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CHARM SPECTROSCOPY, CHRAM DECAYS AND NEW STATES AT *BABAR*.

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This document presents the recent studies of Charmed hadrons at *BABAR* BELLE and CLEO. Here I focus on the recent developments on the study of D^*_{sJ}, observation of $D^+ \rightarrow K^+\pi^0$, $D^0 - \overline{D^0}$ mixing in the doubly cabibbo-suppressed decays using $D^0 \rightarrow K^+\pi^+\pi^0$ and the measurement of the decay constants using the leptonic D decays.

1. Introduction

At the B-factories, charm states are produced in $e^+e^-\rightarrow c\overline{c}$ continuum events, in the e^+e^-annihilation following the initial state radiations(ISR), in $e^+e^-\rightarrow e^+e^-c\overline{c}$ two-photon events, and in the B decays proceeding through the dominant $b \rightarrow c$ transition.

2. Study for the D_{SJ} states

The $D^*_{sJ}(2317)^+$ and $D^*_{sJ}(2460)^+$ mesons were first reported by the *BABAR* collaboration [1] and the CLEO collaboration [2] in $c\overline{c}$ continuum events. and then by the BELLE collaboration [3] in B decay.

The masses of these states are unusual than explained by the potential model for the $c\overline{s}$ system. [4] The narrow widths of these states can be explained with the isospin-violating or electro-magnetic decays, which are kinematically allowed. Also the decay pattern and angular distribution for the $D^*_{sJ}(2317)^+$ and $D^*_{sJ}(2460)^+$ are consistent with their interpretation as conventional P-wave $c\overline{s}$ mesons with $J^P = 0^+$ and $J^P = 1^+$, respectively.

BABAR has recently updated this analysis using 232fb^{-1} of data and has performed a detailed study [5] of D_{sJ} decays to D^+_s plus one or two charged pions, neutral pions, or photons. The $D^*_{sJ}(2317)^+$ is seen in one

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only channel: $D^*_{sJ}(2317)^+ \rightarrow D^+_s\pi^0$, which is the only allowed channel leading to the discovery of $D^*_{sJ}(2317)^+$. Searches in all other channels yield only upper limits. *BABAR* measures the $D^*_{sJ}(2317)^+$ mass and width: $m = (2319.6 \pm 0.2 \pm 1.4)\mathrm{MeV}/c^2$, $\Gamma < 3.8\mathrm{MeV}$@95%C.L. A Search for neutral or doubly-charged partners of the $D^*_{sJ}(2317)^+$ in $D^+_s\pi^\pm$ modes leads towards the non-existence of such states, which concludes that $D^*_{sJ}(2317)^+$ is an isoscalar.
Belle has studied the decay angular distribution [6] for $D^*_{sJ}(2317)^+$ in $B \rightarrow \overline{D}D^*_{sJ}(2317)^+$, $D^*_{sJ}(2317)^+ \rightarrow D^+_s\pi^0$. The helicity distribution for the $D^*_{sJ}(2317)^+ \rightarrow D^+_s\pi^0$ is found to be consistent with spin 0 and inconsistent with spin 1 hypothesis, indicating that $D^*_{sJ}(2317)^+$ is $J^P = 0^+$ particle. *BABAR* has observed the $D^*_{sJ}(2460)^+$ in three different modes: $D^+_s\gamma$, $D^*_s(2112)^+\pi^0$ with $D^*_s(2112)^+ \rightarrow D^+_s\gamma$, and $D^+_s\pi^+\pi^-$, and measures the ratio of the branching fractions(BFs):

$$\frac{B(D^*_{sJ}(2460)^+ \rightarrow D^+_s\gamma)}{B(D^*_{sJ}(2460)^+ \rightarrow D^+_s\pi^0\gamma)} = 0.337 \pm 0.036 \pm 0.038.$$

They also see a significant signal in $D^*_{sJ}(2460)^+ \rightarrow D^+_s\pi^+\pi^-$ with a decent peak for $D_{s1}(2536)^+$. No hint is found for the $D^*_{sJ}(2317)^+$ in this mass distribution. They measure the masses, widths more precisely for all these states charged final states: $m = (2460.2 \pm 0.2 \pm 0.8)\mathrm{MeV}/c^2, \Gamma < 3.5\mathrm{MeV}$@95%C.L. and $m = (2534.6 \pm 0.3 \pm 0.7)\mathrm{MeV}/c^2$, $\Gamma < 2.5\mathrm{MeV}$@95%C.L., respectively and also the BFs as follows:

$$\frac{B(D^{*_{sJ}}(2460)^+ \rightarrow D^+_s\pi^+\pi^-)}{B(D^{*_{sJ}}(2460)^+ \rightarrow D^+_s\pi^0\gamma)} = 0.077 \pm 0.013 \pm 0.008.$$

BELLE has studied the same resonance [6] in $B \rightarrow \overline{D}D^{*_{sJ}}(2460)^+$ decays with angular distribution for $D^*_{sJ}(2460)^+ \rightarrow D^+_s\gamma$ as well as $D^*_{sJ}(2460)^+ \rightarrow D^*_s(2112)^+\pi^0$. For the $D^+_s\gamma$ final state, the angular distribution is consistent with the spin-1 hypothesis and is inconsistent with the spin-2 hypothesis. The spin-0 hypothesis is ruled out by the conservation of angular momentum and parity, photon is missing the spin 0 state. Using the $D^*_s(2112)^+\pi^0$ final state to establish the spin parity for $D^*_{sJ}(2460)^+$ with $D^{*_s}(2112)^+$; the distribution is found consistent with the $J^P = 1^+$ hypothesis and is pure S-wave between $D^*_s(2112)^+$ and the π^0 (although the appropriate combination of S- and D-wave could also produce similar distribution). The data is found to be inconsistent with the $J^P = 1^-$ hypothesis, concluding that $D^*_{sJ}(2460)^+$ is a spin 1 particle with positive parity.

BABAR has also studied for the first time the absolute BFs [7] for the $D^*_{sJ}(2460)^+$, with one B meson is fully reconstructed on one side and study the decays of the other $B \rightarrow D^{\pm/0}X$. Here they study the missing mass (m_x) recoiling against the charged or neutral D or D^*. Using *BABAR*ś previous study [8] on the exclusive BFs $B \rightarrow \overline{D}^{(*)} D^{*_{sJ}}(2460)^+$, $D^{*_{sJ}}(2460)^+$ to $(D^*_s(2112)^+\pi^0)/(D^+_s\gamma)$, obtains: $B(D^{*_{sJ}}(2460)^+ \rightarrow D^{*_s}(2112)^+\pi^0) = 0.56 \pm 0.13 \pm 0.09$, $B(D^{*_{sJ}}(2460)^+ \rightarrow D^+_s\gamma) = 0.16 \pm 0.04 \pm 0.03$

3. D meson study

BABAR has reported the first observation and measurement of the BF for the Cabibbo-suppressed decay [9] $D^+ \rightarrow K^+\pi^0$ and also an improved measurement of the BFs measurement $D^+ \rightarrow \pi^+\pi^0$, using the world average BF [10] for $B(D^+ \rightarrow K^-\pi^+\pi^+)$:$B(\mathrm{D}^+ \rightarrow K^+\pi^0) = (0.246 \pm 0.046 \pm 0.024 \pm 0.016) \times 10^{-3}$, $B(D^+ \rightarrow \pi^+\pi^0) = (1.22 \pm 0.10 \pm 0.08 \pm 0.08) \times 10^{-3}$, the last error is due to the experimental uncertainty in the $D^+ \rightarrow K^-\pi^+\pi^+$ branching fraction measurement. CLEO$_c$ has reported [11] the absolute BFs for several decays: $D^+ \rightarrow K^+\pi^+\pi^+$, $D^0 \rightarrow K^-\pi^0$, and for D^+_s to K_sK^+, $K^+K^-\pi^+$, $K^+K^-\pi^+\pi^0$, and $\pi^+\pi^+\pi^-$ [12]. They measure the absolute BFs: $B(D^+ \rightarrow K^-\pi^+\pi^+) = (9.52 \pm 0.52 \pm 0.27)\%$, $B(D^0 \rightarrow K^-\pi^+) = (3.91 \pm 0.08 \pm 0.09)\%$. Over all error on the D^+_s measurements is approximately 11%, which cab be improved with more data.

4. D^0 - $\overline{D}^0$ Mixing

Charm mixing is characterized by a two parameters $x \equiv \frac{\Delta m}{\Gamma}$ and $y \equiv \frac{\Delta\Gamma}{2\Gamma}$, where $\Delta m(\Delta\Gamma)$ is the mass(width) difference between the two neutral D meson and Γ; the average width is related to the life time, τ_{D^0}, as $\Gamma.\tau_{D^0} = \hbar$. D^0 - $\overline{D}^0$ Mixing will only occur if either x or y are non-zero and new physics will emerge if $x >> y$.

Using $234\,\mathrm{fb}^{-1}$ of data, *BABAR* has presented a search for D^0 - $\overline{D}^0$ Mixing in the D^0 to $K\pi\pi^0$ and enhanced Cabibbo-favored rate using cuts on the Dalitz plot and suppressing the doubly-Cabibbo suppressed rate. For the CP conserving fit they find $R_M < 0.054\%$ with 95% C.L., and also data is found to be consistent with no mixing at 4.5% confidence. [13]

5. Leptonic D decays

A detailed study of the leptonic decays is one of the sources of progress in the heavy-flavor physics and provides an insight into the B-decay measurements and will help in mastering the knowledge of hadronic effects through decay constants f_{Ds}.

BABAR has measured [14] the ratio of the partial decay widths for $D_s^+ \rightarrow \mu^+\nu_\mu$ to $D_s^+ \rightarrow \phi\pi^+$ and the decay constant f_{D_s}:(281 $\pm 17 \pm 6 \pm 19$)MeV(a best measurement so far). Using the previously measured $B(D_s^+ \rightarrow \phi\pi^+)$ [15] they also measure the $B(D_s^+ \rightarrow \mu^+\nu_\mu) = (6.5 \pm 0.8 \pm 0.3 \pm 0.9) \times 10^{-3}$, where the last error is due the uncertainty on $D_s^+ \rightarrow \phi\pi^+$ BFs.

CLEO$_c$ has also reported [16] for the leptonic decay: $B(D^+ \rightarrow \mu^+\nu_\mu) = (4.40 \pm 0.66^{+0.09}_{-0.12}) \times 10^{-4}$ and $f_{D^+} = (222.6 \pm 16.7^{+2.8}_{-3.4})$MeV. The ratio of the *BABAR* value for f_{D_s} to f_D from CLEO$_c$ measurement is: $\frac{f_{D_s}}{f_{D^+}} = 1.26 \pm 0.15$.

6. Conclusion

B-factories like *BABAR* and Belle has and excellent charm physics program. This document presents few results from B-factories as well as from CLEO$_c$. We can look forward to see and improve in our understanding of the standard model and beyond with the more data coming from these experiments.

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