transitions of the type $\Sigma^- + p \rightarrow \Sigma^0 + n$ if $g' = 0$[9]; in other words, the first Born approximation gives zero cross-section for such processes. On the other hand, just because the interaction is not weak, the Born expansion does not converge rapidly, and the higher order terms may well be large enough to account for the observations, even without invoking other kinds of mediating processes, like those involving K mesons, or those due to a small g' term (Sec. 4).[10]

[9] More precisely, this holds for all transitions which are first forbidden in the corresponding weak-coupling theory (e.g., elastic Λ-nucleon scattering). This similarity between strong-coupling and weak-coupling matrix elements for baryon-baryon interactions is easily derived (as in the nucleon-nucleon case) by considering the static self-energy of a pair of baryons kept at a given (not too small) distance.

[10] J. J. DeSwart and C. K. Iddings (to be published; I thank the authors for showing me their results and for valuable comments) have made a thorough numerical study of hyperon-nucleon interactions, based on a Schrödinger equation with pion-mediated potentials (including two-pion exchanges and repulsive cores), with the aim of finding out what values of the two coupling constants $f_{\Lambda\Sigma}$ (related to our g) and $f_{\Sigma\Sigma}$ ($\sim$our g') give the best fit to all experimental data now available. They conclude that $f_{\Sigma\Sigma}=0$ is not ruled out, and even favored by some data, including those of reference 8.

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Elastic Scattering of Lambda Hyperons from Protons*

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The Λ-proton elastic scattering cross section has been measured to be 20 ± 5 mb. This value represents an average over the momentum interval 150–1500 MeV/c. It is based on 26 events observed in a propane bubble chamber. The Λ hyperons were produced by the interactions of 1.15-BeV/c K^- mesons in the propane.

INTRODUCTION

It is of value to experimentally determine the cross sections for the various reactions involving hyperons and nucleons in that these data may provide some criteria for judging the validity of the various baryon-nucleon symmetry schemes.[1] Of the various hyperon-nucleon reactions possible, Λ-proton elastic scattering is the most amenable to experimental investigation. Three measurements of the cross section for this process have been reported in the literature at this date. Crawford *et al.*[2] have estimated a value of 40 ± 20 mb based on 4 events. Recently, Alexander *et al.*[3] reported a value of 22.3 ± 5.9 mb on the basis of 14 events, and Arbuzov *et al.*[4] have estimated the cross section to be 36 ± 14 mb from a sample of 20 events. The results to be reported in this paper, based on 26 events, are seen to be in agreement with these earlier results.

PROCEDURE

The 30-in. propane bubble chamber used in this experiment has been described in considerable detail elsewhere.[5] The chamber was placed in a magnetic field of 13 kG and exposed to the 1.15-BeV/c K^- meson beam[6] at the Lawrence Radiation Laboratory Bevatron. A total of about 105 000 stereo-pairs of photographs were obtained during the run. Of these, 103 000 pairs were scanned for this experiment.

Scanning Procedure and Data Analysis

The scanning procedure followed in this experiment provided a means for the systematic detection of two types of kinematical configurations. Of primary interest were the elastic scattering configurations. These involved three vertices: the K^- beam interaction responsible for the production of the Λ via $K^- + N \rightarrow \Lambda + \pi$; the Λ-proton elastic scattering vertex, and the Λ-decay reaction $\Lambda \rightarrow p + \pi^-$. Also of interest were the two vertex configurations indicating K^- production of Λ followed by Λ decay without intervening interaction of the Λ prior to decay. There were too many examples of these latter configurations to make individual analysis of all of them feasible. Consequently, a count of them was kept and a smaller sample of them prepared for detailed analysis—a procedure yielding all of the information needed to provide the normalization for the cross-section calculation.

Events located in the scan were measured on digitizing devices and analyzed using the Fog IV Data Reduction System.[7] Included in the analysis were least-square fitting calculations in which the configurations were constrained to fit hypothetical event interpretations by requiring that the interactions conserve energy and momentum within the framework of the proposed interpretations.

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† Submitted in partial fulfillment of the requirements for the Ph.D. degree at the University of Wisconsin. Present address: Purdue University, Lafayette, Indiana.

[1] For example, see M. Gell-Mann, Phys. Rev. **125**, 1067 (1962). This paper includes references to earlier work.

[2] F. S. Crawford, M. Cresti, M. L. Good, F. T. Solmitz, M. L. Stevenson, and H. K. Ticho, Phys. Rev. Letters **2**, 174 (1959).

[3] G. Alexander, J. A. Anderson, F. S. Crawford, W. Laskar, and L. J. Lloyd, Phys. Rev. Letters **7**, 348 (1961).

[4] B. A. Arbuzov, Ye. N. Kladnitskaya, V. N. Penev, and R. N. Faustov, Dubna Report D-820, 1962 [J. Exptl. Theoret. Phys. (to be published)].

[5] W. M. Powell, W. B. Fowler, and L. O. Oswald, Rev. Sci. Instr. **29**, 874 (1958).

[6] P. E. Eberhard, M. L. Good, and H. K. Ticho, Rev. Sci. Instr. **31**, 1054 (1960).

[7] Howard S. White, University of California Radiation Laboratory Report UCRL-9475 (unpublished).

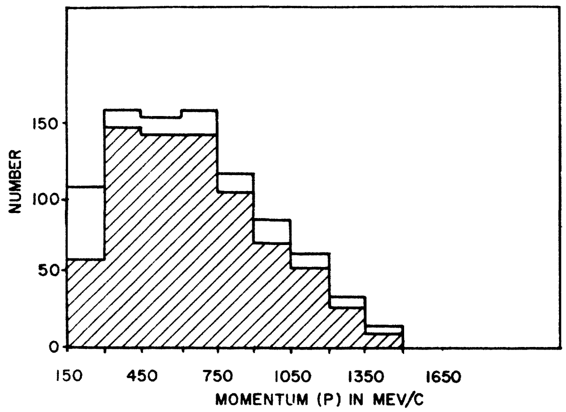

FIG. 1. Momentum histogram for the final Λ-decay sample of 748 events. The plain histogram has been corrected for geometrical losses. The cross-hatched portion is the uncorrected, experimentally observed distribution.

It should be noted that both event types peculiar to this experiment are highly overdetermined: The simple Λ production and decay configuration permits a 3-constraint test at the decay vertex; the scattering configuration can be given 3-constraint tests at both decay and scattering vertices. No such calculations were made on the Λ production vertices because of the large number of cases in which the Λ was produced via K^- interaction with nucleons bound in carbon nuclei.

At the completion of the data analysis the sample of two-vertex configurations (Λ production and decay without scattering) contained 748 events considered to be legitimate examples of these processes. A momentum histogram of these events is shown in Fig. 1. The geometrical corrections applied to these data is discussed in detail shortly.

Of the 250 possible scattering configurations located by the scan, 31 configurations proved to be good examples of Λ-proton elastic scatterings. Most of the remaining events were judged to be either cases where the Λ particle decayed without prior interaction (i.e., the proposed recoil proton track was incorrectly associated with what was actually a two-vertex Λ production and decay configuration) or examples of interactions of either Λ hyperons or $\bar{K}^0$ mesons with nucleons bound in carbon nuclei such that Λ hyperons were included in the final-state products. Details of the good events are given in Table I. It is of some interest to note that of these 31 events, 17 are examples in which the Λ scattered into the forward hemisphere in the center-of-mass coordinate system while in the remaining 14 events the Λ scattered into the backward hemisphere. The polar-to-equatorial ratio is 16:15. Five of these events were rejected for use in calculating the cross section for geometrical reasons, as indicated.

TABLE I. Details of the elastic scatterings.

Picture number	Incident Λ laboratory momentum (MeV/c)	Scattered Λ center-of-mass momentum (MeV/c)	Center-of-mass Λ scattering angle (degrees)
1419	1249	510	39.5
3940[a]	917	391	82.5
8212	1134	471	51.0
15 469	515	229	90.6
15 899[a]	885	379	86.1
17 698	785	340	101.5
20 398	335	151	72.8
26 412	753	327	151.2
28 502	420	188	125.2
30 741	1450	577	112.9
38 838	750	326	79.9
40 663	765	332	40.1
42 083	601	265	45.0
43 629	757	329	67.9
44 791	1242	508	68.7
52 198	1374	552	123.6
52 955	581	257	139.4
54 348	919	392	121.3
58 717[a]	1332	538	65.4
67 066	1184	488	72.4
67 785[b]	1359	547	86.0
71 390[c]	1001	422	92.5
75 161	673	295	126.9
79 683	434	195	133.4
83 775	1038	436	71.0
90 115	901	385	50.5
93 059	765	332	121.0
94 162	554	246	68.9
95 352	630	278	43.2
95 752	827	356	152.8
100 833	1091	455	120.7

[a] Production vertex located above upper fiducial boundary.
[b] Λ flight path between production vertex and scattering vertex greater than 24 cm. (Actual distance was 27 cm.)
[c] Both decay tracks under 2 cm in length.

Contamination of the Data

The two types of event configurations considered in this experiment (two-vertex Λ production and decay, three-vertex scattering configurations) are not of an unambiguous nature; hence the possibility of unwanted interactions contaminating the data must be considered. In the case of the two-vertex Λ production and decay configurations, only one type of contaminating configuration need be taken seriously, namely, neutral K-meson production and decay via $K_1^0 \to \pi^+ + \pi^-$. Neutral K mesons are produced in the charge exchange reaction $K^- + p \to \bar{K}^0 + n$ and though they are not produced as copiously as Λ particles, their presence in the experiment must be acknowledged. The decay $K_1^0 \to \pi^+ + \pi^-$ becomes increasingly difficult to separate from $\Lambda \to p + \pi^-$ as one considers higher initial momenta of the decaying neutral particles. A limited rescan was carried out in an effort to estimate the correction needed to compensate for this source of contamination. One thousand photographs were scanned and the 273 V^0 decays located were analyzed on the scanning table. Of these 273 V^0 configurations, 179 were unambiguous Λ decays, 32 were unambiguous K_1^0 decays, and 62 were ambiguous decays. From these data it is estimated that a correction factor of 0.96±0.01 is needed to correct the total count of decays for K_1^0 contamination. The error on this correction is statistical.

The scattering configurations are vulnerable to several sources of contamination. Certain examples of the neutral K-meson processes,

$$K + p \to K + p, \quad K_1^0 \to \pi^+ + \pi^- \tag{1}$$

and

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

may be confused with the scattering configuration considered in this experiment. Above the threshold for Σ production by Λ particles (640 MeV/c) the processes

$$\Lambda+p\rightarrow\Sigma^0+p,\quad \Sigma^0\rightarrow\Lambda+\gamma \quad (3)$$

taken together have the same general appearance as Λ-proton elastic scattering due to the very fast decay of the Σ^0 (the Σ^0 production and decay vertices cannot be resolved in the film) and the small probability that the photon converts in the chamber. Finally, one must consider the possibility of Λ particles scattering inelastically off carbon nuclei such that a single proton is the only visible final-state product (taking the Λ to be invisible). Most of the time such interactions are so inelastic that they may be rejected on the scanning table as unsuitable for Λ-proton elastic scatterings, but a correction must be estimated for the quasi-elastic events which pass through all stages of the data analysis remaining to contaminate the final data. Although one can think of additional reactions having the same topology as the scattering configuration of interest here, it is believed that these are the only sources of contamination to the data needing serious consideration.

Because the mathematics of the least-square fitting calculation is the same for both of the neutral K-meson processes (1) and (2) and the Λ-proton elastic scattering configuration, it was a simple matter to test ambiguous scattering configurations under the alternate hypotheses (1), (2), or both. The results of this procedure indicated that due to the high degree of overdeterminacy inherent in the configuration, the ambiguity with respect to (1) and (2) was reduced to a near-zero level by the data analysis calculations. [Although the analyzed data showed examples of reactions (1) and (2), none of the acceptable examples of Λ-proton elastic scattering would have also been acceptable as examples of neutral K-meson interactions and vice versa.]

Unfortunately, the Σ^0 processes (3) do not lend themselves readily to the least-square-fit type of calculation due to the presence of the two unresolved vertices. The situation is further complicated in this case since the momentum of the incident Λ is unknown (most of the Λ productions involved carbon nuclei). Even if it had been possible to make the calculation, it would have been difficult to make a good quantitative comparison of the results with the results of the elastic scattering calculation since the two calculations are not of the same type (as were the elastic scattering and the neutral K-meson calculations). For these reasons a Monte-Carlo technique was used to estimate the contamination of our data by Σ^0 events.

A sample of 100 events of type (3) was generated on an IBM 704 computer in a manner as nearly in accord with the conditions in this experiment as was feasible. The preparation of this sample required two assumptions which could not be checked experimentally: the nature of the two center-of-mass angular distributions in (3). The simplest assumptions were the ones decided upon: Both processes were taken to be isotropic in their center-of-mass systems. These 100 events were then analyzed as though they were Λ-proton elastic scatterings. Only one event successfully passed all of the acceptance criteria used to select Λ-proton elastic scattering events. These results indicate it to be unlikely that the data are contaminated by Σ^0 events.

The method used to estimate the level of contamination due to the inelastic interactions of Λ hyperons with carbon nuclei was an outgrowth of the Monte-Carlo calculation just described in connection with Σ^0 events. This time a sample of 100 inelastic Λ-proton interactions was generated on the computer. The following assumptions were made in an effort to simulate the Λ-carbon interactions considered most likely to cause contamination in our results:

1. The only process of importance is $\Lambda+{}_6C^{12}\rightarrow\Lambda+p+{}_5B^{11}$. This process is adequately simulated if one ignores the presence of the boron nucleus, treats the interaction as a two-body process, and makes the remaining assumptions.
2. The interaction proton has a fixed total energy of 922 MeV. (It is bound with a fixed energy of 16 MeV.)
3. The vector momentum of the interaction proton prior to the interaction is directed randomly in space following a half-Gaussian probability distribution with a standard deviation of 125 MeV/c. (This implies an average magnitude of 215 MeV/c.[8])
4. The process, treated as a two-body interaction, is isotropic in its center-of-mass system.

After this sample of 100 inelastic events had been analyzed as Λ-proton elastic scatterings the results were normalized using the background data in this experiment. In this manner the level of contamination of good scattering events by inelastic Λ interactions with carbon nuclei has been estimated to be $(10\pm5)\%$. (The error is an estimate.)

Geometrical Considerations and Event Loss Factors

A number of corrections for event losses have to be included with the data before a correct estimate of the cross section can be made. Specifically, the two-vertex Λ production and decay events remain undetected if the Λ decay occurs after the Λ particle has left the chamber or if the decay configuration is of a difficult-to-recognize type. (A considerable percentage of the low-momentum Λ decays are missed because the decay proton lacks sufficient momentum to leave a visible track; high-momentum decays are more likely to be lost because the Λ particle escapes from the chamber prior to decay.) Scattering configurations are missed for similar reasons: The scattered Λ may leave the

[8] In choosing these values the following work was used as a guide: J. B. Cladis, W. N. Hess, and B. J. Moyer, Phys. Rev. 87, 425 (1952).

TABLE II. Values of the geometricalfactor s: $F_s(p,\theta)=n_s(p,\theta)/n(p,\theta)$ and $F_d(p,\theta)=n_d(p,\theta)/n(p,\theta)$.

	Production angle (θ) in degrees								
p[a]	10	30	50	70	90	110	130	150	170
				$n(p,\theta)$					
225	100	200	100	100	100	100	100	100	0[b]
375	300	400	300	300	200	200	100	100	100
525	300	400	400	200	100	100	0	0	0
675	300	500	300	200	100	0	0	100	0
825	300	400	200	100	100	0	0	0	0
975	300	300	100	100	0	0	0	0	0
1125	300	300	100	0	0	0	0	0	0
1275	300	100	0	0	0	0	0	0	0
1425	100	100	0	100	0	0	0	0	0
				$n_s(p,\theta)$					
225	6	8	1	2	2	2	3	2	···
375	77	96	73	88	48	41	20	25	24
525	144	168	158	77	39	37	···	···	···
675	169	245	140	97	47	···	···	52	···
825	161	184	107	48	49	···	···	···	···
975	167	148	45	41	···	···	···	···	···
1125	160	146	47	···	···	···	···	···	···
1275	177	52	···	···	···	···	···	···	···
1425	45	60	···	31	···	···	···	···	···
				$n_d(p,\theta)$					
225	62	115	47	58	58	51	46	60	···
375	282	380	290	277	164	171	92	97	95
525	285	384	363	172	81	92	···	···	···
675	278	471	255	162	74	···	···	86	···
825	264	360	170	84	75	···	···	···	···
975	271	256	74	69	···	···	···	···	···
1125	257	263	75	···	···	···	···	···	···
1275	238	78	···	···	···	···	···	···	···
1425	83	73	···	54	···	···	···	···	···

[a] The numbers in this column are Λ laboratory momenta in MeV/c.
[b] If $N_d(p,\theta)=0$, geometrical factors were not computed for these values of p and θ. (See Table III.)

chamber prior to decay or its decay in the chamber may be unrecognizable; if the momentum transfer is too small the recoil proton does not leave a visible track.

To aid in the calculation of the required loss factors the following requirements were made for all events used in the cross-section estimate (all track and flight path lengths are distances projected on the horizontal plane in the chamber):

1. All vertices in the configuration had to be situated within the fiducial volume of the chamber. This volume was taken to be 50 cm in the nominal direction of the beam, 30 cm at right angles to and in the plane of the beam, and 16.5 cm in height.
2. All neutral particle flight paths had to be shorter than 24 cm.
3. The proton track lengths had to exceed 5 mm.
4. The decay pion track length had to exceed 5 mm unless the pion stopped in the chamber in which case no length requirement was enforced.
5. One of the Λ-decay tracks was required to exceed 2 cm in length.

Using these requirements event loss calculations were made on the computer in a Monte-Carlo fashion. A total of 18 400 simulated Λ productions were made over nine fixed values of Λ momentum and nine fixed production angles for both types of event configurations dealt with in this experiment. The results of this calculation were 162 numbers, 81 for each configuration, which are denoted by $F_s(p,\theta)$ and $F_d(p,\theta)$. The subscripts reference the two different configurations (scattering and production decay); p and θ are the fixed Λ momentum and production angle parameters. These quantities (F_s and F_d) are the ratios of the number of events considered recognized $[n_s(p,\theta)$ and $n_d(p,\theta)]$ to the total number of Λ productions $[n(p,\theta)]$ for those particular values of p,θ and event configuration type (equal numbers of Λ productions were generated for the two configurations at each p-θ point). Table II gives a tabulation of these results. If they are averaged over the seven most significant momentum-angle intervals, one finds the average absolute detection factor for scatterings to be 0.44, for decays 0.93, and the relative detection factor (the one that actually enters the cross-section calculation) to be 0.48.

Scanning Efficiency

To determine the scanning efficiency in this experiment, a limited rescan of some 15 000 photographs was carried out. The composition of the film used in this rescan was determined by dividing the film into groups according to which person had originally scanned it and weighting the selection of film from each group according to the size of the group (in other words, the relative size of that scanner's contribution to the total scanning effort). Within a given grouping the film was chosen with an unsophisticated attempt at randomness.

The same scanning procedures were followed during the rescan that had been used during the original scan. Individual efficiencies were computed on the basis of events found in the original scan, events found during the rescan, and events found in both scans. The individual efficiencies were combined in a weighted average to give an over-all efficiency of $(89\pm5)\%$. (The error is an estimate.)

The above scanning efficiency applies to the recognition of scattering configurations. Periodic checks during the original scan indicated that the efficiency for recognition of production-decay configurations was not significantly less than 100%.

Cross-Section Calculation

The usual expression used to estimate a total cross section is $\sigma=N/\rho L$, where N is the number of interactions, L is the total track length accumulated by the projectile particles, and ρ is the number of target nucleons per unit volume. In this experiment a somewhat different, though equivalent, expression is used which is more readily suited to the type of event loss calculation described earlier. If S_0 is the total number of scatterings observed in the experiment, then

$$S_0=\sigma\frac{\rho\tau c}{M}\int\int p\frac{F_s(p,\theta)}{F_d(p,\theta)}N_d(p,\theta)dpd\theta. \quad (4)$$

TABLE III. Values of the Λ production distribution, $N_d(p,\theta)$.

	Production angle (θ) in degrees[a]								
p[b]	20	40	60	80	100	120	140	160	180
300	5	16	9	8	8	4	4	3	0
450	21	41	25	26	10	11	7	2	2
600	25	47	44	15	7	3	0	0	0
750	38	60	27	11	4	0	0	1	0
900	39	42	13	6	1	0	0	0	0
1050	33	33	5	1	0	0	0	0	0
1200	27	25	1	0	0	0	0	0	0
1350	23	4	0	0	0	0	0	0	0
1500	7	3	0	1	0	0	0	0	0

[a] The numbers shown are the upper bounds of the intervals. The intervals are 20 deg in width.
[b] The numbers in this column are Λ laboratory momenta in MeV/c. The numbers shown are the upper bounds of the intervals. The intervals are 150 MeV/c in width.

In this expression σ is the total elastic scattering cross section (assumed to be independent of momentum over the integration interval), τ is the Λ-particle lifetime, c is the velocity of light, M is the Λ mass, p is the incident Λ momentum, θ is the Λ production angle, F_s and F_d are the loss factors discussed earlier, and $N_d(p,\theta)$ is the observed distribution of Λ momentum and production angle. Table III gives the values of $N_d(p,\theta)$ based on the sample of 748 good Λ production-decay events.

If

$$I=\int\int p\frac{F_s(p,\theta)}{F_d(p,\theta)}N_d(p,\theta)dpd\theta, \tag{5}$$

then numerical integration of the data yields the result $I=(2.4\pm0.1)\times10^5$ MeV/c. This result is based on the sample of 748 good Λ production-decay events [i.e., $\int\int N_d(p,\theta)dpd\theta=748$] and must be renormalized to the total number of such events in the experiment before it can be inserted in (4). A total of 22 449 two-vertex Λ production-decay events was obtained during the scan. Experience with the sample of these events indicates that $(62\pm2)\%$ of them are acceptable for use

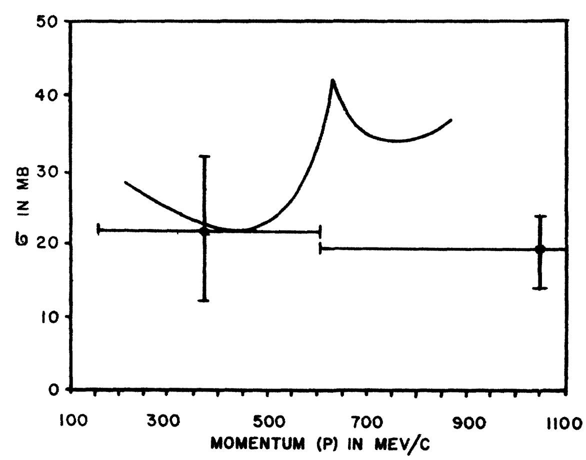

FIG. 2. The total elastic scattering cross section as a function of incident Λ laboratory momentum, from the calculation of de Swart and Dullemond. Our experimental values are shown.

in the cross-section calculation. Introducing the K_1^0 correction at this point, the corrected number of events is found to be 13 500±500. Renormalizing the calculation to this number, one finds: $I=(4.3\pm0.3)\times10^6$ MeV/c. The error is based on linear propagation of statistical errors. Taking the density of propane to be 0.415 g/cc and the values for the rest of the factors from Barkas and Rosenfeld's estimates,[9] the total elastic scattering cross section calculated is 20±5 mb.

DISCUSSION

The previous measurements of the Λ-proton elastic scattering cross section have been mentioned earlier in this paper. The result of Crawford *et al.*[2] (40±20 mb) represents an average over approximately the same momentum interval that was present in the experiment of Alexander *et al.*[3] which yielded the cross-section value 22.3±5.9 mb. This interval was 400–1000 MeV/c. The result of Arbuzov *et al.*[4] (36±14 mb) is averaged over the interval 200–5700 MeV/c. If this interval is reduced to 400–1500 MeV/c, their result is 42±16 mb based on 16 events. Their mean momentum in this case is 1 BeV/c. Our value of 20±5 mb from the momentum interval 150–1500 MeV/c is in good agreement with these results particularly the recent measurement by Alexander *et al.*

Two theoretical estimates of the Λ-proton elastic scattering cross section are known to the author. Kovacs and Lichtenberg[10] have given estimates at 416 MeV/c (75 MeV) and at 598 MeV/c (150 MeV) incident Λ momentum. Assuming a Λ-nucleon central potential with a hard core and an exponential falloff outside the core and neglecting all partial waves with orbital angular momentum greater than 2, they find cross-section values of 26 and 21 mb at 417 and 598 MeV/c, respectively, without a spin-orbit contribution, and 34 and 32 mb when a spin-orbit contribution is included.

If the data in this experiment are divided at 600 MeV/c, a cross section of 22±10 mb, based on 6 events, is found for the interval 150–600 MeV/c. Although this result agrees with the calculated values of Kovacs and Lichtenberg the statistics are too poor to furnish insight on the importance of the spin-orbit contribution.

Recently, de Swart and Dullemond[11] have investigated hyperon-nucleon interactions within the framework of the theory of global symmetry. Their results for the total cross section for Λ-proton elastic scattering are shown in Fig. 2. The values from this experiment

[9] W. H. Barkas and A. H. Rosenfeld, in *Proceedings of the 1960 Annual International Conference on High-Energy Physics at Rochester*, edited by E. C. G. Sudarshan, J. H. Tinlot, and A. C. Melissions (Interscience Publishers, Inc., New York, 1960), p. 878.
[10] J. S. Kovacs and D. B. Lichtenberg, Nuovo Cimento 13, 371 (1959).
[11] J. J. de Swart and C. Dullemond, Ann. Phys. (N. Y.) 16, 263 (1961).

for the intervals 150–600 MeV/c and 600–1500 MeV/c are also shown. They are 22 ± 10 mb (6 events) and 19 ± 5 mb (20 events), respectively. The agreement is considered satisfactory particularly in the lower momentum interval. In the upper interval the calculated results are less certain since they are derived from a neutron-proton potential considered unreliable at these energies.

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K_{l4} Decays and the Structure of the $\Delta S=1$ Currents

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It is shown that the search for various modes of K_{l4} decays may give valuable information regarding the structure of the strangeness-nonconserving currents. At the same time such a search provides a severe test for a class of theories of weak interactions, in which all charged currents are coupled to the leptonic current and satisfy the abstract properties of Gürsey's model.

RECENT experiments indicate the existence of isotopic spin $I=\frac{3}{2}$ vector currents.[1–4] If the assumptions are made that (i) CP invariance holds in the K_{l3} decays and (ii) the form factors describing these processes depend weakly on the pion energy, the combined data of references 1 and 3 support also the existence of $I=\frac{1}{2}$ vector currents.[5,6] It is also important to note that the conclusions of these experiments are in conflict with the rigorous predictions of partially conserved vector currents constructed on the basis of second rank simple Lie algebras, i.e., those simple algebras which allow for just two additive quantum numbers for the strong interactions (SU_3, $Sp[2]$, and G_2).[7,8]

A question which naturally arises at this stage is whether or not axial vector $I=\frac{3}{2}$ currents exist in the weak interactions. Certainly such a question is important on purely phenomenological grounds. There are, however, some specific theoretical arguments which motivate such a quest, which will be briefly discussed.

Gürsey has shown[9] that it is possible to construct a theory of strong interactions invariant under an eight-dimensional orthogonal group of transformations $[O_8]$, which allows for partially conserved $\Delta S=0$ and $\Delta S=1$ vector and axial vector currents. The currents of this theory possess the following properties: (a) They are conserved in the limit of vanishing meson masses, and (b) both $I=\frac{1}{2}$ and $I=\frac{3}{2}$ currents are allowed in the vector interaction, but only $I=\frac{1}{2}$ currents are present in the axial vector part. Independently of this model for the strong interactions, Gürsey has also emphasized that parity mixtures are not allowed for the $I=\frac{3}{2}$ currents if (a) holds and certain assumptions are made concerning the nature of the existing mesons and the

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1 R. P. Ely, W. M. Powell, H. White *et al.*, Phys. Rev. Letters 8, 132 (1962).

2 A. Barbaro-Galtieri, W. H. Barkas, H. H. Heckman *et al.*, Phys. Rev. Letters 9, 26 (1962).

3 G. Alexander, S. P. Almeida, and F. S. Crawford, Jr., Phys. Rev. Letters 9, 69 (1962).

4 Because many parities are relative, we adopt the convention that the K meson has negative parity. With this convention, the currents contributing to the K_{l2} and K_{l3} decays behave as axial vectors and vectors, respectively.

5 The relevant formulas for the isospin analysis of K_{l3} decays are given by R. E. Behrends and A. Sirlin, Phys. Rev. Letters 8, 221 (1962) and lectures at the Second International School of Physics, University of Bergen (to be published).

6 Assumption (ii) is partially supported by recent experiments. See J. L. Brown *et al.*, Phys. Rev. Letters 8, 450 (1962).

7 A discussion of this problem and of its implications for the strong interactions was given in the first paper of reference 5. In the case of the G_2 algebra, the prediction of reference 5 is exact to first order in the weak coupling constant and to zero order in α, subject to two qualifications: (a) the assumed CP invariance of the K_{l3} decays and (b) the neglect of possible nonlocal effects of the weak interactions in the K_{l3} decays.

8 It is interesting to note that, from the data of reference 3, one of the two possible predictions of conservation under the G_2 algebra gives $M_1/M_2=-(2.3_{-0.1}{}^{+0.2})$, where M_1 and M_2 are the matrix elements for $K_1{}^0\to\pi^-+e^++\nu$ and $K_2{}^0\to\pi^-+e^++\nu$. This number is compatible with the measured time dependence of the total decay rate of K^0 into the channels $\pi^-+e^++\nu$ and $\pi^++e^-+\bar{\nu}$, but is in conflict with the sign of the charge asymmetry (see reference 1).

9 F. Gürsey, Ann. Phys. (N. Y.) 12, 91 (1961).