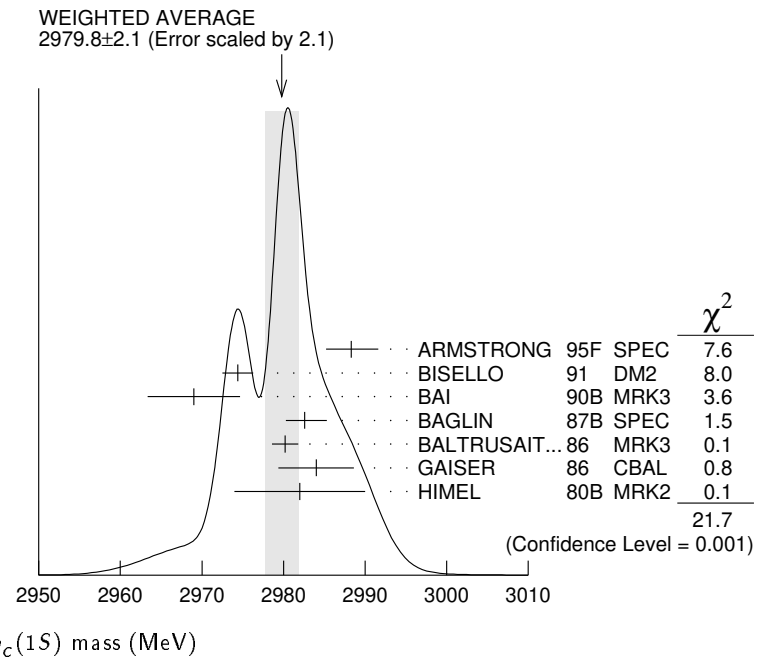
$\eta_c(1S)$

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

$\eta_c(1S)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
2979.8± 2.1 OUR AVERAGE		Error includes scale factor of 2.1. See the ideogram below.			
$2988.3^{+3.3}_{-3.1}$		ARMSTRONG	95F	SPEC	$\overline{p}p \to \gamma\gamma$
2974.4± 1.9		[1] BISELLO	91	DM2	$J/\psi \to \eta_c\gamma$
2969 ± 4 ± 4	80	BAI	90B	MRK3	$J/\psi \to \gamma K^+K^-K^+K^-$
$2982.6^{+2.7}_{-2.3}$	12	BAGLIN	87B	SPEC	$\overline{p}p \to \gamma\gamma$
2980.2± 1.6		[1] BALTRUSAIT...	86	MRK3	$J/\psi \to \eta_c\gamma$
2984 ± 2.3± 4.0		GAISER	86	CBAL	$J/\psi \to \gamma$X, $\psi(2S) \to \gamma$X
2982 ± 8	18	[2] HIMEL	80B	MRK2	e^+e^-
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2956 ±12 ±12		BAI	90B	MRK3	$J/\psi \to \gamma K^+K^-K^0_SK^0_L$
2976 ± 8		[3] BALTRUSAIT...	84	MRK3	$J/\psi \to 2\phi\gamma$
2980 ± 9		[2] PARTRIDGE	80B	CBAL	e^+e^-

[1] Average of several decay modes.
[2] Mass adjusted by us to correspond to $J/\psi(1S)$ mass = 3097 MeV.
[3] $\eta_c \to \phi\phi$.



$\eta_c(1S)$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
$13.2^{+3.8}_{-3.2}$ OUR AVERAGE						
$23.9^{+12.6}_{-7.1}$			ARMSTRONG	95F	SPEC	$\overline{p}p \to \gamma\gamma$
$7.0^{+7.5}_{-7.0}$		12	BAGLIN	87B	SPEC	$\overline{p}p \to \gamma\gamma$
$10.1^{+33.0}_{-8.2}$		23	[4] BALTRUSAIT...	86	MRK3	$J/\psi \to \gamma p\overline{p}$
11.5± 4.5			GAISER	86	CBAL	$J/\psi \to \gamma$X, $\psi(2S) \to \gamma$X
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<40	90	18	HIMEL	80B	MRK2	e^+e^-
<20	90		PARTRIDGE	80B	CBAL	e^+e^-

[4] Positive and negative errors correspond to 90% confidence level.

$\eta_c(1S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
	Decays involving hadronic resonances		
Γ_1	$\eta'(958)\pi\pi$	(4.1 ± 1.7) %	
Γ_2	$\rho\rho$	(2.6 ± 0.9) %	
Γ_3	$K^*(892)^0 K^- \pi^+ +$ c.c.	(2.0 ± 0.7) %	
Γ_4	$K^*(892)\overline{K}^*(892)$	$(8.5 \pm 3.1) \times 10^{-3}$	
Γ_5	$\phi\phi$	$(7.1 \pm 2.8) \times 10^{-3}$	
Γ_6	$a_0(980)\pi$	< 2 %	90%
Γ_7	$a_2(1320)\pi$	< 2 %	90%
Γ_8	$K^*(892)\overline{K} +$ c.c.	< 1.28 %	90%
Γ_9	$f_2(1270)\eta$	< 1.1 %	90%
Γ_{10}	$\omega\omega$	$< 3.1 \times 10^{-3}$	90%
	Decays into stable hadrons		
Γ_{11}	$K\overline{K}\pi$	(5.5 ± 1.7) %	
Γ_{12}	$\eta\pi\pi$	(4.9 ± 1.8) %	
Γ_{13}	$\pi^+\pi^- K^+ K^-$	$(2.0\ ^{+0.7}_{-0.6})$ %	
Γ_{14}	$2(K^+K^-)$	(2.1 ± 1.2) %	
Γ_{15}	$2(\pi^+\pi^-)$	(1.2 ± 0.4) %	
Γ_{16}	$p\overline{p}$	$(1.2 \pm 0.4) \times 10^{-3}$	
Γ_{17}	$K\overline{K}\eta$	< 3.1 %	90%
Γ_{18}	$\pi^+\pi^- p\overline{p}$	< 1.2 %	90%
Γ_{19}	$\Lambda\overline{\Lambda}$	$< 2 \times 10^{-3}$	90%
	Radiative decays		
Γ_{20}	$\gamma\gamma$	$(3.0 \pm 1.2) \times 10^{-4}$	

$\eta_c(1S)$ PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$ Γ_{20}

VALUE (keV)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$7.5^{+\ 1.6}_{=\ 1.4}$ OUR AVERAGE					
$6.7^{+\ 2.4}_{-\ 1.7} \pm 2.3$			ARMSTRONG	95F SPEC	$\overline{p}p \to \gamma\gamma$
11.3 ± 4.2			ALBRECHT	94H ARG	$\gamma\gamma$
$8.0 \pm 2.3 \pm 2.4$		17	ADRIANI	93N L3	$e^+e^- \to e^+e^-\eta_c$
$5.9^{+\ 2.1}_{-\ 1.8} \pm 1.9$			CHEN	90B CLEO	$e^+e^- \to e^+e^-\eta_c$
$6.4^{+\ 5.0}_{-\ 3.4}$			AIHARA	88D TPC	$e^+e^- \to e^+e^-$ X
28 ± 15			[5] BERGER	86 PLUT	$\gamma\gamma \to K\overline{K}\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<11	90		BLINOV	86 MD1	$e^+e^- \to e^+e^-$ X

[5] Re-evaluated by AIHARA 88D.

$\eta_c(1S)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}\pi) \times \Gamma(\gamma\gamma)/\Gamma_{total}$ $\Gamma_{11}\Gamma_{20}/\Gamma$

VALUE (keV)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
0.94 ± 0.18 OUR AVERAGE					
0.84 ± 0.21			[6] ALBRECHT	94H ARG	$\gamma\gamma \to K^\pm K^0_S \pi^\mp$
$1.06 \pm 0.41 \pm 0.27$		11	BRAUNSCH...	89 TASS	$\gamma\gamma \to K\overline{K}\pi$
$1.5\ ^{+0.60}_{-0.45} \pm 0.3$		7	[6] BERGER	86 PLUT	$\gamma\gamma \to K\overline{K}\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.63	95		[6] BEHREND	89 CELL	$\gamma\gamma \to K^0_S K^\pm \pi^\mp$
<4.4	95		ALTHOFF	85B TASS	$\gamma\gamma \to K\overline{K}\pi$

[6] $K^\pm K^0_S \pi^\mp$ corrected to $K\overline{K}\pi$ by factor 3.

$\eta_c(1S)$ BRANCHING RATIOS

HADRONIC DECAYS

$\Gamma(\eta'(958)\pi\pi)/\Gamma_{total}$ **Γ_1/Γ**

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.041±0.017	14	[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(\rho\rho)/\Gamma_{total}$ **Γ_2/Γ**

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
26 ± 9 OUR EVALUATION (Treating systematic errors as correlated.)						
25 ± 8 OUR AVERAGE						
26.0± 2.4±8.8		113	[7] BISELLO	91	DM2	$J/\psi \to \gamma\rho^0\rho^0$
23.6±10.6±8.2		32	[7] BISELLO	91	DM2	$J/\psi \to \gamma\rho^+\rho^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<140	90		[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(K^*(892)^0 K^-\pi^+ + \text{c.c.})/\Gamma_{total}$ **Γ_3/Γ**

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.02 ±0.007	63	[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(K^*(892)\overline{K}^*(892))/\Gamma_{total}$ **Γ_4/Γ**

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
85±31 OUR AVERAGE					
82±28±27	14	[7] BISELLO	91	DM2	$e^+e^- \to \gamma K^+K^-\pi^+\pi^-$
90±50	9	[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(K^*(892)\overline{K} + \text{c.c.})/\Gamma_{total}$ **Γ_8/Γ**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.0128	90	BISELLO	91	DM2	$J/\psi \to \gamma K^0_S K^\pm\pi^\mp$
<0.0132	90	[7] BISELLO	91	DM2	$J/\psi \to \gamma K^+K^-\pi^0$

$\Gamma(\phi\phi)/\Gamma_{total}$ **Γ_5/Γ**

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
71±28 OUR EVALUATION (Treating systematic errors as correlated.)					
71±22 OUR AVERAGE					
74±18±24	80	[7] BAI	90B	MRK3	$J/\psi \to \gamma K^+K^-K^+K^-$
67±21±24		[7] BAI	90B	MRK3	$J/\psi \to \gamma K^+K^-K^0_S K^0_L$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
31± 7±10	19	[7] BISELLO	91	DM2	$J/\psi \to \gamma K^+K^-K^+K^-$
$30^{+18}_{-12}\pm10$	5	[7] BISELLO	91	DM2	$J/\psi \to \gamma K^+K^-K^0_S K^0_L$

$\Gamma(a_0(980)\pi)/\Gamma_{total}$ **Γ_6/Γ**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.02	90	[7,8] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(a_2(1320)\pi)/\Gamma_{total}$ **Γ_7/Γ**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.02	90	[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(f_2(1270)\eta)/\Gamma_{total}$ **Γ_9/Γ**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.011	90	[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$

$\Gamma(\omega\omega)/\Gamma_{total}$ **Γ_{10}/Γ**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.0031	90	[7] BALTRUSAIT...86		MRK3	$J/\psi \to \eta_c\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0063		[7] BISELLO	91	DM2	$J/\psi \to \gamma\omega\omega$

$\Gamma(K\overline{K}\pi)/\Gamma_{total}$ Γ_{11}/Γ

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.055 ±0.017 OUR EVALUATION			(Treating systematic errors as correlated.)			
0.055 ±0.008 OUR AVERAGE						
0.0690±0.0142±0.0132		33	[7] BISELLO	91	DM2	$J/\psi \to \gamma K^+ K^- \pi^0$
0.0543±0.0094±0.0094		68	[7] BISELLO	91	DM2	$J/\psi \to \gamma K^\pm \pi^\mp K^0_S$
0.048 ±0.011		95	[7,9] BALTRUSAIT..86		MRK3	$J/\psi \to \eta_c \gamma$
$0.161\ ^{+0.092}_{-0.073}$			[10] HIMEL	80B	MRK2	$\psi(2S) \to \eta_c \gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.107	90		[7] PARTRIDGE	80B	CBAL	$J/\psi \to \eta_c \gamma$

$\Gamma(\eta\pi\pi)/\Gamma_{total}$ Γ_{12}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.049±0.018 OUR EVALUATION					
0.047±0.015 OUR AVERAGE					
0.054±0.020	75	[7] BALTRUSAIT..86		MRK3	$J/\psi \to \eta_c \gamma$
0.037±0.013±0.020	18	[7] PARTRIDGE	80B	CBAL	$J/\psi \to \eta \pi^+ \pi^- \gamma$

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
$\mathbf{0.020^{+0.007}_{-0.006}}$ **OUR AVERAGE**					
0.021±0.007	110	[7] BALTRUSAIT..86		MRK3	$J/\psi \to \eta_c \gamma$
$0.014^{+0.022}_{-0.009}$		[10] HIMEL	80B	MRK2	$\psi(2S) \to \eta_c \gamma$

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.012 ±0.004 OUR EVALUATION					
0.0120±0.0031 OUR AVERAGE					
0.0105±0.0017±0.0034	137	[7] BISELLO	91	DM2	$J/\psi \to \gamma 2\pi^+ 2\pi^-$
0.013 ±0.006	25	[7] BALTRUSAIT..86		MRK3	$J/\psi \to \eta_c \gamma$
$0.020\ ^{+0.015}_{-0.010}$		[10] HIMEL	80B	MRK2	$\psi(2S) \to \eta_c \gamma$

$\Gamma(2(K^+K^-))/\Gamma_{total}$ Γ_{14}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.021±0.010±0.006	ALBRECHT	94H	ARG	$\gamma\gamma \to K^+ K^- K^+ K^-$

$\Gamma(p\overline{p})/\Gamma_{total}$ Γ_{16}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
12± 4 OUR AVERAGE					
10± 3±4	18	[7] BISELLO	91	DM2	$J/\psi \to \gamma p\overline{p}$
11± 6	23	[7] BALTRUSAIT..86		MRK3	$J/\psi \to \eta_c \gamma$
29^{+29}_{-15}		[10] HIMEL	80B	MRK2	$\psi(2S) \to \eta_c \gamma$

$\Gamma(K\overline{K}\eta)/\Gamma_{total}$ Γ_{17}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.031	90	[7] BALTRUSAIT..86		MRK3	$J/\psi \to \eta_c \gamma$

$\Gamma(\pi^+\pi^- p\overline{p})/\Gamma_{total}$ Γ_{18}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.012	90	HIMEL	80B	MRK2	$\psi(2S) \to \eta_c \gamma$

$\Gamma(\Lambda\overline{\Lambda})/\Gamma_{total}$ Γ_{19}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.002	90	[7] BISELLO	91	DM2	$e^+ e^- \to \gamma\Lambda\overline{\Lambda}$

$\Gamma_i\Gamma_f/\Gamma^2_{\rm total}$ in $p\overline{p}\to\eta_c(1S)\to\phi\phi$ $\Gamma_{16}\Gamma_5/\Gamma^2$

VALUE (units 10^{-5})	DOCUMENT ID		TECN	COMMENT
$4.0^{+3.5}_{-3.2}$	BAGLIN	89	SPEC	$\overline{p}p\to K^+K^-K^+K^-$

[7] The quoted branching ratios use $B(J/\psi(1S)\to\gamma\eta_c(1S)) = 0.0127\pm0.0036$. Where relevant, the error in this branching ratio is treated as a common systematic in computing averages.

[8] We are assuming $B(a_0(980)\to\eta\pi) > 0.5$.

[9] Average from $K^+K^-\pi^0$ and $K^\pm K^0{}_S\pi^\mp$ decay channels.

[10] Estimated using $B(\psi(2S)\to\gamma\eta_c(1S)) = 0.0028\pm0.0006$.

RADIATIVE DECAYS

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

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
3.0 ±1.2 OUR AVERAGE					
$2.80^{+0.67}_{-0.58}\pm1.0$		ARMSTRONG	95F	SPEC	$\overline{p}p\to\gamma\gamma$
$6\ ^{+4}_{-3}\ \pm4$		BAGLIN	87B	SPEC	$\overline{p}p\to\gamma\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 9	90	[7] BISELLO	91	DM2	$J/\psi\to\gamma\gamma\gamma$
<18	90	[11] BLOOM	83	CBAL	$J/\psi\to\eta_c\gamma$

[11] Using $B(J/\psi(1S)\to\gamma\eta_c(1S)) = 0.0127\pm0.0036$.

$\Gamma_i\Gamma_f/\Gamma^2_{\rm total}$ in $p\overline{p}\to\eta_c(1S)\to\gamma\gamma$ $\Gamma_{16}\Gamma_{20}/\Gamma^2$

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	COMMENT
0.36 $^{+0.08}_{-0.07}$ OUR AVERAGE Error includes scale factor of 1.1.					
$0.336^{+0.080}_{-0.070}$		ARMSTRONG	95F	SPEC	$\overline{p}p\to\gamma\gamma$
$0.68\ ^{+0.42}_{-0.31}$	12	BAGLIN	87B	SPEC	$\overline{p}p\to\gamma\gamma$

$\eta_c(1S)$ REFERENCES

ARMSTRONG	95F	PR D52 4839	+Bettoni+	(FNAL, FERR, GENO, UCI, NWES+)
ALBRECHT	94H	PL B338 390	+Hamacher, Hofmann+	(ARGUS Collab.)
ADRIANI	93N	PL B318 575	+Aguilar-Benitez, Ahlen+	(L3 Collab.)
BISELLO	91	NP B350 1	+Busetto+	(DM2 Collab.)
BAI	90B	PRL 65 1309	+Blaylock+	(Mark III Collab.)
CHEN	90B	PL B243 169	+McIlwain+	(CLEO Collab.)
BAGLIN	89	PL B231 557	+Baird, Bassompierre	(R704 Collab.)
BEHREND	89	ZPHY C42 367	+Criegee+	(CELLO Collab.)
BRAUNSCH...	89	ZPHY C41 533	Braunschweig, Bock+	(TASSO Collab.)
AIHARA	88D	PRL 60 2355	+Alston-Garnjost+	(TPC Collab.)
BAGLIN	87B	PL B187 191	+Baird, Bassompierre, Borreani+	(R704 Collab.)
BALTRUSAIT...	86	PR D33 629	Baltrusaitis, Coffman, Hauser+	(Mark III Collab.)
BERGER	86	PL 167B 120	+Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BLINOV	86		+Blinov, Bondar, Bukin+	(NOVO)
Proc. XXIII Int.		HEP Conf., Berkeley, CA (1986); World Scientific, Singapore, 1987, ed. S.C. Loken		
GAISER	86	PR D34 711	+Bloom, Bulos, Godfrey+	(Crystal Ball Collab.)
ALTHOFF	85B	ZPHY C29 189	+Braunschweig, Kirschfink+	(TASSO Collab.)
BALTRUSAIT...	84	PRL 52 2126	Baltrusaitis+	(CIT, UCSC, ILL, SLAC, WASH) JP
BLOOM	83	ARNS 33 143	+Peck	(SLAC, CIT)
HIMEL	80B	PRL 45 1146	+Trilling, Abrams, Alam+	(SLAC, LBL, UCB)
PARTRIDGE	80B	PRL 45 1150	+Peck+	(CIT, HARV, PRIN, STAN, SLAC)

OTHER RELATED PAPERS

ARMSTRONG	89	PL B221 216	+Benayoun+	(CERN, CDEF, BIRM, BARI, ATHU, CURIN+)
BLOOM	79	Fermilab Symp. 92		(CIT, HARV, PRIN, SLAC, STAN)