I review the phenomenology of new physics in low energy processes using the notion of minimal flavor violation (vs. non-minimal flavor violation). I compare the predictions of beyond-the-standard models and show that among certain observables in rare $b$-decays pattern arise, which allow to distinguish between extensions of the Standard Model. I discuss the status and future of the model independent analysis of $b \to s$ processes.

1 Introduction

There are several reasons why we are unhappy with the Standard Model (SM). We observed phenomena which are not part of the SM, such as finite neutrino masses, dark energy $\Omega_{DE} \approx 75\%$, gravity and the matter anti-matter asymmetry $(n - \bar{n})/s \sim 10^{-10}$. We do have questions which cannot be answered within the SM. For example, about unification and the origin of flavor and breaking of CP symmetry because in the SM the CKM matrix elements and fermion masses (also in the lepton sector) are just parameters. Moreover, the SM has consistency problems. There is the strong CP problem, i.e. why is the CKM phase order one whereas the strong phase is small $\bar{\theta} \leq 10^{-10}$ and the gauge hierarchy problem. In the SM, scalar masses receive quadratic radiative corrections $\delta m^2 \sim \Lambda^2/16\pi^2$. For a high cut-off such as the Planck scale $\Lambda \sim \Lambda_{Pl}$ a huge amount of fine-tuning is required to render the renormalized scalar, i.e. Higgs mass of the order of the electroweak scale. In other words, the SM is only natural up to $\Lambda \sim 1$ TeV. Excitingly, we probe even higher energies in the near future at the Tevatron and the LHC.

Models of electroweak symmetry breaking where the Higgs masses are protected can be build by using supersymmetry (SUSY), extra dimensions, strong dynamics (technicolor,little Higgs theories) plus hybrids. In all of these extensions of the SM we expect to see new physics (NP) at the TeV scale. The reach in indirect signals below 5 GeV such as in rare $b, c, K, \tau$ decays, meson mixing and electric dipole moments depends sensitively on how much beyond the SM flavor and/or CP violation is in the model. This is illustrated in Fig. 1 where the prospects for NP in $b$-data are shown as a function of a particular realization of a model type, for details see [1].

It is customary to classify NP models into those which are minimal flavor violating (MFV) and those who are not. A model is MFV if it does not contain more flavor and CP violation than the SM, i.e. what is contained in the Yukawas (CKM). We come back to a formal definition in Section 3. As an example, the two Higgs doublet models (2HDM) I and II are MFV. The same is true for the minimal supersymmetric standard model (MSSM) with flavor blind SUSY.

---

1 Invited talk at FPCP 2003, the 2nd Conference on Flavor Physics And CP Violation, 3-6 June 2003, Paris, France; to be published in the proceedings.
breaking and no further CP violation such as gauge mediated SUSY breaking with $A$-terms being proportional to the corresponding Yukawas and squark masses proportional to the unit matrix. (We neglect small effects from renormalization group running.) Non-MFV models are the 2HDM III with tree level flavor changing neutral currents (FCNC), models with fourth generation quarks, vector like down quarks with tree level FCNC to the $Z$ and the generic MSSM with/or without R-parity conservation. Hence, MFV theories require very different model building from those which are not.

Experimental signals for non-MFV include

1. non-standard CP violation, e.g. $\sin 2\beta(\phi K_S) \neq \sin 2\beta(J/\Psi K_S)$,
2. right-handed currents, which are generically suppressed in $b \to s$ transitions in MFV models $\sim m_s/m_b$,
3. certain shapes of the Forward-Backward asymmetry $A_{FB}$ for inclusive and exclusive $B \to (X_s, K^*)\ell^+\ell^-$ decays, see Fig. 2 where currently allowed possibilities are shown. Note that the displayed curves exhibit discrete differences rather than being gradually distinct, hence, can be cleanly investigated with the exclusive decay \[3\]. Furthermore, iv beyond MFV there is no “CKM-link” among $b \to s, b \to d$ and $s \to d$ transitions.

There is an existent 2.7$\sigma$ hint for NP which is non-MFV, namely beyond the SM CP violation
in $B \rightarrow \phi K_S$ decay, see Table 1\textsuperscript{2}. Data yield $\sin 2\beta_{\text{ave}} = +0.736 \pm 0.049$ \cite{8}, in agreement with the fit to the unitarity triangle $\sin 2\beta_{JT_{fu}} = +0.74 \pm 0.10$ @95\%C.L. \cite{5} and $\lambda \simeq 0.22$. The

|            | BaBar \cite{6} | Belle \cite{7} | average | SM+MFV |
|------------|----------------|----------------|---------|--------|
| $S_{\phi K_S}$ | $-0.18 \pm 0.51 \pm 0.07$ | $-0.73 \pm 0.64 \pm 0.22$ | $-0.38 \pm 0.41$ | $\sin 2\beta + \mathcal{O}(\lambda^2)$ |
| $C_{\phi K_S}$ | $-0.80 \pm 0.38 \pm 0.12$ | $+0.56 \pm 0.41 \pm 0.16$ | $-0.19 \pm 0.30$ | $\mathcal{O}(\lambda^2)$ |

Table 1: Data on time dependent asymmetries in $B \rightarrow \phi K_S$ vs. SM and MFV theories.

$\mathcal{O}(\lambda^2)$ correction from the $u\bar{u}$ loop maybe dynamically enhanced \cite{8}, e.g. by large rescattering. This SM background can be constrained using SU(3) flavor analysis. Currently, we have the not very stringent bound $|\xi_{\phi K}| \leq 0.25$, where $|\sin 2\beta(\phi K_S) - \sin 2\beta| \leq 2 \cos 2\beta|\xi_{\phi K}|$ \cite{9}. It is derived from upper bounds on $B(B^+ \rightarrow \phi \pi^+)$, $B(B^+ \rightarrow \bar{K}^0 K^+)$ and can be experimentally improved soon. It assumes that no large amplitudes in the charged $B$-decay cancel, i.e. $|\xi_{\phi K}| \leq |\xi_{\phi K^+}|$. The bound can be made independent of this assumption by improved data on 11 further branching ratios, see \cite{3}. This will be important if experimental errors on $S_{\phi K_S}$ shrink and the central value moves closer to the SM expectation. Note that one obtains $|\xi_{\eta'K^0}| \leq 0.36$ or $|\xi_{\eta'K^0}| \leq |\xi_{\eta'K^+}| \leq 0.09$, if $N_c$ counting works for the tree level contributions to $B^{0/\pm} \rightarrow \eta'/K^{0/\pm}$ \cite{9}.

## 2 Models with non-MFV

In order to obtain the current central value of $S_{\phi K_S}$ an $O(1)$ NP contribution with an $O(1)$ CP phase is required on the decay amplitude \cite{10} \cite{11}. This NP can be in the coefficients of QCD $C_{3\ldots6}^{(l)}$, electroweak penguins $C_{7\ldots16}^{(l)}$ and/or the chromomagnetic dipole $C_{sg}^{(l)}$ \cite{12}. (The operators are e.g. given in \cite{11}.) We discuss two possible explanations and show how to distinguish them.

Non-SM $sZb$-couplings arise generically in many models such as vector like down quarks, 4th generation, non-MFV SUSY, anomalous couplings, $Z'$ models. They can be written as

$$L_Z = \frac{g^2}{4\pi^2} \frac{g}{2\cos \Theta_W} (\bar{b}_L \gamma_\mu s_L Z_{sb} + \bar{b}_R \gamma_\mu s_R Z_{s'b}) Z^\mu + h.c. \quad (1)$$

They modify the coefficients of the 4-Fermi operators $O_{3,7,9}^{(l)}$ which contribute to $b \rightarrow s s s$ decays \cite{11}. The $sZb$-couplings are experimentally constrained as

$$\sqrt{|Z_{sb} + Z_{s'b}^M|^2 + |Z_{s'b}|^2} \leq 0.08 \quad Z_{s'b}^{SM} = -V_{tb}V_{ts}^* \sin^2 \Theta_W C_{10l}^{SM} \simeq -0.04 \quad (2)$$

The bound in Eq. (2) is based on inclusive $B \rightarrow X_s e^+ e^-$ decays at NNLO \cite{2} and corresponds to an enhancement of 2 to 3 over the SM value. $Z_{s'b}$ large and complex can explain the anomaly

\textsuperscript{2}During the completion of this write-up both BaBar and Belle issued improved measurements of $S_{\phi K_S}^{BaBar} = +0.45 \pm 0.43 \pm 0.07$, $C_{\phi K_S}^{BaBar} = -0.38 \pm 0.37 \pm 0.12$ and $S_{\phi K_S}^{Belle} = -0.96 \pm 0.50 \pm 0.09$ \cite{5} based on larger data samples \cite{3}. The new error weighted averages are $S_{\phi K_S}^{ave} = -0.15 \pm 0.33$, still 2.7 $\sigma$ away from the SM and $C_{\phi K_S}^{ave} = -0.05 \pm 0.24$, i.e. consistent with small direct CP violation. We note, however, that there is no good agreement between the two experiments in $S_{\phi K_S}$. Note also the new Belle result $S_{\eta'K_S}^{Belle} = +0.43 \pm 0.27 \pm 0.05$ updating $S_{\eta'K}^{Belle2002} = +0.71 \pm 0.37 \pm 0.05$, which with $S_{\phi K_S}^{Belle} = +0.02 \pm 0.34 \pm 0.03$ leads to $S_{\eta'K_S}^{ave} = +0.27 \pm 0.21$ \cite{3}. \newpage
in $B \rightarrow \phi K_S$ decay [10]. The implications of anomalous $sZb$-couplings include distortion of dilepton spectra and the $A_{FB}$ shape in $b \rightarrow s \ell^+ \ell^-$ decays and the $b \rightarrow s \nu \bar{\nu}$ branching ratio. They further induce a non-zero Forward-Backward-CP asymmetry $A_{FB}^{CP} \equiv \frac{A_{FB} + A_{FB}^\ast}{A_{FB} - A_{FB}^\ast} \sim \frac{\text{Im}(C_{10L})}{\text{Re}(C_{10L})}$ which probes the phase of the $sZb$ vertex. The SM background is tiny $A_{FB}^{CP} < 10^{-3}$ [13]. There is experimental support for the possibility of large electroweak penguins in $B \rightarrow K \pi$ decays [14], which, for example, could be induced by non-standard $Z$-penguins.

| $B(b \rightarrow s \ell^+ \ell^-)$, $A_{FB}(b \rightarrow s \ell^+ \ell^-)$ | $Z$-penguins | MSSM with $(\delta_{23}^R)^{RR}$ |
|----------------|----------|------------------|
| $B(B_s \rightarrow \mu^+ \mu^-)$ | up to $\mathcal{O}(1)$ effects | MFV MSSM like [2] |
| $\Delta m_s$ | up to $\mathcal{O}(10) \cdot \mathcal{B}_{SM}$ [13] | up to $\mathcal{B}_{exp, bound} \sim \mathcal{O}(10^3) \cdot \mathcal{B}_{SM}$ |
| $b \rightarrow s \gamma$ helicity flip | up to $0.5 \cdot \Delta m_s \cdot \mathcal{B}_{SM}$ [11] | $\Delta m_s SM$ up to few 100 ps$^{-1}$ |
| $a_{CP}(b \rightarrow s \gamma)$ | SM like | $|C_{7}(\mu_b')/C_{7}(\mu_b)| \lesssim 0.4$ |

Table 2: Predictions of two beyond the SM models.

The MSSM with large and complex mixing between right-handed $\tilde{s}$ and $\tilde{b}$, denoted here as $(\delta_{23}^R)^{RR}$ (which is inspired from large $\nu_\mu - \nu_e$ mixing in SO(10) GUTs) can accommodate large departures in $S_{\phi K_S}$ from the SM [15], for other recent studies of gluino mediated effects in $B \rightarrow \phi K_S$ decay see [16]. The model gives contributions to the flipped 4-Fermi $O_7^\prime$, and dipole operators $O_{7\gamma}$, $O_{9\gamma}$. An enhancement of $B(b \rightarrow s \gamma)$ can be avoided by having the gluino mass sufficiently lighter than the squark masses. The $B_s\bar{B}_s$ mixing can be huge $\Delta m_s \sim 100$ ps$^{-1}$. The presence of large right handed currents imply flipped helicity contributions to $b \rightarrow s \gamma$, see Section 3. Direct CP violation in $b \rightarrow s \gamma$ is SM like, since only flipped coefficients have a NP phase and different helicities do not interfere.

Predictions of both non-MFV models are compared in Table 2. Further means to distinguish them is to study CP asymmetries of the “golden” modes $B \rightarrow (c\bar{c})K$ [11]. Order one NP in $b \rightarrow s \bar{s}s$ decays implies $\mathcal{O}(10\%)$ effects in $b \rightarrow c\bar{c}s$, which is within the errors of the UT fit. Since the NP effect is split among final states with the same flavor content but different CP quantum numbers we compare vector $V = J/\Psi, \Psi'$ and axial vector $A = \chi, \eta_c$ coupling charmonia. Current data $\sin 2\beta(AK_S) - \sin 2\beta(VK_S) = -0.05 \pm 0.26$ [17] are not significant yet. The correlation with $\phi K_S$ is shown in Fig. 3 for both models. Since $C_{8g}^{(0)}$ is color octet suppressing in $b \rightarrow c\bar{c}s$ decays this distinguishes NP in the chromomagnetic dipole from NP in the 4-Fermi operators. Note that this SM test is independent of improvement of the UT fit.

3 Model independent analysis

The search for NP in $b \rightarrow s$ transitions can systematically be performed in terms of an effective low energy theory $\mathcal{H}_{eff} = -4G_F/\sqrt{2}V_{ts}V_{ts}^* \sum_i (C_i O_i + C'_i O'_i)$. Important operators are given in Table 3. The primed (flipped) operators are obtained from interchanging $L \leftrightarrow R$. The coefficients of the SM operator basis $C_{7\gamma}, C_{8g}, C_{9\ell}, C_{10\ell}$ have been studied recently [2]. From the $b \rightarrow s \gamma$ branching ratio bounds in the $C_{7\gamma}$-$C_{8g}$ plane have been obtained, allowing for two different solutions with different sign of $C_{7\gamma}$ each of which can be accessed in the MFV MSSM.
Figure 3: $\sin 2\beta_{A_{K_S}} - \sin 2\beta_{V_{K_S}}$ as a function of $\sin 2\beta_{\phi_{K_S}} - \sin 2\beta_{V_{K_S}}$ in the non-SM $Z$-scenario (blue) and in the MSSM with additional flavor violation induced by $\delta_{RR}^{P}$. The latter butterfly type correlation is shown for two values of the matrix element of $O_{8g}$. Figure taken from [11].

There is a bound $|C_{8g}(m_W)/C_{8g_{SM}}(m_W)| \leq 10$ from charmless $B$-decay and theory input [18]. Constraints on the dilepton couplings $C_{9t}-C_{10t}$ for each branch have been worked out from $b \rightarrow s \ell^{+} \ell^{-}$ decays. Currently, the inclusive $B \rightarrow X_s \ell^{+} \ell^{-}$ (with $q^2 > 0.2$ GeV) and exclusive $B \rightarrow K \ell^{+} \ell^{-}$ decays with electron and muon modes combined ($\ell = e, \mu$) have been observed $^3$.

\[
\begin{align*}
\mathcal{B}(B \rightarrow X_s \ell^+ \ell^-) &= (6.1 \pm 1.4^{+1.4}_{-1.1}) \cdot 10^{-6} \quad \text{(Belle [20])} \\
\mathcal{B}(B \rightarrow X_s \ell^+ \ell^-) &= (6.3 \pm 1.6^{+1.8}_{-1.5}) \cdot 10^{-6} \quad \text{(BaBar [21])} \\
\mathcal{B}(B \rightarrow K \ell^+ \ell^-) &= (0.78^{+0.24+0.11}_{-0.20-0.18}) \cdot 10^{-6} \quad \text{(BaBar [22])} \\
\mathcal{B}(B \rightarrow K \ell^+ \ell^-) &= (0.58^{+0.17}_{-0.15} \pm 0.06) \cdot 10^{-6} \quad \text{(Belle [23])}
\end{align*}
\]

They are in agreement with the SM $\mathcal{B}(B \rightarrow X_s \ell^+ \ell^-)_{SM} = 4.2 \pm 0.7 \cdot 10^{-6}$ and $\mathcal{B}(B \rightarrow K \ell^+ \ell^-)_{SM} = 0.35 \pm 0.12 \cdot 10^{-6}$ for the same cuts [2]. While the use of $\mathcal{B}(b \rightarrow s \gamma)$ here is without further progress currently exhausted by theory errors, semileptonic rare decays will yield much information in the near future beyond branching ratios, in particular from $A_{FB}$. Note that curve 2 in Fig. 2 corresponds to the non-SM sign solution to $C_{7\gamma}$. The $A_{FB}$ has a zero in the SM, see Fig. 2 which position is known to high accuracy for inclusive $s^{NNLL}_{SM} = 0.162 \pm 0.002(8)$ [24] and exclusive $B \rightarrow K^{*+} \ell^{-}$ decays [3] [25] $s^{NNLL}_{SM} = 4.2 \pm 0.6$ GeV$^{-2}$ [26].

In the SM the scalar/pseudoscalar couplings $C_{S,P}^{SM} \sim m_\ell m_b/m_W^2$ are very small even for $\ell = \tau$, but they can be important in the MFV MSSM at large $\tan \beta$. Constraints on $C_{S,P}$ from $B_s \rightarrow \mu^+ \mu^-$ decay have been worked out [27]. This decay is helicity suppressed in the SM with $\mathcal{B}(B_s \rightarrow \mu^+ \mu^-)_{SM} = 3.2 \pm 1.5 \times 10^{-9}$ like the corresponding $B_d$-decay $\mathcal{B}(B_d \rightarrow \mu^+ \mu^-)_{SM} = \mathcal{O}(10^{-9})$ [28]. Substantially smaller errors can be obtained using the correlation (even in some models beyond the SM) with the measured values of $\Delta m_{d,s}$ thus getting rid of the decay constant and CKM dependence of the $B_{d,s} \rightarrow \mu^+ \mu^-$ branching ratio [29].

$^3$New numbers were presented at LP03 [19], i.e. $\mathcal{B}(B \rightarrow K^{*+} \ell^-)_{BaBar} = (0.69^{+0.15}_{-0.13} \pm 0.06) \cdot 10^{-6}$, $\mathcal{B}(B \rightarrow K^{*+} \ell^-)_{Belle} = (0.48^{+0.10}_{-0.09} \pm 0.03 \pm 0.01) \cdot 10^{-6}$ and Belle’s observation of the $K^*$ mode $\mathcal{B}(B \rightarrow K^* \ell^-)_{Belle} = (1.15^{+0.26}_{-0.24} \pm 0.07 \pm 0.04) \cdot 10^{-6}$.
upper 90 % C.L. bounds are $B(B_d \rightarrow \mu^+\mu^-) < 1.6 \cdot 10^{-7}$ (Belle) and $B(B_s \rightarrow \mu^+\mu^-) < 9.5 \cdot 10^{-7}$ (CDF Run II) \[30\]. The MFV MSSM predicts interesting correlations, namely barring large cancellations that $B(B_{d,s} \rightarrow \mu^+\mu^-)$ and $\Delta m_s$ cannot be both enhanced w.r.t. their SM values \[30\] and that the ratio $B(B_d \rightarrow \mu^+\mu^-)/B(B_s \rightarrow \mu^+\mu^-) \simeq |V_{td}/V_{ts}|^2$ holds. The latter can be broken by $O(1)$ beyond minimal models \[28\]. Note that $\Delta m_d/\Delta m_s$ does not follow this pattern of CKM hierarchy in the MFV MSSM \[31\].

So far only a small fraction of Table 3 has been experimentally accessed. This program can be extended by allowing for CP phases \[32\], taking more than the SM operators into account \[33\], search for right handed currents, e.g. with polarization studies in $\Lambda_b$ \[34\], radiative $B$ \[35\] and $B \rightarrow (K^* \rightarrow K \pi)\ell^+\ell^-$ decays \[36\]. Hadronic $b$-decays are sensitive to NP in Four-quark operators and $O_{89}^{(1)}$, however, their interpretation in terms of the $C_i^{(n)}$ suffers from hadronic uncertainties. In some cases it is possible to identify classes of operators, e.g. \[11\] \[14\].

The term MFV can be defined within an effective field theory picture. Let the SM be valid up to a cut-off $\Lambda$, the scale of NP $L = L_{SM} + \sum_i O_i^{(n)}/\Lambda^n$ \[37\] \[38\]. The gauge sector of the SM, i.e. $L_{SM}$ with all the Yukawas switched off $Y_u = Y_d = Y_e = 0$ possesses a $G_F = U(3)^5$ flavor symmetry. Postulate now that $G_F$ is exact but only broken by the Yukawas which are interpreted as fields which get a vev $Y \simeq < \phi >$. Then the effective theory is called MFV if all operators $O_i^{(n)}$ constructed from the SM and the “$Y$” fields are invariant under $G_F$. Phenomenological bounds from meson mixing and rare decays give (with 1 Higgs doublet) $\Lambda \gtrsim$ few TeV, similar to the ones from electroweak precision data \[38\]. If nature turns out to be of the MFV kind, this might be an appropriate model independent framework also with strong couplings at $\Lambda$.

## 4 Summary

With NP @ TeV the impact on low energy observables depends on the amount of flavor/CP violation, the presence of large parameters (e.g. $\tan \beta$ in models with two Higgs doublets), the actual new particle spectrum and errors. Order one signals are possible in $b \rightarrow s$ processes beyond MFV, e.g. in $A_{FB}(B \rightarrow (X_s, K^*)\ell^+\ell^-)$. This is very complementary to direct collider searches which probe the flavor diagonal sector of the theory. “SM-zero” observables might return surprises, such as searches for non-SM helicity operators or differences in CP asymmetries.
\sin 2 \beta (c \bar{c}_A K) - \sin 2 \beta (c \bar{c}_V K). While non-MFV models do have a richer phenomenology in rare processes, there can be sizeable effects in MFV ones as well. For example, large MFV contributions to the helicity flip operators $\bar{q}_L \Gamma b_R$ in the MSSM at large $\tan \beta$ lead to an enhanced $B(B_{d,s} \rightarrow \mu^+ \mu^-)$ which at the same time strongly favors $\Delta m_s$ to be below its SM value. A precision long term study in semileptonic FCNC’s $b \rightarrow s \ell^+ \ell^-$, $s \nu \bar{\nu}$, $s \rightarrow d \ell^+ \ell^-$, $d \nu \bar{\nu}$ decays is promising to test the SM within a potential MFV paradigm. Currently the most salient indication for non-MFV physics beyond the SM is in $B \rightarrow \phi K_S$ decays. Further experimental study of rare processes will decide whether MFV is realized or not hopefully soon.

References

[1] G. Hiller, Nucl. Phys. Proc. Suppl. 115, 76 (2003) arXiv:hep-ph/0207121.
[2] A. Ali et al., Phys. Rev. D 66, 034002 (2002) arXiv:hep-ph/0112300.
[3] A. Ali et al., Phys. Rev. D 61, 074024 (2000) arXiv:hep-ph/9910221.
[4] Talk given by Tom Browder at Lepton-Photon (LP03), August 11-16, 2003, Batavia IL.
[5] A. Höcker, talk given at FBCP May16-18, 2002, Philadelphia, USA.
[6] G. Hamel De Monchenault [BABAR Collaboration], arXiv:hep-ex/0305055
[7] K. Abe et al. [BELLE Collaboration], Phys. Rev. D 67, 031102 (2003) arXiv:hep-ex/0212062.
[8] Y. Grossman, G. Isidori and M. P. Worah, Phys. Rev. D 58, 057504 (1998) arXiv:hep-ph/9708305.
[9] Y. Grossman et al., Phys. Rev. D 68, 015004 (2003) arXiv:hep-ph/0303171.
[10] G. Hiller, Phys. Rev. D 66, 071502 (2002) arXiv:hep-ph/0207356.
[11] D. Atwood and G. Hiller, arXiv:hep-ph/0307251
[12] A. Kagan, arXiv:hep-ph/9806266
[13] G. Buchalla, G. Hiller and G. Isidori, Phys. Rev. D 63, 014015 (2001) arXiv:hep-ph/0006136.
[14] T. Yoshikawa, arXiv:hep-ph/0306147 M. Gronau and J. L. Rosner, arXiv:hep-ph/0307095
[15] R. Harnik et al., arXiv:hep-ph/0212180
[16] E. Lunghi and D. Wyler, Phys. Lett. B 521, 320 (2001) arXiv:hep-ph/0109149; A. Kagan, Lecture given at the SLAC SSI 2002, S. Khalil and E. Kou, Phys. Rev. D 67, 055009 (2003) arXiv:hep-ph/0212023; G. Kane et al., arXiv:hep-ph/0212092 M. Ciuchini et al., arXiv:hep-ph/0212397; K. Agashe and C. Carone, arXiv:hep-ph/0304229; J. Cheng,
[17] B. Aubert et al. [BABAR Collaboration], Phys. Rev. Lett. **89**, 201802 (2002) [arXiv:hep-ex/0207042].

[18] C. Greub and P. Liniger, Phys. Rev. D **63**, 054025 (2001) [arXiv:hep-ph/0009144].

[19] Talk given by Mikihiko Nakao at Lepton-Photon (LP03), August 11-16, 2003, Batavia IL.

[20] J. Kaneko et al. [Belle Collaboration], Phys. Rev. Lett. **90**, 021801 (2003) [arXiv:hep-ex/0208029].

[21] B. Aubert [BABAR Collaboration], [arXiv:hep-ex/0308016]

[22] B. Aubert et al. [BABAR Collaboration], [arXiv:hep-ex/0207082]

[23] Talk given by S. Nishida for the Belle collaboration at ICHEP02, July 2002, Amsterdam; BELLE-CONF-0241.

[24] A. Ghinculov et al., Nucl. Phys. B **648**, 254 (2003) [arXiv:hep-ph/0208088]; H. M. Asatrian et al., Phys. Rev. D **66**, 094013 (2002) [arXiv:hep-ph/0209006].

[25] G. Burdman, Phys. Rev. D **52**, 6400 (1995) [arXiv:hep-ph/9505352].

[26] M. Beneke, T. Feldmann and D. Seidel, Nucl. Phys. B **612**, 25 (2001) [arXiv:hep-ph/0106067].

[27] C. Bobeth et al., Phys. Rev. D **64**, 074014 (2001) [arXiv:hep-ph/0104284].

[28] C. Bobeth et al., Phys. Rev. D **66**, 074021 (2002) [arXiv:hep-ph/0204225].

[29] A. J. Buras, Phys. Lett. B **566**, 115 (2003) [arXiv:hep-ph/0303060].

[30] A. J. Buras et al., Phys. Lett. B **546**, 96 (2002) [arXiv:hep-ph/0207241].

[31] A. J. Buras et al., Nucl. Phys. B **619**, 434 (2001) [arXiv:hep-ph/0107048]; G. Isidori and A. Retico, JHEP **0111**, 001 (2001) [arXiv:hep-ph/0110121].

[32] A. L. Kagan and M. Neubert, Phys. Rev. D **58**, 094012 (1998) [arXiv:hep-ph/9803368].

[33] G. Hiller and F. Krüger, LMU 18/03, TUM-HEP-519/03.

[34] T. Mannel and S. Recksiegel, Acta Phys. Polon. B **28**, 2489 (1997) [arXiv:hep-ph/9710287]; G. Hiller and A. Kagan, Phys. Rev. D **65**, 074038 (2002) [arXiv:hep-ph/0108074].

[35] M. Gronau et al., Phys. Rev. Lett. **88**, 051802 (2002) [arXiv:hep-ph/0107254].

[36] F. Krüger et al., Phys. Rev. D **61**, 114028 (2000) [Erratum-ibid. D **63**, 019901 (2001)] [arXiv:hep-ph/9907386].
[37] R. S. Chivukula and H. Georgi, Phys. Lett. B 188, 99 (1987).

[38] G. D’Ambrosio et al., Nucl. Phys. B 645, 155 (2002) arXiv:hep-ph/0207036.