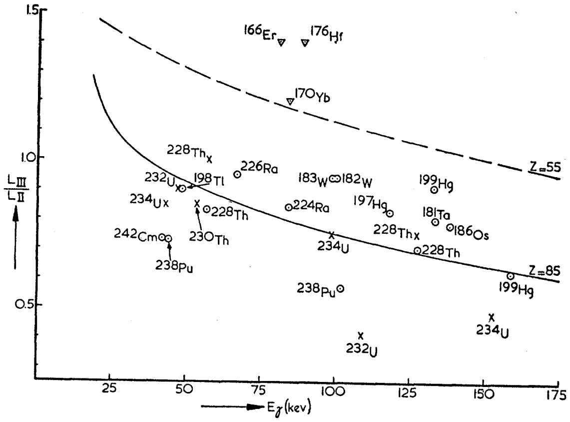

FIG. 1. L_{III}/L_{II} conversion ratios of $E2$ transitions.

present at 1.010 and 1.065 Mev in Th^{230}. In U^{234}, excited levels at 1.145 and 1.190 Mev were observed. Although the level schemes of these nuclides are not unambiguous, it is quite likely that these close lying levels also represent a rotational band system.

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[1] A. Bohr and B. R. Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **27**, No. 16 (1953); Physica **18**, 1066 (1952); A. Bohr, *Nuclear Rotational States* (Ejnar Munksgård, Copenhagen 1954).
[2] Ong Ping Hok, thesis, Vrije Universiteit, Amsterdam, March, 1955 (unpublished).
[3] Stoker, Hok, de Haan, and Sizoo, Physica **20**, 337 (1954).
[4] Gellman, Griffith, and Stanley, Phys. Rev. **80**, 866 (1950).
[5] M. E. Rose in *Beta and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, 1955), p. 906.
[6] F. Asaro and I. Perlman, Ann. Rev. Nuc. Sci. **4**, 157 (1954).
[7] Slätis, Rasmussen, and Atterling, Phys. Rev. **93**, 646 (1954).

Elementary Particles as Self-Maintained Excitations

F. A. KAEMPFFER

Department of Physics, University of British Columbia, Vancouver, British Columbia, Canada

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IT is well known that contemporary theories of elementary particles are unsatisfactory for two reasons. On one hand the coupling of the various particles with the electromagnetic field and with each other is not sufficiently understood, this lack of understanding manifesting itself in the illfamed divergence problems (which can be "removed" in a fashion in some special cases by so-called renormalization procedures); on the other hand the origin of the masses of the various particles remains a complete mystery, this fact manifesting itself in the necessity of introducing for each newly discovered particle its mass phenomenologically into the theory.

It is the purpose of this Letter to propose a line of attack which promises to remove these two difficulties in one stroke at an early stage of the theory, i.e., prior to quantization of the field variables which describe the "particle."

Consider the following simple model. We imagine a "particle" to be a self-maintained excitation of a medium, described in terms of the usual electromagnetic potentials A_μ and a spinor field ψ of vanishing mechanical mass, so that the following gauge-invariant and Lorentz-invariant variational principle is satisfied:

$$\delta\int L d\tau=0;\quad L=\hbar c i\psi^\dagger\sum_\nu \gamma_\nu\left(\frac{\partial}{\partial x_\nu}-\frac{i\epsilon}{c}A_\nu\right)\psi -\frac{1}{16\pi}\sum_{\mu,\nu}\left(\frac{\partial A_\nu}{\partial x_\mu}-\frac{\partial A_\mu}{\partial x_\nu}\right)^2-\frac{1}{8\pi}\left(\sum_\mu\frac{\partial A_\mu}{\partial x_\mu}\right)^2, \quad (1)$$

where

$$\psi^\dagger=i\psi^*\beta;\quad \gamma_k=i\alpha_k\beta;\quad \gamma_4=\beta;\quad \gamma_\mu\gamma_\nu+\gamma_\nu\gamma_\mu=2\delta_{\mu\nu};\quad x_4=ict. \quad (2)$$

Independent variation of $\psi^\dagger$ and A_ν yields the field equations

$$\sum_\nu \gamma_\nu\frac{\partial\psi}{\partial x_\nu}=\frac{i\epsilon}{c}\sum_\nu\gamma_\nu A_\nu\psi, \quad (3)$$

$$\sum_\mu\frac{\partial^2 A_\nu}{\partial x_\mu^2}=-4\pi\hbar\epsilon\psi^\dagger\gamma_\nu\psi. \quad (4)$$

On the potentials A_ν we impose, as usual, the condition

$$\sum_\nu\frac{\partial A_\nu}{\partial x_\nu}=0. \quad (5)$$

We shall now label any solution of this nonlinear simultaneous system of Eqs. (3), (4), (5) a "particle," provided some reasonable boundary conditions are satisfied by that solution. Regions in which the current appearing on the right-hand side of Eq. (4) is negligible will be called the "exterior" of the particle, and regions in which this current is appreciable will be called the "interior" of the particle. One might say that in this primitive model photons and neutrinos are considered as basic building stones, each acting as the glue, as it were, which holds the other together, and thus forming a compound called "particle."

Now any regular stationary solution for the interior which can be joined to a solution for the exterior corresponding to, say, an electric pole and a magnetic dipole, would reveal itself to an external observer as a stable particle, carrying charge and magnetic moment. The mass of the particle can be defined then in terms of the canonical energy momentum tensor as

$$m=-\frac{1}{c^2}\int T_{44}dV;$$

$$T_{44}=-\frac{i\hbar c}{2}\left(\psi^\dagger\gamma_4\frac{\partial\psi}{\partial x_4}-\frac{\partial\psi^\dagger}{\partial x_4}\gamma_4\psi\right)$$

$$-\sum_\nu\frac{\partial A_\nu}{\partial x_4}\frac{\partial L}{\partial(\partial A_\nu/\partial x_4)}+L, \quad (6)$$

and would consist, in the case of solutions that are regular everywhere, of finite contributions from both the spinor field and the electromagnetic field. It is clear that different types of solutions should yield different masses corresponding to these solutions. We anticipate, in fact, the appearance of a mass spectrum.[1]

It should also be possible to understand by a theory of this type the reason for the fact that certain kinds of particles, like magnetic poles, do not exist in nature, because it is conceivable that no solutions regular in the interior can be found which would fit to a solution of the exterior corresponding to, say, a magnetic pole.

It appears also reasonable to expect that within the framework of such a theory one may be able to grasp unstable particles, and particles which possess excited states. In fact, the ultimate aim of this effort is to understand all particles, from the electron up to the unstable nuclei of the heaviest elements in terms of excitations of a medium which is described by a variational principle of the type (1).

Work to produce solutions of the field equations [(3), (4), (5)] is under way.

[1] Since the basic action principle (1) does not contain any constants from which one can build any constant of the dimension of mass, it is obvious that the anticipated mass spectrum must appear in terms of a smallest mass which remains completely undetermined in the classical theory, and which by similarity transformation of the solutions may be fitted to the experimental value. The situation is analogous to that encountered by J. A. Wheeler in his theory of classical geons [Phys. Rev. 97, 511 (1955)], which may be called "particles" built up out of gravitons and photons.

Classification of the Nucleonic States in Deformed Nuclei

B. R. MOTTELSON AND S. G. NILSSON

CERN, Theoretical Study Division and the Institutes for Theoretical Physics, Universities of Copenhagen and Lund, Denmark*

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THE nuclear shell structure and the equilibrium shape of the nucleus are intimately related. Thus, the nuclear distortions are a consequence of the centrifugal pressures exerted by the individual nucleons.[1] In turn the deformation of the nuclear field implies important modifications of the nucleonic motion.[2] This interplay between nucleonic motion and nuclear distortion is most easily studied in nuclei possessing large equilibrium distortions. In the present note we report a classification of the nucleonic states in the deformed nuclei in the region $150<A<194$. From the ground-state configurations we then calculate the equilibrium deformations.[3,4]

The level spectrum of individual particle motion in an ellipsoidal potential with the inclusion of a spin-orbit force has been calculated as a function of the nuclear eccentricity.[5] The adjustable parameters in the potential, such as the strength of the spin-orbit force, have been chosen to reproduce as well as possible the observed single-particle spectra in the approximately spherical nuclei near closed shells.[6] It is found necessary to choose slightly different parameters to reproduce the neutron and proton spectra respectively. For the protons we use the parameters corresponding to Table Ib of reference 5, while for the neutrons the parameters of Table I of the same reference are employed. The differences between these two choices of the parameters are in the general sense of favoring proton orbits of higher angular momentum as compared with the corresponding neutron orbits.

The parts of the spectra relevant to the present discussion are reproduced in Fig. 1, which covers the

TABLE I. The expected ground-state spins, I_{theo}, obtained from Figs. 1 and 2, are compared with measured nuclear spins taken from reference 6. The assumed nuclear deformations are deduced from the measured intrinsic quadrupole moments where available; in other cases interpolated values are employed.

Nucleus	Assumed deformations	I_{theo}	I_{exp}
${}^{88}{}_{63}Eu^{151}$	0.16	3/2±, 5/2±	5/2
${}^{90}{}_{63}Eu^{153}$	0.30	5/2+, 3/2+	5/2
${}^{94}{}_{65}Tb^{159}$	0.31	3/2+, 5/2+	3/2
${}^{98}{}_{67}Ho^{165}$	0.30	7/2−, 1/2+	7/2
${}^{100}{}_{69}Tm^{169}$	0.28	1/2+, 7/2−	1/2
${}^{104}{}_{71}Lu^{175}$	0.28	7/2+, 5/2+	7/2
${}^{108}{}_{73}Ta^{181}$	0.23	5/2+, 7/2+	7/2
${}^{110}{}_{75}Re^{185}$	0.19[a]	9/2−, (5/2+)	5/2
${}^{112}{}_{75}Re^{187}$	0.19	9/2−, (5/2+)	5/2
${}^{114}{}_{77}Ir^{191}$	0.14	3/2+, 1/2+, 11/2−	3/2
${}^{116}{}_{77}Ir^{193}$	0.12[a]	3/2+, 1/2+, 11/2−	3/2
${}^{91}{}_{64}Gd^{155}$	0.31[a]	5/2+, 3/2−	≥3/2
${}^{93}{}_{64}Gd^{157}$	0.31[a]	3/2−, 5/2+	≥3/2
${}^{95}{}_{66}Dy^{161}$	0.31[a]	5/2−	
${}^{97}{}_{66}Dy^{163}$		b	
${}^{99}{}_{68}Er^{167}$	0.29[a]	1/2−, 7/2+	7/2
${}^{101}{}_{70}Yb^{171}$	0.29[a]	7/2+, 1/2−	1/2
${}^{103}{}_{70}Yb^{173}$	0.29[a]	5/2−	5/2
${}^{105}{}_{72}Hf^{177}$	0.26	7/2−	
${}^{107}{}_{72}Hf^{179}$	0.27	9/2+	
${}^{109}{}_{74}W^{183}$	0.21	1/2−, 7/2−, 3/2−	1/2
${}^{111}{}_{76}Os^{187}$	0.18[a]	1/2−, 3/2−, 9/2+	
${}^{113}{}_{76}Os^{189}$	0.15[a]	1/2−, 3/2−, 11/2+	3/2

[a] Interpolated value.
[b] Prediction sensitive to assumed deformation.