SLAC – PUB – 5721
December 1991
T/E

$J^P = 1^-$ RADIAL EXCITATIONS FROM LASS DATA*

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ABSTRACT

The experimental status of the strange 1^- mesons is briefly reviewed and compared with the non-strange sector and quark model expectations. The results described are taken from a 4.1 event/nb exposure of the LASS spectrometer to an 11 GeV/c K^- beam.

INTRODUCTION

The non-relativistic quark model provides a rather good description of the known light quark spectra.[1,2] In particular, the experimental situation is quite well understood in the strange meson sector, from channels where production of $q\bar{q}$ mesons seems to dominate and there is high quality data available from the LASS collaboration at SLAC.[3] This talk reviews the evidence in that experiment for (mostly strange) 1^- mesons and their classification within the quark model; detailed descriptions of the analyses can be found elsewhere.[4–7] The state of our knowledge of the strange 0^+ and 2^+ mesons in particular[8] and a review of LASS' programmatic approach to spectroscopy in general[9] are to be found elsewhere at this conference.

There are a number of experimental and theoretical difficulties in classifying the states which are found. The radial excitations are expected to be broad, and to lie in the 1–2 GeV/c^2 mass region which also contains many spin excited states and a large number of states in total that overlap and can cause experimental confusion. The situation is somewhat better in the strange sector because the isospin of the final state resonance is unambiguous. Even so, high statistics experiments with large acceptance spectrometers and full Partial Wave Analyses (PWA) in several different channels are required to sort out the many states and to determine their quantum numbers. When candidate radial states are found, there is generally a classification

* Work supported in part by the Department of Energy under contract No. DE-AC03-76SF00515; the National Science Foundation under grant Nos. PHY82-09144, PHY85-13808, and the Japan U.S. Cooperative Research Project on High Energy Physics.

Invited talk presented by D. Aston at the International Conference on Hadron Spectroscopy, College Park, Maryland, August 12–16, 1991

ambiguity. That is, in the "naive" quark model,[1] the first radially excited $q\bar{q}$ state 2^3L_{L+1} may lie very near in mass to the lowest-spin triplet ground state $1^3(L+2)_{L+1}$ which has exactly the same quantum numbers.

LASS RESULTS

The evidence discussed below comes from the reactions:

$$K^-p \rightarrow \overline{K}^o\pi^-\pi^+n^{[4]}; \quad (1)$$

$$K^-p \rightarrow K^-\pi^+n^{[5]}; \quad (2)$$

$$K^-p \rightarrow \overline{K}^o\pi^-p^{[6]} \text{ and}; \quad (3)$$

$$K^-p \rightarrow \pi^-\pi^+\Lambda.^{[7]} \quad (4)$$

The 1^3S_1 ground state $K^*(890)$ is very well known and is clearly seen in reactions (1)–(3); in reaction (1) it is used as an isobar in the three-body PWA. Its classification within the quark model is clear and it will not be further discussed here.

The 1^- $\overline{K}^o\pi^-\pi^+$ waves and phases extracted from 34k events of reaction (1) with $|t'| \leq 0.3(\text{GeV/c})^2$ are shown in Fig. 1. There is a clear peak in the $1^-0^-K^*P$ wave at ~ 1.4 GeV/c^2 which is not present in the $1^-0^-\rho P$ wave. The curves shown are the result of a simultaneous two resonance fit to the 1^- waves and the leading K^*'s in the 2^+ and 3^- waves (not shown) including their relative phases. The behaviour of the $1^-0^-K^*P$ reference phase is shown in Fig. 1(c) and is completely consistent with the resonances in the $1^-0^-\rho P$ (Fig. 1(d)), 2^+ and 3^- waves.

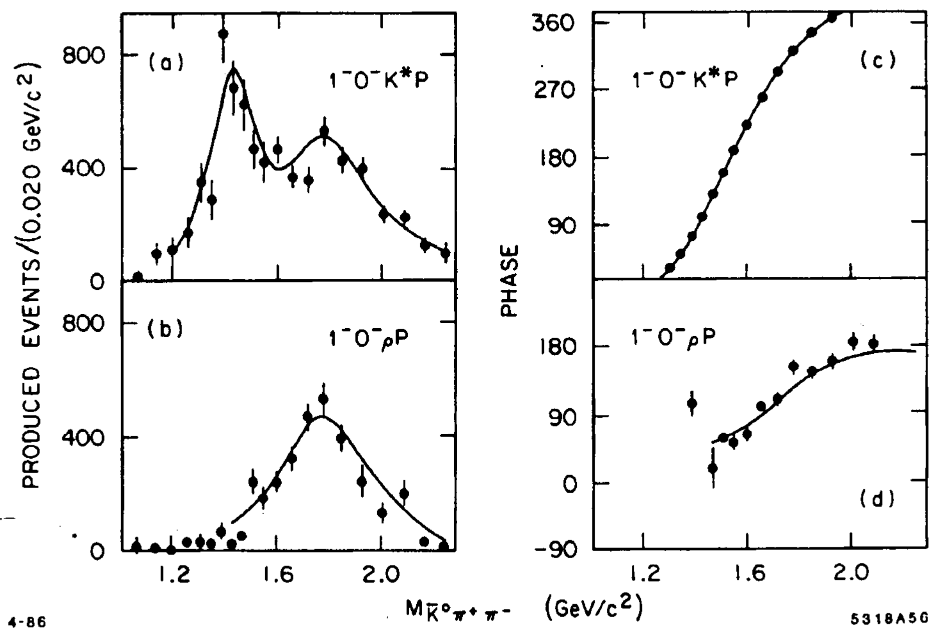

Fig. 1. The dominant 1^- waves from reaction (1); the curves are described in the text.

The t'-dependence of these waves (Fig. 2) shows interesting systematics. The 1^- and 1^+ $K^*\pi$ waves in the low mass region have a shallow slope consistent with production by exchange of a heavy object whereas the 1^- waves in the high mass region have steeper slopes more consistent with production by π-exchange.

The P-wave amplitude derived from a π-pole extrapolation of reaction (2) (151k events with $|t'| \leq 0.2(\mathrm{GeV/c})^2$) is shown in Fig. 3; the solid curve is a three resonance fit. That a third is required by both the amplitude and phase is shown by the dashed line which is a fit to only two resonances. The small $K\pi$ coupling of the $\sim$ 1.4 GeV/c^2 state is consistent

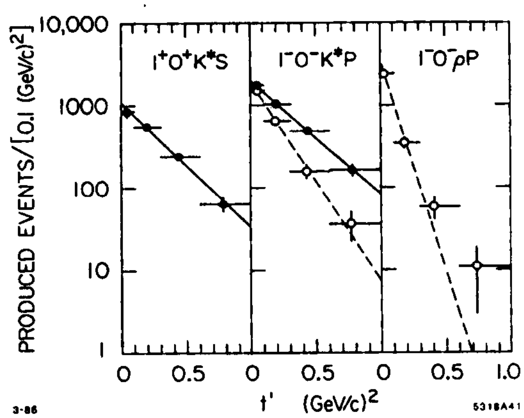

Fig. 2. The t'-dependence of the spin 1 waves from reaction (1). The solid points and lines are at low $\overline{K}^{\circ}\pi^-\pi^+$ mass, open points and dashed lines at high mass.

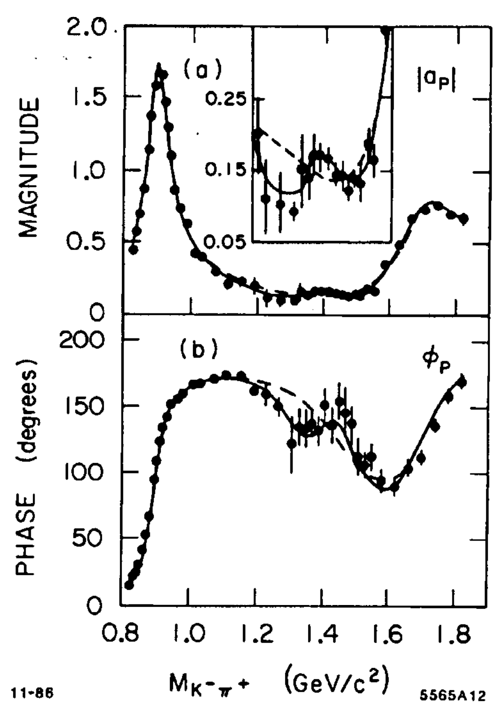

Fig. 3. The magnitude and phase of the P wave from reaction (2). The curves are described in the text

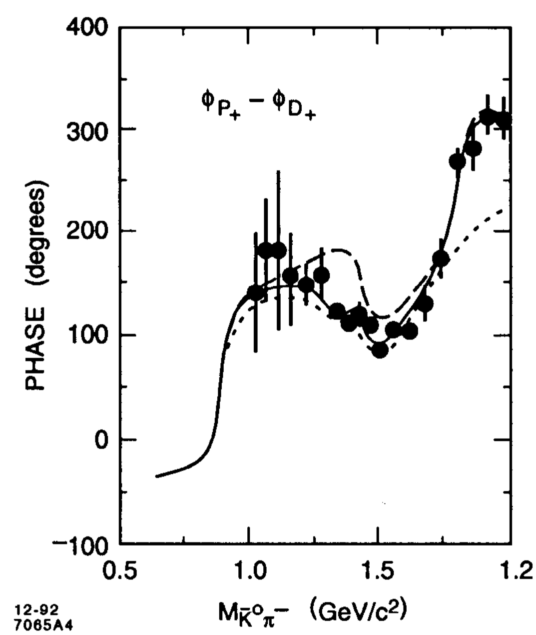

Fig. 4. The relative phase of the P_+ and D_+ waves from reaction (3). The curves are described in the text.

with the shallow t' slope observed in reaction (1). An amplitude analysis of 98k events of reaction (3) does not show conclusive effects in the magnitude of the P_+ wave, but its phase relative to the D_+ wave shown in Fig. 4 also requires two non-leading 1^- resonances for a satisfactory description of the data. The solid curve is a fit incorporating three resonances in the P_+ wave and two in the D_+ wave. The dashed curve shows the effect of omitting the ~ 1.4 GeV/c^2 1^- state, the dotted curve omission of the high mass 2^+ state.

The results of the fits to the non-leading $1^- K^*$'s in reactions (1)–(3) are summarised below. For the low mass "$K^*(1370)$"[2] state:

$$\begin{aligned} \overline{K}^\circ \pi^- \pi^+ \quad M, \Gamma &= 1.420 \pm 0.012,\ 0.240 \pm 0.022 \text{ GeV/c}^2 ; \\ K^- \pi^+ \quad &= 1.380 \pm 0.028,\ 0.176 \pm 0.056 \text{ GeV/c}^2 ; \\ \overline{K}^\circ \pi^- \quad &= 1.367 \pm 0.054,\ 0.114 \pm 0.101 \text{ GeV/c}^2 , \end{aligned}$$

where M is the invariant mass, Γ is the width and systematic errors have been added in quadrature. The three measurements are in reasonable agreement. For the higher mass "$K^*(1680)$"[2] state:

$$\begin{aligned} \overline{K}^\circ \pi^- \pi^+ \quad M, \Gamma &= 1.735 \pm 0.022,\ 0.423 \pm 0.035 \text{ GeV/c}^2 ; \\ K^- \pi^+ \quad &= 1.677 \pm 0.034,\ 0.205 \pm 0.038 \text{ GeV/c}^2 ; \\ \overline{K}^\circ \pi^- \quad &= 1.678 \pm 0.064,\ 0.454 \pm 0.270 \text{ GeV/c}^2 , \end{aligned}$$

and there is some discrepancy between the two- and three-body measurements —the latter is somewhat higher in mass and wider, though the leading edges are in good agreement. It is most natural to associate the "$K^*(1370)$" with the 2^3S_1 first radial excitation of the $K^*(890)$ and the "$K^*(1680)$" with the 1^3D_1 member of the leading 3^- triplet. With this interpretation, the triplet mass splitting is reasonably small (as seen elsewhere) and the radial excitation decouples from $K\pi$—models[10] have been developed which explain the small coupling of heavy 1^- states to the elastic channel as due to nodes in the radial wave function. One might also speculate that a third state (the 3^3S_1), whose $K\pi$ coupling is similarly suppressed, could explain the discrepancy between the measurements of the "$K^*(1680)$" though a non-resonant background can certainly not be excluded.

Of course, we expect to see a similar pattern of states in the non-strange sector. A recent LASS analysis of reaction (4)[7] gives strong evidence for the existence of a ρ' candidate corresponding to the "$K^*(1370)$." Figure 5 shows the magnitude of the P_+ wave extracted

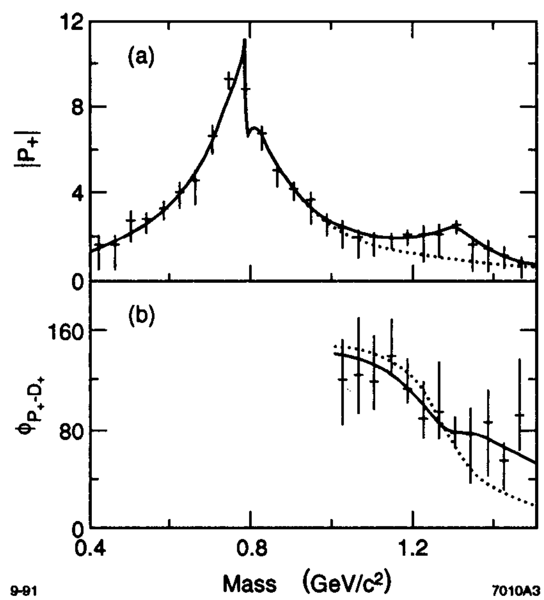

Fig. 5. The magnitude of the P_+ wave from reaction (4) and its phase relative to the D_+ wave. The curves are described in the text.

from this analysis and its phase relative to the D_+ wave. The solid curve is a fit with ρ, ω and a ρ' in the P_+ wave with the D_+ wave fixed to the $f_2(1270)$ parameters.[2] The results of the fit are $M = 1.302^{+0.028}_{-0.025}$ GeV/c^2, $\Gamma = 0.140^{+0.048}_{-0.040}$ GeV/c^2 and the dotted curve shows the effect of omitting this new state, the $\rho'(1300)$. Since the production mechanism is hypercharge exchange, the $\pi\pi$ coupling could be quite small, and indeed this state has not been claimed in analyses of $\pi\pi$ scattering though the most significant data[11] have room for such a state —even a hint of it, since their P-wave fit has some discrepancies in the 1.3 GeV/c^2 mass region which are explicable in terms of a $\rho'(1300)$. There is also evidence for it in the $\pi\pi$ spectra of the $J/\psi \rightarrow \pi^+\pi^-\pi^\circ$ decay reported in this session.[12]

CONCLUSIONS

The "$K^*(1370)$" is a clear candidate for the 2^3S_1 radial excitation of the $K^*(890)$ and the pattern of states compares well with the ρ sector provided the $\rho'(1300)$ is confirmed. However, the latter state is quite controversial; a low-mass ρ' has been claimed many times, but never generally accepted. It has not been clearly identified in other decay modes, and there are some theoretical difficulties in reconciling it with e^+e^- data, which will be reviewed by Prof. Donnachie in this session.[13]

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