Angular distributions in three-body baryonic B decays

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We study the angular distributions of the baryon-antibaryon low-mass enhancements in the three-body baryonic B decays of $B \to p\bar{p}M$ ($M = K$ and π) in the framework of the perturbative QCD. By writing the most general forms for the transition form factors of $B \to p\bar{p}$, we find that the angular distribution asymmetry in $B^- \to p\bar{p}K^-$ measured by Belle Collaboration can be explained. We give a quantitative description on the Dalitz plot asymmetry in $B^- \to p\bar{p}K^-$ shown by *BABAR* Collaboration and demonstrate that it is equivalent to the angular asymmetry. In addition, we present our results on $\bar{B}^0 \to p\bar{p}K_S$ and $B^- \to p\bar{p}\pi^-$ and we obtain that their angular asymmetries are -0.35 ± 0.11 and 0.45 ± 0.10, respectively, which can be tested by the ongoing experiments at the B factories.

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The three-body baryonic B decays of $B \to p\bar{p}M(M = K^{(*)}, \pi)$ with a near threshold enhancement in the $p\bar{p}$ invariant mass spectrum have been observed by Belle [1,2] and *BABAR* [3] Collaborations. In fact, the dibaryon threshold enhancement has been also observed in other decays, such as the charmless modes $\bar{B}^0 \to \Lambda\bar{p}\pi^+$, $B^- \to \Lambda\bar{p}\gamma$, and $B^- \to \Lambda\bar{\Lambda}K^-$ [4,5] and the charmful ones $\bar{B}^0 \to p\bar{p}D^{(*)0}$, $\bar{B}^0 \to n\bar{p}D^{*+}$, and $B^- \to \Lambda_c^+\bar{p}\pi^-$ [6] as well as the J/Ψ decays $J/\Psi \to p\bar{p}\gamma$ and $J/\Psi \to \bar{\Lambda}pK^-$ [7]. Theoretically, the dibaryon threshold enhancements in the three-body baryonic B decays were first conjectured in Ref. [8]. Subsequently, various interpretations, including models with a baryon-antibaryon bound state or baryonium [9], exotic glueball states [10,11], fragmentation [11], and final state interactions [12] have been proposed. Furthermore, the enhancements in $B \to \mathbf{B}\bar{\mathbf{B}}'M$ ($\mathbf{B}, \mathbf{B}' = p, \Lambda$ and $M = D, K, \pi, \gamma$) have been successfully understood [13–17] within the framework of the perturbative QCD (PQCD) based on the QCD counting rules [18,19] due to the power expanded baryonic form factors. On the other hand, the threshold enhancements in the J/Ψ decays are still in favor of some bound states [7].

To find out the origin of the threshold enhancements and distinguish among the above theoretical models, various experimental studies have been performed [20]. Belle Collaboration has studied the angular distribution asymmetry [2] in the helicity frame for the decays of $B^- \to p\bar{p}K^-$, $\bar{B}^0 \to p\bar{p}K_S$, and $\bar{B}^0 \to \Lambda\bar{p}\pi^+$, while *BABAR* Collaboration has measured the Dalitz plot asymmetry [3] in the decay of $B^- \to p\bar{p}K^-$, which is sensitive to the physical nature at the threshold as well as the decay mechanism. In particular, both data support the quark fragmentation mechanism but disfavor the gluonic picture. So far, there is no consistent understanding of the two asymmetries and thus one cannot directly compare the data between the two collaborations.

The angular distribution in $\bar{B}^0 \to \Lambda\bar{p}\pi^+$ has been examined in Refs. [14,21] based on the QCD counting rules and the result is consistent with the data [2]. However, such an approach faces a difficulty [21,22] to understand the shapes for the modes of $B \to p\bar{p}K$ [2] due to the lack of understanding of the baryonic transition form factors in $B \to p\bar{p}$. Moreover, quantitative descriptions of the Dalitz plot asymmetries are not yet available besides qualitative quark fragmentation mechanism [11].

In this paper, we will concentrate on the three-body charmless baryonic decays of $B \to p\bar{p}M(M = K, \pi)$. We will first write down the most general form of the $B \to \mathbf{B}\bar{\mathbf{B}}'$ transition matrix element and then fix the unknown form factors by the experimental data. In our study, we will use the QCD counting rules as well as the $SU(3)$ flavor symmetry to get and relate the behaviors of the form factors. We will demonstrate that when these form factors are constructed, the data of the angular distribution [2] and Dalitz plot [3] asymmetries in $B^- \to p\bar{p}K^-$ can be understood. We will show that the two asymmetries are equivalent by describing the same physics. Furthermore, we will extend our investigation to the decays of $\bar{B}^0 \to p\bar{p}K_S$ and $B^- \to p\bar{p}\pi^-$.

From the effective Hamiltonian at quark level [23], the decay amplitude of $B^- \to p\bar{p}K^-$ is separated into two parts, given by

$$\begin{aligned}
\mathcal{A}(B^- \to p\bar{p}K^-) &= \mathcal{C}(B^- \to p\bar{p}K^-) + \mathcal{T}(B^- \to p\bar{p}K^-),\\
\mathcal{C}(B^- \to p\bar{p}K^-) &= \frac{G_F}{\sqrt{2}}\bigg\{V_{ub}V_{us}^* a_2\langle p\bar{p}|(\bar{u}u)_{V-A}|0\rangle - V_{tb}V_{ts}^*\bigg[a_3\langle p\bar{p}|(\bar{u}u+\bar{d}d)_{V-A}|0\rangle + a_5\langle p\bar{p}|(\bar{u}u+\bar{d}d)_{V+A}|0\rangle\\
&\quad + \frac{a_9}{2}\langle p\bar{p}|(2\bar{u}u-\bar{d}d)_{V-A}|0\rangle\bigg]\bigg\}\langle K^-|(\bar{s}b)_{V-A}|B^-\rangle,\\
\mathcal{T}(B^- \to p\bar{p}K^-) &= \frac{G_F}{\sqrt{2}}\{(V_{ub}V_{us}^* a_1 - V_{tb}V_{ts}^* a_4)\langle K^-|(\bar{s}u)_{V-A}|0\rangle\langle p\bar{p}|(\bar{u}b)_{V-A}|B^-\rangle\\
&\quad + V_{tb}V_{ts}^* 2a_6\langle K^-|(\bar{s}u)_{S+P}|0\rangle\langle p\bar{p}|(\bar{u}b)_{S-P}|B^-\rangle\},
\end{aligned} \tag{1}$$

where G_F is the Fermi constant, $V_{q_iq_j}$ are the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements, $(\bar{q}_iq_j)_{V-A} = \bar{q}_i\gamma_\mu(1-\gamma_5)q_j$, $(\bar{q}_iq_j)_{S\pm P} = \bar{q}_i(1\pm\gamma_5)q_j$, and $a_i = c_i^{\rm eff} + c_{i\pm1}^{\rm eff}/N_c$ for $i =$ odd (even) in terms of the effective Wilson coefficients $c_i^{\rm eff}$, defined in Refs. [23,24], and the color number N_c. In Eq. (1), we have assumed the factorization approximation. As seen in Eq. (1), the current part of the amplitude involves timelike baryonic form factors from $\langle p\bar{p}|(\bar{q}q)_{V,A}|0\rangle$ and $B\to K$ transition form factors, which can be referred to in Refs. [17,25], respectively. On the other hand, for the transition part of the amplitude, we need to evaluate the transition matrix elements of $B\to p\bar{p}$. Based on Lorentz invariance, the most general forms for the $B\to\mathbf{B}\bar{\mathbf{B}}'$ transition matrix elements due to scalar, pseudoscalar, vector, and axial-vector currents are given by

$$\begin{aligned}
\langle\mathbf{B}\bar{\mathbf{B}}'|S^b|B\rangle &= i\bar{u}(p_{\mathbf{B}})[f_A\not{p} + f_P]\gamma_5 v(p_{\bar{\mathbf{B}}'}),\\
\langle\mathbf{B}\bar{\mathbf{B}}'|P^b|B\rangle &= i\bar{u}(p_{\mathbf{B}})[f_V\not{p} + f_S]v(p_{\bar{\mathbf{B}}'}),\\
\langle\mathbf{B}\bar{\mathbf{B}}'|V_\mu^b|B\rangle &= i\bar{u}(p_{\mathbf{B}})[g_1\gamma_\mu + g_2 i\sigma_{\mu\nu}p^\nu + g_3 p_\mu\\
&\quad + g_4(p_{\bar{\mathbf{B}}'}+p_{\mathbf{B}})_\mu + g_5(p_{\bar{\mathbf{B}}'}-p_{\mathbf{B}})_\mu]\\
&\quad \times\gamma_5 v(p_{\bar{\mathbf{B}}'}),\\
\langle\mathbf{B}\bar{\mathbf{B}}'|A_\mu^b|B\rangle &= i\bar{u}(p_{\mathbf{B}})[f_1\gamma_\mu + f_2 i\sigma_{\mu\nu}p^\nu + f_3 p_\mu\\
&\quad + f_4(p_{\bar{\mathbf{B}}'}+p_{\mathbf{B}})_\mu + f_5(p_{\bar{\mathbf{B}}'}-p_{\mathbf{B}})_\mu]v(p_{\bar{\mathbf{B}}'}),
\end{aligned} \tag{2}$$

respectively, where $S^b = \bar{q}b$, $P^b = \bar{q}\gamma_5 b$, $V_\mu^b = \bar{q}\gamma_\mu b$, and $A_\mu^b = \bar{q}\gamma_\mu\gamma_5 b$ with $q = u, d$, and s, $p = p_B - p_{\mathbf{B}} - p_{\bar{\mathbf{B}}'}$ is the emitted four-momentum, and g_i and f_i are the form factors to be determined. Here the parity conservation in strong interactions is used. We note that the forms for the scalar and pseudoscalar currents in Eq. (2) have been studied (e.g., see Ref. [13]), but those involving the vector and axial-vector currents in Eq. (2) have not been given in the literature previously.

At the scale of $m_b \simeq 4$ GeV, the $t \equiv (p_{\mathbf{B}} + p_{\bar{\mathbf{B}}'})^2$ dependences of the form factors in Eq. (2) can be parametrized according to the power counting rules of the PQCD [26,27] based on the hard gluons needed in the process. For example, in the transition of $B\to\mathbf{B}\bar{\mathbf{B}}'$, three hard gluons are needed to produce $\mathbf{B}\bar{\mathbf{B}}'$, in which two of them create the valence quark pairs and the third one is responsible for kicking the spectator quark in B [21]. Since each of the gluons has a propagator $\sim 1/q^2$ with q^2 proportional to the momentum of the $\mathbf{B}\bar{\mathbf{B}}'$ pair, all of the form factors f_i and g_i have to fall off as $1/t^3$, in which the propagator can be realized to contain a zero-mass pole inducing threshold enhancement [8]. Explicitly, we have

$$g_i = \frac{C_{g_i}}{t^3}, \qquad f_i = \frac{C_{f_i}}{t^3}, \tag{3}$$

where C_{g_i} and C_{f_i} are new sets of form factors to be determined.

From an equation of motion, we can relate the form factors in Eq. (2) and we obtain

$$\begin{aligned}
m_b f_A &= g_1, \qquad m_b f_P = m_B[g_4 E_M + g_5(E_{\bar{\mathbf{B}}'} - E_{\mathbf{B}})],\\
m_b f_V &= f_1, \qquad m_b f_S = m_B[f_4 E_M + f_5(E_{\bar{\mathbf{B}}'} - E_{\mathbf{B}})],
\end{aligned} \tag{4}$$

where E_M, $E_{\bar{\mathbf{B}}'}$, and $E_{\mathbf{B}}$ are the energies of the M meson, $\bar{\mathbf{B}}'$ and $\mathbf{B}$, respectively. In Eq. (4), g_2 and f_2 disappear, while g_3 and f_3 are neglected since the corresponding terms are proportional to $m_{\mathbf{M}}^2$ which is small comparing to $m_B E_M$ and $m_B(E_{\bar{\mathbf{B}}'} - E_{\mathbf{B}})$. The form factors in Eq. (3) can be related by the spin $SU(2)$ and flavor $SU(3)$ symmetries. In Table I, we show the relations for the form factors in $\langle p\bar{p}|(\bar{u}b)_{V,A}|B^{-,0}\rangle$.

The decay width Γ of $B^-\to p\bar{p}K^-$ is given by [28]

$$\Gamma = \int_{-1}^{+1}\int_{4m_p^2}^{(m_B-m_K)^2}\frac{\beta_p\lambda_t^{1/2}}{(8\pi m_B)^3}|\bar{\mathcal{A}}|^2 dt\, d\cos\theta, \tag{5}$$

where $\beta_p = (1-4m_p^2/t)^{1/2}$, $\lambda_t = m_B^4 + m_K^4 + t^2 - 2m_K^2 t - 2m_B^2 t - 2m_K^2 m_B^2$, θ is the angle between the

TABLE I. Relations between the $B\to p\bar{p}$ transition form factors with $i = 2,\cdots,5$.

Form Factor	C_{g_1}	C_{f_1}	$C_{g_i} = -C_{g_i}$
$\langle p\bar{p}|(\bar{u}b)_{V,A}|B^-\rangle$	$\frac{5}{3}N_\parallel - \frac{1}{3}N_{\bar{\parallel}}$	$\frac{5}{3}M_\parallel + \frac{1}{3}M_{\bar{\parallel}}$	$\frac{4}{3}M_\parallel^i$
$\langle p\bar{p}|(\bar{d}b)_{V,A}|\bar{B}^0\rangle$	$\frac{1}{3}N_\parallel - \frac{2}{3}N_{\bar{\parallel}}$	$\frac{1}{3}M_\parallel + \frac{2}{3}M_{\bar{\parallel}}$	$-\frac{1}{3}M_\parallel^i$

three-momenta of the K meson and the proton in the dibaryon rest frame, and $|\bar{\mathcal{A}}|^2$ is the squared amplitude of Eq. (1) by summing over all spins. Note that $4m_B E_{p(\bar{p})} = m_B^2 + t - m_p^2 \pm \beta_p \lambda_t^{1/2} \cos\theta$. From Eq. (5), we can study the partial decay width $d\Gamma/d\cos\theta$ as a function of $\cos\theta$, i.e., the angular distribution. We may also define the angular asymmetry by

$$A_\theta \equiv \frac{\int_0^{+1} \frac{d\Gamma}{d\cos\theta} d\cos\theta - \int_{-1}^{0} \frac{d\Gamma}{d\cos\theta} d\cos\theta}{\int_0^{+1} \frac{d\Gamma}{d\cos\theta} d\cos\theta + \int_{-1}^{0} \frac{d\Gamma}{d\cos\theta} d\cos\theta}, \tag{6}$$

which is equal to $(N_+ - N_-)/(N_+ + N_-)$, where $N_\pm$ are the events with $\cos\theta > 0$ and $\cos\theta < 0$, respectively. The angular asymmetry in $B^- \to p\bar{p}K^-$ has been measured by Belle Collaboration [2] to be

$$A_\theta(B^- \to p\bar{p}K^-) = 0.59^{+0.08}_{-0.07}, \tag{7}$$

implying that the protons are emitted along the K^- direction most of the time [2] in the $p\bar{p}$ rest frame, which seems to be unexpected from the previous B studies in the PQCD picture [22].

In general, when a decay mode mixes with vector (axial-vector) and scalar (pseudoscalar) currents, it makes the partial decay width as a form of

$$\frac{d\Gamma}{d\cos\theta} = a\cos^2\theta + b\cos\theta + c. \tag{8}$$

For $\bar{B}^0 \to \Lambda\bar{p}\pi^+$, one gets that $c > -a > 0$ with $b \simeq 0$ [14]. Therefore, its angular distribution as a function of $\cos\theta$ is figured as a parabolic curve opening downward [21,22], which is consistent with the data [2]. On the other hand, the angular distribution of $B^- \to p\bar{p}K^-$ [2] is gradually bent up as $\cos\theta = -1$ shifts to $+1$ (see Fig 3a in Ref. [2]), leading to an asymmetric A_θ in Eq. (7), which is unexpected since the decay is dominated by $V \cdot V$ and $A \cdot A$ contributions [13,16]. Clearly, the data for $B^- \to p\bar{p}K^-$ indicates a non-neglected $\cos\theta$ term which is comparable with the $\cos^2\theta$ one in Eq. (8), i.e., $a \simeq b > 0$. To find out a large $\cos\theta$ term, it is important to note that the energy difference of the proton pair $E_{\bar{p}} - E_p$ is proportional to $\cos\theta$ and related to g_5 and f_5 as seen from Eq. (4), which could provide a new source of the angular dependence. We now summarize all possible $\cos\theta$ and $\cos^2\theta$ terms in $B^- \to p\bar{p}K^-$ as follows:

$$\begin{aligned} &V_1 \cdot V_5, V_4 \cdot V_5, A_1 \cdot A_4, A_4 \cdot A_5 \propto \cos\theta, \\ &V_{1(5)} \cdot V_{1(5)}, A_{1(5)} \cdot A_{1(5)}, A_1 \cdot A_5, \propto \cos^2\theta, \end{aligned} \tag{9}$$

where we have denoted the terms corresponding to g_i and f_i in Eq. (2) as V_i and A_i, respectively. The squared amplitude in Eq. (5) is reduced to be

$$\begin{aligned} |\bar{\mathcal{A}}|^2 &= \left(\frac{G_F}{\sqrt{2}} f_K m_B^3 \alpha_K\right)^2 (\rho_0 + \rho_\theta \cos\theta + \rho_{\theta^2}\cos^2\theta), \\ \rho_0 &= \frac{g_1^2}{2m_B^2}(1-\hat{t})^2 + 4\frac{g_1}{m_B} g_4 \hat{E}_K \hat{m}_p (1-\hat{t}) + 2g_4^2 \hat{E}_K^2 \hat{t} \\ &\quad + \left(\frac{\beta_K}{\alpha_K}\right)^2 \left[\frac{f_1^2}{2m_B^2}(1-\hat{t})^2 + 2\hat{E}_K^2 f_4^2 (\hat{t} - 4\hat{m}_p^2)\right], \\ \rho_\theta &= 2\beta_p \hat{\lambda}_t^{1/2} \left\{\frac{g_1 g_5}{m_B} \hat{m}_p (1-\hat{t}) + g_4 g_5 \hat{E}_K \hat{t} \right. \\ &\quad \left. + \left(\frac{\beta_K}{\alpha_K}\right)^2 \hat{E}_K \left[2\frac{f_1 f_4}{m_B} \hat{m}_p + f_4 f_5 (\hat{t} - 4\hat{m}_p^2)\right]\right\}, \\ \rho_{\theta^2} &= \frac{1}{2}\beta_p^2 \hat{\lambda}_t \left\{-\frac{g_1^2}{m_B^2} + g_5^2 \hat{t} + \left(\frac{\beta_K}{\alpha_K}\right)^2 \left[-\frac{f_1^2}{m_B^2} + 4\frac{f_1 f_5}{m_B}\hat{m}_p \right.\right. \\ &\quad \left.\left. + f_5^2(\hat{t} - 4\hat{m}_p^2)\right]\right\}, \end{aligned} \tag{10}$$

with $(\hat{t}, \hat{\lambda}_t^{1/2}) = (t, \lambda_t^{1/2})/m_B^2$, $(\hat{m}_p, \hat{E}_K) = (m_p, E_K)/m_B$, and

$$\alpha_K(\beta_K) = V_{ub}V_{us}^* a_1 - V_{tb}V_{ts}^* \left[a_4 \pm \frac{2a_6 m_K^2}{m_b(m_s + m_u)}\right]. \tag{11}$$

Here, to simplify our formula we have ignored the current contribution of $\mathcal{C}(B^- \to p\bar{p}K^-)$ in Eq. (1), estimated around 1% of the measured one by using the values of the timelike baryonic form factors in [17]. However, all terms are kept in our numerical calculation.

In our numerical analysis, we take the 10 data points of $d\,\mathrm{Br}/d\cos\theta$ in $B^- \to p\bar{p}K^-$ from Fig. 3a in Ref. [2] (see also Fig. 1) and measured decay branching ratios [2] of (5.74 ± 0.61) and $(1.20 \pm 0.35) \times 10^{-6}$ for $B^- \to p\bar{p}K^-$ and $\bar{B}^0 \to p\bar{p}K_S$, respectively, as input values, along with the CKM matrix elements referred to in Ref. [29], $(a_1, a_4, a_6) = (1.05, -0.0441 - 0.0072i, -0.0609 - 0.0072i)$ [23], $m_u(m_b) = 3.2$ MeV, $m_s(m_b) = 90$ MeV [23], and $m_b(m_b) = 4.19 \pm 0.05$ GeV [30]. We note that the ratio of $(\beta_K/\alpha_K)^2$ is around 15% which suppresses $f_{V,S}$ (or $f_{1,4,5}$) terms in Eqs. (2) and (4). Although there is no surprise that $V_1 \cdot V_1$ and $A_1 \cdot A_1$ create $\cos^2\theta$ with an expected minus sign, the dominant contribution arises from the g_5^2 term with t around 4–25 GeV^2 and as a

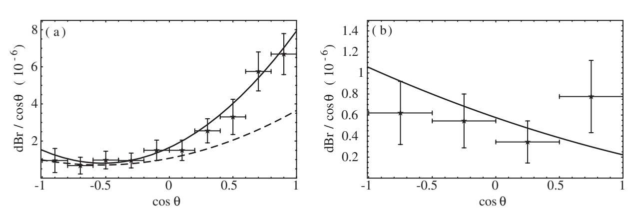

FIG. 1. Branching fraction vs $\cos\theta$ in the $p\bar{p}$ rest frame for (a) $B^- \to p\bar{p}K^-(\pi^-)$ with solid (dashed) curve and (b) $\bar{B}^0 \to p\bar{p}K_S$, where the data points (stars) in (a) and (b) are from Ref. [2].

consequence, ρ_θ and ρ_{θ^2} can be both positive with the same size and the condition of $a \simeq b > 0$ is fulfilled. By performing the fitting, $N_{\parallel,\bar{\parallel}}$ and $M_{\parallel}^{4,5}$ in Table I are determined to be

$$\begin{aligned} N_{\parallel} &= 127.1 \pm 26.6 \text{ GeV}^5, \\ N_{\bar{\parallel}} &= -200.9 \pm 51.9 \text{ GeV}^5, \\ M_{\parallel}^4 &= -25.0 \pm 15.4 \text{ GeV}^4, \\ M_{\parallel}^5 &= 227.3 \pm 22.0 \text{ GeV}^4. \end{aligned} \tag{12}$$

As seen in Fig. 1(a), our result (solid curve) for $d\,\mathrm{Br}(B^- \to p\bar{p}K^-)/d\cos\theta$ as a function of $\cos\theta$ explains the data [2] well and it is in agreement with the Belle data of A_θ in Eq. (7). For $\bar{B}^0 \to p\bar{p}K_S$, the angular distribution is shown in Fig. 1(b), which is also consistent with the data except the one point close to $\cos\theta = 0.8$. Clearly, more data at the ongoing B factories are needed. In addition, we predict

$$\begin{aligned} A_\theta(B^- \to p\bar{p}\pi^-) &= 0.45 \pm 0.11, \\ A_\theta(\bar{B}^0 \to p\bar{p}K_S) &= -0.35 \pm 0.10. \end{aligned} \tag{13}$$

The result in Eq. (13) for $A_\theta(B^- \to p\bar{p}\pi^-)$ is anticipated since the decay is similar to $B^- \to p\bar{p}K^-$ although it is dominated by the tree diagram. It is interesting to point out that the minus sign for $A_\theta(\bar{B}^0 \to p\bar{p}K_S)$ in Eq. (13) is different from the expectation of the fragmentation mechanism [11]. We note that from our fitted form factors we obtain

$$\mathrm{Br}\,(B^- \to p\bar{p}\pi^-) = (3.0 \pm 0.4) \times 10^{-6}, \tag{14}$$

which supports the Belle measurement of $(3.06^{+0.73}_{-0.62} \pm 0.37) \times 10^{-6}$ [1], but is higher than the *BABAR* data of $(1.24 \pm 0.32 \pm 0.10) \times 10^{-6}$ [20]. We look forward to having the future experiments at Belle and *BABAR* to check our predictions in Eqs. (13) and (14).

It is known that the asymmetric Dalitz plot for $B^- \to p\bar{p}K^-$ reported by *BABAR* Collaboration [3,20] supports the fragmentation mechanism [11] but disfavors the gluonic resonance state [10,11] as well as another intermediate state in the pole model [31]. We now examine if we can give a quantitative description on the Dalitz plot in the PQCD approach. To do this, we define the Dalitz plot asymmetry for $B \to \mathbf{B}\bar{\mathbf{B}}'M$ as

$$A_{\mathrm{DP}} = \frac{\Gamma(m_{\bar{\mathbf{B}}'\mathbf{M}})_> - \Gamma(m_{\mathbf{BM}})_>}{\Gamma(m_{\bar{\mathbf{B}}'\mathbf{M}})_> + \Gamma(m_{\mathbf{BM}})_>}, \tag{15}$$

where $\Gamma(m_{\mathbf{BM}})_>$ $[\Gamma(m_{\bar{\mathbf{B}}'\mathbf{M}})_>]$ denotes the decay width for

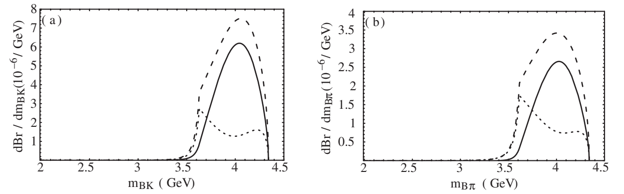

FIG. 2. Branching fraction of $\mathrm{Br}(B^- \to p\bar{p}M^-)/dm_{\mathbf{B}M}$ with (a) $M = K$ and (b) $M = \pi$ as functions of $m_{\mathbf{B}M}$ ($\mathbf{B} = \bar{p}, p$) with the dashed, dotted, and solid curves representing (i) $m_{\bar{p}M^-} > m_{pM^-}$, (ii) $m_{\bar{p}M^-} < m_{pM^-}$, and (iii) difference between (i) and (ii), respectively.

the range of $m_{\mathbf{BM}} > m_{\bar{\mathbf{B}}'\mathbf{M}}$ $(m_{\bar{\mathbf{B}}'\mathbf{M}} > m_{\mathbf{BM}})$ divided by the line of $m_{\mathbf{BM}} = m_{\bar{\mathbf{B}}'\mathbf{M}}$ in the Dalitz plot. It is easy to see that for $B^- \to p\bar{p}K^-$, i.e., $\mathbf{B} = \mathbf{B}'$, the Dalitz plot asymmetry is identical to the angular asymmetry in Eq. (6) due to the fact that these two asymmetries arise from the same source of ρ_θ in Eq. (10) with the relations of $\cos\theta = \beta_p^{-1}\lambda^{-1/2}(m^2_{\bar{p}K^-} - m^2_{pK^-})$ and $t = m_B^2 + 2m_p^2 + m_K^2 - (m^2_{\bar{p}K^-} + m^2_{pK^-})$. Explicitly, in Fig. 2(a), we show the decay branching fraction of $B^- \to p\bar{p}K^-$ as functions of $m_{\bar{p}K^-,pK^-}$ with the dashed, dotted, and solid curves representing (i) $m_{\bar{p}K^-} > m_{pK^-}$, (ii) $m_{\bar{p}K^-} < m_{pK^-}$, and (iii) difference between (i) and (ii), respectively. It is interesting to note that, as seen from the figure, the Dalitz plot asymmetry peaked around 4 GeV is exactly the same as the data in Ref. [3]. However, our prediction for $B^- \to p\bar{p}\pi^-$ shown in Fig. 2(b) is different from the *BABAR* unpublished result in [20] like the decay branching fraction. Clearly, more precise data for the Dalitz plot distribution on the π mode are needed.

Finally, we remark that the form factors in Eq. (2) determined by the angular distribution in $B^- \to p\bar{p}K^-$ can be used to examine other experimental measured three-body baryonic B decays with a vector meson in the final state, such as $B \to p\bar{p}K^*$ and $B^- \to \Lambda\bar{p}J/\Psi$ [1,6], which have not been theoretically explored yet. Furthermore, direct CP violation in $B^- \to p\bar{p}K^{(*)-}$ can be also investigated. Moreover, our study on the angular distribution can be extended to the above modes as well as the decay of $B^- \to \Lambda\bar{p}\gamma$, which has only been discussed in the pole model [32].

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