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EVENTS OF POSSIBLE ASSOCIATED PRODUCTION OF THE CHARMED PARTICLES IN NUCLEAR EMULSION

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In the course of scanning the nuclear emulsions, exposed to the 200 $^{Gev}/c$ proton beam, two stars were found in which single electron (or positron) came out nearly from the star centre (with uncertainty about 3 μ).

There is some evidence of the simultaneous production in the same star of the short-lived particle with the mass in the vicinity of 2 Gev. These events may be interpreted as the manifestation of the associated production of the charmed meson and baryon.

The probability that these events are generated by the semileptonic (leptonic) decays of known particles or result from the nonobservation of one of the Dalitz pair component was estimated and turned out to be very small ($< 10^{-5}$ for each star).

EVENTS OF POSSIBLE ASSOCIATED PRODUCTION OF THE CHARMED PARTICLES IN NUCLEAR EMULSION

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1. One of the possible explanations of the Ψ-particle properties is based on the assumption that it is compound system of charmed quarks /1÷5/. The direct consequence of this assumption is the statement that in nature there exist charmed mesons (M_c) and baryons (B_c), which may be produced in association in strong and electromagnetic interactions.

The masses of the charmed mesons are estimated to lie around 2,2 $Gev/_c2$. The estimates of the charmed baryon masses are less certain. But these masses are definitely larger than 2 Gev/c^2 possibly exceed $3^{Gev}/c^2$ and reach even higher values.

Large masses of M_c and B_c lead to the large Q-values in weak decays of M_c,s and B_c,s (for the latter if their masses are less than 3,2 $^{Gev}/c^2$) and consequently to the lifetimes which are smaller than the lifetimes of the strange particles. The lifetimes of these new particles lie in the range 10^{-13} ÷ 10^{-15} sec.[x)] At accelerator energies (hundreds GeV, $\gamma \approx 10$) decay lengths of such particles are rather small (3÷ 30μ). This means that electron (positron) originating in the process of semileptonic(leptonic)decay of M_c or B_c will be seen coming out nearly from the centre of the star, produced in the nuclear emulsion.

x) In the literature there are already indications /6,7/ on the existence of the particles with lifetimes 10^{-13} – 10^{-14} sec.

2. This specific feature was chosen as a criterion for the selection of the events in the analysis of the stars produced by the protons with the momentum 200 $^{Gev}/c$ in the nuclear emulsion BR-2 exposed at FNAL (The size of layers was 10cm x 20 cm x 600μ). In the course of studying secondery particles in p - N- interactions we have found two stars of the type (0 + 0 + 13 p and 0 + 0 + 10 p) in which there were single electrons of high energy appearing from the centre of the star with uncertainty $\leq 3\mu$. We have measured the moments of all charged secondary particles from these stars. At Fig.1 the projection of the star I on the emulsion plane is shown. At Fig.2 and Fig.3 the target (a) and P_L(b) diagrams for both stars are given. The electrons were identified using momentum-ionisation relation and by taking into account the character of energy losses. The momentum was determined by measuring multiple coulomb scattering. (Emulsions had small distortions, what enabled to measure momentum up to 100 $^{Gev}/c$ on the length ~ 5 cm with an error about 20 - 30 %). The ionisation of the particles was measured relative to the ionisation of the beam protons with p = = 200 $^{Gev}/c$. (Below $\mathcal{J}$ is a relative ionisation). When it was necessary tracks were followed in adjoining layers up to the length 10 cm. The characteristics and results of the analysis of the two stars are presented in the next sections.

3. The star I, type 0 + 0 + 13 p (N 4-20 - 305).

The particle N 12 from this star was identified as an electron. The arguments are:

i) The momentum of the particle along the track varied as follows

$(p\beta)_{12}$ $=(1,0 \pm 0.1)$ $^{Gev}/c$ (first 30 mm)

$(p\beta)'_{12}$ $=(0,43 \pm 0,11)$ $^{Gev}/c$ (next 3,6 mm)

$(p\beta)''_{12}$ $=(0,26 \pm 0,05)$ $^{Gev}/c$ (next 6,2 mm)

Then after scattering on the angle $\theta = 14^{\circ}$

$(p\beta)_{12} = (0.023 \pm 0,006)$ $^{Gev}/c$.

ii) The ionisation near the star was $\mathcal{J}_{12} = 1.01 \pm 0.03$., that is corresponding to the plateau. On the final part of the track the ionisation was $\mathcal{J}_{12} = 1.00 \pm 0.05$.

The particle N 13 nearest to the particle N 12 (Fig.2a) by measuring its momentum and ionisation along the track was identified as π-meson.

It is interesting to note that this event has two particles (N 2 and N 7) with rather large transverse momentum (~ 1 $^{Gev}/c$). Another peculiarity of this event is its asymmetry. Most of the secondary particles go in a centre of mass system in a forward hemisphere ($\theta_L < 2^{\circ}$ for 10 particles, Fig.2a). The total momentum of the secondary particles equals 200 $^{Gev}/c$ with an error 10 - 15%.

4. The star II , type 0 + 0 + 10 p (N 4 - 20 - 079)

The particle N 8 was identified as an electron for following reasons:

i) Its initial momentum and ionisation were:

$(p\beta)_8$ $=(0,45 \pm 0,10)$ Gev/c, $\mathcal{J}_8 = 1.00 \pm 0.03$

ii) After 2,1 mm they became

$$(p\beta)'_8 = (0.055 \pm 0.015)\ ^{Gev}/c,\ J'_8 = 1.01 \pm 0.03$$

iii) On the length 6,5 mm particle N 8 has suffered five scatterings on the angles from 1^o to 3^o.

The particle N 9 nearest to the particle N 8 (Fig.3a) has momentum $(p\beta)_9 = (4,8 \pm ^{1,3}_{0,9})$ Gev/c and ionization $J_9 = 0,88 \pm 0,03$. It was followed in 5 plates up to the length 30 mm and suffered neither energy losses nor scatterings. Thus this particle is not an electron.

Two particles in this star (N 1 and N 7)also have large transverse moments (0,8 $^{Gev}/c$ and 0,6 $^{Gev}/c$, respectively).

The total energy of the charged secondaries is about 100 Gev.

5. Single electrons coming out practically from the star centres in two cases described above present rather unusual feature of these events [x] and may serve as an indication of the weak decay with lepton emission of the heavy, rather short-lived particle (in both cases $\tau \lesssim 10^{-15}$ sec).As was noticed in section 1 such properties can be expected for charmed particles. So we can suggest that in two stars we have examples of the semileptonic decay of the D_e or M_e . If so in

x) Weak decays of known particles and nonobservation of one of the Dalitz pair components as a source of single electrons were considered and found highly improbable (10^{-3} for each star) at given conditions.

both stars there should be manifestations of the production and decay of the charmed partner to the particle with leptonic decay. There is some evidence favouring this.

Typical decay mode of M_c is $M_c \to K + \pi$. We now recall that in both stars we have particles with large transverse momenta. If for the star I we identify particles N 2 and N 7 with decay products of M_c (π- and K-meson or vice-versa) then the mass of their parent particle will be (2,0 ÷ 2,2) $^{Gev}/c$. If for the star II similar assumption is made in respect to particles N 1 and N 7, the mass of their parent is (1,7 ÷ 1,9) $^{Gev}/c^2$.

In both cases invariant masses are rather close to the expected value of M_c-mass. This gives further support to the assumption that the events I and II are the examples of the associated production of the charmed particles, for instance B_c and M_c. Then our observations may correspond to the decay schemes:

$$B_c \to \Sigma(\Lambda) + e^+ + \nu_e + n\pi$$
$$M_c \to K + \pi$$

It is possible that this interpretation is not unique. The analysis of the described events will be continued.

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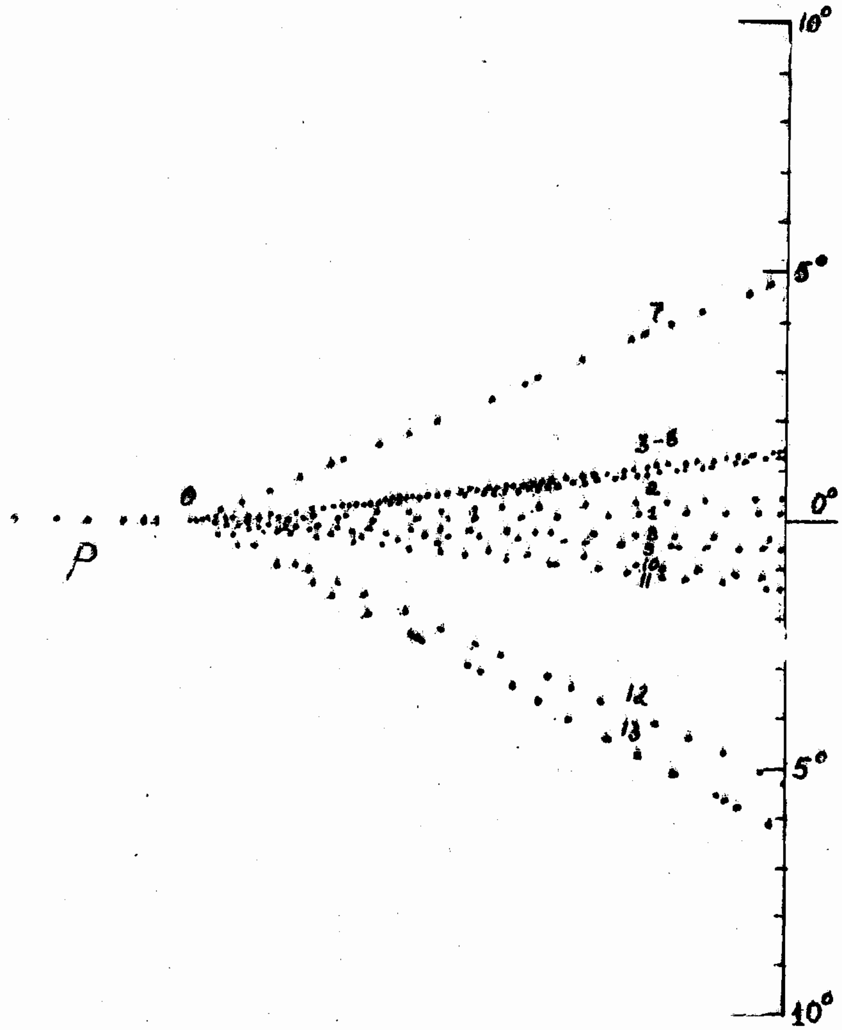
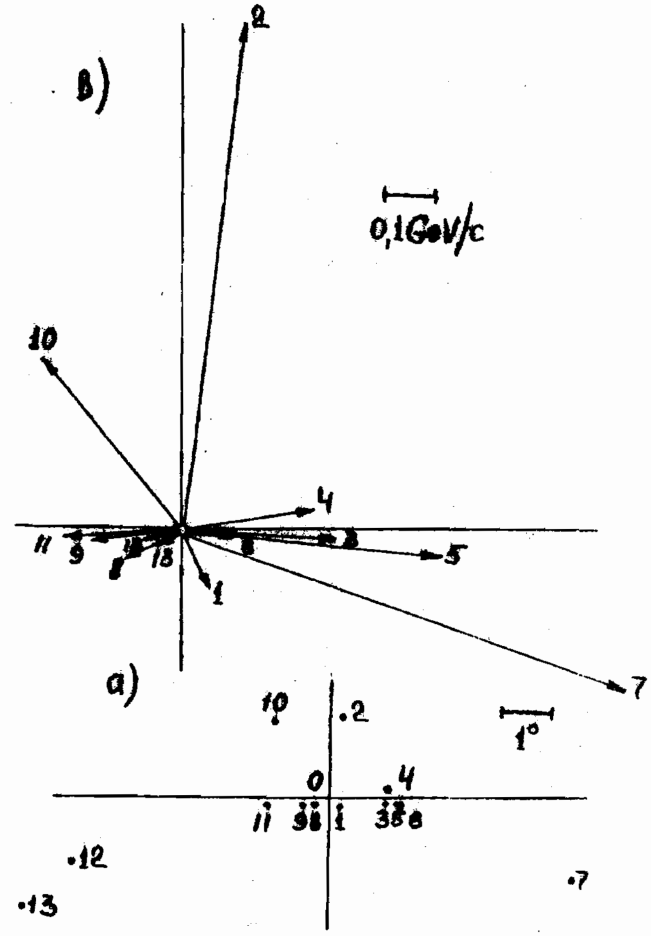


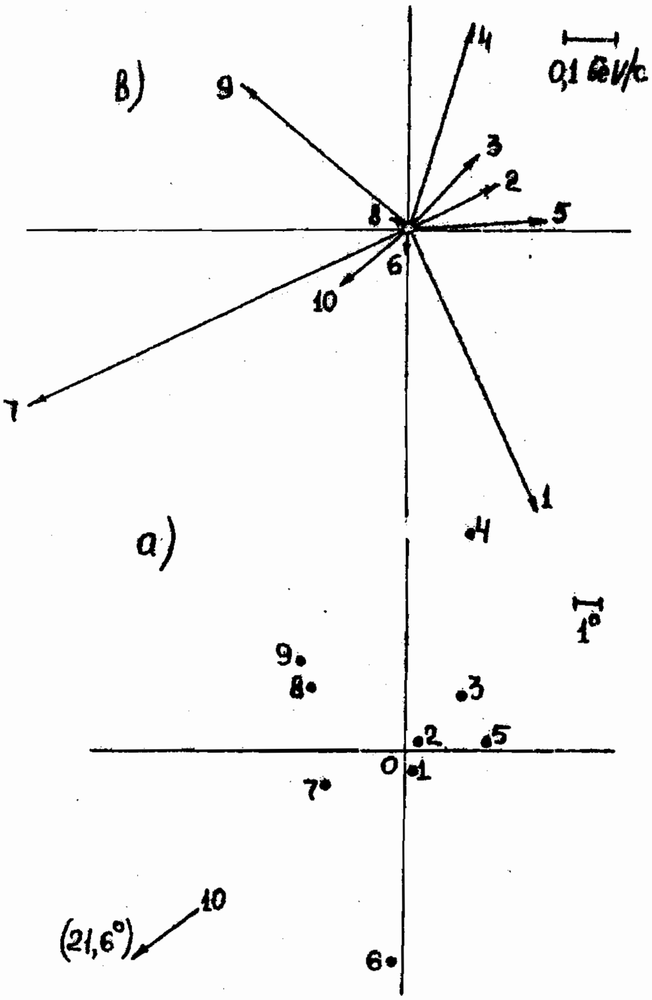
Projection of the star I (type 0 + 0 + 13 p)
on the emulsion plane.

Fig.1.



Diagramms of the target (2) and $P_{\perp}$ (b) for the star I

Fig.2.



Diagramms of the target(a) and $P_{\perp}$ (b) for the star II

Fig.3.