Poster Number-34

Investigation of Ground state observables of even-even Lead (Pb) isotopes in heavy mass region based on Covariant Density Functional Theory

Virender Thakur[1,†], Pankaj Kumar[1], Vikesh Kumar[1], Smriti Thakur[1],Shashi K. Dhiman[1]

[1]Department of Physics, Himachal Pradesh University, Shimla-05, India

[†]*virenthakur2154@gmail.com*

29th Symposium of the Hellenic Nuclear Physics Society (HNPS-2021)

NCSR Demokritos, Athens, Greece

24 - 25 September, 2021.

ABSTRACT

Static nuclear ground state properties has been investigated with the Covariant Density Functional Theory. Investigation is done for even-even isotopes of Lead (Pb) as a representative of the heavey mass range nuclei in the periodic table. The nuclear ground state observables like charge radii, proton radii, neutron radii, root mean square radius and neutron skin thickness reflecting the size of the nucleus are studied. Theoretical results for shell closure parameter dS_{2n} based on two neutron separation energy S_{2n} are also presented. All the theoretical estimates are computed by using Relativistic nuclear density functional based on parameters DD-PCX and DD-ME2 and also compared with the available experimental data. Theoretical model predictions related to the observables for which experimental data is not available are also presented in this work.

INTRODUCTION

- The study of the nuclear structure is a very fascinating area of the research today but very complicated at the same time.
- In recent times, the discoveries of new nuclides far from the stability region extended the branch of experimental and theoretical research in Nuclear Structure Physics.
- We have chosen Lead(Pb) nuclei from the periodic table as a representative of the heavy mass range systems for our theoretical study.
- The study nuclear structure in heavy mass region is one of the active areas of research both theoretically and experimenatally.

THEORETICAL FRAMEWORK

The total Lagrangian density of mesons exchange model can be written as [1]:

$$\begin{aligned}\mathcal{L} &= \sum_i \overline{\psi_i}(i\gamma_\mu\partial^\mu - m)\psi_i + \frac{1}{2}\partial_\mu\sigma\partial^\mu\sigma - \frac{1}{2}m_\sigma^2\sigma^2 - \frac{1}{2}\Omega_{\mu\nu}\Omega^{\mu\nu} \\ &+\frac{1}{2}m_\omega^2\omega_\mu\omega^\mu - \frac{1}{4}\vec{R}_{\mu\nu}\vec{R}^{\mu\nu} + \frac{1}{2}m_\rho^2\vec{\rho}_\mu.\vec{\rho}^{\,\mu} - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} \\ &-g_\sigma\overline{\psi}\psi\sigma - g_\omega\overline{\psi}\gamma^\mu\psi\omega_\mu - g_\rho\overline{\psi}\vec{\tau}\gamma^\mu\psi.\vec{\rho}_\mu - e\overline{\psi}\gamma^\mu\psi A_\mu. \end{aligned} \quad (1)$$

The Lagrangian density of point coupling models is given by [2,3]:

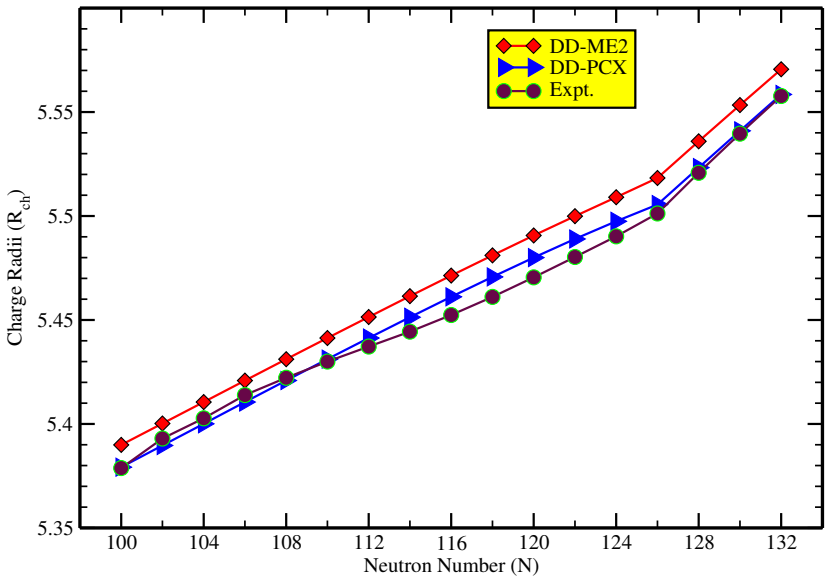
$$\begin{aligned}\mathcal{L} &= \overline{\psi}(i\gamma.\partial - m)\psi - \frac{1}{2}\alpha_S(\rho)(\overline{\psi}\psi)(\overline{\psi}\psi) - \frac{1}{2}\alpha_V(\rho)(\overline{\psi}\gamma^\mu\psi)(\overline{\psi}\gamma_\mu\psi) \\ &-\frac{1}{2}\alpha_{TV}(\rho)(\overline{\psi}\vec{\tau}\gamma^\mu\psi)(\overline{\psi}\vec{\tau}\gamma_\mu\psi) - \frac{1}{2}\delta_S(\partial_\nu\overline{\psi}\psi)(\partial^\nu\overline{\psi}\psi) \\ &-e\overline{\psi}\gamma.A\frac{1-\tau_3}{2}\psi. \end{aligned} \quad (2)$$

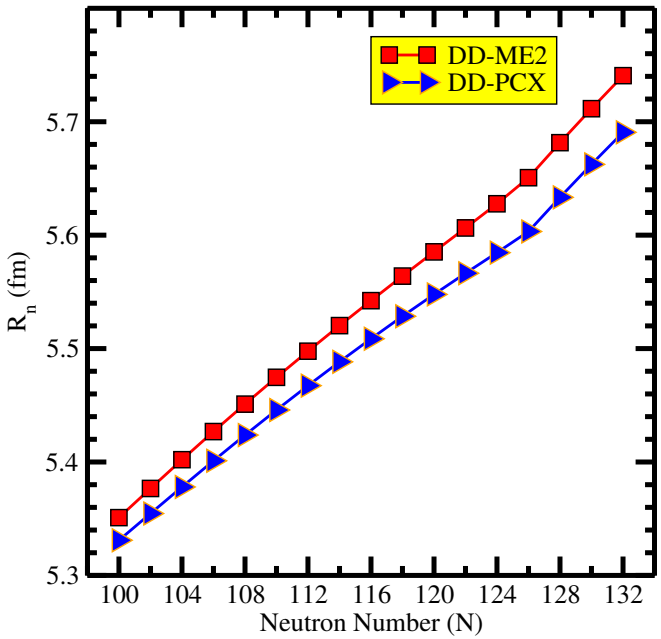
---

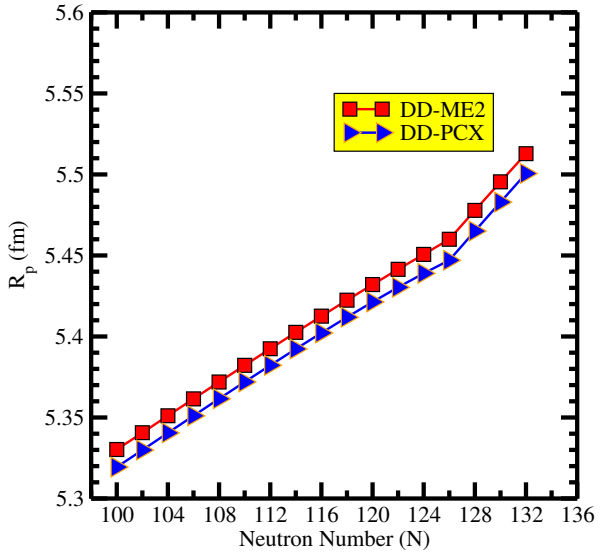
[1] G.A. Lalazissis, et al., *Phys. Rev. C* **71**, (2005) 024312.
[2] T. Niksic, et al., *Phys. Rev. C* **78**, (2008) 034318.
[3] E. Yuksel, et al., *Phys. Rev. C* **99**, (2019) 034318.

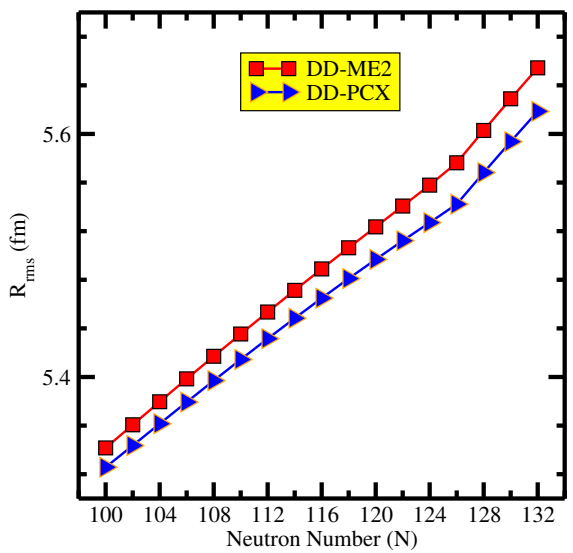
RESULT AND CONCLUSION

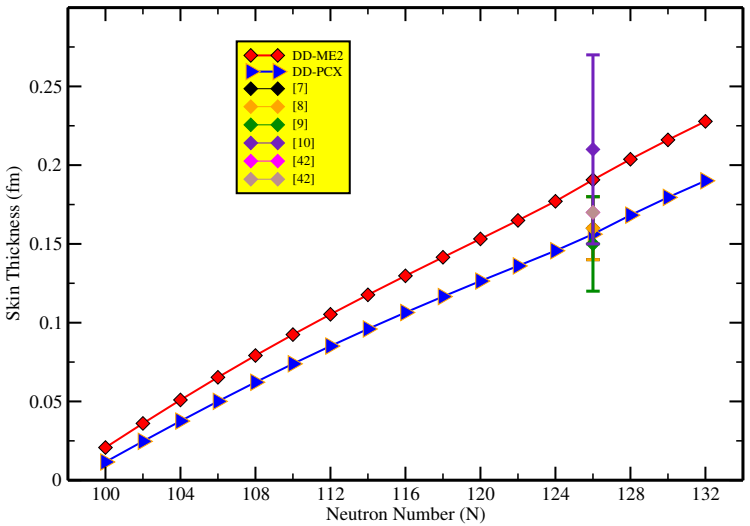
Static nuclear ground state properties has been investigated with the Covariant Density Functional Theory for the even-even isotopes of Lead (Pb) as a representative of the heavey mass range nuclei in the periodic table. The nuclear ground state observables like charge radii, proton radii, neutron radii, root mean square radius and neutron skin thickness reflecting the size of the nucleus and binding energies with its derived physical observables like shell closure paramter (dS_{2n}) based on two neutron separation energy are studied and compared with available experimental data. Based upon the investigation of our theoretical estimations presented in this paper with the help of Covariant DFT with effective interactions of types DD-PCX and DD-ME2, we can deduce some of the important conclusions. Our estimates provide strong indications for the ability of the Covariant DFT to describe the nuclear structure properties in its ground state. DD-PCX parameters are more efficient to reproduce experimental results than DD-ME2 in the selected heavy mass range region. The theoretically calculated results are in good agreement with the experimental data and also predict the values of observables for which experimental data is not available.

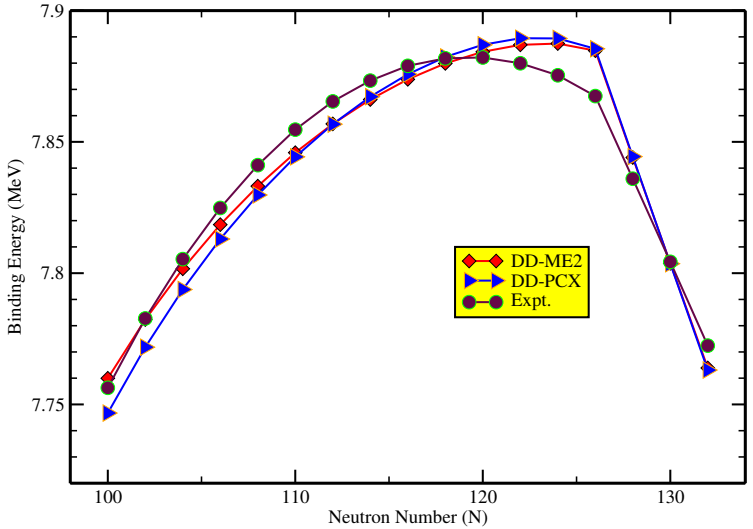


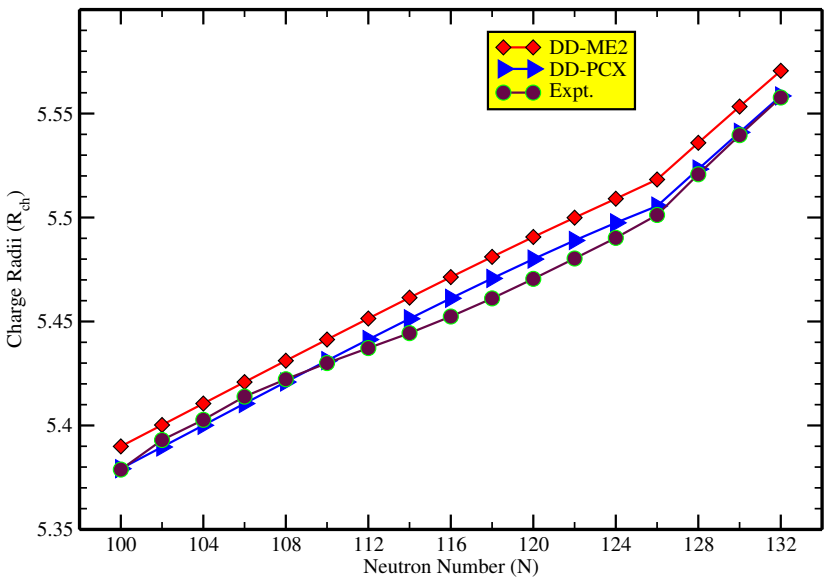


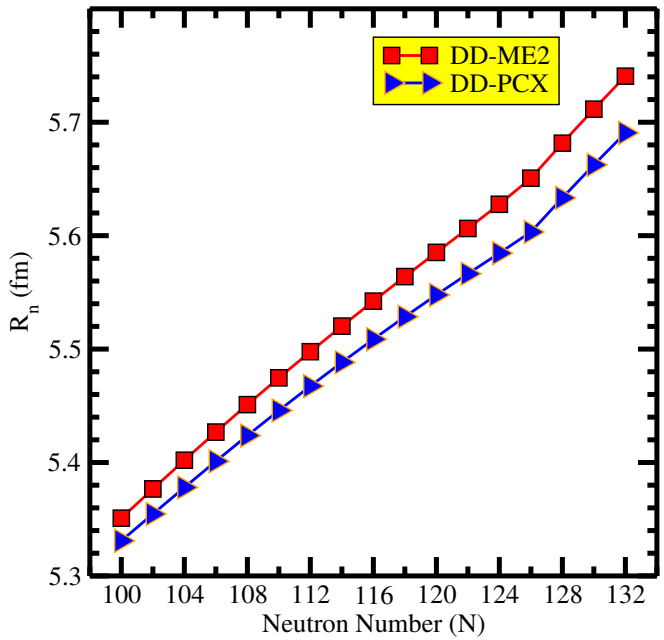

DD-ME2
DD-PCX
R_p (fm)
Neutron Number (N)


DD-ME2
DD-PCX
R_{rms} (fm)
Neutron Number (N)


DD-ME2
DD-PCX
[7]
[8]
[9]
[10]
[42]
[42]
Skin Thickness (fm)
Neutron Number (N)


DD-ME2
DD-PCX
Expt.
Binding Energy (MeV)
Neutron Number (N)





Theoretical calculations are computed with DIRHB code [4] and experimental data is taken from the reference [5].

Acknowledgements

Virender Thakur is highly thankful to Himachal Pradesh University (HPU) for giving access to the computational facilities and DST-INSPIRE (Govt. of India) for providing financial support (JRF/SRF scheme).

---

[4] Tamara Niksic, et al., Computer Physics Communications, 185(6):1808-1821, 2014.

[5] Meng Wang, et al., Chinese Physics C, 41(3):030003, 2017.