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MEASUREMENT OF THE POLARIZATION IN THE DECAY $B^0 \to J/\psi K^{*0}$ IN $\bar{p}p$ COLLISIONS AT $\sqrt{s} = 1.8$ TeV

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ABSTRACT

We report on a measurement of the polarization in the decay $B^0 \to J/\psi K^{*0}$ using data collected at the Collider Detector at Fermilab in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV. B^0 mesons were reconstructed through the decay chain $B^0 \to J/\psi K^{*0}, J/\psi \to \mu^+\mu^-, K^{*0} \to K^+\pi^-$. The result, based on a sample of 60 ± 11 events, is $\Gamma_L/\Gamma = 0.66 \pm 0.10$ (stat) $^{+0.08}_{-0.10}$ (sys).

The pseudoscalar to vector-vector decay $B^0 \to J/\psi K^{*0}$ allows different polarizations in the final state. The measurement of this polarization tests the factorization hypothesis for hadronic decays and also helps determine if the decay is useful for studies of CP violation. Using the form factor calculated with the model of Bauer, Stech, and Wirbel,[1] Kramer and Palmer predict Γ_L/Γ =0.57. If instead heavy quark symmetries are used to relate the experimental results for $D \to K^* l\nu$ to $B^0 \to J/\psi K^{*0}$, the prediction is $\Gamma_L/\Gamma = 0.73$.[2] Measurements from ARGUS suggest that the decay is completely longitudinally polarized.[3] A recent result from CLEO gives the value $\Gamma_L/\Gamma = 0.80 \pm 0.08 \pm 0.05$.[4] This paper describes a preliminary polarization measurement performed by the CDF collaboration using 19 pb^{-1} of $\bar{p}p$ collisions collected during the 1992-93 run at the Fermilab Tevatron.

The CDF detector has been described in detail elsewhere.[5] B^0 mesons were reconstructed through the decay chain $B^0 \to J/\psi K^{*0}$, $J/\psi \to \mu^+\mu^-$, $K^{*0} \to K^+\pi^-$ using a data sample selected online by dimuon triggers in the CDF three level trigger system. At Level 1 two charged track segments were required in the muon chambers. The Level 2 trigger required that at least one of the muon segments was matched in azimuthal angle to a track in the Central Tracking Chamber (CTC). At Level 3 the trigger, using online track reconstruction software, required a pair of oppositely charged muons with an invariant mass between 2.8 and 3.4 GeV/c^2.

In order to isolate the J/ψ signal, and to keep the systematic effects from the trigger under control, additional offline requirements were placed on the muons. The match between the extrapolated CTC track and the segment in the muon chamber

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was required to be less than 3σ, where σ is the expected multiple scattering error combined in quadrature with the measurement errors. Information from the Silicon Vertex Detector (SVX) was added to the CTC tracks when it was available. Both muons were required to have a transverse momentum greater than 2.0 GeV/c, and at least one had to have a transverse momentum greater than 2.8 GeV/c. The invariant mass of the dimuon pair was formed while constraining the muon tracks to come from a common vertex. After all of the above requirements were applied there were approximately 41000 J/ψ candidates remaining, with a signal width of about 20 MeV.

Those dimuon pairs within 80 MeV/c^2 of the world average J/ψ mass were combined with other charged tracks to search for B^0 mesons. K^{*0} candidates were formed by selecting pairs of oppositely charged tracks. Both $K^{\pm}\pi^{\mp}$ mass assignments were tried. The assignment closer to the K^{*0} mass was used, and the candidate was kept if the $K\pi$ invariant mass was within 80 MeV/c^2 of the mass of the K^{*0}. All of the tracks were constrained to come from a common vertex, and the dimuons were mass constrained to the world average J/ψ mass. Combinatoric backgrounds were reduced by applying requirements on the proper decay distance $c\tau$ and transverse momentum of the B^0 candidate, and on the transverse momentum of the K^{*0}. The requirements were $c\tau > 100$ μm, $P_{T_B} > 8.0$ GeV/c and $P_{T_{K^{*0}}} > 2.0$ GeV/c. After all the constraints were applied there were 60 ± 11 B^0 candidates remaining in the signal region defined by $|m_{\mu\mu K\pi} - m_B| < 0.03$ GeV/c^2.

The polarization was measured using a helicity angle analysis. The differential decay distribution for $B^0 \to J/\psi K^{*0}$, $J/\psi \to \mu^+\mu^-$, $K^{*0} \to K^+\pi^-$ can be written in terms of the helicity amplitudes H_λ as (*e.g.* see Ref. 2)

$$\frac{d^2\Gamma}{d\cos\theta_{K^*} d\cos\theta_\psi} \propto \frac{1}{4}\sin^2\theta_{K^*}(1+\cos^2\theta_\psi)(|H_{+1}|^2 + |H_{-1}|^2) + \cos^2\theta_{K^*}\sin^2\theta_\psi |H_0|^2 \quad (1)$$

where the helicity angle θ_{K^*} is the decay angle of the kaon in the K^{*0} rest frame with respect to the K^{*0} direction in the B^0 rest frame. Similarly, θ_ψ is the decay angle of the muon in the J/ψ rest frame with respect to the J/ψ direction in the B^0 rest frame. Integrating separately over θ_{K^*} and θ_ψ gives the relations

$$\frac{d\Gamma}{d\cos\theta_{K^*}} \propto \frac{1}{2} - \alpha\left(-\frac{1}{2} + \cos^2\theta_{K^*}\right); \qquad \frac{d\Gamma}{d\cos\theta_\psi} \propto 1 + \alpha\cos^2\theta_\psi \quad (2)$$

where $\alpha = (1 - 3\Gamma_L/\Gamma)/(1+\Gamma_L/\Gamma)$. The ratio Γ_L/Γ measures the amount of longitudinally polarized K^{*0} or J/ψ.

The helicity angles were calculated for events in the B^0 signal region. An unbinned likelihood fit was performed using information from both the K^{*0} and the J/ψ by forming an event by event product of likelihoods

$$L = \prod_{i=1}^{n} L_{K_i^*} L_{\psi_i} \quad (3)$$

where the main components of $L_{K_i^*}$ and L_{ψ_i} are the theoretical distributions in equation 2, the acceptance functions, and the background shapes. The acceptance functions were calculated using Monte Carlo and the background shapes were determined by studying events in the sidebands of the B^0 invariant mass distribution. The fit results in a polarization measurement of $\Gamma_L/\Gamma = 0.66 \pm 0.10$ (stat) $^{+0.08}_{-0.10}$ (sys). The fit is projected onto background subtracted, acceptance corrected, data plots in Fig. 1. The systematic error is dominated by the uncertainty associated with the background estimation.

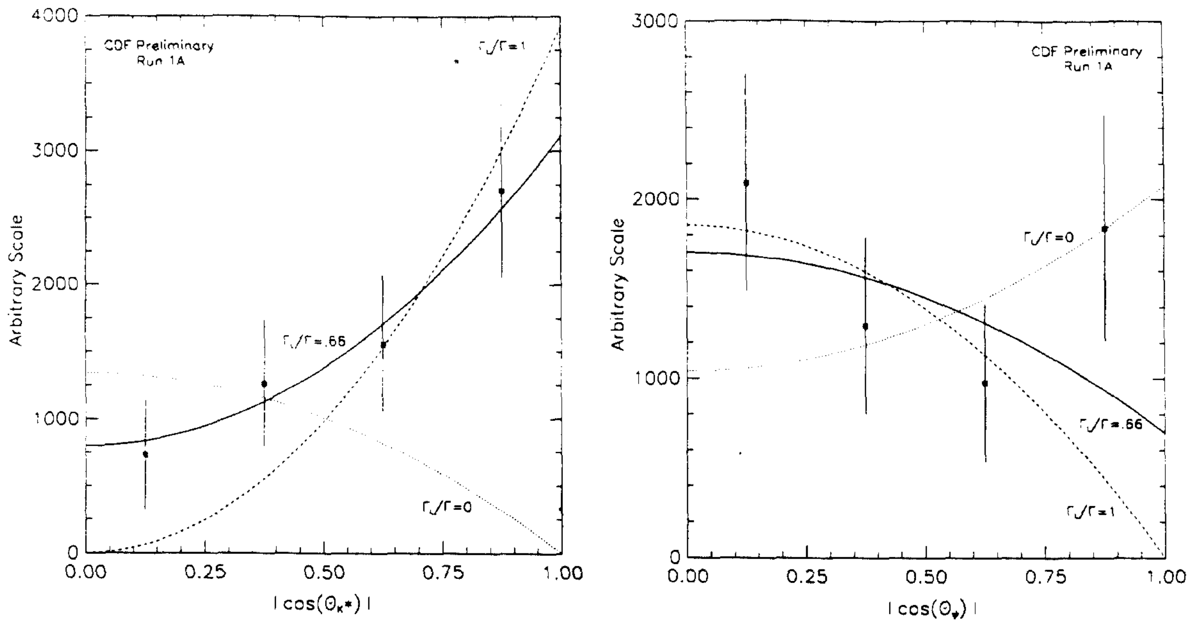

Fig. 1. **a)** K^{*0} helicity angle distribution and **b)** J/ψ helicity angle distribution. The fit value of $\Gamma_L/\Gamma = 0.66$ is shown along with the extremes.

This preliminary result is in good agreement with the recent CLEO measurement. Although not fully polarized, this decay mode still appears to be useful for CP violation studies at B factories. This result also demonstrates the feasibility of studying the dynamics of B meson decays in a hadron collider environment.

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