

$\psi(4415)$

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

$\psi(4415)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
4421 ± 4	OUR ESTIMATE		
4415.1 ± 7.9	¹ ABLIKIM	08D BES2	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •			
4412 ± 15	² MO	10 RVUE	$e^+e^- \rightarrow$ hadrons
4411 ± 7	³ PAKHLOVA	08A BELL	10.6 $e^+e^- \rightarrow D^0 D^- \pi^+ \gamma$
4425 ± 6	⁴ SETH	05A RVUE	$e^+e^- \rightarrow$ hadrons
4429 ± 9	⁵ SETH	05A RVUE	$e^+e^- \rightarrow$ 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	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •			
118 ± 32	⁷ MO	10 RVUE	$e^+e^- \rightarrow$ hadrons
77 ± 20	⁸ PAKHLOVA	08A BELL	10.6 $e^+e^- \rightarrow D^0 D^- \pi^+ \gamma$
119 ± 16	⁹ SETH	05A RVUE	$e^+e^- \rightarrow$ hadrons
118 ± 35	¹⁰ SETH	05A RVUE	$e^+e^- \rightarrow$ 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 $c\bar{c}$ 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 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 $D\bar{D}$	seen	
Γ_2 $D^0\bar{D}^0$	seen	
Γ_3 D^+D^-	seen	
Γ_4 $D^*\bar{D} + \text{c.c.}$	seen	
Γ_5 $D^*(2007)^0\bar{D}^0 + \text{c.c.}$	seen	
Γ_6 $D^*(2010)^+D^- + \text{c.c.}$	seen	
Γ_7 $D^*\bar{D}^*$	seen	
Γ_8 $D^*(2007)^0\bar{D}^*(2007)^0 + \text{c.c.}$	seen	
Γ_9 $D^*(2010)^+D^*(2010)^- + \text{c.c.}$	seen	
Γ_{10} $D^0D^-\pi^+$ (excl. $D^*(2007)^0\bar{D}^0 + \text{c.c.}, D^*(2010)^+D^- + \text{c.c.}$)	< 2.3 %	90%
Γ_{11} $D\bar{D}_2^*(2460) \rightarrow D^0D^-\pi^+ + \text{c.c.}$	(10 ± 4) %	
Γ_{12} $D^0D^{*-}\pi^+ + \text{c.c.}$	< 11 %	90%
Γ_{13} $D_s^+D_s^-$	not seen	
Γ_{14} $\omega\chi_{c2}$	possibly seen	
Γ_{15} $D_s^{*+}D_s^- + \text{c.c.}$	seen	
Γ_{16} $D_s^{*+}D_s^{*-}$	not seen	
Γ_{17} $\psi_2(3823)\pi^+\pi^-$	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^-	$(9.4 \pm 3.2) \times 10^{-6}$	

$\psi(4415)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$	DOCUMENT ID	TECN	COMMENT	Γ_{21}
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.

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

$\Gamma(J/\psi\eta) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$					$\Gamma_{18}\Gamma_{21}/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	
<3.6	90	WANG	13B	BELL	$e^+e^- \rightarrow J/\psi\eta\gamma$

$\Gamma(\chi_{c1}\gamma) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$					$\Gamma_{19}\Gamma_{21}/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	
<0.47	90	¹⁵ HAN	15	BELL	$10.58 e^+e^- \rightarrow \chi_{c1}\gamma$

¹⁵ Using $B(\eta \rightarrow \gamma\gamma) = (39.41 \pm 0.21)\%$.

$\Gamma(\chi_{c2}\gamma) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$					$\Gamma_{20}\Gamma_{21}/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	
<2.3	90	¹⁶ HAN	15	BELL	$10.58 e^+e^- \rightarrow \chi_{c2}\gamma$

¹⁶ Using $B(\eta \rightarrow \gamma\gamma) = (39.41 \pm 0.21)\%$.

$\psi(4415)$ BRANCHING RATIOS

$\Gamma(D^0\bar{D}^0)/\Gamma_{\text{total}}$					Γ_2/Γ
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	$e^+e^- \rightarrow D^0\bar{D}^0\gamma$

$\Gamma(D^+D^-)/\Gamma_{\text{total}}$					Γ_3/Γ
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	$e^+e^- \rightarrow D^+D^-\gamma$

$\Gamma(D\bar{D})/\Gamma(D^*\bar{D}^*)$					Γ_1/Γ_7
VALUE		DOCUMENT ID	TECN	COMMENT	
0.14±0.12±0.03		AUBERT	09M	BABR	$e^+e^- \rightarrow \gamma D^{(*)}\bar{D}^{(*)}$

$\Gamma(D^*(2007)^0\bar{D}^0 + \text{c.c.})/\Gamma_{\text{total}}$					Γ_5/Γ
VALUE		DOCUMENT ID	TECN	COMMENT	
seen		AUBERT	09M	BABR	$e^+e^- \rightarrow D^{*0}\bar{D}^0\gamma$

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

VALUE	DOCUMENT ID	TECN	COMMENT
seen	17 ZHUKOVA	18 BELL	$e^+ e^- \rightarrow D^{*+} D^- \gamma$
seen	AUBERT	09M BABR	$e^+ e^- \rightarrow D^{*+} D^- \gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
seen	PAKHLOVA	07 BELL	$e^+ e^- \rightarrow D^{*+} D^- \gamma$
17 Supersedes PAKHLOVA 07.			

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

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

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

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

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

VALUE	DOCUMENT ID	TECN	COMMENT
seen	18 ZHUKOVA	18 BELL	$e^+ e^- \rightarrow D^{*+} D^{*-} \gamma$
seen	AUBERT	09M BABR	$e^+ e^- \rightarrow D^{*+} D^{*-} \gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
seen	PAKHLOVA	07 BELL	$e^+ e^- \rightarrow D^{*+} D^{*-} \gamma$
18 Supersedes PAKHLOVA 07.			

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

VALUE (units 10^{-2})	DOCUMENT ID	TECN	COMMENT
10.5 ± 2.4 ± 3.8	19 PAKHLOVA	08A BELL	$10.6 e^+ e^- \rightarrow D^0 D^- \pi^+ \gamma$
19 Using 4421 ± 4 MeV for the mass and 62 ± 20 MeV for the width of $\psi(4415)$.			

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.22	90	20 PAKHLOVA	08A BELL	$10.6 e^+ e^- \rightarrow D^0 D^- \pi^+ \gamma$
20 Using 4421 ± 4 MeV for the mass and 62 ± 20 MeV for the width of $\psi(4415)$.				

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.99 × 10⁻⁶	90	21 PAKHLOVA	09 BELL	$e^+ e^- \rightarrow D^0 D^{*-} \pi^+$
21 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	$e^+ e^- \rightarrow D_s^+ D_s^- \gamma$
not seen	DEL-AMO-SA..10N	BABR	$e^+ e^- \rightarrow D_s^+ D_s^- \gamma$

$\Gamma(\omega\chi_{c2})/\Gamma_{\text{total}}$				Γ_{14}/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
possibly seen	ABLIKIM	16A	BES3	$e^+e^- \rightarrow \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$

$\Gamma(D_s^{*+}D_s^- + \text{c.c.})/\Gamma_{\text{total}}$				Γ_{15}/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
seen	PAKHLOVA	11	BELL	$e^+e^- \rightarrow D_s^{*+}D_s^-\gamma$
seen	DEL-AMO-SA..10N	BABR		$e^+e^- \rightarrow D_s^{*+}D_s^-\gamma$

$\Gamma(D_s^{*+}D_s^{*-})/\Gamma_{\text{total}}$				Γ_{16}/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
not seen	PAKHLOVA	11	BELL	$e^+e^- \rightarrow D_s^{*+}D_s^{*-}\gamma$
not seen	DEL-AMO-SA..10N	BABR		$e^+e^- \rightarrow D_s^{*+}D_s^{*-}\gamma$

$\Gamma(\psi_2(3823)\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ_{17}/Γ	
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
possibly seen	19	²² ABLIKIM	15S	BES3	$e^+e^- \rightarrow \pi^+\pi^-\chi_{c1}\gamma$

²² From a fit of $e^+e^- \rightarrow \pi^+\pi^-\psi_2(3823)$, $\psi_2(3823) \rightarrow \chi_{c1}\gamma$ 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

ZHUKOVA	18	PR D97 012002	V. Zhukova <i>et al.</i>	(BELLE Collab.)
ABLIKIM	16A	PR D93 011102	M. Ablikim <i>et al.</i>	(BES III Collab.)
ABLIKIM	15S	PRL 115 011803	M. Ablikim <i>et al.</i>	(BES III Collab.)
HAN	15	PR D92 012011	Y.L. Han <i>et al.</i>	(BELLE Collab.)
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)