$\chi_{b2}(1P)$

$I^G(J^{PC}) = 0^+(2^{++})$
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*
9912.21±0.26±0.31 OUR EVALUATION	From average γ energy below, using $\Upsilon(2S)$ mass = 10023.26 ± 0.31 MeV

γ ENERGY IN $\Upsilon(2S)$ DECAY

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

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

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\gamma\,\Upsilon(1S)$	(19.1±1.2) %	
Γ_2	$D^0 X$	< 7.9 %	90%
Γ_3	$\pi^+\pi^-K^+K^-\pi^0$	(8 ±5) × 10^{-5}	
Γ_4	$2\pi^+\pi^-K^-K^0_S$	< 1.0 × 10^{-4}	90%
Γ_5	$2\pi^+\pi^-K^-K^0_S2\pi^0$	(5.3±2.4) × 10^{-4}	
Γ_6	$2\pi^+2\pi^-2\pi^0$	(3.5±1.4) × 10^{-4}	
Γ_7	$2\pi^+2\pi^-K^+K^-$	(1.1±0.4) × 10^{-4}	
Γ_8	$2\pi^+2\pi^-K^+K^-\pi^0$	(2.1±0.9) × 10^{-4}	
Γ_9	$2\pi^+2\pi^-K^+K^-2\pi^0$	(3.9±1.8) × 10^{-4}	
Γ_{10}	$3\pi^+2\pi^-K^-K^0_S\pi^0$	< 5 × 10^{-4}	90%
Γ_{11}	$3\pi^+3\pi^-$	(7.0±3.1) × 10^{-5}	
Γ_{12}	$3\pi^+3\pi^-2\pi^0$	(1.0±0.4) × 10^{-3}	
Γ_{13}	$3\pi^+3\pi^-K^+K^-$	< 8 × 10^{-5}	90%
Γ_{14}	$3\pi^+3\pi^-K^+K^-\pi^0$	(3.6±1.5) × 10^{-4}	
Γ_{15}	$4\pi^+4\pi^-$	(8 ±4) × 10^{-5}	
Γ_{16}	$4\pi^+4\pi^-2\pi^0$	(1.8±0.7) × 10^{-3}	

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

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.191±0.012 OUR AVERAGE					
0.186±0.011±0.009	1770	[1,2] KORNICER	11	CLEO	$e^+e^- \to \gamma\gamma\ell^+\ell^-$
$0.194^{+0.014}_{-0.017}\pm0.009$	8k	[3] LEES	11J	BABR	$\Upsilon(2S) \to X\gamma$
0.27 ±0.06 ±0.06		WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
0.20 ±0.05		KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

[1] Assuming B($\Upsilon(1S) \to \ell^+\ell^-$) = (2.48 ± 0.05)%.

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

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

$\Gamma(D^0 X)/\Gamma_{total}$ — Γ_2/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<7.9 \times 10^{-2}$	90	[4,5] BRIERE	08	CLEO	$\Upsilon(2S) \to \gamma D^0 X$

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

[5] The authors also present their result as $(5.4 \pm 1.9 \pm 0.5) \times 10^{-2}$.

$\Gamma(\pi^+\pi^-K^+K^-\pi^0)/\Gamma_{total}$ — Γ_3/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
0.84±0.50±0.04	8	[6] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma\pi^+\pi^-K^+K^-\pi^0$

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

$\Gamma(2\pi^+\pi^-K^-K^0_S)/\Gamma_{total}$ — Γ_4/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.0	90	[7] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+\pi^-K^-K^0_S$

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

$\Gamma(2\pi^+\pi^-K^-K^0_S 2\pi^0)/\Gamma_{total}$ — Γ_5/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
5.3±2.4±0.3	11	[8] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+\pi^-K^-2\pi^0$

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

$\Gamma(2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{total}$ Γ_6/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
3.5±1.4±0.2	19	[9] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+ 2\pi^- 2\pi^0$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.1±0.4±0.1	14	[10] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+ 2\pi^- K^+ K^-$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
2.1±0.9±0.1	13	[11] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$

[11] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \to 2\pi^+ 2\pi^- K^+ K^- \pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma \chi_{b2}(1P))] = (15 \pm 5 \pm 4) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
3.9±1.8±0.2	11	[12] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$

[12] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \to 2\pi^+ 2\pi^- K^+ K^- 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma \chi_{b2}(1P))] = (28 \pm 11 \pm 7) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(3\pi^+ 2\pi^- K^- K^0_S \pi^0)/\Gamma_{total}$ Γ_{10}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<5	90	[13] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 2\pi^- K^- K^0_S \pi^0$

[13] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \to 3\pi^+ 2\pi^- K^- K^0_S \pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma \chi_{b2}(1P))] < 36 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma \chi_{b2}(1P)) = 7.15 \times 10^{-2}$.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
0.70±0.31±0.03	9	[14] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 3\pi^-$

[14] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \to 3\pi^+ 3\pi^-)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma \chi_{b2}(1P))] = (5 \pm 2 \pm 1) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma \chi_{b2}(1P)) = (7.15 \pm 0.35) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
10.2±3.6±0.5	34	[15] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+3\pi^-2\pi^0$

[15] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+3\pi^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (73 \pm 16 \pm 20) \times 10^{-6}$ 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.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.8	90	[16] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+3\pi^-K^+K^-$

[16] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+3\pi^-K^+K^-)/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] < 6 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = 7.15 \times 10^{-2}$.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
3.6±1.5±0.2	14	[17] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+3\pi^-K^+K^-\pi^0$

[17] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 3\pi^+3\pi^-K^+K^-\pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (26 \pm 8 \pm 7) \times 10^{-6}$ 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.

$\Gamma(4\pi^+4\pi^-)/\Gamma_{total}$ — Γ_{15}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
0.84±0.40±0.04	7	[18] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+4\pi^-$

[18] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 4\pi^+4\pi^-)/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (6 \pm 2 \pm 2) \times 10^{-6}$ 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.

$\Gamma(4\pi^+4\pi^-2\pi^0)/\Gamma_{total}$ — Γ_{16}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
18±7±1	29	[19] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+4\pi^-2\pi^0$

[19] ASNER 08A reports $[\Gamma(\chi_{b2}(1P) \rightarrow 4\pi^+4\pi^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))] = (132 \pm 31 \pm 40) \times 10^{-6}$ 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.

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

$\Gamma(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{total} \times \Gamma(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{total}$ — $\Gamma_1/\Gamma \times \Gamma_{14}^{\Upsilon(2S)}/\Gamma^{\Upsilon(2S)}$

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

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

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.29±0.09±0.16	1770	KORNICER	11	CLEO	$e^+ e^- \to \gamma\gamma\ell^+ \ell^-$

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

VALUE (units 10^{-5})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.56±0.40±0.41	126	KORNICER	11	CLEO	$e^+ e^- \to \gamma\gamma\ell^+ \ell^-$

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

KORNICER	11	PR D83 054003	M. Kornicer *et al.*	(CLEO Collab.)
LEES	11J	PR D84 072002	J.P. Lees *et al.*	(BABAR Collab.)
ASNER	08A	PR D78 091103	D.M. Asner *et al.*	(CLEO Collab.)
BRIERE	08	PR D78 092007	R.A. Briere *et al.*	(CLEO Collab.)
ARTUSO	05	PRL 94 032001	M. Artuso *et al.*	(CLEO Collab.)
EDWARDS	99	PR D59 032003	K.W. Edwards *et al.*	(CLEO Collab.)
SKWARNICKI	87	PRL 58 972	T. Skwarnicki *et al.*	(Crystal Ball Collab.) J
WALK	86	PR D34 2611	W.S. Walk *et al.*	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	H. Albrecht *et al.*	(ARGUS Collab.)
NERNST	85	PRL 54 2195	R. Nernst *et al.*	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	J. Haas *et al.*	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	C. Klopfenstein *et al.*	(CUSB Collab.)
PAUSS	83	PL 130B 439	F. Pauss *et al.*	(MPIM, COLU, CORN, LSU+)