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THE JINR EXPERIMENTAL PROGRAMME IN HIGH ENERGY PHYSICS

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ABSTRACT

A review is given of recent works of the Dubna experimentalists in the high energy physics.

1. INTRODUCTION

The topic of my lecture is the scientific programme of the Joint Institute for Nuclear Research, Dubna, in particle physics.

Let me say firstly few words about the structure and organization of the Institute.

The Joint Institute for Nuclear Research in Dubna was established almost 30 years ago, in March 1956, on the basis of two soviet scientific laboratories. One of them disposed of the 680 MeV synchrocyclotron which operated since 1949. In the other laboratory the construction of the 10 GeV synchrophasotron was in the final stage. This accelerator was put into operation in 1957.

At present eleven member states - Bulgaria, Hungary, Vietnam, the German Democratic Republic, the Korean People's Democratic Republic, Cuba,Mongolia, Poland, Romania, USSR and Czechoslovakia contribute to the Institute. JINR employs about one thousand scientists, more than six thousand people work in its laboratories, one thousand and a half visiting scientists from the member states come annually to work in Dubna.

Table 1 shows the structure of the Joint Institute Administration.

The supreme body of the Institute is the Committee of Plenipotentiaries of the governments of Member States which is convened annually and considers the major problems of the Institute's activity.

The Finance Committee is concerned with the annual budget, contributions from the member states, etc.

The research policy of JINR is determined by the Scientific Council which is convened twice a year. The Council submits its recommendations on experimental planning and finances, the construction of new facilities and buildings to the Committee of Plenipotentiaries. There are also 3 sections of the Council on High Energy Physics, Low Energy Physics and Theoretical Physics. The Sections of the Council have specialized committees which are concerned with research techniques.

The JINR directorate is reelected each three years. Since 1965 the Director of the Institute is the distinguished Soviet physicist and mathematician N.N.Bogolubov. The present Vice-directors are Professor Elias Entralgo from Cuba who is responsible for research in High Energy Physics, and Professor Aureliu Sandulescu from Romania, who is responsible for research in Low Energy Physics. Professor Yuri Denisov is appointed as

Administrative Director.

JINR has 6 laboratories, each almost equivalent to a large institute, and associated departments. Table 2 presents the structure of the JINR's laboratories and the subjects of their research.

As you see, the scale of the scientific research at the JINR is quite large. The Joint Institute is one of the rare centers where almost all branches of the nuclear sciences are developed, namely, research in High Energy Physics and Low Energy Physics, in physics of condensed matter, in neutron physics, theoretical physics, development of the accelerators. This fact prooves that there are large possibilities to enrich the research in the intermediate branches of sciences.

The Institute provides good facilities to accomplish the various experiments. Table 3 gives the image of the facilities at the Institute.

But one of the most important instrument to probe Nature and promote science is the international cooperation owing to which physisicsts have the possibility to use most sophisticated machines at other laboratories and centers.

Let me proceed to the main topic.

As I already said, one of the principal trends of the JINR scientific programme is research in high energy physics. The experiments are carried out mainly at the Serpukhov proton-synchrotron and CERN's accelerators.

But there is another branch of physics developed in Dubna by the initiative of academician A.M.Baldin which is called relativistic nuclear physics. The programme of the investigations in this field started in 1970 at the Dubna synchrophasotron and now is considerably enlarged. By 1988 the construction of the NUCLOTRON - accelerator of relativistic nuclei on superconducting magnets - is planned.

A number of experiments on elementary particle physics are carried out at the Dubna low energy facilitiies, for example, at the Dubna neutron reactor.

2. EXPERIMENT CARRIED OUT AT THE SERPUKHOV PS.

Let me say in more details about the physics programme and experiments carried out at the Serpukhov proton-synchrotron.

During more than 17 years the Joint Institute collaborates with the Institute of High Energy Physics in Serpukhov. 25 large experimental set up of the Institute were used to carry out experiments at the Serpukhov PS. 30-50% of operational time of the PS was used for JINR.

Actually the Serpukhov machine started to operate in the Booster mode. Table 4 shows the principal installations of the Joint Institute used at the Serpukhov PS.

2.1. The BIS-2 - filmless spark chamber spectrometer is an "old" set-up located in the neutron beam of the PS. The energy of neutrons - 20-70 GeV/c. Experiments are designed for a search of charmed particles produced in the diffraction processes. During last two years charmed baryons Λ_c^+ produced

in the interaction of the 40-70 GeV neutrons with various targets have been studied. The analysis of the two channel production of Λ_c^+ was made:

$$\Lambda_c^+ \to \Lambda^\circ \pi^+ \pi^- \pi^+; \quad (1)$$

$$\Lambda_c^+ \to \bar{K}^\circ p \pi^+ \pi^-. \quad (2)$$

It was found that the invariant cross section which is described by the relation

$$E\frac{d^3\sigma}{dp^3} \approx e^{-Bp_\perp} \cdot (1-X)^n,$$

where $p_\perp$ is transverse momentum, X is scale variable has the following parameters:

$$B = (2{,}5 \pm 0{,}6)\ (\mathrm{GeV/c})^{-1}; \quad n = 1{,}5 \pm 0{,}5.$$

The asymmetry of outgoing baryons Λ° and P in the Λ_c^+ decays into two channels 1 and 2 relative to the Λ_c^+ plane production has been studied for the first time. The value of the asymmetry have been found as follows:

$$A(\Lambda^\circ) = +(0{,}34 \pm 0{,}22); \quad A(p) = -(0{,}23 \pm 0{,}12).$$

It may be considered as indications of Λ_c^+ being produced polarized (see fig. 1).

2.2. The liquid hydrogen bubble chamber "Liudmila" was used over many years in the experiments studing processes of multiparticle production at high energies. The chamber has a track sensitive target filled with a liquid deuterium. It was exposed in the beams of the 22.4 GeV antiprotons and 11.5 antideuterons.

The last results are concerned with the study of the interaction of antideuterons with deuterons and protons at 12.2 GeV.

On the basis of $\bar{d}d$-interaction analysis the topological cross sections σ_n have been determined, as well as average multiplicities of charged particles $\langle n \rangle$, the ratio $\langle n \rangle / D$ (where D is the standard deviation), the correlation function f_2^{--} and KNO-distribution for $\bar{d}d$-interactions at 12.2 GeV/c and $\bar{n}n$-annihilation at 6.1 GeV/c. For the latter process the values of $\langle n \rangle = 4.67 \pm 0.05$ and $\langle n \rangle / D = 2.20 \pm 0.04$ have been obtained. In the case of multinucleon interactions the values of $\langle n \rangle$ and $\langle n \rangle / D$ are higher by 30%. The estimation of the bottom limit of the cross section of the full annihilation of antideuteron with deuteron has been found as follows:

$$\sigma_{an}^{\bar{d}d} > 0{,}12 \text{ mb}.$$

With the help of statistics on dp-events the analysis of elastic $\bar{n}p$-

interactions at 6.1 GeV/c in the reaction $\bar{d}p \to \bar{p}p\bar{n}$ has been performed. The total cross section of this channel of the reactions (10.4±0.7) mb and the dependence of the differential cross section over the square of the momentum transferred agree with the calculations by the Glauber model. For the elastic cross section of the $\bar{n}n$-interactions the slope of the diffraction cone $b=12.7\pm1.3$ in the region $|t| < 0.2$ GeV/c^2 agrees with the value of the b parameter for the $\bar{p}p$-interactions at the close energies. This result does not confirm the difference of the value b (which was observed earlier from the $\bar{p}p$-interactions data) determined for the $\bar{p}n$-interactions.(see fig.2).

2.3. The next JINR installation operated at the Serpukhov PS is the 5 meter magnetic spark chamber spectrometer MIS.

With the use of this spectrometer the joint CERN-JINR experiment is carried out. The physicists from Italy (INFN) participated actively in this experiment. The analysis of the resonances in the 3 pion system produced in the coherent processes on nuclei in now completed. The following processes

$$\pi^- + A \to \pi^+ + \pi^- + \pi^- + A$$

were studied at the energy of the incident π-meson of 40 GeV.

As the result of the investigation of the 3 pion system, the spectrum of π-meson excitation levels has been experimentally studied for the first time both by orbital and by radial quantum number. The discovery of the two new states of the pi-meson which are interpreted as radial excitations of the quark-antiquark system has been made. This prooves the composite structure of the lightest hadron. Recently these results were adequately confirmed in the experiments carried out at the FNAL's machine in Batavia.

Besides this result, some indications about a possible existence of the resonance states corresponding to the radial excitations of the A1, A2 and A3 mesons have been obtained. The widths and possible probabilities of the A3-meson decay into three channels have been determined: A3 $\to f\pi$, $\rho\pi$ and $\epsilon\pi$.

Table 5 demonstrates the parameters of the resonance states in the 3 pion system found in the experiment performed with the MIS spectrometer.

2.4. The SIGMA-AJAX experimental set-up consists of a broad-aperture magnet and a gamma-spectrometer designed to study the structure of light hadrons. It is being used in the joint JINR-IHEP experiment. The study of the processes of the pion pair production by pions near threshold in the Coulomb field of nuclei has been completed. The cross section of the reaction

$$\pi^- + (A, Z) \to \pi^- + \pi^\circ + (A, Z)$$

was determined for nuclei C, Fe, Cu, in the field of the Coulomb production $t < 10^{-3}$ (GeV/c)^2 and invariant masses of the system $(\pi^-\pi^\circ)$ $S < 10 m_\pi^2$. The results of this experiment agree with the generally adopted assumption about the availability of three colour degrees of freedom of quarks (included in 1965 by Bogolubov, Struminsky, Tavkhelidze, and Han, Nambu) and, therefore, are an independent confirmation of the fundamental postulate of the QCD

taking into account the validity of the important theorem on chirality anomalies which relates the amplitudes of the processes $\gamma \to 3\pi$ and $\pi^\circ \to 2\gamma$. (see fig. 3a).

The analysis of data obtained in this study of Compton effect on the pion allowed to determine for the first time the value of the pion electromagnetic polarizability equal to $\beta_\pi = (-7.1 \pm 2.8)\ 10^{-43} cm^3$. The experimental estimation of the sum of electric (α_π) and magnetic (β_π) polarizability of the pion was also obtained. It is equal to $\alpha_\pi + \beta_\pi = (1.4 \pm 3.1)\ 10^{-43}\ cm^3$ (see fig. 3b).

2.5. The physics program of the experiment carried out with the help of the magnetic spectrometer "POSITRONIUM" is now completed. The value of the relative probability of the decay of π°-meson into the positronium and gamma-quantum is obtained: $W = (1 \div 2)\ 10^{-9}$. To compare, the rarest from the earlier observed particle decays, the K^O decay $K^\circ \to \mu^+\mu^-$ has the probability equal to $W = (9.1 \pm 1.9)\ 10^{-9}$.

2.6. The analysis of data on measurement of the polarization in the $\pi^- + p \to \pi^\circ + n$ charge exchange reaction has been performed in the joint JINR-IHEP experiment with the help of the "POLARIMETER" set-up. The energy of the incident pion was 40 GeV/c. Data published previously did not take into account the neutron recoil. The actual analysis has included both the neutron recoil and pions. It was found that the dependence of the polarization from the momentum transferred had a complicated character (see Fig. 4a) and 4b) and cannot be explained in the framework of the standard theoretical approaches.

The azimuthal asymmetry was changed in the reactions $\pi^- p \to \omega n$ and $\pi^- p \quad K^O + \Lambda$ within the momenta transferred of $0.15 \leq t \leq 1.2\ (GeV/c)^2$. The average value of the asymmetry in this momentum range was $(22 \pm 5)\%$ for the reaction $(\pi^- p \to \omega n)$.

The asymmetry was measured for the first time in the reaction $\pi^- p \to \pi^\circ + X$ of the inclusive production of zero pions at 40 GeV/c at the angle of 90^O in the cms. An interesting result of these preliminary measurements is the asymmetry different from the zero in the inclusive process. The average value of the asymmetry within the momenta transferred of $1.2 \leq p_\perp \leq 2.2$ GeV/c is $(10.0 \pm 3.4)\%$.

A number of joint JINR-IHEP experiments will be soon carried out with the help of installations developed and built by mutual efforts. At the end of this year the neutrino detector will be put into operation at the Serpukhov PS. The program to study the so-called "tagged" neutrinos is being developed, as well as the project of Hadron Spectrometer of a new generation is under way.

3. JOINT EXPERIMENTS PERFORMED AT THE CERN ACCELERATORS

3.1. Dubna physisicts together with Italian colleagues from universities of Torino, Padua and Pavia participate in the experiments performed at the LEAR (low energy antiproton ring). The low energy antiproton interaction

with ^{4}He and ^{20}Ne nuclei has been studied. The cross sections of different channels of the annihilation of antiprotons with these nuclei have been determined. The data on $\bar{p}$ ^{4}He interaction were used to obtain a very important cosmological limitation of the antimatter quantity in the early Universe (at the period of time $10^3 < t < 10^{13}$ sec from the beginning of expansion). It was Ya.B.Zeldovich who for the first time paid attention to a possible existence of the connection between the $\bar{p}^4$He annihilation characteristics and astrophysical parameters. The analysis of the LEAR experimental data allowed to obtain the value of the limitation for an admissible tolerance of antimatter in the early Universe as follows: $R \leq (0.7 \div 1.1)10^{-3}$, where $R = n_{\bar{p}}/n_p$.

3.2. In the joint JINR-CERN muon experiment to study the deep inelastic muon scattering on nuclei of deuterium, nitrogen and iron at 280 GeV it was shown that the ratio of nucleon structure functions obtained for data with the use of iron, deuterium, and nitrogen, deuterium targets and at the fixed value of the scalar variable X, was not dependent from the square of 4-momenta transferred Q^2. The decrease of the structure function ratio with the increase of X within $0.2 \leq X \leq 0.7$ and at the energies of $50 \leq Q^2 \leq 200$ $(GeV/c)^2$ is well described by the linear law R=a + bx, with the parameters: a=1.16±0.03; b=-0.56±0.08 for Fe/D_2 and a=1.10±0.04; b=-0.39±0.09 for N_2/D_2 (see Figs. 5a,b).

To fit data on the ratio of nucleon structure functions obtained in the deep inelastic electron-nuclei and muon-nuclei reactions in the region of $X < 0.4$, it was proposed to use in the analysis of the eA-scattering an assumption about the dependence of the ratio of the longitudinal and transversal virtual photon cross sections from the atomic weight of the nucleus A in the form:

$$R(A) = \sigma_L/\sigma_T = aA^{1/3}$$

with the parameter d=0.08.

3.3. It is known that JINR is responsible for a production and testing of the DELPHI Hadron Calorimeter detectors in the framework of the Agreement between JINR and CERN.

Now the workshop and technological line to produce streamer detectors are ready to be put into operation.

4. EXPERIMENTS CARRIED OUT AT THE DUBNA SYNCHROPHASOTRON

Relativistic nuclear physics is a new region of research which, from the one hand, opens large perspectives to develop nuclear physics and, from the other hand, is closely related to the elementary particle physics at high energies.

Relativistic nuclear physics gives possibilities to investigate not only the behaviour of nuclear matter at small internucleon distances and extreme conditions, for example, high pression and temperatures, but to study the states of hadron matter - the quark-gluon plasma. This enables to verify in

principle the theory of strong interactions-quantum chronodynamics, to study closely such problems as confinement and multiquarks interactions.

The scientific program on relativistic nuclear physics in Dubna is carried out by using the unique beams of relativistic nuclei of the synchrophasotron. These beams with the energy of 4 GeV/nucleon were obtained due to the development and construction of new types of multicharged ion and nuclei sources and also to the improvement of a whole system of the accelerator. Table 6 demonstrates experimental facilities which are used in these investigations.

Let me say about some principal results:

The criterion is formulated to define the region of kinematical variables in which hadrons are failed to proceed as quasiparticles of nuclear matter:

$$b_{ik} = -\left(\frac{p_i}{m_i} - \frac{p_k}{n_k}\right)^2 \geq 5$$

where P_i, is the 4 momenta of particles with the mass m_i partcipating in the reaction. The condition $b_{II,I} > 5$ for primary particles indicates that the energy of interacting particles per nucleon has to be more than 4 GeV when the limiting fragmentation begins. Thus, two conditions are essential to discriminate quark degrees of freedom in the cumulative particle production: $b_{II,I} > 5$, $X > 1$. X is the scale variable - the ratio of the energy of produced particle to the initial energy. The region of $10^{-2} < b_{ik} < 5$ is transitional from the domination of the nucleon degrees of freedom to the quark-gluon degrees which are manifested in relativistic nuclear collisions.

Experimental data for the ratio of K^+/K^- mesons yielding in cumulative proton-nuclei interactions (see Fig. 6) show that the sea quark distribution in the $X > 1$ is different from the momentum distribution of valence quarks by the constant $S(X)=1/5OU(X)$.

By using the DISK-2 experimental set-up, the data have been obtained to determine the A dependence of the cumulative pion cross sections at X=1,3 and X=2,1 (see Figs. 7 a,b) in proton-nuclei interactions at P=9 GeV/c. Two series of measurements have been performed. The first one corresponded to the pion momentum of 500 MeV/c and the emission angle of 168^O, the second serie - to the momentum of 800 MeV/c and the emission angle of 162^O. As targets the following elements were used:

- the first serie: ^{6}Li, ^{7}Li, Be, C, Mg, Al, Si, ^{54}Fe, ^{56}Fe, ^{58}Fe, ^{58}Ni, ^{61}Ni, ^{64}Ni, Cu, ^{64}Zn, ^{112}Sn, ^{118}Sn, ^{144}Sm, ^{154}Sm, ^{182}W, ^{186}W, Pb;
- the second serie: ^{6}Li, Be, C, Al, Cu, ^{144}Sn, ^{124}Sn, Sn, W, Pb.

The dependence of the cross section ratio per nucleon from the atomic number of the nucleus at X=1.3, namely, the increase of cross section with the increase of a A at $A \lesssim 30$ differs from the ratio obtained at SLAC for $X < 1$, where the ratio of structure functions decreases with the increase of A. This indicates to the change of the interaction mechanism at the transition to the cumulative region.

Meanwhile, the character of the A-dependence of the ratio σ_A / σ_{Pb} at X=2,1 remains the same as at X=1,3 regardless of the decrease of the cross section absolute values approximately by a factor of 500.

The relativistically invariant description of multiparticle processes is proposed for the case when hadrons and nuclei collide in the space of relative 4-velocities b_{ik}. The main goal of the transition to the b_{ik} variables instead of the classic variables - momenta and energies - is to demonstrate that at $b_{ik} >> 1$ the function of distribution

$$F(b_{I\,II}\ ,\ B_{I1}\ ,\ b_{I2},\ \dots\ ,\ b_{II\,1}\ ,\ b_{II\,2}\ ,\ \dots\ ,\ b_{12},\ \dots)$$

which corresponds to the invariant cross section of the n-particle production is monotonously and sufficiently fast decreased with the increase of b_{ik}. This property may be presented as the principle of correlation relaxation which was proposed by N.N.Bogolubov in statistical physics. On the base of this conception a new relativistically invariant determination of the secondary particle jets has been done instead of the traditional approach by using the variables "spherecity","trust" etc. Fig. 8 shows the distribution of negative pions by b_k in jets produced in the π^- C interactions at the momentum of 40 GeV/c. It is seen that the distributions by the b_k variable for the both jets (in the region of the nucleus fragmentation and in the region of fragmentation of the π^--meson) coincide within the experimental errors. In the region of $b_k \gtrsim 4$ of the π^--mesons distribution the ratio of dN/db_k is described by exponential function $F(b_k)=A \exp(-b_k/ \langle b_k \rangle)$ with average value $\langle b_k \rangle \approx 4$ in both jets.

The study of the characteristics of K^o-mesons and Λ-hyperons produced in the quarks and diquark fragmentation processes of π-p and π^--C cumulative interactions at P=40 GeV/c has denoted that the fragmentation of quarks into K^o-mesons and Λ-hyperons was similar to the fragmentation in the e^+e^--annihilation (See Figs. 9 a,b). The functions of the diquark fragmentation for π^--p and cumulative π^-C-interactions are identical. This conclusion demonstrates the universal character of the quark and diquark fragmentation in soft and hard processes.

The study of the cumulative hadrons (protons and pions) properties in the pC-interactions produced in the 2 meter propane chamber at 10 GeV/c was extended. The analysis of the invariant inclusive cross sections of cumulative hadrons and corresponding spectra of pions and protons emitted in the backward semisphere in l.c.s. lead to the conclusion of the independent character of the processes of the cumulative proton and pion emission.

The comparison of the pC, dC, α C and CC inelastic interactions shows that their general characteristics are satisfactorily described in the framework of the cascade model. Experimental data on multiplicity and relations of the π-meson inclusive cross sections in dC, αC and CC-interactions are correctly explained by the model of multiple scattering. The character of the dependence of angular and momentum characteristics of mesons and protons from the cumulative variable is adequate for various types of colliding nuclei and is similar in the case of pions and protons.

With the help of the Recoil Particle Spectrometer the fragmentation of the nuclei Be, C, Al, Cu, Ag, Au in the beam of α-particle has been investigated at 3.33 GeV/c. The doubled differential cross sections of the helium and hydrogen isotope production were measured in the region of fragmentation of the nucleus-target at the angles of 45^{o}, 90^{o}, 135^{o}.

To describe data the thermodynamical model with a source moving inside the nucleus has been developed. It was shown that in the region of the fragment energies (E_{Φ}) less than 50 MeV the mechanism of evaporation contributed in the great extent. When considering the ratio of the ^{3}H output to the $^{3}H_{2}$ output it was found that this ratio is greater than the ratio of the quantity of neutrons to the quantity of protons in the fragment emitting system. The analysis of the function

$$R = \sigma_{^{3}H_{1}} / \sigma_{^{3}He_{2}} = R(E_{\Phi})$$

has shown that the $^{3}H_{1}$ and $^{3}He_{2}$ fragments were "sensible" to the full Coulomb field of the nucleus-target.

The analysis of the data obtained and from the references in the framework of the adhesion model has shown that the region of the fragment formation was equal to 3.2 and depended neither on the nucleus of the target, nor on the beam nucleus.

The obtained boundaries of the limiting fragmentation of nuclei (3.5 ÷ 4.0 GeV/nucleon) allowed the Dubna synchrophasotron to get an exceptional position of the machine which possesses beams of nuclei with energies above this limit. The universality of these results obtained at the Dubna synchrophasotron has been largely proved in the lepton-nuclei experiments at the energies up to 400 GeV at CERN, FNAL and SLAC.

5. INVESTIGATIONS ON PARTICLE PHYSICS PERFORMED AT THE JINR PULSED REACTOR AND OTHER FACILITIES

In 1983 an interesting experiment on measurement of the spirality of a neutrino from the ^{152m}Eu decay has been carried out by using the gamma quanta circular polarization. This work was stipulated by a situation with regard to new calculations of the gamma quanta circular polarization H which took into account the heat motion of atoms of the emitter and absorber and also a possible probability of the electron capture from the L- and M-atom shells. The following value of H was obtained: H=-0.93. The previous theoretical value has been obtained without taking into account the above-mentioned effects and was equal to H=-0.84 that was in agreement with the results of the experiments carried out in Sweden and USA (see Table 7).

In contrast to the classical Godhaber experiment, in the present experiment the Ge(li) detector, 100 cm^{3} in volume, was used with a high energy resolution. The measurements were performed in the multichannel amplitude mode which allowed to separate all the background effects.

The data of this experiment have given such a value of the circular polarization $H_\gamma = -0.87 \pm 0.10$ that agreed with a new theoretical value for H_γ and confirmed the assumption on the full left longitudinal polarization of the neutrino.

The JINR pulsed reactors of fast neutrons, IBR-30 and IBR-2, are used to perform such important investigations as the parity nonconservation in neutron reactions, the (n, α) reactions on radioactive nuclei, spectrometry of the p-wave neutrons and others.

The study of the enhancement of the CP-violation in the total cross sections of interactions of the resonance neutrons with nuclei which has been performed in 1981-1982 at JINR, has verified a theoretical model of the compound state mixing of different parities.

According to the model, one should expect to get the enchanced effects in the neutron reactions with charged particles when the corresponding s- and p-wave resonances are available. The experiment to verify this prediction for the (n,p) reaction on ^{35}Cl has been carried out by the collaboration of the Leningrad Institute of Nuclear Physics and Laboratory of Neutron Physics of the JINR. It was performed in the beam of the transversely polarized hot neutrons of the reactor VVR-M. The 0.6 MeV protons were registered by a proportional chamber in which the $BaCl_2$ target, 60x1100 mm^2 in size, has been located. The coefficient of the asymmetry $a_p = (\overleftarrow{N} - \overrightarrow{N}) / (\overrightarrow{N} + \overleftarrow{N})$ was measured where $\overleftarrow{N}$ and $\overrightarrow{N}$ are the number of the chamber countings for the opposite directions of the neutron polarization which changed every 2,8 seconds. The p-odd asymmetry of the proton emission has been found. After introducing the correction for a partial polarization and average cosine of the angle of the proton outlet relatively the neutron spin, the following result has been obtained: $a_p = -(1.5 \pm 0.3) \cdot 10^{-4}$.

In the course of the experiment the parity conservating effect of the wright-left asymmetry of the proton outlet in the plane perpendicular to the neutron spin direction has been measured: $a = -(2.6 \pm 0.4) \cdot 10^{-4}$.

By using these results and parameters of the s- and p-mixing resonances in ^{35}Cl (at the energies of $E_s = -180$ eV and $E_p = +398$ eV) the experimental value of the matrix element violating the parity of interactions $W_{sp} \approx 0.1$ eV has been determined.

The interpretation of experiments on the parity nonconservation in the interactions of resonance neutrons with nuclei depends significantly from the spectrometric data, for example, from the partial parameters Γ_{nj} of the p-resonance widths (by the full neutron spin). To obtain such an information the study of correlations in the gamma quanta angular correlations at the neutron capture in p-resonances has begun at the JINR IBR-30 reactor.

Using the HaK detector, 200x200 mm^2 in size, located at the angle of 90° to the neutron beam, the exit of the 9.3 MeV gamma-rays has been measured in the reaction $^{117}Sn(n, \gamma)$ in the neighbourhood of the p-wave resonance of 1.33 eV with regard to the sign of polarization of the neutron

beam, oriented perpendicularly to the reaction. Fig. 10 shows the results presented in the form the relation

$$N^{\uparrow},\ N^{\downarrow} \text{ and } \epsilon = \frac{N^{\uparrow}-N^{\downarrow}}{N^{\downarrow}+N^{\uparrow}}$$

depending from the neutron time of flight. They correspond to the appearance of the right-left asymmetry of the gamma ray exit which has the resonance character. This effect is due to the interference of the S- and p-waves. The value of the relative amplitude of the neutron widths $\sqrt{\Gamma_{n_{1/2}}}/\sqrt{\Gamma_n}$ has been determined by the channel $j = 1/2$ for the resonance of 1.33 eV.

In my review I has considered only few aspects of the scientific program of JINR in the particle physics. Future investigations are related mainly to the constructions of such machines as the UNK Accelerator Storage Complex in Serpukhov, LEP Collider at CERN, the superconducting relativistic accelerator NUCLOTRON in Dubna.

Table 1

JINR Administration (JINR governing bodies)

ADMINISTRATION

STRUCTURE AND MEMBERSHIP

COMMITTEE OF PLENIPOTENTIARIES

FINANCE COMMITTEE

SCIENTIFIC COUNCIL

Chairman - academician N.N.Bogolubov
professor E.Entralgo
professor A.Sandulesku
Chief scientific secretary - doctor A.N.Sissakian

Bulgaria Hungary Vietnam Socialist Republic Germany Democr. Republic Korea People's DR Cuba Mongoliy Poland Romania USSR Czechoslovakia

SC section on High Energy Physics

Chamber Committee | Electronic Experimental Committee | Photoemulsion Experiments Committee

SC section on Theoretical Physics

SC section on Low Energy Physics

Neutron Physics Committee | Nuclear Structure Committee | Heavy ion Physics Committee

Table 2

The structure of the Institute. Scientific program of the JINR Laboratories

JOINT INSTITUTE FOR NUCLEAR RESEARCH

STRUCTURE AND RESEARCH ACTIVITIES

DIRECTORATE

Director - N.N.Bogolubov
Vice-director - E.Entralgo
Vice-director - A.Sandulesku

Laboratory of Theoretical Physics	Laboratory of High Energy Physics	Laboratory of Nuclear Problems	Laboratory of Nuclear Reactions	Laboratory of Neutron Physics	Laboratory of Computing Technique & Automation	Main Divisions
Director - N.N.Bogolubov	Director - A.M.Baldin	Director - V.P.Dzhelepov	Director - G.N.Flerov	Director - I.M.Frank	Director - M.G.Meshcheryakov	Division of New Methods of Acceleration
Research activities:	Research activities:	Research activities:	Research activities:	Research activities:	Research activities:	Serpukhov Scientific Experimental Division
- elementary particles; - atomic nucleus theory; - condensed matter theory	- nucleon structure; - strong interactions; - resonant states; - electromagnetic interactions	- strong, weak, el/m interactions; - search of new particles; - nuclear structure	- search of superheavy elements; - transuranium isotopes; - complex nuclei interactions	-neutron spectrometry; - neutron basic properties; - nuclear structure & dynamics of solid & liquid matter; - light nuclei reactions	- computation; - auto-systems for chamber film procession; - computer equipment of experimental facilities; - software systems	Division of Chief Scientific Secretary Scientific & Technical Information Service Experimental Physics Facilities Division

Table 3

JINR search facilities

I. SYNCHROPHASOTRON

1. Injector - linac

energy - 10 GeV

intensity - 4.10^{12} proton/cycle

2. Injector - polyrized dueteron source

energy - 4·2 GeV/nucleon

intensity $\sim 1\cdot10^{8}$ deuteron/cycle

degree of polyrization $\sim$50%

3. Injector - laser

energy - 4 GeV/nucleon

beam intensity per cycle:

P - $2\cdot10^{12}$	^{7}Li - $2\cdot10^{9}$
d - $1.2\cdot10^{12}$	^{12}C - $5\cdot10^{8}$
^{3}He - $3\cdot10^{10}$	^{16}O - 5.10^{7}
^{4}He - $2\cdot10^{10}$	^{22}Ne - $1\cdot10^{4}$
^{6}Li - $1.5\cdot10^{8}$	^{24}Mg - $1\cdot10^{5}$

II. SYNCHROCYCLOTRON (under reconstruction)

energy - 680 MeV

III. CYCLOTRONS

1. Heavy ion cyclotron U-300

energy of accelerated particles - 250 Z^2/A MeV

mass/charge A/Z - 4.5÷7

intensity - 10^{11}÷10^{14} particle/sec

2. Heavy ion cyclotron U-400

energy of accelerated particles - 650 Z^2/A MeV

mass/charge A/Z - 4÷20

intensity - 10^{12}÷10^{14} particle/sec

3. Microtron MT-22

energy of electrons - 22 MeV

averyge current - 20 mkA

pulsed current - 20 mA

pulse duration - 2.3 microsec

IV. FAST NEUTRON PULSED REACTORS

1. IBR-30

average heat output - 30 kW

output per pulse - 150 mW

pulse duration $\sim$ 50 microsec

intensity - $5\cdot10^{14}$ neutr/cm^2·sec

2. IBR-2

average heat output - 2 M.W.

output per pulse - 1350 M.W.

pulse duration - 230 microsec

intensity - 10^{16} neutr/cm^2·sec

Table 4

Experimental facilities used at the Serpukhov PS

BIS-2 Diffraction Spectrometer with proportional chambers; angle resolution: 0.2-0.4 mrad mass resolution: 2-5 MeV (put in operation in 1978)	Search for charmed and narrow baryon resonanses: Charmed baryon have been registered via the decays $\Lambda_c^+ \to \bar{K}^0 p \pi^+ \pi^-$ (1) $\to \Lambda^0 \pi^+ \pi^+ \pi^-$ (2) $\sigma \cdot B(1) \simeq 60 \pm 15 \mu b$ per nucleon. New baryon resonance found $N_\varphi \to \Sigma^-(1385) K^+$; $M_{N_\varphi} = 1956 \pm 8$ MeV/c^2 $\Gamma_{N_\varphi} = (27 \pm 15)$ MeV/c^2
HYPERON Missing Mass Spectrometer (JINR-IHEP) Spark and proportional chambers; Shower electron and γ-quanta detectors (put in operation in 1978)	Study of multiparticles processes and binary $\pi^+ p \to K^+ \Sigma^+, \Sigma^+_{1385}$; Hyper charge exchange reactions at 12 GeV; Decays of K^+- and K^0-mesons.
LUDMILA Hydrogen Chamber Volume: 860 l; track sensitive internal target of 10 l filled with liquid deuterium (put in operation in 1976)	Investigation of the $\bar{d}$ - d interactions
POLARIMETER (JINR-IHEP) Spectrometer with a "frozen" polarized proton target; proportional chambers (put in operation in 1976)	Investigation of the polarization effects in the hadron-hadron collisions in a broad range of momenta transfered at the energies up to 60 GeV
RISK 3 Film Streamer Chamber in a magnetic field; (put in operation in 1978)	Study of the π^-, K^-p interactions with hydrogen and different nuclei at 40 GeV. Search for new charms. Investigation of the transversal momenta processes: $P_T > 1.0$ GeV/c
POSITRONIUM Magnetic Spectrometer with a drift chambers (put in operation in 1982)	Study of the reaction $\pi^0 \to \gamma + (e^+e^-)$-atom relativistic positronium interaction with matter
MIS 2 Magnetic Spark Spectrometer with film data taking; proportional chambers and scintillation counter trigger system	Investigation of the bozon resonances in the dissociation processes of meson on nuclei. The mass and the width of the radial excitations of the π-meson has been determined: $M_{\pi'} = (1240 \pm 30)$ MeV; $\Gamma = (360 \pm 120)$ MeV and $M_{\pi''} = (1770 \pm 30)$ MeV; $\Gamma = (310 \pm 50)$ MeV
SIGMA-AJAX Magnetic Spectrometer (JINR-IHEP) spark and proportional chambers; gamma spectrometer on lead glass (put in operation in 1980)	The first time the compton effect on π^--meson has been investigated. Polarizability of the pion in the external field found; fundamental constant $\alpha_\pi = (6.8 \pm 1.4) \cdot 10^{-43}$ cm^3 was determined as well. Coupling constant $\gamma \to 3\pi$ was measured for the first time, $F^{\gamma 3\pi} = 13.0 \pm 1.5$, the result confirming the chiral anomaly hypothesis.
NEUTRINO DETECTOR (JINR-IHEP) target-calorimeter; muon spectrometer; vertex detector; shower detector of e- and γ-quanta (to be put in operation in 1985)	The cross section production, life time and decay modes of the short lived particles in the beam of muon neutrinos. Weak current structure; deep inelastic scattering of neutrinos on nucleons

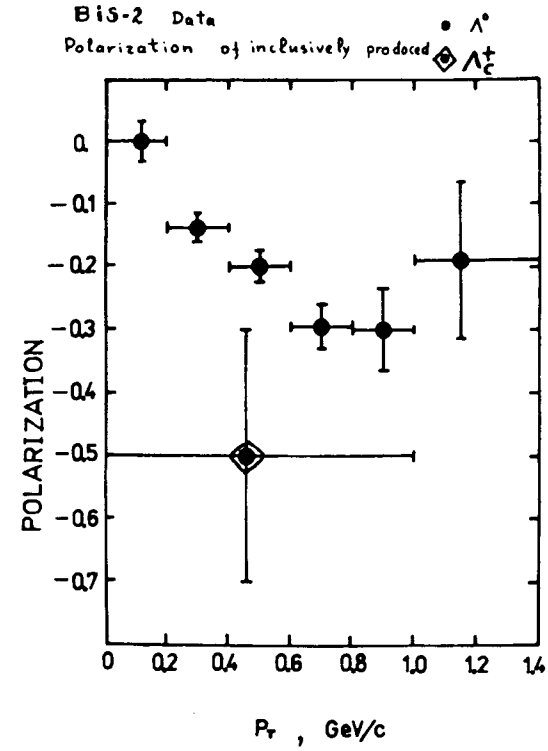


Fig. 1. Polarization in the inclusive production of the Λ_c^+ (BIS-2 experimental set-up).

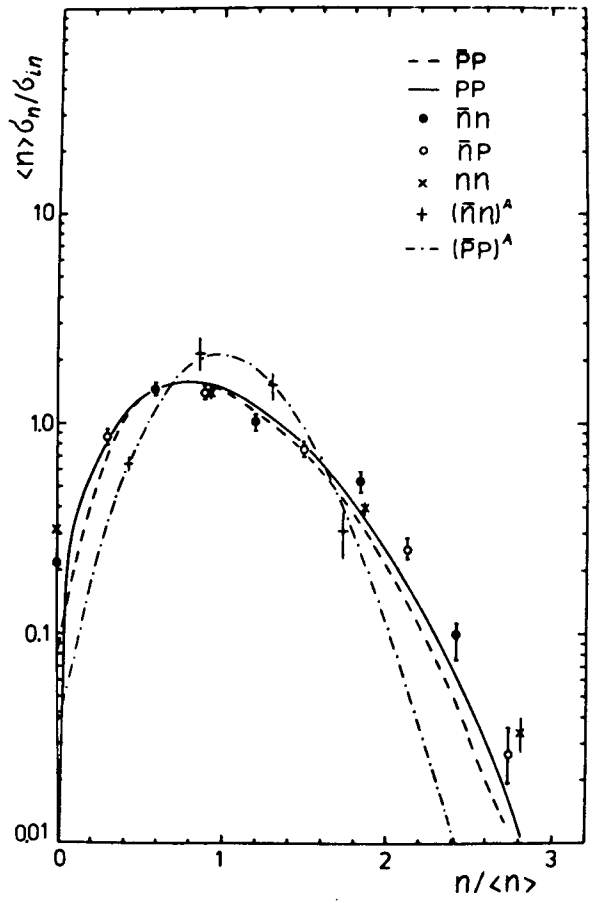


Fig. 2. Probe of KNO scaling: charged multiplicity distributions for $\bar{n}n$ and nn interactions, and πn annihilations at 6.1 GeV/c, in the Liudmila hydrogen chamber.

Table 5

Resonance states observed in the process
$\pi^- + A \to \pi^+ + \pi^- + \pi^- + A$ using the MIS-2 spectrometer

Particle	J^P	Mass (MeV/c^2)	Width (MeV)	Decay channel	Branching ratio (%)
π'	0^-	1240±30	360±120	$\varepsilon\pi$	~100
π''	0^-	1770±30	360±50	$\varepsilon\pi$	100
A1	1^+	1255±23	292±40	$\rho\pi$	98
A1′	1^+	1670±90	300±100	$\rho\pi$	100
A3	2^-S	1624±21	304±22	$f\pi$	60
	2^-P	1622±35	404±108	$\rho\pi$	30
	2^-D	1693±28	330±90	$\varepsilon\pi$	10
A3′	2^-	~1850	~300	$f\pi$	
A2	2^+	1320	~100	$\rho\pi$	
A2′	2^+	1750	—	$f\pi$	

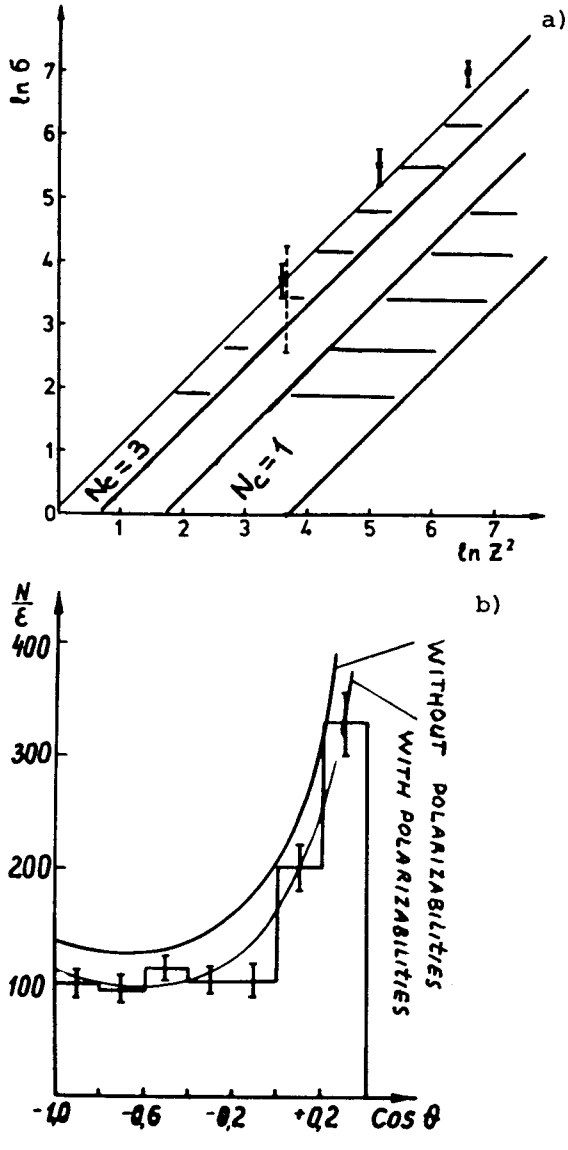


Fig. 3a) Cross section of the reaction of pion pair production in the nuclei Coulomb field as a function of the Z nucleus charge. Theoretical calculations for various numbers N_c of the quark colour degrees of freedom are shown by dashed lines. Dots show a systematic error for cross section of the pion pair production on ^{12}C. In the study of pion pair production in the πAl and πFe interactions the systematic error is less than the statistical one.
b) Polarization of the pion.
(Results of the SIGMA-AJAX experiment.)

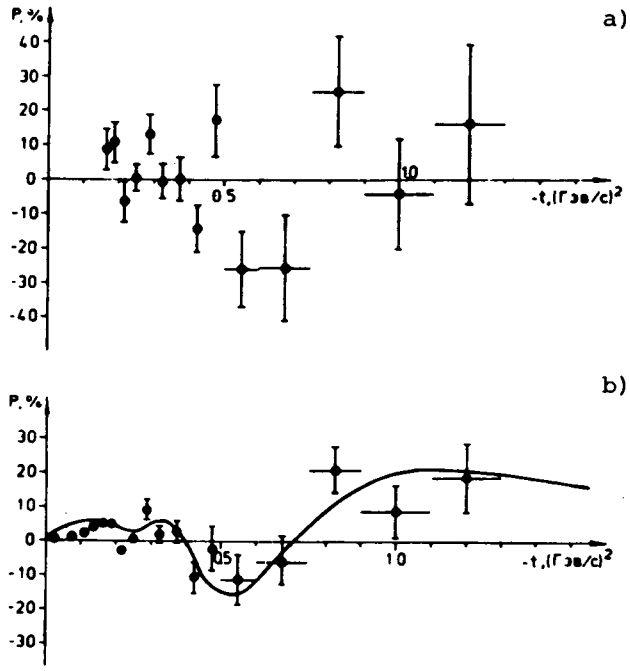


Fig. 4. Polarization in the reaction versus the square of the four-momentum transfer at an incident pion energy of 40 GeV/c. a) Without n-recoil; b) new data. (PROSA-POLARIMETER.)

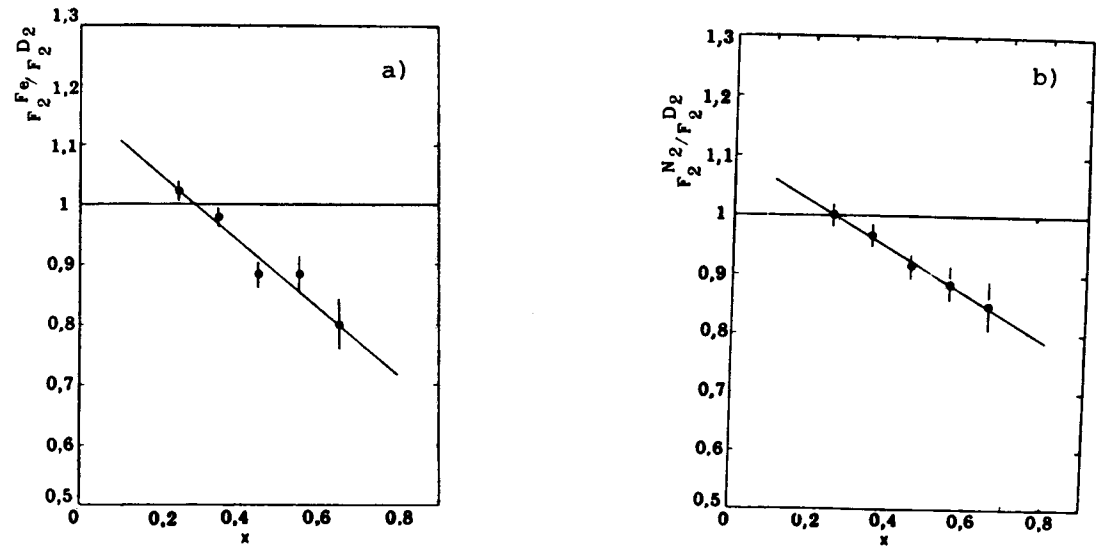


Fig. 5. Ratio of the nucleon functions obtained in the deep inelastic muon scattering experiments at 280 GeV: a) with iron and deuterium targets; b) with nitrogen and deuterium targets (NA4 experiment).

Table 6

Experimental facilities for research in relativistic nuclear physics located in the synchrophasotron area.

2 m propane bubble chamber Volume: 210 x 65 x 43 cm^3 magnetic field: H=15.5 ke $\frac{\Delta p}{p}$ = 5-12%	Study of interactions of relativistic nuclei and neutrino with light and heavy nuclei for a search of multiquark states
ALPHA 3C Proportional and drift chamber magnetic spectrometer + time flight and ionization hodoscopes; $\frac{\Delta p}{p}$=0.3%;$\Delta\theta$=0.8 mrad	Search of highly excited states of the few nucleon systems in experiments on scattering and fragmentation of relativistic nuclei. Deuteron wave function was measured in the reaction
Recoil Particle Spectrometer semiconductor telescope; gaz identificator; scintillation magnetic spectrometer in the internal beam of the accelerator	Study of the p, ^{3}He, ^{4}He, ^{6}He, ^{6}Li, ^{7}Li in the 6.6 GeV proton interaction with nuclei. Behaviour of structure functions at 6-400 GeV. Proof of the hypothesis of nuclear scalar invariance.
DISK 3 Cerenkov and scintillation counters $\frac{\Delta p}{p}$= 6%; Time flight resolution - 1 nsec	Investigation of the particle cumulative production in the relativistic nuclear physics
130 channel Cerenkov Mass Spectrometer	Search and study of the resonance production and decay into e^+e^- pairs and γ-quanta
RESONANCE Streamer chamber with a liquid hydrogen target in the magnetic field	Search for 6 quark strange dibaryon systems
MASSPEAK Magnetic spectrometer with wire chambers	Study of nuclear interactions at relativistic energies. Search for multiquark states in nuclei
Hybrid Streamer Chamber Magnetic Spectrometer including vertex detector, system of the beam testing, fast processors, proportional chambers volume: 2 x 1 x 0.6 m^3 magnetic field of 1,5 tesla	Study of the inelastic nuclei-nuclei collisions; compression of nuclear matter; search for abnormal superdense nuclei.

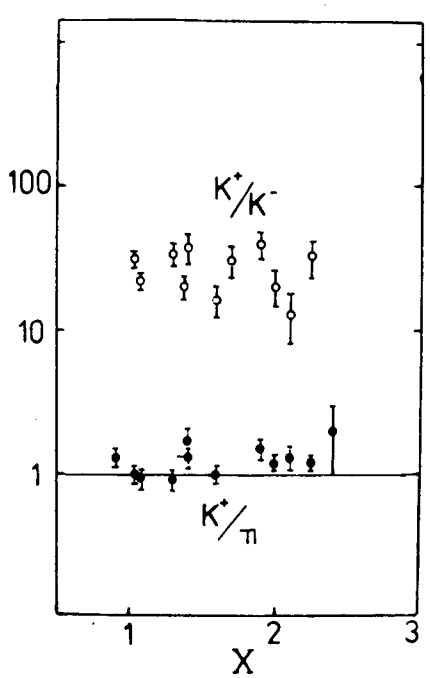
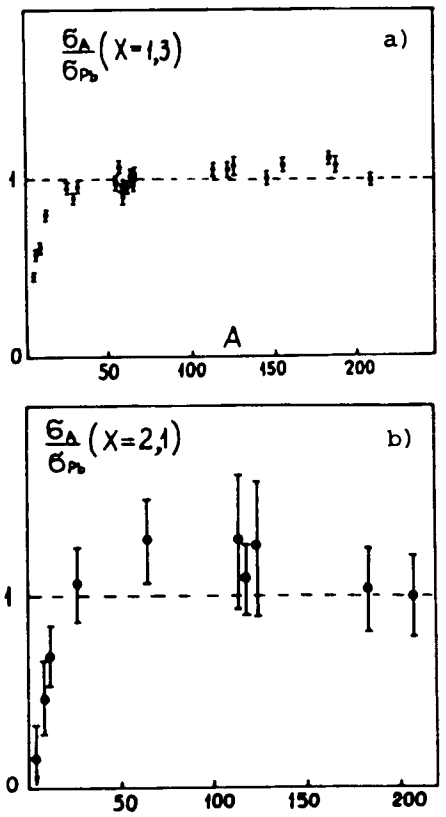


Fig. 6. The cumulative π^- and K-meson events in the proton-nuclei interactions at the incident proton momentum of 9 GeV/c.



Figs. 7. The A-dependence of the cumulative pion cross sections in proton-nuclei interactions at P=9 GeV/c: a) at X values X=1.3; b) X=2.1.

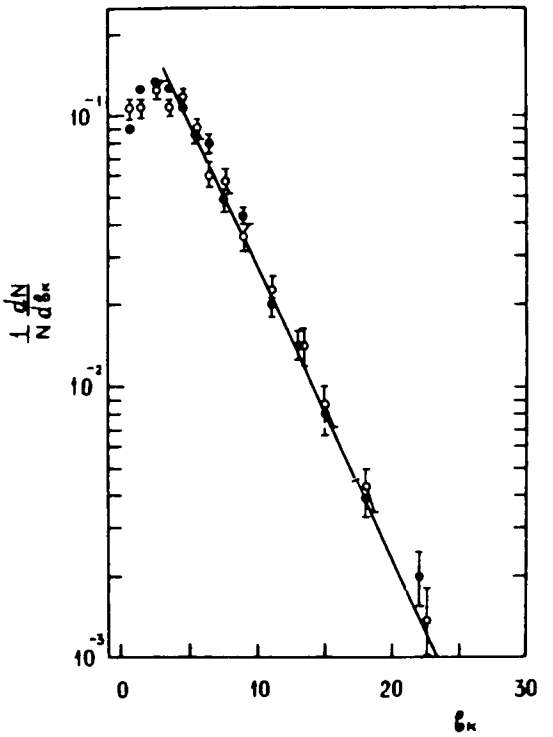


Fig. 8. The distribution of mesons by the value of b_k in jets produced in π-C interactions at p=40 GeV/c: (·) - in the region of the target fragmentation; (o) - flying toward the primary π-meson motion; the solid line is the result of the exponential dependence approximation.

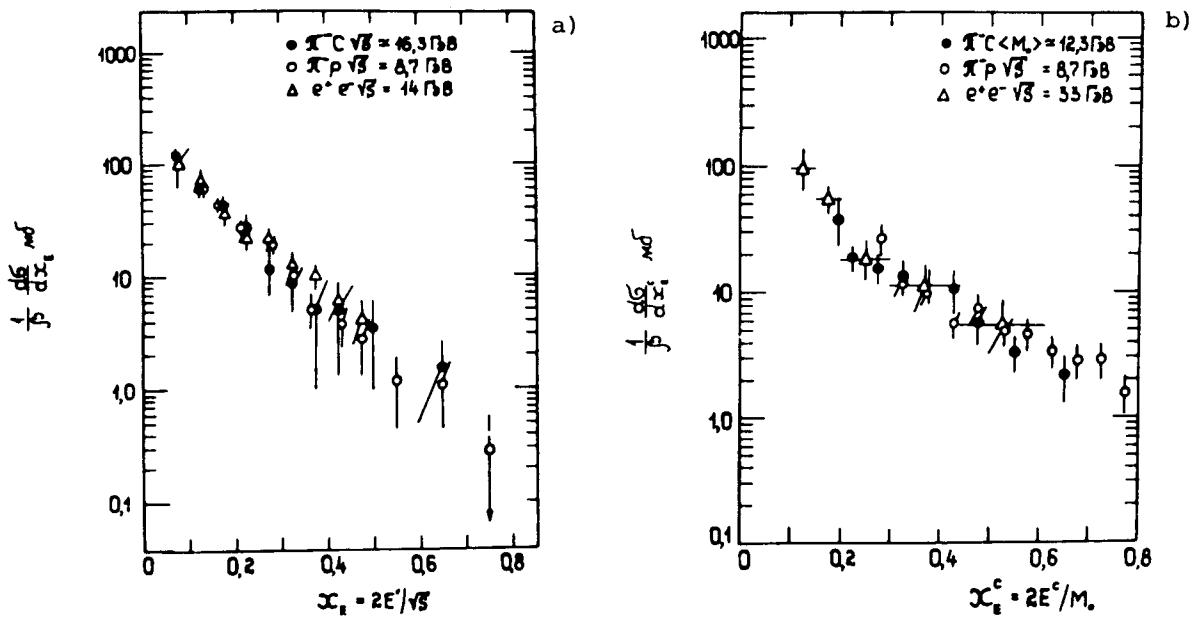


Fig. 9. Invariant cross sections of the strange particle production in different interactions: a) for K^0-mesons; b) for Λ-hyperons, versus the part of energy which is carried away.

Table 7

The measurement of the circular polarization of gamma-quanta

No.	Authors	Year	Detector	H_γ (%)
1	Goldhaber et al.	1958	NaI(Tl)	$-(67 \pm 10)$
2	Marklund, Page	1958	NaI(Tl)	$-(80 \pm 30)$
3	Palathingal	1970	NaI(Tl)	$-(61 \pm 12)$
4	Average	-	-	$-(66 \pm 8)$
5	Calculated	1958	-	-84
6	Calculated	1983	-	-93
7	Present work	1983	Ge(Li)	$-(87 \pm 10)$

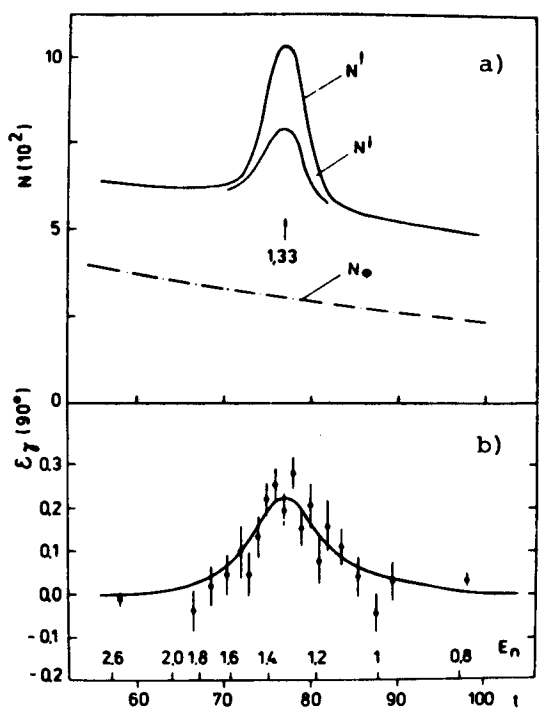


Fig. 10. The right-left asymmetry of the gamma-quanta emission with E_γ=9.3 MeV in the p-wave resonance of 1.33 eV in the nucleus of ^{117}Sn: a) experimental spectra of the emitted rays at the angle of 90° to the beam for the opposite directions of the neutron spin; b) the right-left asymmetry reduced to the 100% polarization of neutrons.