Study of $K^+p \rightarrow K^0\Delta^{++}(1236)$, $K^-p \rightarrow \bar{K}^0 n$, and $K^-p \rightarrow \bar{K}^0\Delta^0(1236)$*

K. J. Foley, W. A. Love, S. Ozaki, E. D. Platner,
A. C. Saulys, and E. H. Willen
Brookhaven National Laboratory, Upton, New York 11973

S. J. Lindenbaum
Brookhaven National Laboratory, Upton, New York 11973
and City College of the City University of New York, New York, New York 10031

M. A. Kramer
City College of the City University of New York, New York, New York 10031
(Received 2 August 1973)

We have studied the reactions $K^+p \rightarrow K^0\Delta^{++}(1236)$ at 15.7 GeV/c, $K^-p \rightarrow \bar{K}^0 n$ at 10.7 and 15.7 GeV/c, and $K^-p \rightarrow \bar{K}^0\Delta^0(1236)$ at 15.7 GeV/c in the BNL Double Vee Magnetic Spectrometer. The π^+ and π^- from the decays of forward K^0's were detected and the above reactions were identified by a missing-mass technique. Total and differential cross sections are presented for the first two reactions and a total cross section for the third.

I. INTRODUCTION

We have studied the reactions

$$K^+p \rightarrow K^0\Delta^{++} \quad (15.7\ \mathrm{GeV}/c)\,, \tag{1}$$

$$K^-p \rightarrow \bar{K}^0 n \quad (10.7\ \text{and}\ 15.7\ \mathrm{GeV}/c)\,, \tag{2}$$

$$K^-p \rightarrow \bar{K}^0\Delta^0 \quad (15.7\ \mathrm{GeV}/c) \tag{3}$$

in the forward arm of the BNL Double Vee Magnetic Spectrometer.[1] The triggering, detection, and analysis of reactions (1) through (3) were identical to those used for a study of $\pi^-p \rightarrow K^0(\Lambda, \Sigma^0)$ (Ref. 2) except for the arrangement of three threshold Čerenkov counters used to tag incident kaons, and thus only a brief description will be presented here. Preliminary results have been presented earlier.[3]

II. APPARATUS AND EXPERIMENTAL PROCEDURE

The beam used for this experiment was an unseparated charged secondary beam produced at 0° at target station A by the slow extracted proton beam from the Brookhaven AGS (see Fig. 1). The K^- experiment was run simultaneously with the π^-p experiment mentioned above. Two threshold Čerenkov counters, $CT1$ and $CT3$, were set to veto pions and one, $CT2$, to count kaons. Kaons constituted about 1.2% of the negative beams. The first 60% of the K^+ running was done with the same Čerenkov-counter configuration in a positive beam obtained by reversing the magnet polarities. Protons were below threshold for $CT2$ and thus did not count directly. However, about 1% did produce counts via the production of knock-on electrons. Since the positive beam contained only ~0.5% K^+'s and ~85% protons, the knock-on electrons from protons in $CT2$ led to a significant contamination of protons in the "K" beam. This introduces a normalization problem but does not effect the missing-mass spectrum in the region of the $K^+p \rightarrow K^0\Delta^{++}(1236)$ events.[4] The later runs were done with one counter ($CT1$) set to veto π's and two counters ($CT2$, $CT3$) set to accept K's and reject protons, thus reducing the proton contamination to a negligible level ($P/K^+ < 0.01$).

The apparatus is shown in Fig. 2. The trigger was designed to select a neutral forward particle leaving the target and subsequently decaying into two charged particles in a region downstream of the target. This was done by requiring a single particle in each of the beam hodoscopes ($H1, H2, H3$), no signal in counter A, a signal in counter B and two or more particles in each of counter hodoscopes $H4$ and $H4'$. The trigger rate was about 2×10^{-4} per incident kaon for these triggers.

Wire spark chambers were used to measure the trajectories of the two forward charged tracks from the neutral vee decay before and after a 48D48 bending magnet. The data were recorded on magnetic tape along with data from the various hodoscopes. A sample of the data was transmitted to a PDP-10 computer for on-line monitoring and analysis. The final data reduction was performed off-line on the BNL CDC 6600 computers.

III. DATA ANALYSIS

The effective mass of all neutral vees was calculated assuming both decay particles were pions. Figure 3 is a plot of the effective mass of such forward vees from the $K^-p \rightarrow \bar{K}^0(\mathrm{MM})$ trigger at 15.7 GeV/c. Events with masses between 485 and

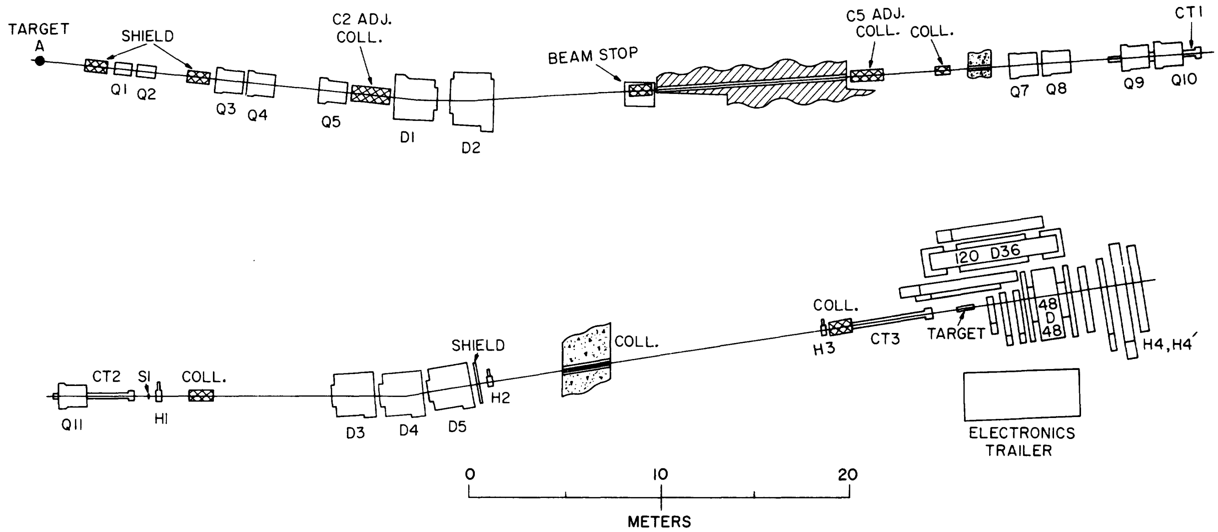

FIG. 1. The layout of the beam to the BNL Double Vee Magnetic Spectrometer.

510 MeV were accepted as K^0's. The background under the K^0 peak was <1% for all of the reactions. Approximately 17% of the triggers for the 15.7-GeV/c reactions and 9% for the 10.7-GeV/c reaction contained a good K^0. The resulting numbers of events were

$K^+p \to K^0(\mathrm{MM})^{++}$ at 15.7 GeV/c—569 events,

$K^-p \to \bar{K}^0(\mathrm{MM})^0$ at 10.7 GeV/c—1080 events,

$K^-p \to \bar{K}^0(\mathrm{MM})^0$ at 15.7 GeV/c—1294 events.

The four-momentum transfer squared (t) and the missing recoil mass were calculated for the above selected events. A more complete description of the apparatus and the analysis technique has been published.[1,2]

IV. ACCEPTANCE

The acceptance has been calculated for each of the three reactions as a function of t' ($t' = t - t_{\min}$) by a Monte Carlo program. The calculation took into account the distribution of the incident beam

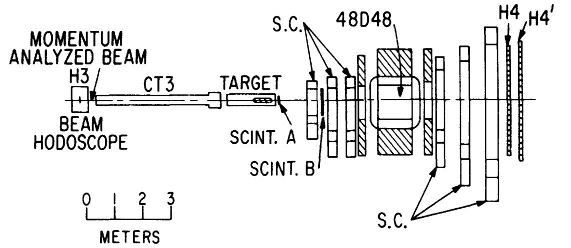

FIG. 2. Plan view of the apparatus. The labels S.C. identify wire spark-chamber modules.

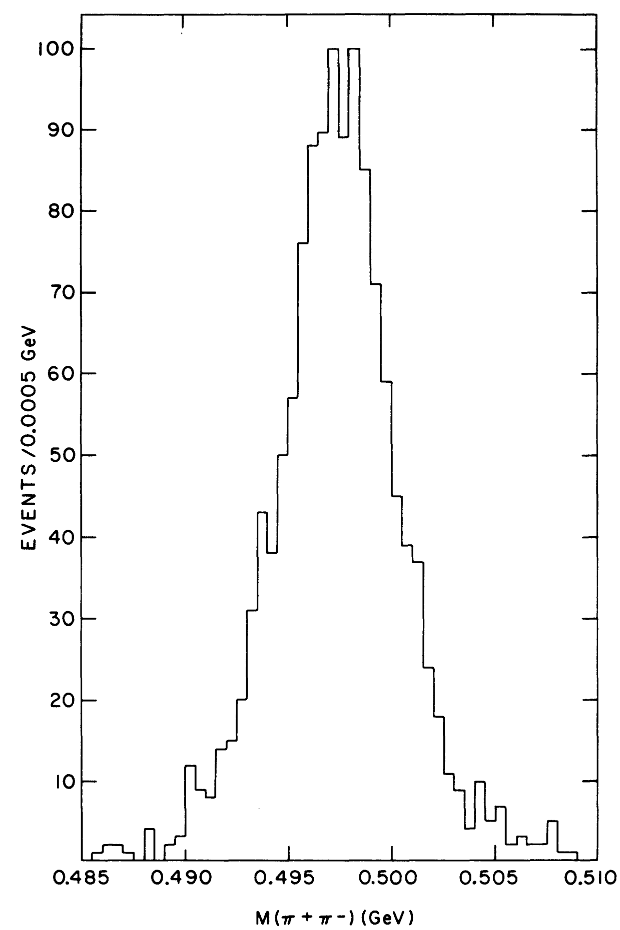

FIG. 3. The $\pi^+\pi^-$ effective mass for neutral vee's found in the trigger for $K^-p \to \bar{K}^0(\mathrm{MM})^0$ at 15.7 GeV/c. The width of the distribution is 5 MeV (FWHM).

TABLE I. Number of events, acceptance, and differential cross section as a function of t' for the reaction $K^+p \to K^0\Delta^{++}(1236)$ at 15.7 GeV/c.

t [(GeV/c)^2]	Events	Acceptance	$\frac{d\sigma}{dt}$ [μb/(GeV/c)^2][a]
0 → 0.05	19	0.22 ± 0.01	114 ± 26
0.05 → 0.1	31	0.22 ± 0.01	180 ± 32
0.1 → 0.15	30	0.20 ± 0.01	191 ± 35
0.15 → 0.2	21	0.19 ± 0.01	141 ± 30
0.2 → 0.3	17	0.17 ± 0.01	66 ± 15
0.3 → 0.4	4.5	0.15 ± 0.01	19 ± 9

[a] Errors shown are statistical only. There is also a 10% over-all systematic error.

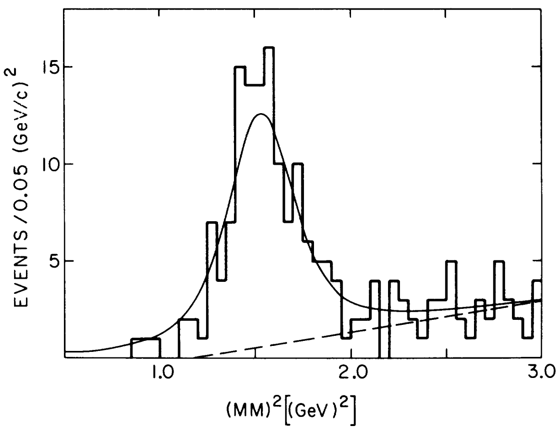

FIG. 4. Number of events versus the missing mass squared recoiling from the K^0 for the 15.7-GeV/c $K^-p \to K^0(\mathrm{MM})^0$ data. The solid line is the fitted curve. The dashed line is the fitted background.

as well as geometric cuts applied to the data. Events were traced through the apparatus and were tested against various effects that could lose events. The details of this calculation are similar to those described in Ref. 2. The results of this calculation are included in Tables I and II. The statistical errors of the Monte Carlo calculations are less than 30% of the statistical errors of the associated data points in all cases.

V. RESULTS

A. $K^+p \to K^0\Delta^{++}(1236)$

The over-all missing-mass-squared spectrum for $K^+p \to K^0(\mathrm{MM})^{++}$ is shown in Fig. 4. The data were divided into t' bins and a maximum-likelihood technique was used to fit each histogrammed missing-mass-squared spectrum over the region $0.5 \le (\mathrm{MM})^2 \le 3.0$ GeV^2 with a $\Delta(1236)$ peak broadened by our resolution[5] (standard deviation $\sigma = 0.104$ GeV^2), and a background quadratic in $(\mathrm{MM})^2$ beginning at $(\mathrm{MM})^2 = 1.16$ GeV^2. The mass and width of the $\Delta(1236)$ were fixed at the values listed in the Tables of Particle Properties[6]. The fitted background in each t' bin ranged from 0 to 24% and its contribution to the over-all error was small compared to statistical errors of the peak. Table III lists the major corrections to the data and their associated errors. Table I and Fig. 5 (see Ref. 7) present the differential cross sections. The data show a pronounced forward dip.

In order to calculate a total cross section for this reaction, we fitted the data in the region 0.15

TABLE II. Number of events, acceptance, and differential cross section as a function of t' for the reaction $K^-p \to \bar{K}^0n$ at 10.7 and 15.7 GeV/c.

	$-t'$ [(GeV/c)^2]	Events	Acceptance	$\frac{d\sigma}{dt}$ [μb/(GeV/c^2][a]
10.7 GeV/c	0 → 0.05	59	0.18±0.01	147 ± 19
	0.05 → 0.10	64	0.15±0.01	186 ± 22
	0.10 → 0.15	49	0.12 ± 0.01	173 ± 24
	0.15 → 0.20	30	0.09 ± 0.01	141 ± 25
	0.20 → 0.30	31	0.07 ± 0.01	95 ± 17
	0.30 → 0.40	16	0.045 ± 0.005	80 ± 19
	0.40 → 0.50	6	0.035 ± 0.005	40 ± 16
	0.50 → 0.70	3	0.020 ± 0.005	18 ± 10.5
15.7 GeV/c	0 → 0.05	35	0.24 ± 0.01	115 ± 19
	0.05 → 0.10	31	0.25 ± 0.01	98 ± 18
	0.10 → 0.15	28	0.24 ± 0.01	91 ± 17
	0.15 → 0.20	21	0.22 ± 0.01	72 ± 15
	0.20 → 0.30	28	0.20 ± 0.01	53 ± 10
	0.30 → 0.40	24	0.18 ± 0.01	53 ± 11
	0.40 → 0.50	3	0.15 ± 0.01	7.8 ± 4.5
	0.50 → 0.70	4	0.10 ± 0.01	7.4 ± 3.6

[a] Errors are statistical only. There is also a 10% over-all systematic error.

TABLE III. Systematic corrections to the data and their associated errors.

	$K^+p \to K^0\Delta^{++}(1236)$	$K^-p \to \bar{K}^0 n$ 10.7 GeV/c	$K^-p \to \bar{K}^0 n$ 15.7 GeV/c
Program efficiency	1.16 ± 0.06	1.18 ± 0.06	1.18 ± 0.07
Trigger efficiency	1.05 ± 0.05	1.05 ± 0.05	1.05 ± 0.05
Pion decay in spectrometer	1.04 ± 0.01	1.06 ± 0.01	1.04 ± 0.01
Nuclear attenuation in the target	1.04 ± 0.005	1.045 ± 0.01	1.045 ± 0.01
Beam contamination	1.05 ± 0.03 [a]	none	none
Empty target	0.97 ± 0.01	0.98 ± 0.01	0.98 ± 0.01

[a] 2.3 ± 0.1 for the sample with single Čerenkov counting K^+'s (see text).

$< -t' < 0.4$ (GeV/c)^2 to the form $Ae^{bt'}$ and obtained $b = 11.5 \pm 2.8$ (GeV/c)$^{-2}$. Summing the bins for $-t' < 0.4$ (GeV/c)^2 and integrating the fit for 0.4 $< -t' < t_{max}$ (GeV/c)^2 (this integral adds about 1 μb) yields

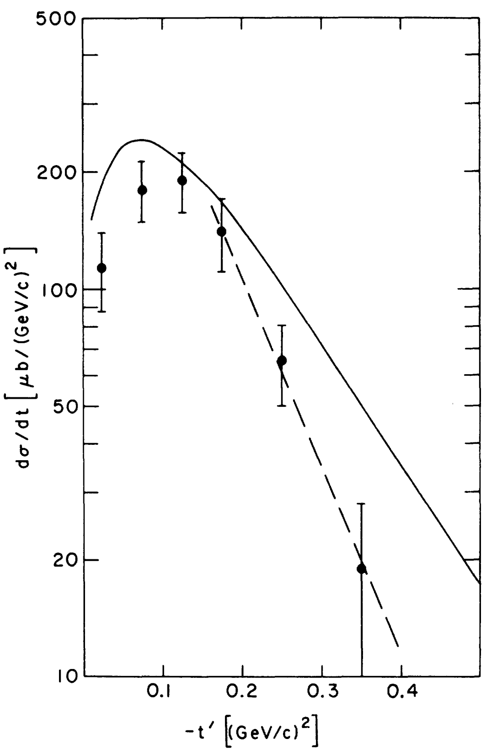

FIG. 5. $d\sigma/dt$ versus $-t'$ for $K^+p \to K^0\Delta^{++}(1236)$ at 15.7 GeV/c. The errors indicated are statistical only. There is an additional 10% systematic error. The dashed line indicates a fit to the form $e^{bt'}$ for $0.15 < -t' < 0.4$ (GeV/c)^2 used for extracting a total cross section. The solid line represents a calculation of this cross section based on a Regge-pole model fit provided by M. Krammer and U. Maor (Ref. 7). This calculation is based on the parameters of solution 1 of Table 2 of their publication (Ref. 7).

$$\sigma_T(K^+p \to K^0\Delta^{++}) = 41 \pm 6 \ \mu\text{b} ,$$

where the quoted error includes a 10% systematic error (see Table III). Fitting the data for 0.1 $< -t' < 0.4$ (GeV/c)^2 changes b to 9.8 ± 1.8 (GeV/c)$^{-2}$, but changes the contribution from the integral by less than 0.5 μb.

Figure 6 is a plot of the available total-cross-section data[8] for this reaction above 2 GeV/c. A least-squares fit to the momentum dependence of the form $\sigma_T \sim P_{lab}^{-n}$ yields $n = 1.85 \pm 0.07$.

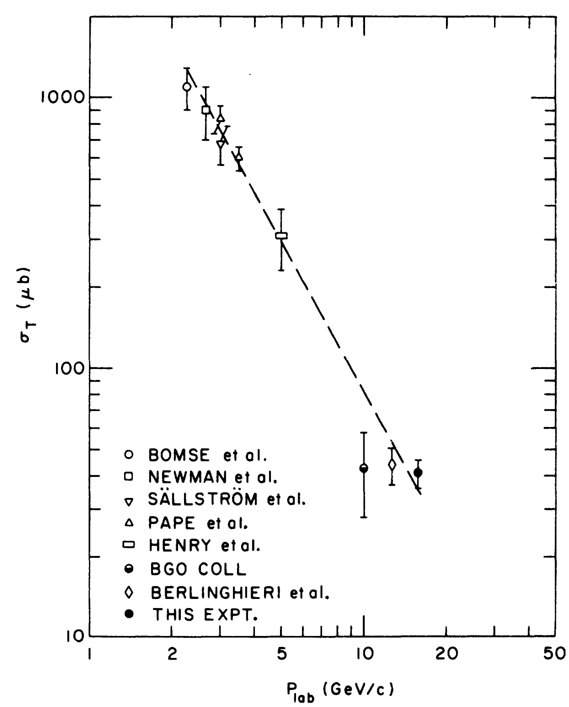

FIG. 6. $\sigma_T(K^+p \to K^0\Delta^{++}(1236))$ versus laboratory momentum. See Ref. 8. The line is a fit to the form $\sigma_T \sim P_{lab}^{-n}$.

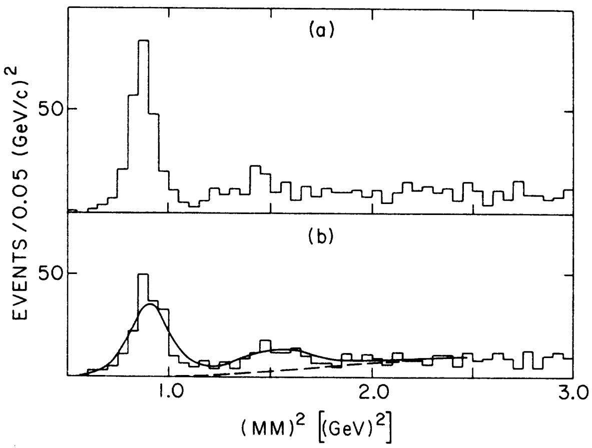

FIG. 7. (a) Number of events versus the missing mass squared for the reaction $K^-p \to \bar{K}^0(\mathrm{MM})^0$ at 10.7 GeV/c. (b) Number of events versus the missing mass squared for the reaction $K^-p \to \bar{K}^0(\mathrm{MM})^0$ at 15.7 GeV/c. The solid line is a fit to the data containing neutron, $\Delta^0(1236)$, and $N^*(1470)$ peaks plus a quadratic background. The dashed line is the sum of the $N^*(1470)$ contribution and the background [i.e., the effective background for the neutron and $\Delta^0(1236)$ fits].

B. $K^-p \to \bar{K}^0(n)$

The over-all missing-mass spectrum for $K^-p \to \bar{K}^0(\mathrm{MM})^0$ at 10.7 and 15.7 GeV/c is shown in Figs. 7(a) and 7(b), respectively. The missing-mass-squared resolution σ was better at 10.7 GeV/c ($\sigma \approx 0.075$ GeV^2), so there was essentially no background (< 2%) under the neutron peak. Differential cross sections were obtained by dividing the data into t' bins. No fitting was done and the number of events was just taken to be the sum of events with $0.76 < (\mathrm{MM})^2 < 1.06$ GeV^2. The 15.7-GeV/c data in the region $0.5 < (\mathrm{MM})^2 < 1.25$ GeV^2 was fitted to a sum of the neutron peak and a linear background. The background is small [less than 10% for all t' bins except $0.4 < -t' < 0.5$ (GeV/c)^2 where it is 20%], and its error is small compared to the statistics of the peak. The analysis is insensitive to the choice of the threshold for the background or the introduction of a quadratic term. Including a $\Delta^0(1236)$ peak in the fit had little effect on the neutron results ($\lesssim 5\%$). The major systematic corrections to the data are listed in Table III.

The differential cross sections are given in Table II and Fig. 8. Errors shown are statistical only. The data at 10.7 GeV/c show a possible forward dip. The 15.7-GeV/c data also appear to deviate from a pure exponential form, but the shape of the curve is not clear.

In order to calculate total cross sections, we fitted the differential cross sections in the region $0.15 < -t' < 0.7$ (GeV/c)^2 to the form $Ae^{bt'}$ and obtained $b = 4.4 \pm 1.0$ (GeV/c)$^{-2}$ at 10.7 GeV/c and $b = 5.4 \pm 1.4$ (GeV/c)$^{-2}$ at 15.7 GeV/c. The total cross sections were calculated by summing the bins below $-t' = 0.7$ (GeV/c)^2 and integrating the fit above $-t' = 0.7$ (GeV/c)^2. The integral adds ~3 μb at 10.7 GeV/c and about 1 μb at 15.7 GeV/c. The results are

$$\sigma_T(K^-p \to \bar{K}^0 n) = 61 \pm 8 \ \mu\mathrm{b} \text{ at } 10.7 \text{ GeV}/c\,,$$

$$\sigma_T(K^-p \to \bar{K}^0 n) = 33 \pm 4 \ \mu\mathrm{b} \text{ at } 15.7 \text{ GeV}/c\,.$$

The errors include a 10% systematic error.

The value $b = 4.43 \pm 1.0$ (GeV/c)$^{-2}$ is consistent with the values of b obtained as the fitted t' region for the 10.7-GeV/c data was varied from $0.2 < -t' < 0.7$ to $0.05 < -t' < 0.7$ (GeV/c)^2. The value of b for the 15.7-GeV/c data changes significantly as the fitted t' region is varied, but the value of the integrated cross section changes less than 0.5 μb. The available total-cross-section data[9] for this reaction above 4 GeV/c are shown in Fig. 9. A least-squares fit to the momentum dependence of the form $\sigma_T \sim P_{\mathrm{lab}}^{-n}$ yields $n = 1.54 \pm 0.05$.

C. $K^-p \to \bar{K}^0\Delta^0(1236)$

In order to extract a total cross section for the $\Delta^0(1236)$, the over-all (i.e., summed over t')

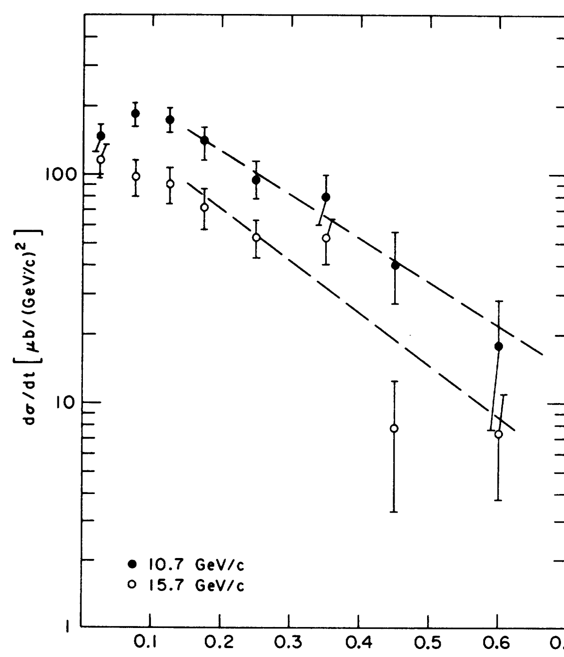

FIG. 8. $d\sigma/dt$ versus $-t'$ for $K^-p \to \bar{K}^0 n$ at 10.7 and 15.7 GeV/c. The errors indicated are statistical only. There is an additional 10% systematic error. The dashed lines indicate fits to $e^{bt'}$ for $0.15 < -t' < 0.7$ (GeV/c)^2 used for extracting total cross sections.

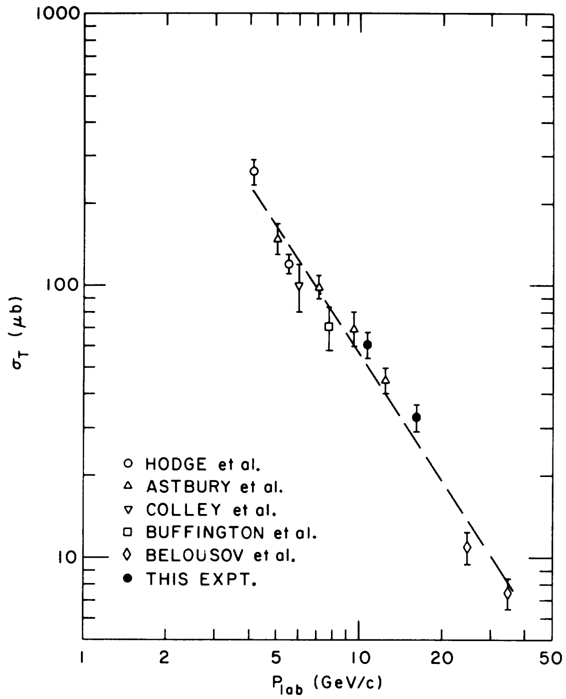

FIG. 9. $\sigma_T(K^-p\to\bar{K}^0n)$ versus laboratory momentum. See Ref. 9. The solid line is the fit to the form $\sigma_T\sim P_{lab}^{-n}$.

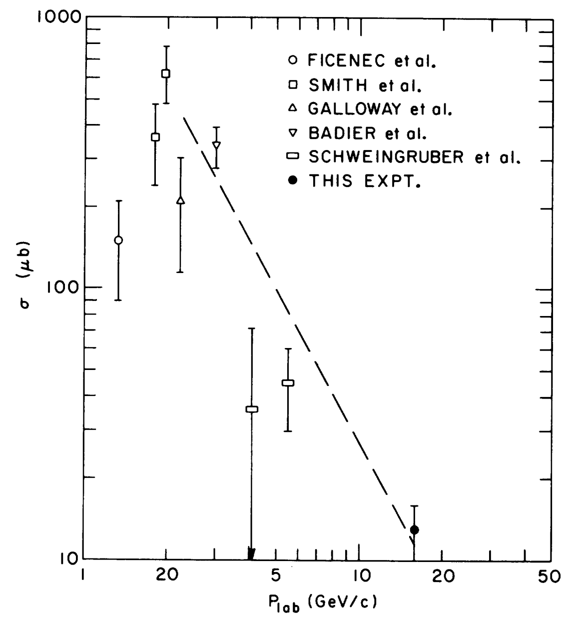

FIG. 10. $\sigma_T(K^-p\to\bar{K}^0\Delta^0(1236))$ versus laboratory momentum. See Ref. 10. The line is the fit to $\sigma_T(K^+p\to K^0\Delta^{++}(1236))$ divided by 3 (see Fig. 6).

missing-mass-squared spectrum at 15.7 GeV/c [see Fig. 7(b)] was fitted to a sum of neutron, $\Delta^0(1236)$, and $N^0(1470)$ peaks broadened by our resolution and a quadratic background. The inclusion of the $N(1470)$ has only a slight effect on the number of events found in the neutron peak ($\lesssim 1\%$) or the Δ^0 peak ($\sim 6\%$). The combination of poor statistics (95 events) and background prohibits any significant analysis on the t' distribution of the $\Delta^0(1236)$ events. In order to calculate an average acceptance we have assumed the t dependence of the $\Delta^0(1236)$ cross section to be the same as that of the reaction $K^+p\to K^0\Delta^{++}$ [reaction (1)] to which it is related by line reversal and isospin. This yields

$$\sigma_T(K^-p\to\bar{K}^0\Delta^0)=13\pm 3\ \mu\text{b}\ .$$

Figure 10 shows the available data[10] on this reaction. The dashed curve is the fit to $\sigma_T(K^+p\to K^0\Delta^{++}(1236))$ divided by 3 (the factor predicted by isospin and line reversal). The agreement is satisfactory.

ACKNOWLEDGMENTS

We wish to thank the members of the AGS and EP&S Division of the Accelerator Department of Brookhaven National Laboratory for their help in the execution of this experiment. We thank our group technicians for their extended and valuable efforts in the construction and operation of the spectrometer. We acknowledge with thanks the aid and cooperation of the staff of the BNL On-Line Data Facility during the course of this experiment. We express our appreciation to Dr. David Cheng for his assistance with the programming in the early stages of this experiment.

---

*This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1]K. J. Foley, S. J. Lindenbaum, W. A. Love, S. Ozaki, E. D. Platner, A. C. Saulys, and E. H. Willen, Nucl. Instrum. Methods 108, 33 (1973).

[2]K. J. Foley, S. J. Lindenbaum, W. A. Love, S. Ozaki, E. D. Platner, A. C. Saulys, and E. H. Willen, Phys. Rev. D 8, 27 (1973).

[3]E. H. Willen, K. J. Foley, M. A. Kramer, S. J. Lindenbaum, W. A. Love, S. Ozaki, E. D. Platner, and A. C. Saulys, in *Proceedings of the Fourth International Conference on High Energy Collisions, Oxford, England, 1972*, edited by J. R. Smith (Rutherford High Energy Laboratory, Chilton, Didcot, Berkshire, England 1972), Vol. 2, pp. 1–24.

[4]Misidentified events of the type $pp\to K^0X^{++}$ will produce a $M(X^{++})\lesssim 1.8$ GeV. Events of the type $pp\to\Lambda X^{++}$ where the incident p is misidentified as a K^+ and the

Λ misidentified as a K^0 can have $M(X^{++}) \gtrsim 1.430$ GeV ($= M_p + M_K$). However, less than 10% of the Λ's at these energies can be kinematically confused with K^0's. In addition, simultaneous data taken on $pp \to \Lambda X^{++}$ indicates that for the number of protons contaminating the "K" sample one would expect about $(2\times 10^{-2})X^{++}$ recoils below 1.48 GeV. Thus we expect a background contribution to reaction 1 for this contamination of less than 2×10^{-3} event.

[5]We do not have enough data in these plots to determine the resolution so we used the missing-mass resolution as determined for the 15.7-GeV/c run of the $\pi^- p \to K^0 Y^0$ experiment (Ref. 2) which was a Gaussian resolution function with a fitted width (σ) of 0.104 GeV^2.

[6]Particle Data Group, Phys. Lett. 39B, 1 (1972).

[7]M. Krammer and U. Maor, private communication; Nucl. Phys. B13, 651 (1969).

[8]F. Bomse, S. Borenstein, J. Cole, D. Gillespie, R. Kraemer, G. Luste, I. Miller, E. Moses, A. Pevsner, R. Singh, and R. Zdanis, Phys. Rev. 158, 1298 (1967); R. Newman, W. Chinowsky, and J. Schultz, Phys. Rev. 158, 1310 (1967); P. Sällström and G. Blomqvist, Ark. Fys. 37, 463 (1968); Birmingham-Glasgow-Oxford Collaboration, in *Proceedings of the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968* (CERN, Geneva, 1968); J. C. Berlinghieri, M. S. Farber, T. Ferbel, B. E. Forman, A. C. Melissinos, P. F. Slattery, and H. Yuta, Nucl. Phys. B8, 333 (1968); Henry *et al.*, private communication to Particle Data Group as reported in Ref. 6; Pape *et al.*, Lab. des Hautes Energies (Belgium) Report No. 96, 1968 (unpublished).

[9]D. R. Hodge, R. W. Hartung, Y. Y. Lee, S. Mikamo, D. D. Reeder, and A. Subramanian, Bull. Am. Phys. Soc. 12, 505 (1967); P. Astbury, G. Brautti, G. Finocchiaro, A. Michelini, K. Terwilliger, D. Websdale, C. H. West, P. Zanella, W. Beusch, W. Fischer, B. Gobbi, M. Pepin, and E. Polgar, Phys. Lett. 23, 396 (1966); D. C. Colley, W. P. Dodd, F. MacDonald, B. Musgrave, S. K. Tuli, W. Blair, R. Erskine, J. Gordon, I. Hughes, R. Turnbull, P. Chaudhuri, A. Eskreys, S. J. Goldsack, K. Paler, K. Sisterson, W. Blum, G. Dehm, N. Schmitz, W. Schrankel, J. Allison, W. W. M. Allison, A. D. Brody, D. H. Locke, L. Lyons, P. Finney, C. Fischer, L. K. Rangan, and A. Segar, Nuovo Cimento 53A, 522 (1968); A. Buffington, D. H. Frisch, C. E. W. Ward, Phys. Rev. 176, 1628 (1968); V. I. Belousov, B. N. Bolotov, M. I. Devishev, V. V. Isakov, D. B. Kakauridze, Yu. D. Karpekov, V. A. Kachanov, V. F. Konstantinov, V. M. Kutjin, A. A. Lednev, G. M. Makarov, B. E. Postoev, Yu. D. Prokoshkin, A. N. Prokhorov, V. K. Semenov, V. A. Sergeev, Yu. N. Simonov, and V. P. Sugonjaev, Phys. Lett. 43B, 76 (1973).

[10]J. R. Ficenec, R. I. Hulsizer, W. P. Swanson, and W. P. Trower, Phys. Rev. 169, 1034 (1968); L. T. Smith, D. H. Stork, and H. K. Ticho, in *Proceedings of the Topical Conference on Resonant Particles, 10–12 June 1965*, edited by B. A. Munir (Ohio Univ. Press, Athens, Ohio, 1965); K. F. Galloway, E. D. Alyea, Jr., J. P. Chandler, R. R. Crittenden, and H. J. Martin, Jr., Nucl. Phys. B8, 545 (1968); J. Badier, M. Demoulin, J. Goldberg, B. P. Gregory, C. Pelletier, A. Rouge, R. Barloutaud, A. Derem, A. Leveque, J. Meyer, P. Schlein, A. Verglas, D. J. Holthuizen, W. Hoogland, J. C. Kluyver, and A. G. Tenner, Comm. Energie Atomique, Saclay, Report No. R3037, 1966 (unpublished); F. Schweingruber, M. Derrick, T. Fields, D. Griffiths, L. G. Hyman, R. J. Jabbur, J. Loken, R. Ammar, R. E. P. Davis, W. Kropac, and J. Mott, Phys. Rev. 166, 1317 (1968).