Lifetime measurement in ^{122}Ba and ^{122}Cs using Doppler Shift Attenuation Method (DSAM)

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Introduction

The nuclear structure exhibits transitional behaviour in the A≃125 mass region as the nuclei lie between the spherical (Sn, Z=50) and deformed (Ce, Z=58) structures. Here exists a unique parity intruder subshell, $h_{11/2}$, which can be accessed by both the protons and the neutrons. These $h_{11/2}$ nucleons have opposite deformation driving effects which lead to an interplay of prolate, oblate or triaxial nuclear shapes[1].

Experiments conducted in the recent past have shown the presence of octupole correlations[2] and chirality in the A≃125 mass region [2, 3]. Interactions between the nucleons of opposite-parity orbitals, whose angular momenta have the value $\Delta I=3\hbar$, give rise to octupole correlations in nuclei. Calculations show that nuclei that have proton and neutron numbers 34($g_{9/2} \leftrightarrow p_{3/2}$), 56($h_{11/2} \leftrightarrow d_{5/2}$), etc. show softness towards octupole deformation[4].

Chirality, a key signature of nuclear triaxiality, arises when in a said configuration, the $h_{11/2}$ valence proton and neutron are aligned along the short axis and long axis of the triaxial core respectively while the angular momentum of the rotational core is directed along the intermediate axis. These three mutually-perpendicular angular momenta give rise to a system which is either left- or right-handed[5] where these can be mutually transformed into one another by the combined operations of time reversal and spatial rotation by 180°. As these bands differ in only their intrinsic chirality, the chiral symmetry is effectively broken. The need to restore it yields nearly degenerate doublet bands from the doubling of the spin-I band members. Recently, the observation of chiral doublet bands and octupole correlations in ^{124}Cs[2] offers a unique example of interplay between axially-asymmetric and reflection-asymmetric shapes. The motivation behind the present study is to look for such signatures of octupole correlations and chirality in the neighbouring ^{122}Cs and ^{122}Ba isotopes. The objective is to determine the lifetimes of the levels involved using the Doppler Shift Attenuation Method (DSAM).

Experimental Details

The excited states of ^{122}Cs and ^{122}Ba were populated using the reaction ^{94}Mo(^{32}S, 3pn/2p2n)^{122}Cs/^{122}Ba. The ^{32}S beam having 150 MeV energy was provided by the 14UD pelletron accelerator at TIFR, Mumbai. The tar-

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get comprised of a 1.5 mg/cm^2 thick layer of ^{94}Mo having a 10 mg/cm^2 gold backing. The in-beam γ-rays were detected using Indian National Gamma Array (INGA) that had 19 Compton-suppressed clover-type HPGe detectors at the time of the experiment. The compressed data was analysed with the RADWARE software package and the level lifetimes were determined with the LINESHAPE programs[6].

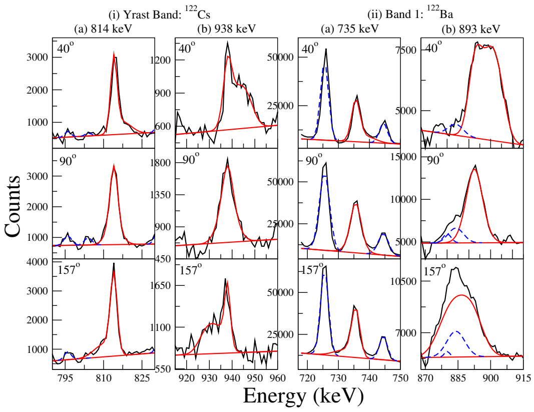

FIG. 1: Representative spectra of experimental and fitted lineshapes are shown for (i) yrast band of ^{122}Cs and (ii) band 1 of ^{122}Ba.

Results and Discussion

In the present work, the lifetimes of a few of the excited states of the yrast band of ^{122}Cs and that of two bands of ^{122}Ba were determined. The simulation was performed for 5000 histories of nuclei recoiling through the target and backing materials with a time step of 0.001 ps and the stopping powers were calculated using the Northcliffe and Schilling method[7]. Then these simulated lineshapes were fitted with the experimental ones for the forward(40°), 90°, and backward(153°) angles to extract the level lifetimes.

Preliminary measurements of the lifetimes have been done for the $18^+(0.35\ ^{+0.03}_{-0.04}$ ps), $20^+(0.11\ ^{+0.01}_{-.001}$ ps), and $22^+(0.58\ ^{+0.04}_{-0.03}$ ps) levels of the yrast band of ^{122}Cs. The transition quadrupole moment, Q_t, is an average of $4.80\ ^{+0.45}_{-0.53}$ eb in the 18-20$\hbar$ spin range which decreases to $1.83\ ^{+0.12}_{-0.11}$ eb for the 22$\hbar$ spin, indicative of shape change.

In addition, lifetimes have been determined for the $14^+(0.14\ ^{+0.01}_{-0.01}$ ps), $16^+(0.40\ ^{+0.04}_{-0.03}$ ps), $18^+(0.21\ ^{+0.03}_{-0.02}$ ps), and $20^+(0.37\ ^{+0.03}_{-0.04}$ ps) levels of band 1 and the $15^-(0.33\ ^{+0.05}_{-0.03}$ ps), $17^-(0.37\ ^{+0.04}_{-0.04}$ ps), $19^-(0.22\ ^{+0.02}_{-0.03}$ ps), and $21^-(0.24\ ^{+0.03}_{-0.03}$ ps) levels of band 2 of ^{122}Ba.

The study is in its preliminary state. Spectroscopic investigation is under way to look for the missing partner of the chiral band in ^{122}Cs[8]. Also, efforts are being made to establish connections of band 5 of ^{122}Ba to the main level scheme[9].

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References

[1] A. Granderath, *et al*. Nucl. Phys. A 597, 427 (1996).
[2] K. Selvakumar *et al.*, Phys. Rev. C 92, 064307 (2015).
[3] E. Grodner *et al.*, Physics Letters B 703, 46 (2011).
[4] W. Nazarewicz *et al.*, Nucl. Phys. A 429, 269 (1984).
[5] V. I. Dimitrov *et al.*, Phys. Rev. Lett. 84, 5732 (2000).
[6] J. C. Wells and N. R. Johnson, ORNL Physics Division Progress Report NO. ORNL-6689 (1991) (unpublished).
[7] L. C. Northcliffe and R. F. Schilling, Nucl. Data Tables 7, 233 (1970).
[8] R. Kumar *et al.*, Phys. Rev. C 72, 044319 (2005).
[9] C. M. Petrache *et al.*. Eur. Phys. J. A 12, 135–137 (2001).