# CONCERNING THE GRAVITATIONAL MASSES OF $K^0$ AND $\overline{K}^0$ MESONS

É. O. OKONOV, M. I. PODGORETSKIĬ, and O. A. KHRUSTALEV

Joint Institute for Nuclear Research

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The possibility of an experimental investigation of the gravitational properties of the $\overline{K}^0$ meson is discussed.

INTEREST in the question of "antigravity" has recently increased.[1-5] It is known that the framework of contemporary physics assumes the absence of "antigravity."* At the same time, the fundamental importance of the question compels us to look for an experimental method of verifying this assumption.

In principle, it would be possible to investigate the direction of vertical deflection of horizontal particle and antiparticle beams. If, for example, we have a horizontal beam of $K_2^0$ particles then if the gravitational mass of the $\overline{K}^0$ is negative the initial beam separates into two beams, with the $K^0$ particles deflected downward and the $\overline{K}^0$ upward. In practice, of course, this experiment is not feasible inasmuch as one is talking about macroscopic deflections. It is possible, however, to change the experiment in such a way that it may be possible to notice a deflection of the order of a de Broglie wavelength.

For this purpose we consider a vertical beam of $K_2^0$ mesons, assuming that the gravitation mass of the $\overline{K}^0$ is negative. Upon passing through a height difference H, the difference in the $K^0$ and $\overline{K}^0$ energies becomes equal to 2mgH, causing a phase shift between the respective wave functions $\psi$ and $\overline{\psi}$ and leading ultimately to the transformation of the $K_2^0$ particles into $K_1^0$ particles with subsequent decay into $2\pi$**.†

To estimate the possible effect, we start from the equations that describe the behavior of the $K_1^0$ and $K_2^0$ particles, taking attenuation into account:

$$d\psi_1/dt = im_1\psi_1 - \delta\psi_2 - \lambda_1\psi_1/2,$$
$$d\psi_2/dt = im_2\psi_2 + \delta\psi_1 - \lambda_2\psi_2/2,$$

where $m_1$, $\lambda_1$ and $m_2$, $\lambda_2$ are the masses and decay constants of $K_1^0$ and $K_2^0$ mesons, and $\delta = mgvt/\sqrt{1-\beta^2}$ (v is the velocity of the $K_2^0$ particle). Neglecting the time derivative of $\delta$ and assuming $\delta/\lambda_1 \ll 1$, the solution of these equations gives the following formula for the number of $K_2^0$ particles at a height H

$$N(H) = N(0)\exp\left[-\lambda_2\frac{H}{v} - \frac{4}{3}\lambda_1\frac{\delta^2}{\lambda_1^2 + 4(m_1-m_2)^2}\left(\frac{H}{v}\right)^3\right].$$

For a velocity $v \sim 2c/3$, the $K_2^0$ particle beam decreases to 1/e times its original value at a height $H \approx 9$ m.

The ratio of the number of two-pion decays to the number of three-particle decays at a height H (neglecting the little-likely decay of the $K_1^0$ meson into three particles) equals

$$n(K_1^0)/n(K_2^0) = 4\delta^2 (H/v)^2 \lambda_1/\lambda_2 [\lambda_1^2 + 4(m_1-m_2)^2], \quad (2)$$

which leads, for $\lambda_1 \sim 10^{10}$ sec$^{-1}$ and $\lambda_2 \sim 1.7 \times 10^7$ sec$^{-1}$, to the value

$$n(K_1^0)/n(K_2^0) \sim 5\cdot 10^{-6} H^2.$$

It is not difficult to see that Eq. (2) is correct both for a vertical beam and for an inclined beam with vertical component equal to H. It is necessary to emphasize that at present we cannot offer a closed system in which antigravitation and the conservation of gravitational mass could coexist with the interference properties of the $K^0$ mesons. By the same token, we cannot prove on the basis of logical arguments alone that such a coexistence is impossible. Therefore it seems to us that a logical analysis of the situation would be usefully supplemented by the actual performance of the experiment discussed above.

It is obvious that a difference in the inertial masses of the $K^0$ and $\overline{K}^0$ particles

*Otherwise it is easy to arrive at either a violation of the energy conservation law or else the necessity of introducing an absolute potential.[6] It is possible to bypass these difficulties by assuming that the gravitational mass is conserved in processes involving the creation and annihilation of pairs of particles and antiparticles.

†If an absolute potential is introduced into the discussion, an analogous process can also occur for a horizontal $K_2^0$ beam.[6] The authors thank M. Good for sending a copy of his article before publication.

$[M(K^0) - M(\bar{K}^0)]$ also leads to the appearance of $K_1^0$ decays in a beam of $K_2^0$ mesons. In this case the ratio of both types of decays will be

$$n(K_1^0)/n(K_2^0) = (\lambda_1/\lambda_2)(M(K^0) - M(\bar{K}^0))^2/[\lambda_1^2 + 4(m_1 - m_2)^2].$$

Investigations of the decay properties of $K_2^0$ mesons have shown[7 8] that $n(K_1^0)/n(K_2^0) \lesssim 1/400$. Assuming $|m_1 - m_2| \sim \lambda_1$, we obtain $|M(K^0) - M(K^0)|/M \leq 10^{-17}$.

A more detailed account of the questions which have been considered is contained in [9,10].

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