SEARCH FOR EVIDENCE OF A K^+K^+ RESONANCE

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We have recently finished examining a sample of events of the type

$$K^+ + p \rightarrow K^+ + K^+ + \Lambda^0, \quad (1)$$

$$K^+ + p \rightarrow K^+ + K^+ + \Sigma^0. \quad (2)$$

These were produced in the 80-inch Brookhaven National Laboratory hydrogen bubble chamber by a separated K^+ beam with mean momentum of 3.535 BeV/c. The sensitivity of the experiment was such as to yield 5.1 ± 0.4 events per microbarn.[1] A similar experiment performed at CERN[2] obtained evidence for a K^+K^+ resonance at 1280 MeV/c^2 with a width of about 100 MeV/c^2. The existence of such a resonance would be of great importance as it would indicate the excitation of a 27-fold multiplet. The main differences between the present experiment and the one performed at CERN are that we use only events containing a K^+K^+ pair in the final state and all of our events were produced at a single energy.

Figure 1(a) shows a histogram of the K^+K^+ invariant-mass distribution obtained by combining events with a Λ^0 or Σ^0 in the final state. There was no discernable difference when Λ^0 or Σ^0 events were plotted separately. The agreement with a simple phase-space distribution has a χ^2 probability of about 45%. Since with small statistics it is possible to obtain some variety in appearance by appropriate choice of bin size and position, we have attempted to show in Fig. 1(b) the maximum irregularity one might hope to achieve in that way by plotting an "ideogram" giving all events a 50-MeV/c^2 width. It can be seen that the histogram of Fig. 1(a) does not conceal much detail nor does it show any statistically significant evidence for a resonance at 1280 MeV/c^2 with a 100-MeV/c^2 width.

Figure 2 shows our momentum-transfer spectrum to the hyperon, broken into the same four mass intervals used in the CERN experiment.[2] There appears to be no anomalous peaking for the mass region around 1280 MeV/c^2. The significant information seems to be that the whole production process is in some sense peripheral.

In considering the possibility of a K^+K^+ resonance we have adopted the two following approaches[3]: (i) Since our cross section of 31 ± 4 μb for Reaction (1) plus (2) agrees quite well with the 29 μb obtained by CERN at about the same energy, perhaps it is only a statistical fluctuation that produces the different appearance

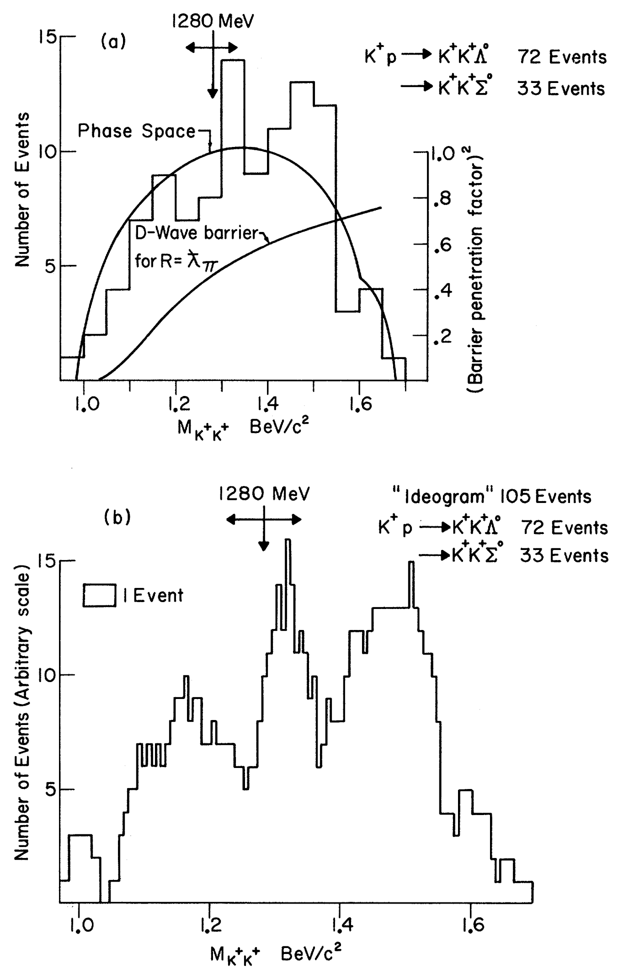

FIG. 1. (a) Number of events versus effective mass of the K^+K^+ system for the combined sample of $K^+K^+\Lambda^0$ and $K^+K^+\Sigma^0$ final states. The d-wave angular-momentum-barrier penetration factor in the K^+K^+ system for a radius equal to the pion Compton wavelength can be read on the right-hand ordinate. The phase space shown is a weighted average for Λ^0 and Σ^0 final states. (b) Ideogram of the effective K^+K^+ mass using 50 MeV/c^2 as the "error width" on each event.

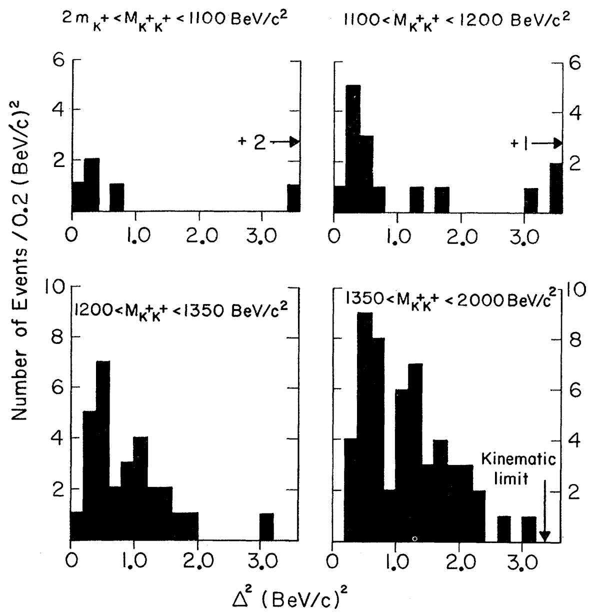

FIG. 2. Momentum-transfer spectra for the four K^+K^+ mass intervals used in the CERN experiment (Ref. 2). Arrows in the lower two mass intervals refer to the number of events falling outside the Δ^2 interval plotted. The upper limit on Δ^2 fixed by kinematics is marked on the plot for the largest mass interval.

in our data. In that case we ask what size K^+K^+ scattering cross section is implied by the data, and is that size of resonant proportions. (ii) We have looked to see if there is a simple, alternative mechanism that will describe the data without involving a K^+K^+ interaction directly.

Dominance by K^+K^+ scattering. —The momentum-transfer spectrum is such that one might hope to explain the production by having the baryon emit a K^+ or K^{*+} which subsequently scatters with the incident K^+. When we consider only $K^+K^+\Lambda^0$ final states, there appears to be no direct evidence for K^* exchange, since the Treiman-Yang plot[4,5] made on this assumption has a 50% χ^2 probability of being flat. Furthermore, spin and statistics forbid K^* exchange when the K^+K^+ state has angular momentum less then 2^+. Since the angular-momentum barrier for $L=2$ at a radius of $\lambda\!\!\!^{-}_\pi$ rises to about one half at the middle of our phase space [see Fig. 1(a)], we have compared events in the upper and lower halves of the K^+K^+ mass plot with regard to the Treiman-Yang angle, K-K scattering angle, and momentum-transfer spectrum. There appear to be no detectable differences. To the extent that one believes in A-parity conservation,[6] a $K^+ + K^{*+} \rightarrow K^+ + K^+$ vertex would not be expected in any case.[7]

The remarks just made concerning the absence of K^* exchange for the $K^+K^+\Lambda^0$ events cannot be made with the same conviction when discussing the $K^+K^+\Sigma^0$ events. The Treiman-Yang plot for the Σ^0 events has only an 8% χ^2 probability of being flat. Thus we temporarily limit ourselves to the Λ^0 events and attempt to use the Chew-Low[8] formula for K^+ exchange to obtain an order-of-magnitude guess for the value of the K^+K^+ scattering cross section under the assumption that the K^+K^+ interaction dominates the over-all reaction in that particular manner. For the ΛKN coupling constant we use the value required by SU(6), since experiment seems to support that prediction.[9,10]

The result of this simple calculation is that $\sigma_{KK} \approx 0.2$ mb over the K^+-K^+ mass accessible to us. However, there is an apparent need for an absorption correction since the momentum-transfer spectrum peaks too sharply at low values to be explained so easily. Using the simple absorption model[5,11,12] for our average K-K mass and fitting the final-state scattering parameters to our observed momentum-transfer spectrum, we find that σ_{KK} should be corrected up by at least a factor of 12 to agree well with the data. This gives $\sigma_{K^+K^+} \approx 2.4$ mb which is not too far from the value $\pi\lambda\!\!\!^{-}_\rho{}^2 \approx 2$ mb that is to be expected if K^+K^+ scattering were due to ρ^0 exchange.

Bose statistics for the K^+K^+ system limit its lowest two angular-momentum and parity states to 0^+ and 2^+. For identical particles the corresponding resonant cross sections would be $8\pi\lambda\!\!\!^{-}{}^2$ and $40\pi\lambda\!\!\!^{-}{}^2$, respectively, or about 59 and 294 mb for a K^+-K^+ mass of 1280 MeV/c^2. With the absorption we have suggested this makes a K^+K^+ resonance seem rather unlikely in both our data and the CERN data. In particular, the possibility of a d-wave resonance seems especially remote because the K-K scattering angular distribution can accommodate practically no d-wave amplitude if only s-wave and d-wave amplitudes are allowed.

Although we have managed to obtain moderately good agreement between the data for the $K^+K^+\Lambda^0$ events and K^+ exchange, we cannot simultaneously explain the $K^+K^+\Sigma^0$ events this way because of the relatively large number of Σ^0's observed. The f/d ratio of SU(6) implies $\Sigma^0/\Lambda^0 = 1/27$.[9,13] The value obtained in the present experiment is $\Sigma^0/\Lambda^0 = 0.46 \pm 0.10$. The values obtained in the CERN experiment are also too large.

Vector exchange.—An alternative production mechanism which is a priori applicable to all events is the vector-exchange diagram in which the incident K^+ emits some vector particle which subsequently scatters on the proton, yielding the hyperon and a second K^+ meson. The momentum spectrum of the two K mesons in this experiment is such that in most events the K's are "distinguishable" according to momentum transfer. The K^+ with the smaller momentum transfer will be referred to as K_1; the other K^+ is assigned to the baryon vertex and referred to as K_2.

Since it is difficult in general to predict how misleading such a selection criterion may be when applied to a particular distribution, we have systematically compared our experimental results to those obtained from a Monte-Carlo–generated phase-space sample that has been assigned the same center-of-mass angular distribution for the hyperon that we observe experimentally. The Monte Carlo events then undergo the same selection on smaller momentum transfer as the true events. The features we report here are significant in that they differ from what would be predicted by this "peripheral phase space."

When analyzed with regard to vector exchange as described, the data contain several notable features: (1) The momentum-transfer spectrum to the Y^0-K_2^+ system peaks at a value about 50% lower than the spectrum for momentum transfer to the hyperon alone. (2) The Treiman-Yang plot for $K^+K^+\Lambda^0$ events has a χ^2 probability of less than 0.1% for agreement either with isotropy or with the "peripheral phase space." It fits the general form

$$d\sigma/d\Omega = A + B\cos\varphi + C\cos 2\varphi$$

postulated for spin-1 exchange by Stodolsky and Sakurai,[14,15] although a relatively large $\cos\varphi$ term effectively rules out the possibility that the Λ^0-K_2^+ is produced in a single state of angular momentum and parity via the Stodolsky-Sakurai model.[15] (3) The Λ^0 events seem to differ significantly from the Σ^0 events in the three angular distributions suggested by the Sakurai-Stodolsky model. (4) The Y^0-K_2^+ mass spectrum does not show much evidence for the known isobars at 1688, 2190, and 1920 MeV/c^2.

Conclusions.—Our data do not yield any direct evidence for a K^+K^+ resonance. They would seem to imply instead that the K^+K^+ scattering cross section is at best quite small.

It would seem that there is rather strong evidence for a vector-exchange diagram that does not involve K^+K^+ scattering directly. The observed data, however, are consistent with some admixture of diagrams which might be very difficult to sort out, even with large numbers of events.

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$SU(6)_W$ AND MESON RESONANCES OF EVEN PARITY*

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It was shown recently that if the three-particle vertices involving the pseudoscalar and vector octet and singlet mesons are invariant to the group $SU(6)_W$, the one-M (-meson) exchange force may bootstrap the M as P-wave, MM bound states.[1] In this model, there are forces in states of even orbital angular momentum that are of the same order as the P-wave forces. These even-l forces will lead to predicted meson resonances of even parity. The purpose of this note is to list the quantum numbers and relative coupling strengths of different decay modes of the predicted even-parity mesons, and to compare some of the results with experiment.

The basic odd-parity mesons M are taken to be degenerate. The $SU(6)_W$-symmetric MMM vertices are given in Ref. 1; alternatively, they may be determined from the work of Sakita and Wali.[2] The method of calculation involves constructing the vertices so that the $SU(6)_W$ symmetry is preserved if one particle is off the mass shell, and then examining the various one-M-exchange amplitudes in Born approximation at the physical threshold energy. The many-channel amplitudes corresponding to particular initial and final orbital angular momenta are then diagonalized. The threshold value of an eigenamplitude is called the eigenvalue. It is assumed that resonances or bound states may be associated with the largest positive eigenvalues, and that the relative constants of interaction of the different two-particle configurations of a composite particle are equal to the relative components of the configurations in the corresponding eigenamplitude.

It is shown in Ref. 1 that the one-M-exchange amplitude at threshold for any specific pair of MM states may be written in the form $A_{ij} \times(\vec{k}-\vec{k}')_i(\vec{k}-\vec{k}')_j$, where i and j label the spatial axes, $\vec{k}$ and $\vec{k}'$ are the initial and final three-momenta in the center-of-mass system, and A_{ij} is an operator in the space of the intrinsic spins of the initial and final mesons. Those amplitudes that are linear in both $\vec{k}$ and $\vec{k}'$ are P-wave amplitudes. However, amplitudes quadratic in either $\vec{k}$ or $\vec{k}'$ are of the same order; these amplitudes represent both S-wave scattering and S-D transitions.

At present there is no reliable way to estimate the relative importance of S-S and S-D amplitudes, since these amplitudes are associated with different phase-space factors.[3] In this note we will neglect the S-S amplitudes, because this assumption leads to simple results, and because D-wave decays of even-parity meson resonances are observed to be important experimentally.

All S-D transitions corresponding to the SU(3) representations $\underline{10}$, $\underline{10}^*$, and $\underline{27}$ vanish, for reasons discussed at the end of this note. Since only S-D transitions are considered, the total S-wave component and total D-wave component of each eigenamplitude are of equal magnitude,

Table I. Quantum numbers of the meson states of positive eigenvalue.

Eigenvalue	States
$(5)^{1/2}$	$(\underline{1}, 1)^+$
$(11/4)^{1/2}$	$(\underline{1}, 5)^+$
$(5/4)^{1/2}$	$(\underline{1}, 3)^-$, $(\underline{8}, 1)^+$, $(\underline{8}, 5)^+$, $(\underline{8}, 3)^+$, $(\underline{8}, 3)^-$