Isotopic yield distribution of neutron-rich fragment nuclei produced in thermal neutron induced fission

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Introduction

Nuclear fission allows us to produce and study the properties of the nuclei with a higher neutron to proton ratio. Spectroscopic studies of such neutron-rich fragment nuclei provide direct information on the nuclear excited states. Such studies help to explore the new regions of nuclear deformations, and to extend the theoretical model(s) to regions which have hitherto been inaccessible. A lot of work has already been done on these set of nuclei by means of spontaneous fission of ^{252}Cf and ^{248}Cm sources, heavy-ion induced fusion-fission reactions, and also using deep-inelastic reactions. More recently, spectroscopic studies were performed using thermal neutron induced fission of ^{235}U using CIRUS reactor facility [1].

It has been observed that the nuclear shell closures have strong influence on the fission fragment mass distribution [2]. New fission mode has been reported earlier from the fragment mass measurement, but the results remain somewhat controversial [3]. All these facts point toward the critical aspects of the fission process which require detailed understanding by measuring various experimental observables with improved experimental techniques. The prompt γ-γ coincidence technique has earlier been successfully used to measure the individual isotopic yield distribution of fragment nuclei. Here we report the yield distribution of the isotopes, produced in thermal neutron induced fission of ^{235}U, using prompt γ-γ coincidence measurement technique.

Experimental details

The experiment was performed at the PF1B line of the high-flux reactor facility at the Institut Laue-Langevin (ILL), Grenoble, France. The collimated neutron beam flux at the target position was of the order of 10^8 n. s^{-1} cm^{-2}. Proper beam collimation was done by a series of lithium and boron collimators mounted upstream of the target. UO_2 target of thickness $\sim$600 μg/cm^2 and 99.7% ^{235}U enrichment was bombarded by this collimated neutron beam flux in order to produce the fission fragment nuclei. The target was put between thick backings to stop the fission fragment nuclei. This was instrumental in avoiding the Doppler shifts of the γ peaks. De-exciting γ-rays from the fission fragment nuclei were detected by an efficient array of Ge detectors which consisted of eight EXOGAM large clovers, six large coaxial detectors from GASP and the two clovers from the ILL. The EXOGAM and GASP detectors were mounted with their anti-Compton shields. The eight EXOGAM clovers were mounted in a 90° ring around the target position. The other detectors were positioned in two other rings with angles of 45° and 135°. The total photo peak efficiency for the 16 Ge

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detectors set-up was about 6%. The data were collected with a trigger-less digital data acquisition system based on 14 bit 100 MHz CAEN digitizers. Details about the electronics and data acquisition systems can be found in [4].

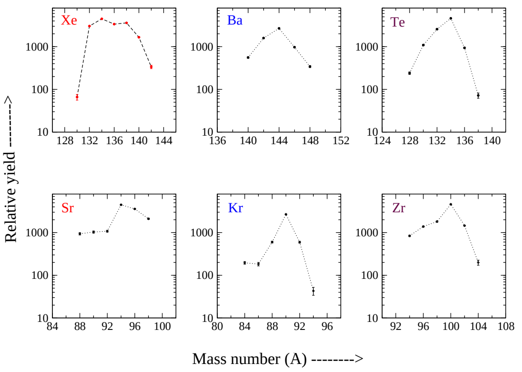

FIG. 1: Isotopic yield distribution of fragment nuclei as obtained from the data.

Results and discussion

The raw data were sorted using the "lst2root" code provided by ILL which generated structured ROOT tree files for a given coincidence time window, supplied by the user. An in-house further data processing code was developed which reads the ROOT tree files, applies quadratic calibration and generates spectra (for each detector segment as well as add-back) in RADWARE file format and symmetric γ-γ matrix. Further development of this code is in progress.

From the analysis of the γ-γ coincidence matrix, several complementary fragments were identified. The relative isotopic yield distributions of several even-even isotopes of the complementary charge pairs, viz., (Xe-Sr), (Ba-Kr), and (Te-Zr) have been obtained (Fig. 1). Fig. 2 shows a representative gated spectrum, where gates were put on the lower-lying transitions (feeding the 2^+ state) of ^{138}Xe. In addition to the transitions in ^{138}Xe, the strong γ-rays of ^{94}Sr(4n), ^{95}Sr(3n), and ^{96}Sr(2n) were clearly visible. From here, the coincidence rates of various isotopes of an element (in coincidence with a particular complementary fragment nucleus) are being measured. This will give the information on the dominant neutron (evaporation) channel for a particular fragment element pair.

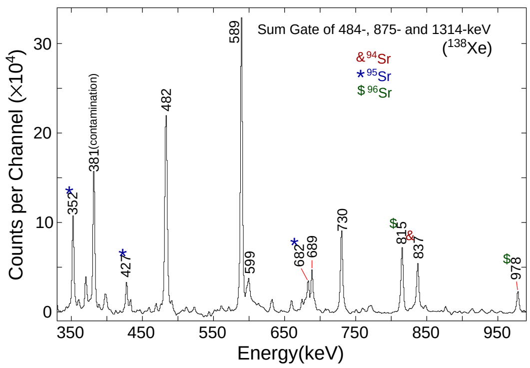

FIG. 2: Representative gated spectrum of ^{138}Xe. The known strong transitions of this nucleus and its complementary fragments are labeled.

The relative intensities of the prompt transitions which depopulate the yrast levels of the ground state band provide us with an estimation of the mean fragment angular momentum for the even-even fission products. The procedure described in Ref. [1] and the reference therein will be followed. Detailed analysis on these aspects are in progress and will be presented during the symposium.

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