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ON THE SPIN OF THE K^* RESONANCE

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On the Spin of the K^* Resonance[†]

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The production of the K^* resonance[1] in the reaction[2] $K^+ + p \to K^* + N_{33}^*$ at 1.96 BeV/c has permitted us to identify the K^* as a vector meson. Following a method due to Adair,[3] we examined the distribution in the angle α between the outgoing K^+ meson in the K^* c.m. and the incident K^+ direction. We find a strong anisotropy which can be fitted with $\cos^2\alpha$, and hence conclude that the spin[4,5] of the K^* is ≥ 1. Alston et al. presented evidence for the K^* spin to be less than 2 within 3 standard deviations.[1] This result, combined with the present data, allows us to assign spin 1^- to the K^*.[6]

The experiment was carried out with the 20-inch Brookhaven bubble chamber[7] in a separated beam[8] tuned to K^+ mesons.

The reaction we have studied is

$$K^+ + p \to K^+ + \pi^- + p + \pi^+. \qquad (1)$$

This reaction, which amounts to about 10% of the total cross section, has the property that a large proportion of events occur in the double resonant state:

$$\begin{tikzcd} K^+ + p \rightarrow K^{*0} \arrow[d] & + & N_{33}^{*++} \arrow[d] \\ K^+ + \pi^- & & p + \pi^+ . \end{tikzcd} \qquad (2)$$

The evidence for Reaction (2) is shown in Fig. 1, where we present a plot of the effective mass distribution $M_{p\pi^+}$ against $M_{K^+\pi^-}$. The triangle shown in the figure gives the kinematic mass limits for the two particle states $K\pi$ and $p\pi$. It should be noted that this is not a "uniform-density surface" in phase space. The projections on the two mass axes are also shown in the figure. Here we have defined events with effective mass $840 \leq M_{K^+\pi^-} \leq 940$ MeV as lying within the K^* resonance and events with $1130 \leq M_{p\pi^+} \leq 1300$ MeV as lying within the N_{33}^* resonance. These mass limits corresponds roughly to a level of 10% of the respective peak values. To date we have completed the analysis[9] of about 80% of our available data, namely 310 events. Of these, 201 events lie within both of the above mass limits, i.e., within the "double resonance region." In what follows, we confine our discussion to these latter events, which can then be considered as examples of a "two-particle" reaction, as given in (2).

We observe that the production angle of the K^* is strongly forward peaked, as shown in Fig. 2. Here θ_{K^*} is the angle between the incident K^+ meson and the outgoing K^* in the K^+-p c.m. system.

In order to perform an "Adair analysis," we now limit ourselves further to those events for which $1.0 \geq \cos\theta_{K^*} \geq 0.8$. There are 69 such events in our sample. In Figs. 3(a) and 3(b) we present the unfolded and folded distributions in the K^* decay angle, α, defined above. The nonisotropy of the distribution immediately rules out a spin-zero assignment for the K^*. In the decay of a spin-one K^*, the angular distribution depends on the state of alignment of the K^* spin as determined by the dynamics of the production reaction. For the cases of maximal alignment of the spin vector with respect to the incident direction, the distributions would have the forms given in Table I. For a nonaligned spin this distribution would be isotropic. Also given there are the corresponding distributions for the N^* decay. Any combination of the listed distributions is allowed. The observed distribution in the K^* decay angle is fitted well with a pure $\cos^2 \alpha$ intensity distribution. In Figs. 4(a) and 4(b) we present the corresponding distributions for the N^* decay angle β. For a completely aligned N^* with $m_s(N^*) = \pm 1/2$, the predicted distribution is $1 + 3 \cos^2\beta$ (see curve in Fig. 4b). Such a fit is consistent[10] with our data ($\chi^2 = 7.0$).

These distributions thus imply a strong alignment of the K^* spin, with the component $m_s(K^*) = 0$ along the incident beam direction. It is perhaps worth noting that just such an alignment would result if the one-pion exchange were a dominant contributor to the production reaction. This can be seen by noting that for events with $\cos\theta_{K^*} \geqslant 0.8$, the angle α differs little from the $K\pi$ scattering angle at the K^* vertex. At that vertex the K^* spin can have only the projection $m_s(K^*) = 0$ on the "incident" K-π axis, since here we are dealing with two spin-zero "incident" particles. Hence the projection on the incident beam direction (i.e., K-p axis) is also zero, which then results in a $\cos^2\alpha$ distribution.

We wish to take this opportunity to thank the many members of the staff of the Brookhaven National Laboratory for their very helpful attitude in making this experiment possible. In particular, we would like to express our appreciation to Dr. Hildred Blewett, Dr. Hugh Brown, Dr. Ralph Shutt, Dr. James Sanford, Mr. Julius Spiro, Dr. Metford Webster, and the AGS crew.

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Footnotes and References

† Work done under the auspices of the U. S. Atomic Energy Commission.

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8. C. Baltay, J. Sandweiss, J. Sanford, H. Brown, M. Webster, and S. Yamamoto, in *Proceedings of the 1962 International Conference on Intrumentation for High Energy Physics at CERN, Geneva, Switzerland* (in publication).

9. In this work we utilized a modification of the geometrical reconstruction (PANG) and kinematical fitting (KICK) programs of the Alvarez Group. J. P. Berge, F. T. Solmitz, and H. D. Taft, Rev. Sci. Instr. (in press), and A. H. Rosenfeld and J. M. Snyder, Rev. Sci. Instr. (in press).

10. With the present data an isotropic fit to the observed distribution in β is equally likely ($\chi^2 = 6.5$).

Table I. Allowed spin projections on the incident K^+p axis of a spin-one K^* and the N^*_{33} for an initial proton spin projection of $m = 1/2$. The corresponding angular distributions for the K^* decay angle, α, and the N^* decay angle, β, are also given.

$m_s(K^*)$	$m_s(N^*)$	$I(\alpha)$	$I(\beta)$
+1	- 1/2	$\frac{1}{2}\sin^2\alpha$	$1 + 3\cos^2\beta$
0	+ 1/2	$\cos^2\alpha$	$1 + 3\cos^2\beta$
-1	+ 3/2	$\frac{1}{2}\sin^2\alpha$	$3\sin^2\beta$

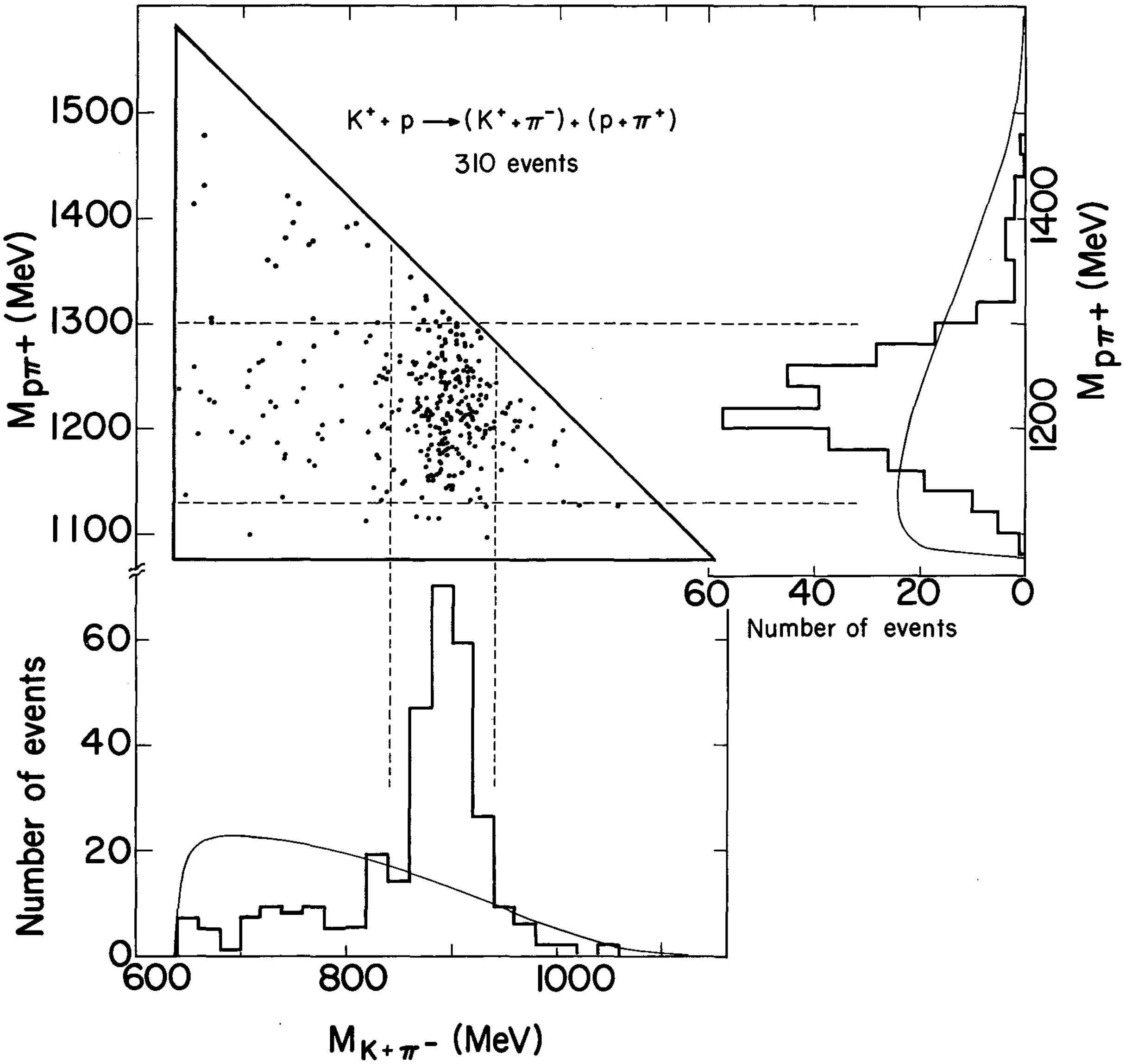
Figure Captions

Fig. 1. Scatter diagram of the effective mass distribution $M_{p\pi^+}$ versus $M_{K^+\pi^-}$. The triangle delineates the kinematical limits. The projections on the $M_{p\pi^+}$ mass axis show the N_{33}^* production, while the projection on the $M_{K^+\pi^-}$ axis shows the simultaneous K^* production. The curves give the distributions expected from phase-space calculations without dynamic effects.

Fig. 2. The angular distribution for K^* production. The events shown here are chosen to lie inside both the N^* and K^* resonances.

Fig. 3. The angular distribution of α, the angle of the outgoing K^+ in the K^* c.m. system with respect to the incident K^+ direction. The 69 events shown are selected to lie inside the N^* and K^* resonances.

Fig. 4. The angular distribution of β, the angle of the outgoing proton in the N^* c.m. system with respect to the incident K^+ direction. The same events described in Fig. 3 are shown here.



MUB-1285

Fig. 1

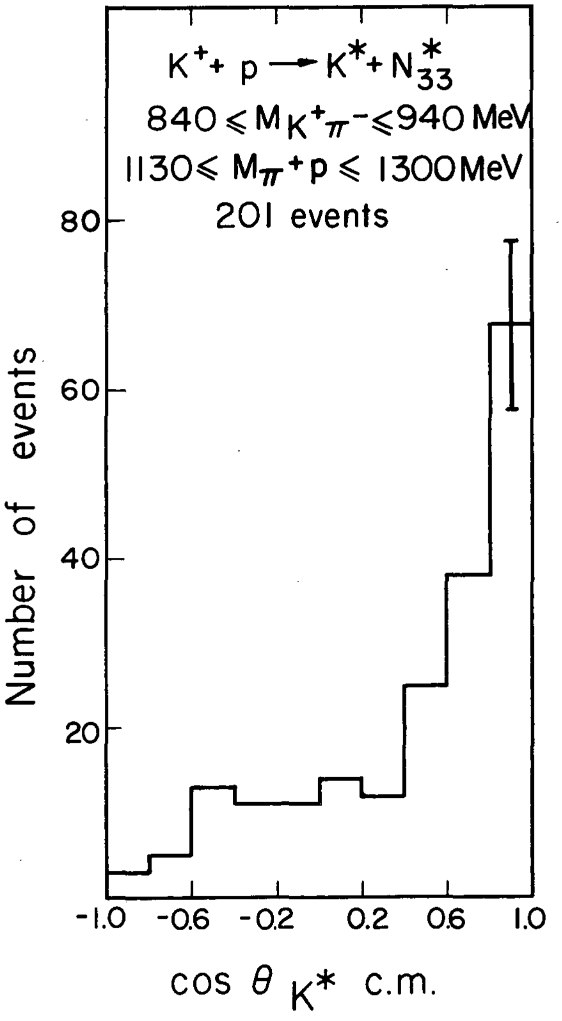


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Fig. 2

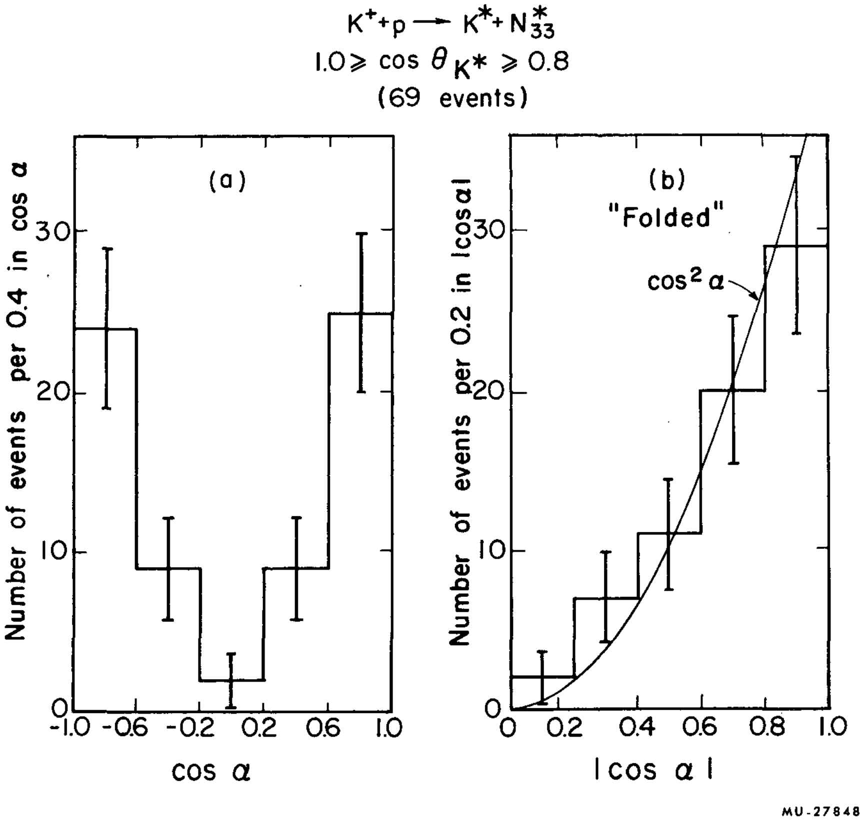
$K^+ + p \longrightarrow K^{*+} N_{33}^*$
$1.0 \geq \cos\theta_{K^*} \geq 0.8$
(69 events)
(a)
Number of events per 0.4 in cos α
0
10
20
30
-1.0
-0.6
-0.2
0.2
0.6
1.0
cos α
(b)
"Folded"
$\cos^2\alpha$
Number of events per 0.2 in |cos α|
0
10
20
30
0
0.2
0.4
0.6
0.8
1.0
|cos α|
MU-27848

Fig. 3

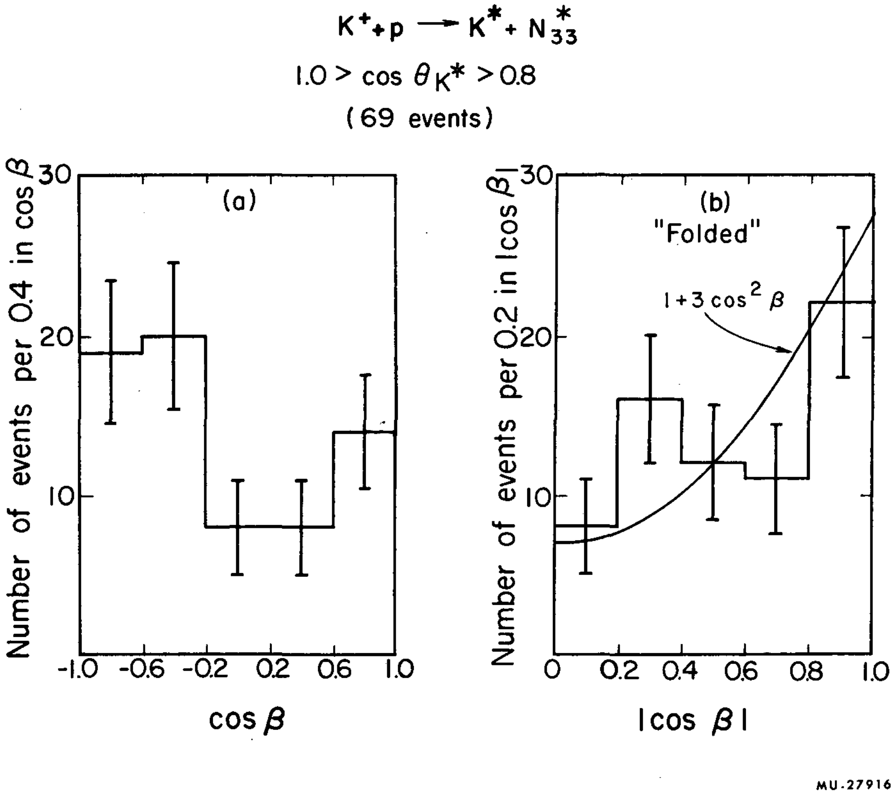
$K^+ + p \longrightarrow K^* + N^*_{33}$
$1.0 > \cos\theta_{K^*} > 0.8$
(69 events)
(a)
Number of events per 0.4 in cos β
30
20
10
-1.0
-0.6
-0.2
0.2
0.6
1.0
cos β
(b)
"Folded"
1 + 3 cos² β
Number of events per 0.2 in |cos β|
0
0.2
0.4
0.6
0.8
1.0
|cos β|
MU-27916

Fig. 4