$f_1(1420)$

$I^G(J^{PC}) = 0^+(1^{++})$

See also minireview under non-$q\overline{q}$ candidates.

THE $f_1(1420)$

This particle is the axial-vector component of the old puzzling E/ι, which has caused much trouble.

In hadron-induced reactions, the $f_1(1420)$ is observed in centrally produced $K\overline{K}\pi$ systems obtained with π and p beams (DIONISI 80, ARMSTRONG 84, 89). A Dalitz-plot analysis gives its quantum numbers and the dominant decay mode. For instance, ARMSTRONG 89 finds that the signal is totally consistent with being an 1^{++} state with a dominant quasi-two-body S-wave decay into $K^*(892)\overline{K}$; furthermore, no 0^{-+} or 1^{+-} waves are required to fit the data. A G parity of $+1$ is suggested by the positive interference between the two overlapping $K^*(892)$ (ARMSTRONG 84). No significant signals in the $\eta\pi\pi$ or 4π decay modes are found in centrally produced 4π systems (ARMSTRONG 89G). All of this is in line with the previous observations made in $\overline{p}p$ annihilations.

In $\gamma\gamma$ fusion from e^+e^- annihilations, a signal at about 1420 MeV is seen only in single-tag events (AIHARA 86C, GIDAL 87B, BEHREND 89, HILL 89), where one of the two photons is off the mass shell; by contrast, it is totally absent in the untagged events where both photons are real and hence they cannot produce a spin-1 meson, because of the Yang-Landau theorem. This clearly implies $J = 1$ and $C = +1$. As for the parity, AIHARA 88B, 88C (same analysis as AIHARA 86C, with 25% more events) and BEHREND 89 all find angular distributions with positive parity preferred, but negative parity not excluded.

Although some uncertainties still remain, the state seen in hadronic interactions and that seen in spacelike virtual photon fusion from e^+e^- annihilations are often identified with one another since there are more similarities than differences. In particular, all experiments agree that this state appears only in $K^*(892)\overline{K}$. The same conclusions are obtained from partial wave analyses of $J/\psi(1S) \to \gamma K\overline{K}\pi$ (BAI 90C, AUGUSTIN 91).

BITYUKOV 88 studied the radiative decay $1^{++} \to \phi\gamma$. Since the ϕ is (almost) a pure $s\overline{s}$ state, the $\phi\gamma$ decay seems to be a good analyser to extract the $s\overline{s}$ component in the wave function of the decaying meson. Finding the $f_1(1285)$

but not the $f_1(1420)$, BITYUKOV 88 concludes that the $f_1(1420)$ cannot be the $s\overline{s}$ isoscalar member of the $q\overline{q}$ nonet containing the $f_1(1285)$. On the other hand, AIHARA 88C argues that, assuming they both belong to the same nonet and using several hypotheses, the octet-singlet mixing angle obtained is compatible with the $f_1(1420)$ being mostly $s\overline{s}$ and the $f_1(1285)$ being mostly $(u\overline{u}+d\overline{d})/\sqrt{2}$, although both require large admixtures of other $q\overline{q}$ components.

Arguments favoring the possibility the $f_1(1420)$ is a hybrid $q\overline{q}g$ meson or a four-quark state are put forward by ISHIDA 89 and by CALDWELL 90, respectively.

LONGACRE 90 argues that this particle is inconsistent with a QCD arrangement of quarks and gluons. He then develops a final-state rescattering mechanism with successive interactions between a K, a $\overline{K}$, and a π. The $f_1(1420)$ would then be a molecular state formed by the π orbiting in a P wave around an S-wave $K\overline{K}$ state.

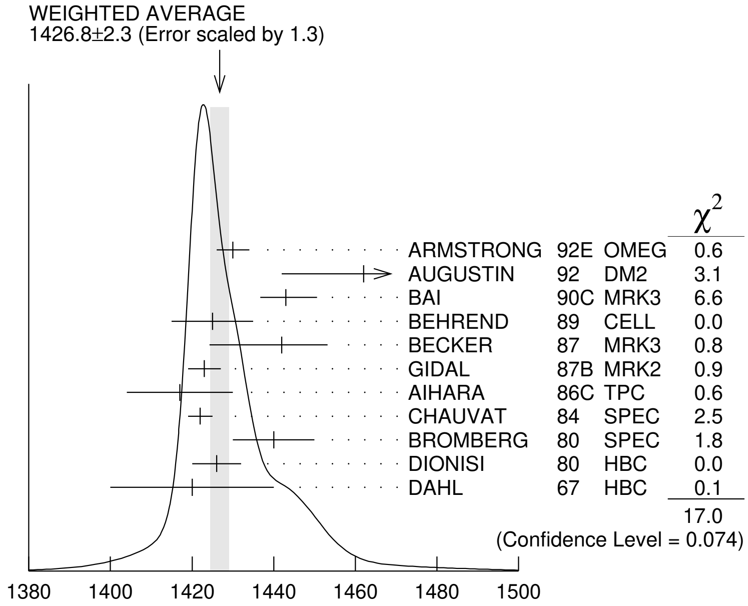
$f_1(1420)$ MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1426.8± 2.3 OUR AVERAGE		Error includes scale factor of 1.3. See the ideogram below.		
1430 $\pm$ 4		[1] ARMSTRONG 92E	OMEG	85,300 $\pi^+ p$, $pp \rightarrow \pi^+ p$, $pp(K\overline{K}\pi)$
1462 $\pm$20		[2] AUGUSTIN 92	DM2	$J/\psi \rightarrow \gamma K\overline{K}\pi$
1443 $^{+7}_{-6}$ $^{+3}_{-2}$	1100	BAI 90C	MRK3	$J/\psi \rightarrow \gamma K^0_S K^\pm \pi^\mp$
1425 $\pm$10	17	BEHREND 89	CELL	$\gamma\gamma \rightarrow K^0_S K^\pm \pi^\mp$
1442 $\pm$ 5 $^{+10}_{-17}$	111	BECKER 87	MRK3	$e^+ e^-$, $\omega K\overline{K}\pi$
1423 $\pm$ 4		GIDAL 87B	MRK2	$e^+ e^- \rightarrow e^+ e^- K\overline{K}\pi$
1417 $\pm$13	13	AIHARA 86C	TPC	$e^+ e^- \rightarrow e^+ e^- K\overline{K}\pi$
1422 $\pm$ 3		CHAUVAT 84	SPEC	ISR 31.5 pp
1440 $\pm$10		[3] BROMBERG 80	SPEC	100 $\pi^- p \rightarrow K\overline{K}\pi X$
1426 $\pm$ 6	221	DIONISI 80	HBC	4 $\pi^- p \rightarrow K\overline{K}\pi n$
1420 $\pm$20		DAHL 67	HBC	1.6–4.2 $\pi^- p$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1429 $\pm$ 3	389	ARMSTRONG 89	OMEG	300 $pp \rightarrow K\overline{K}\pi pp$
1425 $\pm$ 2	1520	ARMSTRONG 84	OMEG	85 $\pi^+ p$, $pp \rightarrow (\pi^+, p)(K\overline{K}\pi)p$

[1] This result supersedes ARMSTRONG 84, ARMSTRONG 89.

[2] From fit to the $K^*(892)K$ 1^{++} partial wave.

[3] Mass error increased to account for $a_0(980)$ mass cut uncertainties.



$f_1(1420)$ mass (MeV)

$f_1(1420)$ WIDTH

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
53± 5 OUR AVERAGE					
58±10		[4] ARMSTRONG	92E	OMEG	85,300 $\pi^+ p$, $pp \rightarrow \pi^+ p$, $pp(K\overline{K}\pi)$
129±41		[5] AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K\overline{K}\pi$
$68^{+29}_{-18}{}^{+8}_{-9}$	1100	BAI	90C	MRK3	$J/\psi \rightarrow \gamma K^0_S K^\pm \pi^\mp$
42±22	17	BEHREND	89	CELL	$\gamma\gamma \rightarrow K^0_S K^\pm \pi^\mp$
$40^{+17}_{-13}\pm5$	111	BECKER	87	MRK3	$e^+ e^- \rightarrow \omega K\overline{K}\pi$
35^{+47}_{-20}	13	AIHARA	86C	TPC	$e^+ e^- \rightarrow e^+ e^- K\overline{K}\pi$
47±10		CHAUVAT	84	SPEC	ISR 31.5 pp
62±14		BROMBERG	80	SPEC	100 $\pi^- p \rightarrow K\overline{K}\pi X$
40±15	221	DIONISI	80	HBC	4 $\pi^- p \rightarrow K\overline{K}\pi n$
60±20		DAHL	67	HBC	1.6–4.2 $\pi^- p$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
58± 8	389	ARMSTRONG	89	OMEG	300 $pp \rightarrow K\overline{K}\pi pp$
62± 5	1520	ARMSTRONG	84	OMEG	85 $\pi^+ p$, $pp \rightarrow (\pi^+, p)(K\overline{K}\pi)p$

[4] This result supersedes ARMSTRONG 84, ARMSTRONG 89.
[5] From fit to the $K^*(892)K$ 1^{++} partial wave.

$f_1(1420)$ DECAY MODES

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

$f_1(1420)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(K\overline{K}\pi) \times \Gamma(\gamma\gamma^*)/\Gamma_{\text{total}}$ — $\Gamma_1\Gamma_7/\Gamma$

VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
1.7±0.4 OUR AVERAGE					
3.0±0.9±0.7		[6,7] BEHREND	89	CELL	$e^+e^- \to e^+e^- K^0_S K\pi$
$2.3^{+1.0}_{-0.9}$±0.8		HILL	89	JADE	$e^+e^- \to e^+e^- K^\pm K^0_S \pi^\mp$
1.3±0.5±0.3		AIHARA	88B	TPC	$e^+e^- \to e^+e^- K^\pm K^0_S \pi^\mp$
1.6±0.7±0.3		[6,8] GIDAL	87B	MRK2	$e^+e^- \to e^+e^- K\overline{K}\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<8.0	95	JENNI	83	MRK2	$e^+e^- \to e^+e^- K\overline{K}\pi$

[6] Assume a ρ-pole form factor.
[7] A ϕ - pole form factor gives considerably smaller widths.
[8] Published value divided by 2.

$f_1(1420)$ BRANCHING RATIOS

$\Gamma(K\overline{K}^*(892)+\text{c.c.})/\Gamma(K\overline{K}\pi)$ — Γ_5/Γ_1

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.76±0.06	BROMBERG	80	SPEC	$100\ \pi^- p \to K\overline{K}\pi X$
0.86±0.12	DIONISI	80	HBC	$4\ \pi^- p \to K\overline{K}\pi n$

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.3	95	CORDEN	78	OMEG	12–15 $\pi^- p$
<2.0		DAHL	67	HBC	1.6–4.2 $\pi^- p$

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

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.1	95	ARMSTRONG	91B	OMEG	$300\ pp \to pp\eta\pi^+\pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.35±0.75		KOPKE	89	MRK3	$J/\psi \to \omega\eta\pi\pi(K\overline{K}\pi)$
<0.6	90	GIDAL	87	MRK2	$e^+e^- \to e^+e^-\eta\pi^+\pi^-$
<0.5	95	CORDEN	78	OMEG	12–15 $\pi^- p$
1.5 ±0.8		DEFOIX	72	HBC	0.7 $\overline{p}p$

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

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen in either mode	ANDO	86	SPEC	8 $\pi^- p$
not seen in either mode	CORDEN	78	OMEG	12–15 $\pi^- p$
0.4±0.2	DEFOIX	72	HBC	0.7 $\overline{p}p \to 7\pi$

$\Gamma(4\pi)/\Gamma(K\overline{K}^*(892)+\text{c.c.})$ — Γ_6/Γ_5

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.90	95	DIONISI	80	HBC	4 $\pi^- p$

$\Gamma(K\overline{K}\pi)/\left[\Gamma(a_0(980)\pi)+\Gamma(K\overline{K}^*(892)+\text{c.c.})\right]$ — $\Gamma_1/(\Gamma_3+\Gamma_5)$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.65±0.27	[9] DIONISI	80	HBC	4 $\pi^- p$

[9] Calculated using $\Gamma(K\overline{K})/\Gamma(\eta\pi) = 0.24 \pm 0.07$ for $a_0(980)$ fractions.

$\Gamma(a_0(980)\pi)/\Gamma(K\overline{K}^*(892)+\text{c.c.})$ — Γ_3/Γ_5

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.04	68	ARMSTRONG	84	OMEG	85 $\pi^+ p$

$\Gamma(4\pi)/\Gamma(K\overline{K}\pi)$ — Γ_6/Γ_1

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.62	95	ARMSTRONG 89G	OMEG	85 $\pi p \rightarrow 4\pi X$

$\Gamma(\rho^0\gamma)/\Gamma_{\text{total}}$ — Γ_8/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.08	95	[10] ARMSTRONG 92C	SPEC	300 $pp \rightarrow pp\pi^+\pi^-\gamma$

[10] Using the data on the $\overline{K}K\pi$ mode from ARMSTRONG 89.

$f_1(1420)$ REFERENCES

ARMSTRONG	92C	ZPHY C54 371	+Barnes, Benayoun+	(ATHU, BARI, BIRM, CERN, CDEF)
ARMSTRONG	92E	ZPHY 56 29	+Benayoun+	(ATHU, BARI, BIRM, CERN, CDEF)JPC
AUGUSTIN	92	PR D46 1951	+Cosme	(DM2 Collab.)
ARMSTRONG	91B	ZPHY C52 389	+Barnes+	(ATHU, BARI, BIRM, CERN, CDEF)
BAI	90C	PRL 65 2507	+Blaylock+	(Mark III Collab.)
ARMSTRONG	89	PL B221 216	+Benayoun+	(CERN, CDEF, BIRM, BARI, ATHU, CURIN+)JPC
ARMSTRONG	89G	ZPHY C43 55	+Bloodworth+	(CERN, BIRM, BARI, ATHU, CURIN+)
BEHREND	89	ZPHY C42 367	+Criegee+	(CELLO Collab.)
HILL	89	ZPHY C42 355	+Olsson+	(JADE Collab.)JP
KOPKE	89	PRPL 174 67	+Wermes+	(CERN)
AIHARA	88B	PL B209 107	+Alston-Garnjost+	(TPC-2γ Collab.)
BECKER	87	PRL 59 186	+Blaylock, Bolton, Brown+	(Mark III Collab.)JP
GIDAL	87	PRL 59 2012	+Boyer, Butler, Cords, Abrams+	(LBL, SLAC, HARV)
GIDAL	87B	PRL 59 2016	+Boyer, Butler, Cords, Abrams+	(LBL, SLAC, HARV)
AIHARA	86C	PRL 57 2500	+Alston-Garnjost+	(TPC-2γ Collab.)JP
ANDO	86	PRL 57 1296	+Imai+	(KEK, KYOT, NIRS, SAGA, INUS, TSUK+)
ARMSTRONG	84	PL 146B 273	+Bloodworth, Burns+	(ATHU, BARI, BIRM, CERN)JP
CHAUVAT	84	PL 148B 382	+Meritet, Bonino+	(CERN, CLER, UCLA, SACL)
JENNI	83	PR D27 1031	+Burke, Telnov, Abrams, Blocker+	(SLAC, LBL)
BROMBERG	80	PR D22 1513	+Haggerty, Abrams, Dzierba	(CIT, FNAL, ILLC, IND)
DIONISI	80	NP B169 1	+Gavillet+	(CERN, MADR, CDEF, STOH)IJP
CORDEN	78	NP B144 253	+Corbett, Alexander+	(BIRM, RHEL, TELA, LOWC)
DEFOIX	72	NP B44 125	+Nascimento, Bizzarri+	(CDEF, CERN)
DAHL	67	PR 163 1377	+Hardy, Hess, Kirz, Miller	(LRL)IJP
Also	65	PRL 14 1074	Miller, Chung, Dahl, Hess, Hardy, Kirz+	(LRL, UCB)

OTHER RELATED PAPERS

IIZUKA	91	PTP 86 885	+Koibuchi	(NAGO)
CALDWELL	90	Hadron 89 Conf. p 127		(UCSB)
ISHIDA	89	PTP 82 119	+Oda, Sawazaki, Yamada	(NIHO)
AIHARA	88C	PR D38 1	+Alston-Garnjost+	(TPC-2γ Collab.)JPC
BITYUKOV	88	PL B203 327	+Borisov, Dorofeev+	(SERP)
PROTOPOP...	87B	Hadron 87 Conf.	Protopopescu, Chung	(BNL)