Fermi National Accelerator Laboratory

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CDF

Limit on the Rare Decay $B \to \mu^+\mu^- K^\pm$

The CDF Collaboration

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Abstract

We report on a search for flavor-changing neutral current decays of B mesons into $\mu\mu K^\pm$ using data obtained in the Collider Detector at Fermilab (CDF) 1992-1993 data taking run.[1] To reduce the amount of background in our data we use precise tracking information from the CDF silicon vertex detector to pinpoint the location of the decay vertex of the B candidate, and accept only events which have a large decay time. We compare this data to a B meson signal obtained in a similar fashion, but where the muon pairs originate from ψ decays, and calculate the relative branching ratios. In absence of any indication of flavor-changing neutral current decay we set an upper limit on the branching ratio of 3.2×10^{-5}, which is consistent with Standard Model expectations but leaves little room for non-standard physics.

1 Introduction

Rare B decays provide us a way to test the Standard Model against possible effects of different form factors, anomalous magnetic moment of the W, and charged Higgs. Several theorists have predicted the rate of this decay. Differences in the form factors used in these calculations give relatively small uncertainties, but deviations from Standard Model physics can drastically increase the expected rate. For a top quark mass of 150 GeV/c^2, A. Ali [1] predicts a branching ratio of 4.4×10^{-7} using the hadronic matrix elements of Isgur and Wise [2]. G. Baillie [3] has also used heavy quark effective theory to calculate the ratio of the decay rate in a portion of the non-resonant dimuon mass spectrum to the decay rate of $B \to \psi K, \psi \to \mu\mu$). He finds the ratio of the decay rates to be 2×10^{-3} at a top quark mass of 170 GeV/c^2. The portion of the non-resonant dimuon mass spectrum he uses goes from $\hat{s} \equiv q^2/M_B^2 = 0.35$ to 0.48 and 0.50 to $\hat{s}_{max}$, similar to the region we use here. We use the same non-resonant theoretical differential decay rate as a function of dimuon mass to extrapolatate our results from the small dimuon mass region to the overall non-resonant region.

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2 Data and Method

At CDF [4] we have accurate momentum resolution in the central tracking chamber (CTC), made more accurate by using vertex position information from the silicon vertex detector (SVX) [5]. In this analysis we accept only pairs of muons which have traversed the SVX, the CTC, and left muon stubs in the central muon chambers (up to $\eta = 0.6$).

We select muon pairs with an invariant mass between 2.8 and 4.5 GeV/c^2, assign the

K$^{\pm}$ mass to tracks in the central tracking chamber and use a secondary vertex fit to help reconstruct candidate B's. In accepting events with reconstructed B masses from a fairly generous range, combinatoric background might be significant, but is essentially eliminated with tight cuts on the vertex fit quality and the transverse proper B candidate decay time. Background from hadronic punch-through is largely reduced by requiring the B candidate to carry the majority of the momentum in a cone. The transverse momentum cuts on the events are as follows: Pt(B) $>$ 5.0 GeV/c, Pt(K) $>$ 1.0 GeV/c, Pt(μ) $>$ 2.0 GeV/c, with one Pt(μ) $>$ 2.8 GeV/c.

We divide the dimuon mass region from 2.8 to 4.5 GeV/c^2 into the following two regions: the ψ region which has dimuon mass between 3.017 and 3.177 GeV/c^2, and the non-resonant region which is in two parts, 3.3 to 3.6 and 3.8 to 4.5 GeV/c^2. Events in the B candidate mass spectrum which fall between 5.24 and 5.32 GeV/c^2 are counted as signal events, and the background is estimated from the rest of the spectrum between 5.0 and 5.5 GeV/c^2.

After making the cuts above, we compare the number of $\psi K^{\pm}$ events to the number of $\mu\mu K^{\pm}$ events. Using BR($B \to \psi K^{\pm}$) = $6.49 \pm 1.0 \times 10^{-5}$ [6] we can calculate the relative efficiencies of these decays and then the branching ratio limit on $\mu\mu K^{\pm}$ using the method of G. Zech [8], which is expanded for this analysis in [9]. In this preliminary analysis, we assume the efficiencies to be equal in the different dimuon mass windows, noting that preliminary Monte Carlo studies have shown this to be conservative.

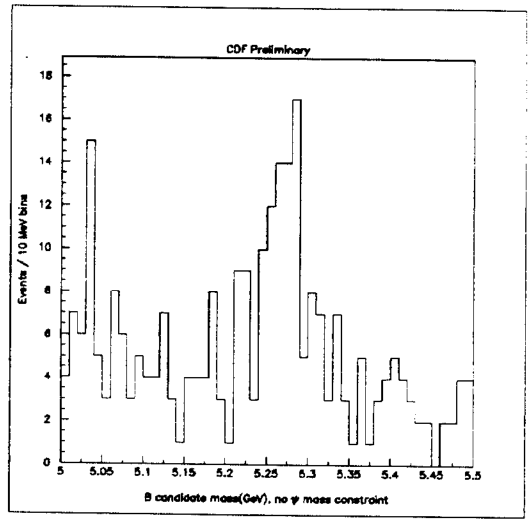

Figure 1: Invariant mass of $\psi K^{\pm}$ events.

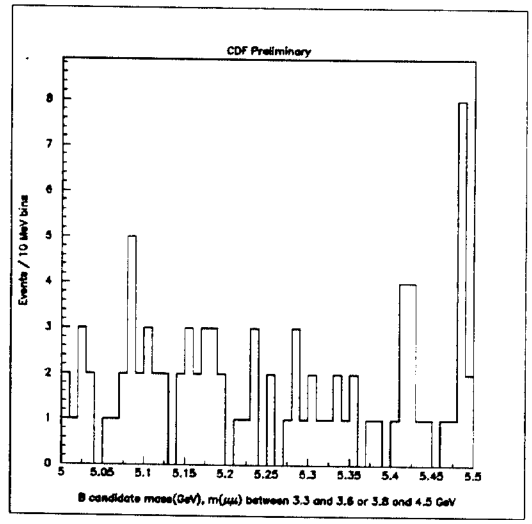

Figure 2: Invariant mass of non-resonant $\mu^+\mu^- K^{\pm}$ events.

3 Results

In the end, we see 50.3 ± 9.4 $\psi K^{\pm}$ events above background as shown in Figure 1. We see 10

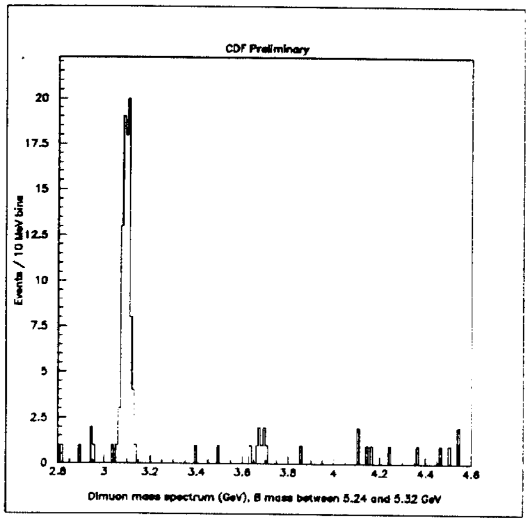

Figure 3: Dimuon mass spectrum from events with B candidate in peak.

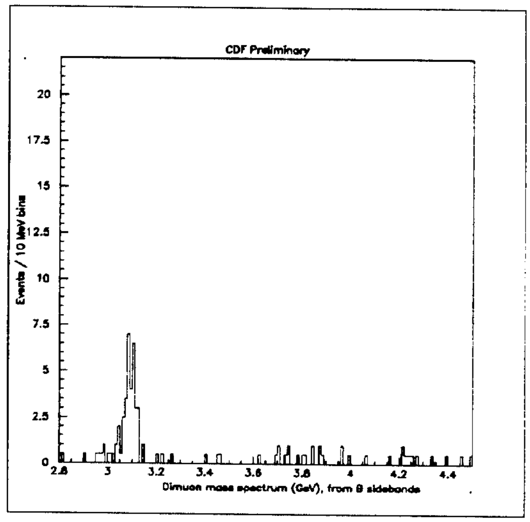

Figure 4: Background to Figure 3 estimated from B candidate sidebands.

events with B candidate mass between 5.24 and 5.32 GeV/c^2 in the non-resonant dimuon sample with the background estimated to be 14.7 ± 1.7 events as shown in Figure 2. Note that other analyses from CDF have a narrower B peak because they constrain the two muons to the ψ mass, which would be inappropriate for this analysis. Figure 3 shows the dimuon mass distribution for events which fall in the B mass window from 5.24 to 5.32 GeV/c^2. Figure 4 shows the dimuon mass distribution for events which fall in the sidebands of the B peak, from 5.14 to 5.22 GeV/c^2 and from 5.34 to 5.42 GeV/c^2. The events are weighted with a factor of 1/2 so that they accurately reflect the background present in figure 3. From the information in the first two figures, we can calculate the following results:

$$\frac{\mathrm{BR}(B \to \mu\mu K, partial)}{\mathrm{BR}(B \to \psi K, \psi \to \mu\mu)} < .11$$

$$\frac{\mathrm{BR}(B \to \mu\mu K)}{\mathrm{BR}(B \to \psi K, \psi \to \mu\mu)} < .48$$

$$\mathrm{BR}(B \to \mu\mu K, partial) < 7.4 \times 10^{-6}$$

$$\mathrm{BR}(B \to \mu\mu K) < 3.2 \times 10^{-5}$$

where all limits are 90% confidence, and "partial" means the limit is calculated only on the dimuon mass region from 3.3 to 3.6 and 3.8 to 4.5 GeV/c^2.

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References

[1] A. Ali, Rare Decays of B Mesons, DESY 91-080 (1991), Proceedings of the First International A. D. Sakharov Conference On Physics, Lebedev Physicsl Institute, Moscow, USSR (1991).

[2] N. Isgur and M. B. Wise, Phys. Lett. B 232 (1989) 113 and Phys. Lett. B 237 (1990) 527.

[3] G. Baillie, Observing $b \to s\mu^+\mu^-$ Decays at Hadron Colliders, UCLA/93/TEP/26, hep-ph 9307369.

[4] CDF detector, F. Abe *et al.* Nucl. Inst. and Meth. A271 (1988) 387, and references therein.

[5] Silicon vertex detector, B. Barnett *et al.* Nucl. Inst. and Meth. A315 (1992) 125.

[6] BR($B \to \psi K^{\pm}, \psi \to \mu\mu$), T. Browder, K. Honscheid, S. Playfer, A Review of Hadronic and Rare B Decays, CLNS 93/1261, Jan 15, 1994.

[7] M. B. Çakir, Angular distribution and helicity dependence in $B \to K^{(*)}l^+l^-$, Phys. Rev. D, 46 (1992) 2961.

[8] G. Zech, Upper Limits in Experiments with Backgound or Measurement Errors, NIM, A 277 (1989) 608.

[9] C. Anway-Wiese, Calculating Branching Ratio Limits When Comparing Related Decay Modes, CDF/ANAL/BOTTOM/-CDFR/2496