neutron interaction while maintaining the interpretation of the experiments of Hofstadter *et al.*[7] on electron-proton scattering in terms of extended charge and moment distributions. Assume for simplicity that the K particle has spin 0. The K therefore interacts with the Σ-nucleon fields with a scalar or with a pseudoscalar coupling, depending on the relative intrinsic parities of the K, Σ, and nucleons.

The desired cancellation of the π cloud of the neutron is possible with scalar coupling in spite of the large mass of the K ($M_K \approx 3M_\pi$) because the rms radius of the charge density for mesons with a scalar coupling is larger by a factor[8] of about 1.6 than the rms radius of the charge density for mesons of the same mass interacting with derivative pseudoscalar coupling. With an $S(S)$ coupling constant of $g^2 \approx 0.4$, an electron-neutron interaction of $+1$ kev is obtained in a second-order perturbation calculation with fixed source.[8]

It is suggestive that, if one uses this value for the coupling constant, the Born approximation to the elastic scattering cross section of nonrelativistic K^+ particles on nucleons is

$$\sigma = 4\pi(g^2)^2/\omega_K^2 \approx 4 \text{ mb},$$

which is in agreement with the rough experimental value.[9]

A scalar coupling does not contribute appreciably to the anomalous magnetic moments of the nucleons. A pseudoscalar coupling, on the other hand, diminishes the ratio of neutron to proton anomaly, which is much greater than the observed one according to perturbation theory. Scalar and pseudoscalar coupling are perhaps two facets of the same picture, for there is evidence that there exist in nature two K particles, with nearly equal masses and probably with opposite parities.

I am greatly indebted to Professor Sidney Drell and Professor Bruno Rossi for their continued advice.

[1] We use M. Gell-Mann's assignments of isotopic spin [*Proceedings of the Glasgow Conference on Nuclear and Meson Physics* (Pergamon Press, London, 1955), p. 342]. Other possible reactions are $n \rightarrow \Xi^- + K^+ + K^0$, $p \rightarrow \Lambda^0 + K^+$, $p \rightarrow \Xi^- + K^+ + K^+$, $p \rightarrow \Xi^0 + K^0 + K^+$. These types of interactions are disregarded here for simplicity since they do not alter the qualitative picture.

[2] According to A. Pais' assignment (model III) in *Proceedings of the Glasgow Conference* (see reference 1), $n \rightarrow \Sigma^+ + K^-$ is allowed. In this model we would also have $p \rightarrow \Sigma^{++} + K^-$.

[3] Hughes, Harvey, Goldberg, and Stafne, Phys. Rev. **90**, 497 (1953); also Melkonian, Rustad, and Havens, Bull. Am. Phys. Soc. Series II, **1**, 62 (1956).

[4] L. Foldy, Phys. Rev. **87**, 693 (1952).

[5] B. D. Fried, Phys. Rev. **88**, 1142 (1952).

[6] G. Salzman [Phys. Rev. **99**, 973 (1955)] has applied Chew's cutoff theory to the problem, obtaining a contribution of about 8 kev from the π cloud. He suggests cancelling this charge density by spreading the proton core.

[7] R. Hofstadter and R. W. McAllister, Phys. Rev. **98**, 217 (1955).

[8] This factor is obtained with the perturbation approximation and is cutoff-dependent, as is apparent from Salzman's work (reference 6). With scalar coupling the electron-neutron potential can be calculated without cutoff but the total mesonic charge depends logarithmically on the cutoff.

[9] The results of Berkeley and Massachusetts Institute of Technology give $\sigma \sim 5$ mb [Goldhaber, Pevsner, and Ritson (private communication)].

Interaction of Positive K-Mesons

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WITH the availability of focused K-meson beams at the Bevatron,[1] it became possible to make a systematic study of the interactions of positive K-mesons.[2] The method used was to observe interactions of K-mesons in flight in nuclear emulsions.

The experimental arrangement and scanning method were described previously in the report[3] on the K^+-lifetime. The K-meson beam is a mixture of all K-meson types and (or) modes of decay and is known to consist predominantly of $K_{\mu 2}$, $K_{\pi 2}$, and τ mesons ($\sim$58% $K_{\mu 2}$, $\sim$30% $K_{\pi 2}$, and $\sim$7% τ).[4] in this work we have not separated the interactions of the various types of decay; however, almost all types have been seen to interact.[5]

In scanning along the track, we have observed the interactions of K-mesons ranging in kinetic energy from 30 to 120 Mev. In 38.5 meters of K-meson track we have found 60 elastic[6] and inelastic scatterings greater than 20°. In addition there were four events in which no K-meson was found to be re-emitted. These are consistent with the charge-exchange reaction $K^+ + n \rightarrow K^0 + p$. In none of the above 64 interactions was any π-meson or hyperon production observed and, in fact, the visible energy release never exceeded the kinetic energy of the K-meson.

TABLE I. The observed distribution of elastic and inelastic scattering of K^+-mesons in emulsion.

K-meson energy (Mev)	K-meson scattering angle (lab) 20°–40° Elastic	20°–40° Inelastic[a]	40°–60° Elastic	40°–60° Inelastic	60°–120° Elastic	60°–120° Inelastic	120°–180° Elastic	120°–180° Inelastic	Path length (meters)
30–75	11	3	3	1	4	7	···	5	18.6
75–120	13	1	2	1	2	3	···	4	19.9

[a] Inelastic events include (1) scattering with a clear energy loss and (or) emission of two or more additional prongs, (2) scattering in which one additional prong is emitted without momentum conservation, and (3) events in which an allowance was made for single neutron emission corresponding to cases of single proton emission in class (2). All other events were classified as elastic scattering. As we cannot separate "slightly inelastic" scattering (energy loss of a few Mev) from elastic scattering, such events, if present, would be classified as "elastic" here.

These experimental facts are in good agreement with a number of schemes[7] that have recently been proposed to describe the behavior of heavy mesons and hyperons. All these schemes contain a new quantum number (e.g., "strangeness"), which is conserved in fast reactions. They predict only three types of interactions for positive

K-mesons, *viz.*, elastic, inelastic, and charge-exchange scattering. Absorption reactions, including the production of π mesons and hyperons, are forbidden in the energy range studied. This behavior can be contrasted with that of negative K-mesons for which absorption reactions (e.g., $K^- + p \rightarrow \Sigma^{0,\pm} + \pi^{0,\mp}$) are observed[8,9] and are consistent with the conservation of "strangeness" in a fast reaction.

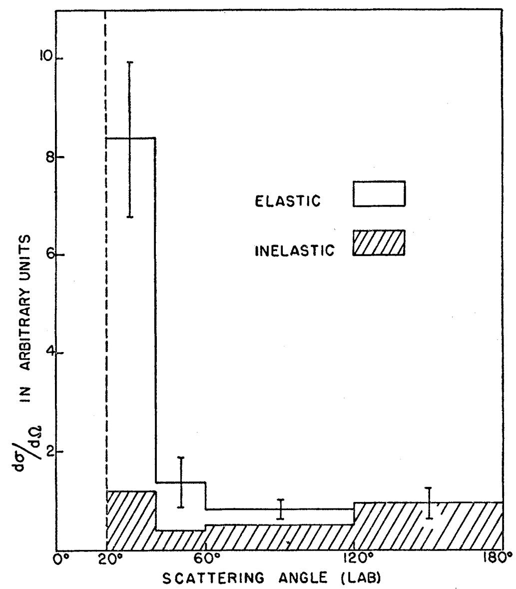

FIG. 1. The differential scattering cross section of K^+-mesons, in arbitrary units.

Another striking difference between K^+- and K^--interactions is the comparatively small cross section we find for K^+-interactions in emulsion. We observe a mean free path for K^+-interactions in emulsion of 95 cm (which corresponds to 6 mb per nucleon)[10] as compared to $\sim$25 cm, which is observed in K^--interactions.[8]

Table I gives the angular distribution of the scattering of K^+-mesons in the two energy regions 30 to 75 Mev and 75 to 120 Mev, as well as the separation into elastic and inelastic events. There is some indication of a decrease in the cross section in the high-energy interval.

Figure 1 gives the differential scattering cross section in arbitrary units. It can be seen that from 40° to 180° the differential cross section is isotropic within our statistics. This fact, together with the observed energy dependence, indicates a large S-wave component in the scattering cross section. From 40° down to 20° (our cut-off angle) a steep rise in the differential cross section is observed. The extension of this work to smaller angles and the analysis in terms of Coulomb and coherent scattering is in progress.

The mean free path of 95±16 cm in emulsion and the resulting cross section $\sigma \simeq 6$ mb per nucleon[10] [$\sigma \approx (\sigma_n + \sigma_p)/2$] were obtained by extrapolating the isotropic distribution to 0°, and thus do not include diffraction and Coulomb effects. A contribution due to charge-exchange events was also included. There were four charge-exchange and 36 non-charge-exchange events (extrapolated isotropically to 0°). This proportion of charge-exchange events is consistent with perturbation theory results.[11]

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11 It has been pointed out to us independently by K. A. Brueckner and by A. Pais that our data are understandable in terms of a perturbation theory in which the K^+-nucleon scattering process is described as follows: The nucleon first emits a K-meson to give an intermediate state with two K-mesons and a Σ or Λ^0 particle, the Σ or Λ^0 particle reabsorbs the K-meson to give the final state. This theory predicts for $g^2 \sim \frac{1}{2}$ a cross section of the order of 5 mb. In addition, for a Σ in the intermediate state it gives a ratio of charge exchange to non-charge exchange of 1:5 and for a Λ^0 in the intermediate state, a ratio of 1:1. The potentials for the charge-exchange part are opposite in sign, and a mixture of intermediate states could give a ratio even smaller than 1:5 for the charge-exchange to non-charge-exchange cross sections.