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PRODUCTION OF SHORT-LIVED PARTICLES IN NUCLEAR EMULSION BY π^--MESONS AT 200 GEV/C

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Abstract

As a result of scanning up to 800 μm the neighbourhood of the 1300 stars produced in nuclear emulsion by 200 Gev/c pions, at the distance up to 65 μm 9 events were singled out which could not be accounted for by the ordinary processes and that probably can be caused by the decays of charmed particles. The analysis of these events is given.

PRODUCTION OF SHORT-LIVED PARTICLES IN NUCLEAR EMULSION BY π^- - MESONS AT 200 GEV/C

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1. Introduction.

In our previous paper [1] we have reported on observation of 9 events of possible charmed particles decays in nuclear emulsion irradiated by protons with the momentum 400 Gev/c. The majority of these events has been associated with the charmed baryons decays and their estimated life-time constituted $1.5\cdot10^{-14}$sec. Since the events corresponding to the charmed meson decay were not practically observed in [1], the assumption has been put forward that the life-time of charmed mesons is less than 10^{-14}sec and for that reason their decay lengths in the experimental conditions were too small for their observation. For small meson's life-times most favourable processes for their observation are the processes in which the produced mesons are sufficiently fast and their decay lengths in the emulsion are not too small ($\gtrsim$ 10 μm). For this reason we have

x) One could also discuss life-times much larger than 10^{-14}sec, what would be more in line with the existing theoretical predictions (see [2]), but experiment gives some indications in favour of smaller life-times undertaken a search for charmed particle production in πN-collisions, in which by analogy with strange particle production one could expect that the produced charmed mesons will be fast while the baryons will be rather slow.

2. Method of charmed particle search.

This work was performed with the stack of nuclear emulsions of the type BR-2 exposed in the beam of π - mesons with the momentum 200 Gev/c at FNAL. Beam's intensity was 2.10^4 p/cm^2 and angular spread $\sim 2 \cdot 10^{-4}$ rad. The size of pellicles was $10 \times 20 \times 0.06$ cm^3. This sample of emulsion had a sensitivity to the relativistic particles about 25 grains per 100 μm of the track.

The search for nuclear interactions along the tracks of primary particles and analysis of these interactions was done on the microscope MBI-9 with magnification 60 x 15 x 1. Futher measurements of ionization, multiple Coulomb scattering and angles were made on the microscope KSM-1. The momenta of the secondary particles were measured with a mean accuracy 15-20 per cents. The electrons were singled out among the secondaries by their specific energy losses along the track and change in ionization.

In the process of emulsion scanning 1300 πA-interactions were found. In search for secondary interactions or decays the forward cone of stars was carefully examined up to the distances: $\Delta x = 780$ μm, $\Delta y = \pm 70$ μm, $\Delta z = \pm 70$ μm, where x - axis was oriented along the beam direction, y - axis lay in the emulsion plane and z - axis was perpendicular to them. These values of Δx, Δy, Δz corresponded to maximum angle of particle flight direction relative to the cone axis $\pm 5.3^{\circ}$.

The search for secondary events was carried out along x - axis in strips, each 100 μm wide. The secondary interaction was treated as possible decay if:

1) there were no black or grey tracks, recoil nuclei and β - electrons;
2) the number of relativistic particles n_s was even or odd depending on the charge of the decaying particle $(0, \pm 1e)$;
3) opening angle of V - events was more than $5 \cdot 10^{-3}$ rad.

Further details of the analysis of such events one can find in [1] .

3. Experimental data.

As a result of the analysis of 1300 πN-interactions 9 secondary events with black and grey tracks have been found what agreed well with expectation. Besides 38 secondary stars of the type $0+0+n_s$ ("clean" stars) were found, while the expected number should be of the order 10% of the number of secondary stars with black and grey tracks, i.e. 1-2. The "clean" stars were subjected to further analysis. In the course of this analysis the following results have been obtained:

21 of the "clean" stars were caused by the production of e^+e^- pairs with rather large opening angles (from 0.3^o to 7^o);

5 stars turned out be the result of accidental origination of the e^+e^- pair in the close vicinity of the charged particle track;

2 stars proved to be ordinary secondary interactions with $n_s = 4$ and $n_s \geq 10$.

They occured at the distances 360 μm and 230 μm from the parent stars.

The rest 10 stars were considered as potential candidates for short-lived particle decays. Their main characteristics are given in Table 1.

The analysis of the selected events showed:

1) All assumed decays (except for the event No 4 of ambiguous nature) occured at the distances 65 μm from the point of primary interaction, while the rest 28 secondary stars were distributed uniformly up to 800 μm.

2) In the event No 1 there was a direct electron, coming out from the primary star. It allows to assume the presence of the second short-lived particle decaying in immediate neighbourhood of the primary star.

3) Event No 10 contained a e^+e^- pair in the secondary star that could imply that this was an example of the decay caused by the neutral currents (for more details see [3]).

4) Directions of movement of the decaying particle and of its charged decay products in the 0+0+3p type events and in a number of 0+0+2n type events are such, that neutral compo-

nents should be present (Fig. 1).

Estimates of the background arising in the interval up to 65 μm due to ordinary processes and imitating decays are presented in Table 2. It shows that the number of background events is small.

4. Discussion.

A measurements of particle momenta enables one to determine an effective mass of the groups of secondary particles by varying identifications of the decay products that, in turn, gives a possibility to evaluate the life-times of the short-lived particles. By means of this procedure all events have been divided in two groups: one group with life-times less that 10^{-14} sec (No 1,6,7,8,9), another - with life-times of the order 10^{-14}sec (No 2,3,5,10). The first group using the reasoning of [1], can be connected with the charmed mesons, while the second one - with the baryons. As it follows from Table 1 the mesons on the average carry larger momentum than baryons. Just this behaviour could be expected for the charmed particles produced in πN-interactions. Table 3 shows that in baryon group one can easily obtain the mass of the order 2 Gev/c^2 by varying identification of the particles. In a meson group, however, there are no combinations which give a mass value characteristic for the charmed particles. This difficulty can be overcome by taking into account the presence of neutral particles in these events which is motivated by the kinematical considerations (see Fig 1). By adding K_s^0 or π^0 with an energy 20-30 Gev to the secondary charged particles one can obtain the needed mass value (see Table 3). To determine genuine values Γ_{corr} and τ_{corr} we have used the exact values of D - meson and baryon masses and have obtained from time-plot for 6 mesons an estimate $\tau_o = 0.2 \cdot 10^{-14}$ sec (Fig 2). For 3 baryons one gets the life-times in the range $2-3 \cdot 10^{-14}$ sec, that is not too far from values, quoted in [1].

Thus, analysing 1300 inelastic π A-interactions at 200 Gev we have found 9 cases which were interpreted as charmed particle production and decay. Assuming that practically all decay modes (except neutral ones) are detected in the emulsion and suggesting that $\sigma_{\pi A}^{ch} = A \cdot \sigma_{\pi N}^{ch}$ and $\sigma_{\pi A}^{inel} = A^{3/4} \cdot \sigma_{\pi N}^{inel}$ we have

$$Y_{em}^{ch} / Y_{em}^{inel} = \frac{\sigma_{\pi N}^{ch} \sum n_i A_i}{\sigma_{\pi N}^{inel} \sum n_i A_i^{3/4}} \approx 2.7 \frac{\sigma_{\pi N}^{ch}}{\sigma_{\pi N}^{inel}}$$

For $\sigma_{\pi N}^{inel} = 22$ mb one obtains $\sigma_{\pi N}^{ch} = 60$ μb. Of coures this estimate is very crude one but it is interesting to notice that it agrees well with the recen value for σ_{NN}^{ch} [4].

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Table 1. Characteristics of the events associated with the decays.

Type of decay	No	No and type of the primary star	Distance from the primary star (μ)	No of track	θ^o	ψ^o	Momentum (Gev/c)
0+0+2π	1	B-5-43-26 (10+5+5p)	17	5	0.65	114	25.7 ± 7.4
				6	1.12	112	26.2 ± 4.8
	2	B5-54-55 (13+6+25p)	64	11	1.91	124	8.5 ± 0.8
				12	1.66	135	9.4 ± 2.1
	3	B5-54-62 (7+5+9p)	51	7	1.00	177	12.6 ± 1.4
				8	1.28	168	23.2 ± 5.7
	4	B5-54-184 (1+5+17p)	544x)	18	0.28	316	4.2 ± 0.7
				19	2.70	186	10.4 ± 1.9
	5	B5-57-55 (13+6+26p)	35	17	6.42	111	0.61 ± 0.04
				18	6.43	113	7.7 ± 2.2
0+0+4π	6	B5-57-001 (11+7+16p)	22	2	0.71	52	4.8 ± 0.4
				3	0.73	50	18.4 ± 4.4
				12	0.57	204	12.1 ± 2.5
				13	0.70	169	5.5 ± 1.4
0+0+3p	7	B5-40-126 ($4+3+7p+e^-$)	17	5	0.12	235	17.0 ± 2.2
				6	0.64	227	12.3 ± 1.8
				7	0.88	205	20.0 ± 3.7
	8	B5-43-45 (4+3+19p)	25	9	0.50	192	41 ± 16
				10	1.16	127	7.0 ± 1.0
				11	1.14	190	29.8 ± 5.3
	9	B5-54-179 (0+1+5p)	19	4	0.95	100	49 ± 12
				5	0.33	218	61 ± 18
				6	0.53	181	67 ± 19
0+0+5p	10	B5-47-003 (21+6+23p)	42	18	4.89	214	0.25 ± 0.01
				19	4.36	195	0.68 ± 0.06xx)
				20	4.69	206	4.5 ± 0.4
				21	4.55	194	1.70 ± 0.25xxx)
				22	4.86	205	2.0 ± 0.2

x) This secondary star is probably a ordinary interaction for its path up to the point of decay is larger than in other cases.

xx) Particle No 19 is electron because its momentum changes along the followed track with the total length 72,5 mm from 0,68 ± 0,06 to 0,04 ± 0,01 Gev/c.

xxx) Particle No 21 is electron because its momentum changes along the followed track with the total length 61,5 mm from 1,70 ± 0,25 to 0,11 ± 0,03 Gev/c.

Table 2. Estimates of the background in the interval 65 μm from the primary star.

The type of decay	Observed number of events	Estimated background	The source of background
0+0+2n	4[x)]	$< 2\cdot10^{-2}$	Decays The secondary interaction of the neutral particles
0+0+4n	1	$<10^{-3}$	The secondary interaction of the neutral particles
0+0+3p	3	$\leq 10^{-2}$	The secondary interaction (coherent production)
0+0+5p	1	$<10^{-11}$	The secondary interaction

x) V is at the distance 544 μm, it has indefinite nature.

Table 3. Invariant masses and life-times of the short-lived particles.

No	Code number of the event	Mass, Gev/c^2	γ	τ, 10^{-14} sec.	Probable type, mass, Gev/c^2	$\gamma_{corr.}$	τ_{corr}, 10^{-14} sec.
1	B5-43-26	0.8($K\pi$) 1.7($\pi\pi K_s^0$)	- 47.3	- 0.12	meson 1.86	- 43	- 0.13
2	B5-54-55	1.7($\Sigma\pi$)	10.5	2.0	baryon 2.25	8.0	2.6
3	B5-54-62	0.9($K\pi$) 2.0($\Sigma\pi$) 1.9($\pi\pi K_s^0$)	- 17.6 33.8	- 1.0 0.5	meson 1.86	- 15.6 34.5	- 1.1 0.49
4	B5-54-184 *)	2.1($\Sigma\pi$)	6.9	26.3	?	-	-
5	B5-57-55	2.6($\pi\Sigma$)	3.3	3.6	baryon 2.25	3.8	3.1
6	B5-57-001	1.9($\pi K\pi\pi$)	21.5	0.34	meson 1.86	22	0.33
7	B5-40-126	1.1($\pi\pi K$) 1.6($\pi\pi\pi K_s^0$)	- 44.3	- 0.13	meson 1.87	- 37.9	- 0.15
8	B5-43-45	1.8($\pi K\pi$) 1.9($\pi K\pi\pi^0$)	- 43.8	- 0.2	meson 1.87	- 42.5	- 0.21
9	B5-54-179	1.3($\pi\pi K$) 1.9($\pi\pi\pi K_s^0$)	- 101.4	- 0.06	meson 1.87	- 103.5	- 0.06
10	B5-47-003	2.2($e^+e^-\bar{p}\pi\pi$)	4.2	3.3	baryon? 2.25	4.1	3.4

*) If this event is associated with the primary star among the decay products the neutrals must be present.

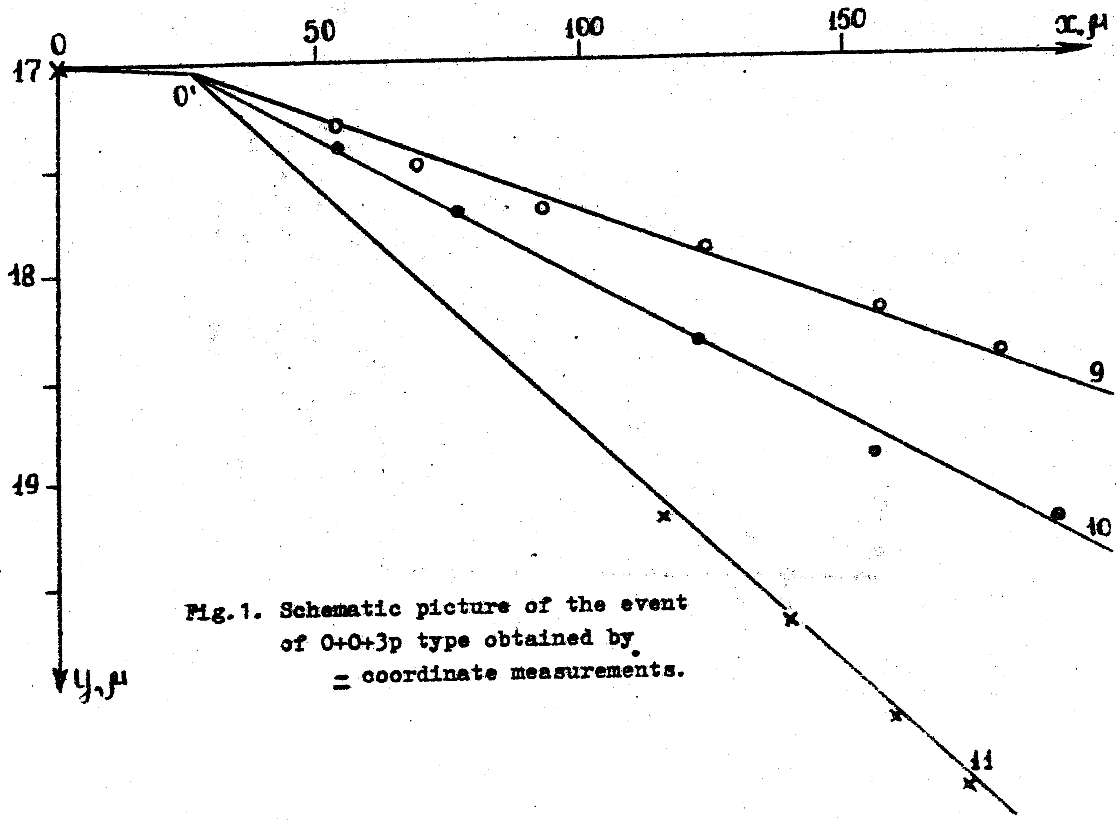

Fig. 1. Schematic picture of the event of 0+0+3p type obtained by coordinate measurements.

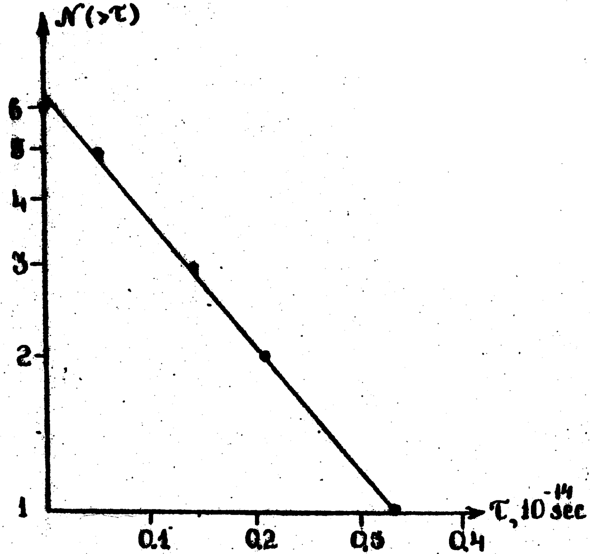

Fig. 2. Integral distribution of the charmed mesons relative time passed in their rest frame to the moment of decay.

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