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Baryonic B decays at BABAR

$B^0 \to \bar{\Lambda} p \pi^-$

$\bar{B}^0 \to \Lambda_c^+ \bar{p} K^- \pi^+$

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The BABAR Collaboration has performed studies of the decays $B^0 \to \bar{\Lambda} p \pi^-$ and $\bar{B}^0 \to \Lambda_c^+ \bar{p} K^- \pi^+$ using a data sample of 467×10^6 $B\bar{B}$ pairs. For the decay $B^0 \to \bar{\Lambda} p \pi^-$ we measure the branching fraction $\mathscr{B}(B^0 \to \bar{\Lambda} p \pi^-) = [3.07 \pm 0.31(stat.) \pm 0.23(syst.)] \times 10^{-6}$ and a branching-fraction asymmetry compatible with zero. The $\bar{\Lambda}$ polarization for large values of the $\bar{\Lambda}$ energy in the B^0 rest frame ($E^*_{\bar{\Lambda}}$) is consistent with full longitudinal right-handed polarization. The decay $\bar{B}^0 \to \Lambda_c^+ \bar{p} K^- \pi^+$ is observed for the first time and a branching fraction $\mathscr{B}(\bar{B}^0 \to \Lambda_c^+ \bar{p} K^- \pi^+) = [4.33 \pm 0.82(stat.) \pm 0.33(syst.) \pm 1.13(\mathscr{B}(\Lambda_c^+))] \times 10^{-5}$ is measured where the last uncertainty comes from the uncertainty on the branching fraction $\mathscr{B}(\Lambda_c^+ \to p K^- \pi^+)$. Evidence for the resonant decay $\bar{B}^0 \to \Sigma_c^{++}(2455) \bar{p} K^-$ is also found and the branching fraction is measured to be $[1.11 \pm 0.30(stat.) \pm 0.09(syst.) \pm 0.29(\mathscr{B}(\Lambda_c^+))] \times 10^{-5}$. For the decay $\bar{B}^0 \to \Lambda_c^+ \bar{p} \bar{K}^{*0}$ we obtain an upper limit of 2.42×10^{-5} at 90% confidence level.

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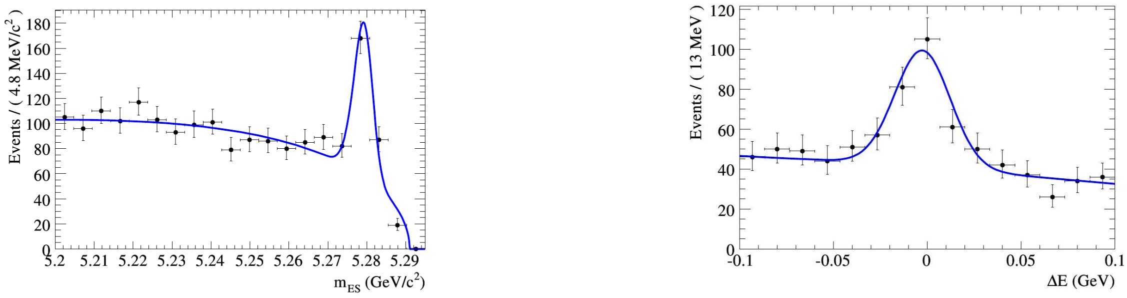

Figure 1: Projections of the two dimensional fit to $m_{\rm ES}$-ΔE for the decay $B^0 \to \overline{\Lambda} p \pi^-$

1. Introduction

Though approximately 7% of B-meson decays have baryons in the final state, the sum of all exclusive branching fractions measured so far is only about 1% [1] and very little is known about the decay mechanisms behind these decays. B-mesons decay dominantly via $b \to c$ transitions but charmless three-body baryonic B decays have been reported recently too [2]-[4]. A common feature of these decay modes is a threshold enhancement in the baryon-antibaryon invariant mass spectrum. This feature may also explain the increase in branching fraction with final state multiplicity and the apparent suppression of two-body decays to baryons [5],[6].

Both studies of baryonic B-decays are based on a data sample of about $426\,{\rm fb}^{-1}$ corresponding to 467×10^6 $B\bar{B}$ pairs, collected at the $\Upsilon(4S)$ resonance with the BABAR detector [7] at the PEP-II asymmetric-energy e^+e^- collider, and assume $\mathscr{B}(\Upsilon(4S) -> B^0\bar{B}^0) = \mathscr{B}(\Upsilon(4S) -> B^+B^-) = 0.5$.

2. Study of $B^0 \to \overline{\Lambda} p \pi^-$ [8]

To study $B^0 \to \overline{\Lambda} p \pi^-$, the $\overline{\Lambda}$ candidates are reconstructed from the decay mode $\overline{\Lambda} \to \overline{p}\pi^+$, while the invariant mass of $\overline{\Lambda}$ candidates has to be in between $1.111\,{\rm GeV}/c^2$ and $1.121\,{\rm GeV}/c^2$. For such candidates a mass constraint fit requiring a common vertex for the p and π was performed. $\overline{\Lambda}$ candidates for which this fit was successful are then combined with two oppositely charged proton and pion candidates. The full decay chain is fitted to reconstruct the B^0 vertex using the total beam energy and the position of the beam spot as constraints and the probability of this vertex fit has to be greater than 10^{-6}. To get a very clean $\overline{\Lambda}$ sample the flight length of the $\overline{\Lambda}$ candidate divided by its error must exceed 20. Event shape variables are used to reduce the background $e^+e^- \to q\bar{q}$, where $q = u, d, s$ or c, and are combined in a Fisher discriminant. The cut on the output of the Fisher discriminant is made to reduce the background by 92% while keeping 72% of the signal. We remove background from the decay $\bar{B}^0 \to \Lambda_c^+ \overline{p}$, $\Lambda_c^+ \to \Lambda\pi^+$, which has the same final state as the signal, by requiring the invariant mass of the $\overline{\Lambda}\pi^-$ system to differ more than $20\,{\rm MeV}/c^2$ (five standard deviations) from the nominal Λ_c^+ mass [1].

For candidates which fulfill all requirements a two dimensional maximum likelihood fit is performed in which the signal is described by two Gaussians for $m_{\rm ES}$ and two Gaussians for ΔE, and the background by an ARGUS function [9] for $m_{\rm ES}$ and a first order polynomial for ΔE. $m_{\rm ES}$ is defined as $m_{\rm ES} = \sqrt{(s/2 + \mathbf{p_0}\cdot\mathbf{p_B})^2/E_0^2 - \mathbf{p_B}^2}$, where $(E_0, \mathbf{p_0})$ is the four momentum of the

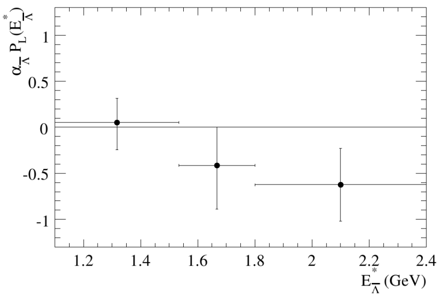

Figure 2: longitudinal $\overline{\Lambda}$ polarization measurement in the decay $B^0 \to \overline{\Lambda} p \pi^-$

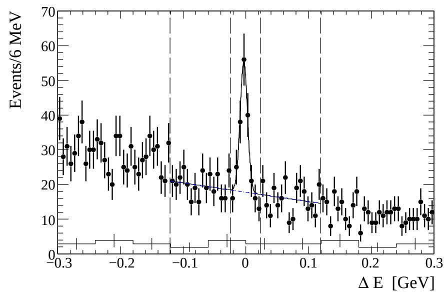

Figure 3: ΔE distribution for the whole phase space in the decay $\bar{B}^0 \to \Lambda_c^+ \overline{p} K^- \pi^+$

e^+e^- system and $\mathbf{p_B}$ the B candidate momentum, both measured in the laboratory frame. ΔE is the difference of reconstructed B energy and half of the total energy, $\sqrt{s}$, in the e^+e^- center of mass frame. The means of the narrow ΔE and m_{ES} signal Gaussians, the parameter of the ARGUS function, the linear coefficient of the polynomial for ΔE, and the event yields for signal and background are fitted while all other parameters are fixed to values obtained from MC. The one dimensional projections of this fit are shown in figure 1. Once the fit provides the best estimates of the PDF parameters, the ${}_s\mathscr{P}lot$ technique [10] is used to reconstruct the efficiency corrected $m(\overline{\Lambda} p)$ distribution and to measure the branching fraction. The $\overline{\Lambda}$ polarization is measured as a function of $E^*_{\overline{\Lambda}}$ using a four-dimensional maximum likelihood fit in m_{ES}, ΔE, $E^*_{\overline{\Lambda}}$ and $\cos\theta_h$, where $\cos\theta_h$ is the helicity angle for the $\overline{\Lambda}$ decay.

The branching fraction is found to be

$$\mathscr{B}(B^0 \to \overline{\Lambda} p \pi^-) = [3.07 \pm 0.31(stat.) \pm 0.23(syst.)] \times 10^{-6} \tag{2.1}$$

and the branching fraction asymmetry is found to be

$$\mathscr{A} = \frac{\mathscr{B}(\bar{B}^0 \to \Lambda \overline{p} \pi^+) - \mathscr{B}(B^0 \to \overline{\Lambda} p \pi^-)}{\mathscr{B}(\bar{B}^0 \to \Lambda \overline{p} \pi^+) + \mathscr{B}(B^0 \to \overline{\Lambda} p \pi^-)} = -0.10 \pm 0.10(stat.) \pm 0.02(syst.) \tag{2.2}$$

which is compatible with zero asymmetry. The result for the longitudinal polarization measurement is shown in figure 2, where $P_L(E^*_{\overline{\Lambda}})$ is the component of the $\overline{\Lambda}$ polarization in the direction of $\overline{\Lambda}$ in the B^0 rest frame. It is consistent with full longitudinal right-handed polarization of the $\overline{\Lambda}$ at large $E^*_{\overline{\Lambda}}$.

3. Study of $\bar{B}^0 \to \Lambda_c^+ \overline{p} K^- \pi^+$ [11]

Λ_c^+ candidates are reconstructed from the decay $\Lambda_c^+ \to p K^- \pi^+$. They must have an invariant mass between 2.277 GeV/c^2 and 2.295 GeV/c^2. They are combined with $\overline{p}$, K^- and π^+ candidates to form $\bar{B}^0$ candidates. $\bar{B}^0$ daughters momenta are refitted with the constraints that they origin from a common vertex and that the Λ_c^+ invariant mass is equal to the nominal one [1]. The fit probability of this vertex fit must be greater than 0.002. If there are multiple $\bar{B}^0$ candidates in an event, the one with $m(pK^-\pi^+)$ closest to the nominal Λ_c^+ mass is used. For multiple $\bar{B}^0$ candidates with the same Λ_c^+ candidate, the one with the highest vertex fit probability is used.

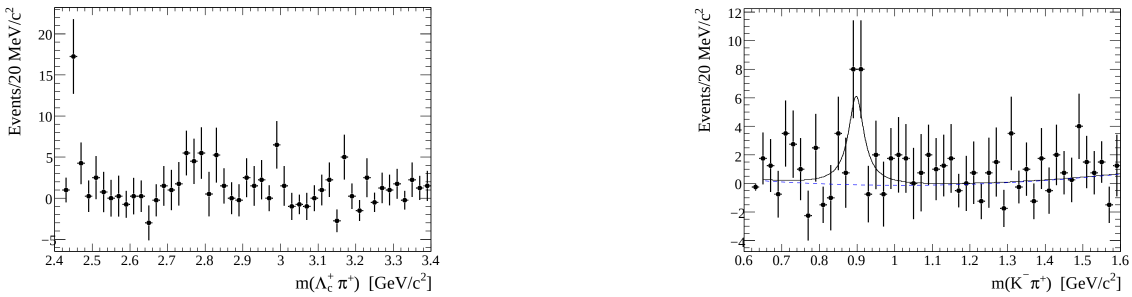

Figure 4: Mass distribution $m(\Lambda_c^+\pi^+)$ (left) and $m(K^-\pi^+)$ (right) for the resonant sub modes of the decay $\bar{B}^0 \to \Lambda_c^+\overline{p}K^-\pi^+$

The phase space is divided into different regions to account for resonances and efficiency variation. To determine the branching fraction, the signal yield is extracted by fits to the ΔE distribution for candidates with $5.275\,\mathrm{GeV}/c^2 < m_{\mathrm{ES}} < 5.286\,\mathrm{GeV}/c^2$ (fig.3). The branching fraction for the resonant decay modes $\bar{B}^0 \to \Sigma_c^{++}(2455)\overline{p}K^-$ and $\bar{B}^0 \to \Lambda_c^+\overline{p}\bar{K}^{*0}$ is obtained from the signal yield extracted from background subtracted $m(\Lambda_c^+\pi^+)$ and $m(K^-\pi^+)$ distributions (fig.4).

The branching fraction for the 4-body decay mode is found to be

$$\mathscr{B}(\bar{B}^0 \to \Lambda_c^+\overline{p}K^-\pi^+) = [4.33 \pm 0.82(stat.) \pm 0.33(syst.) \pm 1.13(\mathscr{B}(\Lambda_c^+))] \times 10^{-5} \tag{3.1}$$

where the last uncertainty comes from the uncertainty of the Λ_c^+ branching fraction for used Λ_c^+ decay mode. The branching fractions for the resonant decay modes are found to be

$$\mathscr{B}(\bar{B}^0 \to \Sigma_c^{++}\overline{p}K^-) = [1.11 \pm 0.30(stat.) \pm 0.09(syst.) \pm 0.29(\mathscr{B}(\Lambda_c^+))] \times 10^{-5} \tag{3.2}$$

and

$$\mathscr{B}(\bar{B}^0 \to \Lambda_c^+\overline{p}\bar{K}^{*0}) < 2.42 \times 10^{-5} \tag{3.3}$$

at 90% confidence level.

4. baryon-antibaryon mass distribution

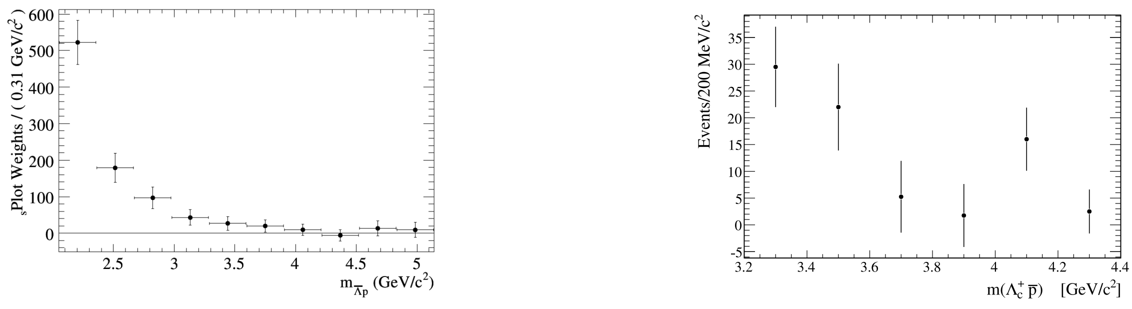

Figure 5: baryon-antibaryon invariant mass distribution for the baryon-antibaryon system from the decay $B^0 \to \overline{\Lambda}p\pi^-$ (left) and $\bar{B}^0 \to \Lambda_c^+\overline{p}K^-\pi^+$ (right)

The mass distributions for $m(\overline{\Lambda}p)$ and $m(\Lambda_c^+\overline{p})$ are shown in figure 5. For both decay modes a threshold enhancement is visible.

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