Measurement of the $e^+e^- \rightarrow D^0D^*-\pi^+$ cross section using initial-state radiation

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Numerous measurements of exclusive properties of the \( \psi(4008) \) and the \( \psi(4660) \) seen by Belle. No clear evidence for open charm production associated with any of these states has been observed. In fact the \( \psi(4260) \) peak position appears to be close to a local minimum of both the total hadronic cross section and of the exclusive cross section for \( e^+e^- \rightarrow D^0\bar{D}^+\pi^+ \) decays. The analysis is based on a data sample collected with the Belle detector at or near a center-of-mass energy of 10.58 GeV with an integrated luminosity of 695 fb\(^{-1}\) at the KEKB asymmetric-energy \( e^+e^- \) collider.

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Studies of exclusive open charm production near threshold in \( e^+e^- \) annihilation provide important information on the dynamics of charm quarks and on the properties of the \( \psi \) states. During the past three years numerous measurements of exclusive \( e^+e^- \) cross sections for charmed hadron pairs have been reported. Most of these measurements were performed at \( B \) -factories using initial-state radiation (ISR). Belle presented the first results on the \( e^+e^- \) cross sections to the \( D\bar{D}, D^+D^- \) \cite{1}, \( D^{*+}D^-, D^0D^-\pi^+ \) (including the first observation of \( \psi(4415) \rightarrow D\bar{D}_s^0(2460) \) decays) \cite{2,3,4} and \( \Lambda_c^+\Lambda_c^- \) final states. BaBar measured \( e^+e^- \) cross sections to \( D\bar{D} \) and recently to the \( D\bar{D}^*, D^*\bar{D}^0 \) final states \cite{5,6}. CLEO-c performed a scan over the energy range from 3.97 to 4.26 GeV and measured exclusive cross sections for the \( D\bar{D}, D\bar{D}^* \) and \( D^*\bar{D}^0 \) final states at thirteen points with high accuracy \cite{7}. The measured open charm final states nearly saturate the total cross section for charm hadron production in \( e^+e^- \) annihilation in the \( \sqrt{s} \) region up to \( \sim 4.3 \) GeV. In the energy range above \( \sim 4.3 \) GeV some room for contributions to the \( \psi(4415) \) state from unmeasured channels still remains. The exclusive cross sections for charm strange meson pairs have been measured to be an order of magnitude smaller than charm meson production \cite{8}. Charm baryon-antibaryon pair production occurs at energies above 4.5 GeV.

Another motivation for studying exclusive open charm production is the existence of a mysterious family of charmonium-like states with masses above open-charm threshold and quantum numbers \( J^{PC} = 1^- \). Although these have been known for over four years, the nature of these states, found in \( e^+e^- \rightarrow \pi^+\pi^-J/\psi(2S)\gamma\)ISR processes, remains unclear. Among them are the \( Y(4260) \) state observed by BaBar \cite{9,10}, confirmed by CLEO \cite{11,12} and Belle \cite{13}; the \( Y(4350) \) discovered by BaBar \cite{14} and confirmed by Belle \cite{15}; and two structures, the

\[ Y(4008) \] and the \( Y(4660) \) seen by Belle. No clear evidence for open charm production associated with any of these states has been observed. In fact the \( Y(4260) \) peak position appears to be close to a local minimum of both the total hadronic cross section and of the exclusive cross section for \( e^+e^- \rightarrow D^0\bar{D}^+\pi^+ \) decays. The analysis is based on a data sample collected with the Belle detector at or near a center-of-mass energy of 10.58 GeV with an integrated luminosity of 695 fb\(^{-1}\) at the KEKB asymmetric-energy \( e^+e^- \) collider. No clear evidence for open charm production associated with any of these states has been observed. In fact the \( Y(4260) \) peak position appears to be close to a local minimum of both the total hadronic cross section and of the exclusive cross section for \( e^+e^- \rightarrow D^0\bar{D}^+\pi^+ \) decays. The analysis is based on a data sample collected with the Belle detector at or near a center-of-mass energy of 10.58 GeV with an integrated luminosity of 695 fb\(^{-1}\) at the KEKB asymmetric-energy \( e^+e^- \) collider.
charm production in this mass range. The analysis is based on a data sample collected with the Belle detector \cite{22} at the \(\Upsilon(4S)\) resonance and nearby continuum with an integrated luminosity of 695 fb\(^{-1}\) at the KEKB asymmetric-energy \(e^+e^-\) collider \cite{23}.

We employ the reconstruction method that was used for \(e^+e^- \rightarrow D\bar{D}\) and \(e^+e^- \rightarrow D^0\bar{D}^0\) exclusive cross section measurements \cite{2,4}. We select \(e^+e^- \rightarrow D^0\bar{D}^0\) signal events by reconstructing the \(D^0\), \(D^*\) and \(\pi^+\) mesons. In general the \(\gamma_{\text{ISR}}\) is not required to be detected; instead, its presence in the event is inferred from a peak at zero in the spectrum of recoil mass squared against the \(D^0\) mass. The square of the recoil mass is defined as:

\[
M_{\text{recoil}}^2(D^0D^*-\pi^+) = (E_{\text{cm}} - E_{D^0D^*\pi^+})^2 - p_{D^0D^*\pi^+}^2
\]

Here \(E_{\text{cm}}\) is the initial \(e^+e^-\) center-of-mass (c.m.) energy, \(E_{D^0D^*\pi^+}\) and \(p_{D^0D^*\pi^+}\) are the c.m. energy and momentum of the \(D^0D^*\pi^+\) combination, respectively. To suppress background, the c.m. mass is required to be \(|\cos(\theta_{D^0D^*\pi^+})| > 0.9\); (2) the fast \(\gamma_{\text{ISR}}\) is within the detector acceptance \(|\cos(\theta_{p_{D^0D^*\pi^+}})| < 0.9\), in which case it is required to be detected and the mass of the \(D^0D^*\pi^+\gamma_{\text{ISR}}\) combination must be greater than \(E_{\text{cm}} - 0.58\) GeV/c\(^2\). To suppress background from \(e^+e^- \rightarrow D^0D^*\pi^+2\) (2)\(\pi^+\gamma_{\text{ISR}}\) processes we exclude events that contain additional charged tracks that are not used in \(D^0\), \(D^*\) or \(\pi^+\) reconstruction.

All charged tracks are required to originate from the vicinity of the interaction point (IP); we impose the requirements \(dr < 1\) cm and \(|dz| < 4\) cm, where \(dr\) and \(|dz|\) are the impact parameters perpendicular to and along the beam direction with respect to the IP. Charged kaons are required to have a ratio of particle identification likelihood, \(P_K = \mathcal{L}_K / (\mathcal{L}_K + \mathcal{L}_\pi)\), larger than 0.6 \cite{31}. Charged tracks not identified as kaons are assumed to be pions.

\(K_S^0\) candidates are reconstructed from \(\pi^+\pi^-\) pairs with an invariant mass within 10 MeV/c\(^2\) of the \(K_S^0\) mass. The distance between the two pion tracks at the \(K_S^0\) vertex must be less than 1 cm, the transverse flight direction from the IP is required to be greater than 0.1 cm, and the angle between the \(K_S^0\) momentum direction and the flight direction in the \(x-y\) plane should be smaller than 0.1 rad.

Photons are reconstructed from showers in the electromagnetic calorimeter with energies greater than 50 MeV that are not associated with charged tracks. ISR photon candidates are required to have energies greater than 2.5 GeV. Pairs of photons are combined to form \(\pi^0\) candidates. If the mass of a \(\gamma\) pair lies within 15 MeV/c\(^2\) of the \(\pi^0\) mass, the pair is fitted with a \(\pi^0\) mass constraint and considered as a \(\pi^0\) candidate.

\(D^0\) candidates are reconstructed using five decay modes: \(K^-\pi^+, K^-\bar{K}^+, K^-\pi^-\pi^+\pi^+, K_S^0\pi^+\pi^-\) and \(K^-\pi^+\pi^0\). A \(\pm 15\) MeV/c\(^2\) mass window is used for all modes except for \(K^-\pi^+\pi^+\pi^-\) where a \(\pm 10\) MeV/c\(^2\) requirement is applied (~2.5 \(\sigma\) in each case). \(D^+\) candidates are reconstructed using \(K^-\pi^+\pi^+\) and \(K_S^0\pi^+\) decay modes \cite{22}; a \(\pm 15\) MeV/c\(^2\) mass window is used for both \(D^+\) modes. To improve the momentum resolution of \(D\) meson candidates, final tracks are fitted to a common vertex with a mass constraint on the \(D^0\) or \(D^*\) mass. \(D^*\) candidates are selected via the \(D^{*+} \rightarrow D^0\pi^+\) and \(D^{*0} \rightarrow D^0\pi^0\) (for background study) decay modes with a \(\pm 2\) MeV/c\(^2\) \(D^* - D\) mass-difference window (~3 \(\sigma\)). A mass- and vertex-constrained fit is also applied to \(D^*\) candidates.

To remove contributions from the \(e^+e^- \rightarrow D^{*+}\gamma_{\text{ISR}}\) process, we exclude \(D^0\pi^+\) combinations with invariant mass within \(\pm 5\) MeV/c\(^2\) of the nominal \(D^0\) mass.

\(D^0\), \(D^+\), \(D^{*-}\) and \(D^{*0}\) mass sidebands are selected for the background study; these are four times as large as the signal region and are subdivided into windows of the same width as the signal. To avoid signal over-subtraction, the selected \(D^0\) sidebands are shifted by \(30\) MeV/c\(^2\) (20 MeV/c\(^2\) for the \(D^0 \rightarrow K^-\pi^-\pi^+\pi^+\) mode) from the signal region. The \(D\) candidates from these sidebands are refitted to the central mass value of each window. \(D^*\) sidebands are shifted by \(4\) MeV/c\(^2\) to the higher mass side of the signal region.

The distribution of \(M_{\text{recoil}}^2(D^0D^*\pi^+)\) for the signal region in the data for \(M_{D^0D^*\pi^+} < 5.2\) GeV/c\(^2\) is shown in Fig. [1a]. A clear peak corresponding to the \(e^+e^- \rightarrow D^0D^*\pi^+\gamma_{\text{ISR}}\) process is evident around zero. The shoulder at positive values is due to the \(e^+e^- \rightarrow D^0D^*\pi^+\gamma_{\text{ISR}}\) process and is evident around zero.

The invariant-mass distribution of \(D^0D^*\pi^+\gamma_{\text{ISR}}\) combinations in the data after the requirement on \(M_{\text{recoil}}^2(D^0D^*\pi^+)\) and the polar angle distribution of \(D^0D^*\pi^+\) combinations shown in Fig. [1b], c) are typical of ISR production and are in agreement with the MC simulation. The \(M_{D^0D^*\pi^+}\) spectrum obtained after all the requirements is shown in Fig. [2].

The contribution of multiple entries after all the requirements is found to be less than \(6\%\). In such case the single \(D^0D^*\pi^+\) combination with the minimum value of \(\chi^2_{\text{tot}} = \chi^2_{\text{M(D)}} + \chi^2_{\text{M(D*)}}\) is chosen, where \(\chi^2_{\text{M(D)}}\) and \(\chi^2_{\text{M(D*)}}\) correspond to the mass fits for \(D^0\) and \(D^{*0}\) candidates.

The following sources of background are considered:

1. combinatorial background under the \(D^0(D^{*-})\) peak combined with a real \(D^{*-}(D^0)\) coming from the signal or other processes;
2. both \(D^0\) and \(D^{*-}\) are combinatorial;
3. the reflection from the processes \(e^+e^- \rightarrow D^0D^*\pi^+\pi^0\) miss:\(\gamma_{\text{ISR}}\), where the \(\pi^0\) miss is not reconstructed, including \(D^{*0} \rightarrow D^0\pi^0\) decays;
4. the reflection from the process \(e^+e^- \rightarrow \).
we use a two-dimensional sideband region, when events are selected from both the \( M_{D^0} \) and the \( M_{D^*} \) sidebands. The total contribution from the combinatorial backgrounds (1–2) is shown in Figs. 1, 2 as a hatched histogram.

Most of the background (3–4) events are suppressed by the tight requirement on \( M_{\text{recoil}}^2(D^0D^*-\pi^+) \). The remainder of background (3) is estimated directly from the data by applying a similar reconstruction method to the isospin-conjugate process \( e^+e^- \rightarrow D^0D^*-\pi^+\pi_{\text{miss}}\gamma_{\text{ISR}} \). Since there is a charge imbalance in the \( D^0\bar{D}^0\gamma_{\text{ISR}} \) final state, only events with a missing extra \( \pi_{\text{miss}} \) can contribute to the \( M_{\text{recoil}}^2(D^+D^*-\pi^+) \) signal window. To extract the level of background (3), the \( D^+D^*-\pi^+ \) mass spectrum is rescaled according to the ratio of \( D^- \) and \( D^0 \) reconstruction efficiencies and an isospin factor of 1/2. A negligibly small contribution of background (3) is found: only one event with \( M_{D^+D^-\pi^+} < 5.2 \text{ GeV}/c^2 \). Uncertainties in this estimate are included in the systematic error. The remainder of background (4) is estimated from the data assuming isospin symmetry. We measure the process \( e^+e^- \rightarrow D^0\bar{D}^0\pi^+\pi^-\gamma_{\text{ISR}} \) \( (D^0 \rightarrow D^0\pi^0) \) by applying a similar reconstruction method. Only three events with \( M_{D^0D^*-\pi^+} < 5.2 \text{ GeV}/c^2 \) are found in the data. Thus the contribution of background (4) is also found to be negligibly small; uncertainties in this estimate are included in the systematic error.

The contribution of background (5) is determined from the data using fully reconstructed \( e^+e^- \rightarrow D^0D^*-\pi^+\pi^0 \) events including the reconstruction of an energetic \( \pi^0 \). Only one event with \( M_{D^0D^*-\pi^+} < 5.2 \text{ GeV}/c^2 \) and \( M_{D^0D^*-\pi^+\pi^0} > 10 \text{ GeV}/c^2 \) is found in the data. Assuming a uniform \( \pi^0 \) polar angle distribution, this background contribution to the \( |\cos(\theta_{D^0D^*-\pi^+})| > 0.9 \) signal sub-sample (case 1) is 1 event/9\( \eta_{\pi^0} \sim 0.2 \) events in the entire \( M_{D^0D^*-\pi^+} \) mass range, where \( \eta_{\pi^0} \) is the \( \pi^0 \) reconstruction efficiency. The probability of \( \pi^0 \rightarrow \gamma \) misidentification due to asymmetric \( \pi^0 \rightarrow \gamma \) decays is also estimated to be \( \ll 1 \). Thus the contribution of background (5) is found to be negligibly small; uncertainties in this estimate are included in the systematic error.

The \( e^+e^- \rightarrow D^0D^*-\pi^+ \) cross section is extracted from the background subtracted \( D^0D^*-\pi^+ \) mass distribution

\[
\sigma(e^+e^- \rightarrow D^0D^*-\pi^+) = \frac{dN/dm}{\eta_{\text{tot}}dL/dm},
\]

where \( m \equiv M_{D^0D^*-\pi^+}, \) \( dN/dm \) is the mass spectrum obtained without corrections for resolution and higher-order radiation, \( \eta_{\text{tot}} \) is the total efficiency, and the factor \( dL/dm \) is the differential ISR luminosity \([33]\). The total efficiency determined by MC simulation grows quadratically with energy from 0.0077% near threshold to 0.036% at 5.2 GeV/c^2. The resulting \( e^+e^- \rightarrow D^0D^*-\pi^+ \) exclusive cross section averaged over the bin width is shown in Fig. 3 with statistical uncertainties only. Since the bin width is much larger than the \( M_{D^0D^*-\pi^+} \) resolution, which varies from \( \sim 3 \text{ MeV}/c^2 \) around threshold to \( \sim 6 \text{ MeV}/c^2 \) at \( M_{D^0D^*-\pi^+} = 5.2 \text{ GeV}/c^2 \), no correction
for resolution is applied.

The systematic errors for the \( \sigma(e^+e^- \rightarrow D^0D^{*-}\pi^+) \) measurement are summarized in Table I. The system-

| Source                  | Error [%] |
|-------------------------|-----------|
| Background subtraction  | ±3        |
| Cross section calculation| ±6        |
| \( B(D) \)             | ±3        |
| Reconstruction          | ±7        |
| Kaon identification     | ±2        |
| Total                   | ±10       |

atic errors associated with the background (1–2) subtraction are estimated to be 2% due to the uncertainty in the scaling factors for the sideband subtractions. This is estimated from fits to the \( M_{D^0} \) and \( M_{D^{*-}} \) distributions in the data that use different signal and background parameterizations. Uncertainties in backgrounds (3–5) are estimated conservatively to be each smaller than 1% of the signal. The systematic error ascribed to the cross section calculation includes a 1.5% error on the differential luminosity and a 6% error in the total efficiency function. Another source of systematic errors is the uncertainties in track and photon reconstruction efficiencies (1% per track, 1.5% per photon and 5% per \( K_S^0 \)). Other contributions come from the uncertainty in the identification efficiency and the absolute \( D^0 \) and \( D^{*-} \) branching fractions. The final contribution by an\( \epsilon \) systematic uncertainty is 10%.

We perform a likelihood fit to the \( M_{D^0D^{*-}\pi^+} \) distribution where we parameterize a possible \( \psi(4415) \) signal contribution by an s-wave relativistic Breit-Wigner (RBW) function with a free normalization. We use PDG values to fix its mass and total width. To take a non-resonant \( D^0D^{*-}\pi^+ \) contribution into account we use a threshold function \( \sqrt{m_{D^0} - m_{D^{*-}} + m_{\pi^+}} \) with a free normalization. Finally, the sum of the signal and non-resonant functions is multiplied by a mass-dependent second-order polynomial efficiency function and differential ISR luminosity.

The fit yields \( 14.4 \pm 6.2 \text{(stat.)}^{+1.0}_{-0.95} \text{(sys.)} \) signal events for the \( \psi(4415) \) state. The statistical significance for the \( \psi(4415) \) signal is determined to be 3.1\( \sigma \) from the quantity \( -2 \ln(L_0/L_{\text{max}}) \), where \( L_{\text{max}} \) is the maximum likelihood returned by the fit, and \( L_0 \) is the likelihood with the amplitude of the RBW function set to zero. The goodness of the fit is \( \chi^2/n.d.f = 1.17 \). The systematic errors of the fit yield are obtained by varying the mass and total width within their uncertainties, histogram bin size and the parameterization of the background function and efficiency.

We calculate the peak cross section for the \( e^+e^- \rightarrow \psi(4415) \rightarrow D^0D^{*-}\pi^+ \) process at \( E_{\text{c.m.}} = m_{\psi(4415)} \) from the amplitude of the RBW function in the fit to be \( \sigma(e^+e^- \rightarrow \psi(4415)) \times B(\psi(4415) \rightarrow D^0D^{*-}\pi^+) < 0.76 \) nb at the 90% C.L. Using \( \sigma(e^+e^- \rightarrow \psi(4415)) = 12\pi/m^2_{\psi(4415)} \times (B_{\text{ee}}) \) and PDG values of the \( \psi(4415) \) mass, full width and electron width, we found \( B_{\text{ee}} \times B(\psi(4415) \rightarrow D^0D^{*-}\pi^+) < 9.9 \times 10^{-6} \) at the 90% C.L. and \( B(\psi(4415) \rightarrow D^0D^{*-}\pi^+) < 10.6% \) at the 90% C.L. All presented upper limit values include systematic uncertainties. For illustration we include the corresponding fit function on the cross section distribution plot shown in Fig. 3.

To obtain limits on the decays \( X \rightarrow D^0D^{*-}\pi^+ \), where \( X \) denotes \( Y(4260), Y(4350), Y(4660) \) or \( X(4630) \) states, we perform 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 we use 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. The sum of the signal and non-resonant functions is multiplied by the mass-dependent second-order polynomial efficiency function and differential ISR luminosity.

FIG. 3: The exclusive cross section for \( e^+e^- \rightarrow D^0D^{*-}\pi^+ \) 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.

The significances for the \( Y(4260), Y(4350), Y(4660) \) and \( X(4630) \) signal are found to be 0.9\( \sigma \), 1.4\( \sigma \), and 1.8\( \sigma \), respectively. The calculated upper limits (at the 90% C.L.) on the peak cross sections for \( e^+e^- \rightarrow X \rightarrow D^0D^{*-}\pi^+ \) processes at \( E_{\text{c.m.}} = m_X \) are presented in Table II. Using fixed values of \( X \) masses and full widths we obtain upper limits on \( B_{\text{ee}} \times B(X \rightarrow D^0D^{*-}\pi^+) \) at the 90% C.L. Finally, for the \( Y(4260) \) state we estimate the upper limit on \( B(Y(4260) \rightarrow D^0D^{*-}\pi^+)/B(Y(4260) \rightarrow \pi^+\pi^-J/\psi) \) at the 90% C.L.
using $\mathcal{B}_c \times \Gamma(\pi^+\pi^-J/\psi)$ \cite{34}. For the $Y(4350)$ and $Y(4660)$ states we calculate $\mathcal{B}(X \to D^0D^{*-}\pi^+)/\mathcal{B}(X \to \pi^+\pi^-J/\psi(2S))$ at the 90% C.L. taking into account $\mathcal{B}_c \times \Gamma(\pi^+\pi^-J/\psi(2S))$ \cite{33}. All upper limits presented in Table \ref{tab:limits} are determined by choosing the maximum signal amplitudes that emerge from: varying masses and widths of the $X$ states within their uncertainties; varying the histogram bin size; and changing the parameterizations of the background & efficiency functions.

To estimate the effects of possible interference between final states we 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. We found two solutions both with $\chi^2/n.d.f. = 1.28$; the interference is constructive for one solution and destructive for the other. From the fit with destructive interference we find an upper limit on the peak cross section for $e^+e^- \to \psi(4415) \to D^0D^{*-}\pi^+$ process to be $<(e^+e^- \to \psi(4415)) \times \mathcal{B}(\psi(4415) \to D^0D^{*-}\pi^+) < 1.93$ nb at the 90% C.L.

In addition we 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. We found four solutions for each fit with similar goodness-of-fit ($\chi^2/n.d.f.$ = 1.39, 1.23, 1.39 & 1.21) and obtained the upper limits on the peak cross sections for $e^+e^- \to X \to D^0D^{*-}\pi^+$ process to be $\sigma(e^+e^- \to X) \times \mathcal{B}(X \to D^0D^{*-}\pi^+) < 1.44, 1.92, 1.38$ and 0.98 nb at the 90% C.L. for $Y(4260), Y(4350), Y(4660)$ and $X(4630)$, respectively.

In summary, we report the first measurement of the $e^+e^- \to D^0D^{*-}\pi^+$ exclusive cross section over the center-of-mass energy range from 4.0 GeV to 5.2 GeV. We calculate an upper limit on the peak cross section for the $e^+e^- \to \psi(4415) \to D^0D^{*-}\pi^+$ process at $E_{c.m.} = m_{\psi(4415)}$ to be 0.76 nb at the 90% C.L. The values of the amplitude of the $Y(4260)$, $Y(4350)$, $Y(4660)$ and $X(4630)$ signal function obtained in the fit to the $M_{D^0D^{*-}\pi^+}$ spectrum are found to be consistent with zero within errors. We see no evidence for $Y(4260) \to D^0D^{*-}\pi^+$ decays as predicted by hybrid models and obtain the upper limit $\mathcal{B}(Y(4260) \to D^0D^{*-}\pi^+)/\mathcal{B}(Y(4260) \to \pi^+\pi^-J/\psi) < 9$ at the 90% C.L.

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

| $\sigma(e^+e^- \rightarrow X) \times B(X \rightarrow D^0D^{*-}\pi^+)$, [nb] | $Y(4260)$ | $Y(4350)$ | $Y(4660)$ | $X(4630)$ |
|-------------------------------------------------|----------|----------|----------|----------|
| $B_{ee} \times B(X \rightarrow D^0D^{*-}\pi^+)$, [×10^{-6}] | 0.36 | 0.55 | 0.25 | 0.45 |
| $B(X \rightarrow D^0D^{*-}\pi^+)/B(X \rightarrow \pi^+\pi^-J/\psi)$ | 9 | 8 | 10 | 66 |

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