

$\Upsilon(3S)$

$$J^{PC} = 0^{-}(1^{-}-)$$

$\Upsilon(3S)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
10355.2±0.5	¹ ARTAMONOV 00	MD1	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •			
10355.3±0.5	^{2,3} BARU	86B REDE	$e^+e^- \rightarrow$ hadrons
¹ Reanalysis of BARU 86B using new electron mass (COHEN 87).			
² Reanalysis of ARTAMONOV 84.			
³ Superseded by ARTAMONOV 00.			

$m_{\Upsilon(3S)} - m_{\Upsilon(2S)}$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
331.50±0.02±0.13	LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^-X$

$\Upsilon(3S)$ WIDTH

VALUE (keV)	DOCUMENT ID
20.32±1.85 OUR EVALUATION	See the Note on "Width Determinations of the Υ States"

$\Upsilon(3S)$ DECAY MODES

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1 $\Upsilon(2S)$ anything	(10.6 ±0.8) %	
Γ_2 $\Upsilon(2S)\pi^+\pi^-$	(2.82±0.18) %	S=1.6
Γ_3 $\Upsilon(2S)\pi^0\pi^0$	(1.85±0.14) %	
Γ_4 $\Upsilon(2S)\gamma\gamma$	(5.0 ±0.7) %	
Γ_5 $\Upsilon(2S)\pi^0$	< 5.1 × 10 ⁻⁴	CL=90%
Γ_6 $\Upsilon(1S)\pi^+\pi^-$	(4.37±0.08) %	
Γ_7 $\Upsilon(1S)\pi^0\pi^0$	(2.20±0.13) %	
Γ_8 $\Upsilon(1S)\eta$	< 1 × 10 ⁻⁴	CL=90%
Γ_9 $\Upsilon(1S)\pi^0$	< 7 × 10 ⁻⁵	CL=90%
Γ_{10} $h_b(1P)\pi^0$	< 1.2 × 10 ⁻³	CL=90%
Γ_{11} $h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0$	(4.3 ±1.4) × 10 ⁻⁴	
Γ_{12} $h_b(1P)\pi^+\pi^-$	< 1.2 × 10 ⁻⁴	CL=90%
Γ_{13} $\tau^+\tau^-$	(2.29±0.30) %	
Γ_{14} $\mu^+\mu^-$	(2.18±0.21) %	S=2.1
Γ_{15} e^+e^-	seen	
Γ_{16} hadrons		
Γ_{17} ggg	(35.7 ±2.6) %	
Γ_{18} γgg	(9.7 ±1.8) × 10 ⁻³	

Radiative decays

Γ_{19}	$\gamma\chi_{b2}(2P)$	$(13.1 \pm 1.6) \%$	$S=3.4$
Γ_{20}	$\gamma\chi_{b1}(2P)$	$(12.6 \pm 1.2) \%$	$S=2.4$
Γ_{21}	$\gamma\chi_{b0}(2P)$	$(5.9 \pm 0.6) \%$	$S=1.4$
Γ_{22}	$\gamma\chi_{b2}(1P)$	$(9.9 \pm 1.3) \times 10^{-3}$	$S=2.0$
Γ_{23}	$\gamma A^0 \rightarrow \gamma \text{hadrons}$	$< 8 \times 10^{-5}$	$CL=90\%$
Γ_{24}	$\gamma\chi_{b1}(1P)$	$(9 \pm 5) \times 10^{-4}$	$S=1.9$
Γ_{25}	$\gamma\chi_{b0}(1P)$	$(2.7 \pm 0.4) \times 10^{-3}$	
Γ_{26}	$\gamma\eta_b(2S)$	$< 6.2 \times 10^{-4}$	$CL=90\%$
Γ_{27}	$\gamma\eta_b(1S)$	$(5.1 \pm 0.7) \times 10^{-4}$	
Γ_{28}	$\gamma X \rightarrow \gamma + \geq 4 \text{ prongs}$	[a] $< 2.2 \times 10^{-4}$	$CL=95\%$
Γ_{29}	$\gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-$	$< 5.5 \times 10^{-6}$	$CL=90\%$
Γ_{30}	$\gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-$	[b] $< 1.6 \times 10^{-4}$	$CL=90\%$

Lepton Family number (LF) violating modes

Γ_{31}	$e^\pm \tau^\mp$	LF	$< 4.2 \times 10^{-6}$	$CL=90\%$
Γ_{32}	$\mu^\pm \tau^\mp$	LF	$< 3.1 \times 10^{-6}$	$CL=90\%$

[a] $1.5 \text{ GeV} < m_X < 5.0 \text{ GeV}$

[b] For $m_{\tau^+ \tau^-}$ in the ranges 4.03–9.52 and 9.61–10.10 GeV.

$\Upsilon(3S) \Gamma(i)\Gamma(e^+ e^-)/\Gamma(\text{total})$

$\Gamma(\text{hadrons}) \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$ $\Gamma_{16}\Gamma_{15}/\Gamma$

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.414±0.007 OUR AVERAGE			
0.413±0.004±0.006	ROSNER	06 CLEO	10.4 $e^+ e^- \rightarrow \text{hadrons}$
0.45 ±0.03 ±0.03	⁴ GILES	84B CLEO	$e^+ e^- \rightarrow \text{hadrons}$

⁴ Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

$\Gamma(\Upsilon(1S)\pi^+\pi^-) \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$ $\Gamma_6\Gamma_{15}/\Gamma$

<u>VALUE (eV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
18.46±0.27±0.77	6.4K	⁵ AUBERT	08BP BABR	$e^+ e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$

⁵ Using $B(\Upsilon(1S) \rightarrow e^+ e^-) = (2.38 \pm 0.11)\%$ and $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.48 \pm 0.05)\%$.

$\Upsilon(3S)$ PARTIAL WIDTHS

$\Gamma(e^+ e^-)$ Γ_{15}

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>
0.443±0.008 OUR EVALUATION	

$\Upsilon(3S)$ BRANCHING RATIOS

$\Gamma(\Upsilon(2S)\text{anything})/\Gamma_{\text{total}}$

Γ_1/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.106 ± 0.008	OUR AVERAGE			
0.1023 ± 0.0105	4625	6,7,8 BUTLER	94B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-X$
0.111 ± 0.012	4891	7,8,9 BROCK	91	CLEO $e^+e^- \rightarrow \pi^+\pi^-X,$ $\pi^+\pi^-\ell^+\ell^-$

⁶ Using $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) = (0.038 \pm 0.007)\%$, and $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) = (1/2)B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-)$.

⁷ Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$. With the assumption of $e\mu$ universality.

⁸ Using $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-) = (18.5 \pm 0.8)\%$.

⁹ Using $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$, $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.188 \pm 0.035)\%$, and $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.436 \pm 0.056)\%$. With the assumption of $e\mu$ universality.

$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{\text{total}}$

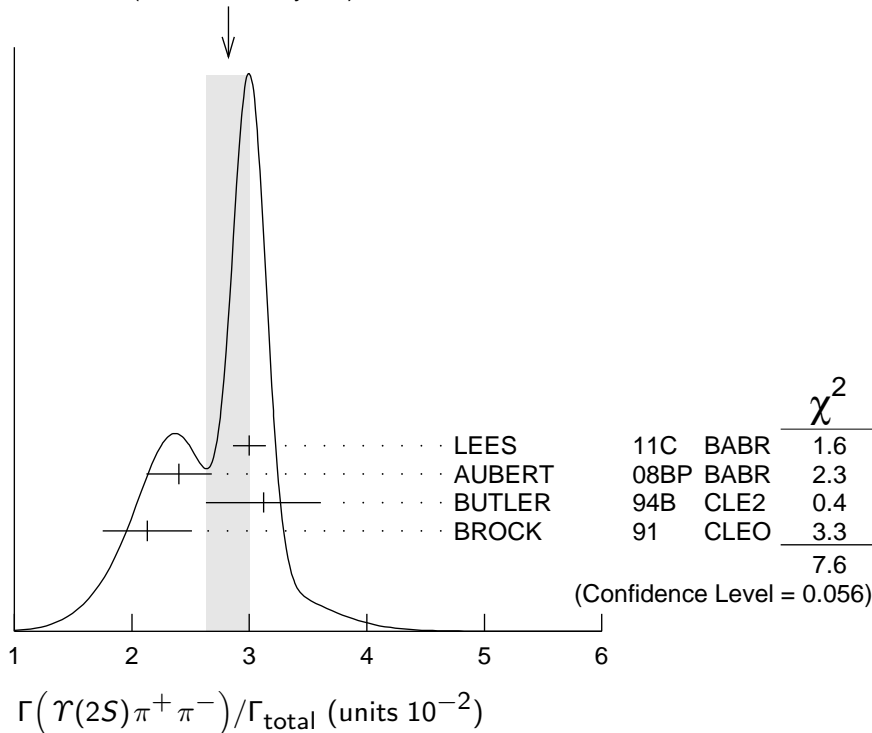
Γ_2/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
2.82 ± 0.18	OUR AVERAGE	Error includes scale factor of 1.6. See the ideogram below.		
3.00 ± 0.02 ± 0.14	543k	LEES	11C	BABR $e^+e^- \rightarrow \pi^+\pi^-X$
2.40 ± 0.10 ± 0.26	800	¹⁰ AUBERT	08BP	BABR $e^+e^- \rightarrow \gamma\pi^+\pi^-e^+e^-$
3.12 ± 0.49	980	^{11,12} BUTLER	94B	CLE2 $e^+e^- \rightarrow \pi^+\pi^-\ell^+\ell^-$
2.13 ± 0.38	974	¹³ BROCK	91	CLEO $e^+e^- \rightarrow \pi^+\pi^-X,$ $\pi^+\pi^-\ell^+\ell^-$

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

4.82 ± 0.65 ± 0.53	138	¹³ WU	93	CUSB $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
3.1 ± 2.0	5	MAGERAS	82	CUSB $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$

WEIGHTED AVERAGE
2.82 ± 0.18 (Error scaled by 1.6)



¹⁰ Using $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$, $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$, and $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$ keV.

¹¹ From the exclusive mode.

¹² Using $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) = (0.038 \pm 0.007)\%$, and $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) = (1/2)B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-)$.

¹³ Using $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$, $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.188 \pm 0.035)\%$, and $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.436 \pm 0.056)\%$. With the assumption of $e\mu$ universality.

$\Gamma(\Upsilon(2S)\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
1.85±0.14 OUR AVERAGE				
1.82±0.09±0.12	4391	¹⁴ BHARI	09	CLEO $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
2.16±0.39		^{15,16} BUTLER	94B	CLE2 $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
1.7 ±0.5 ±0.2	10	¹⁷ HEINTZ	92	CSB2 $e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$

¹⁴ Authors assume $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.06\%$.

¹⁵ $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$ and assuming $e\mu$ universality.

¹⁶ From the exclusive mode.

¹⁷ $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.44 \pm 0.10)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\Upsilon(2S)\gamma\gamma)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.0502±0.0069	¹⁸ BUTLER	94B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-2\gamma$

¹⁸ From the exclusive mode.

$\Gamma(\Upsilon(2S)\pi^0)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (units 10^{-3})	CL%	DOCUMENT ID	TECN	COMMENT
<0.51	90	¹⁹ HE	08A	CLEO $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

¹⁹ Authors assume $B(\Upsilon(2S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.06\%$.

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_6/Γ

Abbreviation MM in the COMMENT field below stands for missing mass.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
4.37±0.08 OUR AVERAGE				
4.32±0.07±0.13	90k	²⁰ LEES	11L	BABR $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
4.46±0.01±0.13	190k	²¹ BHARI	09	CLEO $e^+e^- \rightarrow \pi^+\pi^-$ MM
4.17±0.06±0.19	6.4K	²² AUBERT	08BP	BABR 10.58 $e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$
4.52±0.35	11830	²³ BUTLER	94B	CLE2 $e^+e^- \rightarrow \pi^+\pi^-X$, $\pi^+\pi^-\ell^+\ell^-$
4.46±0.34±0.50	451	²³ WU	93	CUSB $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
4.46±0.30	11221	²³ BROCK	91	CLEO $e^+e^- \rightarrow \pi^+\pi^-X$, $\pi^+\pi^-\ell^+\ell^-$

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

4.9 ±1.0	22	GREEN	82	CLEO $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
3.9 ±1.3	26	MAGERAS	82	CUSB $\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$

²⁰ Using $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$ and $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$.

²¹ A weighted average of the inclusive and exclusive results.

²² Using $B(\Upsilon(2S) \rightarrow e^+e^-) = (1.91 \pm 0.16)\%$, $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.93 \pm 0.17)\%$, and $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$ keV.

²³ Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$. With the assumption of $e\mu$ universality.

$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ Γ_2/Γ_6

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

$0.577 \pm 0.026 \pm 0.060$	800	²⁴ AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$
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²⁴ Using $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$, $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$, $B(\Upsilon(2S) \rightarrow e^+e^-) = (1.91 \pm 0.16)\%$, and $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.93 \pm 0.17)\%$. Not independent of other values reported by AUBERT 08BP.

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
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2.20 ± 0.13 OUR AVERAGE

$2.24 \pm 0.09 \pm 0.11$	6584	²⁵ BHARI	09 CLEO	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
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1.99 ± 0.34	56	²⁶ BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
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$2.2 \pm 0.4 \pm 0.3$	33	²⁷ HEINTZ	92 CSB2	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
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²⁵ Authors assume $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$.

²⁶ Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$ and assuming $e\mu$ universality.

²⁷ Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.07)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ Γ_7/Γ_6

VALUE	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.501 ± 0.043	²⁸ BHARI	09 CLEO	$e^+e^- \rightarrow \Upsilon(3S)$
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²⁸ Not independent of other values reported by BHARI 09.

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (units 10^{-3})	CL%	DOCUMENT ID	TECN	COMMENT
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<0.1	90	²⁹ LEES	11L BABR	$\Upsilon(3S) \rightarrow (\pi^+\pi^-)(\gamma\gamma)\ell^+\ell^-$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<0.8	90	^{29,30} AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$
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<0.18	90	³¹ HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\eta$
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<2.2	90	BROCK	91 CLEO	$e^+e^- \rightarrow \ell^+\ell^-\eta$
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²⁹ Using $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.38 \pm 0.11)\%$, $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.05)\%$.

³⁰ Using $\Gamma_{ee}(\Upsilon(3S)) = 0.443 \pm 0.008$ keV.

³¹ Authors assume $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$.

$\Gamma(\Upsilon(1S)\eta)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ Γ_8/Γ_6

VALUE (units 10^{-2})	CL%	DOCUMENT ID	TECN	COMMENT
<0.23	90	³² LEES	11L BABR	$\Upsilon(3S) \rightarrow (\pi^+\pi^-)(\gamma\gamma)\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<1.9	90	³³ AUBERT	08BP BABR	$e^+e^- \rightarrow \gamma\pi^+\pi^-(\pi^0)\ell^+\ell^-$
³² Not independent of other values reported by LEES 11L.				
³³ Not independent of other values reported by AUBERT 08BP.				

$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE (units 10^{-3})	CL%	DOCUMENT ID	TECN	COMMENT
<0.07	90	³⁴ HE	08A CLEO	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
³⁴ Authors assume $B(\Upsilon(1S) \rightarrow e^+e^-) + B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 4.96\%$.				

$\Gamma(h_b(1P)\pi^0)/\Gamma_{\text{total}}$ Γ_{10}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<1.2 $\times 10^{-3}$	90	³⁵ GE	11 CLEO	$\Upsilon(3S) \rightarrow \pi^0$ anything
³⁵ Assuming $M(h_b(1P)) = 9900$ MeV and $\Gamma(h_b(1P)) = 0$ MeV, and allowing $B(h_b(1P) \rightarrow \gamma\eta_b(1S))$ to vary from 0–100%.				

$\Gamma(h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0)/\Gamma_{\text{total}}$ Γ_{11}/Γ

VALUE (units 10^{-4})	DOCUMENT ID	TECN	COMMENT
4.3 \pm 1.1 \pm 0.9	LEES	11K BABR	$\Upsilon(3S) \rightarrow \eta_b\gamma\pi^0$

$\Gamma(h_b(1P)\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{12}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
< 1.2	90	³⁶ LEES	11C BABR	$e^+e^- \rightarrow \pi^+\pi^-X$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<18		³⁶ BUTLER	94B CLE2	$e^+e^- \rightarrow \pi^+\pi^-X$
<15		³⁶ BROCK	91 CLEO	$e^+e^- \rightarrow \pi^+\pi^-X$
³⁶ For $M(h_b(1P)) = 9900$ MeV.				

$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$ Γ_{13}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
2.29 \pm 0.21 \pm 0.22	15k	³⁷ BESSON	07 CLEO	$e^+e^- \rightarrow \Upsilon(3S) \rightarrow \tau^+\tau^-$
³⁷ BESSON 07 reports $[\Gamma(\Upsilon(3S) \rightarrow \tau^+\tau^-)/\Gamma_{\text{total}}] / [B(\Upsilon(3S) \rightarrow \mu^+\mu^-)] = 1.05 \pm 0.08 \pm 0.05$ which we multiply by our best value $B(\Upsilon(3S) \rightarrow \mu^+\mu^-) = (2.18 \pm 0.21) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.				

$\Gamma(\tau^+\tau^-)/\Gamma(\mu^+\mu^-)$ Γ_{13}/Γ_{14}

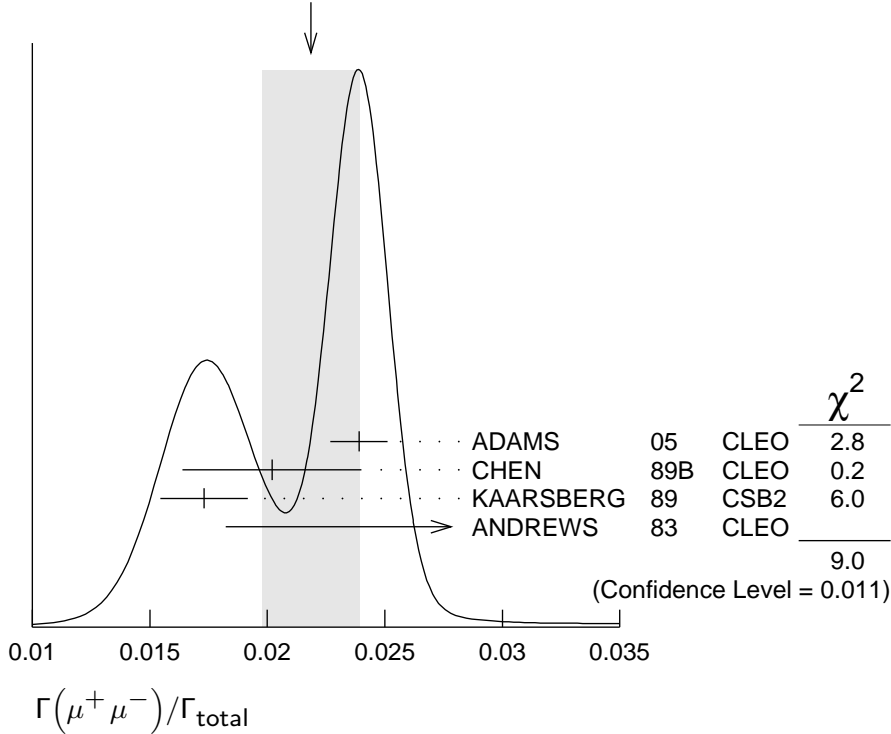
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
1.05 \pm 0.08 \pm 0.05	15k	BESSON	07 CLEO	$e^+e^- \rightarrow \Upsilon(3S)$

$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$

Γ_{14}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0218 ± 0.0021 OUR AVERAGE				Error includes scale factor of 2.1. See the ideogram below.
0.0239 ± 0.0007 ± 0.0010	81k	ADAMS	05	CLEO $e^+e^- \rightarrow \mu^+\mu^-$
0.0202 ± 0.0019 ± 0.0033		CHEN	89B	CLEO $e^+e^- \rightarrow \mu^+\mu^-$
0.0173 ± 0.0015 ± 0.0011		KAARSBERG	89	CSB2 $e^+e^- \rightarrow \mu^+\mu^-$
0.033 ± 0.013 ± 0.007	1096	ANDREWS	83	CLEO $e^+e^- \rightarrow \mu^+\mu^-$

WEIGHTED AVERAGE
0.0218 ± 0.0021 (Error scaled by 2.1)



$\Gamma(ggg)/\Gamma_{\text{total}}$

Γ_{17}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
35.7 ± 2.6	3M	38 BESSON	06A	CLEO $\Upsilon(3S) \rightarrow \text{hadrons}$

³⁸ Calculated using BESSON 06A value of $\Gamma(\gamma gg)/\Gamma(ggg) = (2.72 \pm 0.06 \pm 0.32 \pm 0.37)\%$ and the PDG 08 values of $B(\Upsilon(2S) + \text{anything}) = (10.6 \pm 0.8)\%$, $B(\pi^+\pi^-\Upsilon(1S)) = (4.40 \pm 0.10)\%$, $B(\pi^0\pi^0\Upsilon(1S)) = (2.20 \pm 0.13)\%$, $B(\gamma\chi_{b2}(2P)) = (13.1 \pm 1.6)\%$, $B(\gamma\chi_{b1}(2P)) = (12.6 \pm 1.2)\%$, $B(\gamma\chi_{b0}(2P)) = (5.9 \pm 0.6)\%$, $B(\gamma\chi_{b0}(1P)) = (0.30 \pm 0.11)\%$, $B(\mu^+\mu^-) = (2.18 \pm 0.21)\%$, and $R_{\text{hadrons}} = 3.51$. The statistical error is negligible and the systematic error is partially correlated with $\Gamma(\gamma gg)/\Gamma_{\text{total}}$ BESSON 06A value.

$\Gamma(\gamma gg)/\Gamma_{\text{total}}$

Γ_{18}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
0.97 ± 0.18	60k	³⁹ BESSON	06A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$

³⁹ Calculated using BESSON 06A values of $\Gamma(\gamma gg)/\Gamma(ggg) = (2.72 \pm 0.06 \pm 0.32 \pm 0.37)\%$ and $\Gamma(ggg)/\Gamma_{\text{total}}$. The statistical error is negligible and the systematic error is partially correlated with $\Gamma(ggg)/\Gamma_{\text{total}}$ BESSON 06A value.

$\Gamma(\gamma g g)/\Gamma(g g g)$

Γ_{18}/Γ_{17}

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
$2.72 \pm 0.06 \pm 0.49$	3M	BESSION	06A	CLEO $\Upsilon(3S) \rightarrow (\gamma +)$ hadrons

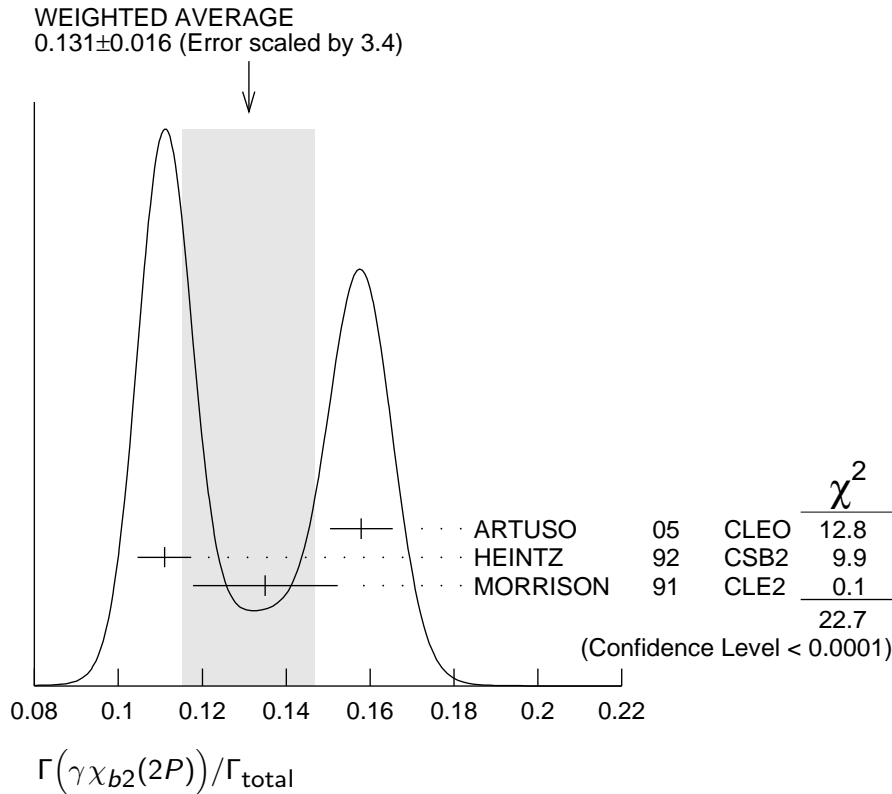
$\Gamma(\gamma \chi_{b2}(2P))/\Gamma_{total}$

Γ_{19}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.131 ± 0.016 OUR AVERAGE				Error includes scale factor of 3.4. See the ideogram below.

$0.1579 \pm 0.0017 \pm 0.0073$	568k	ARTUSO	05	CLEO $e^+ e^- \rightarrow \gamma X$
$0.111 \pm 0.005 \pm 0.004$	10319	⁴⁰ HEINTZ	92	CSB2 $e^+ e^- \rightarrow \gamma X$
$0.135 \pm 0.003 \pm 0.017$	30741	MORRISON	91	CLE2 $e^+ e^- \rightarrow \gamma X$

⁴⁰ Supersedes NARAIN 91.



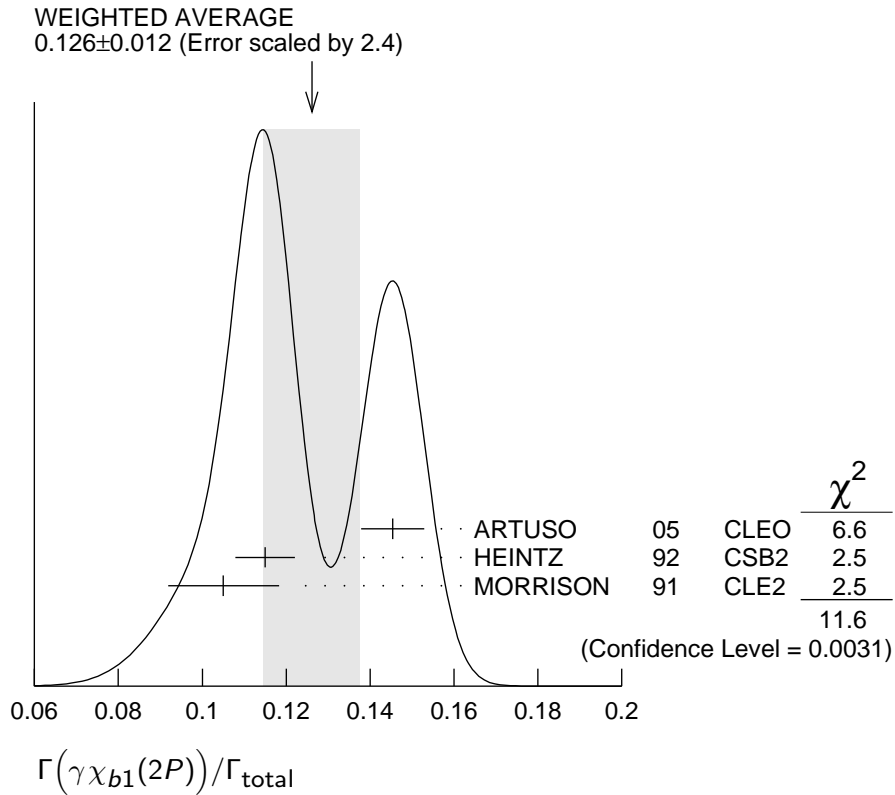
$\Gamma(\gamma \chi_{b1}(2P))/\Gamma_{total}$

Γ_{20}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.126 ± 0.012 OUR AVERAGE				Error includes scale factor of 2.4. See the ideogram below.

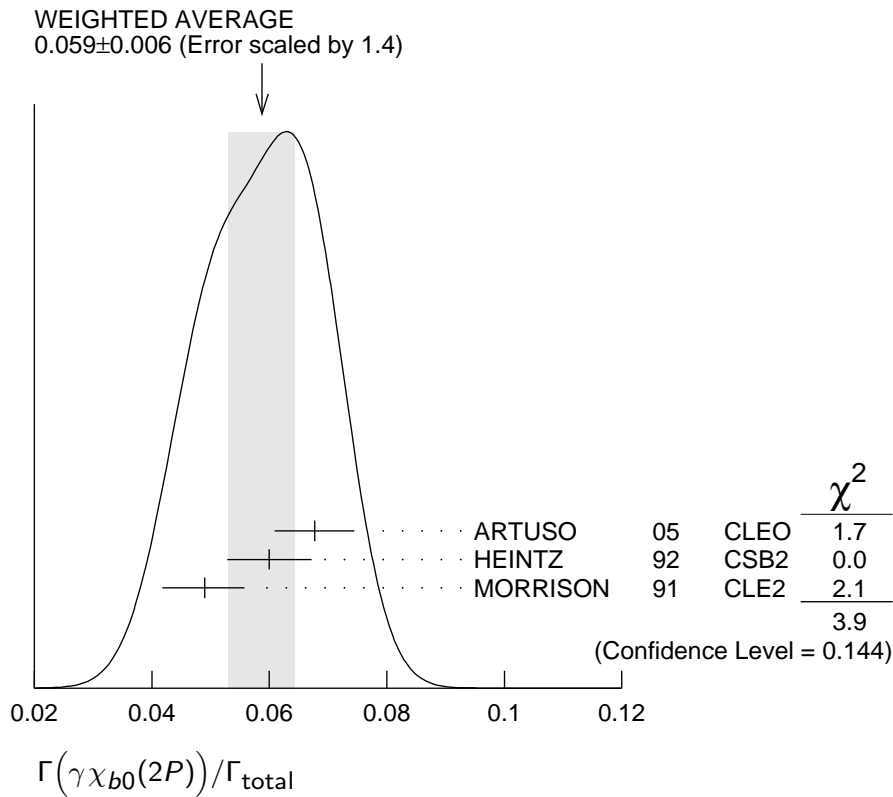
$0.1454 \pm 0.0018 \pm 0.0073$	537k	ARTUSO	05	CLEO $e^+ e^- \rightarrow \gamma X$
$0.115 \pm 0.005 \pm 0.005$	11147	⁴¹ HEINTZ	92	CSB2 $e^+ e^- \rightarrow \gamma X$
$0.105 \begin{matrix} +0.003 \\ -0.002 \end{matrix} \pm 0.013$	25759	MORRISON	91	CLE2 $e^+ e^- \rightarrow \gamma X$

⁴¹Supersedes NARAIN 91.



$\Gamma(\gamma\chi_{b0}(2P))/\Gamma_{total}$						Γ_{21}/Γ	
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT			
0.059 ± 0.006	OUR AVERAGE	Error includes scale factor of 1.4. See the ideogram below.					
0.0677 ± 0.0020 ± 0.0065	225k	ARTUSO	05	CLEO	$e^+e^- \rightarrow \gamma X$		
0.060 ± 0.004 ± 0.006	4959	⁴² HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X$		
0.049 $\begin{smallmatrix} +0.003 \\ -0.004 \end{smallmatrix}$ ± 0.006	9903	MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$		

⁴²Supersedes NARAIN 91.



$\Gamma(\gamma\chi_{b2}(1P))/\Gamma_{\text{total}}$ **Γ_{22}/Γ**

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
9.9 ± 1.3 OUR AVERAGE			Error includes scale factor of 2.0.		
$7.5 \pm 1.2 \pm 0.5$		126	^{43,44} KORNICER	11	CLEO $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$
$10.5 \pm 0.3^{+0.7}_{-0.6}$		9.7k	LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$

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

<19 seen	90	⁴⁵ ASNER	08A	CLEO	$\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
		⁴⁶ HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

⁴³ Assuming $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (2.48 \pm 0.05)\%$.

⁴⁴ KORNICER 11 reports $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{\text{total}}] \times [B(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S))]$
 $= (1.435 \pm 0.162 \pm 0.169) \times 10^{-3}$ which we divide by our best value $B(\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S)) = (19.1 \pm 1.2) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

⁴⁵ ASNER 08A reports $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{\text{total}}] / [B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P))]$
 $< 27.1 \times 10^{-2}$ which we multiply by our best value $B(\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)) = 7.15 \times 10^{-2}$.

⁴⁶ HEINTZ 92, while unable to distinguish between different J states, measures $\sum_J B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}) \times B(\chi_{bJ} \rightarrow \gamma\Upsilon(1S)) = (1.7 \pm 0.4 \pm 0.6) \times 10^{-3}$ for $J = 0,1,2$ using inclusive $\Upsilon(1S)$ decays and $(1.2^{+0.4}_{-0.3} \pm 0.09) \times 10^{-3}$ for $J = 1,2$ using $\Upsilon(1S) \rightarrow \ell^+\ell^-$.

$\Gamma(\gamma\chi_{b1}(1P))/\Gamma_{\text{total}}$ Γ_{24}/Γ

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
0.9±0.5 OUR AVERAGE Error includes scale factor of 1.9.					
1.6±0.5±0.1		50	^{47,48} KORNICER	11	CLEO $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$
0.5±0.3 ^{+0.2} _{-0.1}			LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$

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

<1.7 seen	90		⁴⁹ ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
			⁵⁰ HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma\gamma\ell^+\ell^-$

⁴⁷ Assuming $B(\Upsilon(1S) \rightarrow \ell^+\ell^-) = (2.48 \pm 0.05)\%$.

⁴⁸ KORNICER 11 reports $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(1P))/\Gamma_{\text{total}}] \times [B(\chi_{b1}(1P) \rightarrow \gamma\Upsilon(1S))] = (5.38 \pm 1.20 \pm 0.95) \times 10^{-4}$ which we divide by our best value $B(\chi_{b1}(1P) \rightarrow \gamma\Upsilon(1S)) = (33.9 \pm 2.2) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

⁴⁹ ASNER 08A reports $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b1}(1P))/\Gamma_{\text{total}}] / [B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P))] < 2.5 \times 10^{-2}$ which we multiply by our best value $B(\Upsilon(2S) \rightarrow \gamma\chi_{b1}(1P)) = 6.9 \times 10^{-2}$.

⁵⁰ HEINTZ 92, while unable to distinguish between different J states, measures $\sum_J B(\Upsilon(3S) \rightarrow \gamma\chi_{bJ}) \times B(\chi_{bJ} \rightarrow \gamma\Upsilon(1S)) = (1.7 \pm 0.4 \pm 0.6) \times 10^{-3}$ for $J = 0,1,2$ using inclusive $\Upsilon(1S)$ decays and $(1.2^{+0.4}_{-0.3} \pm 0.09) \times 10^{-3}$ for $J = 1,2$ using $\Upsilon(1S) \rightarrow \ell^+\ell^-$.

 $\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{\text{total}}$ Γ_{25}/Γ

VALUE (units 10^{-2})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
0.27±0.04 OUR AVERAGE					
0.27±0.04±0.02		2.3k	LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
0.30±0.04±0.10		8.7k	ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$

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

<0.8	90		⁵¹ ASNER	08A	CLEO $\Upsilon(3S) \rightarrow \gamma + \text{hadrons}$
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⁵¹ ASNER 08A reports $[\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(1P))/\Gamma_{\text{total}}] / [B(\Upsilon(2S) \rightarrow \gamma\chi_{b0}(1P))] < 21.9 \times 10^{-2}$ which we multiply by our best value $B(\Upsilon(2S) \rightarrow \gamma\chi_{b0}(1P)) = 3.8 \times 10^{-2}$.

 $\Gamma(\gamma\eta_b(2S))/\Gamma_{\text{total}}$ Γ_{26}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
< 6.2				
	90	ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$

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

<19	90	LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
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 $\Gamma(\gamma\eta_b(1S))/\Gamma_{\text{total}}$ Γ_{27}/Γ

VALUE (units 10^{-4})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
5.1±0.7 OUR AVERAGE					
7.1±1.8±1.3		2.3±0.5k	⁵² BONVICINI	10	CLEO $\Upsilon(3S) \rightarrow \gamma X$
4.8±0.5±0.6		19±3k	⁵² AUBERT	09AQ	BABR $\Upsilon(3S) \rightarrow \gamma X$

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

<8.5	90		LEES	11J	BABR $\Upsilon(3S) \rightarrow X\gamma$
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4.8±0.5±1.2		19±3k	^{52,53} AUBERT	08V	BABR $\Upsilon(3S) \rightarrow \gamma X$
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<4.3	90		⁵⁴ ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$
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⁵² Assuming $\Gamma_{\eta_b(1S)} = 10$ MeV.

⁵³ Systematic error re-evaluated by AUBERT 09AQ.

⁵⁴ Superseded by BONVICINI 10.

$\Gamma(\gamma X \rightarrow \gamma + \geq 4 \text{ prongs})/\Gamma_{\text{total}}$ **Γ_{28}/Γ**
 (1.5 GeV < m_X < 5.0 GeV)

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<2.2	95	ROSNER	07A	CLEO $e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-)/\Gamma_{\text{total}}$ **Γ_{29}/Γ**

VALUE (units 10^{-6})	CL%	DOCUMENT ID	TECN	COMMENT
<5.5	90	⁵⁵ AUBERT	09Z	BABR $e^+e^- \rightarrow \gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-$

⁵⁵ For a narrow scalar or pseudoscalar a_1^0 with mass in the range 212–9300 MeV, excluding J/ψ and $\psi(2S)$. Measured 90% CL limits as a function of $m_{a_1^0}$ range from 0.27–5.5 $\times 10^{-6}$.

$\Gamma(\gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-)/\Gamma_{\text{total}}$ **Γ_{30}/Γ**

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<1.6 $\times 10^{-4}$	90	⁵⁶ AUBERT	09P	BABR $e^+e^- \rightarrow \gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-$

⁵⁶ For a narrow scalar or pseudoscalar a_1^0 with $M(\tau^+ \tau^-)$ in the ranges 4.03–9.52 and 9.61–10.10 GeV. Measured 90% CL limits as a function of $M(\tau^+ \tau^-)$ range from 1.5–16 $\times 10^{-5}$.

$\Gamma(\gamma A^0 \rightarrow \gamma \text{hadrons})/\Gamma_{\text{total}}$ **Γ_{23}/Γ**
 (0.3 GeV < m_{A^0} < 7 GeV)

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<8 $\times 10^{-5}$	90	⁵⁷ LEES	11H	BABR $\Upsilon(3S) \rightarrow \gamma \text{hadrons}$

⁵⁷ For a narrow scalar or pseudoscalar A^0 , excluding known resonances, with mass in the range 0.3–7 GeV. Measured 90% CL limits as a function of m_{A^0} range from 1 $\times 10^{-6}$ to 8 $\times 10^{-5}$.

————— **LEPTON FAMILY NUMBER (LF) VIOLATING MODES** —————

$\Gamma(e^\pm \tau^\mp)/\Gamma_{\text{total}}$ **Γ_{31}/Γ**

VALUE (units 10^{-6})	CL%	DOCUMENT ID	TECN	COMMENT
<4.2	90	LEES	10B	BABR $e^+e^- \rightarrow e^\pm \tau^\mp$

$\Gamma(\mu^\pm \tau^\mp)/\Gamma_{\text{total}}$ **Γ_{32}/Γ**

VALUE (units 10^{-6})	CL%	DOCUMENT ID	TECN	COMMENT
< 3.1	90	LEES	10B	BABR $e^+e^- \rightarrow \mu^\pm \tau^\mp$

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

<20.3	95	LOVE	08A	CLEO $e^+e^- \rightarrow \mu^\pm \tau^\mp$
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$\tau(3S)$ REFERENCES

GE	11	PR D84 032008	J.Y. Ge <i>et al.</i>	(CLEO Collab.)
KORNICER	11	PR D83 054003	M. Kornicer <i>et al.</i>	(CLEO Collab.)
LEES	11C	PR D84 011104	J.P. Lees <i>et al.</i>	(BABAR Collab.)
LEES	11H	PRL 107 221803	J.P. Lees <i>et al.</i>	(BABAR Collab.)
LEES	11J	PR D84 072002	J.P. Lees <i>et al.</i>	(BABAR Collab.)
LEES	11K	PR D84 091101	J.P. Lees <i>et al.</i>	(BABAR Collab.)
LEES	11L	PR D84 092003	J.P. Lees <i>et al.</i>	(BABAR Collab.)
BONVICINI	10	PR D81 031104	G. Bonvicini <i>et al.</i>	(CLEO Collab.)
LEES	10B	PRL 104 151802	J.P. Lees <i>et al.</i>	(BABAR Collab.)
AUBERT	09AQ	PRL 103 161801	B. Aubert <i>et al.</i>	(BABAR Collab.)
AUBERT	09P	PRL 103 181801	B. Aubert <i>et al.</i>	(BABAR Collab.)
AUBERT	09Z	PRL 103 081803	B. Aubert <i>et al.</i>	(BABAR Collab.)
BHARI	09	PR D79 011103	S.R. Bhari <i>et al.</i>	(CLEO Collab.)
ASNER	08A	PR D78 091103	D.M. Asner <i>et al.</i>	(CLEO Collab.)
AUBERT	08BP	PR D78 112002	B. Aubert <i>et al.</i>	(BABAR Collab.)
AUBERT	08V	PRL 101 071801	B. Aubert <i>et al.</i>	(BABAR Collab.)
HE	08A	PRL 101 192001	Q. He <i>et al.</i>	(CLEO Collab.)
LOVE	08A	PRL 101 201601	W. Love <i>et al.</i>	(CLEO Collab.)
PDG	08	PL B667 1	C. Amsler <i>et al.</i>	(PDG Collab.)
BESSON	07	PRL 98 052002	D. Besson <i>et al.</i>	(CLEO Collab.)
ROSNER	07A	PR D76 117102	J.L. Rosner <i>et al.</i>	(CLEO Collab.)
BESSON	06A	PR D74 012003	D. Besson <i>et al.</i>	(CLEO Collab.)
ROSNER	06	PRL 96 092003	J.L. Rosner <i>et al.</i>	(CLEO Collab.)
ADAMS	05	PRL 94 012001	G.S. Adams <i>et al.</i>	(CLEO Collab.)
ARTUSO	05	PRL 94 032001	M. Artuso <i>et al.</i>	(CLEO Collab.)
ARTAMONOV	00	PL B474 427	A.S. Artamonov <i>et al.</i>	
BUTLER	94B	PR D49 40	F. Butler <i>et al.</i>	(CLEO Collab.)
WU	93	PL B301 307	Q.W. Wu <i>et al.</i>	(CUSB Collab.)
HEINTZ	92	PR D46 1928	U. Heintz <i>et al.</i>	(CUSB II Collab.)
BROCK	91	PR D43 1448	I.C. Brock <i>et al.</i>	(CLEO 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.)
CHEN	89B	PR D39 3528	W.Y. Chen <i>et al.</i>	(CLEO Collab.)
KAARSBERG	89	PRL 62 2077	T.M. Kaarsberg <i>et al.</i>	(CUSB Collab.)
BUCHMUEL...	88	HE e^+e^- Physics 412	W. Buchmueller, S. Cooper	(HANN, DESY, MIT)
Editors: A. Ali and P. Soeding, World Scientific, Singapore				
COHEN	87	RMP 59 1121	E.R. Cohen, B.N. Taylor	(RISC, NBS)
BARU	86B	ZPHY C32 622 (erratum)	S.E. Baru <i>et al.</i>	(NOVO)
KURAEV	85	SJNP 41 466	E.A. Kuraev, V.S. Fadin	(NOVO)
Translated from YAF 41 733.				
ARTAMONOV	84	PL 137B 272	A.S. Artamonov <i>et al.</i>	(NOVO)
GILES	84B	PR D29 1285	R. Giles <i>et al.</i>	(CLEO Collab.)
ANDREWS	83	PRL 50 807	D.E. Andrews <i>et al.</i>	(CLEO Collab.)
GREEN	82	PRL 49 617	J. Green <i>et al.</i>	(CLEO Collab.)
MAGERAS	82	PL 118B 453	G. Mageras <i>et al.</i>	(COLU, CORN, LSU+)