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SEARCH FOR NEW $\bar{S}\bar{S}$ STATES IN THE K^- INDUCED K^+K^- SYSTEM

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ABSTRACT

Results from the first PWA of the K^+K^- system produced by incident K^- , are presented in the mass range from the threshold to 1.70 GeV. In the P and D waves only the ϕ and f' mesons are observed and their production mechanism studied. A broad S-wave peaking at 1.4 GeV is observed but the lack of information about its phase makes the search for new 0^{++} mesons inconclusive.

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1. Introduction

In this paper we present a P.W.A. of the K^+K^- system produced in the reaction

$$K^-p \rightarrow K^-K^+ (\Lambda/\Sigma^0) \quad (1)$$

at 18.5 GeV/c.

This analysis is part of a more general systematic search for ϕ -like mesons produced in K^-p hypercharge exchange reactions. It is well known⁽¹⁾ that in reaction (1) the production of mesons with a rich content of $s\bar{s}$ quarks is strongly enhanced with respect to mesons made of u and d quarks. A preliminary study showing the existence of a $J^{PC} = 3^{--}$ state has already been published⁽²⁾. In this paper we present the first detailed study of the lower mass region ($.980 \leq M(K^+K^-) \leq 1.7$ GeV) and results about the search for non leading states. Present strong interaction phenomenology opens a wide range of possible interpretation for these states: glueballs, radial excitations, exotics and also missing $q\bar{q}$ states. As an example the existence of a new $s\bar{s}$ $J^{PC} = 0^{++}$ meson with mass similar to that of the f' is required by a model⁽³⁾ which identifies the other components of a magically mixed 0^{++} $q\bar{q}$ nonet with the mesons $\delta'(1300)$, $\epsilon(1300)$, $\kappa(1350)$. This model also interprets the lower mass scalar waves ($\delta(980)$, $\epsilon(700)$, $S^*(975)$, $\kappa(1200)$) as members of an exotic $qq\bar{q}\bar{q}$ nonet.

Furthermore the existence of a vector meson, corresponding to the first radial excitation of the ϕ , at about the mass of the f' , is required by models⁽⁴⁾ which, as suggested by QCD, use a combination of a linear and a Coulomb potential between quarks to interpret the spectrum of known mesons. On the contrary models which make use of a harmonic potential predict such a state around 1.8 GeV⁽⁵⁾.

Section 2 describes the experimental set up and the trigger, section 3 illustrates the data handling and the selection of reaction (1). The P.W.A. technique and the results are given in section 4, and the conclusions in section 5.

2. The apparatus and the trigger

2.1 . The experimental set-up.

A schematic view of the spectrometer is shown in Fig. 1. The RF separated S1 beam located in the West Area of CERN was tuned to K^- 's of 18.5 GeV/c. A typical intensity of $2 \cdot 10^5$ K^- /burst was used (1% momentum bite) corresponding to a total beam intensity of $5 \cdot 10^5$ /burst.

The K^- 's are identified by means of a differential Cerenkov counter (CEDAR), their momenta are measured with precision of 0.3 % by a spectrometer located in the beam line and their angles are determined by a set of 5 MWPC's placed upstream of the target. More details on the properties of the beam can be found in reference (6).

A set of scintillation counters $S_1 V_1 S_2 S_3 V_3 V_B$ is used to define an interacting beam particle. The 60 cm long H_2 target, located in the Ω' (7) magnet is surrounded by a 24 element barrel scintillator counter (TS) and by four lead scintillator counters ($V_4, \dots, V_7$). These counters flagged charged particles and γ 's emitted at large angle, but were not used in the trigger.

Immediately following the target box a two-plane (y,z) 500 μ m MWPC (HPC1) is present. It is used in conjunction with the barrel counter to measure the charged multiplicity around the target. Tracks of the charged particles in the magnetic field are recorded by 6 two-plane (u/v, y) (+) MWPC's (B chambers) and by 5 three-plane (u, y, v) MWPC's (A chambers) (7). For part of the run the most downstream A chamber was replaced by a three plane (y, z, u) chamber. To improve the momentum measurement of fast tracks two large drift chamber modules (DC1, DC2) consisting of 4 planes each (y, u, v, y) were placed in the fringe field of the magnet. The bending power of the Ω' field deflects low transverse momentum ($|P_y| \leq 1.5$ GeV/c) positive particles on one side (positive side) and negative particles on the other one (negative side).

Following the magnet a multicell atmospheric pressure Cerenkov counter (C1) filled with Freon, giving a pion threshold at 2.6 GeV/c, is sandwiched

(+) y are planes of vertical wires and u/v are planes of inclined wires at $\pm 10.14^\circ$ to the vertical.

between two hodoscopes (H1 and H2). Light from the C1 cells is viewed by 32 photomultipliers, 16 above and 16 below the median plane. Secondary tracks coming from the target give signals in up to four photomultipliers (PM). Only the signals from the PM's placed on the positive side are used in the trigger. Signals from up and down elements are OR-ed in the trigger logic. H1 consists of 16 partly overlapping vertical elements which after decoding are equivalent to 31 channels (6cm wide). The hodoscope covered only the positive side. The second hodoscope (H2) consists of 37 partly overlapping elements and covers both sides of C1. The information from these elements, once decoded, is equivalent to 62 elements, 31 placed on the positive and 31 on the negative side.

Following H2 a second multicell atmospheric Cerenkov counter C2 filled with nitrogen, giving a pion threshold at 5.6 GeV/c, is present. It is viewed by 30 photomultipliers placed above and below the median plane. Only elements on the positive side are used in the trigger.

The last element of the spectrometer consists of two scintillator hodoscopes H3 and H4 separated by a sheet of lead (1.5 cm thick). H3 consists of 30 elements (20 cm wide) placed above and 30 elements placed below the median plane. Similarly H4 has 28 elements (38 cm wide), 14 above and 14 below. Signals from the hodoscope H4 in anticoincidence with signals from the corresponding elements of H3 are used to veto events with forward γ 's.

2.2. The trigger

The trigger was designed to select K^- interactions in the hydrogen target with a K^+/p in the final state with momentum bigger than 2.6 GeV/c. The following requirements had to be satisfied:

- i) An incoming interacting K^- identified by the condition:

$$CEDAR \cdot S_1 \cdot S_2 \cdot S_3 \cdot \bar{V}_1 \cdot \bar{V}_3 \cdot \bar{V}_B \quad (2)$$

- ii) A charged multiplicity around the target

$$2 \leq (MY \text{ or } MZ) \leq 7 \quad (3)$$

where MY(MZ) is the sum of the clusters in the TS and HPCLy(z) plane.

iii) A "slow" or a "fast" K^+ /p.

The "slow" K^+ /p is defined by a coincidence between corresponding elements of H1 and H2 and an anticoincidence between elements of H2 and C1. The requirement of the anticoincidence of C1 selected K^+ with momentum between 2.6 and 9.4 GeV/c or protons with momentum above 2.6 GeV/c.

The "fast" trigger required a coincidence between elements of H1 H2 and H2 H3 and an anticoincidence between H3 and channels of C2. This trigger selected K^+ or protons with momentum up to 18.5 GeV/c.

The coincidence matrices between the hodoscopes were determined by tracing positive tracks with $2.6 \leq P \leq 18.5$ GeV/c and $0. \leq P_{\perp} \leq 1.5$ GeV/c from the hydrogen target. The correlations between hodoscopes and Cerenkov elements were previously determined experimentally by observing the correlation given by particles emitting light. The logic related to the "fast" and "slow" trigger was implemented using MBNIM electronics and is described elsewhere⁽⁸⁾.

iv) A limited downstream charged multiplicity

$$N(H1) = 1,2 \quad (4)$$

$$N(H2 \text{ positive}) = 1 \quad (5)$$

$$N(H3 \text{ positive}) \leq 1 \quad (6)$$

$$N(H2 \text{ negative}) \leq 1 \quad (7)$$

$$N(H3 \text{ negative}) \leq 1 \quad (8)$$

where $N(H)$ indicates the number of hits in the hodoscope H.

For part of the data taking less stringent conditions were required; conditions (6) and (8) were replaced by:

$$N(H3 \text{ negative}) \leq 2 \quad (7')$$

v) The absence of a forward γ signal defined by an anticoincidence between H4 and H3 elements.

During the data taking the pattern units of all the elements of H1, H2, H3, C1, C2 were recorded, allowing the identification of fast negative particles. In addition to the above mentioned trigger a sample of events (3% of

the total) satisfying condition i) and having at least one hit in the TS counter was recorded to monitor the efficiency of the trigger elements. We will refer to these events as the "interaction trigger" sample.

3. Data handling

3.1. Off line data processing.

$7.2 \cdot 10^6$ triggers (including the "interaction triggers") were recorded and processed using a modified version of the pattern recognition and geometry program Trident⁽⁹⁾. Processing of an event was stopped if:

- 1) the recorded information was insufficient to reconstruct the beam direction (9%);
- 2) more than six clusters were present in the y planes of at least three of the four last B chambers (8%);
- 3) no track was reconstructed in the Ω' chambers compatible with the triggering tracks (17%);
- 4) a "fast" trigger had light present in C_2 because of inefficiency of the coincidence $H_3 \bar{C}_2$ (3%);
- 5) forward γ 's were present because of inefficiency of the coincidence $\bar{H}_3 H_4$ (7%).

These conditions reduced the number of reconstructed events to $3.7 \cdot 10^6$. Furthermore these events were processed using a special program⁽¹⁰⁾ to improve the efficiency in reconstructing V^0 vertices. The beam flux sensitivity after these selections, for 100% acceptance, is 12 ev/nb.

3.2. Mass assignment by Cerenkov information

The multicell Cerenkov counters C_1 and C_2 had nominal thresholds for pions of 2.6 GeV/c and 5.6 GeV/c. Fig. 2 shows, for events of the interaction trigger sample, the fraction of particles reaching H2 (H3) which give light in C_1 (C_2). Thresholds for pions and kaons are evident. The identification of secondary particles was carried out off-line, combining the information from both the Cerenkov counters with the rules reported in Table 1. The presence of two Cerenkov counters gives the possibility of measuring their efficiencies $\epsilon(C_1)$, $\epsilon(C_2)$.

The efficiency of C_1 far from threshold is consistent with 100%. The efficiency of C_2 was measured as a function of momentum for pions in the range $7.4 \leq P \leq 9.4$ GeV/c. After rejection of the last 19% of the data, the measured efficiency was in agreement with the expected threshold

behaviour⁽¹¹⁾. In the range 9.4 - 18.0 GeV/c the extrapolated inefficiency is $2.1 \cdot 10^{-3}$. This inefficiency causes a misidentification of π as K above 9.4 GeV/c and was taken into account in the analysis as will be discussed in Section 3.4. The last 19% of the data are affected by a higher inefficiency and therefore are not used in the P.W.A. for $M(K^+K^-) \geq 1.042$ GeV.

3.3. Corrections for acceptance and detection inefficiencies.

A fraction of the produced events belonging to reaction (1) is not observed either because they are not accepted by the geometry of the experimental set-up or because of inefficiencies in the trigger and detection elements. A correction is applied for:

- (i) Geometrical acceptance. This has been computed by tracing in the Ω' field, up to the downstream triggering hodoscopes, tracks generated with an uniform distribution around the beam direction (ϕ) on a grid of p , $p_{\perp}$ and x_V (200 MeV/c, 50 MeV/c and 12 cm steps). The mean correction factor due to geometrical acceptance for the events of reaction (1) is 1.71.
- (ii) K^+ decay. The correction for the decay of the triggering K^+ is computed from the probability that the K^+ decays before reaching the last hodoscope required in the trigger. The mean correction factor is 1.22.
- (iii) Secondary interactions. The probability that the triggering track interacts is computed from the material crossed from the main vertex up to the last trigger element. The interaction probability for the other tracks is computed requiring that at least four modules of MWPC's have to be crossed. The mean correction weight is 1.13.
- (iv) Inefficiency of the multiplicity trigger around the target. This is computed from the efficiencies, measured from the "interaction trigger" data, of the TS counter elements and of the HPC1 planes. The mean efficiencies over the run are: $\epsilon(\text{HPC1}(y)) = 94.6\%$, $\epsilon(\text{HPC1}(z)) = 93.7\%$, $\epsilon(\text{TS}) = 96.3\%$. The mean correction for the two

prong events of reaction (1) is only 1.01 due to the fact that more than 90% of the events have both tracks in HPC1. The correction for the three prong sample is negligible.

- (v) Inefficiency of the "slow" or "fast" trigger. This is computed taking into account for each event the hodoscopes required in the trigger. The efficiencies of the hodoscope elements have also been computed using the "interaction trigger" sample. The mean efficiencies of the H1, H2 and H3 hodoscopes are: $\epsilon(H_1) = 98.3\%$, $\epsilon(H_2) = 97.7\%$, $\epsilon(H_3) = 93.5\%$. The mean weight is 1.08.
- (vi) Inefficiency of the Ω' chambers. In all the planes of the Ω' MWPC's there was a region of low efficiency which extends along the whole chamber in the y direction and is localized between 0.5 and 2.0 cm in the z coordinate. A weight to correct this effect has been calculated by simulating the digitizings in the Ω' MWPC's with the standard GEANT⁽¹²⁾ program taking into account the observed inefficiency. The fraction of the generated tracks that are reconstructed by TRIDENT gives the inverse of the weight as a function of the momentum, the dip angle (λ) and the vertex position. The mean value of this weight for the events of reaction (1) is 1.09. In the low mass interval ($M(K^-K^+) < 1.042$ GeV) the loss of events is too high to be corrected with the weighting procedure. In this interval, events with at least one track with the dip angle in the range $-2 \leq \lambda \leq 20$ mrad have been rejected. The effect of this cut has been corrected for in the P.W.A. by the Linear Algebra Method (see section 4.1).

3.4. Channel selection and contamination.

Reaction (1) is selected from the two prong charge conserving sample ($\sim 10^6$ events) and from the three prong sample ($++-$) ($\sim 6 \cdot 10^5$ events). The three prong ($++-$) events result from Λ 's decaying close to the production vertex with a slow π^- not detected in the Ω' chambers and a proton which appears to come from the production vertex itself. No evidence of the reaction is found in the three prong ($+-$) or four prong topology⁽¹³⁾.

To select reaction (1) we require:

- a) a main vertex in hydrogen
- b) the momentum of the incident K^- measured by the beam spectrometer.
- c) both secondary particles compatible with the K mass assignment.

In the sample, events from the competing reactions

$$K^- p \rightarrow p \bar{p} (\Lambda/\Sigma^0) \quad (9)$$

$$K^- p \rightarrow K^- \pi^+ (n/\Delta^0) \quad (10)$$

are present; the presence of reaction (10) is due to the C2 inefficiency described in section 3.2, and affects only the sample with the positive track unambiguously identified as a K^+ ($P > 9.4$ GeV/c). For each event the missing masses (MM) corresponding to the reaction (1), (9), (10) and consistent with the Cerenkov mass assignment, have been computed with their errors. Reaction (1) is then selected requiring the following further conditions:

$$d) \left| \frac{MM^2(K^- K^+) - m^2(\Lambda)}{\sigma(MM^2(K^- K^+))} \right| < 2.5 \text{ or } \left| \frac{MM^2(K^- K^+) - m^2(\Sigma^0)}{\sigma(MM^2(K^- K^+))} \right| < 2.5 \quad (11)$$

e) for the events with a uniquely identified K^+ ($P \geq 9.4$ GeV/c)

$$\left| \frac{MM^2(K^- K^+) - m^2(\Lambda)}{\sigma(MM^2(K^- K^+))} \right| < \left| \frac{MM^2(K^- \pi^+) - m^2(n)}{\sigma(MM^2(K^- \pi^+))} \right| \quad (12)$$

f) $t'_p/(\Lambda/\Sigma^0) < 1$ GeV².

In Fig.3 the $MM^2(K^+ K^-)$ for the events satisfying the conditions (a), (b) and (c) is shown (full line) up to 2.2 GeV². Large peaks corresponding to Λ/Σ^0 and $\Lambda(1405)/\Sigma(1385)$ are observed. The shoulder on the low mass side of the Λ/Σ^0 is a reflection of the missing neutron of reaction (10). The broken line shows the missing mass for the 25400 events obtained after selections d), e) and f).

In this sample 67% of the events have at least one kaon unambiguously identified. The residual contamination from reaction (9) is due to events

with no track uniquely identified ($P \leq 10.5$ GeV/c). It has been estimated to be 5% by using the events with an uniquely identified $p(\bar{p})$ and assuming that the ratio reaction (9)/reaction (1) is the same for $p(\bar{p})$ momentum below and above 10.5 GeV/c.

A residual contamination from reaction (10) is evident from the presence of the $K^{*0}(890)$ resonance in the $(K^-\pi^+)$ mass spectrum obtained by plotting the events of reaction (1) as belonging to reaction (10). This contamination mainly affects the effective masses $M(K^+K^-) \geq 1.04$ GeV. The P.W.A. in this mass region has been performed by eliminating the last 19% of the data from the studied sample (see section 3.2). The " ϕ region" ($M(K^+K^-) \leq 1.042$ GeV) is studied using the whole data sample. The remaining contamination is taken into account by subtracting from the angular distribution of the K^+K^- system the contribution of the $K^-\pi^+$ events as a function of the mass. Events of reaction (10) have been generated by Monte Carlo using the $t_{(p \rightarrow (n/\Delta))}$ and decay angular distributions observed at 13 GeV/c⁽¹⁴⁾ and passing them through our trigger simulating program. The absolute value of the contamination (5%) is determined by normalizing the simulated $K^{*0}(890)$ to the number of $K^{*0}(890)$ events observed in our data. The C_2 inefficiency in the threshold region is well represented by⁽¹¹⁾

$$I_{C_2} = e^{-n_p} \quad (13)$$

with n_p given by

$$n_p = n_\infty [1 - (p_{th}/p)^2] \quad (14)$$

where n_p is the number of photoelectrons emitted at momentum p ($n_\infty=8$) and p_{th} is the nominal threshold value ($p_{th} = 5.6$ GeV/c) for pions. The unshaded histograms in Fig. 4a,b show the raw K^+K^- effective mass spectrum for the selected events. The amount of the contamination from reaction (10) as a function of $M(K^+K^-)$ is shown by the shaded area in Fig. 4b.

4. Data analysis.

4.1. Determination of the statistical tensors.

The statistical tensors $T_L^M \equiv t_\lambda (M \geq 0)$ of the K^+K^- system in the t-channel helicity frame have been computed as a function of the K^+K^- effective mass by the Linear Algebra Method⁽¹⁵⁾ solving the system of equations

$$b_\lambda = \sum_{\lambda'} A_{\lambda\lambda'} t_{\lambda'} \quad (15)$$

The b_λ are the unnormalized moments ($N_{\text{obs}} \langle \text{Re } Y_L^M \rangle$) of the experimental angular distributions weighted for the inefficiency of the trigger elements and secondary interactions of the K^+/K^- and corrected for the contamination of reaction (10).

$A_{\lambda\lambda'}$ is a matrix given by

$$A_{\lambda\lambda'}(M(K^+K^-)) = \int_0^{1 \text{ GeV}^2} \int_{\Omega} Y_\lambda A(M, t', \Omega) Y_{\lambda'} f(M, t') dt' d\Omega \quad (16)$$

where $f(M, t')$ is the observed $t'_{p \rightarrow (\Lambda/\Sigma^0)}$ distribution and $A(M, t', \Omega)$ is the acceptance due to the geometry of the trigger, decay of K^+/K^- and inefficiency of the Ω' MWPC. $A(M, t', \Omega)$ is computed by Monte Carlo as a function of $M(K^+K^-)$, $t'_{p \rightarrow (\Lambda/\Sigma^0)}$ and Ω which represents the decay variables $(\cos\theta_J, \phi_J)$ of the K^+K^- system in the t-channel helicity frame.

Since more equations than statistical tensors are considered the system (10) is overdetermined and has been solved by χ^2 minimization. The correct behaviour of the Linear Algebra Method under our experimental conditions has been checked by Monte Carlo.

In the present analysis 28 equations have been considered, corresponding to experimental moments b_λ up to $L=6$ and $M=6$. In the ϕ region ($1.002 \leq M(K^+K^-) \leq 1.042$ GeV), where fits are performed in 4 MeV mass intervals, only the six t_λ with $L \leq 2$ and $M \leq 2$ were found necessary to fit the data. In the higher mass range ($1.042 \leq M(K^+K^-) \leq 1.700$ GeV), where the fits are performed in 40 MeV mass intervals, tensors up to $L=4$

and $M=2$ are necessary. The corrected number of events $N = \sqrt{4\pi} t_0^0$ is shown in Figs. 4a and 4b (points with error bars). The unnormalized moments $N \text{Re}\langle Y_L^M \rangle = t_L^M \cdot \epsilon_L^M$ ($\epsilon_L^M = 1$ if $M=0$, $\epsilon_L^M = 0.5$ if $M \neq 0$) are shown in Figs. 5 and 6.

4.2. Partial wave analysis.

The partial wave decomposition is performed by expressing the moments as the sum of bilinear products of amplitudes $L_{\lambda\pm}$ describing, to leading order in energy, the production of a (K^+K^-) system of spin J and helicity λ by NPE and UPE respectively⁽¹⁶⁾. The moments $\text{Re}\langle Y_L^M \rangle$ with $L \leq 4$ and $M \leq 2$ are expressed in terms of S , P and D waves as shown in Table 2. We use the notation $L_{\pm}$ for $L_{1\pm}$ and L_0 for L_{0-} . A sum over helicity flip and non-flip amplitudes at the baryon vertex is implicit. The interference terms are expressed as

$$\text{Re}(LL'^*) = |L| \cdot |L'| \cdot \xi_{LL'} \cos \phi_{LL'} \quad (17)$$

where $\xi_{LL'}$ is the degree of hyperon spin coherence ($0 \leq \xi_{LL'} \leq 1$) and $\phi_{LL'}$ is the relative phase between amplitudes L and L' . It is well known⁽¹⁷⁾ that the knowledge of the angular distribution of a system of two pseudo-scalar mesons is not sufficient for an unambiguous determination of the amplitude except for the highest spin waves (P for $M(K^+K^-) \leq 1.042 \text{ GeV}$ and D for $1.042 \leq M(K^+K^-) \leq 1.70 \text{ GeV}$ in our case). In the natural parity sector the number of ambiguous solutions is $2^{(J-1)}$. For $M(K^+K^-) \leq 1.042 \text{ GeV}$ we have only one solution; for $1.042 \leq M(K^+K^-) \leq 1.70 \text{ GeV}$ we have two solutions only differing in the sign of $\phi_{D_+P_+}$. In the unnatural parity sector there are 2^J solutions, if the L_- waves are negligible. In our case we have 2 solutions in the low mass range with different sign of the S - P_0 relative phase. In the high mass range there are four solutions which can be divided into two groups with different S and P_0 intensity. Inside each group there is a further ambiguity related to the different sign of ϕ_{SD_0} and $\phi_{P_0D_0}$.

4.3. The $1.002 \leq M(K^+K^-) \leq 1.042$ GeV region.

As a starting point (fit A) the intensities of the S, P_0 , P_- , P_+ waves and the phases ϕ_{SP_0} , ϕ_{SP_-} have been fitted fixing the hyperon spin coherence:

$$\xi_{LL'} = 1 \quad (18)$$

The P_+ and P_0 waves, related to the production of the ϕ meson by NPE and UPE are dominant. The P_- wave is small. The S wave (3% of the P_+ wave) is structureless and is required by the non zero values of $N \cdot \text{Re} \langle Y_1^0 \rangle$ and $N \cdot \text{Re} \langle Y_1^1 \rangle$.

To check that the P wave solutions are not significantly dependent on hypothesis (18) a second fit (fit B) has been performed to the P wave intensities and to the phase $\phi_{P_0P_-}$ setting the intensity of the S wave to zero and neglecting the second and third equation in Table 2. The P wave intensities given by fit B differ by less than 1 s.d. from the intensity given by fit A and are shown in Figs. 7a,b and 8a,b. The continuous lines in Figs. 7b, 8b represent the result of the fit performed in the interval $1.006 \leq M(K^+K^-) \leq 1.038$ GeV of a relativistic $J=1$ Breit Wigner function of the form

$$BW(M, \Gamma) = \frac{M_0 \Gamma}{M^2 - M_0^2 - i \Gamma M_0} \quad (19)$$

$$\Gamma = \Gamma_0 \cdot \left(\frac{q}{q_0}\right)^{2J+1} \quad (20)$$

with the experimental resolution folded in and Γ_0 set to 4.1 MeV.

Values of

$$\begin{aligned} M_0(\phi) &= 1021 \pm 0.2 \text{ MeV} \quad \text{and} \\ M_0(\phi) &= 1020 \pm 0.5 \text{ MeV} \end{aligned} \quad (21)$$

are obtained from the fit on the P_+ and P_0 waves respectively. Taking into account the resonance tails outside the considered interval and the branching ratio of .486 into K^+K^- the following cross sections are obtained: $\sigma(\phi_{P_+}) = 4.24 \pm 0.25 \text{ } \mu\text{b}$, $\sigma(\phi_{P_0}) = 0.72 \pm 0.06 \text{ } \mu\text{b}$, $\sigma(\phi_{P_-}) = 0.165 \pm 0.012 \text{ } \mu\text{b}$, for ϕ meson production in the t' interval 0 -1 GeV².

The total ϕ production cross section for $t' \leq 1 \text{ GeV}^2$ is $\sigma(\phi) = 5.14 \pm .31 \text{ } \mu\text{b}$. These cross sections together with the results of similar studies at lower energies^(1,18,19) are listed in Table 3 and displayed in Fig.9. A fit of the form $\sigma \propto s^{-n}$ gives for the coefficient n the values reported in Table 3. The various production mechanisms have a different energy dependence. While at low energy (4.2 GeV/c) the unnatural parity exchange accounts for 42% of the total ϕ production cross section, this contribution is reduced to 17% at our energy. Using the relation $n = 2\alpha(\bar{t}) - 2$ ⁽²⁰⁾ we find $\alpha^{\text{NPE}}(\bar{t}) = 0.15 \pm 0.02$, $\alpha_0^{\text{UPE}}(\bar{t}) = -0.14 \pm 0.04$ and $\alpha_-^{\text{UPE}}(\bar{t}) = -0.73 \pm 0.04$.

The differential cross section of ϕ meson production has been determined by solving the system (15) for the events in the $1.002 \leq M(K^-K^+) \leq 1.042 \text{ GeV}$ range and nine different t' intervals, setting the S wave intensity to zero. The differential cross sections $\frac{d\sigma}{dt'}$, $\frac{d\sigma_+}{dt'}$ and $\frac{d(\sigma_0 + \sigma_-)}{dt'}$ are given in Table 4 and shown in Fig.10. The NPE and UPE differential cross sections cannot be described by the same parametrization. The NPE part was fitted with the formula

$$\frac{d\sigma_+}{dt'} = C(A + t') e^{-Bt'} \quad (22)$$

and gave the following set of values: $A = 0.047 \pm 0.0054 \text{ GeV}^2$, $B = 5.31 \pm 0.05 \text{ GeV}^{-2}$ and $C = 47.7 \pm 1.1 \text{ } \mu\text{b/GeV}^4$ with a $\chi^2/\text{NDF} = 1.56$. The fit is shown by the full line in Fig.10b. To fit the UPE contributions a simple exponential

$$\frac{d(\sigma_0 + \sigma_-)}{dt'} = A e^{-Bt'} \quad (23)$$

was used giving the values $A = 2.05 \pm 0.15 \text{ } \mu\text{b/GeV}^2$, $B = 4.1 \pm 0.2 \text{ GeV}^{-2}$. The corresponding χ^2/NDF is 0.38. In eq. (22) the purely exponential term corresponds approximately to the contribution of zero net helicity flip. From the fitted parameters values we estimate that $26 \pm 4\%$ of the NPE contribution is due to zero net helicity flip. Comparing our data for the channel $\phi\Lambda/\Sigma^0$ with the corresponding data at 4.2 GeV/c⁽¹⁹⁾, the effective Regge trajectories may be determined experimentally. The results of the calculations are shown in Fig.11 for UPE and NPE together with the linear trajectories drawn through $K^*(890)$, $K^*(1420)$, for NPE and through K , $Q_1(1270)$ for UPE.

The computed values agree well with the above trajectories and are also consistent with the $\alpha(\bar{t})$ values determined from the variation of the cross sections with the incident energy.

4.4 The region $1.042 \leq M(K^+K^-) \leq 1.700$ GeV.

In this mass range the production of D_0 , D_- and D_+ waves is considered due to the non zero values of the tensors with $L=3$ and 4. As a starting point, a fit (Fit A) has been performed with the assumption (18) and

$$\phi(L_-) = \phi(L_0) + n\pi \quad (24)$$

where n is a fitted parameter which can assume values 0 or 1. Relation (24) is expected to be true when the L_- waves result from the absorption of L_0 waves and is usually assumed when π exchange is involved⁽²¹⁾.

Regardless of the phases of the various waves, two solutions are found: one with a large S wave and a small P_0 wave (solution 1) and another with a small S wave and a large P_0 wave peaking around 1.5 GeV (solution 2). The two solutions for the P_+ wave (which are not completely degenerate due to non zero L_0L_- interference terms) are shown in Fig.7c. The P_+ wave shows a smooth decrease which is represented by the extrapolation of the Breit Wigner fit on the ϕ plus a small contribution (5%) of the ρ^0 tail⁽⁺⁾. This contribution has been estimated from the measured cross sections $K^-p \rightarrow \rho\Lambda/\Sigma^0$ taking a branching ratio of 8% for the ρ^0 decay into KK ⁽²²⁾. We conclude that the P_+ wave from the threshold to 1.70 GeV is mainly due to the ϕ meson, with a small ρ^0 contribution. Since the exchange of natural and unnatural parity trajectories are of comparable importance in hypercharge exchange processes we expect the P_0 and P_- waves to have a behaviour similar to the P_+ wave. For this reason we will consider from now on only the solution with the smooth P_0 wave (solution 1). This choice is also supported by the following arguments:

(+) If we exclude the point at 1.520 GeV, which we interpret as a bias in the f' region, we obtain a $\chi^2/\text{NDF} = 25/16$.

- (i) Solution 2 has in general a worse confidence level than solution 1, particularly in the 1.5 GeV region where the P_0 wave shows a structure (probabilities for the two fits in the two bins of the mass interval $1.46 \leq M(K^+K^-) \leq 1.54$ GeV are 91%, 61% for solution 1 and 2%, 0.5% for solution 2).
- (ii) In the region where the P_0 wave of solution 2 shows a peak no corresponding structure is found in the reactions $\gamma P \rightarrow K^+ K^- p$ ⁽²³⁾ or $e^+ e^- \rightarrow K \bar{K}$ ⁽²⁴⁾ where it should be present.
- (iii) The P_0 wave of solution 1 is also well explained by the presence of the ϕ meson and a small ρ^0 contribution only. Fig. 8c shows the P_0 solution. The curve represents an extrapolation of the Breit Wigner fitted in the ϕ region ($\chi^2/\text{NDF} = 19/17$).

We conclude that the P_0 wave from the threshold to 1.70 GeV is also essentially due to the ϕ meson. A similar conclusion is valid for the P_- wave (not shown) which is very small and compatible with zero (with an error of ~ 5 nb in each bin) in the mass range $1.042 \leq M(K^+K^-) \leq 1.70$ GeV.

The above results on the P waves are used to perform a second PWA (fit B) for $M(K^+K^-) \geq 1.042$ GeV in which the P_+ , P_0 , P_- intensities are fixed to the ϕ tails (curves of Figs. 7c, 8c), $\xi_{P_0 P_-} = +0.39$ and $\cos(\phi_{P_0 P_-}) = -1.0$ in agreement with the results obtained in the ϕ region. These assumptions allow us to release conditions (18) and (24) on the other waves and to perform a one constraint fit. Condition (24) is not a priori justified in the large $t'_{p \rightarrow (\Lambda/\Sigma)}$ range used while condition (18) may be not satisfied because the data include two different reactions (Λ/Σ^0).

An acceptable χ^2 is obtained for all the fits except that at 1.52 GeV; the mean χ^2 -probability is 15%.

The S and D waves intensities resulting from fit B are shown in Fig.12. In the NPE sector the P_+ wave is well determined and can be used as a reference wave. The P_0 wave, which is the only UPE wave which is well interpreted and covers the full studied range, is weaker than the corresponding

P_+ . As a consequence the phase terms with respect to it (not shown) are affected by large errors (± 0.5) and do not give reliable information.

The D waves are small everywhere except in the 1.45 - 1.60 GeV mass region where a clear structure identified with the f' meson is seen. The term $\xi_{D_+P_+} \cos(\phi_{D_+P_+})$ (Fig. 12e) shows the variation expected for a resonance ($\xi_{D_+P_+} = 0.5$). A fit to the total D wave intensity ($|D_0^2| + |D_-^2| + |D_+^2|$) with a $J = 2$ relativistic Breit Wigner gives the following parameters for the f' meson

$$M_{f'} = 1529 \pm 3 \text{ MeV}$$

$$\Gamma_{f'} = 83 \pm 15 \text{ MeV}$$

The total, natural and unnatural exchange cross section of the f' meson in reaction (1) are: $\sigma(f') = 0.86 \pm 0.10 \text{ } \mu\text{b}$, $\sigma_+(f') = 0.39 \pm 0.03 \text{ } \mu\text{b}$, $\sigma_0(f') = 0.35 \pm 0.06 \text{ } \mu\text{b}$ and $\sigma_-(f') = 0.12 \pm 0.04 \text{ } \mu\text{b}$.

The existing data on f' production in reaction (1) are obtained under the assumption of pure resonance production. They are collected in Table 5 and shown in Fig. 13 as a function of s . A fit of the form $\sigma \propto s^{-n}$ gives for n the values reported in Table 5. The differential cross section for the f' production is obtained by solving system (15) and performing the P.W.A. with the assumptions of Fit B for six t' intervals in the effective mass range $1.46 \leq M(K^- K^+) \leq 1.58 \text{ GeV}$. The results are reported in Table 6 and shown in Fig. 14. The differential cross section for the f' production by NPE $\frac{d\sigma_+}{dt'}$ is well represented by a form $\frac{d\sigma_+}{dt'} = C(A + t')e^{-Bt'}$ ($\chi^2/\text{NDF} = 0.12$). The values obtained for the parameters are $C = 10.3 \pm 2.6 \text{ } \mu\text{b}/\text{GeV}^4$, $B = 5.5 \pm 0.60 \text{ GeV}^{-2}$, $A = 0.0002 \pm 0.08 \text{ GeV}^2$.

The production by UPE $\frac{d(\sigma_0 + \sigma_-)}{dt'}$ (Fig. 14c) is represented by a pure exponential $\frac{d\sigma}{dt'} = Ae^{-Bt'}$ with parameters $A = 1.5 \pm 0.3 \text{ } \mu\text{b}/\text{GeV}^2$, $B = 3.5 \pm 0.6 \text{ GeV}^{-2}$ ($\chi^2/\text{NDF} = 0.37$)

The S wave intensity is difficult to establish in the presence of large incoherence effects since it is obtained from the difference between the total spectrum and the higher waves. Its intensity, which is affected by large errors in the f' region, (Fig. 12a) shows a broad structure peaking around 1.4 GeV where it takes into account 50% of the events.

The indetermination of its phase makes it difficult to conclude about its nature. Comparison with existing data on the channel $K^- p \rightarrow \pi^- \pi^+ \Lambda$ shows that it cannot be entirely due to the production of the $\epsilon(1300)$. (Assuming $BR(\epsilon \rightarrow K\bar{K}) \leq 0.1$).

A similar analyses based on a smaller statistics (958 events with $1.05 \leq M(K^+K^-) \leq 1.75$ GeV) but using the Λ polarization has been performed at 8.2 GeV/c⁽²⁵⁾. Assuming a p^{-2} dependence the S wave intensity found in both experiments is consistent within 2 s.d..

Conclusions

From a partial wave decomposition of the K^+K^- system produced in reaction (1) at 18.5 GeV/c performed in the mass interval 0.98 - 1.7 GeV we observe:

- 1) The D wave dominates at high mass and is well explained by the production of the f' meson which is produced about equally by NPE and UPE.
- 2) The P wave is well described by the production of the ϕ meson over the whole mass range. The ϕ meson is dominantly (83%) produced by NPE and its production is well explained by the exchange of natural (K^* , K^{**}) and unnatural (K , Q_1) Regge trajectories.
- 3) The S wave shows a broad structure around 1.4 GeV, but the lack of information about the phase makes the search for new 0^{++} states inconclusive.

References

- 1) a. G.W. Brandenburg et al., Nucl. Phys. B104 (1976) 413;
b. F. Barreiro et al., Nucl. Phys. B121 (1977) 237;
c. S. Al-Harran et al., Nucl. Phys. B191 (1981) 26.
- 2) T. Armstrong et al., Phys. Lett. 110B (1982) 77.
- 3) R.L. Jaffe, Phys. Rev. D15 (1977) 267;
R.L. Jaffe and F.E. Low, Phys. Rev. D19 (1979) 2105.
- 4) D.B. Lichtenberg and J.G. Willis, Phys. Rev. Lett. 35 (1975) 1055;
Ditsas et al., Nucl. Phys. B146 (1978) 191.
- 5) A.J.C. Hey, Argonne Summer Symposium, July 1975;
A.J.C. Hey and D. Morgan, Rutherford Laboratory 77/060/A.
- 6) D.E. Plane - CERN-SPS/EA/78-7 (1978).
- 7) Ω' Project. Working Group CERN/SPSC/77-70 SPSC/T-17 (1977).
- 8) A. Beer et al., Nucl. Instr. and Methods 160 (1979) 217;
T. Armstrong et al., Nucl. Instr. and Methods 175 (1980) 543.
- 9) J.C. Lassalle, F. Carena, S. Pensotti, Nucl. Instr. and Methods 176 (1980) 371.
- 10) D. Frame, University of Glasgow - "V⁰" reconstruction program.
Private communication.
- 11) J. Eades OM/SPS/81-11 and private communication.
- 12) GEANT - R. Brun, R. Hagelberg, M. Hansroul, J.C. Lassalle
CERN DD 78-2 (1978).
- 13) M.F. Worsell thesis - University of Birmingham 1981.
- 14) P. Estabrook et al., Nucl. Phys. B133 (1978) 490 and private communication.
- 15) G. Grayer et al., Nucl. Phys. B75 (1974) 189.
- 16) A.D. Martin and Michael, Nucl. Phys. B84 (1975) 83.
- 17) A. Gersten, Nucl. Phys. B12 (1969) 537;
E. Barrelet, Nuovo Cimento 8A (1972) 331.

- 18) C. Evangelista et al., Nucl. Phys. B127 (1977) 384.
- 19) M.J. Losty et al., Nucl. Phys. B133 (1978) 38.
- 20) A.C. Irving and R.P. Worden, Phys. Report 34 (1977) 117.
- 21) D. Cohen et al., Phys. Rev. D22 (1980) 2593.
- 22) L. Görlich et al., Nucl. Phys. B (1980) 16.
- 23) D. Aston et al., Nucl. Phys. B172 (1980) 1.
- 24) B. Delcourt et al., Phys. Lett. B99 (1981) 257;
F. Massé et al., Phys. Lett. B99 (1981) 261.
- 25) M. Baubillier et al.- Contribution to the XXI High Energy Conference
Paris 1982.
- 26) M. Aguilar-Benitez et al., Zeit. für Phys. C8 (1981) 313.

Table captions

- Table 1 . Cerenkov identification. The assignments of single tracks are given according to the Cerenkov status.
L(N) indicates light (no light) in the appropriate Cerenkov cells. The symbol (*) indicates an unphysical condition for which no mass assignment has been performed.
- Table 2 . Decomposition of the moments $N \cdot \text{Re} \langle Y_L^M \rangle$ in terms of S, P and D waves.
- Table 3 . Cross sections for the reaction $K^- p \rightarrow \phi \Lambda / \Sigma^0$ for $t' < 1 \text{ GeV}^2$ at various energies. The last column gives the value of n determined by fits to the total cross sections with the formula $\sigma \propto s^{-n}$.
- Table 4 . Values of the differential cross sections $\frac{d\sigma}{dt}$, for the reaction $K^- p \rightarrow \phi \Lambda / \Sigma^0$.
- Table 5 . Cross sections for the reactions $K^- p \rightarrow f' \Lambda / \Sigma^0$ for $t' < 1 \text{ GeV}^2$ at various energies. The last column gives the value of n determined by fits to the total cross sections with the formula $\sigma \propto s^{-n}$.
- Table 6 . Values of the differential cross sections $\frac{d\sigma}{dt}$, for the reaction $K^- p \rightarrow f' \Lambda / \Sigma^0$.

T A B L E 1

Cerenkov status		Secondary momentum							
C ₁	C ₂	p<2.6	2.6<p<3.	3.0<p<5.6	5.6<p<7.4	7.4<p<9.4	9.4<p<10.5	p >10.5	
L		*	π	π	π	π	π/K	π/K	
N		π/K/p	π/K/p	K/p	K/p	K/p	K/p	p	
L	L	*	*	*	π	π	π	π	
L	N	*	π	π	π	π	K	K	
N	N	π/K/p	π/K/p	K/p	K/p	K/p	K/p	p	

T A B L E 2

$$\begin{aligned}
 \sqrt{4\pi} \langle Y_0^0 \rangle &= S_0^2 + P_0^2 + P_-^2 + P_+^2 + D_0^2 + D_-^2 + D_+^2 \\
 \sqrt{4\pi} \langle Y_0^1 \rangle &= 2S_0P_0 + 1.789 P_0D_0 + 1.549(P_-D_- + P_+D_+) \\
 \sqrt{4\pi} \langle Y_1^1 \rangle &= 1.414 S_0P_- + 1.095 P_0D_- - 0.632 P_-D_0 \\
 \sqrt{4\pi} \langle Y_0^2 \rangle &= 2S_0D_0 + 0.894 P_0^2 - 0.447(P_-^2 + P_+^2) + 0.639 D_0^2 + 0.319(D_-^2 + D_+^2) \\
 \sqrt{4\pi} \langle Y_1^2 \rangle &= 1.414 S_0D_- + 1.095 P_0P_- + 0.452 D_0D_- \\
 \sqrt{4\pi} \langle Y_2^2 \rangle &= 0.548(P_-^2 - P_+^2) + 0.391(D_-^2 - D_+^2) \\
 \sqrt{4\pi} \langle Y_0^3 \rangle &= 1.757 P_0D_0 - 1.014(P_-D_- + P_+D_+) \\
 \sqrt{4\pi} \langle Y_1^3 \rangle &= 1.171 P_0D_- + 1.014 P_-D_0 \\
 \sqrt{4\pi} \langle Y_2^3 \rangle &= 0.926(P_-D_- - P_+D_+) \\
 \sqrt{4\pi} \langle Y_0^4 \rangle &= 0.857 D_0^2 - 0.571(D_-^2 + D_+^2) \\
 \sqrt{4\pi} \langle Y_1^4 \rangle &= 1.107 D_0D_- \\
 \sqrt{4\pi} \langle Y_2^4 \rangle &= 0.452(D_-^2 - D_+^2)
 \end{aligned}$$

T A B L E 3

$P_{lab} (GeV/c)$ $\sigma (\mu b)$	4.2 (19)	$10^{(18)}$	$13^{(1a)}$	18.5 this exp.	n
σ_{tot}	84.6 ± 1.4	11.9 ± 1.8	12.0 ± 0.5	5.1 ± 0.5	1.99 ± 0.03
σ_{NPE}	49.1 ± 1.4	9.0 ± 1.6	9.6 ± 0.4	4.2 ± 0.25	1.71 ± 0.09
σ_{UPE}	17.8 ± 1.1	1.1 ± 0.8	2.0 ± 0.1	0.72 ± 0.06	2.28 ± 0.07
σ_1	19.1 ± 1.4	1.7 ± 0.9	0.3 ± 0.1	0.16 ± 0.01	3.47 ± 0.08

T A B L E 4

$t' \text{ GeV}^2$	$d\sigma_{\text{tot}}/dt'$	$d\sigma_+/dt'$	$d(\sigma_0+\sigma_-)/dt'$
0.0 - 0.1	5.040 ± 0.216	3.232 ± 0.258	1.810 ± 0.263
0.1 - 0.2	5.695 ± 0.190	4.677 ± 0.295	1.019 ± 0.199
0.2 - 0.3	4.679 ± 0.151	3.901 ± 0.242	0.778 ± 0.141
0.3 - 0.4	3.522 ± 0.121	2.930 ± 0.185	0.593 ± 0.134
0.4 - 0.5	2.352 ± 0.093	2.073 ± 0.132	0.292 ± 0.067
0.5 - 0.6	1.633 ± 0.077	1.466 ± 0.097	0.167 ± 0.073
0.6 - 0.7	1.149 ± 0.064	0.979 ± 0.068	0.186 ± 0.044
0.7 - 0.8	0.862 ± 0.056	0.755 ± 0.056	0.108 ± 0.045
0.8 - 1.0	0.492 ± 0.030	0.440 ± 0.032	0.056 ± 0.019

T A B L E 5

$P_{lab} \text{ (GeV/c)}$ $\sigma \text{ (}\mu\text{b)}$	4.2 (1b), (26)	$_{10} \text{ (18)}$	$_{13} \text{ (1a)}$	18.5 this exp.	n
σ_{tot}	23.3 ± 3.1	4.6 ± 0.9	2.00 ± 0.40	1.72 ± 0.20	1.98 ± 0.14
σ_{NPE}	5.55 ± 1.29	1.38 ± 0.43	1.04 ± 0.24	0.78 ± 0.06	1.34 ± 0.05
σ_{0}^{UPE}	13.53 ± 1.46	2.02 ± 0.54	0.70 ± 0.20	0.70 ± 0.12	2.42 ± 0.16
σ_{1}^{UPE}	5.42 ± 1.29	1.20 ± 0.40	0.22 ± 0.13	0.24 ± 0.08	2.52 ± 0.06

T A B L E 6

$t' \text{ GeV}^2$	$d\sigma_{\text{tot}}/dt'$	$d\sigma_+/dt'$	$d(\sigma_0+\sigma_-)/dt'$
0.0 - 0.1	1.756 ± 0.370	0.375 ± 0.191	1.381 ± 0.317
0.1 - 0.2	1.452 ± 0.306	0.711 ± 0.171	0.741 ± 0.254
0.2 - 0.3	1.335 ± 0.372	0.616 ± 0.191	0.719 ± 0.319
0.3 - 0.4	0.946 ± 0.227	0.463 ± 0.128	0.483 ± 0.188
0.4 - 0.6	0.703 ± 0.152	0.323 ± 0.081	0.380 ± 0.129
0.6 - 1.0	0.199 ± 0.052	0.116 ± 0.030	0.083 ± 0.043

Figure captions

- Fig. 1. Layout of the Ω' spectrometer used in the present experiment.
- Fig. 2. Response R of the threshold Cerenkov counters as a function of secondary momentum. R is the ratio of the number of tracks giving Cerenkov light to the total number a) C_1 b) C_2 .
- Fig. 3. $MM^2(K^+K^-)$ to all two prong ($+-$) and three prong ($++-$) events with both fast secondaries compatible with the K mass assignment (full line) and after the selections d), e) and f) described in the text (broken line).
- Fig. 4. K^+K^- effective mass for $t'_{p \rightarrow (\Lambda/\Sigma^0)} < 1.0 \text{ GeV}^2$. The histograms show the uncorrected mass spectrum. The shaded area indicates the contamination from reaction (10). The points with error bars show the fully corrected mass spectrum. a) $M(K^+K^-) \leq 1.040 \text{ GeV}$ b) $1.040 \leq M(K^+K^-) \leq 2.0 \text{ GeV}$.
- Fig. 5. Unnormalized moments $N \cdot \text{Re} \langle Y_\ell^m \rangle$ for $M(K^+K^-) \leq 1.042 \text{ GeV}$
- Fig. 6. Unnormalized moments $N \cdot \text{Re} \langle Y_\ell^m \rangle$ for $1.042 \leq M(K^+K^-) \leq 1.7 \text{ GeV}$.
- Fig. 7. P_+ wave intensity a) in the region $1.006 \leq M(K^+K^-) \leq 1.700 \text{ GeV}$ b) in the region $1.006 \leq M(K^+K^-) \leq 1.038 \text{ GeV}$. The curve represents the Breit-Wigner fit described in the text. c) in the region $1.038 \leq M(K^+K^-) \leq 1.700 \text{ GeV}$. The points and the crosses represent solutions 1 and 2 of fit A respectively. The curve represents the extrapolation of the Breit-Wigner fitted in the ϕ region plus a ρ^0 contribution (see text).
- Fig. 8. P_0 wave intensity. a) in the region $1.006 \leq M(K^+K^-) \leq 1.700 \text{ GeV}$ b) in the region $1.006 \leq M(K^+K^-) \leq 1.038 \text{ GeV}$. The continuous line represents the Breit-Wigner fit described in the text. c) in the region $1.038 \leq M(K^+K^-) \leq 1.700 \text{ GeV}$. The points represent solution 1 of fit A. The curve represents the extrapolation of the Breit-Wigner fitted in the ϕ region plus a ρ^0 contribution (see text).

Fig. 9. Cross sections for the reaction $K^- p \rightarrow \phi(\Lambda/\Sigma^0)$ for $t' < 1 \text{ GeV}^2$ as a function of s . a) total b) production by NPE c) production by helicity zero UPE d) production by helicity one UPE.

Fig.10. $d\sigma/dt'$ distribution for ϕ production in the reaction $K^- p \rightarrow \phi(\Lambda/\Sigma^0)$. a) $\frac{d\sigma_{\text{tot}}}{dt'}$ b) $\frac{d\sigma_+}{dt'}$ c) $\frac{d(\sigma_0+\sigma_-)}{dt'}$. The curves show the fits described in the text.

Fig.11. Effective trajectories for the reaction $K^- p \rightarrow \phi(\Lambda/\Sigma^0)$. a) for natural parity exchange b) for the sum of helicity 0 and helicity 1 UPE. Lines are drawn through the K^* , K^{**} and K , Q_1 masses.

Fig.12. Results of the fit B described in the text. Intensities of (a) S wave (b) D_0 wave (c) D_+ wave (d) D_- wave. The term $\xi_{P_+D_+} \cos \phi_{P_+D_+}$ is shown in (e). The curve represents the variation expected for the f' meson with $\xi = 0.5$.

Fig.13. Cross sections for the reaction $K^- p \rightarrow f'(\Lambda/\Sigma^0)$ for $t' < 1 \text{ GeV}^2$ as a function of s . a) total b) production by NPE c) production by helicity zero UPE d) production by helicity one UPE.

Fig.14. $d\sigma/dt'$ distribution for f' production in the reaction $K^- p \rightarrow f'(\Lambda/\Sigma^0)$. a) $\frac{d\sigma_{\text{tot}}}{dt'}$ b) $\frac{d\sigma_+}{dt'}$ c) $\frac{d(\sigma_0+\sigma_-)}{dt'}$. The curves show the fits described in the text.

Fig. 1

Fig. 2

Fig. 3

Fig. 4 (a)

Fig. 4 (b)

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 14