure the differential decay rate and form factors in $\Lambda_c^+ \to \Lambda e^+ \nu_e$ and provide the direct comparisons with those predicted by the LQCD calculations [15].

Details about the BESIII detector design and performance are provided in Ref. [29]. A GEANT4-based [30] Monte Carlo (MC) detector simulation is used to determine signal detection efficiencies and to estimate potential backgrounds. Signal MC samples of $e^+e^- \to \Lambda_c^+ \bar{\Lambda}_c^-$ with one Λ_c^+ baryon decaying to $\Lambda e^+ \nu_e$ together with a $\bar{\Lambda}_c^-$ decaying to the hadronic decay mode used for this analysis are generated by KKMC [31] with EVTGEN [32]. This includes initial-state radiation [33] and final-state radiation [34] effects. The signal MC sample of the SL decay $\Lambda_c^+ \to \Lambda e^+ \nu_e$ is generated using the form factors measured in this Letter. To study the backgrounds, an inclusive MC sample consisting of open-charm states, radiative return to charmonium(like) ψ states at lower masses, and continuum processes of $q\bar{q}$ ($q = u$, d, and s), along with Bhabha scattering, $\mu^+\mu^-$, $\tau^+\tau^-$, and $\gamma\gamma$ events are generated. All known decay modes of open-charm and ψ states are simulated using BFs specified by the Particle Data Group (PDG) [3], while the remaining unknown ψ decays are modeled with LUNDCHARM [35,36].

We select the "single tag" (ST) and "double tag" (DT) samples as described in Refs. [6,8]. STs are $\bar{\Lambda}_c^-$ baryons reconstructed from their daughter particles in one of 14 hadronic decays as used in Ref. [37]. DTs are events with a ST and a Λ_c^+ baryon reconstructed as $\Lambda e^+ \nu_e$. The ST $\bar{\Lambda}_c^-$ signals are identified using the beam-constrained mass:

$$M_{\rm BC} = \sqrt{(\sqrt{s}/2)^2 - |\vec{p}_{\bar{\Lambda}_c^-}|^2},$$

where $\vec{p}_{\bar{\Lambda}_c^-}$ is the measured momentum of the ST $\bar{\Lambda}_c^-$. A kinematic variable $\Delta E = E_{\rm beam} - E_{\bar{\Lambda}_c^-}$ is required to improve the signal significance for ST $\bar{\Lambda}_c^-$ baryons. If an event satisfies more than one $\bar{\Lambda}_c^-$ tag, only the tag with the minimum $|\Delta E|$ is kept to avoid double-counting among STs with the same final state. The ΔE requirements, $M_{\rm BC}$ distributions, and their ST yields are documented in Ref. [37]. The total ST yield reconstructed with 14 ST modes is $N_{\rm ST} = 122\,268 \pm 474$, where the uncertainty is calculated by the weighted average according to the fit results of each tag mode.

Candidates for $\Lambda_c^+ \to \Lambda e^+ \nu_e$ are selected from the remaining tracks recoiling against the ST $\bar{\Lambda}_c^-$ candidates in the signal mass window. To select the Λ, the same criteria as those used in the ST selection are applied [37]. Detection and reconstruction of the positron follow the procedures in Ref. [6]. As the neutrino is not detected, we employ the kinematic variable $U_{\rm miss} = E_{\rm miss} - c|\vec{p}_{\rm miss}|$ to obtain information on the neutrino, where $E_{\rm miss}$ and $\vec{p}_{\rm miss}$ are the missing energy and momentum carried by the neutrino, respectively, and are defined in the same way as in Ref. [6]. The left panel of Fig. 1 shows the distribution of $M_{p\pi^-}$ versus $U_{\rm miss}$ for the $\Lambda_c^+ \to \Lambda e^+ \nu_e$ candidates in data. A cluster of the events is located around the intersection of the Λ mass and $\Lambda e^+\nu_e$ signal region near $U_{\rm miss} \simeq 0$. Requiring $M_{p\pi^-}$ to be within the Λ signal region, we project the distribution onto the $U_{\rm miss}$ axis, as shown in the right panel of Fig. 1. To obtain the number of signal events, the $U_{\rm miss}$ distribution is fitted with a signal function f which consists of a Gaussian to describe the core of the $U_{\rm miss}$ distribution and two power-law tails to account for initial- and final-state radiations [6,38]. Two MC-simulated background shapes are used to describe the peaking backgrounds from $\Lambda_c^+ \to \Lambda \pi^+ \pi^0$ and $\Lambda_c^+ \to \Lambda \mu^+ \nu_\mu$, and a MC-simulated nonresonant background shape is used to describe the continuous background. From the fit, we obtain the yield of $\Lambda_c^+ \to \Lambda e^+ \nu_e$ decay $N^{\rm DT} = 1253 \pm 39$, where the uncertainty is statistical only.

The absolute BF for $\Lambda_c^+ \to \Lambda e^+ \nu_e$ is determined by

$$\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = \frac{N^{\rm DT}}{N^{\rm ST} \times \varepsilon_{\rm semi}}, \tag{1}$$

where $\varepsilon_{\rm semi} = (\sum_{ij} N_{ij}^{\rm ST} \times \epsilon_{ij}^{\rm DT}/\epsilon_{ij}^{\rm ST})/N^{\rm ST} = 0.2876$ is the average efficiency for detecting the $\Lambda_c^+ \to \Lambda e^+ \nu_e$ decay in ST events [6], and i and j represent the ST modes and the data samples at different center-of-mass energies, respectively. The parameters $N_{ij}^{\rm ST}$, $\epsilon_{ij}^{\rm ST}$, and $\epsilon_{ij}^{\rm DT}$ are the ST yield, and the ST and DT efficiencies, respectively. Inserting the values of $N^{\rm DT}$, $N^{\rm ST}$, and $\epsilon_{\rm semi}$ in Eq. (1), we measure $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.56 \pm 0.11 \pm 0.07)\%$, where the first uncertainty is statistical, and the second is systematic, as described below.

With the DT technique, the BF measurements are insensitive to the systematic uncertainties of the ST selection. The remaining systematic uncertainties in the BF measurement are now described. The uncertainties of the e^+ tracking and particle identification (PID) efficiencies are determined to be 0.4% and 0.5% using radiative Bhabha events. The uncertainty due to Λ reconstruction is determined to be 0.2%, using $J/\psi \to pK^-\bar{\Lambda}$ and $J/\psi \to \Lambda\bar{\Lambda}$ control samples. The uncertainty associated with the simulation of the SL signal model is estimated to be 0.6% by varying the input form-factor parameters, determined in this Letter, by 1 standard deviation. The ST yield (1.0%) is evaluated by using alternative signal shapes in fits to the $M_{\rm BC}$ spectra. We also considered the following systematic uncertainties: the fit to the $U_{\rm miss}$ distribution (1.0%) estimated by using alternative signal shapes and background shapes, the quoted BF for $\Lambda \to p\pi^-$ (0.8%), and the MC statistics (0.8%). Adding these contributions in quadrature gives a total systematic uncertainty of 2.0% for the $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$ measurement.

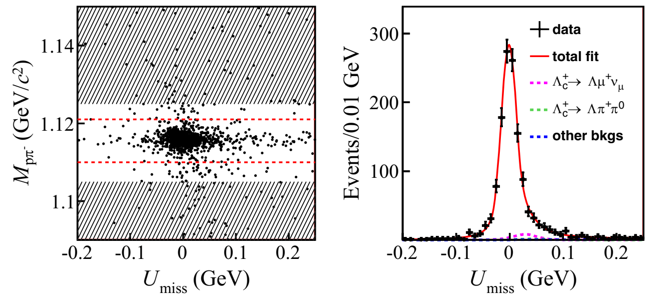

FIG. 1. Left: the $M_{p\pi^-}$ versus $U_{\rm miss}$ distribution for the $\Lambda_c^+ \to \Lambda e^+ \nu_e$ candidates. The area between the dashed lines denotes the Λ signal region, and the hatched areas indicate the Λ sideband regions. Right: projected $U_{\rm miss}$ distribution within the Λ signal region together with the fit.

The differential decay rate of $\Lambda_c^+ \to \Lambda e^+ \nu_e$ can be expressed using four variables: the $e^+\nu_e$ mass squared (q^2), the angle between the proton momentum in the Λ rest frame and the Λ momentum in the Λ_c rest frame (θ_p), the angle between the positron momentum in the decay of $W^+ \to e^+\nu_e$ rest frame and the Λ momentum in the Λ_c rest frame (θ_e), and the acoplanarity angle between the Λ and W^+ decay planes (χ). It can be described in terms of helicity amplitudes $H_{\lambda_\Lambda \lambda_W}$ by [39–41]

$$\begin{aligned}\frac{d^4\Gamma}{dq^2 d\cos\theta_e d\cos\theta_p d\chi} = {} & \frac{G_F^2 |V_{cs}|^2}{2(2\pi)^4} \cdot \frac{Pq^2}{24M_{\Lambda_c}^2} \left\{ \frac{3}{8}(1-\cos\theta_e)^2 |H_{\frac{1}{2}1}|^2 (1+\alpha_\Lambda \cos\theta_p) + \frac{3}{8}(1+\cos\theta_e)^2 |H_{-\frac{1}{2}-1}|^2 (1-\alpha_\Lambda\cos\theta_p) \right. \\ & + \frac{3}{4}\sin^2\theta_e [|H_{\frac{1}{2}0}|^2 (1+\alpha_\Lambda\cos\theta_p) + |H_{-\frac{1}{2}0}|^2(1-\alpha_\Lambda\cos\theta_p)] + \frac{3}{2\sqrt{2}}\alpha_\Lambda \cos\chi \sin\theta_e \sin\theta_p \\ & \left. \times [(1-\cos\theta_e) H_{-\frac{1}{2}0} H_{\frac{1}{2}1} + (1+\cos\theta_e) H_{\frac{1}{2}0} H_{-\frac{1}{2}-1}] \right\},\end{aligned} \tag{2}$$

where $H_{\lambda_\Lambda \lambda_W} = H^V_{\lambda_\Lambda \lambda_W} - H^A_{\lambda_\Lambda \lambda_W}$ and $H^{V(A)}_{-\lambda_\Lambda -\lambda_W} = +(-)H^{V(A)}_{\lambda_\Lambda \lambda_W}$, G_F is the Fermi coupling constant, $|V_{cs}| = 0.97320 \pm 0.00011$ [3] is a CKM matrix element, P is the magnitude of the Λ momentum in the Λ_c rest frame, M_{Λ_c} is the mass of Λ_c [3], and α_Λ is the $\Lambda \to p\pi^-$ decay asymmetry parameter [3].

The helicity amplitudes parametrized in Eq. (2) are related to four form factors by [15]

$$H^V_{\frac{1}{2}1} = \sqrt{2Q_-} f_\perp(q^2), \qquad H^A_{\frac{1}{2}1} = \sqrt{2Q_+} g_\perp(q^2),$$
$$H^V_{\frac{1}{2}0} = \sqrt{Q_-/q^2} f_+(q^2)(M_{\Lambda_c} + M_\Lambda),$$
$$H^A_{\frac{1}{2}0} = \sqrt{Q_+/q^2} g_+(q^2)(M_{\Lambda_c} - M_\Lambda), \tag{3}$$

where $Q_\pm = (M_{\Lambda_c} \pm M_\Lambda)^2 - q^2$ and M_Λ is the Λ mass [3]. The form factors $f_{\perp,+}(q^2)$ and $g_{\perp,+}(q^2)$ are defined following a z-expansion of the parameters as in Ref. [15]:

$$f(q^2) = \frac{a_0^f}{1 - q^2/(m^f_{\rm pole})^2}[1 + \alpha_1^f \times z(q^2)], \tag{4}$$

where $m^f_{\rm pole}$ is the pole mass; a_0^f, α_1^f are free parameters; and $z(q^2) = [(\sqrt{t_+ - q^2} - \sqrt{t_+ - t_0})/(\sqrt{t_+ - q^2} + \sqrt{t_+ - t_0})]$ with $t_0 = q^2_{\rm max} = (m_{\Lambda_c} - m_\Lambda)^2$, $t_+ = (m_D + m_K)^2$, $m_D = 1.870\ {\rm GeV}/c^2$, and $m_K = 0.494\ {\rm GeV}/c^2$. The pole masses are $m^{f_+,f_\perp}_{\rm pole} = 2.112\,{\rm GeV}/c^2$ and $m^{g_+,g_\perp}_{\rm pole} = 2.460\,{\rm GeV}/c^2$ [15].

For these four form factors, the amplitudes at $q^2 = 0$ are denoted as $a_0^{f_\perp}$, $a_0^{f_+}$, $a_0^{g_\perp}$, and $a_0^{g_+}$, respectively. As the differential decay rate defined in Eq. (2) has to be normalized, we can only determine the ratios of these amplitudes and α_1^f in the maximum-likelihood (ML) fit. Here, we choose $a_0^{g_\perp}$ as the reference, since the terms with form-factor parameters $a_0^{g_{\perp,+}}$ are dominant compared with those with $a_0^{f_{\perp,+}}$ in the $\Lambda_c^+ \to \Lambda e^+ \nu_e$ decay. Furthermore, we set $\alpha_1^{g_\perp} \equiv \alpha_1^{g_+}$ and $\alpha_1^{f_\perp} \equiv \alpha_1^{f_+}$, taking into account that the kinematic dependences of $g_\perp(q^2)$ and $g_+(q^2)$, $f_\perp(q^2)$ and $f_+(q^2)$ as functions of q^2 are similar according to the LQCD calculation [15]. Hence, there are five independent free parameters in the ML fit for the differential decay amplitude: $\alpha_1^{g_\perp}$, $\alpha_1^{f_\perp}$, $r_{f_+} = a_0^{f_+}/a_0^{g_\perp}$, $r_{f_\perp} = a_0^{f_\perp}/a_0^{g_\perp}$, and $r_{g_+} = a_0^{g_+}/a_0^{g_\perp}$.

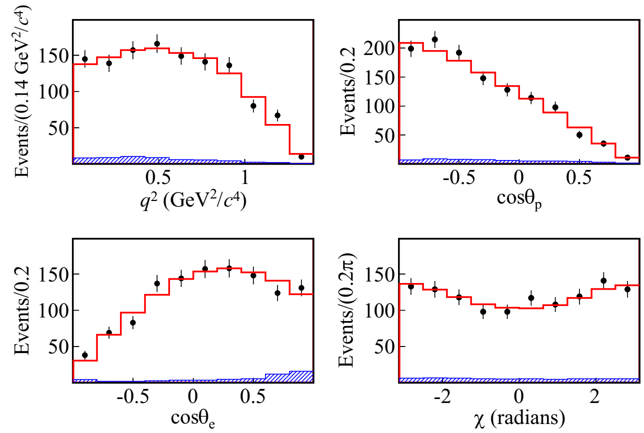

FIG. 2. Projections of the fitted kinematic variables, comparing data (dots with error bars) and MC. Solid and shadowed histograms are the MC-simulated signal plus background and the MC-simulated background.

A four-dimensional ML fit is performed as a function of q^2, $\cos\theta_e$, $\cos\theta_p$, and χ for $\Lambda_c^+ \to \Lambda e^+ \nu_e$ events within $-0.06 < U_{\rm miss} < 0.06$ GeV. The projections of the fit onto q^2, $\cos\theta_e$, $\cos\theta_p$, and χ are shown in Fig. 2. The fit procedure is validated using large inclusive MC samples, and the pull distribution of each fitted parameter is consistent with a normal distribution. The fitted form-factor parameters of $\alpha_1^{g_\perp}$, $\alpha_1^{f_\perp}$, r_{f_+}, $r_{f_\perp}$, r_{g_+} are given in Table I. The goodness of fit is estimated by using χ^2/d.o.f. with a similar method as applied in Ref. [42], where d.o.f. denotes the number of degrees of freedom. The χ^2 is calculated from the comparison between the measured and expected number of events in the four-dimensional space of the kinematic variables q^2, $\cos\theta_e$, $\cos\theta_p$, and χ, which are initially divided into 2, 3, 3, and 3 bins, respectively.

TABLE I. Measured form-factor parameters, where the first errors are statistical and the second are systematic. The lower table shows the correlation coefficients of statistical and systematic uncertainties between the form-factor parameters.

Parameters	$\alpha_1^{g_\perp}$	$\alpha_1^{f_\perp}$	r_{f_+}	$r_{f_\perp}$	r_{g_+}
Values	$1.43 \pm 2.09 \pm 0.16$	$-8.15 \pm 1.58 \pm 0.05$	$1.75 \pm 0.32 \pm 0.01$	$3.62 \pm 0.65 \pm 0.02$	$1.13 \pm 0.13 \pm 0.01$
Coefficients	$\alpha_1^{g_\perp}$	$\alpha_1^{f_\perp}$	r_{f_+}	$r_{f_\perp}$	r_{g_+}
$a_0^{g_\perp}$	−0.64	0.60	−0.66	−0.83	−0.40
$\alpha_1^{g_\perp}$		−0.63	0.62	0.53	−0.33
$\alpha_1^{f_\perp}$			−0.79	−0.67	−0.07
r_{f_+}				0.57	−0.09
$r_{f_\perp}$					0.39

TABLE II. Systematic uncertainties (in %) of the fitted parameters.

Parameter	Tracking&PID&Λ	Normalization	α_Λ	Total
$a_1^{f_\perp}$	0.6	0.5	0.1	0.8
$a_1^{g_\perp}$	6.0	7.2	2.8	9.8
r_{f_+}	0.1	0.5	0.7	0.9
$r_{g_\perp}$	0.3	0.1	0.6	0.7
r_{g_+}	0.3	1.5	0.1	1.5

The value of $\chi^2/\mathrm{d.o.f.}$ is evaluated to be 0.85. The systematic uncertainties arise mainly from the uncertainties related to positron tracking and PID efficiencies, Λ reconstruction efficiency, the background normalization, and the Λ decay parameter. The systematic uncertainties arising from the requirements placed on the positron and Λ are estimated by varying the positron tracking, PID efficiencies, and Λ reconstruction efficiency by $\pm 0.4\%$, $\pm 0.5\%$, and $\pm 0.2\%$, respectively. The systematic uncertainty because of the background normalization is estimated by varying its value by $\pm 13\%$, which takes into account the uncertainty of the background estimations. The systematic uncertainty in α_Λ is evaluated by varying its nominal value by $\pm 1\sigma$. All of the variations mentioned above will result in differences of the fitted parameters from their values under the nominal conditions. These differences are assigned as the systematic uncertainties and summarized in Table II, where the total systematic uncertainty is obtained by adding all contributions in quadrature.

In order to determine the parameter of $a_0^{g_\perp}$, the differential decay rate is related to $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$ measured in this Letter and the lifetime of Λ_c (τ_{Λ_c}) by

$$\int_0^{q^2_{\max}} \frac{d\Gamma}{dq^2} dq^2 = \frac{\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)}{\tau_{\Lambda_c}}, \qquad (5)$$

where $d\Gamma/dq^2$ is the integration of the differential decay rate given in Eq. (2) over the other three kinematic variables and expressed as

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2 |V_{cs}|^2}{192\pi^3 M_{\Lambda_c}^2} \times P q^2 \times [|H_{\frac{1}{2}1}|^2 + |H_{-\frac{1}{2}-1}|^2 + |H_{\frac{1}{2}0}|^2 + |H_{-\frac{1}{2}0}|^2]. \qquad (6)$$

Inserting $\tau_{\Lambda_c} = 202.4 \pm 3.1$ fs [3], the CKM element $|V_{cs}| = 0.97320 \pm 0.00011$ [3], and the helicity amplitudes parametrized with form factors as in Eq. (3), we determine $a_0^{g_\perp} = 0.54 \pm 0.04_{\mathrm{stat}} \pm 0.01_{\mathrm{syst}}$.

With the measured parameters and their correlation coefficients shown in Table I, we obtain the dependences of form factors of $f_\perp(q^2)$, $f_+(q^2)$, $g_\perp(q^2)$, and $g_+(q^2)$, and the differential decay rate as a function of q^2 in the SL decay $\Lambda_c^+ \to \Lambda e^+ \nu_e$. Figures 3 and 4 show comparisons of the FFs and the differential decay rate between measurements in this Letter and in LQCD calculations. Results of LQCD calculations are obtained using the nominal values listed in Table IV in Ref. [15]. We note that the dependences of measured FFs show different kinematic behavior compared to those predicted from LQCD calculations. In particular, discrepancies can be seen at high-q^2 regions for $f_\perp(q^2)$ and $g_\perp(q^2)$, as well as at low-q^2 regions for $f_+(q^2)$. For $f_+(q^2)$ and $f_\perp(q^2)$, our measurement tends to have a steeper slope than those from LQCD calculations, while the opposite is true for $g_+(q^2)$ and $g_\perp(q^2)$. The corresponding comparison on differential decay rates, shown in Fig. 4, gives fair agreement throughout the q^2 region.

In summary, we report an improved measurement of the absolute BF for $\Lambda_c^+ \to \Lambda e^+ \nu_e$, $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.56 \pm 0.11 \pm 0.07)\%$, based on 4.5 fb^{-1} of data collected at center-of-mass energies ranging from 4.600 GeV to 4.699 GeV with BESIII. This Letter supersedes our previous measurement [6] and improves the precision of the world average value more than threefold. Comparisons of the BF from this Letter and theoretical predictions are

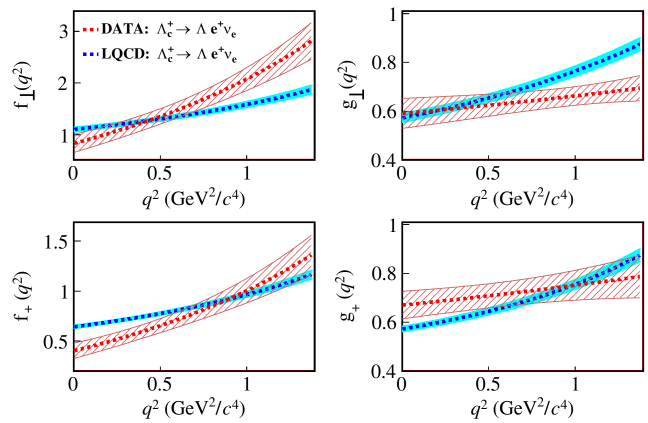

FIG. 3. Comparison of form factors with LQCD calculations. The bands show the total uncertainties.

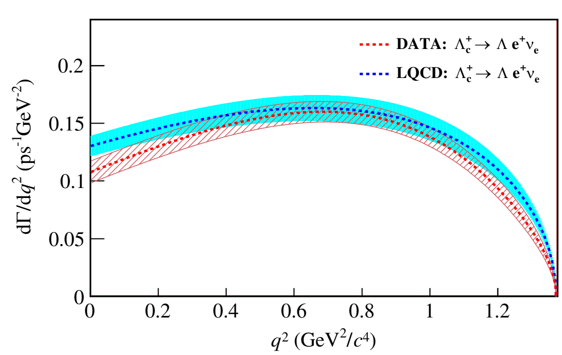

FIG. 4. Comparison of the differential decay rates with LQCD predictions. The band shows the total uncertainty.

TABLE III. Comparison of $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$ from theoretical calculations and our measurement.

	$\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$ (%)
Constituent quark model (HONR) [9]	4.25
Light-front approach [10]	1.63
Covariant quark model [11]	2.78
Relativistic quark model [12]	3.25
Non-relativistic quark model [13]	3.84
Light-cone sum rule [14]	3.0 ± 0.3
Lattice QCD [15]	3.80 ± 0.22
$SU(3)$ [16]	3.6 ± 0.4
Light-front constituent quark model [17]	3.36 ± 0.87
MIT bag model [17]	3.48
Light-front quark model [18]	4.04 ± 0.75
This Letter	$3.56 \pm 0.11 \pm 0.07$

shown in Table III. The predicted BFs in Refs. [9–13] differ by more than 2 standard deviations with respect to the mean value of our measured $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$. Thus, our measurement disfavors these predictions at a confidence level of more than 95%. Combining $\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$ measured in this Letter, τ_{Λ_c}, and the q^2-integrated rate predicted by LQCD [15], we determine $|V_{cs}| = 0.936 \pm 0.017_{\mathcal{B}} \pm 0.024_{\rm LQCD} \pm 0.007_{\tau_{\Lambda_c}}$, which is inconsistent with $|V_{cs}| = 0.939 \pm 0.038$ measured in $D \to K\ell\nu_\ell$ decays [3] within 1 standard deviation.

Furthermore, by analyzing the dynamics of $\Lambda_c^+ \to \Lambda e^+ \nu_e$, we measure the $\Lambda_c^+ \to \Lambda$ decay form factors for the first time. Our results provide the first direct comparisons on the differential decay rates and form factors with those obtained from LQCD calculations. Currently, the statistical uncertainty dominates in the total uncertainty of our result, and the measurement can be improved with more experimental data available in the future [43]. The comparisons of differential decay rate and form factors between experimental measurements and LQCD predictions presented in this Letter provide important inputs in understanding the SL decays of charmed baryons. Our results will also help calibrate the calculation of SL decays of other charmed baryons [44,45], as well as the Λ_b [18–20,25,46–49].

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