Projected Shell Model Studies on Tantalum Isotopes

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1. Introduction

The study of nuclear structure, especially at high spins, has been a fascinating research area in nuclear physics. In the case of nuclei with A=150-190 and $A > 220$, they are inherently deformed. Atomic nucleus is a strongly interacting, many-body quantum mechanical system that exhibits varieties of shapes and excitation modes. Most of the nuclei in the nuclear chart are deformed, except those in the vicinity of magic numbers [1]. Shell model is the fundamental way of describing many-nucleon systems, but it becomes unfeasible when dealing with nuclei of large proton and neutron numbers [2]. Also the spherical single particle basis employed by shell model is not applicable in the case of deformed nuclei.

In the present work we discuss the Projected Shell Model (PSM) theoretical studies of Tantalum isotopes we have carried out at high spin regime. Nuclei at high spins exhibit interesting properties such as shape changes, backbending, band-crossing etc. PSM calculations were performed with the introduction of deformed potential known as Nilsson+BCS potential and the results can be interpreted in simple physical terms. Here we studied odd-odd (OO) and even-odd (EO) Tantalum isotopes in the mass range A=167 to 197. The band diagrams and energy difference diagrams were plotted for these isotopes.

2. Theoretical formalisms

Projected shell model (PSM) is a modification of the standard shell model to improve the quality of computations made on the deformed nuclei. Recently it was extended to deal with the super deformed systems also. The particular computer program used here was developed by Sun and Hara [2] and is known as the PSM code. The successive BCS calculations for the Nilsson states provide the pairing correlation. It causes rotational symmetry breaking and is restored by projecting the intrinsic state onto good angular momenta. Then the rotational invariant shell model Hamiltonian is diagonalised using this projected state.

$$\hat{H} = \hat{H}_0 - \frac{1}{2}\chi \sum_{\mu} \hat{Q_\mu}^{\dagger} \hat{Q_\mu} - G_M \hat{P}^{\dagger}\hat{P} - G_Q \hat{P}^{\dagger}_{\mu}\hat{P}_{\mu} \quad (1)$$

where $\hat{H}_0$ represents the spherical single-particle Hamiltonian, the second term represents the quadrupole-quadrupole interaction, and the last two terms are monopole and quadrupole pairing strengths respectively. The final term gives the quadrupole pairing force.

3. Results and discussion

The work is carried out on odd-odd and even-odd isotopes of Ta, in the mass range A=167-197. The values of stretched deformation parameters, the quadrupole (ϵ_2) and hexadecapole (ϵ_4) are taken from FRDM data sheet [3]. Energies of different bands were plotted against spin in band diagrams and energy difference diagrams were also plotted. Energy difference diagrams for Even-Odd Tantalum isotopes are shown in Figure 1. Table 1 shows the Fermi energy (Mev) and gap energy (Mev) of odd-odd Tantalum isotopes.

4. Conclusion

In the present work Projected shell model has been used to study the isotopic chains of Tantalum. The energy difference diagrams of even-odd Tantalum isotopes show signature splitting or staggering in energy

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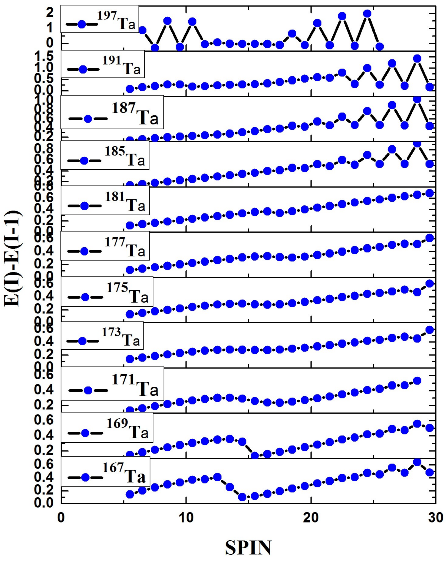

FIG. 1: Energy difference diagrams of Even-Odd Ta isotopes

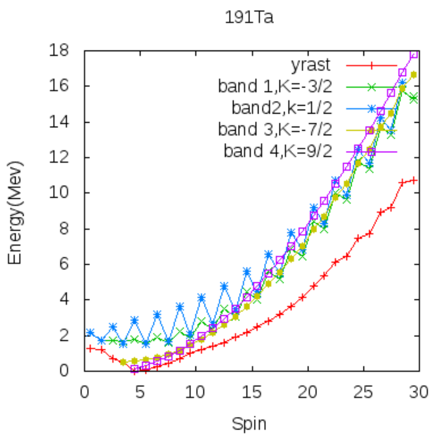

FIG. 2: Band diagram of ^{191}Ta

states. This behaviour shows a decreasing trend as the neutron number increases upto ^{181}Ta. This decrease is directly related to alignment changes between angular momentum states. After ^{181}Ta signature splitting in-

TABLE I: Fermi energy and Pairing gap energy of odd-odd Ta isotopes

Ta nuclei	Neutron		Proton	
	$\lambda(Mev)$	$\Delta(Mev)$	$\lambda(Mev)$	$\Delta(Mev)$
^{168}Ta	51.0681	0.8902	42.7594	0.6465
^{170}Ta	51.3169	0.7812	42.500	0.6335
^{172}Ta	51.5708	0.6795	42.3277	0.6032
^{174}Ta	51.7668	0.6715	42.0107	0.5657
^{176}Ta	51.9998	0.5715	41.7007	0.5451
^{178}Ta	52.3073	0.4662	41.4001	0.5233
^{180}Ta	52.5075	0.3486	41.0230	0.5102
^{182}Ta	53.4766	0.2997	40.7413	0.4867
^{184}Ta	53.6404	0.3488	40.3850	0.4770
^{186}Ta	53.8830	0.3228	40.0151	0.4952
^{188}Ta	54.0557	0.2554	39.6568	0.5161
^{192}Ta	55.0075	0.2526	38.7615	0.7205
^{194}Ta	54.5529	0.2290	38.5520	0.8153

creases rapidly. Large signature splitting is dependent on the quantum triaxiality of the nucleus. Further investigations in this mass range is required to confirm the exact behaviour.

References

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