$\psi_2(3823)$

$I^G(J^{PC}) = 0^-(2^{--})$
I, J, P need confirmation.

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

Seen by BHARDWAJ 13 in $B \to \chi_{c1}\gamma K$ and ABLIKIM 15S in $e^+e^- \to \pi^+\pi^-\gamma\chi_{c1}$ 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
3823.7 ±0.5 OUR AVERAGE		Error includes scale factor of 1.1.			
3824.08±0.53±0.14	137	[1] AAIJ	20S	LHCB	$B^+ \to J/\psi\pi^+\pi^- K^+$
3821.7 ±1.3 ±0.7	19 ± 5	[2] ABLIKIM	15S	BES3	$e^+e^- \to \pi^+\pi^-\chi_{c1}\gamma$
3823.1 ±1.8 ±0.7	33±10	[3] BHARDWAJ	13	BELL	$B^\pm \to \chi_{c1}\gamma K^\pm$

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

[2] From a simultaneous unbinned maximum likelihood fit of $e^+e^- \to \pi^+\pi^-\chi_{c1}\gamma$ 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 $\psi(2S) \to \chi_{c1}\gamma$ and $\psi_2(3823) \to \chi_{c1}\gamma$ 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.

[3] From a simultaneous fit to $B^\pm \to (\chi_{c1}\gamma)K^\pm$ and $B^0 \to (\chi_{c1}\gamma)K^0_S$ with significance 4.0σ including systematics. Corrected for the measured $\psi(2S)$ mass using $B \to \psi(2S)K \to (\gamma\chi_{c1})K$ 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	[1] AAIJ	20S	LHCB	$B^+ \to J/\psi\pi^+\pi^- K^+$

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

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

[2] From a fit of $e^+e^- \to \pi^+\pi^-\chi_{c1}\gamma$ 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.

[3] From a simultaneous fit to $B^\pm \to (\chi_{c1}\gamma)K^\pm$ and $B^0 \to (\chi_{c1}\gamma)K^0_S$ 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

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
not seen		[1] ABLIKIM	21O	BES3	$e^+e^- \to \pi^+\pi^- X$
seen	137 ± 26	AAIJ	20S	LHCB	$B^+ \to J/\psi\pi^+\pi^- K^+$

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

$\Gamma(J/\psi(1S)\pi^+\pi^-)/\Gamma(\chi_{c1}\gamma)$ Γ_1/Γ_6

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.06	90	[1] ABLIKIM	21O	BES3	$e^+e^- \to \pi^+\pi^- X$

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

$\Gamma(J/\psi(1S)\pi^0\pi^0)/\Gamma(\chi_{c1}\gamma)$ Γ_2/Γ_6

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.11	90	[1] ABLIKIM	21O	BES3	$e^+e^- \to \pi^+\pi^- X$

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

$\Gamma(J/\psi(1S)\pi^0)/\Gamma(\chi_{c1}\gamma)$ Γ_3/Γ_6

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.03	90	[1] ABLIKIM	21O	BES3	$e^+e^- \to \pi^+\pi^- X$

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

$\Gamma(J/\psi(1S)\eta)/\Gamma(\chi_{c1}\gamma)$ Γ_4/Γ_6

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.14	90	[1] ABLIKIM	21O	BES3	$e^+e^- \to \pi^+\pi^- X$

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

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

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
not seen	[1] ABLIKIM 21O	BES3	$e^+e^- \to \pi^+\pi^- X$

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

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
seen	33 ± 10	[1] BHARDWAJ 13	BELL	$B^\pm \to \chi_{c1}\gamma K^\pm$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	63 ± 9	[2] ABLIKIM 21O	BES3	$e^+e^- \to \pi^+\pi^- X$
seen	16 ± 5	[3] ABLIKIM 21O	BES3	$e^+e^- \to \pi^0\pi^0 X$

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

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

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

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.24	90	[1] ABLIKIM 21O	BES3	$e^+e^- \to \pi^+\pi^- X$

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

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

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
seen	[1] ABLIKIM 21O	BES3	$e^+e^- \to \pi^+\pi^- X$
not seen	[2] ABLIKIM 15S	BES3	$e^+e^- \to \pi^+\pi^-\chi_{c2}\gamma$
not seen	[3] BHARDWAJ 13	BELL	$B^\pm \to \chi_{c2}\gamma K^\pm$

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

[2] From a simultaneous unbinned maximum likelihood fit of $e^+e^- \to \pi^+\pi^-\chi_{c2}\gamma$ 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 $\psi(2S) \to \chi_{c2}\gamma$ and $\psi_2(3823) \to \chi_{c2}\gamma$ 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$(B^\pm \to \psi_2(3823)K^\pm) \times$ B$(\psi_2(3823) \to \gamma\chi_{c2}) < 3.6 \times 10^{-6}$ at 90% CL.

$\Gamma(\chi_{c2}\gamma)/\Gamma(\chi_{c1}\gamma)$ $\qquad\qquad$ Γ_7/Γ_6

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$0.28^{+0.14}_{-0.11}\pm0.02$		9 ± 4	[1] ABLIKIM 21O	BES3	$e^+e^- \to \pi^+\pi^-\chi_{c2}\gamma$

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

<0.42	90	[2] ABLIKIM	15S	BES3	$e^+ e^- \to \pi^+ \pi^- \chi_{c2} \gamma$
<0.41	90	BHARDWAJ	13	BELL	$B^{\pm} \to \chi_{c1/c2} \gamma K^{\pm}$

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

[2] From a simultaneous unbinned maximum likelihood fit of $e^+ e^- \to \pi^+ \pi^- \chi_{c1(2)} \gamma$ 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 $\psi(2S) \to \chi_{c1(2)} \gamma$ and $\psi_2(3823) \to \chi_{c1(2)} \gamma$ 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	21O	PR D103 L091102	M. Ablikim *et al.*	(BESIII Collab.)
AAIJ	20S	JHEP 2008 123	R. Aaij *et al.*	(LHCb Collab.)
ABLIKIM	15S	PRL 115 011803	M. Ablikim *et al.*	(BESIII Collab.)
BHARDWAJ	13	PRL 111 032001	V. Bhardwaj *et al.*	(BELLE Collab.)