$b\overline{b}$ MESONS

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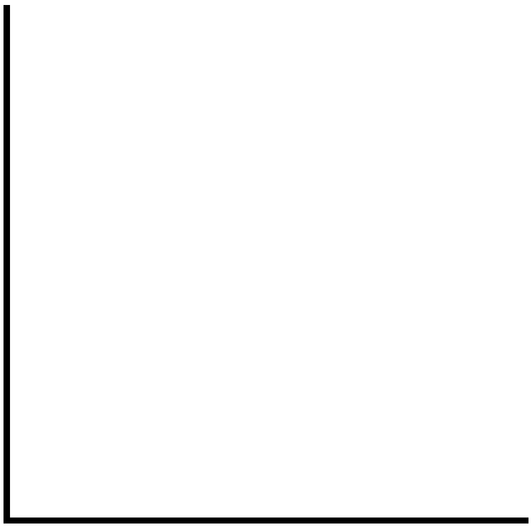
$\Upsilon(1S)$ or $\Upsilon(9460)$

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

$\Upsilon(1S)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
9460.37±0.21 OUR AVERAGE	Error includes scale factor of 2.7. See the ideogram below.			
9460.60±0.09±0.05	[1] BARU	92B	REDE	$e^+e^- \rightarrow$ hadrons
9460.6 ±0.4	[2] ARTAMONOV	84	REDE	$e^+e^- \rightarrow$ hadrons
9459.97±0.11±0.07	MACKAY	84	REDE	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
9460.59±0.12	BARU	86	REDE	$e^+e^- \rightarrow$ hadrons

[1] Superseding BARU 86.
[2] Value includes data of ARTAMONOV 82.



$\Upsilon(1S)$ mass (MeV)

$\Upsilon(1S)$ WIDTH

VALUE (keV)	*DOCUMENT ID*
52.5±1.8 OUR EVALUATION	See Υ mini-review.

$\Upsilon(1S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\tau^+\tau^-$	$(2.67^{+0.14}_{-0.16})$ %	
Γ_2	e^+e^-	(2.52 ± 0.17) %	
Γ_3	$\mu^+\mu^-$	(2.48 ± 0.07) %	S=1.1

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)

Hadronic decays

Γ_4	$J/\psi(1S)$anything	$(1.1 \pm 0.4) \times 10^{-3}$	
Γ_5	$\rho\pi$	$< 2 \times 10^{-4}$	CL=90%
Γ_6	$\pi^+\pi^-$	$< 5 \times 10^{-4}$	CL=90%
Γ_7	K^+K^-	$< 5 \times 10^{-4}$	CL=90%
Γ_8	$p\overline{p}$	$< 9 \times 10^{-4}$	CL=90%

Radiative decays

Γ_9	$\gamma 2h^+ 2h^-$	$(7.0 \pm 1.5) \times 10^{-4}$	
Γ_{10}	$\gamma 3h^+ 3h^-$	$(5.4 \pm 2.0) \times 10^{-4}$	
Γ_{11}	$\gamma 4h^+ 4h^-$	$(7.4 \pm 3.5) \times 10^{-4}$	
Γ_{12}	$\gamma \pi^+\pi^- K^+K^-$	$(2.9 \pm 0.9) \times 10^{-4}$	
Γ_{13}	$\gamma 2\pi^+ 2\pi^-$	$(2.5 \pm 0.9) \times 10^{-4}$	
Γ_{14}	$\gamma 3\pi^+ 3\pi^-$	$(2.5 \pm 1.2) \times 10^{-4}$	
Γ_{15}	$\gamma 2\pi^+ 2\pi^- K^+K^-$	$(2.4 \pm 1.2) \times 10^{-4}$	
Γ_{16}	$\gamma \pi^+\pi^- p\overline{p}$	$(1.5 \pm 0.6) \times 10^{-4}$	
Γ_{17}	$\gamma 2\pi^+ 2\pi^- p\overline{p}$	$(4 \pm 6) \times 10^{-5}$	
Γ_{18}	$\gamma 2K^+ 2K^-$	$(2.0 \pm 2.0) \times 10^{-5}$	
Γ_{19}	$\gamma \eta'(958)$	$< 1.3 \times 10^{-3}$	CL=90%
Γ_{20}	$\gamma \eta$	$< 3.5 \times 10^{-4}$	CL=90%
Γ_{21}	$\gamma f'_2(1525)$	$< 1.4 \times 10^{-4}$	CL=90%
Γ_{22}	$\gamma f_2(1270)$	$< 1.3 \times 10^{-4}$	CL=90%
Γ_{23}	$\gamma \eta(1440)$	$< 8.2 \times 10^{-5}$	CL=90%
Γ_{24}	$\gamma f_J(1710) \to \gamma K\overline{K}$	$< 2.6 \times 10^{-4}$	CL=90%
Γ_{25}	$\gamma f_4(2220) \to \gamma K^+K^-$	$< 1.5 \times 10^{-5}$	CL=90%

Hadronic decays

Γ_{26}	$D^*(2010)^{\pm}$ anything	[a]	

[a] The value is for the sum of the charge states indicated.

$\Upsilon(1S)$ $\Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

$\Gamma(e^+e^-) \times \Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ — $\Gamma_2\Gamma_3/\Gamma$

VALUE (eV)	*DOCUMENT ID*		*TECN*	*COMMENT*
31.2±1.6±1.7	KOBEL	92	CBAL	$e^+e^- \to \mu^+\mu^-$

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ — $\Gamma_0\Gamma_2/\Gamma$

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1.216±0.027 OUR AVERAGE				
1.187±0.023±0.031	[3] BARU	92B	MD1	$e^+e^- \to$ hadrons
1.23 ±0.02 ±0.05	[3] JAKUBOWSKI	88	CBAL	$e^+e^- \to$ hadrons
1.37 ±0.06 ±0.09	[4] GILES	84B	CLEO	$e^+e^- \to$ hadrons
1.23 ±0.08 ±0.04	[4] ALBRECHT	82	DASP	$e^+e^- \to$ hadrons
1.13 ±0.07 ±0.11	[4] NICZYPORUK	82	LENA	$e^+e^- \to$ hadrons
1.09 ±0.25	[4] BOCK	80	CNTR	$e^+e^- \to$ hadrons
1.35 ±0.14	[5] BERGER	79	PLUT	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.17 ±0.06 ±0.10	[4] TUTS	83	CUSB	$e^+e^- \to$ hadrons

[3] Radiative corrections evaluated following KURAEV 85.
[4] Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.
[5] Radiative corrections reevaluated by ALEXANDER 89 using B($\mu\mu$) = 0.026.

$\Upsilon(1S)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ — Γ_2

VALUE (keV)	*DOCUMENT ID*
1.32±0.03 OUR EVALUATION	See Υ mini-review.

$\Upsilon(1S)$ BRANCHING RATIOS

$\Gamma(\tau^+\tau^-)/\Gamma_{total}$ — Γ_1/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.0267^{+0.0014}_{-0.0016}$ OUR AVERAGE				
$0.0261\pm0.0012^{+0.0009}_{-0.0013}$	25k	CINABRO 94B	CLE2	$e^+e^- \to \tau^+\tau^-$
$0.027\pm0.004\pm0.002$		[6] ALBRECHT 85C	ARG	$\Upsilon(2S) \to \pi^+\pi^-\tau^+\tau^-$
$0.034\pm0.004\pm0.004$		GILES 83	CLEO	$e^+e^- \to \tau^+\tau^-$

[6] Using $B(\Upsilon(1S) \to ee) = B(\Upsilon(1S) \to \mu\mu) = 0.0256$; not used for width evaluations.

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0248 ± 0.0007 OUR AVERAGE Error includes scale factor of 1.1.				
$0.0212\pm0.0020\pm0.0010$		[7] BARU 92	MD1	$e^+e^- \to \mu^+\mu^-$
$0.0231\pm0.0012\pm0.0010$		[7] KOBEL 92	CBAL	$e^+e^- \to \mu^+\mu^-$
$0.0252\pm0.0007\pm0.0007$		CHEN 89B	CLEO	$e^+e^- \to \mu^+\mu^-$
$0.0261\pm0.0009\pm0.0011$		KAARSBERG 89	CSB2	$e^+e^- \to \mu^+\mu^-$
$0.0230\pm0.0025\pm0.0013$	86	ALBRECHT 87	ARG	$\Upsilon(2S) \to \pi^+\pi^-\mu^+\mu^-$
$0.029\pm0.003\pm0.002$	864	BESSON 84	CLEO	$\Upsilon(2S) \to \pi^+\pi^-\mu^+\mu^-$
$0.027\pm0.003\pm0.003$		ANDREWS 83	CLEO	$e^+e^- \to \mu^+\mu^-$
$0.032\pm0.013\pm0.003$		ALBRECHT 82	DASP	$e^+e^- \to \mu^+\mu^-$
$0.038\pm0.015\pm0.002$		NICZYPORUK 82	LENA	$e^+e^- \to \mu^+\mu^-$
$0.014^{+0.034}_{-0.014}$		BOCK 80	CNTR	$e^+e^- \to \mu^+\mu^-$
0.022 ± 0.020		BERGER 79	PLUT	$e^+e^- \to \mu^+\mu^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.027\pm0.003\pm0.003$		TUTS 83	CUSB	$e^+e^- \to \mu^+\mu^-$

[7] Taking into account interference between the resonance and continuum.

$\Gamma(e^+e^-)/\Gamma_{total}$ — Γ_2/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0252 ± 0.0017 OUR AVERAGE				
$0.0242\pm0.0014\pm0.0014$	307	ALBRECHT 87	ARG	$\Upsilon(2S) \to \pi^+\pi^-e^+e^-$
$0.028\pm0.003\pm0.002$	826	BESSON 84	CLEO	$\Upsilon(2S) \to \pi^+\pi^-e^+e^-$
0.051 ± 0.030		BERGER 80C	PLUT	$e^+e^- \to e^+e^-$

$\Gamma(J/\psi(1S)\text{anything})/\Gamma_{total}$ — Γ_4/Γ

VALUE (units 10^{-3})	CL%	DOCUMENT ID	TECN	COMMENT
<0.68	90	ALBRECHT 92J	ARG	$e^+e^- \to e^+e^-X$, $e^+e^- \to \mu^+\mu^-X$
$1.1\pm0.4\pm0.2$		[8] FULTON 89	CLEO	$e^+e^- \to \mu^+\mu^-X$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<1.7	90	MASCHMANN 90	CBAL	$e^+e^- \to$ hadrons
<20	90	NICZYPORUK 83	LENA	

[8] Using $B((J/\psi) \to \mu^+\mu^-) = (6.9\pm0.9)\%$.

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<5	90	BARU 92	MD1	$\Upsilon(1S) \to \pi^+\pi^-$

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<5	90	BARU 92	MD1	$\Upsilon(1S) \to K^+K^-$

$\Gamma(p\overline{p})/\Gamma_{total}$ — Γ_8/Γ

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<9	90	BARU	92	MD1	$\Upsilon(1S) \rightarrow p\overline{p}$

$\Gamma(\gamma 2\pi^+ 2\pi^-)/\Gamma_{total}$ — Γ_{13}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.5±0.7±0.5	26 ± 7	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma \pi^+ \pi^- K^+ K^-)/\Gamma_{total}$ — Γ_{12}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.9±0.7±0.6	29 ± 8	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma \pi^+ \pi^- p\overline{p})/\Gamma_{total}$ — Γ_{16}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1.5±0.5±0.3	22 ± 6	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 2K^+ 2K^-)/\Gamma_{total}$ — Γ_{18}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.2 ±0.2	2 ± 2	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 3\pi^+ 3\pi^-)/\Gamma_{total}$ — Γ_{14}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.5±0.9±0.8	17 ± 5	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 2\pi^+ 2\pi^- K^+ K^-)/\Gamma_{total}$ — Γ_{15}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.4±0.9±0.8	18 ± 7	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 2\pi^+ 2\pi^- p\overline{p})/\Gamma_{total}$ — Γ_{17}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.4±0.4±0.4	7 ± 6	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 2h^+ 2h^-)/\Gamma_{total}$ — Γ_9/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
7.0±1.1±1.0	80 ± 12	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 3h^+ 3h^-)/\Gamma_{total}$ — Γ_{10}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
5.4±1.5±1.3	39 ± 11	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\gamma 4h^+ 4h^-)/\Gamma_{total}$ — Γ_{11}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
7.4±2.5±2.5	36 ± 12	FULTON	90B	CLEO	$e^+e^- \rightarrow$ hadrons

$\Gamma(\rho\pi)/\Gamma_{total}$ — Γ_5/Γ

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 2	90	FULTON	90B		$\Upsilon(1S) \rightarrow \rho^0\pi^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<10	90	BLINOV	90	MD1	$\Upsilon(1S) \rightarrow \rho^0\pi^0$
<21	90	NICZYPORUK	83	LENA	$\Upsilon(1S) \rightarrow \rho^0\pi^0$

$\Gamma(D^*(2010)^\pm \text{ anything})/\Gamma_{total}$ — Γ_{26}/Γ

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<19	90	[9] ALBRECHT	92J	ARG	$e^+e^- \rightarrow D^0\pi^\pm X$

[9] For $x_p > 0.2$.

$\Gamma(\gamma\eta(1440))/\Gamma_{total}$ — Γ_{23}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<8.2	90	[10] FULTON	90B	CLEO	$\Upsilon(1S) \to \gamma K^+\pi^\mp K^0_S$

[10] Includes unknown branching ratio of $\eta(1440) \to K^\pm\pi^\mp K^0_S$.

$\Gamma(\gamma\eta'(958))/\Gamma_{total}$ — Γ_{19}/Γ

VALUE (units 10^{-3})	CL%	DOCUMENT ID		TECN	COMMENT
<1.3	90	SCHMITT	88	CBAL	$\Upsilon(1S) \to \gamma X$

$\Gamma(\gamma\eta)/\Gamma_{total}$ — Γ_{20}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<3.5	90	SCHMITT	88	CBAL	$\Upsilon(1S) \to \gamma X$

$\Gamma(\gamma f'_2(1525))/\Gamma_{total}$ — Γ_{21}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<14	90	[11] FULTON	90B	CLEO	$\Upsilon(1S) \to \gamma K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<19.4	90	[11] ALBRECHT	89	ARG	$\Upsilon(1S) \to \gamma K^+K^-$

[11] Assuming $B(f'_2(1525) \to K\overline{K}) = 0.71$.

$\Gamma(\gamma f_J(1710) \to \gamma K\overline{K})/\Gamma_{total}$ — Γ_{24}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
< 2.6	90	[12] ALBRECHT	89	ARG	$\Upsilon(1S) \to \gamma K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 6.3	90	[12] FULTON	90B	CLEO	$\Upsilon(1S) \to \gamma K^+K^-$
<19	90	[12] FULTON	90B	CLEO	$\Upsilon(1S) \to \gamma K^0_S K^0_S$
< 8	90	[13] ALBRECHT	89	ARG	$\Upsilon(1S) \to \gamma\pi^+\pi^-$
<24	90	[14] SCHMITT	88	CBAL	$\Upsilon(1S) \to \gamma X$

[12] Assuming $B(f_J(1710) \to K\overline{K}) = 0.38$.
[13] Assuming $B(f_J(1710) \to \pi\pi) = 0.04$.
[14] Assuming $B(f_J(1710) \to \eta\eta) = 0.18$.

$\Gamma(\gamma f_2(1270))/\Gamma_{total}$ — Γ_{22}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<13	90	[15] ALBRECHT	89	ARG	$\Upsilon(1S) \to \gamma\pi^+\pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<21	90	[15] FULTON	90B	CLEO	$\Upsilon(1S) \to \gamma\pi^+\pi^-$
<81	90	SCHMITT	88	CBAL	$\Upsilon(1S) \to \gamma X$

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

$\Gamma(\gamma f_4(2220) \to \gamma K^+K^-)/\Gamma_{total}$ — Γ_{25}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
< 1.5	90	[16] FULTON	90B	CLEO	$\Upsilon(1S) \to \gamma K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 2.9	90	[16] ALBRECHT	89	ARG	$\Upsilon(1S) \to \gamma K^+K^-$
<20	90	[16] BARU	89	MD1	$\Upsilon(1S) \to \gamma K^+K^-$

[16] Including unknown branching ratio of $f_4(2220) \to K^+K^-$.

$\Upsilon(1S)$ REFERENCES

CINABRO	94B	PL B340 129	+Liu, Saulnier, Wilson+	(CLEO Collab.)
ALBRECHT	92J	ZPHY C55 25	+Ehrlichmann, Hamacher+	(ARGUS Collab.)
BARU	92	ZPHY C54 229	+Beilin, Blinov+	(NOVO)
BARU	92B	BINP 92-46 Preprint	+Blinov, Blinov, Bondar+	(NOVO)
KOBEL	92	ZPHY C53 193	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
BLINOV	90	PL B245 311	+Bondar+	(NOVO)
FULTON	90B	PR D41 1401	+Hempstead+	(CLEO Collab.)
MASCHMANN	90	ZPHY C46 555	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
ALBRECHT	89	ZPHY C42 349	+Boeckmann, Glaeser, Harder+	(ARGUS Collab.)
ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)
BARU	89	ZPHY C42 505	+Beilin, Blinov+	(NOVO)
CHEN	89B	PR D39 3528	+McIlwain, Miller+	(CLEO Collab.)
FULTON	89	PL B224 445	+Haas, Hempstead+	(CLEO 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
SCHMITT	88	ZPHY C40 199	+Antreasyan+	(Crystal Ball Collab.)

ALBRECHT	87	ZPHY C35 283	+Binder, Boeckmann, Glaeser+	(ARGUS Collab.)
BARU	86	ZPHY C30 551	+Blinov, Bondar, Bukin+	(NOVO)
ALBRECHT	85C	PL 154B 452	+Drescher, Heller+	(ARGUS Collab.)
KURAEV	85	SJNP 41 466	+Fadin	(ASCI)
		Translated from YAF 41 733.		
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
BESSON	84	PR D30 1433	+Green, Hicks, Namjoshi, Sannes+	(CLEO Collab.)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
MACKAY	84	PR D29 2483	+Hasard, Giles, Hempstead+	(CUSB Collab.)
ANDREWS	83	PRL 50 807	+Avery, Berkelman, Cassel+	(CLEO Collab.)
GILES	83	PRL 50 877	+	(HARV, OSU, ROCH, RUTG, SYRA, VAND+)
NICZYPORUK	83	ZPHY C17 197	+Jakubowski, Zeludziewicz+	(LENA Collab.)
TUTS	83	Cornell Conf. 284		(CUSB Collab.)
ALBRECHT	82	PL 116B 383	+Hofmann+	(DESY, DORT, HEIDH, LUND, ITEP)
ARTAMONOV	82	PL 118B 225	+Baru, Blinov, Bondar, Bukin, Groshev+	(NOVO)
NICZYPORUK	82	ZPHY C15 299	+Folger, Bienlein+	(LENA Collab.)
BERGER	80C	PL 93B 497	+Lackas, Raupach+	(PLUTO Collab.)
BOCK	80	ZPHY C6 125	+Blanar, Blum+	(HEIDP, MPIM, DESY, HAMB)
BERGER	79	ZPHY C1 343	+Alexander+	(PLUTO Collab.)

OTHER RELATED PAPERS

COOPER	86	Berkeley Conf. 67		(MIT)
KOENIGS...	86	DESY 86/136	Koenigsmann	(DESY)
ALBRECHT	84	PL 134B 137	+Drescher, Heller+	(ARGUS Collab.)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
ARTAMONOV	82	PL 118B 225	+Baru, Blinov, Bondar, Bukin, Groshev+	(NOVO)
BERGER	78	PL 76B 243	+Alexander, Daum+	(PLUTO Collab.)
BIENLEIN	78	PL 78B 360	+Glawe, Bock, Blanar+	(DESY, HAMB, HEIDP, MPIM)
DARDEN	78	PL 76B 246	+Hofmann, Schubert+	(DESY, DORT, HEIDH, LUND)
GARELICK	78	PR D18 945	+Gauthier, Hicks, Oliver+	(NEAS, WASH, TUFTS)
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)

$\chi_{b0}(1P)$ or $\chi_{b0}(9860)$

$I^G(J^{PC}) = ?^?(0 \text{ preferred}^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$.

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

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
9859.8±1.3 OUR AVERAGE				
9860.0±0.5±1.4	[1] ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
9858.3±1.6±2.7	[1] NERNST	85	CBAL	$\Upsilon(2S) \to \gamma X$
9864.1±7 ±1	[1] HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
• • • We do not use the following data for averages, fits, limits, etc. • • •				
9872.8±0.7±5.0	[1] KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma X$

[1] From γ energy below, assuming $\Upsilon(2S)$ mass = 10023.4 MeV.

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
162.3±1.3 OUR AVERAGE				
162.1±0.5±1.4	ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
163.8±1.6±2.7	NERNST	85	CBAL	$\Upsilon(2S) \to \gamma X$
158.0±7 ±1	HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
• • • We do not use the following data for averages, fits, limits, etc. • • •				
149.4±0.7±5.0	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma X$

$\chi_{b0}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\gamma\,\Upsilon(1S)$	<6 %	90%

$\chi_{b0}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{total}$ Γ_1/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.06	90	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.11	90	PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

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

WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB Collab.)
PAUSS	83	PL 130B 439	+Dietl, Eigen+	(MPIM, COLU, CORN, LSU, STON)

$\chi_{b1}(1P)$ or $\chi_{b1}(9890)$

$I^G(J^{PC}) = ?^?(1^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$. $J = 1$ from SKWARNICKI 87.

$\chi_{b1}(1P)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
9891.9±0.7 OUR AVERAGE				
9890.8±0.9±1.3	[1] WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
9890.8±0.3±1.1	[1] ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
9892.0±0.8±2.4	[1] NERNST	85	CBAL	$\Upsilon(2S) \to \gamma$X
9893.6±0.8±1.0	[1] HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
9894.4±0.4±3.0	[1] KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma$X
9892.0±3.0	[1] PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

[1] From γ energy below, assuming $\Upsilon(2S)$ mass = 10023.4 MeV.

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
130.6±0.7 OUR AVERAGE				
131.7±0.9±1.3	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
131.7±0.3±1.1	ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
130.6±0.8±2.4	NERNST	85	CBAL	$\Upsilon(2S) \to \gamma$X
129.0±0.8±1.0	HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
128.1±0.4±3.0	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma$X
130.6±3.0	PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

$\chi_{b1}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\gamma\,\Upsilon(1S)$	(35±8) %

$\chi_{b1}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{total}$ Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.35±0.08 OUR AVERAGE				
0.32±0.06±0.07	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
0.47±0.18	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

$\chi_{b1}(1P)$ REFERENCES

SKWARNICKI	87	PRL 58 972	+Antreasyan, Besset+	(Crystal Ball Collab.)J
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB Collab.)
PAUSS	83	PL 130B 439	+Dietl, Eigen+	(MPIM, COLU, CORN, LSU, STON)

$\chi_{b2}(1P)$ or $\chi_{b2}(9915)$

$I^G(J^{PC}) = ?^?(2^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$. $J = 2$ from SKWARNICKI 87.

$\chi_{b2}(1P)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
9913.2±0.6 OUR AVERAGE				
9915.8±1.1±1.3	[1] WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
9912.2±0.3±0.9	[1] ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
9912.4±0.8±2.2	[1] NERNST	85	CBAL	$\Upsilon(2S) \to \gamma$X
9913.3±0.7±1.0	[1] HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
9914.6±0.3±2.0	[1] KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma$X
9914.0±4.0	[1] PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

[1] From γ energy below, assuming $\Upsilon(2S)$ mass = 10023.4 MeV.

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
109.6±0.6 OUR AVERAGE				
107.0±1.1±1.3	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
110.6±0.3±0.9	ALBRECHT	85E	ARG	$\Upsilon(2S) \to$ conv.γX
110.4±0.8±2.2	NERNST	85	CBAL	$\Upsilon(2S) \to \gamma$X
109.5±0.7±1.0	HAAS	84	CLEO	$\Upsilon(2S) \to$ conv.γX
108.2±0.3±2.0	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma$X
108.8±4.0	PAUSS	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

$\chi_{b2}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\gamma\Upsilon(1S)$	(22±4) %

$\chi_{b2}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma\Upsilon(1S))/\Gamma_{total}$ **Γ_1/Γ**

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.22±0.04 OUR AVERAGE				
0.27±0.06±0.06	WALK	86	CBAL	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$
0.20±0.05	KLOPFEN...	83	CUSB	$\Upsilon(2S) \to \gamma\gamma\ell^+\ell^-$

$\chi_{b2}(1P)$ REFERENCES

SKWARNICKI	87	PRL 58 972	+Antreasyan, Besset+	(Crystal Ball Collab.) J
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
KLOPFEN...	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB Collab.)
PAUSS	83	PL 130B 439	+Dietl, Eigen+	(MPIM, COLU, CORN, LSU, STON)

$\Upsilon(2S)$ or $\Upsilon(10023)$

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

$\Upsilon(2S)$ MASS

VALUE (GeV)		DOCUMENT ID		TECN	COMMENT
10.02330±0.00031 OUR AVERAGE					
10.0236 ±0.0005	[1]	BARU	86B	REDE	$e^+e^- \rightarrow$ hadrons
10.0231 ±0.0004		BARBER	84	REDE	$e^+e^- \rightarrow$ 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}	$\gamma f_4(2220)$		

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

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

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

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

VALUE (keV)		DOCUMENT ID		TECN	COMMENT
0.554±0.030 OUR AVERAGE					
0.54 ±0.04 ±0.02	[2]	JAKUBOWSKI	88	CBAL	$e^+e^- \rightarrow$ hadrons
0.58 ±0.03 ±0.04	[3]	GILES	84B	CLEO	$e^+e^- \rightarrow$ hadrons
0.60 ±0.12 ±0.07	[3]	ALBRECHT	82	DASP	$e^+e^- \rightarrow$ hadrons
0.54 ±0.07 $^{+0.09}_{-0.05}$	[3]	NICZYPORUK	81C	LENA	$e^+e^- \rightarrow$ hadrons
0.41 ±0.18	[3]	BOCK	80	CNTR	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.59 ±0.03 ±0.05	[3]	TUTS	83	CUSB	$e^+e^- \rightarrow$ hadrons

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

$\Upsilon(2S)$ 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

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}$ 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	$e^+e^- \rightarrow \ell^+\ell^-\pi^+\pi^-$

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{total}$ 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	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$

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

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

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
0.0131±0.0021 OUR AVERAGE					
0.0122±0.0028±0.0019		[4] 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		[5] 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	$e^+e^- \rightarrow \mu^+\mu^-$

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

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

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

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

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.067±0.009 OUR AVERAGE				
0.091±0.018±0.022	ALBRECHT	85E	ARG	$e^+e^- \rightarrow \gamma$conv. X
0.065±0.007±0.012	NERNST	85	CBAL	$e^+e^- \rightarrow \gamma$X
0.080±0.017±0.016	HAAS	84	CLEO	$e^+e^- \rightarrow \gamma$conv. X
0.059±0.014	KLOPFEN...	83	CUSB	$e^+e^- \rightarrow \gamma$X

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.066±0.009 OUR AVERAGE				
0.098±0.021±0.024	ALBRECHT	85E	ARG	$e^+e^- \rightarrow \gamma$conv. X
0.058±0.007±0.010	NERNST	85	CBAL	$e^+e^- \rightarrow \gamma$X
0.102±0.018±0.021	HAAS	84	CLEO	$e^+e^- \rightarrow \gamma$conv. X
0.061±0.014	KLOPFEN...	83	CUSB	$e^+e^- \rightarrow \gamma$X

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.043±0.010 OUR AVERAGE				
0.064±0.014±0.016	ALBRECHT	85E	ARG	$e^+e^- \rightarrow \gamma$conv. X
0.036±0.008±0.009	NERNST	85	CBAL	$e^+e^- \rightarrow \gamma X$
0.044±0.023±0.009	HAAS	84	CLEO	$e^+e^- \rightarrow \gamma$conv. X
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.035±0.014	KLOPFEN...	83	CUSB	$e^+e^- \rightarrow \gamma X$

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

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<59	90	[6] ALBRECHT	89	ARG	$\Upsilon(2S) \rightarrow \gamma K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 5.9	90	[7] ALBRECHT	89	ARG	$\Upsilon(2S) \rightarrow \gamma\pi^+\pi^-$

[6] Re-evaluated assuming B($f_J(1710) \rightarrow K^+K^-$) = 0.19.

[7] Includes unknown branching ratio of $f_J(1710) \rightarrow \pi^+\pi^-$.

$\Gamma(\gamma f'_2(1525))/\Gamma_{total}$ — Γ_{13}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<53	90	[8] ALBRECHT	89	ARG	$\Upsilon(2S) \rightarrow \gamma K^+K^-$

[8] Re-evaluated assuming B($f'_2(1525) \rightarrow K\overline{K}$) = 0.71.

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

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<24.1	90	[9] ALBRECHT	89	ARG	$\Upsilon(2S) \rightarrow \gamma\pi^+\pi^-$

[9] Using B($f_2(1270) \rightarrow \pi\pi$) = 0.84.

$\Gamma(\gamma f_4(2220))/\Gamma_{total}$ — 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	[10] ALBRECHT	89	ARG	$\Upsilon(2S) \rightarrow \gamma K^+K^-$

[10] Includes unknown branching ratio of $f_4(2220) \rightarrow K^+K^-$.

$\Upsilon(2S)$ REFERENCES

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 662 +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 (ASCI)
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)

$\chi_{b0}(2P)$ or $\chi_{b0}(10235)$

$I^G(J^{PC}) = ?^?(0$ preferred $^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$.

$\chi_{b0}(2P)$ MASS

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
10.2321±0.0006 OUR AVERAGE				
10.2312±0.0008±0.0012	[1] HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X, \ell^+\ell^-\gamma\gamma$
10.2323±0.0007	[2] MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

[1] From the average photon energy for inclusive and exclusive events and assuming $\Upsilon(3S)$ mass = 10355.3 ± 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.

[2] From γ energy below assuming $\Upsilon(3S)$ mass = 10355.3 ± 0.5 MeV. The error on the $\Upsilon(3S)$ mass is not included in the individual measurements. It is included in the final average.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
122.8±0.5 OUR AVERAGE	Error includes scale factor of 1.1.				
123.0±0.8	4959±339	[3] HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X$
124.6±1.4	17 ± 7	[4] HEINTZ	92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
122.3±0.3±0.6	9903±550	MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

[3] A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91.

[4] A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

$\chi_{b0}(2P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\gamma\,\Upsilon(2S)$	(4.6±2.1) %
Γ_2	$\gamma\,\Upsilon(1S)$	(9 ±6) × 10^{-3}

$\chi_{b0}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma\,\Upsilon(2S))/\Gamma_{total}$ — Γ_1/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.089	90	[5] CRAWFORD	92B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.046±0.020±0.007		[6] HEINTZ	92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

[5] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \rightarrow \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) < 1.19×10^{-4}, and B($\Upsilon(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049.

[6] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 ± 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\gamma\, \Upsilon(1S))/\Gamma_{total}$ — Γ_2/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.025	90	[7] CRAWFORD	92B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.009±0.006±0.001		[8] HEINTZ	92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

[7] Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.07)\%$, $B(\Upsilon(3S) \rightarrow \gamma\gamma\,\Upsilon(1S)) \times 2\, B(\Upsilon(1S) \rightarrow \mu^+\mu^-) < 0.63 \times 10^{-4}$, and $B(\Upsilon(3S) \rightarrow \chi_{b0}(2P)\gamma) = 0.049$.

[8] Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.57 \pm 0.07)\%$, $B(\Upsilon(3S) \rightarrow \gamma\chi_{b0}(2P)) = (6.0 \pm 0.4 \pm 0.6)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\chi_{b0}(2P)$ REFERENCES

CRAWFORD	92B	PL B294 139	+Fulton	(CLEO II Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO II Collab.)
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)

OTHER RELATED PAPERS

TUTS	83	Cornell Conf. 284		(CUSB Collab.)
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)

$\chi_{b1}(2P)$ or $\chi_{b1}(10255)$

$I^G(J^{PC}) = ?^?(1 \text{ preferred } ^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$.

$\chi_{b1}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.2552±0.0005 OUR AVERAGE				
10.2547±0.0004±0.0010	[1] HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X, \ell^+\ell^-\gamma\gamma$
10.2553±0.0005	[2] MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

[1] From the average photon energy for inclusive and exclusive events and assuming $\Upsilon(3S)$ mass = 10355.3 ± 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.

[2] From γ energy below assuming $\Upsilon(3S)$ mass = 10355.3 ± 0.5 MeV. The error on the $\Upsilon(3S)$ mass is not included in the individual measurements. It is included in the final evaluation.

$m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)}$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
23.5±0.7±0.7	[3] HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X, \ell^+\ell^-\gamma\gamma$

[3] From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
99.90±0.26 OUR AVERAGE					
99 ±1	169	CRAWFORD	92B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
100.1 ±0.4	11147±462	[4] HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X$
100.2 ±0.5	223±17	[5] HEINTZ	92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
99.5 ±0.1 ±0.5	25759±510	MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

[4] A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91.

[5] A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

$\chi_{b1}(2P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ_1	$\gamma\,\Upsilon(2S)$	(21 ±4) %	1.5
Γ_2	$\gamma\,\Upsilon(1S)$	(8.5±1.3) %	1.3

$\chi_{b1}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma\,\Upsilon(2S))/\Gamma_{\rm total}$ — Γ_1/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.21 ±0.04 OUR AVERAGE	Error includes scale factor of 1.5.		
0.356±0.042±0.092	[6] CRAWFORD 92B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.199±0.020±0.022	[7] HEINTZ 92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

[6] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \rightarrow \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (10.23±1.20±1.26)×$10^{-4}$, and B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = $0.105^{+0.003}_{-0.002}$ ± 0.013.

[7] Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = (11.5 ± 0.5 ± 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\gamma\,\Upsilon(1S))/\Gamma_{\rm total}$ — Γ_2/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.085±0.013 OUR AVERAGE	Error includes scale factor of 1.3.		
0.120±0.021±0.021	[8] CRAWFORD 92B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
0.080±0.009±0.007	[9] HEINTZ 92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

[8] Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \rightarrow \gamma\gamma\,\Upsilon(1S)$)×2 B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (6.47 ± 1.12 ± 0.82) × 10^{-4} and B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = $0.105^{+0.003}_{-0.002}$ ± 0.013.

[9] Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$)=(2.57 ± 0.07)%, B($\Upsilon(3S) \rightarrow \gamma\chi_{b1}(2P)$) = (11.5 ± 0.5 ± 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\chi_{b1}(2P)$ REFERENCES

CRAWFORD	92B	PL B294 139	+Fulton	(CLEO II Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO II Collab.)
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)

OTHER RELATED PAPERS

TUTS	83	Cornell Conf. 284		(CUSB Collab.)
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)

$\chi_{b2}(2P)$ or $\chi_{b2}(10270)$

$I^G(J^{PC}) = ?^?(2$ preferred $^{++})$
J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore $P = +$.

$\chi_{b2}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
10.2685±0.0004 OUR AVERAGE			
10.2681±0.0004±0.0010	[1] HEINTZ 92	CSB2	$e^+e^- \rightarrow \gamma X, \ell^+\ell^-\gamma\gamma$
10.2685±0.0004	[2] MORRISON 91	CLE2	$e^+e^- \rightarrow \gamma X$

[1] From the average photon energy for inclusive and exclusive events and assuming $\Upsilon(3S)$ mass = 10355.3 ± 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.

[2] From γ energy below, assuming $\Upsilon(3S)$ mass = 10355.3 ± 0.5 MeV. The error on the $\Upsilon(3S)$ mass is not included in the individual measurements. It is included in the final average.

$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)}$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
13.5±0.4±0.5	[3] HEINTZ	92	CSB2	$e^+e^- \to \gamma X, \ell^+\ell^-\gamma\gamma$

[3] From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
86.64±0.23 OUR AVERAGE					
86 ±1	101	CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
86.7 ±0.4	10319± 478	[4] HEINTZ	92	CSB2	$e^+e^- \to \gamma X$
86.9 ±0.4	157± 15	[5] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
86.4 ±0.1 ±0.4	30741± 560	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

[4] A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91.
[5] A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

$\chi_{b2}(2P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\gamma\,\Upsilon(2S)$	(16.2±2.4) %
Γ_2	$\gamma\,\Upsilon(1S)$	(7.1±1.0) %

$\chi_{b2}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma\,\Upsilon(2S))/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.162±0.024 OUR AVERAGE				
0.135±0.025±0.035	[6] CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
0.173±0.021±0.019	[7] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[6] Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \to \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(2S) \to \mu^+\mu^-$) = (4.98 ± 0.94 ± 0.62)×10^{-4}, and B($\Upsilon(3S) \to \gamma\chi_{b2}(2P)$) = 0.135 ± 0.003 ± 0.017.
[7] Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(3S) \to \gamma\chi_{b2}(2P)$) = (11.1 ± 0.5 ± 0.4)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\gamma\,\Upsilon(1S))/\Gamma_{total}$ — Γ_2/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.071±0.010 OUR AVERAGE				
0.072±0.014±0.013	[8] CRAWFORD	92B	CLE2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$
0.070±0.010±0.006	[9] HEINTZ	92	CSB2	$e^+e^- \to \ell^+\ell^-\gamma\gamma$

[8] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \to \gamma\gamma\,\Upsilon(2S)$)×2 B($\Upsilon(1S) \to \mu^+\mu^-$) = (5.03 ± 0.94 ± 0.63)×10^{-4}, and B($\Upsilon(3S) \to \gamma\chi_{b2}(2P)$) = 0.135 ± 0.003 ± 0.017.
[9] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \to \gamma\chi_{b2}(2P)$) = (11.1 ± 0.5 ± 0.4)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\chi_{b2}(2P)$ REFERENCES

CRAWFORD	92B	PL B294 139	+Fulton	(CLEO II Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO II Collab.)
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)

OTHER RELATED PAPERS

TUTS	83	Cornell Conf. 284		(CUSB Collab.)
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)

$\Upsilon(3S)$ or $\Upsilon(10355)$

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

$\Upsilon(3S)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.3553±0.0005	[1] BARU	86B	REDE	$e^+e^- \rightarrow$ hadrons

[1] Reanalysis of ARTAMONOV 84.

$\Upsilon(3S)$ WIDTH

VALUE (keV)	DOCUMENT ID
26.3±3.5 OUR EVALUATION	See Υ mini-review.

$\Upsilon(3S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ_1	$\Upsilon(2S)$anything	(10.6 ±0.8) %	
Γ_2	$\Upsilon(2S)\pi^+\pi^-$	(2.8 ±0.6) %	2.2
Γ_3	$\Upsilon(2S)\pi^0\pi^0$	(2.00±0.32) %	
Γ_4	$\Upsilon(2S)\gamma\gamma$	(5.0 ±0.7) %	
Γ_5	$\Upsilon(1S)\pi^+\pi^-$	(4.48±0.21) %	
Γ_6	$\Upsilon(1S)\pi^0\pi^0$	(2.06±0.28) %	
Γ_7	$\Upsilon(1S)\eta$		
Γ_8	$\mu^+\mu^-$	(1.81±0.17) %	
Γ_9	e^+e^-	seen	
	Radiative decays		
Γ_{10}	$\gamma\chi_{b2}(2P)$	(11.4 ±0.8) %	1.3
Γ_{11}	$\gamma\chi_{b1}(2P)$	(11.3 ±0.6) %	
Γ_{12}	$\gamma\chi_{b0}(2P)$	(5.4 ±0.6) %	1.1

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

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ — $\Gamma_0\Gamma_9/\Gamma$

VALUE (keV)	DOCUMENT ID		TECN	COMMENT
0.45±0.03±0.03	[2] GILES	84B	CLEO	$e^+e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.39±0.02±0.03	[2] TUTS	83	CUSB	$e^+e^- \rightarrow$ hadrons

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

$\Upsilon(3S)$ 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	[3,4,5] BUTLER	94B	CLE2	$e^+e^- \rightarrow \ell^+\ell^- X$
0.111 ±0.012	4891	[4,5,6] BROCK	91	CLEO	$e^+e^- \rightarrow \pi^+\pi^- X$, $\pi^+\pi^-\ell^+\ell^-$

$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{\text{total}}$ — Γ_2/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.028 ±0.006 OUR AVERAGE	Error includes scale factor of 2.2. See the ideogram below.				
0.0312±0.0049	980	[3,7] BUTLER	94B	CLE2	$e^+e^- \rightarrow \pi^+\pi^-\ell^+\ell^-$
0.0482±0.0065±0.0053	138	[6] WU	93	CUSB	$\Upsilon(3S) \rightarrow \pi^+\pi^-\ell^+\ell^-$
0.0213±0.0038	974	[6] 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. • • •

0.031 ±0.020	5	MAGERAS	82	CUSB	$\Upsilon(3S) \rightarrow \pi^+ \pi^- \ell^+ \ell^-$

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

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0200±0.0032 OUR AVERAGE					
0.0216±0.0039		[7,8] BUTLER	94B	CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- \pi^0 \pi^0$
0.017 ±0.005 ±0.002	10	[9] HEINTZ	92	CSB2	$e^+ e^- \rightarrow \ell^+ \ell^- \pi^0 \pi^0$

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.0502±0.0069	[7] BUTLER	94B	CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- 2\gamma$

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$ — Γ_5/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0448±0.0021 OUR AVERAGE					
0.0452±0.0035	11830	[4] BUTLER	94B	CLE2	$e^+ e^- \rightarrow \pi^+ \pi^-$ X, $\pi^+ \pi^- \ell^+ \ell^-$
0.0446±0.0034±0.0050	451	[4] WU	93	CUSB	$\Upsilon(3S) \rightarrow \pi^+ \pi^- \ell^+ \ell^-$
0.0446±0.0030	11221	[4] 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. • • •					
0.049 ±0.010	22	GREEN	82	CLEO	$\Upsilon(3S) \rightarrow \pi^+ \pi^- \ell^+ \ell^-$
0.039 ±0.013	26	MAGERAS	82	CUSB	$\Upsilon(3S) \rightarrow \pi^+ \pi^- \ell^+ \ell^-$

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0206±0.0028 OUR AVERAGE					
0.0199±0.0034	56	[4] BUTLER	94B	CLE2	$e^+ e^- \rightarrow \ell^+ \ell^- \pi^0 \pi^0$
0.022 ±0.004 ±0.003	33	[10] HEINTZ	92	CSB2	$e^+ e^- \rightarrow \ell^+ \ell^- \pi^0 \pi^0$

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.0022	90	BROCK	91	CLEO	$e^+ e^- \rightarrow \pi^+ \pi^- \pi^0 \ell^+ \ell^-$

$\Gamma(\mu^+\mu^-)/\Gamma_{total}$ Γ_8/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0181±0.0017 OUR AVERAGE					
0.0202±0.0019±0.0033		CHEN	89B	CLEO	$e^+e^- \to \mu^+\mu^-$
0.0173±0.0015±0.0011		KAARSBERG	89	CSB2	$e^+e^- \to \mu^+\mu^-$
0.033 ±0.013 ±0.007	1096	ANDREWS	83	CLEO	$e^+e^- \to \mu^+\mu^-$

$\Gamma(\gamma\chi_{b2}(2P))/\Gamma_{total}$ Γ_{10}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.114±0.008 OUR AVERAGE	Error includes scale factor of 1.3.				
0.111±0.005±0.004	10319±478	[11] HEINTZ	92	CSB2	$e^+e^- \to \gamma$
0.135±0.003±0.017	30741±560	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

$\Gamma(\gamma\chi_{b1}(2P))/\Gamma_{total}$ Γ_{11}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.113±0.006 OUR AVERAGE					
0.115±0.005±0.005	11147±462	[11] HEINTZ	92	CSB2	$e^+e^- \to \gamma$
$0.105^{+0.003}_{-0.002}\pm0.013$	25759±510	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

$\Gamma(\gamma\chi_{b0}(2P))/\Gamma_{total}$ Γ_{12}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.054±0.006 OUR AVERAGE	Error includes scale factor of 1.1.				
0.060±0.004±0.006	4959±339	[11] HEINTZ	92	CSB2	$e^+e^- \to \gamma$
$0.049^{+0.003}_{-0.004}\pm0.006$	9903±550	MORRISON	91	CLE2	$e^+e^- \to \gamma X$

[3] Using B($\Upsilon(2S) \to \Upsilon(1S)\gamma\gamma$) = (0.038 ± 0.007)%, and B($\Upsilon(2S) \to \Upsilon(1S)\pi^0\pi^0$) = (1/2)B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$).

[4] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.06)%. With the assumption of $e\mu$ universality.

[5] Using B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$) = (18.5 ± 0.8)%.

[6] Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.31 ± 0.21)%, B($\Upsilon(2S) \to \Upsilon(1S)\gamma\gamma$)×2B($\Upsilon(1S) \to \mu^+\mu^-$) = (0.188 ± 0.035)%, and B($\Upsilon(2S) \to \Upsilon(1S)\pi^0\pi^0$)×2B($\Upsilon(1S) \to \mu^+\mu^-$) = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality.

[7] From the exclusive mode.

[8] B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.31 ± 0.21)% and assuming $e\mu$ universality.

[9] B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

[10] Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 0.07)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

[11] Supersedes NARAIN 91.

$\Upsilon(3S)$ REFERENCES

BUTLER	94B	PR D49 40	+Fu, Kalbfleisch, Lambrecht+	(CLEO Collab.)
WU	93	PL B301 307	+Franzini, Kanekal+	(CUSB Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CUSB II Collab.)
BROCK	91	PR D43 1448	+Ferguson+	(CLEO Collab.)
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO II Collab.)
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)
CHEN	89B	PR D39 3528	+McIlwain, Miller+	(CLEO 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		
BARU	86B	ZPHY C32 662	+Blinov, Bondar, Bukin+	(NOVO)
KURAEV	85	SJNP 41 466	+Fadin	(ASCI)
		Translated from YAF 41 733.		
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
ANDREWS	83	PRL 50 807	+Avery, Berkelman, Cassel+	(CLEO Collab.)
TUTS	83	Cornell Conf. 284		(CUSB Collab.)
GREEN	82	PRL 49 617	+Sannes, Skubic, Snyder+	(CLEO Collab.)
MAGERAS	82	PL 118B 453	+Herb, Imlay+	(COLU, CORN, LSU, MPIM, STON)

OTHER RELATED PAPERS

ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)
PETERSON	82	PL 114B 277	+Giannini, Lee-Franzini+	(CUSB Collab.)
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)

$\Upsilon(4S)$ or $\Upsilon(10580)$

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

$\Upsilon(4S)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.5800±0.0035	[1] BEBEK	87	CLEO	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
10.5774±0.0010	[2] LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

[1] Reanalysis of BESSON 85.
[2] No systematic error given.

$\Upsilon(4S)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
23.8±2.2 OUR AVERAGE				
20.0±2 ±4	BESSON	85	CLEO	$e^+e^- \to$ hadrons
25 ±2.5	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

$\Upsilon(4S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	e^+e^-	$(1.01\pm0.21)\times10^{-5}$	
Γ_2	$J/\psi(3097)$anything	$(2.2\pm0.7)\times10^{-3}$	
Γ_3	D^{*+}anything + c.c.	< 7.4 %	90%
Γ_4	ϕanything	$< 2.3\times10^{-3}$	90%
Γ_5	$\Upsilon(1S)$anything	$< 4\times10^{-3}$	90%
Γ_6	$B\overline{B}$	99.78	

$\Upsilon(4S)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ — Γ_1

VALUE (keV)	DOCUMENT ID		TECN	COMMENT
0.24 ±0.05 OUR AVERAGE	Error includes scale factor of 1.7.			
0.192±0.007±0.038	BESSON	85	CLEO	$e^+e^- \to$ hadrons
0.283±0.037	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

$\Upsilon(4S)$ BRANCHING RATIOS

$\Gamma(J/\psi(3097)\text{anything})/\Gamma_{total}$ — Γ_2/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.0022±0.0006±0.0004	ALEXANDER	90C	CLEO	e^+e^-

$[\Gamma(D^{*+}\text{anything}) + \Gamma(\text{c.c.})]/\Gamma_{total}$ — Γ_3/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.074	90	[3] ALEXANDER	90C	CLEO	e^+e^-

[3] For $x >$ 0.473.

$\Gamma(\phi\text{anything})/\Gamma_{total}$ — Γ_4/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.0023	90	[4] ALEXANDER	90C	CLEO	e^+e^-

[4] For $x >$ 0.52.

$\Gamma(\Upsilon(1S)\text{anything})/\Gamma_{\text{total}}$ **Γ_5/Γ**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.004	90	ALEXANDER	90C	CLEO	e^+e^-

$\Upsilon(4S)$ REFERENCES

ALEXANDER	90C	PRL 64 2226	+Artuso+	(CLEO Collab.)
BEBEK	87	PR D36 1289	+Berkelman, Blucher, Cassel+	(CLEO Collab.)
BESSON	85	PRL 54 381	+Green, Namjoshi, Sannes+	(CLEO Collab.)
LOVELOCK	85	PRL 54 377	+Horstkotte, Klopfenstein+	(CUSB Collab.)

OTHER RELATED PAPERS

ANDREWS	80B	PRL 45 219	+Berkelman, Cabenda, Cassel+	(CLEO Collab.)
FINOCCHI...	80	PRL 45 222	Finocchiaro, Giannini, Lee-Franzini+	(CUSB Collab.)

$\Upsilon(10860)$

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

$\Upsilon(10860)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.865±0.008 OUR AVERAGE	Error includes scale factor of 1.1.			
10.868±0.006±0.005	BESSON	85	CLEO	$e^+e^- \rightarrow$ hadrons
10.845±0.020	LOVELOCK	85	CUSB	$e^+e^- \rightarrow$ hadrons

$\Upsilon(10860)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
110 ±13 OUR AVERAGE				
112.0±17 ±23	BESSON	85	CLEO	$e^+e^- \rightarrow$ hadrons
110.0±15.0	LOVELOCK	85	CUSB	$e^+e^- \rightarrow$ hadrons

$\Upsilon(10860)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	e^+e^-	$(2.8\pm0.7)\times10^{-6}$

$\Upsilon(10860)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ **Γ_1**

VALUE (keV)	DOCUMENT ID		TECN	COMMENT
0.31 ±0.07 OUR AVERAGE	Error includes scale factor of 1.3.			
0.22 ±0.05 ±0.07	BESSON	85	CLEO	$e^+e^- \rightarrow$ hadrons
0.365±0.070	LOVELOCK	85	CUSB	$e^+e^- \rightarrow$ hadrons

$\Upsilon(10860)$ REFERENCES

BESSON	85	PRL 54 381	+Green, Namjoshi, Sannes+	(CLEO Collab.)
LOVELOCK	85	PRL 54 377	+Horstkotte, Klopfenstein+	(CUSB Collab.)

$\Upsilon(11020)$

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

$\Upsilon(11020)$ MASS

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
11.019±0.008 OUR AVERAGE				
11.019±0.005±0.007	BESSON	85	CLEO	$e^+e^- \to$ hadrons
11.020±0.030	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

$\Upsilon(11020)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
79 ±16 OUR AVERAGE				
61.0±13 ±22	BESSON	85	CLEO	$e^+e^- \to$ hadrons
90.0±20.0	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

$\Upsilon(11020)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	e^+e^-	$(1.6\pm0.5)\times10^{-6}$

$\Upsilon(11020)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ **Γ_1**

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.130±0.030 OUR AVERAGE				
0.095±0.03 ±0.035	BESSON	85	CLEO	$e^+e^- \to$ hadrons
0.156±0.040	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

$\Upsilon(11020)$ REFERENCES

BESSON	85	PRL 54 381	+Green, Namjoshi, Sannes+	(CLEO Collab.)
LOVELOCK	85	PRL 54 377	+Horstkotte, Klopfenstein+	(CUSB Collab.)

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)