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ELASTIC SCATTERING OF LOW-ENERGY K^- MESONS ON PROTONS

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Following the CERN Conference in 1958[1] there was considerable interest shown in the possibility of a peak at ~30-Mev K^--meson laboratory energy in the elastic scattering cross section of K^- mesons on protons. Matthews and Salam[2] proposed an interpretation of the peak in terms of a $J=1/2$ resonance of the K^--p system. However, Jackson and Wyld[3] pointed out that the peak could also be satisfactorily understood on the basis of S-wave zero-range K^--p scattering theory and a repulsive K^--p nuclear interaction. The resonance proposal has also been discounted by Dalitz and Tuan[4] who pointed out that the effective range of the K^--p interaction would have to be unreasonably large in order to exhibit the observed elastic scattering cross sections at the low-energy values in the region of the so-called resonance.

At the Kiev Conference in 1959, bubble chamber results[5] were presented which no longer exhibited a peak in the low-energy elastic K^--p scattering cross section. However, further emulsion results[6] by the combined Bologna-Munich-Paris-Parma laboratories still tended to show the elastic cross-section flattening off at the lowest energies.

Emulsion data from the European K^- Collaboration groups[7] have now been carefully scrutinized for low-energy K^--proton elastic scattering events. All two-pronged events which could possibly be attributed to K^--p elastic scattering have been analyzed. Low-energy elastic scattering events on free protons can be readily recognized because these only will show coplanarity with complete balance of momentum and energy. Moreover, since the fraction of inelastic scattering events in which the K^- meson re-emerges from emulsion nuclei is known[8] to be only a few percent for energies in the range 30-100 Mev, there is a negligibly small chance of an apparent K^--p scattering occurring on an internal proton of an emulsion nucleus, especially for K^- meson energies below 10 Mev.

The results of our investigations, based on a study of 10 850 K^- mesons coming to rest and 2060 K^- mesons decaying or interacting in flight, are shown in Table I. Our results, which are shown with others of the bubble chamber[5] and emulsion[6] groups in Fig. 1, appear to indicate that the elastic K^--p scattering cross section is

Table I. Summary of low-energy K^--p elastic scattering events.

p (Mev/c)	53		93		133		173		213		253
Number of events		4		6		14		15		17	
Track lengths (cm)		659		1769		3977		6804		10 497	
$\sigma_{el}(K^-$-$p)$ (mb)		187		105		108		68		50	

increasing in the region of lowest K^--meson momentum. Although the statistics are still quite poor, on the basis of our observations, there is only an approximate 10% probability that the K^--p elastic scattering cross-section curve flattens off at momenta lower than 120 Mev/c.

There are possibly two explanations of the observed flattening in the earlier emulsion experiments. One could possibly be that because the track lengths in the lowest energy intervals were so small, different experimental groups probably made energy cutoffs at different values. In our present investigation we have consistently worked down to a K-meson momentum of 53 Mev/c, for which the residual range is 100 microns.

The other possible reason that many low-energy scattering events may not have been recorded is that they were classified as "double stars," i.e., they were regarded as K-meson capture stars and secondary stars resulting from interactions or decays of hyperons or hyperfragments. Photographs of two very low energy K^--p scattering events are shown in Fig. 2.

There is, of course, a third possibility: that the differences are largely statistical.

At the very low K^--meson energies considered in these experiments there may be, in point of fact, a significant contribution to the elastic scattering from the Coulomb field of the proton. The Coulomb effect on the total elastic scattering cross section has already been calculated, for the conditions of our experiment, by Jackson and

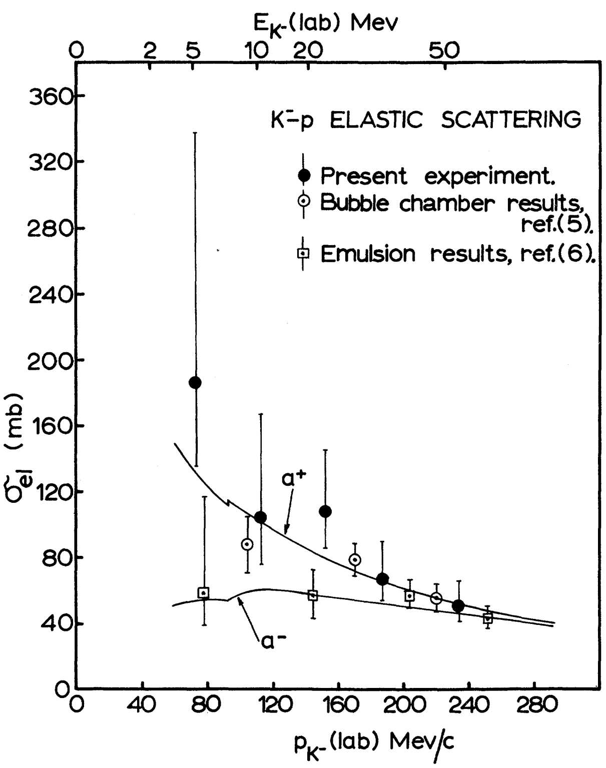

FIG. 1. Total elastic K^--p scattering cross sections versus K^--meson momentum. The curves, which were taken from the theory of Jackson and Wyld,[3] show the σ_{el} variation to be expected from constructive interference a+ and destructive interference a- between the Coulomb and nuclear parts of the K^--p scattering.

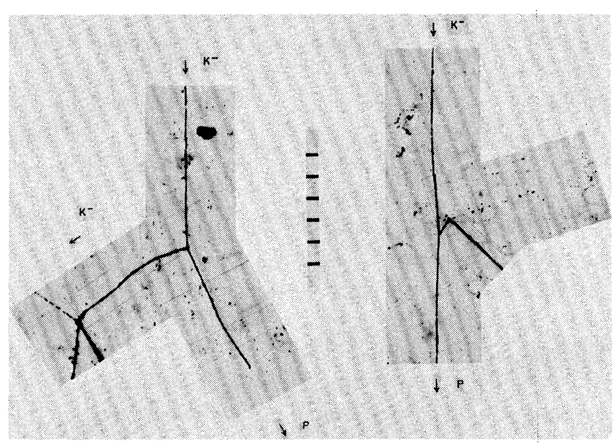

FIG. 2. Two examples of low-energy K^--p elastic scattering events. The energies of the incident K^- mesons are 5.5 and 5.3 Mev. Scale divisions (between photographs) are 10 microns apart.

Wyld.[3] They considered two cases, $a+$ and $a-$, of the nuclear $K^- - p$ scattering phase shifts, and these two curves are shown in Fig. 1. It is seen that our results, as also those of the Berkeley bubble chamber group, suggest the attractive $a+$ set of $K^- - p$ nuclear phase shifts.

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Ξ^- PRODUCTION BY K^- MESONS

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The Berkeley 30-inch propane chamber was operated in a 1.17-Bev/c K^- beam[1] at the Bevatron to produce cascade particles. Out of the 100 000 pictures taken, there have been 18 positively identified negative cascade decays with the decay mode $\Xi^- \rightarrow \Lambda + \pi^-$. Of these, six were produced with a K^+ meson and three were accompanied by a visible θ_1 decay. Three of the events with a K^+ satisfy the kinematics for the hydrogen interaction

$$K^- + p \rightarrow \Xi^- + K^+,$$

and the other three are assumed to have been produced from protons in carbon. Two of the K^+ decayed in the chamber and the other four were identified by comparing momentum and ionization. Since only one-third of the K^0 produced in the interaction

$$K^- + n \rightarrow \Xi^- + K^0$$

decay into a visible mode, it is quite consistent to attribute the nine events in which no positive-strangeness K particle was observed to the neutral mode of the θ_1 decay, to the θ_2 decay, or to a K^+ that could not be distinguished from a proton.

The 18 events were selected from a sample of 47 in which a V particle was thought to come from a prong of a K^- interaction which appeared to decay into a π^-. The selection consisted of a series of two single-origin constraints on an IBM-704 calculator: (a) the Q of the V particle was required to be consistent with that of a Λ, 37 Mev, and its line of flight consistent with the assumed Ξ^- decay origin; (b) the Λ and the π^- were required to be coplanar with the assumed Ξ^- and to balance transverse momentum. Revised estimates of the momentum and angles of the Λ and π^- were obtained from the constraint program, and the average mass of the Ξ^- for the 18 surviving events, weighted by the estimated probable error of each event, was found to be

$$M_{\Xi^-} = 1317.9 \pm 1.9 \text{ Mev}.$$

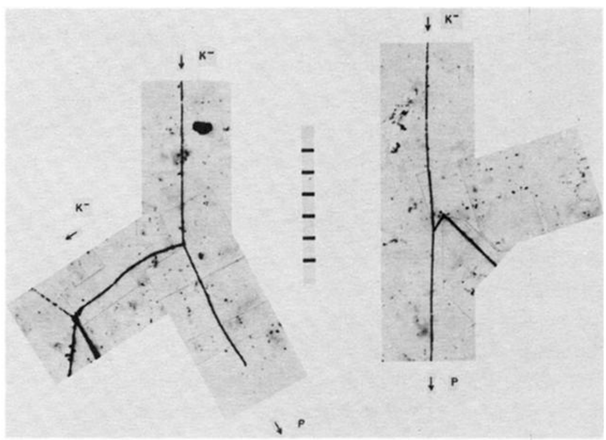

FIG. 2. Two examples of low-energy K^--p elastic scattering events. The energies of the incident K^- mesons are 5.5 and 5.3 Mev. Scale divisions (between photographs) are 10 microns apart.