

$\psi_2(3823)$

$$I^G(J^{PC}) = 0^-(2^{--})$$

I, J, P need confirmation.

was $\psi(3823)$, $X(3823)$

Seen by BHARDWAJ 13 in $B \rightarrow \chi_{c1} \gamma K$ and ABLIKIM 15S in $e^+ e^- \rightarrow \pi^+ \pi^- \gamma \chi_{c1}$ decays as a narrow peak in the invariant mass distribution of the $\chi_{c1} \gamma$ system. Properties consistent with the $\psi_2(1^3D_2) c\bar{c}$ state.

 $\psi_2(3823)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
3823.5 ± 0.5	OUR AVERAGE	Error includes scale factor of 1.4.		
$3823.12 \pm 0.43 \pm 0.13$	120	ABLIKIM	22R	BES3 $e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
$3824.08 \pm 0.53 \pm 0.14$	137	¹ AAIJ	20S	LHCB $B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
$3823.1 \pm 1.8 \pm 0.7$	33 ± 10	² BHARDWAJ	13	BELL $B^\pm \rightarrow \chi_{c1} \gamma K^\pm$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
$3821.7 \pm 1.3 \pm 0.7$	19 ± 5	³ ABLIKIM	15S	BES3 $e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$

¹ Using the measured $m_{\psi_2(3823)} - m_{\psi(2S)} = 137.98 \pm 0.53 \pm 0.14$ MeV.

² From a simultaneous fit to $B^\pm \rightarrow (\chi_{c1} \gamma) K^\pm$ and $B^0 \rightarrow (\chi_{c1} \gamma) K_S^0$ with significance 4.0σ including systematics. Corrected for the measured $\psi(2S)$ mass using $B \rightarrow \psi(2S) K \rightarrow (\gamma \chi_{c1}) K$ decays.

³ From a simultaneous unbinned maximum likelihood fit of $e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$ data (the $\pi^+ \pi^-$ recoil mass) taken at \sqrt{s} values of 4.23, 4.26, 4.36, 4.42, and 4.60 GeV to simulated events including both $\psi(2S) \rightarrow \chi_{c1} \gamma$ and $\psi_2(3823) \rightarrow \chi_{c1} \gamma$ together, with floating mass scale offset for $\psi(2S)$, floating $\psi_2(3823)$ mass, and zero $\psi_2(3823)$ width, resulting in a significance of 5.9σ when including systematic uncertainties. Superseded by ABLIKIM 22R.

 $m_{\psi_2(3823)} - m_{\psi(2S)}$

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
$137.98 \pm 0.53 \pm 0.14$	137	¹ AAIJ	20S	LHCB $B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
¹ AAIJ 20S also reports $m_{\chi_{c1}(3872)} - m_{\psi_2(3823)} = 47.50 \pm 0.53 \pm 0.13$ MeV.				

 $\psi_2(3823)$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
< 2.9	90	120	ABLIKIM	22R	BES3 $e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
< 5.2	90		¹ AAIJ	20S	LHCB $B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
< 16	90		² ABLIKIM	15S	BES3 $e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
< 24	90		³ BHARDWAJ	13	BELL $B^\pm \rightarrow \chi_{c1} \gamma K^\pm$

¹AAIJ 20S also provides a limit of < 6.6 MeV with 95% CL.

²From a fit of $e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$ data (the $\pi^+ \pi^-$ recoil mass) taken at \sqrt{s} values of 4.23, 4.26, 4.36, 4.42, and 4.60 GeV to a Breit-Wigner function with the mass fixed from the likelihood fit above, Gaussian resolution smearing, and floating width.

³From a simultaneous fit to $B^\pm \rightarrow (\chi_{c1} \gamma) K^\pm$ and $B^0 \rightarrow (\chi_{c1} \gamma) K_S^0$ with significance 4.0σ including systematics.

$\psi_2(3823)$ DECAY MODES

Branching fractions are given relative to the one **DEFINED AS 1**.

Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1 $J/\psi(1S)\pi^+\pi^-$	<0.06	90%
Γ_2 $J/\psi(1S)\pi^0\pi^0$	<0.11	90%
Γ_3 $J/\psi(1S)\pi^0$	<0.030	90%
Γ_4 $J/\psi(1S)\eta$	<0.14	90%
Γ_5 $\chi_{c0}\gamma$	<0.24	90%
Γ_6 $\chi_{c1}\gamma$	DEFINED AS 1	
Γ_7 $\chi_{c2}\gamma$	0.28 $\begin{smallmatrix} +0.14 \\ -0.11 \end{smallmatrix}$	

$\psi_2(3823)$ BRANCHING RATIOS

$\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$	Γ_1/Γ
<u>VALUE</u>	<u>EVTS</u>

<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●		
not seen	¹ ABLIKIM 210 BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
seen	137 ± 26 AAIJ 20S LHCb	$B^+ \rightarrow J/\psi\pi^+\pi^-K^+$
¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^-X$.		

$\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma(\chi_{c1}\gamma)$	Γ_1/Γ_6
<u>VALUE</u>	<u>CL%</u>

<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<0.06	90	¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^-X$
¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^-X$.		

$\Gamma(J/\psi(1S)\pi^0\pi^0)/\Gamma(\chi_{c1}\gamma)$	Γ_2/Γ_6
<u>VALUE</u>	<u>CL%</u>

<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<0.11	90	¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^-X$
¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^-X$.		

$\Gamma(J/\psi(1S)\pi^0)/\Gamma(\chi_{c1}\gamma)$	Γ_3/Γ_6
<u>VALUE</u>	<u>CL%</u>

<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<0.03	90	¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^-X$
¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^-X$.		

$\Gamma(J/\psi(1S)\eta)/\Gamma(\chi_{c1}\gamma)$	Γ_4/Γ_6
<u>VALUE</u>	<u>CL%</u>

<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<0.14	90	¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^-X$
¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^-X$.		

$\Gamma(J/\psi(1S)\eta)/\Gamma(J/\psi(1S)\pi^+\pi^-)$ Γ_4/Γ_1

VALUE	DOCUMENT ID	TECN	COMMENT
$4.4^{+2.5}_{-1.9} \pm 0.9$	¹ AAIJ	22D	LHCB $B^+ \rightarrow J/\psi(1S)\eta K^+$

¹ Using the branching ratio for $B^+ \rightarrow \psi_2(3823) K^+$ with $\psi_2(3823) \rightarrow J/\psi(1S)\pi^+\pi^-$ from AAIJ 20s.

$\Gamma(\chi_{c0}\gamma)/\Gamma_{\text{total}}$ Γ_5/Γ

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

not seen ¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^- X$

¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^- X$.

$\Gamma(\chi_{c1}\gamma)/\Gamma_{\text{total}}$ Γ_6/Γ

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

seen 120 ¹ ABLIKIM 22R BES3 $e^+e^- \rightarrow \pi^+\pi^-\chi_{c1}\gamma$

seen 63 ± 9 ² ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^- X$

seen 16 ± 5 ³ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^0\pi^0 X$

seen 33 ± 10 ⁴ BHARDWAJ 13 BELL $B^\pm \rightarrow \chi_{c1}\gamma K^\pm$

¹ From a fit to the $e^+e^- \rightarrow \pi^+\pi^-\psi(3823)$ cross section between 4.23 and 4.70 GeV with two coherent Breit-Wigner resonances. The data is also consistent with a single peak R with mass $4417.5 \pm 26.2 \pm 3.5$ MeV and width $245 \pm 48 \pm 13$ MeV, which leads to $\Gamma(e^+e^-) B(R \rightarrow \pi^+\pi^-\psi_2(3823)) B(\psi_2(3823) \rightarrow \chi_{c1}\gamma) = 0.57 \pm 0.08$ eV.

² From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^- X$. Signal has a 11.8 σ significance.

³ From a fit of the invariant $\pi^0\pi^0$ recoil-mass distribution. Signal has a 4.3 σ significance.

⁴ BHARDWAJ 13 reports $B(B^\pm \rightarrow \psi_2(3823) K^\pm) \times B(\psi_2(3823) \rightarrow \gamma\chi_{c1}) = (9.7 \pm 2.8 \pm 1.1) \times 10^{-6}$ with statistical significance 3.8 σ .

$\Gamma(\chi_{c0}\gamma)/\Gamma(\chi_{c1}\gamma)$ Γ_5/Γ_6

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<0.24 90 ¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^- X$

¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^- X$.

$\Gamma(\chi_{c2}\gamma)/\Gamma_{\text{total}}$ Γ_7/Γ

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

seen ¹ ABLIKIM 210 BES3 $e^+e^- \rightarrow \pi^+\pi^- X$

not seen ² ABLIKIM 15S BES3 $e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$

not seen ³ BHARDWAJ 13 BELL $B^\pm \rightarrow \chi_{c2}\gamma K^\pm$

¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^- X$. Signal has a 3.2 σ significance.

² From a simultaneous unbinned maximum likelihood fit of $e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$ data (the $\pi^+\pi^-$ recoil mass) taken at \sqrt{s} values of 4.23, 4.26, 4.36, 4.42, and 4.60 GeV to

simulated events including both $\psi(2S) \rightarrow \chi_{c2}\gamma$ and $\psi_2(3823) \rightarrow \chi_{c2}\gamma$ together, with floating mass scale offset for $\psi(2S)$, $\psi_2(3823)$ mass floating (fixed to that above), and zero $\psi_2(3823)$ width.

³ BHARDWAJ 13 reports $B(B^\pm \rightarrow \psi_2(3823)K^\pm) \times B(\psi_2(3823) \rightarrow \gamma\chi_{c2}) < 3.6 \times 10^{-6}$ at 90% CL.

$\Gamma(\chi_{c2}\gamma)/\Gamma(\chi_{c1}\gamma)$						Γ_7/Γ_6
VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT	
$0.28^{+0.14}_{-0.11} \pm 0.02$		9 ± 4	¹ ABLIKIM	210 BES3	$e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
<0.42	90		² ABLIKIM	15S BES3	$e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$	
<0.41	90		BHARDWAJ	13 BELL	$B^\pm \rightarrow \chi_{c1/c2}\gamma K^\pm$	

¹ From a simultaneous unbinned maximum likelihood fit of the $\pi^+\pi^-$ recoil mass distributions of seven decay channels in the process $e^+e^- \rightarrow \pi^+\pi^-X$.

² From a simultaneous unbinned maximum likelihood fit of $e^+e^- \rightarrow \pi^+\pi^-\chi_{c1(2)}\gamma$ data (the $\pi^+\pi^-$ recoil mass) taken at \sqrt{s} values of 4.23, 4.26, 4.36, 4.42, and 4.60 GeV to simulated events including both $\psi(2S) \rightarrow \chi_{c1(2)}\gamma$ and $\psi_2(3823) \rightarrow \chi_{c1(2)}\gamma$ together, with floating mass scale offset for $\psi(2S)$, $\psi_2(3823)$ mass floating (fixed to that above), and zero $\psi_2(3823)$ width.

$\psi_2(3823)$ REFERENCES

AAIJ	22D	JHEP 2204 046	R. Aaij <i>et al.</i>	(LHCb Collab.)
ABLIKIM	22R	PRL 129 102003	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	21O	PR D103 L091102	M. Ablikim <i>et al.</i>	(BESIII Collab.)
AAIJ	20S	JHEP 2008 123	R. Aaij <i>et al.</i>	(LHCb Collab.)
ABLIKIM	15S	PRL 115 011803	M. Ablikim <i>et al.</i>	(BESIII Collab.)
BHARDWAJ	13	PRL 111 032001	V. Bhardwaj <i>et al.</i>	(BELLE Collab.)