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Letter to the Editor

Neutron detector at the focal plane of the set up VASSILISSA ☆

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Abstract

For experiments aimed at the study of spontaneous fission of transfermium nuclei improvements in the focal plane detector system of recoil separator VASSILISSA have been made. The neutron detector consisting of 72 ^{3}He filled counters has been mounted around the focal plane detector chamber. In the first experiment the multiplicity of prompt neutrons emitted in spontaneous fission of ^{252}No was measured.

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A big number of even–even isotopes of transfermium elements decay solely by spontaneous fission. Even in the case of some odd-mass heavy nuclei such as, for example, ^{259,261}Lr and ^{261,263}Db the spontaneous fission probability is comparable with that of α-decay. Presently available experimental information on spontaneous fission of transfermium elements mainly concerns partial half lives. For Fm and No isotopes and for a few Md, Lr and Rf isotopes the total kinetic energy (TKE) and mass distributions of fission fragments from spontaneous fission were also accurately measured [1]. A multiplicity distribution of prompt neutrons emitted in spontaneous fission was measured for elements not heavier than fermium [2], and the only one measurement was performed for the isotope ^{252}No [3].

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These experiments were mainly performed using different mechanical systems which accomplished transportation of evaporation residues (ERs), formed in complete fusion reactions with accelerated ions, from the target to the detector area. Typically, ERs were implanted into the catcher foils or were stopped in gas after which they were transported to the detectors. These experimental set ups had critical limitations in the transportation speed, i.e. half life measurements, as well as in background conditions, due to rather low suppression factors of unwanted reaction products and necessity to place detectors close to the target position.

From the early 1980s, the recoil in-flight separators were widely used for the synthesis and study of decay properties of transfermium nuclei [4]. A high level of suppression of beam particles and unwanted reaction products, having high production rates in the region of charge and mass of target nuclei, has been achieved. Slow heavy ERs which are studied in complete fusion reactions with heavy ions after passing through such experimental set-ups and time-of-flight detectors are implanted in the focal plane semiconductor detectors. The transportation time amounts to a few microseconds allowing the investigation of very short-lived isotopes. The focal plane detector assemblies can have a well structure [5], providing a possibility to measure energy of both fission fragments (TKE) from spontaneous fission of implanted ERs, when one of the fission fragments is registered by the focal plane detector and the second one—by the side detector.

One of such experimental set ups used for the synthesis and study of decay properties of transfermium nuclei is a recoil separator VASSILISSA [6,7]. Extremely low background conditions at the focal plane of the separator, situated behind a 2 m concrete wall, allow one to build sophisticated detector systems around the focal plane implantation detector.

For the purpose of the study of spontaneous fission of transfermium nuclei in more detail a neutron detector consisting of 72 ^{3}He filled counters was mounted around the focal plane detector chamber.

The detector system consisting of two (start and stop) time-of-flight detectors and an array of silicon detectors have been developed and installed in the separator focal plane. Thin plastic foils (30–70 $\mu g/cm^2$ in thickness), emitting secondary electrons and microchannel plates for detecting these electrons are used in both time-of-flight detectors. The typical time resolution of about 0.5 ns was obtained for slow (total energy of 10–20 MeV) recoil nuclei having mass numbers of about 200. The value of 99.95% was achieved for the probability of detection of such recoil nuclei by making use of a single timing detector.

Having passed the time-of-flight detectors, the recoil nuclei are implanted into the silicon detectors. In order to improve the sensitivity of the experimental set-up, a new detector array has been manufactured and installed at the focal plane. The detector array consists of five identical 16-strip silicon wafers.

The active area of a single silicon strip detector is $60 \times 60\,mm^2$. As for the stop detector, its every strip is position sensitive in the vertical direction with a resolution of 0.3–0.5 mm between α decays of the α decay chain. The average energy resolution is 20 keV for α's of the ^{241}Am source. Four wafers are mounted in the backward hemisphere facing the stop detector. They measure escaping α's or fission fragments, and the total geometrical efficiency is 85% of 4π. As for the backward detectors, the strips do not have any position resolution and each four neighboring strips are connected galvanically so that 16 energy sensitive segments are formed [5]. In the case of backward detectors, we obtained an energy resolution of about 150 keV. The reason for that is a broader range of energy losses for escaping α-particles hitting the backward detectors over a wide range of angles. Fig. 1 presents the sum of energies of both fission fragments, the TKE spectrum for the ^{252}No spontaneous fission from the reaction $^{48}Ca + {}^{206}Pb \rightarrow {}^{254}No^*$, measured in the test experiment. For the calibration of TKE spectra data from [1] were used.

The focal plane detector assembly was lodged in a cylinder vacuum chamber 210 mm in diameter. Neutron counters were placed around this cylinder chamber and thus three layers were arranged (see Fig. 2). From the outside, neutron counters were covered by plexiglass, 5 cm in thickness, and boron