

# $\chi_{b1}(1P)$

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

$J$  needs confirmation.

Observed in radiative decay of the  $\Upsilon(2S)$ , therefore  $C = +$ . Branching ratio requires E1 transition, M1 is strongly disfavored, therefore  $P = +$ .  $J = 1$  from SKWARNICKI 87.

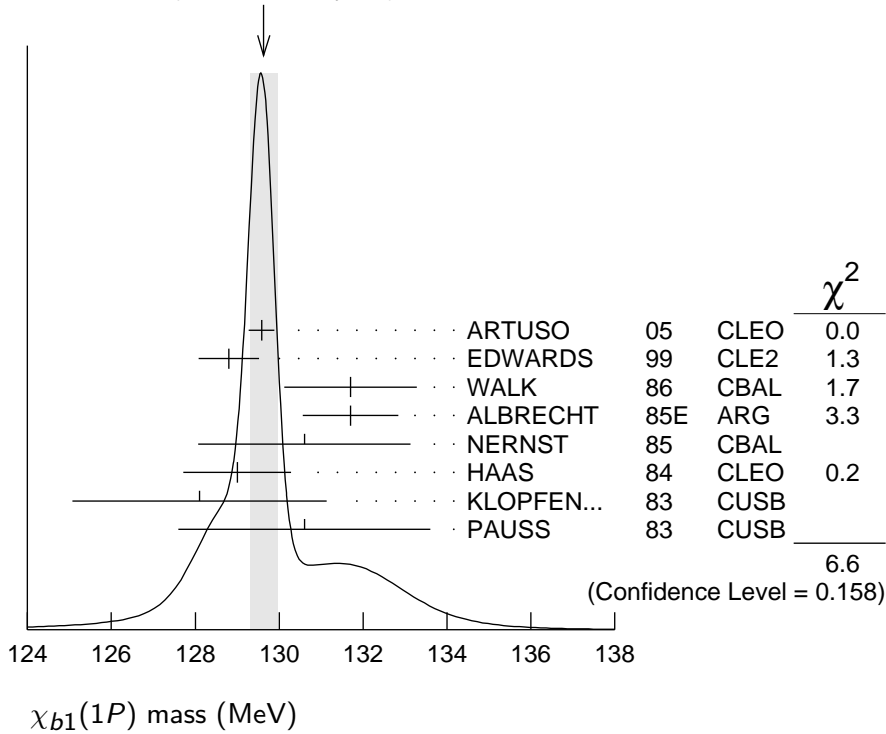
## $\chi_{b1}(1P)$ MASS

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>
<b>9892.78 ± 0.26 ± 0.31 OUR EVALUATION</b>	From average $\gamma$ energy below, using $\Upsilon(2S)$ mass = 10023.26 ± 0.31 MeV

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

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>129.63 ± 0.33 OUR AVERAGE</b>	Error includes scale factor of 1.3. See the ideogram below.		
129.58 ± 0.09 ± 0.29	ARTUSO	05	CLEO $\Upsilon(2S) \rightarrow \gamma X$
128.8 ± 0.4 ± 0.6	EDWARDS	99	CLE2 $\Upsilon(2S) \rightarrow \gamma \chi(1P)$
131.7 ± 0.9 ± 1.3	WALK	86	CBAL $\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
131.7 ± 0.3 ± 1.1	ALBRECHT	85E	ARG $\Upsilon(2S) \rightarrow \text{conv. } \gamma X$
130.6 ± 0.8 ± 2.4	NERNST	85	CBAL $\Upsilon(2S) \rightarrow \gamma X$
129 ± 0.8 ± 1	HAAS	84	CLEO $\Upsilon(2S) \rightarrow \text{conv. } \gamma X$
128.1 ± 0.4 ± 3.0	KLOPFEN...	83	CUSB $\Upsilon(2S) \rightarrow \gamma X$
130.6 ± 3.0	PAUSS	83	CUSB $\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

**WEIGHTED AVERAGE**  
129.63 ± 0.33 (Error scaled by 1.3)



### $\chi_{b1}(1P)$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level
$\Gamma_1$ $\gamma \Upsilon(1S)$	(35.0 $\pm$ 2.1) %	
$\Gamma_2$ $D^0 X$	(12.6 $\pm$ 2.2) %	
$\Gamma_3$ $\pi^+ \pi^- K^+ K^- \pi^0$	( 2.0 $\pm$ 0.6) $\times 10^{-4}$	
$\Gamma_4$ $2\pi^+ \pi^- K^- K_S^0$	( 1.3 $\pm$ 0.5) $\times 10^{-4}$	
$\Gamma_5$ $2\pi^+ \pi^- K^- K_S^0 2\pi^0$	< 6 $\times 10^{-4}$	90%
$\Gamma_6$ $2\pi^+ 2\pi^- 2\pi^0$	( 8.0 $\pm$ 2.5) $\times 10^{-4}$	
$\Gamma_7$ $2\pi^+ 2\pi^- K^+ K^-$	( 1.5 $\pm$ 0.5) $\times 10^{-4}$	
$\Gamma_8$ $2\pi^+ 2\pi^- K^+ K^- \pi^0$	( 3.5 $\pm$ 1.2) $\times 10^{-4}$	
$\Gamma_9$ $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	( 8.6 $\pm$ 3.2) $\times 10^{-4}$	
$\Gamma_{10}$ $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	( 9.3 $\pm$ 3.3) $\times 10^{-4}$	
$\Gamma_{11}$ $3\pi^+ 3\pi^-$	( 1.9 $\pm$ 0.6) $\times 10^{-4}$	
$\Gamma_{12}$ $3\pi^+ 3\pi^- 2\pi^0$	( 1.7 $\pm$ 0.5) $\times 10^{-3}$	
$\Gamma_{13}$ $3\pi^+ 3\pi^- K^+ K^-$	( 2.6 $\pm$ 0.8) $\times 10^{-4}$	
$\Gamma_{14}$ $3\pi^+ 3\pi^- K^+ K^- \pi^0$	( 7.5 $\pm$ 2.6) $\times 10^{-4}$	
$\Gamma_{15}$ $4\pi^+ 4\pi^-$	( 2.6 $\pm$ 0.9) $\times 10^{-4}$	
$\Gamma_{16}$ $4\pi^+ 4\pi^- 2\pi^0$	( 1.4 $\pm$ 0.6) $\times 10^{-3}$	
$\Gamma_{17}$ $\omega$ anything	( 4.9 $\pm$ 1.4) %	
$\Gamma_{18}$ $\omega X_{tetra}$	< 4.44 $\times 10^{-4}$	90%
$\Gamma_{19}$ $J/\psi J/\psi$	< 2.7 $\times 10^{-5}$	90%
$\Gamma_{20}$ $J/\psi \psi(2S)$	< 1.7 $\times 10^{-5}$	90%
$\Gamma_{21}$ $\psi(2S) \psi(2S)$	< 6 $\times 10^{-5}$	90%
$\Gamma_{22}$ $J/\psi(1S)$ anything	< 1.1 $\times 10^{-3}$	90%
$\Gamma_{23}$ $J/\psi(1S) X_{tetra}$	< 2.27 $\times 10^{-4}$	90%

### $\chi_{b1}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{total}$	$\Gamma_1/\Gamma$			
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.350<math>\pm</math>0.021 OUR AVERAGE</b>				
0.364 $\pm$ 0.017 $\pm$ 0.019	1,2,3	LEES	14M BABR	$\Upsilon(2S) \rightarrow \gamma \gamma \mu^+ \mu^-$
0.331 $\pm$ 0.018 $\pm$ 0.017	3222	3,4 KORNICER	11 CLEO	$e^+ e^- \rightarrow \gamma \gamma \ell^+ \ell^-$
0.350 $\pm$ 0.023 $\pm$ 0.018	13k	5 LEES	11J BABR	$\Upsilon(2S) \rightarrow X \gamma$
0.34 $\pm$ 0.07 $\pm$ 0.02	53	3,6,7 WALK	86 CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
0.47 $\pm$ 0.18		KLOPFEN...	83 CUSB	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

<sup>1</sup> LEES 14M quotes  $\Gamma(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{total} \times \Gamma(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))/\Gamma_{total} = (2.51 \pm 0.12)$  % combining the results from samples of  $\Upsilon(2S) \rightarrow \gamma \gamma \mu^+ \mu^-$  with and without converted photons.

<sup>2</sup> LEES 14M reports  $[\Gamma(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))] = (2.51 \pm 0.12) \times 10^{-2}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

<sup>3</sup> Assuming  $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.48 \pm 0.05)$  %.

<sup>4</sup> KORNICER 11 reports  $[\Gamma(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (22.8 \pm 0.4 \pm 1.2) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is  
the systematic error from using our best value.

<sup>5</sup> LEES 11J reports  $[\Gamma(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (24.1 \pm 0.6 \pm 1.5) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is  
the systematic error from using our best value.

<sup>6</sup> WALK 86 quotes  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) \times B(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(1S) \rightarrow$   
 $\ell^+ \ell^-) = (5.8 \pm 0.9 \pm 0.7) \%$ .

<sup>7</sup> WALK 86 reports  $[\Gamma(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (23.4 \pm 3.63 \pm 2.82) \times 10^{-3}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is  
the systematic error from using our best value.

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>12.6±1.9±1.1</b>	2310	<sup>8</sup> BRIERE	08	CLEO $\Upsilon(2S) \rightarrow \gamma D^0 X$

<sup>8</sup> For  $p_{D^0} > 2.5$  GeV/c.

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>2.0±0.6±0.1</b>	18	<sup>9</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^- K^+ K^- \pi^0$

<sup>9</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow \pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow$   
 $\gamma \chi_{b1}(1P))]$   $= (14 \pm 3 \pm 3) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow$   
 $\gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our  
second error is the systematic error from using our best value.

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1.3±0.5±0.1</b>	11	<sup>10</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ \pi^- K^- K_S^0$

<sup>10</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ \pi^- K^- K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow$   
 $\gamma \chi_{b1}(1P))]$   $= (9 \pm 3 \pm 2) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow$   
 $\gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our  
second error is the systematic error from using our best value.

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;6</b>	90	<sup>11</sup> ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ \pi^- K^- 2\pi^0$

<sup>11</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ \pi^- K^- K_S^0 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow$   
 $\gamma \chi_{b1}(1P))]$   $< 42 \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= 6.9 \times 10^{-2}$ .

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>8.0 \pm 2.4 \pm 0.4</math></b>	46	<sup>12</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- 2\pi^0$

<sup>12</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (55 \pm 9 \pm 14) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . 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
<b><math>1.5 \pm 0.5 \pm 0.1</math></b>	18	<sup>13</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^-$

<sup>13</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (10 \pm 3 \pm 2) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . 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>3.5 \pm 1.2 \pm 0.2</math></b>	22	<sup>14</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$

<sup>14</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (24 \pm 6 \pm 6) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . 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>8.6 \pm 3.2 \pm 0.4</math></b>	26	<sup>15</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$

<sup>15</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (59 \pm 14 \pm 17) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . 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 $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>9.3 \pm 3.3 \pm 0.5</math></b>	21	<sup>16</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 2\pi^- K^- K_S^0 \pi^0$

<sup>16</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 3\pi^+ 2\pi^- K^- K_S^0 \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (64 \pm 16 \pm 16) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b><math>1.9 \pm 0.6 \pm 0.1</math></b>	25	<sup>17</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^-$

<sup>17</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 3\pi^+ 3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (13 \pm 3 \pm 3) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . 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>17±5±1</b>	56	<sup>18</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- 2\pi^0$

<sup>18</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (119 \pm 18 \pm 32) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))$   
 $= (6.9 \pm 0.4) \times 10^{-2}$ . 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 $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.6±0.8±0.1</b>	21	<sup>19</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^-$

<sup>19</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 3\pi^+ 3\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (18 \pm 4 \pm 4) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>7.5±2.6±0.4</b>	28	<sup>20</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

<sup>20</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (52 \pm 11 \pm 14) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . 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>2.6±0.9±0.1</b>	24	<sup>21</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+ 4\pi^-$

<sup>21</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 4\pi^+ 4\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (18 \pm 4 \pm 5) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . 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>14±5±1</b>	26	<sup>22</sup> ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+ 4\pi^- 2\pi^0$

<sup>22</sup> ASNER 08A reports  $[\Gamma(\chi_{b1}(1P) \rightarrow 4\pi^+ 4\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P))]$   
 $= (96 \pm 24 \pm 29) \times 10^{-6}$  which we divide by our best value  $B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>4.9±1.3±0.6</b>	51k	JIA	17A BELL	$e^+ e^- \rightarrow \text{hadrons}$

$\Gamma(\omega X_{tetra})/\Gamma_{total}$   $\Gamma_{18}/\Gamma$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<44.4 \times 10^{-5}$	90	23 JIA	17A BELL	$e^+e^- \rightarrow$ hadrons

<sup>23</sup> For a tetraquark state  $X_{tetra}$ , with mass in the range 1.16–2.46 GeV and width in the range 0–0.3 GeV. Measured 90% CL limits as a function of  $X_{tetra}$  mass and width range from  $3.3 \times 10^{-5}$  to  $44.4 \times 10^{-5}$ .

$\Gamma(J/\psi J/\psi)/\Gamma_{total}$   $\Gamma_{19}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$<2.7$	90	24 SHEN	12 BELL	$\Upsilon(2S) \rightarrow \gamma\psi X$

<sup>24</sup> SHEN 12 reports  $< 2.7 \times 10^{-5}$  from a measurement of  $[\Gamma(\chi_{b1}(1P) \rightarrow J/\psi J/\psi)/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))]$  assuming  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ .

$\Gamma(J/\psi\psi(2S))/\Gamma_{total}$   $\Gamma_{20}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$<1.7$	90	25 SHEN	12 BELL	$\Upsilon(2S) \rightarrow \gamma\psi X$

<sup>25</sup> SHEN 12 reports  $< 1.7 \times 10^{-5}$  from a measurement of  $[\Gamma(\chi_{b1}(1P) \rightarrow J/\psi\psi(2S))/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))]$  assuming  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ .

$\Gamma(\psi(2S)\psi(2S))/\Gamma_{total}$   $\Gamma_{21}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
$<6$	90	26 SHEN	12 BELL	$\Upsilon(2S) \rightarrow \gamma\psi X$

<sup>26</sup> SHEN 12 reports  $< 6.2 \times 10^{-5}$  from a measurement of  $[\Gamma(\chi_{b1}(1P) \rightarrow \psi(2S)\psi(2S))/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))]$  assuming  $B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$ .

$\Gamma(J/\psi(1S)\text{anything})/\Gamma_{total}$   $\Gamma_{22}/\Gamma$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<1.1 \times 10^{-3}$	90	JIA	17A BELL	$e^+e^- \rightarrow$ hadrons

$\Gamma(J/\psi(1S)X_{tetra})/\Gamma_{total}$   $\Gamma_{23}/\Gamma$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<22.7 \times 10^{-5}$	90	27 JIA	17A BELL	$e^+e^- \rightarrow$ hadrons

<sup>27</sup> For a tetraquark state  $X_{tetra}$ , with mass in the range 1.16–2.46 GeV and width in the range 0–0.3 GeV. Measured 90% CL limits as a function of  $X_{tetra}$  mass and width range from  $1.8 \times 10^{-5}$  to  $22.7 \times 10^{-5}$ .

**$\chi_{b1}(1P)$  Cross-Particle Branching Ratios**

$\Gamma(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S))/\Gamma_{total} \times \Gamma(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))/\Gamma_{total}$   
 $\Gamma_1/\Gamma \times \Gamma_{50}^{\Upsilon(2S)}/\Gamma_{\Upsilon(2S)}$

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
$24.1 \pm 0.6 \pm 1.5$	13k	LEES	11J BABR	$\Upsilon(2S) \rightarrow X\gamma$

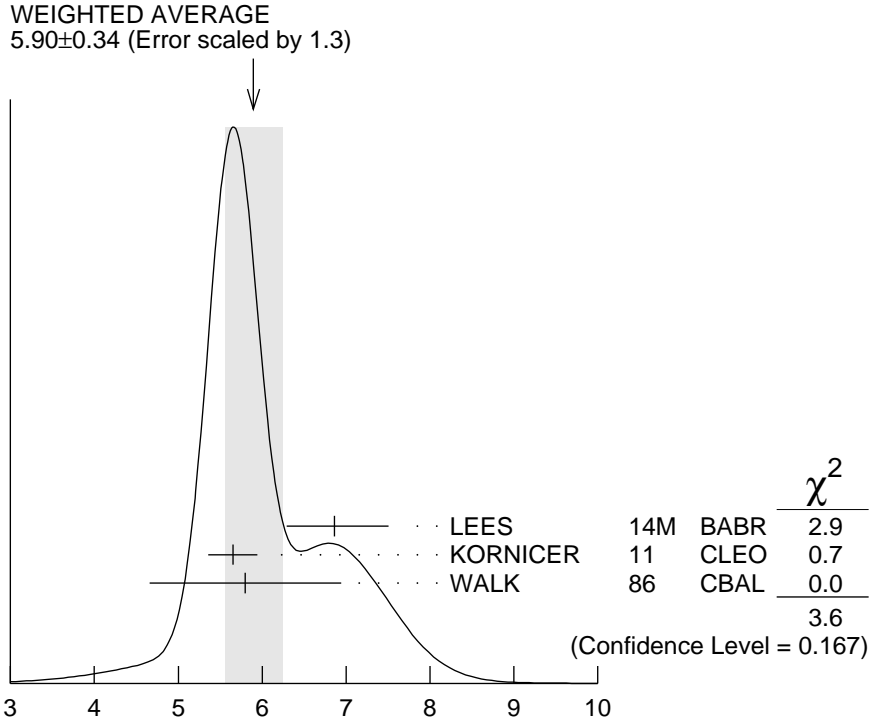
**$B(\chi_{b1}(1P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(2S) \rightarrow \gamma \chi_{b1}(1P)) \times B(\Upsilon(1S) \rightarrow \ell^+ \ell^-)$**

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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**5.90±0.34 OUR AVERAGE** Error includes scale factor of 1.3. See the ideogram below.

6.86 <sup>+0.47+0.44</sup> -0.45-0.35		28 LEES	14M BABR	$\Upsilon(2S) \rightarrow \gamma \gamma \mu^+ \mu^-$
5.65±0.11±0.27	3222	KORNICER	11 CLEO	$e^+ e^- \rightarrow \gamma \gamma \ell^+ \ell^-$
5.8 ±0.9 ±0.7	53	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 one converted photon.



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

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

VALUE (units $10^{-5}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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**1.30±0.34 OUR AVERAGE**

1.16 <sup>+0.78+0.14</sup> -0.67-0.16		29 LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
1.33±0.30±0.23	50	KORNICER	11 CLEO	$e^+ e^- \rightarrow \gamma \gamma \ell^+ \ell^-$

<sup>29</sup> From a sample of  $\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$  with converted photons.

**$B(\chi_{b2}(1P) \rightarrow \rho X + \bar{\rho} X) / B(\chi_{b1}(1P) \rightarrow \rho X + \bar{\rho} X)$**

VALUE	DOCUMENT ID	TECN	COMMENT
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**1.068±0.010±0.040** BRIERE 07 CLEO  $\Upsilon(2S) \rightarrow \gamma \chi_{bJ}(1P)$

**$B(\chi_{b0}(1P) \rightarrow \rho X + \bar{\rho} X) / B(\chi_{b1}(1P) \rightarrow \rho X + \bar{\rho} X)$**

VALUE	DOCUMENT ID	TECN	COMMENT
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**1.11±0.15±0.20** BRIERE 07 CLEO  $\Upsilon(2S) \rightarrow \gamma \chi_{bJ}(1P)$

$\chi_{b1}(1P)$  REFERENCES

JIA	17A	PR D96 112002	S. Jia <i>et al.</i>	(BELLE Collab.)
LEES	14M	PR D90 112010	J.P. Lees <i>et al.</i>	(BABAR Collab.)
SHEN	12	PR D85 071102	C.P. Shen <i>et al.</i>	(BELLE Collab.)
KORNICER	11	PR D83 054003	M. Kornicer <i>et al.</i>	(CLEO Collab.)
LEES	11J	PR D84 072002	J.P. Lees <i>et al.</i>	(BABAR Collab.)
ASNER	08A	PR D78 091103	D.M. Asner <i>et al.</i>	(CLEO Collab.)
BRIERE	08	PR D78 092007	R.A. Briere <i>et al.</i>	(CLEO Collab.)
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ARTUSO	05	PRL 94 032001	M. Artuso <i>et al.</i>	(CLEO Collab.)
EDWARDS	99	PR D59 032003	K.W. Edwards <i>et al.</i>	(CLEO Collab.)
SKWARNICKI	87	PRL 58 972	T. Skwarnicki <i>et al.</i>	(Crystal Ball Collab.) J
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ALBRECHT	85E	PL 160B 331	H. Albrecht <i>et al.</i>	(ARGUS Collab.)
NERNST	85	PRL 54 2195	R. Nernst <i>et al.</i>	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	J. Haas <i>et al.</i>	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	C. Klopfenstein <i>et al.</i>	(CUSB Collab.)
PAUSS	83	PL 130B 439	F. Pauss <i>et al.</i>	(MPIM, COLU, CORN, LSU+)

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