$f_0(1710)$

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

THE $f_0(1710)$

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The $f_0(1710)$ is seen in the radiative decay $J/\psi(1S) \rightarrow \gamma f_0(1710)$; therefore $C = +1$. It decays into $\eta\eta$ and $K^0_S K^0_S$, which implies $I^G J^{PC} = 0^+(even)^{++}$. The spin of the $f_0(1710)$ has been controversial, but evidence for spin 0 has accumulated recently in all production modes.

An analysis of radiative J/ψ decays at BES into $\pi^+\pi^-\pi^+\pi^-$ (BAI 00) clearly favors spin 0. Combined amplitude analyses of the K^+K^-, $K^0_S K^0_S$ and $\pi^+\pi^-$ systems produced in $J/\psi(1S)$ radiative decay by MARK III (CHEN 91 and more recently DUNWOODIE 97) find a large spin-0 component, and at the same time reproduce known parameters of the $f_2(1270)$ and $f'_2(1525)$. In addition, a recent reanalysis (BUGG 95) of the 4π channel from MARK III, allowing both $\rho\rho$ and two $\pi\pi$ S-waves, also finds a 0^{++} assignment for the $f_0(1710)$. Earlier analyses of this final state (BISELLO 89B, BALTRUSAITIS 86B) found only pseudoscalar activity in the $f_0(1710)$ region, but considered only the process $J/\psi \rightarrow \gamma\rho\rho$. Similarly, earlier analyses of the K^+K^- system based on less statistics (BALTRUSAITIS 87, BAI 96) found a spin of 2 for the $f_0(1710)$.

A similar situation is present in central production, with earlier analyses favoring spin 2 over spin 0 (ARMSTRONG 89D). More recent analyses with greater statistics by BARBERIS 99 (K^+K^-,$K^0_S K^0_S$), BARBERIS 99B ($\pi^+\pi^-$), and FRENCH 99 (K^+K^-) however clearly indicate spin 0, and exclude spin 2. Generally, analyses preferring spin 2 concentrate on angular distributions in the $f_0(1710)$ region, and do not include possible interferences or distortion due to the nearby $f'_2(1525)$.

The $f_0(1710)$ is also observed in $K\overline{K}$ (FALVARD 88) in $J/\psi(1S) \rightarrow \omega K\overline{K}$ and $J/\psi(1S) \rightarrow \phi K\overline{K}$, but with no spin-parity analysis, as well as in $\eta\eta$ in radiative J/ψ decays (EDWARDS 82). It is also clearly seen in 300-GeV/c pp central production in both K^+K^- and $K^0_S K^0_S$ (ARMSTRONG 89D). Mass and width are determined via a fit to non-interfering Breit-Wigners over a polynomial background, which leads to large systematic errors for the width. ARMSTRONG 93C also sees a broad peak in $\eta\eta$ at 1747 MeV, which may be the $f_0(1710)$.

This resonance is not observed in the hypercharge-exchange reactions $K^-p \rightarrow K^0_S K^0_S \Lambda$ (ASTON 88D) and $K^-p \rightarrow K^0_S K^0_S Y^*$ (BOLONKIN 86); these non-observations are explained by a spin of 0 (LINDENBAUM 92). A possible observation in $\gamma\gamma$ collisions leading to $K^0_S K^0_S$ (BRACCINI 99, but no spin determination), and a non-observation in $\gamma\gamma \rightarrow \pi^+\pi^-$ (BARATE 00E) is consistent with a large $\overline{s}s$ component.

$f_0(1710)$ MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1715± 7	**OUR AVERAGE**	Error includes scale factor of 1.1.			
1740^{+30}_{-25}		[1] BAI	00	BES	$J/\psi \rightarrow \gamma(\pi^+\pi^-\pi^+\pi^-)$
1710±25		[2] FRENCH	99		300 $pp \rightarrow p_f(K^+K^-)p_s$
1707±10		[3] AUGUSTIN	88	DM2	$J/\psi \rightarrow \gamma K^+K^-$, $K^0_S K^0_S$
1698±15		[3] AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma\pi^+\pi^-$
1720±10 ±10		[4] BALTRUSAIT...	87	MRK3	$J/\psi \rightarrow \gamma K^+K^-$
1742±15		[3] WILLIAMS	84	MPSF	200 $\pi^- N \rightarrow 2K^0_S X$
1670±50		BLOOM	83	CBAL	$J/\psi \rightarrow \gamma 2\eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1770±12		[5] ANISOVICH	99B	SPEC	0.6–1.2 $p\overline{p} \rightarrow \eta\eta\pi^0$
1730±15		[1] BARBERIS	99	OMEG	450 $pp \rightarrow p_s p_f K^+K^-$
1750±20		[1] BARBERIS	99B	OMEG	450 $pp \rightarrow p_s p_f \pi^+\pi^-$
1710±12 ±11		[6] BARBERIS	99D	OMEG	450 $pp \rightarrow K^+K^-$, $\pi^+\pi^-$

1750±30		[7] ANISOVICH	98B	RVUE	Compilation
1720±39		BAI	98H	BES	$J/\psi \to \gamma \pi^0 \pi^0$
1775± 1.5	57	[8] BARKOV	98		$\pi^- p \to K^0_S K^0_S n$
1690±11		[9] ABREU	96C	DLPH	$Z^0 \to K^+ K^- X$
1696± 5 $^{+9}_{-34}$		[4] BAI	96C	BES	$J/\psi \to \gamma K^+ K^-$
1781± 8 $^{+10}_{-31}$		[1] BAI	96C	BES	$J/\psi \to \gamma K^+ K^-$
1768±14		BALOSHIN	95	SPEC	40 π^- C $\to K^0_S K^0_S X$
1750±15		[10] BUGG	95	MRK3	$J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$
1620±16		[4] BUGG	95	MRK3	$J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$
1748±10		[3] ARMSTRONG	93C	E760	$\overline{p} p \to \pi^0 \eta \eta \to 6\gamma$
∼ 1750		BREAKSTONE	93	SFM	$p p \to p p \pi^+ \pi^- \pi^+ \pi^-$
1744±15		[11] ALDE	92D	GAM2	38 $\pi^- p \to \eta \eta n$
1713±10		[12] ARMSTRONG	89D	OMEG	300 $p p \to p p K^+ K^-$
1706±10		[12] ARMSTRONG	89D	OMEG	300 $p p \to p p K^0_S K^0_S$
1700±15		[4] BOLONKIN	88	SPEC	40 $\pi^- p \to K^0_S K^0_S n$
1720±60		[1] BOLONKIN	88	SPEC	40 $\pi^- p \to K^0_S K^0_S n$
1638±10		[13] FALVARD	88	DM2	$J/\psi \to \phi K^+ K^-$, $K^0_S K^0_S$
1690± 4		[14] FALVARD	88	DM2	$J/\psi \to \phi K^+ K^-$, $K^0_S K^0_S$
1755± 8		[15] ALDE	86C	GAM2	38 $\pi^- p \to n 2\eta$
1730$^{+2}_{-10}$		[16] LONGACRE	86	RVUE	22 $\pi^- p \to n 2 K^0_S$
1650±50		BURKE	82	MRK2	$J/\psi \to \gamma 2\rho$
1640±50		[17,18] EDWARDS	82D	CBAL	$J/\psi \to \gamma 2\eta$
1730±10 ±20		[19] ETKIN	82C	MPS	23 $\pi^- p \to n 2 K^0_S$

[1] $J^P = 0^+$.
[2] $J^P = 0^+$, supersedes by ARMSTRONG 89D.
[3] No J^{PC} determination.
[4] $J^P = 2^+$.
[5] Preliminary data from CBAR, $J^P = 0^+$.
[6] Supersedes BARBERIS 99 and BARBERIS 99B.
[7] T-matrix pole, assuming $J^P = 0^+$
[8] No J^{PC} determination.
[9] No J^{PC} determination, width not determined.
[10] From a fit to the 0^+ partial wave.
[11] ALDE 92D combines all the GAMS-2000 data.
[12] $J^P = 2^+$, superseded by FRENCH 99.
[13] From an analysis ignoring interference with $f'_2(1525)$.
[14] From an analysis including interference with $f'_2(1525)$.
[15] Superseded by ALDE 92D.
[16] Uses MRK3 data. From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but assuming spin 2. Fit with constrained inelasticity.
[17] $J^P = 2^+$ preferred.
[18] From fit neglecting nearby $f'_2(1525)$. Replaced by BLOOM 83.
[19] Superseded by LONGACRE 86.

$f_0(1710)$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
125 ± 12 OUR AVERAGE						
120^{+50}_{-40}			[20] BAI	00	BES	$J/\psi \to \gamma(\pi^+\pi^-\pi^+\pi^-)$
105 ± 34			[21] FRENCH	99		300 $pp \to p_f(K^+K^-)p_s$
166.4 ± 33.2			[22] AUGUSTIN	88	DM2	$J/\psi \to \gamma K^+K^-$, $K^0_S K^0_S$
136 ± 28			[22] AUGUSTIN	87	DM2	$J/\psi \to \gamma\pi^+\pi^-$
130 ± 20			[23] BALTRUSAIT...	87	MRK3	$J/\psi \to \gamma K^+K^-$
57 ± 38			[3] WILLIAMS	84	MPSF	200 $\pi^- N \to 2K^0_S X$
160 ± 80			BLOOM	83	CBAL	$J/\psi \to \gamma 2\eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
220 ± 42			[24] ANISOVICH	99B	SPEC	0.6–1.2 $p\overline{p} \to \eta\eta\pi^0$
100 ± 25			[20] BARBERIS	99	OMEG	450 $pp \to p_s p_f K^+K^-$
160 ± 30			[20] BARBERIS	99B	OMEG	450 $pp \to p_s p_f \pi^+\pi^-$
126 ± 16 ± 18			[25] BARBERIS	99D	OMEG	450 $pp \to K^+K^-$, $\pi^+\pi^-$
250 ± 140			[26] ANISOVICH	98B	RVUE	Compilation
30 ± 7		57	[27] BARKOV	98		$\pi^- p \to K^0_S K^0_S n$
$103 \pm 18^{+30}_{-11}$			[23] BAI	96C	BES	$J/\psi \to \gamma K^+K^-$
$85 \pm 24^{+22}_{-19}$			[20] BAI	96C	BES	$J/\psi \to \gamma K^+K^-$
56 ± 19			BALOSHIN	95	SPEC	40 $\pi^- C \to K^0_S K^0_S X$
160 ± 40			[28] BUGG	95	MRK3	$J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$
160^{+60}_{-20}			[23] BUGG	95	MRK3	$J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$
264 ± 25			[22] ARMSTRONG	93C	E760	$\overline{p}p \to \pi^0\eta\eta \to 6\gamma$
200 to 300			BREAKSTONE	93	SFM	$pp \to pp\pi^+\pi^-\pi^+\pi^-$
< 80	90		[29] ALDE	92D	GAM2	38 $\pi^- p \to \eta\eta N^*$
181 ± 30			[30] ARMSTRONG	89D	OMEG	300 $pp \to ppK^+K^-$
104 ± 30			[30] ARMSTRONG	89D	OMEG	300 $pp \to ppK^0_S K^0_S$
30 ± 20			[23] BOLONKIN	88	SPEC	40 $\pi^- p \to K^0_S K^0_S n$

350 ±150	20	BOLONKIN	88	SPEC	40 $\pi^- p \to K^0_S K^0_S n$
148 ± 17	31	FALVARD	88	DM2	$J/\psi \to \phi K^+ K^-$, $K^0_S K^0_S$
184 ± 6	32	FALVARD	88	DM2	$J/\psi \to \phi K^+ K^-$, $K^0_S K^0_S$
122 $^{+74}_{-15}$	33	LONGACRE	86	RVUE	22 $\pi^- p \to n 2K^0_S$
200 ±100		BURKE	82	MRK2	$J/\psi \to \gamma 2\rho$
220 $^{+100}_{-70}$	34,35	EDWARDS	82D	CBAL	$J/\psi \to \gamma 2\eta$
200.0 $^{+156.0}_{-9.0}$	36	ETKIN	82B	MPS	23 $\pi^- p \to n 2K^0_S$

[20] $J^P = 0^+$.
[21] $J^P = 0^+$, supersedes by ARMSTRONG 89D.
[22] No J^{PC} determination.
[23] $J^P = 2^+$.
[24] Preliminary data from CBAR, $J^P = 0^+$.
[25] Supersedes BARBERIS 99 and BARBERIS 99B.
[26] T-matrix pole, assuming $J^P = 0^+$
[27] No J^{PC} determination.
[28] From a fit to the 0^+ partial wave.
[29] ALDE 92D combines all the GAMS-2000 data.
[30] $J^P = 2^+$, (0^+ excluded).
[31] From an analysis ignoring interference with $f'_2(1525)$.
[32] From an analysis including interference with $f'_2(1525)$.
[33] Uses MRK3 data. From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but assuming spin 2. Fit with constrained inelasticity.
[34] $J^P = 2^+$ preferred.
[35] From fit neglecting nearby $f'_2(1525)$. Replaced by BLOOM 83.
[36] From an amplitude analysis of the $K^0_S K^0_S$ system, superseded by LONGACRE 86.

$f_0(1710)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$K\overline{K}$	seen
Γ_2	$\eta\eta$	seen
Γ_3	$\pi\pi$	seen
Γ_4	$\gamma\gamma$	

$f_0(1710)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ — $\Gamma_1\Gamma_4/\Gamma$

VALUE (keV)	*CL%*		*DOCUMENT ID*		*TECN*	*COMMENT*
<0.11	95	37	BEHREND	89C	CELL	$\gamma\gamma \to K^0_S K^0_S$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.48	95		ALBRECHT	90G	ARG	$\gamma\gamma \to K^+ K^-$
<0.28	95	37	ALTHOFF	85B	TASS	$\gamma\gamma \to K\overline{K}\pi$

[37] Assuming helicity 2.

$\Gamma(\pi\pi) \times \Gamma(\gamma\gamma)/\Gamma_{total}$ — $\Gamma_3\Gamma_4/\Gamma$

VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
<0.82	95	[38] BARATE	00E	ALEP	$\gamma\gamma \to \pi^+\pi^-$

[38] Assuming spin 0.

$f_0(1710)$ BRANCHING RATIOS

$\Gamma(K\overline{K})/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.38^{+0.09}_{-0.19}$	[39,40] LONGACRE	86	MPS	$22\ \pi^- p \to n 2K^0_S$

$\Gamma(\eta\eta)/\Gamma_{total}$ — Γ_2/Γ

VALUE	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$0.18^{+0.03}_{-0.13}$	[39,40] LONGACRE	86	RVUE

$\Gamma(\pi\pi)/\Gamma_{total}$ — Γ_3/Γ

VALUE	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$0.039^{+0.002}_{-0.024}$	[39,40] LONGACRE	86	RVUE

$\Gamma(\pi\pi)/\Gamma(K\overline{K})$ — Γ_3/Γ_1

VALUE	DOCUMENT ID		TECN	COMMENT
0.39±0.14	ARMSTRONG	91	OMEG	$300\ pp \to pp\pi\pi,\ ppK\overline{K}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.2 ±0.024±0.036	BARBERIS	99D	OMEG	$450\ pp \to K^+K^-,\ \pi^+\pi^-$

$\Gamma(\eta\eta)/\Gamma(K\overline{K})$ — Γ_2/Γ_1

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.02	90	[41] PROKOSHKIN	91	GA24	$300\ \pi^- p \to \pi^- p\eta\eta$

[39] From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but assuming spin 2.
[40] Fit with constrained inelasticity.
[41] Combining results of GAM4 with those of ARMSTRONG 89D.

$f_0(1710)$ REFERENCES

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BARATE	00E	PL B472 189	R. Barate *et al.*	(ALEPH Collab.)
ANISOVICH	99B	PL B449 154	A.V. Anisovich *et al.*	
BARBERIS	99	PL B453 305	D. Barberis *et al.*	(Omega expt.)
BARBERIS	99B	PL B453 316	D. Barberis *et al.*	(Omega expt.)
BARBERIS	99D	PL B462 462	D. Barberis *et al.*	(Omega expt.)
FRENCH	99	PL B214 213	B. French *et al.*	(WA76 Collab.)
ANISOVICH	98B	UFN 41 419	V.V. Anisovich *et al.*	
BAI	98H	PRL 81 1179	J.Z. Bai *et al.*	(BES Collab.)
BARKOV	98	JEPTL 68 764	B.P. Barkov *et al.*	
ABREU	96C	PL B379 309	P. Abreu *et al.*	(DELPHI Collab.)
BAI	96C	PRL 77 3959	J.Z. Bai *et al.*	(BES Collab.)
BALOSHIN	95	PAN 58 46	O.N. Baloshin *et al.*	(ITEP)
		Translated from YAF 58 50.		
BUGG	95	PL B353 378	D.V. Bugg *et al.*	(LOQM, PNPI, WASH)
ARMSTRONG	93C	PL B307 394	T.A. Armstrong *et al.*	(FNAL, FERR, GENO+)
BREAKSTONE	93	ZPHY C58 251	A.M. Breakstone *et al.*	(IOWA, CERN, DORT+)
ALDE	92D	PL B284 457	D.M. Alde *et al.*	(GAM2 Collab.)
Also	91	SJNP 54 451	D.M. Alde *et al.*	(GAM2 Collab.)
		Translated from YAF 54 745.		
ARMSTRONG	91	ZPHY C51 351	T.A. Armstrong *et al.*	(ATHU, BARI, BIRM+)
PROKOSHKIN	91	SPD 36 155	Y.D. Prokoshkin	(GAM2, GAM4 Collab.)
		Translated from DANS 316 900.		
ALBRECHT	90G	ZPHY C48 183	H. Albrecht *et al.*	(ARGUS Collab.)
ARMSTRONG	89D	PL B227 186	T.A. Armstrong, M. Benayoun	(ATHU, BARI, BIRM+)
BEHREND	89C	ZPHY C43 91	H.J. Behrend *et al.*	(CELLO Collab.)
AUGUSTIN	88	PRL 60 2238	J.E. Augustin *et al.*	(DM2 Collab.)
BOLONKIN	88	NP B309 426	B.V. Bolonkin *et al.*	(ITEP, SERP)
FALVARD	88	PR D38 2706	A. Falvard *et al.*	(CLER, FRAS, LALO+)
AUGUSTIN	87	ZPHY C36 369	J.E. Augustin *et al.*	(LALO, CLER, FRAS+)
BALTRUSAIT...	87	PR D35 2077	R.M. Baltrusaitis *et al.*	(Mark III Collab.)
ALDE	86C	PL B182 105	D.M. Alde *et al.*	(SERP, BELG, LANL, LAPP)
LONGACRE	86	PL B177 223	R.S. Longacre *et al.*	(BNL, BRAN, CUNY+)
ALTHOFF	85B	ZPHY C29 189	M. Althoff *et al.*	(TASSO Collab.)
WILLIAMS	84	PR D30 877	E.G.H. Williams *et al.*	(VAND, NDAM, TUFTS+)
BLOOM	83	ARNS 33 143	E.D. Bloom, C. Peck	(SLAC, CIT)
BURKE	82	PRL 49 632	D.L. Burke *et al.*	(LBL, SLAC)
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BISELLO	89B	PR D39 701	G. Busetto *et al.*	(DM2 Collab.)
ASTON	88D	NP B301 525	D. Aston *et al.*	(SLAC, NAGO, CINC, INUS)
AKESSON	86	NP B264 154	T. Akesson *et al.*	(Axial Field Spec. Collab.)
ARMSTRONG	86B	PL 167B 133	T.A. Armstrong *et al.*	(ATHU, BARI, BIRM+)
BALTRUSAIT...	86B	PR D33 1222	R.M. Baltrusaitis *et al.*	(Mark III Collab.)
ALTHOFF	83	PL 121B 216	M. Althoff *et al.*	(TASSO Collab.)
BARNETT	83B	PL 120B 455	B. Barnett *et al.*	(JHU)
ALTHOFF	82	ZPHY C16 13	M. Althoff *et al.*	(TASSO Collab.)
BARNES	82	PL B116 365	T. Barnes, F.E. Close	(RHEL)
BARNES	82B	NP B198 360	T. Barnes, F.E. Close, S. Monaghan	(RHEL, OXFTP)
TANIMOTO	82	PL 116B 198	M. Tanimoto	(BIEL)