STATUS OF B PHYSICS AND THE EURIDICE CONTRIBUTION*

L. Oliver

Laboratoire de Physique Théorique†
Université de Paris XI, Bâtiment 210, 91405 Orsay Cedex, France

(Received July 2, 2007)

In this talk the landscape in B physics at the time of the Moscow ICHEP 2006 Conference is sketched, underlying a few highlights. Also a brief review of the contributions in the field within the Euridice EC network in the last four years is presented.

PACS numbers: 13.20.He, 14.20.Mr, 14.40.Nd, 14.65.Fy

1. Introduction

The present situation in Particle Physics is characterized, on the one hand, by a very rich activity in a number of fields, both theoretical and experimental, and a moment of tension and suspense, waiting for the LHC, the clarification of the origin of Electroweak Symmetry Breaking and the possible discovery of New Physics that we hope it will provide.

Among the fields in which a great effort is being developed presently and has been in the recent past, there are the following:

— The extraordinary data from the B-factories BaBar and BELLE, and their theoretical interpretation. The attained luminosity is of the order of 1000 fb^{-1} $\sim 10^9 B\overline{B}$ pairs, far beyond the designed one.

— The recent very important measurement of Δm_s at CDF.

— The progress in lattice QCD with dynamical fermions.

— The great effort and success achieved in Neutrino Physics with the indirect evidence of New Physics due to the see-saw mechanism.

— The indirect evidence for dark matter in Observational Cosmology.

* Presented at The Final EURIDICE Meeting "Effective Theories of Colours and Flavours: from EURODAPHNE to EURIDICE", Kazimierz, Poland, 24–27 August, 2006.

† Unité Mixte de Recherche UMR 8627 — CNRS.

Concerning Flavor physics and CP Violation, already many observables are over-constraining the unitarity triangle. These observables are of quite different nature, and it is important to distinguish among them. The main reason is that the present issue is to put in evidence if there are discrepancies with the Standard Model (SM) or, if this is not the case, why New Physics is not flavor sensitive. On the other hand, we know that new sources of CP violation beyond the Standard Model must exist due to the matter-antimatter asymmetry of the universe.

There are three different ways to analyze the Unitarity Triangle (UT) [1, 2]:

(1) To consider the UT constructed from CP violating (CPV) observables $(\varepsilon_K, \alpha, \beta, \gamma)$ *versus* the UT dependent CP conserving (CPC) observables $(|V_{ub}|/|V_{cb}|, \Delta m_d, \Delta m_s)$.

(2) The UT from QCD free quantities (α, β, γ) *versus* the UT with QCD dependent quantities $(\varepsilon_K, |V_{ub}|/|V_{cb}|, \Delta m_d, \Delta m_s)$.

(3) The UT from tree quantities $(|V_{ub}|/|V_{cb}|, \gamma)$ *versus* the UT from loop quantities $(\varepsilon_K, \Delta m_d, \Delta m_s, \alpha, \beta, K_{\mathrm{L}} \to \pi^0 \nu\overline{\nu})$.

Each of these ways of analysis pursues very crucial different goals. The QCD-dependent observables would allow to check the lattice calculations, that are attaining a great precision, and the agreement or not with the SM for the electroweak part. The third method is the most appropriate in the search of New Physics, since heavy particles beyond the SM would contribute within loops to the observables that appear in the SM only at the quantum level.

One could adopt each of these three ways of analyzing the data. We will adopt the third method, that distinguishes between loop and tree quantities, suitable in the search of New Physics. More generally, besides the precise determination of the UT triangle by different observables, loop processes are the ideal place to look for New Physics, either in CP conserving (rare decays like $B \to X_s\gamma$), or in CP violating (*e.g.* $B \to \varphi K_s$ asymmetries) processes.

In the first part of this talk (Section 2) we will sketch the main results of the ICHEP 06 Conference on Heavy Flavors Physics, in particular we will follow closely some aspects of the summary talks by Okada [3], Hazumi [4,5], Kowalewski [6], Barlow [7] and Glenzinski [8], experimental contributions by CDF, BaBar and BELLE and theoretical talks at the parallel sessions. In Section 3 we will list the topics studied at the Euridice EC network in Heavy Flavour physics in the last four years, and we will give some details on a few contributions of importance.

2. Status of B physics at ICHEP 2006

2.1. Tree level observables in the Unitarity Triangle

The CKM parameters that can be determined by tree-level processes are the quantities $|V_{cb}|, |V_{ub}|$ and their relative phase γ

$$\frac{V_{ub}}{V_{cb}} = \frac{|V_{ub}|}{|V_{cb}|}\, e^{-i\gamma}\,.$$

The most delicate quantity to measure is γ, on which further improvement is essential.

Semileptonic inclusive or exclusive $\overline{B} \to X_{c,u}\ell\overline{\nu}_\ell$ decays allow to measure $|V_{ub}|$ and $|V_{cb}|$, while the interference between common final states $(D^0, \overline{D}^0 \to f)$

$$A\left(B^- \to K^- f\right) = A\left(B^- \to K^- D^0 \to K^- f\right) + A\left(B^- \to K^- \overline{D}^0 \to K^- f\right)$$

allows to measure γ as these amplitudes are respectively proportional to $A(B^- \to K^- D^0) \sim V_{cb}$ (D^0 production) and $A(B^- \to K^- \overline{D}^0) \sim V_{ub}$ ($\overline{D}^0$ emission).

2.1.1. The sides $|V_{cb}|$ and $|V_{ub}|$

There is consistency [9–11] between the determination of $|V_{cb}|$ using $\overline{B} \to X_c\ell\overline{\nu}_\ell$ moments within the OPE + QCD corrections in the kinetic [12–14], and $1S$ schemes [15, 16]. $|V_{cb}|$ is presently known to better than 2%,

$$|V_{cb}|_{\text{inclusive}} = (42.0 \pm 0.23 \pm 0.69) \times 10^{-3}\,.$$

The exclusive determination relies on $\overline{B} \to D^{(*)}\ell\overline{\nu}_\ell$. The present more thorough experimental study by BaBar [17, 18] gives

$$F(1)|V_{cb}| = (34.68 \pm 0.32 \pm 1.15) \times 10^{-3}\,,$$

while the slope of the form factor $h_{A_1}(w)$ is determined to be

$$\rho^2 = 1.179 \pm 0.048 \pm 0.028\,.$$

The form factor at zero recoil has been calculated in quenched lattice QCD [19], yielding

$$F(1) = 0.919 \pm 0.030$$

giving the result

$$|V_{cb}|_{\text{exclusive}} = (39.4 \pm 0.9 \pm 1.5) \times 10^{-3}\,.$$

There has been a major effort in the last years to obtain $|V_{ub}|$ based on the OPE within HQET and SCET [20, 21]. One needs the Shape Function (SF) of the quark b about which one can have information by relating the decay $b \to u\ell\overline{\nu}_\ell$ to $b \to s\gamma$. The SF moments $\langle E_\gamma \rangle$ and $\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2$ are respectively related to the HQET parameters $m_b/2$ and μ_π^2.

The result obtained is [6, 22]

$$|V_{ub}|_{\text{inclusive}} = (4.49 \pm 0.19 \pm 0.27) \times 10^{-3} \,.$$

The exclusive determination of $|V_{ub}|$ is based on the decays $\overline{B} \to \pi(\rho)\ell\overline{\nu}_\ell$ and depends on the theoretical determination of the heavy-to-light form factors within Light-Cone Sum Rules or lattice QCD.

At ICHEP 06 there have been results on the clean mode $\overline{B} \to \pi\ell\overline{\nu}_\ell$ from BELLE, BaBar [23–25] and CLEO giving the branching ratio [6]

$$\mathrm{BR}\,(B \to \pi\ell\overline{\nu}_\ell) = (1.37 \pm 0.06 \pm 0.06) \times 10^{-4} \,.$$

Averaging over the theoretical predictions for the form factors obtained from Light-Cone Sum Rules and lattice QCD (HPQCD, FNAL, APE), one gets [6],

$$|V_{ub}|_{\text{exclusive}} = (3.59 \pm 0.21 \pm 0.58) \times 10^{-3} \,.$$

One realizes that there is some discrepancy between $|V_{ub}|_{\text{inclusive}}$ and $|V_{ub}|_{\text{exclusive}}$.

2.1.2. The angle $\gamma(\phi_3)$

To extract the phase γ one needs the interference between tree-level decays, namely $K^{(*)-}$ emission and $\overline{D}^{(*)0}$

$$\begin{aligned} B^- &\to K^{(*)-}D^{(*)0} \to K^{(*)-}f \sim a_1 V_{cb}V_{us}^* \sim O(\lambda^3)\,, \\ B^- &\to K^{(*)-}\overline{D}^{(*)0} \to K^{(*)-}f \sim a_2 V_{ub}V_{cs}^* \sim 0.2 \times O(\lambda^3)\,, \end{aligned}$$

where f is a common decay of $D^{(*)0}$, $\overline{D}^{(*)0} \to f$. The ratio of amplitudes can be parametrized by

$$\frac{A\left(B^- \to K^-\overline{D}^0\right)}{A\,(B^- \to K^-D^0)} = r_B\; e^{i\delta_B}\; e^{-i\gamma}\,,$$

where r_B and δ_B are hadronic parameters. There are therefore for each mode two hadronic parameters r_B, δ_B and the CP angle γ.

A number of methods have been proposed in the literature, according to the chosen common final state $f =$ CP Eigenstate $(K_s\pi^0, \pi^+\pi^-)$ [26], DCSD $(K^+\pi^-)$ [27], $K_s\pi^+\pi^-$ (Dalitz analysis) [28].

Up to now, the method that seems more promising is the last of the listed. The relevant amplitudes are related to the CKM matrix via

$$A\left(B^- \to D^0 K^-\right) \sim V_{cb}V_{us}^*\,, \qquad A\left(B^- \to \overline{D}^0 K^-\right) \sim V_{ub}V_{cs}^*\,,$$
$$A\left(B^+ \to \overline{D}^0 K^+\right) \sim V_{cb}^*V_{us}\,, \qquad A\left(B^+ \to D^0 K^+\right) \sim V_{ub}^*V_{cs}\,.$$

Looking at the common final state $K_s\pi^+\pi^-$ one isolates two superpositions of D^0 and $\overline{D}^0$,

$$B^- \to D^0_- K^- \to K_s\pi^+\pi^- K^-\,, \qquad B^+ \to D^0_+ K^+ \to K_s\pi^+\pi^- K^+\,,$$

where the quantum superpositions are

$$|D^0_-\rangle = |D^0\rangle + re^{i(-\gamma+\delta_B)}|\overline{D}^0\rangle\,, \qquad |D^0_+\rangle = |\overline{D}^0\rangle + re^{i(\gamma+\delta_B)}|D^0\rangle\,.$$

The Dalitz plots for the two modes are

$$M\left(D^0_- \to K_s\pi^+\pi^-\right) = f\left(m_-^2, m_+^2\right) + r_B\ e^{i(-\gamma+\delta_B)}\ f\left(m_+^2, m_-^2\right)\,,$$
$$M\left(D^0_+ \to K_s\pi^+\pi^-\right) = f\left(m_+^2, m_-^2\right) + r_B\ e^{i(\gamma+\delta_B)}\ f\left(m_-^2, m_+^2\right)\,,$$

where $m_+^2 = m_{K_s\pi^+}^2$ and $m_-^2 = m_{K_s\pi^-}^2$. The function $M(\overline{D}^0 \to K_s\pi^+\pi^-) = f(m_+^2, m_-^2)$ can be determined from the continuum, outside the $\Upsilon(4S)$ source of the B mesons.

Due to CP violation, the Dalitz plots for $D^0_- \to K_s\pi^+\pi^-$ and $D^0_+ \to K_s\pi^+\pi^-$ are not identical and allow to determine the parameters (r_B, δ_B, γ). Fitting $\mathrm{Re}(r_B e^{\pm\gamma+\delta_B})$ and $\mathrm{Im}(r_B e^{\pm\gamma+\delta_B})$ from Dalitz distributions one gets $r_B \neq 0$ and the difference between B^+ and B^- gives $\gamma \neq 0$. One obtains [6, 29, 30]

$$r_B \sim 0.1\,, \qquad \gamma = 78 \pm 30^\circ\,.$$

2.1.3. Summary of tree observables

To summarize, one has the following determinations of tree observables [6]

$$|V_{cb}|_{\text{inclusive}} = (42.0 \pm 0.23 \pm 0.69) \times 10^{-3}\,,$$
$$|V_{cb}|_{\text{exclusive}} = (39.4 \pm 0.9 \pm 1.5) \times 10^{-3}\,,$$

$$|V_{ub}|_{\text{inclusive}} = (4.49 \pm 0.19 \pm 0.27) \times 10^{-3}\,,$$
$$|V_{ub}|_{\text{exclusive}} = (3.59 \pm 0.21 \pm 0.58) \times 10^{-3}\,,$$
$$\gamma(\varphi_3) = 78 \pm 30^\circ\,.$$

The present integrated luminosity (BaBar + BELLE) is about 1 ab^{-1} = 1000 fb^{-1}. One expects for 2008 about 2 ab^{-1} from B factories, from which the error on $|V_{ub}/V_{cb}|$ will be of the order $\sim 5\%$ and the error on γ will decrease to about ~ 10–15°.

It is very important to underline that the inclusive and exclusive determinations are complementary. Indeed, there is a 2σ tension between the value of $\sin 2\beta$ obtained from the global fit using $|V_{ub}|_{\text{inclusive}}$ and the measured $\sin 2\beta$, and the inclusive and exclusive determinations of $|V_{ub}|$ do not quite converge. It is crucial that both determinations, that have quite different hadronic uncertainties, agree before drawing firm conclusions about the possibility of New Physics, explored in a number of schemes beyond the Standard Model, like in Little Higgs models [31, 32].

2.2. Loop observables in the Unitary Triangle

In a few years we have become aware that not only there are other observables violating CP besides the ε parameter, but also that it seems likely that the Kobayashi–Maskawa phase is the dominant source of CP violation. The problem that stands in front of us is to know if there are deviations from the CKM picture and new sources of CP violation.

2.2.1. The angle $\beta(\phi_1)$

The cleanest observable of CP violation in the B^0–$\overline{B}^0$ system is the parameter $\sin 2\beta$. The results are the following. From BELLE [33] and the modes $B^0 \to J/\psi K^0$ (K_s, $K_{\rm L}$), from the t-dependent CP asymmetry, one has

$$\begin{aligned}\sin 2\varphi_1 &= 0.642 \pm 0.031 \pm 0.031\\ A &= 0.018 \pm 0.021 \pm 0.014\,,\end{aligned}$$

where A denotes the direct CP violation parameter. From $b \to c\bar{c}s$ transitions $(J/\psi K^0, \psi(2S)K_s, \eta_c K_s, J/\psi K^{*0}, \ldots)$ from BaBar [34]

$$\begin{aligned}\sin 2\beta &= 0.710 \pm 0.034 \pm 0.019\\ A &= -\,0.07 \pm 0.028 \pm 0.018\,,\end{aligned}$$

that gives the average [5]

$$\sin 2\beta = 0.674 \pm 0.026\,.$$

Therefore, $\sin 2\beta$ is now known with 4% accuracy.

It is worth noticing here that this measured value agrees with the value of $\sin 2\beta$ obtained from the global fit to the UT if one uses the exclusive value for $|V_{ub}|$ given above,

$$\sin 2\beta = 0.689 \pm 0.028 \qquad (\text{from } |V_{ub}|_{\text{exclusive}})\,.$$

However, using the inclusive value of $|V_{ub}|$ one gets a much higher value for $\sin 2\beta$ from the global fit

$$\sin 2\beta = 0.734 \pm 0.024 \qquad (\text{from } |V_{ub}|_{\text{inclusive}})\,.$$

There is therefore a tension between the measured value of $\sin 2\beta$ and $|V_{ub}|_{\text{inclusive}}$ [1].

On the other hand, there is a discrete ambiguity, two branches depending on the sign$(\cos 2\beta)$ [34], that has been solved with a number of methods in BaBar and BELLE, namely $B^0 \to D^{*+}D^{*-}K_s$ time-dependent Dalitz analysis [35] , $B^0 \to D^{(*)}h^0 \to K_s\pi^+\pi^-h^0$ time-dependent Dalitz analysis [36,37] or $B^0 \to J/\psi K^{*0}$ angular analysis [38], that all favour the branch $\cos 2\beta > 0$ in agreement with the indirect determinations of $\beta(\varphi_1)$ in the Standard Model.

The time-dependent CP asymmetries in penguin processes $\overline{B}^0 \to \varphi K_s$, φK_{L}, φK^*, $K\overline{K}\,\overline{K}$, $\eta' K_s$, *etc.* measure in principle the same $\sin 2\beta$ CP-violating observable as in the tree process $B^0 \to \psi K^0$. These decays, each with a BR of $\mathcal{O}(10^{-5})$ arise at the one-loop level, and are in principle sensitive to New Physics. BELLE and BaBar have presented new tCPV in $B^0 \to \eta' K_s$ at the level of 5σ. Making the average of all the penguin-induced modes, $\sin 2\beta$ turns out to be smaller than in tree $b \to c\bar{c}s$. The average of all $b \to s$ modes gives [4]

$$(\sin 2\beta)_{\text{Penguin}} = 0.52 \pm 0.05$$

i.e. a 2.6 σ negative deviation of the penguin transitions $b \to s$ *versus* the tree ones $b \to c$. Theory tends to predict a positive shift for $(\sin 2\beta)_{\text{Penguin}} - (\sin 2\beta)_{\text{tree}}$, instead of negative difference, in QCDF [39,40] and SCET [41]. The difference $(\sin 2\beta)_{\text{Penguin}} - (\sin 2\beta)_{\text{tree}}$ varies from mode to mode, from $+\,0.03 \pm 0.02$ for φK_s to $+\,0.10 \pm 0.10$ for ωK_s. Therefore, for the moment there is a hint of deviation from the SM in tCPV in $b \to s$ transitions. However, the disagreement is not the same for all modes, and it is not large. One would need a factor 10 more data to resolve the issue and therefore a new generation of B-factories or LHC-B.

2.2.2. The angle $\alpha(\phi_2)$

There are three possibilities, namely $B \to \pi\pi$, $\rho\rho$, $\pi\rho$, to measure the angle $\alpha(\varphi_2)$ in two-body time-dependent CP asymmetries. The branching ratios are CKM suppressed, and Tree and Penguin diagrams with different CKM phases contribute to these modes, hence the difficulty of the measurement of this angle.

The important news is that BELLE [4, 42, 43] has measured the tCP asymmetry for $B^0 \to \pi^+\pi^-$ with 532 M $B\overline{B}$ pairs. The results are, for the indirect and direct CP violation parameters

$$\begin{aligned} S_{\pi\pi} &= -0.61 \pm 0.10 \pm 0.04\,, \\ A_{\pi\pi} &= +0.55 \pm 0.08 \pm 0.05\,. \end{aligned}$$

One observes that there is a large direct CP violation at the 5.5 σ level and also a large mixing-induced CP violation at 5.6 σ. BaBar [4, 44] has measured at 3.6 σ mixing-induced CPV, but direct CPV has still not been observed,

$$\begin{aligned} S_{\pi\pi} &= -0.53 \pm 0.14 \pm 0.02\,, \\ A_{\pi\pi} &= +0.16 \pm 0.14 \pm 0.02\,. \end{aligned}$$

The observed large direct CPV means a large penguin diagram (P) $\sim$ Tree diagram (T) and a large strong phase between P and T.

SU(3) symmetry allows to relate the $A_{\mathrm{CP}}(K^+\pi^-)$ and the direct CP asymmetry in $\pi^+\pi^-$ [45, 46],

$$A_{\mathrm{CP}}(\pi^+\pi^-) \sim -3A_{\mathrm{CP}}(K^+\pi^-)\,.$$

From the data on $A_{\mathrm{CP}}(K^+\pi^-) = -0.115 \pm 0.018$ one infers $A_{\mathrm{CP}}(\pi^+\pi^-) \sim +0.3$, in agreement with the average value that combines BELLE and BaBar data [4],

$$A_{\mathrm{CP}}(\pi^+\pi^-) \sim +0.39 \pm 0.07\,.$$

However, there are discrete ambiguities for α from $B^0 \to \pi^+\pi^-$, and one needs the other modes $\rho\rho$ and $\rho\pi$. The mode $\rho\rho$ is very useful due to its large BR, small Penguin pollution $\mathrm{BR}(B^0 \to \rho^0\rho^0) \lesssim 10^{-6}$ and the fact that the ρ is $\sim$ 100% longitudinally polarized [47, 48]. This mode was the favorite one till the measurement of $B^0 \to \pi^+\pi^-$. However, in the system $\rho\rho$ the isospin triangle in the complex plane between the amplitudes was not closed. The new measurements for the $\rho^0\rho^0$ and $\rho^+\rho^0$ BR [49] give now a closed isospin triangle as shows the below Table.

Decay mode	BR(10^{-6})
$B^0 \to \rho^+\rho^-$	23.5 ± 4.6
$B^0 \to \rho^0\rho^0$	1.2 ± 0.4
$B^+ \to \rho^+\rho^0$	16.8 ± 3.1

Moreover, Dalitz analysis in the $\pi\rho$ system helps also to lift the discrete degeneracies [50, 51]. All this gives a determination of α with $\pi\pi/\pi\rho/\rho\rho$

$$\alpha = \left(93^{+11}_{-9}\right)^0$$

in agreement with the indirect determination from the global fit $\alpha = \left(98^{+5}_{-19}\right)^0$.

Summarizing, there has been a revival of the $\pi\pi$ mode, $\rho\pi$ is essential to suppress the ambiguity $\alpha \sim 0^0$, 180^0, and there is good agreement with the global CKM fit.

2.2.3. $\mathbf{B_s - \overline{B}_s}$ mixing

One of the great news in Flavor Physics in 2006 was the measurement of the mixing parameter of the B^0_s–$\overline{B}^0_s$ system Δm_s by CDF [8, 52–54]

$$\Delta m_{B_s} = \left(17.31 \begin{array}{c} +0.33 \\ -0.18 \end{array} \pm 0.07\right) \mathrm{ps}^{-1} \quad (\mathrm{CDF})\,,$$

$$17 \ \mathrm{ps}^{-1} < \Delta m_{B_s} < 21 \ \mathrm{ps}^{-1} \quad (\mathrm{D0})\,.$$

It confirms that, as expected in the SM, the B^0_s–$\overline{B}^0_s$ system is quite different from the B^0_d–$\overline{B}^0_d$ one. In the Standard Model one expects indeed $\Delta m_{B_s}/\Delta m_{B_d} \sim 40$, $\Delta\Gamma_{B_s}/\Gamma_{B_s} \sim 10\%$, and almost no CP phase in mixing.

Taking literarily the CDF value, there is some small room left for NP if one compares this value with the indirect determination of Δm_{B_s} from the Unitarity Triangle, since from the global fit of the UT [1] one finds

$$\Delta m_{B_s} = (20.9 \pm 2.6) \ \mathrm{ps}^{-1}\,.$$

If New Physics gives a phase to B_s mixing, this would lead to a time dependent CP asymmetry $S_{\psi\varphi}$ in $B_s \to J/\psi\ \varphi$

$$A^{\mathrm{mixing}}_{\mathrm{CP}}(t) = S_{\psi\varphi} \sin(\Delta M_s t)\,.$$

The correlation between the semileptonic CP asymmetry and the time-dependent one $S_{\psi\varphi}$ has been pointed out as a possible signal of some models of NP like Little Higgs models [31, 32].

2.3. Other processes that could be sensitive to New Physics

We now list some phenomena that could allow to dig out New Physics, or observables that were in disagreement with the Standard Model and for which recent data has shown to be in agreement.

2.3.1. Tauonic B decay.

BELLE has delivered an important measurement, a 3.5σ effect [55–57]

$$\mathrm{BR}\left(B^+ \to \tau^+\nu\tau\right) = \left(1.79 \begin{array}{c} +\ 0.56\ +\ 0.46 \\ -\ 0.49\ -\ 0.51 \end{array}\right) \times 10^{-4}\,.$$

Combining BELLE and BaBar [7] one gets

$$\mathrm{BR}\left(B^+ \to \tau^+\nu\tau\right) = (1.36 \pm 0.48) \times 10^{-4}\,,$$

while the Standard Model predicts

$$\mathrm{BR}\left(B^+ \to \tau^+\nu\tau\right) = (1.59 \pm 0.40) \times 10^{-4}\,.$$

Although there is an agreement within errors, it is worth to notice [7, 56] that this process, due to the large Yukawa couplings to heavy fermions, is sensitive to charged Higgs boson exchange in Two Higgs Doublet Models (2HM) as well as in SUSY. Indeed, the charged Higgs contribution depends on the parameters

$$r = \frac{\tan\beta}{m_{\mathrm{H}}}\,, \qquad \tan\beta = \frac{v_2}{v_1}\,.$$

There is a number of processes that are sensitive to these parameters in a different way, so that they can distinguish between the SM and the 2HM, namely various tauonic B decays [7]: $\mathrm{BR}(b \to c\tau\nu)$ [58], that has been measured at LEP with large errors [59, 60], $\mathrm{BR}(B \to \tau\nu)$ [61] and $\mathrm{BR}(\overline{B} \to D\tau\nu)$ [62]. These decays can give constraints on r and can resolve a two-fold ambiguity between the SM and the 2HM.

2.3.2. Direct CP violation

Direct CP violation has been a major achievement of B-factories. The present results for the $K^+\pi^-$ mode are

$$\begin{aligned} A_{\mathrm{CP}}(K^+\pi^-) &= -0.108 \pm 0.024 \pm 0.007 \quad \text{(BaBar [63])} \\ A_{\mathrm{CP}}(K^+\pi^-) &= -0.093 \pm 0.018 \pm 0.008 \quad \text{(BELLE [64])}\,. \end{aligned}$$

Direct CP violation does not only depend on the CPV phases but also on strong phases, so that the value of these asymmetries does not constitute by itself a test of the SM. However, in the SM a problem could arise comparing the direct CP asymmetries [HFAG ICHEP 06]

$$
\begin{aligned}
A_{\rm CP}(K^+\pi^-) &= -0.093 \pm 0.015\,,\\
A_{\rm CP}(K^+\pi^0) &= +0.047 \pm 0.026
\end{aligned}
$$

that are predicted to be equal [65]. The difference 0.14 ± 0.03 is several σ away from zero. One possible interpretation, although unlikely, is that color-suppressed tree diagrams are responsible for the difference, or maybe New Physics [7].

2.3.3. Update of $B \to K\pi$ ratios

For some time, a number of ratios of rates of $B \to K\pi$ decays have been considered to be in disagreement with the SM and a possible signal of NP. At present there is no more any discrepancy [7, 66]. One of these is the ratio [67]

$$R_{\rm Lipkin} = 2\frac{\Gamma(B^+ \to K^+\pi^0) + \Gamma(B^0 \to K^0\pi^0)}{\Gamma(B^+ \to K^0\pi^+) + \Gamma(B^0 \to K^+\pi^-)}$$

that in the SM, assuming isospin symmetry and penguin-dominated diagrams gives $R_{\rm Lipkin} = 1 + O(10^{-2})$. The present HFAG ICHEP 06 average

$$R_{\rm Lipkin} = 1.06 \pm 0.05$$

shows that there is no more disagreement with the SM.

Two other ratios of interest, predicted to be close to 1 in the SM, are [68]

$$R_n = \frac{\Gamma(B^0 \to K^+\pi^-)}{2\Gamma(B^0 \to K^0\pi^0)}\,, \qquad R_c = 2\,\frac{\Gamma(B^+ \to K^+\pi^0)}{\Gamma(B^+ \to K^0\pi^+)}\,.$$

The present HFAG averages are [66]

$$R_0 = 0.99 \pm 0.07\,, \qquad R_c = 1.11 \pm 0.07\,.$$

Therefore, there is no more $K\pi$ puzzle that could point to New Physics.

2.3.4. $B \to VV$ polarization

As shown in Section 3.6, the chiral structure of SM plus the heavy quark limit and large energy limit for the light meson (LEET) predict approximately, for the longitudinal polarization fraction in $B \to VV$ decays, where V is any light vector meson,

$$f_{\rm L} = 1 - \mathcal{O}\left(\frac{1}{m_Q^2}\right)\,.$$

Experimentally this is indeed the case for the tree modes $B \to \rho\rho$, but there is a disagreement for the penguin-induced decays $B^0 \to \varphi K^{*0}, \ldots$ as shows the below Table.

Decay mode	BR(10^{-6})	$f_{\rm L}$
$B^0 \to \rho^+\rho^-$	23.5 ± 4.6	0.98 ± 0.03
$B^0 \to \rho^0\rho^0$	1.2 ± 0.4	0.86 ± 0.13
$B^0 \to \varphi K^{*0}$	11.1 ± 1.1	0.52 ± 0.05
$B^+ \to \rho^+ K^{*0}$	9.6 ± 2.3	0.52 ± 0.11
$B^0 \to \omega K^{*0}$	2.4 ± 1.3	0.71 ± 0.25

It is important to notice that CDF [69] has confirmed the BaBar [70] and BELLE data on $f_{\rm L}(B \to \varphi K^*)$. Interestingly, Penguin-like modes like $B^+ \to \rho^+ K^{*0}$ give values for $f_{\rm L}$ that are consistent with $B^0 \to \varphi K^{*0}$. There is a number of models that suggest new Standard Model contributions to these longitudinal polarization fractions, like considering the effect of penguin annihilation [71], the effect of the c-Penguin [72] or rescattering effects [73]. We will develop this last mechanism in Section 3.6.

2.3.5. Rare decays $b \to s\gamma$

This is a rare electroweak penguin process that could be sensitive to New Physics. The SM branching ratio, including NLO QCD corrections is [7]

$$\mathrm{BR}(b \to s\gamma) = \left(3.61 \begin{array}{l} +\ 0.37 \\ -\ 0.49 \end{array}\right) \times 10^{-4}\,,$$

to be compared to the BaBar experimental result

$$\mathrm{BR}(b \to s\gamma) = (3.67 \pm 0.53) \times 10^{-4}\,.$$

As it is well known, the NLO corrections are large, of the order of 25% and hence the necessity of calculating the NNLO QCD corrections, that have been reviewed by Hurth [74, 75] and, since Euridice members have been involved in its calculation, will be detailed in Section 3.2.

Another related process is the mixing-induced CP asymmetry in $B \to K^*\gamma \to K_s\pi^0\gamma$ where $K_s\pi^0$ is a CP eigenstate. This asymmetry is sensitive to the right-handed photon operator that could come from NP and is given by the expression

$$A_{\rm CP}^{\rm mix}(B \to K^*\gamma) = \frac{2\ \mathrm{Im}\left(e^{-i\varphi_M} C_7 C_7'\right)}{|C_7|^2 + |C_7'|^2}\,,$$

where the effective Hamiltonian is

$$\mathcal{H} = \frac{4G_{\rm F}}{\sqrt{2}} \left[C_7' \left(\overline{s}_{\rm R} \sigma^{\mu\nu} b_{\rm L} \right) F_{\mu\nu} + C_7 \left(\overline{s}_{\rm L} \sigma^{\mu\nu} b_{\rm R} \right) F_{\mu\nu} + {\rm h.c.} \right] .$$

Naively, since in the SM the photon has a left-handed polarization, the asymmetry is suppressed by the mass ratio $\frac{m_s}{m_b}$ that at most is of the order of a few %. The method has been extended to multibody final states like $B \to K^*(\to K_s \pi^0)\gamma$. In this case, it has been shown using factorization in QCD as follows from SCET, that the separation of NP effects is polluted by terms of order $\Lambda_{\rm QCD}/m_b$ and $A_{\rm CP}^{\rm mix}(B \to K^* \gamma)$ could be of the order of 10% in the SM [76].

2.3.6. Forward–backward asymmetry $B \to K^{(*)} \ell^+ \ell^-$

The forward–backward asymmetry $A_{\rm FB}$ for the processes $B \to K^{(*)} \ell^+ \ell^-$ is a very interesting observable which gives the possibility of testing NP. For example, $A_{\rm FB}$ in $B \to K^* \ell^+ \ell^-$ has a zero in the SM for a very stable value of the effective mass $m^2_{\ell^+ \ell^-}$, as computed within the QCD Factorization approach [77] or within Soft Collinear Effective Theory [78], and the sign is well defined in the low and high values of $m^2(\ell^+ \ell^-)$. Models beyond the SM predict other behaviours for $A_{\rm FB}(m^2_{\ell^+ \ell^-})$, providing clean tests of these models. Both BELLE [79] and BaBar [80] have already measured the branching ratios of $B \to K^{(*)} \ell^+ \ell^-$ and produced preliminary data on the corresponding forward–backward asymmetries.

2.4. Conclusions on the status of B physics

In conclusion, the Standard Model is in rather good quantitative agreement with the data, and CKM physics has entered its precision era.

However, there are some problems or room for New Physics:

(1) In the Penguin modes one obtains, averaging over all modes, $\sin 2\beta_{\rm eff} = 0.52 \pm 0.05$, *i.e.* a 2.6σ effect relatively to the tree mode. One needs much more statistics to settle this problem due to the small BR of the Penguin decays.

(2) There is a $\sim 2\sigma$ tension between $(\sin 2\beta)_{\rm observed}$ and $(\sin 2\beta)_{\rm global\,fit}$ using the recent determination of $|V_{ub}|_{\rm inclusive}$.

(3) There is some room ($\sim 1.5\sigma$) in Δm_s for New Physics.

3. Survey of the Euridice contribution to B physics

3.1. Outline of the topics treated within Euridice

The Euridice network has contributed to a number of topics in B physics in the last four years. Besides the general important synthesis and critical work done within the CKMfitter Group to extract the fundamental parameters of the Standard Model, in which the Marseille node has been very active [2, 81], and the collective work in the CKM matrix Workshop [82], to which several Euridice members have contributed, these topics can be grouped in the following general trends:

1) Higher order QCD corrections to rare decays have been worked out at the nodes of Bern, Frascati and Warsaw, in particular the completion of the NLO QCD calculation to $\overline{B} \to X_s\gamma$ [83], the effect of charm loops in $\overline{B} \to X_s\gamma$ [84], three loop matching of the dipole operators $b \to s\gamma$ and $b \to sg$ [85, 86], NNLO QCD corrections to $\overline{B} \to X_s\gamma$ [87–91] and NNLO calculations for $\overline{B} \to X_s\ell^+\ell^-$ [92–94].

2) Bjorken-like sum rules, theorems on the Isgur–Wise function $\xi(w)$ and on the subleading, at order in $1/m_Q$, form factors in Heavy Quark Effective Theory (Paris node [95–97]).

3) Contributions to QCD Factorization and Soft Collinear Effective Theory have been done at the nodes of Bari, Durham and Paris, in particular the decays of B mesons into axial-vector mesons [98, 99], power corrections in charmless B decays [100], the question of the contribution of the charming penguin to charmless B decays [101], the rare decay $\overline{B} \to \gamma\ell\overline{\nu}_\ell$ [102, 103] and B decays using QCDF and flavour symmetries [104].

4) Light-Cone QCD Sum Rules, has been a main activity in the node of Durham, in particular the decays $B \to \overline{K}^*\gamma$, $\rho\gamma$ [105] and the heavy-to-light form factors of the type $\overline{B} \to \pi$ [106, 107] have been investigated.

5) Constraints on the Unitarity Triangle from CP violating and CP conserving observables (Barcelona and Marseille nodes [2, 81, 108–111]).

6) Exclusive B decays have been studied at the nodes of Bari, Paris and Oslo, in particular the $B \to VV$ [73], $B \to (c\overline{c})K$ [112–115], relations for direct CP asymmetries in $B \to PP$ and $B \to PV$ [116], rates and CP violation in $B \to \pi\pi$ [117, 118] and exclusive rare B decays into D mesons [119–122].

7) New Physics in B decays at the Barcelona, Bari, Durham, Frascati and Paris nodes, in particular Minimal Flavor Violation [123], Two Higgs models in flavour physics [124,125], New Physics in B^0–$\overline{B}^0$ mixing [126, 127], SUSY models in B decays [128–130], Extra Dimensions in B decays [131–133].

8) Quantum Mechanics in B–$\overline{B}$ System (Barcelona node [134]).

It is not possible to review here all these topics, and we will concentrate only on a few most significant results.

3.2. NNLO QCD contributions to rare decays

The rare weak inclusive radiative decay $\overline{B} \to X_s\gamma$ is known to be a sensitive probe of New Physics. The NLO QCD radiative corrections are large, and therefore the corrections have to be computed at higher orders. The status of the calculation of higher orders has been reviewed by Misiak [90], that we sketch now. The situation can be summarized by the formula

$$
\begin{aligned}
\mathrm{BR}(\overline{B} \;\to\; X_s\gamma)_{E_\gamma>1.6\ \mathrm{GeV}} &= \mathrm{BR}(\overline{B} \to X_c e\overline{\nu})_{\exp} \left[\frac{\Gamma(b \to s\gamma)}{\Gamma(b \to ce\overline{\nu})}\right]_{\mathrm{LO\,EW}} \\
&\times f_{\mathrm{LO}} \left[\frac{\alpha_{\mathrm{s}}(M_{\mathrm{W}})}{\alpha_{\mathrm{s}}(m_b)}\right] \Big[1 + \mathcal{O}(\alpha_{\mathrm{s}}) + \mathcal{O}(\alpha_{\mathrm{s}}^2) + \mathcal{O}(\alpha_{\mathrm{em}}) \\
&+ \mathcal{O}\left(\frac{\Lambda^2}{m_b^2}\right) + \mathcal{O}\left(\frac{\Lambda^2}{m_c^2}\right) + \mathcal{O}\left(\frac{\alpha_{\mathrm{s}}\Lambda}{m_b}\right)\Big]\,,
\end{aligned}
$$

where $\mathrm{BR}(\overline{B} \to X_c e\overline{\nu})_{\exp}$ is the measured semileptonic branching ratio, $[\Gamma(b \to s\gamma)/\Gamma(b \to ce\overline{\nu})]_{\mathrm{LO\,EW}}$ is computed perturbatively at the leading order in electroweak interactions and neglecting QCD effects, $f_{\mathrm{LO}}[\alpha_{\mathrm{s}}(M_{\mathrm{W}})/\alpha_{\mathrm{s}}(m_b)]$ is the LO QCD correction factor. Normalization to the semileptonic rate is introduced to eliminate uncertainties from the CKM angles and overall factors of m_b. The corrections are of $\mathcal{O}(\alpha_{\mathrm{s}}) \sim 25\%$ (NLO), $\mathcal{O}(\alpha_{\mathrm{s}}^2) \sim 7\%$ (NNLO), $\mathcal{O}(\alpha_{\mathrm{em}}) \sim 4\%$. The NLO corrections are very large, hence the necessity of a calculation at NNLO. The NNLO estimation quoted above was made sometime ago, before the recent more accurate calculation. An important feature of the inclusive decay is that there are no corrections of order Λ/m_Q and therefore the non-perturbative effects are relatively small $\mathcal{O}(\Lambda^2/m_b^2) \sim 1\%$, $\mathcal{O}(\Lambda^2/m_c^2) \sim 3\%$, $\mathcal{O}(\alpha_{\mathrm{s}}\Lambda/m_b) <\sim 5\%$. Adding the errors in quadrature, the world average experimental branching ratio is $\mathrm{BR}(\overline{B} \to X_s\gamma)_{E_\gamma>1.6\ \mathrm{GeV}} = (3.55 \pm 0.26) \times 10^{-4}$.

An enormous effort has been made to compute the NNLO corrections. The calculations include three-loop matching conditions, four-loop anomalous dimensions and two- and three-loop on-shell amplitudes. Certain parts of the three-loop matrix elements are found by interpolation in the charm quark mass between the large-β_0 approximation in the $m_c = 0$ case and the complete result in the $m_c \gg m_b/2$ case. The NNLO correction to the branching ratio for $E_\gamma > 1.6$ GeV can be parametrized by the expression

$$\mathrm{BR}_{\mathrm{NNLO}}(r) = \mathrm{BR}_{\mathrm{NLO}}(r) + \mathrm{BR}_{\mathrm{NLO}}(0.262)\left[\delta_1 + \delta_2(r) + \delta_3(r)\right] ,$$

where $r = m_c/m_b$, $\mathrm{BR}_{\mathrm{NLO}}(0.262) \cong 3.38 \times 10^{-4}$ and $\delta_1, \delta_2, \delta_3$ depend on the Wilson coefficients

$$C_i(m_b) = C_i^{(0)}(m_b) + \frac{\alpha_{\mathrm{s}}(m_b)}{4\pi} C_i^{(1)}(m_b) + \left(\frac{\alpha_{\mathrm{s}}(m_b)}{4\pi}\right)^2 C_i^{(2)}(m_b) + \dots ,$$

where the index i runs over the operators involved in the process: tree ($i = 1, 2$), Penguin ($i = 3, \dots 6$), magnetic ($i = 7$) and chromomagnetic ($i = 8$) operators. The parameter δ_1 depends on $C_i^{(0)} C_j^{(2)}$ and $C_i^{(1)} C_j^{(1)}$, δ_2 on $C_i^{(0)} C_j^{(0)}$ and δ_3 has terms proportional to $C_i^{(0)} C_j^{(1)}$. The parameter δ_2 can be splitted as $\delta_2 = \delta_2^{\beta_0} + \delta_2^{\mathrm{rem}}$, where $\delta_2^{\beta_0}$ is known for all r while the remaining piece δ_2^{rem} is known only for $r \gg \frac{1}{2}$ and needs to be interpolated at low r. Two ways of interpolation give $3.06 \times 10^{-4} < \mathrm{BR}_{\mathrm{NNLO}} < 3.24 \times 10^{-4}$, a result that is below the $\mathrm{BR}_{\mathrm{NLO}}$ by about 7%.

The average $\mathrm{BR}_{\mathrm{NNLO}} = 3.15 \times 10^{-4}$ is 1.5σ below the experimental result, severely constraining physics beyond the Standard Model.

3.3. Minimal Flavor Violation

In an important paper, D'Ambrosio, Giudice, Isidori and Strumia [123] have made a general analysis of extensions of the Standard Model satisfying the criterion of Minimal Flavor Violation (MFV), underlying the symmetry principle behind MFV.

The hierarchy problem or stabilization of the Higgs mass requires that there should be New Physics at a scale $\Lambda \lesssim$ few TeV. On the other hand, the data seems to indicate that there are no general flavor-violating interactions at a scale $\Lambda \lesssim$ TeV. One way out to solve this contradiction is to ask that NP schemes satisfy the principle of MFV, that schematically asks for all flavour and CP-violating interactions to be related to the known structure of the Yukawa couplings. The interest of MFV is that it is a symmetry principle and can be imposed to NP schemes like *e.g.* extensions of the SM with one Higgs doublet or two-Higgs models, or Supersymmetry.

It is important to underline the algebraic nature of th MFV principle, that we will summarize here. In the SM one has two $\mathrm{SU}(2)_{\mathrm{L}}$ doublets $(Q_{\mathrm{L}}, L_{\mathrm{L}})$ and three $\mathrm{SU}(2)_{\mathrm{L}}$ singlets (U_{R}, D_{R} and E_{R}). Considering this fermion structure plus the $\mathrm{SU}(2)_{\mathrm{L}} \times \mathrm{U}(1)$ gauge group, the global symmetry of the gauge part of the SM is large, $G_{\rm F} = {\rm U}(3)^5$, and can be decomposed as

$$G_{\rm F} = {\rm SU}(3)^3_q \otimes {\rm SU}(3)^2_\ell \otimes {\rm U}(1)_{\rm B} \times {\rm U}(1)_{\rm L} \otimes {\rm U}(1)_{\rm Y} \otimes {\rm U}(1)_{\rm PQ} \otimes {\rm U}(1)_{E_{\rm R}}$$

with ${\rm SU}(3)^3_q = {\rm SU}(3)_{Q_{\rm L}} \otimes {\rm SU}(3)_{U_{\rm R}} \otimes {\rm SU}(3)_{D_{\rm R}}$ and ${\rm SU}(3)^2_\ell = {\rm SU}(3)_{L_{\rm L}} \otimes {\rm SU}(3)_{E_{\rm R}}$.

In the SM the Yukawa interactions

$$\mathcal{L}_{\rm Yukawa} = \overline{Q}_{\rm L} Y_{\rm D} D_{\rm R} H + \overline{Q}_{\rm L} Y_{\rm U} U_{\rm R} H^c + \overline{L}_{\rm L} Y_{\rm E} E_{\rm R} H + {\rm h.c.}$$

break the symmetry group ${\rm SU}(3)^3_q \otimes {\rm SU}(3)^2_\ell \times {\rm U}(1)_{\rm PQ} \times {\rm U}(1)_{E_{\rm R}}$ while they preserve the ${\rm U}(1)_{\rm B} \times {\rm U}(1)_{\rm L} \times {\rm U}(1)_{\rm Y}$ part. The symmetry principle that is imposed is to promote the Yukawa couplings to background dimensionless fields or spurions, transforming like

$$Y_{\rm U} \sim (3, \overline{3}, 1), Y_{\rm U} \sim (3, 1, \overline{3}), \left[\text{under } {\rm SU}(3)^3_q\right], Y_{\rm E} \sim (3, \overline{3}), \left[\text{under } {\rm SU}(3)^2_\ell\right]$$

then, $\mathcal{L}_{\rm Yukawa}$ is consistent with the flavor symmetry and it describes the most general coupling of the Y fields to renormalizable SM operators. Without loss of generality one can rotate the auxiliary fields Y and set

$$Y_{\rm D} = \lambda_d \quad Y_{\rm L} = \lambda_\ell \quad Y_{\rm U} = V^+ \lambda_u \,,$$

where λ are diagonal matrices and V is the CKM matrix.

One then defines any effective theory that satisfies the criterion of MFV if all the higher dimension operators constructed from SM and Y fields are invariant under CP and under the flavour group $G_{\rm F}$. The consequence is that the dynamics of flavour violation is completely determined by the ordinary Yukawa couplings and that the unique CP-violating phase is the CKM phase. Moreover, since the SM Yukawa couplings for all fermions except the top are small, the unique structure is obtained by contracting two $Y_{\rm U}$,

$$(\lambda_{\rm FC})_{ij} = \left(Y_{\rm U} Y_{\rm U}^+\right)(1 - \delta_{ij}) \cong \lambda_t^2 V_{3i}^* V_{3j} (1 - \delta_{ij}) \,,$$

and $\lambda_{\rm FC}$ is the effective coupling governing all FCNC processes with external down quarks.

The rule for the construction of effective NP theories is then to build all possible higher dimension operators made out of the possible dimension three operators that, for example in the case of extensions of the SM with one Higgs doublet, are $\overline{Q}_{\rm L} Y_{\rm U} Y_{\rm U}^+ Q_{\rm L}$, $\overline{D}_{\rm R} Y_{\rm D}^+ Y_{\rm U} Y_{\rm U}^+ Q_{\rm L}$, $\overline{D}_{\rm R} Y_{\rm D}^+ Y_{\rm U} Y_{\rm U}^+ Y_{\rm D} D_{\rm R}$. By expansion in powers of the small Yukawa couplings this gives the only possible bilinear structures $\overline{Q}_{\rm L} \lambda_{\rm FC} Q_{\rm L}$ and $\overline{D}_{\rm R} \lambda_d \lambda_{\rm FC} Q_{\rm L}$.

From this bilinear structures one can construct $\Delta F = 2$ and $\Delta F = 1$ dimension 6 operators $\mathcal{O}_n$ and get the possible NP structure

$$\mathcal{H}_{\text{eff}} = \frac{1}{\Lambda^2} \sum_n a_n \mathcal{O}_n \, .$$

One can then go to phenomenology to constrain the parameters characterizing the NP scheme, *i.e.* a_n/Λ^2. Of course, different observables constrain in different ways these parameters and give an idea of the possible extensions of the SM.

The method has been extended to theories with two Higgs doublets where, due to the possibility of large $\tan\beta$, the bilinear $Y_{\mathrm{D}} Y_{\mathrm{D}}^{+}$ can also enter, and to Supersymmetry, in particular the MSSM with conserved R-parity and supersymmetry soft-breaking terms.

3.4. Bjorken-like sum rules in HQET

Within the Operator Product Expansion, new sum rules have been formulated in Heavy Quark Effective Theory in the heavy quark limit [95, 97] and at order $1/m_Q$ [96], using the non-forward amplitude [135]. These sum rules imply that the elastic Isgur–Wise function $\xi(w)$ is an alternate series in powers of $(w-1)$. Moreover, one obtains that the n-th derivative of $\xi(w)$ at $w = 1$ is bounded by the $(n-1)$-th one

$$(-1)^n \, \xi^{(n)}(1) \geq \frac{2n+1}{4} \left[(-1)^{n-1} \xi^{(n-1)}(1) \right]$$

yielding the absolute bound

$$(-1)^n \, \xi^{(n)}(1) \geq \frac{(2n+1)!!}{2^{2n}} \, .$$

Moreover, for the curvature one has found the stronger bound

$$\xi''(1) \geq \frac{1}{5} \left[4\rho^2 + 3(\rho^2)^2 \right] \, ,$$

where ρ^2 is the slope $\rho^2 = -\xi'(1)$. The simple parametrization

$$\xi(w) = \left(\frac{2}{w+1} \right)^{2\rho^2} \qquad \text{with} \quad \rho^2 \geq \frac{3}{4}$$

satisfies all these bounds. These results are consistent with the dispersive bounds, and they strongly reduce the allowed region of the latter for $\xi(w)$.

The method has been extended to the subleading form factors at order $1/m_Q$, that of two types, Current perturbations and Lagrangian perturbations. Concerning the perturbations of the current, one has derived new simple linear relations between the functions $\xi_3(w)$ and $\overline{\Lambda}\xi(w)$ and the sums

$$\sum_n \Delta E_j^{(n)} \tau_j^{(n)}(1) \tau_j^{(n)}(w) \quad \left(j = \frac{1}{2}, \frac{3}{2}\right)$$

that involve leading quantities, Isgur–Wise functions $\tau_j^{(n)}(w)$ and level spacings $\Delta E_j^{(n)}$. These results follow because the non-forward amplitude depends on three variables $(w_i, w_f, w_{if}) = (v_i \cdot v', v_f \cdot v', v_i \cdot v_f)$ where v_i, v_f are the initial and final four-velocities of the B meson and v' is the one of the intermediate $D^{(n)}$ mesons. At the zero recoil frontier $(w, 1, w)$ only a finite number of $j^P = \left(\frac{1}{2}^+, \frac{3}{2}^+\right)$ states contribute.

New sum rules have also been obtained for the elastic subleading form factors $\chi_i(w)$ $(i = 1, 2, 3)$ at order $1/m_Q$ that originate from the $\mathcal{L}_{\rm kin}$ and $\mathcal{L}_{\rm mag}$ perturbations of the Lagrangian. To the sum rules contribute only the same intermediate states $j^P = \left(\frac{1}{2}^-, \frac{3}{2}^-\right)$ that enter in the $1/m_Q^2$ corrections of the axial form factor $h_{A_1}(w)$ at zero recoil, crucial for the exclusive determination of $|V_{cb}|$. This allows to obtain a lower bound on the correction $-\delta_{1/m^2}^{(A_1)}$ in terms of the $\chi_i(w)$ and derivatives of the elastic IW function $\xi(w)$. An important theoretical implication is that $\chi_1'(1)$, $\chi_2(1)$ and $\chi_3'(1)$ $(\chi_1(1) = \chi_3(1) = 0$ from Luke theorem) must vanish in the limit in which the slope and the curvature attain their lowest values $\rho^2 \to \frac{3}{4}$, $\sigma \to \frac{15}{16}$. These constraints should be taken into account in a realistic parametrization of the functions $\chi_i(w)$ for the extraction of $|V_{cb}|$.

3.5. The decay $\overline{\boldsymbol{B}} \to \gamma \ell \overline{\nu}_\ell$ within QCD Factorization

The rare radiative decay $\overline{B} \to \gamma \ell \overline{\nu}_\ell$ is quite interesting in its apparent hadronic simplicity, since it depends directly on the so-called Light Cone Distribution Amplitudes (LCDA) of the B meson. Descotes-Genon and Sacharadja [102] have studied this process in the framework of QCD Factorization. They have essentially demonstrated that, in the heavy quark limit and at one-loop order, the amplitude can be written as a convolution of a perturbatively hard scattering amplitude with a non-perturbative LCDA of the B-meson.

The amplitude $\overline{B} \to \gamma \ell \overline{\nu}_\ell$ writes in terms of two form factors

$$\begin{aligned} &\langle \gamma(\varepsilon^*, q) | \overline{u} \gamma_\mu (1 - \gamma_5) b | \overline{B}(p) \rangle \\ &= \sqrt{4\pi\alpha} \left\{ \varepsilon_{\mu\nu\rho\sigma} \varepsilon^{*\nu} v^\rho q^\sigma F_V(E_\gamma) + i \left[\varepsilon_\nu^* (v \cdot q) - q_\mu (v \cdot \varepsilon^*) \right] F_A(E_\gamma) \right\} . \end{aligned}$$

They obtain the one-loop factorized expression for the form factors, including the resummation of leading and next-to-leading logarithms,

$$F_V(E_\gamma) = F_A(E_\gamma) = \int dk_+ \Phi_+^B(k_+, \mu_{\rm F}) T(k_+, E_\gamma, \mu_{\rm F})\,,$$

where the LCDA $\Phi_+^B(k_+)$ is the Fourier transform of $\widetilde{\Phi}_+^B(z)$ defined by

$$\begin{aligned}
&\langle 0|\overline{u}_\beta(z)[z,0]b_\alpha(0)|\overline{B}(p)\rangle \\
&= -i\frac{f_B M_B}{4}\left\{\frac{1+\not{v}}{2}\left[2\widetilde{\Phi}_+^B(z) + \frac{\not{z}}{t}\left(\widetilde{\Phi}_-^B(z) - \widetilde{\Phi}_+^B(z)\right)\right]\gamma_5\right\}_{\alpha\beta},
\end{aligned}$$

$v = \frac{p}{M_B}$, $t = v \cdot z$, $\mu_{\rm F} \cong \mathcal{O}(\sqrt{m_b \Lambda_{\rm QCD}})$ and the hard kernel is given by

$$\begin{aligned}
T(k_+, E_\gamma, \mu_{\rm F}) &= C(\mu_{\rm F})\frac{f_B Q_u M_B}{2\sqrt{2}E_\gamma}\frac{1}{k_+} \\
&\times \left\{1 + \frac{C_{\rm F}\alpha_{\rm s}(\mu_{\rm F})}{4\pi}\left[{\rm Log}^2\left(\frac{2q_- k_+}{\mu_{\rm F}^2}\right) - \frac{\pi^2}{6} - 1\right]\right\},
\end{aligned}$$

and $C(\mu_{\rm F}) = C_3(\mu_{\rm F}) = C_6(\mu_{\rm F})$ is the Wilson coefficient of the matching of the current onto the relevant operators O_3, O_6 of the SCET effective theory [136]

$$\overline{u}\gamma^\mu(1-\gamma_5)b = \sum_i C_i(\mu) O_i^\mu(\mu)\,.$$

The differential rate is given by the expression

$$\frac{d\Gamma}{dE_\gamma} = \frac{\alpha G_{\rm F}^2 |V_{ub}|^2 M_B^4}{48\pi^2}\, R(1-R)^3\left[F_V^2(E_\gamma) + F_A^2(E_\gamma)\right],$$

with $R = 1 - 2E_\gamma/M_B$. At leading order one has

$$F_V^{\rm LO}(E_\gamma) = F_A^{\rm LO}(E_\gamma) = \frac{f_B Q_u M_B}{2E_\gamma \lambda_B} = \frac{1}{1-R}\,\frac{f_B Q_u}{\lambda_B}\,,$$

where λ_B is an important parameter, the first inverse moment of the B-meson LCDA

$$\frac{\sqrt{2}}{\lambda_B} = \int_0^\infty \frac{dk_+}{k_+}\Phi_+^B(k_+)$$

for which a number of estimates have been given in the literature. The authors adopt the value of [137] $\lambda_B = (350 \pm 150)$ MeV.

The final integrated branching ratio is found to be at LO,

$$\begin{aligned}\mathrm{BR}^{\mathrm{LO}}(E_\gamma^c) \;&=\; 18.4\times 10^{-6}\left(\frac{|V_{ub}|}{3.6\times 10^{-3}}\right)^2\left(\frac{f_B}{190\ \mathrm{MeV}}\right)^2\\ &\quad\times\left(\frac{350\ \mathrm{Mev}}{\lambda_B}\right)^2 R_c^2\left(1-\frac{2R_c}{3}\right),\end{aligned}$$

where E_λ^c is a lower cut-off on the photon energy. The NLO corrections depend strongly on $R_c = 1 - 2E_\gamma^c/M_B$. The difference between the LO and the NLO results is typically of the order of 25%.

3.6. The riddle of polarization in $B \to VV$ transitions

Colangelo, De Fazio and Pham made an interesting contribution to the possible resolution of this puzzle [73]. As we have seen in Section 1.3.4, the longitudinal polarization fraction is experimentally found much lower in Penguin-induced modes like $\overline{B} \to \varphi\overline{K}^*$ than in similar tree processes like $\overline{B} \to \rho\rho$. There are general reasons to expect that the decay $\overline{B} \to VV$ where V are light vector mesons should be mainly longitudinally polarized [71].

Let us recall the argument within the hypothesis of factorization. The amplitude $A(\overline{B} \to \varphi\overline{K}^*)$ writes then

$$\begin{aligned}A_{\mathrm{fact}}(\overline{B}^0 \to \varphi\overline{K}^{*0}) &= \frac{G_{\mathrm{F}}}{\sqrt{2}} V_{tb}V_{ts}^* a_{\mathrm{W}} f_\varphi M_\varphi \left\{ -i\varepsilon_{\mu\nu\rho\sigma}\varepsilon^{*\mu}\eta^{*\nu}p^\rho p'^\sigma \frac{2V(M_\varphi^2)}{M_B+M_{K^*}}\right.\\ &\left. -(M_B+M_{K^*})A_1(M_\varphi^2)(\eta^*\cdot\varepsilon^*) + \frac{A_2(M_\varphi^2)}{M_B+M_{K^*}}(\eta^*\cdot p)\left[(p+p')\cdot\varepsilon^*\right]\right\},\end{aligned}$$

where a_{W} is a combination of Penguin Wilson coefficients. The transversity amplitudes are proportional to the quantities

$$A_{\mathrm{L}} \propto M_B^3\left\{A_1(M_\varphi^2) - A_2(M_\varphi^2) + \frac{M_{K^*}}{M_B}\left[A_1(M_\varphi^2) + A_2(M_\varphi^2)\right]\right\}$$

$$A_\perp \propto M_B A_1(M_\varphi^2)\,, \qquad A_\parallel \propto M_B V(M_\varphi^2)\,.$$

In the heavy quark limit $M_B \to \infty$ and large energy limit for the light meson the form factors $A_1(q^2)$, $A_2(q^2)$ and $V(q^2)$ depend on two universal functions [139]. The relations between these form factors imply $A_1(0) = A_2(0) = V(0)$, and one expects

$$\frac{\Gamma_{\mathrm{L}}}{\Gamma} \cong 1 + \mathcal{O}\left(\frac{\Lambda^2}{M_B^2}\right), \qquad \frac{\Gamma_\perp}{\Gamma_\parallel} \cong 1\,.$$

Invoking these general arguments, the deviation observed in $\overline{B} \to \varphi \overline{K}^*$ could be interpreted as a signal of New Physics [140]. Without invoking NP, one could advance an explanation of this deviation by invoking, beyond the strict framework of QCD factorization [141], logarithmically divergent annihilation diagrams that can modify the polarization amplitudes in $\overline{B} \to \varphi \overline{K}^*$ [71].

Colangelo *et al.* [73] have invoked another effect that can change the polarization in the Penguin transitions like $\overline{B} \to \varphi \overline{K}^*$ without affecting the observed $\overline{B} \to \rho\rho$, namely rescattering of intermediate charm states arising at the quark level from the process $b \to c\overline{c}s \to s\overline{s}s$, *i.e.* at lowest order the triangle diagram with exchange of $D_s^{(*)}$ in the t-channel,

$$\overline{B} \to \overline{D}_s^{(*)} D^{(*)} \to \varphi \overline{K}^* \,.$$

Such processes can give sizeable contributions to the Penguin amplitude since they involve Wilson coefficients of $\mathcal{O}(1)$, while the Wilson coefficient a_{W} in the Penguin process $b \to s\overline{s}s$ is smaller, of $\mathcal{O}(10^{-2})$. On the other hand, there is not a CKM suppression in such processes because $|V_{tb}V_{ts}^*| \cong |V_{cb}V_{cs}^*|$.

The estimation of these effects is somewhat model-dependent, but can be parametrized in a simple way. The absorptive part of the rescattering diagram can be written in the form

$$\mathrm{Im}\, A_{\mathrm{resc}} \propto \int_{-1}^{+1} d(\cos\theta) A\left(\overline{B}^0 \to D_s^{(*)-} D^{(*)+}\right) A\left(D_s^{(*)-} D^{(*)+} \to \varphi \overline{K}^{*0}\right) ,$$

where θ is the angle between the three-momenta of $D_s^{(*)-}$ and φ. The amplitude $A(\overline{B}^0 \to D_s^{(*)-} D^{(*)+})$ can be estimated using factorization and heavy quark symmetry and t-dependent couplings with a cut-off Λ have to be introduced to compute the triangle diagrams. Writing the total amplitude in the form $A = A_{\mathrm{fact}} + rA_{\mathrm{resc}}$, there are reasonable values of r that can fit the polarization amplitudes in $\overline{B} \to \varphi \overline{K}^*$.

In conclusion, FSI effects can modify the helicity amplitudes in Penguin dominated processes and at the same time the considered rescattering effects are too small to affect the observed $\overline{B} \to \rho\rho$.

In conclusion, the situation of B physics after the Moscow ICHEP 2006 Conference has been presented and a few main topics have been underlined. Also, a review of the contributions in the field within the Euridice EC network in the last four years has been sketched, developing some main works on this field.

We acknowledge support from the EC contracts HPRN-CT-2002-00311 (Euridice) and MRTN-CT-2006-035482 (Flavianet).

REFERENCES

[1] M. Bona *et al.* [UTfit Collaboration], *J. High Energy Phys.* **0610**, 081 (2006) [hep-ph/0606167]

[2] J. Charles [CKMfitter Group], Proceedings of the Flavor Physics and CP Violation Conference, Vancouver, Canada, April 2006, p. 043 [hep-ph/0606046].

[3] Y. Okada, Summary talk "CP Violation and CKM", ICHEP 06, Moscow, July 2006.

[4] M. Hazumi, Summary talk "Measurements of α/φ_2 and β/φ_1", ICHEP 06, Moscow, July 2006.

[5] M. Hazumi, *Nucl. Phys. (Proc. Suppl.)* **B163**, 5 (2007).

[6] R. Kowalewski, Summary talk "Measurements of V_{cb} and V_{ub}", ICHEP 06, Moscow, July 2006 [hep-ex/0610059].

[7] R. Barlow, Summary talk "Rare B and tau decays and searches for New Physics", ICHEP 06, Moscow, July 2006.

[8] D. Glenzinski, Summary talk "Hot topics from CDF and D0", ICHEP 06, Moscow, July 2006.

[9] K. Abe *et al.*, BELLE-CONF-0669, hep-ex/0611047.

[10] O. Buchmüller, H. Flächer, *Phys. Rev.* **D73**, 073008 (2006).

[11] P. Urquijo, [BELLE Collaboration], ICHEP 06, Moscow, July 2006 [hep-ex/0611049].

[12] D. Benson, I.I. Bigi, T. Mannel, N. Uraltsev, *Nucl. Phys.* **B665**, 367 (2003).

[13] P. Gambino, N. Uraltsev, *Eur. Phys. J.* **C34**, 181 (2004).

[14] N. Uraltsev, *Int. J. Mod. Phys.* **A20**, 2099 (2005).

[15] C.W. Bauer, Z. Ligeti, M. Luke, A.V. Manohar, *Phys. Rev.* **D67**, 054012 (2003).

[16] C. W. Bauer, Z. Ligeti, M. Luke, A. V. Manohar, M. Trott, *Phys. Rev.* **D70**, 094017 (2004).

[17] B. Aubert *et al.*, BABAR-PUB-05/052, *Phys. Rev.* **D74**, 092004 (2006) [hep-ex/0602023].

[18] D. Lopes Pegna [BaBar Collaboration], to appear in the Proceedings of ICHEP 06, Moscow, July 2006.

[19] S. Hashimoto *et al.*, *Phys. Rev.* **D66**, 014503 (2002) [hep-ph/0110253].

[20] S.W. Bosch, B. Lange, M. Neubert, G. Paz, *Nucl. Phys.* **B699**, 335 (2004) [hep-ph/0402094].

[21] B. Lange, M. Neubert, G. Paz, *Phys. Rev.* **D72**, 073006 (2005) [hep-ph/0504071]; *J. High Energy Phys.* **0510**, 084 (2005) [hep-ph/0508178].

[22] B. Aubert [BaBar Collaboration], *Phys. Rev. Lett.* **96**, 221801 (2006) [hep-ex/0601046].

[23] B. Aubert *et al.* [BaBar Collaboration], ICHEP 06, Moscow, July 2006 [hep-ex/0607060].

[24] B. Aubert *et al.*] [BaBar Collaboration], *Phys. Rev. Lett.* **97**, 211801 (2006) [hep-ex/0607089].

[25] B. Aubert *et al.*, [BaBar Collaboration], *Phys. Rev. Lett.* **98**, 091801 (2007) [hep-ex/0612020].

[26] M. Gronau, D. Wyler, *Phys. Lett.* **B265**, 172 (1991).

[27] D. Atwood, I. Dunietz, A. Soni, *Phys. Rev. Lett.* **78**, 3257 (1997); *Phys. Rev.* **D63**, 036005 (2001).

[28] A. Giri, Y. Grossman, A. Soffer, J. Zupan, *Phys. Rev.* **D68**, 054018 (2003) [hep-ph/0303187].

[29] A. Poluektov *et al.* [BELLE Collaboration], *Phys. Rev.* **D73**, 112009 (2006) [hep-ex/0604054].

[30] B. Aubert *et al.* [BaBar Collaboration], ICHEP 06, Moscow, July 2006 [hep-ex/0607104].

[31] C. Tarantino, to appear in the Proceedings of ICHEP 06, Moscow, July 2006 [hep-ph/0610306].

[32] M. Blanke, A.J. Buras, A. Poschenrieder, S. Recksiegel, C. Tarantino, *J. High Energy Phys.* **0701**, 066 (2007) [hep-ph/0610298].

[33] O. Tajima [BELLE Collaboration], ICHEP 06, Moscow, July 2006.

[34] K. George, "Measurements of CP violation in $B \to$ charm decays at BaBar", ICHEP 06, Moscow, July 2006.

[35] T.E. Browder, A. Datta, P.J. O'Donnell, S. Pakvasa, *Phys. Rev.* **D61**, 054009 (2000) [hep-ph/9905425].

[36] B. Aubert *et al.*, [BaBar Collaboration], ICHEP 06, Moscow, July 2006 [hep-ex/0607105].

[37] P. Krokovny *et al.* [BELLE Collaboration], *Phys. Rev. Lett.* **97**, 081801 (2006) [hep-ex/0605023].

[38] B. Aubert *et al.* [BaBar Collaboration], *Phys. Rev.* **D71**, 032005 (2005).

[39] M. Beneke, *Phys. Lett.* **B620**, 143 (2005) [hep-ph/0505075].

[40] H.-Y. Cheng, C.-K. Chua, A. Soni, *Phys. Rev.* **D72**, 094003 (2005) [hep-ph/0506268].

[41] A.R. Williamson, J. Zupan, *Phys. Rev.* **D74**, 014003 (2006); Erratum, *Phys. Rev.* **D74**, 03901 (2006) [hep-ph/0601214].

[42] H. Ishino, ICHEP 06, Moscow, July 2006.

[43] H. Ishino *et al.*, BELLE preprint 2006-03.

[44] S. Telnov, ICHEP 06, Moscow, July 2006.

[45] N.G. Deshpande, X.-G. He, *Phys. Rev. Lett.* **75**, 1703 (1995).

[46] M. Gronau, J.L. Rosner, *Phys. Lett.* **B595**, 339 (2004).

[47] A. Somov *et al.* [BELLE Collaboration], *Phys. Rev. Lett.* **96**, 171801 (2006) [`hep-ex/0601024`].

[48] B. Aubert *et al.* [BaBar Collaboration], ICHEP 06, Moscow, July 2006 [`hep-ex/0607098`].

[49] B. Aubert *et al.*, [BaBar Collaboration], ICHEP 06, Moscow, July 2006 [`hep-ex/0607097`].

[50] K. Abe *et al.*, [BELLE Collaboration], ICHEP 06, Moscow, July 2006 [`hep-ex/0609003`].

[51] B. Aubert *et al.* [BaBar Collaboration], ICHEP 06, Moscow, July 2006 [`hep-ex/0608002`].

[52] A. Abulencia *et al.*, *Phys. Rev. Lett.* **97**, 062003 (2006) [`hep-ex/0606027`].

[53] A. Abulencia *et al.*, *Phys. Rev. Lett.* **97**, 242003 (2006) [`hep-ex/0609040`].

[54] S. Giagu, for the CDF Collaboration, ICHEP 06, Moscow, July 2006.

[55] K. Ikado *et al.* [BELLE Collaboration], *Phys. Rev. Lett.* **97**, 252802 (2006) [`hep-ex/0604018`].

[56] T. Browder, "Rare *B* decays with missing energy at BELLE", ICHEP 06, Moscow, July 2006.

[57] T. Browder, presented at ICHEP 06, Moscow, July 2006.

[58] Y. Grossman, H. Haber, Y. Nir, *Phys. Lett.* **B357**, 630 (1995) [`hep-ph/9507213`].

[59] D. Biskulic *et al.* [ALEPH Collaboration], *Phys. Lett.* **B343**, 444 (1995).

[60] M. Acciarri *et al.* [L3 Collaboration], *Phys. Lett.* **B332**, 201 (1994).

[61] W.S. Hou, *Phys. Rev.* **D48**, 2342 (1993).

[62] H. Ito, S. Komine, Y. Okada, *Progr. Theor. Phys.* **114**, 179 (2005) [`hep-ph/0409228`].

[63] E. Di Marco, presented at ICHEP 06, Moscow, July 2006.

[64] Y. Unno, presented at ICHEP 06, Moscow, July 2006.

[65] M. Gronau, *Phys. Lett.* **B627**, 82 (2005) [`hep-ph/0508047`].

[66] J. Dragic, "Charmless two-body B decays at BELLE", ICHEP 06, Moscow, July 2006.

[67] H. J. Lipkin,, *Phys. Lett.* **B445**, 403 (1999) [`hep-ph/9810351`].

[68] A. Buras, R. Fleischer, S. Recksiegel, F. Schwab, *Eur. Phys. J.* **C45**, 701 (2006) [`hep-ph/0512032`].

[69] S. Farrington, "Rare *B* decays at CDF", presented for the CDF Collaboration at ICHEP 06, Moscow, July 2006.

[70] B. Aubert *et al.*, *Phys. Rev. Lett.* **98**, 051801 (2007) [`hep-ex/0610073`].

[71] A. L. Kagan, *Phys. Lett.* **B601**, 151 (2004) [`hep-ph/0405134`].

[72] C. W. Bauer *et al.*, *Phys. Rev.* **D70**, 054015 (2004) [`hep-ph/0401188`].

[73] P. Colangelo, F. De Fazio, T.N. Pham, *Phys. Lett.* **597** 291 (2004) [`hep-ph/0406162`].

[74] T. Hurth, talk given at the ICHEP 06 Conference, Moscow (July 2006), to appear in the Proceedings.

[75] T. Hurth, *Int. J. Mod. Phys.* **A22**, 1781 (2007) [hep-ph/0703226].

[76] B. Grinstein, D. Pirjol, *Phys. Rev.* **D73**, 014013 (2006) [hep-ph/0510104].

[77] M. Beneke, Th. Feldman, D. Seidel, *Nucl. Phys.* **B612**, 25 (2001) [hep-ph/0106067].

[78] A. Ali, G. Kramer, G. Zhu, *Eur. Phys. J.* **C47**, 625 (2006) [hep-ph/0601034].

[79] A. Ishikawa *et al. Phys. Rev. Lett.* **96**, 251801 (2006) [hep-ex/0603018].

[80] B. Aubert *et al.*, *Phys. Rev.* **D73**, 092001 (2006) [hep-ex/0604007].

[81] J. Charles *et al.* [CKMfitter Group], *Eur. Phys. J.* **C41**, 1 (2005) [hep-ph/0406184].

[82] M. Battaglia *et al.*, "The CKM Matrix, the Unitarity Triangle", Proceedings of the Workshop, CERN, Geneva [hep-ph/0304132].

[83] A.J. Buras, A. Czarnecki, M. Misiak, J. Urban, *Nucl. Phys.* **B631**, 219 (2002) [hep-ph/0203135].

[84] M. Misiak, *Nucl. Phys. Proc. Suppl.* **116**, 279 (2003).

[85] M. Misiak, M. Steinhauser, *Nucl. Phys.* **B683**, 277 (2004) [hep-ph/0401041].

[86] M. Gorbahn, U. Haisch, M. Misiak, *Phys. Rev. Lett.* **95**, 102004 (2005) [hep-ph/0504194].

[87] K. Bieri, C. Greub, *Eur. Phys. J.* **C33**, S277 (2004) [hep-ph/0310214].

[88] H.M. Asatrian, A. Hovhannisyan, V. Poghosyan, C. Greub, T. Hurth, Proceedings of the EPS International Europhysics Conference on High Energy Physics, Lisbon, July 2005 [hep-ph/0512097].

[89] M. Misiak *et al.*, *Phys. Rev. Lett.* **98**, 022002 (2007) [hep-ph/0609232].

[90] M. Misiak, Talk given at the 41st Rencontres de Moriond, La Thuile, March 2006 [hep-ph/0609289].

[91] H.M. Asatrian, T. Ewerth, A. Ferroglia, P. Gambino, C. Greub, *Nucl. Phys.* **B762**, 212 (2007) [hep-ph/0607316].

[92] H.H. Asatryan, H.M. Asatrian, C. Greub, M. Walkner, *Phys. Rev.* **D66**, 034009 (2002) [hep-ph/0204341].

[93] A. Ghinculov, T. Hurth, G. Isidori, Y.P. Yao, *Nucl. Phys.* **B648**, 254 (2003) [hep-ph/0208088]; *Nucl. Phys. Proc. Suppl.* **116**, 284 (2003) [hep-ph/0211197]; *Eur. Phys. J.* C **33**, S288 (2004) [hep-ph/0310187]; *Nucl. Phys.* **B685**, 351 (2004) [hep-ph/0312128].

[94] H.M. Asatrian, K. Bieri, C. Greub, A. Hovhannisyan, *Phys. Rev.* **D66**, 094013 (2002) [hep-ph/0209006].

[95] A. Le Yaouanc, L. Oliver, J.-C. Raynal, *Phys. Rev.* **D67**, 114009 (2003) [hep-ph/0210233]; *Phys. Lett.* **B557**, 207 (2003) [hep-ph/0210231]; *Phys. Rev.* **D69**, 094022 (2004) [hep-ph/0307197].

[96] F. Jugeau, A. Le Yaouanc, L. Oliver, J.-C. Raynal, *Phys. Rev.* **D71**, 054031 (2005) [hep-ph/0407176].

[97] F. Jugeau, A. Le Yaouanc, L. Oliver, J.-C. Raynal, *Phys. Rev.* **D74**, 094012 (2006) [hep-ph/0604059].

[98] V. Laporta, G. Narduli, T.N. Pham, *Phys. Rev.* **D74**, 054035 (2006) [hep-ph/0602243].

[99] G. Nardulli, T.N. Pham, *Phys. Lett.* **B623**, 65 (2005) [hep-ph/0505048].

[100] T.N. Pham, G.-H. Zhu, *Phys. Rev.* **D69**, 114016 (2004) [hep-ph/0403213].

[101] T.N. Pham, *Nucl. Phys. Proc. Suppl.* **121**, 267 (2003) [hep-ph/0210102].

[102] S. Descotes-Genon, C.T. Sacharadja, *Nucl. Phys.* **B650**, 356 (2003) [hep-ph/0209216].

[103] P. Ball, E. Kou, *J. High Energy Phys.* **0304**, 029 (2003) [hep-ph/0301135].

[104] S. Descotes-Genon, J. Matias, J. Virto, *Phys. Rev. Lett.* **97**, 061801 (2006) [hep-ph/0603239].

[105] P. Ball, R. Zwicky, *J. High Energy Phys.* **0604**, 046 (2006); *Phys. Lett.* **B625**, 225 (2005) [hep-ph/0507076]; to appear in the Proceedings of 7th Workshop on Continuous Advances in QCD, Minneapolis, Minnesota, 11-14 May 2006 [hep-ph/0608009]; *Phys. Lett.* **B42**, 478 (2006) [hep-ph/0609037].

[106] P. Ball, Proceedings of the 2nd Workshop on the CKM Unitarity Triangle, Durham, April 2003 [hep-ph/0306251].

[107] P. Ball, R. Zwicky, *Phys. Rev.* **D71**, 014015 (2005) [hep-ph/0406232]; *Phys. Lett.* **B625**, 225 (2005) [hep-ph/0507076].

[108] J. Charles *et al.*, hep-ph/0607246.

[109] R. Fleischer, J. Matias, *Phys. Rev.* **D66**, 054009 (2002) [hep-ph/0204101].

[110] J. Matias, *Eur. Phys. J.* **C33**, S364 (2004) [hep-ph/0311042].

[111] D. London, J. Matias, *Phys. Rev.* **D70**, 031502 (2004) [hep-ph/0404009].

[112] T.N. Pham, G.-H. Zhu, *Phys. Lett.* **B619**, 313 (2005) [hep-ph/0412428].

[113] T.N. Pham, Proceedings of QCD@Work, June 2003 [hep-ph/0310129].

[114] P. Colangelo, F. De Fazio, T.N. Pham (2004), *Phys. Rev.* **D69**, 054023 (2004) [hep-ph/0310084].

[115] P. Colangelo, F. De Fazio, T.N. Pham, *Phys. Lett.* **B542**, 71 (2002) [hep-ph/0207061].

[116] T.N. Pham, Proceedings of QCD@Work, June 2005 [hep-ph/0510190].

[117] E. Kou, T.N. Pham, *Phys. Rev.* **D74**, 014010 (2006) [hep-ph/0601272].

[118] T.N. Pham, Workshop on Theory Phenomenology and Experiments in Heavy Flavor Physics, Capri, May 2006 [hep-ph/0610063].

[119] J.O. Eeg, S. Fajfer, A. Hiorth, *Phys. Lett.* **B570**, 46 (2003) [hep-ph/0304112].

[120] J.O. Eeg, S. Fajfer, A. Hiorth, A. Prapotnik, *Nucl. Phys. Proc. Suppl.* **142**, 188 (2005) [hep-ph/0408298].

[121] J.O. Eeg, S. Fajfer, A. Prapotnik, *Eur. Phys. J.* **C42**, 29 (2005) [hep-ph/0501031].

[122] J.O. Eeg, S. Fajfer, A. Prapotnik, Proceedings of QCD@Work, June 2005 [hep-ph:0509252].

[123] G. D'Ambrosio, G.F. Giudice, G. Isidori, A. Strumia, *Nucl. Phys.* **B645**, 155 (2002) [hep-ph/0207036].

[124] G. Isidori, P. Paradisi, *Phys. Lett.* **B639**, 499 (2006) [hep-ph/0605012].

[125] F. Borzumati, C. Greub, Y. Yamada, *Phys. Rev.* **D69**, 055005 (2004) [hep-ph/0311151].

[126] G. Isidori, La Thuile 2003, Results, Perspectives in Particle Physics, p. 393.

[127] P. Ball, R. Fleischer, *Eur. Phys. J.* **C48**, 413 (2006).

[128] G. Isidori, A. Retico, *J. High Energy Phys.* **0209**, 063 (2002) [hep-ph/0208159].

[129] R. Fleischer, G. Isidori, J. Matias, *J. High Energy Phys.* **0305**, 053 (2003) [hep-ph/0302229].

[130] S. Baek, D. London, J. Matias, J. Virto, *J. High Energy Phys.* **0602**, 027 (2006) [hep-ph/0511295].

[131] P. Colangelo, F. De Fazio, R. Ferrandes, T.N. Pham, *Phys. Rev.* **D73**, 115006 (2006) [hep-ph/0604029]; *Phys. Rev.* **D74**, 115006 (2006) [hep-ph/0610044].

[132] C.P. Burgess, J. Matias, F. Quevedo, *Nucl. Phys.* **B706**, 71 (2005) [hep-ph/0640135].

[133] D. London, J. Matias, J. Virto, *Phys. Rev.* **D71**, 014024 (2005) [hep-ph/0410011].

[134] A. Bramon, R. Escribano, G. Garbarino, *J. Mod. Opt.* **52**, 1681 (2005) [quant-phys/0410122]; *Found. Phys.* **36**, 563 (2006) [quant-phys/0501069].

[135] N. Uraltsev, *Phys. Lett.* **B501**, 86 (2001); *J. Phys.* **G27**, 1081 (2001) [hep-ph/0012336].

[136] C.W. Bauer, S. Fleming, D. Pirjol, I.Z. Rothstein, I.W. Stewart, *Phys. Rev.* **D63**, 114020 (2001) [hep-ph/0011336].

[137] M. Beneke, G. Buchalla, M. Neubert, C.T. Sachrajda, *Nucl. Phys.* **B606**, 245 (2001).

[138] P. Colangelo, F. De Fazio, T.N. Pham, *Phys. Lett.* **B597**, 291 (2004) [hep-ph/0406162].

[139] J. Charles, A. Le Yaouanc, L. Oliver, O. Pène, J.-C. Raynal, *Phys. Rev.* **D60**, 014001 (1999).

[140] Y. Grossman, *Int. J. Mod. Phys.* **A19**, 907 (2004).

[141] M. Beneke, G. Buchalla, M. Neubert, C.T. Sachrajda, *Nucl. Phys.* **B591**, 313 (2000).