Determining weak phases using $B \to D^*V$ Decays

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We describe how the angular analysis of vector-vector final states in $B$ decays provides theoretically clean techniques for determination of CP violating phases. The quantity $\sin^2(2\beta + \gamma)$ can be cleanly obtained from the time dependent study of decays such as $B^0_d(t) \to D^{*+}\rho^-$, $D^{*+}a_1^-$ etc. Similarly, one can use $B^0_s(t) \to D^{*+}\pi^0$ to extract $\sin^2 \gamma$. A time independent study of the charged decay modes $B^+ \to D^0 K^{\pm}$ can also be used to extract $\gamma$.

1 Why look at VV modes for determining CPV Phases?

A precise determination of all CP violating angles \cite{11} is one of the major goals of the current and future B Physics experiments. The measured values of these angles may be consistent with the standard model (SM) predictions, or they may indicate the presence of physics beyond the standard model. Early indications are that new physics, if present, is likely to have rather small effects on the angles of the unitarity triangle. Hence, to uncover any new physics, it is extremely important that all the CP violating angles be determined without theoretical uncertainties.

In the early days of the field, it was thought that the CP angles could be easily measured in $B^0_d(t) \to \pi^+\pi^-$ ($\alpha$), $B^0_s(t) \to \Psi K_s(\beta)$, and $B^0_s(t) \to \rho K_s(\gamma)$. However, it soon became clear that things would not be so easy: the presence of penguin amplitudes \cite{2} makes the extraction of $\alpha$ from $B^0_d(t) \to \pi^+\pi^-$ quite difficult, and completely spoil the measurement of $\gamma$ in $B^0_d(t) \to \rho K_s$. In fact, determining $\gamma$ through techniques which are theoretically clean as well as experimentally feasible has been a challenge.

The problem of penguin pollution can be avoided by considering decay modes that involve only tree amplitudes. In this talk we first indicate the practical problems encountered by most of the clean methods to determine $\gamma$, using pseudoscalar-pseudoscalar (PP) and pseudoscalar-vector (PV) final states and involving only tree amplitudes. We next demonstrate, how the use of the corresponding vector-vector (VV) final state modes, resolves these problems. The rich kinematics of the VV modes accessible via an angular analysis, provides a large number of observables which allows clean extraction of CP phases.

As a first example, we consider the PP or PV final states, $f \equiv D^-\pi^+(D^-\pi^0)$. Both $B^0$ and $B^0$ can decay to these final states and only one weak amplitude contributes. Hence, the amplitudes for these decay modes may be written as,

\begin{align}
A &\equiv Amp(B^0 \to f) = ae^{i\phi_a}e^{ib} \\
A' &\equiv Amp(B^0 \to f) = be^{i\phi_b}e^{ib}
\end{align}

where, $\phi_a = 0$ and $\phi_b = -\gamma$. Because of $B^0$-$\bar{B^0}$ mixing, CP violation comes about due to an interference between the amplitudes $B^0 \to f$ and $\bar{B^0} \to \bar{f}$. Note that since both $B^0$ and $\bar{B^0}$ can also decay to $\bar{f}$, one can measure the four time dependent decay rates, $\Gamma(B^0_d(t) \to f)$, $\Gamma(\bar{B^0}_d(t) \to \bar{f})$, $\Gamma(B^0_s(t) \to f)$, and $\Gamma(\bar{B^0}_s(t) \to \bar{f})$. It is therefore possible to determine the weak phase $\phi = (2\beta + \gamma)$ \cite{3 4}. However, the decay amplitude, $b << a$ and hence, the decay rate for $\Gamma(\bar{B^0}_d \to D^-\pi^0)$ is expected to be small. The ratio, $\Gamma(B^0_d \to D^-\pi^+) / \Gamma(\bar{B^0}_d \to D^-\pi^0)$, is essentially $|V_{td}V_{cd}^* / V_{ub}V_{cb}^*|^2 \approx 4 \times 10^{-4}$. Obviously, it will be very difficult to measure this tiny quantity with any precision, and therefore it would not be viable to carry out this method in practice. On the other hand, we will demonstrate that with the corresponding VV final states ($D^{*-}\rho^-$), one can extract $\sin^2(2\beta + \gamma)$ using an angular analysis, without the knowledge of the smaller amplitude $A$.

The second example that we examine, is that of direct CP violation, in the modes: $B^+ \to \bar{D}^0 K^+$, $B^+ \to \bar{D}^0 \pi^+$. In this method \cite{5}, $\gamma$ is obtained from an interference of the mode $B \to D^0 K$ with $B \to D^0 \pi$, which occurs if and only if, both $D^0$ and $\bar{D}^0$ decay to a common final state $f$; in particular, $f$ is taken to be a CP eigenstate. This technique of extracting $\gamma$ requires a measurement of the branching ratio for $B^+ \to D^0 \pi^+$ which is not experimentally feasible as pointed out in \cite{7}. Moreover, the CP violating asymmetries tend to be small as the interfering amplitudes are not comparable. The use of non-CP eigenstates ‘$f$’ has also been considered \cite{8} in literature. Atwood, Dunietz and Soni (ADS) \cite{7} extended this proposal by considering
‘f’ to be non–CP eigenstates that are also doubly Cabibbo suppressed modes of $D$. The two interfering amplitudes then are of the same magnitude resulting in large asymmetries. Their proposal is to use two final states $f_1$ and $f_2$ with at least one being a non–CP eigenstate. The use of more than one final state enables not only the determination of $\gamma$, but also of all the strong phases involved and the difficult to measure branching ratio $Br(B^+ \to D^0 K^+)$. However, an input into the determination of $\gamma$ is the branching ratio of the doubly Cabibbo suppressed mode of $D$. Here again, the VV final states, provide an alternative [9]. (Some other plausible methods have also been recently proposed [10].)

The VV modes $\bar{D}^o K^\pm, \bar{D}^o p^\pm$, enable extraction of $\gamma$ and all the unknowns involved, including the BR for Doubly Cabibbo-suppressed mode of $D$.

2 Vector-Vector final state decay amplitudes

The most general covariant amplitude for a $B$ meson decaying to a pair of vector mesons has the form [11]

$$ A(B(p) \to V_1(k, \epsilon_1) V_2(q, \epsilon_2)) = e^{i\epsilon_1^\mu} e^{i\epsilon_2^\nu} \times $$

$$ \left( a \, g_{\mu\nu} + \frac{b}{m_1 m_2} p_{\mu} p_{\nu} + i \frac{c}{m_1 m_2} \epsilon_{\mu\nu\rho\sigma} q^\rho q^\sigma \right), \tag{3} $$

where, $\epsilon_1, \epsilon_2$ and $m_1, m_2$ represent the polarization vectors and the masses of the vector mesons $V_1$ and $V_2$ respectively.

The coefficients $a, b,$ and $c$ can be expressed in terms of the linear polarization basis $A_0, A_\perp$ and $A_\parallel$ as follows:

$$ A_0 = -xa - (x^2 - 1)b, \quad A_\parallel = \sqrt{2}a, \quad A_\perp = \frac{1}{\sqrt{2}} (x^2 - 1)c, \tag{4} $$

where $x = k.q/(m_1 m_2)$. If both mesons subsequently decay into two $J^P = 0^-$ mesons, i.e. $V_1 \to P_1 P'_1$ and $V_2 \to P_2 P'_2$, the amplitude can be expressed as [9][12]

$$ A_{V1V2} \propto (A_0^\ast \cos \theta_1 \cos \theta_2 + \frac{A_\parallel}{\sqrt{2}} \sin \theta_1 \sin \theta_2 \cos \phi - \frac{A_\perp}{\sqrt{2}} \sin \theta_2 \sin \phi), \tag{5} $$

where $\theta_1(\theta_2)$ is the angle between the $P_1(P_2)$ three-momentum vector, $\vec{k}_1(\vec{k}_2)$ in the $V_1(V_2)$ rest frame and the direction of total $V_1(V_2)$ three-momentum vector defined in the $B$ rest frame. $\phi$ is the angle between the normals to the planes defined by $P_1 P'_1$ and $P_2 P'_2$, in the $B$ rest frame.

3 Time dependent analysis in $B \to VV$

We consider a final state $f$, consisting of two vector mesons, to which both $B^0$ and $\bar{B}^0$ can decay. If only one weak amplitude contributes to $B^0 \to f$ and $\bar{B}^0 \to f$, we can write the helicity amplitudes as follows:

$$ A_\lambda = Amp(B^0 \to f)_\lambda = a e^{i\phi_0} e^{i\phi_0}, \tag{6} $$

$$ A'_\lambda = Amp(\bar{B}^0 \to f)_\lambda = b e^{i\phi_0} e^{i\phi_0}, \tag{7} $$

$$ \bar{A}_\lambda = Amp(B^0 \to \bar{f})_\lambda = a e^{i\phi_0} e^{-i\phi_0}, \tag{8} $$

$$ \bar{A}'_\lambda = Amp(\bar{B}^0 \to \bar{f})_\lambda = b e^{i\phi_0} e^{-i\phi_0}, \tag{9} $$

where the helicity index $\lambda$ takes the values $\{0, \parallel, \perp\}$. In the above, $\phi_0$ and $\delta_0$ are the weak and strong phases, respectively. Using CPT invariance, the total decay amplitudes can be written as

$$ \mathcal{A} = Amp(B^0 \to f) = A_0 g_0 + A_\parallel g_\parallel + i A_\perp g_\perp, \tag{10} $$

$$ \mathcal{A}' = Amp(\bar{B}^0 \to f) = A_0 g_0 + A_\parallel g_\parallel - i A_\perp g_\perp, \tag{11} $$

$$ \mathcal{A}' = Amp(B^0 \to \bar{f}) = A_0 g_0 + A_\parallel g_\parallel + i A_\perp g_\perp, \tag{12} $$

$$ \mathcal{A}'' = Amp(\bar{B}^0 \to \bar{f}) = A_0 g_0 + A_\parallel g_\parallel - i A_\perp g_\perp, \tag{13} $$

where the $g_i$ are the coefficients of the helicity amplitudes, defined using Eq. (5) and depend only on the angles describing the kinematics. With the above equations, the time-dependent decay rate for a $B^0$ decaying into the two vector–meson final state, i.e. $B^0(t) \to f$, can be written as

$$ \Gamma(B^0(t) \to f) = e^{-\frac{t}{\tau}} \sum_{\lambda \in \{0, \parallel, \perp\}} \left( \Lambda_{\lambda \lambda} + \Sigma_{\lambda \lambda} \cos(\Delta M t) \right) g_{\lambda} \bar{g}_{\lambda}. \tag{14} $$

By performing a time-dependent study and angular analysis of the decay $B^0(t) \to f$, one can measure the 18 observables $\Lambda_{\lambda \lambda}, \Sigma_{\lambda \lambda}$ and $\rho_{\lambda \lambda}$. In terms of the helicity amplitudes $A_{0,\lambda \parallel, \lambda \perp}$, these can be expressed as:

$$ \Lambda_{\lambda \lambda} = \frac{|A_\parallel|^2 + |A'_\parallel|^2}{2}, \quad \Sigma_{\lambda \lambda} = \frac{|A_\parallel|^2 - |A'_\parallel|^2}{2}, \quad \rho_{\lambda \lambda} = -\frac{1}{p} A_\parallel A'_\parallel, \tag{15} $$

where $i = [0, \parallel, \perp]$. In the above, $q/p = \exp(-2i \phi_0)$, where $\phi_0$ is the weak phase present in $B^0-\bar{B}^0$ mixing.

Similarly, the decay rate for $\bar{B}^0(t) \to \bar{f}$ is given by

$$ \Gamma(\bar{B}^0(t) \to \bar{f}) = e^{-\frac{t}{\tau}} \sum_{\lambda \in \{0, \parallel, \perp\}} \left( \bar{\Lambda}_{\lambda \lambda} + \bar{\Sigma}_{\lambda \lambda} \cos(\Delta M t) \right) $$

$$ + \bar{\rho}_{\lambda \lambda} \sin(\Delta M t) g_{\lambda} \bar{g}_{\lambda}. \tag{16} $$

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The expressions for these another 18 observables, $\bar{\Lambda}_{\Delta t}$, $\bar{\Sigma}_{\Delta t}$ and $\bar{\rho}_{\Delta t}$ are similar to those given in Eq. (14), with the replacements $A_t \rightarrow \bar{A}_t$ and $A'_t \rightarrow \bar{A}_t$.

Angular analysis is more powerful than previously realized. Due to the interference between the different helicity states, there are enough independent measurement that one can obtain weak phase information as we now show. First, we note that

$$\Lambda_{\Delta t} = \bar{\Lambda}_{\Delta t} = \frac{(a_i^2 + b_i^2)}{2}, \quad \Sigma_{\Delta t} = -\bar{\Sigma}_{\Delta t} = \frac{(a_i^2 - b_i^2)}{2}. \quad (17)$$

Thus, one can determine the magnitudes of the amplitudes appearing in Eqs. (6)-(9), $a_i^2$ and $b_i^2$. However, it must be stressed that the knowledge of $b_i^2$ will not be necessary within our method.

Next, we have

$$\Lambda_{\Delta t} = -\bar{\Lambda}_{\Delta t} = b_i b_i \sin(\delta_\perp - \delta_i + \Delta t) - a_i a_i \sin(\Delta t),$$
$$\Sigma_{\Delta t} = -\bar{\Sigma}_{\Delta t} = -b_i b_i \sin(\delta_\perp - \delta_i + \Delta t) - a_i a_i \sin(\Delta t), \quad (18)$$

where $\Delta t \equiv \delta_i^\perp - \delta_i^\parallel$ and $\delta_i \equiv \delta_i^\parallel - \delta_i^\perp$. Using Eq. (18) one can solve for $a_i a_i \sin(\Delta t)$. We will see that this is the only combination needed to cleanly extract weak phase information.

The coefficients of the $\sin(\Delta t)\tan$ term, which can be obtained in a time-dependent study, can be written as

$$\rho_{\Delta t} = \pm a_i b_i \sin(\phi + \delta_i), \quad \bar{\rho}_{\Delta t} = \pm a_i b_i \sin(\phi - \delta_i), \quad (19)$$

where the sign on the right hand side is positive for $\lambda = ||0,0\rangle$, and negative for $\lambda = ||1,1\rangle$. In the above, we have defined the CP phase $\phi \equiv -2\phi_u + \phi_b - \phi_d$. These quantities can be used to determine

$$2b_i \sin \delta_i = \pm \rho_{\Delta t} \pm \bar{\rho}_{\Delta t}, \quad 2b_i \sin \delta_i = \pm \rho_{\Delta t} - \bar{\rho}_{\Delta t}. \quad (20)$$

Similarly, the terms involving interference of different helicities are given as

$$\rho_{\Delta t} = -a_i b_i \cos(\phi - \delta_i - \Delta t) - a_i b_i \cos(\phi - \delta_i - \Delta t),$$
$$\bar{\rho}_{\Delta t} = -a_i b_i \cos(\phi + \delta_i + \Delta t) + a_i b_i \cos(\phi - \delta_i - \Delta t). \quad (21)$$

Putting all the above information together, we are now in a position to extract the weak phase $\phi$. Using Eq. (20), the expressions in Eq. (21) can be used to yield

$$\rho_{\Delta t} + \bar{\rho}_{\Delta t} = -\cot \phi \, a_i a_i \cos \Delta t \left[ \frac{\rho_i^0 + \bar{\rho}_i^0}{a_i^2} - \frac{\rho_{\Delta t} + \bar{\rho}_{\Delta t}}{a_i^2} \right],$$
$$-a_i a_i \sin \Delta t \left[ \frac{\rho_i^0 - \bar{\rho}_i^0}{a_i^2} + \frac{\rho_{\Delta t} - \bar{\rho}_{\Delta t}}{a_i^2} \right], \quad (22)$$

$$\rho_{\Delta t} - \bar{\rho}_{\Delta t} = \tan \phi \, a_i a_i \cos \Delta t \left[ \frac{\rho_i^0 + \bar{\rho}_i^0}{a_i^2} - \frac{\rho_{\Delta t} + \bar{\rho}_{\Delta t}}{a_i^2} \right],$$
$$-a_i a_i \sin \Delta t \left[ \frac{\rho_i^0 + \bar{\rho}_i^0}{a_i^2} + \frac{\rho_{\Delta t} - \bar{\rho}_{\Delta t}}{a_i^2} \right]. \quad (23)$$

In the above two equations: (i) $\rho_{\Delta t}$ and $\bar{\rho}_{\Delta t}$ are measured quantities; (ii) the $a_i^2$ are determined from the relations in Eq. (17), and (iii) $a_i a_i \cos \Delta t$ is obtained from Eq. (13). Thus, the above two equations involve only two unknown quantities, tan $\phi$ and $a_i a_i \cos \Delta t$, which can easily be solved for (up to a sign ambiguity in each of these quantities). Hence, tan $^2 \phi$ (or, equivalently, $\sin^2 \phi$) can be obtained from the angular analysis.

Note that this method relies on the measurement of the interference terms between different helicities. However, we do not actually require that all three helicity components of the amplitude be used. In fact, one can use observables involving any two of largest helicity amplitudes. In the above description, one could have chosen ‘$||0\rangle$’ instead of ‘$||1,1\rangle$’ or ‘$||0\rangle$’.

We now turn to specific applications of this method. Consider first the final states where $f = \pm \bar{f}$. In this case, the parameters of Eqs. (6)-(9) satisfy $a_i = b_i$, $\delta_i^0 = \delta_i^\perp$ (which implies that $\delta_i = 0$, and $\phi_i = -\phi_i$ (so that $\phi = -2\phi_u + 2\phi_b$). As described above, $a_i^2$ can be obtained from Eq. (17). But now the measurement of $\rho_{\Delta t}$ [Eq. (19)] directly yields sin $\phi$. In fact, this is the conventional way of using the angular analysis to measure the weak phases: each helicity state separately gives clean CP-phase information. Thus, for such states, nothing is gained by including the interference terms.

In order to have final states with only one weak amplitude, we consider states that do not receive penguin contributions. The only such Cabibbo-allowed quark-level decays are $\bar{b} \rightarrow \bar{c}u\bar{d}$, $\bar{u}c\bar{d}$. The meson level examples of these are $B_0^+ / B_d^0 \rightarrow D^{-*} \rho^*$, $D^{*-} \rho$. These are the VV counterparts of the PP/PV modes described in first example of section 1.

As we have already emphasized in the discussion following Eq. (17), none of the observables or combinations required for the analysis to extract sin $^2(2\beta + \gamma)$ are proportional to $b_i^2$. Thus, we avoid the practical problems present in Dunietz’s method [13].

The two decay amplitudes for the final states $D^{*-} \rho^*$ have very different sizes, i.e. $b_i \ll a_i$. This results in a very small CP-violating asymmetry whose size is approximately $|V_{ub}V_{cb}^{\ast}| / V_{ub}V_{ud}^{\ast} \approx 2\%$. Thankfully, the situation is alleviated by the large branching ratio for the decay $B_d^0 \rightarrow D^{*-} \rho^*$, roughly 1%.

The Cabibbo-suppressed quark-level decays which do not receive penguin contributions are $\bar{b} \rightarrow \bar{c}u\bar{s}$, $\bar{u}c\bar{s}$, at meson level these would correspond to $B_d^0 \rightarrow D^{0*} K^{0\ast}$, $D^{0} K^{0\ast}$ and $\bar{B}_d^0 \rightarrow D^{0*} \bar{K}^{0\ast}$, $D^{0} \bar{K}^{0\ast}$, with $K^{0\ast}$ and $\bar{K}^{0\ast}$ decaying to $K \pi^0$. However, in these modes one has the old problem of tagging the neutral $D^*$s [7].

One can also consider $B^0_d$ and $\bar{B}_d^0$ decays, corresponding to the quark-level decays $\bar{b} \rightarrow \bar{c}u\bar{d}$, $\bar{u}c\bar{d}$, or $\bar{b} \rightarrow \bar{c}u\bar{s}$, $\bar{u}c\bar{s}$. The most promising processes are the Cabibbo-suppressed
decay modes \( B^+_s/\bar{B}^-_s \rightarrow D^{\pm}_sK^{\mp} \). Here the \( B^0_s - \bar{B}^0_s \) mixing phase is almost 0, so that the quantity \( \sin^2 \gamma \) can be extracted from the angular analysis of \( B^0_s(t) \rightarrow D^{\pm}_sK^{\mp} \). Other methods for obtaining the CP phase \( \gamma \) using similar final states have also been studied [14].

4 Direct Asymmetry in \( B \rightarrow VV \)

It is also possible to cleanly extract the weak phase \( \gamma \) using only charged \( B^+ \) decays, by studying the angular distribution [9]. The decays \( B^+ \rightarrow D^0V^+ \), \( B^+ \rightarrow \bar{D}^0\bar{V}^+ \) and \( B^- \rightarrow D^0V^- \), \( B^- \rightarrow \bar{D}^0\bar{V}^- \) can be related by CPT. Consider \( D^0/\bar{D}^0 \) decaying into \( D^0\pi^0/\bar{D}^0\pi^0 \), with \( D^0/\bar{D}^0 \) meson further decaying to a final state ‘\( f \)’ that is common to both \( D^0 \) and \( \bar{D}^0 \). \( f \) is chosen to be a Cabibbo-allowed mode of \( D^0 \) or a doubly-suppressed mode of \( \bar{D}^0 \). The amplitudes for the decays of \( B^+ \) and \( B^- \) to a final state involving ‘\( f \)’ will be a sum of the contributions from \( D^0 \) and \( \bar{D}^0 \), and similarly for the CP-conjugate processes. In this case one can experimentally measure the magnitudes of the 12 helicity amplitudes, as well as the interference terms, leading to a total of 24 independent observables. However, there are just 15 unknowns involved in the amplitudes: \( a_i, b_i, \delta_1^i, \delta_2^i, \gamma, \Delta \) and \( R \); where, \( R^2 = \frac{\mu_{(D^0f)} - \mu_{(\bar{D}^0f)}}{\mu_{(D^0\bar{f})} - \mu_{(\bar{D}^0f)}} \), and \( \Delta \) is the strong phase difference between \( D^0 \rightarrow f \) and \( D^0 \rightarrow \bar{f} \). Hence, the weak phase \( \gamma \) may be cleanly extracted.

In addition, this technique has some interesting features:

- The signals of CP violation can be obtained by adding \( B \) and \( \bar{B} \) events, i.e, flavour tagging is not required.
- The CP violation signals are not diluted by the sine of strong phases.

5 Conclusions

We have presented new methods, that use angular analysis in \( B \rightarrow VV \) decay modes, to cleanly extract weak phases. Using modes which do not receive penguin contributions, the weak phases (2\( \beta \) + \( \gamma \)) and \( \gamma \) can be determined. We have shown that the quantity \( \sin^2(2\beta + \gamma) \) can be cleanly obtained from the time dependent angular analysis study of the decays \( B^0_s(t) \rightarrow D^{\pm}\rho^\mp, D^{\pm}\pi^\mp \) etc. Similarly, \( \sin^2 \gamma \) can be cleanly extracted from \( B^0_s(t) \rightarrow D^{\pm}_sK^{\mp} \), or simply from an angular analysis of the decay mode \( B^+ \rightarrow D^0K^+ \). The large number of data samples already collected for the \( B^0_s(t) \rightarrow D^{+}\rho^+ \) mode [13], maybe enable, \( \sin^2(2\beta + \gamma) \) to be the second clean measurement, after sin 2\( \beta \), to be performed at \( B \)-factories.

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References

1. For a review, see H. Quinn and A. I. Sanda, Eur. Phys. J. C15, 626 (2000), in The Review of Particle Physics, (Particle Data Group), D.E. Groom et. al., Eur. Phys. J. C15, 1 (2000).
2. D. London and R. Peccei, Phys. Lett. 223B, 257 (1989); M. Gronau, Phys. Rev. Lett. 63, 1451 (1989), Phys. Lett. 300B, 163 (1993); B. Grinstein, Phys. Lett. 229B, 280 (1989).
3. I. Dunietz, Phys. Lett. 427B, 179 (1998).
4. R. Aleksan, I. Dunietz, B. Kayser and F. Le Diberder, Nucl. Phys. B361, 141 (1991).
5. David London, Nita Sinha & Rahul Sinha, Phys. Rev. Lett. 85, 1807 (1900).
6. M. Gronau and D. Wyler, Phys. Lett. 265B, 172 (1991); M. Gronau and D. London., Phys. Lett. B 253, 483 (1991).
7. D. Atwood, I. Dunietz and A. Soni, Phys. Rev. Lett. 78, 3257 (1997).
8. I. Dunietz, Z. Phys. C56, 129 (1992).
9. N. Sinha and R. Sinha, Phys. Rev. Lett. 80, 3706 (1998).
10. D. Atwood and A. Soni, hep-ph/0206045; R. Aleksan, T. C. Petersen and A. Soffer, Phys. Rev. D 67, 096002 (2003); A. Giri, Y. Grossman, A. Soffer and J. Zupan, hep-ph/0303187; Y. Grossman, Z. Ligeti and A. Soffer, Phys. Rev. D 67, 071301 (2003).
11. G. Valencia, Phys. Rev. D39, 3389 (1989); G. Kramer and W. F. Palmer, Phys. Rev. D. 45, 193 (1992).
12. A. S. Dighe I. Dunietz and R. Fleischer, Eur. Phys. J. C6, 647 (1999).
13. I. Dunietz, H.R. Quinn, A. Snyder, W. Toki and H.J. Lipkin, Phys. Rev. D43, 2193 (1991).
14. R. Aleksan, I. Dunietz and B. Kayser, Zeit. Phys. C54, 653 (1992); I. Dunietz and R. Fleischer, Phys. Lett. 387B, 361 (1996).
15. B. Aubert et. al., BABAR Collaboration, Phys.Rev. D67 (2003) 091101.