$\chi_{b1}(1P)$

$$I^G(J^{PC}) = 0^+(1^{++})$$
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.
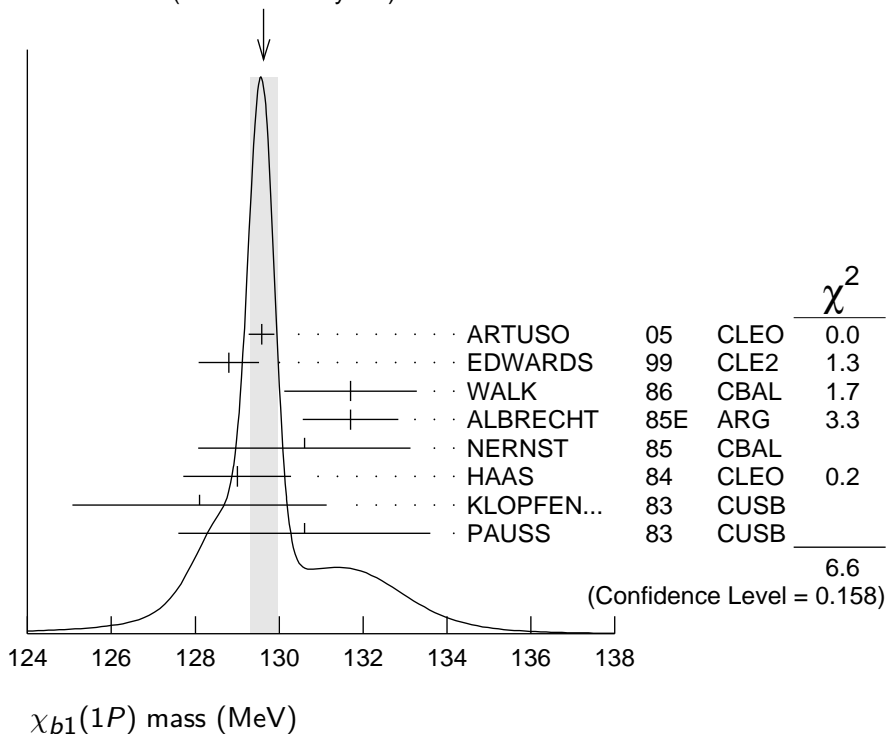
$\chi_{b1}(1P)$ MASS

VALUE (MeV)	DOCUMENT ID
9892.78±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
129.63±0.33 OUR AVERAGE	Error includes scale factor of 1.3. See the ideogram below.			
129.58±0.09±0.29	ARTUSO	05	CLEO	$\Upsilon(2S) \to \gamma X$
128.8 ±0.4 ±0.6	EDWARDS	99	CLE2	$\Upsilon(2S) \to \gamma\chi(1P)$
131.7 ±0.9 ±1.3	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
131.7 ±0.3 ±1.1	ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv. γX
130.6 ±0.8 ±2.4	NERNST	85	CBAL	$\Upsilon(2S) \to \gamma X$
129 ±0.8 ±1	HAAS	84	CLEO	$\Upsilon(2S) \to$ conv. γX
128.1 ±0.4 ±3.0	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma X$
130.6 ±3.0	PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

WEIGHTED AVERAGE
129.63±0.33 (Error scaled by 1.3)

			χ^2
ARTUSO	05	CLEO	0.0
EDWARDS	99	CLE2	1.3
WALK	86	CBAL	1.7
ALBRECHT	85E	ARG	3.3
NERNST	85	CBAL	
HAAS	84	CLEO	0.2
KLOPFEN...	83	CUSB	
PAUSS	83	CUSB	
			6.6

(Confidence Level = 0.158)

$\chi_{b1}(1P)$ mass (MeV)

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

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\gamma\,\Upsilon(1S)$	$(35\ \pm 8\ )\,\%$	
Γ_2	$D^0\,X$	$(12.6\pm 2.2)\,\%$	
Γ_3	$\pi^+\pi^-K^+K^-\pi^0$	$(\ 2.0\pm 0.6)\times 10^{-4}$	
Γ_4	$2\pi^+\pi^-K^-K^0_S$	$(\ 1.3\pm 0.5)\times 10^{-4}$	
Γ_5	$2\pi^+\pi^-K^-K^0_S 2\pi^0$	$<\ 6\ \ \ \ \ \times 10^{-4}$	90%
Γ_6	$2\pi^+ 2\pi^- 2\pi^0$	$(\ 8.0\pm 2.5)\times 10^{-4}$	
Γ_7	$2\pi^+ 2\pi^- K^+K^-$	$(\ 1.5\pm 0.5)\times 10^{-4}$	
Γ_8	$2\pi^+ 2\pi^- K^+K^-\pi^0$	$(\ 3.5\pm 1.2)\times 10^{-4}$	
Γ_9	$2\pi^+ 2\pi^- K^+K^- 2\pi^0$	$(\ 8.6\pm 3.2)\times 10^{-4}$	
Γ_{10}	$3\pi^+ 2\pi^- K^-K^0_S\pi^0$	$(\ 9.3\pm 3.3)\times 10^{-4}$	
Γ_{11}	$3\pi^+ 3\pi^-$	$(\ 1.9\pm 0.6)\times 10^{-4}$	
Γ_{12}	$3\pi^+ 3\pi^- 2\pi^0$	$(\ 1.7\pm 0.5)\times 10^{-3}$	
Γ_{13}	$3\pi^+ 3\pi^- K^+K^-$	$(\ 2.6\pm 0.8)\times 10^{-4}$	
Γ_{14}	$3\pi^+ 3\pi^- K^+K^-\pi^0$	$(\ 7.5\pm 2.6)\times 10^{-4}$	
Γ_{15}	$4\pi^+ 4\pi^-$	$(\ 2.6\pm 0.9)\times 10^{-4}$	
Γ_{16}	$4\pi^+ 4\pi^- 2\pi^0$	$(\ 1.4\pm 0.6)\times 10^{-3}$	

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

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.35±0.08 OUR AVERAGE				
$0.32\pm 0.06\pm 0.07$	WALK	86	CBAL	$\Upsilon(2S)\to\gamma\gamma\ell^+\ell^-$
0.47 ± 0.18	KLOPFEN...	83	CUSB	$\Upsilon(2S)\to\gamma\gamma\ell^+\ell^-$

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

VALUE (units 10^{-2})	EVTS		DOCUMENT ID		TECN	COMMENT
12.6±1.9±1.1	2310	[1]	BRIERE	08	CLEO	$\Upsilon(2S)\to\gamma D^0 X$

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

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

VALUE (units 10^{-4})	EVTS		DOCUMENT ID		TECN	COMMENT
2.0±0.6±0.1	18	[2]	ASNER	08A	CLEO	$\Upsilon(2S)\to\gamma\pi^+\pi^-K^+K^-\pi^0$

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

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

VALUE (units 10^{-4})	EVTS		DOCUMENT ID		TECN	COMMENT
1.3±0.5±0.1	11	[3]	ASNER	08A	CLEO	$\Upsilon(2S)\to\gamma 2\pi^+\pi^-K^-K^0_S$

[3] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+\pi^- K^- K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] = (9 \pm 3 \pm 2) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<6	90	[4] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+\pi^- K^- 2\pi^0$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
8.0±2.4±0.4	46	[5] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- 2\pi^0$

[5] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] = (55 \pm 9 \pm 14) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.5±0.5±0.1	18	[6] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^-$

[6] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] = (10 \pm 3 \pm 2) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
3.5±1.2±0.2	22	[7] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$

[7] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] = (24 \pm 6 \pm 6) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
8.6±3.2±0.4	26	[8] ASNER	08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$

[8] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] = (59 \pm 14 \pm 17) \times 10^{-6}$. 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.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
9.3±3.3±0.5	21	[9] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 2\pi^- K^- K^0_S \pi^0$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.9±0.6±0.1	25	[10] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 3\pi^-$

[10] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \to 3\pi^+ 3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b1}(1P))] = (13 \pm 3 \pm 3) \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
17±5±1	56	[11] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 3\pi^- 2\pi^0$

[11] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \to 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b1}(1P))] = (119 \pm 18 \pm 32) \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
2.6±0.8±0.1	21	[12] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 3\pi^- K^+ K^-$

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

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
7.5±2.6±0.4	28	[13] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

[13] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \to 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b1}(1P))] = (52 \pm 11 \pm 14) \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
2.6±0.9±0.1	24	[14] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 4\pi^+ 4\pi^-$

[14] ASNER 08A reports $[\Gamma(\chi_{b1}(1P) \rightarrow 4\pi^+4\pi^-)/\Gamma_{\text{total}}] \times [\text{B}(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))]$ $= (18 \pm 4 \pm 5) \times 10^{-6}$. We divide by our best value $\text{B}(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P)) = (6.9 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
14±5±1	26	[15] ASNER 08A	CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+4\pi^-2\pi^0$

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

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

$\text{B}(\chi_{b2}(1P) \rightarrow pX + \overline{p}X)/\text{B}(\chi_{b1}(1P) \rightarrow pX + \overline{p}X)$

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

$\text{B}(\chi_{b0}(1P) \rightarrow pX + \overline{p}X)/\text{B}(\chi_{b1}(1P) \rightarrow pX + \overline{p}X)$

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

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

ASNER	08A	PR D78 091103	D.M. Asner *et al.*	(CLEO Collab.)
BRIERE	08	PR D78 092007	R.A. Briere *et al.*	(CLEO Collab.)
BRIERE	07	PR D76 012005	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+)