LOW-MOMENTUM Λ-p ELASTIC SCATTERING CROSS SECTIONS*†

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This note reports on a study of Λ-p elastic scattering, with incident Λ momentum in the interval 120-400 MeV/c. The results are based upon 75 scattering events.

The Λ's were produced in an exposure of the Saclay 81-cm hydrogen bubble chamber at CERN to a beam of stopping K^- mesons. Reactions which produced Λ's in the chamber were

$$K^- + p \to \Lambda + \pi^0; \quad (1a)$$

$$\to \Sigma^0 + \pi^0, \quad \Sigma^0 \to \Lambda + \gamma; \quad (1b)$$

$$\to \Sigma^- + \pi^+, \quad \Sigma^- + p \to \Lambda + n; \quad (2a)$$

$$\to \Sigma^- + \pi^+, \quad \Sigma^- + p \to \Sigma^0 + n, \quad \Sigma^0 \to \Lambda + \gamma. \quad (2b)$$

The (K^-, p) and (Σ^-, p) reactions involved were predominantly at rest. Scanning was done in two views. The charged Λ decay was first located by area scanning and a search was then made for possible origins. If the origin found was a proton recoil, the production point of the Λ was found and the event was measured and processed, using standard bubble chamber techniques. If the origin was a K^- or Σ^- ending, the event was recorded and a search was made for a possible proton recoil. Any scattering candidates found in this manner were also measured and processed. Every event which fit the Λ-p scattering hypothesis is plotted in Fig. 1(a) as a dot or a cross. The coordinates of each event are the incident Λ momentum and the cosine of the Λ scattering angle in the (Λ, p) center of mass.

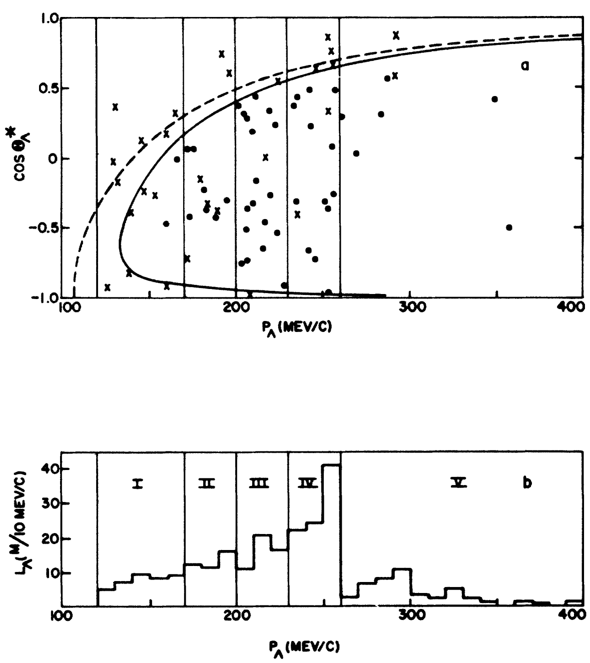

FIG. 1. (a) Scatter plot of incident Λ momentum vs cosine of Λ scattering angle; (b) momentum distribution of Λ path length.

The distribution of Λ path length as a function of incident momentum is shown in Fig. 1(b). It was determined by measuring an unbiased sample of 1000 Λ's and scaling the distribution for those events to reflect the total number of Λ's observed. The total path length in each of five momentum intervals is presented in the third column of Table I.

The scattering cross section in each momentum interval was determined in two ways. Method One took as acceptable events those with proton recoils greater than 2 mm in length. Except for over-all scanning inefficiency, no further losses were assumed. Events satisfying this criterion are all those below the dashed line in Fig. 1(a). Assuming that the scattering is isotropic, the appropriate path-length distribution is the observed distribution times the fraction of solid angle giving rise to acceptable events.

Method Two took as acceptable events those satisfying five criteria. The first four required that the projected lengths of the Λ before and after scatter and of the decay proton be greater than 1 mm and that the projected length of the recoil proton be greater than 2 mm. Events satisfying these criteria were assigned appropriate weights. The fifth criterion, that all events have weight less than 2.0, was then imposed. This restricted the scattering angle to the region bounded by the solid curve in Fig. 1(a). Events satisfying the criteria of Method Two are indicated by dots; those failing any criteria, by crosses. Effective path length was determined as for Method One.

The best estimates of the cross sections in momentum intervals I and II were taken to be the results of Method One. In these intervals, the number of events rejected by the criteria of Method Two indicates that those criteria were far too conservative. For the low-momentum Λ's, the production, scatter, and decay points are in close proximity and the scanner is more sensitive to very short tracks than he is for events which are more spread out. While Method Two

Table I. Summary of data and resulting Λ-p cross sections.

Interval no.	Momentum range (MeV/c)	Λ path length (meters)	No. accepted events	Cross section (mb)	Effective mean momentum (MeV/c)
I	120-170	39	10	130±50	144
II	170-200	40	11	105±34	186
III	200-230	48	18	195±55	216
IV	230-260	87	13	66±22	248
V	260-400	42	6	52±23	291

should still give unbiased results in this region, it reduces the number of acceptable events drastically. The effects of possible scanning losses due to short tracks can be minimized by applying the stricter criteria of Method Two. The results of this method were taken as the best estimates in intervals III, IV, and V. In these intervals the reduction in number of acceptable events was not so severe. In any case, the cross sections as determined by both methods are in good agreement in all five intervals.

The number of acceptable events and the cross section for each interval are presented in the fourth and fifth columns of Table I. The effective mean momenta, in the sixth column of Table I, are the averages, for each interval, of the momentum weighted by the path length and $1/k^2$. The errors quoted with the cross sections reflect the statistical errors on the number of accepted scattering events and an estimated uncertainty of 15% for the product of path length times the ratio of scanning efficiencies for scattered and unscattered Λ's. This ratio was taken to be 1.0.

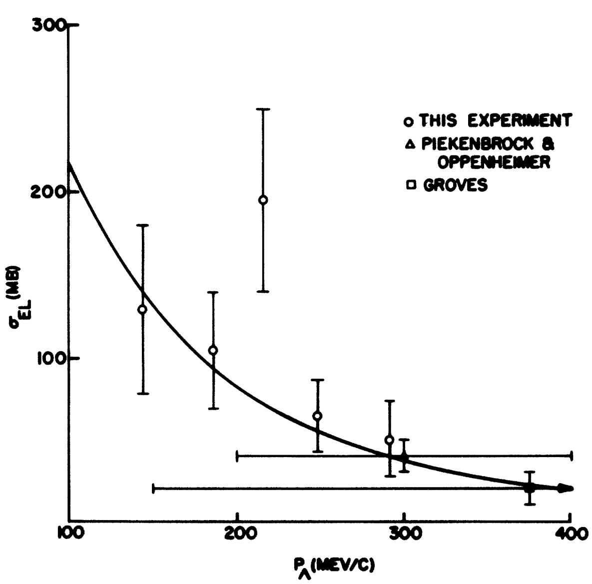

FIG. 2. Λ-p elastic scattering cross sections for Λ momentum between 100 and 400 MeV/c.

Our results, along with those of Groves[1] and Piekenbrock and Oppenheimer,[2] are shown on Fig. 2.

Assuming pure $l=0$ scattering and the effective range approximation, the total (Λ,p) scattering cross section can be written

$$\sigma=\tfrac{3}{4}\sigma_t+\tfrac{1}{4}\sigma_s=\frac{3\pi}{k^2+[1/a_t-\frac{1}{2}r_tk^2]^2}+\frac{\pi}{k^2+[1/a_s-\frac{1}{2}r_sk^2]^2}, \tag{3}$$

where a_t and a_s are the triplet and singlet scattering lengths, and r_t and r_s are the respective effective ranges. The data on Λ binding energies in light hyperfragments, combined with the absence of any experimental indication of (Λ,p) bound states, have been used to deduce approximate values for a_t, a_s, r_t, and r_s. A comprehensive analysis of this subject has been given by de Swart and Dullemond,[3] who derive the following estimates:

$$a_s=-(3.6_{-1.8}^{+3.6})\text{ F},\quad r_s\approx 2\text{ F};$$

and

$$a_t=-(0.53\pm0.12)\text{ F},\quad r_t\approx 5\text{ F}.$$

The solid curve in Fig. 2 is obtained by substituting the central values for a_s and a_t into Eq. (3). The data agree quite well with this curve, indicating the general validity of the theoretical analysis used in deriving these estimates from hyperfragment data. The quoted errors of our (Λ,p) scattering cross sections are too large to yield a significant reduction in the errors assigned to the four parameters a_s, r_s, a_t, and r_t.

There are two other features of the data worthy of comment. The first is the strong forward peaking of the angular distribution of events about 260 MeV/c [see Fig. 1(a)], suggestive of the presence of higher l waves than $l=0$. Such a distribution has been predicted, for this momentum range, by Ram and Downs.[4] The second feature is the large cross section in interval III, $\bar{p}_\Lambda = 216$ MeV/c. No explanation is offered at this time, other than the possibility of a two= standard-deviation fluctuation of the data.

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[1]T. H. Groves, Phys. Rev. 129, 1372 (1963).

[2]L. Piekenbrock and F. Oppenheimer, private communication. The published value of this cross section, Phys. Rev. Letters 12, 625 (1964), has been corrected.

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[4]B. Ram and B. W. Downs, Phys. Rev. 133, B420 (1964).

EXAMPLE OF $K_{\mu 4}$ DECAY IN EMULSION*

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We have accumulated ≈4000 examples of three-prong K^+ decay by scanning emulsion exposed to a stopping K^+ beam from the Bevatron. The direction of each prong was measured with a digitized-coordinate microscope and an IBM-7094 was used to calculate the deviation from coplanarity of the prongs. The events which violated coplanarity were then examined in greater detail.

This process isolated an event which we believe represents the decay mode $K^+ \to \pi^+ + \pi^- + \mu^+ + \nu_\mu$. A projection drawing of it is shown in Fig. 1. The K^+ decayed at rest as well as could be determined. Each prong was traced to its stopping point, and all follow-throughs were verified by an independent observer. The range of each prong was measured with our digitized-coordinate microscope, and the associated energies and momenta were computed from the range-energy relation with an IBM-7094. The program used includes the correction of ranges to standard emulsion density.

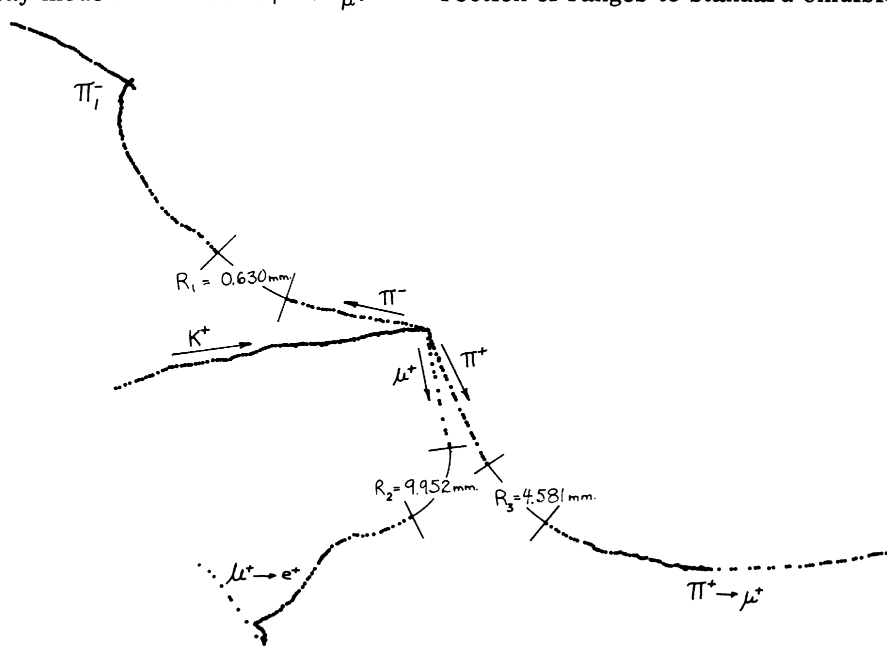

FIG. 1. Projection drawing of $K_{\mu 4}$ event.