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Density of nucleons in heavy nuclei

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Abstract. A shell model description of heavy nuclei is used to show that the density of nucleons in heavy nuclei is of the form $\rho(r)=K(a^2-r^2)^{3/2}$, K, a being constants. Two broad features of this distribution are mentioned.

Keywords. Nucleons; heavy nuclei; shell model density.

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)ne of the earliest developments in the area of nuclear physics was to study the listribution of nucleons in a nucleus. The model which was put forward in the ›eginning was that of uniform distribution of nucleons inside a sphere of radius R. It /as later established by electron scattering (Hofstadter 1956; Brown *et al* 1979) that the ensity distribution does not have a sharp cut-off but has a tail. With the development f nuclear shell model it was possible to calculate the form of the shell model density $\rho(r)$ ›r a number of light nuclei. As the number of nucleons starts increasing one has to arry out summations over a large number of shells. The purpose of the present work is › derive an approximate analytic form of $\rho(r)$ when the number of nucleons becomes ırge.

To keep the formulation simple we shall treat neutrons and protons alike and ɔnsider single nucleon orbits in a harmonic oscillator potential without spin-orbit :rm. The density of single nucleons $\rho(\bar{r})$ can be written as

$$\rho(\bar{r})=\frac{4}{A}\sum_i|\phi_i(\bar{r})|^2, \tag{1}$$

here A is the total number of nucleons and ϕ_i are the single nucleon wave functions. he factor 4 arises from spin and isospin. Also $\rho(\bar{r})$ is normalized so that $\int\rho(\bar{r})\,\mathrm{d}\bar{r}=1$ and ıe sum goes over the occupied orbits.

In a three-dimensional isotropic harmonic oscillator (Morse and Feshbach 1953) the .dial wave functions $R_{nl}(r)$, $n=1, 2, \ldots;\ l=0, 1, 2, \ldots n-1$ are given by

$$R_{nl}=N_{nl}\exp(-\alpha r^2)\,r^l\,M(-(n-1), l+\tfrac{3}{2}, 2\alpha r^2), \tag{2}$$

here N_{nl} is the normalization constant, α the harmonic oscillator parameter and (a, b, x) is the confluent hypergeometric function (Abramowitz and Stegun 1965). ıe wave functions ϕ_i are products of R_{nl} and spherical harmonics. It turns out that