Baryonic B decays at *BABAR*

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We report on the analyses of the baryonic B decays $\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p}$ and $B^- \rightarrow \Sigma_c^{++}\overline{p}\pi^-\pi^-$. The underlying data sample consists of 470×10^6 $B\overline{B}$ pairs generated in the process $e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\overline{B}$ and collected with the *BABAR* detector at the PEP-II storage ring at SLAC. We find $\mathcal{B}(\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p}) \cdot \mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)/5\% < 6.2 \cdot 10^{-6}$ @ 90 % CL and $\mathcal{B}(B^- \rightarrow \Sigma_c^{++}\overline{p}\pi^-\pi^-) = (2.98 \pm 0.16_{(\mathrm{stat})} \pm 0.15_{(\mathrm{syst})} \pm 0.77_{(\Lambda_c)}) \times 10^{-4}$, where the last error is due to the uncertainty in $\mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)$. The data suggest the existence of resonant subchannels $B^- \rightarrow \Lambda_c(2595)^+ \overline{p}\pi^-$ and, possibly, $B^- \rightarrow \Sigma_c^{++}\overline{\Delta}^{--}\pi^-$. We see unexplained structures in $m(\Sigma_c^{++}\pi^-\pi^-)$ at 3.25 GeV/c^2, 3.8 GeV/c^2, and 4.2 GeV/c^2.

1 Introduction

Approximately 7 % [1] of all B mesons have baryons among their decay products. This is a substantial fraction that justifies further investigations which may allow better understanding of baryon production in B decays and, more generally, hadron fragmentation into baryons. The measurement and comparison of exclusive branching fractions of baryonic B decays as well as systematic studies on the dynamic of the decay, i.e. the fraction of resonant subchannels, is a direct way to study the mechanisms of baryonization. In the following, we present the results of two recently completed *BABAR* analyses of the decays $B^- \rightarrow \Sigma_c^{++}\overline{p}\pi^-\pi^-$ and $\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p}$ [2].

2 $B^- \rightarrow \Sigma_c^{++}\overline{p}\pi^-\pi^-$

The decay $B^- \rightarrow \Sigma_c^{++}\overline{p}\pi^-\pi^-$ is a resonant subchannel of the five body final state $B^- \rightarrow \Lambda_c^+ \overline{p}\pi^+\pi^-\pi^-$, which has, until now, the largest known branching fraction among all baryonic B decays and hence is a good starting point for further investigations.

2.1 Reconstruction

We reconstruct the decay in the subchannel $\Sigma_c^{++} \rightarrow \Lambda_c^+ \pi^+$, and $\Lambda_c^+ \rightarrow p\, K^-\, \pi^+$. For the signal selection we use the missing energy of the B candidate in the e^+e^- rest frame: $\Delta E = \sqrt{\mathrm{E}_\mathrm{B}^{2*}} - \sqrt{s}/2$. Figure 1 shows the distribution of ΔE from the sample of reconstructed B events in data after selections for background suppression. From a fit we find 787 ± 43 signal events. The reconstruction efficiency is $(11.3 \pm 0.2_{(\mathrm{stat})})$%. The branching fraction is $\mathcal{B}(B^- \rightarrow \Sigma_c^{++}\overline{p}\pi^-\pi^-) = (2.98 \pm 0.16_{(\mathrm{stat})} \pm 0.15_{(\mathrm{syst})} \pm 0.77_{(\Lambda_c)}) \times 10^{-4}$.

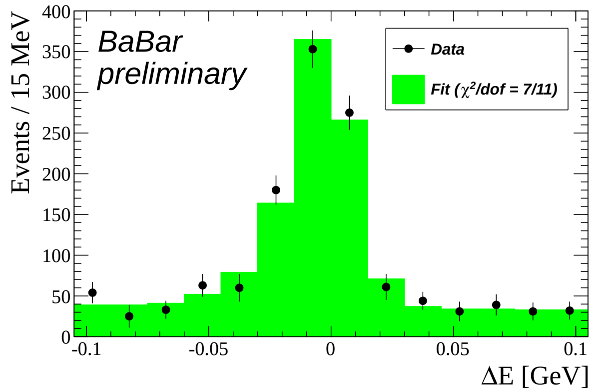
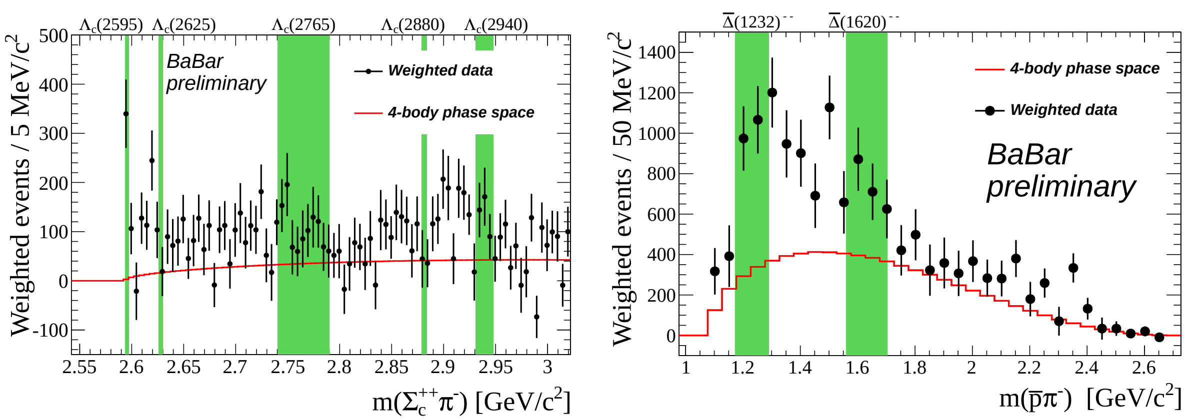


Figure 1: The distribution of ΔE from the *BABAR* data.

2.2 Resonant subchannels

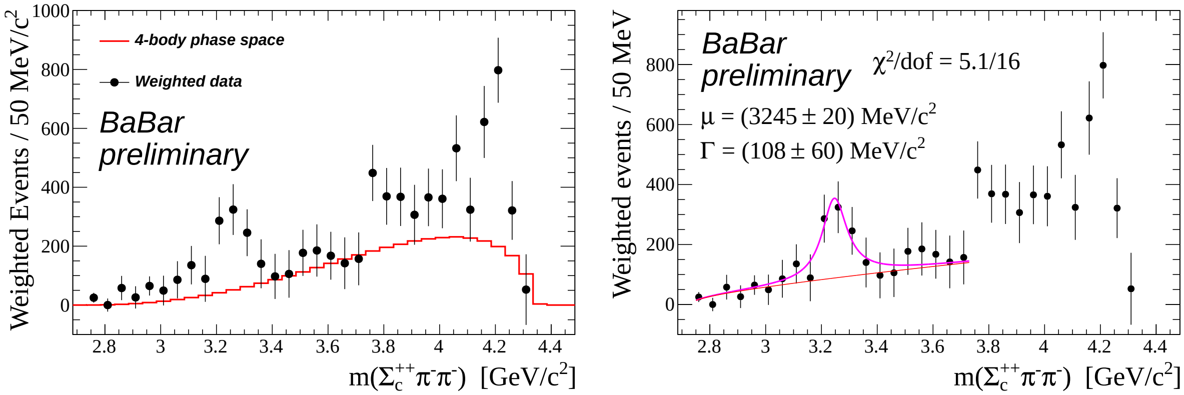
We see large deviations between data and the prediction of four-body phase space (PS) in the two-body and three-body masses of the B daughters. These deviations may be attributed to the resonant intermediate states $\Lambda_c^{*+} \rightarrow \Sigma_c^{++}\pi^-$ and $\overline{\Delta}^{--} \rightarrow \overline{p}\pi^-$.
Figure 2(a) shows the invariant mass distribution of $\Sigma_c^{++}\pi^-$ after a sideband subtraction in ΔE and efficiency correction. The large number of events at the threshold is compatible with the existance of the resonance Λ_c^+ $(2595)^+$. There are no significant signals for other Λ_c^{*+} resonances.
Figure 2(b) shows the invariant mass distribution of $p\pi^-$ after a sideband subtraction in ΔE and efficiency correction. The differences between data and PS in the range of $m(\overline{p}\pi^-) \in (1.2, 1.7)\,\mathrm{GeV}/c^2$ could be due to the existance of the resonances $\overline{\Delta}^{--}(1232, 1600, 1620)$.



(a) (b)

Figure 2: The distribution of m($\Sigma_c^{++}\pi^+$) and m(p π^-) from *BABAR* data and four-body PS.

Figure 3(a) shows the invariant mass distribution of $\Sigma_c^{++}\pi^-\pi^-$ after a sideband subtraction in ΔE and efficiency correction. We see unexplained structures at $3.25\,\mathrm{GeV}/c^2$, $3.8\,\mathrm{GeV}/c^2$, and $4.2\,\mathrm{GeV}/c^2$. In figure 3(b) we present the result of a fit in the range $m(\Sigma_c^{++}\pi^-\pi^-) = 2.750\ldots3.725\,\mathrm{GeV}/c^2$. We choose an ad-hoc parametrization that consists of a Breit-Wigner function with two parameters (width: Γ, mean: μ) for the signal and a two-body phase space distribution with the parameters $m_1 = m(\Sigma_c^{++})$ and $m_2 = 2 \cdot m(\pi^-)$ for the background. The fitted parameters are $\mu = (3245 \pm 20_{(\mathrm{stat})})\,\mathrm{MeV}/c^2$ and $\Gamma = (108 \pm 60_{(\mathrm{stat})})\,\mathrm{MeV}/c^2$.



(a) (b)

Figure 3: The distribution of m($\Sigma_c^{++}\pi^-\ \pi^-$) from *BABAR* data and four-body PS.

2.3 Conclusion

Comparing the branching fractions $\mathcal{B}(B^- \to \Sigma_c^{++}\overline{p}\pi^-\pi^-) = (2.98 \pm 0.8) \times 10^{-4}$ and $\mathcal{B}(B^- \to \Sigma_c^0\overline{p}\pi^+\pi^-) = (4.4 \pm 1.7) \times 10^{-4}$ [3] one finds that the decay $B^- \to \Sigma_c^0\overline{p}\pi^+\pi^-$ is 50% more frequent. This could be due to a number of additional resonant subchannels that contribute to $B^- \to \Sigma_c^0\overline{p}\pi^+\pi^-$, i.e. $B^- \to \Sigma_c^0\overline{N}\pi^-$ and $B^- \to \Sigma_c^0\overline{p}\rho^0$, and would indicate the importance of resonant subchannels in baryonic B decays. Furthermore, the combined branching fraction of $B^- \to \Sigma_c^{++}\overline{p}\pi^-\pi^-$ and $B^- \to \Sigma_c^0\overline{p}\pi^+\pi^-$ makes about 30% of the branching fraction of the five body decay $\mathcal{B}(B^- \to \Lambda_c^+\ \overline{p}\pi^+\pi^-\pi^-) = (22.5 \pm 6.8) \times 10^{-4}$ [3], which also stresses the large impact of intermediate states.

3 $\overline{B}^0 \to \Lambda_c^+\ \overline{p}p\overline{p}$

The decay $\overline{B}^0 \to \Lambda_c^+\ \overline{p}p\overline{p}$ is one of a few allowed B decays with a $b \to c$ transition and four baryons in the final state. It is closely connected to $\overline{B}^0 \to \Lambda_c^+\ \overline{p}\pi^+\pi^-$ ($\mathcal{B} = (1.12 \pm 0.32) \times 10^{-3}$ [4]) and $B^- \to \Lambda_c^+\ \overline{p}\pi^+\pi^-\pi^-$, which have similar quark contents and the (so far) largest measured branching fractions among the baryonic B decays with a Λ_c^+ in the final state. The main differences between the sought decay and the other two decay channels are the absence of possible resonant subchannels and the much smaller phase space ($Q(\overline{B}^0 \to \Lambda_c^+\ \overline{p}p\overline{p}) = 176\,\mathrm{MeV}/c^2, Q(\overline{B}^0 \to \Lambda_c^+\ \overline{p}\pi^+\pi^-) = 1776\,\mathrm{MeV}/c^2$ with $Q = m(\text{mother}) - \sum m(\text{daughter})$. The latter may favour the decay $\overline{B}^0 \to \Lambda_c^+\ \overline{p}p\overline{p}$, in that baryons are more likely to form when quarks are close to each other in momentum space [5], [6]. An example of this behavior is the ratio of $\mathcal{B}(B^- \to \Lambda_c^+\ \overline{\Lambda}_c^-\ K^-)/\mathcal{B}(B^- \to \Lambda_c^+\ \overline{p}\pi^-) \approx 3$ [1], preferring the more massive final state that mainly differs by the size of phasespace since $|V_{cs}| \approx |V_{ud}|$. On the other hand the decay $\overline{B}^0 \to \Lambda_c^+\ \overline{p}p\overline{p}$ may be suppressed by the fact that it does not have resonant subchannels which could play an important role for baryonic B decays, i.e. $\mathcal{B}(\overline{B}^0 \to \Lambda_c^+\ \overline{p}\pi^+\pi^-)_{\text{resonant}}/\mathcal{B}(\overline{B}^0 \to \Lambda_c^+\ \overline{p}\pi^+\pi^-) \approx 40\%$ [1]. The size of the branching fraction may allow to balance the relevance of resonant subchannels against momentum space in baryonic B decays.

3.1 Reconstruction

We reconstruct the decay $\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p}$ in the subchannel $\Lambda_c^+ \rightarrow p\,K^-\,\pi^+$. Besides ΔE, we use the energy substituted mass m_{ES} of the B candidate for the signal selection. In a simplified form, it can be written as $m_{\mathrm{ES}}\prime = \sqrt{(\sqrt{s}/2)^2 - |\vec{p}_{\mathrm{B}}^{\,*}|^2}$, where $\vec{p}_{\mathrm{B}}^{\,*}$ is the momentum of the B candidate in the e^+e^- rest frame. The complete formular of m_{ES} also takes into account the asymmetric energies of e^+ and e^-. m_{ES} is centered at the true B mass for correctly reconstructed B decays. Figure 4 shows the distribution of ΔE vs. m_{ES} with a selection in $m_{pK^-\pi^+}$ for background suppression. There are two B candidates within a signal window that is chosen on the basis of an analysis of simulated signal events. The efficiency in this range is $\varepsilon = (3.66 \pm 0.03_{(\mathrm{stat})})\,\%$. For background estimation we analyze sidebands in $m_{pK^-\pi^+}$ and m_{ES} from the data sample as well as a set of simulated *BABAR* events and find no reliable prediction due to large systematic uncertainties. Therefore we calculate a conservative upper limit by taking the two B candidates as signal. In addition, we exclude the large uncertainty of $\mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+) = (5.0 \pm 1.3)\,\%$ [1]. Consequently, we determine:

$$\mathcal{B}(\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p}) \cdot \frac{\mathcal{B}(\Lambda_c^+ \rightarrow pK^-\pi^+)}{5\,\%} < \frac{N_{up}}{\varepsilon \cdot N_B \cdot 5\,\%} = 6.2 \cdot 10^{-6} \quad @\; CL = 90\% \qquad (1)$$

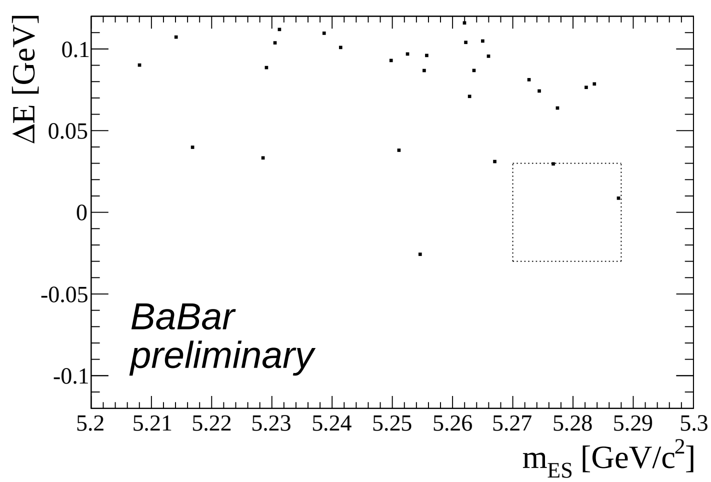


Figure 4: The distribution of ΔE vs. m_{ES} from the *BABAR* data.

As a result we find that $\mathcal{B}(\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p})$ is at least two orders of a magnitude smaller than $\mathcal{B}(\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}\pi^+\pi^-)$ and $\mathcal{B}(B^- \rightarrow \Lambda_c^+ \overline{p}\pi^+\pi^-\pi^-)$ @ $CL = 90\%$. This could indicate, that the phase space of $\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}p\overline{p}$ is too small to favor baryonisation of the quarks and thus increase the decay rate. Furthermore, the nonappearance of resonant subchannels may additionally affect the branching fraction.

References

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