Nonfactorizable contribution in weak hadronic decay of $\bar{B} \to a_1 D$

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Introduction

A lot of work has been done to study the nonfactorization contributions in the weak hadronic decays of $B-$mesons [1-5]. Obtaining the factorizable contributions from the spectator-quark model for $N_c = 3$, a systematics has been identified among the isospin reduced amplitudes for the nonfactorizable terms among $\bar{B} \to PP$ (P stands for pseudoscalar) decay modes [2]. This systematics helps us to derive a generic formula which assists to predict the branching fractions for $\bar{B}^0-$decays. Inspired by this observation, we extend our analysis to *p*-wave meson emitting decays of $B-$meson such as $\bar{B} \to AP$ (A stands for axial vector), which have similar isospin structure and make predictions for $\bar{B}^0-$decays [6], where the experimental measurements are not yet available.

Methodology

The effective weak Hamiltonian for Cabibbo enhanced $B-$mesons decays is given by

$$H_w = \frac{G_F}{\sqrt{2}} V_{cb} V_{ud}^* \begin{bmatrix} c_1(\bar{d}u)(\bar{c}b) \\ +c_2(\bar{c}u)(\bar{d}b) \end{bmatrix}, \tag{1}$$

where $\bar{q}_1 q_2 \equiv \bar{q}_1 \gamma_\mu (1-\gamma_5) q_2$ denotes color singlet $V-A$ Dirac current and c_1 and c_2 are QCD coefficients at bottom mass scale, and Fierz transforming the product of two Dirac currents of (1) in N_c color- space, we get

$$(\bar{d}u)(\bar{c}b) = \frac{1}{N_c}(\bar{c}u)(\bar{d}b) + \frac{1}{2}(\bar{c}\lambda^a u)(\bar{d}\lambda^a b), \tag{2}$$

and similar term for $(\bar{c}u)(\bar{d}b)$, where λ^a are the Gell-Mann matrices. We reduced the effective Hamiltonian to describe color-favored (CF) and color-suppressed (CS) decays, respectively.

Results and Discussion

Using the isospin framework, $\bar{B} \to a_1 D$ decay amplitudes are represented in terms of isospin reduced amplitudes $(A_{1/2}^{a_1 D}, A_{3/2}^{a_1 D})$, and the strong interaction phases $(\delta_{1/2}^{a_1 D}, \delta_{3/2}^{a_1 D})$, in respective Isospin-*1/2* and *3/2* final states, as

$$\begin{aligned} A(\bar{B}^0 \to a_1^- D^+) &= \frac{1}{\sqrt{3}}\left[A_{3/2}^{a_1 D} e^{i\delta_{3/2}^{a_1 D}} + \sqrt{2} A_{1/2}^{a_1 D} e^{i\delta_{1/2}^{a_1 D}} \right], \\ A(\bar{B}^0 \to a_1^0 D^0) &= \frac{1}{\sqrt{3}}\left[\sqrt{2} A_{3/2}^{a_1 D} e^{i\delta_{3/2}^{a_1 D}} - A_{1/2}^{a_1 D} e^{i\delta_{1/2}^{a_1 D}} \right], \\ A(B^- \to a_1^- D^0) &= \sqrt{3} A_{3/2}^{a_1 D} e^{i\delta_{3/2}^{a_1 D}}. \end{aligned} \tag{3}$$

These equations lead to the following relations:

$$\begin{aligned} A_{1/2}^{a_1 D} &= \begin{bmatrix} \left|A(\bar{B}^0 \to a_1^- D^+)\right|^2 + \left|A(\bar{B}^0 \to a_1^0 D^0)\right|^2 \\ -\frac{1}{3}\left|A(B^- \to a_1^- D^0)\right|^2 \end{bmatrix}^{1/2}, \\ A_{3/2}^{a_1 D} &= \sqrt{\frac{1}{3}}\left|A(B^- \to a_1^- D^0)\right|, \end{aligned} \tag{4}$$

and using the experimental value [1] $B(B^- \to a_1^- D^0) = (4 \pm 4) \times 10^{-3}$, we get

$$A(\bar{B}^0 \to a_1^- D^+) = (0.25 \pm 0.25)\ \text{GeV}^2. \tag{5}$$

The isospin formalism assists us to derive a generic relation among the branching fractions of $\bar{B} \to a_1 D$ decays, as follow:

$$B(\bar{B}^0 \to a_1^- D^+) + B(\bar{B}^0 \to a_1^0 D^0)$$

$$= \frac{\tau_{\bar{B}^0}}{3\tau_{B^-}} B(B^- \to a_1^- D^0)$$

$$\times \left[1 + \left\{ \begin{array}{l} \alpha \\ + \dfrac{\left(\sqrt{2}-\alpha\right) A^f(\bar{B}^0 \to a_1^- D^+)}{A(B^- \to a_1^- D^0)} \\ - \dfrac{\left(1+\sqrt{2}\alpha\right) A^f(\bar{B} \to a_1^0 D^0)}{A(B^- \to a_1^- D^0)} \end{array} \right\} \right]^2, \tag{6}$$

with $\alpha \equiv \dfrac{A_{1/2}^{nf}}{A_{3/2}^{nf}} = 0.22$, from the analysis of *s*-wave meson emitting decays of $B-$meson,

$$B(\bar{B}^0 \to a_1^- D^+) + B(\bar{B} \to a_1^0 D^0) = \begin{cases} (4.7 \pm 0.7) \times 10^{-3};\ B(B^-) = 4 \times 10^{-3}, \\ (5.6 \pm 0.3) \times 10^{-3};\ B(B^-) = 8 \times 10^{-3}, \end{cases} \tag{7}$$

which are barely touching the experimental value $B(\bar{B}^0 \to a_1^- D^+) = (6.4 \pm 3.3) \times 10^{-3}$.

Looking at these uncertainties, in Fig 1, we present variation of the sum of

$$\sum B\left(\bar{B}^0 \to decays\right) \equiv B(\bar{B}^0 \to a_1^- D^+) + B(\bar{B} \to a_1^0 D^0) \tag{8}$$

w.r.t $B(B^- \to a_1^- D^0)$ for different values of form factor, $V_0^{\bar{B}a_1}(0) = 0.14$ and 1.20 (the dash line corresponds to $V_0^{\bar{B}a_1}(0) = 0.14$ and the solid line corresponds to $V_0^{\bar{B}a_1}(0) = 1.20$ [5]), which enhances our prediction by a factor of 1.19, *i.e.*,

$$B(\bar{B}^0 \to a_1^- D^+) + B(\bar{B} \to a_1^0 D^0) = (5.6 \pm 0.3) \times 10^{-3}. \tag{9}$$

We also notice that the present data favour $B(B^- \to a_1^- D^0)$ to be on the higher side. A new measurement of branching fractions of these decays would clarify the situation.

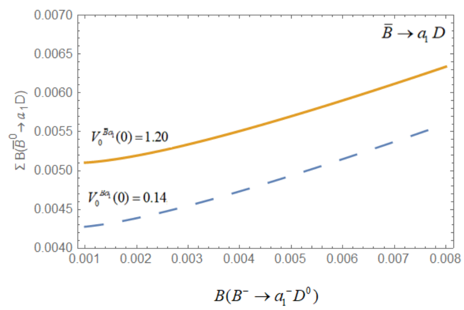

Fig1. Variation of $\sum B\left(\bar{B}^0 \to decays\right)$ with $B(B^- \to a_1^- D^0)$ for different values of form-factor

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