$\Upsilon(3S)$

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

$\Upsilon(3S)$ 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[3] Superseded by ARTAMONOV 00.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^-	(2.18± 0.20) %	
Γ_{16}	hadrons	(93 ±12) %	
Γ_{17}	ggg	(35.7 ± 2.6) %	
Γ_{18}	γgg	(9.7 ± 1.8) × 10^{-3}	
Γ_{19}	^2H anything	(2.33± 0.33) × 10^{-5}	

Radiative decays

Γ_{20}	$\gamma \chi_{b2}(2P)$			$(13.1 \pm 1.6)\%$	S=3.4
Γ_{21}	$\gamma \chi_{b1}(2P)$			$(12.6 \pm 1.2)\%$	S=2.4
Γ_{22}	$\gamma \chi_{b0}(2P)$			$(5.9 \pm 0.6)\%$	S=1.4
Γ_{23}	$\gamma \chi_{b2}(1P)$			$(10.0 \pm 1.0) \times 10^{-3}$	S=1.7
Γ_{24}	$\gamma \chi_{b1}(1P)$			$(9 \pm 5) \times 10^{-4}$	S=1.8
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}	$\gamma A^0 \to \gamma$ hadrons			$< 8 \times 10^{-5}$	CL=90%
Γ_{29}	$\gamma X \to \gamma + \geq 4$ prongs		[a]	$< 2.2 \times 10^{-4}$	CL=95%
Γ_{30}	$\gamma a_1^0 \to \gamma \mu^+ \mu^-$			$< 5.5 \times 10^{-6}$	CL=90%
Γ_{31}	$\gamma a_1^0 \to \gamma \tau^+ \tau^-$		[b]	$< 1.6 \times 10^{-4}$	CL=90%

Lepton Family number (*LF*) violating modes

Γ_{32}	$e^{\pm} \tau^{\mp}$	*LF*		$< 4.2 \times 10^{-6}$	CL=90%
Γ_{33}	$\mu^{\pm} \tau^{\mp}$	*LF*		$< 3.1 \times 10^{-6}$	CL=90%

[a] 1.5 GeV $< m_X <$ 5.0 GeV

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

$\Upsilon(3S)$ Γ(i)$\Gamma(e^+e^-)/\Gamma$(total)

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

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.414±0.007 OUR AVERAGE				
0.413±0.004±0.006	ROSNER	06	CLEO	10.4 $e^+e^- \to$ hadrons
0.45 ±0.03 ±0.03	[4] GILES	84B	CLEO	$e^+e^- \to$ hadrons

[4] Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

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

VALUE (eV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
18.46±0.27±0.77	6.4K	[5] AUBERT	08BP	BABR	$e^+e^- \to \gamma \pi^+ \pi^- \ell^+ \ell^-$

[5] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)% and B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%.

$\Upsilon(3S)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ — Γ_{15}

VALUE (keV)	*DOCUMENT ID*
0.443±0.008 OUR EVALUATION	

$\Upsilon(3S)$ BRANCHING RATIOS

$\Gamma(\Upsilon(2S)\text{anything})/\Gamma_{\text{total}}$ Γ_1/Γ

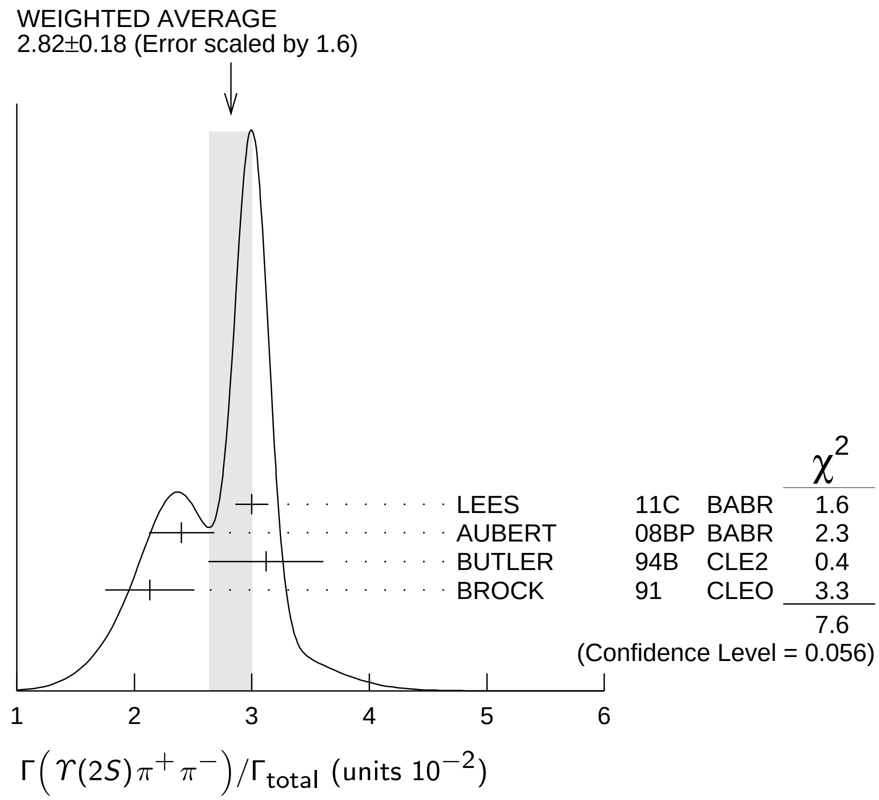
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.106 ±0.008 OUR AVERAGE					
0.1023±0.0105	4625	[6,7,8] BUTLER	94B	CLE2	$e^+e^- \rightarrow \ell^+\ell^- X$
0.111 ±0.012	4891	[7,8,9] BROCK	91	CLEO	$e^+e^- \rightarrow \pi^+\pi^- X$, $\pi^+\pi^-\ell^+\ell^-$

[6] Using B($\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma$) = (0.038 ± 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 ± 0.06)%. With the assumption of $e\mu$ universality.
[8] Using B($\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-$) = (18.5 ± 0.8)%.
[9] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.31 ± 0.21)%, B($\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma$)×2B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (0.188 ± 0.035)%, and B($\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0$)×2B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (0.436 ± 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	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$

[10] Using B($\Upsilon(1S) \rightarrow e^+e^-$) = (2.38 ± 0.11)%, B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (2.48 ± 0.05)%, and Γ_{ee}($\Upsilon(3S)$) = 0.443 ± 0.008 keV.
[11] From the exclusive mode.
[12] Using B($\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma$) = (0.038 ± 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 ± 0.21)%, B($\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma$)×2B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (0.188 ± 0.035)%, and B($\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0$)×2B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality.



$\Gamma(\Upsilon(2S)\pi^0\pi^0)/\Gamma_{total}$ 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 ± 0.21)% and assuming $e\mu$ universality.
[16] From the exclusive mode.
[17] B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\Upsilon(2S)\gamma\gamma)/\Gamma_{total}$ 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.

$\Gamma(\Upsilon(2S)\pi^0)/\Gamma_{total}$ 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%.

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}$ — 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	$\Upsilon(3S) \to \pi^+\pi^-\ell^+\ell^-$
4.46±0.01±0.13	190k	[21] BHARI	09	CLEO	$e^+e^- \to \pi^+\pi^-$ MM
4.17±0.06±0.19	6.4K	[22] AUBERT	08BP	BABR	10.58 $e^+e^- \to \gamma\pi^+\pi^-\ell^+\ell^-$
4.52±0.35	11830	[23] BUTLER	94B	CLE2	$e^+e^- \to \pi^+\pi^-$X, $\pi^+\pi^-\ell^+\ell^-$
4.46±0.34±0.50	451	[23] WU	93	CUSB	$\Upsilon(3S) \to \pi^+\pi^-\ell^+\ell^-$
4.46±0.30	11221	[23] BROCK	91	CLEO	$e^+e^- \to \pi^+\pi^-$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	$\Upsilon(3S) \to \pi^+\pi^-\ell^+\ell^-$
3.9 ±1.3	26	MAGERAS	82	CUSB	$\Upsilon(3S) \to \pi^+\pi^-\ell^+\ell^-$

[20] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)% and B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%.

[21] A weighted average of the inclusive and exclusive results.

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

[23] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 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*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.577±0.026±0.060	800	[24] AUBERT	08BP	BABR	$e^+e^- \to \gamma\pi^+\pi^-\ell^+\ell^-$

[24] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)%, B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%, B($\Upsilon(2S) \to e^+e^-$) = (1.91 ± 0.16)%, and B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.93 ± 0.17)%. Not independent of other values reported by AUBERT 08BP.

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

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.20±0.13 OUR AVERAGE					
2.24±0.09±0.11	6584	[25] BHARI	09	CLEO	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$
1.99±0.34	56	[26] BUTLER	94B	CLE2	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$
2.2 ±0.4 ±0.3	33	[27] HEINTZ	92	CSB2	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$

[25] Authors assume B($\Upsilon(1S) \to e^+e^-$) + B($\Upsilon(1S) \to \mu^+\mu^-$) = 4.96%.

[26] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.06)% and assuming $e\mu$ universality.

[27] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 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*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.501±0.043	[28] BHARI	09	CLEO	$e^+e^- \to \Upsilon(3S)$

[28] Not independent of other values reported by BHARI 09.

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

VALUE (units 10^{-3})	CL%	DOCUMENT ID		TECN	COMMENT
<0.1	90	[29] LEES	11L	BABR	$\Upsilon(3S) \to (\pi^+\pi^-)(\gamma\gamma)\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.8	90	[29,30] AUBERT	08BP	BABR	$e^+e^- \to \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$
<0.18	90	[31] HE	08A	CLEO	$e^+e^- \to \ell^+\ell^-\eta$
<2.2	90	BROCK	91	CLEO	$e^+e^- \to \ell^+\ell^-\eta$

[29] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)%, B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%.
[30] Using $\Gamma_{ee}(\Upsilon(3S))$ = 0.443 ± 0.008 keV.
[31] Authors assume B($\Upsilon(1S) \to e^+e^-$) + B($\Upsilon(1S) \to \mu^+\mu^-$) = 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	$\Upsilon(3S) \to (\pi^+\pi^-)(\gamma\gamma)\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<1.9	90	[33] AUBERT	08BP	BABR	$e^+e^- \to \gamma\pi^+\pi^-(\pi^0)\ell^+\ell^-$

[32] Not independent of other values reported by LEES 11L.
[33] Not independent of other values reported by AUBERT 08BP.

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

VALUE (units 10^{-3})	CL%	DOCUMENT ID		TECN	COMMENT
<0.07	90	[34] HE	08A	CLEO	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[34] Authors assume B($\Upsilon(1S) \to e^+e^-$) + B($\Upsilon(1S) \to \mu^+\mu^-$) = 4.96%.

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.2 \times 10^{-3}$	90	[35] GE	11	CLEO	$\Upsilon(3S) \to \pi^0$ anything

[35] Assuming $M(h_b(1P))$ = 9900 MeV and $\Gamma(h_b(1P))$ = 0 MeV, and allowing B($h_b(1P) \to \gamma\eta_b(1S)$) to vary from 0–100%.

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

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

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

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

[36] For $M(h_b(1P))$ = 9900 MeV.

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
2.29±0.21±0.22	15k	[37] BESSON	07	CLEO	$e^+e^- \rightarrow \Upsilon(3S) \rightarrow \tau^+\tau^-$

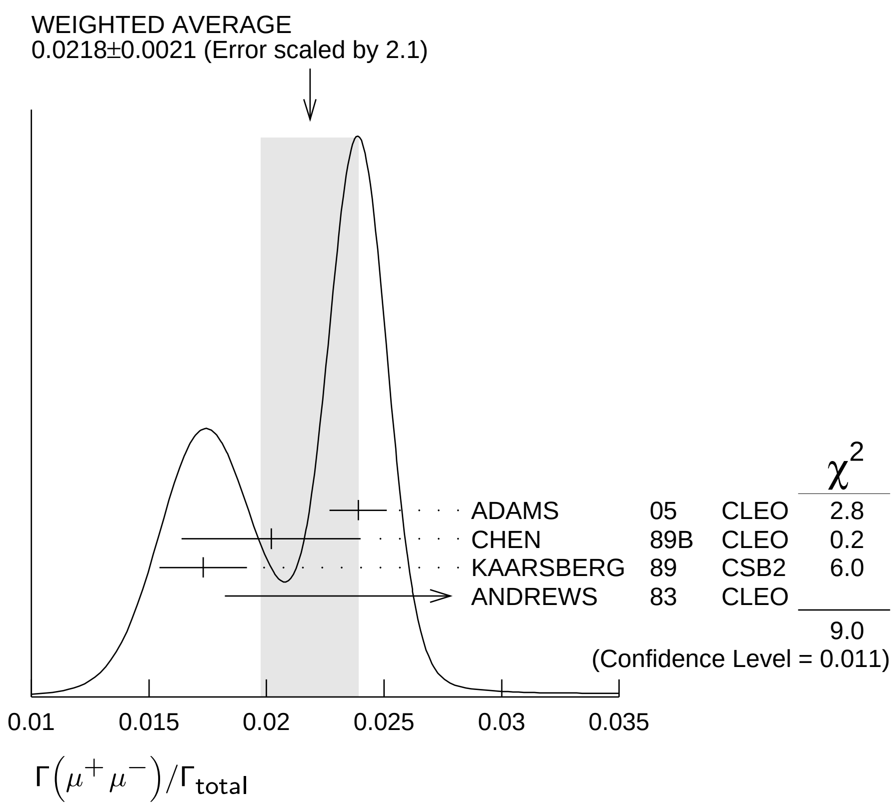
[37] BESSON 07 reports $[\Gamma(\Upsilon(3S) \rightarrow \tau^+\tau^-)/\Gamma_{total}] / [B(\Upsilon(3S) \rightarrow \mu^+\mu^-)] = 1.05 \pm 0.08 \pm 0.05$ which we multiply by our best value $B(\Upsilon(3S) \rightarrow \mu^+\mu^-) = (2.18 \pm 0.21) \times 10^{-2}$. Our first error is their experiment's 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±0.08±0.05	15k	BESSON	07	CLEO	$e^+e^- \rightarrow \Upsilon(3S)$

$\Gamma(\mu^+\mu^-)/\Gamma_{total}$ — 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	$e^+e^- \rightarrow \mu^+\mu^-$



$\Gamma(ggg)/\Gamma_{total}$ — Γ_{17}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
35.7±2.6	3M	[38] BESSON	06A	CLEO	$\Upsilon(3S) \to$ 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($\Upsilon(2S)$ + anything) = (10.6 ± 0.8)%, B($\pi^+\pi^-\Upsilon(1S)$) = (4.40 ± 0.10)%, B($\pi^0\pi^0\Upsilon(1S)$) = (2.20 ± 0.13)%, B($\gamma\chi_{b2}(2P)$) = (13.1 ± 1.6)%, B($\gamma\chi_{b1}(2P)$) = (12.6 ± 1.2)%, B($\gamma\chi_{b0}(2P)$) = (5.9 ± 0.6)%, B($\gamma\chi_{b0}(1P)$) = (0.30 ± 0.11)% ,B($\mu^+\mu^-$) = (2.18 ± 0.21)%, and $R_{hadrons}$ = 3.51. The statistical error is negligible and the systematic error is partially correlated with $\Gamma(\gamma gg)/\Gamma_{total}$ BESSON 06A value.

$\Gamma(\gamma gg)/\Gamma_{total}$ — Γ_{18}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
0.97±0.18	60k	[39] BESSON	06A	CLEO	$\Upsilon(3S) \to \gamma$ + 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 $\Gamma(ggg)/\Gamma_{total}$. The statistical error is negligible and the systematic error is partially correlated with $\Gamma(ggg)/\Gamma_{total}$ BESSON 06A value.

$\Gamma(\gamma gg)/\Gamma(ggg)$ — Γ_{18}/Γ_{17}

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

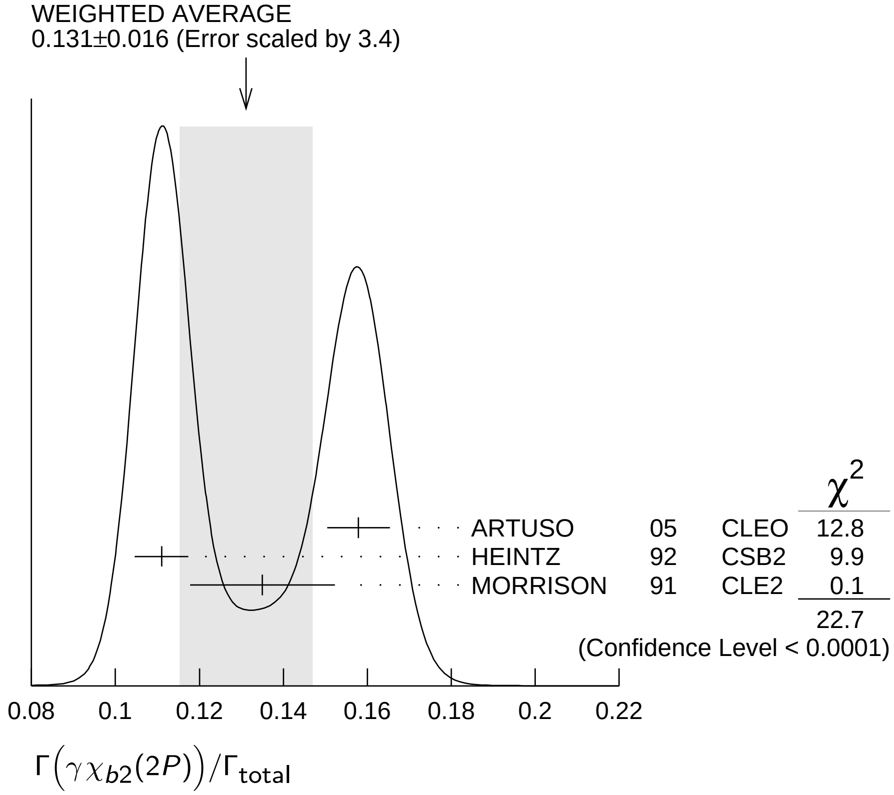
$\Gamma(\overline{^2H}$ anything$)/\Gamma_{total}$ — Γ_{19}/Γ

VALUE (units 10^{-5})	DOCUMENT ID		TECN	COMMENT
$2.33 \pm 0.15^{+0.31}_{-0.28}$	LEES	14G	BABR	$e^+e^- \to \overline{^2H}\,X$

$\Gamma(\gamma\chi_{b2}(2P))/\Gamma_{total}$ — Γ_{20}/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±0.0017±0.0073	568k	ARTUSO	05	CLEO	$e^+e^- \to \gamma X$
0.111 ±0.005 ±0.004	10319	[40] HEINTZ	92	CSB2	$e^+e^- \to \gamma X$
0.135 ±0.003 ±0.017	30741	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

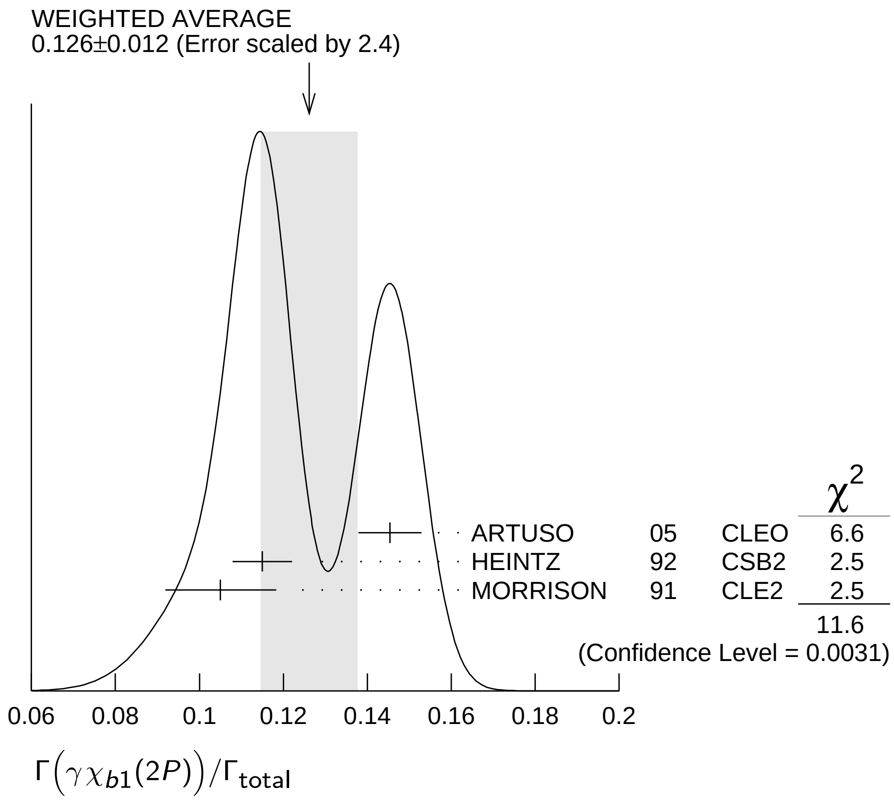
[40] Supersedes NARAIN 91.



$\Gamma\big(\gamma\chi_{b1}(2P)\big)/\Gamma_{total}$ Γ_{21}/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±0.0018±0.0073	537k	ARTUSO 05	CLEO	$e^+e^- \rightarrow \gamma X$
0.115 ±0.005 ±0.005	11147	[41] HEINTZ 92	CSB2	$e^+e^- \rightarrow \gamma X$
0.105 $^{+0.003}_{-0.002}$ ±0.013	25759	MORRISON 91	CLE2	$e^+e^- \rightarrow \gamma X$

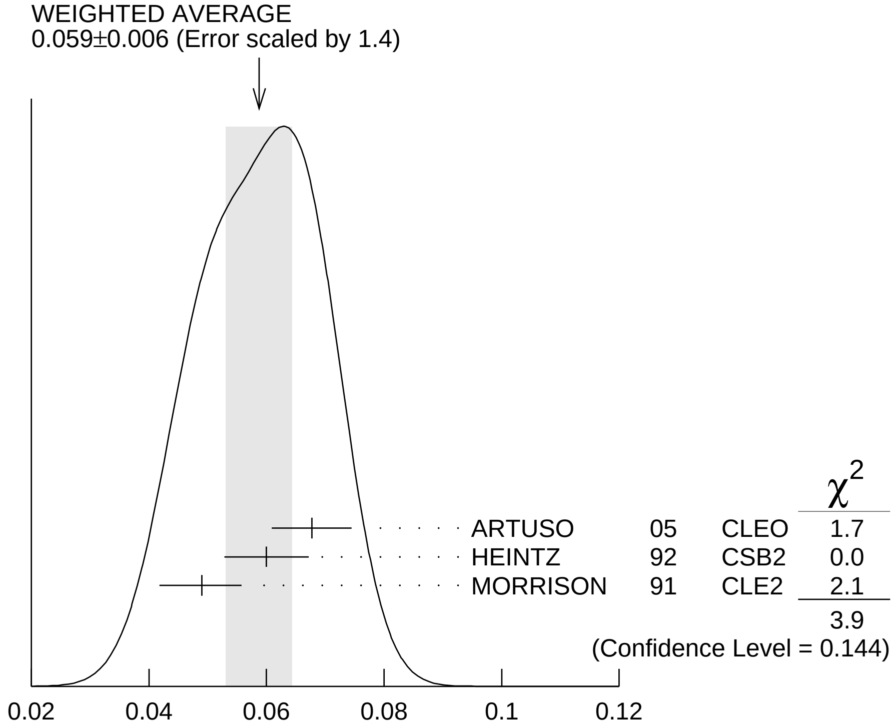
[41] Supersedes NARAIN 91.



$\Gamma(\gamma\chi_{b0}(2P))/\Gamma_{total}$ Γ_{22}/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	$e^+e^- \to \gamma X$
0.060 ±0.004 ±0.006	4959	[42] HEINTZ	92 CSB2	$e^+e^- \to \gamma X$
0.049 $^{+0.003}_{-0.004}$ ±0.006	9903	MORRISON	91 CLE2	$e^+e^- \to \gamma X$

[42] Supersedes NARAIN 91.



$\Gamma\big(\gamma \chi_{b0}(2P)\big)/\Gamma_{total}$

$\Gamma\big(\gamma \chi_{b2}(1P)\big)/\Gamma_{total}$ Γ_{23}/Γ

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
10.0±1.0 OUR AVERAGE			Error includes scale factor of 1.7.		
8.0±1.3±0.4		126	[43,44] KORNICER 11	CLEO	$e^+ e^- \rightarrow \gamma\gamma\ell^+\ell^-$
$10.5\pm0.3^{+0.7}_{-0.6}$		9.7k	LEES 11J	BABR	$\Upsilon(3S) \rightarrow X\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<19	90		[45] ASNER 08A	CLEO	$\Upsilon(3S) \rightarrow \gamma +$ hadrons
seen			[46] HEINTZ 92	CSB2	$e^+ e^- \rightarrow \gamma\gamma\ell^+\ell^-$

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

[44] KORNICER 11 reports [$\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{total}$] × [B($\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S)$)] = (1.435 ± 0.162 ± 0.169) × 10^{-3} which we divide by our best value B($\chi_{b2}(1P) \rightarrow \gamma\Upsilon(1S)$) = (18.0 ± 1.0) × 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 [$\Gamma(\Upsilon(3S) \rightarrow \gamma\chi_{b2}(1P))/\Gamma_{total}$] / [B($\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)$)] < 27.1 × 10^{-2} which we multiply by our best value B($\Upsilon(2S) \rightarrow \gamma\chi_{b2}(1P)$) = 7.15 × 10^{-2}.

[46] HEINTZ 92, while unable to distinguish between different J states, measures $\sum_J$B($\Upsilon(3S) \rightarrow \gamma\chi_{bJ}$) × B($\chi_{bJ} \rightarrow \gamma\Upsilon(1S)$) = (1.7 ± 0.4 ± 0.6) × 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 $\Upsilon(1S) \rightarrow \ell^+\ell^-$.

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

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.9±0.5 OUR AVERAGE Error includes scale factor of 1.8.						
$1.5 \pm 0.4 \pm 0.1$		50	[47,48] KORNICER	11	CLEO	$e^+ e^- \to \gamma\gamma\ell^+\ell^-$
$0.5 \pm 0.3 ^{+0.2}_{-0.1}$			LEES	11J	BABR	$\Upsilon(3S) \to X\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<1.7	90		[49] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma +$ hadrons
seen			[50] HEINTZ	92	CSB2	$e^+ e^- \to \gamma\gamma\ell^+\ell^-$

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

[48] KORNICER 11 reports $[\Gamma(\Upsilon(3S) \to \gamma\chi_{b1}(1P))/\Gamma_{total}] \times [B(\chi_{b1}(1P) \to \gamma\Upsilon(1S))] = (5.38 \pm 1.20 \pm 0.95) \times 10^{-4}$ which we divide by our best value $B(\chi_{b1}(1P) \to \gamma\Upsilon(1S)) = (35.2 \pm 2.0) \times 10^{-2}$. 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 $[\Gamma(\Upsilon(3S) \to \gamma\chi_{b1}(1P))/\Gamma_{total}] / [B(\Upsilon(2S) \to \gamma\chi_{b1}(1P))] < 2.5 \times 10^{-2}$ which we multiply by our best value $B(\Upsilon(2S) \to \gamma\chi_{b1}(1P)) = 6.9 \times 10^{-2}$.

[50] HEINTZ 92, while unable to distinguish between different J states, measures $\sum_J B(\Upsilon(3S) \to \gamma\chi_{bJ}) \times B(\chi_{bJ} \to \gamma\Upsilon(1S)) = (1.7 \pm 0.4 \pm 0.6) \times 10^{-3}$ 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 $\Upsilon(1S) \to \ell^+\ell^-$.

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

VALUE (units 10^{-2})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.27±0.04 OUR AVERAGE						
$0.27 \pm 0.04 \pm 0.02$		2.3k	LEES	11J	BABR	$\Upsilon(3S) \to X\gamma$
$0.30 \pm 0.04 \pm 0.10$		8.7k	ARTUSO	05	CLEO	$e^+ e^- \to \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.8	90		[51] ASNER	08A	CLEO	$\Upsilon(3S) \to \gamma +$ hadrons

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

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
< 6.2	90	ARTUSO	05	CLEO	$e^+ e^- \to \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<19	90	LEES	11J	BABR	$\Upsilon(3S) \to X\gamma$

$\Gamma(\gamma \eta_b(1S))/\Gamma_{total}$ Γ_{27}/Γ

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

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

<8.5	90		LEES	11J	BABR	$\Upsilon(3S) \to X\gamma$
4.8±0.5±1.2		19 ± 3k	[52,53] AUBERT	08V	BABR	$\Upsilon(3S) \to \gamma X$
<4.3	90		[54] ARTUSO	05	CLEO	$e^+e^- \to \gamma X$

[52] Assuming $\Gamma_{\eta_b(1S)}$ = 10 MeV.
[53] Systematic error re-evaluated by AUBERT 09AQ.
[54] Superseded by BONVICINI 10.

$\Gamma(\gamma A^0 \to \gamma \text{hadrons})/\Gamma_{\text{total}}$ — Γ_{28}/Γ

(0.3 GeV < m_{A^0} < 7 GeV)

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<8 × 10⁻⁵	90	[55] LEES	11H	BABR	$\Upsilon(3S) \to \gamma$ hadrons

[55] 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 1×10^{-6} to 8×10^{-5}.

$\Gamma(\gamma X \to \gamma + \geq 4 \text{ prongs})/\Gamma_{\text{total}}$ — Γ_{29}/Γ

(1.5 GeV < m_X < 5.0 GeV)

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

$\Gamma(\gamma a_1^0 \to \gamma \mu^+\mu^-)/\Gamma_{\text{total}}$ — Γ_{30}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<5.5	90	[56] AUBERT	09Z	BABR	$e^+e^- \to \gamma a_1^0 \to \gamma \mu^+\mu^-$

[56] 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 × 10^{-6}.

$\Gamma(\gamma a_1^0 \to \gamma \tau^+\tau^-)/\Gamma_{\text{total}}$ — Γ_{31}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<1.6 × 10⁻⁴	90	[57] AUBERT	09P	BABR	$e^+e^- \to \gamma a_1^0 \to \gamma \tau^+\tau^-$

[57] 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 × 10^{-5}.

LEPTON FAMILY NUMBER (*LF*) VIOLATING MODES

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

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

$\Gamma(\mu^\pm \tau^\mp)/\Gamma_{\text{total}}$ — Γ_{33}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
< 3.1	90	LEES	10B	BABR	$e^+e^- \to \mu^\pm \tau^\mp$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<20.3	95	LOVE	08A	CLEO	$e^+e^- \to \mu^\pm \tau^\mp$

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