

# $\chi_{b2}(1P)$

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

$J$  needs confirmation.

Observed in radiative decay of the  $\Upsilon(2S)$ , therefore  $C = +$ . Branching ratio requires E1 transition, M1 is strongly disfavored, therefore  $P = +$ .  $J = 2$  from SKWARNICKI 87.

## $\chi_{b2}(1P)$ MASS

VALUE (MeV)	DOCUMENT ID
<b>9912.21 ± 0.26 ± 0.31 OUR EVALUATION</b>	From average $\gamma$ energy below, using $\Upsilon(2S)$ mass = 10023.26 ± 0.31 MeV

## $m_{\chi_{b2}(1P)} - m_{\chi_{b1}(1P)}$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>19.10 ± 0.25 OUR AVERAGE</b>	Error includes scale factor of 1.1.		
19.81 ± 0.65 ± 0.20	<sup>1</sup> AAIJ	14BG LHCB	$pp \rightarrow \gamma \mu^+ \mu^- X$
19.01 ± 0.24	LEES	14M BABR	$\Upsilon(2S) \rightarrow \gamma \mu^+ \mu^-$

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

## $\gamma$ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>110.44 ± 0.29 OUR AVERAGE</b>	Error includes scale factor of 1.1.		
110.58 ± 0.08 ± 0.30	ARTUSO	05 CLEO	$\Upsilon(2S) \rightarrow \gamma X$
110.8 ± 0.3 ± 0.6	EDWARDS	99 CLE2	$\Upsilon(2S) \rightarrow \gamma \chi(1P)$
107.0 ± 1.1 ± 1.3	WALK	86 CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
110.6 ± 0.3 ± 0.9	ALBRECHT	85E ARG	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
110.4 ± 0.8 ± 2.2	NERNST	85 CBAL	$\Upsilon(2S) \rightarrow \gamma X$
109.5 ± 0.7 ± 1.0	HAAS	84 CLEO	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
108.2 ± 0.3 ± 2.0	KLOPFEN...	83 CUSB	$\Upsilon(2S) \rightarrow \gamma X$
108.8 ± 4.0	PAUSS	83 CUSB	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

## $\chi_{b2}(1P)$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level
$\Gamma_1$ $\gamma \Upsilon(1S)$	(18.8 ± 1.1) %	
$\Gamma_2$ $D^0 X$	< 7.9 %	90%
$\Gamma_3$ $\pi^+ \pi^- K^+ K^- \pi^0$	( 8 ± 5 ) × 10 <sup>-5</sup>	
$\Gamma_4$ $2\pi^+ \pi^- K^- K_S^0$	< 1.0 × 10 <sup>-4</sup>	90%
$\Gamma_5$ $2\pi^+ \pi^- K^- K_S^0 2\pi^0$	( 5.3 ± 2.4 ) × 10 <sup>-4</sup>	
$\Gamma_6$ $2\pi^+ 2\pi^- 2\pi^0$	( 3.5 ± 1.4 ) × 10 <sup>-4</sup>	
$\Gamma_7$ $2\pi^+ 2\pi^- K^+ K^-$	( 1.1 ± 0.4 ) × 10 <sup>-4</sup>	
$\Gamma_8$ $2\pi^+ 2\pi^- K^+ K^- \pi^0$	( 2.1 ± 0.9 ) × 10 <sup>-4</sup>	
$\Gamma_9$ $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	( 3.9 ± 1.8 ) × 10 <sup>-4</sup>	
$\Gamma_{10}$ $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	< 5 × 10 <sup>-4</sup>	90%

$\Gamma_{11}$	$3\pi^+3\pi^-$	$(7.0\pm 3.1)\times 10^{-5}$	
$\Gamma_{12}$	$3\pi^+3\pi^-2\pi^0$	$(1.0\pm 0.4)\times 10^{-3}$	
$\Gamma_{13}$	$3\pi^+3\pi^-K^+K^-$	$< 8 \times 10^{-5}$	90%
$\Gamma_{14}$	$3\pi^+3\pi^-K^+K^-\pi^0$	$(3.6\pm 1.5)\times 10^{-4}$	
$\Gamma_{15}$	$4\pi^+4\pi^-$	$(8 \pm 4)\times 10^{-5}$	
$\Gamma_{16}$	$4\pi^+4\pi^-2\pi^0$	$(1.8\pm 0.7)\times 10^{-3}$	
$\Gamma_{17}$	$J/\psi J/\psi$	$< 4 \times 10^{-5}$	90%
$\Gamma_{18}$	$J/\psi\psi(2S)$	$< 5 \times 10^{-5}$	90%
$\Gamma_{19}$	$\psi(2S)\psi(2S)$	$< 1.6 \times 10^{-5}$	90%
$\Gamma_{20}$	$J/\psi(1S)$ anything	$(1.5\pm 0.4)\times 10^{-3}$	

### $\chi_{b2}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma\Upsilon(1S))/\Gamma_{\text{total}}$						$\Gamma_1/\Gamma$
VALUE	EVT S	DOCUMENT ID	TECN	COMMENT		
<b><math>0.188\pm 0.011</math></b>						
<b>OUR AVERAGE</b>						
$0.185\pm 0.008\pm 0.009$	2,3,4	LEES	14M	BABR	$\Upsilon(2S) \rightarrow \gamma\gamma\mu^+\mu^-$	
$0.186\pm 0.011\pm 0.009$	1770	4,5	KORNICER	11	CLEO	$e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$
$0.194^{+0.014}_{-0.017}\pm 0.009$	8k	6	LEES	11J	BABR	$\Upsilon(2S) \rightarrow X\gamma$
$0.25 \pm 0.06 \pm 0.01$	35	4,7,8	WALK	86	CBAL	$\Upsilon(2S) \rightarrow \gamma\gamma\ell^+\ell^-$
$0.20 \pm 0.05$		KLOPFEN...	83	CUSB	$\Upsilon(2S) \rightarrow \gamma\gamma\ell^+\ell^-$	

<sup>2</sup> LEES 14M quotes  $\Gamma(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{\text{total}} = (1.32 \pm 0.06)\%$  combining the results from samples of  $\Upsilon(2S) \rightarrow \gamma\gamma\mu^+\mu^-$  with and without converted photons.

<sup>3</sup> LEES 14M reports  $[\Gamma(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (1.32 \pm 0.06) \times 10^{-2}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>4</sup> Assuming  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$ .

<sup>5</sup> KORNICER 11 reports  $[\Gamma(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (1.33 \pm 0.04 \pm 0.07) \times 10^{-2}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>6</sup> LEES 11J reports  $[\Gamma(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (13.9 \pm 0.5^{+0.9}_{-1.1}) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>7</sup> WALK 86 quotes  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) \times B(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S)) \times B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (4.4 \pm 0.9 \pm 0.5)\%$ .

<sup>8</sup> WALK 86 reports  $[\Gamma(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (17.7 \pm 3.6 \pm 2.0) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(D^0 X)/\Gamma_{\text{total}}$   $\Gamma_2/\Gamma$ 

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<7.9 \times 10^{-2}$	90	9,10 BRIERE	08	CLEO $\Upsilon(2S) \rightarrow \gamma D^0 X$

<sup>9</sup> For  $p_{D^0} > 2.5$  GeV/c.

<sup>10</sup> The authors also present their result as  $(5.4 \pm 1.9 \pm 0.5) \times 10^{-2}$ .

 $\Gamma(\pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$0.84 \pm 0.50 \pm 0.04$	8	<sup>11</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^- K^+ K^- \pi^0$

<sup>11</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow \pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (6 \pm 3 \pm 2) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

 $\Gamma(2\pi^+ \pi^- K^- K_S^0)/\Gamma_{\text{total}}$   $\Gamma_4/\Gamma$ 

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$<1.0$	90	<sup>12</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ \pi^- K^- K_S^0$

<sup>12</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 2\pi^+ \pi^- K^- K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] < 7 \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = 7.15 \times 10^{-2}$ .

 $\Gamma(2\pi^+ \pi^- K^- K_S^0 2\pi^0)/\Gamma_{\text{total}}$   $\Gamma_5/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$5.3 \pm 2.4 \pm 0.3$	11	<sup>13</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ \pi^- K^- 2\pi^0$

<sup>13</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 2\pi^+ \pi^- K^- K_S^0 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (38 \pm 14 \pm 10) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

 $\Gamma(2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$3.5 \pm 1.4 \pm 0.2$	19	<sup>14</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- 2\pi^0$

<sup>14</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (25 \pm 8 \pm 6) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$1.1 \pm 0.4 \pm 0.1$	14	<sup>15</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^-$

<sup>15</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (8 \pm 2 \pm 2) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>2.1 \pm 0.9 \pm 0.1</math></b>	13	<sup>16</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$
<sup>16</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (15 \pm 5 \pm 4) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>3.9 \pm 1.8 \pm 0.2</math></b>	11	<sup>17</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$
<sup>17</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (28 \pm 11 \pm 7) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

 $\Gamma(3\pi^+2\pi^-K^-K_S^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{10}/\Gamma$ 

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;5</b>	90	<sup>18</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 2\pi^- K^- K_S^0 \pi^0$
<sup>18</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+ 2\pi^- K^- K_S^0 \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] < 36 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = 7.15 \times 10^{-2}$ .				

 $\Gamma(3\pi^+3\pi^-)/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.70 \pm 0.31 \pm 0.03</math></b>	9	<sup>19</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^-$
<sup>19</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+ 3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (5 \pm 2 \pm 1) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

 $\Gamma(3\pi^+3\pi^-2\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{12}/\Gamma$ 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>10.2 \pm 3.6 \pm 0.5</math></b>	34	<sup>20</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- 2\pi^0$
<sup>20</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] = (73 \pm 16 \pm 20) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.				

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;0.8</b>	90	<sup>21</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^-$
<sup>21</sup> ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+ 3\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))] < 6 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = 7.15 \times 10^{-2}$ .				

**$\Gamma(3\pi^+3\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}$**   **$\Gamma_{14}/\Gamma$** 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>3.6 \pm 1.5 \pm 0.2</math></b>	14	<sup>22</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

<sup>22</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))]$  =  $(26 \pm 8 \pm 7) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

 **$\Gamma(4\pi^+4\pi^-)/\Gamma_{\text{total}}$**   **$\Gamma_{15}/\Gamma$** 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>0.84 \pm 0.40 \pm 0.04</math></b>	7	<sup>23</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+ 4\pi^-$

<sup>23</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 4\pi^+ 4\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))]$  =  $(6 \pm 2 \pm 2) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

 **$\Gamma(4\pi^+4\pi^-2\pi^0)/\Gamma_{\text{total}}$**   **$\Gamma_{16}/\Gamma$** 

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>18 \pm 7 \pm 1</math></b>	29	<sup>24</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+ 4\pi^- 2\pi^0$

<sup>24</sup> ASNER 08A reports  $[\Gamma(\chi_{b2}(1P) \rightarrow 4\pi^+ 4\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))]$  =  $(132 \pm 31 \pm 40) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b><math>&lt; 5</math></b>	90	<sup>25</sup> SHEN	12 BELL	$\Upsilon(2S) \rightarrow \gamma \psi X$

<sup>25</sup> SHEN 12 reports  $< 4.5 \times 10^{-5}$  from a measurement of  $[\Gamma(\chi_{b2}(1P) \rightarrow J/\psi J/\psi)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))]$  assuming  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ .

 **$\Gamma(J/\psi \psi(2S))/\Gamma_{\text{total}}$**   **$\Gamma_{18}/\Gamma$** 

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b><math>&lt; 5</math></b>	90	<sup>26</sup> SHEN	12 BELL	$\Upsilon(2S) \rightarrow \gamma \psi X$

<sup>26</sup> SHEN 12 reports  $< 4.9 \times 10^{-5}$  from a measurement of  $[\Gamma(\chi_{b2}(1P) \rightarrow J/\psi \psi(2S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))]$  assuming  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ .

 **$\Gamma(\psi(2S) \psi(2S))/\Gamma_{\text{total}}$**   **$\Gamma_{19}/\Gamma$** 

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b><math>&lt; 1.6</math></b>	90	<sup>27</sup> SHEN	12 BELL	$\Upsilon(2S) \rightarrow \gamma \psi X$

<sup>27</sup> SHEN 12 reports  $< 1.6 \times 10^{-5}$  from a measurement of  $[\Gamma(\chi_{b2}(1P) \rightarrow \psi(2S) \psi(2S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P))]$  assuming  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$ .

$\Gamma(J/\psi(1S)\text{anything})/\Gamma_{\text{total}}$					$\Gamma_{20}/\Gamma$
VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT	
<b><math>1.50 \pm 0.34 \pm 0.22</math></b>	462	JIA	17A	BELL	$e^+e^- \rightarrow \text{hadrons}$

 **$\chi_{b2}(1P)$  Cross-Particle Branching Ratios**

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

$$\Gamma_1/\Gamma \times \Gamma_{51}^{\Upsilon(2S)}/\Gamma_{\Upsilon(2S)}$$

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>13.9 \pm 0.5^{+0.9}_{-1.1}</math></b>	8k	LEES	11J	BABR $\Upsilon(2S) \rightarrow X\gamma$

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>3.38 \pm 0.16</math> OUR AVERAGE</b>				

$3.63^{+0.36+0.18}_{-0.34-0.19}$		<sup>28</sup> LEES	14M	BABR $\Upsilon(2S) \rightarrow \gamma\gamma\mu^+\mu^-$
$3.29 \pm 0.09 \pm 0.16$	1770	KORNICER	11	CLEO $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$
$4.4 \pm 0.9 \pm 0.5$	35	WALK	86	CBAL $\Upsilon(2S) \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>28</sup> From a sample of  $\Upsilon(2S) \rightarrow \gamma\gamma\mu^+\mu^-$  with converted photons.

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

VALUE (%)	DOCUMENT ID	TECN	COMMENT
<b><math>55.6 \pm 1.6</math></b>	<sup>29</sup> LEES	14M	BABR $\Upsilon(2S) \rightarrow \gamma\gamma\mu^+\mu^-$

<sup>29</sup> From a sample of  $\Upsilon(2S) \rightarrow \gamma\gamma\mu^+\mu^-$  events without converted photons.

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

VALUE (units $10^{-5}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>3.8 \pm 0.5</math> OUR AVERAGE</b>				

$4.68^{+0.99}_{-0.92} \pm 0.37$		<sup>30</sup> LEES	14M	BABR $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
$3.56 \pm 0.40 \pm 0.41$	126	KORNICER	11	CLEO $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

<sup>30</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$  with converted photons.

 **$\chi_{b2}(1P)$  REFERENCES**

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