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SEARCH FOR SUPERFRAGMENTS IN PROTON-NUCLEAR INTERACTIONS AT 70 AND 250 GEV

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In 1975 attention was payed to one interesting property of particles with a new quantum number conserving in strong interactions [1], which had not been considered earlier. It is connected with the behaviour of charmed baryons in a nuclear matter. In paper [1] there was proposed a possibility of the existence of nuclei of a new type, where one of the nucleons is replaced by a charmed baryon and which are stable with respect to strong interaction. These hypothetic nuclei were called superfragments or supernuclei.

The predicted characteristic properties of supernucleus decay and production may be formulated in the following way:

1) An abnormally large energy release (as compared with hypernuclei) should be observed: 2 GeV in case if a charmed baryon mass is equal to 3 GeV (the model with charm [2]), or 3 GeV if a baryon mass is equal to 4.5 GeV (the model with colour hadrons) [3,4,5].

2) Supernuclei should have an abnormally short lifetime as compared with hypernuclei, of the order of 10^{-12}-10^{-14}sec, and, consequently, they should decay at distances of the order of 10μ from the point of their production.

3) To prove the existence of supernuclei the observation of associative particle production with abnormally short life-time should be of decisive importance.

As for predictions concerning the nature of products of charmed baryon supposed decay, they are model-dependent. In particular, strange particles should be observed in a model with charm in about 50% of cases /6/; in colour hadrons model strange particles may not be observed /7/.

In February 1975 an experiment, aimed at the search for nuclei of a new type, was begun at the photoemulsion department of the Laboratory of Nuclear Problems. An emulsion stack exposed previously at the IHEP to 70 GeV proton beam was used on the first stage of the experiment. The photoemulsion stack was further exposed especially to search for supernuclei. The stack consisted of layers of NIKFI-BR-2 photoemulsion of 200x100x0.6 mm^3. The total number of layers was about 160, and the total volume of the stack was ~ 2l. The exposure density was $\sim 10^5 p/cm^2$. The scheme of the exposure is shown in Fig.1.

In July 1975 a similar photoemultion stack was sent to Batavia and exposed there to 250 GeV proton beam according to the same scheme as at the IHEP. The photoemulsion stacks were developed in the Laboratory of High Energies. Scanning and preanalysis of the registered events have been finished by now. As is shown in Fig.1 , the layers were scanned by square with 225x magnification, the scanning field diameter was about 1 mm. All nuclear splittings caused by primary protons in photoemulsion were registe-

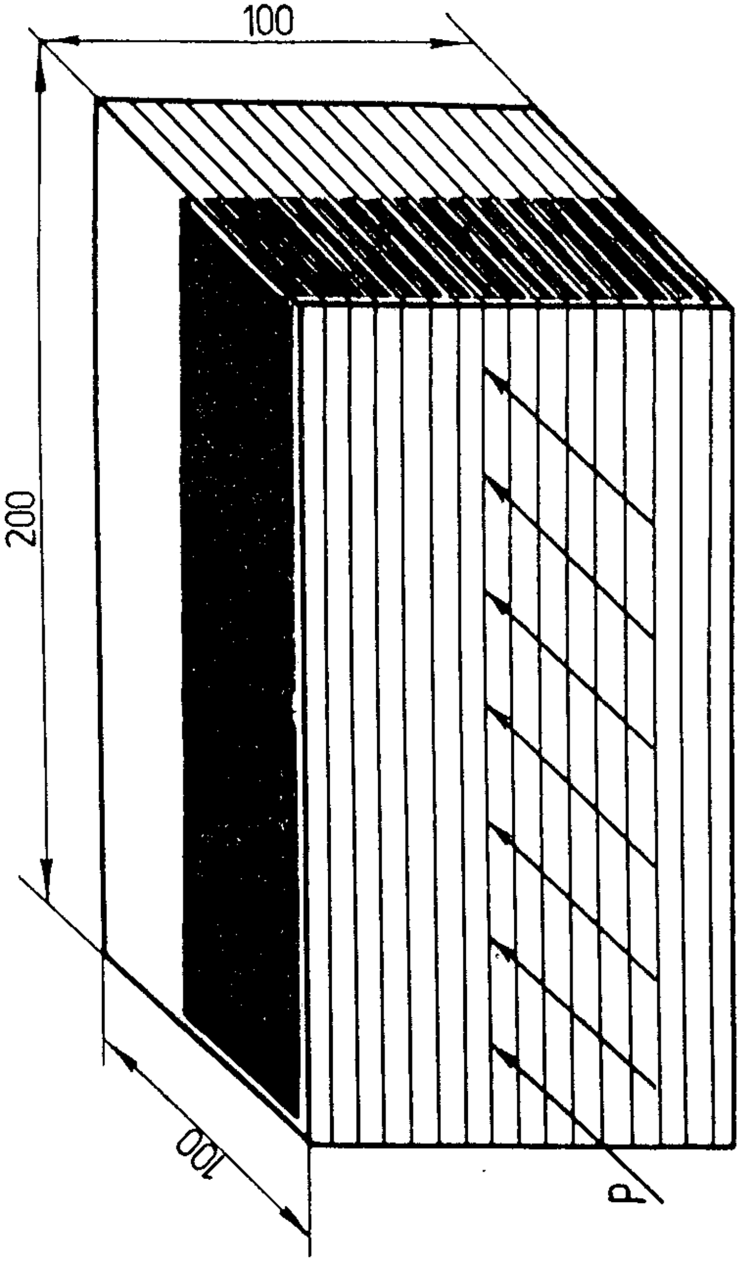

Fig.1. The diagram of the exposure of the photoemulsion stack.

red. Then with 1350x magnification and with about 130μ scanning field diameter the neighbourhoods of stars were scanned ,and "double" stars connected with a primary star by a black or grey connecting track were registered.

100.000 nuclear splittings caused by 70 GeV protons and 150.000 nuclear splittings caused by 250 GeV protons were registered. For selection of events and their further analysis, in order to determine their belonging to supernuclei, the following two criteria were to be satisfied:

1) There should be at least one minimally ionized track in a secondary star (for distinction from hypernuclei).

2) In order to safely determine the number of tracks in the secondary star, i.e., to determine energy release,the angle of the connecting track with respect to the primary one should be sufficiently large.

As a result of the pre-analysis 2 and 3 events at 70 and 250 GeV, respectively, were selected by the specified criteria.(A few events were rejected by the second criterion). The connecting track was black in all the events. All the tracks from the selected secondary stars were traced either prior to the flight beyond the emulsion stack or before the decay or interaction point in the stack. The analysis of the secondary tracks showed that all particles in their low energy part with ranges ≤ 5 cm consist either of π-mesons or "protons". π-mesons were unambiguously identified by the nature of their stoppings and stable particles or nuclei (mainly hydrogen and helium isotopes)

Table I

Characteristics of Secondary Stars

No	Primary proton energy, GeV	Connecting track length, μ	Particle identification in the secondary stars	Charged meson total energy, GeV	Visible energy release, GeV
I.	70	6.8±I.2	2p + 4π	I.20±0.08	2.I±0.2
2.	70	9.0±I.2	I5p + 5π	I.62±0.I5	2.0±0.2
3.	250	8.2±I.2	7p + 3π	0.34±0.0I	I.5±0.2
4.	250	7.9±I.2	I0p + 2π	0.50±0.03	I.0±0.I
5.	250	2.I±I.2	3p + 3π	0.82±0.04	I.0±0.I

causing no secondary phenomena at stopping were conditionally referred to as protons. Other particles, i.e.,strange ones or leptons in spectrum low energy part were not found.

To identify tracks of fast particles and determine their energy ionization and Coulomb scattering have been measured. Figure 2 presents dependence of ionization on the value of $p\beta$. Identification of very fast particles is less unambiguous. However within the limits of the measuring errors particles of other nature than protons and π -mesons are not found either.

Figures 3,4 present schematic view of two registered events. The results of the analysis of all the events are presented in the Table. As is seen from the Table, all the events are concentrated from 2 to 9 μ distance from the center of the primary interaction and have a visible energy release from 1.0 to 2.6 GeV*. The relative probability of observing such events makes up 2×10^{-5} with respect to all inelastic 70 and 250 GeV proton interactions.

So, the fact of the secondary star production (with the probability of 2×10^{-5}) with a visible energy release 1.0-2.6 GeV at less than 10μ distances, which are connected by the black track with the point of 70 and 250 GeV proton- nucleus interaction in the photoemulsion, has been established experimentally. Interpretation of

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* A visible energy release is equal to the sum of charged particle kinematic energy, π -meson rest mass, and nucleon binding energy

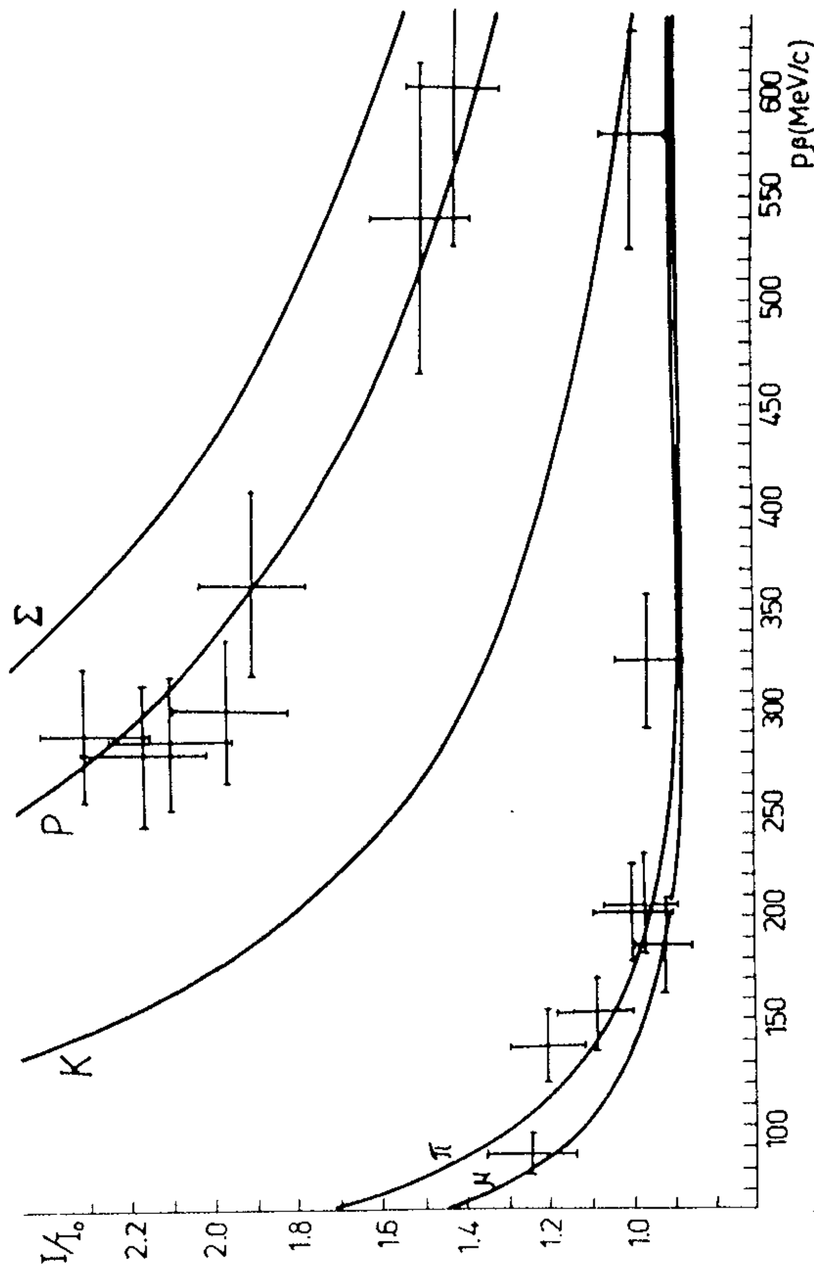

Fig.2. Dependence of relative ionization on $p\beta$ particles from the secondary stars.

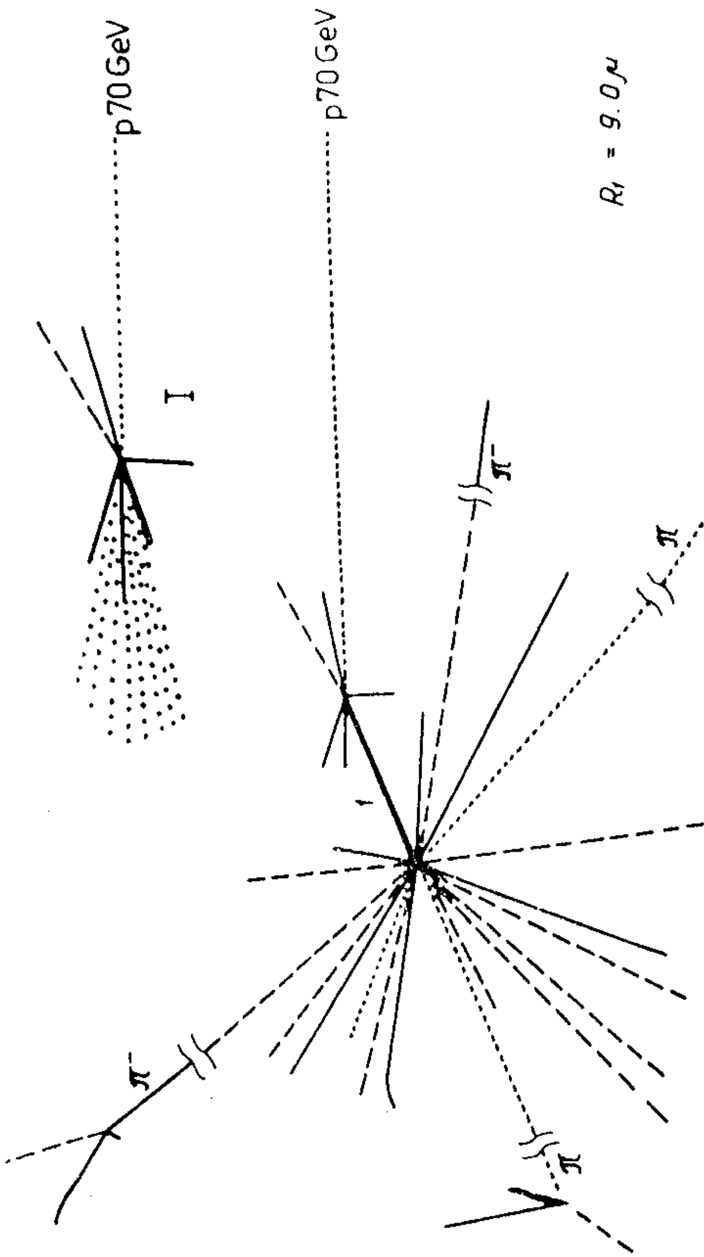

Fig.3. Schematic view of a "double" star with abnormal energy release at 70 GeV.

this fact as antiproton and antideuteron production presents grate difficulties.

As is seen from the Table, energy release in two events at 70 GeV and likely in one event at 250 GeV exceeds the maximum energy released in antiproton annihilation. If these cases are to be interpreted as antideuteron annihilation, the yield of $p < 60$ MeV/c slow antideuterons (three events out of five) will turn out to be of the same order as that of slow antiprotons - $R(\bar{D})/R(\bar{p}) \approx 1$, and according to our rough estimates, $R(\bar{D}/\pi^-)$ will make up 10^{-3}-10^{-4}.

According to measurements made by Yu.M.Antipov et al.[8], at ~12 GeV/c momentum the ratio $R(\bar{D})/R(\bar{p})$ is 10^{-4} and decreases with momentum decrease; at 10 GeV/c momentum the antideuteron relative yield is equal to $\sim 10^{-7}$.

Event concentration at less than 10 μ distances is difficult to explain; as is mentioned above, "double" stars were searched for at distances up to 500 μ . No event with high energy release was found at distances from 10μ to 500μ .

Another explanation possible seemed to be connected with supernuclei. Yet, to prove the existence of supernuclei observation of associative production of other particle with abnormally short life-time 10^{-12}-10^{-13} sec should be of prime importance.

To search for associative production all particle tracks from the primary stars were traced in view to observe charged particle decay and the neighbourhoods of the primary stars were scanned at a distance up to 3 mm in an effort to observe neutral particle

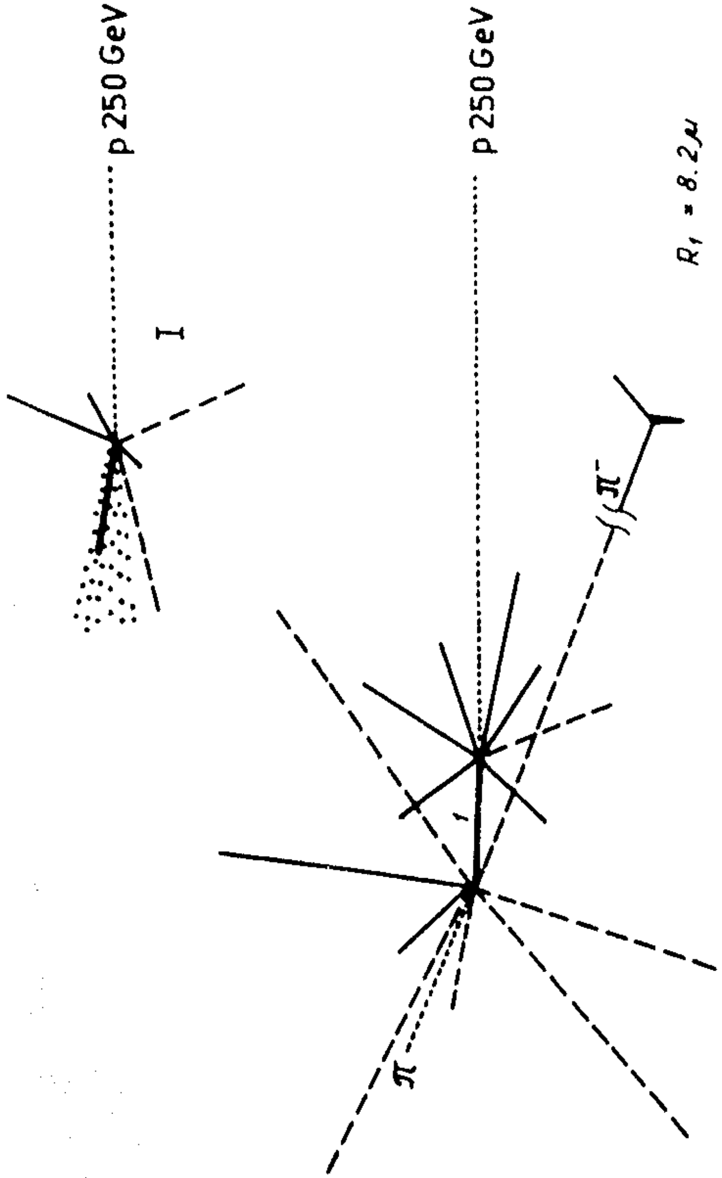

Fig.4. Schematic view of a "double" star at 250 GeV.

decays. No indications of particle decay were found. Therefore we believe that the splitting under observation cannot be with certainty attributed to a new type of nuclei with predicted properties.

The upper boundary of supernucleus observation may be represented as a product of the cross section for superon production in proton-nucleon interactions and the probability of a charmed baryon to be captured by a nucleus. At 70 GeV proton energy it is equal to 3.2×10^{-31} cm^2 and at 250 GeV proton energy it is equal to 2.2×10^{-31}cm^2.

To interpret unambiguously the observed secondary star production at short distances with abnormal energy release a detailed study of rare processes for appearance of high energy secondary interactions is necessary.

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