$\chi_{b0}(2P)$

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

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

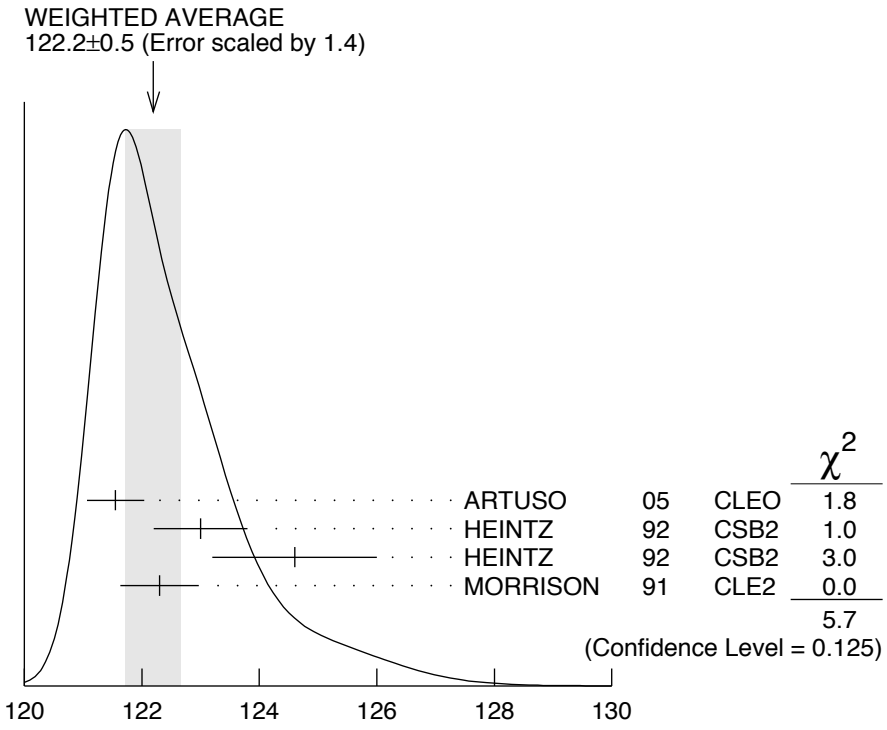
$\chi_{b0}(2P)$ MASS

VALUE (GeV)	*DOCUMENT ID*
10.2325±0.0004±0.0005 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.



$\chi_{b0}(2P)$ 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^0X	< 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	$2\pi^+\pi^-K^-K^0_S2\pi^0$	< 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
$0.046\pm0.020\pm0.007$		[3] HEINTZ	92	CSB2	$e^+e^-\to\ \ell^+\ell^-\gamma\gamma$

• • • We do not use the following data for averages, fits, limits, etc. • • •

<0.089	90	[4] 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] Using B($\Upsilon(2S)\to\ \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S)\to\ \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(2S)\to\ \mu^+\mu^-$) $<\ 1.19\times10^{-4}$, 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
$0.009\pm0.006\pm0.001$		[5] HEINTZ	92	CSB2	$e^+e^-\to\ \ell^+\ell^-\gamma\gamma$

• • • We do not use the following data for averages, fits, limits, etc. • • •

<0.025	90	[6] CRAWFORD	92B	CLE2	$e^+e^-\to\ \ell^+\ell^-\gamma\gamma$

[5] 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.

[6] Using B($\Upsilon(1S)\to\ \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S)\to\ \gamma\gamma\,\Upsilon(1S)$)×2 B($\Upsilon(1S)\to\ \mu^+\mu^-$) $<\ 0.63\times10^{-4}$, 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	[7,8] BRIERE	08	CLEO	$\Upsilon(3S) \to \gamma D^0 X$

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

[8] 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	[9] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma\pi^+\pi^- K^+ K^- \pi^0$

[9] 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 $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

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

[10] 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 $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.2	90	[11] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+\pi^- K^- 2\pi^0$

[11] 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 $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.4	90	[12] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- 2\pi^0$

[12] 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 $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.5	90	[13] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^-$

[13] 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 $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.2	90	[14] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^- \pi^0$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<11	90	[15] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<7	90	[16] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 2\pi^- K^- K^0_S \pi^0$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<0.7	90	[17] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^-$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<12	90	[18] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- 2\pi^0$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.5	90	[19] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- K^+ K^-$

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<7	90	[20] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$

[20] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))] < 43 \times 10^{-6}$ 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	[21] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 4\pi^+ 4\pi^-$

[21] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 4\pi^+4\pi^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))]$ $< 10\times10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9\times10^{-2}$.

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

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<6	90	[22] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma 4\pi^+ 4\pi^- 2\pi^0$

[22] ASNER 08A reports $[\Gamma(\chi_{b0}(2P) \to 4\pi^+4\pi^-2\pi^0)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \gamma\chi_{b0}(2P))]$ $< 38\times10^{-6}$ which we divide by our best value $B(\Upsilon(3S) \to \gamma\chi_{b0}(2P)) = 5.9\times10^{-2}$.

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