OBSERVATION OF DECAYS OF CHARGED PARTICLES IN A DOUBLE CLOUD CHAMBER*

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The authors analyze ten events, observed in a cloud chamber, of the decay of unstable charged particles produced in penetrating showers by cosmic rays at an altitude of 1800 meters above sea level. The $V^{\pm}$ decays are divided into two groups, depending on the place of generation. The upper limit of the mean lifetime for one of these groups is estimated to be $\tau \leq (1.44 \pm 0.83) \times 10^{-10}$ seconds. An analysis is proposed for one anomalous decay, which cannot be explained on the basis of any of the K-particle or hyperon decay schemes existing at present.

1. The first to estimate the lifetime of charged $V^{\pm}$ particles was Barker,[1] who has shown, that the lifetime of the decaying particles lies in the range $10^{-8} \geq \tau \geq 10^{-9}$ seconds. Further investigations[2-4] have shown that $V^{\pm}$ events contain both a long-lived K component with a lifetime longer than 10^{-9} seconds, as well as a short-lived one, on the order of 10^{-10} seconds.

Jork et al.,[2] using two cloud chambers with an absorber placed between them, obtained a uniform distribution of the decay points, with an average ratio $x/x_0 = 0.46 \pm 0.05$, for the charged particles produced in a generator placed over the chambers. On the other hand, the decays connected with the interaction in the middle absorber gave a clearly pronounced asymmetry with a ratio $x/x_0 = 0.31 \pm 0.05$. These data have led the authors to conclude the existence of a short-lived component with a lifetime in the interval $1.5 \times 10^{-10} \leq \tau \leq 2.8 \times 10^{-10}$ sec. The presence of protons[2,5] among the products of the short-lived component indicates, in the authors' opinion, the presence of hyperons among the decaying particles. However, in some cases it was possible to identify decays of lighter particles, making it difficult to attribute the short-lived components to decays of hyperons alone. Later investigations made by the same group[6] and carried out under somewhat different conditions, have not confirmed the preceding results, which apparently are explained by the impossibility of observing decays in the direct vicinity of the generator in this series of experiments.

Thompson[4] et al. also found a short-lived component with a decay point near the upper wall of the chamber, and a long-lived component with uniform distribution of events. In this experiment, unlike in those of Jork et al,[2] negative particles predominate in the short-lived components.

2. In this work we analyzed ten events of decay of heavy charged particles, observed with a setup similar to that of Jork.[2] The observations were made at the El'brus High-Altitude Cosmic Laboratory, 1800 meters above sea level. The apparatus consisted of a rectangular double cloud chamber[7] placed in a magnetic field. The principal diagram of the setup is shown in Fig. 1.

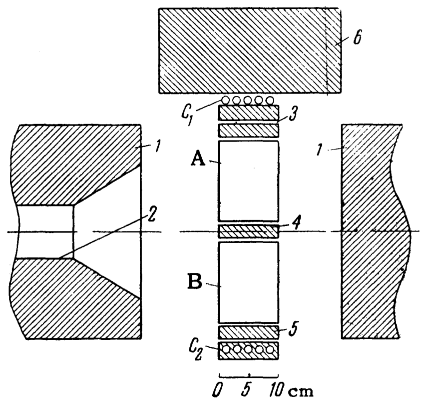

FIG. 1. Principal diagram of apparatus: A, B – working chambers; C_1 and C_2 – Geiger-Müller counters; 1 – poles of electromagnets, 2 – opening for photography, 3, 4, 5, 6 – absorber.

The cloud chamber combines in one housing two independent working chambers each $280 \times 100 \times 110$ mm, and three absorber compartments, isolated from the working chambers. The chamber was filled with argon to a pressure of 1,000 mm

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TABLE I. Data for Ten Events of Decay of V Particles

Number of event	Momentum of primary particle, $P_1(10^8$ ev/c)	Momentum of secondary particle, $P_2(10^8$ ev/c)	Ionization of primary particle, $(J/J_0)_1$	Ionization of secondary particle $(J/J_0)_2$	Aperture angle $\theta°$	Sign
82,179	Not measured	$1.72^{+0.88}_{-0.44}$	1	1	76	+
92,98	"	$3.60^{+2.30}_{-1.02}$	<1.5	1	60	+
101,14	"	Not measured	2—4	1	42	?
105,90	"	$1.09^{+0.04}_{-0.04}$	15—20	1	107	+
101,76	"	Not measured	<1.5	<1.5	31	?
115,115	"	$1.07^{+0.23}_{-0.16}$	>6	1	124	—
117,61	"	$3.52^{+0.94}_{-0.61}$	>20	<1.5	95	+
117,85	"	$0.62^{+0.04}_{-0.04}$	1	1.5—3	25	—
132,12	"	$1.43^{+0.32}_{-0.32}$	1	1	86	—
147,69	$5.78^{+3.10}_{-1.49}$	$2.59^{+1.60}_{-0.72}$	<1.5	1	28	—

Hg. The condensate employed was a mixture of 70% ethyl alcohol and 30% water. The working chambers were illuminated from both directions with IPS-1500 photoflash lamps. The tracks were photographed on "Panchrom 10-800" film with two "Helios-42" objectives at an effective aperture of 10. The base of the photograph is 42.8 mm, and the average magnification is 15. The chamber is controlled by penetrating showers, sorted out by a system consisting of two series of Geiger counters, connected for 1 — 4 coincidence. The showers were generated in absorbers 55 and 25 mm thick located correspondingly over the working volumes of the chamber. To shield against the soft-component, the entire setup was covered with an absorber 160 mm thick.

Copper absorbers were used in one series of experiments, and lead was used in the other.

A magnetic field was produced with a type SP-13 electromagnet with stabilized supply.[8] The field intensity in the working volume of the chamber was approximately 4300 oersted with no more than 5% deviation.

3. After 2836 hours of operation, 11,559 photographs with records of 2269 penetrating showers were obtained. Ten fork-like tracks, which could be interpreted as V decays were observed in these photographs. In addition, we found 22 V^0 decays, a τ^+-meson decay, decays of two π mesons in flight, and 13 stars in the gas of the chamber. The sorted $V^\pm$ decays were thoroughly checked for the presence of a common peak for the two tracks and for the absence of a recoil nucleus at the bend. The momenta and the arrangements of the tracks were determined by the coordinate method,[9,10] used in our laboratory during the past few years. The rms error in the curvature of tracks 10 cm long was 48 m^{-1}, corresponding to a maximum measured momentum of 6 Bev/c. The error in the depths of the points of the track was ±1.4 mm. The error in the angle between the tracks was not more than 3 to 4°. The ionizing ability of the particles was estimated by measuring the optical density of the tracks with a microphotometer. Unity blackening was taken to be the optical density of tracks of relativistic particles located in the same frame. The measured momenta and angles, and estimates of the ionization, are given in Table I.

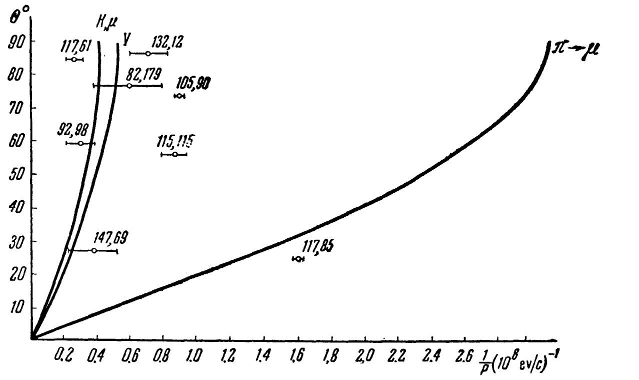

FIG. 2. (p_2, θ) plot.

Since the momenta of the decaying particles cannot be measured, in most cases, owing to the short length of the tracks, it is impossible to carry out a complete analysis of each event. Nevertheless, some information can be gained from the dynamics of the decay and from the ionization measurements.

If p^*_{max} is the maximum value of the momentum of the decay product in the rest system, and p_t is the transverse component of the momentum, then it follows from the relation $p_t \leq p^*_{max}$ that

$$1/p_2 \geqslant \sin\theta / p^*_{max}, \tag{1}$$

where θ is the emission angle and p_2 is the momentum of the charged product in the laboratory system.

Figure 2 gives the limit curves obtained from (1) for various decay schemes and from the (p_2, θ) plot of the observed decays, with the exception of two unmeasured events. All decays, with the exception of 117,61, lie within the allowed region for hyperons and K mesons, within the experimental error. Decay of the π meson is excluded in event 117,85, since at the observed momentum and emission angle of the secondary particle, the π meson should be at least triply ionized. Only one event, namely 147,69, for which the momenta of both tracks could be measured, can reliably be interpreted as a K-meson decay; it is impossible to distinguish between K and Y decays in the remaining cases. It must be noted that not one proton was observed among the decay products.

It is difficult to explain event 117,61, which lies outside the allowed region for Y and K decays, on the basis of experimental error. It will be analyzed separately in Sec. 5.

4. The $V^{\pm}$ decays can be divided into two groups in accordance with the character of their production.

The six relativistic particles, comprising the first group, are accompanied by penetrating showers from the upper and middle absorbers. This group of events features minimum ionization by the primary particles and decay points that are distributed near the generator.

The second group consists of four slow highly-ionized particles which are not connected with visible interaction and which enter into the illuminated portion of the chamber from the side of the electromagnet poles; they are apparently generated far away from the decay point.

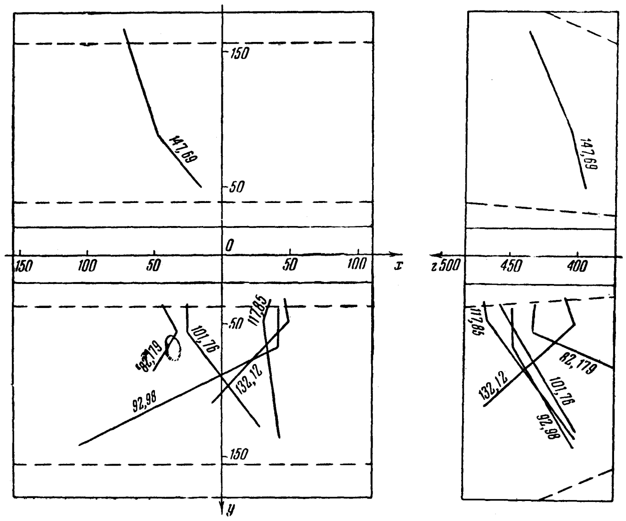

FIG. 3. Distribution of the decays of the first group in the chamber. The origin coincides with the optical center of one of the objectives. The distances are in millimeters.

The distribution of the decay points of the particles of the first and second group is shown in Figs. 3 and 4. The corresponding real and virtual

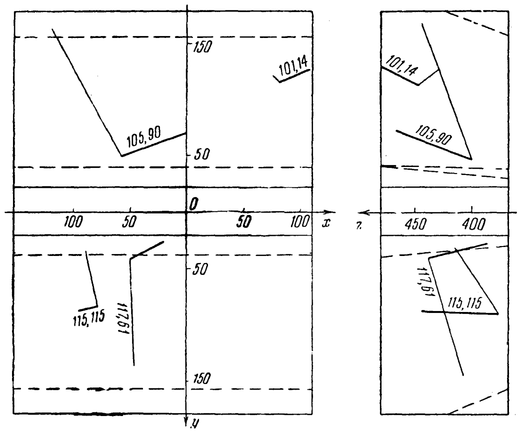

FIG. 4. Distribution of the decays of the second group in the chamber.

ranges are given in Tables II and III. The mean values of the ratios of the real ranges to the virtual ones is 0.30 for the particles of the first group, and 0.64 for the particles of the second group.

TABLE II. Real and Virtual Ranges of Particles Accompanied by Showers from the Upper and Middle Absorber

Number of event	Real range x, cm	Virtual range x_0, cm	x/x_0
82,179	2.7	14.1	0.19
92,98	4.0	13.4	0.30
101,76	2.3	11.6	0.20
117,85	2.0	14.6	0.16
132,12	2.5	6.7	0.37
147,69	9.1	15.4	0.59

The difference in the distribution of the decay points and in the ionization indicates a shorter lifetime for the first group of particles. Starting with minimum ionization of the primary particles, it is possible to determine the upper limit of the lifetime, assuming that their velocities are $\beta \geq 0.7$, i.e., ionization of not more than a multiple of 1.5. Calculation by the maximum probability method,[11]

TABLE III. Real and Virtual Ranges of Particles Without Visible Shower Accompaniment

Number of event	Real range x, cm	Virtual range x_0, cm	x/x_0
101,14	4.7	13.8	0.34
105,90	9.5	12.9	0.74
115,115	7.3	7.7	0.94
117,61	6.2	11.1	0.56

based on this assumption, shows that the average lifetime of the particles of the first group is

$$\tau \leqslant (1.44 \pm 0.83) \cdot 10^{-10} \text{ sec.}$$

If an attempt is made to attribute our relatively short mean lifetimes to the structural features of the cloud chamber, features which made it possible to observe particles in the nearest vicinity of the middle absorber, it becomes advisable to consider separately the five particles coming from this absorber. By so doing, we eliminate event 147,69 from the first group, which we identified as a K-meson decay. The average real to virtual range ratio for particles generated in a middle absorber is 0.23. The probability of effecting such a selection from uniform distribution is less than 0.24%. The average lifetime calculated under the assumption $\beta \geq 0.7$ does not exceed

$$\tau \leqslant (1.00 \pm 0.54) \cdot 10^{-10} \text{ sec.}$$

5. Event 117,61 is of particular interest.

As indicated in Section 3, in the (p_2, θ) plot decay 117,61 lies outside the allowed region for hyperons, K-mesons and π mesons (see Fig. 2). We consider it therefore necessary to analyze this case in detail.

A slow particle, with ionization not less than a multiple of 20, without visible accompaniment of nuclear interaction, enters into the chamber from the forward side. Without experiencing noticeable scattering, it decays in the well-illuminated region into a like charged particle having minimum ionization. The charged decay product is emitted at an angle of 95° to the direction or motion of the primaries and has a momentum 352^{+94}_{-61} Mev/c. The momentum of the transverse component, in this case 351 Mev/c, is substantially less than the maximum momentum of the decay product in the proper system for all known decay schemes of hyperons and K mesons. In fact, at a given positive-particle momentum and a given emission angle, the negative product can be not more than triply ionized for all three schemes, although the ionization observed is more than by a factor of 20.

The anomaly of this case is difficult to attribute to the experimental errors. The track of the secondary particle is 10 cm long and has a smooth curvature. Since it passes near a cloud cluster, we measured several tracks of hard μ mesons without a magnetic field, passing through similar photography defects. Measurements have shown that these clusters do not lead to track distortion.

The measured momenta could not be sensitive to systematic errors in the measurement of the curvature, since such errors amount to 0.03 m^{-1} in our chamber. To attribute this event to K-meson decay it becomes necessary to assume errors equal to three standard deviations, an assumption having a probability of 0.3%.

All this gives ground for assuming that in this case the decaying particle is heavier than a K meson. It is possible to assume that this case is a charged analogue of the neutral meson, whose decay was observed by Cowan.[12]

We have included a photograph of this event in an earlier preliminary report.[13]

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