THE MAIN ACHIEVEMENTS OF NSC KIPT IN NUCLEAR PHYSICS FOR 70 YEARS AFTER ATOMIC NUCLEUS DISINTEGRATION

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Brief review of works on nuclear physics executed in NSC KIPT since 1932 is given.
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In April 1932 J.D. Cockroft and E.T. Walton in England carried out nuclear reaction by artificially accelerated particles – protons. On October 10, 1932 A.K. Val'ter, A.I. Leipunsky, G.D. Latyschev and C.D. Sinel'nikov disintegrated the Li nucleus using the accelerated protons, too [1]. Since then the atomic nucleus investigations became one of the main scientific trends in NSC KIPT. Reviews, reflected nuclear physics development in NSC KIPT were published before different remarkable dates. In the present review the attempt to analyze the main achievements in nuclear physics, obtained in NSC KIPT during 70 years after atomic nucleus disintegration, was made.

During the last years the considerable amount of accelerators of different types was developed, and by means of them the accelerated electron, proton, deuteron, helium and heavy ion beams have been obtained. The different methods of investigations in nuclear physics have been developed, a lot of unique in that time scientific information concerning the atomic nucleus structure and nuclear reactions mechanism have been obtained. It is difficult to reflect all obtained scientific information in the relatively small review, so we'll try to reflect only main from out point of view results obtained in NSC KIPT after the atomic nucleus disintegration in 1932.

Besides our institute hundreds of leading world scientific centers worked in the field of nuclear physics during all the time after atomic nucleus disintegration. Certain idea about atomic nuclear structure and nuclear reaction mechanisms have been developed as the result of carried out researches. Main results obtained at NSC KIPT seem to be worth considering in the connection of the world achievements in the atomic nucleus investigations.

The atomic nucleus is an unique object for investigations comparing with other ones, for example, solids. Restricted number of particles in nucleus comparing with that in solids causes this. On the other hand the number of nucleons in nucleus changes from 2 in deuteron to 250...300 in transuranium elements. It determines the essential distinctions of properties of nuclei exited states. For the lightest nuclei the level density is not large and equals to some exited states and this states are described by comparatively simple atomic nuclei models such as shell model. But with the increasing of the nucleons number in nuclei the number of exited states in nuclei, and their density increase and for their describing the complicated models have been developed. These models takes into account many-particle-hole, fourquasiparticles and others excitations. For very heavy nuclei such as uranium and transuranium ones with the increasing of the excitation energy the nuclei are usually disintegrated into two decay products. For all atomic nuclei under large excitations strong rearrange of the whole atomic nucleus is observed so one can observe giant resonances but not the single nuclei levels. For example the dipole giant resonances are observed when all protons are moved relative to all neutrons and quadrupole giant resonances are connected with nucleus form changing. Such resonances may be electric and magnetic giant ones. If the excitation energy of nuclei, especially lights, will more increase, the disintegration into clusters will be observed. The schematic picture of atomic nuclei structure is shown on Fig. 1.

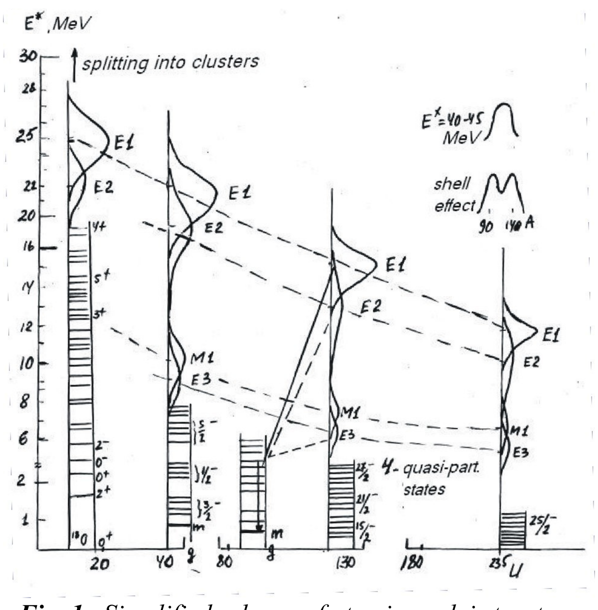

Fig. 1. *Simplified scheme of atomic nuclei structure*

Of course, it is too general and not full description of the atomic nuclei features, but even it shows the diversity of the subject. It is also shows that great efforts of the whole international community of nuclear physicists needed for the compiling of the today picture of atomic nuclei properties. Of course, future investigations will make possible to obtain more compete and diverse information about atomic nuclei structure.

We would like to consider the deposit of NSC KIPT in the investigation of atomic nuclei structure and the mechanisms of the nuclear reactions.

In the 1939-1940 years at the vertical electrostatic accelerator of the Van de Graaf type (energy up to 2.5 MeV, conductor diameter 10 m, accelerator tube length 10 m) K.D. Sinelnikov and co. showed that ^{3}He is not radioactive and hence the tritium nucleus mass is larger than ^{3}He one.

In 1948-1954 years at the same restored after war accelerator A.K. Walter, A.P. Klutscharev, P.I. Vatset and co. studied in details the excitation functions of D+D, D+T, D+ ^{3}He, ^{6}Li(n,α)T and other reactions. The cross-sections of this processes were necessary for the development of new weapons and thermonuclear reactions. In those researches the quantum characteristics of the excited states of ^{5}He, ^{5}Li and other nuclei have been obtained. For the investigation of ^{6}Li(n,α)T reaction (Fig. 2) P.I. Vatset was awarded with State Prize of the USSR [2].

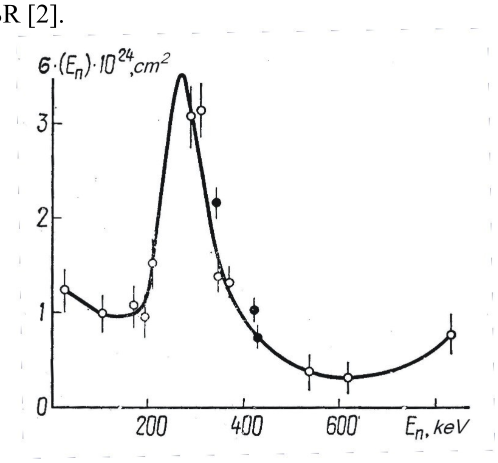

Fig. 2. *Dependence of the total cross-section of ^{6}Li(n,α)^{3}T, measured by photomethod (o) and ionization chamber(•)*

Since 1963 investigations of the lightest nuclei were continued at electron and photon beams obtained at linear electron accelerator. P.I. Vatset and V.I. Voloshchuk and co. investigated in details the interaction of γ-quantum with ^{4}He. The authors have obtained information about total cross-section of different reaction channels, angular distributions, photodisintegration mechanism, the contributions of electromagnetic transitions (E1, M1 etc.) in ^{4}He nucleus, the isotropic mixture of states, the excitation states of ^{4}He and so on. For the investigation of the ^{4}He photodisintegration P.I. Vatset and V.I. Voloshchuk were awarded with State Prize of the USSR.

In 1953 the precise electrostatic accelerator with energy up to 4.5 MeV was put into operation. The energy stability of this device was very high and investigation of light nuclei excited states began. The investigations have been carried out by S.P. Tsytko, E.G. Kopanets, U.P. Antuf'ev with coworkers. The nuclei of 1d2s and 1f2p shells have been investigated in details. For many light nuclei the nuclear levels decay scheme has been determined, the excited functions have been measured, the matrix elements of electromagnetic transitions has been obtained, isobar-analog and twice analog states have been investigated in details and so on. These experiments and theoretical works (E.V. Inopin, V.U. Gonchar et al.) led to the conclusion that the general model was valid to describe the light nuclei and so the deformation of light nuclei have been proved.

The experiments with polarized beams that were carried out by R.P. Slabospitskiy, I.M. Karnaukhov and A.S. Deineko with coworkers [1] made an essential contribution to the investigation of nuclei structure. Unique possibilities of the polarized experiments gave the opportunity to define the quantum characteristics of more than 20 light nuclei and to show that nuclei with 1p-shells are better described by shell models with intermediate coupling, and 2s1d nuclei by general model with intermediate coupling. By means of polarized protons it was shown for the first time that threshold anomalies in the proton channel of the elastic scattering at the energies, when neutron channel became open, are connected with the existence of (2^-) level in compound nucleus near unveiling of S-wave channel. Also for the first time by means of polarized deuterons beam the resonances of the intermediate structures in nuclei have been investigated. It was also shown that these resonances were input states and can be explained by the fine structure of the giant resonances and isobar-analog states of nuclei. R.P. Slabospitskiy was honored by the State Prize for those fulfilled experiments (Fig. 3).

V.E. Storizhko, B.A. Nemashkalo with coworkers made the noticeable contribution to the investigations of middle nuclei (1f2p- shell, A=40-80). They developed the method of averaged resonances, which gave the possibility to investigate the angular and energy dependencies of cross-sections and to determine their peculiarities for the width about 100 keV. It was shown that the (p,n,γ) reaction at the energy less then 3 MeV has the static character, while in other channels deflection from static description takes place. It may be explained by the model of valency capture.

If the strong excitation of nucleus takes place, it opens the possibility of investigation of giant electrical and magnetic resonances. These investigations have been done by N.G. Afanas'ev, G.A. Savitsky et al. by means of accelerated electrons with energy up to 300 MeV. They measured in details not only the dipole and quadrupole resonances but they also represented the statistically defined evidence of the hexagonal electrical resonance(E4). It was shown that the method of chaotic phases was bad approximation for description of the octupole resonance(E3). It will be needed to use more realistic models[3].

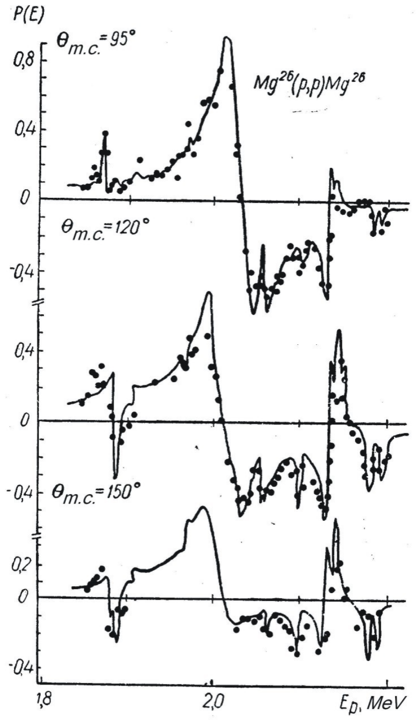

Fig. 3. *Polarization dependence on energy for proton scattering at Mg^{26} nuclei*

Magnetic giant resonances are less studied comparing with electric ones, but they could yield further information about nuclei. Magnetic dipole resonances (M1) posses unique possibilities in the investigation of the meson exchange currents contribution in the transition probabilities between different excited states in nuclei. Besides, M1 transitions give the most complete information about spin and isospin dependence of nuclear forces. Sufficiently compete information on position and strength of the M1 resonance has been obtained on electron and photons inelastic scattering, but only for even-even nuclei of *sd*-shell. It is not sufficient as very valuable information can be obtained while studying M1 resonances in the odd-odd nuclei. The investigation of these nuclei is very difficult to perform by means of electron and photons the odd-odd nuclei are radioactive. A.S. Kachan with coworkers studied in details M1 resonances in such nuclei. They discovered a new phenomena connected with triplet coupling between odd neutron and proton at the same orbit. While this the position of the M1-resonance gravity center in odd-odd nuclei is 3 MeV lower comparing with even-even (4N) nuclei and 1.5 MeV lower comparing with even-even (4N+2n) nuclei. The authors proposed model, explaining this phenomena and evaluated the location and the strength of M1-resonance for those nuclei where the data were absent at presence.

Yu.N. Ranuyk with coworkers also made great contribution to the investigations of ultra heavy nuclei. In 1967 it was the first successful attempt of observation of ^{238}U disintegration by electrons and in 1969 – by positrons. These works opened the way for detail exploration of atomic nuclei fission induced by electrons and positrons and fission cross-section ratios. Comparison of data for photo- and electro-fission cross-sections gives us the data about multipolarity of adsorbed photons. Using of electrons gave the opportunity to obtain the information about higher multipoles comparing with real photons. In 1999 journal "Nuclear Physics" determined the best works. It was dedicated to the 275-th anniversary of Russian academy of Science. Work of Yu.N. Ranuyk and coauthors (one from the whole Ukraine) concerning delay electrofission of transuranium element nuclei was considered as one of the best ones, published in the journal for the whole its history. The scientists of NSC KIPT made a great contribution not only to investigations of the nuclei excited states, but also to the investigations of the generalized nuclei(especially isotopes) properties as function of number of nucleons in nuclei.

From 1955 A.P. Klutscharev with coworkers studied in details the isotope effect at proton elastic scattering on atomic nuclei[1]. While this intensity of scattering at large angles decreases with number of neutrons in nuclei increasing. And this discrepancy caresses with the colliding proton energy increasing. Methods of isotope targets obtaining were developed. It was shown that diffraction picture violation in nuclear potential scattering of protons is caused with additional protons passed compound nucleus and scattered at large angles. This effect is observed for nucleus in which at given energies the competing channels is closed or made strongly weaker. It was established as a consequence of the investigation of the proton scattering at low energy that nuclear interaction radius is not a monotonous function of mass number.

Elastic and inelastic scattering of accelerated electrons on nuclei has been studied by N.G. Shevchenko and coworkers. They investigated in details the charge distributions in the 1*f*2*d* and 1*g* shells nuclei. It was shown that the thickness of the surface layer of the charge distribution in nucleus is very sensitive to the shell effects. If there are two protons or neutrons above filled in shell or subshell the thickness of the surface layer abrupt increases. When the shell (subshell) is neutron or proton closed the thickness of surface layer decreases. It was established for the first time that the nuclei with larger thickness of surface layer have higher reduced probability of the quadrupole and octupole transition from ground to lower excited state. Thus, it can be stated that shell effects of charge distribution in nuclei are very strong and sufficiently larger than it can be obtained from the calculation by mean of Khartry-Fock method with Scirma fources.

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