Excited 0^+ states and deformed structures in the transitional nucleus ^{98}Zr

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Introduction

Neutron-rich nuclei in the A∼100 mass region have received a lot of experimental and theoretical attention over the years due to their exotic behaviour as well as many open questions. The sudden onset of deformation and then its immediate saturation in the Sr and Zr nuclei around N∼60 has remained one of the intriguing cases in this mass region. The addition of 2 more neutrons to the N=58 ^{96}Sr and ^{98}Zr nuclei changes their characteristic spectra from spherical nuclei to strongly deformed rigid rotors. It is believed that this deformation finds its origin in the substantial occupancy of the deformation driving $g_{9/2}$ proton and $h_{11/2}$ neutron orbitals [1]. The N=58 ^{96}Sr and ^{98}Zr nuclei, which rest exactly at the transition point, were predicted to have deformed excited 0^+ states with rotational bands built on those. Furthermore, it also remains to be seen whether these nuclei undergo a shape change from spherical to deformed with increasing spin. It is to be noted that these nuclei are mainly studied from the ^{252}Cf and ^{248}Cm spontaneous-fission data sets. The observations from these two data sets remain inconclusive on a few aspects.

Here in this paper, we report new observations in the low- and medium spin structures of ^{98}Zr nucleus from the data obtained from thermal neutron induced fission of ^{235}U.

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 was of the order of 10^8 n. s^{-1} cm^{-2} at the target position. A series of lithium and boron collimators mounted upstream of the target were instrumental in doing proper beam collimation. This collimated neutron beam was impinged upon a UO_2 target of thickness ∼600 μg/cm^2 and 99.7% ^{235}U enrichment in order to produce the fission fragment nuclei. The target was put between thick backings in order to stop the fission fragment nuclei and avoid the Doppler shifts of the γ peaks. Deexciting γ-rays from the fission fragment nuclei were detected by an array of Ge detectors which consisted of eight EXOGAM large clovers, six large coaxial detectors from GASP and the two clovers from the ILL. BGO anti-Compton shields were used as Compton suppressors for the EXOGAM and GASP detectors in the array. 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 array

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was estimated as 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 [2].

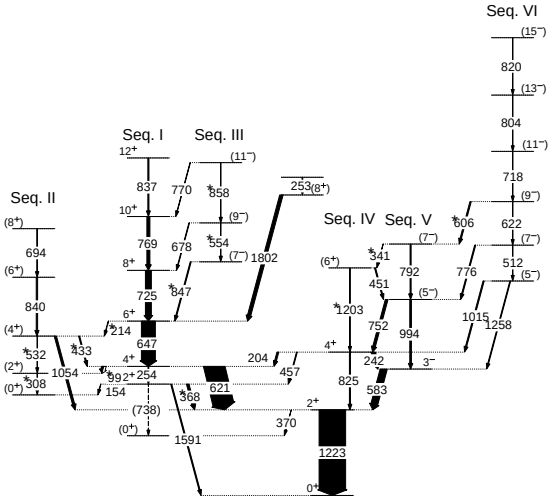

FIG. 1: Partial level scheme of ^{98}Zr as obtained in the present study. The transitions marked with "∗" are newly observed.

Results and discussion

The partial level scheme of ^{98}Zr as obtained in the present study is shown in Fig. 1. Several new crucial transitions were observed in the analysis of the γ-ray coincidence data. Apart from the observation of almost all the previously reported levels, clear evidences were found in support of the existence of the $0^+_{2,3}$ and $2^+_{2,3}$ states. It is to be noted that the non-observation of these states in the ^{248}Cm spontaneous-fission data was attributed to the different population mechanism [1]. The 370-keV transition which connects the yrast 2^+ and the 0^+_2 states, was clearly observed in the data. The existence of the 2^+_2 level was further affirmed with the observation of new transitions. The 0^+_3 and the 2^+_3 levels have been firmly established in this analysis with the new observation of the 308 keV ($2^+_3 \rightarrow 0^+_3$) and 532 keV ($4^+_3 \rightarrow 2^+_3$) transitions. Furthermore, new observation of the interband E2 transitions from the yrast quasi-rotational states in Seq. I to the states in Seq. II is indicative of the fact that the Seq. II could be a candidate for the previously suggested deformed band on top of the 0^+_3 state [1]. The 3^- level (E_x=1806 keV) was suggested earlier as the collective octupole level [3]. An octupole deformed structure built on this 3^- level has now been proposed. The 1203- and 341-keV γ rays which are crucial to this proposition have been newly observed. The γ rays between the levels in Seq. III have also been observed for the first time. Results and interpretation in detail will be presented during the symposium.

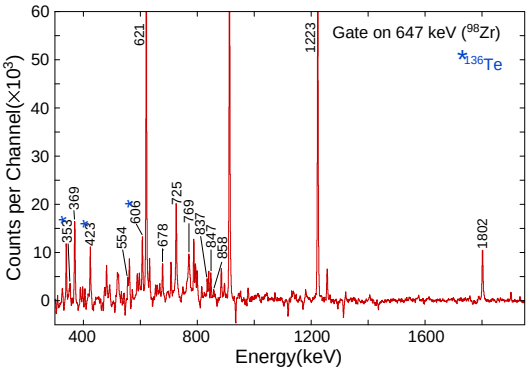

FIG. 2: Representative gated spectrum of ^{98}Zr with gate on 647-keV transition. The known strong transitions of this nucleus and its complementary fragments are labeled.

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