Direct determination of mean-field from data on matter density

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In this work we consider the single particle Schrodinger equation and develop a method for determining the single particle potential *V* from a given single particle wave function $\Psi(\vec{r})$ or matter density, assuming it is known for all $\vec{r}$. In particular, we consider the case of spherical symmetry. The results of this work are very important for investigation of the validity of the shell model and for the development of a modern EDF which provides enhanced predictive power for properties of nuclei and the equation of state (EOS) of nuclear matter (NM).

For the single particle Schrodinger equation,

$$-\frac{\hbar^2}{2m}\Delta\Psi + V\Psi = E\Psi \ , \tag{1}$$

we have that for a given single particle wave function $\Psi(\vec{r})$, known for all $\vec{r}$, the corresponding single particle potential *V* is uniquely determined [1] from

$$V(\vec{r}) = E + \frac{\hbar^2}{2m}\frac{\Delta\Psi(\vec{r})}{\Psi(\vec{r})} \ . \tag{2}$$

Note that for a nonsingular *V*, $\Delta\Psi(\vec{r}) = 0$ when $\Psi(\vec{r}) = 0$. In the spherical case we have for the centroid potential

$$V_{cen}(r) = E + \frac{\hbar^2}{2m}\frac{d^2R_{nlj}}{dr^2}\frac{1}{R_{nlj}(r)} - \frac{\hbar^2}{2m}\frac{l(l+1)}{r} - \frac{1}{2}(1-\tau_z)V_{coul}(r) - c_{ls}\,V_{s.o.}(r) \ . \tag{3}$$

Here, $V_{cen}(r), \vec{s}\cdot\vec{l}\,V_{s.o.}(r)$ *and* $\frac{1}{2}(1-\tau_z)V_{coul}(r)$, are the central, spin-orbit and coulomb potentials, respectively, and τ_z=1 for a neutron and -1 for a proton.

We consider, in particular, the charge density difference, $\Delta\rho_c(r)$, between the isotones ^{206}Pb – ^{205}Tl, associated with the proton $3S_{1/2}$ single particle orbit, and determine the corresponding single particle potential. The experimental data for the charge densities, $\rho_c(r)$, of the isotones ^{206}Pb and ^{205}Tl, obtained from accurate elastic electron scattering experiments, are taken from Ref. [1]. In Fig. 1a we present the experimental data for the charge density difference, $\Delta\rho_c(r)$, between the isotones ^{206}Pb – ^{205}Tl, shown by the dashed line. It is normalized to a total charge of one proton (Z=1). The dotted lines indicate the experimental uncertainty. Note that the two nodes associated with the proton $3S_{1/2}$ orbit are clearly seen in the figure. To extract the corresponding single particle potential we need the point proton distribution, $\Delta\rho_p(r)$. This is obtained by determining the point proton form factor, $F_p(q)$, and then extracting $\Delta\rho_p(r)$. The results are shown in Fig. 1b. Note that $\Delta\rho_p(r)$ (dashed line) is slightly negative at the first node (at

~2.6 fm) and above zero at the second node (r~4.9 fm). Using these results we determine the corresponding mean field associated with the $3S_{1/2}$ orbit in ^{206}Pb [2].

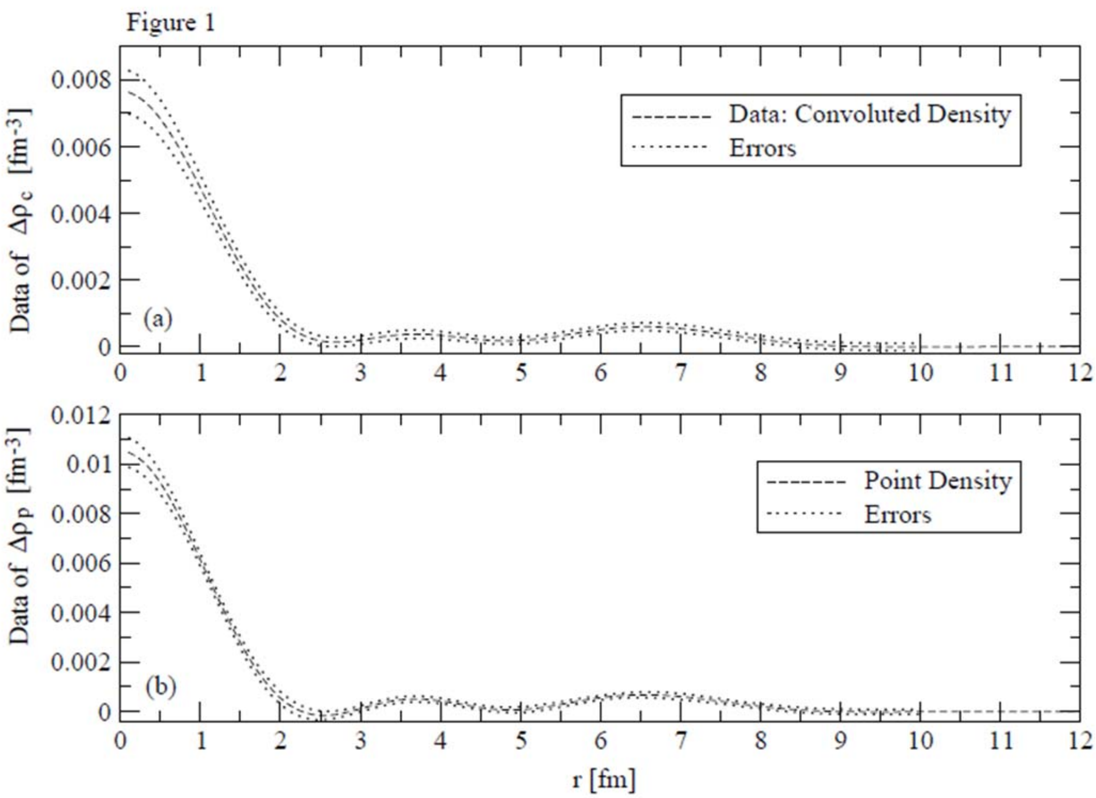

FIG. 1. Charge density (a) and point density (b) for the $3_{S1/2}$ orbit in ^{206}Pb.

[1] J.M. Cavedon *et al.*, Phys. Rev. Lett. **49**, 978 (1982).

[2] M.R. Anders, S. Shlomo and I. Talmi, in preparation.