PRESENTATIONS OF THE NEW RESULTS AND PROPOSALS BY FLNR YOUNG SCIENTISTS IN THE FIELD OF NUCLEAR PHYSICS

1.

M. Tezekbayeva, A. Yeremin, A. Svirikhin, A. Lopez-Martensd, M. Chelnokov, V. Chepigin, A. Isaev, I. Izosimov, A. Karpov, A. Kuznetsova, O. Malyshev, R. Mukhin, A. Popeko, Yu. Popov, V. Rachkov, B. Sailaubekov, E. Sokol, K. Hauschildd, H. Jacobd, R. Chakmae, O. Dorvauxf , M. Forgef, B. Gallf, K. Kessacif, B. Andelg , S. Antalicg, A. Bronisg, P. Mosatg.

Detailed study of radioactive decay properties of ^{249}No, ^{250}No with α, β, γ-spectroscopy method.

At FLNR JINR, experiments are aimed at to investigate the radioactive decay properties (α, β, γ spectroscopy) and the cross sections measurements of transfermium elements, synthesized in complete fusion reaction of accelerated heavy ion beam with target nuclei, with subsequent evaporation of several light particles at the kinematic separator SHELS. A number of experiments were devoted to the study of the radioactive decay properties of Nobelium isotopes are produced as a evaporation result of two or three neutrons by a compound nucleus in the reaction of ^{48}Ca beam with ^{204,206,208}Pb targets. These Nobelium isotopes have a sufficiently high production cross-sections, which allow us collect good statistics for studying decay properties by methods of alpha, beta, gamma spectroscopy. Nobelium isotopes are interesting in how the radioactive decay properties change passing through the closed subshell N = 152, thereby could be obtain data are necessary to understanding how the heavy elements properties behave passing through the subshell N = 162.

2.

K. Novikov, E. Kozulin, A. Karpov, G. Knyazheva, A. Bogachev, V. Saiko, I. Vorobiev, I. Pchelintsev, R. Tikhomirov

Creation of a setup and development of a method for studying symmetric combinations in multi-nucleon transfer reactions (^{238}U + ^{238}U)

This work is devoted to the development of a method and the study of the mass-energy and angular distributions of fragments formed in the reaction of multi-nucleon transfers ^{238}U + ^{238}U. The new setup IRINAL was developed based on the existing setup CORSET to accomplish the task. The new setup is equipped with a system for automatic target movement and detector rotation without breaking the vacuum and stopping the beam. The IRINAL setup allows simultaneous study of binary fission and sequential-fission processes. This approach is essential for studying multi-nucleon transfer reactions.

The required geometry and the possibility of registration fragments formed in the reaction ^{238}U + ^{238}U→^{208}Pb + No * have been estimated. The test experiment was

prepared and carried out onthe basis of the calculations. The mass-energy distributions of the products of the reaction ^{90}Zr + ^{nat}Zr were measured, as an analogue of the reaction ^{238}U + ^{238}U. Events of quasi-elastic scattering and deep-inelastic transfers were observed as a result of the measurements carried out in the region of symmetric masses with TKE 160–200 MeV. Quasi-fission events, fast-fission events and possible fusion-fission events are located in the mass region A = 60-120 and TKE 100-160 MeV. Competition of contributions from different processes is observed at the maxima of the squared dispersion of the kinetic energy. The processes of quasi-elastic scattering, deep-inelastic transfers, quasi-fission, fusion-fission and fast-fission compete in the region of symmetric masses. In the area of asymmetric masses, there are only 3 competing processes: quasi-fission, fusion-fission, and fast-fission. The results of the test experiment showed the possibility of separating different processes in the symmetric region and in the asymmetric region of mass distribution. This is extremely important for the study of multi-nucleon transfer reactions, including such an extremely complex reaction as ^{238}U + ^{238}U.
The experimental data obtained as a result of the test experiment are of great interest. In this regard, it is planned to carry out the experiment ^{90}Zr + ^{90}Zr.

3.

S. Stukalov, Yu. Sobolev, Yu. Penionzhkevich, V. Samarin, M. Naumenko, I. Sivachek

Total reaction cross section with lite weakly bound nuclei

The report is devoted to the experiments and methods of total reaction cross section σ_R measurements. The experimental method for direct measurement of σ_R is based on reaction products detection like prompt neutrons and γ-quanta by 4π-detectors. The energy dependence $\sigma_R(E)$ for $^{10-12}$Be+^{28}Si, ^{59}Co, ^{181}Ta reactions are presented. It was found a relation between the structure of weakly bound light nuclei ($^{4-8}$He, $^{6-11}$Li, $^{10-12}$Be) and the peculiarities of total reaction cross sections energy dependence. For instance, it was observed the significant enhancement of $\sigma_R(E)$ for reaction with ^{11}Li halo nuclei over the all measured energy range. At the same time, nuclei with a “skin” structure (^{8}He, ^{6,9}Li) were characterized by local excess of $\sigma_R(E)$ (bump) in the mean Fermi energy region. The presented experimental data $\sigma_R(E)$ for $^{10-12}$Be+^{28}Si, ^{59}Co, ^{181}Ta are in agreement with the previously discovered phenomena.

4.

A. Bodrov, A. Sabelnikov, G. Bozhikov, N. Aksenov, S. Dmitriev

Production of radioactive targets for the first experiments at the Superheavy elements Factory

For implementation of the scientific program, new large-diameter target blocks capable to withstand high intensities of heavy ion beams were developed. Due to usage of new target blocks, the production of actinide radioactive targets of larger area with the following regeneration of it is actual. In the report, the method of molecular plating from organic solvents of hard-to-reach enriched radioactive isotopes of americium, plutonium and uranium on a titanium foil is presented. The irradiated targets were analyzed on the subject of damages and new results are obtained on these targets. The first results on stability of actinide radioactive targets were obtained at record beam intensities 2-6 pμA, and an initial evaluation of the obtained data was carried out. This technique has also been successfully applied to the manufacture of targets from ^{245}Cm. The technique of regeneration of the target material on the example of americium and curium has been worked out.

5.

V. Vedeneev, A. Rodin, L. Krupa, E. Chernysheva, A. Gulyaev, A. Gulyaeva, M. Holik, J. Kliman, P. Kohout, A. Kohoutova, A. Komarov, A. Novoselov, A. Opichal, J. Pechousek, A. Podshibyakin, V. Salamatin, S. Stepantsov, S. Yukhimchuk.

Current status of the cryogenic gas stopping cell

An installation for precision mass measurements of heavy and superheavy nuclides synthesized in fusion reactions at the new DC-280 accelerator is being implemented at the FLNR, JINR. The facility consists of the following parts: a gas-filled pre-separator, a cryogenic gas ion trap and a multi-reflection time-of-flight mass spectrometer. The gas-filled cell separates reaction products from the ion beam. A cryogenic gas ion trap decelerates the flow of exotic nuclei at the separator outlet and forms a continuous beam from these nuclei with energies of several electron volts. The central part of experimental setup is a cryogenic gas stopping cell with de Laval nozzle. The design implemented in Darmstadt for the SHIPTRAP facility was taken as a basis. An experimental investigation performed there showed an overall extraction efficiency for ^{219}Rn recoil ions were circa 67% and the extraction time of about 60 ms. The gas cell itself, cooled down to 40 K, is placed in a vacuum volume. The gas cell contains: a cylindrical eight-electrode transport system (DC electrodes) and a radio-frequency multi-electrode cone (RF funnel). At the outlet of the cell, a de Laval extraction nozzle is installed, which forms a supersonic jet from a mixture of gas and ions and directs it into the volume. In the volume, the neutral gas is evacuated by the pumping system, and the ion beam is transferred to the next volume by the radio-frequency quadrupole transport system, where the next quadrupole

system forms from the continuous ion beam bunches. At the new experimental stand, the cryogenic gas stopping cell is being assembled for offline testing with alpha-active sources.

By this moment, the cryogenic gas cell, located at FLNR experimental stand, is being developed. Pumping system for both vessels was tested. Electrodes assembly and cryogenic part are studied underway.

6.

P. Komarov, S. Mitrofanov, V. Schegolev

Reconstruction of the radiation safety system of the FLNR accelerator complex

FLNR starts the project of reconstruction of radiation safety systems, following the broad program of FLNR accelerator complex modernization (both existing cyclotrons and new ones) and experimental setups based on it, as well as due to worn out of existing dosimetry equipment. The project includes total replacement of equipment, implementation of new software, installation, and commissioning of radiation safety systems.

State-of-art and the road map of the dedicated safety systems, in particular Personnel Access Control System (PACS) and Automated Radiation Monitoring System (ARMS), will be presented both for new cyclotrons DC-140, U-400R and for modernized U-400M. In addition, the report will include operation features of the modern ARMS and PACS, which have already run at the cyclotron DC-280.

7.

A. Protasov, V. Semin, K. Gikal, D. Pugachev

Producing high-intensity beams on the DC-280 cyclotron

The discovery of new superheavy elements (SHE) with Z = 114 - 118 was one of the most striking scientific results of the last two decades. Previous experiments were done at JINR (Dubna, Russia) at the U-400 accelerator complex of the Flerov Nuclear Reactions Laboratory. Synthesis of the SHE was done in the reactions of complete fusion of the doubly magical shell of ^{48}Ca with neutron-redundant actinide nuclei (^{242,244}Pu, ^{243}Am, ^{249}Cm, ^{249}Bk, ^{249}Cf).

Direct synthesis of elements with Z>118 in fusion reactions is associated with the transition to bombarding nuclei are heavier than Ca, because the possibilities of operating target material on nuclear reactors are limited by the production of Cf isotopes. It is expected that the cross sections of the formation of nuclei with Z = 120 in the ^{248}Cm + ^{54}Cr reaction and nuclei with Z = 119 in the ^{249}Bk + ^{50}Ti reaction will

be approximately 10-20 times lower than the cross sections of the formation of SHE isotopes in experiments with ^{48}Ca. For a more detailed study of the nuclear physical and chemical properties of SHE, it is also necessary to significantly increase the efficiency of experiments.

The DC-280 cyclotron was created to solve these problems. Planned beam intensities up to 10 pμA for ions with average masses (A ~ 50) are one order higher than those reached so far at the U-400 cyclotron. The main task of the new accelerator is implementation of the long-term program of researches on the SHE Factory aimed at synthesis of new elements (Z ≥119) and detailed studying of nuclear-physical and chemical properties of earlier opened 112-118 ones.

The report describes the experimental results of obtaining high intensities of ^{48}Ca, ^{48}Ti, ^{52}Cr, ^{54}Cr. It also includes some problems that have arisen in the course of work and a description of their solutions

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8.

K. Avvakumov, S. Zemlyanoy

Ion guide system for GALS setup

The new setup called GALS (GAs cell-based Laser ionization and Separation setup) is being created in Flerov Laboratory of Nuclear Reactions. The aim of the setup is to synthesize and study new heavy neutron rich nuclei in the region of neutron closed shell N = 126. One of the most important parts of the GALS is radio-frequency ion guide, which captures laser-ionized isotopes of interest carried by buffer gas flowing from the gas cell into vacuum through a supersonic nozzle. The ion guide transports the ions through differential pumping volumes towards the high vacuum chamber where they are accelerated, mass-separated by analyzing magnet and then registered by the detector system.

Several possible options were considered for the ion guide system design, e.g. sextupole or quadrupole segmented ion guide etc. To choose the most suitable system design, simulations of different ion guide options were carried out using the SIMION software package. Additional code describing the gas jet was used to complement the hard sphere collision model for ion trajectories simulations in the low vacuum region. A number of additional refinement simulations was performed to optimize various parts of the electrodes system before putting it into production and distributed power supply system development. The final design of the ion guide system and its estimated output parameters will be discussed.
