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SEARCH FOR EXOTIC PHENOMENA IN HIGH ENERGY NUCLEAR INTERACTIONS

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INTRODUCTION

At present it is experimentally established [1,2] that in interactions of various elementary particles and nuclei with nuclei in the nuclei fragmentation region π-mesons and other particles are observed far from kinematical limits for interactions of elementary particles with nucleon (cumulative effect). The bulk of this type experimental data gives us very important information on nuclear matter microstructure. In the last few years the possibility of appearance of some other effects in relativistic nuclei collisions has been widely discussed. This report presents several experimental investigations carried out recently at the High Energy Laboratory, JINR.

1. Cross sections of secondary fragments

An increase of inelastic cross sections of secondary fragments as compared to cross sections of primary nuclei with the same atomic number may be due to decreasing binding energy and other less trivial reasons [3,4]. Pictures of the 2-m propane bubble chamber* exposed to a carbon beam at 4.2 GeV/c per nucleon were used to measure inelastic cross sections of multi-

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* Alma-Ata - Belgrade - Bucharest - Budapest - Cracow - - Dubna - Moscow - Prague - Sofia - Tashkent - Tbilisi - - Ulan-Bator - Varna - Warsaw - Yerevan collaboration headed by Soloviev M.I.

charged stripped fragments. The fragments with momenta $P/Z \geqslant 3$ GeV/c and angles $\theta \leqslant 4^{\circ}$ were defined as stripped ones. To seek an interaction, all secondary fragments were scanned from the primary vertex on a length of 33 cm. Methodical and physical analysis [5] was based on 3700 events with multicharged fragment production.

The main methodical difficulty in such a type of experiment is the effect of overlapping secondary neighbouring tracks and stars. Due to this fact, the cross sections for spectator fragments were measured at a distance of ~ 10 cm from the primary vertex of the star. This corresponds to an excitation lifetime of $\tau_a \sim 10^{-10}$ sec.

Figure 1 presents the interaction cross sections for fragments versus their mass number A_f (circles). The cross sections of interactions [6] with propane for beams of protons, deuterons, helium and carbon are given by triangles. The dashed line is drawn through experimental points for nuclei from the accelerator. The interval of change of mass numbers is given by horizontal lines. Figure 1 shows that there is no appreciable increase of the cross sections for interactions of spectator fragments. This result is not in contradiction with the emulsion experiment data [4], where the conclusion is drawn of a 6%

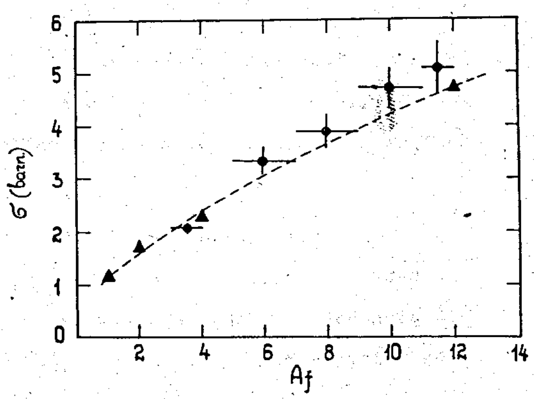


Fig.1. Interaction cross sections of secondary fragments of carbon relativistic nucleus with propane versus their mass number.

contribution of nuclei with abnormally large cross sections and a lifetime of $\tau_a \lesssim 10^{-10}$ sec.

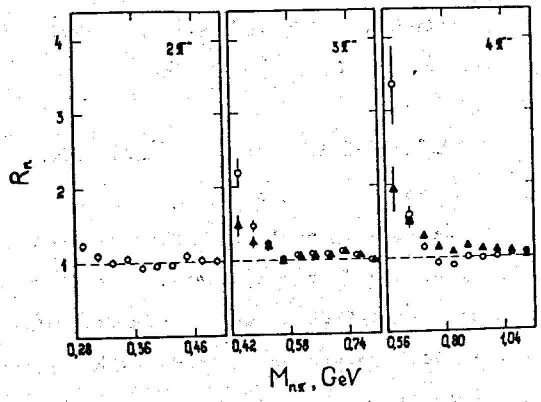
2. Correlated emission of π^--mesons

The observation of the interference effect [7] between two π^--mesons in nucleus-nucleus interactions [8,9] allowed the size of the π-meson generation region to be estimated. A relative contribution of interference phenomena in the systems of identical particles is essentially dependent on the dynamics of interactions. For instance [10], copious isobar production creates good conditions for these effects.

Here are presented data [11] on correlated emission of several π^--mesons produced in the interactions of carbon nucleus with tantalum at $P_0 = 4.2$ GeV/c per nucleon. Three tantalum plates (A=181) 1 mm thick were placed inside the working volume of the 2m propane bubble chamber. The search for correlated emission of π^--mesons was carried out by analysing effective mass spectra $M_{n\pi}$ of $n\pi^-$-mesons (n=2,3,4). The background $M_{n\pi}$-effective mass distributions were obtained by combining π^--mesons taken randomly from different events.

Figure 2 gives values of the ratios of the experimental to the background distributions $R_n = M^{expt}_{n\pi}/M^{backgr.}_{n\pi}$ for $n\pi^-$-meson systems versus $M_{n\pi}$. Tests of two versions of background are presented. The first one (circles) contains combinations made up of π^--mesons all being taken randomly from different events. The second version of background (triangles) differs from the first one in the following: only one of $n\pi^-$-mesons is taken from another event. It is seen that in both cases the experimental distributions exceed the background ones in the region of small effective masses. The effect is more pronounced for higher n.

Fig.2. Ratios of the experimental to the background effective mass distributions $R_n = M_{n\pi}^{expt.}/M_{n\pi}^{backgr.}$ for $n\pi^-$-meson systems versus $M_{n\pi}$.



The fact that the effect is seen against the second version of background indicates that there exist $3\pi^-$- and $4\pi^-$-meson correlations which are not due to 2- and 3-particle correlations, respectively.

3. <u>Abnormal β-decays of nuclei</u>

It is known that the lifetimes of β-active nuclei are $\tau_\beta \geq$ 11 msec and the maximum energy of β-particles is $T_\beta \leq 16.4$ MeV ($^{12}N_7$). If exotic superdense nuclei with large binding energy are formed in relativistic nuclei interactions, then the observation of abnormal β-decays with $\tau_\beta < 11$ msec and $T_\beta > 16.4$ MeV is not excluded [12].

The search for abnormal β-decays of nuclei by methods of hydrogen and propane bubble chambers with internal targets was carried out by Yu.Troyan's team. In the usual mode several particles are incident on the chamber at the time approximately corresponding to the minimum of pressure. If the active beam time is shifted to the left of the minimum, then at some time t_0 there will be no conditions for the formation of bubbles because of too large pressure. For this time t_0 an intensive beam of particles can be passed through the chamber which will

activate the liquid of the chamber and the internal target. As the pressure decreases, the conditions approach those required for bubble formation and at some t_1 $e^\pm$-tracks are well registered. Time $t_1 - t_0$ is a "dead" time of the chamber, and in this case it is equal to (5-10) msec.

The 2m hydrogen bubble chamber with tantalum targets was irradiated by 12.2 GeV/c π^--mesons. The 2m propane bubble chamber with Ni, Cu, Ta, Pb targets was exposed to beams of protons at P_p = (1.9; 3.4; 9.9) GeV/c, of helium nuclei at P_α = 0.95 GeV/c per nucleon and of carbon nuclei at P_c = 3.4 GeV/c per nucleon. No event of β-decay with an energy of $T_\beta > 16.4$ MeV was found. The estimate of the upper limit of the production cross sections for abnormal nuclei with a lifetime of (5-10) msec for different irradiations is between $(10^{-28} - 10^{-33})$ cm^2 per target nucleus.

Under optimal conditions and obtaining 10^5 pictures the given method allows one to measure the cross sections down to 10^{-35} cm^2. Experiments for shorter lifetimes can be done using special bubble chambers and streamer ones.

4. <u>Shock waves</u>

In recent years considerable attention has been given [14] to the theoretical and experimental studies of shock waves which could appear as a maximum in angular distributions of secondary particles. Indications of these features have been obtained in several works [15,16].

Angular distributions of secondary particles in carbon nuclei interactions at 4.5 GeV/c per nucleon with copper and lead nuclei were investigated by E.Okonov's team. The experiment [17] was done by electronics method. Events of central nuclei collisions were selected. The criterion of centrality was the absence of charged projectile fragments in a narrow cone of

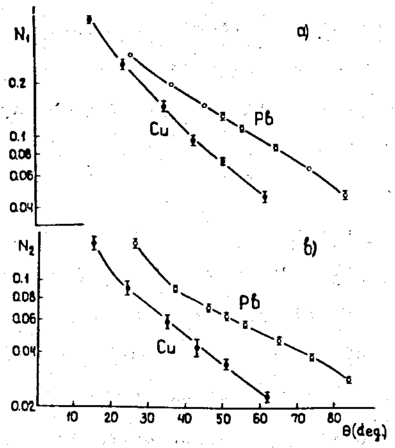


Fig.3. Angular dependence of the proton yield in central C Cu and C Pb-interactions.

$\pm$ 60 mrad. Estimates have shown that such a criterion corresponds to the selection on impact parameter $b \lesssim 2.5$ fm for C-Cu and $b \lesssim 4.5$ fm for C-Pb collisions. The registered particles mainly consisted of protons of two momentum intervals: $P_p \gtrsim 350$ MeV/c and $550 \gtrsim P_p \gtrsim 350$ MeV/c.

Figure 3 shows angular dependences of values N_1 and N_2 in central C-Cu and C-Pb interactions. These values are an average number of particles registered by a telescope per central interaction of carbon nucleus for the first and second momentum intervals. It is seen that anomalies in angular distributions are not observed. This experiment does not exclude the possibility of existance of a peak in angular distributions if it is formed by strong correlated $(\leq 5^{\circ})$ couple, triple particles and so on.

5. Multiplicity of π^--mesons

A maximum number of nucleons takes part in central collisions of nuclei. This creates optimal conditions for appearing collective effects. The experiment was carried out by E.Okonov's

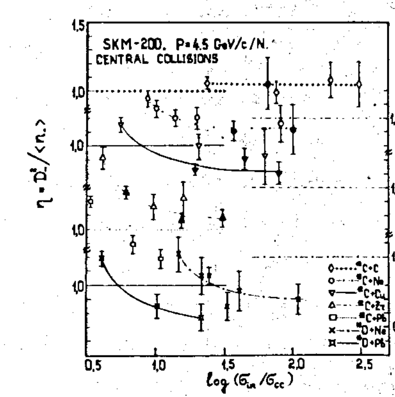
team* using the SKM-200 streamer chamber. The criterion of interaction centrality was the absence of charged projectile fragments A_p in a narrow forward cone of $(0-14)^{\circ}$. A part of experimental material was obtained with the use of a veto on stripped neutrons.

The analysis was based on ~ 12 thousand events. The dependence was investigated of a relative width of the distribution $P(n_-)$ on the multiplicity of π^--mesons $\eta = D_-^2/\langle n_-\rangle$ versus the logarithm of the total inelastic to the central collision cross section $\log(\sigma_{in}/\sigma_{cc})$.

Figure 4 presents values η for different conditions of angular selection. The curves are drawn through the experimental points. The straight lines of the same kind correspond to the Poisson distribution, $\eta = 1$. The black points correspond to trigger with an additional veto on stripped neutrons.

Thus, the conclusion can be drawn that in central collisions of nuclei η is considerably smaller than for inelastic interactions [17]. With increasing σ_{in}/σ_{cc}, i.e. decreasing

Fig.4. Dependence of a relative width of the distribution on the multiplicity of π^--mesons versus the logarithm of the total inelastic to the central collision cross section.



* Alma-Ata - Bucharest - Dubna - Moscow - Tbilisi - Warsaw Collaboration.

average impact parameter, η decreases to the plateau. The level of the plateau falls down to 0.7 - 0.8 with increasing A_t. These experimental data contradict the predictions of thermodynamic models, according to which [18] the distribution $P(n_-)$ in central collisions has to obey the Poisson law [18].

6. Six-quark state in deuteron

The proton spectrum from the deutron fragmentation on carbon at 0^o was measured by L.Strunov's team* using the one-arm magnetic spectrometer "Alfa" [19]. The deutron primary momentum was equal to 8.9 GeV/c. The measurement of proton yield was taken down to kinematical limits of the process.

In Fig.5 the solid curve is computed by the relativized Reid soft core wave function Ψ_{np} and the Glauber theory [20]. In a 5.8 - 6.8 GeV/c interval kinematically corresponding to the intermediate Δ-isobar contribution the experimental values

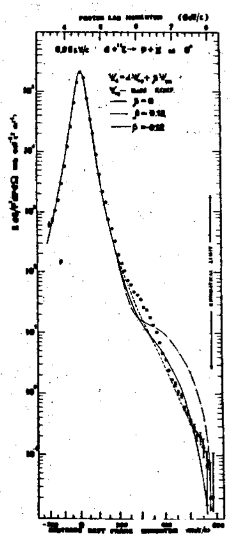


Fig.5. Proton yield at 0^o from deutron fragmentation $d + c \to p + x$ at $P_d = 8.9$ GeV/c.

* Dushanbe - Sofia - Warsaw - Kiev - Dubna Collaboration.

exceed the calculated ones. Using the s-wave oscillator model, the 6q component is introduced into Ψ_d and estimated in a 7 - 7.8 GeV/c region by the interference with Ψ_{np}.

In the frame of this model there is an evidence (see Fig.5) for the destructive interference with the np-state (having here, at small distances negative S-wave) and for the contribution of the 6q-state in deutron $\beta^2 \sim 1\%$.

CONCLUSION

Relativistic nuclei allow multinucleon interactions to be investigated essentially. Then a fundamental question arises. What degrees of freedom in dynamics will be revealed in nuclear matter?

At primary energies per nucleon, when channels of particle multiproduction have been already opened, quark degrees of freedom are of great interest. From this point of view studies of cumulative particle production are very important. These particles can be produced in the collision with flucton comparable to the size of hadrons. The search [21] for multibarion resonances is a problem of today.

The measurement of the yield of elementary particles depending on the atomic number of projectile nucleus is of importance [22]. In this case the primary energy per nucleon of projectile nucleus and the target atomic number are fixed. From physical and methodical points of view it is more convenient to perform an experiment with registration of antiprotons which consist of three antiquarks. Relativistic nucleus in the laboratory system can be presented as a parallel beam of nucleons. At the collision in the target nucleus beams of secondary particles will be created from projectile nucleons. It is supposed that some time is required to form elementary particles from constituents. If the formation time is comparable to the distance between points of interaction of projectile nucleons, quarks can be recombined to elementary particles from different sources. This case corresponds to quark plasma.

If quark plasma is realized, i.e. , overlapping of the beams of secondary particles at the quark stage, then a combinatorial increase of antiproton yield has to be observed with rising the atomic number of projectile nucleus. Binominal coefficient C_n^3 will be of great importance, where n is the number of antiquarks in plasma. Otherwise, the antiproton yield will increase directly as the average number of interacting nucleons of projectile nucleus.

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