MAST

Final States with Three Charged Particles and a Visible $\bar{K}^0$ from K^-d Interactions at 4.5 GeV/c*

W. L. Yen
Department of Physics
Indiana University-Purdue University at Indianapolis
Indianapolis, Indiana 46205 U.S.A.

and

A. C. Ammann, D. D. Carmory, A. F. Garfinkel,
L. J. Gutay, D. H. Miller, and K. Paler
Department of Physics
Purdue University
Lafayette, Indiana 47907 U.S.A.

ABSTRACT

We report on a study of the interactions of 4.48 GeV/c K^- mesons on neutrons. The 372000-picture exposure was taken in the Argonne National Laboratory 30-in. deuterium-filled bubble chamber. $\bar{K}^0$ final states from the three-or four-prong-plus-vee topologies are discussed. The final states investigated include (1) $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$, (2) $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0\pi^0$, (3) $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0n$, (4) $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$ (missing mass), (5) $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0$ (missing mass). These reactions are dominated by $K^*(890)$ and $\Delta(1236)$ production and the quasi-two-body reaction $K^-n \rightarrow K^{*-}\Delta^0$ has been studied. A search for exotic resonances found no evidence for their production. A Reggeized multiperipheral model of Plahte and Roberts has been applied to reactions (1) - (3). Good agreement with our data is obtained for distributions in $i) p_L^*$, $ii) p_T^*$, $iii) \cos \theta^*$, $iv) effective mass$. The model also gives the correct energy dependence between 3 and 4.5 GeV/c.

*Supported in part by the U.S. Atomic Energy Commission

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

1. Introduction

In the last few years, due to the extension of the Regge model to multiparticle production processes, great progress in the understanding of this field has been made[1]. One of the most fruitful approaches has been the parametrization proposed by Chan, Loskiewicz and Allison[2] (referred to hereafter as CLA). With the same set of parameters, this model is able to describe quite successfully the cross-section and single-particle distributions for varying energies and final multiplicities[2-11]. The qualitative differences between reactions initiated by different particles can also be explained. However, this model took no account of resonance production while attempting to describe reactions at energies where the formation of resonances dominates the cross-section. This deficiency has been corrected by Plahte and Roberts[12] who incorporate the resonance production into the model (referred to hereafter as PR). In this paper we have compared the predictions of the PR model to our experimental distributions from the reactions:

$$K^-n \rightarrow p\pi^-\pi^-\bar{K}^0, \quad (1)$$

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

$$+ \pi^+\pi^-\pi^-\bar{K}^0 n. \quad (3)$$

The data were obtained from a 372000 picture exposure (5 events/ μ b per nucleon) National Laboratory 30" deuterium bubble chamber to a beam of 4.48 GeV/c negative kaons. The film was scanned for events of the type three-or four-prong plus associated vee. In the case of four prong events, we demanded that the spectator proton have a momentum less than 0.3 GeV/c. All events of these topologies were measured on three scanning and measuring projectors (SMP) on line to an IBM 360/40-44 system. The programs

TVGP and SQUAW were used to geometrically reconstruct and kinematically fit the events. Out of the approximately 8000 events with an associated vee, 4474 were unambiguously identified as lambdas and 2978 as $\bar{K}^0$'s. In addition, 532 vees were regarded as ambiguous since both mass interpretations fitted the production vertex with at least 0.1% probability and the positive decay track had a momentum greater than 1.2 GeV/c so that identification on the basis of ionization was impossible. The distribution (not shown) of the cosine of the angle between the $\bar{K}^0$ and the outgoing π^+ in the $\bar{K}^0$ rest frame is flat whereas the corresponding distribution for the lambda's has a depression in it which is nicely filled by the ambiguous events. We, therefore, exclude the ambiguous events from the $\bar{K}^0$ sample and have made a small correction to the cross-section for lost events.[13] This paper is limited to those events in which the vee is a $\bar{K}^0$. For results in which the vee is a Λ , see Ref. [13].

The reactions considered, in addition to (1), (2), and (3), are:

$$K^- n \rightarrow p \pi^- \pi^- \bar{K}^0 \text{ MM}, \quad (4)$$

$$+ \pi^+ \pi^- \pi^- \bar{K}^0 \text{ MM}, \quad (5)$$

where MM denotes missing neutrals. The results on $K^*(890)$ events from reaction (1) and the evidence against an $n\pi^-\pi^-$ enhancement at a mass of 1.627 GeV from reaction (3) have been presented earlier [14,15].

II. Experimental Results

The number of events assigned to each reaction is given in Table I together with the corresponding cross-sections. The cross-section calculation was corrected for beam purity, scanning efficiency, Glauber screening effect[16] due to the presence of protons, $\bar{K}^0$ branching ratio, losses due to failures in the reconstruction program, and detection efficiency for

the $\bar{K}^0$. The events fitting reaction (1) constitute a relatively pure sample because the kinematic fit at the production vertex is well constrained. Since this is not the case for other reactions, an arbitrary 10% systematic error was included in the cross-section calculation for reactions (2) to (5). The resonance production cross-section is done by least-squares fit to phase space plus Breit-Wigner shape.

A. The Final State $p\pi^-\pi^-\bar{K}^0$

Fig. 1 shows all the two body effective mass distributions. The most prominent resonance productions are $K^*(890)$ and $\Delta(1236)$. In addition to these two resonances, we see some indication of $N(1525)$, $N(1688)$ and $\Sigma(1770)$ production. The cross sections for resonance production are given in Table I.

Fig. 2 (a-c) shows the production angular distributions for each of the final particles for reaction (1). The general features for this reaction are that the proton goes backward, the $\bar{K}^0$ goes forward, and the π^- is distributed isotropically with weak forward and backward peaks. Fig. 2 (d-f) shows the production angular distributions for the reaction

$$K^-n \rightarrow p\pi^- K^*(890)^-, \quad (6)$$

where the $K^*(890)$ resonance region is defined as $0.84 \leq M(\bar{K}^0\pi^-) \leq 0.94$ GeV. The same general features as in reaction (1) are seen for this reaction except that K^* production is more strongly peaked forward than the $\bar{K}^0$.

Fig. 3 shows all three body effective mass distributions. No appreciable structure can be seen except in the $\pi^-\pi^-\bar{K}^0$ effective mass distribution where some structure can be seen in the region of 1.6 GeV. This will be discussed in Sec. E.

There are 65 events where the $\bar{K}^0\pi_1^-$ effective mass falls in the $K^*(890)$ region and the π_2^-p effective mass falls in the $\Delta(1236)$ region. The $\Delta(1236)$ region is defined as $1.16 < M(p\pi^-) \leq 1.28$ GeV. Fig. 4 shows the differential cross section for these events as a function of t , the four momentum transfer squared. The peripheral peak ($-t \leq 0.8(\text{GeV}/c)^2$) has been fitted to the form $d\sigma/dt = A \exp(Bt)$ with the results

$$A = 181 \pm 41 \text{ } \mu\text{b}/(\text{GeV}/c)^2, \quad (7)$$

$$B = 4.0 \pm 0.8 (\text{GeV}/c)^{-2} \quad (8)$$

The density matrix elements for all t as determined by the method of moments are

$\rho_{00} = 0.35 \pm 0.09$, $\rho_{1-1} = 0.19 \pm 0.07$ and $\text{Re } \rho_{10} = -0.02 \pm 0.06$ for K^{*-} and $\rho_{33} = -0.03 \pm 0.08$, $\text{Re } \rho_{3-1} = 0.12 \pm 0.06$ and $\text{Re } \rho_{31} = 0.06 \pm 0.07$ for Δ^0 . This result appears to indicate a mixture of π and ρ exchange and are quite different from previously observed results of strong π dominance in the reaction

$$K^+p \rightarrow K^{*0} \Delta^{++} \quad (9)$$

at 5 GeV/c[17] where $\rho_{1-1} = 0.00 \pm 0.03$ and $\rho_{33} = 0.15 \pm 0.03$. Fig. 5 shows the $\cos \theta$ and ψ distribution for $\Delta(1236)^0$ and $K^*(890)^-$. The curves are the expected distributions calculated from the experimental density matrix elements.

B. The Final State $p\pi^-\pi^-\bar{K}^0\pi^0$

Fig. 6 shows all two-body effective mass distributions. Again the K^{*-} is the dominant resonance produced. The production of Δ^+ is also evident; however, only weak indication for the production of Δ^0 and $N(1525)$ are seen. Figs. 7 and 8 show all three-body and four-body effective mass distributions respectively. The cross sections for resonance production are

given in Table I. The possibilities of exotic resonances decaying into $\pi^-\pi^-$, $\pi^-\pi^-\bar{K}^0$, $\pi^-\pi^-\pi^0$ and $\pi^-\pi^-\bar{K}^0\pi^0$ will be discussed in Section E. Figure 9 shows the production angular distributions for each of the final particles. The general features of this reaction are that protons go backward and $\bar{K}^0$ s go forward. The charged pions show a weak forward peak in contrast to the neutral pions which show an isotropic distribution. The K^{*-} and Δ^+ are produced forward and backward, respectively.

C. The Final State $\pi^+\pi^-\pi^-\bar{K}^0 n$

Fig. 10 shows all two-body effective mass distributions. The $K^*(890)^-$ and $\Delta(1236)^-$ are the dominant resonances produced in this final state. The ρ^0 , Δ^+ , and $N(1525)$ are weakly produced. Figs. 11 and 12 show all three-body and four-body effective mass distributions. No particular structures can be seen. The cross sections for resonance production are given in Table I. The possibilities of exotic resonances decaying into $\pi^-\pi^-$, $\pi^-\pi^-\bar{K}^0$, $\pi^-\pi^- n$ and $\pi^-\pi^-\bar{K}^0 n$ will be discussed in Sec. E. Fig. 13 shows the production angular distributions for each of the final particles. The general features of this reaction are that the $\bar{K}^0$ goes forward and the neutron goes backward. Both charged pions are produced isotropically. The K^{*-} and Δ^- are produced forward and backward, respectively. The large isotropic component for ρ production in Fig. 13(i) is due to the large amount of background in the ρ^0 band.

D. The Final States $p\pi^+\pi^-\bar{K}^0 + \text{Neutrals}$ and $\pi^+\pi^-\pi^-\bar{K}^0 + \text{Neutrals}$

We present in Figs. 14-18 all possible effective mass distributions from these two final states. Due to the limited statistics for the final state $p\pi^+\pi^-\bar{K}^0 + \text{neutrals}$ (Reaction (4)), nothing quantitative can be said except a rough estimation of the $K^*(890)^-$ production cross section. For the

final state $\pi^+\pi^-\pi^-\bar{K}^0 + \text{neutrals}$ (Reaction (5)) in addition to $K^*(890)^-$ and ρ^0 , we see an enhancement of about 4 standard deviations in the $\pi^+\pi^-\pi^-\bar{K}^0$ effective mass distribution (Fig. 17(e)) at about 1.56 GeV.¹ The missing neutral in this enhancement is strongly associated with $\Delta(1236)^0$. Further study in other channels such as $K^-\pi^+\pi^-\pi^-\bar{K}^0$ and $K^-\pi^+\pi^-\pi^-\bar{K}^0$ is required in order to establish this enhancement as a bona fide resonance. The cross sections for the resonance production are given in Table I.

E. Search for Exotic Resonances

Due to the production of two negative pions in each final state, this is an ideal experiment to look for exotic resonances. We have studied

$$K^-\pi^+ \rightarrow p\bar{K}^0(x)^{--}, (x)^{--} \rightarrow \pi^-\pi^-, \pi^-\pi^-\pi^0; \quad (10)$$

$$\rightarrow p\pi^0\bar{K}^0(x)^{--}, (x)^{--} \rightarrow \pi^-\pi^-; \quad (11a)$$

$$\rightarrow \pi^+\pi^-\bar{K}^0(x)^{--}, (x)^{--} \rightarrow \pi^-\pi^-; \quad (11b)$$

$$\rightarrow p(K^*)^{--}, (K^*)^{--} \rightarrow \pi^-\pi^-\bar{K}^0, \pi^-\pi^-\bar{K}^0\pi^0; \quad (12)$$

$$\rightarrow p\pi^0(K^*)^{--}, (K^*)^{--} \rightarrow \pi^-\pi^-\bar{K}^0; \quad (13a)$$

$$\rightarrow \pi^+\pi^-(K^*)^{--}, (K^*)^{--} \rightarrow \pi^-\pi^-\bar{K}^0; \quad (13b)$$

$$\rightarrow \pi^+\bar{K}^0(N^*)^{--}, (N^*)^{--} \rightarrow \pi^-\pi^-\pi^0; \quad (14)$$

$$\rightarrow \pi^+(Y^*)^{--}, (Y^*)^{--} \rightarrow \pi^-\pi^-\bar{K}^0\pi^0. \quad (15)$$

The effective mass distributions for $(x)^{--}$, $(K^*)^{--}$, $(N^*)^{--}$ and $(Y^*)^{--}$ for the above reactions are shown in Figs. 1(c) and 7(c), 6(g), 10(c), 3(c) and 8(d), 7(b), 11(c), 11(e), and 12(d), respectively. All the distributions have been compared with the predictions of the Reggeized multiperipheral model of Chan et al.[2] as modified by Plahte and Roberts [12] to include resonance production. This model will be discussed in detail in Sec. III. None of the distributions show any enhancement of

more than 3 standard deviations from the background curves. We conclude that we do not have clear evidence for the existence of any exotic resonance. Recently, similar effort has been made by Lys and Chapman[18], Giacomelli et al.[19] and Price et al.[20]. The first two references found no evidence for exotic resonances while Price et al.[20] found evidence for an $n\pi^-\pi^-$ enhancement at a mass of 1.627 GeV from reaction (3). With twice as much data at an overlapping center of mass energy, we do not see the corresponding enhancement in our data[15]. Similar result has been reported by Johnson[21] who studied reaction (3) at 5.5 GeV/c and found no evidence for the 1.627 GeV $n\pi^-\pi^-$ resonance.

III. Reggeized Multiperipheral Model of Plahte and Roberts

The PR model is an improvement upon the CLA model. In the CLA model, the modulus of the amplitude T corresponding to the process $A + B \rightarrow 1 + 2 + \dots + n$, shown in Fig. 19 is written as a product of $(n-1)$ partial amplitudes $T_i(s_i, t_i)$:

$$|T| = \prod_{i=1}^{n-1} T_i(s_i, t_i) ,$$

where $s_i = (p_i + p_{i+1})^2 - (m_i + m_{i+1})^2$,

$$t_i = (p_A - \sum_{r=1}^i p_r)^2$$

p_i = four-momentum of the i th particle

and m_i = mass of the i th particle.

The parametrization of the partial amplitude is

$$T_i(s_i, t_i) = \left(\frac{g_i s_i + c_2 a}{s_i + a} \right) \left(\frac{s_i + a}{a} \right)^{\alpha_i} \left(\frac{s_i + b_i}{b_i} \right)^{t_i} ,$$

where a defines the boundary between the "low-" and "high-" energy regions, g_i corresponds essentially to the coupling constant of the vertices which occur with each exchange of a Regge pole, c_2 is a two-body clustering constant, α_i is

the intercept of the relevant Regge trajectory, and b_i governs the dependence on t of the internal vertices. The main feature of the partial amplitude T_i is that it becomes fully Reggeized whenever the corresponding effective mass is large, while it smooths over in the low effective mass region by an effective constant.

In order to include the resonance production and at the same time to preserve the good features of the CLA model, Plahte and Roberts proposed the following amplitude:

$$|T|^2 = \prod_{i=1}^{n-1} \left[|T_i^{(c)}(s_i, s_i^{(c)}, t_i)|^2 + \sum_r \gamma_r \frac{\frac{1}{4} \Gamma_r^2}{(E_i - m_r)^2 + \frac{\Gamma_r^2}{4}} \right]$$

where

$$T_i^{(c)} = \frac{g_i s_i + c_2 a}{s_i + a} \left(\frac{s_i^{(c)} + a}{a} \right)^{\alpha_i} \left(\frac{s_i^{(c)} + b_i}{b_i} \right)^{t_i},$$

$$s_i^{(c)} = (r_i + q_{i+1})^2 - (v_i + \mu_{i+1})^2,$$

$$r_1 = p_1$$

$$v_1 = m_1$$

$$r_i = p_i + \frac{a}{s_{i-1} + a} r_{i-1}, \quad i > 1$$

$$v_i = m_i + \frac{a}{s_{i-1} + a} v_{i-1}, \quad i > 1$$

$$q_n = p_n$$

$$\mu_n = m_n,$$

$$q_i = p_i + \frac{a}{s_i + a} q_{i+1}, \quad i < n$$

$$\mu_i = m_i + \frac{a}{s_i + a} \mu_{i+1}, \quad i < n$$

γ_r = a measure of the probability for the formation of the resonance r ,

Γ_r = the width of the resonance r ,

$$E_i = (p_i + p_{i+1})^2.$$

The advantage of the PR model over the CLA model is that the PR model includes the resonance production by introducing just a few more parameters. However, the PR model has the defect of double counting.

Recently there has been tremendous interest in the generalized Veneziano model [14,22-25]. In this model, the double counting problem has been taken care of. The application of the generalized Veneziano model on three-body final states has been very successful. Unfortunately, it is impractical to calculate the generalized Veneziano amplitude for final states of more than three out-going particles.

The same authors of the PR model have proposed a simple Veneziano type amplitude to overcome the shortcomings of CLA and PR models[26]. The proposed model is simple and general, applicable to all many-body final states. However, this model does not fit our data. The failure to describe the data appears to be associated with the presence of double poles in the amplitude of this model.

B. Comparison With Our Data

All our calculations have been carried out using the Monte Carlo phase space programme FOWL[27] with the function $|T|^2$ as WEIGHT. The parameters we used were taken from Ref.[2] and were given as follows:

$g_N/g_M = 1.3$, where g_N and g_M were coupling constants of nucleon and meson exchanges, respectively,

$a = 1(\text{GeV})^2$, $c_2 = 1$,

$\alpha_{\omega,\rho} = .57$, $\alpha_{K^*} = .3$, $\alpha_N = -.35$,

$b_{EA} = 1(\text{GeV})^2$ is the constant attached to two external particles including the incident kaon in Fig. 19,

$b_{EB} = 0.5 (\text{GeV})^2$, B corresponds to the neutron target,

$b_I = 1.2 (\text{GeV})^2$ is the constant attached to internal Reggeons,

$\gamma_{K^* \rightarrow \bar{K}\pi^-} = 8.0$, $\gamma_{\Delta^- \rightarrow n\pi^-} = 6.0$, $\gamma_{\Sigma(1765)^+ \rightarrow p\bar{K}^0} = 4$,

$\gamma_{N(1525)^0 \rightarrow p\pi^-} = 1.6$, $\gamma_{N(1688)^0 \rightarrow p\pi^-} = 1.8$, $\gamma_{\rho(1765)^0 \rightarrow \pi^+\pi^-} = 2.5$.

The isospin factor for γ 's has been taken into account. The mass and width of the resonances are taken from the Particle Data Group[28].

1. Longitudinal and Transverse Momenta

The CLA model describes single-particle distributions quite successfully. Thus, the single particle distribution is the natural starting point for the test of the PR model. In order for the PR model to survive, a successful description of the single particle distribution is necessary. Figs. 20-22 show the longitudinal and transverse momenta for the particles from reactions (1) to (3). The predictions of the PR model describe our data quite successfully except for the longitudinal momentum of the K^* and the n of reaction (3).

2. Production Angular Distributions

In Figs. 2, 9, and 13 we show the production angular distributions for reactions (1) to (3). The predictions of the PR model fit our data extremely well. Figs. 1 (d)-(f) are the distributions corresponding to K^* events. The fit of the PR predictions is much better than that of the generalized Veneziano model [14]. However, this is expected since we use more parameters than the generalized Veneziano model does.

3. Effective Mass Distributions

A further check of the PR model can be done by investigating the effective mass distributions. With the parameters used, the fit to the distribution is in general quite good. The model fits the data better in the multiparticle distributions than in the diparticle distributions. This indicates that the prediction of this model can be used to describe the background. This is what we have used in the search for exotic resonance production.

4. Cross Sections

Using our data as input, the PR model predicts the production cross sections of reaction (1) to (3) at 3 GeV/c to be 516 ± 44 , 245 ± 50 and 365 ± 55 μb , respectively, in agreement with the experimental cross sections at 3 GeV/c which were found to be 410 ± 30 , 130 ± 14 , and 200 ± 17 μb , respectively [29].

ACKNOWLEDGEMENTS

We would like to thank the accelerator and bubble chamber staffs at Argonne National Laboratory, in particular, Dr. M. Derrick, Dr. F. Schwein-gruber, and Dr. L. Voyvodic. We wish to express our thanks to the programming group, the scanning and measuring girls, and the technical staff at Purdue.

One of the authors (W.L.Y.) wishes to thank the Purdue Research Foundation for an XL Grant during the summer of 1970. We are grateful to Dr. K. Vasavada of IUPUI for several interesting discussions.

REFERENCES

- [1] O. Czyzewski, Proceedings of the XIV International Conference on High-Energy Physics (Vienna, 1968), p. 367.
- [2] Chan Hong-Mo, J. Loskiewicz and W. W. M. Allison, Nuovo Cimento 57A(1968)93; hereafter referred to as CLA.
- [3] R. Sosnowski and A. Wroblewski, Contribution No.203 to Proceedings of the XIV International Conference on High-Energy Physics (Vienna, 1968).
- [4] Aachen-Berlin-Bonn-CERN-Cracow-Heidelberg-Warsaw Collaboration, Contribution No. 465 to Proceedings of the XIV International Conference on High-Energy Physics (Vienna, 1968).
- [5] J. Bartke and J. LeGuyader, Contribution No. 485 to Proceedings of the XIV International Conference on High-Energy Physics (Vienna, 1968).
- [6] CERN-Brussels Collaboration, G. Bassompierre et al., Nuclear Phys. B9 (1969)295.
- [7] G. Ranft and R. Turnbull, Nuovo Cimento 61B(1969)317.
- [8] G. Ranft, Nuovo Cimento 58A(1968)425.
- [9] Fong-Ching Chen, Nuovo Cimento 62A(1969)113.
- [10] Genova-Hamburg-Milano-Saclay Collaboration, C. Caso et al., Nuovo Cimento 66A(1970)11.
- [11] I. R. Kenyon, Nucl. Phys. B13(1969)255.
- [12] E. Plahte and R. G. Roberts, Nuovo Cimento 60A(1969)33; hereafter referred to as PR.
- [13] A. C. Ammann, Ph.D. Thesis, Purdue University, 1970 (unpublished).
- [14] K. Paler, A. C. Ammann, D. D. Carmony, A. F. Garfinkel, L. J. Gutay, D. H. Miller, and W. L. Yen, Nucl. Phys. B21(1970)407.
- [15] A. C. Ammann, D. D. Carmony, A. F. Garfinkel, L. J. Gutay, D. H. Miller, and W. L. Yen, Phys. Letters 34B(1971)533.
- [16] R. J. Glauber, Phys. Rev. 100(1955)242; W. Galbraith et al., ibid. 138 (1965)B913.
- [17] Bruxelles-CERN Collaboration, Nuovo Cimento 61A(1969)397.
- [18] J. Lys and J. W. Chapman, Phys. Rev. D2(1970)2525.
- [19] SABRE Collaboration, G. Giacomelli et al., Phys. Letters 33B(1970)373.

- [20] R. R. Price et al., Phys. Letters 33B(1970)533.
- [21] D. Johnson, Phys. Letters 34B(1971)428.
- [22] B. Petersson and N. A. Törnqvist, Nucl. Phys. B13(1969)629.
- [23] Chan H.-M., R. O. Raito, G. H. Thomas, and N. A. Törnqvist, Nucl. Phys. B19(1970)173.
- [24] N. A. Törnqvist, Nucl. Phys. B18(1970)530.
- [25] Aachen-Berlin-CERN-London-Vienna Collaboration, J. Bartsch et al., Nucl. Phys. B20(1970)63.
- [26] E. Plahte and R. G. Roberts, Nuovo Cimento Letters 1(1969)187.
- [27] F. James, A General Monte Carlo Phase-space Program, CERN Report 68/15 (1968).
- [28] N. Barash-Schmidt et al., Review of Particle Properties, Phys. Letters 33B, No. 1, August 1970.
- [29] SABRE Collaboration, D. Merrill et al., Nucl. Phys. B18(1970)403.

Table. I CROSS SECTIONS FOR VARIOUS CHANNELS

Reaction	Number of Events	Cross Section (μb)
$K^- n \rightarrow p\pi^-\pi^+\bar{K}^0$	642	368 ± 32
$p\pi^-K^*(890)^-$ $\searrow \pi^-\bar{K}^0$	300 ± 40	172 ± 30
$\pi^-\bar{K}^0\Delta(1236)^0$ $\searrow p\pi^-$	110 ± 40	64 ± 27
$\Delta(1236)^0 K^*(890)^-$ $\searrow p\pi^- \quad \searrow \pi^-\bar{K}^0$	86 ± 17	49 ± 12
$N(1525)\pi^-\bar{K}^0$ $\searrow p\pi^-$	48 ± 20	28 ± 14
$N(1688)\pi^-\bar{K}^0$ $\searrow p\pi^-$	40 ± 20	23 ± 14
$\Sigma(1765)^+\pi^-\pi^-$ $\searrow p\bar{K}^0$	80 ± 40	46 ± 27
$K^- n \rightarrow p\pi^-\pi^+\bar{K}^0\pi^0$	398	248 ± 50
$\pi^-\bar{K}^0\pi^0\Delta(1236)^0$ $\searrow p\pi^-$	40 ± 30	25 ± 19
$\pi^-\pi^-\bar{K}^0\Delta(1236)^+$ $\searrow p\pi^0$	85 ± 60	53 ± 37
$p\pi^-\pi^0 K^*(890)^-$ $\searrow \pi^-\bar{K}^0$	143 ± 37	89 ± 23
$\pi^-\Delta^+(1236)K^*(890)^-$ $\searrow p\pi^- \quad \searrow \pi^-\bar{K}^0$	43 ± 25	27 ± 16
$p\pi^-\pi^0 K^*(890)^0$ $\searrow \pi^0\bar{K}^0$	<10	<6
$\pi^-\bar{K}^0\pi^0 N(1525)$ $\searrow p\pi^-$	30 ± 20	19 ± 12
$K^- n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0 n$	788	493 ± 72
$\pi^+\pi^-\pi^0 K^*(890)^-$ $\searrow \pi^-\bar{K}^0$	245 ± 46	152 ± 29
$\pi^-\bar{K}^0 n p^0$ $\searrow \pi^+\pi^-$	121 ± 51	75 ± 32
$\pi^+\pi^-\bar{K}^0\Delta(1236)^-$ $\searrow \pi^- n$	178 ± 60	111 ± 37
$\pi^+K^*(890)^-\Delta(1236)^-$ $\searrow \pi^-\bar{K}^0 \quad \searrow \pi^- n$	118 ± 42	73 ± 26
$\pi^-\pi^-\bar{K}^0\Delta(1236)^+$ $\searrow \pi^+ n$	60 ± 25	37 ± 16
$\pi^-\pi^-\bar{K}^0 N(1525)^+$ $\searrow \pi^+ n$	32 ± 20	20 ± 12
$\pi^+\pi^-\pi^-\Sigma(1765)^0$ $\searrow \bar{K}^0 n$	25 ± 15	16 ± 9

Reaction	Number of Events	Cross Section (μb)
$K^- n \rightarrow p \pi^- \pi^- \bar{K}^0$ MM	$131 \pm$	81 ± 30
$p \pi^- K^*(890)^- \rightarrow \pi^- \bar{K}^0$ MM	25 ± 15	16 ± 9
$K^- \rightarrow \pi^+ \pi^- \pi^- \bar{K}^0$ MM	679 ± 162	422 ± 121
$\pi^- \rho^0 \bar{K}^0 \rightarrow \pi^+ \pi^-$ MM	30 ± 20	19 ± 12
$\pi^+ \pi^- K^*(890)^- \rightarrow \pi^- \bar{K}^0$ MM	110 ± 40	69 ± 25
$K^- n \rightarrow p K^- K^- K^0$	<35	<22

FIGURE CAPTIONS

1. All two body effective mass distributions for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$. The solid curves are fits from PR.
2. Production angular distributions for each of the final particles for reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$ (a-c) and reactions $K^-n \rightarrow p\pi^-\bar{K}^*(890)^-$. The solid curves are fits from PR.
3. All three body effective mass distributions for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$. The solid curves are fits from PR.
4. Differential cross section for the reaction $K^-n \rightarrow \Delta(1236)^0\bar{K}^*(890)^-$.
5. Decay angular distributions for $\Delta(1236)^0$ and $\bar{K}^*(890)^-$. The solid lines are the expected distributions with the experimental density matrix elements.
6. All two body effective mass distributions for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0\pi^0$. The solid curves are fits from PR.
7. All three body effective mass distributions for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0\pi^0$. The solid curves are fits from PR.
8. All four body effective mass distributions for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0\pi^0$. The solid curves are fits from PR.
9. Production angular distributions for each of the final particles for reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0\pi^0$. The solid curves are fits from PR.
10. All two body effective mass distributions for the reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0n$. The solid curves are fits from PR.
11. All three body effective mass distributions for the reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0n$. The solid curves are fits from PR.
12. All four body effective mass distributions for the reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0n$. The solid curves are fits from PR.
13. Production angular distributions for each of the final particles from reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0n$. The solid curves are fits from PR.
14. Some effective mass distributions (a-g) and missing mass squared distribution (h) for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$ MM.
15. Some effective mass distributions for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$ MM.
16. Some effective mass distributions for reactions $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$ MM (a-d) and $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0$ MM (e-h).

17. Some effective mass distributions (a-g) and missing mass squared distribution (h) for the reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0$ MM.
18. Some effective mass distributions for the reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0$ MM.
19. Graph corresponding to the process $A + B \rightarrow 1 + 2 + \dots + n$.
20. Longitudinal and transverse momenta for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0$. The solid curves are fits from PR.
21. Longitudinal and transverse momenta for the reaction $K^-n \rightarrow p\pi^-\pi^-\bar{K}^0\pi^0$. The solid curves are fits from PR.
22. Longitudinal and transverse momenta for the reaction $K^-n \rightarrow \pi^+\pi^-\pi^-\bar{K}^0n$. The solid curves are fits from PR.

Combinations / 0.04 GeV

Events / 0.04 GeV

GeV

GeV

Events / 0.04 GeV

GeV

Events / 0.04 GeV

GeV

Events / 0.1

Combinations / 0.04 GeV

Combinations / 0.04 GeV

Events / 0.02 GeV²

COMBINATIONS / 0.04 GeV

GeV

GeV

GeV

GeV

GeV²

COMBINATIONS / 0.04 GeV

GeV

COMBINATIONS / 0.04 GeV

GeV

Events / 0.1 GeV/c

Events / 0.05 GeV/c

Events / 0.1 GeV/c

Events / 0.05 GeV/c

P_L^* GeV/c P_T^* GeV/c