$\chi_{b0}(1P)$

$I^G(J^{PC}) = 0^+(0^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$.

$\chi_{b0}(1P)$ MASS

VALUE (MeV)	*DOCUMENT ID*
9859.44±0.42±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*
162.5 ±0.4 OUR AVERAGE				
162.56±0.19±0.42	ARTUSO	05	CLEO	$\Upsilon(2S) \to \gamma X$
162.0 ±0.8 ±1.2	EDWARDS	99	CLE2	$\Upsilon(2S) \to \gamma\chi(1P)$
162.1 ±0.5 ±1.4	ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
163.8 ±1.6 ±2.7	NERNST	85	CBAL	$\Upsilon(2S) \to \gamma$X
158.0 ±7 ±1	HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
• • • We do not use the following data for averages, fits, limits, etc. • • •				
149.4 ±0.7 ±5.0	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma$X

$\chi_{b0}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)		Confidence level
Γ_1	$\gamma\,\Upsilon(1S)$	< 6	%	90%
Γ_2	$D^0 X$	< 10.4	%	90%
Γ_3	$\pi^+\pi^- K^+ K^- \pi^0$	< 1.6	$\times 10^{-4}$	90%
Γ_4	$2\pi^+\pi^- K^- K^0_S$	< 5	$\times 10^{-5}$	90%
Γ_5	$2\pi^+\pi^- K^- K^0_S 2\pi^0$	< 5	$\times 10^{-4}$	90%
Γ_6	$2\pi^+ 2\pi^- 2\pi^0$	< 2.1	$\times 10^{-4}$	90%
Γ_7	$2\pi^+ 2\pi^- K^+ K^-$	(1.1±0.6)	$\times 10^{-4}$	
Γ_8	$2\pi^+ 2\pi^- K^+ K^- \pi^0$	< 2.7	$\times 10^{-4}$	90%
Γ_9	$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	< 5	$\times 10^{-4}$	90%
Γ_{10}	$3\pi^+ 2\pi^- K^- K^0_S \pi^0$	< 1.6	$\times 10^{-4}$	90%
Γ_{11}	$3\pi^+ 3\pi^-$	< 8	$\times 10^{-5}$	90%
Γ_{12}	$3\pi^+ 3\pi^- 2\pi^0$	< 6	$\times 10^{-4}$	90%
Γ_{13}	$3\pi^+ 3\pi^- K^+ K^-$	(2.4±1.2)	$\times 10^{-4}$	
Γ_{14}	$3\pi^+ 3\pi^- K^+ K^- \pi^0$	< 1.0	$\times 10^{-3}$	90%
Γ_{15}	$4\pi^+ 4\pi^-$	< 8	$\times 10^{-5}$	90%
Γ_{16}	$4\pi^+ 4\pi^- 2\pi^0$	< 2.1	$\times 10^{-3}$	90%

$\chi_{b0}(1P)$ BRANCHING RATIOS

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.06	90	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.11	90	PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<10.4 × 10^{-2}	90	[1,2] BRIERE	08	CLEO	$\Upsilon(2S) \to \gamma D^0 X$

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

[2] The authors also present their result as $(5.6 \pm 3.6 \pm 0.5) \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.6	90	[3] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma\pi^+\pi^-K^+K^-\pi^0$

[3] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to \pi^+\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 6 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.5	90	[4] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+\pi^-K^-K^0_S$

[4] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 2\pi^+\pi^-K^-K^0_S)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 2 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

$\Gamma(2\pi^+\pi^-K^-K^0_S2\pi^0)/\Gamma_{\text{total}}$ Γ_5/Γ

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

[5] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 2\pi^+\pi^-K^-K^0_S2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 18 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.1	90	[6] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+2\pi^-2\pi^0$

[6] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 2\pi^+2\pi^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 8 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.1±0.6±0.1	7	[7] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+2\pi^-K^+K^-$

[7] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 2\pi^+2\pi^-K^+K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] = (4 \pm 2 \pm 1) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = (3.8 \pm 0.4) \times 10^{-2}$. 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})	CL%	DOCUMENT ID		TECN	COMMENT
<2.7	90	[8] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+2\pi^-K^+K^-\pi^0$

[8] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 2\pi^+2\pi^-K^+K^-\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 10 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<5	90	[9] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 2\pi^+2\pi^-K^+K^-2\pi^0$

[9] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 2\pi^+2\pi^-K^+K^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 20 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.6	90	[10] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+2\pi^-K^-K^0_S\pi^0$

[10] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 3\pi^+2\pi^-K^-K^0_S\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 6 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.8	90	[11] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+3\pi^-$

[11] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 3\pi^+3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 3 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<6	90	[12] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+3\pi^-2\pi^0$

[12] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 3\pi^+3\pi^-2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 22 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.4±1.2±0.2	9	[13] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 3\pi^+3\pi^-K^+K^-$

[13] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 3\pi^+3\pi^-K^+K^-)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] = (9 \pm 4 \pm 2) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = (3.8 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

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

[14] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 3\pi^+3\pi^-K^+K^-\pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 37 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.8	90	[15] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 4\pi^+4\pi^-$

[15] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 4\pi^+4\pi^-)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 3 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<21	90	[16] ASNER	08A	CLEO	$\Upsilon(2S) \to \gamma 4\pi^+4\pi^-2\pi^0$

[16] ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \to 4\pi^+4\pi^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(2S) \to \gamma\chi_{b0}(1P))] < 77 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(2S) \to \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

$\chi_{b0}(1P)$ 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.)
ARTUSO	05	PRL 94 032001	M. Artuso *et al.*	(CLEO Collab.)
EDWARDS	99	PR D59 032003	K.W. Edwards *et al.*	(CLEO Collab.)
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+)