Identification of collective proton excitations in ^{94}Zr

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Introduction

Evolution of level structure along the chain of Zr-isotopes is depicted in Fig. 1. It is evident from the figure that there exists a closed neutron shell at $N = 50$ (*because of sharp increase in the excitation energy of* 2_1^+ *state in* ^{90}Zr) and a neutron sub-shell closure at $N = 56$ (*because of sudden increase of excitation energy of* 2_1^+ *state in* ^{96}Zr). Lying between these two limits of neutron-closures, ^{92,94}Zr-isotopes appear to have spherical ground states. Our previous experimental results are suggestive of appearance of deformed structure in ^{94}Zr within the excitation regime of $\sim$ 1.3 - 1.7 MeV [1]. This implies that the collectivity in ^{94}Zr is not because of rotationally induced deformation. Excitation of the protons across the $Z = 40$ sub-shell closure was found to play a dominant role in generating the excited deformed structure in ^{94}Zr. Whereas our earlier published work [1] was limited to the discussion on the level structure of ^{94}Zr up to to $E_x =$ 2.3 MeV, the present report highlights the results up to $E_x = 3$ MeV with the placements of several newly found weak and low-energy decay branches in the level scheme; thereby bringing out a comprehensive picture about the evolution of collectivity in this nucleus.

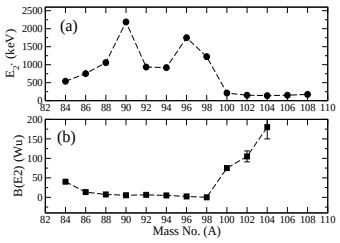

FIG. 1: Variation of (a) energy (in KeV) of 2_1^+ states and (b) $B(E2 : 2_1^+ \rightarrow 0_1^+)$ (in W.u.) along Zr-isotopes. Evolution of different level structure across the chain is obvious.

Experimental Procedure

The excited states in ^{94}Zr were produced by the beta-decay of the ^{94}Y parent nuclide. The radioactive sources of ^{94}Y ($T_{1/2} = 18.7$ min, $J^\pi = 2^-$, $Q_{\beta^-} = 4.918$ MeV) were pro-

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duced by 500-MeV proton-induced fission of a ^{238}UCx target at the TRIUMF Isotope Separator and Accelerator radioactive beam facility. After making proper mass separation of the fission products, the $A = 94$ activities were deposited on a moving tape collector at the center of the 8π spectrometer. The details of the experiment can be found in Ref.[1]. The data were sorted off-line, after proper shift correction, to create a random-background-subtracted $\gamma\gamma$ coincidence matrix. The matrix contained about 2×10^8 events.

Experimental Results

The representative coincidence spectra are depicted in Fig. 2. The observation of very high energy transitions (see Fig. 2(b)) indicate the population of the levels very close to the Q_{β^-} value of the decay of the ^{94}Y parent nuclide. The high-statistics $\gamma\gamma$ coincidence data helped us to place several low-energy gamma transitions in the decay scheme. These transitions are found to have very weak decay branches and were not observed in our earlier $(n,n'\gamma)$ studies [3]. Combining the revised lifetime values from Ref.[4] and the newly measured decay branches, a comprehensive $E2$ decay pattern of the transitions up to $E_x \sim 3$ MeV has been established and presented in Fig. 3. Previous calculations [2] and observations [3] are suggestive of dominance of neutron configurations for the 2_1^+ state; whereas proton excitations from the $2p_{1/2}, 2p_{3/2} \rightarrow 1g_{9/2}$ orbitals seem to play the major role in generating the 2_2^+ state. It is obvious from Fig. 3 that the majority of the excited states decay preferentially to the 2_2^+ state. These observed decay patterns reveal the persistence of dominance of the excitation of the protons across the $Z = 40$ sub-shell closure.

Acknowledgments

This material is based upon work supported by the U.S. National Science Foundation under Grant No. PHY-1305801. Two of the authors (K. M. and A.C.) would like to thank IUAC, New Delhi for financial support through Project Code No. UFR - 56317.

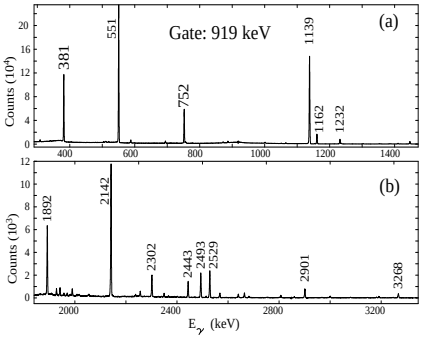

FIG. 2: Coincidence spectra of the 919-keV ($2_1^+ \rightarrow 0_1^+$) transition of ^{94}Zr highlighting a part of the observed (a) low-energy transitions and (b) high-energy transitions.

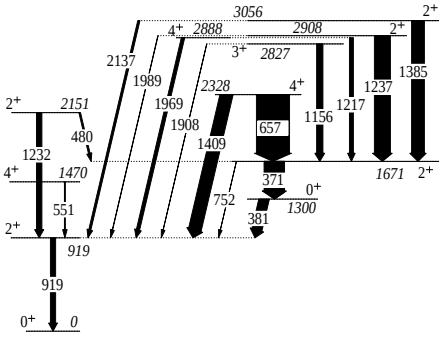

FIG. 3: Comparison of the feeding pattern to the 2_1^+ and 2_2^+ states of ^{94}Zr. The decay branches are labeled by their energies. The width of the arrows are proportional to the $E2$-strengths of the corresponding transitions. The maximum observed $E2$ strength, of about 31 *W.u.*, is carried out by the 657-keV transition.

References

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