A Study of Shell Structure in Si, S, Ar and Ca nuclides within Relativistic Hartree Bogoliubov Approximation

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Introduction: In nuclear many particles system the distribution of quantum states of proton and neutron provide the stability to atomic nuclei and, certain quantum configurations of nucleons are well bound and form the basis of nuclear shell closures. Recently, at ISOLTRAP and RIKEN, neutron-rich calcium isotopes ^{53}Ca and ^{54}Ca have been investigated and, the magicity of ^{52}Ca nucleus was confirmed through trend obtained for the two-neutron separation energies S_{2n}, along with the magicity of ^{54}Ca nucleus was signified[1]. Experimentally, it is known that the magicity of neutron numbers, N = 28 is absent in Z = 14 and Z = 16 isotopic chains at $^{42}_{14}$Si and $^{44}_{16}$S, whereas the mass measurement experiments provide strong evidences for Z = 18 shell closure in $^{46}_{18}$Ar[1]. The purpose of present work to investigate theoretically the magicity of Shell Structure in the isotopic chains of Silicon, Sulphur, Argon, and Calcium.

Methods: We employed Covariant Relativistic self-consistent mean field models analogous to Kohn-Sham density functional theory to construct the Nuclear Density Functionals from Lagrangian densities based on mesons exchange and point coupling models. The pairing correlations of nucleons are considered by the relativistic Hartree-Bogoliubov functional based on quasi-particle operators of Bogoliubov transformations. The nuclear energy density functionals are constructed by using meson coupling model with DDME parameterizations and point coupling model with DDPC parameterizations with a separable pairing interaction [2].

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Results and Discussions: In the present work, we have studied the ground state properties of even-even nuclides of Si, S, Ar and Ca by employing meson coupling model with DDME parameterizations and point coupling model with DDPC parameterizations with a separable pairing interaction. We present the comparison our theoretical results with available experimental data for the parameters of nuclear shell closures D_n by Brown and differential variation in two neutron separation energies dS_{2n} in this paper, however we have also computed the results of one and two nucleon(s) separation energies, nuclear charge radii, nuclear radii and neutron skin thickness (Δr_{np}) and reasonable good in agreement with experimental data.

Shell Closures: The parameter of shell closures $D_n(Z, N)$, are expressed in terms of the large drop in the single neutron separation energies and its sysmetic analysis provide evidence for the shell closures. The $D_n(Z, A)$ can be written in terms $S_n(Z, A)$

$$D_n(Z, A) = (-1)^{N+1}[S_n(Z, A+1) - S_n(Z, A)] \quad (1)$$

In Fig.(1), we present the variation of D_n Eq.(1) as neutron number N for the isotopes of Silicon (left panel) and Sulphur (right panel). The filled circles black line is representing the experimental data and, the symbols of squares blue line and triangles red line are representing respectively, the theoretical results computed with DDME parameterizations and DDPC parameterizations, the shell closure at neutron number N = 28 completely disappeared in case of $^{42}_{14}$Si nucleus, whereas in case of $^{44}_{16}$S, theoretical results indicate small departure from experimental result of the shell closure. Our theoretical results are for the disappearance of magicity at N = 28 for Z = 14 and Z = 16 are good in agreement with the recent experimen-

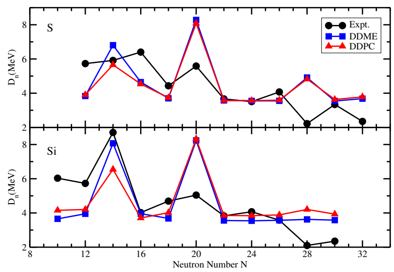

FIG. 1: (color online) The variation of D_n Eq.(1) as neutron number N for the isotopes of Silicon (left panel) and Sulphur (right panel). The filled circles black line is representing the experimental data and, the symbols of squares blue line and triangles red line are representing respectively, the theoretical results computed with DDME parameterizations and DDPC parameterizations.

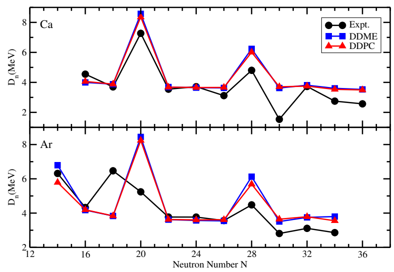

FIG. 2: (color online) Same as Fig.(1) for the isotopes of Argon (left panel) and Calcium (right panel).

tal measurements. Fig.(2) presents the comparison the experimental data with theoretical results for the parameter of shell closure D_n for isotopes of Argon and Calcium, at N = 28, the magicity is clearly establish in both systems, whereas the smaller peak at N = 32 in the right panel indicate the presence of shell closure in ^{52}Ca nucleus.

Differential Variation of Two Neutron Separation Energy: The differential variation of the two-neutron separation dS_{2n} (Z,N) is expressed in terms of the two neutron separation energies as:

$$dS_{2n}(Z,N) = \frac{S_{2n}(Z,N+2) - S_{2n}(Z,N)}{2} \tag{2}$$

In Figs. (3 and 4), we present the compar-

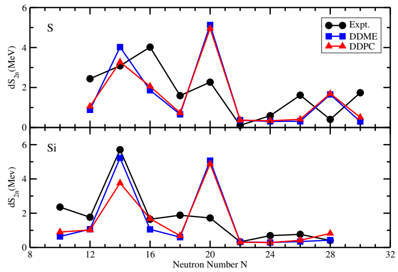

FIG. 3: (color online) The variation of dS_{2n} Eq.(2) differential as a function of neutron number N for the isotopes Silicon (left panel) and Sulphur (right panel). The filled cicles black line is representing the experimental data and, the symbols of squares blue line and triangles red line are representing respectively, the theoretical results computed with DDME parameterizations and DDPC parameterizations.

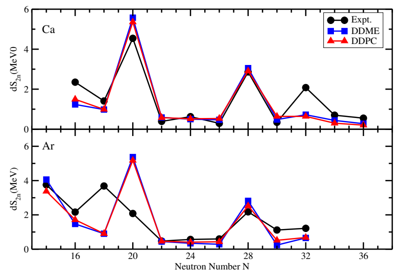

FIG. 4: (color online) Same as Fig.(3) The dS_{2n}, for the isotopes of Argon (left panel) and Calcium (right panel).

ison of experimental and theoretical results the parameter of differential variation of the two neutrons separation energies dS_{2n} defined in Eq.(2). The both theoretical and experimental results clearly indicate the present of magicity at N = 28 in $^{42}_{14}$Si, $^{44}_{16}$S, $^{46}_{18}$Ar and at N = 32 $^{52}_{20}$Ca nuclei.

References

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