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We have exposed a large stack of Ilford K.5 emulsion to the 1.15-Bev/c separated K^- beam developed by Good and Ticho.[1] By area scanning we have located some 600 interactions with emulsion nuclei. This report deals with two groups of data: (A) An unbiased sample of 102 interactions, and (B) A selected group of interactions which produced more than one prong near the minimum of ionization or which gave evidence of strange-particle production in the plate in which the event was located.

The results of this study are as follows:

(a) clear evidence for the reactions $K^- + N \rightarrow \pi + \pi + Y$ and $K^- + N \rightarrow K^- + N + \pi + \pi$,

(b) evidence for the reaction $K^- + N + N \rightarrow Y + Y + K^0$ or $K^- + N \rightarrow \Xi^- + K^0$ followed by $\Xi^- + N \rightarrow Y + Y$,

(c) a possible case of a "cascade hyperfragment", that is, one which contains two units of negative strangeness,

(d) no cascade particle or K^+ meson was definitely identified.

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[1] Alvarez, Eberhard, Good, Graziano, Ticho, and Wojcicki, Phys. Rev. Lett. 2, 215 (1959).

A. The Analysis of an Unbiased Sample of 102 Stars

The interactions studied in this portion of our analysis include all of the events located in a single pellicle. Based upon the relative populations of K:π:μ in the beam as estimated by Alvarez et al.,[1] we estimate that 93% of these stars were produced by K^- mesons.

In Table I we summarize the salient features of this analysis.

Table I

Summary of analysis of 102 stars

K^-	Prong Distribution		Distribution of reaction products							
Bev/c	Mean	Mode	HF	$\Sigma^{\pm}$	2π	1π	$\pi^{\pm}$	$K^-_{inelastic}$	Stable	π^+/π^-
1.15	6.5	5	7	25	7	35	49	3	584	9/19

All the particles produced in these interactions were followed until they came to rest (594), or interacted, decayed, or left the emulsion stack, (74). In only a few cases were the tracks not suitably oriented for analysis.

It is recognized that area scanning could bias our prong distribution toward large stars. The observed distribution extended to 15 prongs (1 event) and reached a maximum at 5 prongs (17 events). Only 3 stars of 2 prongs were found, which leads us to believe that 0- and 1-prong stars are probably rare. The shape of the distribution implies that the scanning bias may be slight.

Of the 7 hyperfragments, four have sufficient range ($>10\mu$) to be clearly separated from the K^- star; the others have ranges less than 2μ. Six are nonmesonic decays, but one of the very short hyperfragments is a possible mesonic decay. All of the hyperfragments observed are produced in stars with eight or more prongs, and of the four largest stars (12 to 15 prongs), three give rise to hyperfragments.

The energy distribution of the charged Σ hyperons is shown in Fig. 1. A total of 25 prongs were identified as Σ particles by their subsequent decay in flight or by their interaction, either in flight or at rest. There was no clear case of a decay at rest. We have not as yet followed the secondaries from the Σ decays in flight, and thus no reliable estimate of the Σ^+/Σ^- ratio can be given. No estimates have been made of the number of Σ hyperons missed among 0-prong Σ^- interactions at rest nor among Σ^+ decays in flight via $\Sigma^+ \rightarrow p + \pi^0$, which may have been interpreted as small-angle proton scatters.

Combining the numbers of hyperfragments and charged Σ hyperons, we find that about one-third of the stars yield visible negative strangeness.

We have observed seven interactions that lead to double-pion emission. In this sample of stars, no event was found in which both pions came to rest. However, one of the pair came to rest in six cases, and in all cases the accompanying pions were clearly identified by differential grain counting. A charged Σ hyperon was also produced in two examples exhibiting double-pion emission.

There were 35 events in which a single charged pion was emitted; of these, 13 were accompanied by a charged hyperon.

A total of 19 π^- and 9 π^+ mesons emitted from stars came to rest in the emulsion. Figure 2 presents the energy distribution of all the emitted pions. The general form of the distribution is a broad peak of the energies between 10 and 70 Mev, with a high-energy tail extending to about 700 Mev. The low-energy portion of the distribution can be attributed to the effects of multiple collisions of the pions within the nucleus before emission and to the general reduction of energy due to multiple pion production.

Three cases of K^- re-emission were observed. In each instance the kinetic energy was greater than 250 Mev, and none of these K mesons came to rest. The high energy of the K particles together with the fact that there was no evidence for associated production makes it unlikely that any of these particles were K^+ mesons.

B. The Analysis of Selected Events

From those events selected according to criteria for Group (B) as described above, we have chosen 52 events which actually produced evidence of strange-particle production for this section. None of the events which comprise Group A are included in this analysis. The reasons for employing these criteria for the selection of events were to search more effectively for cascade particles, or evidence for them, and to place upon a firmer basis the reactions (a) and (b) that were observed or indicated in Group A.

The results of these analyses are summarized in Table II.

Table II

Summary of data on selected stars from which strange particles emerge

Type	H.F., 0π	H.F., 1π	H.F., 2π	Σ, 0π	Σ, 1π	Σ, 2π	K^-, 0π	K^-, 1π	K^-, 2π	2Σ	2H.F.	Cascade H.F.
Number	11	6	0	11	7	6	1	3	1	4	1	1
Average stable prongs	6.4	6.9	-	4.9	3.3	3.2	4	2.0	2	3.75	3	6

Double-pion production [reaction (1)] was observed in 7 stars. In three of these, both pions were brought to rest. Two negative pions stopped in two of these cases ($\Sigma^+ + 2\pi^-$), and pions of opposite charge stopped in the other ($\Sigma^- + \pi^- + \pi^+$). The pions were associated with Σ hyperons ($3\Sigma^+$, $2\Sigma^-$, $1\Sigma^{\pm}$) in six events and with a re-emitted K^- in one event. No event in which three or more charged pions were emitted was detected.

Five events were found that indicated production of two hyperons. Only one case was definite. In this case two prongs were hyperfragments, one undergoing mesonic decay and the other forming a two-prong star. In the less-well-defined events, all of the interactions emitted one Σ hyperon that was identified by its decay. In each instance, however, an additional prong interacted, either in flight or at rest, in such a manner as to strongly indicate that it was a Σ particle.

Only one K^- interaction displayed the necessary features for the emission of a cascade hyperfragment. (The absorption of a cascade particle in a nucleus is expected to yield two lambda hyperons of relatively low energy.) The event appears as a triple-centered star. The prongs are but several microns long and their identification was not possible. Although this event fits the criteria for a cascade hyperfragment as described above, an equally valid interpretation would be the formation of a hyperfragment by a slow Σ^- hyperon.

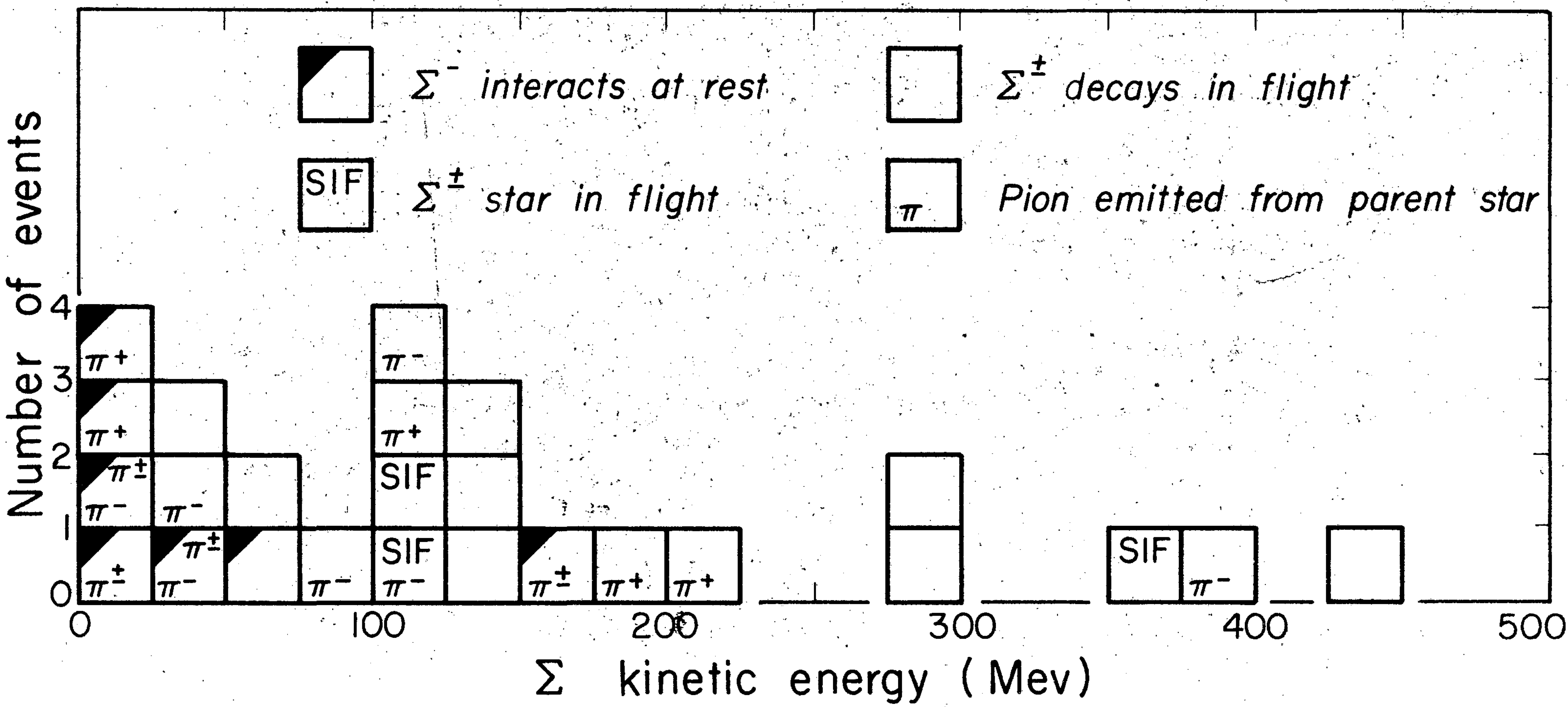
Inelastically scattered K^- mesons accompanied by 0, 1, and 2 pions were seen. The K^- particles were identified by their characteristic interactions (4 at rest, 1 in flight). The energy distribution of the re-emitted K^- mesons varied from 6 to 270 Mev. Despite the bias of our selection criteria, it appears significant that pions are so frequently produced in association with inelastic scattering. It also accounts for the broad energy spectrum of the scattered K^- mesons, which otherwise could only be understood by assumption of multiple collisions within the nucleus.

We wish to acknowlddge the assistance afforded us during the emulsion exposure by Dr. Myron Good and Professor Harold K. Ticho. Our group of scanning technicians must be given recognition for their rapid and highly efficient work that contributed much to this study.

FIGURE LEGENDS

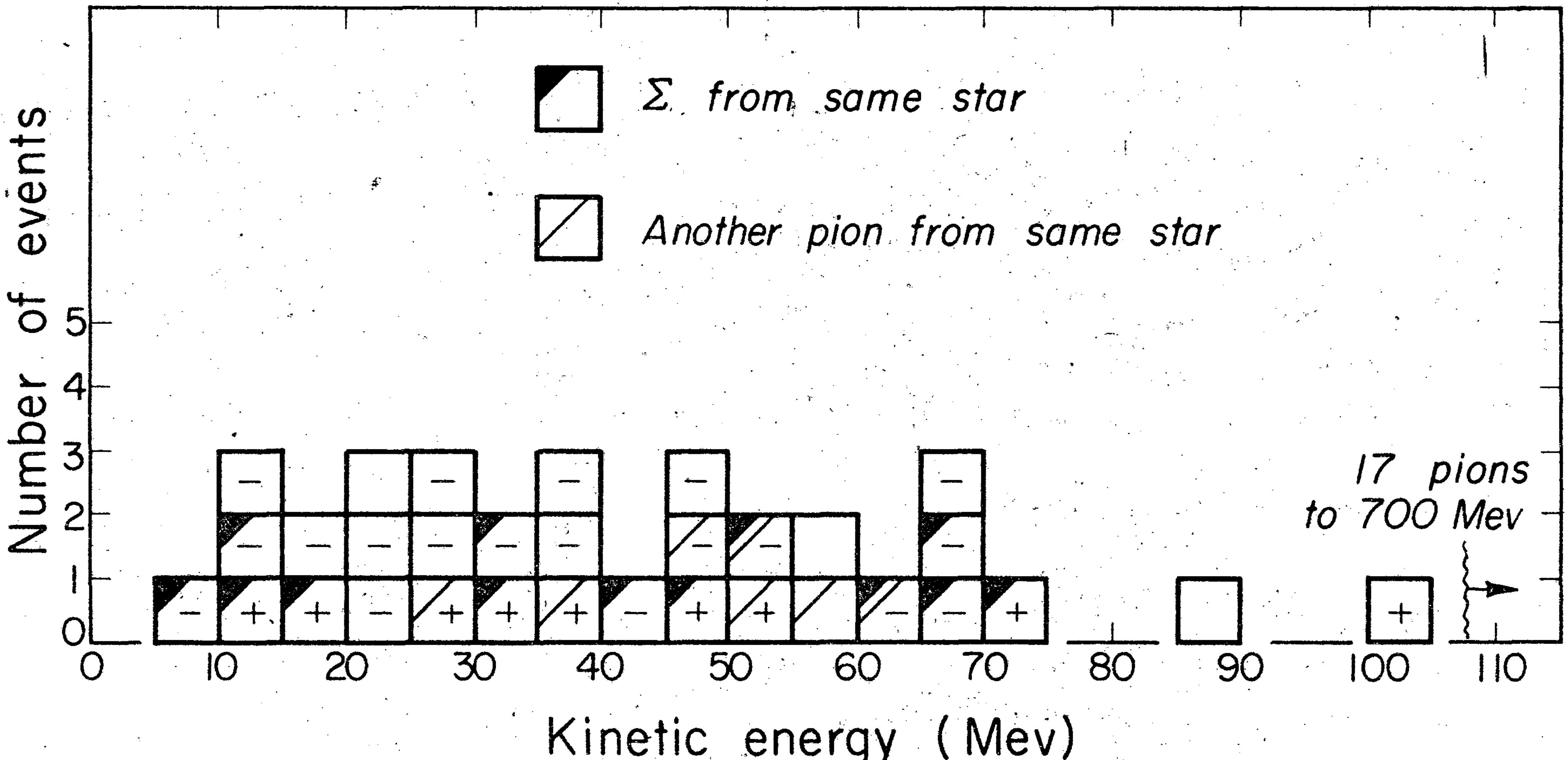
Fig. 1. Observed energy distribution of the charged Σ hyperons based upon an unbiased sample of 102 interactions.

Fig. 2. Observed distribution of kinetic energies for the emitted charged pions. Charge is assigned for pions that came to rest in emulsion.



Σ^- interacts at rest
$\Sigma^\pm$ decays in flight
SIF
$\Sigma^\pm$ star in flight
π
Pion emitted from parent star
Number of events
0
1
2
3
4
π^+
π^+
$\pi^\pm$
π^-
π^-
$\pi^\pm$
$\pi^\pm$
π^-
π^-
π^-
π^+
SIF
SIF
π^-
$\pi^\pm$
π^+
π^+
SIF
π^-
0
100
200
300
400
500
Σ kinetic energy (Mev)

55425-1


Σ from same star
Another pion from same star
Number of events
0
1
2
3
4
5
17 pions
to 700 Mev
0
10
20
30
40
50
60
70
80
90
100
110
Kinetic energy (Mev)

55424-1