To investigate the composite spectrum for a colloidal sample, let us designate by n_a the number of spheres of radius a. Then the total spectrum for all spheres will be a superposition of curves (see Fig. 3 of reference 3), where the maximum intensity of each curve is proportional to an_a and the range of the abscissa for each is proportional to a^2. Note that the number of particles of a given size is more important than their relative volume. In general, an exhaustive count of the several particle sizes must be made in order to determine the probable shape of the spectrum. If observations are made by means of a variable-frequency spectrometer in a fixed magnetic field, the absorption decreases rather sharply toward the high frequencies. The "position" of the line is determined approximately by the point of maximum slope on this high-frequency edge of the line. The uncertainty of this determination is reduced if the very small (<150 A) particles predominate. Furthermore, the edge will appear at slightly lower frequencies for such a distribution.

Two colloid samples were prepared as suspensions in albumen and gelatin, respectively. As may be seen in the electron micrographs of Fig. 1, each sample contained spherical particles, the majority of which are less than 200 A in diameter. This sort of distribution would tend to produce a resonance whose "position" is slightly lower in frequency than the corresponding position for a colloid containing a larger proportion of larger spheres. Our measurements of the nuclear resonance absorption indicate that the metallic line shift for superconducting Hg is $\Delta H/H \lesssim 0.5\%$. Reif's result ($\sim 1.5\%$) is for a different particle-size distribution and for lower magnetic fields. In view of the different conditions in the two experiments, the results are not necessarily inconsistent. For normal Hg, $\Delta H/H = 2.5 \pm 0.1\%$.[3,4]

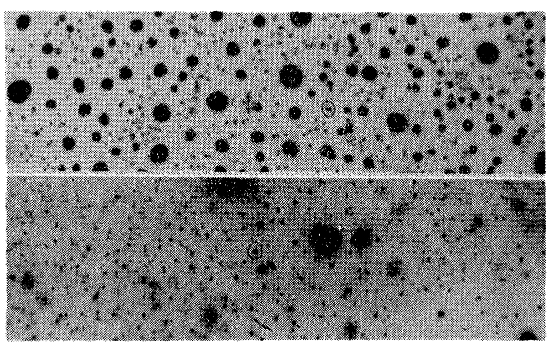

FIG. 1. Electron micrographs of colloidal Hg prepared as suspensions in albumen (top photograph) and gelatin (bottom photograph). The specimens were enclosed in a thin sandwich of SiO before exposure in the electron microscope. In each picture, the circled particle has a diameter of approximately 300 A.

The result is of some significance in considering the electron-nuclear interaction in a superconductor: $\Delta H/H \sim \chi_p P_F$, where χ_p is the spin susceptibility for the Fermi electrons and P_F is the average electronic wave function for s states over the Fermi surface. For a superconductor, the small value of $\Delta H/H$ requires that χ_p or P_F, or both, are considerably smaller than for a normal metal.

The exact value of $\Delta H/H$ is difficult to determine experimentally: (1) the line width in normal Hg is considerable, (2) the shape of the resonance in the superconductor depends on the distribution of particle sizes, and (3) the range of the chemical shifts in Hg is not known.[5] We are attempting to perform experiments with multiple uniform thin films of Pb and Sn. Here the geometry is simpler, the uniformity in sample size will greatly simplify the analysis of line shape, and the widths of the normal lines are smaller.

We are greatly indebted to Mr. R. T. Haines, of the Crookes Laboratories, Ltd., London, for preparing the samples, and to Professor Robley Williams for advice concerning their examination with the electron microscope. We have benefited from conversations with Professor C. Kittel, Professor W. A. Nierenberg, and Mr. A. Mitchell about the interpretation of the experiments. After we had obtained a preliminary result, we learned of Dr. Reif's work. We are grateful to him for discussions of the results.

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Associated Production of Hyperons and K Mesons*

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THERE are now several pieces of experimental evidence indicating definite asymmetries in the angular distributions of Λ^0 and K^0 particles that are produced in association in pion-nucleon and nucleon-nucleon collisions.[1–4] Experimental evidence also exists for asymmetries in the angular distributions of Σ^- and K^+ particles produced in pion-nucleon collisions.[1–4] This note concerns a suggestion for a possible interpretation of these asymmetries in terms of a coupling between pions and K mesons and a coupling between pions and hyperons. These remarks were considered originally in connection with an experiment performed by Osher and Moyer,[5] in which they observed the angular distribution of neutral unstable particles, produced by bombarding a copper target with protons of various energies ranging from 2 to 6.2 Bev. The angular distribution of the K^0 produced in the reaction $p+n \rightarrow Y+K+N$ was fitted with a $\cos^{14}\theta$ in the center-of-mass system, at all energies in the range. This very high power of the cosine is difficult to understand in terms of the angular momentum states available to the system at the lower energies, if the interaction radius is considered to be on the order of $(m_K)^{-1}$. A longer-range interaction that will give strong forward and backward peaking of the hyperons and K mesons is needed. The production mechanisms suggested are shown diagrammatically in Fig. 1. The processes represented by graphs (a) and (b)

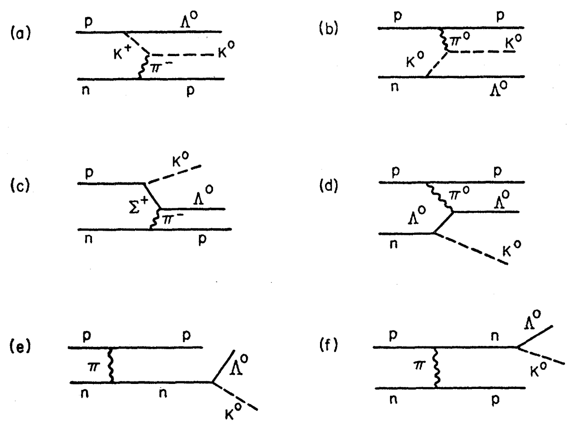

FIG. 1. Feynman graphs for the process $p+n\rightarrow\Lambda^0+K^0+p$.

involve the pion-nucleon coupling constant, G; the nucleon—hyperon—K-meson coupling constant, G_{YK}; and a pion—K-meson coupling constant, $G_{\pi K}$. The π-K interaction is assumed of the form $K_e{}^+\tau_\alpha K_0\pi_\alpha$, where $K_e(K_0)$ represents the field operator of the K meson of spin and parity $0^+(0^-)$, the π_α represent the pion field operators, and the τ_α are the Pauli isotopic spin matrices. The processes represented by graphs (c) and (d) involve G, G_{YK}, and a pion-hyperon-hyperon coupling constant, $G_{Y\pi}$. It should be noted that if one is to allow K mesons of either parity to be emitted in either even or odd angular momentum states, then there must be Σ and Λ particles with both positive and negative parity relative to the nucleon. Thus, for example, the nucleon-lambda-K-meson interaction will be of the form $\bar{N}\Lambda_e K_e+\bar{N}\gamma_5\Lambda_0 K_e+\bar{N}\Lambda_0 K_0+\bar{N}\gamma_5\Lambda_e K_0$ and the sigma—sigma—π-meson interaction will have the form $\bar{\Sigma}_{e(0)}\gamma_5\tau_\alpha\Sigma_{e(0)}\pi_\alpha+\bar{\Sigma}_{e(0)}\tau_\alpha\Sigma_{0(e)}\pi_\alpha$. The γ_5 dependence of these vertices leads nonrelativistically to a dependence on the momentum of the bosons which tends to enhance peaking effects.

Processes of graphs (a) and (c) of Fig. 1 lead to a peaking of the K mesons forward, while those for (b) and (d) lead to a peaking of the K mesons backward. The peaking of the K mesons is most pronounced in the processes of graphs (c) and (d), because the K carries much of the momentum of one of the initial nucleons forward or backward, respectively, in the center-of-mass system. The production process may also occur through the mechanisms indicated in graphs (e) and (f). These mechanisms can lead to backward and forward peaking, respectively, for both the Λ^0 and K^0. If we have $G>G_{\pi K}$ or $G_{Y\pi}$, the processes shown in these graphs may make a large contribution to the total cross section. The question arises as to what is the relative contribution to the peaking of the processes in graphs (a) and (b) on the one hand, and in (c) and (d) on the other. If we look now at the production of Λ^0 and K^0 in pion-nucleon collisions we get a partial answer. What has been observed in π^--p collisions is a very strong peaking of the Λ^0 backward and the K^0 forward.[4] The production processes are shown diagrammatically in Fig. 2. That

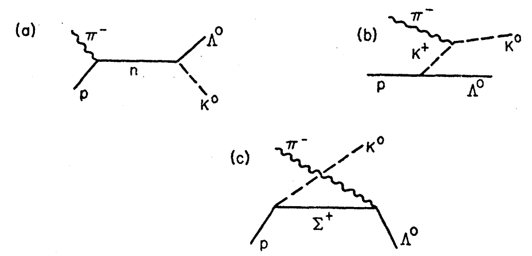

FIG. 2. Feynman graphs for the process $\pi^-+p\rightarrow\Lambda^0+K^0$.

of graph (a) leads to an essentially isotropic distribution; that of graph (b),[6] involving $G_{\pi K}$, peaks the K^0 strongly forward; however, process (c), involving $G_{Y\pi}$, peaks the K^0 strongly backward. That the latter effect is not observed, indicates that we have $G_{Y\pi}<G_{\pi K}$. The coupling of the pion to the isotopic bosons Λ and Σ must be smaller than that of the pion to the isotopic fermions K_e and K_0 if this picture of the production mechanism is to be consistent for both π-N and N-N collisions.

A detailed calculation is in progress to see if the angular distribution of the Osher experiment can be fitted with the matrix element from graphs (e) and (f) and the graphs involving $G_{\pi K}$ in Fig. 2. If not, the question is then how much of the process involving $G_{Y\pi}$ can be introduced consistent with the absence of the backward peak in π-N collisions.

Finally we note that the production of Σ^- and K^+ in π^--p collisions occurs through the processes shown in Fig. 3. Experiment indicates that the K^+ tend to go

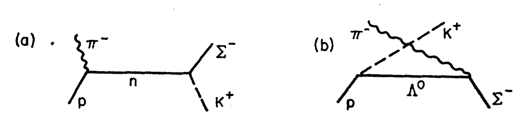

FIG. 3. Feynman graphs for the process $\pi^-+p\rightarrow\Sigma^-+K^+$.

backward and the Σ^- forward in the center of mass. This is consistent with the mechanism in graph (b). The smaller number of Σ^-K^+ events[4] than of Λ^0K^0 events is consistent with the absence of the production mode involving $G_{\pi K}$ in π^--p collisions. If $G_{\pi K}>G_{Y\pi}$, the Σ^- produced in n-p collisions should come off predominantly backwards in the center-of-mass system.

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Neutron and Proton Distributions in Pb†

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In 1953, Johnson and Teller[1] proposed a model of the nucleus which predicted neutrons at larger radii than protons in nuclei with a neutron excess. Since that time some experimental data and several theoretical discussions have appeared bearing on this subject.[2] Piccioni[3] suggested that a difference between neutron and proton radii could be experimentally detected by a measurement of the difference in the absorption cross sections of a heavy nucleus for positive and negative pions of 700-Mev kinetic energy. Since $\sigma(\pi^-,p)$ is 2.6 times larger than $\sigma(\pi^+,p)$ at this energy,[4] neutrons[5] at larger radii than protons will be less transparent for π^+ than for π^-; the central region, on the other hand, is so nearly opaque that its transmission is insensitive to small changes in neutron and proton densities. Hence, the Johnson-Teller model would predict a larger absorption for positive pions than for negative. A relative measurement of this kind can be carried out with high accuracy so that even small differences can be observed.

Courant,[6] using the optical model,[7] computed the magnitude of the effect to be expected in the case of Pb.

Table I. Calculated and experimental values for the ratio $q=[\sigma(\pi^-)-\sigma(\pi^+)]/\sigma(\pi^+)$ in Pb. The computed values are based on the optical model using square-well nucleon distributions. The values of r_0 are given in units of 10^{-13} cm.

Pion kinetic energy in Mev (lab)	$q=[\sigma(\pi^-)-\sigma(\pi^+)]/\sigma(\pi^+)$ Computed for $r_n=r_p=r_0A^{\frac{1}{3}}$		Computed for $r_n=r_0A^{\frac{1}{3}}$, $r_p=r_0[Z/(A-Z)]^{\frac{1}{3}}$		Experimental values
	$r_0=1.4$	$r_0=1.3$	$r_0=1.4$	$r_0=1.3$	
700	+0.033	+0.044	−0.027	−0.024	+0.050±0.011
1100	+0.039	+0.045	+0.030	+0.034	+0.017±0.012

We have recomputed this effect using the recent, more accurate values of the elementary cross sections.[4] The elementary cross sections used in the calculation were averaged over a 20-Mev Fermi energy distribution. Following Courant, we used a square-well distribution, taking $r_n=r_0A^{\frac{1}{3}}$ and $r_p=r_n[Z/(A-Z)]^{\frac{1}{3}}$, which leads to equal densities of neutrons and protons within the nucleus; we also compute for $r_n=r_p=r_0A^{\frac{1}{3}}$. Results for the ratio $q=[\sigma(\pi^-)-\sigma(\pi^+)]/\sigma(\pi^+)$ are given in Table I for $r_0=1.3\times10^{-13}$ cm and 1.4×10^{-13} cm at 700-Mev and at 1100-Mev pion kinetic energies. The computed results include an electrostatic factor $[1\pm2Ze^2/RE]$.[6]

The apparatus is shown in Fig. 1. Both positive and negative pions were available by simply reversing the

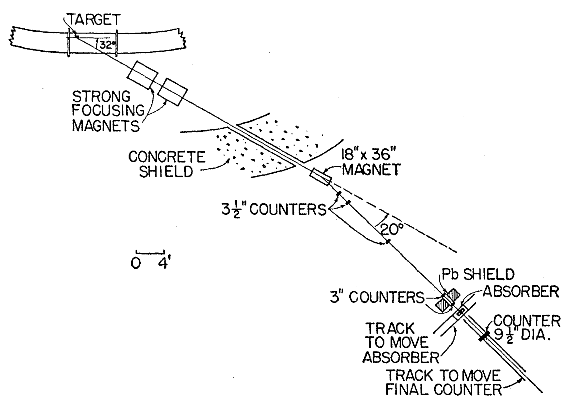

Fig. 1. Schematic arrangement of the apparatus.

currents in the electromagnets. The proton contamination in the pion beam was reduced to less than 1% by time-of-flight discrimination previously described.[4] The absorption was obtained by counting anticoincidences between a large final counter and the beam-defining telescope, with and without Pb absorber. The angle θ subtended by the final counter was chosen such that relatively few pions which suffer diffraction scattering or multiple Coulomb scattering are counted as absorptions. The value of q is insensitive to the fact that a small fraction of inelastic events may project a secondary within the angle θ.

The measurements have been corrected for chance coincidences in the final counter. These corrections amount to 1.3% for π^+ and 0.6% for π^-. A correction of 0.4% for π^+ was necessary because of chance coincidences in the beam-defining telescope. Muons originating from pions that decay after the momentum analysis are clearly proportional to the pion intensity and the ratio q is, to a sufficient approximation, independent of this source of muon contamination. However, muons from pions decaying before the momentum analysis are not strictly proportional to the momentum-selected pion beam intensity. This difference results from the fact that pions ranging from the selected momentum p_0 up to $1.75p_0$ can contribute muons of the correct momentum, while the π^+ and π^- production