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BaBar: Rare Charmless B Decays

David Hutchcroft*
University of Liverpool, UK
E-mail: David.Hutchcroft@cern.ch
for the BaBar Collaboration

Three two body and two resonance decays of the B mesons have been measured using data from the *BABAR* detector: $B^0 \to \pi^{\pm}, K^{\mp}, K^+K^-, K^0_S\pi^+\pi^-$ and $B^0 \to a_1^+(1260)\pi^-$. The branching ratios and that of some intermediate resonances are presented along with the *CP* asymmetry of the decay $B^0 \to K^{*+}\pi^-$.

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*Speaker.

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1. Introduction

Charmless hadronic two body and three-body decays of B mesons provide information on CP violation in the B system and can be used to measure all three angles in the unitarity triangle. They also provide insight into the quark couplings described by the Cabibbo-Kobayashi-Maskawa matrix.

Knowledge of the decay rates of B mesons to two, three and four mesons are necessary to understand the underlying hadron dynamics of the B meson decays which are required to extract the maximum CP information from the data. The various theoretical approaches to calculating the branching ratios give differing predictions for the rates, and so the measurements can indicate which approaches yield the most accurate results.

The *BABAR* collaboration has measured the charmless two body branching ratios[1] of $B^0 \to \pi^+\pi^-$ and π^+K^- and performed a search for $B^0 \to K^+K^-$. The branching ratio of another two body decay, $B^0 \to a_1^+(1260)\pi^-$, where the $a_1^+(1260)$ decays to $\pi^+\pi^-\pi^+$ has also been measured. Some of the parameters of the $a_1^+(1260)$ have been determined from this decay. The branching fractions for the charmless three body decays to the £nal state $K_S^0\pi^+\pi^-$ are also measured, including the resonance channels $f_0(\to \pi\pi)K_S^0$ and $K^{*+}\pi^-$. The CP asymmetry of the decay $B^0 \to K^{*+}\pi^-$ was measured on that sub-sample of the events.

2. *BABAR* detector and data sample

The data for these analyses were taken at the PEP-II asymmetric e^+e^- storage ring at SLAC with the *BABAR* detector[1]. The data sample used in these analyses has an integrated luminosity of 210 fb^{-1} at the $\Upsilon(4S)$ resonance. This data set corresponds to $(231.8 \pm 2.5) \times 10^6$ $B\bar{B}$ pairs, it is assumed that the $\Upsilon(4S)$ decays equally to $B^0\bar{B}^0$ and B^+B^- pairs. An additional 21.6 fb^{-1} of data taken 40 MeV below the $\Upsilon(4S)$ resonance was also used to understand the backgrounds.

3. Reconstruction

Two kinematic variables are de£ned to separate signal from $q\bar{q}$ backgrounds, the energy substituted mass $m_{\rm ES} = \sqrt{(s/2 + \mathbf{p}_0 \cdot \mathbf{p}_B)^2/E_0^2 - \mathbf{p}_B^2}$, where $\sqrt{s}$ is the energy of the e^+e^- system, $\mathbf{p}_B$ is the B momentum and $(E_0, \mathbf{p}_0)$ is the 4-momentum of the $\Upsilon(4S)$ system, and the difference between the reconstructed energy and half the beam energy, $\Delta E = E_B - \sqrt{s}/2$ where E_B is the reconstructed energy of the B meson.

3.1 $B^0 \to \pi^+\pi^-$, π^+K^- or K^+K^-

The two body decays $B^0 \to \pi^+\pi^-$, π^+K^- and K^+K^- the full selection is described in Ref. [2] and [3], although there is no requirement on Δz for the branching ratio measurements. Events are selected where there are two opposite charge tracks identi£ed as pions or kaons by their Cherenkov angles, θ_i, and which satisfy $5.20 < m_{\rm ES} < 5.29\,{\rm GeV}/c^2$ and $|\Delta E| < 150\,{\rm MeV}$. Additional requirements on the rest of the event are made through a Fisher Discriminant ($\mathscr{F}$) tuned on MC backgrounds [4]. The total number of events after the selection is 69,264 with the ef£ciencies quoted

[1] Charge conjugation is assumed throughout

Mode	No FSR	PHOTOS	QED
$\pi^+\,\pi^-$	40.9 ± 0.2	39.9 ± 0.2	39.4 ± 0.2
$K^+\,\pi^-$	49.9 ± 0.2	38.9 ± 0.2	38.4 ± 0.2
$K^+\,K^-$	48.6 ± 0.3	37.8 ± 0.3	37.6 ± 0.3

Table 1: Ef£ciencies (%) for 2-body decay modes from MC samples reconstructed in GEANT without FSR effects, with the PHOTOS package and with a leading order QED calculation. The QED calculation is used in measuring the branching ratios.

in Table 1. A detailed calculation of the QED effects up to 2nd order has been applied [5], the difference to the PHOTOS package [6] prediction is taken as a systematic error.

The 5 variables ($m_{\rm ES}$, ΔE, θ_i and $\mathscr{F}$) are £t with an unbinned maximum likelihood (ML) £t where the likelihood function is the product of 1D likelihoods for each variable for signal and backgrounds [7].

3.2 $B^0 \to K^0_S \pi^+ \pi^-$

The selection for the decay $B^0 \to K^0_S \pi^+ \pi^-$ [8] £rst selects $K^0_S \to \pi^+ \pi^-$ candidates, then two oppositely charged tracks that pass the pion selection are added. Cuts on the B^0 ¤ight length and decay angles are imposed. Two of the possible intermediate resonances are selected from within the main sample, $K^{*+}\pi^-$ with $0.776 < m_{K^0_S\pi} < 1.010\,{\rm GeV}/c^2$ and $f_0 K^0_S$ with $0.879 < {\rm m}_{\pi^+\pi^-} < 1.069\,{\rm GeV/c}^2$. After the selection there are about $80,000$ events which were £tted with a ML £t with the $m_{\rm ES}$, ΔE and $\mathscr{F}$ variables. For the $B^0 \to K^{*+}\pi^-$ subsample the CP asymmetry $A_{K^*\pi} = (\Gamma_{\bar{B}^0\to K^{*-}\pi^+} - \Gamma_{\bar{B}^0\to K^{*+}\pi^-})/(\Gamma_{\bar{B}^0\to K^{*-}\pi^+} + \Gamma_{\bar{B}^0\to K^{*+}\pi^-})$ was also £tted.

3.3 $B^0 \to a_1^+(1260)\pi^-$

The decay of $B^0 \to a_1^+(1260)\pi^-$ and subsequent $a_1^+(1260) \to \pi^+\pi^-\pi^+$ proceeds mainly via the intermediate states $(\pi\pi)_\rho\pi$ and $(\pi\pi)_\sigma\pi$; however the two intermediate states are not distinguished in this analysis. The properties of the $a_1^+(1260)$ are not well measured and are determined from the £nal £t in this analysis [9]. Events are selected if $5.25 < m_{\rm ES} < 5.29\,{\rm GeV}/c^2$, $|\Delta E| < 200\,{\rm MeV}$ and $0.8 < m_{a1} < 1.89\,{\rm GeV}/c^2$; the intermediate di-pion state should have a mass between 0.51 and $1.1\,{\rm GeV}/c^2$ and the momentum of the $a_1^+(1260)$ in the center-of-mass frame should be between 2.3 and $2.7\,{\rm GeV}/c$. Other cuts are applied on the helicity of the decays to reduce continuum backgrounds. An additional angular variable A is de£ned which is the cosine in the B^0 meson rest frame of the plane of the decay pions and the other pion in the decay. This allows the separation of the $a_2^+(1320)\pi^-$ and $\pi^+(1300)\pi^-$ decays also expected in the data. After the selection the events were £tted with a unbinned maximum likelihood £t with the $m_{\rm ES}$, ΔE, $\mathscr{F}$ and A variables.

4. Results

The number of $B^0 \to \pi^+\pi^-$ £t in the data sample was $491 \pm 35 \pm 11$[2] which corresponds to a

[2] Statistical then systematic errors throughout

branching ratio of $(5.5 \pm 0.4 \pm 0.3) \times 10^{-6}$, the number of $B^0 \to K^+\pi^-$ is $1674 \pm 53 \pm 15$ giving a branching ratio of $(19.2 \pm 0.6 \pm 0.6) \times 10^{-6}$ and the number of $B^0 \to K^+K^-$ is $3.0 \pm 13.1 \pm 6.8$ (< 25.9) giving a branching ratio of less than 0.4×10^{-6} at 90% C.L.. These branching ratios are $6-8$% higher than the previous branching ratio[2] as the FSR effects have now been taken into account.

The number of event for the decay $B^0 \to K^0\pi^+\pi^-$ was measured to be 860 ± 47 giving a branching ratio of $(43.0 \pm 2.3 \pm 2.3) \times 10^{-6}$. The subsample $B^0 \to K^0 f_0(\to \pi^+\pi^-)$ was £tted to have 120 ± 16 event giving a branching ratio[3] of $(5.5 \pm 0.7 \pm 0.6 \pm 0.3) \times 10^-6$. The other subsample of $B^0 \to K^{*+}\pi^-$ had 140 ± 19 events, giving a branching ratio of $11.0 \pm 1.5 \pm 0.5 \pm 0.4$, the £tted value of the asymmetry $A_{K^*\pi} = -0.11 \pm 0.14 \pm 0.05$.

The decay $B^0 \to a_1^+(1260)\pi^-$ was measured to have 867 ± 85 events in the data. This gave a branching ratio of $(40.2 \pm 3.9 \pm 3.9) \times 10^{-6}$ and the parameters for the $a_1^+(1260)$ of $m_{a1} = 1.22 \pm 0.02\,\mathrm{GeV}/c^2$ and $\Gamma_{a1} = 0.423 \pm 0.050\,\mathrm{GeV}/c^2$.

5. Conclusion

The three 2-body and two resonance decays of the B mesons have been measured using data from the *BABAR* detector. The measurements are in agreement with those previously made by the *BABAR* collaboration and are compatible with the standard model predictions for their values.

References

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[3] 3rd error is due to uncertainties in the interference effects