Review of Particle Physics: R.M. Barnett *et al.* (Particle Data Group), Phys. Rev. **D54**, 1 (1996)

$\Upsilon(2S)$

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

$\Upsilon(2S)$ MASS

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
10.02330±0.00031 OUR AVERAGE				
10.0236 ±0.0005	[1] BARU	86B	REDE	$e^+e^- \to$ hadrons
10.0231 ±0.0004	BARBER	84	REDE	$e^+e^- \to$ hadrons

[1] Reanalysis of ARTAMONOV 84.

$\Upsilon(2S)$ WIDTH

VALUE (keV)	*DOCUMENT ID*
44±7 OUR EVALUATION	See Υ mini-review.

$\Upsilon(2S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\Upsilon(1S)\pi^+\pi^-$	(18.5 ±0.8) %	
Γ_2	$\Upsilon(1S)\pi^0\pi^0$	(8.8 ±1.1) %	
Γ_3	$\tau^+\tau^-$	(1.7 ±1.6) %	
Γ_4	$\mu^+\mu^-$	(1.31±0.21) %	
Γ_5	e^+e^-	seen	
Γ_6	$\Upsilon(1S)\pi^0$	$< 8 \times 10^{-3}$	90%
Γ_7	$\Upsilon(1S)\eta$	$< 2 \times 10^{-3}$	90%
Γ_8	$J/\psi(1S)$anything	$< 6 \times 10^{-3}$	90%
	Radiative decays		
Γ_9	$\gamma\chi_{b1}(1P)$	(6.7 ±0.9) %	
Γ_{10}	$\gamma\chi_{b2}(1P)$	(6.6 ±0.9) %	
Γ_{11}	$\gamma\chi_{b0}(1P)$	(4.3 ±1.0) %	
Γ_{12}	$\gamma f_J(1710)$	$< 5.9 \times 10^{-4}$	90%
Γ_{13}	$\gamma f'_2(1525)$	$< 5.3 \times 10^{-4}$	90%
Γ_{14}	$\gamma f_2(1270)$	$< 2.41 \times 10^{-4}$	90%
Γ_{15}	$\gamma f_J(2220)$		

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

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

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

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ — $\Gamma_0\Gamma_5/\Gamma$

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.553±0.023 OUR AVERAGE				
0.552±0.031±0.017	[2] BARU	96	MD1	$e^+e^- \to$ hadrons
0.54 ±0.04 ±0.02	[2] JAKUBOWSKI	88	CBAL	$e^+e^- \to$ hadrons
0.58 ±0.03 ±0.04	[3] GILES	84B	CLEO	$e^+e^- \to$ hadrons
0.60 ±0.12 ±0.07	[3] ALBRECHT	82	DASP	$e^+e^- \to$ hadrons
0.54 ±0.07 $^{+0.09}_{-0.05}$	[3] NICZYPORUK	81C	LENA	$e^+e^- \to$ hadrons
0.41 ±0.18	[3] BOCK	80	CNTR	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.59 ±0.03 ±0.05	[3] TUTS	83	CUSB	$e^+e^- \to$ hadrons

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

$\Upsilon(2S)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ — Γ_5

VALUE (keV)	DOCUMENT ID	TECN	COMMENT
0.52 ±0.03 OUR ESTIMATE			
0.52 ±0.03 ±0.01	[4] ALBRECHT 95E	ARG	$e^+e^- \rightarrow$ hadrons

[4] Applying the formula of Kuraev and Fadin.

$\Upsilon(2S)$ BRANCHING RATIOS

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

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

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.185±0.008 OUR AVERAGE				
0.181±0.005±0.010	11.6k	ALBRECHT 87	ARG	$e^+e^- \rightarrow \pi^+\pi^-$ MM
0.169±0.040		GELPHMAN 85	CBAL	$e^+e^- \rightarrow e^+e^-\pi^+\pi^-$
0.191±0.012±0.006		BESSON 84	CLEO	$\pi^+\pi^-$ MM
0.189±0.026		FONSECA 84	CUSB	$e^+e^- \rightarrow \ell^+\ell^-\pi^+\pi^-$
0.21 ±0.07	7	NICZYPORUK 81B	LENA	$e^+e^- \rightarrow \ell^+\ell^-\pi^+\pi^-$

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.088±0.011 OUR AVERAGE				
0.095±0.019±0.019	25	ALBRECHT 87	ARG	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
0.080±0.015		GELPHMAN 85	CBAL	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$
0.103±0.023		FONSECA 84	CUSB	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$

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

VALUE	DOCUMENT ID	TECN	COMMENT
0.017±0.015±0.006	HAAS 84B	CLEO	$e^+e^- \rightarrow \tau^+\tau^-$

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
0.0131±0.0021 OUR AVERAGE				
0.0122±0.0028±0.0019		[5] KOBEL 92	CBAL	$e^+e^- \rightarrow \mu^+\mu^-$
0.0138±0.0025±0.0015		KAARSBERG 89	CSB2	$e^+e^- \rightarrow \mu^+\mu^-$
0.009 ±0.006 ±0.006		[6] ALBRECHT 85	ARG	$e^+e^- \rightarrow \mu^+\mu^-$
0.018 ±0.008 ±0.005		HAAS 84B	CLEO	$e^+e^- \rightarrow \mu^+\mu^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.038	90	NICZYPORUK 81C	LENA	$e^+e^- \rightarrow \mu^+\mu^-$

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

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.008	90	LURZ 87	CBAL	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.002	90	FONSECA 84	CUSB	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.005	90	ALBRECHT 87	ARG	$e^+e^- \rightarrow \pi^+\pi^-\ell^+\ell^-$ MM
<0.007	90	LURZ 87	CBAL	$e^+e^- \rightarrow \ell^+\ell^-(\gamma\gamma, 3\pi^0)$
<0.010	90	BESSON 84	CLEO	

$\Gamma(\gamma\chi_{b1}(1P))/\Gamma_{\text{total}}$ — Γ_9/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.067±0.009 OUR AVERAGE				
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	$e^+e^- \to \gamma X$

$\Gamma(\gamma\chi_{b2}(1P))/\Gamma_{\text{total}}$ — Γ_{10}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.066±0.009 OUR AVERAGE				
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	$e^+e^- \to \gamma X$

$\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{\text{total}}$ — Γ_{11}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.043±0.010 OUR AVERAGE				
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	$e^+e^- \to \gamma X$

$\Gamma(\gamma f_J(1710))/\Gamma_{\text{total}}$ — Γ_{12}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<59	90	[7] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 5.9	90	[8] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma\pi^+\pi^-$

[7] Re-evaluated assuming B($f_J(1710) \to K^+K^-$) = 0.19.
[8] Includes unknown branching ratio of $f_J(1710) \to \pi^+\pi^-$.

$\Gamma(\gamma f_2'(1525))/\Gamma_{\text{total}}$ — Γ_{13}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<53	90	[9] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma K^+K^-$

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

$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$ — Γ_{14}/Γ

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

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

$\Gamma(\gamma f_J(2220))/\Gamma_{\text{total}}$ — Γ_{15}/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	[11] ALBRECHT	89	ARG	$\Upsilon(2S) \to \gamma K^+K^-$

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

$\Upsilon(2S)$ REFERENCES

BARU	96	PRPL 267 71	+Blinov, Blinov, Bondar+	(NOVO)
ALBRECHT	95E	ZPHY C65 619	+Hamacher+	(ARGUS Collab.)
KOBEL	92	ZPHY C53 193	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
MASCHMANN	90	ZPHY C46 555	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
ALBRECHT	89	ZPHY C42 349	+Boeckmann, Glaeser, Harder+	(ARGUS Collab.)
KAARSBERG	89	PRL 62 2077	+Heintz+	(CUSB Collab.)
BUCHMUEL...	88	HE e^+e^- Physics 412	Buchmueller, Cooper	(HANN, DESY, MIT)
		Editors: A. Ali and P. Soeding, World Scientific, Singapore		
JAKUBOWSKI	88	ZPHY C40 49	+Antreasyan, Bartels+	(Crystal Ball Collab.)IGJPC
ALBRECHT	87	ZPHY C35 283	+Binder, Boeckmann, Glaeser+	(ARGUS Collab.)
LURZ	87	ZPHY C36 383	+Antreasyan, Besset+	(Crystal Ball Collab.)
BARU	86B	ZPHY C32 622	+Blinov, Bondar, Bukin+	(NOVO)
ALBRECHT	85	ZPHY C28 45	+Dreschell, Heller+	(ARGUS Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS Collab.)
GELPHMAN	85	PR D11 2893	+Lurz, Antreasyan+	(Crystal Ball Collab.)
KURAEV	85	SJNP 41 466	+Fadin	(NOVO)
		Translated from YAF 41 733.		

NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball Collab.)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
BARBER	84	PL 135B 498	+	(DESY, ARGUS Collab., Crystal Ball Collab.)
BESSON	84	PR D30 1433	+Green, Hicks, Namjoshi, Sannes+	(CLEO Collab.)
FONSECA	84	NP B242 31	+Mageras, Son, Dietl, Eigen+	(CUSB Collab.)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
HAAS	84B	PR D30 1996	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB Collab.)
TUTS	83	Cornell Conf. 284		(CUSB Collab.)
ALBRECHT	82	PL 116B 383	+Hofmann+	(DESY, DORT, HEIDH, LUND, ITEP)
NICZYPORUK	81B	PL 100B 95	+Chen, Folger, Lurz+	(LENA Collab.)
NICZYPORUK	81C	PL 99B 169	+Chen, Vogel, Wegener+	(LENA Collab.)
BOCK	80	ZPHY C6 125	+Blanar, Blum+	(HEIDP, MPIM, DESY, HAMB)

OTHER RELATED PAPERS

ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)
COOPER	86	Berkeley Conf. 67		(MIT)
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	84	PL 134B 137	+Drescher, Heller+	(ARGUS Collab.)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
ANDREWS	83	PRL 50 807	+Avery, Berkelman, Cassel+	(CLEO Collab.)
GREEN	82	PRL 49 617	+Sannes, Skubic, Snyder+	(CLEO Collab.)
BIENLEIN	78	PL 78B 360	+Glawe, Bock, Blanar+	(DESY, HAMB, HEIDP, MPIM)
DARDEN	78	PL 76B 246	+Hofmann, Schubert+	(DESY, DORT, HEIDH, LUND)
KAPLAN	78	PRL 40 435	+Appel, Herb, Hom+	(STON, FNAL, COLU)
YOH	78	PRL 41 684	+Herb, Hom, Lederman+	(COLU, FNAL, STON)
COBB	77	PL 72B 273	+Iwata, Fabjan+	(BNL, CERN, SYRA, YALE)
HERB	77	PRL 39 252	+Hom, Lederman, Appel, Ito+	(COLU, FNAL, STON)
INNES	77	PRL 39 1240	+Appel, Brown, Herb, Hom+	(COLU, FNAL, STON)