A study of neutron-rich Mo isotopes by the projected shell model

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Neutron-rich nuclei in the mass region A~100 are of particular interest from both experimental and theoretical points of view since they exhibit many interesting structural phenomena. The research in this mass region started with an important discovery made by Cheifetz *et al* [1] who observed a sudden onset of deformation in Zr isotopes and thereby discovered a new region of large and stable deformation. The well developed rotational spectra were observed in several highly neutron-rich isotopes of Zr and Mo during the study of fission fragments of ^{252}Cf. Hua *et al* [2] have extended the level schemes of neutron-rich Mo isotopes beyond the first band crossing region. They have extended the ground state band of ^{103}Mo upto spin $39/2^+$ and negative-parity band upto $39/2^-$. The ground state bands of even-even $^{104-108}$Mo are established upto spin 16^+ and 20^+. The identified multi-quasiparticle bands with diverse phenomena in structure make these nuclei an ideal testing grounds for various theoretical models. The crossing frequency of the aligned bands in these nuclei is reproduced well by the Cranked Shell Model Calculations. The systematics of one quasi-particle configurations in odd neutron-rich Mo isotopes was studied by Hartree-Fock Bogoliubov plus equal filling approximation method with the Gogny energy density functional [3]. However, to describe the observed rotational bands, more quantitative model calculations are desired.

In the present work, the projected shell model (PSM) is applied to analyse systematically the yrast band structures in $^{102-105}$Mo. The PSM [4] is a kind of shell model approach. However, unlike the conventional shell model, the PSM begins with the deformed Nilsson type single particle basis. Its advantage over the conventional shell model is that the important nuclear correlations can easily be taken into account and the configuration space is manageable, thus making the shell model treatment for the heavy systems possible. The Hamiltonian which has been used in the present work is described as follows

$$\hat{H} = H_0 - \frac{1}{2}\chi\sum_{\mu}\hat{Q}^{\dagger}_{\mu}\hat{Q}_{\mu} - G_M\hat{P}^{\dagger}\hat{P} - G_Q\sum_{\mu}\hat{P}^{\dagger}_{\mu}\hat{P}_{\mu}$$

where H_0 is the spherical single particle Hamiltonian. The second term is the quadrupole-quadrupole interaction and the last two terms are the monopole and quadrupole pairing interactions, respectively. The quadrupole interaction strength χ is adjusted so that the known quadrupole deformation ϵ_2 from the HFB self consistent procedure is obtained. The single particle space consists of three major shells N=2, 3, 4 for protons and N=3, 4, 5 for neutrons.

In Fig. 1, the calculated yrast bands of $^{102-105}$Mo isotopes are compared with the experimental data. The experimental data in case of ^{102,104}Mo nuclei is available up to spin 16^+ and 18^+, respectively and is well reproduced by the PSM calculations whereas in ^{103,105}Mo, the experimental data is available for positive and negative parity bands but the yrast band is of positive parity in ^{103}Mo and negative parity in ^{105}Mo with band heads at spins $3/2^+$ and $5/2^-$, respectively. From Fig. 1, it is seen that the experimental energies of these nuclei are reproduced by the PSM calculations qualitatively.

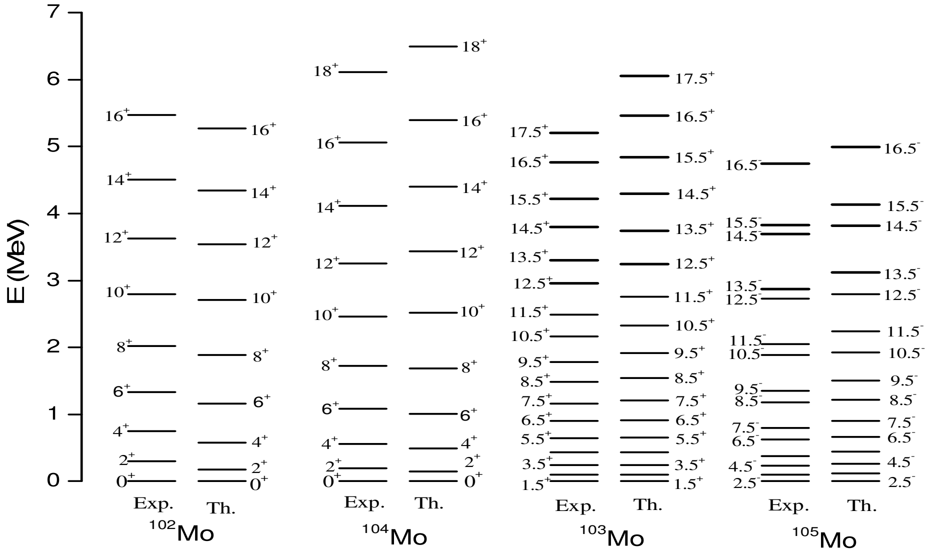

Fig.1. Comparison of calculated yrast energies of $^{102\text{-}105}$Mo isotopes with the experimental data.

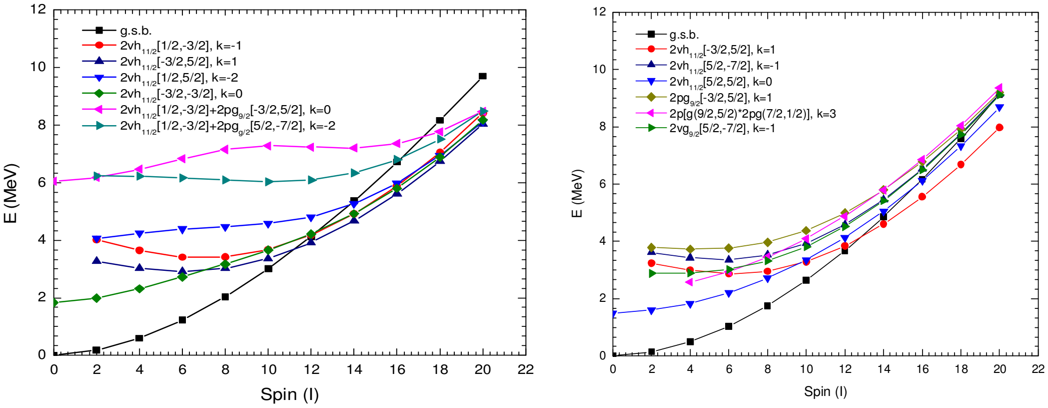

Fig. 2. Band diagrams of ^{102,104}Mo.

The band diagrams of ^{102,104}Mo nuclei are displayed in Fig. 2. From the analysis of the band diagrams of these nuclei, it is seen that the yrast band arises from pure zero quasi-particle (qp) configuration up to spin 10^+ and higher yrast states arise from superposition of 2 qp neutron $h_{11/2}$ bands. From the PSM wave functions, the B(E2) transition probabilities are also calculated that show good agreement with the experimentally known data. The calculation of other bands in odd mass nuclei and even-even nuclei is under progress and would be presented in the symposium.

References

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