The investigation of properties of short-lived SF isotopes (Z > 100) at the focal plane of VASSILISSA separator.

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Introduction

Presently the available experimental information on the 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].

It should be noted, that the multiplicity distribution of prompt neutrons is one of the important characteristics of spontaneous fission. Experimental measurements of this parameter are very important for the theory, especially for the predictions of the spontaneous fission properties of isotopes of elements close to the "Island of stability". For all of these reasons, we have begun a comprehensive study of SF systematics from the heavy actinides to the SHE which is both timely and relevant.

Experimental setup

Recoil in – flight separator VASSILISSA [2] is widely used for the synthesis and study of decay properties of heavy and superheavy nuclei. The time of flight of the ERs through the separator is about 2 μs. For the registration of heavy ER in the focal plane of the separator, a new system with a 16-strip detector assembly, 60x60 mm^2 in size, and surrounded by backward detectors was developed. Each strip in the focal plane assembly is position sensitive in the longitudinal direction. The value of 0.5 mm (FWHM) was obtained for sequential α - α decays, 0.8 mm for ER - α and 1.0 mm for ER - SF events using test reactions with ^{40}Ar, ^{48}Ca-beam and ^{176}Yb,^{164}Dy-targets. These values were obtained for energies of the implanted ER in the range from 4 to 15 MeV. A typical energy resolution of about 25 keV for the focal plane detector was obtained for α - particles in the energy range from 6 to 9 MeV. In the case of backward detectors, we obtained the energy resolution of about 150 keV. The reason for this degradation is the broad range of energy losses for escaping α - particles that hit the backward detectors over a wide range of angles.

For the purpose of the study of spontaneous fission of short-lived SF isotopes in more detail a neutron detector consisting of 54 ^{3}He filled counters was mounted around the focal plane detector chamber of VASSILISSA separator. Neutron detectors with ^{3}He filled counters placed in a moderator are typically used for experimental studies of prompt spontaneous fission neutrons because of their constant high efficiency in a broad range of neutron energy (in thick detectors). The main advantages of ^{3}He-based neutron detector system are a practically zero energy threshold, the absence of cross-talk and a low sensitivity to gamma rays. They have stable parameters during long measurements with low intrinsic background. The geometry of the detectors can be easily chosen for various experimental demands. The focal plane detector assembly was housed in a cylindrical vacuum chamber 120 mm in diameter. Neutron counters were placed around this chamber in three concentric rings (see fig. 1).

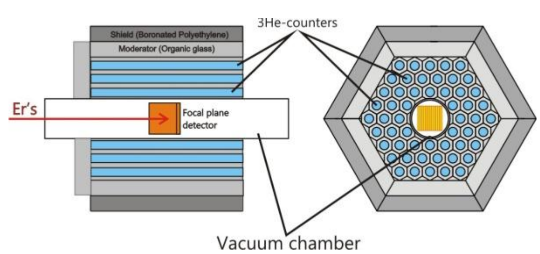

Fig. 1 Schematic view of focal plane detector surrounded by neutron counters and moderator.

From the outside, neutron counters were covered by separate elements of organic glass and boron polyethylene, both of 5 cm in thickness, to slow down and capture background neutrons from the outside of the neutron counter. It allowed us to reduce the neutron background by one order of magnitude. When the ^{40}Ar beam intensity was about 0.5 pμA on the Faraday cup of experimental set up, the counting rate of background neutrons was equal to 100 Hz.

Experiments and future plans.

In the last ten years we carried out several experiments aimed to investigate properties of short-lived SF isotopes.

Heavy-ion fusion reactions ^{48}Ca + ^{204}Pb and ^{44}Ca + ^{208}Pb leading to the same compound nucleus ^{252}No were run in attempts to produce new neutron-deficient spontaneous-fission isotopes of ^{249,250}No using the electrostatic separator VASSILISSA in the year 2002. Production cross-sections for the spontaneous fission activities with the half-lives 5.6 and 54 μs observed in these reactions are compared with the measured ones for the well-known isotopes of $^{251-255}$No formed in the heavy-ion fusion reactions ^{48}Ca + ^{206}Pb and ^{48}Ca + ^{208}Pb [3].

In the year 2004 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 first edition of 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 [4]. The efficiency of detection of one neutron measured using a ^{248}Cm source, placed in the position of focal plane semiconductor detector, was 25%. A multiplicity distribution of prompt neutrons emitted in spontaneous fission of ^{252}No, formed in the reaction ^{48}Ca(^{206}Pb,2n), was measured in test experiments and was equal to 4.43± 0.45. This value is in good agreement with that from literature (4.15± 0.3) [5].

The neutron-deficient isotope ^{246}Fm, produced in the complete fusion reaction ^{40}Ar + ^{208}Pb, was investigated in the year 2008. The main goal of the experiment was to determine the neutron multiplicity at spontaneous fission of this isotope. 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. A neutron detector consisting of 54 ^{3}He-filled counters has been mounted around the focal plane detector chamber (Fig. 1). From the experimental data the average number of neutrons per spontaneous fission of ^{246}Fm was determined ($\bar{\nu}$ = 3.55 ± 0.5) [6].

Most recently, in collaboration with Manipal University, we carried out an experiment aimed at investigating the properties of spontaneous fission of neutron deficient isotopes of ^{252}No and ^{244}Fm produced in the reaction with ^{48}Ca, ^{40}Ar-beam and ^{206}Pb-target. Data analysis is in progress. Concurrently, a theoretical study of SF systematics is also in progress.

We propose to undertake a comprehensive study of SF in very heavy short lived neutron deficient isotopes is planned including in the lighter Cf –No region. In the near future, these experiments can be carried out at facilities around India and later at Dubna, after the modernization of VASSILISSA (2011).

Acknowledgments

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