$\chi_{b1}(2P)$

$I^G(J^{PC}) = 0^+(1^{++})$
J needs confirmation.

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

$\chi_{b1}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID
10.25546±0.00022±0.00050 OUR EVALUATION	From γ energy below, using $\Upsilon(3S)$ mass = 10355.2 ± 0.5 MeV

$m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)}$

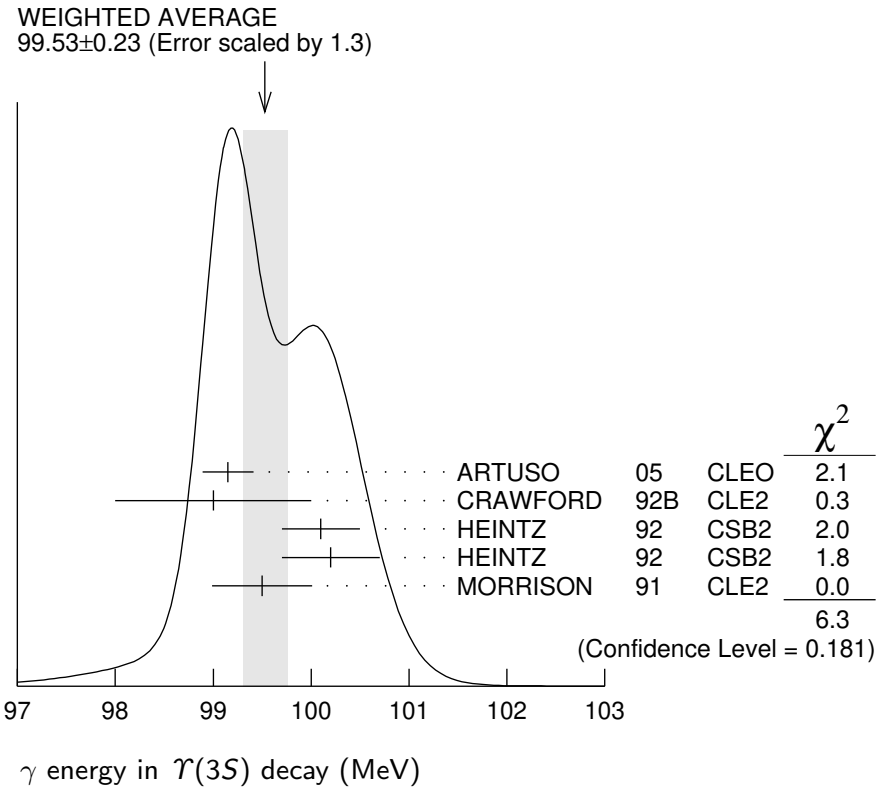
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
23.5±0.7±0.7	[1] HEINTZ	92	CSB2	$e^+e^- \to \gamma X, \ell^+\ell^-\gamma\gamma$

[1] From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
99.26±0.22 OUR EVALUATION		Treating systematic errors as correlated			
99.53±0.23 OUR AVERAGE		Error includes scale factor of 1.3. See the ideogram below.			
99.15±0.07±0.25		ARTUSO	05	CLEO	$\Upsilon(3S) \to \gamma X$
99 ±1	169	CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
100.1 ±0.4	11147	[2] HEINTZ	92	CSB2	$e^+e^- \to \gamma X$
100.2 ±0.5	223	[3] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
99.5 ±0.1 ±0.5	25759	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

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



$\chi_{b1}(2P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ_1	$\omega\,\Upsilon(1S)$	$(1.63^{+0.38}_{-0.34})$ %	
Γ_2	$\gamma\,\Upsilon(2S)$	(21 ± 4) %	1.5
Γ_3	$\gamma\,\Upsilon(1S)$	(8.5 ± 1.3) %	1.3
Γ_4	$\pi\pi\,\chi_{b1}(1P)$	$(8.6 \pm 3.1) \times 10^{-3}$	

$\chi_{b1}(2P)$ BRANCHING RATIOS

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
$\mathbf{1.63^{+0.35}_{-0.31}{}^{+0.16}_{-0.15}}$	$32.6^{+6.9}_{-6.1}$	[4] CRONIN-HEN..04	CLE3	$\Upsilon(3S) \to \gamma\omega\,\Upsilon(1S)$

[4] Using $B(\Upsilon(3S) \to \gamma\chi_{b1}(2P)) = (11.3 \pm 0.6)\%$ and $B(\Upsilon(1S) \to \ell^+\ell^-) = 2\,B(\Upsilon(1S) \to \mu^+\mu^-) = 2\,(2.48 \pm 0.06)\%$.

$\Gamma(\gamma\,\Upsilon(2S))/\Gamma_{total}$ — Γ_2/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.21 ±0.04 OUR AVERAGE	Error includes scale factor of 1.5.		
0.356±0.042±0.092	[5] CRAWFORD 92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
0.199±0.020±0.022	[6] HEINTZ 92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[5] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \rightarrow \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (10.23±1.20±1.26)×$10^{-4}$, and B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = $0.105^{+0.003}_{-0.002}$ ± 0.013.

[6] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = (11.5 ± 0.5 ± 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\gamma\,\Upsilon(1S))/\Gamma_{total}$ — Γ_3/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.085±0.013 OUR AVERAGE	Error includes scale factor of 1.3.			
0.120±0.021±0.021	[7] CRAWFORD	92B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.080±0.009±0.007	[8] HEINTZ	92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

[7] Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \rightarrow \gamma\gamma\,\Upsilon(1S)$)×2 B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (6.47 ± 1.12 ± 0.82) × 10^{-4} and B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = $0.105^{+0.003}_{-0.002}$ ± 0.013.

[8] Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$)=(2.57 ± 0.07)%, B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = (11.5 ± 0.5 ± 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\pi\pi\chi_{b1}(1P))/\Gamma_{total}$ — Γ_4/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
8.6±2.3±2.1	[9] CAWLFIELD	06	CLE3	$\Upsilon(3S) \rightarrow 2(\gamma\pi\ell)$

[9] CAWLFIELD 06 quote $\Gamma(\chi_b(2P) \rightarrow \pi\pi\chi_b(1P))$ = 0.83 ± 0.22 ± 0.08 ± 0.19 keV assuming I-spin conservation, no D-wave contribution, $\Gamma(\chi_{b1}(2P))$ = 96 ± 16keV, and $\Gamma(\chi_{b2}(2P))$ = 138 ± 19 keV.

$\chi_{b1}(2P)$ REFERENCES

CAWLFIELD	06	PR D73 012003	C. Cawlfield et al.	(CLEO Collab.)
ARTUSO	05	PRL 94 032001	M. Artuso et al.	(CLEO Collab.)
CRONIN-HEN...	04	PRL 92 222002	D. Cronin-Hennessy et al.	(CLEO3 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.)

OTHER RELATED PAPERS

EIGEN	82	PRL 49 1616	G. Eigen et al.	(CUSB Collab.)
HAN	82	PRL 49 1612	K. Han et al.	(CUSB Collab.)