$h_c(1P)$

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

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[3] Superseded by DOBBS 08A.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	[5] 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	[6] 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	$\overline{p}p \to J/\psi \pi^0$

[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	$\eta_c(1S)\gamma$	$(51 \pm 6)\,\%$
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				
$54.3\pm 6.7\pm5.2$	3679	ABLIKIM 10B	BES3	$\psi(2S) \to \pi^0\gamma\eta_c$
$48 \pm 6 \pm7$		[8] DOBBS 08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$48 \pm 6 \pm7$	1282	[9] DOBBS 08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
$46 \pm12 \pm7$	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 $[\Gamma(h_c(1P) \to \pi^+\pi^-\pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] < 0.19\times10^{-5}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = 8.6\times10^{-4}$.

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

$\Gamma(3\pi^+ 3\pi^- \pi^0)/\Gamma_{total}$ $\qquad$ 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 $B(\psi(2S) \to \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

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

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.

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

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+)