

SOME DEVELOPMENTS IN LIGHT QUARK SPECTROSCOPY

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ABSTRACT

Among the many unresolved questions in light quark spectroscopy, the underlying structure of the scalar mesons and the identification of states with a gluonic content rank high. Recently, new information has come from ϕ radiative decays, J/ψ , τ , D and D_s meson decays. Other papers in this conference review radiative transitions of ϕ and J/ψ . This paper discusses new information on the scalar sector primarily that from decays of D and D_s mesons.

1 Introduction

One important reason for continuing to study light quark spectroscopy is to search for glueballs and exotics predicted by QCD.

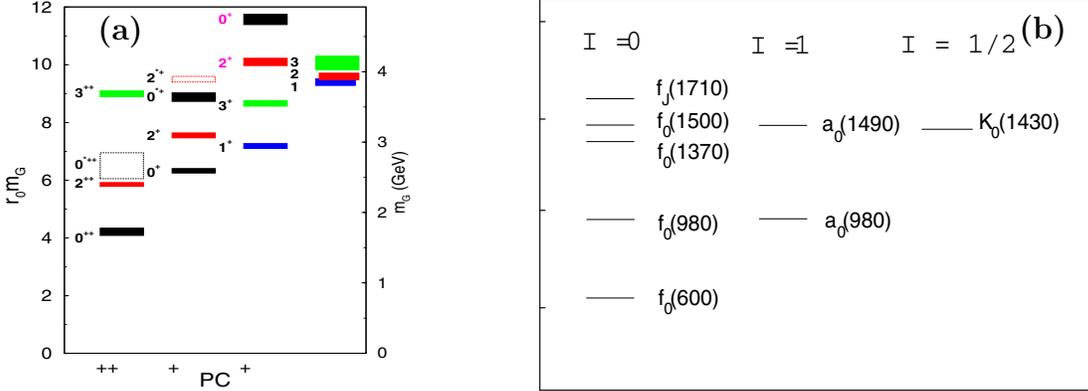


Figure 1: (a) Spectrum predicted from unquenched QCD for glueball states from a recent summary by Morningstar [1]. (b) Scalar states in the PDG [2] listings with masses below 1900 MeV/c².

Unquenched lattice QCD computations, summarized in Figure 1(a), places the lightest Glueball with $J^{PC} = 0^{++}$ at about 1.7 GeV. Unfortunately, much confusion persists on the existence and nature of scalar states in or below this region. They are wide enough to be mixtures of each other or with glueball states, so a better understanding of the scalar meson spectrum would help identify this state.

Fifteen scalar states, shown in Figure 1(b) are listed by the Particle Data Group [2] (PDG). The existence of the $f_0(600)$ has long been established, but its pole position has been difficult to pin down due to interference with s wave background in $\pi\pi$ and $K\bar{K}$ systems in which it has been studied mostly. There is disagreement on whether this state is broad and above, or narrower and below the ρ mass. The composition of the $J^{PC} = 0^{++}$ states $a_0(980)$ and $f_0(980)$ - $K\bar{K}$ molecule, $q\bar{q}q\bar{q}$ or $q\bar{q}$ - is unknown. The spin of the $f_J(1710)$ has been controversial though most experiments now agree that $J = 0$. Possibly as a result of some confusion on the identity of the state studied, a few results still hint at $J = 2$.

Only one strange scalar meson is established to exist, allowing for only one nonet. The hint of a further, lower mass K^* (the “ κ ”) seen in the decay of the D^+ meson has recently been published [3]. Should its existence be confirmed, a second, light scalar nonet may be established, casting new light on the identity of the scalar glueball. This, and other recent information on the scalar spectrum are the subject of this paper. Some prospects for the future are also discussed.

2 Data from Charmed Meson Decays

Until recently, the majority of knowledge of light quark systems has come from experiments dedicated to their study. Many of these are listed in Table 1.

Table 1: Experiments that have contributed significantly to current knowledge of meson spectroscopy.

“Peripheral model” extrapolations:	$\pi^- \pi^+ \rightarrow \pi^- \pi^+, \pi^0 \pi^0$ $\pi^- \pi^+ \rightarrow K^- K^+, K^0 K^0$ $\pi^- \pi^+ \rightarrow \eta \eta, \eta \eta'$ $K^- \pi^+ \rightarrow K^- \pi^+$ $K^- K^+ \rightarrow K^- K^+, K^0 K^0$	$\pi N \rightarrow$, E852, <i>etc.</i> . ” ” $K^- p$, LASS $K^- p$ (not at pole)
$p\bar{p}$ and $Z\bar{N}$ annihilations	$p\bar{p} \rightarrow 3\pi^0, 5\pi^0, \pi^0 \pi^0 \eta,$ $\eta \eta \pi^0, \eta \eta' \pi^0, Z\bar{N} \rightarrow$ mesons	Crys. Barrl; FNAL E760, Obelix
ϕ c.f. ω $s\bar{s}$ content:	$J/\psi \rightarrow \phi \pi \pi, \phi K \bar{K}, \omega \pi \pi, \omega K \bar{K}$	Mark II, III
Gluon enriched:	$J/\psi \rightarrow \gamma \pi \pi, \gamma K \bar{K}, \gamma \eta \eta, \gamma \eta \eta'$ $pp \rightarrow pp + X_{central}$ $\psi' \rightarrow J/\psi \pi \pi, Y'(Y'') \rightarrow Y \pi \pi$	Mark III WA76, WA102 Mark III
Gluon suppressed:	$\gamma \gamma \rightarrow \pi \pi, K \bar{K}$	TPC

Recently, decays of D and D_s^+ ¹ mesons to three pseudoscalar mesons have also begun to provide information. These decays often have large branching fractions providing good statistical accuracy, and generally proceed through intermediate, two meson systems with natural parity. Kinematics and angular momentum barrier factors generally favor scalar ($J^P = 0^+$) over vector 1^- or tensor 2^+ systems resulting in an important source of new information on scalar states.

2.1 The Isobar Model

In most analyses, D decays to three pseudoscalars i, j and k are described as a coherent sum of “isobar amplitudes” \mathcal{A}_R , each corresponding to a quasi two body decay $D \rightarrow R(\rightarrow ij)k$. \mathcal{A}_R satisfies Lorentz invariance and conserves total spin and has the form $\mathcal{A}_R(s_{ij}, s_{ik}) = F_D(q, r_D) F_R(p, r_R) \times BW_R(s_{ij}) \times (-2)^J |\vec{p}|^J |\vec{q}|^J P_J(\hat{p} \cdot \hat{q})$ where \vec{p}, \vec{q} are momenta of i and k in the (ij) and D rest frames, respectively. Form factors F_D (F_R) for D (R) are parameterized in terms of effective radii R_D (R_R)

¹Except where indicated otherwise, charge conjugate systems are implied in this paper.

for the decaying meson and the resonance R , respectively. A Breit Wigner (BW) propagator $BW_R = [s_R - s_{ij} - i\sqrt{s_R} \Gamma(s_{ij})]^{-1}$ describes the resonance with spin J , mass $M_R = \sqrt{s_R}$. Suffix R denotes a quantity evaluated at $s_{ij} = s_R$.

The distribution of decays in Dalitz plot coordinates (s_{ij}, s_{ik}) (squared invariant mass combinations) is

$$\mathcal{P}_S(s_{ij}, s_{ik}) = \left| a_{NR} e^{i\delta_{NR}} + \sum_R a_R e^{i\delta_R} \mathcal{A}_R(s_{ij}, s_{ik}) \right|^2$$

Decays directly to three bodies (NR), not involving a resonance, are described by a constant, “contact” amplitude $a_{NR} e^{i\delta_{NR}}$ in the expression above.

Fits are made to obtain values for complex coefficients $ae^{i\delta}$ and resonance parameters. Experimentally, incoherent backgrounds from sources other than D decay, and efficiencies affecting the observed distributions are carefully modelled and incorporated into the fits.

3 A Hint of a “ κ ” Meson

E791 reports [3] an isobar model analysis of a large sample of $D^+ \rightarrow K^- \pi^+ \pi^+$ decays. The Dalitz plot in Figure 2(a) shows strong $K_1(890)$, $K_0(1430)$, and $K_2(1430)$. The

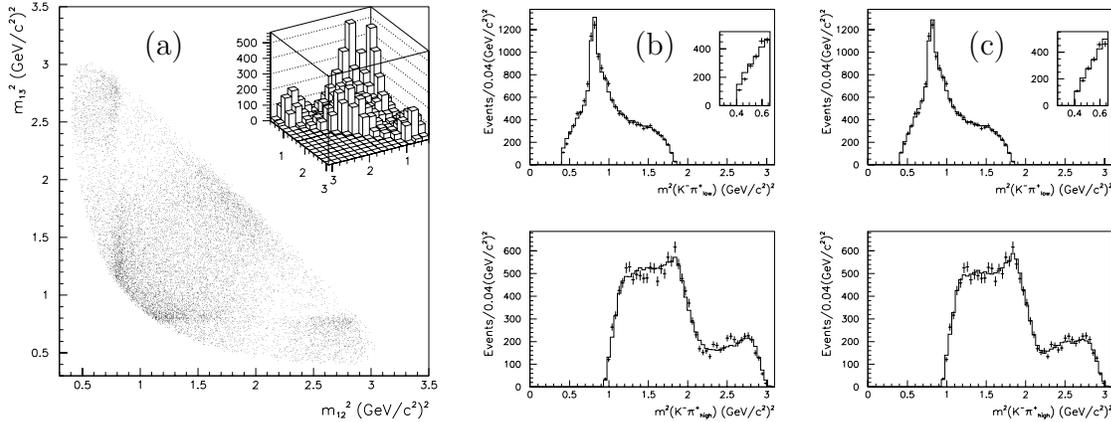


Figure 2: (a) Dalitz plot for 15,090 $D^+ \rightarrow K^- \pi^+ \pi^+$ decays with $\sim 6\%$ background from E791. (b) $K^- \pi^+$ mass projections showing data (error bars) and fit (solid histogram) to model A (no κ) and (c) model B which includes a $\kappa\pi$ amplitude.

asymmetry pattern in the $K_1(890)$ indicates significant, underlying $K^- \pi^+$ s -wave interference.

Model A, with an NR contribution and only isobars found in the PDG listings, gives the results in Table 2. Masses and widths are fixed at their PDG

values. There are obvious problems with this model, many seen in earlier analyses

Table 2: Fits to the E791 $D^+ \rightarrow K^- \pi^+ \pi^+$ Dalitz plot. Models A and B are described in the text.

	Model A ($\chi^2/\text{dof} = 167/63$)		Model B ($\chi^2/\text{dof} = 46/63$)	
Mode	%	phase	%	phase
$\kappa\pi^+$	-	-	$47.8 \pm 12.1 \pm 3.7\%$	$187 \pm 8 \pm 17^\circ$
NR	$90.0 \pm 2.6\%$	0° (fixed)	$13.0 \pm 5.8 \pm 2.6\%$	$349 \pm 14 \pm 8^\circ$
$K^*(890)\pi^+$	$13.8 \pm 0.5\%$	$54 \pm 2^\circ$	$12.3 \pm 1.0 \pm 0.9\%$	0° (fixed)
$K^*_0(1430)\pi^+$	$30.6 \pm 1.6\%$	$109 \pm 2^\circ$	$12.5 \pm 1.4 \pm 0.4\%$	$48 \pm 7 \pm 10^\circ$
$K^*_2(1430)\pi^+$	$0.4 \pm 0.1\%$	$33 \pm 8^\circ$	$0.5 \pm 0.1 \pm 0.2\%$	$306 \pm 8 \pm 6^\circ$
$K^*_1(1680)\pi^+$	$3.2 \pm 0.3\%$	$66 \pm 3^\circ$	$2.5 \pm 0.7 \pm 0.2\%$	$28 \pm 13 \pm 15^\circ$

[4]. The NR contribution is large - an effect not usually seen in other three body D decays - and fractions of the modes sum to $\sim 140\%$. This indicates significant interference, mostly with the NR component. Unlike the earlier analyses, E791's statistical significance shows that this model gives an unacceptable fit, with $\chi^2/\text{dof} = 2.7$ in 63 bins in the Dalitz plot. The fit quality is worst in the low $K\pi$ mass region, and its reflection at $\sim 2.5 \text{ GeV}^2$ as seen in the $K^- \pi^+$ mass projection in Figure 2(b). In analyzing $D^0 \rightarrow K^- \pi^+ \pi^0$ decay data, the CLEO collaboration [5] also obtain a poor fit in this region.

Introduction of another scalar resonance, with mass and width determined by the fit, is required to obtain a good fit. This fit (Model B) gives the results in Table 2, mass projections in Figure 2(c) and converges on a mass and width for κ of $M_\kappa = 797 \pm 19 \pm 42 \text{ MeV}/c^2$ and $\Gamma_\kappa = 410 \pm 43 \pm 85 \text{ MeV}/c^2$. The $\kappa\pi^+$ amplitude is dominant and the NR fraction becomes insignificant ($\sim 2\sigma$). The sum of fractions is $\sim 90\%$ and very good fit quality is found in all Dalitz plot regions. However, the $K^*_0(1430)$ parameters from this fit (Table 3) are inconsistent with PDG values.

3.1 New $K^*_0(1430)$ Parameters

Data for this state are dominated by results from LASS experiment E135 [7] in which it was discovered. Recently, this collaboration reports [6] that new central values for mass and width, in Table 3, are obtained when the fit to their $K^- \pi^+$ scattering data is limited to the elastic range (below $K\eta'$ threshold). This implies that a larger systematic uncertainty should be attributed to these parameters than indicated by the PDG listing.

Table 3: New $K^*(1430)$ parameters from E791 and LASS collaboration [6]

	E791 Model B with κ	Published LASS values	LASS Re-fit for $M_{K^-\pi^+} < M_{K\eta'}$	PDG
$M_{K^*(1430)}$	$1459 \pm 7 \pm 6$	1412 ± 7	1435 ± 9	$1412 \pm 6 \text{ MeV}/c^2$
$\Gamma_{K^*(1430)}$	$175 \pm 12 \pm 12$	294 ± 40	279 ± 40	$294 \pm 23 \text{ MeV}/c^2$

4 Evidence for a Low Mass “ σ ”

Analysis of $D^+ \rightarrow \pi^-\pi^+\pi^+$ decays by the E791 collaboration [8] provides an indication of a clear signal that may correspond to the $f_0(600)$, known as the σ meson. The Dalitz plot was fit to isobars summarized in model A in Table 4 and shown in the $\pi^-\pi^+$ mass projection in Figure 3(a). In this model, no $\sigma\pi^+$ amplitude is

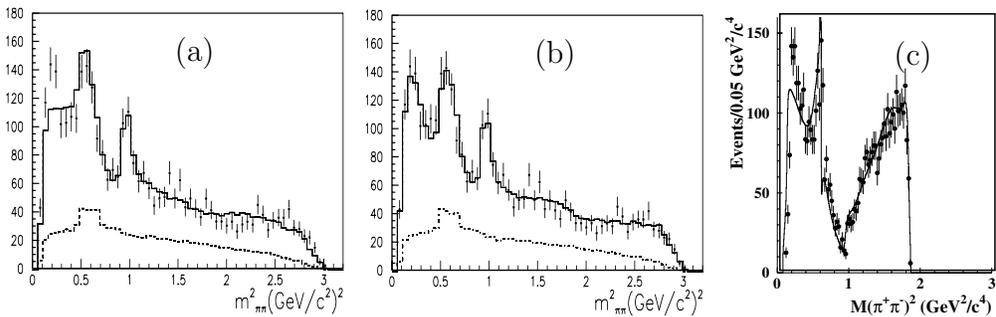


Figure 3: (a) Projection onto the $\pi^-\pi^+$ mass axis of E791 sample of 1170 ± 65 $D^+ \rightarrow \pi^-\pi^+\pi^+$ decays. Structure is obvious in the ρ^0 and $f_0(980)$ regions. There are two entries per event. Data (error bars) and the fit (solid line) to model A described in the text are shown. (c) $\pi^-\pi^+$ mass squared projection from $D^0 \rightarrow K^0(\bar{K}^0)\pi^-\pi^+$ decays from ref. [10]. The fit (solid line) shown does not include a σ amplitude.

included. The fit is poor with $\chi^2 \sim 80$ for 63 degrees of freedom. The NR decay is dominant and the amplitudes for $\rho(1450)$ and $\rho(770)$ are almost equally strong - an odd situation. The fit is particularly bad in the low mass $\pi^+\pi^-$ region. These results are generally compatible with the only previous measurements of this decay mode by the E687 collaboration [9].

In model B, a $\sigma\pi^+$ amplitude with scalar BW parameters, M_σ , Γ_σ , allowed to float freely, is introduced. Values for M_σ , Γ_σ that result are in Table 5, indicating a σ below the $\rho(770)$. The fit, whose results are in Table 4, is of a significantly improved quality, $\chi^2 \sim 57$ for 63 degrees of freedom. It describes the low mass $\pi^-\pi^+$ mass region shown in Figure 3(b) well. The $\sigma\pi^+$ mode dominates the decay

Table 4: Results of isobar model fit to $D^+ \rightarrow \pi^- \pi^+ \pi^+$ Dalitz plot. Model A and Model B are described in the text.

Mode	Model A		Model B	
	Fraction	Phase	Fraction	Phase
$\sigma\pi^+$	—	—	$46.3 \pm 9.0 \pm 2.1\%$	$206 \pm 8 \pm 5^\circ$
non resonant	$38.6 \pm 1.4\%$	$150 \pm 12^\circ$	$7.8 \pm 6.0 \pm 2.7\%$	$57 \pm 20 \pm 6^\circ$
$\rho(770)\pi^+$	$20.8 \pm 2.3\%$	0° (fixed)	$33.6 \pm 3.2 \pm 2.2\%$	0° (fixed)
$f_0(980)\pi^+$	$7.4 \pm 4.3\%$	$152 \pm 16^\circ$	$6.2 \pm 1.3 \pm 0.4\%$	$165 \pm 11 \pm 3^\circ$
$f_2(1270)\pi^+$	$6.3 \pm 3.3\%$	$103 \pm 16^\circ$	$19.4 \pm 2.5 \pm 0.4\%$	$57.3 \pm 7.5 \pm 5^\circ$
$f_0(1370)\pi^+$	$10.7 \pm 7.7\%$	$143 \pm 10^\circ$	$2.3 \pm 1.5 \pm 0.8\%$	$105.4 \pm 18 \pm 0.6^\circ$
$\rho(1450)\pi^+$	$22.6 \pm 2.1\%$	$46 \pm 15^\circ$	$0.7 \pm 0.7 \pm 0.3\%$	$319 \pm 39 \pm 11^\circ$

- but the NR amplitude becomes negligibly small as does that for the $\rho(1450)\pi$.

5 Comments on E791 σ and κ Signals

Tests made by E791 reveal that the scalar BW phase motion is important in obtaining acceptable fits [8, 3]. Fits to a “real BW” (a peak, no phase motion) result in poor χ^2 and large sum of resonant fractions. Fits to vector and tensor forms are also significantly worse. Nevertheless, the isobar model used by E791 - with a scalar BW for the σ and κ - may not be formally correct. ²

E791 plans a *model independent measurement* of the s wave $\pi^- \pi^+$ and $K^- \pi^+$ magnitudes and phases as a function of mass, using interference between the two identical π^+ (Bose symmetrized) amplitudes in these D decays. This could help resolve whether or not poles really exist in these systems.

What can certainly be said is that E791 data clearly indicate the need for some phase motion in the s wave meson- meson systems and that a scalar BW is one model that works well. The possibility that another parameterization, possibly with no scalar states at all, could also fit the data satisfactorily is not excluded.

6 Other Evidence for σ

In $D^0 \rightarrow K^0(\bar{K}^0)\pi^- \pi^+$ decays, CLEO [10] note that an acceptable fit requires a $K^0\sigma$ contribution with mass and width similar to those found in E791. A fit without σ ,

²Unitarity is ignored. It may be necessary to include constraints from $\pi\pi$ or $K^- \pi^+$ elastic scattering and from chiral symmetry.

Table 5: Fits to various neutral dipion systems.

Channels	Data	M_σ MeV/c ²	Γ_σ MeV/c ²	Low Mass
$D^+ \rightarrow \pi^- \pi^+ \pi^+$	E791	$478_{-23}^{+24} \pm 17$	$324_{-40}^{+42} \pm 21$	enhanced
$\tau \rightarrow \nu_\tau \pi^- (\pi^- \pi^+ \pi^0)$	CLEO	860^\dagger	880^\dagger	enhanced
$D^0 \rightarrow K^0 (\bar{K}^0) \pi^- \pi^+$	CLEO	478^*	324^*	enhanced
$\phi \rightarrow \pi^0 \pi^0 \gamma$	KLOE	478^*	324^*	enhanced
$J/\psi \rightarrow \omega \pi^0 \pi^+$	DM2	482 ± 3	710 ± 30	enhanced
$pp \rightarrow \pi^0 \pi^0$ (central)	GAMS	590 ± 10	325 ± 10	enhanced
$J/\psi \rightarrow \phi \pi \pi, \phi K \bar{K}$	Mark II			suppressed
$\Upsilon(2S) \rightarrow \Upsilon(1S) \pi \pi,$	CLEO, ARG, CUSB, Cr Ball			suppressed
$\Upsilon(3S) \rightarrow \Upsilon(2S) \pi \pi,$	CLEO	526_{-37}^{+48}	301_{-100}^{+145}	suppressed
$\Upsilon(3S) \rightarrow \Upsilon(1S) \pi \pi,$	CLEO			enhanced
$\psi(2S) \rightarrow J/\psi \pi \pi$	Cr Ball			suppressed
$I = 0$ s wave $\pi \pi \rightarrow \pi \pi$		602 ± 26	392 ± 54	suppressed

[†] Values fixed at prediction of Tornqvist, Z. Phys. C68, 647 (1995).

* Values from E791 used in the fits.

shown in figure 3(c), fails to account for the low $\pi^- \pi^+$ mass region.

Other instances where a σ pole is added in the description of the neutral di-pion systems are summarized in table 5. The CLEO collaboration [11] observe, in $\tau \rightarrow \nu_\tau \pi^- (\pi^- \pi^+ \pi^0)$ decays, that the three pion systems (dominantly $J^P = 1^+$) require a $\sigma \pi^-$ amplitude to obtain an acceptable fit. In analyzing $\phi \rightarrow \pi^0 \pi^0 \gamma$ radiative decays, the KLOE collaboration found the best fit among those tried was obtained if a σ with parameters taken from E791 is included.

Low mass enhancements are observed in di-pion systems in $J/\psi \rightarrow \omega \pi^0 \pi^+$, $\Upsilon(3S) \rightarrow \Upsilon(1S) \pi^- \pi^+$ decays and $\pi^0 \pi^0$ from pp central production. However, in other cases, the low mass di-pion system is suppressed. The “sigma collaboration”³ suggest that all these data can be fit with a model where interference between contact and σ pole terms can cause either enhancement or suppression [12, 13]. Their fits to data in these channels, in table 5 indicate that in these systems, σ masses group around the mass region $\sim 500 - 600$ MeV/c². Results from BES, with 58M J/ψ should be an interesting test for these ideas which are not universally accepted

³M. Y. Ishida, S. Ishida, T. Ishida, T. Komada, A. M. Ma, H. Shimizu, K. Takamatsu, T. Tsuru Tokyo Inst. Tech., Nihon U, KEK, IHEP Beijing, Yamagata U., CROSS. They also fit [17] s wave $\pi \pi$ and $K^- \pi^+$ elastic scattering data to this model with a “background” with a falling phase to accommodate the σ and κ .

in the theoretical community.

7 New $f_0(980)$ Data

More information on the $f_0(980)$ and $a_0(980)$ have recently come from measurements at KLOE, SND and CMD-2 of radiative decays of ϕ . These results were reviewed in this conference [14]. The radiative transition branching fractions are about an order of magnitude larger than expected for pure $s\bar{s}$ or $K\bar{K}$ composition, possibly indicating significant $q\bar{q}q\bar{q}$ content.

$D_s^+ \rightarrow f_0(980)\pi^+$ decays which would be expected to reveal information on the $s\bar{s}$ component of $f_0(980)$ have also been examined by both the E791 [15] and FOCUS [16] collaborations. BaBar also plans to use their large data sample for this. In Figure 4(c), $\pi^-\pi^+$ mass spectra and Dalitz plots for $D_s^+ \rightarrow \pi^-\pi^+\pi^+$ events are shown. Unlike the E791 and FOCUS plots, the BaBar data are a preliminary sample ($\sim 20fb^{-1}$) and no results are yet available. The $f_0(980)$ signals are seen as clear peaks on a small background, in contrast with observations in $\pi\pi$ and KK scattering where, due to the underlying background phase, the state usually appears as a dip in the cross section.

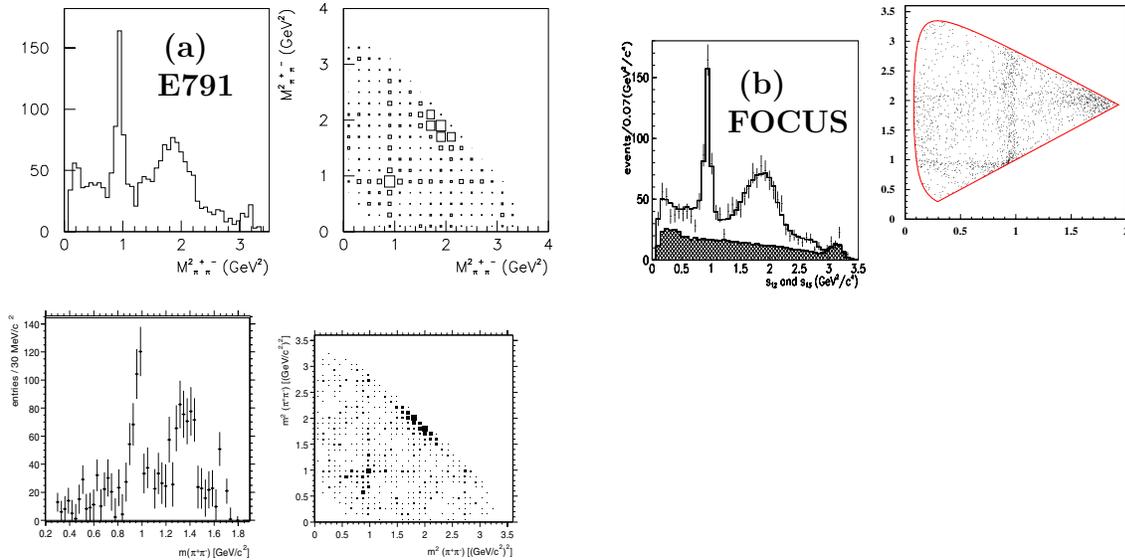


Figure 4: $\pi^-\pi^+$ effective mass distributions and Dalitz plots from $D_s^+ \rightarrow \pi^-\pi^+\pi^+$ decays for (a) E791 (848 ± 44 events); (b) FOCUS (1445 ± 50 events); and (c) BaBar (~ 800 events).

Both $f_0(980)$ and $a_0(980)$ have a line shape complicated by proximity to $K\bar{K}$ threshold. It is described approximately by $CC(s) = [s - m_0^2 + im_0(\Gamma_K + \Gamma_\pi)]^{-1}$

Table 6: The $f_0(980)$ parameters from the statistically most significant experiments. Systematic uncertainties are included, where given, in parentheses. Experiments are labelled as D_s decay (A), pp central production (B) or ϕ radiative decay (C).

	M_0	Γ_0	g_K	g_π	g_K/g_π	
E791	$977 \pm 3(2)$	$44 \pm 2(2)$	$0.02 \pm .04(.03)$	$0.09 \pm .01(.01)$	$0.22 \pm .44$	A
FOCUS	982 ± 30	89 to 32	-	-	$2.09 \pm .53$	A
WA76	979 ± 4	72 ± 8	0.56 ± 0.18	0.28 ± 0.04	$2.00 \pm .70$	B
WA102	$987 \pm 6(6)$	$48 \pm 12(8)$	$0.19 \pm .03(.04)$	$0.40 \pm .04(.04)$	$2.10 \pm .62$	B
KLOE	973 ± 1	-	2.79 ± 0.12	-	$4.00 \pm .14$	C
CMD2	$975 \pm 7(2)$	-	1.48 ± 0.32	-	$3.61 \pm .62$	C
SND	969 ± 5	-	2.47 ± 0.73	-	$4.40 \pm .8$	C

where $\Gamma_\pi = g_\pi \sqrt{s/4 - m_\pi^2}$ $\Gamma_K = \frac{g_K}{2} \left(\sqrt{s/4 - m_K^2} + \sqrt{s - m_{K^0}^2} \right)$ In the fits to E791 and FOCUS data, account was taken of this, and measurement of the ratio of the $\pi\pi$ and $K\bar{K}$ couplings g_K and g_π was attempted. In E791 this line shape was fitted directly and in FOCUS a K matrix fit was used.

Results are summarized in Table 6 where they can be compared with pp central production and radiative ϕ decay results. Mass and width parameters from a simple s wave BW are also given. There is considerable disagreement in these parameters, even between E791 and FOCUS. Apparently, large systematic effects arise both from the various production mechanisms and the fit methods. These differences may be due in part to assumptions made in background $\pi\pi$ s wave shapes in pp central production and ϕ radiative decays. Probably the difficulty in including effective mass resolution in line shapes in the D_s fits also plays a role ⁴.

What is needed in future D_s meson studies with larger samples is a coupled channel approach including $\pi\pi$, $K\bar{K}$ and $\eta\pi$ decay modes and the $a_0(980)$. The BaBar collaboration plans such an approach and this will hopefully help in sorting out this confusing situation.

8 Other f_0 Results

Both FOCUS and E791 see evidence for an additional f_0 signal at a mass above the $f_0(980)$. In fitting their Dalitz plots, mass and width parameters for a scalar

⁴Perhaps striking is that the signals observed in D_s data, whose spectator model decays would be expected to produce an $s\bar{s}$ system, is narrow. If this signal were an $s\bar{s}$ state, the preferred decay to $K\bar{K}$ would be kinematically restricted, making the state narrow. One is tempted to question whether or not the $f_0(980)$ is really a unique state.

Table 7: “ $f_0(1370)$ ” parameters from fits to $D_s^+ \rightarrow \pi^- \pi^+ \pi^+$ decays from E791 and FOCUS experiments.

	E791	FOCUS	PDG
M_0 (MeV/c ²)	$1434 \pm 18 \pm 9$	1473 ± 8	1200-1500
Γ_0 (MeV/c ²)	$172 \pm 32 \pm 6$	112 ± 17	200-500

BW for this isobar were allowed to float. Other discrepancies exist between the D_s results from the two experiments, but they agree quite well on mass and width of this f_0 . It is not clear this state can be identified with $f_0(1370)$. Measurements in this mass range from $\pi\pi \rightarrow \pi\pi$, $K\bar{K}$, $\eta\eta$, $\sigma\sigma$, *etc* scattering have suffered from interference with a large, uncertain s wave background and indicate a broad pole near 1370 MeV/c² whose parameters depend on interference with the narrower $f_0(1500)$. Neither E791 nor FOCUS find much evidence for $f_0(1500)$ in the D_s fits.

The clean $f_0(980)$ signal observed in these decays suggests that a clearer interpretation of pole positions of f_0 states may be possible than before. However, this seems far from realization at this stage.

9 Summary

The hint of a κ state in E791 is an important development. Equally important are a growing number of instances where a low mass, relatively narrow σ amplitude can describe data that comes from a number of sources not examined in this way before. A number of discrepancies in f_0 parameters do remain, however.

These observations have required large samples of data. Hopefully they will be better understood when even more data, in other channels and in other charge states, are analyzed. These should come from FOCUS, BaBar and BELLE, BES, GSI and CLEO C in the foreseeable future.

Hopes for progress in defining the scalar spectrum hinge on the proof that a κ pole really exists and on finding a reliable way to determine both σ and κ pole parameters. More data may come, but a consensus on the way to describe these observations and also s wave $I = 1/2$ $K\pi$ and $I = 0$ $\pi\pi$ scattering data in a consistent way is badly needed.

Acknowledgements

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