Charm Decays at BaBar

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Abstract. In this talk I go over recent results involving charm decays obtained with the data collected by the BaBar experiment. I cover here results on leptonic and semileptonic charm decays, D meson branching fractions, Dalitz analyses and charm baryons.

1. The $D^+_s \rightarrow \mu^+ \nu$ decay constant

Leptonic and semileptonic decays are of special interest from the theoretical point of view since all the hadronic effects are parameterized as decay constants or form factors. Measurements of these decays can thus serve to validate non-perturbative Lattice-QCD calculations. BaBar has recently measured the $f_{D_s}$ decay constant in $D^+_s \rightarrow \mu^+ \nu^1$ decays [1]. In a sample of 230 fb$^{-1}$ data, $5 \times 10^5$ charm events are tagged using several hadronic modes. $D_s^+ \rightarrow \gamma D_s^+$ decays with $D_s^+ \rightarrow \mu^+ \nu$ are reconstructed in the recoil. The signal peaks in the mass difference $M(D_s^+) - M(D^0)$. After subtracting wrong tag candidates and semileptonic decays the mass difference distribution, shown in Fig. 1, yields $489 \pm 55$ signal events. The $D^+_s \rightarrow \mu^+ \nu$ branching fraction is measured by reconstructing the $D^+_s \rightarrow \phi \pi^+$ decay as normalization channel. Using the average $B(D^+_s \rightarrow \phi \pi^+)$ from [2] gives: $B(D^+_s \rightarrow \mu^+ \nu) = (6.74 \pm 0.83 \pm 0.26 \pm 0.66) \times 10^{-3}$, the errors being statistical, systematic, and from the $B(D^+_s \rightarrow \phi \pi^+)$ uncertainty, respectively. The decay constant results in $f_{D_s} = (283 \pm 17 \pm 7 \pm 14)$ MeV. This result is in agreement with preliminary results from CLEO-c [3] and prior lattice-QCD computations [4]. It is about two sigmas larger than new results from lattice-QCD [5]. One should note the impressive accuracy reached by the new Lattice-QCD computations, which are at the 1% level and makes necessary more accurate measurements.

2. $D^0 \rightarrow K^- e^+ \nu$ form factor

The form factor of the $D^0 \rightarrow K^- e^+ \nu$ decay is measured in a sample of 75 fb$^{-1}$ [6]. The $D^{*+} \rightarrow D^0 \pi^+$ is reconstructed with the $D^0$ decaying in the semileptonic channel. About 85000 candidates are selected in the mass difference $\delta m = m(D^{*+}) - m(D^0) < 0.16$ GeV/c$^2$. The four momentum transfer between the $D^0$ and the kaon, $q^2$, is obtained from a kinematic fit, which includes information of the missing energy in the event and an estimate of the D meson direction. The form factor in this transition, $f_+(q^2)$, is extracted from the unfolded $q^2$ distribution. It is shown in Fig. 2. This distribution can be parameterized using several shapes. The most common are based on pole dominance and depend on one parameter $m_{pole}$ or $\alpha_{pole}$. Results are $m_{pole} = 1.884 \pm 0.012 \pm 0.015$ GeV/c$^2$ and $\alpha_{pole} = 0.377 \pm 0.023 \pm 0.029$,

1 Charge conjugation is implicit through this document.
being the most precise up to date. The $D^0 \rightarrow K^- e^+ \nu$ branching fraction is measured with respect to the $D^0 \rightarrow K^- \pi^+$ channel. Reconstructing the latter with similar conditions as compared to the semileptonic channel, and using the world average for $B(D^0 \rightarrow K^- \pi^+)$[8], it gives $B(D^0 \rightarrow K^- e^+ \nu) = (3.522 \pm 0.027 \pm 0.045 \pm 0.065)\%$, where the last error comes from the uncertainty in the normalization channel. The normalization of the form factor is also measured to be $f_+(0) = 0.727 \pm 0.007 \pm 0.005 \pm 0.007$, the last error coming from external inputs. This result is ten times more precise than current lattice QCD computations [4].

3. $D^0 \rightarrow K^- \pi^+$ branching fraction
Charm decays can in addition be studied in $B$ meson decays. The $D^0 \rightarrow K^- \pi^+$ decay channel is measured from partial reconstruction of semileptonic $B$ decays, $\bar{B}^0 \rightarrow D^{*+} \ell^- \nu$, in a sample of 210fb$^{-1}$, where the $D^{*+}$ is tagged through its decaying soft pion [9]. The missing mass squared $M^2_{\nu} = (E_{\text{beam}} - E_{D^*} - E_{\ell})^2 - (\vec{p}_{D^*} + \vec{p}_{\ell})^2$ is obtained approximating the $D^*$ direction to be the one of the soft pion. In the signal region $M^2_{\nu} > -2$ GeV$^2/$c$^4$ one finds $2171 \pm 3 \pm 18 \times 10^3$ $D^0$ inclusive decays. An exclusive reconstruction of $D^0 \rightarrow K^- \pi^+$ decays is then performed in this sample, and 33810 \pm 290 candidates are selected in the mass difference distribution $142.4 < m(D^0 \pi^+) - m(D^0) < 149$ MeV/c$^2$. Taking the efficiency to reconstruct these events from the BABAR simulation one gets: $B(D^0 \rightarrow K^- \pi^+) = (4.007 \pm 0.037 \pm 0.070)\%$.

4. Dalitz analysis of the $D^0 \rightarrow K^+ K^- \pi^0$ decay
The Dalitz plot of the $D^0 \rightarrow K^+ K^- \pi^0$ decay allows to extract the strong phase difference, $\delta_D$, between the $\bar{D}^0$ and $D^0$ decays into $K^*(892)^+ K^-$ and their amplitude ratio, $r_D$, which are key parameters in the measurement of the $\gamma$ angle in CP violation studies. It serves in addition to provide information on scalar structures. Using 385fb$^{-1}$ the amplitudes of the $D^0 \rightarrow K^+ K^- \pi^0$ are studied. An isobar model is assumed, where Breit-Wigner amplitudes for the $D^0$ decays into P- and D-wave states are considered. Several parameterizations are used for the $K^- \pi^0$ S-wave component. For the $K^- \pi^0$ S-wave state a couple-channel Breit-Wigner amplitude for the $f_0(980)$ and $a_0(980)$ is used [10]. A fit to data gives a large contribution from $K^*(892)^+(45\%)$, $K^*(892)^-(16\%)$ and $\phi(1020)(19\%)$ states. A contribution from $f_0$ or $a_0$ of 6-7\% and a 16\% of $K\pi$ S-wave state consistent with the LASS amplitude and with no $\kappa(800)$ are measured. Fig. 3 shows

\[ \begin{align*}
\text{Figure 1. } M(\mu^+\mu^-) - M(\mu^+\mu^-) & \text{ distribution. The solid line shows the fitted distribution, the background is superimposed with a dashed line. The fit yields } 489 \pm 55 \text{ signal } D_{s}^{+} \rightarrow \gamma D_{s}^{-} \rightarrow \gamma \mu^+\mu^- \text{ events.} \\
\text{Figure 2. } \text{Normalized form factor } f_+(q^2)/f_+(0) & \text{ measured by BABAR and compared with results from FOCUS [7] and Lattice-QCD calculations [4].}
\end{align*} \]
the Dalitz plot and the results of the fit for the three mass projections. A partial wave analysis is performed in addition by weighting events with spherical harmonic functions depending on the helicity angle. The S- and P-waves amplitudes and their relative phase are obtained and found to be consistent with the isobar model fit. The results are \( \delta_\pi = (-35.5 \pm 1.9 \pm 2.2)\)° and \( r_D = 0.599 \pm 0.013 \pm 0.011 \).

**Figure 3.** Dalitz plot (a) and corresponding squared invariant mass projections (b-d). Dots with error bars are the data and solid lines correspond to the best isobar fit models.

5. Production and decay of the \( \Omega_c^0 \) baryon

**BABAR** has exclusively reconstructed the \( \Omega_c^0 \) baryon into \( \Omega^-\pi^+, \Omega^-\pi^+\pi^0, \Omega^-\pi^+\pi^+\pi^-, \) and \( \Xi^-K^-\pi^+\pi^+ \) decay channels in a 231 fb\(^{-1} \) sample [11]. A total of 177 ± 16, 64 ± 15, 25 ± 8 and 45 ± 12 candidates are selected for each mode respectively, which give the following relative branching fractions: \( \mathcal{B}(\Omega_c^0 \rightarrow \Omega^-\pi^+\pi^0) = 1.27 \pm 0.31 \pm 0.11, \mathcal{B}(\Omega_c^0 \rightarrow \Omega^-\pi^+\pi^+\pi^-)/\mathcal{B}(\Omega_c^0 \rightarrow \Omega^-\pi^+) = 0.28 \pm 0.09 \pm 0.01 \) and \( \mathcal{B}(\Omega_c^0 \rightarrow \Xi^-K^-\pi^+\pi^+)/\mathcal{B}(\Omega_c^0 \rightarrow \Omega^-\pi^+) = 0.46 \pm 0.13 \pm 0.03 \). In addition the \( \Omega_c^0 \) momentum spectrum is measured for the \( \Omega_c^0 \rightarrow \Omega^-\pi^+ \) channel (Fig. 4). The peak at low momentum gives the first evidence for \( \Omega_c^0 \) production in B decays.

**Figure 4.** \( \Omega_c^0 \) momentum spectrum after background subtraction and efficiency correction. Points represent the data including systematic uncertainties. The histogram shows a fit of \( \Omega_c^0 \) baryons produced in \( \pi^-\pi^+ \) events to the Bowler fragmentation function, for \( p^* > 2 \text{ GeV/c} \).

References
[1] B. Aubert *et al.* BABAR Collaboration. Phys.Rev.Lett. 98, 141801 (2007). arXiv:hep-ex/0607094.
[2] B. Aubert *et al.* BABAR Collaboration. Phys.Rev.D 71, 091104 (2005). arXiv:hep-ex/0502041.
[3] T.K. Pedlar *et al.* CLEO Collaboration. arXiv:0704.0437.
[4] C. Aubin *et al.* Fermilab Lattice, MILC and HPQCD Collaborations. Phys.Rev.Lett.95, 122002 (2005). arXiv:hep-lat/0506030.
[5] E. Follana *et al.* HPQCD and UKQCD Collaborations. arXiv:0706.1726 [hep-lat].
[6] B. Aubert *et al.* BABAR Collaboration. Phys.Rev.D 76, 052005 (2007). arXiv:0704.0020 [hep-ex].
[7] J.M. Link *et al.* FOCUS Collaboration. Phys.Lett.B 607, 233 (2005). arXiv:hep-ex/0410097.
[8] W.-M. Yao *et al.* Review of Particle Physics. Journal of Physics G 33 1 (2006).
[9] B. Aubert *et al.* BABAR Collaboration. Submitted to Phys.Rev.Lett. arXiv:0704.2080 [hep-ex].
[10] B. Aubert *et al.* BABAR Collaboration. Phys.Rev.D 76, 011102(R) (2007). arXiv:0704.3593 [hep-ex].
[11] B. Aubert *et al.* BABAR Collaboration. Phys.Rev.Lett. 99, 062001 (2007). arXiv:hep-ex/0703030.