Existence of strongly bound states of pions in nuclei

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References are given to mostly unknown work on velocity-dependent potentials of the kind used in optical pion-nucleus models for which the possibility of an infinity of strongly bound states has been recently suggested.

[NUCLEAR REACTIONS Pion-nucleus optical potential; nuclear bound states of pions in nuclei; complex velocity-dependent potential.]

Recently, Friedman, Gal, and Mandelzweig[1] (FGM) have studied the possible existence of strongly bound states of pions in nuclei. This possibility was first suggested by Ericson and Myhrer[2] (EM) and has been reconsidered by FGM in view of the new data on levels in pionic atoms.[3] It seems that some comments on that question would be worthwhile, in order to clarify the situation.

At low energies, the pion-nucleus optical potential is usually taken as

$$2\mu V(r,p) = 2\mu V_1(r) + 2\mu V_2(r,p)\,, \tag{1}$$

sum of a "static" weakly repulsive term

$$2\mu V_1(r) = q(r)\,, \tag{2}$$

and a velocity-dependent attractive term

$$2\mu V_2(r,p) = -\vec{p}\cdot\alpha(r)\vec{p}\,. \tag{3}$$

Here, μ represents the reduced mass of the pion-nucleus system. The intensity parameters[1] entering the expressions of $q(r)$ and $\alpha(r)$ are taken to be complex, to account for the absorption of pions in nuclei.

Assuming, in a simplified model, a real square well shape for $\alpha(r)$ in Eq. (3), EM show that a velocity-dependent potential can produce an infinity of bound states of indefinitely high binding energy. This result, rediscovered by EM in the context of the pion-nucleus system, had been reported earlier.[4] Besides this, EM note that, for general shape $\alpha(r)$, the wave equation and the wave function present a singularity when $\alpha(r) = 1$. This fact was quoted and thoroughly discussed a long time ago.[5] Provided $\alpha(r)$ passes linearly through the value 1, the wave function is physically acceptable, in spite of its logarithmic singularity, as it is square integrable.

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