A Study of Temperature Induced Pairing Correlation in Relativistic Mean Field Theory in ^{150}Sm$_{62}$ Nuclei

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1. Introduction

The Nuclear Structure exhibits many similarities with atomic structure of materials. In both the cases, we deal with fermionic system. Among materials, Superconductors are familiar to us. Moreover, it is well known that the pairing correlations in a superconductor are destroyed by increasing the temperature or external magnetic field. The critical value of temperature of field decides the boundary of superconducting and normal phase. The Standard theory regarding this pairing correlation is Bardeen-Cooper-Schrieffer (BCS) theory, which is mean field approximation based on grand-canonical ensemble. The pairing correlation in nuclear many body problems was first proposed by Bohr and Mottelson, and Pines in 1958[1].Although, it is quite evident from the analysis of the properties of nuclei, for instance, the suppression of the moments of inertia of rotating nuclei and the observed energy gaps, that the pairing is essential for describing atomic nuclei [2]. But most of these properties of nuclei are studied at zero temperature. So ,the study of nuclear properties at non zero temperature has been important subject of research from a long time [3].Moreover, the pairing field depicts a sudden transitional behavior as a function of rotational frequency and temperature[4]. Thus, the projection at finite temperature is more important part as it leads to study of more realistic models.The purpose of present work is to study the pairing correlations using finite temperature BCS approach (FTBCS), i.e. Temperature dependency of gap parameter. The thermal occupancy of quasi particles which are basically fermions are taken into account. Moreover, this FTBCS pairing is introduced in relativistic mean field calculations to study various nuclear parameters. The nucleus for which these calculations were performed is ^{150}Sm$_{62}$ .It is an even-even nucleus, one of the stable isotopes of Samarium. The study of properties of even-even Samarium (Sm) isotopes has been the focal point of large number of experimental studies in the past[5].The study of Samarium nuclei has been a challenging theoretical problem too, since they lie in the range from near spherical to well deformed shapes.^{148}Sm was believed to be basically spherical while ^{154}Sm is thought to be well deformed nucleus and $^{150-152}$Sm are transitional nuclei[6].So, In the present work this ^{150}Sm$_{62}$ nuclei is studied using RMF along with FTBCS approach to get various nuclear parameters.

2. Method of the calculations and Discussions

In our calculation both Relativistic Mean Field RMF codes are used.The RMF calculations reported here include the axially symmetric deformation of nuclei wherein pairing forces are treated using the BCS theory.We have used the improved version of NL3 parameter set(NL3*) for our calculations[7].The ground state properties like the BE, quadruple deformation parameters ,charge radii (r_c) ,and other bulk properties are evaluated by using relativistic parameter set at zero temperature.

The various nuclear parameters such as binding energy per nucleon, deformation, is calculated using RMF-FTBCS model for nuclei for T=0.0. MeV to 1.5 MeV. Figure 1 shows the variation of proton gap parameter(Δ_p) and neutron gap parameter (Δ_n) with temperature for T=0.0 to 1.5 MeV.Both Δ_n and Δ_p decreases with temperature.The calculated gap parameter at zero temperature (T=0) is 0.98 MeV

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TABLE I: The RMF (NL3*) results for BE, BE/A, the quadruple deformation parameter ,charge radii (r_{ch}) for ^{150}Sm$_{62}$

	Theoretical	Experimental[8]
BE (MeV)	1238.210	1239.243
BE/A(MeV)	8.255	8.262
β_2	0.19982	0.206
r_{ch}	5.047	5.037 ± 0.0026

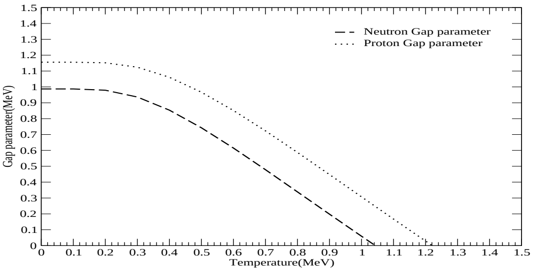

FIG. 1: The calculated Δ_p and Δ_n as a function of temperature for ^{150}Sm$_{62}$.

and 1.47 MeV for neutron and proton respectively. The value of critical temperature T_c =1.03 MeV and 1.23 MeV for Δ_n and Δ_p respectively. This is value where pairing phase transition takes place i.e. from superconducting state to normal state. This is transition point for nuclei which is strongly dependent of temperature.One can infer that interaction between nucleons becomes weaker at finite value of temperature and coopers pairs are destroyed.Figure 2 shows the binding energy variation with temperature. The binding energy decreases with temperature. The decrease in binding energy shows the fact that nucleons become loosely bound with the rise in temperature. The fast fall of curve at critical temperature shows that nucleons will become free at very high temperature. Figure 3 shows the deformation of ^{150}Sm nuclei. The deformation value suddenly decreases initially at T=0.1 MeV. The variation in deformation parameter confirms the shape transition in ^{150}Sm nuclei with the variation of temperature. Initially the nuclei were in prolate shape.At T=0.1 MeV, it suddenly goes to nearly spherical. As the temperature increases, the ^{150}Sm nuclei again change its shape from spherical to prolate shape. After critical value of temperature, the nuclei again transits to spherical shape.At very high value of temperature the nuclei seems to be spherical in shape.

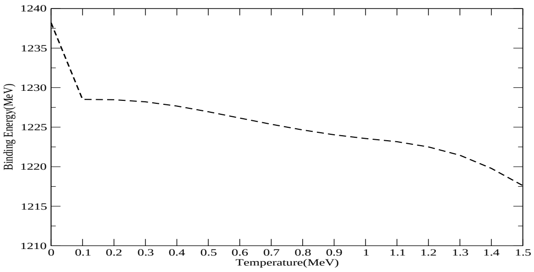

FIG. 2: The calculated binding energy as a function of temperature for ^{150}Sm$_{62}$.

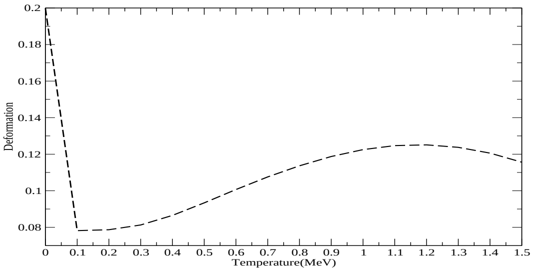

FIG. 3: The calculated deformation parameter (β_2) as a function of temperature for ^{150}Sm$_{62}$.

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