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Study of Charmless Hadronic B decays at *BABAR*

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We report a number of recent measurements of B-meson decays to purely hadronic final states that do not contain charm mesons. These studies are based on the very large sample of $B\bar{B}$ events collected by the *BABAR* detector at SLAC's e^+e^- asymmetric collider B-factory when it operated on the $\Upsilon(4S)$. We include in this paper the results of: a Dalitz plot analysis of $B^0 \to K^0_S K^0_S K^0_S$ which provides a determination of the total branching fraction and those of intermediate states; inclusive branching fraction measurements of $B^0 \to \pi^+ K^0_S K^-$ and of $B^+ \to K^+ \pi^0 \pi^0$; a search for B-meson decays to the axial-vector vector final state $a_1^+ K^{*0}$, and measurements of B-meson decays to $\eta' \rho$, $\eta' f_0$ and $\eta' K^*$, where K^*stands for a vector, scalar, or tensor strange meson and in which we also measure, where applicable, the charge asymmetries.

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1. Introduction

Charmless hadronic B decays are sensitive probes to investigate effects of new physics arising from new particles and couplings entering the loop amplitudes through which these decays proceed [1]. These effects include shifts in the time-dependent CP asymmetries with respect to the value predicted by the standard model, enhancements or suppressions of branching fractions, and modifications of the decay dynamics. One of the outstanding problems is the so called *polarization puzzle* which consists in the fact that in some penguin dominated decays, such as $B \to \phi K^*$ [2], the longitudinal polarization fraction f_L is measured to be about 0.5, contrary to the prediction based on simple helicity arguments, of $f_L \sim 1$.

In the following, a number of recent measurements performed at the *BABAR* experiment will be presented; all of them use the full dataset, consisting of about 465×10^6 $B\bar{B}$ pairs. In all the analyses the final state is fully reconstructed; thanks to the fact that the kinematics of the production of B mesons is precisely known in the e^+e^- collider environment, the energy substituted mass $m_{\rm ES}$ and the difference ΔE between the energy of the reconstructed B candidate and its expected value are powerful variables to discriminate signal events against the backgrounds, arising mostly from $e^+e^- \to q\bar{q}$ ($q = u, d, s, c$) events, which typically exhibit a jet-like topology. Fisher discriminants or neural networks using variables sensitive to the event shape are used to suppress this background.

2. Two-body B decays

The measurement of the branching fractions of $B \to \eta' K^*$ allow us to test the pattern of interference predicted for $B \to \eta^{(\prime)} X$ decays; moreover, there is a discrepancy in the predictions of the branching fraction of $B^+ \to \eta' \rho^+$ between QCD Factorization and Perturbative QCD, which predict a branching fraction of the order of $6 - 9 \times 10^{-6}$, and SCET, which gives $\sim 0.4 \times 10^{-6}$. We measure the branching fractions of $B \to \eta' \rho, \eta' f_0$, and $\eta' K^*$ [3], where K^* indicates the vector $K^*(892)$, the tensor $K_2^*(1430)$, and the scalar component arising from the interference of the $K_0^*(1430)$ with the nonresonant $K\pi$. We obtain the first observation of four final states, among which $B^+ \to \eta' \rho^+$, whose branching fraction is measured to be $(9.7^{+1.9}_{-1.8} \pm 1.1) \times 10^{-6}$, and evidence for all the other modes besides $B^0 \to \eta' \rho^0$ and $B^0 \to \eta' f_0$, for which we set upper limits. Fig. 1 shows the signal enhanced projection plots over the $\pi\pi$ or $K\pi$ invariant mass of the modes investigated. The branching fractions of the tensor $K_2^*(1430)$ components are measured to be significantly higher than the vector $K^*(892)$, a fact also observed in $B \to \omega K^*$ decays [4]. predictions.

In [5] we also report a search for the decay $B^+ \to a_1^+ K^{*0}$. The main motivation for doing this study is to check the theoretical predictions on its branching fraction: while QCD Factorization predicts $\sim 11 \times 10^{-6}$, naïve factorization computes a branching fraction one order of magnitude smaller. Given that this is a decay of a pseudo-scalar meson to an axial-vector and a vector mesons, we can measure the longitudinal polarization fraction f_L in order to better characterize the pattern on the *polarization puzzle*. We find no significant signal for this mode, and set an upper limit at the 90% confidence level for its branching fraction at 1.8×10^{-6}.

3. Three-body B decays

The charmless hadronic decays of B mesons to three-body final states are useful to investigate

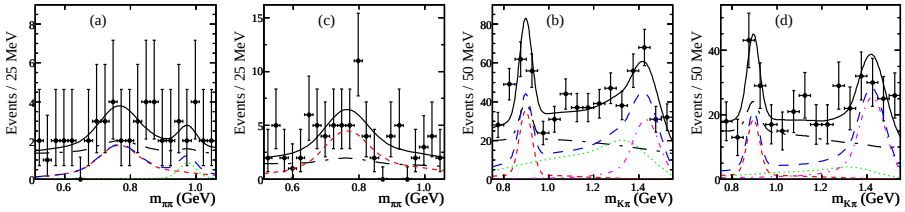

Figure 1: B-candidate $m_{\pi\pi}$ projections for (a) $\eta'\rho^0/\eta' f_0$, (b) $\eta'\rho^+$, and $m_{K\pi}$ for (c) $\eta' K^{*0}$, (d) $\eta' K^{*+}$. The solid curve is the fit function, black long-dash-dotted is the total background, and the blue dashed curve is the total signal contribution. In (a) we separate the ρ^0 component (red dashed) from the f_0 (green dotted). In (c,d) we separate the $K^*(892)$ (red dashed), the $(K\pi)^*_0$ (green dotted), and $K^*_2(1430)$ (magenta dot-dashed) components.

the existence and the properties of little known resonances through the study of the Dalitz plot (DP) of the decay. Moreover, the study of the $B \to K\pi\pi$ decays can provide useful information for the study of the $B \to K^*\pi$ system, which may help in the solution of the long-standing issues related to the *CP*-asymmetry and branching fractions of the $K\pi$ system.

We report the preliminary result of the first inclusive measurement of the decay $B^+ \to K^+\pi^0\pi^0$ [6]. The study of the DP of this decay may allow the investigation of the poorly known $f_X(1300)$, seen to decay into the $\pi^+\pi^-$ final state. The fit exploits the variable $m_{\rm ES}$ and the output of the neural network used to suppress the $q\bar{q}$ background. The fraction of incorrectly reconstructed signal events (self-crossfeed) is determined from the data using an iterative procedure and its average over the DP is measured to be 9.7%. The fit yields 1220 ± 85 signal events and the measured inclusive branching fraction is $(15.5 \pm 1.1 \pm 1.6) \times 10^{-6}$, with a significance of 10 standard deviations.

The decay $B^0 \to K^0_S K\pi$, whose first observation is reported in [7], proceeds via both $b \to d$ penguin and $b \to u$ tree amplitudes; a significant enhancement (or suppression) of the branching fraction with respect to the standard model predictions would be a sign of new physics. Moreover, the DP analysis of this channel can be exploited to search for an isospin partner of the $f_X(1500)$ resonance, which has been seen to decay to the K^+K^- final state in $B^+ \to K^+K^-\pi^+$ decays [8]. The fit yields 262 ± 47 signal events, which lead to the measurement of an inclusive branching fraction of $(3.2 \pm 0.5 \pm 0.3) \times 10^{-6}$. The inspection of the DP projections does not show any significant evidence of an isospin partner of the $f_X(1500)$ decaying to $K^0_S K^+$.

The decay $B^0 \to K^0_S K^0_S K^0_S$ has been used to get a determination of $\sin(2\beta)$ through the time-dependent *CP* analysis of the inclusive mode [9]; here we report the first Dalitz plot analysis [10] of this mode. Given that there are three identical particles in the final state, the probability density function can be symmetrized and the analysis performed using only $1/6^{th}$ of the DP. Moreover, in order to avoid problems modeling the efficiency along the edges of the DP, we move to the *Squared Dalitz Plot* formalism by considering the cosines of the helicity angles in place of the squared invariant masses of the pairs of particles. We obtain 200 ± 15 signal events, on top of a combinatorial background of 305 ± 18 events. The DP structure is described using the Isobar Model; the baseline model includes the $f_0(980)$ and the χ_{c0} resonances and a non resonant component. We scan for other resonances varying the mass and the width of an additional component and searching for significant minima in the 2-dimensional distribution of the negative log-likelihood (see Fig. 2).

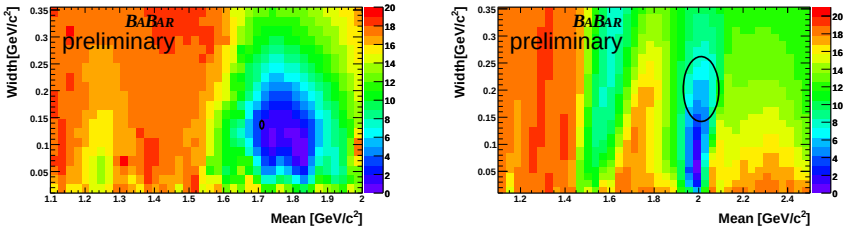

Figure 2: Variations of $-2\Delta\log\mathscr{L}$ in the scan over the central value of the mass and the width of a scalar resonance (left plot) and a tensor (right) in the Dalitz Plot analysis of $B^0 \to K^0_S K^0_S K^0_S$. The black ellipses represent the $f_0(1710)$ and the $f_2(2010)$ ([11]), no significant minima have been found for other resonances.

We find contributions from the $f_0(1710)$ and the $f_2(2010)$ components, while we do not see any evidence of the $f_X(1500)$ decaying to the $K^0_S K^0_S$ final state. This may be an indication of an odd spin for this resonance.

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