$X(3872)$

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

Seen by CHOI 03 in $B \to K\pi^+\pi^- J/\psi(1S)$ decays as a narrow peak in the invariant mass distribution of the $\pi^+\pi^- J/\psi(1S)$ final state, but not seen in the $\gamma\chi_{c1}$ final state of these decays. Possibly absent in the invariant mass spectrum of the final state $\pi^+\pi^- J/\psi(1S)$ in e^+e^- collisions. Interpretation as a 1^{--} charmonium state not favored. Isovector hypothesis excluded by AUBERT 05B. A helicity amplitude analysis of the $X(3872) \to J/\psi\pi^+\pi^-$ decay gives two possible J^{PC} assignments: $J^{PC} = 1^{++}$ and 2^{-+} (ABULENCIA 07E).

See our note "New charmonium-like states" in the 2008 edition of this *Review* (PDG 08) and the extensive chapter on Spectroscopy in N. Brambilla *etal*. (Quarkonium Working Group), to be published in the Eur. Phys. J. in 2010.

$X(3872)$ MASS FROM $J/\psi\pi\pi$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3871.56± 0.22 OUR AVERAGE					
3871.61± 0.16±0.19	6k	[1,2] AALTONEN	09AU	CDF2	$p\overline{p} \to J/\psi\pi^+\pi^- X$
3871.4 ± 0.6 ±0.1	93.4	AUBERT	08Y	BABR	$B^+ \to K^+ J/\psi\pi^+\pi^-$
3868.7 ± 1.5 ±0.4	9.4	AUBERT	08Y	BABR	$B^0 \to K^0_S J/\psi\pi^+\pi^-$
3871.8 ± 3.1 ±3.0	522	[2,3] ABAZOV	04F	D0	$p\overline{p} \to J/\psi\pi^+\pi^- X$
3872.0 ± 0.6 ±0.5	36	CHOI	03	BELL	$B \to K\pi^+\pi^- J/\psi$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3868.6 ± 1.2 ±0.2	8	[4] AUBERT	06	BABR	$B^0 \to K^0_S J/\psi\pi^+\pi^-$
3871.3 ± 0.6 ±0.1	61	[4] AUBERT	06	BABR	$B^- \to K^- J/\psi\pi^+\pi^-$
3873.4 ± 1.4	25	[5] AUBERT	05R	BABR	$B^+ \to K^+ J/\psi\pi^+\pi^-$
3871.3 ± 0.7 ±0.4	730	[2,6] ACOSTA	04	CDF2	$p\overline{p} \to J/\psi\pi^+\pi^- X$
3836 ±13	58	[2,7] ANTONIAZZI	94	E705	300 $\pi^\pm$Li $\to$ $J/\psi\pi^+\pi^- X$

[1] A possible equal mixture of two states with a mass difference greater than 3.6 MeV/c^2 is excluded at 95% CL.
[2] Width consistent with detector resolution.
[3] Calculated from the corresponding $m_{X(3872)} - m_{J/\psi}$ using $m_{J/\psi}$=3096.916 MeV.
[4] Calculated from the corresponding $m_{X(3872)} - m_{\psi(2S)}$ using $m_{\psi(2S)} = 3686.093$ MeV. Superseded by AUBERT 08Y.
[5] Calculated from the corresponding $m_{X(3872)} - m_{\psi(2S)}$ using $m_{\psi(2S)} = 3685.96$MeV. Superseded by AUBERT 06.
[6] Superseded by AALTONEN 09AU.
[7] A lower mass value can be due to an incorrect momentum scale for soft pions.

$X(3872)$ MASS FROM $\overline{D}^{*0} D^0$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$3872.9^{+0.6+0.4}_{-0.4-0.5}$	50	[8,9] AUSHEV	10	BELL	$B \to \overline{D}^{*0} D^0 K$
$3875.1^{+0.7}_{-0.5} \pm 0.5$	33 ± 6	[9] AUBERT	08B	BABR	$B \to \overline{D}^{*0} D^0 K$
$3875.2 \pm 0.7^{+0.9}_{-1.8}$	24 ± 6	[9,10] GOKHROO	06	BELL	$B \to D^0 \overline{D}^0 \pi^0 K$

[8] Calculated from the measured $m_{X(3872)} - m_{D^{*0}} - m_{\overline{D}^0} = 1.1^{+0.6+0.1}_{-0.4-0.3}$ MeV.

[9] Experiments report $D^{*0}\overline{D}^0$ invariant mass above $D^{*0}\overline{D}^0$ threshold because D^{*0} decay products are kinematically constrained to the D^{*0} mass, even though the D^{*0} may decay off-shell.

[10] Superseded by AUSHEV 10.

$m_{X(3872)} - m_{J/\psi}$

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$774.9 \pm 3.1 \pm 3.0$	522	ABAZOV	04F	D0	$p\overline{p} \to J/\psi \pi^+ \pi^- X$

$m_{X(3872)} - m_{\psi(2S)}$

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
187.4 ± 1.4	25	[11] AUBERT	05R	BABR	$B^+ \to K^+ J/\psi \pi^+ \pi^-$

[11] Superseded by AUBERT 06.

$X(3872)$ WIDTH

VALUE (MeV)	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
<2.3	90	36	CHOI	03	BELL	$B \to K \pi^+ \pi^- J/\psi$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<3.3	90		AUBERT	08Y	BABR	$B^+ \to K^+ J/\psi \pi^+ \pi^-$
<4.1	90	69	AUBERT	06	BABR	$B \to K \pi^+ \pi^- J/\psi$

$X(3872)$ WIDTH FROM $\overline{D}^{*0} D^0$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$3.9^{+2.8+0.2}_{-1.4-1.1}$	50	[12] AUSHEV	10	BELL	$B \to \overline{D}^{*0} D^0 K$
$3.0^{+1.9}_{-1.4} \pm 0.9$	33 ± 6	AUBERT	08B	BABR	$B \to \overline{D}^{*0} D^0 K$

[12] With a measured value of $B(B \to X(3872) K) \times B(X(3872) \to D^{*0}\overline{D}^0) = (0.80 \pm 0.20 \pm 0.10) \times 10^{-4}$, assumed to be equal for both charged and neutral modes.

$X(3872)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$e^+ e^-$	
Γ_2	$\pi^+\pi^- J/\psi(1S)$	>2.6 %
Γ_3	$\rho^0 J/\psi(1S)$	
Γ_4	$D^0\overline{D}^0\pi^0$	$>3.2\times10^{-3}$
Γ_5	$\overline{D}^{*0} D^0$	$>5\times10^{-3}$
Γ_6	$\gamma\gamma$	
Γ_7	$D^0\overline{D}^0$	
Γ_8	$D^+ D^-$	
Γ_9	$\gamma\chi_{c1}$	
Γ_{10}	$\eta J/\psi$	
Γ_{11}	$\gamma J/\psi$	$>9\times10^{-3}$
Γ_{12}	$\gamma\psi(2S)$	>3.0 %

$X(3872)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ Γ_1

VALUE (keV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.28	90	[13] YUAN	04	RVUE	$e^+e^- \to \pi^+\pi^- J/\psi$

[13] Using BAI 98E data on $e^+e^- \to \pi^+\pi^-\ell^+\ell^-$. Assuming that $\Gamma(\pi^+\pi^- J/\psi)$ of $X(3872)$ is the same as that of $\psi(2S)$ (85.4 keV).

$X(3872)$ $\Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(\pi^+\pi^- J/\psi(1S)) \times \Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_2\Gamma_1/\Gamma$

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 6.2	90	[14,15] AUBERT	05D	BABR	10.6 $e^+e^- \to K^+K^-\pi^+\pi^-\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 8.3	90	[15] DOBBS	05	CLE3	$e^+e^- \to \pi^+\pi^- J/\psi$
<10	90	[16] YUAN	04	RVUE	$e^+e^- \to \pi^+\pi^- J/\psi$

[14] Using $B(X(3872) \to J/\psi\pi^+\pi^-)\cdot B(J/\psi \to \mu^+\mu^-)\cdot\Gamma(X(3872) \to e^+e^-) < 0.37$ eV from AUBERT 05D and $B(J/\psi \to \mu^+\mu^-) = 0.0588 \pm 0.0010$ from the PDG 04.

[15] Assuming $X(3872)$ has $J^{PC} = 1^{--}$.

[16] Using BAI 98E data on $e^+e^- \to \pi^+\pi^-\ell^+\ell^-$. From theoretical calculation of the production cross section and using $B(J/\psi \to \mu^+\mu^-) = (5.88 \pm 0.10)\%$.

$X(3872)$ Γ(i)Γ(γγ)/Γ(total)

$\Gamma(\gamma\gamma) \times \Gamma(\pi^+\pi^- J/\psi(1S))/\Gamma_{\text{total}}$ $\Gamma_6\Gamma_2/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<12.9	90	[17] DOBBS	05	CLE3	$e^+e^- \to \pi^+\pi^- J/\psi\gamma$

[17] Assuming $X(3872)$ has positive C parity and spin 0.

$X(3872)$ BRANCHING RATIOS

$\Gamma(\pi^+\pi^- J/\psi(1S))/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
>0.026	93 ± 17	[18] AUBERT	08Y	BABR	$B \to X(3872)K$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>0.04	30	[19] AUBERT	05R	BABR	$B^+ \to K^+ J/\psi\pi^+\pi^-$
>0.04	36 ± 7	[20] CHOI	03	BABR	$B^+ \to K^+ J/\psi\pi^+\pi^-$

[18] AUBERT 08Y reports $[\Gamma(X(3872) \to \pi^+\pi^- J/\psi(1S))/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (8.4 \pm 1.5 \pm 0.7) \times 10^{-6}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

[19] Superseded by AUBERT 08Y. AUBERT 05R reports $[\Gamma(X(3872) \to \pi^+\pi^- J/\psi(1S))/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (1.28 \pm 0.41) \times 10^{-5}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

[20] CHOI 03 reports $[\Gamma(X(3872) \to \pi^+\pi^- J/\psi(1S))/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] / [\text{B}(B^+ \to \psi(2S)K^+)] / [\text{B}(\psi(2S) \to J/\psi(1S)\pi^+\pi^-)] = 0.063 \pm 0.012 \pm 0.007$ which we multiply or divide by our best values $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$, $\text{B}(B^+ \to \psi(2S)K^+) = (6.46 \pm 0.33) \times 10^{-4}$, $\text{B}(\psi(2S) \to J/\psi(1S)\pi^+\pi^-) = (33.6 \pm 0.4) \times 10^{-2}$.

$\Gamma(D^0\overline{D}{}^0\pi^0)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
>3.2 × 10⁻³	17 ± 5	[21] GOKHROO	06	BELL	$B^+ \to D^0\overline{D}{}^0\pi^0 K^+$

[21] GOKHROO 06 reports $[\Gamma(X(3872) \to D^0\overline{D}{}^0\pi^0)/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (1.02 \pm 0.31^{+0.21}_{-0.29}) \times 10^{-6}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

$\Gamma(\overline{D}{}^{*0}D^0)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
>5 × 10⁻³	27 ± 6	[22] AUBERT	08B	BABR	$B^+ \to \overline{D}{}^{*0}D^0 K^+$

[22] AUBERT 08B reports $[\Gamma(X(3872) \to \overline{D}{}^{*0}D^0)/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (1.67 \pm 0.36 \pm 0.47) \times 10^{-6}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

$\Gamma(D^0\overline{D}^0\pi^0)/\Gamma(\pi^+\pi^- J/\psi(1S))$ Γ_4/Γ_2

VALUE	DOCUMENT ID		TECN	COMMENT
seen	[23] GOKHROO	06	BELL	$B \to D^0\overline{D}^0\pi^0 K$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	AUSHEV	10	BELL	$B \to D^0\overline{D}^0\pi^0 K$

[23] May not necessarily be the same state as that observed in the $J/\psi\pi^+\pi^-$ mode. Supersedes CHISTOV 04.

$\Gamma(D^0\overline{D}^0)/\Gamma(\pi^+\pi^- J/\psi(1S))$ Γ_7/Γ_2

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	CHISTOV	04	BELL	$B \to K D^0\overline{D}^0$

$\Gamma(D^+D^-)/\Gamma(\pi^+\pi^- J/\psi(1S))$ Γ_8/Γ_2

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	CHISTOV	04	BELL	$B \to K D^+ D^-$

$\Gamma(\gamma\chi_{c1})/\Gamma(\pi^+\pi^- J/\psi(1S))$ Γ_9/Γ_2

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.89	90	CHOI	03	BELL	$B \to K\pi^+\pi^- J/\psi$

$\Gamma(\eta J/\psi)/\Gamma(\pi^+\pi^- J/\psi(1S))$ Γ_{10}/Γ_2

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.6	90	AUBERT	04Y	BABR	$B \to K\eta J/\psi$

$\Gamma(\gamma J/\psi)/\Gamma_{\text{total}}$ Γ_{11}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
>9 $\times 10^{-3}$	23 ± 6	[24] AUBERT	09B	BABR	$B^+ \to \gamma J/\psi K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
>0.010	19	[25] AUBERT,BE	06M	BABR	$B^+ \to \gamma J/\psi K^+$

[24] AUBERT 09B reports $[\Gamma(X(3872) \to \gamma J/\psi)/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (2.8 \pm 0.8 \pm 0.1) \times 10^{-6}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

[25] Superseded by AUBERT 09B. AUBERT,BE 06M reports $[\Gamma(X(3872) \to \gamma J/\psi)/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (3.3 \pm 1.0 \pm 0.3) \times 10^{-6}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

$\Gamma(\gamma\psi(2S))/\Gamma_{\text{total}}$ Γ_{12}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
>0.030	25 ± 7	[26] AUBERT	09B	BABR	$B^+ \to \gamma\psi(2S)K^+$

[26] AUBERT 09B reports $[\Gamma(X(3872) \to \gamma\psi(2S))/\Gamma_{\text{total}}] \times [\text{B}(B^+ \to X(3872)K^+)] = (9.5 \pm 2.7 \pm 0.6) \times 10^{-6}$ which we divide by our best value $\text{B}(B^+ \to X(3872)K^+) < 3.2 \times 10^{-4}$.

$\Gamma(\gamma\psi(2S))/\Gamma(\gamma J/\psi)$ **Γ_{12}/Γ_{11}**

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
3.4±1.4	AUBERT	09B	BABR	$B^+ \to \gamma c\overline{c} K'$

X(3872) REFERENCES

AUSHEV	10	PR D81 031103	T. Aushev *et al.*	(BELLE Collab.)
AALTONEN	09AU	PRL 103 152001	T. Aaltonen *et al.*	(CDF Collab.)
AUBERT	09B	PRL 102 132001	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	08B	PR D77 011102R	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	08Y	PR D77 111101R	B. Aubert *et al.*	(BABAR Collab.)
PDG	08	PL B667 1	C. Amsler *et al.*	(PDG Collab.)
ABULENCIA	07E	PRL 98 132002	A. Abulencia *et al.*	(CDF Collab.)
AUBERT	06	PR D73 011101R	B. Aubert *et al.*	(BABAR Collab.)
AUBERT,BE	06M	PR D74 071101R	B. Aubert *et al.*	(BABAR Collab.)
GOKHROO	06	PRL 97 162002	G. Gokhroo *et al.*	(BELLE Collab.)
AUBERT	05B	PR D71 031501R	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	05D	PR D71 052001	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	05R	PR D71 071103R	B. Aubert *et al.*	(BABAR Collab.)
DOBBS	05	PRL 94 032004	S. Dobbs *et al.*	(CLEO Collab.)
ABAZOV	04F	PRL 93 162002	V.M. Abazov *et al.*	(D0 Collab.)
ACOSTA	04	PRL 93 072001	D. Acosta *et al.*	(CDF Collab.)
AUBERT	04Y	PRL 93 041801	B. Aubert *et al.*	(BaBar Collab.)
CHISTOV	04	PRL 93 051803	R. Chistov *et al.*	(BELLE Collab.)
PDG	04	PL B592 1	S. Eidelman *et al.*	(PDG Collab.)
YUAN	04	PL B579 74	C.Z. Yuan *et al.*	
CHOI	03	PRL 91 262001	S.-K. Choi *et al.*	(BELLE Collab.)
BAI	98E	PR D57 3854	J.Z. Bai *et al.*	(BES Collab.)
ANTONIAZZI	94	PR D50 4258	L. Antoniazzi *et al.*	(E705 Collab.)