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

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

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

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **3510.53± 0.12 OUR AVERAGE** | | | | | |
| 3510.53± 0.04±0.12 | 513 | ARMSTRONG | 92 | SPEC | $\overline{p}p \rightarrow e^+e^-\gamma$ |
| 3511.3 ± 0.4 ±0.4 | 30 | BAGLIN | 86B | SPEC | $\overline{p}p \rightarrow e^+e^-X$ |
| 3512.3 ± 0.3 ±4.0 | | [1] GAISER | 86 | CBAL | $\psi(2S) \rightarrow \gamma X$ |
| 3507.4 ± 1.7 | 91 | [2] LEMOIGNE | 82 | GOLI | 190 GeV $\pi^-$ Be $\rightarrow \gamma 2\mu$ |
| 3510.4 ± 0.6 | | OREGLIA | 82 | CBAL | $e^+e^- \rightarrow J/\psi 2\gamma$ |
| 3510.1 ± 1.1 | 254 | [3] HIMEL | 80 | MRK2 | $e^+e^- \rightarrow J/\psi 2\gamma$ |
| 3509 ±11 | 21 | BRANDELIK | 79B | DASP | $e^+e^- \rightarrow J/\psi 2\gamma$ |
| 3507 ± 3 | | [3] BARTEL | 78B | CNTR | $e^+e^- \rightarrow J/\psi 2\gamma$ |
| 3505.0 ± 4 ±4 | | [3,4] TANENBAUM | 78 | MRK1 | $e^+e^-$ |
| 3513 ± 7 | 367 | [3] BIDDICK | 77 | CNTR | $\psi(2S) \rightarrow \gamma X$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 3510 ±20 | | BARTEL | 76B | CNTR | $e^+e^- \rightarrow J/\psi 2\gamma$ |
| 3500 ±10 | 40 | TANENBAUM | 75 | MRK1 | Hadrons $\gamma$ |
| 3507 ± 7 | 7 | WIIK | 75 | DASP | $e^+e^- \rightarrow J/\psi 2\gamma$ |

[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* |
|---|---|---|---|---|---|---|
| **0.88±0.11±0.08** | | 513 | ARMSTRONG | 92 | SPEC | $\overline{p}p \rightarrow e^+e^-\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <1.3 | 95 | | BAGLIN | 86B | SPEC | $\overline{p}p \rightarrow e^+e^-X$ |
| <3.8 | 90 | | GAISER | 86 | CBAL | $\psi(2S) \rightarrow \gamma X$ |

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

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| | **Hadronic decays** | |
| $\Gamma_1$ | $3(\pi^+\pi^-)$ | ( 2.2±0.8) % |
| $\Gamma_2$ | $2(\pi^+\pi^-)$ | ( 1.6±0.5) % |
| $\Gamma_3$ | $\pi^+\pi^-K^+K^-$ | ( 9 ±4 ) $\times 10^{-3}$ |
| $\Gamma_4$ | $\rho^0\pi^+\pi^-$ | ( 3.9±3.5) $\times 10^{-3}$ |
| $\Gamma_5$ | $K^+\overline{K}^*(892)^0\pi^-$ + c.c. | ( 3.2±2.1) $\times 10^{-3}$ |
| $\Gamma_6$ | $\pi^+\pi^-p\overline{p}$ | ( 1.4±0.9) $\times 10^{-3}$ |
| $\Gamma_7$ | $p\overline{p}$ | ( 8.6±1.2) $\times 10^{-5}$ |
| $\Gamma_8$ | $\pi^+\pi^- + K^+K^-$ | < 2.1 $\times 10^{-3}$ |

### Radiative decays

$\Gamma_9$ $\gamma J/\psi(1S)$ (27.3 ± 1.6) %

$\Gamma_{10}$ $\gamma\gamma$

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

### $\Gamma(p\overline{p})$ $\Gamma_7$

| VALUE (eV) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **74 ± 9 OUR AVERAGE** | | | | | |
| 76 ± 10 ± 5 | 513 | [5] ARMSTRONG | 92 | SPEC | $\overline{p}p \rightarrow e^+e^-\gamma$ |
| $69^{+16}_{-13} \pm 4$ | | [5] BAGLIN | 86B | SPEC | $\overline{p}p \rightarrow e^+e^-$X |

[5] Restated by us using $B(\chi_{c1}(1P) \rightarrow J/\psi(1S)\gamma)B(J/\psi(1S) \rightarrow e^+e^-) = 0.0171 \pm 0.0011$.

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

### HADRONIC DECAYS

### $\Gamma(3(\pi^+\pi^-))/\Gamma_{total}$ $\Gamma_1/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.022 ± 0.008** | [7] TANENBAUM | 78 | MRK1 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |

### $\Gamma(2(\pi^+\pi^-))/\Gamma_{total}$ $\Gamma_2/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.016 ± 0.005** | [7] TANENBAUM | 78 | MRK1 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |

### $\Gamma(\pi^+\pi^- K^+K^-)/\Gamma_{total}$ $\Gamma_3/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **90 ± 40** | [7] TANENBAUM | 78 | MRK1 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |

### $\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{total}$ $\Gamma_4/\Gamma$

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

### $\Gamma(K^+\overline{K}^*(892)^0\pi^- + \text{c.c.})/\Gamma_{total}$ $\Gamma_5/\Gamma$

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

### $\Gamma(\pi^+\pi^- p\overline{p})/\Gamma_{total}$ $\Gamma_6/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **14 ± 9** | [7] TANENBAUM | 78 | MRK1 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |

### $\Gamma(p\overline{p})/\Gamma_{total}$ $\Gamma_7/\Gamma$

| VALUE (units $10^{-4}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **0.86±0.12** | | 513 | [6] ARMSTRONG | 92 | SPEC | $\overline{p}p \rightarrow e^+e^-\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| > 0.54 | 95 | | BAGLIN | 86B | SPEC | $\overline{p}p \rightarrow e^+e^-X$ |
| <12.0 | 90 | | [7] BRANDELIK | 79B | DASP | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |

[6] Restated by us using $B(\chi_{c1}(1P) \rightarrow J/\psi(1S)\gamma)B(J/\psi(1S) \rightarrow e^+e^-) = 0.0171 \pm 0.0011$.

### $[\Gamma(\pi^+\pi^-) + \Gamma(K^+K^-)]/\Gamma_{total}$ $\Gamma_8/\Gamma$

| 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 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |

[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

### $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ $\Gamma_9/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.273±0.016 OUR AVERAGE** | | | | | |
| 0.284±0.021 | | GAISER | 86 | CBAL | $\psi(2S) \rightarrow \gamma X$ |
| 0.274±0.046 | 943 | [8] OREGLIA | 82 | CBAL | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |
| 0.28 ±0.07 | | [8] HIMEL | 80 | MRK2 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |
| 0.19 ±0.05 | | [8] BRANDELIK | 79B | DASP | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |
| 0.29 ±0.05 | | [8] BARTEL | 78B | CNTR | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |
| 0.28 ±0.09 | | [8] TANENBAUM | 78 | MRK1 | $\psi(2S) \rightarrow \gamma\chi_{c1}$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.57 ±0.17 | | [8] BIDDICK | 77 | CNTR | $\psi(2S) \rightarrow \gamma X$ |

### $\Gamma(\gamma\gamma)/\Gamma_{total}$ $\Gamma_{10}/\Gamma$

| 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 | $e^+e^- \rightarrow 3\gamma$ |

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

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


| | | | | |
|---|---|---|---|---|
| ARMSTRONG | 92 | NP B373 35 | +Bettoni+ | (FNAL, FERR, GENO, UCI, NWES+) |
| Also | 92B | PRL 68 1468 | Armstrong, Bettoni+ | (FNAL, FERR, GENO, UCI, NWES+) |
| BAGLIN | 86B | PL B172 455 | | (LAPP, CERN, GENO, LYON, OSLO, ROMA+) |
| GAISER | 86 | PR D34 711 | +Bloom, Bulos, Godfrey+ | (Crystal Ball Collab.) |
| LEMOIGNE | 82 | PL 113B 509 | +Barate, Astbury+ | (SACL, LOIC, SHMP, IND) |
| OREGLIA | 82 | PR D25 2259 | +Partridge+ | (SLAC, CIT, HARV, PRIN, STAN) |
| Also | 82B | Private Comm. | Oreglia | (EFI) |
| HIMEL | 80 | PRL 44 920 | +Abrams, Alam, Blocker+ | (LBL, SLAC) |
| Also | 82 | Private Comm. | Trilling | (LBL, UCB) |
| BRANDELIK | 79B | NP B160 426 | +Cords+ | (DASP Collab.) |
| BARTEL | 78B | PL 79B 492 | +Dittmann, Duinker, Olsson, O'Neill+ | (DESY, HEIDP) |
| TANENBAUM | 78 | PR D17 1731 | +Alam, Boyarski+ | (SLAC, LBL) |
| Also | 82 | Private Comm. | Trilling | (LBL, UCB) |
| BIDDICK | 77 | PRL 38 1324 | +Burnett+ | (UCSD, UMD, PAVI, PRIN, SLAC, STAN) |
| FELDMAN | 77 | PRPL 33C 285 | +Perl | (LBL, SLAC) |
| YAMADA | 77 | Hamburg Conf. 69 | | (DASP Collab.) |
| BARTEL | 76B | Tbilisi Conf. N75 | +Duinker, Olsson, Heintze+ | (DESY, HEIDP) |
| TANENBAUM | 75 | PRL 35 1323 | +Whitaker, Abrams+ | (LBL, SLAC) |
| WIIK | 75 | Stanford Symp. 69 | | (DESY) |


## OTHER RELATED PAPERS


| | | | | |
|---|---|---|---|---|
| BARATE | 83 | PL 121B 449 | +Bareyre, Bonamy+ | (SACL, LOIC, SHMP, IND) |
| BRAUNSCH... | 75B | PL 57B 407 | Braunschweig, Konigs+ | (DASP Collab.) |
| FELDMAN | 75 | Stanford Symp. 39 | | (SLAC) |
| HEINTZE | 75 | Stanford Symp. 97 | | (HEIDP) |
| SIMPSON | 75 | PRL 35 699 | +Beron, Ford, Hilger, Hofstadter+ | (STAN, PENN) |