Nuclear Structure Studies using Fast Neutrons

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The investigation of low-lying level structure of nearly spherical and deformed nuclei have been carried out at the University of Kentucky Accelerator Laboratory (UKAL) [1]. The nearly mono-energetic well-bunched fast neutron beams were produced via the ^{3}H(p,n)^{3}He reaction. The nuclei were produced at the excited states following the inelastic scattering of neutrons from the target material. For singles measurements, the gamma rays from the excited states were detected using a high-efficiency HPGe detector surrounded by BGO anti-Compton shield. Time-of-flight gating was implemented to suppress background radiation and to improve the quality of the spectra. The experiments involved the measurements of excitation function (where the yield of a particular γ ray was measured as function of incident beam energy) and angular distribution (where the yield of a particular γ ray was measured as function of detection angle with respect to the incident beam). All the required spectroscopic quantities such as spins, mixing ratios, level lifetimes, level thresholds *etc.* could be extracted during the detail off-line analysis of the data. As the (n,n$'\gamma$) is a non-selective probe, all the yrast and non-yrast levels are expected to be populated with almost the same strength. This makes it possible for a comprehensive mapping of the nuclear level structure up to a certain range of spin and excitation. A brief discussion of a few of our findings related to the low-spin nuclear structure issues is given below.

Mapping of Multi-phonon excitation in ^{62}Ni

The level structure of ^{62}Ni was investigated up to an excitation energy of 3.8 MeV using the ^{62}Ni(n,n$'\gamma$) reaction. The lifetime of the excited levels were extracted with the Doppler-shift attenuation method. The experimentally deduced values of reduced transition probabilities were compared with the predictions of the quadrupole vibrator model and with large-scale shell model calculations in fp shell configuration space. Two-phonon quadrupole states were found to exist with some notable deviation from the prediction of the quadrupole vibrator model, but no evidence for the existence of three-phonon quadrupole states could be established. The configurations involving $Z = 28$ proton core excitations are found to play a major role in understanding the observed level structure [2].

Observation of New Decay Pattern of Negative Parity States at N = 90

The low-lying level structure of ^{150}Nd have been established combining the data from ^{150}Nd(n,n$'\gamma$) and ^{150}Nd(n,n$'\gamma\gamma$) experiments. In addition to the previously known $K^{\pi} = 0^{-}$ band, a new $K^{\pi} = 2^{-}$ band has been established. The level lifetimes were determined for all the members of this newly established band [3]. A representative plot for the Doppler shift of the 365.11-keV γ ray decaying from the 1565-keV, 4_1^- level of the $K^{\pi} = 2^{-}$ band is shown in Fig. 1. These lifetime data reveal a pattern of enhanced $E1$ transition strengths (of the order of mW.u.), similar to that observed in the neighboring ^{152}Sm. These new findings are suggestive of existence of systematic pattern of octupole collectivity in the N = 90 isotones. It is worth noting that the newly observed pattern lies outside of the various model descriptions that have been put forward for nuclei in this region.

Shape Co-existence in ^{94}Zr

The excited band with the 0_2^+ band head at E$_x$

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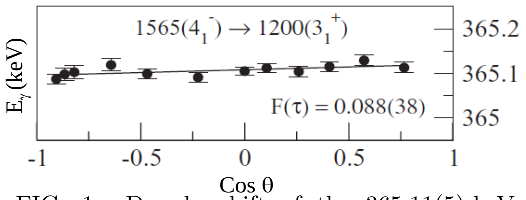

FIG. 1: Doppler-shift of the 365.11(5)-keV γ ray from ^{150}Nd. The experimental $F(\tau)$ value is 0.088(38), which corresponds to a lifetime of 479^{+407}_{-159} fs.

= 1300 keV (see Fig. 2) has been established based on results from a measurement of weak decay branches [*viz.*, the 371($2_2^+ \rightarrow 0_2^+$)-keV transition] observed following the β^- decay of ^{94}Y and on lifetime data from a study of ^{94}Zr by inelastic neutron scattering [4]. The measured decay intensity of the 371-keV transition is 0.15% of the total decay branches from the 2_2^+ state. The observed $B(E2)$ strengths of the underlying transitions (see Fig. 2) suggests the existence of collective structure in the excited band. The deduced deformation parameter, β for the first and second 2^+ states are found to be 0.09 and 0.18, respectively. These results establish the shape co-existence phenomena in the closed sub-shell nucleus ^{94}Zr; thereby suggesting the importance of the role of sub-shells for nuclear collectivity.

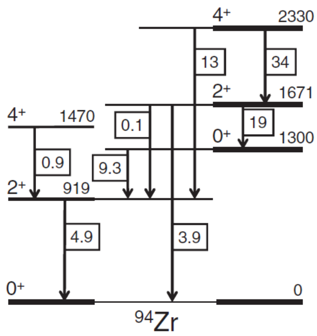

FIG. 2: Decay pattern of the low-lying levels of ^{94}Zr. The band with 0_2^+ band head has been newly established. The experimentally deduced $B(E2)$ values (in W.u.) have been given in boxes.

Issues of E(5) structure in ^{130,132}Xe

Xe-isotopes have been considered to be good examples for exhibiting E(5) behavior over the last few years. New spectroscopic results have recently been obtained following our (n,n$'\gamma$) study on ^{130,132}Xe isotopes. The targets used in these set of experiments were in the form of solidified XeF_2. Considering the decay properties of the 0_2^+ and 0_3^+ states (see Fig. 3 for the decay pattern of ^{130}Xe), it appears that none of the xenon isotopes are the true representations of an E(5) critical-point nucleus [5].

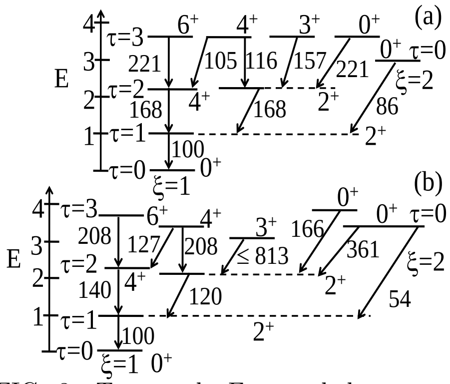

FIG. 3: Top-panel: Expected decay pattern of a nucleus exhibiting E(5) symmetry [following F. Iachello, Phys. Rev. Lett. **85**, 3580 (2000)]. Energies are given relative to E(2_1^+) and B(E2)s [the quoted values adjacent to each of the arrowhead] are given relative to $B(E2: 2_1^+ \rightarrow 0_1^+$. Bottom-panel: Observed decay pattern of ^{130}Xe obtained from our (n,n$'\gamma$) study. The figure has been drawn in the same format as that in the top panel.

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