PROCEEDINGS OF SCIENCE

Measurement of the CP Violating Phase β_s in B_s^0 Decays

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I present the latest CDF results on the determination of the CP violating phase β_s in B_s^0 decays, based on an angular- and time-dependent analysis of the $B_s^0 \to J/\psi\phi$ mode, including determination of the flavor of the B_s^0 meson at production. I discuss the compatibility of the results with Standard Model predictions, combination with other results, and prospects for an improved measurement.

XXth Hadron Collider Physics Symposium
November 16 – 20, 2009
Evian, France

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PoS(HCP2009)092

1. Introduction

Determination of the CP violating phase β_s in B_s^0 mixing is an important test of the Standard Model. This phase, analogous to the CP violating phase β in B^0 decays, appears in the interference between direct decays and decays via mixing. In the Standard Model, β_s is predicted to be very small ($\beta_s \approx 0.02$). The phase β_s can be measured on $B_s^0 \to J/\psi\phi$ decays. Any measured deviation from the Standard Model prediction would be an unequivocal sign of new physics in B_s^0 mixing, indicating the presence of new physics participation in the mixing loop diagram.

2. Analysis Strategy

This measurement combines an angular analysis with a time-dependent, flavor-tagged analysis. In the decay mode of interest, the scalar meson B_s^0 decays to two vector particles, J/ψ and ϕ. The final state angular momentum distribution includes S,P and D-wave contributions, and is a mixture of CP-even (S,D) and odd (P) states. By fitting the angular distribution, it is possible to determine the relative proportion of CP-even to CP-odd in the final state.

Sensitivity to β_s is increased by separately tracking the time evolution of the B_s^0 and $\bar{B}_s^0$ mesons. To distinguish the particle from the antiparticle, it is necessary to know the $B_s^0/\bar{B}_s^0$ oscillation frequency, and the initial flavor of the meson at production. The former is well-measured at the Tevatron, with Δm_s = 17.77±0.12. The production flavor of the B_s^0 meson is determined with opposite side and same side flavor tagging algorithms.

The angular fit and time-dependent, flavor-tagged fit are combined in an un-binned maximum likelihood procedure from which we extract β_s and other parameters of interest, such as $\Delta\Gamma$ (the decay width difference between the $B_s^0/\bar{B}_s^0$ mass eigenstates) and the B_s^0 average lifetime, $1/\Gamma$. We perform the analysis on $2.8 fb^{-1}$ of data collected with the CDF detector, corresponding to 3150±60 B_s^0 signal events. This measurement is an update of a previous result on a 1.35 fb^{-1} data set [1].

3. Results

We quote a confidence region in the $\beta_s/\Delta\Gamma$ plane, given in the left-hand plot in Figure 1. We use a likelihood ratio ordering method to adjust the confidence region to include systematic errors and to account for the non-parabolic shape of the likelihood. This measurement favors a non-zero, positive value for β_s, and excludes β_s^{SM} at the 1.7σ confidence level.

A complementary analysis was performed by the D0 collaboration, and a result consistent with CDF's observation was observed. The CDF/D0 combined contour is shown in the right-hand plot in Fig. 1. For the combined result, β_s^{SM} is excluded at the 2.3σ level.

4. Possible Contamination

Concerns have been raised that non-resonant K^+K^- from $B_s^0 \to J/\psi\, K^+K^-$ could contaminate the signal and bias the measurement of β_s. We propose to address this concern in the coming update of this analysis by fitting for an S-wave contribution, as well as the dominant P- and D-wave contributions considered in the previous iterations of the analysis. Our fit has been extended

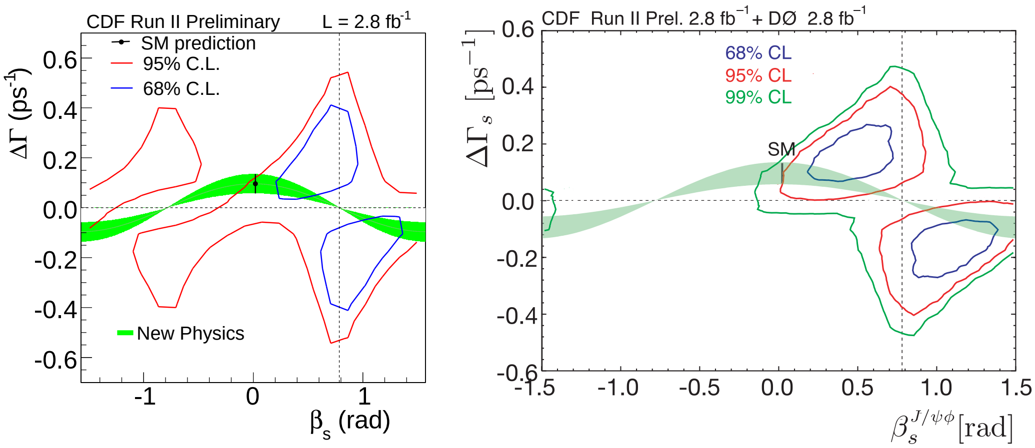

Figure 1: CDF measured confidence region in the $\beta_s/\Delta\Gamma$ plane (left), combined CDF/D0 result (right).

to include an *S*-wave fraction and associated phase, and the extension has been tested successfully on toy Monte Carlo pseudo-experiments.

5. Predicted Sensitivity

Since errors on β_s are statistically dominated, an increased data set will most effectively increase our sensitivity. We estimate our sensitivity to β_s as a function of the size of the data set using toy Monte Carlo pseudo-experiments. We assume a value for β_s of 0.4, and calculate the probability of measuring a significant deviation from β_s^{SM} for different values of the integrated luminosity. Results are shown in Fig. 2. For a data set corresponding to an integrated luminosity of $5fb^{-1}$, the projected probability is 50% that one would measure a 3σ deviation from β_s^{SM}, if β_s=0.4. An update on a data set of this size is nearing completion.

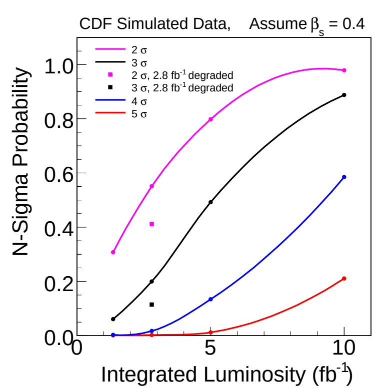

Figure 2: Projected sensitivity to β_s as a function of luminosity, assuming that β_s=0.4.

References

[1] T. Aaltonen et. al (CDF collaboration), PRL 100, 161802 (2008)