

$\chi_{b2}(2P)$ 

$$I^G(J^{PC}) = 0^+(2^{++})$$

$J$  needs confirmation.

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

 **$\chi_{b2}(2P)$  MASS**

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>
<b>10268.65 ± 0.22 ± 0.50 OUR EVALUATION</b>	From $\gamma$ energy below, using $\Upsilon(3S)$ mass = 10355.2 ± 0.5 MeV

 **$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)}$** 

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>13.10 ± 0.24 OUR AVERAGE</b>			
12.3 ± 2.6 ± 0.6	<sup>1</sup> AAIJ	14BG LHCb	$pp \rightarrow \gamma \mu^+ \mu^- X$
13.04 ± 0.26	LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \mu^+ \mu^-$
13.5 ± 0.4 ± 0.5	<sup>2</sup> HEINTZ	92 CSB2	$e^+ e^- \rightarrow \gamma X, \ell^+ \ell^- \gamma \gamma$

<sup>1</sup> From the  $\chi_{bj}(2P) \rightarrow \Upsilon(1S)\gamma$  transition.

<sup>2</sup> From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

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

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>86.19 ± 0.22 OUR EVALUATION</b>				Treating systematic errors as correlated
<b>86.40 ± 0.18 OUR AVERAGE</b>				
86.04 ± 0.06 ± 0.27		ARTUSO	05 CLEO	$\Upsilon(3S) \rightarrow \gamma X$
86 ± 1	101	CRAWFORD	92B CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$
86.7 ± 0.4	10319	<sup>3</sup> HEINTZ	92 CSB2	$e^+ e^- \rightarrow \gamma X$
86.9 ± 0.4	157	<sup>4</sup> HEINTZ	92 CSB2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$
86.4 ± 0.1 ± 0.4	30741	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.

 **$\chi_{b2}(2P)$  DECAY MODES**

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level
$\Gamma_1 \quad \omega \Upsilon(1S)$	(1.10 <sup>+0.34</sup> <sub>-0.30</sub> ) %	
$\Gamma_2 \quad \gamma \Upsilon(2S)$	(8.9 ± 1.2) %	
$\Gamma_3 \quad \gamma \Upsilon(1S)$	(6.6 ± 0.8) %	
$\Gamma_4 \quad \pi \pi \chi_{b2}(1P)$	(5.1 ± 0.9) × 10 <sup>-3</sup>	
$\Gamma_5 \quad D^0 X$	< 2.4 %	90%
$\Gamma_6 \quad \pi^+ \pi^- K^+ K^- \pi^0$	< 1.1 × 10 <sup>-4</sup>	90%

$\Gamma_7$	$2\pi^+\pi^-K^-K_S^0$	$< 9$	$\times 10^{-5}$	90%
$\Gamma_8$	$2\pi^+\pi^-K^-K_S^02\pi^0$	$< 7$	$\times 10^{-4}$	90%
$\Gamma_9$	$2\pi^+2\pi^-2\pi^0$	$(3.9 \pm 1.6)$	$\times 10^{-4}$	
$\Gamma_{10}$	$2\pi^+2\pi^-K^+K^-$	$(9 \pm 4)$	$\times 10^{-5}$	
$\Gamma_{11}$	$2\pi^+2\pi^-K^+K^-\pi^0$	$(2.4 \pm 1.1)$	$\times 10^{-4}$	
$\Gamma_{12}$	$2\pi^+2\pi^-K^+K^-2\pi^0$	$(4.7 \pm 2.3)$	$\times 10^{-4}$	
$\Gamma_{13}$	$3\pi^+2\pi^-K^-K_S^0\pi^0$	$< 4$	$\times 10^{-4}$	90%
$\Gamma_{14}$	$3\pi^+3\pi^-$	$(9 \pm 4)$	$\times 10^{-5}$	
$\Gamma_{15}$	$3\pi^+3\pi^-2\pi^0$	$(1.2 \pm 0.4)$	$\times 10^{-3}$	
$\Gamma_{16}$	$3\pi^+3\pi^-K^+K^-$	$(1.4 \pm 0.7)$	$\times 10^{-4}$	
$\Gamma_{17}$	$3\pi^+3\pi^-K^+K^-\pi^0$	$(4.2 \pm 1.7)$	$\times 10^{-4}$	
$\Gamma_{18}$	$4\pi^+4\pi^-$	$(9 \pm 5)$	$\times 10^{-5}$	
$\Gamma_{19}$	$4\pi^+4\pi^-2\pi^0$	$(1.3 \pm 0.5)$	$\times 10^{-3}$	

### $\chi_{b2}(2P)$ BRANCHING RATIOS

$\Gamma(\omega \Upsilon(1S))/\Gamma_{\text{total}}$	$\Gamma_1/\Gamma$			
VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$1.10^{+0.32+0.11}_{-0.28-0.10}$	$20.1^{+5.8}_{-5.1}$	<sup>5</sup> CRONIN-HEN..04	CLE3	$\Upsilon(3S) \rightarrow \gamma\omega \Upsilon(1S)$

<sup>5</sup> Using  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (11.4 \pm 0.8)\%$  and  $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = 2 B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 2 (2.48 \pm 0.06)\%$ .

$\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$	$\Gamma_2/\Gamma$			
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.089 \pm 0.012</math> OUR AVERAGE</b>				
$0.085 \pm 0.010 \pm 0.010$	<sup>6,7,8</sup>	LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
$0.084 \pm 0.011 \pm 0.010$	<sup>9</sup>	LEES	11J BABR	$\Upsilon(3S) \rightarrow X\gamma$
$0.096 \pm 0.022 \pm 0.012$	<sup>7,10</sup>	CRAWFORD	92B CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
$0.106 \pm 0.016 \pm 0.013$	<sup>7,11</sup>	HEINTZ	92 CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

<sup>6</sup> LEES 14M quotes  $\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))/\Gamma_{\text{total}} = (1.12 \pm 0.13)\%$  combining the results from samples of  $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$  with and without converted photons.

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

<sup>8</sup> LEES 14M reports  $[\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (1.12 \pm 0.13) \times 10^{-2}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>9</sup> LEES 11J reports  $[\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (1.1 \pm 0.1 \pm 0.1) \times 10^{-2}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>10</sup> CRAWFORD 92B quotes  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S)) \times 2 B(\Upsilon(2S) \rightarrow \ell^+\ell^-) = (4.98 \pm 0.94 \pm 0.62) 10^{-4}$ .

<sup>11</sup> Recalculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) \times B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S)) = (1.90 \pm 0.23 \pm 0.18) \%$  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>0.066±0.008 OUR AVERAGE</b>				
0.061±0.004±0.007	12,13,14	LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
0.070±0.004±0.008	11k 15	LEES	11J BABR	$\Upsilon(3S) \rightarrow X\gamma$
0.077±0.018±0.009	13,16	CRAWFORD	92B CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.061±0.009±0.007	13,17	HEINTZ	92 CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

<sup>12</sup> LEES 14M quotes  $\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))/\Gamma_{\text{total}} = (8.03 \pm 0.50) \times 10^{-3}$  combining the results from samples of  $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$  with and without converted photons.

<sup>13</sup> Assuming  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$ .

<sup>14</sup> LEES 14M reports  $[\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (8.03 \pm 0.50) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>15</sup> LEES 11J reports  $[\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (9.2 \pm 0.3 \pm 0.4) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>16</sup> CRAWFORD 92B quotes  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) \times B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S)) \times 2 B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (5.03 \pm 0.94 \pm 0.63) 10^{-4}$ .

<sup>17</sup> Recalculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) \times B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S)) = (0.77 \pm 0.11 \pm 0.05)\%$  using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.05)\%$ . Supersedes HEINTZ 91.

 $\Gamma(\pi\pi\chi_{b2}(1P))/\Gamma_{\text{total}}$  $\Gamma_4/\Gamma$ 

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>5.1±0.9 OUR AVERAGE</b>				
4.9±0.7±0.6	17k	18 LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^-X$
6.0±1.6±1.4		19 CAWLFIELD	06 CLE3	$\Upsilon(3S) \rightarrow 2(\gamma\pi\ell)$

<sup>18</sup>  $(0.64 \pm 0.05 \pm 0.08) \times 10^{-3}$ . We derive the value assuming  $B(\Upsilon(3S) \rightarrow \chi_{b2}(2P)X) = B(\Upsilon(3S) \rightarrow \chi_{b2}(2P)\gamma) = (13.1 \pm 1.6) \times 10^{-2}$ .

<sup>19</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.

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;2.4 × 10<sup>-2</sup></b>	90	20,21 BRIERE	08 CLEO	$\Upsilon(3S) \rightarrow \gamma D^0 X$

<sup>20</sup> For  $p_{D^0} > 2.5$  GeV/c.

<sup>21</sup> The authors also present their result as  $(0.2 \pm 1.4 \pm 0.1) \times 10^{-2}$ .

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;1.1</b>	90	22 ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma\pi^+\pi^-K^+K^-\pi^0$

<sup>22</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow \pi^+\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] < 14 \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = 13.1 \times 10^{-2}$ .

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;0.9</b>	90	<sup>23</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+\pi^-K^-K_S^0$
<sup>23</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+\pi^-K^-K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] < 12 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = 13.1 \times 10^{-2}$ .				

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;7</b>	90	<sup>24</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+\pi^-K^-2\pi^0$
<sup>24</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+\pi^-K^-K_S^0 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] < 87 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = 13.1 \times 10^{-2}$ .				

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>3.9 \pm 1.6 \pm 0.5</math></b>	23	<sup>25</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-2\pi^0$
<sup>25</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+2\pi^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (51 \pm 16 \pm 13) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.9 \pm 0.4 \pm 0.1</math></b>	11	<sup>26</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-$
<sup>26</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (12 \pm 4 \pm 3) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>2.4 \pm 1.0 \pm 0.3</math></b>	16	<sup>27</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-\pi^0$
<sup>27</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (32 \pm 11 \pm 8) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>4.7 \pm 2.2 \pm 0.6</math></b>	14	<sup>28</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-2\pi^0$
<sup>28</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (62 \pm 23 \pm 17) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;4</b>	90	<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  $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+ 2\pi^- K^- K_S^0 \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   $< 58 \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) = 13.1 \times 10^{-2}$ .

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.9 \pm 0.4 \pm 0.1</math></b>	14	<sup>30</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^-$

<sup>30</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+ 3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   $= (12 \pm 4 \pm 3) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>12 \pm 4 \pm 1</math></b>	45	<sup>31</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- 2\pi^0$

<sup>31</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   $= (159 \pm 33 \pm 43) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>1.4 \pm 0.7 \pm 0.2</math></b>	12	<sup>32</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^-$

<sup>32</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+ 3\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   $= (19 \pm 7 \pm 5) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>4.2 \pm 1.7 \pm 0.5</math></b>	16	<sup>33</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

<sup>33</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   $= (55 \pm 16 \pm 15) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.9 \pm 0.4 \pm 0.1</math></b>	9	<sup>34</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+ 4\pi^-$

<sup>34</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow 4\pi^+ 4\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   $= (12 \pm 5 \pm 3) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>13±5±2</b>	27	<sup>35</sup> ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+ 4\pi^- 2\pi^0$

<sup>35</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(2P) \rightarrow 4\pi^+ 4\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))]$   
 $= (165 \pm 46 \pm 50) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))$   
 $= (13.1 \pm 1.6) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\chi_{b2}(2P)$  Cross-Particle Branching Ratios

$\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))/\Gamma_{\text{total}}$   
 $\Gamma_3/\Gamma \times \Gamma_{20}^{\Upsilon(3S)}/\Gamma \Upsilon(3S)$

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>9.2±0.3±0.4</b>	11k	LEES	11J BABR	$\Upsilon(3S) \rightarrow X\gamma$

$\Gamma(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))/\Gamma_{\text{total}}$   
 $\Gamma_2/\Gamma \times \Gamma_{20}^{\Upsilon(3S)}/\Gamma \Upsilon(3S)$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>1.1±0.1±0.1</b>	2.5k	LEES	11J BABR	$\Upsilon(3S) \rightarrow X\gamma$

$B(\chi_{b2}(2P) \rightarrow \chi_{b2}(1P)\pi^+\pi^-) \times B(\Upsilon(3S) \rightarrow \chi_{b2}(2P)X)$

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.64±0.05±0.08</b>	17k	LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^-X$

$B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) \times B(\Upsilon(1S) \rightarrow \ell^+\ell^-)$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.02±0.18 OUR AVERAGE</b>				

$1.95^{+0.22+0.10}_{-0.21-0.16}$		<sup>36</sup> LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
$2.52 \pm 0.47 \pm 0.32$	48	<sup>37</sup> CRAWFORD	92B CLE2	$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$
$1.98 \pm 0.28 \pm 0.12$		<sup>38</sup> HEINTZ	92 CSB2	$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$

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

<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  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) \times B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S)) = (0.77 \pm 0.11 \pm 0.05)\%$  using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.05)\%$ .

$[B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))] / [B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$

VALUE (%)	DOCUMENT ID	TECN	COMMENT
<b>66.6±3.0</b>	<sup>39</sup> LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$

<sup>39</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$  events without converted photons.

**$B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) \times B(\Upsilon(2S) \rightarrow \ell^+ \ell^-)$** 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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**2.74 ± 0.29 OUR AVERAGE**

3.22 <sup>+0.58+0.16</sup> <sub>-0.53-0.71</sub>		40 LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
2.49 ± 0.47 ± 0.31	53	41 CRAWFORD	92B CLE2	$\Upsilon(3S) \rightarrow \gamma \gamma \ell^+ \ell^-$
2.74 ± 0.33 ± 0.18		42 HEINTZ	92 CSB2	$\Upsilon(3S) \rightarrow \gamma \gamma \ell^+ \ell^-$

<sup>40</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$  with converted photons.

<sup>41</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>42</sup> Calculated by us. HEINTZ 92 quotes  $B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P)) \times B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S)) = (1.90 \pm 0.23 \pm 0.18) \%$  using  $B(\Upsilon(2S) \rightarrow \mu^+ \mu^-) = (1.44 \pm 0.10) \%$ .

 **$[B(\chi_{b2}(2P) \rightarrow \gamma \Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b2}(2P))] / [B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P))]$** 

VALUE (%)	DOCUMENT ID	TECN	COMMENT
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<b>46.9 ± 2.0</b>	43 LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
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<sup>43</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$  without converted photons.

 **$\chi_{b2}(2P)$  REFERENCES**

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