Measurement of the $B_s^0$ lifetime in the CP-odd decay channel $B_s^0 \rightarrow J/\psi f_0(980)$ in the D0 experiment

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(On behalf of the D0 Collaboration)

The lifetime measurement of the $B_s^0$ meson in the CP-odd decay channel $B_s^0 \rightarrow J/\psi f_0(980)$ is reported. Data equivalent to 10.4 fb$^{-1}$, collected with the D0 detector in the Run II of the Tevatron is used. The lifetime of the CP-odd component of the $B_s^0$ meson is measured, obtaining a result of $\tau(B_s^0) = 1.70 \pm 0.14$ (stat) $\pm 0.05$ (syst) ps.
1. Introduction

The $B_s^0$ and $\bar{B}_s^0$ mesons are produced as flavor eigenstates, but the particles propagate as mass eigenstates. In the absence of CP-violation in mixing, the mass eigenstates are also CP eigenstates.

The $B_s^0 \rightarrow J/\psi f_0(980)$ decay channel corresponds to a nearly pure CP-odd eigenstate decay. A measurement of the $B_s^0$ lifetime in this channel gives access to the lifetime of the heavy mass eigenstate.

We report the lifetime of the $B_s^0$ meson measured in the decay channel $B_s^0 \rightarrow J/\psi f_0(980)$.

2. Data Selection

The data were collected with the D0 detector during Run II of the Tevatron collider at a center-of-mass energy of 1.96 TeV. The D0 detector is described here [1].

The reconstruction begins by reconstructing $J/\psi \rightarrow \mu^+ \mu^-$, followed by searching for $f_0(980) \rightarrow \pi^+ \pi^-$ candidates. The $B_s^0$ candidates are reconstructed by performing a constrained fit to a common vertex for the charged tracks.

3. Analysis and Results

The lifetime measurement is based on the transverse decay length method: The proper transverse decay length, $\lambda$, for the $B_s^0$ candidate is given by:

$$\lambda = L_{xy} \frac{c M_B}{p_T},$$

(3.1)

where $M_B$ is the average mass value of the $B_s^0$ meson.

A simultaneous unbinned maximum likelihood fit to the mass and proper decay length distributions is performed to measure the lifetime. The components of the model are:

- **Signal**: mass modeled with a Gaussian.
- **Cross-feed background** (mis-reconstructed B decays): mass modeled with a wide Gaussian.
- **$B^+$ background** ($B^+ \rightarrow J/\psi K^+$ with accidental track): mass distribution taken from data.
- **Combinatorial background**: mass modeled with an exponential.

Proper decay lengths are modeled with an exponential convoluted with a Gaussian resolution in all cases. The distribution of the decay length uncertainty is described by a phenomenological model for all the components, using an exponential convoluted with a Gaussian.

The fit yields $\tau(B_s^0) = 504 \pm 42 \; \mu$m and the numbers of signal decays to be $494 \pm 85$.

We test the modeling and fitting method used to estimate the lifetime using data generated in pseudoexperiments. We correct for a small -4.4 $\mu$m fit bias which arises due to imperfect separation of signal and background.
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Figure 1: Distributions of (a) invariant mass, (b) proper transverse decay length, and (c) proper transverse decay length uncertainty for $B_0^s$ candidates.

4. Systematic Uncertainties

<table>
<thead>
<tr>
<th>Source</th>
<th>Variation ($\mu$m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment</td>
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<tr>
<td>$\pi^+\pi^-$ invariant mass window</td>
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<tr>
<td>Fit bias</td>
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<td>Distribution models</td>
<td>12.5</td>
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<tr>
<td>Total (sum in quadrature)</td>
<td>16.4</td>
</tr>
</tbody>
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5. Conclusions

In summary, the lifetime of the $B_0^s$ is measured [2] to be:

$$c \tau(B_0^s) = 508 \pm 42 \text{ (stat)} \pm 16 \text{ (syst)} \mu m,$$

from which we determine:

$$\tau(B_0^s) = 1.70 \pm 0.14 \text{ (stat)} \pm 0.05 \text{ (syst)} \text{ ps},$$
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in the decay channel $B_0^s \to J/\psi \pi^+\pi^-$ with $880 \leq M_{\pi^+\pi^-} \leq 1080$ MeV/c$^2$.

CDF [3] and LHCb [4] have measured this lifetime, reporting $\tau(B_0^s) = (1.70 \pm 0.12 \pm 0.03)$ ps and $\tau(B_0^s) = (1.70 \pm 0.04 \pm 0.026)$ ps respectively.

Our result is in good agreement with previous measurements and provides an independent confirmation of the longer lifetime for the CP-odd eigenstate of the $B^0_s/\bar{B}^0_s$ system.

6. Acknowledgements

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References

[2] V.M. Abazov et al. (D0 Collaboration), $B_0^s$ lifetime measurement in the CP-odd decay channel $B_0^s \to J/\psi f_0(980)$, Phys. Rev. D 94, 012001 (2016)
[3] T. Aaltonen et al. (CDF Collaboration), Measurement of branching ratio and $B_0^s$ lifetime in the decay $B_0^s \to J/\psi f_0(980)$ at CDF, Phys. Rev. D 84, 052012 (2011).