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MACROSCOPIC CAUSALITY-VIOLATION EFFECTS IN THE LEE AND WICK THEORY WITH INDEFINITE METRIC

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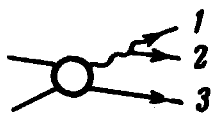
Recently Lee and Wick proposed a field-theory formulation that includes states with an indefinite metric (see [1]). The purpose of introducing an indefinite metric in [1] was, as usual, to the field-theory divergences. The authors of [1] propose and prove this possibility in a simple model, and also that no additional difficulties connected with violation of unitarity and causality arise in such a theory if it assumed that unusual states (with negative norm) are unstable with width $\Gamma \sim 10 - 50$ meV.

The unusual states (which we shall henceforth call LW particles) must appear as complex e attering-matrix poles lying on a physical sheet. We shall show that the existence of such poles at high energies should lead, in principle, to violation of causality on macroscopic scales.

Let the process



(1)

correspond to production of an LW particle and to its subsequent decay into two particles (1 and 2). For concreteness, we shall trace the behavior of particle 1.

In the rest system of the resonance, the coordinate of particle 1 is given by

$$R_0 = v_0(t - \tau_0), \tag{2}$$

where t_0 is the instant of registration, τ_0 is the lifetime of the unstable particle, and v_0 is the velocity of the particle 1. Unlike the normal Breit-Wigner resonance, in this case we have $\tau_0 < 0$, leading to the appearance of non-causal effects. In the Lee and Wick model, however, $|\tau_0| \sim \Gamma^{-1}\ 10^{-13}$ cm, so that no macroscopic causality violation takes place.

Let us consider now the decay of a rapidly moving resonance resulting from a collision at high energy. The coordinate of particle 1 can be obtained in this case with the aid of a Lorentz transformation of formula (2). It then turns out that

$$R = u\tau + v(t - \tau), \tag{3}$$

where R and t are the position of the first particle and the instant of its registration in the lab (t = 0 corresponds to the instant of collision in reaction (1) and R = 0 is the collision point), u and v are the velocities of the resonance and of particle 1, and $t = \tau/\sqrt{1 - u^2}$ is the lifetime of the resonance (LW particle) in the lab. A more rigorous proof of (3) is given in [2], which contains a space-time description of the reaction (1) with the aid of wave packets.

Owing to the growth of $|\tau| \sim E/m\Gamma$ with increasing energy in (3) at high energies (E - energy of LW particles), we can expect the appearance of macroscopic causality-violation effects. However, if $\vec{u} \approx \vec{v}$ then, as follows from (3), R = vt and no noticeable non-causal effects appear. Interest attaches therefore to the case when the velocities u and v do not coincide. At high energies this can occur only if particle 1 has zero mass.

Let us consider, for example, the case when

$$\vec{u} = -\vec{v}, \quad |\vec{v}| = c = 1$$

corresponding to the decay of an LW particle with emission of a photon or a neutrino in a direction opposite to that of the motion of the LW particle. It then follows from (3) that

$$r = t + 2|\tau|.$$

Thus, the effective velocity ($v_{eff} \approx 1 + 2|\tau|/t$) of the propagation of a signal between two events, namely the collision and the instant of registration, may turn out to be noticeably larger than the speed of light at high energies. For example, if Γ = 50 meV, m = 10 GeV, and the energy is $E \sim 10^{23}$ eV we have $|\tau| \sim E/m\Gamma \sim$ cm, i.e., $|\tau|/t \sim 1$ at $t \sim 1$ cm.

The wavelength of the first particle, at the decay kinematics under consideration, equals $\lambda \sim E/m^2$, i.e., $\lambda/|\tau| \sim \Gamma/m \ll 1$. This means that particle 1 can in principle be localized with an accuracy sufficient for the observation of non-causal effects.

It seems to us that the possibility, in principle, of appearance of macroscopic causality violation at high energies is more readily an argument against the theory developed by Lee and Wick.

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FLUCTUATION CONDUCTIVITY OF A TUNNEL CONTACT AT TEMPERATURES ABOVE CRITICAL

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It is known that at temperatures above T_c the superconducting-ordering parameter Δ does not vanish identically, but fluctuates with a certain (small) amplitude) whose value increases as T_c is approached. As shown in [1], this leads to additional conductivity of the fluctuation pairs, equal in the case of thin film to

$$\sigma' = \frac{e^2}{16\hbar d} \frac{T_c}{T - T_c}.$$

We consider in this paper an analogous effect for a tunnel contact between two superconductors. In the case when the voltage across the barrier V does not vanish and $T > T_c$, the fluctuation conductivity of the contact oscillates as a function of the time with the Josephson frequency $\omega = 2eV/\hbar$. (A more detailed exposition of the theory of this effect will be published in the