# Linear dependence of the single particle potential on asymmetry parameter

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The nuclear single particle potential or the nuclear mean field is a basic ingredient for proper understanding of nucleon-nucleus scattering data at intermediate and high energies. The in-medium single particle potential of a nucleon generally depends not only on the nuclear density and its momentum but also on asymmetry $\beta = \frac{\rho_n - \rho_p}{\rho}$. To study the momentum, density and asymmetry dependence of the single particle potential of asymmetric nuclear matter (ANM) in non relativistic mean field approximation we have used a simple finite range effective interaction [1].

$$V_{eff}(r) = t_0\left(1 + x_0 P_\sigma\right)\delta\left(\vec{r}\right) + \frac{t_3}{6}\left(1 + x_3 P_\sigma\right)\rho^\gamma(R)\delta\left(\vec{r}\right) + \left(W + B P_\sigma - H P_\tau - M P_\sigma P_\tau\right) f(r) \quad \text{------------(1)}$$

where $f(r)$ represents a short-range interaction of conventional form, such as Yukawa, Gaussian or exponential, and specified by single range parameter $\alpha$. The other symbol in equation (1) has their usual meanings. This form of effective interaction is very similar to Skyrme-type of interactions except for the fact that the $t_1$ and $t_2$ terms in the latter case have been replaced by the short-range interaction $\left(W + B P_\sigma - H P_\tau - M P_\sigma P_\tau\right) \times f(r)$.

The neutron proton mean field can be obtained from the above effective interaction as:

$$u^\tau(k,\rho,\beta) = \frac{3t_0}{4}\rho + \frac{t_3}{16}(\gamma+2)\rho^{\gamma+1} + 4\pi\alpha^3\left(W - \frac{M}{4}\right)\rho + 4\pi\alpha^3\left(M - \frac{W}{4}\right)\rho I(k,\rho) \pm \left[-\left\{\frac{t_0}{4}\rho\left(1+2x_0\right) + \frac{t_3}{24}\rho^{\gamma+1}\left(1-2x_3\right) + \pi\alpha^3 M\rho + \pi\alpha^3 W\rho I(k,\rho)\right\}\right]\beta + \left[-\frac{t_3}{48}\gamma\rho^{\gamma+1}\left(1+2x_3\right)\right]\beta^2 \quad \text{------------ (2)}$$

Here $\tau = n, p$ respectively. The plus sign before the 1st square bracketed term is for neutron and minus sign for proton.

For the charge symmetry of nuclear interaction under the exchange of neutron and proton the nuclear single particle potential or mean field can be expanded in power series of asymmetry parameter $\beta$ as [2]:

$$u^\tau(k,\rho,\beta) = u_0(k,\rho) \pm u_{sym,1}(k,\rho)\beta + u_{sym,2}\beta^2 \quad \text{---------------- (3)}$$

where $u_0(\rho,k) = u_n(\rho,k,\beta=0) = u_p(\rho,k,\beta=0)$ is the single nucleon potential in symmetric nuclear matter (SNM), $u_{sym,1}(\rho,k)$ being the well known nuclear symmetry potential [3] and the higher order term $u_{sym,2}(\rho,k)$ being called as the 2nd order nuclear potential here. Neglecting higher order term, equation (3) reduces to lane potential [4].

$$u_0(k,\rho) = u_\tau(k,\rho,\beta)\big|_{\beta=0},$$

$$u_{sym,1} = \pm\frac{1}{1!}\frac{\delta u^\tau(k,\rho,\beta)}{\delta\beta}\bigg|_{\beta=0},$$

$$u_{sym,2} = \frac{1}{2!}\frac{\delta^2 u^\tau(k,\rho,\beta)}{\delta\beta^2}\bigg|_{\beta=0}.$$

The neutron-protons mean fields $u^\tau(k,\rho,\beta)$ of ANM is plotted as a function of momentum for asymmetry $\beta$ = 0, 0.4, 0.8 in Fig. 1 and is found as an increasing function of k for all values of $\beta$. For ANM, the neutron and proton mean fields are strongly attractive at k=0 and lying above and below the SNM curve (β=0) respectively. .All the curves merges at k=5fm$^{-1}$showing asymmetry independence. Since the 2nd order mean field $u_{sym,2}(\rho,k)$ is independent of momentum k, so the contribution of $u_{sym,1}(\rho,k)$ is responsible for this behavior. It is found that $u_{sym,1}(\rho,k)$ is decreasing function of k and at k > 6fm$^{-1}$, it changes sign, whereas, at density $\rho < \rho0$ this value does not change sign for any value of momenta. Further, $u^\tau(k,\rho_0,\beta)$ is plotted as a function of $\beta$ for momentum k = 0 and k = $k_f$ (Fermi momentum) in Fig. 2 where the neutron mean field is an increasing function of $\beta$ and proton mean field is decreasing function of $\beta$. This variation is due to the "±" symbol present in equation (3). This fact supports the linear dependence of the depth of the single particle potential on, which is the consequence of lane equation.

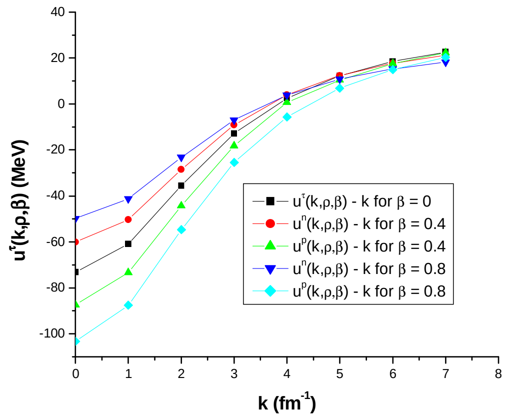


fig.1

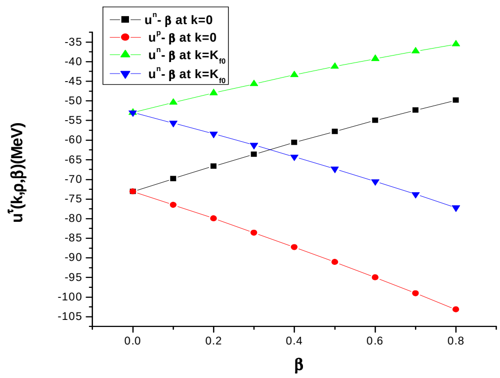


Fig. 2

## References


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