Meson and Nucleon Excited-State Trajectories in Stabilized Yukawa-Type Models.

J. KRAŚKIEWICZ and R. RACZKA
Institute for Nuclear Studies - Warsaw

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Summary. — We demonstrate first that the conventional Yukawa model with $(\lambda/4)\phi^4$ meson self-interaction is unstable. Next we introduce the concept of stabilizing self-interactions. We show that stabilizing self-interactions contrary to $(\lambda/4)\phi^4$ possess in the meson sector the classical particle-like solution $\phi_0(t, x)$. The expansion of boson-fermion Green's functions in path integral formalism around $\phi_0$ yields a new WKB-type expansion with dressed propagators. Calculating one-particle meson and nucleon propagators up to $O(\hbar^2)$, we find that these propagators have a sequence of mass-squared singularities which in the mass-squared spin plane form finite, almost linear trajectories similar to those observed experimentally.

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1. — Introduction.

One of the most striking experimental facts in particle physics is the existence of trajectories of excited meson and baryon states (1). These trajectories, in the mass squared-spin plane are approximately linear for mesons as well as for baryons (1). In our previous work we have presented the idea that the ex-

istence of boson and fermion trajectories is typical for boson-fermion field theories in which in the boson sector the nonlinear classical field equations admit a so-called particlelike solution (2). In this work we shall try to obtain trajectories of excited meson and nucleon states for the Yukawa-type interactions. The conventional Yukawa theory with \((-\lambda/4)(\varphi^2)^2\) meson self-interaction is unstable in the same sense that its energy operator has the spectrum unbounded from below (3). Hence it is interesting to consider other self-interactions \(L_1(\varphi)\) which have a chance to stabilize the Yukawa theory. As we show in sect. 2 the behaviour for strong meson fields of the fermion contribution to the effective boson action integral dictates the admissible forms of stabilizing self-interactions. Out of many possible stabilizing interactions we have chosen two distinguished self-interactions: one which is the lowest-order polynomial self-interaction and the second one which is the lowest growing self-interaction. We show in sect. 3 that these stabilizing self-interactions—contrary to \((-\lambda/4)(\varphi^2)^2\) interaction—do admit the particlelike solutions in the meson sector. This implies that one-particle meson and nucleon propagators have a sequence of singularities which in the plane mass-squared–spin form the specific trajectories similar to those observed experimentally. Thus a stabilization of the conventional Yukawa interactions leads to the existence of meson and nucleon excited-state trajectories, which are desirable from the physical point of view.

In sect. 2 we discuss the problem of instability of the conventional Yukawa interaction and the concept of stabilizing self-interactions. We show that two distinguished stabilizing self-interactions possess particlelike solutions. We derive in sect. 3 an expansion formula for an arbitrary meson-nucleon Green's function around a particlelike solution. The obtained formula represents a new \(\hbar\)-expansion in terms of the dressed propagators which contain the non-perturbative pieces of information. We analyse in sect. 4 the \(\hbar\)-expansion of the meson propagator up to \(O(\hbar^2)\). We show that in this approximation the mass singularities of the meson propagator form in the mass-squared–spin plane the characteristic trajectories which resemble the observed experimental trajectories. Similar analysis is carried out in sect. 5 for nucleon propagator: it is shown there that also in this case the mass singularities form in the mass-squared–spin plane the trajectory which is similar to the experimental one.

The above analysis seems to indicate that a stability of a given model may be an important criterion for a selection of a physical model out of a set of models admissible by other criteria.

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