$\psi(4415)$

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

$\psi(4415)$ MASS

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

[1] 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 $\delta = (234 \pm 88)^\circ$.

[2] 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.

[3] Systematic uncertainties not estimated.

[4] From a fit to Crystal Ball (OSTERHELD 86) data.

[5] From a fit to BES (BAI 02C) data.

$\psi(4415)$ WIDTH

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

[6] 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 $\delta = (234 \pm 88)^\circ$.

[7] 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.

[8] Systematic uncertainties not estimated.

[9] From a fit to Crystal Ball (OSTERHELD 86) data.

[10] From a fit to BES (BAI 02C) data.

$\psi(4415)$ DECAY MODES

Due to the complexity of the $c\overline{c}$ 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 2σ above zero, without regard to any peaking behavior in $\sqrt{s}$ or absence thereof. See mode listing(s) for details and references.

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$D\overline{D}$	seen	
Γ_2	$D^0\overline{D}^0$	seen	
Γ_3	D^+D^-	seen	
Γ_4	$D^*\overline{D}$ + c.c.	seen	
Γ_5	$D^*(2007)^0\overline{D}^0$ + c.c.	seen	
Γ_6	$D^*(2010)^+D^-$ + c.c.	seen	
Γ_7	$D^*\overline{D}^*$	seen	
Γ_8	$D^*(2007)^0\overline{D}^*(2007)^0$ + c.c.	seen	
Γ_9	$D^*(2010)^+D^*(2010)^-$ + c.c.	seen	
Γ_{10}	$D^0D^-\pi^+$ (excl. $D^*(2007)^0\overline{D}^0$ +c.c., $D^*(2010)^+D^-$ +c.c.	< 2.3 %	90%
Γ_{11}	$D\overline{D}_2^*(2460) \rightarrow D^0D^-\pi^+$ +c.c.	(10 ±4) %	
Γ_{12}	$D^0D^{*-}\pi^+$ +c.c.	< 11 %	90%
Γ_{13}	$D_s^+D_s^-$	not seen	
Γ_{14}	$\omega\chi_{c2}$	possibly seen	
Γ_{15}	$D_s^{*+}D_s^-$ +c.c.	seen	
Γ_{16}	$D_s^{*+}D_s^{*-}$	not seen	
Γ_{17}	$\psi(3823)\pi^+\pi^-$	possibly seen	
Γ_{18}	$J/\psi\eta$	$< 6 \times 10^{-3}$	90%
Γ_{19}	$\chi_{c1}\gamma$	$< 8 \times 10^{-4}$	90%
Γ_{20}	$\chi_{c2}\gamma$	$< 4 \times 10^{-3}$	90%
Γ_{21}	e^+e^-	$(9.4\pm3.2) \times 10^{-6}$	

$\psi(4415)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ Γ_{21}

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

[11] 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 $\delta = (234 \pm 88)^\circ$.

[12] 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.

[13] From a fit to Crystal Ball (OSTERHELD 86) data.

[14] From a fit to BES (BAI 02C) data.

$\psi(4415)$ $\Gamma(i) \times \Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(J/\psi\eta) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{18}\Gamma_{21}/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
<3.6	90	WANG	13B	BELL	$e^+e^- \to J/\psi\eta\gamma$

$\Gamma(\chi_{c1}\gamma) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{19}\Gamma_{21}/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
<0.47	90	[15] HAN	15	BELL	10.58 $e^+e^- \to \chi_{c1}\gamma$

[15] Using B($\eta \to \gamma\gamma$) = (39.41 ± 0.21)%.

$\Gamma(\chi_{c2}\gamma) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{20}\Gamma_{21}/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
<2.3	90	[16] HAN	15	BELL	10.58 $e^+e^- \to \chi_{c2}\gamma$

[16] Using B($\eta \to \gamma\gamma$) = (39.41 ± 0.21)%.

$\psi(4415)$ BRANCHING RATIOS

$\Gamma(D^0\overline{D}^0)/\Gamma_{total}$ Γ_2/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	PAKHLOVA	08	BELL	$e^+e^- \to D^0\overline{D}^0\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	AUBERT	09M	BABR	$e^+e^- \to D^0\overline{D}^0\gamma$

$\Gamma(D^+D^-)/\Gamma_{total}$ Γ_3/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	PAKHLOVA	08	BELL	$e^+e^- \to D^+D^-\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	AUBERT	09M	BABR	$e^+e^- \to D^+D^-\gamma$

$\Gamma(D\overline{D})/\Gamma(D^*\overline{D}^*)$ Γ_1/Γ_7

VALUE	DOCUMENT ID		TECN	COMMENT
0.14±0.12±0.03	AUBERT	09M	BABR	$e^+e^- \to \gamma D^{(*)}\overline{D}^{(*)}$

$\Gamma(D^*(2007)^0\overline{D}^0 + c.c.)/\Gamma_{total}$ Γ_5/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	AUBERT	09M	BABR	$e^+e^- \to D^{*0}\overline{D}^0\gamma$

$\Gamma(D^*(2010)^+ D^- + \text{c.c.})/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	AUBERT	09M	BABR	$e^+e^- \to D^{*+}D^-\gamma$
seen	PAKHLOVA	07	BELL	$e^+e^- \to D^{*+}D^-\gamma$

$\Gamma(D^*\overline{D} + \text{c.c.})/\Gamma(D^*\overline{D}^*)$ Γ_4/Γ_7

VALUE	DOCUMENT ID		TECN	COMMENT
0.17±0.25±0.03	AUBERT	09M	BABR	$e^+e^- \to \gamma D^{(*)}\overline{D}^{(*)}$

$\Gamma(D^*(2007)^0\overline{D}^*(2007)^0 + \text{c.c.})/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	AUBERT	09M	BABR	$e^+e^- \to D^{*0}\overline{D}^{*0}\gamma$

$\Gamma(D^*(2010)^+ D^*(2010)^- + \text{c.c.})/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	AUBERT	09M	BABR	$e^+e^- \to D^{*+}D^{*-}\gamma$
seen	PAKHLOVA	07	BELL	$e^+e^- \to D^{*+}D^{*-}\gamma$

$\Gamma(D\overline{D}_2^*(2460) \to D^0 D^-\pi^+ + \text{c.c.})/\Gamma_{\text{total}}$ Γ_{11}/Γ

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
10.5±2.4±3.8	[17] PAKHLOVA	08A	BELL	10.6 $e^+e^- \to D^0 D^-\pi^+\gamma$

[17] Using 4421 ± 4 MeV for the mass and 62 ± 20 MeV for the width of $\psi(4415)$.

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.22	90	[18] PAKHLOVA	08A	BELL	10.6 $e^+e^- \to D^0 D^-\pi^+\gamma$

[18] Using 4421 ± 4 MeV for the mass and 62 ± 20 MeV for the width of $\psi(4415)$.

$\Gamma(D^0 D^{*-}\pi^+ + \text{c.c.})/\Gamma_{\text{total}} \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_{12}/\Gamma \times \Gamma_{21}/\Gamma$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.99 × 10^{-6}	90	[19] PAKHLOVA	09	BELL	$e^+e^- \to D^0 D^{*-}\pi^+$

[19] Using 4421 ± 4 MeV for the mass of $\psi(4415)$.

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

VALUE	DOCUMENT ID		TECN	COMMENT
not seen	PAKHLOVA	11	BELL	$e^+e^- \to D_s^+ D_s^-\gamma$
not seen	DEL-AMO-SA..	10N	BABR	$e^+e^- \to D_s^+ D_s^-\gamma$

$\Gamma(\omega\chi_{c2})/\Gamma_{\text{total}}$ Γ_{14}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
possibly seen	ABLIKIM	16A	BES3	$e^+e^- \to \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$

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

VALUE	DOCUMENT ID		TECN	COMMENT
seen	PAKHLOVA	11	BELL	$e^+e^- \to D_s^{*+} D_s^-\gamma$
seen	DEL-AMO-SA..	10N	BABR	$e^+e^- \to D_s^{*+} D_s^-\gamma$

$\Gamma(D_s^{*+} D_s^{*-})/\Gamma_{\text{total}}$ Γ_{16}/Γ

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

$\Gamma(\psi(3823)\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{17}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
possibly seen	19	[20] ABLIKIM	15S	BES3	$e^+e^- \to \pi^+\pi^-\chi_{c1}\gamma$

[20] From a fit of $e^+e^- \to \pi^+\pi^-\psi(3823)$, $\psi(3823) \to \chi_{c1}\gamma$ cross sections taken at $\sqrt{s}$ values of 4.23, 4.26, 4.36, 4.42, and 4.60 GeV to the $\psi(4415)$ line shape.

$\psi(4415)$ REFERENCES

ABLIKIM	16A	PR D93 011102	M. Ablikim *et al.*	(BES III Collab.)
ABLIKIM	15S	PRL 115 011803	M. Ablikim *et al.*	(BES III Collab.)
HAN	15	PR D92 012011	Y.L. Han *et al.*	(BELLE Collab.)
WANG	13B	PR D87 051101	X.L. Wang *et al.*	(BELLE Collab.)
PAKHLOVA	11	PR D83 011101	G. Pakhlova *et al.*	(BELLE Collab.)
DEL-AMO-SA...	10N	PR D82 052004	P. del Amo Sanchez *et al.*	(BABAR Collab.)
MO	10	PR D82 077501	X.H. Mo, C.Z. Yuan, P. Wang	(BHEP)
AUBERT	09M	PR D79 092001	B. Aubert *et al.*	(BABAR Collab.)
PAKHLOVA	09	PR D80 091101	G. Pakhlova *et al.*	(BELLE Collab.)
ABLIKIM	08D	PL B660 315	M. Ablikim *et al.*	(BES Collab.)
PAKHLOVA	08	PR D77 011103	G. Pakhlova *et al.*	(BELLE Collab.)
PAKHLOVA	08A	PRL 100 062001	G. Pakhlova *et al.*	(BELLE Collab.)
PAKHLOVA	07	PRL 98 092001	G. Pakhlova *et al.*	(BELLE Collab.)
SETH	05A	PR D72 017501	K.K. Seth	
BAI	02C	PRL 88 101802	J.Z. Bai *et al.*	(BES Collab.)
BAI	00	PRL 84 594	J.Z. Bai *et al.*	(BES Collab.)
OSTERHELD	86	SLAC-PUB-4160	A. Osterheld *et al.*	(SLAC Crystal Ball Collab.)
BRANDELIK	78C	PL 76B 361	R. Brandelik *et al.*	(DASP Collab.)
SIEGRIST	76	PRL 36 700	J.L. Siegrist *et al.*	(LBL, SLAC)