$X(1835)$

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

OMITTED FROM SUMMARY TABLE

Could be a superposition of two states, one with small width appearing as threshold enhancement in $p\overline{p}$, 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*
$1826.5^{+13.0}_{-3.4}$ OUR AVERAGE					
$1825.3 \pm 2.4^{+17.3}_{-2.4}$		[1] ABLIKIM	16J	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$
$1844 \pm 9^{+16}_{-25}$		[2] ABLIKIM	15T	BES3	$J/\psi \to \gamma K^0_S K^0_S \eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1839 \pm 26 \pm 26$		[3] ABLIKIM	18I	BES3	$J/\psi \to \gamma\gamma\phi(1020)$
$1909.5 \pm 15.9^{+9.4}_{-27.5}$		[4] ABLIKIM	16J	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$
$1842.2 \pm 4.2^{+7.1}_{-2.6}$	0.6k	ABLIKIM	13U	BES3	$J/\psi \to \gamma 3(\pi^+\pi^-)$
$1832 \, {}^{+19}_{-5} \pm 26$		[5] ABLIKIM	12D	BES3	$J/\psi \to \gamma p\overline{p}$
$1836.5 \pm 3.0^{+5.6}_{-2.1}$	4265	[6] ABLIKIM	11C	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$
$1877.3 \pm 6.3^{+3.4}_{-7.4}$		[7] ABLIKIM	11J	BES3	$J/\psi \to \omega(\eta\pi^+\pi^-)$
$1837 \, {}^{+10}_{-12} \, {}^{+9}_{-7}$	231	[8,9] ALEXANDER	10	CLEO	$J/\psi \to \gamma p\overline{p}$
$1833.7 \pm 6.1 \pm 2.7$	264	ABLIKIM	05R	BES2	$J/\psi \to \gamma\pi^+\pi^-\eta'$
1831 ± 7		[9,10] ABLIKIM	05R	BES2	$J/\psi \to \gamma p\overline{p}$
$1859 \, {}^{+3}_{-10} \, {}^{+5}_{-25}$		[9] BAI	03F	BES2	$J/\psi \to \gamma p\overline{p}$

[1] From a fit of the measured $\pi^+\pi^-\eta'$ lineshape that accounts for the abrupt distortion observed at the $p\overline{p}$ 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.

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

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

[4] 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 $p\overline{p}$ 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.

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

[6] 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-η' events and $J/\psi \to \pi^0\pi^+\pi^-\eta'$.

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

[8] From a fit of the $p\overline{p}$ mass distribution to a combination of $\gamma X(1835)$, γR with $M(R)$ = 2100 MeV and $\Gamma(R)$ = 160 MeV, and $\gamma p\overline{p}$ phase space, for $M(p\overline{p}) < 2.85$ GeV.

[9] Evidence for a threshold enhancement in the $p\overline{p}$ mass spectrum was also reported by ABE 02K, AUBERT,B 05L, and WANG 05A in $B^+ \to p\overline{p}K^+$, WANG 05A in $B^0 \to p\overline{p}K^0_S$, ABE 02W in $\overline{B}^0 \to p\overline{p}D^0$, DEL-AMO-SANCHEZ 12 in $B \to D(D^*)p\overline{p}(\pi)$, and WEI 08 in $B^+ \to p\overline{p}\pi^+$ decays. Not seen by ATHAR 06 in $\Upsilon(1S) \to p\overline{p}\gamma$.

[10] 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*
242 $^{+14}_{-15}$ OUR AVERAGE						
$245.2 \pm 13.1 ^{+\ 4.6}_{-\ 9.6}$			[1] ABLIKIM	16J	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$
$192\ ^{+20}_{-17}\ ^{+62}_{-43}$			[2] ABLIKIM	15T	BES3	$J/\psi \to \gamma K^0_S K^0_S \eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$175 \pm 57 \pm 25$			[3] ABLIKIM	18I	BES3	$J/\psi \to \gamma\gamma\phi(1020)$
$273.5 \pm 21.4 ^{+\ 6.1}_{-64.0}$			[4] ABLIKIM	16J	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$
$83 \pm 14 \pm 11$		0.6k	ABLIKIM	13U	BES3	$J/\psi \to \gamma 3(\pi^+\pi^-)$
< 76	90		[5] ABLIKIM	12D	BES3	$J/\psi \to \gamma p\overline{p}$
$190 \pm 9\ ^{+38}_{-36}$		4265	[6] ABLIKIM	11C	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$
$57 \pm 12\ ^{+19}_{-\ 4}$			[7] ABLIKIM	11J	BES3	$J/\psi \to \omega(\eta\pi^+\pi^-)$
$0\ ^{+44}_{-\ 0}$		231	[8,9] ALEXANDER	10	CLEO	$J/\psi \to \gamma p\overline{p}$
$67.7 \pm 20.3 \pm 7.7$		264	ABLIKIM	05R	BES2	$J/\psi \to \gamma\pi^+\pi^-\eta'$
< 153	90		[9,10] ABLIKIM	05R	BES2	$J/\psi \to \gamma p\overline{p}$
< 30			[9] BAI	03F	BES2	$J/\psi \to \gamma p\overline{p}$

[1] From a fit of the measured $\pi^+\pi^-\eta'$ lineshape that accounts for the abrupt distortion observed at the $p\overline{p}$ 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.

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

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

[4] 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 $p\overline{p}$ 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.

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

[6] 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-η' events and $J/\psi \to \pi^0\pi^+\pi^-\eta'$.

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

[8] From a fit of the $p\overline{p}$ mass distribution to a combination of $\gamma X(1835)$, γR with $M(R)$ = 2100 MeV and $\Gamma(R)$ = 160 MeV, and $\gamma p\overline{p}$ phase space, for $M(p\overline{p}) < 2.85$ GeV.

[9] Evidence for a threshold enhancement in the $p\overline{p}$ mass spectrum was also reported by ABE 02K, AUBERT,B 05L, and WANG 05A in $B^+ \to p\overline{p}K^+$, WANG 05A in $B^0 \to p\overline{p}K^0_S$, ABE 02W in $\overline{B}^0 \to p\overline{p}D^0$, DEL-AMO-SANCHEZ 12 in $B \to D(D^*)p\overline{p}(\pi)$, and WEI 08 in $B^+ \to p\overline{p}\pi^+$ decays. Not seen by ATHAR 06 in $\Upsilon(1S) \to p\overline{p}\gamma$.

[10] 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	$p\overline{p}$	seen
Γ_2	$\eta'\pi^+\pi^-$	seen
Γ_3	$\gamma\gamma$	not seen
Γ_4	$K^0_S K^0_S \eta$	seen
Γ_5	$\gamma\phi(1020)$	possibly seen
Γ_6	$3(\pi^+\pi^-)$	seen

$X(1835)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(\eta'\pi^+\pi^-) \times \Gamma(\gamma\gamma)/\Gamma_{total}$ $\Gamma_2\Gamma_3/\Gamma$

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	$e^+e^- \to e^+e^-\eta'\pi^+\pi^-$
<83	90	[2] ZHANG	12A	BELL	$e^+e^- \to e^+e^-\eta'\pi^+\pi^-$

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

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

$X(1835)$ BRANCHING RATIOS

$\Gamma(p\overline{p})/\Gamma(\eta'\pi^+\pi^-)$ Γ_1/Γ_2

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.333	ABLIKIM	05R	BES2	$J/\psi \to \gamma\pi^+\pi^-\eta'$

$\Gamma(\eta'\pi^+\pi^-)/\Gamma(K^0_S K^0_S \eta)$ 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	$J/\psi \to \gamma K^0_S K^0_S \eta$

[1] Using resutls from ABLIKIM 05R.

$\Gamma(\eta'\pi^+\pi^-)/\Gamma_{total}$ Γ_2/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	[1] ABLIKIM	16J	BES3	$J/\psi \to \gamma\pi^+\pi^-\eta'$

[1] ABLIKIM 16J quotes B($J/\psi \to \gamma X(1835)$) × B($X(1835) \to \pi^+\pi^-\eta'$) = $(3.93 \pm 0.38^{+0.31}_{-0.84}) \times 10^{-4}$ from a fit of the measured $\pi^+\pi^-\eta'$ lineshape that accounts for the abrupt distortion observed at the $p\overline{p}$ threshold with a Flatte formula in addition to known backgrounds and contributors, as well as an *ad hoc* Breit-Wigner (M ≈ 1919 MeV; Γ ≈ 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.

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

VALUE	DOCUMENT ID		TECN	COMMENT
possibly seen	[1] ABLIKIM	18I	BES3	$J/\psi \to \gamma\gamma\phi(1020)$

[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
$<9.80 \times 10^{-3}$	90	[1] ABLIKIM	18O	BES3	$\psi(2S) \to \pi^+\pi^-\gamma\gamma\gamma$

[1] Using results from ABLIKIM 16J.

$\Gamma(3(\pi^+\pi^-))/\Gamma_{total}$ Γ_6/Γ

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

$X(1835)$ REFERENCES

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