

$\chi_{b1}(2P)$

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

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

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

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

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
23.5 ± 0.7 ± 0.7	¹ HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X, \ell^+\ell^-\gamma\gamma$

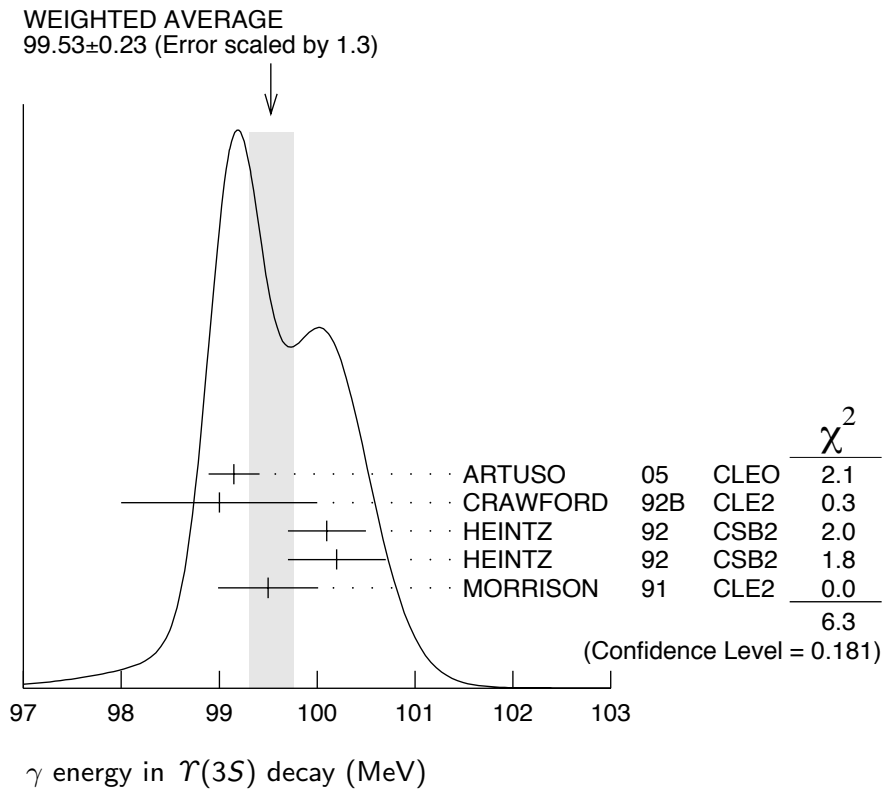
¹From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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 $\Upsilon(3S) \rightarrow \gamma X$
99 ± 1	169	CRAWFORD	92B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
100.1 ± 0.4	11147	² HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X$
100.2 ± 0.5	223	³ HEINTZ	92	CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
99.5 ± 0.1 ± 0.5	25759	MORRISON	91	CLE2 $e^+e^- \rightarrow \gamma X$

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

³A 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 $\gamma \Upsilon(2S)$	$(21 \pm 4)\%$	1.5
Γ_3 $\gamma \Upsilon(1S)$	$(8.5 \pm 1.3)\%$	1.3
Γ_4 $\pi\pi\chi_{b1}(1P)$	$(8.6 \pm 3.1) \times 10^{-3}$	

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

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

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

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

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

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

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

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

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

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

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

$\Gamma(\pi\pi\chi_{b1}(1P))/\Gamma_{\text{total}}$

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 $\Gamma(\chi_b(2P) \rightarrow \pi\pi\chi_b(1P)) = 0.83 \pm 0.22 \pm 0.08 \pm 0.19$ keV assuming l-spin conservation, no D-wave contribution, $\Gamma(\chi_{b1}(2P)) = 96 \pm 16$ keV, and $\Gamma(\chi_{b2}(2P)) = 138 \pm 19$ keV.

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

CAWLFIELD	06	PR D73 012003	C. Cawfield <i>et al.</i>	(CLEO Collab.)
ARTUSO	05	PRL 94 032001	M. Artuso <i>et al.</i>	(CLEO Collab.)
CRONIN-HEN...	04	PRL 92 222002	D. Cronin-Hennessy <i>et al.</i>	(CLEO3 Collab.)
CRAWFORD	92B	PL B294 139	G. Crawford, R. Fulton	(CLEO Collab.)
HEINTZ	92	PR D46 1928	U. Heintz <i>et al.</i>	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	U. Heintz <i>et al.</i>	(CUSB Collab.)
MORRISON	91	PRL 67 1696	R.J. Morrison <i>et al.</i>	(CLEO Collab.)
NARAIN	91	PRL 66 3113	M. Narain <i>et al.</i>	(CUSB Collab.)

OTHER RELATED PAPERS

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