Suppressed charmed B decays

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Summary

This thesis describes the measurement of the branching fractions of the suppressed charmed $B^0 \rightarrow D^{(*)-}a_0^+$ decays and the non-resonant $B^0 \rightarrow D^{(*)-}\eta\pi^+$ decays in approximately 230 million $\Upsilon(4S) \rightarrow B\overline{B}$ events. The data have been collected with the *BABAR* detector at the PEP-II B factory at the Stanford Linear Accelerator Center in California.

Theoretical predictions of the branching fraction of the $B^0 \rightarrow D^{(*)-}a_0^+$ decays show large QCD model dependent uncertainties. Non-factorizing terms, in the naive factorization model, that can be calculated by QCD factorizing models have a large impact on the branching fraction of these decay modes. The predictions of the branching fractions are of the order of 10^{-6}. The measurement of the branching fraction gives more insight into the theoretical models. In general a better understanding of QCD models will be necessary to conduct weak interaction physics at the next level.

The presence of *CP* violation in electroweak interactions allows the differentiation between matter and antimatter in the laws of physics. In the Standard Model, *CP* violation is incorporated in the CKM matrix that describes the weak interaction between quarks. Relations amongst the CKM matrix elements are used to present the two relevant parameters as the apex of a triangle (Unitarity Triangle) in a complex plane. The over-constraining of the CKM triangle by experimental measurements is an important test of the Standard Model. At this moment no stringent direct measurements of the CKM angle γ, one of the interior angles of the Unitarity Triangle, are available.

The measurement of the angle γ can be performed using the decays of neutral B mesons. The $B^0 \rightarrow D^{(*)-}a_0^+$ decay is sensitive to the angle γ and, in comparison to the current decays that are being employed, could significantly enhance the measurement of this angle. However, the low expected branching fraction for the $B^0 \rightarrow D^{(*)-}a_0^+$ decay channels could severely impact the measurement. A prerequisite of the measurement of the CKM angle is the observation of the $B^0 \rightarrow D^{(*)-}a_0^+$ decay on which this thesis reports.

The *BABAR* experiment consists of the *BABAR* detector and the PEP-II e^+e^- collider. The design of the experiment has been optimized for the study of *CP* violation in the decays of neutral B mesons but is also highly suitable for the search for rare B decays such as the $B^0 \rightarrow D^{(*)-}a_0^+$ decay. The PEP-II collider operates at the $\Upsilon(4S)$ resonance and is a clean source of $B\overline{B}$ meson pairs.

The B mesons are fully reconstructed in the desired final state $B^0 \rightarrow D^{(*)-}a_0^+$ where $a_0^+ \rightarrow \eta\pi^+$. No restrictions on the a_0 meson mass are applied in the reconstruction and during the first stages the analysis is set up to select $B^0 \rightarrow D^{(*)-}\eta\pi^+$ decays. About

thirty variables are used to distinguish the signal decays from background decays. The optimization of the rectangular box cuts on the selection variables is performed simultaneously using a dedicated optimization program. After the selection is performed, three observables are employed in an unbinned maximum likelihood fit to further separate the signal events from the background and to distinguish the resonant $B^0 \to D^{(*)-}a_0^+$ events from non-resonant $B^0 \to D^{(*)-}\eta\pi^+$ events. Background $B^0 \to D^{(*)-}D_s^+$ events, where $D_s^+ \to \eta\pi^+$, have the same final state and are described with a separate p.d.f. in the fit. These events are utilized as a control sample and are used to test the validity of the analysis setup.

From the unbinned maximum likelihood fit, the following branching fractions follow:

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\begin{aligned}
\mathcal{B}(B^0 \to D^-a_0^+) \times \mathcal{B}(a_0^+ \to \eta\pi^+) &= (-0.11^{+0.93+0.29}_{-0.67-0.76}) \cdot 10^{-5}, \\
\mathcal{B}(B^0 \to D^{*-}a_0^+) \times \mathcal{B}(a_0^+ \to \eta\pi^+) &= (5.93^{+1.64+2.22}_{-1.48-1.52}) \cdot 10^{-5}, \\
\mathcal{B}(B^0 \to D^-\eta\pi^+) &= (13.41^{+3.54+2.42}_{-3.25-1.94}) \cdot 10^{-5}, \\
\mathcal{B}(B^0 \to D^{*-}\eta\pi^+) &= (33.91^{+5.47+6.86}_{-5.11-5.14}) \cdot 10^{-5},
\end{aligned}
$$

where the first error is the statistical and the second represents the systematic uncertainty. An upper limit is determined for the branching fraction of $\mathcal{B}(B^0 \to D^-a_0^+)$ at $\mathcal{B}(B^0 \to D^-a_0^+) < 2.3 \cdot 10^{-5}$@90%CL. The significance of the observations, including systematic uncertainties, for the measured branching fractions are 5.3, 4.4 and 8.2σ respectively and were determined using a profile likelihood.

This is the first reported observation of the $B^0 \to D^{*-}a_0^+$ and $B^0 \to D^{*-}\eta\pi^+$ decays and the first evidence for the $B^0 \to D^-\eta\pi^+$ decay. The observed branching fraction for the $B^0 \to D^{*-}a_0^+$ signal is a factor ten larger than the theoretical predictions. At present no scenario using naive factorization or QCD factorization models can explain the large observed decay amplitude. A possible scenario is rescattering via the $B^0 \to D^-a_1^+ \to D^{*-}a_0^+$ decay channel.

It is unlikely that the number of $B^0 \to D^{*-}a_0^+$ events present in the currently available *BABAR* dataset is enough for a measurement of the CKM angle γ. However, the advantage of the potential high sensitivity remains, as such, the attempt for a full time-dependent analysis should be made.