Eur. Phys. J. A (2023) 59:229
https://doi.org/10.1140/epja/s10050-023-01147-9

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article - Experimental Physics

Revealing new structures in odd–odd ^{54}Mn nucleus

S. Basu[1,2], G. Mukherjee[1,2,a], S. Nandi[1,2,12], S. S. Nayak[1,2], S. Bhattacharyya[1,2], Soumik Bhattacharya[1,3], Shabir Dar[1,2], Sneha Das[1,2], S. Basak[1,2], D. Kumar[1,2], D. Paul[1,2], K. Banerjee[1,2], Pratap Roy[1,2], S. Manna[1,2], Samir Kundu[1,2], T.K. Rana[1,2], R. Pandey[1,2], S. Chatterjee[4], R. Raut[4], S. S. Ghugre[4], S. Samanta[4,13], R. Banik[5], A. Karmakar[2,6], S. Chattopadhyay[6], S. Das Gupta[7], P. Pallav[7,8], S. Rajbanshi[9], S. Ali[10], H. Pai[6,11]

[1] Variable Energy Cyclotron Centre, Kolkata 700064, India
[2] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India
[3] Florida State University, Tallahassee, FL, USA
[4] UGC-DAE CSR, Kolkata Centre, LB-8, Sector III, Bidhannagar, Kolkata 700106, India
[5] Institute of Engineering and Management, Saltlake Sector V, Kolkata 700091, India
[6] Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700064, India
[7] Victoria Institution (College), Kolkata 700009, India
[8] Department of Physics, School of Basic and Applied Sciences, Adamas University, Kolkata 700126, India
[9] Department of Physics, Presidency University, Kolkata 700073, India
[10] Government General Degree College at Pedong, Kalimpong, India
[11] Extreme Light Infrastructure - Nuclear Physics, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Bucharest-Magurele 077125, Romania
[12] *Present address*: Argonne National Laboratory, 9700 S Cass Ave, Lemont, IL 60439, USA
[13] *Present address*: University of Genoa, Genoa, Italy

Received: 28 April 2023 / Accepted: 5 October 2023 / Published online: 16 October 2023

Communicated by Navin Alahari

Abstract The excited states of odd–odd ^{54}Mn ($Z = 25$, $N = 29$) nucleus have been investigated using the fusion evaporation reaction ^{55}Mn(α, αn)^{54}Mn at the beam energy of 34 MeV. A new and improved level scheme of ^{54}Mn has been proposed in this work with the placement of 22 new γ-ray transitions. Spin and parity (J^{π}) of most of the levels in the revised level scheme have been firmly assigned. The placement of some of the already known γ rays in the level scheme and J^{π} assignments of some of the levels reported earlier have also been revised. The new level scheme, which has been extended up to ~6 MeV, provides new insight and interesting structural aspects of the generation of high angular momentum in this odd–odd Mn isotope with neutron number ($N = 29$) just above the $N = 28$ shell gap. Three octupole-phonon-coupled negative parity states have been identified for the first time in this nucleus. $E3$ transitions have also been observed to decay from these states. Shell model calculations with two different interactions i.e. kb3gpn and gx1pn have been performed which well reproduced the low-lying, few-particle states but fail to reproduce the higher-lying multi-particle states. These higher-lying states have been understood as resulting from collective excitations. An oblate minimum obtained from the Total Routhian Surface calculations provides support to this conjecture.

1 Introduction

The odd–odd ^{54}Mn ($Z = 25, N = 29$) is an interesting nucleus from the point of view of nuclear structure. The proton and neutron Fermi energy levels in ^{54}Mn lie below and above the $Z, N = 28$ shell gap, respectively. In fact, the last proton and the last neutron may occupy the $f_{7/2}$ and $f_{5/2}$ orbitals, the ℓ.s splitting of which creates the shell gap at 28. This is the first shell gap created due to the ℓ.s term which lowers the $1f_{7/2}$ orbital from the rest of the fp space towards the $1d_{3/2}$ orbital [1]. The $N = Z = 28$ nucleus ^{56}Ni is considered as a "soft core" [1,2] compared to the other doubly magic cores in the nuclear chart. For the nuclei in the $A \sim 55$ mass region, the active orbitals are mainly $1f_{7/2}$, $2p_{3/2}$,$1f_{5/2}$ and $2p_{1/2}$. All of these are negative parity orbitals. Therefore, in case of odd–odd nuclei in this region, the excited states are mostly positive parity [3–16]. The negative parity states are mainly observed in the lighter odd–odd nuclei below $A = 50$ [17,18] and only a few negative parity states are known in the nuclei above $A = 50$.

[a] e-mail: gopal@vecc.gov.in (corresponding author)