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A PROPOSAL TO USE CPLEAR AS ANTIGRAVITOMETER

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Abstract.

The reconstructed kinematics of the isotropically emitted $K^0/\overline{K}^0$ and their decay vertex following a $p\overline{p}$ annihilation at rest allows to select events with specific neutral kaon topology *and* energy. Thus, from the accumulated events with CPLEAR one can define high statistics subgroups of any gravitationally oriented neutral kaons with $\sim \pm 60$ cm maximum vertical displacement, in order to search for (anti)gravity effects. The suggested new data analysis allows to combine for the first time upward moving K^0's with downward emitted $\overline{K}^0$'s, and *vice versa*, in order to search for any directional dependence of the CP parameters. The achieved limit for the relative $K^0 - \overline{K}^0$ mass difference ($\sim 10^{-18}$) may be indicative of a probably unique sensitivity for the proposed antigravity search. Existing anomalous energy dependent CP results along with the used non-horizontal kaon beam (having in fact an equal vertical kaon displacement per τ_S as in CPLEAR) are in favour of this proposal whatever the theoretical interpretation.

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1. Introduction

The gravitational force between antimatter and matter has not been measured so far, while the weak equivalence principle, one of the cornerstones of gravity theories, requires that the gravitational acceleration of a falling body be independent of its composition [1]. Antigravity is referred to the notion that antimatter might be gravitationally repelled by matter (i.e. will 'fall' up), while an anomalous gravitational acceleration of antimatter (like antigravity) would appear to violate CPT symmetry; because CPT invariance does require that the gravitational acceleration of an antiparticle in the field of a fictitious 'anti-earth' would be equal to that of the corresponding particle in the field of our earth [2]. That is to say, a negative result in antigravity search is rather a positive test for the CPT theorem, while the origin of an established antigravity may be not that obvious. However, the knowledge of the existence of antigravity has implications in cosmology, including also its relevance to the origin of CP violation itself.

This work suggests a new evaluation method of the data taken by CPLEAR, which allows in fact to have, in the same experiment, two pairs of gravitationally upward and downward inclined K^0 as well as $\overline{K}^0$ beams, which is so far, to the best of my knowledge, a unique feature of a CP experiment.

2. Antigravity effects in CPLEAR

The possibility to use a neutral antiparticle, like the copiously produced $\overline{K}^0$'s in $p\overline{p}$ annihilations (at rest), is experimentally very attractive for antigravity search, because of the missing disturbances coming otherwise even from weakest environmental electromagnetic fields. Therefore, the accumulated $K^0/\overline{K}^0$ tagged events in CPLEAR [3] may be appropriate to search for antigravity effects with incomparable sensitivity. The relation [4]

$$m_{K^0} - m_{\overline{K}^0} \approx 2\frac{(m_{K_L} - m_{K_S})|\eta|(\frac{2}{3}\phi_{+-} + \frac{1}{3}\phi_{00} - \phi_\epsilon)}{sin\phi_\epsilon} \tag{1}$$

provides a connection between different parameters measured in a CP experiment. The obtained relative mass difference [4, 5, 6]

$$\frac{\Delta m_{K^0\overline{K}^0}}{m_{K^0}} \equiv |\frac{m_{K^0} - m_{\overline{K}^0}}{m_{K^0}}| \leq 10^{-18} \tag{2}$$

is so far the best limit for CPT invariance.

With the picture of the Coulomb potential from atomic physics being applied to the earth's gravitational potential, one may easier follow qualitatively antigravity effects. A particle gravitationally bound to the earth looses restmass, which is given by the

Newtonian potential strength at the earth's surface being $|U_\oplus/c^2| \approx 6\times10^{-10}$ [1]. Thus, the binding energy for a K^0 is ≈ 0.3 eV. Assuming that antigravity is at work for the $\overline{K}^0$, then its restmass (at the same position in space) should be bigger than that of K^0 by this 0.3 eV : in the Coulomb picture, the $\overline{K}^0$ being gravitationally 'positively charged' like the earth, it will not loose any binding energy. Therefore, *when a K^0 propagates vertically upwards or downwards, its restmass relative to that of the $\overline{K}^0$ will be decreasing or increasing, respectively, depending on its vertical displacement.* The working principle of this proposal for antigravity is based just on this assumption. Needless to say that at a very long distance from the earth or other stars too, i.e. assuming gravitationally free space, the restmass of K^0 will approach that of $\overline{K}^0$ due to CPT invariance.

Since the potential itself is not observable, but only a potential difference [7], one arrived to the conclusion to consider a non-horizontal kaon beam in a CP violation fixed-target experiment, in order to investigate gravitational effects [7]. The known mixing time of the $K^0-\overline{K}^0$ system ($\approx 6\tau_s$) is just about equal to the time needed for antigravity to generate the amount of regeneration observed in CP violation as well as the mixing time imposed by weak interactions [7]; that is to say, CP violation may be explained, at least partly, by antigravity.

3. Experimental considerations

The relative mass difference between K^0 and $\overline{K}^0$ gives ($c=1$) [4, 5]

$$\Delta m_{K^0\overline{K}^0} \equiv |m_{K^0} - m_{\overline{K}^0}| \leq 5\times10^{-10} eV. \tag{3}$$

For comparison, the earth's gravitational force $|\mathbf{F}_\mathrm{g}|$ (g= 981 cm/s^2) on a K^0 is

$$|\mathbf{F}_\mathrm{g}| = \mathsf{m}_{\mathsf{K}^0}\cdot\mathsf{g} = 5\times10^{-10} eV/cm. \tag{4}$$

Provided antigravity is at work, this means that only after 1 cm of vertical motion, i.e. less than the FWHM of the $K^0/\overline{K}^0$ decay vertex reconstruction in CPLEAR, the change ($\Delta m_{antigravity}$) of the restmass of K^0 compared to that of $\overline{K}^0$ becomes already equal to the experimental upper limit of $\Delta m_{K^0\overline{K}^0}$ (relation (3)). This limit was obtained with neutral kaons being isotropically emitted with respect to the horizontal plane, and therefore, possible antigravity effects may either cancel out, or, they could not show up in the applied data evaluation. Therefore, if the restmass difference between K^0 and $\overline{K}^0$ depends on the kaon's direction of flight *and* the vertex of the $K^0 \rightleftharpoons \overline{K}^0$ transition, then the CPLEAR detector, with the kinematical reconstruction of the $K^0/\overline{K}^0$'s, could be an antigravitometer. All one needs is a new kind of evaluation.

A comparison between realistic gravitational potential changes (e.g. at ± 50 cm in the vertical direction), and, the mass splitting between K_L and K_S (with $\sim 0.36\%$ accuracy [9]) may be of relevance too :

$$\Delta m_{LS} \equiv m_{K_L} - m_{K_S} = (0.531 \pm 0.0019) \times 10^{10} \hbar/s = (3.495 \pm 0.012) \times 10^{-6} eV. \quad (5)$$

For example, if one should compare the difference in $K^0 \rightleftharpoons \overline{K}^0$ transitions at a vertical distance of $+50$ cm to that at -50 cm, the relative restmass difference between K^0 and $\overline{K}^0$ due to the assumed antigravity will be

$$\Delta m_{antigravity} \approx 5 \times 10^{-8} eV \ \approx \ 1.43 \cdot 10^{-2} \cdot (m_{K_L} - m_{K_S}), \quad (6)$$

while the following comparison is much more favourable :

$$\Delta m_{antigravity} \geq 100 \times (|m_{K^0} - m_{\overline{K}^0}|). \quad (7)$$

Although the estimated $\Delta m_{antigravity}$ makes ~ 1.43 % of the present experimental mass difference between K_L and K_S, it is still by factor ~ 4 bigger than the experimental error ($= 1.2 \cdot 10^{-8}$ eV) according to relation (5) for $(m_{K_L} - m_{K_S})$, which may be also somehow indicative for the potential sensitivity to be expected from precision CP experiments.
Previous results : remarkably, the only CP experiment associated with an appropriate change in altitude of the kaon during the mixing time of the weak interactions gave [7, 8]

$$\eta_{+-} = (2.09 \pm 0.02) \times 10^{-3} \quad (8)$$

being in disagreement by $\sim 9\sigma$ below the world average. Also other CP parameters, e.g. $m_{K_L} - m_{K_S}$, evaluated as usually in the $K^0/\overline{K}^0$ rest frame, were energy dependent, i.e. they were dependent on the velocity of this frame of reference with respect to the laboratory (!) . Surprisingly, for this proposal, the kaons 'fell' a vertical distance $\Delta z \approx 2.4$ cm in one K_S mean decay length [8], as it is also the case for the vertically emitted neutral kaons in CPLEAR. Therefore, the question, whether those previously obtained discrepancies are real, could be clarified with CPLEAR's higher precision as well as its ability to define downwards or upwards propagating $K^0/\overline{K}^0$'s, their energy and decay vertex.

4. Suggestion - Discussion

The CPLEAR detector is an optimum apparatus for searching antigravity effects with the $K^0/\overline{K}^0$ system. One has to change 'only' the method of the off-line data analysis.

It is proposed to reevaluate the data already taken by CPLEAR, although the same considerations may be useful for other CP experiments too. In particular, because of the potential of the CPLEAR detector to select from the isotropically emitted kaons, events with *any topology* relative to the direction of the earth's gravitational force, one should reproduce all the parameters measured in a CP experiment for each subgroup of data, and, compare the individual results with each other. If antigravity does not exist for the $\overline{K}^0$ meson, each partial data analysis will reproduce obviously the same parameter values.

It is important to stress that if antigravity exists, the CP parameter values will not only depend on the direction of flight of the initially pure $K^0/\overline{K}^0$ states, but also on the z$-$coordinate (= height) at which the kaons decay or the $K^0 \rightleftharpoons \overline{K}^0$ transition occurs. With CPLEAR's event reconstruction, one has to implement also this potential antigravity related effect in the suggested reevaluation. To do this, one should, for example, further subdivide the data according to the kaon's energy, since such a selection will be associated, on the average, with a bigger or smaller gravitational potential difference to be 'seen' by the kaon, because of the relativistic $\gamma-$dependence of the kaon's lifetime. It is suggested to search for a time dependent asymmetry between K^0 and $\overline{K}^0$, which are emitted into a solid angle above and below the horizontal plane, respectively, and *vice versa.* Therefore, a not constant detector efficiency at different directions will cancel out, improving thus the sensitivity to be achieved.

Surprisingly, antigravity may explain naturally CP parameters with an anomalous energy *and* altitude dependence in old CP experiments [7, 8] : the increased vertical displacement with energy of the non-horizontal neutral kaon beam could be the explanation. This observation certainly supports the proposed analysis of the CPLEAR data whatever the theoretical interpretation. Note that CPLEAR's performance has the advantage of choosing events with any vertical displacement between $\sim \pm 60$ cm of the K^0 or $\overline{K}^0$ involved [3]. With any luck, such a reevaluation could give a first clear experimental result for antigravity.

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