

High-resolution magnetic analyzer MAVR for studying the characteristics of nuclear reactions

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One of the scientific activities of the Flerov Laboratory of Nuclear Reactions, JINR is the study of the mechanisms of nuclear reactions with stable and radioactive beams of accelerated nuclei. The experiments are carried out on the FLNR cyclotrons - U400, U-400M, as well as in cooperation with other research centers in GANIL (France), RIKEN (Japan), and the Cyclotron Laboratory (Jyväskylä, Finland). In all experiments, magnetic spectrometers and separators are used, which makes it possible to obtain a high degree of purification of reaction products from a primary beam and to have a good momentum resolution and, therefore, a good energy and mass resolution of these reaction products.

New possibilities for such studies have opened up with the launch of the **DRIBs** accelerator complex for radioactive beams at FLNR.

To carry out research in this field at FLNR JINR, a project was developed and a new facility was created - the **High-Resolution Magnetic Analyzer (MAVR)** which includes magnetic-optical and detector systems for separation and identification of reaction products in a wide range of masses and charges.

The MAVR analyzer is used on heavy ion beams to study a whole class of problems in atomic and nuclear physics. The inclusion of a doublet of quadrupole lenses in the setup made it possible to increase the solid angle for capturing the products of nuclear reactions at the entrance to the MSP-144 analyzing magnet to 15 msr and made it possible to measure the products of nuclear reactions emitted at angles from 0° to 60° . Two-stage poles of the magnet provide additional focusing of the products of nuclear reactions.

In addition to a large solid angle for capturing reaction products (15 msr), the MAVR magnetic analyzer has a high momentum resolution (10^{-4}) and a large focal plane (1.9 m). The analyzer makes it possible to register the products of nuclear reactions with energies up to 30 MeV/nucleon with a high resolution in momentum and charge ($\sim 1/60$), which is especially important for separation and identification of heavy nuclear reaction products.

The MAVR analyzer can operate both on primary beams of heavy ions and on beams of radioactive nuclei of the accelerating complex of the cyclotrons U400 and U400R (DRIBs-3). It is used directly as an analyzer for measuring the energy spectra of products of nuclear reactions and as a beam energy monochromator.

Measurements of the analyzer characteristics showed that its solid angle increased by more than three times compared to the magnetic analyzer used earlier, the MSP-144.

The analyzer was created in a relatively short time (2015-2018), which made it possible to carry out test experiments on it at the end of 2018 and start experiments on beams of heavy ions of rare isotopes (Ca, Fe, etc.).

To increase the efficiency of registration of the products of nuclear reactions, a multi-detector MULTI system with a large coverage of the focal plane has been developed. Measurement of energy losses (ΔE) and total energy (E) of particles-reaction-products is carried out by a position-sensitive ionization chamber.

A system based on microchannel plates (MCP) is used to measure the time of flight of reaction products.

To date, the facility has succeeded in obtaining new results on the yield of fast charged particles in various reactions on beams of ^{18}O , ^{48}Ca , and ^{56}Fe at angle of 0° and other small angles.