$\chi_{c1}(1P)$

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

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*
3510.51± 0.12 OUR AVERAGE					
3509.4 ± 0.9		BAI	99B	BES	$\psi(2S) \to \gamma X$
3510.53± 0.04±0.12	513	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		[1] GAISER	86	CBAL	$\psi(2S) \to \gamma X$
3507.4 ± 1.7	91	[2] 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	[3] 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		[3] BARTEL	78B	CNTR	$e^+e^- \to J/\psi 2\gamma$
3505.0 ± 4 ±4		[3,4] TANENBAUM	78	MRK1	e^+e^-
3513 ± 7	367	[3] 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] Using mass of $\psi(2S) = 3686.0$ MeV.

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

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

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

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

VALUE (MeV)	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.91±0.13 OUR NEW UNCHECKED FIT [0.92 ± 0.13 MeV OUR 2002 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)	Scale factor
	Hadronic decays		
Γ_1	$3(\pi^+\pi^-)$	$(6.3\pm1.4)\times10^{-3}$	
Γ_2	$2(\pi^+\pi^-)$	$(5.6\pm2.6)\times10^{-3}$	2.2
Γ_3	$\pi^+\pi^-K^+K^-$	$(4.9\pm1.2)\times10^{-3}$	1.1
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	$K^0_SK^+\pi^-$	$(2.5\pm0.8)\times10^{-3}$	
Γ_7	$\pi^+\pi^-p\overline{p}$	$(5.4\pm2.1)\times10^{-4}$	
Γ_8	$K^+K^-K^+K^-$	$(4.2\pm1.9)\times10^{-4}$	
Γ_9	$p\overline{p}$	$(7.2\pm1.3)\times10^{-5}$	
Γ_{10}	$\pi^+\pi^-+K^+K^-$	$<2.1\times10^{-3}$	
	Radiative decays		
Γ_{11}	$\gamma J/\psi(1S)$	(31.6 ± 2.7) %	
Γ_{12}	$\gamma\gamma$		

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

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

$\Gamma(p\overline{p}) \times \Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ — $\Gamma_9\Gamma_{11}/\Gamma$

VALUE (eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
20.9±2.2 OUR NEW UNCHECKED FIT [20.8 ± 2.3 eV OUR 2002 FIT]				
21.3±2.2 OUR AVERAGE				
21.8±1.5±2.2	[5] ARMSTRONG	92	E760	$\overline{p}p \to e^+e^-\gamma$
$19.9^{+4.4}_{-4.0}$	[5] BAGLIN	86B	SPEC	$\overline{p}p \to e^+e^-X$

[5] Calculated by us using B($J/\psi(1S) \to e^+e^-$) = 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*
6.3±1.4 OUR AVERAGE				
5.8±0.7±1.2	[6] BAI	99B	BES	$\psi(2S) \to \gamma\chi_{c1}$
22 ±8	[7] TANENBAUM	78	MRK1	$\psi(2S) \to \gamma\chi_{c1}$

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

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
5.6±2.6 OUR AVERAGE Error includes scale factor of 2.2.				
4.9±0.4±1.2	[6] BAI	99B	BES	$\psi(2S) \to \gamma\chi_{c1}$
16 ±5	[7] TANENBAUM	78	MRK1	$\psi(2S) \to \gamma\chi_{c1}$

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

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
49±12 OUR AVERAGE Error includes scale factor of 1.1.				
45± 4±11	[6] BAI	99B	BES	$\psi(2S) \rightarrow \gamma\chi_{c1}$
90±40	[7] TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$

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

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
39±35	[7] TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$

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

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
32±21	[7] TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$

$\Gamma(K^0_S K^+\pi^-)/\Gamma_{total}$ — Γ_6/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
2.46±0.44±0.65	[6] BAI	99B	BES	$\psi(2S) \rightarrow \gamma\chi_{c1}$

$\Gamma(\pi^+\pi^- p\overline{p})/\Gamma_{total}$ — Γ_7/Γ

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
5.4±2.1 OUR AVERAGE				
4.9±1.3±1.7	[6] BAI	99B	BES	$\psi(2S) \rightarrow \gamma\chi_{c1}$
14 ±9	[7] TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$

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

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
0.42±0.15±0.12	[6] BAI	99B	BES	$\psi(2S) \rightarrow \gamma\chi_{c1}$

$\Gamma(p\overline{p})/\Gamma_{total}$ — Γ_9/Γ

VALUE (units 10^{-4})	DOCUMENT ID
0.72±0.13 OUR FIT	

$[\Gamma(\pi^+\pi^-) + \Gamma(K^+K^-)]/\Gamma_{total}$ — Γ_{10}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<21		[7] FELDMAN	77	MRK1	$\psi(2S) \rightarrow \gamma\chi_{c1}$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<38	90	[7] BRANDELIK	79B	DASP	$\psi(2S) \rightarrow \gamma\chi_{c1}$

[6] Using B($\psi(2S) \rightarrow \gamma\chi_{c1}(1P)$) = 0.087 ± 0.008.

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

RADIATIVE DECAYS

$\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ Γ_{11}/Γ

VALUE	DOCUMENT ID
0.316±0.027 OUR NEW UNCHECKED FIT	[0.316 ± 0.032 OUR 2002 FIT]

$\Gamma(\gamma\gamma)/\Gamma_{total}$ Γ_{12}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0015	90	[8] YAMADA	77	DASP	$e^+e^- \to 3\gamma$

[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.

$\chi_{c1}(1P)$ 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
1.9±0.4 OUR NEW UNCHECKED FIT [(2.0 ± 0.5) × 10^{-5} OUR 2002 FIT]				
1.1±1.0	[9] 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})	DOCUMENT ID		TECN	COMMENT
2.67±0.15 OUR NEW UNCHECKED FIT [(2.66 ± 0.15) × 10^{-2} OUR 2002 FIT]				
2.66±0.16 OUR AVERAGE				
2.56±0.12±0.20	GAISER	86	CBAL	$\psi(2S) \to \gamma X$
2.78±0.30	[10] OREGLIA	82	CBAL	$\psi(2S) \to \gamma\chi_{c1}$
2.2 ±0.5	[11] BRANDELIK	79B	DASP	$\psi(2S) \to \gamma\chi_{c1}$
2.9 ±0.5	[11] BARTEL	78B	CNTR	$\psi(2S) \to \gamma\chi_{c1}$
5.0 ±1.5	[12] BIDDICK	77	CNTR	$e^+e^- \to \gamma X$
2.8 ±0.9	[10] 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})	DOCUMENT ID		TECN	COMMENT
8.4±0.6 OUR NEW UNCHECKED FIT [(8.7 ± 0.7) × 10^{-2} OUR 2002 FIT]				
8.5±2.1	[13] HIMEL	80	MRK2	$\psi(2S) \to \gamma\chi_{c1}$

[9] 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].

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

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

[12] Assumes isotropic gamma distribution.

[13] 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 $B(J/\psi(1S) \to \ell^+\ell^-) = 0.138 \pm 0.18$. 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**					
$0.002 \pm 0.032 \pm 0.004$	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

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	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.)
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OTHER RELATED PAPERS

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SIMPSON	75	PRL 35 699	J.W. Simpson *et al.*	(STAN, PENN)