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Fully Reconstructed B-Meson Decays Using J/ψ and ψ (2S)

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Fully Reconstructed B-meson Decays Using J/ψ and $\psi(2S)$

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In this paper we present CDF B-meson branching ratio results involving color-suppressed $B \rightarrow \Psi\mathrm{K}$ decays, where $\Psi = J/\psi, \psi(2S)$ and $\mathrm{K} = K, K^*$. Fully reconstructed decays of $B \rightarrow J/\psi\mathrm{K}$, $B \rightarrow \psi(2S)\mathrm{K}$, $B^+ \rightarrow J/\psi\pi^+$ and $B_s \rightarrow J/\psi\phi$ are used to extract branching ratios, vector-pseudoscalar ratios and polarization parameters.

1 Introduction

The decay of $B \rightarrow \Psi\mathrm{K}$ is expected to proceed primarily through the 'color-suppressed' $b \rightarrow c\bar{c}s$ diagram. The determination of its magnitude and decay mechanism provide insight into the hadronic B decays. Under the factorization assumption [1], the branching ratios of $B \rightarrow \Psi\mathrm{K}$ decay modes depend only on a_2, where a_2 is the amplitude of internal W-decay in B hadrons. Precise measurements of exclusive $B \rightarrow \Psi\mathrm{K}$ will be useful to determine a_2 and ultimately test the factorization assumption.

The large b production cross section at the Tevatron and the successful implementation of lepton triggers have enabled CDF to join this area of highly competitive b physics. We report here new results[3] from CDF on the branching ratio measurements of $B \rightarrow \Psi\mathrm{K}$ decays. The data were taken during the 1992-1995 runs with the CDF detector (RUN-I) and the integrated luminosity is 110 pb^{-1}.

2 J/ψ and $\psi(2S)$ reconstruction

The data sample used for the inclusive Ψ reconstruction was selected by a three-level trigger system in which two opposite-charged muons with an invariant mass between 2.7 and 4.1 GeV/c^2 were required. A least-squares fit was performed on the two muon candidate tracks constraining the two tracks to originate from a common vertex. Muon candidates were required to possess $P_t > 2GeV/c$ before any vertex constraints were imposed on the track parameters. In the case of $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ reconstruction, all four legs were required to originate from a common vertex. The pre-constrained dipion invariant mass was required to lie in the range $0.31 < M_{\pi\pi} < 0.61$ GeV/c to reduce combinatorial background.

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The excellent triggering, tracking and vertexing at CDF can be demonstrated by the inclusive $J/\psi \to \mu^+\mu^-$. $\psi(2S) \to \mu^+\mu^-$ and $\psi(2S) \to J/\psi\pi^+\pi^-$ mass distributions shown in Fig. 1 and Fig. 2.

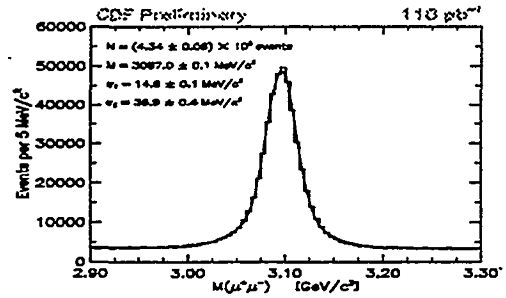

Figure 1: The J/ψ dimuon invariant mass distribution after a vertex constraint.

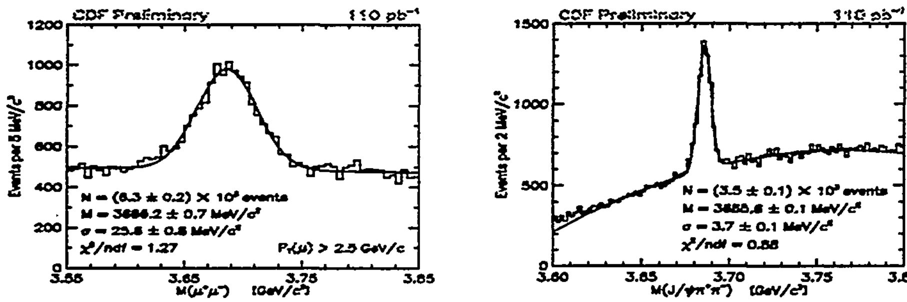

Figure 2: The $\psi(2S)$ dimuon (left) and $J/\psi\pi\pi$ (right) invariant mass distributions after a vertex constraint.

3 $B \to J/\psi$K

After mass constraining its mass to the world average value [2], the J/ψ is combined with a **K** to look for B-mesons where $\mathbf{K} = K^+, K^0, K^*(892)^0$,or $K^*(892)^+$. We reconstruct K^0 through K^0_s. The K^0_s selection requires two oppositely charged tracks with $p_t > 0.35 GeV/c$ and the pairs are vertex constrained. The $K^*(892)^+$ is formed with a K^0_s candidate plus a track, assumed to be a π^+; the $K^*(892)^0$ is formed from two charged tracks assumed to be a K^+ and π^-. The $K^*(892)^+$ and $K^*(892)^0$ candidates are required to have an invariant mass within 75 MeV/c^2 of the PDG value.

The invariant mass spectra of B^+ and B^0 using 19.6 pb^{-1} data (RUN-1A) are shown in Fig 3 and Fig 4. The number of events from fitting and the relative reconstruction efficiency from Monte Carlo study are listed in Table 1.

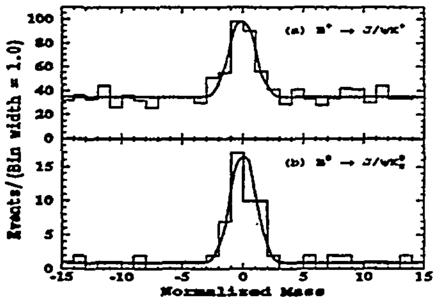

Figure 3: The normalized mass distribution for (a)$B^+ \to J/\psi K^+$ and (b)$B^0 \to J/\psi K_s^0$

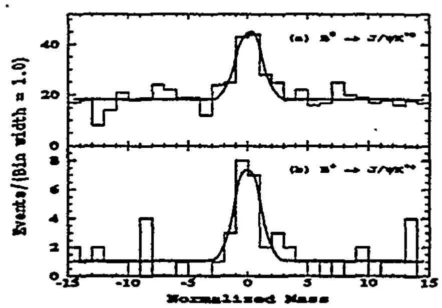

Figure 4: The normalized mass distribution for (a)$B^0 \to J/\psi K^*(892)^0$ and (b)$B^+ \to J/\psi K^*(892)^+$

Table 1. $B \to J/\psi$K result

	$B^+ \to J/\psi K^+$	$B^0 \to J/\psi K_s^0$	$B^0 \to J/\psi K^*(892)^0$	$B^+ \to J/\psi K^*(892)^+$
N_s	169 ± 18	41.8 ± 6.9	71 ± 12	17.0 ± 4.7
ϵ	1.0	1.57 ± 0.08	2.11 ± 0.18	2.53 ± 0.37

The ratios of branching ratios are: $\frac{Br(B^0 \to J/\psi K^0)}{Br(B^+ \to J/\psi K^+)} = 1.13 \pm 0.22 \pm 0.06$, $\frac{Br(B^0 \to J/\psi K^{*0})}{Br(B^+ \to J/\psi K^+)} = 1.33 \pm 0.27 \pm 0.11$ and $\frac{Br(B^+ \to J/\psi K^{*+})}{Br(B^+ \to J/\psi K^+)} = 1.55 \pm 0.46 \pm 0.16$

Using the world average $Br(B^+ \to J/\psi K^+) = (0.102 \pm 0.014)\%$[2], we find

$$Br(B^0 \to J/\psi K^0) = (0.115 \pm 0.023 \pm 0.017)\%$$

$$Br(B^0 \to J/\psi K^{*0}) = (0.136 \pm 0.027 \pm 0.022)\%$$

$$Br(B^+ \to J/\psi K^{*+}) = (0.158 \pm 0.047 \pm 0.027)\%$$

Assuming isospin symmetry, we combine the above results to extract the vector-pseudoscalar ratio

$$R = \frac{Br(B \to J/\psi K^*)}{Br(B \to J/\psi K)} = 1.32 \pm 0.23 \pm 0.16.$$

CDF has published a measurement of J/ψ polarization[4] in $B^0 \to J/\psi K^*(892)^0$,

$$\Gamma_L/\Gamma = 0.65 \pm 0.10 \pm 0.04.$$

It will be interesting to see whether theory models based on the factorization hypothesis and the $B \to K(K^*)$ form factors can reproduce the above results.

4 $B^+ \to J/\psi\pi^+$

The difficult task here is to distinguish the small $B^+ \to J/\psi\pi^+$ signal from large backgrounds. We estimate the signal mass spectrum and background spectra from $B^+ \to J/\psi K^+$, misidentifying the K^+ as a π^+, and combinatorial background using Monte Carlo. From a fit to the $J/\psi\pi^+$ mass spectra, shown in Fig. 5, we find 28^{+10}_{-9} events with a 3.0σ significance. The branching ratio relative to $B^+ \to J/\psi K^+$ is extracted to be

$$\frac{Br(B^+ \to J/\psi\pi^+)}{Br(B^+ \to J/\psi K^+)} = (6.0^{+2.2}_{-2.0} \pm 0.1)\%$$

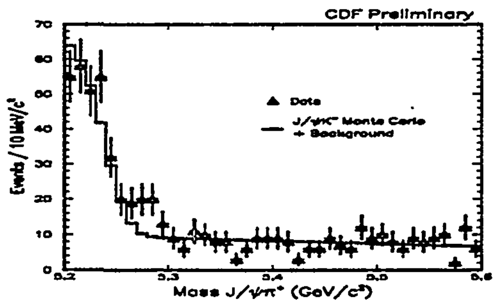

Figure 5: The $M_{J/\psi\pi^+}$ mass distribution. The superimposed curves show the $M_{J/\psi\pi^+}$ distribution for Monte Carlo $B^+ \to J/\psi K^+$ and combinatorial events. There is clearly an excess around the B mass region which is due to the contribution of $B^+ \to J/\psi\pi^+$ decay.

5 $B \to \psi(2S)$K

Using the full available dataset and similar techniques for $B \to J/\psi$K decay, we reconstructed decays of $B^+ \to \psi(2S)K^+$ and $B^0 \to \psi(2S)K^*(892)^0$ as shown in Fig. 6 and Fig. 7. We use the $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^*(892)^0$ as normalization modes. We find:

$$\frac{Br(B^+ \to \psi(2S)K^+)}{Br(B^+ \to J/\psi K^+)} = 0.666 \pm 0.093 \pm 0.101$$

$$\frac{Br(B^0 \to \psi(2S)K^{*0})}{Br(B^0 \to J/\psi K^{*0})} = 0.569 \pm 0.131 \pm 0.074$$

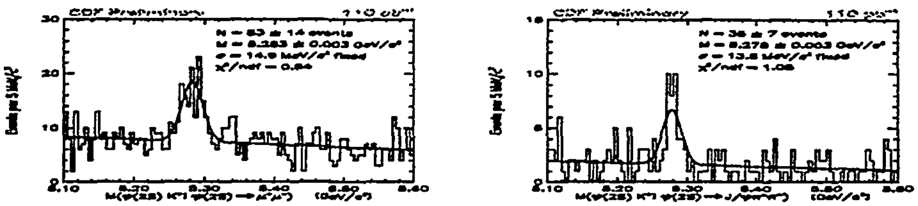

Figure 6: The $\psi(2S)K^+$ invariant mass distribution with $\psi(2S) \rightarrow \mu^+\mu^-$ (left) and $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ (right). The numbers of events are 83 ± 14 and 35 ± 7 respectively for the two decay channels.

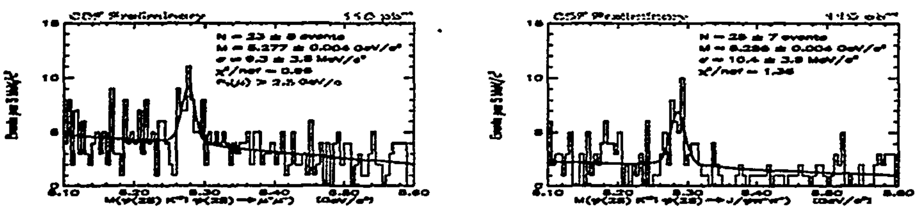

Figure 7: The $\psi(2S)K^*(892)^0$ invariant mass distribution with $\psi(2S) \rightarrow \mu^+\mu^-$ (left) and $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ (right). The numbers of events are 23 ± 8 and 25 ± 7 respectively for the two decay channels.

Using $Br(B^+ \rightarrow J/\psi K^+) = (0.102 \pm 0.014)\%$ and $Br(B^+ \rightarrow J/\psi K^{*0}) = (0.158 \pm 0.28)\%$ [2], we find $Br(B^+ \rightarrow \psi(2S)K^+) = (6.8 \pm 1.0 \pm 1.4) \times 10^{-4}$ and $Br(B^0 \rightarrow \psi(2S)K^{*0}) = (9.0 \pm 2.1 \pm 2.0) \times 10^{-4}$. From isospin symmetry and $\tau^+/\tau^0 = 1.02 \pm 0.05$ [2], we calculate the vector-pseudoscalar ratio

$$R = \frac{Br(B \rightarrow \psi(2S)K^*)}{Br(B \rightarrow \psi(2S)K)} = 1.35 \pm 0.55$$

which is consistent with R calculated with $B \rightarrow J/\psi$ decays.

6 $B_s \rightarrow J/\psi\phi$

The decay of $B_s \rightarrow J/\psi\phi$ is expected to be dominated by CP-even state and the decay is of special interest to extract CP violation in the B_s system. From a data sample of 19.6 pb^{-1}, we find 29.4 ± 6.2 events of $B_s \rightarrow J/\psi\phi$ with $\phi \rightarrow K^+K^-$, as show in Fig. 8. Using the well measured $B \rightarrow J/\psi$K as the normalization mode and their world averaged branching ratio, we find

$$Br(B_s \rightarrow J/\psi\phi) = \frac{f_s}{f_u + f_d}(0.037 \pm 0.011 \pm 0.004)\%$$

where f_u, f_d and f_s are fragmentation fraction of b quarks to B_u,B_d and B_s mesons. Using $f_s/(f_u + f_d) = (0.20 \pm 0.03)$ [5], we have

$$Br(B_s \to J/\psi\phi) = (0.093 \pm 0.028 \pm 0.017)\%.$$

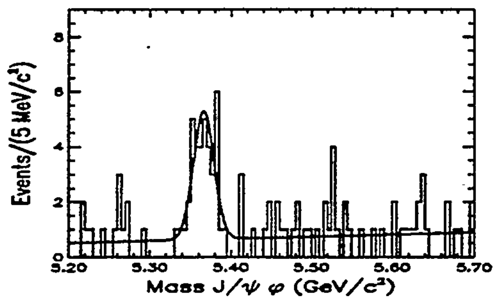

Figure 8: The $J/\psi\phi$ invariant mass distribution.

7 Summary

Using CDF dimuon sample, we measured B-meson branching ratios involving color-suppressed $B \to \Psi\mathbf{K}$ decays, $B \to J/\psi\pi$ and $B_s \to J/\psi\phi$. The vector-pseudoscalar ratios for $B \to J/\psi$ and $B \to \psi(2S)$ are extracted to be $1.32 \pm 0.23 \pm 0.16$ and 1.35 ± 0.55 respectively. Much effort is still being put into updating the above results using the full RUN-I data sample. We can expect excellent new results in the near future.

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