

**X(1835)**

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

## OMITTED FROM SUMMARY TABLE

Could be a superposition of two states, one with small width appearing as threshold enhancement in  $p\bar{p}$ , the other one with a larger width. For the former ABLIKIM 12D determine  $J^{PC} = 0^-+$ .

**X(1835) MASS**

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
<b>1826.5<sup>+13.0</sup><sub>-3.4</sub></b>				<b>OUR AVERAGE</b>
1825.3 ± 2.4 <sup>+17.3</sup> <sub>-2.4</sub>		<sup>1</sup> ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
1844 ± 9 <sup>+16</sup> <sub>-25</sub>		ABLIKIM	15T BES3	$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
1839 ± 26 ± 26		<sup>2</sup> ABLIKIM	18I BES3	$J/\psi \rightarrow \gamma\gamma\phi(1020)$
1909.5 ± 15.9 <sup>+9.4</sup> <sub>-27.5</sub>		<sup>3</sup> ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
1842.2 ± 4.2 <sup>+7.1</sup> <sub>-2.6</sub>	0.6k	ABLIKIM	13U BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
1832 <sup>+19</sup> <sub>-5</sub> ± 26		<sup>4</sup> ABLIKIM	12D BES3	$J/\psi \rightarrow \gamma p\bar{p}$
1836.5 ± 3.0 <sup>+5.6</sup> <sub>-2.1</sub>	4265	<sup>5</sup> ABLIKIM	11C BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
1877.3 ± 6.3 <sup>+3.4</sup> <sub>-7.4</sub>		<sup>6</sup> ABLIKIM	11J BES3	$J/\psi \rightarrow \omega(\eta\pi^+\pi^-)$
1837 <sup>+10</sup> <sub>-12</sub> <sup>+9</sup> <sub>-7</sub>	231	<sup>7,8</sup> ALEXANDER	10 CLEO	$J/\psi \rightarrow \gamma p\bar{p}$
1833.7 ± 6.1 ± 2.7	264	ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
1831 ± 7		<sup>8,9</sup> ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma p\bar{p}$
1859 <sup>+3</sup> <sub>-10</sub> <sup>+5</sup> <sub>-25</sub>		<sup>8</sup> BAI	03F BES2	$J/\psi \rightarrow \gamma p\bar{p}$

<sup>1</sup> From a fit of the measured  $\pi^+\pi^-\eta'$  lineshape that accounts for the abrupt distortion observed at the  $p\bar{p}$  threshold through interference with a second previously unseen narrow resonance near 1870 MeV. The fit uses Breit-Wigner functions for the signal shapes and includes known backgrounds and contributors.

<sup>2</sup> From a fit to  $\gamma\phi$  invariant mass. Angular analysis consistent with  $J^{PC} = 0^-+$ . Other  $J^{PC}$  not excluded.

<sup>3</sup> Pole mass from a fit of the measured  $\pi^+\pi^-\eta'$  lineshape to a Flatte formula that accounts for the abrupt distortion observed at the  $p\bar{p}$  threshold; the fit also includes known backgrounds and contributors, as well as an *ad hoc* Breit-Wigner function ( $M \approx 1919$  MeV;  $\Gamma \approx 51$  MeV) that is required for a good fit.

<sup>4</sup> From the fit including final state interaction effects in isospin 0 S-wave according to SIBIRTSEV 05A. Supersedes ABLIKIM 10G.

<sup>5</sup> From a fit of the  $\pi^+\pi^-\eta'$  mass distribution to a combination of  $\gamma f_1(1510)$ ,  $\gamma X(1835)$ , and two states  $\gamma X(2120)$  and  $\gamma X(2370)$ , for  $M(\pi^+\pi^-\eta') < 2.8$  GeV, and accounting for backgrounds from non- $\eta'$  events and  $J/\psi \rightarrow \pi^0\pi^+\pi^-\eta'$ .

<sup>6</sup> The selected process is  $J/\psi \rightarrow \omega a_0(980)\pi$ . This state may be due also to  $\eta_2(1870)$  or to a combination of  $X(1835)$  and  $\eta_2(1870)$ .

<sup>7</sup> From a fit of the  $p\bar{p}$  mass distribution to a combination of  $\gamma X(1835)$ ,  $\gamma R$  with  $M(R) = 2100$  MeV and  $\Gamma(R) = 160$  MeV, and  $\gamma p\bar{p}$  phase space, for  $M(p\bar{p}) < 2.85$  GeV.

<sup>8</sup>Evidence for a threshold enhancement in the  $p\bar{p}$  mass spectrum was also reported by ABE 02K, AUBERT,B 05L, and WANG 05A in  $B^+ \rightarrow p\bar{p}K^+$ , WANG 05A in  $B^0 \rightarrow p\bar{p}K_S^0$ , ABE 02W in  $\bar{B}^0 \rightarrow p\bar{p}D^0$ , DEL-AMO-SANCHEZ 12 in  $B \rightarrow D(D^*)p\bar{p}(\pi)$ , and WEI 08 in  $B^+ \rightarrow p\bar{p}\pi^+$  decays. Not seen by ATHAR 06 in  $\Upsilon(1S) \rightarrow p\bar{p}\gamma$ .

<sup>9</sup>From the fit including final state interaction effects in isospin 0  $S$ -wave according to SIBIRTSEV 05A. Systematic errors not estimated.

## X(1835) WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>242</b>	<b>+14</b>				
<b>-15</b>					<b>OUR AVERAGE</b>
245.2 ± 13.1	+4.6		<sup>1</sup> ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
	-9.6				
192	+20		ABLIKIM	15T BES3	$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta$
	-17				
	+62				
	-43				
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
175 ± 57	± 25		<sup>2</sup> ABLIKIM	18I BES3	$J/\psi \rightarrow \gamma\gamma\phi(1020)$
273.5 ± 21.4	+6.1		<sup>3</sup> ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
	-64.0				
83 ± 14	± 11	0.6k	ABLIKIM	13U BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
< 76		90	<sup>4</sup> ABLIKIM	12D BES3	$J/\psi \rightarrow \gamma p\bar{p}$
190 ± 9	+38	4265	<sup>5</sup> ABLIKIM	11C BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
	-36				
57 ± 12	+19		<sup>6</sup> ABLIKIM	11J BES3	$J/\psi \rightarrow \omega(\eta\pi^+\pi^-)$
	-4				
0	+44	231	<sup>7,8</sup> ALEXANDER	10 CLEO	$J/\psi \rightarrow \gamma p\bar{p}$
	-0				
67.7 ± 20.3	± 7.7	264	ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
< 153		90	<sup>8,9</sup> ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma p\bar{p}$
< 30			<sup>8</sup> BAI	03F BES2	$J/\psi \rightarrow \gamma p\bar{p}$

<sup>1</sup>From a fit of the measured  $\pi^+\pi^-\eta'$  lineshape that accounts for the abrupt distortion observed at the  $p\bar{p}$  threshold through interference with a second previously unseen narrow resonance near 1870 MeV. The fit uses Breit-Wigner functions for the signal shapes and includes known backgrounds and contributors.

<sup>2</sup>From a fit to  $\gamma\phi$  invariant mass. Angular analysis consistent with  $J^{PC} = 0^{-+}$ . Other  $J^{PC}$  not excluded.

<sup>3</sup>Pole width from a fit of the measured  $\pi^+\pi^-\eta'$  lineshape to a Flatte formula that accounts for the abrupt distortion observed at the  $p\bar{p}$  threshold; the fit also includes known backgrounds and contributors, as well as an *ad hoc* Breit-Wigner function ( $M \approx 1919$  MeV;  $\Gamma \approx 51$  MeV) that is required for a good fit.

<sup>4</sup>From the fit including final state interaction effects in isospin 0  $S$ -wave according to SIBIRTSEV 05A. Supersedes ABLIKIM 10G.

<sup>5</sup>From a fit of the  $\pi^+\pi^-\eta'$  mass distribution to a combination of  $\gamma f_1(1510)$ ,  $\gamma X(1835)$ , and two states  $\gamma X(2120)$  and  $\gamma X(2370)$ , for  $M(\pi^+\pi^-\eta') < 2.8$  GeV, and accounting for backgrounds from non- $\eta'$  events and  $J/\psi \rightarrow \pi^0\pi^+\pi^-\eta'$ .

<sup>6</sup>The selected process is  $J/\psi \rightarrow \omega a_0(980)\pi$ . This state may be due also to  $\eta_2(1870)$  or to a combination of  $X(1835)$  and  $\eta_2(1870)$ .

<sup>7</sup>From a fit of the  $p\bar{p}$  mass distribution to a combination of  $\gamma X(1835)$ ,  $\gamma R$  with  $M(R) = 2100$  MeV and  $\Gamma(R) = 160$  MeV, and  $\gamma p\bar{p}$  phase space, for  $M(p\bar{p}) < 2.85$  GeV.

<sup>8</sup>Evidence for a threshold enhancement in the  $p\bar{p}$  mass spectrum was also reported by ABE 02K, AUBERT,B 05L, and WANG 05A in  $B^+ \rightarrow p\bar{p}K^+$ , WANG 05A in  $B^0 \rightarrow$

$p\bar{p}K_S^0$ , ABE 02W in  $\bar{B}^0 \rightarrow p\bar{p}D^0$ , DEL-AMO-SANCHEZ 12 in  $B \rightarrow D(D^*)p\bar{p}(\pi)$ , and WEI 08 in  $B^+ \rightarrow p\bar{p}\pi^+$  decays. Not seen by ATHAR 06 in  $\Upsilon(1S) \rightarrow p\bar{p}\gamma$ .

<sup>9</sup>From the fit including final state interaction effects in isospin 0 S-wave according to SIBIRTSEV 05A. Systematic errors not estimated.

## X(1835) DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1$ $p\bar{p}$	seen
$\Gamma_2$ $\eta'\pi^+\pi^-$	seen
$\Gamma_3$ $\gamma\gamma$	
$\Gamma_4$ $K_S^0 K_S^0 \eta$	seen
$\Gamma_5$ $\gamma\phi(1020)$	possibly seen
$\Gamma_6$ $3(\pi^+\pi^-)$	seen

## X(1835) $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(\eta'\pi^+\pi^-) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$					$\Gamma_2\Gamma_3/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	

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

<35.6	90	<sup>1</sup> ZHANG	12A BELL	$e^+e^- \rightarrow e^+e^-\eta'\pi^+\pi^-$	
<83	90	<sup>2</sup> ZHANG	12A BELL	$e^+e^- \rightarrow e^+e^-\eta'\pi^+\pi^-$	

<sup>1</sup>From a two-resonance fit and constructive interference of the  $\eta(1760)$  and X(1835), a significance of 2.8  $\sigma$ .

<sup>2</sup>From a two-resonance fit and destructive interference of the  $\eta(1760)$  and X(1835), a significance of 2.8  $\sigma$ .

## X(1835) BRANCHING RATIOS

$\Gamma(p\bar{p})/\Gamma(\eta'\pi^+\pi^-)$				$\Gamma_1/\Gamma_2$
VALUE	DOCUMENT ID	TECN	COMMENT	

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

0.333	ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$	
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$\Gamma(\eta'\pi^+\pi^-)/\Gamma(K_S^0 K_S^0 \eta)$				$\Gamma_2/\Gamma_4$
VALUE	DOCUMENT ID	TECN	COMMENT	

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

$6.7 \pm 1.8$	<sup>1</sup> ABLIKIM	15T BES3	$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta$	
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<sup>1</sup>Using results from ABLIKIM 05R.

$\Gamma(\eta'\pi^+\pi^-)/\Gamma_{\text{total}}$				$\Gamma_2/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT	

seen	<sup>1</sup> ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$	
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<sup>1</sup>ABLIKIM 16J quotes  $B(J/\psi \rightarrow \gamma X(1835)) \times B(X(1835) \rightarrow \pi^+\pi^-\eta') = (3.93 \pm 0.38^{+0.31}_{-0.84}) \times 10^{-4}$  from a fit of the measured  $\pi^+\pi^-\eta'$  lineshape that accounts for the abrupt distortion observed at the  $p\bar{p}$  threshold with a Flatte formula in addition to known

backgrounds and contributors, as well as an *ad hoc* Breit-Wigner ( $M \approx 1919$  MeV;  $\Gamma \approx 51$  MeV) that is required for a good fit. Another explanation for the distortion provided by ABLIKIM 16J is that a second resonance near 1870 MeV interferes with the X(1835); fits to this possibility yield product branching fraction values compatible with that shown within the respective systematic uncertainties.

$\Gamma(\gamma\phi(1020))/\Gamma_{\text{total}}$   $\Gamma_5/\Gamma$

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>possibly seen</b>	<sup>1</sup> ABLIKIM 18I	BES3	$J/\psi \rightarrow \gamma\gamma\phi(1020)$

<sup>1</sup> Seen as a peak in  $\gamma\phi$  invariant mass. Angular analysis consistent with  $J^{PC} = 0^{-+}$ . Other  $J^{PC}$  not excluded.

$\Gamma(\gamma\gamma)/\Gamma(\eta'\pi^+\pi^-)$   $\Gamma_3/\Gamma_2$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;9.80 × 10<sup>-3</sup></b>	90	<sup>1</sup> ABLIKIM 18O	BES3	$\psi(2S) \rightarrow \pi^+\pi^-\gamma\gamma$

<sup>1</sup> Using results from ABLIKIM 16J.

$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>seen</b>	0.6k	ABLIKIM 13U	BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$

**X(1835) REFERENCES**

ABLIKIM 18I	PR D97 051101	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 18O	PR D97 072014	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 16J	PRL 117 042002	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 15T	PRL 115 091803	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 13U	PR D88 091502	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 12D	PRL 108 112003	M. Ablikim <i>et al.</i>	(BESIII Collab.) JPC
DEL-AMO-SA... 12	PR D85 092017	P. del Amo Sanchez <i>et al.</i>	(BABAR Collab.)
ZHANG 12A	PR D86 052002	C.C. Zhang <i>et al.</i>	(BELLE Collab.)
ABLIKIM 11C	PRL 106 072002	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 11J	PRL 107 182001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM 10G	CP C34 421	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ALEXANDER 10	PR D82 092002	J.P. Alexander <i>et al.</i>	(CLEO Collab.)
WEI 08	PL B659 80	J.-T. Wei <i>et al.</i>	(BELLE Collab.)
ATHAR 06	PR D73 032001	S.B. Athar <i>et al.</i>	(CLEO Collab.)
ABLIKIM 05R	PRL 95 262001	M. Ablikim <i>et al.</i>	(BES Collab.)
AUBERT,B 05L	PR D72 051101	B. Aubert <i>et al.</i>	(BABAR Collab.)
SIBIRTSEV 05A	PR D71 054010	A. Sibirtsev, J. Haidenbauer	
WANG 05A	PL B617 141	M.-Z. Wang <i>et al.</i>	(BELLE Collab.)
BAI 03F	PRL 91 022001	J.Z. Bai <i>et al.</i>	(BES II Collab.)
ABE 02K	PRL 88 181803	K. Abe <i>et al.</i>	(BELLE Collab.)
ABE 02W	PRL 89 151802	K. Abe <i>et al.</i>	(BELLE Collab.)