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Emission of Li^8 Fragments in the Interactions of 3.0-GeV/c K^- Mesons with Nuclei in Nuclear Emulsion

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The experimental results of the emission of hammer tracks (^{8,9}Li, ^{8}B nuclei) from 3-GeV/c K^--meson interactions are compared with the theory of nuclear evaporation. The results are only in partial agreement with this theory. The production rate increases with incident energy from 0.8 up to 3 GeV/c. The forward-to-backward ratios decrease when the energy of the incident particle rises.

THE investigation of the fragmentation and hyperfragmentation processes in interactions of K^- mesons with complex nuclei[1–4] was extended to a higher energy of the incoming particles to study the influence of primary energy on these mechanisms.

(a)

(b)

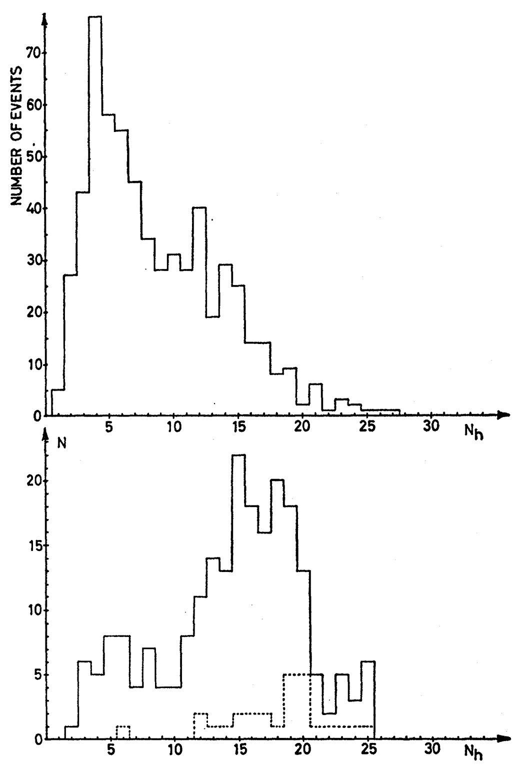

FIG. 1. Distribution of N_h, the number of black plus grey prongs, of (a) a random sample of 606 beam stars without hammer-track emission found at Hamburg, and (b) 221 beam stars with hammer-track emission. The dotted line represents hammer tracks with an energy $E > 40$ MeV.

Two stacks of Ilford $K5$ emulsion [100 pellicles of size (15×30) cm^2×600 μ and 90 pellicles of size (12×20) cm^2×600 μ] were exposed separately to a separated beam of 3.0-GeV/c K^- mesons at CERN. The beam contained about 12% of pion and muon contamination.

The characteristics of 200 stars produced by 3-GeV/c K^- mesons interacting with emulsion nuclei without emission of a hammer track or a hyperfragment are given in Table I, where $\bar{N}_s$, $\bar{N}_g$, and $\bar{N}_b$ are, respectively, the average number of shower tracks (specific ionization $I^* = I/I_{\min} < 1.4$), grey tracks ($1.4 < I^* < 10$), and black tracks ($I^* > 10$) with $\bar{N}_h = \bar{N}_g + \bar{N}_b$ and R representing the range.

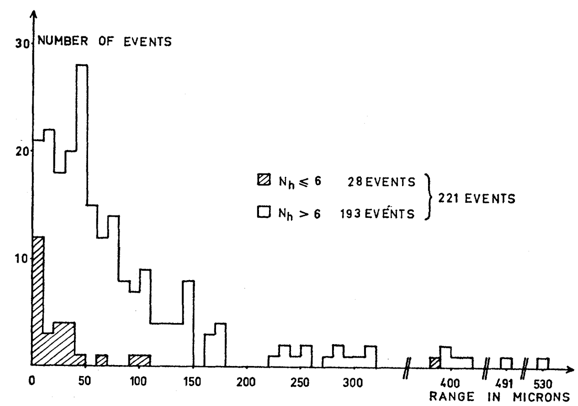

FIG. 2. Range distribution of hammer tracks. Hatching indicates hammer tracks from stars with $N_h \leq 6$.

In an area scan we found 23 000 primary interactions of beam particles giving rise to the emission of 221 hammer tracks (HT). 170 HT were found at Strasbourg, 51 at Hamburg. The details are given in Table II. Three stars show the simultaneous emission of two HT.

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[4] W. Gajewski, J. Suchorzewska, M. F. Votruba, and J. Zakrzewski, Phys. Letters **11**, 177 (1964).

TABLE I. Characteristics of interaction stars without hammer-track or hyperfragment emission.

	Total	Forward	Backward	Forward/Backward
$\bar{N}_s$	1.4±0.2	1.2±0.2	0.2±0.1	5.5±0.1
$\bar{N}_g$	3.3±0.2	2.1±0.2	1.2±0.2	1.8±0.1
$\bar{N}_b$ total	6.1±0.3	3.3±0.3	2.9±0.3	1.1±0.1
$\bar{N}_b$ without δ rays	5.6±0.3	3.0±0.3	2.6±0.3	1.1±0.3
$\bar{N}_b$, $R\geqslant 5\,\mu$	5.7±0.3	3.1±0.3	2.7±0.3	1.2±0.3
Recoil, $R<5\,\mu$	0.4±0.1	0.2±0.1	0.2±0.1	1.3±0.2
$\bar{N}_h$	9.4±0.3	5.4±0.4	4.0±0.4	1.4±0.2
$\dfrac{\bar{N}_h \text{ with } \delta \text{ rays}}{\bar{N}_b \text{ without } \delta \text{ rays}}$	0.030±0.004	0.030±0.005	0.020±0.005	1.5±0.2

The characteristics of stars produced by interactions of 3-GeV/c K^- mesons with emission of a hammer track are given in Table III.

We can see that the two types of interactions give the same number of shower particles, but that the number of grey prongs is higher in the interactions with emission of a hammer track. In the latter type of stars, the nuclear cascade is more strongly developed.

The number of black prongs is also higher in the stars containing a hammer track, corresponding therefore on the average to a higher energy transfer to the nucleus in this latter type of interaction.

The forward/backward ratios F/B do not depend on the presence or absence of a hammer track.

The distributions of N_h, the sum of the numbers of black and grey prongs, for stars without and with HT are shown in Fig. 1. More than 87% of all HT are emitted from stars with $N_h>6$, whereas only 56% of the beam stars without HT have $N_h>6$. This also means that in stars emitting HT the energy transfer to the target nucleus is, on average, larger than in stars that do not emit HT. This phenomenon, which also holds for the emission of hyperfragments (see table on p. 269 of Ref. 5), is in agreement with previous observations.[2–4,6–8]

TABLE II. Production characteristics of hammer tracks.

	No. of HT	No. of HT $N_h\leqslant 6$	No. of HT $N_h>6$	No. of beam stars	No. of stars $N_h>6$	Production rate for $N_h>6$ (uncorrected)
Strasbourg	170	22	148	16 900	11 500	(1.29±0.16)%
Hamburg	51	6	45	6100	3400	(1.32±0.22)%
Total	221	28	193	23 000	14 900	(1.31±0.13)%

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The only significant corrections to be applied to the HT production rate given in Table I are[2]:

(a) the loss of HT passing to neighboring emulsion pellicles. Evaluation of the measured-range spectrum gives a correction factor 1.125;

(b) the loss of HT with inconveniently oriented α tracks. We have not determined this factor, but it is known to be ≈ 1.4.[6] With these correction factors we found a lower limit of the production rate of HT by 3.0-GeV/c K^- mesons interacting with heavy nuclei of $(2.06\pm 0.21)\%$. A comparison with other measurements is given in Table IV. It appears that the production rate increases with increasing incident energy.

The range distribution of HT, given in Fig. 2, shows that nearly all energetic fragments are emitted from stars with $N_h>6$.

The energy distribution of HT from stars with

TABLE III. Characteristics of interaction stars with hammer-track emission.

	Total	Forward	Backward	Forward/Backward
$\bar{N}_s$	1.1±0.2	0.9±0.2	0.20±0.1	4.6±0.2
$\bar{N}_g$	4.2±0.1	2.8±0.2	1.4 ±0.2	4.2±0.1
$\bar{N}_b$ without δ rays	9.3±0.2	5.3±0.2	4.1 ±0.2	1.3±0.2
$\bar{N}_b$ with δ rays	0.5±0.1	0.4±0.1	0.2 ±0.1	2.2±0.2
$\bar{N}_b$ total	10.2±0.2	5.8±0.2	4.4 ±0.2	1.3±0.2
$\bar{N}$ recoil	0.4±0.1	0.3±0.1	0.2 ±0.1	1.6±0.2
$\bar{N}_h$	14.4±0.2	8.6±0.2	5.8 ±0.2	1.5±0.2
$\dfrac{\bar{N}_b \text{ with } \delta \text{ rays}}{\bar{N}_b \text{ without } \delta \text{ rays}}$	0.05	0.06	0.04	

TABLE IV. The emission frequencies of hammer tracks.

Momentum of K	Type of events	Production rate (%)	Reference
800 MeV/c	–	0.20±0.05	1
1.3 GeV/c	$N_h>8$	1.27±0.20	3, 4
1.5 GeV/c	$N_h>8$	1.21±0.18	3, 4
1.5 GeV/c	$N_h>6$	0.98±0.10[a]	2
3.0 GeV/c	$N_h>6$	2.06±0.21	this work

[a] The error given in Ref. 2 was somewhat too low.

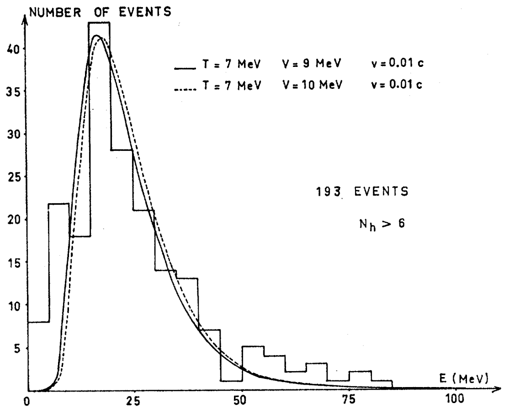

FIG. 3. Energy distribution of hammer tracks from stars with $N_h>6$. T = mean temperature of the evaporating nucleus; V = average height of the effective potential barrier; v = velocity of the evaporating nucleus.

$N_h>6$ is shown in Fig. 3 and compared with theoretical curves which were calculated according to the formula of Skjeggstad and Sørensen[9] assuming an unique temperature of the evaporating nucleus. The deviation of the experimental distribution from the theoretical curve for emission energies higher than 50 MeV and lower than 10 MeV, which was also observed by other authors (see Ref. 10), shows that this simple model of nuclear evaporation does not explain the whole process of fragment emission.

From the angular distribution of the HT relative to the direction of the incoming particle in the laboratory system (Fig. 4), we evaluated the forward/backward ratio F/B for fragments emitted from stars with $N_h>6$, separately for the HT with an energy $E>40$ MeV and for those having an energy $E\leqslant 40$ MeV. In the case of the HT having an energy $E\leqslant 40$ MeV the distribution is isotropic, whereas the HT with the energy $E>40$ MeV have a preferential forward emission (Table V). Whereas the isotropic distribution of the former can be explained by nuclear evaporation, for the latter we have to suppose the existence of a supplementary mechanism.

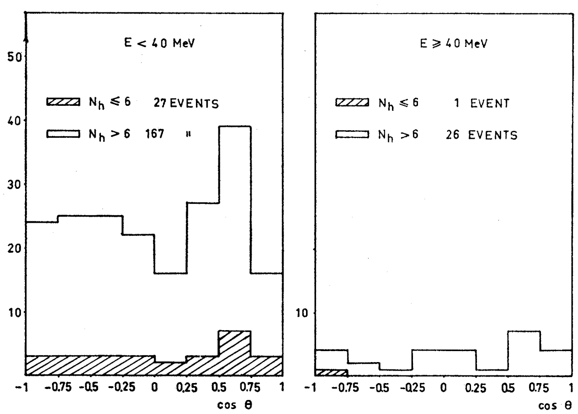

FIG. 4. Angular distribution of hammer tracks for HT with energy $E>40$ MeV, and for HT with energy $E\leqslant 40$ MeV.

TABLE V. Forward/backward ratios F/B.

	F/B	
	K^-, 3.0 GeV/c	K^-, 1.5 GeV/c
$\leqslant 40$ MeV	0.99 ± 0.15	1.70 ± 0.28
>40 MeV	1.60 ± 0.65	$4.8\ \pm2.4$

If we compare these results to those obtained for K^- mesons of 1.5 GeV/c, we find that there is a remarkable decrease of F/B ratios when the energy of the incident particles rises, especially for emission energies greater than 40 MeV.

The same results have been obtained for the interactions of high-energy protons and pions.[8]

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