

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

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

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

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

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

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

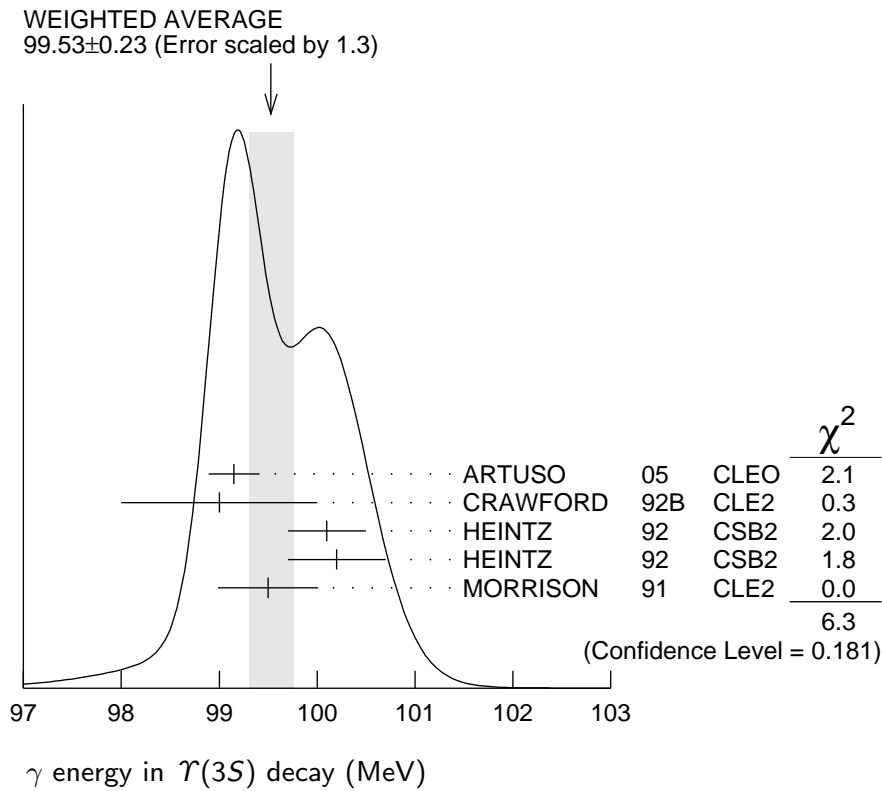
¹From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
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 $e^+e^- \rightarrow \gamma X$

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 $\gamma \Upsilon(2S)$	$(18.1 \pm 1.9)\%$
Γ_3 $\gamma \Upsilon(1S)$	$(9.9 \pm 1.0)\%$
Γ_4 $\pi\pi\chi_{b1}(1P)$	$(9.1 \pm 1.3) \times 10^{-3}$
Γ_5 $D^0 X$	$(8.8 \pm 1.7)\%$
Γ_6 $\pi^+\pi^-K^+K^-\pi^0$	$(3.1 \pm 1.0) \times 10^{-4}$
Γ_7 $2\pi^+\pi^-K^-K_S^0$	$(1.1 \pm 0.5) \times 10^{-4}$
Γ_8 $2\pi^+\pi^-K^-K_S^0 2\pi^0$	$(7.7 \pm 3.2) \times 10^{-4}$
Γ_9 $2\pi^+ 2\pi^- 2\pi^0$	$(5.9 \pm 2.0) \times 10^{-4}$
Γ_{10} $2\pi^+ 2\pi^- K^+ K^-$	$(10 \pm 4) \times 10^{-5}$
Γ_{11} $2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(5.5 \pm 1.8) \times 10^{-4}$
Γ_{12} $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(10 \pm 4) \times 10^{-4}$
Γ_{13} $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$(6.7 \pm 2.6) \times 10^{-4}$
Γ_{14} $3\pi^+ 3\pi^-$	$(1.2 \pm 0.4) \times 10^{-4}$
Γ_{15} $3\pi^+ 3\pi^- 2\pi^0$	$(1.2 \pm 0.4) \times 10^{-3}$
Γ_{16} $3\pi^+ 3\pi^- K^+ K^-$	$(2.0 \pm 0.8) \times 10^{-4}$

Γ_{17}	$3\pi^+3\pi^-K^+K^-\pi^0$	$(6.1 \pm 2.2) \times 10^{-4}$
Γ_{18}	$4\pi^+4\pi^-$	$(1.7 \pm 0.6) \times 10^{-4}$
Γ_{19}	$4\pi^+4\pi^-2\pi^0$	$(1.9 \pm 0.7) \times 10^{-3}$

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

$\Gamma(\omega \Upsilon(1S))/\Gamma_{\text{total}}$ 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				
$0.211 \pm 0.017 \pm 0.019$		^{5,6,7} LEES	14M	BABR $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
$0.190 \pm 0.018 \pm 0.017$	4.3k	⁸ LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
$0.206 \pm 0.035 \pm 0.019$		^{5,9} CRAWFORD	92B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
$0.132 \pm 0.018 \pm 0.012$		^{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				
$0.107 \pm 0.006 \pm 0.010$		^{11,12,13} LEES	14M	BABR $\Upsilon(3S) \rightarrow \gamma\gamma\mu^+\mu^-$
$0.098 \pm 0.005 \pm 0.009$	15k	¹⁴ LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
$0.103 \pm 0.023 \pm 0.009$		^{11,15} CRAWFORD	92B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
$0.075 \pm 0.010 \pm 0.007$		^{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±1.5±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±1.0±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±0.5±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.

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

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

²² ASNER 08A reports $[\Gamma(\chi_{b1}(2P) \rightarrow 2\pi^+\pi^-K^-K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P))]$ = $(97 \pm 30 \pm 26) \times 10^{-6}$ 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±2.0±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±0.4±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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
5.5±1.7±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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
9.6±3.5±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**

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$6.1 \pm 2.1 \pm 0.6$	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**

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$1.7 \pm 0.6 \pm 0.2$	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	$\Upsilon(3S) \rightarrow X\gamma$

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

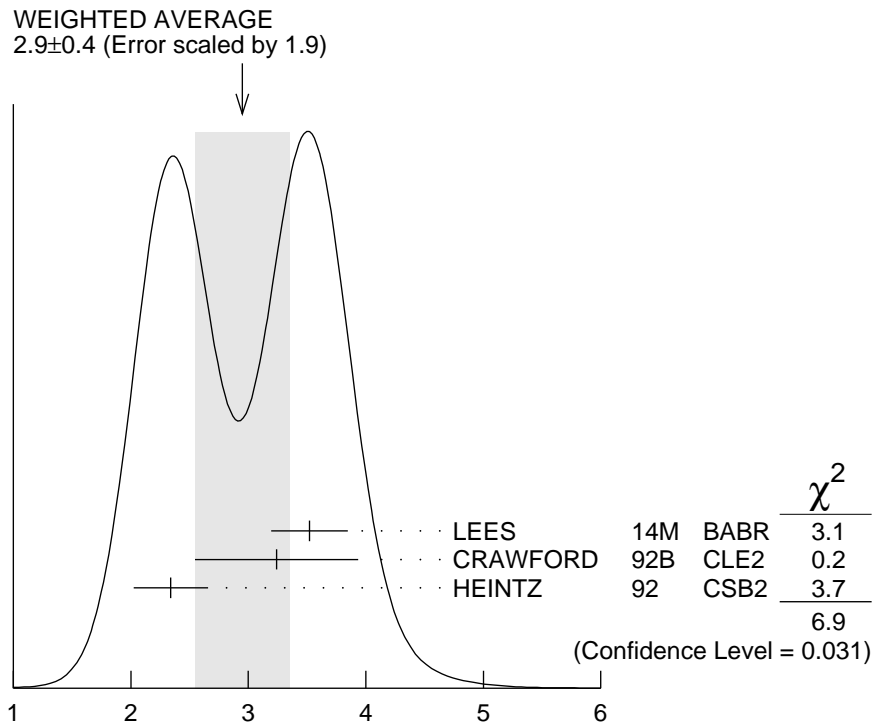
VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
2.9 ±0.4 OUR AVERAGE				Error includes scale factor of 1.9. See the ideogram below.

$3.52^{+0.28+0.17}_{-0.27-0.18}$		³⁴ LEES	14M BABR	$\Upsilon(3S) \rightarrow \gamma \gamma \mu^+ \mu^-$
$3.24 \pm 0.56 \pm 0.41$	58	³⁵ CRAWFORD	92B CLE2	$\Upsilon(3S) \rightarrow \gamma \gamma \ell^+ \ell^-$
$2.34 \pm 0.28 \pm 0.15$		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	$\Upsilon(3S) \rightarrow X\gamma$

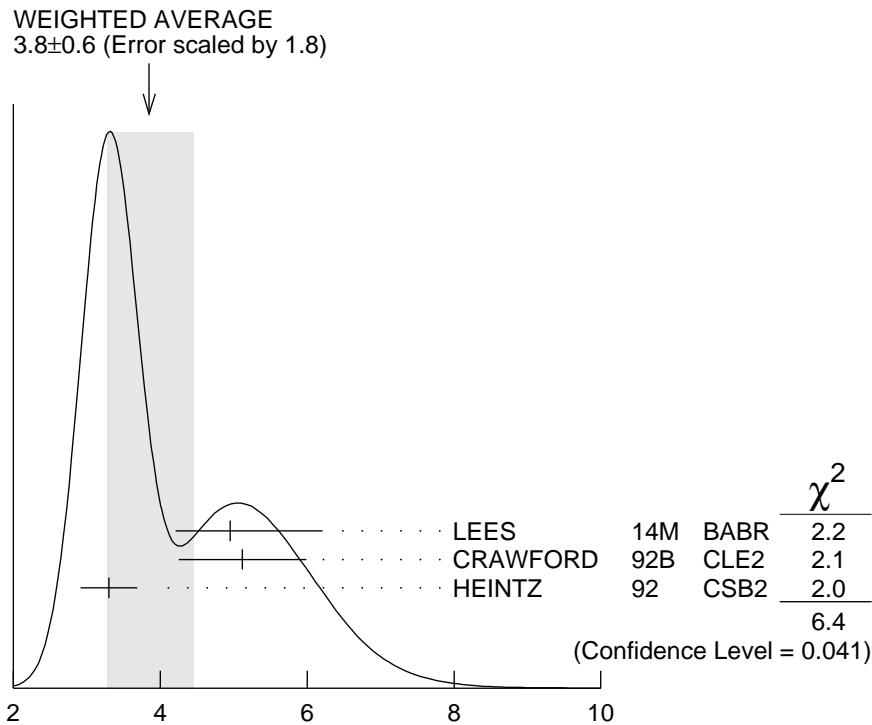
$$B(\chi_{b1}(2P) \rightarrow \gamma \Upsilon(2S)) \times B(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) \times B(\Upsilon(2S) \rightarrow \ell^+ \ell^-)$$

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
$1.16 \pm 0.07 \pm 0.12$	31k	LEES	11C	BABR $e^+ e^- \rightarrow \pi^+ \pi^- X$

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

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

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

VALUE	DOCUMENT ID	TECN	COMMENT
$1.082 \pm 0.025 \pm 0.060$	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.)
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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.)
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NARAIN	91	PRL 66 3113	M. Narain <i>et al.</i>	(CUSB Collab.)