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Implications of β_s measurements

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We present an update of the analysis of B_s mixing by the UTfit Collaboration, including the very recent tagged analyses of $B_s \to J/\Psi\phi$ by the CDF and DØ collaborations. We find that the phase of the B_s mixing amplitude deviates more than 2.9σ from the Standard Model prediction. This results points to extensions of the Standard Model with new sources of CP violation. We compare this result with the analysis of B_d mixing and show that present data favour the presence of a new source of flavour violation.

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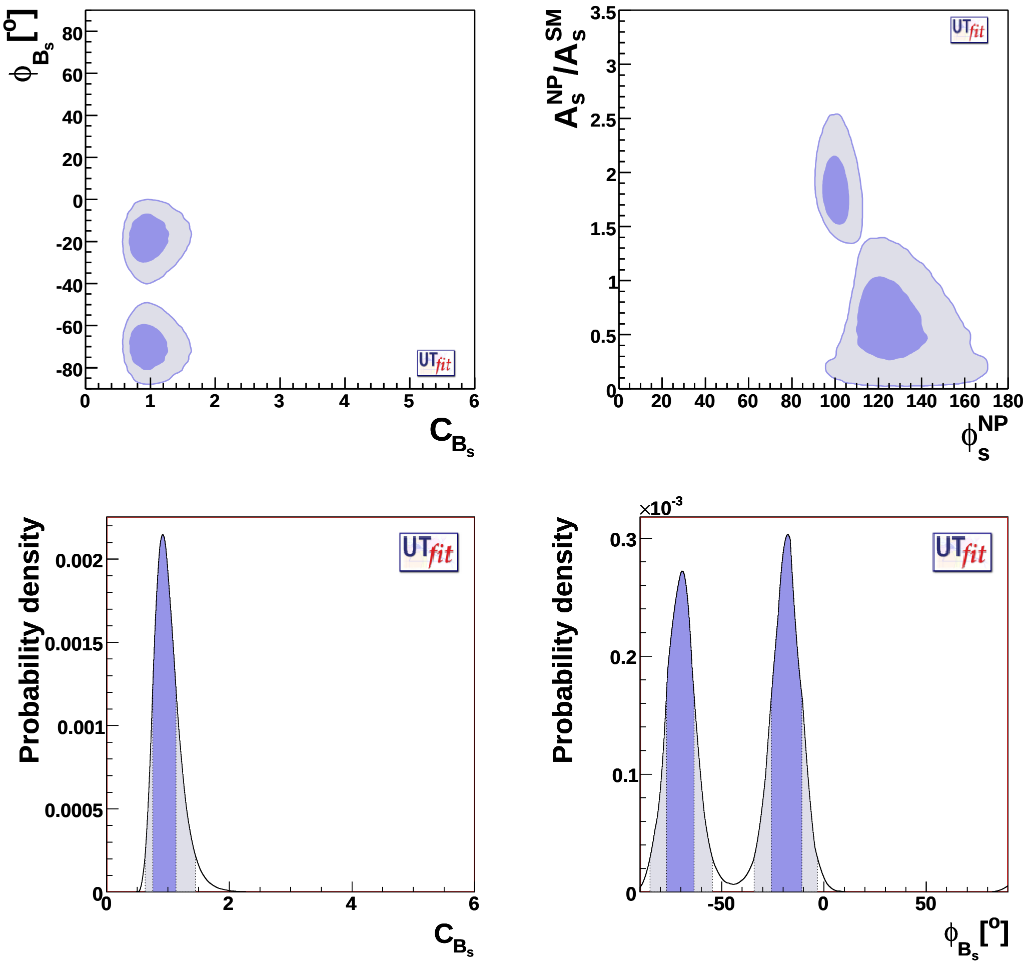

Figure 1: From left to right and from top to bottom, 68% (dark) and 95% (light) probability regions in the $\phi_{B_s} - C_{B_s}$ and $A_s^{\rm NP}/A_s^{\rm SM} - \phi_s^{\rm NP}$ planes and p.d.f for C_{B_s} and ϕ_{B_s}.

Within the Standard Model (SM), CP violation in B_s mixing is very well predicted and small, the phase of the mixing amplitude being predicted as

$$\sin 2\beta_s = 0.037 \pm 0.002 \quad [1]. \tag{1}$$

The result above is also valid in extensions of the SM with Minimal Flavour Violation (MFV). Even allowing for the presence of arbitrary New Physics (NP) in all sectors, the SM contribution to the phase of the B_s mixing amplitude is still tightly constrained:

$$\sin 2\beta_s = 0.041 \pm 0.004 \quad [1]. \tag{2}$$

Thus, observing a mixing phase significantly different from the value in eq. (2) would be a very clean signal of NP in B_s mixing.

The UTfit Collaboration has recently reported evidence of a B_s mixing phase much larger than expected in the SM, with a significance of more than 3σ [1]. This result was obtained by

	68% Prob.	95% Prob.
$\phi_{B_s}[^\circ]$	(-19 ± 8) ∪ (-69 ± 7)	[-36,-5] ∪ [-83,-54]
C_{B_s}	0.94 ± 0.19	[0.63,1.43]
$A^s_{\mathrm{SL}} \cdot 10^2$	-0.42 ± 0.23	[-0.90,0.01]
$A^{\mu\mu}_{\mathrm{SL}} \cdot 10^3$	-2.5 ± 1.1	[-5.1,-0.5]
$\Delta\Gamma_s/\Gamma_s$	(0.13 ± 0.06) ∪ (-0.12 ± 0.05)	[0.02,0.23] ∪ [-0.22,-0.02]

Table 1: Fit results for NP parameters, semileptonic asymmetries and width differences. Whenever present, we list the two solutions due to the ambiguity of the measurements. The first line corresponds to the one closer to the SM.

combining all available experimental information with the method used by the UTfit Collaboration for UT analyses and described in Ref. [2]. We present here an update of this analysis, including the very recent data presented at the summer conferences. We refer the reader to Ref. [1] for the details of the analysis.

We perform a model-independent study of NP contributions to B_s mixing using the following parametrization [3]:

$$C_{B_s} e^{2i\phi_{B_s}} = \frac{A_s^{\mathrm{SM}} e^{-2i\beta_s} + A_s^{\mathrm{NP}} e^{2i(\phi_s^{\mathrm{NP}} - \beta_s)}}{A_s^{\mathrm{SM}} e^{-2i\beta_s}} = \frac{\langle B_s | H_{\mathrm{eff}}^{\mathrm{full}} | \bar{B}_s \rangle}{\langle B_s | H_{\mathrm{eff}}^{\mathrm{SM}} | \bar{B}_s \rangle}, \tag{3}$$

where $H_{\mathrm{eff}}^{\mathrm{full}}$ is the effective Hamiltonian generated by both SM and NP, while $H_{\mathrm{eff}}^{\mathrm{SM}}$ only contains SM contributions.

We use the following experimental input: the CDF measurement of Δm_s [4], the semileptonic asymmetry in B_s decays A^s_{SL} [5], the dimuon charge asymmetry $A^{\mu\mu}_{\mathrm{SL}}$ from DØ [6] and CDF [7], the measurement of the B_s lifetime from flavour-specific final states [8], the two-dimensional likelihood ratio for $\Delta\Gamma_s$ and $\phi_s = 2(\beta_s - \phi_{B_s})$ from the time-dependent tagged angular analysis of $B_s \to J/\psi\phi$ decays by CDF [9] and DO [10]. The values for input parameters can be found in Ref. [1], except for A^s_{SL} for which we use the new value from DØ $A^s_{\mathrm{SL}} = -0.0020 \pm 0.0119$ and for the tagged analysis by DØ, for which we use the new analysis performed with no assumption on the strong phase.

The results of our analysis are summarized in Table 1. The phase ϕ_{B_s} deviates from zero at 99.6% probability, equivalent to 2.9σ. In Fig. 1 we present the two-dimensional 68% and 95% probability regions for the NP parameters C_{B_s} and ϕ_{B_s} and the one-dimensional distributions for NP parameters. Notice that the ambiguity of the tagged analysis of $B_s \to J/\Psi\phi$ is slightly broken by the presence of the CKM-subleading terms in the expression of Γ_{12}/M_{12} (see for example eq. (5) of ref. [11]). The solution around $\phi_{B_s} \sim -20^\circ$ corresponds to $\phi_s^{\mathrm{NP}} \sim -50^\circ$ and $A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}} \sim 75\%$ (see Fig. 1. The second solution is much more distant from the SM and it requires a dominant NP contribution ($A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}} \sim 190\%$). In this case the NP phase is thus very well determined. The strong phase ambiguity affects the sign of $\cos\phi_s$ and thus $A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}} \cos\phi_s^{\mathrm{NP}}$, while $A_s^{\mathrm{NP}}/A_s^{\mathrm{SM}} \sin\phi_s^{\mathrm{NP}} \sim -0.74$ in any case.

To illustrate the impact of the experimental constraints, we show in Fig. 2 the p.d.f. for ϕ_{B_s} obtained with various subsets of experimental constraints. Including only the CDF tagged analysis, we obtain $\phi_{B_s} = (-25 \pm 11)^\circ \cup (-63 \pm 11)^\circ$ ($[-83, -5]^\circ$ at 95% probability). The SM value $\phi_{B_s} = 0$

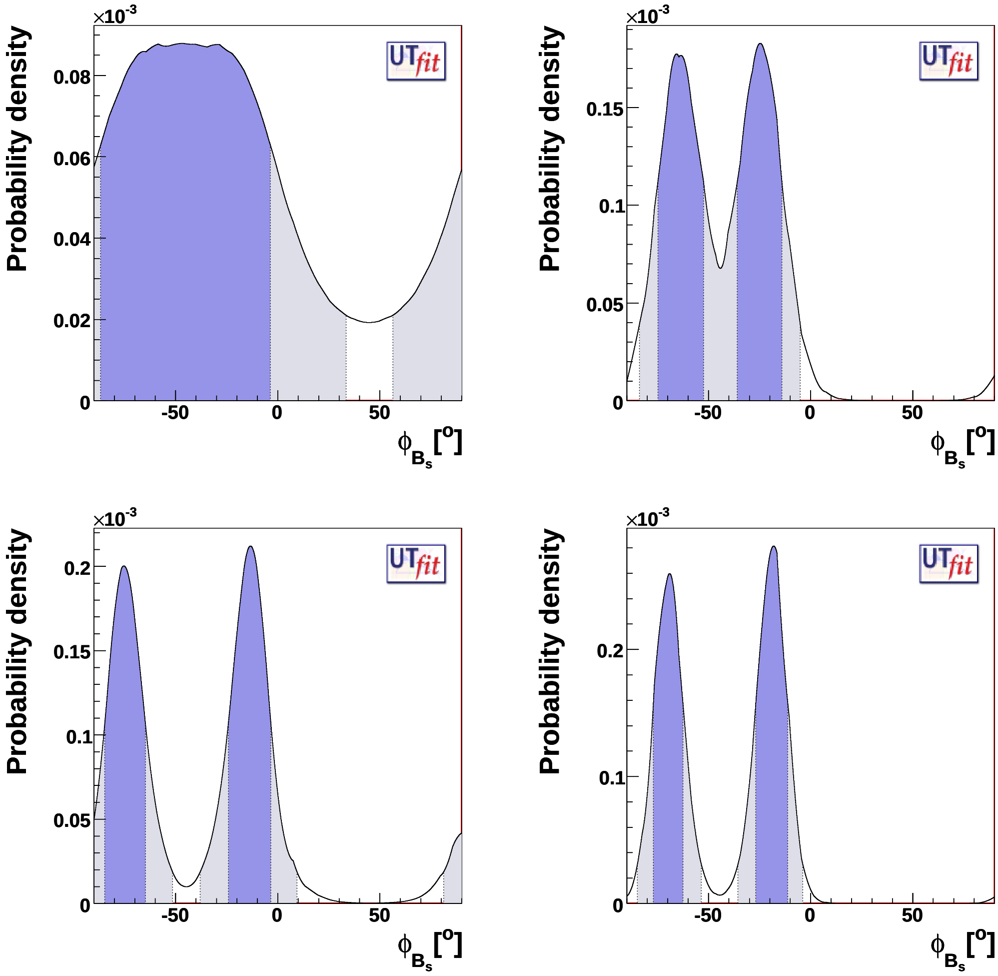

Figure 2: From left to right and from top to bottom, p.d.f. for ϕ_{B_s} without the tagged analysis of $B_s \to J/\Psi\phi$, including only the CDF analysis, including only the DØ analysis, including only the tagged analysis of $B_s \to J/\Psi\phi$ from both experiments. We show 68% (dark) and 95% (light) probability regions.

is only present in the 98% probability range (2.4σ). Using only the DØ tagged analysis, we get $\phi_{B_s} = (-14 \pm 10)^\circ \cup (-75 \pm 10)^\circ$ ($[-99,-52]^\circ \cup [-38,10]^\circ$ at 95% probability), and the SM is included in the 81% probability range (1.3σ). Using both analyses, we obtain $\phi_{B_s} = (-19 \pm 8)^\circ \cup (-70 \pm 7)^\circ$ ($[-84,-54]^\circ \cup [-36,-4]^\circ$ at 95% probability), and the SM is included in the 99% probability range (2.6σ). Semileptonic asymmetries alone give $\phi_{B_s} = (-45 \pm 42)^\circ$ ($[-124,33]^\circ$ at 95% probability). We stress that the different constraints in Fig. 2 are all consistent among themselves and with the combined result. For completeness, in Table 1 we also quote the fit results for A^s_{SL}, $A^{\mu\mu}_{\mathrm{SL}}$ and for $\Delta\Gamma_s/\Gamma_s$.

It is remarkable that to explain the result obtained for ϕ_s, new sources of CP violation beyond the CKM phase are required, strongly disfavouring the MFV hypothesis. These new phases will in general produce correlated effects in $\Delta B = 2$ processes and in $b \to s$ decays. These correlations cannot be studied in a model-independent way, but it will be interesting to analyse them in the

MSSM. Before doing so, we comment on the hierarchy in NP contributions to $\Delta F = 2$ transitions required by present data. From ref. [12] we learn that the NP contribution to B_d mixing cannot exceed 40% of the SM one if NP carries a phase around 130° as required by B_s mixing. This is marginally compatible with the B_s NP amplitude around 70% of the SM as obtained above. Thus, if NP is present in B_s mixing, we must have $A_d^{\rm NP}/A_s^{\rm NP} \times A_s^{\rm SM}/A_d^{\rm SM} \sim \lambda_c$, where λ_c is the Cabibbo angle, rather than $\mathscr{O}(1)$ as expected in models of Next-to-Minimal Flavour violation, in which NP contributions enjoy the same Cabibbo suppression as SM ones. We conclude that the NP causing the observed deviation in Φ_{B_s} must have a nontrivial flavour structure to suppress NP contributions to B_d and K mixing more than what expected from a SM-like Cabibbo structure.

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