Fermi National Accelerator Laboratory

FERMILAB-Conf-93/275-E

CDF

Searches for B Hadrons at CDF

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September 1993

Presented at the *5th International Symposium on Heavy Flavour Physics*, McGill University, Montreal, Quebec, Canada, July 6-10, 1993

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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Abstract

The CDF data from the 1992-93 Tevatron run contains a large, clean sample of events which contain fully reconstructed $J/\psi \rightarrow \mu^+\mu^-$. This data has been employed in a search for B hadrons which contain J/ψ amongst their decay products. An analysis of 8 pb^{-1} of data produces no evidence for $\Lambda_b \rightarrow J/\psi\Lambda$. A signal of 14.0 ± 4.7 events is seen for the $B_s \rightarrow J/\psi\phi$. The B_s mass has been determined to be 5383.3 ± 4.5 (stat) ± 5.0 (syst.).

Published Proceedings 5th International Symposium on Heavy Flavour Physics, McGill University, Montreal, Quebec, Canada, July 6-10, 1993.

The Collider Detector at Fermilab (CDF) recently completed its 1992-93 data run. The experiment collected 21.4 pb^{-1} of $p\bar{p}$ collisions at 1800 GeV center of mass energy. A dimuon trigger was in place throughout this run, which was optimized for the detection of the J/ψ, through its dimuon decay mode. This note will report on the status of our search for new B hadrons which contain the J/ψ among their decay products.

The original CDF detector [1] was upgraded for the 1992-93 run with an increase in central muon coverage, and improved vertexing with a silicon strip vertex chamber (SVX) and a new time projection chamber (VTX). Approximately 60% of events occur with the acceptance of the SVX, where the track spatial resolution is 13 μm in the plane transverse to the beam. Central muon coverage extends over approximately 75% of the pseudorapidity interval $|\eta| < 1.0$. The low level CDF dimuon trigger requires a pair of tracks in the muon chambers, and one matching, 3 GeV/c transverse momentum (p_t) track, found in the central drift chamber (CTC) by the fast track processor. Events which satisfied these requirements were then processed by the software track reconstruction, and events with a measured dimuon mass 2.8 - 3.4 GeV/c^2 were retained. The SVX, VTX, and CTC tracking chambers lie within a 1.4116 T solenoid, and were employed in a full reconstruction of each event offline. The tracking system has a momentum resolution $dp_t/p_t < 0.001\ p_t$. The minimum transverse momentum reconstructed for these analyses was 400 MeV/c, although future refinements will lower this cuttoff to about 250 MeV/c. No particle identification exists at this time.

The J/ψ is reconstructed with a width of 22 Mev/c^2 at a mass consistant with the world average of 3.0969 GeV/c^2[2], and a signal-to-background ratio of about 13:1 at the peak. Our acceptance limits J/ψ detection to $p_t > 4$ GeV/c and $|\eta| < 0.6$. All CDF analyses for exclusive states which contain the J/ψ, select events whose dimuon invariant mass falls within 3σ of the accepted J/ψ mass. The muon tracks are then refit with the constraints that they intersect in a common point, and combine to form the J/ψ mass. For final states where it is appropriate, additional pion and/or kaon tracks are included in the vertex fit. This constrained fitting technique improves our mass resolution, and the quality of the fit can be used to reduce combinatorial backgrounds.

A search for the process $\Lambda_b \rightarrow J/\psi\Lambda$, along with $B^0 \rightarrow J/\psi K^0_s$ as a control sample, has been performed on the first 8 pb^{-1} of data from the recent run. The J/ψ events were chosen as above, and all pairs of oppositely charged, nonmuon tracks found in these events were refit with the constraint that they originated from a common vertex. Both π-π and π-p mass assumptions were used for a K^0_s and Λ search. The proton assignment was given to the track with the highest total momentum in the π-p combination. This assumption is always true for CDF's sensitivity in the Λ mass region. Combinatorial backgrounds under the K^0_s and Λ were then reduced by applying cuts which select for vertices distinct from the interaction. We impose a 1 mm cut on both track impact parameters with respect to the beam postion, and require a positive lifetime for each neutral vertex. A sample of 1600 K^0_s and 324 Λ were found, with widths of 5.5 and 2.6 MeV/c^2 respectively, and masses consistant with the world averages. Neutral vertices found within 2σ of the accepted K^0_s and Λ masses were then combined with the vertex and mass constrained muon tracks to form the $J/\psi K^0_s$ and $J/\psi\Lambda$ invariant mass distributions shown in Figure 1. We estimate our mass resolution for both combinations at approximately 15 MeV/c^2 for the mass ranges shown. A clear signal for the process $B^0 \rightarrow J/\psi K^0_s$ can be seen. However, we have no evidence for $\Lambda_b \rightarrow J/\psi\Lambda$, and are still unable to confirm an earlier observation of this state [3]. Our limit on $F(\Lambda_b)Br(\Lambda_b \rightarrow J/\psi\Lambda)$ from the 1988-89 data [4] stands as our best estimate of this quantity until the entire 1992-93 data set is analyzed.

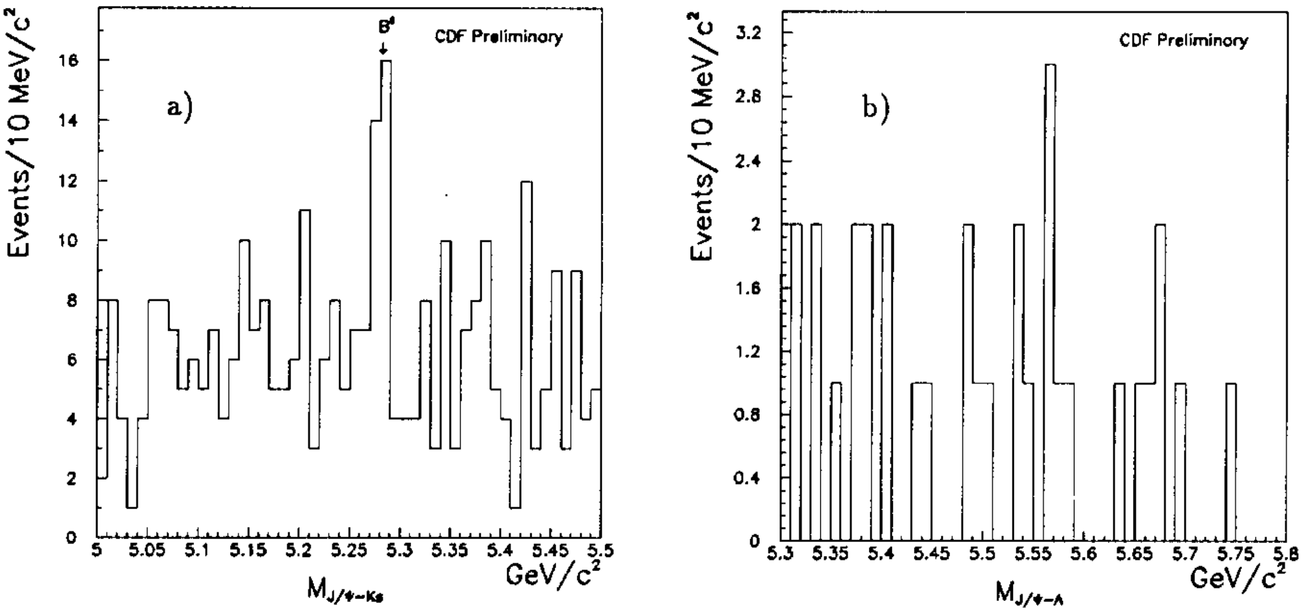

Figure 1: a. $J/\psi K_s^0$ invariant mass distribution b. $J/\psi\Lambda$ invariant mass distribution in the mass range expected to contain the Λ_b

For $B_s \rightarrow J/\psi\phi$, and its control samples $\psi' \rightarrow J/\psi\pi\pi$, $B^+ \rightarrow J/\psi K^+$, and $B^0 \rightarrow J/\psi K^{*0}$, the track refitting employed the constraint that the π/K tracks share the same vertex as the muons from J/ψ decay. A confidence level cut of 1% was required on this fit, to remove badly measured tracks, or tracks which originated from the underlying event. The large background to B signals due to direct J/ψ production can be removed by a displaced vertex requirement. The beam spot size is approximately 40 μm, and a cut on the measured decay length effectively reduces this source of background. Finally, requirements on the transverse momentum of the B candidate and its decay products are known from Monte Carlo simulation to be efficient filters for B candidates.

The reconstruction of $B^\pm \rightarrow J/\psi K^\pm$ was accomplished by assigning all nonmuon tracks the kaon mass. We then required $p_t(K^\pm) > 2$ GeV/c, $p_t(B^\pm) > 8$ GeV/c, and the $\mu^+\mu^-K^\pm$ vertex displacement with respect to the beam $(L_{xy}) > 100\mu$m. The resulting $J/\psi K^\pm$ mass spectrum is shown in Fig. 2. We find 79.5 $\pm$ 11.4 $B^\pm$ candidates.

The K^{*0} candidates used for B^0 reconstruction are found by considering all $K^\pm\pi^\mp$ combinations within 80 MeV/c^2 of the K^{*0} mass. The large combinatorial background is reduced by requiring $p_t(K^{*0}) > 3$ GeV/c, $p_t(B^0) > 8$ GeV/c, and $L_{xy} > 100$ μm. A B^0 signal of 43.7 $\pm$ 8.7 events is found.

The reconstruction of $\psi' \rightarrow J/\psi\pi\pi$ required the assumption that all nonmuon tracks are pions. A cut which requires that the π-π invariant mass fall within the range .45-.58 GeV/c^2 provides sufficient background reduction for a clean signal, and good mass measurement. The reconstructed ψ', $B^\pm$, and B^0 masses, along with their statistical uncertainties, are listed in Table 1. All are within 1σ of the accepted, world averages [2], and all are found with a mass resolution which is consistant with Monte Carlo studies.

The selection of ϕ candidates for the reconstruction of $B_s^0 \rightarrow J/\psi\phi$ requires oppositely charged tracks with a kaon assignment, to fall within 10 MeV of the accepted ϕ mass [2]. As with the other B hadrons, combinatorial backgrounds are reduced by requiring $p_t(\phi) > 2$

GeV/c, and $L_{xy} > 0$. The $J/\psi K^+K^-$ invariant mass distribution obtained appears in Figure 3. A clear signal appears, corresponding to the B_s^0. This signal is stable under a variety of selection criteria. The dotted histogram shown in Figure 3a contains $J/\psi K^+K^-$ masses found for K^+K^- combinations with an invariant mass in the range 1050-1090 MeV/c^2, well away from the ϕ. No enhancement at any mass is indicated. Monte Carlo calculations have been used to estimate the background due to the misidentification of a pion from $B^0 \rightarrow J/\psi K^{*0}$. This contribution to the B_s^0 signal is estimated to be 0.9 $\pm$ 0.9 events. There were no events found which were common to the B^0 and B_s^0 signals. A binned maximum likelihood fit with a Gaussian width fixed at our estimated value of 12 MeV/c^2 yields a B_s^0 signal of 14.0 $\pm$ 4.7 events, with a mass of 5383.3 $\pm$ 4.5 GeV/c^2. If the K^+K^- mass cut is relaxed, and all $J/\psi K^+K^-$ mass within 20 MeV/c^2 of 5380 are chosen, the K^+K^- mass distribution appears as in Figure 3b. A clear enhancement at the ϕ is observed.

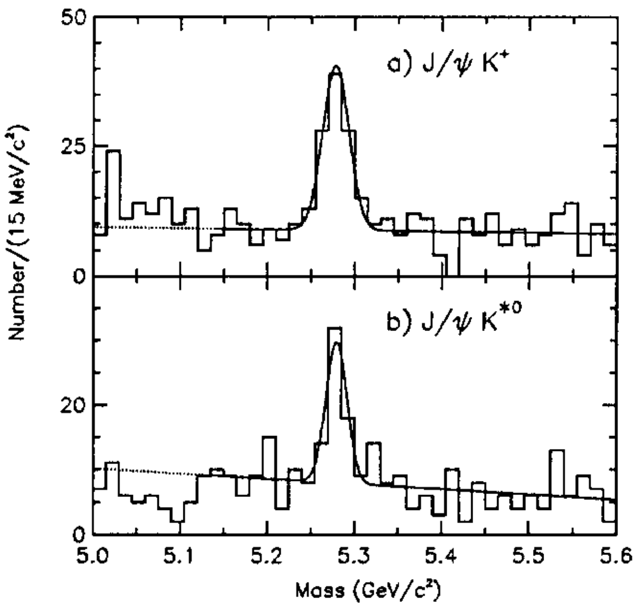

Figure 2: $J/\psi K^{\pm}$ and $J/\psi K^{*0}$ mass distributions. The solid line indicates the fit.

Table 1: Reconstructed masses

	CDF Measurements (MeV/c^2)	PDG (MeV/c^2)[2]
ψ'	3685.7 $\pm$ 0.4	3686.0 $\pm$ 0.1
$B^{\pm}$	5278.2 $\pm$ 2.6	5278.6 $\pm$ 2.0
B^0	5279.6 $\pm$ 2.9	5278.7 $\pm$ 2.1
B_s	5383.3 $\pm$ 4.5	-

Several potential sources of systematic error in our B_s^0 mass measurement have been studied. Error induced by the mass fit procedure was estimated by varying the bin widths and the Gaussian width. The effect of the selection criteria was estimated by varying the values of the cuts used. We also estimate a mass error due to our uncertainty in magnetic field measurement and track chamber calibrations. These systematic affects and their impact on the B_s^0 mass are listed in Table 2. We have combined them in quadrature, and rounded to give an

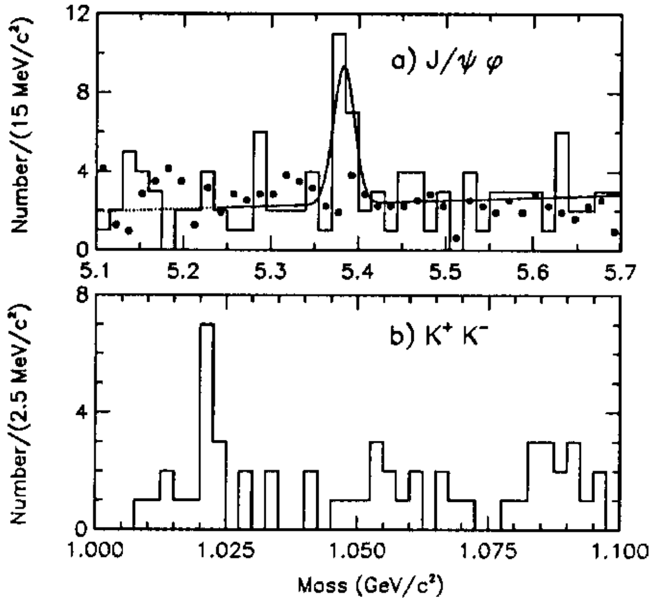

Figure 3: a. $J/\psi\phi$ mass distribution. The solid line indicates the fit, the dots are the normalized sideband distribution. b. The K^+K^- mass distribution for all $J/\psi K^+K^-$ mass in the range 5360 - 5400 MeV/c^2

Table 2: Systematic uncertainties

Effect	Mass Error (MeV/c^2)
Magnetic field	1
Mass fit procedure	2
Track selection	2
Tracking calibration	3
Vertex fit procedure	2
Total estimate	5

estimated systematic uncertainty of 5.0 MeV/c^2. In conclusion, we determine the B_s^0 mass to be 5383.3 $\pm$ 4.5 (stat) $\pm$ 5.0 (syst.)[5].

The large data set that CDF has now, and will acquire in the near future, will make the experiment an important source of new exclusive B hadron states. We have demonstrated our ability to reconstruct the well established states ($B^\pm$, B^0), which provides significant support for our reconstruction of new ones (B_s^0). The larger data set of the near future will probably yield a signal in $\Lambda_b \to J/\psi\Lambda$. When it does, this signal too will be accompanied by a kinematicly similar supporting signal ($B^0 \to J/\psi K_s^0$), which earlier reports have lacked [3]. It is clear that CDF, in its current form and with anticipated upgrades, will contribute significantly to B physics in the next few years.

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