$\chi_{b2}(2P)$

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

VALUE (GeV)	DOCUMENT ID
10.26865±0.00022±0.00050 OUR EVALUATION From γ energy below, using $\Upsilon(3S)$ mass = 10355.2 ± 0.5 MeV	

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

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
13.5±0.4±0.5	[1] HEINTZ	92	CSB2	$e^+e^- \to \gamma X, \ell^+\ell^-\gamma\gamma$

[1] From 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
86.19±0.22 OUR EVALUATION Treating systematic errors as correlated					
86.40±0.18 OUR AVERAGE					
86.04±0.06±0.27		ARTUSO	05	CLEO	$\Upsilon(3S) \to \gamma X$
86 ±1	101	CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
86.7 ±0.4	10319	[2] HEINTZ	92	CSB2	$e^+e^- \to \gamma X$
86.9 ±0.4	157	[3] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
86.4 ±0.1 ±0.4	30741	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

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

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

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\omega\Upsilon(1S)$	$(1.10^{+0.34}_{-0.30})$ %	
Γ_2	$\gamma\Upsilon(2S)$	(16.2 ±2.4) %	
Γ_3	$\gamma\Upsilon(1S)$	(7.1 ±1.0) %	
Γ_4	$\pi\pi\chi_{b2}(1P)$	(6.0 ±2.1) $\times 10^{-3}$	
Γ_5	$D^0 X$	< 2.4 %	90%
Γ_6	$\pi^+\pi^-K^+K^-\pi^0$	< 1.1 $\times 10^{-4}$	90%
Γ_7	$2\pi^+\pi^-K^-K^0_S$	< 9 $\times 10^{-5}$	90%
Γ_8	$2\pi^+\pi^-K^-K^0_S 2\pi^0$	< 7 $\times 10^{-4}$	90%

Γ_9	$2\pi^+ 2\pi^- 2\pi^0$	$(3.9 \pm 1.6) \times 10^{-4}$	
Γ_{10}	$2\pi^+ 2\pi^- K^+ K^-$	$(9 \pm 4) \times 10^{-5}$	
Γ_{11}	$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(2.4 \pm 1.1) \times 10^{-4}$	
Γ_{12}	$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(4.7 \pm 2.3) \times 10^{-4}$	
Γ_{13}	$3\pi^+ 2\pi^- K^- K^0_S \pi^0$	$< 4 \times 10^{-4}$	90%
Γ_{14}	$3\pi^+ 3\pi^-$	$(9 \pm 4) \times 10^{-5}$	
Γ_{15}	$3\pi^+ 3\pi^- 2\pi^0$	$(1.2 \pm 0.4) \times 10^{-3}$	
Γ_{16}	$3\pi^+ 3\pi^- K^+ K^-$	$(1.4 \pm 0.7) \times 10^{-4}$	
Γ_{17}	$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$(4.2 \pm 1.7) \times 10^{-4}$	
Γ_{18}	$4\pi^+ 4\pi^-$	$(9 \pm 5) \times 10^{-5}$	
Γ_{19}	$4\pi^+ 4\pi^- 2\pi^0$	$(1.3 \pm 0.5) \times 10^{-3}$	

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

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
$\mathbf{1.10^{+0.32}_{-0.28}{}^{+0.11}_{-0.10}}$	$20.1^{+5.8}_{-5.1}$	[4] CRONIN-HEN..04		CLE3	$\Upsilon(3S) \to \gamma\omega\Upsilon(1S)$

[4] Using $B(\Upsilon(3S) \to \gamma\chi_{b2}(2P)) = (11.4 \pm 0.8)\%$ and $B(\Upsilon(1S) \to \ell^+\ell^-) = 2\, B(\Upsilon(1S) \to \mu^+\mu^-) = 2\,(2.48 \pm 0.06)\%$.

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.162±0.024 OUR AVERAGE				
0.135±0.025±0.035	[5] CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
0.173±0.021±0.019	[6] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[5] Using $B(\Upsilon(2S) \to \mu^+\mu^-) = (1.37 \pm 0.26)\%$, $B(\Upsilon(3S) \to \gamma\gamma\Upsilon(2S)) \times 2\, B(\Upsilon(2S) \to \mu^+\mu^-) = (4.98 \pm 0.94 \pm 0.62) \times 10^{-4}$, and $B(\Upsilon(3S) \to \gamma\chi_{b2}(2P)) = 0.135 \pm 0.003 \pm 0.017$.

[6] Using $B(\Upsilon(2S) \to \mu^+\mu^-) = (1.44 \pm 0.10)\%$, $B(\Upsilon(3S) \to \gamma\chi_{b2}(2P)) = (11.1 \pm 0.5 \pm 0.4)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.071±0.010 OUR AVERAGE				
0.072±0.014±0.013	[7] CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
0.070±0.010±0.006	[8] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[7] Using $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.57 \pm 0.07)\%$, $B(\Upsilon(3S) \to \gamma\gamma\Upsilon(2S)) \times 2\, B(\Upsilon(1S) \to \mu^+\mu^-) = (5.03 \pm 0.94 \pm 0.63) \times 10^{-4}$, and $B(\Upsilon(3S) \to \gamma\chi_{b2}(2P)) = 0.135 \pm 0.003 \pm 0.017$.

[8] Using $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.57 \pm 0.07)\%$, $B(\Upsilon(3S) \to \gamma\chi_{b2}(2P)) = (11.1 \pm 0.5 \pm 0.4)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\pi\pi\chi_{b2}(1P))/\Gamma_{\text{total}}$ — Γ_4/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
6.0±1.6±1.4	[9] CAWLFIELD	06	CLE3	$\Upsilon(3S) \to 2(\gamma\pi\ell)$

[9] CAWLFIELD 06 quote $\Gamma(\chi_b(2P) \to \pi\pi\chi_b(1P)) = 0.83 \pm 0.22 \pm 0.08 \pm 0.19$ keV assuming I-spin conservation, no D-wave contribution, $\Gamma(\chi_{b1}(2P)) = 96 \pm 16$keV, and $\Gamma(\chi_{b2}(2P)) = 138 \pm 19$ keV.

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<2.4 \times 10^{-2}$	90	[10,11] BRIERE	08	CLEO	$\Upsilon(3S) \to \gamma D^0 X$

[10] For $p_{D^0} > 2.5$ GeV/c.

[11] The authors also present their result as $(0.2 \pm 1.4 \pm 0.1) \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.1	90	[12] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma \pi^+\pi^- K^+ K^- \pi^0$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.9	90	[13] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+\pi^- K^- K^0_S$

[13] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \to 2\pi^+\pi^- K^- K^0_S)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma \chi_{b2}(2P))] < 12 \times 10^{-6}$. We divide by our best value $B(\Upsilon(3S) \to \gamma \chi_{b2}(2P)) = 13.1 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<7	90	[14] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+\pi^- K^- 2\pi^0$

[14] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \to 2\pi^+\pi^- K^- K^0_S 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma \chi_{b2}(2P))] < 87 \times 10^{-6}$. We divide by our best value $B(\Upsilon(3S) \to \gamma \chi_{b2}(2P)) = 13.1 \times 10^{-2}$.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
3.9±1.6±0.5	23	[15] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- 2\pi^0$

[15] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \to 2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma \chi_{b2}(2P))] = (51 \pm 16 \pm 13) \times 10^{-6}$. We divide by our best value $B(\Upsilon(3S) \to \gamma \chi_{b2}(2P)) = (13.1 \pm 1.6) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
0.9±0.4±0.1	11	[16] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^-$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
2.4±1.0±0.3	16	[17] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-\pi^0$

[17] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (32 \pm 11 \pm 8) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
4.7±2.2±0.6	14	[18] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 2\pi^+2\pi^-K^+K^-2\pi^0$

[18] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 2\pi^+2\pi^-K^+K^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (62 \pm 23 \pm 17) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<4	90	[19] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+2\pi^-K^-K^0_S\pi^0$

[19] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+2\pi^-K^-K^0_S\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] < 58 \times 10^{-6}$. We divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P)) = 13.1 \times 10^{-2}$.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
0.9±0.4±0.1	14	[20] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+3\pi^-$

[20] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+3\pi^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (12 \pm 4 \pm 3) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
12±4±1	45	[21] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+3\pi^-2\pi^0$

[21] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+3\pi^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (159 \pm 33 \pm 43) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.4±0.7±0.2	12	[22] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 3\pi^+3\pi^-K^+K^-$

[22] ASNER 08A reports $[\Gamma(\chi_{b2}(2P) \rightarrow 3\pi^+3\pi^-K^+K^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(2P))] = (19 \pm 7 \pm 5) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
4.2±1.7±0.5	16	[23] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
0.9±0.4±0.1	9	[24] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 4\pi^+ 4\pi^-$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
13±5±2	27	[25] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 4\pi^+ 4\pi^- 2\pi^0$

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

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

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