Scientific session of the Nuclear Physics Division of the Academy of Sciences of the USSR

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At the beginning of the present year (19–21 January 1983) at Moscow State University there was a comprehensive session of the Nuclear Physics Division, USSR Academy of Sciences, devoted to current problems of nuclear physics. The program of this session was arranged according to the following subject headings:

1. Common problems of nuclear physics and particle physics (states of a two-nucleon system, hypernuclei, new hadronic atoms, particle production in nuclei, possibilities of use of new high-energy electron accelerators for nuclear physics).

2. The mechanism of nuclear reactions (processes with small momentum transfer to the nucleus, reactions with large momentum transfer and the structure of nuclear matter at small interparticle distances, interaction of very light nuclei).

3. Reactions induced by heavy ions (fusion reactions, questions of the existence of and experimental search for exotic nuclei, collision of relativistic nuclei).

4. The nature of nuclear giant resonances. Some problems of the structure of highly excited states of nuclei.

5. Selected problems of neutron physics (parity nonconservation in reactions produced by slow neutrons; present state and prospects for new experimental directions—neutron optics and neutron interferometry).

In addition, questions of nuclear experimental techniques and problems of development of the apparatus of nuclear theory were discussed.

More than 500 specialists in the fields of nuclear physics and elementary particle physics took part in the work of the session. The program included 77 papers on all the principal subject headings. In view of the limited size of the present report we shall give here the content of only some of the papers presented orally at the plenary sessions.

1. A. A. Borovoĭ discussed the coming into operation of the neutrino laboratory of the I. V. Kurchatov Institute of Atomic Energy at the Atomic Power Station. The flux density of electron antineutrinos at the detector location at the present time is $6 \cdot 10^{12}$ cm$^{-2} \cdot$ sec^{-1}, and the counting rate about 300 events per day. A preliminary estimate of the cross section for the reaction $\bar{\nu}_e p \to ne^+$ is $0.95 \cdot 10^{-43}$ cm^2 with a statistical error of 15% and a systematic error of 12% (the result for $\bar{\nu}_e$ which is considered to be the best at the present time is that of R. Mössbauer and corresponds to a cross section of $1.05 \cdot 10^{-43}$ cm^2). Neutrino detectors are still unique devices. The apparatus built is the first in the USSR and the third in the world (the other two are at Savannah River, USA, and at Grenoble, France).

Yu. I. Stozhkov (Research Institute of Nuclear Physics, Moscow State University and P. N. Lebedev Institute) reported interesting results of analysis of experimental data on correlation of neutrino intensity variations recorded in the Davis experiment with variations of the intensity of galactic cosmic rays.

I. M. Ternov (Moscow State University) presented calculations of the action of an intense laser field on the rate of nuclear β decay. He showed that with amplitudes and frequencies achievable at the present time the increase of the total probability of β decay of tritium, for example, is negligible. This conclusion is important since in the literature (Phys. Rev. Lett. 48, 653, 1982) one encounters statements of the possibility of accelerating nuclear β decay by several orders of magnitude by means of a laser. A laser field which insignificantly affects the integrated decay probability may nevertheless appreciably distort the shape of the β spectrum (especially the soft part). Observation of this effect would be of great interest.

A. É. Tenishev (Khar'kov Physicotechnical Institute) reported measurement of the polarization of protons in the $d(\gamma, n)p$ reaction in a beam of linearly polarized photons with energy 250–450 MeV. This energy interval is interesting from the point of view of search for dibaryon resonances, which are predicted in the bag model and a number of quark models. In this and the previous studies at the Khar'kov Physicotechnical Institute on measurement of the energy behavior of the angular distributions, of the azimuthal asymmetry and the polarization of the protons, no indications of existence of such resonances have been obtained.

V. V. Fetisov (P. N. Lebedev Physics Institute) reviewed the current state and prospects of experimental and theoretical studies on the spectroscopy of hypernuclei in (K^-, π^-) reactions, including the recent discovery of Σ nuclei and the study of their properties, which turned out to be quite remarkable in certain respects (the mean life is an order of magnitude greater than expected).

The current state of the physics of exotic hadronic atoms (a heavy negative hadron and a nucleus) was discussed in the paper by A. E. Kudryavtsev (Institute of Theoretical and Experimental Physics). There have been two main events in this area: a qualitative increase in the accuracy of measurement of the shifts (and widths) of atomic levels as the result of the strong interaction, and the development of a theoretical technique for model-free extraction from these data of in-

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formation on the scattering length (even in cases when it is large). One of the newest results is observation of a large shift of the 2P level in the hadronic atom K^-He^4 ($\Delta E = 43 \pm 10$ eV, $\Gamma = 55 \pm 34$ eV). From this it follows that there is a *nuclear bound state* of the K^- meson with the α particle (binding energy about 60 keV, width about 80 keV). This state can appear, in particular, as a four-baryon resonance in the system $\Lambda n2p$. New data on the shift of the 1S level of the K^-p atom have turned out to be unexpected: the measured shift ($\Delta E = -190 \pm 60$ eV, $\Gamma = 80^{+220}_{-80}$ eV) does not agree with the scattering length obtained from extrapolation (by means of dispersion relations) of the kaon-nucleon scattering amplitude at nonzero momenta (here one obtains a shift $\Delta E(1S) = 270$ eV and width $\Gamma = 580$ eV). A number of other specific problems discussed in the paper (relating in particular to antiprotonic and Σ^- atoms) indicate convincingly the existence of an interesting new direction in nuclear and particle physics.

2. Study of the interactions of intermediate and high energy particles with nuclei has become at the present time an extensive field which has opened up qualitatively new possibilities for study of the mechanism of nuclear reactions and for obtaining information both on nuclear structure and on the properties of elementary particles. The most important results obtained in this area during the last 2–3 years were reported in a review paper by V. M. Kolybasov (P. N. Lebedev Physics Institute). He noted the appearance of a number of studies with measurement of all kinematic variables (so-called complete kinematics experiments), the arrival of the "polarization era"—the period of extremely intense polarization studies and a shift of interest in the investigation of proton-nucleus interactions from the region of a few GeV to energies of several hundred MeV, where the nucleon scattering amplitudes are much better known. This is due mainly to the substantial increase of the intensity of proton beams and the coming on-line of meson factories.

G. Z. Obrant (Leningrad Institute of Nuclear Physics) reported on the experimental study of the $(\pi^-, \pi^- p)$ process in deuterium, carried out with a deuterium bubble chamber at pion momentum of 400–550 MeV/c. The experiment is characterized by closeness in energy to the Δ resonance and by the fact that under the conditions of complete kinematics a wide range of variation of the kinematic invariants was investigated. The reaction mechanism was identified. It was shown that taking into account the quasielastic process together with nucleon-nucleon and pion-nucleon rescattering permits a very good description of the data.

Nuclear emulsion studies of the mechanism of interaction of pions and kaons of intermediate energy with the nuclei C, N, and O at the Leningrad Polytechnic Institute and the Leningrad Institute of Railway Transport were reported by Yu. R. Gismatullin. He showed that at small momentum transfers quasielastic knockout is dominant, and in other regions the knockout of a heavy fragment and the excitation of a nucleus with its subsequent decay are appreciable. It should be noted that these studies of $(\pi, \pi N)$ processes in light nuclei are one of the most complete in scope and diversity of the data. Data which have been accumulated at the present time on knockout reactions indicate that in the region of momentum transfer to the residual nucleus from 0 to 300 MeV/c the observed phenomena are determined mainly by the simplest pole mechanism and by secondary rescatterings. The contribution of more exotic processes (virtual production of highly excited particles, inclusion of isobar admixtures in the nuclear wave function, exchange currents, and so forth) is negligible in this region.

S. L. Belostotskiĭ (Leningrad Institute of Nuclear Physics) reported on the polarization of so-called cumulative protons (i.e., protons emitted at energies and angles which are inaccessible in nucleon-nucleon collisions). Protons emitted from a number of nuclei at angles up to 145° in the laboratory system were studied at a primary-proton energy of 1 GeV. The polarization turned out to be close to zero. This result is very important. It permits one to exclude several very widely discussed theoretical models of cumulative processes, in particular, quasielastic scattering by a highly virtual nucleon. In other words, a cumulative reaction is not necessarily due to the presence of many particle configurations of small size, but can be explained by multiple scattering. This is indicated also by the results of quasiclassical calculations reported at the session by M. M. Nesterov and N. A. Tarasov (Leningrad Institute of Nuclear Physics).

3. In the area of interaction of relativistic nuclei, special attention at the present time is being given to the problem of "anomalons"—secondary fragments produced in interaction with nuclei of ions with energy of the order of several GeV per nucleon, in which the mean free path is anomalously small (the cross section for interaction is significantly greater than the geometrical size of ordinary nuclei).[1)] Papers on anomalons by A. P. Gasparyan (Nuclear Reactions Laboratory, Joint Institute for Nuclear Research), V. A. Kotel'nikov (P. N. Lebedev Physics Institute), and V. A. Karmanov (P. N. Lebedev (Physics Institute) contained a reveiw of experimental data obtained in accelerators (mainly at the Bevalac in the USA) and in cosmic rays, and also of published attempts at theoretical interpretation of the phenomenon (here very diverse hypotheses have been expressed: from the comparatively ordinary idea of an increased yield of neutron-rich isotopes to very exotic models such as the assumption of existence of an anomalously loosely bound state of nuclear matter or a long-range interaction due to an "explicitly colored" gluon field). At the same time the general opinion of those involved in this question reduces to the conclusion that there is insufficient convincing information on the very existence of the effect, which has been observed so far only by means of track techniques (nuclear emulsion, bubble chambers).

4. In nuclear physics so-called resonances have been known for a long time. The term giant refers to saturation of the sum rule and to the widths of these resonances. Previously giant resonances were observed

[1)]In this regard see the brief review by V. A. Karmanov, Usp. Fiz. Nauk 141, 525 (November 1983).

only in transitions corresponding (according to the selection rules) to electric dipole excitations. In the last few years resonances of higher multipolarity have been discovered, and also high-lying monopole excitations (radial oscillations of a nucleus with preservation of the angular symmetry). Great interest for nuclear theory is presented by collectivized spin and isospin excitations, so called resonances of the Gamov-Teller type.

A. A. Ogloblin (Institute of Atomic Energy) reported on the characteristics of the current state of experimental research in this field and, in particular, he gave a list of unsolved problems. He discussed new possibilities of study of Gamow-Teller giant resonances by means of heavy-ion beams, with the reactions (^{6}Li, ^{6}Li*), (^{6}Li, ^{6}He), (^{7}Li, ^{7}Be), which are being carried out at the Kurchatov Institute.

V. G. Solov'ev (Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research) reported on giant resonances in spherical nuclei, which arise on excitation of deep hole one- and two-quasiparticle shell states. These "doorway" states are collectivized (fragmented) as the result of quasiparticle-photon interactions. Numerical calculations of the excitation curves, carried out in the framework of this model, agree satisfactorily with the existing experimental data.

5. A number of important results have been obtained in the field of neutron physics.

V. I. Morozov (V. I. Lenin Institute of Atomic Reactors) reported the achievement of extended storage of ultracold neutrons of energy $(2-3)\cdot 10^{-8}$ eV in a vessel at 80 °K consisting of aluminum with heavy ice frozen onto the walls. The measurements showed that the number of ultracold neutrons under the conditions of this experiment decreased by a factor of two in a time $T_{1/2} = 940 \pm 50$ sec, which within experimental error agrees with the corresponding period of β decay of the neutron. Thus, a neutron gas contained in a vessel up to its β decay has been obtained for the first time. For a long time it was not possible to achieve this (the idea of containment of ultracold neutrons in a vessel was suggested by Ya. B. Zeldovich in 1959, and the experimental possibility of accomplishing this was demonstrated by F. L. Shapiro and his colleagues at the Neutron Physics Laboratory of the Joint Institute for Nuclear Research in 1968, but the storage time was significantly less than theoretically expected).

The report of A. I. Frank (Institute of Atomic Energy) was devoted to a new technical direction—neutron interferometry. This area is being developed intensively at the present time and may turn out to be a very effective means of solving a number of problems of nuclear physics, the physics of condensed media, and perhaps of some fundamental problems. At the present time there are in the world several operating neutron interferometers. A. I. Ioffe (Leningrad Institute of Nuclear Physics) reported on a project for creation of a neutron interferometer in the USSR, in which it is proposed to use as a wave-front divider and as a combiner of the interfering beams diffraction gratings with a rectangular profile of the surface relief on glass, on which a ^{58}Ni layer has subsequently been deposited.

Important events have taken place in the area of study of parity nonconservation in nuclear forces. Usually the experimentally observable effects which are produced here by parity nonconservation (angular asymmetry of γ radiation in capture of polarized neutrons by nuclei, circular polarization of γ radiation) have had a very small magnitude, of the order of 10^{-4}–10^{-5}. It is a remarkable fact that effects have now been observed at the 10% level. L. B. Pikel'ner (Neutron Physics Laboratory of the Joint Institute for Nuclear Research) reported observation of a large resonance effect (up to 8% in ^{81}Br) of helical dichroism on capture of longitudinally polarized neutrons in targets of ^{81}Br and ^{111}Cd. New measurements at a higher confidence level have confirmed similar data for the nuclei ^{117}Sn and ^{139}La obtained in 1981. The phenomenon is explained by the fact that as the result of parity nonconservation there is a small S-state admixture to the dominant P state of the neutron + target system. The high relative probability of capture into the admixed S state leads to an enhancement which permits observation of an almost 10% effect. The observation of resonance behavior of the effect is at present the most convincing observation of parity nonconservation in nuclear forces.

In the report of V. A. Nazarenko (Leningrad Institute of Nuclear Physics and Nuclear Reserach Institute) new data were discussed on the magnitude of the circular polarization of γ rays in radiative capture of neutrons in a hydrogen target, $n(p,\vec{\gamma})d$. An upper limit has been obtained for this reaction, $p_\gamma < 5\cdot 10^{-7}$ (previously the same group found an effect of the order of 10^{-6} within three standard deviations; theoretically one expects a value of about 10^{-8}). The same paper reported a large integrated manifestation ($\sim 10^{-5}$–10^{-4}) of the parity nonconservation effect in (n,γ) reactions in the nuclei Cl, Br, Sn, and La. The circular polarization of the γ rays was measured and, in experiments with polarized neutrons, also their angular asymmetry. There was no discrimination of γ rays in energy, i.e., the γ rays corresponding to the transition to a definite final state were not separated. The result on the angular asymmetry does not fit into the framework of contemporary theoretical ideas, since on averaging over possible final states the asymmetry value should vanish.

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