Yrast structure of the shell model nucleus ^{89}Nb

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Introduction

The level structures of nuclei in the N∼50, Z∼40 region can be well described by the shell model, thereby offering an ideal platform to test its predictions. With respect to an inert ^{56}Ni core, the valence space in these nuclei comprise of the major shell from $Z, N = 28 - 50$, *i.e.*, the orbitals $f_{5/2}$, $p_{3/2}$, $p_{1/2}$, and $g_{9/2}$. Restricting the valence nucleons to occupy the $p_{1/2}$ and $g_{9/2}$ subshells only, the results of shell model calculations have been observed to be in reasonable agreement for the low-spin excitations. However, for explaining the high-spin states, a larger configuration space should be involved and even the excitation across the N=50 shell closure has to be taken into account. Therefore, systematic studies of high-spin states in nuclei near the N∼50, Z∼40 region may provide important information on the core excitation mechanism. In the present work, we report on the study of high-spin states in the $N = 48$ isotone ^{89}Nb, produced through heavy-ion fusion evaporation reaction. The previously known level scheme in this nucleus has been extended to ∼ 10.5 MeV excitation energy and up to spin around $23\hbar$.

Experimental Details and Data Analysis

High-spin states in ^{89}Nb were investigated using the heavy-ion fusion evaporation reaction ^{65}Cu(^{28}Si,2p2n)^{89}Nb. The 14UD TIFR-BARC Pelletron accelerator at Tata Institute of Fundamental Research (TIFR) provided a 105 MeV ^{28}Si beam. The target consisted of a 1.0 mg/cm^2 thick foil of isotopically enriched ^{65}Cu rolled with a foil of ^{197}Au of thickness 6.5 mg/cm^2. The γ-ray coincidence events were measured with the Indian National Gamma Array spectrometer consisting of 15 Compton-suppressed clover detectors [1]. For offline analysis γ^2-matrix and γ^3-cube were constructed.

Results and Discussion

Prior to the present work high-spin states in ^{89}Nb were observed up to an excitation energy of 7 MeV and spin $\sim 33/2\hbar$ by Bödeker *et al.* [2]. In the present work, we have observed around 30 new γ-ray transitions extending the level structure of this nucleus up to spin $45/2\hbar$ and excitation energy 10.5 MeV. A double gated coincidence spectrum is displayed in Fig.1 where the newly identified transitions of ^{89}Nb can be seen.

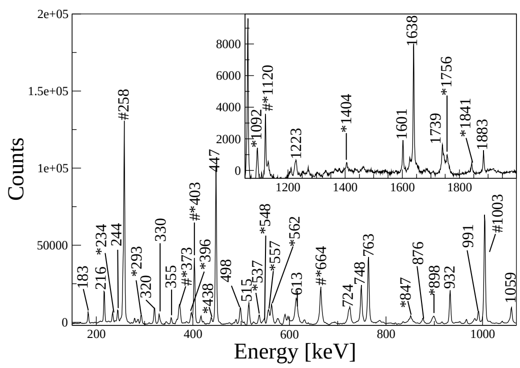

FIG. 1: Double gated γ-ray coincidence spectrum showing transitions depopulating the states in ^{89}Nb. The peaks marked with asterisks denote transitions newly identified in the present work. Hash marked peaks are unresolved doublets.

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In order to understand the configuration of the observed states in ^{89}Nb, shell model calculations have been performed, using the shell-model code ANTOINE [3]. The valence space employed in the calculations, comprise of the major shell $Z, N = 28-50$, with an inert ^{56}Ni core. The valence particles have been 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 [4] and jj44b [5] have been used in the calculations. Both these interactions have been shown to give good agreement with the experimental data in the neighboring ^{89}Zr nucleus [6]. The single-particle energies used with the JUN45 interaction are -8.7087 ($f_{5/2}$), -9.8280 ($p_{3/2}$), -7.8388 ($p_{1/2}$), and -6.2617 ($g_{9/2}$) MeV. For the jj44b interaction, the single particle energies are -9.6566 ($p_{3/2}$), -9.2859 ($f_{5/2}$), -8.2695 ($p_{1/2}$), and -5.8944 ($g_{9/2}$) MeV. A comparison of the experimental excitation energies of the positive and negative parity states of the ^{89}Nb with the predictions of shell-model calculations using JUN45 interaction is shown in Fig. 2.

In general, the results of shell-model calculations using JUN45 interaction have been observed to be in good agreement with experimental observations up to highest spin observed. On the other hand the calculations with jj44b show poor agreement with experimental observation, especially at high spin. The experimentally observed highest spin state with $I^{\pi} = 37/2^{+}$ and $45/2^{-}$ are reproduced in the calculation within 200 keV difference in JUN45 interaction. The fair agreement with shell-model calculations suggest that excitations across $N = 50$ shell gap do not play any significant role in forming the yrast structure of this nucleus up to the highest spin observed in the current experiment. A further detailed study of electromagnetic transition probabilities can give insight into the exact nature of wave functions of these states.

Acknowledgments

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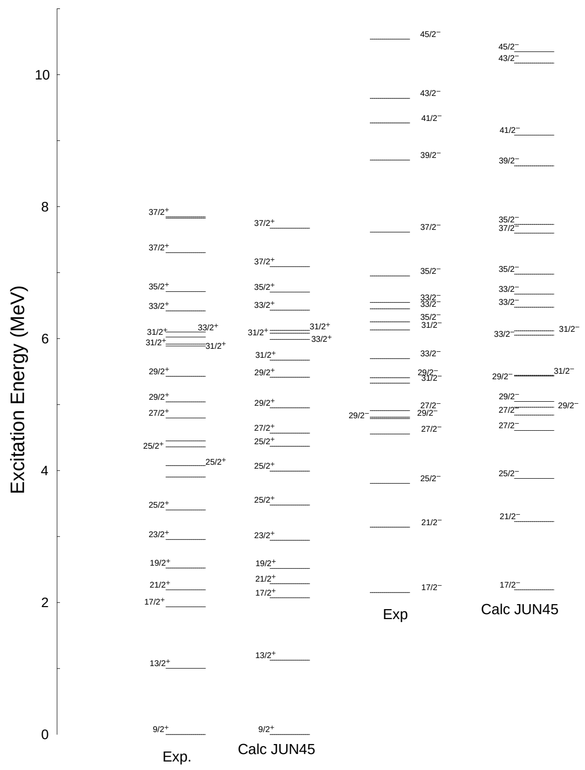

FIG. 2: Experimental and Calculated positive and negative parity states in^{89}Nb.

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