

# $\Upsilon(11020)$

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

## $\Upsilon(11020)$ MASS

| VALUE (MeV)   | DOCUMENT ID           | TECN     | COMMENT   |
|---|-----------------------|----------|---|
| <b>11000 ± 4 OUR AVERAGE</b>  |                       |          |   |
| 11000.0 <sup>+4.0</sup> <sub>-4.5</sub> ± 1.0 <sup>+1.0</sup> <sub>-1.3</sub>   | <sup>1</sup> MIZUK    | 19 BELL  | $e^+e^- \rightarrow \Upsilon(1S, 2S, 3S)\pi^+\pi^-$ |
| 10999.0 <sup>+7.3</sup> <sub>-7.8</sub> ± 16.9 <sup>+16.9</sup> <sub>-1.0</sub> | <sup>2</sup> MIZUK    | 16 BELL  | $e^+e^- \rightarrow h_b(1P, 2P)\pi^+\pi^-$          |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●   |                       |          |   |
| 11001 ± 1   | <sup>3</sup> DONG     | 20A      | $e^+e^- \rightarrow b\bar{b}$                       |
| 11003.0 ± 1.1 <sup>+0.9</sup> <sub>-1.0</sub>                                   | <sup>4,5</sup> SANTEL | 16 BELL  | $e^+e^- \rightarrow$ hadrons                        |
| 10987.5 <sup>+6.4</sup> <sub>-2.5</sub> ± 9.1 <sup>+9.1</sup> <sub>-2.3</sub>   | <sup>6,7</sup> SANTEL | 16 BELL  | $e^+e^- \rightarrow \Upsilon(1S, 2S, 3S)\pi^+\pi^-$ |
| 10996 ± 2   | <sup>8</sup> AUBERT   | 09E BABR | $e^+e^- \rightarrow$ hadrons                        |
| 11019 ± 5 ± 7   | BESSION               | 85 CLEO  | $e^+e^- \rightarrow$ hadrons                        |
| 11020 ± 30  | LOVELOCK              | 85 CUSB  | $e^+e^- \rightarrow$ hadrons                        |

<sup>1</sup> From a simultaneous fit to the  $\Upsilon(nS)\pi^+\pi^-$ ,  $n = 1, 2, 3$ , cross sections at 28 energy points within  $\sqrt{s} = 10.6\text{--}11.05$  GeV, including the initial-state radiation at  $\Upsilon(10860)$ .

<sup>2</sup> From a simultaneous fit to the  $h_b(nP)\pi^+\pi^-$ ,  $n = 1, 2$  cross sections at 22 energy points within  $\sqrt{s} = 10.77\text{--}11.02$  GeV to a pair of interfering Breit-Wigner amplitudes modified by phase space factors, with eight resonance parameters (a mass and width for each of  $\Upsilon(10860)$  and  $\Upsilon(11020)$ , a single relative phase, a single relative amplitude, and two overall normalization factors, one for each  $n$ ). The systematic error estimate is dominated by possible interference with a small nonresonant continuum amplitude.

<sup>3</sup> From a fit to the dressed cross sections of AUBERT 09E by BaBar and SANTEL 16 by Belle above 10.68 GeV with a coherent sum of a continuum amplitude and three Breit-Wigner functions with constant widths.

<sup>4</sup> From a fit to the total hadronic cross sections measured at 60 energy points within  $\sqrt{s} = 10.82\text{--}11.05$  GeV to a pair of interfering Breit-Wigner amplitudes and two floating continuum amplitudes with  $1/\sqrt{s}$  dependence, one coherent with the resonances and one incoherent, with six resonance parameters (a mass, width, and an amplitude for each of  $\Upsilon(10860)$  and  $\Upsilon(11020)$ , one relative phase, and one decoherence coefficient).

<sup>5</sup> Not including uncertain and potentially large systematic errors due to assumed continuum amplitude  $1/\sqrt{s}$  dependence and related interference contributions.

<sup>6</sup> From a simultaneous fit to the  $\Upsilon(nS)\pi^+\pi^-$ ,  $n = 1, 2, 3$ , cross sections at 25 energy points within  $\sqrt{s} = 10.6\text{--}11.05$  GeV to a pair of interfering Breit-Wigner amplitudes modified by phase space factors, with fourteen resonance parameters (a mass, width, and three amplitudes for each of  $\Upsilon(10860)$  and  $\Upsilon(11020)$ , a single universal relative phase, and three decoherence coefficients, one for each  $n$ ). Continuum contributions were measured (and therefore fixed) to be zero.

<sup>7</sup> Superseded by MIZUK 19.

<sup>8</sup> In a model where a flat non-resonant  $b\bar{b}$ -continuum is incoherently added to a second flat component interfering with two Breit-Wigner resonances. Systematic uncertainties not estimated.

**$\Upsilon(11020)$  WIDTH**

| <u>VALUE (MeV)</u>  | <u>DOCUMENT ID</u>    | <u>TECN</u> | <u>COMMENT</u>                                      |
|---|-----------------------|-------------|---|
| <b>24 <math>\pm \frac{8}{6}</math> OUR AVERAGE</b>                            |                       |             |   |
| 23.8 $^{+8.0+0.7}_{-6.8-1.8}$   | <sup>1</sup> MIZUK    | 19 BELL     | $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$         |
| 27 $^{+27+5}_{-11-12}$  | <sup>2</sup> MIZUK    | 16 BELL     | $e^+e^- \rightarrow h_b(1P, 2P)\pi^+\pi^-$          |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                       |             |   |
| 35.1 $\pm 1.2$  | <sup>3</sup> DONG     | 20A         | $e^+e^- \rightarrow b\bar{b}$                       |
| 39.3 $^{+1.7+1.3}_{-1.6-2.4}$   | <sup>4,5</sup> SANTEL | 16 BELL     | $e^+e^- \rightarrow \text{hadrons}$                 |
| 61 $^{+9+2}_{-19-20}$   | <sup>6,7</sup> SANTEL | 16 BELL     | $e^+e^- \rightarrow \Upsilon(1S, 2S, 3S)\pi^+\pi^-$ |
| 37 $\pm 3$  | <sup>8</sup> AUBERT   | 09E BABR    | $e^+e^- \rightarrow \text{hadrons}$                 |
| 61 $\pm 13 \pm 22$  | BESSION               | 85 CLEO     | $e^+e^- \rightarrow \text{hadrons}$                 |
| 90 $\pm 20$   | LOVELOCK              | 85 CUSB     | $e^+e^- \rightarrow \text{hadrons}$                 |

<sup>1</sup> From a simultaneous fit to the  $\Upsilon(nS)\pi^+\pi^-$ ,  $n = 1, 2, 3$ , cross sections at 28 energy points within  $\sqrt{s} = 10.6\text{--}11.05$  GeV, including the initial-state radiation at  $\Upsilon(10860)$ .

<sup>2</sup> From a simultaneous fit to the  $h_b(nP)\pi^+\pi^-$ ,  $n = 1, 2$  cross sections at 22 energy points within  $\sqrt{s} = 10.77\text{--}11.02$  GeV to a pair of interfering Breit-Wigner amplitudes modified by phase space factors, with eight resonance parameters (a mass and width for each of  $\Upsilon(10860)$  and  $\Upsilon(11020)$ , a single relative phase, a single relative amplitude, and two overall normalization factors, one for each  $n$ ). The systematic error estimate is dominated by possible interference with a small nonresonant continuum amplitude.

<sup>3</sup> From a fit to the dressed cross sections of AUBERT 09E by BaBar and SANTEL 16 by Belle above 10.68 GeV with a coherent sum of a continuum amplitude and three Breit-Wigner functions with constant widths.

<sup>4</sup> From a fit to the total hadronic cross sections measured at 60 energy points within  $\sqrt{s} = 10.82\text{--}11.05$  GeV to a pair of interfering Breit-Wigner amplitudes and two floating continuum amplitudes with  $1/\sqrt{s}$  dependence, one coherent with the resonances and one incoherent, with six resonance parameters (a mass, width, and an amplitude for each of  $\Upsilon(10860)$  and  $\Upsilon(11020)$ , one relative phase, and one decoherence coefficient).

<sup>5</sup> Not including uncertain and potentially large systematic errors due to assumed continuum amplitude  $1/\sqrt{s}$  dependence and related interference contributions.

<sup>6</sup> From a simultaneous fit to the  $\Upsilon(nS)\pi^+\pi^-$ ,  $n=1, 2, 3$ , cross sections at 25 energy points within  $\sqrt{s} = 10.6\text{--}11.05$  GeV to a pair of interfering Breit-Wigner amplitudes modified by phase space factors, with fourteen resonance parameters (a mass, width, and three amplitudes for each of  $\Upsilon(10860)$  and  $\Upsilon(11020)$ , a single universal relative phase, and three decoherence coefficients, one for each  $n$ ). Continuum contributions were measured (and therefore fixed) to be zero.

<sup>7</sup> Superseded by MIZUK 19.

<sup>8</sup> In a model where a flat non-resonant  $b\bar{b}$ -continuum is incoherently added to a second flat component interfering with two Breit-Wigner resonances. Systematic uncertainties not estimated.

## $\Upsilon(11020)$ DECAY MODES

| Mode                                      | Fraction ( $\Gamma_i/\Gamma$ )       |
|---|--------------------------------------|
| $\Gamma_1$ $e^+ e^-$                      | $(5.4^{+1.9}_{-2.1}) \times 10^{-6}$ |
| $\Gamma_2$ $\Upsilon(1S)\pi^+\pi^-$       |                                      |
| $\Gamma_3$ $\Upsilon(2S)\pi^+\pi^-$       |                                      |
| $\Gamma_4$ $\Upsilon(3S)\pi^+\pi^-$       |                                      |
| $\Gamma_5$ $\chi_{bJ}(1P)\pi^+\pi^-\pi^0$ | $(9^{+9}_{-8}) \times 10^{-3}$       |
| $\Gamma_6$ $\chi_{b1}(1P)\pi^+\pi^-\pi^0$ | seen                                 |
| $\Gamma_7$ $\chi_{b2}(1P)\pi^+\pi^-\pi^0$ | seen                                 |

## $\Upsilon(11020)$ PARTIAL WIDTHS

| $\Gamma(e^+e^-)$               |             |      |         |                              | $\Gamma_1$ |
|--------------------------------|-------------|------|---------|------------------------------|------------|
| VALUE (keV)                    | DOCUMENT ID | TECN | COMMENT |                              |            |
| <b>0.130±0.030 OUR AVERAGE</b> |             |      |         |                              |            |
| 0.095±0.03 ±0.035              | BESSION     | 85   | CLEO    | $e^+e^- \rightarrow$ hadrons |            |
| 0.156±0.040                    | LOVELOCK    | 85   | CUSB    | $e^+e^- \rightarrow$ hadrons |            |

| $\Gamma(e^+e^-) \times \Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$   |                      |      |         |   | $\Gamma_1\Gamma_2/\Gamma$ |
|--|----------------------|------|---------|---|---------------------------|
| VALUE (eV)   | DOCUMENT ID          | TECN | COMMENT |   |                           |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●  |                      |      |         |   |                           |
| 0.46±0.08  | <sup>1,2</sup> MIZUK | 19   | BELL    | $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$ |                           |
| <sup>1</sup> From a simultaneous fit to the $\Upsilon(nS)\pi^+\pi^-$ , $n = 1, 2, 3$ , cross sections at 28 energy points within $\sqrt{s} = 10.6\text{--}11.05$ GeV, including the initial-state radiation at $\Upsilon(10860)$ .<br><sup>2</sup> Reported as the range 0.38–0.54 eV obtained from multiple solutions of an amplitude fit within a model composed as a sum of Breit-Wigner functions. |                      |      |         |   |                           |

| $\Gamma(e^+e^-) \times \Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{\text{total}}$   |                      |      |         |   | $\Gamma_1\Gamma_3/\Gamma$ |
|--|----------------------|------|---------|---|---------------------------|
| VALUE (eV)   | DOCUMENT ID          | TECN | COMMENT |   |                           |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●  |                      |      |         |   |                           |
| 0.65±0.52  | <sup>1,2</sup> MIZUK | 19   | BELL    | $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$ |                           |
| <sup>1</sup> From a simultaneous fit to the $\Upsilon(nS)\pi^+\pi^-$ , $n = 1, 2, 3$ , cross sections at 28 energy points within $\sqrt{s} = 10.6\text{--}11.05$ GeV, including the initial-state radiation at $\Upsilon(10860)$ .<br><sup>2</sup> Reported as the range 0.13–1.16 eV obtained from multiple solutions of an amplitude fit within a model composed as a sum of Breit-Wigner functions. |                      |      |         |   |                           |

| $\Gamma(e^+e^-) \times \Gamma(\Upsilon(3S)\pi^+\pi^-)/\Gamma_{\text{total}}$   |                      |      |         |   | $\Gamma_1\Gamma_4/\Gamma$ |
|--|----------------------|------|---------|---|---------------------------|
| VALUE (eV)   | DOCUMENT ID          | TECN | COMMENT |   |                           |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●  |                      |      |         |   |                           |
| 0.33±0.16  | <sup>1,2</sup> MIZUK | 19   | BELL    | $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$ |                           |
| <sup>1</sup> From a simultaneous fit to the $\Upsilon(nS)\pi^+\pi^-$ , $n = 1, 2, 3$ , cross sections at 28 energy points within $\sqrt{s} = 10.6\text{--}11.05$ GeV, including the initial-state radiation at $\Upsilon(10860)$ .<br><sup>2</sup> Reported as the range 0.17–0.49 eV obtained from multiple solutions of an amplitude fit within a model composed as a sum of Breit-Wigner functions. |                      |      |         |   |                           |

| $\Gamma(\chi_{bJ}(1P)\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$                |                    |             |                | $\Gamma_5/\Gamma$            |
|---|--------------------|-------------|----------------|------------------------------|
| <u>VALUE (units <math>10^{-3}</math>)</u>                                   | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |                              |
| $8.7 \pm 4.3^{+7.6}_{-6.6}$   | YIN                | 18          | BELL           | $e^+e^- \rightarrow$ hadrons |
| $\Gamma(\chi_{b1}(1P)\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$                |                    |             |                | $\Gamma_6/\Gamma$            |
| <u>VALUE</u>  | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |                              |
| <b>seen</b>   | YIN                | 18          | BELL           | $e^+e^- \rightarrow$ hadrons |
| $\Gamma(\chi_{b2}(1P)\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$                |                    |             |                | $\Gamma_7/\Gamma$            |
| <u>VALUE</u>  | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |                              |
| <b>seen</b>   | YIN                | 18          | BELL           | $e^+e^- \rightarrow$ hadrons |
| $\Gamma(\chi_{b2}(1P)\pi^+\pi^-\pi^0)/\Gamma(\chi_{b1}(1P)\pi^+\pi^-\pi^0)$ |                    |             |                | $\Gamma_7/\Gamma_6$          |
| <u>VALUE</u>  | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |                              |
| $0.4 \pm 0.2$   | YIN                | 18          | BELL           | $e^+e^- \rightarrow$ hadrons |

### $\Upsilon(11020)$ REFERENCES

|          |     |                |                               |                 |
|----------|-----|----------------|-------------------------------|-----------------|
| DONG     | 20A | CP C44 083001  | X.-K. Dong <i>et al.</i>      |                 |
| MIZUK    | 19  | JHEP 1910 220  | R. Mizuk <i>et al.</i>        | (BELLE Collab.) |
| YIN      | 18  | PR D98 091102  | J.H. Yin <i>et al.</i>        | (BELLE Collab.) |
| MIZUK    | 16  | PRL 117 142001 | R. Mizuk <i>et al.</i>        | (BELLE Collab.) |
| SANTEL   | 16  | PR D93 011101  | D. Santel <i>et al.</i>       | (BELLE Collab.) |
| AUBERT   | 09E | PRL 102 012001 | B. Aubert <i>et al.</i>       | (BABAR Collab.) |
| BESSION  | 85  | PRL 54 381     | D. Besson <i>et al.</i>       | (CLEO Collab.)  |
| LOVELOCK | 85  | PRL 54 377     | D.M.J. Lovelock <i>et al.</i> | (CUSB Collab.)  |