

Neutron emission from spontaneous fission of heavy elements at the FLNR

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I. Introduction

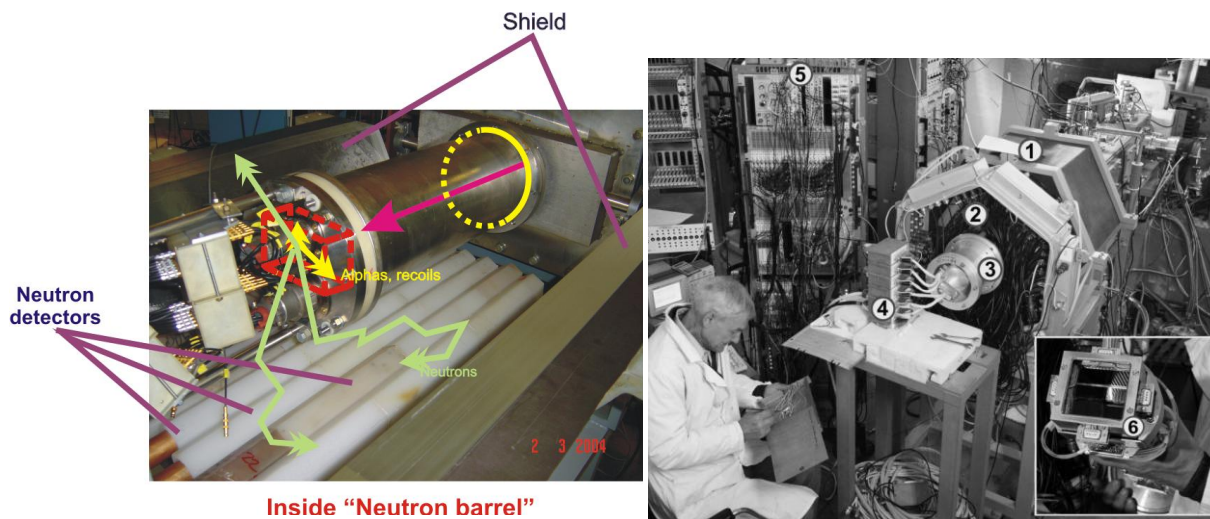
The process of spontaneous fission (SF) was discovered by Petrzhak and Flerov [1939] shortly after induced fission was discovered by Hahn and Strassman. Much research was carried out over many years to determine the half-lives, mass distributions, TKE, neutron emission and other such properties of spontaneous fission [1]. The multiplicity distribution of prompt neutrons is one of the important characteristics of spontaneous fission. An experimental measurements of this parameter is very important for the theory, especially for the predictions of the spontaneous fission properties of the isotopes of the elements close to the "Island of stability". Neutron detectors with ^3He 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). These detectors are also free of "cross talk" effect. They have stable parameters during long measurements with low intrinsic background. The geometry of the detectors can be easily chosen for various experimental demands [2].

In the past a multiplicity distribution of prompt neutrons emitted in spontaneous fission was measured for elements not heavier than fermium, one measurement was performed for the isotope ^{252}No and the first result for the ^{268}Db was observed. The mechanical experimental set ups, used in these experiments had critical limitations in the 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.

In recent times and at present the recoil in - flight separators are widely used for the synthesis and study of decay properties of transfermium nuclei. 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. 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, providing a possibility to measure energy of both fission fragments (TKE) from spontaneous fission of implanted evaporation residues (ERs), when one of the fission fragments is registered by the focal plane detector and the second one - by the side detector.

II. Experimental setup

In the typical experiment, accelerated beam from the FLNR Dubna U400 cyclotron is bombarding the heavy target, placed on rotating wheel. The produced evaporation residues are separating in flight by the VASSILISSA electrostatic separator [3]. The time of flight of ERs through the separator is about 2 μs . For the registration of heavy ER in the focal plane of the dipole magnet, a new system with a 16-strip detector assembly, $60 \times 60 \text{ mm}^2$ in size, and surrounded by side detectors was developed [4]. Each strip in the focal plane assembly is position sensitive in the longitudinal direction. 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 side detectors, we obtained the energy resolution of about 150 keV. The reason for that is a broader range of energy losses for escaping α - particles hit into the side detectors over a wide range of angles.



For the purpose of the study of spontaneous fission of heavy elements in more detail a neutron detector consisting of 54 ^3He filled counters was mounted around the focal plane detector chamber of VASSILISSA separator. Technical details of the detector array and electronics were described in [4,5]. The efficiency of detection of one neutron measured using a ^{248}Cm source, placed in the position of focal plane semiconductor detector, was 40 %.

The right picture present external appearance of the detector system in the VASSILISSA separator: (1) neutron detector shielding, (2) neutron counters, (3) vacuum chamber with SCDs, (4) preamplifiers for the SCD signals, and (5) spectrometric electronics; the SCD array is shown in the inset (6).

In the last years series of experiment aimed to investigation of neutron emission from SF at the new focal plane detector system of the recoil separator VASSILISSA has been performed for ^{246}Fm [5], ^{252}No and ^{244}Fm .

III. The exercise

The main goal of our project is preparing the detection system of VASSILISSA setup for experiments aimed to investigation of neutron properties of spontaneous fissioning heavy nuclei. The students will obtain an experience in working with complicated detection system, calculating the parameters of setup, analyzing experimental data. The preparing of detection system include:

- The calibrating of focal plane and side detectors with alpha- and SF-sources
- Testing and measuring the efficiency of neutron detector with known neutron source
- Testing and tuning of electronic and data-collecting system

IV. Recommended literature

1. D.C. Hoffman et. al., *Nucl. Phys.*, **A502** (1989) p. 21.
2. E.A. Sokol et al., *Nucl. Instr. Meth.* **A400** (1997) p. 96.
3. A.V. Yeregin et, al., *Phys. At. Nucl.*, **66** (2003) p. 1042.
4. A.V. Yeregin et. al., *Nucl. Instr. Meth.* **A539** (2005) p. 441.
5. A.I.Svirikhin et. al., *Eur. Phys. J.* **A44** (2010) p. 393.

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