# Report of the 69th ordinary session of the Scientific Council of the Joint Institute for Nuclear Research

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The 69th ordinary session of the Scientific Council of the Joint Institute for Nuclear Research was held at Dubna from 8 through 15 January 1991. A distinctive feature of the session was the discussion of not only traditional questions but also the program of development of the Joint Institute and its scientific policies for 1991–1995.

The session was opened by the director of the Institute, Academician D. Kiss, who informed the participants of the implementation of the resolutions of the 67th and 68th sessions of the Scientific Council and gave a report on the program of development of the Joint Institute. He noted that the formation of the program had made maximal allowance for the wishes of the participating countries of the Joint Institute as a truly international scientific organization, namely, that the collaboration must acquire a qualitatively new nature and be mutually advantageous and based on realistic possibilities. To this end, work had commenced on normative deeds (Agreements on the Foundation of the Institute, its Statutes, and Personnel Regulations), on the preparation of the Agreement Between the Joint Institute for Nuclear Research and the Soviet Government, and on the conclusion of an agreement with the trade unions. But the main question in the report concerned financing. Having considered possible ways of concentrating resources on the most promising scientific directions, Academician Kiss emphasized the need to relate the long-term program of development of the scientific center in the first place to the creation of a viable basis within the center for fundamental research and the construction at Dubna of a *C*-Tau factory (storage-facility complex for electrons, positrons, and ions).

Representatives of all delegations of the participating countries of the JINR contributed to the discussion of the project. As the high-priority scientific directions for the Joint Institute, the largest number of speakers identified nuclear physics, physics of the condensed state of matter, and elementary-particle physics, the investigations on which should be directed toward CERN and IHEP (Institute of High Energy Physics, Protvino).

The Scientific Council resolved to adopt as a basis the program of development of the JINR, to present it for discussion to the next ordinary session of the Committee of Plenipotentiary Representatives, and to support the recommendations of the meeting of the financial organs of the participating countries (on 11–12 December 1990) on the need to finance the activity of the JINR in freely convertible currency. In view of the difficult financial position of the Joint Institute that has developed, the Scientific Council requested the Committee of Plenipotentiary Representatives to consider the question of the need to increase the JINR budget by 30% (from the level and in the prices of 1990), beginning in 1992, to achieve the possibility of creating a viable scientific basis. The Scientific Council recommended the directors of the Joint Institute to ensure in full measure financing of the basic high-priority facilities and the most important projects of the experimental facilities, to fulfill commitments on experiments at CERN and IHEP (Protvino), and to carry out design work on the storage complex and on the high-resolution neutron source.

The Scientific Council approved the information of the chairman of the Scientific-Coordination Councils of the JINR in accordance with the directions of Professor A. N. Sisakyan and Professor D. Ebert and approved the recommendations of the Commission of Experts (chaired by Academician R. Sosnowski) on the choices of responsibilities.

The session heard reports by the leaders of the laboratories of the Joint Institute on the main results from implementation of the program of scientific research activity of the JINR during 1986–1990 and on the plan for 1991. The Scientific Council noted the main results of implementation of the program of scientific-research studies of the laboratories on the completed subjects.

*Theoretical Physics Laboratory.* The concept of harmonic superspace had been proposed and developed. Finite formulations of SUSY theories with $N = 2$ and Yang–Mills theory with $N = 3$ have been give on its basis. It has been shown that the model of a meson cloud of a hadron leads to a self-consistent description of polarization effects in nucleon–nucleon and meson–nucleon processes at high energies. A new method has been created, and on its basis a parameter-free description of the gross structure of the strength functions for nuclear transitions of different multipolarities has been obtained. It has been shown that at low energies ($\sim 10$ GeV) the main contribution to proton–nucleus production of dilepton pairs is made by decays of vector mesons. The effect is important in the search for extremal states of nuclear matter.

*High Energy Laboratory.* Study of the $d \rightarrow p$ fragmentation reaction using unique beams of relativistic polarized deuterons from the synchrophasotron has led to determination of the momentum dependence of the tensor analyzing power $T_{20}(k)$ of the deuteron up to record momentum values of the nucleon: $k \approx 800$ MeV/$c$ (in the deuteron rest frame). First experimental data on measurement of the coefficient of polarization transfer from the deuteron to the

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proton have been obtained.

New narrow states have been found: baryonium $U/M_S$ and $M_\varphi$. The mean mass of strange baryonium over eight decay channels was found to be $3053 \pm 3 \pm 20$ MeV/$c^2$, and that of baryonium with hidden strangeness, $3255 \pm 3 \pm 20$ MeV/$c^2$. The $A$ dependence of the Φ-meson production cross section has been determined. A study has been made of hadronic production of charmed $\Lambda_C^+$ and $\Sigma_C$ baryons in neutron–nucleus and neutron–proton interactions at energies of the Serpukhov accelerator.

New behavior has been identified in multiparticle production processes (self-similarity of the second kind, correlation weakening, universality of hadron jets and baryonic clusters) on the basis of a relativistically invariant analysis in the space of relative 4-velocities. The foundations have been established for a new method of looking for quasistationary states of highly excited nuclear matter.

In $dp$ interactions, narrow dibaryonic states with masses $M_1 = 2.01$–$2.02$ GeV/$c^2$ and $M_2 = 2.12$–$2.15$ GeV/$c^2$ have been seen. Spatial correlations in $dp$ and $^3$He$p$ interactions have been studied. New data have been obtained on $\alpha$ clusters in the $^{16}$O nucleus. Azimuthal asymmetry of the neutrons in charge-exchange reactions on polarized deuterons has been observed.

A series of investigations on the production of relativistic hypernuclei $^4$H and $^4_\Lambda$H in interactions of $^4$He, $^6$Li, $^7$Li nuclei with carbon has been made. The most accurate values have been obtained for the $^4_\Lambda$H production cross section and lifetime: $\sigma = 0.4^{+0.4}_{-0.2}$ μb, $\tau = (2.6 \pm 0.5) \times 10^{10}$ sec.

A high-efficiency two-dimensional coordinate detector of neutrons measuring $270 \times 150$ mm for structure investigations on neutrons has been developed and tested.

During four years, systems of the superconducting nuclotron accelerator have been created at world technological level. Resource tests have been made in the octant (1/8 part) regime of the magnetic system in position. Fitting of the modules in the tunnel has begun. Two helium coolers, each of power 1600 W, have been commissioned. Successful tests have been made on alignment of the tract for injecting the beam into the tunnel.

*Nuclear Problems Laboratory.* The NEĬTRINNYĬ DETEKTOR facility has been commissioned, and the first physical results obtained. An upper limit has been obtained for the charmed-particle production cross section: $\sigma_{\text{charm}} \leqslant 2.6$ μb/nucleon. Analysis of data on the two decay channels $H^0 \to e^+e^-$ and $H^0 \to \gamma\gamma$ has made it possible to obtain a lower bound on the mass of light Higgs bosons: $M_{H^0} > 100$ MeV/$c^2$.

Construction of the large universal ARES facility has been completed. For the decay $\mu \to 3e$ an upper bound on the branching ratio at the 90% confidence level has been obtained: $\Gamma_{\mu \to 3e} = 3.6 \times 10^{11}$.

The SIGMA–AYaKS facility has been used to measure the sum of the electric and magnetic polarizabilities in a study of the radiative scattering of $\pi$ mesons in the Coulomb field of nuclei. In an experiment to study coherent dissociation of the $\pi$ meson into the $\mu^+\mu^-\mu^-$ system on the copper nucleus at 50 GeV/$c$ the branching ratio of $\rho^0 \to \mu^+\mu^-$ decay has been obtained: $BR(\rho \to \mu^+\mu^-/\rho \to \pi^+\pi^-) = (4.6 + 0.2) \times 10^{-5}$. Measurements have been made of the inclusive cross sections for production of cumulative protons in $\pi^- A$, $K^- A$, and $\bar{p}A$ interactions ($A$ = Be, Al, Cu, Pb) at momentum 40 GeV/$c$. It has been found that the ratios of the invariant cross sections for the different types of beam particle do not depend on the kinetic energy and type of the nucleus.

The POZITRONIĬ–DIMEZOATOMY facility has been used to determine the branching ratio of the decay $\pi^0 \to \gamma + A_{2e}$: $\rho_\pi = (1.84 + 0.29) \times 10^{-9}$, and the coefficient of internal conversion of a photon into a positronium atom. The effect of Coulomb interaction in the system of $\pi^+\pi^-$ mesons generated in $p$Ta interactions at proton energies 70 GeV has been observed.

Investigation of $\pi^-$C reactions with production of muon pairs at 38 GeV/$c$ has led to determination of the total $\mu^+\mu^-$ production cross section: $\sigma = 426 \pm 50$ nb/nucleus, and anomalous production of dimuons in the mass range $0.28 \pm 0.35$ GeV/$c^2$ has been observed.

Analysis of the results on investigation of diffraction of the $K^-$ meson into the $K^-\pi^-\pi^+$ system on nuclei has been completed. The differential and total cross sections of the process have been obtained for the nuclei Be, Cu, Aq, and Pb. The results indicate production of two axial-vector resonances with masses $1400 \pm 20$ and $1300 \pm 20$ MeV/$c^2$. For the first time it has been established that resonance properties of the $K\pi\pi$ system are manifested at mass $\sim 1460$ MeV/$c^2$ in the process of diffraction on the nucleus in the pseudoscalar state $0^-$. These resonance properties can be interpreted as production of a radially excited state of the kaon.

Measurements have been made for the first time of the double differential cross section for production of $K^0$ and $K^{*0}$ mesons on nuclei in the reactions $K^+ + A \to K^0$ and $K^{*0}(892) + X$ at energy 11.2 GeV ($A$ = Be, Cu, Pb) in the beam fragmentation region. The dependence of the form factor on the momentum transfer for the $K^+ \to \pi^0 e^+ \nu$ decay has been investigated. The usual linear parametrization leads to estimates of the scalar and tensor form factors on the basis of an analysis of the Dalitz distribution (the errors are the statistical ones):

$$f_S/f_+(0) = 0.70^{+0.015}_{-0.014}$$

and

$$f_T/f_+ = 0.53^{+0.08}_{-0.09}.$$

This result goes beyond the framework of the adopted $V$–$A$ theory.

The magnetic properties of high-temperature superconductors of the type Re–Ba(Sr)–Cu–O (Re: rare-earth element) have been studied. The formation of magnetic ordering and an antiferromagnetic state have been observed in high-temperature superconductors of this type. The magnetic-field penetration depths and their temperature dependence have been measured.

Measurements have been made of the temperature dependence of the production rate of the mesic molecules $dd\mu$ in gaseous deuterium at pressure 0.4–1.5 kbar in the

temperature range 49–300 K. These have shown the absence of a dependence on the deuterium density.

The experimental complex YaSNAPP-2 has been commissioned. An $h_{11/2}$ isomer state has been found and measured for the first time in the nucleus $^{115}$Tm ($T_{1/2}$ = 23 sec), and the $\gamma$ spectra and $\gamma\gamma$ coincidences have been measured in the decay of $^{159}$Yb (16 sec) and $^{157}$Yb (36 sec). New isomers $^{155-156}$Lu with half-lives from 70 msec and more have been discovered and studied.

At the existing intensity 2.0–2.5 $\mu$A of the extracted proton beam of the JINR phasotron the following meson beam intensities have been achieved by means of a wide-angle magnetic lens: $\sim 10^8$ sec$^{-1}$ for positive pions and $\sim 3 \times 10^7$ sec$^{-1}$ for negative pions. In addition, a beam of so-called surface $\mu$ mesons (energy around 4 MeV) with intensity $\sim 10^6$ sec$^{-1}$ has been obtained.

In biophysics investigations in the framework of the RITM project, studies have been made of the behavior and induction mechanisms of genetic mutations of microscopic organisms exposed to ionizing radiations with different linear energy transfer. It has been established that the relative importance of the biological factor (COC reparation) in the mutation process depends on the linear energy transfer of the radiations.

*Nuclear Reactions Laboratory.* A series of joint experiments with the GANIL center in France on the determination and investigation of the properties of new neutron-rich isotopes of light nuclei has been made. More than 25 new neutron-rich isotopes of light elements from $^{29}$F to $^{51}$Cl have been synthesized and identified by means of the magnetic spectrometer LISE, and $\beta$-delayed emission has been investigated (half-lives and neutron emission probabilities for some isotopes from carbon to sulfur inclusive).

The SPEG facility has been used to measure for the first time the masses of more than 20 neutron-rich nuclei from Ne to Cl with accuracy $\Delta E \approx 100$ keV of the determination. Measurements have been made of the total reaction cross sections for the exotic radioactive nuclides $^9$Li, $^{11}$Li, and $^{12}$Be on a number of targets. It has been established that a significant increase in the interaction range compared with less neutron-rich isotopes is observed.

In a collaboration with chemists from various countries, including Germany, Rumania, and France, a study has been made of the chemical properties of the elements 104 and 105 in aqueous solutions. Work on development of a $4\pi$ gas spectrometer of multiple events—the FOBOS facility—has been completed. The new accelerator U-400M is being assembled. A series of studies on the improvement of ion sources, including the development of sources for external injection and the development of the ÉTsR source, has been completed.

The MC-A spectrometer has been used in a series of experiments to study deep inelastic interactions of two complex nuclei, in particular, in Th + C, Ta + Cr, etc., reactions; the mechanism of formation of compound nuclei has been investigated, and a mechanism of emission of charged fragments—centrifugal fragmentation—has been proposed. The KSI laser facility has been used to measure the differences of the charge radii of a number of isotopes of rare-earth and transuranium elements. The possibility of fast polarization of nuclei by a short laser pulse has been demonstrated. Experiments to measure the lifetimes of excited nuclei have been made by means of the shadow effect. Radiation damage of single crystals of diamond, GuP, and other materials by heavy ions has been investigated. The behavior of Ku in aqueous solutions has been investigated. The chemical properties of heavy transactinides have been studied. Relativistic effects have been found. The chemical properties of mendelevium have been investigated. Methods of separation and radiochemical purification of transplutonium elements from various irradiated targets have been developed.

A method for preparing polypropylene membranes has been developed; it has no analogs in the Soviet Union or abroad. The polypropylene makes it possible to use the membranes to filter aggressive chemical media. Polypropylene membranes of thickness 10 $\mu$m with minimal diameter $\sim$0.2 $\mu$m of conical pores and pore density $8 \times 10^7$ cm$^{-2}$ have a permeability for gaseous nitrogen of $2 \times 10^4$ m$^3$/(m$^2$·h) mPa.

A method has been developed for concentrating and determining the concentration of gold in natural samples using a solid special agent based on tributylphosphate and the x-ray fluorescence or neutron-activation method of analysis. The methods possess high reproducibility and give a detection limit of 0.01 g/ton ( $\sim 10^{-6}$%). The method has been adopted in a number of geological organizations. A study has been made of the change of the yield stress of pure copper (99.998%) after bombardment with boron, neon, and argon ions, and a simple model to explain this effect has been given. The MT-25 microtron has been used to develop a method for obtaining a medical radioisotope preparation of $^{126}$I.

*Neutron Physics Laboratory.* A new measuring center of the laboratory has been created on the basis of RDR-11/70, microVAKS-11, and CM computers and personal computers linked by a local network to each other and to the IVK at Dubna.

*Laboratories of Computational Techniques and Automation.* The following computers have been brought into use: two EC-1066, two EC-1037, two EC-2706 matrix processors, the EC-8371 remote data-analysis processor, and a disk subsystem of Winchester type of capacity 15 Gbyte. The total output of the EC computers is 15 Mips on the base computers and, additionally, 24 Mflops on specialized matrix processors. A multimachine computer complex based on a common disk memory has been created. A cluster of two VAX-8350 computers with common 10 Mbyte disk memory has been brought into operation together with a general-purpose graphics center based on the four-processor MVAX-11 computer and work station MEGATEK; the development of the all-institute network JINET continues; a high-speed local network of type ETHERNET with transmission rate up to 10 Mbyte/sec has been established.

The semiautomatic measuring system PUOS-CAMET-EC-1033 has been developed. During 1986–1990, about 2.25 million tracks (in space) for nine experiments

have been measured. The system AÉLT-2/170 has been used to analyze 50 thousand complex stereographic tracks with coherent particle production. Such events cannot be analyzed in other measuring devices.

Methods have been developed for solving eigenvalue problems for hypersingulator integral quasipotential equations. Calculations of the masses and decay widths of the $J/\psi$ and $\tau$ mesons have been made. Composite programs have been developed, and calculations have been made of the wave functions of nuclei in single- and two-phonon states and of the form factors and differential cross sections of elastic and inelastic scattering of particles by nuclei at low energy. The high-precision BIZON analysis system has been developed and introduced for the calibration, recognition, and geometrical reconstruction of track information.

*Joint JINR–CERN Studies.* The NA/4 experiment has been completed. The most accurate structure functions on nuclei and protons in the world have been obtained. The most accurate value of the QCD parameter has been obtained:

$$\Lambda_{MS}=220\pm 14\ (\text{stat.})\pm 50\ (\text{syst.}).$$

The DELPHT facility has been successfully commissioned at the LEP accelerator at CERN. About 100 thousand events with $Z^0$ bosons have been obtained. The mass and width of the $Z$ boson have been determined, together with the number of generations of light neutrinos, the effective angle of weak mixing (Weinberg angle), and the leptonic decay widths of the $Z^0$ boson; new estimates have also been obtained for the masses of the $t^0$ and $b^-$ quarks, neutral Higgs bosons, and SUSY particles; first results have been obtained on the symmetry of $Z$-boson decays.

*JINR Prizes.* The Scientific Council approved the decision of the jury for the JINR prizes for the best studies during 1990. In the section of scientific-research studies, the first prize was awarded to the paper "Quantum chromodynamics of spin processes." Authors: A. V. Efremov and O. V. Teryaev.

For scientific-research experimental studies, the first prize was awarded for the paper "Investigation of color screening effects in hadron–hadron interactions." Authors: Yu. A. Budagov, V. B. Vinogradov, B. Z. Kopeliovich, Yu. A. Kul'chitskiĭ, L. B. Litov, Yu. F. Lomakin, N. A. Rusakovich, S. Tokar, V. B. Flyagin, and R. Tsenov.

Second prizes were awarded for the papers "Observation of narrow baryonium states in BIS-2 experiments." Authors: A. I. Zinchenko, I. M. Ivanchenko, N. N. Karpekno, V. D. Kekelidze, D. A. Kirillov, M. F. Likhachev, A. L. Lyubimov, V. V. Pal'chik, G. T. Tatishvili, and E. A. Chudakov; and "Experimental and theoretical investigations in the physics of ultrarelativistic positronium atoms." Authors: L. G. Afanas'ev, O. E. Gorchakov, V. V. Karpukhin, V. I. Komarov, V. V. Kruglov, A. V. Kulikov, A. V. Kuptsov, L. L. Nemenov, A. V. Tarasov, and S. V. Trusov.

For scientific-methodological and scientific-technological studies the first prize was awarded for the paper "Gas-filled magnetic separator of products of nuclear reactions in a heavy-ion beam." Authors: V. V. Bekhterev, B. N. Gikal, G. G. Gul'bekyan, Yu. V. Lobanov, V. N. Mel'nikov, Yu. Ts. Oganesyan, A. G. Popeko, Kh. Rigol', Yu. P. Kharitonov, and Yu. S. Tsyganov.

In view of the high level of the papers presented in this section, the competition jury awarded, as an exception, three second prizes for the following papers:

"Crisis dynamics and restoration of intense thermal regimes in normal and superfluid helium." Authors: A. I. Alekseev, V. M. Miklyaev, V. F. Minashkin, S. V. Romanov, I. A. Sergeev, A. V. Srypnik, and Yu. P. Filippov;

"Facility for irradiating nuclear photoemulsions in a strong magnetic field." Authors: N. T. Burnev, M. A. Voevodin, A. Sh. Gaĭtinov, Yu. V. Gusakov, V. I. Kaplin, A. D. Kovalenko, A. G. Muryzin, Sh. Z. Saĭfulin, V. V. Smirnov, and V. Kita;

"Experimental complex for obtaining nuclei far from the beta-facility valley: YaSNAPP-2." Authors: V. K. Kalinnikov, M. Yanitski, Yu. V. Yushkevich, M. Yakhim, V. A. Bystrov, V. P. Afanas'ev, N. Yu. Kotovskiĭ, S. V. Evtisov, I. V. Mirokhin, and S. A. Gustov.

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