Effect of pairing on bubble structure in superheavy nuclei

M. Kumawat[1,2], G. Saxena[1,2],* S. K. Jain[1], and Mamta Aggarwal[3]
[1]*Department of Physics, School of Basic Sciences, Manipal University Jaipur, Jaipur-303007, INDIA*
[2]*Department of Physics (H&S), Govt. Women Engineering College, Ajmer-305002, INDIA and*
[3]*Department of Physics, University of Mumbai, Kalina Campus, Mumbai-400098,INDIA*

In the recent times bubble structure has become an interesting topic in nuclear research. Bubble structure is related to central depletion of nucleonic density which is first observed in early 1940s. In light and mid mass region central depletion occurs due to empty s-state i.e. lower angular momentum state (ℓ=0) and due to the inversion of $2s_{1/2}$ & $1d_{3/2}$ or $3s_{1/2}$ & $1h_{11/2}$ states [1]. Recently, in an experiment, bubble structure has been observed for ^{34}Si [2].

Towards superheavy region, self-consistent Hartree–Bogoliubov approach has been applied for the investigation of bubble structure for proton and nucleon numbers (120$\leq$ Z $\leq$340; 300 $\leq$ A $\leq$ 1000) [3]. Substantial proton depletion fraction (DF=$(\rho_{max}-\rho_c)/\rho_{max}$, where ρ_{max} and ρ_c are maximum and central densities) is observed in spherical doubly magic nuclei ^{292}120 (N=172) and ^{293}120 [4]. Using correlation analysis, bubble structure is described in ^{34}Si, ^{48}Ca and N=82, 126, and 184 isotonic chains and ^{472}164 superheavy system [5] and a prominent central depletion is found in proton density of ^{302}118 and ^{472}164. Using RHFB theory, semibubble nuclei are predicted among Z=120 isotopes, and it is also reported that dynamical correlation and pairing interaction are the factors to quench the bubble phenomena or responsible for antibubble effect [6]. We have also investigated proton depletion fraction in isotopic chains Z=118, Z=120 and Z=122, and found significant amount of depletion fraction in ^{326}118 (N=208), ^{328}120 (N=208) and ^{330}122 superheavy nuclei using RMF(TMA) plus BCS approach [7].

In heavy and superheavy region, depletion in the proton density occurs mainly due to Coulomb repulsion. In case of isotopic chain or constant coulomb interaction, proton D.F. is affected by isospin and neutron number N, and it decreases as we increase isospin and N. In light region, pairing energy and quadrupole deformation reduce the bubble structure but unable to eliminate it. While the temperature completely disappears the bubble effect at a certain critical value of T. We have recently studied the effect of temperature on bubble structure in all mass region including superheavy region [8]. In light mass region, we have also studied the factors (Coulomb and pairing energy, isospin and the quadrupole deformation) which affect the central density depletion. In what manner these factors (Coulomb and pairing energy, neutron to proton ratio and the nuclear deformation) also affect the central depletion in superheavy region, has not been studied so far.

In this paper, the main objective is to see the effect of pairing energy and neutron number N on central depletion of nucleon density of superheavy nuclei simultaneously. For this investigation, we choose isotopes of semimagic number Z=120 as the bubble structure in few of its isotopes have already described in Refs [4, 6, 7], and apply relativistic mean field (RMF) plus BCS approach with NL3* parametrization. RMF calculations have been carried out using the model Lagrangian density with nonlinear terms for both the σ and ω mesons and the corresponding Dirac equations for nucleons and Klein-Gordon equations for mesons obtained with the mean-field approx-

*Electronic address: gauravphy@gmail.com

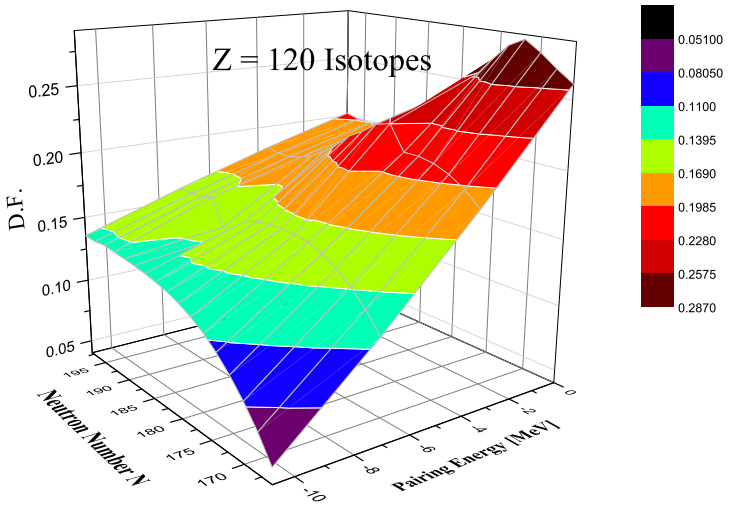

FIG. 1: (Colour Online) Depletion fraction (D.F.) vs. proton pairing energy and neutron number N for Z=120 isotopic chain

imation are solved by the expansion method on widely used axially deformed Harmonic-Oscillator basis. The basis deformation β_0 is set equal to β_{2m} and the quadrupole constrained calculations are performed in order to obtain the potential energy surfaces (PESs) and the ground-state deformations. We calculate depletion fraction (D.F.) from proton density of isotopic chain of Z=120 with the neutron number N=166-200. In Fig.1, we show variation of D.F. with respect to neutron number and proton pairing energy simultaneously. The figure reveals effect of pairing energy on the central depletion and it is clear that pairing energy can quench central depletion in superheavy nuclei which is very similar to what has been observed and reported in light region recently by Luo *et al.* [9]. In this region, proton pairing energy from N=166 to N=172 is found zero which verifies the magicity in Z=120 and also results highest D.F. as can be seen in the figure. As one moves towards more neutron rich side, the pairing energy increases and also the Coulomb repulsion gets counterbalance which simultaneously quench depletion in this isotopic chain.

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