$h_c(1P)$

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

Quantum numbers are quark model prediction, $C = -$ established by $\eta_c \gamma$ decay.

$h_c(1P)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3525.38±0.11 OUR AVERAGE					
3525.31±0.11±0.14	832	[1] ABLIKIM	12N	BES3	$\psi(2S) \to \pi^0 \gamma$ hadrons
3525.40±0.13±0.18	3679	ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0 \gamma \eta_c$
3525.20±0.18±0.12	1282	[2] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0 \eta_c \gamma$
3525.8 ±0.2 ±0.2	13	ANDREOTTI	05B	E835	$\overline{p}p \to \eta_c \gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3525.6 ±0.5	92^{+23}_{-22}	ADAMS	09	CLEO	$\psi(2S) \to 2(\pi^+\pi^-\pi^0)$
3524.4 ±0.6 ±0.4	168 ± 40	[3] ROSNER	05	CLEO	$\psi(2S) \to \pi^0 \eta_c \gamma$
3527 ±8	42	ANTONIAZZI	94	E705	300 $\pi^\pm$, pLi $\to J/\psi \pi^0 X$
3526.28±0.18±0.19	59	[4] ARMSTRONG	92D	E760	$\overline{p}p \to J/\psi \pi^0$
3525.4 ±0.8 ±0.4	5	BAGLIN	86	SPEC	$\overline{p}p \to J/\psi X$

[1] With floating width.

[2] Combination of exclusive and inclusive analyses for the reaction $\psi(2S) \to \pi^0 h_c \to \pi^0 \eta_c \gamma$. This result is the average of DOBBS 08A and ROSNER 05.

[3] Superseded by DOBBS 08A.

[4] Mass central value and systematic error recalculated by us according to Eq. (16) in ARMSTRONG 93B, using the value for the $\psi(2S)$ mass from AULCHENKO 03.

$h_c(1P)$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.70±0.28±0.22		832	[1] ABLIKIM	12N	BES3	$\psi(2S) \to \pi^0 \gamma$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 1.44	90	3679	[2] ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0 \gamma \eta_c$
< 1		13	ANDREOTTI	05B	E835	$\overline{p}p \to \eta_c \gamma$
< 1.1	90	59	ARMSTRONG	92D	E760	$\overline{p}p \to J/\psi \pi^0$

[1] With floating mass.

[2] The central value is $\Gamma = 0.73 \pm 0.45 \pm 0.28$ MeV.

$h_c(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$J/\psi(1S)\pi^0$		
Γ_2	$J/\psi(1S)\pi\pi$	not seen	
Γ_3	$p\overline{p}$	$< 1.5 \times 10^{-4}$	90%
Γ_4	$\pi^+\pi^-\pi^0$	$< 2.2 \times 10^{-3}$	
Γ_5	$2\pi^+2\pi^-\pi^0$	$(2.2^{+0.8}_{-0.7})$ %	
Γ_6	$3\pi^+3\pi^-\pi^0$	< 2.9 %	

Radiative decays

Γ_7	$\gamma\eta$	$(4.7\pm2.1)\times10^{-4}$
Γ_8	$\gamma\eta'(958)$	$(1.5\pm0.4)\times10^{-3}$
Γ_9	$\gamma\eta_c(1S)$	$(51\ \pm6\ )$ %

$h_c(1P)$ PARTIAL WIDTHS

$h_c(1P)$ $\Gamma(i)\Gamma(\overline{p}p)/\Gamma(\text{total})$

$\Gamma(\gamma\eta_c(1S))\times\Gamma(p\overline{p})/\Gamma_{\text{total}}$ — $\Gamma_9\Gamma_3/\Gamma$

VALUE (eV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
12.0 ± 4.5	13	[1] ANDREOTTI	05B	E835	$\overline{p}p\to\eta_c\gamma$

[1] Assuming $\Gamma = 1$ MeV.

$h_c(1P)$ BRANCHING RATIOS

$\Gamma(J/\psi(1S)\pi\pi)/\Gamma(J/\psi(1S)\pi^0)$ — Γ_2/Γ_1

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.18	90	ARMSTRONG	92D	E760	$\overline{p}p\to J/\psi\pi^0$

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ — Γ_4/Γ

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
<2.2	[1] ADAMS	09	CLEO	$\psi(2S)\to\pi^0\gamma\eta_c$

[1] ADAMS 09 reports $[\Gamma(h_c(1P)\to\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}]\times[B(\psi(2S)\to\pi^0 h_c(1P))] < 0.19\times10^{-5}$ which we divide by our best value $B(\psi(2S)\to\pi^0 h_c(1P)) = 8.6\times10^{-4}$.

$\Gamma(2\pi^+2\pi^-\pi^0)/\Gamma_{\text{total}}$ — Γ_5/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
$\mathbf{2.2^{+0.8}_{-0.6}\pm0.3}$	92	[1] ADAMS	09	CLEO	$\psi(2S)\to\pi^0\gamma\eta_c$

[1] ADAMS 09 reports $[\Gamma(h_c(1P)\to 2\pi^+2\pi^-\pi^0)/\Gamma_{\text{total}}]\times[B(\psi(2S)\to\pi^0 h_c(1P))] = (1.88^{+0.48}_{-0.45}{}^{+0.47}_{-0.30})\times10^{-5}$ which we divide by our best value $B(\psi(2S)\to\pi^0 h_c(1P)) = (8.6\pm1.3)\times10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(3\pi^+3\pi^-\pi^0)/\Gamma_{\text{total}}$ — Γ_6/Γ

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
<2.9	[1] ADAMS	09	CLEO	$\psi(2S)\to\pi^0\gamma\eta_c$

[1] ADAMS 09 reports $[\Gamma(h_c(1P)\to 3\pi^+3\pi^-\pi^0)/\Gamma_{\text{total}}]\times[B(\psi(2S)\to\pi^0 h_c(1P))] < 2.5\times10^{-5}$ which we divide by our best value $B(\psi(2S)\to\pi^0 h_c(1P)) = 8.6\times10^{-4}$.

RADIATIVE DECAYS

$\Gamma(\gamma\eta)/\Gamma_{\text{total}}$ — Γ_7/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
$\mathbf{4.7\pm1.5\pm1.4}$	18	ABLIKIM	16I	BES3	$\psi(2S)\to\pi^0\gamma\eta$

$\Gamma(\gamma\eta'(958))/\Gamma_{total}$ — Γ_8/Γ

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	COMMENT
1.52±0.27±0.29	44	ABLIKIM	16I	BES3	$\psi(2S) \to \pi^0\gamma\eta'(958)$

$\Gamma(\gamma\eta_c(1S))/\Gamma_{total}$ — Γ_9/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
51 ± 6 OUR AVERAGE					
54.3± 6.7±5.2	3679	ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0\gamma\eta_c$
48 ± 6 ±7		[1] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
48 ± 6 ±7	1282	[2] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
46 ±12 ±7	168	[3] ROSNER	05	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$

[1] Average of DOBBS 08A and ROSNER 05. DOBBS 08A reports $[\Gamma(h_c(1P) \to \gamma\eta_c(1S))/\Gamma_{total}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[2] DOBBS 08A reports $[\Gamma(h_c(1P) \to \gamma\eta_c(1S))/\Gamma_{total}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.19 \pm 0.32 \pm 0.45) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[3] ROSNER 05 reports $[\Gamma(h_c(1P) \to \gamma\eta_c(1S))/\Gamma_{total}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.0 \pm 0.8 \pm 0.7) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

CROSS-PARTICLE BRANCHING RATIOS

$\Gamma(h_c(1P) \to p\overline{p})/\Gamma_{total} \times \Gamma(\psi(2S) \to \pi^0 h_c(1P))/\Gamma_{total}$ — $\Gamma_3/\Gamma \times \Gamma_{15}^{\psi(2S)}/\Gamma^{\psi(2S)}$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<1.3 × 10^{-7}	90	ABLIKIM	13V	BES3	$\psi(2S) \to \gamma p\overline{p}$

$\Gamma(h_c(1P) \to \gamma\eta_c(1S))/\Gamma_{total} \times \Gamma(\psi(2S) \to \pi^0 h_c(1P))/\Gamma_{total}$ — $\Gamma_9/\Gamma \times \Gamma_{15}^{\psi(2S)}/\Gamma^{\psi(2S)}$

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
4.3 ±0.4 OUR AVERAGE					
4.58±0.40±0.50	3679	[1] ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0\gamma X$
4.16±0.30±0.37	1430	[2] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\gamma\eta_c$

[1] Not independent of other branching fractions in ABLIKIM 10B.

[2] Not independent of other branching fractions in DOBBS 08A.

$h_c(1P)$ REFERENCES

ABLIKIM	16I	PRL 116 251802	M. Ablikim *et al.*	(BES III Collab.)
ABLIKIM	13V	PR D88 112001	M. Ablikim *et al.*	(BES III Collab.)
ABLIKIM	12N	PR D86 092009	M. Ablikim *et al.*	(BES III Collab.)
ABLIKIM	10B	PRL 104 132002	M. Ablikim *et al.*	(BES III Collab.)
ADAMS	09	PR D80 051106	G.S. Adams *et al.*	(CLEO Collab.)
DOBBS	08A	PRL 101 182003	S. Dobbs *et al.*	(CLEO Collab.)
ANDREOTTI	05B	PR D72 032001	M. Andreotti *et al.*	(FNAL E835 Collab.)
ROSNER	05	PRL 95 102003	J.L. Rosner *et al.*	(CLEO Collab.)
AULCHENKO	03	PL B573 63	V.M. Aulchenko *et al.*	(KEDR Collab.)
ANTONIAZZI	94	PR D50 4258	L. Antoniazzi *et al.*	(E705 Collab.)
ARMSTRONG	93B	PR D47 772	T.A. Armstrong *et al.*	(FNAL E760 Collab.)
ARMSTRONG	92D	PRL 69 2337	T.A. Armstrong *et al.*	(FNAL, FERR, GENO+)
BAGLIN	86	PL B171 135	C. Baglin *et al.*	(LAPP, CERN, TORI, STRB+)