PROCEEDINGS OF SCIENCE

Global fits to CKM data

Should I stay (within the SM) or should I go (beyond)?

Sébastien Descotes-Genon[*†]
Laboratoire de Physique Théorique, UMR8627 CNRS/Univ. Paris-Sud 11, 91405 Orsay France
E-mail: descotes@th.u-psud.fr

I review our current understanding of the Cabibbo-Kobayashi-Maskawa matrix in the Standard Model within the frequentist Rfit approach used by CKMfitter. After a brief review of recent experimental inputs, as well as the issue of averaging lattice inputs, I describe some current discrepancies, established or advocated, between the available observables. I discuss the extension of the CKMfitter approach to include New Physics in the $\Delta B = 2$ sector in the light of the recent result on dimuon asymmetry reported by DØ .

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[*]Speaker.
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1. Standard Model global fit

1.1 Framework and status

In the Standard Model (SM), the weak charged-current transitions mix different quark generations, which is encoded in the unitary Cabibbo-Kobayashi-Maskawa (CKM) matrix. In the case of three generations of quarks, the physical content of this matrix reduces to four real parameters, among which one phase, which is the only source of CP violation in the SM, coming from the quark sector. (the lepton sector can also exhibit similar sources of CP violation once masses, provided by New Physics (NP), are considered). One can define these four real parameters as:

$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2+|V_{us}|^2} \qquad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2+|V_{us}|^2} \qquad \bar\rho + i\bar\eta = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\,. \tag{1.1}$$

This parametrisation is exact, unitary to all orders in λ and independent of phase conventions. A Wolfenstein-like parametrisation of the CKM matrix can be derived up to an arbitrary power in the Cabibbo angle $\lambda = \sin\theta_C$, using the unitarity of the matrix to determine all its elements. The challenge over the last decade for both experimentalists and theorists has consisted in extracting information on these parameters from data in the presence of strong interaction. As the precision has increased in B physics, the focus has shifted from the determination of the CKM parameters to the analysis of deviations from the SM, exploiting the quantum sensitivity of flavour processes on NP.

The CKMfitter group follows this programme within the Rfit frequentist approach [1]. A first step consists in a global fit of the CKM matrix elements within the SM. A table of the inputs used for this fit is presented in Table 1 and the fit results in the $(\bar\rho,\bar\eta)$ plane are presented on the left hand-side of fig. 1, with the four real parameters describing the CKM matrix at 68% CL:

$$A = 0.8184^{+0.0094}_{-0.0311}\,, \quad \lambda = 0.22512^{+0.00075}_{-0.00075}\,, \quad \bar\rho = 0.139^{+0.027}_{-0.023}\,, \quad \bar\eta = 0.342^{+0.016}_{-0.015}\,. \tag{1.2}$$

1.2 γ

Babar and Belle have recently updated their determinations of the angle γ (corresponding to the argument of $\bar\rho + i\bar\eta$). The measurement is based on the interference between the colour-allowed $B^-\to D^0K^-$ and colour-suppressed $B^-\to \bar D^0K^-$ decays (as well as their charged conjugates). The accuracy of the method is driven by the size of the ratio $r_B = |A_{\rm suppressed}|/|A_{\rm allowed}| \simeq |V_{ub}V_{cs}^*|/|V_{cb}V_{us}^*|\times O(1/N_c)$ typically of order 0.1-0.2. The different methods try to improve on this ratio by different choices of D decay channels: GLW (D into CP eigenstates), ADS ($D^{(*)}$ into doubly Cabibbo-suppressed states), GGSZ ($D^{(*)}$ into 3-body state and Dalitz analysis). The statistics for GGSZ has been increased, with the inclusion of the following modes: $DK^\pm$, $D^*K^\pm$, $DK^{*\pm}$ with $D^*\to D\pi^0, D^0\gamma$ and $D\to K^0_S\pi^+\pi^-$ (Babar considered also neutral D into $K^0_SK^+K^-$) [2]. Each method allows for a simultaneous determination of γ and the relevant hadronic quantities, in particular the ratio of amplitudes r_B and the relative phase between the suppressed and allowed amplitudes δ_B. After the Babar and Belle updates, these hadronic quantities are in closer agreement among the three methods, which once combined lead to an improved precision on $\gamma = (70^{+14}_{-21})^\circ$. This can be compared with the output of the SM global fit: $\gamma = (67.7^{+3.6}_{-4.1})^\circ$.

Quantity	Experimental information	Theoretical input
$\lvert V_{ud}\rvert$	superallowed β decays	PRC79, 055502 (2009)
$\lvert V_{us}\rvert$	$K_{\ell 3}$ (Flavianet)	$f_+(0) = 0.963 \pm 0.003 \pm 0.005$
ε_K	PDG 08	$\hat{B}_K = 0.723 \pm 0.004 \pm 0.067$
$\lvert V_{ub}\rvert$	$b \to u\ell\nu$, $B \to \pi\ell\nu$	$\lvert V_{ub}\rvert \cdot 10^3 = 3.92 \pm 0.09 \pm 0.45$
$\lvert V_{cb}\rvert$	$b \to c\ell\nu$, $B \to D^{(*)}\ell\nu$	$\lvert V_{cb}\rvert \cdot 10^3 = 40.89 \pm 0.38 \pm 0.59$
Δm_d	last WA B_d-$\bar{B}_d$ mixing	$B_{B_s}/B_{B_d} = 1.05 \pm 0.01 \pm 0.03$
Δm_s	last WA B_s-$\bar{B}_s$ mixing	$B_{B_s} = 1.28 \pm 0.02 \pm 0.03$
β	last WA $J/\psi K^{(*)}$	
α	last WA $\pi\pi, \rho\pi, \rho\rho$	isospin
γ	last WA $B \to D^{(*)}K^{(*)}$	GLW/ADS/GGSZ
$B \to \tau\nu$	$(1.73 \pm 0.35) \cdot 10^{-4}$	$f_{B_s}/f_{B_d} = 1.199 \pm 0.008 \pm 0.023$ $f_{B_s} = 228 \pm 3 \pm 17$ MeV

Table 1: Summary of the inputs for the SM global fit. WA stands for "World average". For further details, see ref. [1] and references therein.

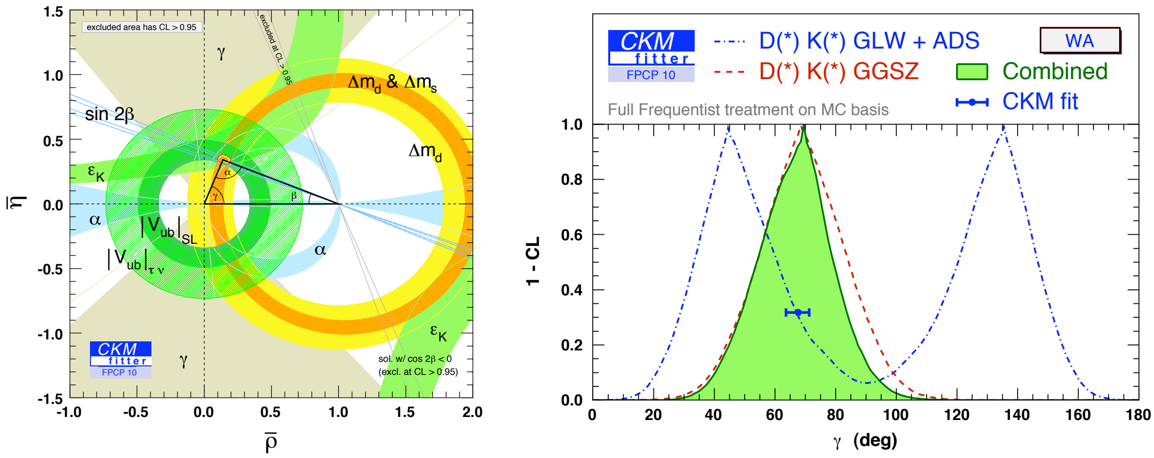

Figure 1: On the left: 95% CL constraints on the unitarity triangle from the SM global fit. On the right: constraints on γ from GLW+ADS (blue), GGSZ (red) and combined (green), based on Babar and Belle data.

1.3 Inputs from lattice gauge theory

Several hadronic inputs are required for the fits presented, and we mostly rely on Lattice QCD (LQCD) simulations to estimate these quantities involving strong interactions at low energies. The presence of results from different lattice QCD collaborations with various statistics and systematics makes it all the more necessary to combine them in a careful way. We have adopted the following procedure. We collect the relevant calculations of the quantity that we are interested in and we take only unquenched results with 2 or 2+1 dynamical fermions, even those from proceedings without a companion article. We consider only published results, and do not include values that are quoted as preliminary or exploratory, and where a proper assessment of systematics was not performed. In these results, we separate the error estimates into a Gaussian part and a flat part that is treated à la Rfit. The Gaussian part collects the uncertainties from purely statistical origin, but also the systematics that can be controlled and treated in a similar way (e.g., interpolation or fitting in some cases). The remaining systematics constitute the Rfit error. If there are several sources of error in the Rfit category, we add them linearly (keeping in mind that in many papers this combination is done in quadrature and the splitting between different sources is not published).

We first combine the Gaussian uncertainties by combining the likelihoods restricted to their Gaussian part. Then we assign to this combination the smallest of the individual Rfit uncertainties. Indeed, the present state of the art cannot allow us to reach a better theoretical accuracy than the best of all estimates, but this best estimate should not be penalized by less precise methods (as it would happen to be the case if one took the dispersion of the individual central values as a guess of the combined theoretical uncertainty). It should be stressed that the concept of a theoretical uncertainty is ill-defined, and the combination of them even more. Thus our approach is only one among the alternatives that can be found in the literature [3, 4]. In contrast to some of the latter, ours is algorithmic and can be reproduced. Moreover, we differ from the PDG-like method advocated in Ref. [4] on two points. We separate systematic and statistic errors, which prevents us from assigning a reduced systematics to a combination of several results suffering from the same systematic uncertainty. We do not attempt at estimating the (partial) correlations between the results from different collaborations (results from the same gauge configuration, using the same procedure to determine the lattice spacing...) which are considered in Ref. [4].

A similar approach is followed in order to combine the inclusive and exclusive determinations of $|V_{ub}|$ and $|V_{cb}|$, which are not completely consistent with each other, leading to the values quoted in Table 1. This discrepancy might be due to some statistical fluctuation in the measurements, or to underestimated systematics in the theoretical methods underlying this extraction [5].

1.4 ε_K

ε_K is another topic discussed recently, which is the only input of the SM global fit from CP-violation in the kaon sector, and is essentially proportional to the CP phase $\phi_K \equiv \arg(-M_{12}^K/\Gamma_{12}^K)$. We can express this quantity in terms of $K\bar{K}$ mixing parameters and the isospin decay amplitudes $A(K_0 \to (\pi\pi)_I) = A_I e^{i\delta_I} = a_I e^{i\theta_I} e^{i\delta_I}$, where a_I, δ_I and θ_I denote the modulus, the "strong" (CP-even) phase and the "weak" (CP-odd) phase of the decay amplitude [6–8]. In view of the phenomenological "$\Delta I = 1/2$ rule" $a_0/a_2 \approx 22$ (and the fact that all other decay modes come with even smaller amplitudes than a_2) one can saturate the inclusive quantity Γ_{12}^K completely by the contribution proportional to a_0^2. Expanding in various small parameters (see Ref. [7] for an elaborate discussion of the approximations involved) one finds:

$$\varepsilon_K = \sin\phi_\varepsilon e^{i\phi_\varepsilon} \left[\frac{\mathrm{Im} M_{12}^K}{\Delta M_K} + \xi\right] \qquad \text{with} \quad \tan\phi_\varepsilon = \frac{2\Delta M_K}{\Delta\Gamma_K} \quad \text{and} \quad \xi = \frac{\mathrm{Im}\, A_0}{\mathrm{Re}\, A_0}. \tag{1.3}$$

The issue of long-distance contributions to M_{12}^K is avoided by converting $2\mathrm{Re}M_{12}^K$ into the experimental value of ΔM_K. Long-distance contributions to $\mathrm{Im}M_{12}^K$ are negligible [9]. In Eq. (1.3) ξ comprises the contribution from $\arg(-\Gamma_{12}^K)$ in the limit of A_0 dominance discussed above. The corrections are of order $(a_2/a_0)^2$ and therefore negligible. The usual expression for ε_K is obtained from this expression by taking the following further approximations: i) use $\phi_\varepsilon = 45°$ instead of the measured value $\phi_\varepsilon = 43.5(7)°$, ii) neglect ξ and iii) compute $\mathrm{Im}M_{12}$ using only the lowest-dimension $d = 6$ operator in the effective Hamiltonian, which is dominated by top and charm box diagrams. The effect of the three simplifications can be parameterised in terms of the parameter κ_ε [10] entering

$$\varepsilon_K = \frac{\kappa_\varepsilon}{\sqrt{2}} e^{i\phi_\varepsilon} \left[\frac{\mathrm{Im}M_{12}^{(6)}}{\Delta M}\right] = C_\varepsilon \kappa_\varepsilon e^{i\phi_\varepsilon} \hat{\mathscr{B}}_K \left[\mathrm{Im}\left[(V_{cs}V_{cd}^*)^2\,\Delta_K^{cc}\right]\eta_{cc}\,S\left(\frac{\overline{m}_c^2}{M_W^2}\right)\right.$$
$$\left. + \mathrm{Im}\left[(V_{ts}V_{td}^*)^2\,\Delta_K^{tt}\right]\eta_{tt}\,S\left(\frac{\overline{m}_t^2}{M_W^2}\right) + 2\,\mathrm{Im}\left(V_{ts}V_{td}^*V_{cs}V_{cd}^*\,\Delta_K^{ct}\right)\eta_{ct}\,S\left(\frac{\overline{m}_c^2}{M_W^2},\frac{\overline{m}_t^2}{M_W^2}\right)\right]. \tag{1.4}$$

The normalisation reads $C_\varepsilon = (G_F^2 F_K^2 m_K M_W^2)/(12\sqrt{2}\pi^2 \Delta M_K)$. The value $\kappa_\varepsilon = 1$ corresponds to the approximations i)—iii) outlined above. When expressed in terms of Wolfenstein parameters to lowest order in λ, Eq. (1.4) defines the hyperbola in fig. 1.

A series of papers [7, 9, 10] has studied how much the factor κ_ε should deviate from 1 in order to account for the terms neglected by the previous approximations. Separating the uncertainties coming from statistic and systematic sources, we obtained the estimate

$$\kappa_\varepsilon = 0.940 \pm 0.013 \pm 0.023\,. \tag{1.5}$$

Within the Rfit framework adopted for averaging $\hat{B}_K$, the inclusion of this correcting factor has no significant impact on the outcome of the fit. It can be seen on the left hand-side of Fig 2, where the prediction on κ_ε from the SM global fit and its actual value are compared. It is interesting to notice how the presence (or the absence) of a discrepancy in a fit depends on the treatment of errors. Indeed, if we include this correction and treat the uncertainty on κ_ε in a Gaussian way (as well as $|V_{cb}|, \hat{B}_K, \eta_{ct,cc,tt}, \bar{m}_{c,t}$), we observe a discrepancy ($\sim 1.3\sigma$) in the SM global fit. But if we stick to our usual and more conservative Rfit treatment of systematics, we observe no discrepancy, as can be seen on the right hand-side in Fig 2. Another reason for the absence of discrepancy comes from the input used for $\hat{B}_K$. As explained in sec 1.3, we add the systematics linearly, leading to a global systematic error of slightly less than 10% on $\hat{B}_K$, larger than the ones obtained through the quadratic combination usually performed by LQCD collaborations.

1.5 $\sin 2\beta_{c\bar{c}}$ versus $B \to \tau\nu$

The SM global fit exhibits a slight discrepancy between the various observables currently. Indeed, the global fit χ^2_{min} drops by $\sim 2.4\sigma$ if $\sin 2\beta_{c\bar{c}}$ or $B \to \tau\nu$ is removed from the inputs. Before claiming any effect from new physics, one should consider the possibility of a fluctuation in the experimental measurements or a change in the theoretical inputs. On the experimental side, both $\sin 2\beta_{c\bar{c}}$ or $B \to \tau\nu$ show a good agreement between Babar and Belle. On the theoretical side, the issue is not restricted to the value of f_{B_d} since one observes a 2.4σ discrepancy from the ratio

$$\frac{\mathscr{B}(B\to\tau\nu)}{\Delta m_d} = \frac{3\pi}{4}\frac{m_\tau^2\tau_B}{m_W^2\eta_B S[x_t]}\left(1-\frac{m_\tau^2}{m_B^2}\right)^2 \frac{\sin^2\beta}{\sin^2(\alpha+\beta)}\frac{1}{|V_{ud}|^2 B_{B_d}}\,. \tag{1.6}$$

indicating that one needs to modify f_{B_d} without affecting $f_{B_d}\sqrt{B_{B_d}}$. Three possible ways of escaping the current discrepancy would be:

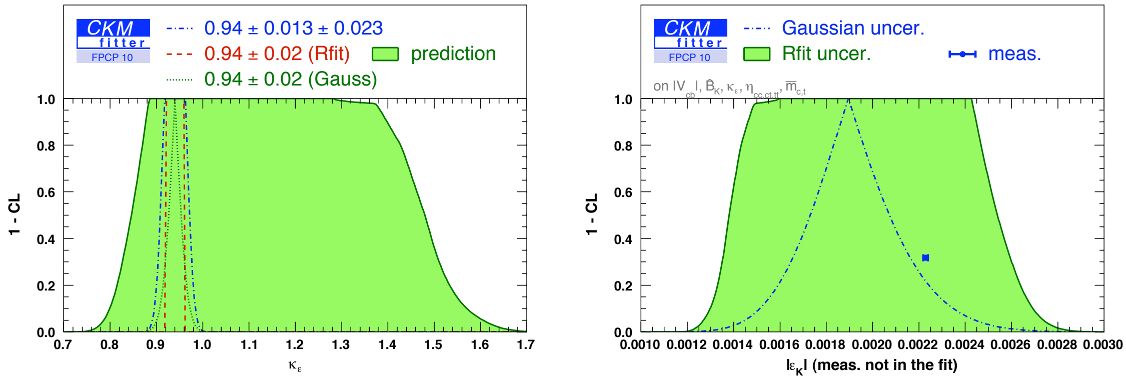

Figure 2: On the left: the prediction on κ_ε from the SM global fit, compared to different estimates ($\kappa_\varepsilon = 0.94 \pm 0.02$ (Gaussian or Rfit), $\kappa_\varepsilon = 0.940 \pm 0.013 \pm 0.023$). On the right: the value of ε_K as determined from the SM global fit (in blue) and the corresponding confidence levels with different treatments of systematics (Gaussian treatment in dashed line, Rfit treatment in green).

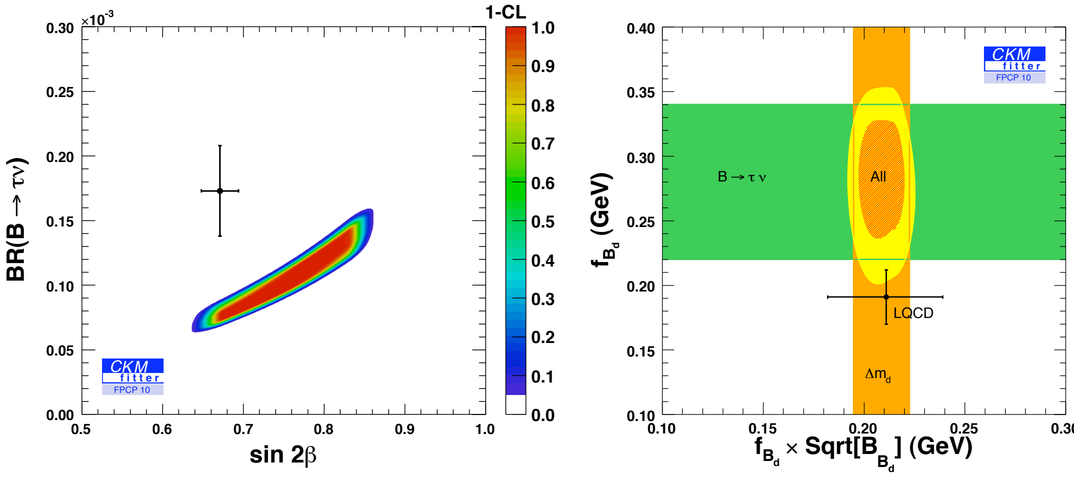

Figure 3: On the left: discrepancy between the measured values of $[\sin 2\beta, Br(B \to \tau\nu)]$ and the preferred values by the SM global fit. On the right: comparison between the inputs for $(f_{B_d}, f_{B_d}\sqrt{B_d})$ and the values obtained through the SM global fit from the measurements of $Br(B \to \tau\nu), \Delta m_s$.

- a change in the measurement of $B \to \tau\nu$. The prediction of the SM global fit for the branching ratio is $Br(B \to \tau\nu) = (0.763^{+0.113}_{-0.061}) \cdot 10^{-4}$, to be compared with the input in table 1.
- a correlated change in lattice estimates of f_{B_d} and B_{B_d}, as is illustrated in Fig. 3. The predicted value for B_{B_d} is much smaller than 1, which would require very significant deviations from the vacuum saturation approximation.
- the presence of NP affecting the interpretation of the parameters in term of the CKM parameters. In the next section, we will discuss an illustration by allowing for NP in the $\Delta B = 2$ sector in a model-independent way [11].

2. New Physics in $\Delta F = 2$ operators

2.1 Model-independent approach

In addition to the discrepancy between $B \to \tau\nu, \sin 2\beta$ and Δm_d, recent results hint at deviations from the SM in $B_s - \bar{B}_s$ mixing [12].. Very recently DØ has presented a new measurement of the inclusive dimuon CP asymmetry $a_{\rm fs}$, mixing B_d and B_s asymmetries $a^d_{\rm fs}$ and $a^s_{\rm fs}$ [13] using 6.1 fb^{-1} integrated luminosity, which shows a 3.2σ deviation from the (almost zero) SM prediction, and is the first direct evidence of a deviation from the SM in B meson observables: $a_{\rm fs} = -0.00957 \pm 0.00251 \pm 0.00146$. The average between the new DØ result and the CDF result $a_{\rm fs} = 0.0080 \pm 0.0090 \pm 0.0068$ [14] reads

$$a_{\rm fs} = -0.0085 \pm 0.0028, \tag{2.1}$$

which is 3.0 standard deviations away from the SM prediction.

In addition, CDF and DØ have presented updates of the time-dependent tagged analyses which have been averaged in ref. [15]. Using this new average, the deviation of the measured value for β_s with respect to the SM value is essentially unchanged and reads 2.3 standard deviations. This average is our default input for the corresponding observables, supplemented by the constraint on the flavour-specific B_s lifetime $\tau^{FS}_{B_s} = (1.417 \pm 0.042) \cdot 10^{-12}$ [16] which can be viewed as an independent measurement of $\Delta\Gamma_s$. New results for $B_s \to J/\psi\phi$ have been presented in Summer 2010 by CDF (with $5.2 fb^{-1}$) [17] and DØ (with $6.1 fb^{-1}$) [20] collaborations, in closer agreement to the SM expectations, but these measurements have not been combined together yet and thus have not been included in the present analysis.

In such a context, it seems natural to look for NP in mixing, i.e., $\Delta B = 2$ operators, assuming that tree decays are not affected by NP effects [11]. $B_q - \bar{B}_q$ oscillations (with $q = d$ or $q = s$) are described by a Schrödinger equation with an evolution matrix for $|B_q(t)\rangle, |\bar{B}_q(t)\rangle$ of the form $M^q - i\Gamma^q/2$, with the hermitian mass and decay matrices M^q and Γ^q. The physical eigenstates $|B^q_H\rangle$ and $|B^q_L\rangle$ with masses M^q_H, M^q_L and decay rates Γ^q_H, Γ^q_L are obtained by diagonalizing $M^q - {\rm i}\,\Gamma^q/2$. The $B_q - \bar{B}_q$ oscillations involve the three physical quantities $|M^q_{12}|$, $|\Gamma^q_{12}|$ and the CP phase $\phi_q = \arg(-M^q_{12}/\Gamma^q_{12})$. The average B_q mass and width is denoted M_{B_q} and Γ_{B_q}, respectively. The mass and width differences between B^q_L and B^q_H can be written as:

$$\Delta M_q \,=\, M^q_H - M^q_L \,=\, 2\,|M^q_{12}|, \qquad \Delta\Gamma_q \,=\, \Gamma^q_L - \Gamma^q_H \,=\, 2\,|\Gamma^q_{12}| \cos\phi_q, \tag{2.2}$$

up to numerically irrelevant corrections of order m_b^2/M_W^2. ΔM_q simply equals the frequency of the $B_q - \bar{B}_q$ oscillations (for details see e.g. [7]). A third quantity probing mixing is the semileptonic CP asymmetry,

$$a^q_{\rm fs} \,=\, 2\left(1 - \left|\frac{q}{p}\right|\right) \,=\, {\rm Im}\,\frac{\Gamma^q_{12}}{M^q_{12}} \,=\, \frac{|\Gamma^q_{12}|}{|M^q_{12}|}\sin\phi_q \,=\, \frac{\Delta\Gamma_q}{\Delta M_q}\tan\phi_q. \tag{2.3}$$

$a^q_{\rm fs}$ is the CP asymmetry in flavour-specific $B_q \to f$ decays, i.e., the decays $\bar{B}_q \to f$ and $B_q \to \bar{f}$ are forbidden. These quantities are expected to be affected by NP in different ways. While M^q_{12} coming from box diagrams is very sensitive to new physics both for B_d and B_s, Γ^s_{12} stems from Cabibbo-favoured tree-level decays and possible new physics effects are expected to be smaller

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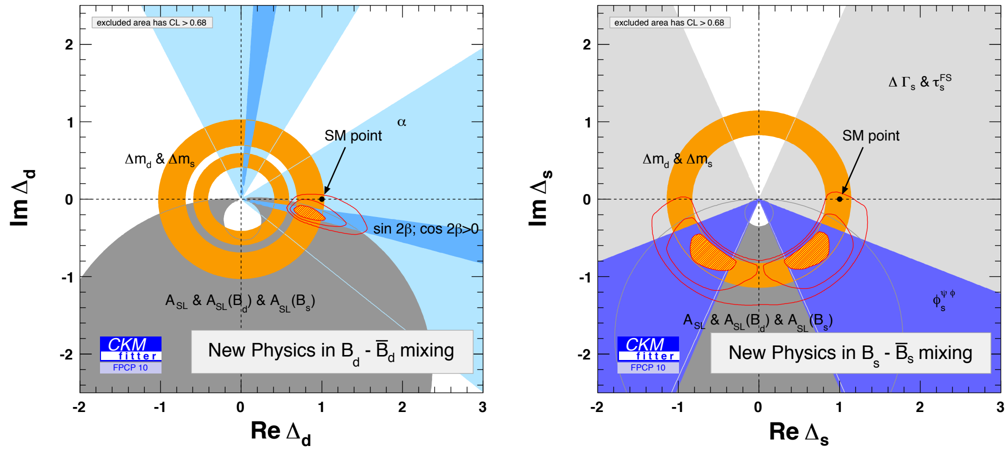

Figure 4: Constraint on the complex parameter Δ_d and Δ_s. For the individual constraints the coloured areas represent regions with CL < 68.3 %. For the combined fit the red area shows the region with CL $<$ 68.3 % while the two additional contour line inscribe the regions with CL < 95.45 %, and CL < 99.73 %, respectively.

than the hadronic uncertainties from decay constants and bag parameters. In the case of Γ_{12}^d though, the contributing decays are Cabibbo-suppressed. As indicated at the beginning of this section, we assume that NP does not enter tree-level decays (a more specific definition can be found in ref. [11]). Hence, new Physics can find its way only by changing the magnitude and/or the phase of M_{12}^q. It is convenient to define the NP complex parameters Δ_q and ϕ_q^Δ ($q = d, s$) through

$$M_{12}^q \equiv M_{12}^{\mathrm{SM},q} \cdot \Delta_q\,, \qquad \Delta_q \equiv |\Delta_q| e^{i\phi_q^\Delta}\,, \qquad \phi_q = \phi_q^{\mathrm{SM}} + \phi_q^\Delta. \tag{2.4}$$

NP in M_{12}^q will not only affect the neutral-meson mixing parameters, but also the time-dependent analyses of decays corresponding to an interference between mixing and decay.

The following inputs of the SM global fit in Table 1 are considered to be free from NP contributions in their extraction from data: $|V_{ud}|$, $|V_{us}|$, $|V_{ub}|$, $|V_{cb}|$ and γ. For the latter, we use both determinations, from $B \to D^{(*)}K^{(*)}$, but also the more precise determination coming from the combination $\gamma(\alpha) \equiv \pi - \alpha - \beta$ in which ϕ_{B_d} cancels, so $\gamma(\alpha)$ is not affected by NP. Also we assume that the leptonic decay $B \to \tau\nu$ is SM-like, even though it could be significantly affected by charged-Higgs exchange contributions [19]. Under these assumptions, a reference unitarity triangle can be constructed, with two solutions for the apex of the unitarity triangle (corresponding to the usual solution and the symmetric one with respect to the origin of the $(\bar{\rho}, \bar{\eta})$ plane). On the other hand, we use several observables, affected by NP in mixing, to determine Δ_d, Δ_s: the oscillation frequencies Δm_d, Δm_s, the lifetime difference $\Delta\Gamma_d$, the time dependent asymmetries related to ϕ_{B_d}, ϕ_{B_s}, the asymmetries a_{fs}^d, a_{fs}^s, a_{fs}, and finally α (from interference between decay and mixing).

2.2 Results

In fig. 4, we show the results in the complex Δ_d and Δ_s planes, respectively. Δ_d and Δ_s are taken as independent in this scenario, but some of the constraints correlate them, such that a_{fs} from

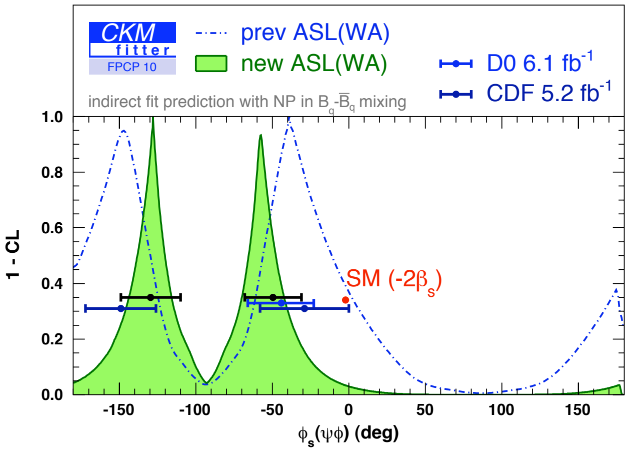

Figure 5: Indirect constraint on the CP phase measured in $B_s \to J/\psi\phi$, compared with the direct TeVatron measurements: previous world average [15] (in black) and the Summer 2010 CDF and DØ updates [17, 18] (in blue). The dotted line represents our NP scenario with the previous world average for $a_{\rm fs}$, while the green curve is the update after the DØ evidence for a non zero dimuon asymmetry.

the inclusive dimuon asymmetry, and the ratio $\Delta m_d/\Delta m_s$. The figures should be understood as two-dimensional projections of a single multidimensional fit, and not as independent computations.

The constraint from Δm_d in the $\mathrm{Re}\Delta_d - \mathrm{Im}\Delta_d$ plane shows two allowed ring-like regions. They correspond to the two allowed solutions in the $\bar\rho - \bar\eta$ plane when $a^d_{\rm fs}$ is excluded from the list of inputs. Indeed, in this NP scenario, Δm_d is proportional to the product $|\Delta_d|^2 \cdot |V_{td}V^*_{tb}|^2$, where the second factor is different for the two allowed solutions since it is the side of the unitarity triangle relating $(1,0)$ and $(\overline{\rho},\overline{\eta})$. The impact of $a^d_{\rm fs}$ highlights the power of this measurement to exclude a large region of the possible NP parameter space. In the combined fit, the inner ring in the complex Δ_d plane is disfavoured. This leaves us with an allowed region for $|\Delta_d|$ which is in agreement with the SM value $\Delta_d = 1$, albeit with possible deviations up to 40 %. The NP phase ϕ^Δ_d, mainly driven by the $\mathscr{B}(B\to\tau\nu)$ vs. $\sin 2\beta$ correlation, can be large and shows currently a deviation from the SM of 2.5 σ. It is interesting to note that the combined individual constraint from $a^d_{\rm fs}$, $a^s_{\rm fs}$ and $a_{\rm fs}$ *also* favours a negative NP phase ϕ_{Δ_d}, mainly due to the measured negative $a^d_{\rm fs}$ value. When $\mathscr{B}(B\to\tau\nu)$ is excluded from the inputs $\mathrm{Im}\Delta_d$ and hence ϕ_{Δ_d} is in good agreement with the SM value. At the same time the allowed range for $|\Delta_d|$ is significantly enlarged since $\mathscr{B}(B\to\tau\nu)$ helps to reduce the uncertainty on Δm_d: the two rings are enlarged and merge.

The constraint on $|\Delta_s|$ from Δm_s is more stringent than that for $|\Delta_d|$ - thanks to the smaller theoretical uncertainty in its prediction compared to Δm_d - and in good agreement with the SM point. It is interesting to note that also for the B_s system the constraint from $\mathscr{B}(B\to\tau\nu)$ plays a non-negligible role: when removing this measurement from the list of inputs the constraint on $|\Delta_s|$ becomes weaker since this measurement improves the input on the decay constant f_{B_s} through the SU(3)-breaking parameter ξ. There is evidence for a non-zero NP phase ϕ^Δ_s at the 3.1 σ level. This discrepancy is driven by $a_{\rm fs}$ as measured by DØand by the ϕ_s analyses from Tevatron, but is expected to be somewhat relaxed by the updated measurements [17, 18]. The indirect fit prediction for the dimuon asymmetry $a_{\rm fs} = (-42^{+19}_{-18}) \times 10^{-4}$ is smaller in magnitude than the DØ measurement $(-95.7 \pm 25.1 \pm 14.6) \times 10^{-4}$, and remain more precise in spite of the uncertainties on the theoretical and NP parameters. Hence future improvements of this measurement are expected to give crucial information on the underlying physics. Although the mixing CP-phase is expected to come back closer to the SM value [17, 18], it remains well compatible with the indirect constraint from the dimuon asymmetry, as shown by Fig. 5.

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