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SPECTROSCOPY OF ^{91}Zr$_{51}$ AT MEDIUM TO HIGH SPINS* **

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Identification of near-yrast states in the β-stable nucleus ^{91}Zr$_{51}$ has been carried out using the fusion evaporation reaction, ^{82}Se(^{13}C,4n)^{91}Zr at an incident beam energy of 50 MeV. States above the reported $\tau = 6\,\mu$s, $I^{\pi} = 21/2^{+}$ isomeric level at $E_x = 3167$ keV have been identified for the first time in this work, a tentative decay scheme of near-yrast states to excitation energies in excess of 10 MeV has been constructed. These states are of relevance to shell model structures formed via limited valence-space configurations in this semi-magic $N = 51$ nucleus.

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1. Introduction

The $N = 51$ semi magic nucleus $^{91}_{40}$Zr$_{51}$ presents a suitable laboratory for the study of shell model states in a spherical basis. Of particular interest are the formation of high-spin states which require the breaking of valence core configurations such as ^{88}Sr and excitations across the $N = 50$ shell closure. Previous work on ^{91}Zr focused on the lower-lying excitations [1–3] with a view to work on microscopic models using a valence space limited

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for the proton excitations to the $1g_{\frac{9}{2}}$ and $2p_{\frac{1}{2}}$ orbitals [1, 4]. The current work aims to provide experimental information on higher angular momentum states in this "simple shell model nucleus" in particular to investigate states associated with four proton excitations into the proton $1g_{\frac{9}{2}}$ orbital and/or excitations associated with the breaking of the $N = 50$ neutron core. Ideally, for such extended spins, large basis shell calculations are required which incorporate excitations into the proton $1f_{\frac{5}{2}}$, $2p_{\frac{1}{2}}$, $1g_{\frac{9}{2}}$ and neutron $1g_{\frac{9}{2}}$, $2d_{\frac{5}{2}}$, $1g_{\frac{7}{2}}$, $3s_{\frac{1}{2}}$, $2d_{\frac{3}{2}}$ and $1h_{\frac{11}{2}}$ orbitals, respectively.

2. Experimental details and results

A beam of ^{13}C ions was accelerated with the Yale ESTU tandem Van De Graaff accelerator [5] to an energy of 50 MeV and incident upon a self-supporting 950 μg/cm^2 target of isotopically enriched ^{82}Se. The nucleus ^{91}Zr was produced through the $4n$ evaporation channel with a predicted cross section of approximately half the fusion cross-section of ∼1 barn as calculated using PACE [6].

Gamma rays from the reaction products were detected using the modified YRASTBALL array [7] consisting of 10 clover detectors in two rings (6 at 90° and 4 at 140° to the beam axis) plus 2 LEPS detectors for enhanced sensitivity for low-energy transitions. Nine of the clover detectors were Compton

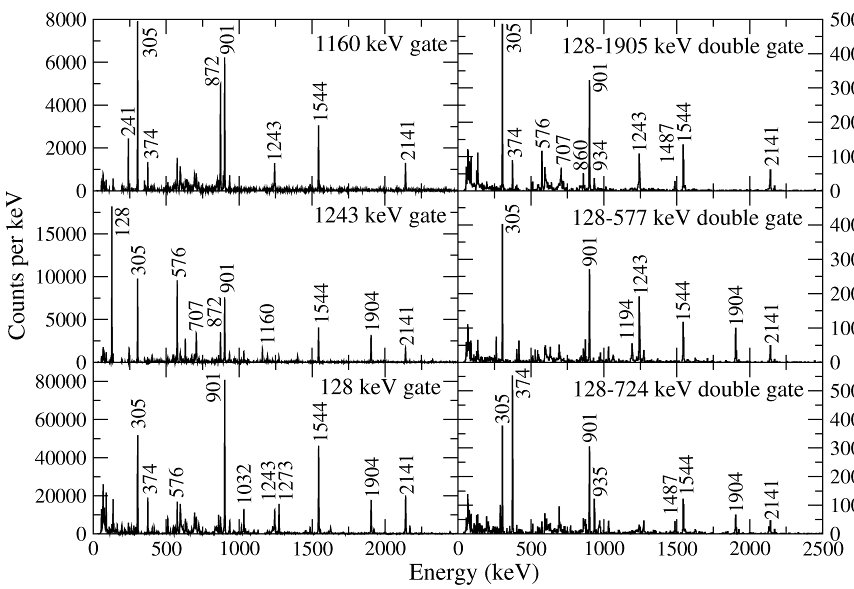

Fig. 1. Single (left) and double (right) coincidence gates for selected transitions identified in ^{91}Zr.

suppressed. The on-target beam current was typically $1\,pnA$ with the master trigger set to double coincidences yielding a total of $\sim 2 \times 10^9 \gamma^2$ events over the course of a one week experiment.

The data were sorted into a series of gamma-ray energy coincidence matrices and cubes which were analyzed using the RADWARE suite of programs [8]. Fig. 1 shows examples of single and double gated spectral projections of matrices and cubes respectively for transitions identified as decay from states above the $\tau = 6\,\mu$s isomeric $I^\pi = 21/2^+$ level at $E_x = 3167$ keV in ^{91}Zr [1]. Evidence for the placement of these transitions above this isomer level in ^{91}Zr has been reported elsewhere [9]. The coincidence relationships between these identified transitions have been used to construct the preliminary decay scheme for ^{91}Zr presented in Fig. 2.

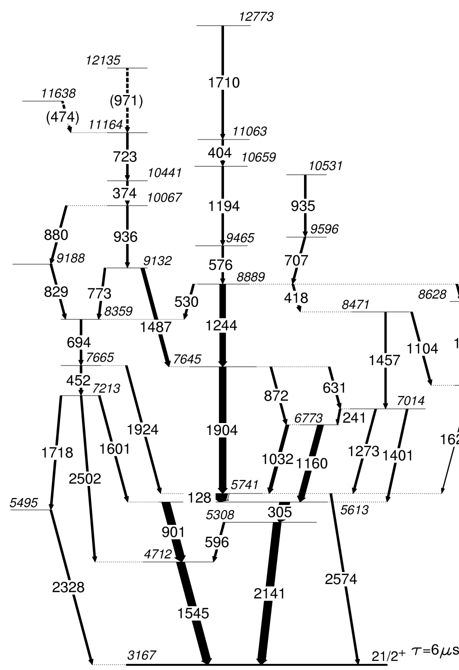

Fig. 2. Preliminary partial level scheme for ^{91}Zr showing previously unreported states above the $I^\pi = (21/2)^+$ 3167 keV isomer [1].

The structure of the isomer at $E_x = 3167\,$keV has been established to be a positive parity state of a simple $(\pi 1g_{\frac{9}{2}})^2 \otimes \nu 2d_{\frac{5}{2}}$ single particle configuration coupled to the maximal allowed spin of $21/2\,\hbar$ [10]. The nature of the low-lying states in ^{91}Zr are dominated by the single neutron excitations of the single neutron outside the $N = 50$ shell closure. Spectroscopic factors measured following nucleon transfer reactions on this nucleus have established candidates for single neutron excitations associated with the population of the neutron $3s_{\frac{1}{2}}$, $1g_{\frac{7}{2}}$, $2d_{\frac{3}{2}}$ and $1h_{\frac{11}{2}}$ orbitals at excitation energies of 1205, 1882, 2042 and 2170 keV, respectively [10]. Coupling the single-particle orbitals to the maximally aligned proton $(1g_{\frac{9}{2}})^2$ configuration sets spin/parity limits on the expected simple 3-particle angular configurations in ^{91}Zr of $17/2^+$, $23/2^+$, $19/2^+$ and $27/2^-$, respectively. Higher spins states can be achieved by coupling extra protons into the proton $1g_{\frac{9}{2}}$ levels and/or by breaking the $N = 50$ core. Since fusion evaporation reactions have a preferentially near-yrast population profile, one expects that such high-spin, core breaking states are those populated in the current work. The spin and parity assignments for states identified in the current work can be deduced following standard angular correlation and linear polarization analyses which are currently in progress.

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