Title

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(To be presented by Harold K. Ticho)

In a study of the reaction,

$$K^- + p \rightarrow \bar{K}^0 + \pi^- + p \qquad (A)$$

at 1.15 GeV/c (E_{cm} = 1863 MeV) Alston et al, have observed an enhancement in the K-π mass spectrum at a value of 885 MeV, which they interpreted as a K-π resonance (K^*).[1] Its specific parameters can be summarized as follows:

(a) The central value is 885 MeV and the full width is 16 MeV.

(b) The decay branching ratio

$$\frac{K^{*-} \rightarrow K^- + \pi^0}{K^{*-} \rightarrow \bar{K}^0 + \pi^-},$$

as determined from a simultaneous study of the reaction

$$K^- + p \rightarrow K^- + \pi^0 + p \qquad (B)$$

points to the isotopic spin assignment of 1/2.

(c) On the basis of the assumption that s-wave production dominates the reaction

$$K^- + p \rightarrow K^{*-} + p, \qquad (C)$$

the decay angular distribution excludes spin 2 or higher assignment for the resonance, but cannot distinguish between spin 0 or 1. The assumption

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appears justified since the energy studied is only slightly above $K^{*}p$ threshold (E_{cm} = 1823 MeV). Furthermore, the production angular distribution, though very limited in statistics, was consistent with this hypothesis.

(d) The total cross section for reaction (A) was found to be 2.0± 0.3 mb. The cross section for the $K^{*-}p$ production was 1.3± 0.3 mb.

The resonance has subsequently been observed in several high energy π^- experiments in the reactions of the type

$$\pi^- + p \rightarrow \Sigma + \pi + K \qquad (D)$$

and

$$\pi^- + p \rightarrow \Lambda + \pi + K, \qquad (E)$$

[2, 3]

as well as in the antiproton annihilation in hydrogen.[4] The pion data are consistent with the assignment of 885 MeV for the central value, as well as 1/2 for the isotopic spin, but indicate a significantly broader width. The statistics in all pion experiments to date have been too limited for a detailed study of angular correlations with the view of determining the spin and parity of the resonance.

In order to investigate properties of the K^* in more detail, we have undertaken a study of reaction (A) at the incident momentum of 1.22 GeV/c ±4% (E_{cm} = 1895 MeV). A separated K^- beam was used to guide approximately 200 000 K^- mesons into the 72-inch hydorgen bubble chamber . Using our PANG, KICK, and EXAMIN programs, we have analyzed approximately 3500 V^0 2-prong events, of which 558 were examples of reaction (A). In the majority of cases (≈ 99%) the kinematic analysis of the decay and production vertices was sufficient to separate this reaction from others with the same topology. In the few remaining cases, the proper identification could be made by examining the ionization of the positive tracks from the production and decay vertices.

Events that failed to give a satisfactory χ^2 to at least one hypothesis were automatically remeasured. We estimate that fewer than 2% of the genuine examples of reaction (A) are missing from our sample because of failing twice to give a satisfactory fit. Furthermore, on the basis of comparison of the two scans (all film was scanned twice), we estimate that less than 2% of the $\overline{K}^0 p \pi^-$ events were missed on both scans. Accordingly, the conclusions we draw from the data could hardly be affected by these missing events.

Figure 1 shows a Dalitz plot of the $\overline{K}^0 p \pi^-$ events. It can be seen that the only resonance playing a prominent part in the reaction is the K^*, which manifests itself as an enhancement along a vertical line centered around $M^2(K-\pi) = 0.8$ GeV^2. There is no evidence for any production of N^* (3, 3 pion-nucleon resonance) which would exhibit itself as a bunching of points along a horizontal line near $M^2(p-\pi^-) = 1.5$ GeV^2. Finally, the presence of some K-nucleon T = 1 resonance would appear as an excess of events along a line parallel to the dashed line indicated in Fig. 1.

Figure 2 shows the mass spectrum for the K-π system. To obtain a best value for the mass and width of the resonance, we fitted the data to a 4-parameter expression of the form

$$N(M) = A\phi(M) + B\phi(M) \frac{1}{(M-M_0)^2 + (\Gamma/2)^2},$$

where $\phi(M)$ is the 3-body phase for the $\overline{K}^0 p \pi^-$ final state, and M_0 and Γ are the respective central value and the width of the resonance. The results of the fit are exhibited in Table I. We should mention here several shortcomings of this fit. First, it depends on the assumption that the 3-body background and the K-π resonance intensities add directly without any interference. Second, even though account is taken of the cutoffs imposed by the phase space, none is taken of the momentum dependence of the matrix element. In other words, if there are higher partial waves present in the K^* production, they will be more inhibited by the centrifugal barrier at the upper end of the spectrum than at the lower end. Accordingly, both the central value and the full width might be underestimated. Finally, if there are any other strong final state interactions, this procedure neglects them completely.

The cross section for all events of type (A)—after correcting for neutral decays and the V's that escape from the chamber before decaying—is 1.61 ± 0.15 mb. Assuming a 3-to-1 K^* to background ratio (see Table I), and correcting for the $K^{*-} \to K^- + \pi^0$ decay mode, we get 1.8 ± 0.4 mb for the $K^{*-}p$ total cross section.

The recently observed K-π resonance around 730 MeV[3] does not play any significant part in reaction (A). The data are consistent with zero cross section for the production of this resonance. If we interpret the slight excess of events between 720 and 730 MeV as due entirely to the resonance of Alexander et al., then this procedure gives us an upper limit of 37 μb on the cross section.

The production angular distribution for the K^* events is shown in Fig. 3. In plotting this and the subsequent angular distributions, we have defined as K^* those events that satisfy the criterion 860 MeV $< M(K-\pi) <$ 910 MeV. The intensity of K^* to 3-body background events in this region is about 15 to 1. We can see from the angular distribution that partial waves higher than s waves contribute to the reaction. Furthermore, it appears that one needs at least $\cos^4\theta$ terms to reproduce the data adequately. A substantial amount of d wave would not be surprising, since the center of mass momentum in the final state is about 280 MeV/c.

To determine the spin of the resonance we have studied the angular distributions in the decay of the K^*. We can characterize the production and decay process by three angles: the production angle θ and the polar and azimuthal decay angles α and ϕ. In practice, it is more convenient to deal with the three interrelated decay angles α (Adair angle), η(angle made by the decay $\overline{K}^0$ with the normal to the production plane), and λ (angle made by the decay $\overline{K}^0$ with the direction of the K^*) (see Fig. 4a, b, c). For spin-0 K^*, the distribution in all three of these decay angles must be isotropic. For spin-1 K^*, the distribution can vary anywhere from $\sin^2\psi$ (where ψ is either α, η or λ) to $\cos^2\psi$. The Adair analysis does not yield a unique answer, even if we restrict ourselves to events produced along the beam direction, because the proton carries off half a unit of angular momentum.

The three decay distributions are illustrated in Fig. 4a, b, c. No production angle cutoff has been imposed. The data on the fits of these distributions to the powers of $\cos\psi$ are tabulated in Table II. We can draw two conclusions: First, all the distributions are quite consistent with isotropy; and second, there is not much evidence for any strong final state interaction, which would show up as a linear term in $\cos\lambda$. In other words, the data show no obvious deviation from the simple two-body production model

$$K^- + p \rightarrow K^{*-} + p,$$

followed by the decay

$$K^{*-} \rightarrow \overline{K}^0 + \pi^-.$$

We have looked, furthermore, at these three distributions as a function of the production angle and have found no deviations from isotropy at any angle. The isotropy does not exclude spin 1, since it is possible, especially with higher partial waves which could cause the decay distributions to vary rapidly with the production angle, to obtain it with a vector K^*. On the other hand, the isotropy does provide a rather strong circumstantial evidence for spin-0 K^*.

Within the past year several theoretical papers have appeared relating the width and cross section for the K^* production to its spin.[5, 6, 7] These arguments tended to favor a vector particle on the basis of the previously reported narrow width. However, the broader width makes the vector assignment no longer the favored one. Furthermore, all these arguments have assumed that the one-pion exchange process (OPE) dominates reaction (A).

We have analyzed our data to see to what extent the OPE model is valid. If a region exists which is dominated by the OPE process, then the data in this region should follow a straight line on a Chew-Low plot and, moreover, this line should pass through the origin. Furthermore, in the incident K^- rest frame there should be no correlation between the plane defined by incoming and outgoing protons and the plane defined by the $\overline{K}^0$ and π^- (Treiman-Yang test).[8] Our data do indicate that the OPE is no longer a satisfacotry model for $p^2 > 10$, where p is the momentum transfer given to the nucleon. Even though the data be consistent with the OPE model for $p^2 < 10$, the test is not statistically significant because of the low number of events in this region.

We are at present investigating reaction (A) at the incident momentum of 1.51 GeV/c. A general preliminary analysis indicates that the reaction is dominated again by the K^* production, whose full width now appears to be approximately 60 MeV, and the central value about 895 MeV. The decay angular distributions are again consistent with isotropy.

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Table I. Fit to the $\overline{K}^0 - \pi^-$ mass spectrum.

No. of degrees of freedom	16
χ^2 probability	18%
Full width (Γ)	47 MeV
Central value (M_0)	890.4 MeV
K^*/background ratio	~3/1

Table II. Fits to the decay distribution.

Angle	Isotropy		$1 + a \cos\psi$			$1 + a\cos\psi + b\cos^2\psi$			
	Degrees of freedom	χ^2 probability	Degrees of freedom	χ^2 probability	a	Degrees of freedom	χ^2 probability	a	b
α	9	7%	8	10%	-0.17± 0.10	7	7%	-0.16± 0.10	-0.09± 0.20
η	9	55%	8	45%	0.05± 0.10	7	40%	0.04± 0.10	-0.11± 0.20
λ	9	45%	8	55%	0.14± 0.10	7	75%	0.17± 0.12	0.39± 0.23

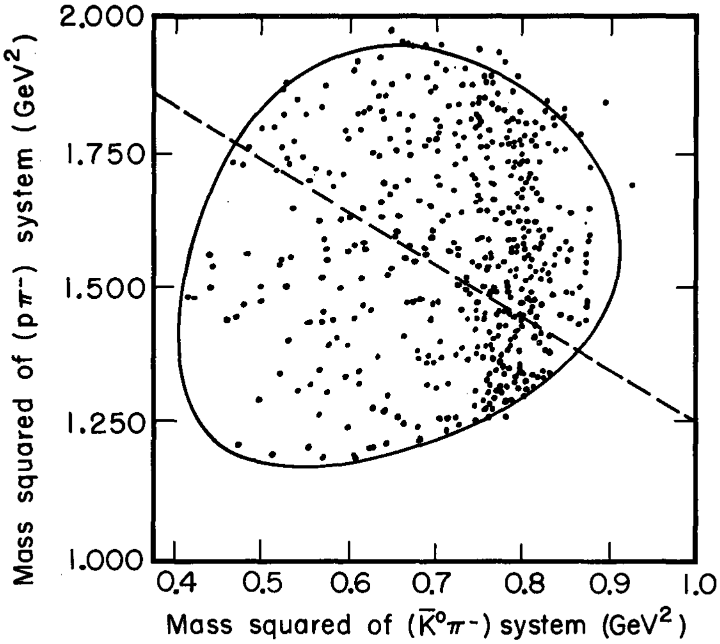
FIGURE LEGENDS

Fig. 1. Dalitz plot for the examples of the reaction $K^- + p \rightarrow \overline{K}^0 + p + \pi^-$. The kinematical boundary corresponds to the incident K^- momenta of 1.22 GeV/c.

Fig. 2. Mass spectrum of the $\overline{K}^0$-π^- system. Typical experimental error is 5 MeV.

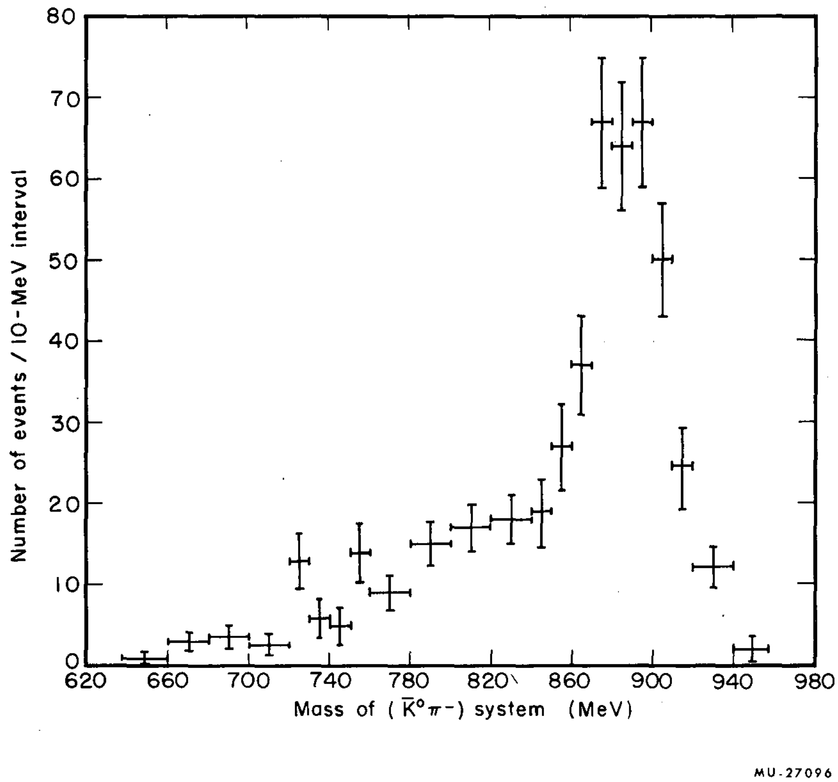
Fig. 3. Production angular distribution for the K^* events.

Fig. 4. The three decay distributions of the K^* events; (a) Adair distribution, (b) distribution with respect to the normal to the production plane, and (c) distribution along the line of flight of the K^*.



MU-27095

Fig. 1



Number of events / 10-MeV interval
0
10
20
30
40
50
60
70
80
620
660
700
740
780
820
860
900
940
980
Mass of ($\bar{K}^{0}\pi^{-}$) system (MeV)
MU-27096

Fig. 2

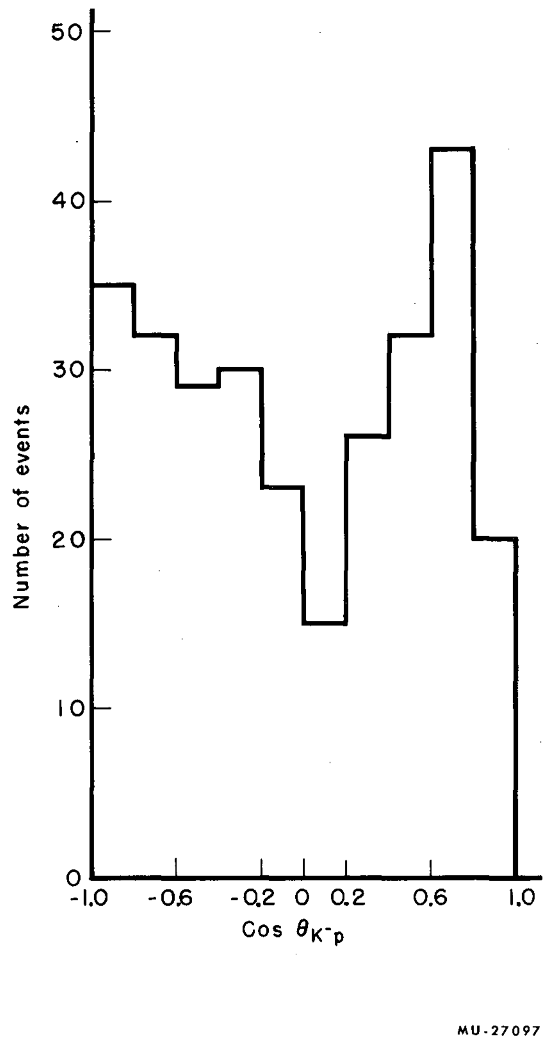
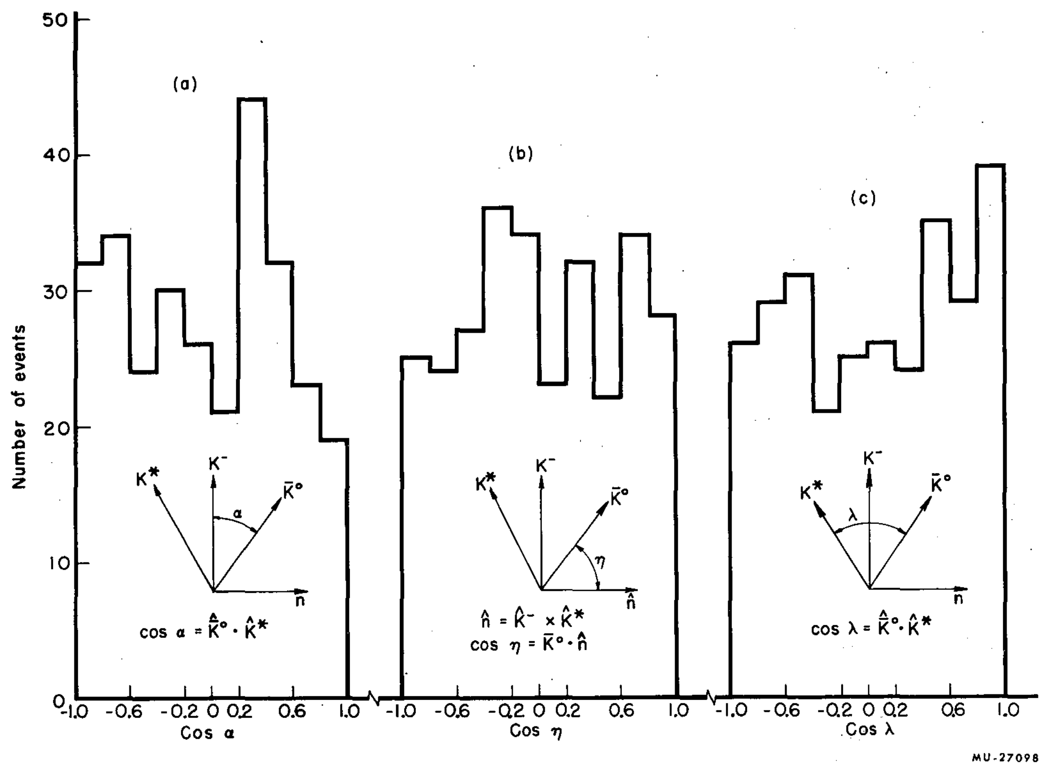

50
40
30
20
10
0
Number of events
-1.0
-0.6
-0.2
0
0.2
0.6
1.0
Cos θ_{K^-p}
MU-27097

Fig. 3



50
40
30
20
10
0
Number of events
(a)
(b)
(c)
K*
K⁻
K̄°
α
cos α = K̂° · K̂*
n
η
n̂
n̂ = K̂⁻ × K̂*
cos η = K̄° · n̂
λ
cos λ = K̂° · K̂*
-1.0 -0.6 -0.2 0 0.2 0.6 1.0
Cos α
Cos η
Cos λ
MU-27098

Fig. 4