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B_s data at Tevatron and possible new physics

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Abstract. The new physics (NP) is parametrized with four model-independent quantities: the magnitudes and phases of the dispersive part M_{12} and the absorptive part Γ_{12} of the NP contribution to the effective Hamiltonian. We constrain these parameters using the four observables ΔM_s, $\Delta\Gamma_s$, the mixing phase $\beta_s^{J/\psi\phi}$ and A_{sl}^b. This formalism is extended to include charge-parity-time reversal (CPT) violation, and it is shown that CPT violation by itself, or even in the presence of CPT-conserving NP without an absorptive part, helps only marginally in the simultaneous resolution of these anomalies.

Keywords. *B* physics; new physics; CPT violation.

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Although most of the data from the Tevatron experiments of CDF and DØ, and to a smaller extent, the B factories Belle and BABAR are consistent with the Standard Model (SM), there are some measurements, which show a significant deviation from the SM expectations, and hence point towards new physics (NP): (i) Measurements in the decay mode $B_s \to J/\psi\phi$ yield a large CP-violating phase $\beta_s^{J/\psi\phi}$ [1]. In addition, $\Delta\Gamma_s$ values that are almost twice the SM prediction, and also opposite in sign, are allowed [2]. (ii) The like-sign dimuon asymmetry A_{sl}^b in the combined B data at DØ [3] is almost 4σ away from the SM expectation. We try to determine, in a model-independent way, which kind of NP would be able to account for both the above anomalies simultaneously. We assume that the NP responsible for the anomalies contributes entirely through the $B_s - \bar{B}_s$ mixing, and parametrize it through the effective Hamiltonian $\mathcal{H}$ for the $B_s - \bar{B}_s$ mixing, which is a 2×2 matrix in the flavour basis, and the relevant NP contribution appears in its off-diagonal elements:

$$\mathcal{H} = \begin{pmatrix} M_{11} & M_{12} \\ M_{12}^* & M_{22} \end{pmatrix} - \frac{i}{2}\begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22} \end{pmatrix}, \tag{1}$$

where M_{ij} and Γ_{ij} are its dispersive and absorptive parts, respectively. When CPT is conserved, $M_{11} = M_{22}$ and $\Gamma_{11} = \Gamma_{22}$. The relevant NP contribution appears in its off-

Table 1. List of observables used in the analysis.

Observables	Experimental value[a]	SM prediction[b]
ΔM_s	$(17.77 \pm 0.10 \pm 0.07)$ ps^{-1}	(17.3 ± 2.6) ps^{-1}
$\beta_s^{J/\psi\phi}$	$(0.41^{+0.18}_{-0.15}) \cup (1.16^{+0.15}_{-0.18})$	0.019 ± 0.001
$\Delta\Gamma_s$	$\pm(0.154^{+0.054}_{-0.070})$ ps^{-1}	(0.087 ± 0.021) ps^{-1}
A^b_{sl}	$-(7.41 \pm 1.93) \times 10^{-3}$	$(-0.23^{+0.05}_{-0.06}) \times 10^{-3}$

[a][1,3,5].
[b][4].

diagonal elements. The NP can then be completely parametrized in terms of four real numbers: $|M_{12}^{\rm NP}|$, Arg$(M_{12}^{\rm NP})$, $|\Gamma_{12}^{\rm NP}|$ and Arg$(\Gamma_{12}^{\rm NP})$. We take the phases Arg$(M_{12}^{\rm NP})$ and Arg$(\Gamma_{12}^{\rm NP})$ to lie in the range of 0–2π. We then perform a χ^2-fit to the observed quantities ΔM_s, $\Delta\Gamma_s$, $\beta_s^{J/\psi\phi}$ and a^s_{sl}, using the NP parameters. For simplicity, we assume all the measurements to be independent, though the measurements of $\Delta\Gamma_s$ and $\beta_s^{J/\psi\phi}$ are somewhat correlated. The values of all the observables and their SM values are given in table 1. In order to take into account the errors on the SM parameters, we add the theoretical and experimental errors on our observed quantities in quadrature. We give our results in terms of the goodness-of-fit contours for the joint estimations of two parameters

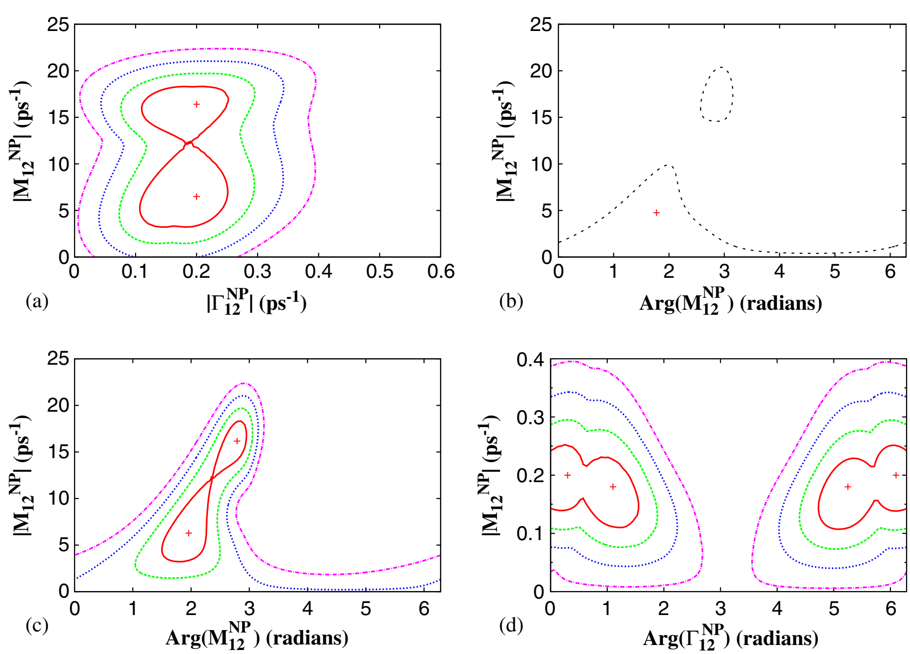

Figure 1. (**a**) Arg$(M_{12}^{\rm NP})$ and Arg$(\Gamma_{12}^{\rm NP})$ marginalized, (**b**) when $|\Gamma_{12}^{\rm NP}| = 0$, $\chi^2_{\rm min} = 13.55$, (**c**, **d**) using different marginalizations.

at a time. The $(1\sigma, 2\sigma, 3\sigma, 4\sigma)$ contours, that are equivalent to confidence levels of (68.27%, 95.45%, 99.73%, 99.99%), correspond to $\chi^2 = (2.295, 6.18, 11.83, 19.35)$, respectively (figure 1).

We also extend our framework to include possible CPT violation in the $B_s - \bar{B}_s$ mixing, parametrized through the difference in diagonal elements of $\mathcal{H}$ [6]:

$$\delta \equiv \frac{H_{22} - H_{11}}{\sqrt{H_{12}H_{21}}} = \frac{2\delta'}{\sqrt{H_{12}H_{21}}} \,, \tag{2}$$

where

$$\mathcal{H} = \begin{pmatrix} M_0 - \frac{i}{2}\Gamma_0 - \delta' & M_{12} - \frac{i}{2}\Gamma_{12} \\ M_{12}^* - \frac{i}{2}\Gamma_{12}^* & M_0 - \frac{i}{2}\Gamma_0 + \delta' \end{pmatrix} . \tag{3}$$

We then perform a χ^2-fit to the observables ΔM_s, $\Delta\Gamma_s$, the effective phase $\beta_s^{J/\psi\phi}$ and a_{sl}^s (figure 2).

If the errors and uncertainties shrink keeping the central values more or less intact, this will mean that the SM is disfavoured. Moreover, the relevant NP should be flavour-dependent, as we do not see much deviation in the $B_d - \bar{B}_d$ sector. The NP models that do not contribute to the absorptive amplitude of the $B_s - \bar{B}_s$ mixing are also strongly

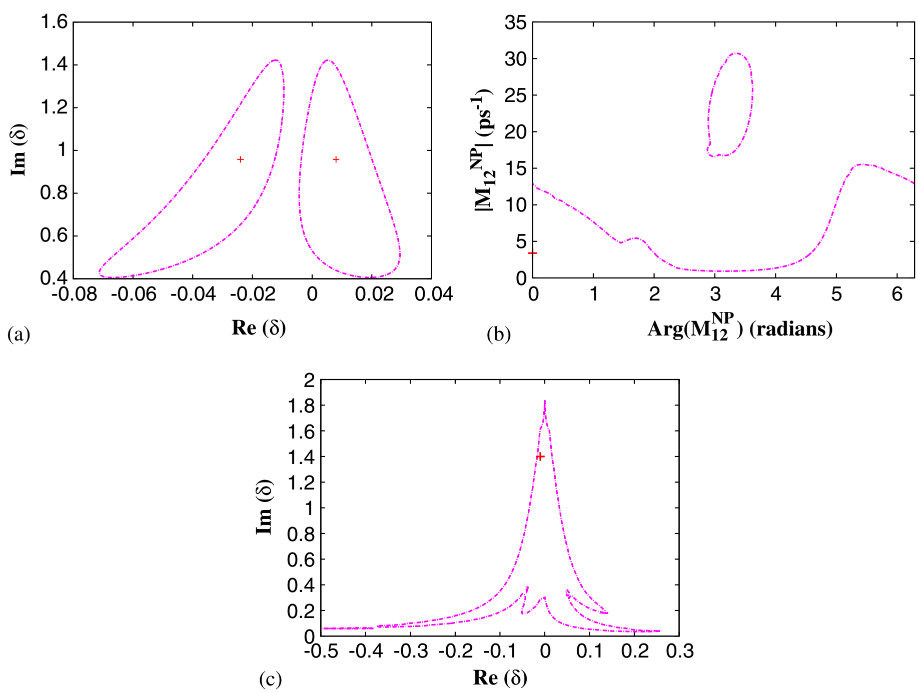

Figure 2. (**a**) No CPT-conserving NP contribution coming from M_{12}^{NP} and Γ_{12}^{NP}, χ^2_{min} is ≈16.4, marginally better than the one obtained in the $(\Gamma_{12}^{NP} = 0, M_{12}^{NP} \neq 0)$ case; (**b**, **c**) CPTV-ing NP, but without an absorptive part: $\Gamma_{12}^{NP} = 0$.

disfavoured if CPT is conserved. CPT violation is only of marginal help, as it cannot enhance the semileptonic asymmetry. Even in combination with the CPT-conserving dispersive NP, it cannot allow regions in the parameter space to better than 3σ. More details on this topic are to be found in ref. [7].

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