Proton Distribution in Heavy Nuclei*

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The Coulomb repulsion tends to force protons as far apart as possible, thereby lowering the proton density at the center of a nucleus. One might conclude that such an expansion would cause a proton excess on the nuclear surface. It is easy to see that the stability against β-decay brings about the opposite result, a neutron excess on the surface.

The top part of Fig. 1 gives a qualitative picture of the average potential acting on neutrons and protons. It is assumed that the proton potential and the neutron potential are the same except for the electrostatic energy. The dashed line indicates the highest filled energy state in the Fermi distribution for both protons and neutrons. Beta-stability requires that the highest filled proton state have the same energy as the highest filled neutron state (actually the proton should have .79 Mev more energy, a difference that may be neglected compared to the Coulomb potential in heavy nuclei). If the nuclear potential at the surface has a finite slope, the dashed line intercepts the potential at a somewhat smaller radius for protons. Consequently, the proton distribution lies inside the neutron distribution. For the heaviest elements the difference in radii could easily be 1/3 to 1/2 the thickness of the sloping part of the nuclear potential; the latter is likely to be of the order of the meson Compton wavelength. Thus the radius of the proton

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distribution may turn out smaller than the neutron radius by about 10^{-13} cm.

A more detailed examination of the nucleon orbits gives qualitatively the same result. The intercept of the energy level with the radial potential determines a point of inflection for the wave function; beyond this point the wave function is always convex to the axis. This point will be different for different angular momenta but will lie at systematically smaller radii for protons. In addition, the higher potential barrier for protons outside this point causes proton wave functions to vanish more rapidly than neutron wave functions. The lower part of Fig. 1 gives a qualitative picture of the proton and neutron densities within the nucleus.

In experiments with nucleons and π-mesons which interact strongly with nuclear matter, one may find the surface of the nucleus at radii where practically no protons are present and the neutron density is well below its plateau value. In experiments with electrons and μ-mesons which interact only with the electrostatic field, one may find the smaller radii characteristic of the proton distribution.

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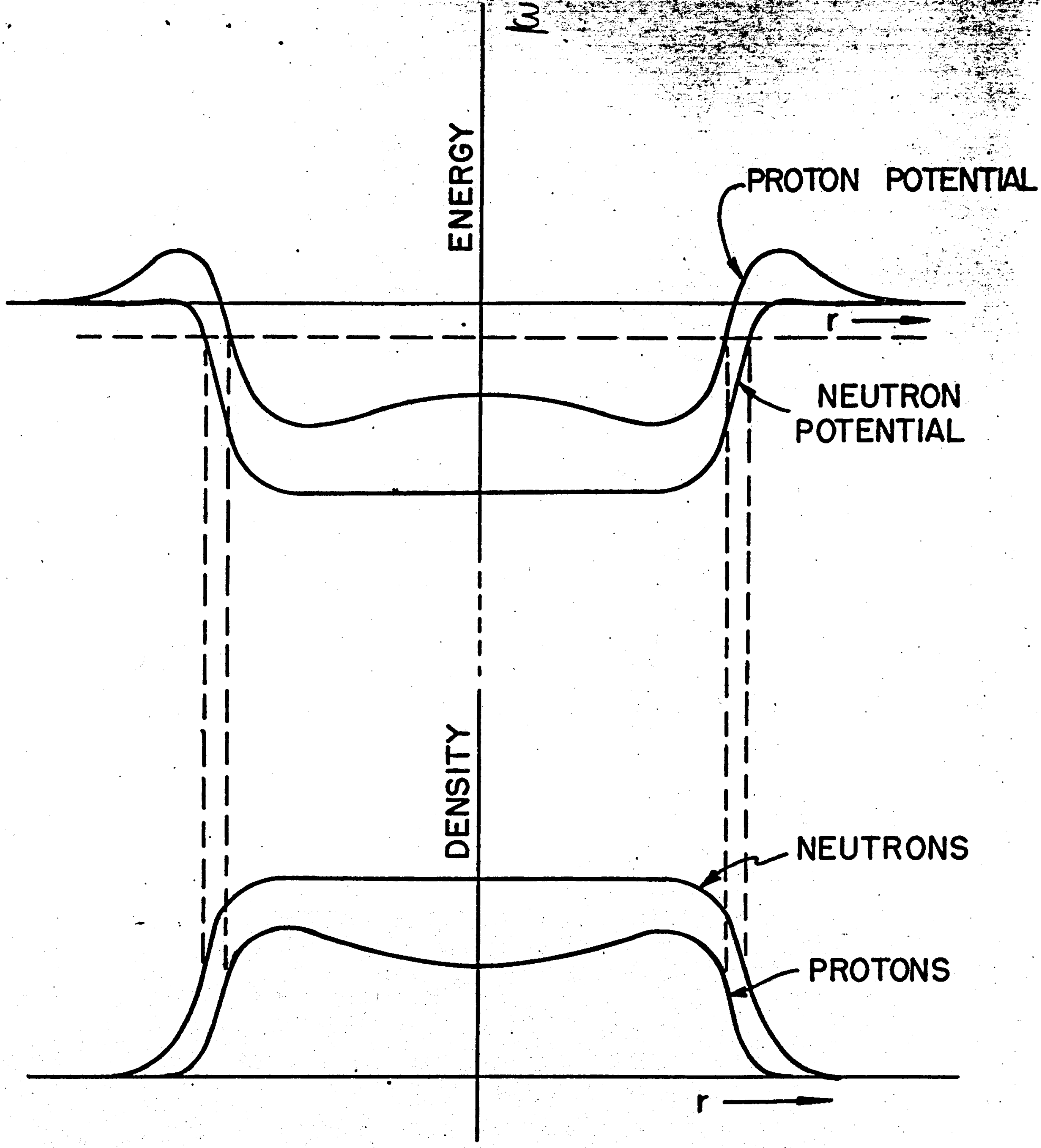

Fig. 1. Potentials and Densities for Protons and Neutrons inside the Nucleus

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