$f_0(1370)$
was $f_0(1300)$

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

NOTE ON SCALAR MESONS

The analysis of the scalar resonances in the $\pi\pi$ S-wave is notoriously difficult. In other partial waves, a resonance may be identified by the behavior of a single dominant channel across a mass range of a few hundred MeV. In contrast, the scalar waves couple strongly to more than one channel, and have overlapping and interfering broad resonances, often extending over more than 1 GeV. In addition, the $K\overline{K}$ and $\eta\eta$ thresholds produce sharp cusps in the partial waves. Thus, given experimental results in one channel, one can derive conclusions affecting the other scalar resonances. For this reason we discuss in this one Note all light scalars, organized in the Listings under the entries f_0(400-1200), $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $a_0(980)$, $a_0(1450)$, and $K_0^*(1430)$. This list is "minimal:" it does not necessarily exhaust the list of actual resonances.

The $I = 0$ states and the $\pi\pi$ S-wave: From the $\pi\pi$ threshold to about 1500 MeV, the claimed isoscalar resonances are found under four separate entries: f_0(400-1200), $f_0(980)$, $f_0(1370)$, and $f_0(1500)$. The data are obtained from resonance decays into the channels $\pi\pi$, $K\overline{K}$, $\eta\eta$, $\eta\eta'$, and 4π.

Below 1100 MeV, the essential contributions come from $\pi\pi$ and $K\overline{K}$ final states. The $\pi\pi$ phase shift δ_0^0 is well known to rise smoothly (GRAYER 74, ROSSELET 77) to 90° at around 900 MeV (HYAMS 73, CASON 76), then shows a rapid step of 180° near the $K\overline{K}$ threshold, due to the $f_0(980)$ resonance, which is superimposed over a large background. Above 1 GeV, the $\pi\pi$ phase shift continues to grow slowly, as expected for a very broad resonance. The $\pi\pi$ S-wave inelasticity is not accurately known, and the reported $\pi\pi \to K\overline{K}$ cross sections (WETZEL 76, POLYCHRONAKOS 79, COHEN 80, ETKIN 82B) may have large uncertainties.

In our editions from 1976 to 1994, this behavior of the phase shift was thought to be due mainly to the narrow $f_0(980)$ and the broad $f_0(1370)$, the latter variously named in earlier editions the $\epsilon(1200)$ and the f_0(1300-1400). It was, however, always uncertain whether there also exists a very broad structure mostly called σ in the literature. Before 1974, when the phase shift was known only up to about 900 MeV, one generally believed in a light σ (also called ϵ or η_{0+}) with a very large and uncertain width.

BECKER 79B excluded a narrow resonance behavior for δ_0^0 in their $\pi^- p$ (polarized) $\rightarrow \pi^+\pi^- n$ data below 900 MeV. In contrast, SVEC 92, 96, using their data on $\pi^+ n$ (polarized) $\rightarrow \pi^+\pi^- p$ from 600 to 900 MeV, suggest a narrow scalar state at 750 MeV with a width of 100 to 200 MeV; the $f_0(980)$ was not included, which can explain the very narrow width obtained. Furthermore, the associated δ_0^0 values differ substantially from recent consensus and would reopen the old Up-Down ambiguity of the early 1970's (see our 1984 edition). Thus, the interpretation of SVEC 92 and others who claim a narrow σ must be treated with reservation, although, as SVEC 96 emphasize, the contribution from a_1 exchange in the $\pi N \rightarrow \pi\pi N$ processes has not been included in most analyses. New data resolving these important ambiguities would be most welcome. For further discussions of earlier analyses on the $\pi\pi$ S-wave, see our Notes in earlier editions and AU 87, MORGAN 93, and ZOU 93.

It has now become evident that the simplest understanding of the conventional $\pi\pi$ S-wave is obtained if one includes, in addition to the $f_0(980)$ and $f_0(1370)$ resonances, a very broad σ with a mass in the region 400-1200 MeV and a width exceeding 500 MeV (AU 87, MORGAN 93, ZOU 93, 94B, ACHASOV 94, TORNQVIST 95, 96, AMSLER 95B, AMSLER 95D, JANSSEN 95). The large spread in the resonance parameters obtained by these groups is due less to differences in the data used than to differences in the models employed. Important input in all analyses for the $f_0(400\text{-}1200)$ are the standard $\pi\pi$ phase shifts below 1200 MeV, the same for all groups.

As to the $f_0(1370)$, all analyses of $\pi\pi$ and $K\overline{K}$ data claim a mainly elastic resonance around 1400 MeV. This still depends strongly on the standard $\pi\pi$ phase shift solution above 1100 MeV, and in particular on the small inelasticity of that solution, as mentioned above.

Above 1300 MeV, there is also evidence for a scalar–isoscalar resonance decaying to 4π. Whether this is the same resonance as the $f_0(1370)$ remains unsettled. There may be two resonances, one seen in elastic $\pi\pi$ scattering and coupling predominantly to $\pi\pi$, and another coupling mainly to 4π via $\rho\rho$ and two $\pi\pi$ S-waves. For now, we list both under the $f_0(1370)$. The 4π decay mode would, however, point to a large inelasticity. The information on the 4π channel comes mainly from the analysis of $\overline{p}n$ or $\overline{p}p \to 5\pi$ (GASPERO 93, ADAMO 93, AMSLER 94). AMSLER 94 finds a large production of a 0^{++} resonance decaying into 4π, mostly $\rho\rho$, with $M = 1374 \pm 38$ MeV and $\Gamma = 375 \pm 61$ MeV, and quotes a 4π:2π branching ratio of order 5:1.

Above the $f_0(1370)$ there is at least one resonance, the $f_0(1500)$, seen by the Crystal Barrel Collaboration (ANTINORI 95, AMSLER 95B, 95C). The $f_0(1590)$ of GAMS (BINON 83) in our 1994 edition is now listed under the same entry as the $f_0(1500)$. For the determination of the resonance parameters, we use only the analyses in terms of T-matrix poles. See also our Note on Non-$q\overline{q}$ Mesons.

The $I = 1$ states: Two states are known, the $a_0(980)$ and the $a_0(1450)$ seen by the Crystal Barrel (AMSLER 94D). For a longer Note on the $a_0(980)$, see our 1994 edition, which includes comments on the nature of this resonance.

The most important fact about the $a_0(980)$ is that it lies very close to the $K\overline{K}$ threshold (like the $f_0(980)$); its shape, mass, and width are strongly distorted by this threshold. A naive Breit-Wigner fit to the resonance bump cannot reveal its true coupling constants to $\eta\pi$ and $K\overline{K}$. To obtain these, one must use a coupled-channel model with energy-dependent widths and mass-shift contributions. For the same reason, the branching ratios to $K\overline{K}$ and $\eta\pi$ are strongly energy dependent and one cannot use quoted width parameters in a naive way to determine the strength of the couplings.

Independently of any model about the nature of the $a_0(980)$ (or the $f_0(980)$), the $K\overline{K}$ component in the wave function of the state must be large. By general quantum mechanical arguments, any state (be it $q\overline{q}$ or whatever) that lies at the S-wave $K\overline{K}$ threshold and to which it couples strongly must have significant mixing with the $K\overline{K}$ continuum. Therefore, one cannot discuss the $a_0(980)$ (or the $f_0(980)$) without taking into account this large continuum component, *e.g.* when calculating $\gamma\gamma$ widths. The $\gamma\gamma$ width will always be suppressed by the $K\overline{K}$ component of the state.

The $I = 1/2$ sector: The $K_0^*(1430)$ (ASTON 88) is certainly the least controversial of the light scalar mesons. The phase shift rises smoothly from threshold, passes 90° at 1350 MeV, and then continues to rise to about 170° at 1600 MeV at the first important inelastic threshold, $K\eta'$. Thus, it behaves just as expected of a single broad, nearly elastic resonance. All analyses agree on a pole mass of about 1430 MeV and a width of about 300 MeV.

Interpretation of the nature of the scalars: Almost every model of the scalar states agrees that the $K_0^*(1430)$ is the 1^3P_0 quark model $s\overline{u}$ (or $s\overline{d}$) state. For the interpretation of the other light scalars, there are two main classes of models:

(i) The two states near the $K\overline{K}$ threshold, the $f_0(980)$ and the $a_0(980)$, are $K\overline{K}$ bound states (WEINSTEIN 89). The $f_0(1370)$ is the 1^3P_0 $u\overline{u}+d\overline{d}$ state, the $a_0(1450)$ is the $u\overline{d}$ state, and the mainly $s\overline{s}$ is still missing. The last is perhaps the state reported by LASS at 1525 MeV (ASTON 88D) or the $f_J(1710)$. The f_0(400-1200) is then left as a background structure. The $f_0(1500)$ is too light and too narrow to be the second radially excited $u\overline{u}+d\overline{d}$ state, and it is not the missing $s\overline{s}$ state, due to its small $K\overline{K}$ branching ratio. A non-$q\overline{q}$ (gluonium) interpretation seems likely (AMSLER 96); see our Note on Non-$q\overline{q}$ Mesons.

(ii) Most, if not all, light scalars are different manifestations of the quark model $^3P_0$ $q\overline{q}$ states. The most economic model for this second alternative is that of TORNQVIST 82, 95, and 96, who fits the f_0(400-1200), $f_0(980)$, $f_0(1370)$, $a_0(980)$, $a_0(1450)$, and $K_0^*(1430)$, as unitarized remnants of $q\overline{q}$ 1^3P_0 states with six parameters and theoretical constraints including flavor symmetry, the OZI rule, the equal-spacing rule for bare $q\overline{q}$ states, Adler zeroes, unitarity, and analyticity. Here the f_0(400-1200) is at the same time the $u\overline{u}+d\overline{d}$ state, the chiral partner of the π, and the Higgs boson of QCD. The $f_0(980)$ and the $f_0(1370)$ are two different manifestations of the unitarized $s\overline{s}$ state, while the $a_0(980)$ and the $a_0(1450)$ are two manifestations of $u\overline{d}$. The interpretation of $f_0(1500)$ is in this scheme an open question.

For other models and more details discussing the interpretations of the scalar resonances, see AU 87, MORGAN 93, ZOU 93, 94B, and JANSSEN 95.

f_0(1370) T-MATRIX POLE POSITION

Note that $\Gamma \approx 2\ \mathrm{Im}(\sqrt{s_{\mathrm{pole}}})$.

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
(1200–1500)−*i*(150–250) OUR ESTIMATE				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$(1330 \pm 50)-i(150 \pm 40)$	[1] AMSLER	95B	CBAR	$\overline{p}p \rightarrow 3\pi^0$
$(1360 \pm 35)-i(150–300)$	[1] AMSLER	95C	CBAR	$\overline{p}p \rightarrow \pi^0\eta\eta$
$1390 \pm 30 - i(190 \pm 40)$	[2] AMSLER	95D	CBAR	$\overline{p}p \rightarrow 3\pi^0$, $\pi^0\eta\eta$, $\pi^0\pi^0\eta$
$1346 - i249$	[3,4] JANSSEN	95	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$

$1214 - i168$	[4,5] TORNQVIST	95	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$, $K\pi$, $\eta\pi$
$1364 - i139$	AMSLER	94D	CBAR	$\overline{p}p \rightarrow \pi^0\pi^0\eta$
$(1365^{+20}_{-55}) - i(134 \pm 35)$	ANISOVICH	94	CBAR	$\overline{p}p \rightarrow 3\pi^0, \pi^0\eta\eta$
$1340 \pm 40 - i(127^{+30}_{-20})$	[6] BUGG	94	RVUE	$\overline{p}p \rightarrow 3\pi^0$, $\eta\eta\pi^0$, $\eta\pi^0\pi^0$
$1515 - i214$	[4,7] ZOU	93	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$
$1420 - i220$	[8] AU	87	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$

[1] Supersedes ANISOVICH 94.
[2] Coupled-channel analysis of $\overline{p}p \rightarrow 3\pi^0$, $\pi^0\eta\eta$, and $\pi^0\pi^0\eta$ on sheet IV. Demonstrates explicitly that $f_0(400\text{–}1200)$ and $f_0(1370)$ are two different poles.
[3] Analysis of data from FALVARD 88.
[4] The pole is on Sheet III. Demonstrates explicitly that $f_0(400\text{–}1200)$ and $f_0(1370)$ are two different poles.
[5] Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CASON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.
[6] Reanalysis of ANISOVICH 94 data.
[7] Analysis of data from OCHS 73, GRAYER 74, and ROSSELET 77.
[8] Analysis of data from OCHS 73,GRAYER 74, BECKER 79, and CASON 83.

$f_0(1370)$ BREIT-WIGNER MASS OR K-MATRIX POLE PARAMETER

VALUE (MeV)	*DOCUMENT ID*
1200 to 1500 OUR ESTIMATE	

$\pi\pi$ MODE

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1186	[9] TORNQVIST	95	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$, $K\pi$, $\eta\pi$
1472 ± 12	ARMSTRONG	91	OMEG	300 $pp \rightarrow pp\pi\pi$, $ppK\overline{K}$
1275 ± 20	BREAKSTONE	90	SFM	62 $pp \rightarrow pp\pi^+\pi^-$
1420 ± 20	AKESSON	86	SPEC	63 $pp \rightarrow pp\pi^+\pi^-$
1256	FROGGATT	77	RVUE	$\pi^+\pi^-$ channel

[9] Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CASON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.

$K\overline{K}$ MODE

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1440 ± 20	CHEN	91	MRK3	$J/\psi \rightarrow \gamma\pi^+\pi^-$, $\gamma K\overline{K}$
1440 ± 50	BOLONKIN	88	SPEC	40 $\pi^- p \rightarrow K^0_S K^0_S n$
1463 ± 9	ETKIN	82B	MPS	23 $\pi^- p \rightarrow n 2K^0_S$
1425 ± 15	WICKLUND	80	SPEC	6 $\pi N \rightarrow K^+K^-N$
~ 1300	POLYCHRO...	79	STRC	7 $\pi^- p \rightarrow n 2K^0_S$

4π MODE $2(\pi\pi)_S + \rho\rho$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1374 ± 38	AMSLER	94	CBAR	0.0 $\overline{p}p \rightarrow \pi^+\pi^-3\pi^0$
1345 ± 12	ADAMO	93	OBLX	$\overline{n}p \rightarrow 3\pi^+2\pi^-$
1386 ± 30	GASPERO	93	DBC	0.0 $\overline{p}n \rightarrow 2\pi^+3\pi^-$

$\eta\eta$ MODE

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1430	AMSLER	92	CBAR	0.0 $\overline{p}p \rightarrow \pi^0\eta\eta$
1220 ± 40	ALDE	86D	GAM4	100 $\pi^- p \rightarrow n 2\eta$

$f_0(1370)$ BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*
300 to 500 OUR ESTIMATE	

$\pi\pi$ MODE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
350	[10] TORNQVIST	95	RVUE	$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$, $\eta\pi$
195±33	ARMSTRONG	91	OMEG	300 $pp \to pp\pi\pi$, $ppK\overline{K}$
285±60	BREAKSTONE	90	SFM	62 $pp \to pp\pi^+\pi^-$
460±50	AKESSON	86	SPEC	63 $pp \to pp\pi^+\pi^-$
~ 400	[11] FROGGATT	77	RVUE	$\pi^+\pi^-$ channel

[10] Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CASON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.
[11] Width defined as distance between 45 and 135° phase shift.

$K\overline{K}$ MODE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
160± 40	CHEN	91	MRK3	$J/\psi \to \gamma\pi^+\pi^-$, $\gamma K\overline{K}$
250± 80	BOLONKIN	88	SPEC	40 $\pi^- p \to K^0_S K^0_S n$
118^{+138}_{-16}	ETKIN	82B	MPS	23 $\pi^- p \to n2K^0_S$
160± 30	WICKLUND	80	SPEC	6 $\pi N \to K^+K^- N$
~ 150	POLYCHRO...	79	STRC	7 $\pi^- p \to n2K^0_S$

4π MODE $2(\pi\pi)_S+\rho\rho$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
375±61	AMSLER	94	CBAR	0.0 $\overline{p}p \to \pi^+\pi^- 3\pi^0$
398±26	ADAMO	93	OBLX	$\overline{n}p \to 3\pi^+ 2\pi^-$
310±50	GASPERO	93	DBC	0.0 $\overline{p}n \to 2\pi^+ 3\pi^-$

$\eta\eta$ MODE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
250	AMSLER	92	CBAR	0.0 $\overline{p}p \to \pi^0\eta\eta$
320±40	ALDE	86D	GAM4	100 $\pi^- p \to n2\eta$

$f_0(1370)$ DECAY MODES

In two-particle decay modes the $\pi\pi$ decay is dominant. We include here the resonance observed in 4π under the same entry as the one decaying to 2 pseudoscalars. See also the minireview under non-$q\overline{q}$ candidates.

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\pi\pi$	seen
Γ_2	4π	seen
Γ_3	$4\pi^0$	
Γ_4	$2\pi^+2\pi^-$	seen
Γ_5	$\pi^+\pi^-2\pi^0$	seen
Γ_6	$\rho\rho$	
Γ_7	$2(\pi\pi)_S$	
Γ_8	$\eta\eta$	seen
Γ_9	$K\overline{K}$	seen
Γ_{10}	$\gamma\gamma$	seen
Γ_{11}	e^+e^-	not seen

$f_0(1370)$ PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$ Γ_{10}

VALUE (eV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
5.4±2.3	MORGAN	90	RVUE	$\gamma\gamma \to \pi^+\pi^-$, $\pi^0\pi^0$

$\Gamma(e^+e^-)$ — Γ_{11}

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
<20	90	VOROBYEV	88	ND	$e^+e^- \rightarrow \pi^0\pi^0$

$f_0(1370)$ BRANCHING RATIOS

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

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.15	[12] AMSLER	94	CBAR	$\overline{p}p \rightarrow \pi^+\pi^- 3\pi^0$
<0.20	GASPERO	93	DBC	$0.0\ \overline{p}n \rightarrow$ hadrons

[12] Using AMSLER 95B ($3\pi^0$).

$\Gamma(4\pi)/\Gamma_{total}$ — $\Gamma_2/\Gamma = (\Gamma_3+\Gamma_4+\Gamma_5)/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.80±0.04	GASPERO	93	DBC	$0.0\ \overline{p}n \rightarrow$ hadrons

$\Gamma(2\pi^+2\pi^-)/\Gamma(4\pi)$ — $\Gamma_4/\Gamma_2 = \Gamma_4/(\Gamma_3+\Gamma_4+\Gamma_5)$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.420±0.014	[13] GASPERO	93	DBC	$0.0\ \overline{p}n \rightarrow 2\pi^+3\pi^-$

[13] Model-dependent evaluation.

$\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(4\pi)$ — $\Gamma_5/\Gamma_2 = \Gamma_5/(\Gamma_3+\Gamma_4+\Gamma_5)$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.512±0.019	[14] GASPERO	93	DBC	$0.0\ \overline{p}n \rightarrow$ hadrons

[14] Model-dependent evaluation.

$\Gamma(\rho\rho)/\Gamma(2(\pi\pi)_S)$ — Γ_6/Γ_7

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.6 ±0.2	AMSLER	94	CBAR	$\overline{p}p \rightarrow \pi^+\pi^- 3\pi^0$
0.58±0.16	GASPERO	93	DBC	$0.0\ \overline{p}n \rightarrow 2\pi^+3\pi^-$

$f_0(1370)$ REFERENCES

AMSLER	95B	PL B342 433	+Armstrong, Brose+	(Crystal Barrel Collab.)
AMSLER	95C	PL B353 571	+Armstrong, Hackman+	(Crystal Barrel Collab.)
AMSLER	95D	PL B355 425	+Armstrong, Spanier+	(Crystal Barrel Collab.)
JANSSEN	95	PR D52 2690	+Pearce, Holinde, Speth	(STON, ADLD, JULI)
TORNQVIST	95	ZPHY C68 647		(HELS)
AMSLER	94	PL B322 431	+Armstrong, Meyer+	(Crystal Barrel Collab.) JPC
AMSLER	94D	PL B333 277	+Anisovich, Spanier+	(Crystal Barrel Collab.)
ANISOVICH	94	PL B323 233	+Armstrong+	(Crystal Barrel Collab.) JPC
BUGG	94	PR D50 4412	+Anisovich+	(LOQM)
ADAMO	93	NP A558 13C	+Agnello+	(OBELIX Collab.) JPC
GASPERO	93	NP A562 407		(ROMAI) JPC
ZOU	93	PR D48 R3948	+Bugg	(LOQM)
AMSLER	92	PL B291 347	+Augustin, Baker+	(Crystal Barrel Collab.)
ARMSTRONG	91	ZPHY C51 351	+Benayoun+	(ATHU, BARI, BIRM, CERN, CDEF)
ARMSTRONG	91B	ZPHY C52 389	+Barnes+	(ATHU, BARI, BIRM, CERN, CDEF)
CHEN	91	Hadron 91 Conf. SLAC-PUB-5669		(Mark III Collab.)
BREAKSTONE	90	ZPHY C48 569	+	(ISU, BGNA, CERN, DORT, HEIDH, WARS)
MORGAN	90	ZPHY C48 623	+Pennington	(RAL, DURH)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+	(SLAC, NAGO, CINC, INUS)
BOLONKIN	88	NP B309 426	+Bloshenko, Gorin+	(ITEP, SERP)
FALVARD	88	PR D38 2706	+Ajaltouni+	(CLER, FRAS, LALO, PADO)
VOROBYEV	88	SJNP 48 273, Translated from YAF 48 436.	+Golubev, Dolinsky, Druzhinin+	(NOVO)
AU	87	PR D35 1633	+Morgan, Pennington	(DURH, RAL)
AKESSON	86	NP B264 154	+Albrow, Almehed+	(Axial Field Spec. Collab.)
ALDE	86D	NP B269 485	+Binon, Bricman+	(BELG, LAPP, SERP, CERN, LANL)
CASON	83	PR D28 1586	+Cannata, Baumbaugh, Bishop+	(NDAM, ANL)
ETKIN	82B	PR D25 1786	+Foley, Lai+	(BNL, CUNY, TUFTS, VAND)
WICKLUND	80	PRL 45 1469	+Ayres, Cohen, Diebold, Pawlicki	(ANL)
BECKER	79	NP B151 46	+Blanar, Blum+	(MPIM, CERN, ZEEM, CRAC)
POLYCHRO...	79	PR D19 1317	Polychronakos, Cason, Bishop+	(NDAM, ANL)
FROGGATT	77	NP B129 89	+Petersen	(GLAS, NORD)
ROSSELET	77	PR D15 574	+Extermann, Fischer, Guisan+	(GEVA, SACL)
GRAYER	74	NP B75 189	+Hyams, Blum, Dietl+	(CERN, MPIM)
HYAMS	73	NP B64 134	+Jones, Weilhammer, Blum, Dietl+	(CERN, MPIM)
OCHS	73	Thesis		(MPIM, MUNI)
BEIER	72B	PRL 29 511	+Buchholtz, Mann+	(PENN)

OTHER RELATED PAPERS

TORNQVIST	96	PRL 76 1575	+Roos	(HELS)
LI	91	PR D43 2161	+Close, Barnes+	(TENN)
BIZZARRI	69	NP B14 169	+Foster, Gavillet, Montanet+	(CERN, CDEF)
BETTINI	66	NC 42A 695	+Cresti, Limentani, Bertanza, Bigi+	(PADO, PISA)