

$\chi_{b1}(2P)$

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

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>
10255.46 ± 0.22 ± 0.50 OUR EVALUATION	From γ energy below, using $\Upsilon(3S)$ mass = 10355.2 ± 0.5 MeV

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

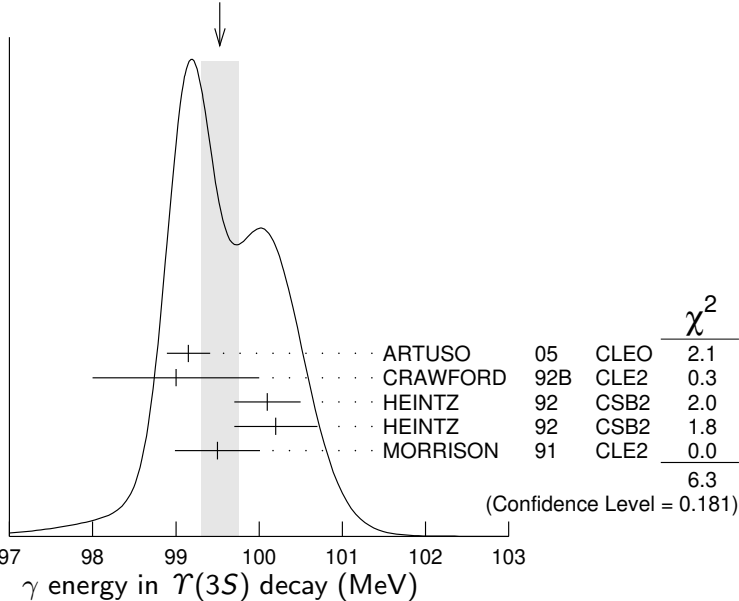
<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
23.5 ± 0.7 ± 0.7	¹ HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X, l^+l^- \gamma\gamma$

¹From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
99.26 ± 0.22 OUR EVALUATION		Treating systematic errors as correlated		
99.53 ± 0.23 OUR AVERAGE		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	² HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X$
100.2 ± 0.5	223	³ HEINTZ	92	CSB2 $e^+e^- \rightarrow l^+l^- \gamma\gamma$
99.5 ± 0.1 ± 0.5	25759	MORRISON	91	CLE2 $e^+e^- \rightarrow \gamma X$

WEIGHTED AVERAGE
99.53 ± 0.23 (Error scaled by 1.3)



²A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91.

³A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

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

Mode	Fraction (Γ_i/Γ)
Γ_1 $\omega \Upsilon(1S)$	(1.63 ^{+0.40} _{-0.34}) %
Γ_2 $\gamma \Upsilon(2S)$	(18.1 ± 1.9) %
Γ_3 $\gamma \Upsilon(1S)$	(9.9 ± 1.0) %
Γ_4 $\pi\pi\chi_{b1}(1P)$	(9.1 ± 1.3) × 10 ⁻³
Γ_5 $D^0 X$	(8.8 ± 1.7) %
Γ_6 $\pi^+\pi^-K^+K^-\pi^0$	(3.1 ± 1.0) × 10 ⁻⁴
Γ_7 $2\pi^+\pi^-K^-K_S^0$	(1.1 ± 0.5) × 10 ⁻⁴
Γ_8 $2\pi^+\pi^-K^-K_S^02\pi^0$	(7.7 ± 3.2) × 10 ⁻⁴
Γ_9 $2\pi^+2\pi^-2\pi^0$	(5.9 ± 2.0) × 10 ⁻⁴
Γ_{10} $2\pi^+2\pi^-K^+K^-$	(10 ± 4) × 10 ⁻⁵
Γ_{11} $2\pi^+2\pi^-K^+K^-\pi^0$	(5.5 ± 1.8) × 10 ⁻⁴
Γ_{12} $2\pi^+2\pi^-K^+K^-2\pi^0$	(10 ± 4) × 10 ⁻⁴
Γ_{13} $3\pi^+2\pi^-K^-K_S^0\pi^0$	(6.7 ± 2.6) × 10 ⁻⁴
Γ_{14} $3\pi^+3\pi^-$	(1.2 ± 0.4) × 10 ⁻⁴
Γ_{15} $3\pi^+3\pi^-2\pi^0$	(1.2 ± 0.4) × 10 ⁻³
Γ_{16} $3\pi^+3\pi^-K^+K^-$	(2.0 ± 0.8) × 10 ⁻⁴
Γ_{17} $3\pi^+3\pi^-K^+K^-\pi^0$	(6.1 ± 2.2) × 10 ⁻⁴
Γ_{18} $4\pi^+4\pi^-$	(1.7 ± 0.6) × 10 ⁻⁴
Γ_{19} $4\pi^+4\pi^-2\pi^0$	(1.9 ± 0.7) × 10 ⁻³

$\chi_{b1}(2P)$ BRANCHING RATIOS

$\Gamma(\omega \Upsilon(1S))/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE (units 10 ⁻²)	EVTS	DOCUMENT ID	TECN	COMMENT
1.63^{+0.35+0.16}_{-0.31-0.15}	32.6 ^{+6.9} _{-6.1}	⁴ CRONIN-HEN..04	CLE3	$\Upsilon(3S) \rightarrow \gamma\omega \Upsilon(1S)$

⁴ Using $B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) = (11.3 \pm 0.6)\%$ and $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = 2$
 $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 2 (2.48 \pm 0.06)\%$.

$\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.181 ± 0.019 OUR AVERAGE				
0.211 ± 0.017 ± 0.019	^{5,6,7}	LEES	14M	BABR $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
0.190 ± 0.018 ± 0.017	4.3k	⁸ LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
0.206 ± 0.035 ± 0.019	^{5,9}	CRAWFORD	92B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.132 ± 0.018 ± 0.012	^{5,10}	HEINTZ	92	CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

⁵ Assuming $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.93 \pm 0.17)\%$.

⁶ 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.

⁷ 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 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 value.

⁸ 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 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 value.

⁹ CRAWFORD 92B quotes $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S)) \times 2 B(\Upsilon(2S) \rightarrow \ell^+ \ell^-) = (10.23 \pm 1.20 \pm 1.26) 10^{-4}$.

¹⁰ 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.

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.099±0.010 OUR AVERAGE				
0.107±0.006±0.010	11,12,13	LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
0.098±0.005±0.009	15k	14 LEES	11J BABR	$\Upsilon(3S) \rightarrow X \gamma$
0.103±0.023±0.009	11,15	CRAWFORD	92B CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$
0.075±0.010±0.007	11,16	HEINTZ	92 CSB2	$e^+ e^- \rightarrow \ell^+ \ell^- \gamma \gamma$

¹¹ Assuming $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.48 \pm 0.05)\%$.

¹² 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.

¹³ 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 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 value.

¹⁴ 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 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 value.

¹⁵ CRAWFORD 92B quotes $B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) \times 2 B(\Upsilon(1S) \rightarrow \ell^+ \ell^-) = (6.47 \pm 1.12 \pm 0.82) 10^{-4}$.

¹⁶ 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.

$\Gamma(\pi \pi \chi_{b1}(1P))/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN	COMMENT
9.1±1.3 OUR AVERAGE				
9.2±1.1±0.8	31k	17 LEES	11C BABR	$e^+ e^- \rightarrow \pi^+ \pi^- X$
8.6±2.3±2.1		18 CAWLFIELD	06 CLE3	$\Upsilon(3S) \rightarrow 2(\gamma \pi \ell)$

¹⁷ 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 $B(\Upsilon(3S) \rightarrow \chi_{b1}(2P) X) = B(\Upsilon(3S) \rightarrow \chi_{b1}(2P) \gamma) = (12.6 \pm 1.2) \times 10^{-2}$.

¹⁸ 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.

$\Gamma(D^0 X)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
$8.8 \pm 1.5 \pm 0.8$	2243	¹⁹ BRIERE	08	CLEO $\Upsilon(3S) \rightarrow \gamma D^0 X$

¹⁹ For $p_{D^0} > 2.5$ GeV/c.

$\Gamma(\pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
$3.1 \pm 1.0 \pm 0.3$	30	²⁰ ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma \pi^+ \pi^- K^+ K^- \pi^0$

²⁰ 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 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 value.

$\Gamma(2\pi^+ \pi^- K^- K_S^0)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
$1.1 \pm 0.5 \pm 0.1$	10	²¹ ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma 2\pi^+ \pi^- K^- K_S^0$

²¹ 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 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 value.

$\Gamma(2\pi^+ \pi^- K^- K_S^0 2\pi^0)/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
$7.7 \pm 3.1 \pm 0.7$	15	²² ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma 2\pi^+ \pi^- K^- 2\pi^0$

²² 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 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 value.

$\Gamma(2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
$5.9 \pm 2.0 \pm 0.5$	36	²³ ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma 2\pi^+ 2\pi^- 2\pi^0$

²³ 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 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 value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
$1.0 \pm 0.4 \pm 0.1$	12	²⁴ ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^-$

²⁴ 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 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 value.

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

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$5.5 \pm 1.7 \pm 0.5$	38	²⁵ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$

²⁵ 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 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 value.

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

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$9.6 \pm 3.5 \pm 0.9$	27	²⁶ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$

²⁶ 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 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 value.

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

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$6.7 \pm 2.5 \pm 0.6$	17	²⁷ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 2\pi^- K^- K_S^0 \pi^0$

²⁷ 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 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 value.

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

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$1.2 \pm 0.4 \pm 0.1$	18	²⁸ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^-$

²⁸ 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 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 value.

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

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$12 \pm 4 \pm 1$	44	²⁹ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- 2\pi^0$

²⁹ 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 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 value.

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

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$2.0 \pm 0.7 \pm 0.2$	16	³⁰ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^-$

³⁰ 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 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 value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
6.1±2.1±0.6	25	³¹ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+3\pi^-K^+K^-\pi^0$

³¹ 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 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 value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
1.7±0.6±0.2	16	³² ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+4\pi^-$

³² 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 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 value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
19±7±2	41	³³ ASNER	08A CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+4\pi^-2\pi^0$

³³ 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 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 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
12.4±0.3±0.6	15k	LEES	11J BABR	$\Upsilon(3S) \rightarrow X\gamma$

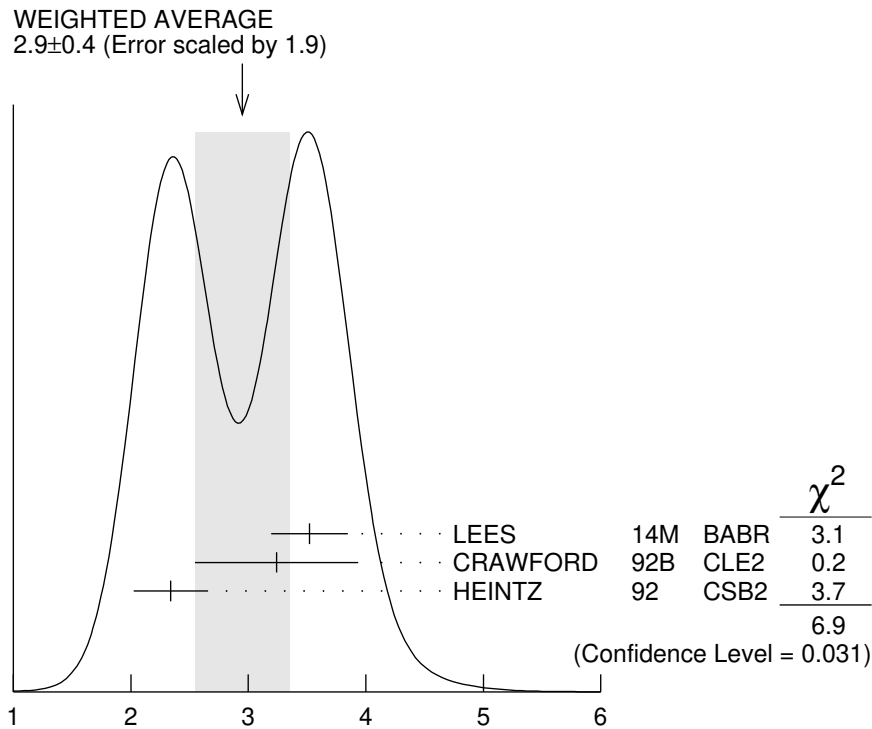
$B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(1S)) \times B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)) \times B(\Upsilon(1S) \rightarrow \ell^+\ell^-)$

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
2.9 ± 0.4 OUR AVERAGE		Error includes scale factor of 1.9. See the ideogram below.		
3.52 ^{+0.28+0.17} _{-0.27-0.18}		³⁴ LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
3.24±0.56±0.41	58	³⁵ CRAWFORD	92B CLE2	$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$
2.34±0.28±0.15		³⁶ HEINTZ	92 CSB2	$\Upsilon(3S) \rightarrow \gamma\gamma\ell^+\ell^-$

³⁴ From a sample of $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$ with one converted photon.

³⁵ CRAWFORD 92B quotes $2 \times B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}(2P)) B(\chi_{bJ}(2P) \rightarrow \gamma \Upsilon(nS)) B(\Upsilon(nS) \rightarrow \ell^+\ell^-)$.

³⁶ 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 $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.05)\%$.



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

(units 10^{-4})

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

$$\Gamma_2 / \Gamma \times \Gamma_{21}^{\Upsilon(3S)} / \Gamma \Upsilon(3S)$$

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

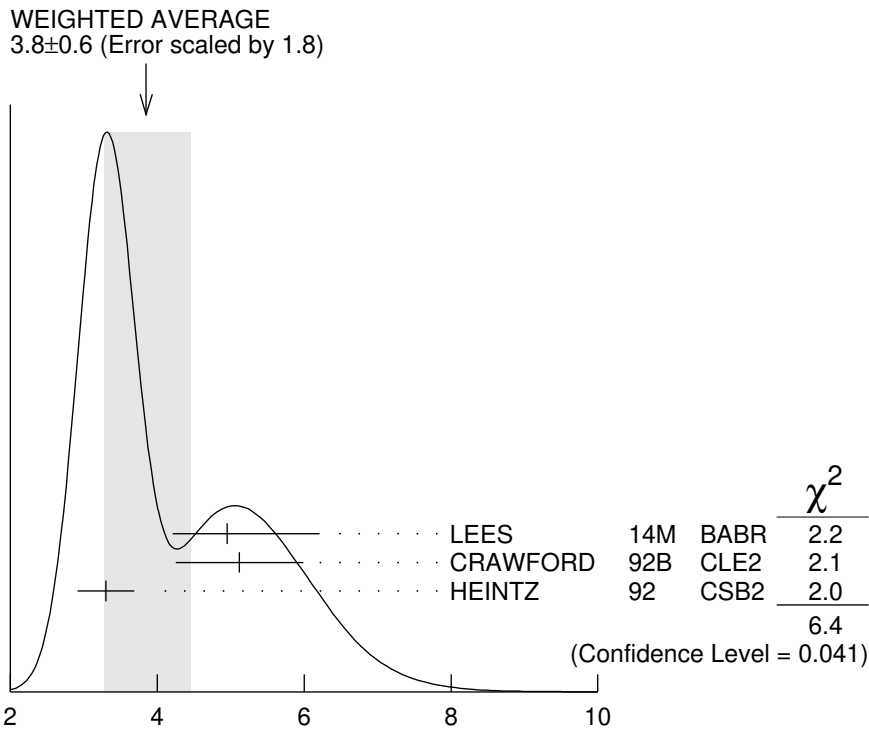
$$B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\Upsilon(2S) \rightarrow \ell^+ \ell^-)$$

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
3.8 ±0.6 OUR AVERAGE		Error includes scale factor of 1.8. See the ideogram below.		
4.95 ^{+0.75+1.01} _{-0.70-0.24}		37 LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
5.12±0.60±0.63	111	38 CRAWFORD	92B CLE2	$\Upsilon(3S) \rightarrow \gamma \gamma \ell^+ \ell^-$
3.30±0.33±0.20		39 HEINTZ	92 CSB2	$\Upsilon(3S) \rightarrow \gamma \gamma \ell^+ \ell^-$

³⁷ From a sample of $\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$ with one converted photon.

³⁸ CRAWFORD 92B quotes $2 \times B(\Upsilon(3S) \rightarrow \gamma \chi_{bJ}(2P)) B(\chi_{bJ}(2P) \rightarrow \gamma \Upsilon(nS)) B(\Upsilon(nS) \rightarrow \ell^+ \ell^-)$.

³⁹ 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 $B(\Upsilon(2S) \rightarrow \mu^+ \mu^-) = (1.44 \pm 0.10) \%$.



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

(units 10^{-4})

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

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN	COMMENT
1.16±0.07±0.12	31k	LEES	11C	BABR $e^+e^- \rightarrow \pi^+\pi^-X$

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

VALUE	DOCUMENT ID	TECN	COMMENT
1.109±0.007±0.040	BRIERE	07	CLEO $\Upsilon(3S) \rightarrow \gamma \chi_{bJ}(2P)$

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

VALUE	DOCUMENT ID	TECN	COMMENT
1.082±0.025±0.060	BRIERE	07	CLEO $\Upsilon(3S) \rightarrow \gamma \chi_{bJ}(2P)$

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

LEES	14M	PR D90 112010	J.P. Lees <i>et al.</i>	(BABAR Collab.)
LEES	11C	PR D84 011104	J.P. Lees <i>et al.</i>	(BABAR 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.)
BRIERE	07	PR D76 012005	R.A. Briere <i>et al.</i>	(CLEO Collab.)
CAWLFIELD	06	PR D73 012003	C. Cawlfeld <i>et al.</i>	(CLEO Collab.)
ARTUSO	05	PRL 94 032001	M. Artuso <i>et al.</i>	(CLEO Collab.)
CRONIN-HEN...	04	PRL 92 222002	D. Cronin-Hennessy <i>et al.</i>	(CLEO Collab.)
CRAWFORD	92B	PL B294 139	G. Crawford <i>et al.</i>	(CLEO Collab.)
HEINTZ	92	PR D46 1928	U. Heintz <i>et al.</i>	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	U. Heintz <i>et al.</i>	(CUSB Collab.)
MORRISON	91	PRL 67 1696	R.J. Morrison <i>et al.</i>	(CLEO Collab.)
NARAIN	91	PRL 66 3113	M. Narain <i>et al.</i>	(CUSB Collab.)