

$\psi_2(3823)$ 

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

$I, J, P$  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
<b>3823.7 ± 0.5 OUR AVERAGE</b>				Error includes scale factor of 1.1.
3824.08 ± 0.53 ± 0.14	137	<sup>1</sup> AAIJ	20S LHCb	$B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
3821.7 ± 1.3 ± 0.7	19 ± 5	<sup>2</sup> ABLIKIM	15S BES3	$e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
3823.1 ± 1.8 ± 0.7	33 ± 10	<sup>3</sup> BHARDWAJ	13 BELL	$B^\pm \rightarrow \chi_{c1} \gamma K^\pm$

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

<sup>2</sup> 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  $5.9\sigma$  when including systematic uncertainties.

<sup>3</sup> 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  $4.0\sigma$  including systematics. Corrected for the measured  $\psi(2S)$  mass using  $B \rightarrow \psi(2S) K \rightarrow (\gamma \chi_{c1}) K$  decays.

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

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	<sup>1</sup> AAIJ	20S LHCb	$B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$

<sup>1</sup> 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%	DOCUMENT ID	TECN	COMMENT
<b>&lt; 5.2</b>	90	<sup>1</sup> AAIJ	20S LHCb	$B^+ \rightarrow J/\psi \pi^+ \pi^- K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<16	90	<sup>2</sup> ABLIKIM	15S BES3	$e^+ e^- \rightarrow \pi^+ \pi^- \chi_{c1} \gamma$
<24	90	<sup>3</sup> BHARDWAJ	13 BELL	$B^\pm \rightarrow \chi_{c1} \gamma K^\pm$

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

<sup>2</sup> 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.

<sup>3</sup> 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  $4.0\sigma$  including systematics.

$\psi_2(3823)$  DECAY MODESBranching fractions are given relative to the one **DEFINED AS 1**.

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level
$\Gamma_1$ $J/\psi(1S)\pi^+\pi^-$	<0.06	90%
$\Gamma_2$ $J/\psi(1S)\pi^0\pi^0$	<0.11	90%
$\Gamma_3$ $J/\psi(1S)\pi^0$	<0.030	90%
$\Gamma_4$ $J/\psi(1S)\eta$	<0.14	90%
$\Gamma_5$ $\chi_{c0}\gamma$	<0.24	90%
$\Gamma_6$ $\chi_{c1}\gamma$	<b>DEFINED AS 1</b>	
$\Gamma_7$ $\chi_{c2}\gamma$	0.28 $^{+0.14}_{-0.11}$	

 $\psi_2(3823)$  BRANCHING RATIOS

$\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	

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

not seen		<sup>1</sup> ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
seen	$137 \pm 26$	AAIJ	20S	LHCB	$B^+ \rightarrow J/\psi\pi^+\pi^-K^+$

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

$\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma(\chi_{c1}\gamma)$					$\Gamma_1/\Gamma_6$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	

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

$\Gamma(J/\psi(1S)\pi^0\pi^0)/\Gamma(\chi_{c1}\gamma)$					$\Gamma_2/\Gamma_6$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	

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

$\Gamma(J/\psi(1S)\pi^0)/\Gamma(\chi_{c1}\gamma)$					$\Gamma_3/\Gamma_6$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	

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

$\Gamma(J/\psi(1S)\eta)/\Gamma(\chi_{c1}\gamma)$					$\Gamma_4/\Gamma_6$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	

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

$\Gamma(\chi_{c0}\gamma)/\Gamma_{\text{total}}$   $\Gamma_5/\Gamma$ 

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

not seen	<sup>1</sup> ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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<sup>1</sup> From a simultaneous unbinned maximum likelihood fit of the  $\pi^+\pi^-$  recoil mass distributions of seven decay channels in the process  $e^+e^- \rightarrow \pi^+\pi^-X$ .

 $\Gamma(\chi_{c1}\gamma)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$ 

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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seen	$33 \pm 10$	<sup>1</sup> BHARDWAJ	13	BELL	$B^\pm \rightarrow \chi_{c1}\gamma K^\pm$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	$63 \pm 9$	<sup>2</sup> ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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seen	$16 \pm 5$	<sup>3</sup> ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^0\pi^0X$
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<sup>1</sup> 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  $3.8 \sigma$ .

<sup>2</sup> 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  $11.8 \sigma$  significance.

<sup>3</sup> From a fit of the invariant  $\pi^0\pi^0$  recoil-mass distribution. Signal has a  $4.3 \sigma$  significance.

 $\Gamma(\chi_{c0}\gamma)/\Gamma(\chi_{c1}\gamma)$   $\Gamma_5/\Gamma_6$ 

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;0.24</b>	90	<sup>1</sup> ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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<sup>1</sup> From a simultaneous unbinned maximum likelihood fit of the  $\pi^+\pi^-$  recoil mass distributions of seven decay channels in the process  $e^+e^- \rightarrow \pi^+\pi^-X$ .

 $\Gamma(\chi_{c2}\gamma)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$ 

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

seen	<sup>1</sup> ABLIKIM	210	BES3	$e^+e^- \rightarrow \pi^+\pi^-X$
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not seen	<sup>2</sup> ABLIKIM	15S	BES3	$e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$
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not seen	<sup>3</sup> BHARDWAJ	13	BELL	$B^\pm \rightarrow \chi_{c2}\gamma K^\pm$
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<sup>1</sup> 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  $3.2 \sigma$  significance.

<sup>2</sup> 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.

<sup>3</sup> 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.

 $\Gamma(\chi_{c2}\gamma)/\Gamma(\chi_{c1}\gamma)$   $\Gamma_7/\Gamma_6$ 

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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$0.28^{+0.14}_{-0.11} \pm 0.02$	$9 \pm 4$		<sup>1</sup> 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	<sup>2</sup> ABLIKIM	15s	BES3	$e^+e^- \rightarrow \pi^+\pi^-\chi_{c2}\gamma$
<0.41	90	BHARDWAJ	13	BELL	$B^\pm \rightarrow \chi_{c1/c2}\gamma K^\pm$

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

<sup>2</sup> 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.

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### $\psi_2(3823)$ REFERENCES

ABLIKIM	210	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.)

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