Single-particle and collective excitations in the A $\sim$ 60 region

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Motivated by a growing interest in the study of neutron-rich nuclei in the A $\sim$ 60 region, we have performed a detailed spectroscopic analysis for the odd-odd ^{62}Co and its neighboring ^{66}Zn nuclei. Using the Gammasphere array coupled to the Fragment Mass Analyzer, excited states in these nuclei were populated and extensive level schemes were developed. Spherical shell model calculations have been performed to study the underlying nuclear structure and the evolution from single-particle excitations at low spins to well-deformed structures at high spins has been investigated.

1. Introduction

The nuclear structure of neutron-rich nuclei in the A $\sim$ 60 region has continued to attract considerable experimental and theoretical attention. Much of this interest is largely attributed to experimental evidence associated with a semi-magic number at $N = 40$ in ^{68}Ni [1]. However, extensive investigations have shown that this sub-shell closure is not robust and that, while single-particle effects dominate the structure at low spin, enhanced collective excitations are known to appear at fairly low spins and moderate excitation energies. This is the case, for example, in neutron-rich isotopes of Cr [2], Mn [3], and Fe [4] where prolate-deformed configurations, built upon single-particle excitations, have been observed at moderate to high spins. A detailed study of the structure of the odd-odd ^{62}Co nucleus and the neighboring ^{66}Zn forms the major focus of the present work.

Early studies on ^{62}Co date back to the 1970s where β-decay studies were performed to measure half-lives of the ground and other isomeric states [5]. This was followed by a spectroscopic investigation of the low-lying structure up to an excitation energy of 2.3 MeV by Warburton *et al* [6]. Later in 2012, based on asymmetry ratios, the spins and parities for the first three low-lying states in this nucleus were tentatively reported by Ref. [7]. No further progress has since been made in the study of ^{62}Co. The present study is thus focused on an extensive spectroscopic analysis of the ^{62}Co nucleus in order to obtain a deeper understanding of the underlying nuclear structure.

In contrast, low-lying states in ^{66}Zn were recently investigated by Refs. [8] and [9] where excited states up to 12.3 MeV and 9.8 MeV were respectively populated using different fusion evaporation reactions. Combined, these studies present a detailed account of the low-spin structure in ^{66}Zn. The present study is, however, focused on the exploration of the high-spin states which are otherwise not accessible with traditional fusion-evaporation reactions. With the extension of the level structure in ^{66}Zn, the present study aimed to investigate the evolution from the observed single-particle structure at low spins to well-deformed structures at high spins.

2. Experiment

The experiment was performed at the Argonne National Laboratory using the Gammasphere array coupled to the Fragment Mass Analyzer (FMA). The Gammasphere array, comprised of 101 Compton suppressed HPGe

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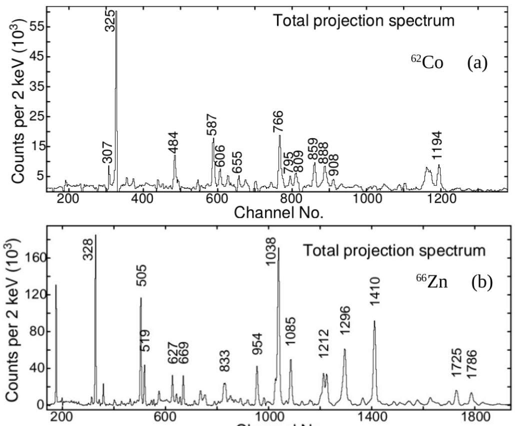

FIG. 1: Total background corrected projection spectrum obtained for (a) ^{62}Co and (b) ^{66}Zn.

detectors was used for the detection of γ rays and the FMA was utilized for the detection of reaction residues according to their mass-to-charge ratios (M/q). As detailed in Ref. [10], the residues were identified on an event-by-event basis from the position and time-of-flight measured in a Micro-Channel Plate (MCP) detector placed at the focal plane of the FMA. The energy loss of the residues was measured using a segmented ionization chamber positioned behind the focal plane of the FMA. The experiment was performed using a ^{26}Mg target and ^{48}Ca beam combination. Beam energies at 200% above the coulomb barrier were employed to achieve a complex multinucleon transfer process. Depending on the particular reaction channel, several neutron rich nuclei were produced. For the present study, excited states in ^{66}Zn and the odd-odd ^{62}Co nuclei were populated from the ($\alpha 4n\gamma$) and ($2\alpha 3np\gamma$) reaction channels, respectively. The emitted γ rays were detected in kinematic coincidence with particle recoils identified in the focal plane ionization chamber and the accumulated events were sorted into symmetrized γ-γ coincidence matrices and γ-γ-γ coincidence cubes for analysis with the `RADWARE` suite of codes [11].

The total background corrected projection spectra obtained for ^{62}Co and ^{66}Zn are shown in Figures 1 (a) and (b), respectively. Based on coincidence analysis, the level schemes of ^{62}Co and ^{66}Zn were deduced. The spins and parities of the various states were assigned on the basis of γ-γ coincidence relationships and angular distributions. To fit the angular distribution data, the Markov-Chain Monte Carlo (MCMC) sampling technique was utilized [12].

3. Discussion

In order to further understand the level structures observed in ^{62}Co and ^{66}Zn, spherical shell model calculations were performed using the `NuShellX` code [13]. For the odd-odd ^{62}Co nucleus, these calculations were performed in the fp model space using the $GXFP1A$ effective interaction while for the case of ^{66}Zn, the low-lying structure was investigated within the $jj44$ model space using the $jj44b$ and $jun45$ interactions. The shell model calculations were seen to reproduce the low-lying states very well in ^{66}Zn but failed to reproduce the levels in ^{62}Co. Details of the shell model calculations and the results obtained therefrom will be presented at the symposium.

Acknowledgments

This work was supported in part by the U.S. DOE, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357 and Grants Nos. DE-FG02-94ER40834 and DE-FG02-08ER41556, by the NSF under Contract No. PHY-0606007, and by the UK Science and Technology Facilities Council (STFC).

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