

X(1835)

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

OMITTED FROM SUMMARY TABLE

Could be a superposition of two states, one appearing as threshold enhancement in $p\bar{p}$ the other one with a lower mass at 1835 MeV.
Coupled-channel analyses with more sophisticated model are needed.

X(1835) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
$1831.8^{+4.0}_{-2.6}$ OUR AVERAGE				
$1832.5 \pm 3.1 \pm 2.5$	21k	¹ ABLIKIM	24B BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
$1825.3 \pm 2.4^{+17.3}_{-2.4}$		² ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
$1844 \pm 9^{+16}_{-25}$		³ 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. • • •				
$1818 \pm 9 \pm 2.5$	37k	⁴ ABLIKIM	24B BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
$1839 \pm 26 \pm 26$		⁵ ABLIKIM	18I BES3	$J/\psi \rightarrow \gamma \gamma \phi(1020)$
$1909.5 \pm 15.9^{+9.4}_{-27.5}$		⁶ ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
$1842.2 \pm 4.2^{+7.1}_{-2.6}$	0.6k	⁷ ABLIKIM	13U BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
$1832^{+19}_{-5} \pm 26$		⁸ ABLIKIM	12D BES3	$J/\psi \rightarrow \gamma p\bar{p}$
$1836.5 \pm 3.0^{+5.6}_{-2.1}$	4265	⁹ ABLIKIM	11C BES3	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
$1877.3 \pm 6.3^{+3.4}_{-7.4}$		¹⁰ ABLIKIM	11J BES3	$J/\psi \rightarrow \omega(\eta \pi^+\pi^-)$
$1837^{+10}_{-12}^{+9}_{-7}$	231	^{11,12} ALEXANDER	10 CLEO	$J/\psi \rightarrow \gamma p\bar{p}$
$1833.7 \pm 6.1 \pm 2.7$	264	ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
1831 ± 7		^{12,13} ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma p\bar{p}$
$1859^{+3}_{-10}^{+5}_{-25}$		¹² BAI	03F BES2	$J/\psi \rightarrow \gamma p\bar{p}$

¹ From a fit of the measured $3(\pi^+\pi^-)$ lineshape that accounts for the abrupt distortion observed at the $p\bar{p}$ threshold through interference with a second previously unseen narrow resonance near 1880 MeV. The fit uses Breit-Wigner functions for the signal shapes and includes known background contributions. A second solution of the fit gives 37k events.

² 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.

³ Decay dominated by $f_0(980)\eta$ hence $I^G(J^{PC}) = 0^+(0^-+)$.

⁴ From a fit of the measured $3(\pi^+\pi^-)$ lineshape to a Flatte formula that accounts for the abrupt distortion observed at the $p\bar{p}$ threshold. The fit also includes known background contributions.

⁵ From a fit to $\gamma\phi$ invariant mass. Angular analysis consistent with $J^{PC} = 0^-+$. Other J^{PC} not excluded.

⁶ 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.

⁷ Superseded by ABLIKIM 24B.

⁸ From the fit including final state interaction effects in isospin 0 S -wave according to SIBIRTSEV 05A. Supersedes ABLIKIM 10G.

⁹ 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 $\gamma \eta(2370)$, for $M(\pi^+\pi^-\eta') < 2.8$ GeV, and accounting for backgrounds from non- η' events and $J/\psi \rightarrow \pi^0\pi^+\pi^-\eta'$.

¹⁰ The selected process is $J/\psi \rightarrow \omega a_0(980)\pi$ with $B(J/\psi \rightarrow \omega X \rightarrow \omega a_0(980)^\pm (\rightarrow \eta\pi^\pm)\pi^\mp) = (1.50 \pm 0.26^{+0.72}_{-0.36}) \times 10^{-4}$. Not seen in $J/\psi(1S) \rightarrow \omega K^+K^-\eta$ by ABLIKIM 24BQ with 90% CL upper limit of 9.55×10^{-7} . This state may be also due to $\eta_2(1870)$ or to a combination of $X(1835)$ and $\eta_2(1870)$.

¹¹ From a fit of the $p\bar{p}$ mass distribution to a combination of $\gamma X(1835)$, γR 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.

¹² 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 $\Upsilon(1S) \rightarrow p\bar{p}\gamma$.

¹³ 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
120 ± 70	OUR AVERAGE		Error includes scale factor of 8.8.		
80.7 ± 5.2 ± 7.7		21k	¹ ABLIKIM	24B BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
245.2 ± 13.1 ⁺ _{-4.6}			² ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
192 ⁺ ₋₁₇ ⁺ ₋₄₃			³ 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. • • •					
175 ± 57 ± 25			⁴ ABLIKIM	18I BES3	$J/\psi \rightarrow \gamma \gamma \phi(1020)$
273.5 ± 21.4 ⁺ _{-64.0}			⁵ ABLIKIM	16J BES3	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
83 ± 14 ± 11		0.6k	⁶ ABLIKIM	13U BES3	$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
< 76	90		⁷ ABLIKIM	12D BES3	$J/\psi \rightarrow \gamma p\bar{p}$
190 ± 9 ⁺ ₋₃₆		4265	⁸ ABLIKIM	11C BES3	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
57 ± 12 ⁺ ₋₄			⁹ ABLIKIM	11J BES3	$J/\psi \rightarrow \omega(\eta\pi^+\pi^-)$
0 ⁺ ₋₀ ⁺ ₋₀		231	^{10,11} ALEXANDER	10 CLEO	$J/\psi \rightarrow \gamma p\bar{p}$
67.7 ± 20.3 ± 7.7		264	ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma \pi^+\pi^-\eta'$
< 153	90		^{11,12} ABLIKIM	05R BES2	$J/\psi \rightarrow \gamma p\bar{p}$
< 30			¹¹ BAI	03F BES2	$J/\psi \rightarrow \gamma p\bar{p}$

¹ From a fit of the measured $3(\pi^+\pi^-)$ lineshape that accounts for the abrupt distortion observed at the $p\bar{p}$ threshold through interference with a second previously unseen narrow resonance near 1880 MeV. The fit uses Breit-Wigner functions for the signal shapes and includes known background contributions. A second solution of the fit gives 37k events.

² 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.

³ Decay dominated by $f_0(980)\eta$ hence $I^G(J^{PC}) = 0^+(0^-+)$.

⁴ From a fit to $\gamma\phi$ invariant mass. Angular analysis consistent with $J^{PC} = 0^-+$. Other J^{PC} not excluded.

⁵ 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.

⁶ Superseded by ABLIKIM 24B.

⁷ From the fit including final state interaction effects in isospin 0 S -wave according to SIBIRTSEV 05A. Supersedes ABLIKIM 10G.

⁸ 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 $\gamma\eta(2370)$, for $M(\pi^+\pi^-\eta') < 2.8$ GeV, and accounting for backgrounds from non- η' events and $J/\psi \rightarrow \pi^0\pi^+\pi^-\eta'$.

⁹ The selected process is $J/\psi \rightarrow \omega a_0(980)\pi$ with $B(J/\psi \rightarrow \omega X \rightarrow \omega a_0(980)^\pm (\rightarrow \eta\pi^\pm)\pi^\mp) = (1.50 \pm 0.26^{+0.72}_{-0.36}) \times 10^{-4}$. Not seen in $J/\psi(1S) \rightarrow \omega K^+K^-\eta$ by ABLIKIM 24BQ with 90% CL upper limit of 9.55×10^{-7} . This state may be also due to $\eta_2(1870)$ or to a combination of $X(1835)$ and $\eta_2(1870)$.

¹⁰ From a fit of the $p\bar{p}$ mass distribution to a combination of $\gamma X(1835)$, γR 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.

¹¹ 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 $\Upsilon(1S) \rightarrow p\bar{p}\gamma$.

¹² 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 (Γ_i/Γ)
Γ_1 $p\bar{p}$	seen
Γ_2 $\eta'\pi^+\pi^-$	seen
Γ_3 $\gamma\gamma$	not seen
Γ_4 $K_S^0 K_S^0 \eta$	seen
Γ_5 $\gamma\phi(1020)$	possibly seen
Γ_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	¹ ZHANG	12A BELL	$e^+e^- \rightarrow e^+e^-\eta'\pi^+\pi^-$
<83	90	² ZHANG	12A BELL	$e^+e^- \rightarrow e^+e^-\eta'\pi^+\pi^-$

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

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

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 $J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$

 $\Gamma(\eta'\pi^+\pi^-)/\Gamma(K_S^0 K_S^0 \eta)$ **Γ_2/Γ_4**

VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
6.7 ± 1.8	¹ ABLIKIM	15T	BES3 $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta$

¹Using results from ABLIKIM 05R. **$\Gamma(\eta'\pi^+\pi^-)/\Gamma_{\text{total}}$** **$\Gamma_2/\Gamma$**

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ ABLIKIM	16J	BES3 $J/\psi \rightarrow \gamma\pi^+\pi^-\eta'$
¹ 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 <i>ad hoc</i> 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.			

 $\Gamma(\gamma\phi(1020))/\Gamma_{\text{total}}$ **Γ_5/Γ**

VALUE	DOCUMENT ID	TECN	COMMENT
possibly seen	¹ ABLIKIM	18I	BES3 $J/\psi \rightarrow \gamma\gamma\phi(1020)$
¹ Seen as a peak in $\gamma\phi$ invariant mass. Angular analysis consistent with $J^{PC} = 0^{-+}$. Other J^{PC} not excluded.			

 $\Gamma(\gamma\gamma)/\Gamma(\eta'\pi^+\pi^-)$ **Γ_3/Γ_2**

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<9.80 × 10⁻³	90	¹ ABLIKIM	18O	BES3 $\psi(2S) \rightarrow \pi^+\pi^-\gamma\gamma$

¹Using results from ABLIKIM 16J. **$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$** **$\Gamma_6/\Gamma$**

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
seen	21k	¹ ABLIKIM	24B	BES3 $J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	0.6k	² ABLIKIM	13U	BES3 $J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$

¹ ABLIKIM 24B quotes $B(J/\psi \rightarrow \gamma X(1835)) \times B(X(1835) \rightarrow 3(\pi^+\pi^-)) = (1.19 \pm 0.30 \pm 0.15) \times 10^{-5}$ for constructive interference and $(2.07 \pm 0.50 \pm 0.36) \times 10^{-5}$ for destructive interference from a fit of the measured $3(\pi^+\pi^-)$ lineshape that accounts for the abrupt distortion observed at the $p\bar{p}$ threshold through interference with a second narrow resonance near 1880 MeV. The solution for destructive interference gives 37k events.

²Superseded by ABLIKIM 24B.

X(1835) REFERENCES

ABLIKIM	24B	PRL 132 151901	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	24BQ	PR D110 052005	M. Ablikim <i>et al.</i>	(BESIII Collab.)
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.)
