$\eta(1405)$

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

THE $\eta(1405)$, $\eta(1475)$ $f_1(1420)$, AND $f_1(1510)$

Revised in March 2006 by C. Amsler (Zürich) and A. Masoni (INFN Cagliari).

The first observation of the $\eta(1440)$ was made in $p\overline{p}$ annihilation at rest into $\eta(1440)\pi^+\pi^-$, $\eta(1440) \to K\overline{K}\pi$ (BAILLON 67). This state was reported to decay through $a_0(980)\pi$ and $K^*(892)\overline{K}$ with roughly equal contributions. The $\eta(1440)$ was also observed in radiative $J/\psi(1S)$ decay to $K\overline{K}\pi$ (SCHARRE 80, EDWARDS 82E, AUGUSTIN 90). There is now evidence for the existence of two pseudoscalars in this mass region, the $\eta(1405)$ and $\eta(1475)$. The former decays mainly through $a_0(980)\pi$ (or direct $K\overline{K}\pi$) and the latter mainly to $K^*(892)\overline{K}$.

The simultaneous observation of two pseudoscalars is reported in three production mechanisms: $\pi^- p$ (RATH 89, ADAMS 01); radiative $J/\psi(1S)$ decay (BAI 90C, AUGUSTIN 92); $\overline{p}p$ annihilation at rest (BERTIN 95, BERTIN 97, CICALO 99, NICHITIU 02). All of them give values for the masses, widths and decay modes in reasonable agreement. However, AUGUSTIN 92 favors a state decaying into $K^*(892)\overline{K}$ at a lower mass than the state decaying into $a_0(980)\pi$, although agreement with MARK-III is not excluded. In $J/\psi(1S)$ radiative decay, the $\eta(1405)$ decays into $K\overline{K}\pi$ through $a_0(980)\pi$ and hence a signal is also expected in the $\eta\pi\pi$ mass spectrum. This was indeed observed by MARK III in $\eta\pi^+\pi^-$ (BOLTON 92B) which report a mass of 1400 MeV, in line with the existence of the $\eta(1405)$ 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 into $\eta\pi\pi$ (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).

The existence of the $\eta(1295)$ is questioned by KLEMPT 05. However, this state has been observed by four $\pi^- p$ experiments (ADAMS 01, FUKUI 91C, ALDE 97B, MANAK 00A) and evidence is also reported in $\overline{p}p$ annihilation (ABELE 98, ANISOVICH 01, AMSLER 04B). In J/ψ radiative decay an $\eta(1295)$ signal is seen in the 0^{-+} $\eta\pi\pi$ wave of DM2 data (AUGUSTIN 92).

Assuming that the $\eta(1295)$ is established, the $\eta(1475)$ 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 the $\eta(1475)$. Also its width matches the expected width for the radially excited $s\overline{s}$ state (CLOSE 97, BARNES 97).

The $K\overline{K}\pi$ and $\eta\pi\pi$ channels were studied in $\gamma\gamma$ collisions (ACCIARRI 01G). The analysis leads to an $\eta(1475)$ signal in $K\overline{K}\pi$, but the $\eta(1405)$ is not observed in $K\overline{K}\pi$ nor in $\eta\pi\pi$. This result is somewhat in disagreement with CLEO-II which did not observe any pseudoscalar signal in $\gamma\gamma \to \eta(1475) \to K^0_S K^\pm \pi^\mp$ (AHOHE 05), but more data are required. Since gluonium production is presumably suppressed in $\gamma\gamma$ collisions, the ACCIARRI 01G results suggest that the $\eta(1405)$ has a large gluonic content (see also CLOSE 97B, LI 03C). The observation of the $\eta(1475)$ combined with the absence of an $\eta(1405)$ signal strengthens the two-resonances hypothesis.

The gluonium interpretation is not favored by lattice gauge theories which predict the 0^{-+} state above 2 GeV (BALI 93). However, the $\eta(1405)$ is an excellent candidate for the 0^{-+} glueball in the flux tube model (FADDEEV 04). In this model

the 0^{++} $f_0(1500)$ glueball is also naturally related to a 0^{-+} glueball with mass degeneracy broken in QCD.

Let us now deal with 1^{++} isoscalars. The $f_1(1420)$, decaying to $K^*\overline{K}$, was first reported in $\pi^- p$ reactions at 4 GeV/c (DIONISI 80). However, later analyses found that the 1400 –1500 MeV region was far more complex (CHUNG 85, REEVES 86, BIRMAN 88). A reanalysis of the MARK III data in radiative $J/\psi(1S)$ decay to $K\overline{K}\pi$ (BAI 90C) shows the $f_1(1420)$ decaying into $K^*\overline{K}$. Also, a C=+1 state is observed in tagged $\gamma\gamma$ collisions (*e.g.*, BEHREND 89).

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

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 report $f_1(1420)$ decaying to $K^*\overline{K}$.

The $f_1(1420)$, decaying into $K\overline{K}\pi$, is also seen in pp central production together with the $f_1(1285)$. The latter decays via $a_0(980)\pi$ and the former only via $K^*\overline{K}$, while the $\eta(1440)$ is absent (ARMSTRONG 89, BARBERIS 97C). The $K_S K_S \pi^0$ decay mode of the $f_1(1420)$ 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 $f_1(1420)$ must be suppressed (ARMSTRONG 91B).

We now turn to the experimental evidence for the $f_1(1510)$. Two states, the $f_1(1420)$ and the $f_1(1510)$, 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 $\pi^- p$ 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 this state being the $s\overline{s}$ member of the 1^{++} nonet. However, the $f_1(1420)$ was reported in $K^- p$ but not in $\pi^- p$ (BITYUKOV 84) while two experiments do not observe the $f_1(1510)$ 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), nor 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 lead to the conclusion that the $f_1(1510)$ needs experimental confirmation (CLOSE 97D).

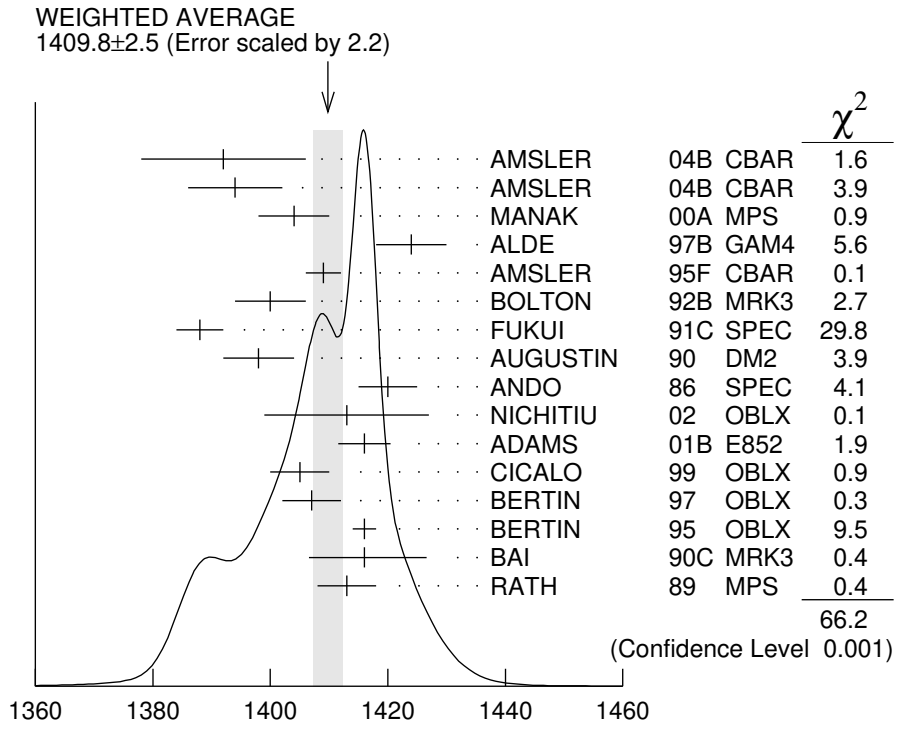
Assigning the $f_1(1420)$ to the 1^{++} nonet one finds a nonet mixing angle of $\sim 50^\circ$ (CLOSE 97D). However, arguments favoring the $f_1(1420)$ being a hybrid $q\overline{q}g$ meson or a four-quark state were put forward by ISHIDA 89 and by CALDWELL 90, respectively, while LONGACRE 90 argued for a molecular state formed by the π orbiting in a P-wave around an S-wave $K\overline{K}$ state.

Summarizing, there is convincing evidence for the $f_1(1420)$ decaying to $K^*\overline{K}$, and for two pseudoscalars in the $\eta(1440)$ region, the $\eta(1405)$ and $\eta(1475)$, decaying to $a_0(980)\pi$ and $K^*\overline{K}$, respectively. The $f_1(1510)$ is not well established.

$\eta(1405)$ MASS

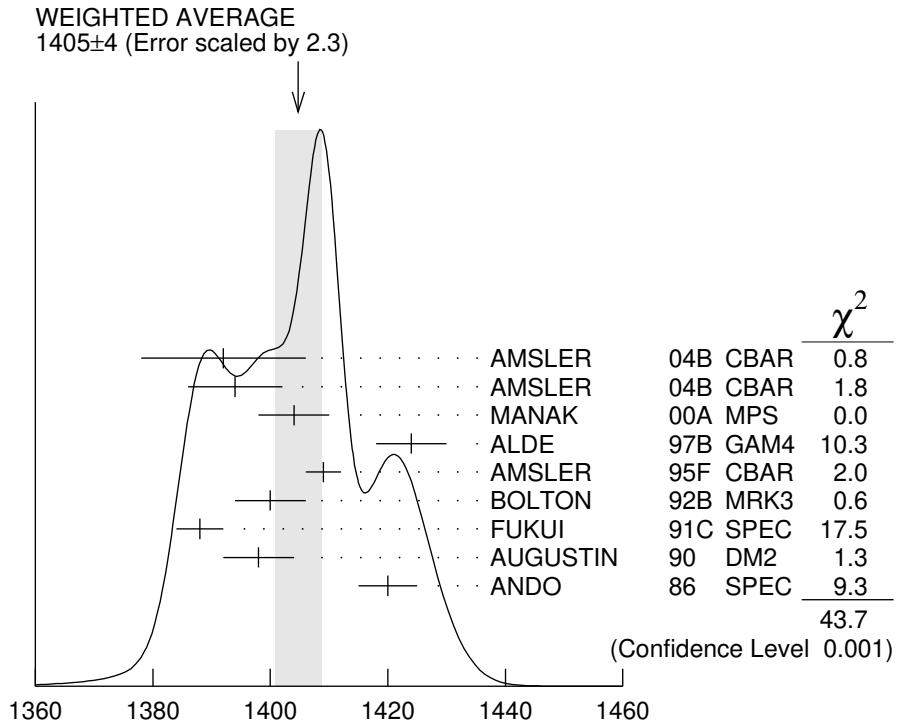
VALUE (MeV)	*DOCUMENT ID*

1409.8±2.5 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 2.2. See the ideogram below.



$\eta\pi\pi$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
The data in this block is included in the average printed for a previous datablock.					
1405± 4 OUR AVERAGE Error includes scale factor of 2.3. See the ideogram below.					
1392±14	900 ± 375	AMSLER	04B	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^+\pi^-\eta$
1394± 8	6.6 ± 2.0k	AMSLER	04B	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0\pi^0\eta$
1404± 6	9082	MANAK	00A	MPS	18 $\pi^- p \rightarrow \eta\pi^+\pi^- n$
1424± 6	2200	ALDE	97B	GAM4	100 $\pi^- p \rightarrow \eta\pi^0\pi^0 n$
1409± 3		AMSLER	95F	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0\pi^0\eta$
1400± 6		[1] BOLTON	92B	MRK3	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$
1388± 4		FUKUI	91C	SPEC	8.95 $\pi^- p \rightarrow \eta\pi^+\pi^- n$
1398± 6	261	[2] AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$
1420± 5		ANDO	86	SPEC	8 $\pi^- p \rightarrow \eta\pi^+\pi^- n$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1385± 7		BAI	99	BES	$J/\psi \rightarrow \gamma\pi^+\pi^-$



$\eta(1405)$ mass, $\eta\pi\pi$ mode (MeV)

$K\overline{K}\pi$ MODE ($a_0(980)\pi$ or direct $K\overline{K}\pi$)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
The data in this block is included in the average printed for a previous datablock.					
1413.9± 1.7 OUR AVERAGE Error includes scale factor of 1.1.					
1413 ±14	3651	[3] NICHITIU	02	OBLX	
1416 ± 4 ±2	20k	ADAMS	01B	E852	18 GeV $\pi^- p \to K^+ K^- \pi^0 n$
1405 ± 5		[4] CICALO	99	OBLX	0 $\overline{p}p \to K^\pm K^0_S \pi^\mp \pi^+ \pi^-$
1407 ± 5		[4] BERTIN	97	OBLX	0 $\overline{p}p \to K^\pm (K^0) \pi^\mp \pi^+ \pi^-$
1416 ± 2		[4] BERTIN	95	OBLX	0 $\overline{p}p \to K\overline{K}\pi\pi\pi$
1416 ± 8 $^{+7}_{-5}$	700	[5] BAI	90C	MRK3	$J/\psi \to \gamma K^0_S K^\pm \pi^\mp$
1413 ± 5		[5] 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. • • •					
1459 ± 5		[6] AUGUSTIN	92	DM2	$J/\psi \to \gamma K\overline{K}\pi$

$\pi\pi\gamma$ MODE

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1390±12	235 ± 91	AMSLER	04B	CBAR	0 $\overline{p}p \to \pi^+\pi^-\pi^+\pi^-\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1424±10±11	547	BAI	04J	BES2	$J/\psi \to \gamma\gamma\pi^+\pi^-$
1401±18		[7,8] AUGUSTIN	90	DM2	$J/\psi \to \pi^+\pi^-\gamma\gamma$
1432± 8		[8] COFFMAN	90	MRK3	$J/\psi \to \pi^+\pi^- 2\gamma$

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	$J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$
1489 ± 12	3270	[9] BISELLO	89B	DM2	$J/\psi \to 4\pi\gamma$

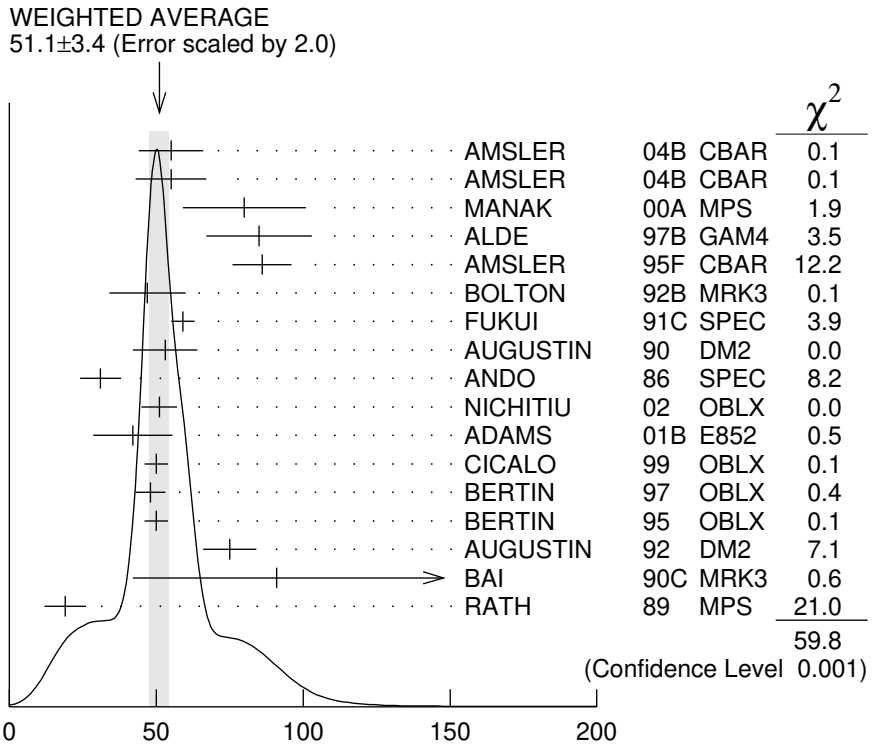
$K\overline{K}\pi$ MODE (unresolved)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1442 ± 10	410	[10] BAI	98C	BES	$J/\psi \to \gamma K^+ K^- \pi^0$
1445 ± 8	693	[10] AUGUSTIN	90	DM2	$J/\psi \to \gamma K^0_S K^\pm \pi^\mp$
1433 ± 8	296	[10] AUGUSTIN	90	DM2	$J/\psi \to \gamma K^+ K^- \pi^0$
1413 ± 8	500	[10] DUCH	89	ASTE	$\overline{p}p \to \pi^+ \pi^- K^\pm \pi^\mp K^0$
1453 ± 7	170	[10] RATH	89	MPS	$21.4\ \pi^- p \to K^0_S K^0_S \pi^0 n$
1419 ± 1	8800	[10] BIRMAN	88	MPS	$8\ \pi^- p \to K^+ \overline{K}^0 \pi^- n$
1424 ± 3	620	[10] REEVES	86	SPEC	$6.6\ p\overline{p} \to K\overline{K}\pi X$
1421 ± 2		[10] CHUNG	85	SPEC	$8\ \pi^- p \to K\overline{K}\pi n$
1440^{+20}_{-15}	174	[10] EDWARDS	82E	CBAL	$J/\psi \to \gamma K^+ K^- \pi^0$
1440^{+10}_{-15}		[10] SCHARRE	80	MRK2	$J/\psi \to \gamma K^0_S K^\pm \pi^\mp$
1425 ± 7	800	[10,11] BAILLON	67	HBC	$0\ \overline{p}p \to K\overline{K}\pi\pi\pi$

[1] From fit to the $a_0(980)\pi$ 0^{-+} partial wave.
[2] Best fit with a single Breit Wigner.
[3] Decaying dominantly directly to $K^+ K^- \pi^0$.
[4] Decaying into $(K\overline{K})_S\pi$, $(K\pi)_S\overline{K}$, and $a_0(980)\pi$.
[5] From fit to the $a_0(980)\pi$ 0^{-+} partial wave. Cannot rule out a $a_0(980)\pi$ 1^{++} partial wave.
[6] Excluded from averaging because averaging would be meaningless.
[7] Best fit with a single Breit Wigner.
[8] This peak in the $\gamma\rho$ channel may not be related to the $\eta(1405)$.
[9] Estimated by us from various fits.
[10] These experiments identify only one pseudoscalar in the 1400–1500 range. Data could also refer to $\eta(1475)$.
[11] From best fit of 0^{-+} partial wave , 50% $K^*(892)K$, 50% $a_0(980)\pi$.

$\eta(1405)$ WIDTH

VALUE (MeV)	DOCUMENT ID
51.1 ± 3.4 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 2.0. See the ideogram below.	



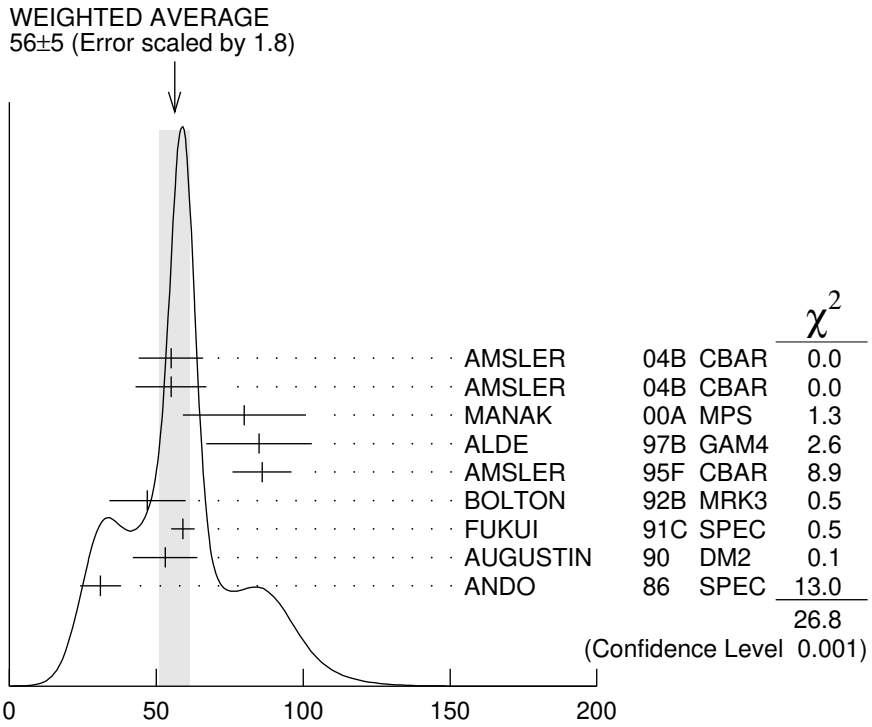
$\eta\pi\pi$ MODE

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*

The data in this block is included in the average printed for a previous datablock.

56± 5 OUR AVERAGE Error includes scale factor of 1.8. See the ideogram below.

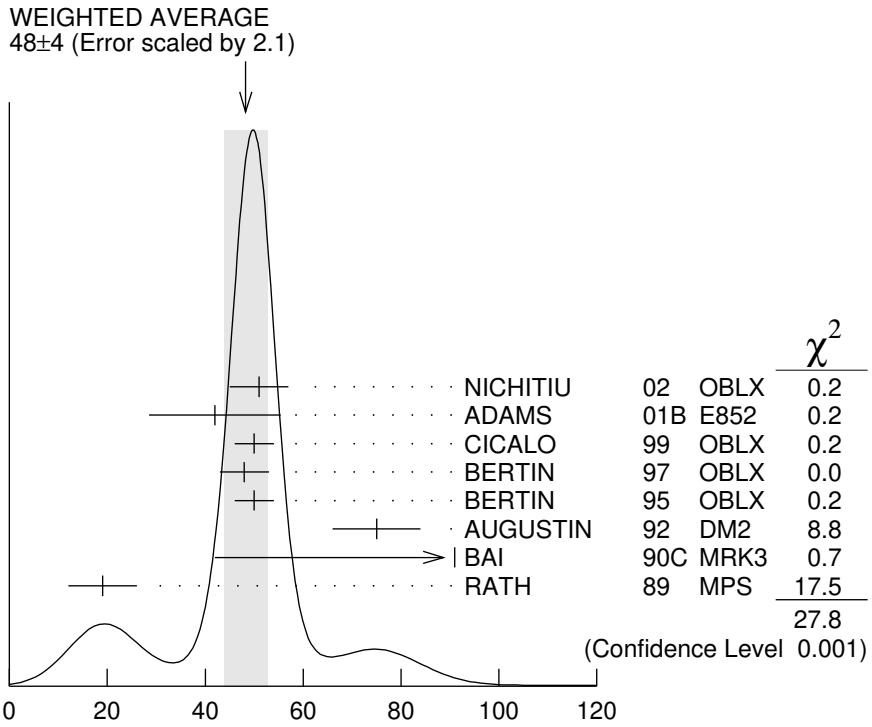
55±11	900 ± 375	AMSLER	04B	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^+\pi^-\eta$
55±12	6.6 ± 2.0k	AMSLER	04B	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0\pi^0\gamma$
80±21	9082	MANAK	00A	MPS	18 $\pi^- p \rightarrow \eta\pi^+\pi^- n$
85±18	2200	ALDE	97B	GAM4	100 $\pi^- p \rightarrow \eta\pi^0\pi^0 n$
86±10		AMSLER	95F	CBAR	0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0\pi^0\eta$
47±13		[12] 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		[13] AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma\eta\pi^+\pi^-$
31± 7		ANDO	86	SPEC	8 $\pi^- p \rightarrow \eta\pi^+\pi^- n$



$\eta(1405)$ width $\eta\pi\pi$ mode (MeV)

$K\overline{K}\pi$ MODE ($a_0(980)\pi$ or direct $K\overline{K}\pi$)

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
The data in this block is included in the average printed for a previous datablock.					
48± 4 OUR AVERAGE	Error includes scale factor of 2.1. See the ideogram below.				
51± 6	3651	[14] NICHITIU	02	OBLX	
42±10± 9	20k	ADAMS	01B	E852	18 GeV $\pi^- p \to K^+ K^- \pi^0 n$
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+15}_{-31-38}		[16] BAI	90C	MRK3	$J/\psi \to \gamma K^0_S K^\pm \pi^\mp$
19± 7		[16] RATH	89	MPS	21.4 $\pi^- p \to n K^0_S K^0_S \pi^0$



$\eta(1405)$ width $K\overline{K}\pi$ mode ($a_0(980)$ π dominant)

$\pi\pi\gamma$ MODE

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
64 ±18	235 ± 91	AMSLER	04B	CBAR	$0\ \overline{p}p \rightarrow\ \pi^+\pi^-\pi^+\pi^-\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
101.0± 8.8±8.8	547	BAI	04J	BES2	$J/\psi \rightarrow\ \gamma\gamma\pi^+\pi^-$
174 ±44		AUGUSTIN	90	DM2	$J/\psi \rightarrow\ \pi^+\pi^-\gamma\gamma$
90 ±26		[17] COFFMAN	90	MRK3	$J/\psi \rightarrow\ \pi^+\pi^-2\gamma$

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	$J/\psi \rightarrow\ \gamma\pi^+\pi^-\pi^+\pi^-$
144±13	3270	[18] BISELLO	89B	DM2	$J/\psi \rightarrow\ 4\pi\gamma$

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

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
93±14	296	[19] AUGUSTIN	90	DM2	$J/\psi \rightarrow\ \gamma K^+K^-\pi^0$
105±10	693	[19] AUGUSTIN	90	DM2	$J/\psi \rightarrow\ \gamma K^0_S K^\pm\pi^\mp$
62±16	500	[19] DUCH	89	ASTE	$\overline{p}p \rightarrow\ K\overline{K}\pi\pi\pi$
100±11	170	[19] RATH	89	MPS	21.4 $\pi^- p \rightarrow$ $K^0_S K^0_S \pi^0 n$
66± 2	8800	[19] BIRMAN	88	MPS	8 $\pi^- p \rightarrow\ K^+\overline{K}^0\pi^- n$

60 ± 10	620	[19] REEVES	86	SPEC	6.6 $p\overline{p} \rightarrow K K \pi X$
60 ± 10		[19] CHUNG	85	SPEC	8 $\pi^- p \rightarrow K \overline{K} \pi n$
55^{+20}_{-30}	174	[19] EDWARDS	82E	CBAL	$J/\psi \rightarrow \gamma K^+ K^- \pi^0$
50^{+30}_{-20}		[19] SCHARRE	80	MRK2	$J/\psi \rightarrow \gamma K^0_S K^\pm \pi^\mp$
80 ± 10	800	[19,20] BAILLON	67	HBC	0.0 $\overline{p} p \rightarrow K \overline{K} \pi \pi \pi$

[12] From fit to the $a_0(980)\pi$ 0^{-+} partial wave.
[13] From $\eta\pi^+\pi^-$ mass distribution - mainly $a_0(980)\pi$ - no spin–parity determination available.
[14] Decaying dominantly directly to $K^+ K^- \pi^0$.
[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.
[17] This peak in the $\gamma\rho$ channel may not be related to the $\eta(1405)$.
[18] Estimated by us from various fits.
[19] These experiments identify only one pseudoscalar in the 1400–1500 range. Data could also refer to $\eta(1475)$.
[20] From best fit to 0^{-+} partial wave , 50% $K^*(892)K$, 50% $a_0(980)\pi$.

$\eta(1405)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$K\overline{K}\pi$	seen	
Γ_2	$\eta\pi\pi$	seen	
Γ_3	$a_0(980)\pi$	seen	
Γ_4	$\eta(\pi\pi)_S$-wave	seen	
Γ_5	$f_0(980)\eta$	seen	
Γ_6	4π	seen	
Γ_7	$\rho\rho$	<58 %	99.85%
Γ_8	$\gamma\gamma$		
Γ_9	$\rho^0\gamma$		
Γ_{10}	$\phi\gamma$		
Γ_{11}	$K^*(892)K$	seen	

$\eta(1405)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

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

VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.035	90	[21,22] AHOHE	05	CLE2	10.6 $e^+e^- \rightarrow e^+e^- K^0_S K^\pm \pi^\mp$

$\Gamma(\eta\pi\pi) \times \Gamma(\gamma\gamma)/\Gamma_{total}$ $\Gamma_2\Gamma_8/\Gamma$

VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
<0.095	95	ACCIARRI	01G	L3	183–202 $e^+e^- \rightarrow e^+e^-\eta\pi^+\pi^-$

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

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	$e^+e^- \to e^+e^-\pi^+\pi^-\gamma$

[21] Using $\eta(1405)$ mass and width 1410 MeV and 51 MeV, respectively.
[22] Assuming three-body phase-space decay to $K^0_S K^\pm \pi^\mp$.

$\eta(1405)$ BRANCHING RATIOS

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.09±0.48		[23] AMSLER	04B	CBAR	$0\,\overline{p}p \to \pi^+\pi^-\pi^+\pi^-\eta$
<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	$0.0\,\overline{p}p$

$\Gamma(\rho^0\gamma)/\Gamma(\eta\pi\pi)$ Γ_9/Γ_2

VALUE	DOCUMENT ID		TECN	COMMENT
0.111±0.064	AMSLER	04B	CBAR	$0\,\overline{p}p$

$\Gamma(a_0(980)\pi)/\Gamma(K\overline{K}\pi)$ Γ_3/Γ_1

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 0.15		[24] BERTIN	95	OBLX	$0\,\overline{p}p \to K\overline{K}\pi\pi\pi$
~ 0.8	500	[24] DUCH	89	ASTE	$\overline{p}p \to \pi^+\pi^- K^\pm\pi^\mp K^0$
~ 0.75		[24] REEVES	86	SPEC	$6.6\,p\overline{p} \to KK\pi X$

$\Gamma(a_0(980)\pi)/\Gamma(\eta\pi\pi)$ Γ_3/Γ_2

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	$0\,p\overline{p} \to \eta\pi^0\pi^0\pi^0$
0.19±0.04	2200	[25] ALDE	97B	GAM4	$100\,\pi^- p \to \eta\pi^0\pi^0 n$
0.56±0.04±0.03		[25] AMSLER	95F	CBAR	$0\,\overline{p}p \to \pi^+\pi^-\pi^0\pi^0\eta$

$\Gamma(a_0(980)\pi)/\Gamma(\eta(\pi\pi)_{S\text{-wave}})$ Γ_3/Γ_4

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.91±0.12		ANISOVICH	01	SPEC	$0.0\,\overline{p}p \to \eta\pi^+\pi^-\pi^+\pi^-$
0.15±0.04	9082	MANAK	00A	MPS	$18\,\pi^- p \to \eta\pi^+\pi^- n$
0.70±0.12±0.20		[26] BAI	99	BES	$J/\psi \to \gamma\eta\pi^+\pi^-$

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.0152±0.0038	[27] COFFMAN	90	MRK3	$J/\psi \to \gamma\gamma\pi^+\pi^-$

$\Gamma(\eta(\pi\pi)_{S\text{-wave}})/\Gamma(\eta\pi\pi)$ Γ_4/Γ_2

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 $\pi^- p \to \eta\pi^0\pi^0 n$

$\Gamma(a_0(980)\pi)/\Gamma(\eta(\pi\pi)_{S\text{-wave}})$ Γ_3/Γ_4

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.32 ± 0.07	[28] ANISOVICH	99I	SPEC	0.9–1.2 $\overline{p}p \to \eta 3\pi^0$

$\Gamma(\rho\rho)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.58	99.85 [23,29]	AMSLER	04B	CBAR	0 $\overline{p}p$

$\Gamma(K^*(892)K)/\Gamma(a_0(980)\pi)$ Γ_{11}/Γ_3

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.084 ± 0.024	[30] ADAMS	01B	E852	18 GeV $\pi^- p \to K^+ K^- \pi^0 n$

$\Gamma(\phi\gamma)/\Gamma(\rho^0\gamma)$ Γ_{10}/Γ_9

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.77	95	[31] BAI	04J	BES2	$J/\psi \to \gamma\gamma K^+ K^-$

[23] Using the data of BAILLON 67 on $\overline{p}p \to K\overline{K}\pi$.
[24] Assuming that the $a_0(980)$ decays only into $K\overline{K}$.
[25] Assuming that the $a_0(980)$ decays only into $\eta\pi$.
[26] Assuming that the $a_0(980)$ decays only into $\eta\pi$.
[27] Using $B(J/\psi \to \gamma\eta(1405) \to \gamma K\overline{K}\pi) = 4.2 \times 10^{-3}$ and $B(J/\psi \to \gamma\eta(1405) \to \gamma\gamma\rho^0) = 6.4 \times 10^{-5}$ and assuming that the $\gamma\rho^0$ signal does not come from the $f_1(1420)$.
[28] Using preliminary Crystal Barrel data.
[29] Assuming that the $\eta(1405)$ decays are saturated by the $\pi\pi\eta$, $K\overline{K}\pi$ and $\rho\rho$ modes.
[30] Statistical error only.
[31] Calculated by us from $B(J/\psi \to \eta(1405)\gamma \to \phi\gamma\gamma) < 0.82 \times 10^{-4}$ and $B(J/\psi \to \eta(1405)\gamma \to \rho^0\gamma\gamma) = (1.07 \pm 0.17 \pm 0.11) \times 10^{-4}$.

$\eta(1405)$ REFERENCES

AHOHE	05	PR D71 072001	R. Ahohe *et al.*	(CLEO Collab.)
AMSLER	04B	EPJ C33 23	C. Amsler *et al.*	(Crystal Barrel Collab.)
BAI	04J	PL B594 47	J.Z. Bai *et al.*	(BES Collab.)
NICHITIU	02	PL B545 261	F. Nichitiu *et al.*	(OBELIX Collab.)
ACCIARRI	01G	PL B501 1	M. Acciarri *et al.*	(L3 Collab.)
ADAMS	01B	PL B516 264	G.S. Adams *et al.*	(BNL E852 Collab.)
ANISOVICH	01	NP A690 567	A.V. Anisovich *et al.*	
MANAK	00A	PR D62 012003	J.J. Manak *et al.*	(BNL E852 Collab.)
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.)
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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.)
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.)
BISELLO	89B	PR D39 701	G. Busetto *et al.*	(DM2 Collab.)
DUCH	89	ZPHY C45 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
ANDO	86	PRL 57 1296	A. Ando *et al.*	(KEK, KYOT, NIRS, SAGA+) IJP
REEVES	86	PR D34 1960	D.F. Reeves *et al.*	(FLOR, BNL, IND+) JP
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+)
EDWARDS	82E	PRL 49 259	C. Edwards *et al.*	(CIT, HARV, PRIN+)
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KING	91	NPBPS B21 11	E. King *et al.*	(FSU, BNL+)
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