Direct CP Violation In B Decays Including $\rho - \omega$ Mixing And Covariant Light-Front Dynamics

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Abstract

Since its discovery in kaon decay in 1964, the origin of CP (Charge-Parity) violation has still not been completely understood. Even though the Standard Model is able to describe this phenomenon, its description involves many theoretical uncertainties. Examples are the parameters of the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements, and the hadronic matrix elements connected to the short and long distance effects. The interest in CP violation has increased with the rise of studies in cosmological physics (baryogenesis) and also with the use of new models so-called "beyond the Standard Model", such as the Higgs model and its derivative, the left-right symmetric models and supersymmetric models.

CP violation can occur via three different modes: it could be an indirect manifestation through the interaction of two initial states, for example $B^0 - \bar{B}^0 \to f$, it could be a direct manifestation due to the initial particle decay, for example, a difference between the decay rates $B^{\pm} \to \rho^0(\omega)\rho^{\pm}$, and finally, it could be a combination of the two processes, decay and mixing, as in $B_d^0 \to \psi K_s$. One exciting way to obtain a more accurate understanding of direct CP violation is to study the details of the CP violating asymmetries in the case where $\rho - \omega$ mixing plays a role in the B meson decay. In fact, $\rho - \omega$ mixing provides an opportunity to erase the phase uncertainty mod(π) in the determination of the CKM angles α (in the case of $B \to \rho\pi$) and γ (in the case of $B \to \rho K$) in the unitarity triangle (UT). This phase uncertainty usually arises from the conventional determination of $\sin 2\alpha$ (or $\sin 2\gamma$) in indirect CP violation. Hence, we have an efficient test to check the picture of direct CP violation within the Standard Model.

To achieve this goal, the present thesis is divided in three parts. Firstly, direct CP violation is studied in the following decays: $B^{\pm,0} \to \rho^0(\omega)M^{\pm,0}$ where $M^{\pm,0}$ is either a pion or a kaon. The mixing (through isospin violation) of an ω to ρ^0 which decays into two pions allows us to obtain a difference of the strong phase reaching its maximum at the ω resonance. The calculation of the hadronic matrix elements is carried out using the so-called naive factorization method. This approach utilizes the knowledge of the transition form factors between pseudoscalars and vector particles. In this first part, these form factors will be directly extracted from the literature. By comparing experimental data with theoretical results, it is possible to constrain uncertainties associated with the form factors and parameters ρ and η of the CKM matrix elements. The experimental data (from BELLE, BABAR and CLEO) for branching ratios such as $\mathscr{B}(B \to \rho\pi)$ and $\mathscr{B}(B \to \rho K)$ will be used in this way. Thus, we are able to determine in first approximation (a correct order of magnitude) the CP violating asymmetry parameter, a_{CP},

for the decays $B^{\pm,0} \to \pi^+\pi^- K^{\pm,0}$ and $B^{\pm,0} \to \pi^+\pi^-\pi^{\pm,0}$.

In order to decrease all the uncertainties mentioned previously, it is necessary to evaluate the transition form factors between pseudoscalar and vector particles. To get these form factors, we first need to calculate the wave functions which are involved in these transitions. We take into account several physical constraints to determine the wave functions for the particles π, K, ρ, ω and B; these include the decay constant, electromagnetic form factor, transition form factor and charge radius. We also consider the normalization to fully constrain the wave functions. We apply an explicitly Covariant Light Front Dynamics (CLFD) formalism in our analysis to compute both wave functions and transition form factors. In this formalism, the state vector describing the system under consideration is defined on a light front plane of arbitrary orientation. It is thus decomposed in Fock state components, each one being expressed in terms of a probability amplitude very similar to a non-relativistic wave function. All off-shell amplitudes are thus explicitly dependent on the orientation of the light-front plane, while any physical amplitude should be independent on it.

Then, the last major uncertainty that remains is related to the final state interactions. To compute the hadronic matrix elements without using naive factorization and the Bjorken assumption, we will apply QCD factorization. By assuming some properties lie in energy scales involved in B decays, it allows us to determine as well as possible the non-factorizable terms which arise during the usual hadronic matrix calculation. Finally, only one uncertainty remains uncontrolled, theoretically speaking: these are the CKM matrix parameters ρ and η. By comparing, once again, experimental results for branching ratios $\mathscr{B}(B \to \rho K)$ and $\mathscr{B}(B \to \rho\pi)$ with the theoretical results obtained in this second approach, we can check firstly the transition form factors determined in CLFD. Secondly, we can use these conclusions to predict the CP violating asymmetry parameter, a_{CP}, for decays $B^{\pm,0} \to \pi^+\pi^- K^{\pm,0}$ and $B^{\pm,0} \to \pi^+\pi^-\pi^{\pm,0}$. Finally, based on these results, we determine some limits for the parameters ρ and η of the Cabibbo-Kobayashi-Maskawa matrix.