

$\chi_{b0}(1P)$

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

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 $\Upsilon(2S) \rightarrow \gamma X$
162.0 ± 0.8 ± 1.2	EDWARDS	99	CLE2 $\Upsilon(2S) \rightarrow \gamma \chi(1P)$
162.1 ± 0.5 ± 1.4	ALBRECHT	85E	ARG $\Upsilon(2S) \rightarrow \text{conv. } \gamma X$
163.8 ± 1.6 ± 2.7	NERNST	85	CBAL $\Upsilon(2S) \rightarrow \gamma X$
158.0 ± 7 ± 1	HAAS	84	CLEO $\Upsilon(2S) \rightarrow \text{conv. } \gamma X$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
149.4 ± 0.7 ± 5.0	KLOPFEN...	83	CUSB $\Upsilon(2S) \rightarrow \gamma X$

$\chi_{b0}(1P)$ 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 × 10 ⁻⁴	90%
Γ_4 $2\pi^+ \pi^- K^- K_S^0$	< 5 × 10 ⁻⁵	90%
Γ_5 $2\pi^+ \pi^- K^- K_S^0 2\pi^0$	< 5 × 10 ⁻⁴	90%
Γ_6 $2\pi^+ 2\pi^- 2\pi^0$	< 2.1 × 10 ⁻⁴	90%
Γ_7 $2\pi^+ 2\pi^- K^+ K^-$	(1.1 ± 0.6) × 10 ⁻⁴	
Γ_8 $2\pi^+ 2\pi^- K^+ K^- \pi^0$	< 2.7 × 10 ⁻⁴	90%
Γ_9 $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	< 5 × 10 ⁻⁴	90%
Γ_{10} $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	< 1.6 × 10 ⁻⁴	90%
Γ_{11} $3\pi^+ 3\pi^-$	< 8 × 10 ⁻⁵	90%
Γ_{12} $3\pi^+ 3\pi^- 2\pi^0$	< 6 × 10 ⁻⁴	90%
Γ_{13} $3\pi^+ 3\pi^- K^+ K^-$	(2.4 ± 1.2) × 10 ⁻⁴	
Γ_{14} $3\pi^+ 3\pi^- K^+ K^- \pi^0$	< 1.0 × 10 ⁻³	90%
Γ_{15} $4\pi^+ 4\pi^-$	< 8 × 10 ⁻⁵	90%
Γ_{16} $4\pi^+ 4\pi^- 2\pi^0$	< 2.1 × 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 $\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.11	90	PAUSS	83	CUSB $\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<10.4 × 10⁻²	90	1,2 BRIERE	08	CLEO $\Upsilon(2S) \rightarrow \gamma D^0 X$
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 $\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^- K^+ K^- \pi^0$
³ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow \pi^+ \pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 6 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	TECN	COMMENT
<0.5	90	⁴ ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ \pi^- K^- K_S^0$
⁴ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 2\pi^+ \pi^- K^- K_S^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 2 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	TECN	COMMENT
<5	90	⁵ ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ \pi^- K^- 2\pi^0$
⁵ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 2\pi^+ \pi^- K^- K_S^0 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 18 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	TECN	COMMENT
<2.1	90	⁶ ASNER	08A	CLEO $\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- 2\pi^0$
⁶ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 2\pi^+ 2\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 8 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
$1.1 \pm 0.6 \pm 0.1$	7	⁷ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^-$
⁷ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] = (4 \pm 2 \pm 1) \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = (3.8 \pm 0.4) \times 10^{-2}$. 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	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^-\pi^0$
⁸ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^-\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 10 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<5	90	⁹ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 2\pi^+ 2\pi^- K^+ K^- 2\pi^0$
⁹ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 2\pi^+ 2\pi^- K^+ K^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 20 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<1.6	90	¹⁰ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 2\pi^- K^- K_S^0 \pi^0$
¹⁰ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 3\pi^+ 2\pi^- K^- K_S^0 \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 6 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<0.8	90	¹¹ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^-$
¹¹ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 3\pi^+ 3\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 3 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<6	90	¹² ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- 2\pi^0$
¹² ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 3\pi^+ 3\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 22 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.				

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

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
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$2.4 \pm 1.2 \pm 0.2$	9	¹³ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^-$
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¹³ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 3\pi^+ 3\pi^- K^+ K^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] = (9 \pm 4 \pm 2) \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = (3.8 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
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< 10	90	¹⁴ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 3\pi^+ 3\pi^- K^+ K^- \pi^0$
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¹⁴ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 3\pi^+ 3\pi^- K^+ K^- \pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 37 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
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< 0.8	90	¹⁵ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+ 4\pi^-$
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¹⁵ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 4\pi^+ 4\pi^-)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 3 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
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< 21	90	¹⁶ ASNER	08A CLEO	$\Upsilon(2S) \rightarrow \gamma 4\pi^+ 4\pi^- 2\pi^0$
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¹⁶ ASNER 08A reports $[\Gamma(\chi_{b0}(1P) \rightarrow 4\pi^+ 4\pi^- 2\pi^0)/\Gamma_{\text{total}}] \times [B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P))] < 77 \times 10^{-6}$. We divide by our best value $B(\Upsilon(2S) \rightarrow \gamma \chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

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

ASNER	08A	PR D78 091103	D.M. Asner <i>et al.</i>	(CLEO Collab.)
BRIERE	08	PR D78 092007	R.A. Briere <i>et al.</i>	(CLEO Collab.)
ARTUSO	05	PRL 94 032001	M. Artuso <i>et al.</i>	(CLEO Collab.)
EDWARDS	99	PR D59 032003	K.W. Edwards <i>et al.</i>	(CLEO Collab.)
WALK	86	PR D34 2611	W.S. Walk <i>et al.</i>	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	H. Albrecht <i>et al.</i>	(ARGUS Collab.)
NERNST	85	PRL 54 2195	R. Nernst <i>et al.</i>	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	J. Haas <i>et al.</i>	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	C. Klopfenstein <i>et al.</i>	(CUSB Collab.)
PAUSS	83	PL 130B 439	F. Pauss <i>et al.</i>	(MPIM, COLU, CORN, LSU+)