$h_c(1P)$

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

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

$h_c(1P)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3525.41±0.16 OUR AVERAGE	Error includes scale factor of 1.2.				
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	[1] 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	[2] 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	[3] 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] 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.

[2] Superseded by DOBBS 08A.

[3] 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
<1		13	ANDREOTTI	05B	E835	$\overline{p}p \to \eta_c\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<1.44	90	3679	[4] ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0\gamma\eta_c$
<1.1	90	59	ARMSTRONG	92D	E760	$\overline{p}p \to J/\psi\pi^0$

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

$h_c(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$J/\psi(1S)\pi^0$	
Γ_2	$J/\psi(1S)\pi\pi$	not seen
Γ_3	$p\overline{p}$	
Γ_4	$\eta_c(1S)\gamma$	(53 ±7) %
Γ_5	$\pi^+\pi^-\pi^0$	< 2.3 $\times 10^{-3}$
Γ_6	$2\pi^+2\pi^-\pi^0$	($2.2^{+0.9}_{-0.8}$) %
Γ_7	$3\pi^+3\pi^-\pi^0$	< 3.0 %

$h_c(1P)$ PARTIAL WIDTHS

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

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

VALUE (eV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
12.0 ± 4.5	13	[5] ANDREOTTI	05B	E835	$\overline{p}p \to \eta_c\gamma$

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

$h_c(1P)$ BRANCHING RATIOS

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

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

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
53 ± 7 OUR AVERAGE					
$54.3\pm 6.7\pm 5.2$	3679	ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0\gamma\eta_c$
$50 \pm 6 \pm10$		[6] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$50 \pm 7 \pm10$	1282	[7] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$
$48 \pm13 \pm 9$	168	[8] ROSNER	05	CLEO	$\psi(2S) \to \pi^0\eta_c\gamma$

[6] Average of DOBBS 08A and ROSNER 05. DOBBS 08A reports $[\Gamma\big(h_c(1P) \to \eta_c(1S)\gamma\big)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.4 \pm 1.6) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[7] DOBBS 08A reports $[\Gamma\big(h_c(1P) \to \eta_c(1S)\gamma\big)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.19 \pm 0.32 \pm 0.45) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.4 \pm 1.6) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[8] ROSNER 05 reports $[\Gamma\big(h_c(1P) \to \eta_c(1S)\gamma\big)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] = (4.0 \pm 0.8 \pm 0.7) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.4 \pm 1.6) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-3})	DOCUMENT ID		TECN	COMMENT
<2.3	[9] ADAMS	09	CLEO	$\psi(2S) \to \pi^0\gamma\eta_c$

[9] ADAMS 09 reports $[\Gamma\big(h_c(1P) \to \pi^+\pi^-\pi^0\big)/\Gamma_{\text{total}}] \times [B(\psi(2S) \to \pi^0 h_c(1P))] < 0.19\times10^{-5}$ which we divide by our best value $B(\psi(2S) \to \pi^0 h_c(1P)) = 8.4\times10^{-4}$.

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

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{2.2^{+0.8}_{-0.6} \pm 0.4}$	92	[10] ADAMS	09	CLEO	$\psi(2S) \to \pi^0 \gamma \eta_c$

[10] 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 $B(\psi(2S) \to \pi^0 h_c(1P)) = (8.4 \pm 1.6) \times 10^{-4}$. 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*
<3.0	[11] ADAMS	09	CLEO	$\psi(2S) \to \pi^0 \gamma \eta_c$

[11] 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 $B(\psi(2S) \to \pi^0 h_c(1P)) = 8.4 \times 10^{-4}$.

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

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
(4.3+-0.4) OUR AVERAGE					
$4.58 \pm 0.40 \pm 0.50$	3679	[12] ABLIKIM	10B	BES3	$\psi(2S) \to \pi^0 \gamma X$
$4.16 \pm 0.30 \pm 0.37$	1430	[13] DOBBS	08A	CLEO	$\psi(2S) \to \pi^0 \gamma \eta_c$

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

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

$h_c(1P)$ REFERENCES

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+)