Single Particle Configurations in ^{63}Cu

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Introduction

Nuclei in the vicinity of the doubly magic ^{56}Ni core exhibit many significant phenomena like single-particle excitations in the lower and medium spin domain and collective configurations in the higher spin domain. The lower spin and excitation energy domain of the nuclei in the proximity of the Ni-core is expected to be dominated by the occupation of the $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$ and $1g_{9/2}$ orbitals, while the states at higher excitations should include occupation of $1g_{9/2}$ orbital. Observations of states based on these configurations notwithstanding, there are also instances that indicate the significant role of proton excitations from $f_{7/2}$ orbital such as in neutron-rich odd-A Cu isotopes like ^{65,67}Cu[1]. The recent investigation by Rai *et al*[4] do not report the possibility of $f_{7/2}$ excitations, contributing in the level structure. However, given the softness of Ni-core, such excitations may have to be considered within the framework of shell model interpretations (calculations)[1]. This motivated us to revisit the level structure of ^{63}Cu based on the experimental data available with the group. The observation of $f_{7/2}$ excitations at low spins and $g_{9/2}$ excitations at high spins, both configurations arising from excitations across shell gaps, would help constrain the shell model calculations.

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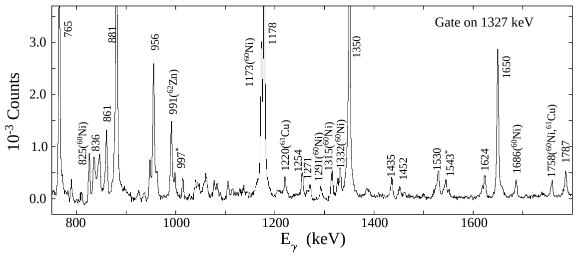

FIG. 1: Representative gated spectrum with the gate set on the 1327-keV ($7/2^- \rightarrow 3/2^-$) transition in ^{63}Cu.

Experiment and Data Analysis

The high spin states in ^{63}Cu were populated following the ^{59}Co(^{7}Li,p2n) reaction at an incident beam energy of 22-24 MeV. The experimental details are provided in Ref. [2, 3].

Results and Discussions

The level scheme of ^{63}Cu has been established up to excitation of $E_x \sim 7$ MeV and spin $J^\pi \sim 11\hbar$, more than 12 new transitions have been identified from the present investigation. The symmetric, as well as asymmetric angle-dependent matrices, have been constructed and used for deducing the level scheme and determination of multipolarities and electromagnetic characters of the observed γ-rays from angular correlations and

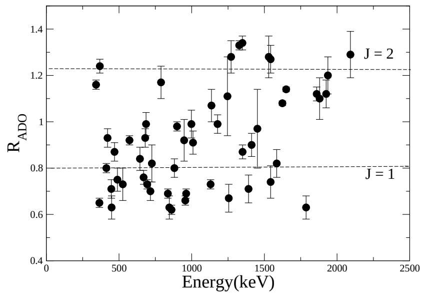

FIG. 2: Plot of ADO values for transitions in ^{63}Cu.

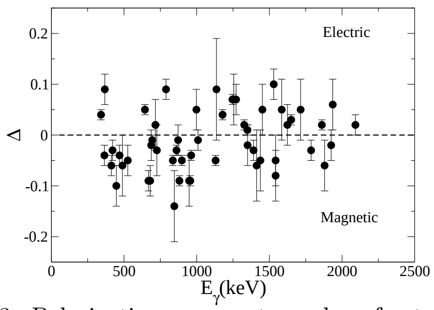

FIG. 3: Polarization asymmetry values for transitions in ^{63}Cu as observed in the present experiment.

linear polarization measurements respectively. The single-particle configurations associated with the states of ^{63}Cu ($Z = 29, N = 34$), with 1 proton and 6 neutrons outside ^{56}Ni ($Z = 28, N = 28$) core, can be envisaged to be built on the occupancy of $f_{5/2}$, $p_{3/2}$ and $p_{1/2}$ orbitals at the lowest energies followed by excitations into the $g_{9/2}$ orbital in the higher energy domain. The corresponding calculations have been implemented through the NuShellX@MSU[8] code, using the jj44bpn[6] interaction. The overlap between the experimental and calculated level energies is excellent for the negative parity states in the low spin regime while discrepancies are observed for certain states at higher spin values. The latter is particularly evident for the yrare and higher states at $9/2^-$ and $11/2^-$. As far as the positive parity states are concerned, the compliance between experimental and calculated energies is generally modest $\sim$ 150-300 keV. Both positive and negative parity states exhibit considerably mixed configurations. In order to probe the role of proton excitations from $f_{7/2}$ orbital, shell model calculations have also been carried out with ^{48}Ca-core($Z = 20, N = 28$) and model space including the $f_{7/2}$ orbital[5] for the protons. The code ANTOINE [7] has been used for the purpose and the interaction chosen was fpg. While the resulting configurations do not indicate dominant contributions of $f_{7/2}$ proton excitations, the latter do constitute $\sim$ 10-20 % of the wave functions of negative parity states. The compliance between the calculated and experimental energies remain approximately similar to those accomplished in the alternative calculations except for the yrare and higher $7/2^-$ states. The calculated energies for these, in the fpg space, are in considerably better agreement with the experimental ones. The ^{63}Cu nucleus may represent a transitional case towards increasing the dominance of core broken configurations based on proton excitations from $f_{7/2}$ orbital.

Acknowledgments

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References

[1] C. Chiara et.al, Phys. Rev. C, 85, 024309, 2012
[2] S. Samanta et.al, Phys. Rev. C, 97, 014319, 2018
[3] S. Samanta et.al, Phys. Rev. C, 99, 014315, 2019
[4] S. Rai et.al, Eur. Phys. J. A, 54, 84, 2018
[5] P. Singh et.al, Eur. Phys. Jour. A, 53, 69, 2017
[6] A. Lisetskiy et.al, Phys. Rev. C, 70, 044314, 2004
[7] E. Caurier et.al, Rev. Mod. Phys., 77, 427, 2005
[8] B. A. Brown et.al, Annu. Rev. Nucl. Part. Sci., 38, 29, 1988