MEASUREMENT OF THE MASSES AND LIFETIMES OF B HADRONS AT THE TEVATRON

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The latest results for the B Hadron sector at the Tevatron Collider are summarized. The properties of B Hadrons can be precisely measured at the Tevatron. In particular we will focus on the masses and lifetimes. The new Tevatron results for the CP violation in B Hadrons will be also discussed.

1 Introduction

The two experiments, CDF and DØ at the Tevatron collider at Fermilab have successfully been taking data with √s = 1.96 TeV. New or updated analysis are based on 0.36 - 1 fb⁻¹ of data. Thanks to the possibility of producing all types of B Hadrons, Tevatron is exploring a wide range of the B sector, performing precise measurements of several properties like masses, lifetimes, production fractions and CP violation.

2 Measurement of B Hadron relative Fragmentation Fractions

In Run I of the Fermilab Tevatron, the fraction of $\bar{B}^0_s$ mesons produced relative to the number of $\bar{B}^0$ mesons was measured 2σ higher at CDF than at LEP experiments. To shed light on the question, recently the CDF experiment performed the first RUN II measurement of $b$ quark fragmentation into $\bar{B}^0$, $B^-$, $\bar{B}^0_s$ and $\Lambda^0_b$ using semileptonic decays reconstructed in 360 pb⁻¹ of data. The corresponding fragmentation fractions were measured to be:

$$\frac{f_u}{f_d} = 1.054 \pm 0.018(stat) +0.025^{+0.045}_{-0.045}(sys) \pm 0.058(BR)$$

$$\frac{f_s}{f_u + f_d} = 0.160 \pm 0.005(stat) +0.011^{+0.010}_{-0.010}(sys) +0.057(BR)$$
\[
\frac{f_{A_0}}{f_u + f_d} = 0.281 \pm 0.012(\text{stat})^{+0.058}_{-0.056}(\text{sys})^{+0.128}_{-0.086}(BR).
\]

Since the measured semileptonic events have an effective \( p_T(B) > 7.0 \) threshold, \( f_q \) in this text indicates \( f_q \equiv f_q(p_T(B) > 7.0 \text{ GeV}/c) \). The relative fragmentation fractions \( \frac{f_s}{(f_u + f_d)} \) and \( \frac{f_{A_0}}{(f_u + f_d)} \) differ from the world averages by 1\( \sigma \) and 2\( \sigma \) respectively.

### 3 Orbitally Excited B Mesons

The quark model predicts the existence of two wide (\( B_0^\ast \) and \( B_1^\ast \)) and two narrow (\( B_1 \) and \( B_2 \)) bound \( P \) states.\(^{[3]}\) The wide states decay via \( S \) wave and therefore have a large width of a few MeV/c\(^2\). Such states are difficult to distinguish from combinatoric background. The narrow states decay via \( D \) wave and therefore should have a small width of around 10MeV/c\(^2\).\(^{[2]}\) The same excited states pattern is predicted for \( B^0 \), \( B^+ \) and \( B_s \) mesons.

#### 3.1 B excited states

Recently the DO experiment studied the narrow \( L = 1 \) states decaying to \( B^{\ast+} \pi \) with exclusively reconstructed \( B \to J/\psi K \) in 1 fb\(^{-1} \) of data. A clear excess of events, with a statistical significance of more than 7\( \sigma \), can be observed in the \( M(B\pi) - M(B) \) distribution of Fig.\([1\text{]}\) (left). This excess can be interpreted in terms of three contributions:

\[
B_1^0 \to B^{++}\pi^-; B^{++} \to B^+\gamma \\
B_2^{0*} \to B^{++}\pi^-; B^{++} \to B^+\gamma \\
B_2^{*0} \to B^+\pi^-;
\]

where the \( \gamma \) from \( B^{++} \) is not reconstructed (that explains the separation between the two \( B_2^{*0} \) decays). The \( B_1^0 \) and \( B_2^{0*} \) masses and width (same width is assumed) are measured:

\[
M(B_1) = 5720.8 \pm 2.5(\text{stat.}) \pm 5.3(\text{syst.}) \text{ MeV}/c^2 \\
M(B_2^0) - M(B_1) = 25.2 \pm 3.0(\text{stat.}) \pm 1.1(\text{syst.}) \text{ MeV}/c^2 \\
\Gamma_1 = \Gamma_2 = 6.6 \pm 5.3(\text{stat.}) \pm 4.2(\text{syst.}) \text{ MeV}/c^2
\]

while the branching ratio of \( B_2^{*0} \) to \( B^* \), the composition of the \( B_j \) sample and the \( B_j \) production rate normalized to the \( B^+ \) one are measured to be:

\[
\frac{Br(B_2^* \to B^*\pi)}{Br(B_2^{*0} \to B^{*+}\pi)} = 0.513 \pm 0.092(\text{stat.}) \pm 0.115(\text{syst.}) \\
\frac{Br(B_1 \to B^{*+}\pi)}{Br(B_j \to B^{*+}\pi)} = 0.545 \pm 0.064(\text{stat.}) \pm 0.071(\text{syst.}) \\
\frac{Br(b \to B_2^{*0} \to B\pi)}{Br(b \to B^+)} = 0.165 \pm 0.024(\text{stat.}) \pm 0.028(\text{syst.})
\]

#### 3.2 \( B_2^0 \) excited states

Using a sample of 1 fb\(^{-1} \) of data the DO experiment observed the process \( B_2^{*0} \to B^+K \). An excess with a statistical significance exceeding 5\( \sigma \) can be observed in Fig.\([3\text{]}\) (right). The \( B_2^{*0} \) mass is measured:

\[
M(B_{s2}^{*0}) = 5839.1 \pm 1.4(\text{stat.}) \pm 1.5(\text{syst.}) \text{ MeV}/c^2
\]

Taking into account that the theory predicts the same mass splitting in the \( \bar{b}d(u) \) and \( \bar{b}s \) systems and considering the results shown in section 3.1, the decay \( B_1^{*0} \to B^{*+}K \) is forbidden (it is under decay threshold) while \( B_{s2}^{*0} \to B^+K \) is strongly suppressed due to phase space.
4 $B_c$ meson properties

Using a sample of 0.8fb$^{-1}$ the CDF experiment recently updated the $B_c \rightarrow J\psi\pi$ exclusive decay analysis. In Fig.2 an excess, with a statistical significance greater than 6$\sigma$, can be observed. The new measurement of the $B_c$ mass is:

$$M(B_c) = 6275.2 \pm 4.3 \text{ (stat.)} \pm 2.3 \text{ (syst.)} \text{ MeV}/c^2$$

Using the decay $B_c \rightarrow J/\psi e\nu$ in 360pb$^{-1}$ of data (in Fig.2 right the pseudo-proper decay length distribution), CDF measured also the $B_c$ lifetime to be:

$$\tau(B_c) = 0.474^{+0.073}_{-0.066} \text{ (stat.)} \pm 0.033 \text{ (syst.)} \text{ ps}$$

5 CP violation parameter in $B^0$ mixing and decay

The CP-violation parameter $\epsilon$ is sensitive to several extensions of the Standard Model and it is considered as one of the first possible indications of physics beyond the Standard Model. The DØ experiment, using 970pb$^{-1}$ of data, measured the dimuon charge asymmetry. As a sensitive cross check, the mean mixing probability $<\chi>$ of hadrons with a $b$ quark was also measured:

$$<\chi> = 0.136 \pm 0.001 \text{ (stat.)} \pm 0.024 \text{ (syst.)}$$

Assuming that the dimuon asymmetry $A_{B^0}$, i.e. the dimuon charge asymmetry from direct-direct decays of $B^0\bar{B}^0$ pairs, is due to asymmetric $B^0 \leftrightarrow \bar{B}^0$ mixing decay, the CP-violation parameter $\epsilon$
parameter of $B^0$ mixing and decay was extracted. The corresponding measurements were found to be:

$$A_{B^0} = 0.0044 \pm 0.0040 \, (\text{stat.}) \pm 0.0028 \, (\text{syst.})$$

$$\frac{\text{Re}(\epsilon_{B^0})}{1 + |\epsilon_{B^0}|^2} = \frac{A_{B^0}}{4} = -0.0011 \pm 0.0010 \, (\text{stat.}) \pm 0.0007 \, (\text{syst.})$$

(4)

6 CP violation and $\Delta \Gamma_{CP}/\Gamma_{CP}$ in $B$ charmless two body decays

The CDF II detector can collect and reconstruct significant samples of $B^0$ and $B_s^0$ charmless two body decays, Fig.8 (left). Recently CDF updated his measurement of the direct CP asymmetry in $B^0 \rightarrow K^+\pi^-$ events using 355 pb$^{-1}$ of data. The new measurement was found to be:

$$A_{CP} = \frac{N(B^0 \rightarrow K^-\pi^+) - N(B^0 \rightarrow K^+\pi^-)}{N(B^0 \rightarrow K^-\pi^+) + N(B^0 \rightarrow K^+\pi^-)} = -0.058 \pm 0.039 \, (\text{stat.}) \pm 0.007 \, (\text{syst.})$$

Using the same data sample, the $B^0$ two body decay and the $B_s^0 \rightarrow K^+K^-$ lifetimes were measured. The corresponding values were found to be:

$$\tau(B^0) = 1.51 \pm 0.08 \, (\text{stat.}) \pm 0.02 \, (\text{syst.}) \, \text{ps}$$

$$\tau(B_s \rightarrow K^+K^-) = 1.53 \pm 0.18 \, (\text{stat.}) \pm 0.02 \, (\text{syst.}) \, \text{ps}$$

lifetime fit projections are shown in Fig.8 (right).

Combining the CDF II measurement of the $B_s^0 \rightarrow K^+K^-$ lifetime with the latest HFAG average $B^0$ lifetime in flavor specific decays $\tau(B_s FS) = 1.454 \pm 0.040 \, \text{ps}$, $\Delta \Gamma_{CP}/\Gamma_{CP}$ was evaluated to be:

$$\frac{\Delta \Gamma_{CP}}{\Gamma_{CP}}(B_s \rightarrow K^+K^-) = -0.08 \pm 0.23 \, (\text{stat.}) \pm 0.03 \, (\text{syst.})$$

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