Influence of $1h_{9/2}$, $1i_{13/2}$ and $3s_{1/2}$ orbitals on shapes of odd-mass Bi, At and Fr isotopes in mass region $\sim$ 200

U. S. Ghosh,* B. Mukherjee, S.Rai,† and A. Biswas
Department of Physics, Visva-Bharati, Santiniketan-731235, India

Introduction

Systematic studies on some nuclei in mass region $\sim$ 200 just bellow and above the Z=82 shell closure show a large variety of interesting phenomena including deformed and superdeformed band, shears mechanism, band termination, shape coexistence, sudden change in ground state deformation etc. Detailed study on Bismuth (Bi), Astatine (At) and Polonium (Po) nuclei, for the last few years with advanced experimental set-up and very selective experimental techniques, have been done, exploring the energy levels and the structures with great success. It is revealed that the shape changes from spherical toward deformed ones with decrease in neutron numbers in case of At, Po and Bi nuclei. Different coupling of protons and neutrons orbitals give rise to isomeric states with different lifetimes and deformed bands - mostly rotational like based on those states, have been observed. Here, we report on some Woods-Saxon calculations for Bi, At and Fr isotopes in order to understand the evolution of shape in this region.

Ground state spin and parity of heavier isotopes of Bi, At and Fr are $9/2^-$ corresponding to the odd proton in $1h_{9/2}$ orbital but it certainly changes to $1/2^+$ for some lower mass At and Bi isotopes. This $1/2^+$ state arises due to the presence of the intruder proton $3s_{1/2}$ orbital in the Nilsson diagram [1, 2]. Another interesting case is the presence of $\pi i_{13/2}$ configuration, which plays the key role for the origin of isomeric $13/2^+$ state in case of many At and Bi isotopes. Rotational bands built on $13/2^+$ state have been observed in case of many lower mass At and Bi isotopes but collectivity gradually becomes disperse with increasing neutron number, i.e for heavier isotopes. From the single particle level systematis of odd - A Bi, At and Fr isotopes, it has been found that there is an orbital overlapping of the intruder states with the ground state, which is very pronounced in case of light At, Bi and Fr isotopes and it indicates that minimization of energy occurs at the cost of deformation.

Results & Discussion

We have done a systematic study of potential energy surfaces of odd-mass even-N At, Bi and Fr isotopes using Woods-Saxon potential. The Hartree-Fock-Bogoliuobov code of Nazarewich et al.[4] is used for the calculations. The Total Routhian Surface (TRS) is calculated at each $\hbar\omega$ in the $\beta_2 - \gamma$ plane with minimization on β_4. In figures 1, 2 and 3 we have shown the contour plots representing the potential energy surfaces for ^{193}Bi, ^{195}Fr and ^{193}At at $\hbar\omega$ = 0.041 MeV. Shell corrections have been taken into account and as a residual interaction, the monopole pairing force has been taken with the strength from Ref.[4] Calculations are done for the (π, α)=(-,+1/2) and the (π, α)=(+,+1/2) proton configurations, where π and α represent parity and signature quantum numbers respectively. Here, the negative-parity, positive signature configuration corresponds to a proton particle in $h_{9/2}$ shell and positive-parity, positive signature configuration corresponds both to a proton hole in the $s_{1/2}$ shell and a proton particle in the $i_{13/2}$ shell.

Calculations for the Fr isotopes corresponding to the (π, α)=(-,+1/2) configuration at $\hbar\omega$=0.041 MeV excitation energy predict deformed triaxial shapes for lower

*Electronic address: usghosh88@gmail.com
†Presently at Salesian College, Siliguri Campus, Siliguri 734001, West Bengal

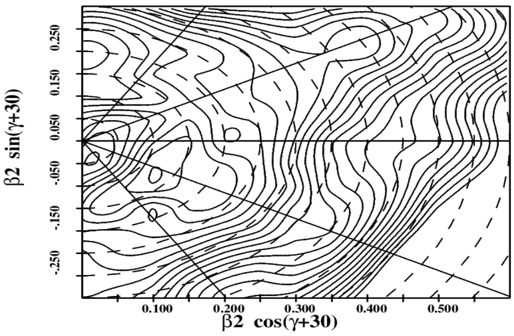

FIG. 1: TRS plot for ^{193}Bi for (π, α)=(+,+ 1/2) configuration at $\hbar\omega$=0.041 MeV.

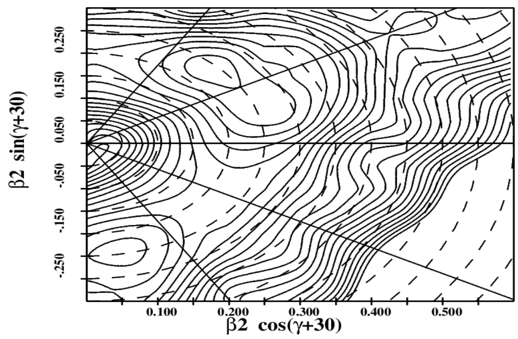

FIG. 2: TRS plot for ^{195}Fr for (π, α)=(+,+ 1/2) configuration at $\hbar\omega$=0.041 MeV.

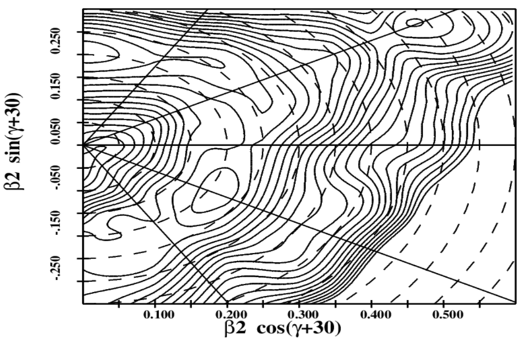

FIG. 3: TRS plot for ^{193}At for (π, α)=(+,+ 1/2) configuration at $\hbar\omega$=0.041 MeV.

mass ^{195,197,199,201}Fr isotopes and it gradually becomes near spherical for heavier isotopes ^{203,205,207}Fr. But calculations with (π,α)=(+,+1/2)configuration, at same energy predict deformed shapes for $^{195-205}$Fr. Deformation parameter β_2 decreases from neutron mid-shell towards shell closure but the shape still remains deformed. Our previous report [5] on At isotopes predicted deformed minima for lower mass At isotopes and a transition from deformed towards spherical shapes occurred with increasing neutron numbers for both configurations and here we have compared the results with Bi and Fr isotopes. Calculations for Bi isotopes for (π,α)=(-,+1/2) configuration predict weakly deformed structure for ^{191}Bi and it moves toward near spherical structure form ^{193}Bi and the shape corresponding to other configuration is deformed up to ^{199}Bi and it appears to be spherical at higher mass numbers. Comparison of the values of the deformation parameter (β_2) for the equal mass predicts quite large deformation for Fr isotopes compared to both Bi and At, which is expected as Fr is far from Z=82 shell closure compared to Bi and At nuclei. Detailed results will be presented during the symposium.

Acknowledgments

The first author would like to acknowledge the financial grants from SERB/DST with file No. EMR/2015/000891.

References

[1] E. Coenen, K. Deneffe, M.Huyse, P. Van Duppen, and J. L. Wood, Phys. Rev. Letters **54**, 1783 (1985).
[2] H. Kettunen et al., Eur. Phys. J A **17**, 537(2003).
[3] Z. Kalaninova et al., Phys. Rev. C **89**, 054312 (2014).
[4] W. Nazarewicz et al., Nucl. Phys. A **512**, 61 (1990).
[5] U. S. Ghosh et al., Proceedings of the DAE symp. on Nucl. Phys. **62** (2017).