$h_c(1P)$

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

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

[1] With floating width.

[2] Combination of exclusive and inclusive analyses for the reaction $\psi(2S) \rightarrow \pi^0 h_c \rightarrow \pi^0 \eta_c \gamma$. 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[3] Superseded by DOBBS 08A.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	[5] ABLIKIM	12N	BES3	$\psi(2S) \rightarrow \pi^0 \gamma$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 1.44	90	3679	[6] ABLIKIM	10B	BES3	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$
< 1		13	ANDREOTTI	05B	E835	$\overline{p} p \rightarrow \eta_c \gamma$
< 1.1	90	59	ARMSTRONG	92D	E760	$\overline{p} p \rightarrow J/\psi \pi^0$

[5] With floating mass.

[6] 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	$\eta_c(1S)\gamma$	(51 ± 6) %
Γ_5	$\pi^+\pi^-\pi^0$	$< 2.2 \times 10^{-3}$
Γ_6	$2\pi^+2\pi^-\pi^0$	$(2.2^{+0.8}_{-0.7})$ %
Γ_7	$3\pi^+3\pi^-\pi^0$	< 2.9 %

$h_c(1P)$ PARTIAL WIDTHS

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

$\Gamma(\eta_c(1S)\gamma) \times \Gamma(p\overline{p})/\Gamma_{\text{total}}$ — $\Gamma_4\Gamma_3/\Gamma$

VALUE (eV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
12.0 ± 4.5	13	[7] ANDREOTTI	05B	E835	$\overline{p}p \to \eta_c\gamma$

[7] 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	$\overline{p}p \to J/\psi\pi^0$

$\Gamma(\eta_c(1S)\gamma)/\Gamma_{\text{total}}$ — Γ_4/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
51 ± 6 OUR AVERAGE					
$54.3 \pm 6.7 \pm 5.2$	3679	ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0\gamma\eta_c$
$48 \pm 6 \pm 7$		[8] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$48 \pm 6 \pm 7$	1282	[9] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
$46 \pm 12 \pm 7$	168	[10] ROSNER	05	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$

[8] Average of DOBBS 08A and ROSNER 05. DOBBS 08A reports $[\Gamma(h_c(1P) \to \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$ 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.

[9] DOBBS 08A reports $[\Gamma(h_c(1P) \to \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.19 \pm 0.32 \pm 0.45) \times 10^{-4}$ 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.

[10] ROSNER 05 reports $[\Gamma(h_c(1P) \to \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.0 \pm 0.8 \pm 0.7) \times 10^{-4}$ 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.

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

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
<2.2	[11] ADAMS	09	CLEO	$\psi(2S) \to \pi^0\gamma\eta_c$

[11] ADAMS 09 reports $[\Gamma(h_c(1P) \to \pi^+\pi^-\pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] < 0.19 \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

$\Gamma(2\pi^+ 2\pi^- \pi^0)/\Gamma_{total}$ Γ_6/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
$2.2^{+0.8}_{-0.6}\pm0.3$	92	[12] ADAMS	09	CLEO	$\psi(2S) \to \pi^0 \gamma \eta_c$

[12] ADAMS 09 reports $[\Gamma(h_c(1P) \to 2\pi^+ 2\pi^- \pi^0)/\Gamma_{total}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (1.88^{+0.48}_{-0.45}{}^{+0.47}_{-0.30}) \times 10^{-5}$ 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.

$\Gamma(3\pi^+ 3\pi^- \pi^0)/\Gamma_{total}$ Γ_7/Γ

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
<2.9	[13] ADAMS	09	CLEO	$\psi(2S) \to \pi^0 \gamma \eta_c$

[13] ADAMS 09 reports $[\Gamma(h_c(1P) \to 3\pi^+ 3\pi^- \pi^0)/\Gamma_{total}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] < 2.5 \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

$\Gamma(h_c(1P) \to \eta_c(1S)\gamma)/\Gamma_{total} \times \Gamma(\psi(2S) \to \pi^0 h_c(1P))/\Gamma_{total}$ $\Gamma_4/\Gamma \times \Gamma^{\psi(2S)}_{15}/\Gamma^{\psi(2S)}$

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
4.3 ±0.4 OUR AVERAGE					
$4.58\pm0.40\pm0.50$	3679	[14] ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0 \gamma X$
$4.16\pm0.30\pm0.37$	1430	[15] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0 \gamma \eta_c$

[14] Not independent of other branching fractions in ABLIKIM 10B.
[15] Not independent of other branching fractions in DOBBS 08A.

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

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

$h_c(1P)$ REFERENCES

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+)