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THE STRANGEONIUM SPECTRUM SEEN IN LASS; IMPLICATIONS FOR GLUEBALL SPECTROSCOPY*

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ABSTRACT

The status of strangeonium spectroscopy is re-assessed following our recent high statistics study of K^- induced hypercharge exchange reactions. The implications of our results for the status of glueball, or otherwise exotic, candidates observed in the same decay modes but produced by different mechanisms are also discussed.

INTRODUCTION

As recently as 1986,[1] only the η/η', $\phi(1020)$ and $f_2'(1525)$ were clearly established as $s\bar{s}$ members of complete meson nonets predicted by the quark model. The $\phi_3(1850)$ was a good candidate for the 3^- nonet, although its spin was undetermined. With the exception of the ground state η/η', calculation of the octet-singlet mixing angles gives values close to the magic value of 35°, so that these states have almost pure s quark content. The $f_1(1420)$, or E meson, had been assigned to the $J^{PC}=1^{++}$ nonet, although there was considerable doubt about its spin-parity

EXPERIMENTAL DETAILS

This talk reviews the analyses of three hypercharge exchange reactions from a 4.1 event/nb sample of 11 GeV/c K^-p interactions detected in the LASS spectrometer at SLAC.[2] The spectrometer is situated in a clean RF separated beam, has an efficient trigger for final states with ≥2 charged particles and a flat acceptance over the full solid

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angle. Efficient track–finding and topology reconstruction combined with good particle identification and application of geometric and kinematic constraints at all decay vertices enabled us to find clean data samples of the reactions:

$$K^- p \rightarrow K^- K^+ \Lambda \quad (1)$$

$$K^- p \rightarrow K^0_S K^0_S \Lambda \quad (2)$$

$$K^- p \rightarrow K^{\mp} K^0_S \pi^{\pm} \Lambda \quad (3)$$

In each case, all V^o decay products are fully reconstructed. All these final states are dominated by hypercharge exchange production of a forward meson system at small momentum transfer $t' \equiv |t - t_{min}|$ from the incident beam. Space constraints permit only a brief description of the analyses; further details can be found in Refs 3—4, 5 and 6 for reactions (1), (2) and (3) respectively, and in the talk of Blair Ratcliff[7] elsewhere in these proceedings.

$s\bar{s}$ RESULTS

The production mechanism is extremely important for selecting $s\bar{s}$ states; the meson final state is not necessarily a good indicator. For example, the K^-K^+ spectrum produced in reaction (1) is totally different from that produced at a similar energy by charge exchange with a π^- beam[8]. Hypercharge exchange produces dominantly I = 0 $s\bar{s}$ states in reactions (1—3).

Figure 1 shows the $\bar{K}K$ spectra from reactions (1) and (2); the $f_2'(1525)$ is clearly seen in both reactions and dominates the $K^0_SK^0_S$ spectrum Since there is no Bose–Einstein restriction to even spin, the K^-K^+ spectrum also shows a large $\phi(1020)$ and evidence of the $\phi_J(1850)$. The corresponding Dalitz plots (Fig 2) show that the continuum in K^-K^+ above ~1.7 GeV/c² is largely due to diffractive production of $N^* \rightarrow K^+\Lambda$. As expected, there is no evidence of such a mechanism in Fig. 2b.

Figure 3 shows the results of a spherical harmonic moments analysis in the Gottfried–Jackson frame of the low t' data from reaction (1) above the $f_2'(1525)$. The peak at ~1.85 GeV/c² in the moments up to L = 6 , but not higher, clearly demonstrates that the $\phi_J(1850)$ has spin 3. There is also some activity around 2.2 GeV/c² in all moments up to L = 8 ; moments with L > 8 (not shown) are consistent with zero A complete amplitude analysis of the $\phi_3(1850)$ region at both low and high t' shows that these data are consistent with a simple model where the leading F–wave interferes with an imaginary diffractive background as suggested by the Dalitz plot. Figure 4 shows linear combinations of the moments which in this model are dominated by interferences between the leading F–wave and S, P and D amplitudes. The superimposed curves are a fit to the model which gives $\phi_3(1850)$ parameters consistent with fits to t^0_0 and the F-wave extracted from the amplitude analysis (see Fig. 13 of Ref. 7).

MASTER

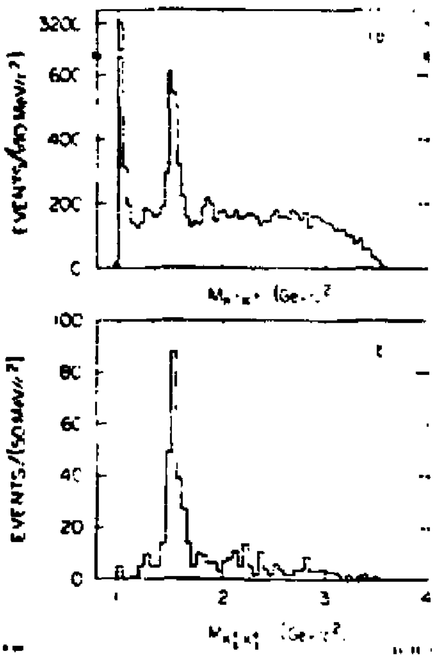

Fig. 1. The $\bar{K}K$ mass spectra from (a) reaction (1) and (b) reaction (2).

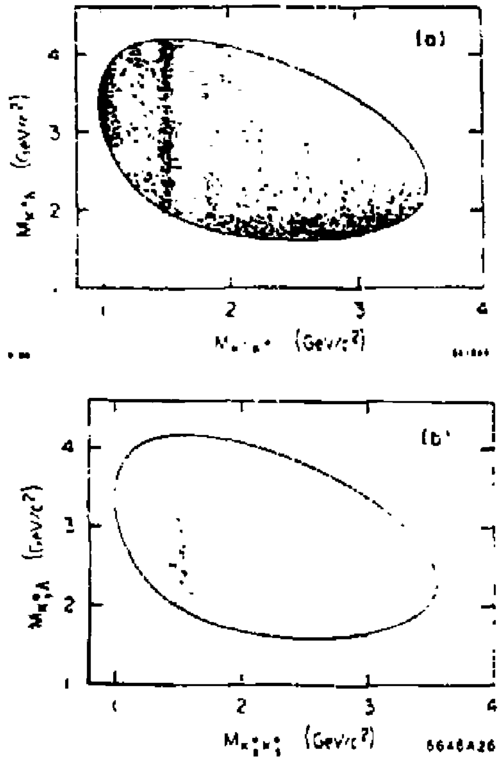

Fig. 2. The Dalitz plots from (a) reaction (1) and (b) reaction (2).

We have extended this model to the high mass data and find that the effect at 2.2 GeV/c^2, as suggested by the vanishing $L > 8$ moments, is consistent with a leading G-wave interfering with a similar background.

Figure 5 shows the constructive interference terms with S, P, D and F amplitudes; their sum (Fig. 14 of Ref. 7) shows a signal in the 2.16—2.28 GeV/c^2 range with significance ~3σ, while the t_7^0 and t_8^0 moments differ from zero by 3.3 and 2.3σ respectively over the same range. Such a $J^{PC} = 4^{++}$ state, the $f_4'(2210)$, has mass and width consistent with those of the X(2220) seen by the Mark III collaboration[9] and fits well as the $s\bar{s}$ member of the 4^+ nonet predicted by the quark model. It should also be noted that our data from reaction (2) in this mass region are consistent with the $K_S^0K_S^0$ spectrum seen by the Mark III and DM2 collaborations in radiative J/ψ decay.

A similar comparison of the low mass spectrum from reaction (2) shows the striking absence of the $f_2(1720)$ from our data, strongly suggesting that this state is not a conventional $s\bar{s}$ meson. Amplitude analysis of the $f_2'(1525)$ region reveals evi-

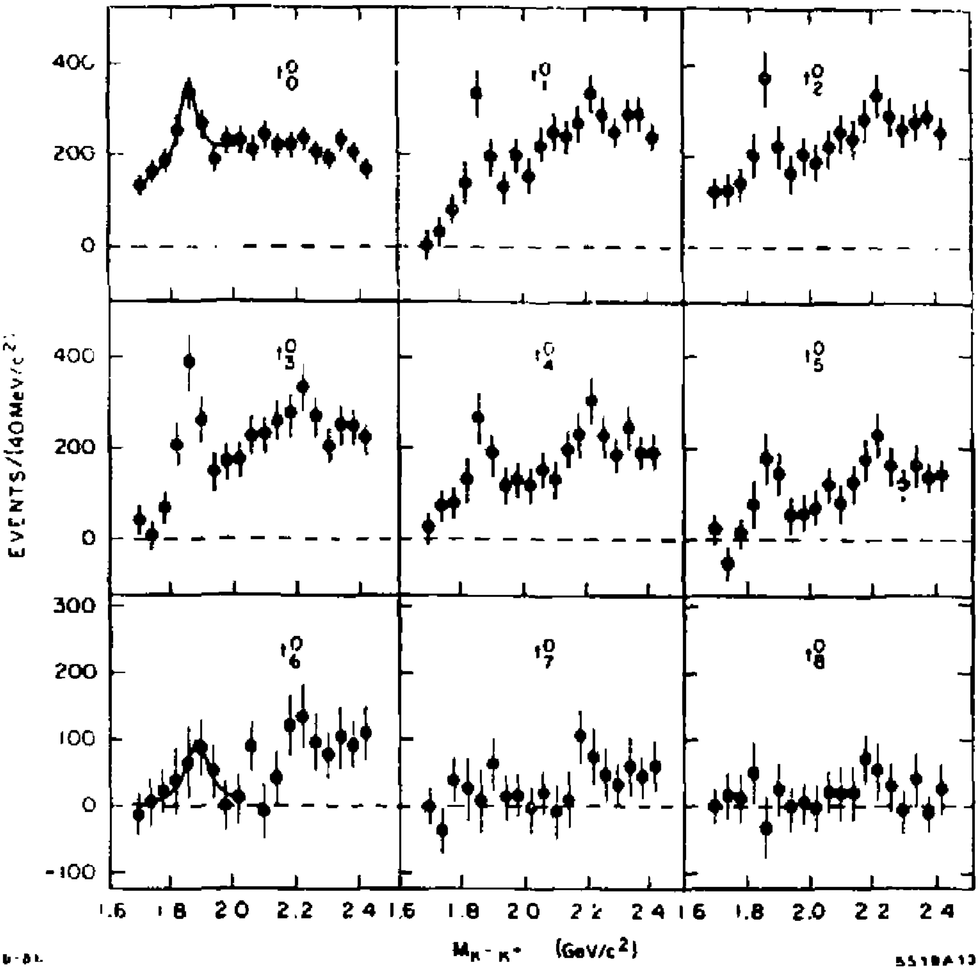

Fig. 3. The unnormalised M = 0 $\bar{K}K$ moments from reaction (1) above the $f_2'(1525)$ with $t' < 0.2(\mathrm{GeV}/c)^2$ required.

dence for an underlying S–wave, shown in Fig. 12a of Ref. 7 which, though poorly measured, is significant at the 5σ level and is produced with a cross–section consistent with expectation for the underlying $s\bar{s}$ 0^{++} triplet state. Finally, the threshold region shown in Fig. 6 has a surprising cluster of six events below $1.03\,\mathrm{GeV}/c^2$. Although not inconsistent with the $f_0(975)$, the pole on the real axis inferred by Au et al [10] from the $\bar{K}K$ and ππ S–wave scattering data provides a better description of these events at the 90% confidence level.

Figure 7 shows the total $\bar{K}K\pi$ mass spectrum from reactions (3). Its dominant features are a sharp rise at K*K threshold and an enhancement in the region of the $f_1'(1530)$ [11] There is little evidence of the $f_1(1420)$ or the η(1440), and just a few

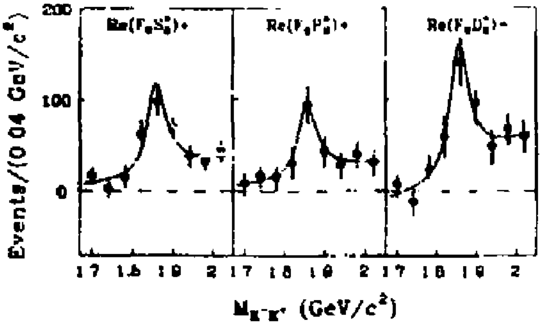

Fig. 4. Moments sums from reaction (1) dominated by leading F–wave interference terms according to the model described in the text.

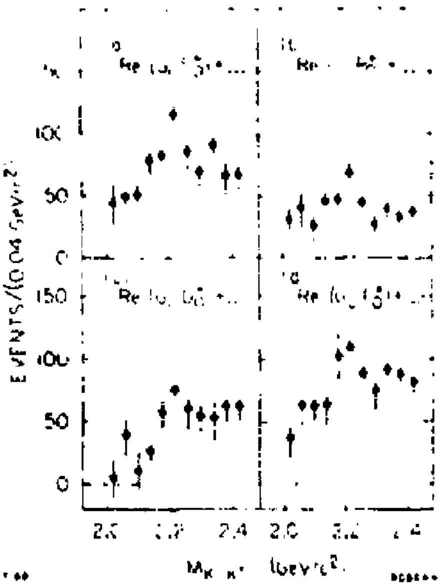

Fig. 5. Moments sums from reaction (1) dominated by leading G–wave interference terms according to the model described in the text

events consistent with the $f_1(1285)$. A three body PWA reveals that production of $J^P=1^+$ K^* waves dominates below 1.6 GeV/c^2. There is evidence of interference between the K^* bands which begins destructively at K^*K threshold, but becomes constructive by ~1.46 GeV/c^2. This effect is seen quite clearly in the Dalitz plots of Fig. 8 and was also present in the data of Ref. 11. By combining the 1^+ waves into G–parity eigenstates (see Fig. 15 b–c of Ref 7) and using the fact that C = G for I = 0 states, we infer the existence of a $J^{PC}=1^{+-}$ $s\bar{s}$ state, the $h_1'(1380)$, right at K^*K threshold and confirm the 1^{++} $f_1'(1530)$. These states complete the two 1^+ nonets expected in the quark model and are consistent with having large $s\bar{s}$ content. It is intriguing that if we then assume magic mixing for these nonets, the calculated masses of the K_1 states are very close to the physically observed masses.

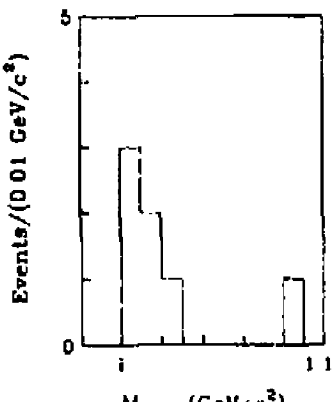

Fig. 6 The KK threshold region of reaction (2)

CONCLUSIONS

The leading natural J^P nonets up to 4^+ all now have good candidates for their mainly $s\bar{s}$ members; in each case the masses are consistent with magic mixing. There are also now two strong candidates to be the strangeonium members of the 1^+ nonets, the $f_1'(1530)$ and $h_1'(1380)$. The possibility of an $s\bar{s}$ scalar underneath the $f_2'(1525)$ suggests a normal pattern of mass splittings for this nonet also. However, there are too many 0^+ mesons! The X(2220) may well be a conventional $s\bar{s}$ state, but there is strong evidence that the $f_1(1420)$, $\eta(1440)$ and $f_2(1720)$ are not.

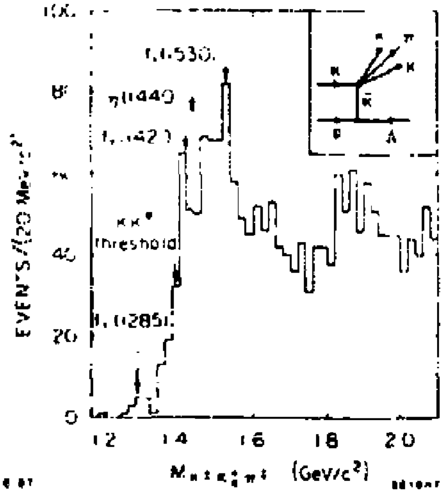

Fig. 7. The $\bar{K}K\pi$ mass spectrum from reactions (3).

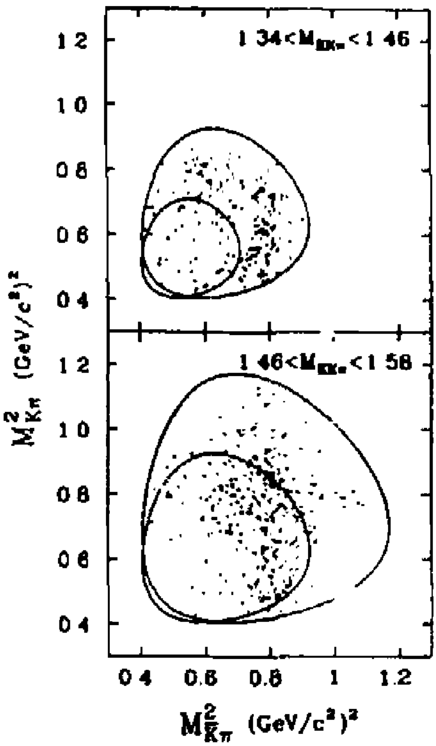

Fig. 8. $\bar{K}K\pi$ Dalitz plots from reactions (3) near K^*K threshold.

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