THE INTERACTIONS OF FREE HYPERONS

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The short lifetimes of the hyperons make it exceedingly difficult to accumulate data on scattering processes. It is well known that almost all our knowledge of hyperon-nucleon forces comes instead from studies of hyperfragments. In fact, I suspect the only reason I have been asked to give this short talk is to give delegates a sense of well-being at the start of the conference.

The following describes the experimental situation.

1. Λ interactions

Table 1

Reaction	No. of events	Cross-section for momentum range 400 to 1500 MeV/c	References
(A) $\Lambda^0 + p \to \Lambda^0 + p$	69	27 ± 5 mb	1), 2), 3), 4)
(B) $\Lambda^0 + p \to \Sigma^0 + p$	3	8.5 ± 4.9 mb	2)
(C) $\Lambda^0 + p \to \Sigma^+ + n$	2	30 ± 20 mb	1)

The cross-section for reaction (A) applies to scattering through angles greater than about 20° in the c.m.s. Within the wide limits allowed by the poor statistics, no change in the cross-section with energy has been detected.

The 72" hydrogen chamber group at Berkeley expect to publish the remaining two-thirds of their data for reaction (A) in the next few months, and have still to report on reaction (C).

The 80 cm hydrogen chamber of the Ecole Polytechnique was recently exposed to 10^6 stopped K^- mesons, and work is to start soon on scanning for Λ-particle interactions. Data from this film will be especially valuable as the momenta of the Λ particles will be small, about 200 MeV/c, and will more readily allow a comparison with theory.

The angular distribution for elastic scattering is almost isotropic, the forward-backward ratio being 27 : 34.

Σ interactions

i) In flight

Table 2

Reaction	No. of events	Cross-sections for momentum ranges: 300 to 1500 MeV/c	< 200 MeV/c	References
(D) $\Sigma^+ + p \rightarrow \Sigma^+ + p$	12	$38\ ^{+18}_{-14}$ mb	-	5), 6), 7)
(E) $\Sigma^- + p \rightarrow \Sigma^- + p$	8	$10\ ^{+6}_{-4}$ mb	-	5), 8)
(F) $\Sigma^- + p \rightarrow \Sigma^0 + n$ (G) $\Sigma^- + p \rightarrow \Lambda^0 + n$	5	-	170 ± 80 mb	8)

The angular distributions give forward to backward ratios of 5 : 7 and 8 : 0 for reactions (D) and (E), respectively.

Thirteen examples of Σ scatterings on complex nuclei have been observed in nuclear emulsion[9]. Based on a study of the other prongs emitted with the Σ particle in eight of these events, reactions (D) and (E) are found to have cross-sections in the ratio of 6 : 2.

ii) At rest

Σ^- hyperons at rest interact through reactions (F) and (G). The following ratio has been observed for Σ^- particles stopped in hydrogen[10]

$$\frac{\Sigma^0}{\Sigma^0 + \Lambda^0} = 0.33 \pm 0.05 \ .$$

In deuterium the ratio is[11]

$$\frac{\Sigma^0}{\Sigma^0 + \Lambda^0} = 0.037 \pm 0.022 \ .$$

The lack of reliable guidance from experiment has necessarily made theoretical work rather speculative.

One may begin from the standpoint of the Doublet Approximation[12] which groups the Λ and Σ particles into two doublets:

$$N_2 = \begin{pmatrix} \Sigma^+ \\ (\Lambda^0 - \Sigma^0/\sqrt{2} \end{pmatrix} \qquad N_3 = \begin{pmatrix} (\Lambda^0 + \Sigma^0)/\sqrt{2} \\ \Sigma^- \end{pmatrix} .$$

Assuming that N_2 and N_3 are couplied with the same strength to the pion field, one may immediately relate the ΛN and ΣN cross-sections. In particular,

$$2[\sigma(A) + \sigma(B)] = [\sigma(D) + \sigma\ (E)] \ ,$$

where $\sigma(A)$ refers to the elastic cross-section for Λ energies above the threshold for Σ^0 production. Experimentally, the values of the left- and right-hand sides of the equation are found to be (57 ± 18) mb and (48 ± 17) mb, respectively.

The Global Symmetry hypothesis[13] is more restrictive, requiring the coupling of N_2 and N_3 to be the same as that of the nucleon doublet N_1. One may now relate the ΛN and ΣN cross-sections to the

NN cross-sections. At first sight this would appear to offer definitive predictions for hyperon scattering as the NN scattering data can be accurately reproduced by various potential models. However, the hyperons are unaffected by the Pauli exclusion principle and so can explore regions of the potential that play only minor roles in p-p scattering, and are consequently not well understood.

de Swart and Dullemond[14]) find cross-sections of about 30 mb for reaction (A), 50 mb for (D), and 33 mb for (E) at momenta of about 600 MeV/c. They require a forward/backward ratio for reaction (A) of 1.5 : 1, which is not in very good agreement with experiment. They successfully reproduce the strong forward peaking observed for (E), but then also require a 2 : 1 forward peaking for reaction (D) which is not indicated by the present data. Ferrari and Fonda[15]), on the other hand, show that if instead of using a Signell-Marshall potential, one adopts the Gammel-Thaler potential, an essentially isotropic distribution is obtained for the latter reaction.

Global symmetry predicts that the ratio $\Sigma^0/(\Sigma^0 + \Lambda^0)$ for Σ^- interactions at rest in hydrogen should have a value of 0.40[14]). The low value found for the ratio in deuterium can be explained in terms of there being only a small energy release, about 0.9 MeV, in the process producing the Σ^0 [16]).

An alternative approach is that of Kovacs and Lichtenberg[17]) who calculate cross-sections for reaction (A) from potentials derived from the binding energies of hyperfragments. The difficulty here is that spin-orbit terms, while having little effect on the binding energies, may be quite important in scattering processes. Cross-sections of 32 mb and 21 mb are obtained with and without spin-orbit corrections.

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II. NUCLEAR EMULSION STUDIES