$e^+e^- \text{ to charm cross sections via ISR}$

Galina Pakhlova
ITEP, Belle collaboration
Motivation to study cross sections $e^+e^- \rightarrow \text{open charm}$

Parameters of the $J^{PC} = 1^{-+}$ conventional charmonia

$\psi(3770), \psi(4040), \psi(4160), \psi(4415)$

$M, \Gamma_{\text{tot}}, \Gamma_{ee}$ remain quite uncertain and model dependent

To fix the resonance parameters we need to know their decay channels to take into account their interference:

- non-resonant contribution
- many open charm thresholds
All possible two-body decays of $\psi(3770)$, $\psi(4040)$, $\psi(4160)$, $\psi(4415)$ are included

$$\psi(3770) \Rightarrow D\bar{D};$$
$$\psi(4040) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, \bar{D}D^*, D_s\bar{D}_s;$$
$$\psi(4160) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, \bar{D}D^*, D_s\bar{D}_s, D_s\bar{D}^*_s;$$
$$\psi(4415) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, \bar{D}D^*, D_s\bar{D}_s, D_s\bar{D}^*_s, D_s^*\bar{D}_s^*.$$

**Significant effect of interference:** model dependent!

To reduce model dependence we need to measure exclusive cross sections to open charm final states.

<table>
<thead>
<tr>
<th>$\psi$</th>
<th>$M$, MeV</th>
<th>$\Gamma_{tot}$, MeV</th>
<th>$\Gamma_{ee}$, keV</th>
<th>$\delta$, deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\psi(3770)$</td>
<td>$3772.92 \pm 0.3$</td>
<td>$27.3 \pm 1.0$</td>
<td>$0.265 \pm 0.018$</td>
<td>PDG09</td>
</tr>
<tr>
<td></td>
<td>$3772.0 \pm 1.9$</td>
<td>$30.4 \pm 8.5$</td>
<td>$0.22 \pm 0.05$</td>
<td>0</td>
</tr>
<tr>
<td>$\psi(4040)$</td>
<td>$4039 \pm 1$</td>
<td>$80 \pm 10$</td>
<td>$0.86 \pm 0.07$</td>
<td>PDG09</td>
</tr>
<tr>
<td></td>
<td>$4039.6 \pm 4.3$</td>
<td>$84.5 \pm 12.3$</td>
<td>$0.83 \pm 0.20$</td>
<td>$130 \pm 4.6$</td>
</tr>
<tr>
<td>$\psi(4160)$</td>
<td>$4153 \pm 3$</td>
<td>$103 \pm 8$</td>
<td>$0.83 \pm 0.07$</td>
<td>PDG09</td>
</tr>
<tr>
<td></td>
<td>$4191.7 \pm 6.5$</td>
<td>$71.8 \pm 12.3$</td>
<td>$0.48 \pm 0.22$</td>
<td>$293 \pm 5.7$</td>
</tr>
<tr>
<td>$\psi(4415)$</td>
<td>$4421 \pm 4$</td>
<td>$62 \pm 20$</td>
<td>$0.58 \pm 0.07$</td>
<td>PDG09</td>
</tr>
</tbody>
</table>
### Potential models & ψ states

#### Mass spectrum
- In general agreement with data

#### Open charm decays
- via nonperturbative gluodynamics
  - difficult to compute
  - good probes of strong QCD
- Only inclusive measurements

#### More theoretical and experimental efforts are required

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**Table:**

<table>
<thead>
<tr>
<th>State</th>
<th>Mode</th>
<th>PDG09</th>
<th>( ^3P_0 )</th>
<th>( \rho K \rho )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \psi(3770) )</td>
<td>( \psi(3770) )</td>
<td>27.3 ± 1.0</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td>( \psi(4040) )</td>
<td>( \psi(4040) )</td>
<td>0.1</td>
<td>2.3</td>
<td>25</td>
</tr>
<tr>
<td>( \psi(4040) )</td>
<td>( \psi(4040) )</td>
<td>25</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>( \psi(4160) )</td>
<td>( \psi(4160) )</td>
<td>12</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>( \psi(4415) )</td>
<td>( \psi(4415) )</td>
<td>27</td>
<td>2.6</td>
<td>6</td>
</tr>
<tr>
<td>( \psi(4415) )</td>
<td>( \psi(4415) )</td>
<td>62 ± 20</td>
<td>60</td>
<td>?</td>
</tr>
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</table>

E. Swanson, Phys. Reports 429(2006)

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**Table:**

<table>
<thead>
<tr>
<th>State</th>
<th>PDG09</th>
<th>GI85</th>
<th>F91</th>
<th>EQ94</th>
<th>ZVR95</th>
<th>EFG03</th>
<th>BGS05</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1^3S_1 ) ( J/\psi )</td>
<td>3096.919 ± 0.011</td>
<td>3098</td>
<td>3104</td>
<td>3097</td>
<td>3100</td>
<td>3096</td>
<td>3090</td>
</tr>
<tr>
<td>( 2^3S_1 ) ( \psi(2S) )</td>
<td>3686.09 ± 0.04</td>
<td>3676</td>
<td>3670</td>
<td>3686</td>
<td>3730</td>
<td>3686</td>
<td>3672</td>
</tr>
<tr>
<td>( 1^3D_1 ) ( \psi(3770) )</td>
<td>3772.92 ± 0.35</td>
<td>3819</td>
<td>3840</td>
<td>3800</td>
<td>3798</td>
<td>3785</td>
<td></td>
</tr>
<tr>
<td>( 3^3S_1 ) ( \psi(4040) )</td>
<td>4039 ± 1</td>
<td>4100</td>
<td></td>
<td>4180</td>
<td>4088</td>
<td>4072</td>
<td></td>
</tr>
<tr>
<td>( 2^3D_1 ) ( \psi(4160) )</td>
<td>4153 ± 3</td>
<td>4194</td>
<td></td>
<td>4142</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( 4^3S_1 ) ( \psi(4415) )</td>
<td>4421 ± 4</td>
<td>4450</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phi to Psi 2009

Galina Pakhlova
One more reason to study $e^+e^-$ to charm cross sections

The nature of the charmoniumlike $1^{--}$ family with masses above open charm threshold remains unclear
  - Their properties are inconsistent with conventional charmonium
$e^+e^- \rightarrow J/\psi \pi^+\pi^- \gamma_{\text{ISR}}$

**Y(4260) ... Y(4008)?**

- **First Y(4260)**
  - $8 \sigma$
  - 233 fb$^{-1}$

- **Y(4260)**
  - $454 \text{ fb}^{-1}$
  - 344 $\pm$ 39 ev
  - 7.5 $\pm$ 0.9 $\pm$ 0.8

- **Y(4008)**
  - arXiv:0808.1543
  - NEW
  - Absence of open charm production is inconsistent with conventional charmonium ($< 0.7$ 90% CL)

**Solution 1**

- **Y(4260)**

**Solution 2**

- **Y(4008)**

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**Confirmed**

- **PRD 74,091104R (2006)**
  - 5.4$\sigma$
  - 13.3 fb$^{-1}$

- **PR 96,162003 (2006)**
  - 11$\sigma$

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**Phi to Psi 2009**

Galina Pakhlova
Absence of open charm production is inconsistent with conventional charmonium.
Y states vs inclusive cross section $e^+e^-\rightarrow\text{hadrons}$

$$R(s) = \frac{\sigma(e^+e^-\rightarrow\text{hadrons})}{\sigma(e^+e^-\rightarrow\mu^+\mu^-)} - R_{uds}$$

- Peak positions for $M(J/\psi\pi\pi)$ & $M(\psi(2S)\pi\pi)$ significantly different
- $Y(4260)$ mass corresponds to dip in inclusive cross section

if $R_{uds}=2.285\pm0.03$ Durham Data Base

BES(2002)
Cleo_c(2008)

Phi to Psi 2009

Galina Pakhlova
Potential models & Y states

No room for Y states among conventional $1^{--}$ charmonium

S.Godfrey and N.Isgur PRD32,189 (1985)

$3^3S_1 = \psi(4040)$

$2^3D_1 = \psi(4160)$

$4^3S_1 = \psi(4415)$

masses of predicted

$3^3D_1$ ($4520$)

$5^3S_1$ ($4760$)

$4^3D_1$ ($4810$)

are higher (lower)
Interpretations of Y states

- **Y(4360) & Y(4660) are conventional charmonia with shifted masses**
  - \( Y(4360) = 3^3D_1 \), \( Y(4660) = 5^3S_1 \)
  - \( 4^3S_1 \neq \psi(4415) = 4^3D_1(4661); Y(4360)=4^3S_1(4389) \), \( Y(4660)=5^3S_1(4614) \) or \( 4^3D_1(4661) \)

- **Charmonium hybrids**
  - *Zhu S.L.; Close F.E.; Kou E. and Pene O.*
  - The lightest hybrid is expected by LQCD around 4.2 GeV
  - The dominant decays \( Y(4260) \rightarrow D(*)D(*)\pi \), via virtual \( D^{**} \)

- **Hadro-charmonium**
  - Specific charmonium state “coated” by excited light-hadron matter
  - *S.Dubinskiy, M.B.Voloshin, A.Gorsky*

- **Multiquark states**
  - \([cq][cq]\) tetraquark
  - \( DD_1 \) or \( D^*D^0 \) molecules
  - *Maiani L., Riquer V., Piccinini F., Polosa A.D.*
  - *Swanson E.; Rosner J.L., Close F.E.*

- **Heavy meson hadronic molecules**
  - \( Y(4660) \) is \( \psi(2S)f_0(980) \) bound state
  - *F.K.Gou, C.Hanhart, S.Krewald, U.G.Meissner*

- **S-wave charm meson thresholds**
  - *Lui X.*
Use ISR to measure open charm exclusive final states

ISR at B factories
- Quantum numbers of final states are fixed $J^{PC} = 1--$
- Continuous ISR spectrum:
  - access to the whole $\sqrt{s}$ interval
- $\alpha_{em}$ suppression compensated by huge luminosity
  - comparable sensitivity to energy scan (CLEOc, BES)
$e^+e^- \rightarrow \text{DD}$ via ISR with full reconstruction

- **Full reconstruction** of hadronic part
- ISR photon detection is not required
  - but used if it is in the detector acceptance
- Translate measured DD mass spectrum to cross section

\[ s = E_{\text{cm}}^2 - 2E_{\gamma}E_{\text{cm}} \]
• Broad structure around 3.9 GeV
  • in qualitative agreement with coupled-channel model?
• Some structure at 4.0-4.2 GeV
  • Statistics are small …$\psi(4040)$? $\psi(4160)$?
• Hint of $\psi(4415)$
$e^+e^- \rightarrow D(\ast)D^*$ via ISR with partial reconstruction

**DD* & D*D**
- **D* partial reconstruction**
  - increase eff $\sim 10\text{-}20$ times
- Detection of ISR photon
- Translate measured mass recoil against $\gamma_{\text{ISR}} \equiv D(\ast)D^*$ mass spectrum to cross section

$\gamma$
Exclusive $e^+e^- \rightarrow D^{(*)}D^*$ cross-sections

Systematic errors $\approx$ statistical errors

- $D^*D^*$
  - complicated shape of cross section
- $DD^*$
  - clear dip at $M(D^*D^*) \sim 4260$ GeV (similar to inclusive R)
- $DD^*$
  - broad peak at threshold (shifted relative to 4040 GeV)

New BaBar: $e^+e^- \rightarrow D(\ast)D^*$

- Full reconstruction of hadronic part
- Both charged and neutral final states
- Fit by sum of $\psi$ states with fixed masses & widths from PDG (due to limited statistics)

No evidence is found for $Y(4260) \rightarrow DD, DD^*, D^*D^*$

\[
\frac{\mathcal{B}(Y(4260) \rightarrow D^* \bar{D})}{\mathcal{B}(Y(4260) \rightarrow J/\psi \pi^+ \pi^-)} < 34
\]

\[
\frac{\mathcal{B}(Y(4260) \rightarrow D^* \bar{D}^*)}{\mathcal{B}(Y(4260) \rightarrow J/\psi \pi^+ \pi^-)} < 40
\]

Br ratios seem to disagree with potential models …

… uncertainties are too large

<table>
<thead>
<tr>
<th>Ratio</th>
<th>measurement</th>
<th>$^3P_0$</th>
<th>$C^3$ and $\rho K_\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) $\mathcal{B}(\psi(4040) \rightarrow D\bar{D})/\mathcal{B}(\psi(4040) \rightarrow D^* \bar{D})$</td>
<td>$0.24 \pm 0.05 \pm 0.12$</td>
<td>0.003</td>
<td>0.14 [14]</td>
</tr>
<tr>
<td>2) $\mathcal{B}(\psi(4040) \rightarrow D^* \bar{D}^<em>)/\mathcal{B}(\psi(4040) \rightarrow D^</em> \bar{D})$</td>
<td>$0.18 \pm 0.14 \pm 0.03$</td>
<td>1.0</td>
<td>0.29 [14]</td>
</tr>
<tr>
<td>3) $\mathcal{B}(\psi(4160) \rightarrow D\bar{D})/\mathcal{B}(\psi(4160) \rightarrow D^* \bar{D}^*)$</td>
<td>$0.02 \pm 0.03 \pm 0.02$</td>
<td>0.46</td>
<td>0.08 [6]</td>
</tr>
<tr>
<td>4) $\mathcal{B}(\psi(4160) \rightarrow D^* \bar{D})/\mathcal{B}(\psi(4160) \rightarrow D^* \bar{D}^*)$</td>
<td>$0.34 \pm 0.14 \pm 0.05$</td>
<td>0.011</td>
<td>0.16 [6]</td>
</tr>
<tr>
<td>5) $\mathcal{B}(\psi(4400) \rightarrow D\bar{D})/\mathcal{B}(\psi(4400) \rightarrow D^* \bar{D}^*)$</td>
<td>$0.14 \pm 0.12 \pm 0.03$</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>6) $\mathcal{B}(\psi(4400) \rightarrow D^* \bar{D})/\mathcal{B}(\psi(4400) \rightarrow D^* \bar{D}^*)$</td>
<td>$0.17 \pm 0.25 \pm 0.03$</td>
<td>0.14</td>
<td></td>
</tr>
</tbody>
</table>
**Belle vs BaBar: $\sigma(e^+e^- \rightarrow D(\ast)D(\ast))$**


**New**


**Sum of two body open charm final states**

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**Belle & BaBar results are in very good agreement**

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_Phi to Psi 2009_  
_Galina Pakhlova_
Three-body final states

$D^0\ D^{(*)-}\pi^+$

- Full reconstruction of hadronic part
- ISR photon detection is not required
  - but used if it is in the detector acceptance
- Translate measured $DD^{(*)}\pi$ mass spectrum to cross section
Resonant structure in $\psi(4415) \rightarrow D^0 D^- \pi^+$

$M(D^0\pi^+) \text{ vs } M(D^-\pi^+)$ from $\psi(4415)$ region

- Clear $D^*_2(2460)$ signals
- No non-$D^*_2(2460)$ contribution

$M = 4411 \pm 7 \text{ MeV}$
$\Gamma_{\text{tot}} = 77 \pm 20 \text{ MeV}$
$N_{\text{ev}} = 109 \pm 25$

Consistent with BES,
PDG06, Barnes et al

$\sigma(e^+e^-\rightarrow\psi(4415)) \times Br(\psi(4415)\rightarrow DD^*_2(2460)) \times Br(D^*_2(2460)\rightarrow D\pi) = (0.74 \pm 0.17 \pm 0.07) \text{ nb}$

$Br(\psi(4415)\rightarrow D(D\pi)_{\text{non } D^*_2(2460)}/Br(\psi(4415)\rightarrow DD^*_2(2460)) < 0.22$
Partial reconstruction with anti-proton tag

Reconstruct $\Lambda_c^+$

Use antiproton tag from inclusive $\Lambda_c^- \rightarrow p^- X$

$\text{Br}(\Lambda_c^+ \rightarrow pX) = (50 \pm 16)\%$

- combinatorial background suppressed by $\approx 10$

Detect the high energy ISR photon

Translate measured mass recoil against $\gamma_{\text{ISR}} \equiv \Lambda_c^+ \Lambda_c^-$ mass spectrum to cross section
partial reconstruction with $\bar{p}$ tag

- Clear peak in $M_{\text{rec}}(\Lambda_c^+\gamma_{\text{ISR}})$ distribution at $\Lambda_c$ mass.

At mass > 2.5 GeV/$c^2$
- Contributions from $\Lambda_c^+\Lambda_c^-\pi^0$
  - Could proceed via $\Lambda_c^+\Sigma^-$; violates isospin and should be strongly suppressed
- And $\Lambda_c^+\Lambda_c^-\pi\pi$
  - Could proceed via $\Lambda_c^+\Lambda_c(2595)^-$, $\Lambda_c^+\Lambda_c(2625)^-$, $\Lambda_c^+\Lambda_c(2765)^-$, $\Lambda_c^+\Lambda_c(2880)^-$

- Total reflection contributions < 5% (included in systematics)
- Look at $M_{\text{recoil}}(\gamma_{\text{ISR}}) \equiv$ Mass spectra of $\Lambda_c^+\Lambda_c^-$

$e^+e^-\rightarrow\Lambda_c^+\Lambda_c^-\gamma_{\text{ISR}}$

$X(4630)$

8.2 $\sigma$

670 fb$^{-1}$

Interpretations for X(4630)

- No peak-like structure

<table>
<thead>
<tr>
<th>State</th>
<th>M, MeV/c²</th>
<th>Γ_{tot}, MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>X(4630)</td>
<td>4634^{+8+5}_{-7-8}</td>
<td>92^{+40+10}_{-24-21}</td>
</tr>
<tr>
<td>Y(4660)</td>
<td>4664 ± 11 ± 5</td>
<td>48 ± 15 ± 3</td>
</tr>
</tbody>
</table>

- X(4630) = Y(4660) = charmonium state 5^{3}S_{1} or 4^{3}D_{1}
  J.Segovia, A.M.Yasser, D.R.Entem, F.Fernandez

- Charmonium state 6^{3}S_{1} B.Q.Li and K.T.Chao

- Threshold effect E.Beveren, G.Rupp

- Y(4660) = ψ(2S)f_{0}(980) bound state
  F.K.Gou, C.Hanhart, S.Krewald, U.G.Meissner

- Point-like baryons R.B.Baldini, S.Pacetti, A.Zallo

- X(4630) = Y(4660) D.V.Bugg

- X(4630) = Y(4660) = tetraquark D.Ebert, R.N.Fausov, V.O. Galkin

- Dibaryon threshold effect?
  • Like in B→pΛπ, J/ψ→γpp

- e^+e^→Λ_c^+Λ_c^-γ_{ISR}

- M(Λ_c^+Λ_c^-) 4.5 < M < 5.5 GeV/c²

- BABAR, DM2

- ce→ΛΛ via ISR

- ce→pp via ISR
Searching for hybrids via their favorite decay modes
$e^+e^- \rightarrow D^0D^{*-}\pi^+$ at $\sqrt{s} \sim 4$–5 GeV via ISR

- Full reconstruction
- No extra tracks
- Detection of $\gamma_{\text{ISR}}$ is not required
  - if $\gamma_{\text{ISR}}$ is detected
  - $M(D^0D^{*-}\pi^+\gamma_{\text{ISR}})$ is required $\sim E_{\text{cm}}$

**Combinatorial bgs are estimated from sidebands $D$ and $D^*$**

**Other bgs are small and taken into account**

**Small efficiency at threshold**

arXiv:0908.0231

670 fb$^{-1}$
in $e^+e^- \rightarrow D^0 D^{*-}\pi^+ \gamma_{\text{isr}}$

$D_1(2420)^0 \rightarrow D^{*-}\pi^+ \leftarrow D_2(2460)^0$

$D^0 D^{*-}\pi^+ \leftrightarrow D^0 D_1(2420)^0 \; \& \; D^0 D_2(2460)^0$

e$^+e^- \rightarrow \psi(4415) \rightarrow D^0 D_2(2460)^0 \rightarrow D^0 D^{-}\pi^+$ is measured

**Main problem is to separate $D^0 D_1(2420)^0$ from $D^0 D_2(2460)^0$**

- $D_1(2420)^0 : \Gamma_{\text{tot}} = 20.4 \pm 1.7$ MeV
- $D_2(2460)^0 : \Gamma_{\text{tot}} = 43 \pm 4$ MeV (PDG08)

Both $D D_1$ & $D^*D_2$ are seen ...

**but the statistics is not enough to study their mass spectra!**

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**Phi to Psi 2009**

**Galina Pakhlova**
New Exclusive $e^+e^-\rightarrow D^0D^{*-}\pi^+$ cross-section

- No evident structures: only UL’s!
- Baseline fit:
  - RBW for $\psi(4415)$ & threshold function for non-resonant contribution without interference between amplitudes
- To obtain limits on $X\rightarrow D^0D^{*-}\pi^+$,
  - $X=Y(4260), Y(4360), Y(4660), X(4630)$
  - perform four fits each with one of the $X$ states, $\psi(4415)$ and non-resonant contribution
- Fix masses and total widths from PDG

Interference could increase these UL’s by factors of 2–4 depending on the final state (for destructive solutions)

\[
\sigma(e^+e^-\rightarrow\psi(4415)) \times \text{Br}(\psi(4415)\rightarrow D^0D^{*-}\pi^+) < 0.76 \text{ nb at 90\% CL}
\]
\[
\text{Br}(\psi(4415)\rightarrow D^0D^{*-}\pi^+) < 10.6 \% \text{ at 90\% CL}
\]

### UL at 90\% CL

<table>
<thead>
<tr>
<th></th>
<th>$Y(4260)$</th>
<th>$Y(4350)$</th>
<th>$Y(4660)$</th>
<th>$X(4630)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(e^+e^-\rightarrow X) \times B(X \rightarrow D^0D^{*-}\pi^+)$, [nb]</td>
<td>0.36</td>
<td>0.55</td>
<td>0.25</td>
<td>0.45</td>
</tr>
<tr>
<td>$B_{ee} \times B(X \rightarrow D^0D^{*-}\pi^+)$, $[\times 10^{-6}]$</td>
<td>0.42</td>
<td>0.72</td>
<td>0.37</td>
<td>0.66</td>
</tr>
<tr>
<td>$B(X \rightarrow D^0D^{*-}\pi^+)/B(X \rightarrow \pi^+\pi^- J/\psi)$</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B(X \rightarrow D^0D^{*-}\pi^+)/B(X \rightarrow \pi^+\pi^- \psi(2S))$</td>
<td></td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

**Phi to Psi 2009**  
**Galina Pakhlova**
Contribution to the inclusive cross section
Y states vs exclusive cross sections

- Y(4008) mass coincides with DD* peak
- Y(4260) mass corresponds to dip in D*D* cross section
- Around Y(4360) mass all measured cross sections are smooth
- Y(4660) mass is close to $\Lambda_c^+\Lambda_c^-$ peak
- Significant “peak-like” enhancement near 3.9 GeV in $e^+e^-$→DD

Coupled channel effect? or something else?

Sum of all exclusive contributions

Only small room for unaccounted contributions

Limited inclusive data above 4.5 GeV

- Charm strange final states
- Charm baryons final states

Galina Pakhlova
Complicated thresholds behaviour

Need improved model to describe standard and to search for new states

E. Eichten - Fermilab
Phi to Psi 2009
6th International Workshop on Heavy Quarkonia - Nara, Japan - Dec. 2-5, 2008
Galina Pakhlova
In conclusion
As Six exclusive open charm final states are measured $DD, D^*D, D^*D^*, DD\pi, DD^*\pi, \Lambda_c\Lambda_c$

and Their sum is close to $e^+e^- \rightarrow \text{hadrons}$

Belle & BaBar & Cleo cross section measurements are nicely consistent with each other

... it’s time to describe these data by realistic common fit and to extract realistic parameters of $\psi$ states ...

In charm meson final states no evident peaks corresponding to members of charmonium-like family are found!

Theoretical efforts to describe charm components of inclusive cross section are kindly requested!

$\Lambda_c\Lambda_c$
- enhancement at threshold, quantum numbers, mass and width are consistent with $Y(4660)$
- Various interpretations

All presented cross sections can be found in Durham Data Base
Thank you!