In-beam spectroscopy of ^{215}Fr

Pragati[1],* A. Y. Deo[1],† Khamosh Yadav[1], S. K. Tandel[2], S. S. Bhattacharjee[3], S. Chakraborty[4], S. Rai[5], S. G. Wahid[2], S. Kumar[6], S. Muralithar[3], R. P. Singh[3], Indu Bala[3], Ritika Garg[3], Swati Garg[1], B. Maheshwari[1], and A. K. Jain[1]

[1]*Department of Physics, Indian Institute of Technology Roorkee, Roorkee - 247667, INDIA*
[2]*UM-DAE Centre of Excellence in Basic Sciences, Mumbai - 400098, INDIA*
[3]*Inter University Accelerator Center, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*
[4]*Department of Physics, Institute of Science, Banaras Hindu University, Varanasi - 221005, INDIA*
[5]*Department of Physics, Visva-Bharati, Santiniketan - 731235, INDIA and*
[6]*Department of Physics and Astrophysics, University of Delhi, New Delhi - 110007, INDIA*

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 lightest 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 ($\sim$ 99% enriched) target of $\sim$ 6 mg/cm^2 thickness. γ 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°, 123° and 148° with respect to the beam direction. The γ-γ 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-

*Electronic address: prag5dph@iitr.ac.in
†Electronic address: aydeofph@iitr.ac.in

nations of planar Ge and co-axial Ge(Li) detectors [10, 11]. The level scheme up to $I^{\pi} = (47/2^{+})$ 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 4n−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 ($11/2^{-} \rightarrow 9/2^{-}$) γ 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.

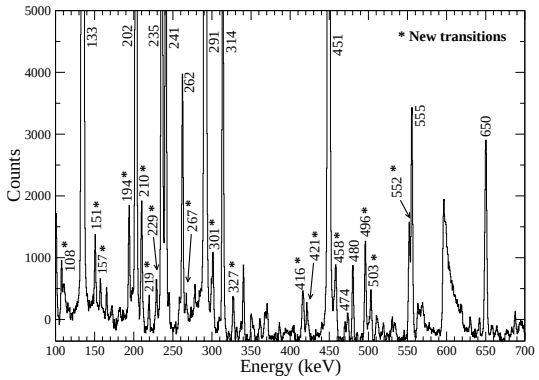

FIG. 1: Spectra showing ^{215}Fr γ rays obtained with gate on 700 keV transition.

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 *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 ~ 20 ns were reported in ^{215}Fr [11]. Further investigation to establish high-spin states in ^{215}Fr is in progress.

Acknowledgments

The authors would like to acknowledge the IUAC technical staff for their assistance during the experiment. Pragati would like to acknowledge the support from MHRD. AYD would like to acknowledge IIT Roorkee for the grant No. IITR/SRIC/218/F.I.G..

References

[1] L .P. Gaffney *et al.*, Nature **497**, 199 (2013).
[2] M. E. Debray *et al.*, Phys. Rev. C **41**, R1895 (1990).
[3] Pragati *et al.*, DAE proceedings **61**, 312 (2016).
[4] D. Horn *et al.*, Nucl. Phys. A **317**, 520 (1979).
[5] G. D. Dracoulis et al., Phys. Rev. C **80**, 054320 (2009).
[6] A. P. Byrne et al., Phys. Lett. B **217**, 38 (1989).
[7] Ajith Kumar B. P. *et al.*, DAE proceedings **44B**, 390 (2001).
[8] D. C. Radford, Nucl. Instrum. Methods Phys. Res., Sect. A **361**, 297 (1995).
[9] Decman *et al.*, Nucl. Phys. A **419**, 163 (1984).
[10] Schulz *et al.*, J. Phys. G: Nucl. Phys. **10**, 1201 (1984).
[11] Drigert *et al.*, Phys. Rev. C **32**, 136 (1985).
[12] T. Lönnroth *et al.*, Phys. Rev. C **27**, 180 (1983).