ACADEMY OF SCIENCES OF THE USSR

P. N. LEBEDEV PHYSICAL INSTITUTE

Physics of Atomic Nuclei and Elementary Particles

Preprint No 149

OBSERVATION OF THE NEW SHORT-LIVED PARTICLES IN NUCLEAR EMULSION EXPOSED TO PROTONS WITH THE MOMENTUM 400 Gev/c.

M.M.Chernyavsky, A.A.Komar, G.I.Orlova,
N.A.Salmanova, M.I.Tretyakova

Moscow 1978

Experiment #463

Submitted to XIX Int.Conf.

on High Energy Physics

Tokyo, 1978

and Journal Yadernaya Fizika

OBSERVATION OF THE NEW SHORT-LIVED PARTICLES IN NUCLEAR EMULSION EXPOSED TO PROTONS WITH THE MOMENTUM 400 Gev/c.[x)]

M.M.Chernyavsky, A.A.Komar, G.I.Orlova,
N.A.Salmanova, M.I.Tretyakova

Lebedev Physical Institute, Moscow.

Abstract.

As a result of scanning up to 1000μ the neighbourhood of the 1120 stars, produced in nuclear emulsion by 400 Gev/c protons, after careful analysis 9 secondary stars were singled out which were interpreted as decays of the charmed particles. Mass values of the decaying particles agree with this interpretation. All decays took place at the distances not exceeding 100μ from the primary star. Estimated life-time of the decaying particles is $2 \cdot 10^{-14}$ sec. Cross-section per nucleon for the charmed particle production from this experiment is about 120 μb .

---

x) Preliminary results of this investigation were treated in the diploma work of N.A.Salmanova, Moscow University, December 1977 (unpublished).

I. Introduction

During past few years a number of anomalous events in nuclear emulsions bombarded by the protons with the energy of hundreds Gev has been observed that could be ascribed to the production and decay of the charmed particles [1-4] . Although the statistics of such events was rather poor estimates indicated that the cross section (per nucleon) of the processes causing these events σ_N^{ch} was not too small and equaled approximately 100 μb . (Different estimate of the cross section of the charmed particles production has been given in the paper [5] about which see below).

Mentioned above value of the cross section σ_N^{ch} recently seemed to contradict negative results of the counter experiments search for charmed particles production in hadronic interactions [6-8] , which were commonly interpreted as evidence of the small value σ_N^{ch} $(\leq 1\ \mu b)$. This interpretation was, however, dropped with establishing of the small values of the branching ratios of those decay modes of D - mesons ($K\pi$, $K\pi\pi$), which were usually selected for their search in counter experiments. With account of these branching ratio values existing data of counter experiments do not rule out σ_N^{ch} on the level of tens microbarn.

The additional very serious evidence for the considerable values of σ_N^{ch} follows from the recent experiments on direct neutrinos [10-12] , under assumption that they originate from the decay of the charmed particles produced in hadronic collisions. In the light of these data indications to high values of σ_N^{ch} obtained earlier in emulsion experiments should be viewed quite differently.

It has been mentioned already that the results of [5] are in contrast with the results of other nuclear emulsion works. The authors of [5] gave the limit $\sigma_N^{ch} < 1{,}5\ \mu b$. It seems to us that this conclusion is in-sufficiently motivated because selection criteria, adopted in [5], had some disput-able points. For instance:

1. all V's that had an angle between the tracks $< 3^{o}$ were treated as e^+e^- - pairs without analysis of the nature of the particles (in particular without studying energy losses along the tracks).
2. all narrow groups of particles produced in secondary interactions were not considered among possible candidates for the decays of charmed particles.

These two criteria could eliminate from the sample a considerable part of the events with the produced charm and hence lead to underestimation of σ_N^{ch}. An evidence in favour of this suggestion is the definite excess in the sample of the "clean" secondary stars originating from neutral particles which, however, is not discussed in the paper.

Being inspired by the indications of the relatively high rate of charmed particle production following from at least part of the emulsion works, including our work [1], about a year ago we started a systematic search for the short-lived particles in nuclear emulsion irradiated by 400 Gev/c protons. The aim of this work was to increase the statistics of the events, which could be associated with charmed particle production and to make an estimate (if it would be possible) of their life-time.

II. Experimental methods

1. Emulsion, exposition and measurements

This work has been performed with the pellicles of the BR-2 nuclear emulsion irradiated by 400 Gev/c protons at FNAL. The proton beam was incident parallel to the emulsion plane (within $2\cdot10^{-3}$ rad accuracy). Its intensity was $(2\div4)\cdot10^{4}$ p/cm^2. The angular spread of the beam was about 10^{-4} rad. The pellicle size was 10x20 cm^2, its thickness (before development) - $550 \div 600\mu$. The sensitivity of this batch of the emulsions to the relativistic tracks was 26 grains per 100μ. To determine the extent of distortions the plates were exposed to the beam perpendicularly to the emulsion plane and the plates with minimal distortion were chosen for the experiment.

The search for the interactions along the tracks of incident protons and analysis of the produced stars aimed at picking out stars with unusual properties have been carried out with the help of MBI-9 microscope at magnification 60x15x1. Further analysis of the events; measurement of angles, momenta, ionisation of the secondary particles have been performed using KSM-1 microscopes. The momenta of the secondary particles were measured by multiple Coulomb scattering with mean accuracy 15 - 20 per cents.

2. Method of decay search

In the process of emulsion scanning 1120 primary proton interactions (stars) have been found. In search for secondary interactions or decays of short-lived particles the forward cone of the stars was carefully examined up to the distances:

$$\Delta x = 1000\mu$$
$$\Delta y = \pm 60\mu$$
$$\Delta z = \pm 50\mu$$

where x - axis was oriented along the beam direction, y - axis lay in the emulsion plane, and z - axis was perpendicular to them. Values Δx , Δy and Δz correspond to the maximum angle of particle flight relative cone axis $\pm 4^{o}$.

The scanning was carried out along x - axis in bands, 100μ wide each. The secondary interaction was considered as possible candidate for decay, provided

1) There were no black and grey tracks recoil nuclei and β - electrons

2) the number of relativistic particles n_s was even or odd

depending on the charge of a decaying particle (0, ± 1 e).

If the secondary interaction or decay took place inside the examined band, one could see a typical picture presented at Fig.1. If interaction or decay took place in the previous 100 μ band, this could be established by the presence of the group of tracks which intersected the tracks from the primary star and visually seemed to meet at the point, different from the star ve tex. In cases when such tracks were found in the field of microscope vision, they were followed back to the star up to the point of their intersection. This method allowed to detect secondary interactions in which particles flew out at the angles $\theta_{\perp} \leq 10^{-2}$ rad relative the direction of flight of the particle, which generated the event. The coordinates of verteces of the secondary stars were fixed relative the vertex of the primary star.

3. Search method of narrow V-events, related to the primary star

Inside of the scanned area two close tracks nearly parallel to each other, having minimum ionization and directed towards the star vertex were looked for. After being found these tracks were traced back up to the vertex of the V-event. Then angles $\varphi = \frac{\Delta y}{\Delta x}$ and $\alpha = \frac{\Delta z}{\Delta x}$ were calculated for the V-event vertex and near-by point along the tracks If within experimental errors these angles coincided V-event was considered as related to the primary star. This method allowed to detect V-events with opening angle $\lesssim 0{,}1$ rad.

If it was difficult to establish visually the position of V-event vertex (due to a large number of other tracks) then y_i - coordinates of the neighbouring tracks were measured in equal distances and from the results of these measurements the intersection point (V-event vertex) has been found. A schematic drawing showing this procedure of V-event search is presented at Fig.2.

The e^+e^- - pairs were singled out among V-events by analysis of specific interrelation of the opening angles of the tracks and their momentum and ionization values. Typical opening angles for the main part of the V-events are $\geqslant 10^{-2}$ rad. Such angles are characteristic of the e^+e^- - pairs in which at least one of the components has energy $\leqslant$ 100 Mev. This allows to identify easily type of the particle forming V-event because at 100 Mev even π - mesons have increased ionization.

In order to exlude imitations of the secondary interactions, due to the fluctuation of the grain density, measurements of the ionization along the tracks of the primary protons have been made and probability distributions for finding certain amout of grains in intervals 15μ , 30μ , 45μ and 60μ have been constructed (Fig.3).

III. Experimental data

1. General summary and classification of the events

As a result of the analysis of 1120 primary stars 14 secondary stars with black and grey tracks have been found,*) what agreed with expectations. Besides that 21 secondary stars of the $0+0+n_s$ type were found, while the expected number should constitute 1/10 of the number of secondary stars with black and grey tracks, i.e. 1-2. General characteristics of these stars are given in Table 1. These stars became the object of further analysis. In the process of this analysis:

1. events No 10 and No 16 were excluded from the possible candidates to the charmed particle decay because event No 10 had a track with a large deep angle and a type of the event No 16 could not be determined (either decay of the neutral particle into two charged ones or decay of the charged particle into three charged products)

2. event No 7 turned out to be the case of the e^+e^- - pair, produced by hadron in the Coulomb field of the emulsion nucleus.

3. events No 13 and No 18, as it became clear, were connected with the cases when γ - quantum coming out from the primary star produced e^+e^- - pair in a close vicinity of charged particle track, so that within experimental accuracy the pair

*) including 2 stars, generated by the neutral particles

vertex seemed lying on the track. Nature of pair components was established by characteristic energy losses along the tracks. In this cases γ - quanta flew very close to the charged particle track (angle $\leq 10^{-3}$ rad).

4. events NoNo 1,2,3,4,11,14 and 21 turned out to be formed by $e^{+}e^{-}$ - pairs with large opening angles: $0,4^{o}$; $0,5^{o}$; $1,3^{o}$; $0,4^{o}$; $0,5^{o}$; $0,5^{o}$; $0,5^{o}$; $0,2^{o}$. For this reason these events were first considered as having hadromic nature and only momentum measuring and especially establishing of the momentum change allowed to identify particles forming pairs as electrons.

5. events NoNo 5,6,8,9,12,15,17,19,20 were attributed to the decays of the short-lived particles (they are marked by * in Table 1). These events broke into following groups:

a) two decays of the charged particle into three charged ones (type 0+0+3p, events No 17 and No 19)

b) four decays of the neutral particle into two charged ones (type 0+0+2n, events No 6,12,15,20)

c) three decays of the neutral particle into four charged ones (type 0+0+4n, events No 5,8,9).

2. Decays of the 0+0+3p type

The target diagrams for the stars in which such decays were found (events No 17 and No 19) are shown in Fig's 4 and 5. Characteristics of the decay products are given in

Table 2. The decays occured at the distances 90μ and 63μ from the primary star. In both cases directions of flight of the decaying particle and its decay products do not contradict the assumption of absence of the neutral decay products. Possible variants of the identification of the decay products and corresponding values of mass of the decaying particle are shown in Table 3. From the Table 3 it is clear that if one assumes presence of baryon among the decay products one gets in some variants for the masses of the decaying particles values (underlined) close to the mass of charmed baryon. In combination with the short decay length this is a serious indication that these events are the examples of the charmed particle decays. This conclusion is also supported by the estimate of the number of secondary stars of the type 0+0+3p expected on 1 mm in all observed stars.

Mean multiplicity of the charged relativistic particles in the forward cone ($\theta_L \leq 4^o$) is $\langle n_s \rangle \approx 6$ (this is mostly π - mesons). Effective total length of all tracks examined in this experiment is $L_{eff} = 6 \cdot 1120 \cdot 10^{-1}$ cm = 672 cm. A mean free path for inelastic interaction of the pions in the emulsion is $L_{int} = 45$ cm. The total number of secondary stars is thus $\frac{L_{eff}}{L_{int}} = {}^{672}/45 = 15$. From them "clean" stars constitute 1/10, i.e. their number should be equal 1÷2, and fraction of the stars of the 0+0+3p type according to the nuclear emulsion data is about 1/5 ÷ 1/10 of all "clean" stars. This makes their number $\lesssim$ 0,4.

Observed events of the 0+0+3p type are rather "narrow". Narrow flying groups of particles usually originate in the process of coherent generation on emulsion nuclei. Free path λ_{coh} for coherent generation of the triplets with $\sum_i \sin\theta_i < 0,4$ varies (for different energies) from 16 to 75 m. Let us take $\lambda_{coh} = 40$ m. Then the expected number of narrow 0+0+3p stars is 6,7/40 = 0.1, what is much less than the observed number 2.

Let us notice that total estimated number of secondary stars (15) is in good agreement with observed number 12+0,1·12 = 13.

3. Decays of the 0+0+2n type

The target diagrams of the corresponding stars (events NoNo 6,12,15,20) are presented in Fig's 6-9. Angles and momenta of the particles forming V-events are given in Table 4. V-events originated at the distances 25 μ, 29 μ, 35 μ and 22 μ from the centres of primary stars In all cases data agree with absence of neutral decay products.

Possible values of masses of the decaying particles under various assumptions about the nature of the decay products are given in Table 5. One should notice that in cases when baryon is present among the decay products masses of the decaying particles in some variants (underlined) are close to the mass of the charmed baryon (2,25 Gev/c^2). This peculiarity of the analyzed events as that for the decays 0+0+3p was considered by us as an evidence in favour of the detection of charmed baryon decays.

Specific background for hadronic V-events arises from the $K_s^0 \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$ decays. Their contribution is however small. To evaluate it we have included in Table 5 the decay modes: $\pi\pi$ and $p\pi$. One can see that in case of the $\pi\pi$ mode only for the event 10 - 70 - 90 we obtain invariant mass close to K_s^0 mass. Energy of the decaying particle in this case is equal 45 Gev and $\gamma = \frac{E}{m_{K^0}} \approx 90$. Corresponding decay length of K_s^0 is $\sim$ 250 cm and probability to detect its decay on 25μ is equal 10^{-5}, i.e. extremely small.

Another way to see that the background due to $K_s^0 \to \pi^+\pi^-$ decays is negligible is to estimate the expected number of K_s^0-decays on the distance of the order 30μ in all observed stars. Taking into account that on the average 0,1 K_s^0 decaying into $\pi^+\pi^-$ is produced per star (according to [13]) and $\langle \gamma_{K_s^0} \rangle \geqslant 10$, for the expected number of K_s^0 we get value less than $1120 \cdot 0{,}1 \cdot \frac{30 \cdot 10^{-4}}{30} \approx 10^{-2}$ against one possible candidate. The probability of such deviation from the expected number is sufficiently small. The situation with the $\Lambda \to p\pi^-$ decay is analogous. For this decay in all cases we can find variants of identification giving invariant mass close to Λ - mass. But this circumstance is most probably the accidental consequence of the momentum combinatorics. Indeed on the average only 0,1 Λ is produced per star [13] and we can put $\bar{\gamma}_\Lambda = 10$ (for the considered events provided they are genuine Λ - decays γ_Λ would vary from 4 to 40). Then for the expected number of Λ - decays $(\Lambda \to p\pi^-)$ in the region $20 \div 35\mu$ for all stars we get $1120 \cdot 0,1 \cdot \frac{15 \cdot 10^{-4}}{80}\ 0,6 \approx 10^{-3}$ while we observed 4 events. Thus these events should have origin not connected with K^o_s and Λ - decays. Possible background caused by neutral hadrons will be discussed below.

4. Decays of the 0+0+4n type

Target diagrams of the stars, containing these decays (events NoNo 5,8,9 of Table 1) are given in Fig's 10-12. Angles and momenta of the decay products are presented in Table 6. The decays occured at the distances 28μ, 72μ and 12μ from the star centre respectively. All decays of the 0+0+4n type have additional peculiar features. In the event No 5 (10-70-002) one of the particles (track N21) transforms in 182μ into three charged ones (star of the 0+0+3p type). The probability of interaction on this length leading to a "clean" trident is equal $\frac{182 \cdot 10^{-4}}{40} \cdot 10^{-2} \approx 4 \cdot 10^{-6}$. In the event No 8 (10-70-148) one of the decay products (track No 3) is identified as an electron. Besides on the track No 6 of the other decay product there is a kink at the distance 195μ from the decay point. Probability of hadron scattering on the length 195μ is very small ($< 4 \cdot 10^{-6}$) and one of the possible explanation of the kink - registration of the decay $\Sigma \to N\pi$, though probability of such decay is $\sim 2 \cdot 10^{-3}$. In the event No 9 (10-70-213) decay particle No 7 turned out to be an electron. Moreover it was established that particle No 1, coming out from the centre of the primary star is also an electron.

Peculiar features of the events NoNo 5,8,9 described above, in particular presence of the single electrons among secondaries, indicate to the nontrivial origin of these events and strongly favour the idea that they are connected with the decays of the charmed particles (in two cases semileptonic decays). For the masses of these decaying particles one can give only lower boundary, because in the events No 8 and No 9 one should suggest presence of the neutrinos and in the event No 5 for one of the decay products (track No 21) momentum had great uncertainty. (Analysis showed that in its transformation into three particles neutral particle is also involved). Nevertheless mass estimates made for different identifications of the decay products gave values close to 2 Gev/c^2 (see, for example, Table 7). With account of possible baryonic nature of the track No 6 in the event No 8 this event most naturally could be treated as decay of the charmed baryon. Events No 5 and No 9 could be connected either with charmed meson or baryon decay.

Secondary stars of the 0+0+2n and 0+0+4n types could in principle be generated by neutrons and neutral strange particles produced in the primary stars. Estimates however show that number of secondary stars from this source is small.

In fact on the average 0,3 fast neutrons are produced per star. Their free path is 35 cm. All observed secondary stars are found at distances, not exceeding 100μ . Total number of secondary stars generated by neutrons on this length should be equal $\frac{0,3\cdot 100\cdot 10^{-4}}{35}\cdot 1120 \approx 0,1$. Average number of neutral strange particles in forward cone is 0,2 per star. Their free path is ~50 cm. Number of secondary stars generated by them on 100 μ is $\frac{0,2\cdot 100\cdot 10^{-4}}{50}\cdot 1120 = 0,04$. Thus total number of secondary stars from neutral particles is 0,14. "Clean" stars are only 1/10 of this number, i.e. $1,4\cdot 10^{-2}$. And stars of 0+0+2n and 0+0+4n types together constitute 1/5 of the number of "clean" stars. Finally in our case expected number of secondary stars from neutral hadrons is $3\cdot 10^{-3}$ against 7 observed.

IY. Discussion.

Main characteristics of the observed decays of the short-lived particles are summarized in Table 8. Table shows the most probable (on basis of mass estimates) decay modes, errors in mass determinations, due to the inaccuracies in the momentum measurements and time passed till decay in the rest frame of the decaying particles. It should be noticed that if one assumes charmed nature of the decaying particles the majority of the observed decays are that of charmed baryons.

Another peculiarity of the discussed decays is connected with the fact that all of them took place within 100 μ from the primary star centres. This is a serious indication to the order of magnitude of the life-time of the decaying particles. On basis of our data we have made an attempt to determine life-time of the detected charmed particles summing up all observed cases of decay in the integral curve $\mathcal{N}(>\tau)$. Some justification of this procedure is the prevailing baryon nature of the decaying particles. The curve $\mathcal{N}(>\tau)$ is shown in Fig.13. It can be seen that in semilogarithmic scale points are well fitted by the straight line. From its slope one gets $\tau_0 = 2 \cdot 10^{-14}$ sec. Since decaying particles might in general be different types of charmed baryons (and in some cases mesons), rather small spread of the points around straight line could indicate to the closeness of the life-times of the different types of charmed baryons. Obtained value of $\tau_0 = 2 \cdot 10^{-14}$ sec should be considered as preliminary. It may be not quite correct because some decay events could be overlooked at large times (respectively distances) especially when angles at which decay products came out were large, and some events could be missed at small times for which scanning is difficult.

In each of the cases described above the decay of only one particle, identified as charmed, has been observed. The only exception is the event No 9 (10-70-213), in which there is an electron, coming out directly from the primary star and possibly signalling of the semileptonic decay of the second charmed particle. Thus associative production was not reliably observed. One of the possible reasons for that is a shorter life-time of the second charmed partner (probably of D - meson). For τ_0^D several times smaller than $2 \cdot 10^{-14}$ sec the decays of D - mesons will occur in the vicinity of the star centre ($\leq 10\mu$) and would be hardly recognizable. There are indications that this could be the case in the event No 9 (10-70-213) and in the event published earlier [1].

In conclusion let us touch upon the question of the charmed particle production cross-section in hadronic collisions resulting from our data. Among 1120 stars we detected 9 events which were interpreted as charmed particle decays (plus possible events No 10 and No 16 excluded as presenting difficulty for the analysis). Hence for nuclear emulsion ratio of the yields is $Y_{em}^{ch} / Y_{em}^{inel} \approx 10^{-2}$. From the experiments on J/ψ production on nuclei [14] it follows that approximately $\sigma_A^{\psi} = A\sigma_N^{\psi}$. This allows one to assume, that $\sigma_A^{ch} = A\sigma_N^{ch}$. At the same time the available data 15,16 give, that $\sigma_A^{inel} \approx A^{3/4}\sigma_N^{inel}$. Since

$$Y_{em}^{ch} / Y_{em}^{inel} = \frac{\sigma_N^{ch} \sum^{em} n_i A_i}{\sigma_N^{inel} \sum_i n_i A_i^{3/4}} \approx 2{,}7 \frac{\sigma_N^{ch}}{\sigma_N^{inel}}$$

and at 400 Gev/c $\sigma_N^{inel} \approx 33$ mb, one gets $\sigma_N^{ch} = \frac{33 \cdot 10^{-2}}{2{,}7}$ mb $\approx 120\,\mu b$. Thus cross-section per nucleon for the charmed particle production in hadronic collisions evaluated on the basis of the presented data turns out to be about $100\,\mu b$ in the agreement with the data on direct neutrinos [10-12] .

The authors are grateful to the directorate of FNAL and

Nuclear Physics Division of the Academy of Sciences of the USSR for their promotion of the experiment, to Profs. L.Voyvodich and I.V.Chuvilo for their help in the exposition of the emulsions and to Mrs. E.A.Krupetskova and Mrs. M.V.Tyurina for scanning and measurements.

References

1. A.A.Komar, G.I.Orlova, M.I.Tretyakova and M.M.Chernyavsky Zhetph, pisma 21,518 (1975), Jadernaya fizika 24,529 (1976)
2. K.Hoshino et al. Prog.Theor.Phys. 53, 1859 (1975)
3. P.L.Jain, B.Girard Phys.Rev.Lett. 34, 1238 (1975)
4. B.P.Bannic et al. Zhetph, pisma 25,586 (1977), 26,399(1977)
5. G.Coremans-Bertrand et al. Phys.Lett. 65B, 480 (1976)
6. D.Bintinger et al. Phys.Rev.lett. 37, 732 (1976)
   W.R.Ditzler et al. Phys.Lett. 71B, 451 (1977)
7. J.C.Alder et al. Phys.Lett. 66B, 401 (1977)
8. M.A.Abolins et al. Phys.Lett. 73B, 355 (1978)
9. I.Peruzzi et al. Phys.Rev.Lett. 39, 1301 (1977)
10. P.Alibran et al. Phys.Lett. 74B, 134 (1978)
11. T.Hansl et al. Phys.Lett. 74B, 139 (1978)
12. P.C.Bosetti et al. Phys.Lett. 74B, 143 (1978)
13. G.Charlton et al. Phys.Rev.Lett. 30, 574 (1973)
14. M.Binkley et al. Phys.Rev.Lett. 37, 571 (1976)
15. P.V.R.Murthy et al. Nucl.Phys. B92, 269 (1975)
16. F.Fumuro et al. Proc. of 15th Int. Cosmic Ray Conf. v7 p 59 Bulgaria (1977).

Table 1. "Clean" secondary stars.

No	Code number of the event	Type of the primary star	Distance to the secondary star (μ)	Type of the secondary star	Origin of the secondary star
1	10-66-007	0+0+17p	155	0+0+2n	e^+e^--pair
2	10-66-47	0+1+9p	70	0+0+2n	"-"
3	10-66-95	8+1+11p	270	0+0+2n	"-"
4	10-66-116	2+1+10p	40	0+0+2n	"-"
5	10-70-002	15+3+20p	28	0+0+4n	*
6	10-70-90	5+2+1p	25	0+0+2n	*
7	10-70-122	$N_h=7; n_s>15$	280	0+0+3p	he^+e^-
8	10-70-148	7+7+26p	77	0+0+4n	*
9	10-70-213	1+1+7p	12	0+0+4n	*
10	10-74-132	4+2+15p	78	0+0+3p	$\theta > 70°$ for one of the particles
11	10-74-200	8+5+27p	595	0+0+2n	e^+e^--pair
12	10-74-236	5+3+18p	29	0+0+2n	*
13	10-74-252	4+0+3p	432	0+0+3p	e^+e^--pair overlapping with hadron
14	10-74-325	12+2+36p	280	0+0+2n	e^+e^--pair
15	10-74-341	13+7+42p	35	0+0+2n	*
16	10-78-25	$N_h \sim 10; n_s \sim 15$	100	0+0+2n or 0+0+3p	
17	10-78-97	1+3+35p	90	0+0+3p	*
18	10-78-156	3+1+9p	34	0+0+3p	e^+e^--pair overlapping with hadron
19	10-78-210	1+5+20p	63	0+0+3p	*
20	10-78-277	6+12+17p	22	0+0+2n	*
21	10-78-211	$N_h>10; n_s>10$	150	0+0+2n	e^+e^--pair

Table 2. Angles and momenta of the decay products for 0+0+3p secondary stars.

Code number of the event	Number of the track	θ^0	ψ^0	Momentum (Gev/c)	Length for momentum measurment (mm)
10-78-210	16	0.45	171	46^{+18}_{-10}	49
	17	0.62	188	14 ± 2	48
	18	0.75	187	11.5 ± 1.7	50
10-78-97	1	0.49	29	27^{+9}_{-7}	50
	2	0.50	350	9.2 ± 1.6	81
	3	0.59	356	12.8 ± 2.7	67

Table 3. Invariant masses for 0+0+3p decays.

Assumed decay mode	Mass (Gev/c^2)	
	10-78-97	10-78-210
$K2\pi$	0.8 - 1.3	0.8 - 1.3
$pK\pi$	1.8	1.7
$Kp\pi$	<u>2.4</u>	<u>2.2</u>
πpK	2.5	2.5
πKp	<u>2.2</u>	2.7
$K\pi p$	<u>2.0</u>	<u>2.4</u>
$p\pi K$	1.7	1.7
$\Sigma\pi\pi$	1.7	1.6
$\pi\Sigma\pi$	2.9	2.7
$\pi\pi\Sigma$	<u>2.4</u>	<u>2.2</u>

Table 4. Angles and momenta of the decay products for 0+0+2n secondary stars.

Code number of the event	Number of the track	θ^o	ψ^o	Momentum (Gev/c)	Length for momentum measurment (mm)
10-70-90	2	0.55	31.6	31^{+10}_{-6}	48 x)
	3	1.55	72.2	15.6 ± 3.4	34 xx)
10-74-236	5	4.4	54.8	2.8 ± 0.4	44.8
	6	4.2	58.2	1.6 ± 0.2	53.5
10-74-341	4	2.8	297	1.9 ± 0.3	38.2
	5	2.9	303	14.6 ± 2.8	41
10-78-277	4	3.5	55.2	7.3 ± 1.5	56.7
	5	3.2	38.2	2.2 ± 0.4	78

x) the secondary star $N_h > 8$; $n_s = 6$ xx) the secondary star 2+1+8p

Table 5. Invariant masses for 0+0+2n decays.

Assumed decay mode	Mass (Gev/c^2)			
	10-70-90	10-74-236	10-74-341	10-78-277
$\pi^+\pi^-$	0.51	0.30	0.29	0.28
Kπ	0.79	0.85	0.52	0.54
πK	0.98	0.67	0.63	1.00
πp	1.7	1.2	1.1	1.2
pπ	1.2	1.6	2.2	1.9
pK	1.4	1.7	2.3	1.5
Kp	1.8	1.4	1.6	1.3
$\Sigma\pi$	1.5	2.0	2.9	1.4
$\pi\Sigma$	2.1	1.5	1.3	2.5

Table 6. Angles and momenta of the decay products for 0+0+4n secondary stars.

Code number of the event	Number of the track	θ^{o}	ψ^{o}	Momentum (Gev/c).	Length for momentum measurment (mm)
10-70-002	17	1.2	214	3.0 ± 0.5	45 x)
	18	1.3	168	$12.2^{+2.6}_{-1.8}$	47
	20	1.8	210	13.5 ± 3.4	114
	21	1.7	176	18	0.182 xx)
10-70-148	3	0.59	301	0.69 ± 0.23^{s}	2
				0.36 ± 0.02	25
				0.28 ± 0.04^{s}	6.3
				0.022 ± 0.007^{s}	1.2
	4	0.57	305	1.0 ± 0.1	54
	5	0.68	302	14.6 ± 2.2	46
	6	0.56	313	3.5 ± 0.6 xxx)	49
10-70-213	5	0.30	127	25 ± 5	68.5
	6	0.28	149	90 ± 22	73.5
	7	0.30	197	$7.7^{+1.8}_{-1.2}$	40.5
				$4.0^{+1.6}_{-0.9}$	17.5
				$0.17^{+0.05}_{-0.02}$	4
				$0.078^{+0.023}_{-0.015}$	1.9
	8	0.33	196	40 ± 10	92
	1	0.56	68	0.37 ± 0.07^{s}	5.4
				0.55 ± 0.09^{s}	3.6
				0.44 ± 0.08^{s}	7.4
				0.19 ± 0.02	6
				0.085 ± 0.015	3.8
				0.11 ± 0.01	8.5
	2	0.50	355	28 ± 6	94

x) the secondary star 7+3+1p   xx) the secondary star 0+0+3

xxx) After 195 μ there is a kink (angle 1.5°), final momentum (3.5 ± 0.6) Gev/c.

Index "s" denotes fact of scattering.

Table 7. Invariant masses for 0+0+4n decay.

(10-70-002)

Assumed decay mode	Mass (Gev/c^2) 10-70-002
$K\pi\pi\pi$	2.0
$\pi K\pi\pi$	1.2
$\pi\pi K\pi$	1.0
$\pi\pi\pi K$	1.2
$\Sigma\pi\pi\pi$	4.7
$\pi\Sigma\pi\pi$	2.4
$\pi\pi\Sigma\pi$	2.1
$\pi\pi\pi\Sigma$	2.1
$pK\pi\pi$	3.9
$p\pi K\pi$	3.8
$p\pi\pi K$	3.8
$Kp\pi\pi$	2.7
$K\pi p\pi$	2.5
$K\pi\pi p$	2.3

Table 8. Characterestics of the decaying particles.

No	Type of the secondary star	Code ev.number. Type of the primary star	Distance from the primary star (μ)	Inv. Mass (Gev/c^2)	γ	$\tau \cdot 10^{-14}$ sec
1	0 + 0 +3p	10-78-210 (1+5+20p)	63	2.2 ± 0.3 (ππΣ, Kπp)	33	0.65
2		10-78-097 (1+3+35p)	90	2.1 ± 0.3 (Kπp)	23	1.3
3	0 + 0 + 2n	10-70-090 (5+2+21p)	25	2.1 ± 0.3 (πΣ)	22	0.4
4		10-74-236 (5+3+18p)	29	2.0 ± 0.2 (πΣ)	22	4.4
5		10-74-341 (13+7+42p)	35	2.3 ± 0.2 (pK)	8	1.5
6		10-78-277 (6+12+17p)	82	2.5 ± 0.4 (πΣ)	3.2	2.3
7	0 + 0 + 4n	10-70-002 (15+3+20p)	28 x)	2.0 ± 0.4 (K3π) 2.1 ± 0.3 (Σ3π)	23	0.4
8		10-70-148 (7+7+26p)	77 xx)	2.2 ± 0.3 (e2πΣ)	8.8	2.9
9		10-70-213 (1+1+7p)	12	2.5 ± 0.4 (e2πΣ)	67	0.06

x) At l_{21} =182μ from the secondary star there is a star 0+0+3p.

xx) At l_6 = 195μ from the secondary star there is a kink (angle 1.5°), final momentum p_δ = (3.5 ± 0.6)Gev/c.

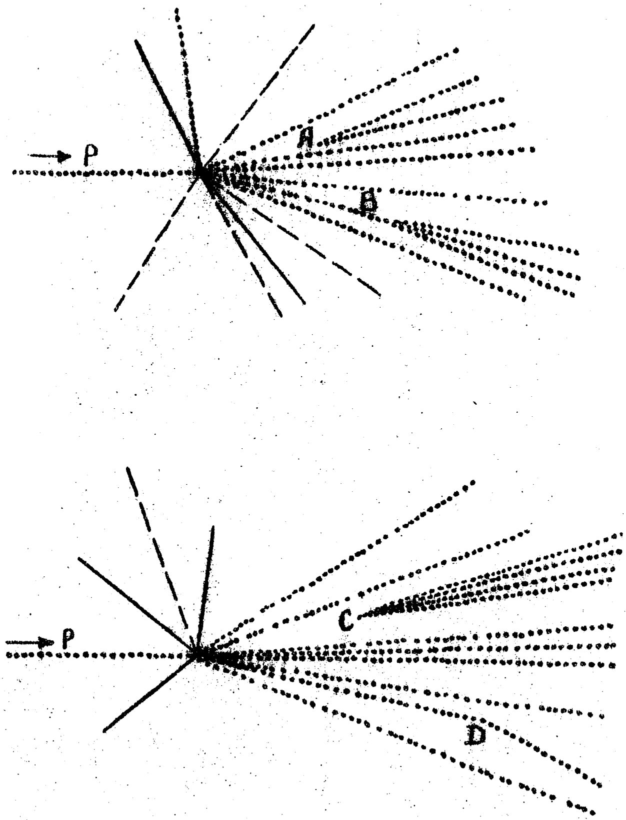

Fig.1 Schematic picture of the: A - V-event; B -charged particle decay; C - neutral particle decay; D-kink.

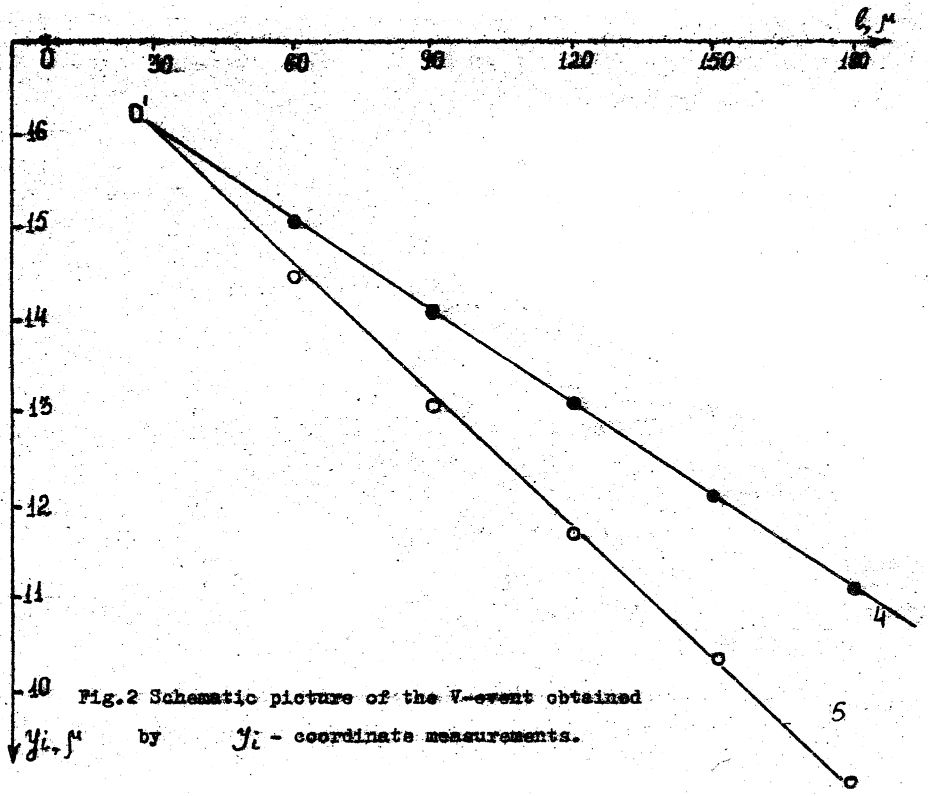

Fig.2 Schematic picture of the V-event obtained by y_i - coordinate measurements.

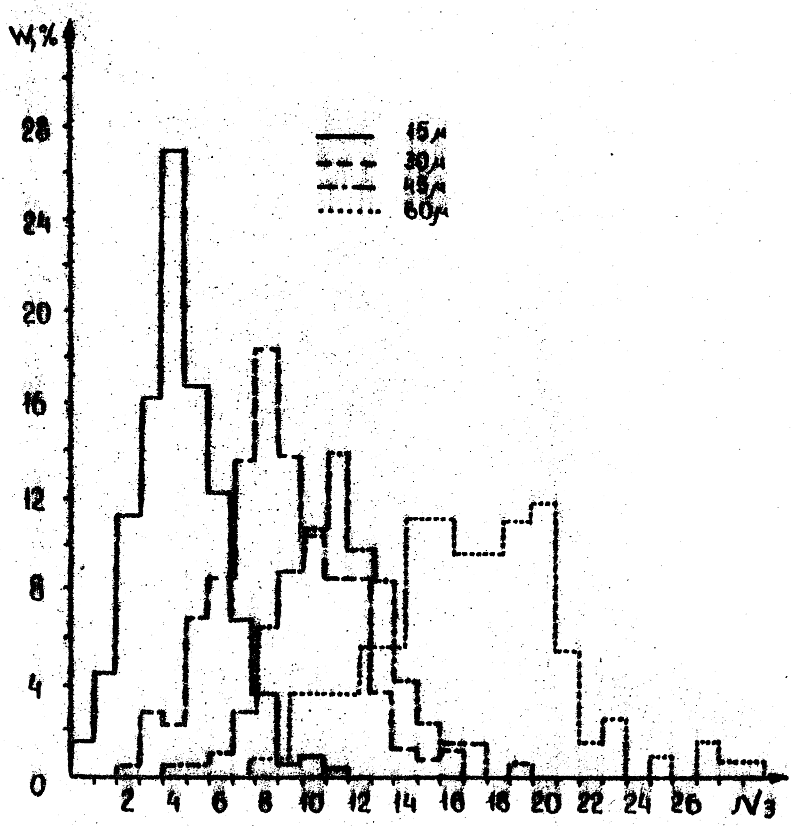

Fig.3 Probability distribution of the number of grains in different intervals of the primary tracks.

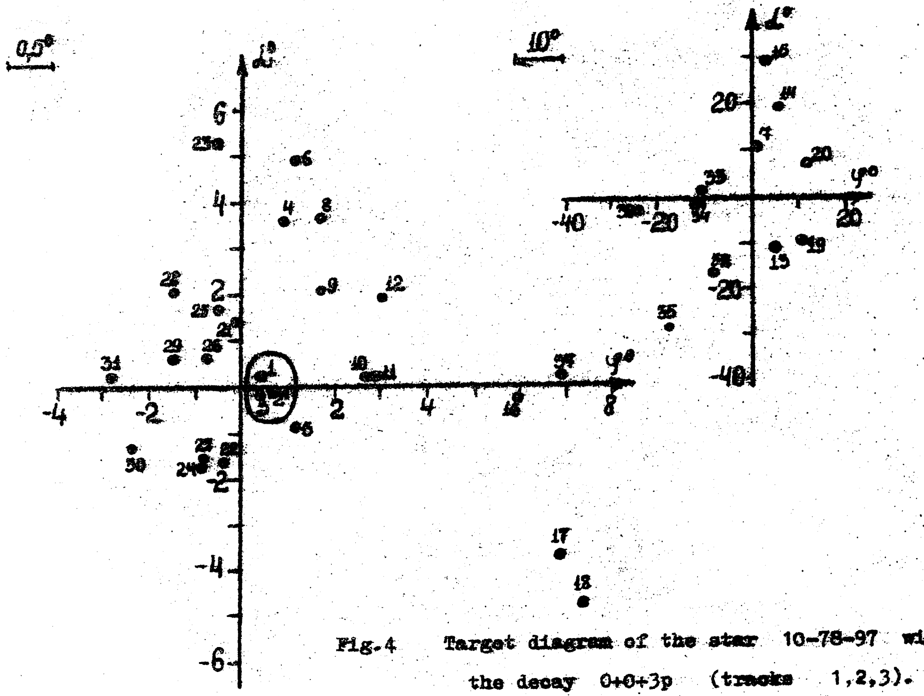

Fig.4 Target diagram of the star 10-78-97 with the decay 0+0+3p (tracks 1,2,3).

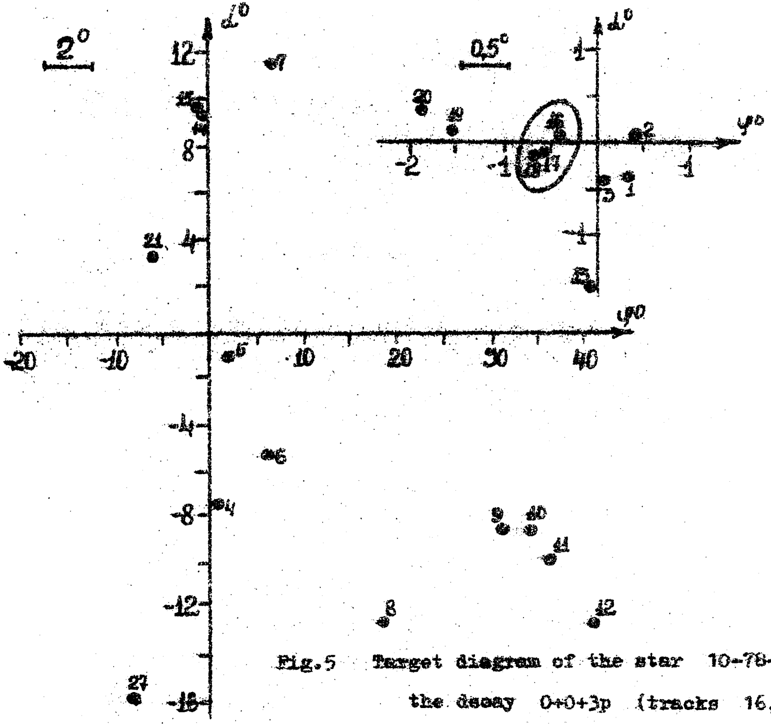

Fig.5 Target diagram of the star 10-78-210 with the decay O+O+3p (tracks 16,17,18).

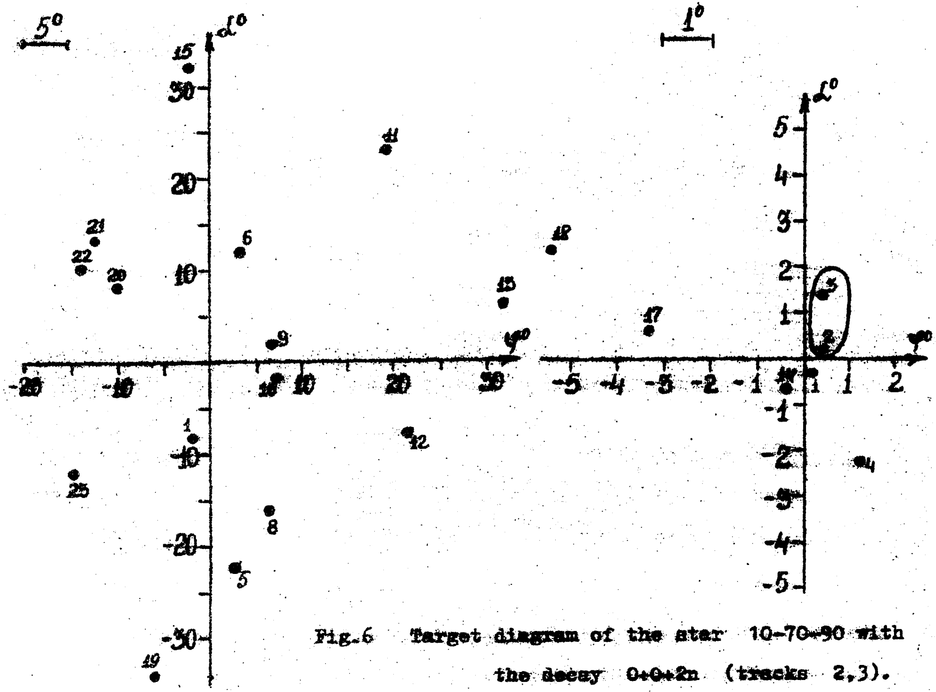

Fig.6 Target diagram of the star 10-70-90 with the decay 0+0+2n (tracks 2,3).

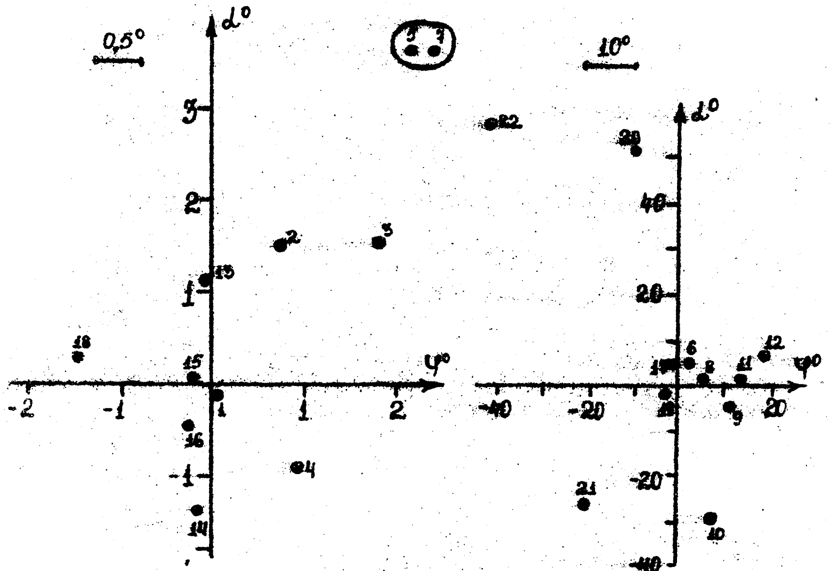

Fig.7 Target diagram of the star 10-74-236 with the decay 0+0+2n (tracks 5,7).

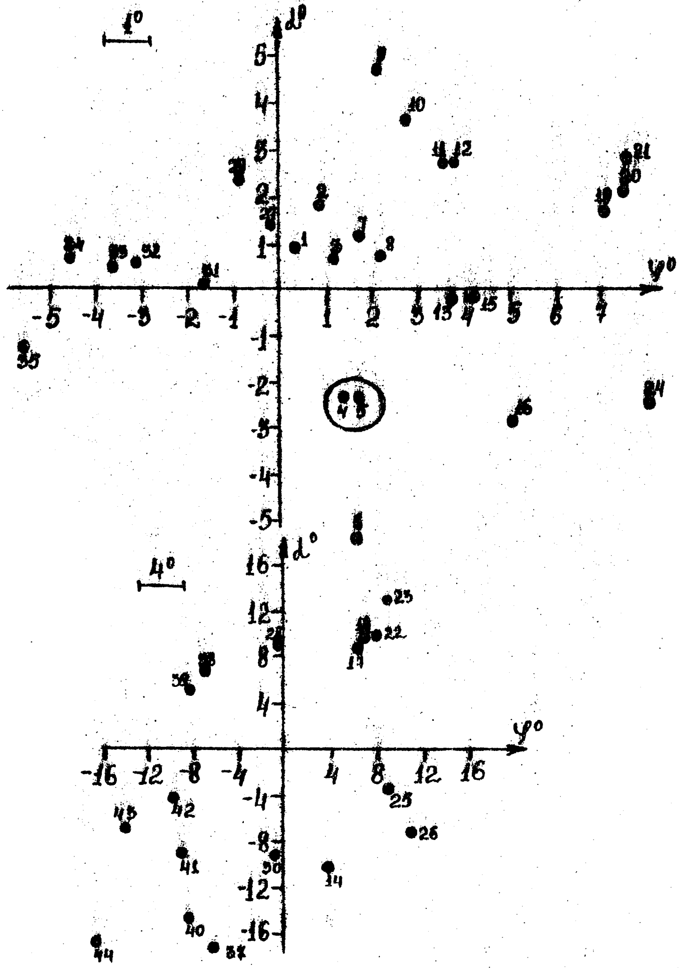

Fig.8 Target diagram of the star 10-74-341 with the decay 0+0+2n (tracks 4,5).

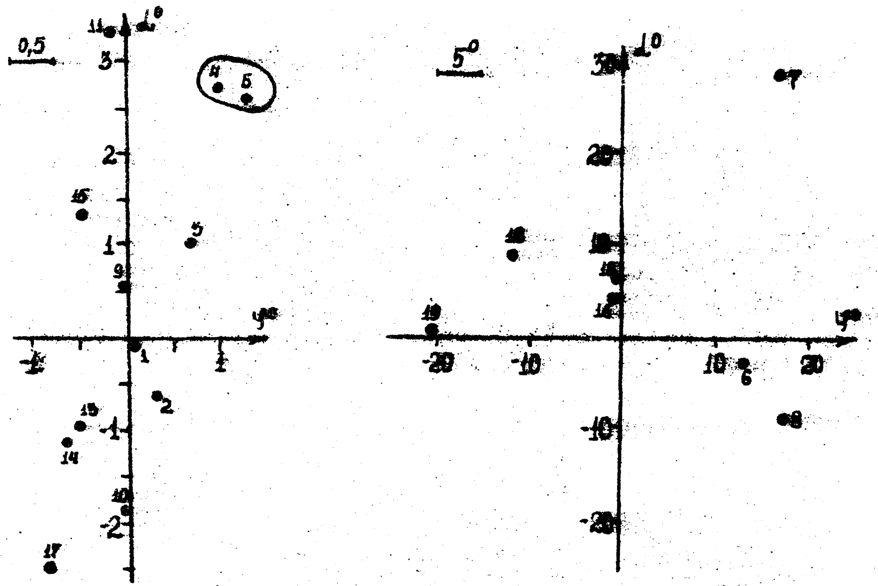

Fig.9 Target diagram of the star 10-78-277 with the decay 0+0+2n (tracks 4,5).

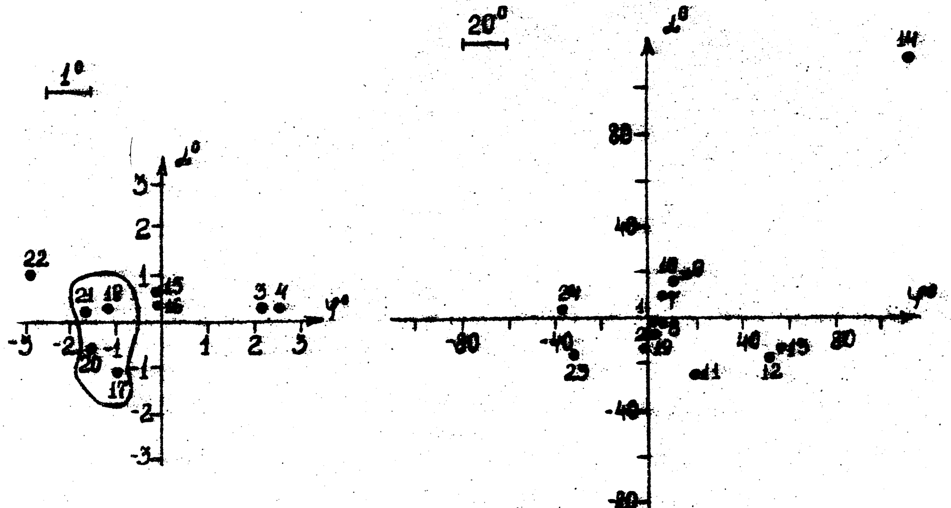

Fig.10 Target diagram of the star 10-70-002 with the decay 0+0+4n (tracks 17,18,20,21).

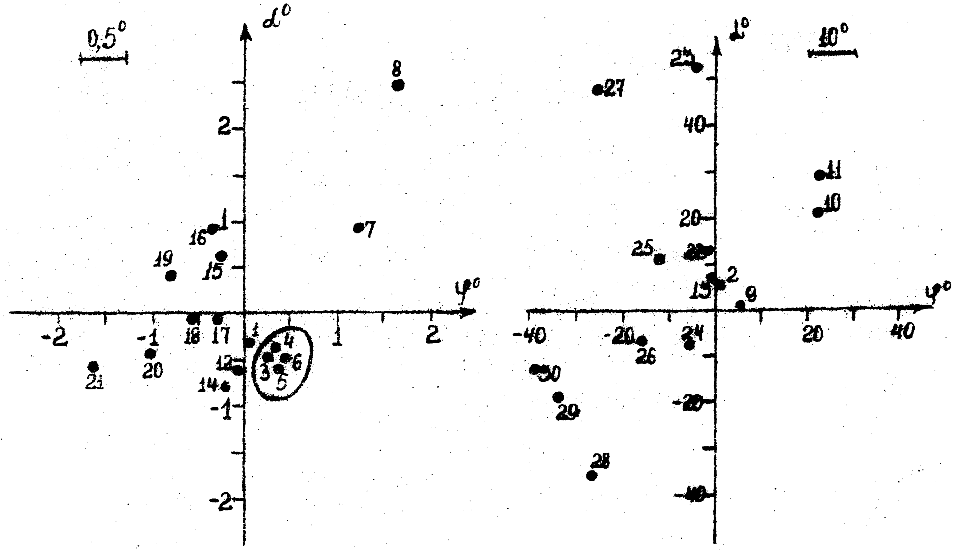

Fig.11 Target diagram of the star 10-70-148 with the decay 0+0+4n (tracks 3,4,5,6).

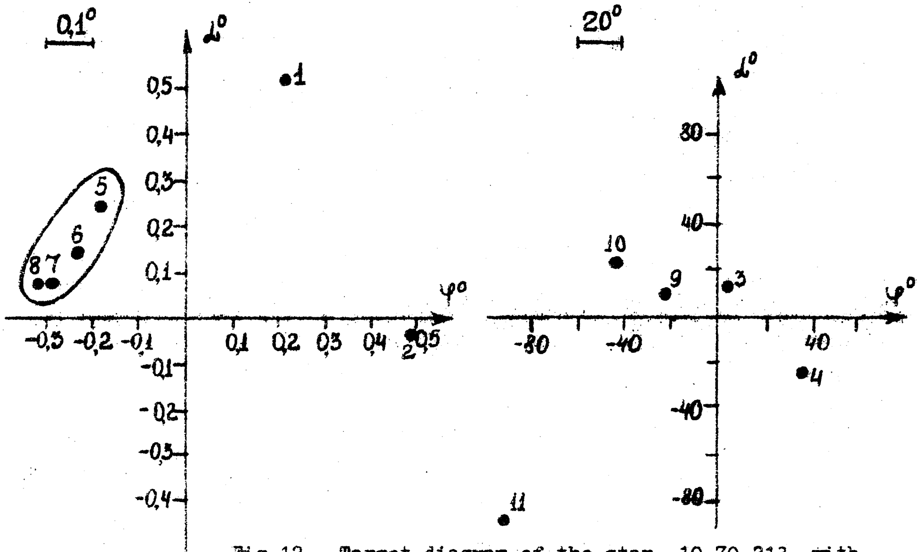

Fig.12 Target diagram of the star 10-70-213 with the decay 0+0+4n (tracks 5,6,7,8).

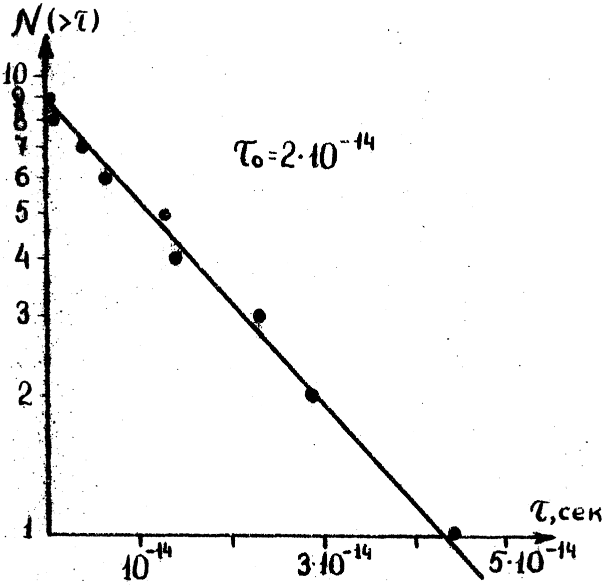

Fig.13 Integral distribution of the charmed particles relative time passed in their rest frame up to the moment of decay.

Т - 13794

Подписано в печать 28 июля 1978 года

Заказ № 381, Тираж 100 экз.

Отпечатано на ротапринте в ФИАН СССР

Москва, В-312, Ленинский проспект, 53