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

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

## $\chi_{c1}(1P)$ 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 $\pi^-$ 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 $\gamma$ |

[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 | 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 ($\Gamma_i/\Gamma$) | Scale factor |
|---|---|---|---|
| | **Hadronic decays** | | |
| $\Gamma_1$ | $3(\pi^+\pi^-)$ | $(6.3\pm1.4)\times10^{-3}$ | |
| $\Gamma_2$ | $2(\pi^+\pi^-)$ | $(5.6\pm2.6)\times10^{-3}$ | 2.2 |
| $\Gamma_3$ | $\pi^+\pi^-K^+K^-$ | $(4.9\pm1.2)\times10^{-3}$ | 1.1 |
| $\Gamma_4$ | $\rho^0\pi^+\pi^-$ | $(3.9\pm3.5)\times10^{-3}$ | |
| $\Gamma_5$ | $K^+\overline{K}^*(892)^0\pi^- +$ c.c. | $(3.2\pm2.1)\times10^{-3}$ | |
| $\Gamma_6$ | $K^0_S K^+\pi^-$ | $(2.5\pm0.8)\times10^{-3}$ | |
| $\Gamma_7$ | $\pi^+\pi^- p\overline{p}$ | $(5.4\pm2.1)\times10^{-4}$ | |
| $\Gamma_8$ | $K^+K^-K^+K^-$ | $(4.2\pm1.9)\times10^{-4}$ | |
| $\Gamma_9$ | $p\overline{p}$ | $(8.2\pm1.3)\times10^{-5}$ | 1.2 |
| $\Gamma_{10}$ | $\pi^+\pi^- + K^+K^-$ | $< 2.1 \times10^{-3}$ | |
| | **Radiative decays** | | |
| $\Gamma_{11}$ | $\gamma J/\psi(1S)$ | (27.3±1.6) % | |
| $\Gamma_{12}$ | $\gamma\gamma$ | | |

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

### $\Gamma(p\overline{p})$ $\Gamma_9$

| *VALUE* (eV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **74± 9 OUR AVERAGE** | | | | | |
| 76±10±5 | 513 | [5] ARMSTRONG | 92 | E760 | $\overline{p}p \to e^+e^-\gamma$ |
| $69^{+16}_{-13}\pm4$ | | [5] BAGLIN | 86B | SPEC | $\overline{p}p \to e^+e^-$X |

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

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

### HADRONIC DECAYS

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

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

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

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

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

| 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 | $\psi(2S) \to \gamma\chi_{c1}$ |
| 90±40 | [7] TANENBAUM | 78 | MRK1 | $\psi(2S) \to \gamma\chi_{c1}$ |

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

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

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

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

## $\Gamma(K^0_S K^+\pi^-)/\Gamma_{total}$ $\Gamma_6/\Gamma$

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

## $\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{total}$ $\Gamma_7/\Gamma$

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

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

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

## $\Gamma(p\overline{p})/\Gamma_{total}$ $\Gamma_9/\Gamma$

| VALUE (units $10^{-4}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **0.82±0.13 OUR AVERAGE** Error includes scale factor of 1.2. | | | | | | |
| 0.42±0.22±0.28 | | 4.2 ± 2.2 | [6] BAI | 98I | BES | $\psi(2S) \to \gamma\chi_{c1}$ |
| 0.86±0.12 | | 513 | [8] ARMSTRONG | 92 | E760 | $\overline{p}p \to e^+e^-\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| > 0.54 | 95 | | BAGLIN | 86B | SPEC | $\overline{p}p \to e^+e^-X$ |
| <12.0 | 90 | | [7] BRANDELIK | 79B | DASP | $\psi(2S) \to \gamma\chi_{c1}$ |

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

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

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

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

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

## RADIATIVE DECAYS

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

| 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 | [9] OREGLIA | 82 | CBAL | $\psi(2S) \rightarrow \gamma \chi_{c1}$ |
| 0.28 ±0.07 | | [9] HIMEL | 80 | MRK2 | $\psi(2S) \rightarrow \gamma \chi_{c1}$ |
| 0.19 ±0.05 | | [9] BRANDELIK | 79B | DASP | $\psi(2S) \rightarrow \gamma \chi_{c1}$ |
| 0.29 ±0.05 | | [9] BARTEL | 78B | CNTR | $\psi(2S) \rightarrow \gamma \chi_{c1}$ |
| 0.28 ±0.09 | | [9] 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 | | [9] BIDDICK | 77 | CNTR | $\psi(2S) \rightarrow \gamma X$ |

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

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.0015 | 90 | [9] YAMADA | 77 | DASP | $e^+ e^- \rightarrow 3\gamma$ |

[9] 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


| | | | | |
|---|---|---|---|---|
| BAI | 99B | PR D60 072001 | 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+) |
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| 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) |
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