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PROCEEDINGS OF THE 19th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

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B 11 Multibaryon Interactions at Relativistic Energies

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Great success of the quark models in describing both the static properties of hadrons and the reactions involving them makes it possible to apply to the study of more complicated and perhaps more critical phenomena for the test of the theory. In this connection, the study of the reactions involving multibaryon configurations have recently become still more popular in high energy physics. At the XVIII International Conference on High Energy Physics in Tbilisi several talks[1-5] were devoted to effects for which small internucleon spacings in the interaction of high energy particles with nuclei are essential. It is obvious that if these spacings are of the order of the confinement radius or less then the quark degrees of freedom must play a definite role. There exist estimates of the order of magnitude of the density of nuclear matter at which it transforms to a state of "quark plasma" and even possibly to a crystalline state.

The collisions of high energy particles and relativistic nuclei with nuclei are presently interpreted on the basis of the idea of asymptotic freedom and quark-parton models. The problem of confinement and quark interaction at large distances is also of great importance for their interpretation. Information on multibaryon resonances appears, in turn, to contribute greatly to clarifying the problem of confinement. The (ΛP) and possibly $(\Lambda\Lambda)$ and $(\Lambda\Lambda P)$ resonances discovered by Shakhbasian[7] have recently been interpreted[8,9] as multi-quark formations in a single "bag." The confirmation of the existence*[1] of such large "quark plasmons" would be very important, in particular, it would mean that we have already discovered a metastable state of superdense nuclear matter, *i.e.*, multibaryon states possessing elementary particle density.

Among a very large number of papers on interactions of high energy particles with nuclei and on the physics of relativistic nuclei submitted to the present Conference we have chosen only the results which deal in some way or other with the problems mentioned above and which are most adequate to the programme of the present Conference. Our attention is focussed on the one-particle distributions of particles produced in particle–nucleus and nucleus–nucleus collisions. Of most interest in the particle production is the region of limiting fragmentation of nuclei which is kinematically forbidden for one-nucleon collisions.

The particle production in this region is given the name of cumulative effect and the first data on cumulative production of mesons by relativistic deuterons on nuclei was reported as early as in 1972 at the XVI International Conference on High Energy Physics in Batavia.[10] Since that time a great deal of information on this effect relative to the class of hard collisions was accumulated. The kinematic limits are defined by the cumulative number N, that is by the effective number of the nucleons of a fragmenting nucleus involved in the reaction. For one-particle distributions the minimal value of N is determined by the kinematic limits imposed on the mass of the object taking part in the collision

$$\mathrm{I}+\mathrm{II}\rightarrow 1+\cdots \tag{1}$$

When $\exp|y_{\mathrm{I}}-y_{\mathrm{II}}|\gg 1$ in the region of the limiting fragmentation of nucleus I the relativistically invariant quantity $N^{\min}$ assumes the following values

$$N^{\min}=\begin{cases}\dfrac{E_1-P_{1L}}{m_p} & \text{in the rest system of nucleus I}\\[2ex] \dfrac{P_{1L}}{P_{\mathrm{I}}^0} & \text{in the rest system of a particle or nucleus II}\end{cases} \tag{2}$$

where P_{I}^0 is the momentum per nucleon, m_p the proton mass, $y_{\mathrm{I,II}}$ the rapidities, P_{1L} the longitudinal momentum. The cumulative effect corresponds to the region defined as $N^{\min}>1$. The scaling with the variable $N^{\min}$ is valid much better than with x_F.

The cumulative effect was predicted[12] on the

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*[1] See also H. Ikeda *et al.* contribution No. 625, session A5 of this Conference.

basis of the following assumptions. In the spirit of the parton models the one-particle distribution $\rho_{\mathrm{I}}^{\mathrm{II}}=(1/\sigma_{\mathrm{in}})E_1(d\sigma/dp_1)$ in the region of the limiting fragmentation of nucleus I is taken in the form of a superposition of the one-particle distributions which are due to the limiting fragmentation of the objects of mass Nm_{p} inside nucleus I

$$\rho_{\mathrm{I}}^{\mathrm{II}}=\sum_N P_N\rho_N^{\mathrm{II}} \tag{3}$$

Without further assumptions on the probability P_N for finding a constituent with mass Nm_{p} inside the nucleus and on an explicit form of ρ_N the following properties of the cumulative effect can be indicated:

1. The dependence of ρ on the properties of the target (particle II) must practically be absent due to limiting fragmentation. Thus, it is clear that to study the spectra of secondary particle beams which are due to the collisions of relativistic heavy ions the latter need not be accelerated. It is enough to study particle production on these nuclei at angles close to 180° under the action of e. g. protons. It was just in such experiments that the basic data on the cumulative effect had been obtained.[11]

2. The most important characteristic of the cumulative effect is the dependence of $\rho_{\mathrm{I}}^{\mathrm{II}}$ on the atomic weight of the fragmenting nucleus A_{I} since it enables us to make definite conclusions on P_N. The ρ_N values are expected to be identical for various nuclei.

3. The kinematic boundary enters ρ_N and defines in eq. (3) the lower limit of summation or integration over N if it is supposed in the spirit of parton models that N assumes continuous values. This means that the A_{I} dependence of ρ must be variable with changing kinematic boundary. The selection of the events containing cumulative particles (or group of particles) is the selection of the configurations in the wave function of a nucleus which contains N nucleons at so small distances at which their parton quark constituents are collectivized. The quark collectivization must strongly be affected by the increase of the quark interaction potential providing quark confinement. The order of magnitude of the cross section of the cumulative effect and the A_{I} dependence of ρ were predicted on the basis of the following assumptions:

a) The constituents move in the nucleus in an uncorrelated manner, that is, P_N is described by a binomial distribution

$$\frac{A!}{N!(A-N)!}\,q^N(1-q)^{A-N} \tag{4}$$

where q is the probability for a constituent to fall into the region occupied by a multinucleon cluster. The distance at which the nucleons lose their individuality was assumed to be $r\sim 0.6-0.7$ fm. This estimate is well confirmed by experiment.

b) The multinucleon cluster, or the large parton, possesses the properties of a usual hadron and to get estimates ρ can be taken from the data on particle production in p–p collisions.

The above assumptions enabled us to predict the following properties of the cumulative effect: If we insert in (4) $q=(\tau/\tau_0A^{1/3})^2\sim 1/A^{2/3}$ then a fast increase of the A dependence with increasing cumulative number is obtained (approximately an additional factor $A^{1/3}$ with increasing N by unity). The P_N probability must decrease rapidly with increasing N independently of our specific assumptions. Therefore it is natural to consider only the first term in (3), coresponding to $N=N^{\min}$. It follows from this consideration that in the region of cumulative particle production by relativistic nuclei $\sigma_{\mathrm{in}}\rho$ must depend on the atomic weight in an exponential manner A^m, where m increases monotonously with secondary particle momentum $m\simeq(2/3)+(1/3)(P_1/P_{\mathrm{I}}^0)$. At $P_1>P_{\mathrm{I}}^0$ the power exponent must exceed unity. The dependence of the cross sections on the atomic weight of target-nucleus II in the fragmentation region of nucleus I must vanish due to the property 1. As a result, the dependence of the cross section on the atomic weight A_{I} with changing y_1 from the values near y_{I} to the values in the vicinity of y_{II} changes very strongly: the exponent m changes by more than a factor of 10!.

The predicted properties of the cumulative effect have well been confirmed experimentally. The discovered dependences on the cumulative particle energy are described by simple exponentials. It is interesting to note that the simplest dependence

$$\sigma_{\mathrm{in}}\rho=\mathrm{const}\cdot A_{\mathrm{II}}^{n}A_{\mathrm{I}}^{m}\exp\left[-aN^{\min}\right] \tag{5}$$

where a is constant and $n\approx 1/3$, describes satisfactorily all the main regularities of the cumu-

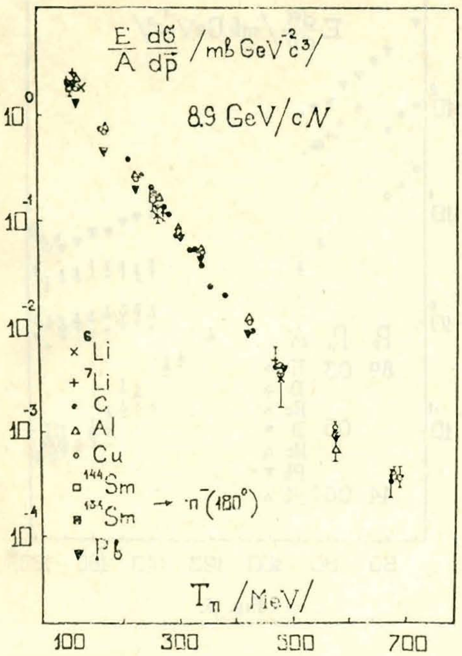

Fig. 1.

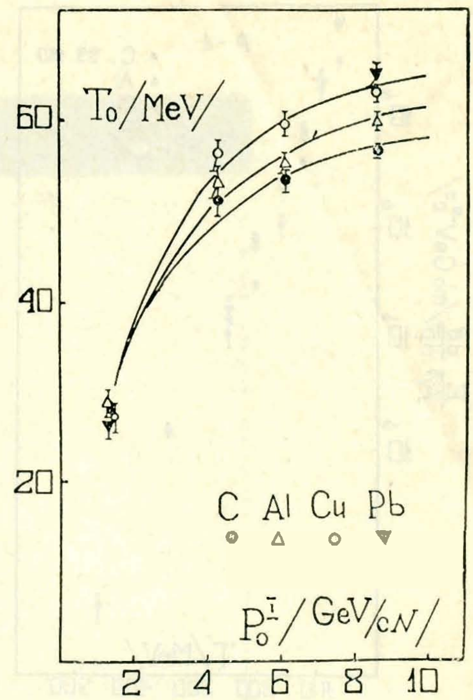

Fig. 2.

lative particle production including the angular distributions.

The main properties of the cumulative meson production were discovered in 1971 and studied by Stavinsky and his co-workers at Dubna.[1,10] The limiting fragmentation of nuclei from deuterium to uranium in the range of the cumulative numbers up to 4 had been investigated by this team. Pions, protons and nuclear fragments played the role of the cumulative particles.

Figure 1 shows[13] new data on the one-particle distributions in the reaction $P+A\to\pi(180°)$ in the region of fragmentation of nuclei at a proton momentum 8.9 GeV/c. The cumulative number $N^{\min}=1$ corresponds to $T_\pi=$ 270 MeV and $N^{\min}=2$ to $T_\pi=629$ MeV. The cross sections are normalized to the atomic weight. Similar data are obtained for other proton energies. A large amount of experimental data for the cumulative numbers from 1 to 2 is described by the simple formula

$$E_\pi\frac{d\sigma}{dp_\pi}=C\cdot A\cdot\exp\left[-\frac{T_\pi}{T_0}\right] \qquad (6)$$

where T_π is the pion kinetic energy, C and T_0 are constants. Figure 2 gives the dependence of T_0 on the momentum per nucleon $P_{\rm I}^0$ of the nucleus in the anti-lab. system for different nuclei. As is seen from the figure, T_0 weakly increases with A, the limiting fragmentation of nuclei into pions (independence of the cross section of $P_{\rm I}^0$) begins in the region $P_{\rm I}^0\approx 4$ GeV/c which is in accordance with the condition $|y_{\rm I}-y_{\rm II}|>L$, where $L\approx 2$ is the correlation length in the rapidity space.*² Figure 3 presents the data on fragmentation of nuclei into deuterons in the reaction $pA\to d(180°)$. The cross sections are in this case normalized to $A^{5/3}$ which shows the existence of A^m dependences with m larger than unity. Figure 4 gives new data on the limiting fragmentation of the lightest nuclei. The extreme points correspond to an almost absolute kinematic limit. Figure 5 shows the dependence of the inclusive meson production cross sections for different nuclei (H, D, He, Pb) on the emission angle for fixed meson momenta.

Protons and pions emitted in the backward direction in high energy hadron-nucleus interactions are studied by Fujioka *et al.*[14] The energy range is measured to be for protons and pions from ~80 to 300 MeV, the energy

*² It follows from this consideration that for the case when particle II is a pion, gamma quantum or a neutrino the limiting fragmentation of nuclei must begin at an energy lower than 1 GeV.

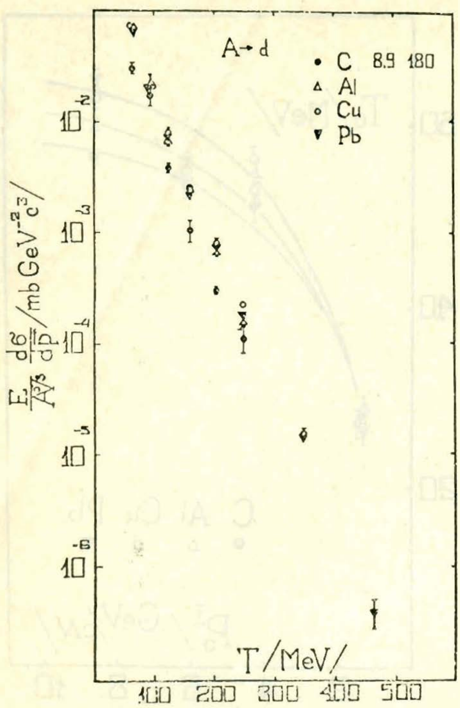

Fig. 3.

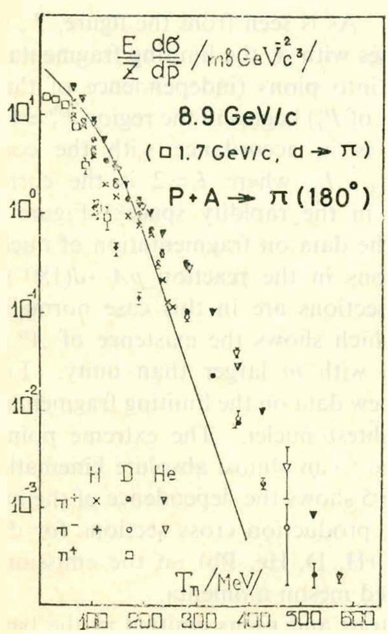

Fig. 4.

spectra are expressed by exp $[-T/T_0]$. T_0 for protons is 40–45 MeV within the range of primary momenta from 4 to 205 GeV/c. T_0 for pions is 60–65 MeV within the range of primary momenta from 12.6 to 28.5 GeV/c (see Fig. 6). The data obtained in such a

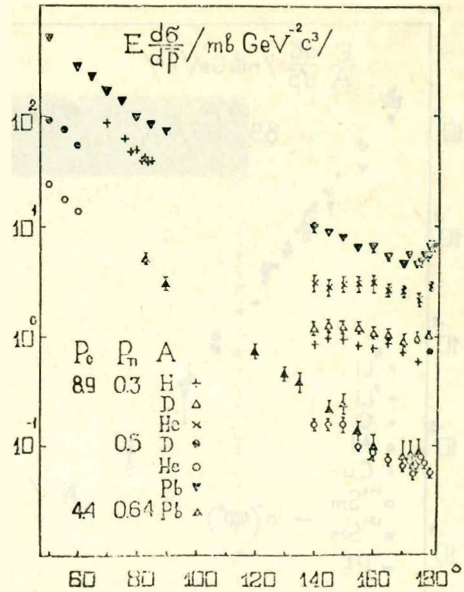

Fig. 5.

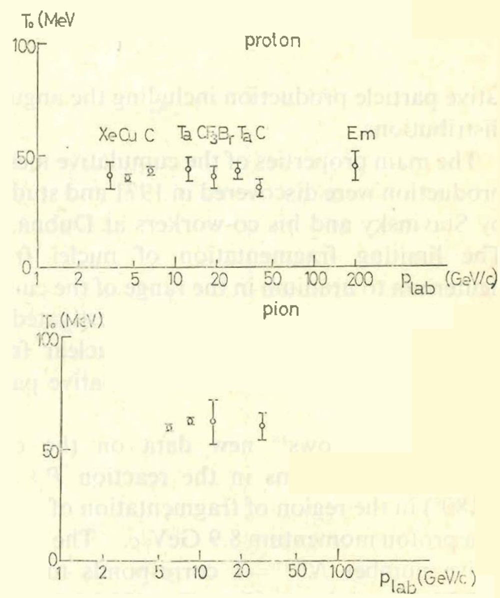

Fig. 6.

wide energy range well supplement the data for low energies and demonstrate that the limiting fragmentation of nuclei begins at rather low energies (cf. Figs. 2, 8 and 6). A good illustration of this assertion is Fig. 7 from ref. 15 which shows the distributions of mainly pions in the (πA) and (pA) reactions up to an energy of 400 GeV over the pseudo-rapidities of secondary particles. The region of limiting fragmentation corresponds to $-2<\eta<1$.

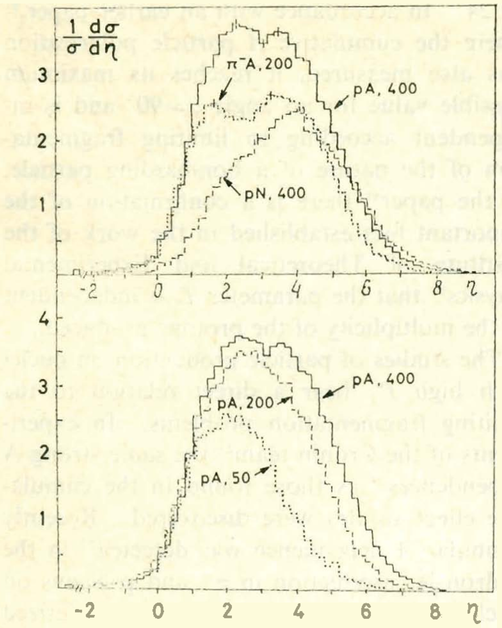

Fig. 7.

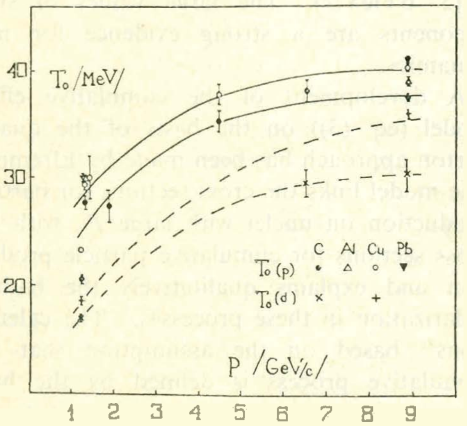

Fig. 8.

The yield of cumulative protons exceeds by about two orders of magnitude that of cumulative pions and the study of the cumulative protons had begun long before the notions of scale invariance and limiting fragmentation of nuclei became of current use. Figure 8 shows the T_0 values for different fragmenting nuclei as functions of the momentum of primaly protons: 1.22 GeV/c (180°); 1.28 GeV/c (140°)[17]; 1.39 GeV/c (150°)[18]; 1.86; 4.50; 6.57 GeV/c (137°)[19]; 8.9 GeV/c (180°)[20]. The dependences are seen to be regular and the agreement with the data of Fig. 6 gives evidence for the validity of limiting fragmentation. A

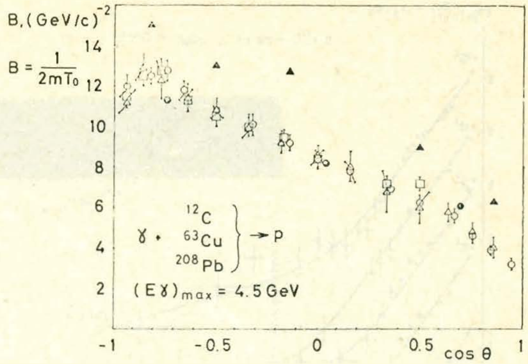

Fig. 9.

special emphasis should be placed on the investigations on proton production from nuclei at large angles performed by Leksin and his co-workers[19] and discussed in Tbilisi.[2]

A very interesting confirmation of the universal dependences such as exp $[-T/T_0]$ was obtained in Batavia where the cross section for proton production in the backward hemisphere in the antineutrino-neon interactions was studied (see the review by Nezrick[21]) and on the Erevan accelerator[22] where gamma quanta were used as particles II. Figure 9 gives the angular dependence of the parameter $B=1/2\, m_p T_0$, where m_p is the proton mass obtained in reactions of limiting fragmentation of nuclei C^{12} (⚲), Cu^{63} (⚲) and Pb^{208} (⚲) induced by gamma quanta with an energy $(E_\gamma)_{max}=4.5$ GeV from ref. 22. The data marked by (▲) are taken from ref. 23 and are relative to an energy $(E_\gamma)_{max}=1.2$ GeV. It is worth noting that the T_0 value obtained in this case for angles close to 180° is in satisfactory agreement with the discussed above ($T_0 \sim$ 40–50 MeV). New data on cumulative production of protons and Λ hyperons in the fragmentation of ^{12}C nuclei are reported in ref. 24. Pions with a 4 GeV/c momentum and neutrons with an average momentum $\langle P_n \rangle=$ 7 GeV/c were used as particle II. A large statistics enables us to see deviations from the simple exponential of the type exp $[-T/T_0]$. In Fig. 10, where the kinetic energy distribution of protons is given, attention is drawn to an irregularity in the region of $T\sim$ 60 MeV which is similar to that observed in the reaction d+p→p(pn). For the latter reaction the nature of this irregularity is quite clear: it is due to the interaction of

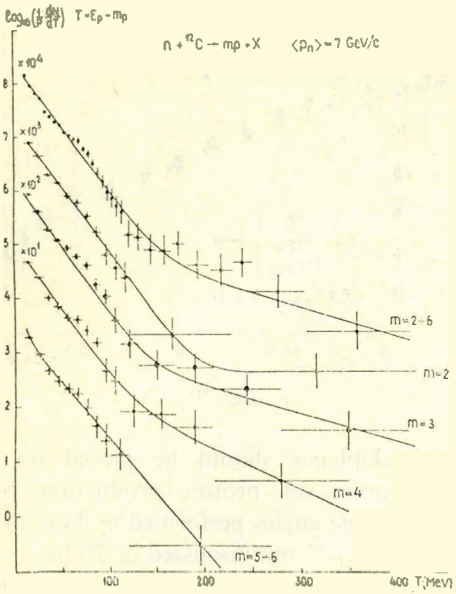

Fig. 10.

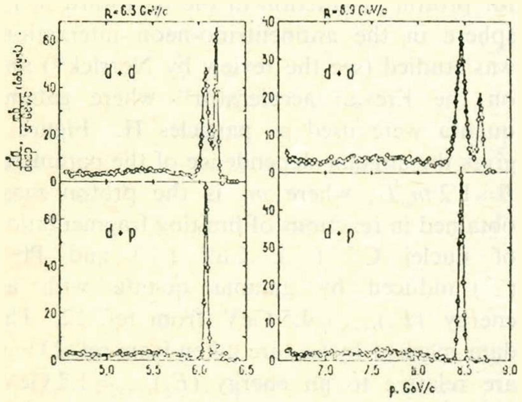

Fig. 11.

the two remaining nucleons in the final state.[20] This fact may indicate that a considerable fraction of the cumulative effect for baryon systems is due to the interaction in the final state which is disregarded in the theories based on the idea about hard scattering processes.

The importance of the effects of multiple interaction of nucleons in the relativistic collision of nuclei with relatively large momentum transfers is shown in ref. 26, where the interactions of 6.3 and 8.9 GeV/c deuterons with protons and deuterons for four-momenta transfers $|t|=0.41$ and 0.80 $(\text{GeV}/c)^2$ resp. were studied (see Fig. 11).

Of a particular interest for the theory is the cumulative Λ particle polarization measured in ref.24. In accordance with an earlier paper,[27] where the cumulative Λ particle polarization was also measured, it reaches its maximum possible value for an angle $\theta=90°$ and is independent according to limiting fragmentation of the nature of a bombarding particle. In the paper[24] there is a confirmation of the important fact established in the work of the Institute of Theoretical and Experimental Physics[28] that the parameter T_0 is independent of the multiplicity of the protons produced.

The studies of particle production on nuclei with high $P_\perp$ bear a direct relation to the limiting fragmentation problems. In experiments of the Cronin team[29] the same strong A dependences[59] as those found in the cumulative effect studies were discovered. Recently a similar A dependence was detected[30] in the hadron jet production in π^- and p beams on nuclei at high energies. If it is parameterized as A^m then m (π^- incident)$\simeq 1.3$ and m (p incident)$\simeq 1.45$ and roughly constant with $P_\perp(3-6\ \text{GeV}/c)$. The large values of such exponents are a strong evidence for new dynamics.

A development of the cumulative effect model (eq. (3)) on the basis of the quark-parton approach has been made by Efremov.[3] The model links the cross sections for particle production on nuclei with large $P_\perp$ with the cross sections for cumulative particle production and explains qualitatively the hadron polarization in these processes. The calculations[31] based on the assumption that the cumulative process is defined by the hard binary collision of a "fluctuons" 's parton with the parton of an incident particle give

$$d\sigma \approx \sum_q^A P_q^A d\sigma_N\left(x_2, \frac{x_1}{q}\right)\left(1-\frac{x_1}{q}\right)^{a(q-1)} \qquad (7)$$

The "fluctuons" are multibaryon configurations of mass $N^{\min} m$ at small relative distances, P_q^A is the same as P_N in eq. (3)

$$x_1 = -\frac{u}{s} \approx N^{\min}, \quad x_2 = -\frac{t}{s} = \frac{E_1}{E_{\text{II}}}$$

The hypothesis about nuclear density fluctuations was suggested by Blokhintsev[32] for expalining the knocking out of light nuclei by protons[33] from heavier nuclei when the momentum transferred to a light nucleus is much larger than the binding energy of this nucleus. As the estimates based on the quark bag model show,[31,34] the probabilities for the existence of multiquark fluctuons in nuclei are enough to account for the order of magnitude of P_N. A parton recombination model of cumulative hadron production which is similar to the one of ref. 31 was developed by Takagi.[35]

A very interesting rough version of the model specified by eq. (3) was proposed in ref. 36. The simplification of eq. (3) consists in the following (let particle II be a proton)

$$\rho_{\rm p}^{\rm I}(s, y, p_\perp) \approx \rho_{\rm p}^{\rm p}(\langle N_{\rm I}\rangle s, y+\log\langle N_{\rm I}\rangle, p_\perp) \quad (8)$$

where $\langle N_{\rm I}\rangle \simeq A_{\rm I}^{1/3}$ is the effective number of the nucleons involved in the collision. Dar and some other authors showed that eq. (8) is a very ecomonic way for describing a large amount of experimental material. In ref. 15 it is indicated that this version encounters some difficulties which seem to some of its authors[37] to be only a restriction on the range of applicability. There is also a certain development of the Strikman and Frankfurt suggestion[4] about the predominance of the pairing correlations in the wave function of nuclei for explaining the cumulative particle production.[38] In ref. 39 it is pointed to the importance of experimental study of the vector meson cumulative production and to a possibility of observing in these processes manifestation of the dynamic properties of the conserved quantum numbers (isospin, hypercharge and baryon number) suggested by the Yang–Mills theory.

In refs. 40, 41 the cumulative effect regularities are accounted for on the basis of the cluster model. In the rest system of the nucleus the pion decay spectrum of a moving cluster has, contrary to eq. (6), the form

$$f = \text{const}\cdot\exp\left[-\frac{P_\mu u^\mu}{T_0}\right]$$

where u^μ is the four-velocity of the cluster and P_μ the four-momentum of the detected pion. The pion production outside the kinematic limits for nucleon-nucleon collision is in this model due to the large mass of a cluster produced in the process of successive collisions.

At the Tbilisi Conference much attention was also paid to the opposite (with respect to the cumulative) part of single-particle spectra in the longitudinal rapidity space, that is, the region of fast particles produced on nuclei, and especially, to the problem of attenuation of fast particles with increasing atomic number. The

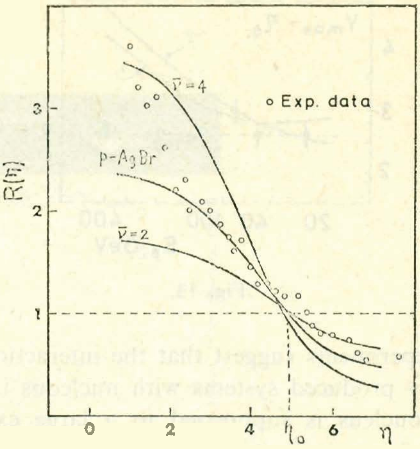

Fig. 12.

papers[15,42,45–49,61] submitted to the persent Conference are just devoted to this problem. The importance of the study of hadron–nucleus collisions in this region is due to the unique possibility of obtaining information about the space–time evolution of the collision process and the interaction of prehadronic matter.

Figure 12 from the paper by Suzuki[42] presents the comparison of the theoretical calculations by the fireball cascade model with the experimental data[15] for the ratio

$$\frac{1}{\sigma_{\rm pA}}\cdot\frac{d\sigma_{\rm pA}}{d\eta}\Big/\frac{1}{\sigma_{\rm pN}}\frac{d\sigma_{\rm pN}}{d\eta}$$

where $\eta = -\ln tg\,\theta/2$ is the pseudorapidity. In the range $\eta > 5$ R becomes smaller than unity and strongly decreases with increasing A. This manifestation of the many-nucleon effects has for the past two years been an object of many theoretical investigations including those on the basis of quark–parton models. In ref. 15 attention is paid to the position of the point η_0 where $R(\eta_0)=1$ as a function of energy which is especially important in connection with the new data on $R(\eta)$ at an energy 400 GeV.[15] The available experimental data indicate that $Y_{\rm max}-\eta_0 \approx$ const. Figure 13 gives the comparison of the dependence $(Y_{\rm max}-\eta)$ as a function of energy with the existing theories. The curves 1 and 2 are the results of calculations by the parton–cascade model.[43] Alternatively in the eikonal type models[44] this quantity should be constant and equal to ≈ 2.6 (the dotted line) which is in excellent agreement with experiment.

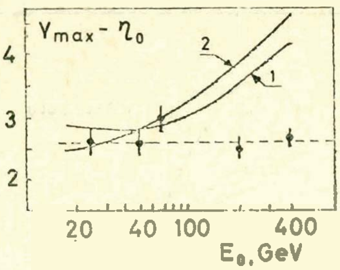

Fig. 13.

Experiments suggest that the interaction of newly produced systems with nucleons inside the nucleus is suppressed to a large extent. In order to understand these effects there have been various attempts to incorporate the space–time evolution in the model of multiple production on nuclei. However, up to the present we have at our disposal no theory of a sufficiently predictive power, the available theories can mainly give a partial explanation of the existing experimental data.

The radio of the multiplicities $R_0=\langle n\rangle_A/\langle n\rangle_p$ for pion production on nuclei and protons in the central region $(1.10\leq\eta\leq3.34)$ was measured by Bellini *et al.*[50] The experimental data can be approximated by the power function A^α with $\alpha=0.011\pm0.02$ which is in agreement with the predictions of the coherent tube model and the quark model in the impulse approximation[51] and is in disagreement with the version of the parton model developed in ref. 52.

The above considerations show that in the study of the processes of interaction of high energy particles with nuclei it is of particular interest to single out multiple production events which involve a few nucleons of the nucleus (multinucleon interactions). There are the following methods of such an extraction:

1. Extraction of cumulative particles in the region of limiting fragmentation (see above),

2. Extraction by the charge (hypercharge) of produced particles. In the papers submitted to the present Conference the multinucleon interactions are singled out on the basis of the followint criteria:

a) the charge $Q=n_+-n_-$, where n_+ is the number of π^+ mesons and fast protons, and n^- is the number of negative particles. For the reactions $\pi^-+{}^{12}C$ the events with $Q>0$ are attributed to the interactions with several (ν) protons ($\nu\geq Q+1$). The data on $\pi^-(\nu p)$ interactions[58] are compared with those on (π^-p) at the same energy (40 GeV). The quantity

$$R=\frac{1}{\sigma_{in}}\cdot\frac{d\sigma_{\pi(\nu p)}}{dP_L}\Big/\frac{1}{\sigma_{in}}\cdot\frac{d\sigma_{\pi p}}{dP_L}$$

as a function of the longitudinal momentum P_L in the lab. frame passes unity for $P_L=5$–7 GeV/c and $R<1$ for large P_L in agreement with the data discussed above.[15] A detailed comparison of the data[53] on inclusive reaction $\pi^-+C^{12}\to\pi^+(\pi^-)$ with the presently available theories of multiparticle production on nuclei is given in ref. 54.

b) double charge exchange $\pi^-+A\to\pi^+$. As the study[55] of this reaction shows at an incident momentum 4.7 GeV/c the main part of the cross section is described by a two-step mechanism using the well-known data on πN interaction. In the high energy tail of the positive particle spectrum we should apparently take into account the few-nucleon mechanism.

3. Large possibilities of extracting multinucleon interactions come from the investigations with relativistic nuclei.[11] In addition to the cumulative effect studies with relativistic nuclei started as early as in 1971,[10] the determination of ν by the number of the proton spectators Z_s: $\langle\nu\rangle=2(Z-\langle Z_s\rangle)$ (Z is the incident nucleus charge, $\langle Z_s\rangle$ the average charge of stripped particles) was also found to be a good method.[58] The latter was used to establish[56] that the π^- meson and fast proton multiplicities increase in proportion to $\langle\nu\rangle$ while the change in the g-particle multiplicity is slower with increasing $\langle\nu\rangle$.

In earliest discussions of perspectives of the relativistic nuclear physics sceptics asserted that the nucleus–nucleus collisions would be very complicated and would give little information. The invalidity of this scepticism is shown in Fig. 14 which gives a photograph obtained from the Dubna propane bubble chamber.[56] The event is a peripheral interaction of a relativistic carbon nucleus of an energy of 50 GeV with a carbon nucleus of propane with a subsequent central interaction of the nucleus fragment with the carbon nucleus. The multiparticle production of this type is found to be simpler from the topological viewpoint than those in p–p collisions at an energy of hundreds of GeV. The experimental data show that

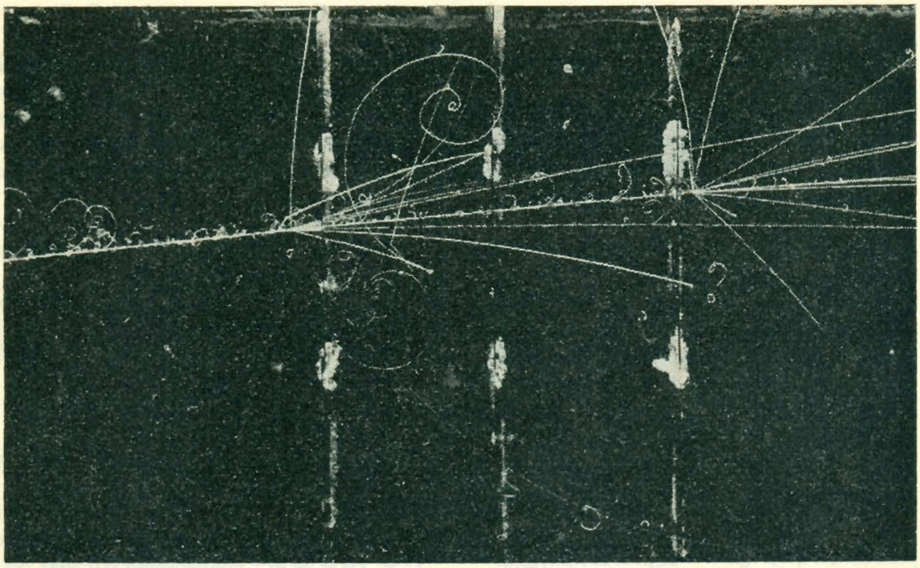

Fig. 14.

the average number of the nucleons of the bombarding nucleus interacting with a target-nucleus $\langle \nu \rangle$ is rather large. For example, it reaches $\langle \nu \rangle = 6.00 \pm 0.60$ for the collision of the carbon nucleus with the tantalum nucleus. The tantalum plates were placed inside the working volume of the propane chamber.

The similarity of multiparticle processes occuring in nucleus–nucleus and p–p collisions has clearly been proved on a streamer chamber.[57,25] The inelastic nucleus-nucleus cross sections are large and agree well with a simple geometric picture.[56–58,60]

Conclusions

1. Since the XVIII International Conference in Tbilisi a large amount of experimental information on multinucleon interactions has been obtained.

(a) The range of an approximate validity of the limiting fragmentation of nuclei has been clarified.

(b) The universal energy dependences of the cross sections in the cumulative region have been clarified and improved.

(c) Data on the angular distributions and polarization of the cumulative particles have been obtained.

(d) Strong A dependences have been observed not only in the cumulative effect and production of particle with large $P_{\perp}$, but also in the production on nuclei of hadron jets.

(e) Some dependences of the cumulative particles on the quantum numbers have been established.

2. The study of different manifestations of quark plasmons (fluctuons) in nuclei and multibaryon resonances predicted by quark models is an important and extensively developed trend of the high energy physics.

3. The attempts to construct a theory of phenomena related to large momentum transfers to multinucleon systems must cover all the balk of experimental data from (a) to (e). The most promising candidate for such a theory—the quark–parton theory of hard collisions—needs further development.

4. The possibility of studying the space–time picture of development of the strong interaction process by means of hadron–nucleus interaction and the particle formation length concept need further theoretical and experimental grounds.

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59. In the paper by J. Kishiro, *et al.* (contribution No. 409, Section B11 of the present Conference) similar strong A dependences have been observed for inclusive π^+ production for $0.3 \leq P_\perp \leq 1.0$GeV/$c$ in p nucleus and π^+ nucleus collisions at $P_{\mathrm{Lab.}} = 4.3$ GeV/c, that is in the region of relatively low energies.
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