

# $\Upsilon(3S)$

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

## $\Upsilon(3S)$ MASS

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>10355.1±0.5</b>	<sup>1</sup> SHAMOV 23	RVUE	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •			
10355.2±0.5	<sup>2,3</sup> ARTAMONOV 00	MD1	$e^+e^- \rightarrow$ hadrons
10355.3±0.5	<sup>4,5</sup> BARU 86B	MD1	$e^+e^- \rightarrow$ hadrons

<sup>1</sup> Reanalysis of MD1 data using the electron mass from COHEN 87, the radiative corrections from KURAEV 85 and interference effects.

<sup>2</sup> Reanalysis of BARU 86B using new electron mass (COHEN 87).

<sup>3</sup> Superseded by SHAMOV 23.

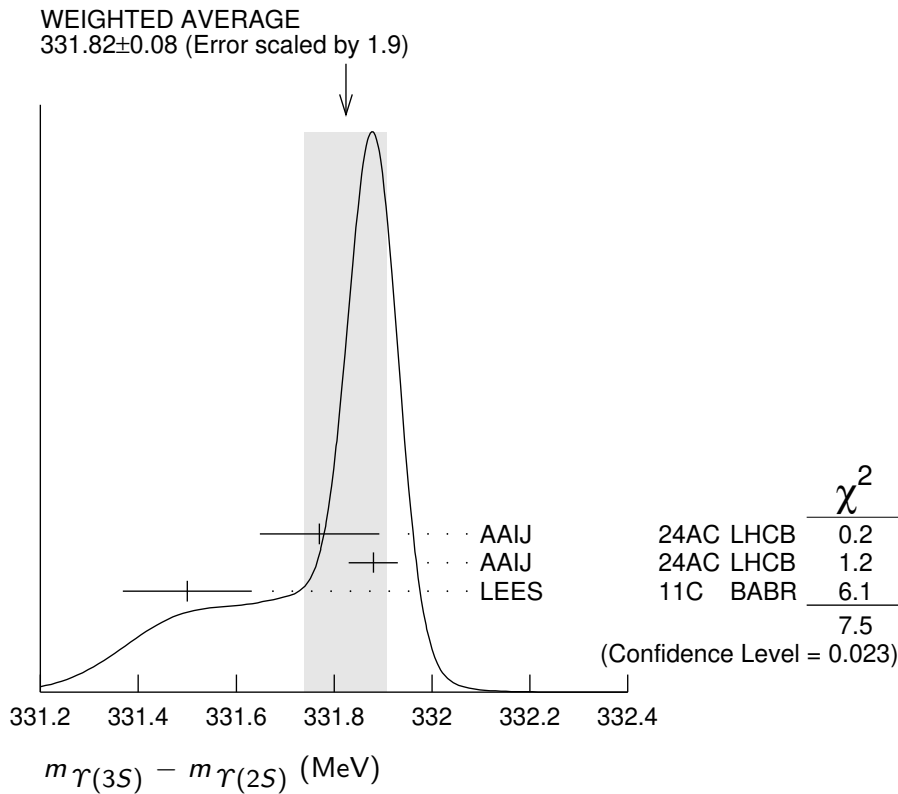
<sup>4</sup> Reanalysis of ARTAMONOV 84.

<sup>5</sup> Superseded by ARTAMONOV 00.

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

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>331.82±0.08 OUR AVERAGE</b>		Error includes scale factor of 1.9. See the ideogram below.		
331.77±0.07±0.10	1.8M	<sup>6</sup> AAIJ 24AC	LHCB	$\Upsilon \rightarrow \mu^+\mu^-$
331.88±0.03±0.04	1.5k	<sup>6</sup> AAIJ 24AC	LHCB	$\Upsilon(3S) \rightarrow \Upsilon(2S)\pi^+\pi^-$
331.50±0.02±0.13		LEES 11C	BABR	$e^+e^- \rightarrow \pi^+\pi^-X$

<sup>6</sup> Observed in prompt  $pp$  production.



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

VALUE (keV)

DOCUMENT ID

**20.32 ± 1.85 OUR EVALUATION** 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 ± 1.6) %	S=3.4
$\Gamma_{21}$ $\gamma\chi_{b1}(2P)$	(12.6 ± 1.2) %	S=2.4
$\Gamma_{22}$ $\gamma\chi_{b0}(2P)$	(5.9 ± 0.6) %	S=1.4
$\Gamma_{23}$ $\gamma\chi_{b2}(1P)$	(10.0 ± 1.0) × 10 <sup>-3</sup>	S=1.7
$\Gamma_{24}$ $\gamma\chi_{b1}(1P)$	(9 ± 5) × 10 <sup>-4</sup>	S=1.8
$\Gamma_{25}$ $\gamma\chi_{b0}(1P)$	(2.7 ± 0.4) × 10 <sup>-3</sup>	
$\Gamma_{26}$ $\gamma\eta_b(2S)$	< 6.2 × 10 <sup>-4</sup>	CL=90%
$\Gamma_{27}$ $\gamma\eta_b(1S)$	(5.1 ± 0.7) × 10 <sup>-4</sup>	
$\Gamma_{28}$ $\gamma A^0 \rightarrow \gamma$ hadrons	< 8 × 10 <sup>-5</sup>	CL=90%
$\Gamma_{29}$ $\gamma X \rightarrow \gamma + \geq 4$ prongs	[a] < 2.2 × 10 <sup>-4</sup>	CL=95%
$\Gamma_{30}$ $\gamma A^0 \rightarrow \gamma\mu^+\mu^-$	< 5.5 × 10 <sup>-6</sup>	CL=90%
$\Gamma_{31}$ $\gamma A^0 \rightarrow \gamma\tau^+\tau^-$	[b] < 1.6 × 10 <sup>-4</sup>	CL=90%

**Lepton Family number (LF) violating modes**

$\Gamma_{32}$ $e^\pm\tau^\mp$	LF < 4.2 × 10 <sup>-6</sup>	CL=90%
$\Gamma_{33}$ $e^\pm\mu^\mp$	LF < 3.6 × 10 <sup>-7</sup>	CL=90%

$$\Gamma_{34} \mu^\pm \tau^\mp \quad LF \quad < 3.1 \quad \times 10^{-6} \quad CL=90\%$$

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

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

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

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

VALUE (keV)	DOCUMENT ID	TECN	COMMENT
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#### **0.414 ± 0.007 OUR AVERAGE**

0.413 ± 0.004 ± 0.006	ROSNER	06	CLEO $10.4 e^+e^- \rightarrow \text{hadrons}$
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0.45 ± 0.03 ± 0.03	<sup>7</sup> GILES	84B	CLEO $e^+e^- \rightarrow \text{hadrons}$
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<sup>7</sup> Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

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

VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT
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<b>18.46 ± 0.27 ± 0.77</b>	6.4k	<sup>8</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$
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<sup>8</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

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

VALUE (keV)	DOCUMENT ID
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#### **0.443 ± 0.008 OUR EVALUATION**

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

$$\Gamma(\Upsilon(2S)\text{anything})/\Gamma_{\text{total}} \quad \Gamma_1/\Gamma$$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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#### **0.106 ± 0.008 OUR AVERAGE**

0.1023 ± 0.0105	4625 <sup>9,10,11</sup>	BUTLER	94B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-X$
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0.111 ± 0.012	4891 <sup>10,11,12</sup>	BROCK	91	CLEO $e^+e^- \rightarrow \pi^+\pi^-X, \pi^+\pi^-\ell^+\ell^-$
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<sup>9</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>10</sup> Using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$ . With the assumption of  $e\mu$  universality.

<sup>11</sup> Using  $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-) = (18.5 \pm 0.8)\%$ .

<sup>12</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.

$$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{\text{total}} \quad \Gamma_2/\Gamma$$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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#### **2.82 ± 0.18 OUR AVERAGE** Error includes scale factor of 1.6. See the ideogram below.

3.00 ± 0.02 ± 0.14	543k	LEES	11C	BABR $e^+e^- \rightarrow \pi^+\pi^-X$
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2.40 ± 0.10 ± 0.26	800	<sup>13</sup> AUBERT	08BP	BABR $e^+e^- \rightarrow \gamma\pi^+\pi^-e^+e^-$
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$\Gamma(\Upsilon(2S)\gamma\gamma)/\Gamma_{\text{total}}$  $\Gamma_4/\Gamma$ 

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<b>0.0502±0.0069</b>		<sup>21</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \ell^+\ell^-2\gamma$

<sup>21</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>22</sup> HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

<sup>22</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	<sup>23</sup> LEES	11L BABR	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
4.46±0.01±0.13	190k	<sup>24</sup> BHARI	09 CLEO	$e^+e^- \rightarrow \pi^+\pi^- \text{MM}$
4.17±0.06±0.19	6.4k	<sup>25</sup> AUBERT	08BP BABR	10.58 $e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$
4.52±0.35	11830	<sup>26</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^+\pi^-X$ , $\pi^+\pi^-\ell^+\ell^-$
4.46±0.34±0.50	451	<sup>26</sup> WU	93 CUSB	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
4.46±0.30	11221	<sup>26</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. • • •

4.9 ±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>23</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>24</sup> A weighted average of the inclusive and exclusive results.<sup>25</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>26</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
<b>0.577±0.026±0.060</b>	800	<sup>27</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$

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

<sup>27</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	<sup>28</sup> BHARI	09 CLEO	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
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1.99±0.34	56	<sup>29</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
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2.2 ±0.4 ±0.3	33	<sup>30</sup> HEINTZ	92 CSB2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
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<sup>28</sup> Authors assume  $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$ .<sup>29</sup> Using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$  and assuming  $e\mu$  universality.<sup>30</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	CL%	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.501±0.043		<sup>31</sup> BHARI	09	CLEO $e^+e^- \rightarrow \Upsilon(3S)$
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<sup>31</sup> Not independent of other values reported by BHARI 09.

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

VALUE (units 10 <sup>-3</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
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<0.1	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. • • •

<0.8	90	<sup>32,33</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$
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<0.18	90	<sup>34</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>32</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>33</sup> Using  $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$  keV.

<sup>34</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 <sup>-2</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
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<0.23	90	<sup>35</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>36</sup> AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-(\pi^0)\ell^+\ell^-$
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<sup>35</sup> Not independent of other values reported by LEES 11L.

<sup>36</sup> Not independent of other values reported by AUBERT 08BP.

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

VALUE (units 10 <sup>-3</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
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<0.07	90	<sup>37</sup> HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
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<sup>37</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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<1.2 × 10 <sup>-3</sup>	90	<sup>38</sup> GE	11 CLEO	$\Upsilon(3S) \rightarrow \pi^0$ anything
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<sup>38</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 <sup>-4</sup> )	DOCUMENT ID	TECN	COMMENT
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4.3±1.1±0.9	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 <sup>-4</sup> )	CL%	DOCUMENT ID	TECN	COMMENT
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< 1.2	90	<sup>39</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>39</sup> BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^+\pi^-X$
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<15		<sup>39</sup> BROCK	91 CLEO	$e^+e^- \rightarrow \pi^+\pi^-X$
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<sup>39</sup> For  $M(h_b(1P)) = 9900$  MeV.

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

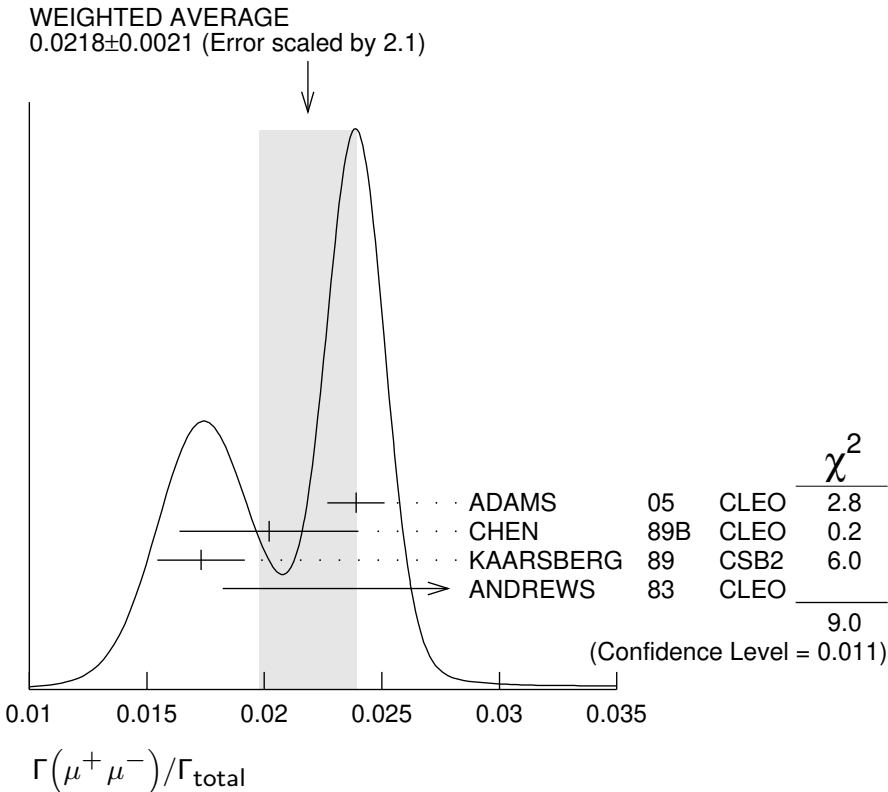
VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.29 ± 0.21 ± 0.22</b>	15k	<sup>40</sup> BESSON	07	CLEO $e^+e^- \rightarrow \Upsilon(3S) \rightarrow \tau^+\tau^-$
<sup>40</sup> BESSON 07 reports $[\Gamma(\Upsilon(3S) \rightarrow \tau^+\tau^-)/\Gamma_{\text{total}}] / [B(\Upsilon(3S) \rightarrow \mu^+\mu^-)] = 1.05 \pm 0.08 \pm 0.05$ which we multiply by our best (shown rounded) 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 (shown rounded) value.				

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.968 ± 0.016 OUR AVERAGE</b>				
0.966 ± 0.008 ± 0.014	2.2M	LEES	20E	BABR $e^+e^- \rightarrow \Upsilon(3S)$
1.05 ± 0.08 ± 0.05	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>0.0218 ± 0.0021 OUR AVERAGE</b>				Error includes scale factor of 2.1. See the ideogram below.
0.0239 ± 0.0007 ± 0.0010	81k	ADAMS	05	CLEO $e^+e^- \rightarrow \mu^+\mu^-$
0.0202 ± 0.0019 ± 0.0033		CHEN	89B	CLEO $e^+e^- \rightarrow \mu^+\mu^-$
0.0173 ± 0.0015 ± 0.0011		KAARSBERG	89	CSB2 $e^+e^- \rightarrow \mu^+\mu^-$
0.033 ± 0.013 ± 0.007	1096	ANDREWS	83	CLEO $e^+e^- \rightarrow \mu^+\mu^-$



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

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>35.7 \pm 2.6</math></b>	3M	<sup>41</sup> BESSON	06A CLEO	$\Upsilon(3S) \rightarrow \text{hadrons}$

<sup>41</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><math>0.97 \pm 0.18</math></b>	60k	<sup>42</sup> BESSON	06A CLEO	$\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$

<sup>42</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><math>2.72 \pm 0.06 \pm 0.49</math></b>	3M	BESSON	06A CLEO	$\Upsilon(3S) \rightarrow (\gamma +) \text{hadrons}$

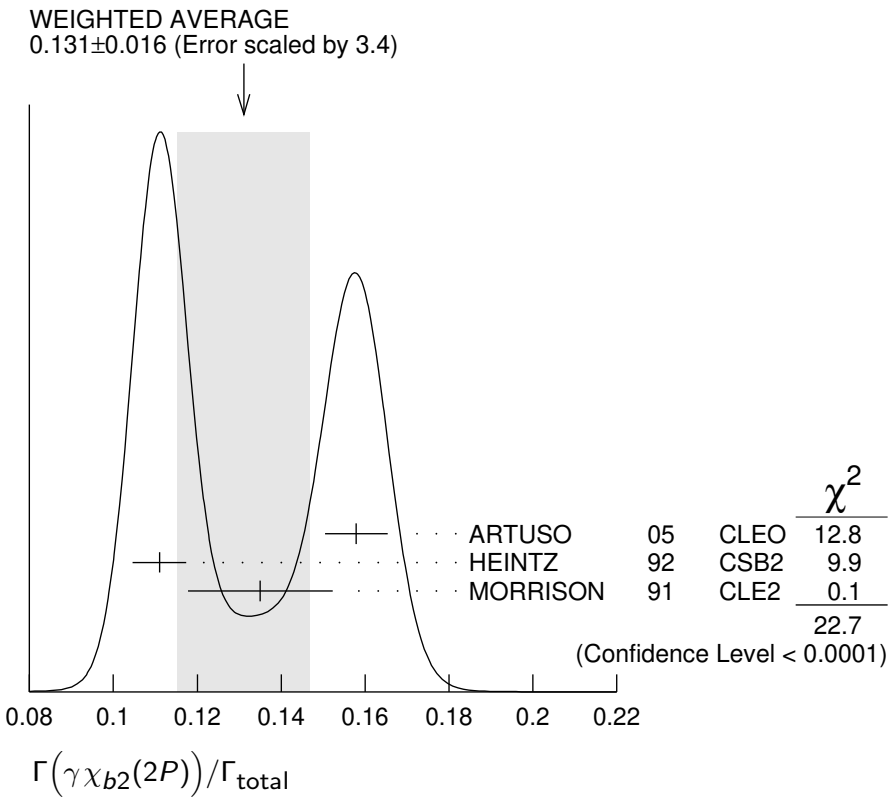
 $\Gamma(\overline{2H} \text{ anything})/\Gamma_{\text{total}}$   $\Gamma_{19}/\Gamma$ 

VALUE (units $10^{-5}$ )	DOCUMENT ID	TECN	COMMENT
<b><math>2.33 \pm 0.15^{+0.31}_{-0.28}</math></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><math>0.131 \pm 0.016</math> OUR AVERAGE</b>				Error includes scale factor of 3.4. See the ideogram below.
$0.1579 \pm 0.0017 \pm 0.0073$	568k	ARTUSO	05 CLEO	$e^+ e^- \rightarrow \gamma X$
$0.111 \pm 0.005 \pm 0.004$	10319	<sup>43</sup> HEINTZ	92 CSB2	$e^+ e^- \rightarrow \gamma X$
$0.135 \pm 0.003 \pm 0.017$	30741	MORRISON	91 CLE2	$e^+ e^- \rightarrow \gamma X$

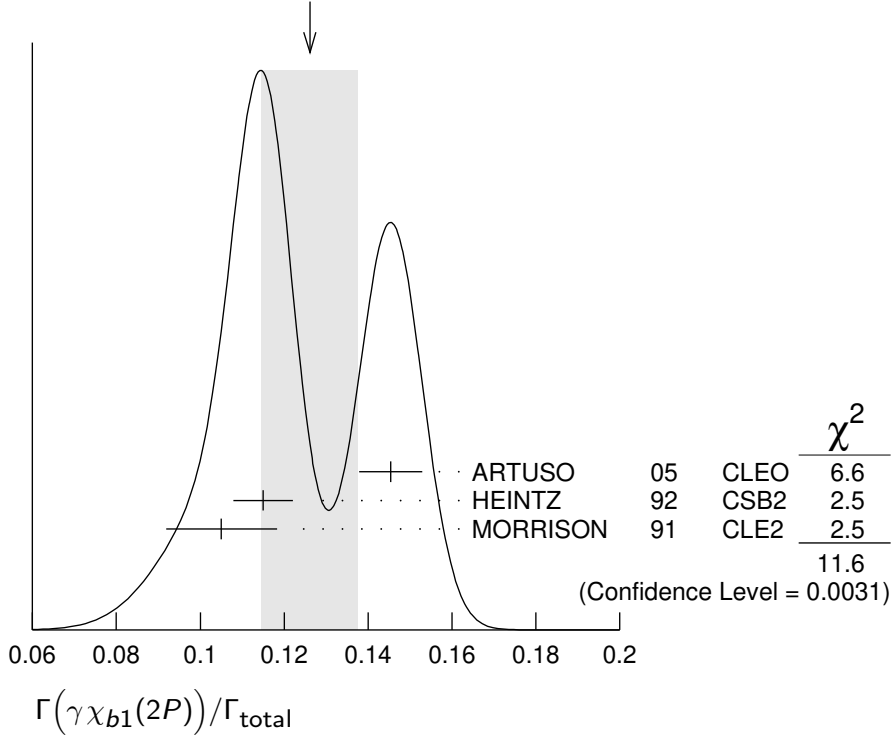
<sup>43</sup> Supersedes NARAIN 91.



$\Gamma(\gamma\chi_{b1}(2P))/\Gamma_{\text{total}}$					$\Gamma_{21}/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
<b><math>0.126 \pm 0.012</math></b>	<b>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>44</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	$e^+e^- \rightarrow \gamma X$

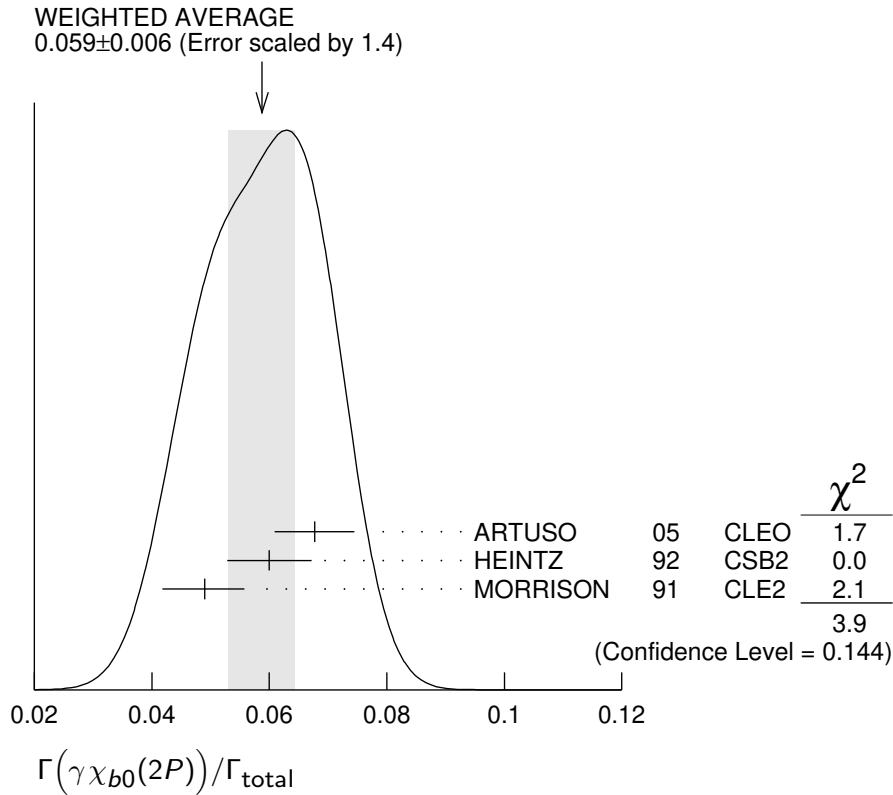
<sup>44</sup> Supersedes NARAIN 91.

WEIGHTED AVERAGE  
 $0.126 \pm 0.012$  (Error scaled by 2.4)



$\Gamma(\gamma\chi_{b0}(2P))/\Gamma_{\text{total}}$						$\Gamma_{22}/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT		
<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	$e^+e^- \rightarrow \gamma X$	
$0.060 \pm 0.004 \pm 0.006$	4959	<sup>45</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>45</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> OUR AVERAGE</b>			Error includes scale factor of 1.7.		
$8.0 \pm 1.3 \pm 0.4$		126	<sup>46,47</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>48</sup> ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
		<sup>49</sup> HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>46</sup> Assuming  $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (2.48 \pm 0.05)\%$ .

<sup>47</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 (shown rounded) 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 (shown rounded)  
value.

<sup>48</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 (shown rounded) value  $B(\Upsilon(2S) \rightarrow$   
 $\gamma\chi_{b2}(1P)) = 7.15 \times 10^{-2}$ .

<sup>49</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>50,51</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>52</sup> ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
			<sup>53</sup> HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>50</sup> Assuming  $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (2.48 \pm 0.05)\%$ .

<sup>51</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 (shown rounded) 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 (shown rounded)  
 value.

<sup>52</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 (shown rounded) value  $B(\Upsilon(2S) \rightarrow$   
 $\gamma\chi_{b1}(1P)) = 6.9 \times 10^{-2}$ .

<sup>53</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>54</sup> ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
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<sup>54</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 (shown rounded) 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%	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>55</sup> BONVICINI	10	CLEO $\Upsilon(3S) \rightarrow \gamma X$
4.8±0.5±0.6		19±3k	<sup>55</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>55,56</sup> AUBERT	08V	BABR $\Upsilon(3S) \rightarrow \gamma X$
<4.3	90		<sup>57</sup> ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$

<sup>55</sup> Assuming  $\Gamma_{\eta_b(1S)} = 10$  MeV.

<sup>56</sup> Systematic error re-evaluated by AUBERT 09AQ.

<sup>57</sup> Superseded by BONVICINI 10.

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$< 8 \times 10^{-5}$	90	<sup>58</sup> LEES	11H BABR	$\Upsilon(3S) \rightarrow \gamma \text{hadrons}$

<sup>58</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  $8 \times 10^{-5}$ .

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$< 2.2$	95	ROSNER	07A CLEO	$e^+e^- \rightarrow \gamma X$

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

VALUE (units $10^{-6}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$< 5.5$	90	<sup>59</sup> AUBERT	09Z BABR	$e^+e^- \rightarrow \gamma A^0 \rightarrow \gamma \mu^+ \mu^-$

<sup>59</sup> For a narrow scalar or pseudoscalar,  $A^0$ , with mass in the range 212–9300 MeV, excluding  $J/\psi$  and  $\psi(2S)$ . Measured 90% CL limits as a function of  $m_{A^0}$  range from 0.27– $5.5 \times 10^{-6}$ .

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$< 1.6 \times 10^{-4}$	90	<sup>60</sup> AUBERT	09P BABR	$e^+e^- \rightarrow \gamma A^0 \rightarrow \gamma \tau^+ \tau^-$

<sup>60</sup> For a narrow scalar or pseudoscalar,  $A^0$ , 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  $1.5\text{--}16 \times 10^{-5}$ .

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

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

VALUE (units $10^{-6}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$< 4.2$	90	LEES	10B BABR	$e^+e^- \rightarrow e^\pm \tau^\mp$

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$< 3.6 \times 10^{-7}$	90	LEES	22A BABR	$e^+e^- \rightarrow e^\pm \mu^\mp$

**$\Gamma(\mu^\pm \tau^\mp)/\Gamma_{\text{total}}$**   **$\Gamma_{34}/\Gamma$**

VALUE (units $10^{-6}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$< 3.1$	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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