In-beam spectroscopy of $^{215}$Fr


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Introduction

In the last couple of decades, trans-lead region has revealed some interesting nuclear structure phenomena. Nuclei near $A = 220$, in the Ra-Th region are known to have well-defined octupole deformation [1], while $^{216}$Fr is the heaviest nucleus from where octupole deformation has been observed to begin [2, 3]. High-spin study of nuclei lying between the doubly magic $^{208}$Pb nucleus and $^{216}$Fr nucleus, such as $^{215}$Fr, will shed some light on the evolution of nuclear shape from spherical to octupole.

In the nuclei just above the $Z = 82$ and $N = 126$ shell closure, nuclear structure is governed by the proton $h_9/2$, $i_{13/2}$ and $f_7/2$ orbitals coupled with the neutron $g_9/2$, $i_{11/2}$ and $j_{15/2}$ orbitals. The structure of $N = 126$ isotones can primarily be interpreted in terms of proton single-particle excitations [4]. However, the structure of $N = 128$ isotones involves coupling of neutron excitations to the above proton orbitals. Besides, large number of high-spin yrast isomers are present in this region which is an indication of change in single-particle configuration [5, 6]. Thus, lying on the edge of transitional region, $^{215}$Fr nucleus is well suited for studying the interplay between single-particle and collective states.

In addition, information on the unique positive parity $i_{13/2}$ proton orbital in the odd-Z nuclei is very scarce. This orbital can be accessed from single-particle excitation of proton which can directly provide relative energy spacing between the $h_9/2$ and $i_{13/2}$ orbitals. This energy difference can be further used as input for shell-model calculations. Here, preliminary results on high-spin states of $^{215}$Fr are reported.

Experimental Setup

Excited states in $^{215}$Fr were populated using $^{208}$Pb ($^{11}$B, 4n) fusion-evaporation reaction. The $^{11}$B beam in the 54–62 MeV energy range, from 15-UD Pelletron accelerator at IUAC, New Delhi, was impinged on a self-supporting $^{208}$Pb (~99% enriched) target of ~ 6 mg/cm$^2$ thickness. $\gamma$ rays from residual nuclei populated in the reaction were detected by an array of 14 Compton suppressed clover detectors. The detectors were positioned at 90°, 125° and 148° with respect to the beam direction. The $\gamma-\gamma$ coincidence data were acquired using CANDLE [7] and further sorted into various RADWARE [8] compatible histograms using a code developed at IIT Roorkee.

Results and Discussion

Decman et al. had studied $^{215}$Fr via in-beam spectroscopy for the first time [9]. Afterwards, Schulz et al. and Drigert et al. extensively investigated it using different combi-
nations of planar Ge and co-axial Ge(Li) detectors [10, 11]. The level scheme up to \( \pi = (47/2^+) \) was established from the earlier studies.

The excitation function study performed at the beginning of the experiment indicates that at the 62 MeV beam energy, the cross-section of \( \alpha \)–evaporation channel leading to \(^{215}\)Fr maximizes [3]. This is consistent with the statistical-model code predictions. Figure 1 shows some new transitions in coincidence with the 700 keV \((11/2^- \rightarrow 9/2^-) \) transition, in addition to those reported in the earlier work [9–11]. \( \gamma \)–\( \gamma \) coincidence spectra with gates on known transitions reveal several new transitions.

![FIG. 1: Spectra showing \(^{215}\)Fr \( \gamma \) rays obtained with gate on 700 keV transition.](image)

Nuclei with the \( Z > 82 \) and \( N \geq 126 \) are known to have isomers. Among the \( N = 126 \) isotones, \(^{212}\)Rn and \(^{213}\)Fr are known to have highest spin isomer at 12 MeV and 8 MeV, respectively. These isomers are interpreted in terms of neutron core-excitations [5, 6]. Lönnroth \textit{et al.} have observed isomeric states in the \( N = 128 \) isotones, viz., \(^{214}\)Rn and \(^{216}\)Ra [12]. In this study, transitions deexciting known isomers in \(^{214}\)Rn and \(^{216}\)Ra with \( T_{1/2} \) ranging from 10–250 and \( \sim 10 \) ns, respectively were observed. Also, few isomers with \( T_{1/2} \sim 4 \) ns and two with \( \sim 20 \) ns were reported in \(^{215}\)Fr [11]. Further investigation to establish high-spin states in \(^{215}\)Fr is in progress.

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**References**


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