$\chi_{c1}(1P)$

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

See the Review on "$\psi(2S)$ and χ_c branching ratios" before the $\chi_{c0}(1P)$ Listings.

$\chi_{c1}(1P)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3510.59± 0.10 OUR AVERAGE		Error includes scale factor of 1.1.			
3509.4 ± 0.9		BAI	99B	BES	$\psi(2S) \to \gamma X$
3510.61± 0.04±0.09	513	[1] ARMSTRONG	92	E760	$\overline{p}p \to e^+e^-\gamma$
3511.3 ± 0.4 ±0.4	30	BAGLIN	86B	SPEC	$\overline{p}p \to e^+e^- X$
3512.3 ± 0.3 ±4.0		[2] GAISER	86	CBAL	$\psi(2S) \to \gamma X$
3507.4 ± 1.7	91	[3] LEMOIGNE	82	GOLI	190 π^- Be $\to \gamma 2\mu$
3510.4 ± 0.6		OREGLIA	82	CBAL	$e^+e^- \to J/\psi 2\gamma$
3510.1 ± 1.1	254	[4] HIMEL	80	MRK2	$e^+e^- \to J/\psi 2\gamma$
3509 ±11	21	BRANDELIK	79B	DASP	$e^+e^- \to J/\psi 2\gamma$
3507 ± 3		[4] BARTEL	78B	CNTR	$e^+e^- \to J/\psi 2\gamma$
3505.0 ± 4 ±4		[4,5] TANENBAUM	78	MRK1	e^+e^-
3513 ± 7	367	[4] BIDDICK	77	CNTR	$\psi(2S) \to \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3500 ±10	40	TANENBAUM	75	MRK1	Hadrons γ

[1] Mass central value and systematic error recalculated by us according to Eq. (16) in ARMSTRONG 93B, using the value for the $\psi(2S)$ mass from AULCHENKO 03.

[2] Using mass of $\psi(2S) = 3686.0$ MeV.

[3] $J/\psi(1S)$ mass constrained to 3097 MeV.

[4] Mass value shifted by us by amount appropriate for $\psi(2S)$ mass = 3686 MeV and $J/\psi(1S)$ mass = 3097 MeV.

[5] From a simultaneous fit to radiative and hadronic decay channels.

$\chi_{c1}(1P)$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.96±0.12 OUR FIT						
0.88±0.11±0.08		513	ARMSTRONG	92	E760	$\overline{p}p \to e^+e^-\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<1.3	95		BAGLIN	86B	SPEC	$\overline{p}p \to e^+e^- X$
<3.8	90		GAISER	86	CBAL	$\psi(2S) \to \gamma X$

$\chi_{c1}(1P)$ DECAY MODES

Mode	Fraction (Γ_i/Γ)

Hadronic decays

Γ_1	$3(\pi^+\pi^-)$	$(6.2\pm1.6)\times10^{-3}$
Γ_2	$2(\pi^+\pi^-)$	$(8.2\pm2.9)\times10^{-3}$
Γ_3	$\pi^+\pi^-K^+K^-$	$(4.9\pm1.1)\times10^{-3}$
Γ_4	$\rho^0\pi^+\pi^-$	$(3.9\pm3.5)\times10^{-3}$
Γ_5	$K^+\overline{K}^*(892)^0\pi^-$ + c.c.	$(3.2\pm2.1)\times10^{-3}$
Γ_6	$K^*(892)^0\overline{K}^*(892)^0$	$(1.6\pm0.4)\times10^{-3}$
Γ_7	$K^0_SK^+\pi^-$ + c.c.	$(2.5\pm0.7)\times10^{-3}$
Γ_8	$\pi^+\pi^-p\overline{p}$	$(5.3\pm2.1)\times10^{-4}$
Γ_9	$K^+K^-K^+K^-$	$(4.2\pm1.9)\times10^{-4}$
Γ_{10}	$p\overline{p}$	$(6.7\pm0.9)\times10^{-5}$
Γ_{11}	$\Lambda\overline{\Lambda}$	$(2.6\pm1.2)\times10^{-4}$
Γ_{12}	$\pi^+\pi^-$ + K^+K^-	$< 2.1 \times10^{-3}$

Radiative decays

Γ_{13}	$\gamma J/\psi(1S)$	(31.6 ± 2.3) %
Γ_{14}	$\gamma\gamma$	

$\chi_{c1}(1P)$ PARTIAL WIDTHS

$\chi_{c1}(1P)$ $\Gamma(i)\Gamma(\gamma J/\psi(1S))/\Gamma(\text{total})$

$\Gamma(p\overline{p}) \times \Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ — $\Gamma_{10}\Gamma_{13}/\Gamma$

VALUE (eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
20.2±2.1 OUR FIT				
21.3±2.2 OUR AVERAGE				
21.8±1.5±2.2	[6] ARMSTRONG	92	E760	$\overline{p}p \rightarrow e^+e^-\gamma$
$19.9^{+4.4}_{-4.0}$	[6] BAGLIN	86B	SPEC	$\overline{p}p \rightarrow e^+e^-X$

[6] Calculated by us using B($J/\psi(1S) \rightarrow e^+e^-$) = 0.0593 ± 0.0010.

$\chi_{c1}(1P)$ BRANCHING RATIOS

HADRONIC DECAYS

$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ — Γ_1/Γ

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
6.2±1.6 OUR EVALUATION	Treating systematic error as correlated.			
6.2±1.3 OUR AVERAGE				
5.8±0.7±1.1	[7] BAI	99B	BES	$\psi(2S) \rightarrow \gamma\chi_{c1}$
17.2±6.4±1.7	[7] TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$

$\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}$ — Γ_2/Γ

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
8.2±2.9 OUR EVALUATION	Treating systematic error as correlated.			
8 ±4 OUR AVERAGE	Error includes scale factor of 1.5.			
4.9±2.2±2.8	[7] BAI	99B	BES	$\psi(2S) \rightarrow \gamma\chi_{c1}$
13.5±4.5±1.3	[7] TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$

$\Gamma(\pi^+\pi^- K^+ K^-)/\Gamma_{total}$ — Γ_3/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
4.9±1.1 OUR EVALUATION	Treating systematic error as correlated.			
4.9±1.1 OUR AVERAGE				
4.5±0.4±1.1	[7] BAI	99B	BES	$\psi(2S) \to \gamma\chi_{c1}$
7.9±3.2±0.8	[7] TANENBAUM	78	MRK1	$\psi(2S) \to \gamma\chi_{c1}$

$\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{total}$ — Γ_4/Γ

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
39±35	[8] TANENBAUM	78	MRK1	$\psi(2S) \to \gamma\chi_{c1}$

$\Gamma(K^+\overline{K}^*(892)^0\pi^- + \text{c.c.})/\Gamma_{total}$ — Γ_5/Γ

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
32±21	[8] TANENBAUM	78	MRK1	$\psi(2S) \to \gamma\chi_{c1}$

$\Gamma(K^*(892)^0\overline{K}^*(892)^0)/\Gamma_{total}$ — Γ_6/Γ

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	COMMENT
1.6±0.4±0.1	28.4 ± 5.5	[9,10] ABLIKIM	04H	BES	$\psi(2S) \to \gamma K^+ K^- \pi^+ \pi^-$

$\Gamma(K^0_S K^+\pi^- + \text{c.c.})/\Gamma_{total}$ — Γ_7/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
2.5±0.4±0.6	[7] BAI	99B	BES	$\psi(2S) \to \gamma\chi_{c1}$

$\Gamma(\pi^+\pi^- p\overline{p})/\Gamma_{total}$ — Γ_8/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
0.53±0.21 OUR EVALUATION	Treating systematic error as correlated.			
0.53±0.21 OUR AVERAGE				
0.49±0.13±0.17	[7] BAI	99B	BES	$\psi(2S) \to \gamma\chi_{c1}$
1.16±0.82±0.11	[7] TANENBAUM	78	MRK1	$\psi(2S) \to \gamma\chi_{c1}$

$\Gamma(K^+K^-K^+K^-)/\Gamma_{total}$ — Γ_9/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
0.42±0.15±0.12	[7] BAI	99B	BES	$\psi(2S) \to \gamma\chi_{c1}$

$\Gamma(p\overline{p})/\Gamma_{total}$ — Γ_{10}/Γ

VALUE (units 10^{-4})	DOCUMENT ID
0.67±0.09 OUR FIT	

$\Gamma(\Lambda\overline{\Lambda})/\Gamma_{total}$ — Γ_{11}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
2.6±1.0±0.6	$9.0^{+3.5}_{-3.1}$	[7] BAI	03E	BES	$\psi(2S) \to \gamma\chi_{c1} \to \gamma\Lambda\overline{\Lambda}$

$\left[\Gamma(\pi^+\pi^-) + \Gamma(K^+K^-)\right]/\Gamma_{\text{total}}$ Γ_{12}/Γ

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<21		[8] FELDMAN	77	MRK1	$\psi(2S) \to \gamma\chi_{c1}$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<38	90	[8] BRANDELIK	79B	DASP	$\psi(2S) \to \gamma\chi_{c1}$

[7] Rescaled by us using B($\psi(2S) \to \gamma\chi_{c1}$) = (8.4 ± 0.8)% and B($\psi(2S) \to J/\psi(1S)\pi^+\pi^-$) = 0.317 ± 0.011.

[8] Estimated using B($\psi(2S) \to \gamma\chi_{c1}(1P)$) = 0.087. The errors do not contain the uncertainty in the $\psi(2S)$ decay.

[9] ABLIKIM 04H reports [B($\chi_{c1}(1P) \to K^*(892)^0\overline{K}^*(892)^0$) × B($\psi(2S) \to \gamma\chi_{c1}(1P)$)] = (1.40 ± 0.27 ± 0.22) × 10^{-4}. We divide by our best value B($\psi(2S) \to \gamma\chi_{c1}(1P)$) = (8.7 ± 0.5) × 10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[10] Assumes B($K^*(892)^0 \to K^-\pi^+$) = 2/3.

RADIATIVE DECAYS

$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ Γ_{13}/Γ

VALUE	*DOCUMENT ID*
0.316±0.023 OUR FIT	

$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{14}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0015	90	[11] YAMADA	77	DASP	$e^+e^- \to 3\gamma$

[11] Estimated using B($\psi(2S) \to \gamma\chi_{c1}(1P)$) = 0.087. The errors do not contain the uncertainty in the $\psi(2S)$ decay.

$\chi_{c1}(1P)$ CROSS-PARTICLE BRANCHING RATIOS

$B(\chi_{c1}(1P) \to p\overline{p}) \times \frac{\Gamma(\psi(2S) \to \gamma\chi_{c1}(1P))}{\Gamma(\psi(2S) \to J/\psi(1S)\pi^+\pi^-)}$

VALUE (units 10^{-5})	*DOCUMENT ID*		*TECN*	*COMMENT*
1.8±0.3 OUR FIT				
1.1±1.0	[12] BAI	98I	BES	$\psi(2S) \to \gamma\chi_{c1} \to \gamma\overline{p}p$

$B(\chi_{c1}(1P) \to \gamma J/\psi(1S)) \times B(\psi(2S) \to \gamma\chi_{c1}(1P))$

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.76±0.13 OUR FIT					
2.70±0.13 OUR AVERAGE					
2.81±0.05±0.23	13k	BAI	04I	BES2	$\psi(2S) \to J/\psi\gamma\gamma$
2.56±0.12±0.20		GAISER	86	CBAL	$\psi(2S) \to \gamma X$
2.78±0.30		[13] OREGLIA	82	CBAL	$\psi(2S) \to \gamma\chi_{c1}$
2.2 ±0.5		[14] BRANDELIK	79B	DASP	$\psi(2S) \to \gamma\chi_{c1}$
2.9 ±0.5		[14] BARTEL	78B	CNTR	$\psi(2S) \to \gamma\chi_{c1}$
5.0 ±1.5		[15] BIDDICK	77	CNTR	$e^+e^- \to \gamma X$
2.8 ±0.9		[13] WHITAKER	76	MRK1	e^+e^-

$B(\chi_{c1}(1P) \to \gamma J/\psi(1S)) \times \frac{\Gamma(\psi(2S) \to \gamma\chi_{c1}(1P))}{\Gamma(\psi(2S) \to J/\psi(1S)\pi^+\pi^-)}$

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
8.7±0.6 OUR FIT				
9.5±1.8 OUR AVERAGE				
12.6±0.3±3.8	3k	[16] ABLIKIM 04B	BES	$\psi(2S) \to J/\psi X$
8.5±2.1		[17] HIMEL 80	MRK2	$\psi(2S) \to \gamma\chi_{c1}$

$B(\chi_{c1}(1P) \to p\overline{p}) \times B(\psi(2S) \to \gamma\chi_{c1}(1P))$

VALUE (units 10^{-6})	EVTS	DOCUMENT ID	TECN	COMMENT
5.8±0.9 OUR FIT				
$\mathbf{4.8^{+1.4}_{-1.3}\pm0.6}$	$18.2^{+5.5}_{-4.9}$	BAI 04F	BES	$\psi(2S) \to \gamma\chi_{c1}(1P) \to \gamma\overline{p}p$

[12] Calculated by us. The value for $B(\chi_{c1} \to p\overline{p})$ reported in BAI 98I is derived using $B(\psi(2S) \to \gamma\chi_{c1}) = (8.7 \pm 0.8)\%$ and $B(\psi(2S) \to J/\psi(1S)\pi^+\pi^-) = (32.4 \pm 2.6)\%$ [BAI 98D].

[13] Recalculated by us using $B(J/\psi(1S) \to \ell^+\ell^-) = 0.1181 \pm 0.0020$.

[14] Recalculated by us using $B(J/\psi(1S) \to \mu^+\mu^-) = 0.0588 \pm 0.0010$.

[15] Assumes isotropic gamma distribution.

[16] From a fit to the J/ψ recoil mass spectra.

[17] The value for $B(\psi(2S) \to \gamma\chi_{c1})\times B(\chi_{c1} \to \gamma J/\psi(1S))$ quoted in HIMEL 80 is derived using $B(\psi(2S) \to J/\psi(1S)\pi^+\pi^-) = (33 \pm 3)\%$ and $B(J/\psi(1S) \to \ell^+\ell^-) = 0.138 \pm 0.018$. Calculated by us using $B(J/\psi(1S) \to \ell^+\ell^-) = 0.1181 \pm 0.0020$.

MULTIPOLE AMPLITUDES IN $\chi_{c1}(1P) \to \gamma J/\psi(1S)$

$a_2 = M2/\sqrt{E1^2 + M2^2}$ Magnetic quadrupole fractional transition amplitude

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$\mathbf{-0.002^{+0.008}_{-0.017}}$ **OUR AVERAGE**				
0.002±0.032±0.004	2090	AMBROGIANI 02	E835	$p\overline{p} \to \chi_{c1} \to J/\psi\gamma$
$-0.002^{+0.008}_{-0.020}$	921	OREGLIA 82	CBAL	$\psi(2S) \to \chi_{c1}\gamma \to J/\psi\gamma\gamma$

$\chi_{c1}(1P)$ REFERENCES

ABLIKIM	04B	PR D70 012003	M. Ablikim et al.	(BES Collab.)
ABLIKIM	04H	PR D70 092003	M. Ablikim et al.	(BES Collab.)
BAI	04F	PR D69 092001	J.Z. Bai et al.	(BES Collab.)
BAI	04I	PR D70 012006	J.Z. Bai et al.	(BES Collab.)
AULCHENKO	03	PL B573 63	V.M. Aulchenko et al.	(KEDR Collab.)
BAI	03E	PR D67 112001	J.Z. Bai et al.	(BES Collab.)
AMBROGIANI	02	PR D65 052002	M. Ambrogiani et al.	(FNAL E835 Collab.)
BAI	99B	PR D60 072001	J.Z. Bai et al.	(BES Collab.)
BAI	98D	PR D58 092006	J.Z. Bai et al.	(BES Collab.)
BAI	98I	PRL 81 3091	J.Z. Bai et al.	(BES Collab.)
ARMSTRONG	93B	PR D47 772	T.A. Armstrong et al.	(FNAL E760 Collab.)
ARMSTRONG	92	NP B373 35	T.A. Armstrong et al.	(FNAL, FERR, GENO+)
Also	92B	PRL 68 1468	T.A. Armstrong et al.	(FNAL, FERR, GENO+)
BAGLIN	86B	PL B172 455	C. Baglin	(LAPP, CERN, GENO, LYON, OSLO+)

GAISER	86	PR D34 711	J. Gaiser *et al.*	(Crystal Ball Collab.)
LEMOIGNE	82	PL 113B 509	Y. Lemoigne *et al.*	(SACL, LOIC, SHMP+)
OREGLIA	82	PR D25 2259	M.J. Oreglia *et al.*	(SLAC, CIT, HARV+)
Also	82B	Private Comm.	M.J. Oreglia	(EFI)
HIMEL	80	PRL 44 920	T. Himel *et al.*	(LBL, SLAC)
Also	82	Private Comm.	G. Trilling	(LBL, UCB)
BRANDELIK	79B	NP B160 426	R. Brandelik *et al.*	(DASP Collab.)
BARTEL	78B	PL 79B 492	W. Bartel *et al.*	(DESY, HEIDP)
TANENBAUM	78	PR D17 1731	W.M. Tanenbaum *et al.*	(SLAC, LBL)
Also	82	Private Comm.	G. Trilling	(LBL, UCB)
BIDDICK	77	PRL 38 1324	C.J. Biddick *et al.*	(UCSD, UMD, PAVI+)
FELDMAN	77	PRPL 33C 285	G.J. Feldman, M.L. Perl	(LBL, SLAC)
YAMADA	77	Hamburg Conf. 69	S. Yamada	(DASP Collab.)
WHITAKER	76	PRL 37 1596	J.S. Whitaker *et al.*	(SLAC, LBL)
TANENBAUM	75	PRL 35 1323	W.M. Tanenbaum *et al.*	(LBL, SLAC)

OTHER RELATED PAPERS

BARBERIS	00G	PL B485 357	D. Barberis *et al.*	(Omega Expt.)
BARATE	83	PL 121B 449	R. Barate *et al.*	(SACL, LOIC, SHMP, IND)
BRAUNSCH...	75B	PL 57B 407	W. Braunschweig *et al.*	(DASP Collab.)
SIMPSON	75	PRL 35 699	J.W. Simpson *et al.*	(STAN, PENN)