$\psi(4415)$

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

$\psi(4415)$ 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}	$D\overline{D}_2^*(2460)\to D^0D^-\pi^+$+c.c.	(10 $\pm$4) %	
Γ_{12}	$D^0D^{*-}\pi^+$+c.c.	$<$ 11 %	90%
Γ_{13}	$D_1(2420)\overline{D}+$ c.c.	possibly seen	
Γ_{14}	$D_s^+D_s^-$	not seen	
Γ_{15}	$\omega\chi_{c2}$	possibly seen	
Γ_{16}	$D_s^{*+}D_s^-$ +c.c.	seen	
Γ_{17}	$D_s^{*+}D_s^{*-}$	not seen	
Γ_{18}	$\psi_2(3823)\pi^+\pi^-$	possibly seen	
Γ_{19}	$\psi(3770)\pi^+\pi^-$	possibly seen	
Γ_{20}	$J/\psi\eta$	$<$ 6 $\times10^{-3}$	90%
Γ_{21}	$\chi_{c1}\gamma$	$<$ 8 $\times10^{-4}$	90%
Γ_{22}	$\chi_{c2}\gamma$	$<$ 4 $\times10^{-3}$	90%
Γ_{23}	$\Lambda\overline{\Lambda}$	$<$ 3.1 $\times10^{-6}$	90%
Γ_{24}	e^+e^-	(9.4$\pm$3.2) $\times10^{-6}$	
Γ_{25}	$\mu^+\mu^-$	(2.0$\pm$1.0) $\times10^{-5}$	

$\psi(4415)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ Γ_{24}

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.58$\pm$0.07 OUR ESTIMATE				
0.35$\pm$0.12	[11] ABLIKIM	08D	BES2	$e^+e^-\to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.4 to 0.8	[12] MO	10	RVUE	$e^+e^-\to$ hadrons
0.72$\pm$0.11	[13] SETH	05A	RVUE	$e^+e^-\to$ 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.

$\Gamma(\mu^+\mu^-)$ Γ_{25}

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
$1.25 \pm 0.28 \pm 0.35$	[15,16] ABLIKIM	20AG	BES3	$e^+e^- \rightarrow \mu^+\mu^-$

[15] From a fit to the $e^+e^- \rightarrow \mu^+\mu^-$ cross section between 3.8 and 4.6 GeV to the coherent sum of four resonant amplitudes assuming $\Gamma(\mu^+\mu^-) = \Gamma(e^+e^-)$.

[16] From solution 1 of 8 with equal fit quality. Other solutions range from $1.24 \pm 0.28 \pm 0.35$ to $1.27 \pm 0.41 \pm 0.36$ keV.

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

$\Gamma(J/\psi\eta) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{20}\Gamma_{24}/\Gamma$

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

$\Gamma(\chi_{c1}\gamma) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{21}\Gamma_{24}/\Gamma$

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.47	90	[17] HAN	15	BELL	10.58 $e^+e^- \rightarrow \chi_{c1}\gamma$

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

$\Gamma(\chi_{c2}\gamma) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{22}\Gamma_{24}/\Gamma$

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<2.3	90	[18] HAN	15	BELL	10.58 $e^+e^- \rightarrow \chi_{c2}\gamma$

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

$\Gamma(\Lambda\overline{\Lambda}) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{23}\Gamma_{24}/\Gamma$

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.8 \times 10^{-3}$	90	[19] ABLIKIM	21AS	BES3	$e^+e^- \rightarrow \psi(4415)$

[19] From a measurement of the $e^+e^- \rightarrow \Lambda\overline{\Lambda}$ cross section between 3.5 and 4.6 GeV.

$\psi(4415)$ BRANCHING RATIOS

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

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	PAKHLOVA	08	BELL	$e^+e^- \rightarrow D^0\overline{D}^0\gamma$

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

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

$\Gamma(D^+D^-)/\Gamma_{\text{total}}$ 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	$e^+e^- \to \gamma D^{(*)}\overline{D}^{(*)}$

$\Gamma(D^*(2007)^0\overline{D}^0 + \text{c.c.})/\Gamma_{\text{total}}$ 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	[20]	ZHUKOVA	18	BELL	$e^+e^- \to D^{*+}D^-\gamma$
seen		AUBERT	09M	BABR	$e^+e^- \to D^{*+}D^-\gamma$

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

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

[20] Supersedes PAKHLOVA 07.

$\Gamma(D^*\overline{D} + \text{c.c.})/\Gamma(D^*\overline{D}^*)$ 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	[21]	ZHUKOVA	18	BELL	$e^+e^- \to D^{*+}D^{*-}\gamma$
seen		AUBERT	09M	BABR	$e^+e^- \to D^{*+}D^{*-}\gamma$

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

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

[21] Supersedes PAKHLOVA 07.

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

VALUE (units 10^{-2})		DOCUMENT ID		TECN	COMMENT
10.5±2.4±3.8	[22]	PAKHLOVA	08A	BELL	10.6 $e^+e^- \to D^0D^-\pi^+\gamma$

[22] 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	[23] PAKHLOVA	08A	BELL	10.6 $e^+ e^- \to D^0 D^- \pi^+ \gamma$

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

$\Gamma(D^0 D^{*-} \pi^+ + \text{c.c.})/\Gamma_{\text{total}} \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$ $\Gamma_{12}/\Gamma \times \Gamma_{24}/\Gamma$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<0.99 \times 10^{-6}$	90	[24] PAKHLOVA	09	BELL	$e^+ e^- \to D^0 D^{*-} \pi^+$

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

$\Gamma(D_1(2420) \overline{D} + \text{c.c.})/\Gamma_{\text{total}}$ Γ_{13}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
possibly seen	[25] ABLIKIM	19AR	BES3	$e^+ e^- \to \pi^+ \pi^- D \overline{D}$

[25] Evidence for $e^+ e^- \to D_1(2420) \overline{D} +$ c.c. between $\sqrt{s} = 4.3$ and 4.6 GeV, not necessarily resonant.

$\Gamma(D_s^+ D_s^-)/\Gamma_{\text{total}}$ Γ_{14}/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_{15}/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_{16}/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_{17}/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	$e^+ e^- \to D_s^{*+} D_s^{*-} \gamma$

$\Gamma(\psi(3770) \pi^+ \pi^-)/\Gamma_{\text{total}}$ Γ_{19}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
possibly seen	[26] ABLIKIM	19AR	BES3	$e^+ e^- \to \pi^+ \pi^- D \overline{D}$

[26] Observe $e^+ e^- \to \pi^+ \pi^- \psi(3770)$ at $\sqrt{s} = 4.26$, 4.36, and 4.42 GeV but cannot establish if continuum or resonant.

$\Gamma(\psi_2(3823) \pi^+ \pi^-)/\Gamma_{\text{total}}$ Γ_{18}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
possibly seen	19	[27] ABLIKIM	15S	BES3	$e^+ e^- \to \pi^+ \pi^- \chi_{c1} \gamma$

[27] From a fit of $e^+ e^- \to \pi^+ \pi^- \psi_2(3823)$, $\psi_2(3823) \to \chi_{c1} \gamma$ 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.

ψ(4415) REFERENCES

ABLIKIM	21AS	PR D104 L091104	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	20AG	PR D102 112009	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	19AR	PR D100 032005	M. Ablikim *et al.*	(BESIII Collab.)
ZHUKOVA	18	PR D97 012002	V. Zhukova *et al.*	(BELLE Collab.)
ABLIKIM	16A	PR D93 011102	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	15S	PRL 115 011803	M. Ablikim *et al.*	(BESIII 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)