

$\psi_2(3823)$

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

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
3823.51 ± 0.34 OUR AVERAGE				
3824.5 ± 2.4 ± 1.0	30	¹ ABLIKIM	23J BES3	$e^+ e^- \rightarrow \pi^0 \pi^0 \chi_{c1} \gamma$
3823.12 ± 0.43 ± 0.13	120	ABLIKIM	22R BES3	$e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
3824.08 ± 0.53 ± 0.14	137	² AAIJ	20S LHCB	$B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
3823.1 ± 1.8 ± 0.7	33 ± 10	³ 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 ± 1.3 ± 0.7	19 ± 5	⁴ ABLIKIM	15S BES3	$e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$

¹ Using the measured $m_{\psi_2(3823)} - m_{\psi(2S)}$ and assuming $m_{\psi(2S)} = 3686.097$ MeV from PDG 22.

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

³ 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.

⁴ 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 Superseded by ABLIKIM 22R.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 ± 0.53 ± 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. • • •					
< 18.8	90	30	¹ ABLIKIM	23J BES3	$e^+ e^- \rightarrow \pi^0 \pi^0 \chi_{c1} \gamma$
< 5.2	90		² AAIJ	20S LHCB	$B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
< 16	90		³ ABLIKIM	15S BES3	$e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
< 24	90		⁴ BHARDWAJ	13 BELL	$B^\pm \rightarrow \chi_{c1} \gamma K^\pm$

¹ From a fit of $e^+ e^- \rightarrow \pi^0 \pi^0 \chi_{c1} \gamma$ data at $\sqrt{s}$ values from 4.23 to 4.70 GeV to a Breit-Wigner function with floating width, using the Bayesian approach.

² AAIJ 20S also provides a limit of < 6.6 MeV with 95% CL.

³ From 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.

⁴ 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.

$\psi_2(3823)$ 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	$\chi_{c2}\gamma$	$0.28^{+0.14}_{-0.11}$	

$\psi_2(3823)$ BRANCHING RATIOS

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

VALUE	EVTs	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	$e^+e^- \rightarrow \pi^+\pi^-X$
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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<0.06	90	¹ ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<0.11	90	¹ ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<0.03	90	¹ ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<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 $e^+e^- \rightarrow \pi^+\pi^-X$.

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 $\Gamma(\chi_{c1}\gamma)/\Gamma_{\text{total}}$ 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	$e^+e^- \rightarrow \pi^0\pi^0X$
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
<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
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$0.28^{+0.14}_{-0.11} \pm 0.02$	9 ± 4	¹ ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$
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• • • 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

ABLIKIM	23J	JHEP 2302 171	M. Ablikim <i>et al.</i>	(BESIII Collab.)
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.)
PDG	22	PTEP 2022 083C01	R.L. Workman <i>et al.</i>	(PDG 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.)