Generation of particles with a lifetime of 10^{-14}–10^{-13} sec in collisions of 70-GeV protons and 50-GeV π^--mesons with emulsion nuclei

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The statistics for 3×10^4 primary stars, which were identified as a result of irradiation of emulsion nuclei by 70-GeV protons and 50-GeV π^- mesons, were used to record particles with a lifetime of 10^{-14}–10^{-13} sec. Two events were associated with semileptonic decays and three events were identified as hadronic decays of neutral particles.

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In our previous investigations[1,2] we have detected four semileptonic decays of particles with a lifetime in the range of 10^{-14} to 10^{-13} sec, which were observed at a distance up to 100 μm from the primary interactions, by using the statistics of 24,000 interactions of 70-GeV protons and 60-GeV π^- mesons. We also showed in those studies that the background of semileptonic decays is negligible.

The systematic problems (ionization losses, resolution of the decay point of a primary star from the intersection of the tracks), which make it possible to discriminate reliably the events of the decay of neutral and charged particles at distances of $\approx 10\ \mu$ from the primary stars, were analyzed in greater detail in Refs. 3 and 4.

We have identified in this investigation two events of semileptonic decays and three events of hadronic decays of short-lived, neutral particles by using the new statistics comprised of 3×10^4 primary stars produced by 70-GeV protons and 50-GeV π^- mesons. The search for decays was carried out at distances up to 100 μ from the primary stars in a cone with aperture angle of 45° in the direction of escape of a primary hadron.

The estimate of the level of background events for the decay of neutral hadrons (K° and Λ°), according to Ref. 5, shows that the probability for the occurrence of a background event is $\sim 3\times10^{-3}$ for the given statistics of the primary stars and of the decay path (3×10^4 and 100 μm).

The decay of a neutral particle was determined from the gap $l = AB$ between the center of the primary star A and the vertex formed by the intersection of the secondary

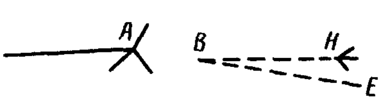

FIG. 1. Decay scheme for the events No. 1 and No. 2.

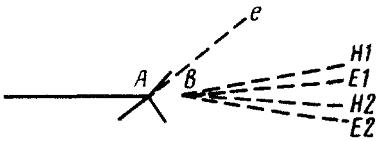

FIG. 2. Decay scheme for the event No. 5.

tracks B. The probability that the grains are missing in the region l was calculated on the basis of the Poisson distribution $w(0) = e^{-l}/100^{n_0}$, where l is in microns and n_0 is the number of grains produced as a result of a twofold or fourfold ionization (due to the decay of a neutral particle into two or four charged particles with angles of divergence for which the separation of particles from each other a distance l is smaller than the diameter of the emulsion grain). Figure 1 shows the decay schemes of neutral particles in the events 1 and 2 for which the distances AB between the vertex of the primary star and the decay point are equal to 24 μm and 12 μm and $w(0)$ is equal to 0.0007 and 0.27 respectively. One secondary track in these events undoubtedly is a hadron, since it produces a star in the emulsion. The second particle leaves the emulsion after traveling a distance of more than 10 cm. The measurements of the $p\beta$ values in different parts of the track indicate that the particle momentum is constant and that these particles, therefore, have a hadronic (or μ-mesonic) nature.

Both secondary tracks in the event No. 3 [$AB = 12, w(0) = 0.027$], after covering a distance of 11 cm and 15 cm, leave the emulsion without an interaction or a change in momentum, i.e., they are hadrons. One track in the event No. 4 [$AB = 90\,\mu\text{m}, w(0) \approx 0$] produces a star and the other track with an initial momentum of 0.17 GeV and mini-

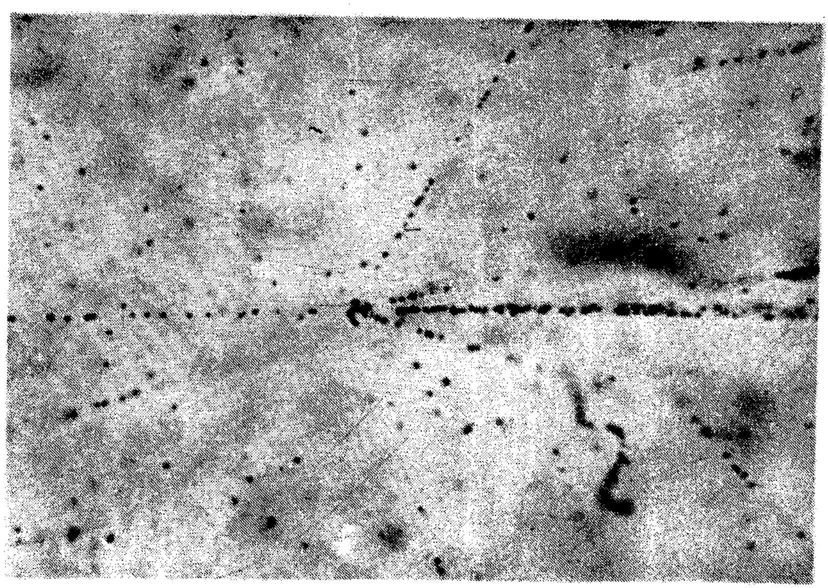

FIG. 3. Photomicrograph of the event No. 5.

TABLE I.

Event	1	2	3	4	5
Decay	$\pi\pi K^{\circ}$			$\pi e\nu$	πeKe
Mass-GeV	0.77	2.81	2.12	0.2	0.75
Decay	$K\pi\pi^{\circ}$			keV	$KeKe$
M	1.1	2.9	2.52	0.57	1.24
Decay	$K\pi K^{\circ}$			$Pe\nu$	πePe
M	1.28	3.06	2.63	1.03	1.18
Decay	$P\pi\pi^{\circ}$			$\Sigma e\nu$	$PeKe$
M	1.98	—	—	1.3	2.15
$<\tau>$ sec	1.0×10^{-14}	0.5×10^{-14}	0.5×10^{-14}	1.5×10^{-13}	0.2×10^{-14}

TABLE II.

Event	Spacing between the star and the decay point (μm)	Track	Emission angle	Momentum GeV/c	Relative ionization	Track length cm	Particle identification
1	24	$BH1$	1.01	5.8 ± 1.08	0.994	5.7	h
		$BH2$	0.8	2.44 ± 0.24	0.96	11.6	h
		$BH1$	7.33	4.6 ± 0.92	1.01	2.925	h
2	12	$BH2$	5.87	12.7 ± 1.65	0.93	10.525	h
3	12	$BH1$	1.13	6.53 ± 0.73	1.07	10.9	h
		$BH2$	2.16	22.68 ± 3.7	1.12	15.2	h
4	90	BH	1.29	1.58 ± 0.14	1.08	7.425	h
		BE	1.37	0.17 ± 0.01	0.93	7.75	e
		$BH1$	1.48	4.4 ± 0.54	0.98	8.275	h
5	6	$BE1$	3.92	0.082 ± 0.08	0.91	2.825	e
		$BH2$	2.77	16.13 ± 4.16	0.99	4.7	h
		$BH2$	0.6	0.119 ± 0.018	0.96	1.275	e

h — hadron e — electron

mum ionization losses comes to a stop after being scattered. This proves that it belongs to an electron.

The scheme of the event 5 is illustrated in Fig. 2 and its photomicrograph is shown in Fig. 3 [$AB = 6\,\mu\text{m}, w(0) = 0.023$]. According to the criteria cited previously, two tracks in this event belong to hadrons and to two electrons. It should be noted that the primary star, which releases a neutral particle, also has one electron, which indicates that an associative production of a pair of charmed particles is possible. One of these particles, whose decay point cannot be separated from the primary star, decays in 10^{-15} sec.

Table I gives the lifetimes of decay neutral particles and their masses, which were calculated for the cases 1–4 under the assumption that the neutral particle escapes at right angles to its momentum in the center-of-mass system of the disintegrating particle. This case is the most probable one, since it corresponds to a larger solid angle in the center-of-mass system. In the case No. 5 the mass was calculated ignoring the escape of neutral particles. If we jointly analyze the integral distribution of the lifetimes of five particles identified in our investigation and four particles identified in Refs. 1 and 2, then we can see that they are not situated on a single line in a semilogarithmic scale; it is more likely that there are two groups of particles with lifetimes of $\sim 10^{-14}$ and 10^{-13} sec. Such a breakdown is consistent with the results[6] obtained as a result of irradiation of the emulsions by a neutrino beam of the accelerator at FNAL.

Table II gives the experimental parameters of particles in the cases considered.

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