DEUTSCHES ELEKTRONEN-SYNCHROTRON

DESY 94-139
August 1994

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ISSN 0418-9833

NOTKESTRASSE 85 - 22603 HAMBURG

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[1] DESY, IfH Zeuthen
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[3] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 056DD11P.
[4] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 054ER12P.
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[9] Supported by the German Bundesministerium für Forschung und Technologie, under contract number 055KA11P.
[10] Supported by the Ministry of Science and Technology of the Republic of Slovenia and the Internationales Büro KfA, Jülich.

Abstract

Polarization in the exclusive decay $B \to J/\psi K^*$ was measured using the ARGUS detector at the e^+e^- storage ring DORIS II. The ratio of the transverse to the total decay width was found to be $\Gamma_T/\Gamma=0.03\pm0.16\pm0.15$. This measurement demonstrates that the $B^0 \to J/\psi K^{*0}$ decay channel can be effectively used for CP violation studies.

A measurement of the polarization in the $B \to J/\psi K^*$ decay channel is of special interest for CP violation studies[1]. The longitudinally polarized helicity state of the $B^0 \to J/\psi K^{*0}$ decay followed by $K^{*0} \to K^0_S\pi^0$ is a pure CP eigenstate. If longitudinal polarization dominates this decay channel can be used as an important complement to the gold plated $B^0 \to J/\psi K^0_S$ decay channel for CP violation measurements [2].

Moreover the polarization measurements of two body $B \to J/\psi K^*$ decays give an important opportunity to test different theoretical approaches. The ratio of the transverse to the total decay width Γ_T/Γ, calculated in the framework of HQET and the BSW model, varies from 0.43 using the standard form factor approach to 0.27 using alternative form factors[3]. A model of Lepage and Brodsky predicts the ratio Γ_T/Γ=0.17 in the framework of perturbative QCD [4]. The ARGUS study of J/ψ polarization in inclusive $B \to J/\psi X$ decays [5] implied a dominant contribution of the longitudinal polarization.

In this paper we concentrate on a polarization study of the exclusive decay $B \to J/\psi K^*$ in order to separate the pure two vector mesons final states, and complement the analysis by a K^* polarization study. The polarization in such two body decays can be measured in the framework of the helicity representation [2], extracting the amount of the transversely polarized K^* and J/ψ mesons from the angular distributions of their decay products.

The analysis is based on data collected using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY. The data sample comprises an integrated luminosity of 246 pb^{-1} on the $\Upsilon(4S)$ resonance and 98 pb^{-1} in the nearby continuum. The number of B mesons in the sample is 418000±19000. The ARGUS detector, its trigger and particle identification capabilities are described in detail elsewhere [6].

Charged particles are identified on the basis of specific ionization in the drift chamber, time-of-flight measurements, energy deposition and shower shape in the electromagnetic calorimeter and, for muons, penetration through absorber to the muon chambers. This information is combined into an overall likelihood ratio [6] for each of the allowed particle hypotheses (e, μ, π, K and p). All hadron hypotheses for which the likelihood ratio exceeds 0.01 are accepted.

Good particle identification and geometrical acceptance are assured by requiring that all particles have a polar angle θ, with respect to the beam axis, within the region $| cos\theta |< 0.92$ and a momentum larger than 60 MeV/c. All combinations of two photons with an invariant mass between 100 MeV/c^2 and 170 MeV/c^2 are accepted as π^0 candidates. Energetic π^0 mesons, whose daughter photons merge into a single cluster in the electromagnetic calorimeter, are included in the analysis by considering all shower clusters with an energy greater than 800 MeV as π^0 candidates. K_s^0 mesons are reconstructed from their $\pi^+\pi^-$ decay mode. Tracks of K_s^0 candidates could either form a secondary vertex or come from the main vertex. The invariant $\pi^+\pi^-$ mass of K_s^0 candidates is required to lie within ± 30 MeV/c^2 of the nominal K_s^0 mass.

Multihadron events were selected by requiring a total multiplicity $(n_{ch} + n_\gamma/2)$ larger than 5, where n_{ch} is the number of charged particles and n_γ is the number of photons. Lepton pairs from converted photons were not included in n_{ch} but were counted as one photon. QED and continuum backgrounds are further suppressed by requiring the second Fox-Wolfram moment H_2 to be smaller than 0.4. In addition, an event was rejected if the momentum of any charged particle was greater than 3 GeV/c.

Two exclusive B meson decay channels $B^0 \to J/\psi K^{*0}$ and $B^- \to J/\psi K^{*-}$ were studied in this analysis. J/ψ mesons were reconstructed in their leptonic decay modes. In order to increase the J/ψ identification efficiency the lepton pairs were selected requiring one lepton with likelihood ratio larger than 0.7, with the second track having only to be consistent with the lepton hypothesis (likelihood ratio larger than 0.01). Lepton momenta were required to be larger than 0.9 GeV/c, which is the kinematical limit for leptons from J/ψ mesons produced in B meson decays. For further analysis a mass-constrained fit was applied to lepton pairs having an invariant mass within ± 100 MeV/c^2 of the nominal J/ψ mass. K^* mesons were reconstructed in both isospin combinations of $K\pi$. All $K\pi$ combinations with invariant masses within $\pm 100 MeV/c^2$ of the nominal K^* mass [7] were accepted as K^* candidates.

B meson candidates were formed from $J/\psi K^*$ combinations having an energy within three standard deviations of the beam energy. A kinematic fit was then applied to the B candidates, constraining their energy to the beam energy. The fit improves the mass resolution by an order of magnitude to about 5.5 MeV/c^2. To avoid multiple counting, only one combination per event was allowed: the candidate with the maximum total probability calculated for the sum of all χ^2 contributions from kinematic fits and particle identification was selected. Only candidates with the total probability larger than 1% and a mass larger than 5.17 GeV/c^2 were accepted.

The resulting $J/\psi K^*$ mass spectrum is shown in fig.1a. This spectrum was fitted with the sum of a Gaussian describing the signal and a function which parametrizes the background:

$$f(M) = aM\sqrt{1 - M^2/E_{beam}^2}exp(-b(1 - M^2/E_{beam}^2)),$$

where a and b are free parameters [8]. The width of the Gaussian was fixed from

Monte Carlo calculations to σ=5.5 MeV/c^2 and the B meson mass to its nominal value of M_B=5.279 GeV/c^2 [9]. The fit procedure resulted in 13.4 ± 4.2 reconstructed B mesons. In order to estimate the nonresonant $K\pi$ background contribution the same analysis was repeated for ± 50 MeV/c^2 wide sidebands immediately below and above the accepted K^* mass region. We obtained 1.0 ± 1.6 B candidates in the sideband regions (see fig.1b). Such a small nonresonant contribution in the sidebands indicates that the nonresonant background under the K^* signal is negligible. It is taken into account as a systematic uncertainty.

J/ψ and K^* combinations with an invariant mass larger than 5.26 GeV/c^2 were used for the angular analysis. The combinatorial background under the B meson signal was estimated to be 1.9 ± 0.7 events and was also included in the systematic uncertainty.

Since the B meson is a pseudoscalar it decays into two vector mesons J/ψ and K^* with three possible final helicity states:(-1,-1),(0,0),(+1,+1). Longitudinally and transversely polarized J/ψ mesons have different $cos\theta_{J/\psi}$ distributions, where $\theta_{J/\psi}$ is the angle between the J/ψ direction in the rest frame of the B meson and the direction of the positive lepton in the J/ψ rest frame. Similarily the polarization of K^* mesons results in different angular distributions for their decay products. The expected angular distributions for the pure helicity states are [1]:

$$d\Gamma_L/d(cos\theta_{J/\psi}) = 3/4 \ * \ sin^2\theta_{J/\psi},$$
$$d\Gamma_T/d(cos\theta_{J/\psi}) = 3/8 \ * \ (1 + cos^2\theta_{J/\psi});$$
$$d\Gamma_L/d(cos\theta_{K^*}) \ = \ 3/2 \ * \ cos^2\theta_{K^*},$$
$$d\Gamma_T/d(cos\theta_{K^*}) \ = \ 3/4 \ * \ sin^2\theta_{K^*}.$$

The ratio of the transverse to the total decay width was obtained by fitting the linear combination of these functions to the corresponding experimental angular distributions after the boost to the B meson rest frame.

The acceptance corrected and normalized angular distributions are shown in figure 2. The reconstruction efficiencies in different angular intervals were determined from a detailed Monte Carlo simulation and appeared to be flat. Both angular distributions are well described by longitudinally polarized J/ψ and K^* mesons only. A simultaneous fit of both angular distributions gives the ratio Γ_T/Γ=0.03±0.16±0.15. The systematic error comes from the efficiency determination (±0.03), the combinatorial background under the B meson signal (±0.12) and the possible $K\pi$ nonresonant background contribution (±0.08). The systematic uncertainties caused by the combinatorial background and the nonresonant $K\pi$ contribution were calculated by varing their polarization from 0 to 1. The obtained result disfavours HQET and the BSW model with standard form factors[3].

In conclusion, we have measured the ratio of the transverse to the total decay width in the decays $B \to J/\psi K^*$ to be Γ_T/Γ=0.03±0.16±0.15. Therefore the balance of $B^0 \to J/\psi K^{*0}$ decays followed by $K^{*0} \to K_S^0\pi^0$ results in a pure CP eigenstate and this decay can be effectively used in future measurements of CP violation[1].

Acknowledgements

It is a pleasure to thank U.Djuanda, E.Konrad, E.Michel, and W.Reinsch for their competent technical help in running the experiment and processing the data. We thank Dr.H.Nesemann, B.Sarau, and the DORIS group for the excellent operation of the storage ring. The visiting groups wish to thank the DESY directorate for the support and kind hospitality extended to them.

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Figure Captions

Figure 1: The invariant mass distribution of $J/\psi K\pi$ combinations (points). Solid lines show the fit results. (a) $K\pi$ invariant mass within $\pm 100\ MeV/c^2$ of the nominal K^* mass. (b) $K\pi$ invariant mass within left and right sideband regions shifted from the nominal K^* mass by $0.15\ GeV/c^2$.

Figure 2: Angular distributions in the decay $B \to J/\psi K^*$ (points). Solid lines show the fit results. (a) $cos\theta_{J/\psi}$ angular distributions, where $\theta_{J/\psi}$ is the angle between the J/ψ direction in the rest frame of the B meson and the direction of the positive lepton in the J/ψ rest frame. (b) $cos\theta_{K^*}$ angular distributions, where θ_{K^*} is the angle between the K^* direction in the rest frame of the B meson and the direction of the K meson in the K^* rest frame.

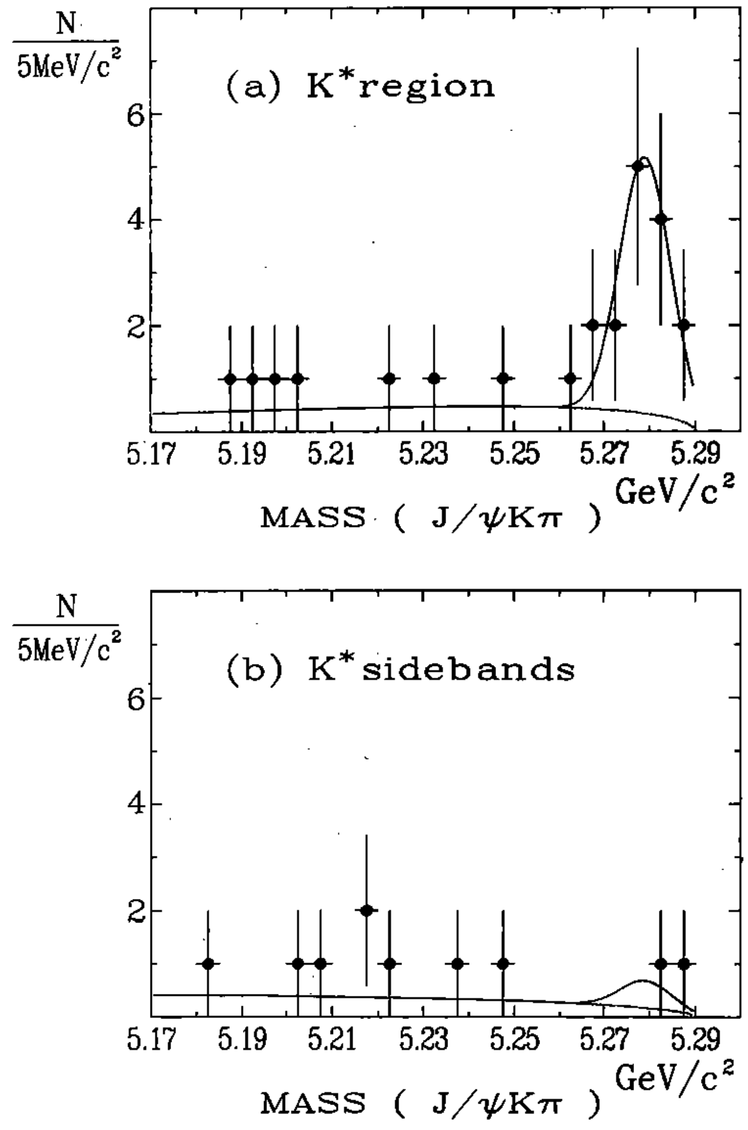
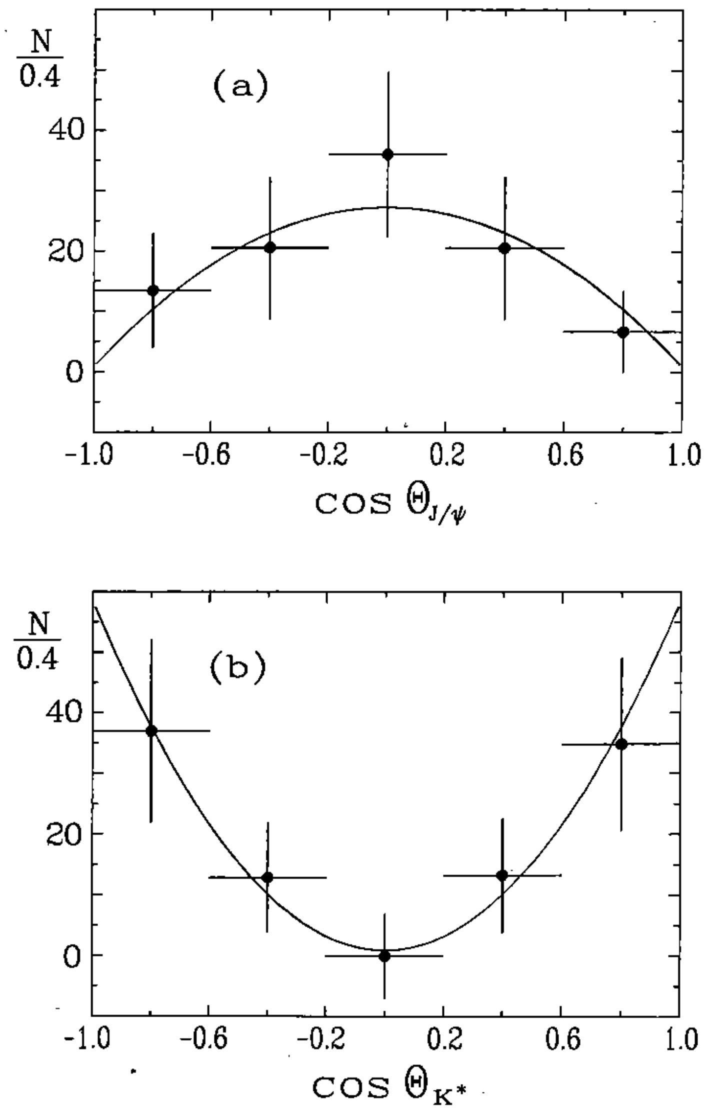


Figure 1.



N/0.4
(a)
40
20
0
-1.0
-0.6
-0.2
0.2
0.6
1.0
cos Θ_J/ψ
N/0.4
(b)
40
20
0
-1.0
-0.6
-0.2
0.2
0.6
1.0
cos Θ_K*

Figure 2.