**B decays to baryons**

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Abstract. From inclusive measurements it is known that about 7\% of all $B$ mesons decay into final states with baryons. In these decays, some striking features become visible compared to mesonic decays. The largest branching fractions come with quite moderate multiplicities of 3-4 hadrons. We note that two-body decays to baryons are suppressed relative to three- and four-body decays. In most of these analyses, the invariant baryon-antibaryon mass shows an enhancement near the threshold. We propose a phenomenological interpretation of this quite common feature of hadronization to baryons.

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1. Decay dynamics

A common feature observed in several $B$ decays to baryons but also outside the $B$-physics sector is an enhancement at the invariant baryon-antibaryon mass threshold which can be seen for three examples in Fig. 1.

![Figure 1](image)

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Another feature of these decays is the multiplicity dependence of the branching fractions. Measurements from $BABAR$, Belle and CLEO show that the largest branching fractions for $B$ decays to baryons come with quite moderate multiplicities. Comparing the

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branching fractions for $B \rightarrow \Lambda_c^+ \overline{p} (n \cdot \pi)$, as shown in Fig. 2, a rise in the branching fractions up to a multiplicity of five can be observed. The most prominent rise occurs when comparing the two-body mode with the three-body mode for non-resonant decays. For resonant decays ($B^- \rightarrow \Sigma^0_c (2455) \overline{p}$) the difference between the two-body and the three-body mode is not as prominent.

\[
\begin{align*}
B (B^0 \rightarrow \Lambda_c^+ \overline{p}) & \times 14 \\
B (B^- \rightarrow \Lambda_c^+ \overline{p} \pi^-)_{\text{non-res}} & \times 2.3 \\
B (B^0 \rightarrow \Lambda_c^+ \overline{p} \pi^+ \pi^-)_{\text{non-res}} & \times 3.4 \\
B (B^- \rightarrow \Lambda_c^+ \overline{p} \pi^- \pi^+ \pi^-) & \\
b \bar{q} s p & \bar{b} \bar{q} s p \\
b \bar{q} s & \bar{q} s \bar{p} \bar{q} \\
b \bar{q} s p & \bar{b} \bar{q} s p
\end{align*}
\]

Figure 2. Relative change of the branching fractions for a subset of baryonic $B$ decays.

A comparison of $B$ decays with a charmed meson in the final state, e.g. $B \rightarrow D^{(*)} \overline{p} (n \cdot \pi)$, shows the highest branching fractions for a multiplicity of four hadrons in the final state.

2. Phenomenological interpretation

Several approaches to explain the suppression of the two-body decay as well as the threshold enhancement in the invariant baryon-antibaryon mass have been suggested. A simple model is given by M. Suzuki [4]. His interpretation is that for a baryon-antibaryon pair in a two-body decay a hard gluon (highly off mass shell) is needed, while in a decay mode with a higher multiplicity only soft gluons are needed. In consequence the two-body mode has to be suppressed. A more detailed model is given by T. Hartmann [5] which can explain the absence of a threshold enhancement in $B$ decays to baryons. There, all contributing Feynman diagrams are divided into two contributing classes. For convenience for both classes the $W$ exchange can be contracted to an effective four point interaction.

In the meson-meson class (Fig. 3) the quarks can be rearranged into a meson-meson configuration with one of the mesons decaying into a baryon-antibaryon pair. In these decays the second meson carries away momentum and reduces the remaining phase space for the baryon-antibaryon pair. This leads to the often observed threshold enhancement. Higher multiplicities are achieved by subsequent decays of the (pseudo-)mesons.

Figure 3. Effective Feynman diagrams for the initial meson-meson configuration.
In the second class the quarks are rearranged into a diquark-antidiquark configuration. Since color-confinement requires a quark-antiquark pair created from the gluon field the diquark-antidiquark configuration equals an initial baryon-antibaryon configuration. In consequence no threshold enhancement should be visible for decays proceeding via this type only. An example for a decay proceeding exclusively via this configuration would be $B^0 \rightarrow \Sigma^0 \eta \pi^+$. Possible initial baryon-antibaryon states could be $B^0 \rightarrow \Sigma^0 N$ with $N \rightarrow \bar{p}n^+$ or $B^0 \rightarrow \Lambda^+ \bar{p}$ with $\Lambda^+ \rightarrow \Sigma^0 \pi^+$. 

![Effective Feynman diagrams for the initial diquark-antidiquark configuration.](image)

### 3. Interpretation of $B^0 \rightarrow \Lambda_c^+ \bar{K}^-$ results

A recent BABAR analysis of the decay $B^0 \rightarrow \Lambda_c^+ \bar{K}^-$ [6] shows no significant enhancement at the baryon-antibaryon threshold (Fig. 5). The aforementioned model gives a natural explanation for this. Three Feynman diagrams contribute to this decay. But only one of them can be rearranged into the meson-meson configuration which is necessary for the threshold enhancement. Depending on the relative strengths of the three contributing Feynman diagrams this provides a natural explanation for the absence of a strong enhancement. 

![Invariant two body mass distributions for the decay $B^0 \rightarrow \Lambda_c^+ \bar{K}^-$ (●) compared the a phase space model (red histogram).](image)

### References

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