# Nuclear matter and finite nuclei properties using simple effective interaction

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The last three decades have seen a regular interest to explain consistently the properties of nuclear matter, finite nuclei and nuclear reactions (nucleon-nucleus and nucleus-nucleus) with an effective interaction that has the efficiency to describe the two body system accurately. The relativistic and non-relativistic microscopic models, such as, Dirac-Brueckner-Hartree-Fock (DBHF), Brueckner-Hartree-Fock (BHF) and calculations using realistic interaction are considered to be standard techniques for reference in the regime of nuclear matter (NM), but *ab initio* extension to finite nucleus calculation in these models is still in rudimentary stage.

In an early work, [1,2] it was shown that in the simplest way the behaviour of the momentum dependence of nuclear mean field consistent with the form as extracted from flow data analysis can be reproduced by replacing the $t_1$- and $t_2$- terms of the Skryme intercation by a finite range interaction of conventional form, either Yukawa, Gaussian or exponential.

The form of the simple effective interaction (SEI) used in the calculation of NM and finite nucleus properties is given by,

$$\begin{aligned} v_{eff}(r) &= t_0(1+x_0P_\sigma)\delta(r) \\ &+t_3(1+x_3P_\sigma)\left(\frac{\rho(\mathbf{R})}{1+b\rho(\mathbf{R})}\right)^\gamma\delta(r) \\ &+(W+BP_\sigma-HP_\tau-MP_\sigma P_\tau)\,f(r), \quad (1) \end{aligned}$$

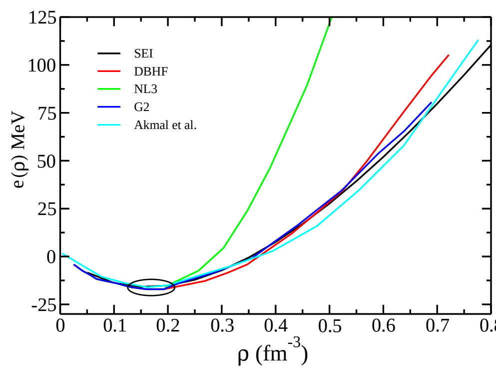


FIG. 1: The simple effective interaction SEI prediction for EOS of infinite nuclear matter compare with other DBHF [3], NL3 [4], G2 [4] and realistic calculation [5]. See text for details.

where, $f(r)$ is the functional form of the finite range interaction conttaining the single range parameter $\alpha$. In this work it is taken to be of Gaussian form, $e^{-r^2/\alpha^2}$. The other terms have their usual meaning [6]. The modified density dependence with the parameter $b$ in the denominator is considered, as in earlier Refs. [6] and therein, in order to prevent the superlumineous behaviour in NM. The interaction in Eqn. (1) contains altogether 11-parameters, namely $t_0$, $x_0$, $t_3$, $x_3$, $b$, $W$, $B$, $H$, $M$, $\gamma$ and $\alpha$. The expression of the energy density $H_T(\rho_n,\rho_p)$, mean fields and other relavant quanties in ANM for the interaction in Eqn. (1) having Gussian form for $f(r)$ obtained. Again, the neutron and proton single particle energies $\epsilon_T^{n,p}(\mathbf{k},\rho_n,\rho_p)$ can be now obtained as the respective functional derivatives

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TABLE I: The simple effective interaction SEI results for BE, $r_{ch}$, compared with the Expt. data [9].

| Nucleus | Force | BE/A | $r_{ch}$ |
|---|---|---|---|
| $^{16}$O | SEI | 8.02 | 2.73 |
| | Expt. | 7.98 | 2.73 |
| $^{40}$Ca | SEI | 8.54 | 3.45 |
| | Expt. | 8.55 | 3.48 |
| $^{48}$Ca | SEI | 8.71 | 3.48 |
| | Expt. | 8.67 | 3.48 |
| $^{90}$Zr | SEI | 8.69 | 4.23 |
| | Expt. | 8.71 | 4.27 |
| $^{208}$Pb | SEI | 7.87 | 5.45 |
| | Expt. | 7.87 | 5.51 |

of the energy density $H_T(\rho_n, \rho_p)$ and are given as

$$\epsilon_T^{n,p}(\mathbf{k}, \rho_n, \rho_p) = \frac{\hbar^2 k^2}{2M} + u_T^{n,p}(\mathbf{k}, \rho_n, \rho_p) \quad (2)$$

where, the first term is the kinetic energy of the neutron (proton) under consideration and $u_T^{n,p}$ are the respective mean fields. The details of calculation for Yukawa form of $f(r)$ have been done in some earlier works [6,7]. Here, we have presented the results for the Gaussian form of $f(r)$ and detailed work will be published else where [8].

In this work we have used the standard values for $Mc^2$=939 MeV, $e(\rho_0)$**=-15.9** MeV and $\frac{\hbar^2 k_{f_0}^2}{2M}$**=37** MeV (corresponding to $\rho_0$=**0.1610258**$fm^{-3}$). The rest two strength parameters $\varepsilon_0$ and $\varepsilon_\gamma$ can be obtained from the saturation conditions. The exponent $\gamma$ that determines the stiffness of the EOS of symmetric nuclear matter SNM have been taken as $\gamma$=**0.5** which gives the value of incompressibility at normal NM density, $K(\rho_0)$=**245** MeV. The above defined nine parameters reduces to six parameters in SNM thus determined the energy per particle $e(\rho)$ (shown in Fig.1), pressure density $P(\rho)$ and symmetric energy $E_s$ as functions of density. Here our main aim is to show the efficiency of the SEI parameters both in infinite nuclear matter and finite nuclei study. For the same, the *ab initio* extenation of the simple effective interaction in Eqn. (1) having Gaussian form for $f(r)$ to finite nuclei has been performed in the quasilocal Density Functional Theory (DFT) model [9]. We note here that all the nine parameters defined above along with $\alpha$, $b$ and $\gamma$ are adjusted from the study of asymmetric nuclear matter (ANM) keeping two interaction parameters open. Here we consider $t_0$ and $x_0$ of the interaction as the open parameters which along with $W_0$ (spin-orbit strength) are adjusted to produced the bulk properties and single particle spectra of double closed nuclei.

The calculated binding energies and root mean square radii of the doubly closed nuclei are compared with the experimental data [10] are listed in Table I. In addition to these, we have tested our interaction for whole region of the nuclear chart, single particle energy spectra and splitting of the level are well demonstrated [8]. Finally we get all the results obtained from our interaction resionably good with other theoretical and experimental predictions for both in infinite nuclear matter as well as finite nuclei.

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