Re-visiting the band structure of neutron-deficient ^{39}Ca nuclei

Subodh[1],* B. R. Behera[1], R. P. Singh[2], A. Jhingan[2], S. S. Tiwary[3], Anuj[4], Yashraj[2], H. Arora[2], Amit[1], Chetan Sharma[1], Raghav[1], Bharti Rohila[1], P. S. Rawat[4], Indu Bala[2], and M. Kumar[2]

[1]*Department of Physics, Panjab University, Chandigarh-160014, INDIA*

[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*

[3]*Department of Physics, Manipal University Jaipur, Jaipur-302033, India and*

[4]*Department of Physics and Astrophysics, University of Delhi, Delhi-110007, INDIA*

Introduction

Nuclei in the mass region A∼40 within the upper sd shell provide a fundamental ground for investigating several nuclear structure models. This mass region exhibits various significant nuclear structure phenomena, such as α-cluster structures, shape coexistence, and superdeformed states [1, 2]. Typically, upper sd shell nuclei in this mass region display spherical single particle excitations at low spin values. However, at higher spin values, these states evolve into strong collective modes [3]. The excitation spectra of nuclei near doubly closed shells can be effectively described using the spherical shell model. As a neutron-deficient nucleus, ^{39}Ca presents a valuable opportunity to explore the nuclear structure and shell closure properties from nuclear physics perspective. ^{39}Ca is also an important nuclei from astrophysics point of view [4]. The level structure of ^{39}Ca above the proton threshold at 5770.9 keV plays a crucial role in determining the ^{38}K(p, γ)^{39}Ca thermonuclear reaction rate at temperatures typical of explosive hydrogen burning in the novae. In order to reduce uncertainties in the reaction rate relevant to nucleosynthesis, it is essential to acquire accurate excitation energies and spin-parity assignments for the nuclei in this region [4]. Previously, the level scheme of neutron-deficient ^{39}Ca nuclei was studied up to 7.750 MeV ($I^{\pi} = (19/2^{-})$) using the ^{28}Si + ^{16}O reaction at 125 MeV [5]. In the reported work [6], the identified γ-rays matched those reported in ref. [5]. However, states were only observed up to 6.9 MeV excitation energy, with no further updates on the spin-parity of the energy levels. Although, the intensity of the reported γ-rays was calculated with a systematic error inclusion of ∼7%.

In this study, the high spin states of ^{39}Ca nuclei were re-investigated through a γ-ray spectroscopy experiment.

Experimental details

The high-spin states of ^{39}Ca nuclei were populated through the fusion evaporation reaction ^{nat}Si(^{16}O, αn) at 50 Mev beam energy using the 15UD Pelletron accelerator at the Inter-University Accelerator Centre (IUAC), New Delhi. The detection of γ-rays was carried out using 11 Compton suppressed clover detectors of Indian National Gamma Array (INGA) [7] facility at IUAC, New Delhi. These detectors were mounted at three different angles: 32° (3), 90° (4), and 148° (4) with respect to the beam axis. The data was recorded in singles and γ-γ coincidence mode using the VERSA Module Euro (VME) based data acquisition system at IUAC, New Delhi [8]. The offline data analysis was carried out using RADWARE software.

Results and discussion

In the present work, in the initial analysis the placement of the γ-rays were carried out using energy gated γ-γ coincidence technique

*Electronic address: subodhlookhi@gmail.com

using symmetric matrix. The γ-transition were observed in coincidence gated spectra of 2797 keV, 1094 keV, 843 keV, 251 keV, 1511 keV, 850 keV, 1030 keV, 1749 keV, and 3008 keV transitions. In our analysis so far, we were unable to confirm any new γ-rays in the level scheme. However, the confirmation and placement of all the γ-rays reported in refs. [5, 6] have been successfully carried out. A typical gated spectra of 2797 keV is shown in Fig. 1. The relative intensities of these transitions were adopted from ref. [6]. The spin assignments for the energy levels were determined and confirmed using R_{DCO} analysis, and the results are consistent with previous studies [5, 6]. The partial level scheme proposed in the initial analysis of ^{39}Ca of present experiment is shown in Fig. 2. Further analysis to investigate new γ-transitions and to determine their R_{DCO} values will be conducted in the future.

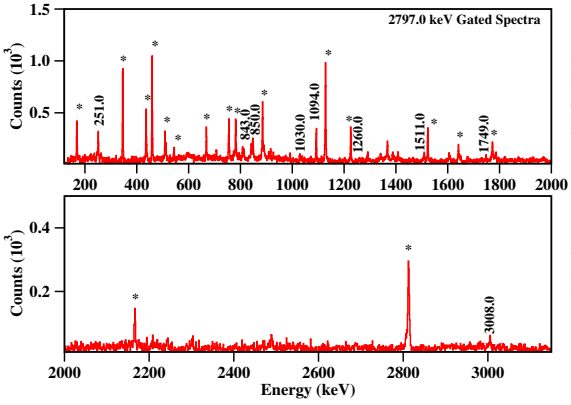

FIG. 1: A typical gated spectrum on the 2797 keV transition is shown, with the coincident γ-transitions from ^{39}Ca nuclei. Peaks marked with an asterisk (*) represent foreign transitions in the spectrum.

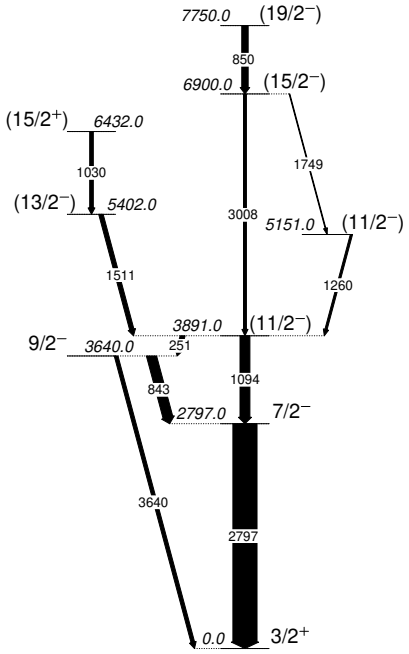

FIG. 2: The proposed partial level scheme of ^{39}Ca from the present study is presented. The width of the arrows indicates the relative intensities [6] of the γ-rays.

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