[3]See A. O. Barut and H. Kleinert, Phys. Rev. 160, 1149 (1967); H. Kleinert, Phys. Rev. 163, 1807 (1967), and thesis, University of Colorado, 1967 (unpublished).

[4]See the latest published curve up to $|t| \cong 10$ GeV/c^2 [W. Albrecht et al., Phys. Rev. Letters 18, 1014 (1967)], and the more recent measurements from Stanford up to $|t| \approx 25$ (GeV/c)^2 (R. Taylor et al., to be published).

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GENERALIZED DECK EFFECT AND $\bar{K}^{**}(1300)$ PRODUCTION IN $K^- + p \to K^- + \pi^+ + \pi^- + p$ AT 5.5 BeV/c †

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We report on a comparison of the generalized Deck effect (discussed recently by Ross and Yam[1]) with our data from a K^-p experiment in which the 30-in. Midwestern Universities Research Association hydrogen bubble chamber was exposed to a 5.5-BeV/c separated K^- beam at the zero-gradient synchrotron of the Argonne National Laboratory. In a sample of four-prong events (exposure equivalent to 1 event/0.3 μb) we identified 3368 examples of the reaction

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

1304 of these events with an invariant mass, $M(K^-\pi^+)$, in the interval 0.84-0.94 BeV are due in large part to the reaction

$$K^- + p \to \bar{K}^{*0} + \pi^- + p, \quad \bar{K}^{*0} \to K^- + \pi^+. \qquad (2)$$

The background to $\bar{K}^*$ events is estimated to be less than 15%; it is mostly associated with $N^{*++}(1236)$ production. There is little if any ρ^0 [<~7% of reaction (1)] or $Y^{*0}(1520)$, $Y^{*0}(1770)$, and/or $Y^{*0}(1815)$ (all Y^{*0} <~6%).

The $M(\bar{K}^{*0}\pi^-)$ distribution shows a broad enhancement in the mass region 1.2-1.5 BeV.[2] Part of this enhancement may be shown (by a detailed study of decay angular distributions[3]) to be due to $\bar{K}^{**}(1430)$ production. The remainder of the enhancement is presumably due to the "Deck" background as well as to possible other $\bar{K}^*\pi$ resonances. The purpose of the present study was to compare the data with the background predicted by the Ross-Yam model in order to see whether the data could or could not be understood without invoking the existence of genuine resonances.

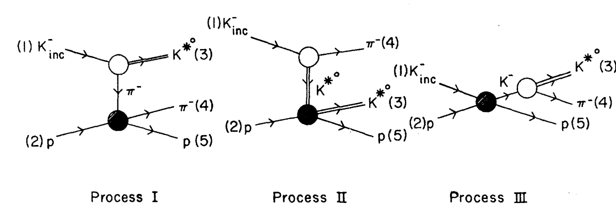

FIG. 1. Three processes associated with the dissociation, $K \to K^* + \pi$, considered in the model.

The Ross and Yam model we want to consider involves three processes corresponding to the dissociation of K^- into $\bar{K}^{*0}$ and π^- with (virtual) elastic scattering of each of the three particles with the target proton, as shown in Fig. 1. In addition to the usual Deck model (process I in Fig. 1) the model includes two other processes and mutual interferences. The relative phases of the amplitudes are determined by means of approximating each (virtual) elastic-scattering amplitude by the corresponding asymptotic form associated with the vacuon exchange. For example, the invariant amplitude for the process II in Fig. 1 is

$$\mathfrak{M} = gF(m_1^2, m_4^2, y^2)\frac{1}{y^2 - m_{K^*}^2}\left[-2iM_{35}q_{35}\sigma_T(\bar{K}^{*0}p)e^{\frac{1}{2}A(\bar{K}^{*0}p)\tau}\right]\left[p_{14} - \frac{p_{14}\cdot y}{M_{K^*}^2}\right]\cdot\epsilon(\lambda),$$

where g is the $\bar{K}^{*0}K^-\pi^+$ coupling constant, F the form factor function associated with the $\bar{K}^*$ vertex, and $\epsilon(\lambda)$, the polarization vector of $\bar{K}^*$. σ_T and A represent, respectively, the total cross section and the slope of the diffraction peak. Further notations used are $p_{14}=p_1+p_4$, $y=p_1-p_4$, $\tau=(p_2-p_5)^2$; M_{35} is the mass, and q_{35} the center-of-mass momentum of the $\bar{K}^*p$ system.

We assume, ignoring the off-mass-shell effects, that σ_T's and A's are not much different from the corresponding physical quantities, namely: (a) for π^-p, $\sigma_T=35$ mb, $A=8$ BeV^{-2}, which describe reasonably well the π^-p process[4] in the invariant-mass range, 1.78-2.75 BeV, appropriate to our case; (b) for K^-p, $\sigma_T=28$ mb, $A=8$ BeV^{-2} at our incident lab momentum of 5.5 BeV/c [5]; and finally (c) in the absence of any information on the $\bar{K}^*p$ process we take $\sigma_T=35$ mb and $A=8$ BeV^{-2}.

In order to remove possible complications due to N^{*0}'s, we apply the requirement $M(\pi^-p)>1.78$ BeV. Also the region $|\tau|=\Delta^2(p)>1$ BeV has been excluded. To examine the effect of N^{*++} we make the analysis with and without removal of events with $1.135<M(p\pi^+)<1.315$ BeV. The cuts are applied consistently to both the model and the data, thereby eliminating any possibility of kinematic bias.

The calculations were performed by a Monte-Carlo technique. We have explored the effect of modest variations in the parameters σ_T, A as well as the inclusion of form factors of the form

$$F(p_i^{\,2})=(m_i^{\,2}-\Lambda_i^{\,2})/(p_i^{\,2}-\Lambda_i^{\,2})$$

which involves a constant cutoff mass, Λ_i, and is normalized to 1 on the mass shell, $p_i^{\,2}=m_i^{\,2}$.

Some results are given in Table I and in the curves of Fig. 2. We find that the model predicts a broad peak in the $M(\bar{K}^{*0}\pi^-)$ spectrum of width about 500 MeV centered somewhere in the mass region 1.3-1.4 BeV. The shape of this peak is rather insensitive to the parameters σ_T, A and presence of form factors with reasonable cutoff masses. It appears, in particular, that the width cannot be reduced significantly (say, to 300 MeV, the total width of the experimental peak) unless form factors with unreasonably small cutoff masses and high slopes are allowed. The calculated cross section is, of course, subject to the uncertainty in the form factors to be used and other possible effects such as the off-mass-shell corrections to the virtual elastic scatterings. In the following we have chosen to use the predictions of the model without form factors (set 1 in Table I) multiplied by an arbitrary normalization factor fixed to give agreement with the data in the region above the resonances, $1.5<M(\bar{K}^{*0}\pi^-)<1.9$ BeV. With this normalization the calculated cross section for reaction (2), with $M(p\pi^-)>1.78$ BeV and $\Delta^2(p)<1$ (BeV/c)^2, is 62 μb [$=238\times$(isospin factor of $\frac{2}{3}$)$\times$(normalization factor of 0.41)]. The experimental cross section is 142 ± 24 μb.

Figure 2 shows comparisons of our data with the predictions of the model. In each histogram the unshaded (shaded) distribution refers to all events (events with N^{*++} removal). Figures 2(a)-2(g) refer to events with $M(p\pi^-)>1.78$ BeV and $|\tau|<1$ BeV^2. The solid curves α (β) are

Table I. Parameters and results for several calculations of the model. We have used $g^2/4\pi=1.6$ corresponding to the K^{*0} partial decay width$=\frac{2}{3}\times 49$ MeV. The calculated cross sections include the cuts $\Delta^2(p)<1$ BeV^2 and $M(p\pi^-)>1.78$ BeV.

Set	Parameters: σ_T(mb)/A(BeV^{-2}) π^-p	$\bar{K}^{*0}p$	K^-p	Form factors Λ^2 [a] (BeV^2) $\Lambda_1^{\,2}$	$\Lambda_2^{\,2}$	$\sigma(K^-+p\to K^{*0}+\pi^-+p)$ (μb)	$M(\bar{K}^{*0}\pi^-)$ peak M (BeV) [b]	Γ (BeV) [b]
1	35/8.0	35/8.0	28/8.0	···	···	238	1.40	0.53
2	35/8.0	c	···	···	···	95	1.45	0.53
3	···	35/8.0	···	···	···	67	1.53	0.60
4	···	···	28/8.0	···	···	64	1.38	0.60
5	35/8.0	35/8.0	28/8.0	1.0	2.0	87	1.33	0.50
6	35/10.0	35.10.0	28/8.0	···	···	174	1.40	0.50
7	35/10.0	35.10.0	28/8.0	1.0	2.0	79	1.33	0.45

[a]No form factor was tried for process III (Fig. 1).
[b]M and Γ stand for the center and the full width at half-maximum, respectively, of the peak.
[c]Not used.

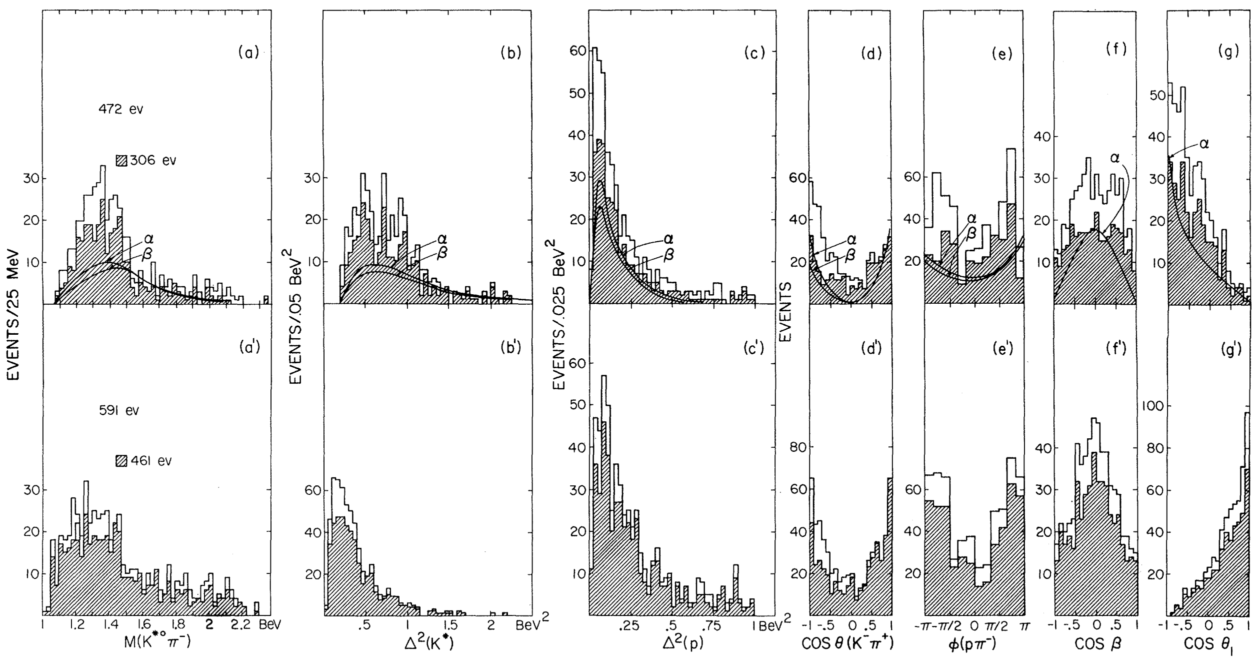

FIG. 2. (a) $M(\bar{K}^{*0}\pi^-)$, (b) $\Delta^2(\bar{K}^{*0})$, (c) $\Delta^2(p)$, (d) decay cosine of $\bar{K}^{*0}$, (e) Trieman-Yang angle of the π^-p system, (f) $\cos\beta$, and (g) $\cos\theta_1$. The last two angles describe the decay of the $\bar{K}^{*0}\pi^-$ system; in the rest frame of $\bar{K}^{*0}$ and π^- let $\vec{z}=\vec{K}_{\rm inc}^-$ (unit vector along the incident K^-), $\vec{z}_h=\vec{K}^-+\vec{\pi}^+$, $\vec{n}=\vec{K}^-\times\vec{\pi}^+$, then $\cos\beta=\vec{n}\cdot\vec{z}$ and $\cos\theta_1=\vec{z}_h\cdot\vec{z}$. The cuts $0.84<M(K^-\pi^+)<0.94$ BeV and $\Delta^2(p)<1$ BeV^2 apply to all distributions shown. (a) through (g) are for the case $M(p\pi^-)>1.78$ BeV and (a′) through (g′) for $M(p\pi^-)<1.78$ BeV. Shaded distributions are due to removing N^{*++}. The curves labeled α (β) in (a) through (g) are the predictions of the model (set 1, Table I), normalized as explained in the text, without (with) the N^{*++} removal.

predictions of the model without (with) the N^{*++} cut. The remaining distributions, Figs. 2(a′)-2(g′), refer to events with $M(p\pi^-)<1.78$ BeV and $|\tau|<1$ BeV^2.

We note the following features:

(a) Figure 2(a) shows an excess of about 60 events in the $\bar{K}^{**}(1430)$ region (1.38-1.5 BeV). This corresponds to a cross section of about 19 μb, which is reasonable when compared with the independent estimate 26 ± 3 μb.[3] In the mass region 1.2-1.38 BeV, we observe 182 events (55 μb) whereas the normalized model predicts 59 events (18 μb). We interpret this effect as being due to a genuine resonance in the $\bar{K}^*\pi$ system, namely the $\bar{K}^{**}(1300)$.[2]

(b) The remaining distributions [Figs. 2(b)-2(g)] are in rough qualitative agreement with the predictions of the model. Those discrepancies that do exist can be understood as being due chiefly to events in the $\bar{K}^{**}(1300)$ region.

We summarize briefly some properties of events in the $\bar{K}^{**}(1300)$ region, suggesting the production of a 1^+ $\bar{K}^*\pi$ system via vacuon exchange: (a) The $\Delta^2(p)$ distribution is extremely narrow, with a width of about 0.2 BeV^2. (b) The $\cos\beta$ distribution shows characteristics expected for the decay of a $\bar{K}^*\pi$ system with $J^P=1^+, 2^-, \cdots$, produced mainly with $J_z=0$.[6] (c) The $\cos\theta_1$ distribution is consistent with being flat, indicating the dominance of s-wave decay.

Ross and Yam gave a qualitative argument that the model gives rise to the $\bar{K}^*\pi$ system mainly in the $J^P=1^+$ state. It follows that, while our data support the assignment $J^P=1^+$ for the $\bar{K}^{**}(1300)$, interference makes it difficult to separate the $\bar{K}^{**}(1300)$ from the background.

We wish to thank Professor M. Ross and Dr. Y. Y. Yam for suggesting the model to us and for many helpful discussions.[7] We gratefully acknowledge the combined effort of the zero-gradient synchrotron and bubble-chamber staffs at Argonne and that of the scanning and measuring personnal at Illinois.

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Commission.

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[2]Several experimental groups have discussed $K^*\pi$ enhancement around 1.3 BeV in reactions $K^{\pm}+p\rightarrow K+\pi+\pi+p$ at various incident momenta ranging from 4 to 13 BeV/c. Some recent reports are J. Berlinghieri et al., Phys. Rev. Letters 18, 1087; C. Y. Chien et al., "Spin and Parity of the $T=\frac{1}{2}$ $K\pi\pi$ System Near 1.3 GeV" (to be published). In addition, evidence for $K^{**}(1300)$ in the reaction $\pi^-+p\rightarrow K+\Lambda+\pi+\pi$ has been reported by D. J. Crennell et al., Phys. Rev. Letters 19, 44 (1967). For further references we refer to the above papers.

[3]J. C. Park et al., Bull. Am. Phys. Soc. 12, 540 (1967). A detailed report of this analysis is in preparation.

[4]M. N. Focacci and G. Giacomelli, CERN Report No. 66-18, 1966 (unpublished).

[5]J. Mott et al., Phys. Letters 23, 171 (1966).

[6]S. M. Berman and M. Jacob, Phys. Rev. 139, B1023 (1965). We note that if ρ_{00} dominates as in the case of 0^+ exchange, then the $\cos\beta$ distribution for $J^P=0^-, 1^+, 2^-, \cdots$ should be of the form $a_0+a_2\sin^2\beta+\cdots+a_{2J}\times\sin^{2J}\beta$, where, in particular, $a_0=0$ for 1^+.

[7]One of us (J.C.P.) would like to apologize for an error made in the preliminary computation of the cross section for our reaction, which is quoted in Ref. 1.