show several points obtained by other workers.[6,7]

In conclusion we should like to express our deep gratitude to A. I. Alikhanian, who made the present research possible at Alagez, and to A. D. Maiorov for his help in carrying out the experiments.

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Investigation of σ-Stars Induced by Negative π-Mesons

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The properties of σ-stars produced by π^--mesons stopping in an emulsion chamber were investigated. Data obtained from the analysis of 938 σ-stars were used to determine the distribution of the number of prongs as well as the energy distribution of secondary particles. The obtained energy spectrum is compared to the data on σ-stars produced by K^--mesons.

1. THE properties of σ-stars, produced by π^--mesons stopping in emulsion, were investigated by Menon, Muirhead and Rochat[1]. In particular, data were given on the energy distribution of the secondary particles formed in the interaction. This information is of considerable interest for the sake of elucidating of the capture process of π^--mesons by nuclei, and for comparison with σ-stars produced by other unstable particles, for instance, the K^--mesons. This is especially true for secondary particles of energy higher than 30 mev.

The experimental data, however, are grossly inaccurate in this energy region. This is due to the fact that the particles under consideration have a very long range, and therefore cannot come to a stop in relatively thin single emulsion layers used by the authors of Ref. 1. The energy could therefore have been determined only by ionization measurement or, in a few cases, by multiple scattering, procedures which are connected with large errors.

In order to avoid this limitation, the σ-stars were investigated in the present work by means of an emulsion chamber, consisting of a large number of stripped emulsion layers. An appreciable part of the secondary particles came to a stop within the chamber, which made it possible to determine their energy simply from the value of their ionization range. The emulsion chamber used consisted of 126 type P emulsion layers, each 450μ thick. The layers had the shape of a circle 10 cm in diameter. The chamber was exposed in the stratosphere for 7 hours.

For every disk, the central part only, 4 cm in diameter, was scanned at a low magnification. Since the range of the investigated secondary particles is not larger than 3 cm, the particles of even highest energy could leave the chamber through its top or bottom surface only, which permitted a simple calculation of the geometrical corrections. In fact, these corrections were necessary only for the case these corrections were necessary only for the case of protons with energy greater than 60 mev and even in this case were very small. The cases of light negative mesons coming to a stop were noted in scanning and the cases possessing at least one heavy charged secondary were selected. In this way, the cases of π^-- and μ^--mesons were practically separated. Furthermore, the inherent length of each track was determined, the track being followed from one emulsion to another if necessary, up to the end point of the trajectory.

The secondary particles were not positively identified, and therefore the energy of each was determined conditionally from its range under the assumption that the particle was a proton. In the energy region of interest, this assumption does not lead to serious errors, since in this region the secondary particles are, in fact, mainly protons.

Those σ-stars, from the center of which tracks of slow electrons emerged, were especially noted in scanning. Such electrons are connected with the mesic atom stage of the negative pion capture and are as a rule formed in π^--meson capture by the heavy (Ag and Br) emulsion nuclei. Very slow electrons have such a small range that their tracks appear as blobs consisting of several adjoining grains. Such events were ascribed to slow electrons and the corresponding σ-stars were assumed to represent the disintegration of the Ag and Br nuclei.

A minor part of the σ-stars with slow electrons and blobs can, in fact, be due to the random overlapping of grains. Some 103 cases of the π-μ-decay of positive pions were selected to estimate the real contribution of this background effect. In nine of them, slow electrons and blobs, which seemed to be connected with the points of stopping of pions, were observed. Corresponding corrections were introduced in all the succeeding data.

2. The distribution of the prong number, obtained from the analysis of 983 σ-stars, is given in Table I. The results are in good agreement with those of Ref. 1.

Analogous distributions for stars with and without slow electrons and blobs are given in Tables II and III, respectively. The comparison shows that, during the capture of π^--mesons by heavy nuclei, σ-stars with a small number of prongs are more frequently produced. This result is also in accord with the data of Ref. 1.

TABLE I. Prong number distribution of σ-stars. Mean number of prongs 2.06 ± 0.03.

Number of prongs	1	2	3	4	5	6	Total
Number of stars. .	395	262	213	95	16	2	983
%	40.1 ± 2.0	26.7 ± 1.6	21.7 ± 1.3	9.7 ± 1.0	1.6 ± 0.4	0.2 ± 0.2	100

TABLE II. σ-Stars without slow electrons and blobs. Mean number of prongs 2.63 ± 0.05.

Number of prongs	1	2	3	4	5	6	Total
Number of stars. .	82	102	137	76	16	2	415
%	19.3 ± 3.8	24.6 ± 4.0	33.0 ± 4.5	18.3 ± 3.7	3.8 ± 1.8	0.5 ± 0.5	100

TABLE III. σ-Stars with slow electrons and blobs. Mean number of prongs 1.65 ± 0.03.

Number of prongs	1	2	3	4	5	6	Total
Number of stars. .	313	160	76	19	0	0	568
%	55.1 ± 4.1	28.2 ± 3.7	13.4 ± 2.8	3.3 ± 1.5	0	0	100

We shall now pass on to the discussion of energy relations. Data on the number of secondary particles of various energies, for stars with different number of prongs, are given in Tables IV and V. It should be noted that, since the energy of secondary particles was determined from the range under the assumption that all the particles were protons, the data in the low energy region represent the range spectrum rather than the energy spectrum. Table IV pertains to 356 stars possessing slow electrons and blobs, and Table V to 622 stars not having any. The number of the σ-stars with secondary particles of energies greater than 30 mev amounts to 20.1 ± 1.3%*, which differs appreciably from the value 11.9 ± 1.4% given in Ref. 1. The difference is probably due to the fact that, in the present work, the energy of the secondary particles was determined from their range under the assumption that all of them were protons, while in Ref. 1 the particle energy was determined basically from the ionization.

TABLE IV. Energy spectrum of secondary particles produced in heavy emulsion nuclei disintegrations.

Energy region, mev	Number of prongs in star					
	1	2	3	4	5	6
	Number of secondary particles					
0—5	51	125	141	49	—	—
5—10	84	90	45	10	—	—
10—15	45	25	14	7	—	—
15—20	27	22	6	2	—	—
20—25	20	13	6	2	—	—
25—30	21	7	6	—	—	—
30—35	11	14	5	1	—	—
35—40	12	8	2	2	—	—
40—45	12	4	1	1	—	—
45—50	9	7	—	—	—	—
50—55	9	—	—	—	—	—
55—60	5	—	—	—	—	—
60—65	2	1	—	1	—	—
65—70	2	1	—	—	—	—
70—75	1	—	—	—	—	—
75—80	—	—	—	—	—	—
80—85	1	—	—	—	—	—
85—90	1	—	—	—	—	—
90—95	—	—	—	—	—	—

It is interesting to note that the proportion of stars with secondary particles with $E \geq 30$ mev is almost the same for both heavy and light nuclei. For the σ-stars with slow electrons and blobs, their share amounts to 20.5 ± 1.8%, while for the other stars, it equals 19.5 ± 1.8%. An analogous statement can be made with respect to the energy distribution of secondary particles in the energy region represented in the histograms 1, 2 and 3. Figure 1 pertains to the case of the σ-stars with slow electrons and blobs, Fig. 2 to the σ-stars without them, and Fig. 3 to all σ-stars. The histograms all have a similar shape. The mean energy values, calculated for particles with $E \geq 30$ mev are, correspondingly, almost identical.

It is interesting to compare the obtained energy spectrum with the data on the σ-stars produced by K^--mesons. It is thought at present[2,3] that, during the nuclear capture of a stopping K^--meson, a fast pion and a hyperon are created. The latter remains mostly within the nucleus in a bound state and finally transforms into a Λ^0-particle. The possibility that the Λ^0-particle is created in the primary reaction is also not excluded. The relatively slow pion, produced in the decay of the Λ^0-particle, is kept in the nucleus and creates a star similar to the σ-stars produced by pions. If the fast pion produced in the first stage of the process transfers its energy to the nucleus, then the star will be of considerably higher energy than a pion produced σ-star. In this way, σ-stars produced by K^--mesons will, on the average, possess secondary particles of higher energy, and also with

* We recall that only σ-stars with at least one charged secondary were considered.

TABLE V. Energy spectrum of secondary particles produced in light emulsion nuclei disintegrations.

Energy region, mev	Number of prongs in star: 1	2	3	4	5	6
	Number of secondary particles					
0—5	16	98	255	195	51	7
5—10	27	39	87	49	12	2
10—15	5	19	21	21	6	1
15—20	9	12	16	11	4	—
20—25	4	6	9	7	2	—
25—30	6	7	7	6	—	1
30—35	5	8	5	10	2	—
35—40	3	4	4	1	—	1
40—45	2	1	5	1	—	—
45—50	1	3	2	2	—	—
50—55	2	3	2	—	—	—
55—60	—	—	—	1	1	—
60—65	—	2	2	—	—	—
65—70	—	1	2	—	—	—
70—75	1	—	—	—	—	—
75—80	—	—	1	—	—	—
80—85	—	1	—	—	—	—
85—90	1	—	—	—	—	—
90—95	—	—	1	—	—	—

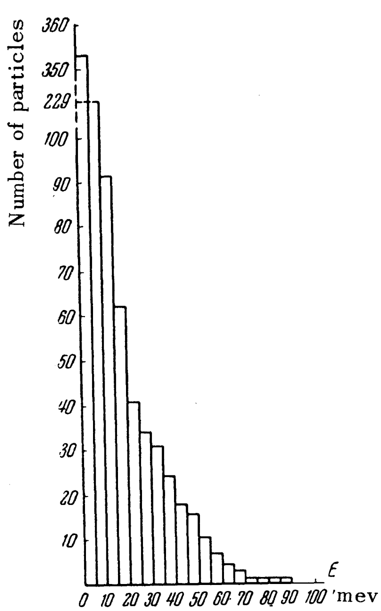

FIG. 1. $\bar{E} = (43.3 \pm 0.9)$ mev.

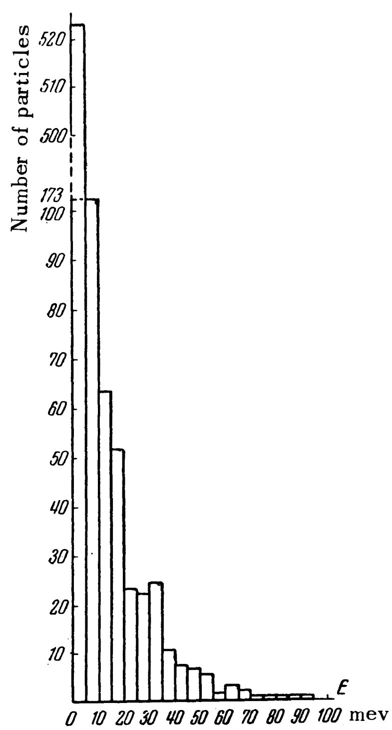

FIG. 2. $\bar{E} = (44.3 \pm 1.2)$ mev.

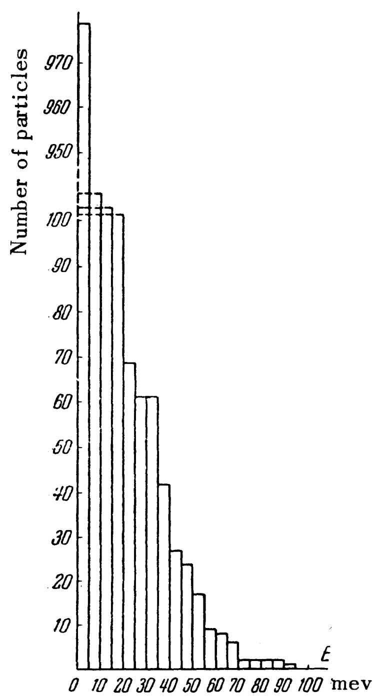

FIG. 3. $\bar{E} = (42.7 \pm 0.6)$ mev.

a greater frequency, than will the π^--meson produced σ-stars. This deduction is in good agreement with experimental data[4-7].

We shall now consider only those σ-stars produced by K^--mesons which do not contain π-meson tracks. Among such stars, 65.4 ± 10.0% possess secondary particles of energy $E \geq 30$ mev, which is considerably more than the corresponding value for the π^--meson produced σ-stars. The mean value of the energy, calculated for secondary particles with $E \geq 30$ mev, equals 79.2 ± 8.5 mev, i.e., is also much higher than for the secondary particles in the π^--meson produced σ-stars.

The energy distribution of secondary particles in K^--meson produced σ-stars is shown in Fig. 4 . Comparison with Fig. 3 reveals a slower decrease of the histogram with increasing E and the presence of secondary particles of considerably higher energy than is the case for the π^--meson produced σ-stars.

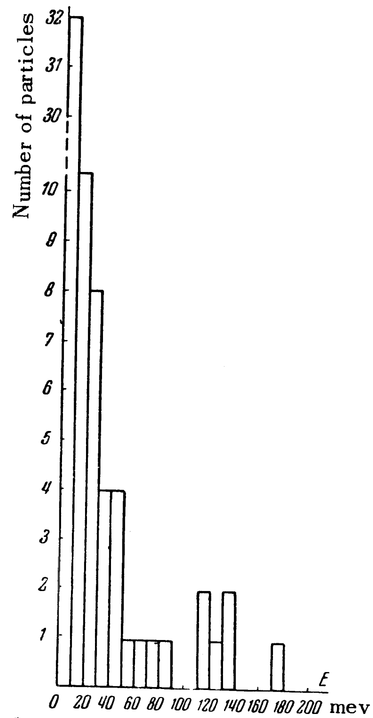

FIG. 4. $\bar{E} = (79.2 \pm 8.5)$ mev.

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