

$\psi(4415)$ 

$$J^{PC} = 0^-(1^{--})$$

### $\psi(4415)$ MASS

| VALUE (MeV)   | DOCUMENT ID           | TECN     | COMMENT  |
|---|-----------------------|----------|--|
| <b>4421 ± 4 OUR ESTIMATE</b>  |                       |          |  |
| <b>4415.1 ± 7.9</b>   | <sup>1</sup> ABLIKIM  | 08D BES2 | $e^+e^- \rightarrow$ hadrons                   |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                       |          |  |
| 4412 ± 15   | <sup>2</sup> MO       | 10 RVUE  | $e^+e^- \rightarrow$ hadrons                   |
| 4411 ± 7  | <sup>3</sup> PAKHLOVA | 08A BELL | 10.6 $e^+e^- \rightarrow D^0 D^- \pi^+ \gamma$ |
| 4425 ± 6  | <sup>4</sup> SETH     | 05A RVUE | $e^+e^- \rightarrow$ hadrons                   |
| 4429 ± 9  | <sup>5</sup> SETH     | 05A RVUE | $e^+e^- \rightarrow$ hadrons                   |
| 4417 ± 10   | BRANDELIK             | 78C DASP | $e^+e^-$                                       |
| 4414 ± 7  | SIEGRIST              | 76 MRK1  | $e^+e^-$                                       |

<sup>1</sup> Reanalysis of data presented in BAI 02C. From a global fit over the center-of-mass energy region 3.7–5.0 GeV covering the  $\psi(3770)$ ,  $\psi(4040)$ ,  $\psi(4160)$ , and  $\psi(4415)$  resonances. Phase angle fixed in the fit to  $\delta = (234 \pm 88)^\circ$ .

<sup>2</sup> Reanalysis of data presented in BAI 00 and BAI 02C. From a global fit over the center-of-mass energy 3.8–4.8 GeV covering the  $\psi(4040)$ ,  $\psi(4160)$  and  $\psi(4415)$  resonances and including interference effects.

<sup>3</sup> Systematic uncertainties not estimated.

<sup>4</sup> From a fit to Crystal Ball (OSTERHELD 86) data.

<sup>5</sup> From a fit to BES (BAI 02C) data.

### $\psi(4415)$ WIDTH

| VALUE (MeV)   | DOCUMENT ID           | TECN     | COMMENT  |
|---|-----------------------|----------|--|
| <b>62 ± 20 OUR ESTIMATE</b>   |                       |          |  |
| <b>71.5 ± 19.0</b>  | <sup>6</sup> ABLIKIM  | 08D BES2 | $e^+e^- \rightarrow$ hadrons                   |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                       |          |  |
| 118 ± 32  | <sup>7</sup> MO       | 10 RVUE  | $e^+e^- \rightarrow$ hadrons                   |
| 77 ± 20   | <sup>8</sup> PAKHLOVA | 08A BELL | 10.6 $e^+e^- \rightarrow D^0 D^- \pi^+ \gamma$ |
| 119 ± 16  | <sup>9</sup> SETH     | 05A RVUE | $e^+e^- \rightarrow$ hadrons                   |
| 118 ± 35  | <sup>10</sup> SETH    | 05A RVUE | $e^+e^- \rightarrow$ hadrons                   |
| 66 ± 15   | BRANDELIK             | 78C DASP | $e^+e^-$                                       |
| 33 ± 10   | SIEGRIST              | 76 MRK1  | $e^+e^-$                                       |

<sup>6</sup> Reanalysis of data presented in BAI 02C. From a global fit over the center-of-mass energy region 3.7–5.0 GeV covering the  $\psi(3770)$ ,  $\psi(4040)$ ,  $\psi(4160)$ , and  $\psi(4415)$  resonances. Phase angle fixed in the fit to  $\delta = (234 \pm 88)^\circ$ .

<sup>7</sup> Reanalysis of data presented in BAI 00 and BAI 02C. From a global fit over the center-of-mass energy 3.8–4.8 GeV covering the  $\psi(4040)$ ,  $\psi(4160)$  and  $\psi(4415)$  resonances and including interference effects.

<sup>8</sup> Systematic uncertainties not estimated.

<sup>9</sup> From a fit to Crystal Ball (OSTERHELD 86) data.

<sup>10</sup> From a fit to BES (BAI 02C) data.

## $\psi(4415)$ DECAY MODES

Due to the complexity of the  $c\bar{c}$  threshold region, in this listing, “seen” (“not seen”) means that a cross section for the mode in question has been measured at effective  $\sqrt{s}$  near this particle’s central mass value, more (less) than  $2\sigma$  above zero, without regard to any peaking behavior in  $\sqrt{s}$  or absence thereof. See mode listing(s) for details and references.

| Mode  | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level |
|---|--------------------------------|------------------|
| $\Gamma_1$ $D\bar{D}$   | not seen                       |                  |
| $\Gamma_2$ $D^0\bar{D}^0$   | seen                           |                  |
| $\Gamma_3$ $D^+D^-$   | seen                           |                  |
| $\Gamma_4$ $D^*\bar{D} + \text{c.c.}$   | not seen                       |                  |
| $\Gamma_5$ $D^*(2007)^0\bar{D}^0 + \text{c.c.}$   | seen                           |                  |
| $\Gamma_6$ $D^*(2010)^+D^- + \text{c.c.}$   | seen                           |                  |
| $\Gamma_7$ $D^*\bar{D}^*$   | not seen                       |                  |
| $\Gamma_8$ $D^*(2007)^0\bar{D}^*(2007)^0 + \text{c.c.}$                                     | seen                           |                  |
| $\Gamma_9$ $D^*(2010)^+D^*(2010)^- + \text{c.c.}$   | seen                           |                  |
| $\Gamma_{10}$ $D^0D^-\pi^+$ (excl. $D^*(2007)^0\bar{D}^0$<br>+c.c., $D^*(2010)^+D^-$ +c.c.) | $< 2.3$ %                      | 90%              |
| $\Gamma_{11}$ $D\bar{D}_2^*(2460) \rightarrow D^0D^-\pi^+ + \text{c.c.}$                    | $(10 \pm 4)$ %                 |                  |
| $\Gamma_{12}$ $D^0D^{*-}\pi^+ + \text{c.c.}$  | $< 11$ %                       | 90%              |
| $\Gamma_{13}$ $D_s^+D_s^-$  | not seen                       |                  |
| $\Gamma_{14}$ $D_s^{*+}D_s^- + \text{c.c.}$   | seen                           |                  |
| $\Gamma_{15}$ $D_s^{*+}D_s^{*-}$  | not seen                       |                  |
| $\Gamma_{16}$ $J/\psi\eta$  | $< 6 \times 10^{-3}$           | 90%              |
| $\Gamma_{17}$ $e^+e^-$  | $(9.4 \pm 3.2) \times 10^{-6}$ |                  |

## $\psi(4415)$ PARTIAL WIDTHS

| $\Gamma(e^+e^-)$  | VALUE (keV) | DOCUMENT ID           | TECN | COMMENT                           | $\Gamma_{17}$ |
|---|-------------|-----------------------|------|-----------------------------------|---------------|
| <b><math>0.58 \pm 0.07</math> OUR ESTIMATE</b>                                |             |                       |      |                                   |               |
| <b><math>0.35 \pm 0.12</math></b>   |             | <sup>11</sup> ABLIKIM | 08D  | BES2 $e^+e^- \rightarrow$ hadrons |               |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |             |                       |      |                                   |               |
| 0.4 to 0.8  |             | <sup>12</sup> MO      | 10   | RVUE $e^+e^- \rightarrow$ hadrons |               |
| $0.72 \pm 0.11$   |             | <sup>13</sup> SETH    | 05A  | RVUE $e^+e^- \rightarrow$ hadrons |               |
| $0.64 \pm 0.23$   |             | <sup>14</sup> SETH    | 05A  | RVUE $e^+e^- \rightarrow$ hadrons |               |
| $0.49 \pm 0.13$   |             | BRANDELIK             | 78C  | DASP $e^+e^-$                     |               |
| $0.44 \pm 0.14$   |             | SIEGRIST              | 76   | MRK1 $e^+e^-$                     |               |

<sup>11</sup> Reanalysis of data presented in BAI 02C. From a global fit over the center-of-mass energy region 3.7–5.0 GeV covering the  $\psi(3770)$ ,  $\psi(4040)$ ,  $\psi(4160)$ , and  $\psi(4415)$  resonances. Phase angle fixed in the fit to  $\delta = (234 \pm 88)^\circ$ .

<sup>12</sup> Reanalysis of data presented in BAI 00 and BAI 02C. From a global fit over the center-of-mass energy 3.8–4.8 GeV covering the  $\psi(4040)$ ,  $\psi(4160)$  and  $\psi(4415)$  resonances and including interference effects. Four sets of solutions are obtained with the same fit

quality, mass and total width, but with different  $e^+e^-$  partial widths. We quote only the range of values.

<sup>13</sup> From a fit to Crystal Ball (OSTERHELD 86) data.

<sup>14</sup> From a fit to BES (BAI 02C) data.

### $\psi(4415) \Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

| $\Gamma(J/\psi\eta) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ |     |             |      |         | $\Gamma_{16}\Gamma_{17}/\Gamma$       |
|--|-----|-------------|------|---------|---------------------------------------|
| VALUE (eV)   | CL% | DOCUMENT ID | TECN | COMMENT |                                       |
| <3.6   | 90  | WANG        | 13B  | BELL    | $e^+e^- \rightarrow J/\psi\eta\gamma$ |

### $\psi(4415)$ BRANCHING RATIOS

| $\Gamma(D^0\bar{D}^0)/\Gamma_{\text{total}}$ |  |             |      |         | $\Gamma_2/\Gamma$ |
|--|--|-------------|------|---------|-------------------|
| VALUE  |  | DOCUMENT ID | TECN | COMMENT |                   |

seen PAKHLOVA 08 BELL  $e^+e^- \rightarrow D^0\bar{D}^0\gamma$

• • • We do not use the following data for averages, fits, limits, etc. • • •

not seen AUBERT 09M BABR  $e^+e^- \rightarrow D^0\bar{D}^0\gamma$

| $\Gamma(D^+D^-)/\Gamma_{\text{total}}$ |  |             |      |         | $\Gamma_3/\Gamma$ |
|--|--|-------------|------|---------|-------------------|
| VALUE                                  |  | DOCUMENT ID | TECN | COMMENT |                   |

seen PAKHLOVA 08 BELL  $e^+e^- \rightarrow D^+D^-\gamma$

• • • We do not use the following data for averages, fits, limits, etc. • • •

not seen AUBERT 09M BABR  $e^+e^- \rightarrow D^+D^-\gamma$

| $\Gamma(D\bar{D})/\Gamma(D^*\bar{D}^*)$ |  |             |      |         | $\Gamma_1/\Gamma_7$ |
|---|--|-------------|------|---------|---------------------|
| VALUE                                   |  | DOCUMENT ID | TECN | COMMENT |                     |

$0.14 \pm 0.12 \pm 0.03$  AUBERT 09M BABR  $e^+e^- \rightarrow \gamma D^{(*)}\bar{D}^{(*)}$

| $\Gamma(D^*(2007)^0\bar{D}^0 + \text{c.c.})/\Gamma_{\text{total}}$ |  |             |      |         | $\Gamma_5/\Gamma$ |
|--|--|-------------|------|---------|-------------------|
| VALUE  |  | DOCUMENT ID | TECN | COMMENT |                   |

seen AUBERT 09M BABR  $e^+e^- \rightarrow D^{*0}\bar{D}^0\gamma$

| $\Gamma(D^*(2010)^+D^- + \text{c.c.})/\Gamma_{\text{total}}$ |  |             |      |         | $\Gamma_6/\Gamma$ |
|--|--|-------------|------|---------|-------------------|
| VALUE  |  | DOCUMENT ID | TECN | COMMENT |                   |

seen AUBERT 09M BABR  $e^+e^- \rightarrow D^{*+}D^-\gamma$

seen PAKHLOVA 07 BELL  $e^+e^- \rightarrow D^{*+}D^-\gamma$

| $\Gamma(D^*\bar{D} + \text{c.c.})/\Gamma(D^*\bar{D}^*)$ |  |             |      |         | $\Gamma_4/\Gamma_7$ |
|---|--|-------------|------|---------|---------------------|
| VALUE   |  | DOCUMENT ID | TECN | COMMENT |                     |

$0.17 \pm 0.25 \pm 0.03$  AUBERT 09M BABR  $e^+e^- \rightarrow \gamma D^{(*)}\bar{D}^{(*)}$

| $\Gamma(D^*(2007)^0\bar{D}^*(2007)^0 + \text{c.c.})/\Gamma_{\text{total}}$ |  |             |      |         | $\Gamma_8/\Gamma$ |
|--|--|-------------|------|---------|-------------------|
| VALUE  |  | DOCUMENT ID | TECN | COMMENT |                   |

seen AUBERT 09M BABR  $e^+e^- \rightarrow D^{*0}\bar{D}^{*0}\gamma$

$\Gamma(D^*(2010)^+ D^*(2010)^- + \text{c.c.})/\Gamma_{\text{total}}$   $\Gamma_9/\Gamma$

| VALUE       | DOCUMENT ID | TECN | COMMENT   |
|-------------|-------------|------|---|
| <b>seen</b> | AUBERT      | 09M  | BABR $e^+ e^- \rightarrow D^{*+} D^{*-} \gamma$ |
| <b>seen</b> | PAKHLOVA    | 07   | BELL $e^+ e^- \rightarrow D^{*+} D^{*-} \gamma$ |

$\Gamma(D\bar{D}_2^*(2460) \rightarrow D^0 D^- \pi^+ + \text{c.c.})/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$

| VALUE (units $10^{-2}$ ) | DOCUMENT ID            | TECN | COMMENT  |
|--------------------------|------------------------|------|--|
| <b>10.5 ± 2.4 ± 3.8</b>  | <sup>15</sup> PAKHLOVA | 08A  | BELL $10.6 e^+ e^- \rightarrow D^0 D^- \pi^+ \gamma$ |

<sup>15</sup> Using  $4421 \pm 4$  MeV for the mass and  $62 \pm 20$  MeV for the width of  $\psi(4415)$ .

$\Gamma(D^0 D^- \pi^+ (\text{excl. } D^*(2007)^0 \bar{D}^0 + \text{c.c.}, D^*(2010)^+ D^- + \text{c.c.})/\Gamma(D\bar{D}_2^*(2460) \rightarrow D^0 D^- \pi^+ + \text{c.c.})$   $\Gamma_{10}/\Gamma_{11}$

| VALUE           | CL% | DOCUMENT ID            | TECN | COMMENT  |
|-----------------|-----|------------------------|------|--|
| <b>&lt;0.22</b> | 90  | <sup>16</sup> PAKHLOVA | 08A  | BELL $10.6 e^+ e^- \rightarrow D^0 D^- \pi^+ \gamma$ |

<sup>16</sup> Using  $4421 \pm 4$  MeV for the mass and  $62 \pm 20$  MeV for the width of  $\psi(4415)$ .

$\Gamma(D^0 D^{*-} \pi^+ + \text{c.c.})/\Gamma_{\text{total}} \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{12}/\Gamma \times \Gamma_{17}/\Gamma$

| VALUE                             | CL% | DOCUMENT ID            | TECN | COMMENT                                     |
|-----------------------------------|-----|------------------------|------|---|
| <b>&lt;0.99 × 10<sup>-6</sup></b> | 90  | <sup>17</sup> PAKHLOVA | 09   | BELL $e^+ e^- \rightarrow D^0 D^{*-} \pi^+$ |

<sup>17</sup> Using  $4421 \pm 4$  MeV for the mass of  $\psi(4415)$ .

$\Gamma(D_s^+ D_s^-)/\Gamma_{\text{total}}$   $\Gamma_{13}/\Gamma$

| VALUE           | DOCUMENT ID      | TECN | COMMENT                                       |
|-----------------|------------------|------|---|
| <b>not seen</b> | PAKHLOVA         | 11   | BELL $e^+ e^- \rightarrow D_s^+ D_s^- \gamma$ |
| <b>not seen</b> | DEL-AMO-SA...10N | BABR | $e^+ e^- \rightarrow D_s^+ D_s^- \gamma$      |

$\Gamma(D_s^{*+} D_s^- + \text{c.c.})/\Gamma_{\text{total}}$   $\Gamma_{14}/\Gamma$

| VALUE       | DOCUMENT ID      | TECN | COMMENT  |
|-------------|------------------|------|--|
| <b>seen</b> | PAKHLOVA         | 11   | BELL $e^+ e^- \rightarrow D_s^{*+} D_s^- \gamma$ |
| <b>seen</b> | DEL-AMO-SA...10N | BABR | $e^+ e^- \rightarrow D_s^{*+} D_s^- \gamma$      |

$\Gamma(D_s^{*+} D_s^{*-})/\Gamma_{\text{total}}$   $\Gamma_{15}/\Gamma$

| VALUE           | DOCUMENT ID      | TECN | COMMENT   |
|-----------------|------------------|------|---|
| <b>not seen</b> | PAKHLOVA         | 11   | BELL $e^+ e^- \rightarrow D_s^{*+} D_s^{*-} \gamma$ |
| <b>not seen</b> | DEL-AMO-SA...10N | BABR | $e^+ e^- \rightarrow D_s^{*+} D_s^{*-} \gamma$      |

**$\psi(4415)$  REFERENCES**

|               |     |               |                                  |                 |
|---------------|-----|---------------|----------------------------------|-----------------|
| WANG          | 13B | PR D87 051101 | X.L. Wang <i>et al.</i>          | (BELLE Collab.) |
| PAKHLOVA      | 11  | PR D83 011101 | G. Pakhlova <i>et al.</i>        | (BELLE Collab.) |
| DEL-AMO-SA... | 10N | PR D82 052004 | P. del Amo Sanchez <i>et al.</i> | (BABAR Collab.) |
| MO            | 10  | PR D82 077501 | X.H. Mo, C.Z. Yuan, P. Wang      | (BHEP)          |
| AUBERT        | 09M | PR D79 092001 | B. Aubert <i>et al.</i>          | (BABAR Collab.) |
| PAKHLOVA      | 09  | PR D80 091101 | G. Pakhlova <i>et al.</i>        | (BELLE Collab.) |
| ABLIKIM       | 08D | PL B660 315   | M. Ablikim <i>et al.</i>         | (BES Collab.)   |
| PAKHLOVA      | 08  | PR D77 011103 | G. Pakhlova <i>et al.</i>        | (BELLE Collab.) |

|           |     |                |                             |                             |
|-----------|-----|----------------|-----------------------------|-----------------------------|
| PAKHLOVA  | 08A | PRL 100 062001 | G. Pakhlova <i>et al.</i>   | (BELLE Collab.)             |
| PAKHLOVA  | 07  | PRL 98 092001  | G. Pakhlova <i>et al.</i>   | (BELLE Collab.)             |
| SETH      | 05A | PR D72 017501  | K.K. Seth                   |                             |
| BAI       | 02C | PRL 88 101802  | J.Z. Bai <i>et al.</i>      | (BES Collab.)               |
| BAI       | 00  | PRL 84 594     | J.Z. Bai <i>et al.</i>      | (BES Collab.)               |
| OSTERHELD | 86  | SLAC-PUB-4160  | A. Osterheld <i>et al.</i>  | (SLAC Crystal Ball Collab.) |
| BRANDELIK | 78C | PL 76B 361     | R. Brandelik <i>et al.</i>  | (DASP Collab.)              |
| SIEGRIST  | 76  | PRL 36 700     | J.L. Siegrist <i>et al.</i> | (LBL, SLAC)                 |

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