Potential energy surfaces of even-mass $^{190-200}$Po isotopes and shape driving effect of $h_{9/2}$ proton

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Introduction

Shape coexistence has been observed by now all through the nuclear mass region, encompassing light nuclei (for example, ^{16}O), proceeding up to the region of very heavy nuclei in the Pb region and has been reviewed in a number of reports over a period of spanning about three decades. Recent advances in experimental methods to explore nuclei, have opened up possibilities to explore the appearance and behaviour of shape coexistence in series of isotopes and isotones. In particular, in Pb nuclei and just below the Z=82 proton-shell closure (i.e, in Hg & Pt isotopes), extensive studies using different experimental approaches have made it possible to develop nuclear models describing transition from spherical shapes to deformed ones and vice versa [1]. Here, we report on some Woods-Saxon calculations on even-mass $^{190-200}$Po and ^{201}At nuclei corresponding to different configurations.

Results & Discussion

The equivalence between particles and holes leads to the formation of low-lying deformed states, also called intruder states - which are observed in Bi, even-even Po and Rn isotopes. The strong finger-print of shape coexistence in even Po isotopes is the low-lying 0^+ intruder states with rotational-like bands built on top of that and a significant amount of reduction of excitation energy of these intruder states with respect to the ground state with decreasing neutron numbers. The orbital overlapping of these intruder states with the ground state is very pronounced in case of light Po isotopes which drives the lighter isotopes from spherical toward deformed shape. In order to look into the development of this behaviour of shape changes, we have calculated the total potential energy surfaces of ^{190,192,194,196,198,200}Po and ^{201}At isotopes using the Hartree-Fock-Bogoliuobov code of Nazarewich et al. [2], for zero quasi-particle (for ^{190,192,194,196,198,200}Po), two quasi-particles (for ^{200}Po) and three quasi-particles (for ^{201}At) configurations respectively. The Total Routhian Surface (TRS) is calculated at each $\hbar\omega$ in the $\beta_2\gamma$ plane with minimization of β_4. Here, two quasi-particle calculation for ^{200}Po corresponds to the configuration $\pi h_{9/2} \otimes \pi i_{13/2}$. This configuration leads to the isomeric 11^- state in ^{200}Po. The three quasi-particle calculations for ^{201}At corresponds to the configuration $\pi h_{9/2}\otimes \mid {}^{200}\text{Po}; 11^- >$ (which leads to the recently observed isomeric $\frac{29}{2}^+$ state in ^{201}At [4]) and $\pi s_{1/2}\otimes \mid {}^{200}\text{Po}; 11^- >$ or $\pi i_{13/2}\otimes \mid {}^{200}\text{Po}; 11^- >$. Calculations for ^{190,192,194,196,198,200}Po corresponding to zero quasi-particle excitation show a deformed oblate shape for ^{192}Po at $\beta_2 \approx 0.2$ and near prolate shape for ^{190}Po at $\beta_2 \approx 0.26$ and it gradually approaches toward spherical shapes for ^{194,196,198,200}Po [FIG.1] with increasing neutron numbers.

Recent studies on ^{190,192,194}Po [3], using IBM-CM (Interacting Boson Model with Configuration Mixing) approach in which the model space is restricted to 0p-0h and 2p-2h excitations have produced results which are similar to the TRS calculations reported here.

From FIG.2, it is clear that the shape of 11^- isomeric state is nearly spherical and the cal-

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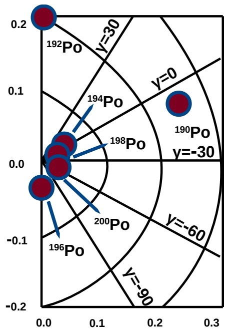

FIG. 1: A representative diagram showing the locations of energy minima for even-mass $^{190-200}$Po isotopes in (β_2, γ) plane for zero quasi-particle excitation at $\hbar\omega$=0.041 MeV. Here x and y axes represent $\beta_2 \cos(\gamma + 30)$ and $\beta_2 \sin(\gamma + 30)$ respectively. Please see text for detail.

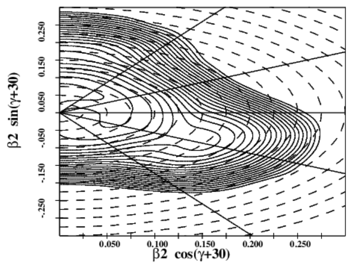

FIG. 2: Total Routhian Surface (TRS) for ^{200}Po for the configuration $\pi h_{9/2} \otimes \pi i_{13/2}$ at $\hbar\omega = 0.041$ MeV. The contours are 250 KeV apart.

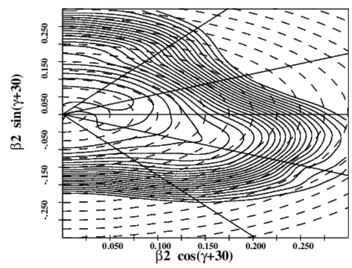

FIG. 3: Same as FIG.2 for ^{201}At for the configuration $\pi s_{1/2} \otimes \mid {}^{200}\mathrm{Po}; 11^- >$ or $\pi i_{13/2} \otimes \mid {}^{200}\mathrm{Po}; 11^- >$ at $\hbar\omega = 0.041$ MeV.

culations predict minima at $\beta_2 \approx 0.05$. The calculations for the configuration $\pi s_{1/2} \otimes \mid {}^{200}\mathrm{Po}; 11^- >$ or $\pi i_{13/2} \otimes \mid {}^{200}\mathrm{Po}; 11^- >$ show minima at $\beta_2 \approx 0.06$ [FIG.3] and similarly we can assume a near spherical shape for this configuration.

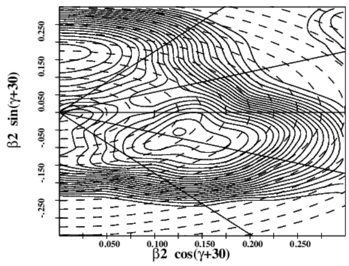

FIG. 4: Same as FIG.2 for ^{201}At for the configuration $\pi h_{9/2} \otimes \mid {}^{200}\mathrm{Po}; 11^- >$ at $\hbar\omega = 0.041$ MeV.

Interesting point is the results for the other configuration i.e, for $\pi h_{9/2} \otimes \mid {}^{200}\mathrm{Po}; 11^- >$, where we can easily see that the minima have shifted towards non-collective oblate shape and the corresponding β_2 value is quite large (≈ 0.2) relative to the previous two configurations and a prominent second minima is also appearing at a collective oblate shape [FIG.4]. We can conclude here, that the coupling of a $s_{1/2}$ or $i_{13/2}$ proton with 11^- state of Po does not have significant deformation driving effect and near spherical shape is retained. But situation becomes different for the coupling of a proton from $h_{9/2}$ shell with 11^- state, which is dominantly driving the shape from spherical towards deformed one. Detail reports and discussion will be presented in the workshop.

Acknowledgments

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References

[1] N. Bijnens et al., Phys. Rev. Lett. **75**, 25(1995).
[2] W. Nazarewicz et al., Nucl. Phys. A **512**, 61(1990).
[3] J. E. García-Ramos and K. Heyde, Phys. Rev. C **92**, 034309(2015).
[4] K. Auranen et al., Phys. Rev. C **91**, 024324(2015).