Review of Particle Physics: C. Caso *et al.* (Particle Data Group), European Physical Journal **C3**, 1 (1998)

# $\psi(2S)$

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

## $\psi(2S)$ MASS

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **3686.00±0.09 OUR AVERAGE** | | | | | |
| 3686.02±0.09±0.27 | | ARMSTRONG | 93B | E760 | $\overline{p}p \rightarrow e^+e^-$ |
| 3686.00±0.10 | 413 | ZHOLENTZ | 80 | OLYA | $e^+e^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 3684 ±2 | | GRIBUSHIN | 96 | FMPS | 515 $\pi^-$ Be $\rightarrow 2\mu X$ |
| 3683 ±5 | 77 | ANTONIAZZI | 94 | E705 | 300 $\pi^\pm$, $p$ Li $\rightarrow$ $J/\psi\,\pi^+\pi^-$ X |

## $m_{\psi(2S)} - m_{J/\psi(1S)}$

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **589.07±0.13 OUR AVERAGE** | | | | |
| 589.7 ±1.2 | LEMOIGNE | 82 | GOLI | 190 $\pi^-$ Be $\rightarrow 2\mu$ |
| 589.07±0.13 | [1] ZHOLENTZ | 80 | OLYA | $e^+e^-$ |
| 588.7 ±0.8 | LUTH | 75 | MRK1 | |

[1] Redundant with data in mass above.

## $\psi(2S)$ WIDTH

| *VALUE* (keV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **277±31 OUR AVERAGE** Error includes scale factor of 1.1. | | | | |
| 306±36±16 | ARMSTRONG | 93B | E760 | $\overline{p}p \rightarrow e^+e^-$ |
| 243±43 | [2] PDG | 92 | RVUE | |

[2] Uses $\Gamma(ee)$ from ALEXANDER 89 and $B(ee) = (88 \pm 13) \times 10^{-4}$ from FELDMAN 77.

## $\psi(2S)$ DECAY MODES

| | Mode | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level |
|---|---|---|---|
| $\Gamma_1$ | hadrons | (98.10±0.30) % | |
| $\Gamma_2$ | virtual $\gamma \rightarrow$ hadrons | ( 2.9 ±0.4 ) % | |
| $\Gamma_3$ | $e^+e^-$ | ( 8.5 ±0.7 ) $\times 10^{-3}$ | |
| $\Gamma_4$ | $\mu^+\mu^-$ | ( 7.7 ±1.7 ) $\times 10^{-3}$ | |
| | **Decays into $J/\psi(1S)$ and anything** | | |
| $\Gamma_5$ | $J/\psi(1S)$ anything | (54.2 ±3.0 ) % | |
| $\Gamma_6$ | $J/\psi(1S)$ neutrals | (22.8 ±1.7 ) % | |
| $\Gamma_7$ | $J/\psi(1S)\,\pi^+\pi^-$ | (30.2 ±1.9 ) % | |
| $\Gamma_8$ | $J/\psi(1S)\,\pi^0\pi^0$ | (17.9 ±1.8 ) % | |
| $\Gamma_9$ | $J/\psi(1S)\,\eta$ | ( 2.7 ±0.4 ) % | S=1.7 |
| $\Gamma_{10}$ | $J/\psi(1S)\,\pi^0$ | ( 9.7 ±2.1 ) $\times 10^{-4}$ | |
| $\Gamma_{11}$ | $J/\psi(1S)\,\mu^+\mu^-$ | (10.0 ±3.3 ) $\times 10^{-3}$ | |

### Hadronic decays

| | | | | | |
|---|---|---|---|---|---|
| $\Gamma_{12}$ | $3(\pi^+\pi^-)\pi^0$ | ( 3.5 | $\pm 1.6$ ) | $\times 10^{-3}$ | |
| $\Gamma_{13}$ | $2(\pi^+\pi^-)\pi^0$ | ( 3.0 | $\pm 0.8$ ) | $\times 10^{-3}$ | |
| $\Gamma_{14}$ | $\pi^+\pi^- K^+ K^-$ | ( 1.6 | $\pm 0.4$ ) | $\times 10^{-3}$ | |
| $\Gamma_{15}$ | $\pi^+\pi^- p\overline{p}$ | ( 8.0 | $\pm 2.0$ ) | $\times 10^{-4}$ | |
| $\Gamma_{16}$ | $K^+\overline{K}^*(892)^0\pi^-$ + c.c. | ( 6.7 | $\pm 2.5$ ) | $\times 10^{-4}$ | |
| $\Gamma_{17}$ | $2(\pi^+\pi^-)$ | ( 4.5 | $\pm 1.0$ ) | $\times 10^{-4}$ | |
| $\Gamma_{18}$ | $\rho^0\pi^+\pi^-$ | ( 4.2 | $\pm 1.5$ ) | $\times 10^{-4}$ | |
| $\Gamma_{19}$ | $\overline{p}p$ | ( 1.9 | $\pm 0.5$ ) | $\times 10^{-4}$ | |
| $\Gamma_{20}$ | $3(\pi^+\pi^-)$ | ( 1.5 | $\pm 1.0$ ) | $\times 10^{-4}$ | |
| $\Gamma_{21}$ | $\overline{p}p\pi^0$ | ( 1.4 | $\pm 0.5$ ) | $\times 10^{-4}$ | |
| $\Gamma_{22}$ | $K^+K^-$ | ( 1.0 | $\pm 0.7$ ) | $\times 10^{-4}$ | |
| $\Gamma_{23}$ | $\pi^+\pi^-\pi^0$ | ( 9 | $\pm 5$ ) | $\times 10^{-5}$ | |
| $\Gamma_{24}$ | $\rho\pi$ | $<$ 8.3 | | $\times 10^{-5}$ | CL=90% |
| $\Gamma_{25}$ | $\pi^+\pi^-$ | ( 8 | $\pm 5$ ) | $\times 10^{-5}$ | |
| $\Gamma_{26}$ | $\Lambda\overline{\Lambda}$ | $<$ 4 | | $\times 10^{-4}$ | CL=90% |
| $\Gamma_{27}$ | $\Xi^-\overline{\Xi}+$ | $<$ 2 | | $\times 10^{-4}$ | CL=90% |
| $\Gamma_{28}$ | $K^+K^-\pi^0$ | $<$ 2.96 | | $\times 10^{-5}$ | CL=90% |
| $\Gamma_{29}$ | $K^+\overline{K}^*(892)^-$ + c.c. | $<$ 5.4 | | $\times 10^{-5}$ | CL=90% |

### Radiative decays

| | | | | | |
|---|---|---|---|---|---|
| $\Gamma_{30}$ | $\gamma\chi_{c0}(1P)$ | ( 9.3 | $\pm 0.9$ ) | % | |
| $\Gamma_{31}$ | $\gamma\chi_{c1}(1P)$ | ( 8.7 | $\pm 0.8$ ) | % | |
| $\Gamma_{32}$ | $\gamma\chi_{c2}(1P)$ | ( 7.8 | $\pm 0.8$ ) | % | |
| $\Gamma_{33}$ | $\gamma\eta_c(1S)$ | ( 2.8 | $\pm 0.6$ ) | $\times 10^{-3}$ | |
| $\Gamma_{34}$ | $\gamma\eta_c(2S)$ | | | | |
| $\Gamma_{35}$ | $\gamma\pi^0$ | | | | |
| $\Gamma_{36}$ | $\gamma\eta'(958)$ | $<$ 1.1 | | $\times 10^{-3}$ | CL=90% |
| $\Gamma_{37}$ | $\gamma\eta$ | | | | |
| $\Gamma_{38}$ | $\gamma\gamma$ | $<$ 1.6 | | $\times 10^{-4}$ | CL=90% |
| $\Gamma_{39}$ | $\gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi$ | $<$ 1.2 | | $\times 10^{-4}$ | CL=90% |

### Mode needed for fitting purposes

| | | | | |
|---|---|---|---|---|
| $\Gamma_{40}$ | 1. − other fit modes | (22.4 | $\pm 3.3$ ) | % |

## CONSTRAINED FIT INFORMATION

An overall fit to 9 branching ratios uses 17 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2 = 8.9$ for 10 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the $x_i$ whose labels appear in this array to sum to one.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $x_8$ | 25 | | | | | | |
| $x_9$ | 2 | −8 | | | | | |
| $x_{11}$ | 19 | 5 | 0 | | | | |
| $x_{30}$ | 0 | 0 | 0 | 0 | | | |
| $x_{31}$ | 2 | −5 | −1 | 0 | 0 | | |
| $x_{32}$ | 1 | −2 | 0 | 0 | 0 | 0 | |
| $x_{40}$ | −75 | −66 | −10 | −24 | −26 | −22 | −23 |
| | $x_7$ | $x_8$ | $x_9$ | $x_{11}$ | $x_{30}$ | $x_{31}$ | $x_{32}$ |

## $\psi(2S)$ PARTIAL WIDTHS

### $\Gamma$(hadrons) $\Gamma_1$

| VALUE (keV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 224±56 | LUTH | 75 | MRK1 | $e^+e^-$ |

### $\Gamma(e^+e^-)$ $\Gamma_3$

| VALUE (keV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **2.14±0.21** | ALEXANDER | 89 | RVUE | See $\Upsilon$ mini-review |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 2.0 ±0.3 | BRANDELIK | 79C | DASP | $e^+e^-$ |
| 2.1 ±0.3 | [3] LUTH | 75 | MRK1 | $e^+e^-$ |

[3] From a simultaneous fit to $e^+e^-$, $\mu^+\mu^-$, and hadronic channels assuming $\Gamma(e^+e^-) = \Gamma(\mu^+\mu^-)$.

### $\Gamma(\gamma\gamma)$ $\Gamma_{38}$

| VALUE (eV) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<43** | 90 | BRANDELIK | 79C | DASP | $e^+e^-$ |

### $\psi(2S)$ $\Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

This combination of a partial width with the partial width into $e^+e^-$ and with the total width is obtained from the integrated cross section into channel$_i$ in the $e^+e^-$ annihilation. We list only data that have not been used to determine the partial width $\Gamma(i)$ or the branching ratio $\Gamma(i)$/total.

**$\Gamma$(hadrons) × $\Gamma(e^+e^-)/\Gamma_{total}$** — **$\Gamma_1\Gamma_3/\Gamma$**

| VALUE (keV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 2.2±0.4 | ABRAMS | 75 | MRK1 | $e^+e^-$ |

## $\psi(2S)$ BRANCHING RATIOS

**$\Gamma$(hadrons)/$\Gamma_{total}$** — **$\Gamma_1/\Gamma$**

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.981 ±0.003** | [4] LUTH | 75 | MRK1 | $e^+e^-$ |

**$\Gamma$(virtual $\gamma \rightarrow$ hadrons)/$\Gamma_{total}$** — **$\Gamma_2/\Gamma$**

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.029±0.004** | [5] LUTH | 75 | MRK1 | $e^+e^-$ |

**$\Gamma(e^+e^-)/\Gamma_{total}$** — **$\Gamma_3/\Gamma$**

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **85± 7 OUR AVERAGE** | | | | |
| 83± 5±7 | [6] ARMSTRONG | 97 | E760 | $\overline{p}p \rightarrow \psi(2S)X$ |
| 88±13 | [7] FELDMAN | 77 | RVUE | $e^+e^-$ |

**$\Gamma(\mu^+\mu^-)/\Gamma_{total}$** — **$\Gamma_4/\Gamma$**

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **77±17** | [8] HILGER | 75 | SPEC | $e^+e^-$ |

**$\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$** — **$\Gamma_4/\Gamma_3$**

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.89±0.16 | BOYARSKI | 75C | MRK1 | $e^+e^-$ |

[4] Includes cascade decay into $J/\psi(1S)$.
[5] Included in $\Gamma$(hadrons)/$\Gamma_{total}$.
[6] Using B($J/\psi \rightarrow e^+e^-$) = 0.0599+-0.0025 and B($\psi(2S) \rightarrow J/\psi(1S)$anything) = 0.04.
[7] From an overall fit assuming equal partial widths for $e^+e^-$ and $\mu^+\mu^-$. For a measurement of the ratio see the entry $\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$ below. Includes LUTH 75, HILGER 75, BURMESTER 77.
[8] Restated by us using B($\psi(2S) \rightarrow J/\psi(1S)$anything) = 0.55.

## DECAYS INTO $J/\psi(1S)$ AND ANYTHING

### $\Gamma(J/\psi(1S)\text{anything})/\Gamma_{\text{total}}$ $\Gamma_5/\Gamma = (\Gamma_7+\Gamma_8+\Gamma_9+0.273\Gamma_{31}+0.135\Gamma_{32})/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.542±0.030 OUR FIT** | | | | |
| **0.55 ±0.07 OUR AVERAGE** | | | | |
| 0.51 ±0.12 | BRANDELIK | 79C | DASP | $e^+e^- \rightarrow \mu^+\mu^-$X |
| 0.57 ±0.08 | ABRAMS | 75B | MRK1 | $e^+e^- \rightarrow \mu^+\mu^-$X |

### $\Gamma(J/\psi(1S)\text{neutrals})/\Gamma_{\text{total}}$ $\Gamma_6/\Gamma = (0.9761\Gamma_8+0.715\Gamma_9+0.273\Gamma_{31}+0.135\Gamma_{32})/\Gamma$

| VALUE | DOCUMENT ID |
|---|---|
| **0.228±0.017 OUR FIT** | |

### $\Gamma(J/\psi(1S)\text{neutrals})/\Gamma(J/\psi(1S)\text{anything})$ $\Gamma_6/\Gamma_5 = (0.9761\Gamma_8+0.715\Gamma_9+0.273\Gamma_{31}+0.135\Gamma_{32})/(\Gamma_7+\Gamma_8+\Gamma_9+0.273\Gamma_{31}+0.135\Gamma_{32})$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.421±0.021 OUR FIT** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.44 ±0.03 | [9] ABRAMS | 75B | MRK1 | $e^+e^- \rightarrow J/\psi$X |

### $\Gamma(J/\psi(1S)\text{neutrals})/\Gamma(J/\psi(1S)\pi^+\pi^-)$ $\Gamma_6/\Gamma_7 = (0.9761\Gamma_8+0.715\Gamma_9+0.273\Gamma_{31}+0.135\Gamma_{32})/\Gamma_7$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.76±0.07 OUR FIT** | | | | |
| **0.73±0.09** | [9] TANENBAUM | 76 | MRK1 | $e^+e^-$ |

### $\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$ $\Gamma_7/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.302±0.019 OUR FIT** | | | | | |
| **0.296±0.023 OUR AVERAGE** | | | | | |
| 0.283±0.021±0.020 | 363 | [10] ARMSTRONG | 97 | E760 | $\overline{p}p \rightarrow \psi(2S)$X |
| 0.32 ±0.04 | | ABRAMS | 75B | MRK1 | $e^+e^- \rightarrow J/\psi\pi^+\pi^-$ |

### $\Gamma(J/\psi(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$ $\Gamma_8/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.179±0.018 OUR FIT** | | | | | |
| **0.184±0.019±0.013** | 157 | [10] ARMSTRONG | 97 | E760 | $\overline{p}p \rightarrow \psi(2S)$X |

### $\Gamma(J/\psi(1S)\pi^0\pi^0)/\Gamma(J/\psi(1S)\pi^+\pi^-)$ $\Gamma_8/\Gamma_7$

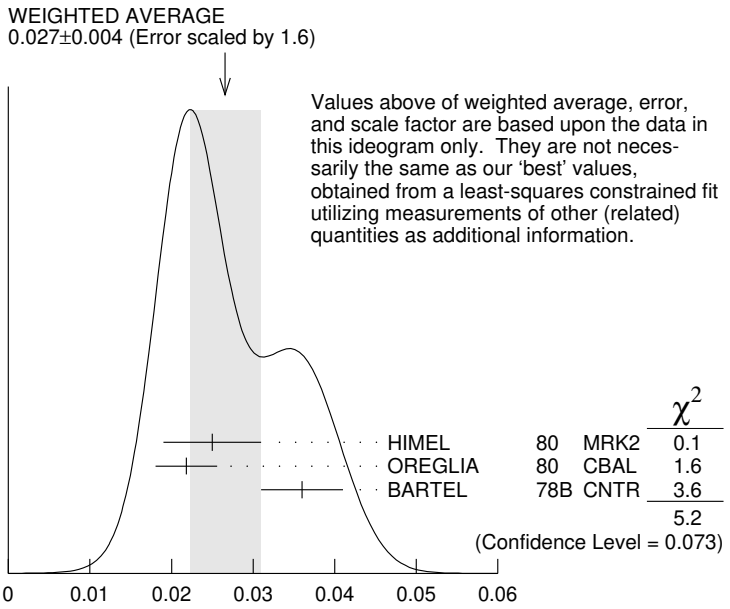
| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.59±0.06 OUR FIT** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.53±0.06 | [11] TANENBAUM | 76 | MRK1 | $e^+e^-$ |
| 0.64±0.15 | [12] HILGER | 75 | SPEC | $e^+e^-$ |

### $\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma(J/\psi(1S)\mu^+\mu^-)$ $\Gamma_7/\Gamma_{11}$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **30 ±10 OUR FIT** | | | | |
| **30.2± 7.1±6.8** | [13] GRIBUSHIN | 96 | FMPS | 515 $\pi^-$Be $\rightarrow 2\mu X$ |

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.027 ±0.004 OUR FIT** Error includes scale factor of 1.7. | | | | | |
| **0.027 ±0.004 OUR AVERAGE** Error includes scale factor of 1.6. See the ideogram below. | | | | | |
| 0.025 ±0.006 | 166 | HIMEL | 80 | MRK2 | $e^+e^-$ |
| 0.0218±0.0014±0.0035 | 386 | OREGLIA | 80 | CBAL | $e^+e^- \to J/\psi 2\gamma$ |
| 0.036 ±0.005 | 164 | BARTEL | 78B | CNTR | $e^+e^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.032 ±0.010 ±0.002 | 36 | [14] ARMSTRONG | 97 | E760 | $\overline{p}p \to \psi(2S)X$ |
| 0.035 ±0.009 | 17 | [14] BRANDELIK | 79B | DASP | $e^+e^- \to J/\psi 2\gamma$ |
| 0.043 ±0.008 | 44 | [14] TANENBAUM | 76 | MRK1 | $e^+e^-$ |




$\Gamma\left(J/\psi(1S)\eta\right)/\Gamma_{total}$

### $\Gamma(J/\psi(1S)\pi^0)/\Gamma_{total}$ $\Gamma_{10}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **9.7±2.1 OUR AVERAGE** | | | | | |
| 15 ±6 | 7 | HIMEL | 80 | MRK2 | $e^+e^-$ |
| 9 ±2 ±1 | 23 | OREGLIA | 80 | CBAL | $\psi(2S) \to J/\psi 2\gamma$ |

[9] The ABRAMS 75B measurement of $\Gamma_6/\Gamma_5$ and the TANENBAUM 76 result for $\Gamma_6/\Gamma_7$ are not independent. The TANENBAUM 76 result is used in the fit because it includes more accurate corrections for angular distributions.

[10] Using B($J/\psi \to e^+e^-$) = 0.0599+-0.0025.

[11] Not independent of the TANENBAUM 76 result for $\Gamma_6/\Gamma_7$.

[12] Ignoring the $J/\psi(1S)\eta$ and $J/\psi(1S)\gamma\gamma$ decays.
[13] Using B($J/\psi(1S) \rightarrow \mu^+\mu^-$) = 0.0597 ± 0.0025.
[14] Low statistics data removed from average.

## HADRONIC DECAYS

### $\Gamma(3(\pi^+\pi^-)\pi^0)/\Gamma_{total}$ $\Gamma_{12}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **35±16** | 6 | FRANKLIN | 83 | MRK2 | $e^+e^- \rightarrow$ hadrons |

### $\Gamma(2(\pi^+\pi^-)\pi^0)/\Gamma_{total}$ $\Gamma_{13}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **30±8** | 42 | FRANKLIN | 83 | MRK2 | $e^+e^-$ |

### $\Gamma(\pi^+\pi^- K^+K^-)/\Gamma_{total}$ $\Gamma_{14}/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **16±4** | [15] TANENBAUM | 78 | MRK1 | $e^+e^-$ |

### $\Gamma(\pi^+\pi^- p\overline{p})/\Gamma_{total}$ $\Gamma_{15}/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **8 ±2** | [15] TANENBAUM | 78 | MRK1 | $e^+e^-$ |

### $\Gamma(K^+\overline{K}^*(892)^0\pi^- + \text{c.c.})/\Gamma_{total}$ $\Gamma_{16}/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **6.7±2.5** | TANENBAUM | 78 | MRK1 | $e^+e^-$ |

### $\Gamma(2(\pi^+\pi^-))/\Gamma_{total}$ $\Gamma_{17}/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **4.5±1.0** | TANENBAUM | 78 | MRK1 | $e^+e^-$ |

### $\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{total}$ $\Gamma_{18}/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **4.2±1.5** | TANENBAUM | 78 | MRK1 | $e^+e^-$ |

### $\Gamma(\overline{p}p)/\Gamma_{total}$ $\Gamma_{19}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.9±0.5 OUR AVERAGE** | | | | | |
| 1.4±0.8 | 4 | BRANDELIK | 79C | DASP | $e^+e^-$ |
| 2.3±0.7 | | FELDMAN | 77 | MRK1 | $e^+e^-$ |

### $\Gamma(3(\pi^+\pi^-))/\Gamma_{total}$ $\Gamma_{20}/\Gamma$

| VALUE (units $10^{-4}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1.5±1.0** | [15] TANENBAUM | 78 | MRK1 | $e^+e^-$ |

### $\Gamma(\overline{p}p\pi^0)/\Gamma_{total}$ $\Gamma_{21}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.4±0.5** | 9 | FRANKLIN | 83 | MRK2 | $e^+e^-$ |

### $\Gamma(K^+K^-)/\Gamma_{total}$ $\Gamma_{22}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.0±0.7** | | BRANDELIK | 79C | DASP | $e^+e^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.5 | 90 | FELDMAN | 77 | MRK1 | $e^+e^-$ |

### $\Gamma(\pi^+\pi^-)/\Gamma_{total}$ $\Gamma_{25}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.8±0.5** | | BRANDELIK | 79C | DASP | $e^+e^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.5 | 90 | FELDMAN | 77 | MRK1 | $e^+e^-$ |

### $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{total}$ $\Gamma_{23}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.85±0.46** | 4 | FRANKLIN | 83 | MRK2 | $e^+e^- \rightarrow$ hadrons |

### $\Gamma(\Lambda\overline{\Lambda})/\Gamma_{total}$ $\Gamma_{26}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<4** | 90 | FELDMAN | 77 | MRK1 | $e^+e^-$ |

### $\Gamma(\Xi^-\overline{\Xi}^+)/\Gamma_{total}$ $\Gamma_{27}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<2** | 90 | FELDMAN | 77 | MRK1 | $e^+e^-$ |

### $\Gamma(\rho\pi)/\Gamma_{total}$ $\Gamma_{24}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **< 0.83** | 90 | 1 | FRANKLIN | 83 | MRK2 | $e^+e^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <10 | 90 | | BARTEL | 76 | CNTR | $e^+e^-$ |
| <10 | 90 | | [16] ABRAMS | 75 | MRK1 | $e^+e^-$ |

### $\Gamma(K^+K^-\pi^0)/\Gamma_{total}$ $\Gamma_{28}/\Gamma$

| VALUE (units $10^{-5}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **<2.96** | 90 | 1 | FRANKLIN | 83 | MRK2 | $e^+e^- \rightarrow$ hadrons |

### $\Gamma(K^+\overline{K}^*(892)^- + \text{c.c.})/\Gamma_{total}$ $\Gamma_{29}/\Gamma$

| VALUE (units $10^{-5}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<5.4** | 90 | FRANKLIN | 83 | MRK2 | $e^+e^- \rightarrow$ hadrons |

[15] Assuming entirely strong decay.
[16] Final state $\rho^0\pi^0$.

## RADIATIVE DECAYS

### $\Gamma(\gamma\chi_{c0}(1P))/\Gamma_{total}$ $\Gamma_{30}/\Gamma$

| VALUE (units $10^{-2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **9.3±0.9 OUR FIT** | | | | |
| **9.3±0.8 OUR AVERAGE** | | | | |
| 9.9±0.5±0.8 | [17] GAISER | 86 | CBAL | $e^+e^- \to \gamma X$ |
| 7.2±2.3 | [17] BIDDICK | 77 | CNTR | $e^+e^- \to \gamma X$ |
| 7.5±2.6 | [17] WHITAKER | 76 | MRK1 | $e^+e^-$ |

### $\Gamma(\gamma\chi_{c1}(1P))/\Gamma_{total}$ $\Gamma_{31}/\Gamma$

| VALUE (units $10^{-2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **8.7±0.8 OUR FIT** | | | | |
| **8.7±0.8 OUR AVERAGE** | | | | |
| 9.0±0.5±0.7 | [18] GAISER | 86 | CBAL | $e^+e^- \to \gamma X$ |
| 7.1±1.9 | [19] BIDDICK | 77 | CNTR | $e^+e^- \to \gamma X$ |

### $\Gamma(\gamma\chi_{c2}(1P))/\Gamma_{total}$ $\Gamma_{32}/\Gamma$

| VALUE (units $10^{-2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **7.8±0.8 OUR FIT** | | | | |
| **7.8±0.8 OUR AVERAGE** | | | | |
| 8.0±0.5±0.7 | [20] GAISER | 86 | CBAL | $e^+e^- \to \gamma X$ |
| 7.0±2.0 | [19] BIDDICK | 77 | CNTR | $e^+e^- \to \gamma X$ |

### $\Gamma(\gamma\eta_c(1S))/\Gamma_{total}$ $\Gamma_{33}/\Gamma$

| VALUE (units $10^{-2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.28±0.06** | GAISER | 86 | CBAL | $e^+e^- \to \gamma X$ |

### $\Gamma(\gamma\eta_c(2S))/\Gamma_{total}$ $\Gamma_{34}/\Gamma$

| VALUE (units $10^{-2}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.2 to 1.3 | 95 | EDWARDS | 82C | CBAL | $e^+e^- \to \gamma X$ |

### $\Gamma(\gamma\pi^0)/\Gamma_{total}$ $\Gamma_{35}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| < 54 | 95 | [21] LIBERMAN | 75 | SPEC | $e^+e^-$ |
| <100 | 90 | WIIK | 75 | DASP | $e^+e^-$ |

### $\Gamma(\gamma\eta'(958))/\Gamma_{total}$ $\Gamma_{36}/\Gamma$

| VALUE (units $10^{-2}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.11** | 90 | [22] BARTEL | 76 | CNTR | $e^+e^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.6 | 90 | [23] BRAUNSCH... | 77 | DASP | $e^+e^-$ |

### $\Gamma(\gamma\eta)/\Gamma_{\text{total}}$ $\Gamma_{37}/\Gamma$

| *VALUE* (units $10^{-2}$) | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.02 | 90 | YAMADA | 77 | DASP | $e^+e^- \to 3\gamma$ |

### $\Gamma(\gamma\eta(1440) \to \gamma K\overline{K}\pi)/\Gamma_{\text{total}}$ $\Gamma_{39}/\Gamma$

| *VALUE* (units $10^{-3}$) | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **<0.12** | 90 | [24] SCHARRE | 80 | MRK1 | $e^+e^-$ |

[17] Angular distribution $(1+\cos^2\theta)$ assumed.
[18] Angular distribution $(1-0.189\ \cos^2\theta)$ assumed.
[19] Valid for isotropic distribution of the photon.
[20] Angular distribution $(1-0.052\ \cos^2\theta)$ assumed.
[21] Restated by us using $B(\psi(2S) \to \mu^+\mu^-) = 0.0077$.
[22] The value is normalized to the branching ratio for $\Gamma(J/\psi(1S)\eta)/\Gamma_{\text{total}}$.
[23] Restated by us using total decay width 228 keV.
[24] Includes unknown branching fraction $\eta(1440) \to K\overline{K}\pi$.

## $\psi(2S)$ REFERENCES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| ARMSTRONG | 97 | PR D55 1153 | +Bettoni, Bharadwaj+ | (E760 Collab.) |
| GRIBUSHIN | 96 | PR D53 4723 | +Abramov, Antipov+ | (E672 Collab., E706 Collab.) |
| ANTONIAZZI | 94 | PR D50 4258 | +Arenton+ | (E705 Collab.) |
| ARMSTRONG | 93B | PR D47 772 | +Bettoni, Bharadwaj+ | (FNAL E760 Collab.) |
| PDG | 92 | PR D45, 1 June, Part II | Hikasa, Barnett, Stone+ | (KEK, LBL, BOST+) |
| ALEXANDER | 89 | NP B320 45 | +Bonvicini, Drell, Frey, Luth | (LBL, MICH, SLAC) |
| GAISER | 86 | PR D34 711 | +Bloom, Bulos, Godfrey+ | (Crystal Ball Collab.) |
| FRANKLIN | 83 | PRL 51 963 | +Franklin, Feldman, Abrams, Alam+ | (LBL, SLAC) |
| EDWARDS | 82C | PRL 48 70 | +Partridge, Peck+ | (CIT, HARV, PRIN, STAN, SLAC) |
| LEMOIGNE | 82 | PL 113B 509 | +Barate, Astbury+ | (SACL, LOIC, SHMP, IND) |
| HIMEL | 80 | PRL 44 920 | +Abrams, Alam, Blocker+ | (LBL, SLAC) |
| OREGLIA | 80 | PRL 45 959 | +Partridge+ | (SLAC, CIT, HARV, PRIN, STAN) |
| SCHARRE | 80 | PL 97B 329 | +Trilling, Abrams, Alam, Blocker+ | (SLAC, LBL) |
| ZHOLENTZ | 80 | PL 96B 214 | +Kurdadze, Lelchuk, Mishnev+ | (NOVO) |
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| | | Translated from YAF 34 1471. | | |
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| BARTEL | 78B | PL 79B 492 | +Dittmann, Duinker, Olsson, O'Neill+ | (DESY, HEIDP) |
| TANENBAUM | 78 | PR D17 1731 | +Alam, Boyarski+ | (SLAC, LBL) |
| BIDDICK | 77 | PRL 38 1324 | +Burnett+ | (UCSD, UMD, PAVI, PRIN, SLAC, STAN) |
| BRAUNSCH... | 77 | PL 67B 249 | Braunschweig+ | (DASP Collab.) |
| BURMESTER | 77 | PL 66B 395 | +Criegee+ | (DESY, HAMB, SIEG, WUPP) |
| FELDMAN | 77 | PRPL 33C 285 | +Perl | (LBL, SLAC) |
| YAMADA | 77 | Hamburg Conf. 69 | | (DASP Collab.) |
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## OTHER RELATED PAPERS


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| JACKSON | 75 | NIM 128 13 | +Scharre | (LBL) |
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