Rotation of ^{92}Nb nucleus about different principal axes

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Introduction

It is well known that the low-lying states in the nuclei around the closed-shell (in the present work $Z \simeq 40$ and $N \simeq 50$) have been dominated by shell model type excitations. On the other hand, the high-spin states of nuclei near closed shells (in A $\sim$ 90 and 140) has developed considerable interest in terms of collectivity via rotation of nucleus about the classically unfavored longest principal axis. However, triaxiality in nucleus plays a leading role in determining the possibility of rotation around any of the three principal axes. The energy of rotation around the shortest principal axis becomes favourable for $\gamma \sim 30°$, rotation around the intermediate axis becomes energetically favourable for $\gamma \sim$ -30° and that around the longest axis is around $\gamma \sim$ -80°.

In this mass region, regular magnetic dipole band structures with very weak or completely suppressed $E2$ crossovers have been observed at high spins (see example of ^{89}Zr [1]). These bands are generated through rotation of nucleus about the possible longest axis. On the contrary, these are akin to the $E2$ bands in mass 140 region [2]. The configurations of high-spin bands are mostly dominated by protons excitations to higher orbitals, and the excitation of the neutrons across the N = 50 neutron core into the next major oscillator shell. In this paper we discuss about the confirmation of spin and parity of different newly observed states by Zheng *etal.* [3] and interpretation of the dipole bands in terms of rotations about various axes.

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Experimental Details

High-spin states in the ^{92}Nb have been populated using the reaction ^{80}Se(^{18}O, p5n)^{92}Nb at a beam energy of 99 MeV. The ^{18}O beam from 14UD pelletron accelerator was bombarded on 1.4 mg/cm^2 ^{80}Se with a backing of 1.5 mg/cm^2 ^{27}Al. The γ-rays were detected with the Indian National Gamma Array (INGA) at TIFR. In the present work, three clover detectors each were kept at 157°, 140°, two at 115°, four at 90°, and one detector at 65° with respect to the beam direction. The data were sorted using an offline analysis code MARCOS to generate γ-γ matrix and γ-γ-γ cube [4]. The software package "RADWARE" was used for offline analysis of data [5]. To obtain information on the multipolarity of γ - rays, two asymmetric matrices were built. The first one includes the events detected in detectors at 157° on one axis and those detected in all detectors on the other axis, whereas the second matrix consists of counts registered in detectors at 90° on one axis and those in all detectors on the other axis. The intensity ratio $R_\theta = \frac{I_\gamma(\gamma 1^{157^\circ}, \gamma 2^{all})}{I_\gamma(\gamma 2^{90^\circ}, \gamma 2^{all})}$ distinguishes between the stretched dipole($\simeq$ 0.7) and quadrupole($\simeq$ 1.4) transitions respectively when gated on quadrupole transition. Clover detectors facilitates the linear polarization measurement studies of EM radiation. The polarization assymetric parameter Δ_{assym} is positive and negative for electric and magnetic transitions respectively. The parameter is defined as $\frac{aN_\perp - N_\parallel}{aN_\perp + N_\parallel}$ where $N_\perp$ and $N_\parallel$ are the number of scattered photons in direction perpendicular and parallel to the direction of reaction plane respectively. The correc-

tion factor a as a function of γ energy comes out to be 1.00(5).

Results and Discussion

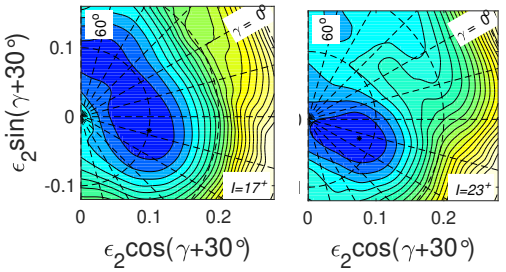

FIG. 1: Total energy surfaces with the constraint, $\pi = +$, $\alpha = 0$. The contour line separation is 0.25 MeV.

We observed most of the transitions as reported by Zheng *etal*. [3]. In addition to already known gamma only a very few new transitions were observed extending the level scheme tentatively up to excitation energy of 11 MeV and $I \sim 22\hbar$. The tentatively assigned spin and parity for all the previously reported new transitions were confirmed. The same will be displayed during the presentation. Zheng *etal*. have assigned configurations to the states in the framework of shell model calculations. Pairing independent cranked Nilsson Strutinsky calculations (CNS) helps in nurturing the collective properties of a nucleus. CNS calculations were performed with parameters derived for A = 80 region [6]. For details of calculation please refer to [2, 7]. The Fig. 1 shows the potential energy surfaces as a function of deformation parameters ε_2 and γ. For low spin states up to 13 $\hbar$ the shape is stabilized with $\gamma \sim$ -10° and $\varepsilon_2 \sim 0.01$. Upto spin 17 $\hbar$ the shape shows collective behaviour with $\gamma \sim$ -43°, $\varepsilon_2 \sim 0.01$ which further collapses to non-collective oblate for higher spin states up to $I \sim 21$ $\hbar$. Beyond $23\hbar$, the energy minimum shifts towards $\gamma \sim$ -50° which signifies probable rotation of the nucleus around the longest principal axis (The state $I \sim 23\hbar$ was not observed till date). Observed excitation energy w.r.t. a liquid drop was plotted as a function of spin (Fig. 2). The same is compared with the calculated results for a few selected configurations. From the plot, it is concluded that configuration [3, 9] can be assigned to band with configuration $\pi(1g^3_{9/2}) \otimes \nu(1g^{-1}_{9/2}(1g^1_{7/2})(2d^1_{5/2})$. For the given configuration, triaxial parameter γ transits from negative value angle $\gamma \sim$ -53° at spin 17 to $\gamma \sim$ -78° at spin 23. Thus, the nucleus can regarded as an example where we can observe transition of rotating nuclei about a given principal axis to another one.

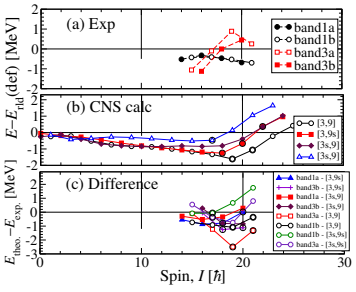

FIG. 2: (a) Experimental excitation energy w.r.t. spin for ^{92}Nb. (b) Calculated excitation energy vs spin for negative parity bands. (c) Comparison of experimental and calculated excitation energies as a function of spin.

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References

[1] S. Saha *et al.*, Phys. Rev. C **99**, 054301 (2019).
[2] B.G.Carlsson, Phys. Rev. C **78**, 034316 (2008) and references therein.
[3] Y. Zheng *et al.*, Phys. Rev. C **100**, 014325 (2019).
[4] R. Palit *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A**680**,90(2012).
[5] D.C. Radford, Nucl. Instrum. Methods A **361**, 297 (1995).
[6] A. V. Afansjev *et al.*, Phys. Rep. 322, 1 (1999), and references therein.
[7] T. Bengtsson and I. Ragnarsson, Nucl. Phys. A436, 14 (1985) and references therein.