

$\Upsilon(11020)$ 

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

### $\Upsilon(11020)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>11000 <math>\pm</math> 4 OUR AVERAGE</b>			
11000.0 <sup>+4.0</sup> <sub>-4.5</sub> <sup>+1.0</sup> <sub>-1.3</sub>	1 MIZUK	19 BELL	$e^+e^- \rightarrow \Upsilon(1S, 2S, 3S)\pi^+\pi^-$
10999.0 <sup>+7.3</sup> <sub>-7.8</sub> <sup>+16.9</sup> <sub>-1.0</sub>	2 MIZUK	16 BELL	$e^+e^- \rightarrow h_b(1P, 2P)\pi^+\pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
11003.0 $\pm$ 1.1 <sup>+</sup> <sub>-1.0</sub> <sup>+0.9</sup> <sub>-1.0</sub>	3,4 SANTEL	16 BELL	$e^+e^- \rightarrow$ hadrons
10987.5 <sup>+6.4</sup> <sub>-2.5</sub> <sup>+9.1</sup> <sub>-2.3</sub>	5,6 SANTEL	16 BELL	$e^+e^- \rightarrow \Upsilon(1S, 2S, 3S)\pi^+\pi^-$
10996 $\pm$ 2	7 AUBERT	09E BABR	$e^+e^- \rightarrow$ hadrons
11019 $\pm$ 5 $\pm$ 7	BESSION	85 CLEO	$e^+e^- \rightarrow$ hadrons
11020 $\pm$ 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 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>4</sup> Not including uncertain and potentially large systematic errors due to assumed continuum amplitude  $1/\sqrt{s}$  dependence and related interference contributions.

<sup>5</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>6</sup> Superseded by MIZUK 19.

<sup>7</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

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>24 <sup>+8</sup><sub>-6</sub> OUR AVERAGE</b>			
23.8 <sup>+8.0</sup> <sub>-6.8</sub> <sup>+0.7</sup> <sub>-1.8</sub>	1 MIZUK	19 BELL	$e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$
27 <sup>+27</sup> <sub>-11</sub> <sup>+5</sup> <sub>-12</sub>	2 MIZUK	16 BELL	$e^+e^- \rightarrow h_b(1P, 2P)\pi^+\pi^-$

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39.3 <sup>+1.7</sup> <sub>-1.6</sub>	<sup>+1.3</sup> <sub>-2.4</sub>	3,4 SANTEL	16	BELL	$e^+e^- \rightarrow \text{hadrons}$
61 <sup>+9</sup> <sub>-19</sub>	<sup>+2</sup> <sub>-20</sub>	5,6 SANTEL	16	BELL	$e^+e^- \rightarrow \Upsilon(1S, 2S, 3S)\pi^+\pi^-$
37 ± 3		<sup>7</sup> AUBERT	09E	BABR	$e^+e^- \rightarrow \text{hadrons}$
61 ± 13	± 22	BESSION	85	CLEO	$e^+e^- \rightarrow \text{hadrons}$
90 ± 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 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>4</sup> Not including uncertain and potentially large systematic errors due to assumed continuum amplitude  $1/\sqrt{s}$  dependence and related interference contributions.

<sup>5</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>6</sup> Superseded by MIZUK 19.

<sup>7</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 $\Gamma(e^+e^-)$   $\Gamma_1$ 

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>0.130 \pm 0.030</math> OUR AVERAGE</b>			
$0.095 \pm 0.03 \pm 0.035$	BESSON	85	CLEO $e^+e^- \rightarrow$ hadrons
$0.156 \pm 0.040$	LOVELOCK	85	CUSB $e^+e^- \rightarrow$ hadrons

 $\Gamma(e^+e^-) \times \Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$   $\Gamma_1\Gamma_2/\Gamma$ 

<u>VALUE (eV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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• • • We do not use the following data for averages, fits, limits, etc. • • •

$0.46 \pm 0.08$	<sup>1,2</sup> MIZUK	19	BELL $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$
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<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> 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.

 $\Gamma(e^+e^-) \times \Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{\text{total}}$   $\Gamma_1\Gamma_3/\Gamma$ 

<u>VALUE (eV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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• • • We do not use the following data for averages, fits, limits, etc. • • •

$0.65 \pm 0.52$	<sup>1,2</sup> MIZUK	19	BELL $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$
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<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> 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.

 $\Gamma(e^+e^-) \times \Gamma(\Upsilon(3S)\pi^+\pi^-)/\Gamma_{\text{total}}$   $\Gamma_1\Gamma_4/\Gamma$ 

<u>VALUE (eV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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• • • We do not use the following data for averages, fits, limits, etc. • • •

$0.33 \pm 0.16$	<sup>1,2</sup> MIZUK	19	BELL $e^+e^- \rightarrow \Upsilon(nS)\pi^+\pi^-$
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<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> 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>
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<b><math>8.7 \pm 4.3^{+7.6}_{-6.6}</math></b>	YIN	18	BELL $e^+e^- \rightarrow$ hadrons
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 $\Gamma(\chi_{b1}(1P)\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$ 

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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<b>seen</b>	YIN	18	BELL $e^+e^- \rightarrow$ hadrons
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 $\Gamma(\chi_{b2}(1P)\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$ 

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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<b>seen</b>	YIN	18	BELL $e^+e^- \rightarrow$ hadrons
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$\Gamma(\chi_{b2}(1P)\pi^+\pi^-\pi^0)/\Gamma(\chi_{b1}(1P)\pi^+\pi^-\pi^0)$				$\Gamma_7/\Gamma_6$
<i>VALUE</i>	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>	
<b>0.4±0.2</b>	YIN	18	BELL	$e^+e^- \rightarrow$ hadrons

### $\Upsilon(11020)$ REFERENCES

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.)
BESSON	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>	(CUSP Collab.)