$\chi_{b0}(2P)$

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

Observed in radiative decay of the $\Upsilon(3S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$.

$\chi_{b0}(2P)$ MASS

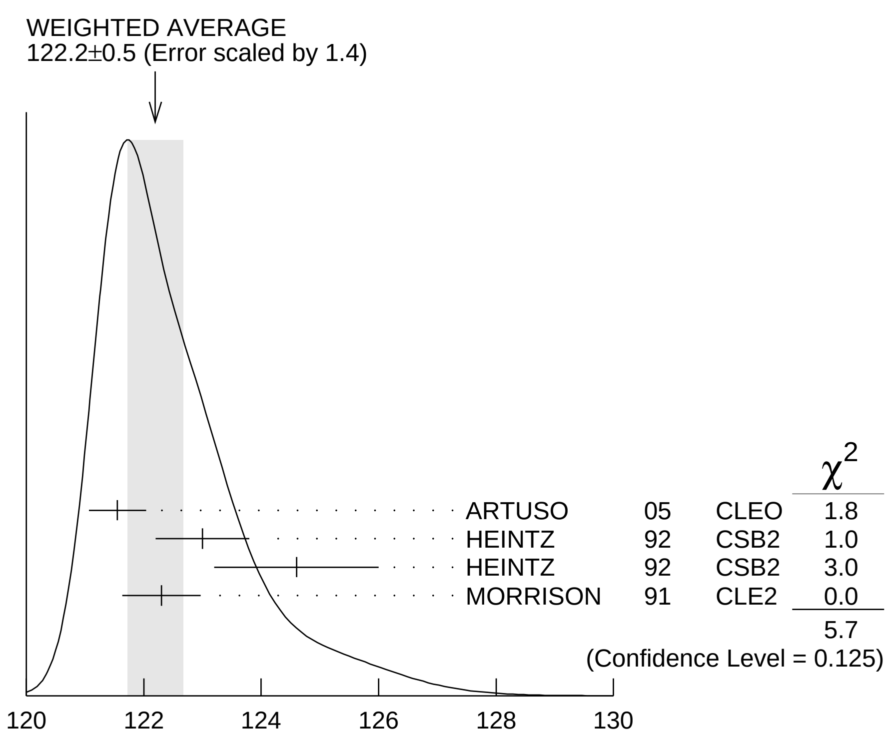
VALUE (MeV)	DOCUMENT ID
10232.5±0.4±0.5 OUR EVALUATION	From γ energy below, using $\Upsilon(3S)$ mass = 10355.2 ± 0.5 MeV

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
121.9 ±0.4 OUR EVALUATION		Treating systematic errors as correlated			
122.2 ±0.5 OUR AVERAGE		Error includes scale factor of 1.4. See the ideogram below.			
121.55±0.16±0.46		ARTUSO	05	CLEO	$\Upsilon(3S) \to \gamma X$
123.0 ±0.8	4959	[1] HEINTZ	92	CSB2	$e^+e^- \to \gamma X$
124.6 ±1.4	17	[2] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
122.3 ±0.3 ±0.6	9903	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

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

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



γ energy in $\Upsilon(3S)$ decay (MeV)

$\chi_{b0}(2P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\gamma\,\Upsilon(2S)$	(4.6 ± 2.1) %	
Γ_2	$\gamma\,\Upsilon(1S)$	$(9\ \pm6\ )\times10^{-3}$	
Γ_3	$D^0 X$	<8.2 %	90%
Γ_4	$\pi^+\pi^- K^+ K^- \pi^0$	$<3.4\times10^{-5}$	90%
Γ_5	$2\pi^+\pi^- K^- K^0_S$	$<5\times10^{-5}$	90%
Γ_6	$2\pi^+\pi^- K^- K^0_S 2\pi^0$	$<2.2\times10^{-4}$	90%
Γ_7	$2\pi^+ 2\pi^- 2\pi^0$	$<2.4\times10^{-4}$	90%
Γ_8	$2\pi^+ 2\pi^- K^+ K^-$	$<1.5\times10^{-4}$	90%
Γ_9	$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$<2.2\times10^{-4}$	90%
Γ_{10}	$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$<1.1\times10^{-3}$	90%
Γ_{11}	$3\pi^+ 2\pi^- K^- K^0_S \pi^0$	$<7\times10^{-4}$	90%
Γ_{12}	$3\pi^+ 3\pi^-$	$<7\times10^{-5}$	90%
Γ_{13}	$3\pi^+ 3\pi^- 2\pi^0$	$<1.2\times10^{-3}$	90%
Γ_{14}	$3\pi^+ 3\pi^- K^+ K^-$	$<1.5\times10^{-4}$	90%
Γ_{15}	$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$<7\times10^{-4}$	90%
Γ_{16}	$4\pi^+ 4\pi^-$	$<1.7\times10^{-4}$	90%
Γ_{17}	$4\pi^+ 4\pi^- 2\pi^0$	$<6\times10^{-4}$	90%

$\chi_{b0}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma\,\Upsilon(2S))/\Gamma_{\text{total}}$ — Γ_1/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
0.046±0.020±0.007		[3] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.028	90	[4] LEES	11J	BABR	$\Upsilon(3S) \to X\gamma$
<0.089	90	[5] CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[3] Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = (6.0 ± 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

[4] LEES 11J quotes a central value of $\Gamma(\chi_{b0}(2P) \to \gamma\,\Upsilon(2S))/\Gamma_{\text{total}} \times \Gamma(\Upsilon(3S) \to \gamma\chi_{b0}(2P))/\Gamma_{\text{total}} = (-0.3 \pm 0.2^{+0.5}_{-0.4})$%.

[5] Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \to \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(2S) \to \mu^+\mu^-$) < 1.19×10^{-4}, and B($\Upsilon(3S) \to \chi_{b0}(2P)\gamma$) = 0.049.

$\Gamma(\gamma\,\Upsilon(1S))/\Gamma_{\text{total}}$ — Γ_2/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
0.009±0.006±0.001		[6] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.012	90	[7] LEES	11J	BABR	$\Upsilon(3S) \to X\gamma$
<0.025	90	[8] CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[6] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = (6.0 ± 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.
[7] LEES 11J quotes a central value of $\Gamma(\chi_{b0}(2P) \to \gamma\Upsilon(1S))/\Gamma_{total} \times \Gamma(\Upsilon(3S) \to \gamma\chi_{b0}(2P))/\Gamma_{total} = (3.9 \pm 2.2^{+1.2}_{-0.6}) \times 10^{-4}$.
[8] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \to \gamma\gamma\Upsilon(1S)$)×2 B($\Upsilon(1S) \to \mu^+\mu^-$) < 0.63×10^{-4}, and B($\Upsilon(3S) \to \chi_{b0}(2P)\gamma$) = 0.049.

$\Gamma(D^0 X)/\Gamma_{total}$ — Γ_3/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<8.2 × 10^{-2}	90	[9,10] BRIERE	08	CLEO	$\Upsilon(3S) \to \gamma D^0 X$

[9] For $p_{D^0} > 2.5$ GeV/c.
[10] The authors also present their result as $(4.1 \pm 3.0 \pm 0.4) \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.34	90	[11] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma\pi^+\pi^- K^+ K^- \pi^0$

[11] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to \pi^+\pi^- K^+ K^- \pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 2 \times 10^{-6}$ which we divide by our best value B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = 5.9×10^{-2}.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.5	90	[12] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+\pi^- K^- K^0_S$

[12] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 2\pi^+\pi^- K^- K^0_S)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 3 \times 10^{-6}$ which we divide by our best value B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = 5.9×10^{-2}.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.2	90	[13] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+\pi^- K^- 2\pi^0$

[13] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 2\pi^+\pi^- K^- K^0_S 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 13 \times 10^{-6}$ which we divide by our best value B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = 5.9×10^{-2}.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.4	90	[14] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- 2\pi^0$

[14] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 14 \times 10^{-6}$ which we divide by our best value B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = 5.9×10^{-2}.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.5	90	[15] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^-$

[15] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 2\pi^+ 2\pi^- K^+ K^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 9 \times 10^{-6}$ which we divide by our best value B($\Upsilon(3S) \to \gamma\chi_{b0}(2P)$) = 5.9×10^{-2}.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.2	90	[16] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$

[16] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 2\pi^+ 2\pi^- K^+ K^- \pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 13 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<11	90	[17] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$

[17] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 2\pi^+ 2\pi^- K^+ K^- 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 63 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

$\Gamma(3\pi^+ 2\pi^- K^- K^0_S \pi^0)/\Gamma_{total}$ — Γ_{11}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<7	90	[18] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 2\pi^- K^- K^0_S \pi^0$

[18] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 3\pi^+ 2\pi^- K^- K^0_S \pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 39 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.7	90	[19] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^-$

[19] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 3\pi^+ 3\pi^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 4 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<12	90	[20] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- 2\pi^0$

[20] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 72 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.5	90	[21] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- K^+ K^-$

[21] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 3\pi^+ 3\pi^- K^+ K^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 9 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<7	90	[22] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

[22] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 43 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.7	90	[23] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+ 4\pi^-$

[23] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \rightarrow 4\pi^+4\pi^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P))] < 10 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

$\Gamma(4\pi^+4\pi^-2\pi^0)/\Gamma_{total}$ Γ_{17}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<6	90	[24] ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma 4\pi^+ 4\pi^- 2\pi^0$

[24] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \rightarrow 4\pi^+4\pi^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P))] < 38 \times 10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

$\Gamma(\chi_{b0}(2P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{total} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P))/\Gamma_{total}$ $\Gamma_2/\Gamma \times \Gamma_{21}^{\Upsilon(3S)}/\Gamma^{\Upsilon(3S)}$

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<8.2	90	[25] LEES	11J	BABR	$\Upsilon(3S) \rightarrow X\gamma$

[25] LEES 11J quotes a central value of $\Gamma(\chi_{b0}(2P) \rightarrow \gamma\Upsilon(1S))/\Gamma_{total} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P))/\Gamma_{total} = (3.9 \pm 2.2^{+1.2}_{-0.6}) \times 10^{-4}$ and derives a 90% CL upper limit of $B(\chi_{b0}(2P) \rightarrow \gamma\Upsilon(1S)) < 1.2\%$ using $B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P)) = (5.9 \pm 0.6)\%$.

$\Gamma(\chi_{b0}(2P) \rightarrow \gamma\Upsilon(2S))/\Gamma_{total} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P))/\Gamma_{total}$ $\Gamma_1/\Gamma \times \Gamma_{21}^{\Upsilon(3S)}/\Gamma^{\Upsilon(3S)}$

VALUE (units 10^{-3})	CL%	DOCUMENT ID		TECN	COMMENT
<1.6	90	[26] LEES	11J	BABR	$\Upsilon(3S) \rightarrow X\gamma$

[26] LEES 11J quotes a central value of $\Gamma(\chi_{b0}(2P) \rightarrow \gamma\Upsilon(2S))/\Gamma_{total} \times \Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P))/\Gamma_{total} = (-0.3 \pm 0.2^{+0.5}_{-0.4})\%$ and derives a 90% CL upper limit of $B(\chi_{b0}(2P) \rightarrow \gamma\Upsilon(2S)) < 2.8\%$ using $B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P)) = (5.9 \pm 0.6)\%$.

$\chi_{b0}(2P)$ REFERENCES

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.)
CRAWFORD	92B	PL B294 139	G. Crawford, R. Fulton	(CLEO Collab.)
HEINTZ	92	PR D46 1928	U. Heintz et al.	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	U. Heintz et al.	(CUSB Collab.)
MORRISON	91	PRL 67 1696	R.J. Morrison et al.	(CLEO Collab.)
NARAIN	91	PRL 66 3113	M. Narain et al.	(CUSB Collab.)