

$h_c(1P)$

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

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	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$
3525.20 ± 0.18 ± 0.12	1282	¹ DOBBS	08A CLEO	$\psi(2S) \rightarrow \pi^0 \eta_c \gamma$
3525.8 ± 0.2 ± 0.2	13	ANDREOTTI	05B E835	$\bar{p} p \rightarrow \eta_c \gamma$
● ● ● 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	² ROSNER	05 CLEO	$\psi(2S) \rightarrow \pi^0 \eta_c \gamma$
3527 ± 8	42	ANTONIAZZI	94 E705	300 $\pi^\pm, p \text{Li} \rightarrow J/\psi \pi^0 X$
3526.28 ± 0.18 ± 0.19	59	³ ARMSTRONG	92D E760	$\bar{p} p \rightarrow J/\psi \pi^0$
3525.4 ± 0.8 ± 0.4	5	BAGLIN	86 SPEC	$\bar{p} p \rightarrow J/\psi X$

¹ 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.

² Superseded by DOBBS 08A.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	$\bar{p} p \rightarrow \eta_c \gamma$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
<1.44	90	3679	⁴ ABLIKIM	10B BES3	$\psi(2S) \rightarrow \pi^0 \gamma \eta_c$
<1.1	90	59	ARMSTRONG	92D E760	$\bar{p} p \rightarrow J/\psi \pi^0$

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 $p \bar{p}$	
Γ_4 $\eta_c(1S) \gamma$	(51 ± 6) %
Γ_5 $\pi^+ \pi^- \pi^0$	< 2.2 × 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

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

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

VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

12.0±4.5	13	⁵ ANDREOTTI	05B	E835	$\bar{p}p \rightarrow \eta_c\gamma$
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⁵ 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
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<0.18	90	ARMSTRONG	92D	E760	$\bar{p}p \rightarrow J/\psi\pi^0$
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$\Gamma(\eta_c(1S)\gamma)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
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51 ± 6 OUR AVERAGE

54.3± 6.7±5.2	3679	ABLIKIM	10B	BES3	$\psi(2S) \rightarrow \pi^0\gamma\eta_c$
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48 ± 6 ± 7		⁶ DOBBS	08A	CLEO	$\psi(2S) \rightarrow \pi^0\eta_c\gamma$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

48 ± 6 ± 7	1282	⁷ DOBBS	08A	CLEO	$\psi(2S) \rightarrow \pi^0\eta_c\gamma$
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46 ± 12 ± 7	168	⁸ ROSNER	05	CLEO	$\psi(2S) \rightarrow \pi^0\eta_c\gamma$
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⁶ Average of DOBBS 08A and ROSNER 05. DOBBS 08A reports $[\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))]$ = $(4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

⁷ DOBBS 08A reports $[\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))]$ = $(4.19 \pm 0.32 \pm 0.45) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

⁸ ROSNER 05 reports $[\Gamma(h_c(1P) \rightarrow \eta_c(1S)\gamma)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))]$ = $(4.0 \pm 0.8 \pm 0.7) \times 10^{-4}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. 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
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<2.2	⁹ ADAMS	09	CLEO	$\psi(2S) \rightarrow \pi^0\gamma\eta_c$
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⁹ ADAMS 09 reports $[\Gamma(h_c(1P) \rightarrow \pi^+\pi^-\pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))]$ < 0.19×10^{-5} which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
$2.2^{+0.8}_{-0.6} \pm 0.3$	92	¹⁰ ADAMS	09	CLEO $\psi(2S) \rightarrow \pi^0 \gamma \eta_c$

¹⁰ ADAMS 09 reports $[\Gamma(h_c(1P) \rightarrow 2\pi^+2\pi^-\pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] = (1.88^{+0.48}_{-0.45} + 0.47_{-0.30}) \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = (8.6 \pm 1.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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

VALUE (units 10^{-2})	DOCUMENT ID	TECN	COMMENT
< 2.9	¹¹ ADAMS	09	CLEO $\psi(2S) \rightarrow \pi^0 \gamma \eta_c$

¹¹ ADAMS 09 reports $[\Gamma(h_c(1P) \rightarrow 3\pi^+3\pi^-\pi^0)/\Gamma_{\text{total}}] \times [B(\psi(2S) \rightarrow \pi^0 h_c(1P))] < 2.5 \times 10^{-5}$ which we divide by our best value $B(\psi(2S) \rightarrow \pi^0 h_c(1P)) = 8.6 \times 10^{-4}$.

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

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

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 <i>et al.</i>	(BES III Collab.)
ADAMS	09	PR D80 051106	G.S. Adams <i>et al.</i>	(CLEO Collab.)
DOBBS	08A	PRL 101 182003	S. Dobbs <i>et al.</i>	(CLEO Collab.)
ANDREOTTI	05B	PR D72 032001	M. Andreotti <i>et al.</i>	(FNAL E835 Collab.)
ROSNER	05	PRL 95 102003	J.L. Rosner <i>et al.</i>	(CLEO Collab.)
AULCHENKO	03	PL B573 63	V.M. Aulchenko <i>et al.</i>	(KEDR Collab.)
ANTONIAZZI	94	PR D50 4258	L. Antoniazzi <i>et al.</i>	(E705 Collab.)
ARMSTRONG	93B	PR D47 772	T.A. Armstrong <i>et al.</i>	(FNAL E760 Collab.)
ARMSTRONG	92D	PRL 69 2337	T.A. Armstrong <i>et al.</i>	(FNAL, FERR, GENO+)
BAGLIN	86	PL B171 135	C. Baglin <i>et al.</i>	(LAPP, CERN, TORI, STRB+)