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Exclusive B decays to charmonium final states

The *BABAR* Collaboration

Abstract

We report on exclusive decays of B mesons into final states containing charmonium using data collected with the *BABAR* detector at the PEP-II storage rings. The charmonium states considered here are J/ψ, $\psi(2S)$, and χ_{c1}. Branching fractions for several exclusive final states, a measurement of the decay amplitudes for the $B^0 \to J/\psi K^*$ decay, and measurements of the B^0 and B^+ masses are presented. All of the results we present here are preliminary.

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1 Introduction

An understanding of the decays of B mesons to final states including a charmonium resonance (J/ψ, $\psi(2S)$, χ_{c1}) is a prerequisite to an analysis of *CP* violation in the B system. In this paper we report the measurement of several branching fractions of exclusive decays, some of which have been used in our measurement of $\sin 2\beta$ [1]. The channels considered are listed in Table 1. Here and throughout this paper the inclusion of charge conjugate states is implied.

Table 1: B meson decay modes considered in this paper.

Channel	Secondary decay mode(s)
$B^0 \to J/\psi K^0_S$	$J/\psi \to \ell^+\ell^-$; $K^0_S \to \pi^+\pi^-$, $\pi^0\pi^0$
$B^+ \to J/\psi K^+$	$J/\psi \to \ell^+\ell^-$
$B^0 \to J/\psi K^{*0}$	$J/\psi \to \ell^+\ell^-$; $K^{*0} \to K^+\pi^-$, $K^0_S\pi^0$
$B^+ \to J/\psi K^{*+}$	$J/\psi \to \ell^+\ell^-$; $K^* \to K^0_S\pi^-$, $K^+\pi^0$
$B^0 \to \psi(2S) K^0_S$	$\psi(2S) \to \ell^+\ell^-$, $J/\psi\pi^+\pi^-$; $K^0_S \to \pi^+\pi^-$
$B^+ \to \psi(2S) K^+$	$\psi(2S) \to \ell^+\ell^-$, $J/\psi\pi^+\pi^-$
$B^+ \to \chi_{c1} K^+$	$\chi_{c1} \to J/\psi\gamma$; $J/\psi \to \ell^+\ell^-$

We have used some of these exclusive modes to measure the masses of the B^+ and B^0 mesons and their mass difference. We also present initial results on the yield of $B^0 \to J/\psi K^0_L$ which will be used for a future *CP* analysis. Finally we describe an amplitude analysis of the $B \to J/\psi K^*$ decay.

2 The *BABAR* detector and dataset

The *BABAR* detector is located at the PEP-II storage ring, an e^+e^- facility operating at the Stanford Linear Accelerator Center. PEP-II collides 9.0 GeV electrons with 3.1 GeV positrons to give a center of mass energy of 10.58 GeV, the mass of the $\Upsilon(4S)$ resonance.

The *BABAR* detector is described elsewhere [2]; here we give only a brief overview. Surrounding the interaction point is a 5-layer double-sided silicon vertex tracker (SVT) which gives precision spatial information for all charged particles, and is the primary detection device for low momentum charged particles. Outside the SVT, a 40-layer drift chamber (DCH) provides measurements of charged particle momenta. The $\mathrm{d}E/\mathrm{d}x$ information from the DCH and SVT is used for particle identification. Beyond the outer radius of the DCH is a detector of internally reflected Cherenkov radiation (DIRC) which is used primarily for charged hadron identification. The detector consists of quartz bars in which Cherenkov light is produced as relativistic charged particles traverse the material. The light is internally reflected, and the Cherenkov rings are measured with an array of photo-multiplier tubes mounted on the rear of the detector. A CsI(Tl) crystal electro-magnetic calorimeter (EMC) is used to detect photons and neutral hadrons, as well as to identify electrons. The EMC is surrounded by a super-conducting solenoid which produces a 1.5 T magnetic field. The Instrumented Flux Return (IFR) consists of multiple layers of resistive plate chambers interleaved with the flux return iron. It is used in the identification of muons and neutral hadrons.

The data used in these analyses correspond to a integrated luminosity of $7.7\,\mathrm{fb}^{-1}$ taken on the $\Upsilon(4S)$ and $1.2\,\mathrm{fb}^{-1}$ taken 0.04 GeV below the peak. The data set contains 8.8×10^6 $B\overline{B}$ events.

For the analysis of the B meson masses we use a restricted set of data corresponding to $4.6\,\mathrm{fb}^{-1}$.

3 Particle reconstruction

Inclusive charmonium reconstruction is described in detail in another contribution to this conference [3].

We here reconstruct J/ψ candidates by combining pairs of oppositely charged tracks within the angular range $0.41 < \theta < 2.41(2.53)$ for electron (muon) candidates, where θ is the polar angle to the beam axis. The invariant mass of the candidate must lie in the range $2.95 < \mathrm{m}_{J/\psi} < 3.14\,\mathrm{GeV}/c^2$ and $3.06 < \mathrm{m}_{J/\psi} < 3.14\,\mathrm{GeV}/c^2$ for decays to e^+e^- and $\mu^+\mu^-$, respectively. When the J/ψ decays to electrons, we demand that at least one of the tracks pass stringent particle identification requirements based on the ratio of the energy deposited in the EMC to the track momentum (E/p), and on the ionization loss of the track in the drift chamber ($\mathrm{d}E/\mathrm{d}x$). For $\mu^+\mu^-$ candidates, one track is required to pass a loose muon selection on the basis of the number of hit layers in the IFR and the other track is required to have an associated energy in the EMC which is consistent with a minimum ionizing particle. In the case of the decay to electrons, we apply a procedure to add photons which are close to the electron tracks and thereby reduce the impact of bremsstrahlung on the reconstruction efficiency.

We select $\psi(2S) \to \ell^+\ell^-$ candidates in a similar way. For the decay to $\mu^+\mu^-$ the invariant mass of the candidate is required to be within $0.05\,\mathrm{GeV}/c^2$ of the nominal mass. In the case of $\psi(2S)$ decays to e^+e^- the lower limit is relaxed to $0.25\,\mathrm{GeV}/c^2$ below the nominal mass value. For the decay $\psi(2S)$ to $J/\psi\pi^+\pi^-$, J/ψ candidates are combined with pairs of oppositely charged tracks which originate from a common vertex, and the mass difference between the resulting $\psi(2S)$ candidate and the J/ψ is required to be within $0.05\,\mathrm{GeV}/c^2$ of the nominal mass difference. For the decay $J/\psi \to e^+e^-$, the mass difference is relaxed to $-0.25 < \mathrm{m}_{\psi(2S)} - \mathrm{m}_{J/\psi} < 0.05\,\mathrm{GeV}/c^2$.

Candidate χ_{c1} mesons are reconstructed via their decay to $J/\psi\,\gamma$. The γ candidates are selected by requiring a neutral cluster in the EMC that has a distribution of crystal energies consistent with a γ shower. The mass difference between the reconstructed χ_{c1} and the J/ψ is required to satisfy $0.35 < \Delta M < 0.45\,\mathrm{GeV}/c^2$, and the momentum of the χ_{c1} in the $\Upsilon(4S)$ rest frame must lie in the range $1.15 < p^* < 1.70\,\mathrm{GeV}/c$.

$K^0_S \to \pi^+\pi^-$ candidates are formed from pairs of oppositely charged tracks which have an invariant mass between 0.489 and $0.507\,\mathrm{GeV}/c^2$. $K^0_S \to \pi^0\pi^0$ candidates are required to have a mass between 0.470 and $0.525\,\mathrm{GeV}/c^2$ and an energy greater than $0.8\,\mathrm{GeV}$. A π^0 decay to two photons is observed in the EMC either as a single neutral cluster with substructure or as two distinct γ clusters. The most probable decay point of the K^0_S is determined after refitting the two π^0 mesons at several points along the path defined by their summed momentum vector and the J/ψ vertex.

We reconstruct K^{*0} decays to $K^+\pi^-$ and $K^0_S\pi^0$, and K^{*+} decays to $K^0_S\pi^+$ and $K^+\pi^0$. In all cases the candidate K^* is required to have an invariant mass within $0.075\,\mathrm{GeV}/c^2$ of the nominal value.

A K^0_L candidate is reconstructed using neutral clusters observed in the EMC or the IFR. For an EMC candidate we require the deposited energy to be between 0.2 and $2.0\,\mathrm{GeV}$ and the cluster center-of-gravity to be well contained within the fiducial volume of the calorimeter ($\cos\theta < 0.935$). We reject candidates that are likely to be produced by photons by means of energy-dependent criteria based on the spatial distribution of the deposited energy in the cluster. A neutral cluster that can be combined with other neutral clusters to form a π^0 or clusters with sub-structure

consistent with a π^0 is also rejected. A K_L^0 candidate observed in the IFR is required to have the cluster center within the fiducial volume ($-0.75 < \cos\theta < 0.93$) and to have a signal in at least two detector layers. We also apply additional isolation criteria to remove candidates that may have been split from clusters produced by charged particles.

4 Exclusive B reconstruction

For the decays $B^0 \to J/\psi K_S^0(\pi^+\pi^-)$ and $B^+ \to J/\psi K^+$, we require $|\cos\theta_H|$, the absolute value of the cosine of the helicity angle of the J/ψ, to be less than 0.8 (0.9) for J/ψ decays to e^+e^- ($\mu^+\mu^-$). In addition we require that the K_S^0 be consistent with having originated from the J/ψ vertex.

For the decay $B^0 \to J/\psi K_S^0(\pi^0\pi^0)$ we require $|\cos\theta_H| < 0.75$ (0.8) for J/ψ decays to e^+e^- ($\mu^+\mu^-$). To further reduce background in the $J/\psi \to e^+e^-$ channel, we require both tracks to satisfy electron identification criteria, one stringent and one loose.

In reconstructing the decays $B^0 \to J/\psi K^{*0}$ and $B^+ \to J/\psi K^{*+}$ we require that a candidate charged kaon satisfy particle identification criteria based on ionization loss in the DCH and SVT and on the Cherenkov angle measured in the DIRC. The candidate π^0 mass is required to lie in the range 0.115 to 0.150 GeV/c^2. We require $|\cos\theta_T| < 0.9$, where θ_T is the angle between the thrust direction of the reconstructed B and that of the rest of the event in the $\Upsilon(4S)$ rest frame. For the decay $K^{*0} \to K^+\pi^-$, the vertices of the K^{*0} and J/ψ must be consistent with a single production point.

For the decays $B^+ \to \psi(2S)K^+$ and $B^0 \to \psi(2S)K_S^0(\pi^+\pi^-)$ we require $|\cos\theta_T| < 0.9$ for $\psi(2S) \to J/\psi\pi^+\pi^-$ decays and $|\cos\theta_H| < 0.8$ for $\psi(2S) \to \ell^+\ell^-$ decays. We also require the K_S^0 flight length to be greater than 2.5 mm and the K^+ to satisfy loose kaon identification criteria.

We reconstruct the decay $B^+ \to \chi_{c1}K^+$ with the requirement $|\cos\theta_T| < 0.9$ and demand that the K^+ pass loose kaon identification criterion to further reduce the background in this channel.

For $B^0 \to J/\psi K_L^0$ decays we require $|\cos\theta_H|$ and $|\cos\theta_B|$ to be less than 0.9, where θ_B is the angle of the B candidate direction with respect to the beam axis in the rest-frame of the $\Upsilon(4S)$. We also require the sum of these quantities to be less than 1.3.

To isolate the signal for each mode we use the variables ΔE, the difference between the reconstructed and expected B meson energy measured in the center-of-mass frame, and $m_{\rm ES}$, the beam-energy substituted mass. These variables are defined as:

$$m_{\rm ES} = \sqrt{E_b^{*2} - \boldsymbol{p}_B^{*2}}, \quad (1)$$

$$\Delta E = E_B^* - E_b^*, \quad (2)$$

where E_b^* is the beam energy in the center-of-mass, i.e., half the center-of-mass energy, and E_B^* and $\boldsymbol{p}_B^*$ are the energy and momentum of the reconstructed B meson in the center-of-mass. For the $B^0 \to J/\psi K_L^0$ selection the momentum of the K_L^0 candidate is obtained by constraining the invariant mass of the K_L^0 and J/ψ combination to the mass of the B meson. Therefore, in this mode only ΔE can be used to separate the signal from background. We exclude any event that passes the other exclusive B selections, has $m_{\rm ES}$ greater than 5.2 GeV/c^2 and $|\Delta E|$ less than 0.1 GeV.

Only one exclusive candidate per event is accepted. If there are multiple candidates, we select the one with the smallest value of $|\Delta E|$. Exceptionally, in the $B^0 \to J/\psi K_L^0$ selection we choose the candidate with the largest K_L^0 energy as measured by the EMC. If none of the candidate K_L^0 mesons have EMC information, we choose the candidate that has the largest number of layers with hits in the IFR.

5 Results

5.1 Branching fraction measurements

When deriving branching fractions we have used the secondary branching fractions and their associated errors published by the Particle Data Group [4].

We determine the number of $B\overline{B}$ events from the difference in the multi-hadron rate on and off the $\Upsilon(4S)$ resonance, normalized to the respective luminosity. This leads to a systematic error of 3.6% on all measured branching fractions. We have assumed the branching fraction of the $\Upsilon(4S)$ to $B\overline{B}$ is 100%, with an equal admixture of charged and neutral B final states.

The efficiencies for each mode have been obtained from Monte Carlo simulations complemented with measurements of tracking and particle identification efficiencies extracted from the data. From particle identification control samples we assign a systematic error of 2% (3%) per electron (muon). We attribute a 5% systematic error to the π^0 reconstruction efficiency and resolution. The track finding efficiency has an uncertainty of 2.5% per track. Uncertainties in the modeling of the track resolution lead to an additional 1–2% error depending on the details of the primary and secondary decays.

For each mode the shape of the beam-energy substituted mass distribution is parameterized with the sum of a Gaussian and the ARGUS function [5]. We assign a systematic error due to our uncertainty of the shape of the background of between 1% and 9% depending on the mode. For the $B \to J/\psi K^*$ channels, a likelihood fit is performed for all the decay modes simultaneously, taking into account the cross-feed between decays.

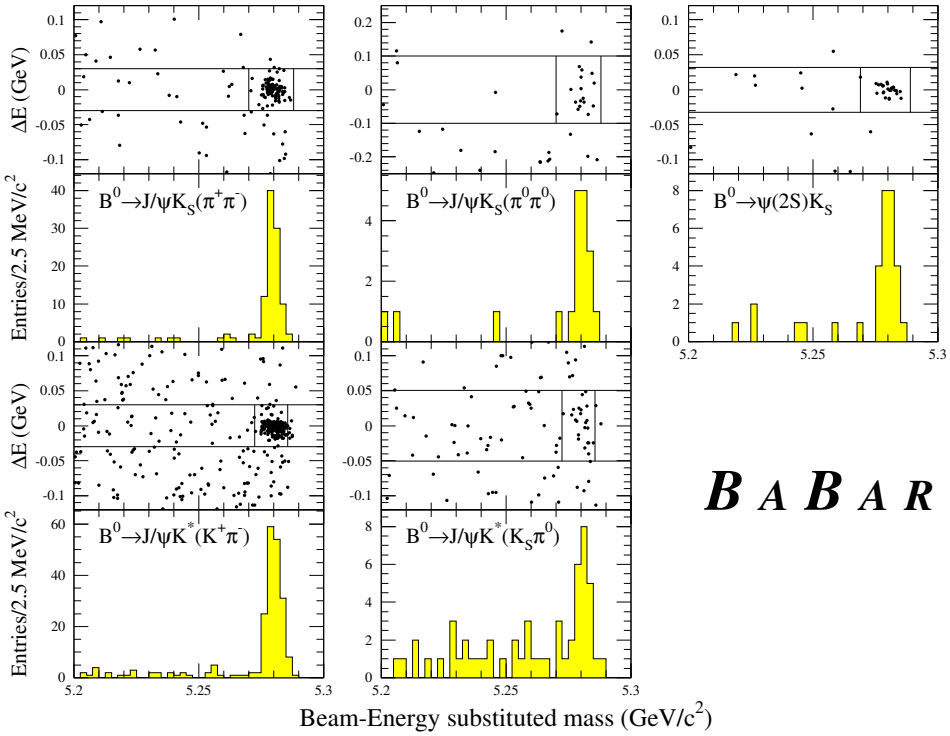
Figure 1 shows the $m_{\rm ES}$ and ΔE distributions of the candidates. In Table 2 we present the yields and measured branching fractions for the individual exclusive modes. Figure 2 shows the measured branching fractions compared to the values compiled by the Particle Data Group [4].

Table 2: The yields and measured branching fractions for exclusive decays of B mesons involving charmonium. The yield only includes the statistical error. For the branching fractions, the first error is statistical and the second systematic. All results are preliminary.

Channel		Yield	Branching fraction/10^{-4}
$B^0 \to J/\psi K^0$	$K^0_S \to \pi^+\pi^-$	93 ± 10	$10.2 \pm 1.1 \pm 1.3$
	$K^0_S \to \pi^0\pi^0$	14 ± 4	$7.5 \pm 2.0 \pm 1.2$
$B^+ \to J/\psi K^+$		445 ± 21	$11.2 \pm 0.5 \pm 1.1$
$B^0 \to J/\psi K^{*0}$		188 ± 14	$13.8 \pm 1.1 \pm 1.8$
$B^+ \to J/\psi K^{*+}$		126 ± 12	$13.2 \pm 1.4 \pm 2.1$
$B^0 \to \psi(2S) K^0$		23 ± 5	$8.8 \pm 1.9 \pm 1.8$
$B^+ \to \psi(2S) K^+$		73 ± 8	$6.3 \pm 0.7 \pm 1.2$
$B^+ \to \chi_{c1} K^+$		44 ± 9	$7.7 \pm 1.6 \pm 0.9$

5.2 Observation of a signal for the decay $B^0 \to J/\psi K^0_L$

Figure 3 shows the ΔE distributions for the $B^0 \to J/\psi K^0_L$ candidates in data and Monte Carlo events. We determine the yield by counting events with $\Delta E < 0.01\,\mathrm{GeV}$ and subtracting the background contributions. There are two categories of background to this mode. The first arises



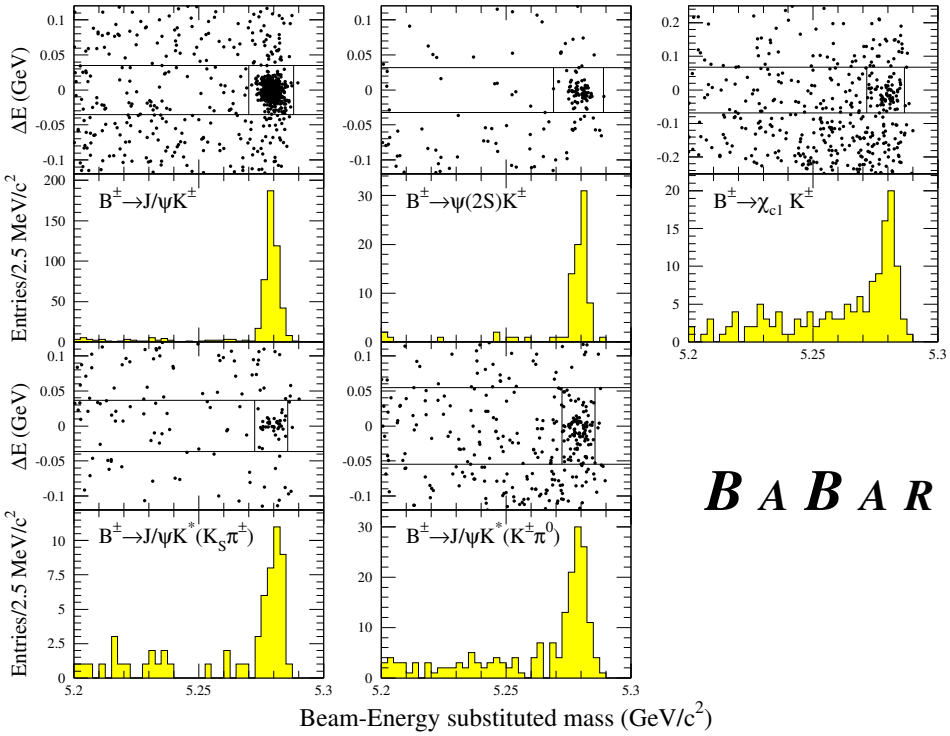


Figure 1: Distributions of candidate events in $m_{\rm ES}$ and ΔE. The upper plot shows the B^0 modes and the lower plot the B^+ modes. All results are preliminary.

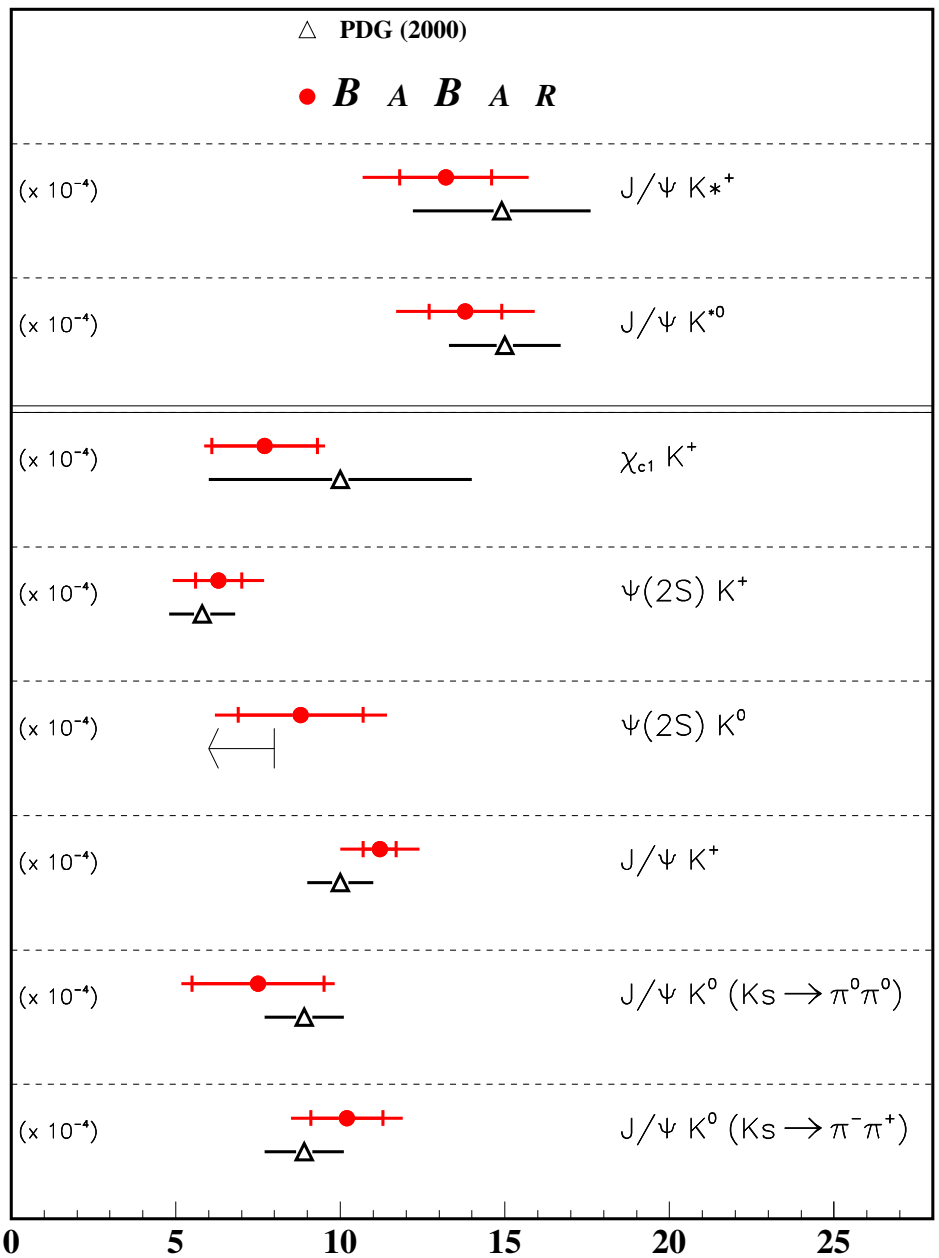


Figure 2: Summary of branching fraction measurements for charmonium + K channels and comparsons with the PDG 2000 values. All results are preliminary.

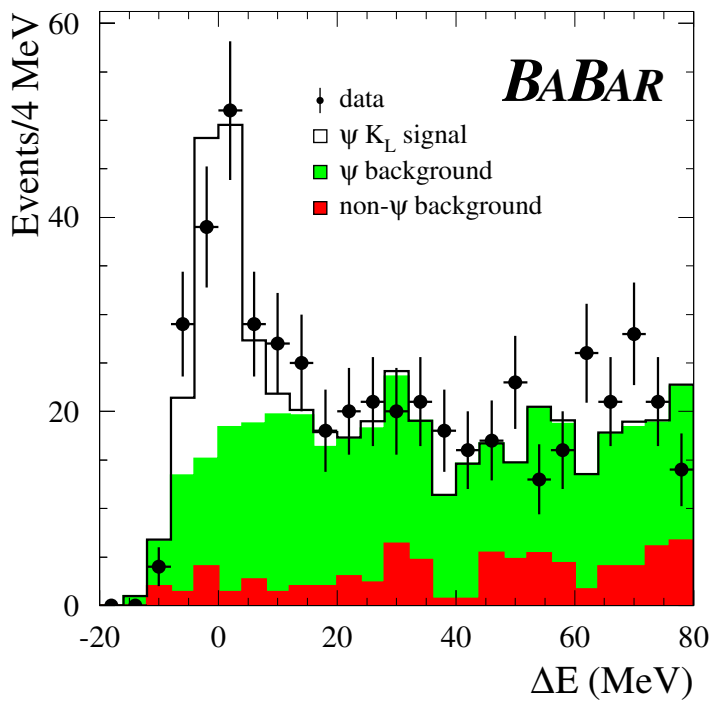


Figure 3: Comparison of data with Monte Carlo simulation for the $B^0 \to J/\psi K_L^0$ selection. The results presented here are preliminary.

from other $B \to J/\psi X$ decays and is estimated from simulations normalized to the measured J/ψ yield. We estimate the systematic error on the yield from this background determination by varying the K_L^0 reconstruction efficiency, the branching fractions of the major background modes, and the helicity amplitudes used in the simulation of $B \to J/\psi K^*$ decays. The second background arises from non-J/ψ modes and is measured from a sideband above the J/ψ peak in the data. The systematic error from this contribution is determined by varying the shape of the background. We measure the yield of $B^0 \to J/\psi K_L^0$ events to be 82 ± 14 (stat) ± 9 (syst). This is in good agreement with the expected number of 93 signal events predicted from Monte Carlo simulation.

5.3 Measurements of the B^0 and B^+ masses

Measurements of the B^0 and B^+ invariant masses have been performed using the decay modes $B^0 \to J/\psi K_S^0(\pi^+\pi^-)$, $B^0 \to J/\psi K^{*0}(K^+\pi^-)$ and $B^+ \to J/\psi K^+$. These modes are chosen because they have small backgrounds and the masses of the secondary decay products are well known. The event selections are as described in section 5.1, with the additional requirements $m_{\rm ES} > 5.27\,{\rm GeV}/c^2$ and $|\Delta E| < 36\,{\rm MeV}$.

The B candidate invariant mass is derived by fitting the decay products to a common vertex, with the masses of the J/ψ and K_S^0 constrained to their nominal values. Uncertainties in the magnetic field and in the internal and relative alignment of the tracking devices can introduce a bias in the momentum measurement. The size of this effect is quantified by comparing the reconstructed

mass of $J/\psi \to \mu^+\mu^-$ candidates, determined by fitting to the invariant mass distribution, to the nominal mass value. Any observed shift is subsequently applied to the track momenta in simulated data to determine a correction to the measured B mass. The systematic error attributed to this correction is derived from statistical uncertainty on the parameters from the fit to the J/ψ invariant mass. The $B^0 \to J/\psi K^0_S(\pi^+\pi^-)$ sample requires special consideration as the decay products of the K^0_S do not come from the interaction point and are sensitive to details of the track parameterization. A fit to the observed $\pi^+\pi^-$ invariant mass is performed and a correction derived in the same way as described above. The correction applied to the $B^0 \to J/\psi K^0_S(\pi^+\pi^-)$ sample is taken to be the mean of the correction factors determined from the fits to the J/ψ and K^0_S distributions, taking the semi-dispersion as the error. The resulting systematic uncertainty is ± 0.62, $^{+0.59}_{-0.62}$ and $^{+0.42}_{-0.44}$ MeV/c^2 for the $B^0 \to J/\psi K^0_S(\pi^+\pi^-)$, $B^0 \to J/\psi K^{*0}(K^+\pi^-)$ and $B^+ \to J/\psi K^+$ modes, respectively.

An additional uncertainty comes from background contamination in the event samples, which are determined from a fit to the sideband events, and is found to be between 2% and 4%. The measurement of the mass is performed by fitting a single Gaussian and a flat background to the B invariant mass distribution. Examples of the mass distributions are shown in Fig. 4. The distortion of the mass measurement due to the presence of background has been estimated by removing the N events with smallest mass and the N events with highest mass, where N is the number of background events in the sample. The corresponding systematic uncertainty is $^{+0.73}_{-0.60}$, $^{+0.62}_{-0.61}$ and $^{+0.30}_{-0.28}$ MeV/c^2 for the $B^0 \to J/\psi K^0_S(\pi^+\pi^-)$, $B^0 \to J/\psi K^{*0}(K^+\pi^-)$ and $B^+ \to J/\psi K^+$ modes, respectively.

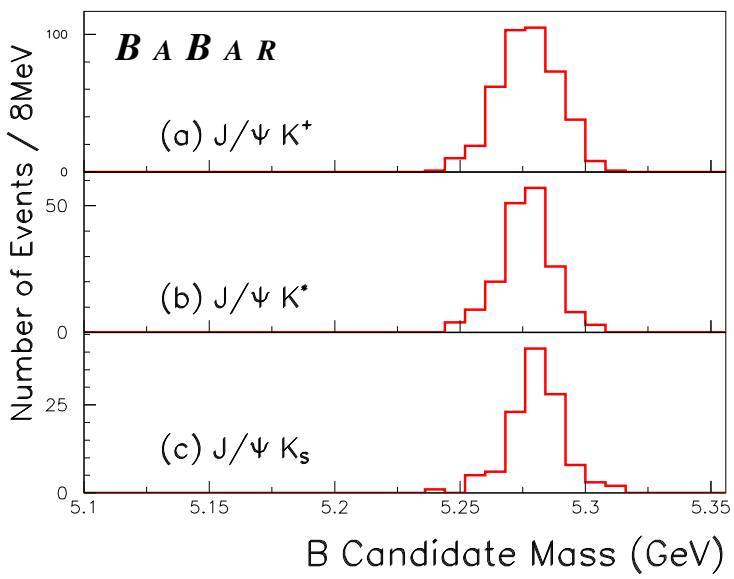


Figure 4: The reconstructed B mass distribution for the (a) $B^+ \to J/\psi K^+$, (b) $B^0 \to J/\psi K^{*0}(K^+\pi^-)$ and (c) $B^0 \to J/\psi K^0_S(\pi^+\pi^-)$ samples. The results presented here are preliminary.

The B masses have been measured to be:

$$\begin{aligned} m(B^0) &= 5279.0 \pm 0.8\ ^{+0.8}_{-0.8}\ \text{MeV}/c^2, \\ m(B^+) &= 5277.9 \pm 0.6\ ^{+0.4}_{-0.4}\ \text{MeV}/c^2, \end{aligned}$$

where the first error is the quadratic sum of the statistical and uncorrelated systematic errors and

the second error is the correlated systematic error.

The mass difference between the B^0 and B^+ mesons is evaluated by fitting the $m_{\rm ES}$ distributions of the three above-mentioned channels with the ARGUS function to describe the background and a Gaussian to describe the signal. The use of $m_{\rm ES}$ has the advantage that it reduces the sensitivity to the measured momentum scale and the uncertainties in the energy scale of the beam particles cancel in the mass difference. The same systematic study has been performed as in the invariant mass measurement described above, and was found to contribute $0.01\,\mathrm{MeV}/c^2$ to the systematic error on the mass difference measurement. Simulations indicate that the effect of the uncertainties in the beam parameters on the mass difference measurement is only $0.001\,\mathrm{MeV}/c^2$.

We also consider how the uncertainty in the shape of the background under the signal affects the mass difference measurement. We estimate the uncertainty by fitting the shape of the distribution in the ΔE sidebands and using these parameters when fitting to the signal. The effect on the mass difference between fixing the background shape or not is found to be $0.04\,\mathrm{MeV}/c^2$.

We measure the mass difference to be:

$$m(B^0) - m(B^+) = 0.28 \pm 0.21 \pm 0.04 \ \ \mathrm{MeV}/c^2$$

where the first error is the quadratic sum of the statistical and uncorrelated systematic errors and the second error is the correlated systematic error.

5.4 Angular analysis of $B \to J/\psi\, K^*$

The $B \to J/\psi\, K^*$ decay proceeds through three amplitudes, corresponding to the three different helicity configurations of the decay products [6]. The transversity formalism involves linear combinations of these amplitudes, denoted by A_0, A_t and $A_{||}$. Both A_0 and $A_{||}$ are *CP* even while A_t is *CP* odd. The size of the *CP* odd contribution in the decay must be known before a value of $\sin 2\beta$ can be extracted from this decay channel.

The event selection is similar to that used for the branching fraction measurement in section 5.1. In this analysis we have considered only those channels which have a final state composed solely of charged particles. B candidates were required to have a reconstructed mass within $\pm 0.01\,\mathrm{GeV}/c^2$ of the nominal value and $|\Delta E| < 0.075\,\mathrm{GeV}$.

The background is determined from the sideband region $m_{\rm ES} < 5.25\,\mathrm{GeV}/c^2$. The amplitudes are determined from a fit using the unbinned extended likelihood method [7], that takes into account the normalization condition $|A_0|^2 + |A_{||}|^2 + |A_t|^2 = 1$, the finite detector acceptance and the background contributions (assumed to have a flat angular distribution).

The 68% contours of the fit are presented in the $|A_0|^2 + |A_{||}|^2 + |A_t|^2 = 1$ plane of the $|A_0|^2$, $|A_{||}|^2$, $|A_t|^2$ space in Fig. 5. The fraction of the amplitude that is *CP* odd is determined to be $|A_t|^2 = 0.13 \pm 0.06 \pm 0.02$, while the longitudinal polarization (Γ_L/Γ) is found to be $|A_0|^2 = 0.60 \pm 0.06 \pm 0.04$.

Systematic errors arising from our knowledge of the background, the acceptance corrections, the cross-feed among $B \to J/\psi\, K^*$ modes, and the contribution due to heavier K^* mesons have been considered. The effect on the transversity amplitudes and phases are summarized in Table 3.

The results obtained are presented in Table 4.

6 Summary

We have presented preliminary measurements of branching fractions of B mesons to several two body charmonium final states. The results are in good agreement with previous measurements. A

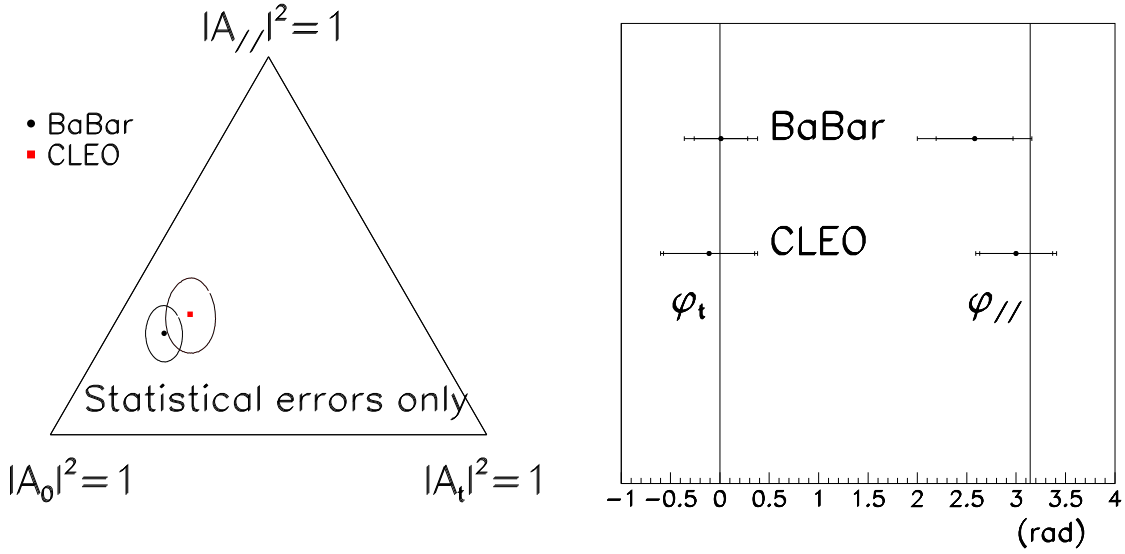


Figure 5: Transversity angle fits. The modulii of the amplitudes are shown as 68% contours in the top plot while the relative phase of the amplitudes are displayed in the bottom plot. Also shown are the results from CLEO [8].

Table 3: Systematic uncertainties in the measurement of transversity amplitudes.

Source	$\|A_0\|^2$	$\|A_t\|^2$	$\|A_{\|\|}\|^2$	$\varphi_{\|\|}$ (rad)	φ_t (rad)
Monte Carlo statistics	0.014	0.014	0.016	0.12	0.08
Backgrounds	0.011	0.009	0.001	0.01	0.03
Angular acceptance	0.020	0.011	0.020	0.13	0.05
Cross-feed background	0.025	0.006	0.030	0.02	0.03
Heavy K^*	0.011	0.004	0.007	0.07	0.01
Total	0.038	0.021	0.040	0.19	0.10

Table 4: Measured transversity amplitudes. The third amplitude is determined from the normalization condition while the phase ϕ_0 is, by convention, set to zero.

$\|A_0\|^2$	$\|A_t\|^2$	$\varphi_{\|\|}$ (rad)	φ_t (rad)
$0.60 \pm 0.06 \pm 0.04$	$0.13 \pm 0.06 \pm 0.02$	$2.58 \pm 0.39 \pm 0.20$	$0.01 \pm 0.27 \pm 0.10$

signal for the decay $B^0 \to J/\psi K^0_L$ is observed, with a yield compatible with our expectation.

The B^0 and B^+ masses and their mass difference have been measured, with results that are in good agreement with the world average values [4].

Finally we have presented an analysis of the transversity amplitudes in the decay $B \to J/\psi K^*$ that confirm that this final state is dominantly *CP* even and the *CP* asymmetry measurements in this channel will have a small dilution.

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