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STRANGEONIUM PRODUCTION FROM LASS*

D. ASTON[1], N. AWAJI[2], T. BIENZ[1‡], F. BIRD[1], J. D'AMORE[3], W. DUNWOODIE[1], R. ENDORF[3], K. FUJII[2], H. HAYASHII[2], S. IWATA[2], W. B. JOHNSON[1], R. KAJIKAWA[2], P. KUNZ[1], Y. KWON[1], D. W. G. S. LEITH[1], L. LEVINSON[1], J. MARTINEZ[3], T. MATSUI[2], B. T. MEADOWS[3], A. MIYAMOTO[2], M. NUSSBAUM[3], H. OZAKI[2], C. O. PAK[2], B. N. RATCLIFF[1], P. RENSING[1], D. SCHULTZ[1], S. SHAPIRO[1], T. SHIMOMURA[2], P. K. SINERVO[1], A. SUGIYAMA[2], S. SUZUKI[2], G. TARNOPOLSKY[1], T. TAUCHI[2], N. TOGE[1], K. UKAI[4], A. WAITE[1], S. WILLIAMS[1]

[1] Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94305, USA
[2] Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464, Japan
[3] University of Cincinnati, Cincinnati, Ohio 45221, USA
[4] Institute for Nuclear Study, University of Tokyo, Midori-cho, Tanashi, Tokyo 188, Japan

Results from recent studies of strangeonium mesons produced in the LASS spectrometer by an 11 GeV/c K^- beam are presented. Data from new analyses of $K^*\bar{K}^*$, $\phi\phi$, and $\eta\pi\pi$ final states are described. Comparisons are made with results from other hadroproduction, radiative J/Ψ decay, and $\gamma\gamma$ experiments.

1. INTRODUCTION

While the strange meson spectrum is quite well understood, with a large number of states known, the details of the strangeonium spectrum are much less certain, and only a handful of states have been confirmed. This, in itself, is a motivation for studying strangeonium spectroscopy. In addition, a number of final states in which exotics are claimed are also final states in which strangeonia would be expected. Thus, it is important to understand the strangeonium spectrum in order to sort out candidates for exotics.

This talk describes the results of analyses of data taken with the LASS spectrometer using a clean RF-separated 11 GeV/c K^- beam. The spectrometer, described in detail elsewhere,[1] has nearly flat acceptance over the entire 4π solid angle, and an interaction trigger which is very efficient for events with at least two charged tracks in the final state. The data sample used in these analyses consists of ~1.13×10^8 K^-p interactions.

Analyses of several strangeonium channels from this experiment have already been published. These analyses included

$$K^-p \rightarrow K^0_S K^0_S \Lambda \quad [2] \tag{1}$$

$$K^-p \rightarrow K^+K^-\Lambda \quad [3,4] \tag{2}$$

$$K^-p \rightarrow K^0_S K\pi\Lambda \quad [5] \tag{3}$$

and will not be discussed further here. This talk concentrates on the final results of recent analyses of the reactions[6]

$$K^-p \rightarrow \eta\pi^+\pi^-\Lambda \tag{4}$$

$$K^-p \rightarrow K^*\bar{K}^*\Lambda \tag{5}$$

$$K^-p \rightarrow \phi\phi\Lambda \tag{6}$$

Preliminary results from these channels have been presented earlier.[7]

2. $s\bar{s}$ SPECTROSCOPY

Although reaction (4) is not as obvious a strangeonium channel as others, the nonet containing the η is not ideally mixed, giving the η some admixture of $s\bar{s}$. In addition, $\Lambda\eta\pi\pi$ is of interest because it is potentially a good channel in which to study the

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‡ Presented by T. Bienz

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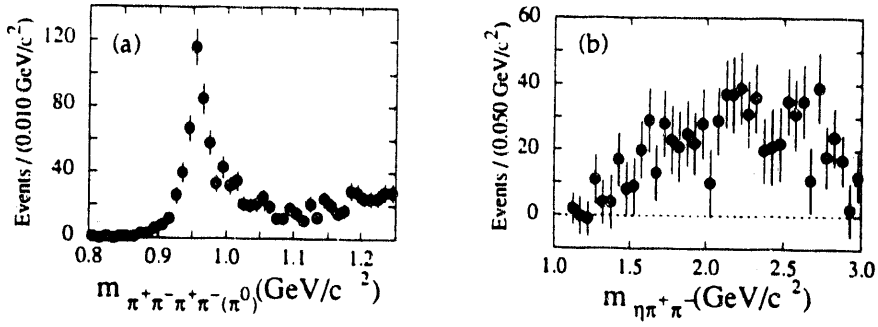

FIGURE 1. Observed $\eta\pi\pi$ mass spectrum from reaction (4); (a) η' region; (b) the remaining spectrum, with the η' removed, and with an η sideband subtraction.

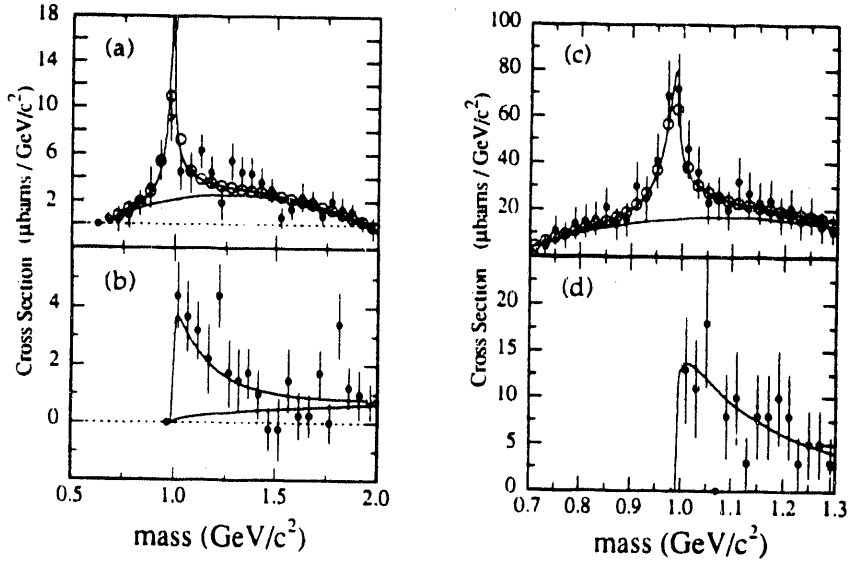

FIGURE 2. Acceptance-corrected mass spectra for the $a_0(980)$ event sample recoiling against a $\Sigma(1385)^+$; (a) LASS $\eta\pi^-$; (b) LASS $K^0_S K^-$; (c) 4.2 GeV/c $\eta\pi^-$; (d) 4.2 GeV/c $K^0_S K^-$. The curves show a Flatté model fit to all four spectra simultaneously, plus a phase space background. The open circles in (a) and (c) are the integrated values of the curve in each mass bin, after smearing for resolution.

$a_0(980)$, an object that is not well-understood, but which is known to decay to $\eta\pi$ and $K\bar{K}$. The observed $\eta\pi\pi$ mass spectrum from reaction (4), shown in Figure 1, is dominated by the well-known η'. If this is removed, the remaining $\eta\pi\pi$ events show no obvious structure, as can be seen in Figure 1b. Subsequent analysis shows that the small excess around 1.285 GeV/c^2 is consistent with being approximately six events produced by the known decay $f_1(1285) \rightarrow a_0\pi$.

Selection of the $\Lambda\pi^+$ mass region around the $\Sigma(1385)^+$ produces the recoil $\eta\pi^-$ spectrum shown in Figure 2a. This spectrum exhibits peaking in the region of the $a_0(980)$, but little obvious structure in

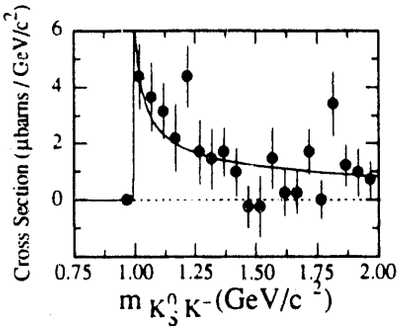

FIGURE 3. $K\bar{K}$ molecule model fit to LASS $K^0_S K^-$ data.

the region of the $a_2(1320)$, which also has a known $\eta\pi$ decay mode.

There are a number of models which attempt to describe the a_0; the simplest is that of Flatté,[8] which describes the a_0 as a single inherently broad resonance that appears narrow in $\eta\pi$ due to $K\bar{K}$ threshold effects. Since an earlier 4.2 GeV/c bubble chamber experiment used $\eta\pi$ and $K\bar{K}$ data to study a_0 production in K^-p interactions,[9] it is interesting to compare their data with the data from LASS. This can be done by performing a simultaneous fit to the $K\bar{K}$ and $\eta\pi$ data from both experiments. The results, shown in Figure 2, indicate that the Flatté model provides a reasonable description of the data from both experiments. One of the parameters of the fit is the relative coupling of the a_0 to $K\bar{K}$ and $\eta\pi$, $g_{K\bar{K}}^2/g_{\eta\pi}^2$. The value obtained from the fit for this ratio is $2.4\ ^{+1.1}_{-0.7}$. The expectation from SU(3) depends on the mixing assumed for the nonet containing the η. If the singlet-octet mixing is ignored, the SU(3) expectation is 3/2, while if a singlet-octet mixing angle of -19.5° is used, the expectation is ~3/4. The latter approach works extremely well in explaining the branching fractions of various K^*'s to $K\eta$.[10] In either case, it appears that the $a_0(980)$ couples somewhat more strongly to $K\bar{K}$ than SU(3) predicts. Finally, models of the $a_0(980)$ as a $K\bar{K}$ molecule have been proposed.[11] The $K\bar{K}$ molecule model also fits the LASS data well, as can be seen in Figure 3, and requires no background term. This model, however, currently makes no prediction about the $\eta\pi$ spectrum.

Studies of the $K^*\bar{K}^*$ system have been carried out in radiative J/Ψ decay,[12,13] two-photon interactions,[14,15] and central production in pp interactions.[16] All groups see the same qualitative structure; a broad enhancement several hundred MeV/c² above threshold, and no other significant structure. After performing an angular analysis, the Mark III group, analyzing $K^*\bar{K}^*$ in radiative J/Ψ decay, claims the enhancement is J^{PC} 0^{-+}. The WA76 group, using pp central production data, claim that the structure has flat angular distributions, and is therefore consistent with being a threshold enhancement. In this experiment, independent analyses were carried out using the charged ($K^0_S\pi^+K^0_S\pi^-$) and neutral ($K^+\pi^-K^-\pi^+$) decay modes. Mass spectra from the various experiments are shown in Figure 4. The independent analyses of the charged and neutral decay modes in LASS provide measurements of the cross section below 3.0 GeV/c² of 3.7±1.0 μbarns and 3.4±0.2 μbarns, respectively. If the threshold enhancement in the LASS neutral $K^*\bar{K}^*$ sample is assumed to be a single resonant object, and fitted with an S-wave relativistic Breit-Wigner, the resonance has a mass of 1.950±0.015 GeV/c², and a width of 0.25±0.05 GeV/c².

An angular analysis, similar to the Mark III analysis, and based on the method of Trueman,[17] and Chang and Nelson,[18] was performed under the assumption that the enhancement was dominated by a single J^{PC}. While the angular distributions, like those in WA76, are consistent with being flat, this can arise from several J^{PC} possibilities. The results of an angular analysis of the low mass region (Table 1) show that the statistics are not sufficient to determine a unique J^{PC} for the threshold enhancement, but that 0^{-+} is strongly disfavored, and 1^{+-}, 2^{-+}, and 2^{++} are slightly favored. Although it is not possible, using the present data, to estab-

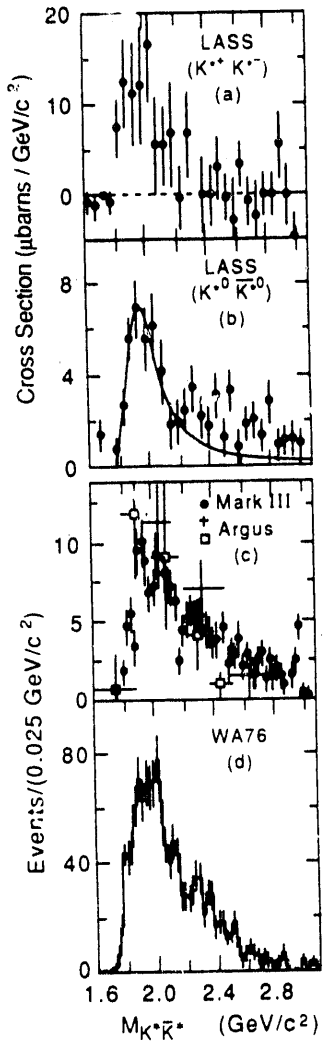

FIGURE 4. $K^*\bar{K}^*$ mass spectra from; (a-b) reaction (5), LASS; (c) radiative J/Ψ decay from MARK III and 2γ production from ARGUS; (d) central production in pp collisions, WA76. The curve on (b) is an S-wave relativistic Breit-Wigner fit to the 1.75–2.20 GeV/c^2 mass region.

lish whether or not the object is resonant, analysis of the Gottfried-Jackson angle indicates that the threshold enhancement populates all angles, as would be expected of a resonance, but not of a kinematic reflection.

TABLE 1. Results of an angular analysis of the $K^*\bar{K}^*$ system in reaction (5), using neutral K^*.

J^{PC}	Confidence Level
0^{++}	0.073
0^{-+}	6.9×10^{-4}
1^{++}	0.053
1^{+-}	0.86
1^{-+}	0.053
1^{--}	0.47
2^{-+}	0.90
2^{--}	0.29
2^{+-}	0.053
2^{++}	0.88

The $\phi\phi$ system is of interest because it is the system in which a group using the MPS spectrometer at Brookhaven claim between one and three $J^{PC} = 2^{++}$glueballs.[19,20] Previous studies of the $\phi\phi$ system in K^-p interactions have been carried out,[21,22] but suffered from low statistics, and no angular analyses were carried out. Finally, a recent Mark III analysis in radiative J/Ψ decay[23] claims a 0^{-+} signal in the threshold region.

The $\phi\phi$ system in reaction (6) has been studied in the final state where both ϕ's decay via the K^+K^- decay mode. The mass spectra from various experiments are shown in Figure 5. The total cross section for reaction (6) in this experiment is 530±80 nanobarns. An angular analysis similar to that performed on the $K^*\bar{K}^*$ reaction has also been carried out. Because of the low statistics, the entire mass spectrum was analyzed at once. The results of the analysis, shown in Table 2, are inconclusive due to the limited statistics. Nevertheless, 0^{-+} is again disfavored if the entire mass spectrum is dominated by a single J^{PC}.

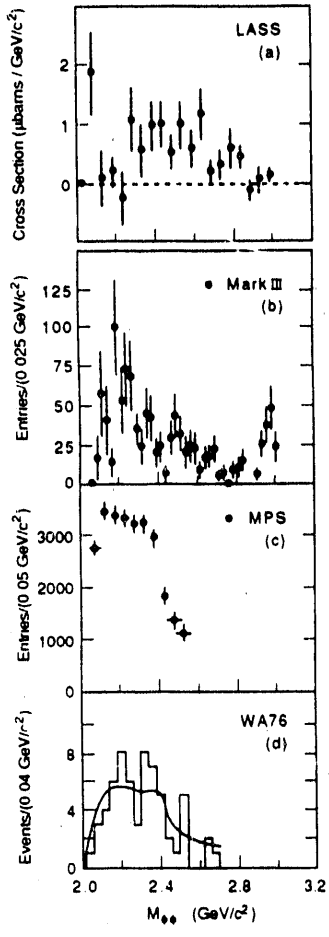

FIGURE 5. $\phi\phi$ mass spectra from; (a) reaction (6), LASS; (b) radiative J/Ψ decay, MARK III; (c) π^-p interactions, MPS spectrometer; (d) central production in pp interactions, WA76.

3. CONCLUSIONS

LASS data has improved the understanding of the strangeonium spectrum, and provided hints of interesting structure in $\eta\pi\pi$, $K^*\bar{K}^*$, and $\phi\phi$. Comparisons with data from other experiments have shown that similarities in mass distributions are not always echoed by similarities in the angular distributions, and hence the underlying J^{PC} structure. Analyses of $\eta\pi\pi$, $K^*\bar{K}^*$, and $\phi\phi$ were strongly limited by statistics. Higher statistics, like those obtainable in the proposed KAON facility[24], would be extremely helpful in sorting out the spectroscopy. A prediction of the $\eta\pi$ mass spectrum from the $K\bar{K}$ molecule model would also be helpful in understanding the $a_0(980)$.

TABLE 2. Results of an angular analysis of the $\phi\phi$ system in reaction (6).

J^{PC}	χ^2 / DOF
0^{++}	1.23
0^{-+}	3.75
1^{++}	1.00
1^{-+}	1.00
2^{-+}	1.39
2^{++}	1.28

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