



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

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Contents

I	Matter Antimatter	1
1	Introduction	3
2	<i>CP</i> violation, a brief overview	7
2.1	The Standard Model	7
2.1.1	Basic concepts	7
2.1.2	The electroweak interaction	9
2.2	The Cabibbo-Kobayashi-Maskawa matrix	11
2.2.1	Sources of <i>CP</i> violation	11
2.2.2	The CKM matrix	11
2.3	<i>CP</i> violation in <i>B</i> meson decays	17
2.3.1	<i>CP</i> violation in mixing	17
2.3.2	<i>CP</i> violation in the interference of decays with and without mixing induced	17
2.3.3	Direct <i>CP</i> violation in <i>B</i> decays	19
II	Branching Ratio and Direct <i>CP</i> Asymmetry in <i>B</i> Decays	21
3	Effective Hamiltonian	23
3.1	Operator Product Expansion	23
3.2	Wilson coefficients	27
3.3	Effective Hamiltonian	29
3.4	Naive factorization	30
4	$\rho - \omega$ mixing	33
4.1	Vector Meson Dominance	33
4.2	$\rho - \omega$ mixing	35
4.2.1	$\rho - \omega$ mixing formalism	35
4.2.2	Electromagnetic pion form factor	39

4.3	$\rho - \omega$ mixing in B decays	40
4.3.1	Inclusion of $\rho - \omega$ mixing in CP violation	40
4.3.2	Inclusion of $\rho - \omega$ mixing in branching ratios	43
5	Branching ratios for B decays into $\rho\pi$ or ρK	45
5.1	Formalism	45
5.2	Calculational details	46
5.2.1	Factorization	46
5.2.2	Form factors	47
5.3	Numerical inputs and experimental results	48
5.3.1	CKM values	48
5.3.2	Quark masses	49
5.3.3	Form factors and decay constants	49
5.3.4	Experimental results	51
5.4	Branching ratios for $B^{\pm,0} \rightarrow \rho^{\pm,0} \pi^{\pm,0}$	52
5.4.1	Formulae	52
5.4.2	Results and discussions	54
5.5	Branching ratios for $B^{\pm,0} \rightarrow \rho^{\pm,0} K^{\pm,0}$	58
5.5.1	Formulae	58
5.5.2	Results and discussions	61
5.6	Summary	67
6	Direct CP violation via $\rho - \omega$ mixing	69
6.1	Calculational details	69
6.2	$B^{\pm,0} \rightarrow \pi^+ \pi^- \pi^{\pm,0}$	70
6.2.1	Formulae	70
6.2.2	Results and discussions	72
6.3	$B^{\pm,0} \rightarrow \pi^+ \pi^- K^{\pm,0}$	80
6.3.1	Formulae	80
6.3.2	Results and discussions	83
6.4	Summary	92
III Covariant Light-Front Dynamics, Wave Functions and Form Factors		95
7	Covariant Light-Front Dynamics - Main properties	97
7.1	Light-Front Dynamics	97
7.2	Covariant Light-Front Dynamics	99
7.2.1	Main properties	99
7.2.2	Kinematical and dynamical transformations	100

7.2.3	S -matrix	101
7.3	Wave function	102
7.3.1	Various parametrizations	103
7.3.2	Equation of motion	104
7.3.3	Normalization	105
8	Meson wave functions	107
8.1	Pseudoscalar wave function	107
8.1.1	Structure of the bound state	107
8.1.2	Radiative corrections to the wave function	108
8.1.3	Physical constraints	111
8.1.4	Numerical results	117
8.2	Vector mesons	127
8.2.1	Formalism	127
8.2.2	Decay constant	128
8.2.3	Numerical results	130
8.3	Summary	133
9	Transition form factors	135
9.1	Weak decay form factors for $P \rightarrow P$ transitions	135
9.1.1	Usual formalism	135
9.1.2	CLFD formalism	137
9.1.3	Semi-leptonic decay	139
9.1.4	Numerical results for $P \rightarrow Pl\nu_l$	140
9.2	Weak decay form factors for $P \rightarrow V$ transitions	141
9.2.1	Vector current	141
9.2.2	Axial current	144
9.2.3	Semi-leptonic decay	147
9.2.4	Numerical results for $P \rightarrow Vlnu_l$	148
9.3	Summary	149
IV	QCD Factorization in B Decays	151
10	QCD factorization	153
10.1	QCD factorization in $B \rightarrow PV$ decays	153
10.2	Effective Hamiltonian	155
10.2.1	The QCD coefficients a_i	157
10.2.2	The weak annihilation coefficients b_i	162
10.3	Input parameters	165

10.3.1	Form factors, decay constants, CKM matrix elements and quark masses	165
10.3.2	Light cone distribution amplitude (LCDA) of the mesons	166
11	Branching ratios for B decays into $\rho\pi$ or ρK in QCDF	169
11.1	Generalities	169
11.2	Branching ratios for $B \rightarrow \rho\pi$	171
11.2.1	Weak annihilation contributions	171
11.2.2	Results and discussions	173
11.3	Branching ratios for $B \rightarrow \rho K$	179
11.3.1	Weak annihilation contributions	179
11.3.2	Results and discussions	181
11.4	Summary	186
12	Direct CP violation in B decays in QCDF	189
12.1	Asymmetry in B decays including annihilation contributions and $\rho - \omega$ mixing effects	189
12.2	CP violation in $B^{\pm,0} \rightarrow \pi^+\pi^-\pi^{\pm,0}$	191
12.3	CP violation in $B^{\pm,0} \rightarrow \pi^+\pi^-K^{\pm,0}$	194
12.4	Constraints	198
12.4.1	Constraints on form factors	199
12.4.2	Constraints on the CKM matrix parameters ρ and η	201
13	Conclusion	205
A	The kernel, one-gluon exchange in CLFD	211
A.1	Functions $\Omega_{1,2}$	211
A.2	Functions $\chi_{1,2}$	212
B	Transition form factor in CLFD	215
B.1	Functions $F_1^{(j)}, F_2^{(j)}$	215
B.2	Functions $F_3^{(j)}$	217
B.3	Transition form factor diagrams	217
C	Annihilation amplitudes in $B \rightarrow \pi^+\pi^-M$	219
C.1	Transition $b \rightarrow u$	219
C.2	Transition $b \rightarrow s$	220
	Bibliography	221

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 $B^0 - \bar{B}^0 \rightarrow f$, it could be a direct manifestation due to the initial particle decay, for example, a difference between the decay rates $B^\pm \rightarrow \rho^0(\omega)\rho^\pm$, and finally, it could be a combination of the two processes, decay and mixing, as in $B_d^0 \rightarrow \psi K_s$. 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 $\text{mod}(\pi)$ in the determination of the CKM angles α (in the case of $B \rightarrow \rho\pi$) and γ (in the case of $B \rightarrow \rho K$) 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: $B^{\pm,0} \rightarrow \rho^0(\omega)M^{\pm,0}$ 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 $\mathcal{B}(B \rightarrow \rho\pi)$ and $\mathcal{B}(B \rightarrow \rho K)$ 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 $B^{\pm,0} \rightarrow \pi^+\pi^-K^{\pm,0}$ and $B^{\pm,0} \rightarrow \pi^+\pi^-\pi^{\pm,0}$.

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 $\mathcal{B}(B \rightarrow \rho K)$ and $\mathcal{B}(B \rightarrow \rho \pi)$ 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 $B^{\pm,0} \rightarrow \pi^+\pi^-K^{\pm,0}$ and $B^{\pm,0} \rightarrow \pi^+\pi^-\pi^{\pm,0}$. Finally, based on these results, we determine some limits for the parameters ρ and η of the Cabibbo-Kobayashi-Maskawa matrix.