Fragmentation fraction f_{Ω_b} and the $\Omega_b \to \Omega J/\psi$ decay in the light-front formalism

Yu-Kuo Hsiao[1,*] and Chong-Chung Lih[2,†]

[1]*School of Physics and Information Engineering, Shanxi Normal University, Taiyuan 030031, China*
[2]*Department of Optometry, Central Taiwan University of Science and Technology, Taichung 40601, Taiwan*

(Received 9 October 2021; accepted 28 February 2022; published 23 March 2022)

One has measured $f_{\Omega_b}\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi)$ at the level of 10^{-6}, where the fragmentation faction f_{Ω_b} is to evaluate the b quark to Ω_b^- production rate. Using the $\Omega_b \to \Omega$ transition form factors calculated in the light-front quark model, we predict $\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi) = (5.3^{+3.3+3.8}_{-2.1-2.7}) \times 10^{-4}$. In particular, we extract $f_{\Omega_b} = (0.54^{+0.34+0.39+0.21}_{-0.22-0.28-0.15}) \times 10^{-2}$, demonstrating that the b to Ω_b productions are much more difficult than the b to $\Lambda_b(\Xi_b)$ ones. Since f_{Ω_b} has not been determined experimentally, f_{Ω_b} added to theoretical branching fractions can be compared to future measurements of the Ω_b decays.

DOI: 10.1103/PhysRevD.105.056015

I. INTRODUCTION

The antitriplet b baryons $(\Lambda_b, \Xi_b^0, \Xi_b^-)$ and Ω_b^- all decay weakly [1], where Ω_b belongs to the sextet b-baryon states. Interestingly, only Ω_b is allowed to have a direct transition to $\mathbf{B}^*$ in the weak interaction, where $\mathbf{B}^*$ stands for a spin-3/2 decuplet baryon. This is due to the fact that Ω_b and $\mathbf{B}^*$ both have totally symmetric quark orderings. By contrast, the antitriplet baryon $\mathbf{B}_b$ consisting of $(q_1q_2 - q_2q_1)b$ mismatches $\mathbf{B}^*$ with $(q_1q_2 + q_2q_1)q_3$ in the $\mathbf{B}_b$ to $\mathbf{B}^*$ transition. Clearly, the Ω_b decay into $\mathbf{B}^*$ is worth an investigation.

One has barely measured the Ω_b decays. Moreover, the fragmentation fraction $f_{\mathbf{B}_b(\Omega_b)}$ that evaluates the b quark to $\mathbf{B}_b(\Omega_b)$ production rate has not been determined yet. Consequently, the charmful Ω_b decay channel $\Omega_b^- \to \Omega^- J/\Psi$ can only be partially measured. In addition to $\Lambda_b \to \Lambda J/\psi$ and $\Xi_b^- \to \Xi^- J/\psi$, the partial branching fractions are given by [1]

$$
\begin{aligned}
f_{\Omega_b}\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi) &= (2.9^{+1.1}_{-0.8}) \times 10^{-6}, \\
f_{\Lambda_b}\mathcal{B}(\Lambda_b \to \Lambda J/\psi) &= (5.8 \pm 0.8) \times 10^{-5}, \\
f_{\Xi_b}\mathcal{B}(\Xi_b^- \to \Xi^- J/\psi) &= (1.02^{+0.26}_{-0.21}) \times 10^{-5}, \qquad (1)
\end{aligned}
$$

where $f_{\Xi_b} = f_{\Xi_b^{-(0)}}$. Some theoretical attempts have been given to extract $f_{\mathbf{B}_b(\Omega_b)}$ [2–4]. Using the calculations of $\mathcal{B}(\Lambda_b \to \Lambda J/\psi)$ and $\mathcal{B}(\Xi_b^- \to \Xi^- J/\psi)$ [2,3], one extracts f_{Λ_b} and f_{Ξ_b} as some certain numbers. Without a careful study of $\Omega_b^- \to \Omega^- J/\Psi$ [2,3], it is roughly estimated that $f_{\Omega_b} < 0.108$. Therefore, it can be an important task to explore the charmful $\Omega_b^- \to \Omega^- J/\Psi$ decay.

See Fig. 1; $\Omega_b^- \to \Omega^- J/\Psi$ is depicted to proceed through the $\Omega_b^- \to \Omega^-$ transition, while J/Ψ is produced from the internal W-boson emission. To calculate the branching fraction, the information of the $\Omega_b \to \Omega$ transition is required. On the other hand, the light-front quark model has provided its calculation on the $\Omega_c \to \Omega$ transition form factors, such that one interprets the relative branching fractions of $\Omega_c^0 \to \Omega^- \rho^+$ and $\Omega_c^0 \to \Omega^- \ell^+ \bar{\nu}_\ell$ to that of $\Omega^- \pi^+$ [5]. Therefore, we propose calculating the $\Omega_b^- \to \Omega^-$ transition form factors in the light-front formalism, as applied to the Ω_c decays as well as the other heavy hadron decays [6–24]. We will be able to predict $\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi)$ and extract f_{Ω_b}. Besides, we will compare the branching fractions of $\Omega_b^- \to \Omega^- J/\Psi$, $\Lambda_b \to \Lambda J/\psi$, and $\Xi_b^- \to \Xi^- J/\psi$ and their fragmentation fractions.

II. FORMALISM

According to Fig. 1, the amplitude of $\Omega_b^- \to \Omega^- J/\Psi$ combines the matrix elements of the $\Omega_b^- \to \Omega^-$ transition and J/Ψ production, written as [2,3]

$$
\begin{aligned}
\mathcal{M}(\Omega_b^- \to \Omega^- J/\Psi) = \frac{G_F}{\sqrt{2}} V_{cb} V_{cs}^* a_2 \langle J/\psi | \bar{c}\gamma^\mu (1-\gamma_5) c | 0 \rangle \\
\times \langle \Omega^- | \bar{s}\gamma_\mu (1-\gamma_5) b | \Omega_b^- \rangle, \qquad (2)
\end{aligned}
$$

*yukuohsiao@gmail.com
†cclih@phys.nthu.edu.tw

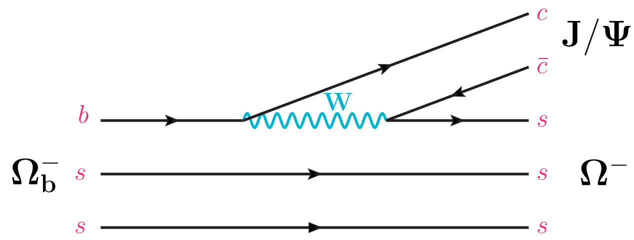

FIG. 1. Feynman diagram for $\Omega_b^- \to \Omega^- J/\Psi$.

where G_F is the Fermi constant and $V_{cb(s)}^{(*)}$ is the Cabibbo-Kobayashi-Maskawa (CKM) matrix element. The factorization derives that $a_2 = c_2^{\rm eff} + c_1^{\rm eff}/N_c$, where $c_{1,2}^{\rm eff}$ are the effective Wilson coefficients and N_c is the color number [25,26]. For the J/Ψ production, the matrix elements read [27]

$$\langle J/\psi|\bar{c}\gamma^\mu(1-\gamma_5)c|0\rangle = m_{J/\psi} f_{J/\psi}\varepsilon_\mu^*, \tag{3}$$

where $m_{J/\psi}$, $f_{J/\psi}$, and ε_μ^* are the mass, decay constant, and polarization 4-vector, respectively. The matrix elements of the $\Omega_b^-(bss) \to \Omega^-(sss)$ transition are parametrized as [21,28]

$$\begin{aligned}\langle T^\mu\rangle &\equiv \langle\Omega(sss)|\bar{s}\gamma^\mu(1-\gamma_5)b|\Omega_b(bss)\rangle \\ &= \bar{u}_\alpha\left[\frac{P^\alpha}{M}\left(\gamma^\mu F_1^V + \frac{P^\mu}{M}F_2^V + \frac{P'^\mu}{M'}F_3^V\right) + g^{\alpha\mu}F_4^V\right]\gamma_5 u \\ &\quad - \bar{u}_\alpha\left[\frac{P^\alpha}{M}\left(\gamma^\mu F_1^A + \frac{P^\mu}{M}F_2^A + \frac{P'^\mu}{M'}F_3^A\right) + g^{\alpha\mu}F_4^A\right]u,\end{aligned} \tag{4}$$

where $M^{(\prime)}$ and $P^{(\prime)}$ represent the mass and momentum of $\Omega_b(\Omega)$, respectively, and $F_i^{V,A}$ $(i = 1, 2, \ldots, 4)$ are the form factors. By substituting the matrix elements of Eqs. (3) and (4) for those of Eq. (2), we derive the amplitude in the helicity basis [28],

$$\mathcal{M} = c_W \sum_{\lambda_\Omega,\lambda_J}(H^V_{\lambda_\Omega\lambda_J} - H^A_{\lambda_\Omega\lambda_J}), \tag{5}$$

where $c_W \equiv (G_F/\sqrt{2})V_{cb}V_{cs}^* a_2 m_{J/\psi} f_{J/\psi}$, and $\lambda_\Omega = (\pm 3/2, \pm 1/2)$ and $\lambda_J = (0, \pm 1)$ denote the helicity states of Ω and J/Ψ, respectively. Because of the helicity conservation, $\lambda_{\Omega_b} = \lambda_\Omega - \lambda_J$ should be respected, where $\lambda_{\Omega_b} = \pm 1/2$. Subsequently, we obtain [28]

$$\begin{aligned}H^{V(A)}_{\frac{1}{2}0} &= \sqrt{\frac{2}{3}\frac{Q_\mp^2}{q^2}}\left[F_1^{V(A)}\left(\frac{Q_\pm^2 \, M_\mp}{2MM'}\right)\right. \\ &\qquad \left. \mp\left(F_2^{V(A)} + F_3^{V(A)}\frac{M}{M'}\right)\left(\frac{|\vec{P}'|^2}{M'}\right) \mp F_4^{V(A)}\bar{M}'_-\right], \\ H^{V(A)}_{\frac{1}{2}1} &= -\sqrt{\frac{Q_\mp^2}{3}}\left[F_1^{V(A)}\left(\frac{Q_\pm^2}{MM'}\right) - F_4^{V(A)}\right], \\ H^{V(A)}_{\frac{3}{2}1} &= \mp\sqrt{Q_\mp^2}F_4^{V(A)},\end{aligned} \tag{6}$$

and $H^{V(A)}_{-\lambda_\Omega-\lambda_J} = \mp H^{V(A)}_{\lambda_\Omega\lambda_f}$, with $M_\pm = M \pm M'$, $Q_\pm^2 = M_\pm^2 - q^2$, $\bar{M}_\pm^{(\prime)} = (M_+M_- \pm q^2)/(2M^{(\prime)})$, and $|\vec{P}'| = \sqrt{Q_+^2 Q_-^2}/(2M)$.

In the light-front quark model, we can calculate the form factors. To start with, we consider the baryon as a bound state that consists of three quarks q_1, q_2, and q_3, where $q_{2,3}$ are combined as a diquark, denoted by $q_{[2,3]}$. Explicitly, the baryon bound state can be written as [9]

$$|\mathbf{B}(P,S,S_z)\rangle = \int\{d^3p_1\}\{d^3p_2\}2(2\pi)^3\delta^3(\tilde{P} - \tilde{p}_1 - \tilde{p}_2)\sum_{\lambda_1,\lambda_2}\Psi^{SS_z}(\tilde{p}_1,\tilde{p}_2,\lambda_1,\lambda_2)|q_1(p_1,\lambda_1)q_{[2,3]}(p_2,\lambda_2)\rangle, \tag{7}$$

where p_i and λ_i stand for the momentum and helicity state, respectively, and $\Psi^{SS_z}(\tilde{p}_1,\tilde{p}_2,\lambda_1,\lambda_2)$ is the momentum-space wave function. In the light-front frame, one defines $P = (P^-, P^+, P_\perp)$ with $P^\pm = P^0 \pm P^3$ and $P_\perp = (P^1, P^2)$, and $p_i = (p_i^-, p_i^+, p_{i\perp})$ with $p_i^\pm = p_i^0 \pm p_i^3$ and $p_{i\perp} = (p_i^1, p_i^2)$, together with $\tilde{P} = (P^+, P_\perp)$ and $\tilde{p}_i = (p_i^+, p_{i\perp})$, which result in $P^+P^- = M^2 + P_\perp^2$ and $p_i^+p_i^- = m_i^2 + p_{i\perp}^2$ with $(m_1, m_2) = (m_{q_1}, m_{q_2} + m_{q_3})$. Moreover, P and p_i are related as $P^+ = p_1^+ + p_2^+$ and $P_\perp = p_{1\perp} + p_{2\perp}$, where

$$\begin{aligned}p_1^+ &= (1-x)P^+, \qquad p_2^+ = xP^+, \\ p_{1\perp} &= (1-x)P_\perp - k_\perp, \qquad p_{2\perp} = xP_\perp + k_\perp,\end{aligned} \tag{8}$$

with $k_\perp$ from $\vec{k} = (k_\perp, k_z)$ the relative momentum. By means of $e_i \equiv \sqrt{m_i^2 + \vec{k}^2}$, the energy of the (di)quark, and $M_0 \equiv e_1 + e_2$, the above parameters can be rewritten as

$$\begin{aligned}(x, 1-x) &= (e_2 - k_z, e_1 + k_z)/(e_1 + e_2), \\ k_z &= \frac{xM_0}{2} - \frac{m_2^2 + k_\perp^2}{2xM_0}.\end{aligned} \tag{9}$$

In addition, we obtain $M_0^2 = (m_1^2 + k_\perp^2)/(1-x) + (m_2^2 + k_\perp^2)/x$. We also get $(\bar{P}_\mu \gamma^\mu - M_0) u(\bar{P}, S_z) = 0$ with $\bar{P} \equiv p_1 + p_2$, where $p_{1,2}$ describe the internal motions of the internal quarks. Under the Melosh transformation [7], we derive Ψ^{SS_z} as [19–22]

$$\Psi^{SS_z}(\tilde{p}_1, \tilde{p}_2, \lambda_1, \lambda_2) = \sqrt{\frac{C}{2(p_1 \cdot \bar{P} + m_1 M_0)}} \bar{u}(p_1, \lambda_1) \Gamma u(\bar{P}, S_z) \phi(x, k_\perp), \tag{10}$$

where $\Gamma = \Gamma_S(\Gamma_A^{(\alpha)})$ represents the vertex function for the scalar (axial-vector) quantity of the diquark, given by [19–22]

$$\Gamma_S = 1,$$
$$\Gamma_A = -\frac{1}{\sqrt{3}} \gamma_5 \not{\epsilon}^*(p_2, \lambda_2), \qquad \Gamma_A^\alpha = \epsilon^{*\alpha}(p_2, \lambda_2). \tag{11}$$

Moreover, the parameter C for $(\Gamma_{S(A)}, \Gamma_A^\alpha)$ is given by

$$C = \left(\frac{3(m_1 M_0 + p_1 \cdot \bar{P})}{3 m_1 M_0 + p_1 \cdot \bar{P} + 2(p_1 \cdot p_2)(p_2 \cdot \bar{P})/m_2^2}, \frac{3 m_2^2 M_0^2}{2 m_2^2 M_0^2 + (p_2 \cdot \bar{P})^2} \right). \tag{12}$$

In Eq. (10), $\phi(x, k_\perp)$ is the wave function that illustrates the momentum distribution of the constituent quark-diquark states. Here, we present $\phi(x, k_\perp)$ in the Gaussian form [5,6,19–23]:

$$\phi(x, k_\perp) = 4 \left(\frac{\pi}{\beta^2} \right)^{3/4} \sqrt{\frac{e_1 e_2}{x(1-x) M_0}} \exp\left(\frac{-\vec{k}^2}{2\beta^2} \right), \tag{13}$$

with $\beta \equiv \beta_{b[ss]}(\beta_{s[ss]})$ to shape the momentum distribution of the b-$[ss]$ (s-$[ss]$) system in the Ω_b (Ω) bound state.

Using the bound states of $|\Omega_b(P, S, S_z)\rangle$ and $|\Omega(P', S', S'_z)\rangle$ in Eq. (7) and the above identities, we derive the matrix elements of the $\Omega_b \to \Omega$ transition in the light-front frame, given by [21]

$$\begin{aligned} \langle \bar{T}^\mu \rangle &\equiv \langle \Omega(P', S' = 3/2, S'_z) | \bar{s} \gamma^\mu (1-\gamma_5) b | \Omega_b(P, S = 1/2, S_z) \rangle \\ &= \int \{d^3 p_2\} \hat{C}^{-1/2} \phi'(x', k'_\perp) \phi(x, k_\perp) \sum_{\lambda_2} \bar{u}_\alpha(\bar{P}', S'_z) [\bar{\Gamma}_A'^{\alpha} (\not{p}'_1 + m'_1) \gamma^\mu (1-\gamma_5)(\not{p}_1 + m_1) \Gamma_A] u(\bar{P}, S_z), \end{aligned} \tag{14}$$

where $m_1^{(\prime)} = m_{b(s)}$, $\bar{\Gamma} = \gamma^0 \Gamma^\dagger \gamma^0$, and $\hat{C} = 4 p_1^+ p_1'^+ (p_1 \cdot \bar{P} + m_1 M_0)(p'_1 \cdot \bar{P}' + m'_1 M'_0)$.

To determine $F_i^{V,A}$, the identities $J^\mu_{(5)} \equiv \bar{u} \Gamma^{\mu\beta} (\gamma_5) u_\beta$ and $\bar{J}^\mu_{(5)} \equiv \bar{u} \bar{\Gamma}^{\mu\beta} (\gamma_5) u_\beta$ can be useful, where $\Gamma^{\mu\beta} = (\gamma^\mu P^\beta, P'^\mu P^\beta, P^\mu P^\beta, g^{\mu\beta})$ and $\bar{\Gamma}^{\mu\beta} = (\gamma^\mu \bar{P}^\beta, \bar{P}'^\mu \bar{P}^\beta, \bar{P}^\mu \bar{P}^\beta, g^{\mu\beta})$. We can hence perform the following calculations [5,21]:

$$\begin{aligned} J_5 \cdot \langle T \rangle &= \mathrm{Tr}\left\{ u_\beta \bar{u}_\alpha \left[\frac{P^\alpha}{M} \left(\gamma^\mu F_1^V + \frac{P^\mu}{M} F_2^V + \frac{P'^\mu}{M'} F_3^V \right) + g^{\alpha\mu} F_4^V \right] \gamma_5 \bar{u} \Gamma^\beta_\mu \gamma_5 \right\}, \\ \bar{J}_5 \cdot \langle \bar{T} \rangle &= \int \{d^3 p_2\} \hat{C}^{-1/2} \phi'(x', k'_\perp) \phi(x, k_\perp) \sum_{\lambda_2} \mathrm{Tr}\{ u_\beta \bar{u}_\alpha [\bar{\Gamma}_A'^{\alpha} (\not{p}'_1 + m'_1) \gamma^\mu (\not{p}_1 + m_1) \Gamma_A] u \bar{\Gamma}^\beta_\mu \gamma_5 \}. \end{aligned} \tag{15}$$

By connecting $J_5 \cdot \langle T \rangle$ to $\bar{J}_5 \cdot \langle \bar{T} \rangle$, that is, $J_5 \cdot \langle T \rangle = \bar{J}_5 \cdot \langle \bar{T} \rangle$, F_i^V in $J_5 \cdot \langle T \rangle$ can be extracted with $\bar{J}_5 \cdot \langle \bar{T} \rangle$ in the light-front quark model, as the other extractions of the $\mathbf{B}_{b(c)} \to \mathbf{B}^{(*)}$ transition form factors [5,6,19–23]. Similarly, $J \cdot \langle T \rangle = \bar{J} \cdot \langle \bar{T} \rangle$ enables us to get F_i^A. We will present our results in the next section.

III. NUMERICAL ANALYSIS

For the numerical analysis, the CKM matrix elements and the mass (decay constant) of the J/Ψ meson state are given by [1]

$$(V_{cb}, V_{cs}) = (A\lambda^2, 1 - \lambda^2/2),$$
$$(m_{J/\Psi}, f_{J/\Psi}) = (3.097, 0.418)\ \text{GeV}, \tag{16}$$

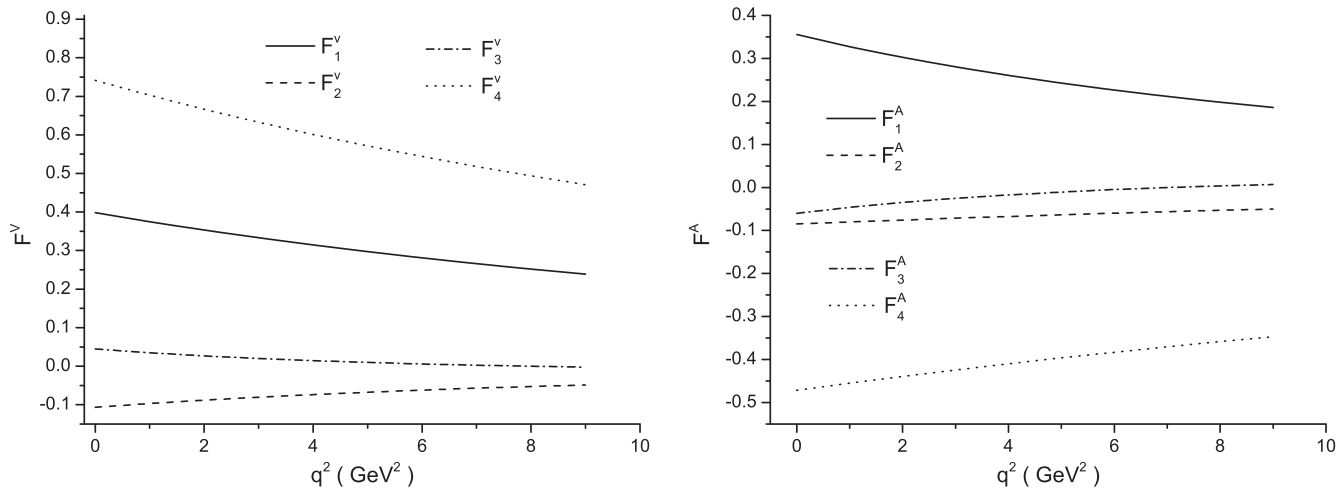

FIG. 2. $F_i^{V(A)}$ vs q^2 ($i = 1, 2, 3, 4$).

with $\lambda = 0.2265$ and $A = 0.790$ in the Wolfenstein parametrization. The effective Wilson coefficients $(c_1^{\rm eff}, c_2^{\rm eff}) = (1.168, -0.365)$ come from Refs. [25,26]. In the generalized version of the factorization approach, N_c is taken as a floating number, in order that the nonfactorizable effects from QCD corrections can be estimated. By adopting $N_c = 2.15 \pm 0.17$ in Refs. [2,3], we obtain $a_2 = 0.18^{+0.05}_{-0.04}$, which has been used to interpret $\mathcal{B}(\Lambda_b \to \Lambda J/\psi)$ and $\mathcal{B}(\Xi_b^- \to \Xi^- J/\psi)$.

In terms of $J_5 \cdot \langle T\rangle = \bar{J}_5 \cdot \langle \bar{T}\rangle$ and $J \cdot \langle T\rangle = \bar{J} \cdot \langle \bar{T}\rangle$ and the theoretical inputs in Eqs. (13), (14), and (15), given by [23]

$$(m_b, \beta_{b[ss]}) = (5.00 \pm 0.20, 0.78 \pm 0.04)\ \text{GeV},$$
$$(m_s, \beta_{s[ss]}) = (0.38, 0.48)\ \text{GeV}, \tag{17}$$

we derive $F_i^{V(A)}$ as the functions of q^2, depicted in Fig. 2. It is common that one parametrizes the form factors in the dipole expressions [16,17,24], which reproduce the momentum dependences derived in the quark model. Subsequently, the form factors can have simple forms to be used in the weak decays. In our case, we present [5,6]

$$F(q^2) = \frac{F(0)}{1 - a(q^2/m_F^2) + b(q^4/m_F^4)}, \tag{18}$$

with m_F, a, b, and $F(0)$ at $q^2 = 0$ given in Table I, in order to describe the momentum behaviors of $F_i^{V,A}$ in Fig. 2.

Thus, we calculate the branching fraction and fragmentation fraction as

$$\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi) = (5.3^{+3.3+3.8}_{-2.1-2.7}) \times 10^{-4},$$
$$f_{\Omega_b} = (0.54^{+0.34+0.39+0.21}_{-0.22-0.28-0.15}) \times 10^{-2}, \tag{19}$$

where f_{Ω_b} is extracted with $\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi)$ and the data in Eq. (1). Moreover, the first and second uncertainties come from a_2 and $F_i^{V,A}$, respectively, and the third one for f_{Ω_b} is from the measurement.

TABLE I. The $\Omega_b \to \Omega$ transition form factors with $(F(0), a, b)$ in Eq. (18), where $m_F = 6.05$ GeV is from m_{Ω_b}. The uncertainties come from m_b and $\beta_{b[ss]}$ in Eq. (17).

	$F(0)$	a	b
F_1^V	$0.371^{+0.045}_{-0.042}$	-2.22	2.37
F_2^V	$-0.104^{+0.022}_{-0.025}$	-3.19	4.69
F_3^V	$0.040^{+0.042}_{-0.035}$	4.11	11.38
F_4^V	$0.692^{+0.054}_{-0.051}$	-2.05	1.91

	$F(0)$	a	b
F_1^A	$0.329^{+0.121}_{-0.110}$	-1.93	2.73
F_2^A	$-0.081^{+0.022}_{-0.020}$	-3.31	4.36
F_3^A	$-0.064^{+0.130}_{-0.140}$	-3.16	0.77
F_4^A	$-0.416^{+0.092}_{-0.082}$	-1.89	0.99

IV. DISCUSSIONS AND CONCLUSIONS

Because of the insufficient information on the $\Omega_b \to \mathbf{B}^*$ transition, the Ω_b decays have not been richly explored. In the light-front quark model, we calculate the $\Omega_b \to \Omega$ transition form factors. We can hence predict $\mathcal{B}(\Omega_b \to \Omega J/\Psi) = (5.3^{+3.3+3.8}_{-2.1-2.7}) \times 10^{-4}$, which is compatible with those of the antitriplet b-baryon decays $\mathcal{B}(\Lambda_b \to \Lambda J/\Psi) = (3.3 \pm 2.0) \times 10^{-4}$ and $\mathcal{B}(\Xi_b^- \to \Xi^- J/\Psi) = (5.1 \pm 3.2) \times 10^{-4}$ [2,3]. On the other hand, $\mathcal{B}(\Omega_b \to \Omega J/\Psi) = 8.1 \times 10^{-4}$ is given by the authors of Ref. [28]. In addition, the total decay width $\Gamma(\Omega_b \to \Omega J/\Psi) = 3.15 a_2^2 \times 10^{10}\ \text{s}^{-1}$ [29] leads to $\mathcal{B}(\Omega_b \to \Omega J/\Psi) = 16.7 \times 10^{-4}$, where we have used $a_2 = 0.18$ for the demonstration.

In the helicity basis, the branching fraction is given by

$$\mathcal{B} \propto (|\mathcal{H}_V|^2 + |\mathcal{H}_A|^2), \tag{20}$$

where $|\mathcal{H}_{V(A)}|^2 \equiv |H^{V(A)}_{\frac{3}{2}1}|^2 + |H^{V(A)}_{\frac{1}{2}1}|^2 + |H^{V(A)}_{\frac{1}{2}0}|^2$. It is found that $(|\mathcal{H}_V|^2, |\mathcal{H}_A|^2)$ give (19,81)% of $\mathcal{B}$; besides, $(|H^A_{\frac{3}{2}1}|^2, |H^A_{\frac{1}{2}1}|^2, |H^A_{\frac{1}{2}0}|^2)/|\mathcal{H}_A|^2 = (54.0, 22.4, 23.6)\%$, such that F^A_4 gives the main contribution to $\mathcal{B}(\Omega_b \to \Omega J/\Psi)$.

In Eq. (19), $f_{\Omega_b} = 0.54 \times 10^{-2}$ agrees with the previous upper limit of 0.108 [2]. By comparing our extraction to $f_{\Lambda_b} = 0.175 \pm 0.106$ and $f_{\Xi_b} = 0.019 \pm 0.013$ [2], it demonstrates that the b to Ω_b productions are much more difficult than the b to $\mathbf{B}_b$ ones. Since the fragmentation fraction has not been determined experimentally, the branching fractions of the Ω_b decays should be partially measured with the factor f_{Ω_b}. Therefore, our extraction for f_{Ω_b} can be useful. With f_{Ω_b} of Eq. (19) added to the branching fractions, one can compare his theoretical results to future measurements of the Ω_b decays.

In summary, we have investigated the charmful Ω_b decay channel $\Omega_b^- \to \Omega^- J/\Psi$. In the light-front quark model, we have studied the $\Omega_b \to \Omega$ transition form factors (F^V_i, F^A_i) $(i = 1, 2, \ldots, 4)$. We have hence predicted $\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi) = (5.3^{+3.3+3.8}_{-2.1-2.7}) \times 10^{-4}$, which is compatible with those of the $\Lambda_b \to \Lambda J/\Psi$ and $\Xi_b^- \to \Xi^- J/\Psi$ decays. In addition, F^A_4 has been found to give the main contribution. Particularly, we have extracted $f_{\Omega_b} = (0.54^{+0.34+0.39+0.21}_{-0.22-0.28-0.15}) \times 10^{-2}$ from the partial observation $f_{\Omega_b}\mathcal{B}(\Omega_b^- \to \Omega^- J/\Psi) = (2.9^{+1.1}_{-0.8}) \times 10^{-6}$. Since f_{Ω_b} has not been determined experimentally, by adding f_{Ω_b} to the branching fractions, one is allowed to compare his calculations to future observations of the Ω_b decays.

ACKNOWLEDGMENTS

Y. K. H. was supported in part by National Science Foundation of China (Grants No. 11675030 and No. 12175128). C. C. L. was supported in part by CTUST (Grant No. CTU109-P-108).

[1] P. A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020).
[2] Y. K. Hsiao, P. Y. Lin, L. W. Luo, and C. Q. Geng, Phys. Lett. B **751**, 127 (2015).
[3] Y. K. Hsiao, P. Y. Lin, C. C. Lih, and C. Q. Geng, Phys. Rev. D **92**, 114013 (2015).
[4] H. Y. Jiang and F. S. Yu, Eur. Phys. J. C **78**, 224 (2018).
[5] Y. K. Hsiao, L. Yang, C. C. Lih, and S. Y. Tsai, Eur. Phys. J. C **80**, 1066 (2020).
[6] Z. X. Zhao, Chin. Phys. C **42**, 093101 (2018).
[7] H. J. Melosh, Phys. Rev. D **9**, 1095 (1974).
[8] P. L. Chung, F. Coester, and W. N. Polyzou, Phys. Lett. B **205**, 545 (1988).
[9] H. G. Dosch, M. Jamin, and B. Stech, Z. Phys. C **42**, 167 (1989).
[10] W. Jaus, Phys. Rev. D **44**, 2851 (1991).
[11] F. Schlumpf, Phys. Rev. D **47**, 4114 (1993); **49**, 6246(E) (1994).
[12] C. Q. Geng, C. C. Lih, and W. M. Zhang, Mod. Phys. Lett. A **15**, 2087 (2000).
[13] C. R. Ji and C. Mitchell, Phys. Rev. D **62**, 085020 (2000).
[14] B. L. G. Bakker and C. R. Ji, Phys. Rev. D **65**, 073002 (2002).
[15] B. L. G. Bakker, H. M. Choi, and C. R. Ji, Phys. Rev. D **67**, 113007 (2003).
[16] H. Y. Cheng, C. K. Chua, and C. W. Hwang, Phys. Rev. D **69**, 074025 (2004).
[17] H. M. Choi and C. R. Ji, Few-Body Syst. **55**, 435 (2014).
[18] C. Q. Geng and C. C. Lih, Eur. Phys. J. C **73**, 2505 (2013).
[19] H. W. Ke, X. H. Yuan, X. Q. Li, Z. T. Wei, and Y. X. Zhang, Phys. Rev. D **86**, 114005 (2012).
[20] H. W. Ke, N. Hao, and X. Q. Li, J. Phys. G **46**, 115003 (2019).
[21] Z. X. Zhao, Eur. Phys. J. C **78**, 756 (2018).
[22] X. H. Hu, R. H. Li, and Z. P. Xing, Eur. Phys. J. C **80**, 320 (2020).
[23] H. W. Ke, N. Hao, and X. Q. Li, Eur. Phys. J. C **79**, 540 (2019).
[24] Y. K. Hsiao, S. Y. Tsai, C. C. Lih, and E. Rodrigues, J. High Energy Phys. 04 (2020) 035.
[25] A. Ali, G. Kramer, and C. D. Lu, Phys. Rev. D **58**, 094009 (1998).
[26] Y. K. Hsiao and C. Q. Geng, Phys. Rev. D **91**, 116007 (2015).
[27] D. Bečirević, G. Duplančić, B. Klajn, B. Melić, and F. Sanfilippo, Nucl. Phys. **B883**, 306 (2014).
[28] T. Gutsche, M. A. Ivanov, J. G. Korner, and V. E. Lyubovitskij, Phys. Rev. D **98**, 074011 (2018).
[29] H. Y. Cheng, Phys. Rev. D **56**, 2799 (1997).