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Measurement of the near-threshold $e^+e^- \to D^{(*)+}D^{*-}$ cross section

Belle measurement

written by G.Pakhlova (Belle)

To select $e^+e^- \to D^{(*)+}D^{*-}\gamma_{\rm ISR}$ signal events Belle used a method that achieves high efficiency by requiring full reconstruction of only one of the $D^{(*)+}$ mesons, the $\gamma_{\rm ISR}$, and the slow $\pi^-_{\rm slow}$ from the other D^{*-} (Abe, 2007). In this case the spectrum of masses recoiling against the $D^{(*)+}\gamma_{\rm ISR}$ system:

$$M_{\rm rec}(D^{(*)+}\gamma_{\rm ISR}) = \sqrt{(E_{\rm c.m.} - E_{D^{(*)+}\gamma_{\rm ISR}})^2 - p^2_{D^{(*)+}\gamma_{\rm ISR}}} \quad (1)$$

peaks at the D^{*-} mass. Here $E_{D^{(*)+}\gamma_{\rm ISR}}$ and $p_{D^{(*)+}\gamma_{\rm ISR}}$ are the c.m. energy and momentum, respectively, of the $D^{(*)+}\gamma_{\rm ISR}$ combination. This peak is expected to be wide and asymmetric due to the photon energy resolution and higher-order corrections to ISR. The resolution of this peak (estimated to be $\sim 300\,{\rm MeV}/c^2$) is not sufficient to separate the $D\overline{D}^*$, $D^*\overline{D}^*$ or $D^{(*)}\overline{D}^*\pi$ final states. To disentangle the contributions from these final states and to suppress combinatorial backgrounds, Belle used the slow pion from the unreconstructed D^{*-}. The difference between the mass recoiling against $D^{(*)+}\gamma_{\rm ISR}$ and $D^{(*)+}\pi^-_{\rm slow}\gamma_{\rm ISR}$ (recoil mass difference):

$$\Delta M_{\rm rec} = M_{\rm rec}(D^{(*)+}\gamma_{\rm ISR}) - M_{\rm rec}(D^{(*)+}\pi^-_{\rm slow}\gamma_{\rm ISR}), \quad (2)$$

has a narrow distribution ($\sigma \sim 1.4\,{\rm MeV}/c^2$) around the $m_{D^{*-}} - m_{\overline{D}^0}$, since the uncertainty in $\gamma_{\rm ISR}$ momentum partially cancels out.

For the measurement of the exclusive cross section Belle determined the $D^{(*)+}D^{*-}$ mass ($\equiv M_{\rm rec}(\gamma_{\rm ISR})$ in the absence of higher-order QED processes). The photon energy resolution results in a typical $M_{\rm rec}(\gamma_{\rm ISR})$ resolution of $\sim 100\,{\rm MeV}$, which is too big for a study of relatively narrow $D^{(*)+}D^{*-}$ mass states. Belle significantly improved the $M_{\rm rec}(\gamma_{\rm ISR})$ resolution by applying a refit that constrained $M_{\rm rec}(D^{(*)+}\gamma_{\rm ISR})$ to the D^{*-} mass. As a result, the $M_{D^{(*)+}D^{*-}}$ resolution was improved by a factor of ~ 10. The recoil mass difference after the refit procedure ($\Delta M^{\rm fit}_{\rm rec}$) had a resolution improved by a factor of ~ 2. The signal region was defined by the requirement that $M_{\rm rec}(D^{*+}\gamma_{\rm ISR})$ be within $\pm 0.2\,{\rm GeV}/c^2$ of the D^{*-} mass and by the tight requirement on $\Delta M^{\rm fit}_{\rm rec}$ within $\pm 2\,{\rm MeV}/c^2$ of the $m_{D^{*-}} - m_{\overline{D}^0}$.

The $e^+e^- \to D^{(*)+}D^{*-}$ cross sections were extracted from the $D^{(*)+}D^{*-}$ mass distributions after background subtraction by the relation described in *ISR METHOD SECTION*. The resulting exclusive $e^+e^- \to D^{(*)+}D^{*-}$ cross sections are shown in Fig. 1 with statistical uncertainties only. The total systematic uncertainties are (11)10% and comparable to the statistical errors in the differential cross section.

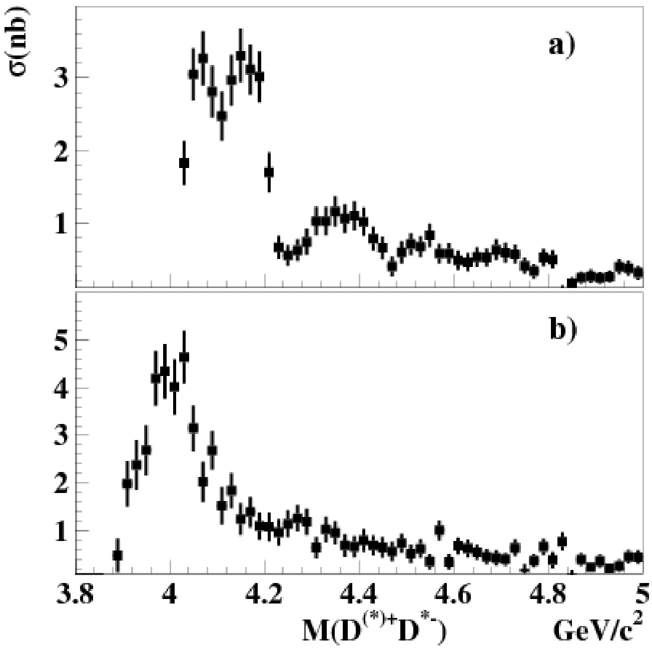

Fig. 1. Belle. The exclusive cross sections for (a) $e^+e^- \to D^{*+}D^{*-}$ and (b) $e^+e^- \to D^+D^{*-}$ + c.c.

BABAR measurement

to be written by A.Polano

Discussion

to be added and corrected...

The shape of the $e^+e^- \to D^{*+}D^{*-}$ cross section is complicated with several local maxima and minima. Aside from a prominent excess near threshold, the $e^+e^- \to D^+D^{*-}$ cross section is relatively featureless. The measured cross sections are compatible (since only charged final states are measured, Belle results should be scaled by a factor of two for this comparison) within errors with the $D\overline{D}^*$ and $D^*\overline{D}^*$ exclusive cross section measured by *BABAR* (Aubert, 2009) and CLEO-c (Cronin-Hennessy et al. (2009)).

Measurement of the near-threshold $e^+e^- \to D\overline{D}$ cross section

Belle measurement

written by G.Pakhlova (Belle)

Belle selected $e^+e^- \to D\overline{D}\gamma_{\rm ISR}$ signal events by reconstructing both the D and $\overline{D}$ mesons, where $D = D^0$ or D^+ (Pakhlova, 2008a). In general, the $\gamma_{\rm ISR}$ is not required to be detected; its presence in the event is inferred from a peak at zero in the spectrum of the recoil mass against the $D\overline{D}$ system. The square of the recoil mass is defined as:

$$M^2_{\rm rec}(D\overline{D}) = (E_{\rm c.m.} - E_{D\overline{D}})^2 - p^2_{D\overline{D}}, \quad (3)$$

where $E_{D\overline{D}}$ and $p_{D\overline{D}}$ are the c.m. energy and momentum of the $D\overline{D}$ combination, respectively. To suppress backgrounds two cases were considered: (1) the $\gamma_{\rm ISR}$ is out of detector acceptance in which case the polar angle for the $D\overline{D}$ combination in the c.m. frame was required to be $|\cos(\theta_{D\overline{D}})| > 0.9$; (2) the fast $\gamma_{\rm ISR}$ is within the detector acceptance ($|\cos(\theta_{D\overline{D}})| < 0.9$), in this case the $\gamma_{\rm ISR}$ was required to be detected and the mass of the $D\overline{D}\gamma_{\rm ISR}$ combination was required to be greater than $E_{\rm c.m.} - 0.58\,{\rm GeV}$. To suppress background from $e^+e^- \to D\overline{D}(n)\pi\gamma_{\rm ISR}$ processes Belle excluded events that contain additional charged tracks that are not used in the D or $\overline{D}$ reconstruction. To suppress the tail of $e^+e^- \to D^{(*)}\overline{D}^{(*)}(n)\pi^0\gamma_{\rm ISR}$ events a signal region was defined by the requirement: $|M^2_{\rm rec}(D\overline{D})| < 0.7(\,{\rm GeV}/c^2)^2$.

The resulting $e^+e^- \to D^0\overline{D}^0$, $e^+e^- \to D^+D^-$ and $e^+e^- \to D\overline{D}$ exclusive cross sections, averaged over the bin width, are shown in Fig. 2 with statistical uncertainties only. The total systematic uncertainties are 10% and comparable to the statistical errors in the differential cross section around the $\psi(3770)$ peak; for the other $M_{D\overline{D}}$ ranges statistical errors dominate.

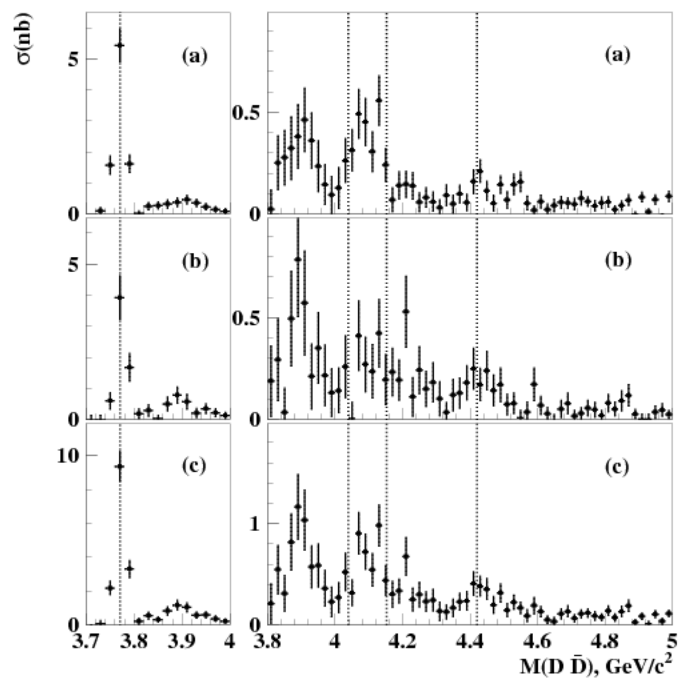

Fig. 2. Belle. The exclusive cross sections for: (a) $e^+e^- \to D^0\overline{D}^0$; (b) $e^+e^- \to D^+D^-$ and (c) $e^+e^- \to D\overline{D}$. The dotted lines correspond to the $\psi(3770)$, $\psi(4040)$, $\psi(4160)$ and $\psi(4415)$ masses.

The cross section ratio $\sigma(e^+e^- \to D^+D^-)/\sigma(e^+e^- \to D^0\overline{D}^0$ was calculated for the $M_{D\overline{D}}$ bin $(3.76-3.78)\,{\rm GeV}/c^2$ corresponding to $M_{D\overline{D}} \approx M_{\psi(3770)}$ to be $(0.72 \pm 0.16 \pm 0.06)$. This value is in agreement within errors with CLEO-c (**?**) and BES (**?**) measurements. The ratio $\sigma(e^+e^- \to D^+D^-)/\sigma(e^+e^- \to D^0\overline{D}^0$ integrated over the $M_{D\overline{D}}$ range from 3.8 to $5.0\,{\rm GeV}/c^2$ is found to be $(1.15 \pm 0.13 \pm 0.10)$ and is consistent with unity.

BABAR measurement

to be written by A.Polano

Discussion

to be added and corrected

The observed $e^+e^- \to D\overline{D}$ exclusive cross sections are consistent with *BABAR* measurements (Aubert, 2007b). This includes a peak at $3.9\,{\rm GeV}/c^2$ that is seen both in Belle and *BABAR* mass spectra.

Measurement of the near-threshold $e^+e^- \to D^0D^-\pi^+$ cross section and observation of $\psi(4415) \to D\overline{D}{}_2^*(2460)$ decay

written by G.Pakhlova (Belle)

Belle used the similar full reconstruction method described above to select $e^+e^- \to D^0D^-\pi^+\gamma_{\rm ISR}$ signal candidates (Pakhlova, 2008c). The $e^+e^- \to D^0D^-\pi^+$ cross section extracted from the background-subtracted $D^0D^-\pi^+$ mass distribution is shown in Fig. 3.

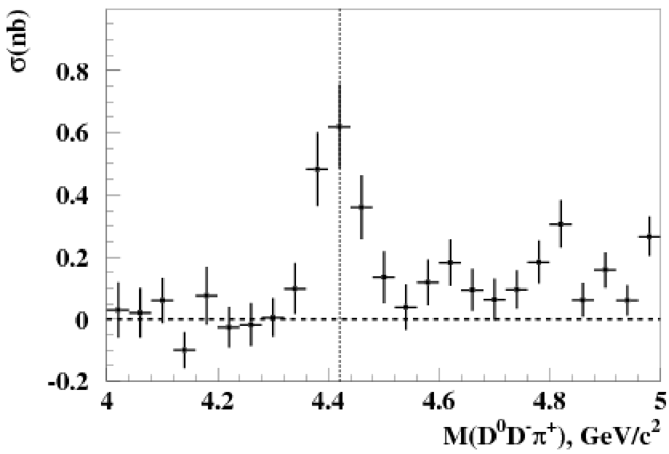

Fig. 3. Belle. The exclusive cross sections for $e^+e^- \to D^0D^-\pi^+$. The dotted line corresponds to the mass of the $\psi(4415)$.

To study the resonant structure in $\psi(4415)$ decays, Belle selected $D^0D^-\pi^+$ combinations from a $\pm 100\,{\rm MeV}/c^2$ mass window around the $\psi(4415)$ mass (Ablikim et al. (2007)). A scatter plot of $M(D^-\pi^+)$ vs. $M(D^0\pi^+)$ and its projections onto both axes evidently demonstrate clear signals for the $\overline{D}{}_2^*(2460)^0$ and $\overline{D}{}_2^*(2460)^+$ mesons and positive interference between the neutral $D^0\overline{D}{}_2^*(2460)^0$ and the charged $D^-\overline{D}{}_2^*(2460)^+$ decay amplitudes leading to the same $D^0D^-\pi^+$ final state for the decay of $C = -1$ state. Because of the interference Belle did not study $D^0\overline{D}{}_2^*(2460)^0$

and $D^-\overline{D}{}_2^*(2460)^+$ final states separately and defined the signal interval for the $D\overline{D}{}_2^*(2460)$ combinations as $|M_{D^-\pi^+} - m_{\overline{D}{}_2^*(2460)^0}| < 50\,\mathrm{MeV}/c^2$ or $|M_{D^0\pi^+} - m_{\overline{D}{}_2^*(2460)^+}| < 50\,\mathrm{MeV}/c^2$.

Belle performed a separate study of $e^+e^- \to D\overline{D}{}_2^*(2460)$ and $e^+e^- \to (D^0D^-\pi^+)_{\mathrm{non}\overline{D}{}_2^*(2460)}$. The $M_{D^0D^-\pi^+}$ spectrum for the $D\overline{D}{}_2^*(2460)$ signal interval is shown in Fig. 4(a). A clear peak corresponding to $\psi(4415) \to D\overline{D}{}_2^*(2460)$ decay is evident near the $D\overline{D}{}_2^*(2460)$ threshold. To compare mass and width of the obtained $\psi(4415)$ signal with the corresponding $\psi(4415)$ resonance parameters measured in the *inclusive* study (Ablikim et al. (2007)), Belle performed a likelihood fit to $M_{D^0D^-\pi^+}$ distribution with the $D\overline{D}{}_2^*(2460)$ signal parameterized by an s-wave RBW function. To account for background and a possible non-resonant $D^0D^-\pi^+$ contribution a threshold function $\sqrt{M - m_D - m_{\overline{D}{}_2^*(2460)}}$ with a floating normalization was used. Finally, the sum of the signal and background functions was multiplied by the mass-dependent linear efficiency function and differential ISR luminosity. The fit, shown as a solid curve in Fig. 4(a), yields $109 \pm 25(\mathrm{stat})$ signal events. The significance for the signal was obtained to be $\sim 10\sigma$. The obtained peak mass $m_{\psi(4415)} = (4.411 \pm 0.007(\mathrm{stat}))\,\mathrm{GeV}/c^2$ and total width $\Gamma_{\mathrm{tot}} = (77 \pm 20(\mathrm{stat}))\,\mathrm{MeV}$ are in good agreement with the PDG (Amsler et al. (2008)) values and the BES results (Ablikim et al. (2007)).

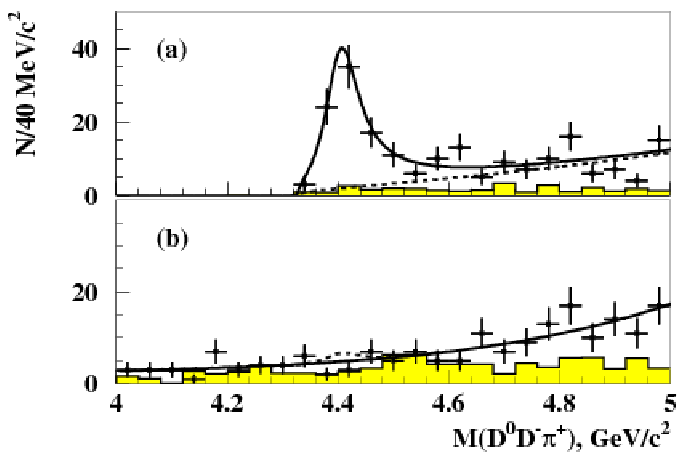

Fig. 4. Belle. (a) The $M_{D^0D^-\pi^+}$ spectrum for the $D\overline{D}{}_2^*(2460)$ signal region. The threshold function is shown by the dashed curve. (b) The $M_{D^0D^-\pi^+}$ spectrum outside the $D\overline{D}{}_2^*(2460)$ signal region. The dashed curve shows the upper limit on the $\psi(4415)$ yield at 90% C.L. Histograms show the normalized contributions from M_{D^0} and M_{D^-} sidebands.

The peak cross section for $e^+e^- \to \psi(4415) \to D\overline{D}{}_2^*(2460)$ process at $E_{\mathrm{c.m.}} = m_{\psi(4415)}$ was calculated from the amplitude of the RBW function in the fit to be $\sigma(e^+e^- \to \psi(4415)) \times \mathcal{B}(\psi(4415) \to D\overline{D}{}_2^*(2460) \times \mathcal{B}(\overline{D}{}_2^*(2460) \to D\pi^+) = (0.74 \pm 0.17 \pm 0.08)\,\mathrm{nb}$. Using $\sigma(e^+e^- \to \psi(4415)) = 12\pi/m^2_{\psi(4415)} \times (\Gamma_{ee}/\Gamma_{\mathrm{tot}})$ Belle calculated the $\mathcal{B}(\psi(4415) \to D\overline{D}{}_2^*(2460)) \times \mathcal{B}(D_2^*(2460) \to D\pi^+) = (10.5 \pm 2.4 \pm 3.8)\%$ using the $\psi(4415)$ parameters from the PDG (Ablikim et al. (2007)) and $(19.5 \pm 4.5 \pm 9.2)\%$ for the $\psi(4415)$ parameters from Ref. (Amsler et al. (2008)). The shape of the $M_{D^0D^-\pi^+}$ spectrum with the $D\overline{D}{}_2^*(2460)$ signal excluded, shown as a solid curve in Fig. 4(b), in the $\psi(4415)$ mass window, is consistent with the combinatorial background. Belle obtained $\mathcal{B}(\psi(4415) \to D^0D^-\pi^+_{\mathrm{non-resonant}})/\mathcal{B}(\psi(4415) \to D\overline{D}{}_2^*(2460)) \to D^0D^-\pi^+) < 0.22$ at 90% C.L.

Measurement of the near-threshold $e^+e^- \to \Lambda_c^+\Lambda_c^-$ cross section

written by G.Pakhlova (Belle)

The selection of $e^+e^- \to \Lambda_c^+\Lambda_c^-\gamma_{\mathrm{ISR}}$ signal events using full reconstruction of both the Λ_c^+ and Λ_c^- baryons suffers from the low Λ_c reconstruction efficiency and small branching fractions for decays to accessible final states. Therefore, in order to achieve higher efficiency Belle required full reconstruction of only one of the Λ_c baryons and the γ_{ISR} photon (Pakhlova, 2008b). In this case the spectrum of masses recoiling against the $\Lambda_c^+\gamma_{\mathrm{ISR}}$ system peaks at the Λ_c^- mass.

For the measurement of the exclusive cross section for $e^+e^- \to \Lambda_c^+\Lambda_c^-$, Belle determined the mass recoiling against the γ_{ISR} photon ($M_{\mathrm{rec}}(\gamma_{\mathrm{ISR}})$). To improve the $M_{\mathrm{rec}}(\gamma_{\mathrm{ISR}})$ resolution (expected to be $\sim 100\,\mathrm{MeV}/c^2$), Belle applied a refit that constrains $M_{\mathrm{rec}}(\Lambda_c^+\gamma_{\mathrm{ISR}})$ to the nominal Λ_c^- mass. As a result, the $M_{\Lambda_c^+\Lambda_c^-}$ resolution was improved substantially; it varied from $\sim 3\,\mathrm{MeV}/c^2$ just above threshold to $\sim 8\,\mathrm{MeV}/c^2$ at $M_{\Lambda_c^+\Lambda_c^-} \sim 5.4\,\mathrm{GeV}/c^2$.

To suppress combinatorial background, Belle required the presence of at least one $\overline{p}$ in the event from the decay of the unreconstructed Λ_c^- ($\overline{p}$ tag). As a result, the combinatorial background was suppressed by a factor of ~ 10 at the expense of about a 40% reduction in signal.

The $M_{\Lambda_c^+\Lambda_c^-}$ spectrum for events in the signal region is shown in Fig. 5 (a).

A clear peak is evident near the $\Lambda_c^+\Lambda_c^-$ threshold. Assuming the observed peak to be a resonance, Belle performed a simultaneous likelihood fit to the $M_{\Lambda_c^+\Lambda_c^-}$ distributions for the Λ_c^+ signal and sideband regions to fix the combinatorial background shapes. As the signal function Belle used a sum of a relativistic s-wave Breit-Wigner function and a threshold function with a floating normalization to take into account a possible non-resonant contribution. The fit, shown as a solid curve in Fig. 5 (a), attributes $142^{+32}_{-28}(\mathrm{stat})$ events to the RBW signal. The obtained peak mass is $M = (4634^{+8}_{-7}{}^{+5}_{-8})\,\mathrm{MeV}/c^2$ and the total width is $\Gamma_{\mathrm{tot}} = (92^{+40}_{-24}{}^{+10}_{-21})\,\mathrm{MeV}$. The significance including systematics is 8.2σ. Belle use $X(4630)$ to denote the observed structure.

As a cross check, Belle presented in Fig. 5 (b) the $M_{\Lambda_c^+\Lambda_c^-}$ spectrum for the signal region for wrong-sign tags, *i.e.* requiring a presence of a proton in the event in addition to the $\Lambda_c^+\gamma_{\mathrm{ISR}}$ combination. The $M_{\Lambda_c^+\Lambda_c^-}$ distribution from the signal Λ_c^+ window is in good agreement with the normalized contributions from the Λ_c^+ sidebands.

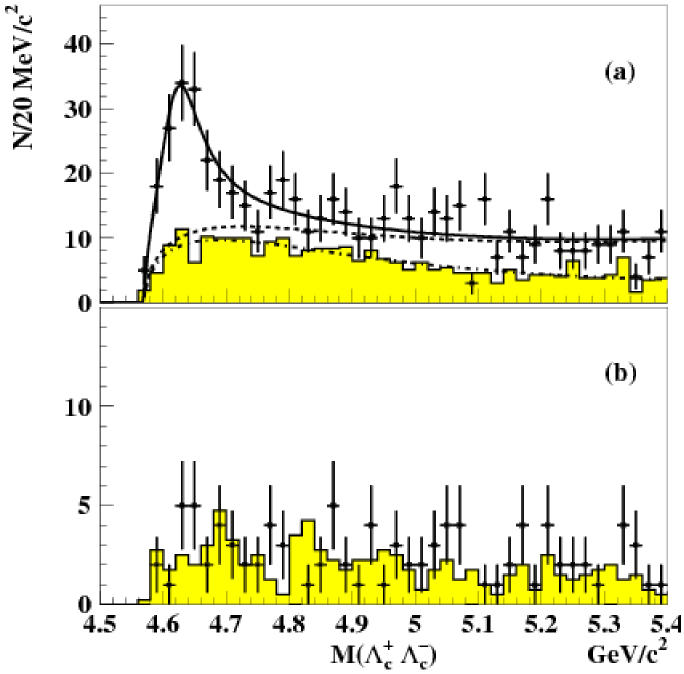

Fig. 5. The $M_{\Lambda_c^+\Lambda_c^-}$ spectrum for the signal region: (a) with $\overline{p}$ tag. The solid curve represents the result of the fit described in the text. The threshold function is shown by the dashed curve. The combinatorial background parameterization is shown by the dashed-dotted curve; (b) with p (wrong-sign) tag. Histograms show the normalized contributions from Λ_c^+ sidebands.

The $e^+e^- \to \Lambda_c^+\Lambda_c^-$ cross section extracted from the background-subtracted $\Lambda_c^+\Lambda_c^-$ mass distribution is shown in Fig. 6 with statistical uncertainties only.

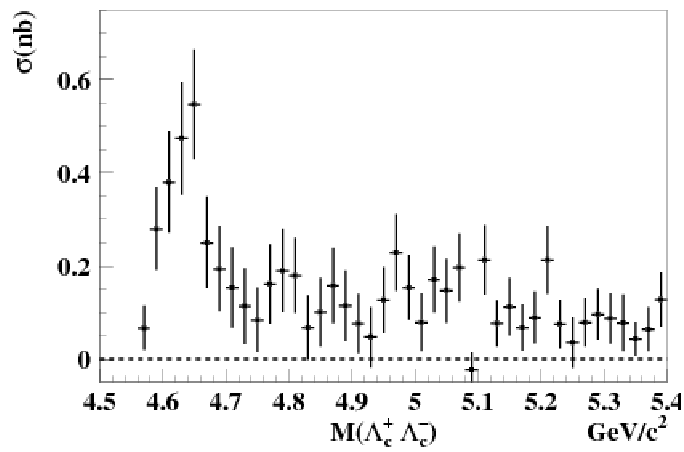

Fig. 6. The cross section for the exclusive process $e^+e^- \to \Lambda_c^+\Lambda_c^-$.

The peak cross section for the $e^+e^- \to \Lambda_c^+\Lambda_c^-$ process at $E_{\mathrm{c.m.}} = m_{X(4630)}$ was calculated from the amplitude of the RBW function in the fit to be $\sigma(e^+e^- \to X(4630))\times\mathcal{B}(X(4630) \to \Lambda_c^+\Lambda_c^-) = (0.47^{+0.11}_{-0.10}{}^{+0.05}_{-0.08}\pm 0.19)$ nb. Belle calculated $\Gamma_{ee}/\Gamma_{\mathrm{tot}} \times \mathcal{B}(X(4630) \to \Lambda_c^+\Lambda_c^-) = (0.68^{+0.16}_{-0.15}{}^{+0.07}_{-0.11} \pm 0.28) \times 10^{-6}$.

the next paragraph to be moved and discussed in EXOTIC CHARMINIUM STATE section...

The nature of significant near-threshold enhancement remains unclear. In many processes including three-body B meson baryon decays, mass peaks are observed near threshold **?**. However, the cross section for $e^-e^- \to \Lambda\bar{\Lambda}$ measured via ISR by *BABAR* (Aubert, 2007a) has a different pattern: it increases sharply at threshold and then decreases gradually without any peak-like structure. Although both mass and width of the $X(4630)$ are consistent within errors with those of the $Y(4660)$, this coincidence does not exclude other interpretations of the $X(4630)$, for example, as the conventional charmonium state **??** or as a baryon-antibaryon threshold effect **?** or .....

Measurement of the near-threshold $e^+e^- \to D^0D^{*-}\pi^+$ cross section

written by G.Pakhlova (Belle)

For measurement of the $e^+e^- \to D^0D^{*-}\pi^+$ cross section (Pakhlova, 2009) Belle employed the full reconstruction method that was used for $e^+e^- \to D\overline{D}$ and $e^+e^- \to D^0D^-\pi^+$. The resulting $e^+e^- \to D^0D^{*-}\pi^+$ exclusive cross section averaged over the bin width is shown in Fig. 7 with statistical uncertainties only. The total systematic uncertainty is 10%.

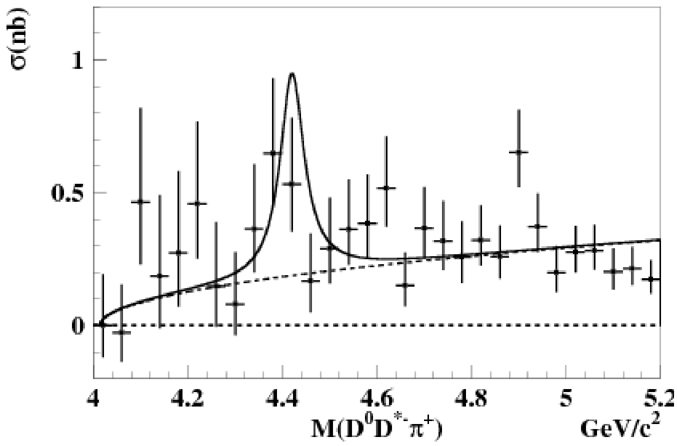

Fig. 7. The exclusive cross section for $e^+e^- \to D^0D^{*-}\pi^+$ averaged over the bin width with statistical uncertainties only. The fit function corresponds to the upper limit on $\psi(4415)$ taking into account systematic uncertainties. The solid line represents the sum of the signal and threshold contributions. The threshold function is shown by the dashed line.

To obtain limit on $e^+e^- \to \psi(4415) \to D^0D^{*-}\pi^+$ process Belle performed a likelihood fit to the $M_{D^0D^{*-}\pi^+}$ distribution where Belle parameterized a possible $\psi(4415)$ signal contribution by an s-wave RBW function with a free normalization. Belle used PDG values (Amsler et al.

(2008)) to fix its mass and total width. To take a non-resonant $D^0D^{*-}\pi^+$ contribution into account Belle used a threshold function $\sqrt{M - m_{D^0} - m_{D^{*-}} - m_{\pi^+}}$ with a free normalization. Finally, the sum of the signal and non-resonant functions was multiplied by a mass-dependent second-order polynomial efficiency function and differential ISR luminosity.

The fit yields $14.4 \pm 6.2^{+1.0}_{-9.5}$ signal events for the $\psi(4415)$ state. The statistical significance for the $\psi(4415)$ signal was determined to be 3.1σ. Belle calculated an upper limit on the peak cross section for the $e^+e^- \to \psi(4415) \to D^0D^{*-}\pi^+$ process at $E_{\mathrm{c.m.}} = m_{\psi(4415)}$ from the amplitude of the RBW function in the fit to be $\sigma(e^+e^- \to \psi(4415)) \times \mathcal{B}(\psi(4415) \to D^0D^{*-}\pi^+) < 0.76$ nb at the 90% C.L. Using $\sigma(e^+e^- \to \psi(4415)) = 12\pi/m^2_{\psi(4415)} \times \mathcal{B}_{\mathrm{ee}}$ and PDG values of the $\psi(4415)$ mass, full width and electron width (Amsler et al. (2008)) Belle founded $\mathcal{B}_{\mathrm{ee}} \times \mathcal{B}(\psi(4415) \to D^0D^{*-}\pi^+) < 0.99 \times 10^{-6}$ at the 90% C.L and $\mathcal{B}(\psi(4415) \to D^0D^{*-}\pi^+) < 10.6\%$ at the 90% C.L. All presented upper limit values include systematic uncertainties. For illustration the corresponding fit function on the cross section distribution plot is shown in Fig. 7.

the next paragraphs to be discussed in EXOTIC CHARMONIUM section...

To obtain limits on the decays $X \to D^0D^{*-}\pi^+$, where X denotes $Y(4260)$, $Y(4350)$, $Y(4660)$ or $X(4630)$ states, Belle performed four likelihood fits to the $M_{D^0D^{*-}\pi^+}$ spectrum each with one of the X states, the $\psi(4415)$ state and a non-resonant contribution. For fit functions Belle used the sum of two s-wave relativistic RBW functions with a free normalization and a threshold function $\sqrt{M - m_{D^0} - m_{D^{*-}} - m_{\pi^+}}$ with a free normalization. For masses and total widths of the $Y(4260)$ and $\psi(4415)$ states PDG values (Amsler et al. (2008)) were used. The corresponding parameters of the $Y(4660)$, $Y(4350)$ and $X(4630)$ states were fixed from Ref.(Liu, Qin, and Yuan (2008)),(Pakhlova, 2008b), respectively.

The significances for the $Y(4260)$, $Y(4350)$, $Y(4660)$ and $X(4630)$ signal were found to be 0.9σ, 1.4σ, 0.1σ and 1.8σ, respectively. The calculated upper limits (at the 90% C.L.) on the peak cross sections for $e^+e^- \to X \to \overline{D}D^{*-}\pi^+$ processes at $E_{\mathrm{c.m.}} = m_X$ are presented in Table 1. Using fixed values of X masses and full widths Belle obtained upper limits on the $\mathcal{B}_{\mathrm{ee}} \times \mathcal{B}(X \to D^0D^{*-}\pi^+)$ at the 90% C.L. Finally, for the $Y(4260)$ state Belle estimated the upper limit on $\mathcal{B}(Y(4260) \to D^0D^{*-}\pi^+)/\mathcal{B}(Y(4260) \to \pi^+\pi^-J/\psi)$ at the 90% C.L. using $\mathcal{B}_{\mathrm{ee}} \times \Gamma(\pi^+\pi^-J/\psi)$ (Amsler et al. (2008)). For the $Y(4350)$ and $Y(4660)$ states Belle calculated $\mathcal{B}(X \to D^0D^{*-}\pi^+)/\mathcal{B}(X \to \pi^+\pi^-\psi(2S))$ at the 90% C.L. taking into account $\mathcal{B}_{\mathrm{ee}} \times \Gamma(\pi^+\pi^-\psi(2S))$ (Liu, Qin, and Yuan (2008)). All upper limits presented in Table 1 include systematic uncertainties.

To estimate the effects of possible interference between final states Belle also performed a fit to the $M_{D^0D^{*-}\pi^+}$ spectrum that includes complete interference between the $\psi(4415)$ RBW amplitude and a non-resonant $D^0D^{*-}\pi^+$ contribution. Belle found two solutions with similar goodness-of-fit; the interference is constructive for one solution and destructive for the other. From the fit with destructive interference Belle found an upper limit on the peak cross section for $e^+e^- \to \psi(4415) \to D^0D^{*-}\pi^+$ process to be $\sigma(e^+e^- \to \psi(4415)) \times \mathcal{B}(\psi(4415) \to D^0D^{*-}\pi^+) < 1.93$ nb at the 90% C.L.

In addition Belle performed four likelihood fits to the $M_{D^0D^{*-}\pi^+}$ spectrum with complete interference between the X and $\psi(4415)$ states' RBW amplitudes and a non-resonant $D^0D^{*-}\pi^+$ contribution. Belle found four solutions for each fit with similar goodness-of-fit and obtained the upper limits on the peak cross sections for $e^+e^- \to X \to D^0D^{*-}\pi^+$ process to be $\sigma(e^+e^- \to X) \times \mathcal{B}(X \to D^0D^{*-}\pi^+)$ less than 1.44, 1.92, 1.38 and 0.98 nb at the 90% C.L. for $Y(4260)$, $Y(4350)$, $Y(4660)$ and $X(4630)$, respectively.

Measurement of the near-threshold $e^+e^- \to D_s^{(*)+}D_s^{(*)-}$ cross sections

BABAR measurement

to be written by A.Polano (arXiv:1008.0338 [hep-ex])

Belle measurement

to be written by G.Pakhlova, paper to be submitted soon

Search for exotic charmonium

Discovery of Y family states

to be written by Y.ChangZheng from Belle (Shen, 2009; Wang, 2007; Yuan, 2007, 2008)

to be written by ?? from BaBar

Search for multilepton final states

to be written by ???

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Table 1. The upper limits on the peak cross section for the processes $e^+e^- \to X \to D^0 D^{*-}\pi^+$ at $E_{\text{c.m.}} = m_X$, $\mathcal{B}_{\text{ee}} \times \mathcal{B}(X \to D^0 D^{*-}\pi^+)$ and $\mathcal{B}(X \to D^0 D^{*-}\pi^+)/\mathcal{B}(X \to \pi^+\pi^- J/\psi\,(\psi(2S)))$ at the 90% C.L., where $X = Y(4260)$, $Y(4350)$, $Y(4660)$, $X(4630)$.

	$Y(4260)$	$Y(4350)$	$Y(4660)$	$X(4630)$
$\sigma(e^-e^- \to X) \times \mathcal{B}(X \to D^0 D^{*-}\pi^+))$, [nb]	0.36	0.55	0.25	0.45
$\mathcal{B}_{\text{ee}} \times \mathcal{B}(X \to D^0 D^{*-}\pi^+))$, [$\times 10^{-6}$]	0.42	0.72	0.37	0.66
$\mathcal{B}(X \to D^0 D^{*-}\pi^+)/\mathcal{B}(X \to \pi^+\pi^- J/\psi)$	9			
$\mathcal{B}(X \to D^0 D^{*-}\pi^+)/\mathcal{B}(X \to \pi^+\pi^- \psi(2S))$		8	10	

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