$\eta(1440)$

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

See also the mini-review under non-$q\overline{q}$ candidates. (See the index for the page number.)

THE $\eta(1440)$, $f_1(1420)$, AND $f_1(1510)$

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The first observation of $\eta(1440)$ was made in $p\overline{p}$ annihilation at rest into $\eta(1440)\pi^+\pi^-$, $\eta(1440) \rightarrow K\overline{K}\pi$ (BAILLON 67). This state was reported to decay through $a_0(980)\pi$ and $K^*(892)\overline{K}$ with roughly equal contributions. The $\eta(1440)$ has also been observed in radiative $J/\psi(1S)$ decay to $K\overline{K}\pi$ (SCHARRE 80, EDWARDS 82E, AUGUSTIN 90).

The $f_1(1420)$, decaying to $K^*\overline{K}$, was reported in π^-p reactions at 4 GeV/c (DIONISI 80). However, later analyses found that the 1400–1500 MeV region is far more complex. In π^-p experiments, (CHUNG 85, REEVES 86, BIRMAN 88) reported 0^{-+} with a dominant $a_0(980)\pi$ contribution to $K\overline{K}\pi$. The π^-p data of RATH 89 at 21 GeV/c suggest the presence of two pseudoscalars decaying to $K\overline{K}\pi$, one around 1410 MeV decaying through $a_0(980)\pi$, and the other around 1470 MeV, decaying to $K^*\overline{K}$. A reanalysis of the MARK III data in radiative $J/\psi(1S)$ decay to $K\overline{K}\pi$ (BAI 90C) also claims the existence of two pseudoscalars in the 1400–1500 MeV range, the lower mass state decaying through $a_0(980)\pi$, and the higher mass state decaying via $K^*\overline{K}$. In addition, $f_1(1420)$ is observed to decay into $K^*\overline{K}$.

In $\pi^-p \rightarrow \eta\pi\pi n$ charge-exchange reactions at 8–9 GeV/c, the $\eta\pi\pi$ mass spectrum is dominated by $\eta(1440)$ and $\eta(1295)$ (ANDO 86, FUKUI 91C), and at 100 GeV/c, ALDE 97B reports $\eta(1295)$ and $\eta(1440)$ decaying to $\eta\pi^0\pi^0$ with a weak $f_1(1285)$ signal, and no evidence for $f_1(1420)$.

An experiment in $\overline{p}p$ annihilation at rest into $K\overline{K}3\pi$ (BERTIN 95) reports two pseudoscalars with decay properties similar to BAI 90C, although the lower state shows, apart from $a_0(980)\pi$, a large contribution from the direct decay $\eta(1440) \to K\overline{K}\pi$.

The result of BERTIN 95 was supported by further $\overline{p}p$ data from the same experiment (BERTIN 97, CICALO 99). In particular, the data of CICALO 99 provided a decisive evidence for the presence of two pseudoscalar states.

We note that the data from AUGUSTIN 92 also suggest two states, but their intermediate states, $a_0(980)\pi$ and $K^*\overline{K}$, are reversed relative to BAI 90C.

Actually the interpretation of AUGUSTIN 92 is disfavored for several reasons: first, it disagrees with all the other $K\overline{K}3\pi$ results reporting two pseudoscalar states (they all agree in assigning the $K^*(892)\overline{K}$ decay mode to the higher mass pseudoscalar); second, it also disagrees with the $\eta\pi\pi$ results, because if the high mass pseudoscalar decays into $a_0(980)\pi$, then this state (and not the one at lower mass) should be seen in $\eta\pi\pi$ (see below).

In $J/\psi(1S)$ radiative decay, the $\eta(1440)$ decays to $K\overline{K}\pi$ through $a_0(980)\pi$, and hence a signal is also expected in the $\eta\pi\pi$ mass spectrum. This has indeed been observed by MARK III in $\eta\pi^+\pi^-$ (BOLTON 92B), which report a mass of 1400 MeV, in line with the existence of a low mass pseudoscalar, in the $\eta(1440)$ structure, decaying to $a_0(980)\pi$. This state is also observed in $\overline{p}p$ annihilation at rest into $\eta\pi^+\pi^-\pi^0\pi^0$, where it decays to $\eta\pi\pi$ (AMSLER 95F). The intermediate $a_0(980)\pi$ accounts for roughly half of the $\eta\pi\pi$ signal, in agreement with MARK III (BOLTON 92B) and DM2 (AUGUSTIN 90). However, ALDE 97B reports only a very small contribution due to $a_0(980)\pi$.

There is now a fairly consistent picture for the existence of two pseudoscalars. We call them η_L and η_H. The first one decays mainly through $a_0(980)\pi$ or direct $K\overline{K}\pi$. The second one decays mainly to $K^*(892)\overline{K}$. The η_L is seen both in $K\overline{K}\pi$ and $\eta\pi\pi$ experiments. The η_H is seen only in $K\overline{K}\pi$ experiments. The simultaneous observation of two pseudoscalars is reported in three production mechanisms by four different experiments: $\pi^- p$ (RATH 89); radiative $J/\psi(1S)$ decay (BAI 90C, AUGUSTIN 92); and $\overline{p}p$ annihilation at rest (BERTIN 95, BERTIN 97, CICALO 99). All of them give values for the masses, widths and decay modes (with the exception of AUGUSTIN 92 quoted above) in reasonable agreement.

A recent paper reports only one pseudoscalar state seen in $J/\psi(1S)$ decay to $K\overline{K}\pi$ (BAI 98C), but its statistics are poorer, by a factor six, with respect to MARK III on the same final state (BAI 90C), and by more than an order of magnitude with respect to $\overline{p}p$ data (BERTIN 95, BERTIN 97, CICALO 99). It is, therefore, not surprising that their analysis is not capable to discriminate between the two states.

One of these two pseudoscalars could be the first radial excitation of the η', with the $\eta(1295)$ being the first radial excitation of the η. Ideal mixing, suggested by the $\eta(1295)$ and $\pi(1300)$ mass degeneracy, would then imply that the second isoscalar in the nonet is mainly $s\overline{s}$, and hence, couples to $K^*\overline{K}$, in agreement with observations for the upper $\eta(1440)$ state.

Also its width matches the expected width for the radially excited $\eta^{s\overline{s}}$ (CLOSE 97, BARNES 97).

This scheme then favors an exotic interpretation of the lower state, perhaps gluonium mixed with $q\overline{q}$ (CLOSE 97B) or a bound state of gluinos (FARRAR 96). The gluonium interpretation is, however, not favored by lattice gauge theories, which predict the 0^{-+} state above 2 GeV (BALI 93).

Axial (1^{++}) mesons are not observed in $\overline{p}p$ annihilation at rest in liquid hydrogen, which proceeds dominantly through S-wave annihilation. However, in gaseous hydrogen, P-wave annihilation is enhanced and, indeed, BERTIN 97 reports $f_1(1420)$ decaying to $K^*\overline{K}$, while confirming their earlier evidence for two pseudoscalars (BERTIN 95).

In $\gamma\gamma$ fusion from e^+e^- annihilations, a signal around 1420 MeV is seen in single-tag events (GIDAL 87B, AIHARA 88B, BEHREND 89, HILL 89), where one of the two photons is off-shell. However, it is totally absent in the untagged events where both photons are real. This points to a spin 1 object, which is not produced by two real (massless) photons (Yang-Landau theorem). The 2γ decay also implies $C = +1$. For the parity, AIHARA 88C and BEHREND 89 both find angular distributions with positive parity preferred, but negative parity cannot be excluded.

The $f_1(1420)$, decaying in $K\overline{K}\pi$, is definitely seen in pp central production at 300 and 450 GeV/c, together with $f_1(1285)$. The latter decays via $a_0(980)\pi$, and the former only via $K^*\overline{K}$, while $\eta(1440)$ is absent (ARMSTRONG 89, BARBERIS 97C). The $K_S K_S \pi^0$ decay mode of $f_1(1420)$ establishes unambiguously C=+1. On the other hand, there is no evidence for any state decaying to $\eta\pi\pi$ around 1400 MeV, and hence, the $\eta\pi\pi$ mode of $f_1(1420)$ is suppressed (ARMSTRONG 91B).

We now turn to the experimental evidence for $f_1(1510)$. Two states, $f_1(1420)$ and $f_1(1510)$, decaying to $K^*\overline{K}$, compete for the $s\overline{s}$ assignment in the 1^{++} nonet. The $f_1(1510)$ was seen in $K^-p \to \Lambda K\overline{K}\pi$ at 4 GeV/c (GAVILLET 82), and at 11 GeV/c (ASTON 88C). Evidence is also reported in π^-p at 8 GeV/c, based on the phase motion of the 1^{++} $K^*\overline{K}$ wave (BIRMAN 88).

The absence of $f_1(1420)$ in K^-p (ASTON 88C) argues against $f_1(1420)$ being the $s\overline{s}$ member of the 1^{++} nonet. However, $f_1(1420)$ has been reported in K^-p, but not in π^-p (BITYUKOV 84) while two experiments do not observe $f_1(1510)$ in K^-p (BITYUKOV 84, KING 91). It is also not seen in radiative $J/\psi(1S)$ decay (BAI 90C, AUGUSTIN 92), central collisions (BARBERIS 97C), or in $\gamma\gamma$ collisions (AIHARA 88C), although, surprisingly for an $s\overline{s}$ state, a signal is reported in 4π decays (BAUER 93B). These facts led to the conclusion that $f_1(1510)$ is not well established, and that its assignment as $s\overline{s}$ member of the 1^{++} nonet is premature (CLOSE 97D). The Particle Data Group has removed this state from the Summary Table. Assigning, instead, the $f_1(1420)$ to the 1^{++} nonet, one finds a nonet mixing angle of $\sim 50°$ (CLOSE 97D). This is derived from the mass formula, and from $f_1(1285)$ radiative decays to $\phi\gamma$ (BITYUKOV 88) and $\rho\gamma$ (AMELIN 95).

Arguments favoring $f_1(1420)$ being a hybrid $q\overline{q}g$ meson or a four-quark state are put forward by ISHIDA 89 and CALDWELL 90, respectively, while LONGACRE 90 argues that this particle is a molecular state formed by the π orbiting in a P-wave around an S-wave $K\overline{K}$ state.

Summarizing, there is rather convincing evidence for $f_1(1420)$, mostly produced in central collisions and decaying to $K^*\overline{K}$, and for $\eta(1440)$, mostly produced in radiative $J/\psi(1S)$ decay and $\overline{p}p$ annihilation at rest, and decaying to $K^*\overline{K}$ and $a_0(980)\pi$. Confusion remains as to which states are observed in π^-p interactions. The $f_1(1510)$ is not well established.

Furthermore, there are fairly strong experimental indications for the presence of two pseudoscalars in the $\eta(1440)$ structure

The available information has led the Particle Data Group to split the $K\overline{K}\pi$ entry for $\eta(1440)$ into $a_0(980)\pi$ and $K^*\overline{K}$.

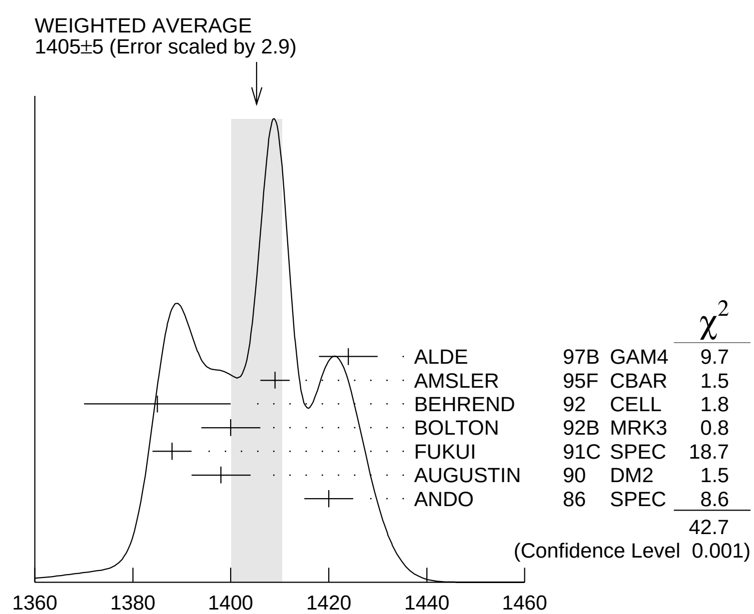
$\eta(1440)$ MASS

VALUE (MeV)	*DOCUMENT ID*
1400 - 1470 OUR ESTIMATE	Contains possibly two overlapping pseudoscalars.

$\eta\pi\pi$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1405± 5 OUR AVERAGE		Error includes scale factor of 2.9. See the ideogram below.			
1424± 6	2200	ALDE	97B	GAM4	100 $\pi^- p \to \eta\pi^0\pi^0 n$
1409± 3		AMSLER	95F	CBAR	0 $\overline{p}p \to \pi^+\pi^-\pi^0\pi^0\eta$
1385±15		[1] BEHREND	92	CELL	$J/\psi \to \gamma\eta\pi^+\pi^-$
1400± 6		[1] BOLTON	92B	MRK3	$J/\psi \to \gamma\eta\pi^+\pi^-$
1388± 4		FUKUI	91C	SPEC	8.95 $\pi^- p \to \eta\pi^+\pi^- n$
1398± 6	261	[2] AUGUSTIN	90	DM2	$J/\psi \to \gamma\eta\pi^+\pi^-$
1420± 5		ANDO	86	SPEC	8 $\pi^- p \to \eta\pi^+\pi^- n$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1385± 7		BAI	99	BES	$J/\psi \to \gamma\pi^+\pi^-$

[1] From fit to the $a_0(980)\pi$ 0^{-+} partial wave.
[2] Best fit with a single Breit Wigner.



$\eta(1440)$ mass, $\eta\pi\pi$ mode (MeV)

$\pi\pi\gamma$ MODE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1401±18	[3,4] AUGUSTIN	90	DM2	$J/\psi \rightarrow \pi^+\pi^-\gamma\gamma$
1432± 8	[4] COFFMAN	90	MRK3	$J/\psi \rightarrow \pi^+\pi^- 2\gamma$

[3] Best fit with a single Breit Wigner.
[4] This peak in the $\gamma\rho$ channel may not be related to the $\eta(1440)$.

4π MODE

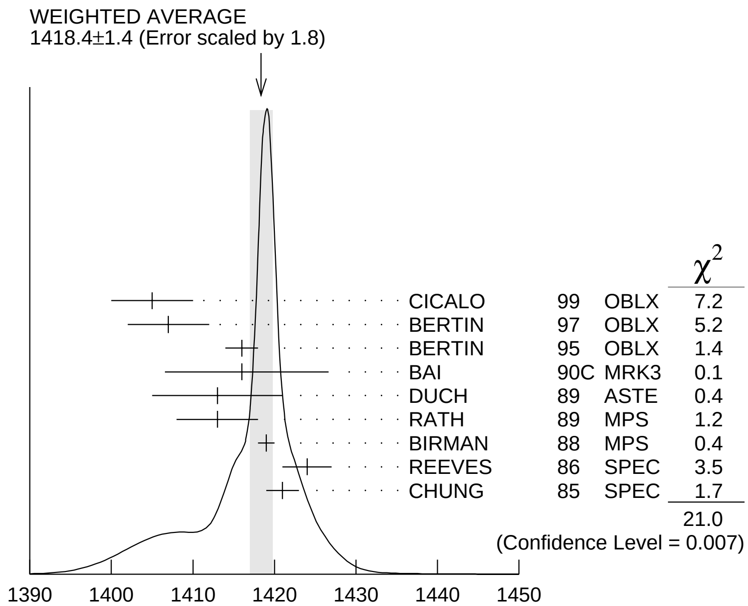
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1420±20		BUGG	95	MRK3	$J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$
1489±12	3270	[5] BISELLO	89B	DM2	$J/\psi \rightarrow 4\pi\gamma$

[5] Estimated by us from various fits.

$K\overline{K}\pi$ MODE ($a_0(980)\,\pi$ dominant)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1418.4±1.4 OUR AVERAGE	Error includes scale factor of 1.8. See the ideogram below.				
1405 ±5		[6] CICALO	99	OBLX	$0\ \overline{p}p \rightarrow K^\pm K^0_S \pi^\mp\pi^+\pi^-$
1407 ±5		[6] BERTIN	97	OBLX	$0\ \overline{p}p \rightarrow K^\pm (K^0)\pi^\mp\pi^+\pi^-$
1416 ±2		[6] BERTIN	95	OBLX	$0\ \overline{p}p \rightarrow K\overline{K}\pi\pi\pi$
1416 ±8 $^{+7}_{-5}$	700	[7] BAI	90C	MRK3	$J/\psi \rightarrow \gamma K^0_S K^\pm \pi^\mp$
1413 ±8	500	DUCH	89	ASTE	$\overline{p}p \rightarrow \pi^+\pi^- K^\pm\pi^\mp K^0$
1413 ±5		[7] RATH	89	MPS	$21.4\ \pi^- p \rightarrow n K^0_S K^0_S \pi^0$
1419 ±1	8800	BIRMAN	88	MPS	$8\ \pi^- p \rightarrow K^+ \overline{K}^0 \pi^- n$
1424 ±3	620	REEVES	86	SPEC	$6.6\ p\overline{p} \rightarrow K\overline{K}\pi X$
1421 ±2		CHUNG	85	SPEC	$8\ \pi^- p \rightarrow K\overline{K}\pi n$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1459 ±5		[8] AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K\overline{K}\pi$

[6] Decaying into $(K\overline{K})_S\pi$, $(K\pi)_S\overline{K}$, and $a_0(980)\pi$.
[7] From fit to the $a_0(980)\pi\ 0^{-+}$ partial wave. Cannot rule out a $a_0(980)\pi\ 1^{++}$ partial wave.
[8] Excluded from averaging because averaging would be meaningless.

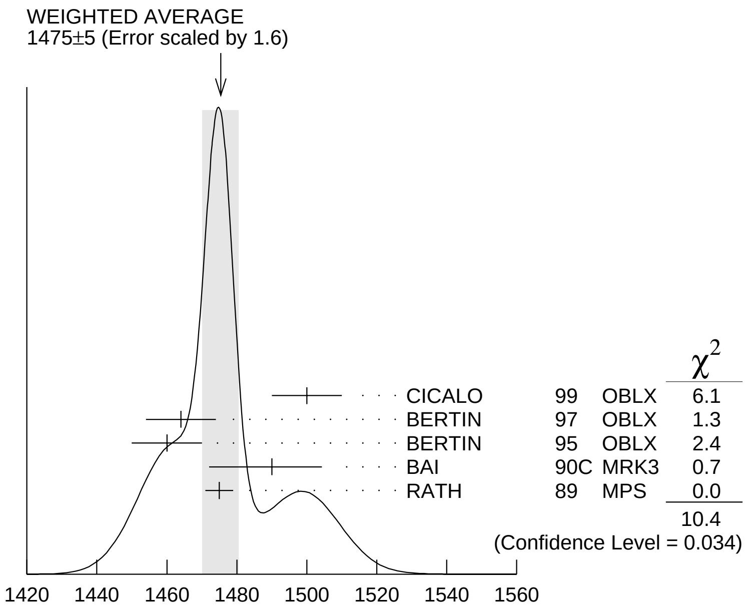


$\eta(1440)$ mass, $K\overline{K}\pi$ mode ($a_0(980)\ \pi$ dominant) (MeV)

$K\overline{K}\pi$ MODE ($K^*(892)$ K dominant)

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
1475± 5 OUR AVERAGE		Error includes scale factor of 1.6. See the ideogram below.			
1500±10		CICALO	99	OBLX	$0\ \overline{p}p \to K^\pm K^0_S \pi^\mp \pi^+ \pi^-$
1464±10		BERTIN	97	OBLX	$0\ \overline{p}p \to K^\pm (K^0) \pi^\mp \pi^+ \pi^-$
1460±10		BERTIN	95	OBLX	$0\ \overline{p}p \to K\overline{K}\pi\pi\pi$
$1490^{+14}_{-8}{}^{+3}_{-16}$	1100	BAI	90C	MRK3	$J/\psi \to \gamma K^0_S K^\pm \pi^\mp$
1475± 4		RATH	89	MPS	$21.4\ \pi^- p \to n K^0_S K^0_S \pi^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1442±10	410	BAI	98C	BES	$J/\psi \to \gamma K^+ K^- \pi^0$
1421±14		[9] AUGUSTIN	92	DM2	$J/\psi \to \gamma K\overline{K}\pi$

[9] Excluded from averaging because averaging would be meaningless.



$\eta(1440)$ mass, $K\overline{K}\pi$ mode ($K^*(892)$ K dominant)

$K\overline{K}\pi$ MODE (unresolved)

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1445\pm\ 8$	693	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K^0_S K^{\pm}\pi^{\mp}$
$1433\pm\ 8$	296	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K^+ K^- \pi^0$
$1453\pm\ 7$	170	RATH	89	MPS	21.4 $\pi^- p \rightarrow K^0_S K^0_S \pi^0 n$
1440^{+20}_{-15}	174	EDWARDS	82E	CBAL	$J/\psi \rightarrow \gamma K^+ K^- \pi^0$
1440^{+10}_{-15}		SCHARRE	80	MRK2	$J/\psi \rightarrow \gamma K^0_S K^{\pm}\pi^{\mp}$
$1425\pm\ 7$	800	[10] BAILLON	67	HBC	0 $\overline{p}p \rightarrow K\overline{K}\pi\pi\pi$

[10] From best fit of 0^{-+} partial wave , 50% $K^*(892)K$, 50% $a_0(980)\pi$.

$\eta(1440)$ WIDTH

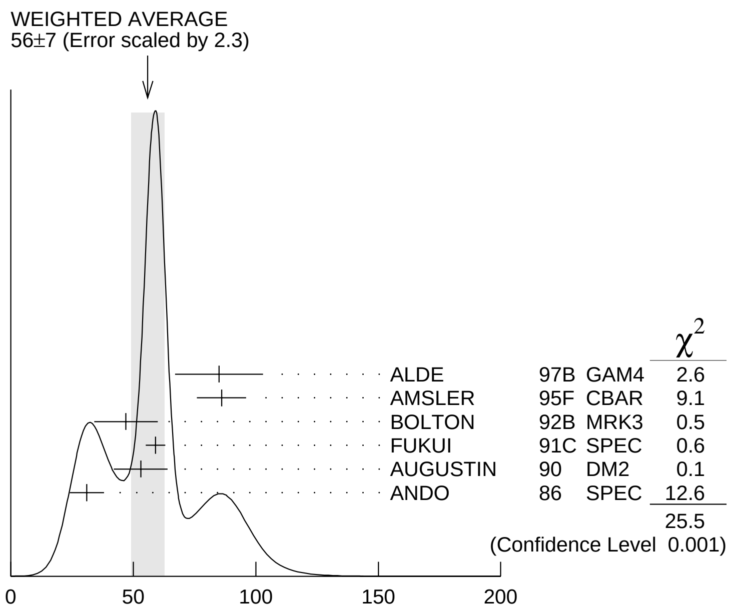
VALUE (MeV)	*DOCUMENT ID*
50 - 80 OUR ESTIMATE	Contains possibly two overlapping pseudoscalars.

$\eta\pi\pi$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
56± 7 OUR AVERAGE		Error includes scale factor of 2.3. See the ideogram below.			
85±18	2200	ALDE	97B	GAM4	100 $\pi^- p \rightarrow \eta\pi^0\pi^0 n$
86±10		AMSLER	95F	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0\pi^0\eta$
47±13		[11] BOLTON	92B	MRK3	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$
59± 4		FUKUI	91C	SPEC	8.95 $\pi^- p \rightarrow \eta\pi^+\pi^- n$
53±11		[12] AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$
31± 7		ANDO	86	SPEC	8 $\pi^- p \rightarrow \eta\pi^+\pi^- n$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 50		[12] BEHREND	92	CELL	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$

[11] From fit to the $a_0(980)\pi$ 0^{-+} partial wave.

[12] From $\eta\pi^+\pi^-$ mass distribution - mainly $a_0(980)\pi$ - no spin–parity determination available.



$\eta(1440)$ width $\eta\pi\pi$ mode (MeV)

$\pi\pi\gamma$ MODE

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
174±44	AUGUSTIN	90	DM2	$J/\psi \rightarrow \pi^+\pi^-\gamma\gamma$
90±26	[13] COFFMAN	90	MRK3	$J/\psi \rightarrow \pi^+\pi^- 2\gamma$

[13] This peak in the $\gamma\rho$ channel may not be related to the $\eta(1440)$.

4π MODE

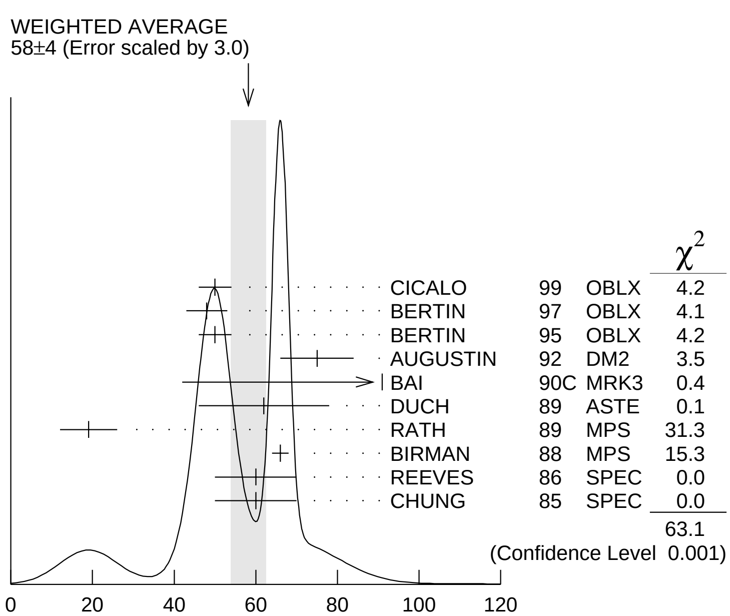
VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
160±30		BUGG	95	MRK3	$J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$
144±13	3270	[14] BISELLO	89B	DM2	$J/\psi \to 4\pi\gamma$

[14] Estimated by us from various fits.

$K\overline{K}\pi$ MODE ($a_0(980)\,\pi$ dominant)

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
58± 4 OUR AVERAGE	Error includes scale factor of 3.0. See the ideogram below.				
50± 4		CICALO	99	OBLX	$0\ \overline{p}p \to K^\pm K^0_S\pi^\mp\pi^+\pi^-$
48± 5		[15] BERTIN	97	OBLX	$0.0\ \overline{p}p \to K^\pm(K^0)\pi^\mp\pi^+\pi^-$
50± 4		[15] BERTIN	95	OBLX	$0\ \overline{p}p \to K\overline{K}\pi\pi\pi$
75± 9		AUGUSTIN	92	DM2	$J/\psi \to \gamma K\overline{K}\pi$
$91^{+67}_{-31}{}^{+15}_{-38}$		[16] BAI	90C	MRK3	$J/\psi \to \gamma K^0_S K^\pm\pi^\mp$
62±16	500	DUCH	89	ASTE	$\overline{p}p \to K\overline{K}\pi\pi\pi$
19± 7		[16] RATH	89	MPS	$21.4\ \pi^- p \to n K^0_S K^0_S \pi^0$
66± 2	8800	BIRMAN	88	MPS	$8\ \pi^- p \to K^+\overline{K}^0\pi^- n$
60±10	620	REEVES	86	SPEC	$6.6\ p\overline{p} \to K K\pi X$
60±10		CHUNG	85	SPEC	$8\ \pi^- p \to K\overline{K}\pi n$

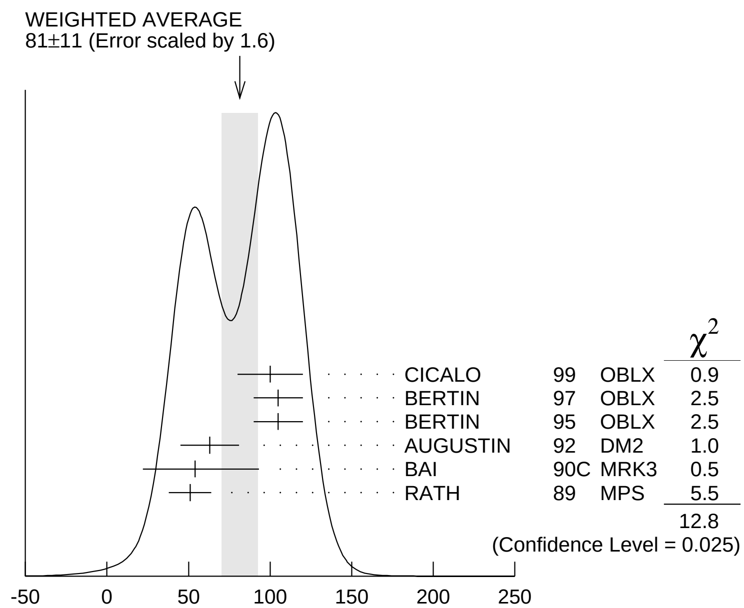
[15] Decaying into $(K\overline{K})_S\pi$, $(K\pi)_S\overline{K}$, and $a_0(980)\pi$.
[16] From fit to the $a_0(980)\pi\ 0^{-+}$ partial wave , but $a_0(980)\pi\ 1^{++}$ cannot be excluded.



$\eta(1440)$ width $K\overline{K}\pi$ mode ($a_0(980)\ \pi$ dominant)

$K\overline{K}\pi$ MODE ($K^*(892)$ K dominant)

VALUE	DOCUMENT ID	TECN	COMMENT
81±11 OUR AVERAGE Error includes scale factor of 1.6. See the ideogram below.			
100±20	CICALO 99	OBLX	0 $\overline{p}p \to K^{\pm}K^0_S\pi^{\mp}\pi^+\pi^-$
105±15	BERTIN 97	OBLX	0.0 $\overline{p}p \to K^{\pm}(K^0)\pi^{\mp}\pi^+\pi^-$
105±15	BERTIN 95	OBLX	0 $\overline{p}p \to K\overline{K}\pi\pi\pi$
63±18	AUGUSTIN 92	DM2	$J/\psi \to \gamma K\overline{K}\pi$
$54^{+37}_{-21}{}^{+13}_{-24}$	BAI 90C	MRK3	$J/\psi \to \gamma K^0_S K^{\pm}\pi^{\mp}$
51±13	RATH 89	MPS	21.4 $\pi^- p \to nK^0_S K^0_S\pi^0$



$\eta(1440)$ width $K\overline{K}\pi$ mode ($K^*(892)$ K dominant)

$K\overline{K}\pi$ MODE (unresolved)

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
93±14	296	AUGUSTIN 90	DM2	$J/\psi \to \gamma K^+K^-\pi^0$
105±10	693	AUGUSTIN 90	DM2	$J/\psi \to \gamma K^0_S K^{\pm}\pi^{\mp}$
100±11	170	RATH 89	MPS	21.4 $\pi^- p \to K^0_S K^0_S\pi^0 n$
55^{+20}_{-30}	174	EDWARDS 82E	CBAL	$J/\psi \to \gamma K^+K^-\pi^0$
50^{+30}_{-20}		SCHARRE 80	MRK2	$J/\psi \to \gamma K^0_S K^{\pm}\pi^{\mp}$
80±10	800	[17] BAILLON 67	HBC	0.0 $\overline{p}p \to K\overline{K}\pi\pi\pi$

[17] From best fit to 0^{-+} partial wave , 50% $K^*(892)K$, 50% $a_0(980)\pi$.

η(1440) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$K\overline{K}\pi$	seen
Γ_2	$K\overline{K}^*(892)+$ c.c.	seen
Γ_3	$\eta\pi\pi$	seen
Γ_4	$a_0(980)\pi$	seen
Γ_5	$\eta(\pi\pi)_{S\text{-wave}}$	seen
Γ_6	$f_0(980)\eta$	seen
Γ_7	4π	seen
Γ_8	$\gamma\gamma$	
Γ_9	$\rho^0\gamma$	

η(1440) $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(K\overline{K}\pi)\times\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ — $\Gamma_1\Gamma_8/\Gamma$

VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
<1.2	95	BEHREND	89	CELL	$\gamma\gamma\to K^0_S K^\pm\pi^\mp$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<1.6	95	AIHARA	86D	TPC	$e^+e^-\to e^+e^-K^0_S K^\pm\pi^\mp$
<2.2	95	ALTHOFF	85B	TASS	$e^+e^-\to e^+e^-K\overline{K}\pi$
<8.0	95	JENNI	83	MRK2	$e^+e^-\to e^+e^-K\overline{K}\pi$

$\Gamma(\eta\pi\pi)\times\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ — $\Gamma_3\Gamma_8/\Gamma$

VALUE (keV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.3	ANTREASYAN	87	CBAL	$e^+e^-\to e^+e^-\eta\pi\pi$

$\Gamma(\rho^0\gamma)\times\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ — $\Gamma_9\Gamma_8/\Gamma$

VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<1.5	95	ALTHOFF	84E	TASS	$e^+e^-\to e^+e^-\pi^+\pi^-\gamma$

η(1440) BRANCHING RATIOS

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.5	90	EDWARDS	83B	CBAL	$J/\psi\to\eta\pi\pi\gamma$
<1.1	90	SCHARRE	80	MRK2	$J/\psi\to\eta\pi\pi\gamma$
<1.5	95	FOSTER	68B	HBC	0.0 $\overline{p}p$

$\Gamma(a_0(980)\pi)/\Gamma(K\overline{K}\pi)$ — Γ_4/Γ_1

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 0.15		[18] BERTIN	95	OBLX	$0\ \overline{p}p \rightarrow K\overline{K}\pi\pi\pi$
~ 0.8	500	[18] DUCH	89	ASTE	$\overline{p}p \rightarrow \pi^+\pi^- K^\pm \pi^\mp K^0$
~ 0.75		[18] REEVES	86	SPEC	$6.6\ p\overline{p} \rightarrow KK\pi X$

[18] Assuming that the $a_0(980)$ decays only into $K\overline{K}$.

$\Gamma(a_0(980)\pi)/\Gamma(\eta\pi\pi)$ — Γ_4/Γ_3

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.29 ± 0.10		ABELE	98E	CBAR	$0\ p\overline{p} \rightarrow \eta\pi^0\pi^0\pi^0$
0.19 ± 0.04	2200	[19] ALDE	97B	GAM4	$100\ \pi^- p \rightarrow \eta\pi^0\pi^0 n$
$0.56\pm0.04\pm0.03$		[19] AMSLER	95F	CBAR	$0\ \overline{p}p \rightarrow \pi^+\pi^-\pi^0\pi^0\eta$

[19] Assuming that the $a_0(980)$ decays only into $\eta\pi$.

$\Gamma(a_0(980)\pi)/\Gamma(\eta(\pi\pi)_{S\text{-wave}})$ — Γ_4/Γ_5

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.70\pm0.12\pm0.20$	[20] BAI	99	BES	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$

[20] Assuming that the $a_0(980)$ decays only into $\eta\pi$.

$\Gamma(K\overline{K}^*(892)+\text{c.c.})/\Gamma(K\overline{K}\pi)$ — Γ_2/Γ_1

VALUE	DOCUMENT ID		TECN	COMMENT
0.50±0.10	BAILLON	67	HBC	$0.0\ \overline{p}p \rightarrow K\overline{K}\pi\pi\pi$

$\Gamma(K\overline{K}^*(892)+\text{c.c.})/[\Gamma(K\overline{K}^*(892)+\text{c.c.})+\Gamma(a_0(980)\pi)]$ — $\Gamma_2/(\Gamma_2+\Gamma_4)$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.25	90	EDWARDS	82E	CBAL	$J/\psi \rightarrow K^+K^-\pi^0\gamma$

$\Gamma(\rho^0\gamma)/\Gamma(K\overline{K}\pi)$ — Γ_9/Γ_1

VALUE	DOCUMENT ID		TECN	COMMENT
0.0152±0.0038	[21] COFFMAN	90	MRK3	$J/\psi \rightarrow \gamma\gamma\pi^+\pi^-$

[21] Using B($J/\psi \rightarrow \gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi$)=$4.2\times10^{-3}$ and B($J/\psi \rightarrow \gamma\eta(1440) \rightarrow \gamma\gamma\rho^0$)=$6.4\times10^{-5}$ and assuming that the $\gamma\rho^0$ signal does not come from the $f_1(1420)$.

$\Gamma(\eta(\pi\pi)_{S\text{-wave}})/\Gamma(\eta\pi\pi)$ — Γ_5/Γ_3

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.81 ± 0.04	2200	ALDE	97B	GAM4	$100\ \pi^- p \rightarrow \eta\pi^0\pi^0 n$

$\Gamma(a_0(980)\pi)/\Gamma(\eta(\pi\pi)_{S\text{-wave}})$ Γ_4/Γ_5

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.32 ± 0.07	[22] ANISOVICH	99I	SPEC	0.9–1.2 $\overline{p}p \rightarrow \eta 3\pi^0$

[22] Using preliminary Crystal Barrel data.

η(1440) REFERENCES

ANISOVICH	99I	PL B468 304	A.V. Anisovich *et al.*	
BAI	99	PL B446 356	J.Z. Bai *et al.*	(BES Collab.)
CICALO	99	PL B462 453	C. Cicalo *et al.*	(OBELIX Collab.)
ABELE	98E	NP B514 45	A. Abele *et al.*	(Crystal Barrel Collab.)
BAI	98C	PL B440 217	J.Z. Bai *et al.*	(BES Collab.)
ALDE	97B	PAN 60 386	D. Alde *et al.*	(GAMS Collab.)
		Translated from YAF 60 458.		
BERTIN	97	PL B400 226	A. Bertin *et al.*	(OBELIX Collab.)
AMSLER	95F	PL B358 389	C. Amsler *et al.*	(Crystal Barrel Collab.)
BERTIN	95	PL B361 187	A. Bertin *et al.*	(OBELIX Collab.)
BUGG	95	PL B353 378	D.V. Bugg *et al.*	(LOQM, PNPI, WASH)
AUGUSTIN	92	PR D46 1951	J.E. Augustin, G. Cosme	(DM2 Collab.)
BEHREND	92	ZPHY C56 381	H.J. Behrend	(CELLO Collab.)
BOLTON	92B	PRL 69 1328	T. Bolton *et al.*	(Mark III Collab.)
FUKUI	91C	PL B267 293	S. Fukui *et al.*	(SUGI, NAGO, KEK, KYOT+)
AUGUSTIN	90	PR D42 10	J.E. Augustin *et al.*	(DM2 Collab.)
BAI	90C	PRL 65 2507	Z. Bai *et al.*	(Mark III Collab.)
COFFMAN	90	PR D41 1410	D.M. Coffman *et al.*	(Mark III Collab.)
BEHREND	89	ZPHY C42 367	H.J. Behrend *et al.*	(CELLO Collab.)
BISELLO	89B	PR D39 701	G. Busetto *et al.*	(DM2 Collab.)
DUCH	89	ZPHY 45 223	K.D. Duch *et al.*	(ASTERIX Collab.) JP
RATH	89	PR D40 693	M.G. Rath *et al.*	(NDAM, BRAN, BNL, CUNY+)
BIRMAN	88	PRL 61 1557	A. Birman *et al.*	(BNL, FSU, IND, MASD) JP
ANTREASYAN	87	PR D36 2633	D. Antreasyan *et al.*	(Crystal Ball Collab.)
AIHARA	86D	PRL 57 51	H. Aihara *et al.*	(TPC-2γ Collab.)
ANDO	86	PRL 57 1296	A. Ando *et al.*	(KEK, KYOT, NIRS, SAGA+) IJP
REEVES	86	PR 34 1960	D.F. Reeves *et al.*	(FLOR, BNL, IND+) JP
ALTHOFF	85B	ZPHY C29 189	M. Althoff *et al.*	(TASSO Collab.)
CHUNG	85	PRL 55 779	S.U. Chung *et al.*	(BNL, FLOR, IND+) JP
ALTHOFF	84E	PL 147B 487	M. Althoff *et al.*	(TASSO Collab.)
EDWARDS	83B	PRL 51 859	C. Edwards *et al.*	(CIT, HARV, PRIN+)
JENNI	83	PR D27 1031	P. Jenni *et al.*	(SLAC, LBL)
EDWARDS	82E	PRL 49 259	C. Edwards *et al.*	(CIT, HARV, PRIN+)
Also	83	PRL 50 219	C. Edwards *et al.*	(CIT, HARV, PRIN+)
SCHARRE	80	PL 97B 329	D.L. Scharre *et al.*	(SLAC, LBL)
FOSTER	68B	NP B8 174	M. Foster *et al.*	(CERN, CDEF)
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LONGACRE	90	PR D42 874	R.S. Longacre	(BNL)

AHMAD	89	NP B (PROC.)8 50	S. Ahmad *et al.*	(ASTERIX Collab.)
ARMSTRONG	89	PL B221 216	T.A. Armstrong *et al.*	(CERN, CDEF, BIRM+)
ARMSTRONG	87	ZPHY C34 23	T.A. Armstrong *et al.*	(CERN, BIRM, BARI+)
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