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Measurement of exclusive B decays to charmonium and K or K^* branching fractions with the *BABAR* detector.

The *BABAR* Collaboration

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Abstract

We report preliminary results on the measurement of branching fractions of exclusive decays of neutral and charged B mesons into two-body final states containing a charmonium state and a light strange meson. The charmonium mesons considered are J/ψ, $\psi(2S)$ and χ_{c1}, and the light mesons are either K or K^*. We use a sample of about 124 million $B\overline{B}$ events collected with the *BABAR* detector at the PEP-II storage ring at the Stanford Linear Accelerator Center.

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1 Introduction

Fully hadronic decays of B mesons have proven to be an effective laboratory to study and provide tests of the theory of heavy quarks as well as the dynamics of strong interactions in heavy meson systems. The tree level diagram of the decays under study is shown in Figure 1.

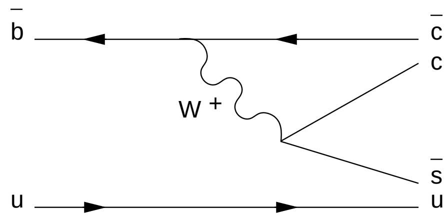

Figure 1: Tree level diagram of a B meson decaying into a charmonium state and a kaon.

The dynamics of the decay is expected to be highly affected by strong interactions effects, especially by the long distance non-pertubative aspect of QCD. There are various phenomenological approaches to treat these decays, which provide different estimates for the branching fractions (see [1] and references [2-12] therein).

Charge asymmetry measurements can be a powerful tool for seeking new physics. The Standard Model predicts small direct *CP* violation [2], thus large charge asymmetries would indicate new physics [3].

The list of the branching fractions measured and decay modes considered in this paper is shown in Table 1.

Table 1: Branching fractions and decay modes considered in this analysis.

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

2 The *BABAR* detector and dataset

The data used in this analysis were collected with the *BABAR* detector at the PEP-II asymmetric e^+e^- storage ring from 1999 to 2003. This represents a total integrated luminosity of 112.4 fb^{-1} taken on the $\Upsilon(4S)$ resonance, producing a sample of 123.95 million $B\overline{B}$ events.

The *BABAR* detector is described elsewhere [4]. Surrounding the interaction point, a 5 layer double-sided silicon vertex tracker (SVT) provides precise reconstruction of track angles and B decay vertices. A 40 layer drift chamber (DCH) provides measurements of the transverse momenta of charged particles. An internally reflecting ring-imaging Cherenkov detector (DIRC) is used for particle identification. A CsI(Tl) crystal electromagnetic calorimeter (EMC) is used to detect photons and electrons. The calorimeter is surrounded by a 1.5T magnetic field. The flux return is instrumented with resistive plate chambers (IFR) used for muon and neutral hadron identification.

3 Analysis Method

Multihadron events are selected by demanding a minimum of three reconstructed charged tracks in the polar-angle range $0.41 < \theta_{lab} < 2.54$ rad. Charged tracks must be reconstructed in the DCH and are required to originate at the nominal beamspot, within 1.5 cm in the plane transverse to the beam and 10 cm along the beam. Events are required to have a primary vertex within 0.5 cm of the average position of the interaction point in the plane transverse to the beamline, and within 6 cm longitudinally.

Charged tracks used in this analysis are required to include at least 12 DCH hits, to have a transverse momentum $p_T >$100 MeV/c.

Photons are reconstructed from EMC clusters. The radial energy profile (LAT) [5] of the cluster is used to discriminate electromagnetic from hadronic clusters. Photons are required to have a minimum energy of 30 MeV, a radial energy profile less than 0.8, and to be in the fiducial volume $0.41 < \theta < 2.41$ rad.

Electron candidates are selected using information from the EMC (radial energy profile and Zernike moment A_{42} [6]) , the ratio of the energy measured in the EMC to the momentum measured by the tracking system (E/p), energy loss (dE/dx) in the drift chamber and the Cherenkov angle measured in the DIRC. Electrons are also required to be in the fiducial volume $0.41 < \theta < 2.41$ rad.

Muon candidates are selected using information from the EMC (energy deposition consistent with a minimum ionizing particle) and the distribution of hits in the IFR. Muons are required to be in the fiducial volume $0.3 < \theta < 2.7$ rad.

The charged kaon and pion candidates are selected using information from the energy loss in the SVT and DCH, and the Cherenkov angle measured in the DIRC. Kaon candidates are required to be in the fiducial volume $0.45 < \theta < 2.45$ rad.

The next step in the analysis is to combine tracks and/or neutral clusters to form candidates. If a particle decays through an intermediate state, this is constrained to its known mass, except for the K^*. The selection has been optimized by maximizing the ratio $S/\sqrt{S+B}$, where S and B are respectively the number of expected signal and background events obtained from GEANT4-based Monte Carlo simulation after the selection.

The J/ψ candidates are required to have an invariant mass $2.95 < M_{e^+e^-} < 3.14$ GeV/c^2 and $3.06 < M_{\mu^+\mu^-} < 3.14$ for $J/\psi \rightarrow e^+e^-$ and $J/\psi \rightarrow \mu^+\mu^-$ decays respectively.

The $\psi(2S)$ candidates are required to have an invariant mass $3.44 < M_{e^+e^-} < 3.74\ \mathrm{GeV}/c^2$ and $3.64 < M_{\mu^+\mu^-} < 3.74\ \mathrm{GeV}/c^2$ for $\psi(2S) \to e^+e^-$ and $\psi(2S) \to \mu^+\mu^-$ decays respectively.

For $J/\psi \to e^+e^-$ and $\psi(2S) \to e^+e^-$ decays, electron candidates are combined with photon candidates in order to recover some of the energy lost through bremsstrahlung. Photons are required to be within 35 mrad in polar angle from the electron track, and to have an azimuthal angle intermediate between the initial track direction (estimated by subtracting 50 mrad opposite to the bend direction of the reconstructed track) and the centroid of the EMC cluster arising from the track.

In the χ_{c1} reconstruction ($\chi_{c1} \to J/\psi\ \gamma$), J/ψ candidates are selected as described above. The associated γ has to fulfill the following requirements: radial energy profile less than 0.8, Zernike moment A_{42} less than 0.15 and energy greater than 0.15 GeV. Furthermore, χ_{c1} candidates are required to satisfy $0.35 < M_{\ell^+\ell^-\gamma} - M_{\ell^+\ell^-} < 0.45\ \mathrm{GeV}/c^2$.

The $\pi^0 \to \gamma\gamma$ candidates are required to satisfy $0.113 < M_{\gamma\gamma} < 0.153\ \mathrm{GeV}/c^2$. The radial energy profile of both photons are required to be less than 0.8. The energy of the soft photon has to be greater than 0.050 GeV and the energy of the hard photon has to be greater than 0.150 GeV.

The $K^0_S \to \pi^+\ \pi^-$ candidates are required to satisfy $0.489 < M_{\pi^+\pi^-} < 0.507\ \mathrm{GeV}/c^2$. The following selection is also required: the K^0_S vertex has be more than 1mm from the charmonium vertex, and the angle in the x-y plane between the K^0_S momentum and the line joining the charmonium and K^0_S vertices has to be smaller than 0.2 rad.

The K^{*0} and K^{*+} candidates are respectively required to satisfy $0.796 < M_{K\pi} < 0.996\ \mathrm{GeV}/c^2$ and $0.792 < M_{K\pi} < 0.992\ \mathrm{GeV}/c^2$. In addition, for channels having a π^0 in the final state, the cosine of the angle between the K momentum defined in the K^* rest frame and the K^* momentum defined in the B rest frame has to be smaller than 0.8 (this helps in removing background coming from events with soft pions).

Finally, B candidates are reconstructed by combining charmonium and kaon meson candidates and are selected by the use of two kinematic variables: the difference between the reconstructed energy of the B candidate and the beam energy in the center-of-mass frame $\Delta E = E^*_B - E^*_{beam}$, and the beam energy substituted mass m_{ES}, defined as $m_{\mathrm{ES}} \equiv \sqrt{E^{*2}_{beam} - \mathbf{p}^{*2}_B}$ (the * refers to quantities in the center of mass). For a true B meson, ΔE is expected to peak at zero, and the energy substituted mass m_{ES} should peak at the B meson mass $5.279\ \mathrm{GeV}/c^2$. Only one reconstructed B meson is allowed per event. For events that have multiple candidates, the candidate having the smallest ΔE is chosen. Depending on the channel, around 10% of the candidates are removed by requesting a single B meson per event. The analysis is performed in the m_{ES} vs ΔE plane, defined as: $5.2 < m_{\mathrm{ES}} < 5.3\ \mathrm{GeV}/c^2$ and $-0.12 < \Delta E < 0.12$ GeV. As an example, Figure 2 shows the ΔE and m_{ES} distributions for the $B \to J/\psi\ K^{*0}\ (K^+\ \pi^-)$ channel. We subsequently define a signal box region in the m_{ES} vs ΔE plane, where the sensitivity is optimal. The signal box region is channel-dependent. For most of the channels, the signal regions are taken as the mean value $\pm 3\sigma$ for both ΔE and m_{ES}. For channels with less statistics ($\psi(2S)\ K^*$ and $\chi_{c1}\ K^*$ channels), the m_{ES} signal region was taken as $5.27 < m_{\mathrm{ES}} < 5.29\ \mathrm{GeV}/c^2$, and the ΔE signal region was taken as $|\Delta E| < 0.04$ GeV for channels with a π^0 in the final state and $|\Delta E| < 0.03$ GeV for the other channels.

The selection efficiencies for each mode are obtained from Monte Carlo and are given by the number of expected signal events divided by the total number of generated events. While the Monte Carlo has been tuned to be as realistic as possible, one still has to correct for residual differences between data and simulated events. We have therefore applied additional corrections

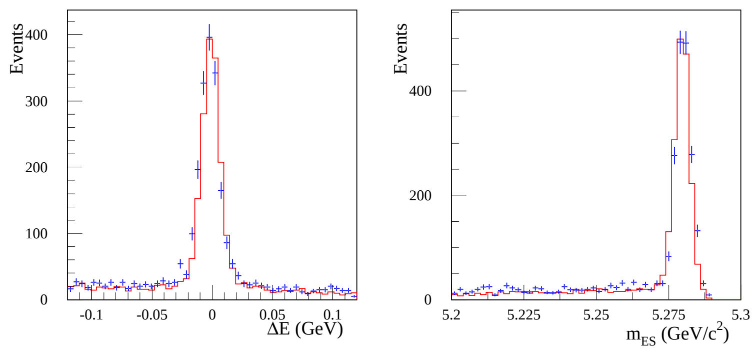

Figure 2: ΔE and $m_{\rm ES}$ distributions for the $B \to J/\psi\ K^{*0}\ (K^+\ \pi^-)$ channel. The blue points represent the Data and the histogram represents the Monte Carlo. An offset between the Monte Carlo and data distributions can be seen. It has been corrected.

to the selection efficiency coming from particle identification, neutral particle, tracking, and K^0_S corrections.

The number of signal events N_S is determined from the number of candidate events $N_{\rm cand}$ after subtracting the background. The $m_{\rm ES}$ distribution within the ΔE signal region is fitted by an Argus function [7] and a Gaussian, and both functions are subsequently integrated within the $m_{\rm ES}$ signal region. The number of candidate events is given by the Gaussian integral. There are two components to the background: the combinatorial background and a peaking component (the component of the background that has ΔE and $m_{\rm ES}$ distributions peaking at $\Delta E = 0$ GeV and $m_{\rm ES} = 5.279$ GeV/c^2 respectively). The combinatorial background is obtained by integrating the Argus function within the $m_{\rm ES}$ and ΔE signal regions. The peaking component is obtained from Monte Carlo. There are two contributions to the peaking background. The first contribution is coming from feed-across events which, in the case of the $J/\psi\ K^{*0}\ (K^0_S\ \pi^0)$ reconstruction, for instance, come from $J/\psi\ K^{*0}\ (K^+\ \pi^-)$, $J/\psi\ K^{*+}\ (K^0_S\ \pi^+)$ and $J/\psi\ K^{*+}\ (K^+\ \pi^0)$. The second contribution is coming from inclusive charmonium. For each of the contributions, the $m_{\rm ES}$ distribution is fitted within the ΔE signal region by an Argus and a Gaussian function, which are subsequently integrated within the $m_{\rm ES}$ signal region. The amount of peaking background is given by the Gaussian integral.

The branching fractions are obtained from:

$$BF = \frac{N_S}{N_{B\overline{B}} \times \epsilon \times f} \tag{1}$$

where $N_{B\overline{B}}$ is the number of $B\overline{B}$ events, ϵ is the selection efficiency and f is the total secondary branching fraction. For channels with a K^* in the final state, the feed-across contribution, which depends on the branching fractions that are being measured, to the peaking background can be important. Therefore an iterative procedure has been employed in which the feed-across contribution is re-estimated at each iteration. The procedure converges quickly as the feed-across is a small fraction of the number of signal events. When allowed by the size of the data sample, the branching fractions have been measured for both $J/\psi \to e^+e^-$ and $J/\psi \to \mu^+\mu^-$ decays separately.

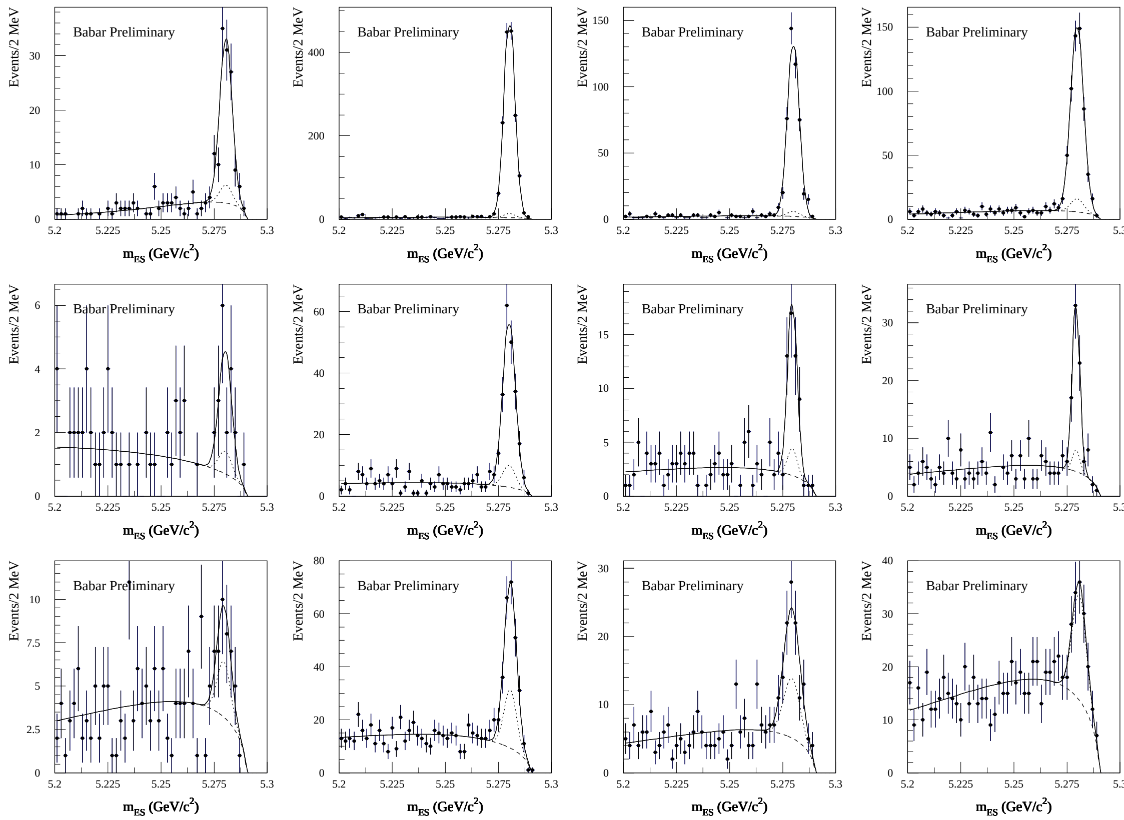

Figure 3: m_{ES} distributions and fits within the ΔE `Signal Box` region for $B \to$ charmonium K^* channels. The top row represents the distributions for the $J/\psi\ K^*$ channels, the middle row the $\psi(2S)\ K^*$ channels, and the bottom row the $\chi_{c1}\ K^*$ channel. From left to right, the columns show the distributions for the $K^{*0} \to K^0_S\ \pi^0$, $K^{*0} \to K^+\ \pi^-$, $K^{*+} \to K^0_S\ \pi^+$, and $K^{*+} \to K^+\ \pi^0$ decay modes. The dashed lines show the combinatorial contribution to the background. The dotted lines show the peaking background contribution.

The m_{ES} distributions within the ΔE signal region for candidate events are shown on Figures 3 and 4.

4 Systematic studies

The systematic errors arise from the uncertainty on the number of $B\overline{B}$ events, the secondary branching fraction, the estimate of the selection efficiency, and the knowledge of the background.

The systematic uncertainty on the number of $B\overline{B}$ events is 1.1%. It is common to all the branching fraction measurements. The secondary branching fractions and their errors have been taken from [8].

For the tracking efficiency, we have used a flat correction of 0.8% per track with an associated error of 1.3% per track. The K^0_S efficiency corrections have been determined by the use of control samples and its errors from varying the K^0_S selection. The resulting error on the K^0_S efficiency varies from 0.8% to 2.0% depending on the channel. The uncertainty on the detection and energy

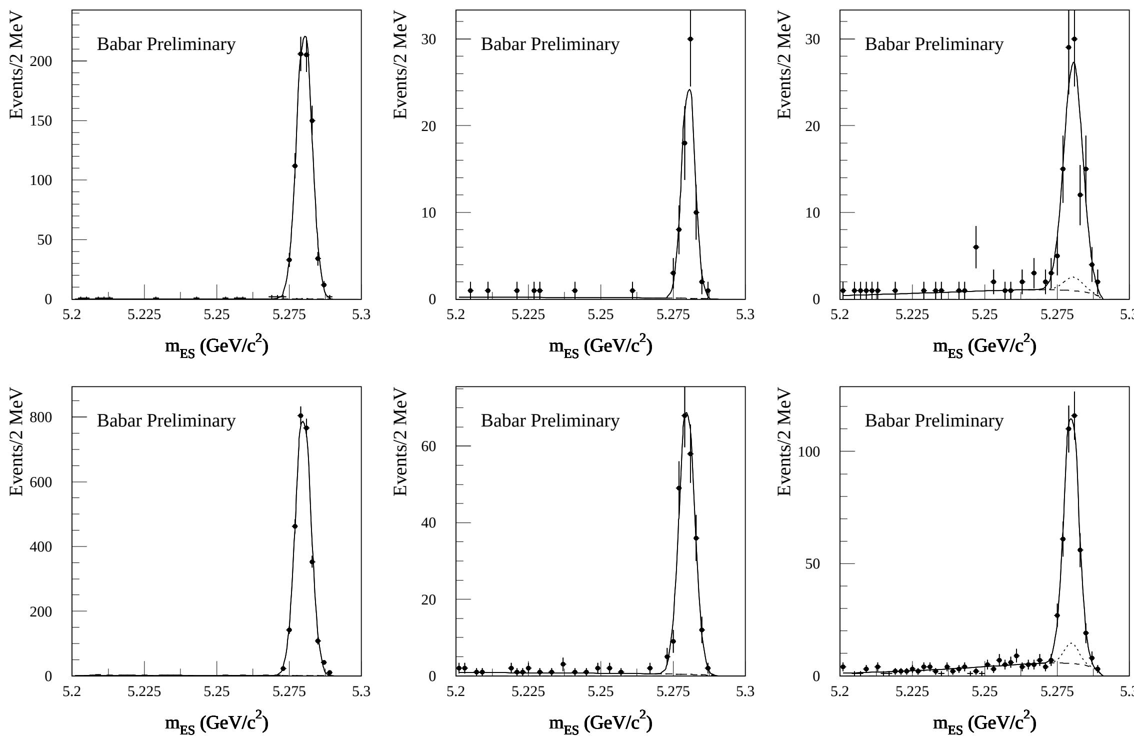

Figure 4: $m_{\rm ES}$ distributions and fits within the ΔE `Signal Box` region for $B \to$ charmonium K^0_S channels (top row) and $B \to$ charmonium K^+ channels (bottom). From left to right, the columns show the distributions for the J/ψ ,$\psi(2S)$ and χ_{c1} channels.

Table 2: Breakdown of contributions to the systematic errors for the J/ψ K^* channels. All values are expressed relative to the measured branching fractions, in percent.

	K^0_S π^0		K^+ π^-		K^0_S π^-		K^+ π^0	
	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$
B counting	1.1		1.1		1.1		1.1	
Tracking	2.6		5.2		3.9		3.9	
Polarizarion	7.37		3.85		4.85		6.86	
K^0_S	0.7		-		0.8		-	
Neutral	5.72	5.27	-		-		5.14	5.61
Second BF	1.69	1.71	1.69	1.70	1.70	1.71	1.69	1.70
PID	0.95	2.14	0.88	3.57	0.90	2.93	0.61	3.73
Background	3.57	3.25	1.18	0.91	1.45	0.96	2.34	2.04
MC statistics	1.24	1.23	1.37	1.32	1.51	1.45	1.80	1.71
Total	10.65	10.49	7.06	7.82	6.97	7.42	10.08	10.90

measurement of photons is 2.5% common to all channels plus an additional channel-dependent correction. The uncertainty on the π^0 reconstruction is 5.0% for all channels plus an additional

Table 3: Breakdown of contributions to the systematic errors for the $\psi(2S)$ K^* channels. All values are expressed relative to the measured branching fractions, in percent.

	$K_S^0\ \pi^0$	$K^+\ \pi^-$	$K_S^0\ \pi^-$	$K^+\ \pi^0$
B counting	1.1	1.1	1.1	1.1
Tracking	2.6	5.2	3.9	3.9
K_S^0	2.0	-	1.9	-
Neutral	7.2	-	-	6.2
Second BF	11.74	11.72	11.72	11.72
PID	0.97	1.62	0.21	0.52
Background	9.36	7.83	8.59	10.82
Polarization	6.11	4.72	4.67	7.19
Mc Statistics	3.45	1.68	2.72	2.27
Total	18.42	15.95	16.13	19.14

Table 4: Breakdown of contributions to the systematic errors for the χ_{c1} K^* channels. All values are expressed relative to the measured branching fractions, in percent.

	$K_S^0\ \pi^0$	$K^+\ \pi^-$	$K_S^0\ \pi^-$	$K^+\ \pi^0$
B counting	1.1	1.1	1.1	1.1
Tracking	2.6	5.2	3.9	3.9
K_S^0	1.1	-	1.1	-
Neutral	9.4	2.5	2.8	8.3
Second BF	10.4	10.4	10.4	10.4
PID	0.35	1.64	0.85	1.23
Background	30.08	16.76	24.25	246.53
Polarization	8.27	5.86	6.81	8.61
MC statistics	2.06	1.38	1.61	1.80
Total	34.40	21.50	27.78	247.08

channel-dependent correction. For the particle identification efficiency correction, we have assigned a systematic error equal to half of the correction. The overall selection efficiency depends on the angular distribution used in the simulation for the decay. It can be written as $\epsilon = a + |A_0|^2 b$, where a and b are functions of the K^* helicity angle, $a = 3/4 \int (1-\cos^2\theta_{K^*})\epsilon(\theta_{K^*})\sin(\theta_{K^*})d\theta_{K^*}$ and $b = 3/4 \int (3\cos^2\theta_{K^*}-1)\epsilon(\theta_{K^*})\sin(\theta_{K^*})d\theta_{K^*}$, and $|A_0|$ is the (unknown) fraction of the longitudinal K^* polarization [9]. We estimate the uncertainty due to our ignorance on the value of $|A_0|$ and derive an associated systematical error varying from 3.4 to 8.6%, depending on the channel. The systematic error due to the finite size of the Monte Carlo statistics varies from 1.23 to 3.45%. Interference effects between K^* events described by a P-wave and non-resonant events described by an S-wave have been considered [10]. The interference term is proportional to the fraction of non-resonant events with respect to the number of signal events [10]. However, this fraction is small for all channels. Furthermore, a large systematic uncertainty (see below) has been assigned to the number of non-resonant events. Thus, no additional systematic uncertainty due to interference

Table 5: Breakdown of contributions to the systematic errors for the K^0_S and K^+ channels. All values are expressed relative to the measured branching fractions, in percent.

	$J/\psi\ K^0_S$		$J/\psi\ K^+$		$\psi(2S)\ K^0_S$		$\psi(2S)\ K^+$		$\chi_{c1}\ K^0_S$		$\chi_{c1}\ K^+$	
	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$	e^+e^-	$\mu^+\mu^-$
B counting	1.1		1.1		1.1		1.1		1.1		1.1	
Tracking	2.6		3.9		2.6		3.9		2.6		3.9	
K^0_S	0.7		-		1.0		-		0.9		-	
PID	0.20	1.55	1.04	1.55	0.22	2.41	0.74	2.08	0.74	1.94	0.82	2.67
Second BF	1.70	1.71	1.69	1.70	4.11	10.96	4.11	10.96	10.27	10.26	10.27	10.27
Background	0.22	0.08	0.17	0.03	0.41	0.27	0.57	0.17	6.72	2.96	1.97	1.84
MC statistics	0.56	0.54	1.07	1.01	1.36	1.31	1.88	1.81	1.14	1.11	1.54	1.50
Total	3.46	3.75	4.64	4.77	5.28	11.69	6.14	12.01	12.70	11.30	11.40	11.665

effects has been introduced.

In the default fit for the determination of the combinatorial background, the shape parameter of the Argus function is not constrained. To determine a systematic error, a second fit with the shape parameter of the Argus function fixed to the value obtained from fitting the data in the ΔE sideband region was performed. We have taken as the systematic uncertainty on the combinatorial background 50% of the difference between the combinatorial background contribution obtained from the default fit and from the second fit. For the feed-across component to the peaking background we have assigned as the systematic error, the uncertainty of the corresponding branching fractions, taken from [8]. For the inclusive charmonium contribution to the peaking background, we have assigned a 50% error, accounting for the poor knowledge of the branching fractions of the contributing decay modes.

The systematic uncertainties for all modes are listed in Tables 2, 3, 4 and 5.

5 Physics results

The branching fractions that have been measured separately for the $J/\psi \to e^+e^-$ and $J/\psi \to \mu^+\mu^-$ decay modes were found to be in good agreement. They have therefore been combined. Furthermore, for K^* channels, the branching fractions from the two neutral sub-modes $K^0_S\ \pi^0$ and $K^+\ \pi^-$ have been averaged together, and the branching fractions from the two charged sub-modes $K^0_S\ \pi^+$ and $K^+\ \pi^0$ have been averaged together as well. The branching fraction measurements are summarized in Table 6.

From these measurements, we have determined the ratios of charged to neutral branching fractions. We have assumed a value of one for the charged to neutral B meson production rate at the $\Upsilon(4S)$. The results are presented in Table 7. The systematic uncertainties of the ratios have been determined by taking into account the correlations of the errors between the branching fractions.

Combining all the measurements, we obtain:

$$\frac{\mathcal{B}(B^+ \to \text{charmonium K}^{(*)+})}{\mathcal{B}(\text{B}^0 \to \text{charmonium K}^{(*)0})} = 1.14 \pm 0.02 \pm 0.03 \tag{2}$$

Table 6: Measured branching fractions for exclusive decays of B mesons to charmonium and kaon final states. The first error is statistical and the second systematic.

Channel	Branching fraction ($\times 10^{-4}$)
$B^0 \to J/\psi\ K^{*0}$	12.92±0.25±0.75
$B^+ \to J/\psi\ K^{*+}$	14.34±0.36±0.94
$B^+ \to J/\psi\ K^+$	10.55±0.15±0.48
$B^0 \to J/\psi\ K^0$	8.73±0.23±0.30
$B^0 \to \psi(2S)\ K^{*0}$	6.65±0.57±1.00
$B^+ \to \psi(2S)\ K^{*+}$	6.03±0.85±0.91
$B^+ \to \psi(2S)\ K^+$	6.31±0.33±0.44
$B^0 \to \psi(2S)\ K^0$	6.60±0.60±0.46
$B^0 \to \chi_{c1}\ K^{*0}$	3.19±0.37±0.64
$B^+ \to \chi_{c1}\ K^{*+}$	2.89±0.69±0.93
$B \to \chi_{c1}\ K^+$	5.72±0.24±0.64
$B^0 \to \chi_{c1}\ K^0$	4.56±0.39±0.51

Table 7: Results for ratios of charged to neutral braching fractios. The first error is statistical and the second systematic.

Ratio	Result
$\mathcal{B}(B^+ \to J/\psi\, K^+)/\mathcal{B}(B^0 \to J/\psi\, K^0)$	1.21±0.04±0.04
$\mathcal{B}(B^+ \to \psi(2S)K^+)/\mathcal{B}(B^0 \to \psi(2S)K^0)$	0.95±0.10±0.03
$\mathcal{B}(B^+ \to \chi_{c1}K^+)/\mathcal{B}(B^0 \to \chi_{c1}K^0)$	1.25±0.12±0.07
$\mathcal{B}(B^+ \to J/\psi\, K^{*+})/\mathcal{B}(B^0 \to J/\psi\, K^{*0})$	1.11±0.04±0.08
$\mathcal{B}(B^+ \to \psi(2S)K^{*+})/\mathcal{B}(B^0 \to \psi(2S)K^{*0})$	0.91±0.15±0.11
$\mathcal{B}(B^+ \to \chi_{c1}K^{*+})/\mathcal{B}(B^0 \to \chi_{c1}K^{*0})$	0.91±0.24±0.31

Assuming isospin invariance in the $B \to$ charmonium K (K^*) decays we can compute our own value for the charged to neutral B meson production. Using the ratio of the charged to neutral B meson lifetimes $\tau_{B^+}/\tau_{B^0} = 1.086 \pm 0.017$ [8]), we obtain:

$$R^{+/0} = \frac{\Gamma(\Upsilon(4S) \to B^+B^-)}{\Gamma(\Upsilon(4S) \to B^0\overline{B}^0)} = 1.05 \pm 0.04 \tag{3}$$

We also determine the ratio of branching fractions for a vector to a pseudo-scalar light meson: $\mathcal{B}(B^0 \to \psi K^{*0})/\mathcal{B}(B^0 \to \psi K^0)$ and $\mathcal{B}(B^+ \to \psi K^{*+})/\mathcal{B}(B^+ \to \psi K^+)$ for the three charmonium states $\psi = J/\psi$, $\psi(2S)$ and χ_{c1}. The results are presented in Table 8. For each of the charmonium states, we also present the average of the charged and neutral measurements.

Finally, charge asymmetries have been measured. The branching fractions for positively and negatively charged B mesons have been determined using the method described above. The selection efficiencies have been determined separately.

Table 8: Results for ratio of the branching fractions for a vector (K^*) versus pseudoscalar (K) light meson. The first error is statistical and the second systematic.

Ratio	Result
$\mathcal{B}(B^0 \to J/\psi\, K^{*0})/\mathcal{B}(B^0 \to J/\psi\, K^0)$	1.48±0.05±0.07
$\mathcal{B}(B^+ \to J/\psi\, K^{*+})/\mathcal{B}(B^+ \to J/\psi\, K^+)$	1.36±0.04±0.08
$\mathcal{B}(B \to J/\psi\, K^*)/\mathcal{B}(B \to J/\psi\, K)$	1.42±0.03±0.05
$\mathcal{B}(B^0 \to \psi(2S)K^{*0})/\mathcal{B}(B^0 \to \psi(2S)K^0)$	1.01±0.13±0.09
$\mathcal{B}(B^+ \to \psi(2S)K^{*+})/\mathcal{B}(B^+ \to \psi(2S)K^+)$	0.96±0.14±0.09
$\mathcal{B}(B \to \psi(2S)K^*)/\mathcal{B}(B \to \psi(2S)K)$	0.99±0.10±0.06
$\mathcal{B}(B^0 \to \chi_{c1}K^{*0})/\mathcal{B}(B^0 \to \chi_{c1}K^0)$	0.70±0.10±0.12
$\mathcal{B}(B^+ \to \chi_{c1}K^{*+})/\mathcal{B}(B^+ \to \chi_{c1}K^+)$	0.51±0.12±0.15
$\mathcal{B}(B \to \chi_{c1}K^*)/\mathcal{B}(B \to \chi_{c1}K)$	0.62±0.08±0.09

$$\frac{\mathcal{B}(B^+ \to J/\psi\, K^+) - \mathcal{B}(B^- \to J/\psi\, K^-)}{\mathcal{B}(B^+ \to J/\psi\, K^+) + \mathcal{B}(B^- \to J/\psi\, K^-)} = -0.029 \pm 0.014 \pm 0.010 \tag{4}$$

$$\frac{\mathcal{B}(B^+ \to J/\psi\, K^{*+}) - \mathcal{B}(B^- \to J/\psi\, K^{*-})}{\mathcal{B}(B^+ \to J/\psi\, K^{*+}) + \mathcal{B}(B^- \to J/\psi\, K^{*-})} = 0.045 \pm 0.025 \pm 0.011 \tag{5}$$

$$\frac{\mathcal{B}(B^+ \to \psi(2S)K^+) - \mathcal{B}(B^- \to \psi(2S)K^-)}{\mathcal{B}(B^+ \to \psi(2S)K^+) + \mathcal{B}(B^- \to \psi(2S)K^-)} = 0.059 \pm 0.051 \pm 0.021 \tag{6}$$

$$\frac{\mathcal{B}(B^+ \to \psi(2S)K^{*+}) - \mathcal{B}(B^- \to \psi(2S)K^{*-})}{\mathcal{B}(B^+ \to \psi(2S)K^{*+}) + \mathcal{B}(B^- \to \psi(2S)K^{*-})} = -0.063 \pm 0.137 \pm 0.050 \tag{7}$$

$$\frac{\mathcal{B}(B^+ \to \chi_{c1}K^+) - \mathcal{B}(B^- \to \chi_{c1}K^-)}{\mathcal{B}(B^+ \to \chi_{c1}K^+) + \mathcal{B}(B^- \to \chi_{c1}K^-)} = 0.011 \pm 0.042 \pm 0.017 \tag{8}$$

$$\frac{\mathcal{B}(B^+ \to \chi_{c1}K^{*+}) - \mathcal{B}(B^- \to \chi_{c1}K^{*-})}{\mathcal{B}(B^+ \to \chi_{c1}K^{*+}) + \mathcal{B}(B^- \to \chi_{c1}K^{*-})} = -0.403 \pm 0.309 \pm 0.237 \tag{9}$$

6 Summary

We have presented preliminary results of branching fraction measurements of exclusive B decays to charmonium and K or K^*. The charmonium mesons considered were J/ψ, $\psi(2S)$ and χ_{c1}. Our results for J/ψ and $\psi(2S)$ are in good agreement with previous measurements [8] with comparable or superior precision. Our χ_{c1} results have much better precision and the $B^+ \to \chi_{c1}\, K^{*+}$ branching fraction was measured for the first time. Assuming isopin invariance, we find the ratio of charged to neutral B meson production on the Υ(4S) resonance to be compatible with unity within two standard deviations. No direct *CP* violation has been observed from the measurements of charge asymmetries as we found them to be compatible with zero.

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