

# $\Upsilon(2S)$

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

## $\Upsilon(2S)$ MASS

| <u>VALUE (GeV)</u>  | <u>DOCUMENT ID</u>        | <u>TECN</u> | <u>COMMENT</u>               |
|---|---------------------------|-------------|------------------------------|
| <b>10.02326 ± 0.00031 OUR AVERAGE</b>   |                           |             |                              |
| 10.0235 ± 0.0005  | <sup>1</sup> ARTAMONOV 00 | MD1         | $e^+e^- \rightarrow$ hadrons |
| 10.0231 ± 0.0004  | BARBER                    | 84 REDE     | $e^+e^- \rightarrow$ hadrons |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ● |                           |             |                              |
| 10.0236 ± 0.0005  | <sup>2,3</sup> BARU       | 86B REDE    | $e^+e^- \rightarrow$ hadrons |
| <sup>1</sup> Reanalysis of BARU 86B using new electron mass (COHEN 87).       |                           |             |                              |
| <sup>2</sup> Reanalysis of ARTAMONOV 84.                                      |                           |             |                              |
| <sup>3</sup> Superseded by ARTAMONOV 00.                                      |                           |             |                              |

## $\Upsilon(2S)$ WIDTH

| <u>VALUE (keV)</u>               | <u>DOCUMENT ID</u>   |
|----------------------------------|--|
| <b>43 ± 6 OUR NEW EVALUATION</b> | See the Note on Width Determinations of the $\Upsilon$ states [44 ± 7 keV OUR 2002 EVALUATION] |

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

| Mode                                       | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level |
|--|--------------------------------|------------------|
| $\Gamma_1 \quad \Upsilon(1S)\pi^+\pi^-$    | ( 18.8 ± 0.6 ) %               |                  |
| $\Gamma_2 \quad \Upsilon(1S)\pi^0\pi^0$    | ( 9.0 ± 0.8 ) %                |                  |
| $\Gamma_3 \quad \tau^+\tau^-$              | ( 1.7 ± 1.6 ) %                |                  |
| $\Gamma_4 \quad \mu^+\mu^-$                | ( 1.31 ± 0.21 ) %              |                  |
| $\Gamma_5 \quad e^+e^-$                    | ( 1.34 ± 0.20 ) %              |                  |
| $\Gamma_6 \quad \Upsilon(1S)\pi^0$         | < 1.1 × 10 <sup>-3</sup>       | 90%              |
| $\Gamma_7 \quad \Upsilon(1S)\eta$          | < 2 × 10 <sup>-3</sup>         | 90%              |
| $\Gamma_8 \quad J/\psi(1S)\text{anything}$ | < 6 × 10 <sup>-3</sup>         | 90%              |

### Radiative decays

|   |                           |     |
|---|---------------------------|-----|
| $\Gamma_9 \quad \gamma\chi_{b1}(1P)$    | ( 6.8 ± 0.7 ) %           |     |
| $\Gamma_{10} \quad \gamma\chi_{b2}(1P)$ | ( 7.0 ± 0.6 ) %           |     |
| $\Gamma_{11} \quad \gamma\chi_{b0}(1P)$ | ( 3.8 ± 0.6 ) %           |     |
| $\Gamma_{12} \quad \gamma f_0(1710)$    | < 5.9 × 10 <sup>-4</sup>  | 90% |
| $\Gamma_{13} \quad \gamma f_2'(1525)$   | < 5.3 × 10 <sup>-4</sup>  | 90% |
| $\Gamma_{14} \quad \gamma f_2(1270)$    | < 2.41 × 10 <sup>-4</sup> | 90% |
| $\Gamma_{15} \quad \gamma f_J(2220)$    |                           |     |

### $\Upsilon(2S) \Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

| $\Gamma(e^+e^-) \times \Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ |                    |             |                | $\Gamma_5\Gamma_4/\Gamma$       |
|--|--------------------|-------------|----------------|---------------------------------|
| <u>VALUE (eV)</u>  | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |                                 |
| <b>6.5±1.5±1.0</b>   | KOBEL              | 92          | CBAL           | $e^+e^- \rightarrow \mu^+\mu^-$ |

| $\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ |                         |             |                | $\Gamma_0\Gamma_5/\Gamma$           |
|--|-------------------------|-------------|----------------|-------------------------------------|
| <u>VALUE (keV)</u>   | <u>DOCUMENT ID</u>      | <u>TECN</u> | <u>COMMENT</u> |                                     |
| <b>0.553±0.023 OUR AVERAGE</b>                                       |                         |             |                |                                     |
| 0.552±0.031±0.017  | <sup>4</sup> BARU       | 96          | MD1            | $e^+e^- \rightarrow \text{hadrons}$ |
| 0.54 ±0.04 ±0.02   | <sup>4</sup> JAKUBOWSKI | 88          | CBAL           | $e^+e^- \rightarrow \text{hadrons}$ |
| 0.58 ±0.03 ±0.04   | <sup>5</sup> GILES      | 84B         | CLEO           | $e^+e^- \rightarrow \text{hadrons}$ |
| 0.60 ±0.12 ±0.07   | <sup>5</sup> ALBRECHT   | 82          | DASP           | $e^+e^- \rightarrow \text{hadrons}$ |
| 0.54 ±0.07 <sup>+0.09</sup><br><sub>-0.05</sub>                      | <sup>5</sup> NICZYPORUK | 81C         | LENA           | $e^+e^- \rightarrow \text{hadrons}$ |
| 0.41 ±0.18   | <sup>5</sup> BOCK       | 80          | CNTR           | $e^+e^- \rightarrow \text{hadrons}$ |

<sup>4</sup> Radiative corrections evaluated following KURAEV 85.

<sup>5</sup> Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

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

| $\Gamma(e^+e^-)$                      |                    |   |  | $\Gamma_5$ |
|---------------------------------------|--------------------|---|--|------------|
| <u>VALUE (keV)</u>                    | <u>DOCUMENT ID</u> |   |  |            |
| <b>0.576±0.024 OUR NEW EVALUATION</b> |                    | [0.586 ± 0.029 keV OUR 1990 EVALUATION] |  |            |

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

| $\Gamma(J/\psi(1S)\text{anything})/\Gamma_{\text{total}}$ |            |                    |             | $\Gamma_8/\Gamma$                   |
|---|------------|--------------------|-------------|-------------------------------------|
| <u>VALUE</u>  | <u>CL%</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                      |
| <b>&lt;0.006</b>  | 90         | MASCHMANN 90       | CBAL        | $e^+e^- \rightarrow \text{hadrons}$ |

| $\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$ |             |                        |             | $\Gamma_1/\Gamma$  |
|--|-------------|------------------------|-------------|--|
| <u>VALUE</u>   | <u>EVTS</u> | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>   |
| <b>0.188±0.006 OUR AVERAGE</b>                         |             |                        |             |  |
| 0.192±0.002±0.010                                      | 52.6k       | <sup>6</sup> ALEXANDER | 98          | CLE2 $\pi^+\pi^-\ell^+\ell^-$ ,<br>$\pi^+\pi^-\text{MM}$ |
| 0.181±0.005±0.010                                      | 11.6k       | ALBRECHT               | 87          | ARG $e^+e^- \rightarrow$<br>$\pi^+\pi^-\text{MM}$        |
| 0.169±0.040  |             | GELPHMAN               | 85          | CBAL $e^+e^- \rightarrow$<br>$e^+e^-\pi^+\pi^-$          |
| 0.191±0.012±0.006                                      |             | BESSION                | 84          | CLEO $\pi^+\pi^-\text{MM}$                               |
| 0.189±0.026  |             | FONSECA                | 84          | CUSB $e^+e^- \rightarrow$<br>$\ell^+\ell^-\pi^+\pi^-$    |
| 0.21 ±0.07   | 7           | NICZYPORUK             | 81B         | LENA $e^+e^- \rightarrow$<br>$\ell^+\ell^-\pi^+\pi^-$    |

<sup>6</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.52 \pm 0.17)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.07)\%$ .

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_2/\Gamma$

| <u>VALUE</u>                   | <u>EPTS</u> | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>                              |
|--------------------------------|-------------|------------------------|-------------|---|
| <b>0.090±0.008 OUR AVERAGE</b> |             |                        |             |   |
| 0.092±0.006±0.008              | 275         | <sup>7</sup> ALEXANDER | 98 CLE2     | $e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$ |
| 0.095±0.019±0.019              | 25          | ALBRECHT               | 87 ARG      | $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$ |
| 0.080±0.015                    |             | GELPHMAN               | 85 CBAL     | $e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$ |
| 0.103±0.023                    |             | FONSECA                | 84 CUSB     | $e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$ |

<sup>7</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.52 \pm 0.17)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.07)\%$ .

$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma$

| <u>VALUE</u>             | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                    |
|--------------------------|--------------------|-------------|-----------------------------------|
| <b>0.017±0.015±0.006</b> | HAAS               | 84B CLEO    | $e^+e^- \rightarrow \tau^+\tau^-$ |

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

| <u>VALUE</u>                     | <u>CL%</u> | <u>DOCUMENT ID</u>    | <u>TECN</u> | <u>COMMENT</u>                  |
|----------------------------------|------------|-----------------------|-------------|---------------------------------|
| <b>0.0131±0.0021 OUR AVERAGE</b> |            |                       |             |                                 |
| 0.0122±0.0028±0.0019             |            | <sup>8</sup> KOBEL    | 92 CBAL     | $e^+e^- \rightarrow \mu^+\mu^-$ |
| 0.0138±0.0025±0.0015             |            | KAARSBERG             | 89 CSB2     | $e^+e^- \rightarrow \mu^+\mu^-$ |
| 0.009 ±0.006 ±0.006              |            | <sup>9</sup> ALBRECHT | 85 ARG      | $e^+e^- \rightarrow \mu^+\mu^-$ |
| 0.018 ±0.008 ±0.005              |            | HAAS                  | 84B CLEO    | $e^+e^- \rightarrow \mu^+\mu^-$ |

• • • We do not use the following data for averages, fits, limits, etc. • • •

|        |    |            |          |                                 |
|--------|----|------------|----------|---------------------------------|
| <0.038 | 90 | NICZYPORUK | 81C LENA | $e^+e^- \rightarrow \mu^+\mu^-$ |
|--------|----|------------|----------|---------------------------------|

<sup>8</sup> Taking into account interference between the resonance and continuum.

<sup>9</sup> Re-evaluated using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 0.026$ .

$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$

| <u>VALUE</u>      | <u>CL%</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                                |
|-------------------|------------|--------------------|-------------|---|
| <b>&lt;0.0011</b> | 90         | ALEXANDER          | 98 CLE2     | $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ |
| <0.008            | 90         | LURZ               | 87 CBAL     | $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ |

• • • We do not use the following data for averages, fits, limits, etc. • • •

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$

| <u>VALUE</u>     | <u>CL%</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>  |
|------------------|------------|--------------------|-------------|---|
| <b>&lt;0.002</b> | 90         | FONSECA            | 84 CUSB     |   |
| <0.0028          | 90         | ALEXANDER          | 98 CLE2     | $e^+e^- \rightarrow \ell^+\ell^-\eta$                   |
| <0.005           | 90         | ALBRECHT           | 87 ARG      | $e^+e^- \rightarrow \pi^+\pi^-\ell^+\ell^- \text{ MM}$  |
| <0.007           | 90         | LURZ               | 87 CBAL     | $e^+e^- \rightarrow \ell^+\ell^-(\gamma\gamma, 3\pi^0)$ |
| <0.010           | 90         | BESSON             | 84 CLEO     |   |

$\Gamma(\Upsilon\chi_{b1}(1P))/\Gamma_{\text{total}}$   $\Gamma_9/\Gamma$

| <u>VALUE</u>                   | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                               |
|--------------------------------|--------------------|-------------|--|
| <b>0.068±0.007 OUR AVERAGE</b> |                    |             |  |
| 0.069±0.005±0.009              | EDWARDS            | 99 CLE2     | $\Upsilon(2S) \rightarrow \Upsilon\chi(1P)$  |
| 0.091±0.018±0.022              | ALBRECHT           | 85E ARG     | $e^+e^- \rightarrow \gamma \text{ conv. } X$ |
| 0.065±0.007±0.012              | NERNST             | 85 CBAL     | $e^+e^- \rightarrow \gamma X$                |
| 0.080±0.017±0.016              | HAAS               | 84 CLEO     | $e^+e^- \rightarrow \gamma \text{ conv. } X$ |
| 0.059±0.014                    | KLOPFEN...         | 83 CUSB     | $e^+e^- \rightarrow \gamma X$                |

$\Gamma(\gamma\chi_{b2}(1P))/\Gamma_{\text{total}}$   $\Gamma_{10}/\Gamma$

| <u>VALUE</u>                   | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                             |
|--------------------------------|--------------------|-------------|--|
| <b>0.070±0.006 OUR AVERAGE</b> |                    |             |  |
| 0.074±0.005±0.008              | EDWARDS            | 99 CLE2     | $\Upsilon(2S) \rightarrow \gamma\chi(1P)$  |
| 0.098±0.021±0.024              | ALBRECHT           | 85E ARG     | $e^+e^- \rightarrow \gamma\text{conv. } X$ |
| 0.058±0.007±0.010              | NERNST             | 85 CBAL     | $e^+e^- \rightarrow \gamma X$              |
| 0.102±0.018±0.021              | HAAS               | 84 CLEO     | $e^+e^- \rightarrow \gamma\text{conv. } X$ |
| 0.061±0.014                    | KLOPFEN...         | 83 CUSB     | $e^+e^- \rightarrow \gamma X$              |

$\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$

| <u>VALUE</u>  | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                             |
|---|--------------------|-------------|--|
| <b>0.038±0.006 OUR AVERAGE</b>  |                    |             |  |
| 0.034±0.005±0.006   | EDWARDS            | 99 CLE2     | $\Upsilon(2S) \rightarrow \gamma\chi(1P)$  |
| 0.064±0.014±0.016   | ALBRECHT           | 85E ARG     | $e^+e^- \rightarrow \gamma\text{conv. } X$ |
| 0.036±0.008±0.009   | NERNST             | 85 CBAL     | $e^+e^- \rightarrow \gamma X$              |
| 0.044±0.023±0.009   | HAAS               | 84 CLEO     | $e^+e^- \rightarrow \gamma\text{conv. } X$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                    |             |  |
| 0.035±0.014   | KLOPFEN...         | 83 CUSB     | $e^+e^- \rightarrow \gamma X$              |

$\Gamma(\gamma f_0(1710))/\Gamma_{\text{total}}$   $\Gamma_{12}/\Gamma$

| <u>VALUE (units 10<sup>-5</sup>)</u>   | <u>CL%</u> | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>                              |
|--|------------|------------------------|-------------|---|
| <b>&lt;59</b>  | 90         | <sup>10</sup> ALBRECHT | 89 ARG      | $\Upsilon(2S) \rightarrow \gamma K^+ K^-$   |
| • • • We do not use the following data for averages, fits, limits, etc. • • •          |            |                        |             |   |
| < 5.9  | 90         | <sup>11</sup> ALBRECHT | 89 ARG      | $\Upsilon(2S) \rightarrow \gamma\pi^+\pi^-$ |
| <sup>10</sup> Re-evaluated assuming $B(f_0(1710) \rightarrow K^+ K^-) = 0.19$ .        |            |                        |             |   |
| <sup>11</sup> Includes unknown branching ratio of $f_0(1710) \rightarrow \pi^+\pi^-$ . |            |                        |             |   |

$\Gamma(\gamma f'_2(1525))/\Gamma_{\text{total}}$   $\Gamma_{13}/\Gamma$

| <u>VALUE (units 10<sup>-5</sup>)</u>  | <u>CL%</u> | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>                            |
|---|------------|------------------------|-------------|---|
| <b>&lt;53</b>   | 90         | <sup>12</sup> ALBRECHT | 89 ARG      | $\Upsilon(2S) \rightarrow \gamma K^+ K^-$ |
| <sup>12</sup> Re-evaluated assuming $B(f'_2(1525) \rightarrow K\bar{K}) = 0.71$ . |            |                        |             |   |

$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$   $\Gamma_{14}/\Gamma$

| <u>VALUE (units 10<sup>-5</sup>)</u>                           | <u>CL%</u> | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>                              |
|--|------------|------------------------|-------------|---|
| <b>&lt;24.1</b>  | 90         | <sup>13</sup> ALBRECHT | 89 ARG      | $\Upsilon(2S) \rightarrow \gamma\pi^+\pi^-$ |
| <sup>13</sup> Using $B(f_2(1270) \rightarrow \pi\pi) = 0.84$ . |            |                        |             |   |

$\Gamma(\gamma f_J(2220))/\Gamma_{\text{total}}$   $\Gamma_{15}/\Gamma$

| <u>VALUE (units 10<sup>-5</sup>)</u>  | <u>CL%</u> | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>                            |
|---|------------|------------------------|-------------|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • •       |            |                        |             |   |
| <6.8  | 90         | <sup>14</sup> ALBRECHT | 89 ARG      | $\Upsilon(2S) \rightarrow \gamma K^+ K^-$ |
| <sup>14</sup> Includes unknown branching ratio of $f_J(2220) \rightarrow K^+ K^-$ . |            |                        |             |   |

## T(2S) REFERENCES

|   |     |                         |                               |                              |
|---|-----|-------------------------|-------------------------------|------------------------------|
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| EDWARDS   | 99  | PR D59 032003           | K.W. Edwards <i>et al.</i>    | (CLEO Collab.)               |
| ALEXANDER   | 98  | PR D58 052004           | J.P. Alexander <i>et al.</i>  | (CLEO Collab.)               |
| BARU  | 96  | PRPL 267 71             | S.E. Baru <i>et al.</i>       | (NOVO)                       |
| KOBEL   | 92  | ZPHY C53 193            | M. Kobel <i>et al.</i>        | (Crystal Ball Collab.)       |
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| Editors: A. Ali and P. Soeding, World Scientific, Singapore |     |                         |                               |                              |
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| COHEN   | 87  | RMP 59 1121             | E.R. Cohen, B.N. Taylor       | (RISC, NBS)                  |
| LURZ  | 87  | ZPHY C36 383            | B. Lurz <i>et al.</i>         | (Crystal Ball Collab.)       |
| BARU  | 86B | ZPHY C32 622            | S.E. Baru <i>et al.</i>       | (NOVO)                       |
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| KURAEV  | 85  | SJNP 41 466             | E.A. KuraeV, V.S. Fadin       | (NOVO)                       |
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| FONSECA   | 84  | NP B242 31              | V. Fonseca <i>et al.</i>      | (CUSB Collab.)               |
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| BOCK  | 80  | ZPHY C6 125             | P. Bock <i>et al.</i>         | (HEIDP, MPIM, DESY, HAMB)    |

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|           |    |             |                              |                         |
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| ALBRECHT  | 84 | PL 134B 137 | H. Albrecht <i>et al.</i>    | (ARGUS Collab.)         |
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| DARDEN    | 78 | PL 76B 246  | C.W. Darden <i>et al.</i>    | (DESY, DORT, HEIDH+)    |
| KAPLAN    | 78 | PRL 40 435  | D.M. Kaplan <i>et al.</i>    | (STON, FNAL, COLU)      |
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