É. E. Berlovich. *Study of nuclei far from the β-stable band.* In recent years, physicists have shown sharply increased interest in nuclides far from the β-stable band; several international conferences have been devoted to discussion of their properties and the results of experimental research. In spite of the great difficulty of producing these nuclides in the laboratory, which arise out of their small cross sections of formation in nuclear reactions and their short lifetimes, information on their properties is very important both from the standpoint of astrophysics, since they are formed continuously in various astrophysical processes (for example, the process of "rapid" neutron capture in supernova explosions, or the reactions of deep splitting, fission, and fragmentation under the action of high-energy protons and α particles in stellar atmospheres, in the envelopes of supernova remnants, and in the interstellar medium) and for the creation of an adequate thoery of the nucleus.

The principal characteristic properties of these nuclides are as follows: 1) an "unusual" relation between the numbers of neutrons are protons; 2) an "unusual" relation between the Coulomb and nuclear forces; 3) a significant difference between the binding energies of the protons and neutrons; 4) a difference in the radii of distribution of the protons and neutrons, which results in the formation of a peripheral "loose" halo containing more nucleons of one type[1,2] (Fig. 1); 5) large β-decay energies.

The presence of a halo of weakly bound excess nucleons around a core of rigidly bound nucleons of both types, together with the other peculiarities mentioned above, should make for differences in the structure of these nuclides and affect such important properties as the type of potential, moment of inertia, shape, etc. Experimental information on nuclei far from the β-stable band is no less important for creation of an adequate theory of the nucleus than information on nuclides in the region of this band.

Certain effects that are to be expected near nucleon-stability boundaries have been considered in Refs. 3–6

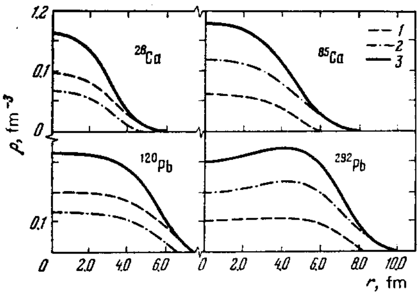

FIG. 1. Proton and neutron distribution profiles for ^{28}Ca, ^{85}Ca, ^{120}Pb, and ^{292}Pb as calculated in Ref. 2. 1) protons; 2) neutrons; 3) all nucleons.

(two-neutron decay,[3] "delayed" emission of ^{3}H and ^{3}He[4] particles); it has been shown[5] that the "delayed" fission phenomenon[7] observed in G. N. Flerov's laboratory (Joint Institutes of Nuclear Research, JINR) is especially common in the region of excess-neutron nuclei, and this should influence development of the "rapid" neutron capture process (r process) and the abundances of elements. Calculation of the r process with allowance for nucleon-shell effects showed[6] that it develops much farther than would be expected from classical calculations[8] and may, at certain values of the parameters, lead to the formation of superheavy elements.

Aspects of effects that depend strongly on energy were considered in Refs. 9 and 10 (double β-decay,[9] contributions of higher order to single β transitions[10] at high decay energies). A whole series of systems designed for study of "far" nuclides produced on proton and heavy-ion accelerators and in reactors are now in operation in various countries. In the USSR, "far" nuclei are being studied on a heavy-ion accelerator in Flerov's laboratory at the JINR.

For several years now, the Leningrad Institute of Nuclear Physics of the USSR Academy of Sciences (LINP) has been producing nuclides with half-lives below ten seconds in reactions initiated by protons accelerated by a synchrocyclotron to an energy of 1 GeV; after fast separation from the boiling-liquid target by flushing with oxygen and converting to volatile oxides, these nuclides were delivered to a background-free room via a pneumatic shuttle. New short-lived osmium and rhenium isotopes were produced for the first time by this method,[11,12] and in the case of rhenium it was possible to proceed 15 mass units from the lightest stable isotope ^{185}Re (^{170}Re, $T_{1/2} = 9 \pm 2$ sec).

At the end of 1975, the LINP started up the IRIS complex, in which a mass separator works "on line" with a synchrocyclotron, so that the emission of nuclides can be studied continuously as they are formed and transported as accelerated ions to a collector with a radiation detector placed in front of it. Figure 2 shows a block diagram of the IRIS complex. This system has been used to study the γ spectra of xenon isotopes (^{118}Xe, ^{119}Xe).[13]

Combining the efforts of the groups at the LINR and in the nuclear spectroscopy and radiochemistry section of the JINR Nuclear Problems Laboratory was a highly effective measure. Using a JINR-developed ion source with surface ionization integrated with a proton-bombarded target and adapted for work with the mass separator of the IRIS system, it was possible to investigate the α decay of 27 isotopes of rare-earth elements.[14] The α decay of isotopes produced in nuclear reactions has usually been studied without a mass separator, and the α radiators have been identified from the excitation functions, i.e., curves of the yield of the particular isotope plotted against energy. Uncertainties and errors were frequent with this method. Some of the errors were brought to light in the studies cited[14]: for example, the α-line energy of the isotope ^{156}Yb was identified correctly, and the new isotope ^{157}Lu was detected and its basic characteristics studied—α-line energy, the relative intensity of the α-decay branch, and the half-life ($T_{1/2} = 5.2 \pm 0.3$ sec). This isotope is 18 mass units distant from the lightest stable isotope of lutecium (^{175}Lu). The IRIS system now has two operating ion beams, and addition of a third is planned; this will make it possible to run simultaneous experiments with three selected isotopes of an element. In addition to the JINR group, staff members of the Leningrad and Tashkent State Universities and the Radium Institute have been called in to work on the IRIS system, and the range of participants is to be expanded further by representatives from other scientific establishments of the Soviet Union and foreign countries.

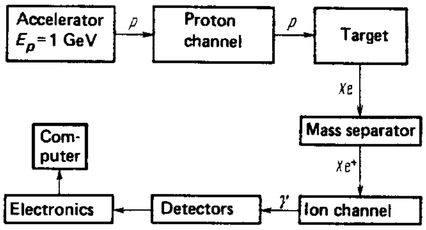

FIG. 2. Block diagram of IRIS complex.

Procedures are being prepared for precision measurements of the masses of "far" nuclides (jointly with the Radium Institute group) on a high-resolution mass spectrometer developed by V. M. Kel'man, for study of the charge radii of nuclei via the isotopic shift of the optical lines using tunable-laser techniques, and for determination of the magnetic and quadrupole moment spins (jointly with V. S. Letokhov's group at the Academy of Sciences Institute of Spectroscopy (ISAN)); the rapid crystal-diffraction spectrometers developed by O. I. Sumbaev's group and the LINP will make it possible to study x-ray line shifts and hyperfine-interaction effects.

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