Search for a new short-lived particle in collisions of 70 GeV/c protons with emulsion nuclei

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In a study of approximately 14,000 interactions between protons and emulsion nuclei we registered three events that can be interpreted as a weak decay of new particles with a lifetime $\sim 10^{-14}$ sec. The cross section for the generation of these particles is 5 μb.

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The discovery of J/ψ particles[1] has increased interest in searches for new particles. Numerous events were observed, interpreted by the authors as possible cases of decays of charmed particles.[2] Modern theory predicts the existence of "charmed" hadrons with mass $M \approx (1-4)$ GeV. The expected lifetime is $\tau \sim 10^{-11}-10^{-15}$ sec.[3,4] This lifetime interval is promising for the search of new particles with the aid of an emulsion procedure.

To search for new particles we used an emulsion stack of type BR-2, bombarded by 70 GeV/c protons from the Serpukhov accelerator. In the scanning we reduced 13 900 interactions of protons (stars) with emulsion nuclei. The search for the particle decays was carried out in the vicinity of each star in the forward cone with aperture angle $\sim 45°$, at a distance up to 100 μm from the star, at a microscope magnification 15×60.

The number of obtained secondary interactions and decays of known particles agreed within the limits of errors with the expected number calculated on the basis of the production cross sections and the average number of the generated particles. The main feature in the search for new particles was the presence of one charged lepton (electron or position) among the secondary products.

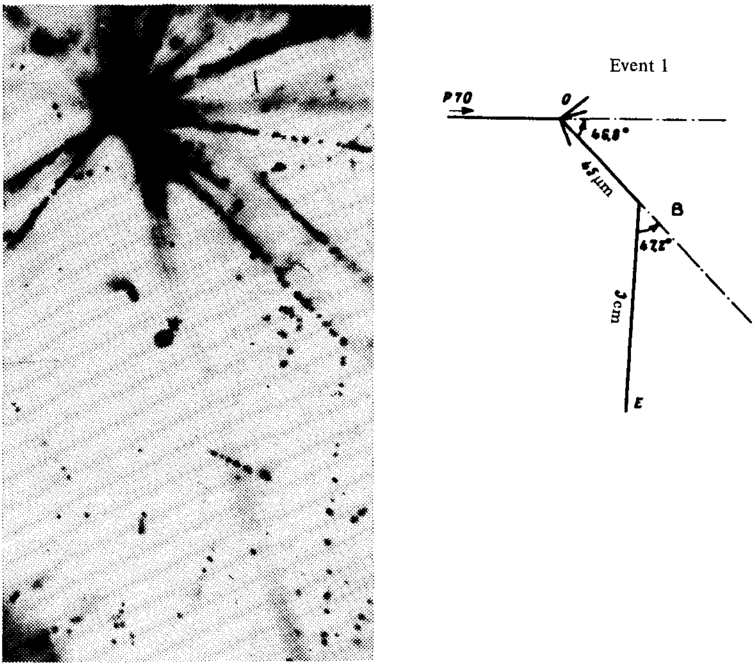

FIG. 1. Microphotograph and decay scheme of first event.

(The background due to such decays of known particles is small). As a result, three events with one charged lepton were separated.

Figure 1 shows a microphotograph and the scheme of one of the events. *BE* is a typical electron track. Measurement of multiple scattering at the end of the tracks yield $P = 116 \pm 21$ MeV/c. The ionization of the track relative to the ionization of the particles with minimum ionization is equal to 0.94 ± 0.05 (see Table I). The track *OB* belongs to a much slower particle. The number of

TABLE I.

Event	Track	Emission angle, deg	Momentum, MeV/c	Length, cm	Relative ionization
1	*OB*	46.80	–	45×10^{-4}	1.97 ± 0.19
	BE	47.20	388 ± 76	3	0.94 ± 0.5
2	*VH*	1.13	2360 ± 404	1	1.05 ± 0.06
	VE	1.08	3475 ± 650	8	1.01 ± 0.05
	OV	8.38	–	$\lesssim 3\times10^{-4}$	–
3	*VH*	1.00	4352 ± 544	7	1.08 ± 0.06
	VE	10.80	50 ± 7	1	0.98 ± 0.06
	OV	21.30	–	37×10^{-4}	–

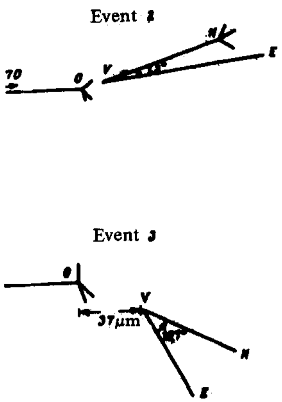

FIG. 2. Decay schemes of second and third events.

;rains on the OB track (the length is equal to 45 μm) is 31, whereas the grain lensity on the tracks of relativistic particles is 35 grains/100 μm. The char- ıcteristics of this event are listed in Table I. The lifetime calculated assuming $\pi^0 e^{\pm}\nu$ decay modes is equal to $\tau_1 \sim 1.5\times10^{-13}$ sec. The background of $K^{\pm}\to\pi^0 e^{\pm}\nu$:vents is less than 2×10^{-3}.

Figure 2 shows decay schemes of two other events. The corresponding char- ıcteristics are given in Table I. The tracks VE belong to electrons, while VH ›elong to high-energy hadrons. In event 2, the visible tracks of the charged ›articles, VE and VH, begin at a distance 12 μm from the center of the star, ›ut the continuations of the tracks towards the star intersects in the immediate ricinity of the star center ($\lesssim 3\mu$m). One can therefore not exclude the possibility hat the two tracks of the event 2 begin at the point where the star is produced.

The lifetime prior to decay for event 3 is $\tau_3 \sim 2.5\times10^{-14}$ sec. The background lue to neutral-particle decays (mainly $K^0\to\pi^{\pm}e^{\pm}\nu$) is less than 4.2×10^{-4}. The ›robability that the electron track in event 2 was produced in asymmetrical de- :ay of a Dalitz pair does not exceed 2.3×10^{-3}. In the calculation of the probabil- ty it was assumed that tracks of electrons of energy larger than 10 keV can be ›bserved in emulsions.

Assuming different three-particle decay modes with isotropic neutrino emis- ;ion, we can estimate the average effective mass M^*. For the first and third :vents the values of M^* turned out to be in the mass interval 1—3 GeV.

The production cross section per nucleon can be estimated in the following nanner

$$\sigma \sim n\sigma_0/N\Sigma K,$$

vhere $n=3$ is the number of events; $\sigma_0=30$ mb is the cross section of the in- ːlastic photon-nucleon interaction; $N=1.4\times10^4$ is the number of stars; Σ :0.25—1.00 is the scanning efficiency; $K=1$—2 is the average number of inter- ıctions of the primary protons inside the emulsion nucleus. Substituting in the ormula for σ the average values of these quantities, we obtain as an estimate ›f the cross section $\langle\sigma\rangle \sim 5$ μb.

The three obtained leptonic cases are difficult to interpret as decays of known particles. An estimate of other possible sources of the background (such as δ electrons, random positions of the tracks, etc.) demonstrates that the probability of imitation of decays of short-lived particles is low. The leptonic cases obtained in the present study can be interpreted as decays of new particles with lifetime $\tau \sim 10^{-13}$—10^{-15} sec.

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