$\chi_{c1}(1P)$

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

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	$K^0_S K^+\pi^-$ + 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	$\psi(2S) \to \gamma\chi_{c1} \to \gamma\Lambda\overline{\Lambda}$

$[\Gamma(\pi^+\pi^-) + \Gamma(K^+K^-)]/\Gamma_{total}$ 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 $B(\psi(2S) \to \gamma\chi_{c1}) = (8.4 \pm 0.8)\%$ and $B(\psi(2S) \to J/\psi(1S)\pi^+\pi^-) = 0.317 \pm 0.011$.

[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 $[B(\chi_{c1}(1P) \to K^*(892)^0\overline{K}^*(892)^0) \times B(\psi(2S) \to \gamma\chi_{c1}(1P))] = (1.40 \pm 0.27 \pm 0.22) \times 10^{-4}$. We divide by our best value $B(\psi(2S) \to \gamma\chi_{c1}(1P)) = (8.7 \pm 0.5) \times 10^{-2}$. 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

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

VALUE	DOCUMENT ID
0.316±0.023 OUR FIT	

$\Gamma(\gamma\gamma)/\Gamma_{total}$ 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)