$\Upsilon(2S)$

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

$\Upsilon(2S)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
10023.26±0.31 OUR AVERAGE				
10023.5 ±0.5	[1] ARTAMONOV	00	MD1	$e^+e^- \to$ hadrons
10023.1 ±0.4	BARBER	84	REDE	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
10023.6 ±0.5	[2,3] BARU	86B	REDE	$e^+e^- \to$ 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[3] Superseded by ARTAMONOV 00.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	$e^+e^- \to \pi^+\pi^- X$

$\Upsilon(2S)$ WIDTH

VALUE (keV)	DOCUMENT ID
31.98±2.63 OUR EVALUATION	See the Note on "Width Determinations of the Υ States"

$\Upsilon(2S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\Upsilon(1S)\pi^+\pi^-$	(17.85± 0.26) %	
Γ_2	$\Upsilon(1S)\pi^0\pi^0$	(8.6 ± 0.4) %	
Γ_3	$\tau^+\tau^-$	(2.00± 0.21) %	
Γ_4	$\mu^+\mu^-$	(1.93± 0.17) %	S=2.2
Γ_5	e^+e^-	(1.91± 0.16) %	
Γ_6	$\Upsilon(1S)\pi^0$	< 4 $\times 10^{-5}$	CL=90%
Γ_7	$\Upsilon(1S)\eta$	(2.9 ± 0.4) $\times 10^{-4}$	S=2.0
Γ_8	$J/\psi(1S)$ anything	< 6 $\times 10^{-3}$	CL=90%
Γ_9	$\overline{d}$ anything	(3.4 ± 0.6) $\times 10^{-5}$	
Γ_{10}	hadrons	(94 ±11) %	
Γ_{11}	ggg	(58.8 ± 1.2) %	
Γ_{12}	γgg	(8.8 ± 1.1) %	
Γ_{13}	ϕK^+K^-	(1.6 ± 0.4) $\times 10^{-6}$	
Γ_{14}	$\omega\pi^+\pi^-$	< 2.58 $\times 10^{-6}$	CL=90%
Γ_{15}	$K^*(892)^0 K^-\pi^+$ + c.c.	(2.3 ± 0.7) $\times 10^{-6}$	

Γ_{16}	$\phi f_2'(1525)$		< 1.33	$\times 10^{-6}$	CL=90%
Γ_{17}	$\omega f_2(1270)$		< 5.7	$\times 10^{-7}$	CL=90%
Γ_{18}	$\rho(770) a_2(1320)$		< 8.8	$\times 10^{-7}$	CL=90%
Γ_{19}	$K^*(892)^0 \overline{K}{}_2^*(1430)^0 +$ c.c.		(1.5 ± 0.6)	$\times 10^{-6}$	
Γ_{20}	$K_1(1270)^{\pm} K^{\mp}$		< 3.22	$\times 10^{-6}$	CL=90%
Γ_{21}	$K_1(1400)^{\pm} K^{\mp}$		< 8.3	$\times 10^{-7}$	CL=90%
Γ_{22}	$b_1(1235)^{\pm} \pi^{\mp}$		< 4.0	$\times 10^{-7}$	CL=90%
Γ_{23}	$\rho \pi$		< 1.16	$\times 10^{-6}$	CL=90%
Γ_{24}	$\pi^+ \pi^- \pi^0$		< 8.0	$\times 10^{-7}$	CL=90%
Γ_{25}	$\omega \pi^0$		< 1.63	$\times 10^{-6}$	CL=90%
Γ_{26}	$\pi^+ \pi^- \pi^0 \pi^0$		(1.30 ± 0.28)	$\times 10^{-5}$	
Γ_{27}	$K_S^0 K^+ \pi^- +$ c.c.		(1.14 ± 0.33)	$\times 10^{-6}$	
Γ_{28}	$K^*(892)^0 \overline{K}{}^0 +$ c.c.		< 4.22	$\times 10^{-6}$	CL=90%
Γ_{29}	$K^*(892)^- K^+ +$ c.c.		< 1.45	$\times 10^{-6}$	CL=90%
Γ_{30}	Sum of 100 exclusive modes		(2.90 ± 0.30)	$\times 10^{-3}$	

Radiative decays

Γ_{31}	$\gamma \chi_{b1}(1P)$		(6.9 ± 0.4) %		
Γ_{32}	$\gamma \chi_{b2}(1P)$		(7.15 ± 0.35) %		
Γ_{33}	$\gamma \chi_{b0}(1P)$		(3.8 ± 0.4) %		
Γ_{34}	$\gamma f_0(1710)$		< 5.9	$\times 10^{-4}$	CL=90%
Γ_{35}	$\gamma f_2'(1525)$		< 5.3	$\times 10^{-4}$	CL=90%
Γ_{36}	$\gamma f_2(1270)$		< 2.41	$\times 10^{-4}$	CL=90%
Γ_{37}	$\gamma f_J(2220)$				
Γ_{38}	$\gamma \eta_c(1S)$		< 2.7	$\times 10^{-5}$	CL=90%
Γ_{39}	$\gamma \chi_{c0}$		< 1.0	$\times 10^{-4}$	CL=90%
Γ_{40}	$\gamma \chi_{c1}$		< 3.6	$\times 10^{-6}$	CL=90%
Γ_{41}	$\gamma \chi_{c2}$		< 1.5	$\times 10^{-5}$	CL=90%
Γ_{42}	$\gamma X(3872) \to \pi^+ \pi^- J/\psi$		< 8	$\times 10^{-7}$	CL=90%
Γ_{43}	$\gamma X(3872) \to \pi^+ \pi^- \pi^0 J/\psi$		< 2.4	$\times 10^{-6}$	CL=90%
Γ_{44}	$\gamma \chi_{c0}(2P) \to \omega J/\psi$		< 2.8	$\times 10^{-6}$	CL=90%
Γ_{45}	$\gamma X(4140) \to \phi J/\psi$		< 1.2	$\times 10^{-6}$	CL=90%
Γ_{46}	$\gamma X(4350) \to \phi J/\psi$		< 1.3	$\times 10^{-6}$	CL=90%
Γ_{47}	$\gamma \eta_b(1S)$		(3.9 ± 1.5)	$\times 10^{-4}$	
Γ_{48}	$\gamma \eta_b(1S) \to \gamma$ Sum of 26 exclusive modes		< 3.7	$\times 10^{-6}$	CL=90%
Γ_{49}	$\gamma X_{b\overline{b}} \to \gamma$ Sum of 26 exclusive modes		< 4.9	$\times 10^{-6}$	CL=90%
Γ_{50}	$\gamma X \to \gamma + \geq 4$ prongs	[a]	< 1.95	$\times 10^{-4}$	CL=95%
Γ_{51}	$\gamma A^0 \to \gamma$ hadrons		< 8	$\times 10^{-5}$	CL=90%
Γ_{52}	$\gamma a_1^0 \to \gamma \mu^+ \mu^-$		< 8.3	$\times 10^{-6}$	CL=90%

Lepton Family number (*LF*) violating modes

Γ_{53}	$e^{\pm}\tau^{\mp}$	*LF*	$<$	3.2	$\times 10^{-6}$	CL=90%
Γ_{54}	$\mu^{\pm}\tau^{\mp}$	*LF*	$<$	3.3	$\times 10^{-6}$	CL=90%

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

CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 13 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2 =$ 11.8 for 11 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

x_7	2
	x_1

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

$\Gamma(\mu^+\mu^-) \times \Gamma(e^+e^-)/\Gamma_{total}$ — $\Gamma_4\Gamma_5/\Gamma$

VALUE (eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
6.5±1.5±1.0	KOBEL	92	CBAL	$e^+e^- \rightarrow \mu^+\mu^-$

$\Gamma(\Upsilon(1S)\pi^+\pi^-) \times \Gamma(e^+e^-)/\Gamma_{total}$ — $\Gamma_1\Gamma_5/\Gamma$

VALUE (eV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
105.4±1.0±4.2	11.8K	[1] AUBERT	08BP	BABR	10.58 $e^+e^- \rightarrow \gamma\pi^+\pi^-\ell^+\ell^-$

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

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{total}$ — $\Gamma_{10}\Gamma_5/\Gamma$

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.577±0.009 OUR AVERAGE				
0.581±0.004±0.009	[1] ROSNER	06	CLEO	10.0 $e^+e^- \rightarrow$ hadrons
0.552±0.031±0.017	[1] BARU	96	MD1	$e^+e^- \rightarrow$ hadrons
0.54 ±0.04 ±0.02	[1] JAKUBOWSKI	88	CBAL	$e^+e^- \rightarrow$ hadrons
0.58 ±0.03 ±0.04	[2] GILES	84B	CLEO	$e^+e^- \rightarrow$ hadrons
0.60 ±0.12 ±0.07	[2] ALBRECHT	82	DASP	$e^+e^- \rightarrow$ hadrons
0.54 ±0.07 $^{+0.09}_{-0.05}$	[2] NICZYPORUK	81C	LENA	$e^+e^- \rightarrow$ hadrons
0.41 ±0.18	[2] BOCK	80	CNTR	$e^+e^- \rightarrow$ hadrons

[1] Radiative corrections evaluated following KURAEV 85.
[2] Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

$\Upsilon(2S)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ — Γ_5

VALUE (keV)	DOCUMENT ID
0.612±0.011 OUR EVALUATION	

$\Upsilon(2S)$ BRANCHING RATIOS

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}$ — Γ_1/Γ

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
17.85±0.26 OUR FIT					
17.92±0.26 OUR AVERAGE					
16.8 ±1.1 ±1.3	906k	[1] LEES	11C	BABR	$e^+e^- \to \pi^+\pi^- X$
17.80±0.05±0.37	170k	[2] LEES	11L	BABR	$\Upsilon(2S) \to \pi^+\pi^-\mu^+\mu^-$
18.02±0.02±0.61	851k	[3] BHARI	09	CLEO	$e^+e^- \to \pi^+\pi^-$ MM
17.22±0.17±0.75	11.8K	[4] AUBERT	08BP	BABR	$e^+e^- \to \gamma\pi^+\pi^-\ell^+\ell^-$
19.2 ±0.2 ±1.0	52.6k	[5] ALEXANDER	98	CLE2	$\pi^+\pi^-\ell^+\ell^-$, $\pi^+\pi^-$ MM
18.1 ±0.5 ±1.0	11.6k	ALBRECHT	87	ARG	$e^+e^- \to \pi^+\pi^-$ MM
16.9 ±4.0		GELPHMAN	85	CBAL	$e^+e^- \to e^+e^-\pi^+\pi^-$
19.1 ±1.2 ±0.6		BESSON	84	CLEO	$\pi^+\pi^-$ MM
18.9 ±2.6		FONSECA	84	CUSB	$e^+e^- \to \ell^+\ell^-\pi^+\pi^-$
21 ±7	7	NICZYPORUK	81B	LENA	$e^+e^- \to \ell^+\ell^-\pi^+\pi^-$

[1] LEES 11C reports $[\Gamma(\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}] \times [B(\Upsilon(3S) \to \Upsilon(2S)\text{anything})] = (1.78 \pm 0.02 \pm 0.11) \times 10^{-2}$ which we divide by our best value $B(\Upsilon(3S) \to \Upsilon(2S)\text{anything}) = (10.6 \pm 0.8) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[2] Using $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.05)\%$.

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

[4] Using $B(\Upsilon(2S) \to e^+e^-) = (1.91 \pm 0.16)\%$, $B(\Upsilon(2S) \to \mu^+\mu^-) = (1.93 \pm 0.17)\%$ and, $\Gamma_{ee}(\Upsilon(2S)) = 0.612 \pm 0.011$ keV.

[5] Using $B(\Upsilon(1S) \to e^+e^-) = (2.52 \pm 0.17)\%$ and $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.07)\%$.

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{total}$ — Γ_2/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
8.6 ±0.4 OUR AVERAGE					
8.43±0.16±0.42	38k	[1] BHARI	09	CLEO	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$
9.2 ±0.6 ±0.8	275	[2] ALEXANDER	98	CLE2	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$
9.5 ±1.9 ±1.9	25	ALBRECHT	87	ARG	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$
8.0 ±1.5		GELPHMAN	85	CBAL	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$
10.3 ±2.3		FONSECA	84	CUSB	$e^+e^- \to \pi^0\pi^0\ell^+\ell^-$

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

[2] Using $B(\Upsilon(1S) \to e^+e^-) = (2.52 \pm 0.17)\%$ and $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.07)\%$.

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ — Γ_2/Γ_1

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.462 ± 0.037	[1] BHARI	09	CLEO	$e^+e^- \to \Upsilon(2S)$

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

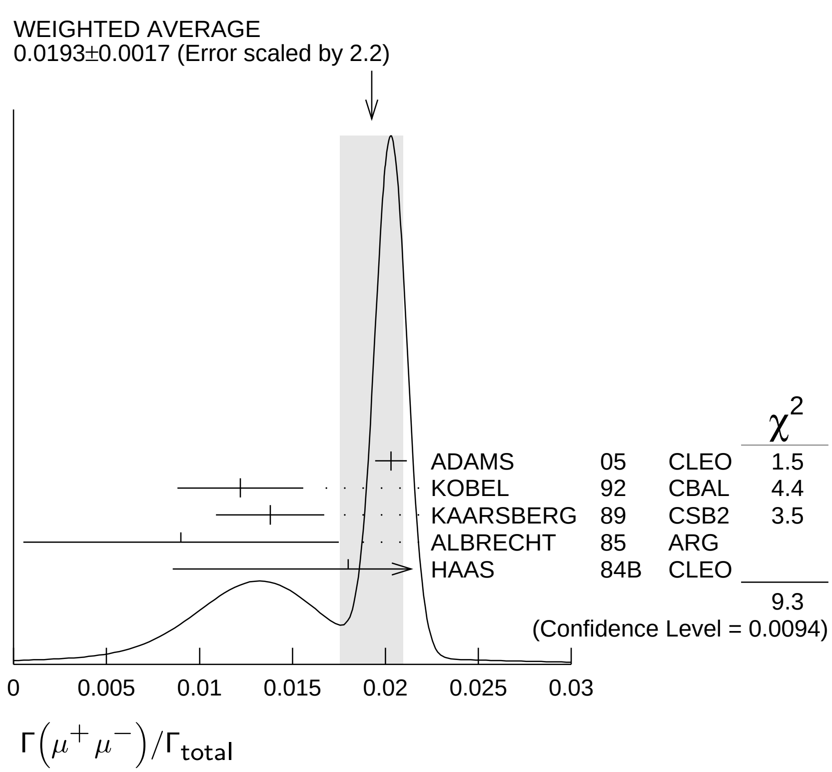
$\Gamma(\tau^+\tau^-)/\Gamma_{total}$ — Γ_3/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
2.00±0.21 OUR AVERAGE					
$2.00\pm0.12\pm0.18$	22k	[1] BESSON	07	CLEO	$e^+e^- \to \Upsilon(2S) \to \tau^+\tau^-$
$1.7\ \pm1.5\ \pm0.6$		HAAS	84B	CLEO	$e^+e^- \to \tau^+\tau^-$

[1] BESSON 07 reports $[\Gamma(\Upsilon(2S) \to \tau^+\tau^-)/\Gamma_{total}]$ / $[B(\Upsilon(2S) \to \mu^+\mu^-)] = 1.04 \pm 0.04 \pm 0.05$ which we multiply by our best value $B(\Upsilon(2S) \to \mu^+\mu^-) = (1.93 \pm 0.17) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(\mu^+\mu^-)/\Gamma_{total}$ — Γ_4/Γ

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.0193±0.0017 OUR AVERAGE Error includes scale factor of 2.2. See the ideogram below.						
$0.0203\pm0.0003\pm0.0008$		120k	ADAMS	05	CLEO	$e^+e^- \to \mu^+\mu^-$
$0.0122\pm0.0028\pm0.0019$			[1] KOBEL	92	CBAL	$e^+e^- \to \mu^+\mu^-$
$0.0138\pm0.0025\pm0.0015$			KAARSBERG	89	CSB2	$e^+e^- \to \mu^+\mu^-$
$0.009\ \pm0.006\ \pm0.006$			[2] ALBRECHT	85	ARG	$e^+e^- \to \mu^+\mu^-$
$0.018\ \pm0.008\ \pm0.005$			HAAS	84B	CLEO	$e^+e^- \to \mu^+\mu^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.038	90		NICZYPORUK	81C	LENA	$e^+e^- \to \mu^+\mu^-$



[1] Taking into account interference between the resonance and continuum.
[2] Re-evaluated using B($\Upsilon(1S) \to \mu^+\mu^-$) = 0.026.

$\Gamma(\tau^+\tau^-)/\Gamma(\mu^+\mu^-)$ — Γ_3/Γ_4

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
1.04±0.04±0.05	22k	BESSON	07	CLEO	$e^+e^- \to \Upsilon(2S)$

$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$ — Γ_6/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 4	90	[1] TAMPONI	13	BELL	$e^+e^- \to \Upsilon(1S)\pi^0$
< 18	90	[2] HE	08A	CLEO	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
<110	90	ALEXANDER	98	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
<800	90	LURZ	87	CBAL	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[1] TAMPONI 13 reports [$\Gamma(\Upsilon(2S) \to \Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$] / [B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$)] < 2.3×10^{-4} which we multiply by our best value B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$) = 17.85×10^{-2}.
[2] Authors assume B($\Upsilon(1S) \to e^+e^-$) + B($\Upsilon(1S) \to \mu^+\mu^-$) = 4.96%.

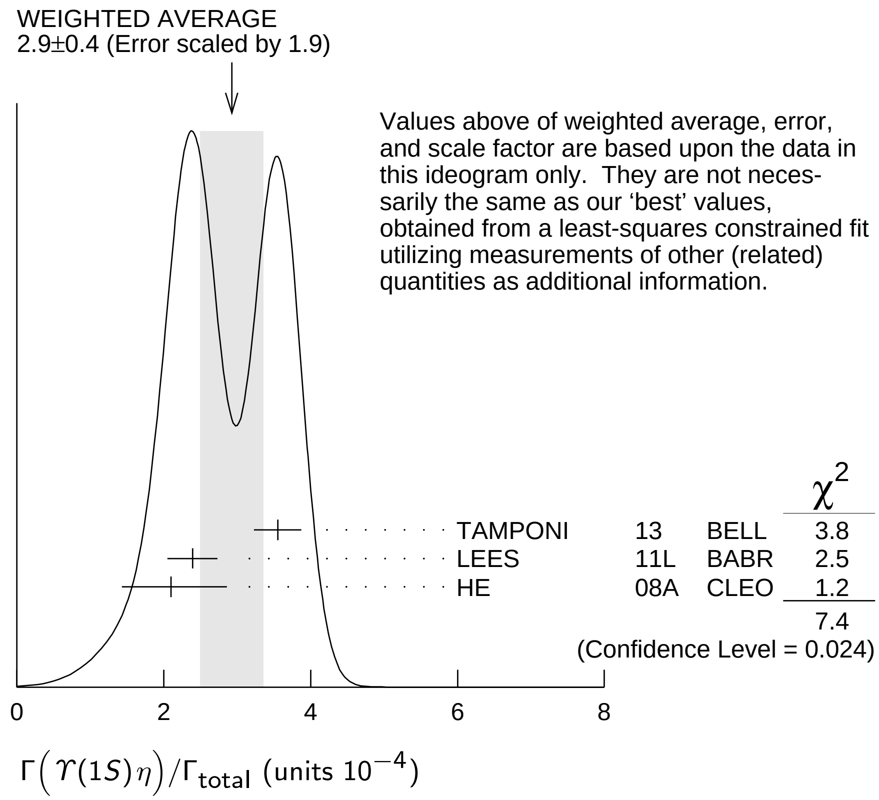
$\Gamma(\Upsilon(1S)\pi^0)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ — Γ_6/Γ_1

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<2.3	90	TAMPONI	13	BELL	$e^+e^- \to \Upsilon(1S)\pi^0$

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$ — Γ_7/Γ

VALUE (units 10^{-4})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
2.9 ±0.4 OUR FIT Error includes scale factor of 2.0.						
2.9 ±0.4 OUR AVERAGE Error includes scale factor of 1.9. See the ideogram below.						
2.39±0.31±0.14		112	[1] LEES	11L	BABR	$\Upsilon(2S) \to \ell^+\ell^-\eta$
2.1 $^{+0.7}_{-0.6}$ ±0.3		14	[2] HE	08A	CLEO	$e^+e^- \to \ell^+\ell^-\eta$
• • • We use the following data for averages but not for fits. • • •						
3.55±0.32±0.05		241	[3] TAMPONI	13	BELL	$e^+e^- \to \Upsilon(1S)\eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 9	90		[1,4] AUBERT	08BP	BABR	$e^+e^- \to \gamma\pi^+\pi^-\pi^0\ell^+\ell^-$
< 28	90		ALEXANDER	98	CLE2	$e^+e^- \to \ell^+\ell^-\eta$
< 50	90		ALBRECHT	87	ARG	$e^+e^- \to \pi^+\pi^-\ell^+\ell^-$ MM
< 70	90		LURZ	87	CBAL	$e^+e^- \to \ell^+\ell^-(\gamma\gamma, 3\pi^0)$
< 100	90		BESSON	84	CLEO	$e^+e^- \to \pi^+\pi^-\ell^+\ell^-$ MM
< 20	90		FONSECA	84	CUSB	$e^+e^- \to \ell^+\ell^-(\gamma\gamma,\pi^+\pi^-\pi^0)$

[1] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)% and B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%.
[2] Authors assume B($\Upsilon(1S) \to e^+e^-$) + B($\Upsilon(1S) \to \mu^+\mu^-$) = 4.96%.
[3] TAMPONI 13 reports [$\Gamma(\Upsilon(2S) \to \Upsilon(1S)\eta)/\Gamma_{\text{total}}$] / [B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$)] = $(1.99 \pm 0.14 \pm 0.11) \times 10^{-3}$ which we multiply by our best value B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$) = $(17.85 \pm 0.26) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.
[4] Using $\Gamma_{ee}(\Upsilon(2S))$ = 0.612 ± 0.011 keV.



$\Gamma\big(\Upsilon(1S)\eta\big)/\Gamma\big(\Upsilon(1S)\pi^+\pi^-\big)$ Γ_7/Γ_1

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
1.64±0.25 OUR FIT		Error includes scale factor of 2.0.				
1.99±0.14±0.11		241	TAMPONI	13	BELL	$e^+e^- \to \Upsilon(1S)\eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1.35±0.17±0.08			[1] LEES	11L	BABR	$\Upsilon(2S) \to (\pi^+\pi^-)(\gamma\gamma)\mu^+\mu^-$
< 5.2	90		[2] AUBERT	08BP	BABR	$e^+e^- \to \gamma\pi^+\pi^-(\pi^0)\ell^+\ell^-$

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

$\Gamma\big(\Upsilon(1S)\pi^0\big)/\Gamma\big(\Upsilon(1S)\eta\big)$ Γ_6/Γ_7

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.13	90	TAMPONI	13	BELL	$e^+e^- \to \Upsilon(1S)\pi^0$

$\Gamma\big(J/\psi(1S)\text{ anything}\big)/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.006	90	MASCHMANN	90	CBAL	$e^+e^- \to$ hadrons

$\Gamma\big(\overline{d}\text{ anything}\big)/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	COMMENT
3.37±0.50±0.25	58	ASNER	07	CLEO	$e^+e^- \to \overline{d}X$

$\Gamma(ggg)/\Gamma_{total}$ — Γ_{11}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
58.8±1.2	6M	[1] BESSON	06A	CLEO	$\Upsilon(2S) \to$ hadrons

[1] Calculated using the value $\Gamma(\gamma g g)/\Gamma(g g g)$ = (3.18 ± 0.04 ± 0.22 ± 0.41)% from BESSON 06A and PDG 08 values of B($\pi^+\pi^-\Upsilon(1S)$) = (18.1 ± 0.4)%, B($\pi^0\pi^0\Upsilon(1S)$) = (8.6 ± 0.4)%, B($\mu^+\mu^-$) = (1.93 ± 0.17)%, and $R_{hadrons}$ = 3.51. The statistical error is negligible and the systematic error is partially correlated with that of $\Gamma(\gamma g g)/\Gamma_{total}$ measurement of BESSON 06A.

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

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	COMMENT
1.58±0.33±0.18	58	SHEN	12A	BELL	$\Upsilon(1S) \to 2(K^+K^-)$

$\Gamma(\omega\pi^+\pi^-)/\Gamma_{total}$ — Γ_{14}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<2.58	90	SHEN	12A	BELL	$\Upsilon(1S) \to 2(\pi^+\pi^-)\pi^0$

$\Gamma(K^*(892)^0 K^- \pi^+ + c.c.)/\Gamma_{total}$ — Γ_{15}/Γ

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	COMMENT
2.32±0.40±0.54	135	SHEN	12A	BELL	$\Upsilon(1S) \to K^+K^-\pi^+\pi^-$

$\Gamma(\phi f'_2(1525))/\Gamma_{total}$ — Γ_{16}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.33	90	SHEN	12A	BELL	$\Upsilon(1S) \to 2(K^+K^-)$

$\Gamma(\omega f_2(1270))/\Gamma_{total}$ — Γ_{17}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<0.57	90	SHEN	12A	BELL	$\Upsilon(1S) \to 2(\pi^+\pi^-)\pi^0$

$\Gamma(\rho(770) a_2(1320))/\Gamma_{total}$ — Γ_{18}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<0.88	90	SHEN	12A	BELL	$\Upsilon(1S) \to 2(\pi^+\pi^-)\pi^0$

$\Gamma(K^*(892)^0 \overline{K}^*_2(1430)^0 + c.c.)/\Gamma_{total}$ — Γ_{19}/Γ

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	COMMENT
1.53±0.52±0.19	32	SHEN	12A	BELL	$\Upsilon(1S) \to K^+K^-\pi^+\pi^-$

$\Gamma(K_1(1270)^{\pm} K^{\mp})/\Gamma_{total}$ — Γ_{20}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<3.22	90	SHEN	12A	BELL	$\Upsilon(1S) \to K^+K^-\pi^+\pi^-$

$\Gamma(K_1(1400)^{\pm} K^{\mp})/\Gamma_{total}$ — Γ_{21}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<0.83	90	SHEN	12A	BELL	$\Upsilon(1S) \to K^+K^-\pi^+\pi^-$

$\Gamma(b_1(1235)^{\pm}\pi^{\mp})/\Gamma_{total}$ — Γ_{22}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<0.40	90	SHEN	12A	BELL	$\Upsilon(1S) \to 2(\pi^+\pi^-)\pi^0$

$\Gamma(\gamma g g)/\Gamma_{total}$ — Γ_{12}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
8.79±1.05	100k	[1] BESSON	06A	CLEO	$\Upsilon(2S) \to \gamma +$ hadrons

[1] Calculated using BESSON 06A values of $\Gamma(\gamma g g)/\Gamma(g g g) = (3.18 \pm 0.04 \pm 0.22 \pm 0.41)\%$ and $\Gamma(g g g)/\Gamma_{total}$. The statistical error is negligible and the systematic error is partially correlated with that of $\Gamma(g g g)/\Gamma_{total}$ measurement of BESSON 06A.

$\Gamma(\gamma g g)/\Gamma(g g g)$ — Γ_{12}/Γ_{11}

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
3.18±0.04±0.47	6M	BESSON	06A	CLEO	$\Upsilon(2S) \to (\gamma +)$ hadrons

$\Gamma(\rho\pi)/\Gamma_{total}$ — Γ_{23}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.16	90	SHEN	13	BELL	$\Upsilon(2S) \to \pi^+\pi^-\pi^0$

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{total}$ — Γ_{24}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<0.80	90	SHEN	13	BELL	$\Upsilon(2S) \to \pi^+\pi^-\pi^0$

$\Gamma(\omega\pi^0)/\Gamma_{total}$ — Γ_{25}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.63	90	SHEN	13	BELL	$\Upsilon(2S) \to \pi^+\pi^-\pi^0\pi^0$

$\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma_{total}$ — Γ_{26}/Γ

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	COMMENT
13.0±1.9±2.1	261 ± 37	SHEN	13	BELL	$\Upsilon(2S) \to \pi^+\pi^-\pi^0\pi^0$

$\Gamma(K^0_S K^+\pi^- + c.c.)/\Gamma_{total}$ — Γ_{27}/Γ

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
1.14±0.30±0.13		40 ± 10	SHEN	13	BELL	$\Upsilon(2S) \to K^0_S K^-\pi^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<3.2	90		[1] DOBBS	12A		$\Upsilon(2S) \to K^0_S K^-\pi^+$

[1] Obtained by analyzing CLEO III data but not authored by the CLEO Collaboration.

$\Gamma(K^*(892)^0\overline{K}^0 + c.c.)/\Gamma_{total}$ — Γ_{28}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<4.22	90	SHEN	13	BELL	$\Upsilon(2S) \to K^0_S K^-\pi^+$

$\Gamma(K^*(892)^- K^+ + c.c.)/\Gamma_{total}$ — Γ_{29}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.45	90	SHEN	13	BELL	$\Upsilon(2S) \to K^0_S K^-\pi^+$

Γ(Sum of 100 exclusive modes)/Γ_{total} — Γ_{30}/Γ

VALUE (units 10^{-2})	DOCUMENT ID		COMMENT
0.29±0.03	[1,2] DOBBS	12A	$\Upsilon(2S) \to$ hadrons

[1] DOBBS 12A presents individual exclusive branching fractions or upper limits for 100 modes of four to ten pions, kaons, or protons.

[2] Obtained by analyzing CLEO III data but not authored by the CLEO Collaboration.

$\Gamma(\gamma\chi_{b1}(1P))/\Gamma_{total}$ — Γ_{31}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.069 ±0.004 OUR AVERAGE					
0.0693±0.0012±0.0041	407k	ARTUSO	05	CLEO	$e^+e^- \to \gamma X$
0.069 ±0.005 ±0.009		EDWARDS	99	CLE2	$\Upsilon(2S) \to \gamma\chi(1P)$
0.091 ±0.018 ±0.022		ALBRECHT	85E	ARG	$e^+e^- \to \gamma$conv. X
0.065 ±0.007 ±0.012		NERNST	85	CBAL	$e^+e^- \to \gamma$X
0.080 ±0.017 ±0.016		HAAS	84	CLEO	$e^+e^- \to \gamma$conv. X
0.059 ±0.014		KLOPFEN...	83	CUSB	$e^+e^- \to \gamma$X

$\Gamma(\gamma\chi_{b2}(1P))/\Gamma_{total}$ — Γ_{32}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0715±0.0035 OUR AVERAGE					
0.0724±0.0011±0.0040	410k	ARTUSO	05	CLEO	$e^+e^- \to \gamma X$
0.074 ±0.005 ±0.008		EDWARDS	99	CLE2	$\Upsilon(2S) \to \gamma\chi(1P)$
0.098 ±0.021 ±0.024		ALBRECHT	85E	ARG	$e^+e^- \to \gamma$conv. X
0.058 ±0.007 ±0.010		NERNST	85	CBAL	$e^+e^- \to \gamma$X
0.102 ±0.018 ±0.021		HAAS	84	CLEO	$e^+e^- \to \gamma$conv. X
0.061 ±0.014		KLOPFEN...	83	CUSB	$e^+e^- \to \gamma$X

$\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{total}$ — Γ_{33}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.038 ±0.004 OUR AVERAGE					
0.0375±0.0012±0.0047	198k	ARTUSO	05	CLEO	$e^+e^- \to \gamma X$
0.034 ±0.005 ±0.006		EDWARDS	99	CLE2	$\Upsilon(2S) \to \gamma\chi(1P)$
0.064 ±0.014 ±0.016		ALBRECHT	85E	ARG	$e^+e^- \to \gamma$conv. X
0.036 ±0.008 ±0.009		NERNST	85	CBAL	$e^+e^- \to \gamma$X
0.044 ±0.023 ±0.009		HAAS	84	CLEO	$e^+e^- \to \gamma$conv. X
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.035 ±0.014		KLOPFEN...	83	CUSB	$e^+e^- \to \gamma$X

$\Gamma(\gamma f_0(1710))/\Gamma_{total}$ — Γ_{34}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<59	90	[1] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 5.9	90	[2] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma\pi^+\pi^-$

[1] Re-evaluated assuming B($f_0(1710) \to K^+K^-$) = 0.19.

[2] Includes unknown branching ratio of $f_0(1710) \to \pi^+\pi^-$.

$\Gamma(\gamma f_2'(1525))/\Gamma_{total}$ — Γ_{35}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<53	90	[1] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma K^+ K^-$

[1] Re-evaluated assuming B($f_2'(1525) \to K\overline{K}$) = 0.71.

$\Gamma(\gamma f_2(1270))/\Gamma_{total}$ — Γ_{36}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<24.1	90	[1] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma \pi^+ \pi^-$

[1] Using B($f_2(1270) \to \pi\pi$) = 0.84.

$\Gamma(\gamma f_J(2220))/\Gamma_{total}$ — Γ_{37}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<6.8	90	[1] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma K^+ K^-$

[1] Includes unknown branching ratio of $f_J(2220) \to K^+ K^-$.

$\Gamma(\gamma \eta_c(1S))/\Gamma_{total}$ — Γ_{38}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<2.7 \times 10^{-5}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma \chi_{c0})/\Gamma_{total}$ — Γ_{39}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.0 \times 10^{-4}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma \chi_{c1})/\Gamma_{total}$ — Γ_{40}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<3.6 \times 10^{-6}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma \chi_{c2})/\Gamma_{total}$ — Γ_{41}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.5 \times 10^{-5}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma X(3872) \to \pi^+ \pi^- J/\psi)/\Gamma_{total}$ — Γ_{42}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<0.8 \times 10^{-6}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma X(3872) \to \pi^+ \pi^- \pi^0 J/\psi)/\Gamma_{total}$ — Γ_{43}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<2.4 \times 10^{-6}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma \chi_{c0}(2P) \to \omega J/\psi)/\Gamma_{total}$ — Γ_{44}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<2.8 \times 10^{-6}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma X(4140) \to \phi J/\psi)/\Gamma_{total}$ — Γ_{45}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<1.2 \times 10^{-6}$	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma X(4350) \to \phi J/\psi)/\Gamma_{total}$ — Γ_{46}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<1.3 × 10⁻⁶	90	WANG	11B	BELL	$\Upsilon(2S) \to \gamma X$

$\Gamma(\gamma \eta_b(1S))/\Gamma_{total}$ — Γ_{47}/Γ

VALUE (units 10^{-4})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
$3.9 \pm 1.1^{+1.1}_{-0.9}$		13 ± 5k	[1] AUBERT	09AQ	BABR	$\Upsilon(2S) \to \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<21	90		LEES	11J	BABR	$\Upsilon(2S) \to X\gamma$
< 8.4	90		[1] BONVICINI	10	CLEO	$\Upsilon(2S) \to \gamma X$
< 5.1	90		[2] ARTUSO	05	CLEO	$e^+e^- \to \gamma X$

[1] Assuming $\Gamma_{\eta_b(1S)} = 10$ MeV.
[2] Superseded by BONVICINI 10.

$\Gamma(\gamma \eta_b(1S) \to \gamma \text{Sum of 26 exclusive modes})/\Gamma_{total}$ — Γ_{48}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<3.7 × 10⁻⁶	90	SANDILYA	13	BELL	$\Upsilon(2S) \to \gamma$ hadrons

$\Gamma(\gamma X_{b\bar{b}} \to \gamma \text{Sum of 26 exclusive modes})/\Gamma_{total}$ — Γ_{49}/Γ

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 4.9	90		SANDILYA	13	BELL	$\Upsilon(2S) \to \gamma$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$46.2^{+29.7}_{-14.2} \pm 10.6$		10	[1] DOBBS	12		$\Upsilon(2S) \to \gamma$ hadrons

[1] Obtained by analyzing CLEO III data but not authored by the CLEO Collaboration.

$\Gamma(\gamma X \to \gamma + \geq 4 \text{ prongs})/\Gamma_{total}$ — Γ_{50}/Γ

(1.5 GeV $< m_X <$ 5.0 GeV)

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.95	95	ROSNER	07A	CLEO	$e^+e^- \to \gamma X$

$\Gamma(\gamma A^0 \to \gamma \text{hadrons})/\Gamma_{total}$ — Γ_{51}/Γ

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<8 × 10⁻⁵	90	[1] LEES	11H	BABR	$\Upsilon(2S) \to \gamma$ hadrons

[1] 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}.

$\Gamma(\gamma a_1^0 \to \gamma \mu^+ \mu^-)/\Gamma_{total}$ — Γ_{52}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<8.3	90	[1] AUBERT	09Z	BABR	$e^+e^- \to \gamma a_1^0 \to \gamma \mu^+ \mu^-$

[1] 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 0.26–8.3 $\times 10^{-6}$.

LEPTON FAMILY NUMBER (*LF*) VIOLATING MODES

$\Gamma(e^\pm\tau^\mp)/\Gamma_{total}$ — Γ_{53}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<3.2	90	LEES	10B	BABR	$e^+e^- \to e^\pm\tau^\mp$

$\Gamma(\mu^\pm\tau^\mp)/\Gamma_{total}$ — Γ_{54}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
< 3.3	90	LEES	10B	BABR	$e^+e^- \to \mu^\pm\tau^\mp$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<14.4	95	LOVE	08A	CLEO	$e^+e^- \to \mu^\pm\tau^\mp$

$\Upsilon(2S)$ Cross-Particle Branching Ratios

$B(\Upsilon(2S) \to \pi^+\pi^-) \times B(\Upsilon(3S) \to \Upsilon(2S)X)$

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
1.78±0.02±0.11	906k	LEES	11C	BABR	$e^+e^- \to \pi^+\pi^- X$

$\Upsilon(2S)$ REFERENCES

SANDILYA	13	PRL 111 112001	S. Sandilya *et al.*	(BELLE Collab.)
SHEN	13	PR D88 011102	C.P. Shen *et al.*	(BELLE Collab.)
TAMPONI	13	PR D87 011104	U. Tamponi *et al.*	(BELLE Collab.)
DOBBS	12	PRL 109 082001	S. Dobbs *et al.*	
DOBBS	12A	PR D86 052003	S. Dobbs *et al.*	
SHEN	12A	PR D86 031102	C.P. Shen *et al.*	(BELLE Collab.)
LEES	11C	PR D84 011104	J.P. Lees *et al.*	(BABAR Collab.)
LEES	11H	PRL 107 221803	J.P. Lees *et al.*	(BABAR Collab.)
LEES	11J	PR D84 072002	J.P. Lees *et al.*	(BABAR Collab.)
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WANG	11B	PR D84 071107	X.L. Wang *et al.*	(BELLE Collab.)
BONVICINI	10	PR D81 031104	G. Bonvicini *et al.*	(CLEO Collab.)
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BHARI	09	PR D79 011103	S.R. Bhari *et al.*	(CLEO Collab.)
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HE	08A	PRL 101 192001	Q. He *et al.*	(CLEO Collab.)
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PDG	08	PL B667 1	C. Amsler *et al.*	(PDG Collab.)
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BESSON	07	PRL 98 052002	D. Besson *et al.*	(CLEO Collab.)
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ALEXANDER	98	PR D58 052004	J.P. Alexander *et al.*	(CLEO Collab.)
BARU	96	PRPL 267 71	S.E. Baru *et al.*	(NOVO)
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MASCHMANN	90	ZPHY C46 555	W.S. Maschmann *et al.*	(Crystal Ball Collab.)
ALBRECHT	89	ZPHY C42 349	H. Albrecht *et al.*	(ARGUS Collab.)
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BARU	86B	ZPHY C32 622 (erratum)	S.E. Baru *et al.*	(NOVO)
ALBRECHT	85	ZPHY C28 45	H. Albrecht *et al.*	(ARGUS Collab.)
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NERNST	85	PRL 54 2195	R. Nernst *et al.*	(Crystal Ball Collab.)
ARTAMONOV	84	PL 137B 272	A.S. Artamonov *et al.*	(NOVO)
BARBER	84	PL 135B 498	D.P. Barber *et al.*	(DESY, ARGUS Collab.+)
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