

$\Upsilon(3S)$ 

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

### $\Upsilon(3S)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>10355.2±0.5</b>	<sup>1</sup> ARTAMONOV 00	MD1	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •			
10355.3±0.5	<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 Superseded by ARTAMONOV 00.			

### $m\Upsilon(3S) - m\Upsilon(2S)$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>331.50±0.02±0.13</b>	LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^-X$

### $\Upsilon(3S)$ WIDTH

VALUE (keV)	DOCUMENT ID	COMMENT
<b>20.32±1.85 OUR EVALUATION</b>	See the Note on "Width Determinations of the $\Upsilon$ States"	

### $\Upsilon(3S)$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level
$\Gamma_1$ $\Upsilon(2S)$ anything	(10.6 ± 0.8) %	
$\Gamma_2$ $\Upsilon(2S)\pi^+\pi^-$	(2.82 ± 0.18) %	S=1.6
$\Gamma_3$ $\Upsilon(2S)\pi^0\pi^0$	(1.85 ± 0.14) %	
$\Gamma_4$ $\Upsilon(2S)\gamma\gamma$	(5.0 ± 0.7) %	
$\Gamma_5$ $\Upsilon(2S)\pi^0$	< 5.1 × 10 <sup>-4</sup>	CL=90%
$\Gamma_6$ $\Upsilon(1S)\pi^+\pi^-$	(4.37 ± 0.08) %	
$\Gamma_7$ $\Upsilon(1S)\pi^0\pi^0$	(2.20 ± 0.13) %	
$\Gamma_8$ $\Upsilon(1S)\eta$	< 1 × 10 <sup>-4</sup>	CL=90%
$\Gamma_9$ $\Upsilon(1S)\pi^0$	< 7 × 10 <sup>-5</sup>	CL=90%
$\Gamma_{10}$ $h_b(1P)\pi^0$	< 1.2 × 10 <sup>-3</sup>	CL=90%
$\Gamma_{11}$ $h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0$	(4.3 ± 1.4) × 10 <sup>-4</sup>	
$\Gamma_{12}$ $h_b(1P)\pi^+\pi^-$	< 1.2 × 10 <sup>-4</sup>	CL=90%
$\Gamma_{13}$ $\tau^+\tau^-$	(2.29 ± 0.30) %	
$\Gamma_{14}$ $\mu^+\mu^-$	(2.18 ± 0.21) %	S=2.1
$\Gamma_{15}$ $e^+e^-$	(2.18 ± 0.20) %	
$\Gamma_{16}$ hadrons	(93 ± 12) %	
$\Gamma_{17}$ $ggg$	(35.7 ± 2.6) %	
$\Gamma_{18}$ $\underline{\gamma}gg$	(9.7 ± 1.8) × 10 <sup>-3</sup>	
$\Gamma_{19}$ ${}^2H$ anything	(2.33 ± 0.33) × 10 <sup>-5</sup>	

### Radiative decays

$\Gamma_{20}$	$\gamma\chi_{b2}(2P)$	$(13.1 \pm 1.6) \%$	$S=3.4$
$\Gamma_{21}$	$\gamma\chi_{b1}(2P)$	$(12.6 \pm 1.2) \%$	$S=2.4$
$\Gamma_{22}$	$\gamma\chi_{b0}(2P)$	$(5.9 \pm 0.6) \%$	$S=1.4$
$\Gamma_{23}$	$\gamma\chi_{b2}(1P)$	$(10.0 \pm 1.0) \times 10^{-3}$	$S=1.7$
$\Gamma_{24}$	$\gamma\chi_{b1}(1P)$	$(9 \pm 5) \times 10^{-4}$	$S=1.8$
$\Gamma_{25}$	$\gamma\chi_{b0}(1P)$	$(2.7 \pm 0.4) \times 10^{-3}$	
$\Gamma_{26}$	$\gamma\eta_b(2S)$	$< 6.2 \times 10^{-4}$	CL=90%
$\Gamma_{27}$	$\gamma\eta_b(1S)$	$(5.1 \pm 0.7) \times 10^{-4}$	
$\Gamma_{28}$	$\gamma A^0 \rightarrow \gamma \text{hadrons}$	$< 8 \times 10^{-5}$	CL=90%
$\Gamma_{29}$	$\gamma X \rightarrow \gamma + \geq 4 \text{ prongs}$	[a] $< 2.2 \times 10^{-4}$	CL=95%
$\Gamma_{30}$	$\gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-$	$< 5.5 \times 10^{-6}$	CL=90%
$\Gamma_{31}$	$\gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-$	[b] $< 1.6 \times 10^{-4}$	CL=90%

### Lepton Family number (LF) violating modes

$\Gamma_{32}$	$e^\pm \tau^\mp$	LF	$< 4.2 \times 10^{-6}$	CL=90%
$\Gamma_{33}$	$\mu^\pm \tau^\mp$	LF	$< 3.1 \times 10^{-6}$	CL=90%

[a]  $1.5 \text{ GeV} < m_X < 5.0 \text{ GeV}$

[b] For  $m_{\tau^+ \tau^-}$  in the ranges 4.03–9.52 and 9.61–10.10 GeV.

### $\Upsilon(3S) \Gamma(i)\Gamma(e^+ e^-)/\Gamma(\text{total})$

$\Gamma(\text{hadrons}) \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{16}\Gamma_{15}/\Gamma$

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.414±0.007 OUR AVERAGE</b>			
0.413±0.004±0.006	ROSNER	06 CLEO	10.4 $e^+ e^- \rightarrow \text{hadrons}$
0.45 ±0.03 ±0.03	<sup>4</sup> GILES	84B CLEO	$e^+ e^- \rightarrow \text{hadrons}$

<sup>4</sup> Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

$\Gamma(\Upsilon(1S)\pi^+\pi^-) \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_6\Gamma_{15}/\Gamma$

<u>VALUE (eV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>18.46±0.27±0.77</b>	6.4K	<sup>5</sup> AUBERT	08BP BABR	$e^+ e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$

<sup>5</sup> Using  $B(\Upsilon(1S) \rightarrow e^+ e^-) = (2.38 \pm 0.11)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.48 \pm 0.05)\%$ .

### $\Upsilon(3S)$ PARTIAL WIDTHS

$\Gamma(e^+ e^-)$   $\Gamma_{15}$

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>
<b>0.443±0.008 OUR EVALUATION</b>	

## $\Upsilon(3S)$ BRANCHING RATIOS

### $\Gamma(\Upsilon(2S)\text{anything})/\Gamma_{\text{total}}$

$\Gamma_1/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.106 ± 0.008 OUR AVERAGE</b>				
0.1023 ± 0.0105	4625	<sup>6,7,8</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \ell^+\ell^- X$
0.111 ± 0.012	4891	<sup>7,8,9</sup> BROCK	91 CLEO	$e^+e^- \rightarrow \pi^+\pi^- X,$ $\pi^+\pi^-\ell^+\ell^-$

<sup>6</sup> Using  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) = (0.038 \pm 0.007)\%$ , and  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) = (1/2)B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-)$ .

<sup>7</sup> Using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$ . With the assumption of  $e\mu$  universality.

<sup>8</sup> Using  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-) = (18.5 \pm 0.8)\%$ .

<sup>9</sup> Using  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$ ,  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.188 \pm 0.035)\%$ , and  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.436 \pm 0.056)\%$ . With the assumption of  $e\mu$  universality.

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

$\Gamma_2/\Gamma$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>2.82 ± 0.18 OUR AVERAGE</b> Error includes scale factor of 1.6. See the ideogram below.				
3.00 ± 0.02 ± 0.14	543k	LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^- X$
2.40 ± 0.10 ± 0.26	800	<sup>10</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^- e^+e^-$
3.12 ± 0.49	980	<sup>11,12</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^+\pi^-\ell^+\ell^-$
2.13 ± 0.38	974	<sup>13</sup> BROCK	91 CLEO	$e^+e^- \rightarrow \pi^+\pi^- X,$ $\pi^+\pi^-\ell^+\ell^-$

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

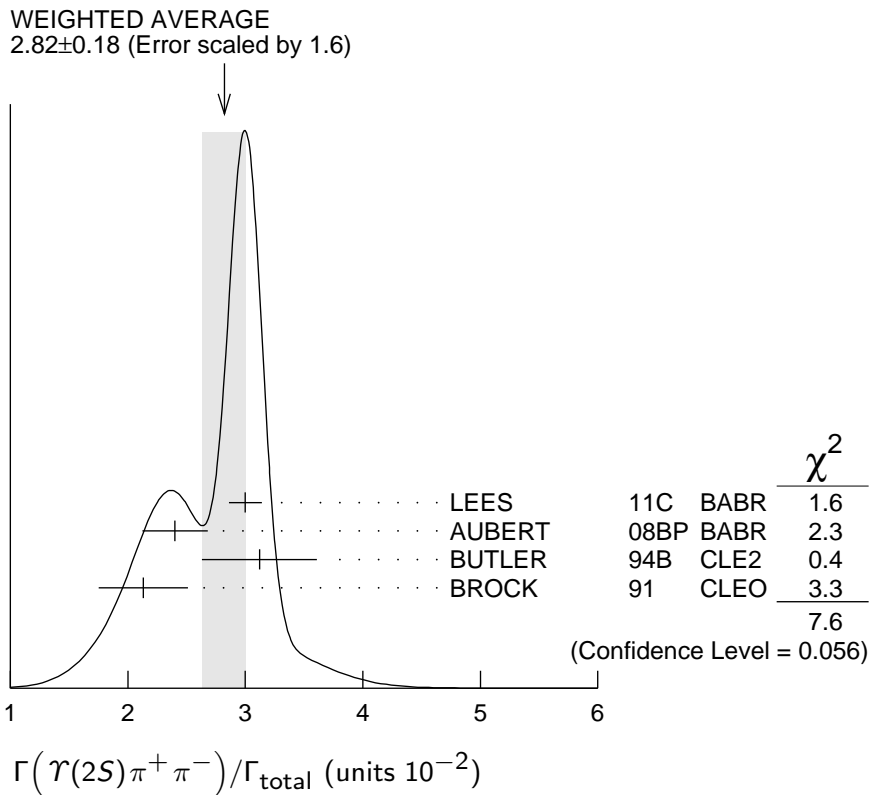
4.82 ± 0.65 ± 0.53	138	<sup>13</sup> WU	93 CUSB	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
3.1 ± 2.0	5	MAGERAS	82 CUSB	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$

<sup>10</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$ ,  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$ , and  $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$  keV.

<sup>11</sup> From the exclusive mode.

<sup>12</sup> Using  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) = (0.038 \pm 0.007)\%$ , and  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) = (1/2)B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-)$ .

<sup>13</sup> Using  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$ ,  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.188 \pm 0.035)\%$ , and  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.436 \pm 0.056)\%$ . With the assumption of  $e\mu$  universality.



**$\Gamma(\Upsilon(2S)\pi^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma$**

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>1.85 \pm 0.14</math></b>	<b>OUR AVERAGE</b>			
$1.82 \pm 0.09 \pm 0.12$	4391	<sup>14</sup> BHARI	09 CLEO	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
$2.16 \pm 0.39$		<sup>15,16</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
$1.7 \pm 0.5 \pm 0.2$	10	<sup>17</sup> HEINTZ	92 CSB2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$

<sup>14</sup> Authors assume  $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.06\%$ .

<sup>15</sup>  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$  and assuming  $e\mu$  universality.

<sup>16</sup> From the exclusive mode.

<sup>17</sup>  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.44 \pm 0.10)\%$  and assuming  $e\mu$  universality. Supersedes HEINTZ 91.

**$\Gamma(\Upsilon(2S)\gamma\gamma)/\Gamma_{\text{total}}$   $\Gamma_4/\Gamma$**

VALUE	DOCUMENT ID	TECN	COMMENT
<b><math>0.0502 \pm 0.0069</math></b>	<sup>18</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \ell^+\ell^-2\gamma$

<sup>18</sup> From the exclusive mode.

**$\Gamma(\Upsilon(2S)\pi^0)/\Gamma_{\text{total}}$   $\Gamma_5/\Gamma$**

VALUE (units $10^{-3}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;0.51</b>	90	<sup>19</sup> HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

<sup>19</sup> Authors assume  $B(\Upsilon(2S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.06\%$ .

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

Abbreviation MM in the COMMENT field below stands for missing mass.

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>4.37±0.08 OUR AVERAGE</b>				
4.32±0.07±0.13	90k	20 LEES	11L BABR	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
4.46±0.01±0.13	190k	21 BHARI	09 CLEO	$e^+e^- \rightarrow \pi^+\pi^-$ MM
4.17±0.06±0.19	6.4K	22 AUBERT	08BP BABR	10.58 $e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$
4.52±0.35	11830	23 BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^+\pi^-X$ , $\pi^+\pi^-\ell^+\ell^-$
4.46±0.34±0.50	451	23 WU	93 CUSB	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
4.46±0.30	11221	23 BROCK	91 CLEO	$e^+e^- \rightarrow \pi^+\pi^-X$ , $\pi^+\pi^-\ell^+\ell^-$

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

4.9 ±1.0      22      GREEN      82      CLEO       $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$ 3.9 ±1.3      26      MAGERAS      82      CUSB       $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$ <sup>20</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$ .<sup>21</sup> A weighted average of the inclusive and exclusive results.<sup>22</sup> Using  $B(\Upsilon(2S) \rightarrow e^+e^-) = (1.91 \pm 0.16)\%$ ,  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.93 \pm 0.17)\%$ , and  $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$  keV.<sup>23</sup> Using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$ . With the assumption of  $e\mu$  universality. $\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$   $\Gamma_2/\Gamma_6$ 

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.577±0.026±0.060	800	24 AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$

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

0.577±0.026±0.060      800      24 AUBERT      08BP BABR       $e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$ <sup>24</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$ ,  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$ ,  $B(\Upsilon(2S) \rightarrow e^+e^-) = (1.91 \pm 0.16)\%$ , and  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.93 \pm 0.17)\%$ . Not independent of other values reported by AUBERT 08BP. $\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$ 

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.20±0.13 OUR AVERAGE</b>				
2.24±0.09±0.11	6584	25 BHARI	09 CLEO	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
1.99±0.34	56	26 BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
2.2 ±0.4 ±0.3	33	27 HEINTZ	92 CSB2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$

**2.20±0.13 OUR AVERAGE**2.24±0.09±0.11      6584      25 BHARI      09 CLEO       $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$ 1.99±0.34      56      26 BUTLER      94B CLE2       $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$ 2.2 ±0.4 ±0.3      33      27 HEINTZ      92 CSB2       $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$ <sup>25</sup> Authors assume  $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$ .<sup>26</sup> Using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$  and assuming  $e\mu$  universality.<sup>27</sup> Using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.07)\%$  and assuming  $e\mu$  universality. Supersedes HEINTZ 91. $\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$   $\Gamma_7/\Gamma_6$ 

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.501±0.043	28 BHARI	09 CLEO	$e^+e^- \rightarrow \Upsilon(3S)$

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

0.501±0.043      28 BHARI      09 CLEO       $e^+e^- \rightarrow \Upsilon(3S)$ <sup>28</sup> Not independent of other values reported by BHARI 09.

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$   $\Gamma_8/\Gamma$

VALUE (units $10^{-3}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;0.1</b>	90	<sup>29</sup> LEES	11L BABR	$\Upsilon(3S) \rightarrow (\pi^+\pi^-)(\gamma\gamma)\ell^+\ell^-$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<0.8	90	<sup>29,30</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$
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<0.18	90	<sup>31</sup> HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\eta$
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<2.2	90	BROCK	91 CLEO	$e^+e^- \rightarrow \ell^+\ell^-\eta$
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<sup>29</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$ ,  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$ .

<sup>30</sup> Using  $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$  keV.

<sup>31</sup> Authors assume  $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$ .

$\Gamma(\Upsilon(1S)\eta)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$   $\Gamma_8/\Gamma_6$

VALUE (units $10^{-2}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;0.23</b>	90	<sup>32</sup> LEES	11L BABR	$\Upsilon(3S) \rightarrow (\pi^+\pi^-)(\gamma\gamma)\ell^+\ell^-$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<1.9	90	<sup>33</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-(\pi^0)\ell^+\ell^-$
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<sup>32</sup> Not independent of other values reported by LEES 11L.

<sup>33</sup> Not independent of other values reported by AUBERT 08BP.

$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$   $\Gamma_9/\Gamma$

VALUE (units $10^{-3}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;0.07</b>	90	<sup>34</sup> HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
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<sup>34</sup> Authors assume  $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$ .

$\Gamma(h_b(1P)\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{10}/\Gamma$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;1.2 × 10<sup>-3</sup></b>	90	<sup>35</sup> GE	11 CLEO	$\Upsilon(3S) \rightarrow \pi^0$ anything
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<sup>35</sup> Assuming  $M(h_b(1P)) = 9900$  MeV and  $\Gamma(h_b(1P)) = 0$  MeV, and allowing  $B(h_b(1P) \rightarrow \gamma\eta_b(1S))$  to vary from 0–100%.

$\Gamma(h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$

VALUE (units $10^{-4}$ )	DOCUMENT ID	TECN	COMMENT
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<b>4.3 ± 1.1 ± 0.9</b>	LEES	11K BABR	$\Upsilon(3S) \rightarrow \eta_b\gamma\pi^0$
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$\Gamma(h_b(1P)\pi^+\pi^-)/\Gamma_{\text{total}}$   $\Gamma_{12}/\Gamma$

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt; 1.2</b>	90	<sup>36</sup> LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^-X$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<18		<sup>36</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^+\pi^-X$
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<15		<sup>36</sup> BROCK	91 CLEO	$e^+e^- \rightarrow \pi^+\pi^-X$
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<sup>36</sup> For  $M(h_b(1P)) = 9900$  MeV.

**$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$**   **$\Gamma_{13}/\Gamma$**

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>2.29 \pm 0.21 \pm 0.22</math></b>	15k	<sup>37</sup> BESSON 07	CLEO	$e^+e^- \rightarrow \Upsilon(3S) \rightarrow \tau^+\tau^-$

<sup>37</sup> BESSON 07 reports  $[\Gamma(\Upsilon(3S) \rightarrow \tau^+\tau^-)/\Gamma_{\text{total}}] / [B(\Upsilon(3S) \rightarrow \mu^+\mu^-)] = 1.05 \pm 0.08 \pm 0.05$  which we multiply by our best value  $B(\Upsilon(3S) \rightarrow \mu^+\mu^-) = (2.18 \pm 0.21) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

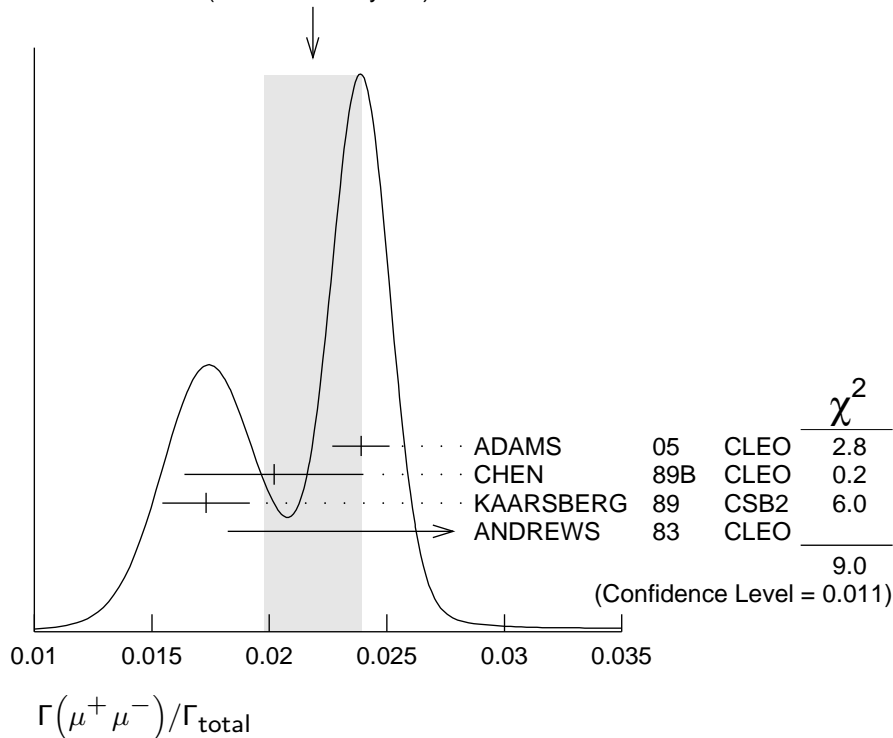
**$\Gamma(\tau^+\tau^-)/\Gamma(\mu^+\mu^-)$**   **$\Gamma_{13}/\Gamma_{14}$**

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>1.05 \pm 0.08 \pm 0.05</math></b>	15k	BESSON 07	CLEO	$e^+e^- \rightarrow \Upsilon(3S)$

**$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$**   **$\Gamma_{14}/\Gamma$**

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.0218 \pm 0.0021</math> OUR AVERAGE</b>		Error includes scale factor of 2.1. See the ideogram below.		
$0.0239 \pm 0.0007 \pm 0.0010$	81k	ADAMS 05	CLEO	$e^+e^- \rightarrow \mu^+\mu^-$
$0.0202 \pm 0.0019 \pm 0.0033$		CHEN 89B	CLEO	$e^+e^- \rightarrow \mu^+\mu^-$
$0.0173 \pm 0.0015 \pm 0.0011$		KAARSBERG 89	CSB2	$e^+e^- \rightarrow \mu^+\mu^-$
$0.033 \pm 0.013 \pm 0.007$	1096	ANDREWS 83	CLEO	$e^+e^- \rightarrow \mu^+\mu^-$

WEIGHTED AVERAGE  
 $0.0218 \pm 0.0021$  (Error scaled by 2.1)



**$\Gamma(ggg)/\Gamma_{\text{total}}$**   **$\Gamma_{17}/\Gamma$**

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>35.7 \pm 2.6</math></b>	3M	<sup>38</sup> BESSON 06A	CLEO	$\Upsilon(3S) \rightarrow \text{hadrons}$

<sup>38</sup> Calculated using BESSON 06A value of  $\Gamma(\gamma g g)/\Gamma(g g g) = (2.72 \pm 0.06 \pm 0.32 \pm 0.37)\%$  and the PDG 08 values of  $B(\Upsilon(2S) + \text{anything}) = (10.6 \pm 0.8)\%$ ,  $B(\pi^+ \pi^- \Upsilon(1S)) = (4.40 \pm 0.10)\%$ ,  $B(\pi^0 \pi^0 \Upsilon(1S)) = (2.20 \pm 0.13)\%$ ,  $B(\gamma \chi_{b2}(2P)) = (13.1 \pm 1.6)\%$ ,  $B(\gamma \chi_{b1}(2P)) = (12.6 \pm 1.2)\%$ ,  $B(\gamma \chi_{b0}(2P)) = (5.9 \pm 0.6)\%$ ,  $B(\gamma \chi_{b0}(1P)) = (0.30 \pm 0.11)\%$ ,  $B(\mu^+ \mu^-) = (2.18 \pm 0.21)\%$ , and  $R_{\text{hadrons}} = 3.51$ . The statistical error is negligible and the systematic error is partially correlated with  $\Gamma(\gamma g g)/\Gamma_{\text{total}}$  BESSON 06A value.

$\Gamma(\gamma g g)/\Gamma_{\text{total}}$					$\Gamma_{18}/\Gamma$
VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT	
<b>0.97 ± 0.18</b>	60k	<sup>39</sup> BESSON	06A	CLEO	$\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$

<sup>39</sup> Calculated using BESSON 06A values of  $\Gamma(\gamma g g)/\Gamma(g g g) = (2.72 \pm 0.06 \pm 0.32 \pm 0.37)\%$  and  $\Gamma(g g g)/\Gamma_{\text{total}}$ . The statistical error is negligible and the systematic error is partially correlated with  $\Gamma(g g g)/\Gamma_{\text{total}}$  BESSON 06A value.

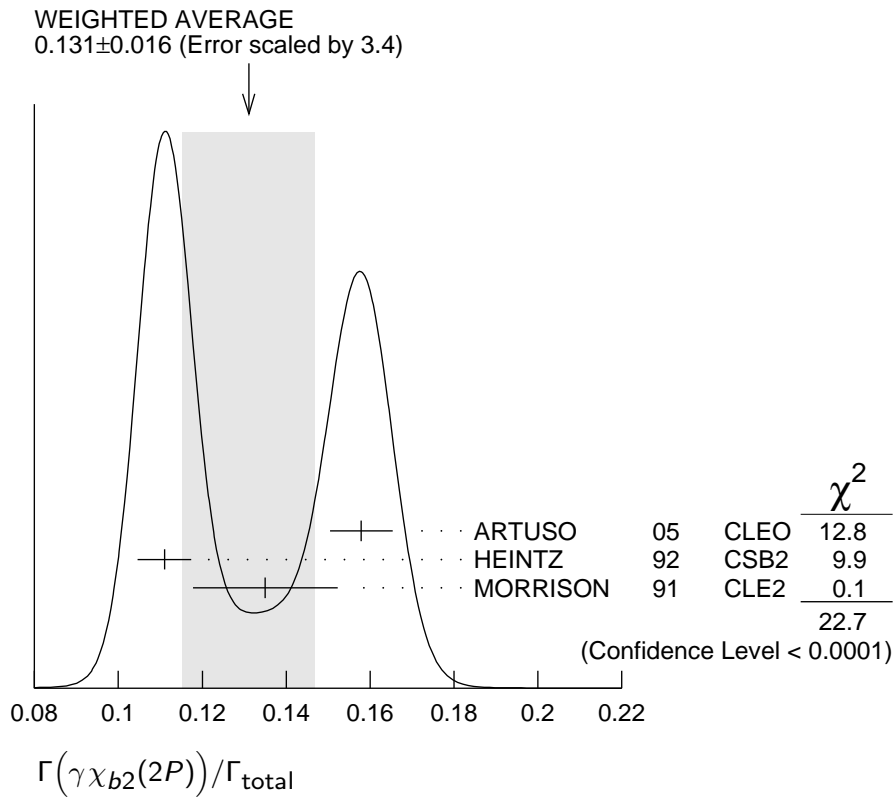
$\Gamma(\gamma g g)/\Gamma(g g g)$					$\Gamma_{18}/\Gamma_{17}$
VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT	
<b>2.72 ± 0.06 ± 0.49</b>	3M	BESSON	06A	CLEO	$\Upsilon(3S) \rightarrow (\gamma +) \text{hadrons}$

$\Gamma(\overline{2H} \text{ anything})/\Gamma_{\text{total}}$					$\Gamma_{19}/\Gamma$
VALUE (units $10^{-5}$ )		DOCUMENT ID	TECN	COMMENT	
<b>2.33 ± 0.15<sup>+0.31</sup><sub>-0.28</sub></b>		LEES	14G	BABR	$e^+ e^- \rightarrow \overline{2H} X$

$\Gamma(\gamma \chi_{b2}(2P))/\Gamma_{\text{total}}$					$\Gamma_{20}/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
<b>0.131 ± 0.016 OUR AVERAGE</b>		Error includes scale factor of 3.4. See the ideogram below.			
0.1579 ± 0.0017 ± 0.0073	568k	ARTUSO	05	CLEO	$e^+ e^- \rightarrow \gamma X$
0.111 ± 0.005 ± 0.004	10319	<sup>40</sup> HEINTZ	92	CSB2	$e^+ e^- \rightarrow \gamma X$
0.135 ± 0.003 ± 0.017	30741	MORRISON	91	CLE2	$e^+ e^- \rightarrow \gamma X$

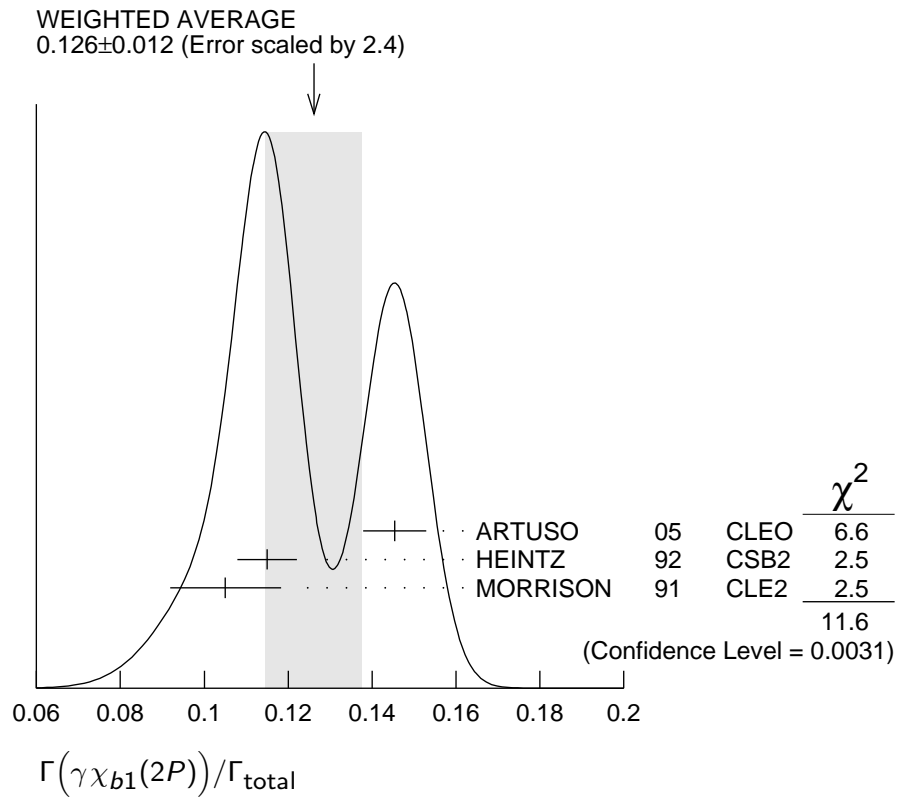
<sup>40</sup> Supersedes NARAIN 91.





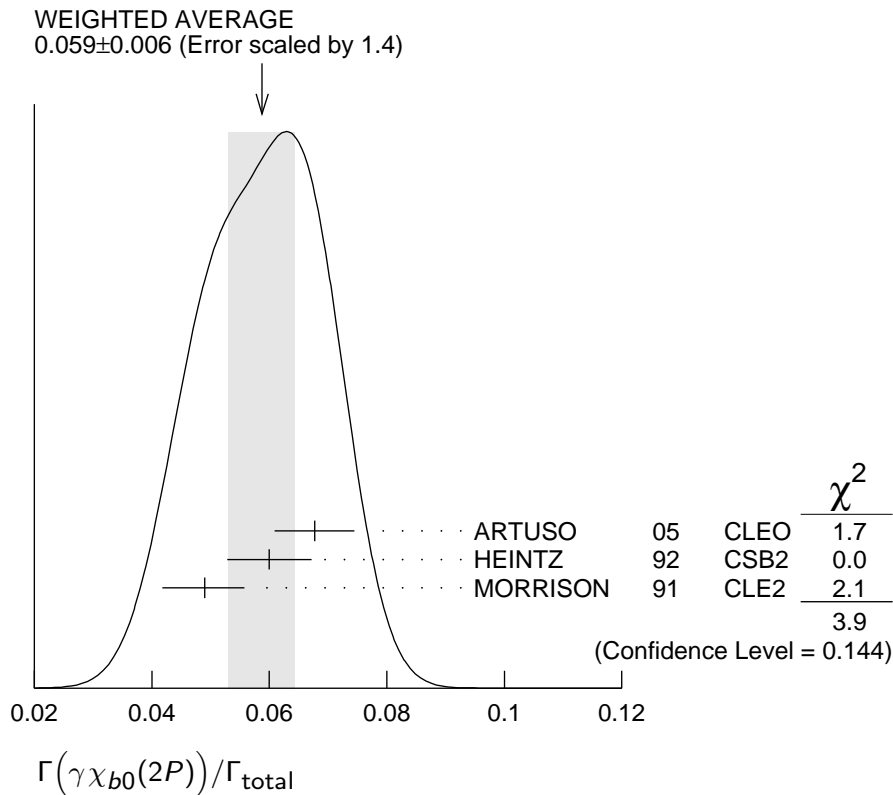
$\Gamma(\gamma\chi_{b1}(2P))/\Gamma_{\text{total}}$						$\Gamma_{21}/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT		
<b><math>0.126 \pm 0.012</math> OUR AVERAGE</b>				Error includes scale factor of 2.4. See the ideogram below.		
$0.1454 \pm 0.0018 \pm 0.0073$	537k	ARTUSO	05	CLEO	$e^+e^- \rightarrow \gamma X$	
$0.115 \pm 0.005 \pm 0.005$	11147	<sup>41</sup> HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X$	
$0.105 \begin{smallmatrix} +0.003 \\ -0.002 \end{smallmatrix} \pm 0.013$	25759	MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$	

<sup>41</sup>Supersedes NARAIN 91.



$\Gamma(\gamma\chi_{b0}(2P))/\Gamma_{\text{total}}$	$\Gamma_{22}/\Gamma$
<u>VALUE</u>	<u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
<b><math>0.059 \pm 0.006</math> OUR AVERAGE</b>	Error includes scale factor of 1.4. See the ideogram below.
$0.0677 \pm 0.0020 \pm 0.0065$	225k    ARTUSO    05    CLEO $e^+e^- \rightarrow \gamma X$
$0.060 \pm 0.004 \pm 0.006$	<sup>42</sup> HEINTZ    92    CSB2 $e^+e^- \rightarrow \gamma X$
$0.049 \begin{smallmatrix} +0.003 \\ -0.004 \end{smallmatrix} \pm 0.006$	9903    MORRISON    91    CLE2 $e^+e^- \rightarrow \gamma X$

<sup>42</sup>Supersedes NARAIN 91.



**$\Gamma(\gamma\chi_{b2}(1P))/\Gamma_{\text{total}}$**   **$\Gamma_{23}/\Gamma$**

VALUE (units $10^{-3}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>10.0 \pm 1.0</math></b>	<b>OUR AVERAGE</b>				Error includes scale factor of 1.7.
$8.0 \pm 1.3 \pm 0.4$		126	<sup>43,44</sup> KORNICER	11	CLEO $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$
$10.5 \pm 0.3^{+0.7}_{-0.6}$		9.7k	LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$

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

<19 seen	90	<sup>45</sup> ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
		<sup>46</sup> HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>43</sup> Assuming  $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (2.48 \pm 0.05)\%$ .

<sup>44</sup> KORNICER 11 reports  $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{\text{total}}] \times [B(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))]$   
 $= (1.435 \pm 0.162 \pm 0.169) \times 10^{-3}$  which we divide by our best value  $B(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S)) = (18.0 \pm 1.0) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>45</sup> ASNER 08A reports  $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{\text{total}}] / [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))]$   
 $< 27.1 \times 10^{-2}$  which we multiply by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = 7.15 \times 10^{-2}$ .

<sup>46</sup> HEINTZ 92, while unable to distinguish between different  $J$  states, measures  $\sum_J B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}) \times B(\chi_{bJ} \rightarrow \gamma\Upsilon(1S)) = (1.7 \pm 0.4 \pm 0.6) \times 10^{-3}$  for  $J = 0,1,2$  using inclusive  $\Upsilon(1S)$  decays and  $(1.2^{+0.4}_{-0.3} \pm 0.09) \times 10^{-3}$  for  $J = 1,2$  using  $\Upsilon(1S) \rightarrow \ell^+\ell^-$ .

$\Gamma(\gamma\chi_{b1}(1P))/\Gamma_{\text{total}}$   $\Gamma_{24}/\Gamma$

VALUE (units $10^{-3}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.9±0.5 OUR AVERAGE</b> Error includes scale factor of 1.8.					
1.5±0.4±0.1		50	<sup>47,48</sup> KORNICER	11	CLEO $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$
0.5±0.3 <sup>+0.2</sup> <sub>-0.1</sub>			LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$

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

<1.7 seen	90		<sup>49</sup> ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
			<sup>50</sup> HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>47</sup> Assuming  $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (2.48 \pm 0.05)\%$ .

<sup>48</sup> KORNICER 11 reports  $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(1P))/\Gamma_{\text{total}}] \times [B(\chi_{b1}(1P) \rightarrow \gamma\Upsilon(1S))] = (5.38 \pm 1.20 \pm 0.95) \times 10^{-4}$  which we divide by our best value  $B(\chi_{b1}(1P) \rightarrow \gamma\Upsilon(1S)) = (35.2 \pm 2.0) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>49</sup> ASNER 08A reports  $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(1P))/\Gamma_{\text{total}}] / [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] < 2.5 \times 10^{-2}$  which we multiply by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P)) = 6.9 \times 10^{-2}$ .

<sup>50</sup> HEINTZ 92, while unable to distinguish between different  $J$  states, measures  $\sum_J B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}) \times B(\chi_{bJ} \rightarrow \gamma\Upsilon(1S)) = (1.7 \pm 0.4 \pm 0.6) \times 10^{-3}$  for  $J = 0,1,2$  using inclusive  $\Upsilon(1S)$  decays and  $(1.2^{+0.4}_{-0.3} \pm 0.09) \times 10^{-3}$  for  $J = 1,2$  using  $\Upsilon(1S) \rightarrow \ell^+\ell^-$ .

$\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{\text{total}}$   $\Gamma_{25}/\Gamma$

VALUE (units $10^{-2}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.27±0.04 OUR AVERAGE</b>					
0.27±0.04±0.02		2.3k	LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
0.30±0.04±0.10		8.7k	ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$

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

<0.8	90		<sup>51</sup> ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
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<sup>51</sup> ASNER 08A reports  $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(1P))/\Gamma_{\text{total}}] / [B(\Upsilon(2S) \rightarrow \gamma\chi_{b0}(1P))] < 21.9 \times 10^{-2}$  which we multiply by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$ .

$\Gamma(\gamma\eta_b(2S))/\Gamma_{\text{total}}$   $\Gamma_{26}/\Gamma$

VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>&lt; 6.2</b>					
	90		ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<19	90		LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$

$\Gamma(\gamma\eta_b(1S))/\Gamma_{\text{total}}$   $\Gamma_{27}/\Gamma$

VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>5.1±0.7 OUR AVERAGE</b>					
7.1±1.8±1.3		2.3±0.5k	<sup>52</sup> BONVICINI	10	CLEO $\Upsilon(3S) \rightarrow \gamma X$
4.8±0.5±0.6		19±3k	<sup>52</sup> AUBERT	09AQ	BABR $\Upsilon(3S) \rightarrow \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<8.5	90		LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
4.8±0.5±1.2		19±3k	<sup>52,53</sup> AUBERT	08V	BABR $\Upsilon(3S) \rightarrow \gamma X$
<4.3	90		<sup>54</sup> ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$

<sup>52</sup> Assuming  $\Gamma_{\eta_b(1S)} = 10$  MeV.

<sup>53</sup> Systematic error re-evaluated by AUBERT 09AQ.

<sup>54</sup> Superseded by BONVICINI 10.

**$\Gamma(\gamma A^0 \rightarrow \gamma \text{hadrons})/\Gamma_{\text{total}}$**   **$\Gamma_{28}/\Gamma$**   
 (0.3 GeV <  $m_{A^0}$  < 7 GeV)

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;8 × 10<sup>-5</sup></b>	90	<sup>55</sup> LEES	11H BABR	$\Upsilon(3S) \rightarrow \gamma \text{hadrons}$

<sup>55</sup> For a narrow scalar or pseudoscalar  $A^0$ , excluding known resonances, with mass in the range 0.3–7 GeV. Measured 90% CL limits as a function of  $m_{A^0}$  range from  $1 \times 10^{-6}$  to  $8 \times 10^{-5}$ .

**$\Gamma(\gamma X \rightarrow \gamma + \geq 4 \text{ prongs})/\Gamma_{\text{total}}$**   **$\Gamma_{29}/\Gamma$**   
 (1.5 GeV <  $m_X$  < 5.0 GeV)

VALUE (units 10 <sup>-4</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;2.2</b>	95	ROSNER	07A CLEO	$e^+e^- \rightarrow \gamma X$

**$\Gamma(\gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-)/\Gamma_{\text{total}}$**   **$\Gamma_{30}/\Gamma$**

VALUE (units 10 <sup>-6</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;5.5</b>	90	<sup>56</sup> AUBERT	09Z BABR	$e^+e^- \rightarrow \gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-$

<sup>56</sup> For a narrow scalar or pseudoscalar  $a_1^0$  with mass in the range 212–9300 MeV, excluding  $J/\psi$  and  $\psi(2S)$ . Measured 90% CL limits as a function of  $m_{a_1^0}$  range from 0.27–5.5 × 10<sup>-6</sup>.

**$\Gamma(\gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-)/\Gamma_{\text{total}}$**   **$\Gamma_{31}/\Gamma$**

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;1.6 × 10<sup>-4</sup></b>	90	<sup>57</sup> AUBERT	09P BABR	$e^+e^- \rightarrow \gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-$

<sup>57</sup> For a narrow scalar or pseudoscalar  $a_1^0$  with  $M(\tau^+ \tau^-)$  in the ranges 4.03–9.52 and 9.61–10.10 GeV. Measured 90% CL limits as a function of  $M(\tau^+ \tau^-)$  range from 1.5–16 × 10<sup>-5</sup>.

————— **LEPTON FAMILY NUMBER (LF) VIOLATING MODES** —————

**$\Gamma(e^\pm \tau^\mp)/\Gamma_{\text{total}}$**   **$\Gamma_{32}/\Gamma$**

VALUE (units 10 <sup>-6</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;4.2</b>	90	LEES	10B BABR	$e^+e^- \rightarrow e^\pm \tau^\mp$

**$\Gamma(\mu^\pm \tau^\mp)/\Gamma_{\text{total}}$**   **$\Gamma_{33}/\Gamma$**

VALUE (units 10 <sup>-6</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt; 3.1</b>	90	LEES	10B BABR	$e^+e^- \rightarrow \mu^\pm \tau^\mp$

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

<20.3	95	LOVE	08A CLEO	$e^+e^- \rightarrow \mu^\pm \tau^\mp$
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