Development of Fast Timing Array at VECC and its Application in Nuclear Structure Study around Z = 50 and N = 82 Shell Closure

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Introduction

The study of nuclear structure around double shell closure of ^{132}Sn (Z = 50, N = 82), far from the β-stability line, is very important as this region is not well studied as compared to the other double shell closures like ^{16}O, ^{40}Ca and ^{208}Pb [1, 2]. The measurement of nuclear level lifetimes and quadrupole moments (QMs) provide an unique opportunity to understand the n-n interactions and the evolution of collectivity associated with the single particle orbitals relevant around Z = 50 and N = 82.

The experimental knowledge, till date, for these neutron rich nuclei is very scanty, mainly due to the experimental difficulty in accessing this region. Taking the advantages of fission reaction followed by radiochemical separation of the fission fragments, it is possible to explore the low lying states of these nuclei. An appropriate lifetime measurement setup to utilise for a wide dynamic range is also necessary and this was possible with the advent of state-of-the-art scintillation detectors, viz. $LaBr_3$(Ce) and $CeBr_3$.

The thesis work outlined in the present abstract was carried out with the motivation to study the neutron rich nuclei around ^{132}Sn through lifetime and quadrupole moment measurement. For this purpose, a $\gamma-\gamma$ fast timing array was developed and used for the planned measurements. The following sections describe the development of the $\gamma-\gamma$ fast timing array and the results from the measurement of lifetime and quadrupole moments in nuclei around ^{132}Sn produced with fission followed by radicochemical separation.

Development of $\gamma - \gamma$ fast timing array (VENTURE):

The $\gamma - \gamma$ fast timing array, abbreviated as VENTURE (VECC Array for Nuclear fast Timing and AngUlar CorRElation Studies), the first $\gamma - \gamma$ fast timing array in India, has been developed at VECC, Kolkata, using several ultra-fast $CeBr_3$ scintillators. Before the development of the array, all the individual $1'' \phi \times 1''$ thick $CeBr_3$ detectors coupled to Hamamatsu R9779 photomultiplier tubes have been characterized by measuring their energy response, energy resolution, timing resolution and detection efficiency with standard sources.

This array could be used in its stand alone mode (Fig. 1A) as well as with the array of Clover HPGe detectors (Fig. 1B, 1C) like VENUS or INGA for the complete γ spectroscopic measurement. The array has been tested and used in both off-beam and in-beam experiments to explore the measurement of lifetimes down to few ps taking the advantages of the Generalised Centroid Difference (GCD) method [3].

In case of off-beam test experiment, the lifetime of few excited levels in ^{106}Pd and ^{133}Cs has been successfully measured. In case of in-beam test measurement, few excited levels in ^{124}I nucleus have been measured successfully. The excited states of ^{124}I nuclei were populated by using ^{nat}Sb(α, xn) reaction with 40 MeV α-beam from K = 130 cyclotron at VECC, Kolkata. It is realized that, for an in-beam experiment, more number of detectors are required in the array to increase the out-

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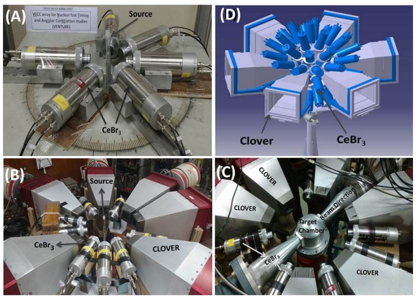

FIG. 1: (A) Stand-alone mode of VENTURE array; Coupled setup of VENTURE array with VENUS array (B) for off-beam testing and (C) for in-beam testing; (D) Design of the second phase of the VENTURE array.

put efficiency. For this purpose, a structure has been designed (Fig. 1D) and, therefore, the next phase of VENTURE array will be developed by adding more number of detectors.

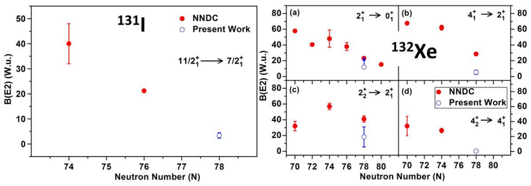

FIG. 2: B(E2) values corroborate with shell closure at N = 82.

Results from lifetime measurement in ^{131}I and ^{132}Xe nuclei:

The structures of the neutron rich ^{131}I and ^{132}Xe nuclei were studied through lifetime measurement using VENTURE array following the successful utilization of GCD method. The excited states of these nuclei were populated as the β-decay of the respective Te parents which were produced with $^{nat}U(\alpha, f)$ reaction using 40 MeV α-beam from K-130 cyclotron at VECC, Kolkata followed by radiochemical separation method. To interpret the experimental results, a Large Basis Shell Model (LBSM) calculation was performed using NUSHELLX code. The measured transition probabilities could be well interpreted from the calculation and corroborate with double shell closure of ^{132}Sn (Fig. 2). The lifetime measurement of the $15/2_1^-$ state established the presence of octupole correlation in ^{131}I [5].

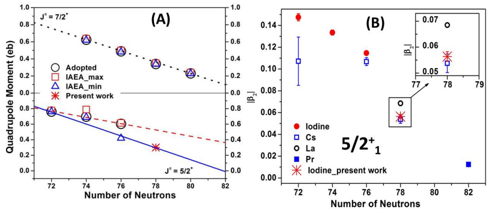

FIG. 3: Systematics of QM (A) and deformation parameter (B) corroborate with shell closure at N = 82.

Results from quadrupole moment measurement in ^{131,132}I:

The thesis work also reports the measurement of EQMs (Electric Quadrupole Moments) for the $5/2_1^+$ level in ^{131}I and 3_1^+ level in ^{132}I using TDPAC (Time Differential Perturbed Angular Correlation) method with $1'' \phi \times 1''$ LaBr$_3$(Ce) detectors. The obtained deformation and quadrupole moments (Fig. 3) corroborate the shell closure at N = 82. The measurement could also resolve the anomaly of quadrupole moments for the $5/2_1^+$ and $7/2_1^+$ levels of N = 82 Iodine [6].

As a part of the developmental program for the measurements of quadrupole moments using TDPAC and IPAC (Integral PAC) method, an angular correlation table has been developed at VECC under this thesis work. The setup was characterized with the unperturbed $\gamma-\gamma$ angular correlation measurement in ^{60}Ni and ^{132}I for the future possibility of the EQMs measurement using IPAC method.

References

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