Identification of levels above 6^- isomeric state in ^{66}Cu using prompt-delayed coincidence technique

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Introduction

The study of neutron-rich nuclei in the vicinity of ^{68}Ni has attracted considerable interest in recent years, since these nuclei provide significant insight into the shell structure evolution away from stability. Several experimental and theoretical efforts have been made to investigate the magicity of ^{68}Ni and to understand the existence of multiple coexisting shapes in this region. However, a satisfactory description of of various nuclear structure phenomena in this mass region is still far from being complete. Efforts are also going on to determine the most appropriate interaction for use in the shell-model calculations. Further experimental information on these nuclei is a crucial step towards providing a coherent understanding of their properties through comparisons with modern theoretical models.

In the present work, we report the results of an in-beam study of excited states in the odd-odd nucleus ^{66}Cu ($Z = 29, N = 37$). Several new transitions have been identified including four transitions feeding the 6^- isomeric state from an investigation of prompt-delayed coincidence events in a multinucleon transfer reaction.

Experimental Details and Data Analysis

Excited states of ^{66}Cu were populated in a reaction between a ^{30}Si beam and a ^{65}Cu target. The 136 MeV ^{30}Si beam was provided by the TIFR-BARC Pelletron LINAC facility at Tata Institute of Fundamental Research (TIFR) Mumbai. The target consisted of a 1.0 mg/cm^2 thick foil of isotopically enriched ^{65}Cu rolled with a 13.8 mg/cm^2 thick ^{197}Au foil. The γ rays emitted by the reaction products were detected with the Indian National Gamma Array (INGA) spectrometer consisting of 19 Compton-suppressed HPGe clover detectors arranged in six rings at 40°, 65°, 90°, 115°, 140° and 157° with respect to the beam direction [1]. Two- and higher-fold clover coincidence events were collected in a fast digital data acquisition (DDAQ) system based on Pixie-16 modules of XIA LLC [2].

For the offline analysis, the data sorting routine "MultipARameter time-stamped-based COincidence Search program (MARCOS)", was used to sort the time-stamped data and generate one-dimensional histograms, γ^2 matrices and γ^3 cubes. The time window for the prompt $\gamma - \gamma$ coincidence was set to 200 ns. In order to identify states above the isomeric level, prompt-delayed coincidence analysis technique was used. In this approach, the prompt γ-ray transitions (within a time window of 100 ns) above the isomer were stored on one axis of the matrix (the prompt axis) and the delayed γ-ray transitions following the decay of isomer (within a time window 400-800 ns) were stored on the other axis (the delayed axis). Detailed discussion on this technique can be found in Ref. [3]. The data analysis was done using the software package RADWARE [4]. To determine the multipolarities of transitions in ^{66}Cu, an angular correlation analysis was performed [5].

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Results And Discussion

Prior to this work, the nucleus ^{66}Cu was studied using a variety of reactions and decay measurements (see Ref. [6] and references therein). Representative double-gated coincidence spectrum confirming part of the previously established decay scheme is given in Fig. 1.

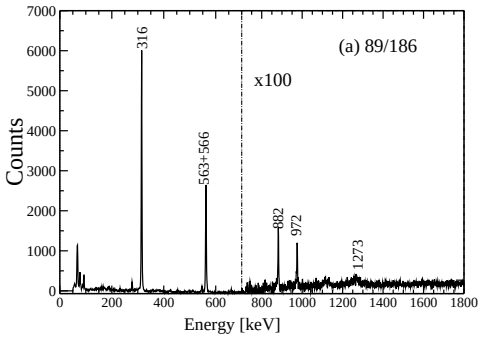

FIG. 1: Background-subtracted coincidence spectrum double gated in the prompt cube on transitions at 89/186 keV. The 1273 keV line is a cross-coincidence transition from the complimentary projectile-like reaction partner ^{29}Si.

In the present work, several new transitions have been identified extending the level structure of this nucleus up to $I^{\pi} = 9^{-}$ from an investigation of prompt-prompt and prompt-delayed coincidence events. The results of present work completes the set of $\pi p_{3/2}\nu g_{9/2}$ multiplets in this nucleus. In addition, four levels above the known 600 ns, 6^{-} isomeric state were identified. The level structure on top of the 6^{-} isomer in ^{66}Cu exhibits single-particle character and no evidence for any collective behavior was observed.

In order to gain detailed insight into the nature of the observed ^{66}Cu states, large-scale shell model calculations were carried out using the shell model code NuShellX@MSU [7]. The valence space employed in the calculations, comprise of the major shell from $Z, N = 28 - 50$, with an inert ^{56}Ni core. The valence particles were allowed to move freely between the $f_{5/2}$, $p_{3/2}$, $p_{1/2}$, and $g_{9/2}$ orbitals. Two recently derived effective interactions, JUN45 [8] and jj44bpn [9] were used in the calculations.

None of the interactions give a very satisfactory agreement with the data. However, an overall comparison between the observed states and those predicted by shell model calculations demonstrate the importance of including both the $f_{7/2}$ and $g_{9/2}$ orbitals in the shell-model calculations. Detailed shell model calculations are in progress.

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