Recent Results in $\psi(3770)$ and Open Charm from BESII and CLEO-c

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BES observed anomalous line shape of cross sections for $e^+e^- \to hadrons$ between 3.65-3.872 GeV and also measured line shapes of $D\bar{D}$ production and the ratio of the production rates of D^+D^- and $D^0\bar{D}^0$ at $\psi(3770)$ resonance. CLEO-c measured D^+ and D_s^+ decay constants with about 800 pb^{-1} and 600 pb^{-1} data sets collected at 3.770 GeV and 4.17 GeV respectively, and measured absolute branching fractions for the exclusive D semileptonic decays.

1 BES-II Results

BESII is the upgraded version of the BES detector [2] operated at the Beijing Electron Positron Collider (BEPC) [3]. With BESII detector, about 33 pb^{-1} data set were collected around 3.773 GeV, in which about 17.3 pb^{-1} collected at $\sqrt{s}$=3.773 GeV, and about 6.4 pb^{-1} data collected at $\sqrt{s}$=3.650 GeV.

1.1 New structure observed around 3.770 GeV

In the energy around 3.770 GeV, the well established $\psi(3770)$ resonance is believed to be the only observed structure. The $\psi(3770)$ resonance is expected to decay almost entirely into pure $D\bar{D}$ [4]. Recently, with different methods, BES Collaboration measured the branching fraction for the inclusive decay of $\psi(3770) \to non-D\bar{D}$ to be $(15 \pm 5)\%$ under assumption that there is only one simple $\psi(3770)$ resonance around 3.770 GeV [5, 6, 7, 8].

However, an examination of analysis previously reported by the BES Collaboration in Ref. [6] shows that the fits to the observed hadronic cross sections are rather poor for the fine-gained energy scan cross section measurements, as well as the fits in the other experiments [9, 10, 11]. To investigate whether there are some new structure in addition to the $\psi(3770)$ resonance around 3.770 GeV, BES Collaboration fits the observed cross sections with one or two amplitudes for the resonance around 3.770 GeV, the full structure around 3.773 GeV.

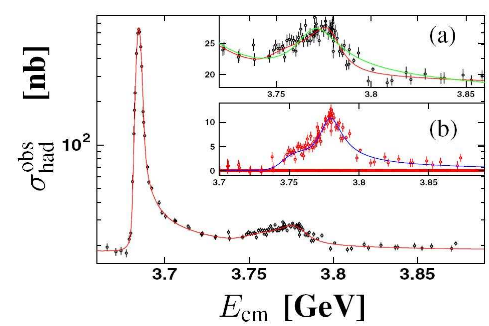

Figure 1: The observed inclusive hadronic cross sections versus the nominal c.m. energies, fit was done with two coherent amplitudes for resonance around 3.770 GeV [12].

Table 1 shows solutions of the fits, and Figure 1 shows the comparison of the fit results between one amplitude and two coherent amplitudes (Solution 2 in Table 1) for the resonance around 3.770 GeV. If no other dynamics effects to distort the pure D-wave

Breit Weigner shape of the cross sections, the result indicates that there is a new structure additional to the single $\psi(3770)$ resonance around 3.770 GeV at 7σ statistical significance, and they are M1=$3762.6 \pm 11.8 \pm 0.5$ MeV and M2=$3781.0 \pm 1.3 \pm 0.5$ MeV, respectively. A detailed description can be found in Ref. [12].

Quantity	two amplitudes (without interference) Solution 1	two amplitudes (interference) Solution 2	one amplitudes
$\chi^2/ndof$	125/103=1.21	112/102=1.10	182/106=1.72
$M_{\psi(3686)}$ [MeV]	3685.5± 0.0 ± 0.5	3685.5± 0.0 ± 0.5	3685.5± 0.0 ± 0.5
$\Gamma^{tot}_{\psi(3686)}$ [keV]	312± 34 ± 1	311± 38 ± 1	304± 36 ± 1
$\Gamma^{ee}_{\psi(3686)}$ [keV]	2.24± 0.04 ± 0.11	2.23± 0.04 ± 0.11	2.24± 0.04 ± 0.11
M_1 [MeV]	3765.0± 2.4 ± 0.5	3762.6± 11.8 ± 0.5	3773.3± 0.5 ± 0.5
Γ^{tot}_1 [MeV]	28.5± 4.6 ± 0.1	49.9± 32.1 ± 0.1	28.2± 2.1 ± 0.1
Γ^{ee}_1 [eV]	155± 34 ± 8	186± 201 ± 8	260± 21 ± 8
M_2 [MeV]	3777.0± 0.6 ± 0.5	3781.0± 1.3 ± 0.5	-
Γ^{tot}_2 [MeV]	12.3± 2.4 ± 0.1	19.3± 3.1 ± 0.1	-
or σ_G [MeV]	-	-	-
Γ^{ee}_2[eV]	93± 26 ± 9	243± 160 ± 9	-
or C	-	-	-
ϕ [°]	-	158± 334 ± 5	-
f	0.4± 5.6 ± 0.6	5.2± 2.5 ± 0.6	0.0± 0.5 ± 0.6

Table 1: The fitted results for the data taken at BES-II in March 2003 and December 2003 [12]

1.2 Line Shape of $D\bar{D}$ Production and Ratios of $\sigma^{D^+D^-}(s)/\sigma^{D^0\bar{D}^0}(s)$

Measurements of the line shapes of D^+D^-, $D^0\bar{D}^0$ and $D\bar{D}$ production and the ratios of the production rates of D^+D^- and $D^0\bar{D}^0$ in e^+e^- annihilation at a series of energy points across the $\psi(3770)$ resonance have special significance in studies of the properties of $\psi(3770)$ and D meson production and decays, as well as their interaction mechanism. Recently, BES Collaboration measured Line Shape of $D\bar{D}$ Production and Ratios of the the production rates $\sigma^{D^+D^-}(s)/\sigma^{D^0\bar{D}^0}(s)$ [13].

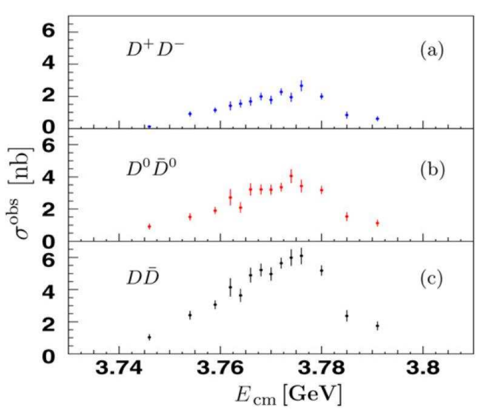

Figure 2: The observed cross sections for $D^0\bar{D}^0$, D^+D^- and $D\bar{D}$ production

The observed cross section for $D^0\bar{D}^0$ and D^+D^- production are determined by the numbers of singly tagged D^0 and D^+ events, the integrated luminosity of the data set, the branching fraction for the tagged modes, and the efficiency for reconstruction of the tagged modes. The D^0 and D^+ mesons are reconstructed by analyzing the decay processes for $D^0 \to K^-\pi^+, K^-\pi^+\pi^+\pi^-$ and $D^+ \to K^-\pi^+\pi^+$. The observed numbers of the singly tagged D^0 and D^+ events are obtained by analyzing the invariant mass spectra of $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$ and $K^-\pi^+\pi^+$ combinations.

Figs. 2 shows the observed cross section for $D^0\bar{D}^0$, D^+D^- and $D\bar{D}$ production, and Figs. 3 shows the ratios of production of D^+D^- and $D^0\bar{D}^0$.

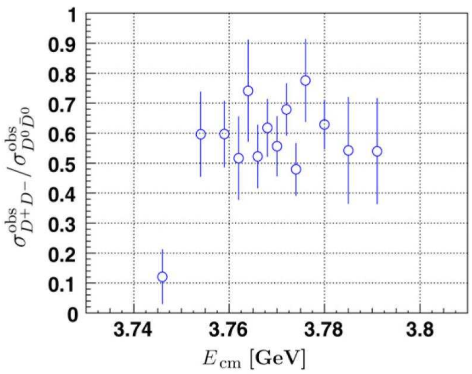

Figure 3: The ratios for $D^0\bar{D}^0$, D^+D^- and $D\bar{D}$ production

2 CLEO-c Results

The CLEO-c detector is a general purpose solenoidal detector operated at the Cornell Electron Storage Ring (CESR). Integrated luminosities of about 818 pb^{-1} data samples of $e^+e^- \to D\bar{D}$ events and 602 pb^{-1} data samples of $e^+e^- \to D_s^{*\pm}D_s^{\mp}$ events were collected by the CLEO-c detector at the center-of-mass (CM) energies 3.774 GeV and 4.170 GeV, respectively. Based on the analyzing these large data sets, measurements of the charm leptonic and semileptonic decays are improved. The main motivation of careful studies of charm leptonic and semileptonic decays is to calibrate strong interaction calculation approaches, so that they can be used in the bottom physics.

The approach for leptonic or semileptonic decays, is to reconstruct one D^- or D_s^- in a hadronic decay to tag the $D^+\bar{D}^-$ or $D_s^{*+}D_s^-$ events, and than search for charm leptonic or semileptonic decay events on the recoil-side of the tagged D^- or D_s^-. The signal for the leptonic or semileptonic decays are obtained by computing the square of the missing mass MM^2, or U_{miss} (determined with the missing energy and missing momentum) for the undetected neutrino in the exclusive leptonic or semileptonic decay events. For $D_s^+ \to \tau^+\nu$, a little extra neutral energy approach works well.

2.1 D and D_s^+ leptonic decays

Purely leptonic decays of heavy mesons involve both weak and strong interactions. The strong interactions arise due to gluon exchanges between the charm quark and the light quark. These are parameterized in terms of the "decay constant" f_{D^+} and $f_{D_s^+}$ for the D^+ and D_s^+ mesons. Within the context of the standard model (SM), measurements of purely leptonic decays of D^+ and D_s^+ provide means of determining the decay constants f_{D^+} and $f_{D_s^+}$.

Figure 4 shows the square of the missing mass distribution from CLEO-c, where MM^2, is computed using D^- tags and one additional opposite sign charged track and no extra energetic showers. The branching ratio is determined to be $B(D^+ \to \mu^+\nu) = (3.82 \pm 0.32 \pm 0.09) \times 10^{-4}$. the decay constant $f_{D^+} = (205.8 \pm 8.5 \pm 2.5)$ MeV is then obtained using 1040 ± 7 fs as the D^+ lifetime and 0.2256 for $|V_{cd}|$ [14].

The D_s^+ analysis uses the same technique as for the D^+ except in the D_s case there is the additional complication of the photon from $D_s^{*+} \to \gamma D_s^+$, since at 4.170 GeV the dominant production mechanism for D_s^+ is $e^+e^- \to D_s^{*+}D_s^-$ events. CLEO-c published the results for $D_s^+ \to \tau^+\nu$ and $D_s^+ \to \mu^+\nu$, the CLEO average is $f_{D_s^+} = (259.5 \pm 6.6 \pm 3.1)$ MeV [15, 16]. The decay constant ratio is $f_{D_s^+}/f_{D^+} = 1.26 \pm 0.06 \pm 0.02$.

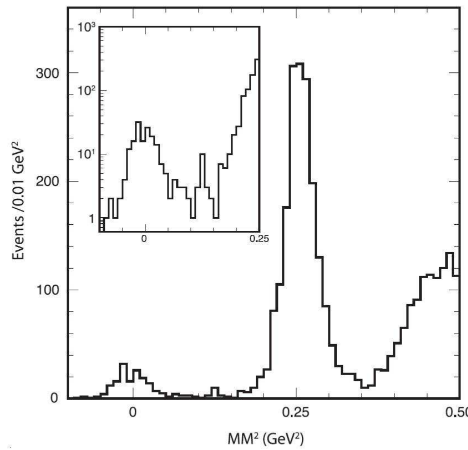

Figure 4: MM^2 using D^- tags and one additional opposite sign charged track and no extra energetic showers. The insert shows the signal region for $D^+ \to \mu^+\nu$ on a log scale. [14]

2.2 D semileptonic decays

In the standard model of particle physics, mixing of the quark mass eigenstates in their charge current interactions is described by the Cabibbo Kobayashi Maskawa (CKM) matrix. Study of the semileptonic decay of D mesons plays a primary role in our understanding of the CKM matrix. These decays allow robust determination of the CKM matrix elements $|V_{cs}|$ and $|V_{cd}|$ by combining measured branching fractions with form fator calculations, such as those based on unquenched lattice QCD (LQCD).

CLEO-c measured the branching fractions for D^+ and D^0 semileptonic decays, the values are $B(D^0 \to \pi^-e^+\nu_e) = 0.299(11)(9)\%$, $B(D^+ \to \pi^0e^+\nu_e) = 0.373(22)(13)\%$, $B(D^0 \to K^-e^+\nu_e) = 3.56(3)(9)\%$ and $B(D^+ \to \bar{K}^0e^+\nu_e) = 8.53(12)(23)\%$. Averaging the D^0 and D^+ results, CLEO-c determined $|V_{cd}| = 0.217(9)(4)(23)$ and $|V_{cs}| = 1.015(10)(11)(106)$, where the final error is the theoretical [17, 18].

CLEO-c also reported the first observation and absolute branching fraction measurement for $D^+ \to \eta e^+\nu_e$ and results of searches for $D^+ \to \eta' e^+\nu_e$ and $D^+ \to \phi e^+\nu_e$. A detailed description can be found in Ref. [19].

3 Acknowledgments

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