

$\eta_c(2S)$

$$I^G(J^{PC}) = 0^+(0^{-+})$$

Quantum numbers are quark model predictions.

 $\eta_c(2S)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
3637.7 ± 0.9	OUR AVERAGE	Error includes scale factor of 1.2.		
3637.90 ± 0.54 ± 1.40	3.7k	AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$
3643.4 ± 2.3 ± 4.4	569	ABLIKIM	22Q BES3	$\psi(2S) \rightarrow \gamma 3(\pi^+ \pi^-)$
3635.1 ± 3.7 ± 2.9	106	XU	18 BELL	$e^+ e^- \rightarrow e^+ e^- \eta' \pi^+ \pi^-$
3633.6 ± 1.7 ± 0.6	106	¹ AAIJ	17AD LHCb	$p p \rightarrow B^+ X \rightarrow p \bar{p} K^+ X$
3636.4 ± 4.1 ± 0.7	365	² AAIJ	17BB LHCb	$p p \rightarrow b \bar{b} X \rightarrow 2(K^+ K^-) X$
3637.0 ± 5.7 ± 3.4	178	^{3,4} LEES	14E BABR	$\gamma \gamma \rightarrow K^+ K^- \pi^0$
3635.1 ± 5.8 ± 2.1	47	^{3,5} LEES	14E BABR	$\gamma \gamma \rightarrow K^+ K^- \eta$
3646.9 ± 1.6 ± 3.6	57	ABLIKIM	13K BES3	$\psi(2S) \rightarrow \gamma K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$
3637.6 ± 2.9 ± 1.6	127	⁶ ABLIKIM	12G BES3	$\psi(2S) \rightarrow \gamma K^0 K \pi, K K \pi^0$
3638.5 ± 1.5 ± 0.8	624	³ DEL-AMO-SA..11M	BABR	$\gamma \gamma \rightarrow K_S^0 K^\pm \pi^\mp$
3640.5 ± 3.2 ± 2.5	1201	³ DEL-AMO-SA..11M	BABR	$\gamma \gamma \rightarrow K^+ K^- \pi^+ \pi^- \pi^0$
3636.1 ^{+3.9} _{-4.2} ^{+0.7} _{-2.0}	128	⁷ VINOKUROVA	11 BELL	$B^\pm \rightarrow K^\pm(K_S^0 K^\pm \pi^\mp)$
3626 ± 5 ± 6	311	⁸ ABE	07 BELL	$e^+ e^- \rightarrow J/\psi(c \bar{c})$
3645.0 ± 5.5 ^{+4.9} _{-7.8}	121	AUBERT	05C BABR	$e^+ e^- \rightarrow J/\psi c \bar{c}$
3642.9 ± 3.1 ± 1.5	61	ASNER	04 CLEO	$\gamma \gamma \rightarrow \eta'_c \rightarrow K_S^0 K^\pm \pi^\mp$

● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●

3639 ± 7	98	⁹ AUBERT	06E BABR	$B^\pm \rightarrow K^\pm X_{c \bar{c}}$
3630.8 ± 3.4 ± 1.0	112	¹⁰ AUBERT	04D BABR	$\gamma \gamma \rightarrow \eta_c(2S) \rightarrow K \bar{K} \pi$
3654 ± 6 ± 8	39	¹¹ CHOI	02 BELL	$B \rightarrow K K_S K^- \pi^+$
3594 ± 5		¹² EDWARDS	82C CBAL	$e^+ e^- \rightarrow \gamma X$

¹ AAIJ 17AD report $m_{\psi(2S)} - m_{\eta_c(2S)} = 52.5 \pm 1.7 \pm 0.6$ MeV. We use the current value $m_{\psi(2S)} = 3686.097 \pm 0.025$ MeV to obtain the quoted mass.² From a fit of the $\phi\phi$ invariant mass with the width of $\eta_c(2S)$ fixed to the PDG 16 value.³ Ignoring possible interference with continuum.⁴ With a width fixed to 11.3 MeV.⁵ With a width fixed to 11.3 MeV. Using both $\eta \rightarrow \gamma\gamma$ and $\eta \rightarrow \pi^+ \pi^- \pi^0$ decays.⁶ From a simultaneous fit to $K_S^0 K^\pm \pi^\mp$ and $K^+ K^- \pi^0$ decay modes.⁷ Accounts for interference with non-resonant continuum.⁸ From a fit of the J/ψ recoil mass spectrum. Supersedes ABE,K 02 and ABE 04G.⁹ From the fit of the kaon momentum spectrum. Systematic errors not evaluated.¹⁰ Superseded by DEL-AMO-SANCHEZ 11M.¹¹ Superseded by VINOKUROVA 11.

¹² Assuming mass of $\psi(2S) = 3686$ MeV. **$\eta_c(2S)$ WIDTH**

VALUE (MeV)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
11.8 ± 1.6	OUR AVERAGE			
10.77 ± 1.62 ± 1.08	3.7k	AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$
19.8 ± 3.9 ± 3.1	569	ABLIKIM	22Q BES3	$\psi(2S) \rightarrow \gamma 3(\pi^+ \pi^-)$
9.9 ± 4.8 ± 2.9	57	ABLIKIM	13K BES3	$\psi(2S) \rightarrow$ $\gamma K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$
16.9 ± 6.4 ± 4.8	127	¹ ABLIKIM	12G BES3	$\psi(2S) \rightarrow \gamma K^0 K \pi,$ $K K \pi^0$
13.4 ± 4.6 ± 3.2	624	² DEL-AMO-SA..11M	BABR	$\gamma \gamma \rightarrow K_S^0 K^\pm \pi^\mp$
6.6 + 8.4 + 2.6 - 5.1 - 0.9	128	³ VINOKUROVA 11	BELL	$B^\pm \rightarrow$ $K^\pm(K_S^0 K^\pm \pi^\mp)$
6.3 ± 12.4 ± 4.0	61	ASNER	04 CLEO	$\gamma \gamma \rightarrow \eta'_c \rightarrow$ $K_S^0 K^\pm \pi^\mp$

• • • We do not use the following data for averages, fits, limits, etc. • • •

< 23	90	98	⁴ AUBERT	06E BABR	$B^\pm \rightarrow K^\pm X_{c\bar{c}}$
22 ± 14		121	AUBERT	05C BABR	$e^+ e^- \rightarrow J/\psi c \bar{c}$
17.0 ± 8.3 ± 2.5		112	⁵ AUBERT	04D BABR	$\gamma \gamma \rightarrow \eta_c(2S) \rightarrow$ $K \bar{K} \pi$
< 55	90	39	⁶ CHOI	02 BELL	$B \rightarrow K K_S K^- \pi^+$
< 8.0	95		⁷ EDWARDS	82C CBAL	$e^+ e^- \rightarrow \gamma X$

¹ From a simultaneous fit to $K_S^0 K^\pm \pi^\mp$ and $K^+ K^- \pi^0$ decay modes.

² Ignoring possible interference with continuum.

³ Accounts for interference with non-resonant continuum.

⁴ From the fit of the kaon momentum spectrum. Systematic errors not evaluated.

⁵ Superseded by DEL-AMO-SANCHEZ 11M.

⁶ For a mass value of 3654 ± 6 MeV. Superseded by VINOKUROVA 11.

⁷ For a mass value of 3594 ± 5 MeV

 $\eta_c(2S)$ DECAY MODES

Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1 hadrons	seen	
Γ_2 $K \bar{K} \pi$	(1.9 ± 1.2) %	
Γ_3 $K \bar{K} \eta$	(5 ± 4) × 10 ⁻³	
Γ_4 $2\pi^+ 2\pi^-$	< 2.1 %	90%
Γ_5 $\rho^0 \rho^0$	< 1.9 × 10 ⁻³	90%
Γ_6 $3\pi^+ 3\pi^-$	(1.3 ± 0.9) %	
Γ_7 $K^+ K^- \pi^+ \pi^-$	< 1.4 %	90%
Γ_8 $K^{*0} \bar{K}^{*0}$	< 2.9 × 10 ⁻³	90%
Γ_9 $K^+ K^- \pi^+ \pi^- \pi^0$	(1.4 ± 1.0) %	
Γ_{10} $K^+ K^- 2\pi^+ 2\pi^-$	< 1.4 %	90%
Γ_{11} $K_S^0 K^- 2\pi^+ \pi^- + c.c.$	(1.0 ± 0.8) %	
Γ_{12} $2K^+ 2K^-$	< 1.3 × 10 ⁻³	90%

Γ_{13}	$\phi\phi$	< 1.1	$\times 10^{-3}$	90%
Γ_{14}	$\rho\bar{\rho}$	< 2.0	$\times 10^{-3}$	90%
Γ_{15}	$\rho\bar{\rho}\pi^+\pi^-$	seen		
Γ_{16}	$\gamma\gamma$	(1.8 ± 1.2)	$\times 10^{-4}$	
Γ_{17}	$\gamma J/\psi(1S)$	< 1.4	%	90%
Γ_{18}	$\pi^+\pi^-\eta$	(4.3 ± 3.2)	$\times 10^{-3}$	
Γ_{19}	$\pi^+\pi^-\eta'$	(2.6 ± 1.9)	$\times 10^{-3}$	
Γ_{20}	$K_2^*(1430)\bar{K} + \text{c.c.}$	seen		
Γ_{21}	$K_0^*(1950)\bar{K} + \text{c.c.}$	seen		
Γ_{22}	$a_0(1710)\pi$	seen		
Γ_{23}	$a_0(1450)\pi$	seen		
Γ_{24}	$a_2(1700)\pi$	seen		
Γ_{25}	$K_0^*(2600)\bar{K} + \text{c.c.}$	seen		
Γ_{26}	$\pi^+\pi^-\eta_c(1S)$	< 25	%	90%

$\eta_c(2S)$ PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$					Γ_{16}
VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT	

••• We do not use the following data for averages, fits, limits, etc. •••

0.44±0.14	106	¹ XU	18	BELL	$e^+e^- \rightarrow e^+e^-\eta'\pi^+\pi^-$
1.3 ±0.6		² ASNER	04	CLEO	$\gamma\gamma \rightarrow \eta'_c \rightarrow K_S^0 K^\pm \pi^\mp$

¹ Assuming that the branching fraction into $\eta'\pi^+\pi^-$ is the same as for $\eta_c(1S)$.

² They measure $\Gamma(\eta_c(2S)\gamma\gamma) B(\eta_c(2S) \rightarrow K\bar{K}\pi) = (0.18 \pm 0.05 \pm 0.02) \Gamma(\eta_c(1S)\gamma\gamma) B(\eta_c(1S) \rightarrow K\bar{K}\pi)$. The value for $\Gamma(\eta_c(2S) \rightarrow \gamma\gamma)$ is derived assuming that the branching fractions for $\eta_c(2S)$ and $\eta_c(1S)$ decays to $K_S K\pi$ are equal and using $\Gamma(\eta_c(1S) \rightarrow \gamma\gamma) = 7.4 \pm 0.4 \pm 2.3$ keV.

$\Gamma(\gamma\gamma) \times \Gamma(\pi^+\pi^-\eta')/\Gamma_{\text{total}}$					$\Gamma_{16}\Gamma_{19}/\Gamma$
VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT	
$5.6_{-1.1}^{+1.2} \pm 1.1$	106	XU	18	BELL	$e^+e^- \rightarrow e^+e^-\eta'\pi^+\pi^-$

$\eta_c(2S)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(K\bar{K}\pi) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$					$\Gamma_2\Gamma_{16}/\Gamma$
VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT	
$41 \pm 4 \pm 6$	624	¹ DEL-AMO-SA..11M	BABR	$\gamma\gamma \rightarrow K_S^0 K^\pm \pi^\mp$	

¹ Not independent from other measurements reported in DEL-AMO-SANCHEZ 11M.

$\Gamma(2\pi^+2\pi^-) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$					$\Gamma_4\Gamma_{16}/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	
< 6.5	90	UEHARA	08	BELL	$\gamma\gamma \rightarrow \eta_c(2S) \rightarrow 2(\pi^+\pi^-)$

$\Gamma(K^+K^-\pi^+\pi^-) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$					$\Gamma_7\Gamma_{16}/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	
< 5.0	90	UEHARA	08	BELL	$\gamma\gamma \rightarrow \eta_c(2S) \rightarrow K^+K^-\pi^+\pi^-$

$\Gamma(K^+K^-\pi^+\pi^-\pi^0) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_9\Gamma_{16}/\Gamma$

VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT
30±6±5	1201	¹ DEL-AMO-SA..11M	BABR	$\gamma\gamma \rightarrow K^+K^-\pi^+\pi^-\pi^0$

¹ Not independent from other measurements reported in DEL-AMO-SANCHEZ 11M.

 $\Gamma(2K^+2K^-) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_{12}\Gamma_{16}/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
<2.9	90	UEHARA	08	BELL $\gamma\gamma \rightarrow \eta_c(2S) \rightarrow 2(K^+K^-)$

 $\Gamma(\pi^+\pi^-\eta_c(1S)) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_{26}\Gamma_{16}/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
<133	90	LEES	12AE	BABR $e^+e^- \rightarrow e^+e^-\pi^+\pi^-\eta_c$

 $\eta_c(2S) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma^2(\text{total})$ $\Gamma(p\bar{p})/\Gamma_{\text{total}} \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_{14}/\Gamma \times \Gamma_{16}/\Gamma$

VALUE (units 10^{-8})	CL%	DOCUMENT ID	TECN	COMMENT
< 5.6	90	^{1,2,3} AMBROGIANI 01	E835	$\bar{p}p \rightarrow \gamma\gamma$

• • • We do not use the following data for averages, fits, limits, etc. • • •

< 8.0	90	^{1,2,4} AMBROGIANI 01	E835	$\bar{p}p \rightarrow \gamma\gamma$
<12.0	90	^{2,4} AMBROGIANI 01	E835	$\bar{p}p \rightarrow \gamma\gamma$

¹ Including the measurements of of ARMSTRONG 95F in the AMBROGIANI 01 analysis.

² For a total width $\Gamma=5$ MeV.

³ For the resonance mass region 3589–3599 MeV/ c^2 .

⁴ For the resonance mass region 3575–3660 MeV/ c^2 .

 $\eta_c(2S)$ BRANCHING RATIOS $\Gamma(\text{hadrons})/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
not seen	ABREU	980	DLPH $e^+e^- \rightarrow e^+e^- + \text{hadrons}$

• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	¹ EDWARDS	82C	CBAL $e^+e^- \rightarrow \gamma X$
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¹ For a mass value of 3594 ± 5 MeV

 $\Gamma(K\bar{K}\pi)/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
1.9±0.4±1.1	59 ± 12	¹ AUBERT	08AB	BABR $B \rightarrow \eta_c(2S)K \rightarrow K\bar{K}\pi K$

• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	127 ± 18	ABLIKIM	12G	BES3 $\psi(2S) \rightarrow \gamma K\bar{K}\pi$
seen	39 ± 11	² CHOI	02	BELL $B \rightarrow KK_S K^-\pi^+$

¹ Derived from a measurement of $[B(B^+ \rightarrow \eta_c(2S)K^+) \times B(\eta_c(2S) \rightarrow K\bar{K}\pi)] / [B(B^+ \rightarrow \eta_c K^+) \times B(\eta_c \rightarrow K\bar{K}\pi)] = (9.6^{+2.0}_{-1.9} \pm 2.5)\%$ and using $B(B^+ \rightarrow \eta_c(2S)K^+) = (3.4 \pm 1.8) \times 10^{-4}$, and $[B(B^+ \rightarrow \eta_c K^+) \times B(\eta_c \rightarrow K\bar{K}\pi)] = (6.88 \pm 0.77^{+0.55}_{-0.66}) \times 10^{-5}$.

² For a mass value of 3654 ± 6 MeV

$\Gamma(K\bar{K}\eta)/\Gamma(K\bar{K}\pi)$ Γ_3/Γ_2

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
$27.3 \pm 7.0 \pm 9.0$	225	¹ LEES	14E BABR	$\gamma\gamma \rightarrow K^+ K^- \gamma\gamma$

¹ LEES 14E reports $B(\eta_c(2S) \rightarrow K^+ K^- \eta)/B(\eta_c(2S) \rightarrow K^+ K^- \pi^0) = 0.82 \pm 0.21 \pm 0.27$, which we divide by 3 to account for isospin symmetry.

 $\Gamma(2\pi^+ 2\pi^-)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	UEHARA	08 BELL	$\gamma\gamma \rightarrow \eta_c(2S)$

 $\Gamma(\rho^0 \rho^0)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	ABLIKIM	11H BES3	$\psi(2S) \rightarrow \gamma 2\pi^+ 2\pi^-$

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

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	UEHARA	08 BELL	$\gamma\gamma \rightarrow \eta_c(2S)$

 $\Gamma(K^*0 \bar{K}^{*0})/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	ABLIKIM	11H BES3	$\psi(2S) \rightarrow \gamma K^+ K^- \pi^+ \pi^-$

 $\Gamma(K^+ K^- \pi^+ \pi^- \pi^0)/\Gamma(K\bar{K}\pi)$ Γ_9/Γ_2

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.73 \pm 0.17 \pm 0.17$	1201	¹ DEL-AMO-SA..11M	BABR	$\gamma\gamma \rightarrow K^+ K^- \pi^+ \pi^- \pi^0$

¹ We have multiplied the value of $\Gamma(K^+ K^- \pi^+ \pi^- \pi^0)/\Gamma(K_S^0 K^\pm \pi^\mp)$ reported in DEL-AMO-SANCHEZ 11M by a factor 1/3 to obtain $\Gamma(K^+ K^- \pi^+ \pi^- \pi^0)/\Gamma(K\bar{K}\pi)$. Not independent from other measurements reported in DEL-AMO-SANCHEZ 11M.

 $\Gamma(K_S^0 K^- 2\pi^+ \pi^- + \text{c.c.})/\Gamma_{\text{total}}$ Γ_{11}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	57 ± 17	ABLIKIM	13K BES3	$\psi(2S) \rightarrow \gamma K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$

 $\Gamma(2K^+ 2K^-)/\Gamma_{\text{total}}$ Γ_{12}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	UEHARA	08 BELL	$\gamma\gamma \rightarrow \eta_c(2S)$

 $\Gamma(\phi\phi)/\Gamma_{\text{total}}$ Γ_{13}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	ABLIKIM	11H BES3	$\psi(2S) \rightarrow \gamma K^+ K^- K^+ K^-$

$\Gamma(p\bar{p})/\Gamma_{\text{total}}$ Γ_{14}/Γ

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

seen 106 ¹ AAIJ 17AD LHCB $p\bar{p} \rightarrow B^+ X \rightarrow p\bar{p}K^+ X$
¹ AAIJ 17AD report a 6.4 standard deviation signal, with $B(B^+ \rightarrow \eta_c(2S)K^+ \rightarrow p\bar{p}K^+)/B(B^+ \rightarrow J/\psi K^+ \rightarrow p\bar{p}K^+) = (1.58 \pm 0.33 \pm 0.09) \times 10^{-2}$.

$\Gamma(p\bar{p}\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{15}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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seen 110 ¹ CHILIKIN 19 BELL $e^+e^- \rightarrow \Upsilon(4S)$
¹ CHILIKIN 19 reports signals in $B^+ \rightarrow \eta_c(2S)K^+$ and $B^0 \rightarrow \eta_c(2S)K_S^0$ with 12.3 and 5.9 standard deviations, respectively.

$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{16}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

$<4 \times 10^{-4}$ 90 ¹ WICHT 08 BELL $B^\pm \rightarrow K^\pm \gamma\gamma$
 not seen AMBROGIANI 01 E835 $\bar{p}p \rightarrow \gamma\gamma$
 <0.01 90 LEE 85 CBAL $\psi' \rightarrow \text{photons}$
¹ WICHT 08 reports $[\Gamma(\eta_c(2S) \rightarrow \gamma\gamma)/\Gamma_{\text{total}}] \times [B(B^+ \rightarrow \eta_c(2S)K^+)] < 0.18 \times 10^{-6}$
 which we divide by our best value $B(B^+ \rightarrow \eta_c(2S)K^+) = 4.4 \times 10^{-4}$.

$\Gamma(\pi^+\pi^-\eta_c(1S))/\Gamma(K\bar{K}\pi)$ Γ_{26}/Γ_2

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<3.33 90 ¹ LEES 12AE BABR $e^+e^- \rightarrow e^+e^-\pi^+\pi^-\eta_c$
¹ We divided the reported limit by 3 to take into account isospin relations.

$\eta_c(2S)$ CROSS-PARTICLE BRANCHING RATIOS

$\Gamma(\eta_c(2S) \rightarrow K\bar{K}\eta)/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_3/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

$<11.8 \times 10^{-6}$ 90 ¹ CRONIN-HEN..10 CLEO $\psi(2S) \rightarrow \gamma K^+ K^- \eta$
¹ CRONIN-HENNESSY 10 reports a limit of $< 5.9 \times 10^{-6}$ for the decay $\eta_c(2S) \rightarrow K^+ K^- \eta$ which we multiply by 2 account for isospin symmetry. It assumes $\Gamma(\eta_c(2S)) = 14$ MeV. It also gives the analytic dependence of limits on width.

$\Gamma(\eta_c(2S) \rightarrow 2\pi^+2\pi^-)/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_4/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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$<14.6 \times 10^{-6}$ 90 ¹ CRONIN-HEN..10 CLEO $\psi(2S) \rightarrow \gamma 2\pi^+ 2\pi^-$
¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$$\Gamma(\eta_c(2S) \rightarrow \rho^0 \rho^0) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_5 / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<12.7 \times 10^{-7}$	90	ABLIKIM	11H BES3	$\psi(2S) \rightarrow \gamma 2\pi^+ 2\pi^-$

$$\Gamma(\eta_c(2S) \rightarrow 3\pi^+ 3\pi^-) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_6 / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$9.2 \pm 1.0 \pm 1.2$		569	ABLIKIM	22Q BES3	$\psi(2S) \rightarrow \gamma 3(\pi^+ \pi^-)$

• • • We do not use the following data for averages, fits, limits, etc. • • •

<13.2	90	¹ CRONIN-HEN..10	CLEO	$\psi(2S) \rightarrow \gamma 3\pi^+ 3\pi^-$
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¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$$\Gamma(\eta_c(2S) \rightarrow K^+ K^- \pi^+ \pi^-) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_7 / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<9.6 \times 10^{-6}$	90	¹ CRONIN-HEN..10	CLEO	$\psi(2S) \rightarrow \gamma K^+ K^- \pi^+ \pi^-$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$$\Gamma(\eta_c(2S) \rightarrow K^{*0} \bar{K}^{*0}) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_8 / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<19.6 \times 10^{-7}$	90	ABLIKIM	11H BES3	$\psi(2S) \rightarrow \gamma K^+ K^- \pi^+ \pi^-$

$$\Gamma(\eta_c(2S) \rightarrow K^+ K^- \pi^+ \pi^- \pi^0) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_9 / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<43.0 \times 10^{-6}$	90	¹ CRONIN-HEN..10	CLEO	$\psi(2S) \rightarrow \gamma K^+ K^- \pi^+ \pi^- \pi^0$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$$\Gamma(\eta_c(2S) \rightarrow K^+ K^- 2\pi^+ 2\pi^-) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_{10} / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<9.7 \times 10^{-6}$	90	¹ CRONIN-HEN..10	CLEO	$\psi(2S) \rightarrow \gamma K^+ K^- 2\pi^+ 2\pi^-$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$$\Gamma(\eta_c(2S) \rightarrow K_S^0 K^- 2\pi^+ \pi^- + \text{c.c.}) / \Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S)) / \Gamma_{\text{total}}$$

$$\Gamma_{11} / \Gamma \times \Gamma_{183}^{\psi(2S)} / \Gamma_{\psi(2S)}$$

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$7.03 \pm 2.10 \pm 0.7$		60	ABLIKIM	13K BES3	$\psi(2S) \rightarrow \gamma K_S^0 K^- 2\pi^+ \pi^- + \text{c.c.}$

• • • We do not use the following data for averages, fits, limits, etc. • • •

< 15.2 90 ¹ CRONIN-HEN..10 CLEO $\psi(2S) \rightarrow \gamma K_S^0 K^- 2\pi^+ \pi^- + c.c.$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$\Gamma(\eta_c(2S) \rightarrow \phi\phi)/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_{13}/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
< 7.8×10^{-7}	90	ABLIKIM	11H BES3	$\psi(2S) \rightarrow \gamma K^+ K^- K^+ K^-$

$\Gamma(\eta_c(2S) \rightarrow p\bar{p})/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_{14}/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
< 1.4×10^{-6}	90	ABLIKIM	13V BES3	$\psi(2S) \rightarrow \gamma p\bar{p}$

$\Gamma(\eta_c(2S) \rightarrow \gamma J/\psi(1S))/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_{17}/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
< 9.7×10^{-6}	90	33	¹ ABLIKIM	17N BES3	$\psi(2S) \rightarrow \gamma\gamma J/\psi$

¹ Uses $B(J/\psi \rightarrow e^+e^-) = (5.971 \pm 0.032)\%$ and $B(J/\psi \rightarrow \mu^+\mu^-) = (5.961 \pm 0.033)\%$.

$\Gamma(\eta_c(2S) \rightarrow \pi^+\pi^-\eta)/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_{18}/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$2.97 \pm 0.81 \pm 0.26$		106	ABLIKIM	23Q BES3	$\psi(2S) \rightarrow \gamma\pi^+\pi^-\eta$

• • • We do not use the following data for averages, fits, limits, etc. • • •

< 4.3 90 ¹ CRONIN-HEN..10 CLEO $\psi(2S) \rightarrow \gamma\pi^+\pi^-\eta$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$\Gamma(\eta_c(2S) \rightarrow \pi^+\pi^-\eta')/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma\eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_{19}/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma\psi(2S)$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
< 14.2×10^{-6}	90	¹ CRONIN-HEN..10	CLEO	$\psi(2S) \rightarrow \gamma\pi^+\pi^-\eta'$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

$\Gamma(K_2^*(1430)\bar{K} + c.c.)/\Gamma_{\text{total}}$ Γ_{20}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K\pi)$

¹ From a Dalitz plot analysis of $\eta_c(2S) \rightarrow K_S^0 K^+ \pi^- + c.c.$

$\Gamma(a_0(1710)\pi)/\Gamma_{\text{total}}$ Γ_{22}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$

¹ From a Dalitz plot analysis of $\eta_c(2S) \rightarrow K_S^0 K^+ \pi^- + \text{c.c.}$.

 $\Gamma(a_0(1450)\pi)/\Gamma_{\text{total}}$ Γ_{23}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$

¹ From a Dalitz plot analysis of $\eta_c(2S) \rightarrow K_S^0 K^+ \pi^- + \text{c.c.}$.

 $\Gamma(a_2(1700)\pi)/\Gamma_{\text{total}}$ Γ_{24}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$

¹ From a Dalitz plot analysis of $\eta_c(2S) \rightarrow K_S^0 K^+ \pi^- + \text{c.c.}$.

 $\Gamma(K_0^*(2600)\bar{K} + \text{c.c.})/\Gamma_{\text{total}}$ Γ_{25}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$

¹ From a Dalitz plot analysis of $\eta_c(2S) \rightarrow K_S^0 K^+ \pi^- + \text{c.c.}$.

 $\Gamma(K_0^*(1950)\bar{K} + \text{c.c.})/\Gamma_{\text{total}}$ Γ_{21}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ AAIJ	23AH LHCb	$B^+ \rightarrow K^+(K_S^0 K \pi)$

¹ From a Dalitz plot analysis of $\eta_c(2S) \rightarrow K_S^0 K^+ \pi^- + \text{c.c.}$.

 $\Gamma(\eta_c(2S) \rightarrow \pi^+ \pi^- \eta_c(1S))/\Gamma_{\text{total}} \times \Gamma(\psi(2S) \rightarrow \gamma \eta_c(2S))/\Gamma_{\text{total}}$ $\Gamma_{26}/\Gamma \times \Gamma_{183}^{\psi(2S)}/\Gamma_{\psi(2S)}$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<1.7 \times 10^{-4}$	90	¹ CRONIN-HEN..10	CLEO	$\psi(2S) \rightarrow \gamma \pi^+ \pi^- \eta_c(1S)$

¹ Assuming $\Gamma(\eta_c(2S)) = 14$ MeV. CRONIN-HENNESSY 10 gives the analytic dependence of limits on width.

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