Thesis and PhD themes

DETERMINATION OF MASSES OF THE SUPER HEAVY ELEMENTS IN THE EXPERIMENTS ON SYNTHESIS OF 112 AND 114 ELEMENTS USING THE REACTIONS ^{48}CA+^{238}U AND ^{48}CA+^{242}PU

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Traditionally, in experiments on synthesis and properties investigation of transuranium and superheavy elements methods are applied, based either on the properties of α-decay radioactive chains ending at well-known nucleus or on radiochemical identification. Thanks to the long lifetimes of most superheavy nuclei (between 0.1 ms and 30 s), high efficiency kinematic separators which can reliable separate the fusion reaction products from the target-like products and from the primary beam are used. However, these separators do not measure the masses of separated atoms. At the FLNR it was shown that the lifetime of the synthesized isotopes of 112 and 114 elements is higher than 0.5 s and both elements are volatile at room temperature. Thus, experiments on mass measurements of the isotopes of these elements by mass-spectrometer technique with ECR ion source and hot catcher can be carried out. For the first time, such a technique was proposed by the FLNR, JINR and the appropriate mass-spectrometer MASHA (Mass-Analyzer of Supper Heavy Atoms) has been planned and realized. The unique property of this mass-spectrometer is his ability to measure masses of the synthesized super heavy isotopes ($m/\Delta m \sim 1300$) simultaneously with registration of their α-decay or spontaneous fission. In the first experiment on synthesis we plan to determine the masses of the super heavy elements 112 and 114 using the reactions ^{48}Ca+^{242}Pu and ^{48}Ca+^{244}Pu at beam energy E_{beam} ~ 5 MeV/n.

Fig. 1 Mass-spectrometer “MASHA” at the beam line of the cyclotron U-400M

Summer practice: Familiarization with experimental setup. Study the papers concerning the synthesis of superheavy elements induced by heavy ions beams. Active participation in controlling and testing the mass-spectrometer “MASHA”.

Goals: Acquirement of practical experience in preparation the experiments on synthesis of superheavy elements.

Results: Data processing and analysis of the last experiment on MASHA using the ion beam ^{40}Ar. Preparation of presentation on MASHA and results obtained on this experimental setup.

THE SYSTEMATIC DETERMINATION OF CROSS SECTIONS FOR THE PRODUCTION OF PROTON-RICH EVAPORATION RESIDUES NEAR THE NEUTRON N = 126 SHELL CLOSURE IN FUSION REACTIONS

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The mass-spectrometer MASHA (Mass-Analyzer of Supper Heavy Atoms) was designed for determination of the masses of superheavy elements. The unique property of this mass-spectrometer is his ability to measure masses of the synthesized super heavy isotopes ($m/\Delta m \sim 1300$) simultaneously with registration of their α-decay or spontaneous fission. The mass-spectrometer is connected to the U-400M cyclotron of the Flerov Laboratory for Nuclear Reactions (FLNR) JINR, Dubna. In order to test the MASHA system we propose to carry out the systematic determination of cross sections for the production of proton-rich evaporation residues (excitation functions) near the neutron N = 126 shell closure in fusion reactions of ^{16,18}O, ^{40}Ar and ^{48}Ca with isotopes of Sm, Tb, Ho, Er, Tm and ^{197}Au. The beam energy will be E_{beam} = 5-6 MeV/n. The fusion reactions with ^{40}Ar and ^{16,18}O were investigated experimentally and theoretically in more detail before. These reactions will be used to obtain the main characteristics of the MASHA setup, first of all the extraction efficiency. The fusion reactions with ^{48}Ca will be carried out for the first time.

Summer practice: Familiarization with experimental setup. Study the papers concerning the synthesis of superheavy elements induced by heavy ions beams. Active participation in controlling and testing the mass-spectrometer "MASHA".

Goals: Acquirement of practical experience in preparation the experiments on synthesis of superheavy elements.

Results: Data processing and analysis of the last experiments on MASHA using the ion beam ^{40}Ar. Preparation of presentation on MASHA and results obtained on this experimental setup.

PRODUCTION AND SPECTROSCOPIC INVESTIGATION OF NEW NEUTRON-RICH ISOTOPES NEAR THE NEUTRON N = 126 SHELL CLOSURE USING THE MULTINUCLEON TRANSFER REACTIONS

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The mass-spectrometer MASHA (Mass-Analyzer of Supper Heavy Atoms) was designed for determination of the masses of superheavy elements. The unique property of this mass-spectrometer is his ability to measure masses of the synthesized super heavy isotopes ($m/\Delta m \sim 1300$) simultaneously with registration of their α-decay or spontaneous fission. The mass-spectrometer is connected to the U-400M cyclotron of the Flerov Laboratory for Nuclear Reactions (FLNR) JINR, Dubna. The position-sensitive quantum counting hybrid pixel detector MEDIPIX provide high spatial resolution and single-quantum detection. This device has an array of 256x256 square pixels of pitch size 55 μm for full sensitive area 14x14 mm^2. It is planned to use the MASHA+MEDIPIX setup in the investigation of neutron rich nuclei produced in multinucleon transfer reactions. MASHA can measure any nucleus from helium up to superheavy elements and MEDIPIX detects with high efficiency the beta particles. Nuclei in this region decay mainly by β^-. We propose to carry out the experiments on the production of new neutron-rich isotopes near the neutron shell closure N = 126 using the multinucleon transfer reactions: ^{40}Ar, ^{48}Ca + ^{208}Pb, ^{205}Tl, ^{204}Hg. E_{beam} = 5-7 MeV/n. The candidates are ^{209,210}Hg and ^{211,212}Tl. For example the decay chain of ^{209}Hg is

$$^{209}Hg \xrightarrow{\beta^-} {}^{209}Tl(2.16\ m) \xrightarrow{\beta^-} {}^{209}Pb(3.25\ h) \xrightarrow{\beta^-} {}^{209}Bi.$$

By measuring the mass, lifetime, energy spectrum of beta particles and by using the position sensitivity of MEDIPIX one can identify these neutron rich nuclei with high accuracy. The cross sections for these isotopes, using the beam ^{40}Ca, range from 10μb up to 10mb which is enough to obtain sufficient statistics. In the case of ^{48}Ca the yield should be even higher, since ^{48}Ca is more neutron rich.

Summer practice: Familiarization with experimental setup. Study the papers concerning the transfer reactions induced by heavy ions beams. Active participation in controlling and testing the mass-spectrometer "MASHA".

Goals: Acquirement of practical experience in preparation the experiments using the heavy ion beams.

Results: Data processing and analysis of the last experiments on MASHA using the ion beam ^{40}Ar. Preparation of presentation on MASHA and results obtained on this experimental setup.

MONTE-CARLO SIMULATION OF FUSION AND MULTINUCLEON TRANSFER REACTIONS IN THE MEDIPIX DETECTOR USING THE GEANT4

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The position-sensitive quantum counting hybrid pixel detector MEDIPIX provide high spatial resolution and single-quantum detection. This device has an array of 256x256 square pixels of pitch size 55μm for full sensitive area 14x14 mm^2. Operating these detectors with the integrated readout interface FITPIX developed by the Prague group one can have a compact and portable radiation camera which operates as an active nuclear emulsion for heavy charged particles and fission fragments, alpha particles, electrons (positrons), X-rays and γ-rays in wide and linear dynamic range for which MEDIPIX ensures 100% detection efficiency and noiseless digital integration (single-quantum counting) with on-line tracking visualization (see example in Fig. 1). With the use of the DAQ and pattern recognition software Pixelman, also developed by Prague group, it is possible to distinguish the various types of particles. The new Timepix device adds the capability of directly measuring the particle energy and arrival time in each

individual pixel. Using the MEDIPIX detector will increase considerably the detection and identification possibilities of mass-spectrometer MASHA. The mass-spectrometer MASHA was designed for determination of the masses of superheavy elements. The unique property of this mass-spectrometer is his ability to measure masses of the synthesized super heavy isotopes (m/Δm ~ 1300) simultaneously with registration of their α-decay or spontaneous fission. The mass-spectrometer is connected to the U-400M cyclotron of the Flerov Laboratory for Nuclear Reactions (FLNR) JINR, Dubna. We plan to use MASHA and MEDIPIX in two types of experiments with heavy ions: Synthesis of heavy and superheavy elements in fusion reactions and production of new neutron-rich isotopes in multinucleon transfer reactions.

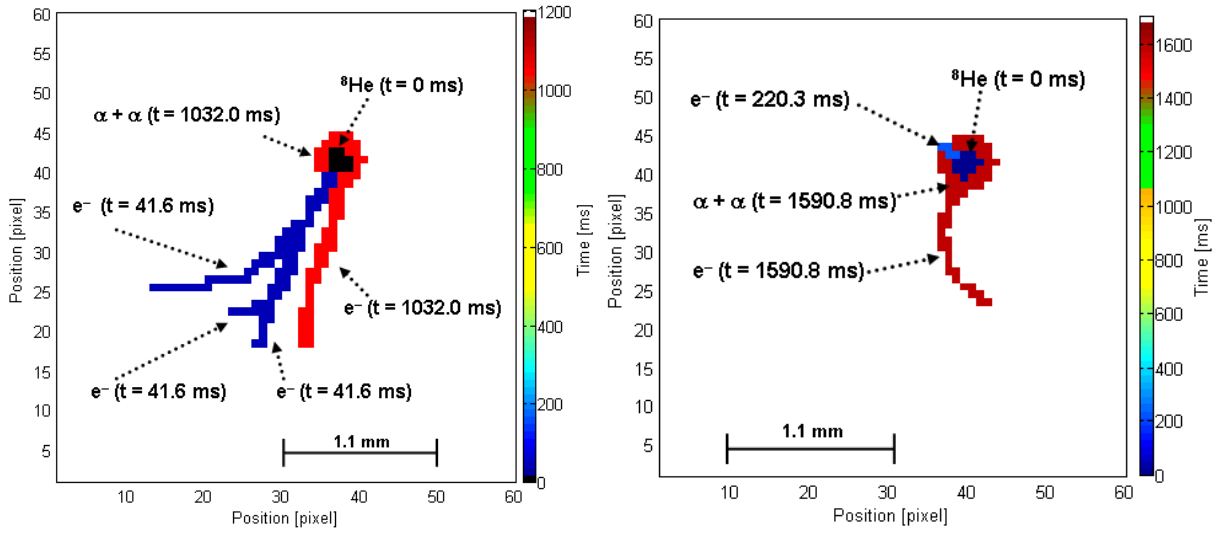

Fig. 1. Registration of arrival of ^{8}He ions (central signal – few pixels in black). Electrons emitted in consecutive β decays (of ^{8}He and ^{8}Li) are registered by the thin tracks. The final decay of two α particles is registered by the round halo surrounding the initial ^{8}He blob. Secondary electrons are registered too (see image on left). Pixels run in time mode (in ms in the vertical scale).

Summer practice: Familiarization with experimental setup. Study the GEANT4 software package. Active participation in controlling and testing "MASHA" and MEDIPIX.

Goals: Acquirement of practical experience in preparation the experiments on synthesis of superheavy elements concerning the simulation of prepared experiment.

Results: Preparation the presentation on MASHA and MEDIPIX from point of view of MONTE-Carlo simulation.

DEVELOPMENT AND TESTING OF A NEW CRYOGENIC GAS-FILLED CATCHER FOR MASHA

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The mass-spectrometer MASHA (Mass-Analyzer of Supper Heavy Atoms) was designed for determination of the masses of superheavy elements. The unique property of this mass-spectrometer is his ability to measure masses of the synthesized super heavy isotopes (m/Δm ~ 1300) simultaneously with

registration of their α-decay or spontaneous fission. The mass-spectrometer is connected to the U-400M cyclotron of the Flerov Laboratory for Nuclear Reactions (FLNR) JINR, Dubna.

Two parameters are very important for the mass-spectrometric investigation of isotopes far from stability: the overall extraction efficiency and the delay time. However, an assembly combining a hot catcher and ECR source allows only ionization of the volatile elements with lifetime at least 1-2 s, thus, strongly limiting the experimental possibilities. In the last several years, gas catchers are widely used for production of radioactive beams and turn out to be more perspective. The main advantages of the gas catchers are namely:

- The technique does not suffer from any dependence on chemical and physical properties of the nuclides whose beams are formed in the catcher.
- It provides an essentially faster extraction time ($\tau \sim 10$ ms) than a hot stopper ($\tau \sim 0.3$ s).
- There is no need of ionization.
- It is possible to reach a high total efficiency for transformation (up to 40%) of the initial nuclear reaction products to a low energy beam for mass-spectrometric analysis.

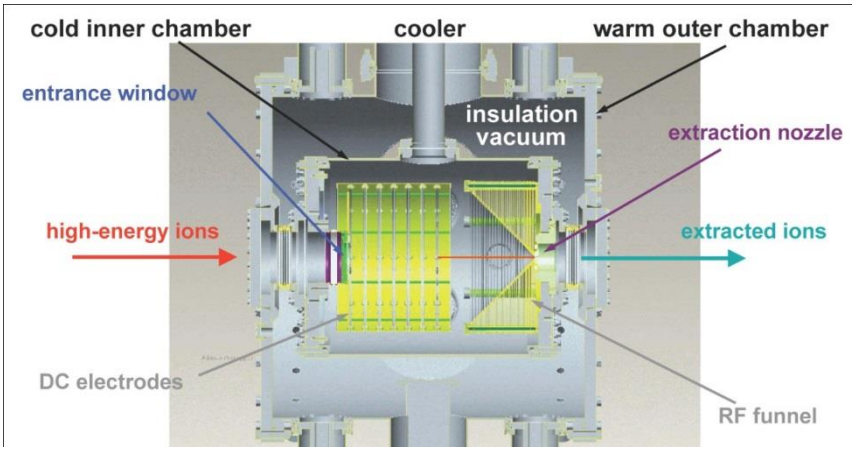

Fig. 1. Cryogenic gas catcher.

Summer practice: Familiarization with experimental setup. Study the papers concerning the gas catcher technique used in heavy ion physics. Active participation in controlling and testing the mass-spectrometer "MASHA" and development the cryogenic gas catcher for MASHA.

Goals: Acquirement of practical experience in preparation the experiments on synthesis of superheavy elements.

Results: Preparation the presentation on gas catchers used in the world for heavy ion physics.

Kontakt v případě zájmu o tato témata

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