

$\chi_{b1}(2P)$ 

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

$J$  needs confirmation.

Observed in radiative decay of the  $\Upsilon(3S)$ , therefore  $C = +$ . Branching ratio requires E1 transition, M1 is strongly disfavored, therefore  $P = +$ .

 **$\chi_{b1}(2P)$  MASS**

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>
<b>10255.46 ± 0.22 ± 0.50 OUR EVALUATION</b>	From $\gamma$ energy below, using $\Upsilon(3S)$ mass = 10355.2 ± 0.5 MeV

 **$m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)}$** 

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>23.5 ± 0.7 ± 0.7</b>	<sup>1</sup> HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X, l^+l^- \gamma\gamma$

<sup>1</sup>From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

 **$m_{\chi_{b1}(2P)} - m_{\Upsilon(1S)}$** 

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>793.57 ± 0.75 ± 0.22</b>	50	<sup>2</sup> AAJ	24AC LHCB	$\chi_{b1}(2P) \rightarrow \Upsilon(1S)\mu^+\mu^-$

<sup>2</sup>Observed in prompt  $p\bar{p}$  production.

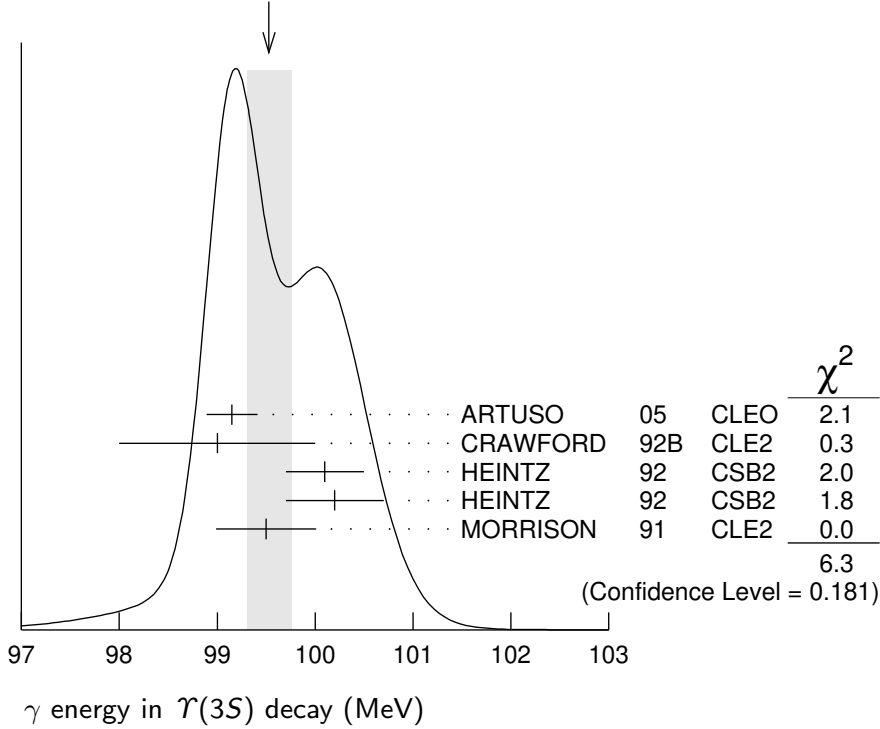
 **$\gamma$  ENERGY IN  $\Upsilon(3S)$  DECAY**

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>99.26 ± 0.22 OUR EVALUATION</b>				Treating systematic errors as correlated
<b>99.53 ± 0.23 OUR AVERAGE</b>				Error includes scale factor of 1.3. See the ideogram below.
99.15 ± 0.07 ± 0.25		ARTUSO	05	CLEO $\Upsilon(3S) \rightarrow \gamma X$
99 ± 1	169	CRAWFORD	92B	CLE2 $e^+e^- \rightarrow l^+l^- \gamma\gamma$
100.1 ± 0.4	11147	<sup>3</sup> HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X$
100.2 ± 0.5	223	<sup>4</sup> HEINTZ	92	CSB2 $e^+e^- \rightarrow l^+l^- \gamma\gamma$
99.5 ± 0.1 ± 0.5	25759	MORRISON	91	CLE2 $e^+e^- \rightarrow \gamma X$

<sup>3</sup>A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91.

<sup>4</sup>A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

WEIGHTED AVERAGE  
 $99.53 \pm 0.23$  (Error scaled by 1.3)



### $\chi_{b1}(2P)$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor
$\Gamma_1$ $\omega \Upsilon(1S)$	( $2.1 \pm 0.4$ ) %	1.6
$\Gamma_2$ $\gamma \Upsilon(2S)$	( $18.1 \pm 1.9$ ) %	
$\Gamma_3$ $\gamma \Upsilon(1S)$	( $9.9 \pm 1.0$ ) %	
$\Gamma_4$ $\pi\pi\chi_{b1}(1P)$	( $9.1 \pm 1.3$ ) $\times 10^{-3}$	
$\Gamma_5$ $D^0 X$	( $8.8 \pm 1.7$ ) %	
$\Gamma_6$ $\pi^+\pi^- K^+ K^- \pi^0$	( $3.1 \pm 1.0$ ) $\times 10^{-4}$	
$\Gamma_7$ $2\pi^+\pi^- K^- K_S^0$	( $1.1 \pm 0.5$ ) $\times 10^{-4}$	
$\Gamma_8$ $2\pi^+\pi^- K^- K_S^0 2\pi^0$	( $7.7 \pm 3.2$ ) $\times 10^{-4}$	
$\Gamma_9$ $2\pi^+ 2\pi^- 2\pi^0$	( $5.9 \pm 2.0$ ) $\times 10^{-4}$	
$\Gamma_{10}$ $2\pi^+ 2\pi^- K^+ K^-$	( $10 \pm 4$ ) $\times 10^{-5}$	
$\Gamma_{11}$ $2\pi^+ 2\pi^- K^+ K^- \pi^0$	( $5.5 \pm 1.8$ ) $\times 10^{-4}$	
$\Gamma_{12}$ $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	( $10 \pm 4$ ) $\times 10^{-4}$	
$\Gamma_{13}$ $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	( $6.7 \pm 2.6$ ) $\times 10^{-4}$	
$\Gamma_{14}$ $3\pi^+ 3\pi^-$	( $1.2 \pm 0.4$ ) $\times 10^{-4}$	
$\Gamma_{15}$ $3\pi^+ 3\pi^- 2\pi^0$	( $1.2 \pm 0.4$ ) $\times 10^{-3}$	
$\Gamma_{16}$ $3\pi^+ 3\pi^- K^+ K^-$	( $2.0 \pm 0.8$ ) $\times 10^{-4}$	
$\Gamma_{17}$ $3\pi^+ 3\pi^- K^+ K^- \pi^0$	( $6.1 \pm 2.2$ ) $\times 10^{-4}$	
$\Gamma_{18}$ $4\pi^+ 4\pi^-$	( $1.7 \pm 0.6$ ) $\times 10^{-4}$	
$\Gamma_{19}$ $4\pi^+ 4\pi^- 2\pi^0$	( $1.9 \pm 0.7$ ) $\times 10^{-3}$	

$\chi_{b1}(2P)$  BRANCHING RATIOS $\Gamma(\omega \Upsilon(1S))/\Gamma_{\text{total}}$  $\Gamma_1/\Gamma$ 

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>2.1 \pm 0.4</math> OUR AVERAGE</b>				Error includes scale factor of 1.6.
$2.39^{+0.20}_{-0.19} \pm 0.24$	304	<sup>5</sup> STOTTLE	25 BELL	$\Upsilon(3S) \rightarrow \gamma \omega \Upsilon(1S)$
$1.46^{+0.34}_{-0.30} \pm 0.13$	$32.6^{+6.9}_{-6.1}$	<sup>6</sup> CRONIN-HEN..04	CLE3	$\Upsilon(3S) \rightarrow \gamma \omega \Upsilon(1S)$

<sup>5</sup> STOTTLE 25 reports  $(2.39^{+0.20}_{-0.19} \pm 0.24) \times 10^{-2}$  from a measurement of  $[\Gamma(\chi_{b1}(2P) \rightarrow \omega \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  assuming  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ .

<sup>6</sup> CRONIN-HENNESSY 04 reports  $(1.63^{+0.35+0.16}_{-0.31-0.15}) \times 10^{-2}$  from a measurement of  $[\Gamma(\chi_{b1}(2P) \rightarrow \omega \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  assuming  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (11.3 \pm 0.6) \times 10^{-2}$ , which we rescale to our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

 $\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$  $\Gamma_2/\Gamma$ 

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.181 \pm 0.019</math> OUR AVERAGE</b>				
$0.211 \pm 0.017 \pm 0.019$		<sup>7,8,9</sup> LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
$0.190 \pm 0.018 \pm 0.017$	4.3k	<sup>10</sup> LEES	11J BABR	$\Upsilon(3S) \rightarrow X \gamma$
$0.206 \pm 0.035 \pm 0.019$		<sup>7,11</sup> CRAWFORD	92B CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$
$0.132 \pm 0.018 \pm 0.012$		<sup>7,12</sup> HEINTZ	92 CSB2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$

<sup>7</sup> Assuming  $B(\Upsilon(2S) \rightarrow \mu^+ \mu^-) = (1.93 \pm 0.17)\%$ .

<sup>8</sup> LEES 14M quotes  $\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))/\Gamma_{\text{total}} = (2.66 \pm 0.22)\%$  combining the results from  $\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$  samples with and without photon conversions.

<sup>9</sup> LEES 14M reports  $[\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))] = (2.66 \pm 0.22) \times 10^{-2}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

<sup>10</sup> LEES 11J reports  $[\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))] = (2.4 \pm 0.1 \pm 0.2) \times 10^{-2}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

<sup>11</sup> CRAWFORD 92B quotes  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S)) \times 2 B(\Upsilon(2S) \rightarrow \ell^+ \ell^-) = (10.23 \pm 1.20 \pm 1.26) 10^{-4}$ .

<sup>12</sup> Recalculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S)) = (2.29 \pm 0.23 \pm 0.21) \%$  using  $B(\Upsilon(2S) \rightarrow \mu^+ \mu^-) = (1.44 \pm 0.10)\%$ . Supersedes HEINTZ 91.

 $\Gamma(\gamma \Upsilon(1S))/\Gamma_{\text{total}}$  $\Gamma_3/\Gamma$ 

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.099 \pm 0.010</math> OUR AVERAGE</b>				
$0.107 \pm 0.006 \pm 0.010$		<sup>13,14,15</sup> LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
$0.098 \pm 0.005 \pm 0.009$	15k	<sup>16</sup> LEES	11J BABR	$\Upsilon(3S) \rightarrow X \gamma$
$0.103 \pm 0.023 \pm 0.009$		<sup>13,17</sup> CRAWFORD	92B CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$
$0.075 \pm 0.010 \pm 0.007$		<sup>13,18</sup> HEINTZ	92 CSB2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$

- <sup>13</sup> Assuming  $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.48 \pm 0.05)\%$ .
- <sup>14</sup> LEES 14M quotes  $\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))/\Gamma_{\text{total}} = (13.48 \pm 0.72) \times 10^{-3}$  combining the results from samples of  $\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$  with and without converted photons.
- <sup>15</sup> LEES 14M reports  $[\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))] = (13.48 \pm 0.72) \times 10^{-3}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.
- <sup>16</sup> LEES 11J reports  $[\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))] = (12.4 \pm 0.3 \pm 0.6) \times 10^{-3}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.
- <sup>17</sup> CRAWFORD 92B quotes  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) \times 2 B(\Upsilon(1S) \rightarrow \ell^+ \ell^-) = (6.47 \pm 1.12 \pm 0.82) 10^{-4}$ .
- <sup>18</sup> Recalculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) = (0.91 \pm 0.11 \pm 0.06)\%$  using  $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.57 \pm 0.05)\%$ . Supersedes HEINTZ 91.

**$\Gamma(\pi \pi \chi_{b1}(1P))/\Gamma_{\text{total}}$   $\Gamma_4/\Gamma$**

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>9.1±1.3 OUR AVERAGE</b>				
9.2±1.1±0.8	31k	<sup>19</sup> LEES	11C BABR	$e^+ e^- \rightarrow \pi^+ \pi^- X$
8.6±2.3±2.1		<sup>20</sup> CAWLFIELD	06 CLE3	$\Upsilon(3S) \rightarrow 2(\gamma \pi \ell)$
<sup>19</sup> LEES 11C measures $B(\Upsilon(3S) \rightarrow \chi_{b1}(2P) X) \times B(\chi_{b1}(2P) \rightarrow \chi_{b1}(1P) \pi^+ \pi^-) = (1.16 \pm 0.07 \pm 0.12) \times 10^{-3}$ . We derive the value assuming $B(\Upsilon(3S) \rightarrow \chi_{b1}(2P) X) = B(\Upsilon(3S) \rightarrow \chi_{b1}(2P) \gamma) = (12.6 \pm 1.2) \times 10^{-2}$ .				
<sup>20</sup> CAWLFIELD 06 quote $\Gamma(\chi_b(2P) \rightarrow \pi \pi \chi_b(1P)) = 0.83 \pm 0.22 \pm 0.08 \pm 0.19$ keV assuming l-spin conservation, no D-wave contribution, $\Gamma(\chi_{b1}(2P)) = 96 \pm 16$ keV, and $\Gamma(\chi_{b2}(2P)) = 138 \pm 19$ keV.				

**$\Gamma(D^0 X)/\Gamma_{\text{total}}$   $\Gamma_5/\Gamma$**

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>8.8±1.5±0.8</b>	2243	<sup>21</sup> BRIERE	08 CLEO	$\Upsilon(3S) \rightarrow \gamma D^0 X$
<sup>21</sup> For $p_{D^0} > 2.5$ GeV/c.				

**$\Gamma(\pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$**

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>3.1±1.0±0.3</b>	30	<sup>22</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma \pi^+ \pi^- K^+ K^- \pi^0$
<sup>22</sup> ASNER 08A reports $[\Gamma(\chi_{b1}(2P) \rightarrow \pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))] = (39 \pm 8 \pm 9) \times 10^{-6}$ which we divide by our best (shown rounded) value $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.				

**$\Gamma(2\pi^+ \pi^- K^- K_S^0)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$**

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1.1±0.5±0.1</b>	10	<sup>23</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+ \pi^- K^- K_S^0$

<sup>23</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+\pi^-K^-K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$  =  $(14 \pm 5 \pm 3) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

### $\Gamma(2\pi^+\pi^-K^-K_S^0 2\pi^0)/\Gamma_{\text{total}}$ $\Gamma_8/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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<b>7.7±3.1±0.7</b>	15	<sup>24</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+\pi^-K^-2\pi^0$
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<sup>24</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+\pi^-K^-K_S^0 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$  =  $(97 \pm 30 \pm 26) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

### $\Gamma(2\pi^+2\pi^-2\pi^0)/\Gamma_{\text{total}}$ $\Gamma_9/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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<b>5.9±2.0±0.5</b>	36	<sup>25</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-2\pi^0$
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<sup>25</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+2\pi^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$  =  $(74 \pm 16 \pm 19) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

### $\Gamma(2\pi^+2\pi^-K^+K^-)/\Gamma_{\text{total}}$ $\Gamma_{10}/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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<b>1.0±0.4±0.1</b>	12	<sup>26</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-$
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<sup>26</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$  =  $(12 \pm 4 \pm 3) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

### $\Gamma(2\pi^+2\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{11}/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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<b>5.5±1.7±0.5</b>	38	<sup>27</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-\pi^0$
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<sup>27</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$  =  $(69 \pm 13 \pm 17) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

### $\Gamma(2\pi^+2\pi^-K^+K^-2\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{12}/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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<b>9.6±3.5±0.9</b>	27	<sup>28</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-2\pi^0$
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<sup>28</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$  =  $(121 \pm 29 \pm 33) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

$\Gamma(3\pi^+2\pi^-K^-K_S^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{13}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>6.7 \pm 2.5 \pm 0.6</math></b>	17	<sup>29</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 2\pi^- K^- K_S^0 \pi^0$

<sup>29</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 3\pi^+ 2\pi^- K^- K_S^0 \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  =  $(85 \pm 23 \pm 22) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

 $\Gamma(3\pi^+3\pi^-)/\Gamma_{\text{total}}$   $\Gamma_{14}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>1.2 \pm 0.4 \pm 0.1</math></b>	18	<sup>30</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^-$

<sup>30</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 3\pi^+ 3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  =  $(15 \pm 4 \pm 3) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

 $\Gamma(3\pi^+3\pi^-2\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{15}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>12 \pm 4 \pm 1</math></b>	44	<sup>31</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- 2\pi^0$

<sup>31</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  =  $(150 \pm 30 \pm 40) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

 $\Gamma(3\pi^+3\pi^-K^+K^-)/\Gamma_{\text{total}}$   $\Gamma_{16}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>2.0 \pm 0.7 \pm 0.2</math></b>	16	<sup>32</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^-$

<sup>32</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 3\pi^+ 3\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  =  $(25 \pm 7 \pm 6) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

 $\Gamma(3\pi^+3\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{17}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>6.1 \pm 2.1 \pm 0.6</math></b>	25	<sup>33</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

<sup>33</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$  =  $(77 \pm 17 \pm 21) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

 $\Gamma(4\pi^+4\pi^-)/\Gamma_{\text{total}}$   $\Gamma_{18}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>1.7 \pm 0.6 \pm 0.2</math></b>	16	<sup>34</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+ 4\pi^-$

<sup>34</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 4\pi^+ 4\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))] = (22 \pm 6 \pm 5) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

**$\Gamma(4\pi^+ 4\pi^- 2\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{19}/\Gamma$**

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>19±7±2</b>	41	<sup>35</sup> ASNER 08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+ 4\pi^- 2\pi^0$

<sup>35</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(2P) \rightarrow 4\pi^+ 4\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))] = (241 \pm 47 \pm 72) \times 10^{-6}$  which we divide by our best (shown rounded) value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (12.6 \pm 1.2) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best (shown rounded) value.

**$\chi_{b1}(2P)$  Cross-Particle Branching Ratios**

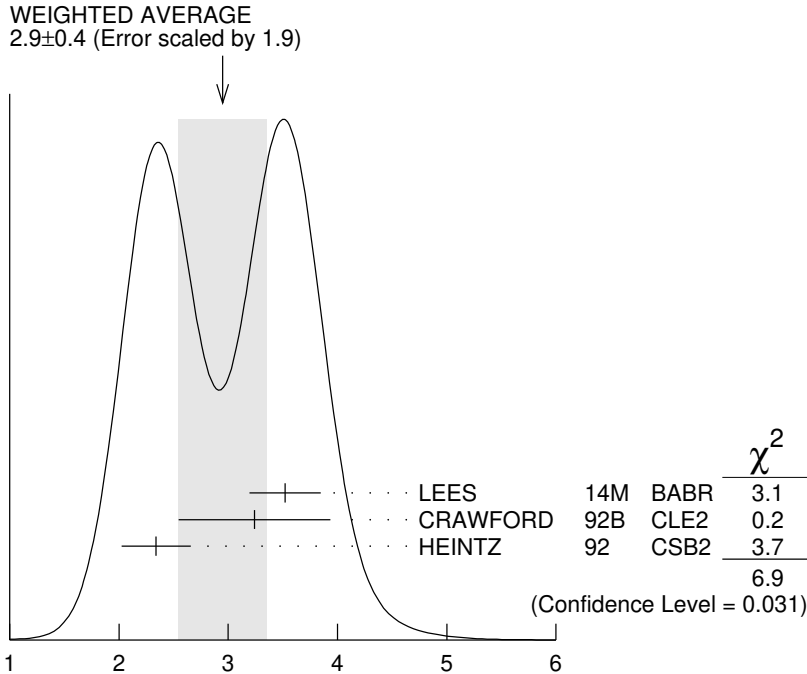
**$\Gamma(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma \times \Gamma_{21}^{\Upsilon(3S)}/\Gamma \Upsilon(3S)$**

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>12.4±0.3±0.6</b>	15k	LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$

**$B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\Upsilon(1S) \rightarrow \ell^+ \ell^-)$**

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.9 ±0.4 OUR AVERAGE</b>		Error includes scale factor of 1.9. See the ideogram below.		

3.52 <sup>+0.28+0.17</sup> <sub>-0.27-0.18</sub>		<sup>36</sup> LEES	14M	BABR $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
3.24±0.56±0.41	58	<sup>37</sup> CRAWFORD	92B	CLE2 $\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$
2.34±0.28±0.15		<sup>38</sup> HEINTZ	92	CSB2 $\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$



$B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\Upsilon(1S) \rightarrow \ell^+ \ell^-)$  (units  $10^{-4}$ )

<sup>36</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$  with one converted photon.

<sup>37</sup> CRAWFORD 92B quotes  $2 \times B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}(2P)) B(\chi_{bJ}(2P) \rightarrow \gamma\Upsilon(nS)) B(\Upsilon(nS) \rightarrow \ell^+\ell^-)$ .

<sup>38</sup> Calculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma\Upsilon(1S)) = (0.91 \pm 0.11 \pm 0.06)\%$  using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.05)\%$ .

$$\frac{\Gamma(\chi_{b1}(2P) \rightarrow \gamma\Upsilon(2S)) / \Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) / \Gamma_{\text{total}}}{\Gamma_2 / \Gamma \times \Gamma_{21}^{\Upsilon(3S)} / \Gamma \Upsilon(3S)}$$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.4±0.1±0.2</b>	4.3k	LEES	11J BABR	$\Upsilon(3S) \rightarrow X\gamma$

$$B(\chi_{b1}(2P) \rightarrow \gamma\Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\Upsilon(2S) \rightarrow \ell^+\ell^-)$$

**3.8 ± 0.6 OUR AVERAGE** Error includes scale factor of 1.8. See the ideogram below.

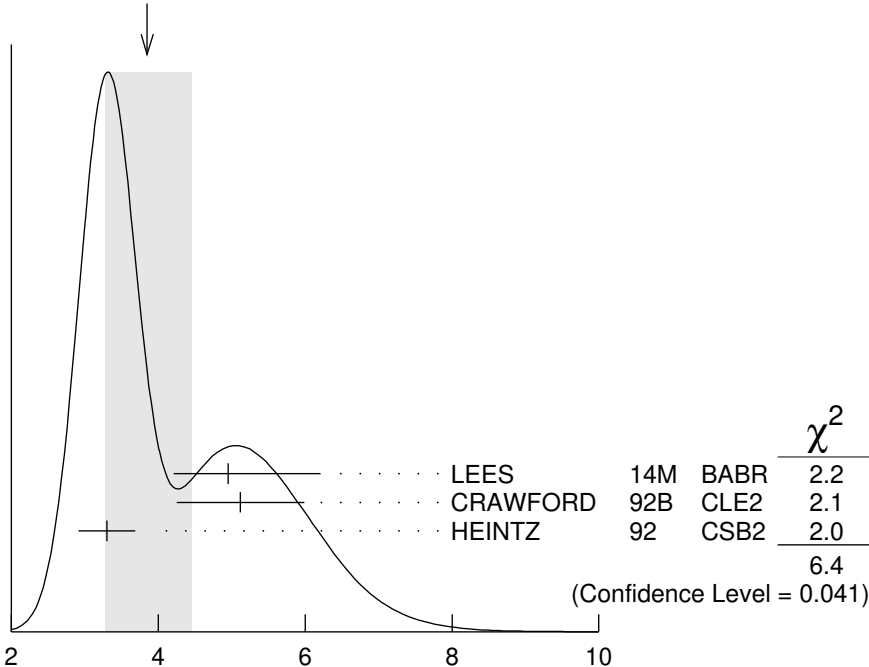
VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$4.95^{+0.75+1.01}_{-0.70-0.24}$		39 LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
$5.12 \pm 0.60 \pm 0.63$	111	40 CRAWFORD 92B	CLE2	$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$
$3.30 \pm 0.33 \pm 0.20$		41 HEINTZ 92	CSB2	$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>39</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$  with one converted photon.

<sup>40</sup> CRAWFORD 92B quotes  $2 \times B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}(2P)) B(\chi_{bJ}(2P) \rightarrow \gamma\Upsilon(nS)) B(\Upsilon(nS) \rightarrow \ell^+\ell^-)$ .

<sup>41</sup> Calculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma\Upsilon(2S)) = (2.29 \pm 0.23 \pm 0.21)\%$  using  $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.44 \pm 0.10)\%$ .

WEIGHTED AVERAGE  
3.8±0.6 (Error scaled by 1.8)



$$B(\chi_{b1}(2P) \rightarrow \gamma\Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\Upsilon(2S) \rightarrow \ell^+\ell^-)$$

(units  $10^{-4}$ )

**$B(\chi_{b1}(2P) \rightarrow \chi_{b1}(1P)\pi^+\pi^-) \times B(\Upsilon(3S) \rightarrow \chi_{b1}(2P)X)$** 

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>1.16 \pm 0.07 \pm 0.12</math></b>	31k	LEES	11C	BABR $e^+e^- \rightarrow \pi^+\pi^-X$

 **$B(\chi_{b2}(2P) \rightarrow \rho X + \bar{\rho} X)/B(\chi_{b1}(2P) \rightarrow \rho X + \bar{\rho} X)$** 

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>1.109 \pm 0.007 \pm 0.040</math></b>	BRIERE	07	CLEO $\Upsilon(3S) \rightarrow \gamma\chi_{bJ}(2P)$

 **$B(\chi_{b0}(2P) \rightarrow \rho X + \bar{\rho} X)/B(\chi_{b1}(2P) \rightarrow \rho X + \bar{\rho} X)$** 

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b><math>1.082 \pm 0.025 \pm 0.060</math></b>	BRIERE	07	CLEO $\Upsilon(3S) \rightarrow \gamma\chi_{bJ}(2P)$

 **$\chi_{b1}(2P)$  REFERENCES**

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LEES	11C	PR D84 011104	J.P. Lees <i>et al.</i>	(BABAR Collab.)
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CRONIN-HEN...	04	PRL 92 222002	D. Cronin-Hennessy <i>et al.</i>	(CLEO Collab.)
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