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Measurement of CP violation phase ϕ_s and charge asymmetries in $B^0_{(s)}$ decays at DØ

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Abstract

The CP violation phase ϕ_s and charge asymmetries in B^0_s decays have been measured by the DØ experiment in Run II of the Fermilab Tevatron Collider where proton anti-proton collisions take place at a center of mass energy of $\sqrt{s} = 1.96$ TeV. The measurements are based on integrated luminosities between 1.0 fb^{-1} and 2.8 fb^{-1}. A 1.8σ deviation from the Standard Model is observed in the measurement of the CP violation phase $\phi_s = -0.57^{+0.24}_{-0.30}$ (stat) $^{+0.07}_{-0.02}$ (syst) rad in the decay channel $B^0_s \to J/\psi\phi$. A combination with CDF results yields a 2.2σ deviation from the Standard Model.

Introduction

One of the ultimate challenges in elementary particle physics is the understanding of all possible sources of violation of CP symmetry. Within the Standard Model (SM) of particle physics, CP symmetry is violated through the CKM mechanism [1]. The level of CP violation in the SM is too small to produce the observed baryon number density in the universe [2]. New phenomena beyond the SM may alter the CP violating mixing phase ϕ_s and subsequently the decay width difference $\Delta\Gamma_s = \Delta\Gamma_s^{SM} \times |\cos\phi_s|$. The mixing parameters $\Delta\Gamma_s$ and ϕ_s are measured in the decay mode $B^0_s \to J/\psi\phi$. Further constraints on these mixing parameters are obtained by measurements of charge asymmetries due to $B^0_{(s)}$ oscillations.

Dimuon charge asymmetry

The dimuon charge asymmetry A has been measured [3] with the DØ detector, making use of an integrated luminosity of 1.0 fb^{-1}. Assuming that the asymmetry A is due to $B^0 \leftrightarrow \bar{B}^0$ mixing and decay the corresponding CP violation parameter is being measured to

$$\frac{\mathcal{R}(\epsilon_{B^0})}{1+|\epsilon_{B^0}|^2} = \frac{A_{B^0}}{4} = -0.0023 \pm 0.0011 \text{ (stat)} \pm 0.0008 \text{ (syst)}. \tag{1}$$

Relaxing the assumption in allowing for CP violation contributions from B_s^0 systems yields

$$A_{B^0} + 0.72 A_{B_s^0} = -0.0092 \pm 0.0044 \text{ (stat)} \pm 0.0032 \text{ (syst)}. \tag{2}$$

CP violation search in semileptonic B_s decays

A search for CP violation in semileptonic B_s^0 decays has been performed with a data sample corresponding to an integrated luminosity of 2.8 fb^{-1}. The flavor of the B_s^0 meson in the final state has been determined by means of the muon charge in the decay $B_s^0 \to D_s^- \mu^+ \nu X$ with $D_s^- \to \phi\pi^-$ and $\phi \to K^+K^-$. A combined tagging method has been used to determine the initial state flavor. A time-dependent fit to B_s^0 candidate distributions yields the CP violation parameter

$$a_{sl}^s = -0.0024 \pm 0.0117 \text{ (stat)}^{+0.0015}_{-0.0024} \text{ (syst)}. \tag{3}$$

Charge asymmetry in semileptonic B_s^0 decays

This first direct measurement [4] of the time integrated flavor untagged charge asymmetry in semileptonic B_s^0 decays. $A_{SL}^{s,\text{unt.}}$ has been obtained from a data sample corresponding to an integrated luminosity of 1.3 fb^{-1} in comparing the decay rate $B_s^0 \to \mu^+ D_s^- \nu X$, $D_s^- \to \phi\pi^-$, $\phi \to K^+K^-$ with its charge conjugated decay rate. The asymmetry amounts to

$$A_{SL}^{s,\text{unt.}} = [1.23 \pm 0.97 \text{ (stat)} \pm 0.17 \text{ (syst)}] \times 10^{-2}, \tag{4}$$

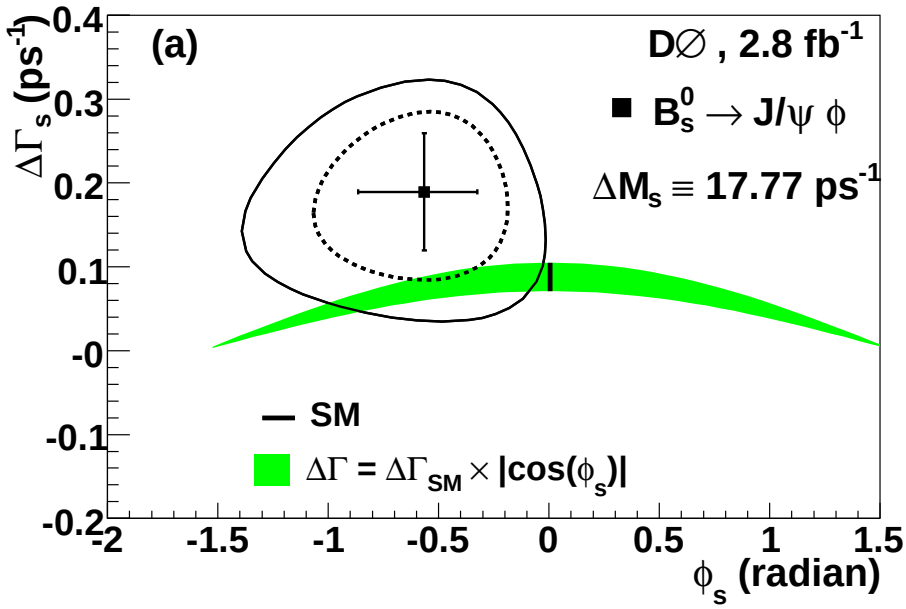

Figure 1: The 1σ and 2σ 2D contours in the plane $(\Delta\Gamma_s, \phi_s)$ for the fit to $B_s^0 \to J/\psi\phi$ (dashed and full line) and the best fit (square) with its 1D 1σ uncertainties (cross), both with constraints on strong phases. The SM prediction is also indicated.

assuming that $\Delta m_s/\overline{\Gamma_s} \gg 1$. The result can be further related to the CP-violating phase in B_s^0 mixing via

$$\frac{\Delta\Gamma_s}{\Delta m_s}\tan\phi_s = [2.45 \pm 1.93\ (\text{stat}) \pm 0.35\ (\text{syst})] \times 10^{-2}. \tag{5}$$

B_s^0 mixing parameters in the decay $B_s^0 \to J/\psi\phi$

B_s^0 mixing parameters [6][7] have been measured [8] by means of the flavor tagged decay $B_s^0 \to J/\psi\phi$, exploiting an integrated luminosity of 2.8 fb^{-1}. The decay width difference between the light and heavy mass eigenstates is determined to

$$\Delta\Gamma_s \equiv (\Gamma_L - \Gamma_H) = 0.19 \pm 0.07\ (\text{stat})^{+0.02}_{-0.01}\ (\text{syst})\ \text{ps}^{-1} \tag{6}$$

and the CP violation phase to

$$\phi_s = -0.57^{+0.24}_{-0.30}\ (\text{stat})^{+0.07}_{-0.02}\ (\text{syst})\ \text{rad}, \tag{7}$$

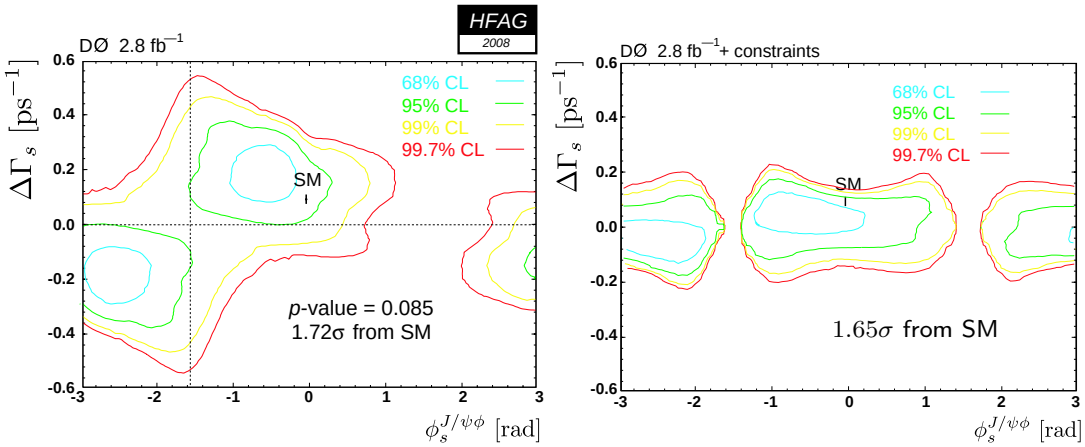

Figure 2: Two dimensional contour plots of the parameter fit in the $(\Delta\Gamma_s, \phi_s)$ plane for different confidence levels. The left plot does not contain any constraints. The right plot takes constraints of the measured charge asymmetry A^s_{SL} and B^0_s lifetime into account.

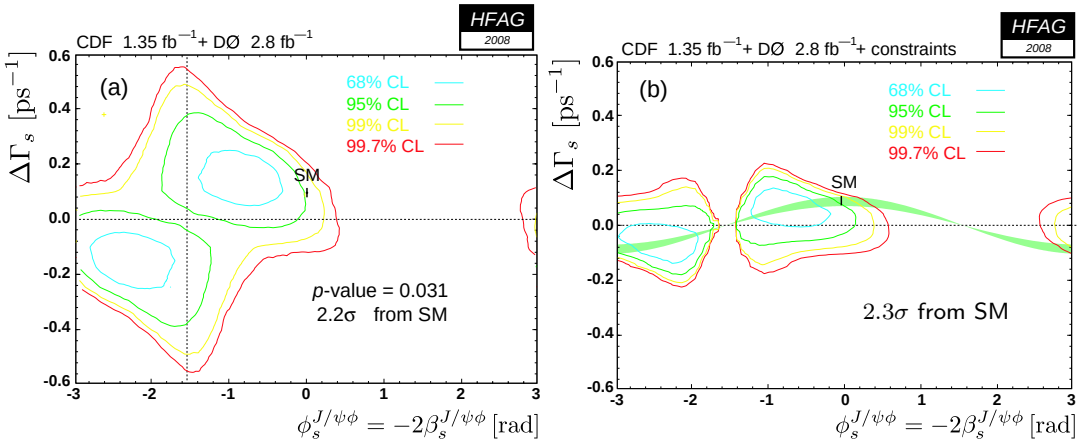

Figure 3: Contour plots of DØ and CDF combined results in the $(\Delta\Gamma_s, \phi_s)$ plane for different confidence levels. The left plot does not contain any constraints. The right plot takes constraints of the measured charge asymmetry A^s_{SL} and B^0_s lifetime into account.

taking constraints on strong phases into account. The results correspond to a 1.8σ deviation from the SM. Fig. 1 shows the two dimensional contour plot of the measurement in the $(\Delta\Gamma_s, \phi_s)$ plane. In Fig. 2 the same kind of contour plots are given, without any constraints (left plot) and taking into account constraints from the measured charge asymmetry A^s_{SL} and B^0_s lifetime (right plot). The preliminary time dependent tagged DØ analysis mentioned above, measuring the CP violation parameter a^s_{sl} is not included yet. The dataset is assumed to be tripled until end of 2009 and a 40% increase in reconstruction efficiency is anticipated leading to an projected increase in significance of about a factor of two. The combinations of present DØ and CDF results [9][10] from the Heavy Flavor Averaging Group [11] are presented in Fig. 3 without any constraints (left plot) and with constraints from charge asymmetry A^s_{SL} and B^0_s lifetime measurements (right plot).

Summary

The CP violation phase ϕ_s and charge asymmetries in B^0_s decays have been measured with the DØ detector. A 1.8σ deviation from the Standard Model is observed in the measurement of the CP violation phase $\phi_s = -0.57^{+0.24}_{-0.30}$ (stat) $^{+0.07}_{-0.02}$ (syst) rad in the decay channel $B^0_s \to J/\psi\phi$, taking constraints on strong phases into account. Without any constraints the deviation changes marginally to 1.72σ. Taking into account constraints of charge asymmetry A^s_{SL} and B^0_s lifetime measurements this value alters to 1.65σ. A combination of the DØ results with the measurement of CDF yields a 2.2σ deviation from the SM if no constraints are applied. Constraints from charge asymmetry A^s_{SL} and B^0_s lifetime measurements increase the deviation slightly to 2.3σ.

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