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Preliminary Partial-Wave Analysis of the $K^+K^0_S\pi^-$ System Produced in 8 GeV/c K^-p Interactions

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We have performed a partial-wave analysis of the $K^+K^0_S\pi^-$ system produced in the reaction $K^-p \rightarrow K^+K^0_S\pi^-\Lambda/\Sigma$ at 8 GeV/c. We present results of a preliminary analysis of approximately 2000 events in the $K\bar{K}\pi$ mass range 1.24 - 1.64 GeV, with $0.0 < -t < 1.4$ GeV^2. In the 1.28 GeV mass region, we observe a small $J^{PG} = 0^{-+}$ contribution but little indication of a 1^{++} wave. We observe a large enhancement of events at the threshold of $K\bar{K}^*$ production. Above this threshold the $J^{PG} = 1^{+-}$, 1^{++} and 0^{-+} waves all contribute, and we see evidence for a 1^{+-} resonance below the $K\bar{K}^*$ threshold.

We report the results of a preliminary partial-wave analysis of the $K^+K^0_S\pi^-$ system produced in the reaction $K^-p \rightarrow K^+K^0_S\pi^-\Lambda/\Sigma$ at 8 GeV/c. The data were taken with the MPS-II spectrometer at Brookhaven National Laboratory as part of a comprehensive study of $K^+K^0_S\pi^-$ states produced by K^-, π^- and $\bar{p}$ beams[1,2,3]. Partial wave fits to the π^- data[3] have already been published.

A schematic view of the apparatus is shown in Figure 1. The MPS facility was operated with a field of 0.5 tesla and a complement of 7 drift chamber modules, totalling 49 measuring planes, and 3 proportional chambers that were used in the triggering. A large high pressure segmented threshold Cerenkov counter (C1) located downstream of the MPS distinguished pions from heavier particles for momenta above 1.5 GeV/c. The trigger consisted of two parts: (i) a multiplicity (MULT) trigger to enhance the sample of K^0_S decays and (ii) a fast forward positive particle (FFP) trigger satisfied by a downstream particle heavier than a pion (i. e. a K^+ candidate). The MULT trigger required ≥ 2 particles in proportional chamber P0 and ≥ 4 in chamber P2. The FFP trigger required the downstream particle to satisfy preselected combinations of PWC wires and hodoscope elements stored in a fast RAM memory. The combinations corresponded to the trajectories of positive particles of momenta greater than 1.5 GeV/c originating in the 60 cm hydrogen target. In addition the FFP trigger required that the appropriate cell of the segmented Cerenkov counter C1 not fire. A high resolution time of flight system (σ

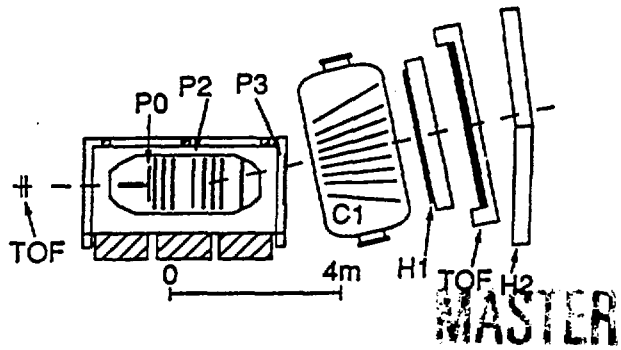

FIGURE 1
Schematic View of the MPS-II Configured for E771

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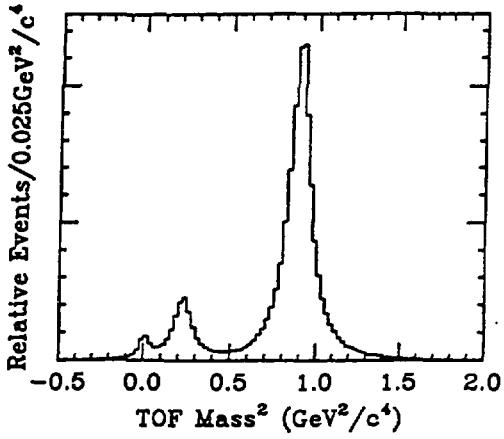

FIGURE 2
TOF Mass Squared Spectrum

= 150 ps) consisting of a 4-element hodoscope located upstream of the hydrogen target and a 32-element downstream hodoscope was used to separate kaons from protons off line ($0.0 < m_K^2 < 0.5$ GeV^2). The small admixture of pions in the TOF spectrum shown in Figure 2 are at very low momentum and were removed by a momentum cut.

The raw data sample of approximately 10^7 triggers was obtained with an exposure of 15 inverse picobarns. The results presented here are based on approximately 90% of the total sample. The data processing required that the events pass several stages of analysis. In the first stage, hits in the detectors were converted to real space coordinates, associated into tracks and assigned the measured three momenta and positions. In addition a production vertex, a K^+ candidate, and at least 4 tracks were required. Approximately 30% of the events survived this stage of processing.

A second stage required that a decay vertex consistent with the K^0_S mass ($0.475 < m_{\pi\pi} < 0.525$ GeV, see Figure 3a) be at least 2 cm downstream of the production vertex, that the K^0_S momentum point back to the production vertex, and that an additional negative particle be on the production vertex. It also required that there be sufficient TOF information to calculate a mass for the K^+ candidate. Approximately 150,000 events passed this stage. The final processing stage required a positive identification of the K^+ by the TOF. We required the K^+ candidate to be incompatible with the decay $\phi \rightarrow K^+ K^-$, and we also excluded K^0_S candidates that satisfied a Λ decay hypothesis. No missing mass cuts were applied at this stage. A total of 9285 events survived all cuts and were written on the data summary tapes.

A sample of 2700 events consistent with the reaction $K^-p \rightarrow K^+K^0_S \pi^- \Lambda/\Sigma$ were selected by requiring the missing mass squared to be between 0.8 GeV^2 and 1.8 GeV^2 and -t to be < 1.4 GeV^2. The missing mass squared spectrum is shown in Figure 3b. The raw $K^+K^0_S \pi^-$ mass spectrum of these events plotted in 10 MeV bins is shown in

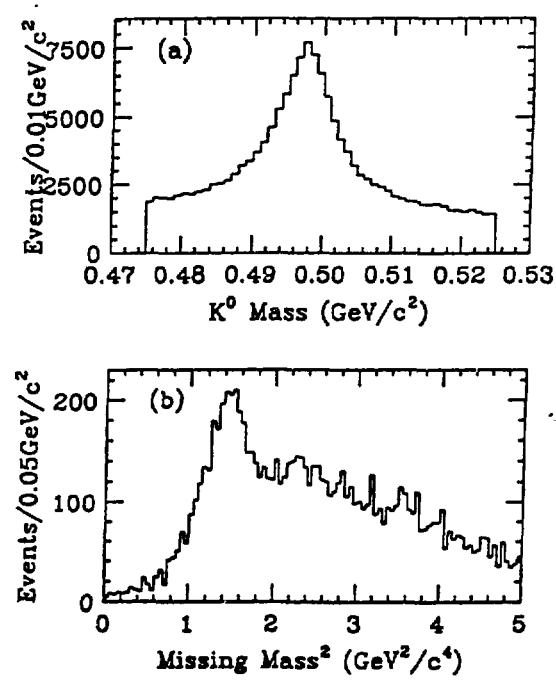

FIGURE 3
(a) $\pi^- \pi^+$ Mass spectrum; (b) Missing Mass Square

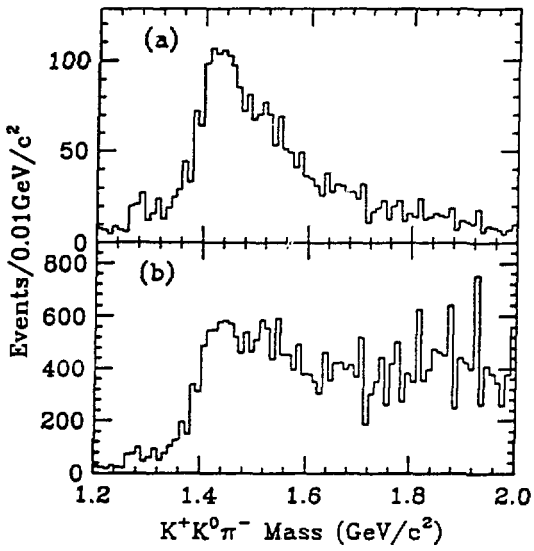

FIGURE 4
(a) $K^+K^0_S\,\pi^-$ mass spectrum, (b) same corrected for phase space

Figure 4a and the corresponding acceptance corrected spectrum in Figure 4b. It is to be emphasized that this spectrum is corrected for phase space only --- it is not the result of a PWA fit. The shape of the spectrum is similar to that reported by LASS[4] for the same reaction at 11 GeV/c and by Ph. Gavillet et al.[5] at 4.2 GeV/c.

The spectra show a strong enhancement at the threshold for KK^* production at 1390 MeV. As compared to our previously published π^- beam data, there are relatively few events in the 1280 MeV mass region. In the region near 1530 GeV there is only a hint of an enhancement in the raw data.

A preliminary partial wave analysis of this data was performed. (A complete partial wave analysis of this data is underway.) The $KK\pi$ system was described as a superposition of states characterized by spin, parity, and G parity, J^{PG}, the projection of spin on the quantization axis, M (≥ 0), and reflectivity (naturality of the exchanged particle), η. We applied the parametrization of the spin-density matrix of Chung and Trueman[7] which ensures that the conditions of positivity, parity conservation, and rank 2 are automatically satisfied with the minimum number of parameters.

We assumed that the final three-meson system is produced in a two-step process involving two isobars: $K^*(890)$ and $a_0(980)$. For a given $KK\pi$ mass, the state is fully specified by five variables: the isobar mass and the polar and azimuthal angles for the primary and secondary decays. We also allowed for an incoherent isotropic background. A PWA program written specifically for this experiment was used. This program uses the extended maxium-likelihood method and includes the effect of finite acceptance in the normalization integrals.

In this preliminary fit to the data the waves $J^{PG} = 0^{-+}, 1^{++}, 1^{+-}$ and 1^{-+} were found to be important in various regions of $K^+K^0_S\,\pi^-$ mass. For each wave

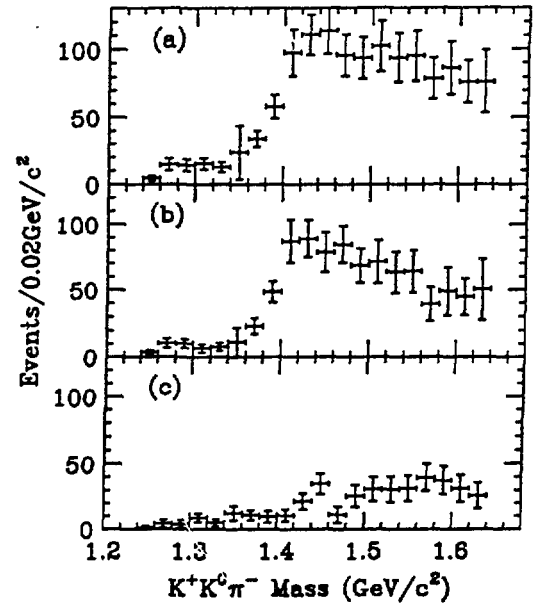

FIGURE 5
Relative number of events in (a) total, (b) partial waves, (c) background term

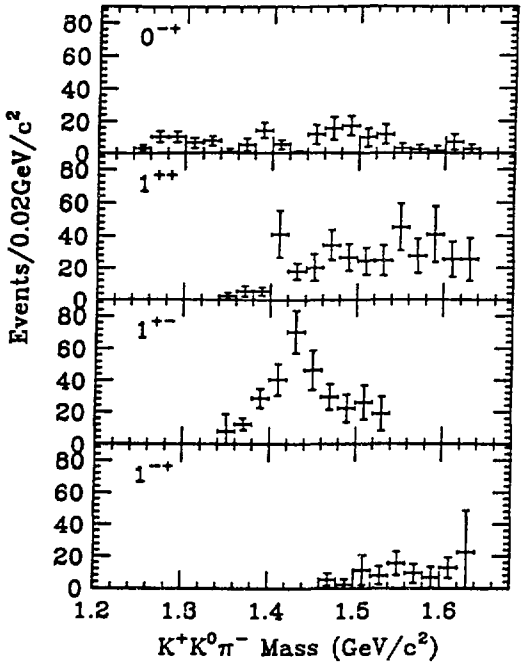

FIGURE 6

Relative number of events in J^{PG} = (a) 0^{-+}, (b) 1^{++}, (c) 1^{+-}, (d) 1^{-+}

in each mass region not all possible combinations of isobar, M and η were found to be significant. For example, the $J^{PG} = 0^{-+}$ wave in the K^*K channel was found to be small and only the decay channel $a_0(980)$ is present in this fit. For $J^{PG} = 1^{++}$ we found that the contribution of $a_0(980)$ to the fit was small. The waves used in this preliminary fit are summarized in Table 1. In addition an incoherent isotropic background was used in the fit.

J^{PG}	M	η	isobar	mass range (GeV)
0^{-+}	0	+	a_0	all
1^{++}	0	+	K^*	mass > 1.34
1^{++}	1	+	K^*	mass > 1.46
1^{++}	1	-	K^*	mass > 1.46
1^{+-}	0	+	K^*	1.34 < mass< 1.54
1^{+-}	1	+	K^*	1.34 < mass< 1.54
1^{-+}	0	-	K^*	mass > 1.46

TABLE 1

Partial waves used in preliminary fit

The analysis was carried out on 2043 events in 20 MeV bins over the mass range 1.24 - 1.64 GeV. The relative number of events attributed to the waves used in the fit and to the background term are shown in Figure 5. The relative number of events in the four J^{PG} partial waves used are shown in Figure 6. The contrast to our π beam data is striking. In this fit we see evidence for a small $J^{PG} = 0^{-+}$ contribution in the 1.28 GeV mass region, while the 1^{++} wave was small enough to be turned off . This is to be compared with our π data where we observed a prominent peak at 1.28 GeV that is dominated by the 1^{++} wave. This is consistent with little or no $s\bar{s}$ content in the $f_1(1285)$. The π data also showed an indication of 0^{-+} in this mass region.

We observe a large enhancement of events at the threshold of KK^* production. Above this threshold the $J^{PG} = 1^{+-}$ and 1^{++} waves dominate with the 1^{+-} wave the most important in the 1420 - 1460 MeV mass region. In our π data the 0^{-+} and 1^{++} waves contributed most significantly above the threshold

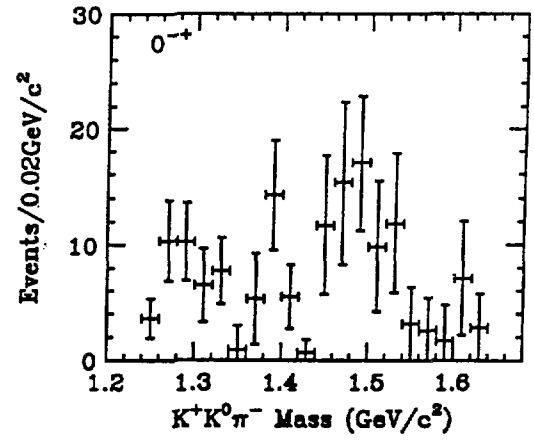

FIGURE 7

Relative number of events for $J^{PG} = 0^{-+}$

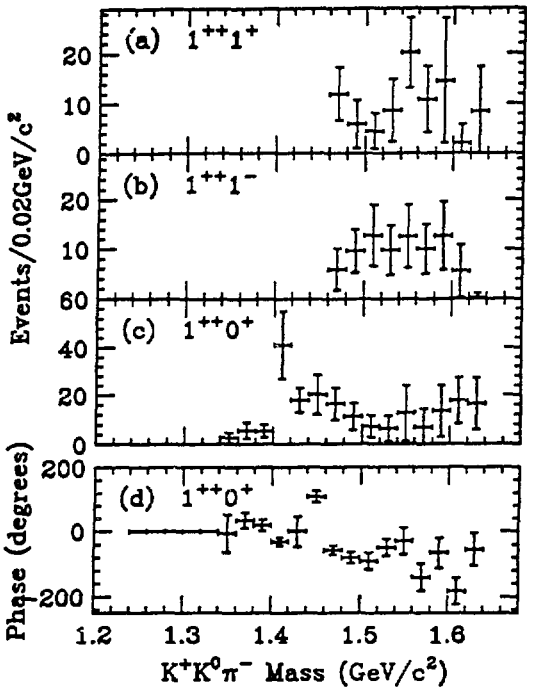

FIGURE 8

(a) - (c) Relative number of events for 1^{++} partial waves, (d) phase of 1^{++} 0^+ K^* vs 0^{-+} 0^+ a_0

with the 0^{-+}, showing the strongest intensity, while the 1^{+-} wave was relatively weak.

The $J^{PG} = 0^{-+}$ partial wave is shown in expanded scale in Figure 7. There is an indication of 2 peaks in the 1400 MeV mass region. The low bin at 1430 Mev has persisted throughout many fits.

The $J^{PG} = 1^{++}$ partial wave intensities for the 3 M^m combinations are shown in Figures 8a-8c, and the phase variation of the $1^{++}0^+$ wave relative to the 0^{-+} 0^+ a_0 partial wave in Figure 8d. The generally decreasing phase of the 1^{++} 0^+ partial wave may be interpreted as evidence supporting resonance behavior in the 0^{-+} wave in this mass region. In the region around 1530 MeV this preliminary fit shows very little indication of the $f_1(1530)$.

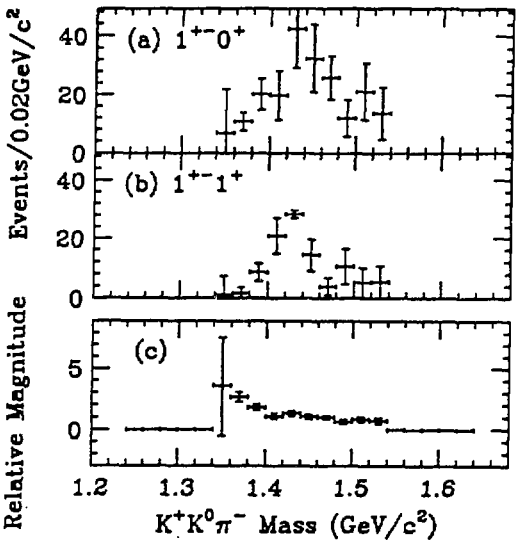

FIGURE 9

Relative number of events (a) $1^{+-}0^+$, (b) $1^{+-}1^+$, (c) relative magnitude of the complex $1^{+-}0^+$ amplitude

Figures 9a and 9b show the relative number of events in the $J^{PG} = 1^{+-}0^-$ and $1^{+-}1^+$ partial waves and Figure 9c shows the relative magnitude of the complex $1^{+-}0^+$ amplitude. From Figure 9 we see that the $1^{+-}0^-$ is stronger than the $1^{+-}1^+$. The $1^{+-}1^+$ was found to be small and is turned off in this preliminary fit. Finally the shape of the magnitude of the complex amplitude (Figure 9c) is consistent with a $J^{PG} = 1^{+-}$ resonance existing below the KK^* threshold. A similar threshold behavior of the 1^{+-} partial wave has been reported by the LASS group.

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